AAVSO

Manual for Visual Observing of Variable Stars

Revised Edition
March 2013

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

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FOREWORD TO 2013 EDITION

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. This manual provides up-to-date information for making variable star observations and reporting them to the AAVSO, and was written by visual observing experts.

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 grouped by subject-matter. There are several 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, John O'Neill, Ron Royer, Michael Saladyga, Mike Simonsen, Matthew Templeton, Elizabeth Waagen and Doug Welch.

Arne A. Henden
AAVSO Director

> *...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. Today, more a quarter million known or suspected variables have been catalogued. Most stars—including the Sun and the North Star—vary in brightness if measured precisely.

Why study variable stars?

The study of variable stars is really the study of the secret lives of stars. How are they formed, how they live out their lives and what changes occur internally and externally as they evolve. We learn about the environments surrounding them, including planets and other companions, and their affect on these partners; and finally, how they end their lives slowly fading away, stripped of their atmospheres or violently exploding, seeding the universe with the materials to build more stars, planets and us.

At almost every phase in a star's life it varies in its light output. If the variation is large enough and occurs on human timescales, we, the observers of the AAVSO, can record and study these changes, and we have now for over 100 years.

In that time we have learned about all kinds of variations in stellar output and how to interpret it. Some stars vary as they pulsate, actually changing size physically, growing and then shrinking again, sometimes with a precise period, sometimes irregularly. We've seen stars that appear to vary because star spots are transported across the face of the star as it rotates. We've witnessed stars being eclipsed by unseen companions in extremely close orbits around their center of gravity, and now we can see the incredibly small changes in the light of a star as a planet crosses in front of it from our point of view.

It is becoming apparent that the more we look, the more we will find planets around stars everywhere. It has also become obvious that the closer we look, the more we will find every star is a variable star to one degree or another at one time or another in its life.

What is the value of visual observations?

There has been a lot of discussion lately about what visual observers can do to make an honest contribution to science. What variable stars are really interesting to astronomers, and what observations are likely to lead to new understanding of the properties of these and other stars? It's no secret that with CCDs being capable of higher precision and numerous surveys covering the sky, with more coming online in the future, visual observers will have to be more selective about what they observe if they want to make a meaningful contribution to science. But there is still a lot the visual observer can do.

First, although a number of large instrumental surveys are currently active, they do not provide the same coverage that visual observers historically have. For one, few surveys fully cover the same brightness range available to visual observers; such coverage requires multiple surveys—smaller telescopes for brighter stars, and larger telescopes for fainter stars. For another, many surveys are single site, and so their coverage depends upon both weather conditions at the site and equipment reliability. Surveys also typically have a limited cadence of no more than a few data points per (local) night, meaning a target may only be observed for a small fraction of a day, if that. Finally, even surveys whose data are fully published do not necessarily guarantee permanent access to the light curves or other data products, and it is unlikely that any survey will ever operate in perpetuity—they are limited to the funding and staffing limitations of the researchers running the survey.

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. Headquartered in Cambridge, Massachusetts, USA, 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 2013, with over 1,100 members from 42 countries, it is the world's largest association of variable star observers.

In 2013, the archives of the AAVSO contained over 23 million observations on over 12,000 stars. Over 2,000 observers from around the world submit about a million observations every year. The observations are checked for errors and added to 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 distributed to astronomers around the world via the AAVSO website (http://www.aavso.org) or upon request to 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 for their research. These collaborative projects include observations by Apollo-Soyuz, HEAO 1 and 2, IUE, EXOSAT, HIPPARCOS, HST, RXTE, EUVE, Chandra, XMM-Newton, Gravity Probe B, CGRO, HETE-2, Swift, and INTEGRAL. 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

The purpose of this manual is to give you some guidance on how to make variable star observations and submit them for inclusion in the AAVSO International Database. In addition to this manual, you will find other useful information in the new member package and in the "For New Observers" section of the AAVSO website (https://www.aavso.org/observers). Please read all materials carefully and feel free to contact the AAVSO at any stage with any questions you might have.

Getting started

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, 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 and can take satisfaction in the knowledge that you have done so.

Help is available

The AAVSO has a long tradition of mentoring its new observers. Since the earliest days of the AAVSO, experienced observers have helped new observers by corresponding, answering questions and even providing personal guidance at the telescope. Today, most of this mentoring is done via email, instant messaging, Skype and by telephone.

The Mentor Program coordinator pairs new observers with experienced partners who can teach them about observing techniques, tools and methods, as well as give them advice on target selection and interesting projects they might pursue.

Because it is manned entirely by volunteers, and their time and effort are a precious resource, the Mentor Program is a member only benefit. Information about this program is included with the new member package.

Other excellent resources available to new and experienced observers alike, are the AAVSO Forums on the AAVSO website. There is a forum specifically for visual observers, as well as forums dedicated to certain types of variable stars, observing campaigns and general questions. Your community of fellow observers is a great resource. Ask them questions. They can help you.

Mike Linnolt (LMK) with his homebuilt 20-inch f/3.6 sphere-mount Newtonian reflector.

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.

Which stars should I observe?

It is highly recommended that new visual observers begin by choosing stars from the "Stars Easy to Observe" list, included with the new member package and posted on the AAVSO website (https://www.aavso.org/easy-stars). This list contains stars visible from all parts of the world, at various seasons of the year, so you will have to pare it down to the ones best suited to your location, equipment, and month when you wish to observe. Unless the stars that you are observing are circumpolar, you will need to add more to your program as the seasons progress and the stars that you were observing are no longer above your horizon at night.

Mary Glennon (GMY) with her 7x50 binoculars.

Expanding your program

As you gain experience and begin to feel comfortable with your variable star work, you will probably wish to expand the selection of stars you are observing beyond the "Easy to Observe" list. For instance, there are often special observing requests outlined in the *Alert Notice* and *Special Notice* both of which are available by email subscription. These, along with other more advanced observing projects, will be listed on the "Observing Campaigns" section of the AAVSO website or in a Forum.

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 by how often you can use it.

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 4 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!

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.

Haldun Menali (MHI) observing from the city.

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.

Equipment Needed

Optical Equipment

Successful variable star observing requires interest, perseverance, and the proper optical tools. A good pair of binoculars or even the unaided eye 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 generally the most 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 advantages. Variable star observers can use any make, model, or types of telescope, as long as the optics are of good quality. The best telescope is the one you will use on a regular basis. A three-inch refractor you can easily transport to the back yard or your favorite observing site is far more useful than the eighteen-inch Dobsonian that is too heavy and too much hassle for you to observe with. You can tailor your observing program to match the capabilities of your telescope. There are lots of variables to choose from no matter what size or type of telescope you use.

Finder — It is important that your telescope be equipped with a good tool for finding the general region of the sky in which the variable is located. Even if you have a GoTo mount, standard finder scopes or 1X red dot/circle aiming devices are very helpful 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 unless 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 the 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.

Atlas

A star atlas or small scale sky chart generated using planetarium software will help greatly with learning the constellations and finding the general region of the sky in which a variable can be found. There are several of these to choose from based on your own needs and preferences.

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 area of the 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 subtended angle 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 15). 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 subtended angle 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
Plössl	moderate	48-52	moderate
Erfle	long	60-70	moderate
"Ultrawide"	long	52-85	very high

Many are listed in Appendix 3 under "Atlases" and "Software".

If you have to mark the position of the variable stars on your Atlas, you can get the RA and Dec coordinates from the header of your AAVSO Star Charts.

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.

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.

The next chapter of this manual contains a detailed description of typical AAVSO Variable Star Charts along with instructions on how to make them using the Variable Star Plotter (VSP) on the AAVSO website.

Clock or Watch

Your timepiece should be readable in near darkness and accurate to within a minute 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.

There are many ways to get accurate time. Among them are GPS devices and "atomic" clocks that use radio signals to update themselves. Accurate time can also be found on the internet from places such as the USNO Master Clock site at http://tycho.usno.navy.mil/simpletime.html.

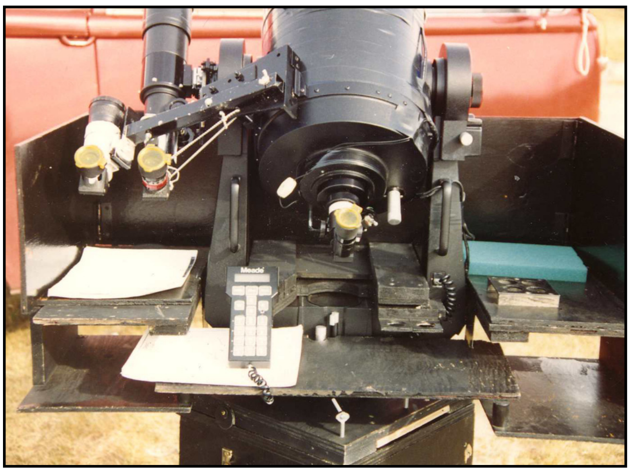
Record-Keeping System

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 below.

Ed Halbach's observing cart



Jack Nordby's "rotating workstation"

Chapter 2 – VARIABLE STAR CHARTS

Locating a variable star is a learned skill. To aid the observer, finding charts with well-determined, visual-magnitude sequences of comparison stars should be used. 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 now generated with the on-line Variable Star Plotter (VSP). These have completely replaced the old, pre-made paper or electronic charts.

> VSP Quick Guide:
>
> A simple, typical example (for R Leonis) will show how easy it is to generate a chart. See Figure 2.1 for reference.
>
> Go to the VSP webpage (www.aavso.org/vsp). Using the "Plot a Quick Chart..." section at the top of the form:
>
> 1. Enter the star's name (e.g. "R Leo") in the box labelled "What is the name, designation, or AUID of the object?". The case does not matter.
>
> 2. Select the chart scale from the "Choose a predefined chart scale" drop down box. In this example we select 'B' scale (which is equivalent to a 3.0 degree field of view).
>
> 3. Accept the default options for the rest of the form.
>
> 4. Click the 'Plot Chart' button.
>
> A new window should open showing the chart in graphics format (.png). This may be printed or saved. The sample chart created using this procedure can be seen in Figure 2.2.

An explanation of the VSP online form follows.

WHAT IS THE NAME, DESIGNATION OR AUID OF THE OBJECT?
Enter either the star's name or other identifier into the box (this will be described in more detail in Chapter 4 of this manual). Alternatively, you can enter the right ascension (RA) and declination (DEC) position you wish to have in the center of the chart in the appropriate boxes below the "PLOT ON COORDINATES" heading.

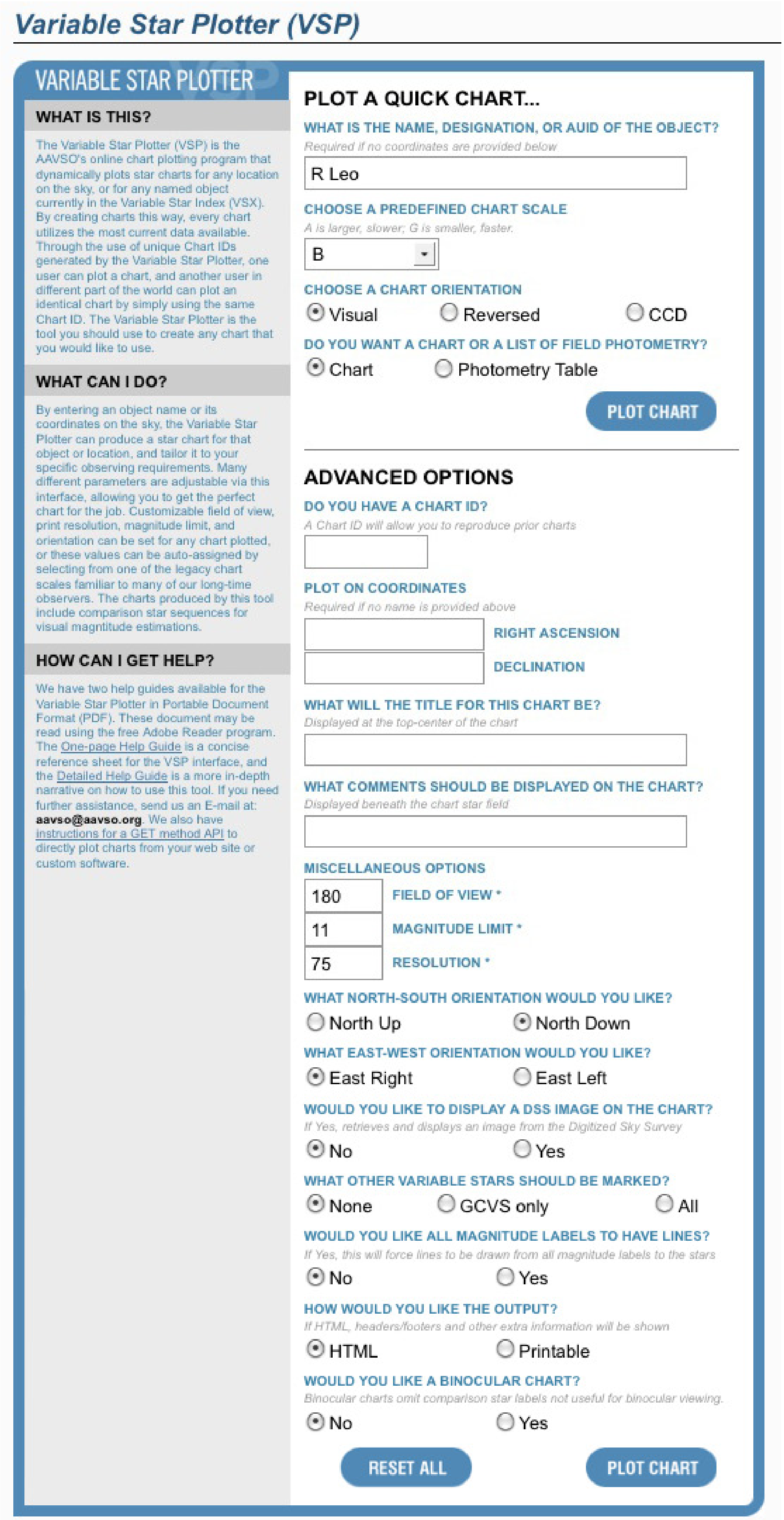
CHOOSE A PREDEFINED CHART SCALE
This drop down menu allows you to set the field of view according to the old finder chart scales. On the menu you will see designations 'A', 'B', 'C', etc. For example, an 'A' chart will show you 15 degrees of sky and stars down to 9th magnitude. A 'B' chart will show you 3 degrees of sky and stars down to 11th magnitude. You need to use a chart, or series of charts, that cover the range of magnitudes of the variable star you are observing. This is also determined by the instrumentation you are using. See Table 2.1 for further explanation of chart scales.

CHOOSE A CHART ORIENTATION
This option will help you to create a chart which, when viewed upright, will show the stars in the same orientation as that seen in your observing equipment. For example, if your telescope gives you an "upside down" image (as with a refractor or reflector using no diagonal), you will want to use the "Visual" option which will give you a chart having south at the top and west toward the left. If you use a diagonal, you may wish to select the "Reversed" option which creates a chart with north up and west to the left. The "CCD" option creates a chart with north at the top and east to the left that can also be useful for binocular and naked eye observing. There is more on chart orientation in Chapter 3.

DO YOU WANT A CHART OR A LIST OF FIELD PHOTOMETRY?
Visual observers should select "Chart". CCD or PEP observers who want access to precise photometry of the comparison stars, may wish to select "Photometry Table" to get a table of multicolor photometry instead of a star chart.

DO YOU HAVE A CHART ID?
Every chart is plotted with a chart id in the upper right hand corner. This number/letter combination should be reported with your variable star

Figure 2.1 — *The Variable Star Plotter*



observations. If you would like to replot a lost chart, just type in the chart id here and the chart will be replicated using all the settngs you used to plot it the first time. This can also be used if you wish to share information relating to the chart you use with other people.

PLOT ON COORDINATES

Instead of typing in a star's name, you may enter the RA and DEC of the center of the chart you create. When entering coordinates, you must separate the hours, minutes, and seconds of RA with either spaces or colons. The same applies to separating degrees, minutes, and seconds in Dec.

WHAT WILL THE TITLE OF THE CHART BE?

The title is a word or phrase you'd like to see displayed at the top of the chart. You do not need to enter anything into the title field. However, a short title can be very useful. Include the star name and chart type such as, "R Leonis B Chart." The big letters are easier to see in the dark and knowing the chart scale may be useful. If you leave this field blank, the star's name will appear in the title field on the chart.

WHAT COMMENTS SHOULD BE DISPLAYED ON THE CHART?

The Comment field can also be left blank, but if you create a chart for a specific purpose that can't be explained in the title field, this is the place to do it. Comments will be placed at the bottom of the chart.

FIELD OF VIEW

This is the chart's field of view expressed in arc minutes. Acceptable values range from 1 to 1200 arc minutes. When you use a predefined scale from drop-down list, the FOV will be filled in for you automatically.

MAGNITUDE LIMIT

This is the limiting magnitude for the field. Stars fainter than this will not be plotted. Be careful not to set the limit too faint. If the field for the star you wish to plot is in the Milky Way, you could wind up with a chart that is completely black with stars!

