Step-by-Step Instructions

1. Find the field - Using an atlas or sky chart, look up and locate the field or region of the sky in which the variable is located. This is where knowing the constellations will be very helpful. Take out your “a” or “b” scale chart and orient it so that it matches what you see in the sky.

2a. Find the variable (using finder/1x) – Look at the “a” or “b” chart and pick out a bright “key star” that appears near the variable. Now look up and try to find this same star in the sky. If you cannot see the key star with your unaided eye (due to moonlight or other adverse conditions), use a finder scope or a very low-power, wide field eyepiece and point the telescope as closely as possible to the position in the sky where the key star should be. Remember that depending on the equipment you are using, the orientation of the stars that you see in your telescope will probably be different than what you see when you look up with the unaided eye. You will need to learn to reconcile N, E, S, W, with your own particular equipment. (See pages 11 and 12 for further explanation.) Verify that you have spotted the correct key star by identifying fainter telescopic stars near it, as shown on the chart.

Now progress slowly (“star-hop”) in the direction of the variable, identifying star configurations (also called asterisms) as you go. Until you become very familiar with the field, it will take many glances —from the chart, to the sky, then through the finder scope, and back again—until you reach the star configuration in the immediate vicinity of the variable. Take your time to ensure proper identification. Sometimes it helps to draw lines on the chart between the stars in each configuration.

2b. Find the variable (using setting circles) – If your telescope is equipped with fairly accurate setting circles (regular or digital), this may be your choice for finding variable star fields. Before starting, ensure that your telescope is properly aligned. The 2000 coordinates which appear at the top of the chart should then be used to “dial” in the variable. The inclusion of the 1900 coordinates allow you to apply precession corrections as we move away from the year 2000.

Remember, the variable may not be immediately apparent. Even though it *might* be in the field of view, you will still need to identify the stars in the immediate vicinity of the variable for positive confirmation. Often, you will find that it is helpful to scan around the field to locate a bright key star or asterism which you can then find on the chart. From there you can progress (“star-hop”) to the variable.

3. Find the comparison stars – When you are sure that you have correctly identified the variable, you are ready to proceed with making an estimate of its brightness by comparing it with other stars of fixed, known brightness. These “comparison” or “comp” stars are generally located near the variable on the chart. Find them through your telescope, being very careful once again to ensure that you have identified them correctly.

4. Estimate brightness – To estimate the magnitude of a variable star, determine which comparison (comp) star or stars are closest in brightness to the variable. Unless the variable is exactly the same brightness as one of the comp stars, you will have to interpolate between a star that is brighter and a star that is fainter than the variable itself. The interpolation exercise in Figure 2.1 (pg. 10) will help to illustrate this procedure.

5. Record your observations – The following information should be recorded in your logbook as soon as possible after each observation:

– **name** and **designation** of the variable (see pages 17 and 18 for more on this subject)
– **date** and **time** of your observation
– **magnitude** estimate for the variable
– **magnitudes of the comparison stars** used for the estimate
– **identification of chart used**
– **notes** on any conditions which might effect seeing (i.e. clouds, haze, moonlight, high wind, etc.)

6. Prepare your report – There is a very specific format for reporting your observations and there are several ways to submit your reports to AAVSO Headquarters. Guidelines for reporting your observations will be covered in detail in Chapter 6 of this manual.

