Guidelines for the Observation of Monochromatic Solar Phenomena

Edited by

Jamey Jenkins

Asst. Coordinator, ALPO Solar Section

Originally compiled by

Randy Tatum

A Handbook of the Association of Lunar & Planetary Observers Solar Section.

January 2010

3rd Edition

Established 1947

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Acknowledgements

Welcome to the world of solar astronomy. The purpose of this book is to bridge the gap between the casual and serious observer wishing to contribute to the knowledge of the nearest star, our Sun. We are a division of the Association of Lunar and Planetary Observers, organized by Walter Hass in 1947; this Section being established in 1982. The function of the Solar Section is to *stimulate, organize, and disseminate* amateur work in the field of solar morphology. Through the archiving of solar observations we provide a resource for the professional community to supplement their research programs. While we do not offer recommendations regarding sunspot counting or radio flare patrolling, we do accept and archive submitted observations of that nature from observers. Any member wishing to involve themselves deeply in such work should additionally contact the American Association of Variable Star Observers (AAVSO) at 49 Bay State Road, Cambridge, MA. 02138 for guidance. Many of our observers participate in both organizations.

Solar morphology is a particularly rewarding field of study for the amateur astronomer since the features of the Sun are the most active and changing in the whole of the solar system. Because of this dynamic, solar activity requires diligent observing. Some work can be done within the space of a day or two while other projects require a commitment of many days, often consecutive. Neither type of observing is any more important than the other, so observers that make a contribution either way are encouraged to do so. The work of the Solar Section and consequently the focus of our efforts is the recording of visual and photographic observations of the Sun. There is a particular emphasis on photographic observations in white and monochromatic light since these are of the most use to the professional community. Space limitations will require some presumptions on our part that you, as an observer are familiar with astronomical terminology and principles. If you are a novice please contact the Solar Section Coordinator for guidance.

The preparation of this booklet required advice from a number of professional and advanced amateur astronomers to insure that the work of the Solar Section would have immediate and lasting value to astronomy. We gratefully acknowledge the support and aid of those listed below. For our observations to retain value, it will take dedication and commitment from our observers towards producing reliable data that will, by virtue of its own high quality be in demand now and in the future.

—ALPO Solar Section

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Monochromatic Observing

Monochromatic light is wavelength specific light. Whereas white light observervations are done with a wide sampling of color from the solar spectrum, the monochromatic observer is using only a comparatively thin slice of light from the whole of the spectrum.

Since 1982, the A.L.P.O. Solar Section has been collecting and reducing solar observations to provide useful data to professional and nonprofessional researchers. The original intention of the Section was to collect white light data of active regions. Since that time many of our observers have become actively involved in more advanced methods of solar study; such as spectroscopic work and imaging in the light of Hydrogen alpha (6562.8Å) or the Calcium K-line (3933.7Å).

The Sun is a very beautiful and complex object to study and the variety of different phenomena to observe in its atmosphere are simply breathtaking at times. Magnetic fields play an important role in the understanding of solar activity. In the convection region, below the photosphere, gas motions dominate magnetic fields, but the opposite is true in the solar atmosphere above the photosphere.

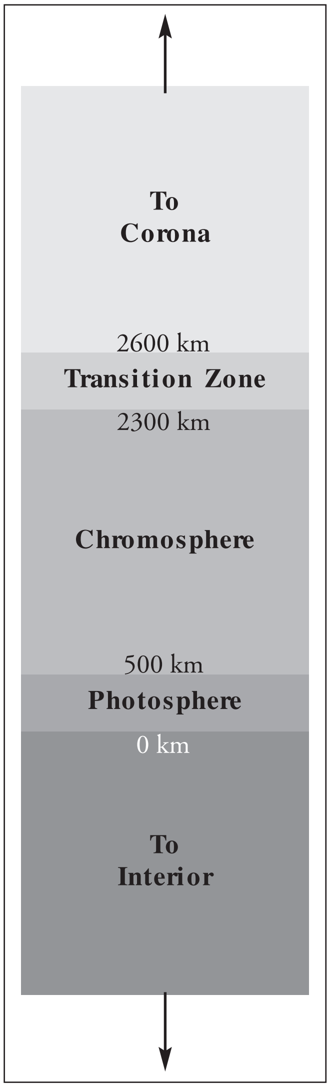
On the practical side, monitoring solar activity is important to our understanding of solar/terrestrial relationships. In truth we live within the atmosphere of the Sun. The solar wind, an ionized gas that flows from coronal holes, carries the Sun's magnetic field through the solar system. The connection between activity on the Sun and the Earth's magnetic field is well established. Coronal holes, disappearing filaments (eruptive prominences) and solar flares cause geomagnetic storms and aurora. Major flares cause communication black outs, power surges and threaten space missions. The effects of activity on the weather and life in general has yet to be proven but the strong connection is suspected. Historical records show long periods when the 11-year sunspot cycle is suppressed, or absent. These periods may be tied to ice ages on Earth. The Sun is the only celestial body in which we physically interact (except for meteors and the occasional asteroid or comet).

The monochromatic information presented here is divided into three sections. The first section is an overview of the history of monochromatic observation with emphasis on instrumentation. The second section describes the numerous solar features to be observed. Several hints and suggestions pertaining to monochromatic observing are discussed in section three.

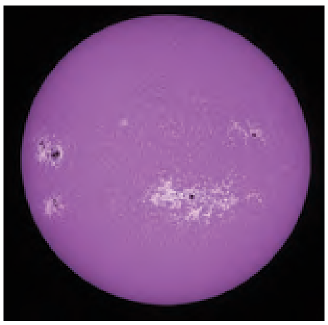
As always caution must be exercised when observing the Sun. The dangers present with white light observation are still a hazard with monochromatic observing.

