AAVSO

Manual for Visual Observing of Variable Stars

Revised Edition
January 2001

The **A**merican **A**ssociation of **V**ariable **S**tar **O**bservers

25 Birch Street
Cambridge, Massachusetts 02138 U. S. A.

Tel: 617-354-0484
Fax: 617-354-0665
Email: aavso@aavso.org
Web: http://www.aavso.org

25 Birch Street
Cambridge, MA 02138
U. S. A.

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FOREWORD AND ACKNOWLEDGEMENTS

It is with great pleasure that we present this revised and improved edition of the *Manual for Visual Observing of Variable Stars*. This manual is intended to be a comprehensive guide to variable star observing. It incorporates a lot of the basic information in the *Manual for Observing Variable Stars*, published in 1970 by the former Director of the AAVSO, Margaret W. Mayall, as well as information from various AAVSO observing materials published since then. This manual provides up-to-date information for making variable star observations and reporting them to the AAVSO.

For new observers, this manual is an essential tool—the one place from which one can gather all the information needed in order to start a variable star observing program. Long-time and experienced observers, and those returning to variable star observing, on the other hand, may find it useful as a ready-reference, quick-resource, or refresher text to help explore new aspects of variable star observing.

This manual will familiarize you with the standardized processes and procedures of variable star observing—a very important part of making and submitting your observations to the AAVSO.

You will find here new information, presented in a useful format, with chapters arranged in order of difficulty and grouped by subject-matter. There are many pull-out pages for those who prefer to put essential information in their own observing notebooks or under a plastic sleeve.

Whether you are a novice or an experienced observer, or even if you are just an armchair observer who wishes to learn more about variable star observing, we hope this manual will help you to increase your knowledge of the fundamentals of variable star observing, improve your work at the telescope, and help you to get more enjoyment and satisfaction from making a real contribution to the science of variable star astronomy.

The information in this manual has been collected from various AAVSO publications and was edited by Sara J. Beck, AAVSO Technical Staff. I sincerely thank Sara for the excellent job she has done in preparing this work.

In addition, many AAVSO members and HQ staff contributed valuable comments and recommendations to this manual. Many thanks to Carl Feehrer, Peter Guilbault, Gene Hanson, Haldun Menali, Paul Norris, Ron Royer, Doug Welch and Michael Saladyga. Our special thanks to Gene Hanson both for providing a chapter in this manual and for his generous contribution toward the cost of publication.

Janet A. Mattei
Director, AAVSO

...it is a fact that only by the observation of variable stars can the amateur turn his modest equipment to practical use, and further to any great extent the pursuit of knowledge in its application to the noblest of the sciences.

—William Tyler Olcott, 1911

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INTRODUCTION

What are variable stars?

Variable stars are stars that change in brightness. Stars often vary in brightness when they are very young or when they are very old. The cause of variability may be intrinsic to the star (expansion, contraction, eruption, etc.), or may be due to extrinsic factors such as eclipses of two or more stars. In the year 2000, over 30,000 variables were known and catalogued while another 14,000 stars were suspected of changing in brightness. Most stars—including the Sun and the North Star—vary in brightness if measured precisely.

Why study variable stars?

Research on variable stars is important because it can provide fundamental information about the physical properties, nature, and evolution of stars. Distance, mass, radius, internal and external structure, composition, temperature, and luminosity can be determined using variable star data. Since professional astronomers have neither the time nor the resources needed to gather data on the brightness changes of thousands of variables, amateurs have been making a real and useful contribution to science by observing variable stars and submitting their observations to the AAVSO or similar organizations.

The importance of the contribution of the serious amateur observer was first recognized in the mid-1800's by Friedrich Wilhelm August Argeländer (1799–1875), a German astronomer, famous for his *Bonner Durchmusterung* (BD) star atlas and catalogue. In 1844 when only 30 variable stars were known, Argeländer wrote in an article: " …I lay these hitherto sorely neglected variables most pressingly on the heart of all lovers of the starry heavens. May you increase your enjoyment by combining the useful and the pleasant while you perform an important part toward the increase of human knowledge." Argeländer's plea is just as appropriate today.

What is the AAVSO?

The American Association of Variable Star Observers (AAVSO) is a worldwide, nonprofit, scientific and educational organization of amateur and professional astronomers who are interested in variable stars. Founded in 1911 by William Tyler Olcott, an amateur astronomer and lawyer by profession, and Edward C. Pickering, Director of the Harvard College Observatory, the AAVSO was part of the Harvard College Observatory until 1954 when it became an independent, private research organization. Its purpose was—and still is—to coordinate, collect, evaluate, analyze, publish, and archive variable star observations made largely by amateur astronomers, and to make these observations available to professional astronomers, educators, and students. In the year 2000, with over 1000 members in 45 countries, and headquartered in Cambridge, Massachusetts, USA, it is the world's largest association of variable star observers.

In 2000, the archives of the AAVSO contained nearly 10 million observations on over 5000 stars. Approximately 600 observers from around the world submit about 350,000 observations every year. At the end of each month, incoming observations are sorted by observer and checked for obvious errors. The observations are then digitized, processed, and added to the data files for each star in the AAVSO International Database. This database is a tribute to the skill, enthusiastic devotion, and dedication of AAVSO observers since 1911.

Services to the Astronomical Community

AAVSO data, both published and unpublished, are disseminated extensively to astronomers around the world, via the AAVSO website (http:\\www.aavso.org) or upon request of AAVSO Headquarters. AAVSO services are sought by astronomers for the following purposes:

a. Real-time, up-to-date information on unusual stellar activity;
b. Assistance in scheduling and executing of variable star observing programs using earth-based large telescopes and instruments aboard satellites;
c. Assistance in simultaneous optical observations of program stars and immediate

notification of their activity during earth-based or satellite observing programs;

d. Correlation of AAVSO optical data with spectroscopic, photometric, and polarimetric multi-wavelength data;

e. Collaborative statistical analysis of stellar behavior using long-term AAVSO data.

Collaboration between the AAVSO and professional astronomers for real-time information or simultaneous optical observations has enabled the successful execution of many observing programs, particularly those using satellites such as Apollo-Soyuz, HEAO 1 and 2, IUE, EXOSAT, HIPPARCOS, HST, RXTE, and EUVE. A significant number of rare events have been observed with these satellites as a result of timely notification by the AAVSO.

Services to Observers and Educators

The AAVSO enables variable star observers to contribute vitally to astronomy by accepting their observations, incorporating them into the AAVSO data files, publishing them, and making them available to the professional astronomer. Incorporating your observations into the AAVSO International Database means that future researchers will have access to those observations, giving you the opportunity to contribute to the science of the future as well as the present.

Upon request, the AAVSO will help set up an appropriate observing program for an individual, an astronomy club, an elementary school, high school, college, etc. In this way, observers, students, and faculty are able to make the best use of their resources and to do valuable science. The AAVSO can also assist in teaching observing techniques and in suggesting stars to be included in a program.

Chapter 1 – PREPARATIONS

Setting up an Observing Program

Getting started

All new members of the AAVSO are given a package of observing materials, including this booklet, and an initial set of AAVSO Charts. Please read these materials carefully and feel free to contact the AAVSO at any stage with questions you might have.

One of the most daunting tasks for a new observer, is locating the variable stars in the sky. The charts included with your package of observing materials are for stars which are considered to be relatively easy to find, due to their proximity to other bright, easily-located stars. In addition, most of the stars are long period and semiregular variables. The large amplitudes and slow rates of variation of these stars allow you to become experienced at making brightness estimates.

Setting up an observing program

Selecting which stars you wish to track, gathering the necessary observing equipment, choosing an observing site, and deciding when and how often you wish to observe, are all part of setting up a successful observing program. To obtain the maximum benefits from variable star observing, which include scientifically useful data and personal satisfaction, you should establish an observing program that is suited to your own personal interests, experience, equipment, and observing site conditions. Even if you submit just one observation a month, you will be making an important contribution to the field of variable star astronomy.

Help is available

Sometimes, there is no substitute for hands-on training. To further assist new observers who request help getting started, the AAVSO has a mentorship program which connects new observers with more experienced observers in their geographical area, whenever possible. Information about this program is also included with the new member package.

Another resource, available to new and experienced observers alike, is the "AAVSO Discussion" group. This is an email based forum in which observers can post their questions or make comments, and other AAVSO members and observers can respond to their inquiries. Information on how to access this service is also included in the new member package and on the AAVSO website.

Some members of "Astronomishe Jugenclub", organized by AAVSO observer Peter Reinhard of Austria

What you should know

Though making variable star observations may sound straightforward as outlined in this manual, the process for the beginner can be very challenging and seemingly impossible at times. THIS IS NORMAL! We state this up front because many have been initially discouraged by the difficulty, believing that things will not get better. We reassure you that things *do* get better. It just takes a little practice.

Expanding your program

As you gain experience and begin to feel comfortable with your variable star work, you will probably wish to expand the list of stars you are observing. You may find it interesting to include different types of variable stars in your program. Unless the stars that you are observing are circumpolar, you will also need to add more stars to your program as the seasons progress and the stars that you were observing are no longer above your horizon at night. Lists of variable stars in the AAVSO program and additional charts may be obtained from AAVSO Headquarters or downloaded from the AAVSO website.

Some factors to consider as you set up, then later expand, your observing program include:

Geographical location – The scale of your observing program will be influenced by the location and terrain of your observing site as well as how often you can use it.

Observing Site Conditions

A remote, dark-sky observing site is by no means required for the visual observation of variable stars. The old axiom that the number of observations accrued per month is inversely proportional to the distance traveled from your home to your observing site is still valid. If you can do your observing from your own backyard several nights a week, perhaps under moderately light-polluted skies, it may actually prove more productive and enjoyable than once a month travelling two hours each way to a remote site with dark skies but obtaining only a handful of estimates. Being successful at variable star observing is more a matter of adapting your observing program to your location and instrumentation than any other factor. It is inspiring to note that quite a number of the AAVSO's leading observers currently reside in, and observe from, urban areas.

Mary Glennon with her 7x50 binoculars

Sky conditions – The more clear nights you have in your location, the more advisable it is to go after stars that require nightly observations, such as the cataclysmic variables and R Coronae Borealis stars (more information about types of variable stars can be found in Chapter 3 of this manual). If a site has clear weather less than 20% of the time, it is recommended that you observe slowly varying, long period variables, since, for these stars, even one observation per month is meaningful.

Light pollution – The amount of light pollution at your observing site greatly affects your selection of stars to observe. An observer living in a city is advised to concentrate on observing bright stars, while observers with dark skies should be challenged to go after stars as faint as their instruments will allow. Some of the most productive AAVSO observers work under very light-polluted conditions!

With more experience

Experienced observers may wish to make observations that can only be made during the morning or evening twilight. Observations made at these times are particularly valuable. This is because the difficulty of observing during twilight leads to a scarcity of observations as a star is entering or emerging from the seasonal gap. The seasonal gap is the period of up to several months when the star is above the horizon only during daylight hours. Observations made between midnight and dawn for stars in the eastern sky also have special value because most observers are active before midnight, when these stars have not yet risen.

Haldun Menali observing in the city

Equipment Needed

Optical Equipment – Successful variable star observing requires interest, perseverance, and the proper optical tools. A good pair of binoculars is sufficient for bright stars, while for fainter stars you need a telescope which can be either portable or permanently mounted. Much information on optical equipment is available from magazines and on the web (see Appendix 3 for more resource information).

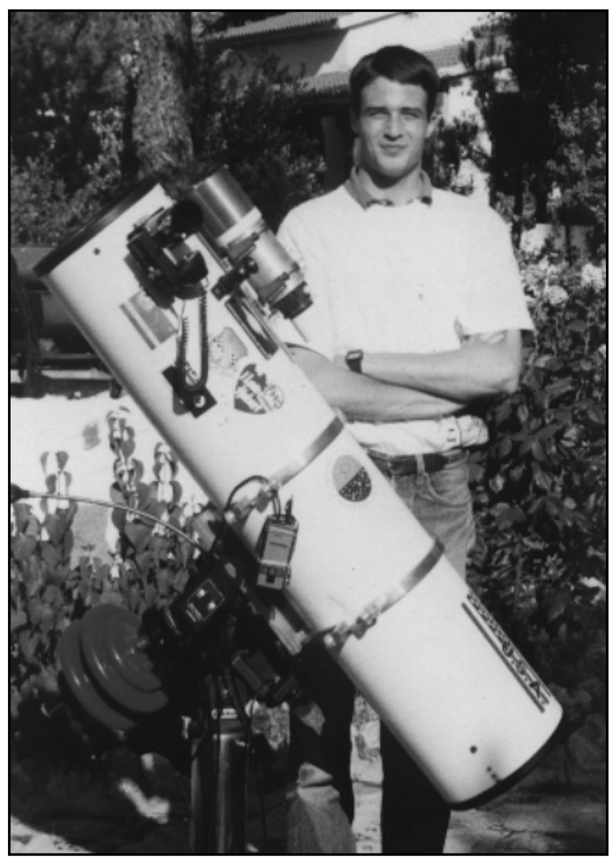
Binoculars – For beginning and experienced observers alike, binoculars are an excellent variable star observing tool. They are portable, easy to use, and provide a relatively large field of view, making it easier to locate the variable star field. Much can be done with a pair of good quality binoculars. Handheld 7x50's or 10x50's are the most generally useful for variable star observing. Higher magnification binoculars also work fine, but will usually require a mount.

Telescope – There is no "ideal" telescope for variable star observing; each has its own special advantage. Variable star observers can use just about every make, model, and type of telescope available. Your own telescope *is* the best scope! The most popular type of telescope among variable star observers is the short focus (f/4–f/8) Newtonian reflector with an aperture of 6 inches (15cm) or more. They are usually far less expensive than other designs and relatively easy to build. In recent years, the Schmidt-Cassegrain and Maksutov telescopes, with their compact design, have gained considerable popularity among new and experienced observers alike.

Finder – It is paramount that your telescope be equipped with a good tool for finding the general region of the sky in which the variable is located. Standard finder scopes, setting circles (regular or digital), or 1X aiming devices, can all be used in variable star observing. Preference varies among observers, so it is suggested that if you are already utilizing one of these systems, you should stick with it, at least in the short term.

Eyepieces – A low-power, wide-field, eyepiece is an important aid in locating variable stars, and it allows the observer to include as many of the comparison stars in the field as possible. High magnification is not necessary until you are observing faint stars (nearer to the limit of your telescope) or crowded fields. The exact size and power of eyepieces you will need depends on the size and type of telescope you use. It is recommended that you have 2 or 3 eyepieces. One of these should be of low power (20X–70X) for use in finding and making observations of the brighter variables. Other eyepieces should be of higher power for viewing fainter stars. Higher quality eyepieces (especially at higher power) afford better star images, which translate into fainter star visibility. A good quality, achromatic, two- or three-power Barlow lens may also be a valuable aid. (See next page for more about eyepieces.)

Mount – Either equatorial or alt-azimuth mounts can be used successfully in variable star observing. Stability is important to prevent jittery star images, and smooth movements help in star-hopping. A drive system can be helpful when high magnification is used, but many observers make do without one.



Nicholas Oliva with Newtonian reflector

A Few Words on Eyepieces by Carl Feehrer, AAVSO Member/Observer

A basic understanding of certain eyepiece parameters helps significantly in choosing chart scales, setting expectations concerning what you will see, and deriving maximum benefit from your equipment. Brief discussions of the more important of these are presented below.

Eye Relief—This refers to the distance that necessarily exists between the eye and the eyepiece at the point where the whole field is visible and in focus. In general, the higher the magnification of the eyepiece, the smaller the exit "hole" through which you look will need to be, and the closer you will have to place your eye to the lens. The need to get very close with some eyepiece designs/magnifications can present a problem for eyeglass wearers in particular, and it may result in discomfort for observers whose eyelashes actually must touch the eyepiece in order to achieve a satisfactory view. "Long" eye relief exists when you are able to place your eye several (e.g. 8–20) millimeters from the eyepiece and still maintain an in-focus, full field view. Fortunately, there are several eyepiece designs that aid in meeting this goal.

Field of View—There are actually two concepts here: True Field (TF), and Apparent Field (AF). TF refers to the angular subtence of sky that you are able to see through your instrument, and it depends upon the amount of magnification provided by the eyepiece. The angle seen by the unaided (i.e.1x power) eye is an example of True Field. AF refers to the angular subtense of the eyepiece alone, and it is dependent upon the diameter of the eyepiece lenses. The fixed frame of a TV monitor provides an example of Apparent Field.

A common empirical method for estimating TF that is based on the time taken for a star to transit the field is given in the section on "Additional Observing Tips" (page 11). If you already know the Apparent Field of View (AFOV) and Magnification (M) of your eyepiece, it can also be estimated from the following relationship:

$$TF = AF/M$$

Thus, a 40-power eyepiece with an AF of 50 deg. will display a true angular subtense of sky equal to 1.25 deg., which is approximately equal to 2.5 times the diameter of the full moon.

Exit Pupil—The exit pupil is the name given to the "hole" through which you look. The response of the eye itself sets practical limits to the size of the exit pupil: If it is greater than about 7mm in diameter, some of the transmitted light is "wasted" because that value is approximately the maximum diameter of the diaphragm of the fully dark-adapted eye of a young, healthy person; if it is less than about 2mm, so little light enters the eye that the brightness of a star that is initially not very bright, may not be able to be judged at all.

If you know the focal length (FL) of your eyepiece and the focal ratio (FR) of your telescope, the exit pupil (EP) can be estimated from the following relationship:

$$EP = FL/FR$$

Thus, an eyepiece with a focal length of 25mm, fitted to a telescope with a focal ratio of 10, has an exit pupil equal to 2.5mm. Note that if you do not know the FR, it can be determined by dividing the focal length of the telescope (in mm.) by the aperture (in mm.)

Contrast Enhancement via Magnification—As the magnifying power of an eyepiece increases, the amount of light reaching the eye decreases. However, a modest increase in magnification is often found to enhance the contrast between stars and the surrounding sky, and this effect can sometimes be exploited when making estimates of relative magnitude in moderately light polluted skies. It is frequently found, for example, that 10x–50mm binoculars are preferable to 7x–50mm binoculars in less than totally dark skies. The same holds true for a telescope, and you may find that an increase from a low power to a medium power eyepiece, say, from 20x to 40x, will provide a more favorable viewing situation under marginal conditions.

Parfocal Eyepieces—Eyepieces that are of similar design and produced by the same manufacturer can often be interchanged without the need to refocus, making them very convenient to use. It is sometimes possible to create a "parfocal" set from a mixed set by slipping O-rings or spacers cut from plastic tubing over the eyepiece barrels.

Eyepiece Designs—Eyepieces come in a wide variety of designs. The older varieties contain as few as two lenses, while newer ones contain as many as eight. Some perform best at low to intermediate powers, while others cover the full range from low to high. Choosing the "right" ones depends upon what you plan to observe, your needs in terms of magnification, resolution, field of view, and how much money you are willing to spend. Rough comparisons of common types with respect to eye relief, apparent field, and cost are presented below.

	Eye Relief re: Kellner	Apparent Field (deg)	Cost re: Kellner
Kellner	(short)	36-45	(low)
Orthoscopic	moderate	40-50	moderate
Plossl	moderate	48-52	moderate
Erfle	long	60-70	moderate
"Ultrawide"	long	52-85	very high

Atlas – A star atlas or small scale sky chart will help greatly with learning the constellations and finding the general region of the sky in which a variable can be found. The *AAVSO Variable Star Atlas* is specially designed for locating variable stars. In addition, there are several other atlases to choose from, based on your own needs and preferences. Many of these are listed in Appendix 3 under "Reading Materials."

AAVSO Star Charts – Once you find the region of the sky in which the variable is located, you will need AAVSO Star Charts of various scales to identify the variable and make an estimate of its brightness. The next two pages of this manual contain a detailed description of a typical AAVSO Variable Star Chart along with a sample of one. A set of charts recommended for use by beginner variable star observers is included with the new member package or available upon request.

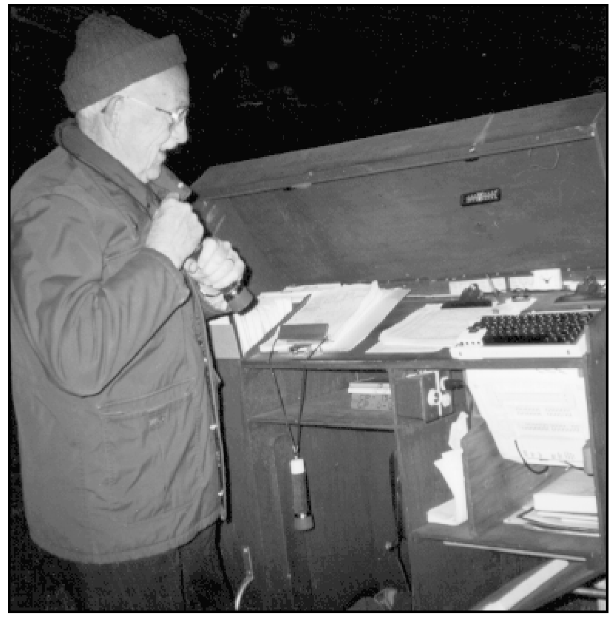
Clock or Watch – Your timepiece should be readable in near darkness and accurate to within a few minutes for most kinds of stars. Accuracy to within seconds is needed for observations of special types of stars such as eclipsing binaries, flare stars, or RR Lyrae stars. Radio time signals available in North America include:

CHU Ottawa, Ontario, Canada
3.330, 7.335, 14.670 MHZ

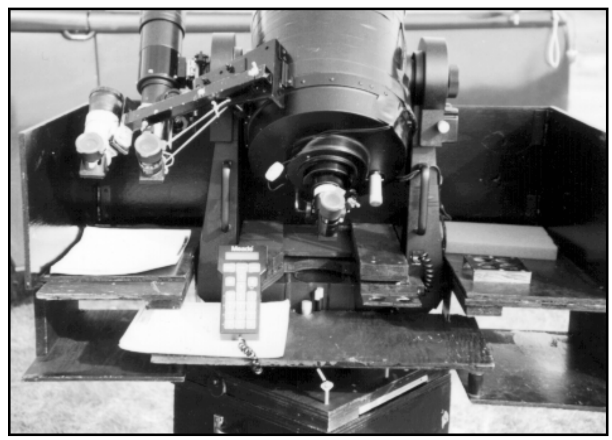
WWV Fort Collins, CO, USA
2.5, 5, 10, 15, 20 MHZ

Record-Keeping System – An efficient record-keeping system is a necessity, and observers have devised many different kinds. Some enter all the observations for the night in a logbook and later copy them on to data sheets for individual stars. Others keep a record sheet for each star at the telescope. Still others enter their observations directly into their computers. No matter what system is adopted, one must not be influenced by previous estimates and should carefully check all records for accuracy.

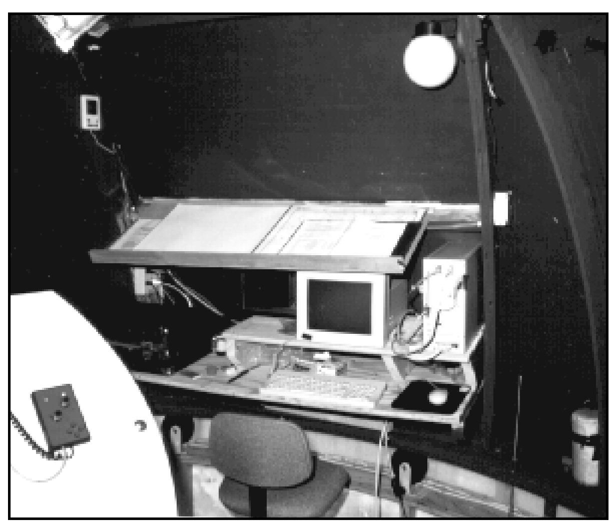
Observing Stand – Most observers use a desk or table to hold charts, record sheets, and other equipment. Many have also constructed a shelter or cover over it to keep things from blowing away in the wind and free of dew. A shielded red light, which does not effect night-vision, is useful for illuminating the charts. Over the years, AAVSO observers have devised many creative solutions to this problem as seen in the photos at right.



Ed Halbach's observing cart



Jack Nordby's "rotating workstation"



Gary Walker's observatory desk

AAVSO Variable Star Charts

Locating a variable star is a learned skill. To aid the observer, finding charts have been prepared with well-determined, visual-magnitude sequences of comparison stars. We urge our observers to use these charts in order to avoid the conflict that can arise when magnitudes for the same comparison star are derived from different sets of charts. This could result in two different values of variation being recorded for the same star on the same night.

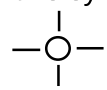
The standard AAVSO charts are 8-1/2 x 11 inches in size, and range in scale from 5 arcminutes per millimeter (“a” charts) to 2.5 arcseconds (“g” charts), a 120-times difference. The scales needed for your observing program will depend on the observing equipment you are using. Table 1.1 below summarizes this information:

Table 1.1 - *Chart Scales*

	arc / mm	area	good for
a	5 minutes	15 degrees	binoculars / finder
ab	2.5 minutes	7.5 degrees	binoculars / finder
b	1 minute	3 degrees	small telescope
c	40 seconds	2 degrees	3–4” telescope
d	20 seconds	1 degree	³ 4” telescope
e	10 seconds	30 minutes	large telescope
f	5 seconds	15 minutes	large telescope
g	2.5 seconds	7.5 minutes	large telescope

Figure 1.1 on the facing page show a typical AAVSO star chart with its features labeled. The heading of each chart contains quite a bit of information including the designation of the variable (see pages 17-18 for a description of this term), a letter identifying the scale of the chart, and the name of the star. Below the variable’s designation are: the range of variation in magnitude; period of variation; class of variable; and spectral type of the star. The position of the variable for the epochs 1900 (or sometimes for 1950) and 2000 are listed below the star’s name. The chart itself corresponds to the earlier of the two epochs given (with the exception of some “b” charts). The coordinates for right ascension are in hours, minutes, and seconds, and those for declination are in degrees, minutes, and tenths of minutes. The latest revision date for the chart is shown in the upper right hand corner of the chart along with the scale of the chart in seconds or minutes of arc per millimeter. Many older style charts may give this information in a different format or be incomplete. The stars on an AAVSO chart are shown as black dots on a white background. The sizes of the dots—particularly for comparison stars—indicate relative brightness. Through a telescope, of course, the stars will appear as points.

