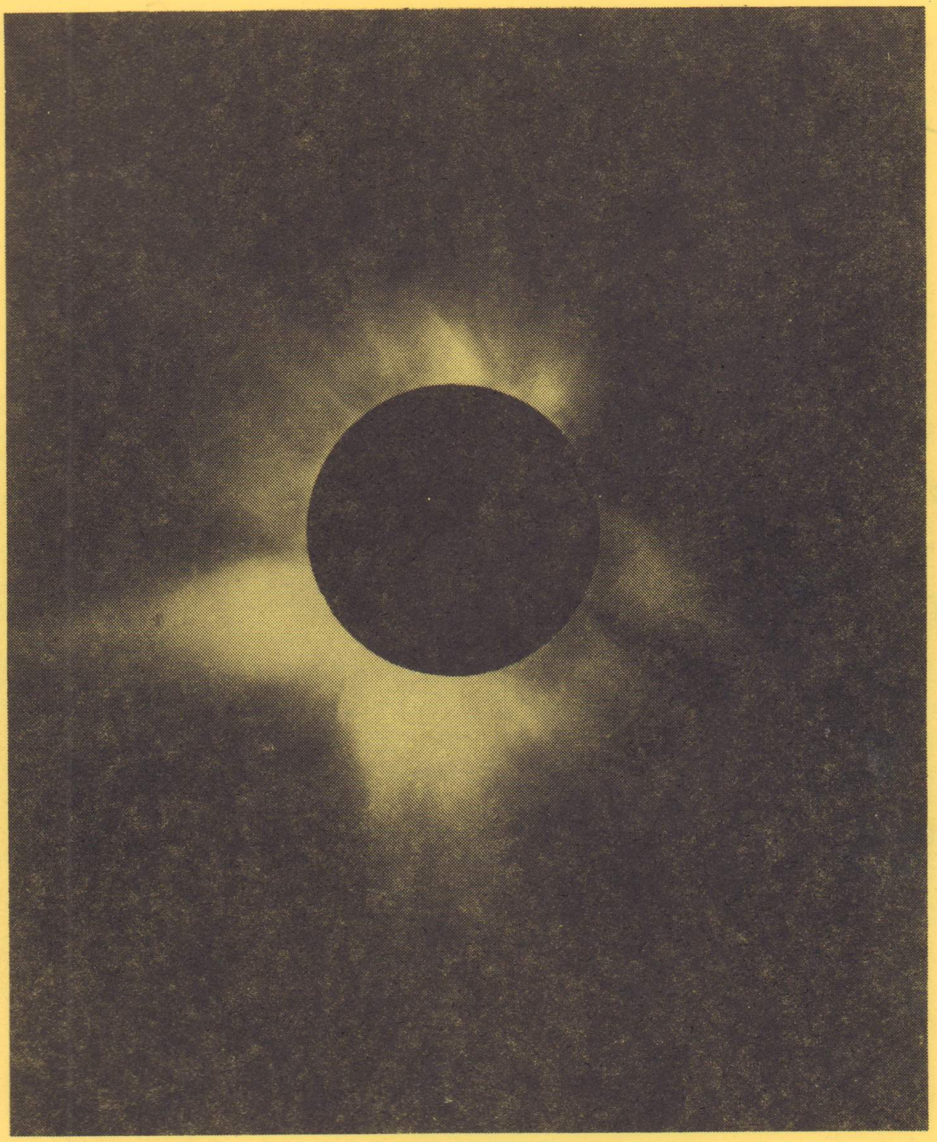
THE NEW OBSERVE



SOLAR ECLIPSE OF MARCH 7, 1970

and Understand the Sun

THE NEW
OBSERVE

A Program for Observing and Photographing the Sun

EDITED BY

Richard E. Hill

Recorder - A.L.P.O. Solar Section

Resident Observer
Warner & Swasey Obs.- Kitt Peak Station

COVER PHOTO - - The solar corona photographed by Gordon Newkirk, Jr. through a radially symmetric neutral density filter about 30 seconds after second contact during the eclipse of March 7, 1970 about 30 miles southwest of San Carlos Yautepec, Mexico. *Courtesy of High Altitude Observatory, National Center for Atmospheric Research. NCAR is sponsored by the National Science Foundation.*

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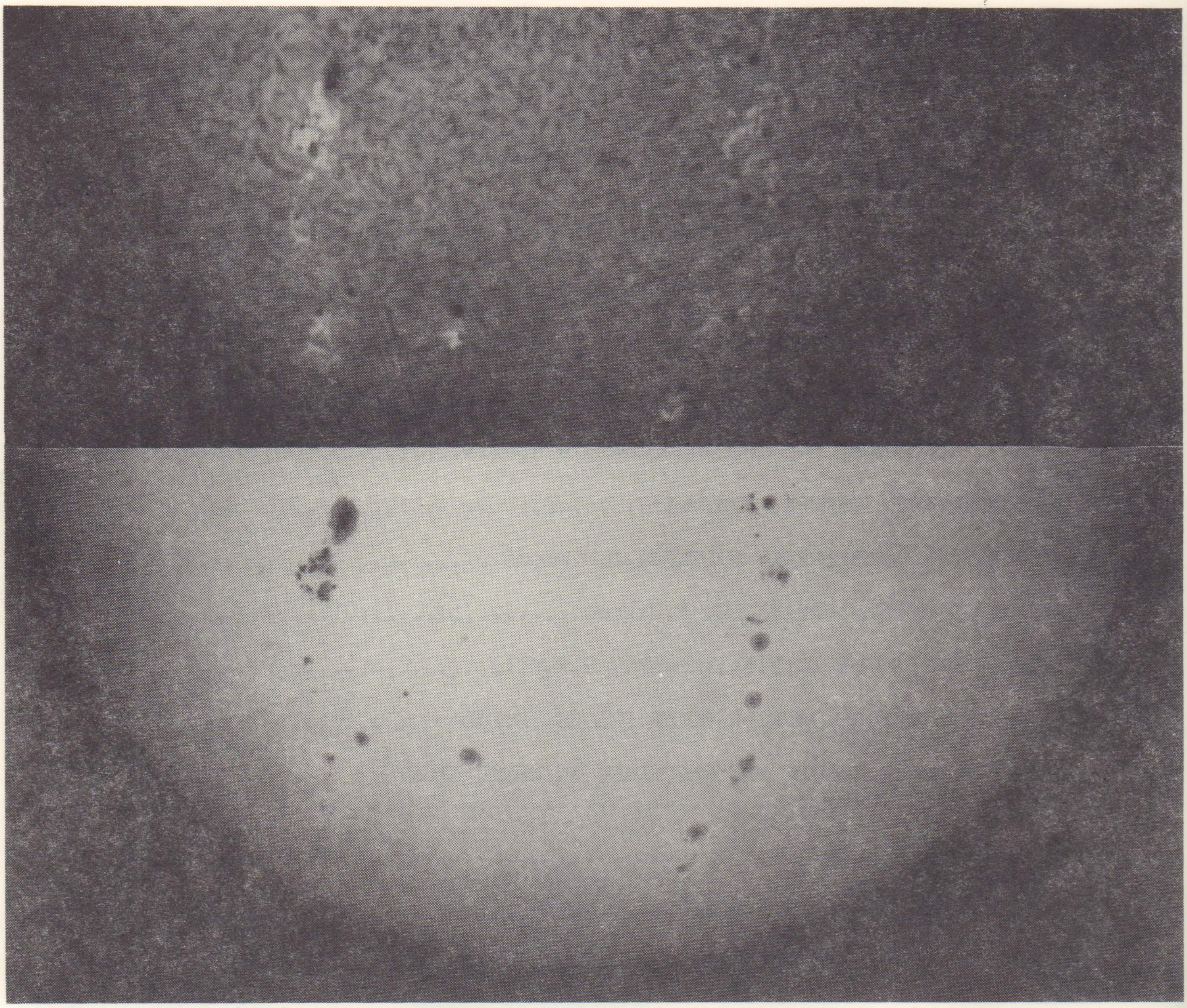
C O N T E N T S



The sun in white light, and the light of hydrogen taken at 1359 and 1556 UT on June 24, 1989, by A.L.P.O. Solar Section observer, Gordon Garcia.

OBSERVE AND UNDERSTAND THE SUN

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W A R N I N G

Observing the sun is the only inherently dangerous observing an amateur astronomer can do. Be aware of this at all times and take all necessary precautions. If you do not know a filter or procedure is safe then do not use it! Always err on the side of safety. An eye once damaged is forever damaged. Filters that let too much INFRARED light through can burn an eye if used visually. There is NO PAIN when this happens. Burned retinas cannot be repaired. Excessive ULTRAVIOLET light has been shown to cause cataracts. So be very careful.

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INTRODUCTION

There is no more dynamic an object in the solar system than the Sun. It can completely change its appearance in a matter of hours or emit more energy in one flare, lasting only a few minutes, than man has used throughout recorded history! Sunspots, far larger than the earth, are born and decay at times with amazing rapidity requiring hourly observation. Complex sunspot groups display violent motions that at times plunge some spots completely through others. With such an exciting object available for observation, a real star only $8\frac{1}{2}$ light minutes away, it would be a shame not to see it.

The purpose of this work is to guide the amateur solar astronomer in safe solar observing techniques. While this can be dangerous, by exercising some reasonable caution you can enjoy hours of delightful observation watching a main sequence G2 dwarf star go through a small part of its life cycle. To encourage this the Astronomical League is instituting a new observing program, THE ASTRONOMICAL LEAGUE SUN SPOTTERS. Details of this can be found following the bibliography.

In this work there is no attempt to discuss current "cutting edge" research. With a science as dynamic as solar research such an attempt would simply cause the writings to be obsolete in a year. There is also little historical background incorporated in these articles as that has been covered much better than could be done here, in some of the works listed in the bibliography.

This work differs from the 1976 edition in many important respects.

First, there is expanded coverage of spectroscopic and monochromatic observing. Besides Frederick Veio's excellent article which was retained from the first edition, we now have an expanded article by Del Woods describing interference filters and how they work, an article by Ed Hirsch on how to use these devices to best advantage, a detailed account by Randy Tatum (A.L.P.O. Solar Section CoRecorder) on monochromatic observing, and a short introductory article on prisms and gratings.

Second, there is an excellent discussion on solar videography by Alex Panzer of the Ohio Spectrographic Service. The easy availability of video-cameras (especially CCD) has not yet become a force in amateur solar astronomy. There are a few that have dabbled with such observing during times of unusually high activity, but on the whole the work thus far has not been scientifically useful.

No observer has maintained a regular synoptic program of video patrolling incorporating accurate time signals. Panzer takes up these matters and shows how such observing might be structured.

Third, one of the most important programs the amateur solar astronomer can engage in is the patrolling and detailed observation of solar flares and pre-flare activity. In order to do this effectively you need to know which sunspot groups are guaranteed to produce flares in any given 24 hour period. A new sunspot group classification system that expands on the old Zurich system is presented. This new system has been instituted in most professional solar observatories and has proven to be of great benefit.

Fourth, the section on photography has been expanded and updated incorporating the 8 years of experience in this field by the A.L.P.O. Solar Section and the expert techniques of Larry Kalinowski, of Roseville, Mich. (author of the LFK Astrophoto Guide). Adding to this are a number of excellent photo and observing tips by long-time observer, Steve Edberg.

Fifth, a new article on the detailed construction of a telescope for solar observing replaces an old article that used parts no longer obtainable.

Sixth, the bibliography has been expanded, reflecting the growth of solar publications. Included in this is a section of historical references and another of professional references. These are designed to give the serious amateur a broader repertoire.

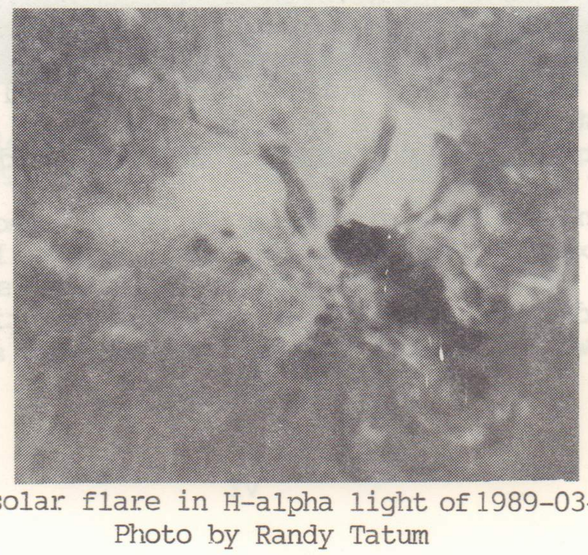
A seventh change is that product recommendations have been left out of this edition intentionally. Products, their quality, and manufacturers vary with time and to include them here would again only introduce rapid obsolescence. Readers interested in specific information about individual products could consult the Astronomical League.

Lastly, articles and most references on solar radio astronomy have been omitted. This observing is handled by the American Association of Variable Star Observers (AAVSO). Their work in this field is detailed in a book of their own published in 1991. To attempt to present that here would only result in mediocre redundancy.

In closing I wish to acknowledge the support and aid of the former Editors of this book: R.P.VanZandt, and J.Sherlin. Their guidance was instrumental in the quality and completion of this project. I am also very grateful to David Levy who recommended this author for the position of Editor of this book. Much thanks goes to Robert Miller, of Lansing, Mich., who prepared the Stonyhurst Disks for the A.L.P.O. Solar Section and allowed their use here. Lastly, I am grateful for the help of Edith Ochter who assisted in the preparation of Mr. Edberg's article.

Richard E. Hill

August, 1990
Tucson, Arizona



A 2B solar flare in H-alpha light of 1989-03-11
Photo by Randy Tatum

THE SUN IN WHITE LIGHT

by
Walter Scott Houston
Fredrick N. Veio
Walter C. Wheeler

Visual observation of the sun with proper filtering or by projection will show **sunspots** (see photograph on previous page) dark areas ranging in diameter from about one arc second to more than one minute. Sunspots may be individually isolated, or may occur in groups of varying complexity, numbering in some cases over 100. Sunspots appear as dark areas called **umbrae**, frequently surrounded by gray areas called **penumbrae.** An individual spot may persist less than half an hour, or for several months, with the largest spots lasting longest.

One hemisphere of the sun -either the eastern or western- characteristically shows a higher sunspot count than the other over a year's time producing a periodicity of about 28 days because the sun makes approximately one rotation in this length of time. There is, of course, the well known 11 year solar cycle. The increased count of one hemisphere over the other is often noted over a whole solar cycle as well as over a year's time.

PENUMBRAE frequently appear around individual sunspots, or complexes of spots, and are most pronounced around the largest spots. Penumbrae may also appear without any included spots. These are known as **penumbral fragments.**

PORES are extremely small (less than one arc second) dark areas without the dark black of a typical sunspot. Pores may, but do not always, develop into sunspots.

FILAMENTS may sometimes be seen (in H-alpha light of hydrogen) as fiber-like appearing gray lines, perhaps one arc second in width and a degree or more in length. The apparent orientation of the filaments is random.

FACULAE are relatively large (greater than one minute of arc in diameter), irregularly shaped, light areas, seen on any part of the solar disk. Sunspots are usually located inside faculae, frequently extending substantial distances beyond sunspot areas. These phenomena are frequently serpentine in appearance and, in the visible spectrum, are more easily seen close to the edge of the disk (limb) of the sun, because of "limb darkening" which provides greater apparent contrast when compared to the center of the sun's disk.

GRANULATION, a fine-grain structure of the photosphere, appears in "fair" to "good" seeing (quality of the earth's atmosphere) in telescopes of 50mm aperture or greater. Individual "grains" may appear to be one to two seconds of arc in diameter. In "poor" seeing , clumps of granules are seen as mottling.

METHODS OF SAFELY VIEWING THE SUN

The sun can be viewed <u>directly</u> in a telescope, provided the incoming light -including INFRARED and ULTRAVIOLET - is adequately reduced by an appropriate filter or filter combination. For considerations of SAFETY AND COMFORT to the human eye and also increased accuracy of count of sunspots, many experienced observers prefer to make their observations by the <u>projection</u> method.

Direct Observation. Several types of objective filters are safe for normal use, with precautions! [For white light direct observing only **PRE -TELESCOPE** filters should be used. Filters between the objective and eyepiece, or eyepiece cap filters should NEVER be used. Destroy any eyepiece filters so they do not wind up in the hands of the uninitiated. -Ed.] Filters used AHEAD of the objective are generally safest being less subject to heat stress breakage.

Welders Filters. Filters used in helmets by welders are supplied by a numerical system, with a particular number representing a known density. The larger the number, the greater the filter density Welders filters may be readily had through most welding supply houses. These filters are usually rectangular in shape' with dimensions of about 2 by 4 inches. The welders filters, as manufactured by American Optical Co., are plane parallel and optically flat to at least one forth wave in sodium light. Some welders supply houses offer such filters which have been cut into discs about 50mm diameter.

The Herschel Wedge is a shallow triangular piece of glass with optically flat surfaces. The divergence of the surfaces is on the order of only 3 degrees. Only a small fraction of the incident sunlight is reflected to the eye. Because of the divergence, only the light reflected from the forward surface is directed to the eyepiece. Light from the rear surface is reflected out of the eyepiece field, preventing double images. Some 95 to 97% of the incident light is passed through both surfaces, and also away from the eyepiece. The 3 to 5% of the light reflected into the eyepiece is still intense enough to require filtration! Based upon testing by R. Maag, it is recommended that a density equivalent to a welders filter #12, be used.

Mylar-type film filters are another recent addition to the list of the solar filters. These filters are an aluminum coated mylar film. The film is tough and can be cut to fit over any type of lens or open end of a reflector type telescope. These filters can be easily damaged, but are safe, so long as tears or holes do not develop in the film.

The transmission of these filters is toward the blue end of the spectrum, where the human eye is less sensitive and, therefore, fine details of the solar image may be lacking, unless the sky is very clear and transparent. When the sun is high in the sky, the sky appears blue because the atmosphere of the earth scatters the blue light from the sun in all directions. At dusk or dawn, with the sun below the horizon, clouds and atmospheric haze are viewed as red, orange and yellow, because only these longer wavelengths can get through the greater amount of atmosphere in the light path. The blue portion of the solar spectrum is both scattered and absorbed. The sharpness of the sun's image depends on the amount of scattering. Considerable scattering will produce a fuzzy blue image, but the image gets progressively sharper with the longer wavelengths which scatter less. Thus, the green is partially scattered, while the yellow, orange and red is largely unaffected and thus reveals a much sharper solar image and one with much finer detail to be seen.

Only in very good to excellent seeing, as well as transparency of the earth's atmosphere, will the image of the sun toward the bluer end of the spectrum not be lacking in detail. Since in most cases seeing and transparency are mostly average, it is best to observe the sun with a filter that presents a yellow to orange image. The human eye has its maximum sensitivity in this range of the visible spectrum. For photography of the sun in white light, it is always best to employ a yellow filter to absorb any of the blue range of the spectrum. [See Astronomical Journal, Vol.71, No.3, Apr., 1966, p.190 for an in depth discussion of this problem. - Ed.] This is a trick always employed by professional astronomers for both solar and lunar photography. In the latter case we must remember the light we see from the moon, reflected to our eyes, is actually sunlight!

We have no criticism of the mylar film filters except what we have just mentioned. We have used such filters with a variety of refractor as well as reflector telescopes and with a wide range of focal ratios. Qualitative tests, comparing such filters with yellow and orange filters, show that with the latter much greater detail (especially around active sunspots) can be seen. Contrast between the umbrae and penumbrae in such sunspots is definitely increased employing the yellow- orange filters. In several observing records made during the past year (1975) when the daily sunspot count has been low, very small sunspots would have been missed had we employed only a mylar film filter while searching the solar disk for such features. Switching to a yellow or orange filter made it possible to see, on several occasions, very minute sunspots that were entirely unobservable with the mylar film using the same telescope, same atmospheric conditions and the same magnifications.

PROJECTION METHOD

Because the daytime atmosphere is always unsteady to some extent, protracted periods of observation are required to catch a few moments of the best possible seeing. Many veteran solar observers, accordingly, favor the projection method of viewing the sun. Eyestrain is significantly less with projection than with direct, ocular observation. With proper technique, the hazard of eye damage is almost completely eliminated, while at the same time the entire visible disk of the sun can be monitored.

In the projection method the eyepiece is used to focus the sun's image upon a screen. If possible, the projection should be made into a darkened room or into a suitably constructed box. Under such conditions, the standard four inch aperture telescope can provide a 30 inch diameter projected image of the sun. Even this is still almost too bright for comfort. In a fixed installation, a rotating screen can enhance the image. The rotation blurs screen defects and ensures one can discriminate between these and minute solar image detail which is unaffected by the rotation.

A screen can be made of plywood or masonite, carefully painted, using several layers of paint and sanding between successive layers. A flat white paint of the type having an acrylic base is preferred and a remarkably smooth and enduring surface can be generated. The screen should, optimally, have a diameter 50 to 100% larger than the diameter of the desired projected image. The screen can be mounted upon a spindle and may be rotated by hand, but it is preferable to rotate it with a motor drive at 10 to 20 r.p.m.s. A phonographic record turntable motor and even the spindle from such a device is an excellent choice in rigging up a screen rotator. A tape recorder motor drive can also be used.

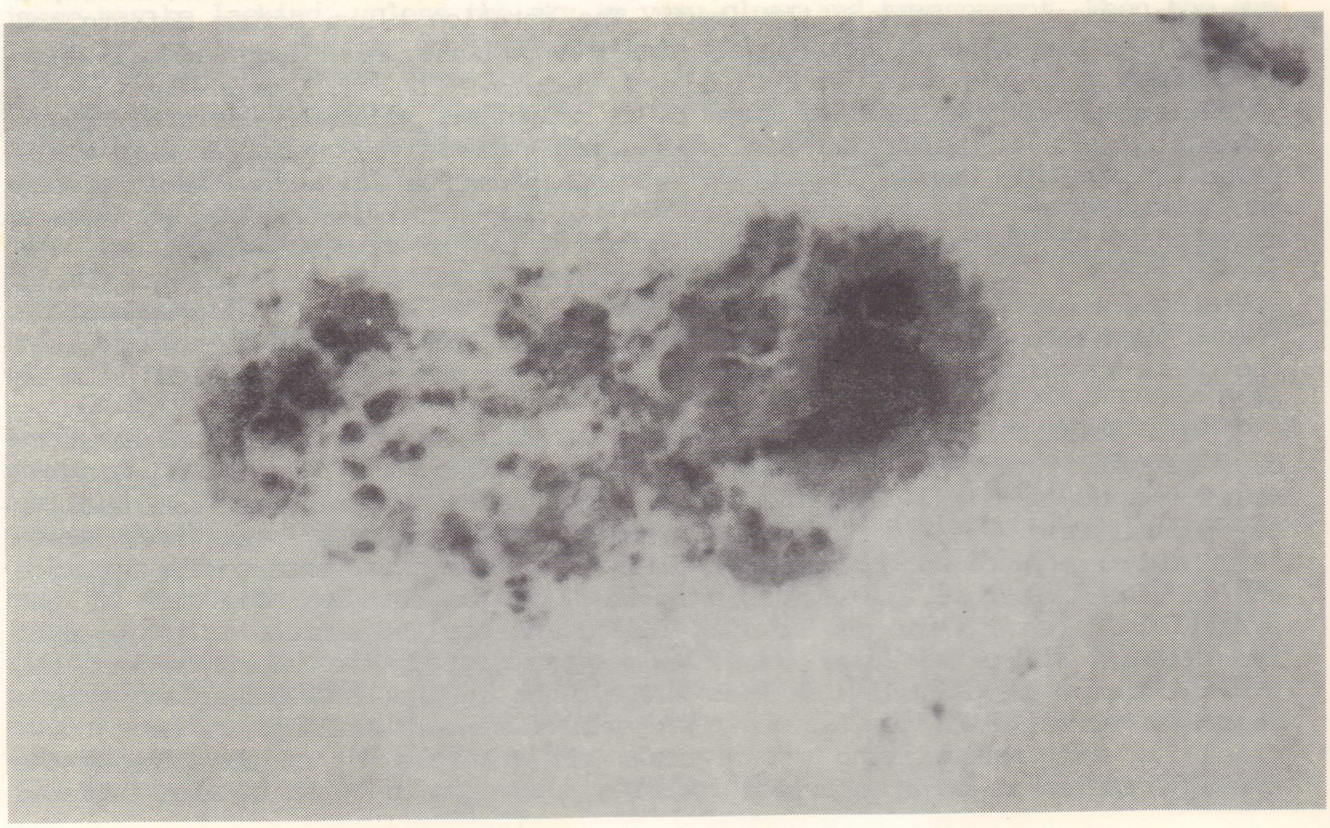
With small refractors or reflectors (the latter preferably of the Maksutov or Cassegrain design), a portable observing box of the "Hossfield Pyramid" design works very well in making white light solar observations. Essentially, the Hossiflield Pyramid consists of a truncated pyramid made from stiff cardboard or plywood and the smaller end of the pyramid fastened to the eyepiece end of the telescope. An access window should be cut into one side of the pyramid large enough for one to look inside and see the surface at the base of the pyramid, where the solar image would be projected. The inside base of the pyramid should be painted with flat white paint in the same manner as we have described above, with the rotating projection screen. Although we have never tried it, some enterprising person could cut a circle out of the base of the pyramid, fasten it to a motorized rotating device which could be also fastened to the outside of the pyramid surface, thus affording one a very effective rotating screen. The whole idea of the pyramid is to cut off stray light from the projected solar image to increase contrast.

THE WOLF SYSTEM OF SUNSPOT COUNT

Also known as the Wolf Number, R_i, is obtained by a daily count of each individual sunspot and adding to this 10 times the number of sunspot groups observed.

Counting sunspots is a matter of persistence and visual acuity. Training the eye to see small sunspots comes with daily practice! Casual observers will most often miss seeing small spots when a comparison is made with an experienced solar observer. The counting of groups of sunspots is more of an art than a science. Generally speaking, a group rarely extends over more than 5 degrees of latitude, and only occasionally over more than 20 degrees of longitude. In the case of two groups of sunspots, within the limits above, one can distinguish between a complex groups and simpler groups, by the presence of a chain of spots or streaks of penumbra between the major centers of activity. One may also assume, generally, that all spots contained with a single facula are members of a single sunspot group.

