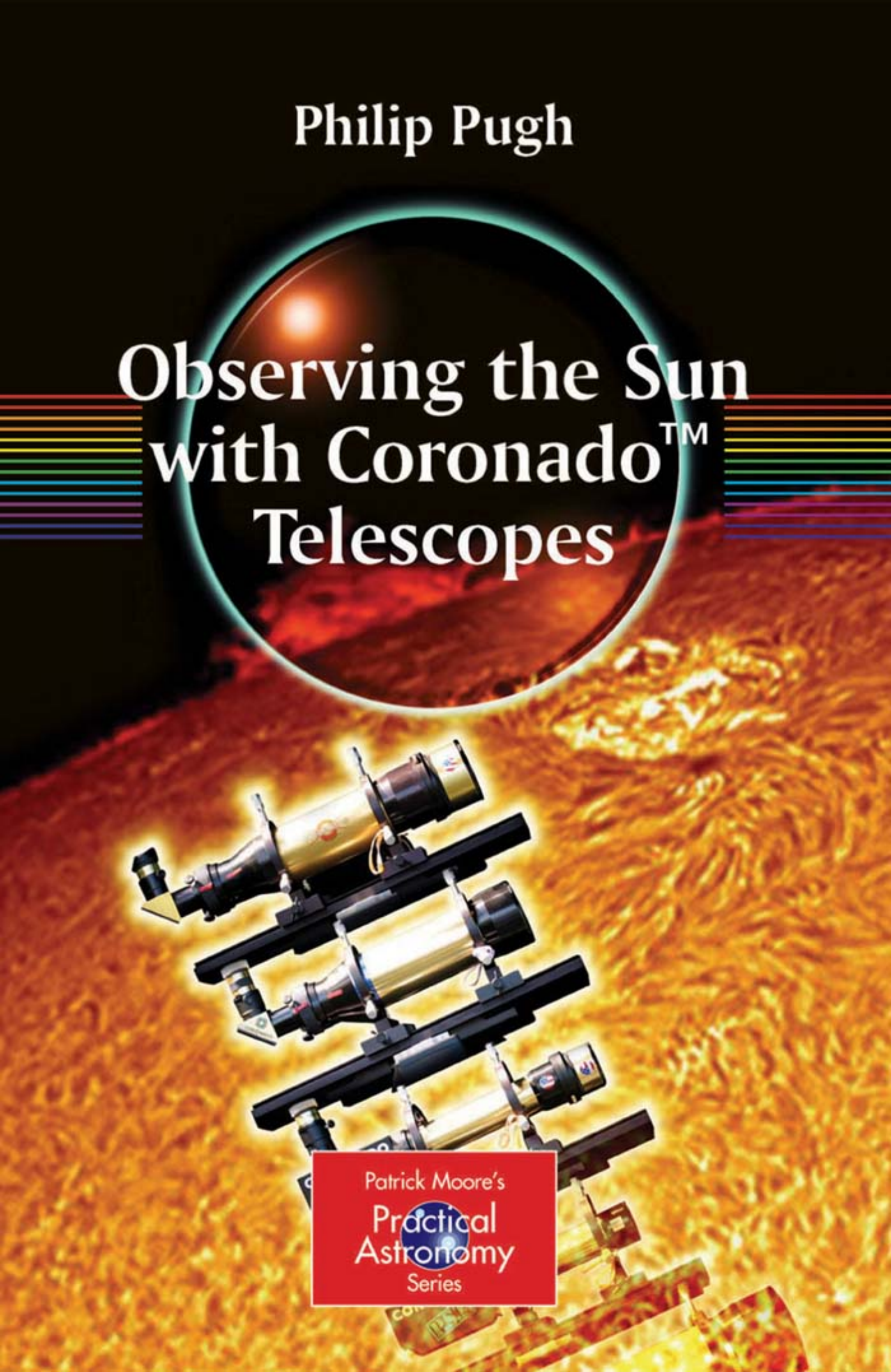
Philip Pugh

Observing the Sun with Coronado™ Telescopes



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Observing the Sun with Coronado™ Telescopes

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This book is dedicated to my wife, Helga, and daughter, Marcela, who gave me a Coronado Personal Solar Telescope (PST) as a 50th birthday present.

Preface

Scientists will often tell you that now is the most exciting time for a particular interest. We will always have just discovered or invented something that will "revolutionize" something or the other. The computer on which I am typing this, for example, is four times faster than its predecessor and slightly cheaper.

However, the last decade or so has seen some advances that have changed the face of amateur solar astronomy. Professional researchers have been using many of the tools and techniques for years but now they are available to amateurs as well.

The use of digital photography and computers has changed all astronomy, not just amateur solar astronomy, and it has certainly made a lot more techniques available for photographing the Sun.

Secondly, the use of "white light" solar filters has improved the detail that can be seen on the solar surface. In the past, the only technique that was available was projection onto a piece of white paper or card.

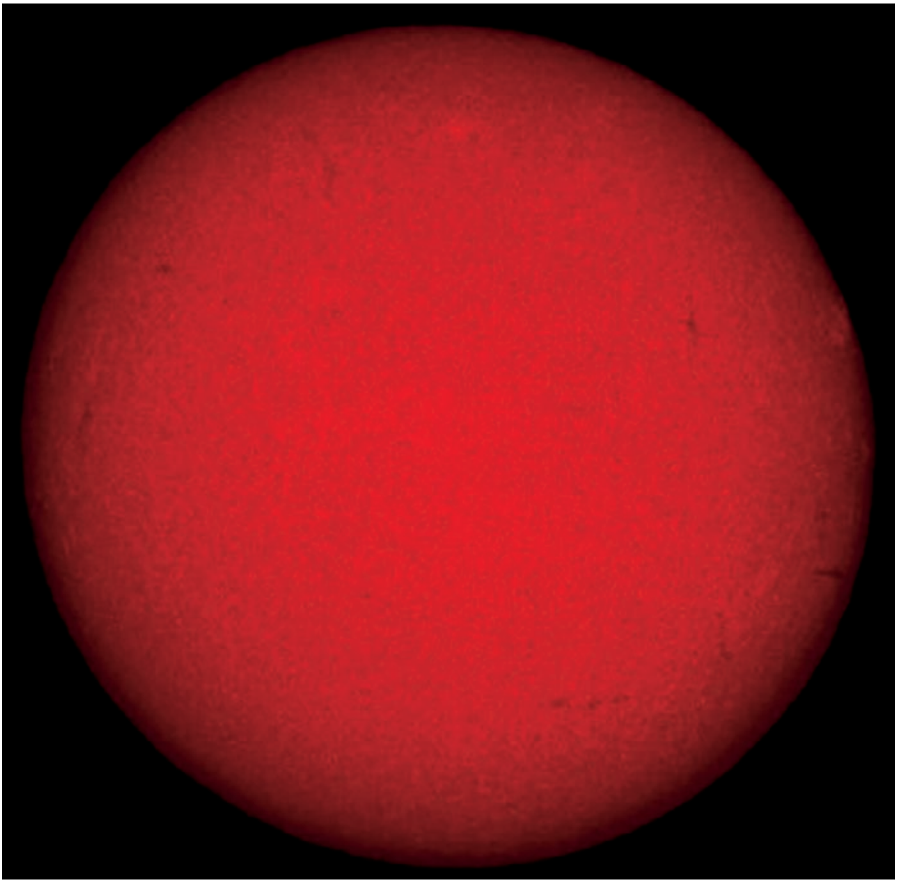
Thirdly, the use of hydrogen alpha filters has recently hit the "affordability barrier" of $500 or £500 for many amateur astronomers. The Coronado Personal Solar Telescope (PST) is a real breakthrough product that has now brought a fascinating branch of astronomy within the reach of many people. In recent months, the same technique has been applied to calcium K filters.

Like many amateur astronomers, I became interested in the Sun as an afterthought. Living in southern England, there is a period of about 7 weeks (more if you live in the Midlands or North) where there is little astronomical darkness at night. If you are at work or in education, it is practical to observe only on Friday and Saturday nights unless you have the ability to forgo sleep. The Moon and the Venus can sometimes be viewed in daylight and the brighter planets and double stars can be viewed in twilight, yet the main object viewable in the day has to be the Sun itself.

The main drawback of viewing the Sun is safety. The Sun is not just bright, it is very bright and even looking straight at it without telescope or binoculars can damage your eyesight. Using a telescope or pair of binoculars without due care can cause blindness, and lack of attention can cause damage to your telescope.

Apart from being a welcome distraction that can be enjoyed during daylight without the need for pristine viewing conditions, the Sun is an interesting object in its own right. It may appear predictable but unlike the Moon and many other objects, it is anything but. It might follow certain patterns but its exact appearance on a day-to-day basis is far from predictable. Indeed, the hydrogen alpha view of the Sun can change in minutes, rather than hours or days, unlike most astronomical objects.

Figure P.1. Sun through a hydrogen alpha PST. Photo by Nick Howes.



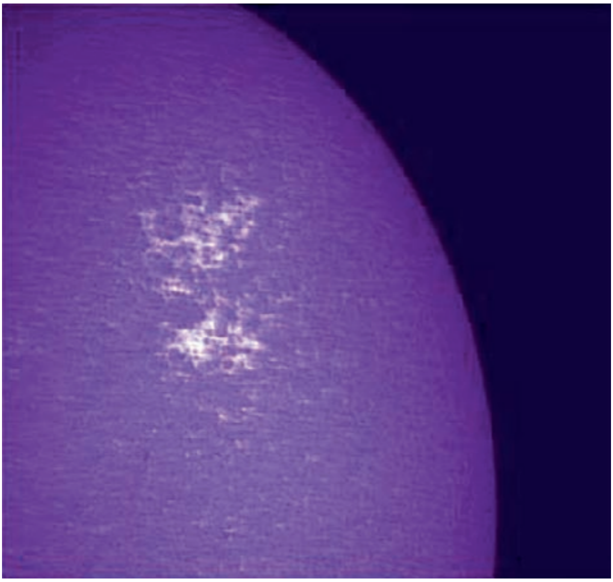


Figure P.2. Sun through a calcium K PST. Photo by Hiram Villarreal.

The Sun is the only chance for amateurs to see a star close-up. Over the past few years, the discs of relatively nearby red giant stars have been imaged with professional telescopes, but this is not available to amateur astronomers (at least not yet).

Whether you are interested in looking at the Sun from a scientific point of view or are interested in what is visible in amateur equipment, it is something you can get hours of enjoyment out of.

I have actually been amazed myself what it is possible to do with even a limited budget. Just as enterprising amateurs have taken some great photos of the night sky objects, so many have turned their attention to the Sun. The ability to buy and use expensive telescopes and photographic equipment is an advantage, but nice photographs can be obtained with modest equipment, as Figures P.1 and P.2 show.

Purpose

This book discusses the various options available for viewing and imaging the Sun using Coronado equipment. It covers the telescopes from the entry-level PST for the keen but financially challenged amateur to the top of the range MaxScope 90. It is the PST and MaxScope 90 that I have chosen to analyze in detail, but I have also provided sufficient information about the other telescopes to help you decide which purchase is most appropriate for you and how to get the best use out of it.

Apart from the convenience of ownership, I have covered the PST in detail, as it is the telescope that people are most likely to buy. To demonstrate the top of the range, Larry Alvarez has done a full write-up on the MaxScope 90.

Although the subject of the book is the Coronado range of telescopes and filters, I have included information about other manufacturers' equipment that can be used separately or in conjunction with Coronado products.

Neither myself nor my coauthors have been able to test every possible combination of equipment with accessories, but we have tried a reasonable amount of ideas that will help you to decide on a purchase and get the most from it.

Even if you are not interested in an imminent purchase, you may find the pictures interesting and you may get the opportunity to see through the telescopes at a public event.

Areas of Expertise

As most of my experience has been with the PST, eight coauthors have added information in their specialist areas in the following table.

CoAuthor	Areas of Expertise
Larry Alvarez	MaxScope 90
Cameran Ashraf	Double-Stacked PST
Marcello Lugli	Separate non-Coronado filters
Nick Howes	Imaging, PST CaK
Jeff Pettit	DayStar filters
Mike Taormina	CaK 70
Hiram Villarreal	PST CaK
John Watson	Mounting bracket for the PST

Acknowledgments

I would like to thank Springer-Verlag for giving me the opportunity to write this book and for providing helpful guidance and feedback. I would also like to thank my coauthors, Larry Alvarez, Cameran Ashraf, Nick Howes, Marcello Lugli, Jeff Pettit, Mike Taormina, and Hiram Villarreal, not just for making contributions but also offering advice and ideas.

Thanks also to John Watson (also of Springer-Verlag) who has supplied me with some materials about mounting options.

I would like to thank BC&F Telescope House for providing me with access to their telescopes and accessories at their showroom and providing me with photographs.

I would like to thank SkyView Optics for the use of a MaxScope 70 for trials.

I also thank Andy Burns for loaning equipment to Nick who used it to take many photographs.

Thanks also to Coronado themselves who have taken the trouble to answer some very difficult questions and provided me with some photographs.

I would also like to thank SolarScope and Ninian Boyle for providing me with permission to use their photographs.

I would also like to thank Thousand Oaks Inc. for allowing me to use the photographs.

Thanks to my parents, Tom, and Jackie Pugh who bought me my first telescope.

Thanks also to Sir Patrick Moore who helped to inspire my original interest in astronomy and to the many hundreds or thousands of people with whom I have shared my interest over the years.

I would finally like to thank my dog, Charles Stuart II (Charlie), for giving me a piece of inspiration while wrestling with a tricky problem with calcium K viewing and photography.

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CHAPTER ONE

Introduction

The Lure of the Sun

History

The first sunspot observation was recorded circa 800 BC in China. It is quite possible that exceptionally large sunspots were seen before that, especially near sunrise/sunset and where there was enough thin cloud to mask most of the sunlight but not enough to block out any detail on its surface. Personally, I have never been able to see a sunspot without optical aid but have seen them in instruments as small as a 5 × 24 finderscope.

"Proper" scientific observation of the Sun and sunspots started with Galileo in 1613, even though he is better known for discovering Jupiter's moons. Indeed, it was some years later when it was realized that the Sun was a star, like those in the night sky but just millions upon millions of times closer. For most of the history of solar observation, normal telescopes were used to monitor the Sun, but their image was projected onto a card, screen, or wall, but the spectrohelioscope was developed over 100 years ago, which permitted observation of the prominences and features that are normally visible only during a total solar eclipse.

Indeed, even today, a total solar eclipse is regarded as one of the most beautiful and fascinating sights in nature and even people with no other interest in astronomy will travel to see one.

From a scientific point of view, the Sun is the only star close enough to make detailed observations. The next nearest, Proxima Centauri, is over 4 light-years away and does not show a disc even in the largest and the best of telescopes. The nearest Sun-like star is Alpha Centauri, which happens to be the third brightest star in the night sky, marginally outshining Arcturus, but is only visible from the Tropic of Cancer and more southerly latitudes. Whilst it splits into two components, one slightly larger (and inherently brighter) than the Sun and one slightly smaller, in a small telescope, it is still too far away for detailed scientific observation. However, its two components can be resolved in telescopes as small as 60 mm and magnifications of 40× and above. I can personally verify this from various visits to the Southern Hemisphere. Recently Betelgeuse, the red supergiant in Orion, has been imaged by professional telescopes and has been shown to exhibit "starspots" similar to sunspots.

Whilst large aperture instruments are the provinces of research establishments, amateur astronomers can enjoy the Sun through their own telescopes, whether they wish to contribute to the scientific community or simply enjoy the view (as I do). Indeed, many amateurs become so interested in the Sun that they lose interest in the night sky. Certainly, I would say that solar observing is almost like having a completely separate hobby.

Early Days

I first became interested in the Sun around 1966, at the young age of 11. I was living in Sunninghill near Ascot in England at the time. Even in Southern England, with a latitude of 50–52° N, there is a period of about 3–4 weeks on each side of the summer solstice where nighttime astronomy is simply not practical for anyone in education or employment. In fact, a few days on each side of the solstice, there is actually no true darkness anywhere in the British Isles.

Being an avid reader at the time, various amateur astronomy books told about viewing the Sun. Had my parents read the books themselves, I would probably have had the telescope locked away during daylight but I was soon projecting the Sun's image onto a piece of paper. I proudly remember showing my teacher and assembled classmates the solar image during a partial eclipse in 1966. I certainly saw sunspots , although with a 40-mm refractor of somewhat dubious quality and a maximum of 45× magnification; I did not see the umbral/penumbral shading I was supposed to see, and I also felt somewhat let down as I could not see faculae (bright regions of the Sun) either. I was able to record sunspots in a series of drawings, which unfortunately I never kept, but I had already realized that it would be better to look at the Sun directly, rather than at a projected image.

I was certainly right but this is the point where my telescope would have been confiscated (permanently) had my parents known exactly what I was planning! I knew all about aperture, so made an aperture mask of 3 mm to fit over the telescope. I was "sensible" enough to know that this was less than the width of a pupil during bright conditions. To be extra "safe," I placed some overexposed camera film over the mask to "further reduce the light getting through." Note that in the unenlightened days of 1966, people still viewed solar eclipses through smoked glass and overexposed film.

It worked! I was able to view the solar image directly but did not resolve any additional detail because I had reduced my aperture to 3 mm, thus reducing the resolution capabilities of an already small aperture telescope to below that of the human eye! Furthermore, a small nudge on the tube knocked the contraption from the objective and only quick thinking prevented me from a lifetime of looking like Long John Silver.

Then, as now, my interest has been mainly observational astronomy. Reading was OK for when it was too cloudy to go out or my parents were reluctant for me to go out in the heat/cold, or whatever reason parents had for children not to go out. Yet I read enough to whet my appetite for more knowledge about the Sun. Its classification as an "yellow dwarf" made it somewhat unspectacular and I bemoaned the fact that we were not orbiting a more "exciting" star, such as Rigel or Betelguese. I cottoned on to the fact that if it was 32.6 light-years (10 parsecs) away, it would be barely noticeable at a magnitude of 4.8, whereas Rigel or Deneb would be brighter than magnitude of −7 at the same distance and would be visible in daylight. Note that the brightness of a star when placed at this distance is called the "absolute magnitude" and is used as a measure of the relative brightness of stars. Nevertheless, this small, faint, and otherwise insignificant star did have the advantage over these celestial beacons of proximity. I read that if you waited for a total solar eclipse you could see prominences or you could get hold of a spectrohelioscope, which was inaccessible to adult amateurs, let alone schoolboys, due to cost.

In the dark, dismal days of the mid- to late-1960s, astrophotography was in its infancy compared to the techniques available to us today.

I continued as a young astronomer until 1969 when I became frustrated at the lack of things that I could see with a small telescope. I also found that, despite a childhood ambition to become a professional scientist, I was becoming more drawn to mathematics and computers. My spare time was spent increasingly playing competitive chess and fishing. My telescope was relegated to the cupboard.

Astronomy and the Sun Resurface

In 1994 (at the tender age of 39), my interest in astronomy was rekindled. My small refractor had been previously donated to a cousin and I started off with a pair of 20 × 50 binoculars, soon to be joined by a refractor (60 mm) and portable reflector (76 mm). I found that using solar projection, I could see sunspots more clearly than I had with my 40-mm refractor. The real breakthrough came in 2001, with an article published in "Astronomy" by Phil Harrington about making solar filters. The most commonly used ones are Baader filters. If you have lots of telescopes and binoculars, the cost of buying ready-made filters gets prohibitive and there is the additional problem of the finderscopes, for which no ready-made filters are commercially available. The only solution is to make your own, a rather daunting prospect for someone who is not very practical minded! Looking at the possibility of making a complete mess of it and ruining my eyesight, I need not have worried. At the time of writing, my fourth year of using the filters was coming to a close and I have shown the Sun through them to various people, including children in their last 2 years of primary school. A further advance came in August 2003 when I bought a Skywatcher 127-mm Maksutov. This is shown in Figure 1.1 with the Personal Solar Telescope (PST) in close attendance during a viewing session. Using these filters, especially with the Maksutov, I am able to see faint sunspots and lots of umbral/penumbral shading. Due to the larger aperture, I can get better resolution of sunspots than I can with the PST. Figure 1.2 shows a close-up of an active sunspot region, taken at high magnification. In fact, the cell structure is just starting to show at this resolution and there are even some faculae surrounding the sunspots. Recent evidence seems to suggest that faculae can be seen more readily using some brands of ready-made filters but I have not done any extensive trials. I did, however, view faculae through a Revelation 80 refractor and proprietary filter while doing extensive trials on a MaxScope 70 while researching this book. Monitoring the Sun in "white light" is indeed a fascinating hobby. I have been getting too lazy to carry my Maksutov outside to do a proper solar photo shoot very often but if I see any interesting sunspot activity at the weekend, the Maksutov comes out for a bit of exercise!

For routine day-to-day monitoring of solar activity, I use a pair of Helios Stellar 15×70 binoculars, which are large enough to see how active the Sun is. I usually take a drawing of the sunspots, which I place onto the computer using

Figure 1.1. Personal Solar Telescope and Maksutov during a solar-viewing session.

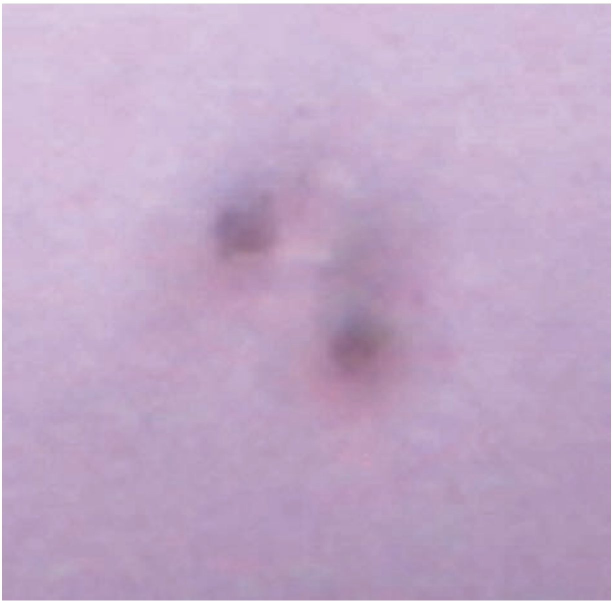


Figure 1.2. Sunspots taken with the Maksutov, showing faculae.

CorelDraw and publish them on my Web site. Figure 1.3 is an example of a solar drawing made near the solar maximum.

I have also combined these drawings to produce animations of the sunspots moving across the solar disc, which I have also published on my Web site, which is http://freespace.virgin.net.pugh.pm/index.html.

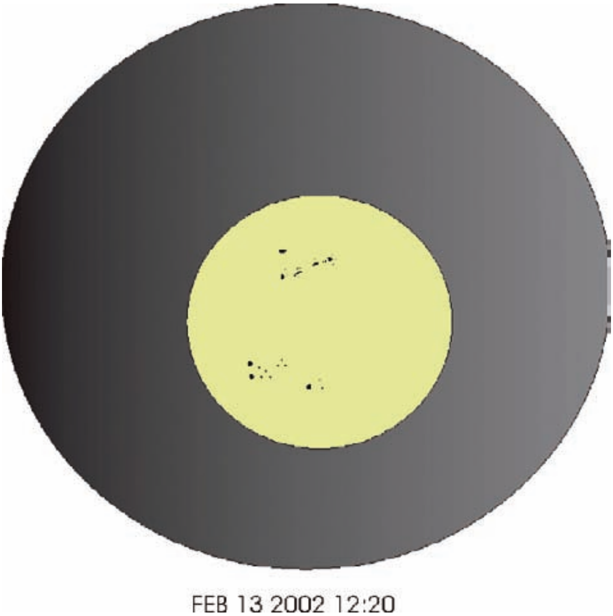


Figure 1.3. Sunspot drawing made from "white light" observations.

If particularly large sunspots are around, I would have been able to see umbral/penumbral shading (where an outer, fainter region of a sunspot surrounds an inner, darker region) in my binoculars, although this is a very rare event and is more common when using higher magnification through a telescope.

As if to prove my point about binoculars being suitable for "white light" solar viewing, Coronado has brought out some dedicated binoculars for the purpose. They are the following:

- BinoMite 10 × 25 binoculars with built-in solar filters
- BinoMite II 12 × 60 binoculars with built-in solar filters

They have built-in white light filters, which reduce the light by a factor of 100,000 times. They are also specifically designed to block out infrared and ultraviolet light, which may otherwise harm your eyesight. Like many larger binoculars, the BinoMite II has a built-in thread to enable you to attach it to a camera tripod.

Binocular observation is not suitable for photography but is very handy for doing a "rain check" of solar activity. Whilst the problems of dark sky viewing in the English summer led me to be interested in the Sun in the first place, solar observation becomes almost as frustrating in an English winter! Even from Southern England, at the winter solstice, the Sun rises barely 15° above the horizon and hardly grazes it from Northern Scotland. From a practical observing point of view, this means observing the Sun from work during breaks, as for 3 months of the year I leave for work before sunrise and arrive home after sunset. Contrary to popular opinion outside the United Kingdom, the "normal" winter weather is around 45° F in the daytime with broken cloud, with occasional milder spells up to 60° and cold snaps where it can remain below freezing during the day. This necessitates the ability to rush outside with binoculars to check the Sun before the next bank of cloud moves in. By comparison, even a small telescope is not always convenient to carry to and from work on a daily basis.

So, I have been following sunspot patterns for a number of years and will continue to do so but there is always something more, is not there?

The Solar Cycle

The 11-year solar cycle has been known about for over 200 years but it has been discovered recently that it is really a 22-year cycle, because the Sun's magnetic field changes polarity at a solar minimum. At a solar maximum, the Sun is constantly dotted with sunspots of all shapes and sizes. At a minimum, the solar surface can appear bland and uninteresting for weeks. By following the solar cycle, it has become apparent that it is not quite so simple. As an example, during 2002, solar activity did not decline as predicted but continued to be high for several months. During a decline toward minimum, activity will subside, only for the odd outburst to occur. This can be a false impression because some sunspots and groups can remain active throughout the solar rotation period, so apparent activity only gives part of the picture. We can never see half of the Sun and the areas around the limbs are quite difficult too. It is easy to forget that the Sun is a sphere. If you rotate a ball with a pattern, you will notice how the pattern distorts as it reaches the edge of visibility. Only the largest and the darkest of sunspots are visible near the limb, so I would say for practical purposes that only 30% of the solar surface is visible at any one time.

Sunspots usually appear in groups and are known as *active regions*. The research community gives each active region a serial number (prefixed by AR), which is shown on Web sites like SOHO and others. Close-up views with "serious" amateur telescopes will show these groups changing in size and shape over a few days. Near a solar maximum, there are usually several active regions visible at one time, but as we move toward a solar minimum, the number of these regions declines and they are also more visible near the solar equator than the poles. Whilst the number of active regions declines toward solar minimum, their size does not. Some active regions and individual sunspots can be very large near a solar minimum and it is strange to see a large active region in an otherwise bland, clear solar disc.

Apart from monitoring the changes as a hobby, the Sun is capable of throwing in a few surprises that the research community does not yet understand. There was the well-publicized *Maunder Minimum* of the seventeenth century, which was accompanied with a colder climate, with the River Thames in London freezing over every winter. Perhaps, researchers into global warming should look at the Sun, as well as analyze the Earth's atmosphere.

At the time of writing (October 2006), the solar minimum had just passed and I was looking forward to five-and-a-half years of rising solar activity. I was also hoping that during this time there would be new advances in solar viewing and digital photography for us all to enjoy.

Limitations of "White Light" Viewing

Sunspot viewing is fascinating, both from an amateur and a professional research perspective. Modern alternatives replace the "traditional" method of solar projection, with safe viewing techniques, and unprecedented detail can be seen and photographed with even the modest equipment. So what is wrong with it?

Nothing is actually "wrong" with it, as such, and I will continue to do it for the foreseeable future. However, experienced observers would have noticed a few things that are as follows:

- Hints of the "cell structure" can be seen with high-quality telescopes at high magnification of 300× and over but are not normally seen under average viewing conditions.
- The faculae (normally associated with sunspot regions) are only seen occasionally. Figure 1.2 shows them quite well, but I would regard it as a "gem", although some white light filters can show them better than others.

- Solar flares have been spotted in "white light" and had been recorded before the invention of the spectrohelioscope, but these are very rare occurrences. I have never seen them.
- Prominences and filaments are never visible, although prominences can be seen during a total solar eclipse.
- The Sun rotates about once per month, although the equatorial regions rotate faster than the polar regions. A change in sunspot position is not normally noticed at less than daily intervals. Apparent changes in position during a day are caused by the Earth's rotation and not the Sun's.
- Sunspots appear, disappear, and change shape but not that frequently. Monitoring more than once per day achieves little. The only exception is during the summer in high latitudes where I (and others) have noticed changes from morning to evening.
- Near a solar minimum, it can be days, even weeks, in between sunspots.

So you can view the Sun in "white light" daily, weather permitting. Using suitable filters, you can check first with binoculars then make follow-up observations (and photographs) with a telescope. But that is it! Unless there are large sunspot groups around for you to try close-ups, a typical "white light" observing session lasts less than half an hour. There is no point in continually staring through the eyepiece until sunset, as the view will simply not change. If it is near a solar minimum, you may see a bland solar disc, with limb darkening and some hint of a cell structure on a very good day. It hardly qualifies as a full morning's entertainment and, indeed, unless Venus and/or the Moon are around, there is just nothing to stay outside for. In fact, I am lazy in that I will only make follow up observations with my Maksutov after I have seen a large sunspot by binocular viewing.

Now had the spectrohelioscope and other advances leading to hydrogen alpha filters never been invented and made available to amateurs, I would be getting nearly all that I could from solar observing and be dreaming of the day I could travel to a total solar eclipse. But now there is a whole new realm out there and it is getting better all the time!

The Outer Limits of Amateur "White Light" Observation

Before moving on to the main subject of the book, the last word does not end with a 127-mm Maksutov and a Baader filter. Indeed, much larger telescopes and better photographic techniques have been used to obtain "white light" views of the Sun that are much better than I have achieved. It is simply a case of adapting "nighttime" techniques to the Sun. Telescopes and cameras that have been successfully used for planetary and deep sky astrophotography can be reused. If I said that you only need a Baader filter, it would be simplistic but it is possible to use normal color filters in addition. Larry Alvarez has used green (no. 58) filters to increase the contrast on the solar disc.

Using telescopes of greater aperture and higher optical quality to get higher resolution and clearer views is always going to achieve better results. So, for the final word on "white light" viewing, I will let Larry's photos speak for themselves (see Figures 1.4–1.9). Note that these photographs have been taken using advanced equipments and techniques and cannot be matched with entry-level telescopes and domestic digital cameras.

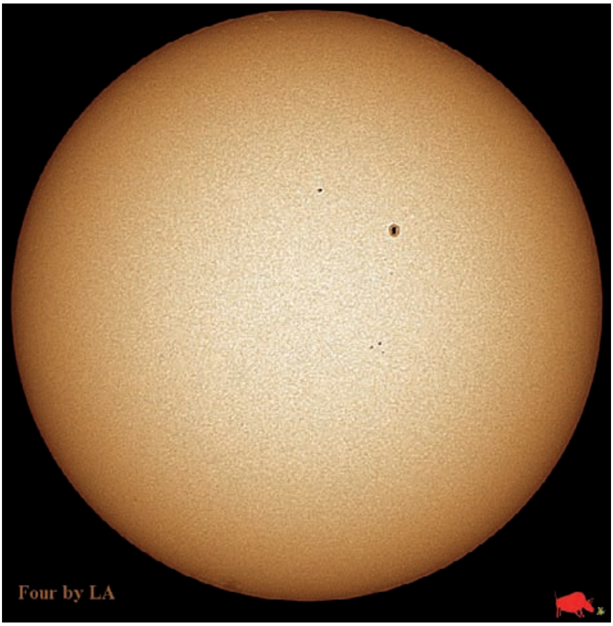


Figure 1.4. Full disc sunspots by Larry Alvarez.

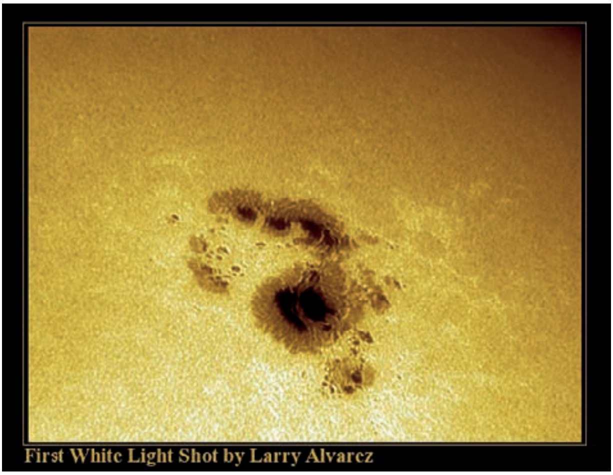


Figure 1.5. White light close-up no. 1 by Larry Alvarez.

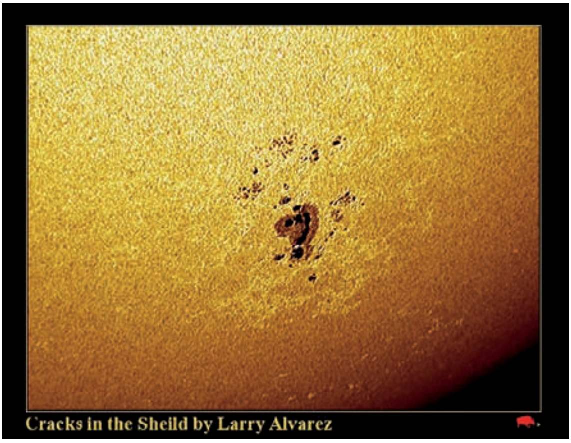


Figure 1.6. White light close-up no. 2 by Larry Alvarez.

Figure 1.7. White light close-up no. 3 by Larry Alvarez.

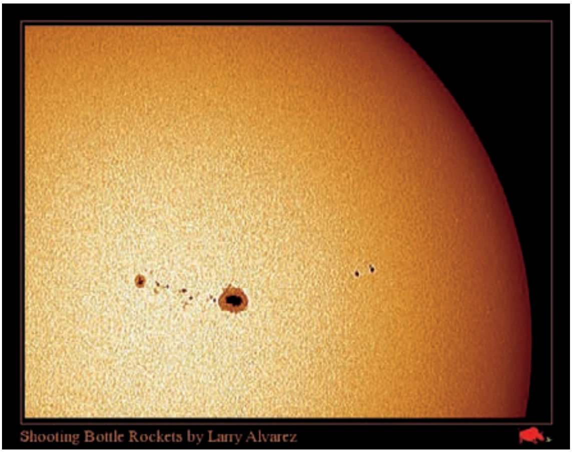


Figure 1.8. White light close-up no. 4 by Larry Alvarez.

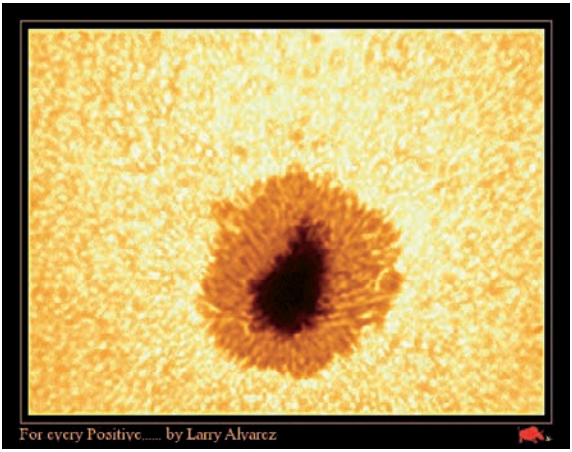


Figure 1.9. White light close-up no. 5 by Larry Alvarez.

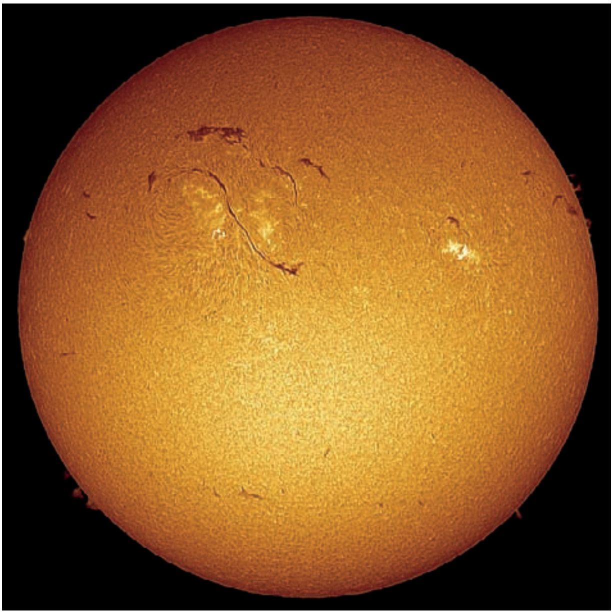


Figure 1.10. Whole solar disc taken by Larry Alvarez on 10 May 2005.

Introduction to Hydrogen Alpha Viewing

Depending on your viewpoint, viewing the Sun in hydrogen alpha light is cheap or expensive! For those working in research, accustomed to the prices of filters, the price of dedicated solar telescopes is cheap. For amateur astronomers wishing to progress from "white light" solar observation, it is expensive. Put simply, a budget of around £500 in the UK currency or $500 in the US currency buys you a "serious" nighttime telescope. Examples include the following:

- 250-mm Dobsonian mounted Newtonian reflector
- 200-mm Equatorially mounted Newtonian reflector
- 127-mm Equatorially mounted Maksutov reflector

However, the same budget gets you into hydrogen alpha viewing at entry level. For the financially challenged, this represents a major outlay and, for many, it will represent one of the few astronomical "big buys" of their life. Again, experience has shown that keen amateurs can be quite inventive in raising funds for purchases! Many telescopes (and hydrogen alpha telescopes are no exception) are bought for societies with society funds and sessions are run for club members and the general public. Indeed, astronomical societies in many countries are given grants if they have an "outreach" program to allow members of the public to look through their equipment.

The market leader in amateur hydrogen alpha viewing has been Coronado Instruments. Indeed, at the time of writing, they were the only company with any offering under $500/£500 at all. Their range of equipment starts with the entry-level PST and (at the time of time of writing) ends with a 90-mm aperture telescope. Competing products listed in Chapters 6 and 7 are worth considering for mid-range upwards.

The challenge for Coronado and its competitors is to produce filters that remove most of the other wavelengths, so that only the hydrogen alpha features are shown and are not "drowned out" by light from other wavelengths.

What Hydrogen Alpha Viewing Is

Despite its official designation as "yellow dwarf," the light emitted by the Sun is generally thought to be "white." Indeed, through a suitable filter or via solar projection, the solar image does appear white. As we know from our schooldays, "white" light is really a mixture of several different colors, as can be seen in a rainbow. What we are not taught at school is that there are not just seven colors of the rainbow that make up white light; there are actually thousands of different wavelengths of light that make it up. When we observe the Sun, we are seeing all of those wavelengths mixed together.

Light and indeed all forms of electromagnetic radiation from gamma rays to radio waves originate when electrons change their orbit around the atomic nuclei. The particular light wavelength for hydrogen alpha light is 6563 Å. You divide 10 m by 10 ten times to obtain an angstrom unit. The hydrogen alpha line is caused when an electron in the second lowest orbit drops to the lowest. There are other hydrogen (and other element) wavelengths, such as hydrogen beta, calcium K, and so on. The hydrogen alpha wavelength is of particular interest to solar astronomers because it shows details of the solar surface or chromosphere. In fact, nighttime observers see details in nebulae using hydrogen alpha and beta filters.

If you read through the advertisements and catalogues, you will see that nighttime hydrogen alpha filters are more expensive than ordinary color filters such as red and blue but much cheaper than solar ones. So it seems that all you have to do is use a Baader filter to reduce the "white light" and a nighttime filter at the eyepiece.

Not so! Nighttime filters are known as *broadband* filters. Whilst this term sounds good when you are dealing with computer network communications, it is not so good when dealing with solar detail. Broadband filters allow light of surrounding wavelengths to pass through, which is OK for night viewing, but it is necessary to use *narrowband* filters to isolate the light to within 0.5Å of the precise hydrogen alpha wavelength (giving a range of 6562.5–6563.5Å and a *bandpass* of 1Å). Indeed, making the range even smaller gives clearer results, although can obscure prominences.

The filter used is called a Fabry–Perot etalon. It consists of two surfaces that allow just the narrow wavelength of hydrogen alpha light to pass through. The two types of etalon available commercially are full aperture filters, as used by most of the Coronado telescopes, and eyepiece filters, which are placed near the focusing tube and eyepiece. Coronado and a known competitor (SolarScope) produce dedicated telescopes, which cannot be used for anything except solar viewing and have filters built-in to the assembly, and both Coronado and competitors market separate filter systems that can be used with nighttime telescopes. The Coronado (entry-level) PST has a filter built into a "magic box" near the eyepiece. This design has been used to reduce the manufacturing and, hence, the purchase price (see Chapter 2 for details). At the time of writing, the PST and its close cousin the PST CaK were the only instruments that used this design.

Certainly, at entry-level and mid-price range, the dedicated telescopes are cheaper than the separate filter systems and the PST is the only option under £500 or $500.

An etalon can be tuned to allow for features that are moving toward the Earth, which are *Doppler shifted*. This tilts the etalon to tune the wavelength of the light allowed through by a fraction of an angstrom unit. Most etalons can be tuned in this way manually. Changes in air pressure may also require an etalon to be tuned.

The other filter used with the objective is an *energy rejection filter* to remove infrared and ultraviolet light. For the entry-level PST, this is built into the coating of the objective, but for other telescopes it is available as a separate filter (including the etalon). These filters can be built into a dedicated telescope or can be purchased separately.

Coronado telescopes other than the PST have a secondary *blocking filter* placed before the eyepiece to further reduce the light passed through to the observer, which also performs the role of the energy rejection filter. If you are buying a Coronado hydrogen alpha filter, you will need to buy a blocking filter to match.

The PST has a range or bandpass of less than 1Å and the other telescopes have a bandpass of 0.7Å. This can be further reduced to 0.6 and 0.5Å for the other telescopes by a technique known as *double stacking*. This means that you need to buy another SolarMax filter but you do not need a (second) blocking filter. In order to use double stacking for instruments other than the PST, you need to send your telescope off to Coronado to ensure that the filters are correctly matched. It certainly does not come cheap and typically adds 60% to the original cost of the telescope. It certainly does, however, increase the contrast of the surface features visible but has a tendency to obscure prominence detail. Note that you will get some improvement using unmatched filters, but matching filters will give you optimum performance and value for your money. Chapter 2 gives you some examples of photographs taken with single- and double-stacked filters at the same time for comparison.

You can add the secondary filter internally (lower aperture) or externally. The external filter is more expensive but yields slightly better results.

Note that other manufacturers produce telescopes and filters using a Fabry–Perot etalon. However, there are also many full aperture filters available, which have a wider bandpass of 1.5Å. Although these will show prominences, they will not show the detailed solar structure than can be seen with a bandpass of 1Å and below. See Chapters 6 and 7 for a description of these products.

Another possible configuration is to use an energy rejection filter with the objective and an etalon in the terminal light path. Whilst this usually results in a wider bandpass than with full aperture filters, it usually results in a lower cost for medium to high aperture options (see Chapters 6 and 7). Indeed, some of these can be used to reduce the bandpass of Coronado hydrogen alpha telescopes.

However, I would be wary of buying such a setup without trying it out first. Some energy rejection filter/etalon combinations claim to deliver a bandpass of about 1Å or less but deliver less detail than the Coronado PST. In addition, some systems reduce the aperture of the telescope in order to increase the focal ratio. Whilst there are some good reasons for this, you need to make sure that the resulting effective aperture is enough to give reasonable resolution.

Indeed, when considering any purchase, you need to consider the bandpass (which eliminates light from the surrounding wavelengths that can drown out hydrogen alpha features) and the effective aperture (which dictates the resolution or smallest feature that you can see or photograph). When in doubt, check the specification and ask to see through the setup and, if possible, try a PST or similar telescope whose capabilities and limitations are well-known and do a head-to-head test.

What It Can Show You

The solar surface is in a state of constant change. This is not readily apparent to observers limited to "white light" viewing who might only see changes over a 12-hour period. Apart from eclipse/occultation events, solar hydrogen alpha observing is the only amateur branch of astronomy where you can see changes occur in minutes. By comparison, features on Jupiter and Mars can be seen to rotate and the lunar terminator can be seen to progress over periods of a few hours.

Writers claim that the changes occur in "near real-time," which means that if you stare at the image continuously you will not notice any changes. However, once I was able to see prominences changing shape, even using the entry-level PST. I knew the effect was real because the rest of the solar disc was not shimmering, as it can do under poor viewing conditions. I would be cautious in raising expectations of this being a normal occurrence, as it has only happened once.

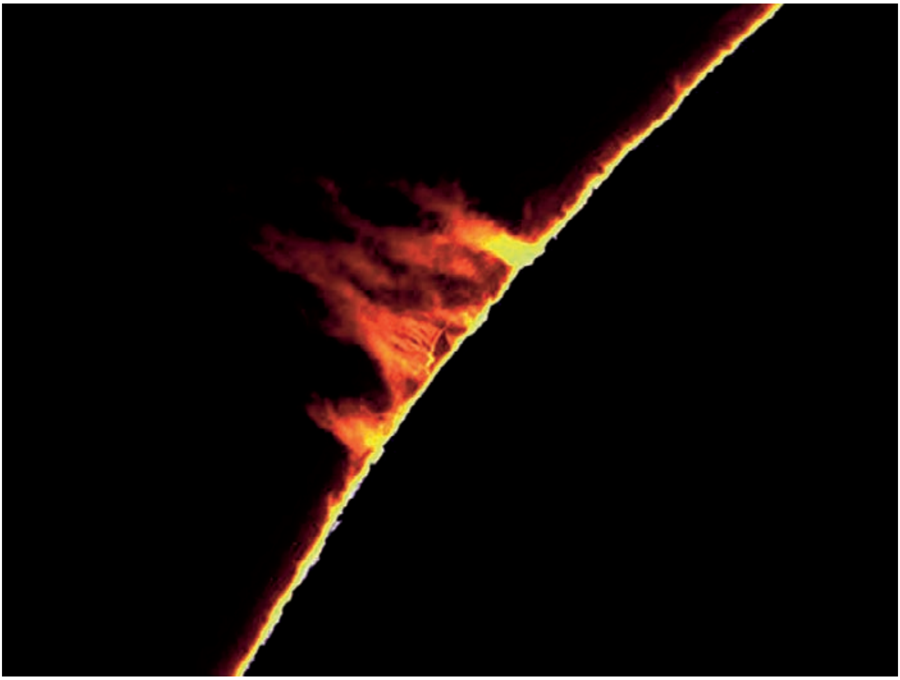
Apart from the obvious limitation of the conditions and the features on the Sun at the time, the telescope aperture and bandpass determine how good the view is. My personal opinion is that aperture plays a big part, while many others would claim that bandpass is more critical. Either way, an increase in aperture and/or decrease in bandpass usually results in a higher price.

You should aim for a bandpass of 1Å or less and an effective aperture of at least 30 mm. By coincidence, this is the specification of the Coronado PST.

Prominences These are where the most change is noticeable and they can be seen at the edge of the solar disc. Figures 1.11–1.13 show prominences photographed at various times.

These appear as "flames" emanating from the solar disc and can be large, small, and can apparently loop round on them. Indeed, I have even seen them appear "detached" from the solar disc. In Figure 1.11, one of them to the upper left appears detached. Despite their appearance, prominences are not "flames" at all. They are areas of plasma flowing between the visible solar disc (or *photosphere*) and the solar corona along the magnetic field lines. They are nice to look at and also interesting from a scientific point of view.

Figure 1.11. Prominences taken on 7 June 2005 by Larry Alvarez.



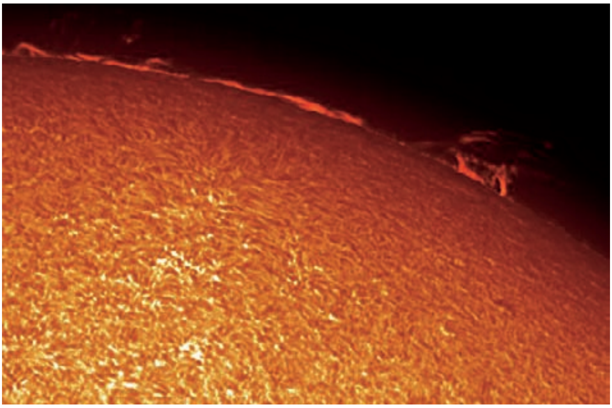


Figure 1.12. Prominences taken on 9 May 2005. Photo by Larry Alvarez.

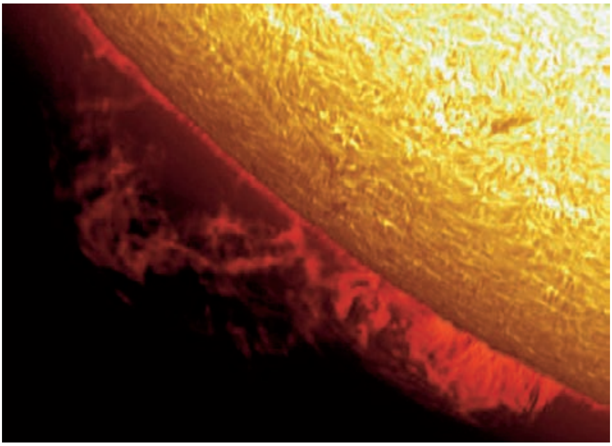


Figure 1.13. Prominences taken on 9 May 2005. Photo courtesy of Larry Alvarez.

In Figure 1.13, there are several small "flames" to the lower right, but there is a large loop to the left where part of it appears to be detached from the solar disc. This demonstrates the "looping" effect that can be detected by telescopes as small as a PST.

Sometimes prominences are associated with other features. In Figure 1.14, you can see a prominence emanating from a facula, which is flanked by a sunspot on either side. Although, it has never appeared this clear in a PST, I have certainly seen the associated prominence and facula through it. However, most of the time there seems to be no obvious association between prominences and other features.

Note that Larry's photographs are taken using the top-of-the range MaxScope 90 and this level of detail may not be seem in telescopes/systems with a higher bandpass or lower effective aperture.

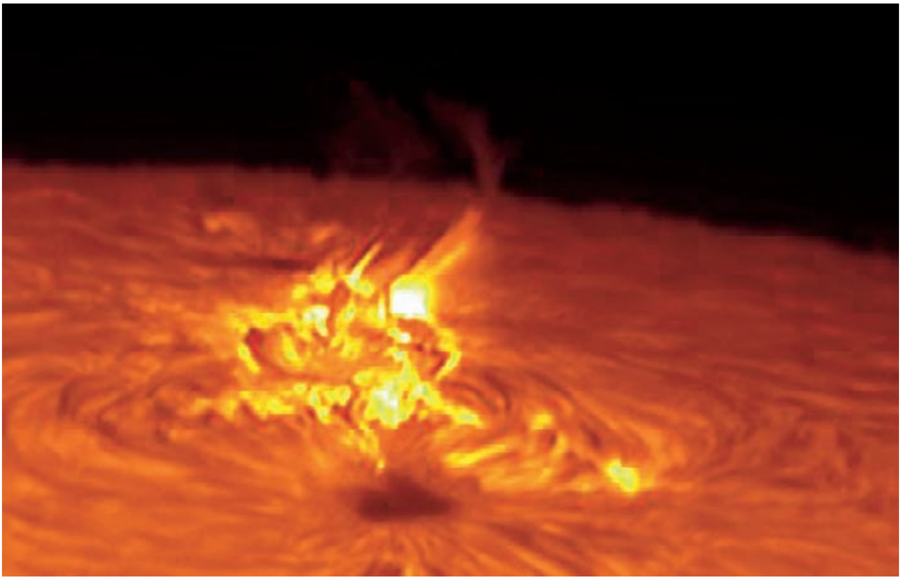


Figure 1.14. Active region near the solar limb. Courtesy of Larry Alvarez.

It was once thought that the Sun was a great ball of fire; however, after its mass and volume were calculated, scientists realized that it would burn out in a few thousand years, so there was obviously something else providing its energy. Therefore, prominences are not flames and the solar nuclear reactions occur in its core, nowhere near the solar surface. Although the mechanics are not fully understood, it appears that prominences, sunspots, and indeed just about all visible solar features are associated with magnetic fields within the Sun. It is the magnetic properties within the Sun that cause the apparent 11-year cycle (actually 22 years because of the reversing polarity).

At the time of writing, we were heading toward a solar minimum. Whilst sunspot activity was low, there was constant activity in hydrogen alpha light.

Filaments Solar prominences appear as "flames" when they are at or near the limb of the solar "disc," as seen from the Earth, and they are visible as *filaments* when they are seen nearer to the middle of the disc. They are visible because they are silhouetted against the disc. When viewed through entry-level (or near entry-level) hydrogen alpha telescopes, they appear as hairs that have accumulated on the telescope's optics! If you move the telescope slightly, you will notice which are real solar features and which are "features" of the optical system. Through larger hydrogen alpha telescopes, armed with quality photographic equipment, they can assume many different shapes. An example is the "Dragon's Neck" shape in Figure 1.15.

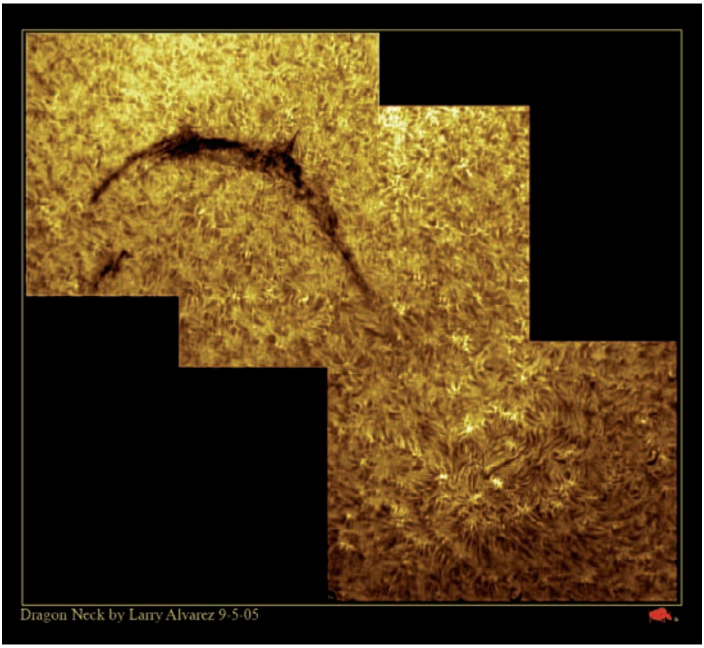


Figure 1.15. Dragon's Neck filament taken on 9 May 2005. Photo courtesy of Larry Alvarez.

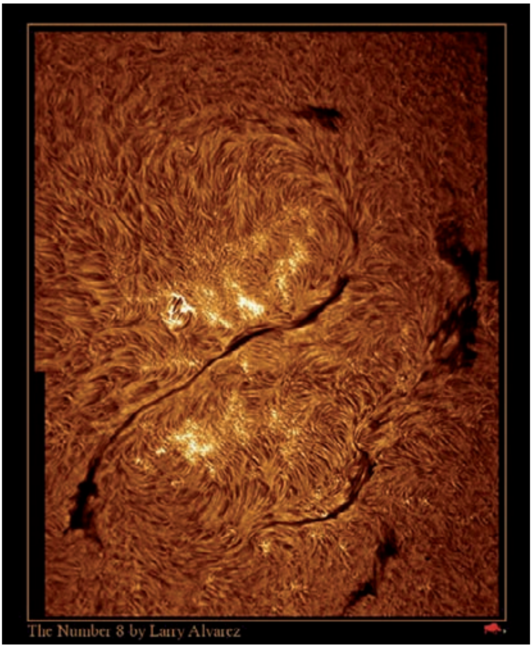


Figure 1.16. Filaments by Larry Alvarez.

Although they do not always show well in photographs taken with a domestic digital camera and entry-level telescope, there are filaments visible on the solar disc on most days. On a particularly fortunate day, it is possible to view filaments ending at the solar limb and "turning" into prominences, thus revealing their true nature (Figure 1.16). The exception is at or near a solar minimum.

Filaments do not change in appearance as quickly as when viewed at the solar limb as prominences but will change over periods of half an hour or so.

Sunspots Ironically enough, sunspots that appear prominent in "white" light seem to be invisible or almost invisible in hydrogen alpha light. Figure 1.17 shows the same active region through hydrogen alpha and "white" light telescopes, respectively. It is quite common for me to see the Sun through my PST without seeing any sunspots, then be amazed at the sunspots I can see through my binoculars.

The moral of the story is that you should continue to monitor the Sun in "white" light for sunspots, however good your hydrogen alpha equipment be.

Solar Cell Structure Viewed in "white" light at low (less than 300×) magnification, the solar disc appears uniformly bland, apart from sunspots and some darkening toward the limbs. Using high magnification, on a good day, with a quality telescope, the solar surface appears to have a cellular structure. In practice, despite having a 127-mm Maksutov, I have not seen this very often.

Although Figure 1.18 was taken using a 90-mm hydrogen alpha telescope, this effect is immediately apparent through a PST, sometimes even before inserting an eyepiece! In reality, the solar surface is not smooth, but with pockets of hot hydrogen "bubbling." This cellular structure, although prominent visually, cannot be photographed easily with domestic digital cameras and low aperture telescopes with a wide bandpass.

Figure 1.17. An active region shown in hydrogen alpha light and "White" light by Larry Alvarez.

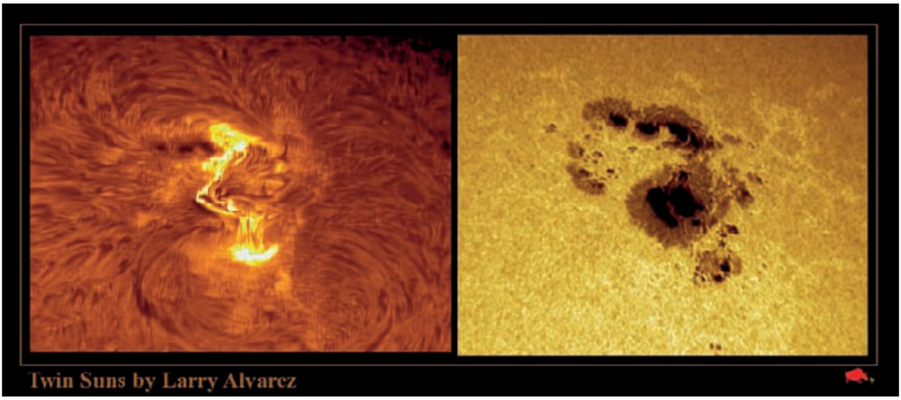
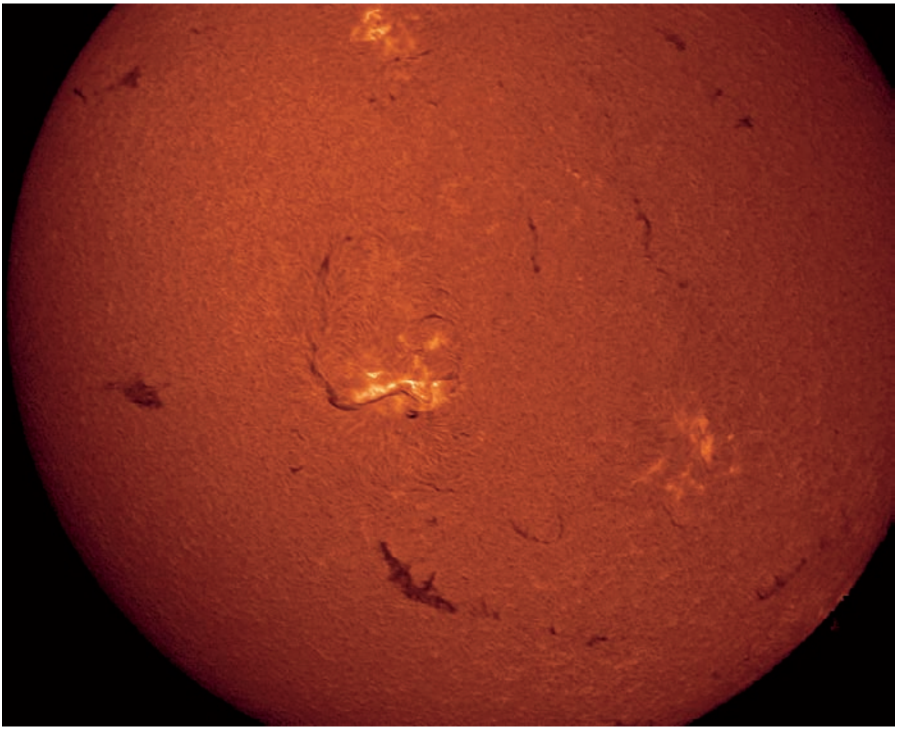


Figure 1.18. Solar disc showing cell structure by Larry Alvarez.



Bright Regions Figure 1.18 and most other photographs show various bright spots on the solar surface that are not usually apparent in "white light." Small regions, normally associated with sunspots, are called faculae. Slightly larger ones, usually seen independently, are known as plages. The largest of all, which can exceptionally be seen in "white" light, are known as solar flares. These are over a million degrees Celsius and are often associated with an ejection of mass from the corona, known as a coronal mass ejection and are the cause of auroras and electrical disturbances on the Earth and other planets with a significant atmosphere.

Considering a Purchase

It is a sad fact that many nighttime telescopes end up in attics and basements and are never used. Fortunately, in my case, the only abandoned ones are "beginner" telescopes that have been superseded but only after years of constructive and enjoyable use. Whilst I am a keen advocate of solar hydrogen alpha viewing, I would admit that it is not for everyone and would advise that any purchase be considered carefully. Whilst a "beginner" telescope for nighttime viewing costs little more than a couple of meals out for a family of four (and sometimes less), the high entry-level price of hydrogen alpha viewing is much more. The good news is that the price is coming down all the time.

This may be stating the obvious, but you need to consider how much use you will get from a hydrogen alpha telescope. Whilst busy people can be inventive about finding time for astronomy, just as financially challenged people can be inventive about obtaining funds for telescopes, if you have little free time in daylight, it is not for you. During summer, it is easy as I often view the Sun in early mornings and late evenings but, during winter, I am restricted to lunch breaks and weekends. On busy days, I just have time to do a quick “white light” observation.

Also, if you are a relative beginner, you would not have (yet) acquired the observing skills necessary to get the best out of hydrogen alpha viewing. You do not need to have a black belt in deep sky astrophotography but a few months’ practice at viewing the Moon will stand you in good stead. I would also strongly recommend some “white light” solar viewing using suitable filters. Although it has its limitations, it is good practice and many keen solar observers still make “white” light observations. For example, I always take a quick “rain check” of the solar disc in white light using binoculars on just about every day possible and make follow-up observations with a telescope if I see anything interesting. Beware of the safety considerations and seek advice from manufacturers. If you are unsure, you can use solar projection or only photography.

Just like nighttime observing, you will probably find that one size does not fit all! As I get questions from my (nonastronomer) wife about why I need another telescope, exactly the same applies to hydrogen alpha viewing. Smaller (hydrogen alpha) telescopes are not only cheaper but also more portable. My PST has accompanied me on business trips to New Zealand, the United States, Russia, Poland, and Brazil, where it attracted a lot of attention from a group of physics students.

Starting with a PST has the advantages of a low initial outlay and portability. It can be transported easily by car or even air. As a frequent bad back sufferer, sometimes my larger instruments can remain unused for several weeks, yet my PST is light enough to set up and use without assistance. Just as I use binoculars, armed with suitable filters, for quick “rain checks” of “white light” activity, a PST can be used to see if anything interesting is happening on the Sun in hydrogen alpha light (there usually is!) before carrying out a larger instrument. In my opinion, I consider it unlikely that the purchase of a much larger hydrogen alpha telescope would condemn a PST to the attic.

The purchase of a larger hydrogen alpha telescope (or even the MaxScope 40, which is the next one up in price) needs careful consideration. The MaxScope 40 has the same aperture as the PST, although it uses it more effectively, but was about double in price (at the time of writing). On the other hand, it is cheaper than a double-stacked PST and has only slightly worse performance. Indeed, before the PST, the MaxScope 40 was the entry-level telescope. In addition to having a lower bandpass of 0.7 Å, it overcomes the focusing disadvantages of the PST but still has similar restrictions of aperture.

Moving to the larger aperture models, the price increases to make them comparable to “flagship” nighttime telescopes. However, the additional light collected allows them to be used in worse conditions than the PST can be used and enables much more details to be seen and photographed.

For serious scientific observation by research establishments, keen amateurs, or societies, the MaxScope 60 is the minimum specification telescope recommended. However, for casual amateur, "browsing" with the PST and MaxScope 40 can produce surprisingly good results. Chapter 5 (by Nick Howes) demonstrates how amazing photographs can be achieved for comparatively little financial outlay.

This book describes each instrument in detail, with particular reference to the PST, which I own, and the MaxScope 90, owned by Larry Alvarez. However, I have included enough information on the other telescopes to guide you when making a purchase.

For reference, Chapter 4 lists the hydrogen alpha telescopes and filters available and Chapter 10 lists the current products and prices.

Whilst, I would unreservedly recommend the PST, having owned it since April 2005, when considering the purchase of anything else, remember that bandpass determines the contrast of the hydrogen alpha features and effective aperture determines the resolution of fine details. If in doubt, try before you buy.

One big issue is that each of us has different eyes. For example, my eyesight was good at the time of writing, especially for one so ancient, yet it is not sensitive to internal reflections, which can negatively impact the view for many observers. This may not only affect your choice of telescope but also any accessories that you may purchase.

Introduction to Calcium K Viewing

Whilst the hydrogen alpha emission line is the primary one used for solar viewing, there are a finite but large number of others. Some are well known to nighttime deep sky specialists, such as hydrogen beta.

However, after hydrogen alpha, the next most useful light for solar viewing is calcium K. This reveals a lower, cooler region of the solar chromosphere than hydrogen alpha light. You can view a network of ionized calcium emissions that result from solar cells sweeping through the magnetic fields. You can see plages, active regions, and magnetic storms. If you compare the differences between the hydrogen alpha and calcium K views in Figures 1.19 and 1.20, the plages are shown up more clearly, but the calcium K view neither shows prominences nor filaments as clearly as the corresponding hydrogen alpha view.

The calcium K line is close to the boundary between the visible light and the near ultraviolet, so many people are unable to see the details visually, and hence the calcium K telescopes are marketed primarily for photographic use. Using a broadband calcium K filter (8 Å bandpass) and 80-mm refractor, I have been able to capture some details on photographs but have been unable to see more than a pale mauve disc. A rather interesting difference is that calcium K viewing uses a wider bandpass. The Coronado Instruments use a bandpass of 2.2 Å and other suppliers use larger bandwidth, such as 8 Å.

It has been said by many that those of us blessed with the wisdom that can only come through an extended life on this planet are disadvantaged when it comes to calcium K viewing. As I am older myself (51 when the book was completed

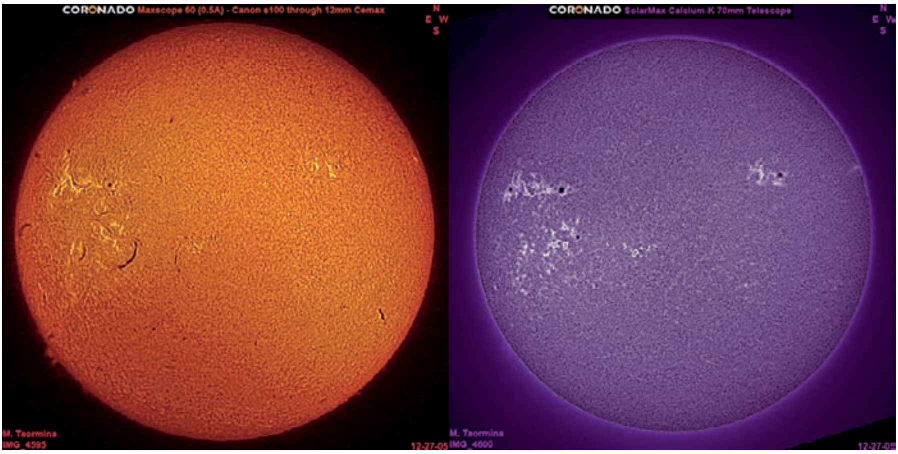
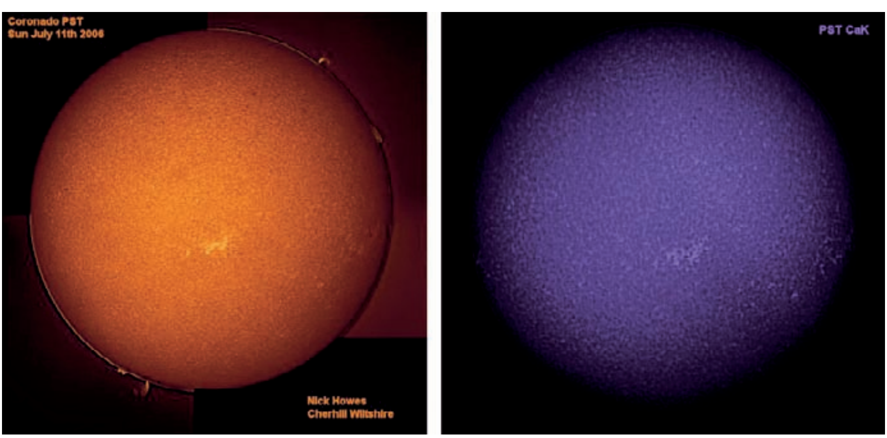


Figure 1.19. Sun in hydrogen alpha light and calcium K light imaged about the same time. Photo by Mike Taormina.

in 2006), I have found that the calcium K image is very difficult for me to see, so apparently simple operations like focusing are quite difficult. Nevertheless, some of the photographs taken, even with entry-level equipment, are more than capable of firing the imagination.

If we were close enough to other stars, we would be able to see their hydrogen alpha features, but only stars known as Population I would show calcium K features, as they have evolved from previous generations of stars that exploded as

Figure 1.20. Same idea but this one by Nick Howes using entry-level Coronado telescopes.



supernovae. Older (Population II) stars are composed almost entirely of hydrogen and helium and do not contain significant quantities of other elements, such as calcium.

Compared to hydrogen alpha viewing, calcium K viewing is in its infancy. At the time of writing, the Coronado models available were the following:

- PST CaK, based on the PST
- CaK 70, based on the MaxScope 70
- CaK 90, based on the MaxScope 90 and hot off the press
- Separate 60-mm filters

As calcium K features are more difficult to resolve than hydrogen alpha features, you will not notice rapid changes. However, monitoring every 20 minutes is recommended to check for changes.

Comparing Dedicated Telescopes Against Filters

At entry level, there is simply no choice. The PST is simply the cheapest instrument available from Coronado or anyone else for that matter. However, a filter system to fit either a 40- or 60-mm telescope is comparable in price to a dedicated telescope, whereas a separate 90-mm filter is slightly cheaper than a dedicated telescope and there are other products that could be worthy of consideration (see Chapter 6).

For a separate filter system by Coronado, it is necessary to add a T-Max tuner at the front of the telescope and a blocking filter at the end, near the eyepiece. This operation takes a matter of minutes, so it is not necessary to reserve a telescope specifically for solar use. The choice of T-Max tuner is dependent on the telescope aperture and the choice of blocking filter is dependent on the focal length of the telescope. A BF30 filter is recommended for telescopes with a focal length of more than 500 mm, but a BF15 (which is cheaper) can be used otherwise.

You may also need to buy an adaptor plate (usually about $100–$200) if the filter does not fit your telescope exactly. As several keen amateur astronomers, including myself, have an 80-mm refractor, it is a shame that Coronado does not make filters in this size but Coronado has a good ear to the marketplace, so I think it is only a matter of time.

The advantages of a separate filter system are the following:

- Can be used with more than one telescope of similar aperture, for example, a Meade ETX90 or long focal length 90-mm refractor
- Can be coupled with a high-quality "nighttime" telescope, such as an APO refractor or Maksutov reflector
- When traveling, it is not necessary to carry both a hydrogen alpha telescope and a nighttime telescope. You just bring your nighttime telescope and filters.

You can also bring a separate calcium K filter system if your telescope is large enough.

However, a dedicated solar telescope would normally be the first choice for a beginner and an experienced astronomer would normally buy separate filters with a high-quality telescope.

There are also filters available from other manufacturers. Some of the full aperture ones have a bandpass of 1.5 Å, so are not as good as the 1- and 0.7-A filters. Also available are those based on the Fabry–Perot etalon, which are placed near the end of the light path, near the eyepiece. They are flexible in that they can be used with more than one telescope and have also been used to double stack Coronado filters down to a limit of just under 0.5 Å.

For calcium K filters, the options are different, with broader band (8 Å) filters being available at lower price than the PST CaK. Having borrowed both from Nick, my personal preference is the PST CaK.

Observing Tips

Most of the observing skills you may have learned from nighttime astronomy are valid for solar hydrogen alpha (or calcium K) viewing. On one hand, it is harder because polar alignment is much more difficult without the Pole Star being visible but, on the other hand, there is no scrambling around the ground for loose screws or dropped accessories and lens caps that you get from dark site observing!

Precise polar alignment of an equatorial mount is not as necessary as for nighttime deep sky photography. It is simply a matter of convenience. Even when taking photographs, long exposure times are simply not necessary, given the amount of light that comes through the telescope. If you are observing from a familiar location, such as your backyard, you will know roughly where north is. You can also estimate an approximate fix by knowing that the Sun is roughly due east at 06:00, south (north in the Southern Hemisphere) at 12:00 and west at 18:00. Remember that you must adjust these times for any local “daylight savings” arrangements.

However, note that Larry Alvarez has a good suggestion in Chapter 3.

For purely visual use at low to medium magnification, an alt-azimuth mount is sufficient, although most low-cost camera tripods do not perform well at elevations greater than 30°. In practice, refinding the Sun at 10–15 minute intervals is not too difficult at low magnification, with wide fields of view. When the Sun is at 60° elevation (or higher), an equatorial mount really comes into its own. However, there are some high-quality alz-azimuth mounts that I have described in Chapter 2 that can be used with the entire range of Coronado hydrogen alpha telescopes.

I have included a separate chapter on astrophotography (Chapter 5), written by Nick Howes, but any stable setup is suitable for simple point-and-click photography using a domestic digital camera. As an aside, I have had some success at using this technique for nighttime photography of the Moon, brighter planets, and double stars.

Whichever telescope you use, it is best to get the widest field of view possible when finding the Sun. Not all of the Coronado hydrogen alpha telescopes are supplied with a finderscope. The PST has a built-in *Sol Ranger*, which is extremely useful and easy to use. Other Coronado telescopes use another type of finder (also confusingly called a Sol Ranger), which is supplied with some models and available as an optional extra with others. Finding the Sun without a finder is not impossible and is easier when the Sun is near the horizon, but it does take longer time without a finderscope. It is achieved by aligning the telescope's shadow onto the ground or a nearby background object and is shown in Chapter 2. In any case, it is best to use a long focal length, wide field of view eyepiece, such as a 32-mm Plossl, to find the Sun and center it in the field of view. This need not be a particularly expensive eyepiece, as you will normally use a shorter focal length (higher magnification) eyepiece for visual or photographic use.

When looking at the Sun (as the Moon at night), it is nice to get the "big picture" by showing the entire solar disc. Again, like the Moon, the Sun can vary in apparent size, with it being its largest when closest to the Earth in early January. It is worth remembering this when choosing eyepieces for photography when using the afocal projection method. Using the entry-level PST as an example, it has a focal length of 400 mm. A 5-mm focal length eyepiece gives a magnification of 80×. If the eyepiece has an apparent field of view of 50°, the actual field of view would be 0.625° or 37 arcminutes. This will always be enough to show the whole solar disc, but you will need constant adjustment to keep the entire solar disc in view. Also vignetting in many domestic digital cameras may mean that the eyepiece might show the entire disc but the camera may not.

I have discovered from nighttime viewing that some eyepiece types, like "Plossls," are excellent for visual use but not so good for photography. Similarly, long eye relief (LER) eyepieces are good for photography, even though they are not always so good for visual use. As a compromise, I have found that the Moonfish Group eyepieces perform well visually and photographically and also have a wide (70°) apparent field of view as well. Using higher quality eyepieces, such as the Meade 4000 or Televue series, can enhance performance further, but for the lower end of the Coronado range of equipment, these are expensive in comparison to the cost of the telescope. In fact, the higher end eyepieces cost more than a PST!

Coronado recommends their own CEMAX eyepieces that were developed specifically for solar viewing. Whilst they are more expensive than "budget" eyepieces, they are not disproportionably expensive compared to the telescopes. In the particular case of the PST, I am happy with the Moonfish Group eyepieces that I also use for nighttime use but I have bought a 12-mm CEMAX eyepiece and, on most days, found that it even outperforms the Moonfish Group eyepieces. I have also used it successfully to view Alpha Centauri, Venus, and Jupiter while away on business in Brazil.