History and Instrumentation

Prior to the year 1868 solar astronomers could observe prominences only during the few minutes of totality of the eclipsed Sun. Knowledge concerning these features hence progressed slowly. The question of whether the prominences were caused by the Sun, Moon, or an optical illusion was solved at the eclipse of 1860 by photography. Early eclipse observers had speculated that prominences were lunar clouds, or mountains on the Sun! During the eclipse of 1868, in India, French astronomer Janssen observed the bright emission lines of a prominence at the Sun's limb, spectroscopically. He was so impressed by the brightness of the prominence in the Hydrogen alpha line that he tried to observe the emission in broad daylight after the eclipse. He found that by placing the spectroscope slit across a prominence, he could trace out its shape. Janssen shared this discovery with Lockyer



The thickness of the various components of the solar atmosphere are illustrated with this diagram. The base of the photosphere is at a starting point of 0 kilometers, the chromosphere begins at a point 500 km above that.



A typical view of the Sun in the light of Calcium on 19 July 2004 by Christian Viladrich.

in England. Huggins developed the technique of widening the spectroscope slit, thereby viewing the entire prominence instead of a thin slice. There is a limit to which the slit can be widened, depending on the spectroscope's dispersion and on the clarity of the atmosphere. The wider the slit, the less contrast a prominence has. The early prominence spectroscopes were short focus and used a train of prisms for dispersion. The slit had to be positioned tangent to the Sun's limb and had to be repositioned several times to observe the entire circumference of the Sun. For over 25 years observers like C. Young in America and Fr. Secchi in Rome observed the Sun with these instruments.

In order to photograph the entire limb of the Sun, in monochromatic light, George E. Hale designed the spectroheliograph in 1891. He used the broad "K-line" of Calcium in the deep blue part of the solar spectrum. The chromosphere and prominences emit light in several spectral lines in addition to Hydrogen alpha, such as the H and K lines of Calcium, the yellow Sodium lines, the yellow Helium D3 line, and the rest of the Balmer series of hydrogen lines. The color of prominences during totality is intense pink since it is a combination of all these emission lines. The H-alpha line in the orange/red part of the spectrum is the dominant emission line. The spectroheliograph creates an image of the Sun on a photographic detector slowly, slit width by slit width, isolating a view in a single spectral line. The first slit of the spectrograph makes the dark absorption lines; and the second slit isolates one particular line for study, letting its light through to the eye or photographic camera. Hale discovered bright clouds of Calcium on the Sun's disk around sunspots. In 1908 he photographed the solar disk in H-alpha light and discovered strong magnetic fields confining the gas around sunspots.

The optical counterpart of the spectroheliograph, the spectrohelioscope, was developed about 1924. In this instrument, the slits move rapidly and repeatedly across the solar image; due to persistence of vision the eye sees a continuous image in monochromatic light. Using this instrument it is possible to measure velocities of features along the line of sight quickly with a device called a line shifter. For visual work, the best line in which to observe is H-alpha. The eye is most sensitive in the green to red end of the spectrum, and the other lines are too narrow in width to be easily used. The importance of the spectrohelioscope in the field of solar/terrestrial relations became evident when radio noise was found to be associated with solar flares in 1942. Ever since Carrington and Hodgson had observed the first white light flare in 1859, astronomers had suspected a connection between flares and geomagnetic disturbances. Hale realized the importance of monitoring solar activity and wanted these instruments to be distributed to observers around the world.

There are many designs for spectrohelioscopes. The solar observer should select the design that best suits his needs. Generally, the spectroscope is fixed in a horizontal or vertical position. Sunlight is fed to it from a single flat heliostat or from a two mirror coelostat system. It would be best that the spectroscope is used in an observatory to protect it from wind and scattered light. Diffraction gratings with 1,200 lines per millimeter will show thousands of Fraunhofer lines in the spectrum and are relatively inexpensive. The lenses used may be single element.

In a large sense, the spectrohelioscope is analogous to your radio or TV receiver, except that it operates in the visible part of the electromagnetic spectrum. Various chemical elements transmit at discrete frequencies, just as do radio and TV stations. The ability of your instrument to "tune in" on specific wavelengths is important to reduce noise in your receiver, or to improve contrast in your spectrohelioscope. The advantage of the spectrohelioscope is that it doesn't limit the observer to one spectral line and offers the entire spectrum at a reasonable price.

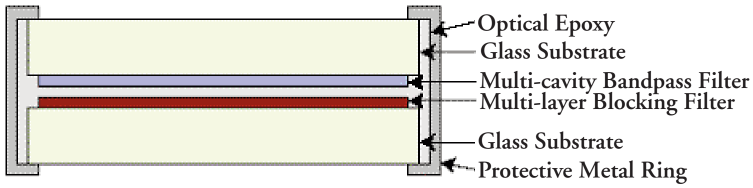
Around 1930, B. Lyot developed a new device to study the Sun, the monochromator. These optical filters were made of quartz and calcite crystals, and had to be kept at a constant temperature to provide the best contrast view. The early filters had passbands of several angstroms and could only be used to study prominences. Great skill was required in the construction of these early filters and only a few names in the amateur ranks come to mind as having accepted the challenge of building them; names such as Henry Paul and Walter Semerau. The H-alpha line is only .6Å in width. A filter with a passband of one angstrom will show prominences easily, but only bright flares on the disc. A .7Å or .8Å filter will give good disk contrast with bright prominences. A .5Å or .6Å filter gives very good disk contrast with subdued prominences. Filters with passbands from 3 to 10 angstroms are adequate for observing prominences and an occulting disc will improve the view.

The development of the *interference filter* improved the efficiency of optical filters by reducing passbands to .1Å. Space age production techniques reduced the cost of these filters and put them into the hands of amateur astronomers. Modern commercial units (of which several are available at the time of this writing) are based on the principles of light interference.

Interference filters are multilayer thin-film devices. They can be designed to function as an edge filter or bandpass filter. In either case, wavelength selection is based on the property of destructive light interference. This is the same principle underlying the operation of a Fabry-Perot interferometer. Incident light is passed through two coated reflecting surfaces. The distance between the reflective coatings determines which wavelengths destructively interfere and which wavelengths are in phase and will ultimately pass through the coatings. If the reflected beams are in phase, the light is passed through two reflective surfaces. If, on the other hand, the multiple reflections are not in phase, destructive interference reduces the transmission of these wavelengths though the device to near zero. This principle strongly attenuates the transmitted intensity of light at wavelengths that are higher or lower than the wavelength of interest.