The sunspot number system is based upon visual observations. To maintain comparability between contemporary counts and data from the past, the system must be maintained. It would be a great loss if any new system were introduced which could not be fitted into existing records. The Wolf Number System, despite its faults, has proven (perhaps quite accidentally) to be an operational measure of several forms of solar activity.



A complex sunspot group of 1989 08 17, taken by J.Dragesco.

A THREE DIMENSIONAL SUNSPOT CLASSIFICATION SYSTEM

by
Richard E. Hill
Recorder-A.L.P.O. Solar Section

In 1938, M. Waldmeir devised what is now known as the Zurich Sunspot Classification of sunspot groups. [Waldmeier 1955] It consists of nine steps or classes (A through J, omitting I) that delineate the characteristic evolutionary stages of sunspot groups, though not all groups go through all classes. Most groups only go part way through the sequence and then either reverse their trend or skip ahead to one of the late classes. In general, the greater the area of a group the more asymmetrical will be its growth curve. A large group will tend to have an asymmetrical growth curve, rising rapidly from class A to E and then decaying more slowly as it goes from classes G to J. [Bray & Loughhead 1964]

It has been known for some time that groups of classes D, E, and F are the flare producing classes. But not all such groups produce flares. This was a problem for those whose job it is to predict flares. Even in the most active class, F, a forecaster had little chance of success in predicting flare probability in any 24 hour period on Zurich Class alone. A new system was needed that took in additional parameters.

Flares are the most energetic events in our solar system. They are eruptions that take place in and around sunspot groups that release large amounts of energy across most of the electromagnetic spectrum. Often they are accompanied by the ejection of subatomic particles at various speeds that may impact the earth's upper atmosphere. The electromagnetic emissions and subatomic particles can cause disruption of radio communications and aurorae. Typically, flares last from a few minutes to as much as four hours though the majority are from ten to twenty minutes in duration. The more energetic flares tend to be of longer duration especially when observed in x-rays. In white light and H-, the relationship is not quite as good. Flares are best seen in monochromatic light such as H-alpha or in the H & K lines of calcium light. Some are bright enough to where they can be seen even in the combined light of the whole visible spectrum, or white light.

But in order for flares to be observed and studied by the astronomer, a reliable system for classifying sunspot groups was needed. This was most true for the detection of white light flares. An observer would have to spend inordinate amounts of time at the telescope observing nearly every well developed sunspot group all the time in hopes of seeing these elusive events. It would be highly advantageous to be able, on the basis of a few parameters, to seed out many of the less productive groups.

In 1966, Patrick McIntosh of the Space Environment Services Center (SESC) at the National Oceanic and Atmospheric Administration (NOAA) introduced a system of sunspot classification that improved the older Zurich Classifications. The new classifications consist of three letters. The first is the **Modified Zurich Class.** It basically retains the old Zurich Classes but G and J were omitted due to morphologic redundancy in the redefinition. But the Modified Zurich Class was used rather than a new system so as to be an inducement for observers reluctant to switch to the new system. The second letter represents an assessment of the **Largest Spot** of the group. The third letter represents and assessment of the **Sunspot Distribution** within the group.

In order to understand the McIntosh Classification system further, two terms have to be defined: [McIntosh 1984]

Unipolar Group-

A single spot, or compact cluster of spots with the greatest separation between spots being less than 3 heliographic degrees. (All distances on the sun's surface will be expressed in heliographic degrees, or degrees on the surface of the sun and not on the sky.) With a Class H group the separation is taken to be the distance between the outer border of the main spot penumbra and the most distant attendant umbra.

Bipolar Group-

Two or more spots forming an elongated cluster with a length of 3 or more heliographic degrees. If there is a large principal spot then the cluster should be greater than 5 heliographic degrees in extent to be bipolar.

The illustrations accompanying this paper should be used with their descriptive texts for classifying sunspot groups.

The McIntosh Classification system has proven over the last 20 years, to be a more accurate predictor of solar flares. Indeed, it has helped solar astronomers understand better the relationship between solar flares and sunspots. Sunspot groups of the flare producing kind are not common. Because of this it has taken several solar cycles of observations to demonstrate the effectiveness of this new system.

Using the old Zurich Classifications it was found that groups of Class F were most likely to produce flares. But it was further found that only a 40% flare probability in a 24 hour period could be predicted on the basis of this parameter alone. With the new system, using just the Modified Zurich Class F, the probability was improved to 60%. Using just the Largest Spot class of "k" the probability in 24 hours was 40 to 50%. If just the Spot Distribution category of "c" were used the flare probability went up to about 70% in a given 24 hour period! But, when all three dimensions of this system were used in the classes of Fsi, Fki, and Fkc, all showed a probability of up to 100% for production of M Flares in a 24 hour period and the McIntosh class Fkc had a further probability of up to 50% in producing X Flares!! This surpasses any former method of flare prediction used including sunspot areas. [McIntosh 1984]

Observers of the A.L.P.O. Solar Section have been using the McIntosh Classification system for years now, especially those involved in the detection of white light flares. Those doing whole disk drawings are most strongly encouraged to do so. Of course, other standard procedures need to be followed as laid out in the Handbook for the Section. These procedures are designed to make the observations of the Section most closely match those being done at NOAA/SESC. Any amateur solar astronomer would benefit by using this system, and by trying to observe white light flares. The same groups that are most likely to produce flares also exhibit sudden changes (especially when flares occur) and rapid internal motions, on time scales of only minutes!

The McIntosh Sunspot Classification system has demonstrated its effectiveness as a tool in the search for solar flares and in understanding the build up storage, and dissipation of the energy in a flare. For the amateur astronomer it can be used as a guide when deciding which solar features deserve further study. Amateurs that want to make their observations of the most use to science should adopt this system as soon as possible. In this way the amateur astronomers can enjoy observing the ever changing solar features while still making a lasting and valuable contribution to science.

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McIntosh, P.S., [1984], "Flare Forecasting Based On Sunspot Classification", in Solar-Terrestrial Predictions: Proceedings of a Workshop at Meudon, France, June 18-22, 1984. Published by NOAA and Air Force Geophysics Laboratory.

Waldmeier, M., [1955] The SUNSPOT ACTIVITY IN THE YEARS 1610-1960, Zurich, Schulthess and Co.

CAPTIONS TO THE FIGURES

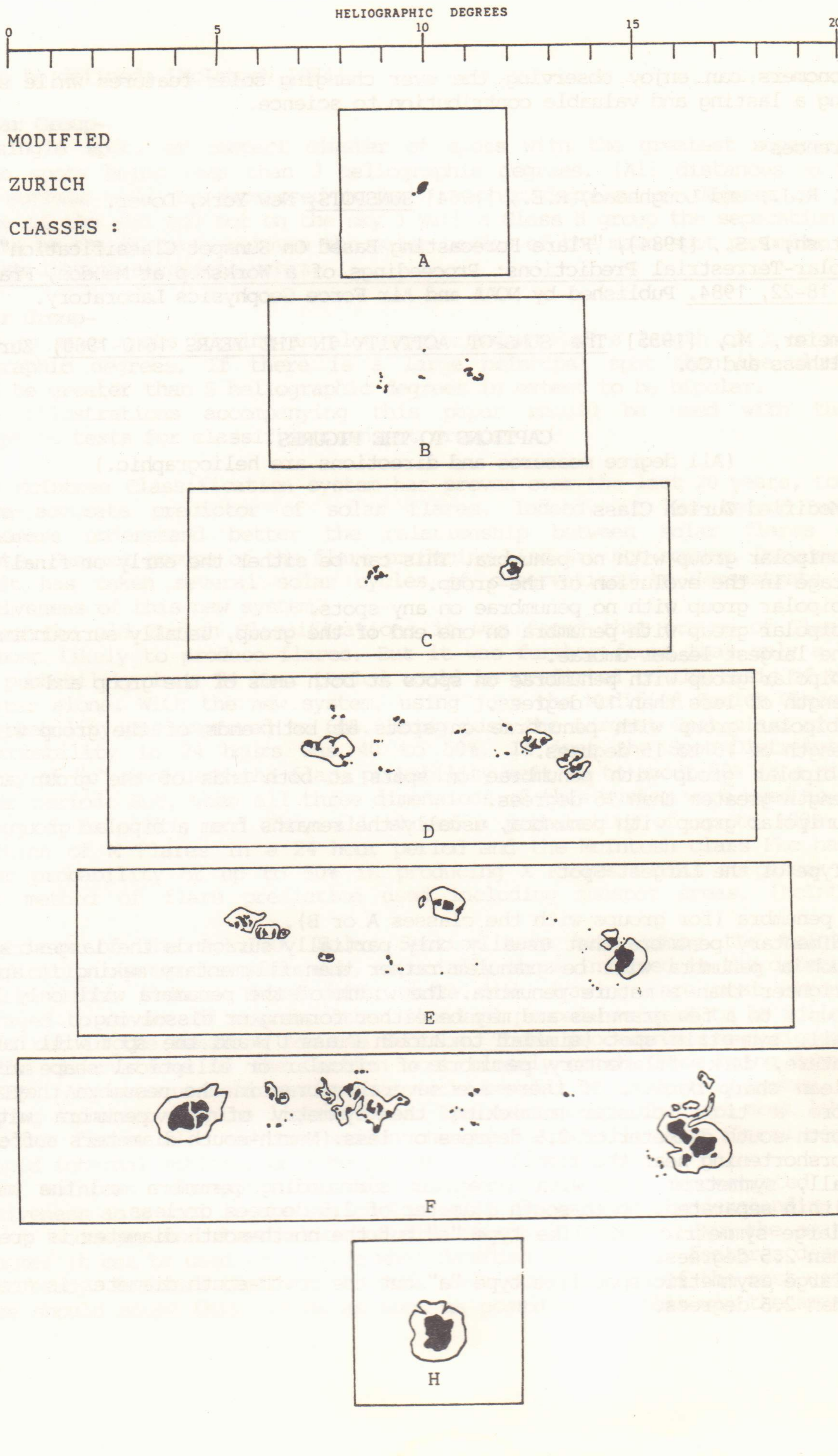
(All degree measures and directions are heliographic.)

1.) Modified Zurich Class

A-A unipolar group with no penumbra. This can be either the early or final stage in the evolution of the group.
B-A bipolar group with no penumbrae on any spots.
C-A bipolar group with penumbra on one end of the group, usually surrounding the largest leader umbrae.
D-A bipolar group with penumbrae on spots at both ends of the group and a length of less than 10 degrees.
E-A bipolar group with penumbrae on spots at both ends of the group with a length of 10 to 15 degrees.
F-A bipolar group with penumbrae on spots at both ends of the group and a length greater than 15 degrees.
H-A unipolar group with penumbra, usually the remains from a bipolar group.

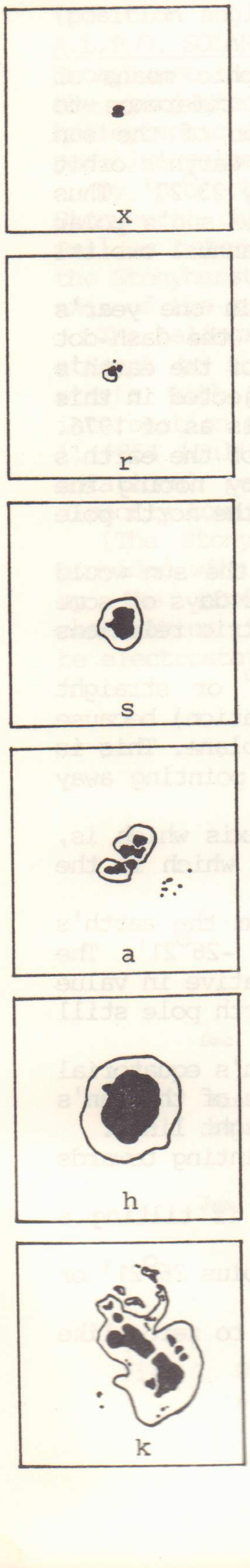
2.) Type of the Largest Spot

x-No penumbra (for groups with the classes A or B).
r-Rudimentary penumbra that usually only partially surrounds the largest spot. Such a penumbra will be granular rather than filamentary making it appear brighter than a mature penumbra. The width of the penumbra will only be a couple to a few granules and may be either forming or dissolving.
s-Small, symmetric spot (similar to Zurich Class J) and the spot will have a mature, dark, filamentary penumbra of circular or elliptical shape with a clean sharp border. If there are several umbrae in the penumbra they will form a tight cluster mimicking the symmetry of the penumbra with a north-south diameter of 2.5 degrees or less.(North-south diameters suffer no forshortening near the limb.)
a-Small, symmetric spot with irregular surrounding penumbra and the umbrae within separated. North-south diameter of 2.5 degrees or less.
h-A large symmetric spot like type "s" but the north-south diameter is greater than 2.5 degrees.
k-A large asymmetric spot like type "a" but the north-south diameter is greater than 2.5 degrees.

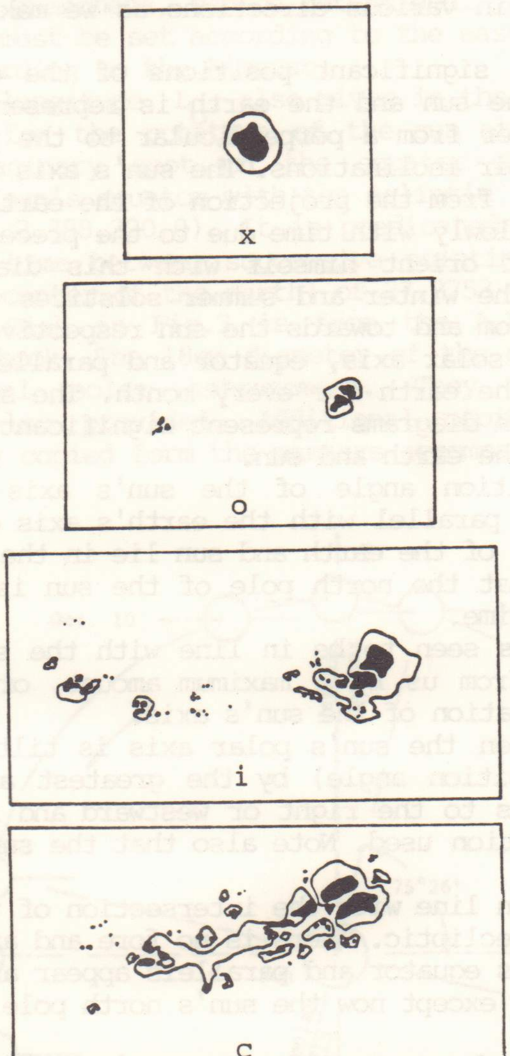

HELIOGRAPHIC DEGREES
0
5
10
15
20
MODIFIED
ZURICH
CLASSES :
A
B
C
D
E
F
H

5^{o} (scale for both figs.)

Largest Spot



Spot Distribution



3.) Sunspot Distribution

x- A unipolar group of Modified Zurich Class A or H (i.e. a solitary spot).

o-Open distribution with with a leader and a follower spot and few or none between. Any spots between will be small umbral spots.

i-Intermediate distribution with numerous umbral spots between the leader and follower spots.

c-Compact distribution where area between leader and follower contains many spots with at least one spot having a penumbra. In extreme cases the whole group may be within one complex penumbra.

THE USE OF STONYHURST CHARTS AND THE HELIOGRAPHIC COORDINATE SYSTEM

by
Ralph N. Buckstaff
Edited by
R.P.VanZandt

The purpose of the Stonyhurst charts is to provide a graphic means of locating sunspots and other features on the solar disk with reference to imaginary lines of latitude and longitude. The axis of rotation of the sun tilts or inclines $7^{\circ}15'$ from a perpendicular to the plane of the earth's orbit (ecliptic). The earth's axis of rotation or polar axis inclines by $23^{\circ}27'$. Thus in viewing the sun with reference to the earth's polar axis, the sun's polar axis would appear to tilt in various directions as we make our annual orbital trip around the sun.

Figure 1 shows various significant positions of the earth in one year's time. The polar axis of the sun and the earth is represented by the dash-dot lines which are slanted over from a perpendicular to the plane of the earth's orbit by the amount of their inclinations. The sun's axis as projected in this view is oriented by $75^{\circ}26'$ from the projection of the earth's axis as of 1976. This angle will increase slowly with time due to the precession of the earth's axis. The reader can best orient himself with this diagram by noting the position of the earth at the winter and summer solstices where the north pole of the earth points away from and towards the sun respectively.

Figure 2 shows how the solar axis, equator and parallels of the sun would appear to an observer on the earth for every month. The specific days of some of the months shown on both diagrams represent significant geometric relations between the polar axes of the earth and sun.

On January 6 the position angle of the sun's axis is 0° or straight north-south (celestial, or parallel with the earth's axis of rotation) because on this date the polar axes of the earth and sun lie in the same plane. This is hard to visualize. Note that the north pole of the sun is also pointing away from us to a bit at this time.

On March 6 the earth is seen to be in line with the sun's axis which is, therefore, pointing away from us by a maximum amount, or $7^{\circ}15'$ which is the previously mentioned inclination of the sun's axis.

April 7 is the time when the sun's polar axis is tilted from the earth's axis (an angle called position angle) by the greatest amount, $-26^{\circ}21'$. The north pole of the sun tilts to the right or westward and is negative in value because of the sign convention used. Note also that the sun's north pole still tilts away from us.

On June 6 the earth is in line with the intersection of the sun's equatorial plane and the plane of the ecliptic. There is no fore and aft tilt of the sun's axis in this position so its equator and parallels appear as straight lines.

July 7 is like January 6 except now the sun's north pole is pointing towards us.

August 8 is like March 6 except that the sun's north pole is tilting a maximum amount towards us.

October 10 is like April 7 except that the position angle is plus $26^{\circ}21'$ or slanted the other way.

Finally on December 8 the fore and aft tilt of the sun is back to zero, like

June 6. These dates and the amount of sideways slants will change as the earth's axis precesses.

The ASTRONOMICAL ALMANAC (see bibliography) shows the amount of fore and aft tilt of the sun's axis (heliogaphic latitude, B_o) and its east-west tilt (position angle, P_o) for every day of the year in Section C SUN. [Also see the A.L.P.O. SOLAR SYSTEM EPHEMERIS or the R.A.S.C. OBSERVER'S HANDBOOK -Ed.] Stonyhurst charts (available from the A.L.P.O. Solar Section) show graphically the projected image of the sun's equator and parallels for different heliographic latitudes. There are 8 charts for different fore and aft tilts of positive value. Negative values are obtained by simply inverting the charts.

By projecting the solar image from a telescope onto the appropriate Stonyhurst chart (Fig.3), coordinates of the sunspots or sunspot groups, as well as other solar phenomena, can be determined. The proper position angle of the Stonyhurst disk must be set according to the east or west tilt of the polar axis of the sun according to the Almanac.

The heliographic longitude, L_o, also given in the Almanac for the sun, is an attempt to account for the rotation of the sun at its equator. Longitude 0^o starts with an imaginary spot on the equator of the sun defined by the intersection of the sun's equator with the ecliptic (ascending node) on January 1, 1854 (Julian Day 2,398,220.0). It is predicated on an assumed mean synodic rotational period (time between successive pointings of this imaginary spot directly toward the center of the earth) of 27.2753 days.

[The Stonyhurst Disk in Fig.3 is from the A.L.P.O. Handbook. A set is provided with this book. The 18cm diameter of the disks is the size preferred by the professional solar astronomers. They are best used with the observation form also provided. Additional copies of these forms should be electrostatically copied form the masters accompanying this book. - Ed]

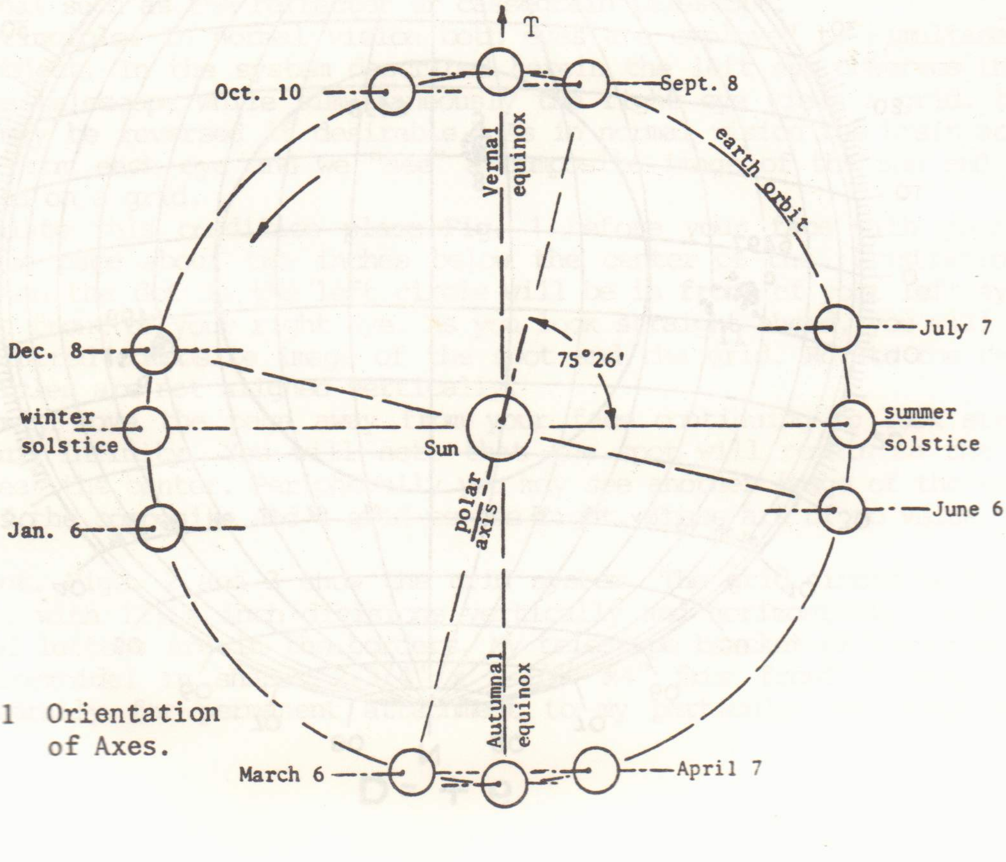


Fig. 1 Orientation of Axes.

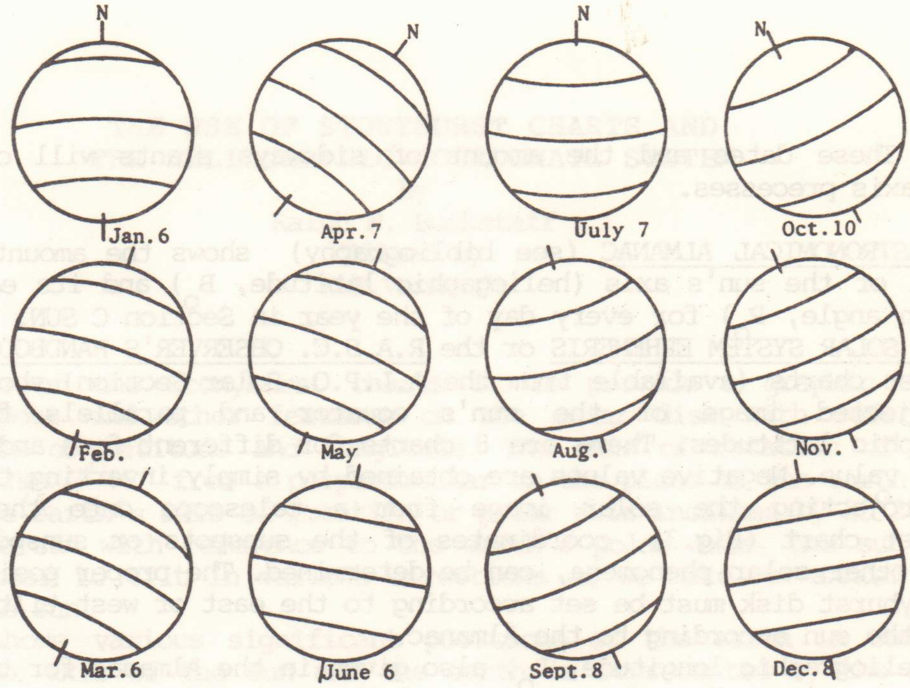
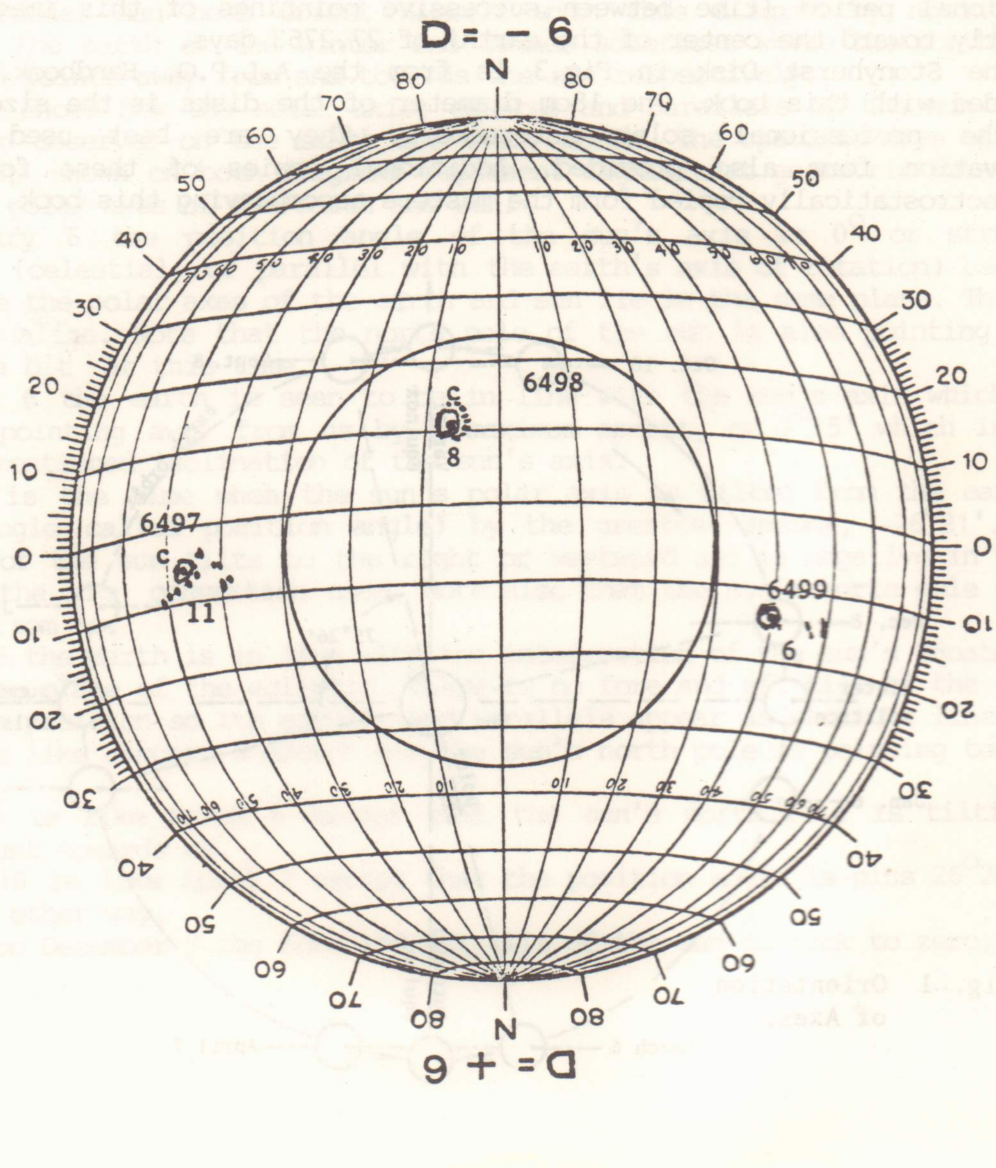


Fig. 2 The monthly positions of the disk of the sun during the year (The earth's axis is straight up and down).