The CEMAX eyepieces outperform similarly priced eyepieces of other types for solar viewing, which I have verified with my own tests and will outperform more expensive eyepieces on many telescopes. Chapter 2, in particular, contains a lot of details about which eyepieces and accessories can be used, because many amateurs are restricted by budget. I have carried out extensive tests with a variety of eyepieces and accessories. However, many specialists who own the larger Coronado hydrogen alpha telescopes, including some coauthors of this book, use the CEMAX eyepieces exclusively. When buying a larger Coronado hydrogen alpha telescope, one or more CEMAX eyepieces may be included in the base price, but it is worth checking with the distributor at the time of purchase for details. A CEMAX 2× Barlow lens is also available and I have found it especially useful with the PST.

The often-stated "rule" for nighttime viewing is that you should not use magnifications greater than twice the diameter of the objective. Well, rules are to be broken and I have often doubled this figure when viewing and photographing the Moon and brighter planets. For the PST, with an objective of 40 mm, I have found that magnifications above 100× do not yield more details than at 100× or lower and often give fuzzy images. Like nighttime viewing, this can also vary with conditions. Again, these conditions may not be immediately apparent to the observer. Sometimes, it is possible to see lots of details at low magnification and increasing it will blur the image. On the other hand, a close up at 60–100× magnification will often reveal detail not apparent at lower magnifications, especially with prominences. To complicate matters even further, you can get conflicting results visually and photographically.

Strangely enough, using larger aperture telescopes does not necessarily mean that the maximum magnification goes up in direct proportion to the aperture. For example, the MaxScope 70 seems to have a maximum magnification of around 140×.

For a hydrogen alpha session, I always start off with the "whole disc" view and usually take a photograph. Assuming that it comes out reasonably well after processing, it goes onto my Web site and is included in my "diary" and hydrogen alpha gallery. I then look at the prominences and any active regions on the inside of the solar disc in more detail using higher magnifications. Again, I will usually take photographs, although not all of these are successful.

Note, however that the popular webcam form of imaging will not capture the entire solar disc. Nick has recommended some tools in Chapter 5 to get round this.

If I am blessed with good viewing conditions and a relaxing day (or at least some extended period), I like to revisit the Sun. Using a PST, the prominences, in particular, can change quite rapidly.

For calcium K use similar principles apply with the following exceptions:

- There is less light gathered even by broader band filters with a bandpass of 8Å; larger apertures help but can be prohibitively expensive.
- Many people, especially the older generation, are less sensitive to the calcium K light wavelength, even if their eyesight is otherwise good.
- Use some sort of shroud when observing/imaging the Sun in calcium K light.

As a result, consider using lower magnifications for calcium K viewing/ photography.

Recording Observations

The most obvious way to record observations is by photography. Even a simple domestic digital camera is capable of recording many of the sunspots. However, a lot of my "white light" solar viewing is undertaken under poor conditions, where any photograph could show more cloud than solar surface. As I have also found out with lunar and planetary photography, trying to take shots in gaps between fast moving clouds is tricky to say the least.

"White light" observation lends itself well to drawing and, not being particularly artistic, I find it easier to draw sunspots using computer-based drawing tools. See Figure 1.3 for an example. However, I have recently used a hydrogen alpha photograph as a blank for solar drawings and made sure that I include a larger portion of the solar disc than before.

I also like to record the days where there were no sunspots, so the result is a "blog"-style observation diary, which also includes nighttime observations. I place these online at http://freespace.virgin.net/pugh.pm/ObservationsMenu.html, where you can access the latest observations plus as many older observations as I can fit into my Web site space. As well as including sunspot details, I also record the conditions under which I viewed them.

Whilst drawing is good for making good records of what I can see through binoculars or small telescopes, it starts to get difficult when using larger instruments, with more precision, such as my 127-mm Maksutov. More umbral/penumbral shadings are visible, as are faculae. Here, using digital photography is recommended, but there have been many good drawings made of the Moon and close-ups of lunar features by amateurs. Drawing certainly is not one of my skills, but I certainly would not discourage anyone from having a go.

One technique where there is a lot of room for experimentation is to manually enhance digital photographs with features that you spotted visually but did not record.

The "blog"-style descriptions are useful for hydrogen alpha viewing; you can use them to describe features that did not come out in the photographs. Using advanced astrophotographical techniques, such as those described by Nick Howes in Chapter 5, enables you to capture details that you cannot spot with the visual view. However, I recommend that you record the time of the photographs to the nearest 5 minutes, as hydrogen alpha detail can change quite rapidly.

On cloudy days, as well as catching up with image processing and trying new techniques, it is nice to view through your records.

History of Coronado Instruments

Coronado Technology Group was founded by David Lunt and Geraldine Hogan from their home in Pearce, AZ. David had been working in research for many years developing ultra narrowband filters. He and Geraldine founded Coronado with the intention of making this technology accessible to amateurs.

In 2000, Coronado moved to Tucson, AZ.

In October 2004, Coronado was bought by Meade Instruments, who are well-known worldwide.

David passed away in January 2005 and his wife, Gerry, continues to organize the "Hands on the Sun" conference each October.

In 2005, the first Calcium K telescope, the PST CaK was produced, followed by the CaK 70 in November.

The CaK 90 dedicated telescope and SolarMax 60 CaK separate filter system were introduced in the summer of 2006.

I expect the future of Coronado and, with it, amateur solar viewing to be at least as exciting as its history.

Outreach Programs

Part of the objective of astronomy, not just for myself but also for many others, is to share it with the members of the nonastronomical public. I have participated in such programs and even organized some. I have shown the Moon and planets to a local primary school that my daughter used to attend and I have also shown the Sun in "white light" to the same audience and been amazed by the interest shown by such young people. I have been careful to restrict solar viewing to the over-nines for safety reasons. I am ashamed to admit that pressure of work, not to mention the writing of this book (!!), has prevented me from doing the same thing with hydrogen alpha and calcium K.

However, I have managed to carry out similar sessions at my workplace and I even managed to show the solar eclipse when we had some business visitors from India. Quite a lot of interest has been shown by those who have seen the ads and almost as many who were curious passers-by.

I also ended up doing an impromptu session for several physicists while away on business in Brazil.

It is one of my beliefs that public science facilities would benefit from one or more hydrogen alpha telescopes and that solar viewing would be a useful part of the school physics curriculum. It is one of the few branches of astronomy that can be carried out during the school days.

Calcium K facilities need much more thought and planning but a well-funded facility would include some sort of projection capability, such as an electronic eyepiece.

CHAPTER TWO

Personal Solar Telescope*

The PST is the entry-level hydrogen alpha telescope in the range of Coronado equipment. Its initial price was $499 in the United States and £499 in the United Kingdom. By November 2005, it had already lost 10% of its retail price. This was comparable to the price of a serious "nighttime" telescope, such as a 127-mm Maksutov or 200-mm equatorially mounted reflector. It had broken through a "psychological" cost barrier of several amateur astronomers who would otherwise be inhibited from spending twice the money or more on any other models from Coronado or one of the few competitors. However, unlike serious nighttime telescopes it does not come supplied with a mount, so you need to consider the various mounting options.

It has been specifically aimed at the budget market, so some of its features are simplified in order to reduce costs. Examples of this are the following:

- Filter (etalon) placed near the eyepiece and not the objective
- Focusing by changing the position of the prism and not the more usual focusing arrangement of larger telescopes
- No tube rings, camera tripod attachment only
- Energy rejection filter placed in the objective

* Chapter written by Philip Pugh, with contributions by John Watson (making a mounting bracket) and Cameran Ashraf (double stacking).

It is a completely different design to the MaxScope series to which most of the Coronado telescopes belong.

For many people, including myself, it was an introduction to solar hydrogen alpha viewing. It was also the first time I had seen prominences, filaments, plages, flares, and faculae.

There was also reason to believe that at least some individual instruments had a bandpass of less than 1 Å, maybe even as low as 0.7 Å. Perhaps, Coronado are/were more cautious about quoting bandpass figures than other manufacturers.

At the time of writing, there was no serious competitor for the entry level into the market.

Facts at a Glance

Aperture (mm)	40
Focal length (mm)	400
Bandpass (Å)	1
Bandpass with double-stacked filters	0.6
Weight (lb)	3

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in Chapter 10.

Physical Description (PST)

It has a 40-mm objective lens with 400-mm focal length and comes supplied with a 12.5-mm Kellner eyepiece, giving a magnification of 32×. It also comes with a built-in solar finder (called a Sol Ranger). It has a thread that can be used for attaching to a camera tripod. The tube assembly is light (3 lb). Despite the light construction, it is made of milled aluminum, rather than plastic. Only objective shroud and cap and part of the eyepiece attachment are made of plastic. This is certainly not dissimilar to most quality nighttime telescopes.

The objective is an achromat made of BK-7 glass. There is no point in providing an apochromatic objective because the light viewed by the PST is of the same wavelength within a very low tolerance (monochromatic light), so it will come to focus at the same point. Using an achromatic objective is much cheaper.

You can order a tabletop mount and carrying case as extras. It comes with a small booklet of instructions.

Figure 2.1 shows the PST from the side view. The objective and eyepiece attachments both have lens caps. The focusing knob is an alternative to the more usual "rack and pinion" focusing arrangements of most telescopes and has to be screwed to the left or right to adjust the focus. One of the few limitations of this telescope is that the focusing range is much less than with many others, making it difficult/impossible to use with some Barlow lenses. However, it works comfortably with the Coronado CEMAX 2× Barlow lens. Further, flexibility can

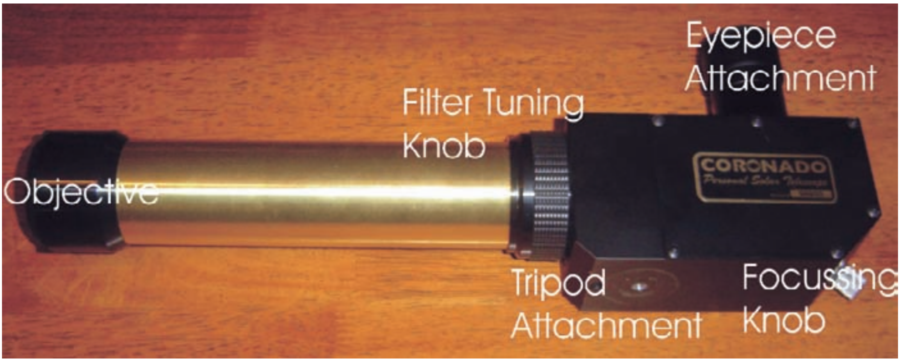


Figure 2.1. Side view of the PST.

be achieved by placing an eyepiece near the top of the attachment, rather than the (more stable) bottom. However, this requires tight screwing and you must be careful not to adjust the focus by exerting pressure on the eyepiece with your eye on a camera. Focusing is actually achieved by the movement of the right angle prism.

The objective has a thread to attach a secondary filter. See "Recommended Accessories" section for details.

The filter used for hydrogen alpha is called a Fabry–Perot etalon that isolates light at 6563 Å. Its tolerance is quoted at < 1 Å – essential for viewing both limb prominences and disc detail. So, depending on the exact position of the filter-tuning knob, a typical range for the light to pass through is 6562.5–6563.5 Å. Unlike other similar products manufactured by Coronado, the etalon is housed nearer the eyepiece. This is a slight disadvantage, compared to the MaxScope 40, as it reduces the effective aperture of the PST to about 30 mm. However, this change was undertaken to reduce the cost.

Note that the competitors of Coronado sell hydrogen alpha filters with a bandpass of 1.5 Å. They are capable of showing some prominence detail but are not capable of showing much on the surface, although (to be fair), they do not make any extravagant claims.

By contrast, the MaxScopes 40, 60, and 90 have a bandpass of 0.7 Å and the MaxScope 70 has a bandpass of 0.8 Å.

There is strong evidence but no conclusive proof that Coronado is cautious about quoting bandpass figures and there is some variation between individual instruments of the same model.

The filter-tuning knob is used to adjust the exact wavelength of light that is allowed through the telescope. According to the literature, different settings can be applied for optimum performance for solar disc detail and prominences. However, the particular telescope I have (and another I have tried) usually shows both prominences and disc detail at the same setting or it may sometimes require minor adjustment. It can be turned through a range of about 130°. It may need to be used due to changes in atmospheric pressure or altitude.

The PST has a "sweet spot" across the central third of the disc, where the image is fully tuned and detailed. The PST can be moved slightly so that other regions fall on the sweet spot in turn or the tuner can be adjusted to shift the sweet spot up or down. Some hydrogen alpha telescopes appear to have a "sweet band," but this is not apparent in my use of it. There is also a very slight hint of "ghosting" at the top limb of the Sun, but most viewers (including myself) do not notice it. Note that the idea behind supplying the Kellner eyepiece was to reduce the ghosting, but it does not appear when I used my normal range of "nighttime" accessories. When the PST is tuned away from the hydrogen alpha wavelength (6563 Å), the view is similar to a "white light" sun except that it appears bright red.

The tripod attachment is the typical/standard "screw in" attachment (1/4 inch × 20 threads per inch) that allows the PST to be used with a standard camera tripod. As this causes metal-to-metal wear (as can be seen in the photo), it is advisable to use some sort of shield, such as plastic or cardboard if you are going to use this method often.

Figure 2.2 shows the top view. The only feature not visible from the side view is the solar finder (Sol Ranger). My first reaction on seeing it was that it was some sort of gimmick, but I was pleased to see that it actually worked very well. Even better, the Sol Ranger is actually better than those supplied with Coronado hydrogen alpha telescopes higher up the range. This chapter includes instructions how to use it to find the Sun and center it into the field of view.

Figure 2.3 shows the supplied eyepiece, which is a Kellner eyepiece of 12.5-mm focal length, giving a magnification of 32× when used without a Barlow lens or other type of image amplifier. Whilst it is not of particularly poor quality, other eyepieces are more likely to be of use, such as Plossls, which are often part of many amateur astronomers' equipment. The supplied eyepiece does little to "sell" the telescope to the user. Had I not owned alternative eyepieces, I would have been disappointed. I also did "head-to-head" tests of the supplied eyepiece and my Moonfish Group 15-mm SWA on Saturn using my Skywatcher 127-mm Maksutov, and the Moonfish Group eyepiece won as it provided better views.

Figure 2.2. Top view of the PST.

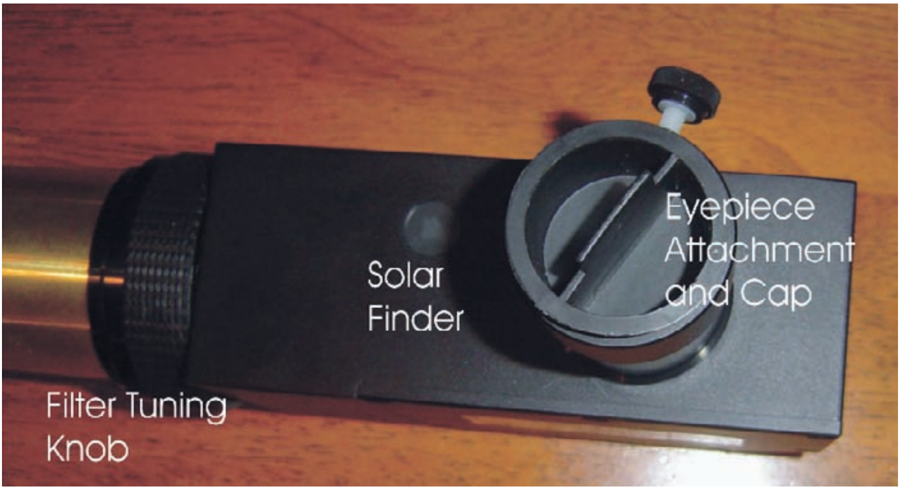


Figure 2.3. Supplied eyepiece.

The difference was particularly noticeable when I cranked up the magnification using a Moonfish Group 3× Barlow lens.

In models supplied around November 2005, the 12.5-mm eyepiece was replaced by one of 20-mm focal length. This is of more use for finding the Sun and centering it in the telescope's field of view but of less use for actually viewing or photographing the Sun.

How to Store

Perhaps rather appropriately, I store it in a champagne box from a bottle given to me for my 50th birthday, for which I received the PST from my wife, Helga, and daughter, Marcela.

I also wrap it in "bubble wrap" for transportation when carrying it by air. It fits nicely in hand luggage.

A carry case is also available as an optional extra. It is shown in Figure 2.4.

Figure 2.4. PST hard case.

This is available from Coronado or their dealers. There is ample room for the PST and its accessories, including a set of eyepieces and a double-stacking filter.

Mounting Options

The lack of tube rings or other suitable attachment means that it cannot be easily attached to an equatorial mount, which is necessary to get the best from it. By a complete stroke of luck, the tube rings on my Skywatcher Startravel 80 telescope come with a thread which I can use to "piggyback" the PST on top of it. This enables me to get a more stable foundation for digital photography and use of higher magnifications up to 100×.

This section discusses the mounting options for the PST. The main mounting options are the following:

- Mounting the PST on a camera tripod (many of these are available on the market, but I used a simple one bought from a high street "camera" shop)
- Mounting the PST with another telescope by piggyback method
- Making your own adaptor plate to attach to a mount of your choice
- Using the MALTA tabletop mount

There are several tripods and mounts available from astronomical suppliers that use the standard camera-type attachment. The AzTech Manhattan and AC562 tripods are discussed in the "Recommended Accessories" section of this chapter. Another example is the Manfrotto range of tripods.

Mounting the PST on a Camera Tripod

Using a budget camera tripod from high street stores is OK for purely visual use, but it is not particularly steady for photographic use. However, I have managed to take some full disc solar photographs using this method, especially when traveling abroad with the PST, when it is not practical to bring a heavier mount/tripod combination. For many types of camera tripod, it is unsuitable for use when the Sun is greater than about 30° above the horizon.

Depending on the camera tripod, this setup should take about 10 minutes for a novice user and 2/3 minutes for an experienced user.

1. By the means appropriate to your particular tripod, remove its retaining block. In Figure 2.5, the small lever at the top right is used to release the retaining block.
2. Attach the retaining block to the tripod attachment of the PST. Be careful not to scratch the base of the PST. You may choose to use a piece of card or plastic to avoid the effects of metal-to-metal contact (Figure 2.6).

Figure 2.5. Mounting the PST on a camera tripod, sequence 1.

Figure 2.6. Mounting the PST on a camera tripod, sequence 2.

Figure 2.7 shows how it should look when complete. It is preferable for you to align the retaining block to be parallel with the telescope tube.

3. Place the retaining block (attached to the PST) back in the tripod and secure. Note that this step should not be rushed, as failure to carry it out correctly can cause damage to your PST (Figure 2.8).

You are now ready for the next step, which is finding and viewing the Sun. See "Finding the Sun" section for details.

Figure 2.7. Mounting the PST on a camera tripod, sequence 3.

Figure 2.8. Mounting the PST on a camera tripod, sequence 4.

Mounting the PST on an EQ1 Equatorial Mount

Use this procedure to mount the PST on top of a telescope (called the "host" telescope) on top of an EQ1 mount. This is commonly known as the piggyback method and will be applicable to other mounts and telescopes as well. This is steady enough for photography, although a heavier mount, such as an EQ3, is even better and it can be used around midday during the summer when the Sun reaches its greatest elevation (about 73° from the Northern United States and southern Europe and around 60° from northern Europe and Canada).

The equatorial mount needs to be polar aligned. This is more difficult during the day, as the Pole Star (Polaris) is not visible. If you are viewing from home, you should have some rough idea where north is and Larry Alvarez in Chapter 3 has a good suggestion.

Solar viewing does not require such precise alignment as long exposure deep sky photography, because even hydrogen alpha telescopes provide enough light to make long photographic exposures unnecessary and often counterproductive. However, approximate polar alignment helps in re-finding the Sun if you are out for a long session, where you hope to monitor the changes in the Sun over a longer period.

Depending on the equatorial mount, this should take about 15 minutes for a novice user and 5 minutes for an experienced user.

1. Bring the telescope on which you wish to piggyback the PST to the required viewing position. Notice that on the piggyback attachment, I have placed a card. The need to do this (or not) becomes apparent when you get to Step 3 (Figure 2.9).
2. Place the PST over the piggyback attachment and turn the PST until it is aligned with the "host" telescope and the PST is securely attached without much "wobble." You may need to choose a piece of card or plastic to avoid the effects of metal-to-metal contact (Figure 2.10).

It is preferable to align the PST to be in parallel with the host telescope tube, as this makes pointing and control easier. If it does not align properly with the "host" telescope and is not secure, unscrew the PST, place a card of suitable thickness on top of the piggyback attachment, and try again (Figure 2.11).

You are now ready for the next step, which is finding and viewing the Sun. See "Finding the Sun" section for details.

Using a Mounting Bracket for the PST

As far as I know at the time of writing, there are no purpose-built mounting brackets available commercially, at least not in the United Kingdom. Whilst an EQ1 mount is OK for simple photography and visual viewing, you may want to use the greater stability and features of another mount, including those with electronic finding and tracking capabilities.

John Watson used the example below. He provided the sketches to an enthusiast with a machine shop, who manufactured it (Figures 2.12–2.14). The price was £50.

Figure 2.9. Mounting the PST on an equatorial mount, sequence 1.

Figure 2.10. Mounting the PST on an equatorial mount, sequence 2.

Figure 2.11. Mounting the PST on an equatorial mount, sequence 3.

Figure 2.12. Mounting bracket for the PST Part 1. Courtesy of John Watson.

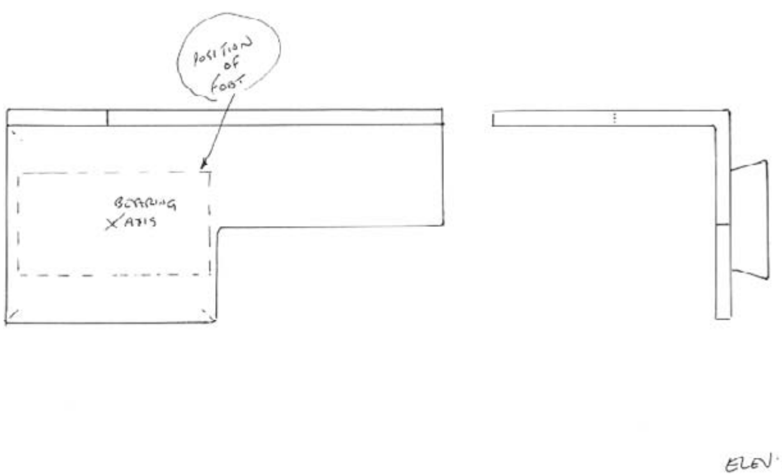


Figure 2.13. Mounting bracket for the PST Part 2. Courtesy of John Watson.

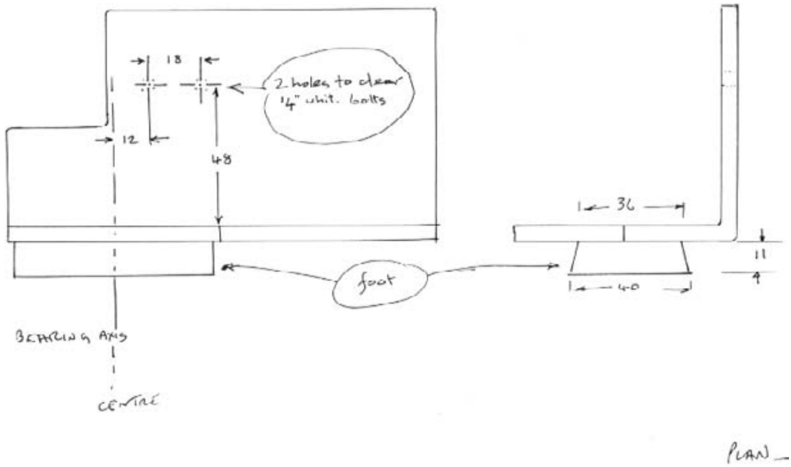
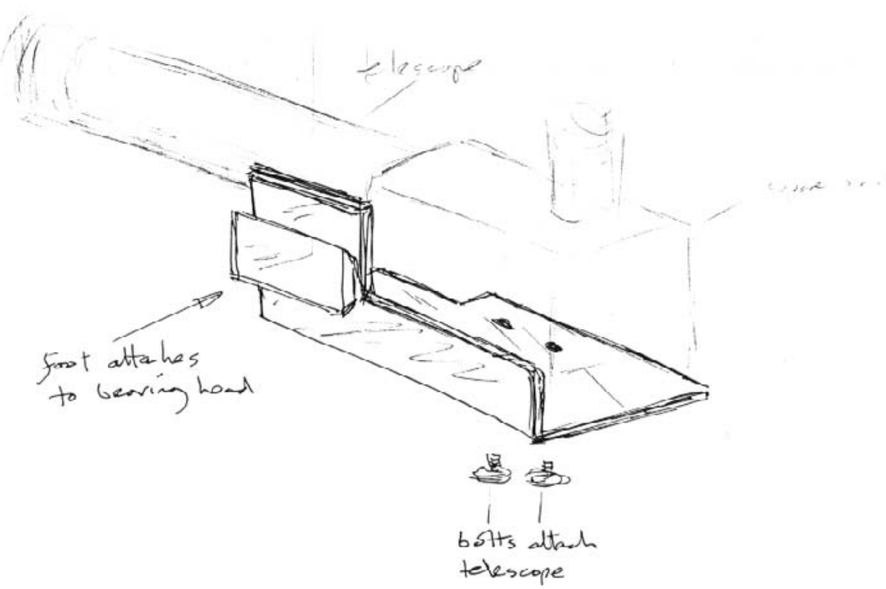


Figure 2.14. Mounting bracket for the PST Part 3. Courtesy of John Watson.



The PST is held to the mount with a standard camera “flash bracket screw,” which you can get at most photographic shops (basically it is a 1/4 inch Whitworth-threaded bolt with a knurled knob). Only one is needed in practice, although the assembly allows for two.

Figure 2.15 shows the finished bracket made of mild steel.

To use, attach the block to the EQ3 mount by the standard procedure using the retaining screws of the mount (Figure 2.16).

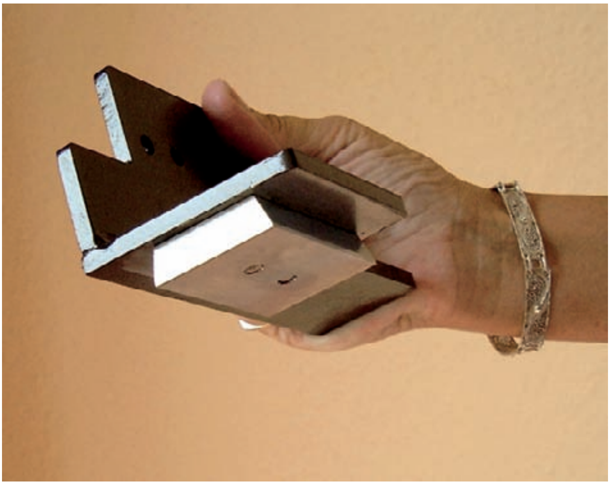


Figure 2.15. Mounting bracket for the PST Part 4. Courtesy of John Watson.

Figure 2.16. Mounting bracket for the PST Part 5. Courtesy of John Watson.

Figure 2.17. Mounting bracket for the PST Part 6: Fitting the PST to the mount. Courtesy of John Watson.

Next, place the PST in the bracket and use the “flash bracket screws” to attach the PST to the mount. For heavier telescopes, I would suggest checking the balance but this is unlikely to be a problem with such a light telescope on a heavy mount (Figure 2.17).

The final result is an equatorially mounted PST (Figure 2.18).

MALTA Mount

The Mount Manual ALTitude Azimuth (MALTA) is a tabletop mount that can be purchased separately from Coronado (Figure 2.19). I have to admit to a level of cynicism of tabletop mounts in general but this one stood up to scrutiny. You do not get the same stability as you do with a heavy-duty equatorial mount but, at least, this mount introduces no noticeable instability over and above that of the table being used.

Unlike many tabletop mounts, you can actually use it for viewing the Sun when it is near the zenith.

The actual procedure for mounting the PST on the MALTA mount is quite tricky, so frequent changing of mounts is not recommended and you should either select to use it as your primary mounting option or as a portable option for air travel.

The MALTA mount can also be used with the MaxScope 40, which is the same weight as the PST. The MaxScope 60 has the fittings to attach it to the MALTA mount but, being heavier, it is not as stable as the PST and MaxScope 40.

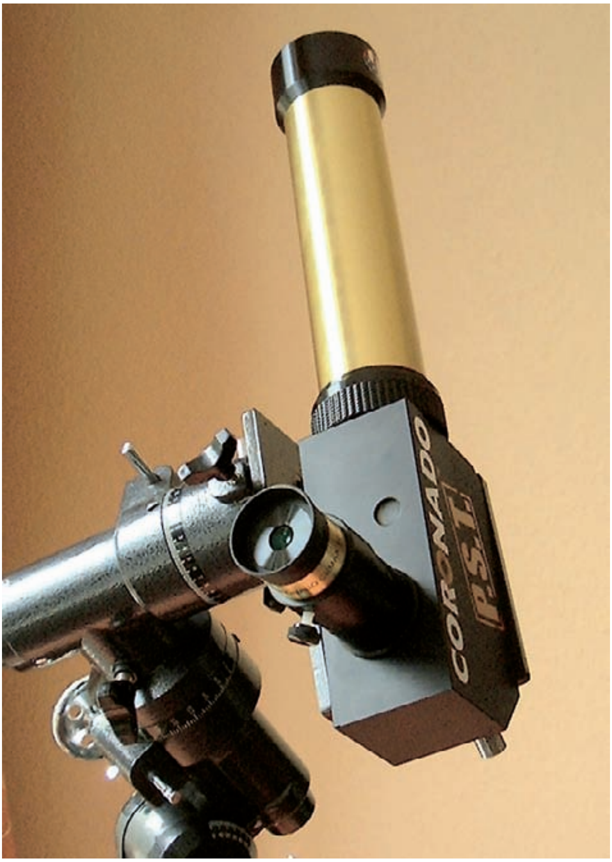


Figure 2.18. Mounting bracket for the PST Part 6. Courtesy of John Watson.

Mounting the PST on the MALTA Mount

Use this procedure to mount the PST on the MALTA mount. Before you begin, detach the PST from any other mounts.

This may take about 10 minutes for the first time, but you get quicker with practice. Lining up the telescope with the retaining screws is the hardest bit.

1. Remove the two retaining screws from the mount. It may be stating the obvious but keep them in a safe place.
   Figure 2.20 shows the MALTA mount without a telescope attached. Notice the two locks (altitude and horizontal) that are used to stabilize the position. These need to be twisted to the right to loosen and to the left to tighten.
2. Tilt the MALTA mount so that the PST attachment is vertical and the altitude lock is horizontal (Figure 2.21).
3. Place the PST against the mount and align it against the holes. Push the screws through and slowly tighten them (Figure 2.22). (This is a bit tricky.)

Once the screws are tight, the PST and MALTA mount are ready for use.

Figure 2.19. PST on the MALTA tabletop mount.

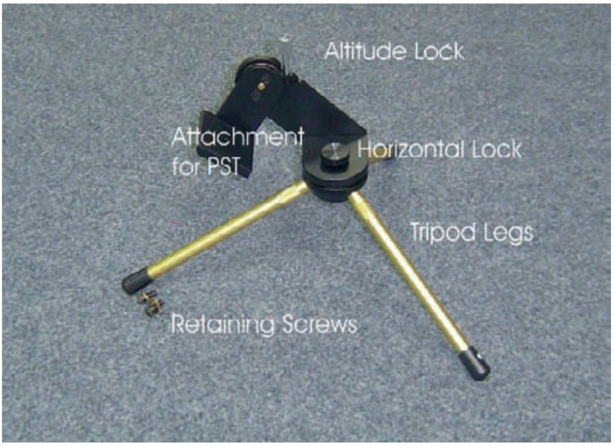


Figure 2.20. MALTA mount setup, sequence 1.

Finding the Sun

Use this procedure to find the Sun. Before you begin, mount the PST ready for use and remove the objective cap and attach an eyepiece.

Note: This example uses an EQ1 mount. The details will change if you are using different mounts. Consult the instructions for your mount for details.

It is recommended that you use a long focal length eyepiece with a wide field of view when finding the Sun. You can change it later for a different eyepiece, with various accessories later, if desired. My personal choice is a 15-mm Moonfish Group SWA eyepiece, but I find that a budget 32-mm Plossl eyepiece also works well.

Figure 2.21. MALTA mount setup, sequence 2.

Figure 2.22. MALTA mount setup, sequence 3.

This may take about 15–20 minutes for the first time, but you get quicker with practice. As an experienced user, I have done it in less than 1 minute and as much as 5 minutes, depending on how accurate my initial guess (approximate alignment) is, at the time. It is usually quicker when the Sun is near the horizon than when it is at the zenith, but the extra time taken to find the Sun when near the zenith is worthwhile, as you get clearer pictures.

1. Obtain approximate alignment by making the telescope's shadow as narrow as possible. You can use a piece of paper (as shown in Figure 2.23) or a card to make it clearer.

Figure 2.23. Finding the Sun, sequence 1.

Figure 2.24. Finding the Sun, sequence 2.

2. Use the fine-tuning controls of your mount to align the telescope's shadow, as necessary, so that it is as small as possible. Check the solar finder (Sol Ranger) to see if the small solar image appears. Check Step 3 for an example of how this should look (Figure 2.24).
   Note: This step is actually the hardest and requires a lot of practice, particularly for those who have never used their mount before for "white light" solar viewing.
3. When the Sun appears in the solar finder, use the fine-tuning controls until the Sun appears as near to the center of the finder as possible.

◇ Figure 2.25 shows the solar image near to the center of the finder. If you have a wide field of view (by using a long focal length eyepiece), you should now be able to see the Sun through the eyepiece. Figure 2.26 shows the solar image almost exactly centered.

Figure 2.25. Finding the Sun, sequence 3.

Figure 2.26. Finding the Sun, sequence 4.

◇ Figures 2.27 and 2.28 show examples of what you might see.

The second example shows a more representative view of what can be seen using superior photographic techniques and equipment. Nick has contributed Chapter 5 entitled “Imaging”.

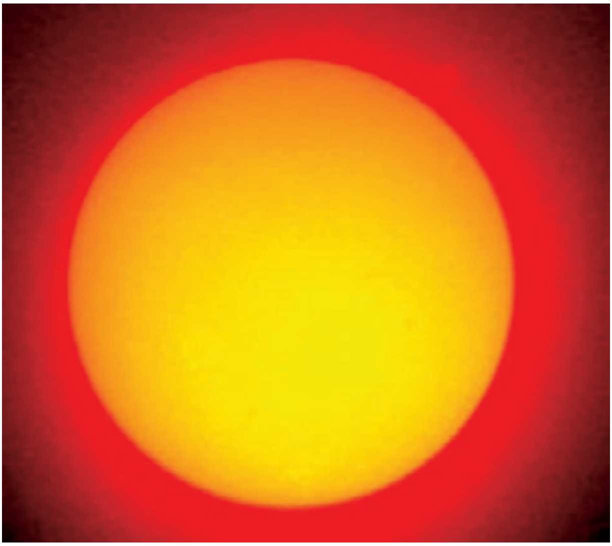


Figure 2.27. Sample view through the PST using a digital camera.

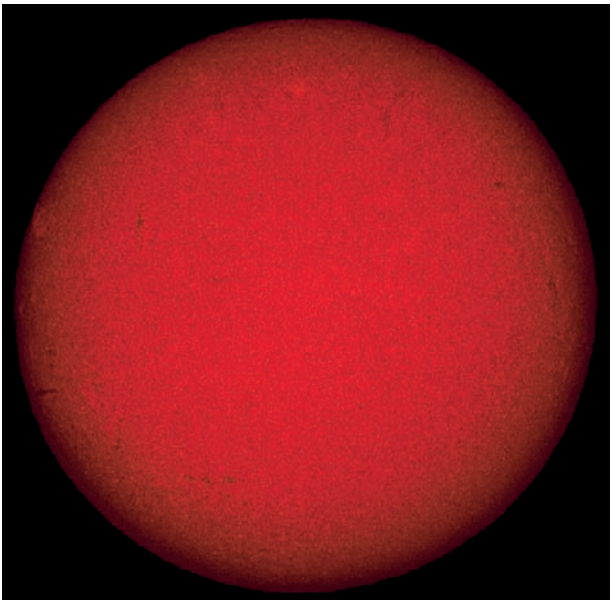


Figure 2.28. Sample picture taken on 27 December 2005 by Nick Howes using PST.

Recommended Accessories

The accessories recommended by Coronado that are available from their distributors are the following:

- PST hard case (shown and described under "How to Store" section)
- MALTA mount (shown under "Mounting Options" section)
- SolarMax 40 filter + T-Max tuner for PST and MaxScope 40 double stacking (see below)
- Aztech Manhattan tripod (see below)
- AC599 Solarmate shade (see below)
- CEMAX hydrogen alpha eyepieces (see below)
- AC645 polarizing filter (see below)

SolarMax 40 Filter + T-Max Tuner

This is used to allow double stacking of the filter to reduce the PST's bandpass from 1 to 0.6 Å. It screws into the thread. Note that it can also be used with the MaxScope 40 to reduce the bandpass from 0.7 to 0.5 Å (Figures 2.29 and 2.30).

Double stacking is described in Chapter 1. Unlike other Coronado hydrogen alpha telescopes, it does not need to be sent back to the Coronado factory for precise filter matching.

Figure 2.29. The SolarMax 40 filter. Photo courtesy of BCF Telescope House.

Figure 2.30. SolarMax filter with blocking filter (blocking filter not used with PST).

Figure 2.31 shows a view of the Sun through a double-stacked PST. It is certainly true that you can see (and photograph) more detail on the solar disc and less light passes through it. This makes it a bit more difficult visually but improves the photographs using a digital camera. The drawback is that prominences tend to be obscured by a double-stacked filter. I feel dubious about the benefits of double stacking a PST, especially because the filter and T-Max tuner were

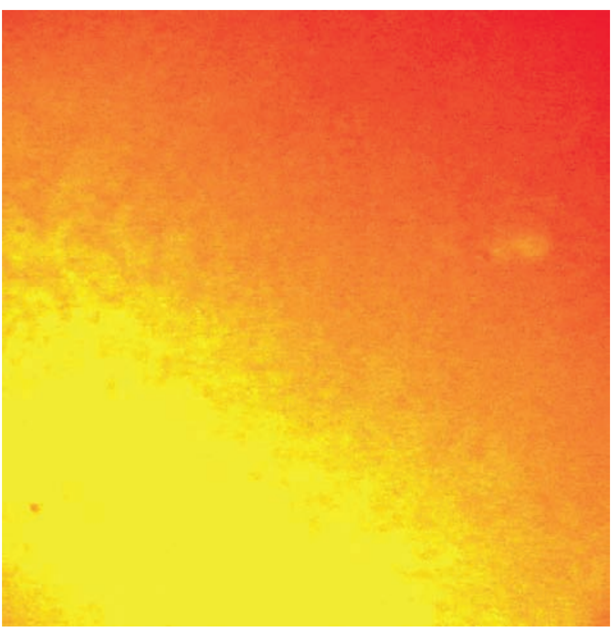


Figure 2.31. Solar surface shown through a double-stacked PST, using the CEMAX 12-mm eyepiece and 2× Barlow lens.

(at the time of writing) more expensive than the MaxScope 40 and set of CEMAX accessories. Although my personal impressions of double stacking a PST were less than encouraging, Cameran Ashraf, who has a more positive take on it, has contributed a section at the end of this chapter to provide strong photographic evidence to the contrary. Certainly, anecdotal evidence is in favor of double stacking the larger Coronado instruments.

Note that triple stacking has been tried but is not recommended by Coronado. Too little light gets through and only a little improvement in contrast has been observed.

For some examples of double stacking using more sophisticated photographic methods, please refer *Double Stacking a PST by Cameran Ashraf* section at the end of the chapter.

Aztech Manhattan Tripod

This is an alz-azimuth mount, which is supplied with either a wooden or an aluminum tripod (Figure 2.32). This offers an alternative from the camera tripod setup and the various equatorial mounting options, described above. The mount solves the problem of many alz-azimuth mounts in that it allows observation of the Sun when near the zenith.

The head (same on both models) is made of steel with the reinforced base being 6-mm thick allowing it to carry even the heaviest of small telescopes. However, this is not a consideration with the PST, which only weighs 3 lb. The alt-azimuth and altitude bearings are made of solid stainless steel with a smooth piston-fit alt-azimuth bearing. The free turning feel of both the azimuth and altitude axis can be precisely varied to the needs of the telescope by instantly adjustable thumbscrews.

Figure 2.32. AzTech Manhattan tripod. Photo courtesy of BCF Telescope House.

The cradle and head can be separated for quick set up and storage. This is accomplished by simply loosening the single alt-azimuth lock screw. The Manhattan head is finished in black and is supplied with all fastenings.

Figure 2.33 shows the mount head. There are two slots for the PST to be attached through.

An alternative is the AzTech AC562 mount, which can also support heavier telescopes such as the MaxScope 60.

Figure 2.34 shows a Revelation 80 telescope mounted on a Manhattan tripod.

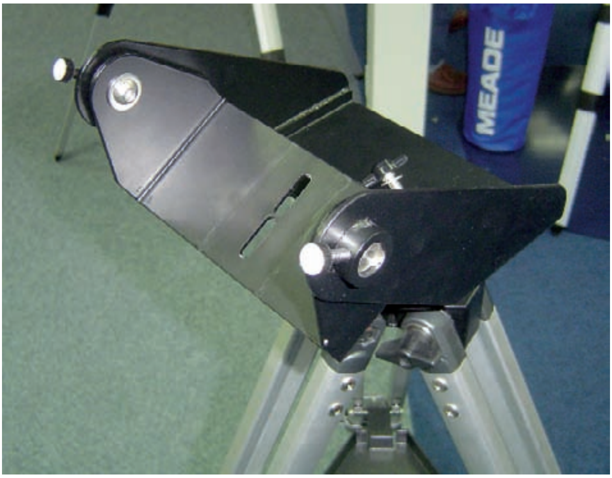


Figure 2.33. Manhattan mount head.

Figure 2.34. Revelation 80 telescope on a Manhattan mount.

Figures 2.35–2.37 show the AC562 mount and tripod together with the MaxScope 60 with the block. Although the MaxScope 60 is somewhat larger than the PST, it (and the MaxScope 40) uses the same mounting options as the PST. The only difference is that the MaxScope 60 is twice as heavy and requires a more solid mount/surface, and the block needs to be screwed more tightly. I did feel rather concerned that there was only one screw to attach the telescope to the mount. Given the cost of these instruments, this could be a worry.

Figure 2.35. AC562 mount.

Figure 2.36. AC562 head.

Figure 2.37. MaxScope 60 with block for AC562.

AC599 SolarMate Shade

This combined observing shade and eyepiece holder offers an option of improved observer comfort by minimizing glare. A telescope offering a moderately dim eyepiece view like the Coronado PST performs significantly better in terms of contrast and detail if steps are taken to reduce local glare. This glare shield is designed to cast a perfect shadow over the eyepiece region of the telescope and create a mini-environment for the observer to ensure that the eyes are always in a comfortable shadow when near the eyepiece. The SolarMate is easy to fit and requires no tools. It simply fits underneath the PST between the tripod and the base of the PST (Figure 2.38). On the rear face of the SolarMate is a panel of useful facts about the physics of the Sun. The shield can also hold three eyepieces conveniently to hand; however, in this role it is only effective up to about 70° altitude. This is never a problem from the United Kingdom, but can be from parts of the United States at midday near the summer solstice. However, discomfort due to heat is more likely to be a more significant factor! The SolarMate is made of lightweight aluminum and is finished in durable black resin powder coat.

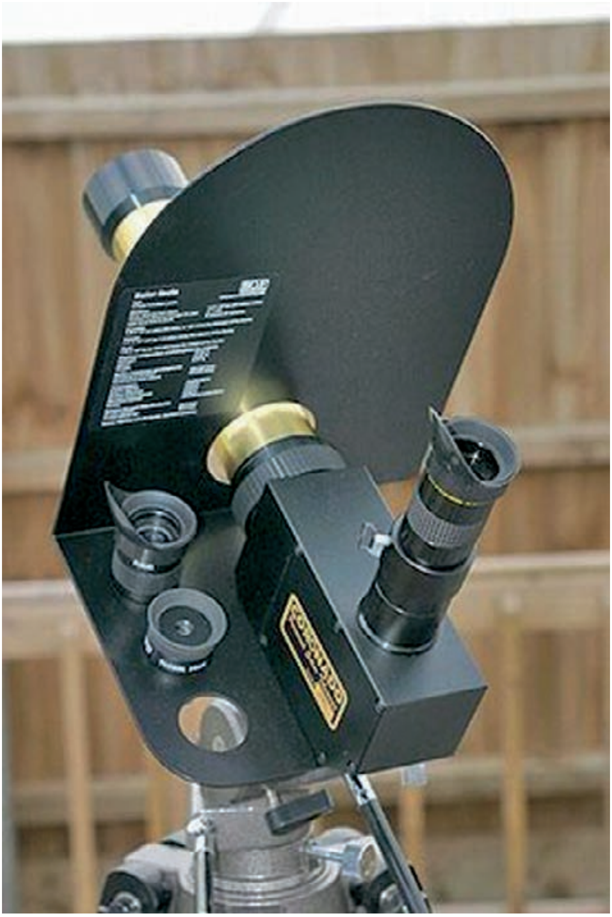


Figure 2.38. The SolarMate observing shade for Coronado PST. Photo courtesy of BCF Telescope House.

CEMAX Hydrogen Alpha Eyepieces

The CEMAX (Contrast Enhanced) series eyepieces are specially designed and coated for solar hydrogen alpha viewing (Figures 2.39 and 2.40). In the construction of solar filters and associated instrumentation, Coronado has optimized contrast by minimizing the number of components and designing them so that they do not result in creating residual reflections and spurious light near the image. The CEMAX series of eyepieces follow this approach. They are multicoated on every surface (including cemented surfaces). They are designed for contrast enhancement for the solar observer. They have 20-mm eye relief and an apparent field of view of 52°. The CEMAX series were available (at the time of writing) in focal lengths of 25, 18, and 12 mm. A fully complimentary and similarly optimized 2× Barlow lens is also available for increasing the magnification options. The barrel on each eyepiece has an indention in it to lock the eyepiece in place and prevent it from slipping out of the holder.

Figure 2.39. CEMAX hydrogen alpha eyepieces. Photo courtesy of BCF Telescope House.

They are based on the Plossl type of eyepiece and their apparent field of view (52°) is similar to most mid-range Plossl eyepieces.

This eyepiece set is available as supplied accessories with top of the range Coronado hydrogen alpha telescopes. At the time of writing, each eyepiece and the Barlow lens retailed at about £70 each in the United Kingdom and £260 for the set. This represents a significant outlay in comparison to the cost of the PST. The prices were about twice the cost of low-end Plossl eyepieces and at the low end of the Meade eyepiece range.

Figure 2.40. CEMAX hydrogen alpha eyepieces, complete with carrying case.

Focal Length (mm)	Magnification without 2× Barlow Lens	Magnification with 2× Barlow Lens	Field of view in Arcminutes without/with Barlow lens
25	16	32	195/97
18	22	44	140/70
12	33	67	90/45

Each eyepiece combination (with the PST) results in the entire solar disc being (comfortably) within the field of view. This certainly makes the use of the 25-mm eyepiece with the PST questionable. Yes, it is excellent for finding the Sun and centering it in the field of view, and it gives better results than other similarly priced eyepieces, but then a 32-mm Plossl eyepiece at half the price will do the job as well or better. Even the use of the 18-mm eyepiece with the PST is debatable. The 2× Barlow lens and 12-mm eyepiece combination is a credible combination and there is no doubt that the results are significantly better than with the supplied eyepiece. Indeed, the results were significantly better than with other eyepieces of similar price.

"Benchmark" tests showed that the CEMAX eyepieces, with or without the Barlow lens, are capable of "teasing out" solar detail and prominences better than other eyepieces of similar price. Although the photograph in Figure 2.41 was taken with a domestic digital camera, it was able to show prominences that (on the day) were simply not visible with any other eyepiece combination. Note that the visual view was more impressive than the photographic one.

Without the use of sophisticated photographic equipment, capturing any detail on the solar disc is difficult with the PST, but I was able to get the "cell structure" effect with the 12-mm eyepiece/2× Barlow lens combination (Figure 2.42).

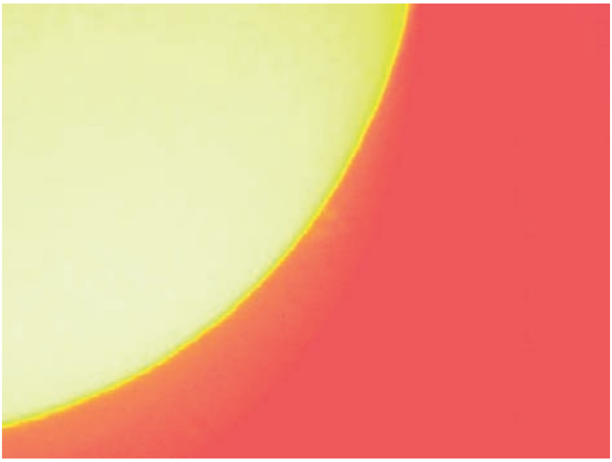


Figure 2.41. Prominences viewed through the PST with the CEMAX 2× Barlow lens and 12-mm eyepiece.

Figure 2.42. Solar disc shown through the PST with the CEMAX 2× Barlow lens and 12-mm eyepiece.

Indeed, if you do have a budget for accessories, either at the time of purchase or later, I recommend the use of the 12-mm CEMAX and the CEMAX Barlow lens.

Since buying the CEMAX, I have found it an excellent all-round nighttime eyepiece too. It has even teased out detail on Jupiter with my 80-mm refractor when even my much-loved Moonfish Group eyepieces have failed. It also managed to split Alpha Centauri very nicely with my 80-mm refractor too. I have also used it to do afocal astrophotography in calcium K light.

One general problem I have with Plossls in general is that they do not take photographs well with domestic digital cameras. However, the CEMAX eyepieces do not seem to have the same problem.

Despite its small size, the PST is capable of delivering close-up views and images of prominences and it is a pity that (at the time of writing) that there were not any shorter focal length eyepieces in the CEMAX range available to support magnifications in the 80–100× range. However, the use the of CEMAX 2× Barlow lens allows the possibility of using eyepieces from other product ranges.

Any slight doubt as to the effectiveness of the CEMAX eyepieces is down to your individual eyes. Although my own experience of them is very positive, others have said that there is no improvement over similarly priced Plossl eyepieces. Although image amplifiers of various types can be used to boost the magnification, I find shorter focal length models are more than welcome.

Figure 2.43. AC645 Polarizing filter.

AC645 Polarizing Filter

This polarizing filter is intended to improve the solar disc detail seen with hydrogen alpha solar observing telescopes. The filter screws to the barrel of any 1.25 inch eyepiece (Figure 2.43). The eyepiece is inserted into the eyepiece holder as usual, and because the hydrogen alpha filter systems cause the light reaching the eyepiece to be polarized, rotation of the eyepiece in the holder will alter the contrast of the disc. The filter is claimed to improve display of detail on the solar disc by as much as 20% but not the contrast of limb detail. The filter works with all apertures of Coronado filter unit and telescopes, and is particularly intended for use with the Coronado PST. The filter is supplied in a foam-lined dust-proof case.

My own tests have shown that the polarizing filter obscures prominence detail and dims the visible light of the PST, without improving the surface detail. However, it has proved to fulfill its claims with the MaxScope 40.

Using Other Accessories

The PST takes eyepieces with the standard 1.25-inch (31 mm) fitting. This allows a huge variety of eyepieces and accessories to be used. The short answer is that most of the nighttime eyepieces that you use are suitable for use with the PST. As a general rule, Plossls are the best for purely visual use, whereas LER eyepieces are better for astrophotography. The biggest restrictions are the following:

- The focusing range is limited, so any long or short focus eyepieces cannot be used. It also limits the Barlow lenses and other "image amplifiers" that can be used with it.

- With a 40-mm aperture, the ability to get sharp images at high magnification is limited. A practical limit appears to be about 100× magnification but this is a lot less during poor viewing conditions.

On the last point, I find it rare that increasing magnification improves the visual results but it can make a huge difference photographically.

This section contains a description of some of the accessories, that I have tried with the PST. It cannot be a comprehensive list, as there are a large number of accessories that will work with the PST. Many of them cost as much as the PST itself or are otherwise disproportionately expensive in relation to the cost of the PST itself. Of course, there is nothing stopping you from using expensive accessories that you have bought previously for nighttime use, but I do not recommend the purchase of them specifically for use with the PST. You would be better off spending your money on a larger Coronado hydrogen alpha telescope.

A long focal length eyepiece is needed to make finding the Sun easier by providing a wider field of view. An eyepiece with a focal length of about 8 mm will enable the whole solar disc to be viewed or photographed comfortably. It is also useful to have an eyepiece/image amplifier combination capable of yielding magnifications in the range 80–100× to show more detail than is visible at lower magnifications. Use of magnifications in excess of 100× does not seem to reveal more detail but this may be possible with very expensive eyepieces. However, I am not able to confirm this, because neither I nor anyone I know has tried them.

Moonfish Group Eyepieces

A good compromise between using LER and Plossl eyepieces is the Moonfish Group eyepiece range (shown in Figure 2.44). I own both the 15- and 20-mm Super Wide Angle (SWA) eyepieces; in addition to their excellent nighttime performance, they match well with my PST. The only drawback is that I cannot use the 3× Moonfish Barlow lens. These eyepieces have an apparent field of view of 70°, which is absolutely astonishing for such a price. A 10-mm focal length eyepiece is available, so I have included it in the table below even though I do not actually own one.

Focal Length (mm)	Magnification	Field of view in Arcminutes
20	20	210
15	26.7	157
10	40	105

I did not specifically buy these eyepieces with the intention of using them with the PST but for viewing and photographing the Moon and the Sun in "white light" with a Skywatcher 127-mm Maksutov. In terms of magnification

Figure 2.44. The eyepieces of 20- and 15-mm focal length from the Moonfish Group.

ranges, without a Barlow lens, they are more suitable for use than the recommended CEMAX eyepieces. As general use budget eyepieces (they turn out to be slightly more expensive than low-end Plossls), I just do not think they can be beaten, although some US manufacturers (by repute) are similar in quality/price.

Although my low-end Plossls slightly outperform these visually, the difference is negligible. The difference is much more noticeable with astrophotography. In that way, my experiences with the PST are no different to those with the Moon.

In order to get the best out of the Moonfish Group eyepieces, a Barlow lens or a range of eyepieces are used to change the available magnifications. Unfortunately, although I have used the Moonfish Group 3× Barlow lens to get some great close-up shots of the Moon, not to mention the planets, the PST simply does not have the same focusing range. By repute, the Meade 2× Barlow lens works with the PST, although it has not worked for me. My advice is to try it if you own one already, but it costs about the same as the CEMAX 2× Barlow lens, which is better (for use with the PST), anyway. I get good use from the BCF Astro Engineering Magni Max Image Amplifier (Figure 2.45).

For most astronomy (night or day), the Moonfish Group eyepieces are my eyepieces of choice.

Magni Max Image Amplifier

It is shown in Figure 2.45. Like just about everything else I have, this was not purchased specifically for use with the PST. It screws into a 1.25-inch (31.5 mm) standard eyepiece fitting. It is manufactured by Broadhurst, Clarkson and Fuller Astro Engineering and retailed at £24.99 initially in 2004. It gives a magnification boost of 1.6× with eyepieces used and does not require a major focusing adjustment. Remember, though, that the field of view is reduced by 37%. For lunar viewing, if there is any chromatic aberration introduced by it, I have not noticed.

Figure 2.45. Magni Max Image Amplifier.

It can also be used with a Barlow lens to increase the magnification even further. If you forgive me for being unfaithful to solar astronomy for a moment, I have managed to take successful lunar shots (Figure 2.46), using it to boost the magnification of a Moonfish Group 3× Barlow lens and 15-mm SWA eyepiece to nearly 500×! However, the Magni Max and the CEMAX 2× Barlow lens combination did not work with the PST.

It is little coincidence that many of the photographs on my Web site have been taken using the Magni Max. I do have a criticism, which I hope is fixed in a future product release: I wish they would put a secondary thread in so that

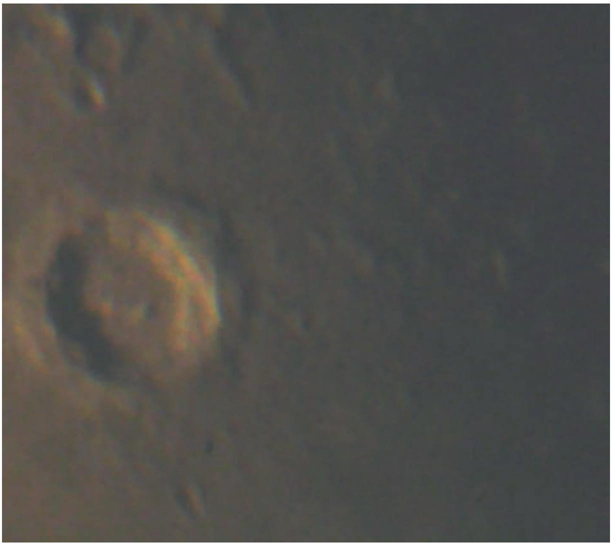


Figure 2.46. The lunar crater Copernicus magnified to nearly 500× magnification using a Magni Max Image Amplifier in conjunction with a Barlow lens.

I can use filters or put a second Magni Max to obtain a magnification boost of 2.56×. Now that could spell an end to budget Barlow lenses!

There are some products that revolutionize amateur astronomy. Whilst I would place the PST at the top of the list, If you are looking for something on the budget side, the Magni Max must be near the top of the list. Just try it for general astronomy too.

Skywatcher Long Eye Relief Eyepieces

These came supplied with my Skywatcher 127-mm Maksutov. It was at a star party that I decided that they did not get the best out of a very good telescope. After buying some Skywatcher Plossls (see below), they were consigned to the accessory case, never to see the light of the day again. That was until a chance observation. Before I bought the Plossls, I was able to photograph sunspots but was not afterwards. I soon realized that these eyepieces did have a use, for simple photography using a digital camera. The 50° field of view is not exactly excellent, especially compared to the Moonfish Group eyepieces, but it is good for whole solar disc shots. The table below shows how the eyepieces perform with the PST.

Focal Length (mm)	Magnification	Field of view in Arcminutes
25	16	150
10	40	60

Since I bought the Moonfish Group eyepieces, only the 10-mm eyepiece was used, often in conjunction with the Magni Max (Figure 2.47). I would not recommend

Figure 2.47. Skywatcher long eye relief eyepieces.

the purchase of these eyepieces specifically for use with the PST; the 10-mm Moonfish SWA is of better quality, with a wider field of view.

Furthermore, the CEMAX 12-mm eyepiece is a better all-round eyepiece and gives reasonable photographic results.

Overall, although these eyepieces match the Moonfish Group ones for photographic use, they are nowhere near as good for visual use and do not have the same field of view.

Skywatcher Zoom Eyepiece

I acquired this as a result of my second Skywatcher telescope, the 80-mm short tube refractor (Figure 2.48). I managed to persuade the retailer (also a member of the same astronomical society as myself), that I did not really need two identical Skywatcher LER eyepieces and, to his credit, he did not try to sell me

Figure 2.48. Skywatcher zoom eyepiece.

a binoviewer! It has a range of 7–21-mm focal length. Early use with the Sun and the Moon convinced me that it was not the wisest of purchases. However, like the LER eyepieces, I found a use for it. Many of the photos on my Web site showing prominence photos were taken with this eyepiece at 7-mm focal length. The focal length adjustment is not quite *parfocal*, so some minor adjustment to the focus is required when zooming in or out. It is certainly a good eyepiece for alternately zooming in and out to look at the features on view in close-up or the whole solar disc.

One minor drawback is that the thread at the back does not take filters or a Magni Max, which is a pity, as it would allow an effective focal length of down to about 4.4-mm to be used, giving a magnification of about 90× with the PST.

Skywatcher Plossls

One of the great things about a star party is that you can swap eyepieces and accessories. The drawback is persuading the better half that I should buy them! Telling her that I will get the money back by writing a review for a magazine and it is cheaper than a new telescope does not always work. And so it came to pass that I managed to acquire these 6.3- and 32-mm focal length eyepieces. These and similar ones retail at about £30–£40 in the United Kingdom. With the PST, the magnification of the 32-mm eyepiece is too small to be used for anything other than finding the Sun and centering it in the field of view. The 6.3-mm eyepiece is another matter. With the PST, it yields a magnification of 63× (101× when coupled with the Magni Max). The table below shows the magnifications and fields of view obtained.

Focal Length (mm)	Magnification	Field of view in Arcminutes
32	12.5	240
6.3	63	53

The only negative point is that they do not produce good photographs with ordinary (domestic) digital cameras. They are great for browsing and for showing off the Sun to an assembled audience. There are many budget Plossls available from other manufacturers (Figure 2.49), such as Tal and Sirius, and they are available in a wide range of focal lengths. Without trying each individual eyepiece, it is a fair speculation that the design and quality are fairly similar and so will be the results. I have noticed that apart from the Coronado CEMAX eyepieces, which are designed specifically for solar use, these Plossls are not noticeably worse than the mid-range Meade Plossls of about twice the price, when used with the PST.

Figure 2.49.
Skywatcher Plossls.

Celestron Moon Filter

Now what would a solar observer do with a moon filter? The PST (or any other solar hydrogen alpha telescope) is totally unsuitable for viewing anything bar the Sun. One of the biggest problems I have with imaging the Sun using simple digital photography is that the image is often overexposed. The use of a moon filter (this one lets through 18% of the light) overcomes that difficulty, although there is often an accompanying loss of definition, unfortunately (Figure 2.50).

Now, I am one of those irritating customers who spend hours browsing in shops and, after careful consideration, end up buying something by mail order! Just every now and then, I do make a purchase and I found this for $13 in a shopping mall in Atlanta while on a business trip to the United States.

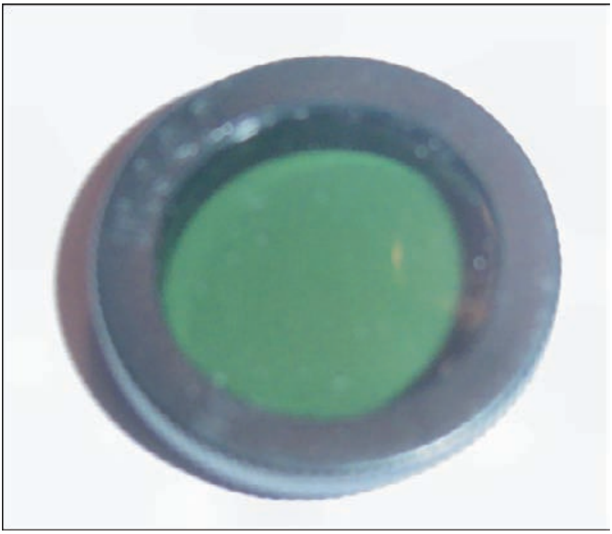


Figure 2.50.
Celestron moon filter.

BC&F Telescope Cleaning Kit

Planetary astrophotography is OK, lunar astrophotography demands clean lenses, but you can get away with the odd hair. Any hair, speck of dust, or hint of grease can ruin an otherwise "trophy" photograph of the Sun. This kit contains a brush for the hairs and dust, and a cloth and fluid for the grease. I recommend that you use this (or something similar) before taking any photographs.

General Guidance on Accessories

Like many telescopes, accessories can be manufactured and retailed under different brand names in different countries. Many manufacturers produce low-end Plossl eyepieces and most will probably perform in a similar manner to my Skywatcher ones. Long eye relief (LER) eyepieces are a recent innovation and they come into their own when used for photography. Both these eyepiece types have an apparent field of view of about 50°. Moonfish Group SWA eyepieces have larger apparent fields of view (about 70°) and are good for all round use (visual and photographic). Chromatic aberration is not a problem for hydrogen alpha viewing, as it might be for nighttime or solar "white light" viewing, so eyepieces that you may have consigned to the bottom of your accessory bag or the attic might just throw up some pleasant surprises when used with the PST. A good example of this is the Skywatcher "zoom" eyepiece, which is prone to chromatic aberration for normal viewing.

Anything that may have come supplied with a nighttime telescope should be tried with the PST, just to see what happens. The focusing range is a limitation, so not all Barlow lenses will work.

I would look for a magnification range of about 20–100× to allow easy centering of the Sun in the field of view and close-ups of prominences and other features.

One word of warning is that personal preference is important here. I am not sensitive to internal reflections that drive other astronomers bananas! The moral of the story is to try things out yourself at a star party or other event.

Photographic Accessories

Whilst Coronado markets the PST as being for visual use, it does not stop enterprising amateurs from taking photographs with it. Personally, I use a domestic Sony Cybershot P72 camera, which has 3.2 megapixels. This was purchased in 2003 at a not inconsiderable expense, but you can now get better ones for less money. I just simply hold the camera to a telescope eyepiece and snap. There are, however, various mounting brackets that you can use that enable a camera to be held steadily against the eyepiece.

I have used this technique for imaging the Moon and have even imaged detail on some of the planets. However, many amateurs achieve much better results using a variety of equipment and these can be applied to the PST. Nick Howes has contributed Chapter 5 to this book and this contains details of what can be done and how to do it. To whet your appetite, here are some example setups.

Figure 2.51 shows the PST with a BCF afocal camera adaptor, which is used to prevent/reduce "camera shake."

If you browse through the pages of many astronomy magazines, you will notice that many planetary images are taken with webcams. The Phillips Toucam is one of the more popular (Figure 2.52). This setup also includes a BCF Barlow adaptor to overcome difficulties with the focusing range.

John Watson has used a Canon Powershot SD450 with a universal mounting bracket (Figures 2.53 and 2.54).

The Universal Camera Adaptor bracket is available in many high street camera stores and retails at about £99.

Amazingly enough, the best camera adaptor for my Sony Cybershot P72 camera was the cheapest. Figures 2.55 and 2.56 show it alone and used for afocal projection with a webcam bought from RadioShack in the United States.

Figure 2.51. PST with afocal adaptor.

Figure 2.52. PST with Phillips Toucam.

Figure 2.53. Canon Powershot SD450.

Figure 2.57 was taken during an attempt to photograph calcium K features.

Nick Howes can perform magic with a webcam and PST, but Figure 2.58 shows one of my attempts while away on business in Brazil.

The RadioShack webcam has the same resolution as popular makes, like the Phillips Toucam, but is much cheaper. It is also a nice way of showing telescope images online. My astronomical activities always seem to attract an audience!

Capabilities and Limitations

First, this is an *entry-level* telescope for hydrogen alpha viewing. It is the only model available for below £500 in the United Kingdom (or $500 in the United States) but, as such, has to be regarded as a serious breakthrough. Its optical quality seems sound enough, but a 40-mm objective (effectively reduced to about 30 mm by the telescope design) and 400-mm focal length mean that the resolution and maximum magnification are limited. Whilst I have managed "white light"

Figure 2.54. Canon Powershot SD450 mounted with the PST.

Figure 2.55. Canon Powershot SD450 used to snap prominences.

Figure 2.56. Afocal camera adaptor.

Figure 2.57. Afocal camera adaptor with Coronado CEMAX eyepiece.

Figure 2.58. PST and RadioShack webcam capturing a PST image on screen.

solar observations under quite appalling conditions, I find that any sort of cloud can ruin the view.

However, during periods of clear (or almost clear) conditions, the PST can open up a world that was previously only open to professionals or amateurs with a large disposable income.

There is lot of talk about the cell structure of the Sun and faculae (brighter regions of the Sun). These are supposedly visible in "white light" using precision telescopes and high magnification (300× or more). As an experienced viewer of the Sun in "white light," I can honestly say that I have rarely seen these features and, on the rare occasions that I have, not particularly clearly. I have seen good umbral/penumbral shading of sunspots but not much more. In fact, medium aperture "white light" viewing shows sunspots better than the PST does.

Now, try a PST on low magnification or even look at the image before inserting an eyepiece. The cell structure is immediately apparent. Now it does not photograph that well using a domestic digital camera but that is hardly the point.

Next look at the faculae. These brighter regions are very clear and also surround sunspots but can also be seen on their own. Filaments also show well but do not show the detailed shapes visible in larger hydrogen alpha telescopes.

Now prominences themselves are the highlight of solar viewing. Superficially, they look like flames emanating from the edge of the solar disc. It is possible to see a solar disc under clear conditions with no prominences at all, but it does not happen very often. Most of the time, there is a small prominence somewhere and quite often there is an associated facula. On rare conditions, I have seen prominences changing in real time, but it is more common to see them changing every 10 minutes or so. Sometimes they can be seen more clearly (and/or photographed better) if you crank up the magnification from 80× to 100× but not always, depending on conditions. The key is to try different ideas to see what works on the day, just like nighttime planetary viewing.

One of the nice features of the PST is its portability. As well as several car trips, it has accompanied me on business trips abroad, enabling me to follow my hobby while away from home.

The PST is not marketed as a photographic instrument and, indeed, does not support prime focus photography (without an adaptor), advocated by many astrophotography experts. However, it does support afocal photography (otherwise known as eyepiece projection) and an afocal adaptor is available (see Chapter 5 for details). Personally, I use a simple domestic digital camera for my photos and it is adequate for simple recording of the more prominent solar features. More sophisticated techniques are covered in Chapter 5.

Buying a solar telescope as we approach a solar minimum, on the surface, may not appear to have been such a wise thing. Yet there can be days, even weeks, where there is not a single sunspot visible in "white" light, but there is hardly a (clear) day when there is not any feature visible in a PST. If the solar disc looks bland, just wait a few minutes or so and something will come into view.

Using a PST and getting the best out of it requires totally different viewing habits to nighttime viewing. You do not need to spend hours staring at the solar image. If you like to relax in the garden on summer weekends, set up your PST and just take a look every few minutes or when you get up for a drink. I like to take it to work and look through it at lunchtime and even nonastronomers will stop to look through it. Astronomy in the daytime! Whatever next?

Appraisal

The "breakthrough" price of less than $500 (or £500) brings it into the "affordability" bracket for the knowledgeable amateur astronomer on a limited budget. However, the low price also means that there is often a long waiting list for it. I would say, though, it is unlikely that the PST will ever be a waste of money. Astronomers can be very inventive about finding funds for additional equipment, so it is probable that many of them will buy a larger aperture solar hydrogen alpha telescope at some time. Yet, the PST can still be kept for travel and for quick setup applications, such as lunch breaks at work.

Under clear conditions it will show features on the solar surface that cannot be seen in "white" light and these features will change over a matter of minutes. During extended sessions you can actually see prominences come into view, change, and disappear.

The inclusion of the Sol Ranger (solar finder) in the "magic box" is actually an advantage, compared to other telescopes in the same range.

Its drawbacks are not many and are as follows:

- It does not have tube rings or anything that will help you to attach it to an equatorial mount directly.

- Its focusing range is small, so not all eyepieces and accessories can be used with it, particularly Barlow lenses.
- The supplied eyepiece does nothing to enhance the telescope. Other eyepieces bought for nighttime viewing with other telescopes are at least as good, if not better.

The 40-mm aperture (reduced effectively to about 30 mm by including the etalon in the "magic box") could be considered a drawback, but it gives it affordability and portability, which may not be true for other telescopes in the same range or from one of the few competitors.

I would not expect the PST or any hydrogen alpha telescope to be of much interest to complete beginners, but someone who has learned how to view the Moon and the planets at night will be able to use it.

The addition of a second filter near the objective reduces the bandpass from 1.0 to 0.6 Å, which is less than that of the MaxScope 40. Almost by coincidence, the additional price brings the total price to about 88% of the price of a single-stacked MaxScope 40 in both the United States and United Kingdom at the time of writing. So there is an interesting choice between a 40-mm PST with a bandpass of 0.6 Å and smaller effective aperture (30 mm) and a 40-mm MaxScope 40 with a bandpass of 0.7 Å but with more light transmission and a bit more money. Rather like the head coach of a sports team who has to decide between two excellent players, it is a nice decision to make!

Verdict: It is a breakthrough for solar observers looking for a bit more than what is available from "white light" solar viewing.

Optical Quality	8 out of 10
Value for Money	7 out of 10
Ease of use	7 out of 10
Overall Rating	8 out of 10, very good

Double Stacking a PST by Cameran Ashraf

This section gives a more detailed appraisal of double stacking over a period of time than the tests carried out by Philip Pugh.

The PST is a remarkable instrument. For its aperture, it provides incredible views of the solar surface and solar activity that astound and amaze observers worldwide. For me, the PST was my first foray into hydrogen alpha viewing. I was hooked! The views were incredible – prominences blasting away on the solar limb and the rare light filament snaking its way across the vast solar surface. These were the views that I was content with day after day until I attended Riverside Telescope Makers' Conference (RTMC) 2005 in Southern California.

The Coronado folks had an array of solar telescopes available for viewing – MaxScopes 90, 70, 60, 40, and PSTs. It was a sight to see! I have never seen so many gold shimmering telescopes pointed at our most important star.

Of course, all these scopes were just nice to look at. I had no intention or even thought of buying one until, however, I was able to get a view through something called a "double-stacked" PST, which had an extra filter screwed in at the objective end. I was only able to look through it briefly as others were waiting, but the view was tremendous. I decided that I would get one since it was an affordable way to get a lower bandpass. When it finally arrived, I was unsure as to what I would see – my time at the Coronado display had been very brief. I decided to go ahead and tune the standard PST and enjoy viewing through it before adding the extra filter. There were a few prominences and a very faint filament on the surface. I decided the time was right to add the second filter now that I had a good view through a single-stacked PST.

At first, the image was in deep red color and looked dimmer. I was little disappointed, but then I remembered that I needed to tune the filter (placed at the objective end) using the small wheel located on the filter. Twisting, turning, tuning –then WOW! Filaments that I could not see with a single-stacked PST literally were leaping off the Sun. It was as if a whole family of filaments had literally exploded into view across the surface. The texture of the Sun was palpable. Active regions were swirling with intense activity and three-dimensional filaments. The Sun truly took on a three-dimensional look as there was greater depth and definition to surface detail than ever before. Prominences showed more detail in my eyes than before, though they were little dimmer. All together the Sun took on an entirely new appearance in my eyes – something that I really was not prepared to see.

Even today, a year after double stacking, I am still in awe of the change in detail from single stacked to double stacked. Seeing the Sun as a heaving, seething mass of plasma, is truly a remarkable sight.

Although the image can sometime be fainter than in a single-stacked PST, there is no loss of detail.

Figures 2.59 and 2.60 show a comparison of the same region of the Sun taken with a single and a double stack. Figures 2.61–2.68 show series of double-stacked images by Cameran Ashraf.

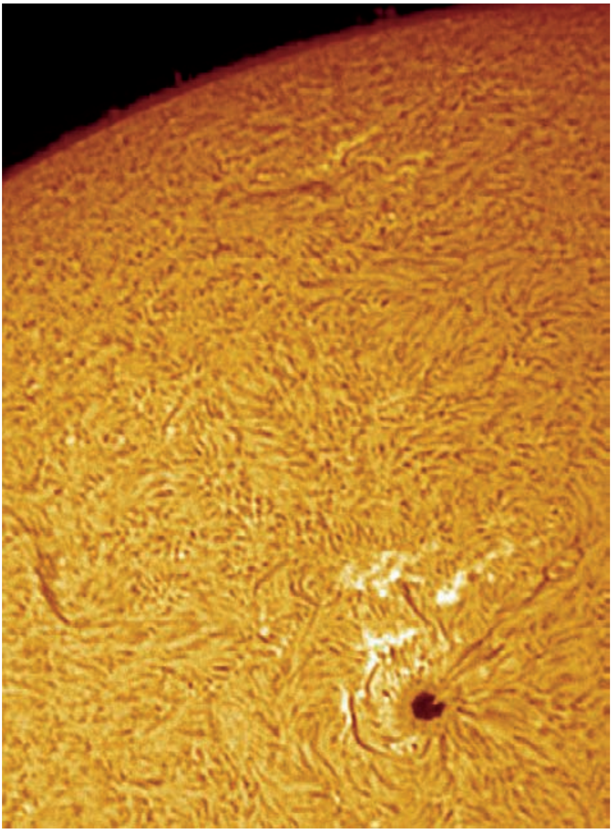


Figure 2.59.
Single-stacked image by Cameran Ashraf.

