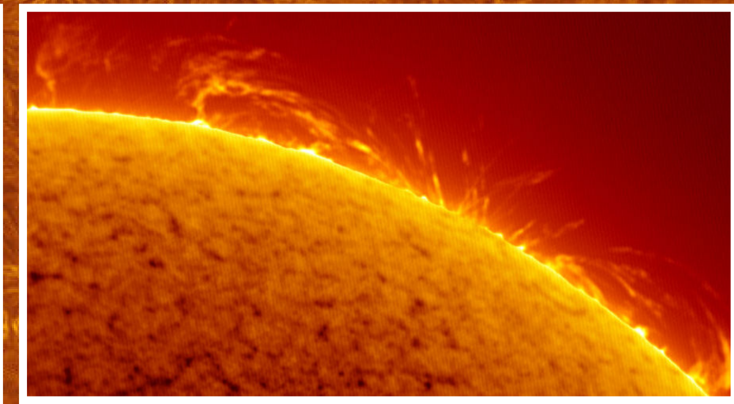
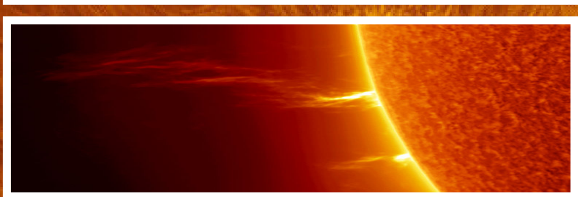
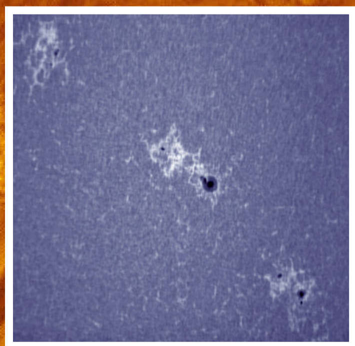
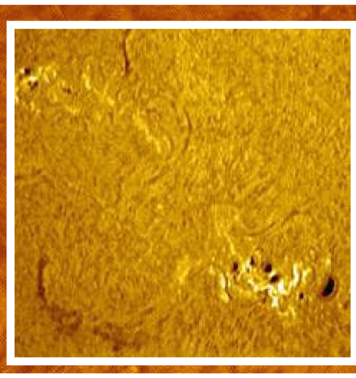
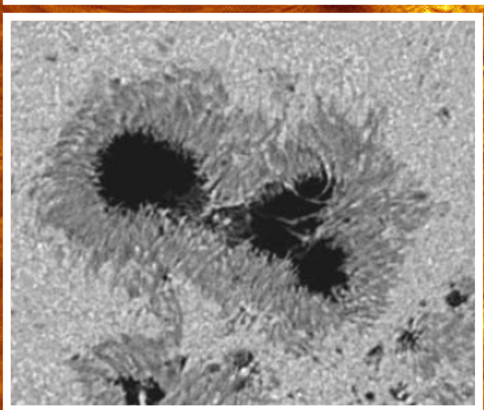
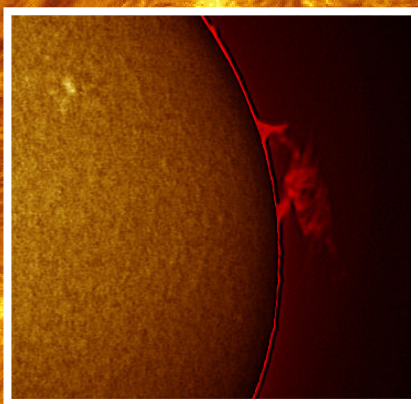
SOLAR OBSERVER

The First Magazine of Solar Astronomy 2010 ISSUE 1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- *Fine structures in solar radio burst emission – nice patterns, only?*
- *The major causes of space weather and how to detect them*

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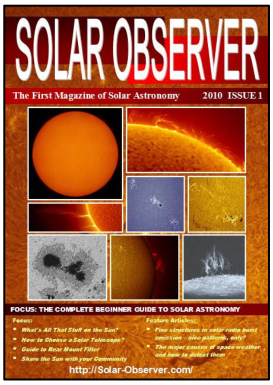

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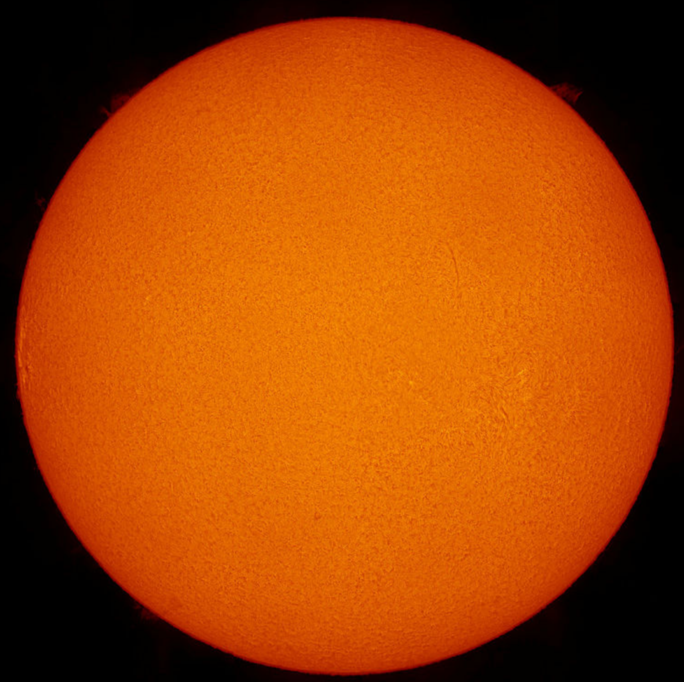
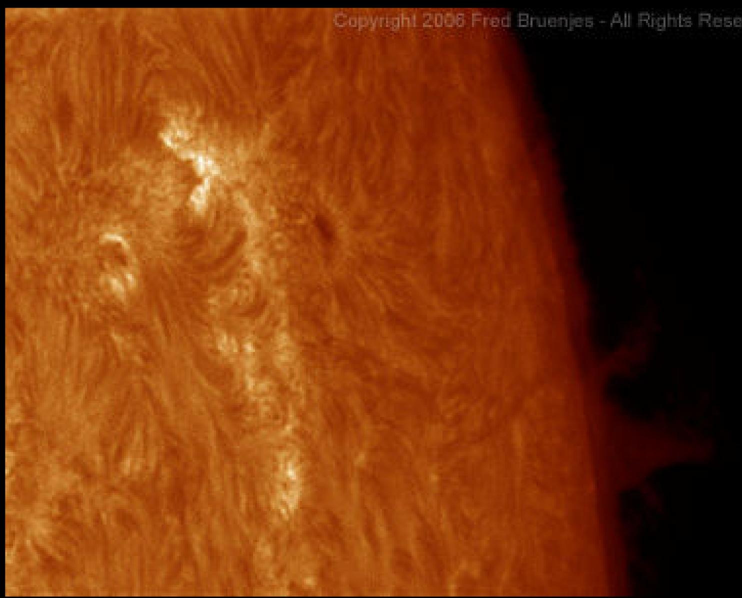
Feature Article

Gear Talk

Content





Fine structures in solar radio burst emission – nice patterns, only?

Henry Aurass
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In years of low solar flare activity it is worth pondering about interesting but more complex events from the whole set of earlier assembled data. Here I try to explain some of the information content of spectral fine structures in solar radio bursts. Let me start with a brief introduction about the solar corona and solar radio emission.

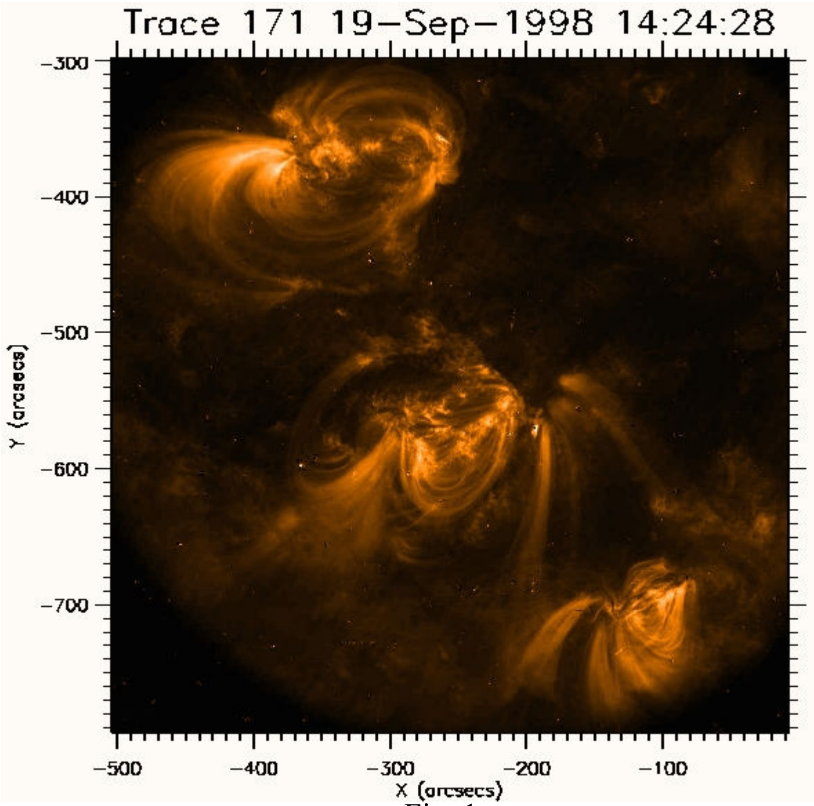

Fig. 1

The solar corona consists of extremely dilute and hot (1.4 Mio Kelvin, on average) and thus fully ionized matter – plasma. It is structured by the solar magnetic field varying in dependence on the source position at the surface and the height level in the corona between some 100 to < 1 Gauss at 0.1 solar radii above the photosphere. The magnetically determined structure formation traces back to the fact that electrons and protons gyrate perpendicular to the local magnetic field and that all particle motion on larger scales is guided parallel to the field direction. This leads to the anisotropy of mean parameters as plasma pressure, heat conduction, resistivity etc.

Already solar occultation observations revealed that the corona is a highly inhomogeneous medium. With orbiting telescopes the coronal ultraviolet light in continuum and spectral lines – for groundbased observers invisible due to its absorption in the earth atmosphere - can be directly seen. Ultra-violet and X-ray radiation is the spectral range where the corona is brightest.

As an example, in Fig.1 a corona image taken by TRACE (The Transition Region And Coronal Explorer [1], prepared from the TRACE data base at http://trace.lmsal.com/trace_cat.html) in the 171 Å iron line reveals plasma structures with temperatures between 0.2 and 2 Mio. K. The image shows a part of the South-East quadrant of the Sun with three active regions. Distinct flux tubes of different spatial scale radiate in that temperature range. This is an argument for the existence of local atmospheres within the flux tubes. Such plasma-magnetic field configurations are called coronal loops.

Coronal loops with internal densities between 10^{11} and 10^{7} electrons cm^{-3} contain the source sites of “nonthermal” decimeter and meter wave radio emission between 3 000 and 30 MHz. This emission is excited by energized electrons which occur in magnetic loops during coronal flares but also during coronal mass ejections. The radio emission signal leaves the coronal plasma and propagates through the interplanetary space to the earth and beyond. The high brightness of nonthermal emission at a certain frequency is quite in contrast to thermal (equilibrium) emission not a direct measure for the (equilibrium) temperature of the radiating body, and follows different spectral laws.

Electron beams accelerated to speeds of about 0.3 of the velocity of light during the dynamic interaction between neighboring magnetic loops lead to comparatively short radio pulses at a given observing frequency occuring with some time delay at lower frequencies, too. In the dynamic frequency spectrum recorded by radio spectrometers an intense trace (dark in the AIP radio spectra shown in Fig. 2, from [2]) starts at high, and decays after drifting and broadening of the signal at lower frequencies. This is called a type III burst – probably the most popular solar radio signature at all. Under certain conditions the electron beam can differently develop in the magnetic loop configuration: its emission can decay before reaching the loop top thus forming a type III with a small total bandwidth as in Fig. 2a. In contrast, the beam can also pass the top of the loop and return downward to its second magnetic footpoint. The corresponding radio spectral signal is the inverted U-type burst.

The beam can also travel along the outer magnetic field envelope of the closed loop in a field structure which is open toward the solar wind. Such type III bursts can be observed down to frequencies far below the ionospheric cut-off frequency and recorded by radio detectors on spacecrafts (e.g. the WIND-WAVES experiment) to frequencies < 1 MHz.

If coronal energy release processes lead to the formation of an isotropic ensemble of energized electrons without a dominant velocity in space as in the case of a beam, the electrons excite a radio continuum out of the whole loop structure in which they are "magnetically trapped" and bounce between the "mirror points" of the loop structure [6]. The radio wave emission is the consequence of the fast formation of an under-represented range – a gap – in the isotropic electron velocity distribution. This is due to the precipitation and loss of those electrons with field-parallel initial velocities which penetrate the mirror points and are thermalized by collisions in the denser atmosphere near the magnetic loop footpoints. After the formation of this gap we say the electrons have a "loss-cone distribution" in the velocity space [6] which has an x-axis in field-parallel and a y-axis in field-perpendicular direction.

Fig. 2b (from [2]) shows a contrasting example. We see a dark, smoothly enhanced background (a broadband continuum) interrupted by a sequence of black-white striated drifting patterns. These have the same drift rate and spectral envelope as the type III bursts recorded at the same

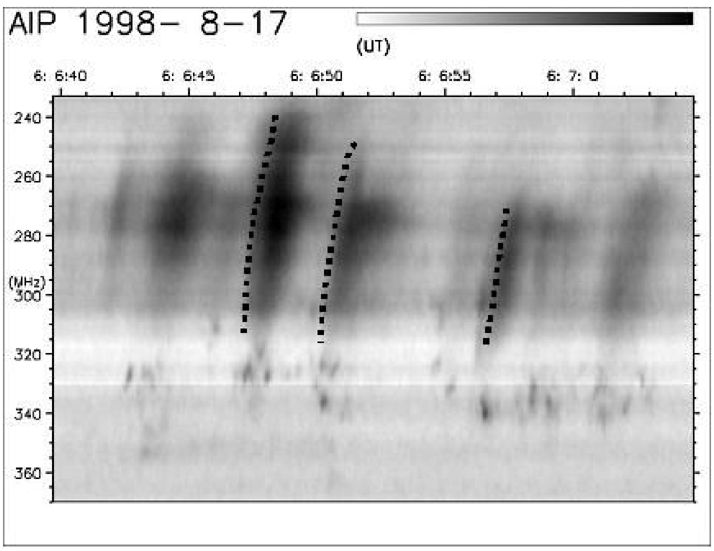

Fig. 2a

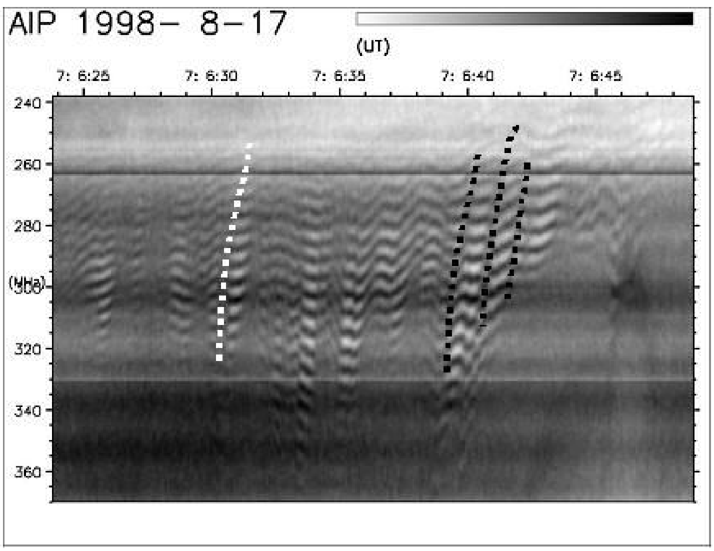

Fig. 2b

frequencies about 1 hour before. The drift rate is enhanced by the dashed lines for guiding the eye. Moreover, as a function of frequency, the radio flux density is heavily modulated in the type III envelopes from stronger than the surrounding continuum down to the pre-event background level (white in this image). How to understand this strange pattern?

In [2] an answer is presented. The authors found that the high complexity of the observed pattern reduces the number of models to a single one as follows: the radio source is formed by three different nonthermal electron ensembles which are superposed on the undisturbed coronal background plasma, and must be coupled in its parameter range. Firstly, a loss-cone distributed electron ensemble is needed to supply the radio continuum emission. In the rhythm of re-occuring type III burst envelopes, electron beams are injected into the source which, for a short time, fill the loss cone and switch-off the continuum emission at those levels in the radio source which are just passed by the beam. This means the continuum is suppressed in that time leading to the white background effect in the type III trace. Simultaneously with the field-parallel propagating beam, as a third component, a group of hot electrons gyrating perpendicular to the field with a high speed (as compared with the mean speed of the continuum-exciting ensemble) is necessary to emit the dark stripes at higher harmonics of the local gyroresonance frequency. Frequency drifts of the stripe patterns as sometimes visible in Fig. 2b, e.g. at 07:06:40 UT, reveal changes of the magnetic field in the source volume.

The described interplay of three different plasma processes acts only in a narrow common parameter "window" relating the electron ensemble properties in detail with each other. This explains our finding that such patterns as shown in Fig. 2b are comparatively rare despite of the fact that sometimes – perhaps always – in coronal radio sources a multitude of nonthermal electron ensembles coexists even if not directly visible in the radio burst spectra. This is easy to presume but it was demonstrated by the discussed observation and theoretical explanation for the first time.

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THE MAJOR CAUSES OF SPACE WEATHER AND HOW TO DETECT THEM

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We all know about the Sun and its importance to us all. It helped to create us and it sustains us – without the Sun life on Earth would never have existed. There is not a single form of energy here on Earth that did not originate from the Sun or the cloud from which the Sun and planets formed. (Go ahead and try it, think of any form of energy and trace it back through all of its changes to its origin.)

Although the big-picture view of the Sun is known to everybody, in this ever-increasingly technological world in which we live more subtle effects from the Sun begin to make their presence known. Further, as we become more and more technologically advanced, these effects become more and more significant. I am referring to the phenomenon known as space weather.

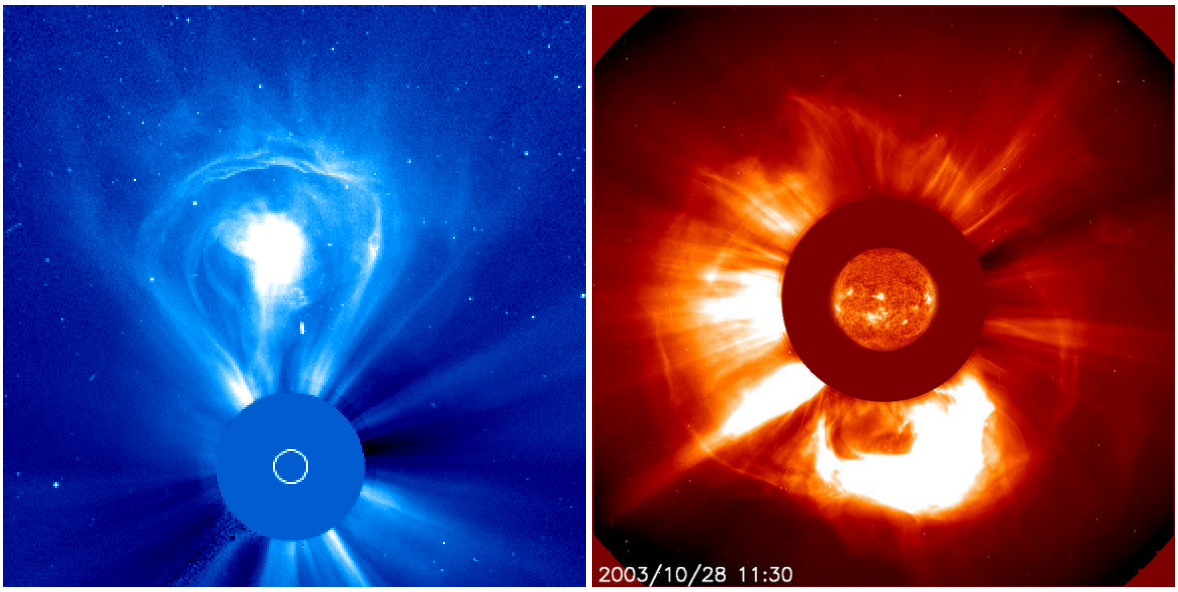

Figure 1: *Two images of coronal mass ejections (CMEs) as observed by spacecraft coronagraphs. These coronagraphs are part of the Large Angle Spectroscopic Coronagraph, or LASCO on board SOHO. The solid disk (blue on the left, red on the right) is the occulting disk and the white circle in the left image represents the surface of the Sun. On the right an extreme ultraviolet image of the Sun has been included and is to scale. The CME on the left is the loop structure extending away from the Sun and the one on the right appears to encircle the Sun because it is heading towards us. This type of CME is called a halo CME. Images courtesy of NASA/ESA.*

The term "space weather" covers a large variety of phenomena, but the most important to us is the most intense form of space weather called the (geo)magnetic storm. Magnetic storms are large disruptions to the Earth's magnetic field that oscillate and reconfigure geomagnetic field lines, drive currents in the ionosphere and increase charged particle density in the ionosphere and magnetosphere. Consequently, they are known to be responsible for a variety of damaging effects to our infrastructure. Some examples include spacecraft damage and destruction, power station damage, communications disruption and increased radiation dosage to aircraft pilots, passengers and astronauts. One magnetic storm in March 1989, for example, left millions of people without electricity for 9 hours while another storm in January 1994 damaged spacecraft and cost the parent company around 70 million dollars [1]. The damaging potential of magnetic storms combined with the increasing demands for more advanced technology by society have made the study of the causes of major space weather a high priority for research, technological and defense institutions.

The Cause of Space Weather (Magnetic Storms)

Contrary to popular belief, these major space weather events are not caused by solar flares. They are caused by solar eruptions that are often associated with flares, which is why they are often mistaken for being caused by them. There is also a historical blunder here, as the solar eruptions that actually cause magnetic storms were discovered a century after flares were, when a thriving flare research community had been established. They would not give up their firmly-held beliefs (and livelihood) without a fight and to this day most people outside the professional solar and space communities believe in the Solar Flare Myth [2].

Magnetic storms are actually caused by coronal mass ejections. Coronal mass ejections, or CMEs are large massive eruptions of plasma and magnetic field from the Sun. They are known to contain masses in excess of 10^{13} kg and can achieve speeds as high as 4000 km/s (14 million km/hr). The energy contained in a CME is over a factor of 10 greater than that in a solar flare. As their name implies, they are only detectable in the solar corona, and so it is necessary to block out the bright light from the solar disk to reveal the fain corona. This is achieved either during a solar eclipse, or by instruments known as coronagraphs.

Coronagraphs block out the solar disk permanently with a disk in the instrument called an occulting disk. Unfortunately even coronagraphs cannot easily detect CMEs, which is why they were not officially discovered until 1973 when we had begun flying coronagraphs on spacecraft. Since their discovery we have developed more and more sophisticated instruments for detecting them, and they are today observed regularly. Figure 1 shows how CMEs appear in coronagraphs. Note the event on the right, which appears to encircle the Sun, is a CME that is heading towards the Earth.

A number of spacecraft have flown coronagraphs over the years (Table 1) and we now know a great deal about these eruptions. We know that their occurrence rate increases with the rise in the solar cycle and that the launch location moves from the solar equator to allover the Sun as the cycle moves toward maximum. We know about the varieties of structures, from erupting loops to so-called “streamer blowouts” to thin jets of material, and we know about their speeds, accelerations and masses. We even have a good idea for why they erupt – it is the Sun trying to remove large amounts of built-up magnetic energy – and we have a good idea of how they end their life in the outer heliosphere. We also know that CMEs, not solar flares, are the primary source of severe space weather at the Earth, and we understand (for the most part) the mechanism by which CMEs achieve this.

Aside from all those things we know, there are still a number of unknowns about CMEs. For example, we do not yet know what causes them, from where in the solar atmosphere they originate or the physics describing their evolution as they continue away from the Sun through the heliosphere. Working on these questions is a community of scientists with tools at their disposal including mathematical models and a large suite of

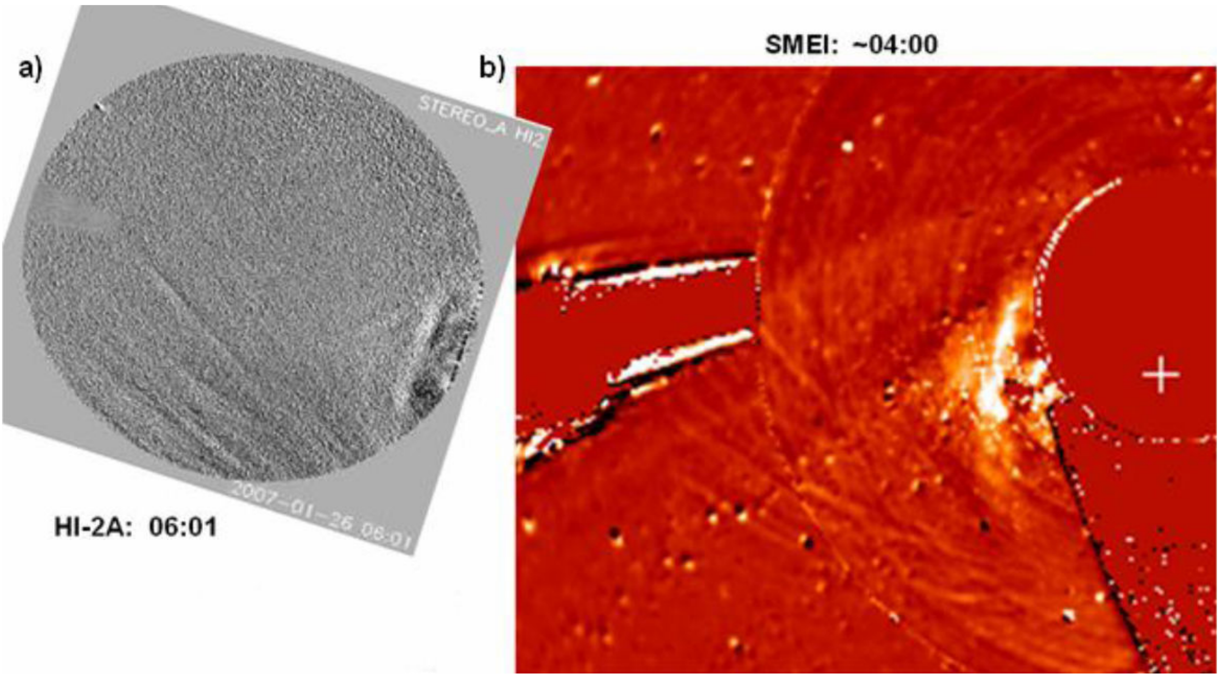

Figure 2: Images of a CME obtained with a) SMEI and b) HI at 06:01 and 04:00 on 26 January 2007 respectively (From Figure 4 of Webb et al. (2009) [4]). In both cases the Sun is to the right and the + in the SMEI image is its location. The CME is the bright structure towards the right of both images. The streaks toward the bottom are from Comet McNaught, which was passing through the sky at this time.

ground-based and spacecraft data. Among this community are myself and some of my colleagues at the Southwest Research Institute.

While coronagraphs have enhanced our understanding of CMEs and space weather a great deal, they do have their limitations. One major problem is that coronagraph images of CMEs are only projections into the sky plane and contain no depth information. How can we tell, for example whether a CME is moving slowly or just looks like it is slow because its images are heavily projected? How can we identify three dimensional structural information about a CME when we only see it in two dimensions? To make matters worse, the CMEs that are of most interest to us (the ones heading directly towards us) are also the ones that suffer the largest projection effects. This limits the ability of individual coronagraphs to improve our understanding of CMEs beyond what we already know, and it also limits our ability to use them for space weather forecasting.

Recent attempts have been made to overcome these projection problems. Most notably is the launch of the *STEREO* spacecraft in October 2006. *STEREO* is a unique spacecraft pair that shares an orbit about the Sun with the Earth, but with an increasing angular separation between each other and the Earth. One spacecraft leads the Earth while the other lags, and the separation increases by around 22° each year. As they move apart their coronagraphs observe CMEs at the same time from different viewpoints, so geometry can be used to remove the projection effects and identify 3-D information about the CME. Developments in this area are still new [3].

Heliospheric Imagers

More recently, more sophisticated instruments have been able to identify and image the very faint CME further from the Sun as it moves through the heliosphere. These represent a major advance to CME study because they can monitor how the structure, speed and acceleration change as CMEs evolve through the solar wind. The first instrument capable of observing them at large distances from the Sun was the E9 zodiacal light experiment on board the *Helios* spacecraft pair (launched 1974 and 1976). This had a very limited field of view and it was not until 20 years after *Helios* that an (almost) all sky version was launched. This was the Solar Mass Ejection Imager (SMEI) which was launched in 2003 and continues to operate to date. The *STEREO* spacecraft, launched in 2006, also carry such an instrument, called the Heliospheric Imager or HI. Figure 2 shows images from HI (a) and SMEI (b) of a single CME observed in January 2007. While they do not detect every CME that is observed by coronagraphs, a large number have been detected and we are beginning to understand more about their evolution.

One discovery about CME evolution made possible by heliospheric imagers is that the physics describing their movement through the interplanetary medium is more complicated than we once thought. Many workers assumed that once the CME had left the Sun its propagation would be governed entirely by the surrounding solar wind. Fast CMEs would slow down and slow ones would speed up in order to equalize their speed with that of the solar wind. We are now aware of a type of CME that do not behave this rule, specifically that some fast CMEs are known to speed up as they move through the heliosphere [5].

Name	Launch Date	End Date
OSO-7	29 September 1971	9 July 1974
Skylab	14 May 1973	11 July 1979
Helios 1	10 September 1974	1982
Helios 2	15 January 1976	1982
Solwind	24 February 1979	13 September 1985
SMM	14 February 1980	2 December 1989
The Shuttle	8 April 1993	7 November 1998
SOHO	2 December 1995	Continues to date.
Coriolis	6 January 2003	Continues to date.
STEREO	25 October 2006	Continues to date.

Table 1: Spacecraft that have flown coronagraphs and heliospheric imagers over the years.

Aside from the advantages of tracking CMEs all the way from the Sun to the Earth, heliospheric imagers also provide us with an opportunity to remove the projection problems we are faced with in coronagraphs. Simply put, the geometrical laws and the physics that enable us to observe CMEs (called Thomson scattering) necessarily remove 3-D information from coronagraphs. They do so, however, with the advantage of far simpler analysis of coronagraph images. With heliospheric imagers this breaks down, and while the analysis becomes far more complex it does so with the advantage that 3-D information is retained. So, with careful analysis of heliospheric images of CMEs we can dig through the analysis and extract the 3-D parameters. This represents a major advance in CME analysis.

Figure 3 shows one such reconstruction for a CME that was observed in November 2007. The locations of the Sun, Earth and both *STEREO* spacecraft at the time of observation are shown. This image not only demonstrates the enormous structure that is the CME, but it was reconstructed purely from heliospheric images of this event. Comparisons with other

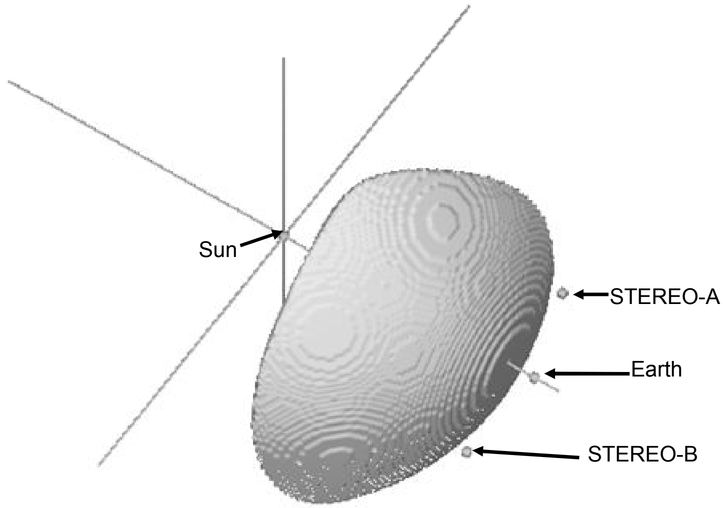

Figure 3: Three-dimensional reconstruction of a CME using entirely heliospheric image data from SME and the HIs [6]. The location of the Sun, Earth and both STEREO spacecraft at the time of this event are indicated. This demonstrates the utility of heliospheric image data for accurate CME reconstruction (removal of projection effects).

observations of this event from other spacecraft have shown this to be a fairly accurate representation of the structure of this particular CME.

Concluding Remarks

Coronal mass ejections are very difficult to detect, only noticeable when we are able to observe the solar corona. We have instruments capable of observing them there, and while they have provided us with a great deal of information about them, they are limited in what they can tell us (3-D information, for example). A new class of instrument capable of observing CMEs when they are even harder to detect are now available, called the heliospheric imager. A heliospheric imager needs to be able to observe brightness levels of the same order as a 10th magnitude star. Not only is their observation here difficult, but the necessary analysis for interpreting heliospheric images is far more complex than coronagraph images. The hard work in detection in analysis does pay off, as we can use heliospheric imagers to extract 3-D information about CMEs in ways that no other instrument can.

By writing this article I hope to raise awareness of both coronal mass ejections and of heliospheric imagers. It is important to debunk the continuing popular belief that major space weather events – magnetic storms – are caused by solar flares. They are not. The energy contained within even the brightest solar flare is insignificant compared with your average CME, and it is the CME that is responsible for the most severe magnetic storms. CMEs are not only an important mechanism for driving space weather at Earth, but they are also important for the evolution of the Sun. They are therefore crucial phenomena worthy of far greater appreciation than is currently provided by the general public.

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Short-term and Long-term Variations of Solar Activity

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The solar parameter of longest history is the sunspots. Study of sunspots can be trace back to 1612, when it was first discovered by Galileo. Through the monitoring sunspots, he showed that the sun rotated once every 27 days and that the spots themselves changed. Later in 1844, Schwabe discovered that the variation of sunspot numbers had a cycle of approximately 11 years. This discovery inspires Rudolf Wolf to carry out systemic observation of sunspots and introduction of a method of quantifying sunspot activity, which is known as Wolf sunspot number. Wolf succeeded in reconstructing a relatively believable variation in the sunspots number back to 1755, therefore the cycle that developed between 1755 and 1766 is taken by convention as cycle 1. The average cycle is approximately 10.5 years but there have been cycles as small as 7 years and as large as 13 years. The cycle 23, from 1996 to 2009, has just ended and lasted more than 13 years.

When only annual values are taking into account, the plot of sunspot numbers shows just one peak about 4 to 5 years after sunspot minimum. In contrast, with finer time scale data (12 month averages), two distinct peaks separated by a few months appear during the sunspot maximum. These peaks and their corresponding gaps - Gnevyshev peaks and gaps, were first discovered by Gnevyshev in 1967 in coronal green line index. In cycle 23, the peaks appear in early 2000 and late 2001. These peaks appear in many other solar parameters (Fig. 1). For solar electromagnetic radiations, such as Lyman-α, 2800 MHz radio emission, the peaks were coincide with the sunspot number, however, in some corpuscular radiations, notably coronal mass ejections (CME), the peaks are displaced by several months.

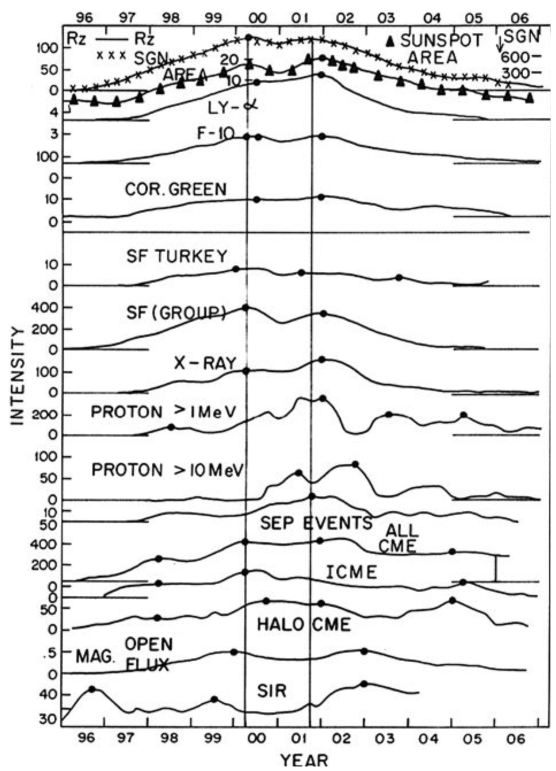

Fig. 1: The 11-year cycle (1996-2006) of several solar parameters. Rz and SGN, Sunspot numbers (crosses joined by line), Sunspot area (triangles), Lyman-alpha, 2800 MHz solar radio emission (F-10), Coronal green line index, Solar flare indices (SF) f Turkey and NOAA group, X-ray and Proton fluxes, Solar energetic particles (SEP), CMEs, ICMEs, Magnetic open flux, and stream-interaction regions (SIR). The two vertical lines indicate the two Gnevyshev peaks.

The peaks displacement is linked to the nature of solar atmosphere. Solar atmosphere is highly dynamic, with the strange fact that the solar corona has a temperature of few millions degrees Celsius, while the solar surface, photosphere has only about 6000 degree Celsius (Fig. 2). Thus, the corona is getting extra energy from somewhere. However, there is no hot body around the Sun, so the heat is coming from the interior of the sun, which is known to have temperatures of several tens of millions of degree Celsius. There are two hypotheses explain how the heat from solar interior reach the corona.

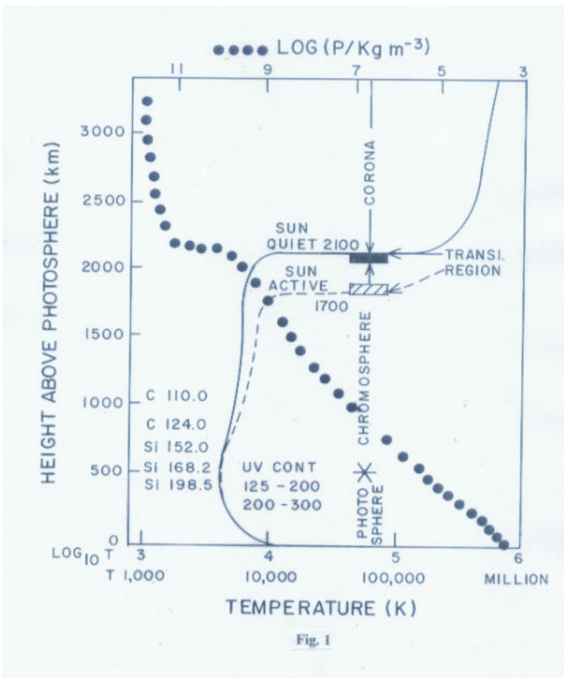

Fig. 2: The temperature structure in solar atmosphere, low (~6000 degrees) at the photosphere, ~10000 degrees in the

chromosphere (upto 2000 km altitude), ~100000 degrees in the transition region (1700-2100 km altitude), and millions of degrees in the corona (above 2100 km altitude).

First hypothesis suggested that Alfvén waves from the interior of the Sun flowing out from it surface and dissipated in the corona, thereby heating it up. This hypothesis is faulty because it cannot explain why Alfvén waves dissipate only in the corona, bypassing the lower solar atmosphere, chromosphere.

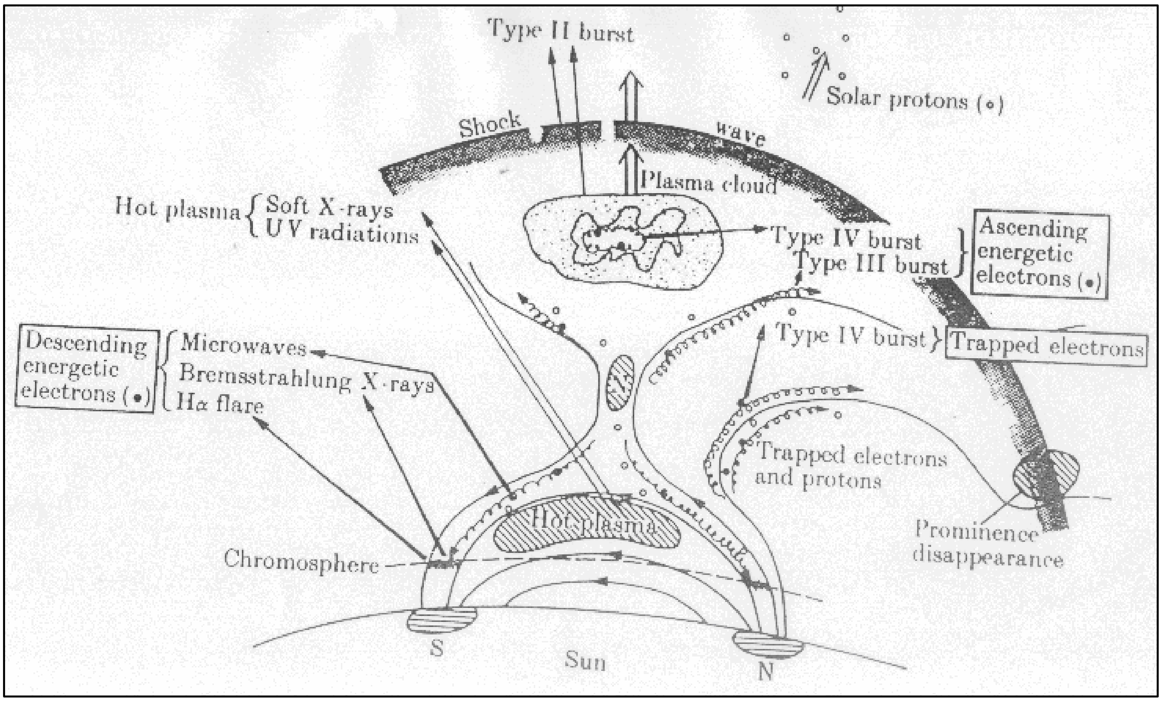

Fig. 3: Model of a Solar Flare.

Another hypothesis is linked to magnetic field annihilation. When magnetic field bubbles out of the solar surface, it forms magnetic loops, with one pole on one sunspot and another pole on another sunspot. Thus, sunspots appear in a bipolar pairs, with a preceding and a following spot connected by a magnetic loop. The bipolar pairs are very stable structure and can persist for several days. Such structure has fixed magnetic polarity. For example, the preceding spot is positive and following spot is negative. When there is another sunspot pair with opposite magnetic structure approaching, i.e. the preceding spot is negative and the following spot is positive, the magnetic loops can cancel each other out (Fig. 3). This might lead to the destruction of bipolar structures and tremendous amount of magnetic energy is converted into radiation and kinetic energy and a solar flare occurs. It involves energies equivalent to several atomic bombs exploding within a few minutes. A part of this energy leaves the Sun as solar flare and ultraviolet radiation. Some of the energy flow to the solar atmosphere.

Although the sunspot pairs are located on the solar surface photosphere, but the top of the magnetic loops is extended into the corona. Therefore, the annihilated magnetic energy can deposit in the corona, while the chromosphere remains unaffected. The heated corona tried to transmit the heat downwards, but it was resisted by dense chromosphere. As a result, there is a thin transition region (Fig. 2) where temperatures are ~100000 degree Celsius (much cooler than corona) while the chromosphere heated up to only ~10000 degree Celsius.

The solar atmosphere is highly dynamic, in which the photosphere and corona possess different temperatures and dynamic upheavals. This explains why the Gnevyshev double peaks displaced in the coronal emission. Since there are a few big solar flares accompany with hundreds of smaller flares, where all heat deposited in the corona, maintaining the high temperature of corona.