A FILTERED, DIRECT VIEW, HELIOGRAPHIC COORDINATE DETERMINATION SYSTEM FOR OBSERVING AND RECORDING SOLAR ACTIVITY

by
Harold J. Stelzer

Today, more amateur astronomers than ever before are equipped to safely and readily observe the sun. One solar filter manufacturer, "Solar Skreen", claims "thousands of satisfied users". I completely agree with that opinion based on very adequate experience. My intention herein is to encourage frequent, regular and meaningful use of direct view solar equipment for the observation and accurate coordinate location of sunspots and other solar activity and to demonstrate the importance, effectiveness and benefit in the organized recording of observations.

For amateur astronomers without highly sophisticated and expensive equipment, I believe the "Direct View" system, employing a safe, professionally-made, front mounted solar filter, has the best combination of advantages over eyepiece filters, Herschel wedges and the conventional projection method. It is safer for the observer and telescope, plus avoids turbulence within the tube. Further advantages are: that the sun's intense light and heat do not enter the telescope, the filter is easily and quickly attached to the telescope, a superior image resolution (resolution of one arc second is needed for fine sunspot detail), maximum contrast of solar features, apparent reduction of atmospheric turbulence (yielding a higher percentage of "good" and "excellent" reports), and the greater interest in viewing directly rather than by the "picture" of projection.

This grid system is very inexpensive and applicable to instruments using a star diagonal such as the refractor or cassegrain telescope.

Basic Principle. In normal vision both eyes are employed to simultaneously view one object. In the system described herein the left eye observes the sun through the telescope while simultaneously the right eye views a grid. (These positions may be reversed if desirable.) As in normal vision the brain accepts the image from each eye and we "see" a composite image of the sun and spots superimposed on a grid.

To simulate this condition place Fig. 1 before your face with your nose touching the page about two inches below the center of the illustration. In this position the dot in the left circle will be in front of your left eye and the grid in front of your right eye. As you look straight ahead, you will see a slightly blurred composite image of the spot and the grid. Rotate the page if the two circles are not aligned vertically.

Now slowly move the page away from your face continuing to look straight ahead toward infinity. You will note that the spot will remain in the grid, possibly near the center. Peripherally you may see another image of the spot to the left of the composite and a grid to the right. These are of no value to our program.

Equipment. Figs. 2 and 3 show the grid system. The grid circle is 6 inches in diameter with 12, $\frac{1}{2}$ inch divisions vertically and horizontally. Coordinate numbers and letters are in the borders. My telescope bracket or mounting plate "A" is trapezoidal in shape: 2-3/4" x 1-3/4" x4" from front to rear. It is curved laterally for permanent attachment to my particular telescope center line by the screws supplied for the attachment of a piggyback camera mount under the telescope.

Bolt "B", which fastens the grid system to the telescope bracket "A", is a $\frac{1}{4}$"-20 screw thread 2" long. Bolt "C", which moves the grid vertically to match the apparent grid image to the sun's image, is a $\frac{1}{4}$"-20 screw thread $6\frac{1}{2}$" long. These bolts are made from threaded rod stock available in many hardware stores.

Bracket "D" is aluminum channel 6-3/8" long, 2" wide with $\frac{1}{2}$" flanges. The upper 3-3/8" is cut and bent as shown. A felt pad, 1-3/4" x 1", is cemented to the top of bracket "D" to facilitate rotation of the grid system for horizontal adjustment.

All other parts are cut from gift box cardboard and glued with Elmer's glue. Nuts, felt, and cardboard are fastened to the aluminum bracket "D" with Epoxy-type cement.

The eyepiece axis must be perpendicular to the grid surface. Also align the eyepiece axis and the horizontal center line of the grid. Horizontally the centers of the eyepiece and the grid should be separated by your interpupillary distance. The vertical distance between the level of the eye and the grid surface averages about 8 inches.

If the star diagonal obstructs the left edge of the grid, an internal grid arc may be added to permit slight lateral movement of the image to establish the coordinates of spots in that area.

Observing Procedure

1. **Do not look at the sun without safe filtering! Eye damage can be instantaneous!**
2. Set up the telescope equatorially, if possible, but not mandatory.
3. Install the solar filter on the observation telescope.
4. Cover the objective lenses of all other instruments attached to the main telescope to prevent damage to their optical elements.
5. Install the eyepiece for which your grid was designed - about 40 to 60 power with about a 35 minute field.
6. Attach the Solar Grid Observing System.
7. Fig.4. The telescope ready for observation.
8. POINT the telescope at the sun. **Do not look at the sun** but adjust by shadows on the telescope or shadows of the telescope on the ground.
9. Focus the telescope on the largest sunspot. If no sunspots are visible, focus on the sun's limb at the center of the field. The sharpest focus possible is necessary to resolve very small spots.
10. For alignment of the grid with the axis of the telescope note the vertical distance of a sunspot from a horizontal grid line. Then move the telescope slowly in azimuth. If the spot does not move parallel to the grid line, slightly rotate platform bracket "D" on bolt "B".
11. Now center the sun in the eyepiece field, then when observing per the Basic Principle, the images of the sun and grid circle should be coincident. If not, first recheck the eyepiece-grid relationship for perpendicularity and alignment, and the interpupillary distance for the eyepiece-grid centers, as covered above. Secondly, reposition the head (the same as rotating the page) per discussion for Fig. 1. Use this position while establishing sunspot locations. Final small adjustments in declination and/or azimuth may be necessary to correct for slight irregularities in system construction and/or the observer's technique.

12. After achieving coincidence, if the sun's image is larger than the Grid circle, move the Grid toward your eyes by the vertical adjustment bolt "C" (Fig.2). If the image is smaller, move the Grid away.
13. Fig.5 The sun and Grid are in register and aligned, ready for recording.
14. Suggestions and remarks. Carefully survey the sun's disk for sunspots between approximately 40^{o} above and below the sun's equator; give special attention to faculae (irregular bright regions) and the sun's limb. You may find that since moving objects are generally easier to note than stationary ones, that small spots, not part of larger groups, are more easily noted by slowly moving the sun's image vertically or horizontally. Survey the sun in narrow bands. Focus attention on the solar granulation when searching for small spots.
15. The easiest spots to locate and enter on your Report Grid are those within about 30^{o} of the east and west limbs. While concentrating on the spot, move the telescope slowly and slightly in R.A. until the limb of the sun closest to the spot is seen in peripheral vision in register with the corresponding section of the Grid circle. This procedure will improve accuracy, thereafter, by setting these high longitude spots (i.e. near the limb) in their Grid locations they may be employed as indices for the locating of other spots.
16. When the only spots visible are in the center 120^{o} of the sun's disk, use either direct or peripheral vision to check coincidence (with the Grid circle) at several points on the limb. As with any new technique, practice, patience and adherence to recommendations will produce ever improving results.
17. The internal arcs on the Grid may be used to bring the east and west limbs to the center of the eyepiece field to more readily and accurately locate spots near the limbs. Also, if the left limb is below the eyepiece and cannot be seen (assuming here that the left eye is observing the sun) merely move that limb to coincidence with the left arc near the center of the eyepiece field.

Do not count pores as sunspots. A pore is a very small dark feature which lacks the characteristic hard black quality of even the tiniest spot. It may disappear in a few minutes. If in addition to the solar filter, you want to slightly dim the solar image, use a neutral, yellow or polarizing filter at the eyepiece. **(These supplementary filters are never to be used alone for solar observation!)** Generally, turbulence is more noticeable during the day than night. However, with patience and experience "good" and "excellent" observations can be made at least 90% of the time.

A short period of adaptation is necessary for sharpest focusing, seeing, and concentration.

"Good" and "excellent" solar observations are not limited to the early morning, but can be made during most daylight hours except possibly the late afternoon.

Based on my experience, objective solar filters, which keep the heat out of the tube, make large aperture reflecting telescopes used at full aperture superior instruments for solar observation.

Recording Observations

The full benefit of your observations will be derived from your records of the movement, growth and decay of sunspots and groups. I suggest the form in Fig. 6. on $8\frac{1}{2}$" x 11" size paper. The Grid is 7" square overall with a 6" circle.

As a sunspot is observed, draw it as closely as possible in the same size and shape and in the same respective location on the report Grid. Sketch in the larger and most readily visible spots first, including penumbrae when present. Then the smaller spots can be entered correspondingly with out the use of the Grid. As a final step, use the highest power possible for seeing conditions to recheck your records and to see small spots (not pores) which were not seen originally.

In this final stage, I use a cover over my head and the eyepiece, similar to a photographer's cloth or hood to keep the sun off my face. It improves my ability to see small spots. Also, when not using the Grid, use an eye patch over the unused eye if it improves your visual acuity.

You may find that focusing on the solar granulation when searching for very small spots improves your acuity. Turbulence "smears" the granulation: therefore, it is more readily visible with better seeing conditions.

While at the telescope and after drawing all visible spots, you may want to tabulate your observations at the bottom of the report. The first column indicates, by letter and number coordinates, the location of each group. In the second column enter the total number of spots in each group. At the top of the sheet enter the date and universal time of your observation and at the far end the seeing condition (P=poor, F=fair, G=good, E=excellent) and the percentage of clouds in your sky (0=none, 1=10%, 2=20% etc. to 10).

Conversion to Heliographic coordinates.

"Stonyhurst Disks" permit the determination of heliographic latitude and longitude on the sun for every day of the year. The set of eight six inch disks and an ephemeris provide a convenient, accurate translation from the rectangular coordinates of our recording Grid to solar coordinates including the apparent declination of the central point of the sun's disk and the position angle of the northern extremity of the solar axis of rotation. [These disks are supplied with this book and additional sets can be obtained through the A.L.P.O. Solar Section. - Ed.]

Using a simple light box or a 35mm slide editor covered with about a 10" square of glass, as in Fig. 7. Sandwich the proper "Stonyhurst Disk" for the day of observation (on bottom) and the report Grid (on top) in the proper register, oriented correctly for the day of observation. Then, as in Fig. 8, trace on the report Grid the equator and the parallel of latitude and longitude adjacent to each sunspot group, and tick marks along the equator for all other 10° of longitude. The degrees of longitude written along the equator are based upon the central meridian longitude at the time of observation taken from an Ephemeris or Almanac.

Foreshortening elsewhere distorts the apparent length. However, parallels of longitude drawn on your report, as in Fig. 9, will provide an acceptable measurement of your observations over almost all of the solar disk. Spot groups near the sun's limb may be difficult to classify. For further information of classifying see the article "A Three Dimensional Sunspot Classification System," elsewhere in this book.

Sunspot Number

To complete the report, Fig. 9, enter in the "Summary" the total of the groups and spots north (N) of the equator and those south (S). In our example we have a total of 5 groups, 3 north and 2 south, plus 17 spots. The sunspot number is derived from: groups times 10 plus the number of spots. Our number here is 5 times 10 plus 17, or 67. Enter it at the top of the report.

I have found the book **SUNSPOTS** by R.J.Bray and R.E.Loughhead, formerly distributed in the United States by Barnes and Noble, Inc., Division of Harper and Row Publishers, Inc., now reprinted by Dover Publishing, most complete, well written and most helpful.

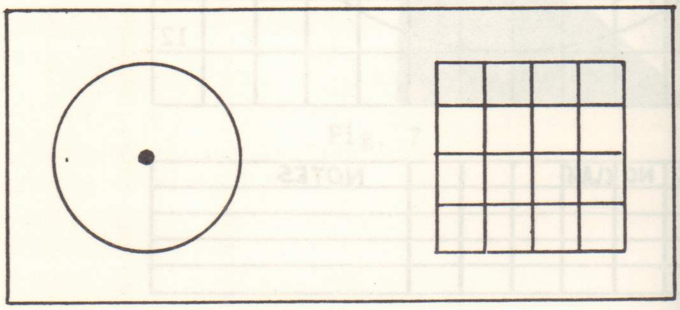


Fig. 1

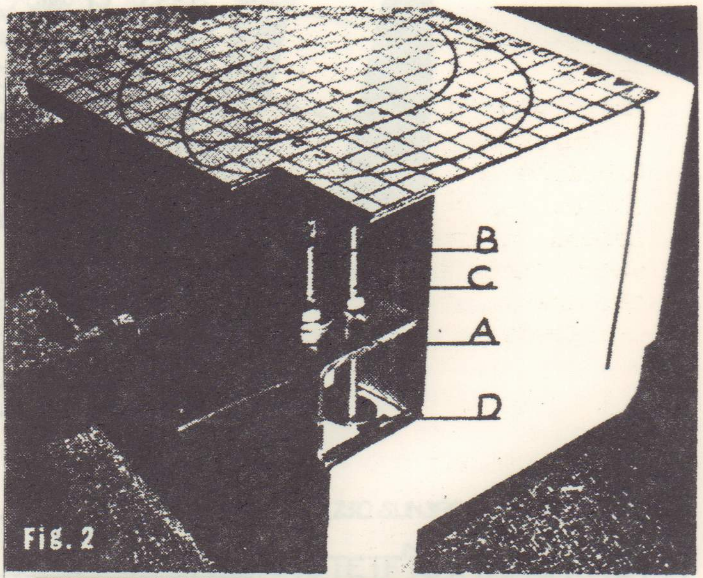


Fig. 2

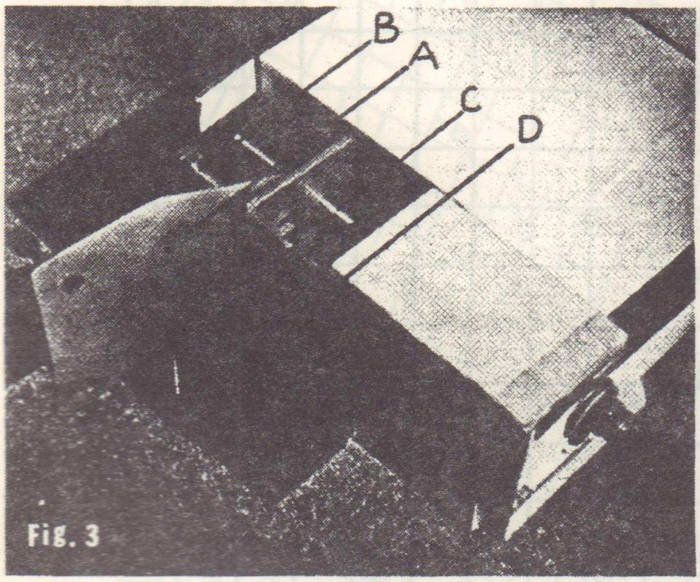


Fig. 3

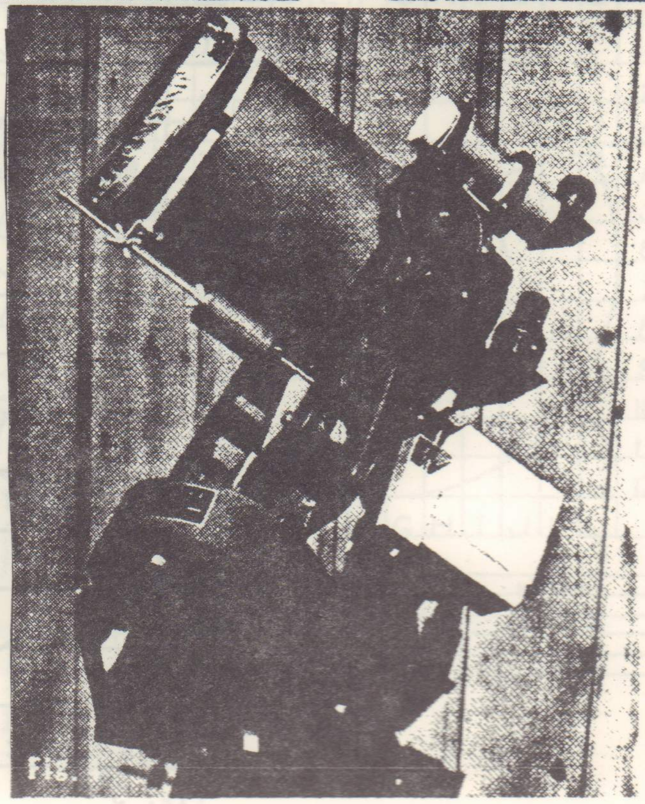
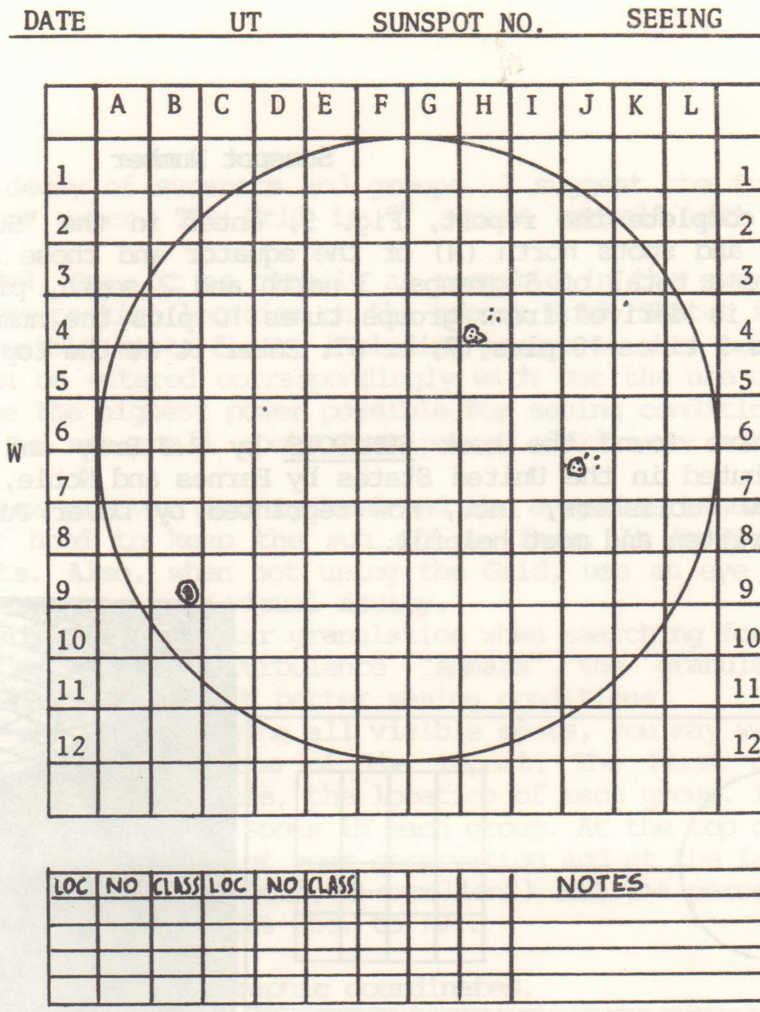


Fig.


DATE
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SUNSPOT NO.
SEEING
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1 2 3 4 5 6 7 8 9 10 11 12
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Fig. 6

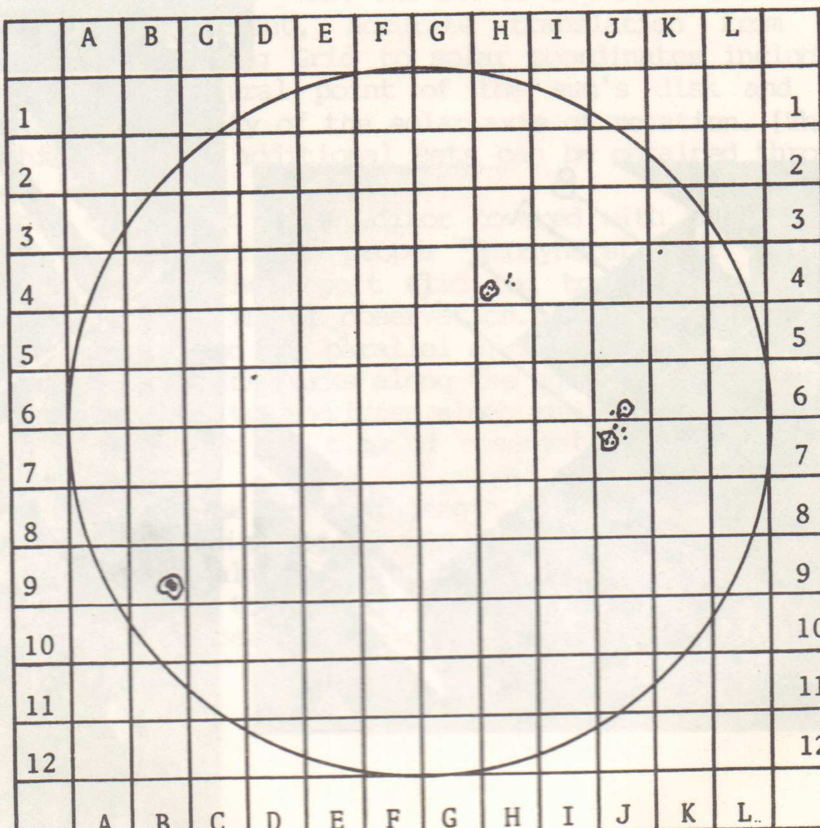
A B C D E F G H I J K L
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Fig. 5