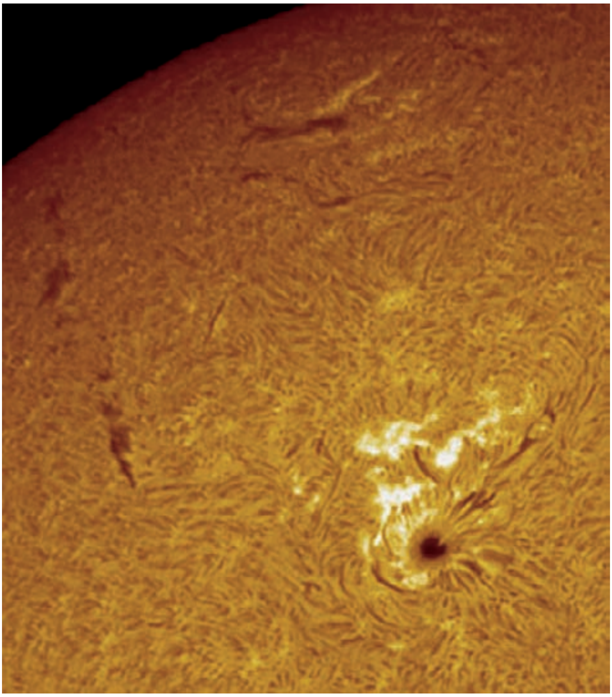


Figure 2.60. Double-stacked image by Cameran Ashraf.

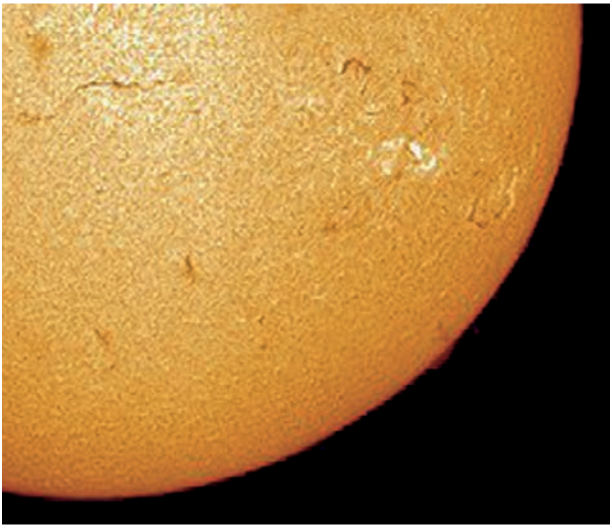


Figure 2.61. No. 1 in a series of double-stacked images by Cameran Ashraf.

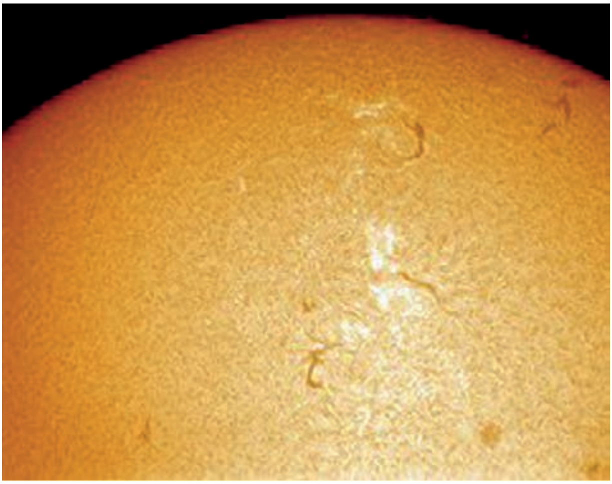


Figure 2.62.
No. 2 in a series of double-stacked images by Cameran Ashraf.

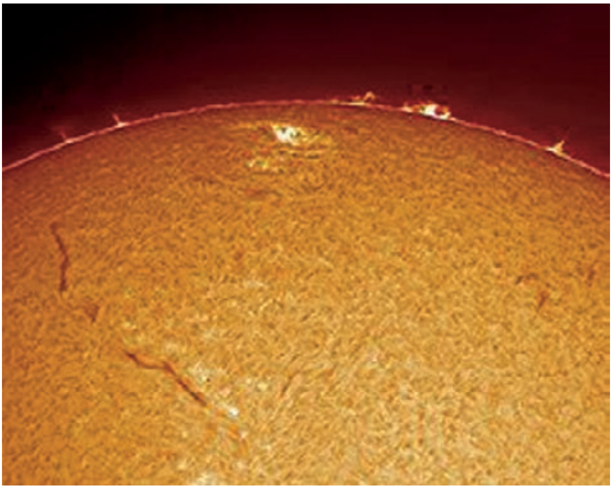


Figure 2.63.
No. 3 in a series of double-stacked images by Cameran Ashraf.

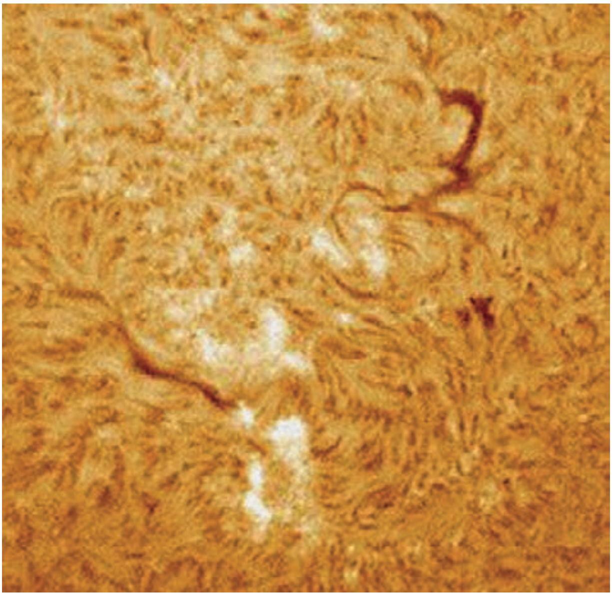


Figure 2.64.
No. 4 in a series of double-stacked images by Cameran Ashraf.

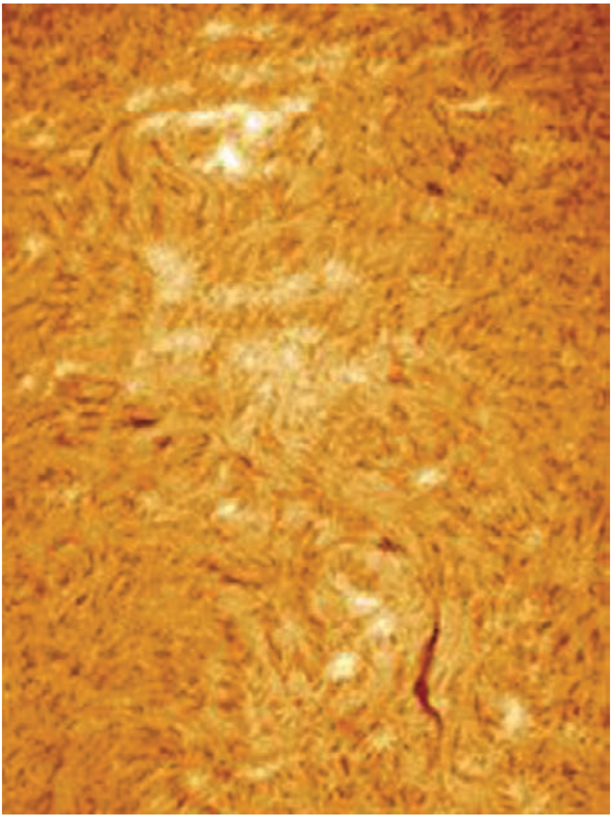


Figure 2.65.
No. 5 in a series of double-stacked images by Cameran Ashraf.

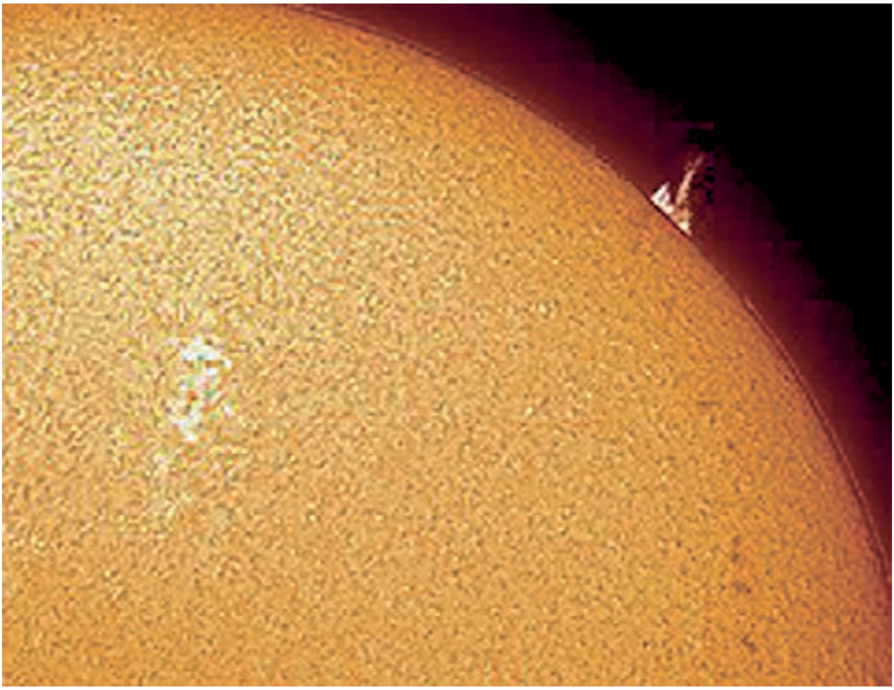


Figure 2.66. No. 6 in a series of double-stacked images by Cameran Ashraf.

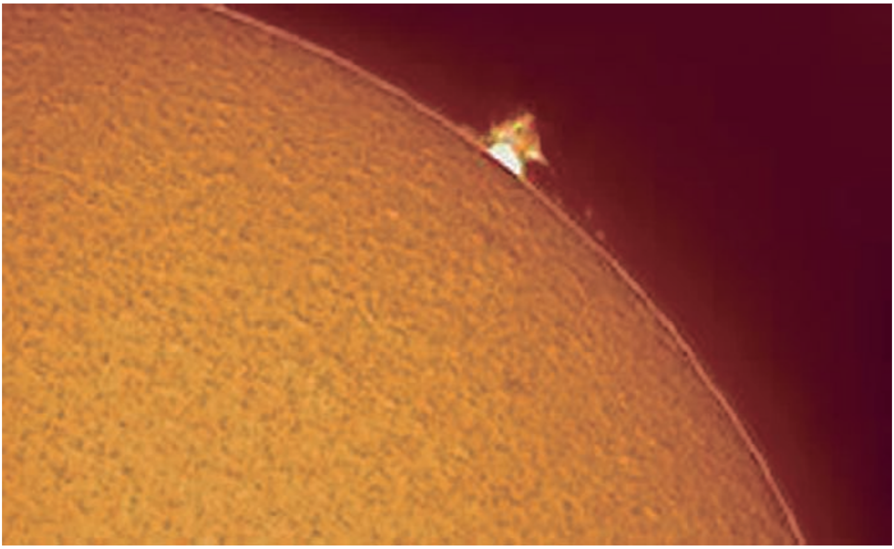


Figure 2.67. No. 7 in a series of double-stacked images by Cameran Ashraf.

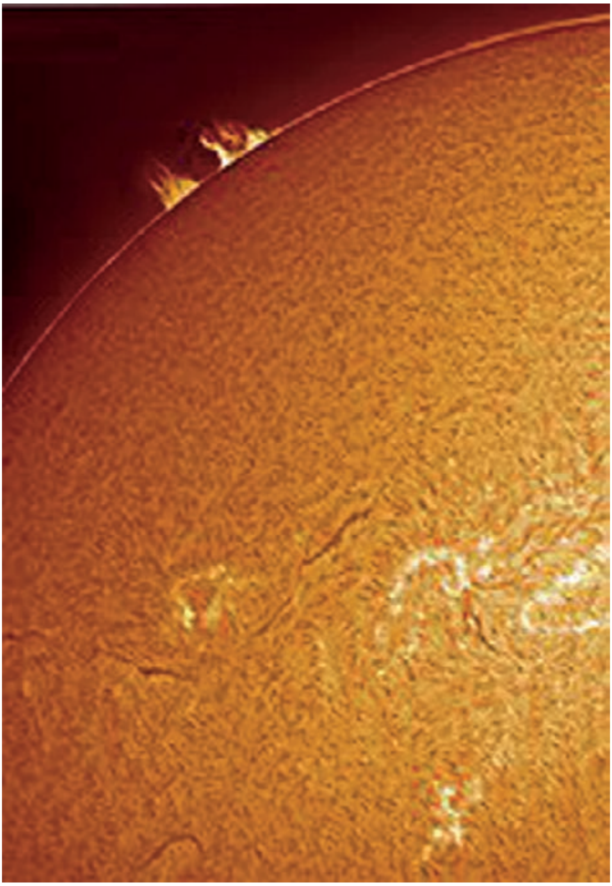


Figure 2.68. No. 8 in a series of double-stacked images by Cameran Ashraf.

CHAPTER THREE

MaxScope 90*

The Coronado MaxScope 90 telescope is a professional grade hydrogen alpha telescope designed to capture minute details on the solar surface and the surrounding photosphere. Being a professional grade telescope, the MaxScope 90 also carries a steep price. At about $12,000 in the United States (£10,000 in the United Kingdom), at the time of writing, for the double-stacked telescope, it is geared more for universities and scientific exploration. While out of reach for many amateur astronomers, it is still a breakthrough in price for the level of quality it delivers. In many cases the images obtainable from this telescope surpass some of the best solar images taken only 15 years ago through much larger instruments. To some degree, the telescope seems limited only by the type of camera being used. Some of the best features of the telescope are the following:

- Relatively lightweight with heavy-duty construction (all anodized machined aluminum).
- It comes equipped with extensions to help to achieve focus relatively easy with just about any camera or any eyepiece/Barlow lens combination.
- A “Sol Ranger” solar finder comes standard with the MaxScope 90’s clamshell ring and allows you to pinpoint the Sun’s location.

* Larry Alvarez

- Comes with a full set of CEMAX hydrogen alpha optimized eyepieces and a 2× CEMAX Barlow lens
- Comes with a lightweight case for transporting the telescope

It has a heavy-duty clamshell ring for mounting the telescope to a tripod.

Whilst it has some of the design features of the MaxScope 40 and MaxScope 60, it has double the focal length.

Facts at a Glance

Aperture (mm)	90
Focal length (mm)	800
Bandpass (Å)	0.7
Bandpass with double-stacked filters	0.5
Weight (lb)	23

Due to the changing nature of the market, details of current price in the United Kingdom and United States and accessories included with the base package are included in an appendix.

Physical Description (MaxScope 90)

The MaxScope 90 (Figure 3.1) has a 90-mm objective lens (made of BK-7 glass) and has 800-mm focal length with an F8.8 focal ratio. There are a couple of different versions of it that vary in the secondary blocking filter used and the amount of sub-angstrom filtering associated with the front primary filter. The secondary blocking filter is placed at the exit end of the telescope. For the MaxScope 90, there are two types of rear blocking filters that can be purchased at the time of purchase of the telescope. You can get the BF15 or the BF30. The numeric value after the BF is the notation in millimeters of the exit hole diameter. The BF30 allows for straight through imaging while the BF15 is built into a 1.25 inch diagonal (Figure 3.2). Both allow you to see the full solar disc but the BF30 is the best for attaching a larger camera like an SLR.

The supplied clamshell ring contains three large holding screws for clamping the upper part of the shell to the lower part (Figure 3.3). At the bottom of the clamshell ring there are three holes for mounting the lower clamshell to a tripod (Figure 3.4). Each hole is threaded to 1/4 inch ×1–20 threads per inch.

All versions of the MaxScope 90 come with a "T-Max" Doppler detuning ring that goes between the front filter and the telescope body (Figure 3.5). The T-Max is made up of two rings that are hinged on one side by a piece of spring steel

Figure 3.1. MaxScope 90 in its carrying case. Photo by Larry Alvarez.

Figure 3.2. BF15. Photo by Larry Alvarez.

or brass and attached on the other side by a double-sided brass screw. In the middle of the brass screw is a small wheel that opens or closes the T-Max ring on one side. This effectively changes the filtering bandpass and detunes the system to allow the visualization of surface detail and prominence detail.

Figure 3.3. MaxScope 90 showing the clamshell with the Sol Ranger on top. Photo by Larry Alvarez.

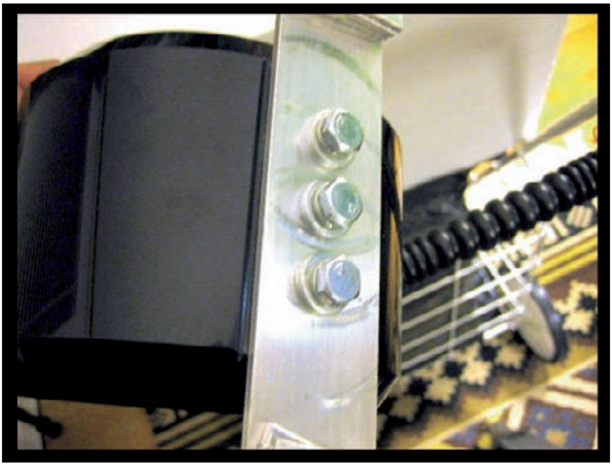


Figure 3.4. Lower view of clamshell with tripod attachment. Photo by Larry Alvarez.

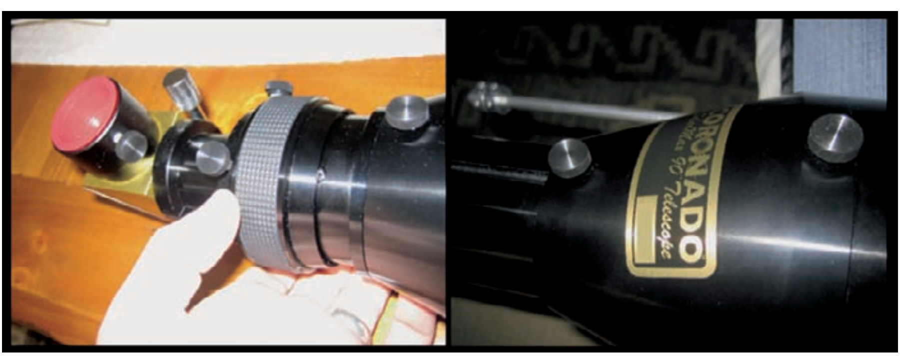
Figure 3.5. T-Max ring attached between the filter and the telescope. Photo by Larry Alvarez.

On a double-stacked (< 0.5 Å) system there is a second internal filter (Figure 3.6) much like the front filter but smaller in size. It has a 60-mm aperture and is mounted inside the telescope almost at the center most section of the telescope. The MaxScope 90 is tuned at the factory for the best bandpass possible and in effect the internal and external filters are matched to work with each other to allow < 0.5 Å filtering.

At the rear of the MaxScope 90 are two nylon thumbscrews that hold the main drawtube in place. Loosening these will allow the main drawtube to be extended. There is also a secondary drawtube connected to the main one that will allow you to reach the focus on almost any camera available. Between the main drawtube and the secondary drawtube is the focuser. It is a helical style focus unit that operates like a large screw. When you screw it in or out it moves the secondary drawtube in or out. The threads on the focusing unit are very fine to allow for fine focusing (Figure 3.7).

Figure 3.6. View through the objective showing the secondary (internal) filter. Photo by Larry Alvarez.

Figure 3.7. Close-up of focusing arrangements. Photo by Larry Alvarez.



The MaxScope 90 comes equipped with a full set of CEMAX eyepieces and a Barlow lens. See the “Recommended Accessories” section of Chapter 2 for a detailed description. However, due to the longer focal length of the MaxScope 90, the magnification/field of view combinations achieved with the eyepieces are different from the PST and are listed below:

Focal length (mm)	Magnification without 2× Barlow lens	Magnification with 2× Barlow lens	Field of view in Arcminutes without/ with Barlow lens
25	32	64	97/48
18	44	88	70/35
12	67	134	45/22

How to Store

Storing the MaxScope 90 is relatively simple. The supplied case is perfect for storage when the scope is not in use. It should be stored in a dry location that is not accessible by the elements or subject to dramatic temperature changes. If you use your telescope in an area with varying temperature ranges or varying humidity ranges, it may be a good idea to put a small package of desiccant in with the telescope to keep dew from forming. Before using the telescope after storage it is best to let it acclimate to the ambient temperature prior to use. Using a set system of storage and retrieval usually helps. I usually take my telescope outside. Let it acclimate for 15–20 minutes while I set up the tripod, table, and micro observatory (see section “Micro Observatory” in this chapter). After 20 minutes I load the telescope on the tripod and start using it. After the session is over, I take the telescope off the tripod, place it back in the case, and close the case. I then finish putting up all the other accessories before I bring the telescope in. The case is not opened once it is inside for at least a couple of hours. It is important when having your case outside that you do not leave it in the Sun. The sealed cell foam inside the case will expand in the Sun and make the case distorted until it comes back to room temperature. If the case is outside during the viewing session, it is best to put the case down in a shaded area when not in use.

Mounting Options

Using the MaxScope 90 requires you to attach it to either an equatorial tripod or alt-azimuth tripod. An alt-azimuth tripod moves the telescope up and down and side to side and allows you to track the Sun by adjusting the telescope in two axes (horizontal and vertical), while an equatorial tripod will allow you to track the Sun by moving in one axis after you polar-align the tripod. For the purposes of imaging or making scientific observations, the equatorial tripod is widely accepted as the best method. It allows for precision tracking and counter compensates for the Earth's rotation. The down side is that it has to be polar-aligned to achieve a high degree of accuracy. So since alignment stars come out at night, you have to leave the tripod setup overnight for use during the day. There are ways to minimize alignment problems that are discussed later in this review under the "Tips and Tricks" section that make setting up an equatorial tripod as easy as setting up an alt-azimuth tripod.

Whether using an alt-azimuth or an equatorial tripod, it is equally important to attach the clamshell ring to the tripod base securely. The three holes at the bottom of the tripod are oddly placed and do not match up to the holes on most tripod heads. After some experimentation and some quick calculations, I made an adaptor to secure my MaxScope 90 to my old Celestron Equatorial tripod. I used 1.5 inch $\times$3 inch stock aluminum bar from my local hardware store, three 1-inch bolts (1/4 inch by 1–20 threads per inch), two 1.5-inch bolts (1/4 inch by 1–20 threads per inch), two nuts for the 1.5-inch bolts, and five lock washes for all the bolts. I cut about 12 inches of the bar for the base of the adaptor and drilled three holes spaced exactly at the same distance as the holes at the bottom of the clamshell in the middle of the adaptor base. I then drilled two more holes toward the outer ends of the base of the adaptor that matched the location of the holes on the tripod base. I then cut six 1 inch $\times$1 inch squares and drilled holes through each one. These would be used as spacers to lift the adaptor base from the base of the tripod and provide proper distance between the two. Figure 3.8 shows the parts and adaptor that was constructed. I used wing nuts to attach the adaptor to the base of the tripod and the lock washers to secure the wings tight. I also used lock washers to secure the bolts to the adaptor base and lower clamshell. The total cost of this project was roughly \$10.00 and has held solid since its creation. My tripod is an older model, so some differences may exist in a newer model.

You may like to compare this to John Watson's arrangement, described in Chapter 2. That will also work with the MaxScope 90.

After the clamshell base is securely fastened to the tripod you can mount the telescope on the pod and attach the top of the clamshell. It is important to leave

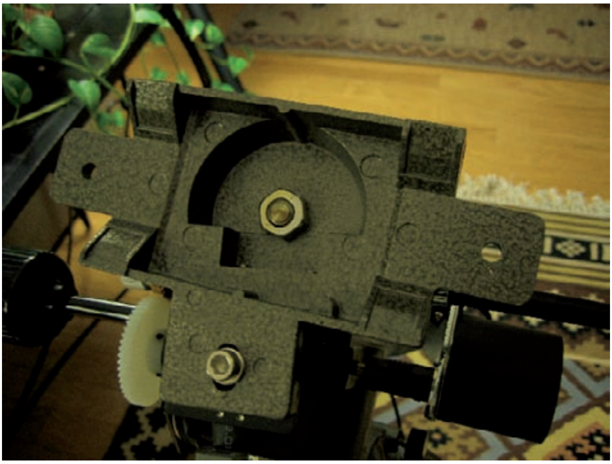


Figure 3.8. Tripod adaptor. Photo by Larry Alvarez.

the top of the clam a little loose so that you can slide the telescope back and forth until you have the best balance. You may have to adjust the lower counterweights on your tripod for the maximum balance. When doing telescope balancing, I like to connect all the accessories I will be using for the imaging session. This allows me to balance the telescope more accurately. After a good balance is reached you should tighten the upper clamshell to hold the telescope securely in place, if you will be using the telescope right away. It may be necessary to reexamine your balance after an hour or so of use to ensure that it is still well balanced. Sometimes changing eyepieces or cameras will have a big effect on the balance and can prevent the tripod from slewing to the target because of the extra weight caused by an unbalanced telescope. The better the balance the better the telescope will move from target to target.

The top part of the clamshell has a built-in “Sol Ranger” finderscope (Figure 3.9). It has a tiny pinhole in the front that projects an image of the Sun on the back-diffused glass plane. Note that this is a different Sol Ranger to the one built into the body of the PST.

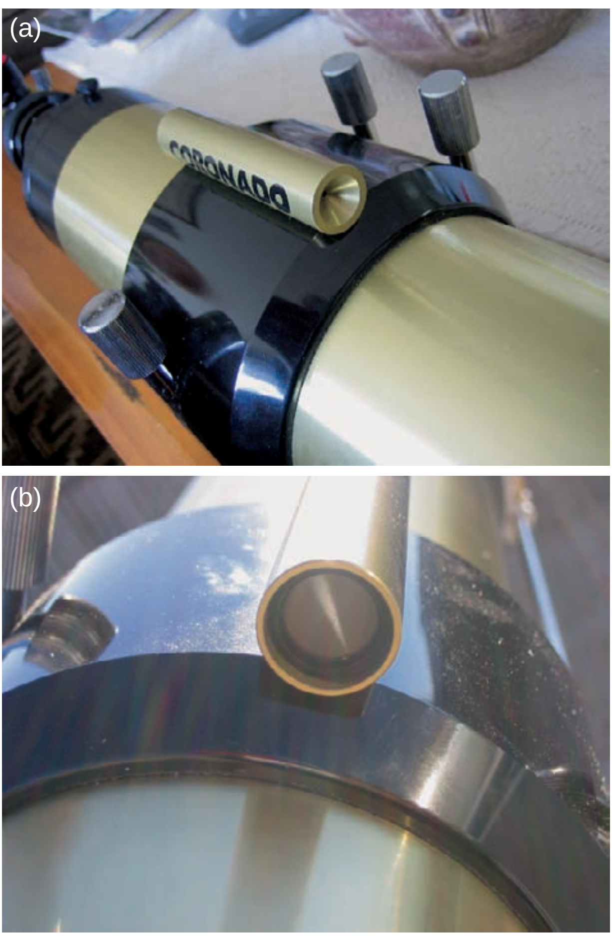


Figure 3.9. Sol Ranger finder. Photos by Larry Alvarez.

I find using the Sol Ranger much easier than a regular finder because it shows arrows that point you in the opposite direction in which to move the telescope to find the center (Figure 3.10). Once the image appears as a dot instead of an arrow you know the Sun will be in the field of view and you can lock in the tripod to that area. The dot should be placed in the center of the Sol Ranger-diffused glass plane for proper alignment. The Sol Ranger that comes standard with the MaxScope 90 is a good way to find the Sun quickly without risking your eyesight.

Note that the Sol Ranger solar finder has the same name as the one supplied with the PST but is totally different.

Before extending the drawtubes to the desired length you should insert the largest size eyepiece into the diagonal and also back out the focuser half way. Once you see the image in focus, while adjusting the drawtubes, you should lock in the tubes. Now with the focuser at midpoint you can go backward and forward through the focal plane to find the best point. To get the best view of prominences and surface detail it will be necessary to adjust the T-Max wheel at the front of the telescope. The T-Max has a very basic design but helps a lot to tune or detune the image to meet your specific needs. Tuning it one way will highlight the edge details and going the other direction will highlight the surface details. It also helps to get rid of the field of view of any ghost images of the Sun. These are harmonic reflections of the solar disc that sometimes fall just inside the field

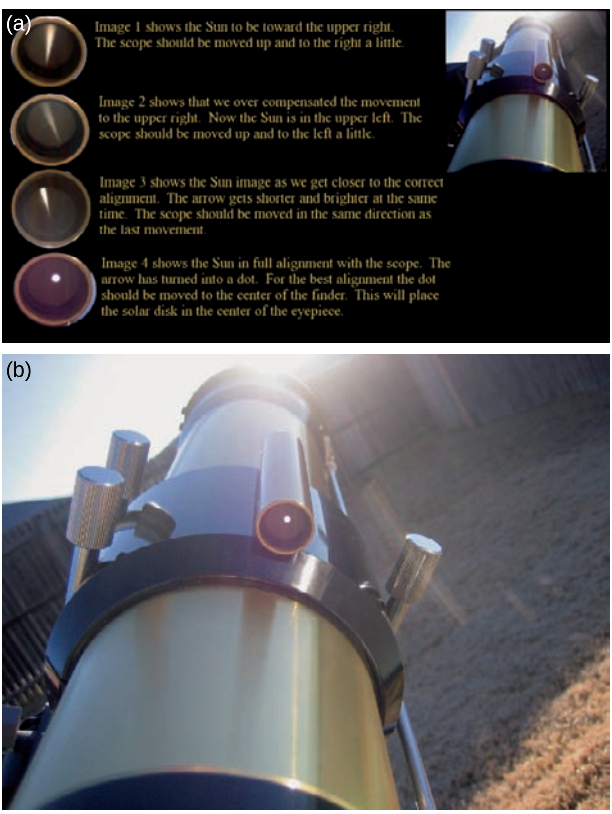


Figure 3.10. Using the Sol Ranger finder. Photos by Larry Alvarez.

of view. Tuning the T-Max will help to get rid of these dim unwanted reflections and leave only the full disc in the center part of the field of view. The T-Max tuner is a very necessary part for calibrating the MaxScope 90 but is located far and away from the rear of the telescope and by proxy the view of the Sun. This makes it difficult to tune and look at the image at the same time. To fix this I created a Crayford style remote control for the T-Max that helps tremendously. This is discussed further in the "Tips and Tricks" section of this review.

Tips and Tricks

The following paragraphs cover building a solid foundation for a tripod, quick equatorial tripod alignment, building a micro observatory for a laptop, building a Crayford style remote control for the T-Max, and choosing the right charge-coupled device (CCD) for imaging. It has been through the steady building of a solar roadmap that I came to all the following conclusions and creations. All of them were solutions to problems that came up during several viewing sessions out in the field. Not all of them may apply to every situation, but I have found each of them to be good starting points.

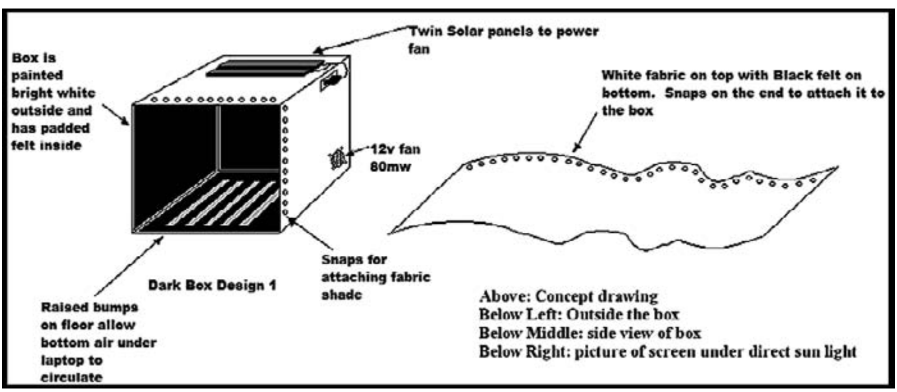
Building a Solid Foundation

Building a solid foundation requires a little planning and measuring. You will need a shovel, two or three 20 pound bags of sand, two or three 20 pound bags of paving stone, three 10- or 8-inch concrete discs (stepping-stone pads), and a weekend of warm, dry weather and few interruptions. Start by setting up the tripod in the desired location. This location should be suited for viewing the Sun at the time you feel most comfortable. For me it was early morning. Once the tripod is in its location, mark where the feet are by placing one of the stepping-stones under each foot. The tripod foot should be in the center of the stone. If the stones are left in this location overnight the grass underneath will become void of color. This is an easy way to plot the circles you need to dig out. You can also use the shovel to mark where the stones are and then remove them. After you have the areas marked where the stones will go, dig out the area about 6–8 inches down. If the hole gets a little bigger than the stepping-stone, this is OK.

After all three holes are dug out, fill the hole with about 3–4 inches of sand and pack it down tight. An easy way to do this is by using the stepping-stone or using a garden hoe. I also put a little water in during the packing to make it even tighter. Next put in enough paving stone (which has a little thicker consistency than sand and is gray) in the hole so that when the stepping-stone is added it is flushed with the ground. Pack it down the same way as the sand was packed. Place the stepping-stone in the hole and fill any gaps around the stepping-stone with sand. The last step is to set up the tripod at night and mark where the leg points are on the stones once the tripod is polar-aligned. I used arrows on each side of the tripod leg to mark where they go. After you do this you can remove the tripod and reset it up in the morning with perfect polar alignment.

Figure 3.11. MaxScope 90 mounted in position. Photo by Larry Alvarez.

Figure 3.12. Design of the micro observatory. Photo by Larry Alvarez.



Figures 3.11 and 3.12 show the telescope mounted on an EQ3 mount and placed in position. Figure 3.12 is a close-up of a single tripod leg.

Micro Observatory

Imaging the Sun can be done in several ways. I used a camera connected to a laptop to image the Sun. I have also used a digital camera and SLR cameras to image on certain occasions. I had issues when I first started trying to use my laptop. The sunlight would wash out the screen to the point where you could barely see it, the laptop would get really hot in the sunlight, and I would also be personally exposed to direct sunlight. All of these factors drove me to create a micro observatory. I started by drawing up plans on how I wanted it to look and what features I wanted it to have. I wanted it to stay cool in the sunlight and provide protection for my laptop and myself. It needed to block all the sunlight so that the laptop screen would be easily visible and it needed to be very portable and lightweight. Figure 3.13 is the wish list and mock up of the micro observatory I planned on the building. Figures 3.13–3.15 are the finished unit).

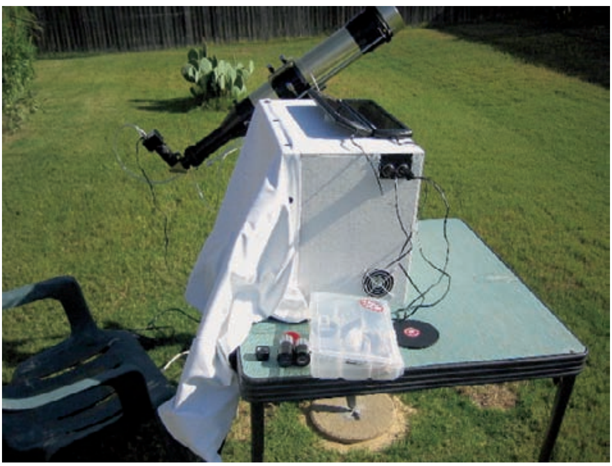


Figure 3.13. Outside view of the box. Photo by Larry Alvarez.

Figure 3.14. Side views of the box. Photo by Larry Alvarez.

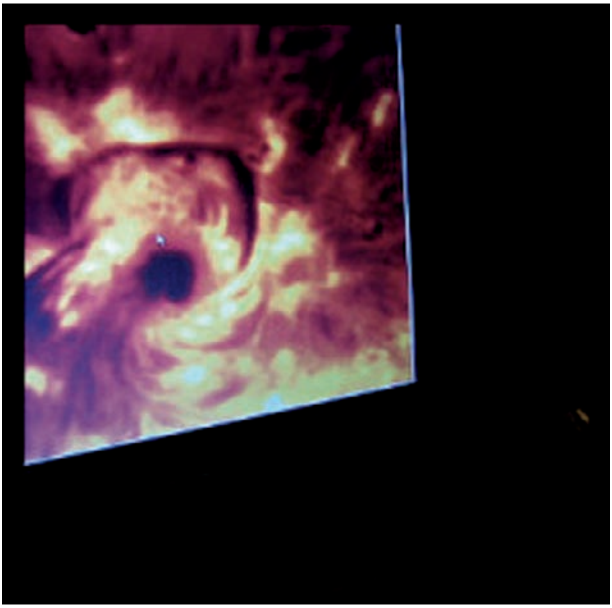


Figure 3.15. Picture of laptop screen. Photo by Larry Alvarez.

The box was constructed first as a skeleton frame made from small 3/4 inch × 1/4 inch × 2 inch wooden sticks. The sticks were cut to allow my laptop to fit easily inside and allow it to open up. I gave it 2 inches on each side for accessory room. The frame was staple gunned together and glued at the joints. After the frame had dried I put 1/8-inch wood sheets around the outside and glued them into place. The box was unbelievably sturdy. I then cut a hole for a computer case fan in the rear side of the box. The fan was rated at 12 Volts by 80 milliWatts. I planned on powering the fan with two car battery solar cell chargers. After the fan was put in place the hold for the solar cell plugs was cut and the fixture was put in place. The inside of the box was lined with black vinyl and the outside was painted bright white. Around the opening of the box I mounted seven snap connectors for connecting a fabric covering. The fabric consists of ultraviolet (UV)-resistant material on top and black fleece at the bottom. The UV-resistant material is the same that is used as a liner for curtains to keep them from fading in the sunlight. Velcro was used to secure the two solar cells to the top of the micro observatory and allow easy removal. The finished unit works extremely well in direct sunlight. Both the laptop and I stay very cool because the fan powered by the solar cells pull in fresh air and pushes out the laptop-heated air. The all white construction on the outside keeps the temperatures underneath cool and the black lining inside keeps everything dark.

Imaging the Sun: Choosing the Right CCD

When I first started imaging I found that there were no cameras out there that were made solely for solar imaging that provided the kind of resolution I wanted. I wanted extremely sharp images with high contrast and low noise.

Prior to getting into solar imaging I had built my own telescope and used a Phillips Toucam Pro webcam to image the planets and the Moon. I also used a Nikon 990 for the same purposes. Hydrogen alpha imaging is much different than regular white light imaging. It was not until I studied the properties of hydrogen alpha light that I finally understood what needed to be obtained to get the kind of resolution I needed. Hydrogen alpha light is a tiny slice of the red part of the visible light spectrum (see Chapter 1 for more details). A filter like the Coronado SolarMax 90 mm filter rejects all light from reaching the imager, except a narrow band around the hydrogen alpha wavelength. Basically, you have a monochromatic light source. Typically, I think of monochrome as black and white. Hydrogen alpha light from a Coronado filter is similar but it is red and dark red. I figured that the best imaging system would be a monochromatic system. When your budget is low you use what you have, so for a while I made do with the Nikon and Toucam. A color CCD image of the hydrogen alpha light through a Coronado telescope looks mostly red. It is not until you process it that you come out with the real detail in the image. Black and white imaging systems do not have this issue because they pick up shades of gray. They also have more resolution because they do not have to use different colored pixels. On a color CCD the pixels are split up into 25% red, 25% blue, and 50% green. For a 4-megapixel camera 1 million pixels would be red, 1 million would be blue, and 2 million would be green. Since each pixel on a photograph needs a red, green and blue pixel the processor inside the camera interpolates, or generates, the needed missing pixel based on the surrounding pixels. In a black and white camera all the pixels are used for capturing a lightness or darkness (otherwise known as *luminance*) and no extra processing is needed. This does not mean that a color imaging system cannot be used to generate some excellent results, but it just means a little extra processing may be needed to get the desired effect. In considering a good imaging system I first took inventory of what I had. The Nikon worked very well for eyepiece projection (afocal coupling). But the speed of its capture was very slow. Although it had a high resolution it could not generate enough frames to use for image stacking. Stacking is a process in which you take several like images at the same time and average them together to cancel out the noise and increase the contrast. There are several programs on the worldwide web that do this. Since the Sun and the Earth are always moving, if the images taken are too far between intervals you will end up with a blurry image because of the movement. To make matters worse, the surface of the Sun is also sliding around and moving. I boiled down what I needed and came up with three things that are as follows:

- First, I needed a fast monochromatic imaging system.
- Second, I needed a system that was not affected by the Sun's brightness during the day.
- Third, I needed a system that had a fast shutter speed.

With the creation of the micro observatory, I had a way to provide the shelter needed to keep the view screen of a laptop dark, which meant that the Toucam could be used. The Toucam was a color imager so I soon found that Sony makes a black and white version of the color CCD chip inside the Toucam. I did a web search on a black and white Toucam and found that there were some people out there that were replacing the chips in the camera and getting good results. I decided to try to find such a camera and finally did. I also found that a company called Atik makes low-cost cameras with the same chip in them. After purchasing the camera, I found that the black and white chip was several times more sensitive to hydrogen alpha light than the color version Toucam. This allows for a faster shutter speed to be used and in turn means that the distortion caused by the atmosphere will be kept to a minimum. This camera was my main workhorse for several months and provided some excellent images, but I wanted something a little faster. I found another camera made by "The Imaging Source" that captured at a faster frame rate and used the same chip. After purchasing this camera I found that the results were even better than the black and white Toucam. I started digging deeper to understand more about why the imagers were so good. Sony provides their specification sheets on their CCDs and I downloaded several of them. I found that the ICX098bl chip inside both the Toucam black and white model and Imaging Source cameras were rated at 65% for the spectral response at the hydrogen alpha wavelength. Both these cameras allow me to generate images for stacking and resolving images through the registration and averaging of the image data. As a conclusion to choosing the right camera I found that a monochromatic system with a CCD rated with a spectral response of 65% or greater that has the ability to capture several frames in succession will yield the best results. This can be done relatively cheaply by getting a modified Toucam camera or Atik CCD monochrome camera or more expensively by getting a camera like the Imaging Source camera or Lumenera brand cameras.

For a more general description of solar imaging techniques, see Chapter 5, written by Nick Howes.

Recommended Accessories

Since the MaxScope 90 comes with CEMAX type eyepieces, clamshell ring, Sol Ranger finder, and T-Max the only other accessories you will need are the tripod, camera, and cleaning supplies to get started. There are several third party accessories that can be purchased to further enhance the view, like binoviewers and special eyepieces. Personally, I own several different styles of eyepieces and Barlow lenses that I like to experiment with from time to time. I found hydrogen alpha monochromatic light very forgiving and a lens set that is not so good for white light viewing due to color separation works good with hydrogen alpha. Some of the cheaper accessories and Barlow lenses really excel with monochromatic light. I have found that the Antares brand 2× Barlow lens with the screw-off front lens actually provides a small brightness boost when imaging compared to my CEMAX 2× Barlow lens, Celestron Ultima, and Televue 2.5× Barlow lens.

It does not fare as well for tricolor images because of color separation but with monochromatic light it works very well. I also keep a supply of Knight Owl eyepieces on hand to experiment with. These eyepieces are very low priced but have a very nice quality. They are multicoated and also have the barrel-locking channel like the CEMAX eyepieces and more expensive brands.

Good house keeping is always important. To keep the telescope in tiptop shape I used a hog hairbrush to detail the outside surface of the telescope and a can of compressed air to clean the filter surfaces. Prior to blowing the filter surfaces it is important to start the flow of air to clear any particles from the direction tube. The case also should not be neglected. It is important to blow this out prior to putting the telescope back in to keep contamination from building up. If you want to use a liquid cleaner make sure it is safe for coated surfaces. Some solvent-based cleaners may damage the filter or coating on an eyepiece. If it only has slight dust on it, it is best not to clean it at all. A little dust will not affect the viewing. On an average, I find that I have to clean the telescope and eyepieces about once in every 3 months. The case is cleaned during every viewing session.

Telescope cleaning kits are also available commercially. See the "Recommended Accessories" section of Chapter 2 for suggestions.

CEMAX Eyepieces

These are the most commonly used ones and a full set is supplied with the MaxScope 90. A full description of them is in Chapter 2.

Antares 2x Barlow Lens

It is a low-cost ($74) Barlow lens, which does not perform well for traditional "nighttime" viewing but performs well with monochromatic hydrogen alpha light. For photographic use, its faster lens allows more light to reach the camera (Figure 3.16).

Figure 3.16. Antares 2x Barlow lens.

Antares 5× Barlow Lens

Antares 5× Barlow lens is shown in Figure 3.17.

Figure 3.17. Antares 5x Barlow lens.

Celestron 2× Ultima Barlow lens

It is an apochromatic Barlow lens that retails at $99 but does not perform as well for hydrogen alpha viewing as for nighttime viewing. It appears that the additional elements used to reduce chromatic aberration also reduce the light transmission (Figure 3.18).

Figure 3.18. Celestron Ultima 2x Barlow Lens.

General Notes on Accessories

I was able to use the 5× Barlow lens without any issue but seeing was a little unstable visually. CCD wise though it worked out well. I have never visually taken a look through the telescope with anything higher than 5×. Of the two Barlow lenses, Celestron Ultima and Antares, Antares is the best for hydrogen alpha. Its lens is faster than the Ultima. For color the Ultima wins, but for hydrogen alpha and monochrome the cheap Antares is the best. I say it is faster, because whenever I used it the gain on the CCD has to be adjusted down to compensate for the extra light it gathers. It is just a little bit faster but it is faster. It is an achromat Barlow lens while the Ultima is apochromatic. I have tested the CEMAX 2× Barlow also and the first one I got had loose lenses. Seeing through it was so bad that I had to send it back to Coronado to get a replacement. They changed it out for free but it worried me when they said that they could not find anything wrong with it. The field of view on it could be seen as sharp on one side and blurry on the other. Speed wise the new one I got was slower than the Antares too. Coronado told me that the optics in the scope as well as in the CEMAX eyepieces are tuned to the red wavelength of light. They are not tuned for the other colors as well. If you take the scope and eyepiece and look at the Moon with it without the hydrogen alpha filters, you would see chromatic separation around the edges. When used for monochrome imaging, it is clearly a winner in my book.

Capabilities and Limitations

Visually, the Coronado MaxScope 90 seems to be limited only by the quality of camera connected to it or the seeing conditions. At 4× the features are super sharp and the detail is astounding. Its ability to display details and fine-tune the bandpass adds to its value. One limitation that should be mentioned is the telescope's weight. The MaxScope 90 is made of high-grade aluminum that is very thick. In the < 0.5 Å configuration it also has the weight of the internal etalon. With the supplied clamshell it weighs over 20 lb. A sturdy tripod is definitely needed to bear this weight. Another limitation is the placement of the T-Max detuner. The seems to be only a limitation on the 90mm model, as the PST, 60mm MaxScope, and 70mm MaxScope have a shorter focal length of 400mm and, hence, shorter tube length. The length of the telescope makes it almost impossible to turn the tuning knob on the T-Max and look through the eyepiece at the same time. Focusing the unit does take some time to get used to it. The MaxScope 90 as well as the other MaxScope series have a helical style focuser. It is a well-built focuser and very beefy, but under the weight of a digital SLR or heavy CCD it binds enough to shake the telescope when focusing. Coronado does make an adaptor that is available ($200 at the time of writing) that will allow you to connect a JMI NGF-C model Crayford focuser. This modification will add a silky smooth focusing system to the telescope but will cost extra due to the price of the adaptor and focuser.

With the proper mount, a good alignment, and excellent seeing conditions the MaxScope 90 can work wonders. Detail within detail can be seen at high magnification and also at low magnification. The extra light pulled in by the telescope

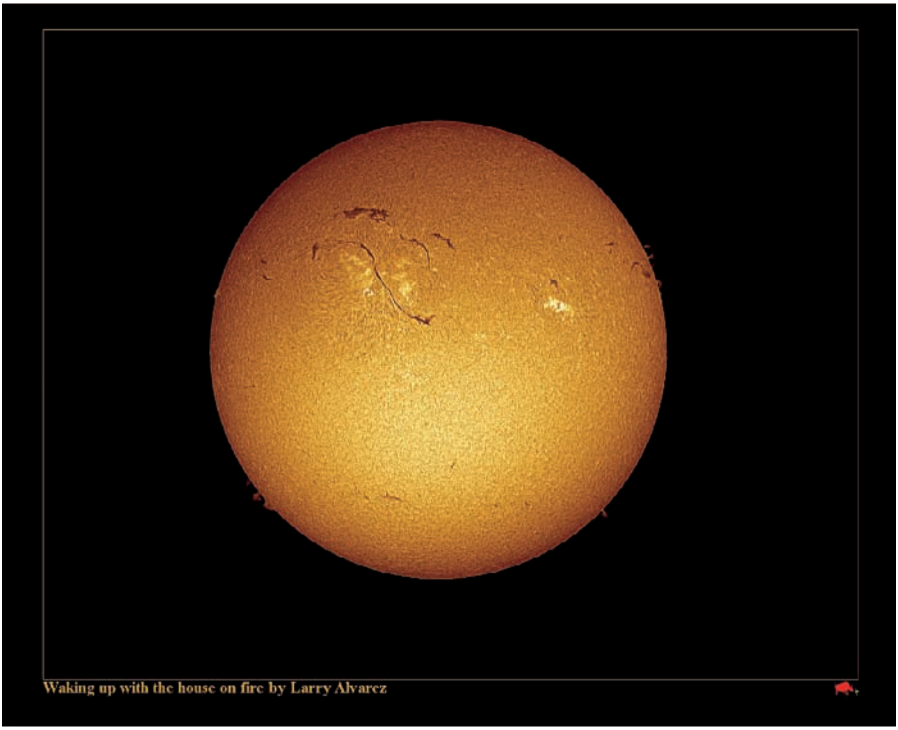


Figure 3.19. MaxScope 90 showing the full disc.

adds to its resolving ability and can make even a mediocre day extraordinary. From personal experience I have been able to image the Sun through thin cloud layers and still see excellent detail.

Whereas, like smaller hydrogen alpha telescopes, the MaxScope 90 can deliver excellent quality pictures of the solar disc (as in Figure 3.19), its main application is to show close-ups of areas of high activity in more detail than can be seen with smaller telescopes.

Figure 3.20 shows filaments and surface cells tracing out the number "8." This is far more in detail than can be obtained using entry-level hydrogen alpha equipment.

Figures 3.21–3.25 also show solar surface features in incredible detail. Figure 3.24 shows a solar flare rising from the surface.

Figures 3.26–3.29 show prominence features. Figure 3.29, in particular, shows spicules, which are not normally seen in much smaller instruments.

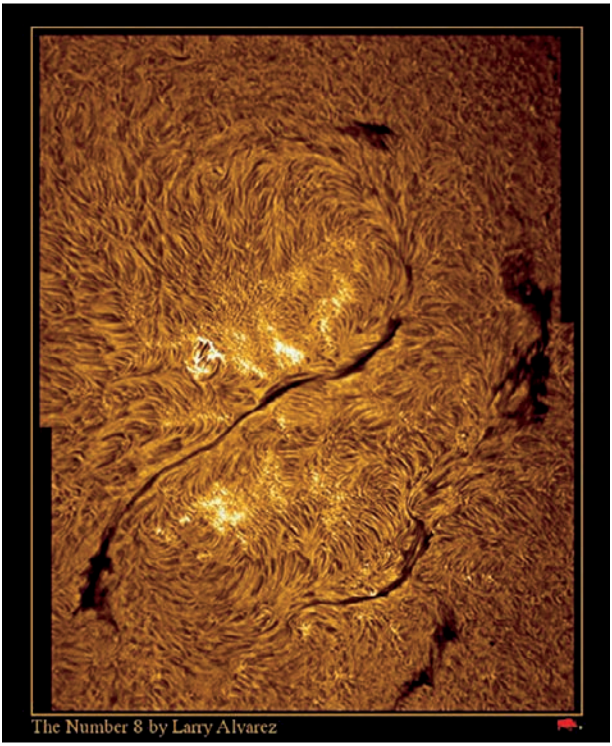


Figure 3.20. Number eight.

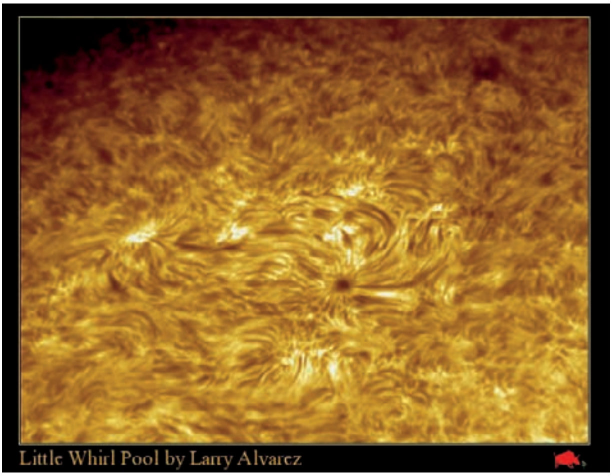


Figure 3.21. Whirlpool.

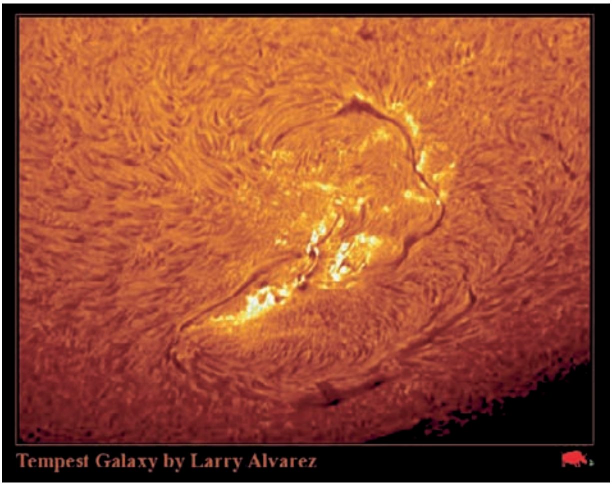


Figure 3.22. Tempest galaxy.

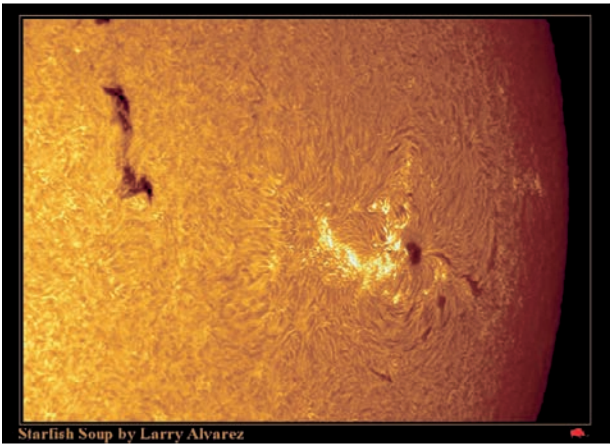


Figure 3.23. Starfish soup.

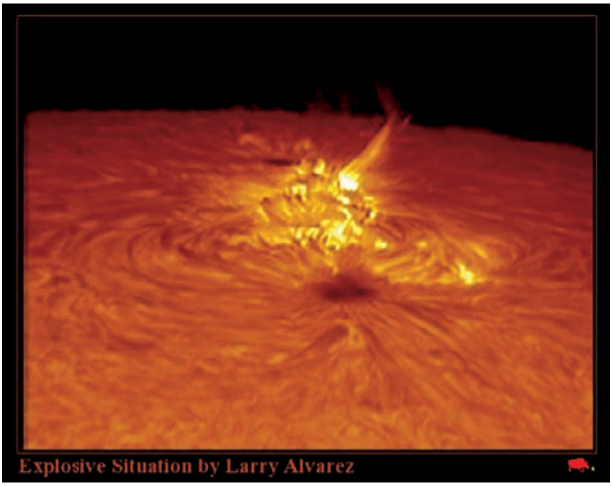


Figure 3.24. Rising flare.

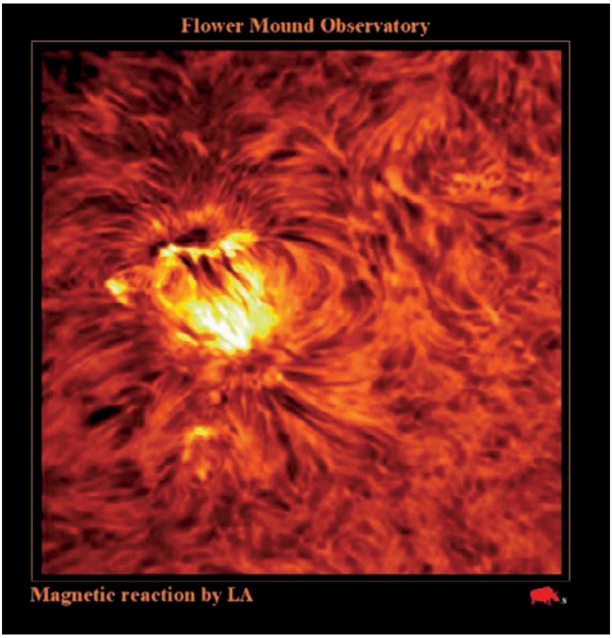


Figure 3.25.
Magnetic reaction.

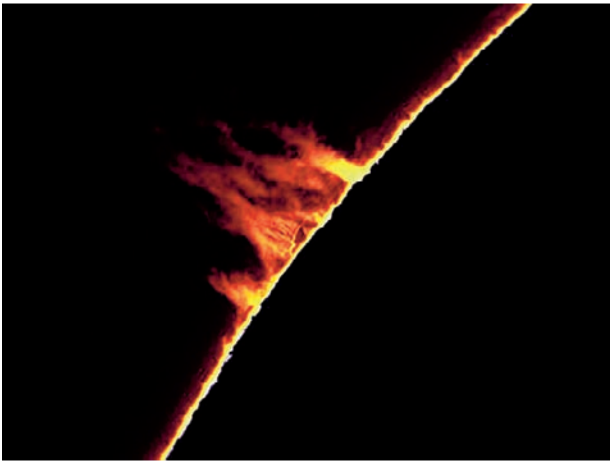


Figure 3.26.
Prominences taken with the MaxScope 90.

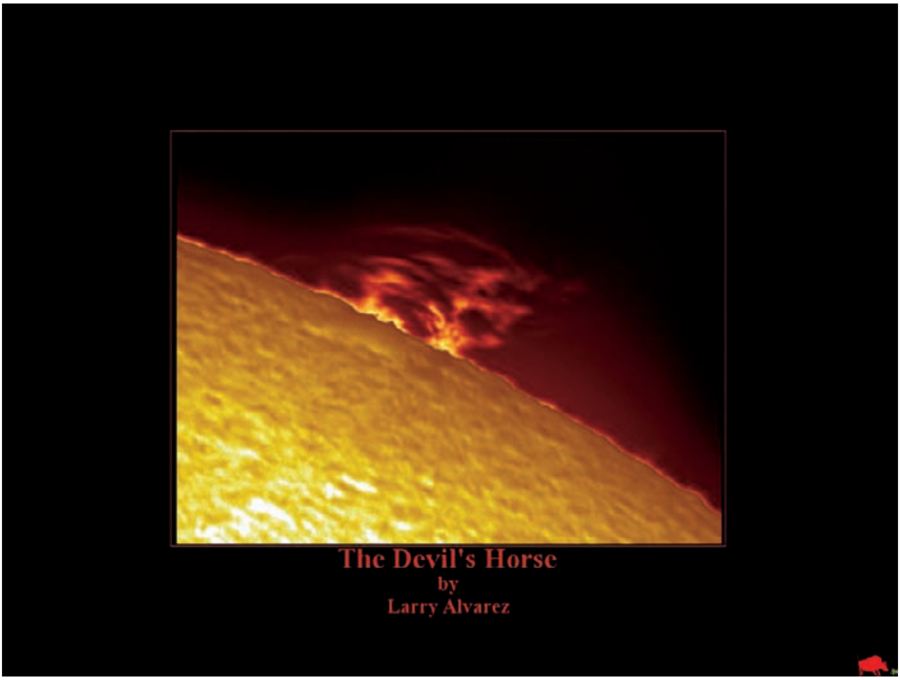


Figure 3.27. The devil's horse.

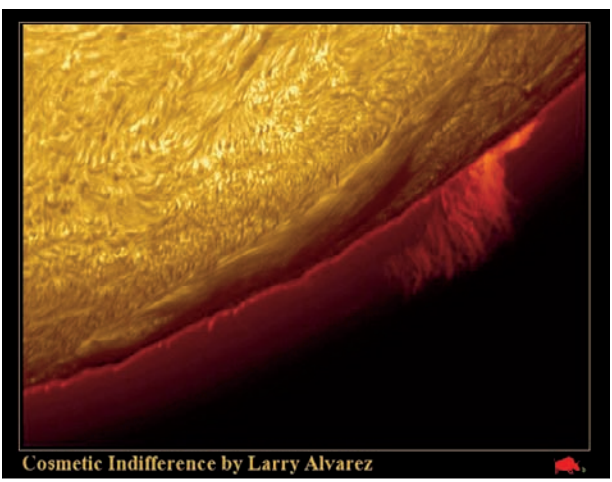


Figure 3.28. More prominences.

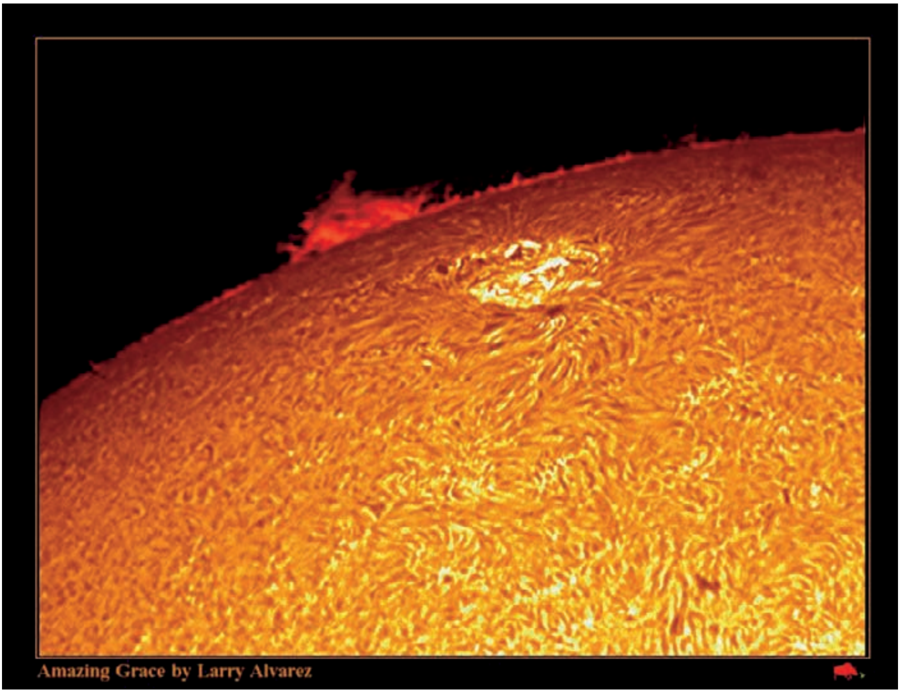


Figure 3.29. View through MaxScope 90 showing spicules.

Appraisal

Based on the high-quality materials used to build the telescope and the excellent view it provides at $< 0.5\,\text{Å}$, the MaxScope 90 is an excellent value for university or professional use. The telescope itself has a beautiful golden anodized finish with glossy black accents and is built to last. Also standard with the telescope are a full set of CEMAX eyepieces, which are optimized for hydrogen alpha, a 2× CEMAX Barlow lens, and a well-built carrying case for storage. There are a few drawbacks but they do not affect the overall performance of the telescope visually or photographically. These items are listed below:

- The Helical focuser is difficult to work with due to slight binding under a heavy load.
- The sealed cell foam in the case expands and distorts the case if left in full sunlight.
- The placement of the T-Max at the front of the telescope is hard to reach.
- The weight of the telescope requires a beefy tripod to handle the load.

The 90-mm aperture provides some of the most breathtaking views imaginable. Given a good polar alignment, excellent seeing conditions, and good photographic equipment, the telescope will perform at a level that is hard to beat. The views through the telescope almost look three-dimensional in appearance and come to life when the T-Max is tuned.

Verdict: The MaxScope 90 is definitely geared toward the professional or scientific market where the highest quality and detail are expected. The build of the telescope does not skimp on materials or manufacturing in any way and comes with several extras. It is a modern masterpiece of design, optical technology, and visual beauty.

Optical quality	10 out of 10
Value for money	7 out of 10
Ease of use	9 out of 10
Overall rating	9 out of 10, excellent

CHAPTER FOUR

Other Coronado Solar Telescopes

PST is the entry-level telescope but many are available with an aperture of up to 90 mm (Figures 4.1 and 4.2). As with nighttime telescopes, the price increases with aperture. Tube assemblies increase in price roughly as the square of the increase in aperture but the extra cost of mounting makes the larger apertures progressively more expensive.

All telescopes use an achromatic objective lens made of BK-7 glass.

The terms "SolarMax" and "MaxScope" for these telescopes appear almost interchangeably in various writings. To make it clearer, I have used the term "SolarMax" for separate filters and "MaxScope" to describe dedicated telescopes with built-in filters. It is the dedicated telescopes that this chapter refers to.

To date, the range included the following:

Name	Description
PST	Entry-level hydrogen alpha telescope
MaxScope 40	40 mm Aperture hydrogen alpha telescope
MaxScope 60	60 mm Aperture hydrogen alpha telescope
MaxScope 70	70 mm Aperture hydrogen alpha telescope
MaxScope 90	90 mm Aperture hydrogen alpha telescope
PST CaK	Entry-level calcium K telescope
CaK 70	70 mm Aperture calcium K telescope
CaK 90	90 mm Aperture calcium K telescope

Figure 4.1. Some of the Coronado range of telescopes.

MaxScope 40

The MaxScope 40 was the entry-level hydrogen alpha telescope in the range of Coronado equipment before the advent of the PST (Figure 4.3). Although, like the PST, it has been coming down in price since its launch, it was (at the time of writing) more than twice the price of the PST but cheaper than a double-stacked PST.

When considering a purchase of the MaxScope 40, it is worth thinking about the relative merits of the two telescopes:

- Filters placed near the objective (of the MaxScope 40) and not the eyepiece, resulting in more effective aperture, despite having the same objective size
- Focusing by using the more usual focusing arrangement, resulting in the use of a wider range of eyepieces and accessories
- No tube rings, clamshell camera tripod attachment only, similar to the PST

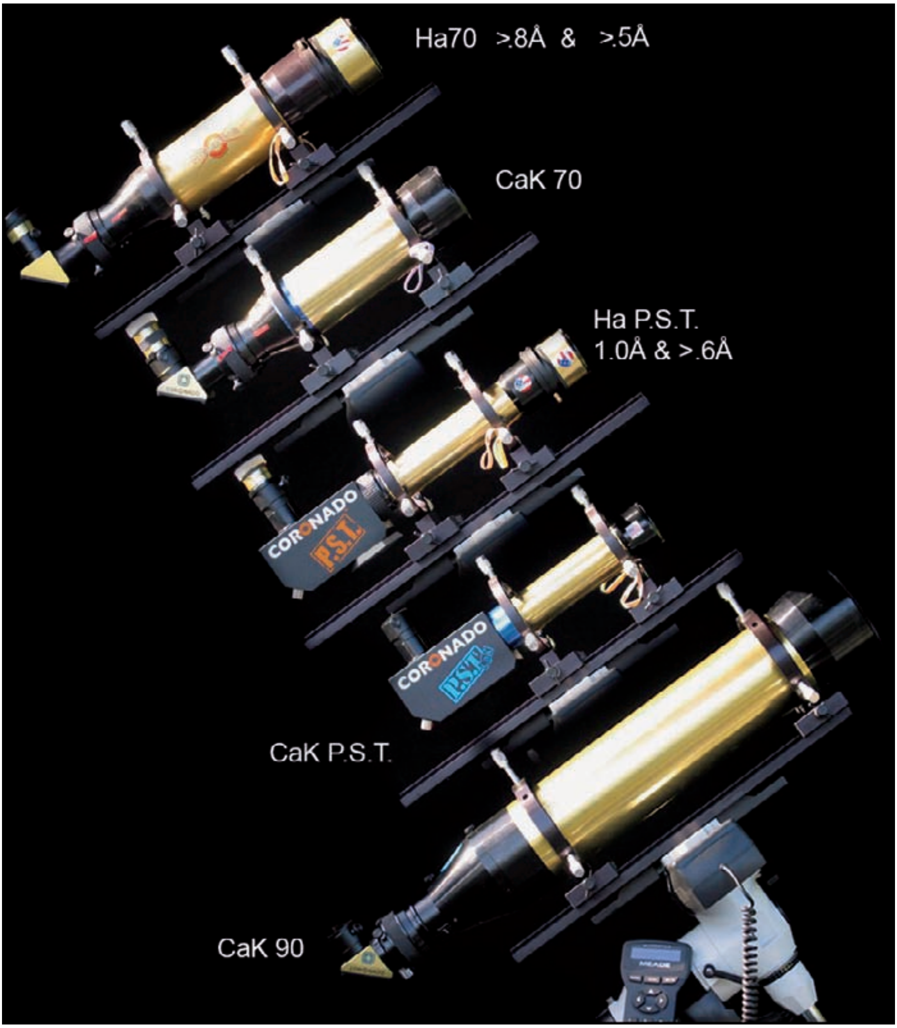


Figure 4.2. More of the Coronado range of telescopes.

- Sol Ranger (solar finder) not supplied as standard with the MaxScope 40
- The MaxScope 40 has a bandpass of 0.7 Å, which is less than the 1 Å of the PST
- Larger "sweet spot" with a greater area of the field of view showing detail

In "head-to-head" tests, the MaxScope 40 definitely outperformed the PST on disc detail (probably due to greater effective aperture and lower bandpass) but showed little advantage with prominences.

Figure 4.3. MaxScope 40 shown on a Manfrotto tripod.

Facts at a Glance

Aperture (mm)	40
Focal length (mm)	400
Bandpass (Å)	0.7
Bandpass with double-stacked filters	0.5
Weight (lb)	3

Due to the changing nature of the market, details of current price in the United Kingdom and the United States, and accessories included with the base package are included in Chapter 10.

Physical Description

It has a 40-mm objective lens with 400-mm focal length. It has a thread, which can be used for attaching to a camera tripod or other types of mount recommended by Coronado. The tube assembly is light (3 lb, as the PST). Despite the light construction, it is made of milled aluminum, rather than plastic. Only the objective shroud and cap, the clamshell, and part of the eyepiece attachment are made of plastic. Unlike the PST, the etalon is placed with the objective and a blocking filter is placed near the eyepiece. This means that the full 40-mm aperture can be fully utilized.

As with the PST, you can order a tabletop mount (MALTA) and carrying case as extras. It comes with a small booklet of instructions.

Figure 4.4 shows the underside of the MaxScope 40.

- The objective and etalon are at the left and the filter adjustment is carried out using an adjusting knob on the other side of the telescope.
- The clamshell attachment has two screw sockets, either of which can be used with a camera mount or, like the PST, can be used with the MALTA mount.
- The star diagonal is like those used for nighttime telescopes and gives a more comfortable and convenient viewing angle.

Figure 4.5 shows the top view of the MaxScope 40.

- The filter adjustment is a small knob near the objective, which is used to tune the filter. Unlike the PST, the correct tuning for prominences and surface detail can be slightly different.
- The coarse focuser enables you to unscrew the drawtube to make large-scale adjustments to the focus, but PLEASE be careful if the telescope is tilted at an angle as the eyepiece and star diagonal can fall out!

Figure 4.4. MaxScope 40 underside view.

Figure 4.5. Topside view of the MaxScope 40.

- The fine focuser is a knob that can be turned to adjust the focus. This is at variance with both the PST and most nighttime telescopes.

No eyepieces are supplied with the MaxScope 40 and the Sol Ranger (if desired) needs to be purchased separately.

How to Store

Being of similar size and weight to the PST, the storing options are as follows:

- Travel Case
- Some other sort of box or bag

See Chapter 2 for details of other options.

Mounting Options

The mounting options are the same as for the PST. See Chapter 2 for step-by-step details on how to mount the PST (or MaxScope 40) on a variety of options.

Like any other telescopes, a firm mount and a tripod are necessary for astrophotography.

The main options are as follows:

- Standard (high street) camera tripod, which is OK for visual use but not ideal for photography
- "Piggy back" mounting on top of another telescope (this is described in detail in Chapter 2)
- Manfrotto, AzTech, and similar mounts
- Making your own mounting bracket (as shown in Chapter 2)
- Use of the MALTA mount (as shown in Chapter 2)

Finding the Sun

Without the use of the Sol Ranger, this can be difficult, especially if the Sun is near the zenith. You may find that the purchase of a long focal length eyepiece, say at least 32 mm, would be useful for getting the Sun near the center of the field of view. Experienced solar viewers, like myself, can find the Sun quite quickly most of the time, but there will be the occasional frustrating day where it can take 10 minutes without having some sort of finderscope. However, the short focal length of the telescope and consequent wide field of view is a great help. It reminds me of a night at a star party where I could not find the Ring Nebula (M57 in Messier's catalogue), when I usually take 5 minutes at the most. Some days/nights are just like that!

To get coarse alignment, you could use the telescope's shadow as described under section "Finding the Sun" in Chapter 2.

Unlike many nighttime telescopes, the MaxScope 40 does not have a bracket for attaching a finderscope. The Sol Ranger (described under "Recommended Accessories" section) is the recommended option.

An alternative is to use the piggyback method onto another telescope (the "host" telescope) and use the host's finderscope to locate the Sun. Note, however that you must use a filter with the finderscope. I have made Baader filters for all my finderscopes.

Focusing the MaxScope 40

In Figure 4.5, you will notice that there is a coarse focuser and a fine focuser. In time, you will know the approximate focusing positions using each of your favorite accessories, like eyepieces and image amplifiers, such as Barlow lenses. When using a new accessory (or combination of them) for the first time, try to achieve focus with the fine focuser. If it does not work, move the fine focuser to about the midpoint position. Now, make sure the telescope is horizontal. Failure to do so may result in the loss of the lower tube assembly of your MaxScope 40 and rude letters being sent to both myself and Coronado. Gently release the screws on the coarse focuser and slide the tube in or out to the approximate position. Now make sure you tighten them, then find the Sun again. Now use the fine focuser to bring the image to focus. If it does not work, repeat the process.

Laborious? Yes, it is but it is cheaper, less time consuming and less embarrassing than contacting Coronado and asking if they supply spare parts!

This arrangement also allows a much better focusing range than the PST.

Recommended Accessories

The accessories recommended by Coronado that are available from their distributors are the following:

- PST hard case (shown and described under section "How to Store" in Chapter 2).
- MALTA mount (shown under "Mounting Options" in Chapter 2).
- SolarMax 40 filter + T-Max tuner for PST and MaxScope 40 double stacking (see below).
- Aztech Manhattan Tripod (see Chapter 2).
- Sol Ranger solar finder (see below).
- CEMAX hydrogen alpha eyepieces (see below).
- AC645 polarizing filter (see below).

SolarMax 40 Filter + T-Max Tuner This is used to allow double stacking of the filter to reduce the MaxScope 40's bandpass from 0.7 to 0.5 Å. A full description of this can be found in Chapter 2.

Here is a result of what can be seen with a double-stacked MaxScope 40 (Figure 4.6):

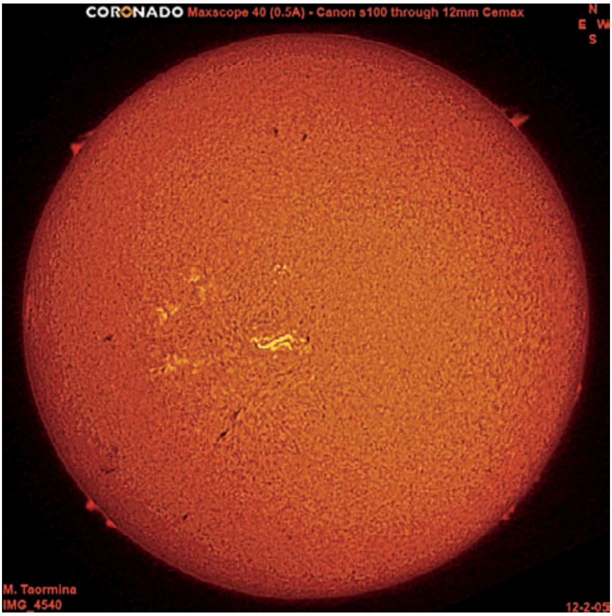


Figure 4.6. Sun through a double-stacked MaxScope 40. Photo by Mike Taormina.

Unlike the PST, the MaxScope 40 needs to be sent away to Coronado to have the filter matched with the existing one. The chances of the two filters matching by random is quite small. Most filters have a small tolerance around the central hydrogen alpha light wavelength and it is best to have one filter with a tolerance one way and the second filter the other. In theory, two identical filters would not reduce the bandpass by much.