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Importance of Studying Direction of Propagation of Coronal Mass Ejections

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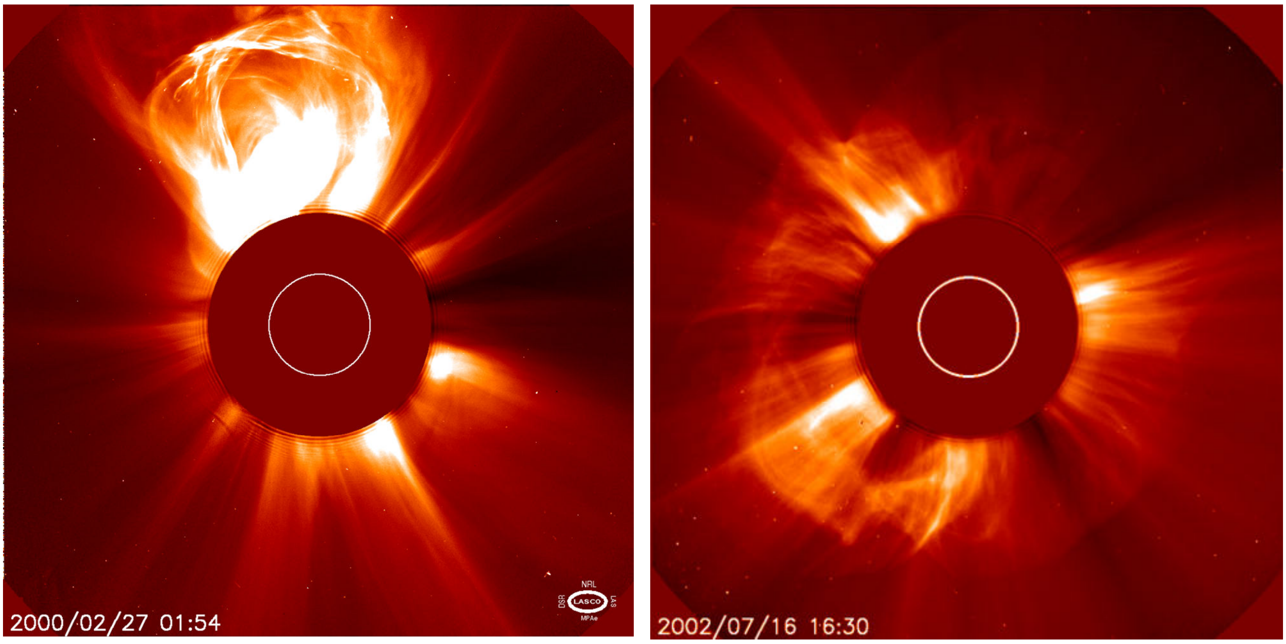

Fig. 1 *Left: The limb CME on 27 February 2000, as observed by the LASCO-C2 coronagraph. Right: The halo CME on 16 July 2002, as observed by the LASCO-C2 coronagraph. The white circle indicates the solar disk. (Courtesy of SOHO/LASCO consortium).*

About Coronal Mass Ejections

The corona is the outermost layer of the Sun's atmosphere, after the photosphere and cromosphere. It gets its name from the crown like appearance evident during a total solar eclipse. The corona stretches far out into space, its expansion being known as the solar wind. The white light corona is very thin and faint and therefore can be seen from Earth only during a total solar eclipse or by using a coronagraph telescope which simulates an eclipse by covering the bright solar disk.

Among the most spectacular and most energetic phenomena observed in the solar atmosphere are coronal mass ejections (or CMEs for short). An example of two CMEs is shown in Fig. 1. CMEs are enormous eruptions of magnetized plasma ejected from the Sun into interplanetary space, over the course of minutes to hours and they are best observed by means of coronagraphs. Average speeds of CMEs are of the order of 400 km/s, although they may exceed 2000 km/s. Since CMEs may travel radially outwards from the Sun in any direction, the observed speed corresponds usually to a component projected on the plane of the sky (or POS for short), i.e. the plane on which the solar disk is projected.

If a CME propagates in the direction of the Sun-Earth line, it will appear as a halo that surrounds the coronagraph's occulter (see Fig. 1, right). Furthermore, if it originates in the visible solar disk, the resulting event will likely hit the Earth. Primarily those events, commonly referred to as front-sided, in contrast with back-sided ones, may trigger intense geomagnetic storms (e.g., Webb 2002), directly visible as beautiful auroras, and occasionally telecommunication outages, power blackouts and damage to satellites (e.g., Dyer 2002). It is thus very important to infer their real speed and propagation direction in order to accurately predict their arrival time at the Earth.

The Instruments and the Data

From only one view direction (e.g. SOHO/LASCO images), it is not possible to infer the direction of propagation of the CMEs, but only the component

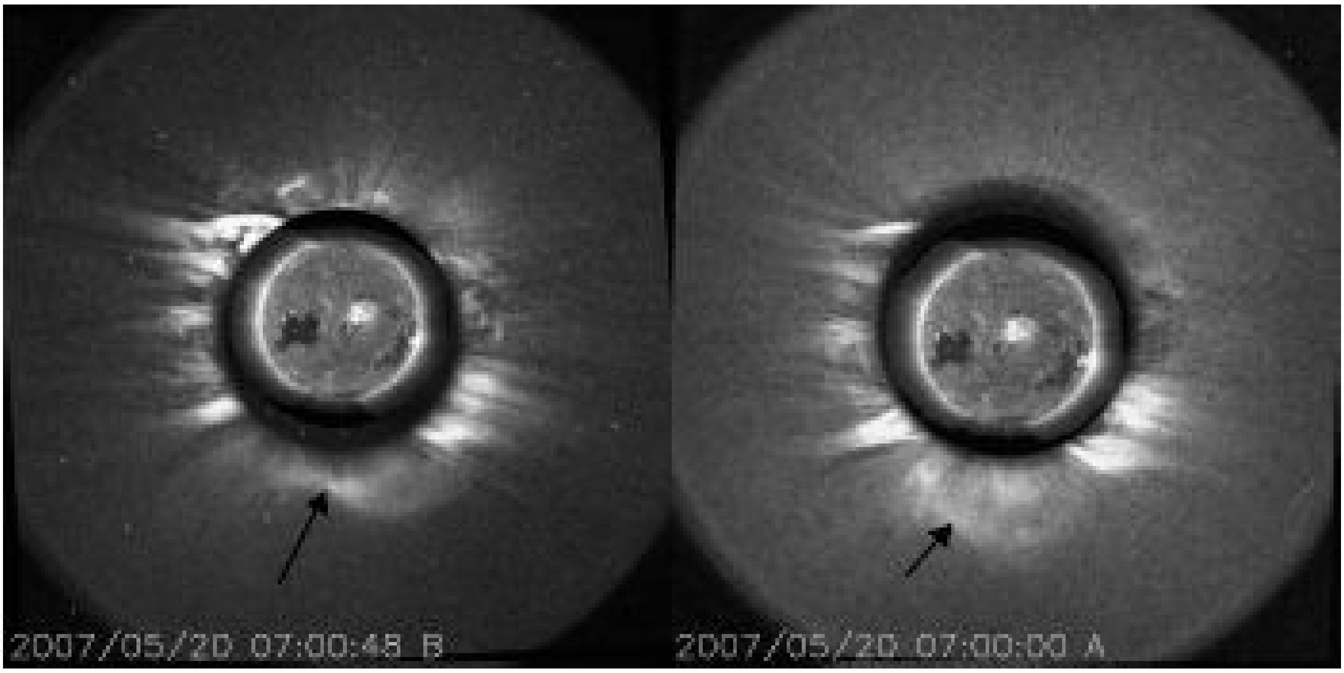

Fig. 2 *SECCHI-EUVI and SECCHI-COR1combined images taken on 20 May 2007 from both A (right) and B (left) spacecraft. The bright region on the disk is the source region of the CME. Arrows indicate the traced feature. (Adapted after Mierla et al. 2008).*

projected on the POS. The new data from the Solar Terrestrial Relations Observatory (STEREO) which was launched in October 2006 provided us with the first-ever stereoscopic images of the Sun's atmosphere. The two STEREO spacecrafts A and B orbit the Sun at approximately 1 AU near the ecliptic plane, one ahead and the other behind the Earth, with a slowly increasing angle of about 45 degrees/year between them. The stereoscopic images obtained from the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) (Howard et al.2008) aboard STEREO will help us to determine the location of the CMEs in space and to derive their direction of propagation.

The SECCHI experiment is a suite of remote-sensing instruments, each consisting of an extreme ultraviolet imager (EUVI), two white light coronagraphs (COR1 and COR2) and two heliospheric imagers (HI1 and HI2). In this study, the images from SECCHI-COR1 were used. The SECCHI-COR1 coronagraph is a classic Lyot internally-occulted coronagraph which observes the white light corona from 1.4 to 4 solar radii (or Rs for short. 1Rs ~ 696000 km).

A CME was observed by SECCHI-COR1, on 20 May 2007, at around 07:00 UT (see Fig. 2). In Fig. 2, EUVI disk images have been inserted in the COR1 images in order to see the region on the Sun from where the CME erupted (i.e., the bright active region at the center of the Sun disk). The images taken by SECCHI-EUVI show the ultraviolet solar corona at a temperature of around 1.5 million Kelvin (or 1.5 MK).

Height-Time measurements

In the past, coronagraphs data have been analyzed by means of height-time (HT) diagrams. HT measurements have been widely used in order to track moving features in the solar corona. Most of these measurements are obtained by choosing a specific feature in a time-lapse movie and tracking its position with time (see Fig.3).

Recently, Mierla et al. (2008) used the HT technique on the images acquired by SECCHDI-COR1 coronagraphs. This technique involves obtaining height – time plots for a well identified feature in a CME from its observations in two STEREO images (see Fig. 2). This yields two independent projected distances from the center of the Sun, from which a 3D position vector of the feature can be constructed if one takes into account the position of the two spacecraft. The HT profiles were used to determine the true direction of propagation of the CME and also the true propagation speed in the field of view of COR1 i.e. up to 4 Rs. For the feature shown in Fig. 2 by the arrows, a longitude of around – 2^{o} was derived, meaning that it is a front side CME, very close to

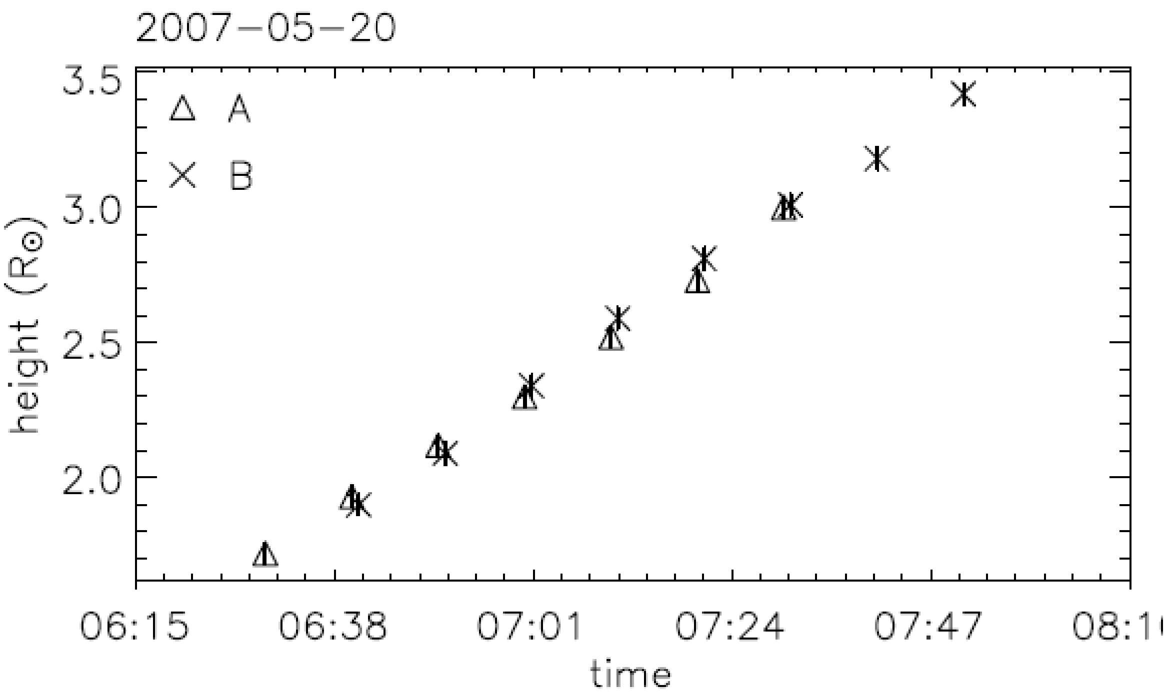

Fig. 3 Plot of height versus time for the features indicated by arrows in Fig. 1. The errors estimate the uncertainties in selecting the tracked features. (Adapted after Mierla et al. 2008).

the central meridian of the Sun. The latitude is around – 30° (south of the solar equator). From the HT diagram the real speed can be inferred. The tracked feature moves with a speed of 548 km/s while the projected speeds measured in A and B spacecraft are 242 km/s and 253 km/s, respectively.

A magnetic cloud associated with the CME of 20 May 2007 arrived at STEREO A in approximately 68 hours and its passage was observed for about 11 hours (see e.g. Liu et al. 2008). With the above calculated speed of around 548 km/s the estimated travel time to the Earth is approximately 75 hours. This is in close agreement with the actual travel time of the CME within the measurement errors. The calculations also show that the plane-of-sky speeds do not provide a good estimate of the travel time which in the present case yields to 163 hours.

In consequence, the HT method applied on COR data gives a quick and good estimate of both the true direction of propagation and speed. Thus, this technique serves as a useful and quick tool for space weather forecasting.

Acknowledgements

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Overview on solar diameter measurements

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The standard value of the angular diameter of the Sun at 1 Astronomical unit is 1919.26" or radius of 959.63". This value has been stated by Auwers (1891) at the end of XIX century, and it is used by the International Astronomical Union as the reference value.

No variation of the solar diameter is expected within the framework of the solar standard model on timescales below some hundreds of millions years. The five minutes oscillations known from helioseismology do not concern the whole diameter, being more than 100 the term of spherical harmonics involved in such oscillations (this spherical harmonic term should be 2 for a dipolar oscillation, involving all diameter at once).

From the point of view of General Relativity it is also interesting the solar oblateness, related to the quadrupole moment J2 of the Sun, especially under the hypothesis of uniform rotation. From classical Newtonian gravitation a quadrupole moment J2 =2 10^{-5} produces a precession of the perihelion of Mercury of 3 arcsec per century. Since the observational accuracy on this precession of 43.1±0.1 arcsec is now well below the predicted precession due to such a quadrupole moment, an assessment on this parameter of the Sun at the level of accuracy well below one parte in 10^5 becomes crucial for General Relativity (Sigismondi, 2005; Sigismondi and Oliva 2005).

The oblateness is given by the ratio Δr/r0=(req-rp)/r0=3/2·J2 (Dicke, 1970). Very accurate measurements of the oblateness presented usually problems similar to these of the diameter itself, or of its variations. In the case of RHESSI satellite and SDS balloon-borne telescope the absolute measurement of the diameter has being considered as constant and some values of oblateness have been recently published. Its value J2 =2 10^{-7} is compatible with a slowly rotating Sun and with Mercury perihelion precession. The presence of active regions at the limbs has been considered in the study of RHESSI (Fivian et al., 2008).

Limb's definition

The Sun is a self gravitating gaseous structure, and its limit is not sharply defined, nevertheless the variation of the density with the height is exponential, and in the wavelengths of visible light the surface of unitary optical depth τ=1 can be considered sharp with respect to the dark sky of the background.

The solar limb darkening function LDF, moreover, describes a decrease of the luminosity down to the 16% of the value attained at the center of the disk. The combination of the LDF with the Point Spread Function PSF of the telescope pours photons out of the geometrical limb. The most suitable definition of solar limb has been chosen as the maximum of the derivative of the luminosity along a radius. This maximum can be detected by derivation of the Fourier anti-transform of the observational data, this method has been considered stable with respect to the seeing effects (Hill, Stebbins and Oleson, 1975). Nowadays the influence of seeing on limb detection is being considered below the arcsecond level (Irbah, et al. 2003).

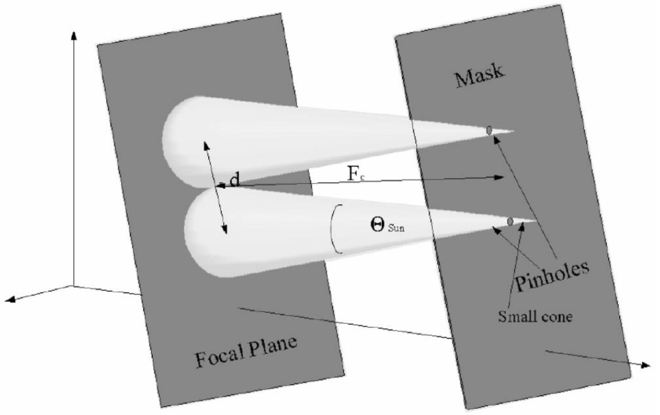
Geometrical variation of the apparent diameter

The accurate measurements of solar diameter played different roles in the last four centuries. When in 1609 Kepler introduced the elliptical orbit for Mars, it become clear that the eccentricity of the orbit of the Earth would have been e=0.0167, instead of the Ptolemaic value e=0.0334, which is exactly the double of the keplerian value. The measurements made at the meridian line of Bologna by Gian Domenico Cassini, who later directed the new Observatory of Paris, in the years 1655-56 solved the problem of the solar theory in favour of the keplerian one.

From aphelion (4 of July) to perihelion (4 of January) the variation of the solar diameter ranges from 1887" to 1952", with a ΔD/D~3 % over 6 months, or ΔD=65". In order to detect such a variation it is necessary to have a stable instrument, without optical distortions over 47° degrees with respect to the meridian transits of summer and winter solstices.

A pinhole meridian line like the one in the basilica of San Petronio in Bologna, or in the Basilica of Santa Maria degli Angeli in Rome, is an instrument perfect for this purpouse. A modern didactical replica of such giant lensless telescopes with focal length larger than 50 meters at winter has been proposed by Sigismondi (2002): a mirror sends the solar light over two pinholes built in a single frame at a fixed distance δ. Each pinhole produces a solar image on a far screen, and their centers are separated by this distance δ, and if the distance is tuned in order to have tangent images at perihelion it is possible to visualize the seasonal variation of the apparent diameter.

Suitable dimensions for this experiment are pinholes of diameter d~4 mm projecting their images at 10-12 m, with separations between the pinholes at ~10-12 cm.

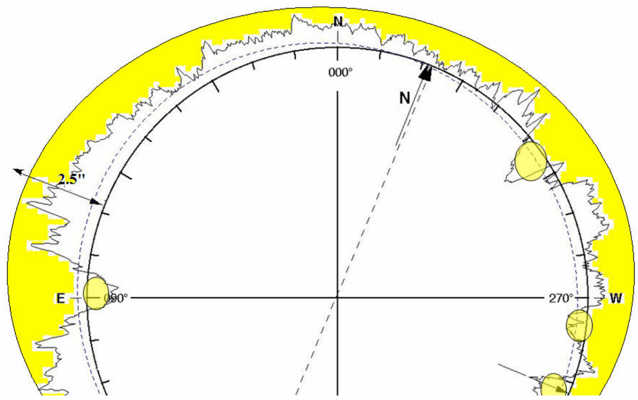


Optical configuration of two-pinholes device for measuring seasonal variations of solar diameter (from Sigismondi, 2002).

Variations with respect to standard diameter

The largest variation with respect to the standard value, not yet falsified, has been claimed by J.A. Eddy in 1978 quoting the observation made at Rome by the Jesuit Christopher Clavius, who published this news on his Commentarius in Sphaeram in the edition of 1581. Clavius observed an annular eclipse in Rome, in 1567. According to modern ephemerides this eclipse should have been total, with a lot of Baily's beads, but Clavius confirmed this observation also to Kepler who through a friend (Johannes Remus) was looking for proofs of lunar atmosphere.

The annularity of this Roman annular eclipse of 1567 would imply a solar radius at least 2.5" larger than the standard value.



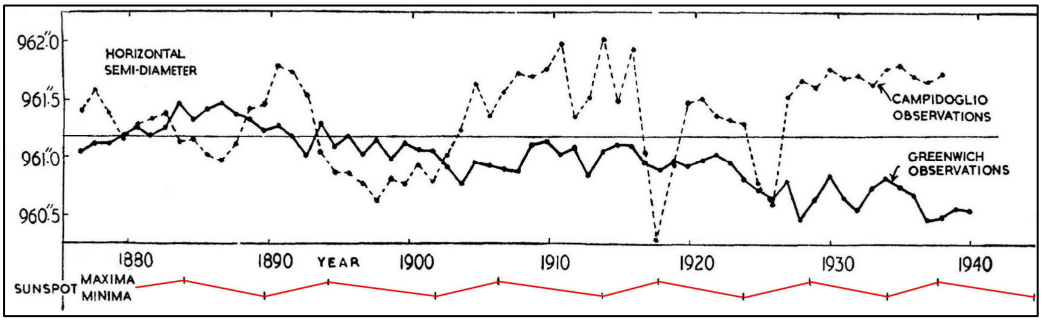
In this image is skectched the lunar rugged profile and four beads, where the valleys are so deep that the smaller Sun can shine through them. The outer solar profile is with a radius exceeding the solar standard radius of 2.5".

From arguments of solar physics such a diameter's variation of more than 2 parts over 1000 is nowadays not explainable in a standard solar model. Nevertheless the explanation of inner corona, proposed by Stephenson et al. (1997) to explain the ring observed by Clavius is not confirmed by our eclipse observations, since we could see very well the asymmetric solar corona from the edge of centerline, i.e. in a similar conditions of illumination and background of 1567 eclipse. In other words we did not see a circular corona, suitable to be confused with a circular photosphere.

Total solar eclipse of 2006 from Egypt at shadow's borders, image by Fady Morcos. A single bead is left and is over-exposed. The corona has been clearly visible by naked eye for more than 4 minutes, the same duration of maximum totality along the centerline of the eclipse.

Transits' measurement of solar diameter on meridians and almucantarts.

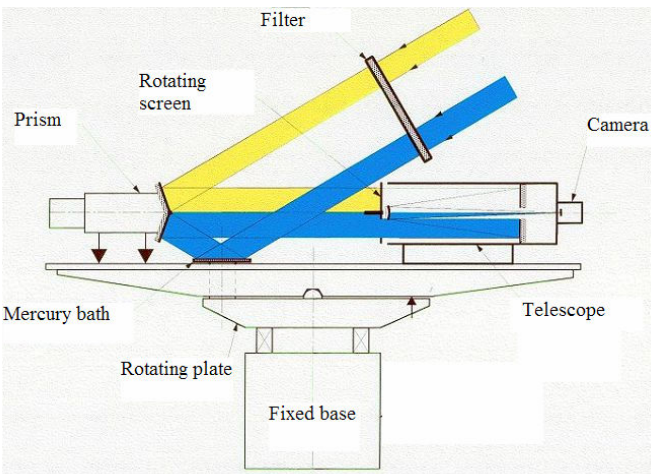
The same method adopted by Gian Domenico Cassini with the meridian line of Bologna, has been used with meridian telescopes in the following centuries. In particular joint measurements have been conducted in Rome at the former Capitol Observatory, and in Greenwich Observatory from 1877 to 1937.



As it is evident from the figure adapted from Gething (1955) the range of oscillation of measured diameter is near 2", and the fluctuations observed in Rome and in Greenwich do not show significant correlations between them and with the Sunspot cycle.

Therefore it is necessary to clarify whether these oscillations are real or spurious, and the new domain of atmospheric optics in daytime rose up.

Another method with fixed instruments has been proposed by Danjon in the first half of XX century, with the astrolabes, devoted to timing a transit on a fixed almucantarat, i.e. a circle of a given height above the horizon. This transit is determined by the contacts between two images the direct one and the reflected one over a mirror of mercury.



The most recent experiment of transits over an almucantarat is DORAYSOL, Définition et Obsevation du RAYon SOLaire, who worked on the plateau of Calern (1260 m) near Nice (FR). This is its scheme.

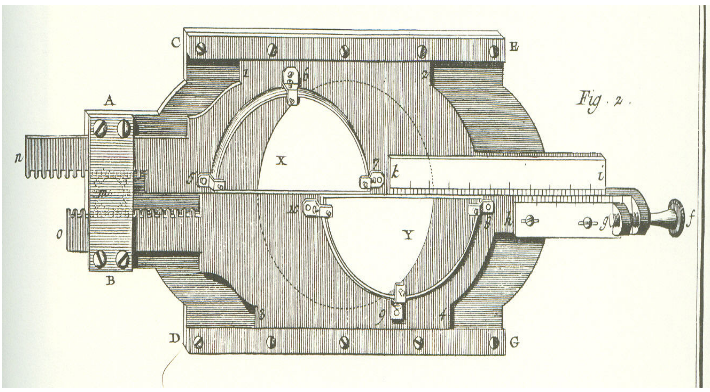
All these measurements were heavily affected by the local seeing, leading to the need of skipping this problem using larger telescopes with apertures significantly larger than the seeing length scale (10 cm), and to parameterize the seeing contribution, which produces a shrinking of the observed value of the diameter.

Some studies dealt with the relationship between this shrinking and the seeing parameters at the moment of the observations, this was the most important contribution of the DORAYSOL experiment up to now (Irbah et al. 2003).

Direct angular measurements

From the astrometric point of view the Sun is an extended source and it spans over half a degree. This angular span is enough large to be apart of the optical axis of the telescope where optical distortions become important.

The idea of the Heliometer was successful in stellar parallax observations, always based on the generation of two twins images by a lens.



The Frahunhofer's Heliometer.

The variant of Goettingen (Schur and Ambronn, 1905) with a prism allowed to exploit the par-axial region of the lens, by studying the gap between the two images of the Sun produced on the focal plane near its center.

The same solution has been used in the Solar Disk Sextant experiment, which flew over the stratosphere at 3 mBar of pressure (quote of 37 Km) four times in 1992, 1994, 1995 and 1998. Another flight is expected to be done in 2010 when the French satellite PICARD will work (Launch after February 15, 2010).

The PICARD optics will exploit similar principles, by generating 5 images of the Sun one central and 4 quadrants symmetrically disposed, in order to give a simultaneous measurement of the diameter and of the oblateness of the Sun.

Space measurements: Eclipses

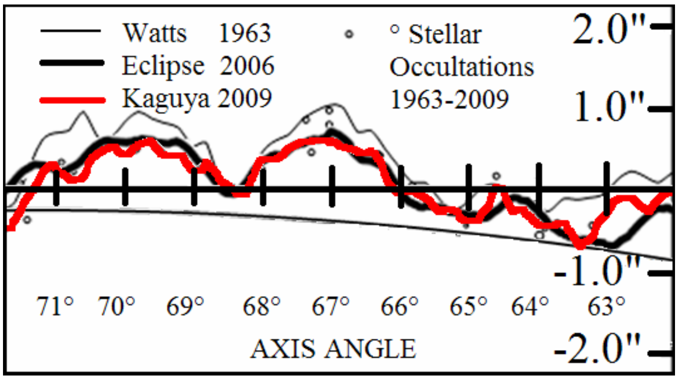
The orbital motion of the Moon and of Venus and Mercury are very well known. As an example of this accuracy we know that the tropical year was already known with one second of accuracy in 1700 at the meridian line of the meridian line of St. Maria degli Angeli in Rome. One second over one year is better than one part over one million. This level in the accuracy of orbital motions allows to have nowadays very good ephemerides, and even if there are some shifts in absolute timings, mainly due to the Earth's spin irregularities, the relative timings or the time intervals between beginning and end of an eclipse or of a planetary transits have an accuracy much better than one part over a million.

The ratio between observed timings of transits or eclipses and the calculated ones with standard solar diameter, yields directly the ratio between real and standard diameter.

For this reason the ancient eclipses and transits observations can give precious information on the solar diameter in the past. The total eclipses, in particular, can be precisely timed in their totality phase because the decrease of luminosity is sudden, and independent on atmospheric seeing conditions, but only on the geometry of Moon and Sun determined outside of the atmosphere.

The influence of the atmosphere on eclipse observations is in the timing of Baily beads, which can be slightly affected by scintillation, especially for grazing eclipses where the beads luminosity decreases slowly. Scintillation is significant for telescopes with apertures of 2-3 cm (Sigismondi, Nugent and Dangl 2009 to be published in Proc. of 3rd Stueckelberg Meeting Pescara 2008), while it is reduced by using telescopes larger than 7 cm with a good contrast of the image, obtainable by projection or with a filter of density ≥4 i.e. ≤10^(-4) of transmitted radiation.

The use of Baily beads in the measurement of solar diameter requires the precise knowledge of the lunar profile at the moment of the eclipse. This is now possible with the data provided by the Kaguya Japanese lunar probe and available with the free software edited by Dave Herald named Occult 4. Kaguya Laser Altimeter data have a sampling rate each 1.5 km near lunar poles and 10 km near the equator; each altitude is known with ±1m. Before November 2009 our knowledge of lunar profile was limited by the Watts (1963) profile obtained by photo during more than 18 years of observations of the lunar limb. Their accuracy was optimistically estimated in ±0.2", i.e. ±400 m at the distance Earth - Moon. Now we have a negligible uncertainty in the heights of the lunar profiles, and a sampling each 0.75" to 5" from poles to equator.



In this image are compared Watts, Kaguya and Eclipse 2006 profiles, with the scattered data of stellar occultations. The Kaguya satellite data are now the new reference standards for all occultation works. Watts' departures from Eclipse and Kaguya profiles show the variable error induced by using Watts profiles in the previous analyses of eclipse data. Eclipse 2006 profile is published in Kilcik, Sigismondi, Rozelot and Guhl (2009).

The identification of Baily's beads from a video can be much more accurate with Kaguya data with respect to the recent past. Some of the position angles (on the lunar limb counterclockwise from lunar North pole) of the published beads (Sigismondi, et al. 2009) can be found slightly different by reprocessing the video of the eclipses. Nothing will change in their timings which are the main issues of these observational data.

Once we have a set of Baily beads identified from a video of a suitable grazing eclipse (Sigismondi, 2009), let say N, we could calculate the radius of a circle of which are known N points, or of an ellipse to include also oblateness effects. The accuracy increases proportionally to √N, improving by a factor √(N/2) the measurements based only on the totality duration (equivalent to N=2). Using the Occult 4 software it is possible to compute the value of excess or defect of the real solar radius with respect to the standard one for each bead. A fast computation of the global excess or defect of real radius with respect to the standard one is simply given by the average and dispersion of such values, regardless to the oblateness.

Typically the uncertainty on N=2 can be of the order of 0.1 s, which over a totality duration of 100 s gives only 2" of accuracy in the observed diameter, but with N~50 beads an accuracy of 0.4" can be reached. This is the case of centerline observations with poor time resolution. Fast imaging and bigger telescopes allows to improve this resolution up to 0.01 s, and the 0.04" accuracy can be attained with 50 beads.

The situation becomes even better when the duration of the totality of the eclipse is nearly zero or even negative (the first bead after the maximum phase is illuminated while the last of the decreasing phase is still active). In that case the number of observed beads can be larger than 30, while the duration of totality, T, varies proportionally to the square root of the distance De from the edge of the shadow: T~√De.

The comparison between totality duration T and position of the observer, measured with GPS at ± 1 m accuracy, and the calculated position for the same T yields the real radius of the Sun. For example a shift outwards of 15 m ± 1 m of the totality shadow, when the calculated umbral shadow spans 300 Km, means that the solar radius is smaller than its standard value of 15m/150 Km, 1part/10000, i.e. 0.1".

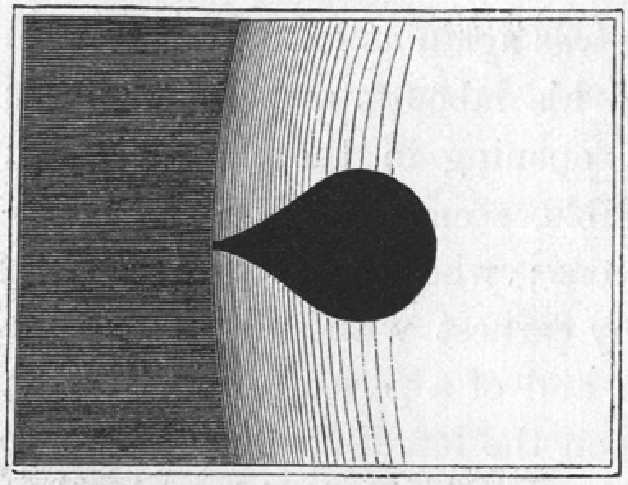
As an example I can quote the solar radius determination during the eclipse of 29 March 2006 when ΔR=-0.43"±0.04"(Kilcik, Sigismondi, Rozelot and Guhl, 2009).

Going to observe solar eclipses, both annular and total, at the shadow limit allows to make such determinations very precisely.

Solar diameter from planetary transits

For the planetary transits, it is well known the problem of the black drop described by Captain James Cook in 1769 during Venus' transit. This phenomenon is due to the interplay between instrumental Point Spread Function and the Limb Darkening Function of the Sun. It is unavoidable, and critically dependant on the instrument.

Fig. 160.



VENUS DURING ITS TRANSIT IN 1769.

By extrapolating the instant at which the chord cut by the points of contact between Sun and transiting Planet it is possible to avoid the black drop effect, at least in its maximum appearance when the celestial bodies appear nearly tangent. In this way I could recover with ± 1s and ± 8s the instants of the 3rd and the 2nd contacts of the last Venus transit from Athens from only 50 photos. The difference in the accuracies is due to the worse seeing occurred at the second contact nearer to the horizon. A whole error of 8 s over a total transit duration of 20000 s yields 0.4" of accuracy in the solar diameter determination. I obtained ΔR=0.34"±0.38" in H alpha line, compatible with Neckel's data (1994) who has measured the limb extension at different wavelengths.

Satellite perspectives

The SOHO satellite has been already used to measure the solar diameter, it has been absolutely calibrated with the Mercury transit of 2003, and it has shown no variation of the diameter along several years (Kuhn et al. 2004). The diameter of the Sun during that transit has been estimated as 959.25", i. e. ΔR=-0.38", which is in good agreement with the one measured in 2006 eclipse.

The PICARD mission, a French satellite expected to fly on 15 February 2010, has to monitor the solar diameter up to one milliarcsecond accuracy (1 part over a million) for three years. Contemporarily a replica will observe the Sun from the Earth in order to assess and correctly model the influence of the atmosphere on these measurements.

After the end of the satellite mission, the replica called PICARD-sol (ground), should continue this monitoring with a suitable procedure which will take into proper account the influence of the atmospheric seeing.

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North-South and East-West Distribution of Active Prominences on the Solar Surface during 23rd Solar Cycle

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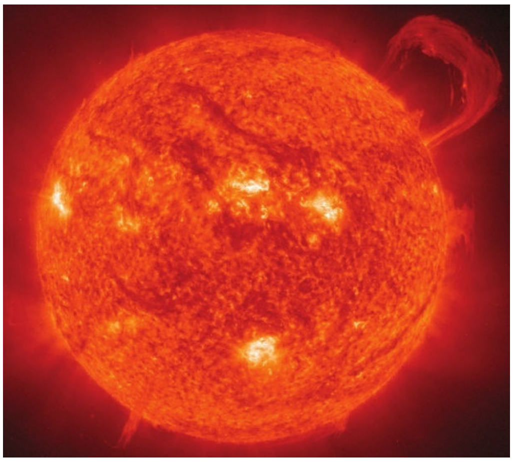
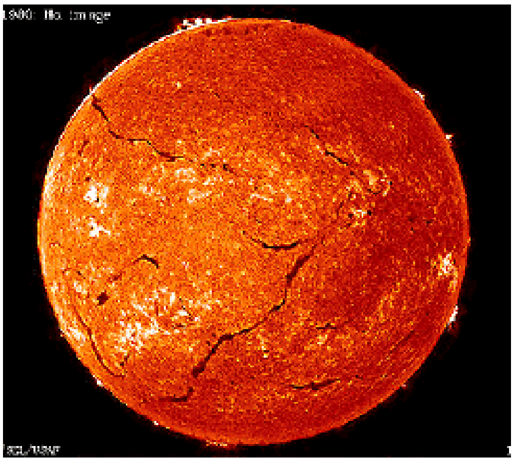


Prominence



Filament

The Sun has caught attention of astronomers from ancient times. Being the nearest star it provides a unique opportunity to study the various ongoing physical processes in the other stars in exquisite spatial and temporal resolution. Magnetic field generated inside the Sun pervades the solar atmosphere, accounting for sunspots and other powerful explosion events such as solar flares, active prominences, and coronal mass ejections. Study of these eruptive events is important because they affect earth's upper atmosphere (Geosphere and Ionosphere). Filament and prominences are simply the two different projections of the same object and generally appear as a dark filament against a bright solar disk when observed in Hα. It is called prominence when observed on the limb of the Sun and there it appears bright against the sky background. The term solar cycle refers to a quasi-periodic variation with a period of about 11 years, observable in many features of the Sun. The cycle is most easily observed in phenomena directly related to Sun's magnetic field such as sunspots.

The distribution of various solar activity phenomena (sunspot number, sunspot area, solar flares, active prominences/filament, coronal mass ejection, etc) with respect to heliographic latitudes and longitude as a function of time indicate that a solar cycle is not symmetric considering the distribution of a solar activity separately in northern and southern (as well as eastern and western) hemispheres. This intrinsic feature is known as asymmetry. Two types of asymmetries have been observed; N-S and E-W asymmetry. The N-S asymmetry in solar activity provides valuable constraints for solar dynamo theories. The hemispheric asymmetry of the solar activity plays an important role in determining the character of the solar cycle.

In our article we investigate the spatial distribution and asymmetry of active prominences in the northern and southern (as well as eastern and western) hemisphere of the Sun that occurred during the period 1996 to 2008 (solar cycle 23). The solar active prominence data include limb and disk features and events and have been downloaded from National Geophysical Data Center's (NGDC's) anonymous ftp server a s: ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FILAMENTS.

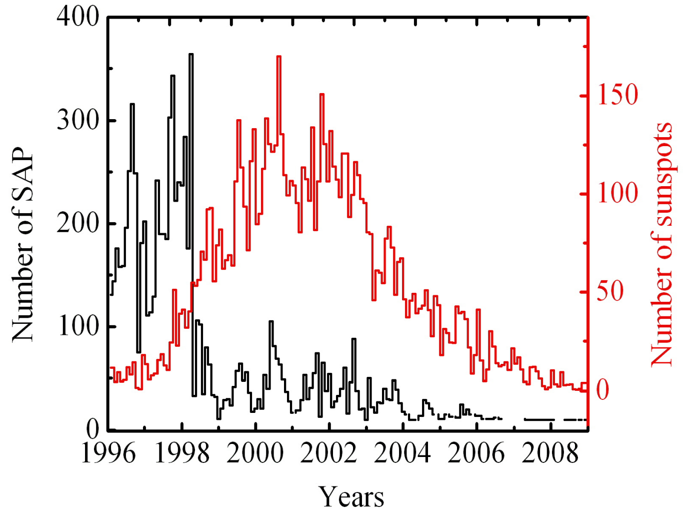


Figure 1

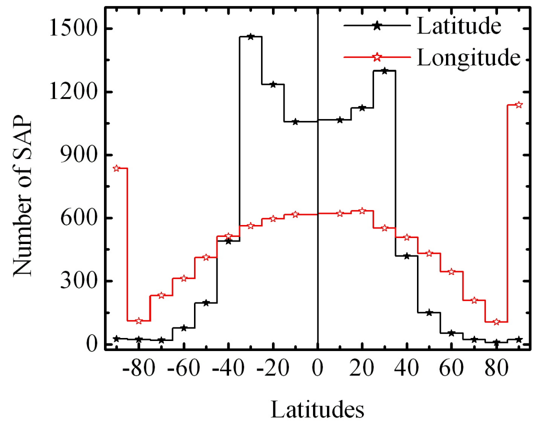


Figure 2

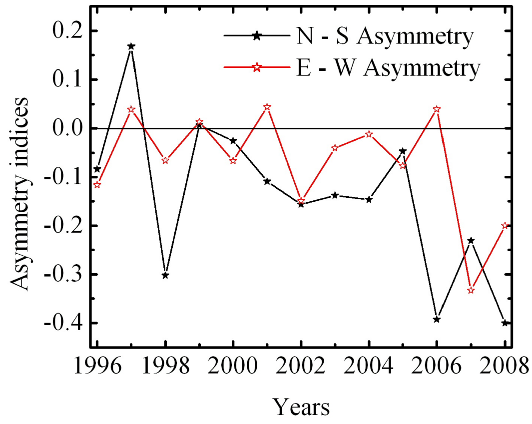


Figure 3

A total number of 8778 solar active prominences have been reported during this period of 4393 days. In Figure 1, monthly variation of solar active prominences (black line) and monthly mean sunspot number (red line) from 1996 to 2008 has been plotted. It is clear from this figure that maximum number of solar active prominences is observed during the rising phase (from 1996 to 2008), showing different nature than that of sunspot number which are maximum in maximum phase (2000-2001) of solar cycle 23.

For studying north - south and east - west asymmetry analysis we have been calculated the north - south and east - west asymmetry index using the formula north-south asymmetry index (A_{NS}) = $\frac{N-S}{N+S}$ and east-west asymmetry index (A_{EW}) = $\frac{E-W}{E+W}$.

Here N, S, E and W are the number of active prominence in the northern, southern, eastern and western hemispheres. If A_{NS} > 0, the activity in the northern hemisphere dominates or else it will dominates the southern hemisphere. The east - west asymmetry index is defined analogously. To verify the reliability of the observed north - south and east - west asymmetry indices we have used a χ2-test.

In Figure 2 the latitude variation of active prominences in 10° latitudes (black line) and center meridian distances (red line) has been presented. Here 0° represents the equator and center meridian distance of the Sun for latitude and longitude distribution respectively. North-south latitudinal distribution shows that the solar active prominences events are most prolific in the 21-30° slice in the northern and southern hemispheres. From this study it is also clear that low latitudes (1° - 40°) produce maximum number of SAP than the high latitude (50° - 90°). Hence we can say that low latitudes are the active latitude. East-west longitudinal distribution study shows that active prominences events are most prolific in the 81-90° slice in the eastern and western hemispheres. It has been found that the active prominence activity during this cycle is low compared to previous three solar cycles (i.e. solar cycle 20, 21 and 23). Hence we can say that solar cycle 23 was a magnetically weak cycle. Variation on north - south (black line) and east - west (red line) asymmetry indices using yearly values has been shown in Figure 3.

This figure indicates that the activity dominates the northern hemisphere in general during the rising phase of the cycle. The dominance of northern hemisphere shifts towards the southern hemisphere after 1999 and remains there in the successive years. It is also clear from this figure that north - south and east - west asymmetry indices peak near the activity minimum. Our statistical study shows that the north - south asymmetry is more significant then the east - west asymmetry.

This statistical analysis established that the north - south asymmetry of solar activity is a real phenomenon and not due to random fluctuations. The north-south asymmetries can be explained in term of “superactive regions” and “active zones”. superactive regions are large, complex, active regions containing sunspots and produce majority of other activity features. These activity features appear mort frequently in certain area of the Sun, so-called “active zones”. Hence the north - south asymmetry can be attributed to the existence of active zones in the northern and southern hemisphere, which can persist over longer period. N-S asymmetry may be due to the asymmetry in the internal magnetic structure of the Sun. Nonetheless, as E-W asymmetry of solar activity is a more controversial issue than that of the north - south asymmetry. Since the east - west asymmetry is dependent on the observer’s position; there is no obvious physical reason why they should exist over a long period.

The study of Sun is important because it is our powerhouse, sustaining life on Earth. The Sun warms our world, keeping the temperature at a level that allows liquid water to exist and keeps the Earth teeming with life.

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Ulysses/GRB Measurements of Hard X-Ray Flares on the Hidden Face of the Sun

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In a recent article by Tranquille, Hurley and Hudson in the journal Solar Physics, measurements made by the Gamma Ray Burst (GRB) instrument on the Ulysses spacecraft are used to identify energetic X-ray flares originating from the hidden hemisphere of the Sun. This analysis was made possible by the unique orbit of Ulysses, which used the gravity of Jupiter to inject the spacecraft into a highly inclined trajectory (figure1) necessary to perform its main scientific task – the exploration of the heliosphere in three dimensions away from the confines of the ecliptic plane. Although the Ulysses mission finally came to an end in June 2009 (almost 19 years after launch in October 1990), it has provided a wealth of scientific data spanning close to two solar cycles. The GRB instrument provided uninterrupted measurements of X-ray photons in the energy range of 25-150 keV for a total of 13 years, before the experiment was effectively switched off to conserve power required to compensate for the dwindling voltage supplied by the ageing spacecraft radioisotope thermoelectric generator.

