OBSERVING OUR NEAREST STAR

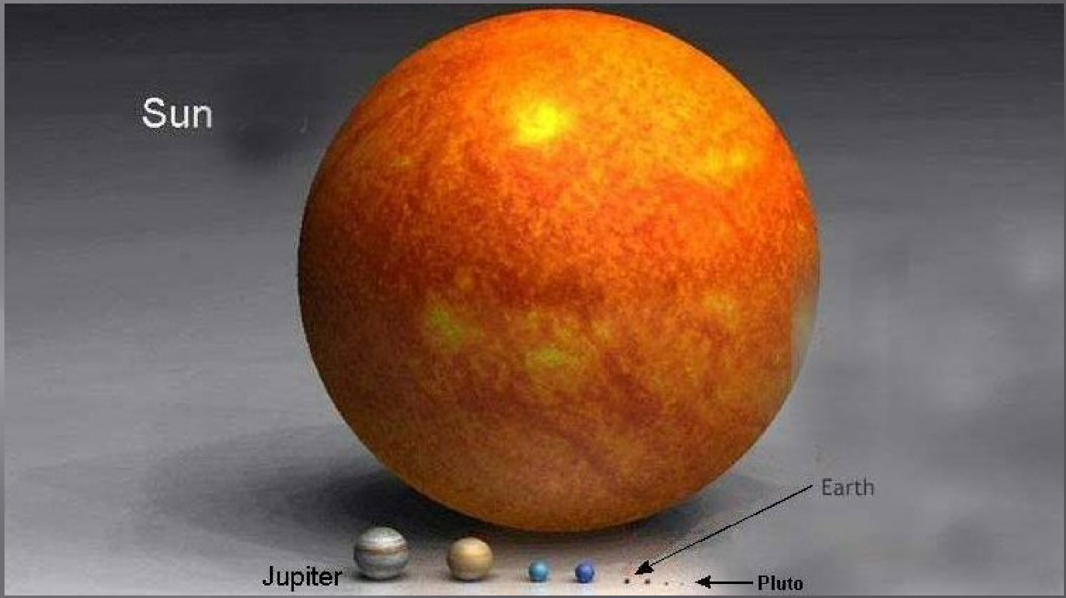
The Sun

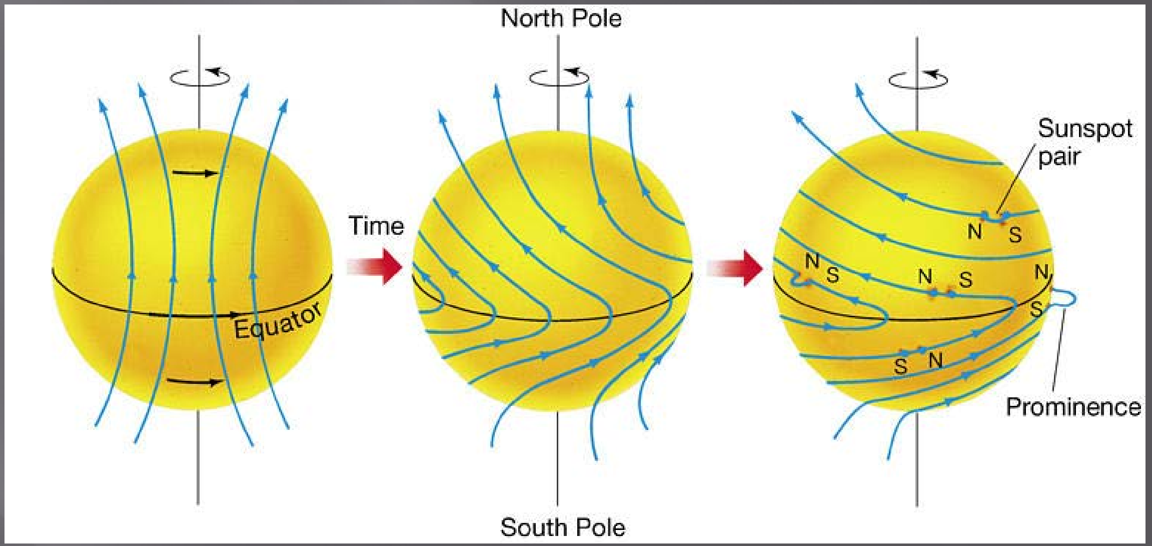
Why Observe the Sun?

- The sun can be observed during the day.
- The sun is the brightest object in the sky and relatively easy to find.
- The sun is a star and by observing the sun, we can learn more about other stars.
- Observing the sun will improve your observing skills.
- You will learn how to classify different features of the sun.
- **Caution: Never look at the sun directly without a proper filter!**

Facts about or Sun

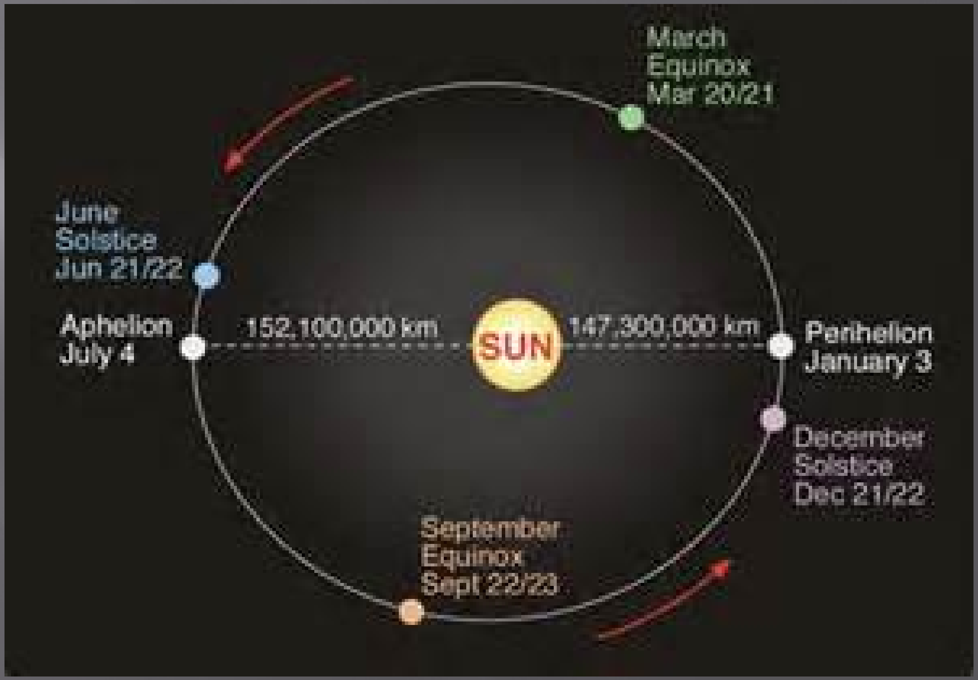
- The Sun is a G-type main-sequence star comprising about 99.86% of the total mass of the Solar System. It is a near-perfect sphere, with an oblateness estimated at about 9 millionths, which means that its polar diameter differs from its equatorial diameter by only 6.2 mi.
- Since the Sun consists of a plasma and is not solid, it rotates faster at its equator than at its poles. This behavior is known as differential rotation and is caused by convection in the Sun and the movement of mass, due to steep temperature gradients from the core outwards.