Double stacking the MaxScope 40 does result in a dimmer image for the eye and the camera and under poor light conditions can result in loss of prominence detail. However, under clear conditions with the Sun at least 40° above the horizon, this should not be as noticeable as with the PST due to the increased effective aperture. There is no doubt that the reduced bandpass achieved by double stacking brings out a lot more detail than can be seen with a single stack.

Some amateurs have reputedly used non-Coronado filters for double stacking a MaxScope 40 but these options, at the time of writing, were more expensive.

Double stacking is described in Chapter 1.

Sol Ranger Solar Finder The Sol Ranger does not come supplied with the MaxScope 40 and is not built-in as the PST. It is almost essential when the Sun is high in the sky, but experienced observers can find the Sun without it when it is low in the sky (Figure 4.7).

As a criticism, the lack of a 90° viewing angle makes it more difficult to use than the one built into the PST.

The Sol Ranger is attached to the MaxScope 40 by placing a piece of cloth over the holes shown in Figure 4.8 on the clamshell and pushing the supports at the bottom into the holes, through the cloth. The cloth can then be trimmed.

Figure 4.7. Sol Ranger solar finder.

Figure 4.8. Holes for the Sol Ranger on the MaxScope 40.

The Sol Ranger can be purchased separately for \$55 at the time of writing (in the United States), £34 (in the United Kingdom) and is fully described in Chapter 3.

CEMAX Hydrogen Alpha Eyepieces These are described in detail in Chapter 2. As the focal length of the MaxScope 40 is the same as the PST, the magnification and field of view of figures are exactly the same.

As for the PST, these eyepieces can obtain more detail from the Sun both visually and photographically than others in the same (or cheaper) price ranges. Due to the short focal length of the MaxScope 40, the most useful accessories are the 12-mm eyepiece and 2× Barlow lens. A budget eyepiece of 25 mm or longer focal length can be used to find the Sun.

Again, as with the PST, these eyepieces will often reveal solar detail on bad days that would not be visible using others of similar or lower price.

AC645 Polarizing Filter This is described in detail in Chapter 2.

This is not the most useful of accessories with the PST but with the MaxScope 40, it provides a definite improvement in the surface detail. However, it tends to obscure the prominences, but, to be fair, Coronado states that it does not improve their appearance.

Although a domestic digital camera does not do justice to any Coronado telescope, the visual view was much better. Figures 4.9 and 4.10 show the difference between the view without and with the filter.

For both photographs, I used the CEMAX 12-mm eyepiece and 2× Barlow lens. This was a remarkable improvement, which was even more noticeable with the visual view.

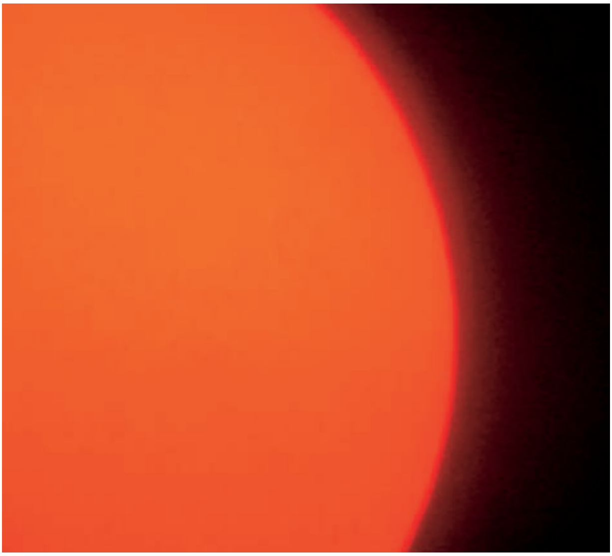


Figure 4.9. Solar disc with the MaxScope 40 without the polarizing filter.

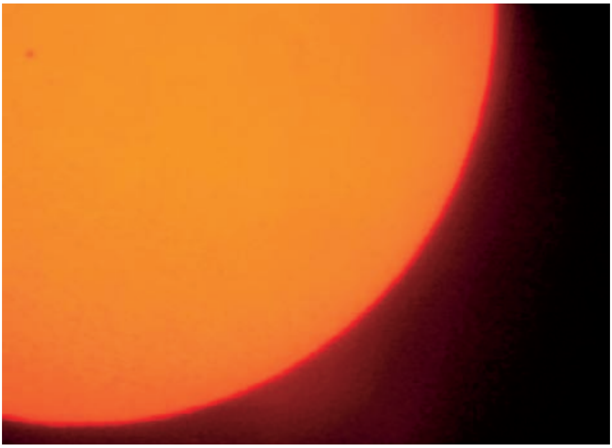


Figure 4.10. Solar disc with the MaxScope 40 with the polarizing filter.

The increase in detail is not as much as can be achieved with double stacking but it is not anywhere near as expensive.

Using Other Accessories

The Coronado MaxScope 40 takes eyepieces with the standard 1.25 in. (31 mm) fitting. This allows a huge variety of eyepieces and accessories to be used. The short answer is that most of the nighttime eyepieces that you use are suitable for use with it. As a general rule, Plossls are the best for purely visual use, whereas LER eyepieces are better for astrophotography. The biggest restriction is that with a 40-mm aperture, the ability to get sharp images at high magnification is limited. A practical limit appears to be about 100× magnification, but this is a lot less under poor viewing conditions.

On the last point, I find it rare that increasing magnification improves the visual results, but it can make a huge difference photographically, as with the PST.

This section contains a description of some of the accessories that I have tried with the MaxScope 40. It cannot be a comprehensive list, as there are a large number of accessories that will work with it. Many of them are otherwise disproportionately expensive in relation to the cost of the MaxScope 40 itself. Of course, there is nothing stopping you from using expensive accessories that you have bought previously for nighttime use, but I do not recommend the purchase of them specifically for use with the MaxScope 40.

Note that as the MaxScope 40 is about the same size as the PST and has the same focal length, many of the accessories are similar to the PST, so some of the detailed descriptions are in Chapter 2, so are cross-referred.

Moonfish Group Eyepieces These are described in detail under the similar heading in Chapter 2. Their main advantage is that they cost about the same as low-end Plossl eyepieces but have a wider field of view and are better for photography.

The difference between using these eyepieces with the PST and the MaxScope 40 is that you can use the Moonfish 3× Barlow lens with it, allowing a greater range of magnifications. The only restriction (like with many telescopes) is that combinations of Barlow lenses and eyepieces can boost the magnification beyond the capabilities of the telescope and/or the prevailing conditions.

Magni Max Image Amplifier This is described in detail under the similar heading in Chapter 2. It provides a magnification boost of 1.6× but narrows the actual field of view by about 37%. It can be used in conjunction with a 3× Barlow lens to boost the magnification to an inappropriately high level, but a more realistic combination for the MaxScope 40 is to use it in conjunction with the CEMAX or Meade 2× Barlow lens to give a combined magnification boost of 3.2×. In theory this should give slightly better results than with a budget 3× Barlow lens, but this will vary according to the actual model used and the conditions of the day.

Skywatcher Long Eye Relief Eyepieces These are described in detail under the similar heading in Chapter 2.

If you already own these eyepieces, they are worth trying with the MaxScope 40, but I would not recommend their specific purchase.

Skywatcher Zoom Eyepiece This is described in detail under the similar heading in Chapter 2. However, unlike with the PST, you can use it with a Barlow lens. However, the maximum magnification with a 3× Barlow lens of about 170× is unlikely to produce good results with the MaxScope 40. However, on its own, it works well with the MaxScope 40.

Skywatcher Plossls These are described in detail under the similar heading in Chapter 2. The 32-mm focal length eyepiece gives superb wide fields of view in the night sky but only yields 12.5× magnification with the MaxScope 40. However, in the absence of a Sol Ranger or other finding equipment, the four-degree field of view is great for finding the Sun and centering it in the field of view.

For hydrogen alpha viewing, the 6.3-mm Plossl does not perform noticeably worse than (more expensive) mid-price range Plossls. It is a pity, however, that Coronado do not supply a CEMAX eyepiece of this focal length. With this in mind, this eyepiece is a useful (low cost) addition to your accessory collection.

Celestron Moon Filter This is described in detail under the similar heading in Chapter 2. Unlike the PST, for the MaxScope 40 the Coronado polarizing filter is preferred and as neither are particularly expensive, this has little use.

BC&F Telescope Cleaning Kit This is described in detail under the similar heading in Chapter 2. Some sort of telescope cleaning is required for the MaxScope 40, especially if you are even thinking of photography.

General Guidance on Accessories

The corresponding section in Chapter 2 describes accessories that will work with the MaxScope 40. The larger effective aperture allows slightly higher magnification to be used.

Anything that may have come supplied with a nighttime telescope should be tried with the MaxScope 40, just to see what happens. Unlike the PST, the focusing range is not a limitation, so most Barlow lenses (and other types of image amplifiers) will work, provided that the magnification is kept to a sensible range, maximum around 100–120×.

I recommend the use of the 12-mm eyepiece and 2× Barlow lens as purchased separately. If you are considering buying an eyepiece that will also be used at night, the use of the MaxScope may well influence your choice.

I would look for a magnification range of about 15–100× to allow easy centering of the Sun in the field of view and close-ups of prominences and other features.

Capabilities and Limitations

First, this is the next level telescope for hydrogen alpha viewing from the PST. Results certainly seem better than with the PST, especially on days where it is difficult to see solar features due to the lack of activity and/or viewing conditions.

Its optical quality seems sound enough but a 40-mm objective and 400-mm focal length mean that the resolution and maximum magnification are limited. Whilst I have managed "white light" solar observations under quite appalling conditions, I find that any sort of cloud can ruin the view. However, unlike the

PST, the MaxScope 40 utilizes the full 40-mm aperture to maximum effect, it is slightly more tolerant of bad conditions.

As a comparison with the PST, there is necessarily no much improvement in the viewing of prominences, but the MaxScope 40 shows any sunspots (most of them that are visible in "white light") and shows the "cell" structure of the Sun quite clearly. Whilst some of this is due to the larger effective aperture, the lower bandpass of 0.7 Å also helps. Figures 4.11 and 4.12 show the Sun on a day of high activity near the upper right limb of the disc.

Faculae and filaments also benefit from the improved clarity of the MaxScope 40 and both disc and limb detail can be enhanced more readily by increasing the magnification to around 100× but the practical limit appears to be around the 120× mark. Figure 4.13 shows some solar surface detail.

Nick Howes took Figures 4.14–4.16.

One of the nice features of the MaxScope 40 is its portability. It weighs only 3 lb, the same as the PST and fits neatly into the hand luggage for air travel.

Figure 4.11. Prominences at the solar limb, picture 1 by Hiram Villarreal.

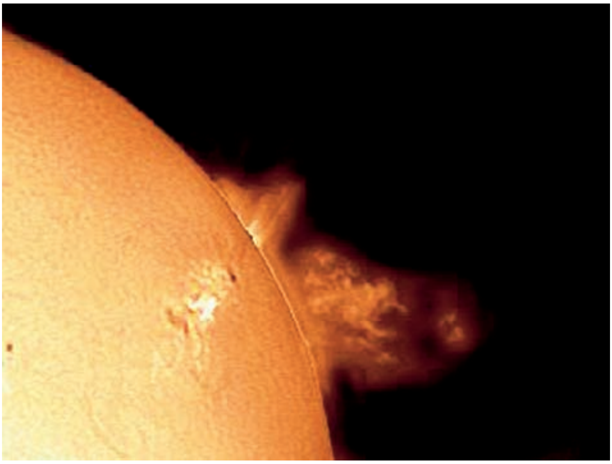


Figure 4.12. Prominences at the solar limb, picture 2 by Hiram Villarreal.

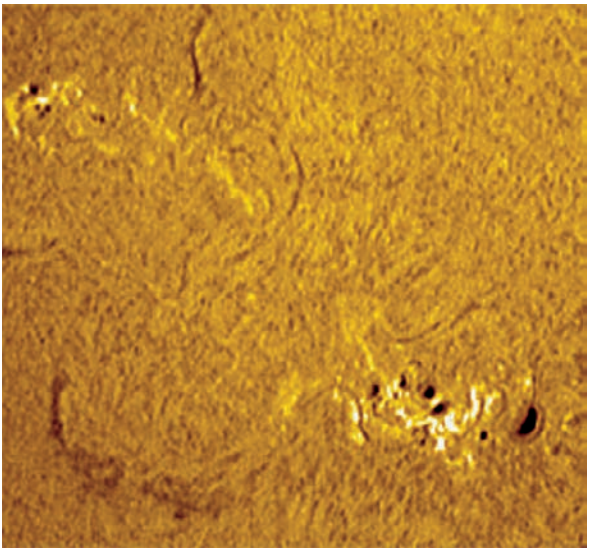
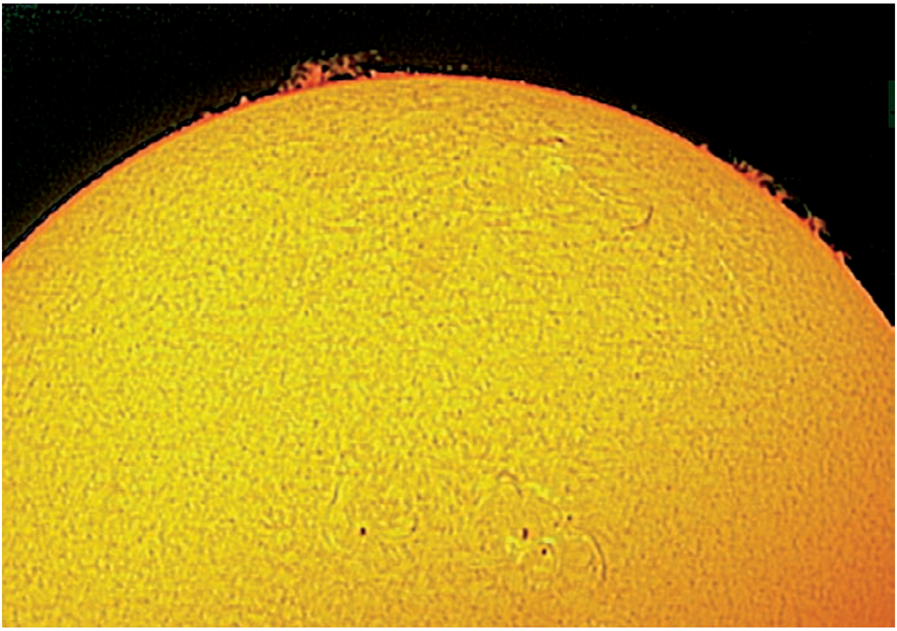


Figure 4.13. Solar surface detail. Photo by Hiram Villarreal.

Figure 4.14. Solar surface and prominences. Photo by Nick Howes.



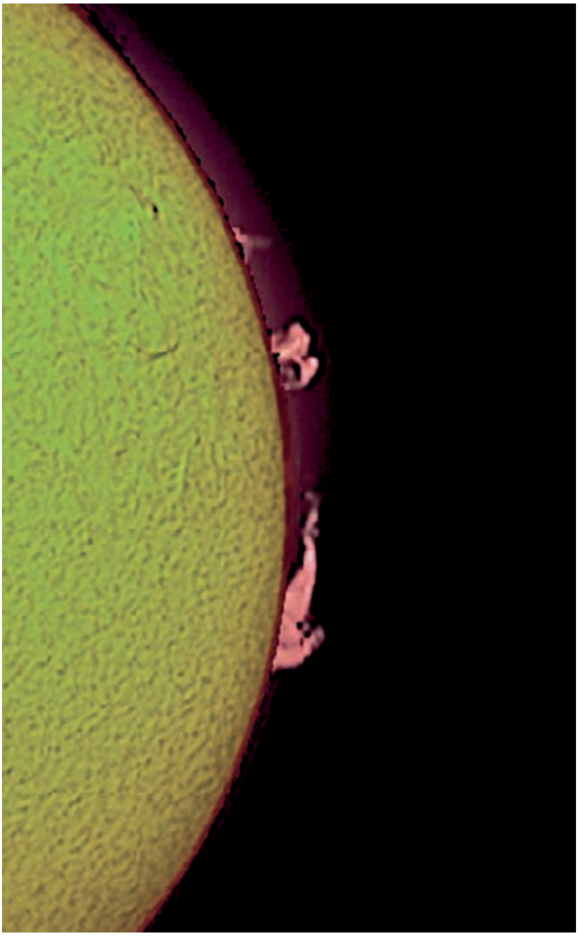


Figure 4.15. Prominences. Photo by Nick Howes.

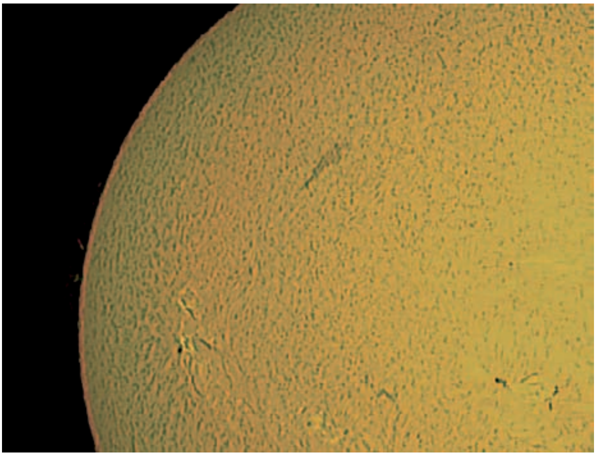


Figure 4.16. Solar surface. Photo by Nick Howes.

It is rare, if not totally impossible, for the MaxScope 40 to show a bland, uniform disc on a clear day and it is even less likely with the MaxScope 40 than with the PST

When double stacked, it can reveal more surface detail without loss of prominence visibility under reasonable conditions.

Appraisal

At the time of writing, the MaxScope 40 was above the psychological price barrier of $1000 in the United States (£1000 in the United Kingdom). This represents a considerable outlay to many amateur astronomers and is priced the same as many high-quality nighttime telescopes. It is also expensive relative to the PST.

However, its effective aperture is more than the PST and its weight of only 3 lb (same as the PST) means that it has the same portability. Perhaps the greater price may require special insurance arrangements when traveling by car or air.

The key "selling" points of the MaxScope 40 are the lower bandpass of 0.7 Å, giving more surface detail than the PST, and full focusing range, allowing a greater variety of accessories to be used.

Like the PST, it is a light, frequent use hydrogen alpha solar telescope, which can be brought outside and set up in minutes. It is easy to transport by car and almost as easy to transport by air. This makes it convenient for winter lunchtime viewing, when many people go to work before sunrise and return after sunset.

The lack of a solar finder included in the price and the fact that the one available as an optional extra does not have a right angle or even 45° viewer make it more difficult to use than the PST.

It does not have any supplied eyepieces, but I do not see this as a disadvantage as most purchasers are likely to have nighttime telescopes and eyepieces. Including a CEMAX 12-mm eyepiece and 2× Barlow lens would increase the headline price.

I would not expect the MaxScope 40 to be of much interest to complete beginners, but someone who has learned how to view the Moon and the planets at night will be able to use it.

The real question is whether the price difference with the PST justifies the purchase when you could buy a PST and a serious nighttime telescope for the same money, not to mention a pair of PSTs to view the Sun in hydrogen alpha and calcium K light simultaneously. Certainly it is better than the PST, at least for optical results, but how much is debatable.

I would not recommend purchase of both the PST and MaxScope 40 unless you intend to do public demonstrations where you might want to show the Sun to more than one person simultaneously.

Verdict: An excellent instrument but its biggest competitor is the PST, which is almost as good but much cheaper.

Optical quality	8.5 out of 10
Value for money	6 out of 10
Ease of use	6 out of 10
Overall rating	7 out of 10, good

MaxScope 60

The MaxScope 60 is like the MaxScope 40 (see Figure 4.17) but it is bigger! Whilst apparently stating the obvious, this has certain implications, which are as follows:

- Because the overall design is the same, most statements that are true about the MaxScope 40 are also true about the MaxScope 60.
- As it is bigger, it will gather more light (2.25 times as much), so it will produce more detail of the prominences and of the surface and is also more expensive and twice as heavy. It will also support a higher magnification range.

The MaxScope 60 does not come equipped with the Sol Ranger but a 25-mm CEMAX eyepiece is supplied.

The MaxScope 60 is one of the few Coronado telescopes to have a direct external competitor, the SolarScope SolarView 60, which retailed at £3795.00 at the time of writing, which was significantly more expensive than the MaxScope 60. Furthermore, the SolarView 60 comes supplied with neither a star diagonal nor any eyepiece. The bandpass of 0.7 Å is the same as the MaxScope 60.

Facts at a Glance

Aperture (mm)	60
Focal length (mm)	400
Bandpass (Å)	0.7
Bandpass with double-stacked filters	0.5
Weight (lb)	6

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in an appendix.

Figure 4.17. MaxScope 60 with Manfrotto block.

Physical Description

It has a 60-mm objective lens with 400-mm focal length. It has a thread, which can be used for attaching to types of mount recommended by Coronado. The tube assembly is light (6 lb, twice that of the MaxScope 40 or PST).

For details of the parts, please refer to the "MaxScope 40, Physical Description" section.

How to Store

Although the MaxScope 60 weighs more than the MaxScope 40 and the PST, it has the same length, so please refer to the "MaxScope 40, How to Store" section.

Mounting Options

The mounting techniques are the same as for the PST. See Chapter 2 for step-by-step details on how to mount the PST on a variety of options. The additional weight does make a small difference to the mounting options, especially when used for photography.

Like any other telescopes, a firm mount and a tripod are necessary for astrophotography.

The main options are the following:

- Standard (high street) camera tripod, which is marginal for visual use but useless for photography
- Piggyback mounting on top of another telescope (this is described in detail in Chapter 2). However, this is NOT recommended with an EQ1 mount and it should be used with a larger telescope on an EQ3 or heavier mount
- Manfrotto, AzTech, and similar mounts
- Making your own mounting bracket (as shown in Chapter 2)

The MaxScope 60 will fit a MALTA tabletop mount but is likely to be too heavy.

Finding the Sun

See "MaxScope 40, Finding the Sun" section for details. It is the same.

Focusing

See "MaxScope 40, Focusing" for details. It is the same.

Recommended Accessories

See "MaxScope 40, Recommended Accessories" and the similar section for the MaxScope 70 for details. Everything that works with the MaxScope 40 and MaxScope 70 also works with the MaxScope 60. However, note that although the 25-mm CEMAX eyepiece is supplied, in my opinion, the 12-mm eyepiece would have been more appropriate.

Where use of further accessories is appropriate is that the 60-mm objective will support about 1.5 times more magnification than the MaxScope 40 under the same conditions, so any eyepiece/Barlow lens combination that delivers magnification up to 200× is worth a try. However, this will also be limited by the conditions.

The other point to consider is that more expensive eyepieces, such as top-range Plossls, are more appropriate with the MaxScope 60, as they represent the same percentage of the telescope price as the CEMAX eyepieces are for the MaxScope 40. However, evidence seems to suggest that CEMAX eyepieces will outperform mid-range and more expensive Plossls for hydrogen alpha and calcium K viewing and photography.

Double stacking requires that the telescope is sent off to Coronado to ensure that the filters are properly matched (see Figure 4.18). It reduces the bandpass from 0.7 to 0.5 Å, which ensures that many more surface features are visible.

Unlike the MaxScope 40 and the PST, the loss of light from double stacking is less of a problem due to the additional light gathering power of the MaxScope 60.

Capabilities and Limitations

Indeed, it would be an obvious statement that the MaxScope 60 is better than the MaxScope 40 and the PST because of the increased aperture. It is a bit like saying a 90-mm refractor will show more stars and more planetary detail than a 60-mm refractor of similar quality. There is the key in that they can be compared directly because they are the same design. Ask any nighttime astronomer whether a 1.5 times aperture jump is worth the extra money and do not expect to hear a "no."

The MaxScope 60 is certainly a superb instrument when used visually. It reveals a lot more detail on the solar surface and reveals smaller prominences, along with more detail on the larger ones. The cell structure starts to take on a more defined appearance, rather than the hint of it revealed by the PST and MaxScope 40.

The real evidence for the effectiveness of this instrument is the set of excellent photographs that have been taken by amateurs. Whilst it is true that many of them have been taken using excellent imaging systems and expert postprocessing, some have been taken using simple point and click techniques using domestic digital cameras.

I would even say that if you are fortunate enough to own a MaxScope 60, it is almost a criminal offence not to publish pictures on the Internet to share them with the wider astronomical community. With the MaxScope 60 being

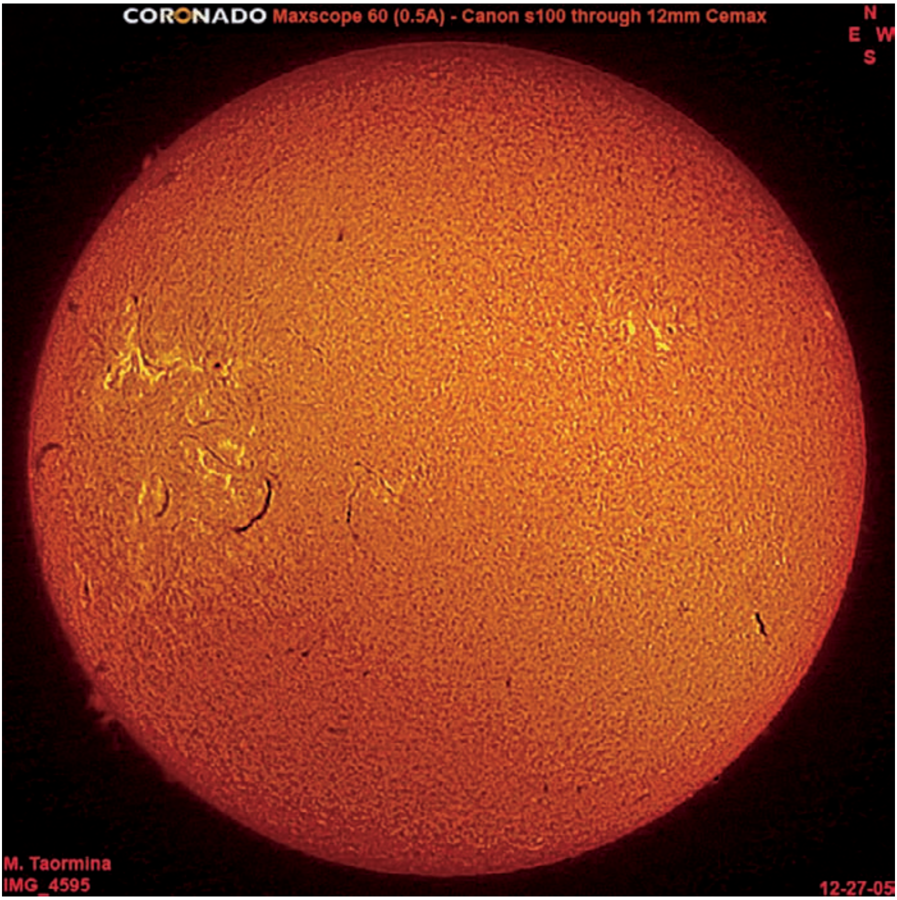


Figure 4.18. Sun through a double-stacked MaxScope 60. Photo by Mike Taormina.

used by serious amateurs, I have divided this section into single- and double-stacked shots. Larry Alvarez, who contributed the Chapter 3, has taken many of these.

Single Stack Shots Figure 4.19 shows an imaginative mosaic composed by Larry. The central full disc shot shows the detail visible on the surface and prominences, while the surrounding shots show the type of detail available using image amplifiers and prime focus photography. Refer to the Chapter 3 for details on how Larry takes his photographs.

Like many of us, Larry is not one to forgo the pleasures of solar viewing in the festive season. He does have the advantage of living in Texas, which has much better solar viewing than I have in England at that time of year, when I am more likely to be enjoying the deep sky objects around Orion and any planets that

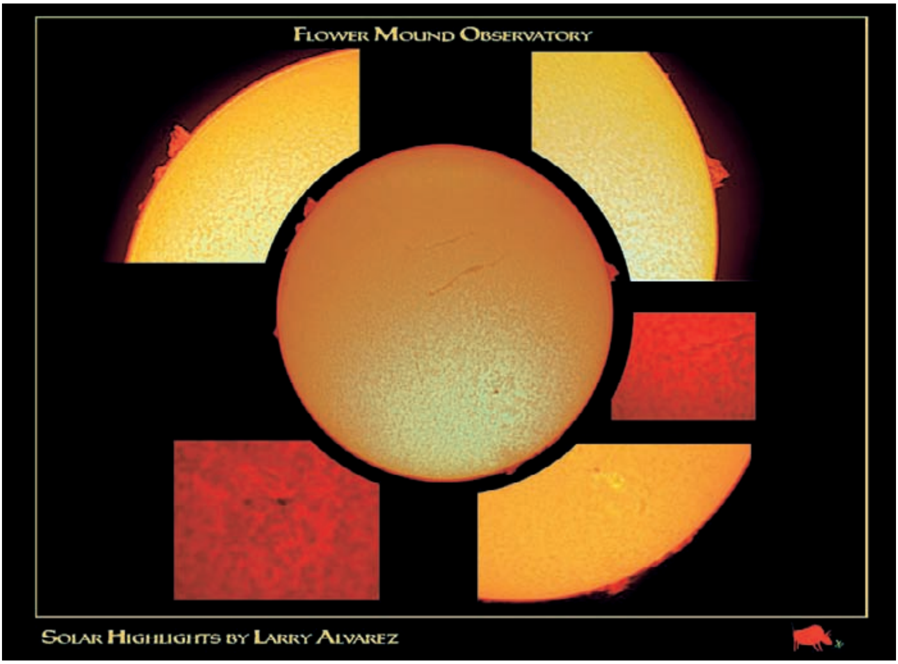


Figure 4.19. Photos taken with a single-stacked MaxScope 60 by Larry Alvarez.

might be visible. Figure 4.20 shows a rather nice seasonal solar feature, along with the full disc.

Just to prove that he does not miss an opportunity on the big day itself, see Figure 4.21.

Figure 4.22 shows another prominence that looks like a shark's fin. Whilst this prominence is large enough to be visible in smaller instruments, the extra resolving power of the MaxScope 60 brings it out.

Double Stack Shots What is particularly remarkable about Figure 4.23 is that such detail is possible with such low elevation. From English skies, I simply do not get to see this amount of detail and usually wait until the Sun is at least 10° above the horizon. The amount of light getting through on this shot was much less than at midday.

Figure 4.24 shows a rich field view. As well as the prominence at the top left, notice the active region near the center of the photograph.

Figure 4.25 shows a prominence through a double-stacked MaxScope 60 demonstrating clearly that loss of prominence detail sometimes experienced in smaller instruments does not apply to the MaxScope 60.

Figure 4.26 shows two shots, both showing a hint of spicules, the small features that can sometimes be seen on the solar limb. They are not so clearly visible in

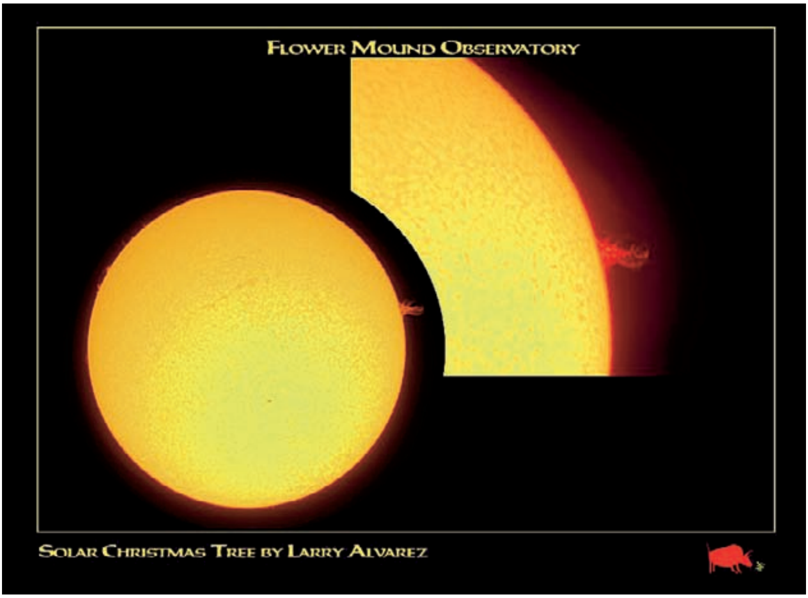
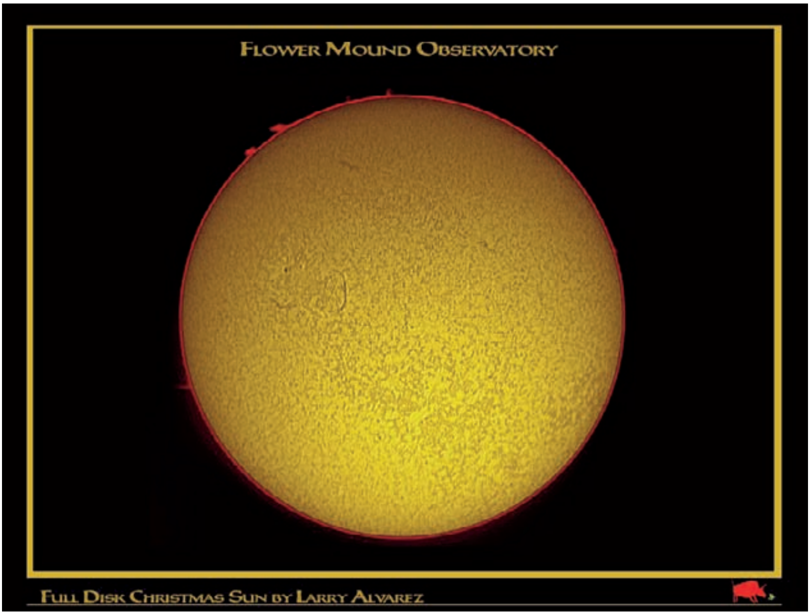


Figure 4.20. Picture of the whole Sun plus prominence close-up by Larry Alvarez.

Figure 4.21. The Sun on Christmas Day 2004 by Larry Alvarez.



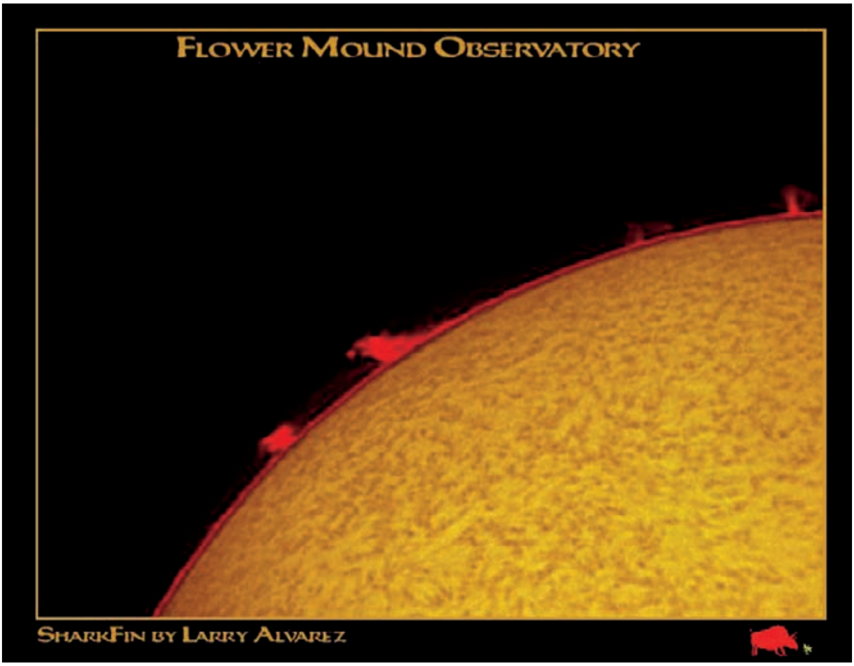
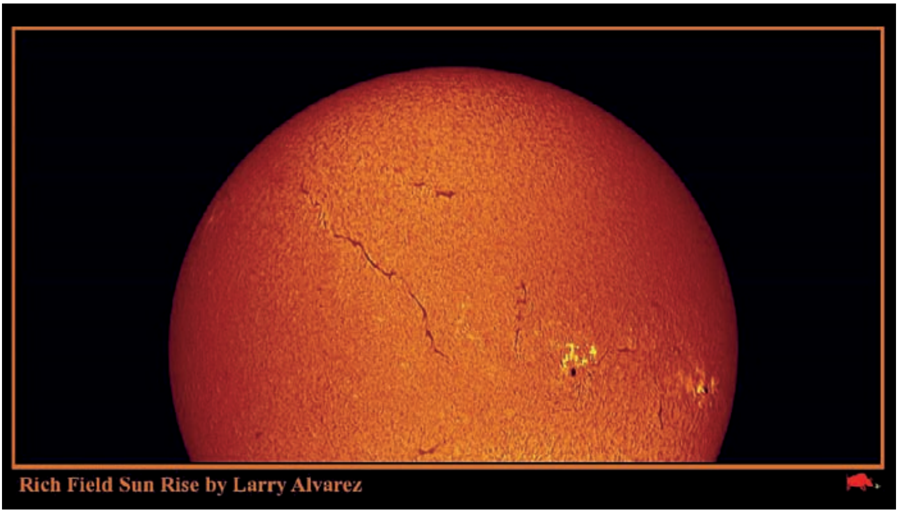


Figure 4.22. Prominence close-up. Courtesy of Larry Alvarez.

Figure 4.23. Sunrise through a double-stacked MaxScope 60.



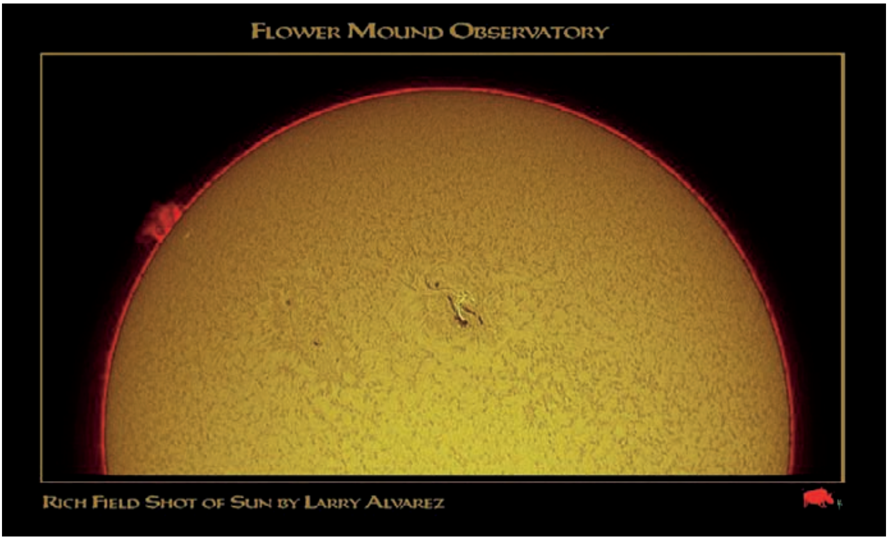
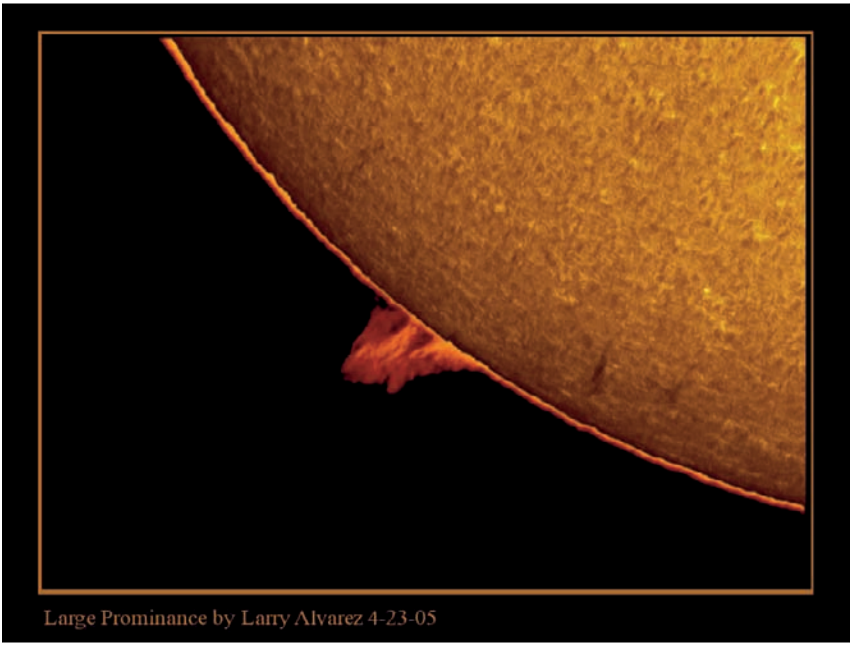


Figure 4.24. Rich field view of the Sun.

Figure 4.25. Prominence by Larry Alvarez.



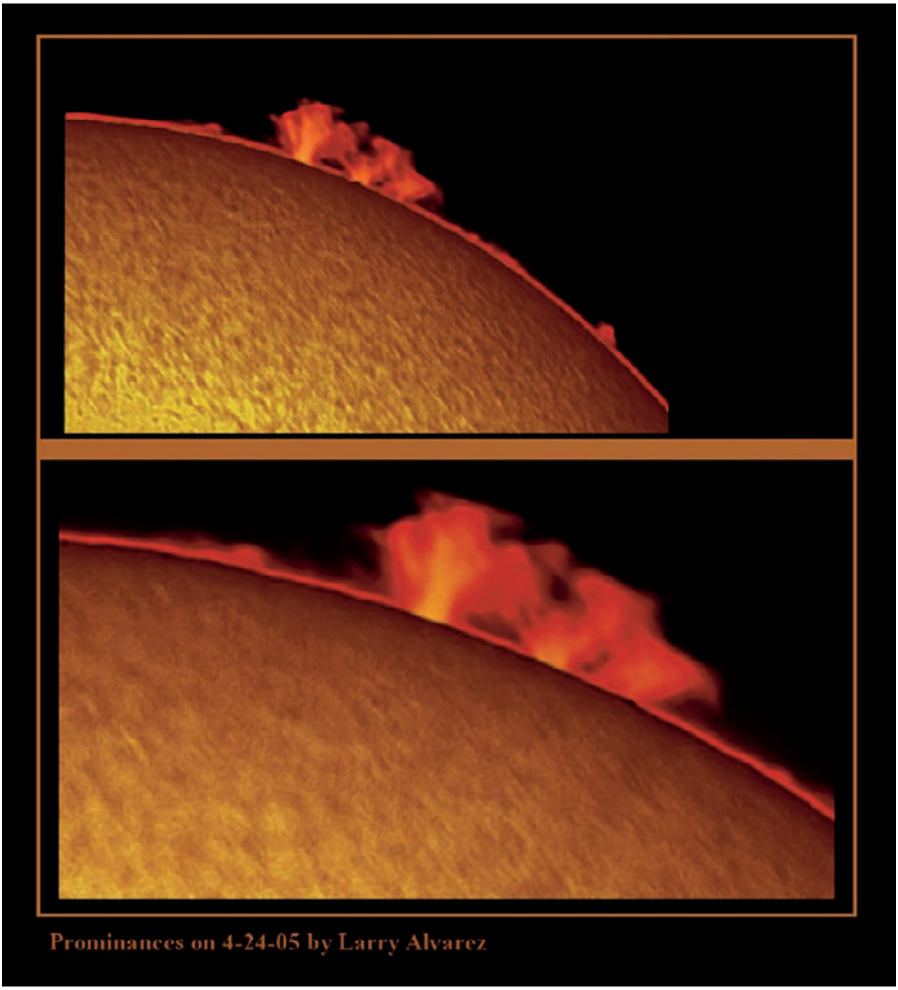


Figure 4.26. Prominences and spicules by Larry Alvarez.

the MaxScope 60 as in the MaxScope 90, but just as the MaxScope 60 shows a significant improvement over the MaxScope 40, so does the MaxScope 90 over the MaxScope 60. Larry will explain it in Chapter 3.

Direct Comparison of Double Stack and Single Stack Although there is no doubt that even a single-stacked MaxScope 60 is an excellent instrument, it is also clear that the addition of a double stack greatly improves the surface detail, without losing the quality of prominence viewing and photography. Figure 4.27 demonstrates the difference clearly.

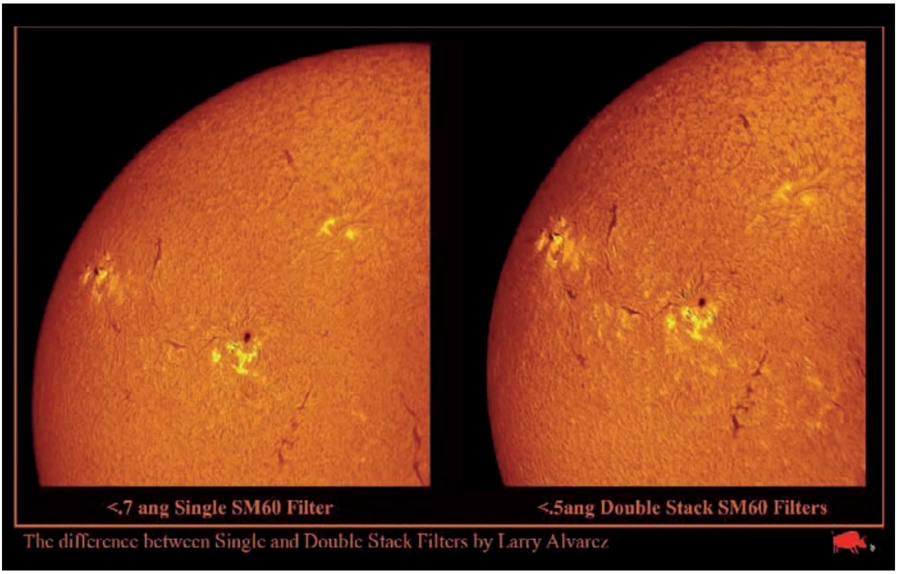


Figure 4.27. Comparison of single- and double-stacked shots with a MaxScope 60.

Appraisal

At the time of writing, the MaxScope 60 was just over twice the price of the MaxScope 40. This places it in the same price bracket as many serious nighttime telescopes and can be prohibitively expensive to many individual amateurs. However, astronomical societies with a permanent base might consider it as a purchase for their members' use.

Its weight of 6 lb makes it less transportable than the MaxScope 40 or PST but I have certainly transported heavier nighttime telescopes by air.

Like the MaxScope 40, the lack of a solar finder included in the price and the fact that the one available as an optional extra does not have a right angle or even 45° viewer make it more difficult to use than the PST.

The supplied CEMAX eyepiece, of 25-mm focal length, is of sound quality but the 12-mm one would have been more appropriate. Yielding a magnification of only 16×, its only real use is for finding the Sun, which can be achieved with a budget 32-mm Plossl more effectively and at half the price. Use of Barlow lenses and other image amplifiers are needed to get the best from it.

I would not expect the MaxScope 60 to be of any interest to complete beginners, but someone who has learned how to view the Moon and the planets at night will be able to use it. If you are in any doubt as to how much use you will be able to get from it, it may be better to purchase a PST first. You need a lot of daylight viewing time to justify buying it.

The real question is not whether you would buy a MaxScope 60 if you had the money and get the use out of it. Although it has some external competition, its main competitors are the double-stacked MaxScope 40 and the MaxScope 70, which are of comparable price.

The double-stacked MaxScope 40 certainly has a lower bandpass but does not have the same resolving power. Also, as amateur astronomers can be quite inventive about finding funds for purchases, you can always double stack the MaxScope 60 at a later date.

The MaxScope 70 has a slightly better light transmission than the MaxScope 60, but its optical design produces a bandpass of 0.8 Å as opposed to the 0.7 Å bandpass of the MaxScope 60. The MaxScope 70 is also slightly cheaper and easier to use. In the words of one amateur: "Both instruments will knock your socks off." My advice? Go somewhere where you can try out both on the same day!

Verdict: An excellent instrument but way above the budget bracket.

Optical quality	8 out of 10
Value for money	7 out of 10
Ease of use	7 out of 10
Overall rating	7 out of 10, good

MaxScope 70

The MaxScope 70 is a different type of telescope from the MaxScope 40, 60, and 90. It is based on the first-ever commercial Coronado solar telescopes, Helios I and NearStar. This design allows an etalon smaller than the objective to be used, as it is placed nearer to the eyepiece. The advantage is that a relatively large objective lens can be used for the cost of the telescope. However, the major disadvantages are as follows:

- The etalon cannot be tuned, as for the other MaxScope telescopes and PST.
- The bandpass at 0.8 Å is slightly higher than the other MaxScopes but still less than the PST.
- The focusing range is not as good as the MaxScope 40, 60, or 90 but is better than the PST.

One of the selling points of the MaxScope 70 is that it is a sealed unit and is considered more suitable for use by beginners and children.

It comes supplied with a 25-mm CEMAX eyepiece and Sol Ranger solar finder. For details of the Sol Ranger, see Chapter 3.

The MaxScope 70 is one of the few Coronado telescopes to have an external competitor, the SolarScope SolarView 60, but its biggest competitor is the MaxScope 60, which was about 20% more expensive at the time of writing. The

SolarView 60 retailed at £3795.00 at the time of writing, which was significantly more expensive than the MaxScope 70 or the MaxScope 60. Furthermore, the SolarView 60 comes supplied with neither a star diagonal nor any eyepiece. The bandpass of 0.7 Å is the same as the MaxScope 60 but slightly less than that of the MaxScope 70.

The other interesting price comparison is that a double-stacked MaxScope 40 is about 10% cheaper.

Facts at a Glance

Aperture (mm)	70
Focal length (mm)	400
Bandpass (Å)	0.8
Bandpass with double-stacked filters	0.6
Weight (lb)	5

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in an appendix.

Physical Description

It has a 70-mm objective lens with 400-mm focal length. It has a thread, which can be used for attaching to types of mount recommended by Coronado (see Figure 4.28). The tube assembly is light (5 lb, nearly twice that of the MaxScope 40 or the PST and slightly less than the MaxScope 60).

For details of the parts, see "MaxScope 40, Physical Description" section. The only difference (externally) is that the MaxScope 70 does not have a filter-tuning knob, as the etalon is internal.

Figure 4.28. MaxScope 70.

How to Store

Although the MaxScope 70 weighs more than the MaxScope 40 and the PST, it has the same length, so please refer to "MaxScope 40, How to Store" section.

Mounting Options

The mounting techniques are the same as for the PST. See Chapter 2 for step-by-step details on how to mount the PST on a variety of options. The additional weight does make a small difference to the mounting options, especially when used for photography. For example, budget high street camera mounts are no longer suitable when used for photography and the use of the MALTA tabletop mount is rather questionable. It is slightly lighter than the MaxScope 60, so please refer to "MaxScope 60" section for more details.

Like any other telescopes, a firm mount and a tripod are necessary for astrophotography.

The main options are as follows:

- Standard (high street) camera tripod, which is marginal for visual use but useless for photography
- Piggyback mounting on top of another telescope (this is described in detail in Chapter 2). However, this is NOT recommended with an EQ1 mount and it should be used with a larger telescope on an EQ3 or heavier mount
- Manfrotto, AzTech, and similar mounts
- Making your own mounting bracket (as shown in Chapter 2).

This section also introduces a new option, the Bresser GIRO.

Bresser GIRO Another mounting option is the Bresser GIRO, which can mount two telescopes at the same time. The photo in Figure 4.29 shows a Revelation 80 armed with a "white light" filter co-mounted with a MaxScope 70. Another idea is to co-mount a CaK 70 to view hydrogen alpha and calcium K features simultaneously. Note that the MaxScope 70 shown is an older model without a Sol Ranger solar finder.

The only problem with the GIRO is that it is alz-azimuth and not equatorial and so for long observation periods or demonstrations, it is necessary to keep refinding the Sun (difficult with older models of the MaxScope 70, which do not come supplied with a Sol Ranger solar finder).

It is about 4 ft 6 in. high and retails at about £400 in the United Kingdom. Note, however, that you need to buy it through a Bresser distributor, as it is more expensive through other outlets.

Figure 4.29. MaxScope 70 and Revelation 80 mounted on a Bresser GIRO.

Finding the Sun

See "MaxScope 90, Finding the Sun" section for details. It is the same, as the Sol Ranger is supplied with both telescopes.

Recommended Accessories

The accessories recommended by Coronado that are available from their distributors are the following:

- Hard case
- SolarMax 70 filter + T-Max tuner for MaxScope 70 double stacking (see below)
- CEMAX hydrogen alpha eyepieces (see below)

SolarMax 70 Filter + T-Max Tuner This is used to allow double stacking of the filter to reduce the MaxScope 70's bandpass from 0.8 to 0.5 Å. Neither my coauthors nor I have tried it, but results should be similar to a double-stacked MaxScope 60.

CEMAX Hydrogen Alpha Eyepieces These are described in detail in Chapter 2. As the focal length of the MaxScope 70 is the same as the PST, the magnification and field of view of figures are exactly the same.

The 25-mm eyepiece is supplied with the MaxScope 70. This allows a wide field of view and makes finding the Sun very easy, especially with the supplied Sol Ranger.

As for the PST, these eyepieces can obtain more detail from the Sun both visually and photographically than others in the same (or cheaper) price ranges. Due to the short focal length of the MaxScope 70, the most useful accessories are the 12-mm eyepiece and 2× Barlow lens.

Many owners of the larger hydrogen alpha telescopes (MaxScope 60, 70, and 90) do not actually use any other eyepieces for day-to-day viewing. Also, unlike the PST, a full set of CEMAX eyepieces is not a significant amount of money compared to the cost of the telescope.

Using Other Accessories

The Coronado MaxScope 70 takes eyepieces with the standard 1.25 inch (31 mm) fitting. This allows a huge variety of eyepieces and accessories to be used. The short answer is that most of the nighttime eyepieces that you use are suitable for use with it. As a general rule, Plossls are the best for purely visual use, whereas LER eyepieces are better for astrophotography. The practical magnification limit does not appear to be significantly higher than the MaxScope 40, despite the larger aperture. The upper limit appears to be about 150×.

This section contains a description of some of the accessories that I have tried with the MaxScope 70. It cannot be a comprehensive list, as there are a large number of accessories that will work with it. Many of them are otherwise disproportionately expensive in relation to the cost of the MaxScope 70 itself. Of course, there is nothing stopping you from using expensive accessories that you have bought previously for nighttime use, but I do not recommend the purchase of them specifically for use with the MaxScope 70.

Note that as the MaxScope 70 has the same focal length as the PST and the MaxScope 40, many of the accessories are similar to the PST, so some of the detailed descriptions are in Chapter 2, so are cross-referred.

Moonfish Group Eyepieces These are described in detail under the similar heading in Chapter 2. Their main advantage is that they cost about the same as low-end Plossl eyepieces but have a wider field of view and are better for photography.

They stood up well against the Revelation Plossls (see below). The detail was about the same but the Moonfish eyepieces have a larger field of view. Note that the results with the MaxScope 70 are different to those with the PST, where the Moonfish Group eyepieces provided better views than with the Revelation eyepieces.

The moral of the story is that it is always worth trying new combinations of telescope, eyepiece, and accessories even if the expected results are not good!

Magni Max Image Amplifier This is described in detail under the similar heading in Chapter 2. It provides a magnification boost of 1.6× but narrows the actual field of view by about 37%. It can be used in conjunction with a 3× Barlow lens to boost the magnification to an inappropriately high level, but a more realistic combination for the MaxScope 70 is to use it in conjunction with the CEMAX, Soligor, or Meade 2× Barlow lens to give a combined magnification boost of 3.2×. In theory this should give slightly better results than with a budget 3× Barlow lens, but this will vary according to the actual model used and the conditions of the day.

Skywatcher Long Eye Relief Eyepieces These are described in detail under the similar heading in Chapter 2.

If you already own these eyepieces, they are worth trying with the MaxScope 70, but I would not recommend their specific purchase. They did not compare well with the Revelation Plossls or Moonfish Group eyepieces on my tests.

Revelation Plossls Quality-wise, these Plossls are mid-range but price-wise anything but! The whole set retails at about £99 (Figure 4.30). I first came across them when attending a showing of Coronado telescopes. They show quite a lot of detail through a MaxScope 70 and certainly did not let the telescope down in any way. Certainly, they outperformed my own Skywatcher Plossls, although I was only able to test the longer focal length eyepieces due to the conditions. They can also work well with the BC&F Magni Max Image Amplifier, which is described in detail in Chapter 2. They also work well with my Soligor 2× Barlow lens (also described in the same chapter).

By using eyepieces of similar focal length, I was able to "benchmark" the eyepieces against my own Moonfish Group eyepieces. The optical quality was fairly similar but the Revelation eyepieces have a 52° apparent field of view, while my Moonfish Group eyepieces have 70°.

If you already own a full set of CEMAX eyepieces and Moonfish Group eyepieces, the purchase of this set may not be necessary but for a general all-round set of medium quality eyepieces and filters at £99 (at the time of writing), it is hardly a great financial risk. Note that no Barlow lens comes with the set and eyepieces cannot be purchased separately.

The table below shows the magnifications and fields of view obtained with each eyepiece in the set.

Figure 4.30. Revelation eyepiece set with filters.

Focal length (mm)	Magnification without 2× Barlow lens	Magnification with 2× Barlow lens	Field of View (arcminutes) without/with Barlow lens
32	12.5	25	195/97
20	20	40	156/78
15	26.6	53.3	116/58
12	33.3	66.6	94/47
9	44.4	88.8	70/35
6	66.6	133.3	47/23

Note that the 6-mm eyepiece with a 2× Barlow lens will not show the full solar disc. The 9-mm eyepiece with the 2× Barlow lens only just gets the solar disc in during winter in the Northern Hemisphere, so some prominences could be missed.

Meade 26-mm Plossl This is supplied as standard with many nighttime telescopes, notably the ETX 90. On its own, it is useful for finding the Sun, but it can be used in combination with various Barlow lenses and other image amplifiers (notably the BCF Magni Max) to produce high-quality visual images.

On its own, it produces a magnification of about 15× and field of view of just over 202 arcminutes. With a 2× Barlow lens and Magni Max used in tandem, the magnification is 49× and the field of view is 63 arcminutes (just over a degree).

Zoom Eyepieces Refer to Chapter 2 for a description of the Skywatcher Zoom eyepiece.

The ones I have tried are the DigimaxT zoom and my Skywatcher zoom. Whilst I am a little sceptical about their use for nighttime viewing, this is less of a concern where all the light is of the same wavelength (monochromatic light), as for hydrogen alpha viewing. The DigimaxT zoom has less internal reflections but the Skywatcher zoom showed more detail on the MaxScope 70. It is really down to personal preference, because, despite having good eyesight, my eyes are not as sensitive to internal reflections as many other people (Figure 4.31).

Figure 4.31. DigimaxT zoom eyepiece.

The DigimaxT has a focal length range of 8–24 mm (as opposed to 7–21 mm for the Skywatcher zoom eyepiece). It has been developed with afocal astrophotography in mind, so the eyepiece cup unscrews to reveal a T-Thread (hence the name!) to allow attachment to an SLR camera. It also has extension tubes to allow a greater range of afocal photography options. Unlike the Skywatcher zoom eyepiece, it allows filters to be threaded into the end, so can be used with the Magni Max Image Amplifier. See Chapter 2 for details.

Both eyepieces are not completely afocal in that if you alter the magnification by changing the focal length, you normally need to make minor adjustments to the focus. This is an inconvenience but probably an inherent flaw in most zoom eyepiece designs.

Both zoom eyepieces worked well with my Soligor 2× Barlow lens.

If you like the idea of having a range of focal length eyepieces without buying a whole set of eyepieces, then a zoom eyepiece could be for you. The Skywatcher zoom retails at about £60 in the United Kingdom and the DigimaxT about twice as much.

Skywatcher Plossls These are described in detail under the similar heading in Chapter 2. The 32-mm focal length eyepiece gives superb wide fields of view in the night sky but only yields 12.5× magnification with the MaxScope 70. However, it is useful for finding the Sun. For hydrogen alpha viewing, the 6.3-mm Plossl does not perform as well as the equivalent Revelation eyepiece on a MaxScope 70 despite working just as well with the PST. It is a pity, however, that Coronado does not supply a CEMAX eyepiece of this focal length. With this in mind, this eyepiece is a useful (low cost) addition to your accessory collection.

Celestron Moon Filter This is described in detail under the similar heading in Chapter 2. Unlike the PST, for the MaxScope 70 the Coronado polarizing filter is preferred, and as neither is particularly expensive, this has little use.

BC&F Telescope Cleaning Kit This is described in detail under the similar heading in Chapter 2. Some sort of telescope cleaning is required for the MaxScope 70, especially if you are even thinking of photography.

General Guidance on Accessories

Refer to Chapter 2 or the "MaxScope 40" section of this chapter for details.

In theory, the set of accessories that works with the PST or the MaxScope 40 should be the same as for the MaxScope 70. The difference one might expect is that the MaxScope 70 should be able to support proportionally higher magnifications than the MaxScope 40 (by 75%). However, tests suggest that the upper magnification limit for the MaxScope 70 is about 150×, decreasing under poor viewing conditions.

Tests also suggest that mid-quality Plossls work better with the MaxScope 70 than with the smaller telescopes.

I tend to be a bit sceptical about making specific purchases for the MaxScope 70 apart from the CEMAX eyepieces, which were specifically designed for this kind of viewing, but it is always worth trying anything you have previously bought for nighttime use, even if it is been consigned to the attic.

You may find that certain accessories I have found more suitable for my own eyes and camera may not work so well with yours and vice-versa. If considering any significant outlay on an eyepiece, accessory, or set of them, I would advise you to try them out with a MaxScope 70 first.

Capabilities and Limitations

The purchase of a Maxscope 70 should not be undertaken lightly by a financially challenged individual, with the possible exception of a solar viewing addict with little or no interest in the night sky! It costs about twice as much as a MaxScope 40 and costs a bit more than a double-stacked MaxScope 40. It is, however, cheaper than the MaxScope 60, as it has a different design. It is comparable in price to many computer-controlled 200-mm Schmidt-Cassegrains.

There is little doubt that it offers both the visual viewer and photographer better results than the MaxScope 40 and the PST. On one very memorable day, it showed some great prominences and they were a sight to behold. Although they were certainly very good with a PST on the same day, the MaxScope 70 showed them to have better effect.

The fast focal ratio of about f5.6 I see as a minor disadvantage for use but it affords more portability. It was significant that although it showed significantly more detail than the smaller telescopes, it seems unable to support a much higher magnification. As a comparison, I find that my nighttime 80-mm refractor (achromatic) of similar focal length does not support high magnifications.

Its biggest competitor is the MaxScope 60. This is about 20% more expensive but also does not come supplied with a Sol Ranger.

Figures 4.32–4.34 show some prominence detail taken on 22 April 2006. Unfortunately, they do not reveal the surface detail (due to photographic over-exposure) that was shown through the eyepieces. It is worth noting that the photos with the Meade 26-mm Plossl and Moonfish Group 20-mm SWA eyepiece were almost identical to the one taken with the 20-mm Revelation Plossl and Magni Max Image Amplifier. Also, please note that these photographs were taken with a digital camera and do not represent what you can achieve visually or with advanced photographic and postprocessing techniques. I have included them to demonstrate the relative merits of the eyepieces.

Appraisal

The MaxScope 70 and the PST are the “odd ones out” in the Coronado range of instruments. Both have a different design from the MaxScope 40, 60, and 90,

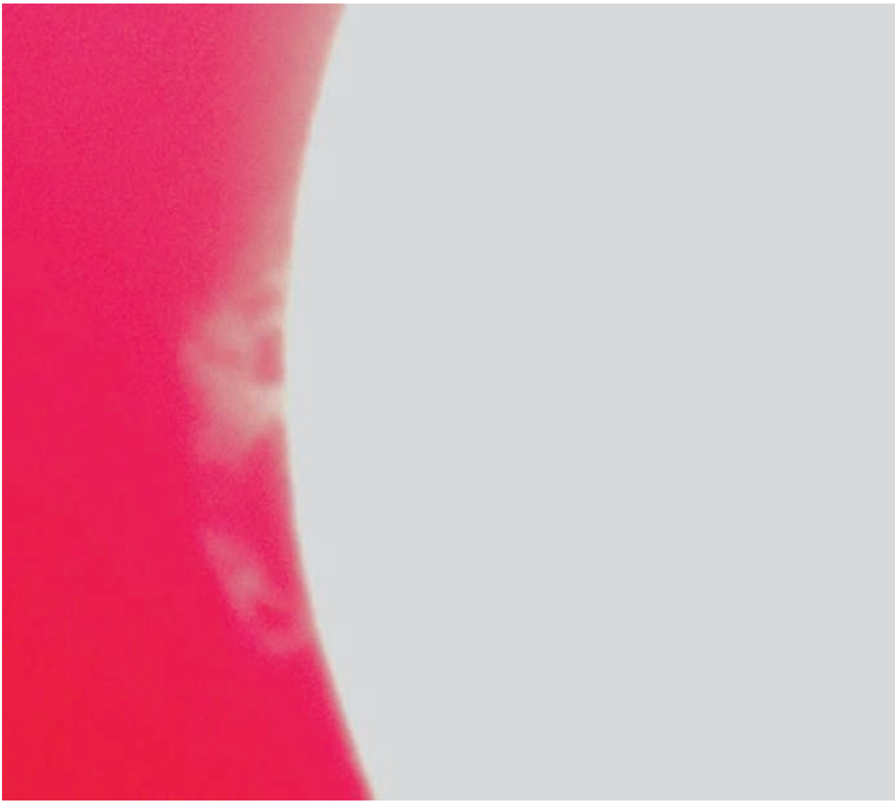


Figure 4.32. MaxScope 70 with Moonfish Group 20-mm SWA and Soligor 2× Barlow lens showing prominences.

which share a common design. The use of the internal etalon makes it easier to use for less-experienced users and reduces the price but does not allow the possibility of being able to tune it.

There is no doubt that it is an excellent addition to the range of telescopes but the big unanswered question is whether to buy it or the MaxScope 60. Certainly, there is little point in purchasing both of them and I recommend that you try out both telescopes before you decide on a purchase. If you are new to solar hydrogen alpha viewing or are an experienced user of the PST or the MaxScope 40, you will fail to be impressed with either telescope.

On a good day, the MaxScope 70 can reveal more detail than the smaller MaxScope 40 and the PST but appears to be unable to support much higher magnifications due to its fast focal ratio. On a bad day, it can allow you to see features on the solar disc that are not possible with the smaller hydrogen alpha telescopes.

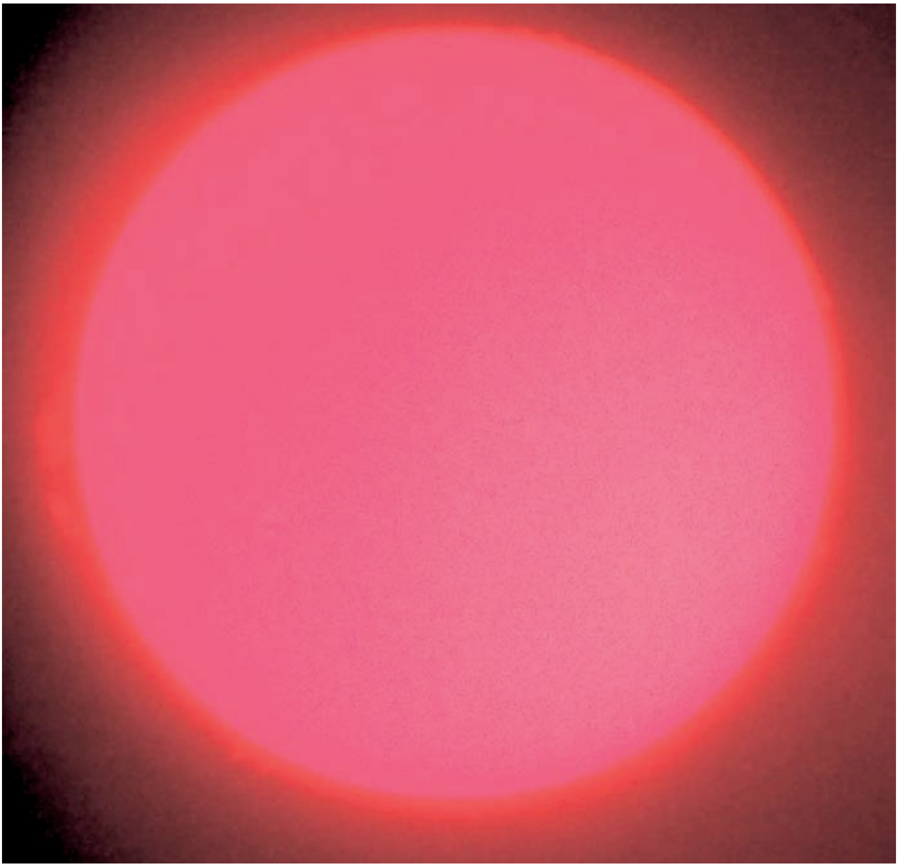


Figure 4.33. MaxScope 70 with Revelation 15-mm Plossl and Magni Max Image Amplifier showing prominences.

Like the other hydrogen alpha telescopes, it pays to try out various accessories than you may have purchased for nighttime use. In particular, various types of image amplifier can be used (even in tandem) to obtain close-up views with the supplied CEMAX 25-mm eyepiece.

Verdict: An excellent instrument but its biggest competitor is the MaxScope 60, which is slightly more expensive but more versatile.

Optical quality	7.5 out of 10
Value for money	6.5 out of 10
Ease of use	7.5 out of 10
Overall rating	7 out of 10, good

Figure 4.34. MaxScope 70 with Revelation 20-mm Plossl and Magni Max Image Amplifier showing prominences.

PST CaK*

Nick's Impressions

For general information about calcium K viewing, please refer to "Introduction to calcium K viewing" section in Chapter 1.

In late 2005, Coronado took another step in producing affordable solar viewing at interesting wavelengths with the introduction of the PST CaK. I decided, after seeing some of the wonderful images posted on various Web sites, to add to my solar imaging arsenal and purchased the PST CaK.

* Section written by Nick Howes and Philip Pugh.

This 40-mm scope at first glance looks remarkably similar to the hydrogen alpha PST, however in further inspection the differences become clear.

The PST CaK (Calcium K PST), like its bigger brothers, the CaK 70 and CaK 90 (along with the newly introduced filter system from Coronado), comes with a distinctive blue livery, aimed at representing the blue/purple color seen when observing with the scope. Unlike the standard PST, the PST CaK, as stated by Coronado, is more of an imaging device than the one for observational work, as the frequency of light it passes, combined with the relatively small aperture, makes the image quite dim. In fact, so dim that certain people, mainly the older generation, cannot pick up the calcium K features it shows at all.

The telescope itself is slightly shorter in length than the hydrogen alpha version, with a similar main body construction barring the blue-colored text, and most notably, no tuning ring for the filter (PST CaK calcium K telescope uses a glass multicoated interference filter and not the Fabry–Perot etalon used in the hydrogen alpha PST). The CaK features do not miss the tuning of the hydrogen alpha, as there is no requirement for the Doppler shift capabilities of the hydrogen alpha version.

The filter has a 2.2 Å width, band centered around the calcium K emission line in the Sun at 3934 Å, which unlike some other CaK filter systems from Baader allows not only surface features to be imaged but also prominences in calcium K light.

Philip's Impressions

I borrowed Nick's PST CaK in September 2006, admittedly rather late in the writing of this book. The objective in writing this section is not to contradict that Nick or anyone has said, but just to add a bit more information that would help you to decide on a purchase.

As one of the "older generation," as Nick refers to, having been a close friend of Henry VIII, my eyesight was generally in quite good shape for my age and, at the time of writing, did not need glasses. However, my eyes were not sensitive to calcium K and my personal "first light" was not a memorable experience for the right reasons.

The telescope itself had a nice, pleasing appearance, with its blue contrasting well with the hydrogen alpha version of the telescope (Figure 4.35). It was late in the day when I arrived home from work, so the Sun was already quite low in the sky, although the conditions were quite clear. I noticed that the image on the Sol Ranger (just like the one in the hydrogen alpha version) was noticeably dimmer, that was not a problem in itself, as I was able to find the Sun quite easily, having had plenty of practice with my own hydrogen alpha PST.

The inherent dimness of the image and my own insensitivity to the calcium K light wavelength made focusing very difficult and I was unable to do it visually at all. I had more success using the family digital camera. Unfortunately, due to the lack of an accurate focus, my pictures showed some granularity but were

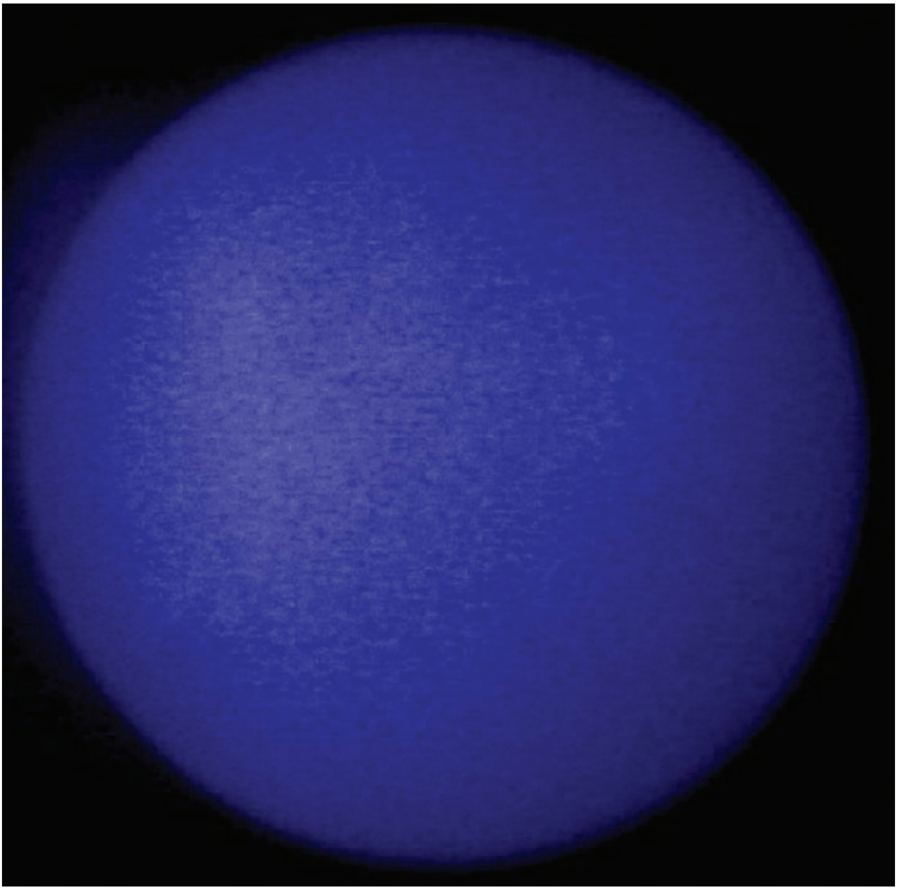


Figure 4.35. Phil gets an image.

somewhat inconclusive. Use of the 12-mm CEMAX eyepiece produced the best results. In retrospect, Nick's blanket approach, with a suitable afocal adaptor (see Chapter 5), or Larry's micro observatory (see Chapter 3) was more necessary for calcium K viewing than for hydrogen alpha.

Now the actual solution to the problem, I would possibly call a stroke of luck, where I randomly hit on an idea. However, it is typical of the thought processes that our amateurs go through. I broke many of the astronomy "rules."

Our dog, Charlie, has a habit of jumping onto our lounge windowsill, regardless of whether the curtains are open or not. Usually he leaves a small gap in the curtains, so I hit on the idea of using the gap to get a shaded view of the Sun! It certainly worked in that I was able to get a purple image, which I could bring to sharp focus. I could only see a hint of the granularity and an even smaller hint photographically. The corresponding hydrogen alpha view was not too exciting either, with even less granularity and two small prominences. Nevertheless, it was a solution to a problem and I had the exact focusing position for the CEMAX 12-mm eyepiece "saved" on the PST CaK.

Not for the first time, I found that completely removing the blue element from the image produced the best result. However, I would suggest to refer to Chapter 5 for a more comprehensive description of calcium K imaging.

My best result came when I was on my "final" drafting of the book on 7 October! I used some of Nick's processing techniques, removing the blue element and using the histogram functions of PaintShop Pro to bring out the granularity. On the same day, I could see a prominence visually in hydrogen alpha light but not in calcium K. The disc detail in hydrogen alpha light was very bland, but the calcium K details showed a not inconsiderable amount of granularity. Thanks to Nick and Charlie, I finally achieved calcium K success.

To make a fair appraisal of the telescope, it is necessary to understand that viewing and imaging in calcium K light are fundamentally different to using hydrogen alpha telescopes. Indeed, it seemed (at the time of writing) that aperture and clarity are more critical for calcium K.

Facts at a Glance

Aperture (mm)	40
Focal length (mm)	400
Bandpass (Å)	2.2
Bandpass with double-stacked filters	Not applicable
Weight (lb)	3

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in an appendix.