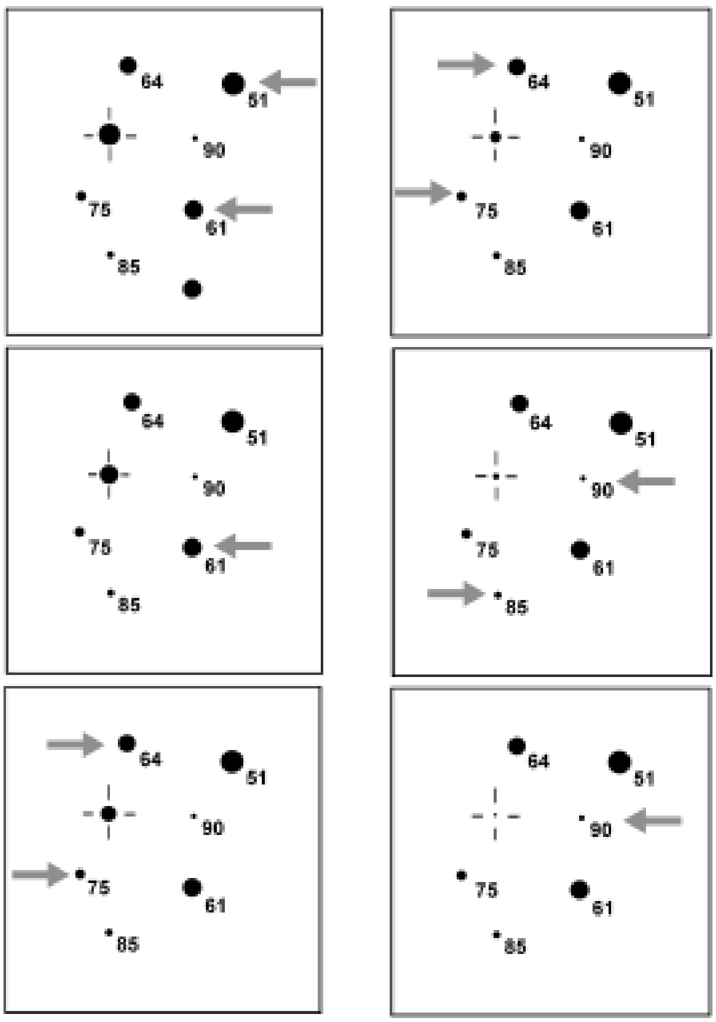
Figure 2.1 – *Interpolation Exercises*

These are some examples showing how to interpolate between comparison stars to determine the magnitude of the variable. Remember that in the real world, the stars all appear as points of light, not as disks of different sizes. The stars used for the interpolation in each example below are marked with arrows.

For more on interpolation, try using the "Telescope Simulator"—a dynamic presentation on how to make variable star magnitude estimates—which can be accessed through the AAVSO website at http://www.aavso.org/aavso/about/powerpoint.shtml.

Magnitude 5.2

Magnitude 7.1



Magnitude 6.1

Magnitude 8.9

Magnitude 6.5

Magnitude < 9.0
("fainter-than" 9.0)

Additional Observing Tips

Field of view

New observers should ascertain the approximate size of the field of view of their telescopes with the different eyepieces. (See also page 4.) Point the telescope at a region not far from the celestial equator and without moving the instrument, allow a bright star to trail through the field. The star will move at a rate of one degree in four minutes, near the equator. For example, if two minutes are required for the star to pass across the center of the field, from edge to edge, the diameter of the field is one-half of one degree.

Once the instrument's field is determined, a circle with the proper diameter may be drawn on the chart, with the variable at the center, as an aid in identifying a new field. Or, it may be useful to represent the field on the chart by using a piece of cardboard with the proper-size hole in it, or by making a wire ring to lay over the chart, etc.