Table 2.1 – *Chart Scales*

	arc/mm	**area**	**good for**
A	5 minutes	15 degrees	binoculars/finder
B	1 minute	3 degrees	small telescope
C	40 seconds	2 degrees	3–4" telescope
D	20 seconds	1 degree	≥ 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

RESOLUTION

This refers to the size of the chart as seen on your computer screen. A resolution of 75 dpi is the default value for most web pages. Higher resolution will give you better quality, but larger images that may not fit on a single printed page. When in doubt, it is probably best to use the default value.

WHAT NORTH-SOUTH ORIENTATION WOULD YOU LIKE? AND WHAT EAST-WEST ORIENTATION WOULD YOU LIKE?

These fields allow you to further customize the orientation of the chart to suit your equipment in case you need something other than the choices given in "CHOOSE A CHART ORIENTATION".

WOULD YOU LIKE TO DISPLAY A DSS IMAGE ON THE CHART?

By default, a black and white chart will be drawn with circles representing stars. If you would prefer to have a real picture of the sky instead, click "Yes" and a picture from the Digitized Sky Survey will be plotted. Charts plotted with this option take longer to create than ones without.

WHAT OTHER VARIABLE STARS SHOULD BE MARKED?

Sometimes, more than one variable star can be found within a field. If you would like these other variables shown on the chart, select either "GCVS only" or "All". General Catalog of Variable Stars (GCVS) variables tend to be more well known. If you select "All" you will also get many new and suspected variable stars which could make the field quite crowded.

WOULD YOU LIKE ALL MAGNITUDE LABELS TO HAVE LINES?
By selecting "Yes" you will force lines to be drawn from all magnitude labels to the stars.

HOW WOULD YOU LIKE THE OUTPUT?
Select "Printable" to get a chart suitable for printing.

WOULD YOU LIKE A BINOCULAR CHART?
Selecting this option produces charts that only label specially selected comparison stars useful for observing stars in the AAVSO Binocular Program. Generally, this means only a handful of comparison stars brighter then 9th magnitude will be shown near these bright binocular variable stars. You will know when you are in this mode because binocular charts are plainly marked in the upper right hand corner. Remember to deselect this button when you wish to make telescopic charts again.

The AAVSO Binocular Program

The AAVSO Binocular Program consists of 153 bright variables in the northern and southern hemispheres. They are mostly semi-regulars and Miras, with a few other types sprinkled in. Most of the stars range between 3.0 and 9.5V and can be observed best using simple hand held binoculars.

Using the specially designed "Binocular Charts" will make it easier for you to find the stars and make estimates which you should submit to the AAVSO in the usual manner.

For a complete listing of the stars in the Binocular Program and more information about the special charts please visit this page: https://www.aavso.org/aavso-binocular-program

Figure 2.2 — *Sample AAVSO star chart*

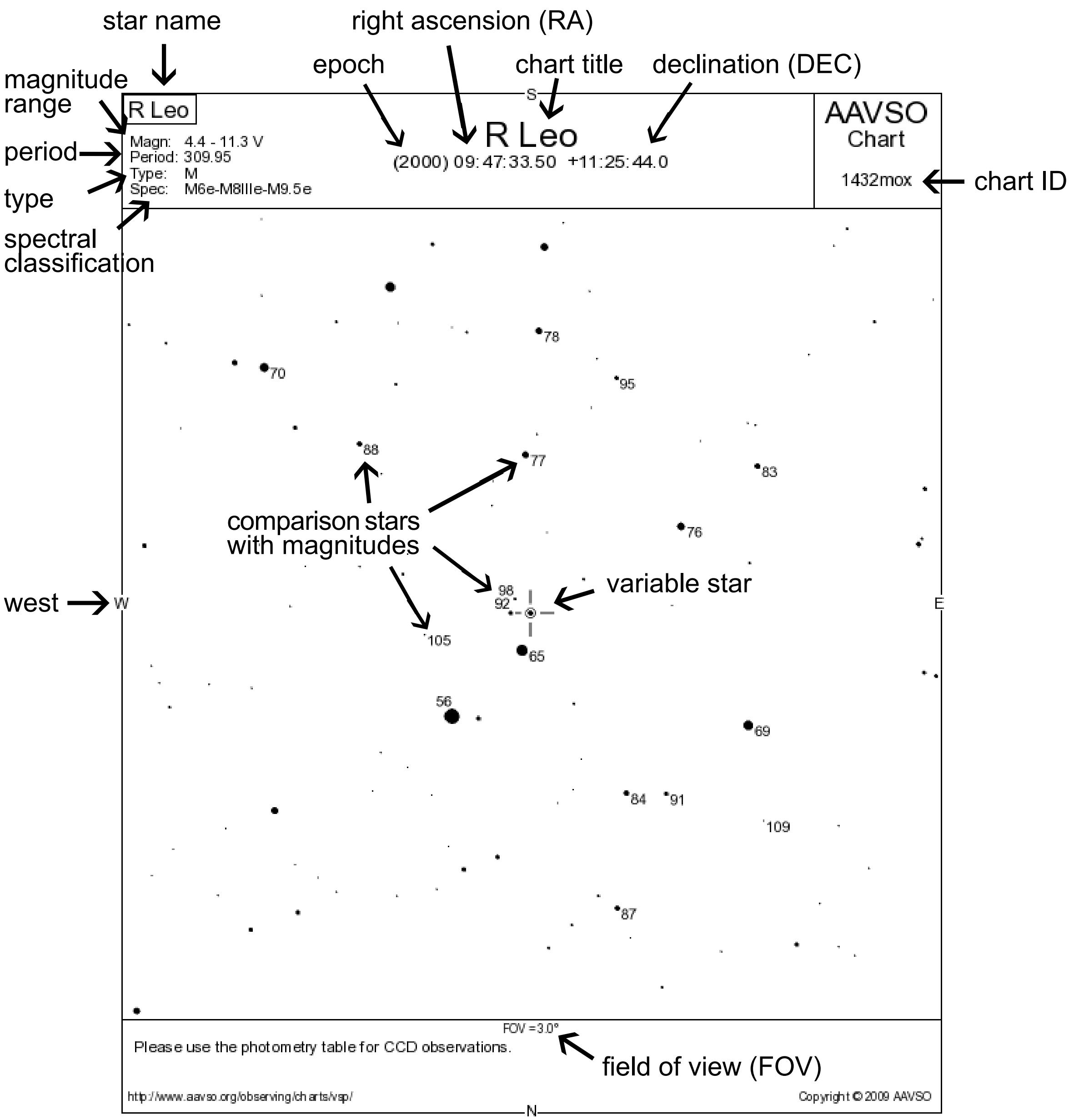


Chart Description

The heading of each chart contains quite a bit of information including the star identifier. Below the variable's name are: the range of variation in magnitude; period of variation; type of variable and spectral type of the star. The position of the variable for the epoch 2000 is listed below the star's identifier. The coordinates for right ascension are in hours, minutes and seconds; those for declination are in degrees, minutes and seconds. The latest revision date for the chart is shown in the bottom right hand corner of the chart. The Field of View (FOV), either in degrees or minutes of arc, appears along the bottom margin of the chart. 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.

In the top right corner the Chart ID is shown. This is unique to each chart and should be reported with your observation (see Chapter 7). You or anyone else may replicate the chart with this code (when doing a new plot of the same chart you just need to enter the Chart ID code, here ‘1432mox’, into the Chart ID box and not bother with anything else).

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 dots. For example, “6.5” would appear on the chart as “65”. The numbers are placed to the right of the disk dot of the star wherever convenient, otherwise a short line connects disk and number.

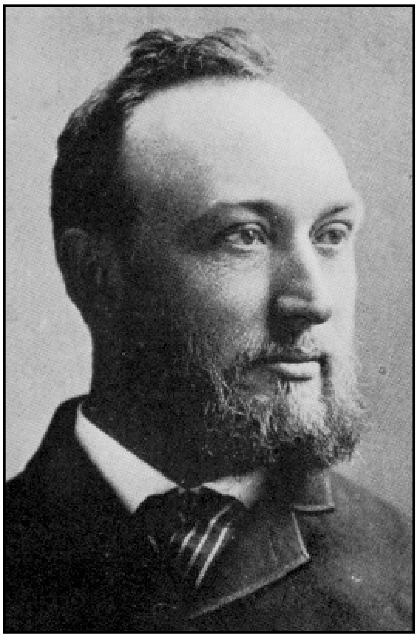
For starting out, it is recommended you pick from the predefined chart scales. The scales needed for your observing program will depend upon the observing equipment you are using. See Table 2.1 for a description of chart scales.

As you become more advanced, you may wish to customize charts. Instead of picking a pre-set chart scale, for instance, you may decide to enter your own field of view (1-1200 arc minutes). If you wish to look at a star in a very dense Milky Way field, you may wish to change the magnitude limit in order to decrease the clutter. The orientation of your chart may also be changed with the ‘North’ and ‘East’ options.

Note: If you are unable to use VSP due to internet limitations, paper copies of the charts you need may be obtained from AAVSO Headquarters upon request.

The first variable star charts...

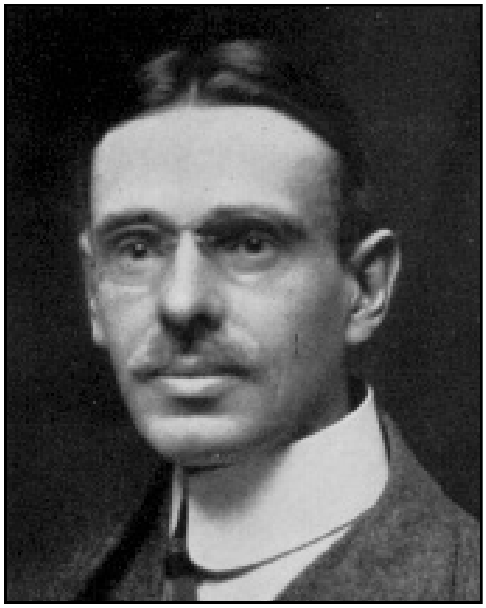
By the mid-1890s, Harvard College Observatory Director, Edward C. Pickering saw that the key to involving many more amateurs in variable star observing—while ensuring the quality and consistency of measurements—would be to provide standard sequences of comparison stars that have assigned magnitudes. 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 Argelander), and it would do away with the laborious reductions needed to derive a light curve.



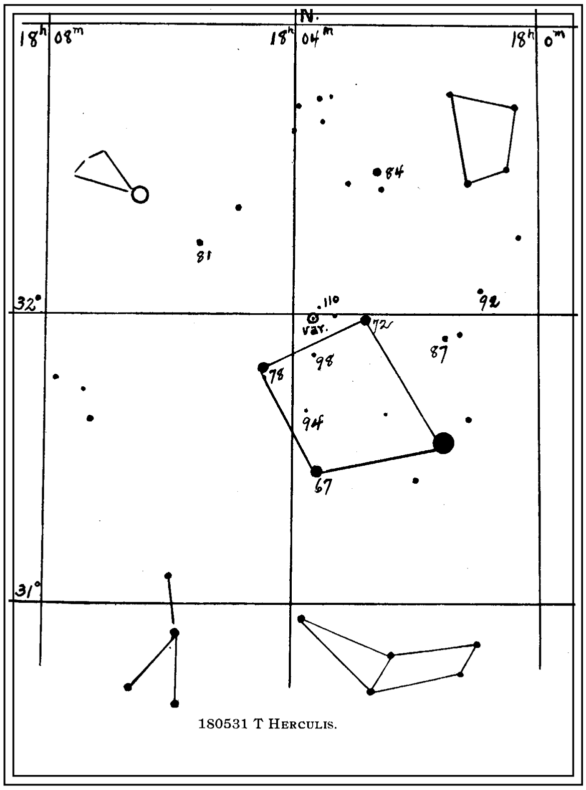
Edward C. Pickering

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".

Chapter 3 – MAKING OBSERVATIONS

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 15 and 16 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 a GoTo mount) — If your telescope is equipped with a GoTo mount, 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.

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 3.1 (page 14) 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:

- **star identifier** for the variable (see pages 22-24 for more on this subject)
- **date** and **time** of your observation
- **magnitude estimate** for the variable
- **magnitudes of the comparison stars** used for the estimate
- **identification of chart used**
- **notes** on any conditions which might effect seeing (i.e. clouds, haze, moonlight, etc.)

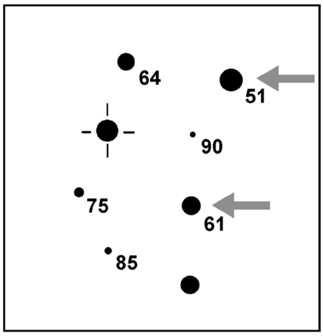
6. Prepare your report — There is a very specific format for reporting your observations and there are preferred tools to submit your reports to AAVSO Headquarters. Guidelines for reporting your observations will be covered in detail in Chapter 7 of this manual.

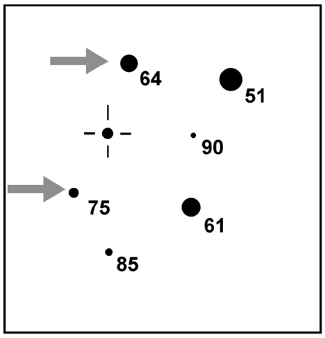
Figure 3.1 – *Interpolation Exercises*

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

For more on interpolation, try using the “Telescope Simulator”—a dynamic presentation on how to make variable star magnitude estimates—which can be accessed through the AAVSO website at https://www.aavso.org/online-resources

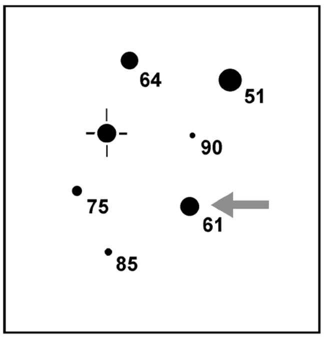
Magnitude 5.2

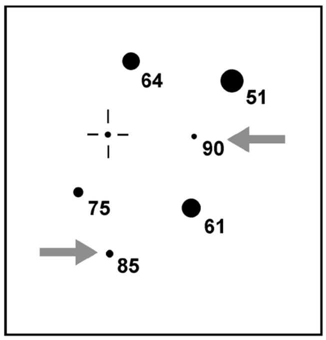




Magnitude 7.1

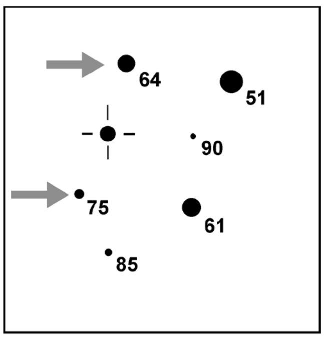
Magnitude 6.1

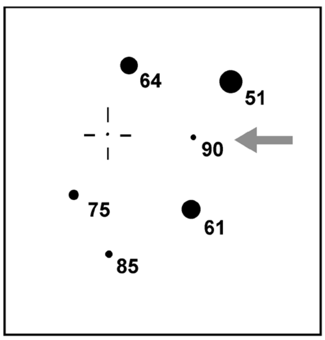




Magnitude 8.9

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 or plastic with the proper-size hole in it, or by making a wire ring to lay over the chart, etc.

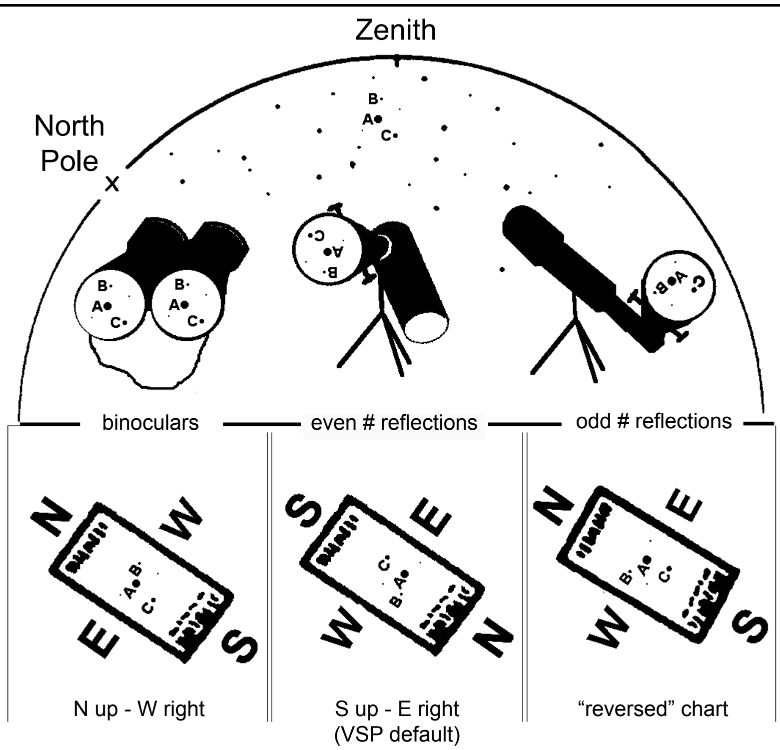
Orientation of charts

In order to use the charts successfully, you must learn how to set the N-S and E-W orientation correctly when you are producing the chart and how to orient them properly to the sky.