The PST CaK comes in a similar sized and shaped box to the original PST, so storage can be via one of the cases made by Coronado, or just simply kept in its box. The telescope features the same integrated finder system used by the original PST, so finding the Sun, which in this case would be almost impossible visually through the eyepiece, is never a problem. It comes with the same screw thread mountings, which adorn the original PST, so again can be mounted on a standard camera tripod, or, as I have done, mounted using tube rings, piggyback style, onto a larger telescope to facilitate tracking.

As stated, visually the PST CaK can initially seem a little underwhelming, when compared to the hydrogen alpha model; however, this chapter is mainly concerned with imaging, and it is in this context I find the PST CaK excels (Figure 4.36).

Figure 4.36. PST CaK.

Physical Description

Please refer to Chapter 2. The only difference is that the PST CaK is tuned to the calcium K wavelength rather than the hydrogen alpha wavelength.

How to Store

The PST CaK is exactly of the same size as the PST, so please refer to "How to Store" section in Chapter 2.

Mounting Options

Please refer to the "Mounting Options" section in Chapter 2. It is exactly the same.

Finding the Sun

Please refer to "Finding the Sun" section in Chapter 2. The PST CaK uses the same built-in Sol Ranger as the PST. Note, however, that the image in the Sol Ranger and through the eyepiece is a bit dimmer than with the PST.

Recommended Accessories

The accessory recommended by Coronado that is available from their distributors is **CEMAX hydrogen alpha eyepieces (see below)**

CEMAX Hydrogen Alpha Eyepieces These are described in detail in Chapter 2. As the focal length of the PST CaK is the same as the PST, the magnification and field of view figures are exactly the same. I can personally vouch for the 12-mm eyepiece but, due to the differing nature of calcium K use, would speculate that the 18- and 25-mm eyepieces would be worth a try.

Using other Accessories

The Coronado PST CaK takes eyepieces with the standard 1.25 inch (31 mm) fitting. This allows a huge variety of eyepieces and accessories to be used. The short answer is that most of the nighttime eyepieces that you use are suitable for use with it. As a general rule, Plossls are the best for purely visual use, whereas LER eyepieces are better for astrophotography. The practical magnification limit appears to be much lower than the PST, probably around 25×, but more experimentation is needed.

General Guidance on Accessories

Refer to Chapter 2 or "MaxScope 40" and "MaxScope 70" sections of this chapter for details.

In theory, the set of accessories that works with the PST, MaxScope 40, or MaxScope 70 should be the same as for the PST CaK. However, the PST CaK does not appear to be tolerant of high magnifications, so use of image amplifiers with short focal length eyepieces appears to be limited.

As most owners of the PST CaK are likely to own at least one hydrogen alpha telescope, it is unlikely that any specific purchase of eyepieces for this telescope is necessary. However, some longer focal length eyepieces, such as the CEMAX 25 mm, are worth considering.

Capabilities and Limitations

The PST CaK is the smallest dedicated telescope optimized for calcium K viewing and imaging. There are cheaper options available but they have a much wider bandpass of about 8 Å.

The problem with calcium K viewing is that not all people can see the features visually, as the light wavelength is near the limit of the human eye. Indeed, some of the coauthors are able to see them and others are not. Coronado does not make any extravagant claims about the ability of people to see the features, so they market it as a photographic instrument. Perhaps, it is because the wavelength is near to the limit of human perception that the PST CaK does not support high magnifications.

In making a comparison with the hydrogen alpha PST, you will see and photograph a lot less because of the difficulties in working with calcium K light and not because of any design or engineering mistakes by Coronado.

Having possibly scared you off of calcium K for life, let us now look at the other side of the coin! Coronado does not make extravagant claims about visual use and market it as for photographical, rather than visual use. I have warned you about the difficulties of focusing, but if you are able to persevere, with it, the rewards are worthwhile and give another dimension to your solar viewing, apart from hydrogen alpha and white light. Chapter 5 tells you how to use the techniques. That Nick and others have been able to produce such stunning images is down to the quality of the telescope, as well as their groundbreaking achievements in this area. I will conclude this section with a sample of some of the images (Figures 4.37 and 4.38). I am sure you will find it worth the effort.

Appraisal

The PST CaK is the entry-level telescope in the calcium K range. You will probably find it more difficult to use than the hydrogen alpha PST, but that is due to the inherent difficulties of using calcium K light, compared to hydrogen alpha. It might be tempting to give the simple answer and say that you should go for a larger aperture telescope, such as the CaK 70, but that is like telling a beginner to start off with an 8 in. Dobsonian for nighttime viewing!

The excellent photographs taken by amateurs show that it is possible to get meaningful results with this telescope. Although it took a lot of experimentation, I was even able to get a meaningful result myself. I would say the postprocessing is even more critical for calcium K than for hydrogen alpha.

My advice is to get some hydrogen alpha experience before learning to use it.

Verdict: It is worth the extra work to get the best from another winner by Coronado, especially if you need portability and are limited by budget.

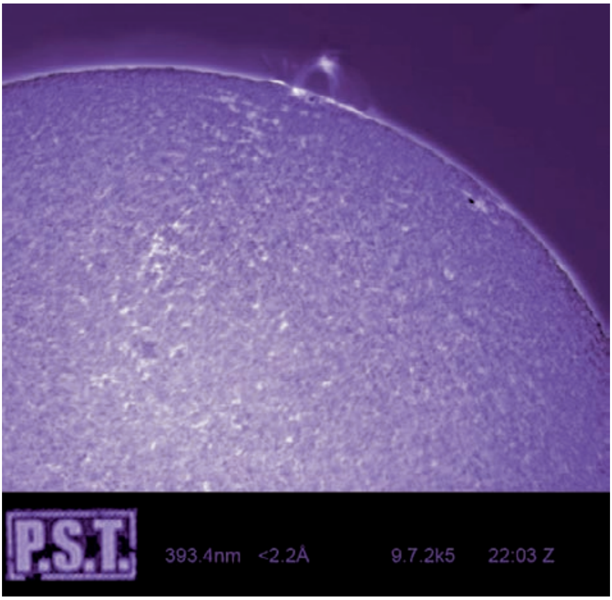


Figure 4.37. PST CaK image 1. Courtesy of Coronado.

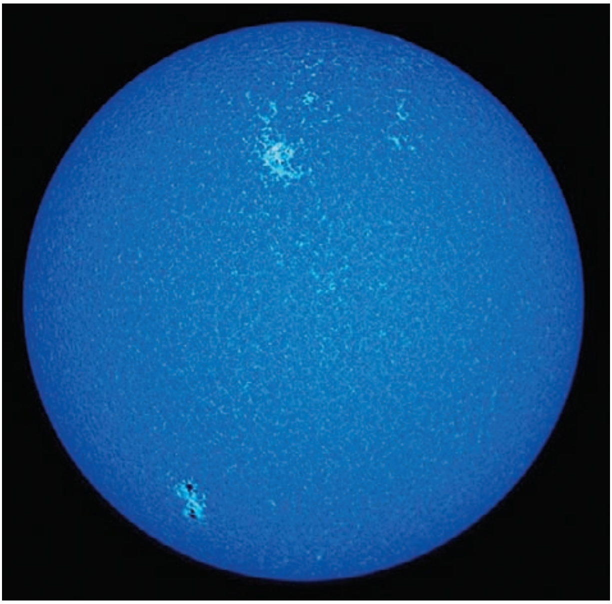


Figure 4.38. PST CaK image 2. courtesy of Coronado.

Optical quality	8 out of 10
Value for money	7 out of 10
Ease of use	7 out of 10
Overall rating	8 out of 10, very good

CaK 70*

For general information about calcium K viewing, please refer to "Introduction to Calcium K Viewing" section in Chapter 1.

Although I have been observing the Sun in hydrogen alpha light since the mid-1980s, I have never had the opportunity to view it in calcium K light until August 2005 when I purchased one of the first production Coronado CaK 70 telescopes. I had first heard about calcium K filters from Del Wood of DayStar Filters Corp., who was the only supplier of calcium K and sub-angstrom hydrogen alpha filters to the amateur solar enthusiast community in the United States at that time. Del had mentioned that not everyone could visually see the Sun in calcium K light, and that it was really for imaging purposes only. The fact that I might not see anything at the eyepiece coupled with the +$2 K price tag was enough

*Section written by Mike Taormina.

to make me quickly forget about getting a calcium K filter, or at least until 20 years later.

In early 2005, Coronado Instruments announced that they were going to release a complete 70 mm, 2.2 Å wide calcium K solar viewing system based on the mechanics of their popular MaxScope 70 hydrogen alpha telescope. Note that the bandpass of 2.2 Å is significantly higher than for the hydrogen alpha version. Coronado clearly stated that their new CaK 70 was intended primarily for imaging, as some individuals might not be able to see anything visually at the eyepiece due to the near ultraviolet nature of calcium K light. Once again, I quickly lost interest in getting a calcium K telescope after hearing that I might not be able to see anything at the eyepiece. However, when the first production CaK 70 units began shipping in the Spring/Summer of 2005, I started to hear talk in the solar forums from satisfied owners of the new calcium K telescopes that they could see the beautiful violet-blue color of the Sun at the eyepiece with their own eyes! After hearing the enthusiastic reports from fellow solar observers and seeing the incredible images they were able to capture, I decided to purchase my own CaK 70.

In August 2005, I took delivery of my new CaK 70, and as luck would have it, it was actually a beautiful cloud-free day. The first thing I noticed about the CaK 70 is how short and stubby it was compared to my other solar telescopes. It is only approximately 15.25 inches in length (with the drawtube retracted) and 3.5 inches at the widest part of the optical tube assembly (OTA), and 4.5 inches wide if you include the clamshell mount and Sol Ranger solar finder.

The CaK 70 is a 70-mm aperture, 400-mm focal length telescope with an integrated 2.2 Å filter whose bandpass is centered on the calcium K wavelength of 393.4 nm (3934 Å as 1 nm contains 10 Å). The CaK 70 includes the hard shell custom carry case, SolRanger solar finder, and clamshell mount that includes 1/4 inch by 20 threaded holes that allow you to mount the scope to a standard photo tripod. The CaK 70 K uses the same 1 1/4 inch helical focuser and drawtube system that Coronado uses in all its other MaxScope solar telescopes. However, just like its hydrogen alpha cousin, the MaxScope 70, the CaK 70 has a nondetachable blocking filter diagonal. The CaK 70 does not come with any eyepiece, but that was not an issue for me, since I already own a complete CEMAX set, which includes eyepieces of focal lengths 12, 18, 25 mm, and 2× Barlow lens. Note that as a comparison, the MaxScope 70 comes supplied with a 25-mm CEMAX eyepiece.

Since my favorite eyepiece for viewing and imaging on my other 400-mm solar scopes is a 12-mm CEMAX (33× magnification), I decided to use it as my first light eyepiece in my CaK 70. After quickly centering CaK 70 on the Sun using the Sol Ranger, I extended the drawtube, locked it in place using the two nylon thumbscrews, looked into the eyepiece, and held my breath in anticipation of what I might (or might not) see.

The first thing I saw was an eerie, deep-purple/violet featureless ball at the center of the field of view. I cupped my hand around the eyepiece to prevent any stray light from getting in and used my other hand to adjust the focus using the helical focuser. As my eyes adjusted to the darkness, the once featureless purple ball began to exhibit surface detail in the form of super granulation cells and plages. The eerie purple glow of the Sun in calcium K light had a surreal, almost supernatural look to it, and reminded me of the color you could see from a "black light" light bulb, which was a popular novelty item in the 1970s.

Since I also own CEMAX 18- and 25-mm eyepieces, I decided to give them a try in the CaK 70. As expected, the 25-mm eyepiece yielded the brightest and the sharpest image, but at the expense of only magnifying the Sun 16 times. The 18-mm eyepiece gave a nice balance between brightness and size, at 22× magnification. I did not even try the Barlow lens, since the 12-mm eyepiece was already approaching the limit of what my eyes could comfortably see.

Next, I decided to capture a few calcium K images through my CaK 70 using my CEMAX 12-mm and Canon s100 2.0Mpix digital camera, since I have had such great success in the past with the same eyepiece/camera combination. In order to capture a properly exposed image with the s100, I had to increase the exposure compensation +2/3 of a stop from the usual default value of zero that I used for capturing hydrogen alpha images. I noticed that the calcium K image appears much brighter on the cameras with liquid-crystal display (LCD) screen than a hydrogen alpha image does. I am not sure if this is because the LCD viewfinder is better at displaying it or the CCD imager is better at capturing it. In either event, I have found that capturing a quality calcium K image is much easier than capturing a hydrogen alpha image. Since I capture all my images by handholding my Canon s100 up to the eyepiece on a scope that is on an unguided and relatively unstable photo tripod, I usually need to capture at least six or seven hydrogen alpha images to get a "good" one. The statistics are just the opposite when using my CaK 70, as I usually need to capture six or seven images in order to get one "bad" image, as the rest are all "good" ones.

In all, first light with my CaK 70 was an experience I will never forget, and I was very relieved that I was actually able to see the Sun in calcium K with my own eyes. While the CaK 70 is sold as a telescope that is "primarily for photographic use," I found the view at the eyepiece to be just as thrilling as the images it can capture.

Facts at a Glance

Aperture (mm)	70
Focal length (mm)	400
Bandpass (Å)	2.2
Bandpass with double-stacked filters	Not applicable
Weight (lb)	5

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in an appendix.

Physical Description

Please refer to the “MaxScope 70, Physical Description” section.

How to Store

Although the CaK 70 weighs more than the MaxScope 40 and the PST, it has the same length, so please refer to the “How to Store” section in Chapter 2.

Mounting Options

The mounting techniques are exactly the same as for the MaxScope 70. See the “MaxScope 70” sections for details.

Finding the Sun

See “Finding the Sun” section in Chapter 3 for details. It is the same, as the Sol Ranger is supplied with both telescopes.

Recommended Accessories

The accessories recommended by Coronado that are available from their distributors are as follows:

- CEMAX hydrogen alpha eyepieces (see below)

CEMAXHydrogen Alpha Eyepieces These are described in detail in Chapter 2. As the focal length of the CaK 70 is the same as the PST, the magnification and field of view of figures are exactly the same.

The 25-mm eyepiece is supplied with the CaK 70. This allows a wide field of view and makes finding the Sun very easy, especially with the supplied Sol Ranger.

The 12-mm eyepiece usually shows the best detail. The 2× Barlow lens does not get much use, as the 12-mm eyepiece is near the resolution limit.

Using Other Accessories

The Coronado CaK 70 takes eyepieces with the standard 1.25-inch (31 mm) fitting. This allows a huge variety of eyepieces and accessories to be used. The practical magnification limit appears to be much lower than the MaxScope 70, probably around 40×, but more experimentation is needed.

General Guidance on Accessories

Refer to Chapter 2 or the "MaxScope 40" and "MaxScope 70" sections of this chapter for details.

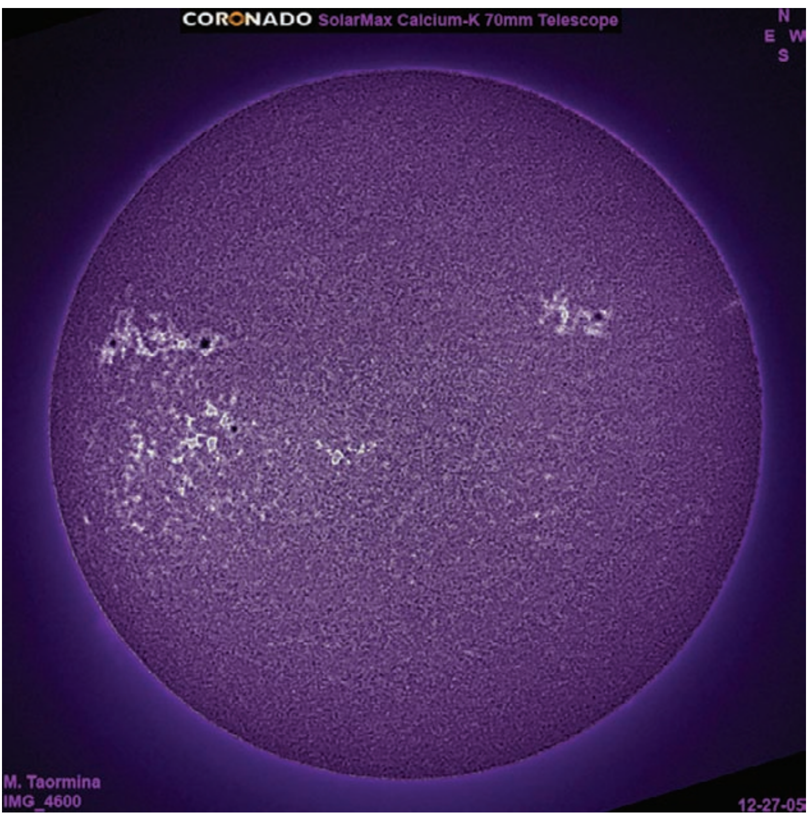
In theory, the set of accessories that works with the PST, MaxScope 40, or MaxScope 70 should be the same as for the CaK 70. However, the CaK 70 does not appear to be tolerant of high magnifications, so use of image amplifiers with short focal length eyepieces appears to be limited.

As most owners of the CaK 70 are likely to own at least one hydrogen alpha telescope, it is unlikely that any specific purchase of eyepieces for this telescope are necessary.

Capabilities and Limitations

The CaK 70 is the top-of-the-range calcium K telescope currently in the market (at the time of writing), but I would be surprised if this remains the case for

Figure 4.39. Calcium K features as shown by the CaK 70. Photo by Mike Taormina.



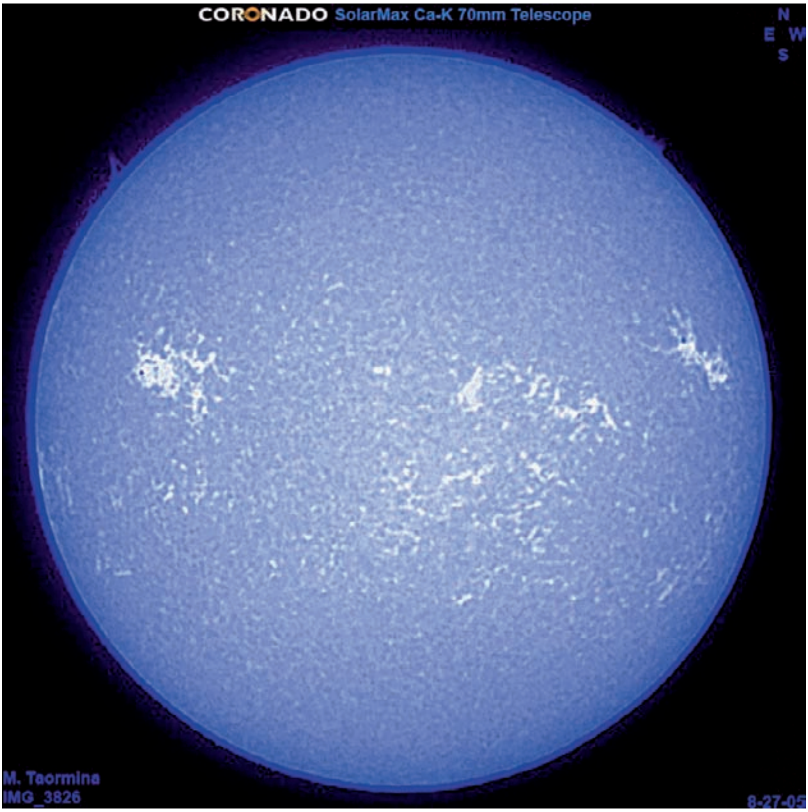
very long. It would not take a lot of imagination to speculate that Coronado will almost certainly produce calcium K versions of their popular MaxScope 40, 60, and 90 models.

Note by Phil: The CaK 90 was available in July 2006 but had not been tested by any of the coauthors.

The problem with any calcium K telescope is that not all people can see the features visually, as the light wavelength is near the limit of the human eye. Indeed, some of the coauthors are able to see them and others are not. Coronado does not make any extravagant claims about the ability of people to see the features, so they market it as a photographic instrument. Perhaps it is because the wavelength is near to the limit of human perception that the CaK 70 does not support high magnifications.

If you compare the calcium K view of the Sun with the hydrogen alpha view, plages, faculae, and sunspots appear to be more prominent, whereas prominences are better in hydrogen alpha light. Figures 4.39–4.43 show some of the features that can be detected photographically using the CaK 70.

Figure 4.40. View through the CaK 70 showing plages. Photo by Mike Taormina.



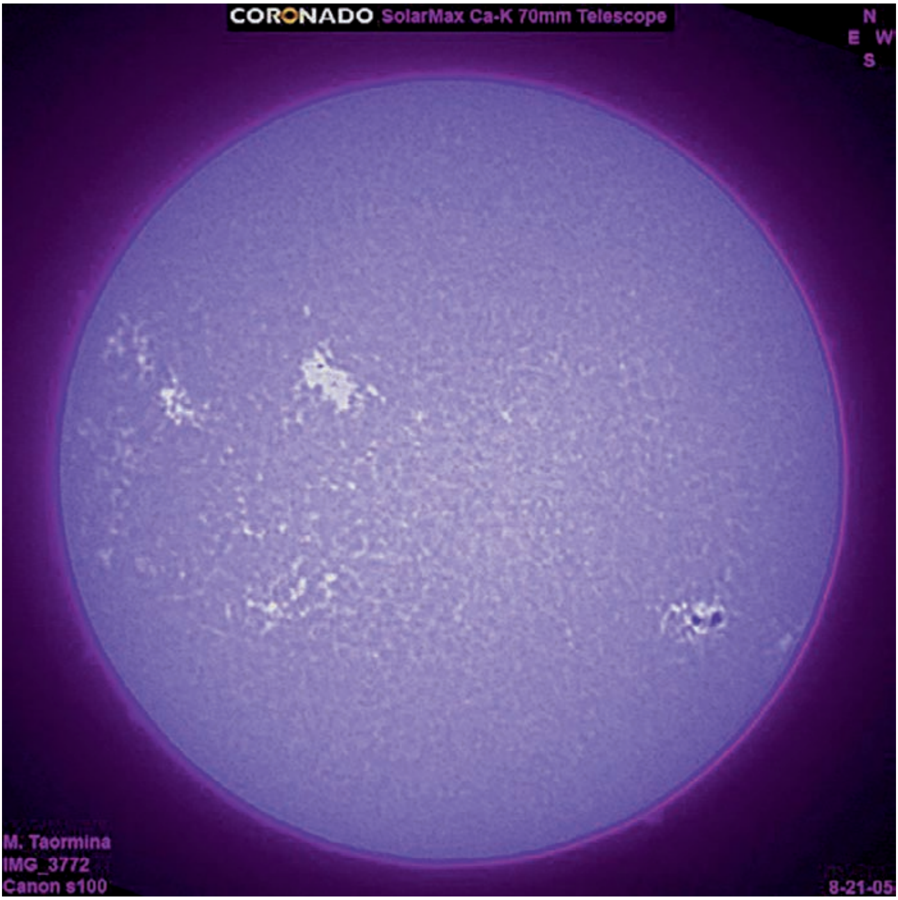


Figure 4.41. View through the CaK 70 showing prominences and sunspots. Photo by Mike Taormina.

Even on a quiet day it is still possible to see faculae and plages in more detail than you can see in its cousin, the MaxScope 70. It certainly gives a different perspective to what you can see with hydrogen alpha light.

Appraisal

The CaK 70 is based on the MaxScope 70, which has a different design to the other telescopes.

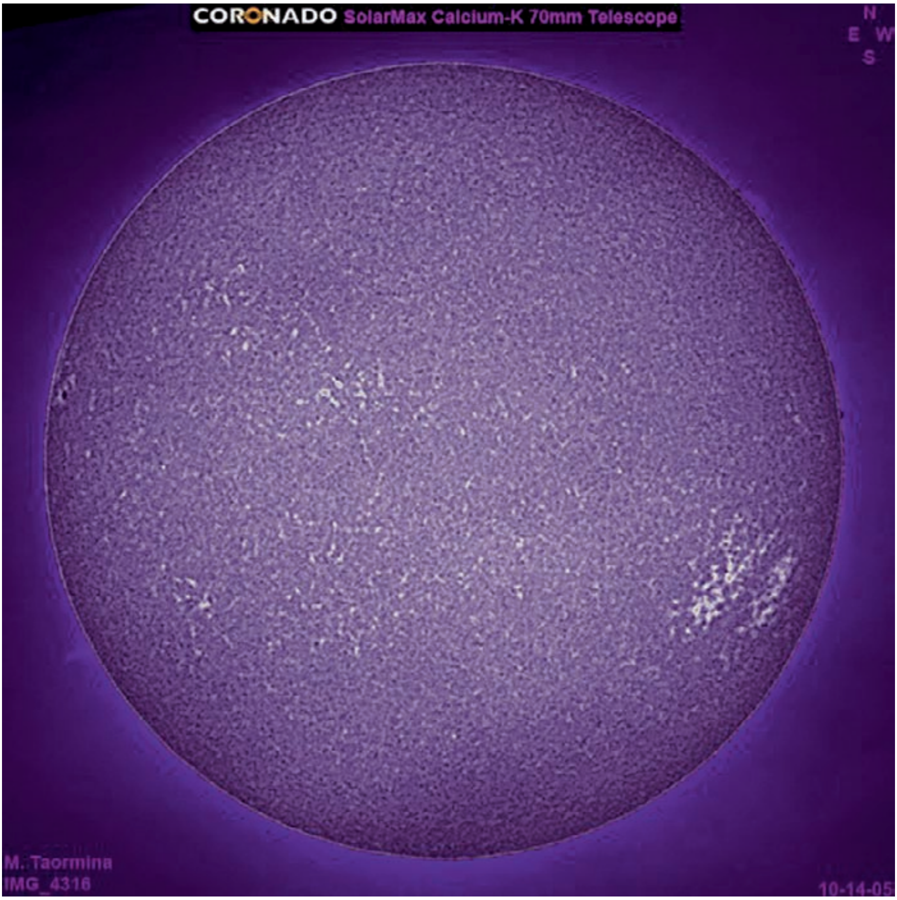


Figure 4.42. A quiet day. Photo by Mike Taormina.

At the time of writing, it was the market leader in dedicated calcium K telescopes and both the PST CaK and CaK 70. There is no real point of comparison, as the budget conscious astronomer, looking for a portable telescope would naturally be drawn to the PST CaK and more financially able astronomers would be drawn to the CaK 70.

Note from Phil: Some weeks after this chapter was completed, Coronado announced the launch of the CaK 90 and the SolarMax CaK 60 separate filter system. Refer to Chapter 7 for details.

If you have been enjoying hydrogen alpha viewing for some time and wish to see the complementary view in calcium K, then this could be the telescope for you. If you are more patient, you might prefer to wait until the next wave of innovations hit the marketplace.

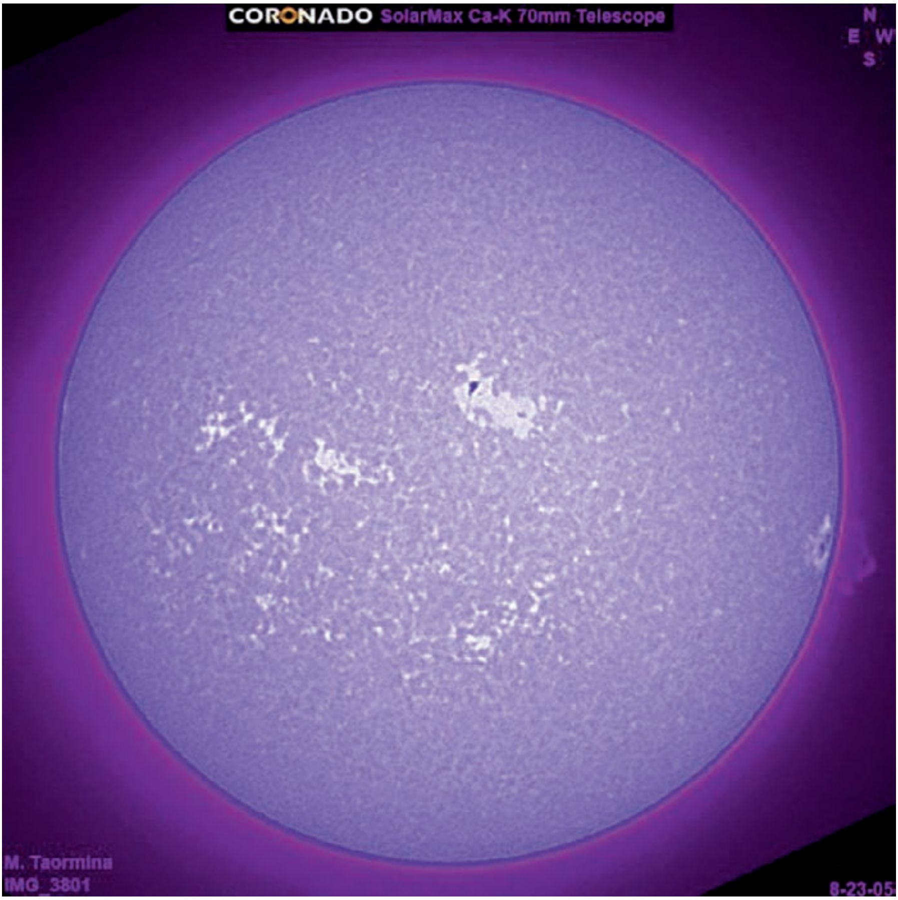


Figure 4.43. A more active day. Photo by Mike Taormina.

Verdict: Another superb innovation and first to market by Coronado but just wait, as I think it will be the second in a long line of calcium K telescopes.

Optical quality	7.5 out of 10
Value for money	7.5 out of 10
Ease of use	7.5 out of 10
Overall rating	7.5 out of 10, good

CHAPTER FIVE

Imaging*

Hydrogen Alpha

During the summer of 2005, I first encountered hydrogen alpha telescopes for viewing our nearest star, and instantly fell in love with the real-time excitement of what I saw. In comparison to nighttime observing and its sedate pace of life, the dynamism of our nearest star, with prominences, flares, and surface events unveiling right before the eyes, was to me a whole new way to appreciate astronomy.

It was because of our local astronomy group's chair, loaning me a Coronado MaxScope 40 scope and an Isle of Man SolarScope SolarView 60 mm, to try to convince me to invest in my own hydrogen alpha telescope that my journey into this field began. Over the course of July and early August 2005, with the weather in the United Kingdom unusually good, I spent more time with these telescopes than any other in my possession. Every evening after work, and most weekends, I would be out, at first just observing the Sun, but then, with the urge to start imaging what I saw started to take hold, as it had done for nighttime observing, I went about determining what would be the best way to start capturing what I was seeing.

With all fields of astronomical imaging, there is no real "right" or "wrong" way to go about it. Amateurs for decades had sworn by standard film camera

* Nick Howes

photography with huge success, but in the latter part of the 1990s and early part of the twenty-first century, film for many astronomers became obsolete for most imaging purposes, as the digital age took over. I must state here that I am not in any way a professional photographer or imager. This chapter aims to provide a useful starting point for anyone interested in imaging the Sun, using popular software, along with tips and techniques I have either developed or picked up from various sources.

The advantages of digital photography at first were simply that the results were immediate, as film offered (and, some would argue, still does) much higher quality than digital cameras, however not having to either develop your own film with a concoction of chemicals and dark rooms, or put it at the mercy of your local photography store, eventually convinced all but the most die hard of film buffs that digital was the way to go.

In late 2002, I had bought my first digital camera, a 2-megapixel Creative Labs 880 "point and shoot" type, with a fixed lens and quite limited control. For daytime pictures of family and events, it was fine, but for any real astronomical imaging, barring quick shots of the Moon, it really was not quite sensitive enough. In 2003, I finally took the plunge into "more serious" astronomical imaging, in readiness for the close approach of Mars, and bought myself a Phillips Toucam 840K web camera, which many forums and users on the Internet astronomy groups were raving over as being the best low-cost camera for planetary imaging. Later in 2004, a newer 3-megapixel Creative Labs camera (I had friends at Creative Labs) was released, with variable exposure capability and a zoom lens, and it was with these two cameras that I first started imaging the Sun in 2004. Later in 2005, I purchased a Canon EOS300D digital SLR camera, specifically to augment my deep sky-imaging setup, which by then also included a Meade DSI camera and a Meade LPI camera, fitted with a specialist filter, which I now use mainly for spectroscopy of stars.

The Toucam, almost since the day of purchase, had been consistently delivering results I was happy with, for planetary work. Being a standard web camera device, fitting it to the telescope itself was the first hurdle I had to cross. A brief look on various astronomical Web sites led me to the "Mogg" webcam adaptor (Figure 5.1). This is a small 1.25 inch adaptor that simply replaced the standard lens on the Toucam with no surgery required. You simply unscrew the Toucam lens and add the adaptor.

Therefore, fitted with this adaptor, I decided that this was going to be the camera I would use to try to image the Sun, being the one I was most confident of using. It was also the lowest cost of the solutions I owned. The rationale for this was that if I got it wrong, or in some way damaged the camera, then the cost to me would be minimal.

Prior to the loan of the hydrogen alpha telescopes, I was using a white light solar filter to observe sunspots and the 2004 transit of Venus. My experiences in white light with the Toucam had proved me that it could capture huge amounts of detail, in sunspots, and gave sharp and well-defined views of Venus during the transit. I knew that with the right settings, imaging with this in hydrogen alpha would be very rewarding.

Once the Toucam was coupled to the scope, I found that for imaging, focusing with both the SolarScope SolarView 60 and the MaxScope 40 was simple, being typical refractor type scopes, with considerable focus travel. The SolarScope

Figure 5.1. Mogg webcam adaptor.

SolarView 60 (Figure 5.2) showing the 50mm model, which is very similar, came with the added bonus of a screw on finder scope, known as the Sol Searcher, which is purpose-built for solar image finding. However, the SolarScope SolarView 60 was on loan only for a few weeks, as our local astronomy chair did not want to miss out too much on the summer Sun. I did find, however, that this simple finder addition, for the time I had the SolarScope SolarView 60, made finding the Sun (a surprisingly difficult task without one) a breeze, and for any imaging it was practically essential unless you wanted to swap over eyepiece and camera all the time. The MaxScope 40, despite having an optional finder of similar design available, did not, in the case of the loan unit, come with one.

The view through both scopes visually, using my range of Celestron, Televue, and Meade eyepieces, was instantly pleasing. Tuning the etalon filter assembly on both scopes was by means of a simple "tuning" filter adjustment dial known

Figure 5.2. SolarScope.

on the Coronado scopes, as the "T-Max." Both scopes were rated as having a hydrogen alpha bandpass of around 0.7 Å, but even without any fine-tuning of the filters, once visual focus was achieved, filaments, prominences, and plage features immediately sprang into view. With the visual observing side covered, I moved swiftly onto some imaging.

With most of the available hydrogen alpha telescopes on the market, "tuning" the etalon filter will change the features of the Sun you actually see, typically moving from an almost "white light" type view (although much redder than typical white light filters), through surface features and granularity, to more of the flare and prominence features. The term tuning is a bit of a misnomer, as the T-Max, found on the Coronado scopes actually detunes the filters toward the blue end of the hydrogen alpha line. It accomplishes this by changing the angle at which the light passes though the etalon. I found that how much you adjust the etalon filter using this "tuner" is dependent on the sky conditions, and also on what you wish to see, as surface detail and prominences can be enhanced by subtle adjustments in the tuning of the etalon. In addition, events that move across the solar disc can be affected by Doppler shift, whereby events that were visible suddenly become invisible (coronal mass ejections being one such event type).

Visually the Sun looks a kind of pinkish red through hydrogen alpha telescopes, with the full disc easily visible in the SolarScope SolarView 60 and MaxScope 40, with eyepieces between 15 and 9 mm (though it depends on the field of view in the eyepiece, some as low as 6 mm will easily show the full disc). As the SolarScope now had to go back to their rightful owner, most of my imaging plans relied on the MaxScope 40 that was on loan for 3 more weeks. Descriptions and advice about tuning the etalon, which are valid for most hydrogen alpha telescopes, are covered in the "How to Use" section of Chapter 2.

So, back to imaging the Sun.

Cometh the Hour…Cometh the Software

Since around 2003, many observers had been using two main applications for astronomical imaging of planets and solar system objects; these are two Windows-based software packages, known as K3CCD and Registax, both available online, and for little or no financial outlay had quickly become the imagers' choice for capturing and then postprocess, combining or "stacking" images to obtain much higher levels of clarity. But what is "stacking?"

When looking at any object in the sky either at night or with the Sun in daylight, you have to peer through almost 100 km of the Earth's rather turbulent atmosphere; the view can and is often very distorted by the effects of movements in the atmospheric layers. This causes the stars to twinkle at night and causes many ground-based telescopes to face their biggest problem in getting high-resolution images.

Many scientific telescopes deploy complex mirror and computer systems to correct this, known as adaptive optics, which is generally out of the financial and technical reach of many amateurs. This is where the software combination of K3CCD and Registax comes into play.

Why Two Software Applications?

Well, one has revolutionized the actual image capturing process and the other has revolutionized image stacking and postprocessing.

The first part, K3CCD, developed by Peter Katerniak and available online via his Web site at http://www.pk3.org/Astro/index.htm?k3ccdtools.htm, made astronomical imaging simpler than ever before. Whilst most digital web cameras come with basic video capturing software, mainly for video conferencing or talking to family and friends, K3CCD was developed from the outset for the purpose of imaging astronomical objects. Having a wide range of focusing and image capture aids to make it almost a "point and shoot" application in its own right. As this had been my long-standing application of choice for imaging planets and the Sun in white light, this would be my software of choice for imaging the Sun in hydrogen alpha.

Swapping my Celestron 15-mm eyepiece over for the Toucam, linked to my laptop, I launched K3CCD and instantly had an exceptionally bright almost "white out" image on the screen. K3CCD, from my previous experience in white light solar imaging, was an application I knew was capable of helping me to take good quality solar images. I had imaged the entire transit of Venus in 2004 using a white light solar filter and my Meade ETX90 with great success. However, I knew that after setting it the previous night for imaging the moon, my settings would need to be adjusted. K3CCD provides a superb live preview of what the camera is seeing, and it can adjust frame rates and shutter speeds (depending on the camera) from ranges of the hundredths of a second up to tenths of a second, very simply, by means of the camera's own control panel that appears as a subwindow within K3CCD itself.

I was instantly struck (once focused and light-level adjusted) with the differences between the visual view of the Sun and that from the CCD. As the CCD size on the Toucam is relatively small, less of the solar disc was visible. In addition to this I found that once the camera settings were adjusted (more on this later), it could pick up more detail than the human eye, adjusting both the etalon filter and the camera exposure times throwing up very different and yet detailed results.

The live preview screen of K3CCD typically looks like Figure 5.3. I will cover the use of K3CCD in more detail later in this chapter.

The Toucam camera field of view with no field reduction devices (focal reducers) or Barlow type image amplifiers, on the Coronado PST, which I had recently acquired, and the MaxScope 40, typically equates to that of a 5–6-mm eyepiece. With such an eyepiece, around 1/4–1/3 of the solar disc is visible, so for an imaging run, I would usually set up the scope with a suitable eyepiece first. Normally, I would get the entire solar disc in the first frame with a 15–9-mm eyepiece prior to swapping over to the Toucam. In almost all occasions, I initially had to refocus; this was relatively simple with the MaxScope 40, but with my newly bought Coronado PST, initially I found this to be practically impossible for reasons, which will be discussed

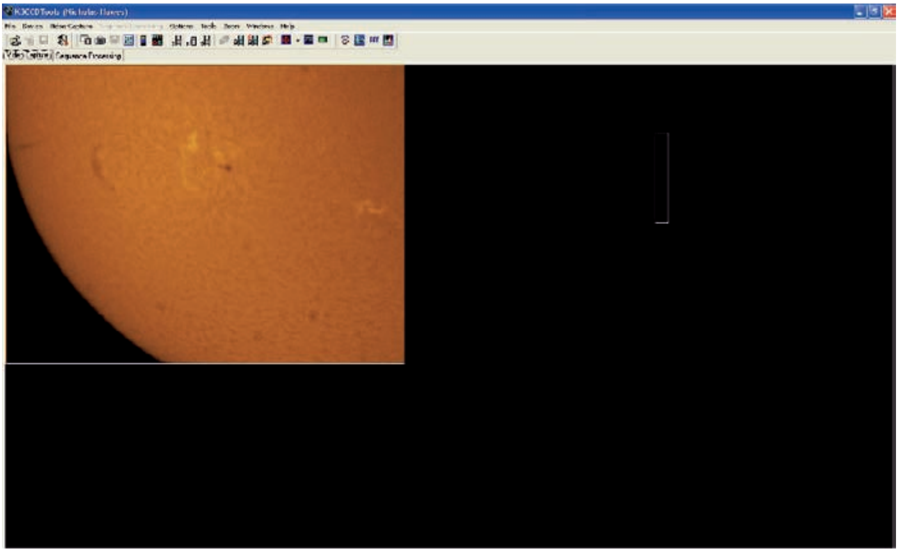


Figure 5.3. K3CCD Live Preview screen with a color Toucam.

later. The MaxScope 40, with the standard Mogg adaptor, just came to focus very easily, and I had quickly managed to set up a "parfocal" ring on my favored 9-mm Celestron eyepiece, so that swapping between it and the Toucam meant that focus was retained.

A parfocal ring is a small metal ring that screws onto an eyepiece or a camera, and allows you to adjust its height from the eyepiece so that small focus adjustments using the actual eyepiece tube travel length can be made (Figure 5.4). Most professional eyepiece sets from companies like Televue, Celestron, or Meade are parfocal, but when swapping between a CCD for imaging and observational astronomy, one would normally need to fit such a ring to avoid having to refocus all the time. With my larger night-time Celestron C8 setup, I had also invested in a "Trutek" flip mirror that allowed me to have the Toucam and an eyepiece connected at the same time, though this arrangement is quite heavy and any changes in the focal distance were not suitable for the PST or, as I found, the MaxScope 40.

Coronado are quite open in the key differences between their top-of-the-range MaxScopes and the PST, with the key differences being the bandpass of the filter (the MaxScope 40 being rated at 0.7 Å, whilst the standard PST was rated at 1 Å) and the other being the focusing. Whilst the MaxScope 40 had a wide focus travel and could take my standard Mogg-adapted Toucam, the PST would simply not come into focus using the same setup. A quick look on various Web sites confirmed this, and a variety of low-cost options were mentioned by users of the PST, the most popular being to add a Barlow lens and the second most popular being a low-profile webcam adaptor. BCF UK (Broadhurst Clarkson Fuller), being the United Kingdom suppliers of the PST, had such a low-profile adaptor (model

Figure 5.4. Parfocal ring.

AC624) item in stock for around £13 ($20), and on online order for this came through in less than 24 hours. Fitting this to the Toucam gave an instant result, with focus now very simple to achieve, but more on that later.

To be honest, despite the cost differences between the MaxScope 40 and the PST, I was more than pleasantly surprised with the visual observation results from both, and for anyone on a budget, the PST does offer stunning results, which do take a bit more work to achieve than the MaxScope 40, but, as you will see, with some work in postprocessing and care with the imaging itself are more than adequate.

So how to do solar imaging?

The Imaging Process and Setting Up

For the purposes of simplicity, I will concentrate on my imaging experiences and how I set up and do an imaging run with the Coronado PST telescope, as this is the more popular (by market share) of the three telescopes I have used, but in essence, the principles of all hydrogen alpha telescopes are roughly the same and barring the different webcam adaptor were almost identical to those I used with the MaxScope 40.

Setup of the Telescope

First thing to remember is that you are normally going to be outside in broad daylight and hopefully with a bright Sun overhead. It is a simple enough thing to take out a laptop at night into the garden for deep sky or planetary imaging, and dim the screen with a red gel filter or adjust the screen background settings via software, but how do you get around imaging the Sun that is washing out all the details you wish to see on your trusty laptop screen. This also applies when you are viewing; as in broad daylight, stray light can and does affect your overall viewing pleasure and the contrast of the solar disc. Whilst some users (Larry Alvarez being one) have built and designed custom solutions for this problem (see Chapter 3 for details), I was looking at a quick and easy common solution, which anyone could setup in minutes.

Typically, when observing or imaging the Sun, I will use a regular size travel blanket (around 1 m × 1 m in size) that will cover both my laptop and me when imaging, or I will put cardboard or wooden side frames strategically around the computer screen, with some Velcro pads or tape, which I find will also do a good job (Figure 5.5, not a ghost, but my trusty white blanket). If you have a good-sized cardboard box, placing a hole in it for the webcam cable and power cables (if required) and simply placing the laptop in the box is an option.

Figure 5.5. Use of the blanket for solar imaging.

The problem with the blanket approach is that unless you have a motorized mount tracking the Sun during your imaging, you constantly have to either remove it or sneak from under it to get to the telescope mount to move it. As the Earth is rotating, the Sun is obviously moving across the sky, and when imaging at quite high resolution, the movement can be quite fast.

The tip here with getting the best outdoor contrast is to decide on a method that works best for you and decide on how much you wish to invest in making or setting up a solution. Imaging the Sun is not typically as long duration as deep sky imaging at night, which runs in my experience to several hours, whereas with solar imaging, a "run," being an image capture session using K3CCD, would normally last less than a minute per image (capturing frames in K3CCD for later image stacking or postprocessing). That is, unless you are making movies of prominence or flare events as they develop, in which case, you can budget to be outside for an entire day, probably for a minute or so every 15 minutes.

The second consideration before you even begin to image is the mount. Coronado, for the PST, recommend and sell a small tabletop mount called the MALTA mount, which whilst useful, unless you have a suitable and very steady table on which to place it, is a bit impractical to use for imaging.

The mount itself does allow easy maneuvering of the scope, but for any serious observations or imaging, a good solid equatorial mount would be my recommendation. I have tried imaging using a high-quality camera tripod mount with slow motion controls, but still find that the constant adjustments to get the Sun back into frame, combined with the fact that any feature you may eventually want to stack in postprocessing software such as the excellent Registax will be moving out of frame, means that a motor-driven and preferably a sturdy equatorial mount is the best option. The MALTA mount is described and shown in Chapter 2.

An anecdotal story related to this comes from my experiences during the annular solar eclipse of 2005 where a group of us from our local astronomy society traveled to Segovia in Spain, armed with a battery of solar imaging devices of various sizes and types, ranging from simple "Baader solar film" tripod-mounted cameras through to white light large aperture scopes, as well as the SolarScope SolarView 60 and the MaxScope 40. In the end, it was the motorized scopes, being a pair of Meade ETX scopes, the SolarScope SolarView 60 refractor on a Sky Watcher HEQ5 mount, and the MaxScope 40 on a Sky Watcher EQ6 "SkyScan" mount, that gave us the most pleasure. The EQ6 mount tracking the entire event from start to finish, without the Sun moving a millimeter out of frame. Both these mounts may be overkill for the relatively small MaxScope 40 or even the PST, but having mounts of this quality made a huge difference to the whole experience; however, both do cost between two and four times the price of the PST and is about the same price as the MaxScope 40 in the case of the EQ6/SkyScan GOTO system we had.

My small Meade ETX90 mount tracked reasonably well in alt/azimuth mode, but when back at home with the PST, I typically use my Celestron C8 motorized mount for solar observing, piggyback attaching the PST to this, being careful at all times to block out all other apertures such as the guide scope and main primary mirror on the C8. As with all solar observing and imaging, you should be extremely careful to make sure that not only your eyes are protected, but also any other equipment that may be pointing in the same direction as the telescopes you are actually looking through or imaging with.

The PST being only 40-mm diameter makes it very easy to fit to a finderscope bracket or guide scope set of rings typically that may be added to most telescopes on the market. For general purpose observing, a more basic mount, including the Coronado MALTA, may be suitable, but for imaging, as previously stated, I would recommend the use of a solid motorized mount.

Whichever mount you opt for, unless it is motorized or driven equatorially or uses alt-azimuth tracking (such as the Meade or Celestron "GOTO" telescopes), typically the Sun will drift out of frame with the Toucam in under 1 minute, and out of view with even a wider field eyepiece in under 10 minutes.

The telescope now set on a good mount, I then, as stated, typically placed a 9-mm eyepiece in the telescope and got the Sun into the field of view, then quickly swap over to the Toucam camera fitted with the low-profile telescope adaptor.

With the PST, unlike the much more expensive MaxScope 40, you get the added bonus of an integrated solar finder called the Sol Ranger. This is described in Chapter 2. These, as mentioned earlier, are optional on the MaxScope 40 telescopes, and if you have one of these in mind, I would say they are essential. The MaxScope 40, I used during the summer of 2005, did not come with one, and it took me on an average 2–3 minutes every time to find the Sun, despite it being a very large target. The integrated one on the PST works by taking the sunlight through a small hole on the front of the "magic box" assembly near to where the etalon filter is housed and filtering it down to a small circular window on the scope. The Sun, when in the field of view, will appear as a bright white dot in the center of this window. This is described more fully in "Finding the Sun" section of Chapter 2. The MaxScope 40 uses a different (optional) type of solar finder, also (perhaps misleadingly) called a Sol Ranger. This is described in "MaxScope 40" section in Chapter 4.

Now that we are all set and the Sun is shining, it is time to actually start imaging. My preferred method is the Toucam option, but others exist, so let us start by discussing the various options available.

Imaging the Sun

The following are the types of imaging solutions.

Fixed Lens/Afocal Digital Imaging At the beginning of this chapter, I mentioned the range of cameras I had acquired for the various types of imaging. The point and shoot digital cameras available today are some of the most popular consumer electronics devices around, and it is a simple fact that film-based camera sales have virtually dropped off to zero for most domestic home use. I purchased mine for a combination of astronomy and convenience for "everyday" images and for the wider field shot options that they gave me.

Imaging the Sun for most people typically takes the form of three different imaging options. The first being the aforementioned regular point and shoot-type affair, whereby a digital camera is held up to the eyepiece in place and you take a quick "snapshot" image of the Sun. This approach is fast, relatively easy to setup, and pretty much anyone who can operate a camera can take this type of image.

These images, whilst offering a wide field of view, easily taking in the entire solar disc, with any eyepiece above around 9 mm with the PST tend to be, in my experience, quite "washed out" and more difficult to see surface detail than with the Toucam or SLR options I will discuss later. This is especially evident when you come to postprocessing, for bringing out the finer solar details. However, they are still a great way to pick up prominences and the entire solar disc, something that the Toucam field of view will not do even with a 0.5× focal reducer. However, as you will see later, there are tricks that can be used to get "whole" solar disc images with even the humble Toucam.

The point and shoot method was something I wanted to try with the PST and so I went about setting up a camera solution to achieve this (Figure 5.6 shows a typical image from a point and shoot camera).

Most people's first astronomical images tend to be taken by literally holding a camera up to the eyepiece and taking the picture. This is how I first started out imaging the Moon, but quickly discovered that for a very small investment, a better solution, which enabled steadier and more precise image acquisition, was available.

Most modern digital and film cameras come with a standard tripod thread adaptor located at the bottom of the camera (Figure 5.7); this is where the Coronado MALTA tripod and most other camera tripod adaptors would fit to a telescope such as the PST, but they can also be used to fit a camera adaptor bracket to press the camera lens up to a standard telescope eyepiece. In the United Kingdom, most astronomy stores sell a model called the PH047 (Figure 5.8), which is made by BCF Astro Engineering. This is an "afocal" camera holder and consists of a simple metal frame assembly for attaching a camera to a telescope eyepiece.

Figure 5.6. Point and shoot image.

Figure 5.7. Camera thread.

The BCF adaptor takes the form of two thin metal rods, attached perpendicular to each other, that can be moved using simple Allen keys to position the camera, fitted to a small threaded adaptor on one of the metal rods as close to the eyepiece as required. The camera effectively then sees what the human eye sees (Figure 5.9).

This type of imaging is known as “afocal” imaging or “digiscoping,” whereby the lens of the camera remains attached (which anyway is the case for most digital point and shoot cameras). In this case, the eyepiece in place determines the magnification achieved. This is shown in Figure 5.10.

With this configuration, as with a standard telescope eyepiece, the overall magnification will equal the objective focal length divided by the eyepiece focal length. So, for example, with a 15-mm eyepiece, which I find gives the highest

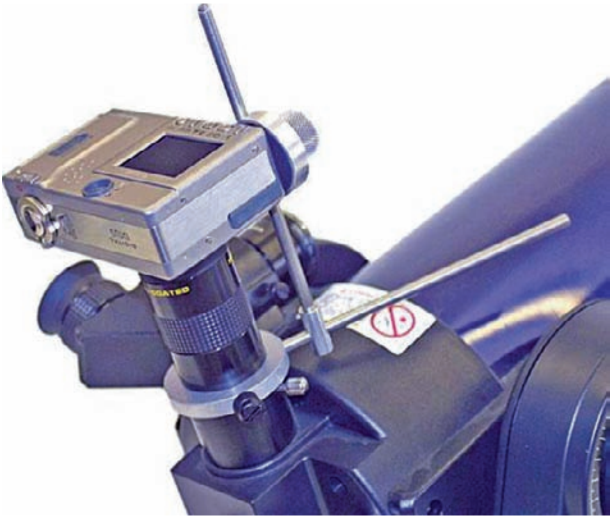


Figure 5.8. PH047.

Figure 5.9. Typically the BCF adapter will steady the point and shoot image.

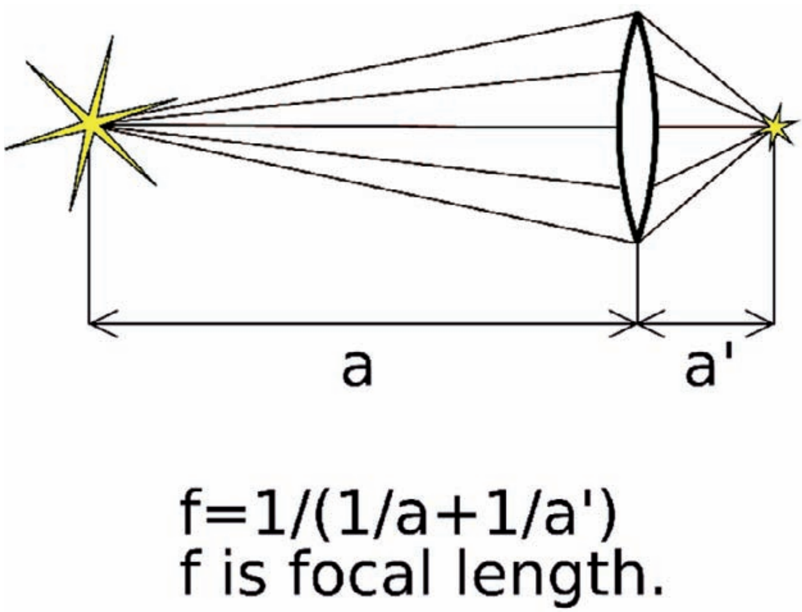
magnification whilst still showing the entire Solar disc and some clear space around it for contrast and effect, fitted to the PST, its focal length of 400 mm will give a magnification of $400/15 = 26.67$ times. The afocal setup I tried first was with my Creative Labs 880 camera. The fixed lens of this 2-megapixel camera made it ideal for use with the PH047 adaptor, as it could be very closely aligned to the eyepiece, with the rubber eye guard providing additional shielding from the daytime Sun. Chapter 2 gives the magnification and field of view combinations achieved by various eyepieces and accessories. These will also be true for any other telescope with 400-mm focal length, such as the MaxScope 40.

The difficulty with this method is that you are at the mercy of the camera's autoexposure settings with many low-cost digital cameras, which can sadly lead to over- or underexposed final images. If you are lucky enough to have settings on your digital camera that may be adjusted, then a typical "sports" setting for digital cameras, I have found, works best for surface detail, whilst the "mountain" setting is better for flares and prominences. On top of this, you have typically no control over white balance on the low-cost digital cameras, which can result in strange image coloration, and also with most low-cost digital cameras, you will have fixed gamma and saturation settings (more on these settings later).

However, if you can adjust the settings, the advantage of the live preview screen on most digital cameras (Figure 5.11) (something that digital SLR cameras barring some very expensive dedicated astronomical versions do not have) is that it will enable you to set up a nice whole disc shot in a matter of seconds.

Tuning the PST etalon whilst the camera is in place will show you the range of features that you will be able to image. Unlike with film, the results with digital point and shoot cameras are instant and can be deleted or adjusted at a later stage. You also do not have to worry typically with refocusing the telescope, as the eyepiece focus you will have set will usually be close or exactly what you will need for the image.

Figure 5.10. F length.



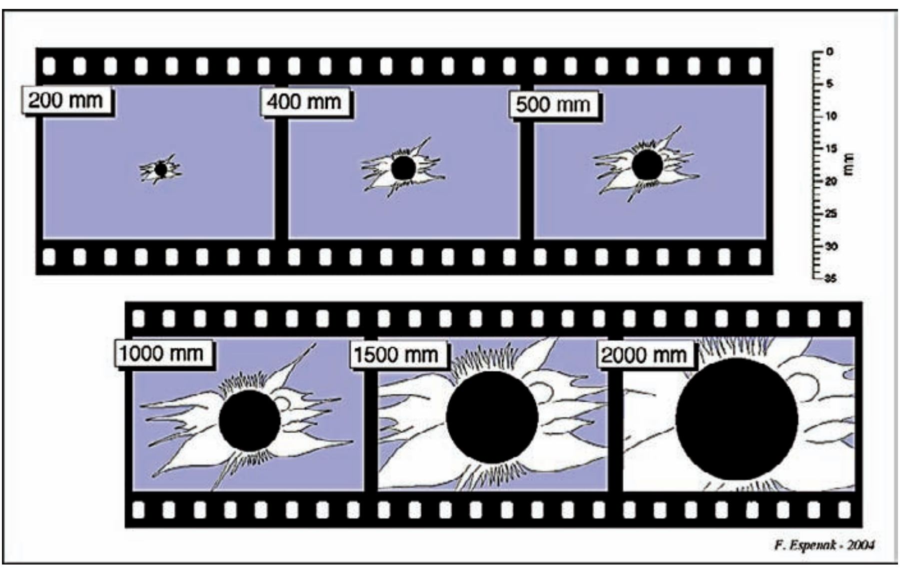


Figure 5.11. LCD preview image.

Typically a single-shot image will come out looking like the image in Figure 5.12.

As you can see with this first image, very little surface detail can be seen, and the flare/prominences as well as the outer edge of the solar disc appear a bit washed out. This is common with point and shoot imaging if focus is not 100% or exposure times are incorrect, but can, in some cases, still be rescued in postprocessing. For this method of imaging, K3CCD and Registax are largely not used unless your digital point and shoot camera doubles up as a web camera. In the case of my two Creative Labs cameras, this was not the case. Therefore, the more traditional imaging method of just "pressing the shutter" and taking the picture was used.

The downside of this is that until you copy the image to your computer, you are solely reliant on the generally small LCD preview screen on the back of the camera to check your focus. Whilst most of these allow you to zoom in on taken images, the focus with astronomical objects can be so critical that being out by a small fraction can turn a great image into an average one.

The live preview screen on most point and shoot digital cameras may be augmented by a more traditional viewfinder that pretty much all digital cameras will have, but from personal experience I have found that the viewfinder is hard to get to with an afocal camera adaptor bracket in place, as the metal rods can literally poke your eye out if care is not taken, and even when not, the small size of most viewfinders makes it just as difficult, if not more so than the LCD preview screen to use for focusing.

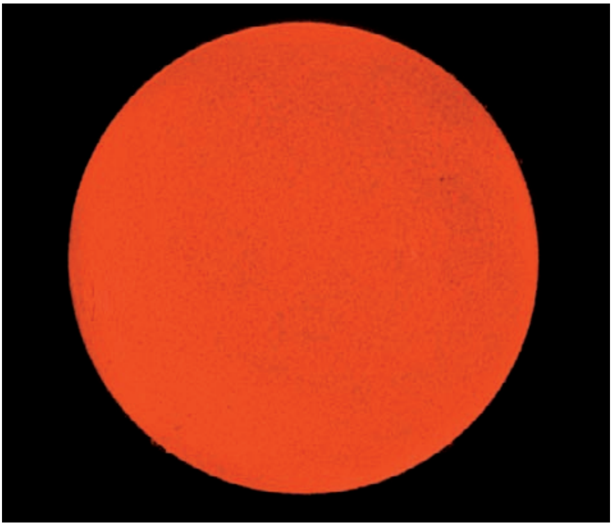


Figure 5.12. Same image 3 times...!.

You would expect that the focus you may have achieved on the telescope eyepiece was sufficiently good enough, but remember that the distance from the eyepiece to the camera lens may be different to that from your eye, and some digital cameras have autofocus routines that, whilst suited to general day-to-day objects, can sometimes struggle with astronomical imaging. Best bet, as it is digital and you would not be wasting any film, is to keep practicing moving the camera on the mount and adjusting where possible the focus and imaging settings until you get a result you are pleased with. Then write down the camera settings and try to lock the afocal adaptor bracket (if you are using one) in place. A word of caution with cameras that have integrated zoom lenses is that when using them with the afocal camera adaptor brackets, caution should be taken to allow enough room for the lens to fully extend, as the camera may autofocus and press the lens against the eyepiece forcibly, which may result in damage to the camera.

The key advantage of these adaptor brackets is that once an image is framed and set up correctly, you can take images all day, knowing that they will all be in focus, and show all the solar detail that you wish, depending on the camera and scope settings.

When such an adaptor bracket is not available, simply holding the camera to the eyepiece can sometimes be just as good, although you generally have to be quite steady with your camera. This can also result in misalignment of the camera lens and the eyepiece, resulting in the edge of the eyepiece being in the image more than required.

Again, practice will make perfect, but I would recommend a suitable adaptor bracket, or one of the increasingly popular digital camera adaptors for fixed lens digital cameras sold by companies such as Scopetronix. They make a model known as the "Digi-T" adaptor (Figure 5.13) for a wide range of cameras and unlike the afocal camera bracket they take a different approach, whereby the rubber eye guard on the eyepiece is removed and replaced with a "T ring"

Figure 5.13. Digi T.

and "Step ring" to fit to the lens of your digital camera. This will fit the camera tightly to the eyepiece and will provide an even more secure fit than the afocal adaptor bracket. Scopetronix adaptors cost more than the afocal brackets (typically around £49/$89), but in many ways will give a better result than the afocal brackets.

In addition to this, variable projection eyepiece adaptors, for both fixed lens and digital SLR cameras, are also available from Scopetronix and most good astronomy stores (Figure 5.14). These allow the eyepiece to be held inside an adaptor that can be coupled to a camera, and feature a sliding mechanism, permitting variable projection distances during eyepiece projection photography, avoiding the need to switch to higher power eyepieces when additional projection enlargement is desired.

Figure 5.14. Variable projection adaptor.

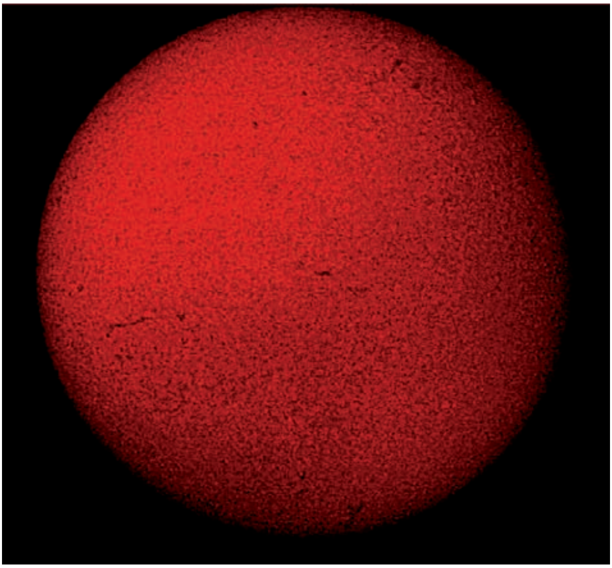


Figure 5.15. Better contrast image, made possible by the use of the afocal adapter bracket.

Whichever version you use, the principles of imaging are basically the same for afocal/digiscoping, so let us go back to imaging using the afocal adaptor bracket method (Figure 5.15).

In this image (Figure 5.15), more surface detail can be detected, mainly the filaments; again however, mainly due to the “point and shoot” nature of the

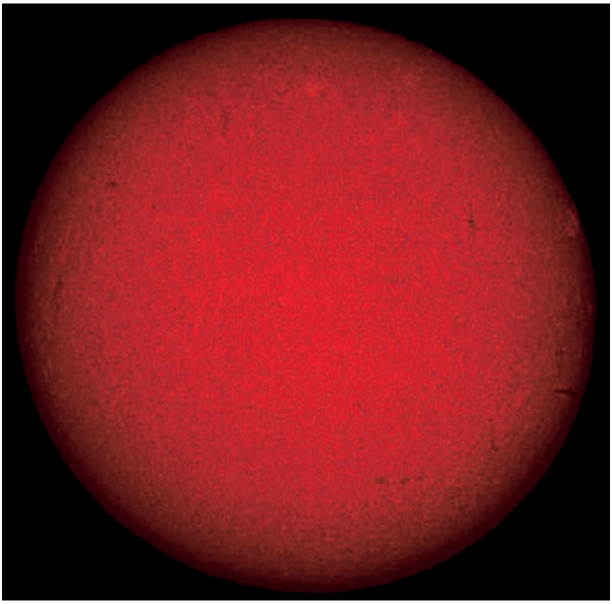


Figure 5.16. Full disc image.

image, it barely corresponds to what your eye would have seen. This can be due to slight overexposure, or light creeping into the side of the digital camera lens. In this case, the exposure time was set to around 1/100th second, which resulted in little surface detail but no prominences, and slightly grainy.

The third next image (Figure 5.16) was taken with a more advanced digital camera that had control over the image/white balance and finder control over the exposure times. With this image, you can see that more surface detail has been achieved by using exposure times around 1/500th of a second, and by tuning the PST etalon to show the surface detail, this image approximates to what the eye sees with the 15-mm eyepiece. For any point and click imaging, some amount of postprocessing (which we will see later in this chapter is essential) will be required to get the best out of the images you take.

The key advantage of the point and shoot setup is that you have a preview in seconds on the digital camera, and you do not have to worry about taking a computer outside to record images. The larger CCD sensors of most modern digital cameras (typically, at time of writing, in excess of 6–10 megapixels) also mean that you can easily fit the entire solar disc into one frame, something which many of the lower cost dedicated astronomical cameras and webcams simply cannot do. For larger events that require visibility of the entire disc such as a solar eclipse (Figure 5.17), if you wish to image it before totality in hydrogen alpha, then the afocal method is one of the best options. Just be careful with the focus, as with a solar eclipse you may have little time to prepare.

Another key point with large format CCD imaging, be it from afocal point and shoot or from some of the other options we will discuss, is that the CCD resolution can create artifacts in the image that you may not initially pick up on the preview LCD. The worst of these is "Newton's Rings."

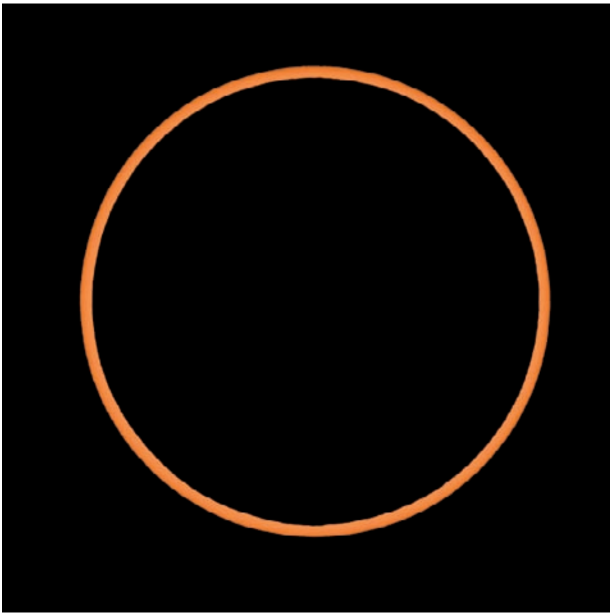


Figure 5.17. Annular Solar eclipse.

Newton's Rings is an interference pattern that large format CCD devices can suffer from when imaging an extremely narrowband signal such as that from a hydrogen alpha telescope. Typically, they appear as a series of concentric, alternating light and dark rings. The light rings are caused by constructive interference between the incident and reflected light rays, while the dark rings are caused by destructive interference. If you find your camera, be it an afocal point and shoot affair or one of the other digital SLR types that we will discuss in this chapter, suffers from this, then unfortunately you may need to change your imaging solution, depending on how bad it gets. This is another reason why I tend to do my solar imaging with the Toucam, as I personally found imaging with a 10-megapixel digital SLR camera suffered very badly with this problem. This, however, brings us neatly onto the use of these types of camera.

Digital SLR/Prime Focus Imaging Since 2003/2004, digital SLR (single lens reflex) cameras have become both high enough in terms of quality and low enough in terms of price to be a justifiable purchase for any amateur astronomer. The advent of the hugely popular Canon EOS300/350D models (known as the Digital Rebel series in the United States) and the Nikon D70/D50 opened up enormous possibilities for wider field imaging, which had previously been the domain of very expensive and dedicated cameras from companies such as SBIG and Starlight Express. The dedicated cameras advantage being that they typically used cooled CCD chips were sometimes mono (which offers better resolution and sensitivity normally and were astronomical imaging and photometric measurements) and could be easily computer-controlled. The mono advantage lays in the fact that professional astronomical cameras had no "Bayer" matrix typically above the CCD chip.

A Bayer filter mosaic is a color filter array that lies on top of a camera CCD, and its purpose is to arrange color filters on top of a square grid of CCD sensors. The term derives from the name of its inventor, Bryce Bayer of Eastman Kodak, and refers to a particular arrangement of color filters used in most single-chip color digital cameras.

Bryce Bayer's design called the green photo sensors as "luminance-sensitive" elements and the red and blue ones as "chrominance-sensitive" elements. He used twice as many green elements as red or blue ones to mimic the human eye's greater resolving power with green light. These elements are referred to as samples and after interpolation become pixels.

The raw output of Bayer filter cameras is referred to as a "Bayer Pattern" image. Since each pixel is filtered to record only one of the three colors, two-thirds of the color data are missing from each. This is where the overall "real world" loss in resolution for a typical color camera comes from.

The camera will then typically utilize a demosaic algorithm to interpolate (construct new data points based on the raw data) a set of complete red, green, and blue values for each point to make an RGB/Color image. Many different algorithms exist to do this and different camera manufacturers use differing techniques.

With mono astronomical cameras, users will typically obtain color images by exposing the image through tricolor filters, and then through mono or via a specialist filter (maybe light pollution) to get the so-called "luminance" or light level channel. These are then combined in software to create a color image.

Mono astronomical cameras are very popular for nighttime astronomical imaging, where the objects are typically very faint and light levels are crucial. The cooling that also contributes to their cost is used to reduce the thermal noise in the camera. Typically the electronic components in a digital camera will be, by their natural heat up, causing what is known as "dark current" and this will increase the levels of background noise captured on the CCD, and hence in the image. Imagers of nighttime objects tend to image "dark frames" that measure and collect this noise, which can then, again, via software be subtracted from the final image.

Almost all domestic digital "point and shoot" and SLR cameras do not have any cooling mechanisms but still have the large and relatively sensitive CCDs used in the more expensive astronomical cameras. Therefore, as with Registax you can combine many shorter frames, where the noise buildup is not so great, into one "pseudo" long exposure.

Luckily, with the Sun, as the object being imaged is incredibly bright, these methods just do not really come in to play. Imaging times for the Sun at most go to just under 1/10th of a second in my experience with both white light and hydrogen alpha light.

Whilst digital SLR cameras can be used for afocal imaging, they are much better suited to prime focus imaging of astronomical objects, and indeed the Sun, again using suitable adaptors.

SLR cameras all use fit on lenses that can be swapped and changed over to increase the field of view or magnification. They can also be removed to reveal a thread to which the lenses fit. To this thread, an adaptor, again commonly available from most astronomical stores known as a "T-Thread" adaptor (Figure 5.18), can be added. These can then be coupled directly to most telescopes that have suitable fittings, but in the case of the PST and MaxScope 40 scopes, the T-Thread adaptor would usually be combined with a 1.25 inch nosepiece adaptor, similar in style to the webcam adaptors discussed earlier, and then fitted to the telescope eyepiece holder.

The advantage of this method again is one of stability. Not manually holding the camera in place means that the camera is less likely to shake when imaging, and the telescope acts as the camera's lens, so focusing is the same as if you were using an eyepiece.

The major problem with this approach is again the focusing that is even worse than with the "point and shoot" method. Why? Well, SLR cameras use a flip mirror to bounce the light to the viewfinder. When you have the image in the viewfinder and it is focused, you press the shutter and the mirror will flip to reveal the CCD (or film in the old days). This means that you have no live preview of the object being imaged on the LCD screen, only when the shot is taken will the image typically appear.

There are software applications such as Maxim DL/DSLR (www.cyanogen.com) and DSLRFocus (http://www.dslrfocus.com/), as well as a few others that can assist with real-time focusing; by constantly taking brief shots and displaying them on screen, and using Maxim DL myself, I can testify to its usefulness. However, the software, in some cases, can again cost almost as much as either

Figure 5.18.
T-Thread adaptor.

the camera or the telescope, and it negates the real advantage again of using a point and click camera, in so much that a computer is not needed.

Canon, at the time of writing, had developed a new high spec digital SLR camera known as the 20Da (A being "Astronomy") that did have a live preview mode, but at over $2000 (£1700) it was really aimed at only dedicated nighttime observers, and the live preview mode did not work with bright daytime objects, including the Sun.

So, how do you get around the focus issue?

There are again various methods, but the simplest is just to keep taking images, previewing them on the LCD or on your computer, if you so wish, and adjusting the focus/light levels accordingly until you achieve an image you are happy with. This is the approach I currently use; however, various adaptors exist that can fit onto the viewfinder and either increase the magnification or can connect to a small preview LCD to give live preview modes.

One such device is the "Zigview" (Figure 5.19) that costs around $175 (£115) and is available from most good camera stores. This clip on device connects to the SLR viewfinder and converts the light into digital data, which is then projected onto a small LCD display.

A low-cost solution (depending on where you buy it from) is a right-angle finder (Figure 5.20) that again can be fitted to the viewfinder, and typically will magnify the image by up to 3×, which may not sound much, but when it comes to focusing an SLR, it is very useful. These can be rotated 360° and as such can be used with scopes in all positions. These can range from around $50 (£30) online or via auction sites like eBay up to over $200 (£140) from camera stores.

If you have neither, then the first approach of just taking lots of images works just as well and is free.

Figure 5.19. Zigview.

Digital SLR cameras typically have much higher resolutions and CCD sizes than webcams, and are normally better than most point and shoot type cameras. For example, with my Canon EOS300D camera (Figure 5.21), the CCD size is 22.7 mm $\times$ 15.1 mm and gives 6.3-megapixel resolution, whereas on the Toucam the CCD is 4.6 mm $\times$ 3.97 mm and gives 0.35-megapixel resolution. The newer EOS350D has 8-megapixel resolution, and 12+-megapixel digital SLR cameras are now becoming more common.

Using the T-Thread (available from all good camera stores) and nosepiece adaptors (available from most good astronomy stores), the SLR camera can be hooked up directly to the hydrogen alpha telescope and images taken. You may find that additional "Barlow" type lenses or other ways to change the focal length are required to achieve focus with an SLR camera when using the PST, but with the MaxScope 40 this generally is not an issue.

The advanced features of many digital SLR cameras, such as shutter speed control, mirror lock capability (not a standard feature of the EOS300D, but can be added via a software patch…Google search for this, and be careful as it will invalidate your warranty if you use it), which stops the shudder commonly caused by the mirror moving just prior to the CCD being exposed, can result in very high-quality solar images being taken. As the CCD is so large, these images will usually encompass the entire solar disc as seen in Figure 5.22.

Figure 5.20.
Right-angle viewer.

Using the nosepiece adaptor method, it is also possible to thread filters, focal reducers, or Barlow lenses onto the camera to increase or magnify the field of view. If you wish to take high-resolution close-up images, for example, of a particular solar region or flare, then adding a Barlow lens, again, may be the best way to achieve this.

To take images of prominences and surface detail, I would normally take two images, one at around 1/500–1/1000th of a second for the surface detail at around ISO 100/200, and one at around ISO100 at 1/50th–1/20th of a second for flares/prominences, by typically adjusting the etalon filter on the PST to a suitable location (as it is not graduated it is difficult to exactly determine or relate this position).

ISO speed (or its equivalent in digital cameras) was the traditional way of measuring a film's sensitivity to light. As the digital camera uses a CCD and not film, it denotes how sensitive the CCD sensor will be to light. If you adjust the ISO speed much higher, the increased sensitivity to light may wash out the solar image, and, as you increase the ISO speed, you increase the CCD sensitivity to noise. This is more critical for nighttime astronomical observations where longer

Figure 5.21. Canon EOS300D camera.