Except on the “a” and “b” charts, the position of the variable is generally in the center of the field and is indicated by this symbol:



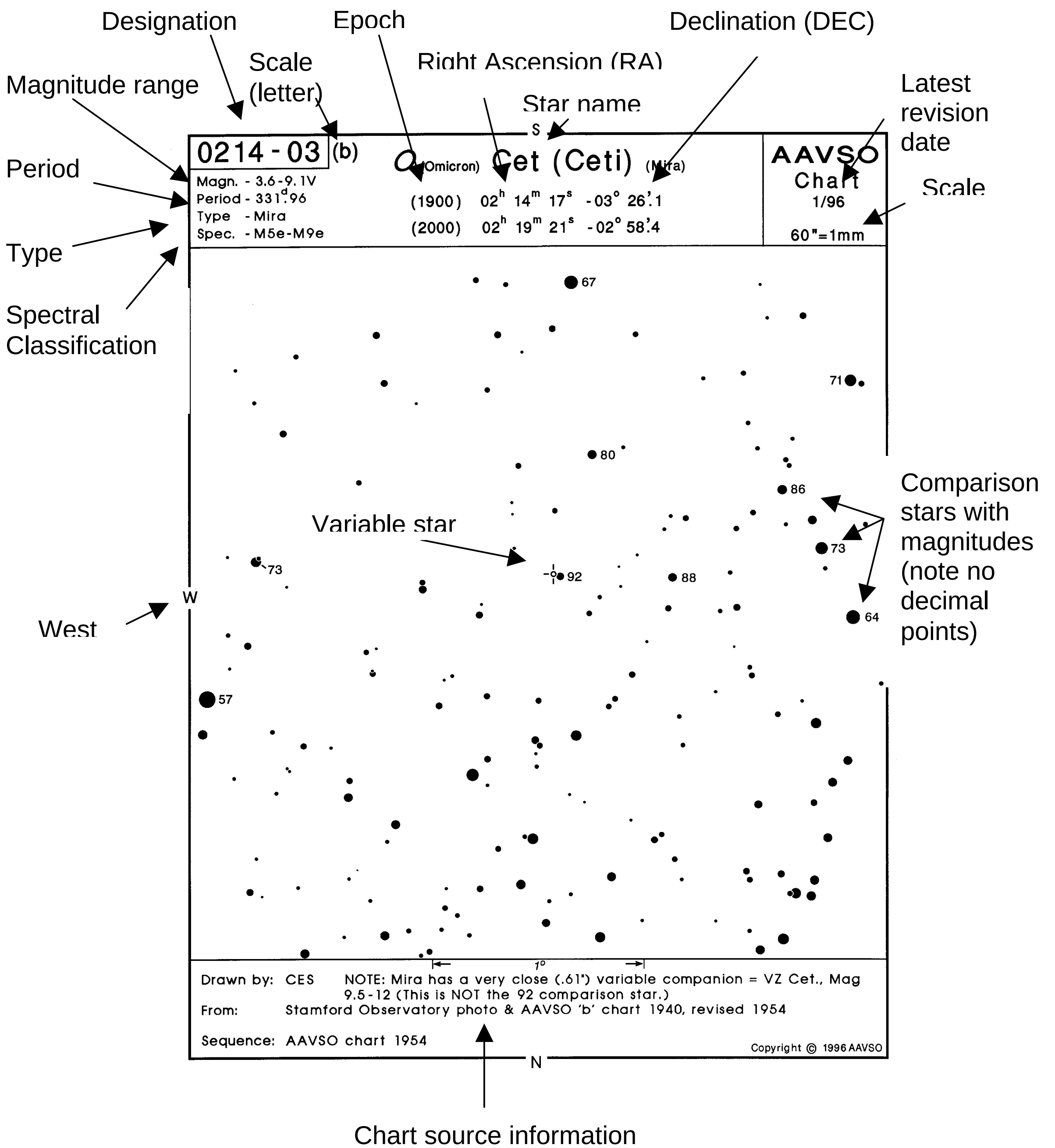
On some of the older charts, the variable is indicated by a simple open circle, sometimes with a dot in the middle. In most cases, when more than one variable in the AAVSO program occurs on the chart, an additional heading is provided for each.

Surrounding the variable star(s) are stars of known constant magnitude called comparison stars. These are used to estimate the brightness of a variable. The comparison stars are recognizable by the fact that they have magnitudes associated with them. These magnitudes are determined to the nearest tenth of a magnitude, the decimal point being omitted to avoid possible confusion with star disks. For example, “8.6” would appear on the chart as “86”. The numbers are placed to the right of the disk spot of the star wherever convenient, otherwise a short line connects disk and number.

Comparison star sequences (magnitudes) have been determined visually and photovisually at Harvard and elsewhere, except for stars measured by photoelectric photometry (underlined) and CCD (overlined).

In addition to the *standard* AAVSO charts, there are available: charts which have been *reversed* west to east for use with telescopes with an odd number of reflections (such as Schmidt-Cassagrains or refractors with diagonal mirrors); *preliminary* charts (subject to revision); 4" x 5" *finder* charts which show a large area of the sky; and special purpose charts such as those used for observing eclipsing binary or RR Lyrae stars or by observers with photoelectric photometry or CCD equipment.

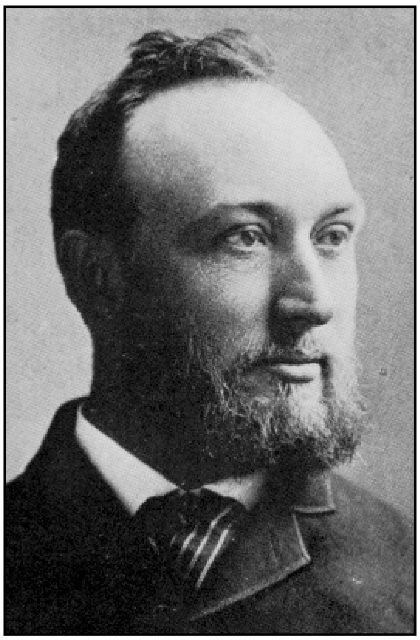
Figure 1.1 – *Sample AAVSO star chart*



All AAVSO charts can be obtained on paper by postal mail, and most are available on-line through the AAVSO website (http://www.aavso.org) and ftp site (ftp://ftp.aavso.org).

The first variable star charts...

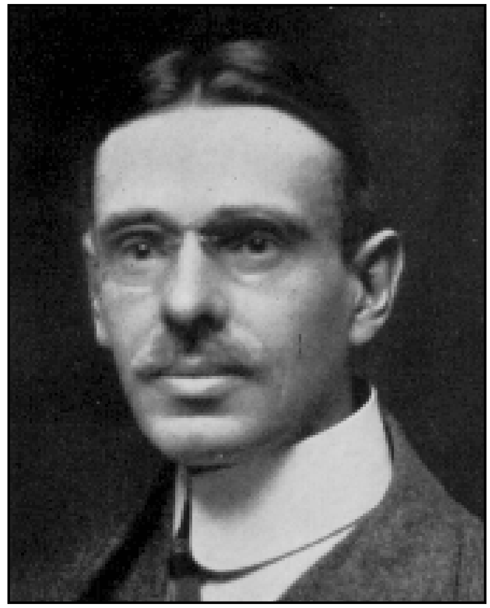
By the mid-1890s, Harvard College Observatory Director, Edward C. Pickering saw that the key to involving many more amateurs in variable star observing—while ensuring the quality and consistency of measurements—would be to provide standard sequences of comparison stars that have assigned magnitudes. For the novice observer, this would make variable star measurement a much simpler activity than having to follow the cumbersome step method (invented by William Herschel and promoted and refined by Argeländer), and it would do away with the laborious reductions needed to derive a light curve.



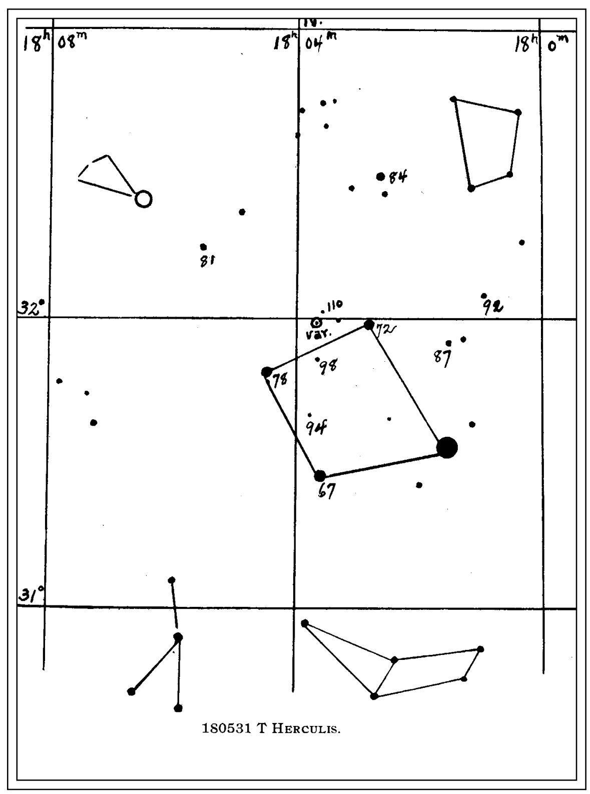
Edward C. Pickering

Pickering (and later AAVSO Co-founder William Tyler Olcott) began providing variable star observers with sets of charts which had the variable star and its comparison stars marked directly on them. The charts were traced from the German star atlas, the *Bonner Durchmusterung*, and the comparison stars were marked with letter-names (a, b, etc.).

In 1906, Pickering made an important change to his chart format, which went hand-in-hand with the way that variable star estimates were to be made. He now entered the photovisual magnitudes of a sequence of comparison stars directly onto photographically reproduced charts. The observation is made by comparing the variable directly with a brighter and a fainter comparison star, and matching or interpolating the variable's magnitude from the given comparison star values. It is a method commonly in use today.



William Tyler Olcott



One of the early variable star charts provided by E. C. Pickering, which W.T. Olcott used in his 1911 Popular Astronomy article, "Variable Star Work for the Amateur with Small Telescopes".

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:

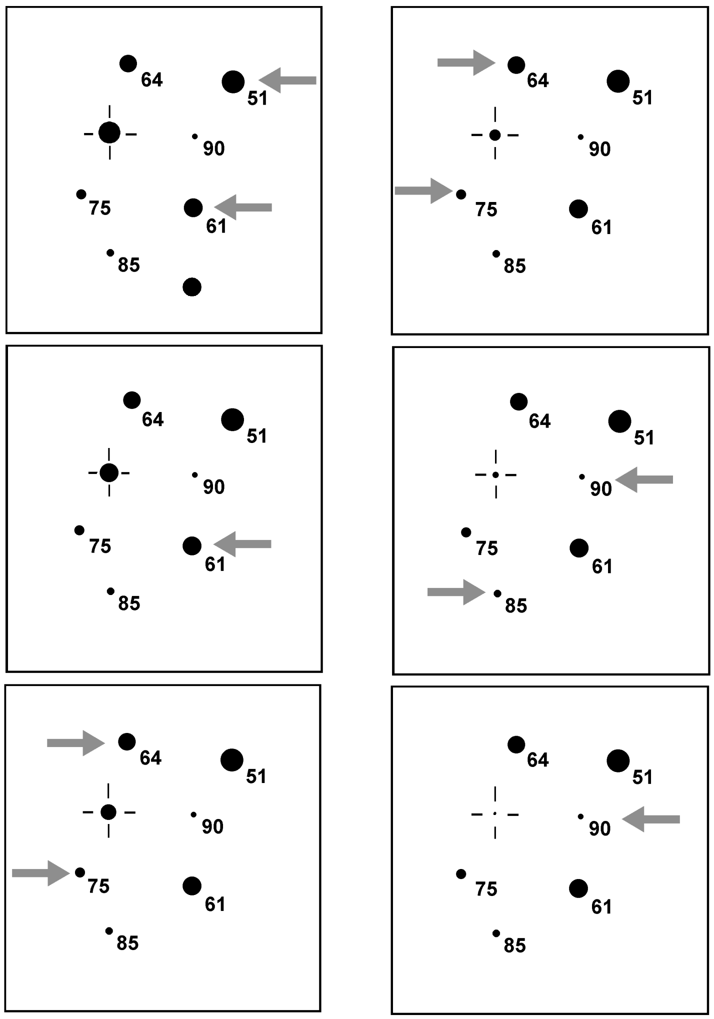
– **name** and **designation** of the variable (see pages 17 and 18 for more on this subject)
– **date** and **time** of your observation
– **magnitude** estimate for the variable
– **magnitudes of the comparison stars** used for the estimate
– **identification of chart and scale used**
– **notes** on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

6. Prepare your report – All variable star observations made in one month should be collected, formatted, and submitted to the AAVSO as soon as possible after the next month begins, if not before. 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 or http://www.aavso.org/powerpoint/welcome.stm.



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.

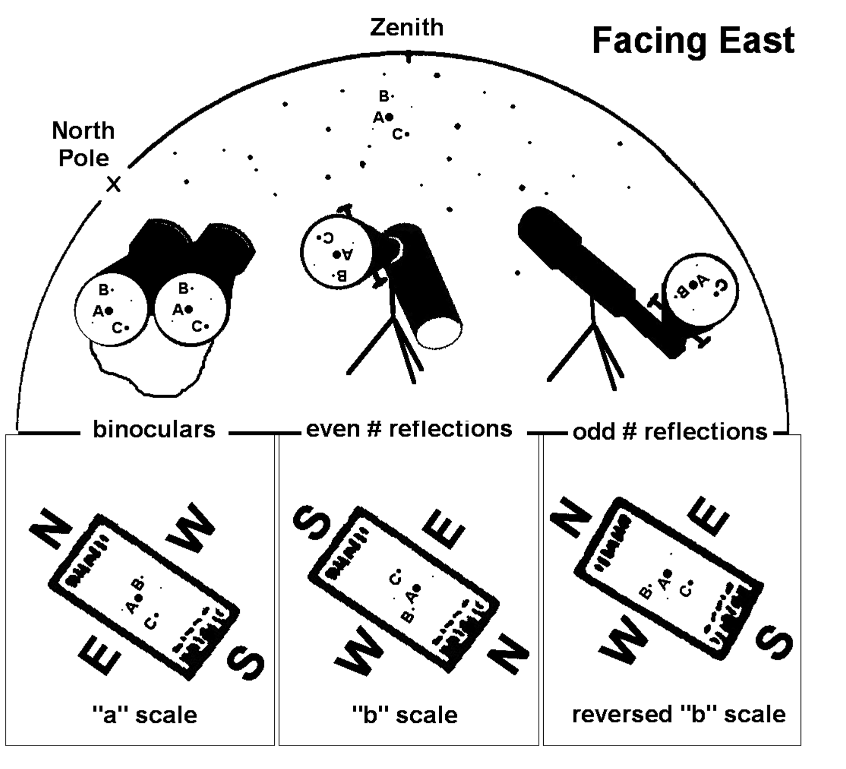
Orientation of charts

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.

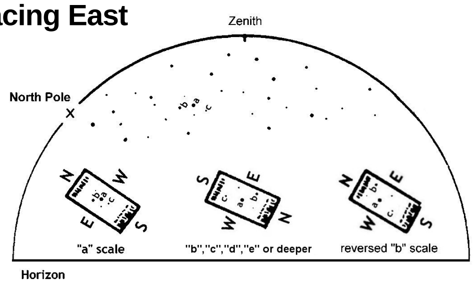
2. Hold the chart up over your head next to the variable star.

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.

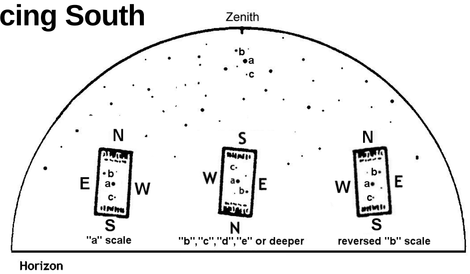
4. Bring the chart down to a comfortable working position without changing its orientation.

Northern Hemisphere

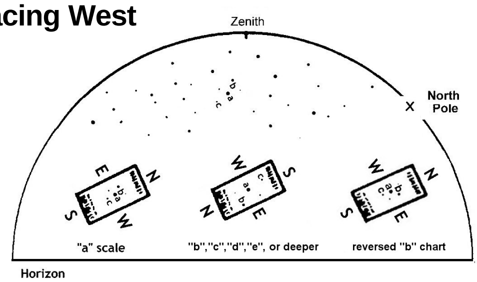
Facing East



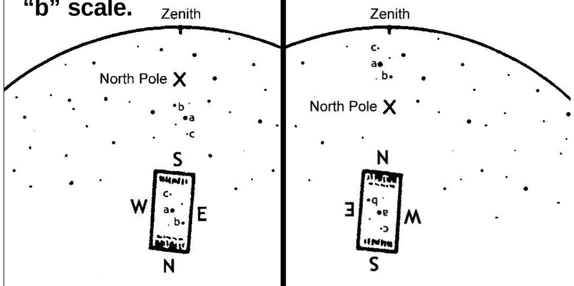
Facing South



Facing West



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

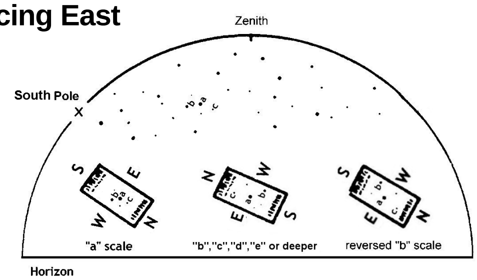


variable between Polaris and horizon

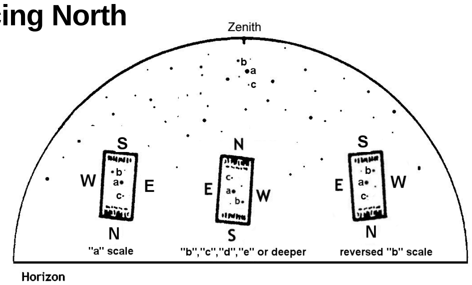
variable between Polaris and zenith

Southern Hemisphere

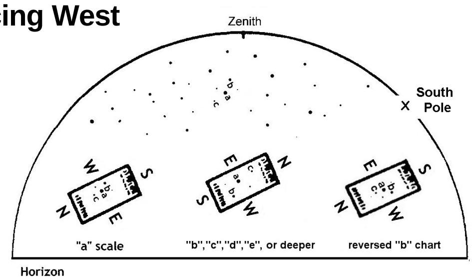
Facing East



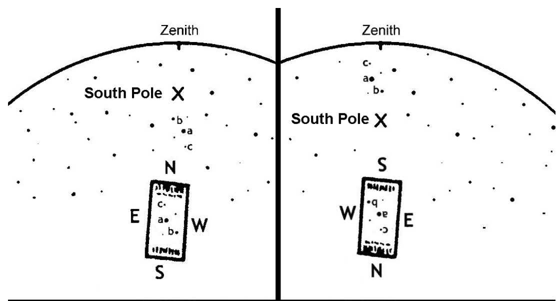
Facing North



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 naked-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.

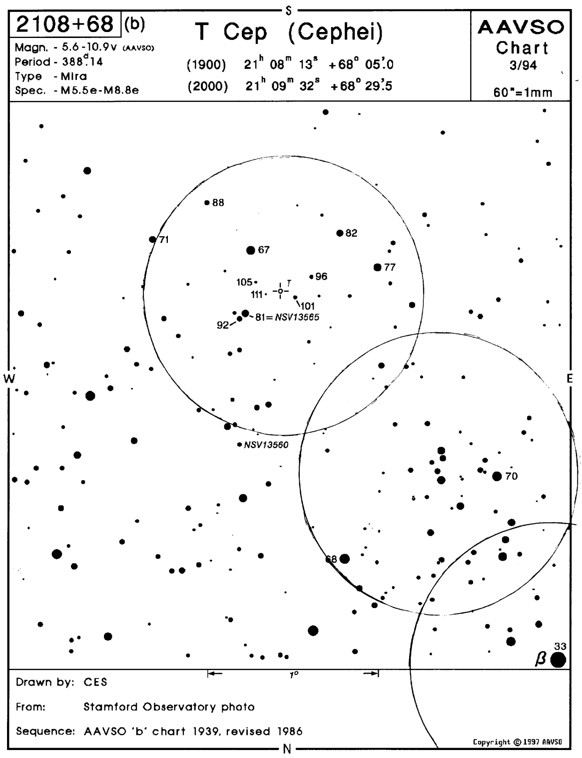
When you think that you have located the variable, compare the region around it with the chart very carefully. If there are any stars in the field which do not seem to match, either in brightness or location, then you may be looking at the wrong star. Try again.

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.

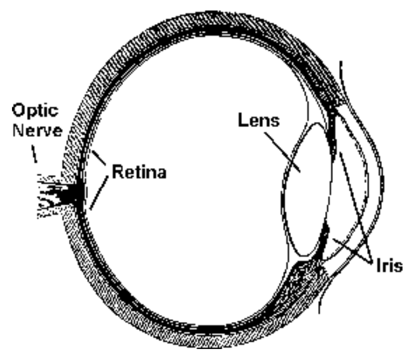
In the heading of each page of your record book, note the Julian day (explained in Chapter 4) and the day of the week, as well as the year, month, and day of observation. It is well to use the "double-day" notation to avoid confusion in observations made after midnight; e.g., JD 2451821, Tue.–Wed., October 3–4, 2000. 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.

The Naming of Variable Stars

The name of a variable star generally consists of one or two capital letters or a Greek letter, followed by a three letter constellation abbreviation. There are also variables with names such as V746 Oph and V1668 Cyg. These are stars in constellations for which all of the letter combinations have been exhausted. (i.e. V746 Oph is the 746th variable to be discovered in Ophiuchus.) See the panel at right for a more detailed explanation of variable star names.

examples: SS Cyg
Z Cam
alpha Ori
V2134 Sgr

Table 3.1 (page 19) lists all of the official constellation name abbreviations.

There are also some special kinds of star names. For instance, sometimes stars are given temporary names until such time as the editors of the *General Catalogue of Variable Stars* assign the star a permanent name. An example of this would be N Cyg 1998—a nova in the constellation of Cygnus which was discovered in 1998. Another case is of a star that is suspected but not confirmed to be variable. These stars are given names such as NSV 251 or CSV 3335. The first part of this name indicates the catalogue in which the star is published, while the second part is the catalogue entry number for that star.

Variable Star Designations

In addition to its proper name, a variable star is also referred to by its *Harvard Designation*. This designation is simply an indication of a star's position coordinates, given in hours and minutes of right ascension (R.A.) plus or minus the degrees of declination (Dec.) of the star for epoch 1900. See sidebar on the next page for more information on how the Harvard Designation is determined.

examples: 2138+43 1405-12A
0214-03 1151+58

Note that in one example given, the designation is followed by the letter "A". This is because there is another variable in the proximity, with the designation 1405-12B which was discovered later.

Variable Star Naming Conventions

Variable star names are determined by a committee appointed by the International Astronomical Union (I.A.U.). The assignments are made in the order in which the variable stars were discovered in a constellation. If one of the stars that has a Greek letter name is found to be variable, the star will still be referred to by that name. Otherwise, the first variable in a constellation would be given the letter R, the next S, and so on to the letter Z. The next star is named RR, then RS, and so on to RZ; SS to SZ, and so on to ZZ. Then, the naming starts over at the beginning of the alphabet: AA, AB, and continuing on to QZ. This system (the letter J is omitted) can accommodate 334 names. There are so many variables in some constellations in the Milky Way, however, that additional nomenclature is necessary. After QZ, variables are named V335, V336, and so on. The letters representing stars are then combined with the genitive Latin form of the constellation name as given in Table 3.1. For all but the most formal usage, and for reports you submit to the AAVSO, the three letter abbreviations should be used.

This system of nomenclature was initiated in the mid-1800s by Friedrich Argeländer. He started with an uppercase R for two reasons: the lowercase letters and the first part of the alphabet had already been allocated for other objects, leaving capitals towards the end of the alphabet mostly unused. Argeländer also believed that stellar variability was a rare phenomenon and that no more than 9 variables would be discovered in any constellation (which is certainly not the case!).

The Harvard Designation of Variable Stars by Margaret W. Mayall
from the *Journal of the AAVSO*, Volume 5, Number 1

In the late 1800's and early 1900's, Harvard College Observatory was the center of most variable star work. Director Edward C. Pickering encouraged both photographic and visual observations. Several catalogues of variable stars were published by the Observatory, and the number of known variables grew so large that astronomers felt the need for a designation that would give a better clue to location in the sky, rather than just a list by constellations. The result was the Harvard Designation, described in the Harvard Observatory *Annals*, vol. 48, p. 93, 1903.

Many suggestions were considered, and it was finally decided to use six numbers to indicate Right Ascension and Declination, epoch 1900. This method is not intended to give an accurate position. It is, as Webster's Dictionary says, an "indication." There has been some confusion concerning the method of determining the designation.

Suppose the position of a variable is given by Right Ascension in hours, minutes, and seconds of time and by Declination in degrees, minutes and tenths of arc, epoch 1900. The first step in determining the Harvard designation is to reduce the Right Ascension to hours, minutes, and tenths, and the Declination to degrees and whole minutes of arc. Then drop the tenths of Right Ascension and the minutes of Declination. The remaining six figures make up the Harvard Designation.

For southern variables, a minus sign is inserted before the degrees of Declination, or the degrees may be underscored or italicized.

Ambiguous cases are covered by a special rule. If, for example, the Right Ascension ends with 21 seconds, dividing by 60, to get tenths of minutes will give 0.35. In such cases, adopt the nearest even number, 0.4 in this case. As further examples, 51 seconds would give 8 tenths, and 57 seconds would give 0 tenths of the next higher minute. In the reduction of Declination, the critical case comes at 59 minutes. If the tenths are 5 or more, change the last two figures of the Designation to the next higher degree.

EXAMPLES

	Coordinates (1900)		Reduced		Designation
RR And	$00^h45^m57^s$	$+ 33°50'.0$	$00^h46^m.0$	$+ 33°50'$	004633
SU And	23 59 28	+ 42 59.7	23 59.5	+ 43 00	235943
TW Aqr	20 58 55	- 02 26.5	20 58.9	- 02 26	2058-02 or $2058\underline{02}$
U Aur	05 35 38	+ 31 59.4	05 35.6	+ 31 59	053531

An easy way to remember the rule is that if the Right Ascension is 57 seconds or more, the minutes would be increased by one; if less, the minutes would not change. In Declination, if the minutes are $59'.5$ or more, the Declination would increase 1°, if less, the Declination remains the same.

Table 3.1 – *Constellation Names and Abbreviations*

The list below shows the I.A.U. conventions for constellation names. Given for each constellation is the Latin name, nominative and genitive, as well as the approved three-letter abbreviation.

Nominative	***Genitive***	***Abbreviation***	***Nominative***	***Genitive***	***Abbreviation***
Andromeda	Andromedae	And	Lacerta	Lacertae	Lac
Antlia	Antliae	Ant	Leo	Leonis	Leo
Apus	Apodis	Aps	Leo Minor	Leonis Minoris	LMi
Aquarius	Aquarii	Aqr	Lepus	Leporis	Lep
Aquila	Aquilae	Aql	Libra	Librae	Lib
Ara	Arae	Ara	Lupus	Lupi	Lup
Aries	Arietis	Ari	Lynx	Lyncis	Lyn
Auriga	Aurigae	Aur	Lyra	Lyrae	Lyr
Bootes	Bootis	Boo	Mensa	Mensae	Men
Caelum	Caeli	Cae	Microscopium	Microscopii	Mic
Camelopardalis	Camelopardalis	Cam	Monoceros	Monocerotis	Mon
Cancer	Cancri	Cnc	Musca	Muscae	Mus
Canes Venatici	Canum Venaticorum	CVn	Norma	Normae	Nor
Canis Major	Canis Majoris	CMa	Octans	Octantis	Oct
Canis Minor	Canis Minoris	CMi	Ophiuchus	Ophiuchi	Oph
Capricornus	Capricorni	Cap	Orion	Orionis	Ori
Carina	Carinae	Car	Pavo	Pavonis	Pav
Cassiopeia	Cassiopeiae	Cas	Pegasus	Pegasi	Peg
Centaurus	Centauri	Cen	Perseus	Persei	Per
Cepheus	Cephei	Cep	Phoenix	Phoenicis	Phe
Cetus	Ceti	Cet	Pictor	Pictoris	Pic
Chamaeleon	Chamaeleontis	Cha	Pisces	Piscium	Psc
Circinus	Circini	Cir	Piscis Austrinus	Piscis Austrini	PsA
Columba	Columbae	Col	Puppis	Puppis	Pup
Coma Berenices	Comae Berenices	Com	Pyxis	Pyxidis	Pyx
Corona Austrina	Coronae Austrinae	CrA	Reticulum	Reticuli	Ret
Corona Borealis	Coronae Borealis	CrB	Sagitta	Sagittae	Sge
Corvus	Corvi	Crv	Sagittarius	Sagittarii	Sgr
Crater	Crateris	Crt	Scorpius	Scorpii	Sco
Crux	Crucis	Cru	Sculptor	Sculptoris	Scl
Cygnus	Cygni	Cyg	Scutum	Scuti	Sct
Delphinus	Delphini	Del	Serpens	Serpentis	Ser
Dorado	Doradus	Dor	Sextans	Sextantis	Sex
Draco	Draconis	Dra	Taurus	Tauri	Tau
Equuleus	Equulei	Equ	Telescopium	Telescopii	Tel
Eridanus	Eridani	Eri	Triangulum	Trianguli	Tri
Fornax	Fornacis	For	Triangulum Australe	Trianguli Australis	TrA
Gemini	Geminorum	Gem	Tucana	Tucanae	Tuc
Grus	Gruis	Gru	Ursa Major	Ursae Majoris	UMa
Hercules	Herculis	Her	Ursa Minor	Ursae Minoris	UMi
Horologium	Horologii	Hor	Vela	Velorum	Vel
Hydra	Hydrae	Hya	Virgo	Virginis	Vir
Hydrus	Hydri	Hyi	Volans	Volantis	Vol
Indus	Indi	Ind	Vulpecula	Vulpeculae	Vul

Types of Variable Stars

There are two kinds of variable stars: **intrinsic,** in which variation is due to physical changes in the star or stellar system, and **extrinsic,** in which variability is due to the eclipse of one star by another or the effect of stellar rotation. Variable stars are frequently divided into four main classes: the *intrinsic* **pulsating** and **cataclysmic** (eruptive) variables, and the *extrinsic* **eclipsing binary** and **rotating stars**.