In an interference filter, the gap between the reflecting surfaces is a thin film of dielectric material called a spacer. It has a thickness of one-half wave at the desired peak transmission wavelength. On either side of this gap are the two reflecting layers. The reflecting layers actually consist of several film layers, each of which is a quarterwave thick. This sandwich of quarterwave layers is made up of an alternating pattern of high and low index material, usually zinc sulfide and cryolite, respectively. Together, the quarterwave coatings forming the reflective layer is called a stack. The combination of two stacks and the spacer comprise a one cavity bandpass filter. The number of layers in the stack is adjusted to tailor the width of the bandpass.

Typical Interference Filter



In practice, a single cavity bandpass filter does not exhibit a sharp transition between the passband and out-of-passband wavelengths. To sharpen this cutoff, it is common practice that several cavities are layered sequentially into a multicavity filter design. A multicavity design also dramatically reduces the transmission of out-of-band wavelengths. To complete the interference filter, another set of thin-film coatings are applied to the second substrate to block the transmission of wavelengths that are further away from the passband of interest. This blocking layer is essential in filters to prevent "shoot through" of undesired wavelengths from the illumination source to the detector. The blocking layers and passband layers are held together in a protective metal case using optical epoxy.

Interference filters are sensitive to temperature and tilt. Tilting the filter shifts the passband to the blue wing of the H-alpha line. When one observes in the core of the line, one is observing high in the chromosphere and sees maximum contrast of the prominences, filaments, plages and flares. When a filter is tuned off band to the red or blue wing, one sees lower into the chromosphere, and less H-alpha detail is visible. Doppler shifted features such as surges and active filaments will appear dark in the wings of the line. The farther an H-alpha feature is observed from the H-alpha core, the greater its radial velocity in the line of sight. The twisted, violent motions of active prominences become evident when viewed spectroscopically. Often one part is blue shifted and another is red-shifted, indicating helical motions. Sunspot umbrae are well seen in the core, but small umbrae are sometimes lost in the detail of the chromosphere. Penumbrae are visible, but the contrast is low. With a filter tuned about 1Å outside the core the Sun generally appears as it does in white light.

Because interference filters are sensitive to tilt, the light passing through them must be parallel or nearly so. If the light is not parallel a "sweet spot" of on-band filtering occurs surrounded by increasingly off-band transmittance. This is combated in several designs by operating at focal ratios of f/30 or greater in which the light is a nearly parallel beam or through the use of a collimating lens system between the objective and filter. A prefilter may also be required for protection from ultraviolet light and to provide a "cooler" beam to the interference filter. Narrow passband filters are often enclosed in a heated oven for precision tuning through temperature control.

Filter Terminology

Bandpass—The range (or band) of wavelengths passed by a wavelength-selective optic.

Bandpass Interference Filter—An interference filter designed to transmit a specific band of wavelengths.

Blocking—The degree of light attenuation at wavelengths outside the passband of the filter.

Center Wavelength (CWL)—The wavelength at the midpoint of the half power bandwidth.

Energy Rejection Filter (ERF)—A filter that is placed over the telescope aperture for the purpose of reducing the heat load and absorbing UV light.

Etalon—Essentially an optical filter that operates by multiple-beam interference of light reflected and transmitted by a pair of parallel flat reflecting plates.

Filter Cavity—An optical "sandwich" of two partially reflective substrate layers separated by an evaporated coating which forms the dielectric spacer layer. Interference filters can be constructed with one or several cavities arranged in series.

Full-width Half-Maximum (FWHM)—The width of the bandpass, in nanometers, at one-half of the maximum transmission.

Interference Filter—An optical filter consisting of multiple layers of evaporated coatings on a substrate, whose spectral properties are the result of wavelength interference rather than absorption.

Oven—An electrically controlled device for regulating the operating temperature of a filter.

Peak Transmission—The maximum percentage transmission within the passband.

Telecentric Lens—A supplementary lens intended to create parallel light rays from the converging light rays of the primary optic.

Chromospheric Features

Without a doubt, **solar prominences** are among the most beautiful and interesting objects to observe in the heavens. No other objects change size, shape, and brightness as do prominences. They are usually classified as *quiescent* (quiet) and *eruptive* (active), but all show activity and are evolving. Their lifetime can range from minutes to weeks.

The classification system by Menzel and Evans (see below) groups prominences according to whether they originate in the corona or the chromosphere, and if they are associated with sunspots. The names suggest the appearance of the prominence. **No one classification scheme can describe all the phenomena observed.**

As in the McIntosh sunspot system this is a three-letter designation classification. The first letter will designate the place of origin of the prominence, basically whether it is descending from the Corona or ascending from the Chromosphere. The second letter whether the prominence is related to a sunspot or not and the third letter is a description of the appearance of the prominence.

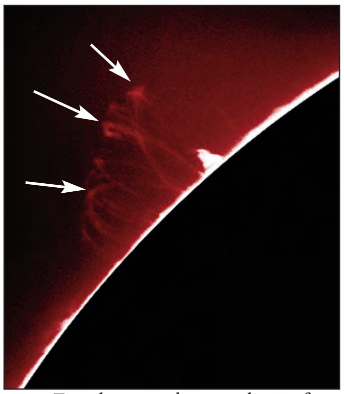
The delicate loops pictured on page 6 would be classed as **ASl**. They were

A—PROMINENCES ORIGINATING IN CORONA *(Descending)*

S-(Spot Prominences)		N-(Nonspot Prominences)	
a.	Rain	a.	Coronal rain
f.	Funnel	b.	Tree trunk
l.	Loop	c.	Tree
		d.	Hedgerow
		f.	Suspended cloud
		m.	Mound

B—PROMINENCES ORIGINATING IN CHROMOSPHERE *(Ascending)*

S-(Spot Prominences)		N-(Nonspot Prominences)	
s.	Surge	s.	Spicule
p.	Puff		



Fine loops and coronal rain from 2015UT on April 1, 2001.

originating from above so as to be descending (see arrows), hence the "A" classification. There is a spot just coming around the limb with which these prominences were associated, therefore an "S" for the second letter. Being in the form of loops the third letter is to be "l". The bright surge just to the north (right) of the loops would be classified as **BSs.**

Prominences are identical to the dark **filaments** seen on the solar disk. At the limb, they are viewed as bright emission features against a dark sky. On the disk, they are seen as dark absorption features against the bright surface of the Sun. Filaments vary greatly in length and may extend for more than a solar diameter. They have complex structures made up of numerous strands of gas, normally in a vertical pattern.