Facts about or Sun

- The mean distance of the Sun from the Earth is approximately 1 astronomical unit (93,000,000 mi), though the distance varies as the Earth moves from perihelion in January to aphelion in July. At this average distance, light travels from the Sun to Earth in about 8 minutes and 19 seconds. The energy of this sunlight supports almost all life on Earth by photosynthesis, and drives Earth's climate and weather. The enormous effect of the Sun on the Earth has been recognized since prehistoric times, and the Sun has been regarded by some cultures as a deity.

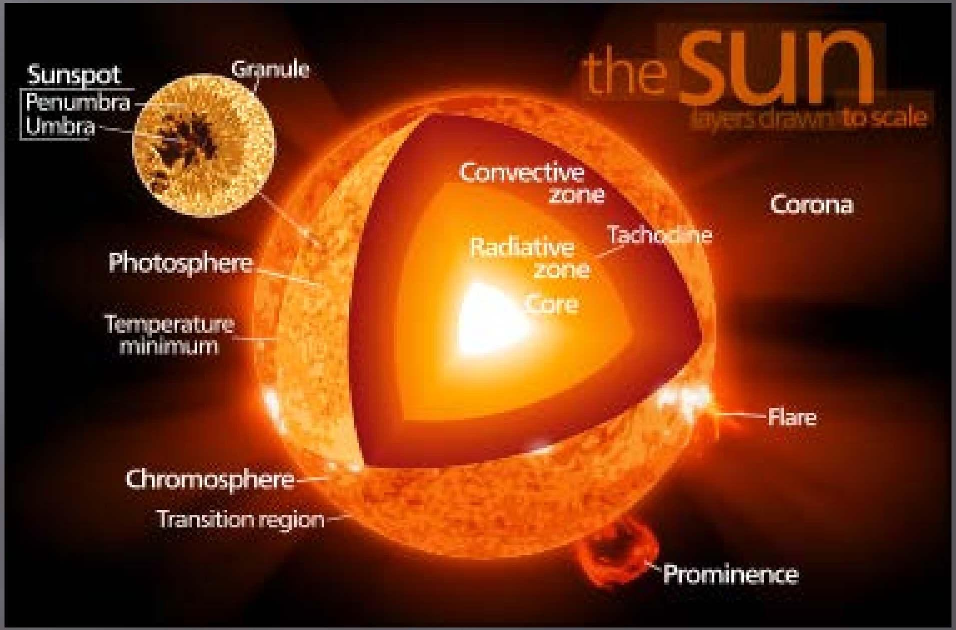


Facts about or Sun

- The English proper noun *Sun* developed from Old English *sunne* and may be related to *south*. Cognates to English *sun* appear in other Germanic languages, including Old Frisian *sunne, sonne*, Old Saxon *sunna*, Middle Dutch *sonne*, modern Dutch *zon*, Old High German *sunna*, modern German *Sonne*, Old Norse *sunna*, and Gothic *sunnō*. In relation, the Sun is personified as a goddess in Germanic paganism Sunna. Scholars theorize that the Sun, as a Germanic goddess, may represent an extension of an earlier Proto-Indo-European sun deity due to Indo-European linguistic connections between Old Norse *Sól*, Sanskrit *Surya*, Gaulish *Sulis*, Lithuanian *Saulė*, and Slavic *Solntse*.
- The English weekday name *Sunday* is attested in Old English (*Sunnandæg*; "Sun's day", from before 700) and is ultimately a result of a Germanic interpretation of Latin *dies solis*, itself a translation of the Greek. The Latin name for the star, *Sol*, is widely known but is not common in general English language use; the adjectival form is the related word *solar*.

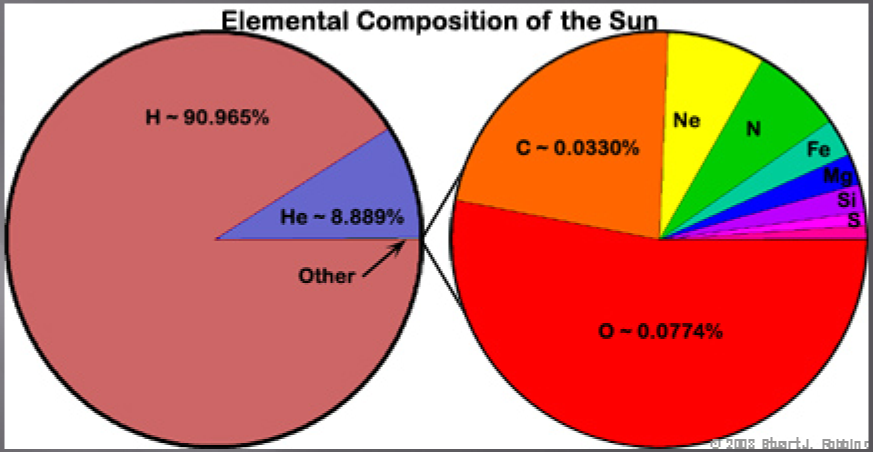
Facts about or Sun

- The core is the only region in the Sun that produces an appreciable amount of thermal energy through fusion; 99% of the power is generated within 24% of the Sun's radius, and by 30% of the radius, fusion has stopped nearly entirely. The rest of the star is heated by energy that is transferred outward by radiation from the core to the convective layers just outside.
- The gamma rays released in fusion reactions are absorbed in only a few millimeters of solar plasma and then re-emitted again in a random direction and at slightly lower energy. Therefore it takes a long time for radiation to reach the Sun's surface. Estimates of the photon travel time range between 10,000 and 170,000 years.
- During the final part of the photon's trip out of the sun, in the convective outer layer, collisions are fewer and far between, and they have less energy. The photosphere is the transparent surface of the Sun where the photons escape as visible light. Each gamma ray in the Sun's core is converted into several million photons of visible light before escaping into space.