If you are observing with binoculars or the unaided eye, for example, you will want to create your chart so that north is up and west is to the right. On the other hand, if you are using a reflecting telescope where there is an even number of reflections (resulting in a field that is seen upside-down) you would want to make a chart in which south is up and east is to the right. For refracting and Schmidt-Cassegrain telescopes, a right-angle prism (diagonal) is often 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, you will find it easier to use AAVSO reversed charts on which north is up and east is to the right. Figure 3.2 (below) illustrates the different ways to set up your charts while the illustrations on the next page show you how to hold them up with respect to the sky.

Figure 3.2 – *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 Cassegrain 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.

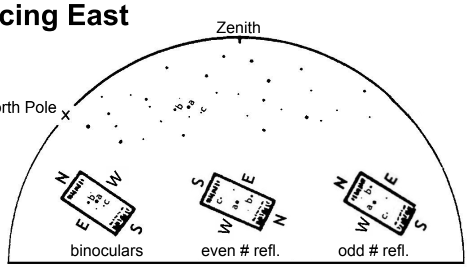
2. Hold the chart up over your head next to the variable star.

3. With regular (S up - E right) charts, rotate the chart so that South is pointing toward Polaris. (In the Southern Hemisphere, point North toward the South Celestial Pole.) When using a chart made for binoculars or a "reversed" chart, point North toward Polaris.

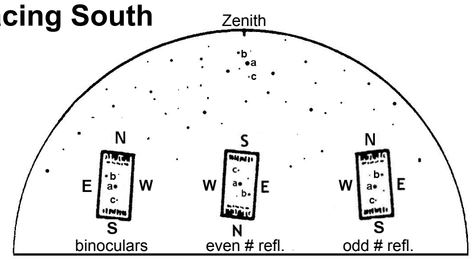
4. Bring the chart down to a comfortable working position without changing its orientation.

Northern Hemisphere

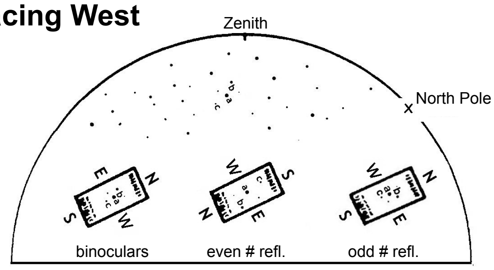
Facing East



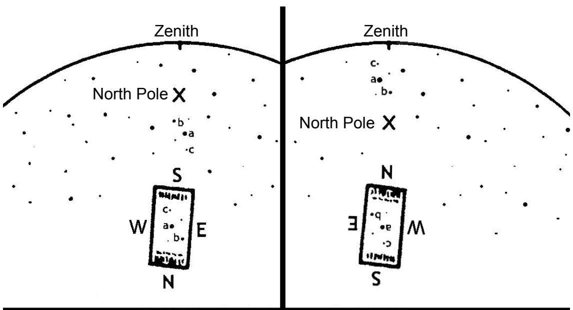
Facing South



Facing West



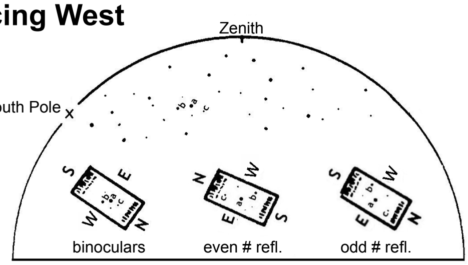
Facing North - Chart must be held upside down if variable is above the North Celestial Pole (Polaris).



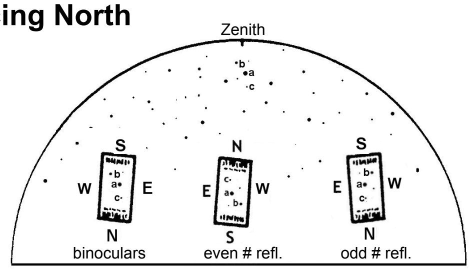
variable between Polaris and horizon | variable between Polaris and zenith

Southern Hemisphere

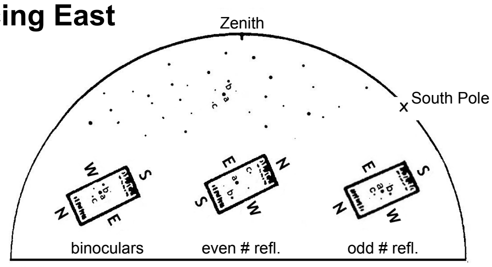
Facing West



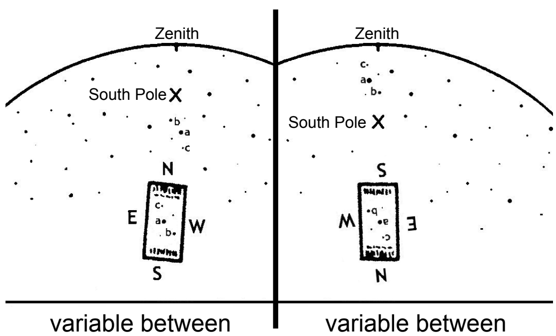
Facing North



Facing East



Facing South - chart must be held upside down if variable is above the South Celestial Pole (SCP).



variable between SCP and horizon | variable between SCP and zenith

The magnitude scale

The scale of magnitudes may seem confusing at first, because the larger the number, the fainter the star. The average limit of unaided-eye visibility is 6th magnitude under very good conditions. 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 very carefully with special instruments (photoelectric photometers, and CCDs) 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 binoculars 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 Variable Star Astronomy 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 about 2½ times brighter, so a change in 5 magnitudes would seem to be 2.5^5 (or 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 (max)	-4.6	Polaris	2.0

Table 3.1 – *Typical limiting magnitudes*

		Eye	Binoc.	6” (15cm)	10” (25cm)	16” (40cm)
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

Table 3.1 (above) serves as an approximate guide to limiting magnitude 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. Do not spend time on variables below your telescope limit - the results will not be good.

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.

Identification of the variable

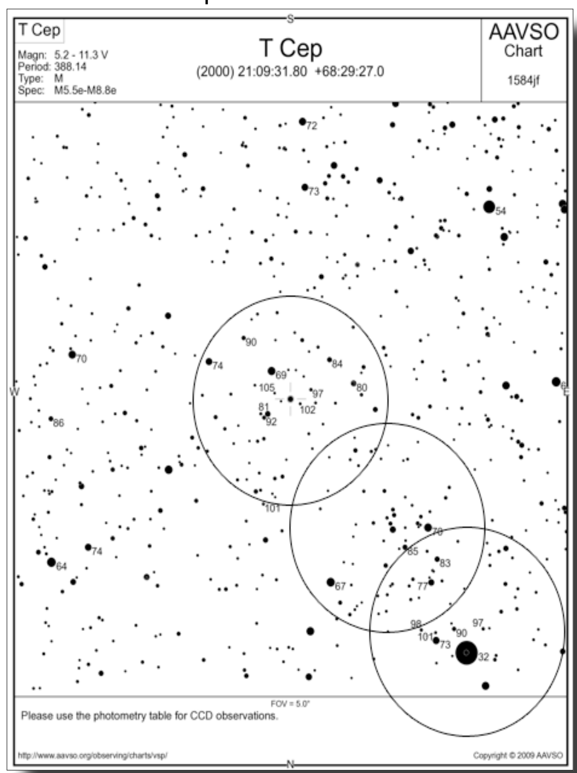
Remember that the variable may or may not be visible with your telescope at the time you are searching for it, depending on whether the star is near maximum or minimum brightness, or somewhere in between.

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 3.3 – *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.



Find the comparison stars

In order to make your estimate, you should 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.

Estimating the variable's brightness

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 biased by your previous estimates or by what you THINK the star should be doing.

As you contemplate your estimate, please keep in mind the following three things:

Placement

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 more aberration of the image the closer it is to the edge of the field of view.

If the variable and the comparison star are close together, they should be placed at equal distance from the center of the field of view. If they are far apart, they should not be viewed simultaneously but instead, they should be brought successively into the center of the field. You may have to move your telescope back and forth between the two stars several times before you can make your estimate.

Position Angle

As you look back and forth between the variable and a comparison star, it is important that you move your head or turn your erecting prism (if used) in such a way as to keep an imaginary line drawn between the two stars parallel to a line connecting the center of your two eyes. Failure to do this could result in a "position angle error" which could affect your final magnitude estimate by up to half a magnitude.

Purkinje Effect

When observing variables that 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.

Faint stars

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.

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."

Chris Stephan (SET) consults his atlas.

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.

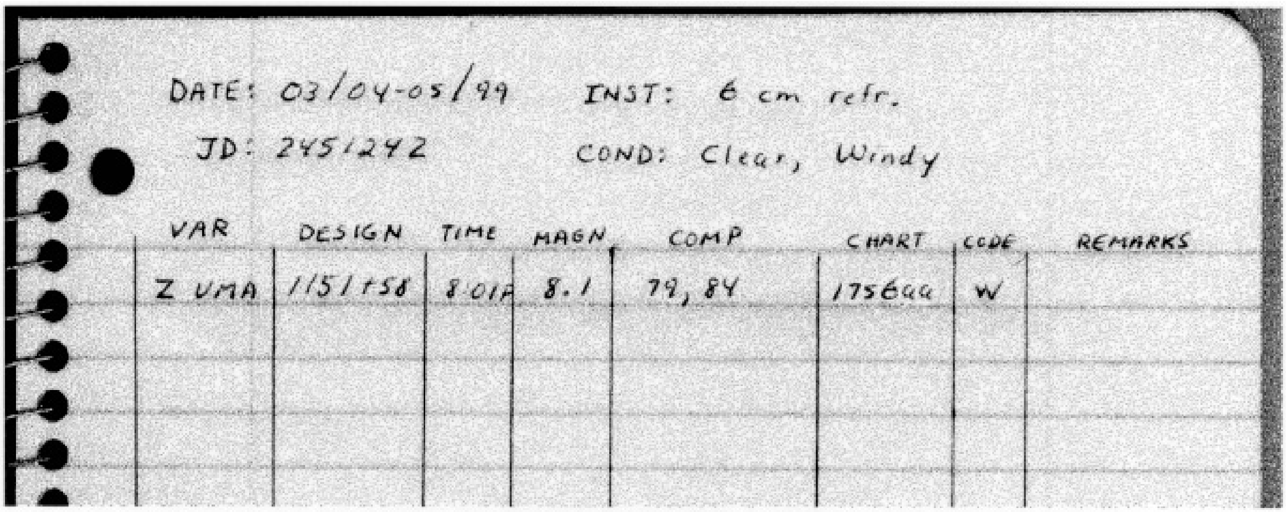
If for any reason your magnitude estimate is doubtful, state this in your record, giving the reasons for your doubt.

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 5) 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 2455388, Sat.–Sun., July 10–11, 2010. 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.

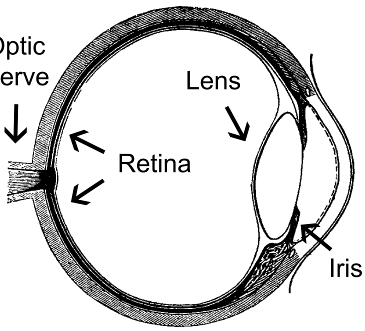
Excerpt from the observing notebook of Gene Hanson (HSG).



Starlight in your eyes - *from the AAVSO Variable Star Astronomy 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 8 cm 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 8 cm. This variable "zoom lens" changes with age and the minimum focus distance grows until it is difficult to focus on objects even 40 cm away, making charts and instruments more difficult to read. The aging eye gradually alters the way we perceive the universe.

Chapter 4 – ABOUT VARIABLE STARS

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
alf Ori
V2134 Sgr

Table 4.1 (page 23) 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* (GCVS) 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.

Many new variable stars have been discovered in recent years through large photometric sky surveys, data mining, and other means. Such stars may eventually be assigned a GCVS name, but they can also be referred to by the designator they have been assigned in the catalog created by the survey. A listing of many of these catalogs and the syntax used for their designations is given in Appendix 4 of this manual.

Variable Star Naming Conventions

Variable star names as published in the *General Catalog of Variable Stars* (GCVS) are determined by a team at the Sternberg Astronomical Institute in Moscow. 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 4.1. 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 Argelander. 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. Argelander 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 GCVS is available online at: http://www.sai.msu.su/gcvs/index.htm.

AUID

The AAVSO Unique Identifier (AUID) is in an alphanumeric “license plate”: 000-XXX-000 where the 0’s are 0-9 and the X’s A-Z. This allows for 17,576,000,000 possible combinations. Every star in the AAVSO International Database has had an AUID assigned. As new stars are added, new AUIDs will be assigned.

Table 4.1 – *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

Within the databases that the AAVSO maintains, each different object has its own AUID number. As far as the database is concerned, this AUID is the object's name. This name, or key, is used to uniquely identify objects across various databases.

As an observer you may never come across an AUID or really need to know what, for example, is the AUID of SS Del (000-BCM-129). As astronomy moves increasingly toward data mining, however, the knowledge of what "glues" our various databases together may be increasingly important, especially to those writing utilities to access or reference various databases.

The International Variable Star Index

The International Variable Star Index (VSX) is a tool which can be used to learn more about a particular variable star. To use VSX, simply type the name of a star into the text box labelled "Star Finder" located in the upper right-hand corner of the AAVSO home page and click "Search VSX". By clicking on the name of the star on the resulting list, you can obtain accurate position information, alternative names for the same star, information about the star's period and spectral type, a list of references, and other useful information about the star you selected.

> 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 Argelander (1844)
> the "father of variable star astronomy"

Greek Letters and Star Names in the AAVSO

by Elizabeth O. Waagen and Sara Beck, AAVSO Staff

When searching for a star in the International Variable Star Index (VSX) or reporting observations to the AAVSO International Database via WebObs, it is not possible to enter a Greek letter if the star has a Greek letter as part of its name – one cannot search for "μ Cep" or "ν Pav". There has been ongoing confusion about how to spell out some of the Greek letters used in star names, and in particular about how to spell out μ and ν.

Why does it matter how they are spelled?

There are stars whose Argelander names look the same as those with Greek names, especially to case-independent software. Thus, to VSX or WebObs "mu Cep" (μ Cep) looks the same as "MU Cep" (M-U Cep), and "nu Pav" (ν Pav) looks the same as "NU Pav" (N-U Pav).

So how do I keep them straight?

The AAVSO has decided to use a three-letter version of the the Russian *General Catalog of Variable Stars* (GCVS) Team spellings for the Greek letters as shown in the table to the right, in the column labelled "AID". With this system, μ becomes "miu", ν becomes "niu" and "chi Cyg" becomes "khi Cyg". Please use these GCVS abbreviations for Greek letters and "MU" and "NU" for Argelander names. Otherwise, your data may wind up assigned to the wrong star or you may not get the chart you thought you were requesting.

Just to add a little confusion…

When you use the VSX, you may notice that the "primary name" given for a star like "μ Cep" is "mu. Cep" (note the period after the "u"). There are also other ways to denote this star such as "* mu Cep", "HR 8316", or "SAO 33693". These are known as "aliases" and technically it is OK to use them for data submission, plotting the light curve of the star, or creating a chart. However, for data submission we prefer that you use the abbreviated GCVS spelling "miu Cep" because it is simple, unambiguous, and looks less like a typographical error than some of the other aliases.

One more thing

On a parallel issue, there has been the ongoing problem of "u Her" versus "U Her". Since our database cannot distinguish upper from lower case letters, please report "u Her" as "u. Her" or "68 Her".

	AID	**GCVS**	**English**
α	alf	alfa	alpha
β	bet	beta	beta
γ	gam	gamma	gamma
δ	del	delta	delta
ε	eps	eps	epsilon
ζ	zet	zeta	zeta
η	eta	eta	eta
θ	tet	teta	theta
ι	iot	iota	iota
κ	kap	kappa	kappa
λ	lam	lambda	lambda
μ	miu	miu	mu
ν	niu	niu	nu
ξ	ksi	ksi	xi
ο	omi	omicron	omicron
π	pi	pi	pi
ρ	rho	rho	rho
σ	sig	sigma	sigma
τ	tau	tau	tau
υ	ups	upsilon	upsilon
φ	phi	phi	phi
χ	khi	khi	chi
ψ	psi	psi	psi
ω	ome	omega	omega

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 five main classes: the *intrinsic* **pulsating**, **cataclysmic**, and **eruptive** variables, and the *extrinsic* **eclipsing binary** and **rotating stars**.

A brief description of some of the major types of variables in each class is given in this chapter. For a more complete listing of all the classes and subclasses of variable stars visit the website for the *General Catalog of Variable Stars (GCVS)* at http://www.sai.msu.su/gcvs/gcvs/iii/vartype.txt.

Included in each description, is 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.

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.

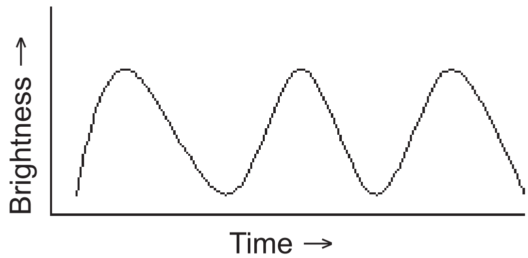
PULSATING VARIABLES

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.

<u>*Cepheids*</u> – 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?

