THE NEW

OBSERVE AND UNDERSTAND THE SUN

EDITED BY

Richard E. Hill
Coordinator - A.L.P.O. Solar Section
Senior Research Specialist
Lunar & Planetary Laboratory
University of Arizona

Astronomical League
Science Service Building
1719 N. Street, NW
Washington, D.C. 20036

THE SUN IN WHITE LIGHT

by

Walter Scott Houston
Frederick N. Veio
Walter C. Wheeler

Visual observation of the Sun with proper filtering or by projection will show sunspots, 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 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 grey lines, perhaps one arc second in width and a degree or more (heliographic degree) 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 directly 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 sunspot count, many experienced observers prefer to make their observations by the projection 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 the 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.

Welder's Filters. Filters used in the helmets worn 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. Welder's filters may be readily had through most welding supply houses. These filters are usually rectangular in shape with dimensions of about 2x4 inches. The welder's filters, as manufactured by American Optical Co., are plane parallel and optically flat to at least one fourth wave in sodium light. Some welder's supply houses offer such filters which have been cut into discs about 50mm in diameter.

The Herschel Wedge is a shallow triangular piece of glass [crossection] 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 [when one surface of this wedge is used as an uncoated diagonal mirror in a Newtonian or refractor -Ed.]. 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 3-5% of the light reflected into the eyepiece is still intense enough to require filtration! Based upon testing by R. Maag, it is recommended that at density equivalent to a welder's 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 are largely unaffected and so reveal a much sharper solar image and one with much finer detail.

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 year 1975, when the daily sunspot count was 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. Eye strain is significantly less with the 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 rpm. 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. [Named after the former Chairman of the AAVSO Solar Division. -Ed.] Essentially, the Hossfield Pyramid consists of a truncated pyramid made from stiff cardboard or plywood with 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 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. [R(I) is known as the "International Sunspot Number" while R(A) compiled by the AAVSO is known as the "American Sunspot Number". -Ed]

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 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 within 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 THREE DIMENSIONAL SUNSPOT CLASSIFICATION SYSTEM

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

In 1938, M. Waldmeir devised what is now known as the Zurich Sunspot Classification System of sunspot groups. [Waldmeir 1955] It consists of nine steps or classes (A through J, omitting I) that delineate 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 later 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 was 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 based 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 releasing 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-alpha, 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 (blue and near UV at 3968.492 and 3933.682 angstroms respectively). Some are bright enough to be seen even in the combined light of the whole visible spectrum, white light.

But in order for flares to be observed and studied by the astronomer, a more predictive 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 weed out many of the less productive groups.

In 1966, Patrick McIntosh of the Space Environment Services Center of the National Oceanic and Atmospheric Administration introduced a sunspot classification system that improved the older Zurich system. The new classifications consist of three letters. First is the Modified Zurich Class. It basically retains the old Zurich Class, but G and J were removed as being redundant. A Modified Zurich Class was used rather than a totally new system, making it easier for observers to switch to the new system. The second letter represents an assessment of the largest spot of the group. This is not necessarily the leading spot, but rather the LARGEST. The third letter represents an assessment of the spot distribution within the group. It takes only slightly longer than the old system to classify all the groups on the Sun for a given day using the McIntosh System, but the information returned and its usefulness makes it worth the added effort.

In order to understand the McIntosh Classification system better, two terms have to be defined:

Unipolar Sunspot Group

This is a single spot or compact cluster of spots with the greatest separation between spots being less than 3 heliographic degrees (degrees on the Sun's surface). With a Class H group the separation is taken to be the distance between the outer border of the main sunspot penumbra and the most distant attendant umbra.