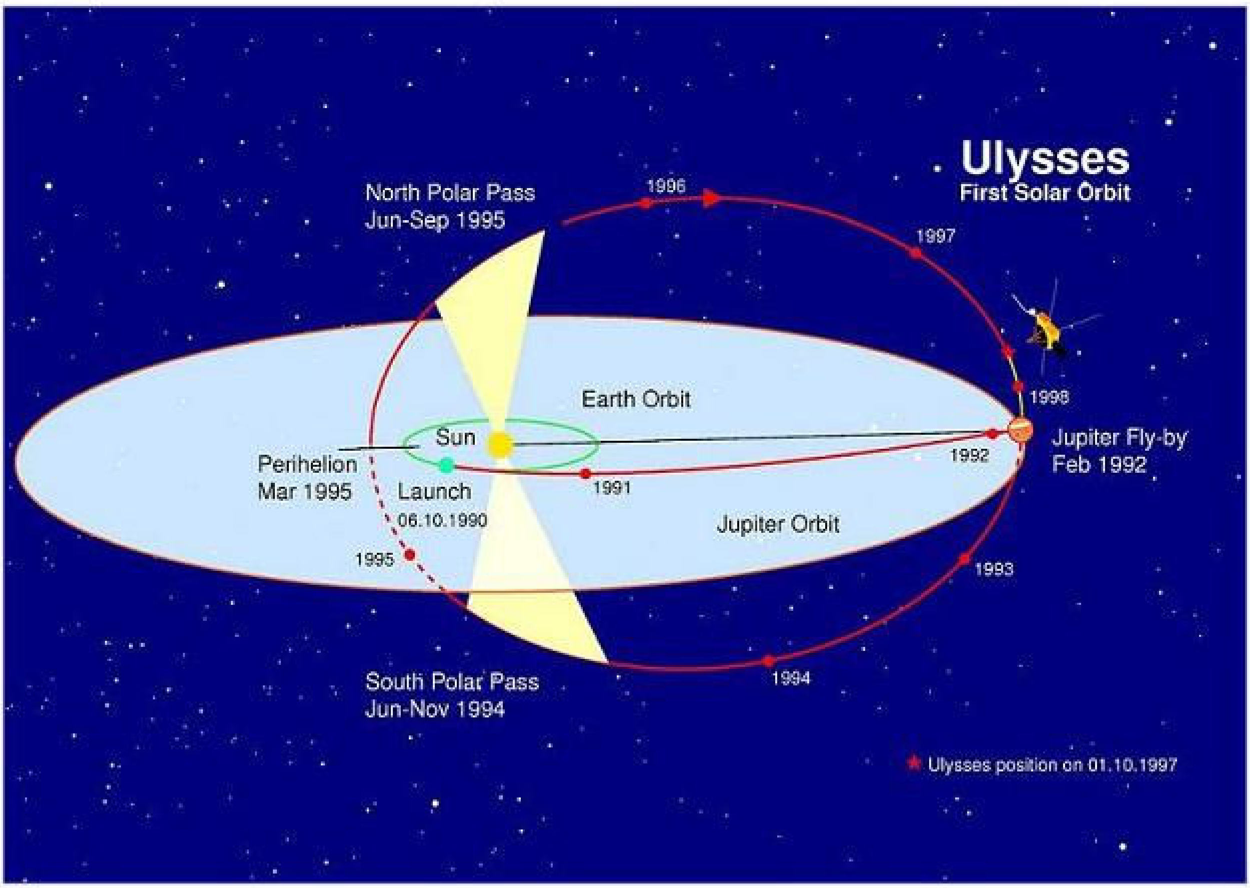

Figure 1: launch, transit to Jupiter and the first solar orbit of Ulysses

Most satellites that monitor solar X-rays (such as GOES and RHESSI, and previously SMM and YOHKOH) operate in near Earth orbit and only see flares occurring on the visible face of the Sun as seen from Earth. Sometimes occulted flares extend from behind the solar limb if the flare loop is sufficiently high or if its geometry is favourable. The orbit of Ulysses was such that its heliographic longitude and latitude were constantly changing with respect to the Sun-Earth line, allowing flares on the farside of the Sun to come into view. Figure 2 is an animation of the visibility of the solar surface from the different vantage points of the Earth and the Ulysses spacecraft. The disk represents the view of the Sun from Earth and is

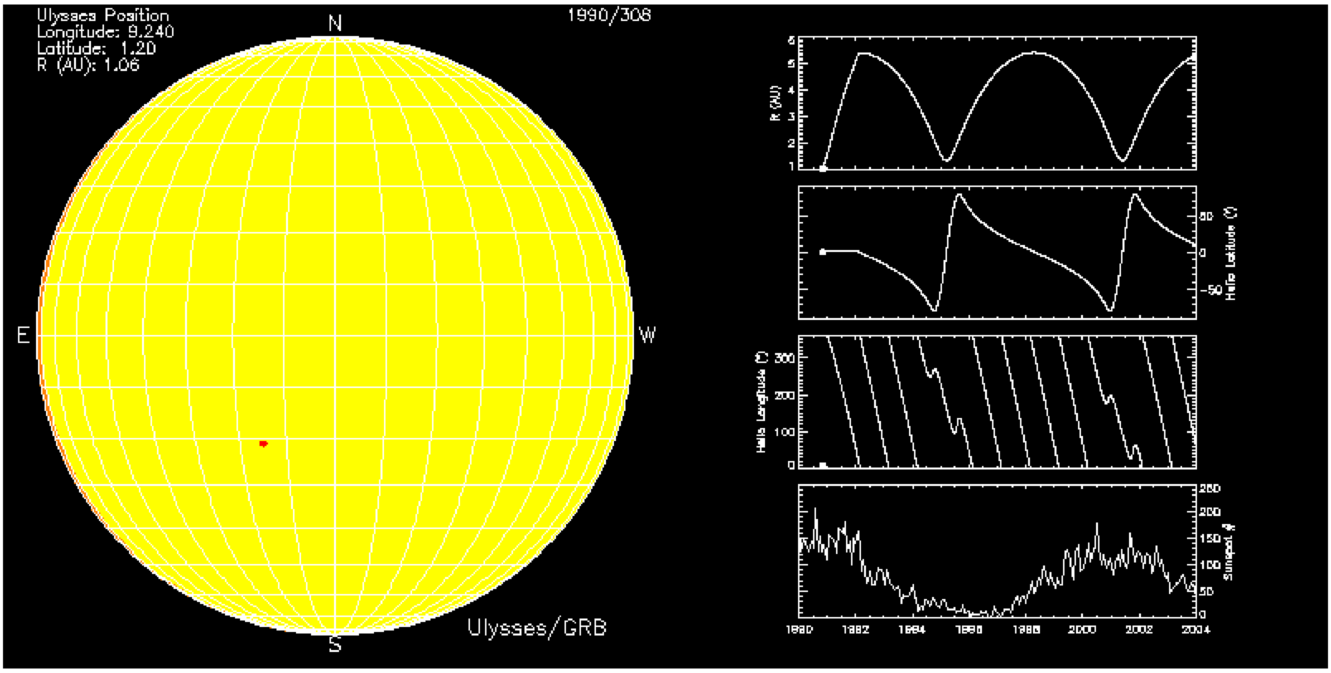

Figure 2: the solar surface viewed from Earth and the orbit of Ulysses

shaded in yellow for regions visible by Ulysses, and in orange for regions that remain hidden from the spacecraft line of sight. The red dots on the Sun that track from East to West are X- and M-class solar flares obtained from the GOES event list made available from the joint USAF/NOAA Solar and Geophysical Activity Summary reports. The panels on the right provide details of the Ulysses orbit showing (from top to bottom) the radial distance of the spacecraft, and its heliographic latitude and longitude. The final panel shows a smoothed solar sunspot number to quantify solar activity throughout the 13 years of GRB observations.

The GOES X-class events were first correlated with GRB measurements to identify hard solar flares originating from the visible face of the Sun in the Ulysses data set. The total number of these common flares was 65, of which 59 registered significant count rate increases in the GRB time profiles (five of the remaining events could not be accounted for due to telemetry or instrument background issues). This excellent correlation between the GRB and GOES data suggests that X-class flares always have a hard, non-thermal component which extends in energy well above 25 keV. A scaling law was derived between the peak normalized GRB count rate for each event and the intensity assigned to the flare from GOES measurements. Details of this correlation and analysis to account for instrument artefacts in the GRB measurements for the most intense events can be found in the Solar Physics paper.

Signatures of intense solar X-ray activity left in the GRB data set that do not correspond to any events catalogued by the GOES spacecraft can thus be classified as farside events. In total, 82 such events (an example of which is shown in figure 3) were found and tabulated with information about the timing of the flare and the equivalent GOES intensity, obtained by employing the scaling law derived from the 59 common events. In addition, it is possible to provide a coarse location for the flare site for many events by considering the region of the hidden solar hemisphere visible to Ulysses.

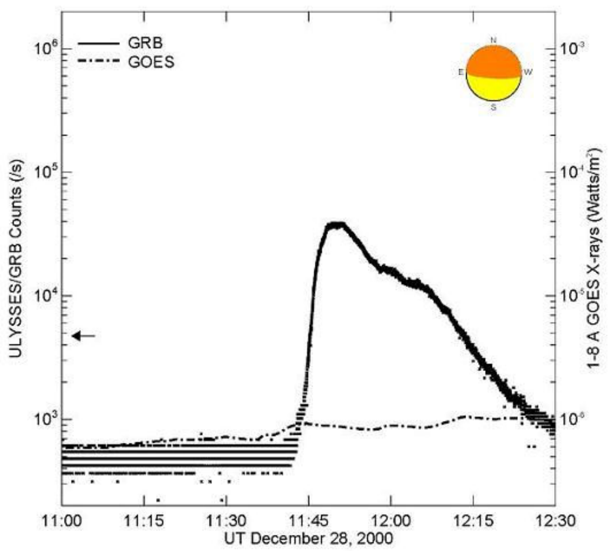

Figure 3: an example of a farside event seen by Ulysses/GRB – the horizontal arrow represents the GRB count rate threshold for an X-class flare

The complete GRB catalogue of X-ray flares exceeds 1500 events, of which approximately 10% can be categorized as X-class. This catalogue is included in the supplementary material accompanying the Solar Physics article. GRB data (as well as data from other experiments flown on Ulysses) can be obtained from the Ulysses Data System (http://helio.esa.int/ulysses/) maintained by the European Space Agency and from NASA's National Space Science Data Center (http://nssdc.gsfc.nasa.gov/). Routine imaging of the (near) complete solar surface is currently possible with the dual spacecraft mission STEREO and with advanced analysis techniques used by the Global Oscillation Network Group (GONG) as well as the SOHO instruments SWAN and MDI. In the future, these efforts may be complemented by planned missions such as NASA's Solar Sentinels.

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SOLAR CYCLE VARIATIONS ON THE MILLENNIAL TIME SCALE: A CHALLENGE FOR SOLAR DYNAMO THEORY

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The Sun is a variable star. Although the amount of total solar irradiance is fairly constant (within 0.1%) in time, leading to the somewhat confusing term "solar constant", solar magnetic activity does change greatly, as can be readily traced by the sunspots. The number of visible spots on the Sun grows for several years and then gradually decreases, repeating this pattern in a cyclic manner with a period of about 11 years. This is well-known as the 11 year solar cycle, which modulates space weather and affects in various ways the life of human beings, especially now when our civilization is so dependent on the satellite technology.

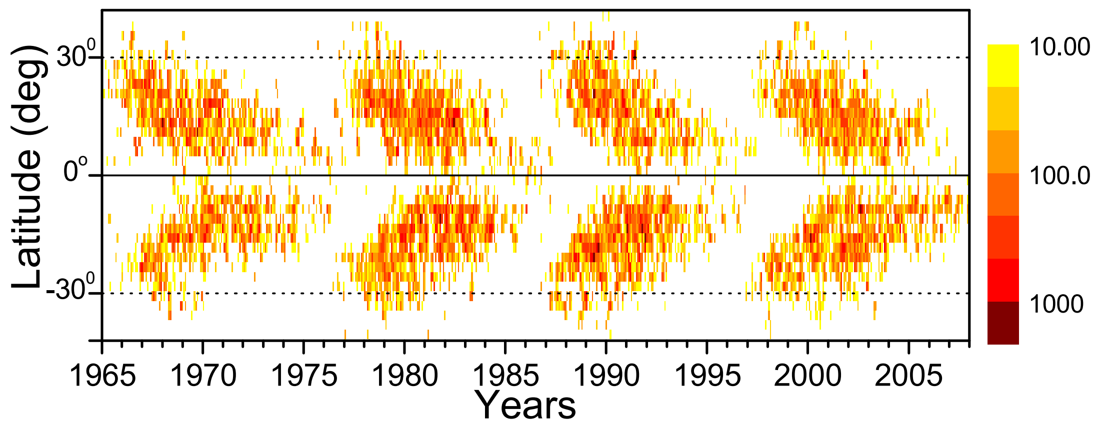

Figure 1. Latitudinal distribution of sunspots (the butterfly diagram) for the last four solar cycles. Color represents the sunspot area in millionths of the solar disc (color scale on the right). Data are from the Greenwich Observatory.

A conventional index of solar activity is related to sunspot formation and quantified by the relative sunspot number, which is defined as the tenfold number of distinct sunspot groups plus the number of individual spots observed at a given moment (usually at 12:00 UT every day) on the solar disc. Note that this relative sunspot number is always larger than the number of observed spots, e.g., the minimum possible non-zero sunspot number is 11 (one sunspot forms also one group, which scores 10, giving 10×1+1=11). Sunspots have been scientifically observed, by recording the results and often drawing the solar disc, since 1610, i.e. soon after the invention of the telescope. Thus we currently possess a 400-year long series of sunspot data, which is one of the longest direct instrumental datasets in existence.

The underlying physical mechanism of the 11 year cycle is the equatorward propagation of a belt of

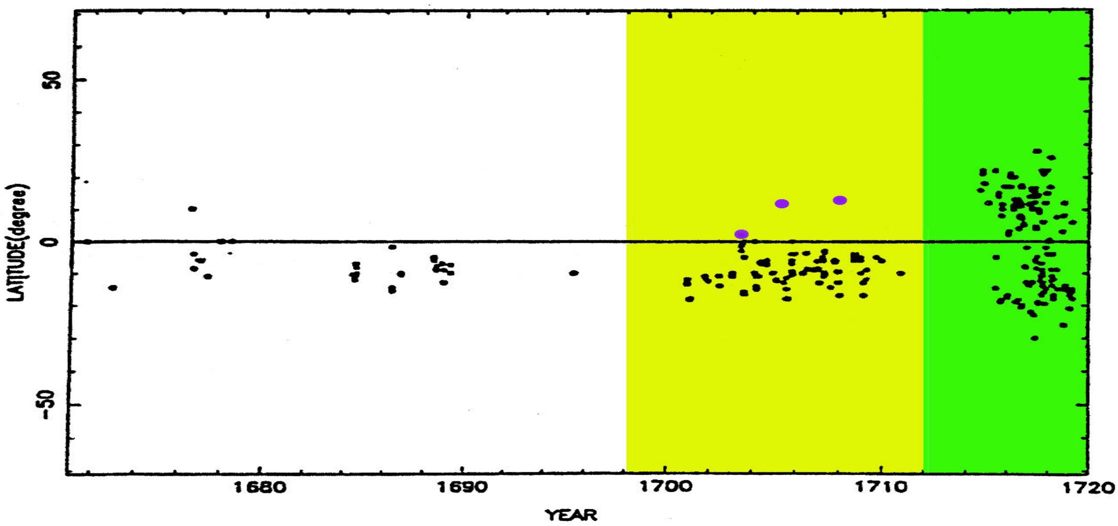

Figure 2. Sunspot butterfly diagram for the end of the Maunder minimum, according to the data from ref. [6]. One can see irregular asymmetric cycles before 1696, a fairly regular but asymmetric cycle in 1696-1712 (yellow background) and a normal symmetric cycle after 1712 (green background).

enhanced magnetic field somewhere inside the Sun. This periodic migration of magnetic field is believed to be driven by the solar dynamo, which is a result of the joint action of the solar rotation and the convective flows. The dynamo operates in the outer layer (about 30% of the radius) of the Sun in which turbulent convection occurs - the convective zone. The propagation of this activity wave at the solar surface during the 11-year cycle can be illustrated by what is known as the "butterfly diagram" (Fig. 1), in which the latitude of observed sunspots is plotted against the time of their appearance. The diagram resembles a sequence of butterflies. This kind of diagram to visualize the spatial-temporal patterns of the solar cycle was first used by the British astronomer Walter Maunder and the German astronomer Gustav Spörer in the late 19th Century. The butterfly diagram demonstrates the simultaneous propagation of two activity waves, one in each solar hemisphere, from middle latitudes towards the solar equator. We note that there is another wave of coronal bright features that propagates poleward from the mid-latitudes.

Generally the 11-year cycle of solar magnetic activity is a relatively well-understood phenomenon which has been discussed in many scientific papers and books. The details are, however, still not fully resolved. Cycles are not perfectly regular, as, e.g., the wings of individual butterflies have different span, tilt and amplitude, and also the total durations of the cycles vary. Even more dramatically, from time to time the driving engine of the cycle becomes idle leading to a peculiar state of solar activity with few or no visual spots on the Sun for several decades. Such a period of suppressed solar surface activity is usually called a Grand Minimum.

The most recent Grand Minimum occurred in the late 17th century, early in the era of telescopic observations. It was Walter Maunder again who recognized from archival data that the solar activity from the middle of 17th until the beginning of the 18th centuries was very unusual, in that sunspot records from this period were very rare. However, the absence of records does not inevitably mean the absence of sunspots, and Maunder's contemporaries were quite sceptical about his finding. It really is hard to believe that 17th century solar astronomers did observe sunspots accurately and consistently. However, as time passed, the evidence supporting Maunder's idea grew. The late American astronomer John ("Jack") Eddy demonstrated in 1976 [1] that the concentration of the radiocarbon cosmogenic isotope measured in tree rings growing at the time of the Maunder Minimum was unexpectedly high, implying low solar activity, but this evidence was still indirect. The ultimate piece of evidence, completing the puzzle, came from the archives of the Observatoire de Paris. This institution was founded by Louis XIV, the King of France, just at the beginning of the Minimum, with the primary goal of regular sunspot monitoring. A brilliant sequence of French observers performed a very long and careful monitoring of the Sun. In particular, Jean Picard routinely and carefully observed the Sun over a decade, thoroughly recording the results in a notebook, and saw only one sunspot during that period. It is an example of

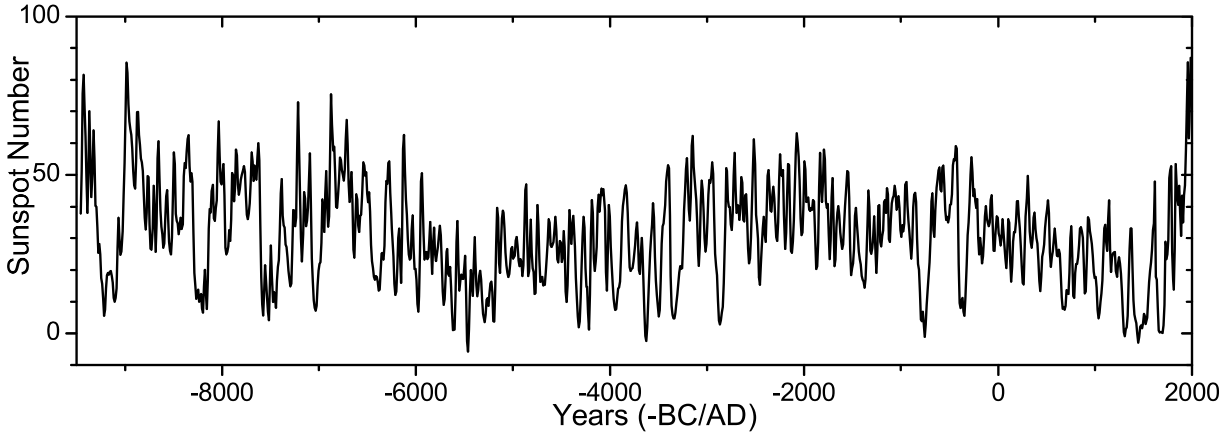

Figure 3. Long-term reconstruction [7] of solar activity from radiocarbon ^{14}C records.

outstanding scientific persistence, which would hardly have been possible without direct Royal patronage of the project. There were other astronomers in Italy and Germany who also observed the Sun during that time. Unfortunately, some records have been lost in course of time, and presently we know only their summaries as cited in later reports. However, many records did survive until the present day.

Careful work by contemporary astronomers has yielded a robust reconstruction of solar activity variations during the time of the Maunder Minimum, which shows a strong suppression of sunspot appearance. These results supported Maunder's interpretation and the Grand Minimum of 1645-1715 was given his name. Other indirect data, such as archival records of the aurora borealis or cosmogenic isotope concentrations, suggest that the solar dynamo was not completely "off" during this time, but kept operating at a reduced level that was barely sufficient to produce a few spots. Further detailed analysis has demonstrated that sunspots were not completely absent during the Maunder minimum. Some sunspots were observed even during the so-called "deep" phase of the Minimum. Thanks to the careful drawings of the solar disc kept in archives, it is possible to construct an informative butterfly diagram, at least for some parts of the Minimum. This diagram looks remarkably different from that of more normal times (Fig. 2). In particular, the (vestigial) wings of the "butterflies" are sometimes visible in one hemisphere only.

The list of peculiarities of the solar cycle variability is not limited to the Maunder Minimum with its suppressed and asymmetric sunspot occurrence. An analysis of the long term sunspot data reveals some other peculiarities such as various deviations from both the North-South and axial symmetries, large variations of the cycle amplitude and duration, short excursions in solar activity such as the Dalton minimum near 1805, etc.

During the 20th Century, substantial progress was made in methods of physical and chemical analysis, in particular acceleration mass spectrometry (AMS), which made it possible to use proxy data such as the cosmogenic isotope record to study solar activity further into the past. Isotopes such as ^{14}C or ^{10}Be are produced in the Earth's atmosphere solely by energetic cosmic rays, whose flux is modulated by the solar magnetic activity. Thus, measurements of the isotope concentration in independently dated natural archives such as tree rings or polar ice cores provide a quantitative estimate of solar variability in the past, with a more-or-less reliable reconstruction reaching to as far as 11,400 years ago (Fig. 3). These proxy data have undoubtedly confirmed the existence of the Maunder Minimum in the 17th Century, but they also showed that it is not an extraordinary phenomenon. A few dozens of similar Grand

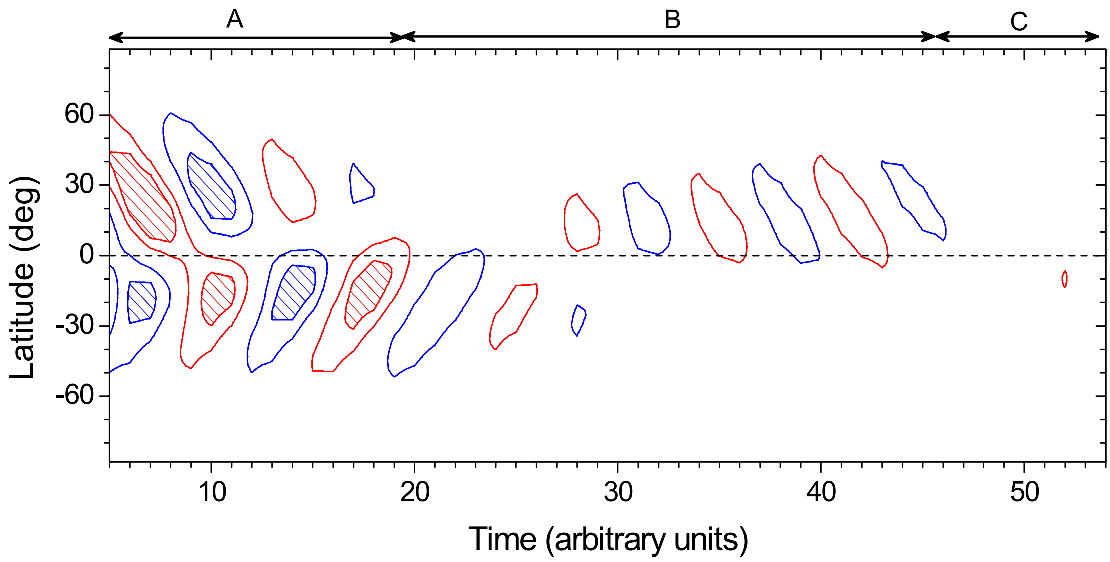

Figure 4. Latitude-time distribution of the toroidal magnetic field (an analogue of the sunspot butterfly diagram) from one of the simulation runs. The equi-spaced contours represent the strength of the field, with red/blue indicating positive/negative values. Labels A, B, and C denote regular cycles, asymmetric cycles, and a Grand Minimum, respectively.

Minima have been identified as occurring during the last 10,000 years.

These findings present an obvious challenge for solar dynamo theory. It is not enough to find a mechanism driving a regular cycle, it is important to find why and how its effect becomes imperfect. This goes beyond a purely academic interest. It appears that such distortions in the activity mechanism can affect the solar irradiance (the amount of solar radiation that strikes the Earth) and also the flux of cosmic rays, and thus the Earth's climate. Moreover, recent observations suggest that the coming solar cycle may be also quite peculiar. In other words the problem is relevant not only to the times of Louis XIV, but also to us now.

A general expectation is the peculiarities discussed above seem likely to require a different physical mechanism from that responsible for the dynamo-driven normal cycles, although other possibilities have been also discussed. This is because these phenomena have timescales quite different from the cycle length, and their manifestations are rather different one from the other. We have attempted to elucidate the problem [2,3], trying first a simple way to perturb the stable cycle. The starting point is that the solar dynamo engine is driven mainly by two components that act as generators - the solar differential rotation and the mirror asymmetry of the solar magnetohydrodynamic (MHD) convection. The latter arises because the action of the Coriolis force in a rotating stratified fluid of the solar convection zone makes the convection statistically mirror-antisymmetric with respect to the solar equator. It is basically the same mechanism which makes the river beds on the Earth asymmetric (the right-hand bank is usually higher and more eroded than to the lower left-hand bank in the northern hemisphere), and also causes winds to blow anticlockwise around low pressure regions in the northern hemisphere, and vice versa in the southern. The effect of the mirror asymmetry effect on the dynamo action is parameterized by a quantity commonly known as α.

Common sense and stellar physics tell us that solar rotation is something much more substantial than mirror asymmetry, and its timescale of variation is expected to be billions of years rather than decades. On the other hand, experience from direct numerical simulations of MHD turbulence shows that the quantity α can be quite noisy, with large variations about its mean value, and these may occur on relatively short timescales. We attempted [2] to determine how important random fluctuations in α can be for the solar cycle. This idea is not very new, e.g. the Dutch astronomer Peter Hoyng [4] discussed this possibility a decade ago, but it was not then explored in full detail.

We performed a long-term simulation of a simple model of the solar dynamo, known as the Parker migratory dynamo as proposed by the American astrophysicist Eugene Parker in 1955 [5]. We ran this model with a noisy α-term to simulate solar activity on a time scale of 10,000 years - the range of solar activity reconstruction from cosmogenic isotope data. Of course, such simulations do not aim to reproduce the solar activity evolution in full detail. This is impossible because the fluctuations in the α-term of the dynamo are random, and so, we can only study similarities in a statistical sense by adopting plausible statistical properties for the relevant quantities. Keeping this in mind, our results look promising. In some simulation runs we obtained simulated butterfly diagrams (an example extracted from such a run is shown in Fig. 4) which contain some known types of distortion of the regular cycles (labelled as A), such as asymmetries with respect to the solar equator (B), a Grand Minimum (C), etc. A long-term series of the simulated solar activity in terms of the averaged magnetic energy depicts quasi-random occurrences of Grand Minima and Grand Maxima that are generally similar to those deduced from the long-term record of cosmogenic isotopes (Fig. 3).

We feel that the success of a simple approach connecting the various distortions of the ideally regular sunspot cycle to only one physical mechanism is plausible and instructive, and satisfies the principle of "Occam's razor". We appreciate, however, that this is not the end but rather a promising beginning to the story. However, it certainly remains possible that the observed distortions of the sunspot cycle discussed above can originate from a more complicated physical mechanism than the one we have considered. Further more detailed research is certainly required to elucidate these and other issues.

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How Reconstruction of Solar Irradiance Variation Helps Us Understand Climate Change

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It is now widely accepted that solar variability might influence climate. Most straightforwardly, this influence might arise through changes in the Sun's brightness in total (wavelength- integrated) light and heat, which is referred to as the total solar irradiance (TSI). But monitoring of TSI with cavity radiometers flown on spacecraft since 1978 has shown only variations caused by the evolution and rotation of dark sunspots and of bright faculae in active regions and in the active network associated with them(1,2). These variations, smoothed to show the fluctuations on time scales of years and over the 11 year cycle, are shown in Fig 1.

The 11 – year brightening of the Sun around peak activity shown in Fig 1 is caused by the net effect of these photospheric magnetic structures. But its amplitude is only about 0.07%, which is too small to produce a significant effect in climate models. Recent reports (e,g. 3) for an 11 – yr modulation of Indian Ocean temperatures by TSI must be regarded with caution – the signal is barely detectable and corrections for the El Nino oscillation have yet to be made.

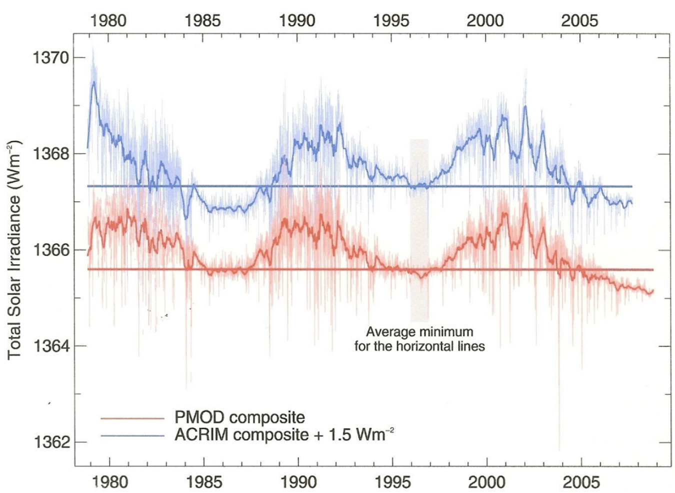

Fig 1: Composite time series of TSI measurements produced by radiometers on several spacecraft since 1978. The PMOD composite was produced by Claus Fröhlich at the Physikalisch -Meteorologisches Observatorium, Davos, Switzerland. The ACRIM composite was produced by Richard Willson, Columbia University, USA. Figure kindly provided by C. Fröhlich.

The 32 year run of TSI radiometry shown in Fig 1 does not rule out possibly larger TSI variations on century or millennial time scales that might arise from deeper lying changes in the Sun. But detailed studies of changes in the solar diameter, in its limb darkening, and in the frequencies of helioseismic modes, have not revealed any changes in the Sun's *internal* structure either. So, while the basic mechanism of warming or cooling of the Earth by changes in solar brightness is relatively well understood, there is presently no reason to believe TSI variation is large enough to drive climate (2).

The Sun's ultraviolet flux variability has also been suggested as a climate driver. Here, the proposed mechanism is much more complex. It involves, first of all, changes to the ozone layer temperature structure driven by solar UV variation in the wavelength range shorter than 240 nm. This stratospheric temperature structure change, according to the models, could change the propagation characteristics of tropospheric planetary waves that carry heat from equatorial regions poleward. In this way, the tiny energy variation represented by sub – 240 nm solar UV flux changes over the 11 –yr cycle might be amplified to modulate tropospheric heat flow sufficiently to change climate.

The models of this mechanism (e.g. 4) are interesting but they are complex. Before we invest too much effort on them, it seems a good idea to check how well the UV flux variation actually *correlates* with the quantity it is supposed to be driving – the global temperature. In other words, if we visualize the complex model as a black box amplifier, we need to compare the time behavior of the input (the UV flux variation) to that of the output (global temperature).

Direct UV flux measurements in the most ozone – effective 170 - 240 nm range of interest here extend back to the 1980's. But reconstruction to earlier time relies on measurement of the changes in solar magnetic plages that cause the variation in solar UV. In this UV range the contribution of dark sunspots is negligible, although it is large in the visible. This is because the UV contrast of plages increases rapidly at shorter wavelengths and their area is about ten times greater than spot areas.

It is useful that changes in the solar *microwave* flux are also caused mainly by these same plage area changes, and this flux has been accurately measured at several microwave frequencies. The longest measurement set, at 10.7 cm wavelength (the well- known F10.7 index) has been made since daily since 1947. Consequently, UV flux reconstructions based on this convenient F10.7 proxy have been available back to that time.

However, to test this model of climate driving we need to reconstruct solar UV over as long a period as possible. Luckily, daily solar images (spectroheliograms) in the chromospheric line Ca K are available in the Mt Wilson Observatory archives back to 1915, with less frequent coverage back to about 1905. Areas of active region plages and active network can be measured from these directly. An example of such an image is shown in Figure 2.

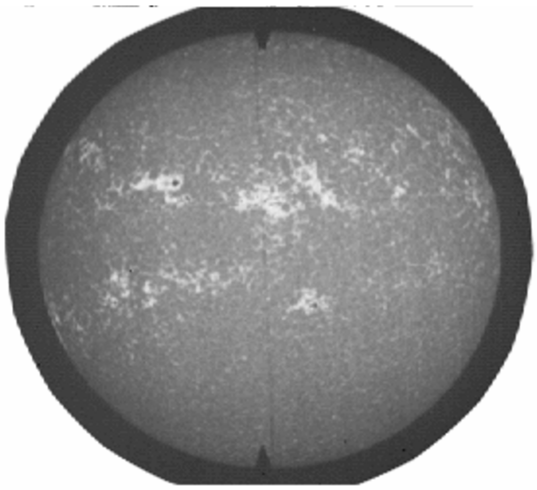

Fig 2: Plages imaged in the Ca K line

However, accurate measurement of the areas required that the photographic spectroheliogram plates be digitized. This task of digitizing the roughly 20,000 Mt Wilson archival Ca K plates was carried out first by our group at Cambridge Research and Instrumentation (CRI, Inc) in the early 1990's. The work was carried out on the premises of the Hale Observatories in Pasadena, California, by CRI employee Morgan Harman. He used a digitizer we built from a 512 – format Pulnix ccd camera available at that time. Custom software was written at CRI to remove instrumental effects and limb darkening, and measure the areas. This work required about two years of effort. To extend the time series beyond 1984 when the Mt Wilson Ca K program terminated, we took the equipment to Sacramento Peak Observatory in Sunspot, New Mexico and digitized a representative sub- set of their Ca K plates from 1985 – 1999.

When the UV flux reconstructed for the entire period 1915 – 1999 was compared with global temperature the correlation turned out to be surprisingly poor. This is shown in Fig 3. It seems that less than 20% of the variance (the *square* of the correlation coefficient, r,) in the 20th century temperature variation arises from UV flux variation. This result was not received enthusiastically by proponents of the UV driving mechanism, and questions were raised about the accuracy of the UV flux reconstruction.

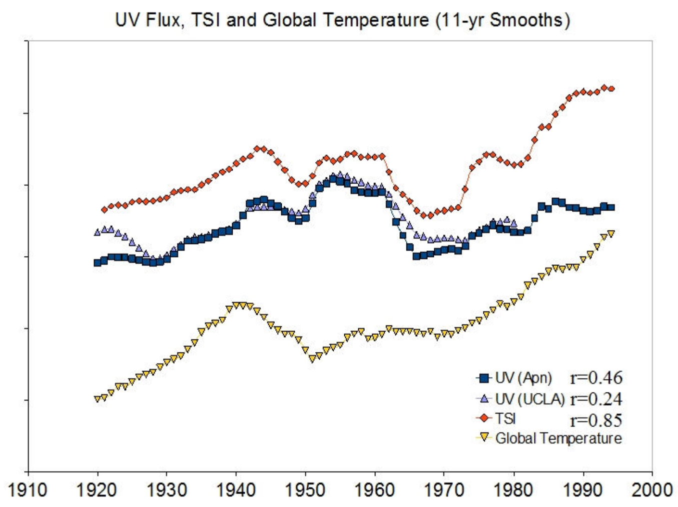

Fig 3: Plot of two separate reconstructed UV flux variations (blue curves) compared to global temperature (yellow curve). A TSI reconstruction (red curve) is shown for comparison. The r- values are correlation coefficients versus the global temperature curve.

However over the past few years, similar reductions of the Mt Wilson plates have been carried out by groups at UCLA (who re-digitized the Mt Wilson plates with a higher – resolution commercial digitizer), and by a Russian group from Pulkovo Observatory, who re- digitized the Sac Peak plates and also reduced the UCLA digitization of the Mt Wilson data independently. The Russian group also digitized and reduced the separate archive at Kodaikanal Observatory in India. Recent comparison of these independent reductions (5) shows some differences, which appear to arise from differences in the passband width of the spectroheliographs used at Mt Wilson, Sac Peak and Kodaikanal. However, the basic finding that slow variations in the UV flux correlate surprisingly poorly with global temperature is confirmed.

These findings have spurred a closer look at the models. It now appears that the solar UV driving in these models is less effective in changing temperature than in possibly driving wind and precipitation patterns. This is interesting, but it makes it less likely that the UV driving mechanism plays a role in explaining global warming since the 17th century. So Morgan Harman's two years of digitizing the Mt Wilson plates has indeed produced some new insights into the ongoing story of possible Sun – Climate influences.

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Probing the depths of sunspots

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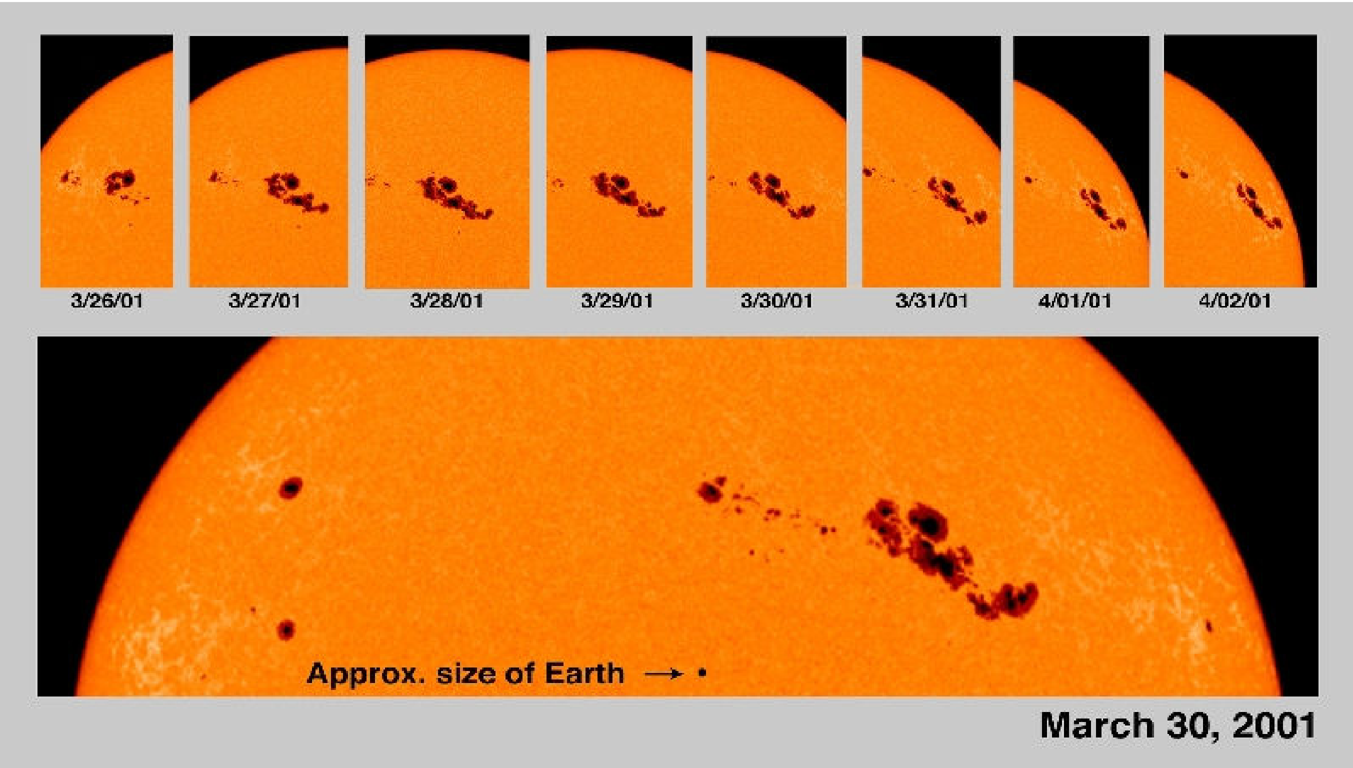
Sunspots have been observed on the surface of the Sun for hundreds of years as dark patches which are cooler than the surrounding photosphere. It is believed that they are caused by strong magnetic fields below the sunspot area which disrupt the convection of the upper layers of the Sun and this stops the transfer of heat into the sunspot.



This image shows the changes in apparent area as a spot moves across the disk, and the changes are a combination of Wilson depression effect and geometrical foreshortening. Courtesy of SOHO/MDI consortium. SOHO is a project of international cooperation between ESA and NASA.

These dark patches have fascinated astronomers for centuries and have been studied in detail by many well known astronomers including Galileo Galilei. After his invention of the telescope in 1609 he turned it towards the sun and observed sunspots (a feat which should not be reproduced!). We now know a great deal about sunspots and some of their properties are simply incredible. The largest sunspot of the last hundred years occurred in 1947 and had an area equivalent to many times the surface area of the Earth! In addition, even though sunspots are cooler than the solar photosphere, they still have temperatures of around 3000K (in comparison to the roughly 6000K of the photosphere).

There is still one major property of sunspots, however, that is very difficult to measure and that is how deep they are. This question is valid as sunspots are not simply dark circles on the photosphere, but recessed bowl shapes in the surface itself. This is caused by the plasma in these areas being cooler which makes the plasma more translucent. As a result, we can see to a slightly deeper layer of the Sun in sunspots giving rise to this bowl shape.

The idea that sunspots were not flat disks but had some sort of shape was first proposed by Alexander Wilson. Wilson was the first person to hold the Regius Chair of Astronomy at the University of Glasgow, Scotland and began his career as a type-founder in the university but quickly gathered an interest in astronomy. In 1774 he submitted an article to the Journal of Philosophical Transactions entitled `Observations on the Solar Spots'. In this article he shows some drawings of his own solar observations and a peculiar feature of sunspots was noted. When a sunspot is near one limb of the sun, the apparent size of the penumbra on the limbward side of the spot increases whereas a decrease in seen in the penumbral area on the opposite side. This can be explained by assuming that sunspots are bowl shaped, with the dark umbra being the base and the penumbra being the sloped walls of the shape. This explanation works because as the spot approaches the solar limb, the base of the sunspot is obscured by the spot wall closest to the disk centre, and as the spot moves closer to the limb, this obscuring effect increases.

It was our goal to calculate the range of depths of sunspots and to do this we first needed a consistent catalogue of sunspot areas. This was achieved using image processing techniques from the field of mathematical morphology and data from the Michelson Doppler Imager instrument onboard the Solar and Heliospheric Observatory, which has been a major source of solar observations for the last 13 years. We use this data to determine the first appearance of each sunspot and this is affected by the instrument we use, as well as the geometry of the spot. It is this link to the spot geometry that makes sunspot appearances a crucial tool for investigating their depth.