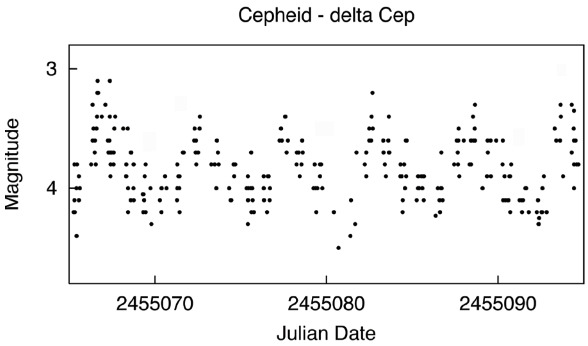
Observations of variable stars are commonly plotted on a graph called a **light curve**, as the apparent brightness (magnitude) versus time, usually in Julian Date (JD). The magnitude scale is plotted so that brightness increases as you go from bottom to top on the Y-axis and the JD increases as you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

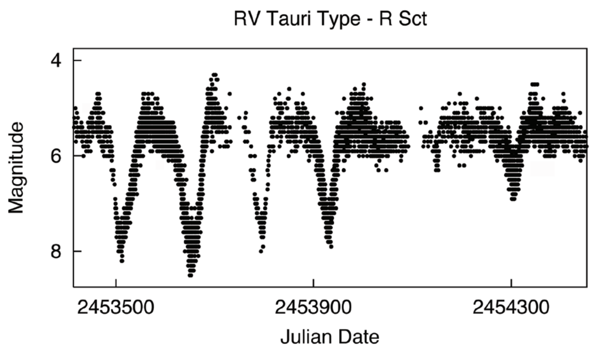
Phase Diagrams

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 30 of this manual to show the characteristic light curve of beta Persei.



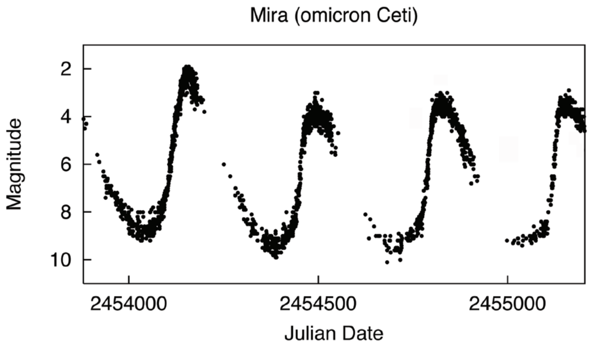
RR Lyrae stars – These are short-period (.05 to 1.2 days), pulsating, white giant stars, usually of spectral class A. They are older and less massive than Cepheids. The amplitude of variation of RR Lyrae stars is generally from 0.3 to 2 magnitudes.

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.

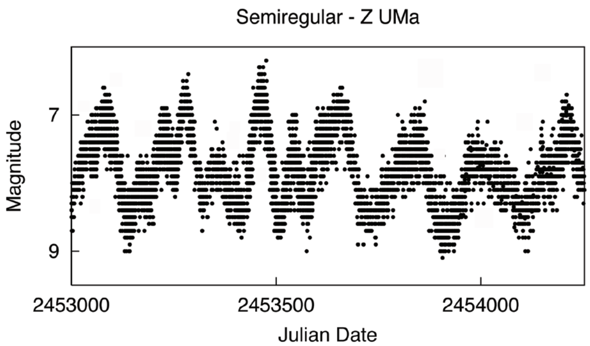


Long Period Variables– Long Period Variables (LPVs) are pulsating red giants or supergiants with periods ranging from 30-1000 days. They are usually of spectral type M, R, C or N. There are two subclasses; Mira and Semiregular.

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.



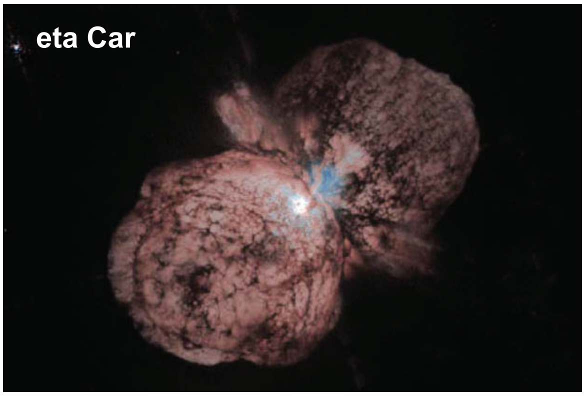
Semiregular – These are giants and supergiants showing appreciable periodicity accompanied by intervals of semiregular or irregular light variation. Their periods range from 30 to 1000 days, generally with amplitude variations of less than 2.5 magnitudes.



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.

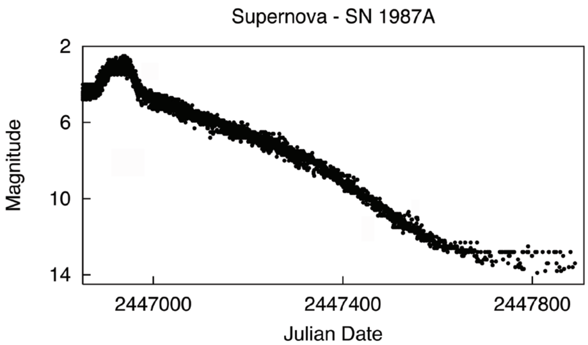
CATACLYSMIC VARIABLES

Cataclysmic variables 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. The majority of these variables are close binary systems, their components having strong mutual influence on the evolution of each star. It is often observed that the hot dwarf component of the system is surrounded by an accretion disk formed by matter lost by the other, cooler, and more extended component.

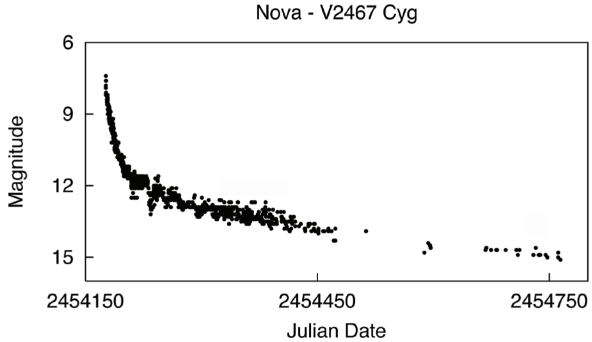


A huge, billowing pair of gas and dust clouds are captured in this stunning NASA Hubble Space Telescope image of the supermassive star eta Carinae. This star was the site of a giant outburst about 150 years ago, when it became one of the brightest stars in the southern sky. Though the star released as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

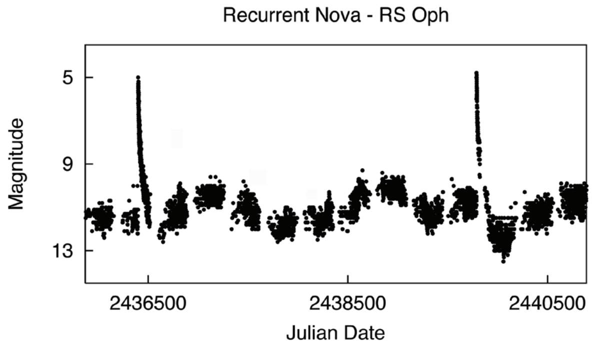
Supernovae – These massive stars show sudden, dramatic, and final magnitude increases of 20 magnitudes or more, as a result of a catastrophic stellar explosion.



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.

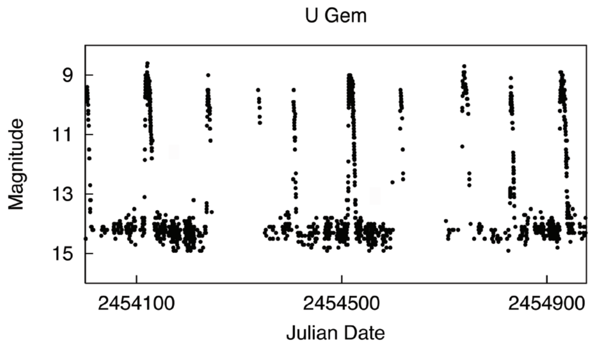


Recurrent Novae – These objects are similar to novae, but have two or more slightly smaller-amplitude outbursts during their recorded history.



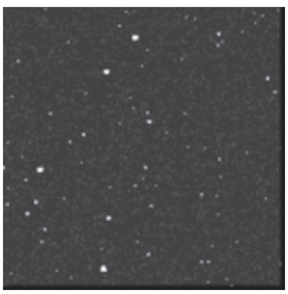
Dwarf Novae – These are close binary systems made up of a red dwarf–a little cooler than our Sun, a white dwarf, and an accretion disk surrounding the white dwarf. The brightening by 2 to 6 magnitudes is due to instability in the disk which forces the disk material to drain down (accrete) onto the white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

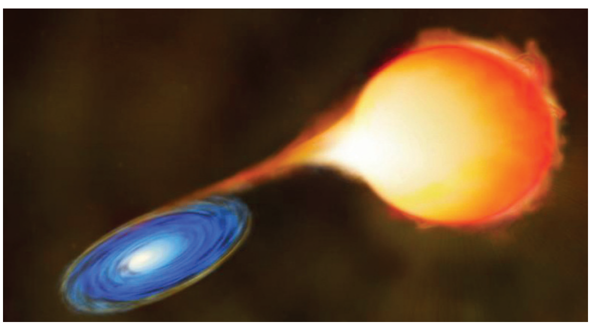
U Geminorum – After intervals of quiescence at minimum light, they suddenly brighten. Depending on the star, the eruptions occur at intervals of 30 to 500 days and last generally 5 to 20 days.



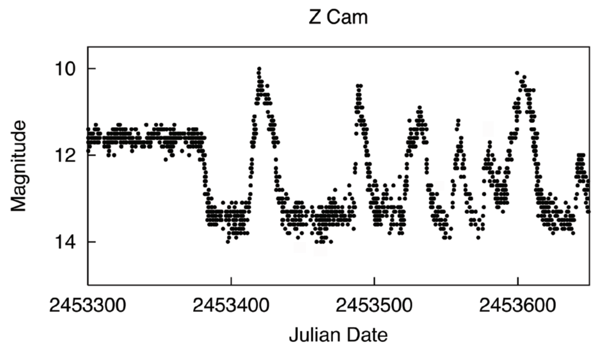
U Geminorum

Below are 20-second exposures of U Gem before outburst and after the start of an outburst. Images were taken by AAVSO Director 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).

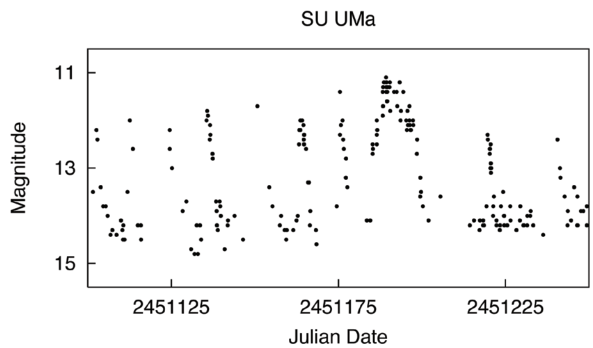




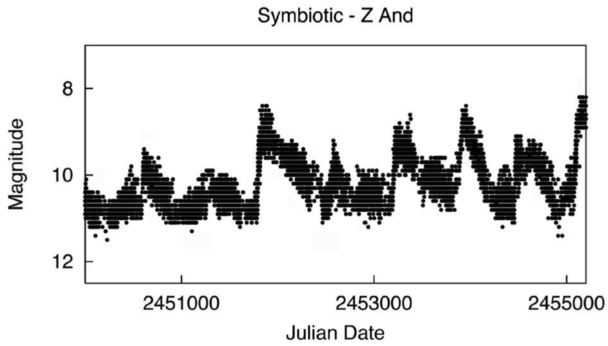
Z Camelopardalis – These stars are physically similar to U Gem stars. They show cyclic variations, interrupted by intervals of constant brightness called "standstills". These standstills last the equivalent of several cycles, with the star "stuck" at the brightness approximately one-third of the way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



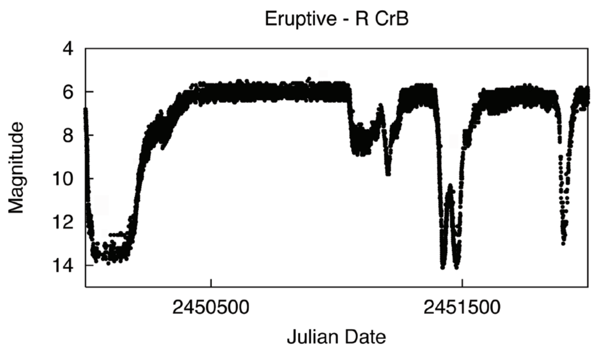
<u>*Symbiotic stars*</u> – These close binary systems consist of a red giant and a hot blue star, both embedded in nebulosity. They show semi-periodic, nova-like outbursts, up to three magnitudes in amplitude.



ERUPTIVE VARIABLES

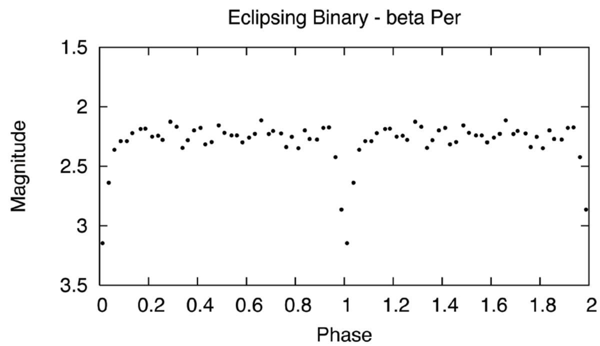
Eruptive variables are stars varying in brightness because of violent processes and flares occurring in their chromospheres and coronae. The light changes are usually accompanied by shell events or mass outflow in the form of stellar winds of variable intensity and/or by interaction with the surrounding interstellar medium.

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.



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.



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.

Chapter 5 – FIGURING THE DATE

Variable star observations reported to the AAVSO must be expressed either in terms of **Universal Time (UT)** or **Julian Day (JD)** and the decimal part of the day given in **Greenwich Mean Astronomical Time (GMAT)**.

UNIVERSAL TIME (UT)

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 5.2) is provided to help you to determine the zone difference for your location.

JULIAN DATE (JD)

JD 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.

DOING THE MATH

There are tools available on the internet and on the AAVSO website to help you figure the JD (see https://www.aavso.org/jd-calculator) so most people don't compute it themselves anymore, but it is still important to know how it is derived.

What follows is a simple procedure for figuring the JD and GMAT decimal of your observations. If you decide to submit your observations using UT, just follow steps 1 through 3.

Step-by-Step Instructions

1. Record the time and date of your observation using the 24-hour clock instead of AM or PM. (i.e. add 12 hrs if PM)

   examples:
   A. June 3, 2013 at 9:34 PM = June 3 at 21:34
   B. June 4, 2013 at 4:16 AM = June 4 at 04:16

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 21:34 DST = June 3 at 20:34
   B. June 4 at 04:16 DST = June 4 at 03:16

3. Convert to UT by adding or subtracting your time zone difference from Greenwich, as the case may be. For this example we will assume that the observer is located 5 hours west of Greenwich.

   A. June 3 at 20:34 + 5hr = June 4 at 01:34 UT
   B. June 4 at 03:16 + 5hr = June 4 at 08:16 UT

4. To convert from UT to Greenwich Mean *Astronomical* Time (GMAT) subtract 12 hours. This is because GMAT runs from noon to noon rather than midnight to midnight.

   A. June 4 at 01:34 UT = June 3 at 13:34 GMAT
   B. June 4 at 08:16 UT = June 3 at 20:16 GMAT

5. Find the decimal equivalent of the hours and minutes of your observation from Table 5.2.

   A. 13:34 GMAT = .5653
   B. 20:16 GMAT = .8444

6. Look up the Julian Date equivalent to the GMAT date of your observation as determined in Step 4 above. You can use the sample JD calendar shown in Figure 5.1.

   A and B: June 3, 2013 = 2,456,447

7. Now add the decimal from Step 5 to the JD integer to arrive at the final result of:

   A. JD = 2456447.5653
   B. JD = 2456447.8444

Sample Calculations

Below are three more examples showing how JDs are calculated using the steps just outlined. All of these examples use the JD Calendar (Figure 5.1) and the JD decimal table (Table 5.2).

Example 1 — Observation from Istanbul, Turkey (2 hrs east of Greenwich) at 1:15 am, January 10, 2013.

Step 1: 01:15 Jan 10 Local Time
Step 2: N/A
Step 3: 01:15 - 2 hrs = 23:15 Jan 9 UT
Step 4: 23:15 - 12 hrs = 11:15 Jan 9 GMAT
Step 5: decimal = .4688
Step 6: JD for Jan 9, 2013 = 2456302
Final Result: 2456302.4688

Example 2 — Observation from Vancouver, BC Canada (8 hrs west of Greenwich) at 5:21 am, February 14, 2013.

Step 1: 05:21 Feb 14 Local Time
Step 2: N/A
Step 3: 05:21 + 8 hrs = 13:21 Feb 14 UT
Step 4: 13:21 - 12 hrs = 01:21 Feb 14 GMAT
Step 5: decimal = .0563
Step 6: JD for Feb 14 = 2456338
Final Result: 2456338.0563

Example 3 — Observation from Auckland, New Zealand (12 hrs east of Greenwich) at 10:25 pm Daylight Savings Time (DST), January 28, 2013.