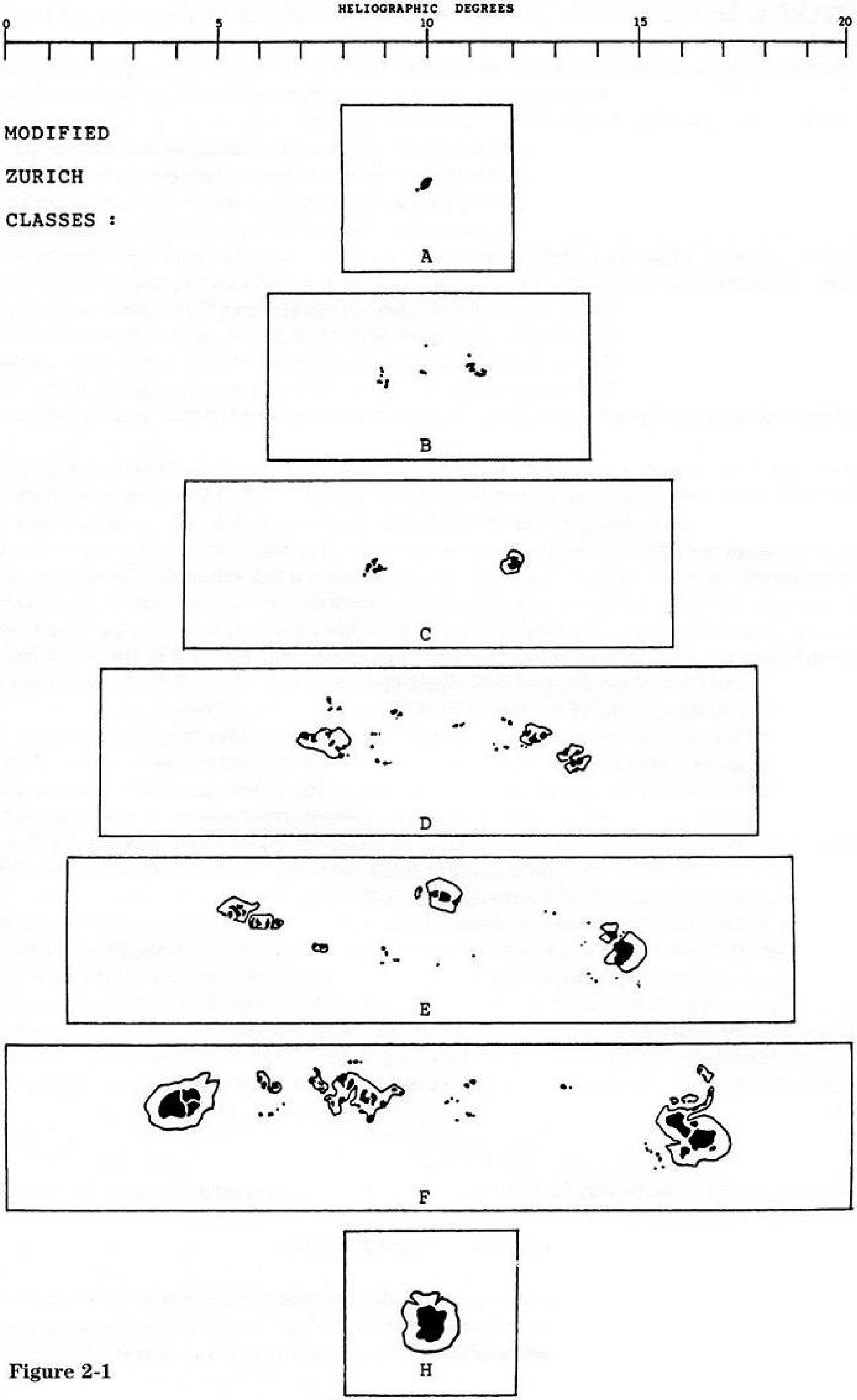

HELIOGRAPHIC DEGREES
0
5
10
15
20
MODIFIED
ZURICH
CLASSES :
A
B
C
D
E
F
H

Figure 2-1

Bipolar Sunspot Group

This is 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 degrees in extent.

Now that we have these defined, below are the descriptive text that define the various classes in the McIntosh System. (All degrees are heliographic.)