Once we calculate the first appearance of each sunspot, we can create a model of sunspot formation and evolution and use this to generate large numbers of simulated sunspots. For simplicity, we assume that sunspots are circular areas with vertical walls (think of a petri dish). By looking at the first appearance of these simulated spots, we can see how similar it is to the patterns seen in the data and this gives us an indication of how accurate our model is. By doing this repeatedly and changing things in the model, such as how big the spots are when they form and how quickly they can grow, we are able to hone in on the best combination of values for these quantities.

We have to be careful when we use this data to calculate the Wilson depression depth of sunspots however, as the areas of the spots are also affected by geometrical foreshortening. This is an effect that causes all parts of a sunspot to be reduced in area as it approaches the limb due to the spot being located on a sphere. As the area moves towards the limb of the sphere, the projected area is reduced (this can be more easily seen by simply drawing areas on a ball and observing the changes in apparent area as the ball rotates).

Comparing the outputs from the model and data give some interesting results. No matter what values are taken for the initial sunspot sizes and the rate at which spots grow, the model and data are always closer to one another once the Wilson depression effect is included. The results that come out of this analysis give an sunspot depth of between 500 and 1500 km which agrees with similar studies undertaken in the past, although they use a variety of different methods. As we know that sunspots cover a large area, this implies most sunspots are very wide and shallow dish shapes which could explain why calculating the depth is so difficult. This shallow nature also explains why the sunspots have to be very close to the limb before we can see their effect.

Sunspots depths have been studied since Wilson's first observations of the effect and much work has been done to constrain the depth that sunspots can take but there are still many questions to be answered in this field. Can we constrain the range for sunspot depths any further? Are larger sunspots generally deeper? And what can be done with these results to improve our understanding of the workings of the sun? It is a topic of great interest that will hopefully obtain answers to these questions in the near future.

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This evolution took place for many reasons. First of all we got lots of questions by the public about what's going on in "our" world. Mostly by students and teachers but also by the main public who visited our public lectures, workshops… Besides, we aim to inspire the next generation, we agreed on making the magazine. Ecological friendly, thus in the PDF format. Easy to print, save and spread around.

Only two pages (out of the standard 50 pages) of one issue are about our own workings. The rest are news and articles about everything that happened in the past month, typical monthly sections and additional articles written by our own members but mostly by other amateur astronomers in the Benelux. So our magazine is really by and for our community! And with success, because every month there are more people willing to write an article, review a telescope or simply talk about their latest observation. So it's getting popular as platform to enjoy and spread our most beloved hobby. Not for any commercial purposes, but for the love of our hobby!

Of course, there is a great team behind the screens, and also some generous sponsors who pay the bills for our internet connection, electricity... Nevertheless, we would be nowhere without the positive support from our readers. So we are, in the first place, very glad that we can bring the community a bit closer together. So hopefully the idea of cooperation will continue to spread. And we will meet other enthusiastic and interesting astronomers... all over the world. Just like we've met Kah Wai Lin, with this small article as proof that about anything is possible... when you work together!

Patrick Jaecques,
Chairman Astro Event Group vzw.

Selecting a Dedicated H-alpha Solar Scope in Today's Market

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www.charliebates.org

Two thousand and ten will prove to be the best year ever for the amateur solar astronomer as far as choices in the marketplace go for a dedicated narrowband solar telescope. There are several strong contenders to choose from nowadays from many different vendors. Hopefully this condition will lead to strong competition among the big players which can only trickle down as better quality, lower prices and faster delivery.

With solar maximum coming and a South Pacific eclipse on the horizon, there has never been a better time to go out and invest in a high quality instrument to study our nearest, live giving star. So let's get down to business. The current dedicated H-alpha scopes range from 40mm to 152mm apertures. There are plenty of oddball sizes and custom external filters out there to choose from but this article is geared more towards the amateur or intermediate user who wants a dedicated scope with a warranty from a reputable dealer.

Daystar

First is the Daystar Company. Daystar is on the web at **www.daystarfilters.com**. Daystar has been around forever and offers a full range of T-scanners and external filters. Their dedicated solar scope is fairly new to the market and there is not a lot of data or photography out there to make a fair statement about image or visual quality.

SolaREDi αlpha series 60mm Imaging Telescope

Daystar offers the following features and options for the SolaRedi scopes:

I have used the SolaRedi 60mm Penta scope and can tell you that it is certainly an attractive unit. The highlight of the scope for me was the beautiful workmanship and styling especially on the Moonlight focuser that comes standard with each scope. The SolaRedi 60mm scope uses a built in 4x Barlow to achieve its focal length of 1375mm. All of the scopes are single, unheated, solid etalons utilizing a mechanical tilt mechanism for tuning the bandpass. The Daystar scope comes with an included Televue Sol Searcher and there version of a 2 inch dovetail mounting plate. Daystar quotes a delivery time of 3 months on their website for the scope.

Pros:
Beautifully styled
Included accessories
reaches focus with all popular add ons

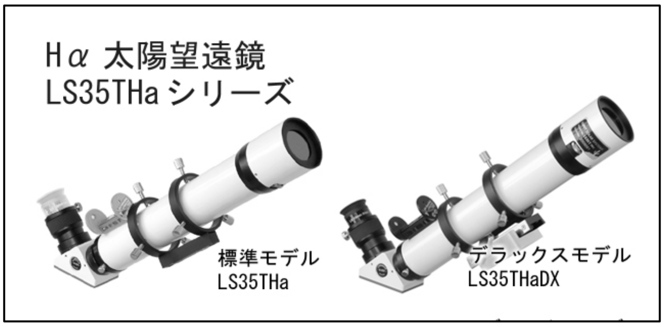
Cons:
Long wait for a scope
VERY expensive
No larger apertures available
There is a lot of glass between you and the objective with the internal 4x Barlow
No supplied case
VERY expensive

Lunt Solar Systems

LUNT Solar Systems out of Tucson is an awesome company! LUNT Solar Systems is on the web at www.luntsolarsystems.com.

Andy Lunt has also been in the field for over 2 decades working with his family at Coronado and then carting off the best of the bunch over to Lunt Solar Systems a few years ago. I must admit that I am an EXTREME fan of this company and have been referred to by a UK colleague as a LUNT "fanboy". I will try and restrain myself... I will also say that since I was thrown off the LUNT yahoo group early on for asking some tough questions of the new products and publishing a not so great review on their early offering, I don't consider myself a "fanboy" but any contact from a UK astronomer is still cool to this Georgia redneck so I will gladly accept the label.

Lunt offers a very wide selection of dedicated solar scopes of very high quality. Lunt also is the hands down leader of innovation and new ideas for observing the Sun. When they introduced the Doppler True Tuning system on their internal etalons this year they immediately made every other scope out there all of the sudden "less sensitive" and some say obsolete. The excitement among astronomers concerning LUNT is palpable at every event I go to with my scopes.



Lunt's low end entry is the LS35THa 35mm visual scope. It is basically a little tube with a small singlet objective and an external 35mm etalon rated at around .7A. It is available with all the accessories in the Dx package or as scope only. It can be double stacked but I wouldn't recommend it as you of course lose 40% of your brightness for each additional etalon added on any Halpha scope. With such small aperture to begin with, you are really digging deep to try and put a second etalon on this unit. I believe that this scope was put out there to compete with the PST in the under $1000 (US) range. They no longer advertise this scope on their website but is still available from many vendors and directly from Lunt. It makes a very nice little grab and go visual scope but has little photographic use as it incorporates a helical focuser that makes it very difficult to use with a camera attached.

Next in line for LUNT is the much sought after and quickly becoming the industry standard LS60THa

This scope is available in a "visual" package and an "imaging" package. The visual package is the single internal etalon scope, case, 6mm blocking filter (B600) and clamshell. The visual package will provide the user with a state of the art visual scope which will last for many years and show you a never ending parade of solar features to watch with friends and family. The scope is rated at <.8A and shows a very bright image with excellent prominence resolution and moderate surface detail. A great scope!

The imaging package adds a Televue Sol Searcher, a B1200 (12mm) blocking filter and a second external 50mm etalon for breathtaking views of <.55A photospheric features.

I own and use this scope almost daily. I can tell you for a fact that this is an excellent scope of extreme quality and dependability. The visual package at $1493 (US) is by far the best value on the market in this users opinion. The air pressure tuning uses a hyperbo9lic chamber which encases the entire internal 35mm etalon assembly. The handle allows the user to vary the air pressure inside the chamber +/- 3 lbs psi. This changes the refractive index of the air in the chamber thus allowing for tuning on either side of centerline for the Halpha wavelength. This has been the single most exciting advancement of the year in solar scopes and has proven to be the bell weather of things to come.
The Lunt focuser is a little shy of the Moonlite unit used on the Daystar but is certainly functional and can easily carry a decent load with stability. Lunt offers an upgrade to a Starlite Instruments Feathertouch focuser which of course blows away anything else on the market. An excellent scope at a great price in either configuration.

Lunt also offers a superb value at 100mm of aperture in the LS100THa.

This scope utilizes an internal 50mm etalon and the Doppler True Tuning system to achieve a bandpass of <.75A. This is an incredibly well made scope with a standard Feather touch focuser, case, Televue Sol Searcher and a big chunk of attitude included as standard accessories.

This is my Black tube prototype LS35THa Double Stack mounted with the Lunt 100THa during an imaging session last year.

100MM H-ALPHA SOLAR-TELESCOPE WITH B1800 BLOCKING FILTER

Price $4,848.00 Art. No. LS100THa/B1800
(contact us directly or buy from dealer)

The LS100T/Ha is a complete Solar Telescope. The refractor based system has a precision aligned singlet chromatic lens with a 100 mm aperture. The front singlet lens reduces the stray-light over an achromat by half. With the matched collimation lens set, it also fully corrects on axis coma, astigmatism and de-centering aberrations and provides a full spherically corrected flat-field Solar-Telescope. The focal length is 800 mm providing a ~7.3 mm image thru a 18 mm blocking filter. Course focus adjustment is via a slide tube. Focusing is achieved with a High Precision 2" Starlight Feather Touch Friction focuser with the a 10:1 reduction as standard equipment.
An internal etalon with tune adjustment allows for a <0.7 Angstrom bandpass.

Addionally the system may also be purchased with the 100mm external, front mounted Double Stack Etalon LS100FHa for a bandpass of <0.5 Angstrom.
See the link at optional accessories down at this side.

Specifications:
- Aperture: 100mm
- Bandpass: <0.7 Angstrom
- Focal length: 800mm
- Blocking filter diameter: 18mm
- 2" Feather-Touch focuser with 10:1 reduction
- Tube diameter: 121mm
- Tube length with blocking filter: 634mm
- Weight: 5 kg

Delivered with order:
- optical tube with 2" feather touch focuser with 2.5" travel, includes adapter
- tube ring
- B1800 blocking filter
- dovetail
- sol-searcher
- transport case

Pre-orders will be shipped in the order they are received.
Prices are subject to change without notice.

Lunt has also released a 152mm version of this scope but it has not shipped yet as of this article. You better believe that I have my order in. :)

Pros:
Absolutely awesome quality
Very value priced, in fact they are constantly the low price leader in dedicated Solar Scopes
Excellent Customer service
Most models available now with no waiting!!
Many available models and options to choose from
excellent, well built and roomy cases

Cons:
I can't think of one other than spotty availability of double stacker etalons!

Coronado

Coronado has historically been the standard for inexpensive amateur H-alpha astronomy. Coronado is on the web at www.coronadofilters.com The Coronado PST was a revolution in Solar astronomy and opened up the hobby to tens of thousands of astronomers worldwide who would never have been able to afford it before. I would venture to guess that there are over 100 times as many PST's in use in the world as any and possibly all other solar telescopes combined.

I of course started H-alpha with a PST like most of my younger colleagues in "Club Red". The PST is what it is; a cheapie solar scope with a rough focuser and a small singlet objective. It is the low price leader and appeals to many as an introductory instrument.

Unfortunately since Coronado was sold to Meade and the recession hit it is almost impossible to get a PST new right now. There is always a used one for sale though so they should not be hard to find. They hold their value well and provide hours of quick grab and go fun in the Sun. You will not find a cheaper scope that performs as well anywhere.

Personal Solar Telescope Product Description
The PST is the latest innovation from Coronado. This 'little' telescope is another step toward our goal of making it possible for everyone to, "Experience the Sun our way."
Sub angstrom H-alpha systems have long been cost prohibitive for the amateur. Designs other than the Coronado are difficult to use because of temperature and F-Ratio requirements. Not only does the PST have a bandpass of <1.0 Angstrom but it is also thermally stable and requires no more time to operate than putting in a eyepiece and adjusting the focus...
The PST represents the same technology and quality that goes into a SolarMax series telescope but with a few unique design characteristics that allow us to offer it for less than some premium eyepieces. The PST will show you prominences, active regions, filaments, as well as other surface details.
At <1.0 Angstrom it will not reveal as much surface detail as the SolarMax series telescopes and filters but it certainly doesn't disappoint.

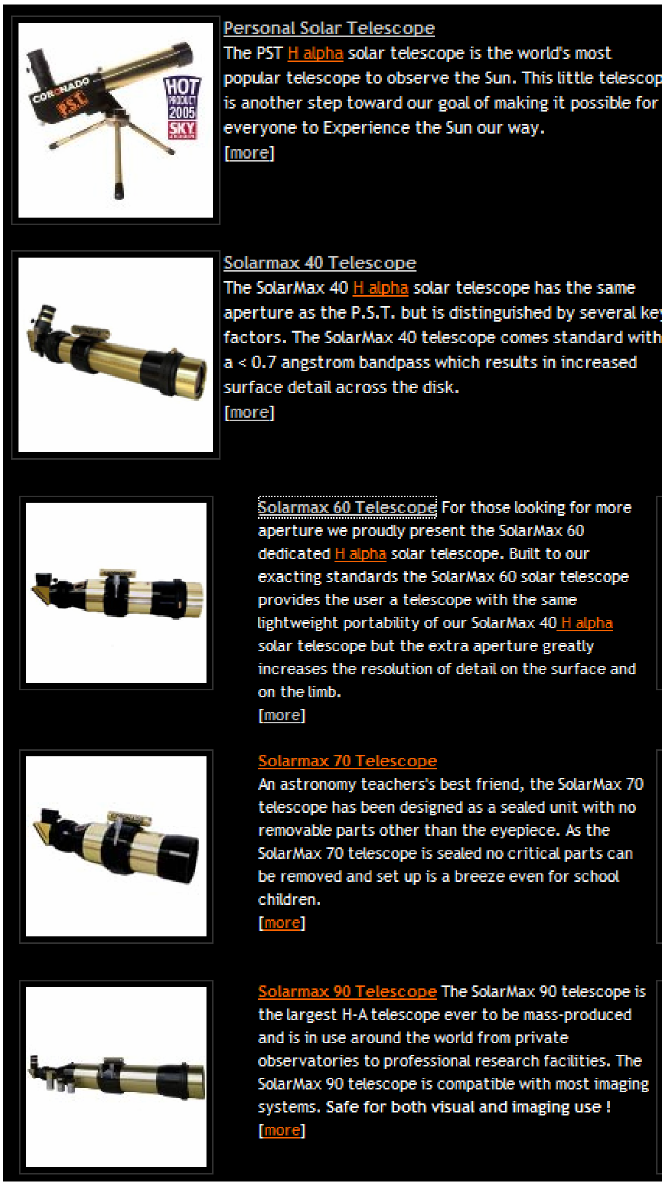
- **Aperture:** **40mm**
- **Focal Length:** **400mm**
- **F/Ratio:** **F/10**
- **Bandwidth:** **<1.0Å**
- **Thermal Stability:** **0.005 Å/°C**
- **Safety Blocking:** **>10^{-5} from EUV/IR**
- **Price:** **$499**

It has limited photographic capabilities but I have seen many fine images taken through this scope or an altered version of this scope. I'd highly recommend I for anyone on a budget to get into the hobby. Good luck finding a new one.

Coronado also offers a 40mm, 60mm, 70mm and 90mm SolarMax scope on their website. The solarmax scopes are all well designed and excellent quality scopes. They are all based on a mechanical tilt air spaced etalon or two and they all use an ill advised helical focuser.

It is somewhat difficult to decipher what is actually available from the Coronado website. Some of the ads show the scope called the MaxScope and in other places it is referred to as the SolarMax. Anyway, the single etalon 60mm MaxScope is priced at $2499(US). This is VERY high for what it is-a single etalon mechanical tilt scope.

Here are the choices:



The prices (US$) for these scopes are as follows from major vendors:

PST	**$ 499**
SolarMax 40 or Maxscope 40 single etalon .7A	**$1699**
SolarMax 60 or Maxscope 60 single etalon .7A	**$2499**
SolarMax 60 or Maxscope 60 double stacked .55A	**$3599**
SolarMax 90 or Maxscope 90 single etalon .7A	**$5999**
SolarMax 90 or Maxscope 90 1 internal 60/1 external 90 etalon .5A	**$7199**
SolarMax 90 or Maxscope 90 double external 90 etalons .5A/BF30	**$9699**

The SolarMax 70mm scope while still on the Coronado website was not available in the US from any vendors.

Yes, it is confusing, isn't it? I own the internal 60/external 90 Coronado SolarMax scope. it is the best scope I own visually or photographically. Of course I have yet to double stack any of my Lunt scopes due to availability. After replacing the helical focuser with a Feathertouch on my Coronado it became an excellent scope for my astrophotography.

I think that the Maxscope denotes external etalons only and the SolarMax scope refers to an internal etalon with a possible external stacked etalon. Coronado's internal etalons are not adjustable. The externals all use a mechanical brass ring tilt mechanism.

Coronado scopes are virtually impossible to locate as of writing this article and there were people waiting over 18 months at my local dealer in Atlanta for a scope. They are pretty darn good scopes if you can find one.

Pros:
lots of choices?
Stylish and unmistakable gold appearance
proven track record

Cons:
extremely high prices
understaffed and unresponsive customer service/repair facility
not available from any vendor I checked at time of article
shabby pressed wood cases
plagued with the rusting blocking filters on all models
very troubled parent company

Solarscope

Solarscope's dedicated solar telescope range is called Solarview (SV). Solarscope is on the web at www.solarscope.co.uk.

Solarscope has a dedicated band of users who swear by the superiority of their instruments. I do not own a Solarscope and have had no success in contacting the manufacturer for a review scope or even to buy one.

They offer the following dedicated solar scopes:

	Solarview-50	Solarview-60
Focal length	400mm	480mm
Focal ratio	f/8	f/8
Objective lens	Achromatic doublet	Achromatic doublet
Full aperture	50mm	60mm
Operating wavelength	656.28nm (H-alpha)	656.28nm (H-alpha)
Bandpass	0.7 Angstroms	0.7 Angstroms
Etalon coating	Ultra Hard multi-layer dielectric reflector	Ultra Hard multi-layer dielectric reflector
Anti-reflective coating	Ultra Hard multi-layer dielectric AR	Ultra Hard multi-layer dielectric AR
Thermal stability	<1Å / 200°C	<1Å / 200°C
Eyepiece tube internal diameter	1-1/4" / 31.8mm	1-1/4" / 31.8mm
Length	355mm / 14"	382mm / 19"
Weight	1.5 kilos / 3.5 lbs	2.25 kilos / 5 lbs
Comes with	Sol-Searcher, foam-lined case	Sol-Searcher, foam-lined case
Mounting type	Solarscope Universal Plate	Solarscope Universal Plate

According to the website the SV60 uses the same .7A airspaced mechanically tuned etalon as the SV50 but has an attachable tube extension that increases the focal length for the larger aperture lens.

The finest amateur pictures I have ever seen have routinely come from Solarscope external filters and these dedicated scopes. However, since I do not own one and have never even seen one I must rely on word of mouth to vouch for their superiority.

Solarscope SV-50 Solarview 50mm 0.7A H-Alpha Telescope

- *On Clearance! Save $580!*
- The **SolarScope SV-50 Solarview** dedicated H-alpha telescope offers 50mm of completely unobstructed aperture, for high contrast, high resolution views.
- Precisely tuned, air-spaced Fabry-Perot etalon 0.7A bandwidth.
- Etalon internal fine-tune tilt adjustment provided to optimize contrast and image resolution or to view Doppler-shifted features.
- The **SolarScope SV-50 Solarview** comes with TeleVue Sol-Searcher, an easy and safe finder for solar observing.
- 400mm, f/8 OTA is portable and lightweight at only 3.5 lbs.
- *Every Solarscope telescope is personally tested before it ships from the Isle of Man. Weather may cause delays, but most Solarscope products can be shipped within a 30 day window. A 10% deposit will be charged when you place your order, and the balance will be charged when your Solarscope is ready to ship.*

Solarscope - SV-50 Solarview 50mm 0.7A H-Alpha Telescope

One company in America offers the scopes and they list a single unit SV50 only as available on clearance for $3920. The scopes do not come with a diagonal as I suppose the blocking filter is inside the tube. Here is what the internet vendor in the US has to say about it:

In closing, while there are many choices now for a dedicated solar telescope in today's market I would strongly encourage you to purchase a scope and do it fast. With all the hoopla about the upcoming solar maximum and the ridiculous hype over the "Mayan prophecies" of the world ending in a couple of years, hadn't you better get to it and start checking out the Sun in H-alpha now before it is too late….just kidding.

If you would like to support my US based non-profit "The Charlie Bates Solar Astronomy Project" with a donation of cash or a working telescope please see my website at www.charliebates.org.

Thanks for reading.

Beginner's Guide to Rear Mount Solar Filters

Fred Bruenjes

Quantum solar filter. Image courtesy DayStar Filters, used with permission

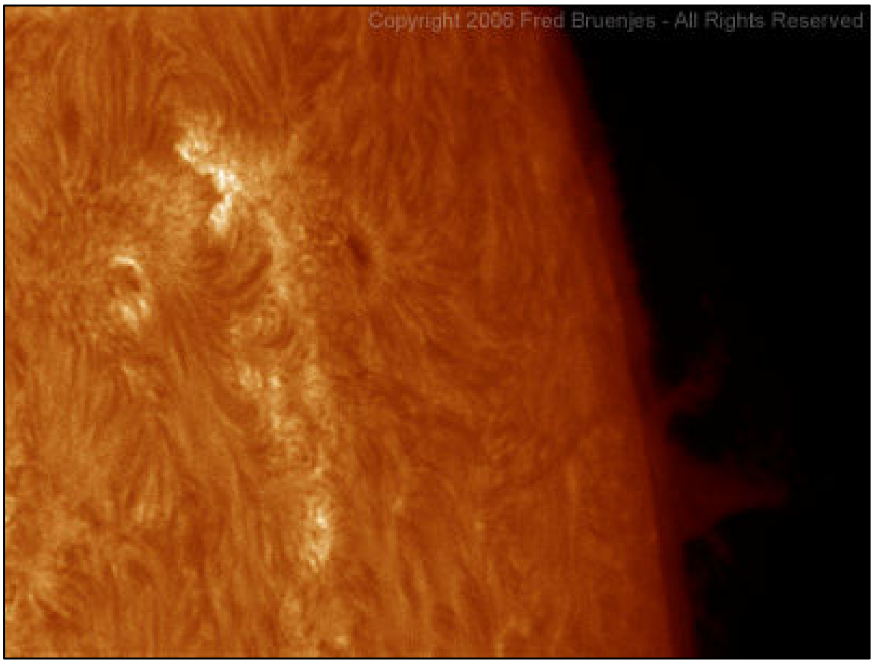
Want to get into Hydrogen-Alpha solar observing, and already own a telescope? Rear mount solar filters may be for you. A popular alternative to dedicated solar telescopes, these advanced devices mount at the rear of a telescope, where your eyepiece goes. If the thought of pointing your telescope at the sun sounds intimidating, then be assured by the thirty-plus years of safe operational history these filters have demonstrated. These filters offer access to larger apertures for lower prices than front mount or dedicated solar telescopes can provide.

The author's primary experience is with DayStar Filters, but other manufacturers produce similar products. The primary component is the filter itself, a small cylinder or box with threads or snouts on the front and rear. Insert it into the drawtube at the rear of your telescope or barlow, then insert your eyepiece or camera into the filter. The filter allows only a narrow range of red light wavelengths to pass, isolating the light emitted or absorbed by the element Hydrogen on the Sun. Other wavelengths like Calcium or Sodium are also available, but everyone starts with a Hydrogen Alpha filter as it gives the most dynamic and diverse view of most solar features.

Rear mount filters are sold by their bandpass, not their aperture, since they are not tied to a specific telescope. Narrower bandpasses like 0.4-0.5 Å (Angstroms) offer more contrasted views of the surface of the Sun, for observing features like spicule, the chromospheres, and flares. Wider bandpasses like 0.7 Å make prominences look larger and brighter. Unlike front mount filters where cumbersome and costly double stacking is required to reach narrower bandpasses, rear mount filters go as narrow as 0.2 or 0.3 Å with a single unit. The final decision on bandpass will depend on your budget and observing goals.

Other essential components of a rear mount setup include an Energy Rejection Filter (ERF) and Barlow lens. The ERF serves to reduce the amount of heat entering the telescope, and so must mount in front of the telescope so that it is the first thing to see sunlight. Typically made from precision polished yellow or red glass, the ERF must be fitted to your telescope, so be sure to order one that matches your telescope model exactly. To be safe, measure the front outside diameter of your

Full disk mosaic, a composite of 23 frames



Prominences through my 0.45Å filter.

Telescope Style	Rating	Notes
F/7 or longer Refractor	*****	Ideal solar telescope.
F/6 or shorter Refractor	****	Requires both aperture stop down and barlow.
Schmidt-Cassegrain, R-C	***	Off axis stop down ERF required.
Maksutov, Dall-Kirkham	**	Some models have difficulty reaching focus.
Newtonian, Dobsonian	-	Usually does not reach focus, off axis ERF required.

Table 1.

telescope with a ruler to ensure the correct ERF is obtained.

Rear mount filters use a solid crystal Fabry-Perot etalon inside, a technology that brings with it several restrictions. One of them is sensitivity to tilt and focal ratio. If the filter is not square to the light entering it, undesired wavelengths can pass through, washing out detail in the image. Fast focal ratio telescopes by definition have strongly angled light, so an aperture reduction mask or telecentric barlow lens must be used to straighten the light out before it passes through the filter. Focal ratios at or above F/30 will allow the filter to perform best, so use the table below to determine which barlow to use with your telescope. TeleVue's Powermates are the best choice for telecentric barlows, and were designed specifically with rear mount filters in mind.

Barlows on large telescopes can result in a high power, narrow field of view, so if you relish a low power full disk view, then it's perfectly acceptable to stop down the front aperture of a telescope to reach F/30. For example, an 8" F/10 Schmidt-Cassegrain would be monstrously high power with a barlow, but instead becomes a manageable 63mm aperture when stopped down with just an ERF and no barlow.

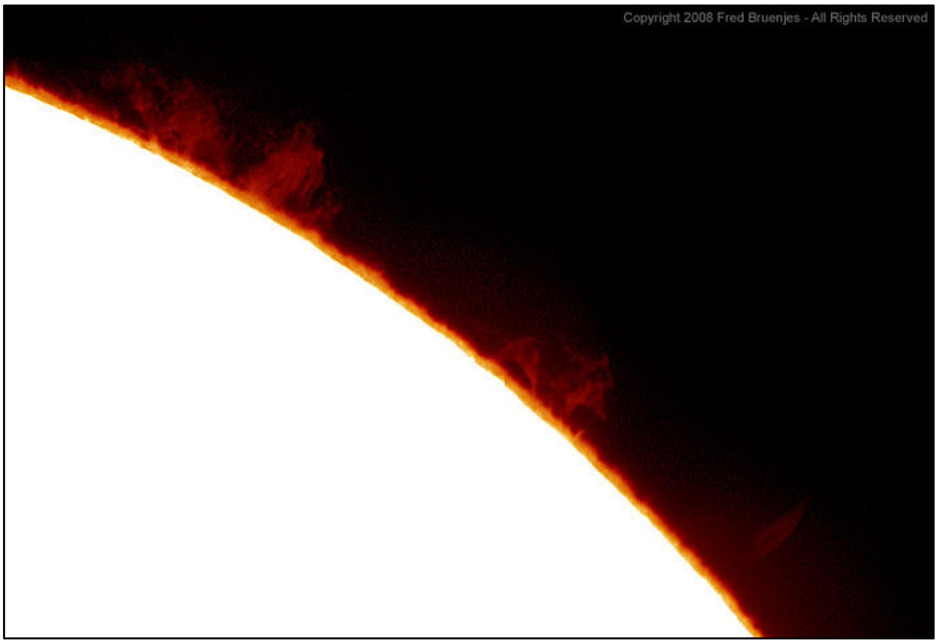
Because of the barlow and F/30 requirements, certain styles of telescopes are more suited to rear mount than others. Table 1 rates the popular designs.

Telescope owners often make a common mistake when using their rear mount filter for the first time. They tend to put in their "favorite" eyepiece, which was previously used at the native, fast focal ratio of the telescope. That eyepiece will now look dimmer and fuzzier, sometimes by a lot, because of switching to F/30. So always start with your widest, longest focal length eyepiece. The author's favorite is a 55mm Plossl. Eyepieces 25mm and under will result in a dim blurry mess because they greatly outresolve the diffraction and seeing limits of the telescope.

Next to consider is the issue of tuning. Tuning is necessary for the filter to be precisely aligned to H-alpha, so that the most contrast and best activity is seen. Rear mount filters can be tuned by tilting or with powered heaters inside. Tilting offers a limited range of outside temperatures it can work in - those in mild climates or casual summertime observers will be satisfied with manually tilt-tuned filters such as the DayStar T-

Telescope Focal Ratio	Recommended Powermate
F/6 or shorter	4x with stop down ERF
F/7 to F/9	4x
F/11 to F/13	2.5x
F/14 to F/15	2x

Table 2.



Closeup of limb through 0.45Å filter and 125mm refractor.

Scanner, but die-hards or folks in frigid climates will want a heated model like the Quantum. Of course the flipside is that a powered filter gets more awkward when observing in the field without electricity. The author has used a battery pack, or a solar panel to power his filter. There's something fitting about using a solar panel while observing the Sun!

When manually tuning a tilting filter, you're looking for the darkest view, which will give the most surface detail. Surface detail usually takes a moment to pop into view, so tuning for the darkest image is the better way to go for best contrast. If one half of the disk seems more detailed than the other, keep playing with the tuning. If all this sounds too hard, heated models offer the simplicity of plug and play operation with no tuning needed.

To recap, figure out what telescope to use with your rear mount filter. Decide how narrow of a bandpass you'll need to see the features on the sun that sound interesting to you. Add a telecentric barlow or stop-down to reach F/30. Put the ERF on the front, filter on the back, and enjoy the view through a wide eyepiece.

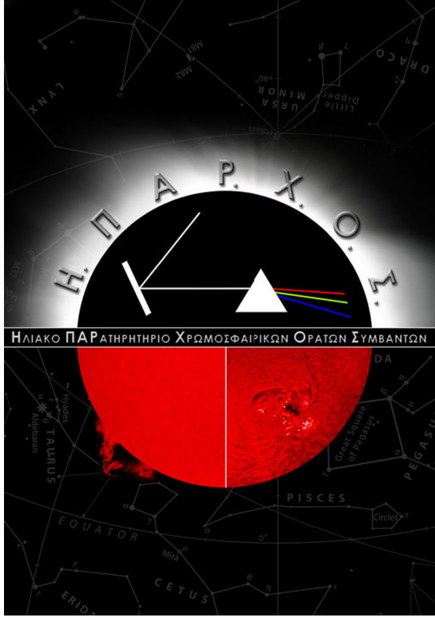
For more information about the process of choosing and using rear mount solar filters, stay tuned to Solar Observer magazine for future articles, visit the manufacturers' websites, talk with other rear mount filter users, and attend events like the NEAF solar star party.

Positives of rear mount filters

- **Usable with a telescope you may already own.**
- **Larger apertures possible, 90-150mm costs the same as 40-60mm.**
- **Larger clear aperture for imaging onto today's digital cameras.**
- **Usable on multiple scopes for an astronomy club.**
- **Narrower bandpasses available for better views, without the complexity or weight of double stacking.**

Negatives of rear mount filters

- **Limited range of focal ratios, dimmer view unless wide eyepiece or focal reducer used.**
- **Long focal train when diagonal, barlow, filter, drawtube, eyepiece all together.**
- **Power required or temperature sensitivity, take your pick.**



Spectral analysis of Coronado SolarMax 60 Hydrogen-alpha filter

~A report from IPARCHOS Solar Observatory

Aristidis Voulgaris
Founder, IPARXHOS Solar Observatory

Translated by
Alexandros Filothodoros
Member, IPARXHOS Solar Observatory

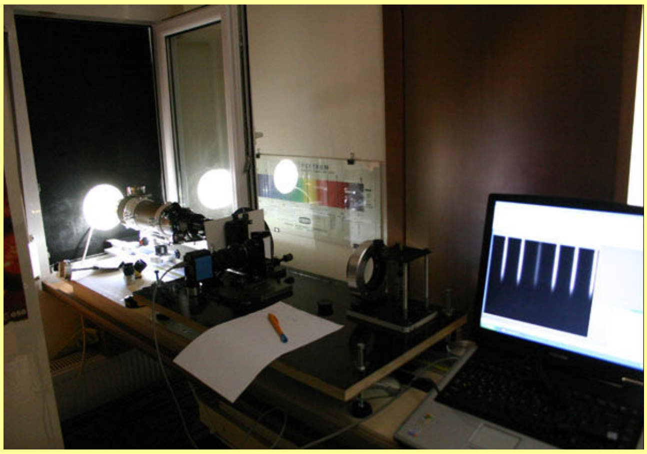
Hydrogen-alpha (H-alpha) filter allows direct observation of solar atmosphere – the chromosphere. The bright and dark features, i.e. prominences and filaments, respectively, are the most spectacular events in the observation of chromospheres by H-alpha filter. Furthermore, H-alpha allows the observation of the solar flares, high energy and particles releases in a surprisingly short period of time (a few minutes).

The color of the chromosphere is deep red, due to the fact that it consists of excited hydrogen line of 656.26A, therefore it called H-alpha. However, the red color of solar prominence can be vary, due to Doppler-Fizeau effect, when it is moving with a relatively high speed.

The etalon of the Coronado 60 adjusted to a Skywatcher ED 80

The Coronado SolarMax 60 H-alpha filter system consists of two parts, 60mm etalon (objective system) of 0.7 ångström bandwidth and blocking filter (consist of blocking filter diagonal mirror, reducing filter and interference filter). The filter system was installed to Synta Skywatcher ED 8, f=600mm telescope in IPARCHOS Solar Observatory.

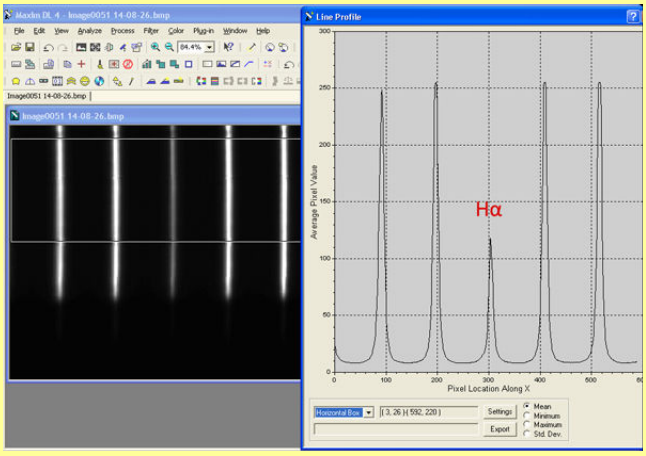
The bandwidth of the filter decides the contrast of chromospheric features during observation. The smaller spectral range reveals higher contrast of chromospheric features.



The telescope with the Hydrogen filter and the spectrograph

By using the observatory's double reflection heliostat, solar light was projected to the telescope's objective system. The measurement of the bandwidth (FWHM) of the H-alpha filter as well as marking the tuning system were performed , which is necessary for calculating the Doppler shift of extreme fast chromospheric features .

The high dispersion spectrograph (0.0923 ångström /pixel) was placed in the other end telescope and the focal point of the telescope was projected at the diaphragm (Perkin Elmer slit) of spectrograph .



The etalon's spectral response in a part of the solar spectrum

At the focal point of the spectrograph's lens, Imaging Source DMK camera was placed. The spectra showed typical interference phenomenon of a Fabry-Perot filter.

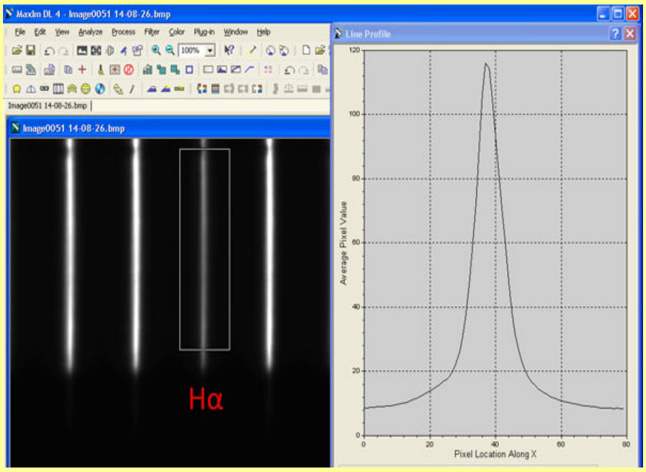
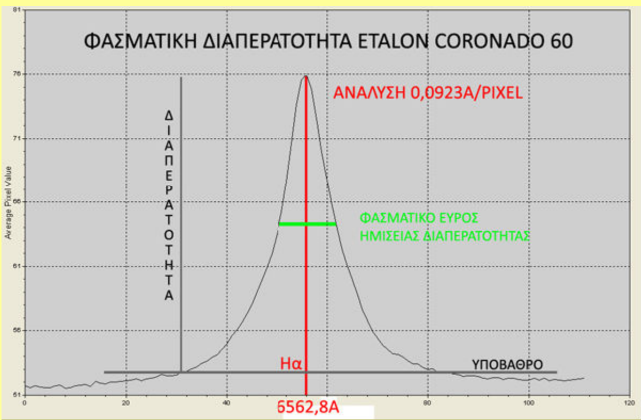


Fig 4. The etalon's spectral response at the Hydrogen Ha region

The interference spectrum at the H-alpha region with wavelength (λ) of 6562.8 ångström was imaged.



The graph of the filter's spectral range calculation

In this figure, the green line defines the bandwidth of the filter, calculated at FWHM. The measurements of the Coronado 60 etalon showed the bandwidth, at FWHM intensity, of 0.64 ångström at the right and left of the H-alpha line and 0.68 ångström at the main H-alpha line.

Marking the Filter's Tuning System

Coronado SolarMax 60 H-alpha filter system comes with a tuning system which can be use for measuring the Doppler shift caused by the eruptive moving solar prominences and filaments at speeds that can reach up to 200 km/sec (at the period of solar maximum). Because of it high speed movement, the color changes during the observation.

However, this effect is not visible to the unaided eye because the variation in the color hue is insignificant compared to the pitch variation of a moving sound source. This is known as "redshift". It happens on the spectra of galaxies when they moving away from us, as well as in the spectra of solar prominences.

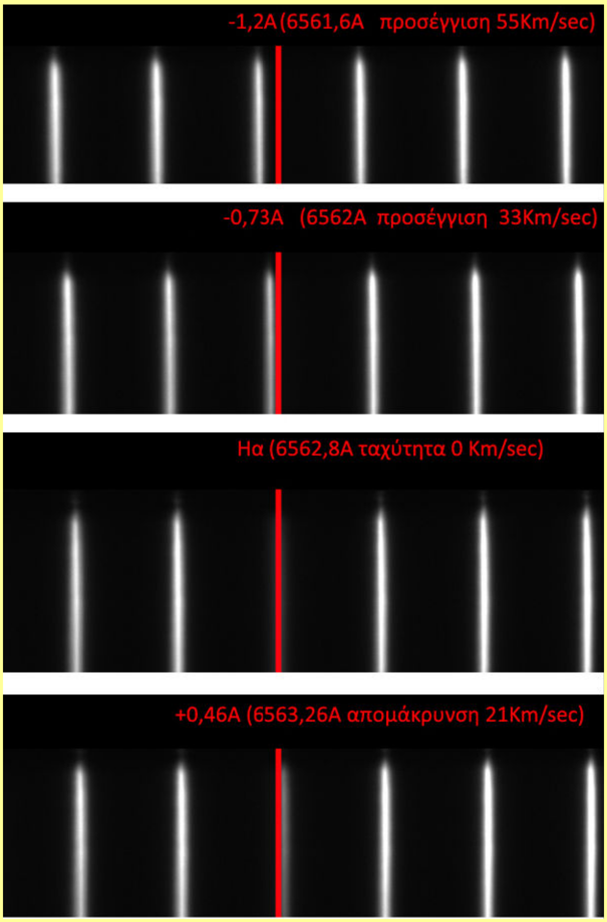
Because of the redshift, the prominences moving away from the observer change their color to deep red in comparison to hydrogen emitted color. In contrast, the blueshift occurred when the prominences approaching the observer, thereby turn into a light red.

The variation (Δλ) of a specific wavelength (e.g. H-alpha λ=6562.8 ångström) is proportional of the moving away or approaching speed of the solar prominence to the speed of light in vacuum.

$$\Delta\lambda/\lambda = U/C$$

U: approaching or moving away speed (km/sec)

C: speed of light in vacuum (km/sec)



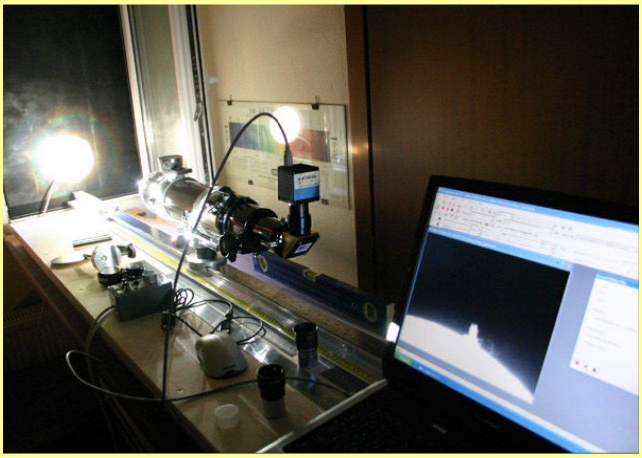
Images taken through the observatory spectrograph in pre-defined areas of the tuning system .The lines shift from the H-alpha line (red line) are seen while the etalon's slope is changed.

The tuning of filter is achieved by changing the etalon's angle between 0° and 1.3°.

In the figure above, we can see the spectral responses taken through our observatory spectrograph in pre-defined areas of the tuning system. The respective velocities of approaching (negative values) or moving away (positive values) were calculated.

Solar spectrum in the region of H-alpha 6562.8A, at 0.0923 ångström /pixel

-1,2 ångström	**55 km/sec**
-0,73 ångström	**33 km/sec**
0 ångström	**still prominence**
+0,46 ångström	**21 km/sec**



The optical array used for the measurements

In images below show an active solar prominence, taken at 7/12/2008, UT: 10:50, with different tunings of the solar filter. The shape of the prominence varies due to the Doppler-Fizeau phenomenon.

Solar prominence at 7/12/2008 with the respective Doppler shifts because of its speed.

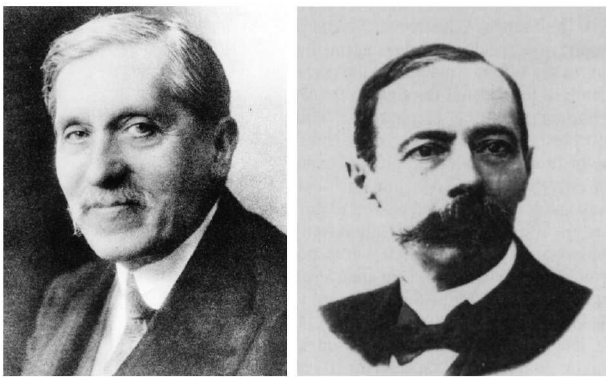
FABRY – PÉROT ETALON

Compiled and edited by Barlow Bob

The Fabry – Pérot etalon is at the heart of all modern Hydrogen-alpha and CaK Calcium narrow bandwidth solar filers. Each solar filter manufacturer created their unique patented system to observe a solar image in one wavelength. While some use layers of mica, others use an air spaced design. The Fabry – Pérot etalon was created in the late nineteen century by two French men Charles Fabry and Alfred Pérot.