Gas condenses out of the much hotter corona at the top of the prominence and filters down to the chromosphere below. Matter must be continuously replaced to maintain the feature. Near the surface, arch-like structures may dominate giving the appearance of feet anchored in the chromosphere. On the disk, long filaments frequently display a smooth side and a scalloped side. The feet mark the location of a *neutral line*, or position where the polarity of the longitudinal magnetic field reverses. The filaments are supported by magnetic fields and are insulated from the much hotter, but rarefied corona.

When a filament is formed near an active region it may have a considerable extension in latitude. Due to differential rotation it will become more inclined and gradually migrate to the poles. One filament/prominence zone is about 10° poleward of the sunspot zones. It follows the migration of sunspots toward the equator during the 11-year solar cycle. Filaments and prominences migrating to the poles form a second zone, which may form a "polar crown" of filaments on occasion. The fact that filaments are observed at all latitudes enables astronomers to map large scale magnetic fields which supplement magnetograms.

Filaments are intimately related to active region evolution and respond violently to solar flares and other magnetic disturbances. Some are observed to fade and gradually disappear. Filaments associated with active regions are often seen breaking up and flowing into sunspot groups. Apparently the magnetic field perpendicular to the filament axis can no longer support it and the field parallel to the axis dominant.

Filaments are observed which suddenly become active without warning and are erupted into the corona. As prominences their appearance is as a giant arch. The gas follows a helical path around the filament axis and is connected to the chromosphere at both ends. The great eruptive prominence of June, 1946, which was followed out to 1.22 solar diameters, was a filament near the south pole of the Sun. Disappearing filaments are a major cause of coronal transients and geomagnetic effects. It is common for a filament to reappear hours or days after its disappearance. The intensity of filaments varies from faint gray to black.

Most eruptive prominences are confined to the latitudes of the sunspot zones. Their frequency follows the 11-year sunspot cycle well. As with quiescent prominences, the descent of gas to the chromosphere is common in active regions. A loop prominence begins with a small spherical cloud condensing out of the corona above a sunspot group. It becomes elongated and breaks up to form streamers forming both sides of the loop. Loop prominences have complex and delicate structures and are used to map magnetic fields above sunspot groups. A giant loop display is particularly impressive as it may consist of as many as twenty separate loops and evolve over several hours. Active loops are only associated with groups that are good flare producers and have strong magnetic fields. As observed at the limb, major flares often produce a tight system of loops which grow rapidly. In less active groups faint, single streamers and knots of gas flow into active regions. This **coronal rain** is related to quiescent prominence activity.

Eruptive prominences have a variety of shapes and sizes. Their lifetime are typically less than 30 minutes. **Surges**, **puffs**, and **sprays** are closely associated with solar flares and centers of high activity. A surge is normally a post-flare phenomenon. Many relatively small flares are followed by an eruption. Observed on the disk, surges appear as dark, elongated features which grow radially from a bright flare. Since they are moving rapidly towards the observer, they will appear blue shifted and are best observed in the "blue wing" of the H-alpha line.

At the limb, surges may appear as bright spikes, or jets which grow rapidly only to fade away, or fall back into the chromosphere. Large eruptions begin as bright knots of gas which quickly expand and fragment into complex forms called sprays. It is believed that eruptive prominences carry the chromospheric magnetic field with them. They can reach distances of several hundred thousand km from the limb. Observers should watch out for bright knots in the chromosphere that appear suddenly. Also, observers should not confuse prominence eruptions with solar flares. Flares are more static and are normally confined to the chromosphere in H-alpha. Flare rich active regions need to be monitored in the blue wing of H-alpha for doppler shifted surges and sprays.

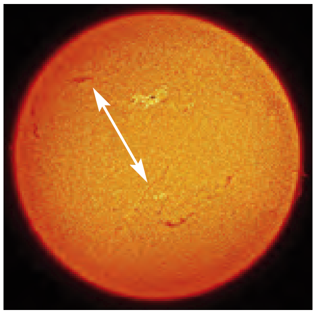
Solar Flares

The chromosphere near active regions is an area of enhanced temperature and brightness. Known as **plages**, these emission features have strong vertical fields up to 800 Gauss. Chromospheric plage is related to faculae in the photosphere. Hot coronal condensations are observed over plages. Small, oval plage are often seen in developing active regions before sunspots appear. Young plage is generally brighter and is associated with "arch filaments". As a sunspot group matures the plage between the preceding and following spots of a bipolar group, becomes divided by a **plage corridor**. The corridor coincides with the neutral line— the line that separates longitudinal magnetic fields of opposite polarity— where strong magnetic field occurs. Young compact groups with strong fields have thin, dark corridors. As groups decay, corridors become diffuse and disappear. Plages become fainter, fragmented and usually outline sunspots. In the K-line of Calcium, plage appears more extensive and brighter than in H-alpha. However, filaments and other absorption features are not as well seen.

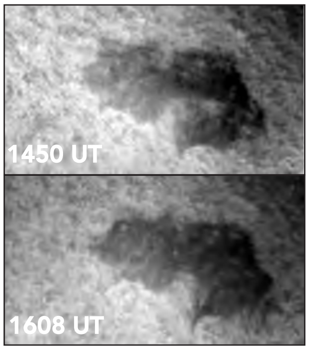
Of all the varied solar phenomena, solar flares are the most violent and interesting. A flare is a sudden release of energy stored in the magnetic fields of active regions and then released in the form of electromagnetic radiation and atomic particles. Radiation from flares covers the entire spectrum from x-rays to radio waves. The radiations at the ends of the spectrum fluctuate the greatest. We must, however, limit ourselves to the morphology of flares as observed in the visual spectrum in the chromosphere.

A solar flare is a brightening of an existing plage region. Intensity of flares increases rapidly, but takes longer to fade to the pre-flare brightness. The time to maximum intensity of a flare may be a few minutes or even an hour. Most large, bright flares have a *flash phase* when a rapid expansion and brightening occurs.