Step 1: 22:25 Jan 28 Local DST
Step 2: 22:25 - 1 hr = 21:25 Jan 28 Standard Time
Step 3: 21:25 -12 = 09:25 Jan 28 UT
Step 4: 09:25 - 12 = 21:25 Jan 27 GMAT
Step 5: decimal = .8924
Step 6: JD for Jan 27 = 2456320
Final Result: 2456320.8924

The calendar in Figure 5.1 (page 33) was taken from the AAVSO website (https://www.aavso.org/jd-calculator). It gives the last four digits of the Julian Day for each day of every month of the year 2013 The months July–December are on the second page (not included in this Manual). For the complete JD, add 2,450,000 to the four digit value given in the calendar for the *Astronomical Day* of your observation.

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".

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

Table 5.2 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 Table 5.1, below, shows the precision needed in the JD for various types of stars.

Table 5.1 – *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
Irregular variables	1 decimal place
Suspected variables	4 decimal places

***Note:** Symbiotic stars and R CrB stars may experience possible small-amplitude, 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.

Table 5.3 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.

example: Jan. 28, 2015
= (JD for Jan 0) + 28
= 2457023+28
= 2457051

Figure 5.1 – *Sample JD Calendar*

AAVSO

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http://www.aavso.org

2013
JULIAN DAY CALENDAR

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

JANUARY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
		1 6294	2 6295	3 6296	4 6297	5 6298
6 6299	7 6300	8 6301	9 6302	10 6303	11 6304	12 6305
13 6306	14 6307	15 6308	16 6309	17 6310	18 6311	19 6312
20 6313	21 6314	22 6315	23 6316	24 6317	25 6318	26 6319
27 6320	28 6321	29 6322	30 6323	31 6324	◑ 5	● 11
◐ 18	○ 27					

FEBRUARY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
					1 6325	2 6326
3 6327	4 6328	5 6329	6 6330	7 6331	8 6332	9 6333
10 6334	11 6335	12 6336	13 6337	14 6338	15 6339	16 6340
17 6341	18 6342	19 6343	20 6344	21 6345	22 6346	23 6347
24 6348	25 6349	26 6350	27 6351	28 6352	◑ 3	● 10
◐ 17	○ 25					

MARCH

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
					1 6353	2 6354
3 6355	4 6356	5 6357	6 6358	7 6359	8 6360	9 6361
10 6362	11 6363	12 6364	13 6365	14 6366	15 6367	16 6368
17 6369	18 6370	19 6371	20 6372	21 6373	22 6374	23 6375
24 6376	25 6377	26 6378	27 6379	28 6380	29 6381	30 6382
31 6383	◑ 4	● 11	◐ 19	○ 27		

APRIL

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
	1 6384	2 6385	3 6386	4 6387	5 6388	6 6389
7 6390	8 6391	9 6392	10 6393	11 6394	12 6395	13 6396
14 6397	15 6398	16 6399	17 6400	18 6401	19 6402	20 6403
21 6404	22 6405	23 6406	24 6407	25 6408	26 6409	27 6410
28 6411	29 6412	30 6413	◑ 3	● 10	◐ 18	○ 25

MAY

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
			1 6414	2 6415	3 6416	4 6417
5 6418	6 6419	7 6420	8 6421	9 6422	10 6423	11 6424
12 6425	13 6426	14 6427	15 6428	16 6429	17 6430	18 6431
19 6432	20 6433	21 6434	22 6435	23 6436	24 6437	25 6438
26 6439	27 6440	28 6441	29 6442	30 6443	31 6444	◑ 2
● 10	◐ 18	○ 25	◑ 31			

JUNE

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
						1 6445
2 6446	3 6447	4 6448	5 6449	6 6450	7 6451	8 6452
9 6453	10 6454	11 6455	12 6456	13 6457	14 6458	15 6459
16 6460	17 6461	18 6462	19 6463	20 6464	21 6465	22 6466
23 6467	24 6468	25 6469	26 6470	27 6471	28 6472	29 6473
30 6474	● 8	◐ 16	○ 23	◑ 30		

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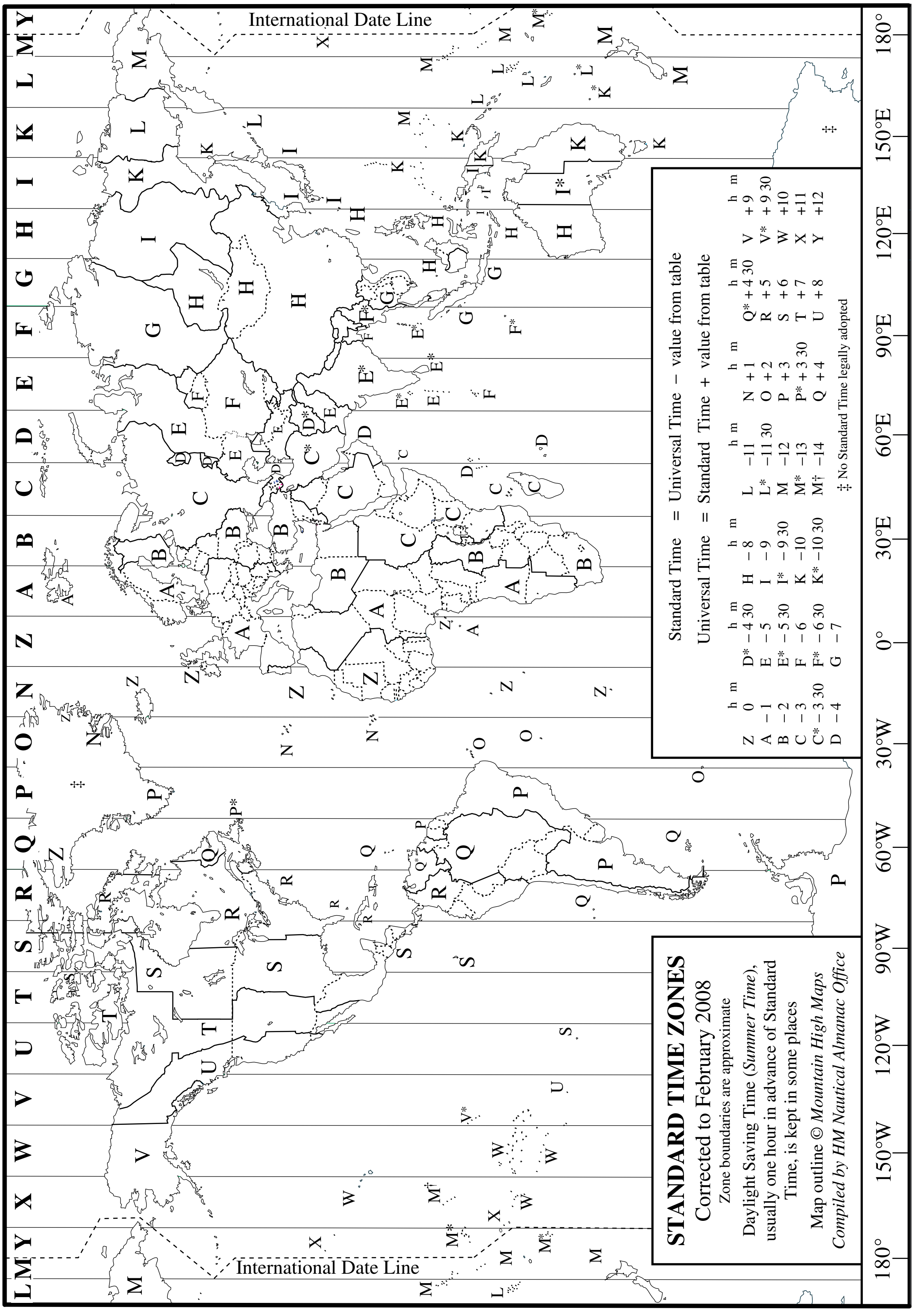
Figure 5.2 – *World Map of Time Zones*



"World Map of Time Zones" produced by HM Nautical Almanac Office Copyright Council for the Central Laboratory of the Research Councils. Reproduced with their permission.

Table 5.2 – *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 31 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

Table 5.3 – *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

Chapter 6 – PLANNING AN OBSERVING SESSION

Making a Plan

It is recommended that you make an overall plan of observing, on 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, monthly constellation chart, or planetarium software 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 6.1 to determine which hours of Right Ascension (RA) 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 the same hours of RA as those given in the table. 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 6.1 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 page 39). 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 17–18 for information on determining your telescope's limiting magnitude.

Table 6.1 – *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 (Hours)
January	1–9
February	3–11
March	5–13
April	7–15
May	11–18
June	13–19
July	15–21
August	16–23
September	18–2
October	19–3
November	21–5
December	23–7

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 6.2, 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.

Table 6.2 – *Frequency of Observations for Different Variable Star Types*

"How often should I observe my program stars?" The answers depend largely on the type of stars you are observing. The following table is a general guideline. As you learn more about the different types of variables, and the personalities of some of the specific stars you choose to observe, you may decide to observe them more or less often than suggested here.

Variable Type	**Cadence in days**
Active Galaxies (AGN)	1
Dwarf Novae (NL, UG, UGSS, UGSU, UGWZ, UGZ)	1
Gamma Cassiopeia (GCAS)	5-10
Irregular	5-10
Miras (LPVs) period <300 days	5-7
Miras (LPVs) period 300-400 days	7-10
Miras (LPVs) period >400 days	14
Novae (N)	1
R Corona Borealis (RCB)	1
Recurrent Novae (NR)	1
RV Tauri (RVTAU)	2-5
S Doradus (SDOR)	5-10
Semi-Regular (SR, SRA, SRB, SRC)	5-10
Supernovae (SNe)	1
Symbiotics (ZAND)	1
Young Stellar Objects (YSOs) active state	1
Young Stellar Objects (YSOs) inactive state	2-5

Observers following eclipsing binaries, RR Lyrae and UGSU in outburst should consult the section leaders for the preferred cadences for time-series type observations of these stars. You may need to observe them from every 30 seconds to every ten minutes depending on the type of variable and its period.

A Typical Observing Routine

Each season, consider last year's program and whether to add stars to this year's. Create new charts using the AAVSO Variable Star Plotter (VSP).

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 *MyNewsFlash* 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 an 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. 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. Submit your observations to AAVSO Headquarters using WebObs (see Chapter 7 for more on how to do this).

Useful AAVSO Publications

AAVSO Bulletin

The *AAVSO Bulletin* is a useful tool in planning your observing sessions. This annual publication contains *predicted* dates of maxima and minima for 381 long period and semiregular variables. This information will help you to determine if you can see a particular star with your telescope on any given night. The *Bulletin* is available for download on the AAVSO website: https://www.aavso.org/aavso-bulletin

In addition to the static .pdf version of the *Bulletin*, there is an intereactive web version called "The Bulletin Generator" which allows the user to request maxima/minima dates for a subset of stars, a constellation, a month, a RA and/or Dec range, as well as the entire *Bulletin* dataset. Data may be retrieved as a .pdf file, an html table, or a comma-separated file (CSV) suitable for loading into a spreadsheet.

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. The Bulletin Generator includes a field "N" which indicates how many observations of that star were made during the prior year so you can use that information to make a judgement for yourself.

AAVSO Alert Notice

AAVSO Headquarters will issue an *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: https://www.aavso.org/observation-notification#alertnotice

AAVSO Special Notice

The *AAVSO Special Notice (ASN)* will include announcements on interesting and/or rare stellar activity that do not involve new coordinated campaigns. The goal is for the *ASN* to be quick and brief. Should the announcement warrant further attention, it may be followed by an *Alert Notice.*

AAVSO Special Notices are available by email subscription (free-of-charge) or through the AAVSO website: https://www.aavso.org/observation-notification#specialnotices/

MyNewsFlash

MyNewsFlash is an automated, customizeable system for sending you variable star activity reports. The reports can be delivered via regular email or as a text message to your pager or cell phone. You can customize a report based on such criteria as star name, type, brightness, activity, date of observation, and more. The reports include observations of variable stars submitted electronically. To read more about *MyNewsFlash* or sign up to receive reports, please visit https://www.aavso.org/observation-notification#mynewsflash

Chapter 7 – SUBMITTING OBSERVATIONS TO THE AAVSO

In order for your observations to be included in the AAVSO International Database, you must submit them to AAVSO Headquarters. There are two ways to submit your observations to the AAVSO, both of which involve using the WebObs utility found on the AAVSO website. For visual observations you may choose between either the "Submit observations individually" or "Upload a file of observations" method.

Once you submit your observations, WebObs will automatically format them to AAVSO specifications. It will also perform various error checking procedures to make sure you entered the data correctly. If there is a problem, you will be notified and the problem observations will not be added to the database.

Immediately after submission, your observations will become part of the AAVSO International Database and available for use. You may view them using the "Light Curve Generator" (https://www.aavso.org/lcg). In addition, a complete listing of your own observations will be available so you can peruse and/or download your contributions to the AAVSO database at any time.

It is fun to look at the "Light Curve Generator" to see how well your observations compare with those made by other observers, but *under no circumstances* should you look at other people's observations until yours have been submitted. By doing so, you may be tempted to change an observation which could introduce a serious bias in the data.

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.

It is also important that you do not send the same observations more than once! If you submit your observations to a club or organization that collects observations, then sends them to the AAVSO, please do not submit them again on your own or duplicate observations may result.

Getting Started with WebObs

Before you can start using WebObs, you must be registered to use the AAVSO website and have an official AAVSO Observer Code.

To register for the website, click the "User login" button in the upper right corner of any page on the website and follow the instructions given.

If you have not yet been assigned an Observer Code, you should log on to the AAVSO website and click the link to "Request Observer Code" which you can find on the "My Account" page. Each AAVSO observer has a unique set of initials that will stay with their observations in the AAVSO International Database forever. These initials are assigned by AAVSO HQ to ensure that they are indeed unique. Most likely, they will be related to the spelling of your name, but this is not always the case.

When you are ready to begin sending in your observations, log onto the website and go to the WebObs page https://www.aavso.org/webobs. There you will be able to choose whether to submit observations individually or as a group in a file.

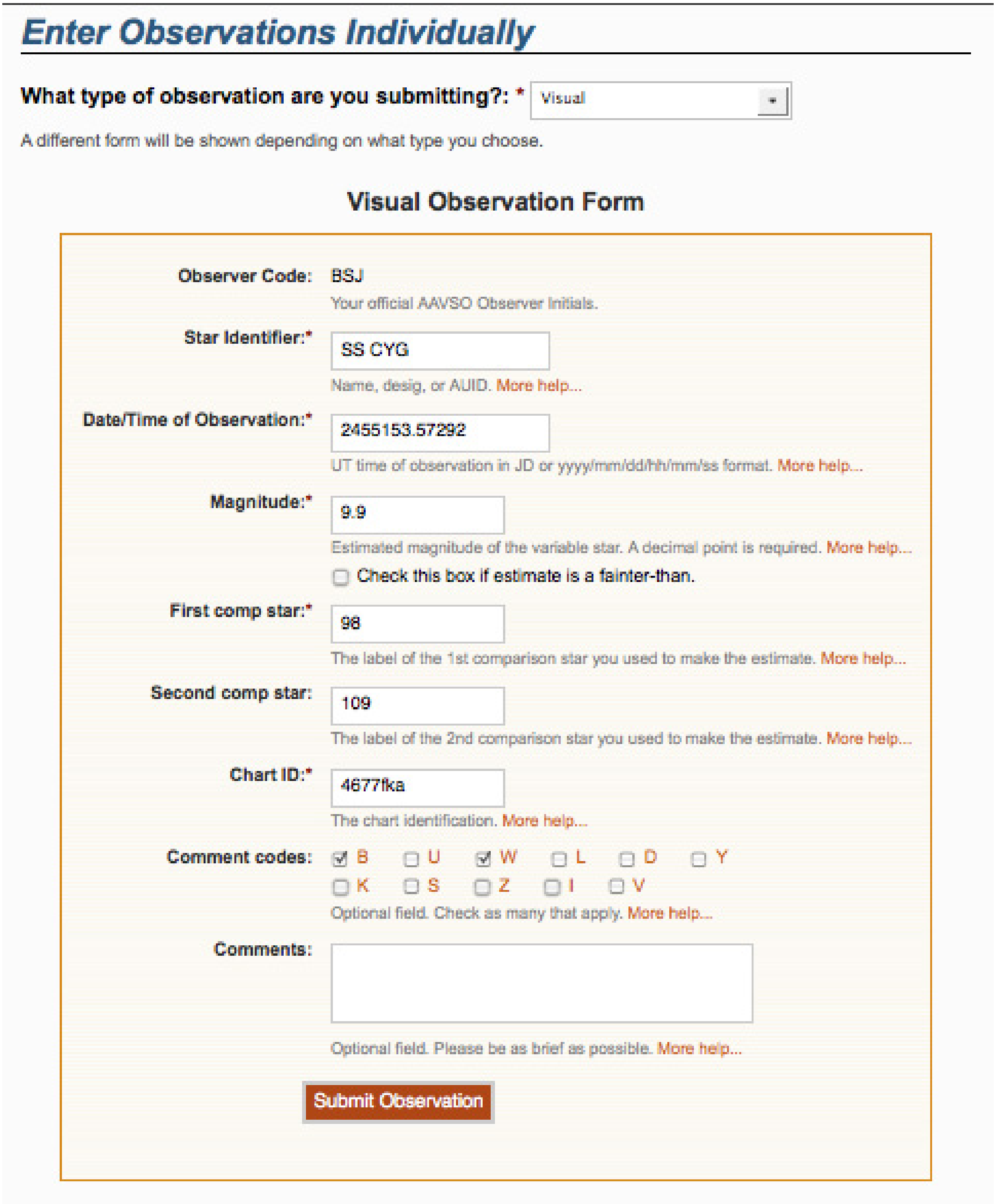
Submit Observations Individually

This option is good for people who are submitting only a few observations on a given night.