In the science of optics, a Fabry - Pérot etalon is usually made of a transparent plate with two reflecting surfaces. A Fabry - Pérot interferometer is usually made of a transparent plate with two reflecting mirrors. The word etalon is from the French étalon, meaning measuring gauge or standard. Etalons are widely used in telecommunications, lasers and spectroscopy to control and measure the wavelengths of light.

The varying transmission function of an etalon is caused by interference between the multiple reflections of light between the two reflecting surfaces. Constructive interference occurs if the transmitted beams are in phase, and this corresponds to a high-transmission peak of the etalon. If the transmitted beams are out-of-phase, destructive interference occurs and this corresponds to a transmission minimum.



Physicists Charles Fabry (below left) and Alfred Pérot (right) published their most important article in 1897 on what is now called the Fabry - Pérot interferometer. Despite the great importance of this instrument for modern research today in physics and astrophysics, its inventors are almost completely unknown to most physicists.

The Fabry - Pérot interferometer is a more widely used research instrument today than at any other time in its 100 year history. Its origin derives from the theory of multibeam interference developed by Charles Fabry in 1890-1892, and incorporated into the design of the first interferometer constructed by Fabry and his colleague, Alfred Pérot in 1897.

In the form first developed by Fabry and Pérot, their Fabry - Pérot interferometer consisted of two perfectly flat glass plates coated on their parallel facing surfaces with thin silver films. In the first interferometer these metal films reflected over 90% of the light incident on them. The portion of the light beam incident on the outer surface of one of the plates, and passing through the silver coating, was then trapped between the silvered plates and reflected back and forth a very large number of times. At each reflection, however, a small fraction (1/10 or less) of the incident beam escaped through the second plate. As a result, a large number of parallel beams of light emerged at the same angle at which they had entered the interferometer and could then be focused to an image by a converging lens. The constructive interference of these many parallel beams of light produced very bright and remarkably sharp interference fringes.

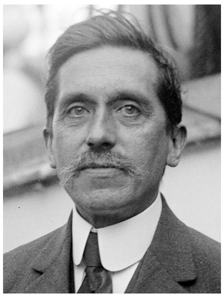
By increasing the reflectivity of the plates and their separation, the resolution of the Fabry - Pérot interferometer can be increased until it is finally limited only by the natural linewidth of the spectral lines emitted by the source.

Later they also made many important contributions to astrophysics, including Fabry's 1913 discovery, with Henri Busson, of the ozone layer in the Earth's atmosphere. Since they used their interferometer to make many important contributions to astrophysics, the names of Fabry and Pérot are more likely to be familiar to astronomers than to physicists. Both were trained as physicists and served as professors of physics, at important French universities throughout their careers.

At the beginning of the twentieth century, Fabry and Pérot were highly regarded by physicists throughout the world for their contributions to optics and spectroscopy. Later they made many important contributions to astrophysics. Fabry and Pérot deserve to be better known and more widely appreciated by the present generation of physicists, astronomers and historians of science.

CHARLES FABRY

Charles Fabry (1867 – 1945) was born on June 11, 1867 in Marseille, France, the seaport city on the Mediterranean in southeast France. When he was 18, he entered the Ecole Polytechnique in Paris. After graduating two years later, returned to his native Marseille and in 1889 he received the license to teach at any State secondary school. Fabry taught at Lycées (High Schools) in Pau, Nevers, Bordeaux, Marseille, and finally at the Lycée Saint Louis in Paris.



During this time he was preparing his doctoral dissertation on the theory of multibeam interference phenomena. This topic had been treated as early as 1831 by George Biddle Airy (1801 – 1892), but not with the depth and sophistication Fabry brought to the subject.

Fabry's interest in astronomy, acquired as a student while observing the night sky with his two brothers, led him to apply the Fabry – Pérot interferometer to the study of the spectra of the sun and stars. For work in astrophysics Fabry and Perot found their interferometer especially well suited for obtaining very high spectral resolution for sources of small angular size, like the other planets or stars. It also achieved medium to high resolution for sources of low surface brightness, like nebula or galaxies. In 1911 Fabry and Buisson discovered the "nebulium" lines in the Orion Nebula. In 1913 they were the first to demonstrate that the ultraviolet absorption in the Earth's upper atmosphere was due to ozone. In 1919 Fabry hosted in Paris the first international meeting on atmospheric ozone.

Soon after his arrival in Marseille in 1894, Fabry entered into a close collaboration with Pérot on the design and construction of a multibeam interferometer, based on the theory Fabry had developed. In 1894 Fabry replaced Alfred Pérot (1863 – 1925) as lecturer at he University of Marseille, where he spent he next 26 years, starting as an assistant in de Lepinay's laboratory. In 1904, when de Lepinay retired, Fabry was appointed to fill his post as Professor of Physics at Marseille.

Fabry has described in his own words how the work began on the instrument that later was named after him and Pérot. "The subject on which we began to work had occurred to me, partly by chance, following an observation in an electrical problem. A young physicist who was working with me wished to study the spark discharges passing between metallic surfaces separated by the very small space of a micron or less. He consulted me as to the method which he could employ to measure such small distances. The idea came to me that it would be easy to solve the problem if it were possible to observe the interferences produced across the metal."

During his career, Fabry published 197 scientific papers, 14 books, and over 100 notes, obituaries and popular articles. For his important scientific achievements he received the Rumford Medal from the Royal Society of London in 1918. In the United States his work was recognized by the Henry Draper Medal from the National Academy of Science in 1919 and the Benjamin Franklin Medal from the Franklin Institute in 1921. In 1927 the honor most coveted by French scientists was bestowed on him: He was elected to the French Academy of Sciences.

Throughout his life Fabry was very interested in the teaching and popularization of science. He wrote both textbooks and popular books on science. For many years he taught an introductory course on electrotechnology every Wednesday evening. The course was scheduled for 9:00 p.m., but the doors of the large lecture room had to be closed at 8:30 p.m., because no more people could squeeze in. He had the ability to capture a diverse audience of science students, engineers, and working men by his clear, witty words and his skillful use of demonstrations. He was both an outstanding research physicist and a spellbinding lecturer. Charles Fabry was truly the Richard P. Feynman (1918 – 1988) of France.

During World War II Fabry left Paris to carry out secret optics research related to the war effort. At the end of the war he returned to Paris, but his health was failing and he died on December 11, 1945. He added much to the established French tradition in optics, reaching back to Etienne Malus (1775 – 1812) and Augustin Fresnel (1788 – 1827).

His own words may be quoted to summarize his brilliant career: "My whole existence has been devoted to science and to teaching, and these two intense passions have brought me very great joy."

ALFRED PÉROT

Alfred Pérot (1863 – 1925) was born in Metz, France and educated at the Lycee in nearby Nancy and then at the Ecole Polytechnique in Paris. After completing his course of studies in 1884, he returned to Nancy to do research in physics under René – Prosper Blondlot. In 1888 Pérot received his Doctorate degree from the University in Paris. After receiving his degree, he was appointed a lecturer at the University at Marseille. He began work in the rapidly developing field of industrial electricity, publishing some research on the electromagnetic waves that Heinrich Heretz had discovered in Karlsruhe in 1888. Soon he became a consultant to the emerging electrical industry. In 1894 he received a special appointment as Professor of Industrial Electricity at Marseille. It was at this time that his fruitful collaboration with Fabry began. Their first research together was the development of the inferferometer that brought them lasing fame. On this project, as in most of their subsequent collaborations in the years 1894 – 1902, Fabry handled most of the theoretical planning, optical measurements, and calculations, while Pérot contributed his great mechanical skill to the design and construction of the instruments needed for their research. Pérot liked to gather a group of talented technicians around him for the construction of needed research apparatus. The first Fabry – Pérot interferometer was undoubtedly so successful because of Pérot's great talent for designing and building equipment.

Fabry and Pérot constantly improved their interferometer, and began to apply it more and more to astrophysical problems. They soon discovered small systematic errors in the earlier work of Kayser and Runge (1888) and that of Rowland (1901) on the solar spectrum. These researchers both had employed large Rowland gratings ruled in Rowland's laboratory in Baltimore. The more accurate Fabry – Pérot interferometer measurements showed convincingly that the solar wavelengths obtained from the grating spectra were too high. The Fabry – Pérot interferometer soon became the preferred instrument for highly accurate wavelength measurements on spectra, whether obtained from sources in the laboratory or in the universe of stars and galaxies.

In 1901 Pérot was asked to organize and direct a new laboratory in Paris. He did an excellent job, but soon grew weary of the heavy administrative load that fell upon him. He resigned this position in 1908 to become a professor at Ecole Polytechnique as successor to Henri Becquerel (1852-1908), while doing most of his research at the Meudon Observatory near Versailles. There Pérot devoted himself more and more to solar physics, and especially to the use of the Fabry – Pérot interferometer for the measurement of Doppler displacements of solar spectral lines. For the remaining years of his career, a deep interest in the relationship between laboratory physics and astrophysics motivated his research. He also continued some work on electricity, making contributions to the development of the triode vacuum tube, and to telegraphy. In 1920-1921 Pérot attempted to verify the gravitational redshift predicted by the general theory of relativity, but failed in this overly ambitious endeavor. He served as a member of the French Bureau of Weights and Measures. In 1915 he published an interesting booklet on the decimal metric system.

Alfred Pérot died on November 28, 1925, at the age of 62. His colleague and close collaborator, Charles Fabry outlived him by 20 years. Pérot was not well known by physicists outside of France. He preferred to remain with his family rather than travel abroad for conferences and meetings. This may explain why Alfred Pérot is not better remembered today.

Next Generation Air Spaced Etalon

Anthony Pirera

My Background -- At the age of 10 years old, I was given a Tasco telescope by my parents. When I showed interest in astronomy and the space program, they thought that it would be a great gift. Although the telescope is long gone, I still have the original Owner's Manual with the notes that I recorded as a ten year old. At fourteen years of age, I built a 10 inch Newtonian F/6.5 telescope, grinding and polishing the mirror and making the Telescope mounting. My father, a professional contractor, did not know what I was intending to build but taught me to work with tools and gave me the pipes I needed to make the mounting. After completion, I wrote a four page article for Sky and Telescope Magazine with pictures of the scope and some photos of the moon taken through the Newtonian.

As I entered high school, I developed a case of aperture fever, so I decided to build a very complex 16 inch f/4 Newtonian Cassegrain telescope. I still have all of my design drawings and pictures of this 600 pound mammoth telescope. I then enrolled in college to study engineering and later pursued an education in thin film optical coatings at UCLA. At some point shortly thereafter, I realized that my interests in optical coatings could offer a promising opportunity to work in a field that I had a passion for, and allow me to build a career around that. After finding a position in an optical coating lab where I gained a lot of on the job experience, I went back to college and added a business degree to my resume.

In 1993, I started my own company which I named Spectrum Thin Films. This proved to be a big success and 17 years later, STF produces optical coatings for major observatories, NASA, high-end telescope companies, and commercial optical companies. In 2008, we were awarded a contract to produce optical coatings for The Mars Phoenix Lander Video Camera and Microscope. Currently, we are working on the James Webb Space Telescope and a key optical component for aligning the mirrors.

In October 2008, STF was joined by Denkmeier Optical. I had hoped to get more involved in the amateur astronomy market place. With the Spectrum/Denkmeier venture, we now have the opportunity to create new products that will facilitate solar viewing. As many amateurs know, Denkmeier Optical Company designs and builds binocular viewers for telescopes. Since we at STF can design, manufacture, and test optical coatings, the synergy of the two companies promises to be a sure winner that brings some new and innovative products to the astronomy market place.

Manufacturing Air Space Etalons

Most solar observing aficionados have heard the term "Air Spaced Etalon" (ASE) but I will explain with a few basics how they work. In order for solar observers to see flares and other fine detail on the Sun's surface, a filter with a very narrow band pass centered on the Hydrogen Alpha wavelength of 656.28nm is required. Most filters being produced today have a bandwidth between 1.0 and 0.5 angstroms, and more typically that of ~ 0.7 angstroms (Fig 1). An Etalon Filter normally consists of two very flat fused silica glass optical components with highly polished surfaces and low wedge factor (parallel relationship) once they have been contacted with one another.

The central aperture of the optics is then coated to produce reflectance of ~88%, though this reflectivity can vary depending on the design. The degree of reflectivity of the coatings will make the transmitted bandwidth narrower, as the reflectivity increases.

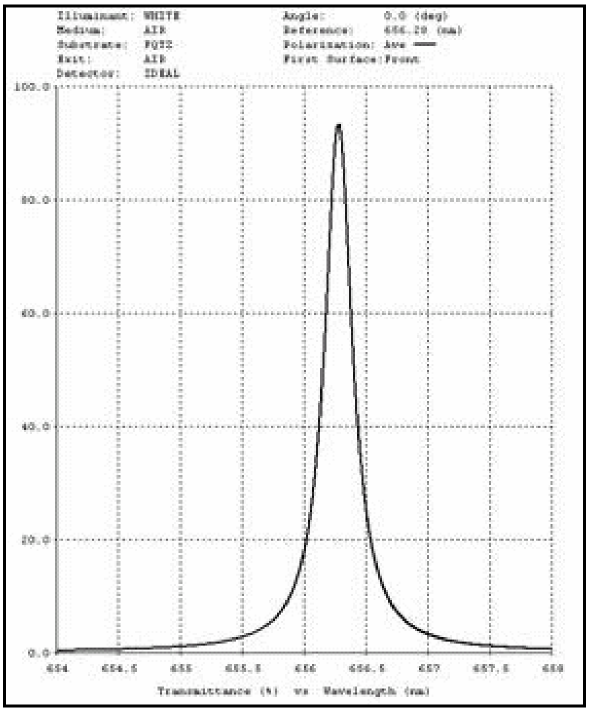


Figure 1. Typical 0.7 Angstrom Transmission Curve

However, for a variety of reasons, designing and executing coatings with higher reflectivity makes the production of the ASE very difficult. It certainly requires the most advanced coating equipment as well as full attention to every detail in order to successfully produce etalon coatings with ideal properties aimed toward achieving a given bandwidth.

After the optical components are properly coated, a spacer must be made that will separate the two respective optical elements. Normally, this spacer consists of a thin glass component that is polished to a precise thickness that has been mathematically calculated. This spacer is optically contacted to the uncoated areas of the optical parts that were described earlier, and must separating them by a very precise distance. During production, this spacer is difficult to accurately manufacture. It must create space between the optical elements, but not produce a deviation from parallelism, also known as wedge, which will degrade the quality of the etalon and also result in “sweet spots”. Maintaining exact and uniform thickness of the spacer during manufacturing procedures is difficult to execute and is very labor intensive. In addition to accurate polishing, the thickness of the spacers must also be a proper match for the reflectivity of the coatings on the two internal surfaces of the main elements of the etalon. Adhering to such stringent guidelines of the particular design becomes a challenge during production, and errors often occur. Failing to produce accurately made components can create banding and aforementioned sweet spots. These artifacts manifest themselves as changes in the solar image as sun is moved to various areas of the field of view.

It should be further noted that adjacent transmission peaks occur. Figure 2 illustrates this phenomenon. They must be filtered out by way of a blocking filter (ex. BF10) which is generally located within a right angle star diagonal. Very accurate IBS coating techniques allow us to control the proximity of these adjacent transmission peaks so that a blocking filter with a bandwidth of 1nm will be effective in removing the residual transmission peaks.

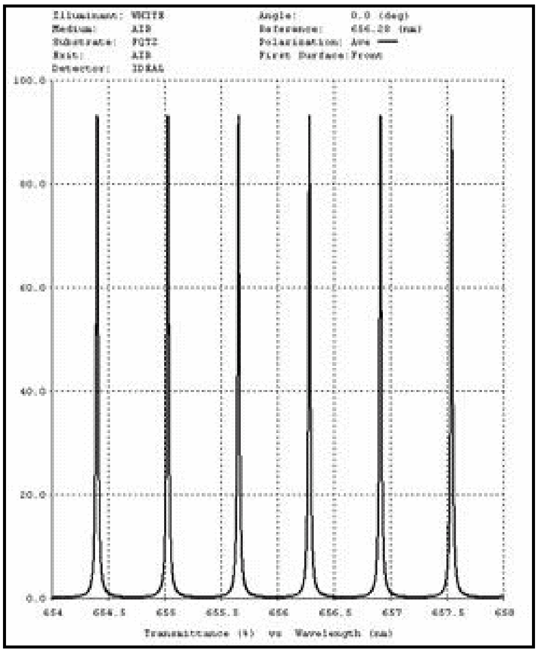


Fig 2. Transmission peaks occurring adjacent to the 656.28 nm area.

To make the bandwidth narrower in order to bring out details that remain unseen when viewing through etalons with wider bandwidths, observers often “double-stack” filters. In other words, they put two air spaced etalons on top of one another in order to produce a narrower bandwidth. While this double-stack method may produce increased filtration of <0.6 angstrom bandwidth, it adds optical elements to the system and is also a very expensive undertaking. Other means may be present in order to compensate for shortcomings as well as the rotation of the Sun. All etalons should have a tuner which actually tilts the filter within a range between 1-4 degrees. This can offset degradation of the image if the etalon coatings are slightly off band.

Our Different Approach to Making Air Spacers

At Spectrum Thin Films/Denkmeier, we have developed a new method of making an ASE with extreme accuracy and greater ease of manufacture. The spacer is not conventionally manufactured and can be produced with up to one hundred times greater accuracy. Because of our new production methods, problems due to wedge that is present in etalons with conventionally made spacers should be a thing of the past. The very costly double stacking technique used to create a narrower band pass for more detailed views will no longer be required. Our new IBS Air Spaced Etalon should be so accurate, that a band pass of 0.5 angstroms or narrower will now be possible without an expensive double stacking requirement.

Figure 2 illustrates the transmission curve of such a filter. Producing a repeatable production model of an etalon that is this narrow in bandwidth made with conventional polishing methods, would be most difficult. It is also now possible for us to narrow or widen the bandwidth of the etalon by controlling the reflectance of the coatings as well as the spacer thickness, and their relationship to one another. This is possible because of the great accuracy of our IBS machine in addition to various proprietary methods that will be employed in production, but cannot be divulged at the time of writing.

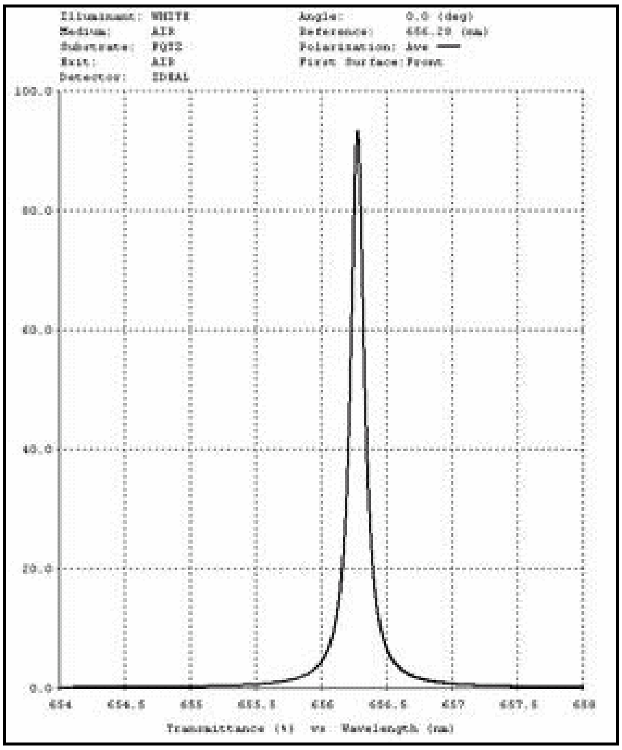


Fig 3. Our Next Generation ASE with 0.5 Angstrom Bandwidth

It should also be noted that our IBS method of producing spacing between the etalon optical elements is not only highly precise in thickness and wedge-free, but also spans a greater area. However, the clear aperture of the etalon is not reduced, despite this greater expanse of the spacers. Not only do we retain maximum clear aperture by our spacing methods, but the etalon becomes more stable due to the larger contact area between the optical components. This is because the methods of deposition allow for a longer contact configuration around the outer perimeter of the etalon aperture. An obstruction-free, highly accurate spacing system with greater contact area gives our Next Generation Air Spaced Etalon significant advantages over more conventional etalons, and our facility in Hauppauge, New York is fully equipped to produce them with consistency and quality.

In addition to producing very accurate IBS spacers, we can select a higher reflectance coating recipe and using IBS sputtering technology, achieve more accuracy and thermal stability of the etalon. Exterior surfaces are coated with ultra-low 0.1% AR coatings. Having access to in-house state of the art IBS technology negates the need to outsource these most crucial processes. Clearly, Denkmeier Optical is now ready to expand our product line and bring innovation to the solar viewing venue.

Our Dedication to Quality and Innovation

At our Spectrum Thin Films Facility in Hauppauge NY, we have state of the art IBS technology and highly trained manpower with the experience that is necessary to evolve our ideas into immediate testing stages. Spectrum Thin Films has produced specialized coatings for a very wide range of applications. Access to the latest computer design software coupled with a very advanced coating facility is the a prerequisite for innovation. However, it is the drive and ideas that really make a difference. The desire to make astronomy better and the ability to bring these ideas to fruition is what ultimately allows a new product to become a reality. Because we do not have to outsource coatings, we can utilize all of the tools at our disposal and test the results very quickly. In this way, we can revise and fine tune our designs immediately. Very few companies making products for the amateur astronomy market are in such a position, especially where high tech optical coatings are concerned. So our very special situation here at Denkmeier/Spectrum lends itself perfectly to our ability to develop innovative filters and make them available in a cost effective way, for those gathering on observing fields across the globe.

Availability

We are targeting the beginning of availability for our line of Next Generation ASE Filters to occur in the later part of 2010 or early 2011. As always, this is dependent on successful testing of the final production systems. The production models must meet our stringent quality requirements and we will not accept customer orders until we can assure that delivery will occur within a projected time frame. We try our best to time the process of producing an ideal product and having it ready for shipment, but quality is the most essential ingredient to long term satisfaction for us, and the customer. Our experiments have proven that we can achieve what we have set out to accomplish; the commercial production of a highly accurate and repeatable ASE with a very narrow bandwidth without the need to double stack etalon filters and we look forward to making this available to the solar observing world as soon as possible.

Our IBS Machine at The Spectrum Thin Films Facility in Hauppauge, NY

References and Online Resources

Resonant Spaces An Introduction to Air Spaced Etalons and Solar Telescope Technology
Part 1: http://www.cloudynights.com/item.php?arch=1&cy=2008&cm=5&cmn=May&item_id=1791
Part 2. http://www.cloudynights.com/item.php?item_id=2015
By Colin Kaminski

Review of Ion Beam Sputtering
http://www.pfonline.com/articles/pfd0027.html
By Ramin Lalezai

What Is All That Stuff On the Sun?

Steve Rismiller, Milford, Ohio, USA

If you have ever looked through a telescope almost every object will show more detail than you ever imagine. Looking at the moon for instance, even the smallest of telescopes will show craters and highland areas outlined with the lunar maria. Just one look at Jupiter and most likely four moons will be visible and many bands will appear across the planet. Who can forget their first view of Saturn and its rings with a telescope? Telescopes are designed to magnify the view of your target, making it appear closer, and therefore show more detail of the target. The larger the telescope, the brighter and more detail will be seen on the moon, planets or deep sky objects.

Fig. 1 Astro Solar Safety Film objective filter in place.

Observing the sun with a telescope is a rewarding experience provided the telescope is fitted with the appropriate solar filter. Solar telescopes are not like telescopes used for nighttime observing where large apertures are need to resolve dim details. Actually the opposite is true. Unlike deep sky objects, the sun is only 93 million miles away and provides a brilliant image. A large telescope will focus too much solar energy to the eyepiece or camera. Fitting a large telescope with a white light solar filter is not practicable due to cost. Also large telescopes will suffer from daytime atmospheric turbulence far more than a small telescope. So, a small telescope will usually provide a great view. Most ideal are refractor telescopes from 40mm through 152 mm in diameter. If you plan to use a large reflecting telescope an external aperture stop must be placed in front of the telescope and fitted with a white light solar filter to control the amount of solar energy entering the system. This article is focused on solar observing in white light. To do this safely, one must have a solar filter to block the visible, IR, and UV light from the sun. There are many filters on the market made from various materials. They each have their own specifications as to what type and size of telescope for which they are to be used. All solar observers should be aware of these specifications and adhere to them. Afterall, failure to use the correct filter or use of a faulty filter will most likely cause eye damage to the observer. For white light observing, my personal preference is the Astro Solar Safety Film by Baader Planetarium (see Fig.1). This material is used to make an objective filter that is securely placed in front of the telescope, binoculars or camera system. Astro Solar Safety Film is CE-tested and reduces the solar energy by 99.999 %, which is equivalent to a neutral density 5.0 for visual observations. Placing this filter in front of my Vixen 102ED refractor (Fig.1) creates a wonderful white light solar telescope. What is most appealing to me is the fact that the suns appears a neutral white color and not blue or orange. It has been my experience that a glass filter producing an orange color solar disk makes it extremely difficult to observe the faculae features around sunspots. For more information about the Baader Planetarium Astro Solar Safety Film, check out their web site at http://www.baader-planetarium.com.

Finding the Sun

Once your telescope has been properly outfitted with a white light solar filter, it is time to start observing the sun. Start by either placing a solar filter on all of your finder telescopes or by removing the finders. I have heard many stories about observers getting their cloths burned by the sun shining through the finder telescopes. Other stories include kids removing the dust cap on the finders and trying to look at the sun through an unfiltered finder. On my solar setup, I remove the optical finder and replace it with a solar

Fig. 2 solar finder

finder. My solar finder (Fig. 2) consists of a piece of aluminum tubing with a diameter that will fit in my finder bracket. There is no optics in that tube. In my situation, the tube has an outside diameter of 1.25 inches (the same as many of my eyepiece barrels). I drilled a 4 mm hole in the center of a black eyepiece cap and placed it on the end of the tube that faces the sun. On the other end of the tube I used a clear Vixen eyepiece cap. I used a Vixen cap because it has a logo in the center of the cap and acts as a reticule to center the sun. When this solar finder is aimed at the sun, a bright white dot is seen in the clear Vixen cap. My face can be several feet away from the finder and I can still see the white dot. I just move the telescope until the solar dot is in the center of the clear cap. Now the telescope is pointed at the sun. There are no optics involved so there is no chance of burning your clothes or anyone's eyes.

Your first look at the Sun

To begin looking at the sun, choose a medium power eyepiece, maybe a 20 to 25 mm. Extra wide angle field of view eyepieces are not required to observe the sun. I use 1 ¼ inch orthoscopic eyepieces and they work very well for me. They have a narrow field of view but the entire disk of the sun is a sharp image. Insert the eyepiece into the focuser and focus on the solar disk. To start, work on getting the edge or limb of the sun to a sharp edge. If the sun is uncomfortably bright, you can add a polarizing filter or a weak neutral density filter onto the eyepiece. Keep in mind that as you change eyepieces and increase the magnification the solar disk will get dimmer.

Once the Solar disk is in focus, (Fig. 3) you may start to see some details. The disk that is visible is known as the **photosphere**. The word photosphere comes from two Greek words *photos* meaning light and *sphaira* meaning ball. The photosphere has a temperature between 4500° and 6000° Kelvin. The photosphere is composed of convection cells approximately 1000 kilometers in diameter with hot rising gas in the center and cooler gas falling around the edge of the cell. Each cell or **granule** has a life span of only a few minutes, resulting in a continually shifting "boiling" pattern. To increase your chances of seeing granules, add a green filter to your eyepiece along with the solar filter. Yes, the sun will appear green but if seeing conditions allow, you will see the granulation much easier.

The sun is coming out of a long solar minimum and sunspots are beginning to become more frequent. As this image illustrates, you may see a small black region containing one or more black dots. This is a sunspot or a sunspot group.

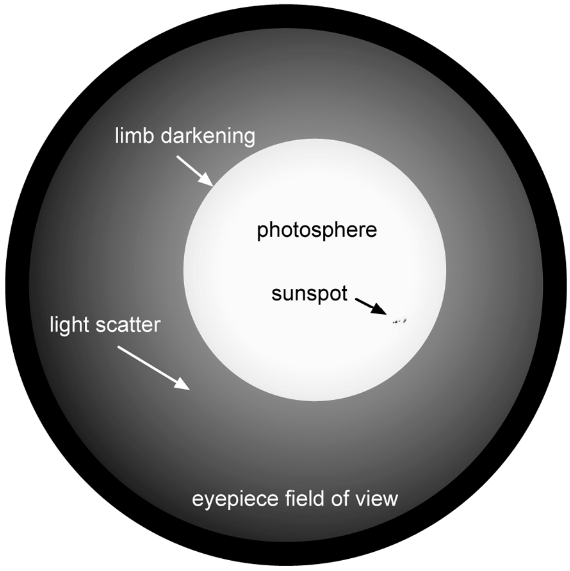


Fig. 3 The sun in the eyepiece

Another thing you may observe is that the sun appears slightly less bright around the edge than in the middle. This is called **limb darkening** (Fig. 3). It is a real phenomenon and it gives the sun the appearance of a sphere and not just a flat disk.

You may also notice the dark space around the sun is not black but charcoal gray. Several things can cause this. First, if you are looking at the sun and the sky is not a deep blue color, then you may be seeing **light scatter** (Fig. 3). The more white looking the sky is to your unaided eye, the brighter the background will become in the eyepiece. There is not much you can do about this since it is controlled by the weather. However, if you see this type of haze in a blue-sky day, then you may have some light leaks in your telescope system.

Follow this checklist to remedy the problem

1. Check the objective solar filter for pinholes. Do this by moving the telescope from the sun and removing the filter. Turn on a bright light in your house and hold the filter between you and the light. You should not see any pinholes or streaks of light. If you do see light, it is time to replace the filter. If you are using the Baader Astro Solar Safety Film, be sure the filter cell is not flexing and causing streaks in the film when you place it on the telescope. The film should be loose and flexible in the cell (Fig. 1). If the cell deforms and stretches the Solar Film, the filter will fail.
2. With the filter still off the telescope, place the telescope dust cap in front of the telescope so no light is entering the telescope. Remove the eyepiece from the focuser. Look through the telescope to see if there is any light entering the system. It should be very dark in the tube assembly. If you see light, fix it so the leak is gone. Once the inside of the telescope is dark, remove the objective dust cap, install the solar filter, insert the eyepiece and check the image. It should be a better image.
3. If you see strange reflections around the sun or in the field of view, carefully tilt the objective solar filter just a few degrees. This will cause the reflection to move out of the field of view and will not noticeably distort the image. Be sure the filter is still secured to the front of the telescope.

Now you have tuned your solar telescope and are ready to do some observing.

Looking for the details

Let's take another look at the sunspots (Fig. 4). **Sunspots** occur where the sun's magnetic field loops up out of the solar surface and cools it slightly, making the surface less bright. If it were possible to lift a sunspot off the sun and look at it against the background of space it would still be very bright object. The sunspot appears dark or black because it is about 1500°C cooler than the surrounding area of the photosphere. Now is a good time to change the eyepiece for higher magnification. As you zoom into the sunspots you will begin to notice the little black spot now has a black central region known as the umbra. The **umbra** appears very dark because there is a close relationship between the darkness of the umbral region and its magnetic strength as well as its temperature. Surrounding the umbra is a lighter gray outer region called the penumbra. The **penumbra** forms from the granules surrounding the umbra. The penumbra is also magnetic in nature and develops filaments looking like dark threads. The **filaments** behave with convective characteristics. Between the dark threads are areas called **penumbral grains**. To observe these dark threads and penumbral grains, your telescope must have a resolution of 1 arc second or better. Use a red filter with you solar filter to help boost the contrast of the filaments in the penumbra. In my experience, daytime seeing conditions make seeing penumbral grains difficult to distinguish. Another feature sometimes seen in sunspots is a **light bridge** (Fig. 5). This feature is seen against the umbra as a white section resembling a bridge crossing the umbra. At times it appears to divide the umbra and even the penumbra. As the sunspot ages and becomes mature, a massive light bridge may develop. When this happens, the sunspot is near the end of its cycle. So what would a sunspot look like in its infancy? Well, young sunspots start out in a zone about 35° north and south of the solar equator. About 7 to 14 days before the sunspot appears, a bright faculae region develops. **Faculae** mean a bright point. Faculae, (Fig 5) like most everything else on the sun are a magnetic feature. It is a hot spot among the granules. Faculae are a white, granular appearing, structure that is difficult to

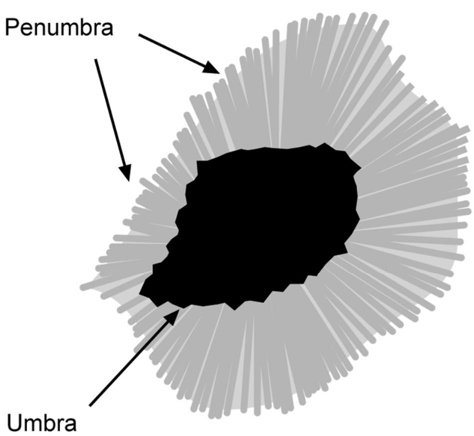


Fig. 4 umbra and penumbra of a sunspot

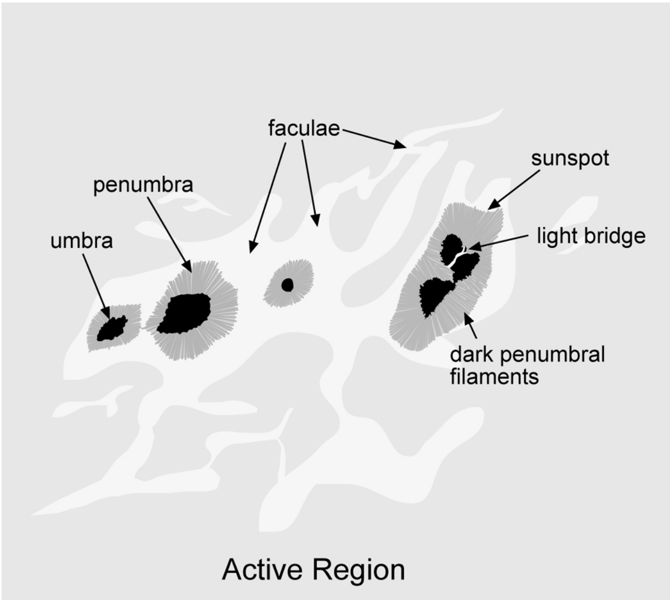


Fig. 5 A grouping of sunspots is known as an active region

see on the photosphere. When it appears close to the solar limb, Faculae are easier to see because of limb darkening. Use of a green filter in conjunction with your solar filter will help you observe faculae. As Faculae magnetism grows, small pores will begin to grow. **Pores** are tiny structures with a diameter from 1 to 5 arc seconds. They are darker than granules but not as dark as the umbra of a sunspot. Small pores may only survive for a few hours and be very dim while large pores will be darker and may grow into a sunspot. Pores can be seen in the area of already developed sunspots.

Active Regions

When sunspots develop into a group, they look something like this illustration in Fig. 5. As sunspots become stable and continue to grow the leading spot will be the one most westerly. How do you know which direction is west? This is easy to figure out. If your telescope mount has a drive on it, turn it off and watch the direction that the sun drifts in several minutes. The sun will drift to the west and out of the field of view. Now you know which direction west is on the sun. The remaining spots will realign themselves becoming parallel to the solar equator. The leading spot will have a magnetic polarity opposite the following sunspots. This grouping is known as a bipolar sunspot group. If a group of sunspots remain in a single concentration with all the spots in a small 3-degree area, this group will be a unipolar sunspot group.

Summing it up

White light solar observing is usually the most economical way to become a solar observer. A small refractor 60 to 100 mm in diameter, working at f/6 to f/9, two or three eyepieces for low, medium, and high power, a solid and steady telescope mount, and a good white light objective solar filter is all that is needed to start observing the sun. The addition of some red and green filters for your eyepieces will help improve the contrast as you progress with your observing skills. From that level, upgrading solar filters, Herschel wedges, Continuum Filters, and eyepieces may improve your views of the photosphere and it features. Those upgrades will increase the cost of your solar observing hobby and in my opinion should be considered after you have spent some time observing out in the sunshine. Solar observing is not for everyone. It is a demanding hobby and requires persistence if you want to learn to observe the details that I have introduced you to in this article. To record your observations, many people use cameras to acquire images while others make sketches. For more information on how to make your observations available for research, check out these organizations:

- Association of Lunar and Planetary Observers Solar Section at www.alpo-astronomy.org
- American Association of Variable Star Observers Solar Division at www.aavso.org/observing/programs/solar/
- British Astronomical Association Solar Section at www.britastro.org/solar
- Belgian Solar Observers at www.bso.vvs.be

Observing the dynamic sun is a very rewarding experience especially when you realize the size and energy that is expelled by the sun as these features develop and fade. Sunspot observation historically is the way that solar cycles have been determined. Work is underway worldwide compiling observations of activity in the solar photosphere to determine the effects of the sun to life on Earth.

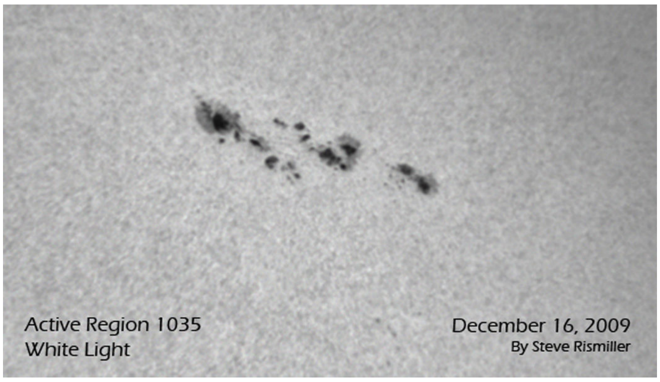
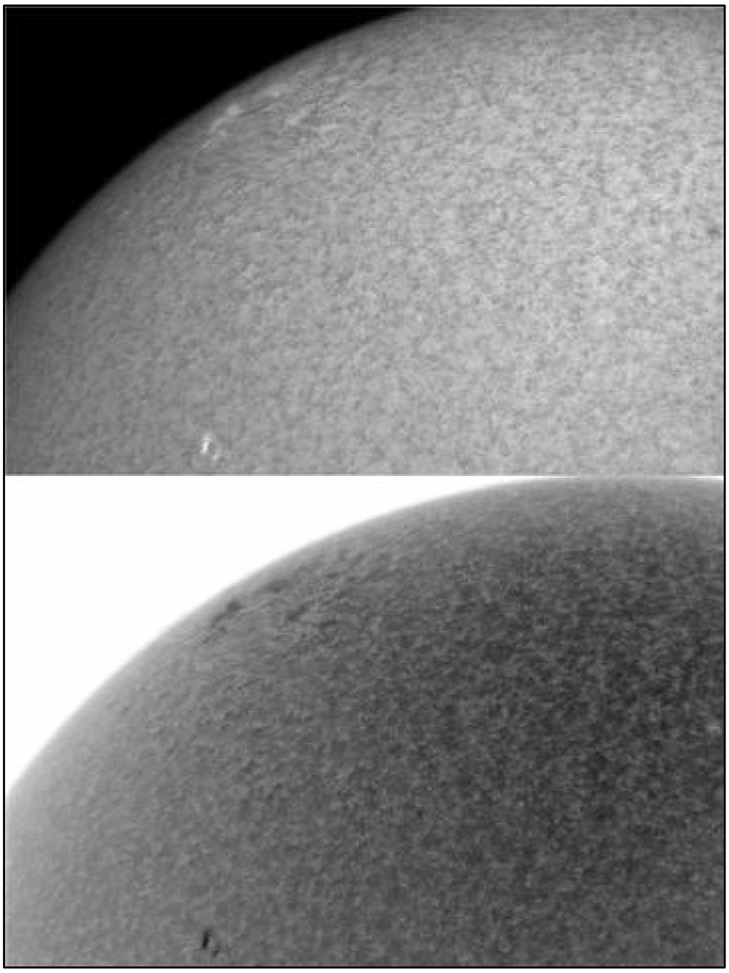


Fig. 6 A white light image of Active Region 1035 imaged by Steve Rismiller. This image was made with a Vixen 102ED refractor at f/6.5, 2.5x Powermate, Baader AstroSolar PhotoFilm (N.D. 3.8), DMK 31AU03.AS imaging camera, UV-IR filter and Baader Continuum filter on the camera. This is a stack of 100 frames.

The Return of Active Region 1029

Matt Wastell

Although we are in the depths of solar minimum – the period where there is the least amount of activity in the solar cycle – there is on the odd occasion some interesting things to observe.



Active Region (AR) 1029 has made a stunning return!

It first appeared on the 23rd October 2009 and quickly grew into the largest active region so far this year. A stunning sight for solar observers who have seen the sun as a blank disc for much of 2009. It was also credited for producing solar flares – bright outbursts caused by the sudden release of energy associated with the magnetic fields of sunspots. But at the end of the month AR 1029 disappeared over the western limb of the sun as it rotated out of view.

Fast forward 14 days and AR 1029 has returned from its dark side journey.

In preparation I set up well before the sun rose, as I did not want to miss an opportunity to view this well travelled region. My equipment is quite modest, a Coronado Solarmax 40 on a basic equatorial motorised mount. The Solarmax 40 allows only light close to the Hydrogen Alpha wavelength to pass through to the eyepiece showing features visible in the sun's chromosphere. The chromosphere is normally invisible to the human eye and is the solar atmosphere above the visible photosphere. Basically you can see what cannot be seen! Even through this 40mm scope Hydrogen Alpha views are stunning.

Starting with a 25mm eyepiece the solar disc was about the size of a tennis ball at arms length glowing a fantastic red. When focus was achieved one of the always-present chromospheric features – Spicules – were easily observed across the entire disc. These are best described as hot gas eruptions that appear as short dark needle like features. These features give the solar disc a great three-dimensional feel as they compress and appear darker due to the foreshortening as you approach the limb.

Even at this low magnification a disturbance in the chromosphere towards the north-eastern limb was easily detected. AR 1029 was back and in an instant I dropped in a 10mm eyepiece to take a closer look.

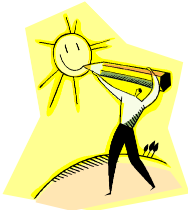
The region is not yet showing the sunspot that featured two weeks ago. Sunspots are caused by intense magnetism that punch holes in the photosphere and inhibit heat transfer. Sunspots are therefore 'cooler' than the surrounding solar material. It is believed Chinese astronomers over two thousand years ago were the first to witness sunspots when dust in the atmosphere filtered the sun's glare and highlighted the dark spots.

I am always surprised how quickly things change on the sun. Uninterrupted viewing allows you to see motion as Spicules dance around the active region and the brighter patches – Plage (the French word for beach) – seem to pulsate with a hypnotic rhythm. A smaller brighter region to the west of AR1029 was also putting on a good show seeming to brighten as the hours passed. And not to be overlooked, a small filament – a cloud of material suspended in the solar atmosphere by magnetism – added more to today's session.

I do love looking at our star.

After several hours of observation I prepared my Imaging Source DMK 31 Monochrome USB CCD camera for some imaging. This camera has the ability to capture 30 frames per second at a resolution of 1024 x 768. I really enjoy using this imager for several reasons – easy software to understand and use, high resolution, a fast refresh rate and a moderate price. The captured AVI files are easily processed in Registax 5 – a free imaging-processing programme that is downloadable from the net.

The included image was taken from my back deck in Brisbane, Australia on Sunday 15th November 2009. It represents the best 300 of 1000 frames stacked and processed in Registax 5. I also like to include an inverted image of my solar work to assist in identifying features that may not be as easily seen at first glance.