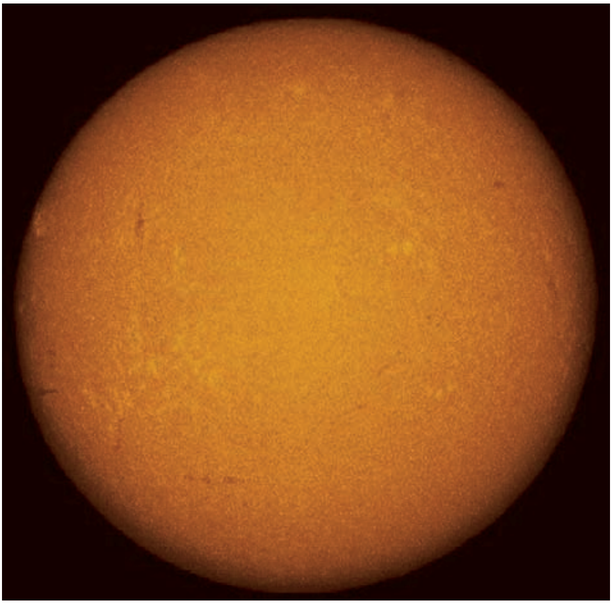


Figure 5.22. Image of whole solar disc using EOS300D with additional colour processing.

exposures are used, but still ISO 100/200 is typically what I would use for solar imaging with the EOS300D.

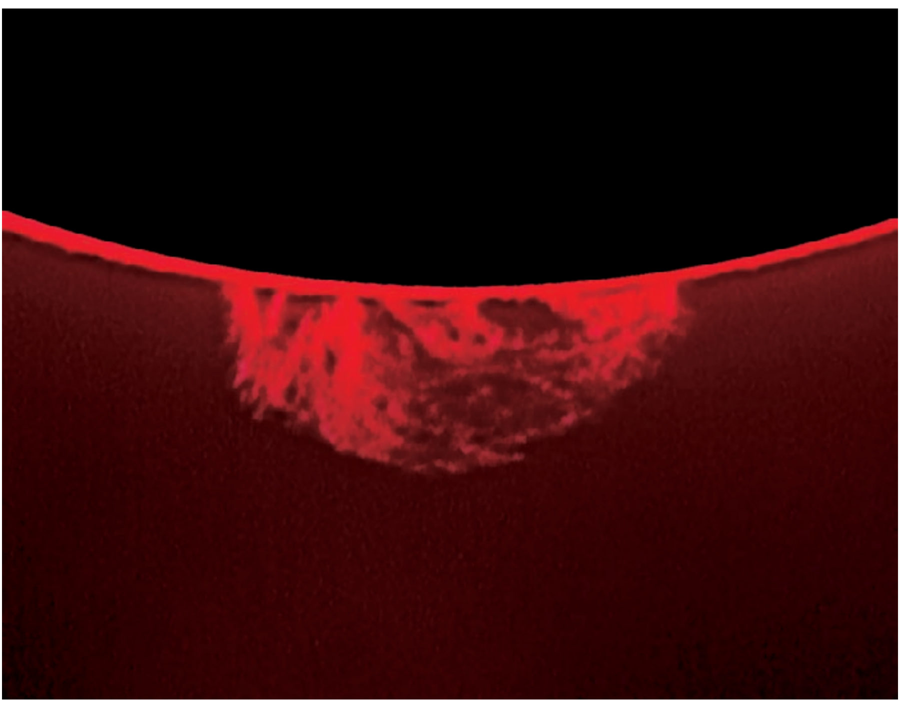
One point of note with most common digital SLR cameras is that they tend to have filters designed to block out the infrared and hydrogen alpha portions of the spectrum, which is normally OK for typical daytime domestic pictures, but cuts off important light information for astronomy. I found that this did not hinder the quality of images I was able to obtain with the EOS300D too much when imaging the Sun, but there are companies such as Hutech (http://www.hutech.com) who produce modified versions of the EOS series for astronomers. This is particularly useful if you plan to use your digital SLR for nighttime astronomical observing as well.

Why take two images?

Well, as with the Toucam imaging, which will be covered later in this chapter, to get the best possible overall image of the Sun with both high levels of surface detail and then flare/prominence (Figures 5.23 and 5.24) and even coronal mass ejections, the filter and the exposures need to be tuned to the feature in question. The two images, as we will see in "PostProcessing Your Solar Images" section, can then be combined to create a final and stunning image.

With most digital SLR cameras, exposures can be controlled via a shutter release cable, or in the case of the EOS even by infrared remote control (Figure 5.25).

Figure 5.23. Prominence details.



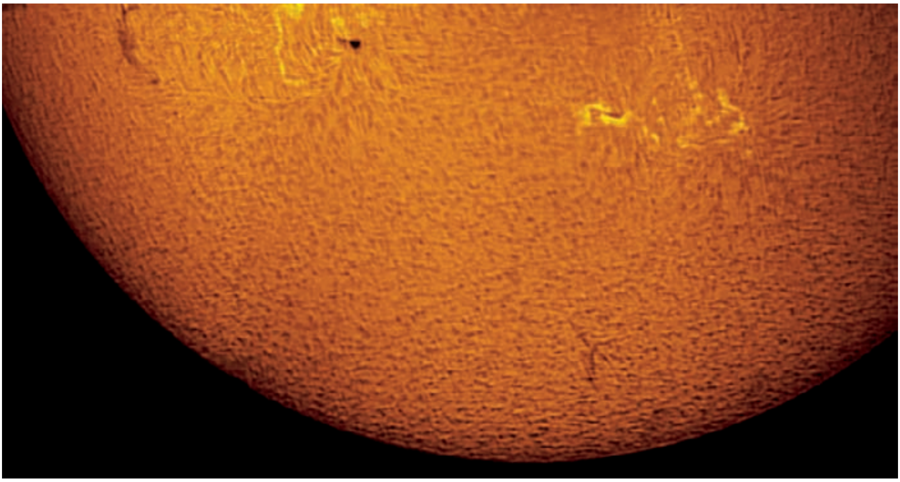


Figure 5.24. Surface details.

This is the option I use, which when again combined with the mirror lock gives me two crisp/precise and steady images every time. These remote controls can be home/DIY made in the case of the cable, if you are confident with electronics (again a Google web search on this topic will bring up plenty of Web sites related to this), buy one from a camera store, or you can also remote control the shutter via software using the aforementioned applications for remote focusing.

If you are still intending to try afocal imaging with the SLR camera, one tip is to stick with manual focus on the SLR, rather than autofocus. As with point and

Figure 5.25. Infrared remote for the Canon EOS.

shoot cameras, the detail you may be trying to pick up on the solar surface may not register correctly with the SLR autofocus routines. Manual focus gives you more control, and again may avoid accidentally slamming the SLR lens into your expensive eyepiece. Again I would recommend the afocal camera adaptor if you intend to work in this way, and be careful if you are using a simple mount, as the overall weight of the SLR camera plus any accessories you may have attached to it could topple the scope over.

But be aware with all digital SLR imaging, as stated just before the start of this section, that bigger does not necessarily mean better. Higher resolution CCD chips can give you more detail, but then I found that my 6-megapixel EOS300D does not suffer with the dreaded "Newton's Rings" whilst higher resolution cameras I have used did.

Webcam and Dedicated Astronomy Camera Imaging Earlier in this chapter we covered the basics of K3CCD and where to get it. Alongside this we discussed the Phillips Toucam as one of the many webcam options (by far the most popular) for astronomy. Now we will look in more detail on how to use both of them for imaging the Sun in hydrogen alpha light, and touch briefly on other camera options and the key differences that make them less or even more suitable for solar imaging.

The Phillips Toucam is not the only webcam suitable for astronomical imaging, but it is the most popular by far. However, if you are looking to buy a webcam for imaging, then there are some important considerations, the most important of which is the image sensor type. They come in two main types with web cameras (and indeed digital cameras): complementary metal oxide semiconductor (CMOS) and charge-coupled device (CCD). For astronomical imaging a CMOS sensor is generally not the preferred choice. This is due to several factors. Up to the time of writing, the image quality produced by a typical CMOS sensor has not been on a par with CCD. CMOS sensors use amplifiers for each pixel element on the chip. These supporting circuits can result in improved noise cancellation at the chip level, but as a result a CMOS sensor can suffer from so-called fixed pattern noise. The amplifiers are not all equal, as this creates a noise pattern across the image. This can be removed using postprocessing, but it is best not to have it in the first place.

In some modern digital SLR cameras, companies have tackled this by first taking the image off the CMOS sensor in the first few milliseconds and then reading just the fixed-pattern noise from the sensor, in the following few milliseconds they subtract the second image from the first. This is very similar to dark frame subtraction, on which astronomical imaging with dedicated cameras for long exposure relies.

There is also the fact that CMOS sensors are generally less sensitive than their CCD counterparts. High-end "full frame" CCD image sensors have a "fill factor" (light coming in getting to the entire CCD) of 100%, because the whole CCD sensor area is being used for light capture, but in a CMOS sensor the fill factor is lower as that extra circuitry alongside each pixel takes up space. This space cannot be used to capture light, and so you lose some of it. Two techniques exist to combat this – first reducing the size of this support circuitry, and secondly the micro lens. Reducing the size of the support circuitry is the less ideal of the two methods – the smaller you make it, harder the sensor is to manufacture and the more expensive it becomes. The micro lens is considered to be the better answer, but it can add to the overall cost. Essentially, the support circuitry is covered by an opaque metal layer, and a microscopic lens is placed over the entire area of the light receptor and support circuitry, redirecting the light that would otherwise fall on the support circuitry and focusing it on the light receptor.

Canon, with the EOS series, utilize some additional techniques to optimize the response and quality of the CMOS sensor, and from personal experience, combined with other user reports, the EOS300/350D cameras do not seem to suffer too badly when it comes to high-quality imaging. However, for lower cost webcams, this is a different story due to many of the aforementioned reasons.

Now that you have some technical background information, the only thing to really consider is that in general, when acquiring a webcam you should opt for one with a CCD sensor if you intend to use it for astronomical imaging.

The Phillips Toucam (Pro models we are talking about here, not the CMOS equipped XS or "Fun" models) uses a Sony ICX098BQ CCD sensor capable of delivering 640 × 480 resolution video frames (typically how you capture astronomical images) and has a light sensitivity level (Lux value) of < 1 lux. This is excellent light sensitivity, which is exactly what you need for taking images of dim planets at night, but not quite on a par with dedicated astronomical imaging cameras that can approach 0 lux sensitivity. The CCD, as previously mentioned, is relatively small, but still more than sufficient to image any solar system planetary body barring our own Moon and the Sun, in its entirety. The beauty of this camera is also the low cost, being around \$60/£40 typically in most computer stores or online. The Toucam is also one of the most heavily modified cameras on the market for astronomical imaging, but we will talk a bit more about that later. For now, let us just focus on the standard Toucam.

Imaging with any webcam relies on a computer being present, and once you have installed the drivers for your webcam that are typically provided in the box with it, you can start to experiment with the camera itself.

Once the camera drivers are installed from the CD that it comes with, then first thing to do is to try it out without the telescope adaptor, as it comes out of the box in broad daylight. It is a webcam after all, so try it out and become familiar with its operation when you are comfortably indoors, and not having to worry about a telescope at the same time. You can use the presupplied imaging software that comes with your webcam, but I would recommend, as this would be the application of choice to use, to download a copy of K3CCD (which is free to use for 35 days, and then must be registered for a very modest fee), and start using it with that.

K3CCD is a Windows-based application, and should be run ideally with Windows 2000/XP/Vista or higher computers; though it will work with older version of the OS, they are now, at time of writing, over 8 years old in the case of Windows 98.

Most modern computers, less than 2 years old, and of Pentium 3 class and above will work fine with this software, but it is worth checking with the K3CCD Web site for details on support. If you find that it does not work for you, then maybe now is the time to upgrade your PC, or maybe check with the author if there are any known issues with your computer. Peter Katreniak is, in my experience, an exceptionally helpful individual.

It is worth pointing out that the ease with which the standard lens may be removed varies between webcam types. In particular, the lenses on the Phillips Toucam models can simply be unscrewed all the way out and thereby removed, whereas to remove the lens from a Creative Labs Live Ultra or Logitech Quick Cam Pro, for example, the camera's case must be opened, which will invalidate the warranty. This also applies to the new Phillips SPC900NC, which is the latest update of the popular Toucam range.

First of all you must have your webcam (Toucam 840K in this case) plugged in to the computer before you start K3CCD. This will ensure that the drivers are running prior to the application itself trying to detect the camera. Once launched K3CCD will typically look like the image in Figure 5.26.

Were I using this for the first time, I would typically start with familiar objects, out of a bedroom window or just around the house. Once you have familiarized yourself with the Toucam control panel software (Figure 5.27) and how it works, then maybe you can set up (if you have one) using a suitable webcam adaptor that is fitted by unscrewing the lens on the Toucam, and simply screwing in the adaptor, connecting the Toucam to a normal astronomical telescope, and then pointing it at a distant object and practice some more. Critically if you are doing this with a normal telescope, do not point it at the Sun. The CCD will be instantly damaged unless you have correct filtering, such as that provided by a hydrogen alpha, or suitable white light filter, such as a Baader filter.

Connecting it up in this way will help you to understand how the camera functions. The most important thing in the control panel, once you have got used to it, is to

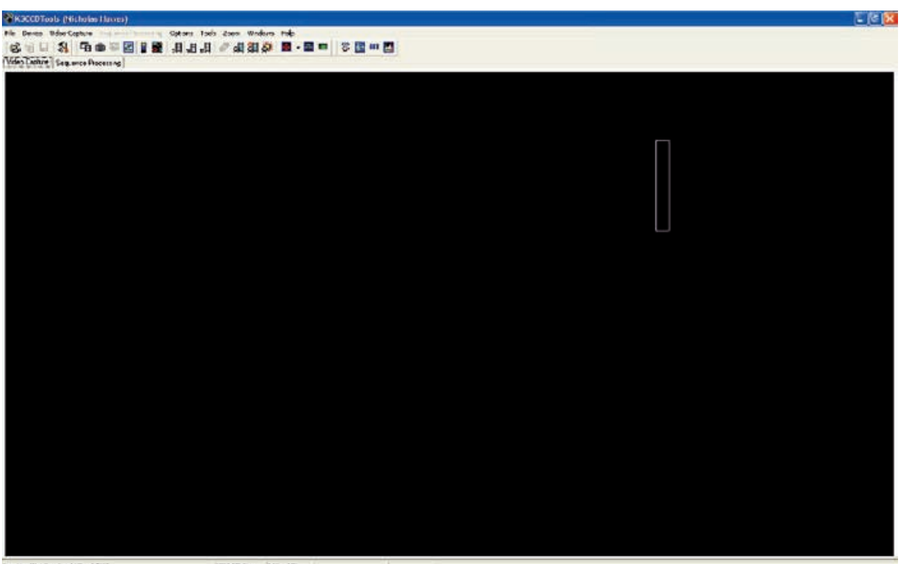


Figure 5.26. K3CCD launch.

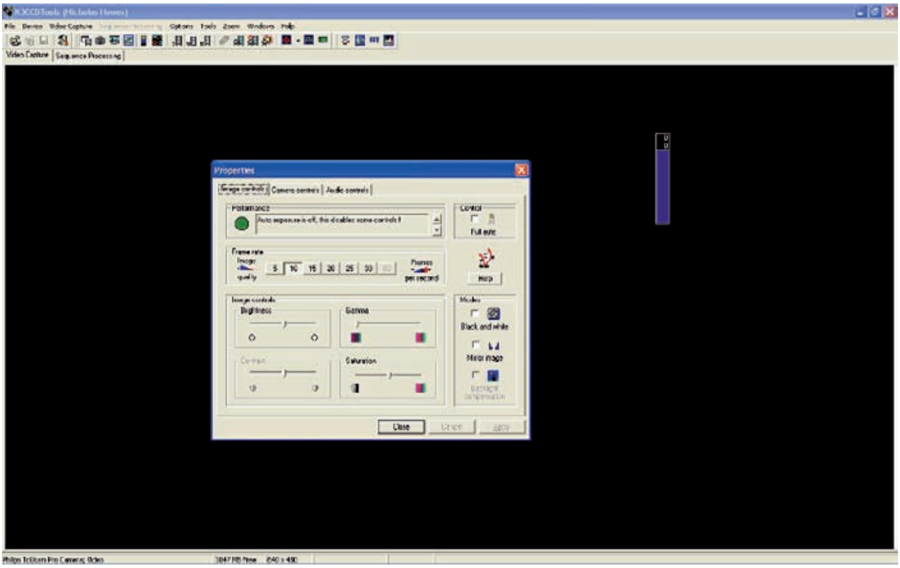


Figure 5.27. Toucam control panel.

turn off the FULL AUTO mode, as the camera, whilst intelligent, will just make it impossible to image anything at night if you leave it on. The full auto mode with the Toucam is primarily designed for use with standard webcam face-to-face type applications, such as MSN Messenger or similar "chat" type programs.

Now, with the Toucam fitted to your hydrogen alpha telescope, you can start to think about imaging.

Remember, as we have stated, that the Toucam at prime focus on a PST or MaxScope 40 will typically only image around 1/4–1/3 of the solar disc, unlike with a digital SLR that will capture the entire disc due to the much larger CCD. Also the reduced pixel size of the Toucam CCD will mean that images of the entire solar disc may not have the same high resolution as the digital SLR images, meaning that finer details may tend to be "pixelated" if you try to blow up the images (unless using it with a Barlow type lens that will increase the resolution of the image on the CCD) and if you wish to print off your images; you may have to restrict the size to which they may be printed.

With the PST, the Sol Ranger finder will help a great deal in getting the solar disc into the frame of the Toucam CCD. You may find that the image you initially see is very white or washed out; this is easily rectified by opening up the Toucam control panel application using your imaging software (typically K3CCD is used by most amateur astronomers for planetary imaging, but the Toucam control panel will be the same no matter which application you use).

If you are imaging outside on a clear cloudless day, then the settings typically I would use as a base reference point for the solar disc, trying to capture any filaments or surface features, would be at around 1/1000th of a second of shutter speed, with the other options for settings of brightness/gamma shown in Figures 5.27 and 5.28. Usually adjusting the brightness setting will result in compromising the final quality of your image, and so should ideally not be used, but left at the default setting using the gain and shutter speed to get the required result. A note here is that modified Toucams' which use RAW firmware, usually require you to factory reset the camera each time you start it up, to utilise the optimizations. For an unmodified Toucam, this is not required, as it will set the control panel into a fully automatic mode, not suitable for astro imaging. You will also have to try different settings with the etalon tuning of the PST or MaxScope 40 (or indeed any hydrogen alpha telescope) to see which gives the best level of surface detail. I personally, with the color nonmodified Toucam, prefer to image with the Toucam set to "Black and White" mode, as I find that the color options can and do wash out the image detail. This means slightly more work when postprocessing the images, but to me, gives better results in the end. However, feel free to try imaging with the color options on in the Toucam (or other, if it is a color CCD) camera control panel.

You may find that a setting you have for the telescope visually may not be the best setting for imaging. Trial and error is what will prevail here, but if you can,

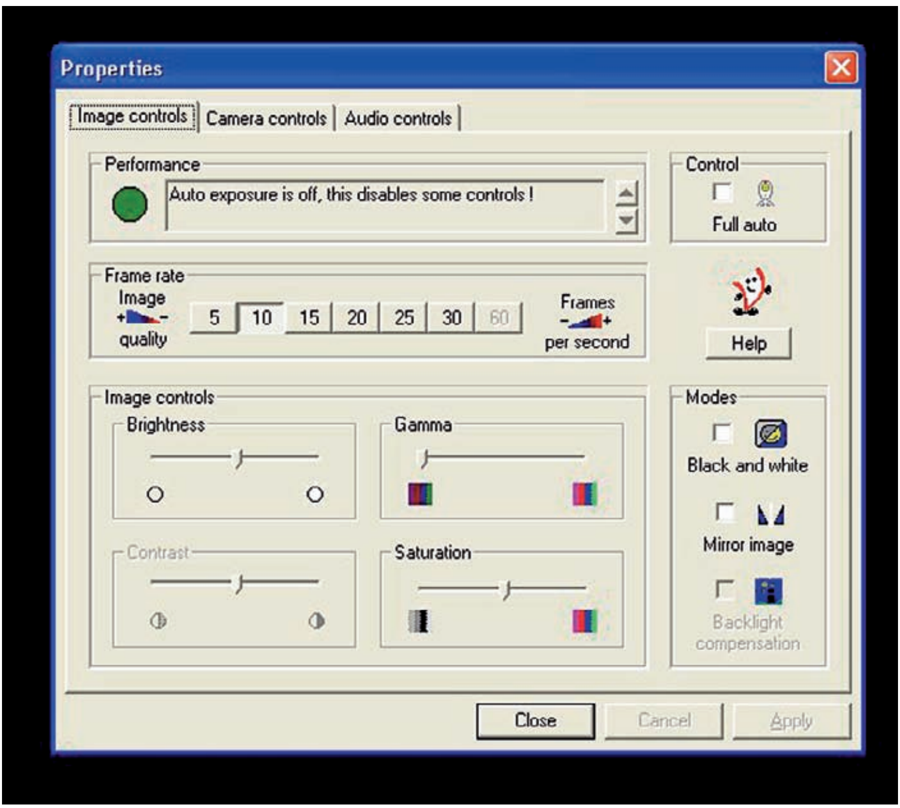


Figure 5.28. Toucam control panel settings.

I would recommend making a small set of marks on the tuning dial of the PST or the etalon tuner of the MaxScope 40, so that a good setting for one particular imaging/viewing session can be quickly and easily returned to (make the marks with something that rubs off easily). Obviously features and the "sweet spot" on the PST do change all the time, so only use these as a rough guide for switching between eyepiece and camera if you feel the need. Tuning the etalon is a relatively simple process, and with the live preview options of most astronomical cameras, can be done on the fly. The idea of making marks is more when using SLR type cameras, where the viewfinder image is small, that also makes focusing more of a challenge. Focus on the Maxscope series of telescopes is far easier to note due to the graded/marked focusing dial.

With white light imaging, as opposed to hydrogen alpha, if you are trying to image, for example, a sunspot in both lights, I find that the image using the Toucam can still be difficult to focus. I typically add a nosepiece infrared blocking filter or Baader Continuum filter for the white light shots. In the case of the IR filter, this will also typically help the overall focusing of the image due to the fact that infrared light focuses slightly differently on the CCD, and as you have removed the lens of the Toucam that contains an integrated infrared blocking filter, IR light can now get to the CCD.

Once in focus, you should start to see on the K3CCD live preview screen (or preview screen option in your imaging software), the main solar disc, hopefully with some sunspots, filaments, or other detail, which will make focusing even easier/better. If you find that the Sun is particularly inactive on the day you start to image it, then try moving the scope to the edge of the solar disc, and use that to attain a sharp focus. Very small focus movements may be needed, but, as stated, try to make a note, if you can, of where focus was achieved.

As K3CCD is typically used to capture a "video" of the object (this helps to eliminate some of the atmospheric blurring effects), once your solar disc is in focus, and you hopefully have some spot or filament detail in view, it is time to capture your first solar video.

Using K3CCD select the video capture tab, select the device menu, and hopefully your Toucam should appear if you have correctly installed the Toucam drivers, (though should be automatic under XP, and the status at time of writing with Vista was still undecided). You can then select video for windows mode or WDM mode. WDM mode allows more than one application to use the camera at the same time (useful if you use the Toucam as a guider camera as well). Then select the frame rate at which you wish to capture the images, using the frame rate tabs in K3CCD.

The video capture method of taking images, besides from helping to reduce the atmospheric noise, has other benefits. As the solar disc and limb are very dynamic and active areas, taking a video over a period of only a few minutes can show emerging flares or prominences, or even motion in surface features if you are lucky.

Typically I would take a video of the Sun lasting around 800–1000 frames in length between 5–10 frames per second with the Toucam if imaging a specific feature for a still image, and anywhere up to 10 hours of video, in 1–2 minute segments with 15 minute gaps if attempting to capture a flare or prominence developing. The limitation is purely down to how the software creates the file, the size of the file it will create, and any subsequent processing you may try to do on a file of this large a size. When it comes to postprocessing, many applications have limits to the size of files they can handle. Note that K3CCD and many other applications will support higher frame rates (such as 60 frames per second), if the camera you choose to use will also support these. This is useful for solar and planetary imaging as you can capture more frames in a shorter space of time when a planet is rotating, however with the Toucam range, increasing the frame rate beyond 10 frames per second can introduce compression artefacts in the image. The higher frame rates however can, in some instances benefit solar imaging, especially with fast-moving limb features such as prominences or active regions on the main disc.

The size/framer rate and compression used will obviously impact on how much video you can take based on the size of your hard disk. Using the standard compression options of the Toucam (which ideally, as we shall see later, should be switched off using a firmware modification) will mean that a simple 150 frame video, at the full resolution of the Toucam (being 640×480) and captured at 15 frames per second, will use around 65 MB of hard disc space; for the standard driver, though modified Toucams, different frame rates and higher frame rates may create even more data than this.

Always remember to set up the Toucam to its highest resolution (640×480), otherwise the more limited 320×240 resolution that it will support may lead to inferior quality and smaller images, which will be more difficult to process later and obtain any fine detail; replace this entire section with Figure 5.29 shows the typical view when using 640x480 mode in K3CCD, and the typical levels of clarity you may find due to atmospheric interference.

The Toucams' USB 1.1 data rate at 640 x 480 resolution will mean that longer videos at 5–10 frames per second will use many gigabytes of hard disc space, so if your computer does not have a large hard disc, be careful, as the performance of the operating system and overall stability of the computer can be seriously affected when you start to run out of disc space. Luckily K3CCD does have an option to warn you if you are running out of disc space, but still be cautious when imaging and back up your hard drive regularly.

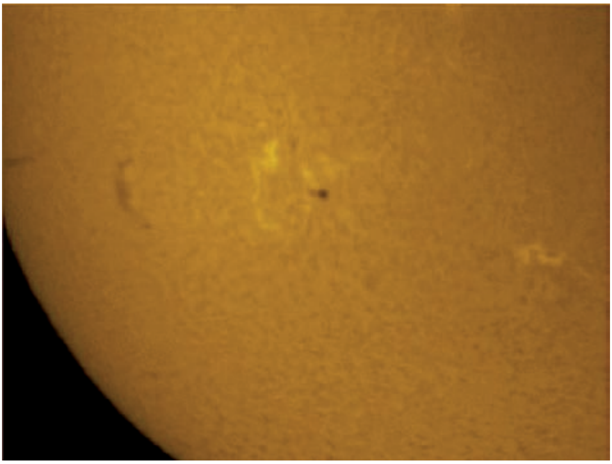


Figure 5.29. Raw frame image of the solar disc captured with the Toucam.

Once the solar disc is imaged, set the Toucam control panel shutter speed to around 1/100th–1/50th of a second or lower (depends on cloud conditions and if you are using any Barlow or focal reduction lenses), and look around the solar limb to see what flares or prominences may be present.

You can swap out the Toucam for a suitable eyepiece to quickly look at the entire disc for any obvious flare or prominence details. As a point of note, you may find that you need to tweak the focus slightly when moving from imaging or even viewing the main solar disc and the limb features, such as prominences (Figure 5.30).

Imaging the Sun in this way, basically creating two videos, one of the disc and the other of the prominences, will allow you later to combine the two images to create a stunning composite of the Sun.

When capturing the solar disc, it is worth spending some time trying to see and image a disc feature (such as a filament or a sunspot) in the preview screen, as we will see when it comes to image processing, having even a small but discernable feature on the disc really does help when the software used to stack the images, namely Registax, has to try and lock onto a feature. This is particularly so if you have a nondriven mount, and the Sun moves across the field of view.

The camera video image, not so much with the Toucam but with some popular CCD/webcam camera models, when captured and played back may appear even at the higher resolution mode to be “striped” horizontally across the image, when you look at them. This can be the result of interlacing, whereby the camera combines image fields into one video frame using odd and even scan lines. This can easily be removed in postprocessing.

Earlier, we mentioned modifications to the camera to get better image quality. Some of these involve replacing chips such as the CCD on the camera, replacing them with more sensitive, higher resolution, or even monochrome CCDs, or modifications for long exposure, which typically entails adding new chips and additional cabling to the Toucam. However, another interesting feature that is not well known with the Phillips Toucam and indeed a few other low-cost web cameras is the ability to use the so-called Color Optimized Non RAW (CONR)

Figure 5.30. Solar limb and prominences captured with Toucam raw frame.

mode. The Toucam, when capturing video frames, tends to automatically "adjust" the image, which can degrade the quality of the image by creating undesirable artefacts effectively sharpening it. Recently, in 2006, a color-optimized version of this so called RAW mode was made available via a software modification. Be warned, this software tool will make a permanent change to your Toucam firmware (which you can reset via the same software), but as such, it may invalidate your warranty if you get it wrong. However, the benefits are quite noticeable as the inbuilt image processing of the camera, which tends to over sharpen images, is removed, and you just get pure RAW quality images in full color that can be postprocessed more effectively. The images may need to be postprocessed to de-Bayer them, but the technique really does yield even higher quality results than the Toucam is typically capable of. If your Toucam is modified with a black and white CCD, the black and white RAW modification to the firmware will give the highest possible quality results from the Toucam according to most Web sites and people who have used it.

A Google search on the internet for "CONR Toucam" will yield a wealth of information on how to perform this software modification to the camera, which will make imaging both the Sun and, if you have a regular telescope, the planets with your Toucam even better. Toucam, as stated, can also be modified for long exposure via hardware tweaks, but for the purposes of solar imaging, this is not necessary, as the light source is more than bright enough to begin with, being the brightest thing in the sky…our Sun.

The Toucam, also as stated, can also be modified for purely black and white operation by replacing the CCD with another similar black and white variant, but this is not for the faint hearted. Typical CCDs replacement includes the Sony ICX098BL and ICX414AL. However, this will yield 2–3 times better light sensitivity as the color filters in the matrix overlaying the CCD absorb about 66% of the incoming light. The images with this modification, and the commercial versions of it available from companies such as Atik, are indeed better than most images I have seen with the regular unmodified Toucam.

However, most people I have spoken to are more than happy with just the basic Toucam operation, and are scared by the prospect of taking a soldering iron to their webcam. Commercial companies such as Astronomiser (www.astronomiser.co.uk/) will perform modifications for a small fee.

I would, however, still recommend the software CONR modification to improve the overall image quality, as the integrated image sharpening provided by the standard Toucam can result in some quality loss with any planetary or solar imaging projects.

Once you have captured your video of the Sun, you can now proceed to the processing and stacking of the images; however, let us first discuss in a bit more detail some of the other camera options available.

Whilst there are a huge number of other webcam-based devices on the market, as we saw earlier, some of them are less suited than others due to the type of chip they use, for astronomical purposes. Various Web sites list the specifications of a range of cameras, and give notes on how suitable they are for this type of work. With the Sun, however, lowlight sensitivity is not as critical an issue as it is when trying to image planets or deep sky objects. One thing you always want of the camera is to support as high a resolution as possible to enable better detail capture, and, depending on the size of the CCD, larger amounts of the surface onto the image in one go.

Some other popular planetary camera devices that are configured for dedicated astronomical use are the Celestron Neximage that utilizes very similar technology to the Toucam, the Lumenera LU075 and SKYnyx, and the Meade LPI (Lunar Planetary Imager), which I own, and use mainly for spectroscopy/and or as a guide camera for my dedicated deep sky imaging setup. If you find that the camera does have a CCD, which delivers interlaced frames (whereby the image is split into two separate scanning runs on the CCD, and then recombined), then software postprocessing options in application such as Registax can be set to remove this.

The LPI specification is very similar to that of the Toucam, in terms of light sensitivity and chip size; using a CMOS chip, however, means that some users still prefer the Toucam, even though the pixel size of 640×480 is the same. The LPI will do long exposures of up to 16 seconds straight out of the box, and has a slightly greater level of control from its software panel. It is also used with the MaxScope 40 scope, and a suitable focal reducer can capture the entire solar disc, much like our previously mentioned digital SLR camera.

My personal findings with this camera and planetary work led me to conclude that the Toucam produced better overall results, which is why I now mostly use the LPI for spectroscopy and guiding, as the longer exposure capabilities make it excellent for guiding and capturing fainter light from stars when I am imaging spectra; however, for imaging the Sun in hydrogen alpha, it is still a competent performer. Again, one needs to be careful on the settings in the LPI control panel, ensuring that you use suitable brightness/contrast and gain settings to capture the disc and prominences. Typically, frame lengths of around 0.015 seconds are suitable, but as with the Toucam, experimentation is the key.

One point of note with the Meade LPI (Figure 5.31) is that the plastic case, in which it is housed, has a relatively thin plastic, which can leak in light. For

Figure 5.31. Meade LPI.

Figure 5.32. The Meade LPI modified with masking tape to reduce the eight levels.

nighttime imaging, this presents little or no problem, but if you are to image the Sun in daytime, the amount of light leakage can result in slightly washed out images.

Whilst it will again invalidate your warranty, the LPI can be opened up, and the inside of the case (the back portion) blacked out with suitable tape or paint that will reduce this problem. Various Web sites cover this procedure in detail, and again a suitable Google search will point you in the right direction, should you wish to modify your own Toucam (Figure 5.32).

Other dedicated imaging cameras, such as the Atik range, Orion's Starshoot, and SAC series can also be used, as well as surveillance cameras used for home security via a suitable video capture card. The internet again is a valuable resource for making your final imaging choice, but it is the opinion of the author that the Toucam Pro series, and its replacement, the SPC900NC, really does take some beating when it comes to pure value for money.

PostProcessing Your Solar Images

Once the images or video's are captured, how do you go about postprocessing the data to create solar images, the like of which you see in many popular astronomy magazines, and on hydrogen alpha imaging Web sites. Your captured image typically will look dull red in color, does not really show much detail, but you will see other images taken at the same time with the same basic equipment, and they will have immense amounts of detail on the surface, and be showing prominences at the same time.

The secret is largely in the postprocessing, as in many of today's film and magazines. Postprocessing, and enhancing images, really can make mediocre shots stand out.

With your basic unprocessed shot the hydrogen alpha etalon and blocking filters eliminate all information except that coming through at around the 656 nm region. This area of the spectrum is very red in color, which is why when looking at the Sun in hydrogen alpha you tend to see a very red image. As with most astronomical images for night-time as well, the information is actually there in the image, but you have to coax it out with modern software; this is a relatively painless process.

The first thing to remember is to create a backup of the image you are going to work on. The reason for this is that if you accidentally make a mistake during postprocessing and decide what you did was wrong, sometime, unless you have that backup, you will be stuck with the final processed version, or possibly some previous steps that led up to it. If your image is in a specific high-resolution format such as TIFF or better still, a RAW output frame from your camera, it is also best practice to work with the image in this mode, so long as your software supports it, as reducing the image or compressing it with compression such as JPEG will also destroy valuable image data.

Most professional astronomical software packages will support TIFF, FITS (a specialist format used mainly in astronomy), and RAW image data import. To help, you may also want to save a backup in the image processing software's own native format (PSD for example with Photoshop), as this can help to speed things up when opening up the image in future.

If you are processing images from a webcam video capture, your first step before even getting to postprocessing inside an application such as Photoshop or Maxim will normally be to "stack" the images using an application like our old friend Registax.

Registax, by Cor Berrevoets, as stated earlier in this chapter has become almost the de facto standard by which other image stacking and processing applications are measured. Due to the fact that we look at astronomical objects through miles of quite turbulent sky, single-frame images can be affected by atmospheric turbulence, thermal currents, and general unsteadiness in the sky.

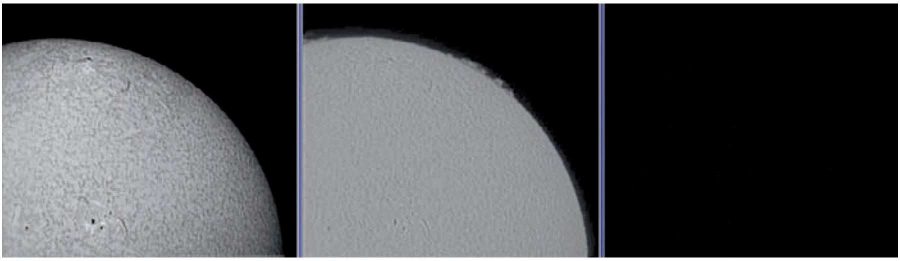
What Registax does is it takes all of the individual video frames, captured normally using K3CCD (which also has this stacking, but many find it not as simple to use as Registax), and scans through them to find the ones where this turbulence is least affecting the image, effectively pulling out the best frames from the video, using clever mathematical techniques to analyze the image.

It does this by the user setting a reference frame from the hundreds or even thousands that may have been captured in K3CCD, and then using algorithms, search through, and reject or accept the quality (which can be set by the user) of each frame. It then takes the average of the best frames, and composites them together to create one much clearer final image. This final image can then be further postprocessed using "wavelet" adjustments, which are almost like sharpening adjusters to bring out more crisp details in the final image.

To demonstrate how this can change an image, let us look at the following example.

In Figure 5.33, we can see the individual channels from a colour image, whilst figure 5.34 we can see a typical video frame from a Toucam capture run taken in K3CCD on an average day. The solar disc appears a bit washed out, but some good detail can be seen on the surface.

Figure 5.33. A colour image of the sun split to its individual red, green and blue channels.



If we select the filament on the surface as our guide marker point for Registax to track and align images against, select a quality minimum level of, for example, 80% for lowest quality and press the "Align" button.

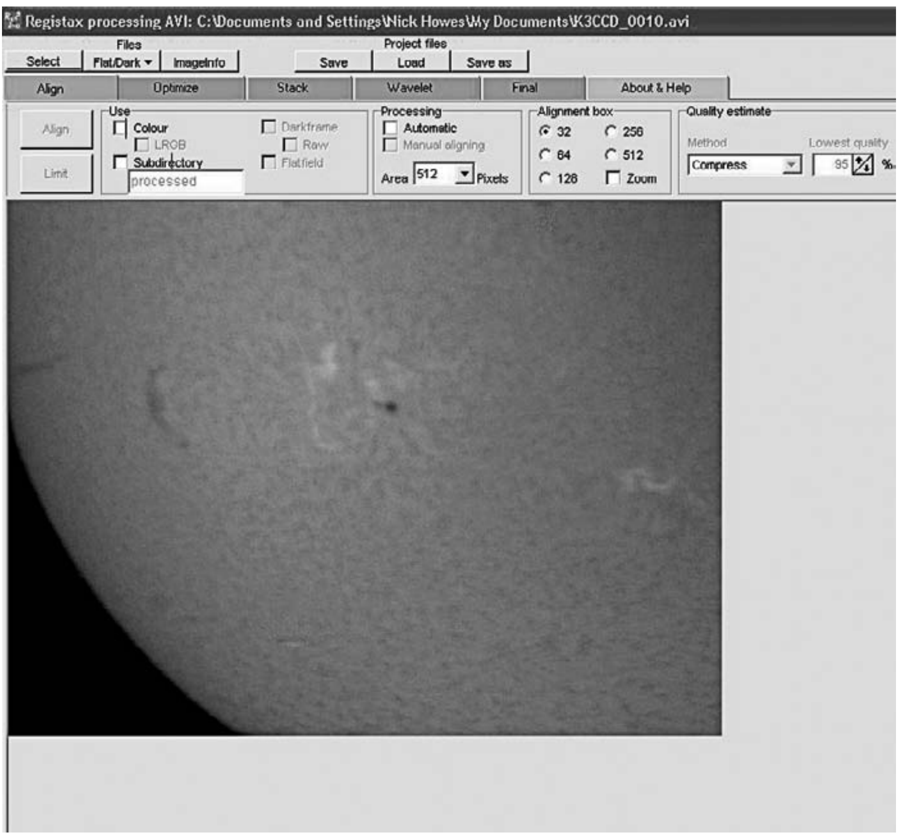


Figure 5.34. RAW unprocessed solar image in Registax.

Typically Registax will then take a few moments to scan through the video file, and select the best frames that are above that quality threshold.

After the alignment completes Registax can then order the images according to their quality. The Limit slider will instruct Registax to work only with images that have a quality higher than the current image you see. This can be changed by using the slider at the bottom of the screen to scan through all of the individual frames one at a time. Registax will then take these images and optimize them or "optimize and stack" them together.

The resultant image after stacking will tend to be better than the one you started out with, although they may still appear blurry if you are not tracking the Sun with a good motor-controlled mount, or if the weather conditions are not so great. However, the great power in Registax comes from the penultimate act in its arsenal, that of wavelet processing.

Wavelets are mathematical functions, which in the context of Registax allow the user to selectively sharpen the final processed image from the video capture to a lesser or greater extent. The wavelets page for solar imaging is particularly good at sharpening up surface filament and sunspot details as well as plage, and for the flares and prominences, it can coax out subtle detail in these features as well.

By taking our filament detail from Figure 5.34, and running it through the basic processes outlined in Registax for selection, alignment, optimization, and stacking, in the Wavelets page, just by simply adjusting slider 6 to maximum, and pressing the "Do All" button in Registax, you see an immediate improvement in the contrast and sharpness of this feature. The beauty of Registax is that it pretty much does most of the hard work for you. Of course there are many advanced options to play with once you become more comfortable with the software and how it works, but for now we will take that tweaked wavelet image of our filament, and proceed to the next step of processing.

Again, if your camera does produce interlaced images, in Registax, on the "additional settings" tab found in the first alignment screen, there is an option to remove the interlacing. The option to remove interlacing is also featured in many software applications such as Paint Shop Pro and PhotoShop as a noise reduction or video processing technique.

Using the "Final" option in Registax, we can make simple adjustments quickly to the image for color hue (if you have imaged in color), brightness, and contrast to change the way our processed image looks. Whilst this is a step in the right direction, the real postprocessing tends to come from more dedicated image manipulation software.

There are many packages available on the market today, ranging from the relatively inexpensive applications such as Paint Shop Pro to the professional area applications such as Photoshop CS2, as well as dedicated astronomical image processing software such as Maxim DL, ImagesPlus, and AstroArt. Freeware applications also exist on the Internet, such as the popular GIMP software. The choice of software can be decided only by the user, but the principles of image processing remain largely the same (though may require different steps) for each application being used.

My methods of processing differ from most people as I like to try and utilize the best aspects of several applications to get the most out of my images. Having picked up tips from the Internet and other solar imagers met at star parties and meetings, there is no real definitive way to process solar images, but here are a few steps that I use to get images that I am happy with.

Step 1: Coaxing the Most Detail Out of the Image

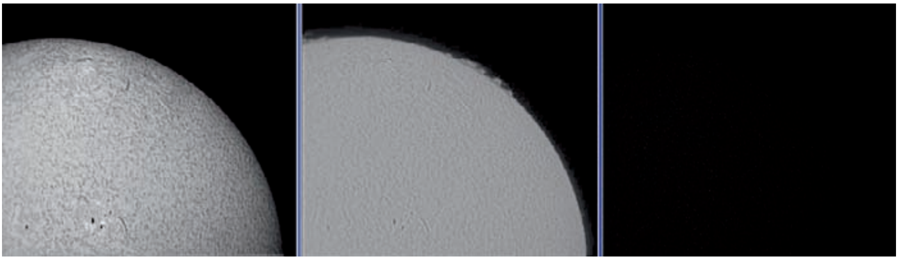
Once the image is inside your software of choice, if it is a color image, the first step I usually undertake is to split it into three primary color components, being red, green, and blue. With most CCD cameras, the red image will be the one that contains the majority of the hydrogen alpha information you wish to work with, but depending on the camera, you may also find quite a bit of detail bleeding in to the other color channels. Splitting the colors is a relatively simple process in many astronomical and general image processing applications, usually from a menu item drop box, split to RGB. If you are imaging using a mono camera or imaging using filters, then select the best processing options for the filters you have used, but for this example, we will focus on the Toucam imaging discussed earlier.

As we can see in Figure 5.35, the red color channel does indeed contain the vast majority of the interesting data that we will try to manipulate. Note though that some consumer grade CCD cameras will leak a large percentage ($>$ 10%) of light into other color channels.

Once we have the channel information split, my next step is usually to sharpen the image using one of the applications for sharpening filters. The ones I find most useful are the "Sharpen More" option in JASC Software's Paint Shop Pro, and the "Unsharp Mask" option in Adobe Photoshop CS2. By taking the red channel image and applying this process, one can instantly see a definitive improvement in the image (as shown in Figure 5.36); however, caution should be taken to ensure that you do not over process the image, and lose valuable information. Most applications have sharpening filters, so feel free to experiment with settings that best suit the image size and resolution you are working on.

Deconvolution algorithms for reducing distortion effects can also be used if available. Maxim DL and AstroArt software both offer a range of deconvolution

Figure 5.35. Solar image split to RGB color channels.



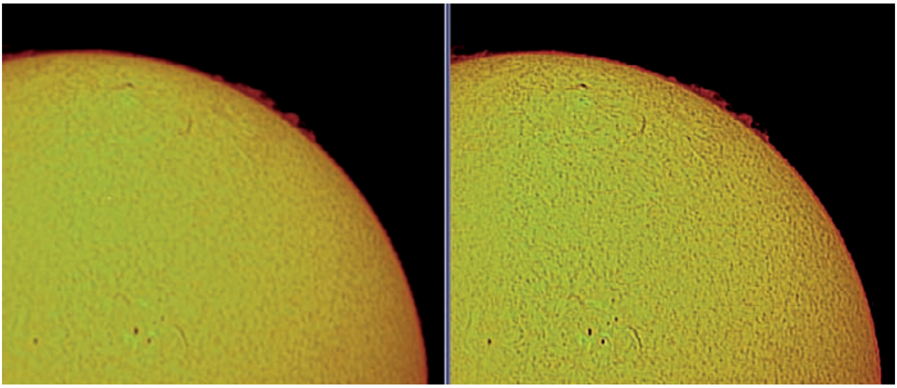


Figure 5.36. Image enhancement using unsharp mask filter in Paint Shop Pro.

options for image processing, such as the Lucy-Richardson algorithm, which is widely used in image processing for astronomy to reduce blurring and atmospheric effects. ImagesPlus software has an excellent version of this with good preset values for the type of processing we are aiming for. Be warned that these deconvolution processes can be very processor intensive, and unless you have a high spec PC, they can take quite some time to complete, depending on the complexity and size of the image being taken. It can almost seem like your PC has crashed when they are being performed, but patience should prevail. If the deconvolution process does not give you the desired result, it may be that you have chosen too many iterations, or "passes" on the image. Reduce the number and reprocess until you achieve the level of image clarity you desire.

Now we have a sharper image file, we can go about stretching the image to obtain even more contrast and detail. I usually do this using the "histogram" function in applications such as Paint Shop Pro, Maxim, or Photoshop. The principles outlined do apply to any software that has a histogram option.

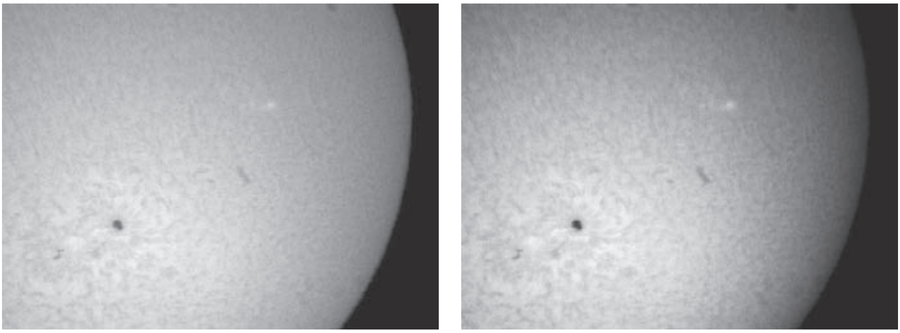
A histogram in the context of an image is a graphical representation of the range of tones from dark to light in the image. Some digital cameras include a histogram feature that enables a precise check on the exposure of the photo, such as the Canon EOS series, where pressing the info key will display a histogram of the image being shown.

Once in the computer, the histogram of your solar image can be viewed and typically adjusted to compress or expand on the light levels at each point, as can be seen in Figure 5.37, which shows the solar image pre- and post-histogram adjustment, with the resultant histogram beneath each image.

Histogram adjustments can also be applied (as can any of the previous steps) to the blue and green channel information, if you wish to try and coax more detail out of these also, or if you find that the color bleed on your camera means that these channels do in fact contain a lot of information.

Remember that even if you are shooting the Sun with a color camera, hydrogen alpha imaging is a single-color process due to the filter, and the color of choice

Figure 5.37. Histogram pre- and post-process images.



here is very definitely red. Any other channels containing data will largely be due to bleed in the CCD.

Once you have achieved the level of contrast for your solar image in the red (and possibly blue and green channels), you can then either combine the channels back to a full color image using your software's combine channels option, or you may refer to just continue to use the red channel information, and "recolor it" to suit your taste in image style. This is what I tend to do with solar images.

Taking the red channel data we have, I will first of all contrast enhance or using Paint Shop Pro's "clarify" function brighten up the image, again not being, when imaging with a colour camera too excessive with the image processing. I will then convert the image to grayscale again using Paint Shop Pro's "grayscale" option, and then switch it back to a 16 million-color image using the "increase color depth" option. Then, using the color balancing options for each channel, I will steadily adjust the red, green, and blue position of the image until I have a color that is aesthetically pleasing, and representative of how most people envision the Sun's color. This is shown in Figure 5.38.

All of the previous steps applied to our image of the solar disc equally apply to the solar limb images with your prominences and flares. Once you have processed each individual part, it is time to combine the images to make our final shot of the Sun.

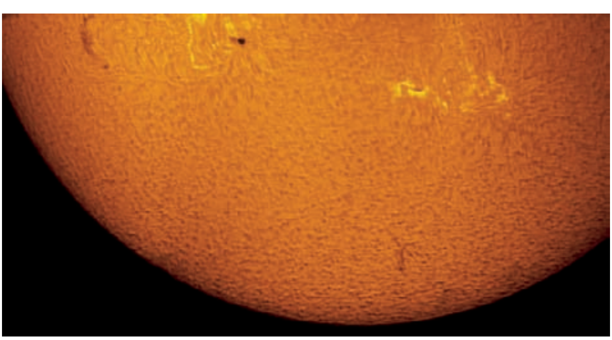


Figure 5.38. Final color image of the solar disc.

Step 2: Compositing the Images to Make the Final Shot

If you were working through the previous step from a full solar disc image, taken, for example, with a digital SLR camera or afocally, then you are ready to composite the two images on top of each other to create your final Sun shot. If not, and you are working with Toucam images or images that only have a portion of the solar disc, then you can still proceed to composite them, or you can use another application to create a mosaic image of the Sun, hopefully with several solar disc images. For example, with the Toucam on a Coronado PST, with no Barlow lens or focal reducer, you will typically be able to image between 1/4 and 1/3, covering the entire solar disc at a time. If you work on taking three or four portions of the Sun in separate images (I find usually four works best, being the Sun split into four quarters, with some overlap in the center region), then using software such as the excellent and free IMerge (http://www.geocities.com/jgroveuk/iMerge.html), or PTGUI (http://www.ptgui.com/) (shareware with a registration fee), you can make a mosaic of the Sun to create a higher resolution solar disc image. An example of which can be seen in Figure 5.39.

Maintaining some overlap in the center is important, as when you come to combine the images either using the software's automatic routines or manually, you will be able to match up features between the various portions of the Sun. It is always useful if a filament or sunspot group overlaps various regions of the image, as I find this makes alignment much easier.

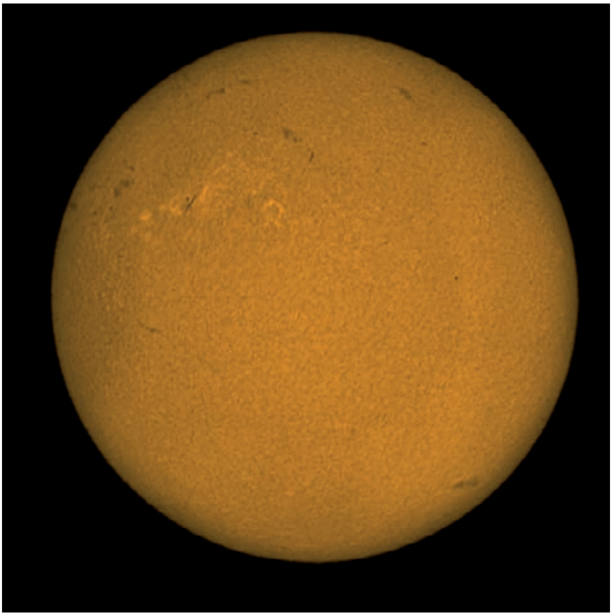
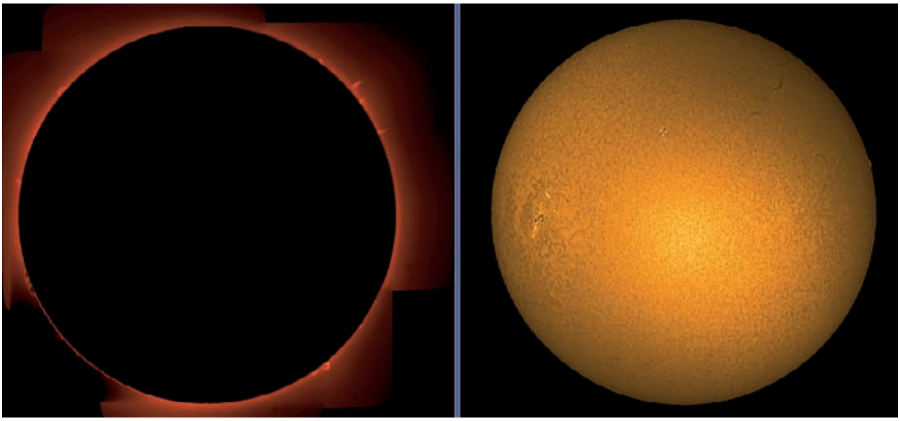


Figure 5.39. Mosaic image of the sun from four Toucam images.

Figure 5.40. Limb and disc selections as separate images precombining.



Now that we have our full solar disc, and hopefully a full solar limb set of images, we can proceed with combining them to make up our final image.

To achieve this, I would usually take the limb images that tend to have a vastly oversaturated disc, and using the magic wand tool in Paint Shop Pro (or just a selection tool for a disc in any application) cut out the disc image, leaving just the limb and any flares or prominences. This can be easily achieved using the "Magic Wand" tool in Paint Shop Pro or Photoshop to select the bright overexposed disc, and then cutting it out.

Using the same tool, I then would select the disc image, removing the surrounding black sky, choosing the disc, using the "feather" option with a few pixels to

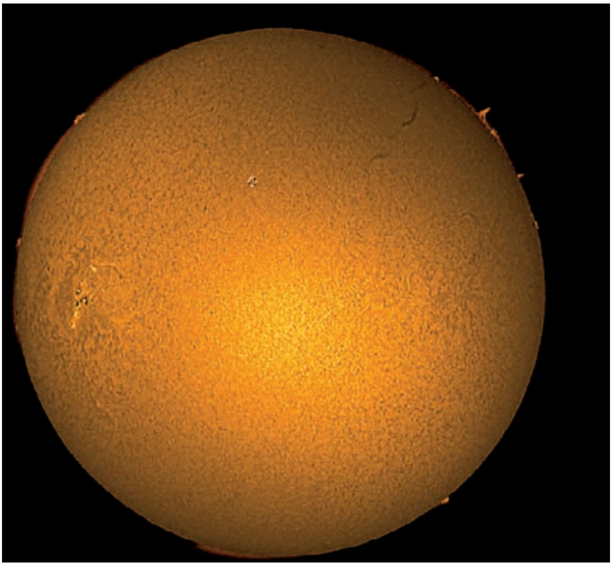


Figure 5.41. Final image.

reduce the unsightly edge effects normally seen on these images. Feathering softens the border of the selected image, removing jagged edges (Figure 5.40).

Now taking these two images, I would paste the disc image onto the limb image, adjusting the position until both the full flare/prominence set on the limb and the disc combine to make one final and hopefully great image of the hydrogen alpha Sun (Figure 5.41).

The Calcium Connection

For a description of the calcium K telescope used in this chapter, please refer to "PST CaK" section in Chapter 4.

As with the PST, we are effectively dealing with a monochromatic signal, so a black and white CCD would give the best results. However, the Toucam (and successors previously noted) again can give and do give excellent results.

Focusing and imaging with the PST CaK are largely similar to the processes previously described with the hydrogen alpha model, as the focuser mechanism is the same. However, there is one notable difference. As the image is a lot dimmer, the gain/exposure times for the camera need should be adjusted to take this into account. This is a simple process using the camera control panel in the imaging software (in my case K3CCD), and my tip here is to focus with an overexposed image until the limb becomes sharp, and then drop the gain down until you start to see the tell-tale supergranule features pop out on the solar disc. Once again, features such as sunspots can aid in the focusing process, but even the relatively large supergranule features may be used to fine tweak the focus.

As with the hydrogen alpha PST, the Toucam (or other camera of choice) can be mounted afocally or at prime focus.

Running up K3CCD, as we did with the hydrogen alpha PST, and once the gain and exposure times are set, the image should look similar to Figure 5.42.

With the Toucam attached to the PST CaK, again the preview will show (with no focal reducers or Barlow lenses) approximately 1/3 of the solar disc. For full disc imaging, I typically split the Sun into four panes, and take 800–1000 frames of video per quarter, attempting where possible to get some overlap with a surface feature between them, making the postprocessing and compositing into a full disc image easier.

Wavelet processing in K3CCD, along with some contrast and brightness adjustment, typically will be more aggressive than with the PST hydrogen alpha images, though this does depend on how good the final-stacked image comes out. As the images can be rather lacking in features, which you can easily track on, I tend to set the tracking box a bit larger than a prominent supergranule, and just let K3CCD run through the images automatically. If the sky conditions are poor, I will manually go through each frame, removing ones that are not so clear, though this can be a time-consuming process.

Once the disc has been imaged, I would then increase the shutter speed and increase the gain quite substantially on the camera, and start hunting around the limb (after a minor refocus) for prominences.

From reading various web-based sources, it appeared that the PST CaK did not have enough aperture/light-gathering capability to capture prominences, unlike

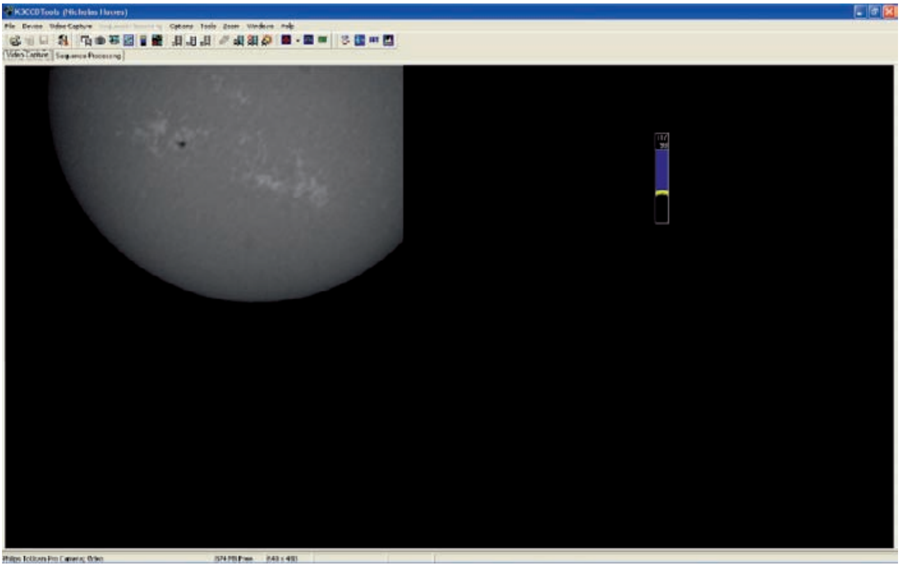


Figure 5.42. Preview screen/PST CaK imaging the solar surface.

its larger siblings. Well, from my own personal findings and from images of other solar photographers, I can state that this is false. In fact, on my first day of imaging with the PST CaK, I managed to capture three large prominences on the solar limb with little trouble. They are indeed very faint, so you have to have a good eye for them (again using some good Sun shielding such as a blanket is a very good idea), but when you see them, they are unmistakable. Figure 5.43 shows a typical prominence image from the K3CCD live preview screen.

Typically again with the prominences, I will capture about 800–1000 frames for stacking, and then attempt to select the prominence feature as the tracking object. This can sometimes yield inconsistent results, as the prominences are quite faint and subtle, and sometimes results in the tracking box losing them. In these cases, I tend to increase the tracking box size and aim for the limb curve against the black sky background as a guide reference.

However, once they are captured and stacked (Figure 5.44), the prominences are every bit as interesting as those in hydrogen alpha are, and I find it useful to compare images taken in both lights to see how the features matchup.

Days when the Sun is seemingly inactive in hydrogen alpha and white light can prove to be very interesting in calcium K light, as the features can either be a precursor to events still to occur in the other frequencies, or residual features left over from activity that has now faded away. Figure 5.45 shows the result after postprocessing and compositing the image of the Sun through the PST CaK.

The PST CaK does lend itself to other imaging methods such as afocal imaging, though more care has to be taken in shielding stray light from the eyepiece. Digital SLR imaging as with hydrogen alpha can also be used, but I find the

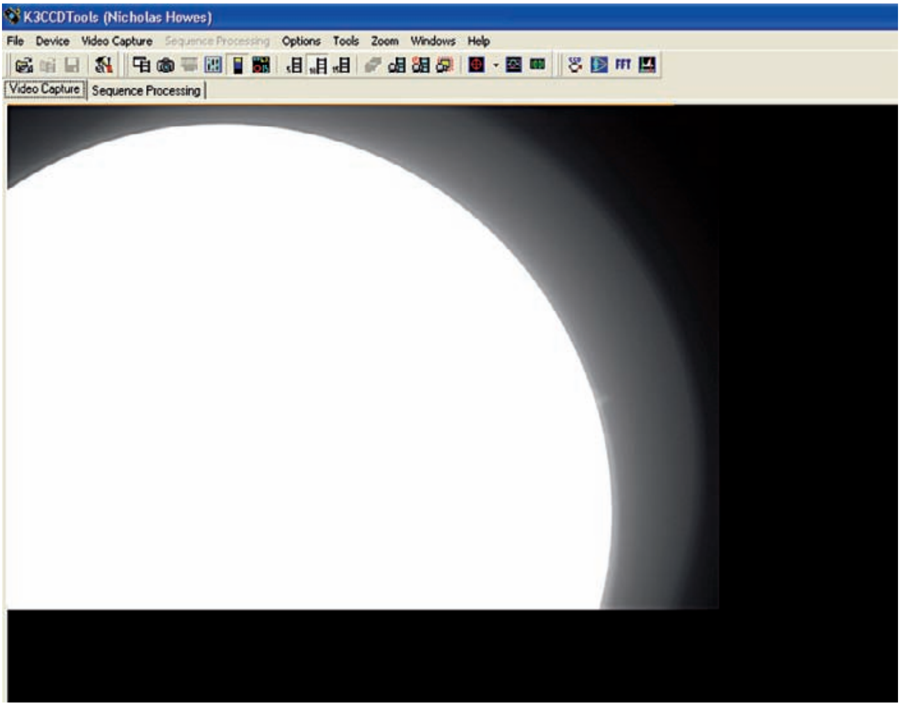


Figure 5.43. CaK prominence live preview.

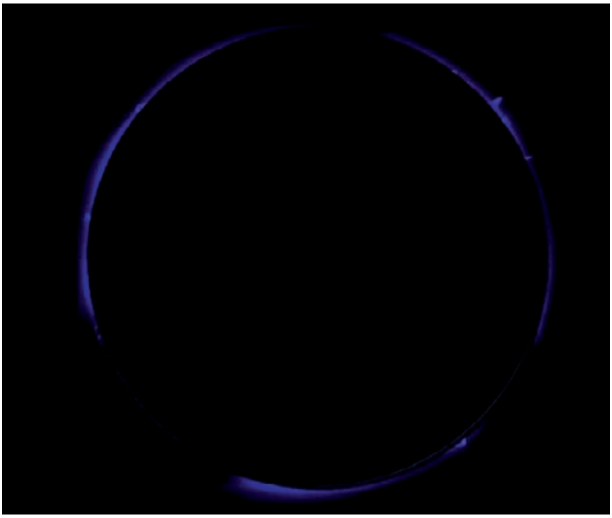


Figure 5.44. CaK prominence stacked image.

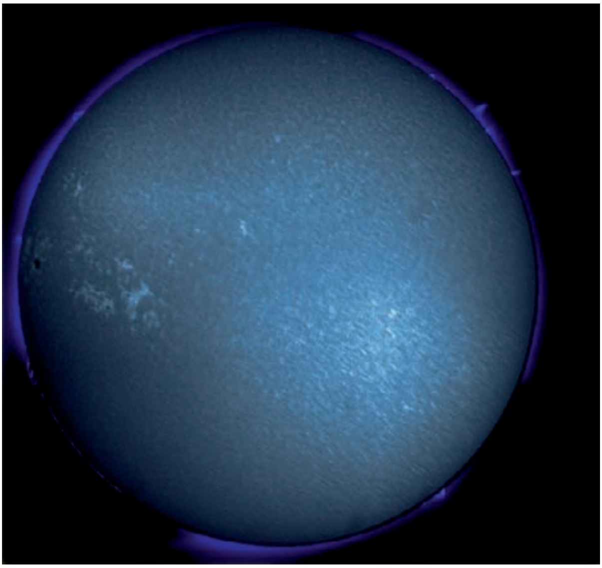


Figure 5.45. CaK disc/prominence combined.

webcam/dedicated astronomical camera option to be the best for seeing the Sun in this interesting light.

So what about viewing?

As stated, the PST CaK at best will yield relatively dim images, especially at higher magnifications; however, a low-cost solution for real-time viewing in CaK does exist in the form of the Meade Electronic Eyepiece and a small battery-powered TFT display.

The idea came from seeing more expensive (but higher quality) deep sky video camera solutions from Mintron and Watec, combined with portable displays

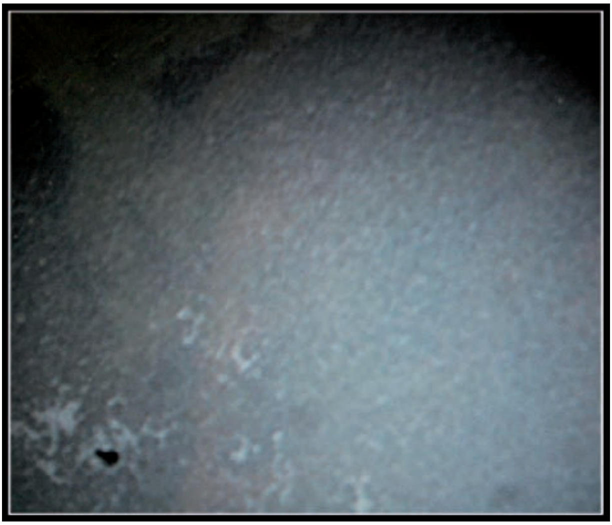


Figure 5.46. PST CaK live viewing option with TFT display.

on various TV shows and at star parties. These solutions are excellent for low light level viewing or galaxies and other dim nighttime features, but are a bit of overkill for the Sun. I picked up a secondhand Meade EEP from the Internet and a secondhand low-cost pocket TFT television. Once connected and the simple contrast control on the Meade EEP adjusted, the calcium K features again just sprang into view. For use at public-viewing events, this is a great way to show people the Sun in calcium K light (Figure 5.46), and neatly gets around the problems of viewing at the ultraviolet end of the spectrum. Some users of this scope have reported some success with the use of fluorescent pens on standard eyepieces to accentuate the ultraviolet end of the spectrum produced by the calcium K telescope. I have personally not tried this but have heard mixed reports as to the success of this method.

Imaging in White Light

Whilst the book title refers to the Coronado range of telescopes, no book would be complete without some information on imaging in white light. Often considered the poor relation to the wonders of hydrogen alpha and calcium K imaging, white light imaging of the Sun can still be a fascinating hobby. At solar minima, as we are in 2006, the number of features visible in white light, such as sunspots and faculae, is relatively small in number, but following a sunspot over the disc and watching or imaging its evolution can be a great way to hone your skills before moving onto the more exotic light frequencies.

White light imaging by its very nature can be exceptionally dangerous compared to hydrogen alpha and calcium K imaging, depending on the type of white light filter used. This is because unlike the dedicated hydrogen alpha and CaK scopes, very few telescopes are dedicated for white light use only. There are a few binocular systems from Coronado, known as Binomites, but in general, users have to fit a filter to the objective end of the telescope or a device known as a Herschel Wedge at the eyepiece end. It should be noted that under no circumstances should you ever use a so-called eyepiece solar filter at the eyepiece end, as they usually end up cracking under the intense heat that builds up. Likewise, the Herschel Wedge discussed in more detail later in this chapter, is not ideal with reflecting type telescopes, again due to the heat buildup that can occur.

What Filter to Use?

Whilst many filters exist on the market, one of the most popular and low-cost solutions is the Baader film solution. Sold in A4 sized sheets or prefitted to metal cells (which clip on to the front of your scope), and larger, this film is a relatively safe solution for solar viewing and imaging. It comes in varieties for imaging only (should never be used for viewing) and viewing (the difference being in the amount of light that passes through). So how does it work, and what is it made of?

To quote Baader "The base material is not Mylar (another commonly used filter film). The basic development of this film was made in laboratories for nuclear – and particle physics."

High-density coatings on both sides of the foil ensure a uniform filtering of the solar disc, while neutralizing the occasional microscopic holes in the coating. The image of the Sun is extremely contrast and of almost neutral color.

It is these "holes" that you as the user should be aware. Small pinholes in the film tend not to be too much of a problem, but should they develop into larger holes, and your eye is at the eyepiece, then blindness could occur. Baader film is exceptionally strong and resists tearing very well. The double-sided coating also aids, as they state, with the safety aspects, but still before every solar viewing session, you should visually inspect the filter for holes by holding it up to the Sun (not attached to the telescope) or another bright light source. If you see large holes, throw the filter away and use another one.

Once fitted to your telescope (Figure 5.47), the Baader filter gives, in my opinion, some of the best images of the Sun in white light you can get. With no artificial coloring of the solar disc, many find the view of the Sun, which is white, a bit disconcerting, but the contrast and definition that this low-cost film can give, I feel, is almost unrivalled.

The other beauty of this solution is that you can really ramp-up the size of the telescope you can use, giving better resolution on smaller features such as sunspots. I have two Baader filter systems both fitted to metal cells that screw on the side of the scope. One for my Meade ETX90 (typically used when traveling) and the other for my larger Celestron C8 telescope. The screw naturally means that the filter cannot accidentally be knocked off or blown off by the wind when observing.

To continue quoting Baader "To produce this special film, the manufacturer uses a patented high-temperature process, similar to annealing, to eliminate internal strains. The material is then ion implanted and metallized with a tough, color-neutral layer on both sides of the film. This ion implantation/metallization process (also patented), produces a high-contrast film that stands up to considerable abuse." From my experience this is true, but still proceed with caution when using any solar filter and always inspect it before use.

Figure 5.47. Baader filter fitted to a Meade ETX90.

Figure 5.48. Astro Engineering solar filter fitted to Meade ETX90.

The other option at the objective end of the scope is a dedicated glass filter. These are made by a variety of companies such as Thousand Oaks and UK company Astro Engineering. I also have the latter glass type on my Meade ETX90 telescope.

The difference with the glass type is that they typically will "tint" the color of the Sun to a more natural-looking (though technically not accurate) yellowish hue. The Astro Engineering model does this and has the added safety feature of being a screw thread model that literally screws tightly onto the front of the Meade ETX with absolutely no danger of falling off see figure 5.48.

I used this setup to image the transit of Venus in 2004, and I was delighted by the views and quality it provided. Not having used the other glass filters personally, I can only comment that users I have spoken to also rate them very highly. Filters made of glass come in all sizes, though the increased resolution gained may not in all cases be necessary. Some companies also offer off-axis filters that fit into front cells with a reduced aperture. Kendrick of Canada being one such supplier.

The Herschel Wedge

This final option for solar viewing and imaging is widely regarded as the best in terms of overall contrast and quality, when used with refractor telescopes. The wedge design (Figure 5.49) dates back to the mid-1800s when a notable astronomer John Herschel, son of William Herschel (famed for his discovery of the planet Uranus), proposed the idea of using a prism and reflective coatings as a way of viewing the Sun.

Refined and now produced by several manufacturers, the wedge again needs to be used with extreme caution. As it uses a combination of filters and a prism to divert 95% of the light out of the path of the viewer, this heat and light has to go somewhere, and it goes out of the wedge via an open "exhaust" vent. If anything is placed in the line of this vent (such as clothing), it will usually get burnt or catch fire. On top of this, if the wedge is not used correctly, in some versions of the wedge, then again blindness can occur.

Figure 5.49. Herschel Wedge.

Despite this, when used properly, the wedge does indeed provide stunning views, and is exceptional for imaging. Baader themselves have a version of this device, which they call the "Herschel Safety Wedge Solar Prism." This variant does not have the problems of heat from the exhaust vent, as they have cleverly added a multilayered perforated steel screen to diffuse all the heat and light energy. On top of this, they have also added a specialized solar viewing filter known as the "Solar Continuum filter." This makes viewing white light features such as sunspots even more pleasurable. Again, quoting Baader "By transmitting a specific spectral region around 540 nm, free of emission and absorption lines, the Solar Continuum filter is able to boost contrast and reduce the effects of atmospheric turbulence. With the Solar Continuum filter in place, images snap to focus, and granulation becomes regularly visible. Details at the limit of visibility become easier to hold, and image motion reduced".

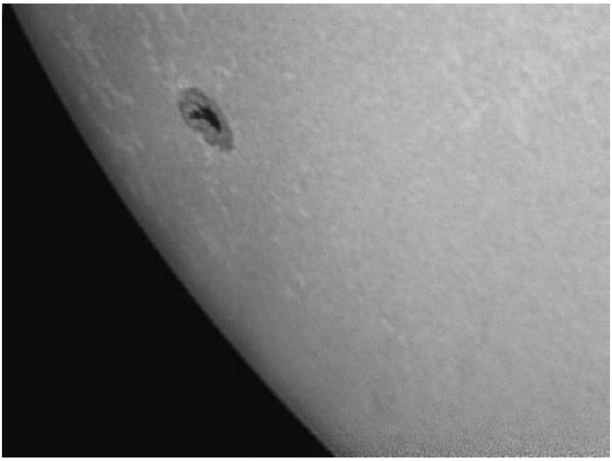


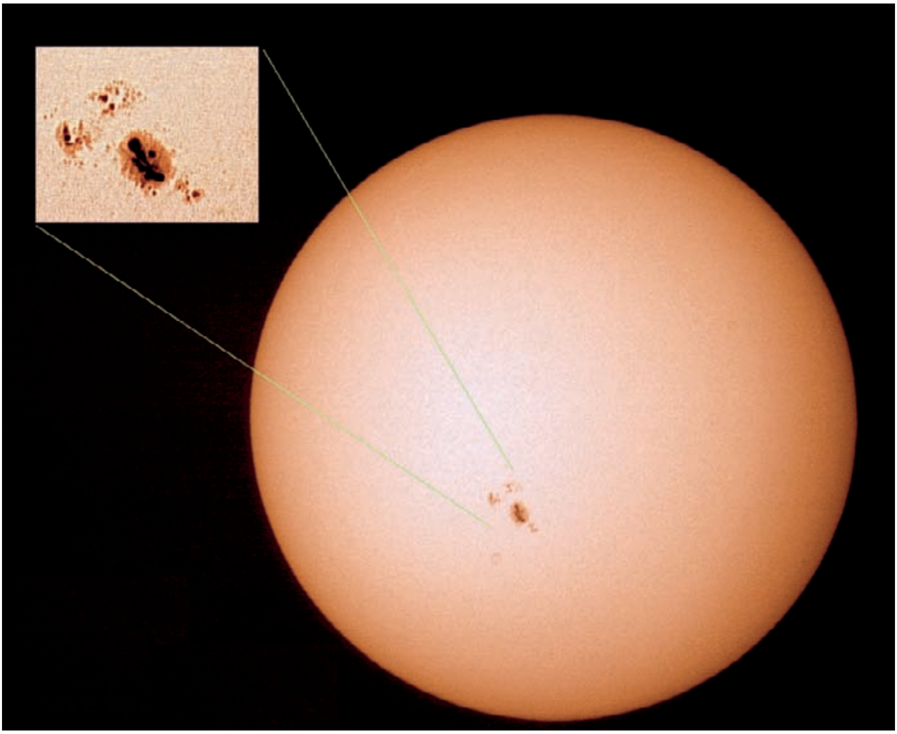
Figure 5.50. Sunspot in white light with the ETX.