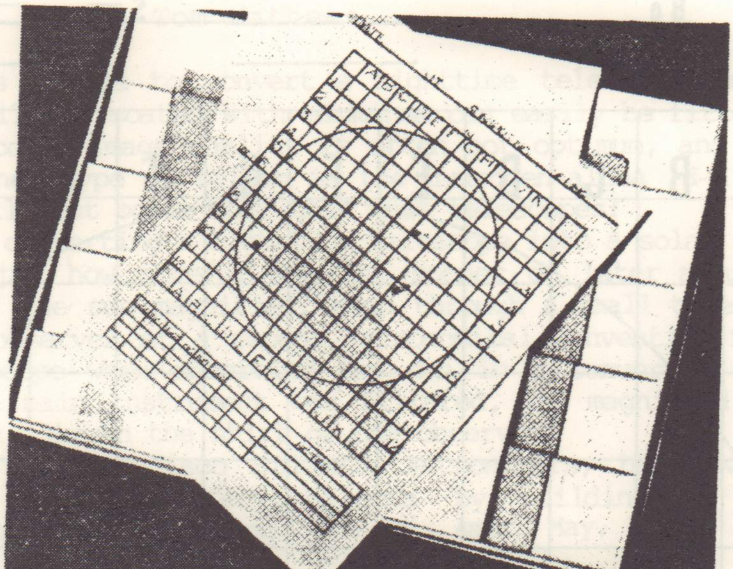


Fig. 7

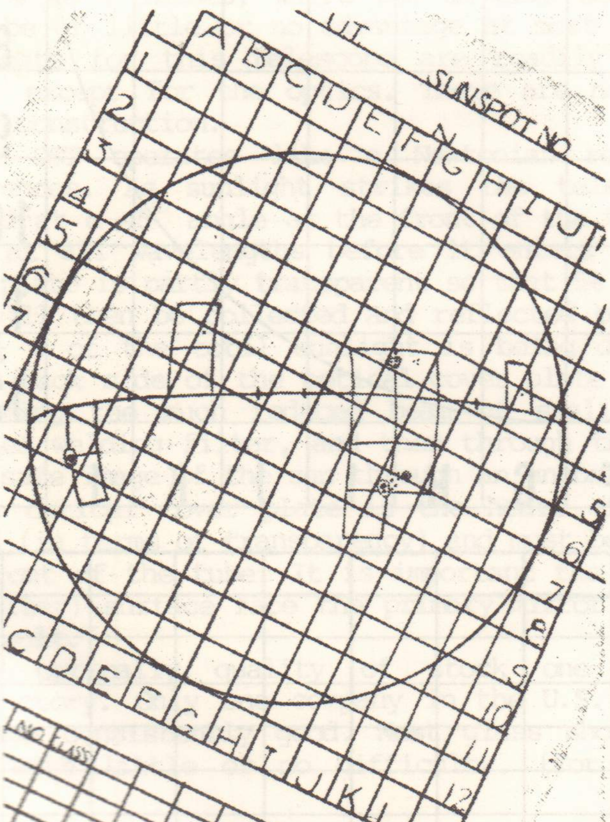


Fig. 8

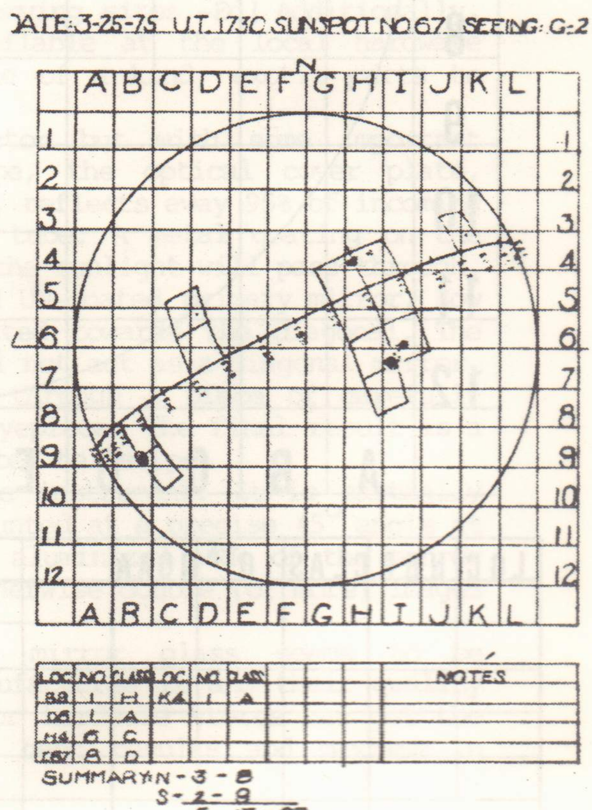


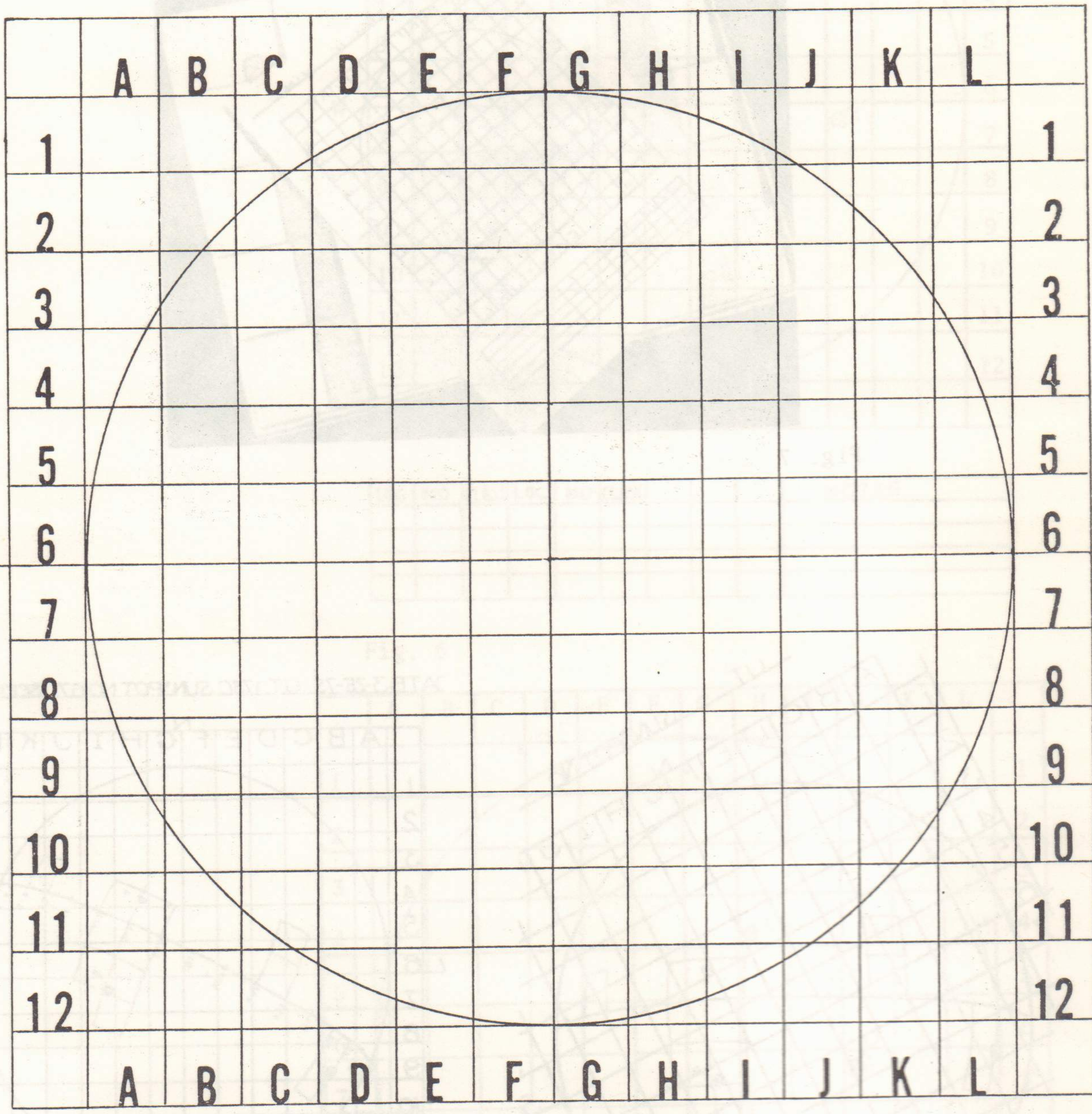
Fig. 9

DATE ____ UT ____ SSP. NBR ____ (noaa ____) ____

P ____ Lo ____ N— —

Bo ____ ____ S— —

____ ____



LOC	NBR	CLAS	10^{-6}	NOAA										

THE DOBSON SOLAR TELESCOPE

by
Tom Mathews

Most solar observers choose to convert a nighttime telescope into a sun telescope. Mylar-type filters coated with aluminum can easily be fitted of the the front of any telescope. Image quality is often not optimum, and I prefer not to use these. Another type of filter is the Hydrogen-alpha (H-a) filter. This works extremely well, but costs more than most telescopes!

A further problem in converting a nighttime telescope into a solar telescope is human error. No matter how careful one is, sooner or later a mistake is made. The full power of the sun magnified, even through a small telescope, is very unforgiving. One observer at a recent astronomical convention failed to cover the finder telescope when observing the sun in a converted nighttime telescope. Although the main instrument was filtered, the magnified sunlight from the finder burned a hole in the shirt of one observer!

John Dobson of the San Francisco Sidewalk Astronomers, has developed a satisfactory solution to the safety dilemma by building a telescope specifically designed for solar observing. (See Sci. Amer. May, 1972.)

THE TELESCOPE

There are many advantages in building a Dobson Solar Telescope (DST). It takes much of the risk out of solar viewing, making it available to the public and school children without any chance of eye damage. Since most of these telescopes are small and portable, they will more often be set up and used for observing. Setting up a large aperture telescope, and making it safe for solar viewing, can be too much trouble after a time. [Not to mention that an aperture above 4 to 6 inches, where the daytime seeing would limit your resolution, would be of little or no advantage at most observing sites.-Ed] Additionally, components for this telescope are readily available at the local hardware store, except for the optics. There are no one of a kind, exotic parts to hamper construction.

The DST operates like a Newtonian reflector but with some important differences. As sunlight strikes the telescope, the optical cover plate, mounted at a 45^{o} angle at the front of the tube, reflects away 95% of incoming light at all wavelengths before it enters the tube. A metal coating on the cover plate is partly transparent so that 5% of the sunlight will pass through. This will then be collected and reflected by an UN-coated primary mirror. Now only $\frac{1}{4}$ % of the total sunlight is being directed towards the diagonal. The coated back side of the optical cover plate will not act as a diagonal mirror, reflecting the much reduced beam of sunlight through a piece of carefully selected welding filter, and then through the eyepiece. The final result is a cool, safe image of the sun through an unobstructed telescope.

The optical cover plate is the heart of the instrument. It is partially coated (in terms of transparency) and must be mounted at a precise 45^{o} angle at the front of the tube. It is important the the aluminized side of the mirror (or filter) surface face the primary mirror, otherwise double (or more) images may result.

The optically quality of stock one way mirror glass seems to be satisfactory. Only one company in the U.S. manufactures it and their quality has been consistently good. Most glass shops or hardware stores can get the glass with little or no difficulty. [For the best results and maximum in resolution one should obtain a piece of white plate or BSC, grind and polish both sides flat to 1/16 wave, and parallel to 0.001 inch.-Ed]

The DST works best at f/ratios of 10 or longer. At these focal lengths parabolizing of 6 inch or smaller apertures is uneccessary. Four to ten inch mirrors work best and are convenient to make. [Again, little would be gained above a 4 to 6 inch aperture, except that you would have a long telescope!-Ed] It is important that the primary remain uncoated as this will further reduce the amount of light needing filtration.

The welding filter is the final filter in the telescope and is designed to filter out residual harmful and unseen infrared (IR), and ultraviolet (UV) radiation. These filters can be found in densities of $1\frac{1}{2}$ to 14, with 14 being highest density (or darkest). If the front plate is transmitting between 5% and 10%, then a density of 9 to 12 will produce an image as bright as a green lawn on a sunny day. The image should not be any brighter!

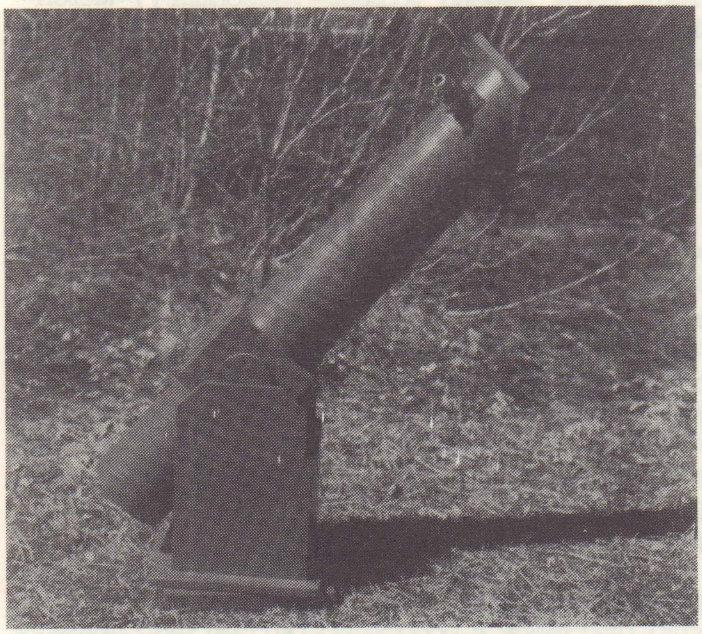
I prefer to mount the welding filter glass on the inside of the tube directly under the focuser. It is of vital importance that the draw tube not be allowed to crank down directly on top of the filter. I use an adjustable circle cutter to cut a hole only as wide as the inside diameter of the tube. The filter must be secured to the telescope tube so there is no chance that it will dislodge during use. Wooden brackets, wood workers glue, and a few screws are and effective combination. Care must be taken that the optical components are not stressed when they are mounted, or the sun may look distorted or badly warped.

To balance the telescope and keep the mounting low by lowering the center of mass, a fairly heavy counterweight can be made and mounted on the back of the tube. I melted some lead scuba diving weights using a Coleman stove and coffee can. Do this outside as the fumes are toxic. I keep a small spray bottle of water handy just in case the seam of the can begins to leak. If it does, I spray the leaking area with water to cool it and keep it sealed. The can is a good mold for the lead. After the lead melts, it is allowed to cool on its own. Pouring water onto the can will create dangerously hot steam and deform the mold! After cooling the can may be peeled away and the counterweight painted with a good sealing paint. During melting it would be advisable to wear safety glasses. Do not try to move the can while the lead is in a hot, liquid form. It is extremely heavy and could easily spill! [Remember, lead is a toxic metal. Ingestion of small amounts or breathing the fumes can cause irreversible brain damage! Also, melted lead will cause 3rd degree burns upon contact!!-Ed]

After the instrument is assembled it will be necessary to collimate the optics. This will require a little patience the first time. First, aim the telescope at the sun, remove the eyepiece and look in the draw tube from a distance of 12 inches. (Be sure the welding filter is in place!) Move the telescope until an illuminated green disk is seen. If the telescope is properly collimated, the disk will appear round. If the disk has the shape of a football, have someone turn the adjusting screws of the primary cell until the disk is round.

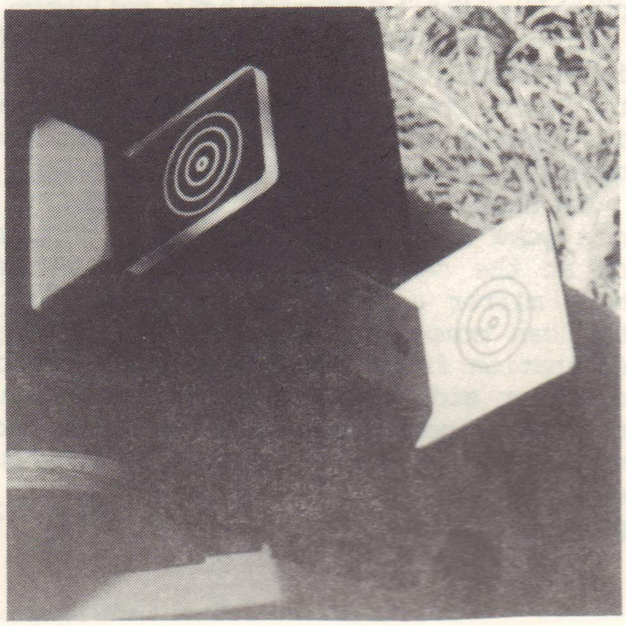
The result is a cool crisp image of the sun through a telescope that is unobstructed and safe. The front plate could fall off or break but then light would no longer be transmitted through the eyepiece. In over 20 years of use in the field, there has never been a problem or injury connected with the DST.

There is one accessory that can be easily constructed for your DST. It is a finder made out of Plexiglas with a primer gray masonite projection screen. A bullseye pattern of concentric circles is etched, painted or scratched onto the Plexiglas. Sunlight passes through this casting a shadow of the pattern onto the masonite projection screen. Once the mirror is properly aligned and the sun is in the center of the eyepiece, a black dot is marked on the screen in the center of the bullseye. Later, if the mirror is out of alignment the dot will not line up with the center. Also, when the public is viewing through the telescope the finder will indicate when the sun is leaving the field of view, eliminating the need for jumping back and forth to the eyepiece between observers.



The telescope. Note the filter mounted at a 45° angle, and of course, the Dobson mounting.

The bullseye finder - an excellent design for solar observing.



A HORIZONTAL SOLAR TELESCOPE

by

Walter Scott Houston

Russell C. Maag

One of the most fascinating instruments for observing the sun is the horizontal solar telescope. Such an instrument is really a combination of two optical systems, a movable mirror (or pair of mirrors) and a telescope. Two common arrangements of mirrors are called a **heliostat** and the **coelostat**. The usual arrangement of both types comprise two optically flat mirrors. The first mirror (primary) directs the sun's light to a second mirror (secondary) which can be moved to direct the incoming light to the objective lens or mirror of a telescope or any other instrument used to study the sun. The heliostat, as the name implies, produces a fixed image of the sun but it has the disadvantage of slowly rotating as the earth rotates. The mirror arrangement of the coelostat produces a stationary and nonrotating image of the sun. It is, however, more complicated mechanically to accommodate for the changing declination of the sun and to avoid blocking of the light path when the sun is near zenith in the spring and fall seasons.

The coelostat can operate with one mirror but this requires the telescope to be moved as the declination of the sun changes.

The heliostat can also operate with one mirror and ideally when the telescope axis is set parallel to the polar axis of the earth, such as the solar telescope at Kitt Peak. A single mirror heliostat will also work with a horizontal telescope.

Both systems - the heliostat and the coelostat - must be reset daily for changes in the declination of the sun.

The focused image of the sun from the telescope can be projected directly from the eyepiece onto a screen, or may be diverted by another flat mirror to any angle from the optical axis of the telescope.

For purposes of our considerations here, and for simplicity of design, we will use circular flat mirrors, each having a diameter at least 50% larger than the telescope objective, and accurate to $\frac{1}{4}$th wave (±1/8 wave) flatness in sodium light. Such mirrors can be purchased on special order from Coulter Optical Co. On most days, "thermals" in the earth's atmosphere will limit the optical system to as much as a full wave error.

In a coelostat, the surface of the first mirror (which collects the sun's light) should be in the exact plane of the polar axis --- not just parallel to it! Since the reflection of the mirror doubles the angle, the polar axis will rotate once in 48 hours, not the usual 24. The first mirror mounted equatorially must, therefore, be rotated at one half clock speed.

As shown in the drawing of Fig. 1, the first mirror should be mounted in a yoke assembly and the whole then mounted upon a flat plate which slides and at the same time moves between cleats or a groove-way guide so that the whole mirror assembly may be moved horizontally in a north-south direction. This can compensate for the sun's position during the year, as it moves in declination from the equinoctial positions (March 21 and September 21, or so) to either side of these positions by an amount of $23\frac{1}{2}^{\circ}$ north or south at the solstitial positions (June 21 and December 21, or so). In addition, two separate grove-way guides must be constructed and mounted on either side of the second mirror support in order that this support not cast a shadow on the first (primary) mirror at noontime each day. The groove-way guides should be placed west and east of the secondary mirror support. The primary mirror support will ride in the east groove-way during the hours BEFORE noon and in the west groove-way during afternoon hours in order to prevent a shadow to fall on the primary mirror at noontime.

By directing the reflected sunlight from the second mirror to the objective of a 3 to 4 inch aperture telescope (refractor) with f/ratio of 10 to 15 or to a mirror (reflector) of 4 to 6 inches aperture with f/ratio of 8 to 12 and , depending upon the eyepiece used, projected images of the sun may be had from 12 to 60 inches in diameter. The image should be projected on a suitable reflecting surface which may be made of ½" to 1" marine plywood or ¼" to ½" masonite and, preferably, shaped into a circle. The circle should be as large as your preferred largest projected image. Experience has shown that a magnification that produces a solar image 24 to 36 inches in diameter has the best resolution. The surface of the disk of plywood or masonite should be painted with **white** acrylic latex paint. If the paint is diluted slightly and applied to the surface with care and all bubbles or any blobs of paint brushed away, a remarkably smooth surface may be achieved. Three to four coats of paint should be thus applied and lightly sanded after each coat to produce a really fine surface. Those who prefer to use aerosol pressure paint are cautioned to not apply the paint too heavily and that rapid brushing with a fine brush even in this type of application is beneficial. After the paint is thoroughly dried (24 to 48 hours) the disk should be located on a wall or table and preferably rotated. A smooth rotating device such as an old phonograph motor drive assembly or a tape recorder is quite satisfactory. The rotation of the disk smoothes the image and enhances the details upon the projected solar disk. Rotation speeds should not exceed 30 to 50 r.p.m.s.

Fig. 2 shows the details of the mirror mount.

Fig. 3 shows some arrangements of a permanent building to house a heliostat and horizontal solar telescope.

Building A is a plan for a two mirror coelostat arrangement into a room with a small reflector telescope. Spherical mirrors may be used for a long focal length telescope. No problem here from a shadow from the building winter or summer.

Building B is a plan for a single mirror heliostat. A single mirror would be hard to control. Diagonal of the reflector mounted half way up in the tube to divert sunlight to display table at the center of the room. Note rotatable flap cover for the opening into the buildings.

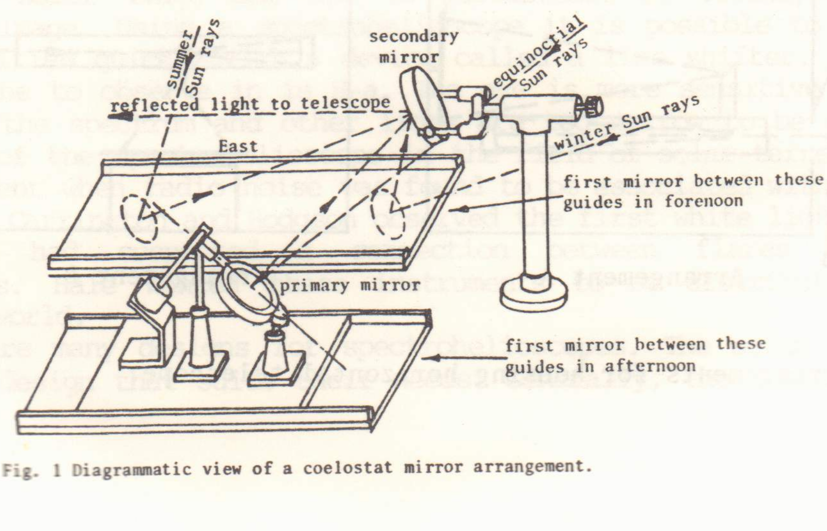


Fig. 1 Diagrammatic view of a coelostat mirror arrangement.

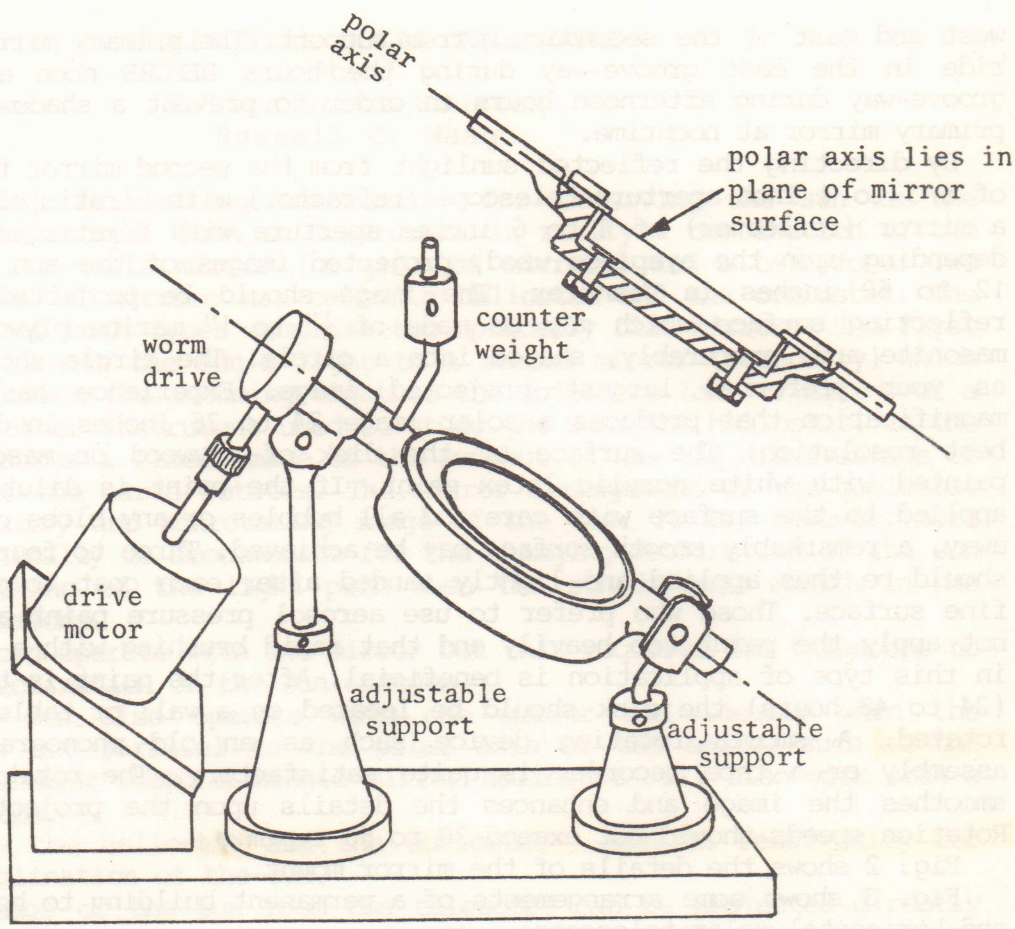


Fig. 2 Details of coelostat mirror mounting.

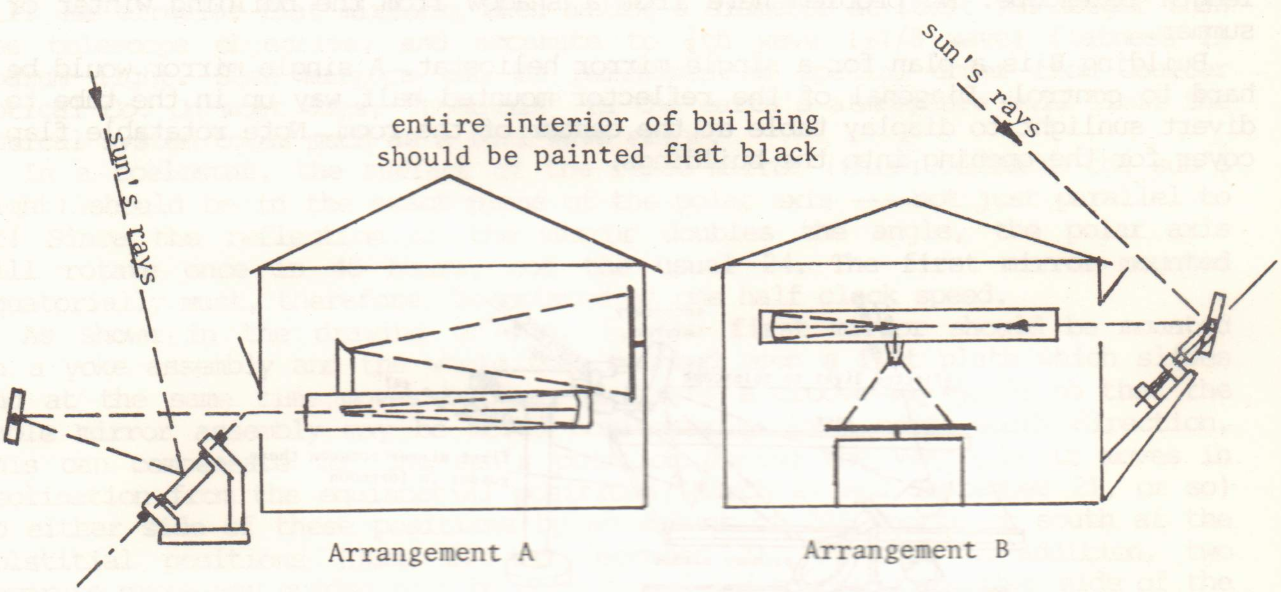


Fig. 3 Arrangements for housing horizontal telescope.