Beginner’s Full Disk White Light Sketches

Erika Rix Sketching the Sun

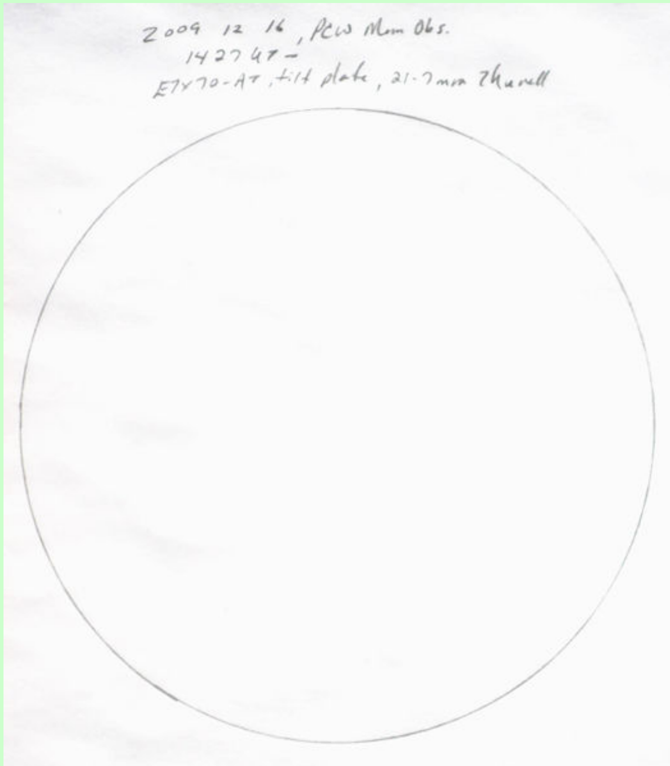
Rarely do I walk out the door for an observing session without grabbing my sketching kit, even if it’s just a piece of photocopy paper, clipboard and a pencil. It all started when I realized that just visually observing an object wasn’t quenching my thirst, and I found trying to image through a telescope frustrating and taking away from my time at the eyepiece observing. Through sketching, I had finally found a relaxing, thorough way for me to study the object I was viewing and have a visual record of it for my astronomy journals to go along with my notes. Everyone has his or her own niches in this hobby.

With regards to sketching, what motivates one person to sketch is often entirely different that what motivates another. Some people enjoy realistic renderings while others enjoy sketching the “feeling” of the object through abstract. Whatever your reasons, styles, or motivations, if you enjoy it...well.... it makes it all worthwhile.

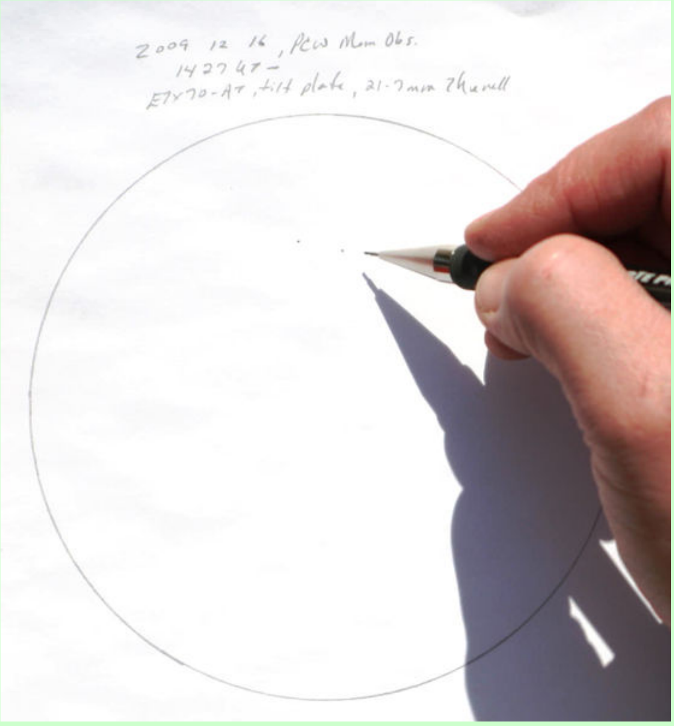
I tend to lean toward realistic renderings and try to make them as accurate to my view through the eyepiece as my ability allows. You will find yourself improving with each observing/sketching session you do. There are so many techniques and sketch media to try, but for this article, we will start out with the basic tools using a white light filter for a simple full disk rendering. During spans of active regions being present, daily simple recordings in white light are a treasure to have with very interesting results.

Tools/equipment used

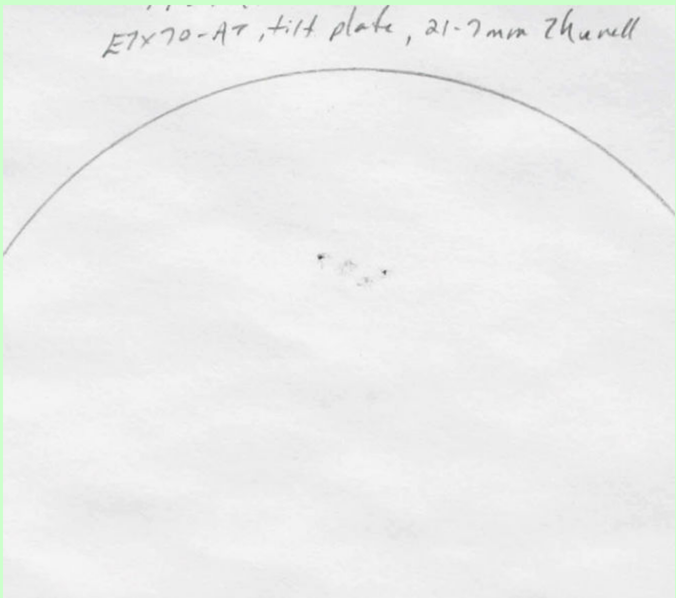
- ETX-AT 70mm with tilt plate (I do not use tracking for this scope, I leave the azimuth clutches unlocked)
- 21-7mm Zhumell eyepiece
- Glass white light filter
- #2 pencil and a 0.5mm mechanical pencil
- White vinyl eraser that can be sharpened to a point for any stray markings
- Compass set around 2-3”
- Sheet of regular photocopy paper on a clipboard – notice, even though my paper is warped, it still serves its purpose well.
- Comfortable chair



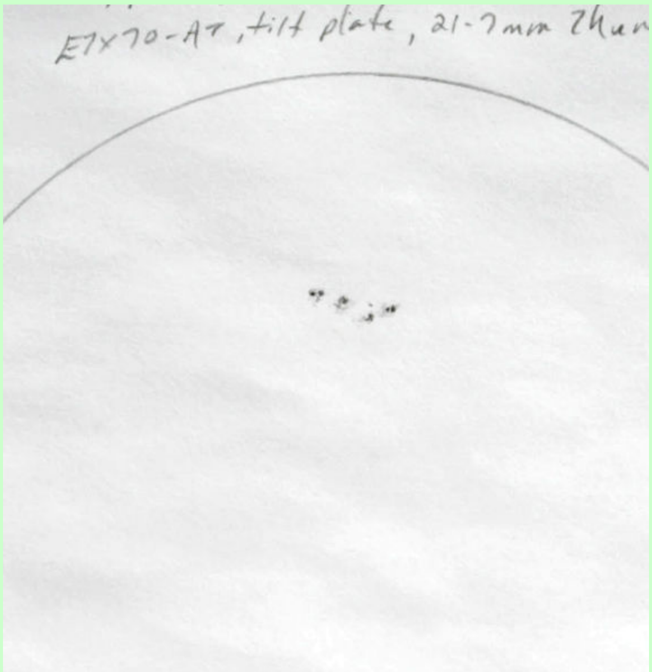
If you prefer, there are solar templates available for daily recordings through sources such as ALPO, Astronomical League, the British Astronomical Association, and countless others. I tend to use plain sheets of paper for my solar sketches for the freedom to do close up renderings or full disks. With the use of a compass and #2 pencil, draw a 5-6” diameter disk and add dates, times, equipment used, and location for future reference. Using a larger sketch area makes it easier to add the finer details and helps to keep features in the appropriate perspectives to the solar disk.



Imagining the solar disk sectioned in quarters or even eighths (and this is where a gridline template or a cross hair eyepiece could come in handy if you prefer), use the mechanical pencil to put in anchor markings. Anchors are defined areas that you can use as reference points as you add additional markings. In this case, I used the dominant preceding and following umbrae of the sunspots in that active region. Pay particular attention to the placement of your anchor markings. It is too easy to misplace the features or sketch extra large so that by the time you are finished with your sketch, you have a mega-active region several times larger than it actually is.

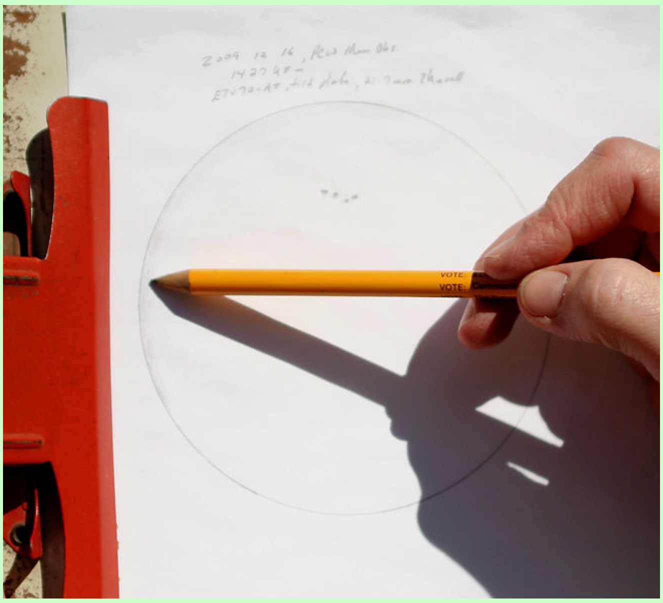


Use the #2 pencil to lightly sketch in penumbrae or any observed contrast areas. Wait for moments of steady seeing. Sometimes it helps to gently tap the telescope to bring out these faint areas. Once you see them clearly, you may be able to increase magnification for rendering precise shapes or contrast within these areas.



Final details to the active region are added by using the mechanical pencil for the additional umbrae or pores and more structure within the penumbral areas. Use the highest magnification that seeing permits for this stage. Wait for moments of steadiness. It helps greatly to use triangulation for placements of features. Every time you add a marking, visualize its position with respect to two other markings.

Then cross-reference it again with another pair of markings.



Limb darkening is often observed in white light, while the middle of the solar disk is a very bright. This is why it can be difficult observing faculae toward the center of the disk, yet being easier to see toward the limb. This specific day, I witnessed no faculae. Adding limb darkening is easily done by grasping the #2 pencil near the end so that you can use a very light touch while moving the pencil tip back and forth just inside the edge of the circle. Press a little harder nearer the edge and feather it out lightly as you move inward. Try not to mark more than 3-5mm deep inward from the edge. Then using your fingertip or a blending stump, blend your markings so that it appears as a smooth shadow creating an almost three-dimensional disk.

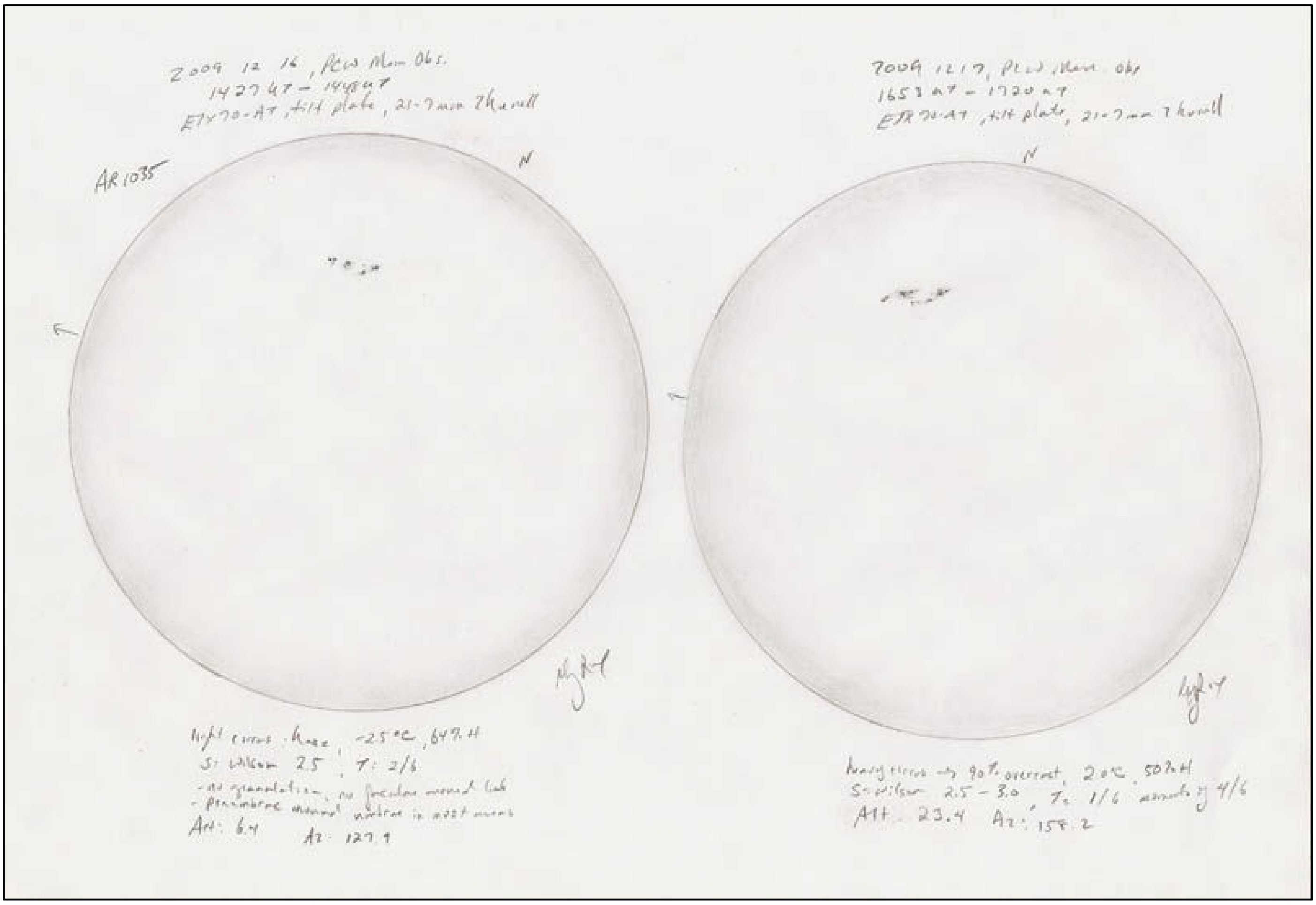
Turning off the tracking on the mount if you use it, let the Sun drift out of your field of view. Use this to mark your orientation with the Sun drifting toward the west. Mine is represented by an arrow...much to my delight when I get tongue-in-cheek comments about my arrow-shaped prominences.

I then record weather and sky conditions, the end time of my observation, and then the solar position at my location.

The sketch below is a two-day comparison of the active region using a white light filter: day one was used for this tutorial; day two was the following day. Notice that I elected to keep the orientation as seen visually during my observing sessions. Some find it helpful to flip the sketches around to match standard solar orientation.

There are many ways we could have added to the presentation of this sketch, made use of various papers or other sketch media to aid the rendering process, other types of filters with an assortment of wonderful solar features to sketch, and various sketching techniques to explore.

Until next time, enjoy your white light sketches!



How to Clean an Eyepiece

Larry Alvarez

Cleaning an eyepiece is a necessary evil at times to maintain excellent seeing quality with a telescope. There are several pitfalls to avoid when taking on this task and items to keep in mind to keep your equipment in top shape and ready for those elusive 10/10 seeing conditions. The main goal of this simple how-to is to provide answers to the questions of when you should think about cleaning your eyepieces, what you should use and how, where can you get the items needed, what should you avoid doing, what can you do to keep them clean, and lastly how much will it cost?

Cleaning Gear – Liquids, Dusters, and Rags

Every good how-to should begin with a list of what it will cost to complete the project. I have included a small list of items below and their relative costs, what to look for on their labels and what to stay away from. I think you'll find that some of these things are items you might already have at home. Some of the items are highly flammable so the proper care, ventilation, and protective gear should be used when handling them or disposing of their remains.

Isopropyl Alcohol

$1 to $2.50 depending on the concentration and amount.

What it does?
It dissolves oily compounds, finger prints, glue, and evaporates quickly. It is safe for household use when used correctly.

What to look for?
This is a common cleaning solvent and antiseptic. It comes in several types and concentrations and is flammable. For the purposes of cleaning an eyepiece it's best to get the 90% to 99% concentration. When purchasing it read the label carefully to make sure it only has Alcohol and water as the ingredients and be sure to take note of the warnings listed on the bottle before opening and using it.

What to watch out for?
The common household "Rubbing Alcohol" is typically a concentration of 70% alcohol mixed with water and other liquids like scents or oils. When this type evaporates it can leave behind residue or oils that you do not want on the surface of the eyepiece.

Methanol

$25.00 for 500ml from Fisher Scientific

What it does?
It dissolves oily compounds, finger prints, glue, and evaporates quickly. It is safe for home usage but is more dangerous and toxic than Isopropyl Alcohol.

What to look for?
This is a chemical similar to Isopropyl Alcohol and is used for industrial optical cleaning, as an additive to automotive fuel, or a cleaning additive for automotive parts. This chemical can be found at camera shops or specialty science equipment stores.

What to watch out for?
If you do purchase this type of solvent cleaner make sure the bottle has a good seal and that the bottle is well marked to avoid confusion with any other type of cleaner. This type of cleaning solvent is more poisonous and flammable than isopropyl alcohol so it is not something to leave sitting around. It should be stored in a cool dry place when not in use away from the reach of children or pets. Again read the label to check for purity. Automotive variations typically have other ingredients that would not work well for cleaning eyepieces.

Camera or Eyeglass Cleaning Solution

$2.50 to $10 depending on amount and brand.

What it does?
It dissolves oily compounds, finger prints, glue, and evaporates. It is safe for home use.

What to look for?
These types of cleaners can usually be purchased in camera shops or at retail stores like Wal-mart. Solutions specifically made for lens cleaning are ideal for the purpose of cleaning eyepieces but it is much more expensive than a bottle of Isopropyl alcohol per ounce. Some of the added benefits of using these types are that some have and anti-static and anti-fogging additive to keep the glass cleaner longer.

What to watch out for?

Many of these cleaners come packed as kits with various other cleaning items like cloths or rubber air blowers and the price for the kit is pretty expensive when you compare the deal to a standard bottle of Isopropyl. Look for the best deal especially if you already have some of the packaged items in your cleaning collection. Typically the small air blower or cleaning cloth is not as good as one you could buy without the kit. These types of cleaning solutions also typically have Isopropyl mixed in so the same care should be taken in storing them as you would any other flammable chemical. While getting everything you need in one kit is nice beware of kits that use cheap materials for the cloth or air blower. Sometimes these parts are substandard. Some of these cleaners may leave a residue on the eyepiece so it is a good idea to try them on a mirror or piece of glass first before using them on an eyepiece.

Compressed air canister

$2.50 – $5.00 for 10oz can.

What it does?

When the can is held upright and the trigger is pressed the can releases an immediate stream of gas. This gas is typically a compressed fluorocarbon gas that resides as a liquid inside the can. The release of the gas at high pressure makes it easy to blow off large particles from an eyepiece.

What to look for?

When looking for "canned air" as it is sometimes referred to look for types that have a small barrel tube tip. This allows for pin point accuracy. Also check the back of the can to make sure it contains no CFC's.

What to watch out for?

This type of duster can be a blessing or a curse depending on how it is used. The can gets cold after extended use because the reaction happening inside where the liquid turns to gas is endothermic. It absorbs the heat as it reacts. Luckily blowing off dust from an eyepiece is a relatively short process. Also, if the can is turned upside down it will expel the compressed liquid. This is not something you want to get on an eyepiece or on your skin. It can damage the eyepiece and the liquid is cold enough to cause frostbite so caution is advised when dealing with a can like this. The best way to use one is to start the flow of gas prior to passing over the eyepiece. This also acts to clean the small needle tip of any particles that may be inside. Never position the needle over the eyepiece and pull the trigger without clearing the tube first. Never keep the needle pointed at the same spot for an extended period of time. This can lead to eyepiece damage due to the extreme cold temperature that builds up and the static charge that builds up could also attract more contamination than it removes.

Painters Paint Brush

$1.00 - $2.50

What it does?

A fine haired brush is a good tool to remove dust and large particles from the surface and body of an eyepiece.

What to look for?

You should look for a brush with fine hair on it. These can usually be found in craft stores or in the school supply section of a retail store or supermarket. These can also be cleaned from time to time with simple dish soap and water.

What to watch out for?

Brushes with plastic hairs do not work as well as ones with real hair. They can also be damaged when used with some of the liquids mentioned. Neither type of brush should be dipped in the liquids mentioned. Most have painted handles and this paint can easily be dissolved to the point that it gets onto the brush hairs and then onto the eyepiece.

Lens Pens

$5.00 - $14.00 depending on model

What it does?

The pen is specifically designed to remove particles and oils like fingerprints from glass lenses.

What to look for?

Depending on the size of the job you will want to get the right pen. The pen should have a retractable brush on one side and a soft tip on the other with a cap. The cap is actually used to recharge the pen tip. The tip is made up of a rubber body that has a micro-fiber covering. The micro-fiber coated tip also has a special carbon compound which absorbs oils. On the inside of the cap is a reservoir of the carbon compound which acts to recharge the tip upon replacement of the cap on the pen. Prior to use, the cap should be turned one time to recharge the tip. On the body of the pen is a small sliding button. This will extend or retract the fine haired brush. This part of the pen is used for removing large particles prior to using the special tip side of the pen. The larger pen is good for rounded lenses and has a cup type tip while the smaller pen is good for flat surface eyepieces.

What to look out for?

When getting a lens pen for use on eyepieces be sure to look for one that has a small flat head. The larger type of pens are mainly for cleaning the curved surface of an SLR lens and as such have a curved tip on the end. One exception that I know of is the Televue Powermate lenses. They have curved lens surfaces that would make use of the larger pen. Since the surface of the pen will be touching the glass surface you want to make sure you get a good lens pen. Look out for cheap clones that may be lacking the brush feature or recharge feature of the pen.

Squeeze Bulb

$1.00 – $5.00 depending on size.

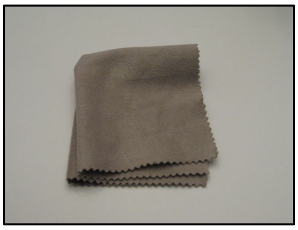
What it does?
This duster works manually buy pressing the rubber bladder down. It releases air though the nozzle in a strong burst to effectively knock off any large contamination.

What to look for?
When looking for a squeeze bulb try to find one with a large bladder. They are typically made of soft rubber and will hold a lot of air and thus provide a strong blow when trying to knock contamination off the lens. These types also have a filtered intake hole on the back of the bladder to prevent contaminated air from entering the bladder.

What to watch out for?
Watch out for the cheap hard plastic types that are usually packed with kits. These kinds have a hole in the middle of the bladder that could suck in contamination from the finger you are using to depress the bladder. Some blowers have a brush on the end that you have to remove to use the blower.

Micro Fiber Cloth

$1.00 – $3.00 depending on size



What it does?
This cloth is mainly used for removing small particles from the surface of the eyepiece. It can also remove small amounts of moisture on the surface or debris left by a liquid clean.

What to look for?
A micro fiber cloth will feel soft to the touch. These cloths have fibers that are 10 microns or smaller in size and are excellent for cleaning up the leftovers that remain from a liquid clean. These cloths are usually sold at locations where quality sunglasses or eyeglasses are sold. They can also be found in stores that sell LCD/LED televisions. You should look for a cloth that is specifically designed for cleaning optics. Ebay is a good location to find these relatively inexpensive tools.

What to watch out for?
Be careful of cloths that have a printed logo on them as the logo can actually scratch the eyepiece glass coatings. Be sure to use the side of the cloth without the logo if it has one. After using the cloth a few times it is important to clean them so that they can release any trapped particles. Cloths should be hand washed with hot water and some mild dish washing detergent. They should then be left to air dry. Not all cloths that come with cleaning kits are microfiber cloths. Typically a microfiber cloth will have the feel of chamois leather and is soft and flexible.

Q-Tips

$1.29 – $3.00 depending on size and quantity.

What it does?
These multipurpose tools are a good way to brush off small particles or apply a small amount of cleaning liquid to the eyepiece surface. The reverse side can then be used to dry the area off.

What to look for?
Look for swabs made with genuine cotton. This can easily be found by looking on the label for the small cotton symbol. The brand "Q-tips" is not necessarily the only brand you can use so long as you get a brand that is cotton. One benefit of the Q-tip brand is that they pride themselves on the extra cotton in the tip. This is a plus for absorbing liquids and an extra guard against scratching the lens or eyepiece with the shaft of the swab. You can usually find these in the health and beauty area of the supermarket. The smaller quantities typically come in a handy plastic container which is excellent for storing the unused swabs for future use.

What to watch out for?
You should watch out for the cheaper types of swabs. Some are made from synthetic materials that do not have the same texture and consistency as cotton. They could also have hard plastic shafts that could damage the surface of the eyepiece if it comes in contact with it. Some of them with the plastic shafts also have a glue to hold the cotton down and this could dissolve off and get on the eyepiece. The plastic type shafts are also a problem if they have a hollow center. This could act as temporary storage for the liquid which could be released upon contacting the surface of the eyepiece. Swabs with paper shafts are best in this case.

Small Flashlight (LED type preferred)

$7.00 – $10.00

What it does?
This handy tool is great for illuminating the surface of the glass on the eyepiece. The small particles can easily be seen on the surface along with any other debris that may have fall on them.

What to look for?
Typically the LED type is best. They typically use AA batteries and last for years on one set. With a red 1.25" filter taped to the front they are also excellent for Astronomy use. Standard flashlights will also work but may not have as much illumination and might require you to view the eyepiece in a darker area.

What to watch out for?
This item is pretty much fool proof. The one caution to watch out for is shining it in someone's eyes. Super bright LEDs are typically used in these and can temporarily blind someone. You do not want to leave these in the reach of small children.

Examination Items Category

▪ Led flashlight	$5.00
▪ Regular flashlight	$1.00

Dusting Off Items category

▪ Isopropyl alcohol	$2.50
▪ Eyeglasses cleaner	$2.50
▪ Camera lens fluid	$2.50
▪ Methanol	$25.00
▪ Q-tips	$1.29

Cleaning Off Items category

▪ Painters paint brush	$1.00
▪ Lens pen brush	$5.00
▪ Canned air	$5.00
▪ Bulb blower	$1.00

Polishing Items category

▪ Lens pen	$14.00
▪ Micro fibres material	$3.00

Cleaning Eyepieces – A Four Step Cleaning Process

Now that we know some of the items that can be used and the pitfalls involved it is time to get down to it. A good thorough clean should be done at least once a year when an eyepiece is in normal use. I say once a year but this really depends on how much you use them and how well you take care of them when not in use.

On average I'll use mine from 4 to 6 times per month. When they are not being used I keep them in storage away from dust and extreme temps. Even with this they still require a good full clean about once a year and a partial clean about every 3 months. You'll know they need a clean when you can shine a flashlight on them at an angle and see particles or debris on them. I like to think of a good clean as a 4 step process, examine, dust off, clean off, and polish.

All 4 steps are equally important and should be followed in order to prevent damage to your eyepieces. To accomplish the clean I'll get an item from the ones mentioned previously. A minimum of one item from each of the categories listed will need to be obtained.

From the categories mentioned above you can mix and match depending on your budget. My personal cleaning kit consists of a Led Flashlight for checking the eyepieces, a Lens pen, canned air, Isopropyl 99%, and Q-tips. To keep all the times themselves contamination free I store them when not in use in a ziplock bag.

Step 1 – The Examination

Take the eyepiece to be cleaned and look at it carefully from top to bottom. Examine the surface as well as the general cosmetics for any sort of contamination build up. The obvious area is the top of the eyepiece but the underside could also be dirty and require cleaning at times. A flashlight or strong light source should be used when viewing the surface. In the image below the eyepiece is set face down on the table. The inside of the tube clearly shows some contaminates around the upper edge of the barrel. These might not be visible without a flash light and were probably caused by the placement and removal of 1.25” filters. Each particle is one that could eventually migrate to the glass surface. Some of these particles could also be metal shavings so they are particularly dangerous to the surface of the glass. When performing a thorough cleaning of an eyepiece you should consider cleaning all external parts including the barrel.

Looking at the top of the eyepiece we can see that there are a lot of particulates. This just happens to be my favorite eyepiece and has a lot of light years on it. Some particles look like stains and others look like small specs of dirt. It is hard to tell exactly what they are but suffices to say the top is also contaminated. Oddly enough without the use of a flashlight in a dimly lit room you can hardly tell it is that dirty. It is also a good idea to shake the eyepiece next to your ear to listen for any rattling elements in it. Sometimes due to the changing temperatures the small slotted ring that holds the elements in place starts to get loose. This can cause unpredictable seeing conditions. If there is no sound then the elements are still locked and in good shape. Keep track of where you saw the particles so that they can be removed in the coming steps.

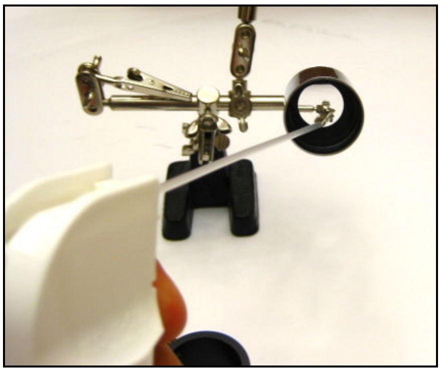
Step 2 – Dusting Off

In this step we will remove the large chunky particles. You can use either a small painters paint brush, lens pen brush, canned air or squeeze bulb. The most effective dusting tools are canned air and the brushes so for the purposes of this demonstration we'll use the canned air and lens pen brush. The squeeze bulb is good for knocking off a few particles at a time but is a lot of work to use on the whole eyepiece. It's a good idea to use the flashlight at the same time you dust off the eyepiece so that you can see what you are cleaning.

Painters brush or Lens Pen Brush

Well first knock off some of the contamination we saw using the lens pen brush. When using either of these two dusters keep the brush bristles at an angle and take full swaths across the surface of the eyepiece to remove large contaminants. Reexamine the areas again with the flash light to see if there were any large pieces missed. While going across the top of the eyepiece examine the surface for streaking. This is usually a sign that there is oil on the surface, probably from touching or from eyelashes. This type of contaminate will be removed in the next step. Pay close attention to the bottom end of the eyepiece. Remove the chrome barrel from the upper portion of the eyepiece to allow easy access to the optical parts. If you see something large brush it towards the shortest distance off the eyepiece. Brush lightly across the surface and never jab at the surface to dislodge a particle.

Canned Air



When using this type of duster, hold the can upright with the needle facing away from the eyepiece surface. Press the trigger to start the gas flow and with the trigger held down make several passes over the eyepiece in the areas that appeared contaminated in the examination step.

Be aware that oily contamination shows up like small spots but does not move when blown on by the canned air. Go for the large pieces first. Reexamine the area with the small flash light and touch up if needed. Do not worry if all of the contamination is not removed. Do the same process for the underside of the eyepiece.

Warning!
There are 3 things you should never do when using canned air. Firstly, do not stay over the same spot for an extended period of time as this can cause damage to the eyepiece. Second, do not spray the can in an upside down position. This will release the liquefied gas which immediately starts turning into a gaseous state again through an endothermic reaction. This reaction creates extremely cold temperatures and can cause frostbite if you get it on your skin. And lastly, do not put the needle over the eyepiece and then pull the trigger. Most people shake the can before pulling the trigger, this puts some of the liquid in the top part of the can and it could expel it upon the initial pull of the trigger. Start the flow before you get over the eyepiece lens and you'll be safe.

Step 3- Cleaning Off

Choosing the correct cleaner for the job is important. If the eyepiece only had large contamination and it was all removed with the dusting off step then you may want to stop here. No need to over do a clean but if there are still some stains or particles continue on. The liquids mentioned at the start of this how-to all pretty much act in the same fashion. They dissolve oils and other solvent susceptible particles. In my experience Isopropyl Alcohol works excellent and is relatively cheap and easy to find so for this demonstration will use it to clean the eyepiece.

Before applying the alcohol remove the cap and pour some in to the cap until it is half way full. This is just the right size to dip the Q-tip in. When dipping the Q-tip only submerge it partially into the Alcohol. The tip should be moist but not drippy. You'll know you have too much on the tip if you touch the eyepiece and the liquid stays on the surface longer than 10 seconds. The right amount will evaporate within a couple seconds. Putting too much liquid on the eyepiece can be trouble if the liquid gets into the eyepiece. This can happen due to a phenomenon called capillary action. Once the liquid gets in it will take the dissolved oils and contamination with it. Start at onc side and glide the Q-tip across the surface as you go across. For grossly dirty eyepieces you'll want to get another Q-tip after each glide across but for mildly dirty ones a single Q-tip will suffice, just rotate the tip slightly after each glide. After a couple passes glide it around the outer most perimeter of the eyepiece glass. If you accidentally put too much on you can use the reverse side to sop it up with. Keep in mind you're gliding it over the top and not pressing it down. The purpose of the Q-tip is to apply the IPA and not to scrub the surface. Let the IPA do the work. Sometimes the liquids mentioned will dissolve the oils but will leave streaks behind when they dry. This is common when there is a large amount of oily debris. Don't panic, just let the eyepiece dry and try again. After a couple times it's best to leave it as is and take care of it in the next step.

If you think you have too much alcohol on the tip don't use it. Get another and try again. Once the critical surfaces of the glass have been cleaned you should also swab the other areas of the eyepiece like the inside of the chrome tube and the outside of the eyepiece housing.

Step 4: Polishing it off

This is the final step of the clean process. You should first examine the surface of the glass for any residual particles. If there are any a quick pass of the canned air may be in order. Be sure that the eyepiece is completely dry before you begin.

For this step I choose to use the lens pen. I used the flat pen on the regular eyepiece and a rounded tip lens pen on my Powermate. This is a unique item because it has a specialized compound on the micro fiber tip that is made from carbon and is specifically made to soak up oils. When using the pen start in the center and make concentric circles until you reach the outer edge. I usually glide it over the top 2 to 3 times, check the surface and then do it again if there are still any streaks left over from the cleaning. Sometime there will be small amounts of debris left over from the lens pen but these typically blow off with the canned air. When you're done you'll have a sparkling clean eyepiece ready for action. If you do not plan on using the eyepiece in the immediate future a good storage plan is to keep them in plastic containers or even zip log bags. This will keep them fresh and contamination free a lot longer and they'll require less cleans.

Share the Sun with your Community

Stephen W. Ramsden

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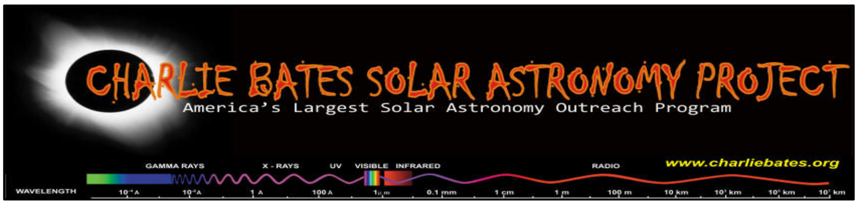


So, you finally own a nice H-alpha/White Light/CaK or Na Solar telescope setup? Me too. Really enjoying those views of our nearest star and giver of life? Me too. What now?

Well, let me tell ya' after all the observing and all the wonderful photography has been attempted and realized with your new setup one of the most rewarding things you can experience as an astronomer is sharing this hobby with someone else. The public has long had a fascination with all things astronomical but very few see anything more than an occasional television special or a headline in the media. When you put someone, and I mean almost anyone, outside of the biggest grouches on the planet, in front of an eyepiece and show them something in the heavens you can count on a smile and a wow.

People seem to drop all of their "walls" when it comes to staring into telescopes. They seem to revert back to their youth with a keen look of wonder and a desire to see more. It is really a great experience for both the observer and the provider of the service.

There are many ways to share the hobby. Some people invite friends or family out with them for observing while others go as far as to hold completely random public events and have any willing passersby take a look. There are many local clubs you can join to expand and share your knowledge as well.

When I started in solar astronomy it seemed a natural extension of my passion to share the experience with others. I decided that I was going to go all out and start my own official outreach program and make sharing the hobby my main priority. I don't know if it was my gregarious nature or my self admitted need for attention that spurned me in this direction but whatever it was, it has been a lot of fun. I would highly recommend it.

What do you need to get started? Well it is

as simple as a photo tripod and a PST or as it can be as complicated as several goto mounts and high-end telescopes. The sky (or the ground) is the limit.

I started with a double-stacked PST and a manual mount. It quickly became apparent to me at my first event that constantly adjusting the aim of the telescope between each viewer was not going to do it. I find that the tracking mounts are necessary to expand my capacity and allow me to lecture more and adjust less during an event.

I find it highly useful to have handouts as well for the crowd. Everyone wants something that they can hold and take with them. In my case I decided to order a few dozen pairs of solar eclipse viewing glasses. You know, the plastic lenses and cardboard frames that fold into sunglasses. These became very popular right off the bat so I knew that I would need to place a larger order soon. This is where the question came up….how much money was I willing to put into this thing as a free public service?

In the United States, our almost indecipherable tax laws allow for the establishment of a nonprofit 501c3 corporation. This is more

commonly known as a charitable organization. Under this structure I could then show any money spent on the outreach as a tax-deductible donation to my own charity. I can also solicit donations and grants from outside sources and allow them to legally deduct their donations from their taxable income at filing time. This setup helps to relieve the financial strain of providing a large outreach program.

If you are only doing it rarely then it would not be necessary to go through this process. Also, if you plan on doing these events for existing nonprofit groups like schools or church youth groups then you can simply show your expenses as donations in-kind to these groups at tax time. That is, in the US. I do not know how other countries handle these types of things.

So, I went through the process of establishing a non-profit corporation. Funny, the establishment of a charity was very expensive, very difficult and very time consuming. I spent several hundred dollars and waited several months for the approval of my charity. I am married to a tax attorney. The process was so complicated and exacting that we finally gave up after 2 rejections

as they provide a never ending supply of handouts and neat stuff for the people I see. They also help advertise and add legitimacy to the program. I would say that they are more geared towards the night time astronomy events but I think that they are getting used to my incessant requests for more solar related materials. Mrs. Ferrari put me in touch with a wonderful gentleman at NASA's Godddard Space Flight Center named Steele Hill. To be honest, I am only assuming this is a man as I have never spoken with Steele. We only communicate through email. Whatever he/she is, they are awesome! Steele always seems to have the right place to get the good stuff and he is always willing to send me the latest stuff to give away at my events. NASA puts out some rather interesting materials from DVD's to holographic cards describing their various solar missions from STEREO to the latest upcoming launch of SDO (Solar Dynamics Observatory). NASA's Space Visualization Studio (http://svs.gsfc.nasa.gov/) also hosts probably the best web site there is dealing with presentations and videos for classroom use.

and hired a specialist in the field to process our application. All told, I finally spent over $1000 and waited about 7 months for the state and federal approval. It seems that since the purpose of a nonprofit is usually to do good for the community at large that the process would be a little easier and less expensive. I guess that isn't the American way. The good news is that the effective date goes back to the original application date so all expenses incurred up to the approval point and all after were still eligible for tax exempt status.

I am now the "Executive Director" of (and only person in) the Charlie Bates Solar Astronomy Project. I named it after a fellow veteran and air traffic controller friend who inspired me with his unending generosity. He died an early death and this was my way to pay tribute to his memory.

You of course do not have to go to these lengths just to share the hobby but that is how I did it. I like to go all the way in everything I do and this was no exception.

Next I realized that I needed some more goodies to give away at my events. In the United States the source of the best space related goodies is of course NASA. I noticed that one of my heroes in the field, Greg Piepol, was a NASA Solar System Ambassador. This sounded like a cool thing to do so I wanted to be one also.

I contacted Kay Ferrari at NASA/JPL and asked to be considered for the same position with them. They have an approval process and there is a sometimes lengthy wait there as well. They only allow new ambassadors during an open season at the end of the calendar year. I put in my application and waited to hear from them. I was finally admitted to the program after a few months and allowed to have access to their stash of NASA goodies in exchange for recording my events and how I used their resources. They do require some initial training in ethics and proper conducting of events so it is not a gimme'.

The NASA SSA program has been extremely helpful in my outreach

After becoming a nonprofit I was able to talk my labor union (NATCA- www.natca.org) to purchase a couple thousand pairs of the eclipse viewing glasses in exchange for printing their logo on them. I also have added legitimacy when approaching companies for grants. I also have to do a lot of individual fundraising to keep it going but most people are happy to contribute a few dollars to a worthy cause such as teaching kids about aviation and science.

So, how do you arrange events?

My first events were for my local astronomy club. They have an endless supply of requests from local teachers and groups to come out and show the stars. I made it known that I was available for Solar events and the rest is history. After making a few appearances locally, the word spread among schools and now I get requests weekly for my program.

I established a website with pictures and videos of my events and also made an automated request form so that people could ask for a visit right from the website. The address is www.charliebates.org. It is very simple to establish a web site. If you can make a Microsoft Word document with pictures then you too can be a professional web designer. It just takes a few hours of practice and a domain name and hosting site. The website has all kinds of advantages as I can list my donors, show actual videos of the events so people know what they are getting, publish oictures of the kids so their parents can see them, etc.. I have found it to be very useful in advertising the program.

Along with the website you should probably have some business card or pamphlets to hand out. These are easily created with any popular word processor.

All of these things are certainly no necessary but this is the way I have established the largest volume Solar Astronomy outreach in America in just a few short years. The long term goal of my project is to build and maintain the countries only observatory dedicated strictly to Solar Astronomy outreach. This way, the public can come to me instead of me going to them. It is a lofty goal but I am a lofty guy, he he.

If you would like help in establishing your program please feel free to contact me at info@charliebates.org. I would love to help you or give you advice on where to turn next to establish your outreach.

Remember, think big and don’t let anything stop you in your dreams.

Community

The Sun in Motion!

Gary Palmer

Congratulations Kah-Wai Lin for creating the very first "dedicated" Solar Magazine!

The Solar-Observer is a dream realized with a roster of editorial contributor's and scientific advisors that is second to none! Kah-Wai's Solar-Observer is cutting edge Solar information that is a "must have" for any closest star enthusiast. I'm looking forward to the launch of "the Solar-Observer"!

Solar observing is exciting! But don't take my word for it, just ask one of the many thousands of Solar enthusiast that are enjoying there Solar telescopes! The beauty of the nighttime sky from a dark site location brings tranquility and intrigue. It's quite an accomplishment that a simple push of a button will slew a telescope to any one of hundreds of thousands of celestial objects and within seconds you are looking back in time at our magnificent universe. When I'm immersed in objects like M-15, the Pleiades, or any star in the universe, I hold in my mind's eye an enhanced understanding of the various solar phenomena. It's this enhanced understanding that brings new awareness to those infinite pinpoint sources of light illuminating the night sky.

Today, even though we are experiencing an extended Solar Minimum it's important to remember that inside the core of the Sun hydrogen is being fused into helium at an astounding rate of 600 million tons a second. Those energized particles carried by photons radiate outward from the core and enter the radiative zone where they may ricochet for hundreds of thousands of years before passing through the interface layer and into the convection zone. Here, its just a quick ride out to the photosphere where the intense glow of those photons create the visual surface of the Sun. Light resisting all of the Sun's gravitational forces continues to radiate outward into the corona and beyond. Now this light traveling at 300,000 kilometers per second makes the 149,597,892 kilometer journey to Earth in as little as 8 minutes to illuminate and nourish our planet with life.

So it comes as no surprise that as Solar enthusiast continue to explore the nearest star and share there discoveries with the Solar-Observer we will be enlightened and entertained far into the future!