Imaging the Sun in white light for me takes the same approach I use for hydrogen alpha and calcium K imaging when imaging sunspots or faculae. With the Baader film in place on my C8 telescope (or the AE glass filter on my ETX90), the Toucam is placed in the eyepiece holder and I focus on the feature I wish to image. Using K3CCD again in live preview mode, typically at between 10 and 15 frames per second (less if using a modified webcam in RAW mode, usually 5–10 frames per second), I will use either the solar limb or a sunspot to focus the telescope. With most normal telescopes fitted with white light filters, a motorized focusing option can be fitted. I personally find this makes focusing far easier than with the PST telescopes, and have added motorized focusing units from Celestron and Meade to my two primary white light telescopes.

As the light levels are higher than either hydrogen alpha or calcium K, the camera shutter speed and gain need to be adjusted accordingly to reduce the light capture, as too much light will result in a washed out image on the computer preview screen, which will usually result in you not being able to find any solar features to image. Typically, with the Toucam, I would start with the gain set to its lowest value and the shutter speed set around 1/500th–1/100th s, and then work upwards from there.

Figure 5.50 shows a typical sunspot in white light imaged via the ETX90.

Figure 5.51. Composite of high resolution and full disc image.



For full disc imaging, I would typically use my Canon EOS digital SLR with a 1.25-inch adaptor fitted via the T-Mount, and place this at the prime focus of the ETX90. Depending on the filter used, exposure times from 1/100th of a second to 1/300th of a second can be used, normally at ISO 100. For full disc imaging (and this applies to most astronomical imaging), if your camera does have a mirror lock feature, use it, as it will reduce the amount of blurring that may be caused by the camera mirror flipping to expose the CCD.

In terms of the final result, what I find interesting is to take full disc images including sunspots when they are present using the EOS, and then image the spot regions at higher resolution with the Toucam, and then using software editing tools, composite, via simple copy and paste, one onto the other to create a pleasing final image. An example of this is shown in Figure 5.51.

Both elements of the composite image (Figure 5.51) taken with the ETX90 telescope, which at only 90-mm aperture, proves that you do not need a large instrument to image the Sun.

CHAPTER SIX

Alternative Products*

Coronado is the market leader in hydrogen alpha viewing and I expect it to remain so for the foreseeable future. As an example, the PST simply has no competitor in terms of price or any sort of equivalent model. Many competing products are simply too expensive. The only gain is that some "niche" market products are available from other sources, which may be used on their own or with Coronado products.

The aim of this chapter is, therefore, to give a slightly more balanced view of the market, rather than a comprehensive one. It does not cover every single possible product or, indeed cover those mentioned in the same depth.

CromixSun†

CromixSun filters are modular units, which I have designed, and are built to my specification (Figure 6.1). The name is derived from their use for viewing the solar chromosphere. Each unit is a narrowband filter with the bandpass centered on the hydrogen alpha light wavelength. Depending on the number of filters used, the bandpass can be from 0.7 to less than 0.5 Å.

* This chapter has several contributors.
† Section contributed by Marcello Lugli, with separate appraisal by Philip Pugh.

Figure 6.1. Marcello with his viewing equipment.

The main features of CromixSun are as follows:

- Possibility to be used with any type of telescope (Refractor, Newtonian, Cassegrain, Maksutov).
- Possibility to be used with any F/ratio.
- It does not require heating or cooling.
- It does not require prefilters in front of the telescope objective.
- It operates in any ambient temperature (from less than 0 to over 50° C).
- It keeps the hydrogen alpha line in band, constantly.
- It is a "modular system," as explained below.

Physical Description

Each filter is set in a particular anodized aluminum container (module) bearing a knob for allowing the "tilting" to center exactly the hydrogen alpha line (Figure 6.2). This practice is known as "tuning" and is similar to filter tuning of the Coronado telescopes using the T-Max.

Figure 6.2.
CromixSun filters.

Each filter must be "tuned" accordingly to the others already mounted in order to achieve the narrowest bandpass possible. Note that, although this is a manual process that needs to be carried out by the observer, it does not require the units to be shipped back for matching, as is required for double stacking of the Coronado MaxScope range.

CromixSun uses the same Fabry–Perot technology as Coronado (see Chapter 1 for a description of how this works).

The whole setup looks like a big eyepiece. It can be fitted in the eyepiece holder (diameter 1.25 inch) of any telescope and it is soon ready to show wonderful vision of bright prominences and hydrogen alpha solar surface details. The weight is 45 g per unit, so will not cause any balance problems on a decent mount.

It is not recommended to use a single filter but to use any number between two and five. A single filter gives similar results to the 1.5 Å filters made by Thousand Oaks and Lumicon but without multiple images and internal reflections (Figure 6.3). The following table summarizes what you can see with progressively more filters.

Number of filters	Bandpass (Å)	What you can see
1	1.5	Some prominence detail (poor) and a little bit of surface detail
2	0.7	Bright prominences and some chromospheric details
3	0.6	Enhanced detail against a darker background
4	0.5	High contrast against a black background
5	< 0.5	Further enhanced contrast between clearer and darker zones

Figure 6.3. CromixSun prefilters.

The units are placed near the end of the light path from the objective. They use standard 1.25-inch connections and have an infrared blocking filter.

Some technical data for a single unit is summarized in the following table.

Bandpass	1.5 Å
Diameter	25 mm
Type of glass	Schott B270
Heat resistance of unit	150° C
Heat resistance of infrared blocking filter	300° C
Shift in the light wavelength	0.0025 per ° C
Module length	22 mm
Module width	50 mm

As well as acting as a filter system in their own right, they can also be used to double stack Coronado and other filter systems. The key limitation is that the minimum bandpass is just under 0.5 Å, so any further addition of units will not reduce the bandpass any further. For example, the Lumicon and Thousand Oaks filters (both 1.5 Å) can be reduced to a bandpass of 0.5 Å by the addition of 3 units. As another example, adding a CromixSun unit to a double-stacked MaxScope 90 (0.5 Å) did not enhance the view. Adding CromixSun units to Coronado telescopes has the advantage that if you own more than one MaxScope, you can move the CromixSun filters from one telescope to another. For larger Coronado telescopes, it can be more cost effective than using a Coronado double stacking solution.

Buying Units

I am a private amateur rather than a commercial company and the prices below are for guideline only and may vary with exchange rates and market conditions. Prices in US Dollars are as follows:

- 2 units $2.990
- 3 units $4.290
- 4 units $5.590
- 5 units $6.890.

Prices include delivery.

Market Penetration

In Italy about 40 amateurs use CromixSun. Some schools, associations, and private observatories also use them.

Two CromixSun are in the Unites States, one in France and three in Switzerland.

Recommended Telescopes for Use

The CromixSun filters can be used with any telescope with a standard eyepiece fitting of 1.25 inch. However, my favorite is a Vixen 102-mm refractor with a focal length of 1000 mm (Figure 6.4).

The limiting magnification appears to be around 100×, not inconsistent with the Coronado dedicated telescopes. This is due to the atmospheric turbulence caused by the Sun's heat.

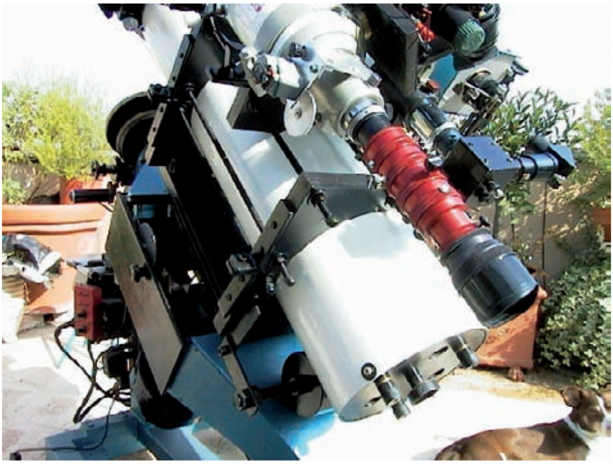


Figure 6.4. CromixSun with the Vixen refractor.

Recommended Accessories

In general most telescopes with a standard 1.25-inch fitting eyepieces and Barlow lenses work with CromixSun.

Telecentric Optic System Nowadays we have many telescopes on the market. Some of them have a limitation in the range of the focuser (for example, the Coronado PST), while others have a long extension.

In the first instruments, in fact, the objective focal plane is just a bit out of the fixed part of the main tube, inside the focuser tube, so that it is difficult to use the star diagonal for observing what is near the zenith.

Sometimes, this may prevent you from the use of several accessories, such as the diagonal, a flip mirror, a filter wheel, or a binocular viewer, unless you use a Barlow lens and accept a magnification boost too.

This may also prevent you from using a CromixSun (three- or four-filter setup) owing to their position totally inside the optical path.

Most amateurs prefer not to make modifications to their telescope tubes, especially if it would invalidate the warranty. My solution was to design the telecentric optic system (TOS), which does not increase the focal length of the telescope (Figures 6.5 and 6.6).

This device is able to move the original focal plane backwards by many centimeters so that in the "new space" achieved you may insert and use your accessories.

TOS is made up of an achromatic negative optical group to use also as a Barlow lens (2.5×) and an apochromatic optical positive group working as focal length reducer (about – 50%).

All the optical components are particularly suitable for observing the Sun owing to their high resistance to heat.

The two optical groups are used combined together.

Owing to their fixed optic powers (negative and positive), the different performances of TOS vary only by different mutual distances between the groups.

The first negative group is inserted like a Barlow lens inside the light path, while the second positive group follows some centimeters behind. The two groups are easily separated by means of different extension tubes with a length up to 10 cm.

The two groups may also be used with a star diagonal for observations near the zenith.

When the two groups are set only near few centimeters from each other, you move the original focal plane about 10 cm backward while achieving also a very low final magnification boost of 1.2–1.3×.

If the groups are set further than 3–4 cm apart, up to 10 cm, you move the original focal plane backward up to 20 cm or more while achieving a reduction in the final magnification up to −20%.

If the distance between the two groups is exactly adjusted, you can move the focal plane backward without varying the magnification with respect to the original focal length of the telescope objective.

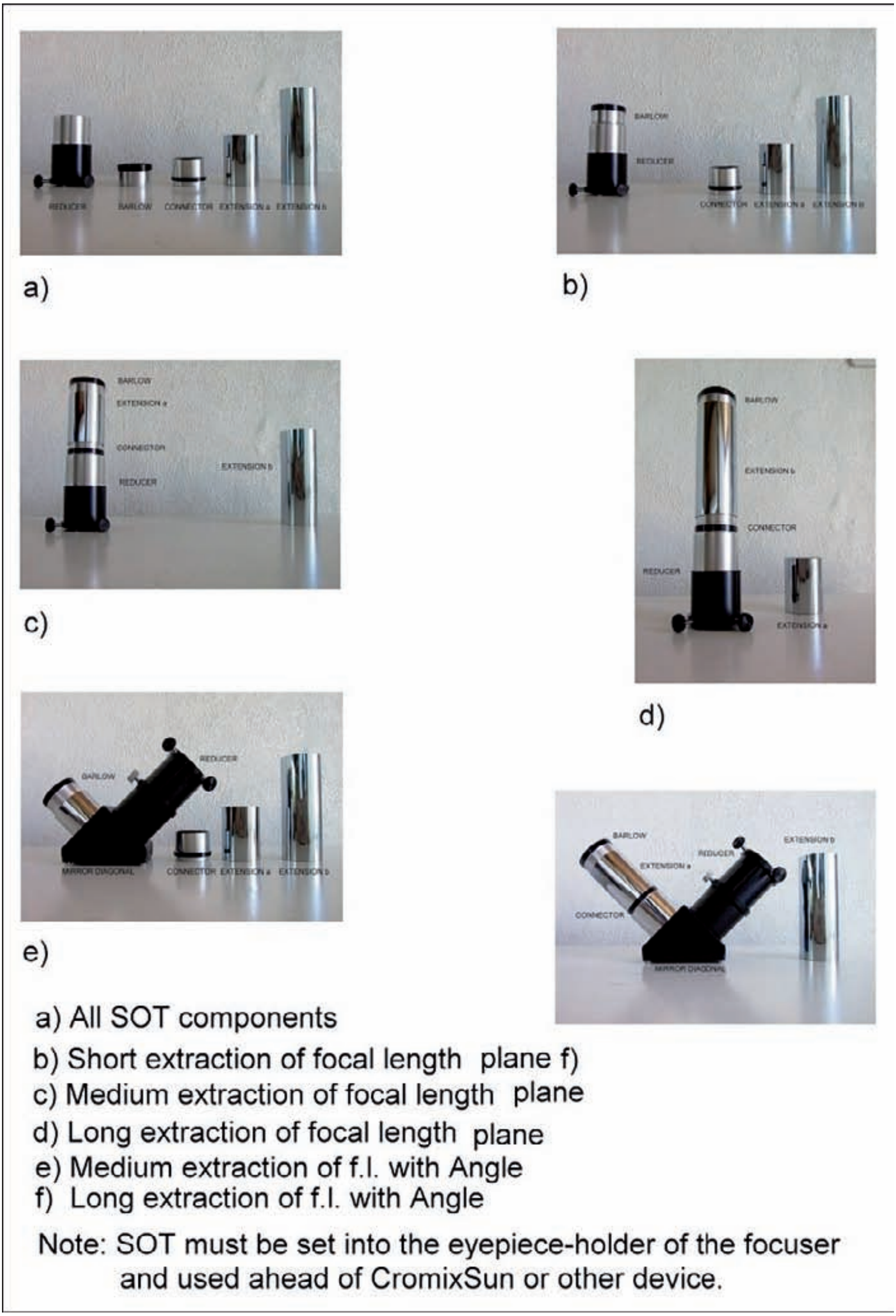


Figure 6.5. Telecentric optic system.

Figure 6.6. CromixSun with telecentric optic system.

The system may show modest vignettes easily removed by the use of appropriate eyepieces.

TOS may also be used for applications other than solar hydrogen alpha viewing.

Capabilities and Limitations

CromixSun is capable of delivering high-quality images to both eye and camera. Its limitation of 100× magnification is more likely due to the warmer weather in Rome, rather than being inherently inferior to the Coronado equipment.

Figures 6.7–6.10 were taken on 25 November 2003.

An advantage over the Coronado multiple stacking is that prominence detail is not lost. If you already own a Coronado telescope or filter system, CromixSun offers an alternative method of double stacking. A double-stacked CromixSun has been used in conjunction with a PST to achieve a bandpass of 0.5 Å. Note that this is more expensive than using a Coronado filter to double stack a PST but the bandpass is smaller.

Where using CromixSun to double stack a Coronado telescope becomes very economical is when used with the MaxScope 90 dedicated telescope. For the MaxScope 60, the double-stacked CromixSun is more expensive but offers more flexibility, as it can also be used with other telescopes.

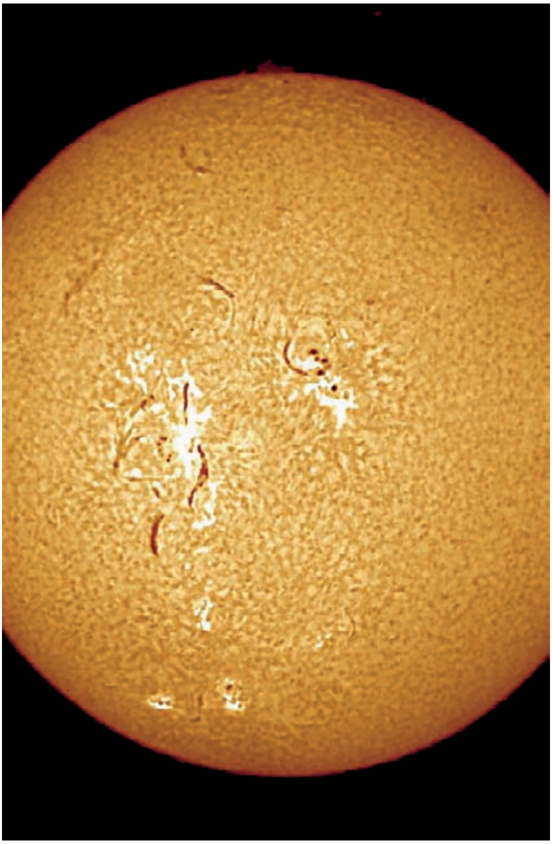


Figure 6.7. Image taken through CromixSun.

Figures 6.11–6.17 were taken on November 2003, when the Sun was more active. They were taken with a 102-mm Vixen refractor with 1000 m focal length and four filters to achieve a bandpass of 0.5 Å. I also used the TOS and exposure times were from 1/30th to 1/8th of a second.

Figures 6.18–6.20 show the thousand faces of the Sun as it is filtered at low, medium, and high level. Each were taken using a 4 unit setup with the Vixen refractor. Note how some features appear and disappear as the level changes.

The final shot (Figure 6.21) is through my Coronagraph Eclissun with an occulting disk to simulate the eclipse; Kodak E200 was used. The exposure time was 1/125 s.

Appraisal

The CromixSun system has an entry-level price that makes it less competitive than a PST, even if double stacked. A two-filter unit is comparable in price to a separate filter system for a 60-mm refractor. Where CromixSun offers a great alternative is for use with telescopes in excess of 60 mm. It gets round the cost limitation, which Coronado has, of matching the filter size to the objective

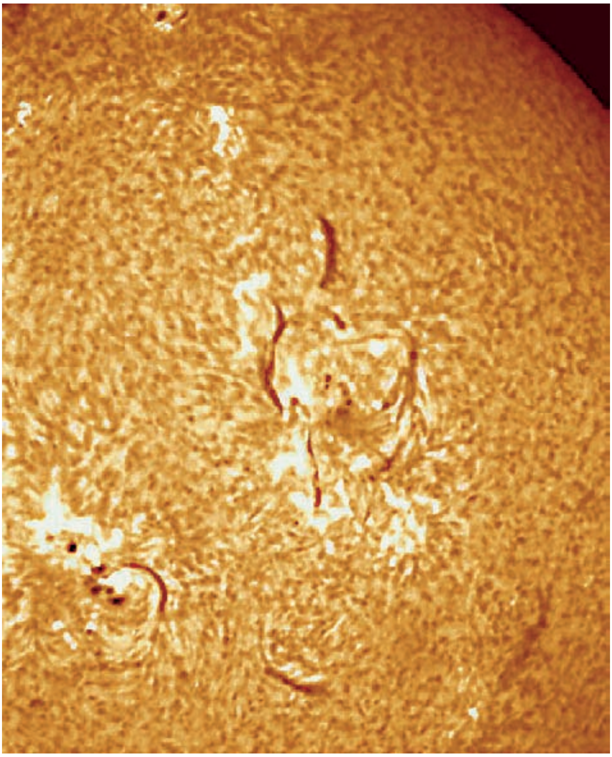


Figure 6.8. Close-up of Figure 6.7.

lens. This has the added advantage of being used with all of your telescopes and not just one, so you can use your favorite nighttime instrument, as well as any portable instruments that you might take away on business. It also offers some excellent double stacking opportunities with Coronado and other products.

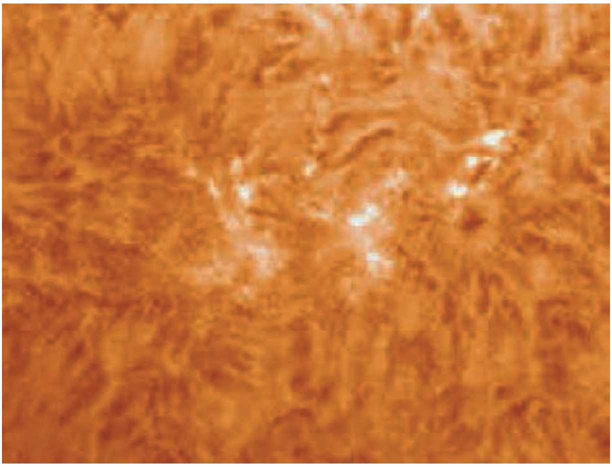


Figure 6.9. Active region.

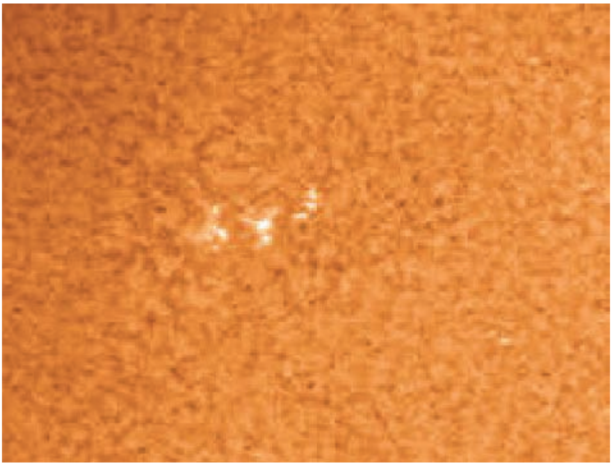


Figure 6.10. Wider angle view of Figure 6.9.

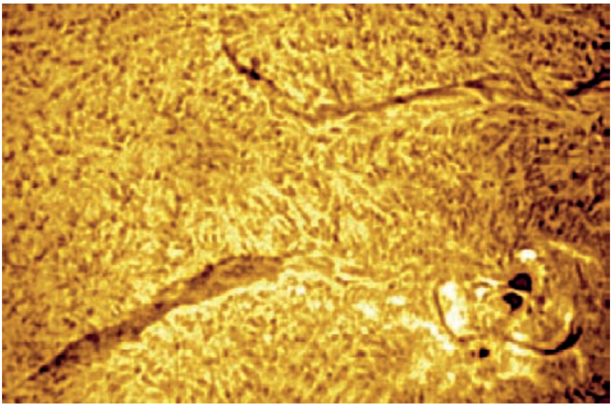


Figure 6.11. Undated filaments.

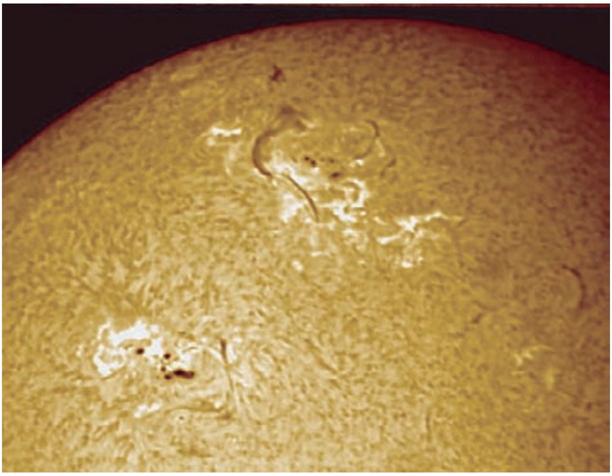


Figure 6.12. Sun in hydrogen alpha, 22 November 2003.

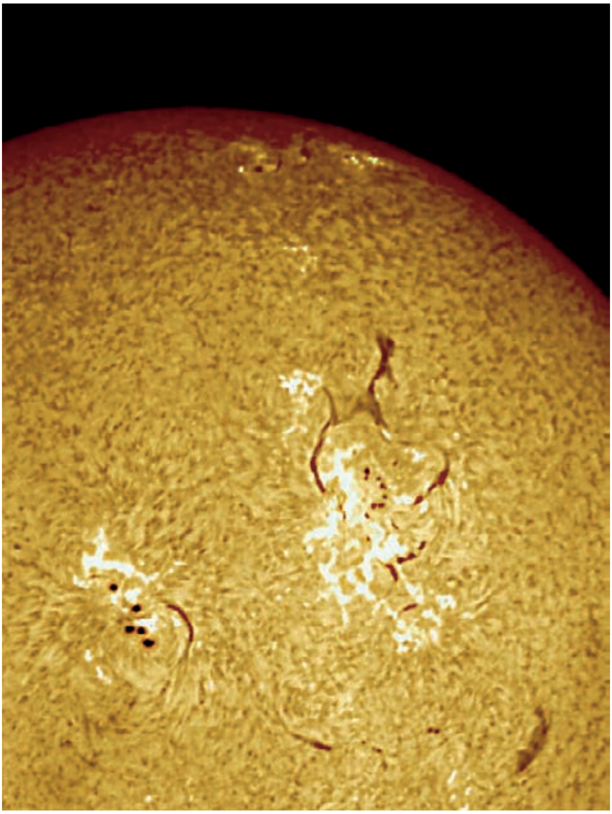


Figure 6.13. Sun in hydrogen alpha, 23 November 2003.

Verdict: Cannot compete at the low end of the market against the smaller Coronado telescopes, but it is a serious alternative in the 60-mm plus aperture bracket and offers more flexibility, as its design makes its use independent of the telescope aperture. It would not force Coronado out of business but can encourage them to keep on their toes

DayStar Filters

These perform the same functions as Marcello Lugli's CromixSun filters (see "CromixSun" section in this chapter) in that they are placed in the eyepiece end of the light path. Prices are fairly similar to the CromixSun and, although none of the writing team have tried using them in that way, we can speculate that they offer a plausible double-stacking solution for Coronado telescopes, although DayStar claims that their filters are designed to be used alone and not with other manufacturers' equipment. Jeff Pettit has used a 0.4-Å Daystar filter system and has contributed a section below.

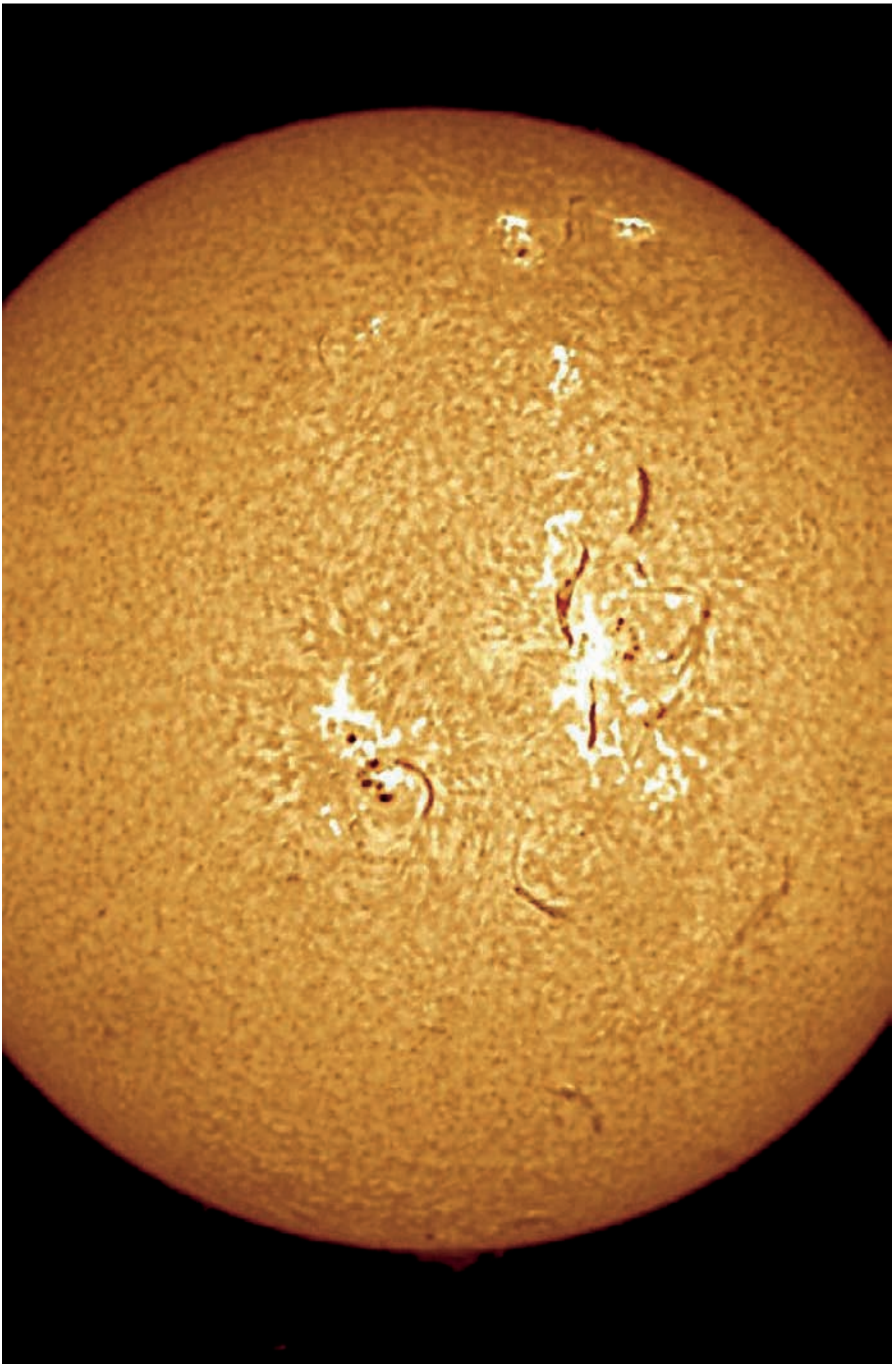


Figure 6.14. Sun in hydrogen alpha, 25 November 2003 No. 1.

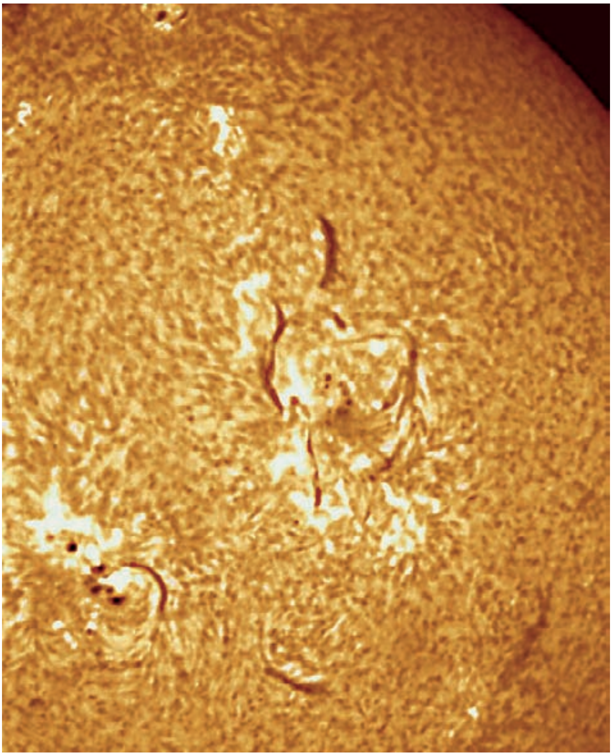


Figure 6.15. Sun in hydrogen alpha, 25 November 2003 No. 2.

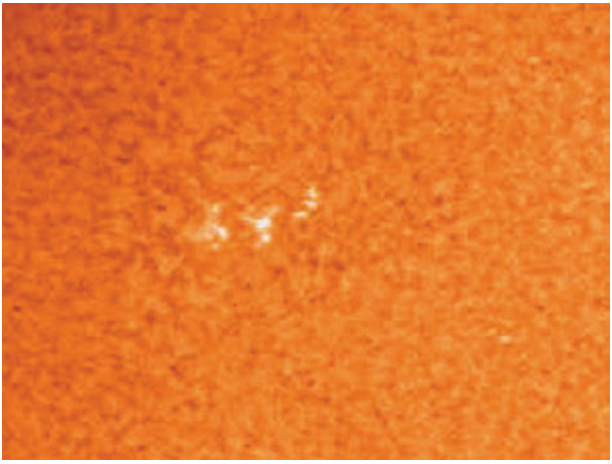


Figure 6.16. Sun in hydrogen alpha, 27 November 2003 No. 1.

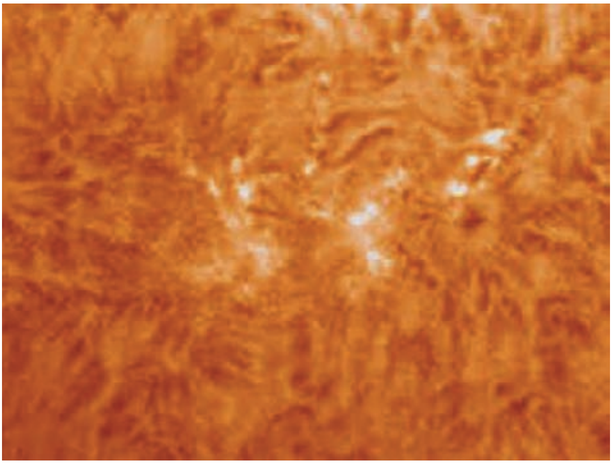


Figure 6.17. Sun in hydrogen alpha, 27 November 2003 No 2.

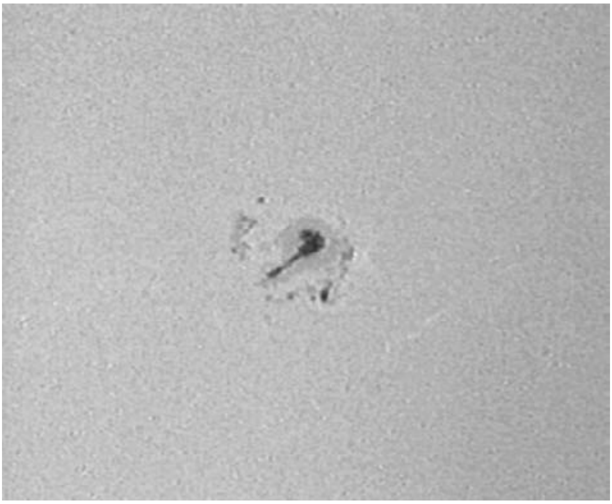


Figure 6.18. Low-level filtered view of the Sun.

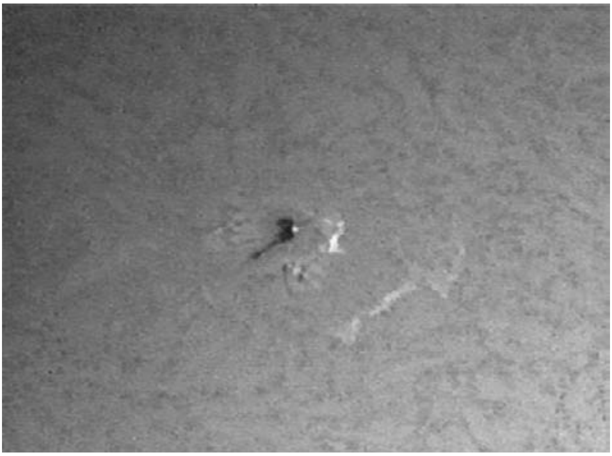


Figure 6.19. Medium-level filtered view of the Sun.

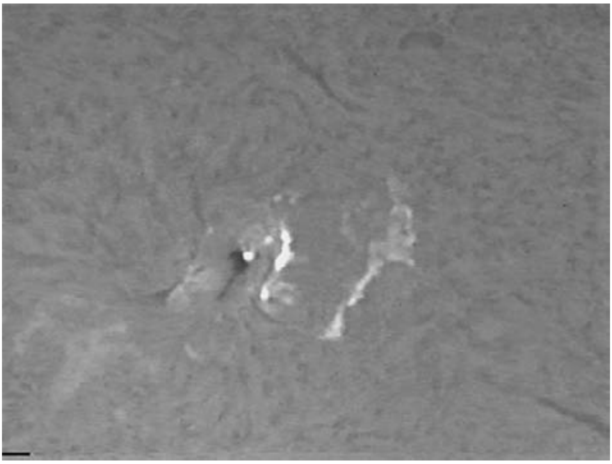


Figure 6.20. High-level filtered view of the Sun.

Figure 6.21. Coronagraph image.

Figure 6.22 shows me with the basic setup. I used a 4-inch f/15 Unitron telescope. I have cut approximately 5 inches off the back end to allow me the room to add the filter and Barlow lens and off axis guider (when used at night). With the original length there was not enough "in focus" to allow me to bring the image to a focus. I have built the mount and drive unit myself and it solves many of the problems that are annoying during setup and observing. This picture was taken at one of the many star parties I have attended. Notice the silver shield at the rear end of the telescope. It casts a shadow behind the telescope and keeps the observer in the shade during viewing. This is a real relief when you are trying to take pictures.

Figure 6.22. Basic Setup.

Figure 6.23 shows the basic setup for observing and picture taking. I still use black and white 35-mm film that I develop and process to obtain my pictures. The disc detail requires exposures of 1/125 second and the prominences exposures of 1/8 second. I have a local photo lab that, after much coaching and agreeing to buy all the trial prints, will print the negatives on their color machine. I then scan these prints and do composites of disc and prominence images for the final picture. As you can see the camera, filter and extension tube all screw together to help eliminate any movement or slop in the system. This was accomplished by removing the 2-inch eyepiece holder and replacing it with a T-threaded tube.

Figure 6.24 shows a close-up of the camera and filter. Figure 6.25 is a close-up of the filter only. I used a 0.4-Å University Grade Daystar filter with a 6.5× clear screen camera viewfinder. This gives the same view as a 25-mm eyepiece and since it is clear and not ground glass the detail is equal to an eyepiece.

I used a 4-inch energy rejection filter, which is a flat and parallel filter glass, that blocks the ultraviolet light to help keep out this very dangerous wavelength

Figure 6.23. Setup for observing and picture taking.

Figure 6.24. Close-up of camera and filter.

for safe observation. I used the 4″ with a 2× Barlow lens for fine detail shots and simply place a 2″ mask over it for full disc viewing without the Barlow lens.

Figure 6.26 shows that the finder for the telescope is simply a hole drilled in the front tube clamp (these are made out of Mahogany wood) and a target on the rear clamp. Alignment consists of pointing the telescope toward the Sun and placing the sunspot over the black dot, and the Sun will be in the eyepiece. An enlargement shows the detail.

Figure 6.27 shows the drive head. The telescope is driven by a 3-Volt motor and a worm gear drive with controlling electronics that were home built. The black plate on top of the gear head is a solar panel that moves along with the telescope making the telescope solar powered! There is a battery back up that automatically switches power in case of clouds or nighttime viewing.

Figure 6.28 shows more detail in the mount. Notice there is no counterbalance arm arrangement. I have eliminated this for several reasons. It makes the mount lighter without 30 lb of counter weight and reduces the swing action associated with it. Another advantage is that the telescope does not require to be "flipped" at noon to continue viewing as is needed with other equatorial mounts. You would not believe how upset people get at a star party when you have to stop to "reset the telescope" before their turn. The drive tracks the Sun and the small motor adjusts the telescope from vertical to horizontal to locate any of my target objects. The mount rings are split and can be opened to slide the telescope tube

Figure 6.25. Close-up of filter only.

Figure 6.26. Finder.

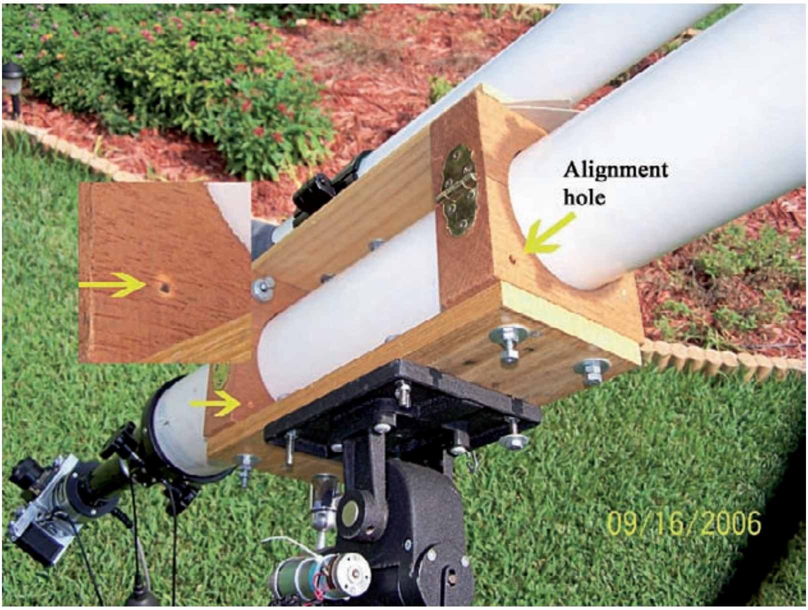


Figure 6.27. Drive head.

up or down for balance depending upon which accessories I am using. When asked, "what about looking north?" my answer is always "If the Sun ever goes north or vertical from my location in Florida I have more to worry about than that!" This arrangement also keeps the Sun in the same position relative to the camera view throughout the entire day of observing.

Figures 6.29 and 6.30 show the raw black and white prints and Figure 6.31 shows the colorized composite.

Figure 6.32 shows the vapor trail left by a passing plane that can be seen in the upper left corner while I was shooting the active flare also seen in the inset. I have seen many planes fly in front of the Sun while observing and this is one of the few I have been able to capture on film.

Figure 6.33 shows a high-resolution image of an active area with good filaments when the active flare area in the lower right erupted; the shock wave made the nearby filaments move, which could be seen in real time.

Figure 6.34 shows an eruptive prominence with material breaking off and drifting away. The scale puts it at about 150,000 km long and to escape the Sun's gravity it must be moving very fast.

Figure 6.35 shows an active Sun with what I call "The Bullhorn" prominence. This was taken on 29 March 2003 Figure 6.36 shows an X-class flare with a close-up insert.

Figure 6.28. More mount detail.

Appraisal

The filter has no dead spots and resolution and bandpass is uniform across the field. There is always something different to look at every time I use it. It can be plugged in easily and various accessories can be attached.

Verdict: An excellent option that is of university grade and simple to use.

Optical quality	10 out of 10
Value for money	10 out of 10
Ease of use	10 out of 10
Overall rating	10 out of 10, excellent

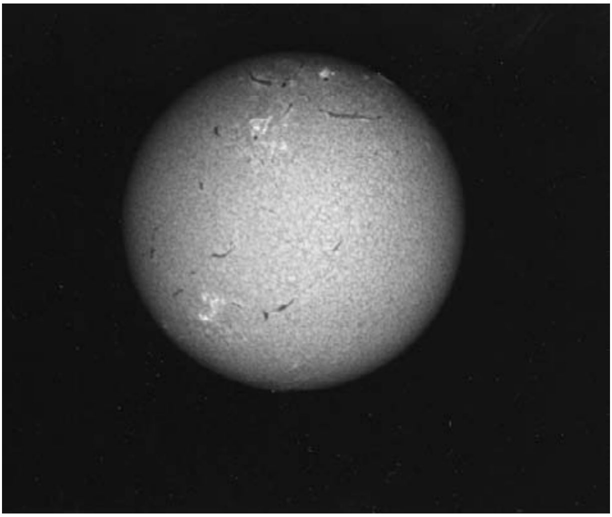


Figure 6.29. Raw black and white print 1.

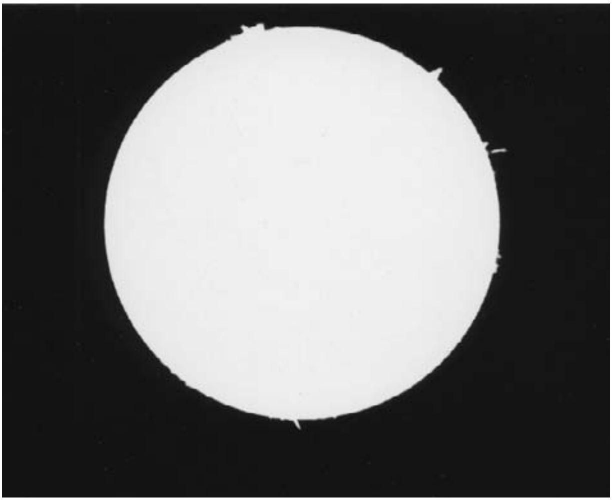


Figure 6.30. Raw black and white print 2.

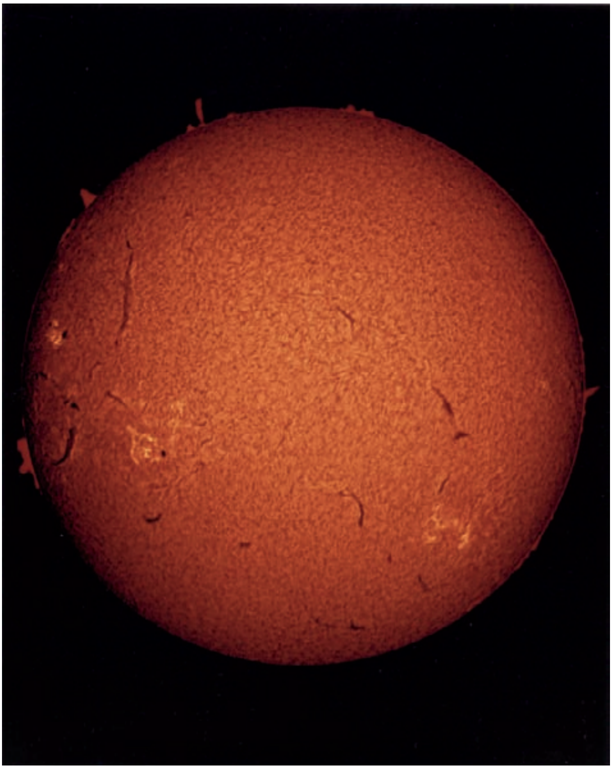


Figure 6.31.
Colorized composite.

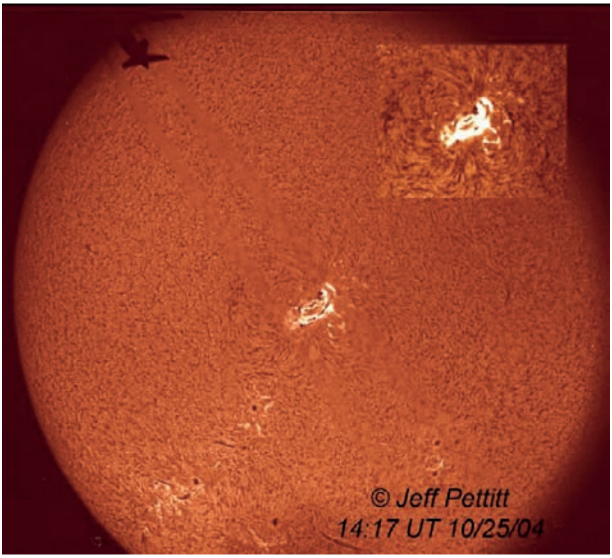


Figure 6.32. Vapor trail.

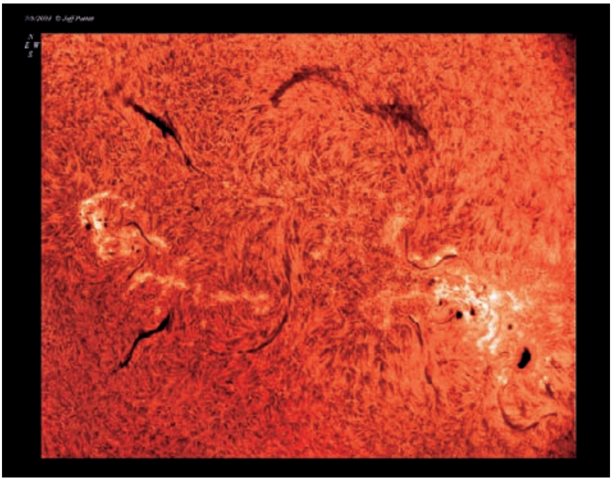


Figure 6.33. High-resolution image of an active area.

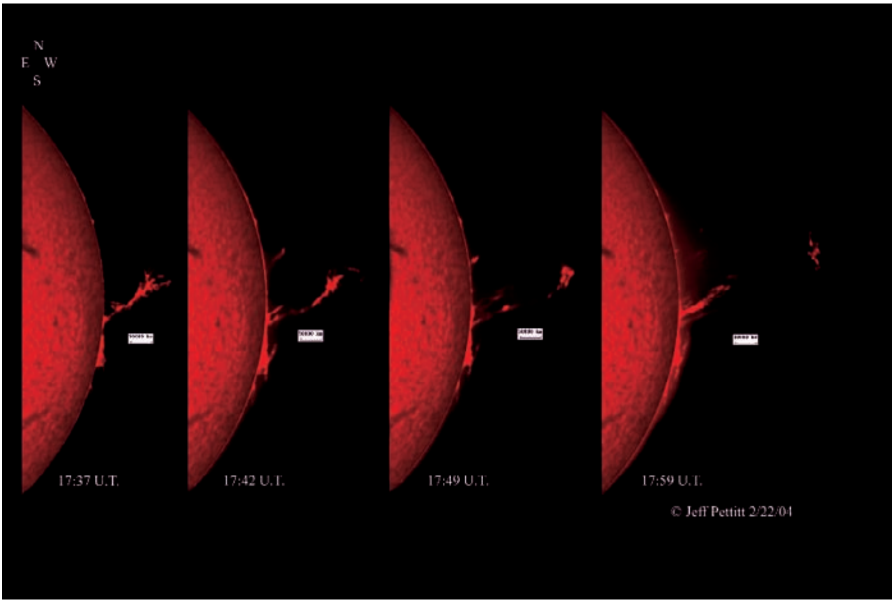


Figure 6.34. Eruptive prominence.

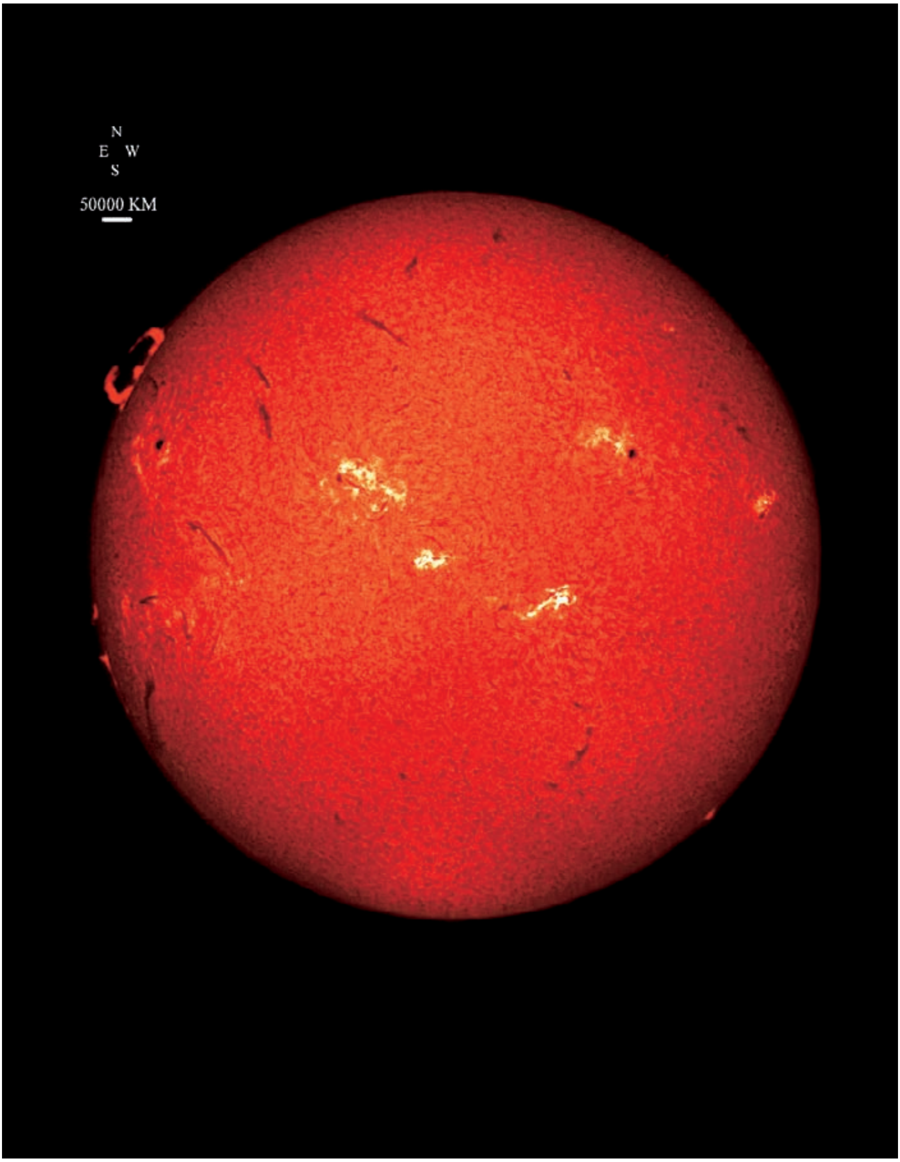


Figure 6.35. Bullhorn prominence.

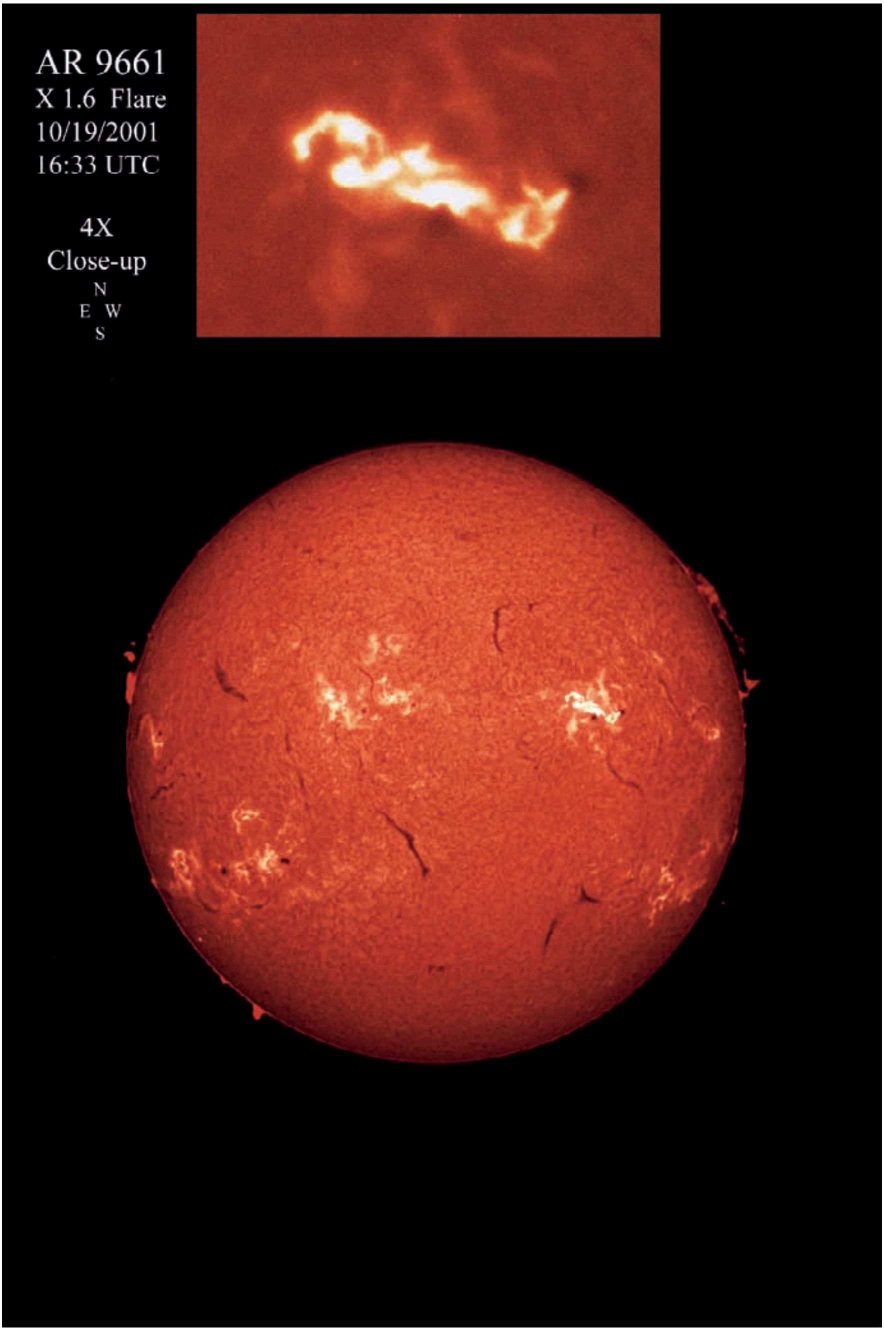


Figure 6.36. X-class flare.

CHAPTER SEVEN

Untried Products

This section contains details of products that might interest the solar enthusiast, but have not been checked out by myself nor any of my coauthors.

SolarMax CaK 60 Filter Set

The SolarMax CaK 60 filter set was the first calcium K filter set available separately from dedicated telescopes by Coronado. With a 60-mm aperture, it will fit any 60 mm or larger telescope, but larger telescopes will need the use of an adaptor plate (Figure 7.1).

At the time of writing it was the only full aperture calcium K filter available and was based on the same ideas as the SolarMax filters. I was expecting it to be the first in a long series of product announcements.

Note that the light frequency is centered on 395 nm (3950 Å) and has a wider bandpass than the solar hydrogen alpha telescopes and filters.

Facts at a Glance

Aperture (mm)	60
Focal length (mm)	Not applicable
Bandpass (Å)	2.0
Bandpass with double-stacked filters	Not available
Weight (lb)	Nominal

Figure 7.1. Coronado SolarMax CaK 60 filter set. Courtesy of Coronado.

Due to the changing nature of the market, details of current price in the United Kingdom and United States and accessories included with the base package are included in Chapter 10.

Using a SolarMax CaK 60 Filter

The SolarMax CaK 60 filter needs a reasonable telescope to use with. It is not necessary to go for a top-quality apochromatic refractor, as the light is very close to monochromatic, so it should all arrive at the same focal point anyway. The telescope should be of reasonable optical quality and should have a reasonable mount. The main filter and T-Max tuner need to be fitted to the objective and the blocking filter needs to be used with the eyepiece/focusing assembly.

The use of long focal length telescopes can potentially cause problems, as calcium K imaging and viewing are not tolerant of as high magnification as hydrogen alpha or "white light."

Recommended Accessories

CEMAX Hydrogen Alpha Eyepieces These are described in detail in Chapter 2.

As for the PST, these eyepieces can obtain more detail from the Sun, both visually and photographically than others in the same (or cheaper) price ranges. Which eyepiece is most suitable is dependent on the focal length of the telescope. It is best to aim to get the entire solar disc in the field of view. For a telescope of 1000-mm focal length, the 12-mm eyepiece will give a magnification of about

80× and an apparent field of view of about 36 minutes, which will just fit the Sun in. The 18-mm eyepiece will give a magnification of about 54× and a field of view of just under a degree.

Note the calcium K viewing and photography are less tolerant of high magnification than hydrogen alpha.

Moonfish Group Eyepieces These are described in detail under the similar heading in Chapter 10. Their main advantage is that they cost about the same as low-end Plossl eyepieces but have a wider field of view and are better for photography.

It is unlikely that you will need to use a Barlow lens with these eyepieces if you have a long focal length telescope.

Magni Max Image Amplifier This is described in detail under the similar heading in Chapter 2. It provides a magnification boost of 1.6× but narrows the actual field of view by about 37%. It seems to be such an all-round useful piece of kit that it must be worth trying.

BC&F Telescope Cleaning Kit This is described in detail under the similar heading in Chapter 2. Some sort of telescope cleaning is required for the filter set, especially if you are even thinking of photography.

General Many nighttime and hydrogen alpha accessories will work with this filter, but bear in mind that the CaK image tends to be fainter than the corresponding hydrogen alpha image, so Moon and polarizing filters are unlikely to be of much use. The faintness of image would suggest a maximum magnification of 80× or less. Zoom eyepieces could be used but many designs reduce the light transmission, resulting in a fainter image.

Capabilities and Limitations

The 2Å bandpass provides excellent contrast for imaging of super granulation, flares and other features that are prominent in calcium K. However, not all eyes are sensitive to detail in the calcium K wavelength.

There is little doubt that the performance is theoretically comparable to that of the CaK 70, as described in the "CaK 70" section of Chapter 4.

CaK 90

The CaK 90 was, at the time of writing, a new product, which was only just becoming available (Figure 7.2). Based on the hugely successful MaxScope 90, I had little doubt that it would become a winner and I was anxiously trying to get as much information about it as possible, with my main hope that I would actually get to try one. Failing that, one of my coauthors might get the chance.

Figure 7.2. CaK 90. Courtesy of Coronado.

At about $9300 in the United States (£8000 in the United Kingdom) at the time of writing, it is more geared for research and society purchase rather than for the financially challenged amateur, who would be advised to check out the more affordable PST CaK and CaK 70, which are described in Chapter 4. There is little doubt, however, that the CaK 90 will break new ground in solar calcium K observing. Due to the dimmer image and the fact that many human eyes are not as sensitive to the calcium K features being near the limit of the violet/ultraviolet boundary, it is expected that it will be used more photographically than visually.

Facts at a Glance

Aperture (mm)	90
Focal length (mm)	800
Bandpass (Å)	2.0
Bandpass with double-stacked filters	Not available
Weight (lb)	23

Due to the changing nature of the market, details of current price in the United Kingdom and the United States and accessories included with the base package are included in Chapter 10.

Physical Description (CaK 90)

The CaK 90 has a 90-mm objective lens (made from BK-7 glass) and a 800-mm focal length with an F8.8 focal ratio.

In other respects, it is identical to the MaxScope 90, so refer to Chapter 3.

The CaK 90 comes equipped with a Sol Ranger solar finder (see Chapter 3 for details) but does not come with supplied eyepieces. It is pretty well assumed that anyone who buys this will also own at least one hydrogen alpha telescope.

How to Store

Refer to Chapter 3.

Mounting Options

Refer to the corresponding section by Larry Alvarez in Chapter 3 and also refer to his "Tips and Tricks" section.

Recommended Accessories

At the time of writing, neither my coauthors nor myself had actually tried one of these telescopes out. As a general rule, anything that works with the hydrogen alpha telescopes should work with this telescope, but please bear in mind the following points:

- The calcium K image is fainter than the hydrogen alpha image, so visual viewing and afocal astrophotography should use lower magnification ranges.
- Binoviewers are not recommended for the same reason.
- Monochrome cameras are better for hydrogen alpha photography, but this is even more true for calcium K viewing. Blue and red pixels in color cameras are triggered by calcium K light and monochromatic light gives a better picture, literally!

Capabilities and Limitations

As yet, neither myself nor the other members of the authoring team have had the opportunity to test this excellent telescope. However, if you look at the "CaK 70" section of Chapter 4 and imagine a significant improvement over them, you can not go far wrong. The light-gathering power and resolution of the CaK 90 is 1.6 times better!

Figures 7.3–7.5 shows the greater resolution of the CaK 90.

SolarScope 50-mm Filter Set

The SolarScope 50-mm filter (see Figures 7.6 and 7.7) is SolarScope's competitive product in the separate filter market. It incorporates the energy rejection filter in the objective with the etalon and, like the Coronado filters, requires the use of a separate blocking filter at the eyepiece end. At the time of writing, Coronado did not have a filter set of this size.

Aimed primarily as a filter to go with the Televue range of telescopes, adaptors for other models of telescope were available on request.

These filters are also available as 60- and 70-mm versions.

Facts at a Glance

Aperture (mm)	50
Focal length (mm)	Not applicable
Bandpass (Å)	0.7
Bandpass with double-stacked filters	Not available
Weight (lb)	Nominal

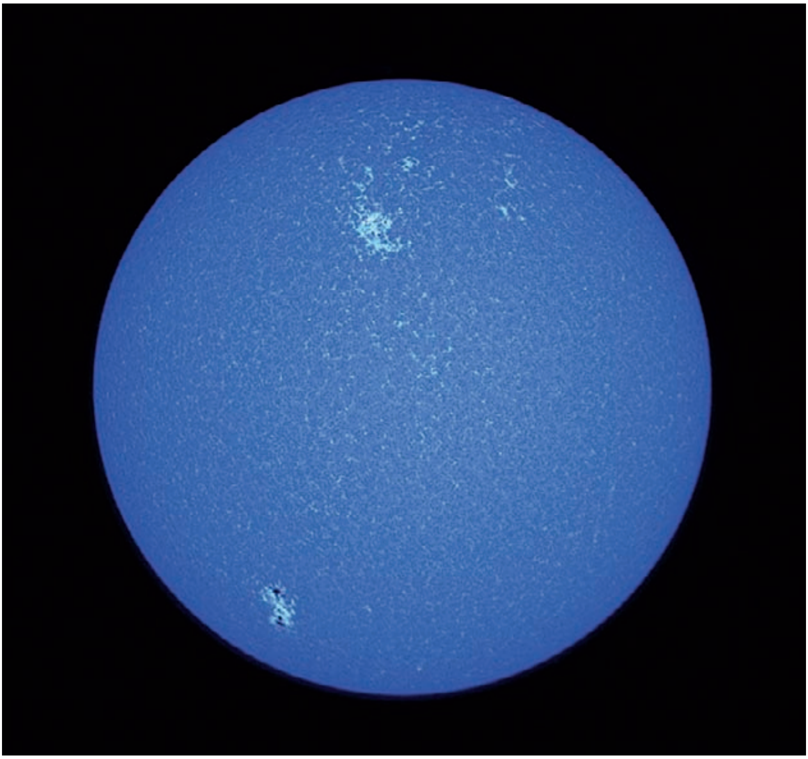


Figure 7.3. Photograph taken through a CaK 90. Image 1 of 3. Courtesy of Coronado Inc.

The UK retail price at the time of writing was £2695.

Using a SolarScope 50-mm Filter Set

The SolarScope 50-mm filter needs a reasonable telescope to use with. It is not necessary to go for a top-quality apochromatic refractor, as the light is very close to monochromatic, so it should all arrive at the same focal point anyway, as for the use of other filters. The telescope should be of reasonable optical quality and should have a reasonable mount.

Recommended Accessories

As this is a hydrogen alpha filter of 50 mm, the maximum magnification should be in the 100–120× range, but the focal length of the telescope and eyepieces should determine the field of view and magnification to be used. With the Televue range of telescopes, the Nagler eyepiece type yields an apparent field of view of

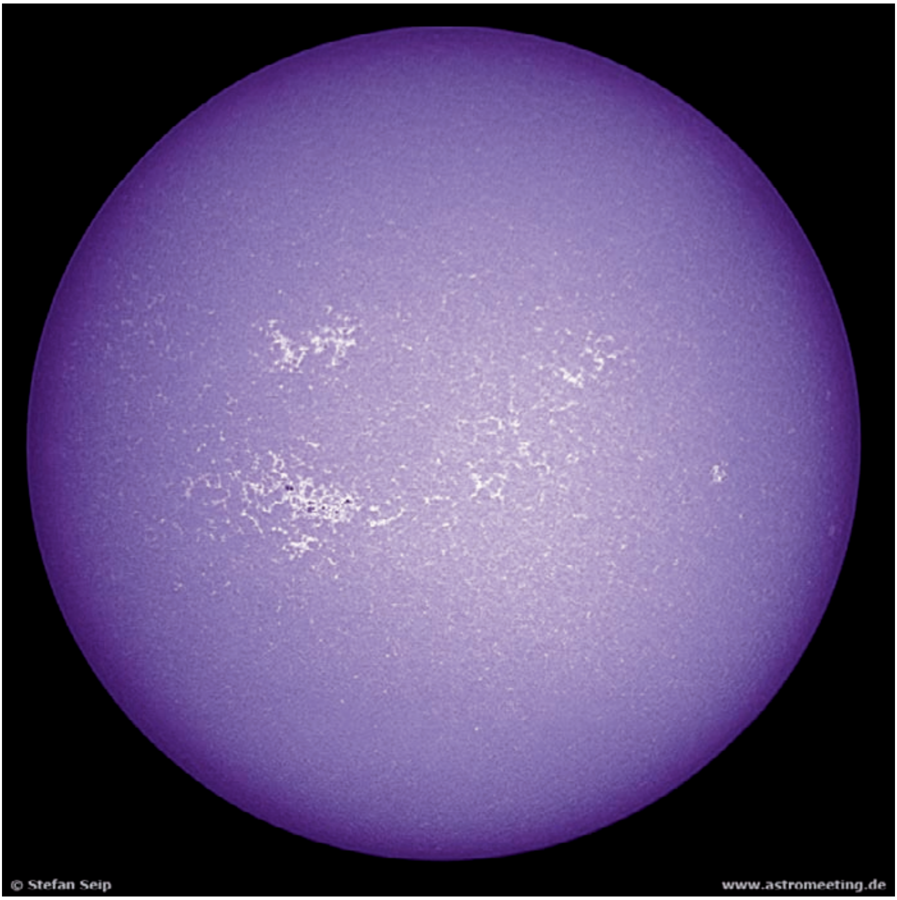


Figure 7.4. Photograph taken through a CaK 90. Image 2 of 3. Courtesy of Coronado Inc.

80°, allowing a magnification of nearly 150×, which will still allow the entire solar disc to be viewed or photographed. For the more conventional Plossl type eyepieces, a practical limit of 90× is more realistic.

Although none of the authoring team have tried it, it is reasonable to assume that anything that works with the MaxScope 40, 60, or 70 will also work with this filter, so refer to Chapter 4 for details.

Capabilities and Limitations

With an aperture of 50 mm, I speculate that the performance should be somewhere between the Coronado MaxScope 40's and the MaxScope 60's performance. The bandpass of 0.7Å is the same.

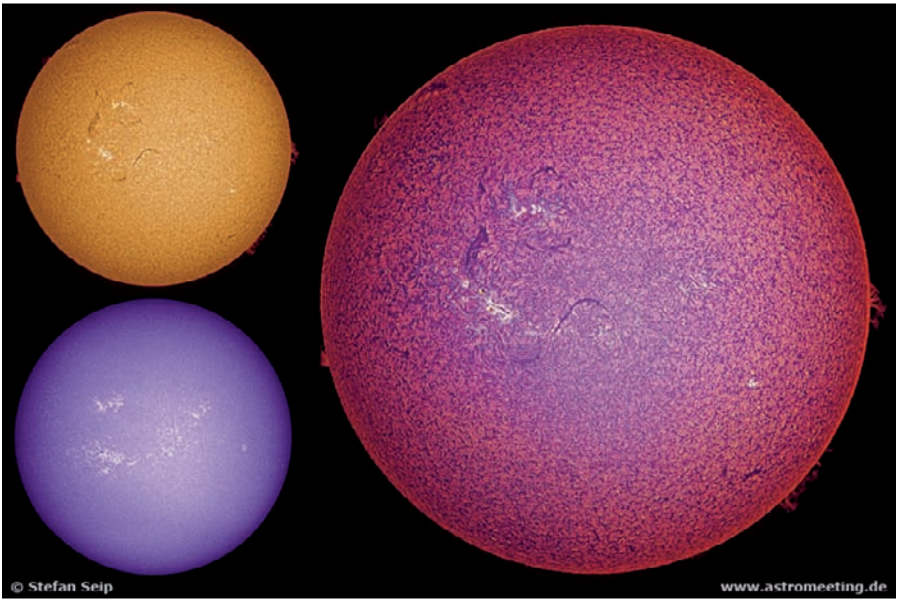


Figure 7.5. Photograph taken through a CaK 90. Image 3 of 3. Courtesy of Coronado Inc.

Figure 7.6. SolarScope 50-mm filter. Courtesy of SolarScope.

Figure 7.7. SolarScope 50-mm filter with Televue Pronto. Courtesy of SolarScope.

SolarScope SolarView 50

The SolarScope SolarView 50 (Figure 7.8) is the dedicated telescope that is equivalent to the 50-mm filter set, described above. At £2995, at the time of writing, it was slightly more expensive than the filter set and the £300 difference could pay for an 80-mm apochromatic refractor to use with the filter or nighttime use.

Performance would be expected to be around the same.

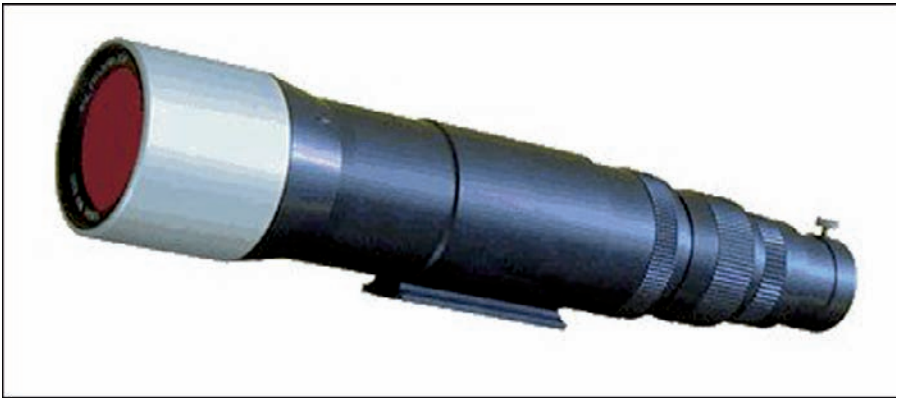


Figure 7.8. SolarView 50. Courtesy of SolarScope.

Facts at a Glance

Aperture (mm)	50
Focal length (mm)	400
Bandpass (Å)	0.7
Bandpass with double stacked filters	Not available
Weight (lb)	3.25

The UK retail price at the time of writing was £2995.

Using a SolarScope SolarView 50

The weight of this telescope is very similar to that of the Coronado PST and has the same mounting arrangements, so please refer to Chapter 2 for details of mounting. Finding the Sun is similar as it uses the TeleVue Sol Searcher.

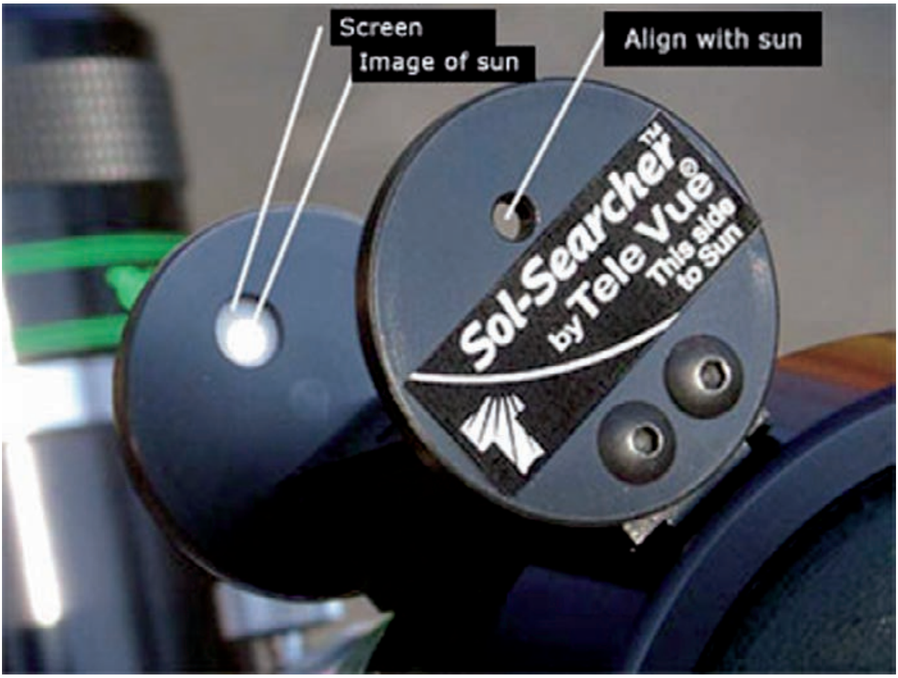


Figure 7.9. Sol Searcher. Courtesy of SolarScope.

Sol Searcher This performs a similar function to the Coronado Sol Ranger but uses an open assembly. To use, you need to align the solar image on a small screen (see Figure 7.9).

Recommended Accessories

As this is a hydrogen alpha telescope of 50-mm aperture and 400-mm focal length, the maximum magnification should be in the 100–120× range. The Nagler eyepiece type yields an apparent field of view of 80°, allowing a magnification of nearly 150×, which will still allow the entire solar disc to be viewed or photographed. For the more conventional Plossl type eyepieces, a practical limit of 90× is more realistic. To achieve a magnification of 120× you need an eyepiece of focal length of 3.3 mm and to achieve a magnification of 100×, you need an eyepiece of focal length 4 mm and for 80× magnification, an eyepiece of 5 mm will do the job. To get the required effective focal length, you can use various types of image amplifier described in Chapter 2.

Although, none of the authoring team have tried it, it is reasonable to assume that anything that works with the MaxScope 40, 60, or 70 will also work with this telescope, so refer to Chapter 4 for detail.

Capabilities and Limitations

With an aperture of 50 mm, I speculate that the performance should be somewhere between the Coronado MaxScope 40's and the MaxScope 60's performance. The bandpass of 0.7Å is the same (Figures 7.10–7.12).

SolarScope SolarView 60

The SolarScopeSolarView 60, shown in Figure 7.13, is the dedicated telescope that is equivalent to the Coronado MaxScope 60, described in Chapter 4. At £3795, at the time of writing, it was more expensive than the MaxScope 60.

Performance would be expected to be around the same.

Facts at a Glance

Aperture (mm)	60
Focal length (mm)	480
Bandpass (Å)	0.7
Bandpass with double-stacked filters	Not available
Weight (lb)	5

The UK retail price at the time of writing was £3795.