Solar flares have been classified according to area since the development of the spectrohelioscope. The classification system used by the NOAA is as follows



Prominences seen against the solar disk (filaments) are seen in this February, 2003 image by Hong Kong amateur astronomer, Vincent Chan.



The changing appearance of this filament is evident in these two images obtained 05 August, 2001. Gordon Garcia used a .3Å H-alpha filter on an APO with an effective aperture of 150mm.

and ranges from S, called subflares, to the largest, called Importance 4. The addition of the sub-codes of F, N, or B are indicators of brightness (faint, normal, or bright). Examples: **Importance 1B, Importance 3N** and so on.

Flares are often measured in millionths of a solar hemisphere, which is 0.02 square degrees or 6.0 square seconds of arc. One second of arc on the Sun is equal to approximately 450 miles (730 km). Due to foreshortening, flares near the limb are difficult to classify.

Twelve Items Concerning Flare Production and Morphology

1. Solar Flares occur close to the neutral lines in active regions.
2. Flares tend to occur near the same location within a sunspot group.
3. Large flares are preceded by smaller flares and brightening of plages.
4. Smaller flares appear as one or more bright points of emission near spots on either side of the neutral line.
5. Large flares form parallel ribbons of emission on both sides of a neutral line and often touch sunspots.
6. When new sunspots grow and interact with older regions, flare production increases.
7. More flares are observed during the growth phase of sunspot groups, when fields are rapidly changing, than during the decay phase.
8. Most flares are produced by type E and F in the Zurich sunspot classification.
9. Flare production is higher in magnetically complex groups with a twisted neutral line. Simple bipolar and unipolar groups may not produce a single flare.
10. Sunspot groups which are compact and have spots of opposite polarity within one large irregular penumbra have the highest flare potential. Such groups are classed as Delta. Due to rotation of close spots such groups may violate Hale's Law of sunspot polarity.
11. Zones of higher flare activity can last for several rotations, or even years.
12. Major flares are most frequent two years after sunspot maximum of the 11-year cycle.

Emergence of magnetic flux and sunspot motions appear to trigger flares. Before a large flare a sheared neutral line with high magnetic gradients is observed. Fibrils run parallel to the line. The filament on the neutral line is destroyed during the flare and becomes a flare spray. Several emission points brighten simultaneously along the line. The flare strand may split to form a Y-shaped flare. The impulsive flare is associated with bright hot kernels close to the neutral line. Flare kernels are related to the Helium D3 line flare

Optical Flare Importance Classification

Code	Area-sqr. degrees	Lifetime	X-ray Class
S	2.0 or less	< 4 min.	C2
1	2.1 - 5.1	4 - 43 min.	M3
2	5.2 - 12.4	10 - 90 min.	X1
3	12.5 - 24.7	20 - 155 min.	X5
4	> 24.7	.9 - 7.2 hr.	X9

Subcodes : F = faint N = normal B = bright and white light flares in the photosphere. Major flares that split into two ribbons often form an arcade of dark or bright loops between the strands. The separation of the ribbons coincides with the white light flare, X-ray and microwave bursts in addition to the acceleration of particles. After the flare transition, arches (fibrils) are seen crossing the neutral line indicating a relaxed field.

H-alpha gives us only one picture of a solar flare. The D3 helium line shows only the intense kernels lower in the chromosphere. The H-alpha wing gives a similar appearance. UV and X-ray photographs from space show a much larger flare which begins in the corona. The hot X-ray cloud is the source of particles (electrons) that penetrate into the chromosphere to form the H-alpha thermal flare. Only large flares produce energetic particles that penetrate to the photosphere. Flares as studied in the X-ray, microwave, etc. are important to the understanding of flares, but are not within the scope of the Solar Section.

There is a type of flare not directly associated with sunspots, called a **Hyder flare**. It is also known as a **"DB"** *or* **Disparition Brusque**. This flare is caused by a disappearing filament. These flares are usually large and long lasting, but are not as energetic as spot flares. DB flares are associated with old decaying plages.

Possibly the most interesting, but also difficult to observe flare related phenomenon is the **Moreton Wave**. It is a shock wave created by the explosive phase and travels rapidly across the Sun. The wave is bright in the H-alpha core, but dark in the wings of the line. It induces a damped vertical oscillatory motion to features. Filaments will appear to "wink" in and out of view, due to doppler shifting through the narrow passband of filters. Flare induced shock waves travel through the solar system.

It is particularly exciting to see an area the size as the distance between the Earth and Moon flare up before your eyes! Large flares are quite a spectacle. Around sunspot maximum there are many times when more than one flare and/or eruptive prominence are occurring simultaneously. There is always great anticipation when setting up your equipment, knowing there is a large group visible. It is possible to predict the location of flares with good accuracy by studying active region morphology. Active regions may become active or quiet without warning.

Chromospheric Background

The chromosphere, at the solar limb, was described as early as 1875 by Secchi. He likened its appearance to that of a "prairie fire". The name chromosphere or "color sphere" is from N. Lockyer. It is seen as a bright rose colored ring just before and after totality of a solar eclipse. The chromosphere is a thin, inhomogeneous layer of gas above the photosphere. It is only about 4,500 km in width. This layer appears to be composed of numerous jets of gas called **spicules**. The average spicule is 1,000 km in diameter and from 6,000 to 10,000 km in length. A spicule rises out of the chromosphere, then falls back or fades in about 5 to 10 minutes. Most are vertical but inclinations of 20° are observed at times. Spicules are generally larger at the Sun's poles and may vary with the sunspot cycle.

Viewed in the core of the H-alpha line, the solar disc shows a large scale **granulation network**. The individual cells average 30,000 km (40 seconds of arc) in diameter and have a lifetime of about one day. This supergranulation is easier to observe than the 1-2 arc second photospheric granulation. The center of a cell is brighter showing faint mottling in smaller telescopes. At the boundary of a cell dark hair-like features are observed. These absorption features on the disk are identical to the spicules seen in bright emission on the limb.