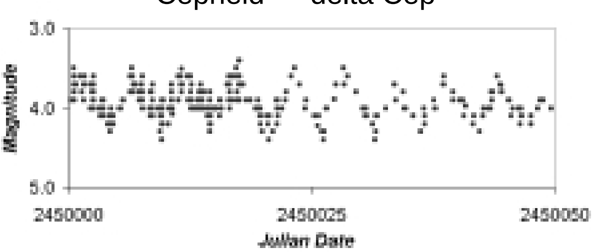
Generally, long period and semiregular pulsating variables are recommended for beginners to observe. These stars have a wide range of variation. Also, they are sufficiently numerous that many of them are found close to bright stars, which is very helpful when it comes to locating them.

A brief description of the major types in each class is covered in this chapter. There is also mention of the star's spectral type. If you are interested in learning more about stellar spectra and stellar evolution, you can find information on these subjects in basic astronomy texts or in some of the books mentioned in Appendix 3.

PULSATING VARIABLES

Pulsating variables are stars that show periodic expansion and contraction of their surface layers. Pulsations may be radial or non-radial. A radially pulsating star remains spherical in shape, while a star experiencing non-radial pulsations may deviate from a sphere periodically. The following types of pulsating variables may be distinguished by the pulsation period, the mass and evolutionary status of the star, and the characteristics of their pulsations.

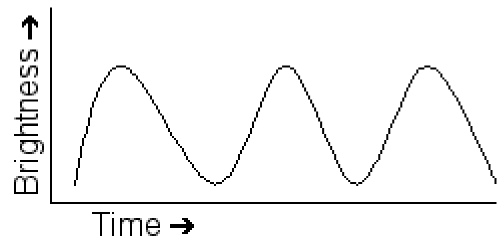
Cepheid — delta Cep



Cepheids – Cepheid variables pulsate with periods from 1 to 70 days, with light variations from 0.1 to 2 magnitudes. These massive stars have high luminosity and are of F spectral class at maximum, and G to K at minimum. The later the spectral class of a Cepheid, the longer is its period. Cepheids obey the period-luminosity relationship. Cepheid variables may be good candidates for student projects because they are bright and have short periods.

What is a Light Curve?

Observations of variable stars are commonly plotted on a graph called a **light curve**, as the apparent brightness (magnitude) versus time, usually in Julian Date (JD). The magnitude scale is plotted so that brightness increases as you go from bottom to top on the Y-axis and the JD increases as you go from left to right on the X-axis.



Information about the periodic behavior of stars, the orbital period of eclipsing binaries, or the degree of regularity (or irregularity) of stellar eruptions, can be directly determined from the light curve. More detailed analysis of the light curve allows astronomers to calculate such information as the masses or sizes of stars. Several years or decades of observational data can reveal the changing period of a star, which could be a signal of a change in the structure of the star.

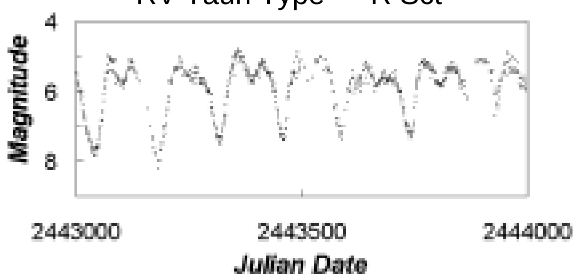
Phase Diagrams

Phase diagrams (also known as "folded light curves") are a useful tool for studying the behavior of periodic stars such as Cepheid variables and eclipsing binaries. In a phase diagram, multiple cycles of brightness variation are superimposed on each other. Instead of plotting magnitude versus JD as with a regular light curve, each observation is plotted as a function of "how far into the cycle" it is. For most variable stars, a cycle starts at maximum brightness (phase=0), runs through minimum and back to maximum again (phase=1). With eclipsing binary stars, phase zero occurs at mid-eclipse (minimum). An example of a phase diagram is given on page 23 of this manual to show the characteristic light curve of beta Persei.

RR Lyrae stars – These are short-period (.05 to 1.2 days), pulsating, white giant stars, usually of spectral class A. They are older and less massive than Cepheids. The amplitude of variation of RR Lyrae stars is generally from 0.3 to 2 magnitudes.

RV Tauri stars – These are yellow supergiants having a characteristic light variation with alternating deep and shallow minima. Their periods, defined as the interval between two deep minima, range from 30 to 150 days. The light variation may be as much as 3 magnitudes. Some of these stars show long-term cyclic variations from hundreds to thousands of days. Generally, the spectral class ranges from G to K.

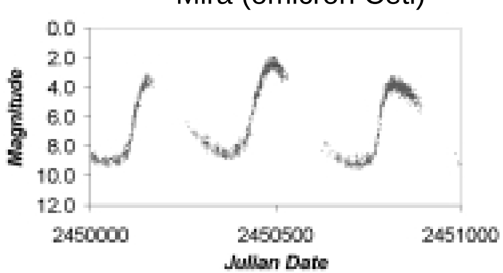
RV Tauri Type — R Sct



Long Period Variables – Long Period Variables (LPVs) are pulsating red giants or supergiants with periods ranging from 30-1000 days. They are usually of spectral type M, R, C or N. There are two subclasses; Mira and Semiregular.

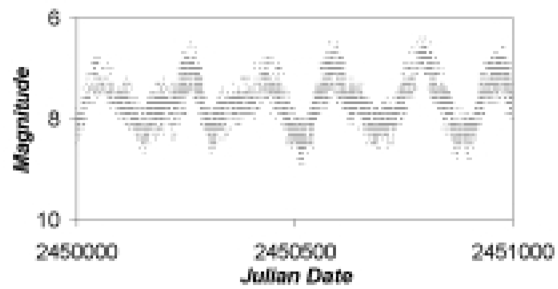
Mira – These periodic red giant variables vary with periods ranging from 80 to 1000 days and visual light variations of more than 2.5 magnitudes.

Mira (omicron Ceti)



Semiregular – These are giants and supergiants showing appreciable periodicity accompanied by intervals of semiregular or irregular light variation. Their periods range from 30 to 1000 days, generally with amplitude variations of less than 2.5 magnitudes.

Semiregular — Z UMa



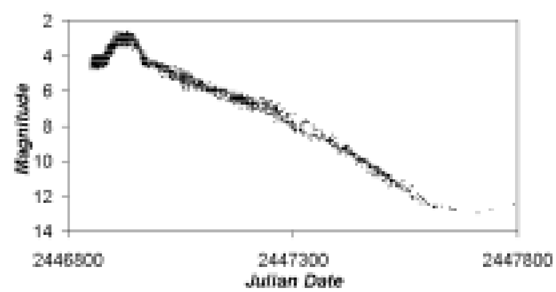
Irregular variables
These stars, which include the majority of red giants, are pulsating variables. As the name implies, these stars show luminosity changes with either no periodicity or with a very slight periodicity.

CATACLYSMIC VARIABLES

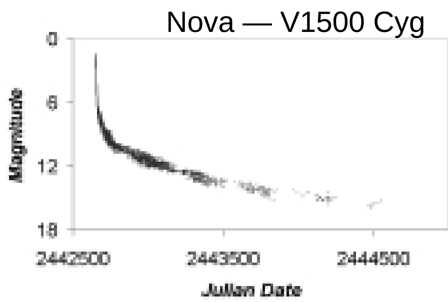
Cataclysmic variables (also known as Eruptive variables), as the name implies, are stars which have occasional violent outbursts caused by thermonuclear processes either in their surface layers or deep within their interiors.

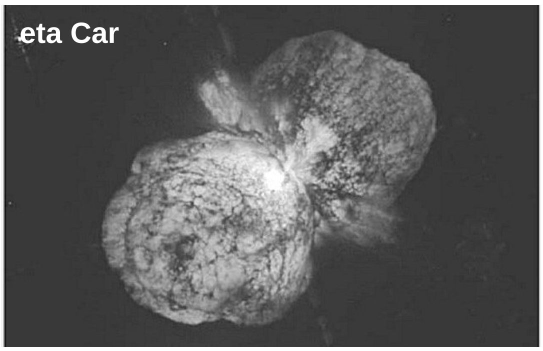
Supernovae – These massive stars show sudden, dramatic, and final magnitude increases of 20 magnitudes or more, as a result of a catastrophic stellar explosion.

SN 1987A



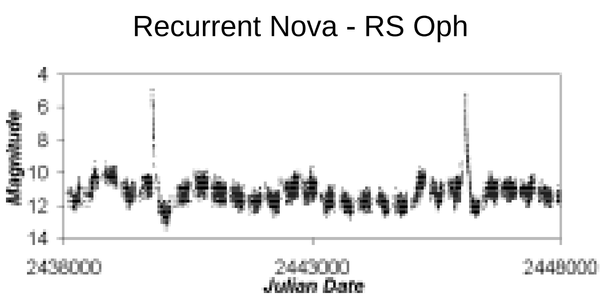
Novae – These close binary systems consist of an accreting white dwarf as a primary and a low-mass main sequence star (a little cooler than the Sun) as the secondary star. Explosive nuclear burning of the surface of the white dwarf, from accumulated material from the secondary, causes the system to brighten 7 to 16 magnitudes in a matter of 1 to several hundred days. After the outburst, the star fades slowly to the initial brightness over several years or decades. Near maximum brightness, the spectrum is generally similar to that of A or F giant stars.





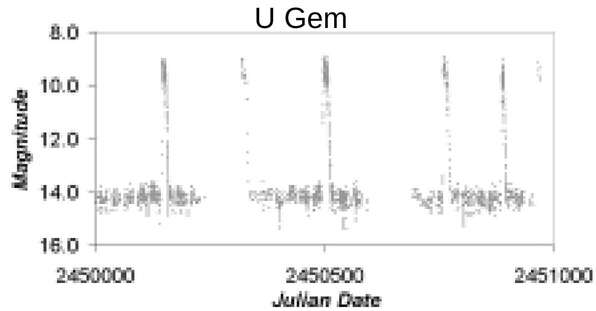
A huge, billowing pair of gas and dust clouds are captured in this stunning NASA Hubble Space Telescope image of the supermassive star eta Carinae. This star was the site of a giant outburst about 150 years ago, when it became one of the brightest stars in the southern sky. Though the star released as much visible light as a supernova explosion, it survived the outburst.

Recurrent Novae – These objects are similar to novae, but have two or more slightly smaller-amplitude outbursts during their recorded history.

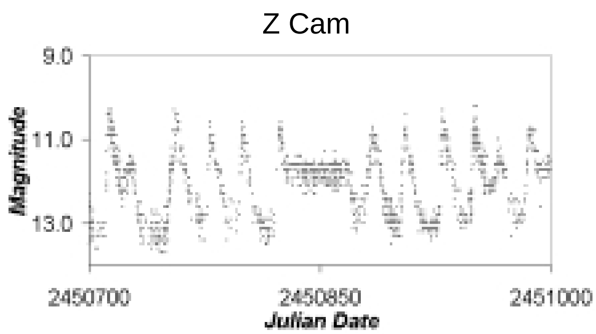


Dwarf Novae These are close binary systems made up of a red dwarf–a little cooler than our Sun, a white dwarf, and an accretion disk surrounding the white dwarf. The brightening by 2 to 6 magnitudes is due to instability in the disk which forces the disk material to drain down (accrete) onto the white dwarf. There are three main subclasses of dwarf novae; U Gem, Z Cam, and SU UMa stars.

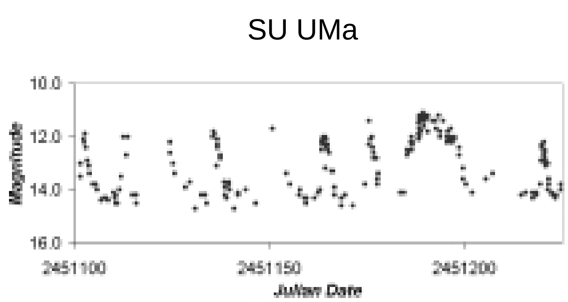
U Geminorum – After intervals of quiescence at minimum light, they suddenly brighten. Depending on the star, the eruptions occur at intervals of 30 to 500 days and last generally 5 to 20 days.



Z Camelopardalis – These stars are physically similar to U Gem stars. They show cyclic variations, interrupted by intervals of constant brightness called “standstills”. These standstills last the equivalent of several cycles, with the star “stuck” at the brightness approximately one-third of the way from maximum to minimum.

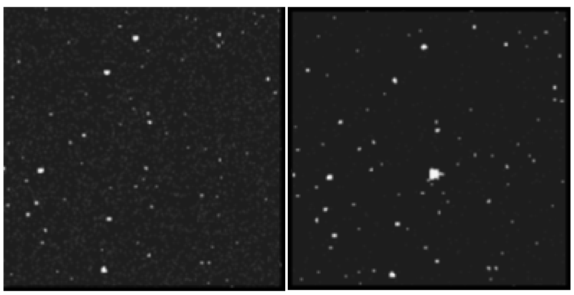


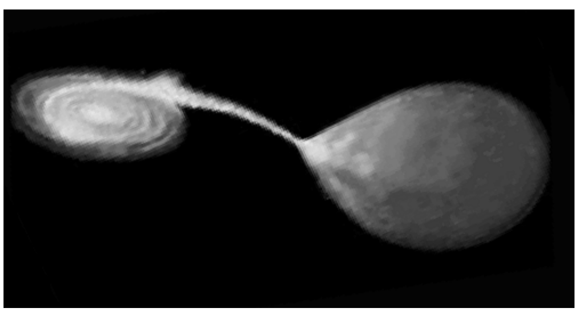
SU Ursae Majoris – Also physically similar to U Gem stars, these systems have two distinct kinds of outbursts: one is faint, frequent, and short, with a duration of 1 to 2 days; the other (“superoutburst”) is bright, less frequent, and long, with a duration of 10 to 20 days. During superoutbursts, small periodic modulations (“superhumps”) appear.



U Geminorum

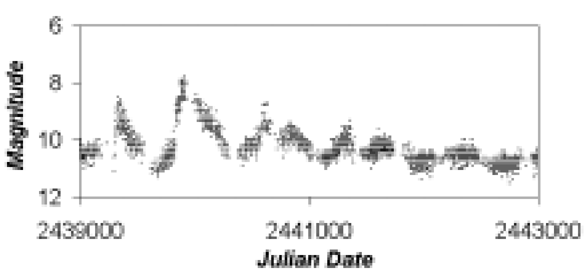
Below are 20-second exposures of U Gem before outburst and after the start of an outburst. Images were taken by AAVSO member Arne Henden, USRA/USNO, using a CCD with a V filter on the U. S. Naval Observatory 1.0-m telescope in Flagstaff, AZ. Beneath the photos is the artist, Dana Berry's, rendition of the U Gem system (note the sun-like star to the right, the white dwarf, and the accretion disk surrounding the white dwarf).





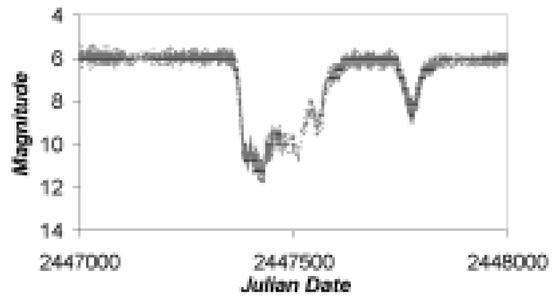
Symbiotic stars – These close binary systems consist of a red giant and a hot blue star, both embedded in nebulosity. They show semi-periodic, nova-like outbursts, up to three magnitudes in amplitude.

Symbiotic – Z And



R Coronae Borealis – These rare, luminous, hydrogen-poor, carbon-rich, supergiants spend most of their time at maximum light, occasionally fading as much as nine magnitudes at irregular intervals. They then slowly recover to their maximum brightness after a few months to a year. Members of this group have F to K and R spectral types.

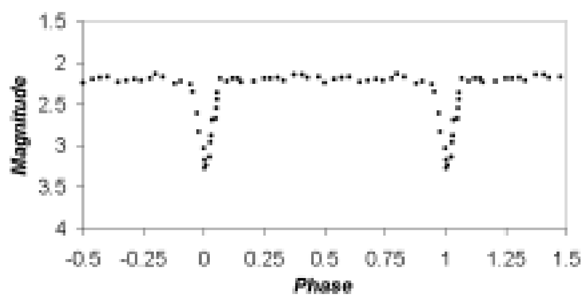
R CrB



ECLIPSING BINARY STARS

These are binary systems of stars with an orbital plane lying near the line-of-sight of the observer. The components periodically eclipse one another, causing a decrease in the apparent brightness of the system as seen by the observer. The period of the eclipse, which coincides with the orbital period of the system, can range from minutes to years.

Eclipsing Binary – beta Per



ROTATING STARS

Rotating stars show small changes in light that may be due to dark or bright spots, or patches on their stellar surfaces ("starspots"). Rotating stars are often binary systems.

Courage! Each step forward brings us nearer the goal, and if we can not reach it, we can at least work so that posterity shall not reproach us for being idle or say that we have not at least made an effort to smooth the way for them.

– Friedrich Argeländer (1844)
the “father of variable star astronomy”

Chapter 4 – COMPUTING THE JULIAN DAY & TIME

Variable star observations reported to the AAVSO should always be expressed in terms of the **Julian Day (JD)** and the decimal part of the day given in **Greenwich Mean Astronomical Time (GMAT)**. This is the standard unit of time used by astronomers because it is convenient and unambiguous. Here are the advantages:

- The astronomical day runs from noon to noon so that you don't have to change calendar dates in the middle of the night.

- A single number represents days, months, years, hours, and minutes.

- Data on the same star from people observing anywhere in the world can be compared easily since they are all relative to the same time zone; that of the prime meridian in Greenwich, England.

What follows is a simple procedure for figuring the JD and GMAT decimal of your observations.

Step-by-Step Instructions

1. Record the astronomical time and date of your observation as ***counted from local noon.*** Use the 24-hour clock instead of AM or PM.

   examples:
   A. June 3 at 9:34 PM = June 3 at 9:34
   B. June 4 at 4:16 AM = June 3 at 16:16

   Note that the date of your observation does not change after midnight because an astronomical day runs from noon to noon *not* midnight to midnight.

2. If your observation was made when Daylight Savings Time (Summer Time) is in effect where you live, subtract one hour to get standard time.

   A. June 3 at 9:34 DST = June 3 at 8:34
   B. June 3 at 16:16 DST = June 3 at 15:16

3. Figure the Julian Date equivalent to the astronomical calendar date of your observation as determined in Step 1 above using the JD calendar shown in Figure 4.1.

   A and B: June 3, 2000 = 2,451,699

4. Find the decimal equivalent of the hours and minutes of your observation from Table 4.1 and add the result to the JD integer found above. Notice that this table also takes into account your longitude (and thus time zone) so that the end result is expressed in GMAT.

   Using the excerpt from Table 4.1 below, you can see that if you observed from the 15°E time zone, the GMAT decimal equivalent of 8:34 is .3. For the observation made at 15:16, it would be .6.

Decimal Part of the Day (GMAT)	Greenwich 0°	Middle European 15°E	Turkey 30°E
0.0			
			3:13
0.1			
	3:36	4:36	5:36
0.2			
	6:01	7:01	8:01
0.3			
	8:24	9:24	10:24
0.4			
	10:49	11:49	12:49
0.5			
	13:12	14:12	15:12
0.6			
	15:37	16:37	17:37
0.7			
	18:00	19:00	20:00
- -			

   Now add the decimal to the JD integer determined in Step 3 to arrive at the final result of:

   A. JD = 2451699.3
   B. JD = 2451699.6

On the following page are several examples of conversion from local time to JD/GMAT. It is recommended that you work through each case until you feel very comfortable with the procedure. Remember that recording the proper date and time for each of your observations is absolutely essential!

Sample Calculations

Example 1 – Observation from Cambridge, MA, USA (75°W time zone) at 9:40 pm Eastern Daylight Time, June 22, 2000

Step 1: astronomical time = 9:40, June 22, 2000
Step 2: 9:40 - 1 = 8:40 on June 22, 2000
Step 3: JD = 2,451,718
Step 4: GMAT decimal = .6
Final result: 2,451,718.6

Example 2 – Observation from Tokyo, Japan (135°E) at 1:15 am, January 10, 2000

Step 1: astronomical time = 13:15, Jan. 9, 2000
Step 2: N/A
Step 3: JD = 2,451,553
Step 4: GMAT decimal = .2
Final Result: 2,451,553.2

Example 3 – Observation from Vancouver, BC Canada (120°W) at 05:21 am, February 14, 2000

Step 1: astronomical time = 17:21, Feb. 13, 2000
Step 2: N/A
Step 3: JD = 2,451,588
Step 4: GMAT decimal = 1.1 (add 1 day)
Final Result: 2,451,589.1

Example 4 – Observation from Auckland, New Zealand (180°E) at 8:25 pm, April 28, 2000

Step 1: astronomical time = 8:25, Apr.28, 2000
Step 2: N/A
Step 3: JD = 2,451,663
Step 4: GMAT decimal = -0.9 (subtract 1 day)
Final Result: 2,451,662.9

Note that as shown in example 4, if the time you observe is exactly the same as a time listed in Table 4.1, you should choose the larger of the two decimals.

Where does JD come from?

In the Julian Day system, all days are numbered consecutively from Julian Day zero, which began at noon on January 1, 4713 BC. Joseph Justus Scaliger, a French classical scholar of the 16th century, determined this as the date on which three important cycles coincided; the 28-year solar cycle, the 19-year lunar cycle, and the 15-year cycle of tax assessment called the "Roman Indiction".

The calendar on page 27 is representative of the one mailed out to AAVSO observers each year. It gives the last four digits of the Julian Day for each day of every month of the year 2000 (On the actual calendar, the months July–December are on the reverse side). For the complete JD, add 2,450,000 to the four digit value given in the calendar for the *Astronomical Day* of your observation.

Some observers prefer to create their own computer programs or use existing ones to calculate JD. See the AAVSO website for links to JD computing programs. (http://www.aavso.org/cdata/jdcalendar.stm)

UT, GMT, and GMAT

Often in astronomy you will see the time of events being expressed in Universal Time (or UT). This is the same as Greenwich Mean Time (GMT) which starts at midnight in Greenwich, England. To find the UT equivalent of a specific time, simply add to it, or subtract from it, as the case may be, the zone difference for your observing location. The "World Map of Time Zones" (Figure 4.2) is provided to help you to determine the zone difference for your location. To convert from UT to Greenwich Mean *Astronomical* Time (GMAT) subtract 12 hours.

Two additional reference tables are provided in this chapter for your convenience:

Table 4.2 lists the JDs for the zero day of each month from 1996 to 2025. The zero day (which is actually the last day of the previous month) is used for ease in calculating the JD of any given day by making it possible to simply add the calendar date to the JD listed.

<u>example</u>: Jan. 28, 2005
= (JD for Jan 0) + 28
= 2453371+28
= 2453399

Table 4.3 can be used to find the GMAT decimal of the day to four decimal places. This degree of accuracy is only needed for certain types of stars (see Table 6.1, page 42).