Facts about or Sun

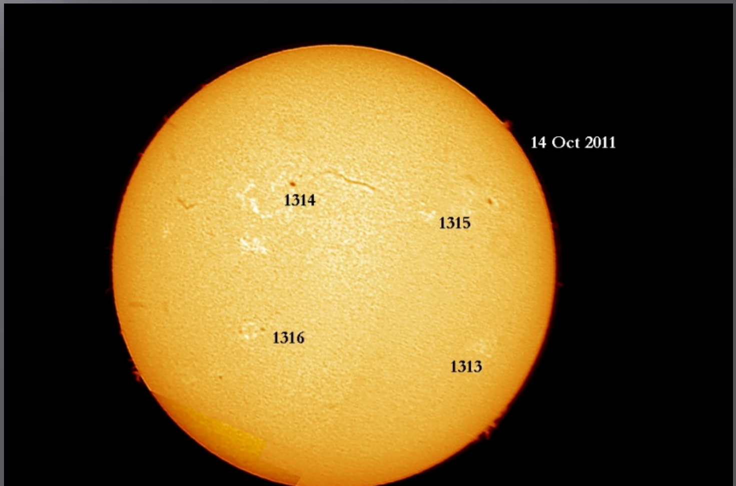
- The Sun is composed primarily of the chemical elements hydrogen and helium; they account for 90.9% and 8.8% of the mass of the Sun in the photosphere, respectively. All heavier elements, called *metals* in astronomy, account for less than .2% of the mass. The most abundant metals are oxygen (roughly .08% of the Sun's mass), carbon (0.03%), neon (0.02%), and iron (0.02%).



Sunspots and the sunspot cycle

- When observing the Sun, with appropriate filtration, the most immediately visible features are usually its sunspots, which are well-defined surface areas that appear darker than their surroundings because of lower temperatures. Sunspots are regions of intense magnetic activity where convection is inhibited by strong magnetic fields, reducing energy transport from the hot interior to the surface. The magnetic field causes strong heating in the corona, forming active regions that are the source of intense solar flares and coronal mass ejections. The largest sunspots can be tens of thousands of miles across.

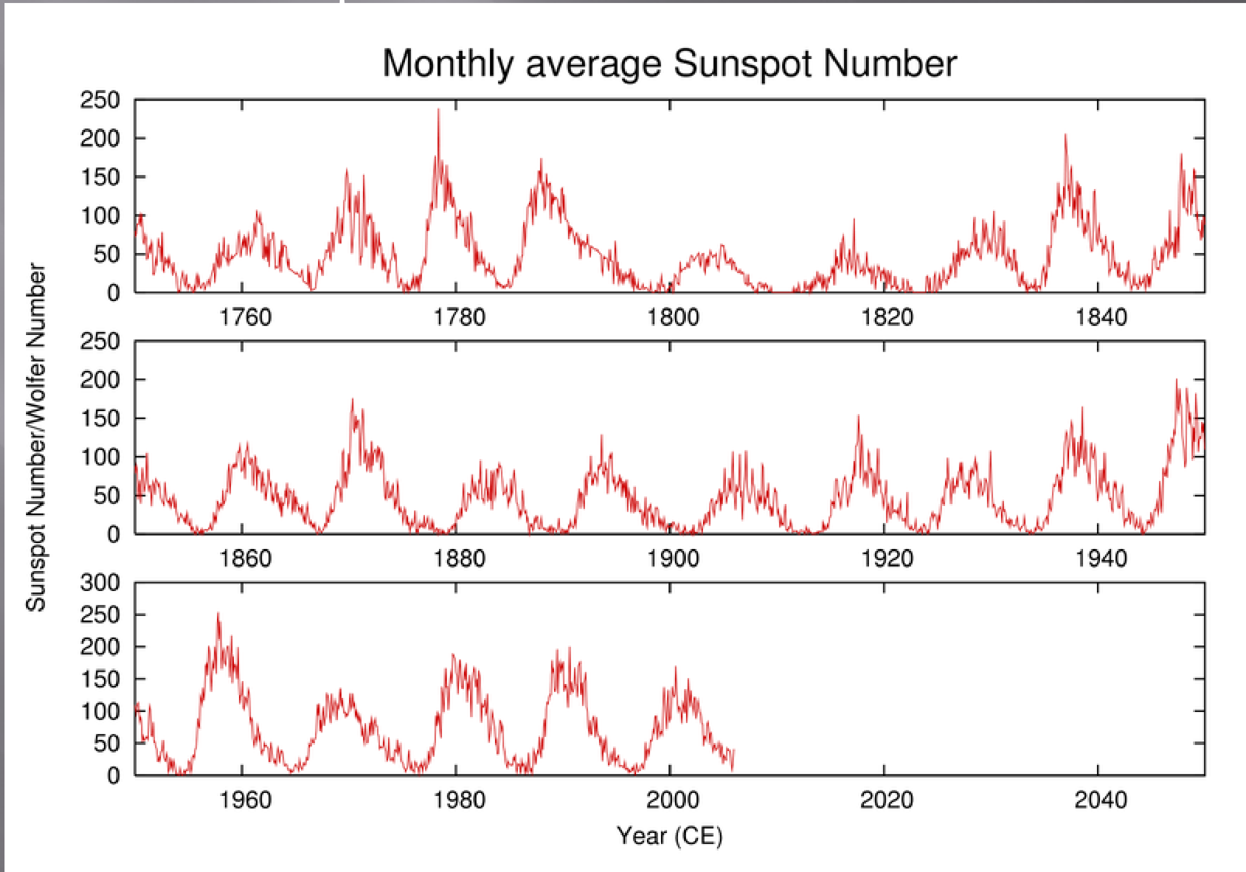
Sunspots in White Light



Sunspots in H- alpha

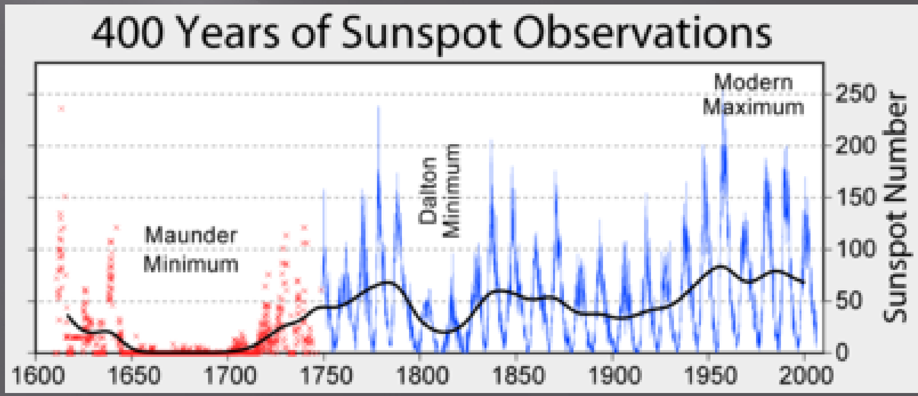
Sunspots and the sunspot cycle

- The number of sunspots visible on the Sun is not constant, but varies over an 11-year cycle known as the solar cycle. At a typical solar minimum, few sunspots are visible, and occasionally none at all can be seen. Those that do appear are at high solar latitudes. As the sunspot cycle progresses, the number of sunspots increases and they move closer to the equator of the Sun.