Rosettes, chains, and brushes are names of patterns that spicules assume on the disk. **Rosettes** are groups of spicules that radiate out of a common center. **Chains** are rows of spicules. **Brushes** are groups of spicules observed near the limb that give the Sun a "hairy" appearance. These patterns are best seen in the wings of the line. Enhanced magnetic fields are found in the supergranual boundaries. In the K-line of Calcium, the chromospheric network is well seen, but the cells are dark and the boundaries are bright. Indeed, in high resolution H-alpha photographs bright points are found at the bases of spicules indicating enhanced temperature.

Near active regions spicules become inclined and enlarged due to the influence of magnetic fields. Known as **fibrils**, these features follow the transverse magnetic fields parallel to the solar surface. They are typically 11,000 km long and 725-2,200 km wide. Fibrils connect regions of opposite polarity and give the chromosphere a complex appearance near active regions. In bipolar groups fibrils give the appearance of iron filings in a magnetic field. They align themselves radially from large sunspots forming an extension of the penumbra, called the **superpenumbra**. They extend out to a distance of about a spot diameter. In large groups a much larger area of nearly radial fibrils are observed which may cover 10% of the visible disk, called the **solar vortex**. A special type of fibril which is observed when an active region is growing is the **arch filament**. Arches are dark, thick features that are observed in young plage. Fibrils and arch filaments are low lying features and are not well observed at the limb. An arch filament system may last three days, but individual filaments only last 10-30 minutes. The neutral line usually bisects an arch filament system. After a sunspot group matures the arch filaments are replaced by fainter field transition arches.

The fibrils near quiescent filaments align themselves by a small angle to the axis of the filament. In the blue wing of H-alpha, featureless bands are often observed where filaments exist. These **filament channels** are observed before a filament forms and remains visible after it disappears.

Moustaches, also called *Ellerman Bombs*, are small bright points that are three seconds of arc or less in diameter. They are best seen in the wings of the line and occur near sunspots. Similar features are found at the bases of spicules and active filaments. Ellerman Bombs may last from a few minutes to several hours and are not generally related to flares.

A great deal of solar detail is visible at the resolution of 1 second of arc, much more than the observer can draw reliably. A 6-inch (15 cm) aperture can resolve to one second of arc in good seeing and a 4-inch (10 cm) will show the chromospheric fine structures well. Smaller apertures can be used effectively on more days than larger ones due to atmospheric seeing limitations. Since the major features are 5 seconds of arc or greater, a large telescope is not required to observe these.

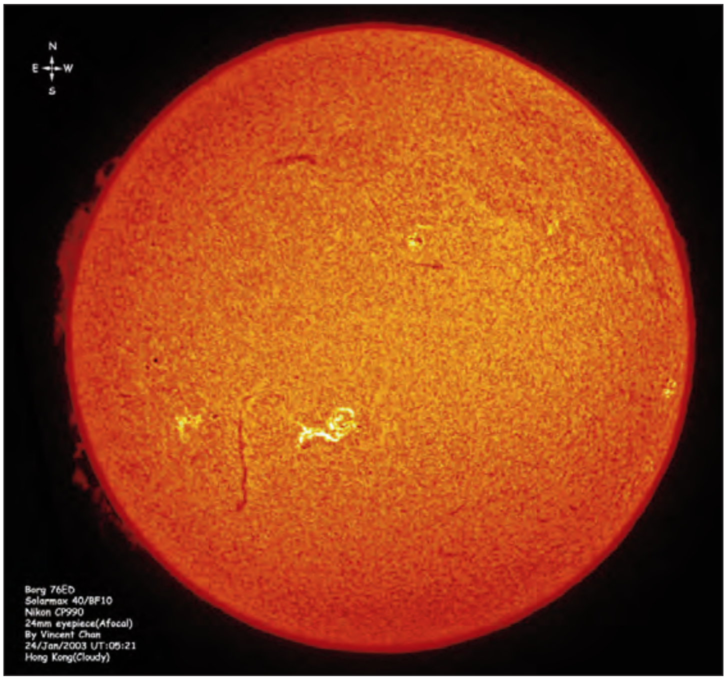
Observing Hints

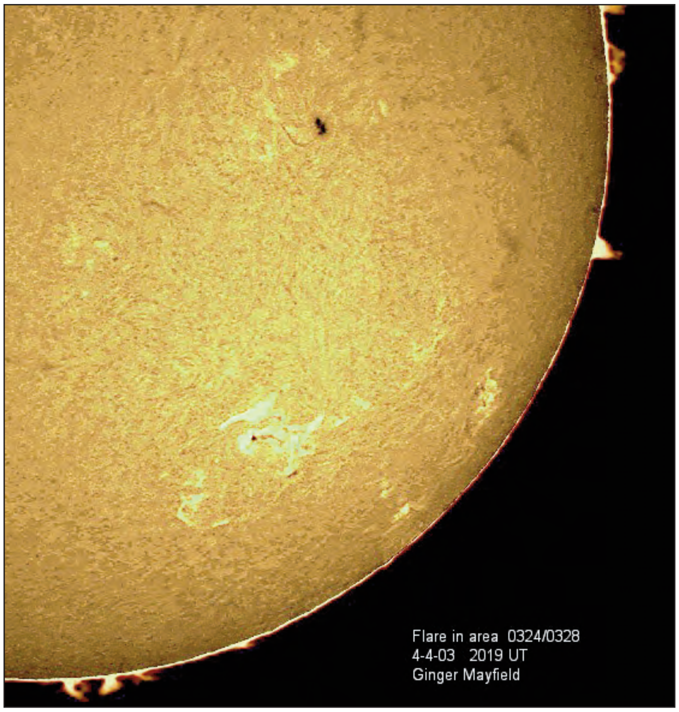
The best choice of telescope to use for solar observing in general, and for monochromatic observing in particular, is a refractor. A Newtonian telescope is not recommended for monochromatic work. On average they have shorter focal lengths, central obstructions, and the access to the focal plane outside the tube (focus travel) ordinarily limits the use of filters and camera attachments. Complete solar telescopes are marketed today which are excellent instruments for monochromatic observing. They come in a variety of apertures and price ranges suited for many amateurs from the novice to the veteran observer.

A prominence telescope or filtering device which uses an occulting disk will necessitate a good driving mechanism for both axles of the equatorial mount. If a heliostat or coelostat is used to feed a stationary telescope, slewing controls will be needed.