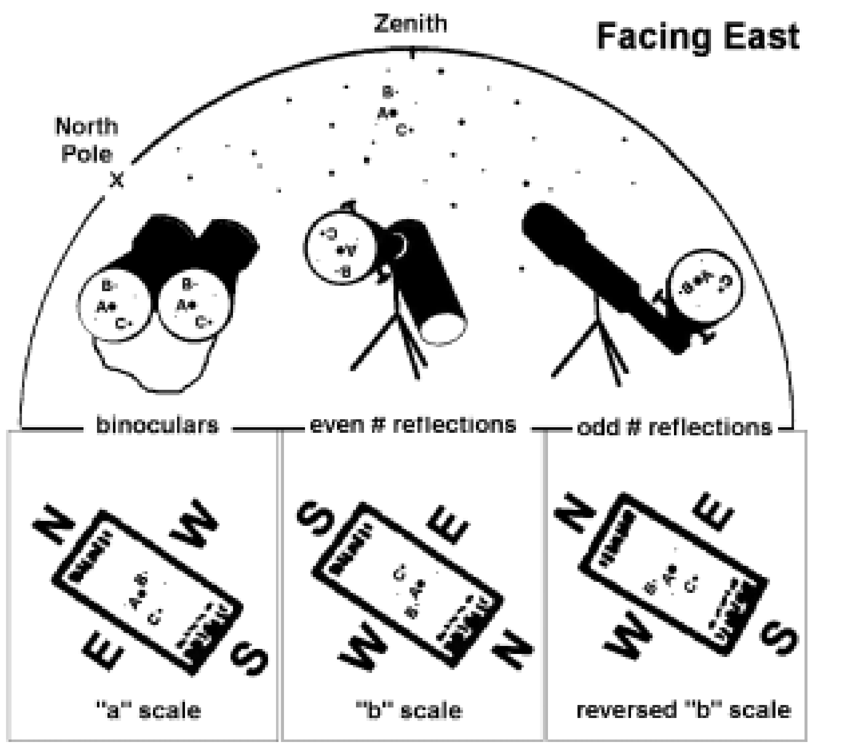
Orientation of charts

In order to use the charts successfully, you must learn how to orient them properly to the sky. On AAVSO chart scales "a", "aa", and "ab", *north is up and east is to the left*. These charts are appropriate for use with the unaided eye or with binoculars.

For chart scales "b" and larger, *south is up and west is to the left*. These charts are appropriate for use with reflecting telescopes where there is an even number of reflections, resulting in a field that is seen upside-down. For refracting and Schmidt-Cassegrain telescopes, a right-angle prism (diagonal) is normally used, resulting in an odd number of reflections. This produces an image which is right-side up, but east and west are flipped (i.e. a mirror image). In this case, whenever possible, you would be well advised to use AAVSO reversed charts on which *north is up and west is to the left*. If you are in need of a reversed chart and one does not yet exist, it may be possible to reverse a chart yourself by either flipping the chart over and redrawing it through the back side, or using computer imaging software to do it for you.

Figure 2.2 – *Chart types*

The drawing at right shows how a group of stars appear in binoculars, in a typical Newtonian reflector with an even number of reflections, and in a typical refractor or Cassagrain telescope with a right angle prism (odd number of reflections). Below each instrument is drawn a chart type commonly used with that instrument. The charts are also oriented correctly.



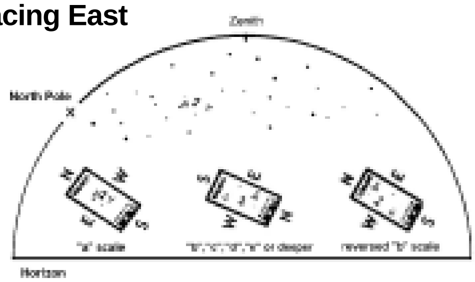
Orientation of Charts

Regardless of what kind of chart you are using, the position of the variable changes relative to the horizon as the earth rotates, and the chart must be held according to the following rules:

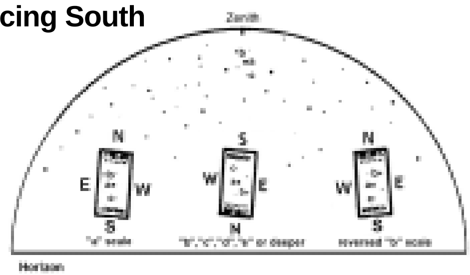
1. Face the direction in which the distance from the variable to the horizon is smallest.
2. Hold the chart up over your head next to the variable star.
3. With regular “b” scale and deeper charts, rotate the chart so that South is pointing toward Polaris. (In the Southern Hemisphere, point North toward the South Celestial Pole.) When using an “a” scale chart or a “reversed” chart, point North toward Polaris.
4. Bring the chart down to a comfortable working position without changing its orientation.

Northern Hemisphere

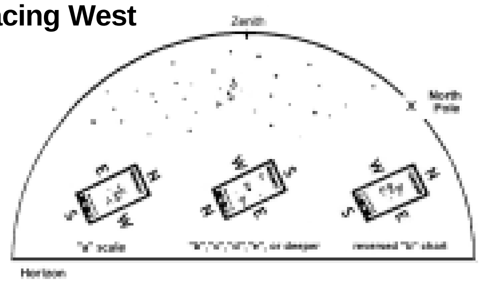
Facing East



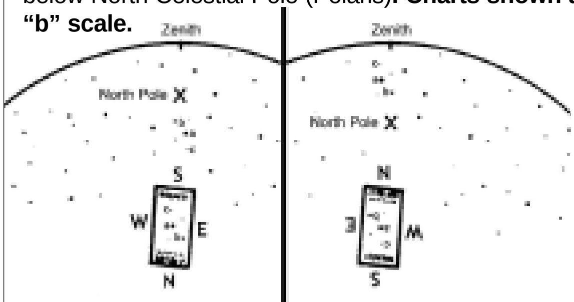
Facing South



Facing West



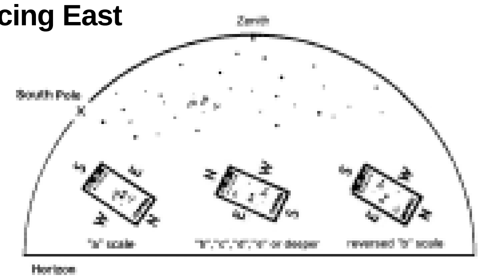
Facing North-note difference if variable is above or below North Celestial Pole (Polaris)**. Charts shown are “b” scale.**