Sunspots and the sunspot cycle

- The solar cycle has a great influence on space weather, and a significant influence on the Earth's climate since the Sun's luminosity has a direct relationship with magnetic activity. Solar activity minima tend to be correlated with colder temperatures, and longer than average solar cycles tend to be correlated with hotter temperatures. In the 17th century, the solar cycle appeared to have stopped entirely for several decades; few sunspots were observed during this period. During this era, known as the Maunder minimum or Little Ice Age, Europe experienced unusually cold temperatures. Earlier extended minima have been discovered through analysis of tree rings and appear to have coincided with lower-than-average global temperatures.



Maunder Minimum

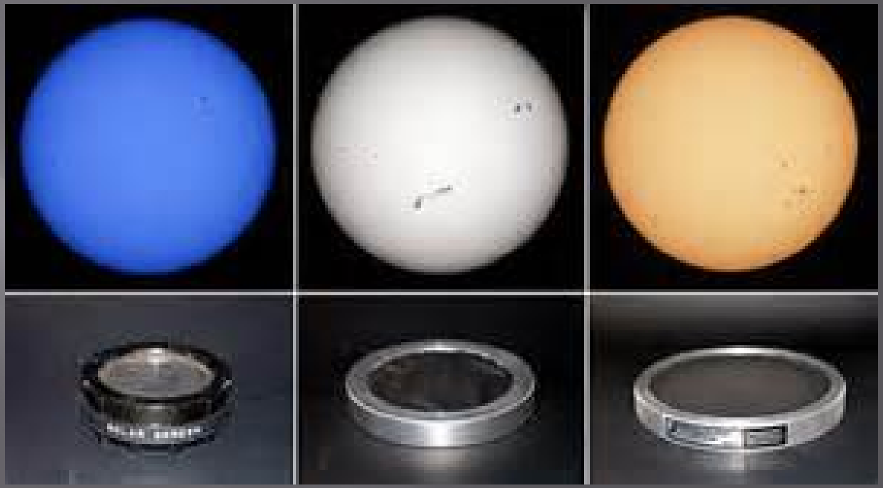
- The Maunder Minimum coincided with the middle—and coldest part—of the Little Ice Age, during which Europe and North America were subjected to bitterly cold winters. A causal connection between low sunspot activity and cold winters has recently been made using data from the NASA's Solar Radiation and Climate Experiment which shows that solar UV output is more variable over the course of the solar cycle than scientists had previously thought.
- Some scientists hypothesize that the dense wood used in Stradivarius instruments was caused by slow tree growth during the cooler period. Instrument maker Antonio Stradivari was born a year before the start of the Maunder Minimum.

How to Observe the Sun

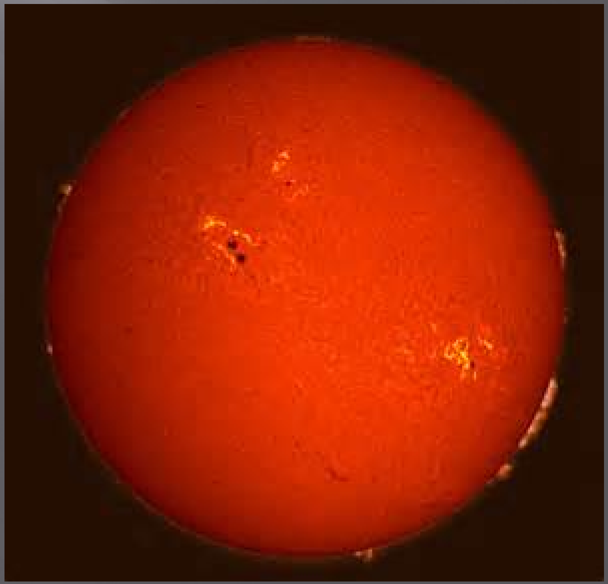
- For amateur astronomers, there are 2 types of filters:
  - White light
  - Hydrogen Alpha

White Light Filters

- A white filter blocks out the harmful rays emitted by the Sun and lets safe wavelengths through, allowing you to observe or photograph sunspots on the surface of the Sun. The filter also lets you experience solar eclipses or planetary transits safely. It is important to choose a solar filter that fits snugly, so before buying your filter, you should measure the outside diameter of your telescope carefully.
- Filters typically cost from $40 to $150 depending on size of scope.



Hydrogen Alpha Filters



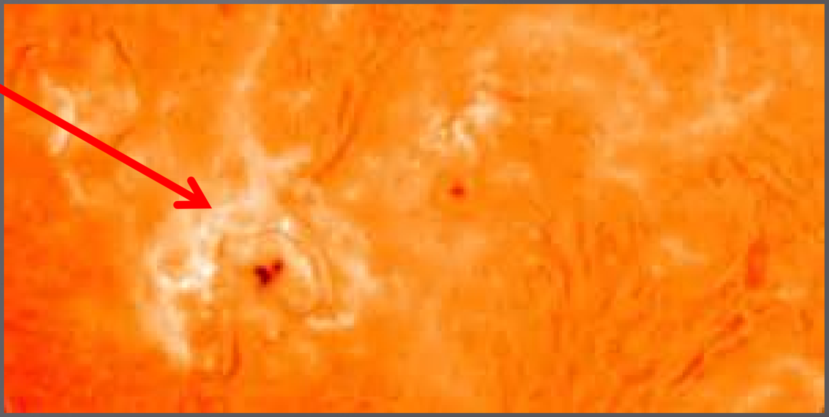
- If you're interested in viewing solar prominences, solar flares, solar corona, and other unusual details using your existing telescope, then a Solar Hydrogen-Alpha (H-alpha) Filter is a perfect choice. These high quality filters are designed for blocking all light except for the H-alpha wave length. This is an important emission line for solar observation, as the Sun's surface layer contains a high proportion of hydrogen. The H-alpha filter allows safe observation of the entire solar disc, providing superb views of prominences, chromosphere, and surface details such as sunspots, plages, flares, filaments, and granulation. They are meant for both visual observing and astrophotography.
- Filters run from $300 to $2000, depending on what size filter you want.

Dedicated H-alpha Telescopes

- A solar telescope is a refractor-based optical system that uses special filters to view specific wavelengths of light, the most common of which is H-alpha. The H-alpha telescope allows safe observation of the entire solar disc, providing superb views of prominences, chromosphere, and surface details such as sunspots, plages, flares, filaments, and granulation. H-Alpha filtering also gives the most "natural" view of the sun, in brilliant yellow, orange, and red.
- Cost is from $599 for a 35mm (1.5 inch) to $9,000 for a 152mm (6 inch) scope.