For the Modified Zurich Classes: (for visual representations of these letters, see accompanying figures.)

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 umbra.
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 10-15 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 of a bipolar group

For the Largest Spot:

(North-south diameters are used since they suffer no foreshortening during rotation.)

x - No penumbra (for groups with classes A & B)

r - Rudimentary penumbra that usually only partially surround the largest spot. Such a penumbra will likely be granular rather than filamentary, making it appear brighter than a mature penumbra. The width of the penumbra will only be a few granules (of the photospheric granulation) 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.

a - Small, asymmetric 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.

For Sunspot Distribution:

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

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

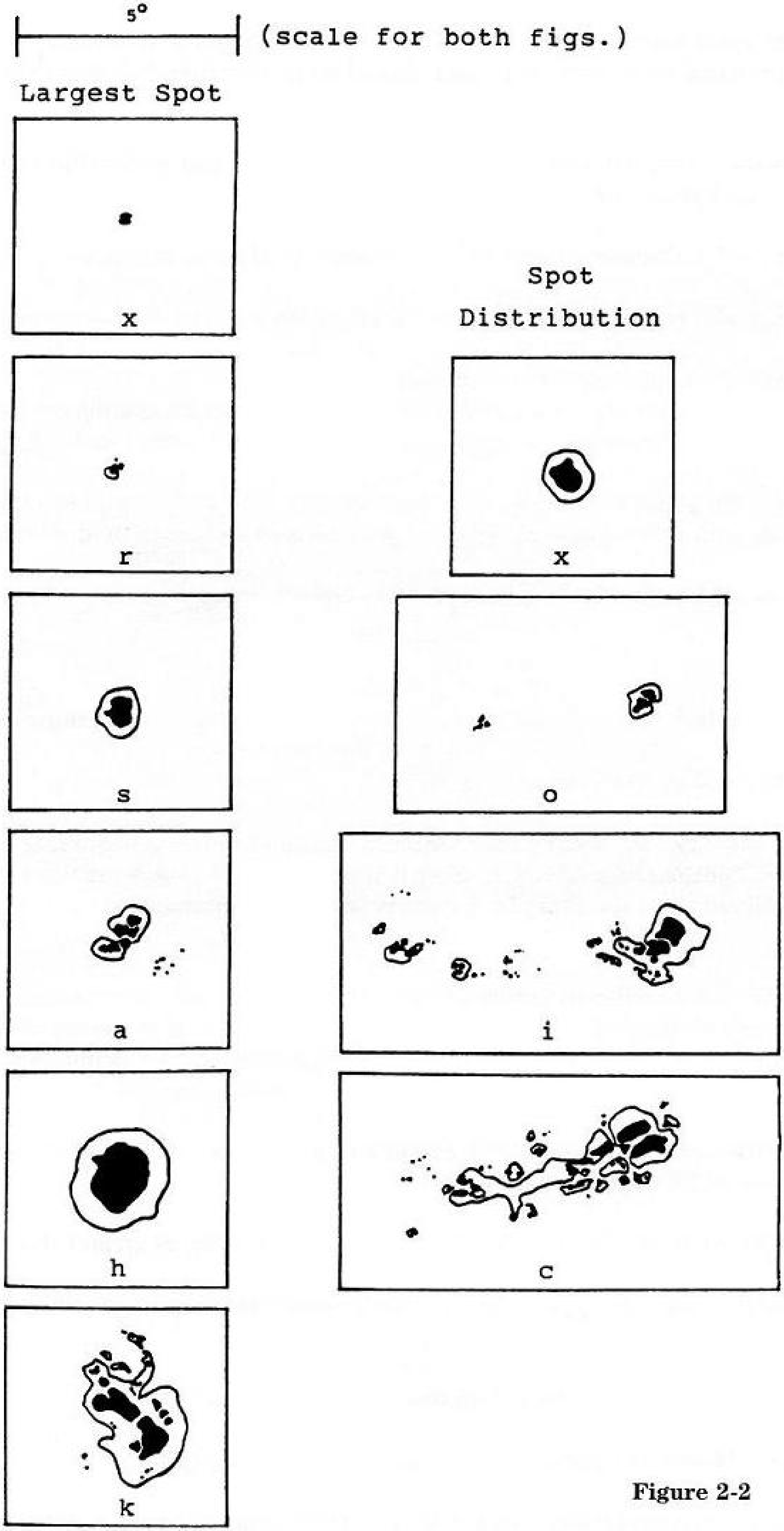

5°
(scale for both figs.)
Largest Spot
x
r
s
a
h
k
Spot
Distribution
x
o
i
c

Figure 2-2

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

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

This system has proven a more accurate predictor of flares in the thirty years of its use. Indeed, it has helped solar astronomers understand better the relationship between flares and sunspots. Sunspot groups that produce flares are relatively rare. Because of this it has taken several solar cycles of observations to demonstrate the effectiveness of the new system.