AN INTRODUCTION TO MONOCHROMATIC SOLAR OBSERVING

by
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Prior to 1868, solar astronomers could only observe prominences during the few minutes of totality of a solar eclipse. Further knowledge concerning these features progressed slowly. The question whether prominences are caused by the sun, moon, or an optical illusion, was solved by photography at the eclipse of 1860. During the eclipse 1868, in India, French astronomer Janssen spectroscopically observed bright emission lines of a prominence at the sun's limb. The hydrogen-alpha (H-a) line brightness of the prominence so impressed him that he tried to observed the emission in broad sunlight after the eclipse. He found by placing the spectroscope slit across a prominence, he could trace out its shape. Janssen shared this discovery with Lockyer in England. Huggins developed the technique of widening the 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 atmospheric clarity. The wider the slit, the less contrast a prominence has. 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 many times to observe the entire circumference of the sun. In order to photograph the entire limb of the sun in monochromatic light, G. Hale designed the spectroheliograph about 1891. He used the broad K line of calcium in the deep blue part of the spectrum. The chromosphere and prominences emit light in several spectral lines in addition to H-a such as the H & K lines of calcium, the yellow sodium D lines, the yellow helium line and the rest of the Balmer hydrogen series. The color of prominences during totality is intense pink since it is a combination of all these emission lines. The H-a line in the red part of the spectrum is the dominant emission line. The spectroheliograph creates an image on a photographic plate slowly slit width by slit width, by isolating a single spectral line. The first slit creates dark absorption lines while the second isolates one particular line letting only its light through to the photographic plate. Hale found that bright ionized clouds of calcium on the sun's disk could be photographed with this instrument. In 1908, he photographed the disk in H-a and discovered strong magnetic fields confining the gas around sunspots.

The optical counterpart of the spectroheliograph, the spectrohelioscope, was designed about 1924. In this instrument the slits move rapidly and repeatedly across the solar image and due to persistence of vision, the eye sees a continuous image. Using a spectrohelioscope it is possible to measure line of sight velocities quickly with a device called a line shifter. For visual work, the best line to observe in is H-a. The eye is more sensitive in the green to red end of the spectrum and other lines are too narrow 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. Since Carrington and Hodgson observed the first white light flare in 1859, astronomers had suspected a connection between flares and geomagnetic disturbances. Hale wanted these instruments to be distributed to observers around the world.

There are many designs for spectrohelioscopes. The solar observers should choose the design that suits their needs. Generally, the spectroscope is fixed in a horizontal or vertical position. Sunlight is fed to it from a single flat heliostat or a coelestat two mirror system. It would be best if the spectroscope is used in an observatory to protect it from wind and scattered light. The average amateur telescope maker could build a spectroheliscope for about $600.00. Diffraction gratings with 1200 lines per mm will show thousands of absorption lines in the solar spectrum, and are relatively inexpensive. The lenses used can be single element. The details of design and construction of a spectroheliscope will not be discussed here. The interested observer should consult the next chapter or references 3 and 6.

In a large sense, the spectroheliscope is analogous to your radio receiver or T.V., except that it operates in the visible part of the electromagnetic spectrum. Various chemical elements transmit at discrete frequencies as do radio and T.V. stations. The ability of your instrument to "tune in" on specific wavelengths is important to reduce noise in your receiver, or improve contrast and resolution in your spectroheliscope.

Around 1930, B. Lyot developed a new device to study the sun, the monochrometer. These optical filters were made of quartz and calcite crystals, and had to be kept at a constant temperature for best contrast. The early filters had passbands of several angstroms (1 Angstrom = 1A = 10^{-8} cm) and could only be used to study prominences. In order to study disk details in H-a, your filter must have a passband of one angstrom (1A) or less. In addition, if the filter's passband is wider than 1A, and occulting disk is needed. A quartz monochrometer could be built by an advanced telescope maker.

The development of the interference filter improved the efficiency of optical filters by reducing passbands to .1A. Space age production techniques reduced the cost of these filters and put them into the hands of amateurs. H-a interference filters used for observing prominences cost several hundred dollars. Filters used for H-a disk study cost at least one thousand dollars. H-a filters allow astronomers to quickly photograph solar features with high resolution. Interference filters are sensitive to temperature and tilt. Tilting the filter shifts the passband to the blue wing of the H-a line. When one observes in the center of the line, one is observing high in the chromosphere and sees maximum contrast of prominences, filaments, plages, and flares. When a filter is tuned off band to the red or blue wing, one sees lower in the chromosphere and less H-a detail is visible. Doppler shifted features such as surges and active filaments will be prominent in the wings of the line. The farther an H-a feature is observed the H-a core, the greater its line of sight velocity. If the filter is tuned about one angstrom or more from line center, sunspots are conspicuous. Below is a description of solar features as seen in H-a light.

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 and eruptive, but all are active and evolving. There lifetimes can range from minutes to weeks.

Quiescent prominences are identical to the dark filaments viewed on the solar disk. At the limb, they are seen as bright emission features against the dark sky. On the disk, they are seen as dark absorption features against the bright surface of the sun. A full grown filament is about 40,000km in height, 6,000km in width, and 200,000km in length. Filaments vary greatly in length and may extend over 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 prominences 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 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 (radial) magnetic field reverses. They are supported by magnetic fields, and are insulated from the much hotter, but rarefied corona. The fact that filaments are observed at all latitudes on the sun enables astronomers to map large scale magnetic fields and supplements magnetograms. Filaments are intimately related to active region evolution and respond violently to solar flares and other magnetic disturbances. Prominences are often observed flowing into sunspot regions. Disturbances may cause a filament to be ejected into the corona. The largest prominences observed, eruptive arches, are erupting filaments.

Most active and eruptive prominences are confined to the latitudes of active regions. Their frequency follows the 11 year cycle well. As with quiescent prominences, the descent of gas to the solar surface is common in active regions. A loop prominence begins with a small spherical cloud appearing above a sunspot group. It becomes elongated and breaks up to form streams on both sides of the loop. Loop prominences have complex and delicate structures, and help map magnetic fields above active sunspot groups. "Coronal rain" is a similar type of activity.

Eruptive prominences have a variety of shapes and sizes. Their lifetimes are typically less than 30 minutes. Surges, puffs, and sprays are closely associated with solar flares and centers of high activity. Surges are normally a post-flare phenomenon. Many relatively small flares are followed by eruptions. 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 are blue shifted and are best observed in the blue wing of the H-a 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 that quickly expand and fragment into complex forms. Eruptive prominences can reach distances of several hundred thousand kilometers from the limb.

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 is released in the form of electromagnetic radiation and atomic particles. Radiation from flares covers the entire electromagnetic spectrum from X-rays to radio waves. These radiations beyond the visible spectrum are important in the understanding of flares, but are not within the scope of this paper.

The chromosphere in the neighborhood of sunspots is often a region of enhanced temperature and brightness. Known as plages, these features are a result of magnetic fields restricting gas motion. In sunspots, fields are strong enough to stop the convection of the gas altogether. They are cooler and darker than their surroundings, In H-a light, a solar flare appears as a brightening of an existing plage region. The intensity of solar flares increases rapidly, usually only a few minutes, but takes much longer to fade to its pre-flare brightness.

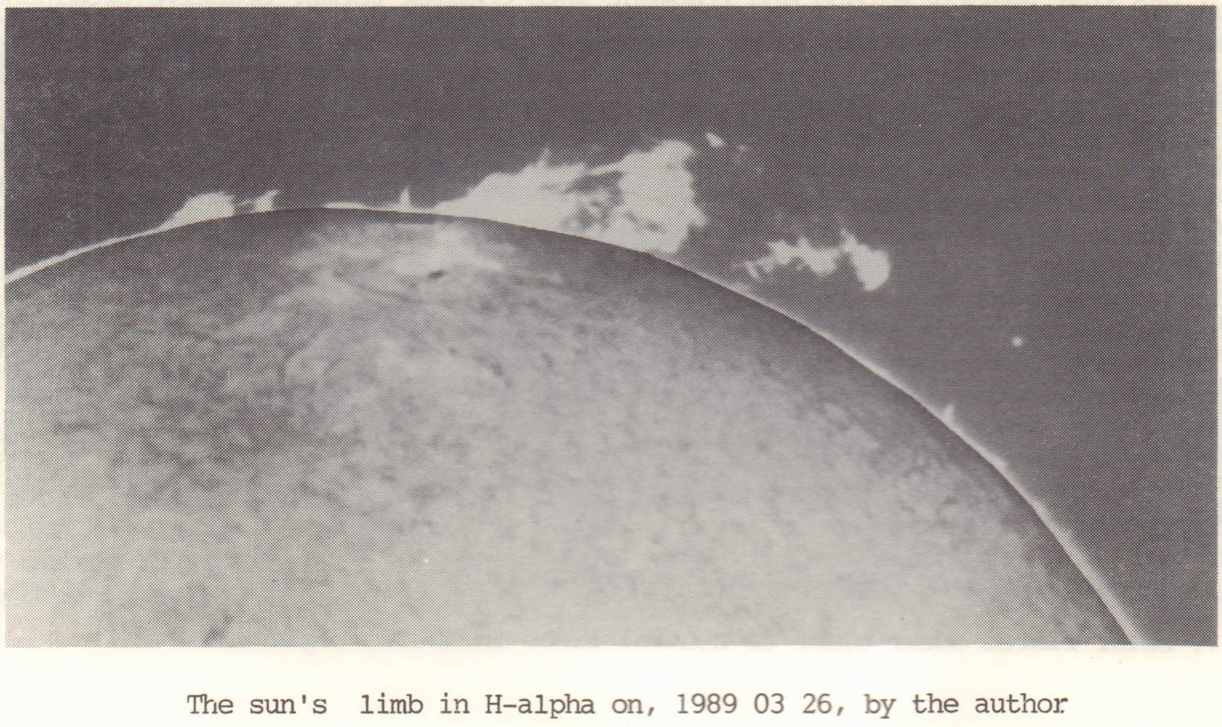
Things to note concerning flare production

1. Solar flares occur close to 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 brightenings of plages.
4. Small flares appear as one or more bright points of emission near spots on either side of a neutral line.
5. Large flares form parallel ribbons of emission on both sides of neutral lines.
6. When new groups grow and interact with older regions, flare production increases.
7. More flares are observed during the growth phase of sunspot groups when fields are changing than during the decay phase.
8. Most flares are produced by E and F groups. [See the chapter on the new classification system, which makes it much easier to predict which sunspot groups will produce flares! - Ed.]
9. Flare production is high in magnetically complex groups. Simple bipolar and unipolar groups may not produce a single flare.
10 Sunspot groups that are compact and have spots of opposite polarity mixed within one large irregular penumbra have a high flare potential.
11. Zones of higher flare activity can last for several solar rotations or even years.

This writer has observed a number of major flares over the past three years, but only a few were observed well during their development phase. It is particularly exciting to see an area the same size as the distance between the earth and moon, flare up before your eyes. Large flares are quite spectacular.

Space does not permit the mention and full descriptions of all solar features in H-a light. For a fuller description of solar features consult references 2, 4, and the A.L.P.O. Solar Observer's Handbook.



The sun's limb in H-alpha on, 1989 03 26, by the author

PRISMS, GRATINGS, AND SPECTROSCOPES

by
Richard E. Hill
Recorder-A.L.P.O.Solar Section

Amateur solar astronomers, while doing excellent observations in white light and H-alpha, have for a long time largely neglected spectroscopy. The reason for this is unclear since the equipment involved is neither complicated nor expensive. Perhaps the reason lies in a lack of understanding about the dispersing elements in the heart of the spectroscope/graph.

The basic principles behind a spectroscope are not difficult to understand. (From here on I will refer only to spectroscopes since any resourceful amateur could easily figure out how to attach a camera to the instrument thus making it a spectrograph. The basics of the dispersing instruments are the same.) Light enters the spectroscope through a slit, set a couple of thousandths to as much as a hundredth of an inch wide. This light can come from a telescope or in the case of a solar instrument can come directly in from the sun. If the instrument is to be used without a collimator the slit should be distant from the dispersing element, perhaps about three feet, with a series of baffles along the tube or shaft. From the slit the light has to be collimated, either mechanically as described in the previous sentence, or optically. The job of the collimator is to make the diverging beam of light coming from the slit, a non-diverging, or parallel beam that will then be dispersed. Next the light is dispersed by either a prism or grating (described below) and passed along to a reimaging device called a telescope, but not necessarily in the sense that we are accustomed to. Behind this the film or plate will be positioned in a spectrograph. It's as simple as that, described in one paragraph!

Prisms are the simplest dispersing element available to the amateur astronomer and amateur telescope maker (ATM). These are easily found at swap meets and amateur conventions. Armed with nothing more than the prism from an old pair of binoculars one can build an instrument capable of showing the main Fraunhofer Lines in the solar spectrum. I have purchased surplus prisms with 2 inch square faces for only a couple of dollars! They did have some edge chips or cosmetic defects but were perfectly usable for a simple spectroscope.

While many may argue that these would not be "research quality" instruments, I would remind them that with an object as dynamic as the sun the value of the observation often lies with those prepared to make the most of serendipity, not necessarily the best equipped!

Gratings, both reflective and transmissive, are another type of dispersing element. They produce a spectrum by exploiting the wave nature of light. Their surfaces are covered with very straight, parallel grooves only a few microns deep and set at a precise pitch. There are thousands of these grooves on the grating, usually around 15,000/inch. When light strikes these grooves it is diffracted by different amounts and at different angles, depending on the wavelength involved, such that spectra are formed. In a reflection grating, a white light image is also formed at normal reflection angles (where the angle of incidence = the angle of reflection). In the transmission grating such an image can simply be seen through the grating.

Gratings are a little harder to acquire than prisms. There are some surplus dealers that occasionally make small ones available (one or two inches square) at very reasonable prices, often about 1 to 10% of original value!

Gratings differ from prisms in some very important respects. A single grating will form a series of spectra to either side of the normal or white light image, whereas the prism forms only one spectrum. (Please note here, a single one is a **spectrum**, while many are **spectra**.) The grating spectra closest to the normal image have the lowest dispersion. A bit further away is another spectrum of greater dispersion, and a bit further on still is yet another of even greater dispersion and so on. These different spectra are called **orders**. First order is closest to the white light or zero order image. Unfortunately, the orders higher than first overlap each other to some degree. So while one can obtain greater dispersion in the higher orders the price paid is that filters must be used to sort out the overlap. These multiple spectra from one input of light means grating spectra are fainter than prism spectra. This is often expressed as prisms being more "light efficient". Grating efficiency is improved by **blazing**. This is a process whereby the groves are cut as a specific pitch throwing more light into a particular order. This helps but little and prisms are still far more efficient. Fortunately, in solar astronomy this is only of minor concern since we usually have plenty of light, unless very high dispersion work is being done.

Another difference between gratings and prisms is in the scale of dispersion. Gratings provide a linear scale where the distance at the focal plane (in inches or millimeters) between equal intervals (in Angstroms) will be the same across the spectrum. That is, if 100 Angstroms (A) around H-alpha (red) is 1cm in length, then 100 A at the H or K line (blue) will also be 1cm. With prisms the scale is logarithmic, being more compressed in the red and less towards the blue.

A third major difference is that reflection gratings, being reflective, are not wavelength limited in their use, whereas prisms, being refractive, cannot work in the ultraviolet (UV) unless they are made of special glass. Even then they are only able to work in the near UV.

So gratings are usually preferred since: one can select dispersions (depending on light available and desired resolution), the measurement of spectral features (being linear) is straightforward, and one can work across the whole spectrum from the infrared (IR) to the far UV.

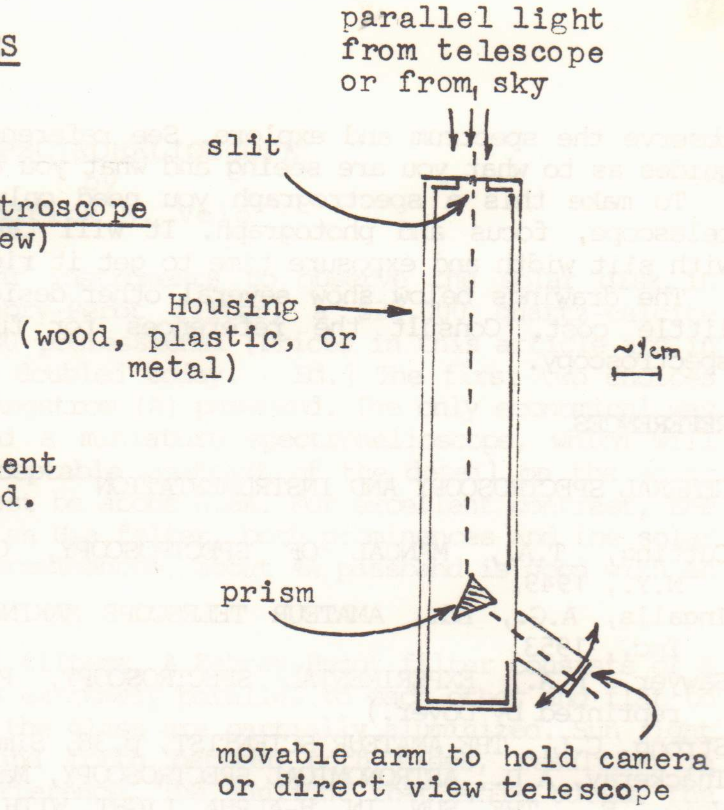
Instrumentation

By far the most simple spectroscope to build is the **Littrow Design**. It involves one slit, a long focus lens, a small telescope capable of focusing at only a few feet, and a plane grating. In a box about 20% longer than the focal length of the lens place the slit at one end, mount the grating in an adjustable mount in the other end. Next to the slit place an observation port in which you can place the telescope. Near the grating place the lens in a mount that can be moved up and down the tube a bit. Both the incoming and return light beam must pass through this lens so it should be about 50% bigger than the diagonal of the lens. Place the lens as close as possible to the grating as possible. If you can look through the lens while shining a bright light through the slit, the light should appear to flood the lens when it is in the correct position. The grating placed behind this will likewise be flooded with light.

Now look through the telescope. Adjust the grating so you are seeing a white light or zero order image of the illuminated slit. (It should not be illuminated with sunlight as even this would be too bright!) Focus the telescope so the image is sharp and clear. Now you can adjust the grating to

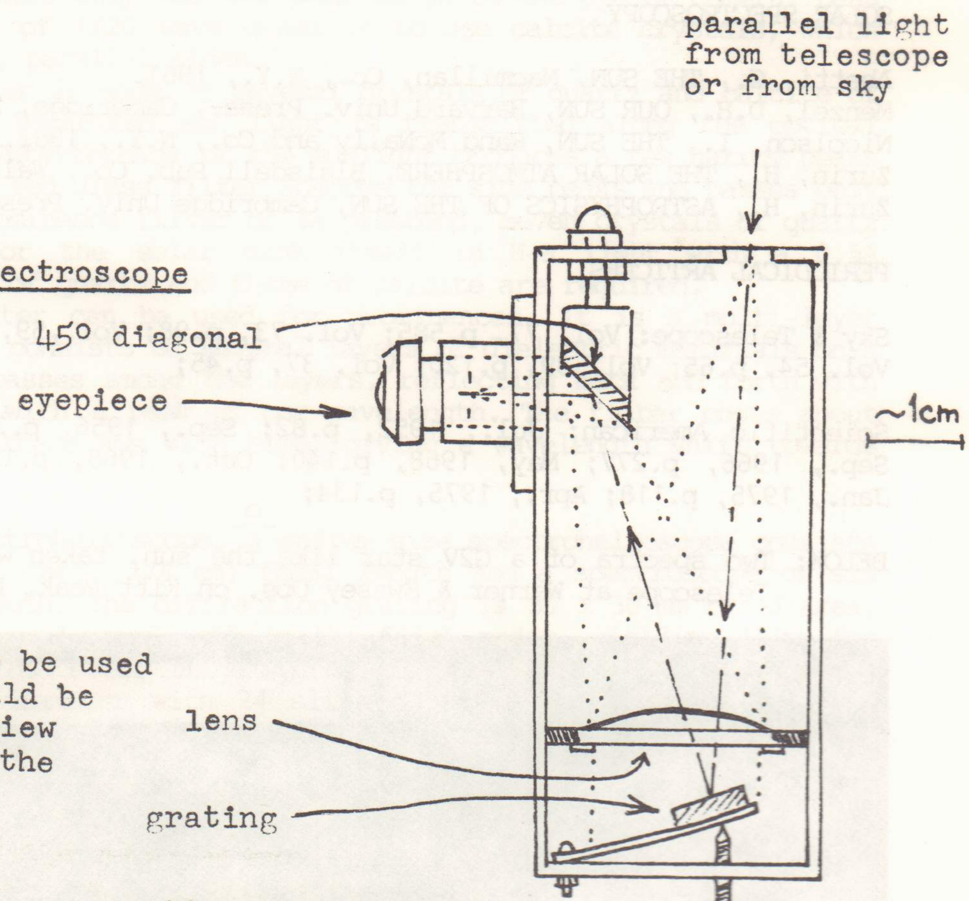
TWO EASY-TO-BUILD SPECTROSCOPES

Prism Spectroscope
(Top view)



The light in this instrument
is mechanically collimated.

Grating Spectroscope



NOTE: If no lens is to be used
then the eyepiece should be
replaced by a direct view
telescope focussed on the
slit.

observe the spectrum and explore. See references at the back of this book for guides as to what you are seeing and what you can do with this spectroscope.

To make this a spectrograph you need only mount a camera body behind the telescope, focus and photograph. It will take some experimentation, playing with slit width and exposure time to get it right.

The drawings below show several other designs all of which can be built for little cost. Consult the references for further projects and enjoy solar spectroscopy.

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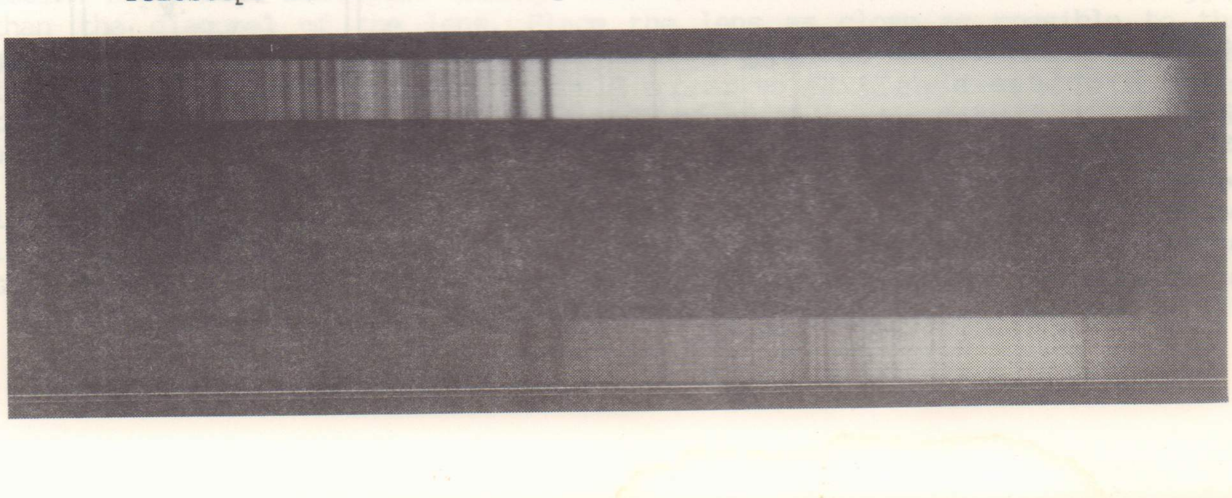
BELOW: Two spectra of a G2V star like the sun, taken with the Burrell Schmidt Telescope at Warner & Swasey Obs. on Kitt Peak. Photo by R. Hill.



THE SPECTROHELIOSCOPE

by
Fredrick N. Veio

There are three kinds of solar instruments to observe the solar disk in H-alpha (H-a) light: $1,000 Fabry-Perot filter, a $22,000 quartz-calcite birefringence filter, and a $5,000 professional [Prices in this article are in 1974 dollars and could be easily doubled today. - Ed.] The first two choices are expensive and are for a 0.5 Angstrom (A) passband. The only economical way out for the amateur is to build a miniature spectroheliscope, which will cost about $400 or less. For **acceptable** contrast of the detail on the solar disk in H-a light, the passband must be about 0.8A. For excellent contrast, the passband **must** be about 0.5A. With an H-a filter, both prominences and the solar disk are seen together. For just prominences, about 4A passband is good with an occulting disk at the prime focus.

Description of different types of filters. A Fabray-Perot filter consists of a piece of glass that has both sides extremely parallel to each other and flat to 1/20 wave or better. The sides of the glass are partially aluminized. Sun light enters one side, bounces back and forth between both sides, resulting in constructive and destructive interference. The sunlight that exits out of the other side consists of peaks of different wavelengths spaced many angstroms apart. A red, multi-layer interference filter of narrow passband absorbs all the side peaks and permits only the H-a peak to go to the eye or camera. Less expensive than a piece of 1/20 wave glass is to use calcite crystals, which cleave easily with flat, parallel sides.

A birefringence filter is made of several crystals of quartz and calcite of different thicknesses. Polarized sun light is transmitted along the optical axis of the crystals. Interference of the sunlight produces a few narrow peaks of light coming out. A red glass filter absorbs the side peaks and passes only the H-a peak. For a prominence filter of 4A passband, seven crystals of quartz must be fabricated. For the solar disk itself in H-a light with a 0.5A passband, four crystals of quartz and three of calcite are required.

Another type of filter can be used for prominences. It is a multi-layer interference filter. It consists of several layers of dielectric materials on a piece of glass. Light passes among the layers, reflecting back and forth with interference, emerging with a peak of one wavelength. The filter costs about $100 or more. These filters age with time, giving a wavelength shift towards the violet.

The Veio design of spectroheliscope. A medium size spectroheliscope consists of a telescope of nine feet (274 cm) focal length and a spectroscope of six feet (183 cm) focal length. The diffraction grating is 30 x 30 mm ruled area, 1200 lines/mm, 5000A blazed wavelength in the first order, yielding 4A/mm for the linear dispersion. The solar image synthesizer is the rotating glass disk, which is 4¼" (10.8cm) diameter with 24 slits of 0.005" width. passing 0.5A. This design was published in SKY & TELESCOPE, January 1969, p.45. It is easily portable.

The amount of detail that can be seen on the solar disk in H-a light with a spectroheliscope depends upon two factors - first, the diameter of the solar image on the entrance slit and second, the width of the slits. With a nine foot focal length telescope giving a one inch (2.54cm) diameter sun image and slit widths of 0.005 inch (0.0127cm), the calculation for average resolution is:

$$\frac{0.005\text{" slit}}{1 \text{ in.dia.sun}} \times \frac{32 \text{ min/arc sun}}{\text{in sky}} = 10\text{"arc resolution}$$

The shape and brightness or darkness of the solar detail determines the actual resolution. For faint plage and faint flares, about 10"arc is a good estimate; for bright plage and bright flares, about 5"arc; for a faint filament, about 10 x 50"arc; for dark filament, about 5" x 25"arc; and prominences, about 5"arc. All classes of flares are easily seen. Most solar detail is 5"arc or larger.