Terms for Observing the Sun

- **Penumbra**: a gray area which frequently, but not always, appears around an individual sunspot or group of sunspots
- **Faculae**: relatively large (greater than an arc minute) irregularly shaped light area; sometimes serpentine in shape. Sunspots are usually located in Facula.
- **Granulation**: fine grain structure of the solar photosphere. Grains appear to be one to two arc-seconds in diameter.

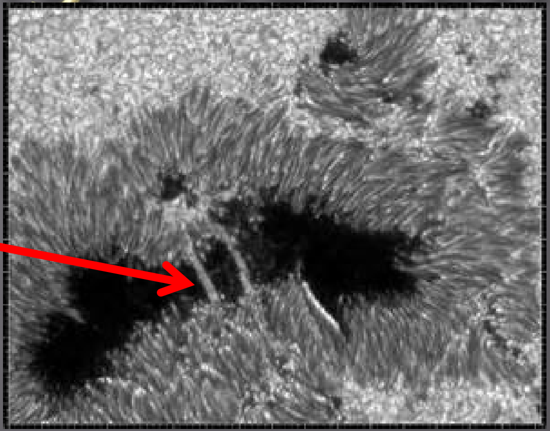


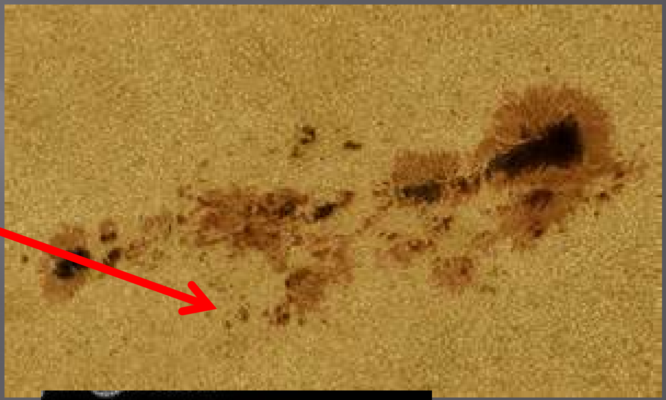
Terms for Observing the Sun

- **Penumbral fibril**: fiber like lines that may appear to radiate out from an umbra into the surrounding penumbra.
- **Penumbral fragment**: a penumbra without a sunspot.
- **Penumbral grain**: granular or small patchy structure that may be visible in the penumbra.

Terms for Observing the Sun

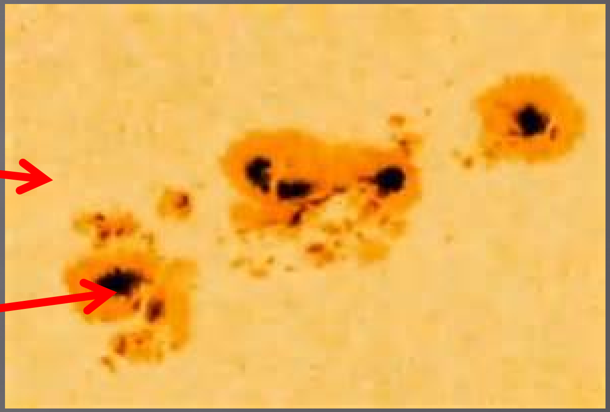
- **Light bridge**: a bright ribbon or band that may appear to connect two sunspots.
- **Pores**: tiny, less than one arc-second, dark areas which are not as dark as a sunspot.
- **Limb darkening**: the effect of perspective where the edge of the solar disk appears darker than the center because it is a sphere.

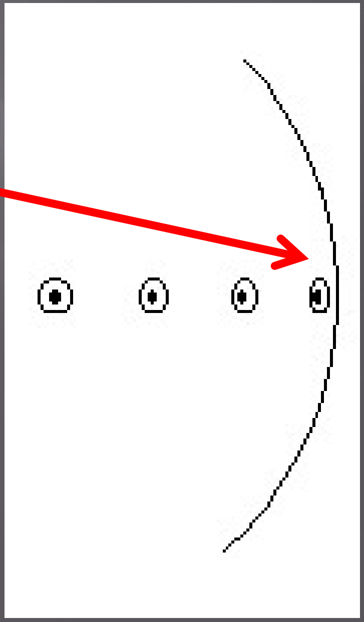




Terms for Observing the Sun

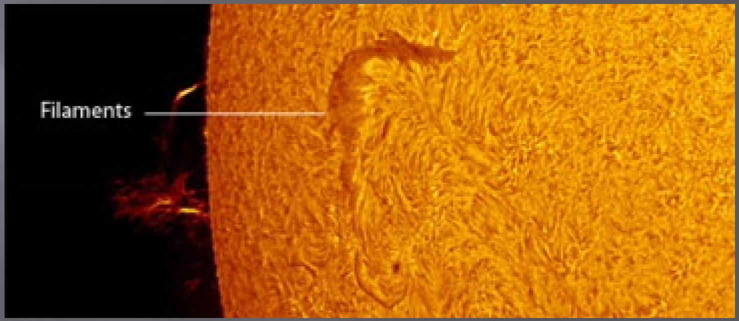
- **Sunspot Group**: A group may be anything from a single isolated sunspot to a complex elongated cluster of spots.
- **Umbra**: The dark black area of a Sunspot.
- **Wilson effect**: This effect of perspective is seen when a sunspot is near the solar limb. The umbra appears displaced within the penumbra, usually toward the center of the sun.