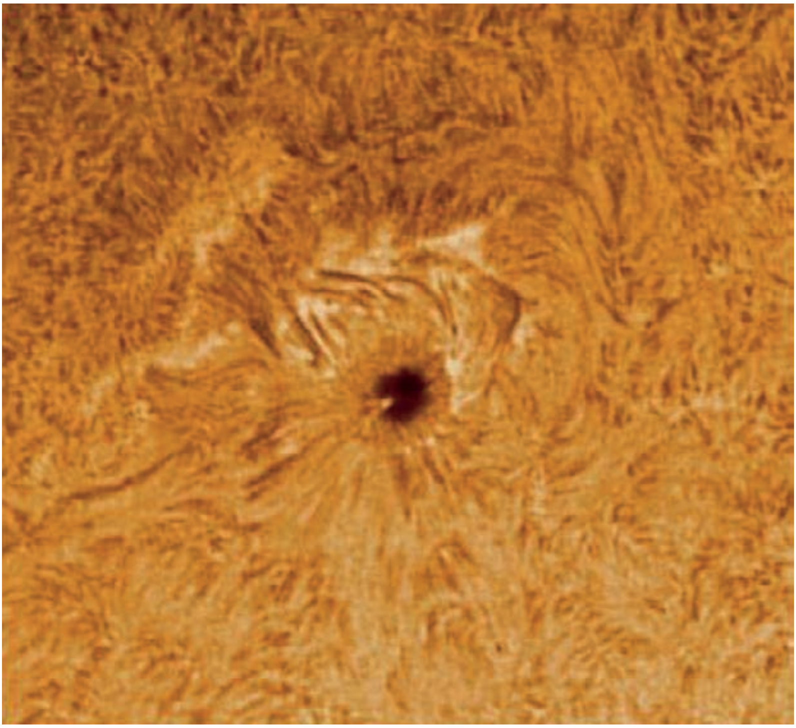


Figure 7.10. Photograph taken using SolarView 50 by Peter Vasey in November 2005. Courtesy of SolarScope.

Using a SolarScope SolarView 60

The weight of this telescope is slightly less than that of the Coronado MaxScope 60 and has the same mounting arrangements, so please refer to Chapter 4 for details of mounting. Finding the Sun is the same as for the SolarView 50, as described above.

Recommended Accessories

As this is a hydrogen alpha telescope of 60-mm aperture and 480-mm focal length, the maximum magnification should be in the 120–140× range. The Nagler eyepiece type yields an apparent field of view of 80° allowing a magnification of nearly 150×, which will still allow the entire solar disc to be viewed or photographed. For the more conventional Plossl type eyepieces, a practical limit of 90× is more realistic. To achieve a magnification of 120× you need an eyepiece of focal length of 4 mm, to achieve a magnification of 100× you need an eyepiece of focal length 4.8 mm, and for 80× magnification, an eyepiece of 6 mm will do

Figure 7.11. Full disc shot taken by Peter Vasey in November 2005. Courtesy of SolarScope.

the job. To get the required effective focal length, you can use various types of image amplifier described in Chapter 2.

Although none of the authoring team have tried it, it is reasonable to assume that anything that works with the MaxScope 40, 60, or 70 will also work with this telescope, so refer to Chapter 4 for details.

Capabilities and Limitations

With an aperture of 60 mm, I speculate that the performance should be somewhere similar to the MaxScope 60's performance. The bandpass of 0.7Å is the same.

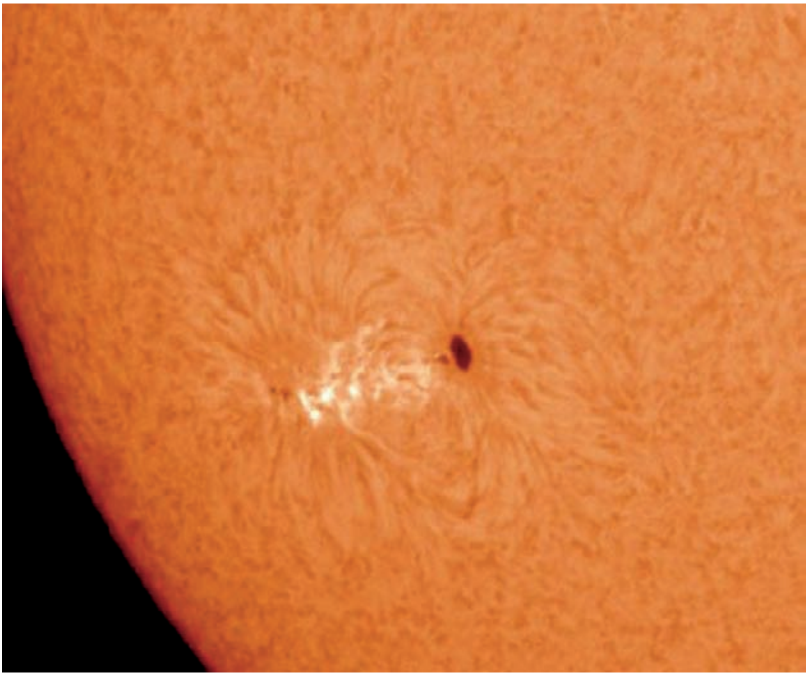


Figure 7.12. Close-up by Peter Vasey during November 2005. Courtesy of SolarScope.

Figure 7.13. SolarView 60. Courtesy of SolarScope.

Lumicon Solar Prominence Filters

These are full aperture filters ranging from about $700–$900 in price, depending on the aperture. Certainly, they are cheaper than Coronado for large aperture use and their 1.5Å bandpass is narrow enough to show prominences. However, Lumicon does not claim it is possible to see anything more than the brighter filaments.

They may offer an inexpensive entry into larger aperture hydrogen alpha viewing for the financially challenged but will not compete with Coronado for image quality. However, DayStar filters (see this chapter) or CromixSun (see Chapter 6) can be used to further reduce the bandpass once funds become available.

Thousand Oaks Filters

Thousand Oaks are probably better known for their white light filters and also produce an alternative system that yields a bandpass of 0.9Å (see Figures 7.14 and 7.15). This is larger than the bandpass offered by the Coronado MaxScope series but smaller than the bandpass of the PST.

The system is based on an energy rejection filter at the telescope objective and a hydrogen alpha unit (HAU) at the eyepiece end. As the HAU increases the length of the items in the light path near the eyepiece, the energy rejection filter increases the focal length to compensate by reducing the aperture.

Energy Rejection Filter

The energy rejection filter has to be matched to the telescope objective. It increases the focal length of the telescope and rejects most light apart from the visible red end of the spectrum. For use with Cassegrains (Schmidt and Maksutov), an off-axis energy rejection filter must be used. Note that Baader and similar "white light" filters cannot be used instead of the energy rejection filter. The energy rejection filter reduces the aperture, which increases the focal ratio of the telescope.

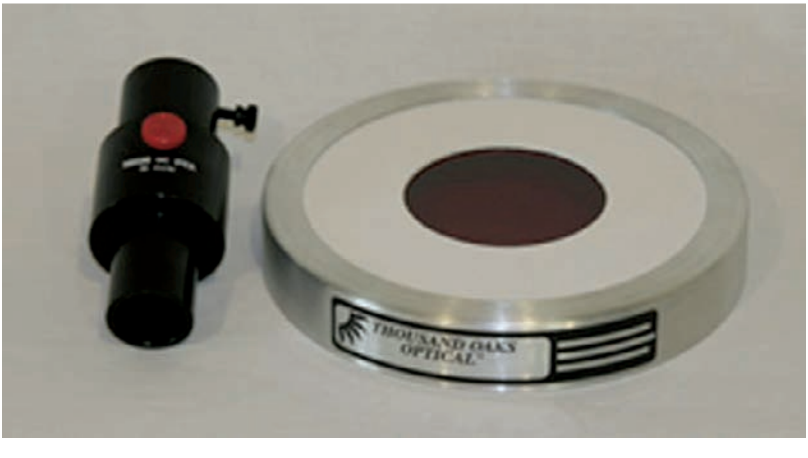


Figure 7.14. Thousand Oaks energy rejection filter and hydrogen alpha unit. Courtesy of Thousand Oaks Optical.

Figure 7.15. Thousand Oaks hydrogen alpha unit attached to a telescope. Courtesy of Thousand Oaks Optical.

Hydrogen Alpha Unit

This weighs about 7 oz (170 g) and is placed in the eyepiece path. It reduces the bandpass to 0.9Å and, at the time of writing, Thousand Oaks have not got their own solution to double stacking. It does not use the etalon as Coronado and SolarScope.

Capabilities and Limitations

One limitation is that the system does not work well with Newtonian reflectors or short tube refractors, such as my Skywatcher Startravel 80 or similar 80-mm models. The limitation is that the telescope and energy rejection filter must combine to give an effective focal length of at least *f*/15. As well as ruling out many popular telescope models, it also means that it can be difficult to get the entire solar disc into the field of view. This also reduces the effective aperture of the telescope in a way that full aperture filters do not. For example, the energy rejection filter reduces the effective aperture of an 80-mm refractor to 40 mm and an 127-mm Maksutov to 37.5 mm (due to the need for an off-axis energy rejection filter). In my opinion, this negates the advantage of using medium aperture instruments over a MaxScope 40 or PST.

On the other hand, the price of $799–$1050 makes it one of the cheaper options for larger aperture viewing, even though the bandpass of 0.9 Å is not as good as many of its competitors.

Figures 7.16–7.18 show a selection of photos. Although the lower bandpass reveals less surface detail than the Coronado 0.7Å filters and much less than the double-stacked Coronado filters, the prominence detail is excellent.

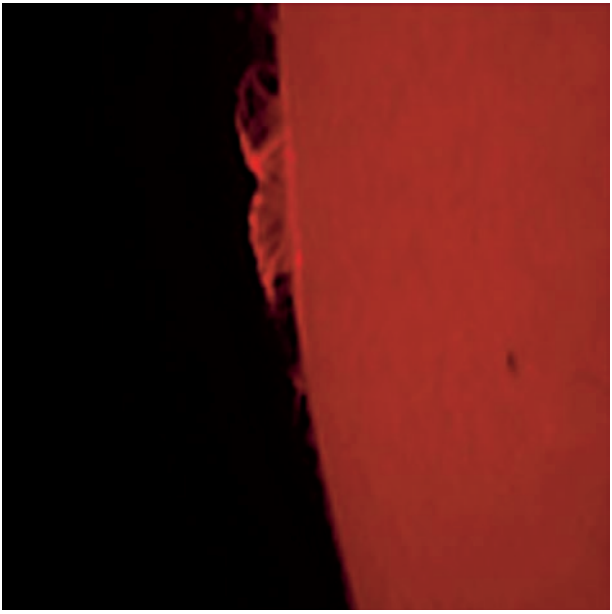


Figure 7.16. Thousand Oaks system: Image 1. Courtesy of Thousand Oaks Optical.

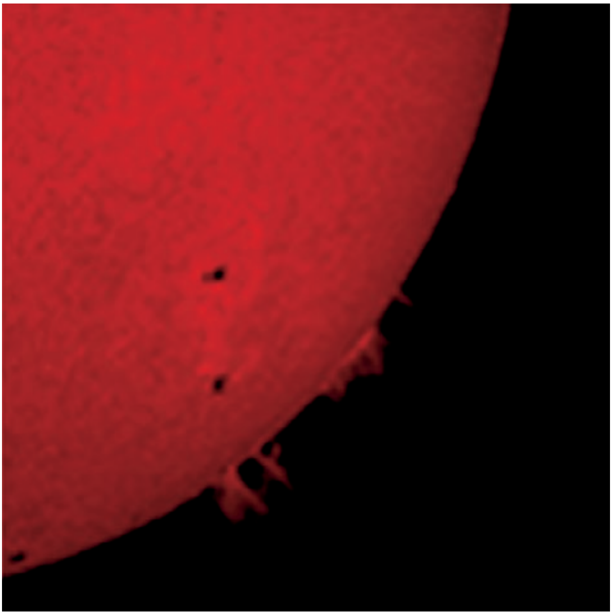


Figure 7.17. Thousand Oaks system: image 2. Courtesy of Thousand Oaks Optical.

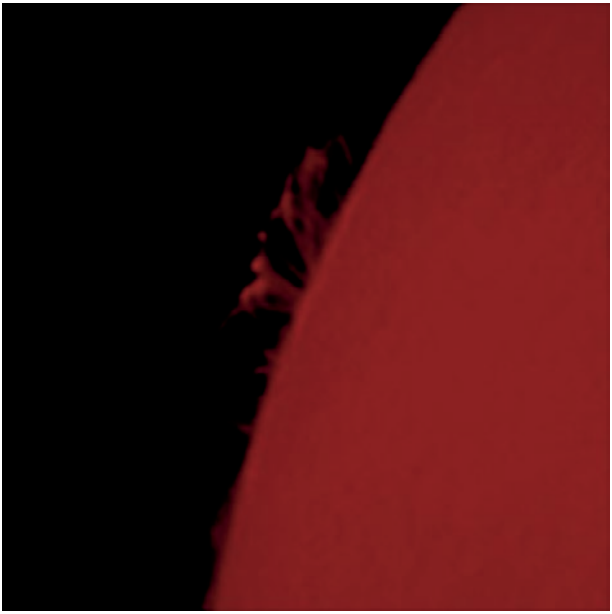


Figure 7.18. Thousand Oaks system: image 3. Courtesy of Thousand Oaks Optical.

CHAPTER EIGHT

Summary

The use of filters for solar viewing has recently opened up a lot of possibilities for amateur astronomers, as well as researchers. As a hobby, it is certainly not cheap compared to nighttime viewing, but once you have bought equipment, it will usually last for several years, given reasonable care.

Even the entry-level PST is capable of showing a wealth of detail to both visual and photographic users. As Nick Howes has shown in Chapter 5 that good photographic results can be obtained on a limited budget, with a bit of ingenuity and work. Indeed, many astronomers will find that the PST is on or near the limitations of their budget, so they will be restricted to it as their sole instrument, especially as the next telescope (the MaxScope 40) costs as much as a computer-controlled 200-mm (8 inch) reflector. For those on a larger budget, or those who subsequently raise more funds for additional purchases, the PST can still be used for quick setup applications and travel. Indeed, whilst the MaxScope 40 does deliver more solar detail than the PST, it is debatable whether it is worth paying the extra price.

The MaxScope 70 costs about five times as much as the PST and the lower aperture but optically superior MaxScope 60 costs about six times as much (as the PST). These represent a very serious outlay for the amateur astronomer, but there is little or no doubt that they can deliver absolutely stunning views of the Sun visually and photographically.

The top-of-the range MaxScope 90 is even more expensive at about 2 1/2 times the price of the MaxScope 60. Larry Alvarez has shown in his chapter, dedicated to this telescope, just what can be achieved with it. It is a highly remarkable instrument.

At the time of writing, there was no Coronado solution to the needs of large aperture observing. When I look through even a PST, let alone the top end hydrogen alpha telescopes, I sometimes doubt whether anything over 90 mm is really necessary, but the drive toward large apertures and greater resolution will always be with us. Filters placed in the light path near the eyepiece were the only solution available and the CromixSun, Thousand Oaks, Lumicon, and DayStar solutions are described in this book.

Whether you own or are deciding to purchase any hydrogen alpha (or calcium K) telescope, at any range, it is important to use the appropriate accessories and photographic equipment. It is significant that users of the larger hydrogen alpha and calcium K telescopes mostly use the CEMAX eyepieces, either supplied with the telescopes or purchased separately. However, with the PST, they represent a considerable cost compared to the cost of the telescope. In my Chapter 2, I have described many eyepieces that can be used and would certainly recommend the CEMAX 12-mm eyepiece, and if you can stretch your budget, the 2× Barlow lens. Indeed, I wish Coronado would make some CEMAX eyepieces of shorter focal lengths too.

I would sincerely doubt that anyone who purchases a PST would ever be disappointed with it. The only doubt I would have about buying a larger telescope is the likelihood that if you waited for a year or so, there would be a better version available at low cost. Home computers, for example, seem to have bottomed out in price, whilst capacity and capability seem to still be on the increase. I expect more great things to come from Coronado over the coming years.

This section summarizes each telescope and some of the major accessories to help you decide on purchases. The last sections summarize the imaging techniques and getting the best use from your telescope(s) or intended purchases.

Personal Solar Telescope

As the entry-level telescope, it is below the affordability barrier for many serious amateur astronomers on a budget, yet is still about the same price as many "serious" nighttime telescopes. Apart from the budgetary advantages, it is extremely portable not just by road but also by air, as I can personally testify.

In the course of writing this book, I have needed to lend it out and I miss it more than if I was without a television. This is from someone who is a serious soap/sport addict!

You do not need to be a genius in using a telescope to use one. Indeed, if you are accustomed to looking at the Moon and the brighter planets through a telescope at night, you already have all the observing skills that you need. The Sol Ranger is not just a gimmick, it really helps you find the Sun.

If it has drawbacks, such as the lack of focusing range, they have been made in order to reduce the cost to make the telescope affordable.

To make the most of it, you need to use the right accessories and the "Accessories" section at the end of this chapter goes through many of the main options. If I had to choose one, it would be the CEMAX 12-mm eyepiece. It really felt like upgrading to a whole new telescope.

I am amazed by what Nick has been able to do with it photographically. It looks just about research grade to me.

Verdict: A breakthrough for solar observers looking for a bit more than what is available from "white light" solar viewing. It is one of the most amazing products to have emerged from the marketplace in recent years.

Optical quality	8 out of 10
Value for money	9 out of 10
Ease of use	7 out of 10
Overall rating	8 out of 10, very good

If you get the opportunity to look through one, do so. You will be hooked.

MaxScope 40

At the time of writing, the MaxScope 40 was above the psychological price barrier of $1000 in the United States (£1000 in the United Kingdom), making it expensive relative to the PST.

However, its effective aperture is more than the PST and its weight of only 3 lb (same as the PST) means that it has the same portability.

The MaxScope 40 has a lower bandpass of 0.7Å, giving more surface detail than the PST and full focusing range, allowing a greater variety of accessories to be used.

Like the PST, it is a light, frequent use hydrogen alpha solar telescope, which can be brought outside and set up in minutes. If you want to get rapid use from it, you must buy the optional Sol Ranger.

It does not have any supplied eyepieces, but I do not see this as a disadvantage as most purchasers are likely to have nighttime telescopes and eyepieces. Including a CEMAX 12-mm eyepiece and 2× Barlow lens would increase the headline price.

The real question is whether the price difference with the PST justifies the purchase, when you could buy a PST and a serious nighttimes telescope (or a PST and PST CaK) for the same money. Certainly, it is better than the PST, at least for optical results but how much is debatable.

I would not recommend purchase of both the PST and MaxScope 40, unless you intend to do public demonstrations where you might want to show the Sun to more than one person, simultaneously.

Verdict: An excellent instrument but its biggest competitor is the PST, which is almost as good but much cheaper.

Optical quality	8.5 out of 10
Value for money	6 out of 10
Ease of use	6 out of 10
Overall rating	7 out of 10, good

MaxScope 70

Next up in the price range from the MaxScope 40 is the MaxScope 70. Whilst the MaxScope 40, 60, and 90 share the same basic design, the MaxScope 70 has a different design. Indeed, it is based on its predecessors, the Helios I and NearStar. It is marketed toward the beginner end of the market, quite rightly in my opinion, as it has little that can go wrong, as it is a sealed unit, unlike the MaxScope 40, 60, and 90. It does, however, have a slightly wider bandpass of 0.8Å.

That it is capable of delivering high-quality visual and photographic images is of little doubt. If I can find any negative at all with it, I would suggest that the maximum magnification seems to be lower than users of the PST and the MaxScope 40 would expect. While the PST suggests a maximum magnification of just over 100×, the MaxScope 70 suggests a maximum magnification of 140×.

It comes supplied with a CEMAX 25-mm eyepiece (I think the 12 mm equivalent would be better) and a Sol Ranger solar finder.

The great unanswered question is whether it is better to buy it or the MaxScope 60.

Verdict: An excellent instrument but its biggest competitor is the MaxScope 60, which is slightly more expensive but more versatile.

Optical quality	7.5 out of 10
Value for money	6.5 out of 10
Ease of use	7.5 out of 10
Overall rating	7 out of 10, good

MaxScope 60

Put quite simply, the MaxScope 60 is an oversized MaxScope 40. It has the same design and same focal length but just 1.5 times more aperture and 2.25 times more light-gathering power. It is priced slightly more expensive than the MaxScope 70 but has a narrower bandpass of 0.7Å and its etalon can be tuned. Like its larger sibling (the MaxScope 90), it is used more for taking photographs, as can be seen here and on the Coronado Web site.

The MaxScope 60 is certainly not for the financially challenged or casual user but will appeal to the serious user and, indeed, still represents a cost-effective entry into this level of power and quality.

Verdict: An excellent instrument but way above the budget bracket. Choosing between this and the MaxScope 70 if you have the budget is a nice decision to have to make.

Optical quality	8 out of 10
Value for money	7 out of 10
Ease of use	7 out of 10
Overall rating	7 out of 10, good

MaxScope 90

The best way to describe this excellent instrument is that it is the Coronado flagship product of hydrogen alpha viewing and imaging. The double-stacked version has produced some excellent photographs for this book and on many image galleries.

It is from the same family of products as the MaxScope 40 and 60, but has a longer focal length, which is reflected in the price. In fact, it is the only product where the cost of a separate filter set differs significantly from the price of a dedicated telescope. In the case of the dedicated telescope, the retail price is equivalent to that of a reasonable secondhand car in the United Kingdom, so it is certainly not cheap. Also, I would suggest that anyone owning or having had significant use of this excellent telescope has a moral duty to share his or her photographs on the web!

Verdict: The MaxScope 90 is definitely geared toward the professional or scientific market where the highest quality and detail are expected. The build of the telescope does not skimp on materials or manufacturing in any way and comes with several extras. It is a modern masterpiece of design, optical technology, and visual beauty.

Optical quality	10 out of 10
Value for money	7 out of 10
Ease of use	9 out of 10
Overall rating	9 out of 10, excellent

Use of Separate Filter Systems

Use of separate filter systems is not as widespread as that of dedicated telescopes, which is reflected in the content and photographs in this book.

Nevertheless, hydrogen alpha and calcium K filters can be matched to any high- or medium-quality telescope to produce excellent results. If the aperture of the filter does not match that of the telescope, it is necessary to buy an adaptor plate, which will add to the cost.

In general, separate filter systems perform better with refractors than reflectors.

Although, I can understand it is easier for Coronado to manufacture filters with the same aperture as their dedicated telescopes, it is a shame that they do not have any 80-mm aperture filters, as many people (including me) own 80-mm refractors.

The alternative is to use a filter in the eyepiece part of the light path, such as CromixSun, DayStar, or Thousand Oaks. Note that for the Thousand Oaks solution you need an energy rejection filter.

Calcium K Equipment

Use of calcium K equipment is in its infancy, as it hit the market place when I was writing this book. At the time of writing, the products available from Coronado were the following:

- PST CaK.
- MaxScope 70 CaK (or CaK 70)
- MaxScope 90 CaK (or CaK 90)
- SolarMax 60 CaK filter set

Although calcium K light shows a lot of details simply not visible in hydrogen alpha light or white light, it is a much harder to use than hydrogen alpha because the calcium K wavelength is close to the near ultraviolet, so it is difficult for human eyes to see the detail and not everybody can. Coronado markets the instruments as primarily for photographic use and photograph they certainly can do as Nick Howes, Mike Taormina and Larry Alvarez have certainly proved. Although, I cannot see the features visually myself (although I will have another go nearer to the solar maximum), I have even managed a passable effort myself.

You certainly need longer exposures for imaging and lower magnifications for visual use and afocal photography, but the general conclusion is that the calcium K range of products deserves another vote of confidence for Coronado.

Accessories

Choice of the right accessories can make a huge difference to your enjoyment of Coronado telescopes. Sometimes, just a minor purchase can make all the difference, yet an ill-thought-out major purchase can burn a whole in your pocket, whilst adding little or no value to your viewing.

Some accessories come supplied with a particular model, so may not apply. For example, the full range of CEMAX eyepieces are supplied with the MaxScope 90 and the PST has a built-in Sol Ranger to help in finding the Sun.

Eyepieces

Just about any eyepiece that you have bought for use with nighttime telescopes can be used with the Coronado range of telescopes. The exception is the PST, which has a narrow focusing range. However, the best and the most cost-effective eyepiece I have heard of so far is the 12-mm CEMAX eyepiece. This is supplied with the MaxScope 90, but it is an almost essential purchase with the other telescopes. Benchmark tests have shown that it can reveal surface and prominence detail that just cannot be seen with other eyepieces, even slightly more expensive ones.

CEMAX eyepieces are also available in focal lengths of 18 and 25 mm. Whilst these are of undoubtedly good quality, their purchase is simply not necessary for hydrogen alpha viewing with the short focal length telescopes from the PST to

MaxScope 60. However, with the MaxScope 90 and for calcium K viewing (where it is best to use a lower magnification) they come into their own. If you own a MaxScope 90, they come supplied. All the other Coronado telescopes have a short focal length of 400 mm, so the 12-mm CEMAX yields a magnification of 33×, with a field of view of 90 arcminutes or nearly three solar diameters. The only need for longer focal length eyepieces is to find the Sun and a low-end Plossl eyepiece can do the job just as well for half the price. Indeed, if/when Coronado sells shorter focal length eyepieces, I will be parting with a bit more money.

On the other hand, if you have bought a separate filter system for an existing telescope, it is more likely to have a long focal length. Many Schmidt–Cassegrains or Maksutov–Cassegrains have focal lengths in excess of 1500 mm, so you are looking at a magnification of 60× with a 25-mm CEMAX eyepiece and a field of view of about 50 arcminutes, which is a great combination for looking at the whole solar disc.

The 12-mm CEMAX eyepiece also works better with Barlow lenses than other types of eyepiece, overcoming some of the PST's focusing range problems. It can also be used for night viewing and afocal photography too.

With the exception of the CEMAX eyepieces, moving from low- to mid-price range eyepieces does not improve either the visual view or the photographs. One of the major disadvantages of budget eyepieces is chromatic aberration, where the light from different wavelengths comes to focus at different places, showing those irritating color fringes around the Moon and other bright objects. Indeed it can be very annoying when viewing Mars, where you cannot always be sure whether you are viewing a real polar ice cap or not. With hydrogen alpha or calcium K viewing, all the light is pretty much of the same wavelength, so this particular problem simply goes away. So hundreds of dollars or pounds can be spent on a problem that simply does not exist for us.

I have found that the Moonfish Group eyepieces, which are similar in design and price to Knight Owl and GSO eyepieces, work well because they have a large apparent field of view of 70°. In this way, they outscore the CEMAX eyepieces. They work well for both visual and photographic use but do not reveal as much detail as the CEMAX eyepieces.

My advice is to try out eyepieces that you already own with Coronado telescopes as you may well find something that works unexpectedly well. Do not assume that because an eyepiece is cheap or does not work well for nighttime viewing, it is not worth trying for solar viewing. A good example of this is a Skywatcher 7–21-mm zoom eyepiece that I use with the PST. It delivers great close-ups.

As a general rule, Plossls are better for visual use, LER eyepieces are better for afocal photography and the Moonfish/Knight Owl/GSO eyepieces are good all-round performers that can be used for both applications.

Top of the shopping list? 12-mm CEMAX without a doubt!

Image Amplifiers

This is a name given to a general type of accessory that is used to increase the magnification of a given telescope/eyepiece combination. The most commonly used one is the Barlow lens. Most of these give the magnification a boost of two times, so are known as "2× Barlow lenses," but some can increase the magnification by three times. An example of this is when you use the 12-mm CEMAX eyepiece with a PST (400-mm focal length). The normal magnification is 33× but with a 2× Barlow lens it is 66×. This is likely to reveal more detail and still keep the entire solar disc within the field of view.

The best and the most cost-effective Barlow lens I have uncovered is the CEMAX 2× Barlow lens, which comes as supplied with the MaxScope 90.

A very useful accessory I use frequently for solar and nighttime viewing is the Astro Engineering Magni Max. Unlike a Barlow lens, it screws into the back of an eyepiece. It gives a magnification boost of 1.6 times, so would yield a magnification of 53× with a CEMAX 12-mm eyepiece and PST. I find this particularly useful for digital photography. Where Astro Engineering have (so far) missed a trick is that they have not built one with a secondary thread to allow you to "chain" them to provide magnification boosts of 2.56 and 4.1, using 2 and 3, respectively.

Although I find the Moonfish Group 3× Barlow lens very good for lunar and planetary use, it does not work with the PST due to the telescope's limited focusing range. It is more appropriate for use with the other Coronado telescopes.

In case you were wondering, yes you can use one with a Barlow lens to provide a combined magnification boost of 3.2× with a 2× Barlow lens.

The other types of image amplifiers on the market go under such names as "ImageMate" and "PowerMate" and can give magnification boosts of around four or five times.

There is an oft-quoted "rule" about the maximum magnification that you can use with a telescope. You are supposed to multiply the aperture of the objective lens by 2. I have found that for nighttime viewing (or solar "white light" viewing), I can break this limit, especially when using a Maksutov–Cassegrain. Extensive trials with the PST have shown that boosting the magnification to around 100× can reveal details not visible at lower magnifications, especially on clear days. Anything above 120× magnification produces a blurry image. For the MaxScope telescopes (with the exception of the MaxScope 70), there seems to be a practical limit of about three times the aperture of the objective lens, but this is dependent on the prevailing conditions and the quality of the eyepiece and image amplifier. To get the best results for viewing or photographing the entire solar disc, magnifications of about 40–64× are recommended. Additional surface and/or prominence detail can be revealed at higher magnifications, such as around 100× for the PST.

If you do not own a MaxScope 90, I would place the CEMAX 2× Barlow lens high on the shopping list and the Astro Engineering Magni Max at the top, regardless.

It is possible to obtain focal reducers for some telescopes, but due to the already short focal length of most of the Coronado telescopes, they have no use, except for calcium K viewing. If you have a separate filter system with a long focal length Cassegrain, they may be useful for getting the entire solar disc in the field of view.

Double Stacking

Double stacking is the act of adding a secondary hydrogen alpha filter to reduce the bandpass on a hydrogen alpha telescope. It is not used for calcium K viewing, which uses a wider bandpass of about 2.2Å, as opposed to 0.5–1.0Å for hydrogen alpha viewing.

Putting quite simply, double stacking is the most expensive addition that you can make to your telescope. In the case of the PST, it is more than double the price but for the MaxScope series, it increases the cost by about 60%.

There is absolutely no doubt that the MaxScope 90 and MaxScope 60 show far more surface detail with double stacking than without it. Some of the photographs that Larry Alvarez has taken with his double-stacked MaxScope 90 are nothing short of remarkable and are as good or better than many photographs taken with research instruments.

As with a lot of things in astronomy, budget is important. If you have unlimited funds, there is no doubt that a double-stacked MaxScope 90 or 60 will greatly enhance what you have. A really debatable point is comparing the price of a double-stacked MaxScope 40 against a single-stacked MaxScope 60 or a double-stacked MaxScope 60 against a single-stacked MaxScope 90.

I would suggest that if in doubt, go for the larger aperture single-stacked telescope. As I have said before, astronomers can be extremely inventive about securing funds for purchases (who needs a large Dobsonian, holiday or golf membership anyway?) and that funds for double stacking may well appear later.

My own somewhat limited trials with a double-stacked PST show that there is no enhancement to prominence detail and there is some improvement to surface detail, but this is offset by a fainter image. However, Cameran Ashraf has produced some stunning results over a longer period of time. Indeed, triple stacking of even the larger instruments seems to have the same problem, only worse.

So to sum up, if I were considering a new purchase, I would put aperture before double stacking but would consider double stacking in an existing instrument if funds became available later, especially if it was one of the larger aperture telescopes. Do not rule out the possibility of non-Coronado double-stacking options either. If you have more than one Coronado hydrogen alpha telescope, you can use non-Coronado solutions (such as CromixSun) to be able to move the extra filters from one telescope to another, as required.

Mounting

The bad news is that none of the Coronado telescopes comes supplied with a mount. The not so bad news is that mounting is not such a critical issue as with many nighttime telescopes. Even for photographic use, long, driven exposures are not only unnecessary, but they are positively harmful. Photographing the Sun is the complete opposite to photographing faint galaxies.

The other thing to note is that even the MaxScope 90 is a light telescope compared to many of the behemoths that are used for nighttime observing. The PST and the MaxScope 40 are both only 3 lb in weight and can be mounted on a domestic camera tripod. Although I do not recommend this setup for photographic use, I have managed to take some photographs using it while traveling. John Watson and Larry Alvarez have provided me with some good ideas about making mounting brackets so that these telescopes can be used with popular mounts such as the EQ3.

For the PST, my favorite method is to "piggyback" it on top of a Skywatcher Startravel 80 on an EQ1. It is not necessary to drive the mount and this setup also gives me the opportunity to make "white light" observations at the same time.

For dedicated mount purchase, some suitable options are following:

- MALTA tabletop mount, which is surprisingly quite solid for a tabletop mount and will suit both the PST and the MaxScope 40
- AzTech Manhattan
- Aztech AC562
- Manfrotto range

Apart from the possibility of damage caused by a lightweight mount unbalancing and causing loss of or damage to a telescope, a sturdy mount also helps to provide good photographic results, especially at high magnification.

Other Accessories

This section lists various other accessories that you may find useful with the Coronado telescopes. They are the following:

- *Sol Ranger*. This is a solar finderscope, which is supplied with the MaxScope 90 but available as an option for other MaxScope telescopes. The PST and PST CaK have a built-in solar finder. I would rate this as an almost essential purchase, as finding the Sun without it is rather laborious, especially if the Sun is anywhere near the zenith.
- *Hard case*. Carrying cases are available for each of the Coronado telescopes. I use a champagne box for my PST and wrap it in bubble wrap for transport by air.
- *Coronado Polarizing Filter*. This filters out stray light. I have tested it with both the PST and MaxScope 40. With the MaxScope 40, it improved the detail on the solar surface but with the PST it did not. It is not an expensive item, so worth a try.
- *SolarMate Shade*. This shades the observer from the Sun and acts as an eyepiece holder too. It is only available with the PST.
- *BC&F Telescope Cleaning Kit*. This allows you to clean your optics without causing any damage to them. I have not tried any others, but this foots the bill. Some sort of telescope cleaning is absolutely essential for solar photography.

Imaging

It seems a strange coincidence that the upsurge in amateur interest in the Sun and solar observing has happened at the same time as new tools and techniques being available for amateur photography.

Many people, like myself, use simple point and click techniques, sometimes with an afocal adaptor to hold the camera steady. As the quality of digital cameras goes up, while the price comes down, better and better results can be achieved using this method. I have certainly managed to record prominences and sometimes disc detail using this method.

However, Nick Howes in Chapter 5 and Larry Alvarez in Chapter 3 have proved that you can use other methods to produce "killer" photos without spending a lot of money. Budget astronomical cameras, such as the Meade LPI and Meade DSI can produce amazing results, but, with a bit of work; so can the cheaper devices like the Phillips Toucam using image stacking techniques and specialized postprocessing tools, such as Paint Shop Pro. Indeed, using such techniques, Nick has been able to produce excellent photos using PSTs. As well as being an expert at obtaining images, he is also very good at postprocessing.

If I had a budget, I would be tempted to start off with point and click imaging and move onto webcams later. I expect imaging costs to come down more rapidly than the cost of hydrogen alpha and calcium K telescopes.

Getting the Most from Your Coronado Telescope

There is a saying that the definition of a good telescope is one that gets used a lot, and a bad telescope is one that gets relegated to the attic. I can say honestly that I own two telescopes that are stored in the attic, but they had plenty of use before I bought higher specification instruments. The only way I can see a Coronado telescope making it to the attic is if you buy a higher specification model at a later date. The exception to this is that if you own a PST or a MaxScope 40, you will wish to keep it for traveling and quick use.

Frequent use is the key to these telescopes. Surface and prominence detail can change in a matter of minutes and you do not get that with nighttime viewing. I will sometimes take my PST to work and have a look at lunchtime and I have been known to view the Sun, in the morning, lunchtime, and evening during the English summer.

Personally, I am not an expert astrophotographer, like Nick, but I will often record solar detail by using a digital camera aimed through the eyepiece. Indeed, it is the choice of eyepieces that can make the difference, especially near a solar minimum, when the activity is quite low.

After a bit of practice, your eyes (well, strictly speaking, your brain!) will learn how to look for solar detail, like prominences, faculae, plages, filaments, and sunspots.

I have learned many postprocessing techniques from Nick but still consider myself an inexperienced astrophotographer.

Health warning: Viewing the Sun through hydrogen alpha and calcium K telescopes can become seriously addictive! In extreme cases, this can lead to sunburn, dehydration, and excessive sweating.

Unanswered Questions and Unquestioned Answers

In the preparation and research for this book, my cowriters and I have tried out a lot of things with different products. I have personally tried just about everything I can with my PST, short of boiling it in water and singing to it. I will embarrass Nick (Howes) by giving him a special mention for his in-depth look at imaging. I have barely scratched the surface by comparison. However, the questions that you may wish to consider, which we have not got straight answers to, are the following:

1. *MaxScope 60*. I managed to look through a MaxScope 60 and managed to do a good analysis on the MaxScope 70, but I can honestly say that I have been unable to look through the two telescopes on the same day and I am still to meet someone who has. My natural leaning is toward the MaxScope 60, as it is a bit more versatile, but if someone offered me a cheap MaxScope 70, I would be far from disappointed
2. *Aperture or bandpass*. We are all on some sort of budget and we are sometimes faced with a choice within a budget range. A narrower bandpass does not usually enhance prominence detail much (if at all) but will certainly show more detail on the surface. However, my personal bias is toward aperture. I live in South West England, where many apparently clear days and nights are blighted by a haze.
3. *Whether to buy now or later*. Just as PCs and digital cameras keep improving and coming down in price, so will the solar telescopes. The PST had already lost some of its launch price at the time of writing. I do not ever see a PST being relegated to the attic, but there is a good chance that larger instruments will be superseded by cheaper models and be available at lower prices on the secondhand market or they could go up.
4. *Coronado*. At the low end, there is little doubt that the PST is the clear market leader by a mile. In terms of quality, the SolarScope range competes at the mid-end but is also noticeably more expensive. At the top end, I am reasonably certain that the MaxScope 90 is the best in class but there are other large aperture solutions, involving the use of an etalon at the eyepiece end of the light path that are much cheaper.

Although you will (hopefully) find this book will give you some ideas, the final choice and responsibility are yours. If possible, look through as well as at any telescope that you are thinking of buying. With a nice chunk of sales commission, I doubt if many sales staff would refuse.

The Final Word

There is absolutely no doubt that amateur solar viewing has made spectacular advances over the last few years. Coronado has been the market leader and, in my opinion, have a near monopoly at the entry level. Even at the medium level, such as the MaxScope 60 and 70, they continue to offer the best value for money.

At the top end, I would certainly not even think of dissuading anyone from buying the excellent 90-mm instruments, unless they did not have enough time during daylight hours to get much use from them. However, separate filters in the eyepiece end of the light path are cheaper and offer the flexibility to use with large aperture instruments.

Now the book is written and my job is done, I will just sit back in my garden and admire the view through my PST!

CHAPTER NINE

The Physics of the Sun

This book is about the observational side of the Sun. It is more than possible to enjoy looking at the Sun without understanding anything much about it at all. Yet, even the least scientific minded amongst us like to understand a little bit about what we are seeing. This is just a light introduction for the uninitiated and contains a few simplifications.

Solar Facts

Radius (km)	695,990
Mass (kg)	1.989×10^{30}
Surface temperature (K)	5770
Surface density (g/cm^3)	2.07×10^{-7} g/cm^3
Surface composition (%)	• Hydrogen, 70
	• Helium, 28
	• Others, 2
Core temperature (K)	15,600,000
Core density (g/cm^3)	150
Core composition (%)	• Hydrogen, 35
	• Helium, 63
	• Others, 2
Age	4,600 million years
Star type	Yellow dwarf
Spectral class	G2V

The Sun as a Star

It is only in the recent past, since the use of the telescope for astronomical purposes, that we have realized that the Sun is a star. Now I could say "just like the others that we can see in the night sky" but that would be wrong on two counts that are as follows:

- Stars do have a lot of characteristics in common but they are also individuals. In that way they are not dissimilar to humans.
- The stars we can see in the night sky are not representative of the stars in our galaxy or the universe. Numerically, there are far more red dwarf stars than any other type of star (or, indeed, all the stars of other types put together). Red dwarves are so faint that we cannot see any without a telescope or binoculars, even though some are quite close by stellar standards. By contrast, the stars we can see are mostly celestial powerhouses, each with eight or more solar masses. The exception is Alpha Centauri, which is a double star system, visible in the southern sky, which has one component rather larger and brighter than the Sun and another slightly smaller.

The Sun is sometimes described as an "average" star but that does not really paint the full picture. It is miniscule compared to large, bright stars such as Rigel and Deneb in both size and luminosity (brightness), yet for every star larger than the Sun, there are about 20 smaller than it. It also has an official designation as an "yellow dwarf" and spectral class G2V. It is also known as a "Population I" star. This means that it has been formed (at least partially) from the remains of previous generations of stars and contains significant amounts (about 2%) of elements heavier than hydrogen and helium. Population II stars (of which many examples have been found in our galaxy) were formed very long ago, probably as the first galaxies were coalescing. The first generation of stars contained only hydrogen and helium and are known as "Population III," yet so far none of these early stars have been found and scientists speculate that they were mostly large and short-lived, so would have ended their lives less than a billion years after the start of the universe.

The Sun is also known as a "main sequence" star. This means that it is converting hydrogen to helium by nuclear reactions (nuclear fusion). Most stars stay on the main sequence for over 90% of their lives and when most of the hydrogen is used up, they convert helium into carbon and swell to become red giants. Red dwarves are not capable of this, but stars of about the same mass as the Sun or larger can. However, the Sun will not produce any elements heavier than carbon (except possibly oxygen), whilst much larger stars will produce all elements up to and including iron. Elements heavier than iron can be created only by a process called nucleosynthesis during a supernova explosion.

Birth, Life, and Death of the Sun

This has really been understood only in the past 50 years or so. We now know that the nebulae that we see in the night sky, such as the well-known Orion Great Nebula, are, in fact, stellar birthplaces. Although composed mostly of hydrogen, they also contain heavier elements such as carbon, oxygen and metals such as sodium and iron. We also know that the nebula that gave birth to the Sun must also have contained elements from a former supernova explosion, due to the presence of heavy metals, such as gold and uranium, which are too heavy to have been formed by nuclear fusion in stars.

It was believed that such a nebula would condense to the point where it would collapse under its own gravity to form a star. What is now known is that clumps form in these nebulae and each clump forms a star, so many stars are born together, although not at exactly the same time, but usually within a few million years of each other. It is also usual for a range of stars to be formed, mostly small, but a few stars like the Sun are formed and a very small number of larger stars. The result is an open cluster, like the well-known Pleiades, Hyades, and Beehive clusters.

Although it is known that interstellar nebulae condense to form stars, the processes that trigger this condensation is not well-known. Supernova explosions are known to trigger the condensation, but it cannot be the only cause, as something must have created the stars that exploded as supernovae in the first place. The presence of black holes and nebulae rotating around them is also believed to play a part.

What we do know is that when the centre of a clump of material gets hot enough, it triggers the fusion of hydrogen into helium. Also its gravitational field attracts more materials and forms an accretion disc from which planets, asteroids, and comets form. Some of the materials from this disc spirals into the star and increases its mass, while other materials are left in the orbit. We now believe most stars form planets but some of the larger ones have strong stellar winds, which inhibit planetary formation.

However, not all clumps have enough mass to condense into stars. Another type of object called a brown dwarf is formed which is sometimes called a "failed star." This is smaller and cooler than a red dwarf but larger and hotter than a planet.

Over periods of millions and billions of years, stars in these clusters disperse around the galaxy, although most of them end up as multiple star systems, interacting with each other gravitationally. Although there has sometimes been speculation about an unseen companion to the Sun (such as a brown dwarf), nothing has been found.

In stellar terms, the Sun is now about 5 billion (5,000 million) years old, so it is about halfway through its life. It is slowly getting hotter and converting its hydrogen to helium at an ever-increasing rate. Within about another billion years, it will become too hot for life to exist on the Earth. After about a further three billion years, it will have used up all of the hydrogen in its core and its core will collapse. The additional pressure and temperature will cause the remaining helium to fuse into carbon and its outer layers will swell to a radius between Venus's and Earth's orbit.

When all of the helium in the core has been converted into carbon, nuclear fusion will stop. With larger stars, the core will collapse again and carbon will fuse into heavier elements, but the Sun is not large enough for this to happen. Instead, the outer layers will disperse into space and a "planetary nebula" will form, leaving a dense white dwarf, which is the remains of the star. White dwarves are hot and dense but will eventually fade over tens of billions of years. In fact, the universe is young enough that no white dwarves have faded out of existence yet. There are some planetary nebulae visible in the night sky, with the Ring in Lyra and the Dumbbell in Vulpecula being visible in binoculars under clear conditions.

The Solar Structure

We can speculate that most stars, particularly those of similar size and spectral type to the Sun, must be structured in a similar way. What may seem surprising at first is that, whilst it appears to, the surface of the Sun is not actually burning at all! Neither it is boiling nor bubbling as it appears to in high-resolution views. The real action takes place in the core.

The Core

By radius/diameter, the solar core is about a quarter of the distance from the center to the surface, so it is about 1/64th of the Sun by volume. The temperature is about 15,000,000° C at the center and it reduces toward the core boundary to about 7,500,000° C. The density is about 150 g/cm^3, reducing to about 20 g/cm^3 at the core boundary. This allows the nuclear fusion of hydrogen into helium (sometimes erroneously referred to as "burning" to take place). The core is the only part of a star where this takes place and it requires both high pressure and temperature before it can occur. Objects (usually somewhat smaller than the Sun) that cannot achieve the temperature and pressure necessary to achieve nuclear fusion are referred to as brown dwarves. High temperature is necessary to make hydrogen move at high speeds and high pressure and density are required to overcome the electrical repulsion between hydrogen nuclei (protons).

Although it is actually a three-step process, the result is that four protons combine to produce a helium nucleus (or alpha particle, consisting of two protons and two neutrons), neutrinos, and a release of energy. This energy actually takes 1 million years to reach the solar surface. Imagine what would happen if all of these energies were released at once! Should the Sun explode, it would temporarily outshine every other star in the galaxy. This is exactly what happens during a supernova explosion, but the good news is that the Sun is too small for this to ever happen.

The Sun's core (and those of other stars) has a delicate balancing act. Gravity acting alone would cause the core to condense further and nuclear fusion alone would cause it to expand to the point where the density and temperature would be too low to support nuclear fusion. In most stars, these two forces balance. In the case of a supernova, the energy produced by fusion runs out as the core becomes all iron or is insufficient to prevent gravitational collapse. In other stars, particularly red giants, the balance keeps changing and the result is a variable star, such as Betelguese in Orion.

The Radiative Zone

The radiative zone starts at the outer edge of the core to the interface layer or tachocline at the base of the convection zone (from 25% of the solar radius from the center to within 30% of the surface), so represents a large proportion of the solar volume. The radiative zone is where the energy released in the core through nuclear fusion is carried by radiation to the upper layers by photons. However, although it is less dense than the core, the radiative zone is still dense enough to slow down the passage of the photons. The density at the bottom of the radiative zone is $20\,g/cm^3$ (about the density of gold) but reduces to about $0.2\,g/cm^3$ (less than the density of water) at the top. The temperature range is from 7,000,000 to about $2,000,000°\,C$. This temperature and density are still very high but not high enough to allow nuclear fusion.

The Interface Layer (Tachocline)

After the radiative zone comes the convection zone, but there is a thin layer where the two meet known as the *interface layer*. It behaves rather like a fluid and its movements are now believed to cause the Sun's magnetic field, without which solar hydrogen alpha viewing would not be anywhere near as interesting as it is. It also appears to have frequent changes in chemical composition, as heavier elements move between the other layers.

The Convection Zone

This is the outermost part of the solar interior and is where the heat from the lower layers is carried toward the solar surface. Its movements are not dissimilar from water heated on a cooker or the central heating system of a house. Warm material rises from the interface layer at $2,000,000°\,C$, then cools to about $5,700°\,C$ at the surface and expands. It then sinks back to the lower levels, while warmer material replaces it. These movements are seen as *granules* on the solar surface and give it its cell-like appearance in hydrogen alpha telescopes, calcium K telescopes, and at high magnification in quality "white light" telescopes.

The Photosphere

This is the visible surface of the Sun, as seen in "white light." Near a solar minimum, it can appear bland and uninteresting for weeks on end. The temperature is about 5,700° C, much cooler than the core, and is about 100 km thick. Near a solar maximum, it takes on the appearance of a currant pudding, even to modest instruments, as it is full of sunspots.

The Chromosphere

This is a layer above the photosphere but is of great interest to amateur solar observers, as this is what we see through our hydrogen alpha and calcium K telescopes. From the top to the bottom of this layer, the temperature rises from 6000 to 20,000° C. It is about 2500 km thick. During a total solar eclipse, it appears as a thin reddish ring surrounding the Moon. This is where its name, meaning color sphere, comes from.

Hydrogen is the main component of the chromosphere, but sodium, magnesium, helium, calcium, and iron are present. It is calcium that produces the distinctive calcium K light. This is absent in older Population II stars, which are composed almost entirely of hydrogen and helium.

The Transition Region

This is a thin layer where the corona transfers heat to the chromosphere, so the temperature at the bottom is 20,000° C, whilst at the top it is 1 million degrees. This layer contains lots of ions of hydrogen (which are difficult to see) and heavier elements, which emit a lot of ultraviolet light, which can be seen from space. As this light is absorbed by the Earth's atmosphere, it cannot be detected by amateur equipment.

The Corona

The solar corona is the outer atmosphere of the Sun. It is extremely thin and hot. It is actually as bright as the full Moon, but the much brighter photosphere renders it invisible, except during a total solar eclipse or using a special instrument known as a coronograph. The NASA/ESA SOHO Web site, which can be found using any of the popular Internet search engines, shows the solar corona, as light from the photosphere has been blocked by an instrument. One side effect of this is that many sun-grazing comets are detected by amateurs watching these SOHO images. Whilst this may be a good diversion during cloudy days, it is unfortunate that a total solar eclipse is the only opportunity most amateurs will get to see the corona first hand.

Due to observations from the SOHO spacecraft, we have discovered that the corona changes appearance quite often and it is much more prominent during a solar maximum than minimum.

The corona is also the source of the solar wind, a stream of material that flows from the Sun in all directions through space until it meets the interstellar medium (gas and dust in the galaxy between stars).

It is also the source of much larger coronal mass ejections, where large amounts of material are ejected into space. These are more frequent around a solar maximum and are the cause of aurorae and electrical disturbances on earth.

One distinguishing feature of the corona is its extremely high temperature of 1 million degrees Celsius. Although not yet fully understood, magnetic fields and flows are believed to be the main driving force. It is also a lot less denser than the solar interior.

CHAPTER TEN

Coronado Price List

This contains a list of the Coronado products and the US and the UK prices as on October 2006. In general, most of the prices have experienced a downward trend. Note that individual prices from dealers may vary and it is recommended to shop around for the best deals. Note that there are dealers in many countries outside of the United States and the United Kingdom.

Telescopes

Name	Description	US price ($)	UK price (£)	Accessories included
PST	Entry-level hydrogen alpha telescope	499	429	20 mm focal length Kellner eyepiece; Sol Ranger solar finder is built into the telescope
PST CaK	Entry-level calcium K telescope	499	439	Sol Ranger solar finder is built into the telescope

(*Continued*)

Name	Description	US price ($)	UK price (£)	Accessories included
MaxScope 40	40-mm aperture hydrogen alpha telescope	1699	1249.99	Hard travel case
Double-stacked MaxScope 40	As above but with an additional filter to reduce the bandpass to 0.5 Å	2595	–	Hard travel case
MaxScope 60	60-mm aperture hydrogen alpha telescope	3685	2799	• Hard travel case • 25-mm CEMAX eyepiece
Double-stacked MaxScope 60	As above but with an additional filter to reduce the bandpass to 0.5 Å	4999	–	• Hard travel case • 25-mm CEMAX eyepiece
MaxScope 70	70-mm aperture hydrogen alpha telescope	2999	2399	• Hard travel case • 25-mm CEMAX eyepiece • Sol Ranger solar finder
MaxScope 70 CaK	70-mm aperture calcium K telescope	2999	2399.99	• Hard travel case • Sol Ranger solar finder
MaxScope 90 Package 1	90-mm aperture hydrogen alpha telescope with BF15 blocking filter	9950	8729.99	• Hard travel case • Sol Ranger solar finder • Full set of CEMAX eyepieces with focal lengths of 12, 18, and 25 mm, with a 2× Barlow lens
MaxScope 90 Package 2	90-mm aperture hydrogen alpha telescope with BF30 blocking filter	10675	7999.99	• Hard travel case • Sol Ranger solar finder • Full set of CEMAX eyepieces with focal lengths of 12, 18, and 25 mm, with a 2× Barlow lens
MaxScope 90 Package 3	Double-stacked 90-mm aperture hydrogen alpha telescope with BF15 blocking filter	12185	10542.99	• Hard travel case • Sol Ranger solar finder • Full set of CEMAX eyepieces with focal lengths of 12, 18, and 25 mm, with a 2× Barlow lens
MaxScope 90 Package 4	Double-stacked 90-mm aperture hydrogen alpha telescope with BF30 blocking filter	12910	10975.99	• Hard travel case • Sol Ranger solar finder • Full set of CEMAX eyepieces with focal lengths of 12, 18, and 25 mm, with a 2× Barlow lens

Binoculars

Name	Description	US price ($)	UK price (£)	Accessories included
BinoMite	10 × 25 White light binoculars	99	52.99	
BinoMite II	12 × 60 White light binoculars	199	129.99	
BinoMax Canon	12 × 36 Image-stabilized hydrogen alpha binoculars		2989.99	

Filters

Filters are either bought separately to use with a "nighttime" telescope, in which case you will need a T-Max adaptor and a blocking filter, or are bought for the purposes of double stacking. Some of the packages include the T-Max adaptor.

Note that for many telescopes you will need to buy an adaptor plate to match the aperture of the filter with your telescope.

Name	Description	US price ($)	UK price (£)	Accessories included
SolarMax 40	40-mm hydrogen alpha filter with T-Max; used for double stacking a PST	1070	839.00	
SolarMax 40 with BF5	40-mm hydrogen alpha filter with T-Max and BF5 blocking filter	1099	1199.00	
SolarMax 40 with BF10	40-mm hydrogen alpha filter with T-Max and BF10 blocking filter	1450	2989.00	
SolarMax 40 with BF15	40-mm hydrogen alpha filter with T-Max and BF15 blocking filter		1399.00	
SolarMax 60	60-mm hydrogen alpha filter with T-Max; used for double stacking a MaxScope 60	2225	2099.00	
SolarMax 60 with BF10	60-mm hydrogen alpha filter with T-Max and BF10 blocking filter	2590	2099.00	
SolarMax 60 with BF15	60-mm hydrogen alpha filter with T-Max and BF15 blocking filter	2865	2349.00	
SolarMax 60 with BF30	60-mm hydrogen alpha filter with T-Max and BF30 blocking filter	3590	2849.00	
SolarMax 90	90-mm hydrogen alpha filter with T-Max; used for double stacking a MaxScope 90	4625	4199.00	

(*Continued*)

Name	Description	US price ($)	UK price (£)	Accessories included
SolarMax 90 with BF10	90-mm hydrogen alpha filter with T-Max and BF10 blocking filter	5045	4199.00	
SolarMax 90 with BF15	90-mm hydrogen alpha filter with T-Max and BF15 blocking filter	5320	4499.00	
SolarMax 90 with BF30	90-mm hydrogen alpha filter with T-Max and BF30 blocking filter	6045	4999.00	

Eyepieces

Coronado telescopes come with a standard 1.25 inch (31.5 mm) thread. This means that most standard nighttime eyepieces will work with them. However, Coronado also manufactures its own eyepieces. If you are thinking of buying a telescope, it is best to check if any of these come supplied with it first.

Each eyepiece has an apparent field of view of 52°.

Name	Description	US price ($)	UK price (£)	Accessories included
25-mm CEMAX eyepiece	25-mm focal length eyepiece	129	69.99	
18-mm CEMAX eyepiece	18-mm focal length eyepiece	129	69.99	
12-mm CEMAX eyepiece	12-mm focal length eyepiece	129	69.99	
CEMAX 2× Barlow lens	Barlow lens	129	69.99	
Full set of above	Three eyepieces plus Barlow lens	389	259.99	Carrying case

Other Accessories

Name	Description	US price ($)	UK price (£)	Accessories included
T-Max detuner 40 mm	40-mm Detuner to adjust filters	145		
T-Max detuner 60 mm	60-mm Detuner to adjust filters	245		

Name	Description	US price ($)	UK price (£)	Accessories included
T-Max detuner 90 mm	90-mm Detuner to adjust filters	345		
BF5	Blocking filter recommended for use with telescopes with a focal length < 500 mm	410		
BF10	Blocking filter recommended for use with telescopes with a focal length < 1000 mm	595		
BF15	Blocking filter recommended for use with telescopes with a focal length < 1500 mm	870		
BF30	Blocking filter recommended for use with telescopes with a focal length < 3000 mm	1595		
Solar Observers' Hat	Cap with neck drape	25.99		
Coronado Polo Shirt	Size up to XL available in light blue, dark blue, and maroon	26.99		
Coronado polo shirt	Size up to XXL available in light blue, dark blue, and maroon	29.99		
Adaptor plates	Plates used to allow filters to be used with nighttime telescopes. Price depends on the size of the telescope	155–632		
Zero length adaptor	Adaptor that allows 1.25 inch. (31.5 mm) eyepieces to be used with 2 in (51.8 mm) focusers	39		
Sol Ranger	Solar finderscope	55	34.99	
PST hard case	Carrying case for the PST	65	44.99	
MALTA mount	Tabletop mount for PST and MaxScope 40	129		

Glossary

This chapter contains a description of some of the technical terms and product names used in hydrogen alpha and calcium K viewing. It is not intended as a general glossary for astronomy.

A

Accessories

This is a general term used for anything that can be added to a telescope that will enable it to be used visually or photographically or change its behavior in some way. Many accessories used for solar viewing are exactly the same as used for general astronomy, such as eyepieces, image amplifiers, and focal reducers.

However, there are specialized accessories that are not only designed for solar viewing but some are actually *essential* to prevent damage to your eyes and/or equipment. They are as follows:

- *Filters*. These block out a large percentage of the solar light. There are broadband filters that allow light of all or many wavelengths to pass, narrowband filters that only allow light close to a specified wavelength to pass and, yes, well, there are some that are somewhat in between.
- *Optimized eyepieces*. All eyepieces will work for general astronomy but some have been designed specifically for use with solar viewing. Ironically enough, many eyepieces that are not that great for general use are actually rather good for solar viewing.
- *Solar finders*. A normal finderscope lets through too much light unless you use a filter; so some finders have been specifically designed for solar use.

These are all discussed later.

Active Region

This is a general term used by the research community to denote a region of the Sun containing active sunspots and associated features. Each active region has a serial number and is denoted AR*xxxx*, where *xxxx* is the serial number.

Afocal Adaptor

Afocal photography is also known as "eyepiece projection" and is the act of taking a photograph through a telescope using an eyepiece. An adaptor allows the camera to be held near the eyepiece to reduce camera shake.

Afocal Coupling

The act of taking photographs through a telescope eyepiece.

Afocal Photography

See *Afocal Coupling*, above.

Afocal Projection

See *Afocal Coupling*, above.

Angstrom/Angstrom Unit

This is a very small unit of measurement used to measure the wavelengths of light and other very small distances. It is 1 m divided by 10 ten times and is one-tenth of a nanometer. It is abbreviated to Å.

Annular Solar Eclipse

A solar eclipse that would be total, except that the relative distances of the Sun and the Moon, means that the lunar disc is not quite large enough to cover the solar disc, so a ring or annulus around the Moon is seen.

Antares

This is a name given to a red giant star in the constellation of Scorpius (Scorpio). It is also used as the brand name of a series of *accessories* (q.v.).

AzTech

This is a brand name for mounts and tripods.

B

Baader Filter

It is a type of "white light" filter that reduces the amount of light reaching the eye. Filters can be bought readymade or the material can be purchased in the form of sheets, which can be made into filters. Note that different thicknesses can be used for visual and photographic applications.

Bandpass

When using a filter, light slightly longer or shorter than the required wavelength is allowed to pass through. The range of wavelengths allowed is known as the *bandpass* and is measured in Å.

Bayer Filter Mosaic

A Bayer filter mosaic is a color filter array (CFA) for arranging RGB color filters on a square grid of photosensors. The term derives from the name of its inventor, Bryce Bayer of Eastman Kodak, and refers to a particular arrangement of color filters used in most single-chip digital cameras.

Bryce Bayer's patent called the green photosensors as *luminance-sensitive elements* and the red and blue ones as *chrominance-sensitive elements*. He used twice as many green elements as red or blue to mimic the human eye's greater resolving power with green light. These elements are referred to as samples and after interpolation become pixels.

The raw output of Bayer filter cameras is referred to as a *Bayer Pattern* image. Since each pixel is filtered to record only one of the three colors, two-thirds of the color data are missing from each. A demosaicing algorithm is used to interpolate a set of complete red, green, and blue values for each point to make an RGB image. Many different algorithms exist.

BCF/BC&F

This is an abbreviation of Broadhurst, Clarkson, and Fuller who distribute Meade and Coronado products in the United Kingdom.

BF5/BF10 and BF15/BF30

Proprietary names for Coronado's blocking filters see below.

BinoMite

Proprietary name for white light binoculars used for viewing the Sun, manufactured by Coronado.

BK-7

Type of glass used for the construction of achromatic lenses and binocular prisms.

Blocking Filter

Secondary filter placed near the eyepiece of the MaxScope 40–90 range of telescopes to reduce the amount of light reaching the eyepiece.

Bresser GIRO

Proprietary name for a double-headed mount that can carry two telescopes simultaneously.

Broadband

Name used to describe a filter that allows a large bandpass. Broadband filters are unsuitable for solar hydrogen alpha or calcium K viewing.

C

CaK/Calcium K

Emission line in the Sun from a layer about 2000 km above the solar surface that is associated with ionized calcium. It is sensitive to magnetic fields. It has a wavelength of 3934 Å and is toward the blue/violet end of the spectrum. Not all people are sensitive to it.

Canon

This is the name of a company that produces cameras from domestic digital models to digital SLRs.

CCD/Charge Coupled Device

One of the two main types of image sensors used in digital cameras. When a picture is taken, the CCD is struck by light coming through the camera's lens. Each of the thousands or millions of tiny pixels that make up the CCD converts this light into electrons. The number of electrons, usually described as the pixel's accumulated charge, is measured, and then converted to a digital value.

Celestron

This is the name of a company that produces telescopes and accessories, many of which are recommended for use for hydrogen alpha and calcium K viewing and photography.

Cell Structure

The solar "surface" appears smooth in "white light" views using small instruments but, in reality, it consists of "bubbles" or cells of hot gas, mostly hydrogen. This structure is visible in hydrogen alpha light, calcium K light, or sometimes in "white light" at high magnification.

CEMAX

Brand name of a special type of Plossl eyepiece made by Coronado, which have been specifically designed for solar viewing. A Barlow lens (2×) is also included in the series of products.

Chromosphere

Layer of the Sun where the photosphere (layer of the Sun visible in "white light") meets the solar corona. It is where the hydrogen alpha and calcium K emission lines originate.

Chromatic Aberration

Undesirable property of many telescopes and accessories, which cause light of different wavelengths to come to different focal points and cause color fringes in the image. This is not a problem with hydrogen alpha and calcium K viewing, as the light is all of the same wavelength (monochrome light, see below).

Chromosphere

This is the layer of the Sun that produces the color features, including hydrogen alpha and calcium K.

CMOS

Abbreviation of complementary metal oxide semiconductor. Pronounced see-moss, CMOS is a widely used type of semiconductor. CMOS semiconductors use both NMOS (negative polarity) and PMOS (positive polarity) circuits. Since only one of the circuit types is on at any given time, CMOS chips require less power than chips using just one type of transistor. This makes them particularly attractive for use in battery-powered devices, such as portable computers.

CONR

Color optimized nonraw. Mode that allows web cameras, which have outputs that include image processing to be disabled.

Convection Zone

This is the part of the solar interior where energy produced from nuclear reactions in the Core are carried to the upper solar layers and, eventually, to the surface where it shows up as electromagnetic radiation, including visible light.

Core

The core is the central part of the Sun where nuclear reactions are converting hydrogen into helium, with an associated release of energy.

Corona

The solar corona is part of the solar atmosphere, which surrounds the Sun, and is normally visible only at a total solar eclipse.

Coronado

Coronado is the brand name for dedicated telescopes, both hydrogen alpha and calcium K. It also produces separate filter systems and accessories. Its proper name is "Coronado Inc." and is now a fully owned subsidiary of Meade Instruments, Inc.

Coronal Mass Ejection

Stream of charged particles that are ejected from the solar corona into the solar system. When they meet the Earth and other planets in the atmosphere, aurorae are seen, sometimes at temperate latitudes, although more usually in polar regions only.

Creative Labs

This is the name of a company that produce advanced astronomical cameras.

CromixSun

This is a separate filter system produced by Marcello Lugli (one of the coauthors of this book). It is placed at the eyepiece end of the light path and is available in batches of 2–5 units. CromixSun units can be used independently with a general use telescope and can be transferred from one telescope to another. Use of more units decreases the bandpass, with the minimum bandpass being 0.5 Å.

CromixSun units have also been used successfully to double stack Coronado and other manufacturers' products.

D

DayStar

DayStar is the name of a company that produces filters that are placed in the eyepiece end of the optical path, similar to CromixSun in concept.

Dedicated Solar Telescope

A dedicated solar telescope is one that has been designed exclusively for narrowband viewing and photography, predominantly hydrogen alpha and calcium K. At the budget end of the market, dedicated telescopes are usually cheaper than separate filter systems, but the balance swings the other way at the top end of the market.

Double Stacking

The act of adding another filter to further reduce the bandpass of a telescope or filter.

E

Energy Rejection Filter

Broadband filter used to block infrared and ultraviolet light, with the intention of preventing damage to equipment or human eyesight.

Etalon

Narrowband filter used to allow only light very close to a specific wavelength to pass through. Typically used for hydrogen alpha light and calcium K light viewing. Also known as *Fabry–Perot etalon*.

F

Fabry–Perot Etalon

See *Etalon*, above.

Facula

Brighter region of the solar surface usually associated with a sunspot region.

Faculae

Plural of *facula*, above.

Filament

Flame-like structure on the Sun. When seen at the limb of the solar disc it is known as a *prominence* (see below) but when it is in the middle of the disc, we see it from above, so it appears like a dark line and is known as a *filament*.

Flare

Exceptionally bright region of the Sun, which is often a precursor to a *coronal mass ejection* (see above).

Focal Reducer

This is the exact opposite of an image amplifier (q.v.).

Full Aperture Filter

A full aperture filter is a filter that is placed at the objective end of the telescope in order to reduce the light coming in. Narrowband full aperture filters are the most effective but can be expensive in the larger sizes. Baader filters for white light viewing reduce the amount of light but do not restrict the wavelengths of light coming through. The other type is energy rejection filters (q.v.).

G

Ghosting

A side effect of some types of eyepiece design where a faint secondary image of an object is also produced.

GIRO

See Bresser GIRO (q.v.).

Granularity

Granularity is the property of the solar surface (Photosphere) and Chromosphere to appear like grains. This is caused by the presence of pockets of hydrogen emanating from lower levels of the Sun.

GSO

GSO is the brand name for eyepieces and related accessories available in many countries worldwide, including the United States of America and New Zealand.

H

H Alpha/Hydrogen Alpha

Emission line in the Sun from a layer about 1700 km above the solar surface that is associated with neutral hydrogen. It has a wavelength of 6563 Å and is toward the red end of the spectrum.

Helios I

This is the brand name of a forerunner of the MaxScope 70.

I

Image Amplifier

General term for a telescope accessory that boosts the magnification of any given eyepiece. The most common type is the Barlow lens.

Interface Layer

The interface layer is where the radiative zone meets the convection zone and energy and matter and exchanged between the two zones. It is a relatively narrow layer.

Interstellar Medium

The interstellar medium is the space between stars, believed mainly to consist of hydrogen and traces of other elements and believed to be less dense than any vacuum produced in a laboratory on the Earth.

K

K3CCD

This is a computer program used to assist with image capture and stacking.

Kellner

This is a type of eyepiece, not commonly used but supplied with the Coronado PST.

Knight Owl

This is a brand name of low-cost eyepieces, which have proved suitable for hydrogen alpha viewing.

L

Long Eye Relief (LER)

Type of eyepiece where the image can be viewed at a further distance than other designs. They are particularly useful for spectacle wearers and are suited to photography.

LPI

This is the abbreviation for the Lunar and Planetary Imager, produced by Meade Instruments and is used for taking astronomical photographs.

Lumicon

Lumicon is a company that produces full aperture filters that are probably described as being best in the gray area between narrowband and broadband, with a bandpass of 1.5 Å. They are not as effective as narrowband filters but do show prominences. They can be used with terminal light path filters (q.v.) to achieve a narrower bandpass.

Luminance

"Luminance layering" is a technique that has been developed independently by Dr Kunihiko Okano and Robert Dalby. It allows astroimagers to overcome the "tricolor" hurdle. When used with RGB filters it is referred to as "Luminance layering" or "LRGB" technique (the "L" referring to "luminance"). The technique can be used with other color filters such as CMY (cyan, magenta, yellow) filters or with film images with comparable success. The basic premise of luminance layering is that by combining an unfiltered high-resolution and high S/N grayscale image with the weaker color data, we can "buy back" the signal and detail lost in our filtered RGB exposures. The end result potentially should be a more aesthetically pleasing high-contrast color image.

Lux Value

The amount of visible light per square meter incident on a surface. 1 lux = 1 lumen/square meter = 0.093 foot-candles

M

Magic Box

This is the part of the Coronado PST that houses the etalon (q.v.) and Sol Ranger (q.v.).

Magnetic Field (Solar)

The solar magnetic field is believed to be the main cause of all the interesting features that we see on the Sun, whether in white light or using narrowband filters.

Magni Max

Proprietary type of *image amplifier* (see above) manufactured by Astro Engineering. It increases the magnification of a given eyepiece by a factor of 1.6 times.

Main Sequence

This is the part of a star's life cycle where it is converting hydrogen into helium, just where the Sun is right now!

Maksutov

Type of reflecting telescope designed to reduce chromatic aberration and produce high-quality images.

MALTA

Proprietary tabletop mount available from Coronado recommended for use with the PST and MaxScope 40.

Manfrotto

This company manufactures mounts and tripods.

Maunder Minimum

Period in the seventeenth century when sunspot activity was exceptionally low and was associated with low temperatures on Earth.

MaxScope

Proprietary name for a range of purpose-built hydrogen alpha telescope built by Coronado. They are sometimes referred to as SolarMax dedicated telescopes but, for the purposes of this book, I have used MaxScope to refer to dedicated telescopes and SolarMax for separate filter systems.

Meade

This is the short name for Meade Instruments Inc. As well as being a major manufacturer and retailer of telescopes and accessories, they are also the parent company of Coronado Inc.

Micro Observatory

This is a solution devised by coauthor Larry Alvarez to combat the problem of using a laptop computer to capture images in bright sunlight.

Monochrome Light

Light that is of the same wavelength. The term "monochrome," as used for "black and white" television, is in fact used incorrectly. Hydrogen alpha and calcium K are examples of monochromatic light.

Moonfish Group

These are makers of eyepieces and accessories that I often use for nighttime and solar viewing.

N

Nagler

This is a type of eyepiece available only to the financially gifted or irresponsible but is very, very good or maybe even better than that!

Nanometer

This is one billionth of a meter and, like the Å, is also used to measure very small distances, such as light wavelengths. It is commonly abbreviated to "nm." There are ten Å in a nanometer.

Narrowband

Term used to describe filters with a low bandpass, which allow only light very close to a specific wavelength to pass through.

NearStar

This (like the Helios I) is a forerunner to the MaxScope 70.

Newton's Rings

The term sounds like something scientific and desirable but is the opposite, being an interference pattern that can appear when taking photographs.

Nikon

This company manufactures cameras, many of which can be used for solar astrophotography.

P

Paint Shop Pro

This is a piece of software used to improve the quality of digital images after capture.

Personal Solar Telescope/PST

Proprietary name for the entry-level hydrogen alpha telescope built by Coronado.

Photoshop

This is a piece of software used to improve the quality of digital images after capture.

Photosphere

Visible layer of the solar "surface," visible in "white light."

Pixelated/Pixelation

Output with large, coarse-looking pixels. Using too high a resolution (pixels smaller than the output device can produce) increases the file size and slows the printing of the image; furthermore, the device will be unable to reproduce the extra detail provided by the higher resolution image.

Plage

Exceptionally bright area of the solar surface.

Plossl

Commonly used type of eyepiece, suitable for visual use.

Population I/II/III

These terms refer to the relative ages of stars, with Population I (which includes the Sun) being the youngest.

PostProcessing

This is the act of improving digital images following capture using a tool such as Paint Shop Pro (q.v.), Photoshop (q.v.), or similar. There are several techniques available for general photography but solar imaging often requires specialized use. For a detailed description, see Nick Howes's Chapter 5.

Prominence

Flame-like solar structure, which appears on the limb of the solar disc.

PST

This is a short name for Personal Solar Telescope (q.v.).

R

Radiative Zone

This is the part of the solar interior just outside the Core, where energy radiates to the higher levels/zones of the Sun.

Registax

This is a nice piece of free software that is used to stack and process astronomical digital images.

Revelation

This is a brand name of eyepieces and also a range of telescopes. Revelation Plossls work well with Coronado dedicated telescopes and do not cost the Earth.

Riverside Telescope Makers' Conference (RTMC)

This is the largest Astronomy exhibition in the Western United States. It is an annual event, held at Memorial Day Weekend (usually weekend of 29 May). Their website is at http://www.rtmcastronomyexpo.org/.

S

Skywatcher

This is the brand name for a large range of telescopes and accessories produced by Synta of China. They produce reasonable quality equipment at a low price, ideal for the financially challenged.

SolarScope

SolarScope is a direct competitor of Coronado, especially in the mid-range of equipment.

SolarView

This is the brand name for dedicated solar telescopes produced by SolarScope (q.v.).

Sol Finder

This is the SolarScope version of the Sol Ranger (q.v.).

Soligor

This is another equipment manufacturer.

Sol Ranger

Proprietary name for the solar finder built by Coronado. There are two types – the one that comes as built-in with the PST and the other used with the MaxScope series of telescopes, which is a separate finderscope.

SolarMax

Proprietary name for separate filters built by Coronado.

Solar Projection

Technique used to use a telescope to project the Sun's image onto a card or screen so that sunspots and other white light features can be seen. Not used much now, due to the presence of filters that allow you to see and photograph the Sun directly.

SolarScope

Manufacturer of competing products based in the Isle of Man.

Sony

Sony produces lots of things but, for our purposes, the most important are digital cameras.

Spicules

Small "spikes" at the edge of the solar disc that can be seen in hydrogen alpha light. They are usually seen in the larger apertures.

Spectrohelioscope

Research-grade instrument used for viewing the types of features that can now be seen in hydrogen alpha telescopes.

Starlight Express

Whilst many people think of Andrew Lloyd Webber, this company manufactures dedicated CCD cameras for astrophotography.

Sunspot

Sunspots are darker regions of the photosphere that are about 1800° cooler than the rest of the photosphere. They are caused by solar magnetic fields.

Super Wide Angle

Type of eyepiece with an increased apparent field of view of 70° or more.

Sweet Spot/Sweet Band

Areas in the view through a hydrogen alpha telescope that show more detail than the rest of the view.

T

Tachocline

This is another name for the interface layer (q.v.).

Televue

These are manufacturers of high-quality equipment but not for the financially challenged.

Terminal Light Path Filters

These are placed at the eyepiece end of a telescope. Although, in general, they are not as effective as full aperture filters (q.v.), they provide a cheaper alternative for larger aperture use. They can also be used to lower the bandpass of full aperture filters, especially budget ones with a bandpass of 1.5 Å.

Thousand Oaks

This company is better known for white light filters but also manufacture hydrogen alpha filters and, thus, is a competitor to Coronado.

T-Max

Proprietary name for filter tuners built by Coronado. It is sometimes referred to as a "detuner." Its purpose is to adjust the central wavelength of the etalon to allow for features that are Doppler shifted toward or away from the Earth and to adjust filters to show prominence or surface detail.

Toucam

The Toucam is a popular webcam used to capture multiple images of objects.

Transition Region

This is a part of the solar interior.

W

WDM Mode

Windows driver model. Microsoft standard for driver access.

Webcam

Abbreviated form of "web camera," which gives a high-quality, low-cost means of astrophotography.

White Light

General term for the collection of light emitted by the Sun in visible wavelengths.

Y

Yellow Dwarf

This is a type of star, of which the Sun is the closest example. The term "dwarf" is a bit of a misnomer because there are more stars smaller than the Sun than larger.

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