Start by selecting the "Submit observations individually" link. Now pick the type of observation you will be submitting using the drop-down list. For the purposes of this Manual only the "Visual" option will be explained.

As you can see from the screen shot of the WebObs individual observation entry form (see Figure 7.1), using this program is fairly simple. Just type your data carefully into the appropriate boxes on the form and click on the button marked "Submit Observation". If you have questions about how to enter data on any field in WebObs, simply click on the "More help..." label associated with that field and an explanation will be given in a separate window.

Figure 7.1 — *WebObs Data Entry Form*



Enter Observations Individually

What type of observation are you submitting?: * Visual

A different form will be shown depending on what type you choose.

Visual Observation Form

Observer Code: BSJ
Your official AAVSO Observer Initials.

Star Identifier:* SS CYG
Name, desig, or AUID. More help...

Date/Time of Observation:* 2455153.57292
UT time of observation in JD or yyyy/mm/dd/hh/mm/ss format. More help...

Magnitude:* 9.9
Estimated magnitude of the variable star. A decimal point is required. More help...
☐ Check this box if estimate is a fainter-than.

First comp star:* 98
The label of the 1st comparison star you used to make the estimate. More help...

Second comp star: 109
The label of the 2nd comparison star you used to make the estimate. More help...

Chart ID:* 4677fka
The chart identification. More help...

Comment codes: ☑ B ☐ U ☑ W ☐ L ☐ D ☐ Y
☐ K ☐ S ☐ Z ☐ I ☐ V
Optional field. Check as many that apply. More help...

Comments:

Optional field. Please be as brief as possible. More help...

Submit Observation

Once you have submitted an observation, it will appear in the list below the form. It is wise to check this over carefully to ensure that your did not make any typographical errors. If you find a mistake, you can click on “edit” to fix it or “delete” to remove it from the database. If you have a slow internet connection or you suspect that your observation did not get into the AAVSO database, please wait a few minutes then look for your observation using the WebObs search feature and be sure it is not there before you assume something went wrong and attempt to send it again. Many duplicate observations have been sent to the database this way!

Upload a File of Observations

The second way to submit data is to create a text file in standard AAVSO format then upload it using the WebObs “Upload a file of observations” option. This option is often a good choice for people who do not wish to stay connected to the internet very long and/or have a large file of observations to submit. Once your file has been uploaded, the observations you just sent can be displayed if desired.

There are a number of ways to produce the text file of data for submission. What is very important is that it has to be in the “AAVSO Visual Format” which is described on the AAVSO website and will be examined in detail in the section which follows.

To help you create a file of observations in the approved format, a few software tools have been developed (and continue to be developed) by other AAVSO observers which you are welcome to use. These programs can be found on the AAVSO website here: https://www.aavso.org/software-directory

AAVSO Visual Format

No matter which method you decide to use for creating your variable star reports, it is required that the data adhere to AAVSO report formatting standards. Specifically, for visual observations, you should use the “AAVSO Visual Format”. The description which follows comes from the AAVSO website (https://www.aavso.org/aavso-visual-file-format).

Note: For CCD and PEP observations you must use the “AAVSO Extended File Format” for your reports.

General

The visual format has two components; *parameters* and *data*. The format is not case sensitive.

Parameters

The parameters are specified at the top of the file and are used to describe the data that follow. Parameters must begin with a pound/hash symbol (#) at the start of the line. There are six specific parameters that are required to exist at the top of the file. Personal comments may also be added as long as they follow a pound/hash symbol (#). These comments will be ignored by the software and are not loaded into the database. However, they will be retained when the complete file is stored in the AAVSO permanent archives.

The six required parameters are:

#TYPE=Visual
#OBSCODE=
#SOFTWARE=
#DELIM=
#DATE=
#OBSTYPE=

TYPE: Should always say Visual for this format.

OBSCODE: The official AAVSO Observer Code which was previously assigned to you by the AAVSO.

SOFTWARE: Name and version of software you used to create your report. If it is private software, put some type of description here. For example: “#SOFTWARE=Excel Spreadsheet by Gary Poyner.”

DELIM: The delimiter used to separate fields in the report. Suggested delimiters are: comma (,) semi-colon(;), exclamation point(!), and pipe(|). The only character that cannot be used is the pound/hash (#) and the “ “ (space). If you want to use a tab, use the word “tab” instead of an actual tab character. Note: Excel users who want to use a comma will have to type “comma” here instead of a “,”. Otherwise Excel will export the field incorrectly.

DATE: The format of the date used in the report. There are two options for this entry; JD or EXCEL. The EXCEL format gives the time in UT and looks like this: MM/DD/YYYY HH:MM:SS AM (or PM). Seconds are optional.

OBSTYPE: The type of observation in the data file. It can be Visual or PTG (for Photographic). If absent, it is assumed to be Visual. If PTG, place a description of your film response and any filter(s) used in the notes field of each observation.

Data

After the parameters come the variable star observations themselves. There should be one observation per line and the fields should be separated by the same character that is defined in the DELIM parameter field. The list of fields are:

NAME: The star's identifier. This can be any of the names for a star listed in VSX. See Chapter 4, page 22 for more on variable star names.

DATE: The date of the observation, in the format specified by the DATE parameter. See Chapter 5 for an explanation on how to compute UT and JD.

MAGNITUDE: The magnitude of the observation. Put a "<" symbol in front of the magnitude if the observation is a "fainter-than".

COMMENTCODE: A one-letter code or series of codes you can use to describe any special circumstances associated with your observation. If you have no comment to make, please type "na" in this field. Possible codes are listed in Table 7.1, page 45.

Multiple comment codes should be separated by spaces or not separated at all. (Ex: "A Z Y" or "AZY").

COMP1: The label of the first comparison star used. Could be the magnitude label on the chart, an auid, or the star's name.

COMP2: The label of the second comparison star used. Could be the magnitude label on the chart, an auid, etc. (if none, use "na".)

CHART: This should be the "chart ID" given in the upper right-hand corner of your chart.

NOTES: Comments or notes about your observation. This field has a maximum length of 100 characters.

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

Some examples of properly formatted reports which are ready for upload:

Example 1:

```
#TYPE=VISUAL
#OBSCODE=TST01
#SOFTWARE=WORD
#DELIM=,
#DATE=JD
SS CYG,2454702.1234,<11.1,U,110,113,070613,Partly cloudy
```

Example 2:

```
#TYPE=VISUAL
#OBSCODE=TST01
#SOFTWARE= TextMate
#DELIM=,
#DATE=JD
#NAME,DATE,MAG,COMMENTCODE,COMP1,COMP2,CHART,NOTES
SS CYG,2454702.1234,10.9,na,110,113,070613,na
SS CYG,2454703.2341,<11.1,B,111,na,070613,na
```

Note the existence of the #NAME,DATE,MAG,COMMENTCODE,COMP1... line in the above format. Since it is prepended with a pound sign and doesn't start with any of the special parameter keywords, it will be ignored by the software as a comment. Feel free to do this if it makes writing and reading the format easier for you.

Example 3:

```
#TYPE=VISUAL
#OBSCODE=TST01
#SOFTWARE=WORD
#DELIM=;
#DATE=JD
#OBSTYPE=Visual
OMI CET;2454704.1402; 6.1;na;59;65;1755eb;na
EPS AUR;2454704.1567;3.3;IZ;32;38;1755dz;my first observation of this star
SS CYG;2454707.1001;9.3;Y;93;95;070613;OUTBURST!
#DELIM=|
#DATE=EXCEL
SS CYG|1/1/2010 11:59 PM|9.3|L|90|95|070613|first obs using UT
SS CYG|1/2/2010 06:15 AM|9.3|na|90|95|070613|na
```

In this example, the observer changes the delimiter and the date format in the middle of the report.

Table 7.1 – *Abbreviations for Comments on AAVSO Reports*

These comment letters go in the "Comment Codes" field on WebObs or in the "COMMENTCODE" field if you are creating your own report for upload. 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 write "a 12-day moon nearby" in the "Notes" field, just put an "B" (for bright sky) in the "Comment Codes" field.

B	*Sky is bright, moon, twilight, light pollution, aurorae*
D	*Unusual Activity (fading, flare, bizarre behavior, etc.)*
I	*Identification of star uncertain*
K	*Non-AAVSO chart*
L	*Low in the sky, near horizon, in trees, obstructed view*
S	*Comparison sequence problem*
U	*Clouds, dust, smoke, haze, etc.*
V	*Faint star, near observing limit, only glimpsed*
W	*Poor seeing*
Y	*Outburst*
Z	*Magnitude of star uncertain*

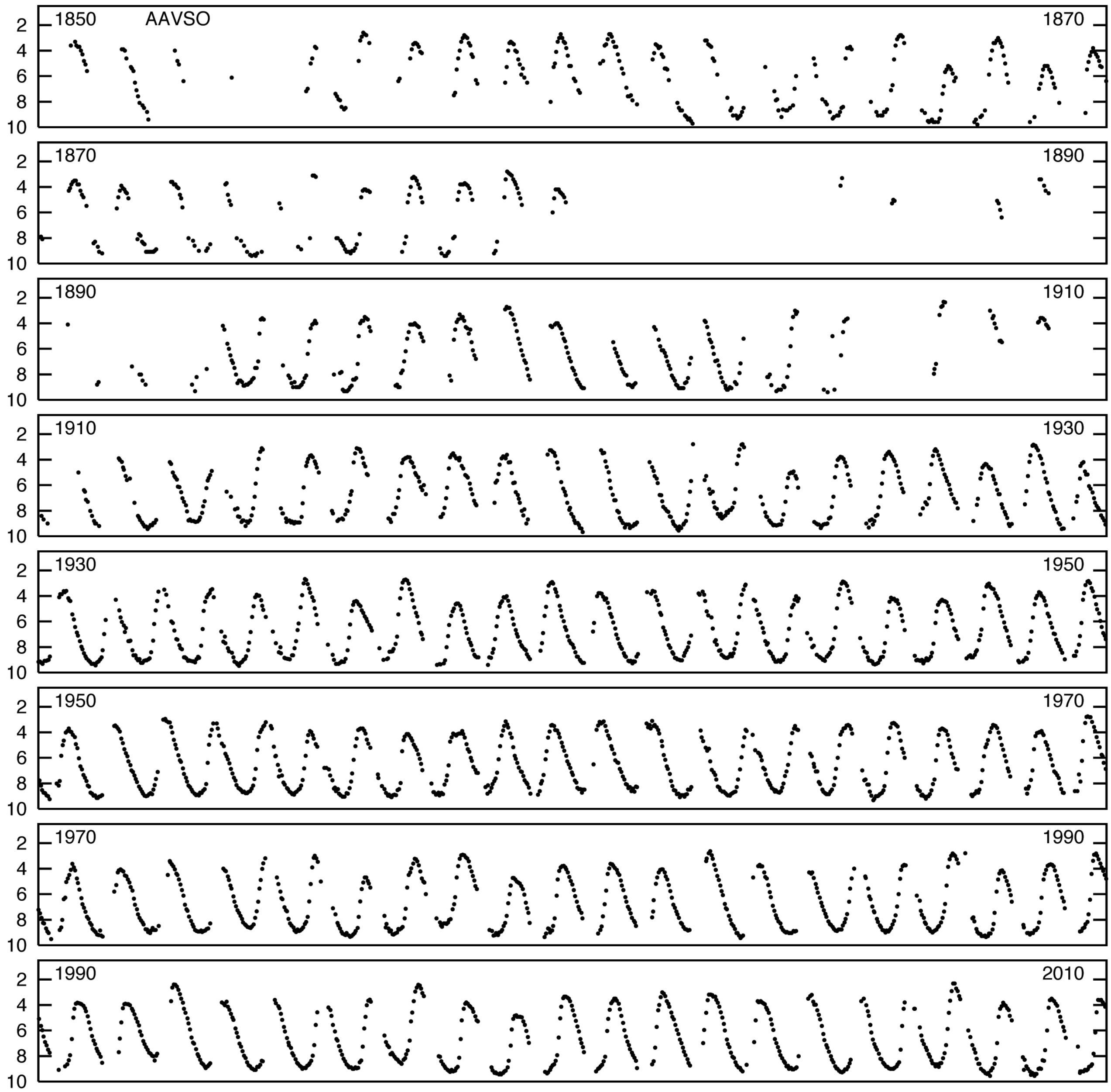
Appendix 1 – SAMPLE LONG-TERM LIGHT CURVES

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.

Omicron Ceti (Mira)

1850–2010 (10-day means)

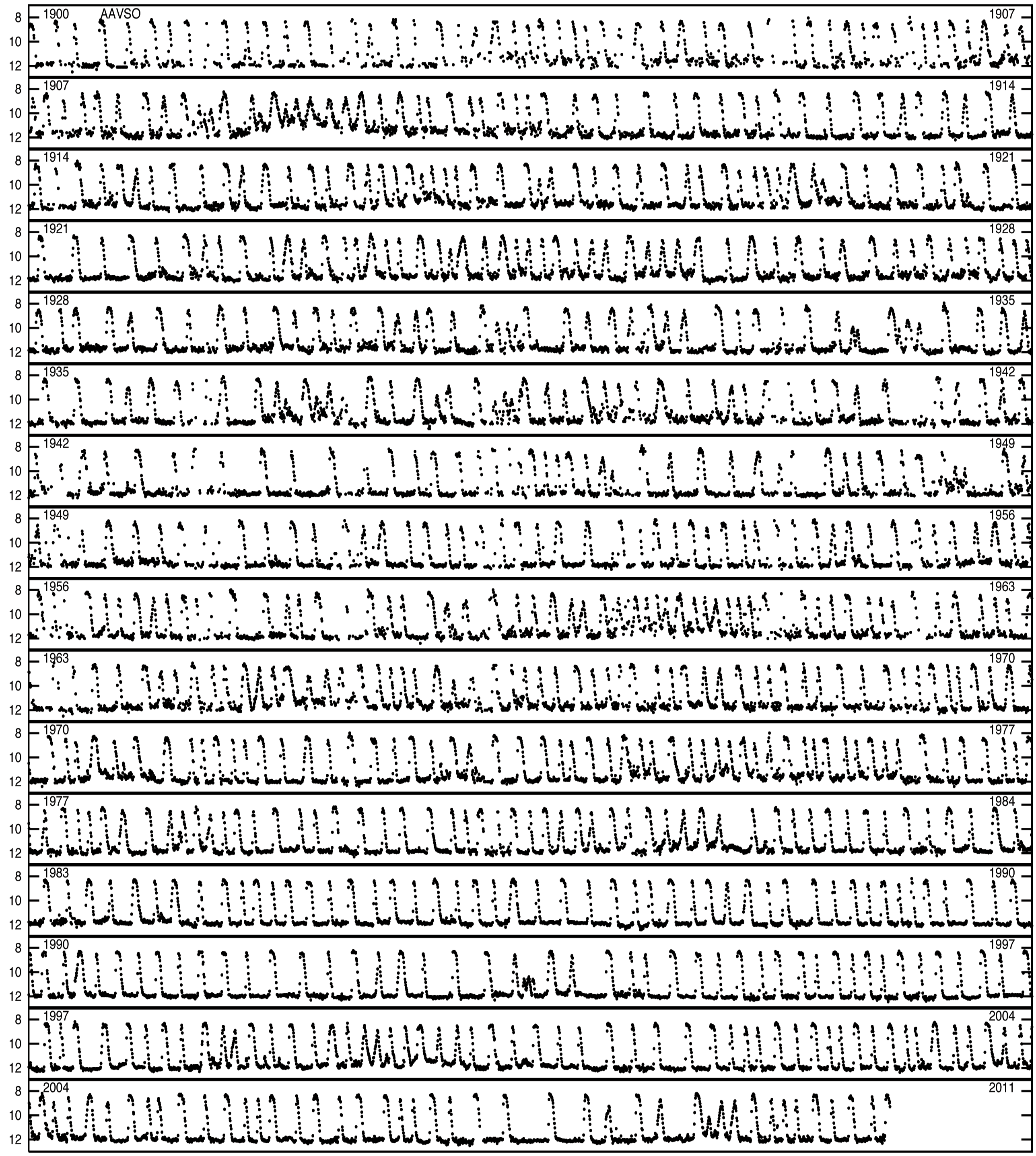
Omicron Ceti (A.K.A. Mira) is the prototype of pulsating long period variables and the first star recognized to have changing brightness. It has a period of 332 days. Generally, Mira varies between magnitudes 3.5 and 9, but the individual maxima and minima may be much brighter or fainter than these mean 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). See https://www.aavso.org/vsots_mira2 for more information on this famous star.