Figure 4.1 – *Sample JD Calendar*

AAVSO

AAVSO, 25 Birch Street, Cambridge, MA 02138, U.S.A.
Tel: 617-354-0484 Fax: 617-354-0665
Internet: aavso@aavso.org
WWW: http://www.aavso.org

JULIAN DAY CALENDAR

2,450,000 plus the value given under each date

JANUARY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 6	◐ 14	○ 21	◑ 28			1
1546	1547	1548	1549	1550	1551	1552
1553	1554	1555	1556	1557	1558	1559
1560	1561	1562	1563	1564	1565	1566
1567	1568	1569	1570	1571	1572	1573
1574	1575					

FEBRUARY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 5	◐ 12	1	2	3	4	5
1581	1582	1583	1584	1585	1586	1587
1588	1589	1590	1591	1592	1593	1594
1595	1596	1597	1598	1599	1600	1601
1602	1603	1604			○ 19	◑ 27

MARCH

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 6	◐ 13	○ 20	1605	1606	1607	1608
1609	1610	1611	1612	1613	1614	1615
1616	1617	1618	1619	1620	1621	1622
1623	1624	1625	1626	1627	1628	1629
1630	1631	1632	1633	1634	1635	◑ 28

APRIL

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 4	◐ 11	○ 18	◑ 26			1636
1637	1638	1639	1640	1641	1642	1643
1644	1645	1646	1647	1648	1649	1650
1651	1652	1653	1654	1655	1656	1657
1658	1659	1660	1661	1662	1663	1664
1665						

MAY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 4	1666	1667	1668	1669	1670	1671
1672	1673	1674	1675	1676	1677	1678
1679	1680	1681	1682	1683	1684	1685
1686	1687	1688	1689	1690	1691	1692
1693	1694	1695	1696	◐ 10	○ 18	◑ 26

JUNE

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
● 2	◐ 9	○ 16	◑ 25	1697	1698	1699
1700	1701	1702	1703	1704	1705	1706
1707	1708	1709	1710	1711	1712	1713
1714	1715	1716	1717	1718	1719	1720
1721	1722	1723	1724	1725	1726	

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Figure 4.2 – *World Map of Time Zones*

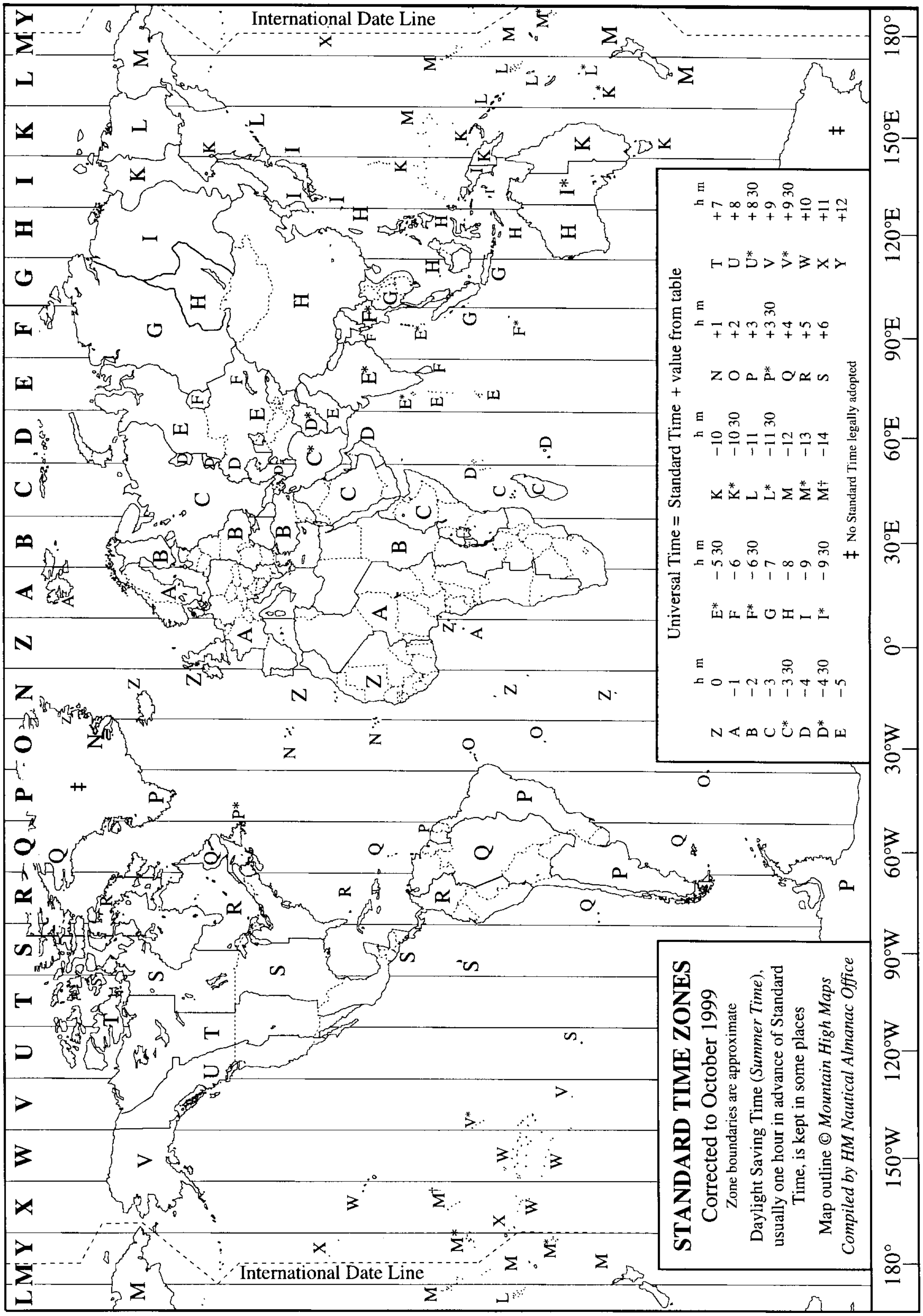

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Table 4.1 - *JD Decimal of the Day* - This chart can be used to convert into a tenth of a day, the time at which an observation is made, expressed in Greenwich Mean Astronomical Time. To use it, find the longitude that best describes the time zone of your observing location, then move down the column until you find the two times that bracket the time of your observation (i.e. one time is earlier and the next time going down the table is later than your observation). Now follow the row across to the left and record the decimal number. This will be added to the JD integer for the date of your observation. If the time of your observation is exactly the same as one of the times given on the table, take the larger of the decimal numbers that bracket it.

West Longitude

Decimal part of the day (GMAT)	*Greenwich* **0°**	*Iceland* **15°W**	*Azores* **30°W**	*Rio de Janeiro* **45°W**	*Atlantic* **60°W**	*Eastern* **75°W**	*Central* **90°W**	*Mountain* **105°W**	*Pacific* **120°W**	*Yukon* **135°W**	*Alaskan* **150°W**	*Aleutian* **165°W**	*International Date Line* **180°W**
0.1													
	3:36	2:36											
0.2													
	6:01	5:01	4:01	3:01									
0.3													
	8:24	7:24	6:24	5:24	4:24	3:24	2:24						
0.4													
	10:49	9:49	8:49	7:49	6:49	5:49	4:49	3:49	2:49				
0.5													
	13:12	12:12	11:12	10:12	9:12	8:12	7:12	6:12	5:12	4:12	3:12	2:12	
0.6													
	15:37	14:37	13:37	12:37	11:37	10:37	9:37	8:37	7:37	6:37	5:37	4:37	3:37
0.7													
	18:00	17:00	16:00	15:00	14:00	13:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00
0.8													
	20:25	19:25	18:25	17:25	16:25	15:25	14:25	13:25	12:25	11:25	10:25	9:25	8:25
0.9													
		21:48	20:48	19:48	18:48	17:48	16:48	15:48	14:48	13:48	12:48	11:48	10:48
0.0													
				22:13	21:13	20:13	19:13	18:13	17:13	16:13	15:13	14:13	13:13
0.1													
						22:36	21:36	20:36	19:36	18:36	17:36	16:36	15:36
0.2													
									22:01	21:01	20:01	19:01	18:01
0.3													

For times below this line, **add one day** plus the decimal on the left to the JD.

East Longitude

Decimal part of the day (GMAT)	*Greenwich* **0°**	*Middle European* **15°E**	*Turkey* **30°E**	*Iraq* **45°E**	*Oman* **60°E**	*Omsk* **75°E**	*Tibet* **90°E**	*Thailand* **105°E**	*Phillipines* **120°E**	*Japan* **135°E**	*New South Wales* **150°E**	*Wake Island* **165°E**	*New Zealand* **180°E**
0.6													
												2:37	3:37
0.7													
										3:00	4:00	5:00	6:00
0.8													
								3:25	4:25	5:25	6:25	7:25	8:25
0.9													
						3:48	4:48	5:48	6:48	7:48	8:48	9:48	10:48
0.0													
			3:13	4:13	5:13	6:13	7:13	8:13	9:13	10:13	11:13	12:13	13:13
0.1													
	3:36	4:36	5:36	6:36	7:36	8:36	9:36	10:36	11:36	12:36	13:36	14:36	15:36
0.2													
	6:01	7:01	8:01	9:01	10:01	11:01	12:01	13:01	14:01	15:01	16:01	17:01	18:01
0.3													
	8:24	9:24	10:24	11:24	12:24	13:24	14:24	15:24	16:24	17:24	18:24	19:24	20:24
0.4													
	10:49	11:49	12:49	13:49	14:49	15:49	16:49	17:49	18:49	19:49	20:49	21:49	22:49
0.5													
	13:12	14:12	15:12	16:12	17:12	18:12	19:12	20:12	21:12	22:12			
0.6													
	15:37	16:37	17:37	18:37	19:37	20:37	21:37						
0.7													
	18:00	19:00	20:00	21:00									
0.8													
	20:25	21:25											
0.9													

For times above this line, **subtract one day** from the JD, then add the decimal to the left.

Table 4.2 – *Julian Day Number 1996–2025*

To use this table, add the calendar date (based on the noon to noon astronomical time) of your observation to the zero day of the appropriate month for the desired year. For example, for an observation made on February 6, 2015, the Julian date would be: 2457054 + 6 = 2457060.

Year	***Jan 0***	***Feb 0***	***Mar 0***	***Apr 0***	***May 0***	***Jun 0***	***Jul 0***	***Aug 0***	***Sep 0***	***Oct 0***	***Nov 0***	***Dec 0***
1996	2450083	2450114	2450143	2450174	2450204	2450235	2450265	2450296	2450327	2450357	2450388	2450418
1997	2450449	2450480	2450508	2450539	2450569	2450600	2450630	2450661	2450692	2450722	2450753	2450783
1998	2450814	2450845	2450873	2450904	2450934	2450965	2450995	2451026	2451057	2451087	2451118	2451148
1999	2451179	2451210	2451238	2451269	2451299	2451330	2451360	2451391	2451422	2451452	2451483	2451513
2000	2451544	2451575	2451604	2451635	2451665	2451696	2451726	2451757	2451788	2451818	2451849	2451879
2001	2451910	2451941	2451969	2452000	2452030	2452061	2452091	2452122	2452153	2452183	2452214	2452244
2002	2452275	2452306	2452334	2452365	2452395	2452426	2452456	2452487	2452518	2452548	2452579	2452609
2003	2452640	2452671	2452699	2452730	2452760	2452791	2452821	2452852	2452883	2452913	2452944	2452974
2004	2453005	2453036	2453065	2453096	2453126	2453157	2453187	2453218	2453249	2453279	2453310	2453340
2005	2453371	2453402	2453430	2453461	2453491	2453522	2453552	2453583	2453614	2453644	2453675	2453705
2006	2453736	2453767	2453795	2453826	2453856	2453887	2453917	2453948	2453979	2454009	2454040	2454070
2007	2454101	2454132	2454160	2454191	2454221	2454252	2454282	2454313	2454344	2454374	2454405	2454435
2008	2454466	2454497	2454526	2454557	2454587	2454618	2454648	2454679	2454710	2454740	2454771	2454801
2009	2454832	2454863	2454891	2454922	2454952	2454983	2455013	2455044	2455075	2455105	2455136	2455166
2010	2455197	2455228	2455256	2455287	2455317	2455348	2455378	2455409	2455440	2455470	2455501	2455531
2011	2455562	2455593	2455621	2455652	2455682	2455713	2455743	2455774	2455805	2455835	2455866	2455896
2012	2455927	2455958	2455987	2456018	2456048	2456079	2456109	2456140	2456171	2456201	2456232	2456262
2013	2456293	2456324	2456352	2456383	2456413	2456444	2456474	2456505	2456536	2456566	2456597	2456627
2014	2456658	2456689	2456717	2456748	2456778	2456809	2456839	2456870	2456901	2456931	2456962	2456992
2015	2457023	2457054	2457082	2457113	2457143	2457174	2457204	2457235	2457266	2457296	2457327	2457357
2016	2457388	2457419	2457448	2457479	2457509	2457540	2457570	2457601	2457632	2457662	2457693	2457723
2017	2457754	2457785	2457813	2457844	2457874	2457905	2457935	2457966	2457997	2458027	2458058	2458088
2018	2458119	2458150	2458178	2458209	2458239	2458270	2458300	2458331	2458362	2458392	2458423	2458453
2019	2458484	2458515	2458543	2458574	2458604	2458635	2458665	2458696	2458727	2458757	2458788	2458818
2020	2458849	2458880	2458909	2458940	2458970	2459001	2459031	2459062	2459093	2459123	2459154	2459184
2021	2459215	2459246	2459274	2459305	2459335	2459366	2459396	2459427	2459458	2459488	2459519	2459549
2022	2459580	2459611	2459639	2459670	2459700	2459731	2459761	2459792	2459823	2459853	2459884	2459914
2023	2459945	2459976	2460004	2460035	2460065	2460096	2460126	2460157	2460188	2460218	2460249	2460279
2024	2460310	2460341	2460370	2460401	2460431	2460462	2460492	2460523	2460554	2460584	2460615	2460645
2025	2460676	2460707	2460735	2460766	2460796	2460827	2460857	2460888	2460919	2460949	2460980	2461010

Table 4.3 – *JD Decimal (to four places)* To use this table, find the **GMAT** hours across the top of the page and the minutes down the side. The result is the fraction of the day represented. GMAT is explained on page 26 of this manual.

GMAT	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h
m	d	d	d	d	d	d	d	d	d	d	d	d
0	0.0000	0.0417	0.0833	0.1250	0.1667	0.2083	0.2500	0.2917	0.3333	0.3750	0.4167	0.4583
1	.0007	.0424	.0840	.1257	.1674	.2090	.2507	.2924	.3340	.3757	.4174	.4590
2	.0014	.0431	.0847	.1264	.1681	.2097	.2514	.2931	.3347	.3764	.4181	.4597
3	.0021	.0437	.0854	.1271	.1688	.2104	.2521	.2938	.3354	.3771	.4188	.4604
4	.0028	.0444	.0861	.1278	.1694	.2111	.2528	.2944	.3361	.3778	.4194	.4611
5	0.0035	0.0451	0.0868	0.1285	0.1701	0.2118	0.2535	0.2951	0.3368	0.3785	0.4201	0.4618
6	.0042	.0458	.0875	.1292	.1708	.2125	.2542	.2958	.3375	.3792	.4208	.4625
7	.0049	.0465	.0882	.1299	.1715	.2132	.2549	.2965	.3382	.3799	.4215	.4632
8	.0056	.0472	.0889	.1306	.1722	.2139	.2556	.2972	.3389	.3806	.4222	.4639
9	.0063	.0479	.0896	.1313	.1729	.2146	.2562	.2979	.3396	.3812	.4229	.4646
10	0.0069	0.0486	0.0903	0.1319	0.1736	0.2153	0.2569	0.2986	0.3403	0.3819	0.4236	0.4653
11	.0076	.0493	.0910	.1326	.1743	.2160	.2576	.2993	.3410	.3826	.4243	.4660
12	.0083	.0500	.0917	.1333	.1750	.2167	.2583	.3000	.3417	.3833	.4250	.4667
13	.0090	.0507	.0924	.1340	.1757	.2174	.2590	.3007	.3424	.3840	.4257	.4674
14	.0097	.0514	.0931	.1347	.1764	.2181	.2597	.3014	.3431	.3847	.4264	.4681
15	0.0104	0.0521	0.0938	0.1354	0.1771	0.2188	0.2604	0.3021	0.3438	0.3854	0.4271	0.4688
16	.0111	.0528	.0944	.1361	.1778	.2194	.2611	.3028	.3444	.3861	.4278	.4694
17	.0118	.0535	.0951	.1368	.1785	.2201	.2618	.3035	.3451	.3868	.4285	.4701
18	.0125	.0542	.0958	.1375	.1792	.2208	.2625	.3042	.3458	.3875	.4292	.4708
19	.0132	.0549	.0965	.1382	.1799	.2215	.2632	.3049	.3465	.3882	.4299	.4715
20	0.0139	0.0556	0.0972	0.1389	0.1806	0.2222	0.2639	0.3056	0.3472	0.3889	0.4306	0.4722
21	.0146	.0563	.0979	.1396	.1812	.2229	.2646	.3063	.3479	.3896	.4313	.4729
22	.0153	.0569	.0986	.1403	.1819	.2236	.2653	.3069	.3486	.3903	.4319	.4736
23	.0160	.0576	.0993	.1410	.1826	.2243	.2660	.3076	.3493	.3910	.4326	.4743
24	.0167	.0583	.1000	.1417	.1833	.2250	.2667	.3083	.3500	.3917	.4333	.4750
25	0.0174	0.0590	0.1007	0.1424	0.1840	0.2257	0.2674	0.3090	0.3507	0.3924	0.4340	0.4757
26	.0181	.0597	.1014	.1431	.1847	.2264	.2681	.3097	.3514	.3931	.4347	.4764
27	.0187	.0604	.1021	.1437	.1854	.2271	.2687	.3104	.3521	.3937	.4354	.4771
28	.0194	.0611	.1028	.1444	.1861	.2278	.2694	.3111	.3528	.3944	.4361	.4778
29	.0201	.0618	.1035	.1451	.1868	.2285	.2701	.3118	.3535	.3951	.4368	.4785
30	0.0208	0.0625	0.1042	0.1458	0.1875	0.2292	0.2708	0.3125	0.3542	0.3958	0.4375	0.4792
31	.0215	.0632	.1049	.1465	.1882	.2299	.2715	.3132	.3549	.3965	.4382	.4799
32	.0222	.0639	.1056	.1472	.1889	.2306	.2722	.3139	.3556	.3972	.4389	.4806
33	.0229	.0646	.1062	.1479	.1896	.2313	.2729	.3146	.3563	.3979	.4396	.4813
34	.0236	.0653	.1069	.1486	.1903	.2319	.2736	.3153	.3569	.3986	.4403	.4819
35	0.0243	0.0660	0.1076	0.1493	0.1910	0.2326	0.2743	0.3160	0.3576	0.3993	0.4410	0.4826
36	.0250	.0667	.1083	.1500	.1917	.2333	.2750	.3167	.3583	.4000	.4417	.4833
37	.0257	.0674	.1090	.1507	.1924	.2340	.2757	.3174	.3590	.4007	.4424	.4840
38	.0264	.0681	.1097	.1514	.1931	.2347	.2764	.3181	.3597	.4014	.4431	.4847
39	.0271	.0688	.1104	.1521	.1938	.2354	.2771	.3187	.3604	.4021	.4437	.4854
40	0.0278	0.0694	0.1111	0.1528	0.1944	0.2361	0.2778	0.3194	0.3611	0.4028	0.4444	0.4861
41	.0285	.0701	.1118	.1535	.1951	.2368	.2785	.3201	.3618	.4035	.4451	.4868
42	.0292	.0708	.1125	.1542	.1958	.2375	.2792	.3208	.3625	.4042	.4458	.4875
43	.0299	.0715	.1132	.1549	.1965	.2382	.2799	.3215	.3632	.4049	.4465	.4882
44	.0306	.0722	.1139	.1556	.1972	.2389	.2806	.3222	.3639	.4056	.4472	.4889
45	0.0313	0.0729	0.1146	0.1563	0.1979	0.2396	0.2813	0.3229	0.3646	0.4063	0.4479	0.4896
46	.0319	.0736	.1153	.1569	.1986	.2403	.2819	.3236	.3653	.4069	.4486	.4903
47	.0326	.0743	.1160	.1576	.1993	.2410	.2826	.3243	.3660	.4076	.4493	.4910
48	.0333	.0750	.1167	.1583	.2000	.2417	.2833	.3250	.3667	.4083	.4500	.4917
49	.0340	.0757	.1174	.1590	.2007	.2424	.2840	.3257	.3674	.4090	.4507	.4924
50	0.0347	0.0764	0.1181	0.1597	0.2014	0.2431	0.2847	0.3264	0.3681	0.4097	0.4514	0.4931
51	.0354	.0771	.1187	.1604	.2021	.2437	.2854	.3271	.3688	.4104	.4521	.4938
52	.0361	.0778	.1194	.1611	.2028	.2444	.2861	.3278	.3694	.4111	.4528	.4944
53	.0368	.0785	.1201	.1618	.2035	.2451	.2868	.3285	.3701	.4118	.4535	.4951
54	.0375	.0792	.1208	.1625	.2042	.2458	.2875	.3292	.3708	.4125	.4542	.4958
55	0.0382	0.0799	0.1215	0.1632	0.2049	0.2465	0.2882	0.3299	0.3715	0.4132	0.4549	0.4965
56	.0389	.0806	.1222	.1639	.2056	.2472	.2889	.3306	.3722	.4139	.4556	.4972
57	.0396	.0813	.1229	.1646	.2062	.2479	.2896	.3312	.3729	.4146	.4562	.4979
58	.0403	.0819	.1236	.1653	.2069	.2486	.2903	.3319	.3736	.4153	.4569	.4986
59	.0410	.0826	.1243	.1660	.2076	.2493	.2910	.3326	.3743	.4160	.4576	.4993
60	0.0417	0.0833	0.1250	0.1667	0.2083	0.2500	0.2917	0.3333	0.3750	0.4167	0.4583	0.5000

GMAT	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
m	d	d	d	d	d	d	d	d	d	d	d	d
0	0.5000	0.5417	0.5833	0.6250	0.6667	0.7083	0.7500	0.7917	0.8333	0.8750	0.9167	0.9583
1	.5007	.5424	.5840	.6257	.6674	.7090	.7507	.7924	.8340	.8757	.9174	.9590
2	.5014	.5431	.5847	.6264	.6681	.7097	.7514	.7931	.8347	.8764	.9181	.9597
3	.5021	.5437	.5854	.6271	.6687	.7104	.7521	.7937	.8354	.8771	.9187	.9604
4	.5028	.5444	.5861	.6278	.6694	.7111	.7528	.7944	.8361	.8778	.9194	.9611
5	0.5035	0.5451	0.5868	0.6285	0.6701	0.7118	0.7535	0.7951	0.8368	0.8785	0.9201	0.9618
6	.5042	.5458	.5875	.6292	.6708	.7125	.7542	.7958	.8375	.8792	.9208	.9625
7	.5049	.5465	.5882	.6299	.6715	.7132	.7549	.7965	.8382	.8799	.9215	.9632
8	.5056	.5472	.5889	.6306	.6722	.7139	.7556	.7972	.8389	.8806	.9222	.9639
9	.5062	.5479	.5896	.6312	.6729	.7146	.7562	.7979	.8396	.8812	.9229	.9646
10	0.5069	0.5486	0.5903	0.6319	0.6736	0.7153	0.7569	0.7986	0.8403	0.8819	0.9236	0.9653
11	.5076	.5493	.5910	.6326	.6743	.7160	.7576	.7993	.8410	.8826	.9243	.9660
12	.5083	.5500	.5917	.6333	.6750	.7167	.7583	.8000	.8417	.8833	.9250	.9667
13	.5090	.5507	.5924	.6340	.6757	.7174	.7590	.8007	.8424	.8840	.9257	.9674
14	.5097	.5514	.5931	.6347	.6764	.7181	.7597	.8014	.8431	.8847	.9264	.9681
15	0.5104	0.5521	0.5938	0.6354	0.6771	0.7188	0.7604	0.8021	0.8438	0.8854	0.9271	0.9688
16	.5111	.5528	.5944	.6361	.6778	.7194	.7611	.8028	.8444	.8861	.9278	.9694
17	.5118	.5535	.5951	.6368	.6785	.7201	.7618	.8035	.8451	.8868	.9285	.9701
18	.5125	.5542	.5958	.6375	.6792	.7208	.7625	.8042	.8458	.8875	.9292	.9708
19	.5132	.5549	.5965	.6382	.6799	.7215	.7632	.8049	.8465	.8882	.9299	.9715
20	0.5139	0.5556	0.5972	0.6389	0.6806	0.7222	0.7639	0.8056	0.8472	0.8889	0.9306	0.9722
21	.5146	.5563	.5979	.6396	.6813	.7229	.7646	.8063	.8479	.8896	.9313	.9729
22	.5153	.5569	.5986	.6403	.6819	.7236	.7653	.8069	.8486	.8903	.9319	.9736
23	.5160	.5576	.5993	.6410	.6826	.7243	.7660	.8076	.8493	.8910	.9326	.9743
24	.5167	.5583	.6000	.6417	.6833	.7250	.7667	.8083	.8500	.8917	.9333	.9750
25	0.5174	0.5590	0.6007	0.6424	0.6840	0.7257	0.7674	0.8090	0.8507	0.8924	0.9340	0.9757
26	.5181	.5597	.6014	.6431	.6847	.7264	.7681	.8097	.8514	.8931	.9347	.9764
27	.5188	.5604	.6021	.6438	.6854	.7271	.7688	.8104	.8521	.8938	.9354	.9771
28	.5194	.5611	.6028	.6444	.6861	.7278	.7694	.8111	.8528	.8944	.9361	.9778
29	.5201	.5618	.6035	.6451	.6868	.7285	.7701	.8118	.8535	.8951	.9368	.9785
30	0.5208	0.5625	0.6042	0.6458	0.6875	0.7292	0.7708	0.8125	0.8542	0.8958	0.9375	0.9792
31	.5215	.5632	.6049	.6465	.6882	.7299	.7715	.8132	.8549	.8965	.9382	.9799
32	.5222	.5639	.6056	.6472	.6889	.7306	.7722	.8139	.8556	.8972	.9389	.9806
33	.5229	.5646	.6062	.6479	.6896	.7312	.7729	.8146	.8562	.8979	.9396	.9812
34	.5236	.5653	.6069	.6486	.6903	.7319	.7736	.8153	.8569	.8986	.9403	.9819
35	0.5243	0.5660	0.6076	0.6493	0.6910	0.7326	0.7743	0.8160	0.8576	0.8993	0.9410	0.9826
36	.5250	.5667	.6083	.6500	.6917	.7333	.7750	.8167	.8583	.9000	.9417	.9833
37	.5257	.5674	.6090	.6507	.6924	.7340	.7757	.8174	.8590	.9007	.9424	.9840
38	.5264	.5681	.6097	.6514	.6931	.7347	.7764	.8181	.8597	.9014	.9431	.9847
39	.5271	.5687	.6104	.6521	.6937	.7354	.7771	.8187	.8604	.9021	.9437	.9854
40	0.5278	0.5694	0.6111	0.6528	0.6944	0.7361	0.7778	0.8194	0.8611	0.9028	0.9444	0.9861
41	.5285	.5701	.6118	.6535	.6951	.7368	.7785	.8201	.8618	.9035	.9451	.9868
42	.5292	.5708	.6125	.6542	.6958	.7375	.7792	.8208	.8625	.9042	.9458	.9875
43	.5299	.5715	.6132	.6549	.6965	.7382	.7799	.8215	.8632	.9049	.9465	.9882
44	.5306	.5722	.6139	.6556	.6972	.7389	.7806	.8222	.8639	.9056	.9472	.9889
45	0.5313	0.5729	0.6146	0.6563	0.6979	0.7396	0.7813	0.8229	0.8646	0.9063	0.9479	0.9896
46	.5319	.5736	.6153	.6569	.6986	.7403	.7819	.8236	.8653	.9069	.9486	.9903
47	.5326	.5743	.6160	.6576	.6993	.7410	.7826	.8243	.8660	.9076	.9493	.9910
48	.5333	.5750	.6167	.6583	.7000	.7417	.7833	.8250	.8667	.9083	.9500	.9917
49	.5340	.5757	.6174	.6590	.7007	.7424	.7840	.8257	.8674	.9090	.9507	.9924
50	0.5347	0.5764	0.6181	0.6597	0.7014	0.7431	0.7847	0.8264	0.8681	0.9097	0.9514	0.9931
51	.5354	.5771	.6188	.6604	.7021	.7438	.7854	.8271	.8688	.9104	.9521	.9938
52	.5361	.5778	.6194	.6611	.7028	.7444	.7861	.8278	.8694	.9111	.9528	.9944
53	.5368	.5785	.6201	.6618	.7035	.7451	.7868	.8285	.8701	.9118	.9535	.9951
54	.5375	.5792	.6208	.6625	.7042	.7458	.7875	.8292	.8708	.9125	.9542	.9958
55	0.5382	0.5799	0.6215	0.6632	0.7049	0.7465	0.7882	0.8299	0.8715	0.9132	0.9549	0.9965
56	.5389	.5806	.6222	.6639	.7056	.7472	.7889	.8306	.8722	.9139	.9556	.9972
57	.5396	.5813	.6229	.6646	.7063	.7479	.7896	.8313	.8729	.9146	.9563	.9979
58	.5403	.5819	.6236	.6653	.7069	.7486	.7903	.8319	.8736	.9153	.9569	.9986
59	.5410	.5826	.6243	.6660	.7076	.7493	.7910	.8326	.8743	.9160	.9576	.9993
60	0.5417	0.5833	0.6250	0.6667	0.7083	0.7500	0.7917	0.8333	0.8750	0.9167	0.9583	1.0000

Chapter 5 – PLANNING AN OBSERVING SESSION

Making a Plan

It is recommended that you make an overall plan of observing, the first of each month, to determine before even going to the telescope on a given night, which stars you would like to observe and how you will find them. Further refinements can be made on the day you intend to observe. By planning ahead and being prepared, you will save yourself much time and frustration, resulting in a more efficient and rewarding observing experience.

Choosing which stars to observe

One way to approach your planning session is to sit down with a list of stars you have chosen for your observing program and for which you have charts. Pick a date and time when you plan to observe, and ask yourself the following questions:

Which of these stars are available for viewing? A planisphere or monthly constellation chart can be very helpful for determining which constellations are visible to you at any given time, and in which direction you should look. Be mindful that these tools usually depict the night sky as if you could see down to the horizon in all directions. Depending on your observing site, your viewing area may be limited by obstructions such as trees, hills, or buildings.