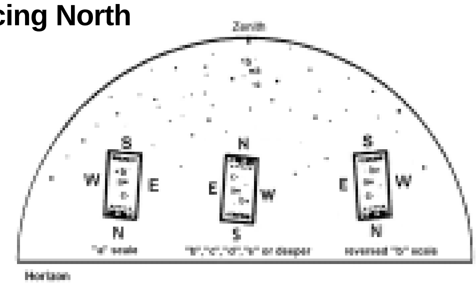
variable between Polaris and horizon | variable between Polaris and zenith

Southern Hemisphere

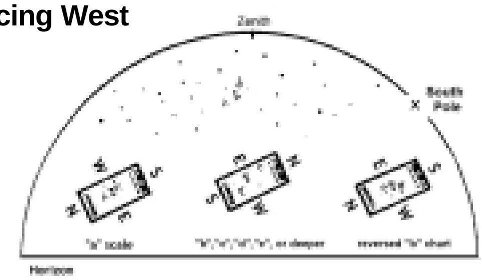
Facing East



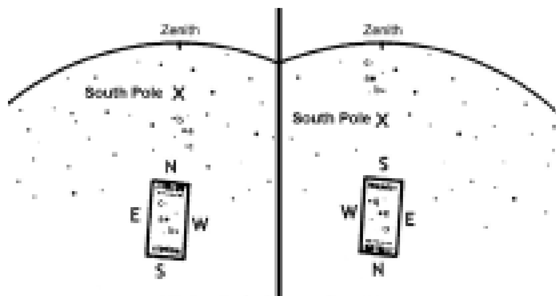
Facing North



Facing West



Facing South-note difference if variable is above or below South Celestial Pole**. Charts shown are “b” scale.**



variable between SCP and horizon | variable between SCP and zenith

The magnitude scale

The scale of magnitudes may seem confusing at first, because the larger the number, the fainter the star. The average limit of unaided-eye visibility is 6th magnitude. Stars like Antares, Spica, and Pollux are 1st magnitude, and Arcturus and Vega are 0 magnitude. The very bright star, Canopus, is -1 (minus one), and the brightest star in the sky, Sirius, is -1.5.

On AAVSO charts, the comparison stars are designated with numbers which indicate their magnitude to tenths. The decimal point is omitted to avoid confusion with the dots which represent stars. Thus 84 and 90 indicate two stars whose magnitudes are 8.4 and 9.0, respectively.

The magnitudes of the comparison stars used on AAVSO charts have been determined carefully with special instruments (iris photometers, photoelectric photometers, and charge-coupled devices) and are considered as measuring rods in estimating the magnitude of the variable. It is important for the observer to keep a record of which comparison stars are used when making an estimate of a variable's brightness.

Because the magnitude scale is actually logarithmic, a star "twice as faint" as another would not be represented by the magnitude number simply doubling in value. (See the side-bar at right, *Measuring the Brightness of Stars*, for a more detailed explanation.) For this reason, the observer must always be careful to use comparison stars that are not too far apart in brightness—not more than 0.5 or 0.6 of a magnitude apart—when making estimates of brightness.

Limiting magnitude

It is best to use only just enough optical aid to enable the variable to be seen with ease. In general, if the variable is brighter than 5th magnitude, the unaided eye is best; if between the 5th and 7th, the finder or a good pair of field glasses is advised; and if below 7th magnitude, high-power binoculars or a telescope of three inches aperture or more, according to the magnitude of the variable, should be used. **Estimates of brightness are easier to make and more accurate when they are 2 to 4 magnitudes above the limit of the instrument.**

Measuring the Brightness of Stars

—Excerpted from the AAVSO Hands-On Astrophysics Manual

The method we use today to compare the *apparent brightness* of stars is rooted in antiquity. Hipparchus, a Greek astronomer who lived in the second century BC, is usually credited with formulating a system to classify the brightness of stars. He called the brightest star in each constellation "first magnitude." Ptolemy, in 140 AD, refined Hipparchus' system and used a 1 to 6 scale to compare star brightness, with 1 being the brightest and 6 being the faintest.