With the old Zurich system it was found that groups of class F were most likely to produce flares. But only a 40% flare probability in a 24 hour period could be predicted using this parameter alone. With the McIntosh System, using Modified Zurich Class F, the probability improved to 60%. With just the largest spot class of "k" the probability in 24 hours was 40-50%. If just spot distribution category "c" were used, flare probability went up to about 70%. But, when all three dimensions of this system were used, classes Fsi, Fki and Fkc showed a probability of up to 100% for production of M flares in a 24 hour period and the McIntosh Class of Fkc had a further probability of up to 50% in X flares (x-ray) production! This surpasses any former method of flare prediction used, including sunspot area. [McIntosh 1984]

Observers of the A.L.P.O. Solar Section have been using the McIntosh Classification System for many years now, especially those involved in the detection of flares. Those doing whole disk drawings are most strongly encouraged to do so. Of course, other standard procedures need to be followed as well. These procedures are designed to make observations of the Section most closely match those being done at NOAA/SEC and can be found on the A.L.P.O. Solar Section webpages at: http://www.lpl.arizona.edu/~rhill/alpo/solar.html. 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 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 energy in a flare. For amateur astronomers 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 can enjoy observing the ever changing solar features while making a lasting and valuable contribution to science.

(See Figures 2-1 and 2-2 for visual representations of modified Zurich Classes. Figure 2-3 is a photograph showing some of the features described in this chapter.)

References:

Bray, R.J., and Loughhead, R.E., [1964] **SUNSPOTS**, New York, Dover.

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.