Another way to figure out which stars are available for viewing is to use Table 5.1 to determine which hours of Right Ascension are overhead during the evening (between 9 PM and midnight local time) for the month you are observing. You can then choose stars in your program that have designations that begin with the same two first digits as the right ascension. (See pages 17-18 for more on variable star designations.) This is an approximation because the table is only for the 15th of the month. If observing past midnight, just expand the second entry of the RA range by the number of hours after midnight you observe. Also, Table 5.1 does not take into account that circumpolar constellations could be visible to you on any night, depending on your latitude.

Are these stars bright enough for me to see? Predicted dates of maximum and minimum brightness for many of the long period variable stars in the AAVSO observing program are published each year in the *AAVSO Bulletin* (see pages 37-38 for more about the *Bulletin* and how to use this valuable tool). This can be a useful aid for obtaining an approximate brightness for a star on any given night. The experienced observer does not spend time on variables below his or her telescope limit. See pages 13–14 for information on determining your telescope's limiting magnitude.

Table 5.1 – *Observing Window*

The table below gives the approximate observing windows centered on the 15th of the month from 2 hours after sunset to midnight.

Month	Right Ascension
January	1 – 9 hours
February	3 – 11 hours
March	5 – 13 hours
April	7 – 15 hours
May	11 – 18 hours
June	13 – 19 hours
July	15 – 21 hours
August	16 – 23 hours
September	18 – 2 hours
October	19 – 3 hours
November	21 – 5 hours
December	23 – 7 hours

When was the last time I observed this star? There are certain types of variables which should ideally be observed no more often than weekly, while others should be observed more frequently. Using the information summarized in Table 5.2, and comparing this to your records of when you last observed a given star, should help you to determine whether it is time for you to look at it again or spend your time with another variable.

Plotting the position of a variable

If your telescope does not have setting circles, it will be helpful for you to find the positions of the variables you have chosen to observe in a star atlas. For all but the brightest variables, this is a necessary step toward locating the star using your telescope's finder or simply sighting along the tube. If you use the *AAVSO Variable Star Atlas*, most* variable stars are already marked for you. If you use another atlas, chances are that the variables will not be indicated. If this is the case, you will have to use the position information given in the header of each chart to plot the star's right ascension and declination coordinates on the atlas. Make sure that the epoch of the position coordinates match the epoch of the atlas you use, or the position you plot will be wrong.

*The *AAVSO Variable Star Atlas* includes all named variable stars with a range of variability exceeding 0.5 magnitude and a maximum brighter than visual magnitude 9.5. Also included, regardless of their magnitudes at maximum, are all other variables in the AAVSO and Royal Astronomical Society of New Zealand observing programs as of 1990.

Table 5.2 – *Frequency of Observations for Different Variable Star Types*

The table below was created to act as a guideline on how often variable star observations should be made for the various types of variable stars described in Chapter 3 of this manual. Due to the wide range of periods and magnitudes of variation from type to type, some stars lend themselves to more frequent observations than others. Cataclysmic variables, for example, should be observed frequently during outbursts because the brightness is changing so rapidly. Too frequent observations by one observer of stars that need observing weekly, such as Mira or semi-regular variables, however, could distort the light curve and the average of observations.

Type of Star	Observing Frequency
Cepheids	every clear night
RR Lyrae stars	every 10 minutes
RV Tauri stars	once per week
Mira variables	once per week
Semiregular	once per week
Cataclysmic Variables	every clear night
Symbiotic stars*	once per week
R CrB stars*–at Max	once per week
R CrB stars–at Min	every clear night
Eclipsing Binaries	every 10 minutes during eclipse
Rotating stars	every 10 minutes
Flare stars	continuously for 10 to 15 minutes
Irregular variables	once per week
Suspected variables	every clear night

*or every clear night to catch possible small amplitude pulsations with these stars.

Many AAVSO observers use computer software to plot variables, thereby creating their own finder charts. This flexibility affords any scale and virtually any limiting magnitude, but once again, it must be emphasized that any such charts can only be used as "finders." All magnitude estimates should only be made using AAVSO Charts and the comparison star magnitudes given on these charts. This is essential for the standardization and homogeneity of variable star observations in the AAVSO International Database.

A Typical Observing Routine

Each season, consider last year's program and whether to add stars to this year's. Order by mail or download new charts from the AAVSO website as necessary. At the beginning of the month, make an overall plan of observing, according to instrumentation, location, anticipated time available, and experience. Use the *AAVSO Bulletin* to schedule long period variables, or the *Newsflash* and *Alert Notices,* to include any new or requested objects. Check the weather forecast for a particular night. Decide what to observe that night—will you observe during the evening? Midnight? Early morning? Plan order of observations, grouping variables near each other together, and taking into account the diurnal motion of the night sky (i.e. the rising/changing order of constellations). Check to make sure you have the necessary atlas and charts for your observing targets and put them in observation order. Check equipment—red flashlight, etc. Eat a good meal for energy and concentration. Begin dark-adapting half an hour before going out (Some observers use red-filtered goggles or sunglasses). Dress warmly! At the start of the observing session, record in your log book the date, time, weather conditions, moon phase, and any unusual situations. As each star is observed, record designation, name, time, magnitude, comparison stars, chart(s) used, and comments in your log book. At the end of your nightly observing, make any necessary notes about the session overall. File the charts used so you can find them again next time. Enter your observations into your computer or transcribe them to your permanent record system, if necessary. If you would like to report some or all of your observations to AAVSO Headquarters right away, you may do so by following the procedures outlined in Chapter 6. At the end of the month, compile any additional observations not yet reported (by hand or by computer) to make your AAVSO-format report. Make and keep a copy of your report. Submit your report to AAVSO Headquarters as soon as possible after the first of the month.

Useful AAVSO Publications

AAVSO Bulletin

The *AAVSO Bulletin* is an essential tool in planning your observing session each month. This annual publication contains *predicted* dates of maxima and minima for about 560 of the more regular variables in the AAVSO program. In addition, there is a schematic representation which shows when a star should be brighter than magnitude 11.0 (denoted by a "+" symbol) or fainter than 13.5 (a "-" symbol) over the course of the year. This information will help you to determine if you can see a particular star with your telescope on any given night. A portion of the *Bulletin* along with an example of its use is given in Figure 5.3.

You might wonder; why should you observe the stars covered in the *Bulletin* if the AAVSO can already predict what they will do? The answer is that the predictions only serve as a guide to the *expected* maxima and minima dates. This may be helpful information when you are planning an observing session. Although long period variables are periodic most of the time, the interval between each maximum may not always be the same. In addition, individual cycles may vary in shape and brightness. By using the predictions and the light curves found in several AAVSO publications and on the AAVSO website, the observer can also see how rapidly the variable may be changing between maximum and minimum.

Another useful bit of information included in the *Bulletin* is a code which indicates how well a particular star is being observed. Those stars that are urgently in need of observation are so indicated. As you become more experienced with observing, and are looking to expand your observing program, you may wish to include some of the stars needing more observation.

AAVSO Alert Notice

Headquarters will issue a special "Alert Notice" whenever a particular star shows unusual behavior, when an unexpected event such as the discovery of a nova or supernova is reported, or when there is a request from an astronomer to observe a certain star in order to know when to schedule observations of it with a satellite or ground-based telescope.

AAVSO Alert Notices are available by email subscription (free-of-charge) or through the AAVSO website. They are also available via postal mail via subscription.

Figure 5.2 – *Sample AAVSO Alert Notice*

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
25 Birch Street, Cambridge, MA 02138 USA
INTERNET: aavso@aavso.org
Tel. 617-354-0484 FAX 617-354-0665

AAVSO ALERT NOTICE 232 (November 18, 1996)

EXTREME FAINTNESS AND UNUSUAL BEHAVIOR OF 0058+40 RX ANDROMEDAE

The dwarf nova (Z Cam subclass) cataclysmic variable RX And [R.A. $01^h\ 01^m\ 46^s$, Decl. $+41^\circ\ 01.9'$ (1950)] is undergoing a period of unprecedented faintness, according to observations dating back to September 1922 in the AAVSO International Database. Its present visual magnitude is approximately 15.4.

RX And was in standstill at magnitude 11.4 from May 1995 and, starting at the beginning of April 1996, declined gradually while still in standstill to 11.8 by early August, then came out of standstill on August 15, declining to 13.9 by August 26, brightening to 12.2 by August 31, and then continuing to decline, reaching an unprecedented visual magnitude of approximately 15.6 by October 28. Since then it has continued to be faint, oscillating between approximately 15.6 and 15.3.

The accompanying AAVSO light curve of RX And for the interval JD 2450270 - 2450420 (December 1994 - December 2, 1996) shows RX And in standstill in April 1996, and then in its present faint state. This light curve of RX And was created from 554 visual and CCD observations submitted to the AAVSO International Database by 68 observers worldwide. We thank each observer for his or her valuable contribution.

The comparison star sequence on the AAVSO RX And charts has been extended by R. Zissell, South Hadley, MA, who carried out extensive CCD(V) photometry on the field. Accompanying are a revised standard "d" scale and preliminary "e" and "f" scale charts of RX And including this extended sequence and prepared by C. Scovil. Please use these charts to observe RX And and report your observations to AAVSO Headquarters by email, fax, or telephone, making sure to indicate which comparison stars you have used.

CHARTS AND LIGHT CURVE AVAILABLE ON AAVSO FTP SITE

Electronic copies of the revised and new AAVSO charts of RX And and the light curve of RX And mentioned in this Alert Notice are available from our FTP site:

ftp.aavso.org (198.116.78.2), in /pub/alert232

The charts and light curve may also be accessed through our Web site at the following address:

http://www.aavso.org

The answering machine at AAVSO Headquarters is on nights and weekends for your convenience. Please call our charge-free number (800-642-3883) to report your observations. If you are cut off when you telephone in your observations, please wait a few minutes and call back to complete your call. We have learned that if someone calls to leave observations on the answering machine and while they are speaking someone else calls, the first person may be cut off. We also encourage observers to send observations by fax to 617-354-0665 or by e-mail through the Internet to observations@aavso.org. We would appreciate it very much if you would report your observations in Universal Time. Many thanks for your valuable astronomical contributions and your efforts.

Good observing!

Janet A. Mattei
Director

AAVSO Newsflash

The *AAVSO Newsflash* is an electronic publication that provides timely information on the eruption of cataclysmic variables and/or unusual variable star activity. Less formal than the *Alert Notices,* this publication is based on the observations reported daily to AAVSO Headquarters. Instructions on how to subscribe (or unsubscribe) to the *Newsflash* free-of-charge are given on the AAVSO website (http://www.aavso.org/publications/emailsubscrip.stm).