Astronomers in the mid-1800's quantified these numbers and modified the old Greek system. Measurements demonstrated that 1st magnitude stars were 100 times brighter than 6th magnitude stars. It has also been calculated that the human eye perceives a one magnitude change as being 2½ times brighter, so a change in 5 magnitudes would seem to be 2.5^5 (or approximately 100) times brighter. Therefore, a difference of 5 magnitudes has been defined as being equal to a factor of exactly 100 in apparent brightness.

It follows that one magnitude is equal to the 5th root of 100, or approximately 2.5; therefore, the apparent brightness of two objects can be compared by subtracting the magnitude of the brighter object from the magnitude of the fainter object, and raising 2.5 to the power equal to that difference. For example, Venus and Sirius have a difference in brightness of about 3 magnitudes. This means that Venus appears 2.5^3 (or about 15) times brighter to the human eye than Sirius. In other words, it would take 15 stars with the brightness of Sirius in one spot in the sky to equal the brightness of Venus.

On this scale, some objects are so bright that they have negative magnitudes, while the most powerful telescopes (such as the Hubble Space Telescope) can "see" objects down to a magnitude of about +30.

Apparent magnitudes of selected objects:

Sun	-26.7	Sirius	-1.5
Full Moon	-12.5	Vega	0.0
Venus	-4.4	Polaris	2.5

The table below serves as an approximate guide to limiting magnitudes versus telescope/ instrument size. What you are actually able to observe with your own equipment may be quite different from this, due to varying seeing conditions and quality of the telescope. You may wish to create your own table of limiting magnitudes by using a star atlas or chart with magnitudes given for easy-to-find non-variable stars.

Table 2.1 – Typical limiting magnitudes

		eye	binoc	6"	10"	16"
City	Avg.	3.2	6.0	10.5	12.0	13.0
	Best	4.0	7.2	11.3	13.2	14.3
Semi-dark	Avg.	4.8	8.0	12.0	13.5	14.5
	Best	5.5	9.9	12.9	14.3	15.4
Very dark	Avg.	6.2	10.6	12.5	14.7	15.6
	Best	6.7	11.2	13.4	15.6	16.5

When a faint companion star is found near a variable, be sure that the two stars are not confused with each other. If the variable is near the limit of visibility and some doubt exists as to positive identity, indicate this in your report.

The experienced observer does not spend time on variables below his/her telescope limit.

Identification of the variable

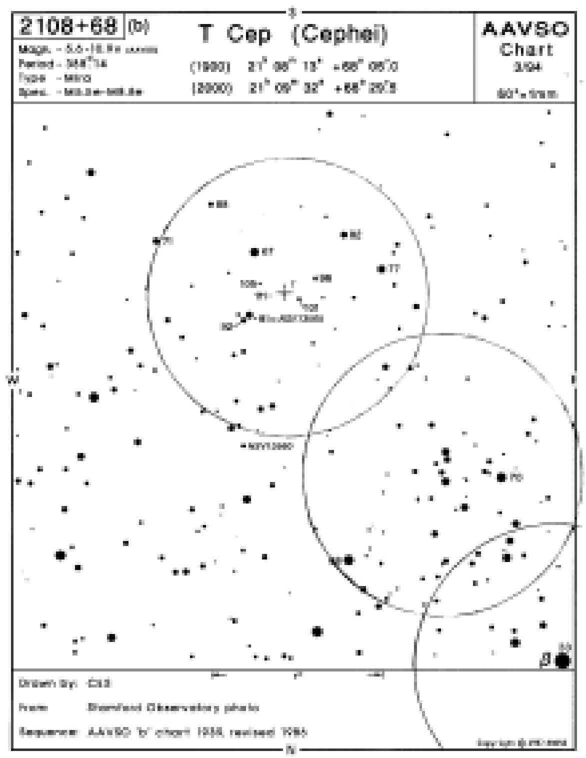
Remember that the variable may or may not be visible with your telescope at the time you are searching for it, depending on whether the star is near maximum or minimum brightness, or somewhere in between.

When you think that you have located the variable, compare the region around it with the chart very carefully. If there are any stars in the field which do not seem to match, either in brightness or location, then you may be looking at the wrong star. Try again.