Different types of solar image synthesizers. (A synthesizer is a device that will convert a single absorption line or wavelength of light, into a complete image, in this case of the sun. There are five types of solar image synthesizer: Anderson prisms, Arcetri slits, Hale's oscillating slits, Seller's vibrating slits (like a tuning fork), and Veio's simplified rotating glass disk. Not any type of synthesizer can be used with any spectroscope design.

Anderson prisms are two separate prisms about four inches (10.16cm) apart and mounted on the ends of an axle that rotates in front of two fixed slits. The slits are in line with each other. The Arcetri slits can be about four inches apart, and they are parallel to each other, using a sideways motion. Hale's oscillating slits are on a flat piece of metal and about four inches apart. The slits are fixed and in line with each other. Seller's slits are on a mechanical spring mechanism with the slits about four inches apart and parallel to each other. The Veio rotating glass disk has 24 slits cut in the paint on the surface. The glass disk is bolted on a metal flange, which is mounted on the output axle of a motor.

Different spectroscope designs. The Arcetri spectroscope design is two nearly identical focal length lenses, one optical flat, and a reflecting grating, all arranged in the form of a U-shape. The sunlight from the entrance slit passes through one lens, off the grating and the optical flat, and through the other lens to the exit slit. There is an even number of reflections, numerically two. The Arcetri design cannot be used with the rotating glass disk, for the solar spectrum is tilted at a 45^{o} angle at the exit slit. The Arcetri synthesizer works only with sideways moving slits. There is also a vibration problem in this system.

All the following spectroscope designs have an odd number of reflections. The Ebert design is one large mirror. The Hale design is two spherical concave mirrors of the same focal length, or nearly so. The Littrow design is one lens or a two element achromat. The shape of the Littrow lens is important in order to remove the two extraneous reflections of sunlight. For a single element lens, a positive meniscus shape is best because the two reflections can be easily blocked out. The rear surface of the lens has a radius of curvature which is equal to the equivalent focal length of the lens. The extraneous light from the entrance slit bounces off the rear concave surface and focuses near the exit slit. The small, but very bright second reflection is blocked out with a small round diaphragm, mounted about one foot (30.48cm) from the spectroscope lens. Synthesizers with moving slits work best with a positive meniscus lens shape. The extraneous reflections can be completely removed.

The Ebert and Hale spectroscope designs have harmful extraneous reflections of sunlight from the entrance slit, which crosses over and reflects off the mirrors and back to the exit slit. The extraneous light can be eliminated by having a screen placed across the optical pathways and holes in the screen in the proper places.

For a portable spectroheliosocope, Arcetri slits, Hale's slits, and Seller's slits present a serious vibration problem. Therefore, only Anderson prisms and the rotating glass disk are recommended. A set of mounted Anderson prisms will cost $500 or more. A set of rotating glass disks will cost about $60. Below is a summary of the solar image synthesizers with certain spectroscope designs:

SYNTHESIZER	SLIT MOTION	ARCETRI	HALE	LITTROW	VIEO
		--------SPECTROSCOPE DESIGN------			
Arcetri slits	sideways	yes	no	no	no
Anderson prisms	fixed	no	yes	yes	yes
Hale's slits	oscillating	no	yes	yes	yes
Seller's slits	vibrating	no	yes	yes	yes
Veio's disk	rotating	no	yes	yes	yes

Diffraction gratings. The resolution of a grating is calculated in a simple manner. With a 32 x 30 mm ruled area, 1200 lines/mm, then 32mm times 1200 lines/mm equals 38,400 total lines. This number of lines divided into the desired wavelength gives the resolution in the first order. Thus, for the H-a line: 6563A/38,400 lines = 0.17A resolution. This is 100% resolution, which seldom happens. About 90% resolution is to be expected, which is about 0.2A with the preceding example. For excellent contrast to solar disk detail, in H-a light, a 0.5A passband is selected. The grating must have a resolution at least half of 0.5A, namely, about 0.25A or better. This is why a small grating of high quality will give fine contrasting views of the solar disk. An inexpensive grating of about 40% resolution yields about 0.4A at best, and they are not recommended.

The efficiency of a grating is the **percent** of sunlight concentrated (blazed) in a particular region of the spectrum. An 85% efficiency at 500A (green) blazed wavelength means that 85% of the green light is located at that wavelength. Other wavelengths in the violet and the red are fainter by about half. Nonetheless, the full spectrum from the violet to the red can be used. There is a fantastic amount of spectral detail that can be seen with a small grating.

Before the mid-1950's, only original gratings were used in spectroheliosocopes, having 600 lines/mm, costing about $1000. Original gratings were difficult to obtain, so sometimes three large prisms were employed. About 1955, three companies perfected the replication technique for a grating. Now a high quality replica grating would cost about $100 or more. Prisms are obsolete now and 1200 lines/mm gratings are preferred over 600 lines/mm because the former has twice as much resolution and linear dispersion for the same grating size.

Details of Veio Spectroheliosocope. The optics for the spectroscope are placed in a wood box about seven feet (213cm) long. At the front of the box is placed a Bodine motor of 60 rpm. The rotating glass disk turns on the output axle of the motor at one rps. The rotating disk has 24 slits, giving 24 sun images into the eye per second, presenting a continuous view of the solar disk in H-a light. Some motors have slight vibration. Never use them, for tiny vibrations slightly shake the spectroscope box and ripple the air inside the box, causing the H-a line to shimmy on and off the exit slit. This gives an uneven view of the solar disk. Always buy a very smooth turning motor. Bodine 10 watt motors are recommended.

There must be two eyepieces, a 2"f.l. for fine detail in the solar spectrum, and a 4.5"f.l. for the full solar disk in H-a light. Plus or minus half an inch is all right. A 2"f.l. eyepiece gives too much power for the solar disk in H-a light. A canvas shroud over the eyepiece end of the telescope must be used to keep the direct glare of the sunlight from the eyes. Single element lenses are all right, since we are using monochromatic light.

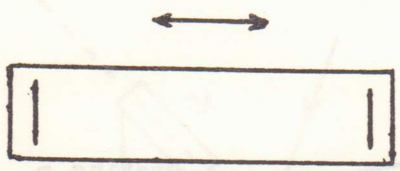
A wood diaphragm is placed a few inches behind the 60 rpm motor with two one inch diameter holes to let the sunlight from the entrance slit pass to the spectroscope lens and grating and then back to the exit slit. The diaphragm prevents stirring up the air in the spectroscope box as the glass disk rotates on the motor axle. The two holes are covered with good quality reticle glass. The air current diaphragm maintains a very uniform field of the solar disk in H-a light.

Different solar reflection systems. A simple heliostat has one mirror that reflects the sunlight into the telescope, which is oriented in a north-south direction. A polar heliostat uses one mirror, which reflects the sunlight into the telescope so that the RA axis and the telescope optical axis are mutually aligned towards the north celestial pole. A two mirror heliostat has the RA axis of the primary mirror aligned towards the north celestial pole. The primary mirror reflects sunlight to a fixed secondary mirror, which sends the sunlight in a vertical or horizontal direction into the telescope. No shadow by the secondary mirror falls on the primary mirror during the year.

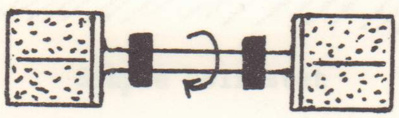
A two mirror coelostat can reflect the sunlight in a vertical and horizontal direction into the telescope. The two mirrors are placed in a north-south direction. The angle of the primary mirror is fixed by the latitude of the observer, and the primary mirror only rotates in RA. The secondary mirror can be tilted to move the prime focus solar image. The primary mirror must be shifted in a north-south position as the sun changes its declination in the year. In the autumn and spring, the secondary mirror casts a shadow so the primary mirror must be moved eastward at forenoon and westward in the afternoon.

MIRROR SYSTEM	ROTATION OR SUN IMAGE	CONSTANT SLOW MOTIONS CONTROLS	RA DRIVE RATE	FINAL GEAR REDUCTION RATIO
simple heliostat	yes $1\frac{1}{2}$day	yes	0.7 rev/ 24 hrs	2000:1
polar heliostat	yes 2/day	no	1.0 rev/ 24 hrs	2880:1
2 mirror heliostat	yes $1\frac{1}{2}$ day	yes	0.7 rev/ 24 hrs	2000:1
2 mirror coelostat	no	no	1.0 rev/ 48 hrs	2880:1

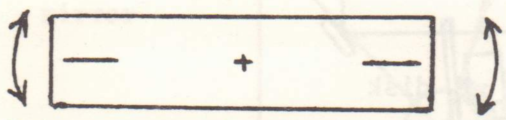
SOLAR IMAGE SYNTHESIZERS



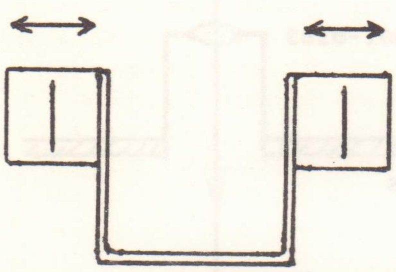
Arcetri - two slits parallel with each other, sideways motion



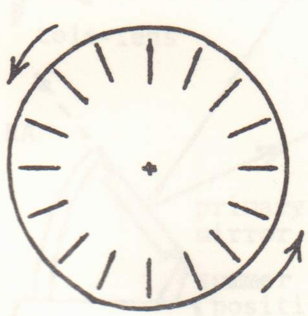
Anderson prisms - two slits in line with each other; slits are fixed, prisms revolve in front of slits



Hale - two slits in line with each other, oscillating motion

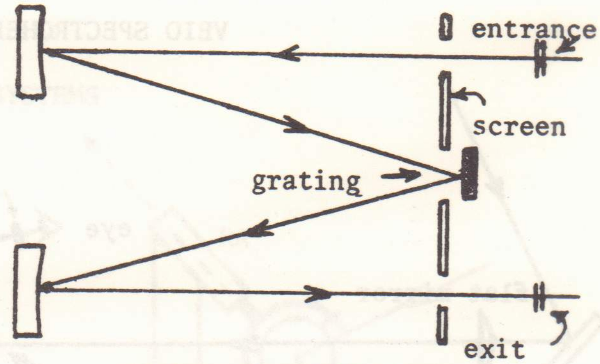


Seller - two slits parallel with each other, vibrating motion

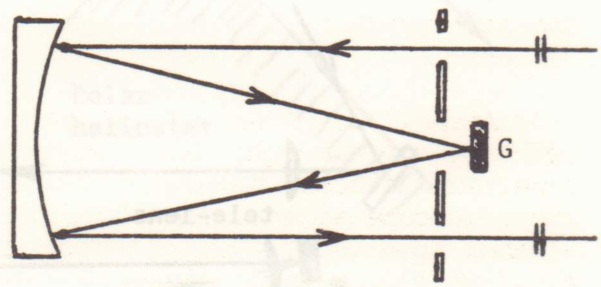


Veio - 4 1/4" diameter rotating glass disk, radial slits rotating motion

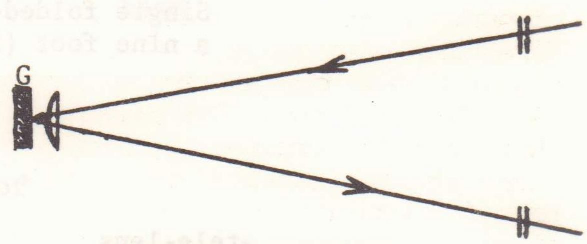
SPECTROSCOPE DESIGNS



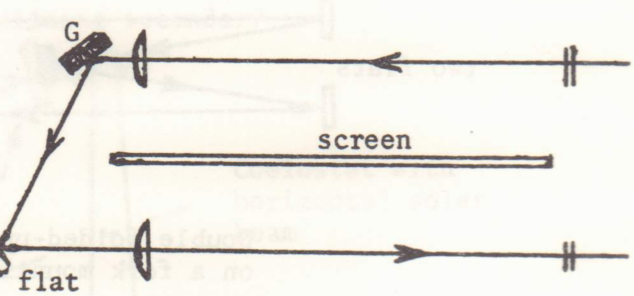
Hale - two spherical mirrors



Ebert - one large spherical mirror



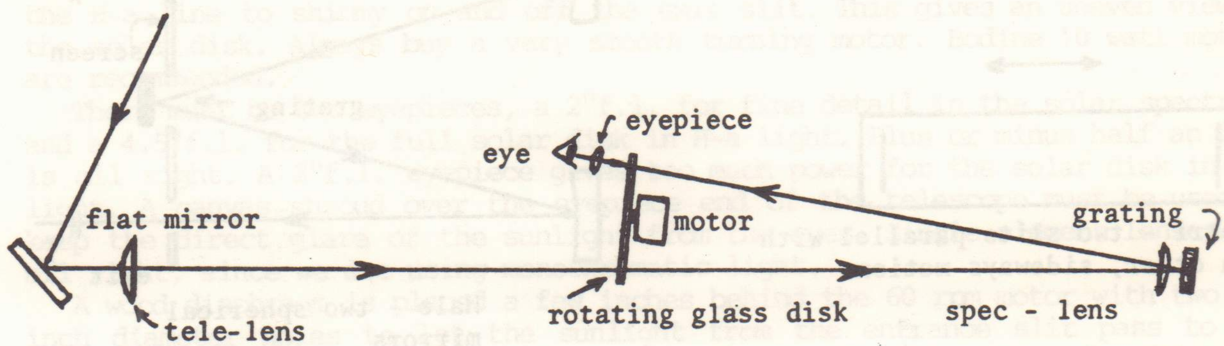
Littrow - one lens



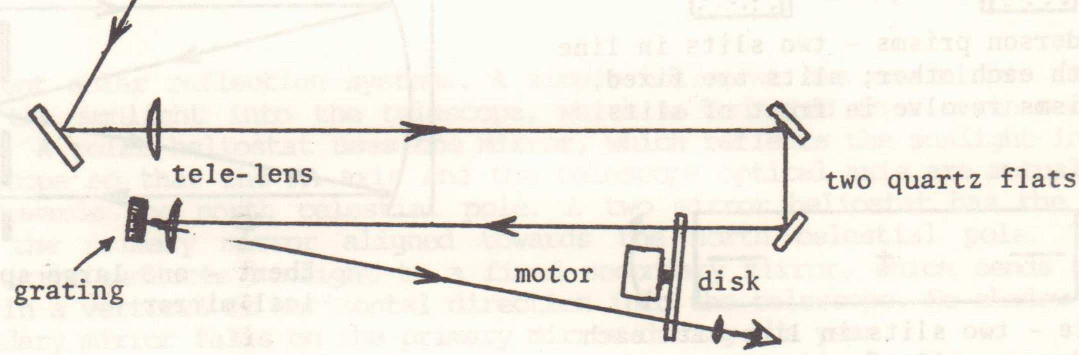
Arcetri - two identical lenses

DIFFERENT ARRANGEMENTS OF

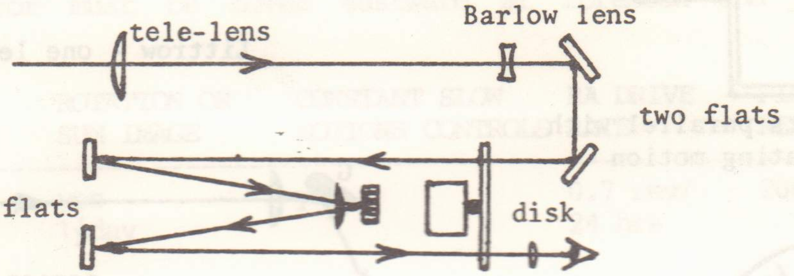
VEIO SPECTROHELIOSCOPE DESIGNS



Straight line design

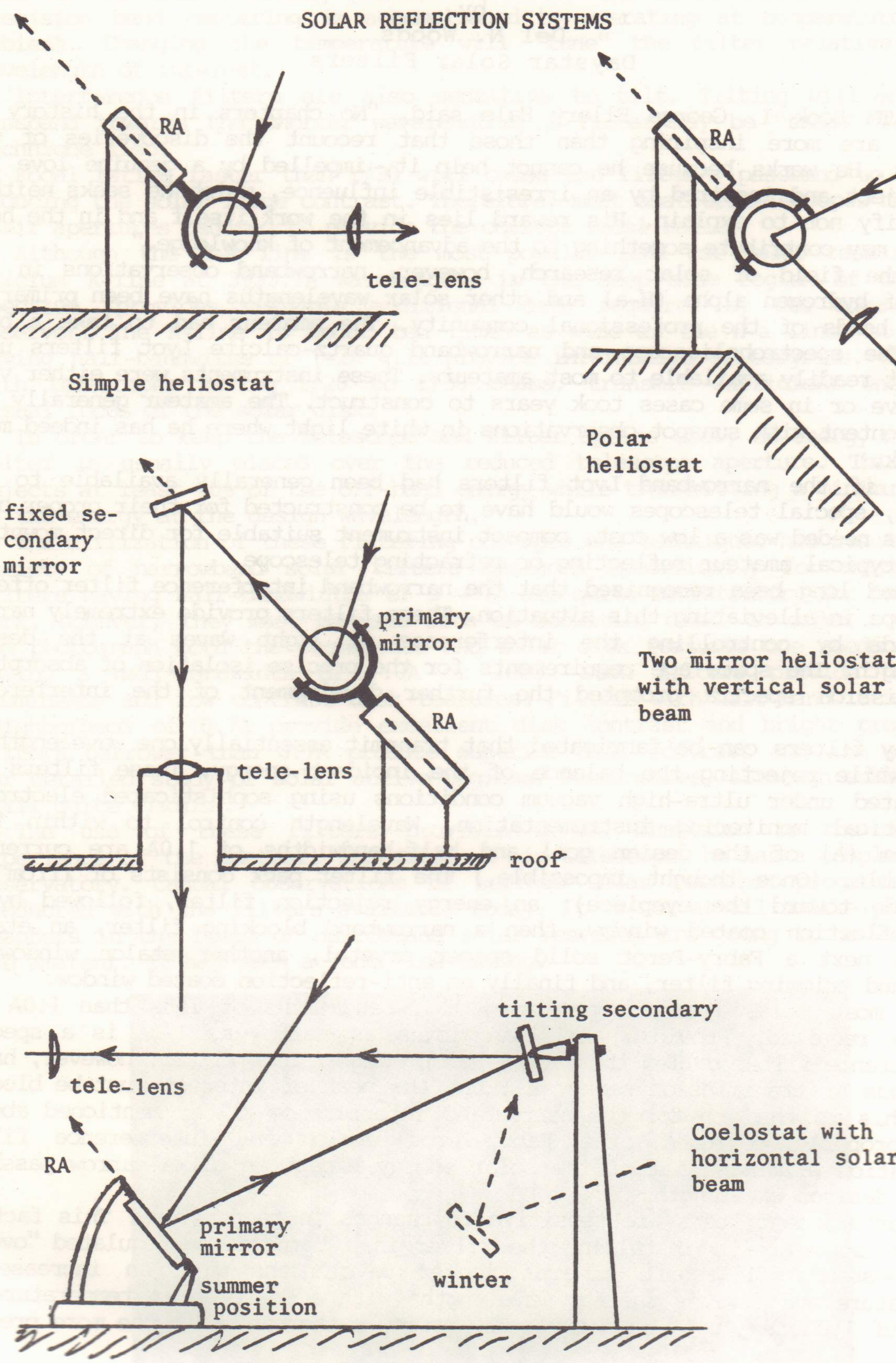


Single folded-up design in
a nine foot (274cm) long box



Double folded-up design
on a fork mounting

SOLAR REFLECTION SYSTEMS



NARROWBAND INTERFERENCE FILTERS

by
Del N. Woods
Daystar Solar Filters

In ATM Book I, George Ellery Hale said, "No chapters in the history of science are more inspiring than those that recount the discoveries of the amateur...He works because he cannot help it, impelled by a genuine love for his subject and inspired by an irresistible influence, which he seeks neither to justify nor to explain. His reward lies in the work itself and in the hope that it may contribute something to the advancement of knowledge."

In the field of solar research, however, narrowband observations in the light of hydrogen alpha (H-a) and other solar wavelengths have been primarily in the hands of the professional community. The amateur had to take a back seat. The spectrohelioscope and narrowband quartz-calcite Lyot filters used were not readily available to most amateurs. These instruments were either very expensive or in some cases took years to construct. The amateur generally had to be content with sunspot observations in white light where he has indeed made his mark.

Even if the narrowband Lyot filters had been generally available to the amateur, special telescopes would have to be constructed for their proper use. What was needed was a low cost, compact instrument suitable for direct mounting on the typical amateur reflecting or refracting telescope.

It had long been recognized that the narrowband interference filter offered some hope in alleviating this situation. These filters provide extremely narrow passbands by controlling the interference of light waves at the design wavelength. The space age requirements for the precise isolation of absorption and emission spectra prompted the further development of the interference filter.

Today filters can be fabricated that transmit essentially one wavelength of light while rejecting the balance of the incident energy. These filters are fabricated under ultra-high vacuum conditions using sophisticated electronic and optical monitoring instrumentation. Wavelength control to within 1/10 angstrom (A) of the design goal and half-bandwidths of 1.0A are currently obtainable. (Once thought impossible.) The filter pack consists of (from the sun side toward the eyepiece): an energy rejection filter, followed by an anti-reflection coated window, then a narrowband blocking filter, an etalon window, next a Fabry-Perot solid spacer crystal, another etalon window, a broadband trimming filter, and finally an anti-reflection coated window.

For most solar research programs, half-bandwidths of less than 1.0A are usually required. Providing half-bandwidths as narrow as 1/3A is a special interference filter called the Fabray-Perot etalon. This filter, however, has a multitude of transmission peaks. All but the peak of interest must be blocked out. This is the job for the narrowband interference filter mentioned above. When properly designed, the Fabry-Perot etalon and interference filter combination eliminate all of the solar energy except an ultra-narrow passband at the desired wavelength.

Interference filters are sensitive to changes in temperature. This fact is used to advantage by installing the filter in a temperature regulated "oven". The passband will shift towards longer wavelengths with an increase in temperature and towards shorter wavelengths with a decrease in temperature. A shift of 1.0A per 16.8^{o} is normal. The narrower the bandwidth the more precise the temperature control must be. Since the H-a absorption line is only 1.2A wide at its half intensity point, control of ±0.05A is absolutely required. Precision band centering is accomplished by operating at temperatures above ambient. Changing the temperature will "tune" the filter relative to the wavelength of interest.

Interference filters are also sensitive to tilt. Tilting will shift the passband towards the shorter wavelengths. A filter may be "tuned" with this technique also.

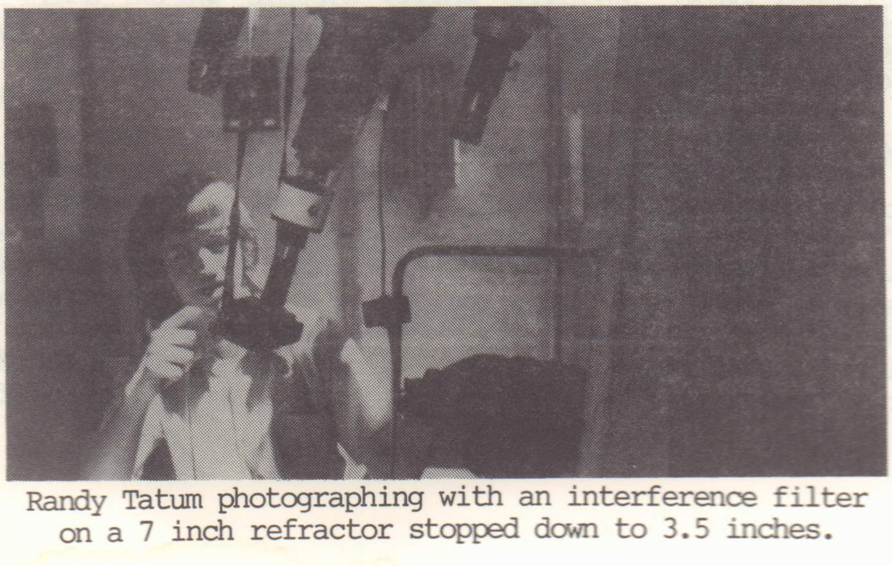
Focal ratios faster than f/30 will cause the filter's passband to broaden, reducing the solar image contrast. Therefore, most amateur telescopes must have their apertures reduced to provide the correct focal ratio.

Although the H-a line is the most popular line for solar research, the Calcium K-line at 3933.7A wavelength, in the deep blue region of the solar spectrum, provides valuable additional data required by the more serious observer. The K-line is about ten times as wide as the H-a line, so filters having half-bandwiths of 1-2A will provide informative filtergrams. When used with telescopes having f/20 to f/30 beams, transmit sufficient energy for visual focus of the solar disk.

In order to keep the telescope and filter optics cool, an energy rejection filter is usually placed over the reduced telescope aperture. This filter rejects at least 80% of the off-band energy while transmitting a minimum of 92% of the energy at the design wavelength.

The utilization of these filtering concepts and techniques has resulted in a variety of narrowband solar filters designed specifically for amateur use. Filters having half-bandwidths of 3 - 7A are quite satisfactory for prominence work, however, they must be used with an occulting disk. In order to observe and photograph both the prominence and solar disk features one needs a filter having a half-bandwidth of 1.0A or less. Such filters provide brilliant prominence and low contrast disk features. Filters with half-bandwidths in the neighborhood of 0.7A provide excellent disk contrast and bright prominence. Filters narrower than 0.7A produce superior disk contrast and are excellent for detailed study of solar active regions. Prominences, although subdued, are still quite visible.

The use of these filters provides a new dimension to the observing experience of the amateur. Installed on his telescope, he has a complete solar observatory. Casual observations or serious solar research programs can be conducted with the filters available today. It is not at all unlikely that new chapters in the field of narrowband solar research are going to be written by the amateur. It has been a long time coming.



Randy Tatum photographing with an interference filter on a 7 inch refractor stopped down to 3.5 inches.

THE SUN AND ITS 1000 FACES
SOLAR OBSERVING WITH AN INTERFERENCE FILTER
by
Edwin Hirsch

==
Our sun is beneficial to the Earth, but dangerous to our eyes. NEVER use eyepiece filters on binoculars or telescopes. Only use safe filter systems with these instruments. Also, it is best, for safety, to remove the finderscope from telescopes when doing solar observing.
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The solar atmosphere can be divided into three principal regions in ascending order from the visible solar surface: photosphere, chromosphere and corona. When observing with an hydrogen-alpha (H-a) narrowband solar filter it is the chromosphere that is revealed. Radiation from the chromosphere is roughly 1000 times fainter than photospheric radiation. For this reason the chromosphere is not visible in ordinary photographs of the sun in white light.