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                                                 (2)                    AAVSO BULLETIN 62 FOR 1999, CONTINUED
-----------------------------------------------------------------------------------------------------------------------
|    DESIGN.      NAME        RANGE      | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB |
-----------------------------------------------------------------------------------------------------------------------
|    0003-39      V Scl #  <9.9-14.6>  |------8m----------     |  ++++++22M+++++ |     |     ------------1m--------- |     |
|    0004+51     SS Cas    <9.8-13.1>  |     |11m  |   +++14M++++    |     1m     | ++++1M++++|     | 19m |     ++20M++++    |
|   *0009+28     UW And     9.6-(15.0  |     |     |     | 16m?|     |     |13M? |     |     |     | 16m?|     |     |
|    0010+46      X And    <9.0-14.8>  |-------18m--------     |+++++++20M+++++++++++ |     |     |     ----------30m-----|
|    0010-32      S Scl    <6.7-12.9>  |++++++++++++++++++++     |     | 23m|     | ++++++++++++++++++++++15M++++++++++++++|
|   *0014+44     VX And     7.9-9.6    |     |     |     |     |13M? |     |     |     |     |   3m?     |     |     |
|    0017+55      T Cas    <7.9-11.9>  |++++++13M++++++++++++++++++++++++     |     | 22m|     | +++++++++++++++++++++++++++|
|    0017+26      T And    <8.5-13.8>  |     |     ------4m---  |     | +++++++++10M+++++++++++     |     | ----10m---|     |
|    0018+38      R And    <6.9-14.3>  |--25m-------     |     +++++++++++++2M+++++++++++++++++++++++     |     |-----------|
|    0018-62      S Tuc &  <9.3-14.5>  |-----10m----     | ++++++++26M+++++++     |     ---------8m---|     |++++++++21M++++++|
|    0019-09      S Cet    <8.2-14.2>  |++++++++25M+++++++++++++++     |     |   -----20m---     |   +++++++++++++12M++++++++|
|   *0022+30     YZ And #  10.1-15.9   |  28M?     |     |     |7m?  |     |     | 23M?     |     |   30m?    |     |     |
|    0024-38A     T Scl &  <9.2-13.0>  |++++++9M++++++++++     |  25m|     +++++++++++31M++++++++     |     |14m   |  +++++++++|
|    0025-46      T Phe &  <9.4-14.2>  |     |+++++3M+++++++     |     |   -----------25m------|     | ++++10M+++++++   |     |
|   *0027+25A     TU And   <8.5-12.5>  |     |     |     |     |  29m?     |     |     |     |11M?  |     |     |     |
|    0031+79      Y Cep    <9.6-15.1>  |     |     ---------------20m------------ |     +++++27M+++++++++     |     |   -------|
|   *0031+62      TY Cas & 10.3-(16.5  |     |13M? |     |     |     |     |     |7m?  |     |     |     |     |     |
|    0040+47      U Cas    <8.4-14.8>  |  ++++++++++6M+++++++++|     |   ----------11m------     |   +++++++++8M++++++++++      |
|    0041+32 •   RW And    <8.7-14.8>  |     +++++++13M+++++++++++++++|     |     -------------------------3m-------------    |
|    0044+35      V And    <9.5-14.4>  |---  |     ++++++++++22M++++++++     |    ---------10m---     | ++++++++++4M++++++++  |
|    0044-35      X Scl &<10.6-(14.2>  |-------16m--------     |     +++25M++++  |     |   ---------4m--------    |     |  ++|
|    0045+33     RR And    <9.1-15.1>  |     | ++++++++++10M++++++++++     |     ---------14m-------------    |     |+++++++++++|
|    0047+46A    RV Cas    <9.4-15.2>  |6m----------     |  ++++++22M++++++++++  |     --------------------3m----------|     |
|    0049+58      W Cas    <8.8-11.8>  |++++++++++++     |     |15m  |     +++++++++++++++++++++++++13M+++++++++++++++++++|
|                                                                   4M?  |     |     |14m? |     |     |8M?  |     |
|                                                                   |++++++++21M++++++++++     |     | -----11m----     |
|                                                                   |15m  |     |++++++11M+++++++ |     |15m  |     |
|                                                                   |     |     |     |  27M?     |     |     |     |
|                                                      -------------|   ++++++++28M+++++++++     |     -------|
|                                                                   |     |     |   ---------------11m-----     |     |
|                                                                   |     |     |  23M?     |     |  28m?     |     |
|                                                                   |  24m?     |  26M?     |     |    10m?   |     |
|                                                      -----------  |  +++++7M++++++   |     | ----------|
|    0112+72      S Cas    <9.7-14.8>  |+++++++18M+++++++++++++++++|     |     |     --------------------------7m---|
|    0112+08      S Psc #  <9.6-15.0>  |------------------     | ++++++18M++++++++++     |     |   ---------------------8m---|
|    0117+12      U Psc   <11.0-14.4>  |     |  23M|     |
|   *0120+20     RX Psc @   9.5-(14.7  |  30M?     |     |
|   *0122-33      R Scl     6.0-9.1    |  28m?     |     |
|    0123+50     RZ Per    <9.4-13.7>  |13M+++++++++++++ |
|    0125+02      R Psc    <8.2-14.3>  |++   |     |     ----
|   *0127+46     SX And     8.6-14.6   |    1M?    |     |
|    0133+38      Y And    <9.2-14.2>  |-----|     +++++31M++
|    0149+58      X Cas   <10.1-12.5>  4M++++++    |     |
|    0152+54      U Per    <8.1-11.3>  |+++++++++++++++++5m++
|    0159+12      S Ari   <10.9-15.2>  |------------13m------
-----------------------------------------------------------------------------------------------------------------------
|                                      | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB |
-----------------------------------------------------------------------------------------------------------------------
                      # - needs more data      & - needs more data urgently      @ - needs more data very urgently
```

U Cas is brighter than magnitude 11.0 (shown by the "+" symbols) from mid-January until the end of April 1999, with the maximum brightness predicted to occur sometime around the 6th of March.

S Tuc is predicted to be fainter than 13.5 ("-" symbols) from the last week in August until the end of October. Minimum brightness is expected to occur October 8th. The "&" symbol next to the star name, means that more data is urgently needed on this star.

Figure 5.3 – *Sample AAVSO Bulletin*

In order for your observations to be included in the AAVSO International Database, you must submit them to Headquarters. There are several ways to produce reports and submit them to the AAVSO but it is important that you **use only one method and do not send the same observations more than once.**

No matter what the means of submission, reports must be in standard AAVSO format as described on pages 41-44 of this manual. It is essential that AAVSO formatting standards be followed in order to ensure the consistency of data in the AAVSO International Database. It also greatly facilitates the processing of the approximately 35,000 observations that come to the AAVSO each month.

If you belong to an astronomy club or make your observations in company with another variable star observer, please note that each person should make their observations independently and submit a separate report.

Internet Data Submission - WebObs

The preferred and by far the easiest way to submit observations to Headquarters is through the AAVSO website. There, you will find a system called WebObs that takes your observations and automatically submits them to the AAVSO. All you need is a connection to the Internet and a web browser. When you submit observations online, WebObs will automatically format them to AAVSO specifications. It will also perform various error checking procedures to make sure you entered the data correctly. In addition, a complete listing of your observations is always available so you can peruse and/or download your contributions to the AAVSO database at any time.

Another advantage to using WebObs is that your variable star observations will be available for use much sooner than if you submit them using one of the other methods which must undergo more processing. For example, observations of cataclysmic variables or stars exhibiting unusual behavior may appear in the *AAVSO Newsflash* (see page 37) the next day after they are submitted. Also within one business day after submission, your observations can be viewed using the online “Light Curve Generator” (http://www.aavso.org/adata/curvegenerator.shtml) and will show up in the online “Quick Look” files.

To start using WebObs all you need to do is fill out a registration form on the AAVSO website. Within about one business day you will receive an email confirming your registration. Then you can begin using the program. There are plenty of tutorials, “frequently asked questions” (FAQs), and help menus available for you. However, most people find it simple enough that they can use it right away. If you have Internet access, visit the AAVSO website (http://www.aavso.org/cdata/webobs/) and take the "3-click Tutorial" on using WebObs.

Email Data Submission

If you do not have ready access to the Internet, but do have email, this may be the next best choice for submitting your reports to the AAVSO. Email reports can be sent to AAVSO Headquarters at any time. Timely observations of cataclysmic variables or other stars exhibiting unusual behavior may become part of the electronic publication *Newsflash* and will be available for viewing with the “Light Curve Generator” or as part of the “Quick Look” files within one business day of when they were received.

To send variable star reports by email, you must first create a text file version of your report in standard AAVSO format. Reports can be produced using software developed by the AAVSO or you may devise your own method of creating a report as long as the result is ***exactly*** the same. This is very important as any observations given in non-standard formats will not be accepted (except in special cases by prior arrangement with AAVSO Headquarters). If you decide to create your own data-entry program you should contact AAVSO for more details on output requirements. As of the publication date of this Manual, there are two data-entry programs available from the AAVSO which are described below. Check the AAVSO website or *Newsletter* announcements for the latest updates or announcements on new programs.

Once a text file is created, it should be sent as an email to the AAVSO “Observations” account (observations@aavso.org). The observations themselves should make up the body of the email and **not be sent as an attached file.** Any additional questions or comments that are not part of the actual report should be sent as a separate email. Also, the subject line of the email should reflect the name of the data file including your observer initials, and the date–given in year, month, date format: (initials)YYMMDD

Subject line example:

for a report by BSJ dated March 24, 2000
the subject line would read: BSJ000324

AAVSO Data-Entry Software

The AAVSO has created data-entry and report-formatting programs that may be used to record variable star observations and prepare monthly reports in AAVSO format. There is currently a Windows-based program called PC Obs and a DOS-based version called KSOLO. The text files created by either program may be sent by email, copied to a diskette which you could send to Headquarters by postal mail, or printed on paper and sent by postal mail or by fax.

To obtain your own copy of one of the AAVSO data-entry and report-formatting programs free-of-charge you may download them from the AAVSO website or contact AAVSO Headquarters to request the diskettes. Instructions for use of these programs are included with the files.

Postal Mail Data Submission

Another way to submit reports to the AAVSO is via postal mail to AAVSO Headquarters. Such reports should be sent in once per month, mailed as soon as possible after the first of the next month. The address is:

AAVSO
25 Birch Street
Cambridge, MA 02138 USA

Observers with a computer but no email or Internet access are encouraged to create a text file of their observations, copy them onto a diskette, and mail the diskette to AAVSO Headquarters. As with other computer generated reports mentioned here, the data files can be created using any report generating software as long as the output is in standard AAVSO format.

If you wish to submit your reports in handwritten or typed form, please use the standard AAVSO report forms supplied with a new member kit or available free-of-charge upon request from AAVSO Headquarters. You may copy these forms or request more when you run out. The forms are also available via download from the AAVSO website (http://www.aavso.org/cdata/obsreportform.stm). A usable blank report form can be found on pgs. 45-46 while a sample of a completed one is given in Figure 6.1, page 43.

Faxed Data Submission

The AAVSO will also accept reports by fax. The fax number of AAVSO Headquarters is: 617-354-0665 (Outside of the USA and Canada you will need to dial the county code, which is 01, as well as any additional numbers required for you to make an international call.) Since a faxed report must be typed into a computer by staff at AAVSO Headquarters, it is important that it be clear and complete, following standard AAVSO format. To produce such a report, you can either print out a file created by a data entry program or write your report by hand on an AAVSO Variable Star Observations report form (see page 45). Please use black or dark blue ink so that the result will be legible.

Special Reports

If you would like to contribute timely data on special variable star events such as outbursts of cataclysmic variables or stars showing rare or unusual behavior, you may report your observations by WebObs, email, fax, or telephone on the night (or the morning after) they are made. Such observations are used to alert and inform the astronomical community of unusual or interesting stellar behavior. It is essential that such reports adhere strictly to AAVSO report formatting standards in order for the data to be processed and made available for use right away. Some of the observations reported in this manner will appear in the electronic publication *Newsflash* as well as in the “Quick Look” files found on the AAVSO website.

NOTE: "Special reports" sent in by fax or passed on verbally by telephone must be resubmitted with a monthly report at a later date in order for them to become a permanent part of the AAVSO International Database. **Observations sent electronically (by WebObs or email)** ***should be submitted only once.*** They will be used for *Newsflash* and the "Quick Look" files, then processed and added to the permanent AAVSO data files. Please do not hesitate to phone (617-354-0484) or email (aavso@aavso.org) Headquarters if you have any questions concerning reporting your observations.

AAVSO Standard Report Formatting

No matter which method you decide to use for making and submitting your variable star reports, it is *required* that the data adhere to AAVSO report formatting standards. With WebObs and AAVSO produced data entry software, some of these formatting requirements will be met automatically.

Header Information

For proper documentation it is important that with each report submitted, you include your name, complete address, the month of the year of your report, the time system used (GMAT), and equipment used for your observations. If you use WebObs, this is done for you from the information you supply when you fill out the registration form. The registration form need only be completed once. If some of the information on it changes, click on the button marked "Modify User Profile & Report Number" located at the bottom of the observation entry page. If you use AAVSO data entry software, you will be prompted for the same header information. If using the paper report forms, please fill out the front of the first sheet of your report completely. Put your name and the month and year of your report on the front and back of all subsequent sheets.

AAVSO Observer Initials are assigned by AAVSO Headquarters technical staff upon receipt of your first report. If you know your AAVSO Observer Initials, please put them on the front and back of each sheet of your report with observations on it (this is done for you with WebObs and AAVSO data entry programs). If you do not know your initials, please leave this space blank. Once your initials are assigned, you will be notified by postal mail or email (usually within 2–3 weeks.)

General Layout

(Not applicable for WebObs or AAVSO data-entry program users because the software automatically accomplishes this.)

List the variables in order of right ascension from 00 to 23 hours. If you make more than one observation of a star, put them together in order of Julian Date. If two or more stars have the same right ascension, list the most northerly one first. For example: 1909+67, 1909+25, 1909-07. (For information on variable star "designations" see pages 17-18.)

At the bottom of the first page of your report, please put the total number of observations (regular plus inner sanctum) and the total number of inner sanctum observations (inner sanctum only) in the *entire* report. An "inner sanctum observation" is a positive observation of a star magnitude 13.8 or fainter, or a fainter-than observation (you could not see the variable) of <14.0 or fainter.

A single page should be numbered "page 1 of 1." If several pages are used, number them consecutively. Thus: page 1 of 4; 2 of 4; 3 of 4; 4 of 4. The last figure (4) is the total number of pages submitted.

Please use dark ink or a typewriter or printer with a dark ribbon to prepare your reports. If you prefer to use pencil, please use a dark, hard lead which does not smudge easily. If you write your report by hand, please print clearly! Do not leave any blank lines between stars.

Designation

The designation for each star observed should be listed in the first column of your report form. You can find the designation in the upper left corner of every AAVSO Variable Star chart if you don't already know what it is. On some of the older charts, the "+" or "-" signs have been left out in favor of an underlined designation for southern stars (e.g. <u>021403</u> instead of 0214-03). Always use the "+" and "-" signs when making your report. (See pages 17-18 for more about variable star names and designations.)

Variable Name

Please use only the constellation abbreviations approved by the International Astronomical Union (IAU) when reporting observations (see Table 3.1–page 19).

NOTE: For an up-to-date list of stars (designations & names) in the AAVSO observing program, please consult the AAVSO website (http://www.aavso.org/cdata/validation.stm).

Julian Date and the Decimal of the Day

The dates and times of observations must be submitted in Julian Date and decimal of the day in Greenwich Mean Astronomical Time (GMAT), not regular calendar or Universal Time dates. See Chapter 4 of this manual for more on this subject. The only exception to this rule is that if you are using WebObs, dates and times in UT *will* be accepted since the program will convert them automatically to JD. A Julian Day calendar may be obtained at no charge from AAVSO Headquarters or downloaded from the AAVSO website. New calendars will be sent each year by postal mail to all members and active AAVSO observers. A current calendar is included with the new member package.

The types of stars observed once a week should have the decimal of the day reported to one decimal place. The types of stars observed every clear night should have the decimal reported to four places. See Table 6.1—*Precision of JD Needed,* right, for different variable star types. Chapter 4, page 25, gives instructions on how to figure the Julian Day and Decimal.

Magnitude

Visual magnitudes should be reported to ONE decimal place. Any visual magnitudes reported to two decimal places will be rounded off before they are added to the AAVSO International Database. Charge-coupled device (CCD) and photoelectric photometry (PEP) observations should be reported to two or three decimal places of magnitude.