An eyepiece of higher power will be necessary when the variable is faint or in a very crowded field of stars. Also, it will probably be necessary to use the “d” or “e” scale charts in order to obtain positive identification of the variable. When you are observing, *relax*. Don’t waste time on variables you cannot locate. If you cannot find a variable star after a reasonable effort, make a note and move on to your next variable. After your observing session, reexamine the atlas and charts and see if you can determine why you could not find the variable. Next time you are observing, try again!

Figure 2.3 – *Star Hopping*

The chart below is being used to illustrate a typical star hop from the bright key star, beta Cep, to the variable star, T Cep. Note that the observer’s telescopic field-of-view has been drawn in and that a bright asterism is being used to help find the way from beta to T Cep.



Estimating the variable’s brightness

Any optical instrument’s resolving power is greatest at its center of field. Thus, when the comparison star and the variable are widely separated, they should not be viewed simultaneously but they should be brought successively into the center of the field.

If the variable and the comparison star are close together, they should be placed at equal distance from the center, and the line between the two stars should be as parallel as possible to the connecting line between your eyes to prevent what is known as “position angle error.”

If this is not the case, turn your head or the erecting prism (if used). The position angle effect can produce errors of up to 0.5 magnitude.

It must be stressed that *all observing must be done near the center of the instrument's field.* Most telescopes do not have 100% illumination over the field of all eyepieces, and there is greater aberration of the image, the further it is positioned toward the edge of the objective in refractors or of the mirror in reflectors.

Use at least two comparison stars, and if possible, more. If the interval between comparison stars is very large, say 0.5 or greater, use extreme care in estimating how the interval between the brighter comparison star and the variable compares with that between the variable and the fainter comparison star.

Record exactly what you see, regardless of seeming discrepancies in your observations. You should go into each observing session with a clear head; do not let your estimate be prejudiced by your previous estimates or by what you THINK the star should be doing.

If the variable is not seen because of extreme faintness, haze, or moonlight, then note the faintest comparison star visible in the region. If that star should be 11.5, record your observation of the variable as <11.5, which means that the variable is invisible and must have been below, or fainter, than, magnitude 11.5. The left-pointing bracket is a symbol for "fainter than."

When observing variables which have a decidedly red color, it is recommended that the estimate be made by the so-called "quick glance" method rather than by prolonged "stares." Due to the *Purkinje effect*, red stars tend to excite the retina of the eye when watched for an extended period of time; accordingly, red stars would appear to become unduly bright in comparison to blue stars, thus producing an erroneous impression of the relative magnitudes.

Another technique that is strongly recommended for making magnitude estimates of red stars, is called the "out-of-focus method." That is, the eyepiece must be drawn out of focus so far that the stars become visible as colorless disks. In this way a systematic error due to the Purkinje effect is avoided. If the color of the variable is visible even when the stars are out-of-focus, you may need to use a smaller telescope or an aperture mask.

For faint stars, you may wish to try making your estimate by using averted vision. To do this, keep the variable and the comparison stars near the center of the field of view while concentrating your gaze to one side, thus using your peripheral vision. The reason this works is explained on the next page.

Record keeping

A permanently bound book (such as a ledger book) should be used for your observing records. Always keep your original record books intact. Any corrections to your records, or reductions, should be entered with a different color ink and dated. A second record book, possibly loose-leaf, can be used to keep on hand records of monthly totals, copies of reports submitted, alert notices, and other information. Computer records should be saved and archived for future reference.

Your observing notes should also include such distractions as people present, lights, noises, or anything else that might have had an effect on your concentration.

If for any reason your magnitude estimate is doubtful, state this in your record, giving the reasons for your doubt.

It is essential that records be kept in such a manner that the observer will not be prejudiced by a knowledge of what magnitude the variable had when it was previously observed. The observer must resolve to make all estimates independent of each other without reference to previous observations.

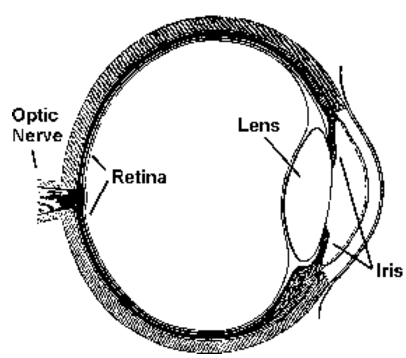
In the heading of each page of your record book, note the Julian day (explained in Chapter 4) and the day of the week, as well as the year, month, and day of observation. It is well to use the "double-day" notation to avoid confusion in observations made after midnight; e.g., JD 2453647, Tue.–Wed., October 3–4, 2005. In case a mistake is made in one, the other tends to indicate which is correct.