Most observers that perform solar patrols with interference filters watch the sun through an optical telescope using a filter tuned to the red H-a line. The red radiation emitted by hydrogen atoms is the first line in the hydrogen Balmer series, at a wavelength of 6563 angstroms (A). This is one of the strongest absorption lines in the solar spectrum. What is seen with an ultra-narrowband filter is a complex monochromatic (red) image with a finely textured background. Scattered over it are a variety of light and dark features, with occasional clusters of detail (active regions) which are associated with sunspots. Flares are seen as slow, transient brightenings in very limited areas in and around active regions.

It is possible to explore chromospheric structure at several levels by using different wavelengths, all in the neighborhood of the H-a line. On center line, where absorption is strongest, the details seen will be several thousand kilometers above the photosphere. If 0.5 to 0.75A away from line center, observed features will be in the lower chromosphere. But, 2A from line center absorption is weak and you will see some photospheric structure. By seeing these different levels in the sun's atmosphere we are looking at the thousand faces of the sun. With a camera you can record these faces and the minute to minute changes that take place on them.

H-a photography can be done quite successfully in metropolitan areas as will as in the countryside. A slight haze or smog usually steadies the atmosphere, improving the seeing. The H-a filter will penetrate haze and smog, permitting sophisticated observation by amateur astronomers, since they can be used with most types of telescopes from refractors to schmidt-cassegrains.

FILTER CHARACTERISTICS AND USE

The H-a filter must be installed in a temperature regulated oven operating at temperatures above ambient. Precise, on-band centering and tuning should be available, since changing the temperature shifts the passband wavelength. This feature allows optimum contrast and off-band observing. Tilting the filter can also be used as a method of tuning to obtain the same result without changing temperature.

H-a filters must be <u>sub-angstrom</u> (0.9A or less) in order to view chromospheric structure. The filters are mounted at the prime focus of the telescope. A diagonal with ocular, or camera can be mated to the rear of the filter for either direct observation or photography respectively. The telescope aperture must be reduced to provide an f/30 focal ratio. Focal ratios faster than f/30 will cause passband wavelengths to broaden, reducing image contrast. Ratios slower than f/30 are acceptable if one can adapt to a less bright image. I have used ratios as slow as f/90. Over the reduced aperture is placed an energy rejection filter. This filter insures a cool beam to the telescope and filter optics but, it must be of high optical quality to avoid image degradation.

A useful accessory is an opaque cloth such as a photographers black cloth. I put it over my head, filter, and focusing device, putting my eyes in a portable darkroom, eliminating almost all daylight. Then the chromospheric image becomes alive with detail, and focusing is a lot easier.

HYDROGEN-ALPHA PHOTOGRAPHY

General astrophotography rules apply to H-a photography with few differences. There is the advantage that you can see what you are doing since you work in sunlight. The H-a image (in red light) is many times less bright than the white light image and careful attention must be paid to focusing. As mentioned previously, it is helpful to keep your eyes out of direct sunlight for viewing and focusing.

Kodak's black and white Technical Pan Film #2415, which is a pan film, is sensitive to the red end of the spectrum and therefore an excellent film for H-a photography. To get high contrast use D-19 developer. Since H-a light is monochromatic, red, color film does not seem to have any advantage and lacks the high contrast needed in making good filtergrams.

Your exposure guide for disk detail would be 1/60 sec., but be sure to "bracket" your exposure on either side of 1/60 sec. (i.e. 1/125 and 1/30 sec. exposures) for the disk and 1/8 sec. (with a bracket of 1/4 and 1/15 sec.). Be sure to record the date, time (to the nearest sec. if possible), sun altitude or hour angle, and general sky and weather conditions since all these will affect your exposures.

Knowing the exact moment to release the shutter (I use an air release) comes from experience, the same kind of experience used in white light solar and lunar astrophotography. Let the image settle down after the previous exposure and wait for the boiling to let up before you make your exposure.

When photographing solar flares, which are not often observed, try to keep taking photographs as fast as is possible. Be careful to watch for quiet air moments, but even without steady air, keep shooting and hope for good luck we all need at times during picture taking sessions. [Also remember to keep recording times, and conditions (should they change) as you do this to increase the scientific value of your work. With flares, times to the nearest second are critically important.-Ed.]

In order to better understand your findings when observing and photographing the sun in white light and H-a, it is valuable to read books on solar observation. You can compare your filtergrams with those published. Soon you will become more sophisticated at understanding the differences in filtergrams at various wavelengths.

Experience the satisfaction in viewing the ever changing detail of the only <u>star</u> on which we can observe detail!

SOLAR PHOTOGRAPHY

by
Larry F. Kalinowski
and
Richard E. Hill

Most amateur astronomers do not observe the sun as a primary endeavor. As a result, they use a telescope designed for night observing as their solar telescope. In a majority of cases these telescopes are Schmidt-Cassegrains (SCT) with the remainder divided between refractors, and Newtonians. After many years of solar observing we have a number of tips that can make any amateur's solar photos better, especially if they own an SCT.

Let's first understand the conditions of solar observing. Daytime seeing is never as good as nighttime seeing because of solar heating.[2] In fact, at the best sites, one arc second seeing is experienced only 1% of the time![1] For amateur astronomers this figure is probably too generous as we usually cannot choose our observing sites! So, rarely, if ever, will a daytime aperture of over 4 inches be useful.

You should first know the focal ratio you are using. With just a camera and lens, the f-ratio will be whatever you choose to set on the lens barrel. However, when shooting through a telescope with your camera, the f-ratio must be calculated in all cases.

THE PRIME FOCUS METHOD (Camera, without lens, mounted to telescope without the eyepiece.)

$$\text{f-ratio} = \frac{OFL}{OD}$$

Where:
OFL = Objective focal length
OD = Objective diameter

THE AFOCAL METHOD (Camera, with lens, mounted to telescope with eyepiece.) Use the second of these if a Barlow or "extender" is used in the system.

$$\text{f-ratio} = \frac{TM \times CFL}{OD}$$

$$\text{f-ratio} = \frac{TM \times CFL \times BMg}{OD}$$

Where:
EFL = Eyepiece focal length
TM = Telescope magnification (OFL divided by EFL)
CFL = Camera lens focal length
BMg = Barlow/Extender magnification

THE NEGATIVE PROJECTION METHOD (Camera, without lens, mounted to telescope with a Barlow lens or extender and no eyepiece.)

$$\text{f-ratio} = \frac{OFL \times BMg}{OD}$$

MORE ON THE AFOCAL METHOD. The afocal method is by far the quickest method of through-the-telescope photography to set up. Both telescope and camera lens should be focused at infinity. First focus the telescope. Then adjust your camera lens at infinity or the farthest distance that will be in focus.

THE EYEPIECE PROJECTION METHOD (Positive Projection). With the positive projection system the camera lens is not used. The telescope eyepiece is used like a slide projector lens. The image formed by the telescope objective is projected, by the eyepiece, onto the film in the camera body. Adjusting the eyepiece position or the position of the film in front of the eyepiece will focus a second image on the film. Obviously, a single lens reflex camera or camera body with a focusing screen must be used.

This system offers advantages the others do not. First, the second focus image on the film can be varied in size by changing eyepieces (a shorter focal length eyepiece will produce a larger image) or changing the film distance (moving the film plane farther away will also produce a larger image). Second, longer effective focal lengths (for photographing solar surface details) are produced with this system. However, it must be realized that longer effective focal lengths produce higher f-ratios with correspondingly longer exposure times.

Below are the necessary mathematics for determining the parameters of your photographic system with positive projection:

$$PM = \frac{B}{A}$$

$$\text{f-ratio} = \frac{PM \times OFL}{OD}$$

Where:
PM = Projection magnification
A = Distance between objective lens focus and center of all optical elements in the eyepiece.
B = Distance between center of all eyepiece elements and camera film plane

F-RATIOS, TELEPHOTO LENSES AND EXTENDERS. One of the fastest ways of putting together a long focal length system is to use a 2x or 3x extender with one of your longest telephoto lenses. Solar eclipse photographers need anywhere from 500 to 1,000 mm to capture the corona properly on 35mm film. Getting an image large enough to see detail in prominences will require 2,000 mm...at least.

Extenders are available at most photographic dealers at modest cost, considering the price of a new telephoto lens. They are designed to fit between your camera body and lens, and are also available for automatic diaphram lenses. They can be stacked in combination to produce even longer focal lengths, however, the image quality produced should not be expected to be the same as the quality produced with just the telephoto lens alone. In fact, no more than one extender is recommended unless the cost of a longer telephoto is prohibitive.

To find the equivalent focal length of a telephoto lens and extender in combination, simply multiply the extender magnification by the focal length of the lens. For instance, a 3x extender with a 500mm lens will produce 1,500mm. A 2x extender with a 200mm lens produces 400mm.

How about two extenders and a lens? Well, a 2x and 3x extender with a 500mm lens produces a grand total of 3,000mm (2x3x500 = 3,000).

All those millimeters are great for astrophotography, but there is a hitch. Your f-ratio also changes with the addition of an extender. Whatever f-ratio you have set on the lens barrel must be multiplied by the extneder magnification. An f/3.5 setting with a 3x extender becomes f/10.5. An f/8 becomes f/24.

The Barlow lens is a similar device, an achromatic, negative lens that is designed to fit into the eyepiece holder of your telescope rather than between camera lens and body. The telescope eyepiece then slides into the Barlow lens. It too is available in 2x and 3x models and it changes the telescope objective parameters (both focal length and f-ratio) in the same manner as the extender, Both optics function in the exactly the same manner, the only difference being the physical size and type of mounting or cell each uses. Some brands of camera extenders are available in zoom form so that the magnification can be varied between 2x and 3x. Standard Barlow lenses can be altered to produce magnifications other than 2x, however, the position of the negative lens in its cell is quite critical and should not be changed unless the user is sure the optical axis of the lens will remain in proper alignment.

CALCULATING YOUR FILM IMAGE SIZE. Quite often the first attempt at photographing the sun is sadly disappointing because the budding solar astrophotographer expects to see a much larger image on the film than is actually there. Even if a single lens reflex type camera is used, the image on the ground glass will not truly represent the image because of light scattering by the ground glass and/or improper focusing. The linear size of the image on film can be determined by the formula:

$$S = \frac{A \times FL}{57.3}$$

Where:
S = linear size
FL = Total effective focal length of the system
A = Angular size of object, in this case the Sun.

In the case of the Sun this general formula approximately reduces to:

$$S = 0.1 \times FL \text{ (in inches)}$$

FILMS FOR SOLAR PHOTOGRAPHY. The best film (in the U.S.) to use for solar photography is Kodak's Technical Pan Film #2415 (TP2415). It's a high contrast, black and white film normally used for photocopy and graphic arts work. With some special developers this film can also be used as a high resolution continuous tone medium. Color films, with their thick, multiple layers of emulsion, defocus the image too much to be useful. Also, with color film there is little control on contrast so you get contrast for portrait photography - too "flat" for solar work. Most black & white emulsions are too grainy. Technical Pan is readily available and nearly grainless if handled properly. If you cannot get TP2415 the try using any graphic arts film like the old Kodalith or High Contrast Copy Film.

DEVELOPERS AND DEVELOPMENT. Unlike nighttime astrophotography, maximum contrast is not necessary. With Technical Pan and it's inherent high contrast, we must be careful for too high a gamma (contrast) can cause loss of information in solar photography. Best results in the Solar Section have been achieved with less contrasty developers like HC 110 (dilution B), modified POTA, and Technidol. These last two are much the same. In solar photography exposure and processing should be such that there is no loss of umbral or penumbral detail at the center or edge of the disk. This is tricky due to limb darkening. With D-19 the edge is often burned away in order to capture details in the center of the disk or the center is "washed out" if the edge is properly exposed. The only other alternative is to make a mask to suppressed limb darkening. This is complicated and can cause the loss of facular detail. It is better to have a less contrasty negative and to control contrast in the printing process.

In detailed photographs of individual features higher contrast developers, like D-19, can be used effectively. But near the limb pulling the detail out of such a contrasty negative with the strong limb darkening will require good printing skills!

SHARPNESS AND FOCUS - THE SKY'S THE LIMIT. Many new observers in the Solar Section submit photos exhibiting severe loss of detail. In nearly every case the cause is due to one of two factors, sometimes both. The first is motion, either of the instrument of atmosphere. Too slow a shutter speed can allow seeing, vibration or drive errors to smear the image. We have lots of light in solar astronomy so why not use it? A filter suitable for visual use is too dense for photography. Camera shutter speeds would be around 1/30 to 1/125 second. The exposure time should be as close to 1/1000 sec. as possible. If you have a multiple layer Mylar-type filter then you might consider mounting each layer separately so lesser density (a single layer) could be used for photography. But, remember, this will not be safe for visual use!! Do not use it around children as they will always try to look when your back is turned! At 1/1000 sec. most atmospheric turbulence and instrumental motion will be frozen. In face, with such an exposure time you will not even need an equatorial mount to catch details of one arc second.

The second factor that causes loss of detail in amateur photographs of the Sun is petzval curvature. All non-concentric SCT's have curved focal planes. In the case of the popular 8 inch f/10 design, the curve works out to be between 150 and 160 mm, curved in the same sense as the primary mirror. This is like the surface of a basketball! [3] For nighttime photography this is not a problem since exposures are long, the image moves about due to seeing, and the film is usually color which cannot resolve the defocusing. But with solar photography of 1/1000 sec. on TP2415, the film has to be curved to fit the focal plane or you will not be able to get both the center and edge of the Sun (or Moon for that matter) in dead sharp focus. This was a big problem for us when we first started the Solar Section. We could not get photographs where penumbral filaments could be seen at the center of the disk but the edge was fuzzy or vice versa. We tried routines of focusing at intermediate distances from the center of the disk but this left both the center and edge a bit out of focus and only a ring between in focus. Then, using a tip from the photographic industry, we found by stopping the instrument to f/20 (4 inch aperture for the 8 inch SCT) the depth of focus was increased enough so good focus was obtained across the whole disk. Since one arc second is about the best you can expect to attain in the daylight, a 4 inch aperture resulted in no loss of detail. Stopping down reduces seeing problems too since a greater depth of focus means the focus can vary by a greater amount without defocusing. Turbulence or "seeing' is caused by air or "seeing cells" of different temperatures and therefore refractive indices passing in front of the telescope. This changes the focus if the cells are the same sizes or larger than the aperture.

No matter what kind of telescope you are using, your photos will improve if you observe before noon (the time maximum heating of the air occurs) and if you restrict the observed bandwidth. At great zenith distances such as those the Sun will be at in the morning, refraction is greater than one arc second.[4] If you are to make good detailed photographs then you need to use a filter/film combination that limits the observed portion of the visual spectrum. TP2415 has a strong H-alpha primary peak response with a secondary response in the violet to ultraviolet (UV), where silver halide is sensitive. By using a filter that cuts out the UV end of the spectrum (which even Mylar-type filters do to some extent) you make use of the H-alpha peak and effectively have a filter. Any further filtration around H-alpha (to ±100 Angstroms or better) will improve the image even more.

Along with these suggestions you should follow good photographic procedures. Always bracket your photographs by making an exposure one stop above and below the optimum. This will ensure that you will have a good negative regardless of unnoticed sky transparency changes, or mechanical variations (shutter speed, filter deterioration, coating deterioration, etc.). Since you will have to set up your photographic routine for your own individual conditions it will therefore be unique to you. No two observers have the same parameters. For this reason more specific suggestions cannot be made.

These are our suggestions borne out by the work of many observers over many years. We encourage experimentation but always with extreme caution. If you are unsure of what you are doing, don't do it! Never endanger your eyes!! It will take a bit of time to set up a routine, but it is time well spent.

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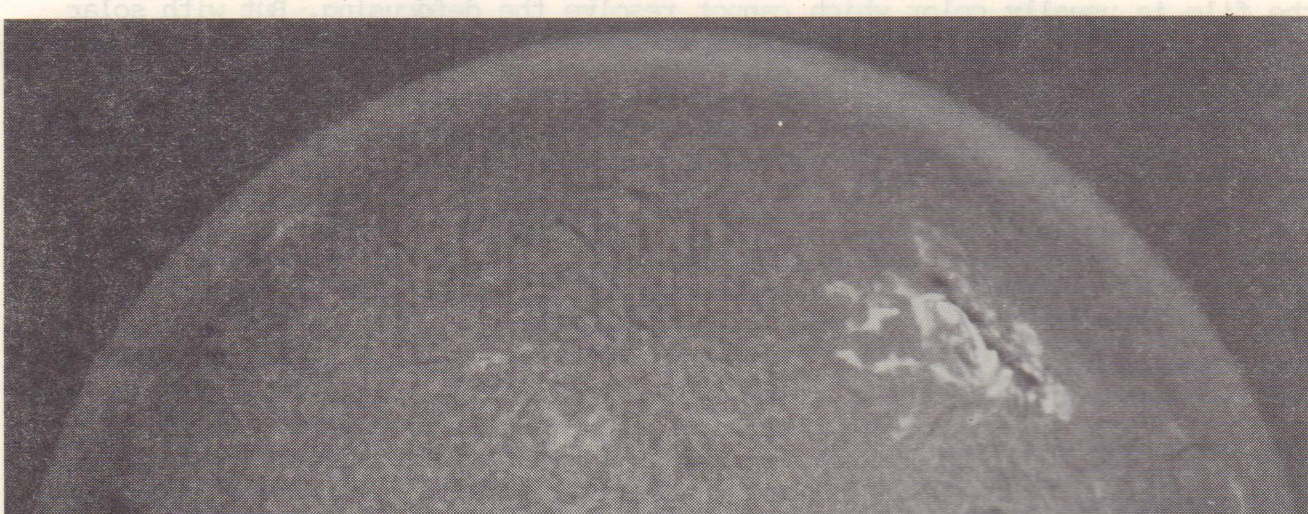
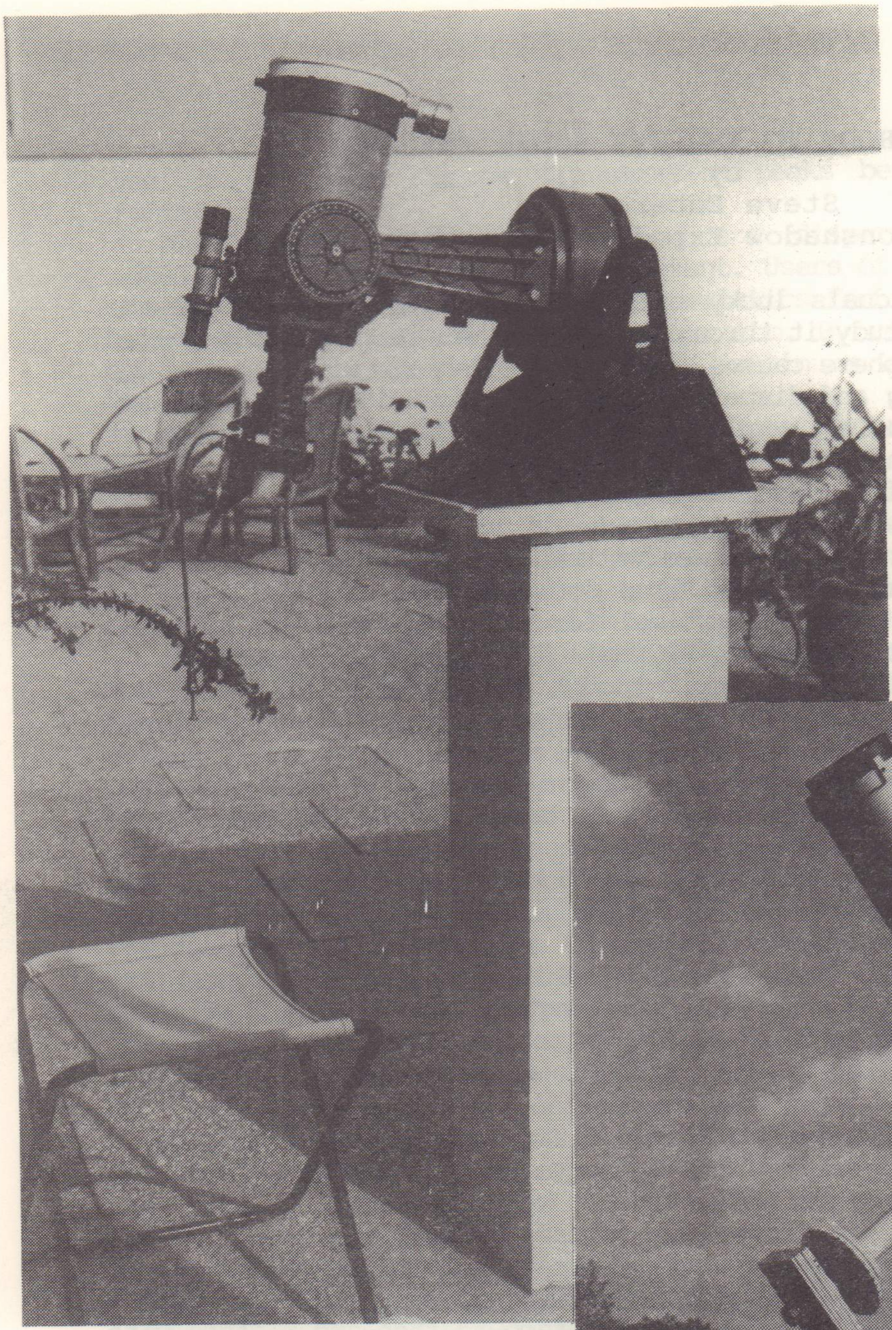
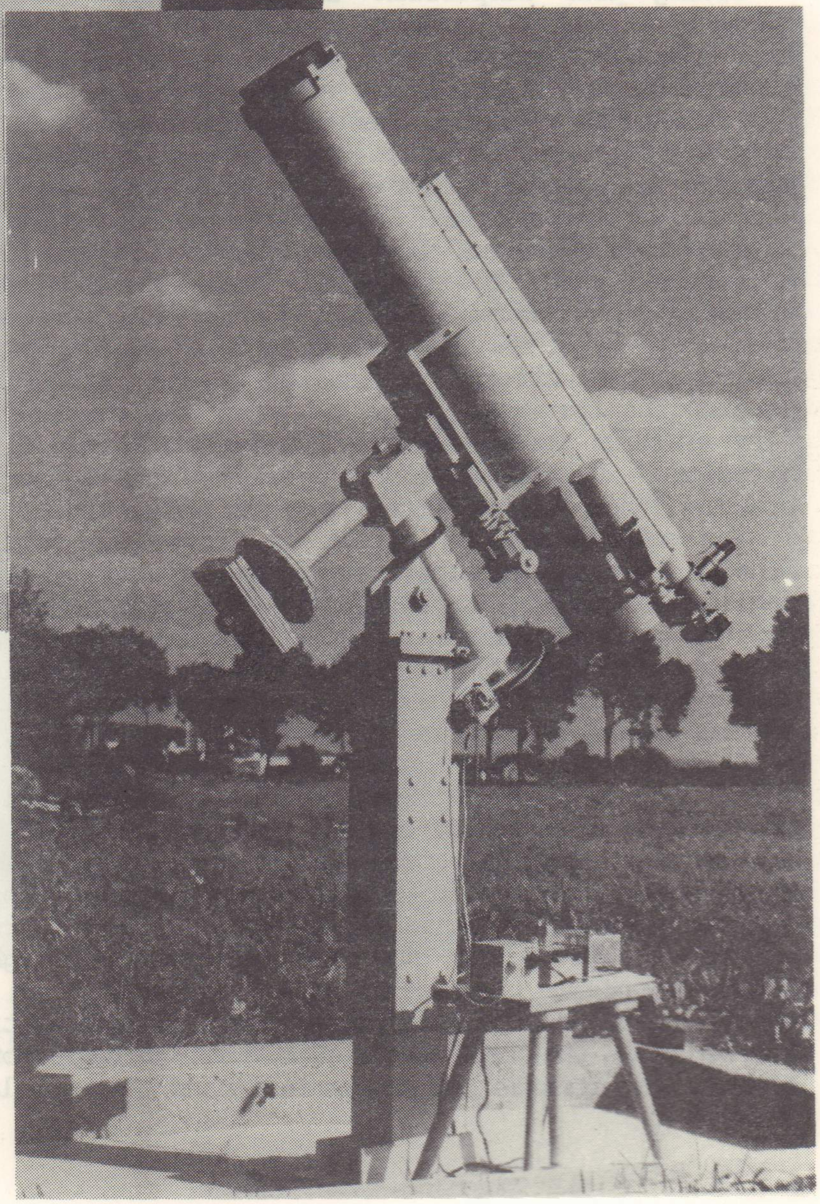


A large sunspot group in flare as seen in H-alpha light on 1989 03 14 1713 UT.
Photo by Robert Morris.



A 5 inch Celestron with which Dr. Jean Dragesco photographs the sun from Benin, West Africa.



A photographic solar folded refractor of H. Treutner of Germany.

SIMPLE METHODS TO IMPROVE SOLAR IMAGES

by
Steve Edberg
Moonshadow Expeditions

Except for the few individuals lucky enough to observe the sun above the atmosphere, most of us must study it through what at times is charitably called "pea soup". The earth's atmosphere causes a number of problems with images. The two most important are seeing and dispersion for the discussion here. "Seeing" refers to the constantly changing, varied distortion of the solar image, most easily seen as changing waviness around the limb of the sun. Dispersion is the result of the varying index of refraction of the atmosphere with wavelength. It is simply chromatic aberration originating outside the telescope (with both refractors or reflectors). An object viewed with dispersion affecting it will show a short spectrum: a rainbow-colored line for a star or colored edges at top and bottom with respect to local vertical for the sun, moon, or planets. The "green rim" seen on the sun at sunset is partially caused by dispersion.

Seeing and dispersion act together, though independently, to reduce image quality. While our present technology cannot prevent these problems from reaching out telescopes, there are optical methods which can minimize their effects. Conveniently, some of the same techniques work on both problems.