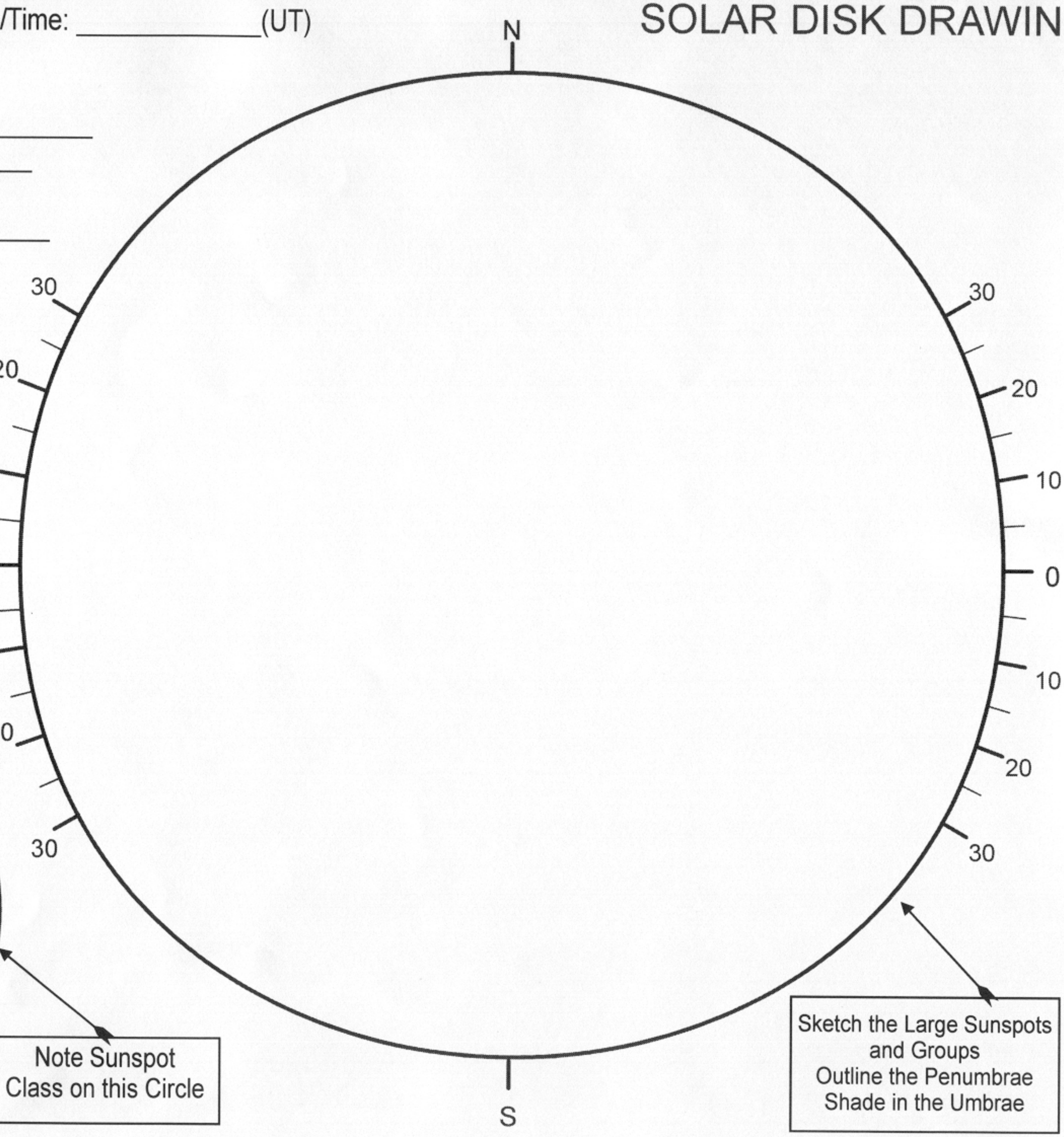
Waldmeir, M., [1955] **THE SUNSPOT ACTIVITY IN THE YEARS 1610-1960**, Zurich, Schulthess & Co.

SOLAR DISK DRAWING

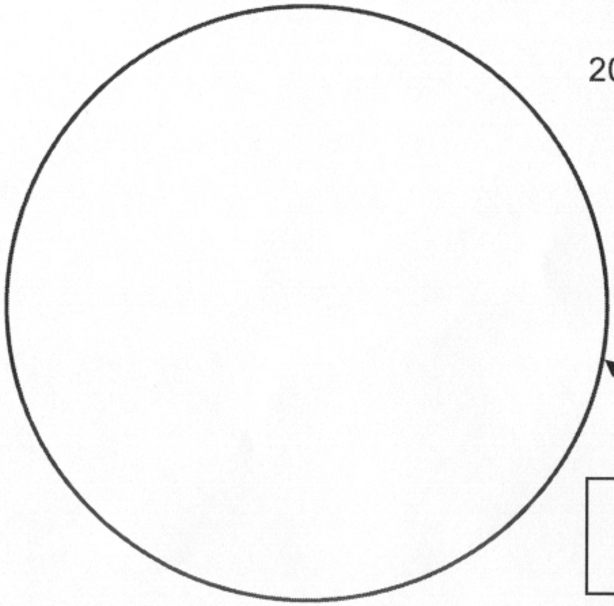
Observer:____________________ Date/Time: ______________(UT)
Location: ____________________
Sky:
Seeing _____ Clouds _________Wind ________
Telescope: __________Type: __________
Aperture Used: _______________
Focal Length _________ Eyepiece ________
Filter: ______________