If you report a "fainter-than" observation (i.e. you could not see the variable), please put a "<" symbol and the magnitude of the faintest comparison star you can see. For example, if you observe a variable and cannot see it, but the faintest comparison star that you can see is 14.5, put "<14.5" on your report.

If there is any uncertainty in your estimate, you may denote this by putting a colon (":") after the magnitude and indicating the reason for the uncertainty in the "Key & Remarks" fields.

Key & Remarks

To make the best use of the data you submit and to help AAVSO Technical Staff evaluate the data, it is very important to know why an observation is marked uncertain, and what comments you might have that affect that observation. The "Key & Remarks" field may be used for explaining the cause of uncertainty in an observation or for making comments about observing conditions, etc.

Table 6.2 contains a list of one-letter abbreviations for comments and their meanings. Please put your remark(s) in the "Remarks" part of the field and put the appropriate one-letter abbreviation(s) in the "Key" part of the field.

Comparison star magnitudes

The magnitudes of the comparison stars that are used to make the observation should be included in the "Comp Stars" field of the report. It is very important to include this information for each observation. It is not necessary to put the decimal point in the comparison star magnitudes. (e.g. 98, 101, 106). If there is more than one comp star of the same magnitude in a variable field, include a compass direction with the magnitude so it will be clear which star you used (e.g. 83, 88NE, 92).

Table 6.1 – *Precision of JD Needed*

Type of Star	***Report JD to***
Cepheids	4 decimal places
RR Lyrae stars	4 decimal places
RV Tauri stars	1 decimal place
Long period variables	1 decimal place
Semiregulars	1 decimal place
Cataclysmic variables	4 decimal places
Symbiotic stars*	1 decimal place
R CrB stars*—*at Max*	1 decimal place
R CrB stars—*at Min*	4 decimal places
Eclipsing Binary stars	4 decimal places
Rotating stars	4 decimal places
Flare stars	4 decimal places
Irregular variables	1 decimal place
Suspected variables	4 decimal places

***Note:** Symbiotic stars and R CrB stars may experience possible small-magnitude, short-period variability. If you are interested in looking for this, then observations should be made every clear night and reported to 4 decimal places.

Chart/Scale/Date

To avoid confusion in the data arising from revisions of AAVSO finder charts and comparison star sequences, and from any non-AAVSO charts/ sequences which may be in use, it is essential that you indicate in the Chart/Scale/Date field the source, scale, and date of the chart(s) you used in making an estimate for every observation in your report. When there is more than one date given on a chart, please use the most recent one.

If you report observations of a star not in the AAVSO's observing program, you must send a copy of the chart and comparison star sequence you used. Your observations cannot be added to the AAVSO International Database without this information.

Please double-check your report before sending it to AAVSO Headquarters!

Figure 6.1 – *Sample AAVSO Report*

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
25 Birch Street, Cambridge, MA 02138, USA

VARIABLE STAR OBSERVATIONS

Sheet 1 of 10 Report No. 294

For Month of March Year 1999

Observer John Doe

Street 13 Main Street

City Anywhere State MA

Country USA Zip Code 01234

Time Used, GMAT or ______

Instrument(s) 6 & 15 cm refr, 44.5 cm refl, 7 x 35 binoculars

AAVSO Observer Initials DJQ

For AAVSO HQ Use Only
Received ______
Entered ______
Verified ______

Chart:
P = AAVSO preliminary
S = AAVSO standard

Designation	Variable	Jul.Day+Dec.	Magn.	Key^	& Remarks	Comp. Stars	Chart/Scale/Date
0017+55	T Cas	2451242.5	9.2	U	Passing Cloud	86,90,94,105	~~85~~ s/b/52
"	"	252.5	9.4			"	"
"	"	262.5	9.4	H		90,94,105	"
0017+26	T And	246.5	<13.7	B		137	s/d/33
0022+17	TV Psc	242.5	5.3	A		48,54,59,61	vSA 54
0041+32	RW And	242.5	10.2			94,100,105,107	s/b/39
"	"	252.5	10.5			100,105,107,110	"
"	"	264.5	10.8			111,115,119	s/d/28
0546-29	R Col	246.5	11.7	L		111,113,116,119,125	s/d/33
"	"	261.5	12.3	L		116,119,121,125	"
0549+74	V Cam	242.5	9.1			84,93,100	s/b/39
"	"	252.5	9.3			"	"
"	"	262.5	9.6:	H O	Visitors distracted	93,100,103	"
0549+20a	U Ori	242.5	10.5			97,103,106,110	s/b/86
"	"	252.6	10.7			103,106,110	"
"	"	264.5	10.8			"	"
0549+07	alpha Ori	242.5	0.9			03,12	s/a/68
"	"	252.5	0.9			"	"

Total Number Inner Sanctums* 24 | Total Number Observations Reported 463

^ KEY field contains AAVSO-selected one-letter abbreviations for REMARKS. See top of page for list.
* An Inner Sanctum is an observation which is magnitude 13.8 or fainter, or <14.0 or fainter.
Observations should be send to AAVSO Headquarters, 25 Birch Street. Cambridge, MA 02138 USA

Table 6.2 – *Abbreviations for Comments on AAVSO Reports*

These comment letters go in the “Key” field on the paper AAVSO report form, or in the “Comment Code” field in electronic report files. If needed, use more than one letter, keeping them in alphabetical order. The letters should serve as a general guide to your comment*; they needn’t be an exact representation* of what’s in the report. For example, if you note in the “Remarks” field “a 12-day moon nearby”, just put an “M” (for moon).

:	uncertain
?	(do not use this symbol)
A	AAVSO Atlas used
B	Sky is bright, light pollution, twilight
F	Unconventional method (out of focus, visual photometer, etc.)
G	Non-AAVSO chart with Guide Star Catalog magnitudes
H	Haze, mist, fog
I	Identification of star is uncertain
J	Non-AAVSO chart with Hipparcos magnitudes
K	Non-AAVSO chart - specify origin
L	Low in sky, horizon, trees, obstruction
M	Moon present or interferes
N	Angle, position angle
O	"Other" comment (last resort if no other code applies!) - MUST be explained
R	Color comment
S	Comparison sequence comment or problem; extrapolation
T	Non-AAVSO chart with Tycho magnitudes
U	Clouds
V	Faint star, glimpse, near limit
W	Weather, wind, poor seeing in general
Y	Activity in star - outburst, fading, flare, unusual behavior
Z	Possibly erroneous, doubtful, fatigue

These multiple-letter comment abbreviations go in the “Key” field on the paper AAVSO report form, or in the “Comment Code” field in electronic report files. If you must use a one-letter abbreviation as well as a multiple-letter comment, skip a space between the two codes.

BLUE	Blue filter used for the observation
CCD	Charge-coupled device (unfiltered)
CCDB	Charge-coupled device (Johnson blue filter)
CCDO	Charge-coupled device (orange filter)
CCDR	Charge-coupled device (Johnson red filter)
CCDV	Charge-coupled device (Johnson visual filter)
CCD-IR	Charge-coupled device (with IR-blocking filter)
COMB	Observation is of nuclear and nebulous regions COMBined
GREEN	Green filter used for the observation
NUC	Observation is of the NUClear region
PEP	Photoelectric photometer (visual band)
PTG	Photographic observation
PV	Photovisual observation
RED	Red filter used
YELLOW	Yellow filter used

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
25 Birch Street, Cambridge, MA 02138, USA

VARIABLE STAR OBSERVATIONS

Sheet ________ of ________ Report No. ________

For Month of ________________ Year ____________

Observer ________________________________

Street ________________________________

City ____________________ State ____________

Country ________________ Zip Code ____________

Time Used, GMAT or ________________________

Instrument(s) ____________________________

AAVSO Observer Initials

____

For AAVSO HQ Use Only

Received ______________

Entered ______________

Verified ______________

Chart:
P = AAVSO preliminary
S = AAVSO standard

Designation	Variable	Jul.Day+Dec.	Magn.	Key^ &	Remarks	Comp. Stars	Chart/Scale/Date

Total Number Inner Sanctums*	Total Number Observations Reported

^ KEY field contains AAVSO-selected one-letter abbreviations for REMARKS. Obtain list from AAVSO Headquarters or web site.
* An Inner Sanctum is an observation which is magnitude 13.8 or fainter, or <14.0 or fainter.
Observations should be sent to AAVSO Headquarters, 25 Birch Street, Cambridge, MA 02138, USA, as soon as possible after the first of each month.

(turn sheet over)

AMERICAN ASSOCIATION OF
VARIABLE STAR OBSERVERS
25 Birch Street
Cambridge, MA 02138 USA

Observer ______________________________

For Month of ________________ Year __________

AAVSO Observer Initials

____

For AAVSO HQ Use Only
Received ______________
Entered ______________
Verified ______________

^Explanation of Key field characters

IMPORTANT – If an observation is uncertain, please put this character : [a colon] immediately after the magnitude. Each time you use the : character, please be sure to include the reason(s) for the uncertainty in the Remarks field and the appropriate one-letter character(s) in the Key field. This will maximize the amount of information contained in your observations, as well as assist the AAVSO in its record-keeping.

The Key field is for AAVSO-selected one-letter abbreviations of comments about an observation, or for multi-letter abbreviations describing instrumentation such as PEP or CCD. The complete list of these abbreviations may be obtained from AAVSO Headquarters or from the AAVSO web site (http://www.aavso.org). Use as many letters as needed for an observation. Even if there is no uncertainty, please use these letter characters whenever you choose to make a remark about any observation. (However, please do NOT use : if there is no uncertainty.) If you do not wish to make any remarks, please leave the Key & Remarks field blank.

Chart:
P = AAVSO preliminary
S = AAVSO standard

Designation	Variable	Jul.Day+Dec.	Magn.	Key^	& Remarks	Comp. Stars	Chart/Scale/Date

Total Number Inner Sanctums*	Total Number Observations Reported

^ KEY field contains AAVSO-selected one-letter abbreviations for REMARKS. Obtain list from AAVSO Headquarters or web site.
* An Inner Sanctum is an observation which is magnitude 13.8 or fainter, or <14.0 or fainter.
Observations should be sent to AAVSO Headquarters, 25 Birch Street, Cambridge, MA 02138, USA, as soon as possible after the first of each month.

(turn sheet over)

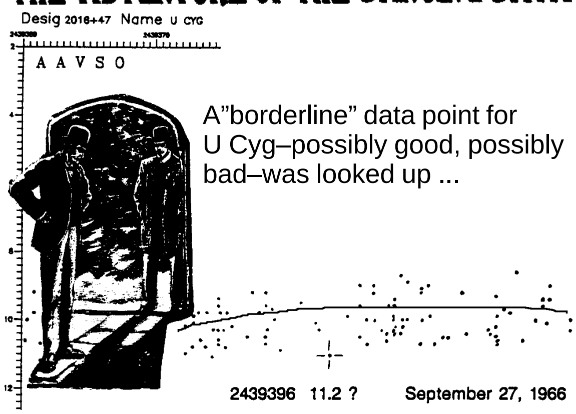
THE BIRCH STREET IRREGULARS:
MYSTERIES FOUND AND RESOLVED IN THE AAVSO DATA ARCHIVES

by Sara J. Beck, Michael Saladyga, Janet A. Mattei and the AAVSO Technical Staff

(Adapted from a paper given at the 1994 AAVSO Spring meeting.)

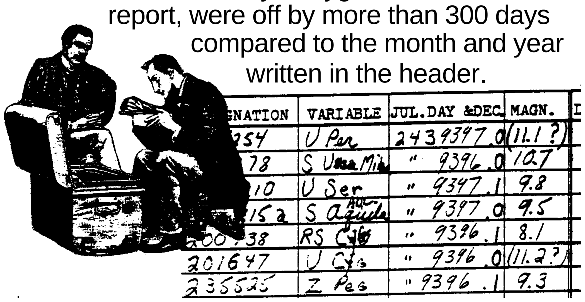
As AAVSO data are evaluated, AAVSO Technical staff and the Director run across several kinds of errors which are tracked down and rectified–a process requiring skillful investigative techniques, a good head for deduction, and dogged tenacity. With apologies to Sir Arthur Conan Doyle, author of Sherlock Holmes, here are a few of the many success stories of the detectives known as the Birch Street Irregulars. These cases also provide the new observer with an idea of some of the common pitfalls experienced by their predecessors.

THE ADVENTURE OF THE DANCING DATA



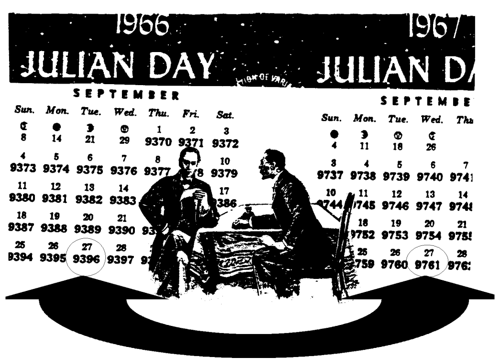
A"borderline" data point for U Cyg–possibly good, possibly bad–was looked up ...

A check on the observer's report showed that the Julian Dates for not only U Cyg, but for the entire report, were off by more than 300 days compared to the month and year written in the header.

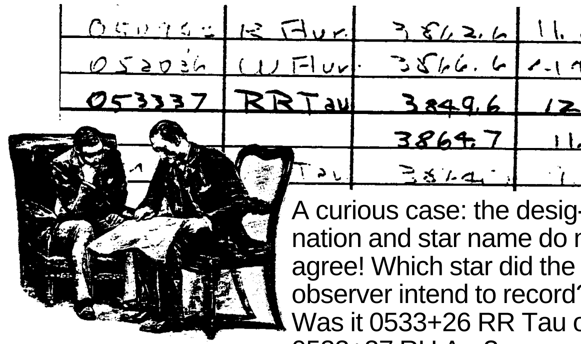


...NATION	VARIABLE	JUL.DAY &DEC.	MAGN.
...354	U Per	2439397.0	11.1 ?
...78	S UMi	" 9396.0	10.7
...10	U Ser	" 9397.1	9.8
...15a	S Aquila	" 9397.0	9.5
200738	RS Cyg	" 9396.1	8.1
201647	U Cyg	" 9396.0	11.2?
235525	Z Peg	" 9396.1	9.3

In comparing the JD calendars for the year of the report and the previous year, it became obvious that the observer had copied the JDs from the previous year's calendar.

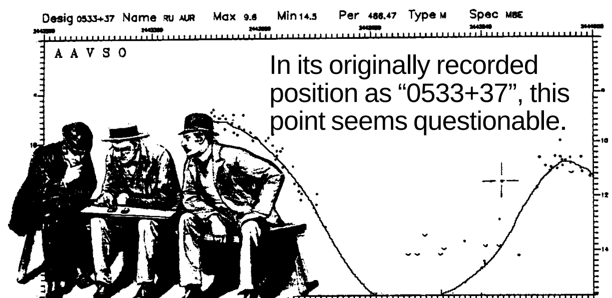


A CASE OF IDENTITY

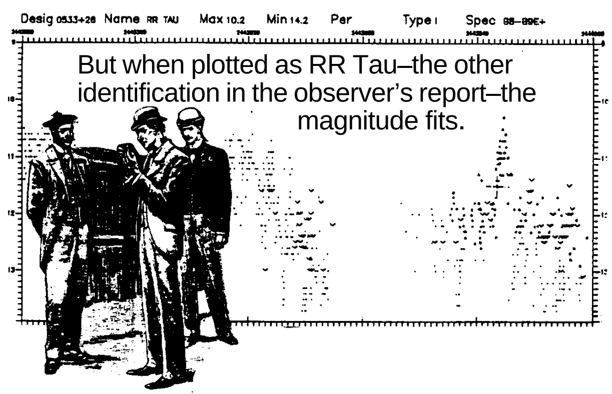


A curious case: the designation and star name do not agree! Which star did the observer intend to record? Was it 0533+26 RR Tau or 0533+37 RU Aur?

The problem: many observations in the archives were recorded with a name and designation for two different stars. The usual causes include: (1) The observer reading the designation or name from the line above in the report form; (2) giving the wrong component letter, or none at all, in the designation; or (3) simply writing one star's name while thinking of another star (for example, WX Cet and WX Cyg).

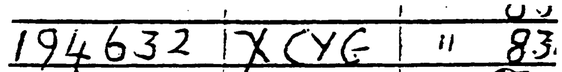


In its originally recorded position as "0533+37", this point seems questionable.



But when plotted as RR Tau–the other identification in the observer's report–the magnitude fits.

THE ADVENTURE OF THE GREEK INTERPRETER

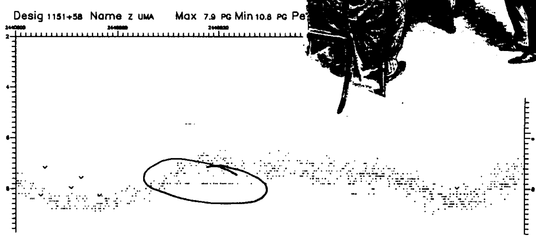


In this instance of star name and designation disagreeing, the observer meant to record chi Cyg, but the handwritten Greek letter chi (c) was read as "X" by the data entry technician.

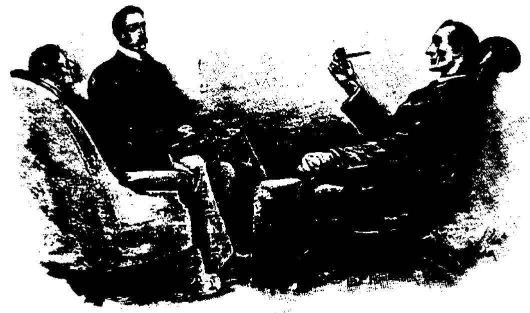
Solution: Always write out the Greek letter names. (eg. beta Per rather than b Per)

THE "MUST BE" RITUAL

For reasons defying explanation, the observers believed that the star they were looking at "must be" the variable star.



Some of the points on this plot were made by the same observer, who probably mistook a nearby star of constant brightness for the variable star.



"IS THERE ANY OTHER POINT WHICH I CAN MAKE CLEAR?"

Chapter 7 – SAMPLE OBSERVATION

by Gene Hanson, experienced AAVSO member/observer and mentor

In this chapter, we will review the step-by-step instructions that were presented in Chapter 2 (page 9) by making a simulated estimate of the variable star Z Ursa Majoris, or “Z UMa.”

1. Find the field – Figures 7.1 and 7.2, on pages 50 and 51, show you the vicinity of this variable. Beginners should find the field of Z UMa easily, because it is located within the “pan” of the Big Dipper. Figure 7.3, below, shows that Z UMa lies fairly close to d (delta) Ursa Majoris.

2. Find the variable – There are several strategies you can use to find the variable. Because it lies relatively close to delta UMa, you might contemplate a star hop from there. However, there is also a 5.9 magnitude star just south of the variable as shown on the “b” scale chart. Both of these are good starting points if you are planning to star hop. Alternatively, you might wish to skip the hop altogether and attempt to zoom directly to the variable. Here are some tips depending on the finding method you are employing.

<u>From delta UMa</u> – Pointing at the third magnitude delta UMa is easy. Figure 7.3 shows the area from delta to the variable on the *AAVSO Variable Star Atlas*.

You now have a choice to star hop by either using the finder (if you have one) or by using a low power eyepiece in the main scope. A good finder scope (8x50 and larger) will show many of the stars on the AAVSO atlas. One advantage of using the main scope is that you can get the orientation correct right away.

<u>From the 5.9 comparison star</u> – Almost any finder scope will reveal the 5.9 star near the variable. Only under the darkest skies will this be visible for use with a 1x finder. However, this star is about equidistant from delta and gamma (see Figure 7.4) so it is easy to point at its location. Because of its brightness, it should be fairly conspicuous in the main scope. From there, you can use the “b” scale chart to do a short star hop to the variable (Figure 7.5).

Figure 7.3 – *Excerpt from AAVSO atlas*

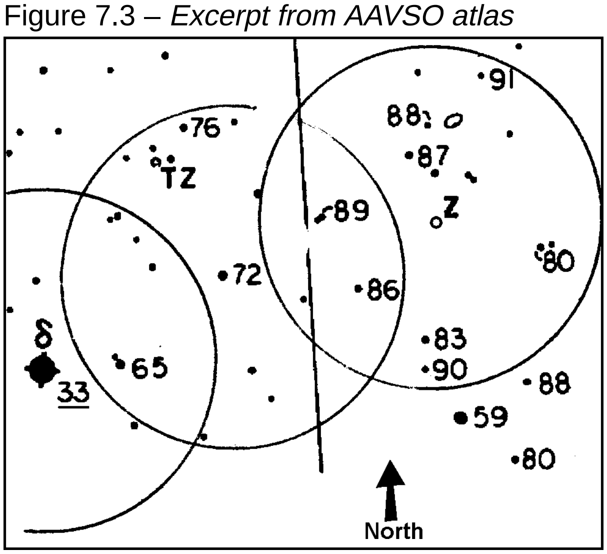


Figure 7.4 – *Excerpt from atlas*

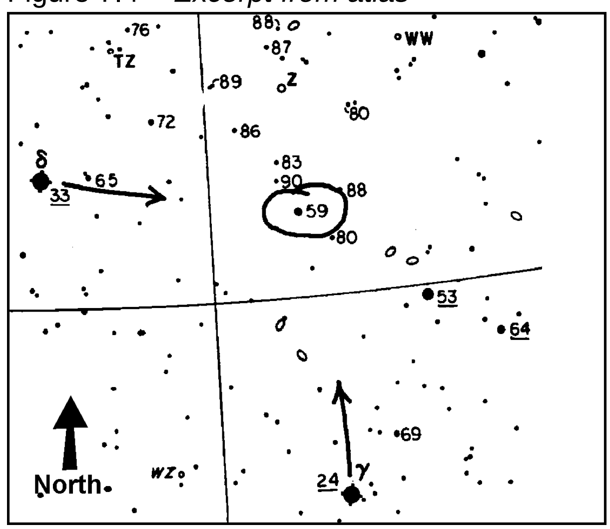


Figure 7.5 – *Excerpt from “b”-scale chart*

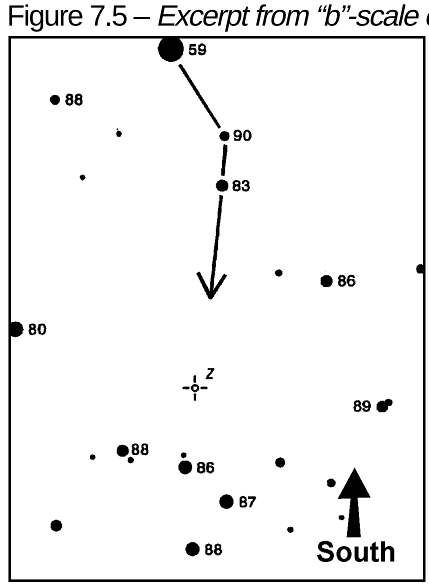
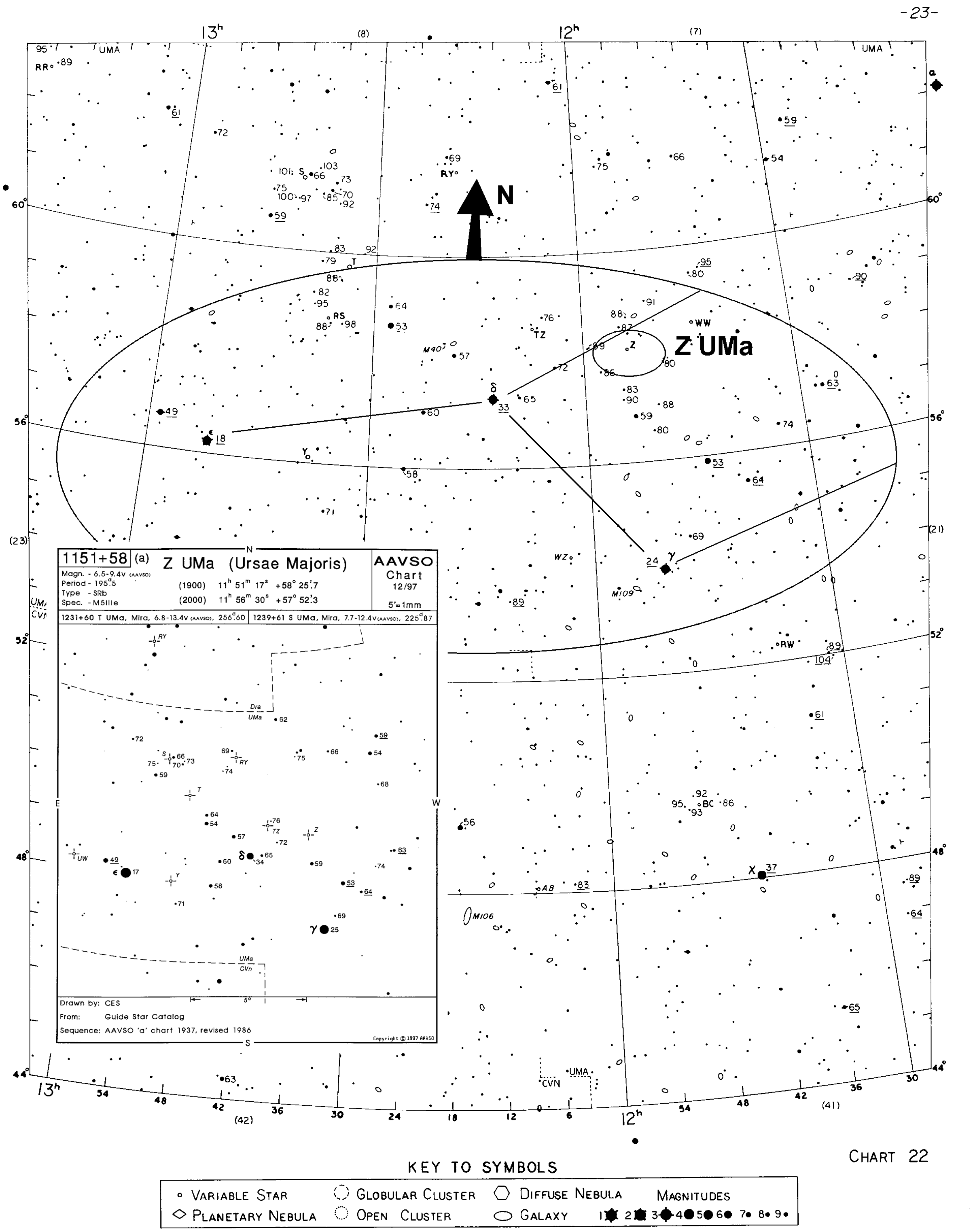


Figure 7.1 – *Finding Z UMa using the AAVSO Variable Star Atlas*. First, use a planisphere or sky chart for the appropriate month to verify that the constellation of Ursa Major is visible during the date and time you wish to observe. If it is, then note the configuration of the brightest stars. Next, go to the Index page of the *AAVSO Variable Star Atlas* and locate the same star configuration. You will probably have to rotate the planisphere to come up with the same orientation. Note that in this example the Index refers you to Chart 22.

Figure 7.2 – *Finding Z UMa using the AAVSO Variable Star Atlas (continued)*. Chart 22 from the *AAVSO Variable Star Atlas* with constellation lines drawn in and Z UMa circled. Note that the orientation is different from that of the Index page (shown in Figure 7.1). A miniature version of the AAVSO "a"-scale chart is shown below for scale comparison.

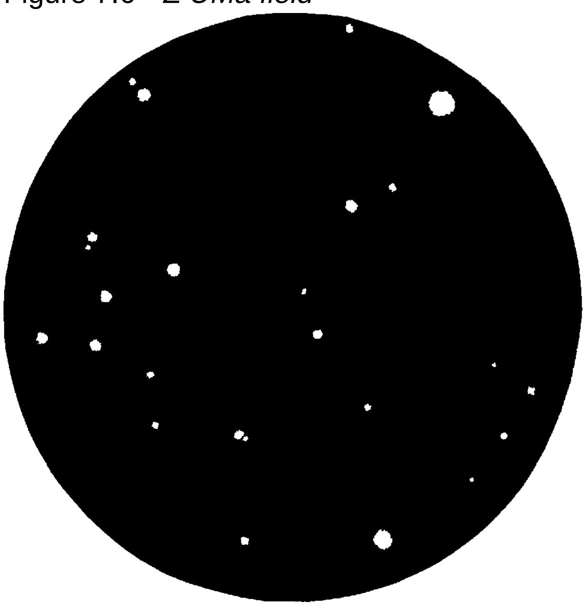


Directly to the variable – This means using your chosen finding method to point as close to the variable as possible before ever looking through the main scope. An observer who only uses setting circles will almost always use this technique. It is probably the most popular method among variable star observers.

With a 1x finder, you will use delta and gamma as guide stars. With a finder scope, you can also use fainter stars (like the 5.9) not visible to the naked eye.

Figure 7.6 below shows a small reflector telescopic view near Z UMa. Just as you would with the real telescopic view, your task is to match this with the estimate chart shown in Figure 7.7 at the right.

Figure 7.6 - *Z UMa field*



The beginner will generally find this challenging for the following reasons:

(1) The orientations probably don't match.
(2) The magnification will almost certainly render an image that's a different scale.
(3) The limiting magnitudes will not match.

All three of these fall in the category of "telescope familiarity" and should become easier for you as you gain experience with your instrument. Here are some tips:

(1) Orientation. Failure to get this right means frustration. You may find it next to impossible to match up star images if the orientation is wrong. A big advantage of star hopping from a bright star or asterism is that the orientation problem is taken care of before you zoom in on the variable. The orientation diagrams presented earlier can be of great help. However, when in doubt you can always let the field drift. The direction of the drift will always be WEST. In Figure 7.6, south is tilted approximately 45 degrees to the right.

Caution: If you are using a telescope with an odd number of reflections (refractor, Schmidt-Cassegrain, etc.), ideally you want to use an AAVSO reversed chart.

(2) Magnification. The "b" scale chart shows a relatively large area of the sky. Therefore, you probably want to use your lowest power eyepiece. You'll also want to know the actual field of view. The field of view shown in Figure 7.6 is 2.3 degrees. This 2.3 degree circle has been drawn onto the "b" scale chart shown in Figure 7.7.

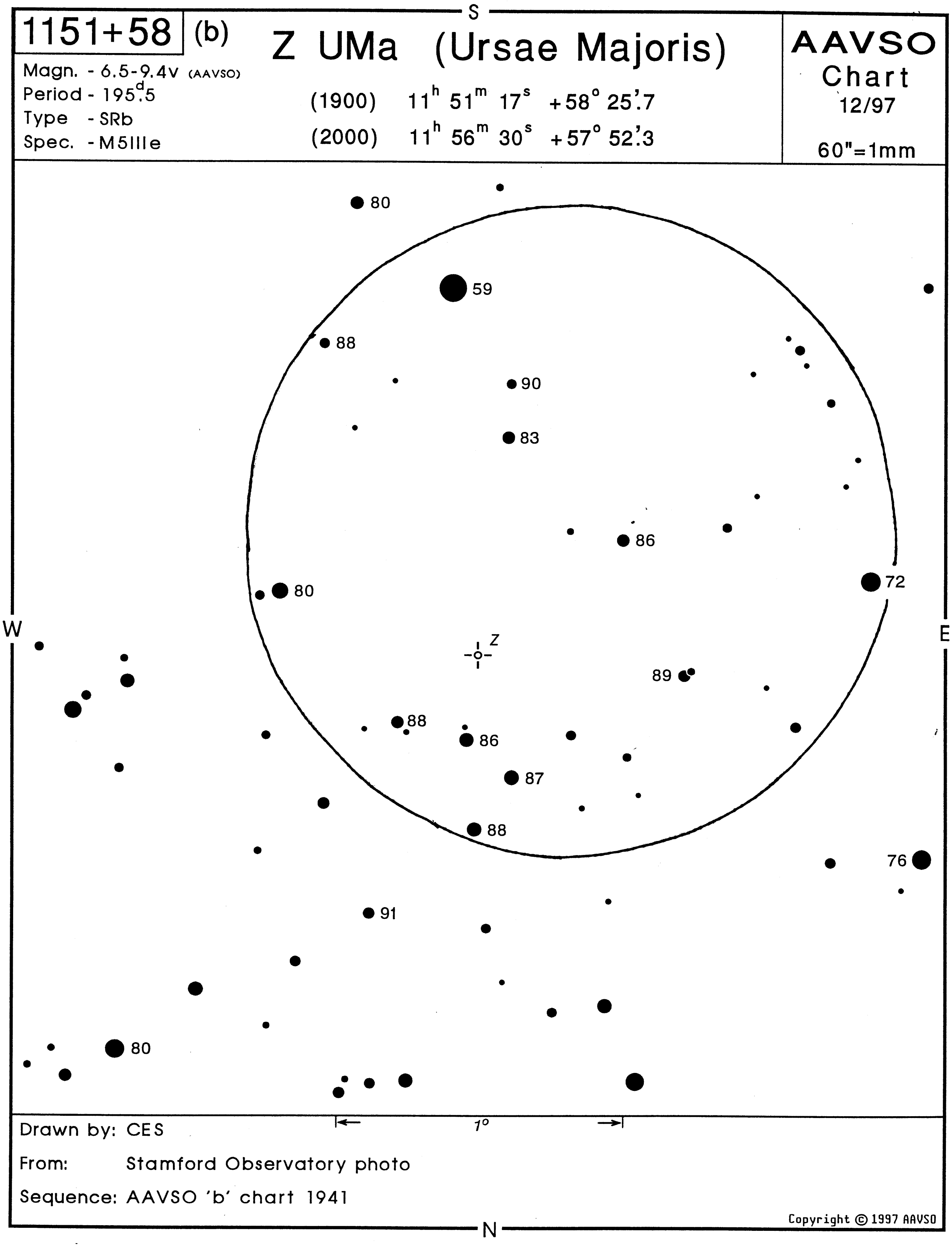
(3) Limiting Magnitude. In general, you will find the "stars" on the charts much more visible than those in the eyepiece! This mismatch can also make field identification difficult. Because it is more difficult to see stars in the scope, it is usually better to look for bright stars or star patterns (asterisms) in the eyepiece first, and then attempt to locate them on the chart.

A technique that many observers utilize who choose the "directly to the variable" approach is the reverse star hop. If the variable field is not readily apparent at first glance, scan around the field looking for asterisms in the field of view (FOV). Once one is spotted, then go to the chart and find it there. You now have a known place from which you can then do the star hop (presumably back) to the variable. Because of the small scale, the "b" charts work particularly well for this method.

In the Z UMa field, there is a trio of 8.6–8.8 magnitude stars just north of the variable. Once you have found these stars in your FOV, the variable is as good as located.

Tip: If you spot what appears to be a very noticeable asterism, draw it on your chart. This will help the next time you are finding this field.