SS Cygni (U Gem type)

1900–2010 (1-day means)

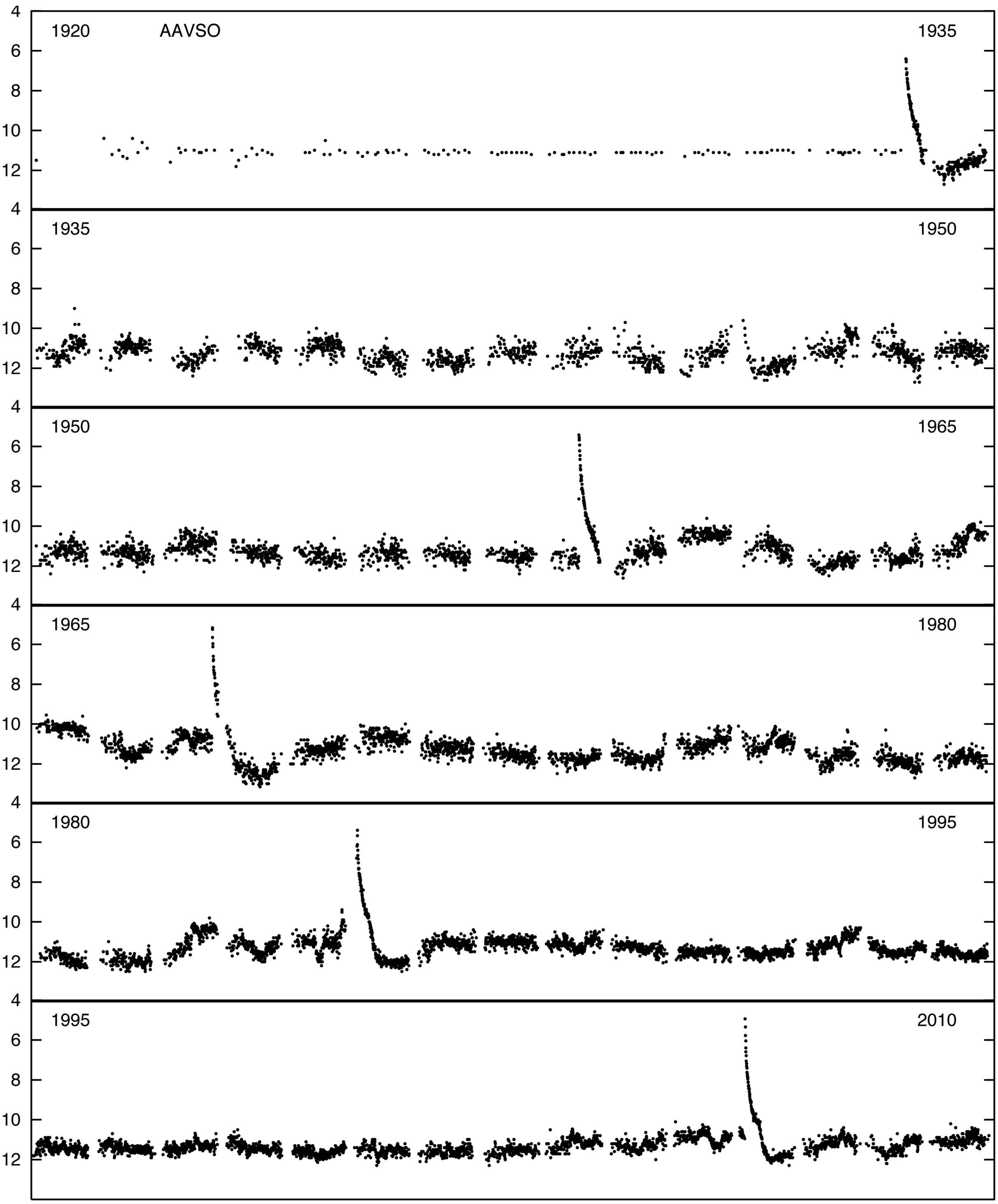
SS Cygni is the brightest dwarf nova type (U Gem subclass) cataclysmic variable in the northern hemisphere. These stars are close binary systems consisting of a red dwarf star–a little cooler than the Sun–and a white dwarf with an accretion disk around it. At approximately 50-day intervals, SS Cyg brightens (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. More information on this fascinating star can be found at https://www.aavso.org/vsots_sscyg



RS Ophiuchi (recurrent nova)

1920–2010 (1-day means)

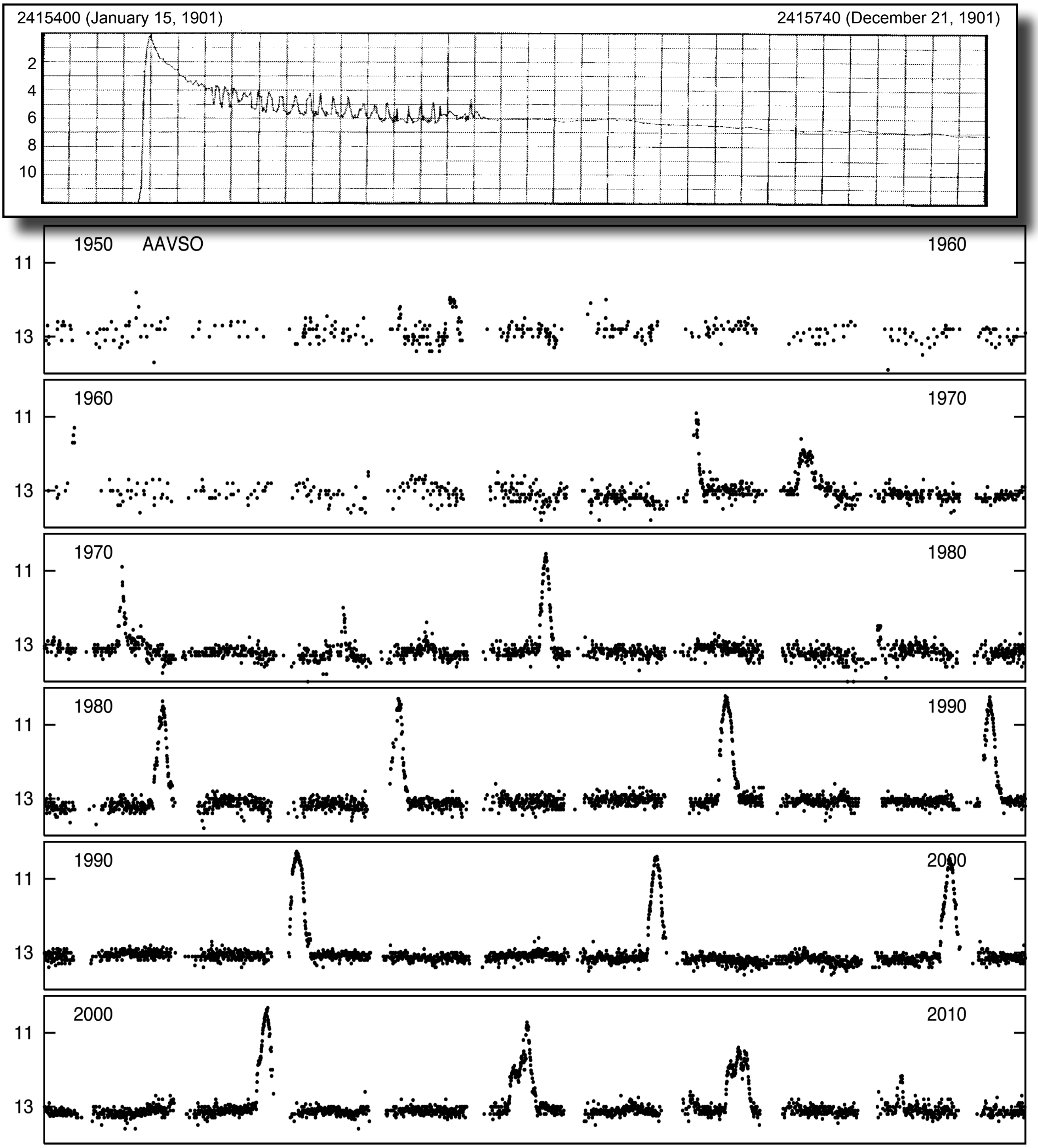
RS Ophiuchi is a recurrent nova. These stars have multiple outbursts ranging in brightness from 7 to 9 magnitudes. The outbursts occur at semiregular intervals ranging from 10 to more than 100 years, depending on the star. The rise to maximum is extremely fast, usually within 24 hours, and the decline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



GK Persei (nova)

1901 Nova-like outburst (from *Harvard Annals*)
1950–2010 (1-day means)

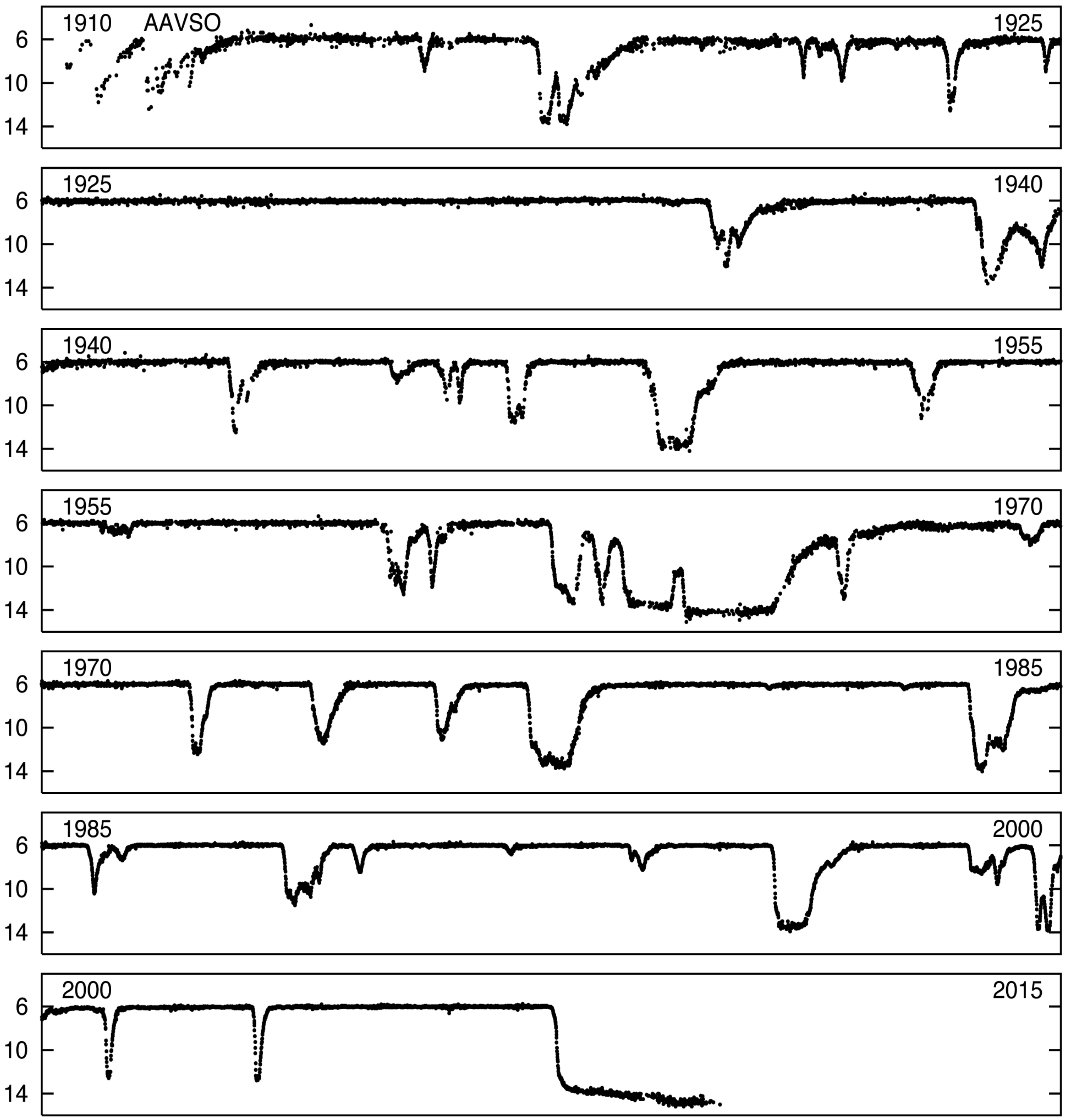
GK Persei is a bright nova of 1901. In this close binary system, eruptions occur due to explosive nuclear burning, on the surface of the white dwarf, of material transferred from the red dwarf. GK Persei is unique in that after the initial fading of 30 days, the star showed semiperiodic rapid variations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



R Coronae Borealis

1910–2010 (1-day means)

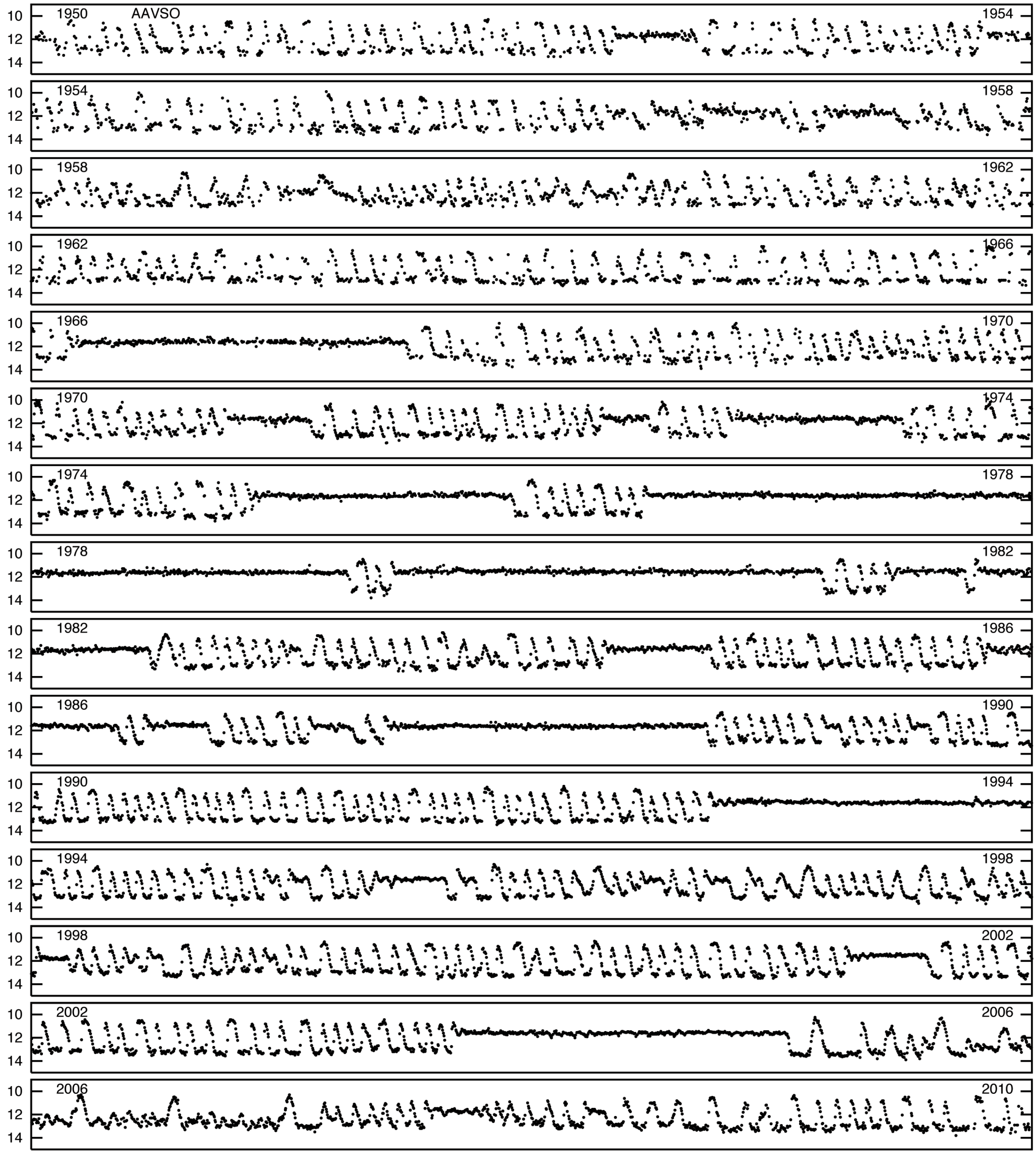
R Coronae Borealis is the prototype of its class. These rare supergiant stars have rich carbon atmospheres. They spend most of their time at maximum brightness but at irregular intervals rapidly fade 1 to 9 magnitudes. The drop in brightness is thought to be caused by carbon clouds expelled from the atmosphere of the star. For more information see https://www.aavso.org/vsots_rcrb



Z Camelopardalis

1950–2010 (1-day means)