If more than one observing instrument is available, note which one is used for each observation.

Starlight in your eyes - *from the AAVSO Hands-On Astrophysics Manual*

The human eye resembles a camera. The eye is equipped with a built-in cleaning and lubricating system, an exposure meter, an automatic field finder, and a continuous supply of film. Light from an object enters the cornea, a transparent covering over the surface of the eye, and passes through a transparent lens held in place by ciliary muscles. An iris in front of the lens opens or closes like the shutter on a camera to regulate the amount of light entering the eye by involuntarily shrinking or dilating the pupil. The iris gradually constricts with age; children and young adults have pupils that can open to 7 or 8 mm in diameter or larger, but by the age of 50 it is not unusual for the maximum pupil size to shrink to 5 mm, greatly reducing the amount of light gathering capability of the eye. The cornea and lens together, act as a lens of variable focal length that focuses light from an object to form a real image on the back surface of the eye, called the retina. Because the pupil size shrinks with age, the retina of a 60-year-old person receives about one third as much light as does that of someone who's 30.

The retina acts like the film of a camera. It contains about 130 million light sensitive cells called cones and rods. Light absorbed by these cells initiates photochemical reactions that cause electrical impulses in nerves attached to the cones and rods. The signals from individual cones and rods are combined in a complicated network of nerve cells and transferred from the eye to the brain via the optic nerve. What we see depends on which cones and rods are excited by absorbing light and on the way in which the electrical signals from different cones and rods are combined and interpreted by the brain. Our eyes do a lot of "thinking" about what information gets sent and what gets discarded.



The cones are concentrated in one part of the retina called the fovea. The fovea is about 0.3 mm in diameter and contains 10,000 cones and no rods. Each cone in this region has a separate nerve fiber that leads to the brain along the optic nerve. Because of the large number of nerves coming from this small area, the fovea is the best part of the retina for resolving the fine details of a bright object. Besides providing a region of high visual acuity, the cones in the fovea and in other parts of the retina are specialized for detecting different colors of light. The ability to "see" the colors of stars is greatly reduced because the intensity of the colors is not great enough to stimulate the cones. Another reason is that the transparency of the lens decreases with age due to increasing opacity. Babies have very transparent lenses that pass wavelengths of light down to 3500 angstroms in the deep violet.

The concentration of cones decreases outside the fovea. In these peripheral regions, the rods predominate. Their density in the retina is about the same as that of the cones in the fovea region. However, the light signals from perhaps 100 adjacent rods are brought together into a single nerve cell that leads to the brain. This combining of the rod signals reduces our ability to see the fine details of an object but helps us see dimly lit objects since many small signals are combined to produce a larger signal. This is why it is easier to estimate the magnitude of a dim variable star by not looking directly at the star, but to one side of the star.

A normal eye can focus on objects located anywhere from about 3 inches to infinity. This ability to focus on objects at different distances is called accommodation. Unlike the camera, which uses a fixed focal length lens and a variable image distance to accommodate different object distances, the eye has a fixed image distance of ~2.1 cm (the distance from the cornea and lens to the retina) and a variable focal length lens system. When the eye looks at distant objects, the ciliary muscle attached to the lens of the eye relaxes, and the lens becomes less curved. When less curved, the focal length increases and an image is formed at the retina. If the lens remains flattened and the object moves closer to the lens, the image will then move back behind the retina, causing a blurred pattern of light on the retina. To avoid this, the ciliary muscles contract and cause an increase in the curvature of the lens, reducing its focal length. With reduced focal length, the image moves forward and again forms a sharp, focused image on the retina. If your eyes become tired after reading for many hours, it is because the ciliary muscles have been tensed to keep the lenses of your eyes curved.

The far point of the eye is the greatest distance to an object on which the relaxed eye can focus. The near point of the eye is the closest distance of an object on which the tensed eye can focus. For the normal eye, the far point is effectively infinity (we can focus on the moon and distant stars) and the near point is about 3 inches. This variable "zoom lens" changes with age and the minimum focus distance grows until it is difficult to focus on objects even 16 inches away, making charts and instruments more difficult to read. The aging eye gradually alters the way we perceive the universe.