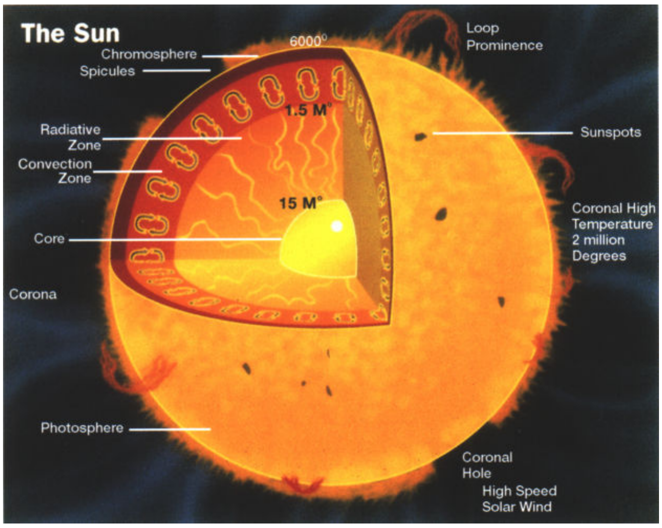
Again, congratulations Kah-Wai!

PHYSICS OF THE SUN – An Introduction

Bob Yoesle

STAR OF LIFE

The Earth orbits the Sun at just the right distance to power the cycle of life, allowing it to thrive. The Sun is neither too close or too far away, making the Earth neither too cold nor too hot. This fortunate circumstance allows liquid water to exist, therefore enabling millions of species of plants and animals to flourish on planet Earth. The Sun warms the oceans and air, lifting water into the atmosphere and creating the winds that push the clouds over the continents. The atmospheric water falls back to the Earth as rain and snow, which then flows through streams, lakes, and rivers back into the seas.



The Sun directly and indirectly provides most of the energy used by mankind today. “Fossil fuels” - buried plants that long ago perished after using sunlight to make sugars, now provide the energy that drives our society. Sunlight, as noted above, also is responsible for large-scale hydroelectric power. Newer technologies, however, with far less damaging environmental effects, are allowing us to use sunlight directly and the wind to generate electricity. Ancient civilizations recognized the importance of the Sun - many believed the Sun to be a god with healing powers, and even today we attribute good health to a suntan (false) and a “sunny” disposition (true).

The physical processes that are responsible for the Sun’s energy, and how that energy manifests itself to us, have been slowly revealed over the years through our deepening understanding of physics and increasingly sophisticated Earth and space-based instruments. In this article I hope to provide a basic introduction to the physical properties and processes that are at work within the Sun. This knowledge can help to explain some of the features we can observe in amateur telescopes equipped with appropriate filters.

SOLAR STATISTICS

Diameter:	**1.391 x 10^6 km**
Mass:	**1.989 x 10^30 kg**
Volume:	**1.412 x 10^27 m^3**
Mean Density:	**1.409 x 10^3 kg / m^3**
Central Density:	**1.531 x 10^5 kg / m^3**
Pressure (center):	**2.334 x 10^11 bar**
Pressure (photosphere):	**0.0001 bar**
Luminosity:	**3.842 x 10^26 W (j/s)**
Temperature (center):	**1.57 x 10^7 K**
Temperature (photosphere):	**5.780 x 10^3 K**
Temperature (chromosphere):	**6 x 10^3 - 2 x 10^4 K**
Temperature (transition region):	**2 x 10^4 - 2 x 10^6 K**
Temperature (corona):	**2 x 10^6 - 3 x 10^6 K**
Magnetic Field (pole):	**10 G (Earth 0.3 – 0.6 G)**
Magnetic Field (sunspot):	**1 x 10^3 – 4 x 10^3 G**
Rotation Period (equator):	**26.8 days**
Rotation Period (+/-60 ° latitude):	**30.8 days**
Visual Magnitude:	**-26.7**
Absolute Magnitude:	**+4.83**
Spectral Type:	**G2V**
Distance Minimum:	**1.471 x 10^8 km**
Mean:	**1.496 x 10^8 km (499 sec = 8.32 light-minutes)**
Maximum:	**1.521 x 10^8 km**
Age:	**4.57 x 10^9 years**

To put some of these figures into perspective, we should note the Sun is an average size star of unexceptional brightness, except for the fact that it is very close to the Earth ~ 92.8 million miles (~150 million kilometers). The next closest star (and very similar to the Sun), Alpha Centauri, is 25 trillion miles (40 trillion kilometers) away. If you could drive to the

Sun at 65 mph (105 km/hr) it would take only a mere 163 years. Driving to Alpha Centauri would take awhile longer - 50 million years.

The Sun's diameter is 864,000 miles (1.39 million kilometers), which is 109 times the Earth's diameter. Over 1.3 million Earth's could fit within the Sun. The size-distance relationship between the Earth and Sun can be visualized as a model where the Sun is a 2 foot (0.6 meter) diameter beach ball, and the Earth is represented by a small ~ 4 millimeter diameter pea 215 feet (65.5 meters) away. On this scale Alpha Centauri would lie over 10,000 miles (16,200 kilometers) away across the Pacific Ocean in Western Australia from where I live in Washington State in the United States.

The Sun's mass is 2,200,000,000,000,000,000,000,000,000 tons, or about 333,000 times the Earth's. The Sun accounts for 99 percent of the mass of the entire solar system, and is composed of 92.1% Hydrogen, 7.8% Helium, and 0.1% of most remaining elements based on the number of atoms (70.7%, 27.4%, and 1.9% respectively by mass).

The Sun's energy output is 384,200 billion-billion Kilowatts - over 13 million times the United States energy consumption in one year - per second. In 1/1000 of a second, the Sun radiates enough energy to supply the world's current energy needs for 5000 years. One square inch of the Sun's surface is as bright as a 90,000-watt incandescent light bulb.

The Sun is one of the more than 200 billion stars in the Milky Way Galaxy (one of over a hundred billion galaxies in the visible universe), and orbits the center of the Galaxy - 27,000 light-years[1] away - once every 230 million years, at a speed of 670,000 mph (1.08 million km/hr).

PHYSICS OF VISUAL OBSERVATION THE SUN

The first thing one needs to understand is that the Sun is composed of layers of gas, which give off and absorb light in differing ways. The baseline of light coming from the Sun consists of a bright "continuous spectrum" of all the colors of the rainbow. This is known as the "thermal" or "blackbody" radiation, and any enclosed dense solid object will produce this radiation (because of the Sun's high internal density, it acts in some ways like a solid object at normal Earthlike temperatures). As the temperature of a blackbody rises, it will shift from giving off predominantly infrared (heat) energy to visible energy, and into ultraviolet light, in the form of a continuous spectrum with a specific peak output of light. Stars are classified on this basis of where the peak of their light output falls in the visible spectrum.

It is the very bright continuous spectrum of light from the Sun's "photosphere" (*sphere of light*) that warms our planet, and also makes it very dangerous to observe without specially designed "white light" filters specifically made for that purpose. These filters, often consisting of mirror-like coatings of metal on glass or polymer substrates, will decrease the intensity of sunlight (including infrared and ultraviolet light) by several orders of magnitude in order to render the Sun safe to view through a telescope.

The relatively cooler gases that lie above the layers producing the bright continuous spectrum can absorb certain frequencies of light. These frequencies correspond to the specific amount of energy required to shift electrons of a given element into a higher energy level, or "orbit." For example, when an electron orbiting the proton of a Hydrogen atom absorbs a discrete amount of energy to shift the electron to a higher energy state, it removes the corresponding color, or discrete frequency (energy), of light from the continuous spectrum coming from below, and an "absorption line" is created in the spectrum.

If one looks closely at the bright continuous spectrum of the Sun, you will observe numerous dark lines corresponding to the various elements of the gases in the photosphere - the "absorption line spectrum." Relatively cool (6000° K) Hydrogen gas in the photosphere absorbs light coming up from below, and we see a dark line in the red part of the spectrum - the "Hydrogen alpha" absorption line. It is a relatively wide and dark spectral line given the large amount of Hydrogen in the photosphere.

The Sun's "chromosphere" (*sphere of color*) lies above the photosphere, and is much hotter – going

[1] A light year is the distance a wave-particle of light, traveling 186,000 miles (299,000 km) per second, traverses in one year – 5.88 trillion miles (9.46 trillion km).

up to 20,000 degrees K. At these higher temperatures we can see what is know as an "emission line spectrum." Here light is being given off as well as being absorbed, corresponding to the energy given off when the Hydrogen electron shifts back down to a lower energy state, and at the same specific energy/frequency or "color" of light which is absorbed in the photosphere. Even though it is much hotter than the photosphere, the amount of light coming from the chromosphere - which is far less dense than the photosphere - is correspondingly less intense by several orders of magnitude. Until the relatively recent invention of the *spectroheliograph, spectrohelioscope,* and sophisticated *interference* filters, the chromosphere could only be observed during a total solar eclipse where the brightness of the photosphere is completely blocked by the Moon.

Therefore, in order to see the chromosphere and its features such as flares, prominences, etc., you must first totally eliminate all the light coming from the photosphere, except where the broad H alpha absorption line is, and let 90+% of that region of the spectrum through. Since the Hydrogen in the photosphere is absorbing the exact wavelength of light we are interested in, all that will be left to see is the relatively weak H-alpha emission coming from the chromosphere. To do this requires very specialized solar H alpha filter systems.

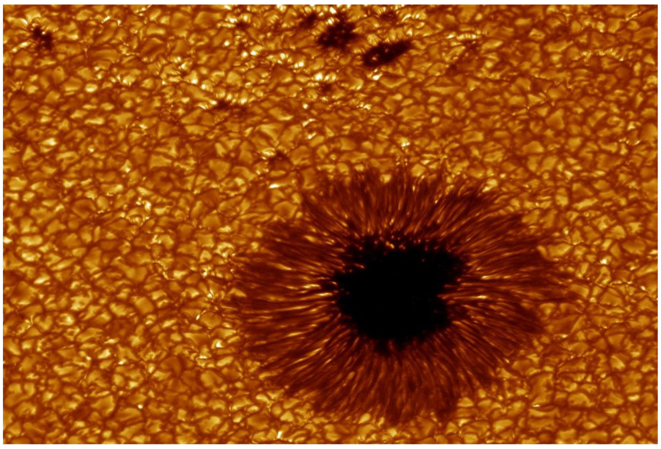
Other wavelengths (colors) of light can also be observed in addition to Hydrogen in the chromosphere, the most important after Hydrogen being that of ionized Calcium (the CaK line emission) in the deep violet portion of the spectrum. Regardless of the wavelength of visible light observed in the chromosphere, the underlying physical principles allowing observation is photosphereic absorption and corresponding chromospheric emission.

THE PHOTOSPHERE

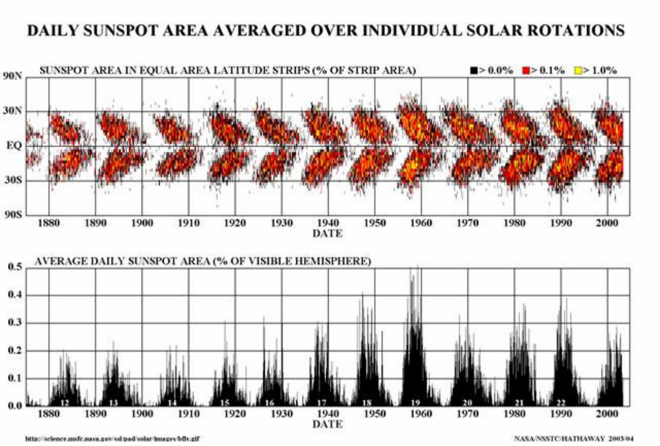
The visible 'surface' of the Sun is called the **photosphere**. It is composed of a thin gas - about 0.01% of the density of the Earth's atmosphere at sea level - which has a temperature of about 6000° K (~11,000° F). The photosphere gas has an opacity that varies with the wavelength of energy, and in the visible spectrum of light it has a depth of 400-500 kilometers. The opacity increases with depth, and as we view the Sun's limb (towards the edge of the solar disc) we are also looking through increasingly more material, which creates a dimming of light intensity that is easily observed as *limb darkening*.

Light from the photosphere is generated by the energy released when the thermonuclear conversion of Hydrogen into Helium takes place deep in the Sun's core (technically known as the *proton-proton* reaction). The core has a density 45 times that of steel and a pressure of 3.3 billion tons per square inch, yet remains gaseous because the temperature is 15.7 million degrees K. This tremendous temperature and pressure results in the fusion of Hydrogen into Helium, which as a byproduct converts about 4.5 million tons of matter per second into a tremendous amount of energy according to Einstein's famous equation E=mc^2. This energy takes the form of gamma radiation, neutrinos - ghostly particles that can travel unimpeded through the Earth, and positrons - antimatter particles with the mass of an electron, only with a positive charge, and which produce more gamma radiation when they encounter ordinary matter in the form of electrons and annihilate each other.

Over an average of about 170,000 years the gamma radiation undergoes untold billions of collisions in the *radiative zone*, where through absorption and re-emission it loses energy. This energy heats gases in the next level, known as the *convective zone*, where the heated gas rises to the surface, cools, and sinks back into the solar interior only to be heated again. This energy eventually leaves the Sun as x-rays, ultraviolet, visible, and infrared light, and even radio waves. Thereafter, this light takes just over 8 minutes to traverse the 93 million miles (150 million kilometers) to the Earth.



Sunspot



Sunspot Cycle

The major features visible on the photosphere are *sunspots* - regions that reveal where powerful magnetic fields erupt through the Sun's surface known *active sunspot regions*. Most of the Sun's magnetic field originates in the *convective zone* (lying just below the photosphere) where hot *ionized* (electrically charged) gas known as *plasma* rises and falls, creating enormous electrical currents and accompanying immense magnetic fields. Being gaseous, the Sun rotates once in 27 days at the equator, and over 35 days near the poles. This *differential rotation* twists and stretches the Sun's internal magnetic fields, until they eventually break the surface. These intense magnetic fields and plasma features are responsible for the majority of activity and energetic phenomena we observe on the Sun.

Sunspots appear dark only because the intense magnetic fields inhibit the transfer of energy from below and the sides, and consequently they are about 2000 degrees K cooler than the photosphere – about 4000K (7000°F). Sunspots generally consist of a dark central portion known as the *umbra*, and a lighter surrounding portion known as the *penumbra*. High-resolution images of sunspots reveal the penumbra to consist of striations of hot plasma and the interaction of nearby convection cells modified by intense magnetic fields, and these sunspot structures and magnetic fields are governed by the complexities of *magnetohydrodynamic theory*.

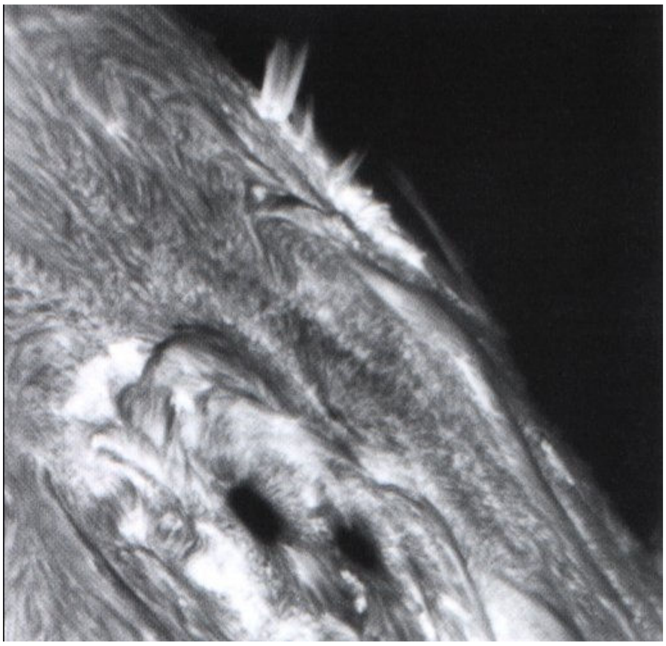
Sunspots can vary in size from that of several hundred miles to many times larger than the Earth, and generally can be found in *sunspot groups* that can become up to hundreds of thousands of kilometers long. These groups usually have two main regions of opposite magnetic polarity, with most of the spots within the group demonstrating similar magnetic characteristics. Most individual sunspots survive for just a few days, while the larger groups may last for several weeks, some surviving for two or more solar rotations. The number of sunspots visible varies over an 11-year *sunspot cycle*, during which time the Sun's overall magnetic field reverses from one pole to the other. These cycles are characterized by their sunspot number minimum and maximum, and the changed polarity of the leading and trailing sunspots when a new cycle begins coming out of a sunspot minimum.

Under ideal atmospheric conditions, you may also be able to see *granulation*, a very fine graininess of the entire photosphere. Granulation defines *convection cells* – regions where hot gas rises from the solar interior, cools, and then falls back to the interior. Each granule on the surface of the Sun is about 1000 kilometers across – about the size of the State of Texas, and on average last only for about 5 minutes. High-resolution time-lapse motion pictures reveal the photosphere to be a boiling mass of convection cells. Another feature of the photosphere you are able to observe are *faculae*, blotched and irregular regions of brightness that are usually more easily viewed when contrasted against the decreased brightness of the solar *limb*, or edge. Faculae are the brightened sides of convection cells heated by locally intense magnetic fields, and intensified by solar active regions and sunspots.

THE CHROMOSPHERE

Lying next to and above the photosphere and rising to about 6200 miles (10,000 kilometers) above is the **chromosphere**. The chromosphere gets its name as the "sphere of color" fist observed during total solar eclipses. This pink-orange layer of the lower solar atmosphere, under high magnification and excellent atmospheric conditions, can also reveal long jet-like spears of gas known as *spicules*, which give the chromosphere the appearance of a "burning prairie." The chromosphere is even less dense than the photosphere, with a temperature rising to 20,000K.

Often rising out of the chromosphere are luminous fountains of hydrogen gas known as *prominences* - some of the most beautiful and impressive sights to be seen in the heavens. Prominences are plasmas suspended in and associated with magnetic fields, and because of the interplay of these electromagnetic forces they may assume many shapes - arches, columns, loops, "trees" and "hedges" - and many sizes. They can surge spaceward at speeds up to one million mph (1.6 million km/hr – an *eruptive prominence*), stream downward towards the Sun's surface, or remain almost motionless in the Sun's atmosphere (the *corona*) like luminous clouds for a few hours or as long as six to eight months (a *quiescent prominence*). Prominences generally are fainter than the chromosphere itself, and when silhouetted against the Sun's chromospheric disc they usually appear as shadowy ribbons known as *filaments*.



Chromosphere

More recently, spacecraft-borne instruments studying the Sun at shorter wavelengths (ultraviolet and x-ray) have revealed a surprisingly complex abundance of magnetically related activity in the chromosphere and lower corona. These generally are revealed in the form of thin loops of very hot gases such as multiply ionized iron at 1 million degrees K, which follow along the curved magnetic fields, and can extend over 500,000 kilometers into the corona.

Also directly linked to active sunspot regions, and usually only visible to amateurs in the chromospheric wavelengths, are *flares* (flares visible in white light are very rare). Flares are usually smaller than prominences, but are tremendously more energetic explosive eruptions of plasma and sub-atomic particles and radiation, releasing as much energy as several billion H-bombs. They are caused by powerful interacting, collapsing, breaking and reconnecting magnetic fields, and appear as rapidly brightening jets or irregular patches within or above active sunspot regions. They often resemble lightning and can last from a few minutes to several hours, and travel at speeds up to 2.5 million mph (4.0 million km/hr).

Following a strong solar flare the Earth may also be exposed to a greatly intensified *solar wind* two or three days later, and this can result in displays of *auroras* (*northern* and/or *southern lights*, where particles from the Sun follow the Earth's magnetic field lines near the poles and cause the oxygen and nitrogen in the upper atmosphere to glow). The largest solar flares can produce radio and electricity disruptions, and the radiation released could prove fatal to any astronauts outside of the Earth's protective magnetic field.

Aurora

THE CORONA

Beyond of the chromosphere lies the Sun's outer atmosphere, generally referred to as the **corona**, which is usually visible only during a total solar eclipse (specialized instruments called *coronagraphs* can observe the lower corona, and on spacecraft can capture the coronas full extent). This faint and extremely tenuous plasma is thought to be heated to over 1 million degrees Kelvin by the intense energy originating from the dynamic solar magnetic fields of convection cells and the chromosphere, and is reshaped, especially during sunspot maximum, by magnetic fields emanating from the solar active regions.

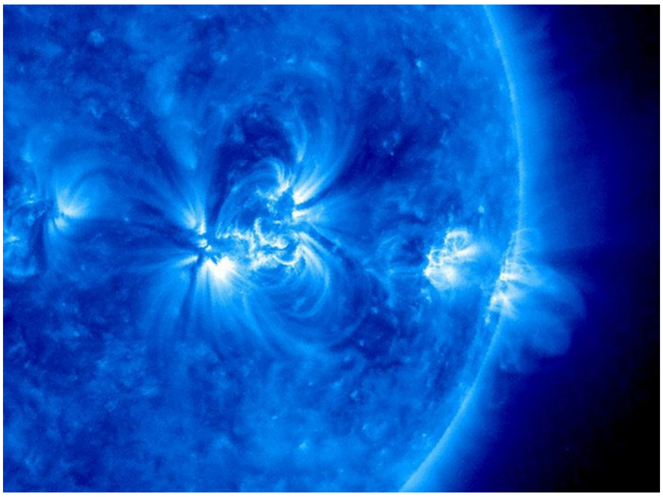


Image from STEREO

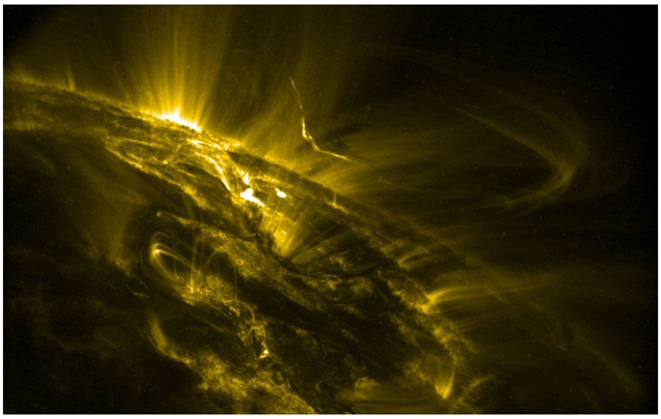
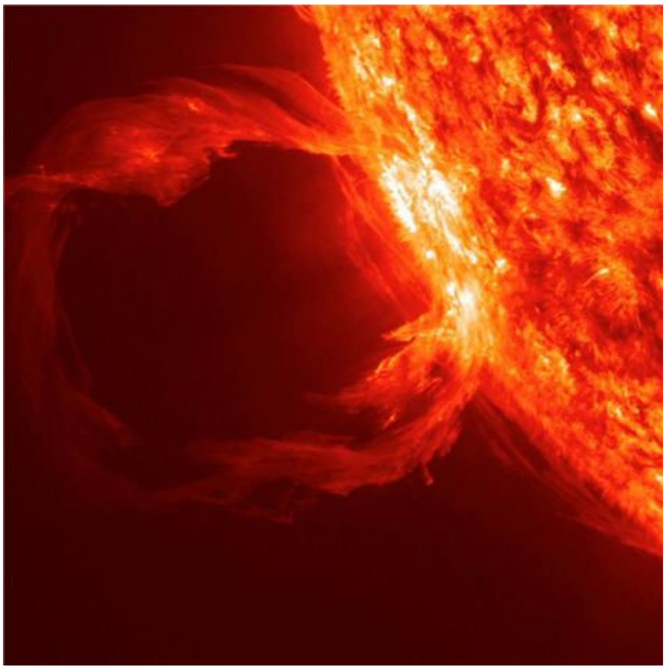


Image from TRACE


Eruptive Prominence by SDO

Spacecraft-borne instruments observing at X-ray wavelengths are able to observe "holes" in the corona itself. These *coronal holes* are regions of the coronal plasma that are less dense and cooler, and therefore appear darker than the rest of the corona. Coronal holes are associated with concentrations of open (unipolar) magnetic field lines. During solar minimum, coronal holes are usually only found at the Sun's polar regions, but can be found at all solar latitudes during solar maximum.

The *solar wind* is a stream of charged particles originating in the atmosphere of the Sun, and consists mostly of protons and electrons driven away by the high temperature of the corona itself, in addition to their intrinsic kinetic energy. The *fast-moving* component (~750 km/s) of the solar wind is known to travel along open magnetic field lines that pass through coronal holes. The composition is similar to that of the photosphere but far less dense. The *slow-moving* component (~400 km/s) of the solar wind originates in the equatorial region of the corona, and is more similar to the composition of the corona itself. The slow-moving solar wind has a more variable nature than the fast moving wind, and a more complex structure that often evidences turbulence. Because the Sun's magnetic field rotates with the Sun itself, the solar wind flows outward in a spiral pattern, much like the pattern of water drops from a rotating sprinkler.

Coronal Mass Ejections (CME's) are huge bursts of fast-moving plasma from the corona, often associated with or even triggered by large solar flares originating from magnetic storms in solar active regions. These "solar storms" can have significant impacts, just as with solar flares, creating geomagnetic storms and knocking out communications satellites, disrupting power grids, and creating beautiful displays of auroras.

PAST & FUTURE

The first stars were born from pure Hydrogen and Helium created when the universe burst forth from the "Big Bang" almost 14 billion years ago. Heavier elements were produced in their cores, as well as when massive stars explode in *super novas*. The Sun is a second or third generation star born from a rotating interstellar cloud of gas and dust, which collapsed about 5 billion years ago out of the remains of these previous stars, and the Hydrogen and Helium of the Big Bang. The planets - including you and me - are the left-over debris from these ancient events: We are all "children of the stars."

The Sun has existed in its present state for about the last 4.6 billion years, and has converted about 37% of its available Hydrogen into Helium. However, as the Sun continues to fuse Hydrogen into Helium, its core will shrink and become hotter. At the same time, the Sun's surface will become brighter, and over the next 500 million years this will have catastrophic effects on the Earth's climate and atmosphere. Within 3 billion years the oceans will boil away and Earth will become completely uninhabitable. In another 7 billion years most of the Hydrogen in the core will be depleted, and the Sun will begin to fuse Helium into heavier elements.

The increased temperature of the core will cause the outer layers of the Sun to expand to 170 times its present size, beyond the orbit of the Mercury and Venus and vaporizing both planets. The Earth's atmosphere will be completely stripped away and its surface will melt. The Sun will now be in its *Red-giant* phase and 2300 times it's current brightness, which will substantially warm the frozen outer planets of the Solar system - temporarily. The Red-giant phase will last for only a few million years, and once the Sun has fused lighter elements into Carbon and Oxygen, its energy will be depleted and gravity will slowly begin the Sun's final collapse. The Sun will have expelled great shells of gaseous matter, while the remaining core - about one-half the Sun's current mass - will finally contract to about the size of the Earth and become a *White-dwarf* star of extraordinary density, where a mere teaspoon of its *degenerate matter* will weigh over 5 tons.

Over untold eons the Sun will slowly radiate the last of its heat into space, becoming a cold dead cinder of extremely dense crystallized Carbon and other elements. The Sun's outer remains - an expanding cloud of gas and dust - eventually will be incorporated into another interstellar cloud, someday perhaps to be reborn as another star - and conceivably another generation of planets. These planets too may give rise to life - possibly even living beings that may wonder about the nature of their sun, the stars, and the astonishingly infinite universe beyond.

References

The Cosmic Mind-Boggling Book, Neil McAlister, Robert Jastrow, Grand Central Publishing, 1982

Earth, Sun, and Sky, Kenneth R. Lang, Springer, Second Edition, 2006

Physics of the Sun, A First Course, Dermott J. Mullan, CRC Press, 2010

National Aeronautics and Space Administration

Historical moments in solar observation

Stephen Ames

Day 1 - And God said, Let there be light...and there was light...

968 - First recorded mention of the solar corona:
"...at the fourth hour of the day ... darkness covered the earth and all the brightest stars shone forth. And is was possible to see the disk of the Sun, dull and unlit, and a dim and feeble glow like a narrow band shining in a circle around the edge of the disk".

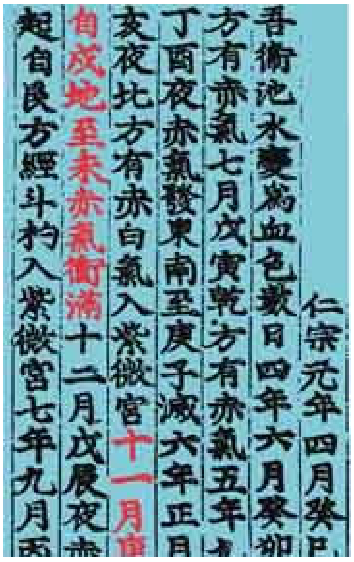
1128 - First recorded sketch, by John Worcester!

"In the third year of Lothar, emperor of the Romans, in the twenty-eighth year of King Henry of the English …on Saturday,8 December, there appeared from the morning right up to the evening two black spheres against the sun."

John of Worcester, recording the event in his Chronicle of the year December 8, 1128, clearly found the sight memorable, and perhaps ominous. The Latin script surrounds a colour diagram of the Sun, marking the position and size of the two sunspots he had seen with the naked eye – this was five centuries before the invention of the telescope!

December 13, 1128 - 5 days later in Korea!

On the night of 13 December 1128, astronomers in Songdo (the modern city of Kaesong), Korea, witnessed a red vapor that "soared and filled the sky" from the north-west to the south-west.

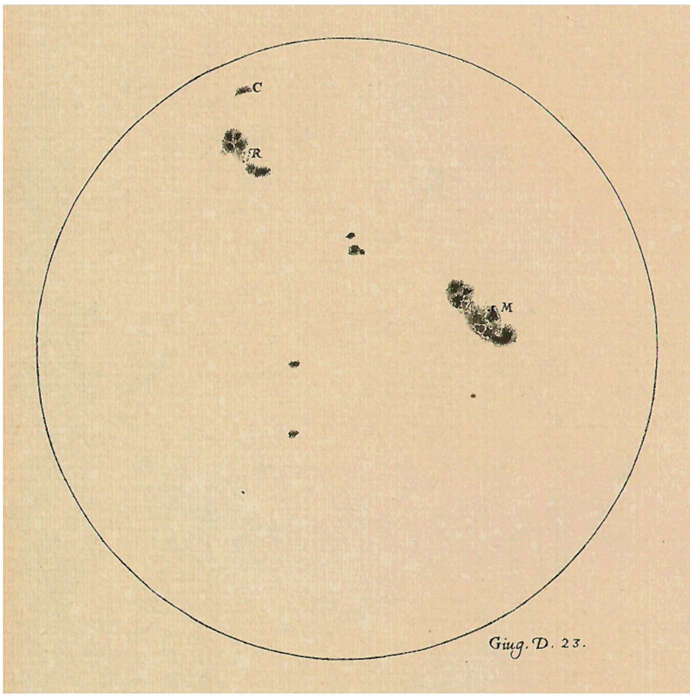


仁宗元年四月癸
吾衛池水變爲血色數日四年六月癸
方有赤氣七月戊寅乾方有赤氣五年
丁酉夜赤氣發東南至庚子滅六年正
亥夜北方有赤白氣入紫微宮十一月
自戌地至未赤氣衝滿十二月戊辰夜
起自艮方經斗杓入紫微宮七年九月

Their observations, of a rare southern manifestation of the aurora, were recorded in the Koryo-sa, the official Korean chronicle of the period, with precise calendrical information determining the date.

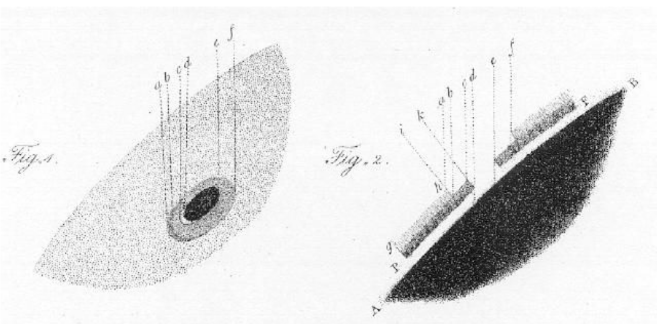
For modern astronomers, the accounts have a striking concurrence, confirming the accuracy of the two chronicles, and providing evidence of unusual solar activity in this period of the twelfth century. Sunspots, and the geomagnetic storms which cause auroral displays, are related effects of active solar regions. A delay of five days is typical of the average delay between the occurrence of a large sunspot group near the centre of the Sun's face – exactly as witnessed by John of Worcester – and the subsequent appearance of the aurora borealis in the night sky at relatively low latitudes.

1613 - One of Galileo's sketches!



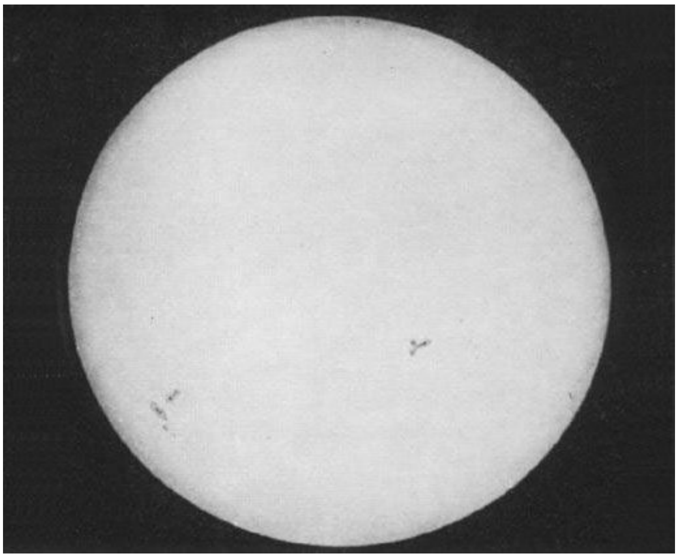
In 1612 during the summer months, Galileo made a series of sunspot observations which were published in Istoria e Dimostrazioni Intorno Alle Macchie Solari e Loro Accidenti Rome (History and Demonstrations Concerning Sunspots and their Properties, published 1613). Because these observations were made at approximately the same time of day, the motion of the spots across the Sun can easily be seen.

1801 - Reproduction of William Herschel's original diagram on the nature of sunspots!



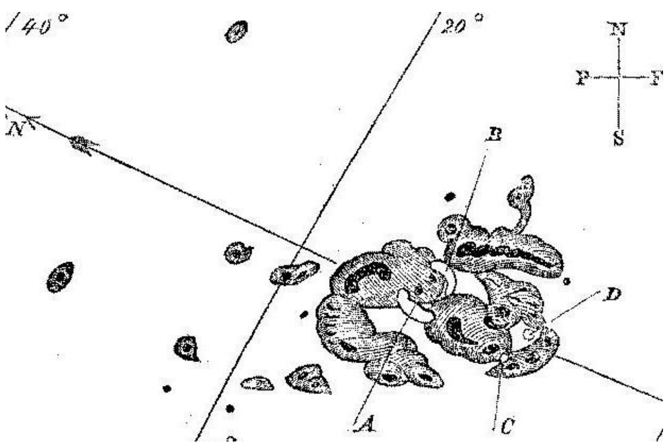
This hypothesis relies heavily on the asymmetric appearance of sunspots when seen near the solar limbs, as originally pointed out by A. Wilson in 1774. The physical nature of sunspots remained a topic of controversy for nearly three centuries. The universally opinionated Galileo proposed, with unusual reservation, that sunspots may perhaps be cloud-like structures in the solar atmosphere. Scheiner believed them to be dense objects embedded in the Sun's luminous atmosphere. In the late eighteenth century William Herschel (discoverer of the planet Uranus), following an hypothesis earlier put forth by A. Wilson in 1774, suggesting that sunspots were opening in the Sun's luminous atmosphere, allowing a view of the underlying, cooler surface of the Sun (likely inhabited, in Herschel's then influential opinion).

1845 - First solar image, by Louis Fizeau!



The first surviving daguerrotype photograph of the sun was taken at the dawn of photography in 1845 by French physicists Louis Fizeau and Lion Foucault. The 5-inch image showed many details including a few sunspots.

1859 - First solar flare sketched, by Richard Carrington!

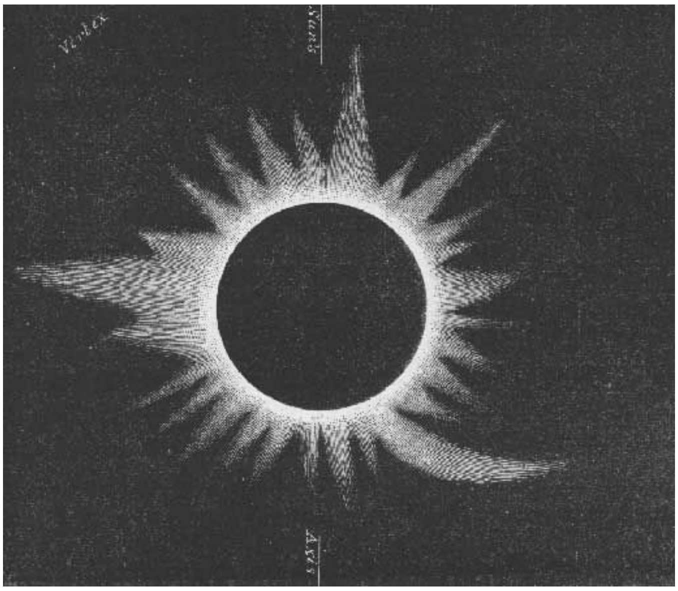


On 1 September 1859, the amateur astronomer Richard C. Carrington was engaged in his daily monitoring of sunspots, when he noticed two rapidly brightening patches of light near the middle of a sunspot group he was studying (indicated by A and B on the drawing above). In the following

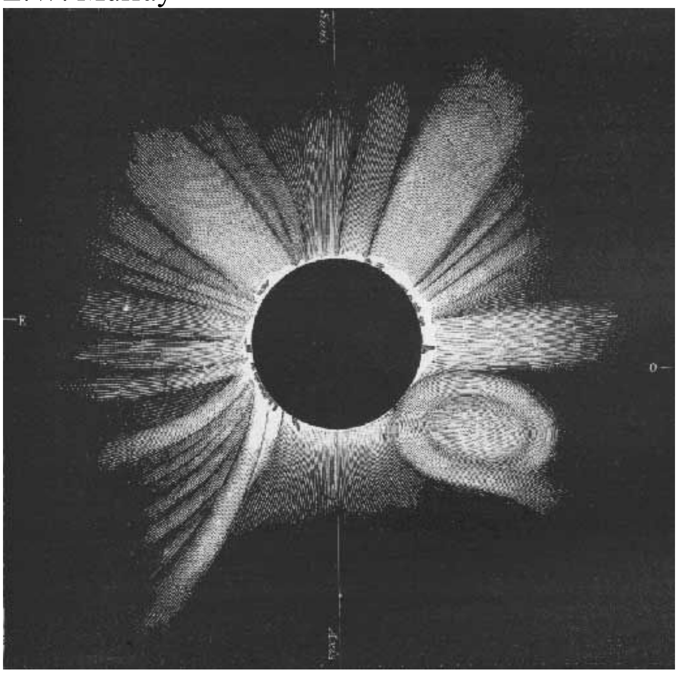
minutes the patches dimmed again while moving with respect to the active region, finally disappearing at positions C and D. This unusual event was also independently observed by R. Hodgson, another British astronomer.

1860 - The total solar eclipse of 18 July 1860

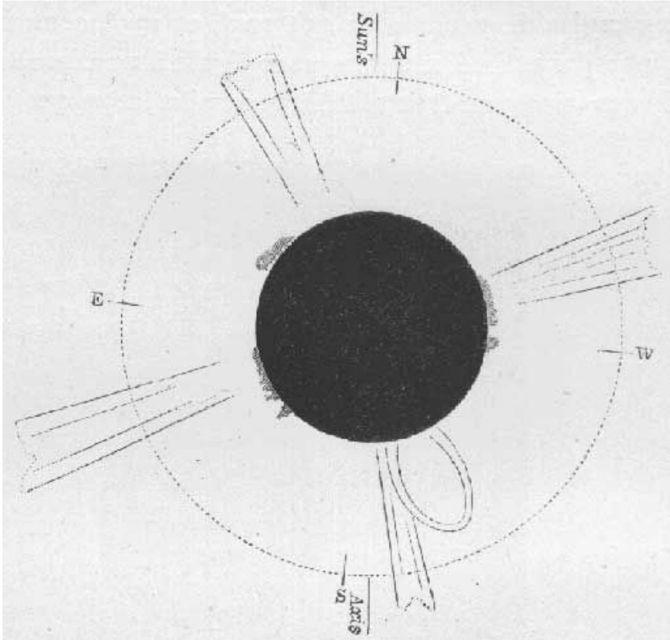
Probably the most thoroughly observed eclipse up to that time. The three drawings are a sample of drawings produced at that time which include depictions of a peculiar feature in the SW (lower right) portion of the corona. Based on comparison with modern coronal observations, it is quite likely that these represent the first record of a Coronal Mass Ejection in progress!



E.W. Murray

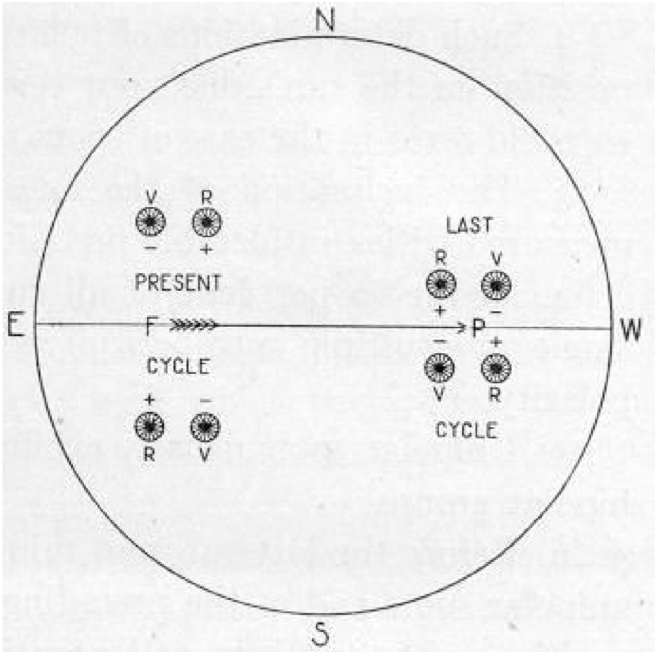


G. Tempel



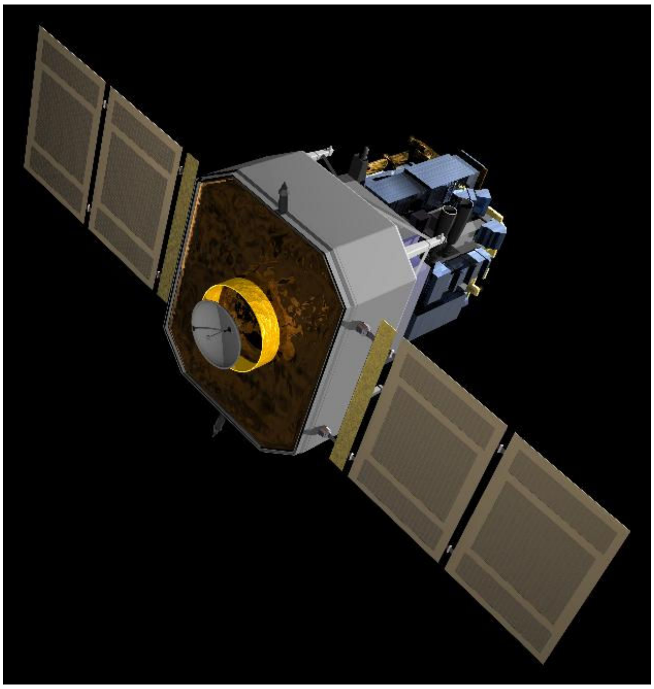
Franz Von Feilitzsch

1919 - A diagram illustrating Hale's Polarity Laws!