Observations:
Direct or Projected (circle one)

Total Sunspot Count:
(N= north of solar equator, S=south)
Groups: N___ +S _____= _____
Spots: N___ +S _____= _____
Wolf Sunspot Number: **R**
R = 10 x **G** + **S** = ________



Sketch the Large Sunspots
and Groups
Outline the Penumbrae
Shade in the Umbrae



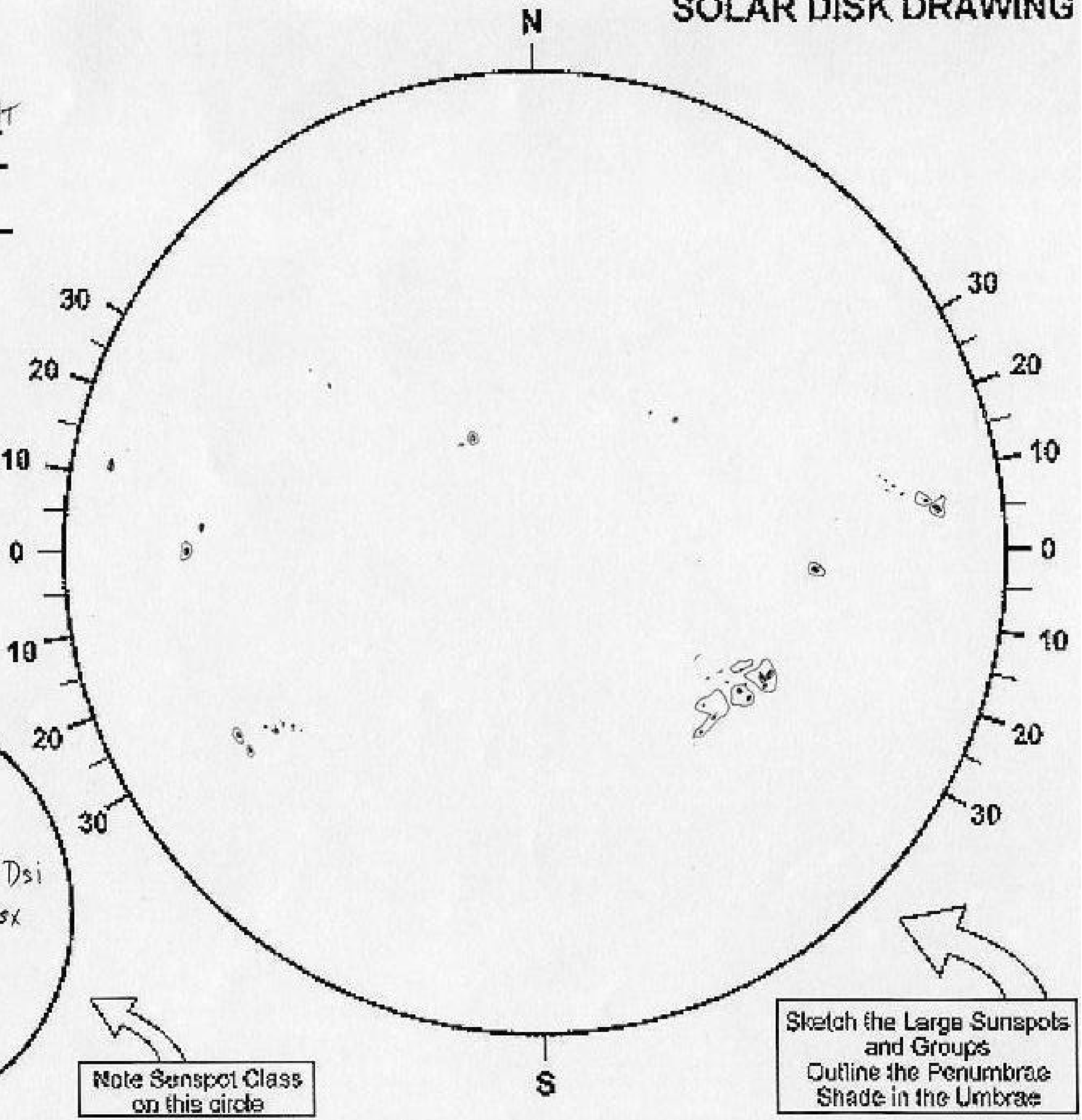
Note Sunspot
Class on this Circle

SOLAR DISK DRAWING

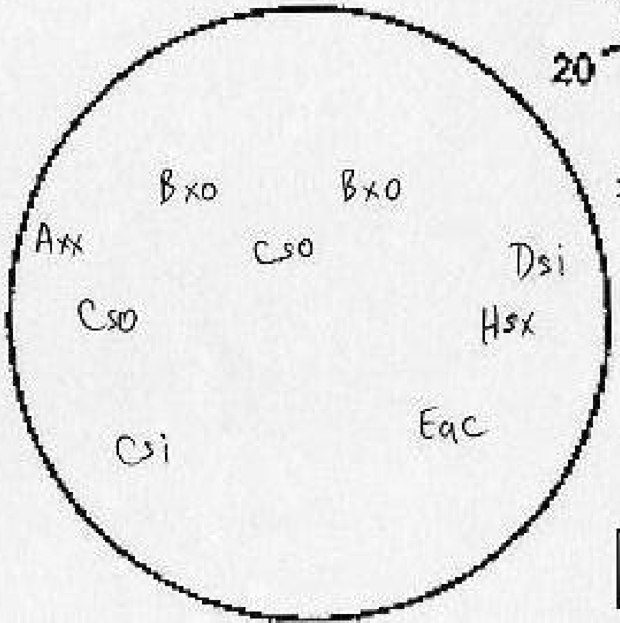
Observer: ____________
Location: ____________
Date/Time 02-07-2002 12.00 (UT)
Sky:
Seeing GOOD Clouds 25% Wind SLIGHT
Telescope 7" Type DOB
Aperture Used 7"
Focal Length 995 Eyepiece 15
Filter BAADEN
Observations:
[✓ Direct] or Projected (circle one)

Total Sunspot Count:
(N=north of solar equator, S=south)
Groups: N 6 +S 3 = 9
Spots: N 16 +S 18 = 34

Wolf Sunspot Number (R):
R= 10G + S = 124



Sketch the Large Sunspots and Groups
Outline the Penumbrae
Shade in the Umbrae



Note Sunspot Class on this circle

SUNSPOT DRAWING

Observer: ______________________

Universal date/time: ________________

Sky quality: ______________________

(Excellent, good, fair, poor)

Seeing in arc seconds: ______________

(smallest detail seen where a photospheric granule is 1.5-2 arc seconds)

Location: ______________________

Telescope effective aperture: ________

Telescope focal length: __________

Eyepiece focal length: __________

Magnification: ______________

Filter type: ____________________

Three letter McIntosh Sunspot Classification: _________________

Label the following on your sunspot drawing:

- Umbra
- Penumbra
- Facula
- Light bridge (if present)
- Penumbril fibril (if visible)
- Show *approximate* direction of Solar North with an arrow