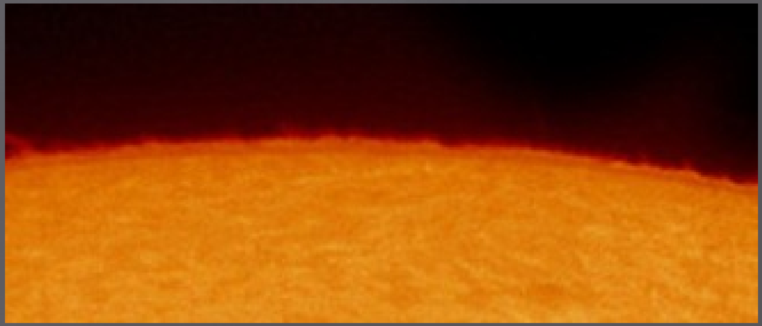




Terms for Observing the Sun

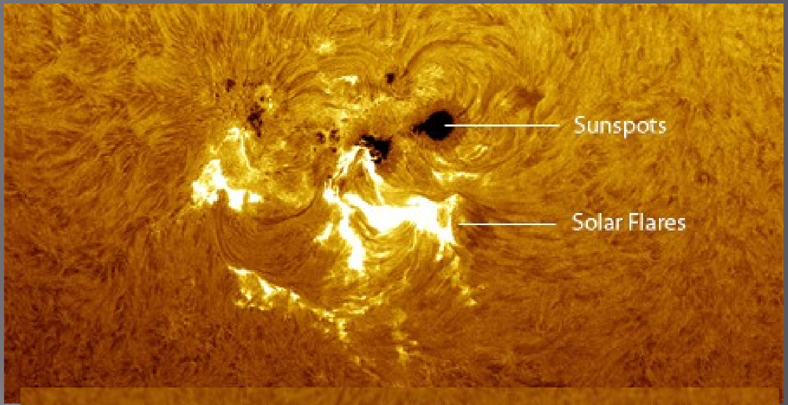
- **Prominence**
- **Filaments**-Prominences seen against the face of the sun, appearing as long, narrow dark streamers or diffuse complex dark areas.
- **Spicules** – Small jets of gas under 10,000 km high, usually seen as a mass of tiny brighter spike-like features on the limb or as tiny darker spikes coming out of network elements.

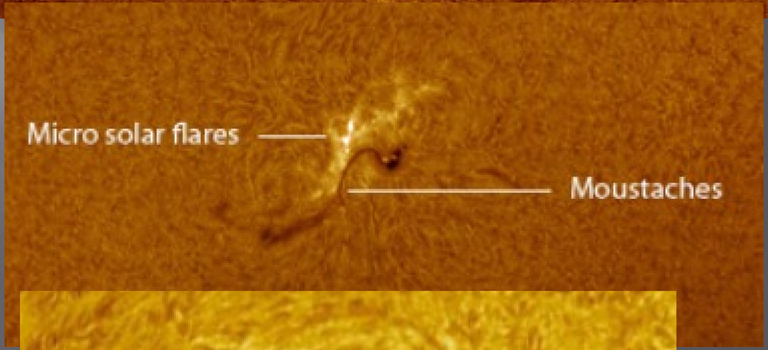


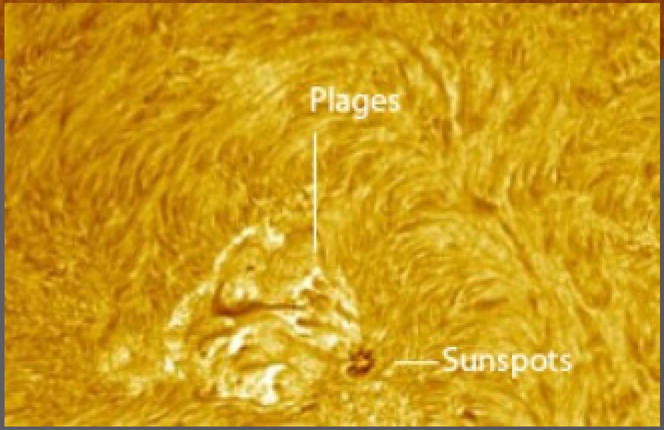


Terms for Observing the Sun

- **Flares** – Intense, abrupt releases of energy which occur in areas where the local magnetic field is rapidly realigning or changing.
- **Elerman Bombs** – Micro solar flares that appear as tiny fairly bright transient points of light, most often found in Emerging Flux Regions or on edges of sunspots where the magnetic field is breaking the surface.
- **Plage** – Patchy H-alpha brightenings on the solar disk, usually found in or near active regions, which can last for several days.





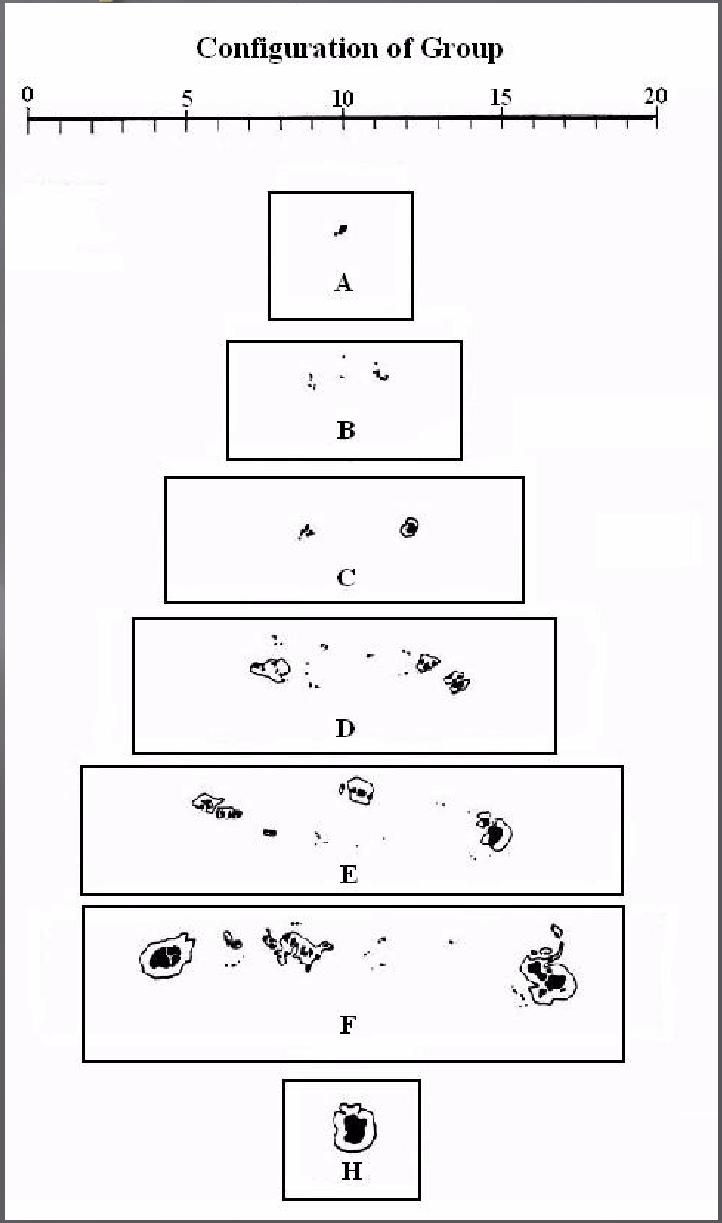


Sunspot Classification

- **Modified Zurich Sunspot Class**: A seven class (A-F, H) system of describing a sunspot group. The size of the group and distribution of penumbrae, if any, are factors.
- **McIntosh Sunspot Classification System**: Adds classes for the type of the largest sunspot and sunspot distribution to the Modified Zurich Class.