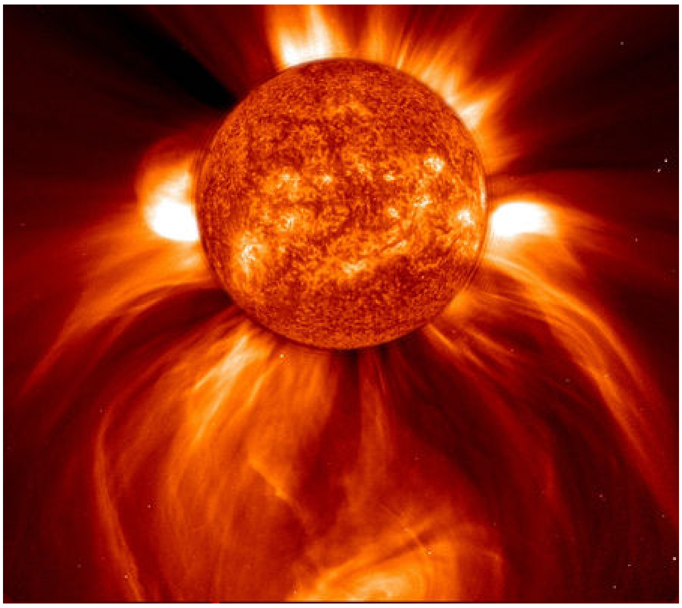
A diagram taken from the 1919 paper by G.E. Hale, F. Ellerman, S.B. Nicholson, and A.H. Joy (in The Astrophysical Journal, vol. 49, pps. 153-178), illustrating what is now known as Hale's polarity laws. This presented solid evidence for the existence of a well-organized large-scale magnetic field in the solar interior, which cyclically changes polarity approximately every 11 years. In the decade following his groundbreaking discovery of sunspot magnetic fields, George Ellery Hale (1868-1938) and his collaborators went on to show that large sunspots pairs almost always (1) show the same magnetic polarity pattern in each solar hemisphere, (2) show opposite polarity patterns between the North and South solar hemispheres, and (3) these polarity patterns are reversed from one sunspot cycle to the next, indicating that the physical magnetic cycle has a period of twice the sunspot cycle period. These empirical observations have stood the test of time and are since known as Hale's polarity Laws. Their physical origin is now now known to originate with the operation of a large scale hydromagnetic dynamo within the solar interior, although the details of the process are far from adequately understood. Because the sun's dynamo generated magnetic field is ultimately responsible for all manifestations of solar activity (flares, coronal mass ejections, etc.), to this day solar dynamo modeling remains a very active area of research in solar physics.

December 2, 1995 – SOHO (SOLAR AND HELIOSPHERIC OBSERVATORY) was launched!

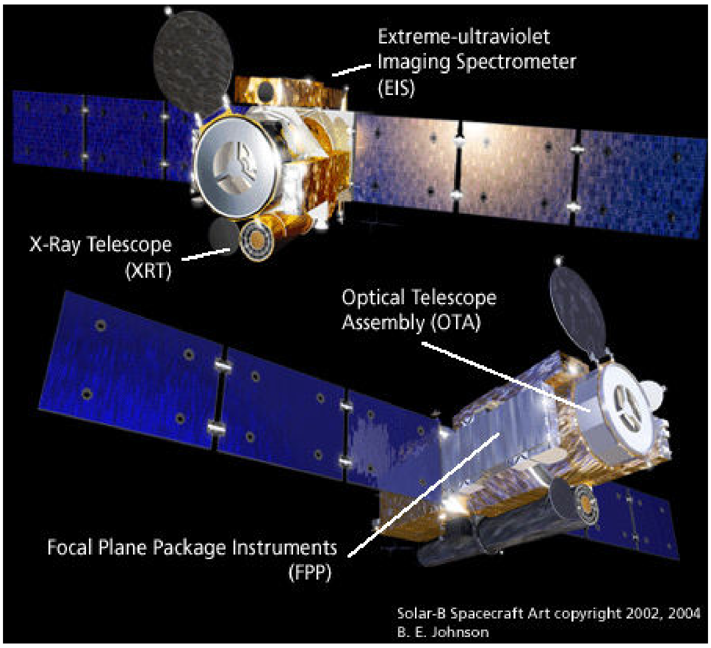


SOHO, the Solar & Heliospheric Observatory, is a project of international collaboration between ESA and NASA to study the Sun from its deep core to the outer corona and the solar wind.

Here is one of SOHO's images:

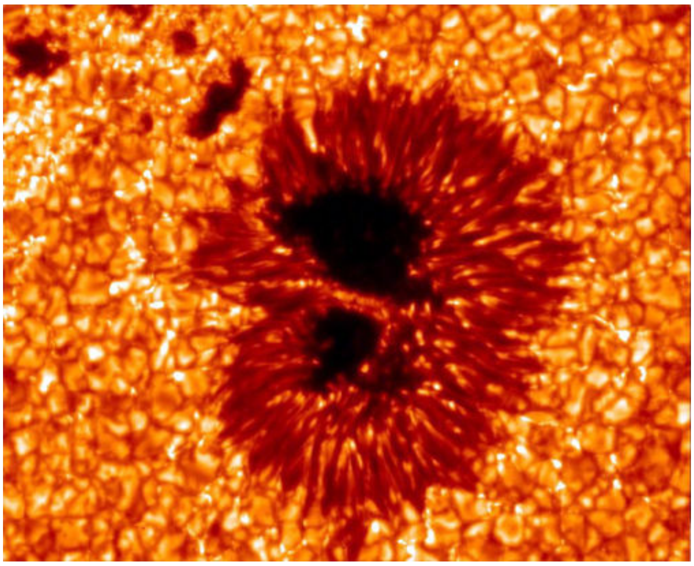


September 23, 2006 – HINODE (SOLAR B) was launched!



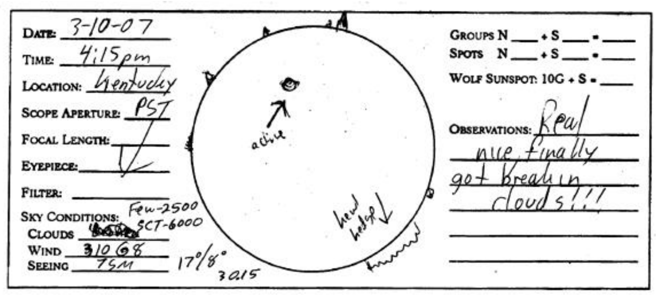
Solar-B's overall goals are to understand how energy generated by magnetic-field changes in the lower solar atmosphere (photosphere) is transmitted to the upper solar atmosphere (corona), to understand how that energy influences the dynamics and structure of that upper atmosphere, and to determine how the energy transfer and atmospheric dynamics affects the interplanetary-space environment.

Here is one of HINODE's images:

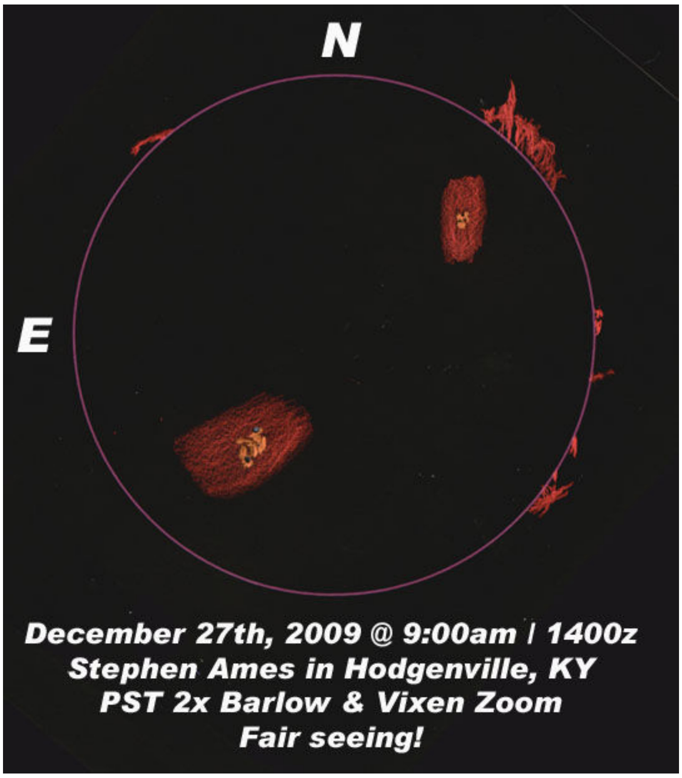


March 6, 2007 - I begin my solar observations!

Here is one of my first sketches from March 9th, 2007, I didn't notice how much it looked like the very first known sketch until I researched this:



Here is one of my most recent as of this writing:



With the affordability of Personal Solar Telescopes there are now more people looking at the Sun than ever before in history and as we come out of a very long Solar Minimum, I expect many more people to learn of and enjoy the unique excitement that comes with Solar Observation!

About Stephen Ames

My name is Stephen "Darkstar" Ames, I live with my wife on our farm in Hodgenville, Kentucky, USA. We have 6 dogs and raise Silkie Chickens and a variety of ducks. I've been viewing since March of 2007, I exclusively use a Coronado Personal Solar Telescope(PST) with a 2x Barlow and 8-24mm Vixen Zoom and weather pending, view every day. If you visit http://www.seemysunspot.com you'll be able to see a daily journal of solar activity since I started viewing.

Solar Imaging on Budget

Emiel Veldhuis

Solarlive
www.Solarlive.nu

This is just a reaching hand for beginners who want to do some solar imaging with a webcam.
It's just the way I do it, not the ONLY way!
So, trying and learning is the best way to solve the solar imaging puzzle.

What do you need?

- Coronado PST or other brand of solar telescope
- Motor driving equatorial mount
- Philips ToU-webcam or DMK camera
- 2X Barlow lens
- Computer
- Software
- Sunshine…lots of it
- And last but not least: a cold beer on a hot summer day! ;)

The setup

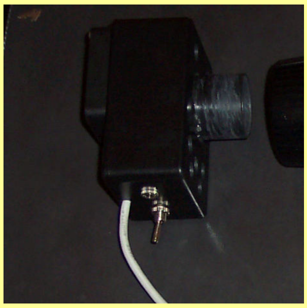
- Set up the telescope and level at north.
- It is important to track the Sun on an equatorial driven mount to keep the Sun centre on the CCD-chip.

The webcam

Cheap webcams suitable for solar-imaging:

- Philips ToUcam PRO I, II
- Philips Vesta PRO
- Quickcam PRO 4000

I use a black & white RAW modded ToU-camII (SC3). My cam has a nosepiece. Otherwise, use a MOGG adapter for connecting the webcam to the PST.



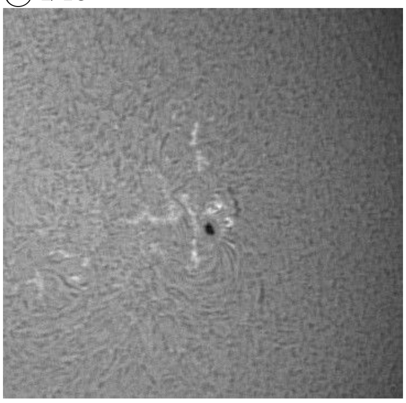
Getting into focus

To get into focus with a PST and webcam, you need a 2X Barlow. The PST works at f/15.

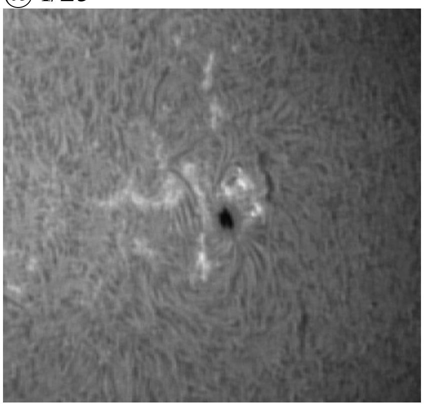
My PST also comes in good focus with a Tele Vue 2,5X Powermate. Now the PST works at f/25.

Sunspot 933

@ f/15



@ f/25



Point to the Sun to get good focus…

Two ways to get good focus on your computer screen:

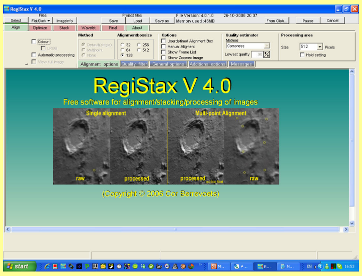
- Make your room as dark as possible

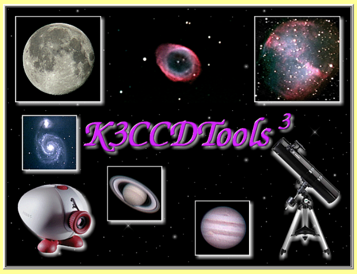
- Use a cardboard box!

Software

Some useful software for imaging and processing:

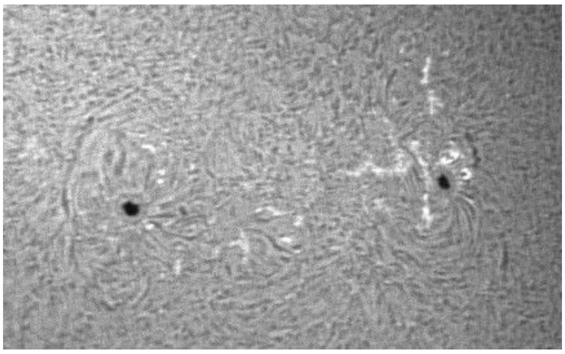
- Original webcam drivers
- Registax V4
- K3ccdTools
- Photoshop, Paintshop Pro or ImagesPlus





Capturing some frames

- Set image format at 640X480 pixels
- Shoot short AVI for about 30 – 45 seconds
- Frame rates of 10 – 15 frames/second
- Always capture in monochrome/black and white



Imaging Parameters

- Brightness: > as possible
- Gamma: < as possible
- Contrast: 50%
- Saturation: 0%
- Mode: black/white
- Exposure time:
  - Prominences: 1/33 – 1/100sec.
  - Sunspots: 1/500 – 1/1000sec.
- Gain: < as possible

Captured some AVI and ready to process the images.

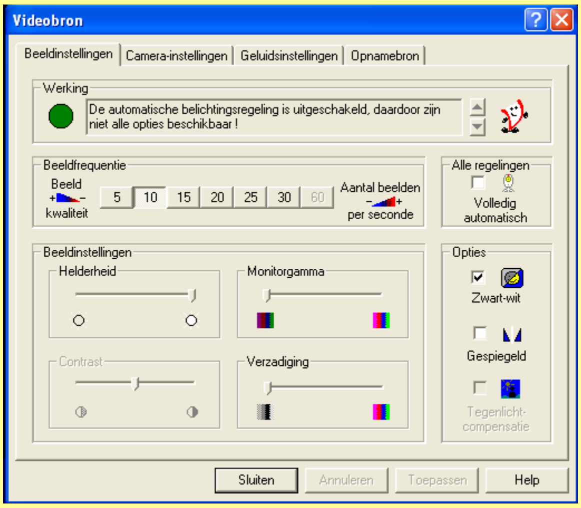
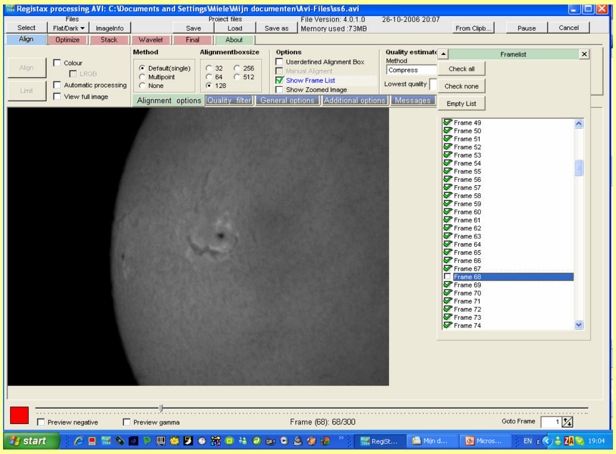
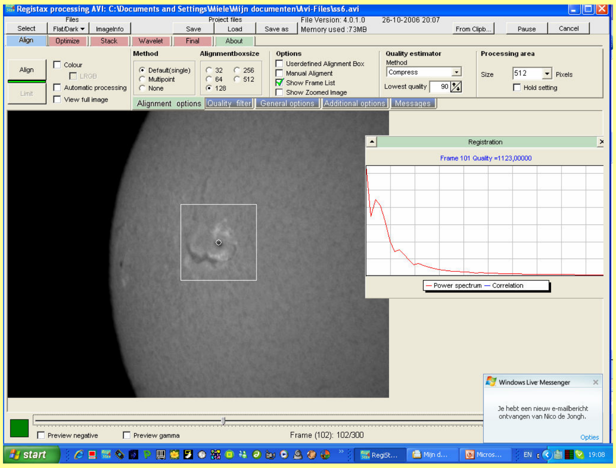


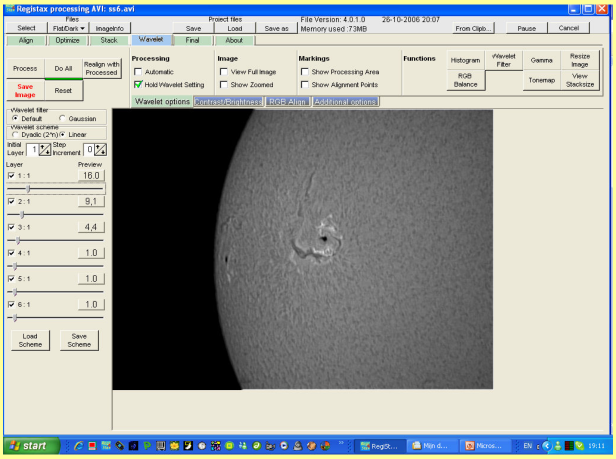
Image Processing in Registax



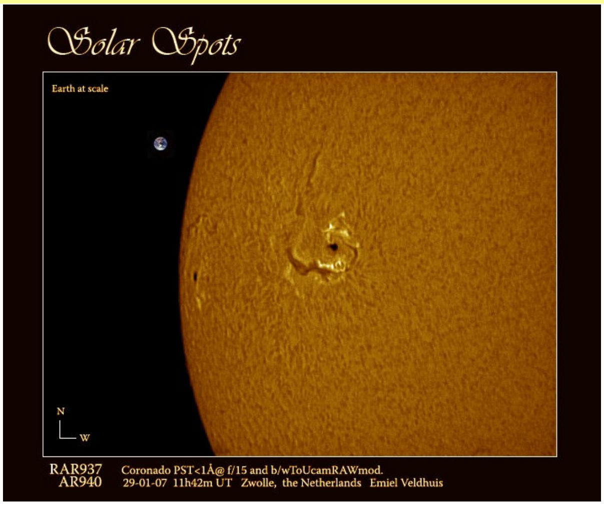
- Open Registax and select an AVI-file
- Uncheck all bad frames
- Select a reference frame
- Choose an alignment box size and put it on a contrast detail like a spot.
- Set the Quality Estimate on Compress and lowest quality on 90%
- Push the align button
- Registax will now align the images from best to worse
- Choose the limited frames to stack, with the slider at the bottom of the screen
- Push the Limit button
- Registax will now stack all selected frames

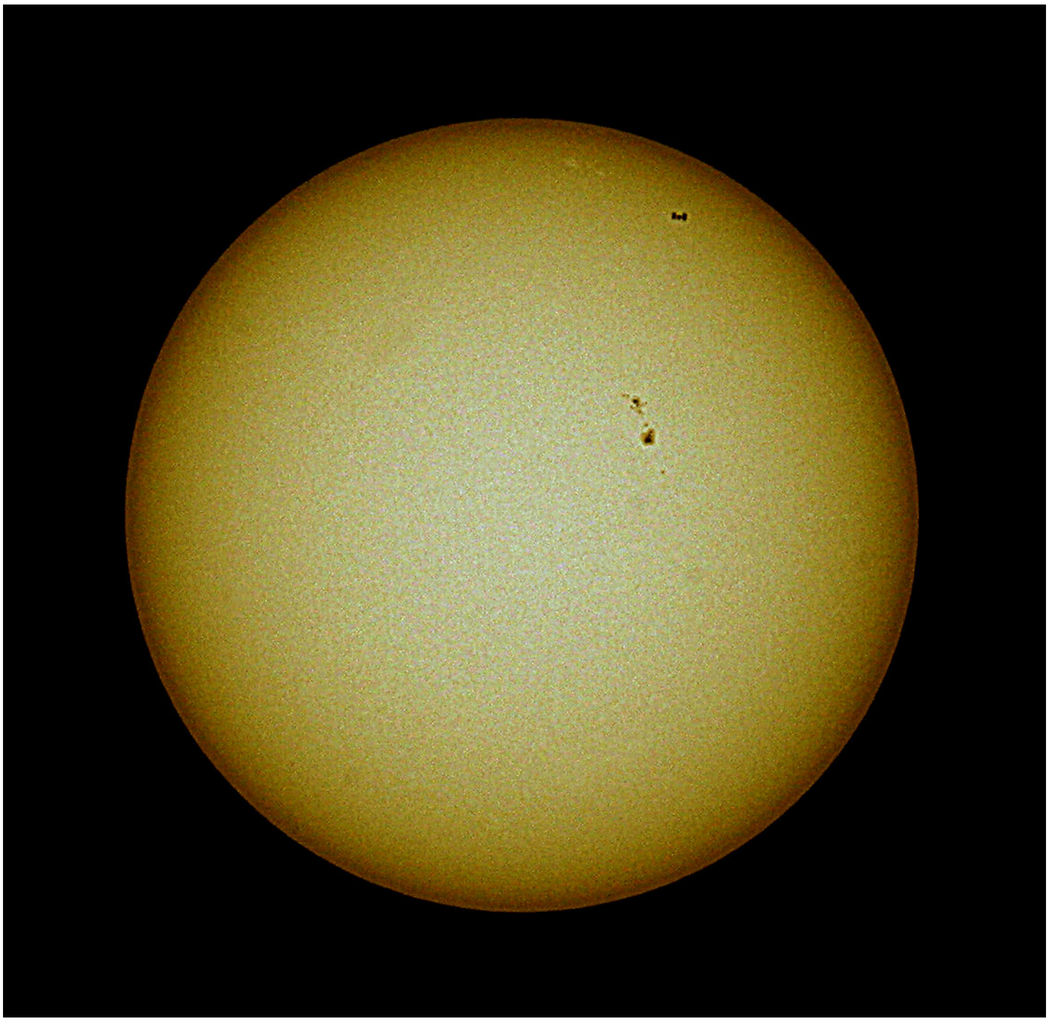


- You end up with the Wavelet screen
- Now you can set the wavelets the way you like, just don't overdo it.
- Push the Do All button
- There is a lot more you can do in this screen, just try it out.
- Save as TIFF or FITT size
- After you saved your images, you can process them further with Photoshop or Paintshop.
- Just try Levels, Curves, Shadows/Highlights and Unsharp Masking.
- I use a H-alpha colorization AVL, but you can give the Sun a real nice color with Color balance and Channel mixer too!. Just playing with those sliders ;)

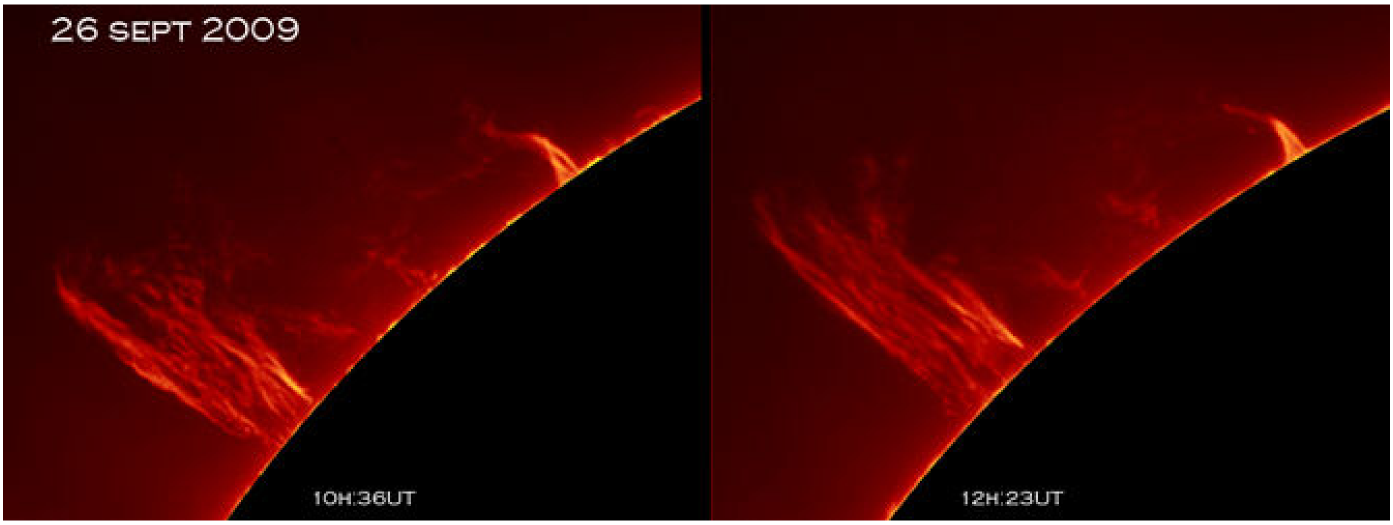


In the next issue of Solar Observer, we take a closer look at how to capture your solar images.

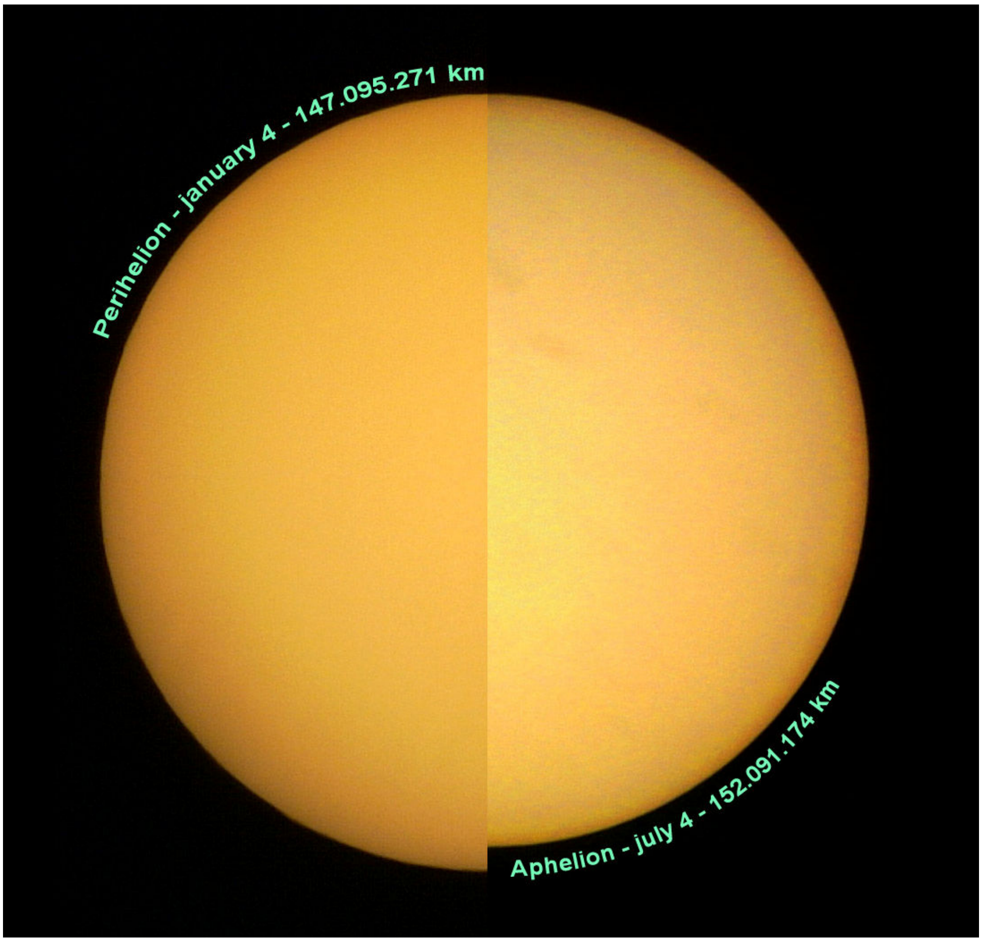


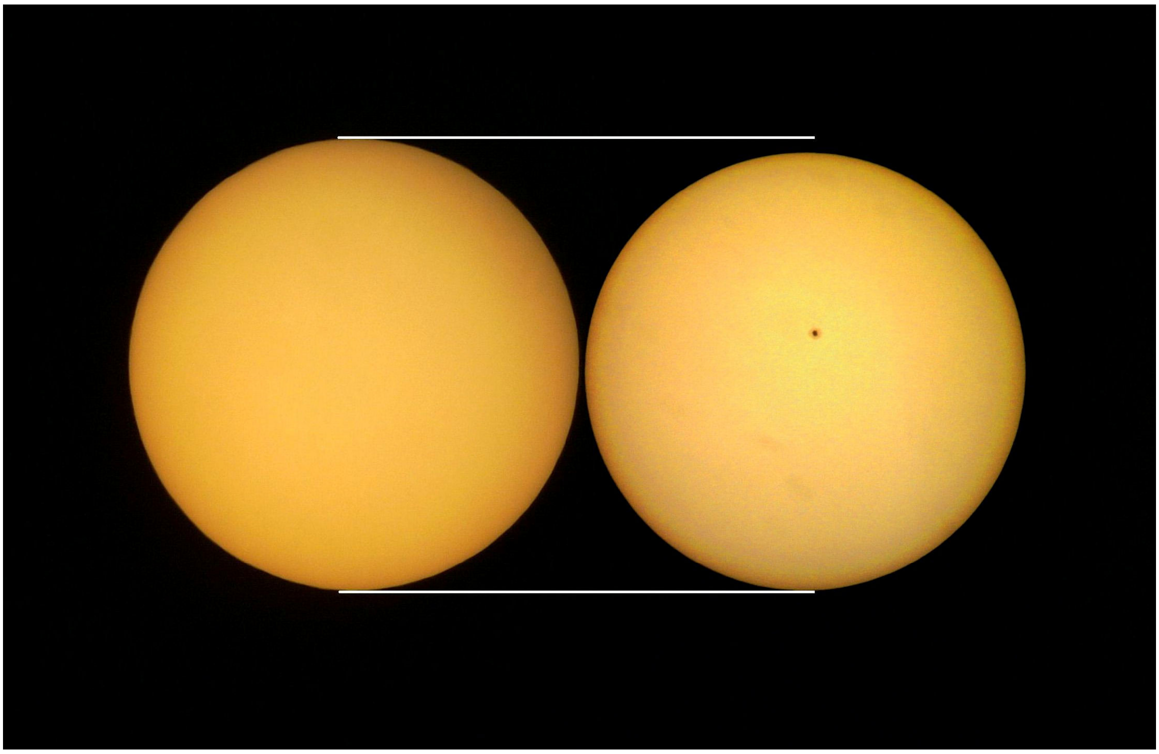


Luigi Fiorentino (Bari, Italy) *captured the transit of the International Space Station over the Sun disk. The picture was taken with an Orion 80ED refractor (600 mm), with Astrosolar film (Density 3.8) and a Canon 350D, at ISO200, 1/2500 sec, in the Bari harbour, Italy on 03/14/2010. Calsky has been used to plan the transit.*

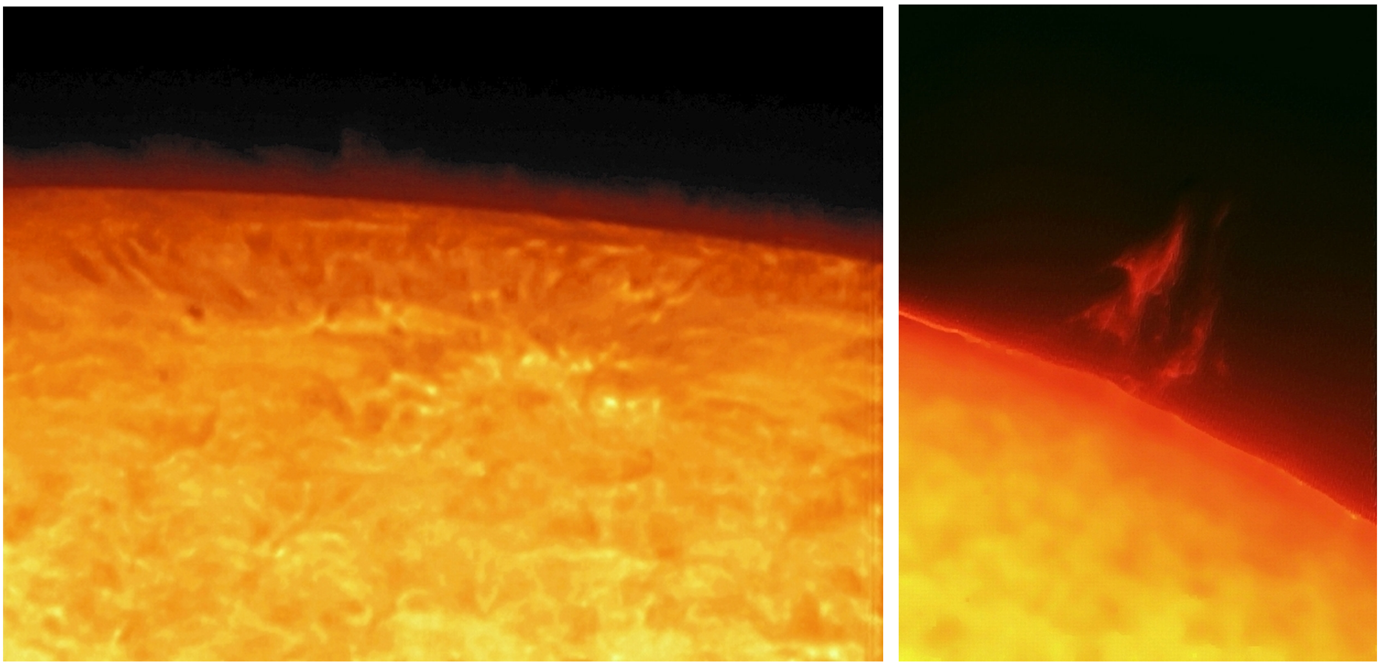


Erio Inglante Rossi *captured this solar prominence in 26 sept 2009, by using Sky Watcher 102/500, with Solar Spectrum 0,5A + TZ4 and DMK31 at final focal length of 2000mm.*



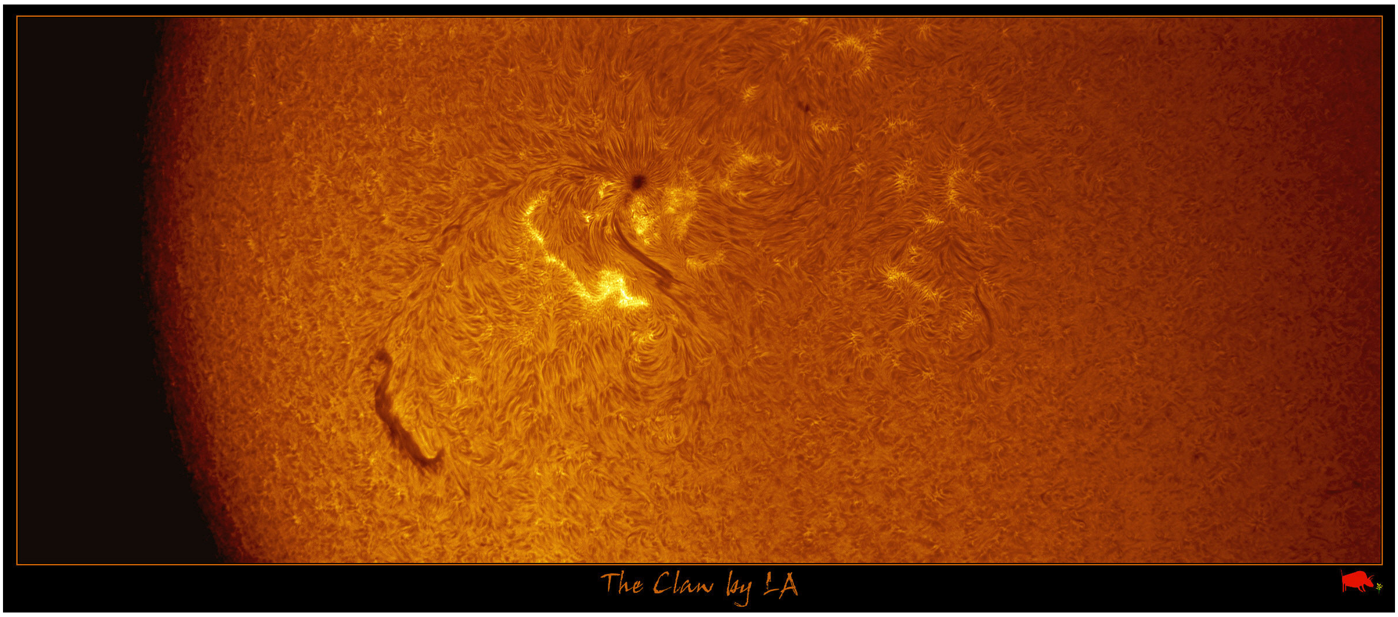


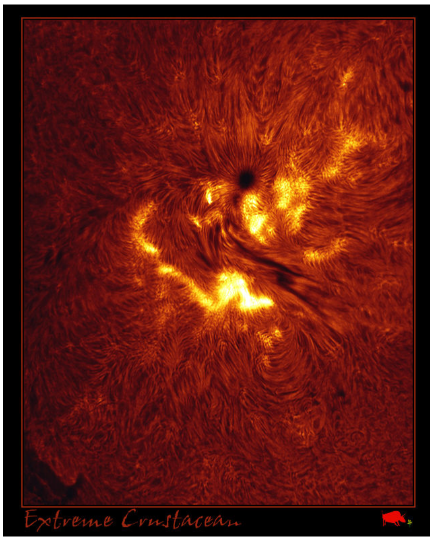
***Enrique Luque Cervigón** captured the different sizes of the sun in the perihelion and aphelion. First photos were taken in January and July 2006. Second photos were taken in January and July 2008. All photos were taken from Alcalá de Henares (Madrid-Spain). Enrique used a Newtonian telescope 130mm (900mm) with a 26mm eyepiece.*

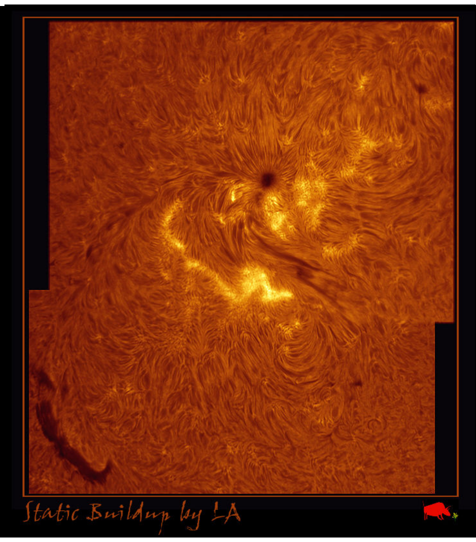


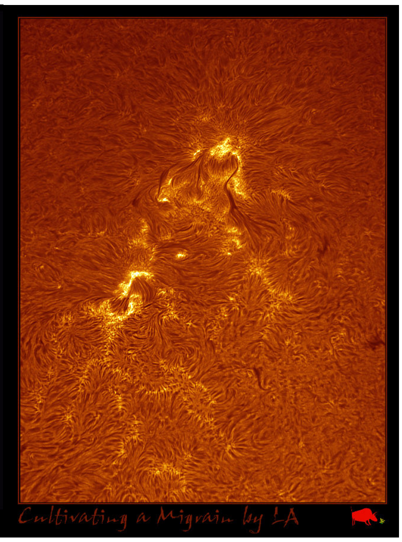
***Ype de Lang** captured the explosions in the chromosphere in July, 26, 2009 (left) and prominence in July 16, 2009 (right) by using Meade 10 inch SCT, ICX098BL webcam, 8,3cm ERF, Daystar 0.6A ATM.*

This is Ype de Lang's telescope placed in a roll-off observatory in Netherlands
http://titans-cctv-observatory.nl









***Larry Alvarez** captured the sunspot 904 on September 11, 2006. The first image is a mosaic image of two separate images spliced together. The images were captured with a Coronado 90mm <0.5A H-alpha MaxScope and Lumenera CCD.*

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Focal Length: 900mm
Bandpass: <0.70 Angstroms

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$4,498

LS100T
The LS100T is a dedicated Solar telescope that provides all the features that one would expect from an advanced Solar package. An increase to the image scale provides the ability for higher magnifications and the study of very fine Hydrogen-alpha details. This system provides the perfect platform for both visual and imaging use. Readily double stackable with an additional 100mm front filter.
Aperture: 100mm (unobstructed)
Focal Length: 700mm
Bandpass: <0.70 Angstroms

$1,493

$2,392

LS60T/PT
Provides the basic essentials for an introduction to Daytime Solar Observing. Includes the newest technology for fine tuning (the pressure tuner) providing the perfect blend of edge and surface detail.
Aperture: 60mm
Focal Length: 500mm
Bandpass: <0.7 Angstroms

LS60T/PT/DS (Double Stack)
Upgrading to the LS60T/PT system puts a research grade instrument into your hands. The addition of the secondary filter to the front dramatically increases the surface detail of the Sun. Larger trimming filter allows the system to be used with most imaging systems.
Aperture: 60mm
Focal Length: 500mm
Bandpass: <0.5 Angstroms

$1,048

$1,947

LS60T
LS60T is a complete introductory Solar Telescope. Refractor system has a 60mm aperture perfectly suited to everyday daytime observing. System provides optimized edge detail, showing Prominences and Flare activity.
Aperture: 60mm
Focal Length: 500mm
Bandpass: <0.75 Angstroms

LS60T/DS (Double Stack)
An upgrade to the basic introductory package with the addition of a LS50F to the front of the scope. The secondary filter reduces the bandpass the of the overall system providing stunning visuals of the Sun's active surface details.
Aperture: 60mm
Focal Length: 500mm
Bandpass: <0.55 Angstroms

$649

$1,048

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LS35T Deluxe Package
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Focal Length: 400mm
Bandpass: <0.75 Angstroms

LS35T/DS (Double Stack)
Aperture: 35mm
Focal Length: 400mm
Bandpass: <0.55 Angstroms

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For Amazing Resolution Through Your PST®
-Includes BF10 Upgrade, Larger Machined Focuser Knob-
CORONADO
P.S.T.
Photo by Greg Piepol
DENKMEIER
Spectrum 60 and 100 upgrade for The PST® made by Denkmeier Optical, Inc. is shown attached to a Coronado PST® by Meade Instruments Corporation. Denkmeier Optical is not affiliated with Meade Instruments.
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- AIR GAP SPACER IS PRODUCED USING IBS TECHNOLOGY (NON-MECHNICAL PRODUCTION METHODS)
- EXTREME SPACER ACCURACY NOW ELIMINATES ANY WEDGE OR HOT SPOTS
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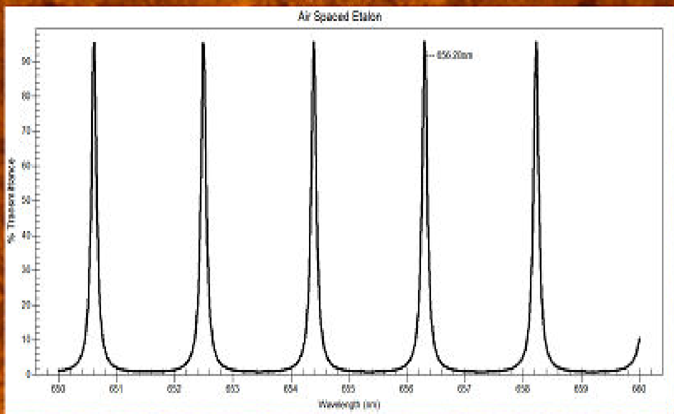
- ULTRA-STABLE PERFORMANCE (NOT TEMPERATURE SENSITIVE)
- SPACER CONTACT HAS HIGHER TOTAL SURFACE AREA, YET ALLOWS GREATER CLEAR APERTURE THAN OTHER ETALONS
- OUR IBS SPACERS ARE EXTRMELY THIN, WHILE MECHANICALLY POLISHED SPACERS ARE LIMITED IN HOW THIN THEY CAN BE
- SELECTABLE BANDWIDTH IS ACHEIVED USING OUR COMPUTER CONTROLLED IBS MACHINE FOR RANGES OF .2, .5, .6, .8, ANGSTROMS



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