Answer the Following

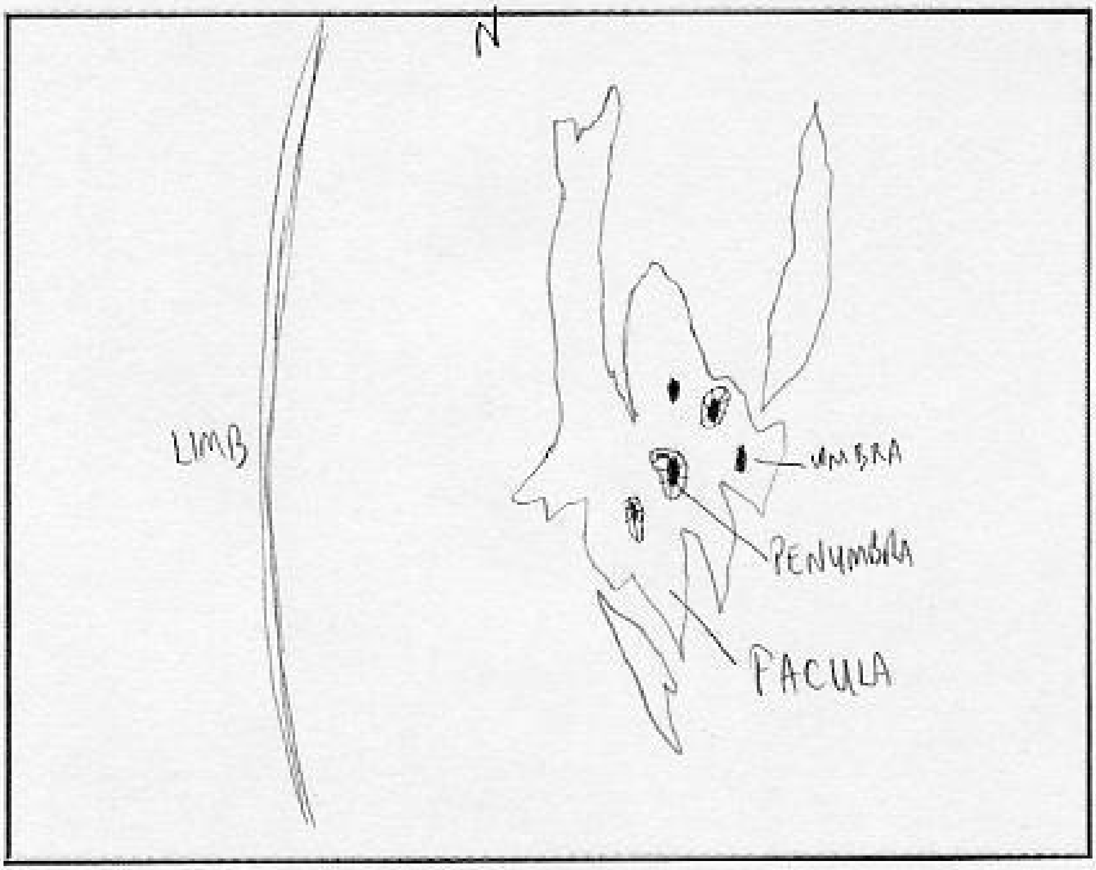
-
- Is granulation visible? yes___ no___
- Is penumbral grain visible? yes __ no __
- Does drawing show Wilson effect? yes __ no __

Sunspot Drawing

Observer [redacted]
Universal date/time: 01-25-2002 18:00
Sky quality: EXCELLENT
(Excellent, good, fair, poor)
Seeing in arc seconds: 2" OR BETTER
(smallest detail seen where a photospheric granule is 1.5-2 arc seconds)

Location: [redacted]
Telescope effective aperture: 7"
Telescope focal length: 995 mm
Eyepiece focal length: 15 mm
Magnification: 66 x
Filter type: BAADER ASTRO FILM

McIntosh Sunspot Classification: Cso



Label the following on your sunspot drawing:

- Umbra
- Penumbra
- Facula
- Light bridge (if present) NONE
- Penumbril fibril (if visible) YES!
- Show *approximate* direction of **Solar** North with an arrow

Answer the Following:

- Is granulation visible? Yes: ____ No: X
- Is penumbral grain visible? Yes: ___ No: X
- Does the drawing show the Wilson effect? Yes: X No: ___ VERY MUCH SO!