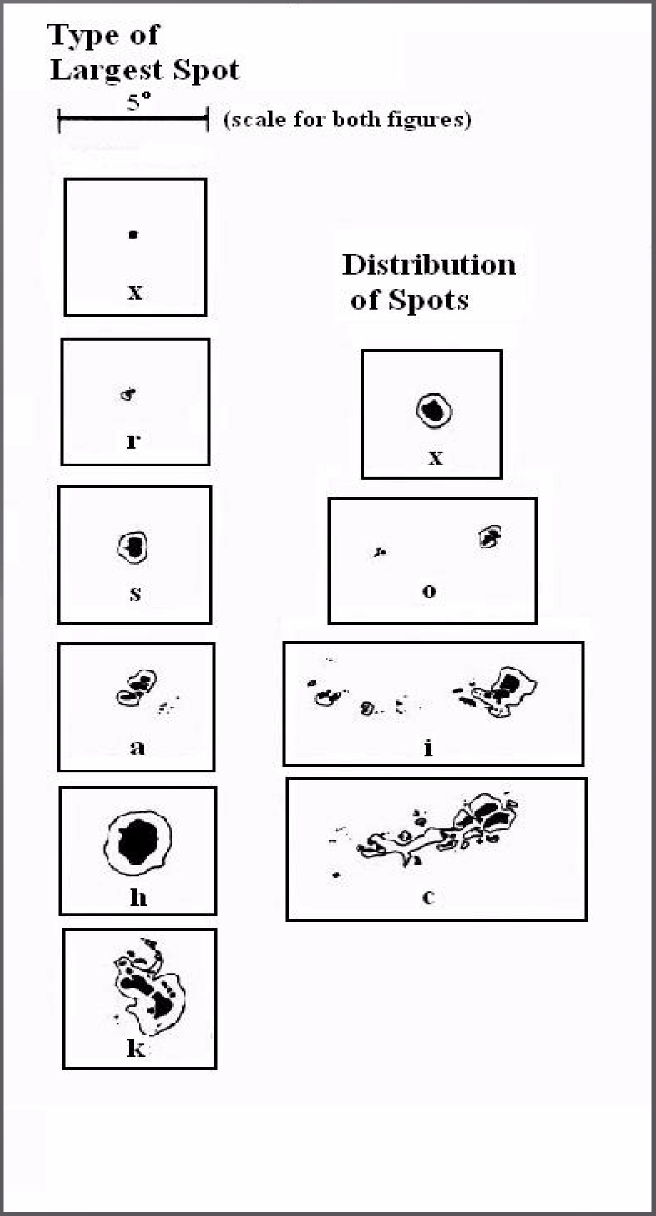
Modified Zurich Sunspot Class

- **A** - Single small spot (single magnetic polarity).
- **B** - Very small distribution of small spots.
- **C** - Two or more small spots, at least one of which has a detectable penumbra.
- **D** - Moderately sized group of spots, several of which may have noticeable penumbrae. Magnetic complexity of D-type regions are usually capable of producing C and low-intensity M-class flares.
- **E** - Moderate to large area of a fairly complex system of sunspots, several of which have noticeable penumbrae and good definition. Often capable of producing minor C-class as well as major M-class flares.
- **F** - Large to very large area of a complex system of sunspots. These regions are often capable of producing major X-class flares as well as numerous major M-class and many C-class events (depending on their magnetic complexity).
- **H** - Single large to very large sunspot (not usually capable of producing significant energetic events). This type of sunspot is usually manifest in the dying phase of a sunspot group.