FILTRATION. Usually, photospheric images are taken with filters that are only roughly neutral (i.e. absorbing all wavelengths equally). In fact, the color seen with a solar filter indicates the portion of the spectrum less blocked by the filter. Seeing causes distortion all across the disk at all wavelengths. However, because of the dispersive effects of the atmosphere, different colors in the white light image (combination of all colors) are affected by different amounts, with blue wavelengths more strongly affected than red - just as a prism bends blue more than red in making a spectrum. To minimize the effects of seeing a red filter, allowing only limited red wavelengths through, should be used. The dispersion, and thus the seeing, can vary even in the wavelengths transmitted by a plain red filter. Of course, a narrowband filter in any region of the spectrum will work better than a braodband or neutral filter, but red works best.

The color-spreading effect of dispersion spreads each image point into a line of lesser or greater length depending on the altitude of the object. It is negligible high in the sky, but can seriously hamper resolution farther down. A pair of optical wedges (thin prisms) can be used face-to-face and rotated with respect to each other to cancel out the atmospheric dispersion with their glass dispersion. A simpler method is to use a color filter to limit the wavelengths in the image. This cuts the image "lines" short, and the narrower the filter band the shorter the line. Thus the resolution is improved. A filter of any color will work but a red, narrowband filter will minimize the effects of both dispersion and seeing.

Suitable wideband color filters are available from camera stores and astronomical equipment manufacturers. Narrowband interference filters are generally expensive from the various manufacturers, However, they can be found on the surplus market. Note that a nebular or light pollution reduction filter (used by night observers), when combined with a suitable broadband color filter, becomes a narrowband filter. The combination will transmit only in the narrow peak that allows transmission through both the wide and the nebular filter. Investigate the transmission of the nebular filter to confirm that it has one or more narrow transmission peaks before selecting the broadband filter.

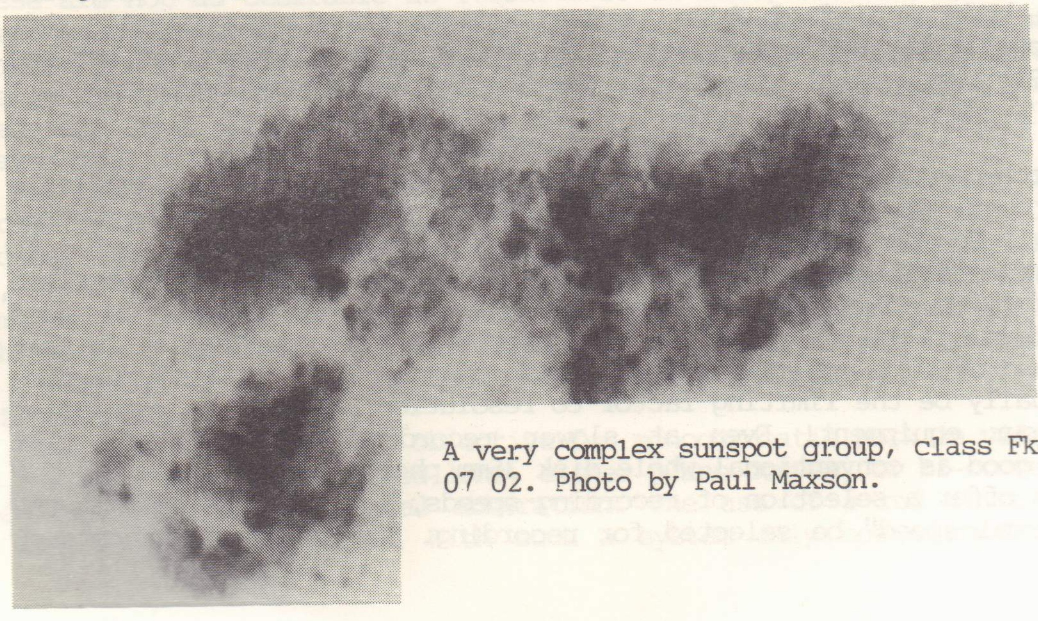
NARROWBAND FILTERS. For seeing and dispersion reduction the specific wavelength of the filter is unimportant. Users of H-alpha filters have a filter exactly matching the favored characteristics for reducing seeing and dispersion and they can observe the chromosphere too. By varying the temperature or tilt of the filter they can also tune to continuum wavelengths for studies of the photosphere.

A common problem, though, with H-alpha photographs made with sub-Angstrom width interference filters is that they usually appear to be off H-alpha line center by a fraction of an Angstrom, even when the filter temperature is correct. This results in lower contrast images not of the chromosphere itself, but of a layer beneath it. The problem occurs because the filter is not mounted perpendicular to the telescope's optical axis. Autocollimation is necessary to assure the filter is oriented properly.

The autocollimation procedure is simple. For filters mounted between the objective and focal plane, study the position of light reflected back out the objective from the filter when the instrument is pointed at the sun's center. A flat, white, small, lollipop-shaped probe should make it easy to see where the outgoing beam strikes the objective. If this beam is not returning centered on the objective the filter is tilted and its orientation needs correction.

For filters used between the sun and the objective a bright image produced by another telescope should be placed at the focal plane of the H-alpha instrument. Leaving the filter off and placing the image at the solar instrument's focal plane so light is going backward through the solar telescope, make certain the optical axes of the telescopes are aligned (the lollipop probe should be useful for this). Once this is confirmed, mount the filter in place and check reflections at the joint focal plane to confirm the filter returns the beam to center.

Using methods described here, observers may significantly improve their results, and at minimum cost and the techniques described can be modified for use in night observing programs. Both visual and photographic results will be significantly improved.



A very complex sunspot group, class Fkc, of 1988 07 02. Photo by Paul Maxson.

VIDEO SOLAR OBSERVING AND RECORDING IN WHITE LIGHT AND H-ALPHA

by
Alex Panzer
Ohio Spectrographic Service
Edited by
R.E.Hill

INTRODUCTION

In recent years, the vidicon TV camera has become inexpensive, and available to almost anyone with a moderate observing budget. With such a camera, a VCR, and some additional electronic equipment, the amateur and professional solar observer can record both real time, and long period solar activity.

While the cost of Charged Coupled Devices (CCD's) are dropping to competative levels, there are two major problems they present to the solar observer. The formats or detection areas are small and there is a tendency for pixels to "bloom" or be affected by adjacent pixel overload when these devices are used at high light levels. Fortunately, at the time of this writing, vidicons are much more inexpensive than comparable CCD's of the same resolution and light detection parameters.

There are many types of vidicon cameras available on the market. Today, all are solid state with very long operating lifetimes. Many are designed for "security observation" and have high light sensitivity. Such cameras are not suited for solar work since most have automatic light level or "gain" control (AGC) that tends to average light inputs, and increases or decreases sensitivity to average total light imput. This often means that in H-alpha, solar prominences tend to be washed out due to the higher intensity of the solar disk. The camera reduces total sensitivity to give a good image of the brighter solar disk reducing the apparent brightness of a prominence rendering it invisible. This AGC should be bypassed allowing manual control of light levels. This is usually easy and can be done by video camera suppliers and repair shops by the change of a few diodes, or connection of jumpers to avoiding AGC control.

These suggestions only apply to black and white video cameras, NOT COLOR cameras. There is nothing to be gained by using a color camera since the solar image in white light is indeed white, and in H-alpha it is all monotonic red! Further, the cost of the B&W camera versus the color is much lower, and for the most part the B&W camera will have higher overall resolution and contrast.

RECORDING THE SOLAR IMAGE

With a vidicon cameral a VCR will be needed. Many of these are now available at reasonable cost. As with the camera, the better the resolution the better the final image. So the buyer of a VCR (and vidicon camera) should strive to get the highest resolution equipment, (horizontal and vertical line) possible within their budget. Even an inexpensive 2 head VCR is capable of good recording capability. The so called '4 head VCR' has some advantages, in that still images and/or high speed images are also better. Keep in mind, daytime seeing will usually be the limiting factor to resolution and not the resolution capacity of your equipment! Even at slower recording speeds images will probably be as good as conventional whole disk 35mm photography.

As all VCR's offer a selection of recording speeds, it is suggested that the highest or "normal speed" be selected for recording. The higher the recording speed, the greater the potential resolution! In addition, if copies of original tapes are to be made, higher recording speeds improve reproduction copy quality.

An important addition to a solar recording observatory is the video enhancer. Several are available, offering greater versatility to observers -similar to darkroom manipulation in photography. Of two we have used, the "MFJ Corp." video enhancer has proved to be the best at reasonable cost. Radio Shack has a more simple, less expensive enhancer which will add much data to picture, but is limited in available adjustment parameters. Even so, it is amazing to see the solar detail that can be pulled out by electronic means.

The electronic equipment market is growing by leaps and bounds spurring the development of new products. CCD's will soon be available at prices competative to vidicons and newer technology, digital TV, and "frame grabbers" (once called "slow scan TV") will allow resolutions higher than is now acheivable with convention film photography. The "frame grabber" feature may well be an important tool in the future for solar astronomers.

CONSIDERATIONS FOR THE TELESCOPE

Comparisons of video image versus visual image seems to show as much detail or more on video, with enhancer, than seen through direct observation or in projection. Our solar observing is done from a fixed optical observing position. There is a distinct advantage to this fixed observing position. The viewing room is enclosed (heated in winter, air conditioned in summer) isolating the observer and recording equipment from the outdoors. A horizontal heliostat is used to transfer the solar image into the observing room.

As with a fixed observing position, a fixed input beam is a decided advantage! In our system, the optical output entering the observing room is sent to an X-Y optical scanning bench where further equipment may be added and adjusted in X-Y, and vertical-horizontal positions. Tracking and image motion control are done with only two relatively light flat mirrors, not a heavy telescope. Once the permanent heliostat is set up and adjusted, it remains in that position ready for observations at a moments notice. No repeated set-up and take-down time is required.

Many amateurs use reflector or compound telescopes for solar work. These are not as desirable as refractors. In fact, reflectors of any kind are never as advantageous as refractive optical systems. Each mirror surface adds scatter to the final image and in telescopes with central obstructions the energy rejection pre-filter (ERF) must be off axis, introducing coma. A wedge used with this type of system to correct coma, and an H-alpha filter still leaves some distortion.

For the best results, a telescope (refractor or reflector) must operate at a focal ratio of f/20 to f/30. Even with a telescope as large as a C14, the ERF reduces the telescope aperture toabout 4 inches. Daytime seeing being what it is, more than 4 or 5 inch aperture is not necessary. It should also be remembered, that when working with monochromatic light (such as H-alpha) an achromatic objective lens is NOT REQUIRED, and if an achromat is used it should be cemented, not air spaced to reduce scattering and inter-surface reflectiobns.

In my opinion, the ideal objective for monochromatic work in video or visual is a single element red glass lens, either plano conves, or bi-convex, that has been corrected for spherical abberation. The use of a red glass lens serves as both objective and ERF. With such a system only one element lies in the optical path and scattering is greatly reduced resulting in increased contrast. This red lens can be fabricated to f/20 or f/30 with little difficulty from Schott glass filter blanks or those of other glass suppliers. I have made several such single red glass lenses from camera filters such as Wratten 25, or better still, Wratten 29. Aircraft camera filters are available in diameters up to 7 inch at low cost from surplus suppliers. But, 2 to 4 inch diameters are ideal and thick enough for the long focal lengths (and mild curves) involved.

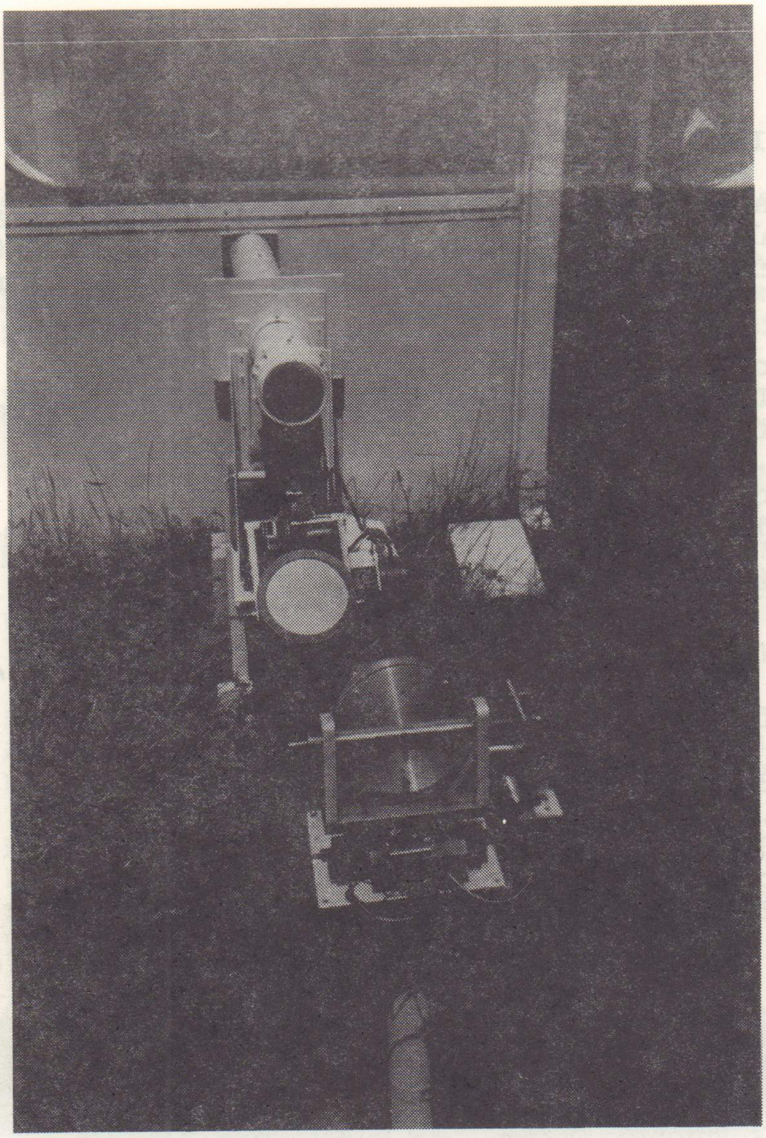
If a conventional telescope is to be used with white light video recording equipment, then a cemented achromat is first choice, an air spaced achromat is second and a reflector (or catadioptric) third. A metal coated objective or pre-filter should be used with a density much the same as that required for visual observation. Additional optics can be used in the white light system since the white light image has much higher contrast than the monochromatic one. and more light is available.

A 4 inch aperture, f/20 (80 inch focal length) or f/30 (120 inch focal length) telescope is a lot of tube to swing over the sky. One way to reduce tube length is to use a short focal length objective, and to introduce a Barlow, or positive projection lens. Both work well for white light observation. If the TV camera has a zoom lens with macro, it can be used to advantage to change image size, blowing up an interesting area of the solar disk. One of the best optical systems we have found is the so called "collimating" arrangement where two cemented achromatic lenses are used, one on either side of the H-alpha filter. Lenses such as a pair of 7x50 binocular objectives can be used. This is similar to optics used in prism spectrographs so the image seen is in collimated, or parallel light. Tube length is another argument in favor of a fixed position, horizontal telescope.

Projection with a Barlow lens is quite satisfactory, and probably preferred over positive lens projection unless the lens is designed specifically for projection and not just eyepiece being used for projection. If a single element red glass objective lens is used for monochromatic video, then a single, concave, red glass lens can also be used as the Barlow, providing some additional ERF protection. Being a single element, it has less scattering than the achromatic Barlow.

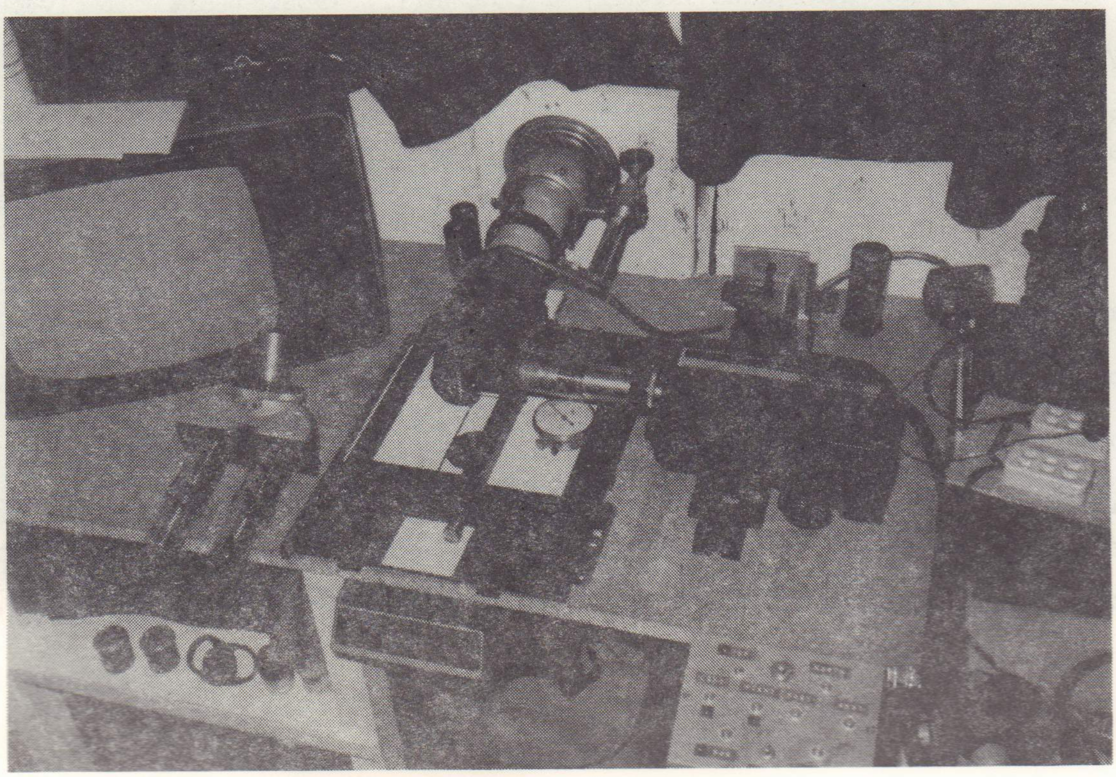
Finally, an interesting complement to video solar observation, or for that matter, any type of solar observation, is the use of Very Low Frequency (VLF) radio monitoring to both detect, and alarm the observer to solar flares. I use a detector designed by Mr. Arthur Stokes of Hudson, Ohio, a prominent AAVSO participant, who recently became interested in solar work. It is a simple radio receiver operating at VLF's of 25 to 30 KHz (Just above the ultrasonic audio region). There are several military radio stations operating 24 hours a day, with multi-megawatts of power, at these frequencies. They produce a strong signal that we monitor both on a strip chart recorder, and a relay alarm trigger attached so a deviation of detected signal, either up or down (that is increase or decrease of signal strength) will trigger an audible alarm signal warning us that a solar flare is in progress. Stokes and I have both detected and verified flare activity with better than 95% reliability for some time now.

Video monitoring used along with VLF monitoring allows the observer to turn on the telescope system when activity warrants it. With several video monitors one can track the sun all day without having to sit at the eyepiece constantly. The radio/alarm can call one to the TV monitor observe as the video system records the event in real time!



ABOVE: An exterior view of Mr. Panzer's two mirror coelostat that feeds a 4 inch red glass, single element objective. The mirrors are 6 and $4\frac{1}{4}$ inches diameter, and both 1/20 wave.

BELOW: An interior view of the telescope with video camera attached and monitor.



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A string of complex sunspot groups near the limb on 1989 09 09. Note the facular filigree. Photo by Prof. J. Dragesco.

THE ASTRONOMICAL LEAGUE
SUN SPOTTERS

The purpose of this program is to encourage solar observing with an eye toward educating the amateur astronomer on solar features and their evolution. By following this regimen the observer will learn the various features of solar activity, learn how these change during their passage across the disk, and learn how to develop a regular observing program.

The program is divided into two parts. The first part assists the observer in the identification of solar features, their classification, and how to note observing conditions. The second part encourages the observer along in regular, standardized, systematic observing. Completion of the first part entitles the observer to PROVISIONAL MEMBERSHIP in the Astronomical League Sunspotters. Complete the second part within one year and you will gain PERMANENT MEMBERSHIP in this League club.

RULES

PART ONE

This should be done for five days, not necessarily consecutive. On a plain white piece of paper draw a 2 x 4 inch box. In that box draw a sunspot group that you observe. Draw only while you are at the telescope and add nothing afterwards. Below the box note the following: Universal Date/Time of the completion of the drawing to the nearest minute, the position of the sunspot group (use the supplied Stonyhurst Disks), the sunspot class (see the article in this book), telescope aperture used, telescope focal length, eyepiece focal length, filter type, magnification, sky quality (E=excellent, G=good, F=fair, P=poor), and seeing (smallest detail seen) in arc seconds where a photospheric granule is 1.5 to 2 arc seconds.

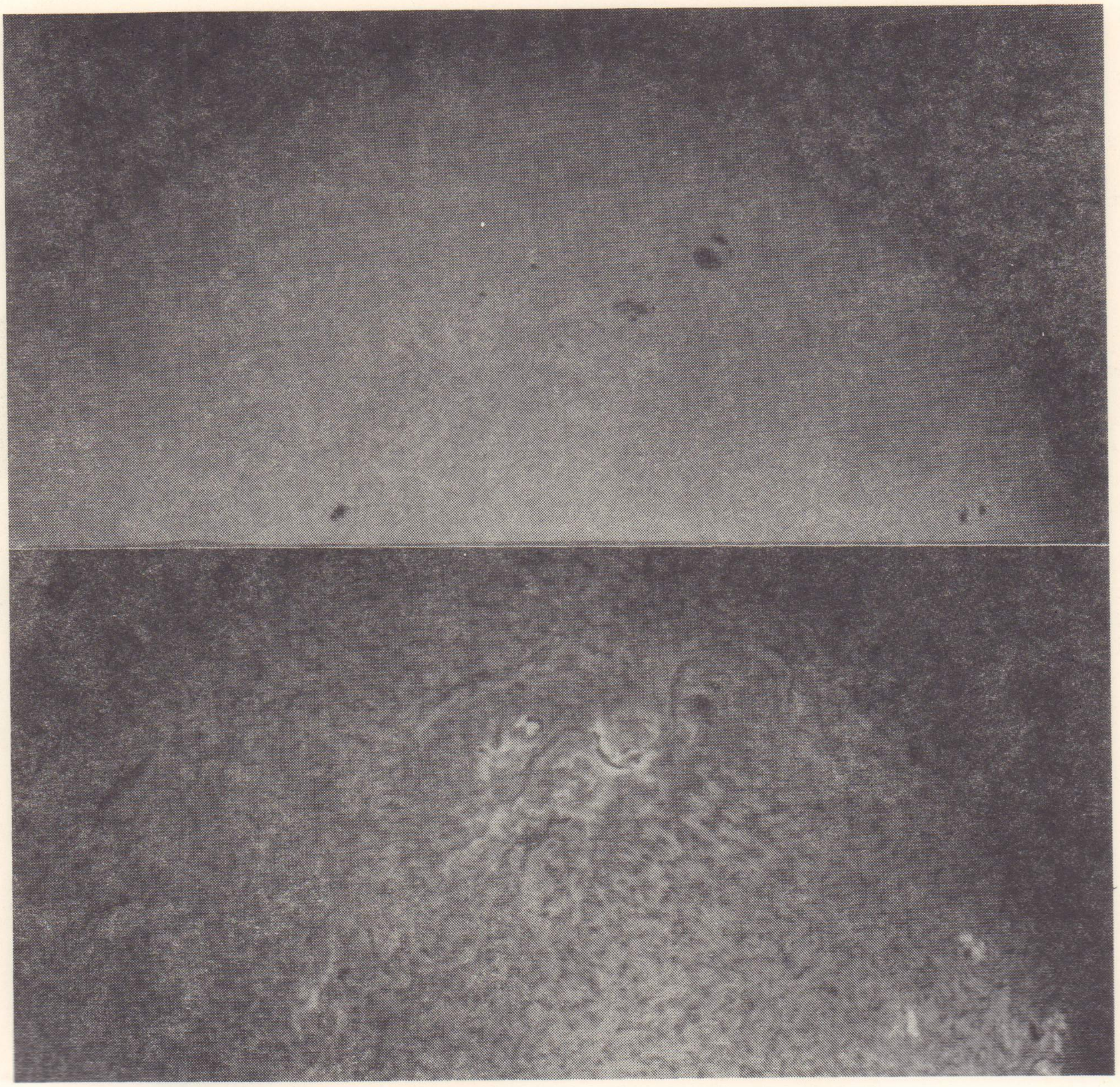
On this same drawing identify the following: umbra, umbral spot, penumbra, facula, and light bridge. In order to identify all these you should choose a rather complex spot group of Modified Zurich Class D, E, or F, and observe it near one of the limbs. If you use an aperture of 4 inches or greater you should also identify the following: granulation, penumbral fibril, penumbral grain.

Have these observations examined by an Officer, or Chief Observer of your Society or a qualified, observational experienced second party. Have this person write a note verifying the work. Send this note and copies of the observations to the Astronomical League Observing Awards Coordinator listed with the League officers in the League publication THE REFLECTOR. Then a CERTIFICATE OF PROVISIONAL MEMBERSHIP in the Astronomical League Sunspotter Club, will be forwarded to the Officer or secondary party for presentation. This will be a quality document, suitable for framing.

PART TWO

Using the enclosed A.L.P.O. Whole Disk Drawing Form, observe and sketch the whole disk of the sun throughout the passage of large sunspot groups during three different rotations. It does not have to be the same group. Do not color or shade in the penumbrae, only outline the outer border of the penumbrae while coloring in the umbrae. (This is standard procedure at professional solar observatories.) At least one of these three sunspot groups should exhibit the so called Wilson Effect. Classify all groups on the disk and note same on the small disk provided on the form. Be sure to fill in all the blanks in the form, computing the sunspot number for each day. Be sure to use accurate Universal Time to the minute. All drawings will be checked. It is realized that weather conditions may inhibit daily observing, but at least half of the days for any given rotation should be observable.

Have your work examined by an Officer, or the Chief Observer of your Society, or a qualified, experienced second party if you do not belong to a Society. Have them submit a letter verifying that you have completed the project specified above. Send copies of the observations, your membership Certificate, and the letter to the Astronomical League Observing Awards Coordinator referred to above. The Certificate will then be validated for PERMANENT MEMBERSHIP with the Astronomical League Sunspotter Club, and returned to the verifying person for formal presentation.



The sun photographed in both white light and H-alpha on 1989 09 30 showing a small flare . Photos by Gordon Garcia.