Figure 7.7 – *AAVSO “b”-scale chart of Z UMa with a 2.3 degree Field of View circle drawn in.*



With More Experience–Another advantage you'll gain over time is a feel for the brightness of stars in your telescope. For example, once you've seen a variety of 9th magnitude stars on the charts, you'll inherently know how bright such a star "should" look. With additional experience, you'll also get a feel for how bright it should look under moonlight or other adverse conditions. This helps immeasurably when finding variable fields.

3. Find the comparison stars – Here your task seems straightforward: find at least one star brighter and at least one star dimmer than the variable. The difficulty will vary in direct proportion to how far away the comparison lies. A technique that often works well is to locate "probable" comp stars in the FOV. That is, locate a star you think is slightly brighter or dimmer than the variable. Then, locate that star on the chart. Chances are, it will indeed be a comp star. If not, try another. When you run out of probable comp stars, then you should consult the chart.

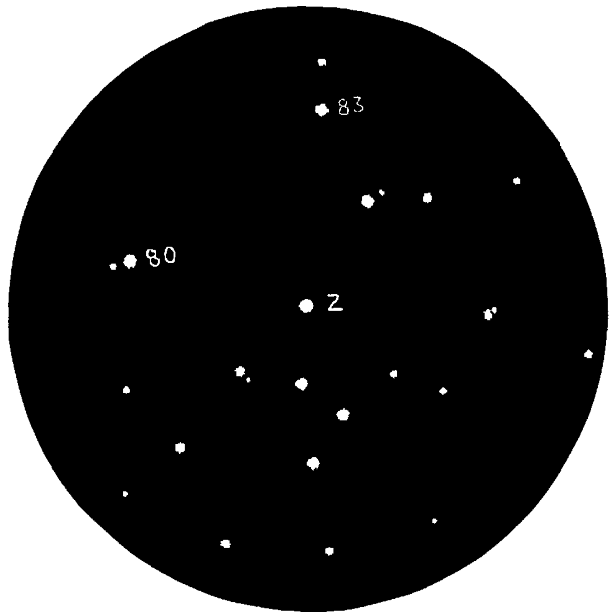
Caution: In your zeal to find the variable, your mind can play tricks. You may be unfortunate enough to find a pattern of stars that "looks" like the chart and believe that you've found the variable! In this step, you are not only finding comparison stars, but you are also helping to prove your identification. Heed simple warning signs. If the chart shows a comp star that is not visible in the scope or very different than the magnitude indicates, chances are greater that you have an identification problem rather than a new variable star!

Though all you need are two stars to bracket the variable, you are strongly urged to locate additional comp stars. Are the magnitudes consistent? If they are not, why? Does just one of the comp stars look suspicious? Be sure to recheck the positions. You will find that stars are plotted on the AAVSO chart with extremely high accuracy. If there is only one comp star that seems off, it is best to disregard it and use the remaining comp stars.

4. Estimate brightness – Once you've located suitable comparison stars, you can finally perform the estimate step. Figure 7.8 (right) shows our field with Z UMa centered and with South up. From this view, it appears that the variable is between the 80 and 83 stars in magnitude, and you will interpolate your estimate from these.

Caution: Most new observers will find the estimating of real variables more challenging than in this demonstration. Does the interval between the 80 and 83 seem small? It is! Consequently, you should not be surprised if your estimates differ a bit from those of other observers.

Figure 7.8 – *Z UMa field with comp stars*



For the purposes of the demonstration, let's assume an estimate of 81.

5. Record your observation – The following information should be recorded:

Name of the variable: Z UMa.

Designation of the variable: Though this is not mandatory because you can theoretically look it up later, writing this at the time of observation will help catch many potential errors. For example, in the cold of an observing session your U's might end up looking like V's and vice-versa. The designation will immediately fix such problems!

Date of your estimate: You can write this for each estimate, but since it is common for observers to start a new page for every night of observing, the date is normally placed at the top of the page. You should always use the double date format to avoid any confusion between before or after midnight.

Time of your estimate: Observers use both local time and Universal Time (UT). You should be consistent, whichever time you use. The precision of your recorded time depends on the type of star. See Table 6.1, page 42 for guidelines. When in doubt, it never hurts to be more precise. Many observers record all their observations to the minute regardless of the variable type.

Magnitude of your estimate: In this case, it was 8.1.

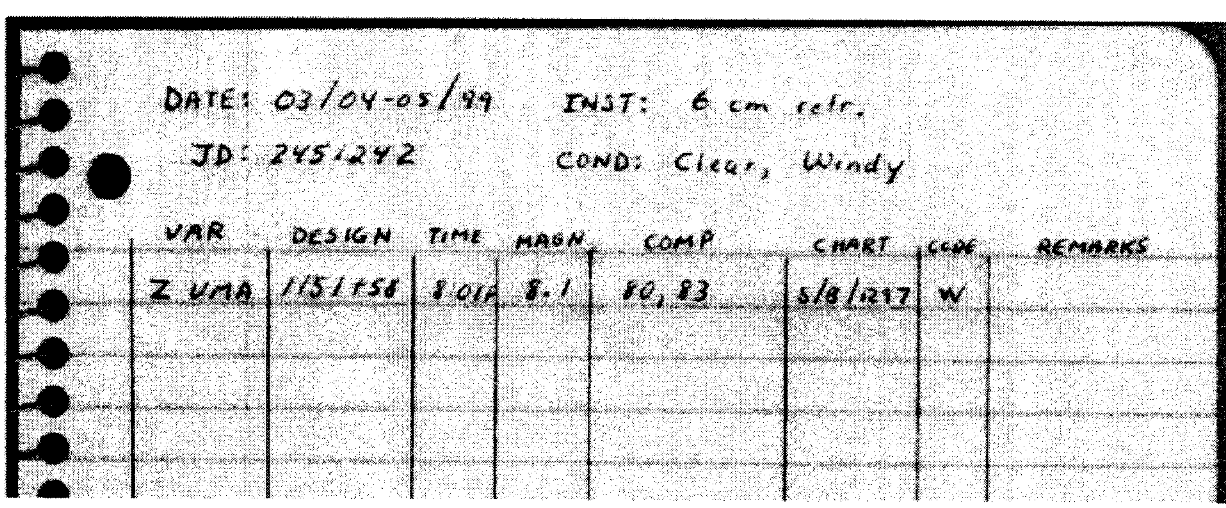
Magnitude of the comp stars used for the estimate: We used the 80 and 83 comp stars.

Chart used for making the estimate: Since we used the standard "b" scale chart dated 12/97 shown in Figure 7.7, we could code this "S/B/1297". The S stands for Standard. The other kind of chart issued is a Preliminary, and this would be noted on the chart itself. New observers should avoid using the preliminary charts. The B stands for the "b" scale of the chart. Had Z UMa turned out to be very bright, you might have used the "a" scale chart. The exact format of this field can vary (For example: S-B-1297, s/b/1297, SB1297 etc.), but all three pieces of information should be present: type of chart, scale, and date. On many of the charts, only the year is given, so that is all you can specify.

Notes on any observing conditions which might effect seeing: Many of the usual conditions like moonlight, haze, clouds, etc., should be coded with the standard abbreviation letter. You will find a list of these in Table 6.2, page 44. Other comments should be written out. Figure 7.9 shows what a sample notebook entry might look like for our sample observation.

Though the "W" code (indicating weather) is specified because of the windy conditions, we did not show the estimate as approximate, as would be indicated as "8.1:". As an observer, this decision is yours. By specifying the code, without the magnitude as approximate, you are indicating that the condition existed, but you didn't feel it impacted the accuracy of the estimate. The opposite cannot occur. If you specify the estimate as approximate, you must specify a reason for the uncertainty.

Figure 7.9 – *Excerpt from observer's notebook*



Gene Hanson with his18-inch f/4.5 Obsession reflector and 6-inch f/5 telescope

Appendix 1 – SAMPLE LONG-TERM LIGHT CURVES

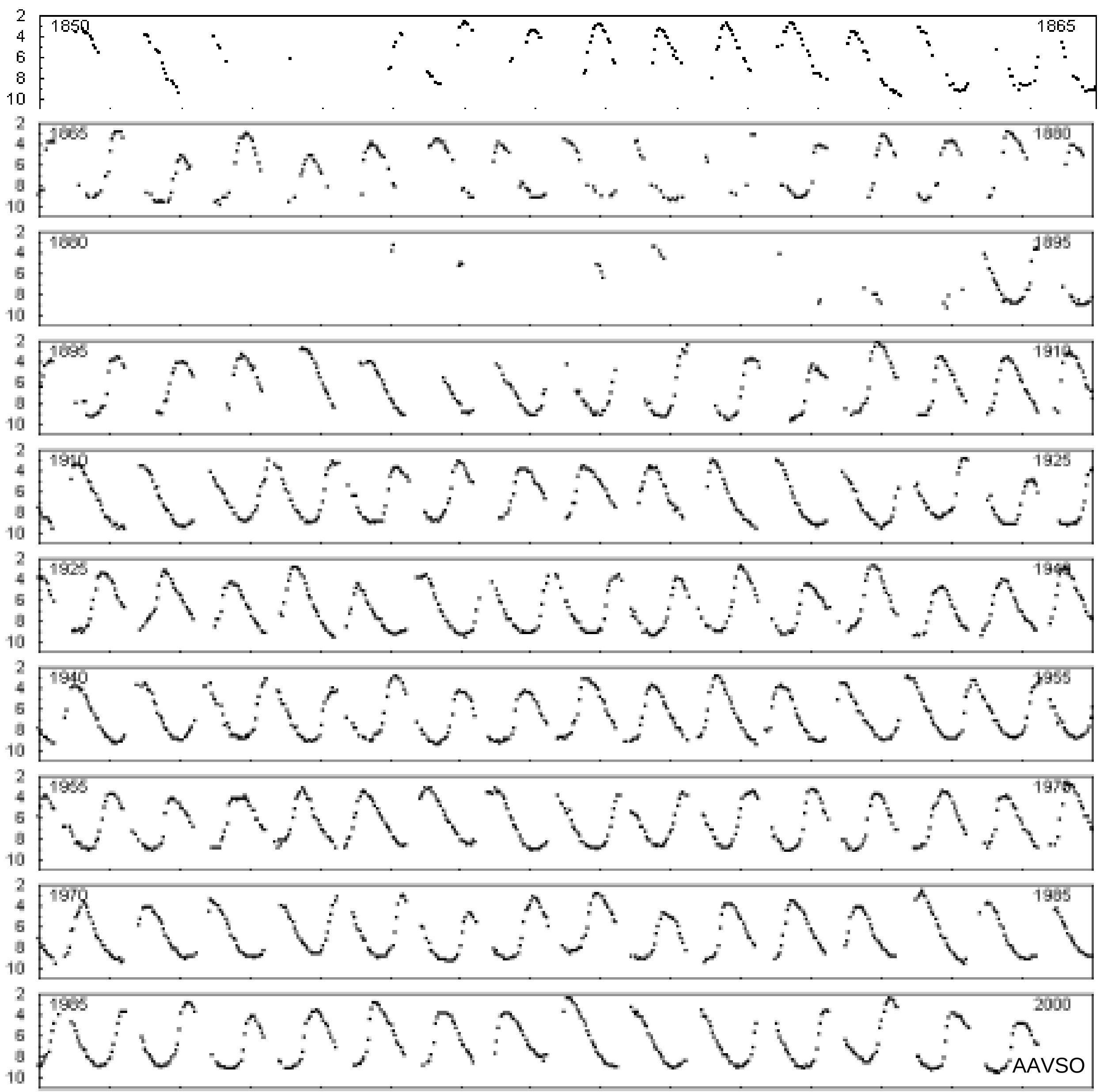
The following pages show examples of long-term light curves of several types of variable stars in the AAVSO visual observing program. Light curves covering such long periods of time can make an interesting study of the long-term behavioral changes which some stars exhibit.

Mira (LPV)

1850–2000 (10-day means)

Mira (omicron Ceti) is the prototype of pulsating long period variables and the first star recognized to have changing brightness. It has a period of 332 days. Generally, Mira varies between magnitudes 3.5 and 9, but the individual maxima and minima may be much brighter or fainter than these mean values. Its large amplitude of variation and its brightness make Mira particularly easy to observe.

Mira is one of the few long period variables with a close companion which is also variable (VZ Ceti).



SS Cygni (U Gem type)

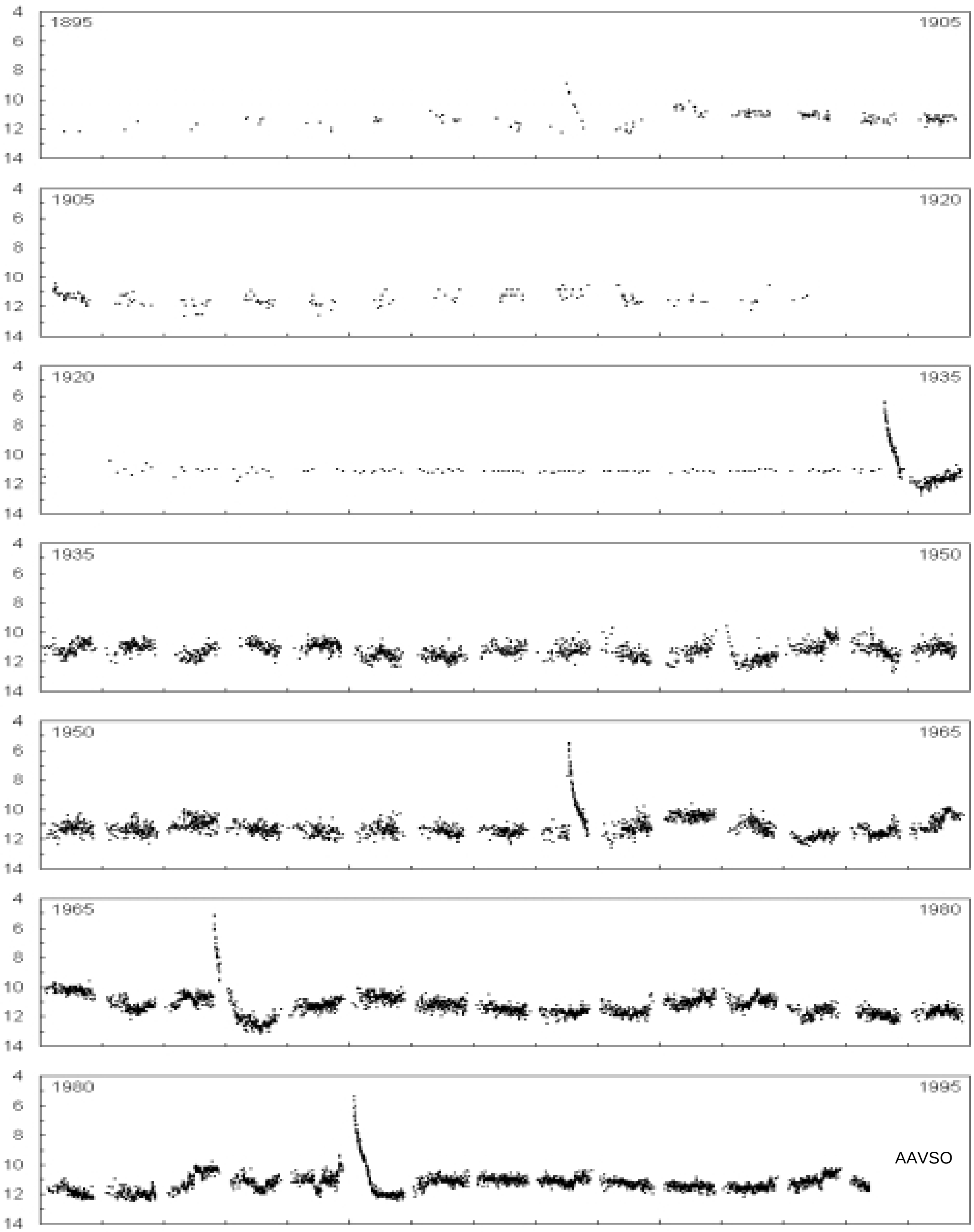
1900–2000 (1-day means)

SS Cygni is the brightest dwarf nova type (U Gem subclass) cataclysmic variable in the northern hemisphere. These stars are close binary systems consisting of a red dwarf star–a little cooler than the Sun–and a white dwarf with an accretion disk around it. At approximately 50-day intervals, SS Cyg brightens (erupts) from magnitude 12.0 to 8.5 due to material from the accretion disk falling onto the white dwarf. The individual intervals between outbursts can be much longer or shorter than 50 days.

RS Ophiuchi (recurrent nova)

1895–1995 (1-day means)

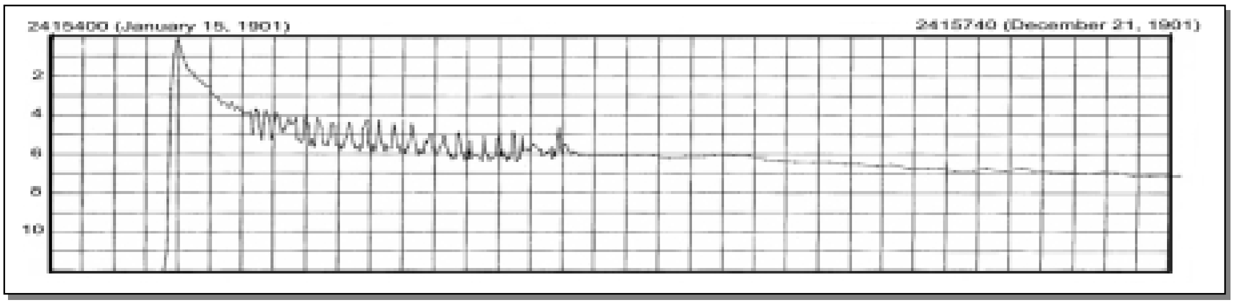
RS Ophiuchi is a recurrent nova. These stars have multiple outbursts ranging in brightness from 7 to 9 magnitudes. The outbursts occur at semiregular intervals ranging from 10 to more than 100 years, depending on the star. The rise to maximum is extremely fast, usually within 24 hours, and the decline may be several months long. The recurrent outbursts are always identical.

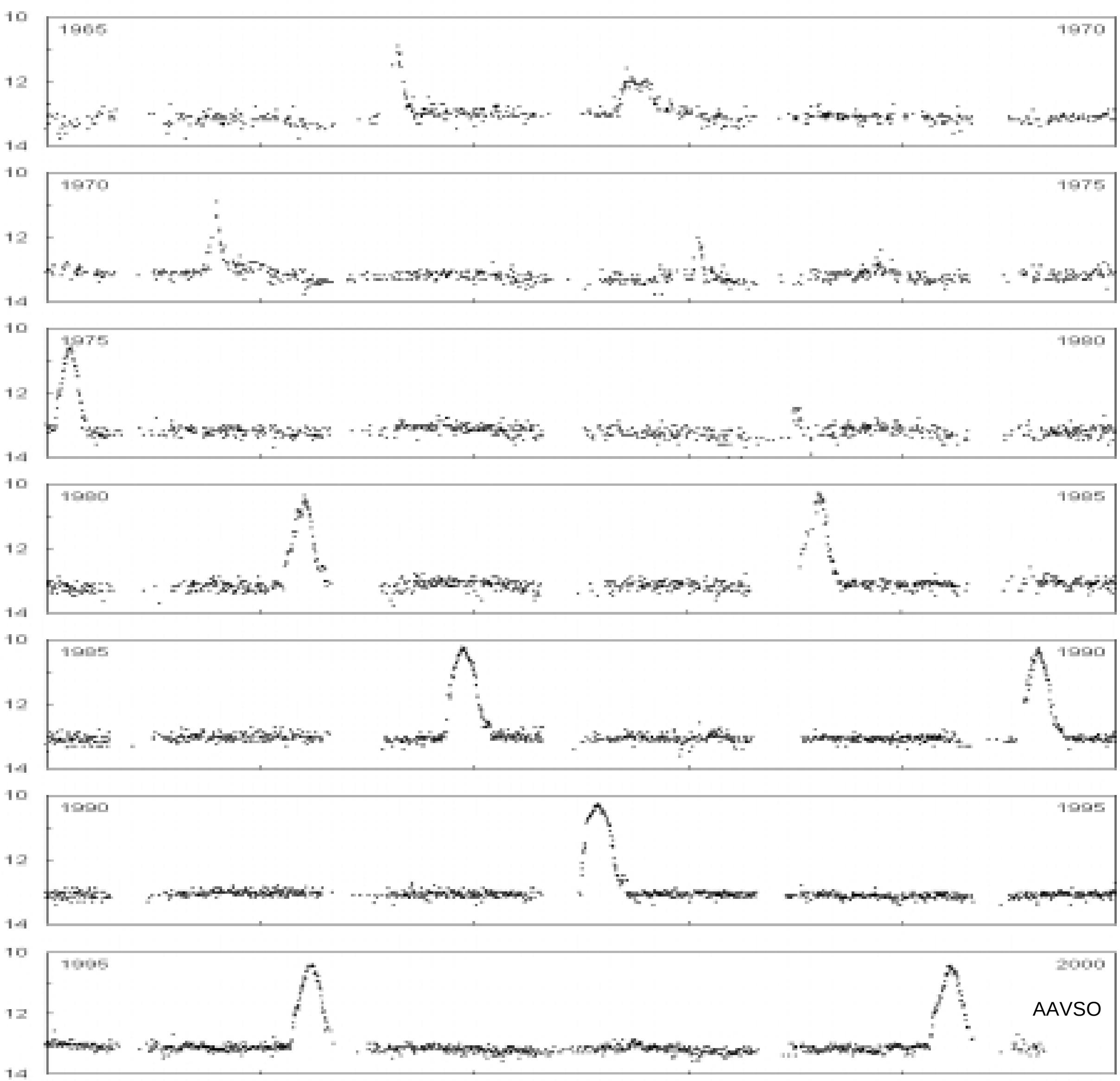


GK Persei (nova)

1901 Nova-like outburst (from *Harvard Annals*)
1965–2000 (1-day means)

GK Persei is a bright nova of 1901. In this close binary system, eruptions occur due to explosive nuclear burning, on the surface of the white dwarf, of material transferred from the red dwarf. GK Persei is unique in that after the initial fading of 30 days, the star showed semiperiodic rapid variations for three weeks and then slowly continued to fade. Decades later, it began having small dwarf nova-like outbursts about every three years.

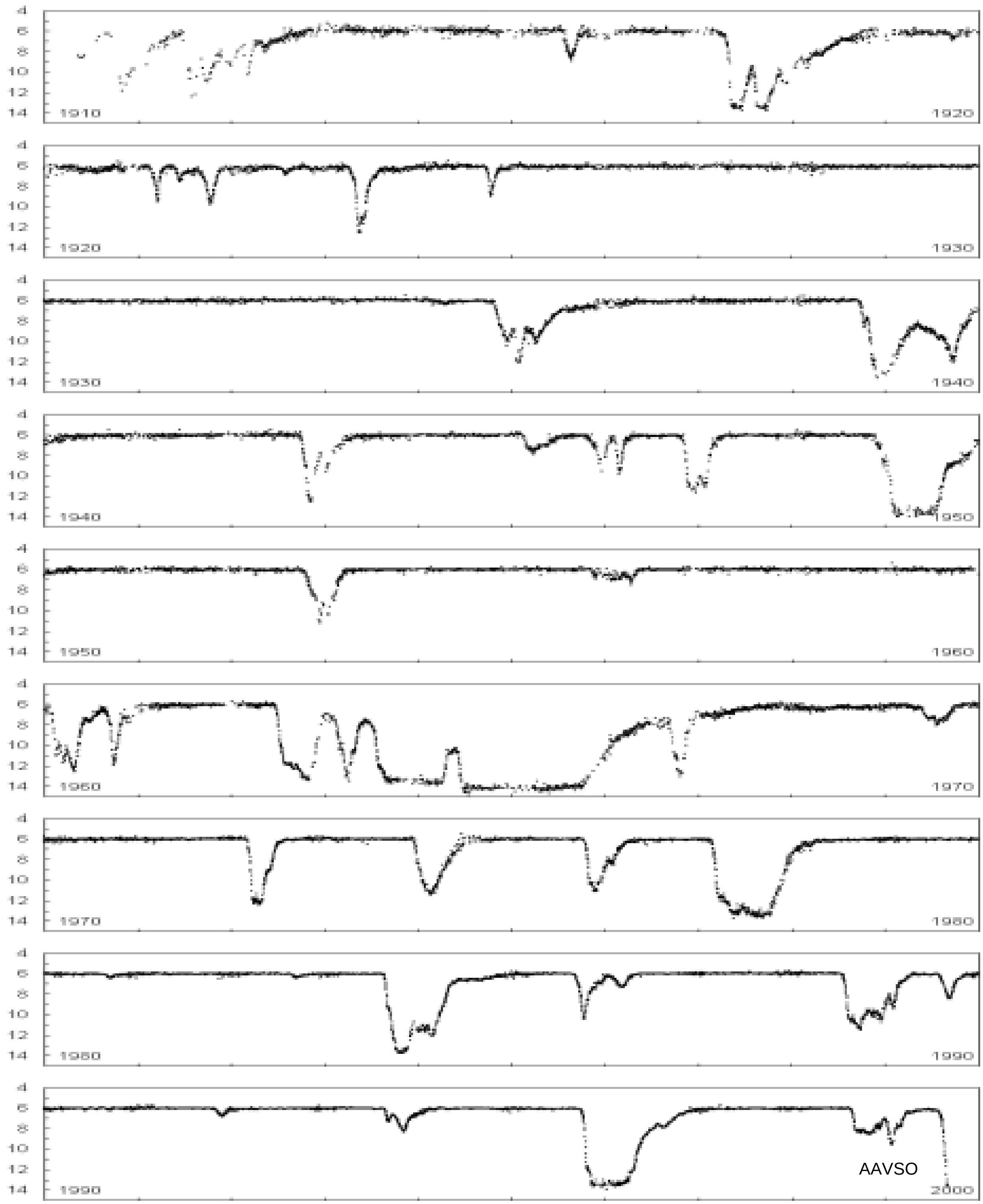




R Coronae Borealis

1910–2000 (1-day means)

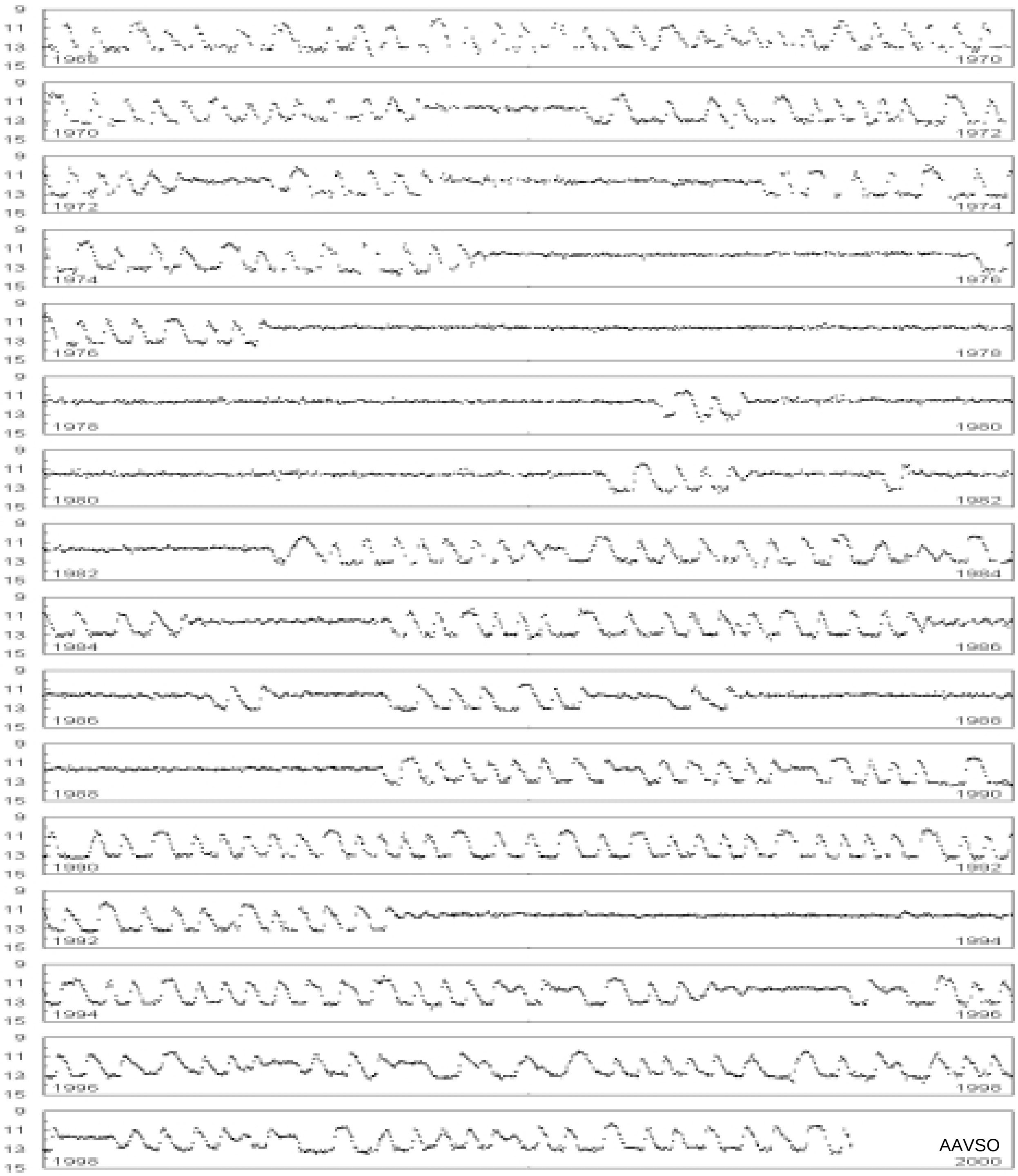
R Coronae Borealis is the prototype of its class. These rare supergiant stars have rich carbon atmospheres. They spend most of their time at maximum brightness but at regular intervals rapidly fade 1 to 9 magnitudes. The drop in brightness is thought to be caused by carbon clouds expelled from the atmosphere of the star.



Z Camelopardalis

1968–2000 (1-day means)

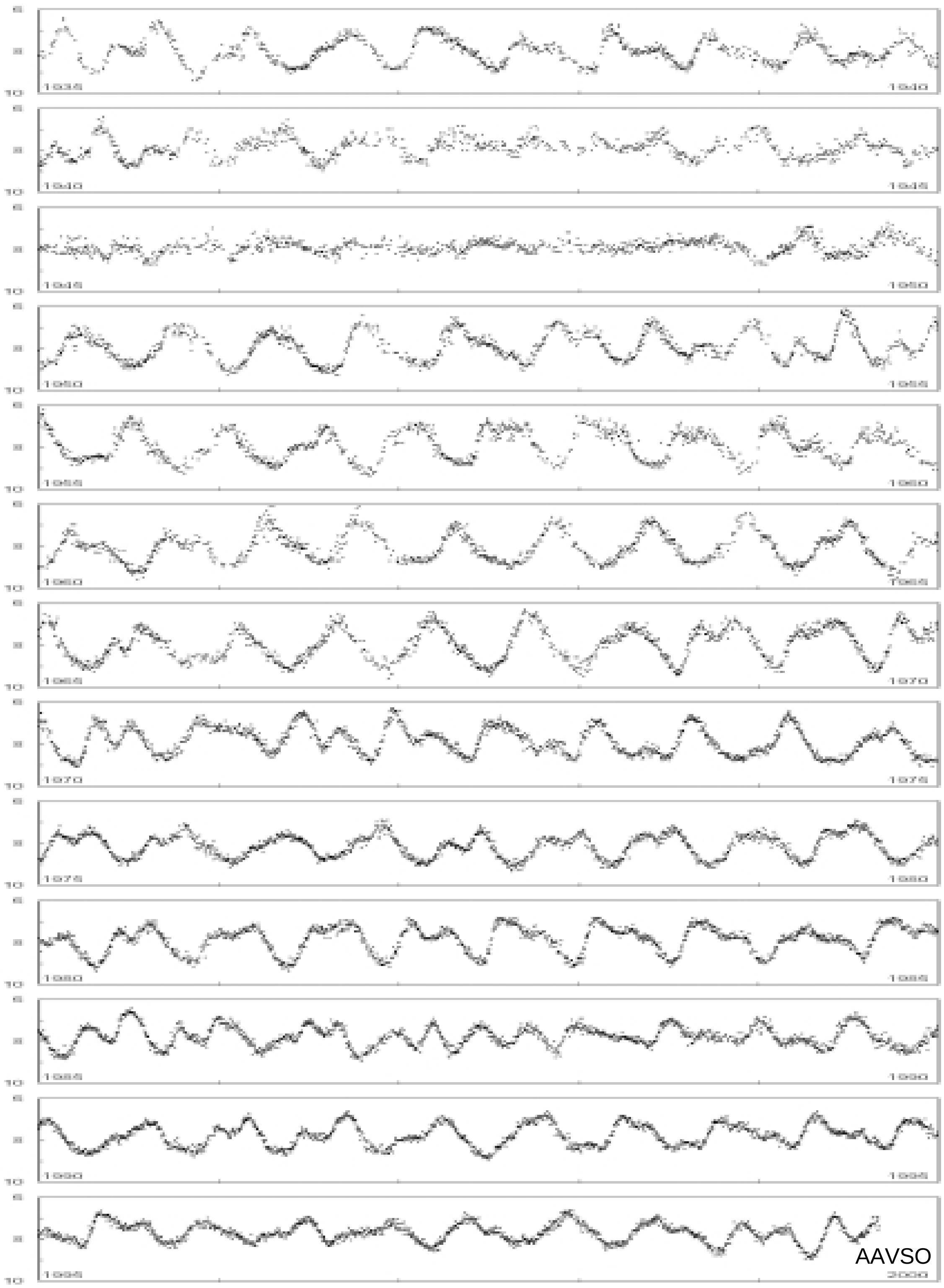
Z Camelopardalis is the prototype star of a sub-class of dwarf nova-type cataclysmic variables. It has U Geminorum-like dwarf nova outbursts about every 26 days, when it brightens from magnitude 13.0 to 10.5. At randomly spaced intervals, it experiences “standstills” in which the brightness stays constant, about one magnitude below normal maximum, for a few days to 1000 days. Standstills occur when the mass transfer rate from the solar-type secondary star into the accretion disk surrounding the white dwarf primary is too high to produce a dwarf nova outburst.



Z Ursae Majoris (semiregular)

1935–2000 (1-day means)

Z Ursae Majoris is a bright, semiregular variable varying between magnitude 7 and 9, with periodicities of 196 and 205 days. Semiregular variables are giant or supergiant stars pulsating with amplitudes of variation less than 2.5 magnitudes. They show intervals of periodic variability accompanied by intervals of irregularity, the relative proportion of which may depend upon the subclass. This behavior may be due to the interplay of multiple periods.



Appendix 2 – COMMITTEES OF THE AAVSO

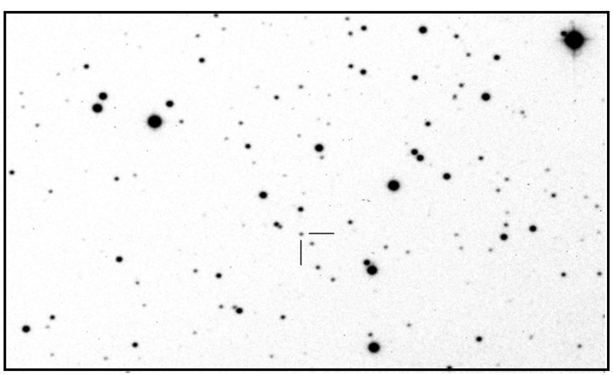
There are several committees within the AAVSO established to accommodate a variety of special interests amongst AAVSO observers. You are invited to become involved with any or all of these programs that interest you.

For more information on a committee, please contact the committee Chair (listed on a separate sheet in the new member package), visit the “Observing Programs” section of the AAVSO website (http://www.aavso.org/committees/) or contact AAVSO Headquarters. In general, all questions, correspondence, requests for charts, and submission of data for any of these committees should be sent directly to the committee Chair.

A brief description of each committee follows:

Charge-Coupled Device (CCD)

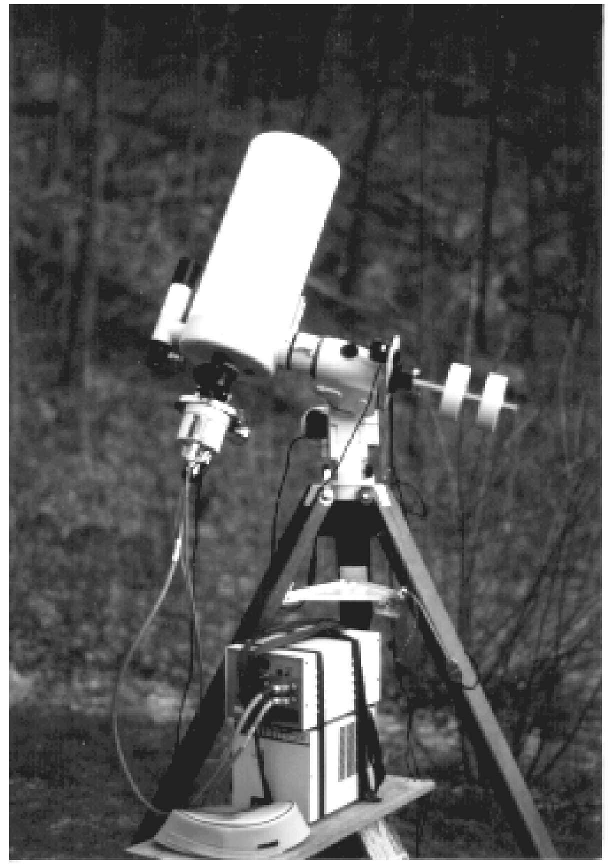
The developing technology of Charge-Coupled Devices (CCDs) plays an important role in the AAVSO’s mission of monitoring variable stars. A CCD camera contains a light-sensitive silicon chip that produces an electrical signal, which in turn is processed and displayed on a computer monitor. When mounted on your telescope, the result is a digital image of the star field you are observing.



CCD image of FO PER by R. Zissell

Since they are about 30 times as sensitive as the best photographic emulsions, CCDs make it possible to obtain fainter observations of variable stars, thus complementing the AAVSO visual and photoelectric programs in a significant way. The data obtained can easily be stored for future analysis.

The AAVSO CCD Committee was formed In 1991 to cover both the scientific aspects of CCD observing and CCD observing issues.



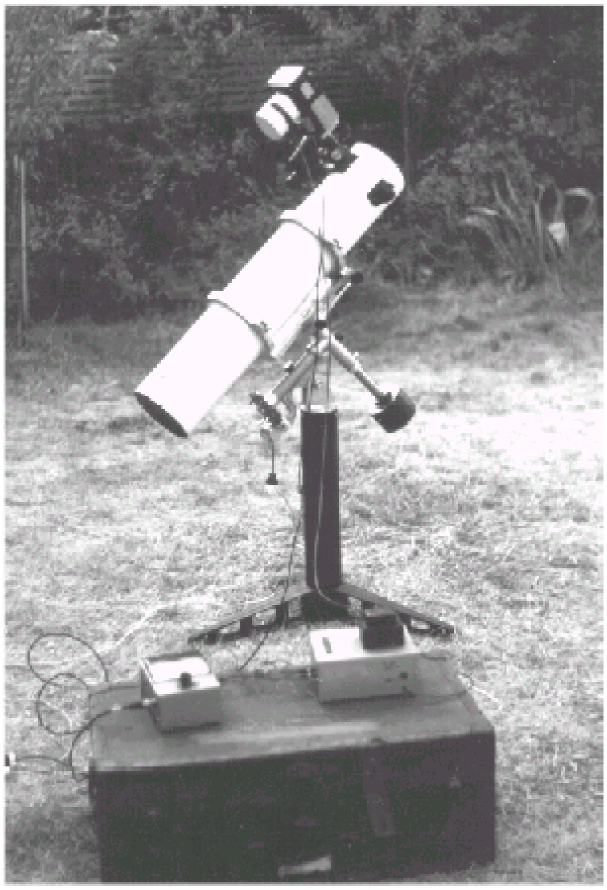
Gary Walker’s telescope with CCD

Standard equipment for CCD observing is a moderate- or large-aperture telescope, a CCD camera, appropriate red-blocked BVRI filters, and CCD reduction software.

The AAVSO has prepared special charts for CCD observing of several stars in its visual observing program which are very faint at minimum. These charts may be obtained free-of-charge from Headquarters or downloaded from the AAVSO website (http://www.aavso.org/committees/ccdcharts.stm).

Photoelectric Photometry (PEP)

If you have a good 6 or 8 inch telescope with a reliable clock drive, and a photoelectric photometer with appropriate filters, you are encouraged to participate in the AAVSO PEP Observing Program. A photoelectric photometer is an electronic device you can make or buy, which converts a low-intensity light signal into an electronic pulse. The pulse is then amplified and displayed as a number from which the magnitude of the object you are observing can be determined very precisely.



Kevin Kriscunas' 6" reflector with Photoelectric Photometer

Of the over 2000 variable stars currently in the AAVSO visual observing program, there are about 100 mostly bright variables that are best observed photoelectrically because of their small amplitude, short period, and/or other interesting features. These stars are in the AAVSO Photoelectric Photometry Observing Program which was initiated in 1983.

To ensure standardized observing of stars in its PEP Observing Program, the AAVSO has developed special PEP finder charts which are available from the Chair of the committee. An AAVSO PEP Chart Catalog is available from AAVSO Headquarters.

Eclipsing Binary (EB) and RR Lyrae Committees

Visual observation of eclipsing binary and RR Lyrae stars is a valuable contribution that interested observers can make (see Chapter 3 for a description of these types of stars). These stars need far more observations on a continuing basis than can be made by professional astronomers. One reason for the importance of making these observations is that many of these stars, especially eclipsing binaries, undergo period changes which need to be tracked.

Special techniques are required for observing EB and RR Lyrae stars, and advance planning is essential to acquiring useful data. For example, with eclipsing binaries, it is only necessary to observe them just before, during, and after an eclipse takes place. Also, since the eclipses often occur in just a matter of hours, the time of each observation must be recorded much more accurately than with regular variable star observations. Charts and more information on observing techniques can be obtained from the committee Chair.

Solar Division

The main activity of the AAVSO Solar Division is the monitoring of sunspots, from which the American Relative Sunspot Numbers (R_a) are computed. This program was started in 1944 when the Solar Division was first formed. The AAVSO American Relative Sunspot Program produces an independent sunspot index.

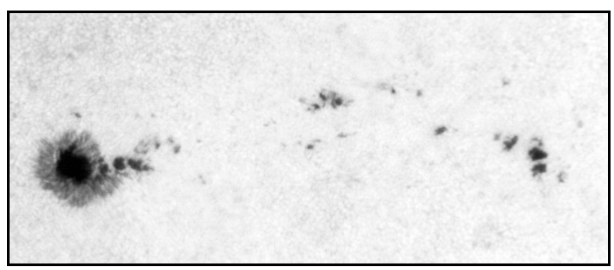


Photo of sunspot group by Art Whipple

Those who participate in the American Relative Sunspot Program use relatively small instruments for sunspot observations. The Sun is observed each clear day, and counts are made of the number of sunspot groups and the total number of spots. These observations are then reported on a standard form which is sent to the Chairman of the AAVSO Solar Division at the end of each month.

The AAVSO Solar Division also includes the work of a smaller group of observers who monitor very low frequency radio stations for sudden enhancements of their signals (Sudden Ionospheric Disturbances or SIDs), and thus detect solar flares indirectly.

Elizabeth Eggleston and Celestron with solar filter

Each month, both the computed values of the American Relative Sunspot Numbers and of the SIDs, are forwarded to the National Geophysical Data Center (NGDC) of the National Oceanic and Atmospheric Administration (NOAA).

NOTE: ***Never look directly at the Sun***, especially when using binoculars or telescopes without using equipment specifically designed for the purpose. The ultraviolet radiation from the Sun will damage the eye and can cause blindness.

Nova Search Committee

The Nova Search Committee of the AAVSO was established in the early 1930's with the belief that a serious stargazer can render valuable contributions to astronomy with a systemized visual search for and discovery of novae in the Milky Way. Those regions in our galaxy where novae are most likely to occur have been divided into areas. An observer who is interested in searching for novae is assigned specific areas, but once you have searched these, you can go on to other areas, thus encouraging a thorough coverage of the sky. In addition to searching specific areas, an observer can also add a "dome search" to his program. This is a naked eye scan of the whole visible sky, whose purpose is to catch a bright nova among the brightest stars (down to 3rd magnitude) of the constellations.

The standard equipment for the AAVSO Nova Search is a good atlas, such as the *AAVSO Variable Star Atlas*, and a pair of 7 x 50 binoculars.

At the end of each month, the observer uses special forms to report the dome and area searches and faintest magnitudes checked. Potential discoveries are verified by an experienced observer. If an object is verified as "new," the AAVSO Director is contacted immediately. Upon having the discovery confirmed, she contacts the Central Bureau for Astronomical Telegrams at the Smithsonian Astrophysical Observatory, to alert the astronomical community via the *International Astronomical Union Circular*.

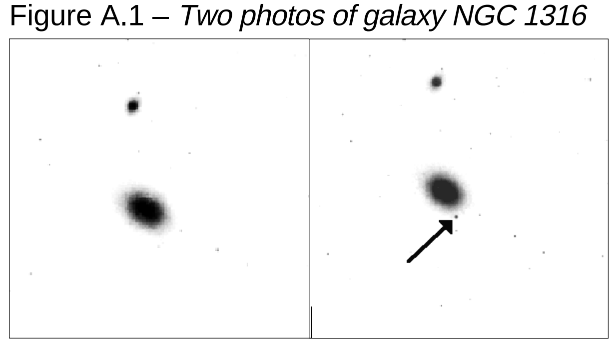
AAVSO Supernova Search committee chair, Robert Evans, presents Nova Award to Samantha Beaman, April 1996

Supernova Search Committee

The purpose of the Supernova Search Committee is to search for supernovae in other galaxies.

Standard equipment for this search is a telescope capable of making useful observations of galaxies (usually "seeing" 14th magnitude stars, at least), and a collection of reference charts and photos showing the normal appearance of all the galaxies which the observer is currently monitoring. Negative galaxy observations and observations of supernovae should be reported to AAVSO Headquarters.

Figure A.1 – *Two photos of galaxy NGC 1316*



ESO "B" survey *Photo by R. Evans showing SN 1981D*

Appendix 3 – ADDITIONAL RESOURCES

For updates to this list go to the AAVSO website and click on Variable Stars - Further Reading (http://www.aavso.org/vstar/furtherreading.stm). You can also find links to numerous websites of interest by clicking on "links" at the bottom of any page.

Reading Materials

Atlases

American Association of Variable Star Observers, Charles Scovil, ed. *AAVSO Variable Star Atlas*. Cambridge, MA: AAVSO, 1990. ISBN 1-878174-00-2. (to magnitude 9.5)

Ridpath, Ian, ed. *Norton's Star Atlas and Reference Handbook*. Addison-Wesley, 1998. ISBN 0-582356-55-5. (to magnitude 6)

Sinnott, Roger W., and Michael A. C. Perryman. *Millennium Star Atlas*. Cambridge, MA: Sky Publishing, 1997. ISBN 0-933346-84-0. (to magnitude 11)

Tirion, Wil, and Roger W. Sinnott. *Sky Atlas 2000.0 (second edition).* Cambridge, MA: Sky Publishing, 1998. ISBN 0-933346-87-5. (to magnitude 8.5)

Tirion, Wil. *Cambridge Star Atlas (second edition)*. New York: Cambridge UP, 1996. ISBN 0-521-56098-5. (to magnitude 6)

Tirion, Wil, Barry Rappaport, and George Lovi. *Uranometria 2000.0.* Richmond Virginia: Willmann-Bell, 1993. Vol. 1: N. Hemisphere ISBN 0-943396-14-X; Vol. 2: S. Hemisphere, ISBN 0-943396-15-8. (to magnitude 9+)

Books on variable star astronomy—basic and introductory topics

American Association of Variable Star Observers. *Variable Star Symposium (History, Science, Associations). Journ. AAVSO* 15.2, 1986. ISSN: 0271-9053.

Campbell, Leon, and Luigi Jacchia. *The Story of Variable Stars*. Philadelphia: Blakiston, 1941.

Furness, Caroline E. *Introduction to the Study of Variable Stars*. Boston: Houghton Mifflin, 1915.

Hoffleit, Dorrit. *Women in the History of Variable Star Astronomy*. Cambridge, MA: AAVSO, 1993.

Hoffmeister, Cuno, G. Richter, and W. Wenzel. *Variable Stars*. New York/Berlin: Springer-Verlag, 1985. ISBN 3540-13403-4.

Kolman, Roger S. Observe and Understand Variable Stars. The Astronomical League, 1999.

Levy, David H. *Observing Variable Stars: A Guide for the Beginner*. New York: Cambridge UP, 1989. ISBN 0-521-32113-1.

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