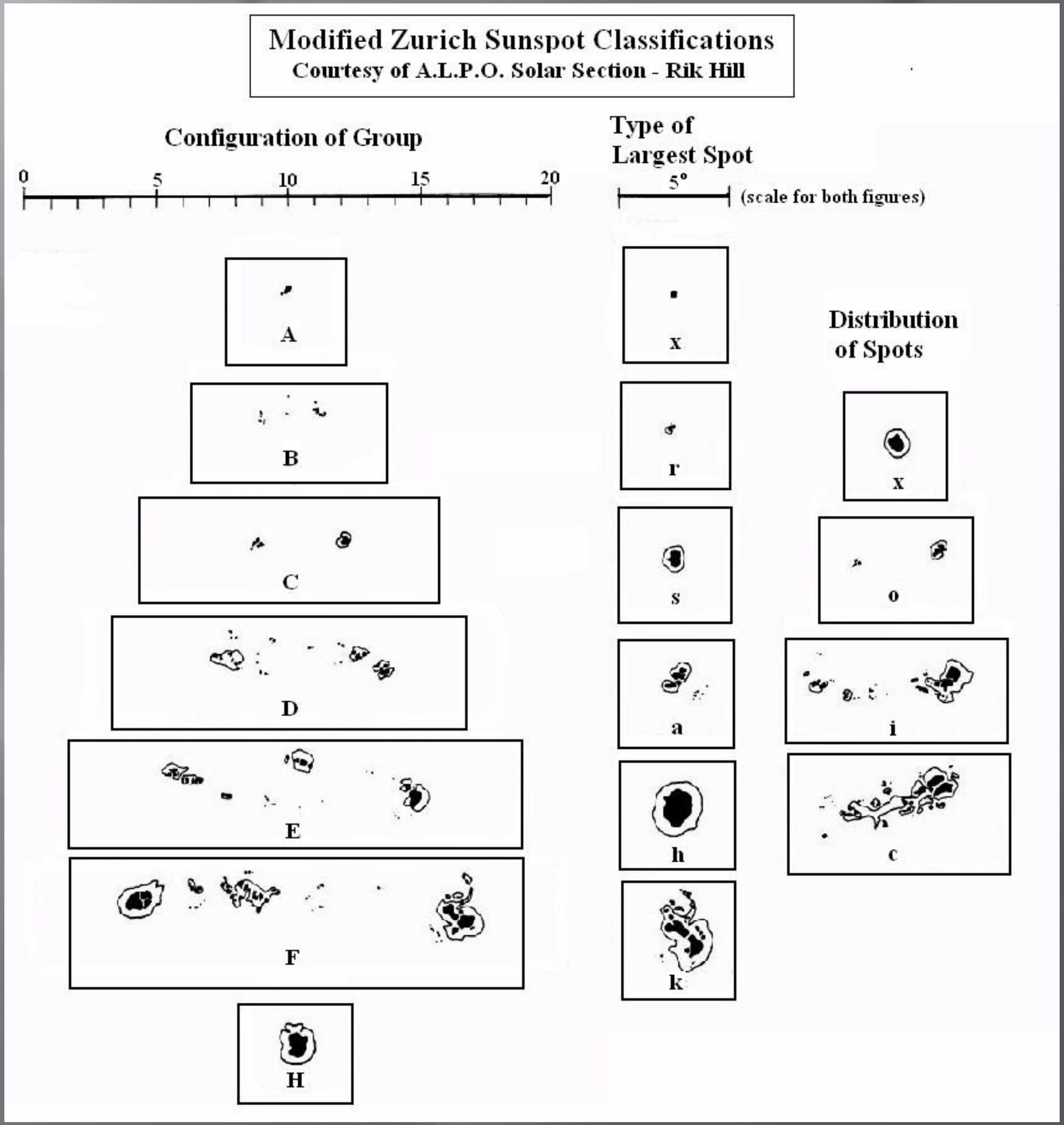


McIntosh Sunspot Classification System

- *p - Penumbra type of the largest spot in the group.*
  - **x** - Single spot.
  - **r** - Rudimentary.
  - **s** - Small symmetric.
  - **a** - Small asymmetric.
  - **h** - Large symmetric.
  - **k** - Large asymmetric.
- *c - Relative sunspot distribution or compactness of the group.*
  - **x** - Single spot.
  - **o** - Open group (separated by quite a wide space).
  - **i** - Intermediate (moderate sunspot compactness in the group).
  - **c** - Compact (very dense and complex spots within the group).



One system all together



Sun spotters Observing Program

- In the League's Sunspotter program, you will make two sets of drawings. The first set is five detailed sketches of sunspot groups. The second set is 20 or more sketches of the whole solar disk during two solar rotations (one rotation is about 30 days).
- Your five sunspot sketches must be done on five different days. These sunspot group drawings must be accurately labeled as to time, observing conditions, equipment used, and sunspot class. On each drawing, several features must be identified. In order to see and identify all of the items, you will need to observe a rather complex sunspot group of Modified Zurich class D, E, or F. You may need to observe the sunspot group close to the limb to pick out all the details.

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:

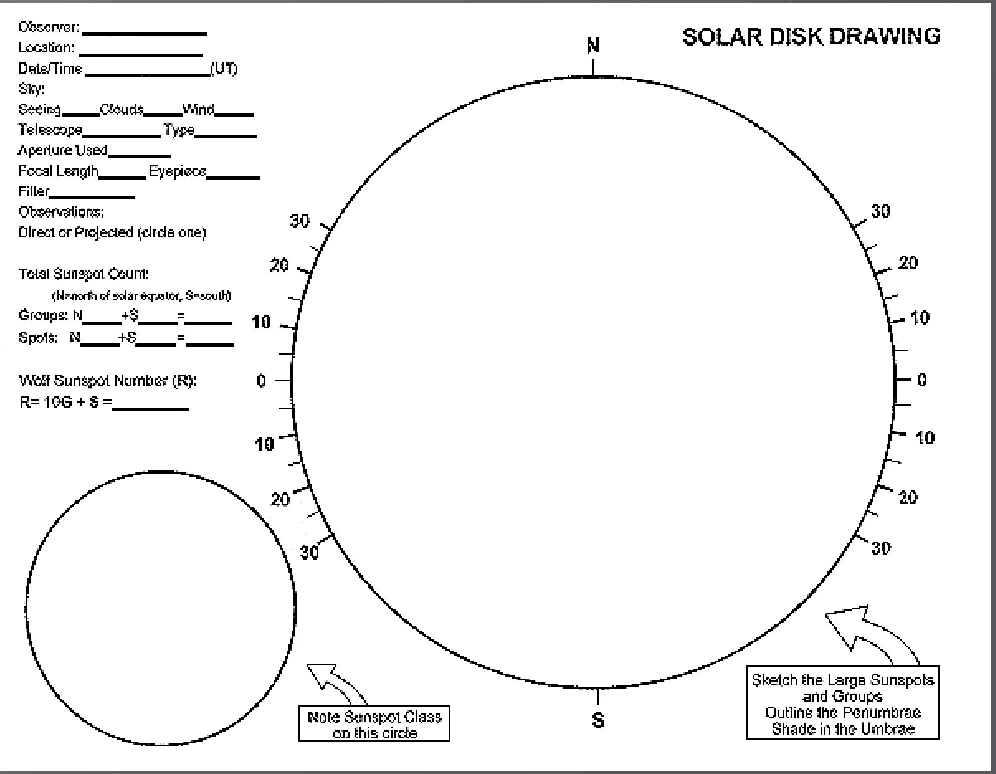
- Umbra
- Penumbra
- Facula
- Light bridge (if present)
- Penumbril fibril (if visible)
- Show *approximate* direction of Solar North with an arrow

Answer the Following

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

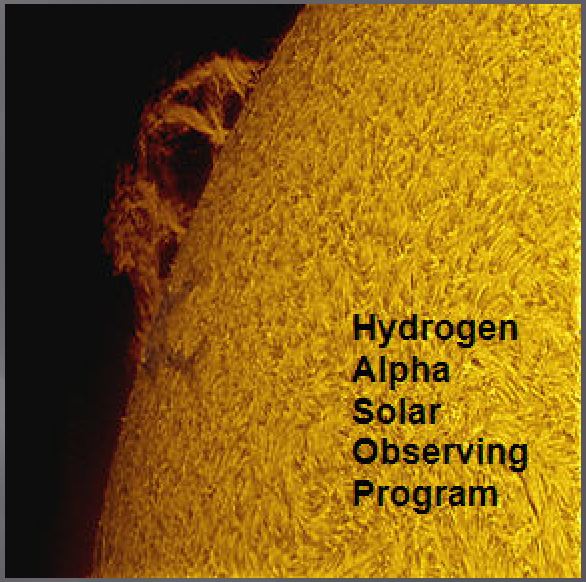
Sun spotters Observing Program

- In the second set of drawings, you will sketch the whole disk of the sun throughout the passage of large sunspot groups during two different solar rotations. Outline the sunspot penumbrae and shade in the umbrae on the large circle. Classify all the sunspot groups on the disk and show the McIntosh classification letters on the small circle. Do a sunspot count, compute the Wolf Number, and fill out all the other blanks on the form. One of your sketches (in either the first or second set of drawings) should show the "Wilson effect".



H-Alpha Solar Observing Program

- The program can be completed visually or by imaging. To accomplish the program, an observer will be required to make three sets of drawings or images.
- The first set is 20 or more sketches or images of the whole solar disk during two solar rotations (one rotation is about 30 days). Only the main features need to be drawn: filaments, plages, flares, and sunspot umbra. The penumbra may be omitted since it has lower contrast in H-alpha than in white light.
- The second set is detailed sketches or images of the different forms that solar prominences take on the limb of the Sun.
- In the third set, you will make detailed sketches or images of individual features on the disk of the Chromospheric Sun, which MUST include <u>six</u> of the nine specific features.



Our Nearest Star

- The OAS has an 8 inch white light filter and an 8 inch H-alpha filter for check out as well as the scope they fit onto.
- Try the sun, you will enjoy looking at our nearest star!