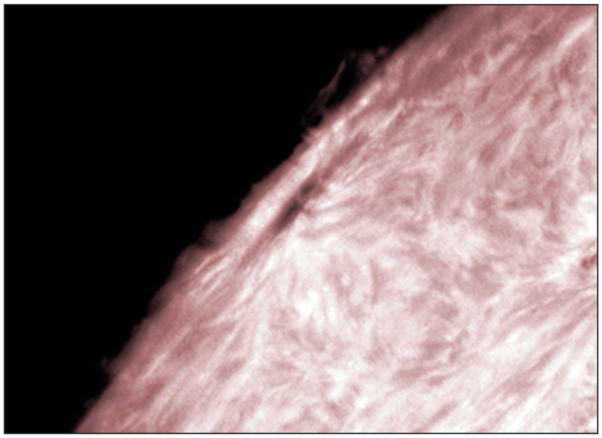
Seeing condition information as discussed in the white light edition of this handbook will apply also here. Domes, while fine for windy mountain tops, contribute to poor local seeing and are best avoided. An open air situation with minimal heat traps (such as surrounding buildings, asphalt or concrete drives) is better. Observatories with a roll-off or split roof are preferred. Study your local weather patterns and learn when the seeing is good and be prepared to observe at those times. Often morning is good before local heating destroys seeing. Watch high pressure areas and cold fronts, then note how they affect your seeing conditions. Sky transparency is important when observing limb phenomena. Hazy skies with a lot of scatter reduce the contrast of prominences making them increasingly difficult to observe.

Observers should try using an eye shield or head cover to eliminate scattered sunlight at the eyepiece. The monochromatic view is usually fainter than a white light, and a shield will help adapt the eye to seeing fainter detail.

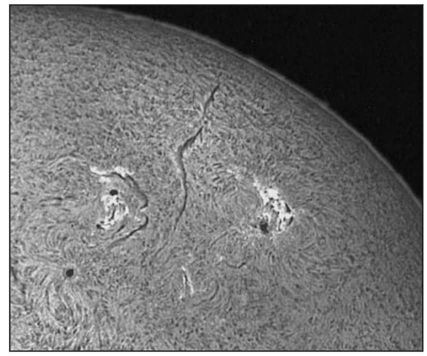




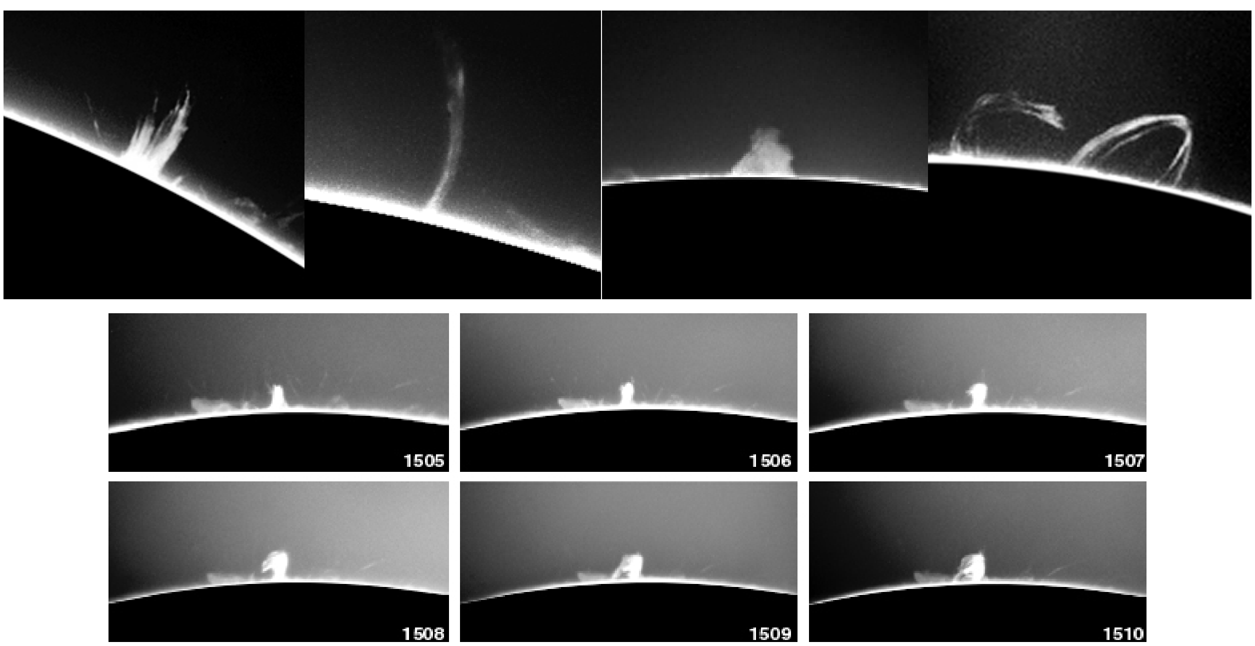
*These samples illustrate the various means our observers have chosen to place the technical infomation within their images. What is important is that the questions **what, when, who,** and **how** are addressed. We cannot stress enough the attention needed to include this information with all observations submitted. Refer to the photography form for requested information.*



Fine detail of the gas suspended above the solar limb in this Gordon Garcia image from 14 May, 2000.



Flares and filamentary detail near a sunspot group on 18 August, 2001. Image by Vic and Jen Winter with a .4Å H-alpha filter on a 4.75" singlet red glass lens operating at f/30.



The upper four images illustrate several forms of limb activity. The three on the left are surge prominences of the spray, jet, and mound variety. A classic loop system is on the right. The lower grouping was obtained 22 August, 2001 during Rotation 1979 depicting the rapid development of a surge at 60 second intervals beginning at 1505 UT. J. Jenkins observed with a 125mm f/18 refractor and a 10Å H-alpha filter.

Suggested Reading List

(Ed.note—while no list can be complete because it will be out of date yearly as new books are published, this listing will satisfy most readers and supply sources to answer many questions not addressed in this Handbook.)

Books of Primarily Historical Interest

Abbot, C.G., **THE SUN**, D. Appleton & Co., NY, 1912
Abetti, G., **THE SUN**, Macmillan Co., NY, 1961
Abetti, G., **SOLAR RESEARCH**, Macmillan Co., NY 1963
Baxter, W.M., **THE SUN AND THE AMATEUR ASTRONOMER**, Drake Publ. Inc., NY, 1973
Ellison, M.A., **THE SUN AND ITS INFLUENCE**, Macmillan Co., NY, 1955
Kuiper, G.P., editor, **THE SUN**, University of Chicago Press, Chicago, 1953
Meadows, A., **EARLY SOLAR PHYSICS**, Pergamon Press, 1970
Menzel, D.H., **OUR SUN**, Harvard University Press, Cambridge, MA, 1959
Mitchell, S.A., **ECLIPSES OF THE SUN**, Columbia University Press, NY, 1935
Moore, P., **THE SUN**, Norton, NY, 1968
Newton, H.W., **THE FACE OF THE SUN**, Penguin Books, London, 1958
Pepin, R.O., **THE ANCIENT SUN**, Pergamon Press, NY, 1979
Proctor, M., **ROMANCE OF THE SUN**, Harper & Bros. Publishing, NY, 1927
Stetson, H.T., **SUNSPOTS IN ACTION**, Ronald Press, NY, 1947
Thackery, A.D., **ASTRONOMICAL SPECTROSCOPY**, Macmillan, NY, 1961
Young, C.A., **THE SUN**, D. Appelton & Co., NY, 1898
Zurin, H., **THE SOLAR ATMOSPHERE**, Blaisdell Publishing, Waltham, MA, 1966

General Interest Reading

Giovanelli, R.G., **SECRETS OF THE SUN**, Cambridge University Press, NY, 1984
Lang, K.R., **THE CAMBRIDGE ENCYCLOPEDIA OF THE SUN**, Cambridge University Press, NY, 2001
McKinnon, J.A., **SUNSPOT NUMBERS: 1610-1985**, World Data Center, Boulder, CO, 1987
Nicholson, I., **THE SUN**, Rand McNally, NY, 1982
Noyes, R.W., **THE SUN, OUR STAR**, Harvard University Press, Cambridge, MA, 1982
Pasachoff, J.M., **THE COMPLETE IDIOT'S GUIDE TO THE SUN**, Alpha, NY, 2003
Waldmeir, M., **THE SUNSPOT ACTIVITY IN THE YEARS 1610-1960**, Zurich, 1961

Novice/Intermediate/Advanced Reading

Beck, R., **SOLAR ASTRONOMY HANDBOOK**, Willman-Bell, Richmond, VA, 1988
Bray, R.J./Loughhead, R.E., **SUNSPOTS**, Dover, NY, 1964
Bray, R.J./Loughhead, R.E., **THE SOLAR CHROMOSPHERE**, Dover, NY, 1974
Bray, R.J./Loughhead, R.E., **THE SOLAR GRANULATION**, Chapman & Hall, London, 1967
Brody, J., **THE ENIGMA OF SUNSPOTS**, Floris Books, Edinburgh, Scotland, 2002
Cram,L.E./Thomas, J.H., **THE PHYSICS OF SUNSPOTS**, Sacramento Peak, Sunspot, NM, 1981
Espenak, F., **FIFTY YEAR CANON OF SOLAR ECLIPSES 1986-2035**, NASA, Washington, D.C., 1987

<u>Novice/Intermediate/Advanced Reading *(cont.)*</u>

Foukal, P.V., **SOLAR ASTROPHYSICS**, Wiley & Sons, NY, 1990
Gibson, E.G., **THE QUIET SUN**, NASA, Washington, D.C., 1973
Henderson, S.T., **DAYLIGHT AND ITS SPECTRUM**, Halstead Press, NY, 1977
Jenkins, J.L., **THE SUN AND HOW TO OBSERVE IT**, Springer-Verlag, NY, 2009
Kippenhahn, R., **DISCOVERING THE SECRETS OF THE SUN**, Wiley & Sons,NY, 1994
Kitchin, C., **SOLAR OBSERVING TECHNIQUES**, Springer-Verlag, London, 2002
Kitchin, C., **OPTICAL ASTRONOMICAL SPECTROSCOPY**, IoP Press, 1995
Macdonald, L., **HOW TO OBSERVE THE SUN SAFELY**, Springer-Verlag, London, 2003
Neidig, D.F., **THE LOWER ATMOSPHERE OF SOLAR FLARES**, Sacramento Peak, Sunspot, NM, 1981
Phillips, K.J.H., **GUIDE TO THE SUN**, Cambridge University Press, NY, 1992
Sawyer, R.A., **EXPERIMENTAL SPECTROSCOPY**, Prentice-Hall, 1946 (Dover, 1963)
Spence, P., **SUN OBSERVER'S GUIDE**, Firefly Books, Richmond Hill, Ontario, 2004
Stix, M., **SUN**, Springer-Verlag, London, 1991
Strong, C.L., **THE AMATEUR SCIENTIST**, Simon & Schuster, NY, 1960
Sturrock, P.A., editor, **SOLAR FLARES**, Colorado Assoc. University Press, Boulder, CO, 1980
Sturrock, P.A., editor, **PHYSICS OF THE SUN**, D. Reidel Publishing, Dordrecht, 1986
Svestka, Z., **SOLAR FLARES**, D. Reidel Publishing, Dordrecht, 1976
Tandberg-Hanssen, E., **SOLAR PROMINENCES**, D. Reidel, 1974
Taylor, P., **OBSERVING THE SUN**, Cambridge University Press, NY, 1991
Taylor, P./Hendrickson, N., **BEGINNER'S GUIDE TO THE SUN**, Kalmbach Books, WI, 1995
Veio, F., **THE SUN IN H-ALPHA LIGHT WITH A SPECTROHELIOSCOPE**, Veio, 1991
White, O., **THE SOLAR OUTPUT AND ITS VARIATION**, Colorado University Press, Boulder, Co, 1977
Xanthankis, J.N., **SOLAR PHYSICS**, Wiley & Sons, NY, 1968
Zurin, H., **ASTROPHYSICS OF THE SUN**, Cambridge University Press, NY, 1968