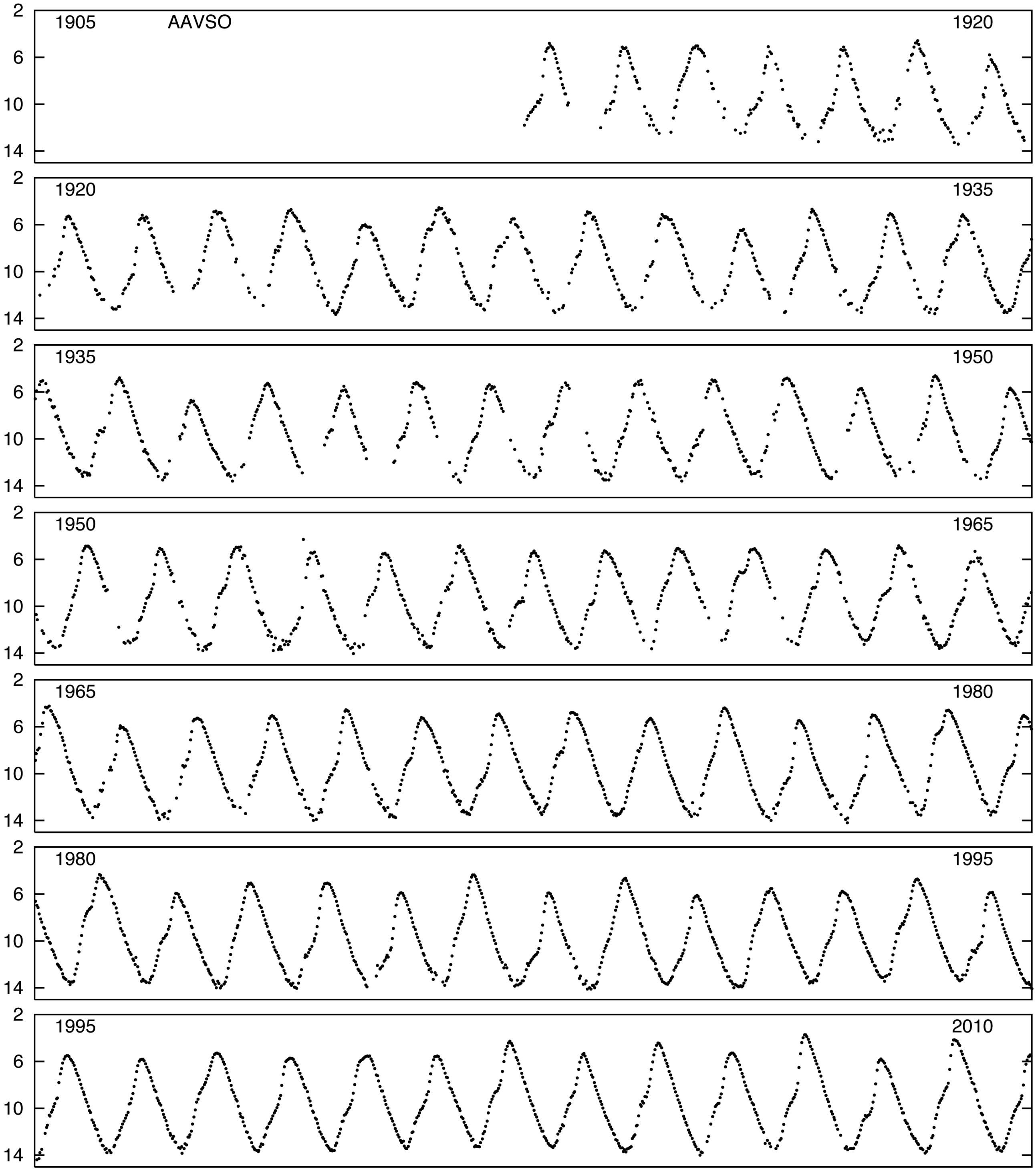
Z Camelopardalis is the prototype star of a sub-class of dwarf nova-type cataclysmic variables. It has U Geminorum-like dwarf nova outbursts about every 26 days, when it brightens from magnitude 13.0 to 10.5. At randomly spaced intervals, it experiences “standstills” in which the brightness stays constant, 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. See https://www.aavso.org/vsots_zcam



Chi Cygni (Mira)

1905–2010 (7-day means)

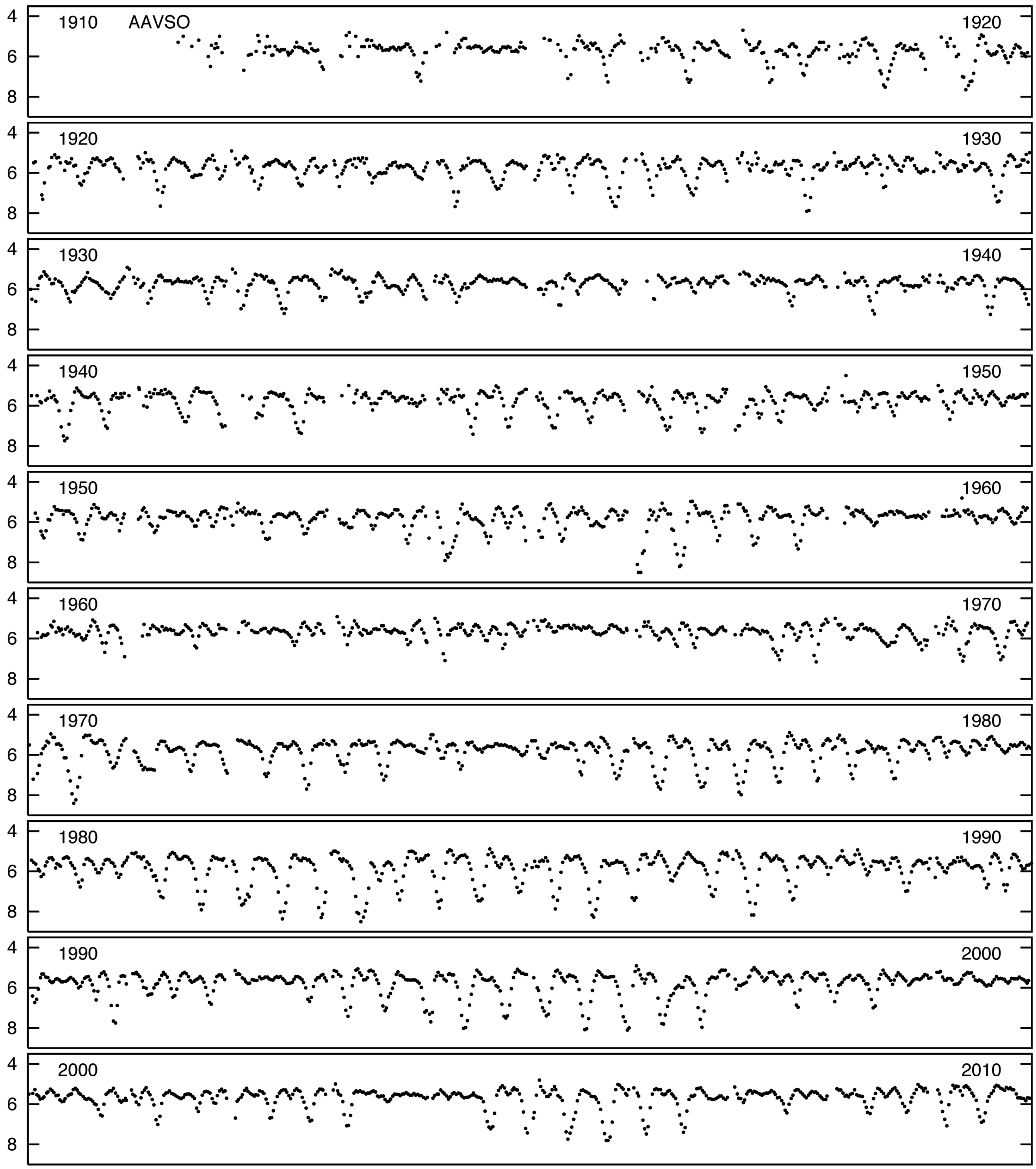
Chi Cygni (or Khi Cyg) is a Mira-type star that shows one of the largest variations in magnitude known. Typically it brightens and fades from 5th to 13th magnitude but in August 2006 it got as bright as 3.8. The average period of this brightness fluctuation is 407 days.



R Scuti (RV Tauri)

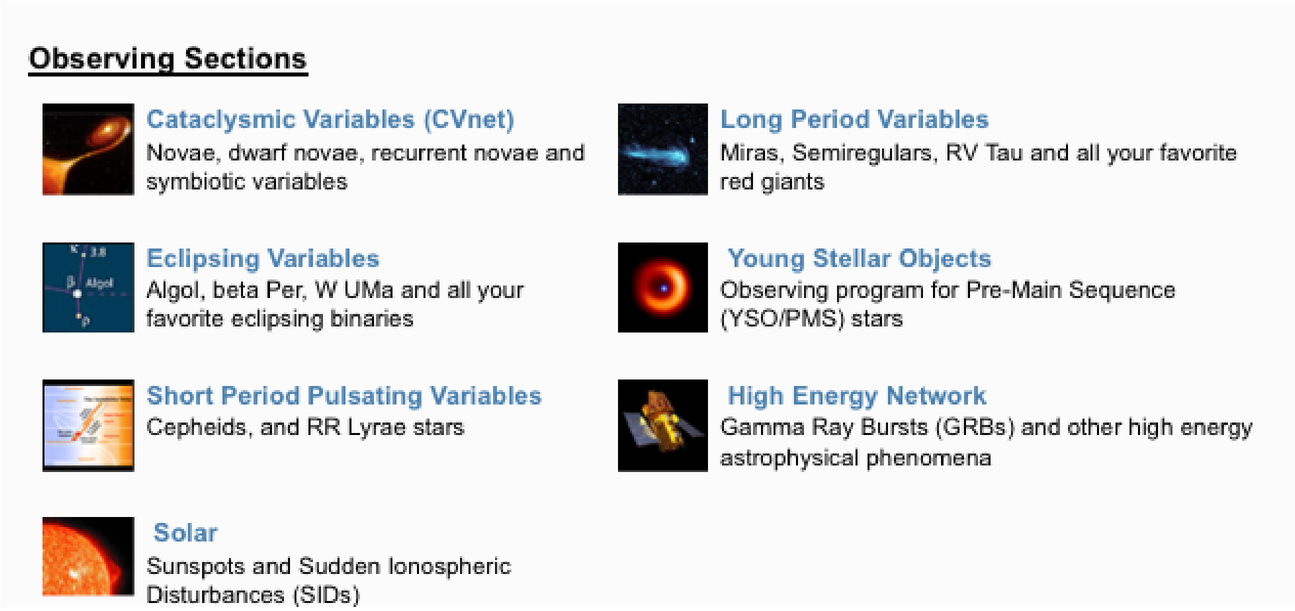
1910–2010 (7-day means)

R Sct is an example of an RV Tauri type star. These stars have characteristic light variation that show an alternating pattern of deep (primary) and shallow (secondary) minima, with the amplitude varying by as much as 4 magnitudes. The period is defined as the interval between two deep minima and ranges from 30 to 150 days. They are typically of spectral type F to G at maximum and K to M at minimum. See https://www.aavso.org/vsots_rsct for more information on R Sct.



Appendix 2 – AAVSO SECTIONS

There are several sections within the AAVSO, established to accommodate a variety of interests amongst AAVSO observers. To find out what sections exist and learn more about them, please visit the “Observers’ Landing Page” on the AAVSO website (https://www.aavso.org/observers) and click on the section of interest to you.



Observing Sections

Cataclysmic Variables (CVnet)
Novae, dwarf novae, recurrent novae and symbiotic variables

Long Period Variables
Miras, Semiregulars, RV Tau and all your favorite red giants

Eclipsing Variables
Algol, beta Per, W UMa and all your favorite eclipsing binaries

Young Stellar Objects
Observing program for Pre-Main Sequence (YSO/PMS) stars

Short Period Pulsating Variables
Cepheids, and RR Lyrae stars

High Energy Network
Gamma Ray Bursts (GRBs) and other high energy astrophysical phenomena

Solar
Sunspots and Sudden Ionospheric Disturbances (SIDs)

Appendix 3 – ADDITIONAL RESOURCES

There are numerous resources available to you as a new variable star observer. Many of these can be found on the AAVSO website through the "Observers' Landing Page": https://www.aavso.org/observers. Other useful resources are listed below.

Atlases

Ridpath, Ian, ed. *Norton's Star Atlas and Reference Handbook* (20th edition), 2007 corrected printing by Dutton imprint of the Penguin Group. ISBN 0-582356-55-5. (to magnitude 6).
Sinnott, Roger. *S&T Pocket Sky Atlas*, Sky Publishing, 2006 (to magnitude 7.6).
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. *The Cambridge Star Atlas* (fourth edition). New York: Cambridge UP, 2011. ISBN 978-0-521173-63-6. (to magnitude 6.5)
Tirion, Wil, Barry Rappaport, and W. Remarkus. *Uranometria 2000.0* (2nd edition). Richmond Virginia: Willmann-Bell, 2001. Vol. 1: N. Hemisphere to dec -6; Vol. 2: S. Hemisphere to dec +6 (to magnitude 9+). Now reprinted as an all-sky edition.

Books and web resources on variable star astronomy—basic and introductory topics

AAVSO. Variable Star of the Season. https://www.aavso.org/vstar/vsots/
AAVSO Variable Star Astronomy https://www.aavso.org/education/vsa/
Hoffmeister, Cuno, G. Richter, and W. Wenzel. *Variable Stars*. New York/Berlin: Springer-Verlag, 1985. ISBN 3540-13403-4.
Isles, John E., *Webb Society Deep Sky Observer's Handbook*, Vol. 8: Variable Stars. Hillside, NJ: Enslow, 1991.
Levy, David H., *Observing Variable Stars* (second edition). New York: Cambridge UP, 2005.
North, G., *Observing Variable Stars*, Novae and Supernovae, Cambridge UP, 2004.
Peltier, Leslie C., *Starlight Nights: The Adventures of a Stargazer*, Cambridge, MA: Sky Publishing, 1999. (reprint of 1st ed pub. by Harper & Row, NY 1965) ISBN 0-933-346948.
Percy, John R, *Understanding Variable Stars*, Cambridge UP, 2007.

Other astronomy books—with related variable star or other useful material topics

Kelly, Patrick, ed. *Observer's Handbook* [published annually]. Toronto: Royal Astronomical Society of Canada, 136 Dupont Street, Toronto M5R IV2, Canada.
Burnham, Robert, Jr. *Burnham's Celestial Handbook* (3 Volumes). New York: Dover, 1978.
Harrington, Philip S., *Star Ware: The Amateur Astronomer's Guide to Choosing, Buying, and Using Telescopes and Accessories*. (Fourth edition) New York: Wiley, 2007.
Kaler, James B., *The Cambridge Encyclopedia of Stars*, Cambridge UP, 2006.
Kaler, James B., *Stars and their Spectra: An Introduction to the Spectral Sequence (second edition)*. New York: Cambridge UP, 2011. ISBN 978-0-521-899543.
Karttunen, H. et al, *Fundamental Astronomy*, Fifth edition, Springer, 2007.
Levy, David H.,*The Sky, A User's Guide*. New York: Cambridge UP, 1993. ISBN 0-521-39112-1.
Levy, David H., *Guide to the Night Sky*, Cambridge UP, 2001.
MacRobert, Alan., *Star Hopping for Backyard Astronomers*, Belmont, MA: Sky Publishing, 1994.

Moore, Patrick, *Exploring the Night Sky with Binoculars*, Fourth edition, New York: Cambridge UP, 2000, ISBN 0-521-36866-9.
Norton, Andrew J., *Observing the Universe*, Cambridge UP, 2004.
Pasachoff, Jay M., *Peterson Field Guide to the Stars and Planets*, Fourth edition, Boston: Houghton Mifflin, 2000. ISBN 0-395-93431-1.

Software

AstroPlanner, iLanga, Inc., Kirkland, WA (www.astroplanner.net).
Guide. Project Pluto, Bowdoinham, ME (www.projectpluto.com).
MegaStar. Willmann-Bell, Richmond, VA (www.willbell.com).
Red Shift. Maris Multimedia, Ltd., Kingston, UK (www.maris.com).
SkyTools, Skyhound, Cloudcroft, NM (www.skyhound.com).
Starry Night Backyard and Starry Night Pro. Sienna Software, Toronto, Ontario, Canada (www.siennasoft.com).
TheSky and RealSky. Software Bisque, Golden, CO (www.bisque.com).
VStar. Data analysis software from the AAVSO (https://www.aavso.org/vstar-overview).

Appendix 4 - STAR NAMES

The following description of variable star names was written by observer/mentor/AAVSO Council member Mike Simonsen for Eyepiece Views *in July 2002. It was revised and expanded in May 2017.*

The conventional system for naming variable stars is archaic, but has served us for over 150 years.

In order not to get variables confused with stars assigned Bayer lower case letters ‘a’ through ‘q’, Friedrich Argelander began naming variables with the letters ‘R’ through ‘Z’, followed by the three-letter constellation abbreviation (see Table 4.1 on page 20 for a list of all the official constellation abbreviations). After those were used up, ‘RR’ through ‘RZ’, ‘SS’ through ‘SZ’, etc. were assigned. Then they start over with ‘AA’ through ‘AZ’, ‘BB’ through ‘BZ’, etc. all the way to ‘QZ’ (skipping the J’s). This allows for 334 names. After the letters are used up the stars are simply named V335, V336, V337 and on and on.

As if that weren’t confusing enough, there are now a host of other prefixes and numbers assigned to variable stars and objects. The following is a guide to help the reader understand what these names mean and where they came from.

NSV xxxxx - These are stars in the *New Catalogue of Suspected Variable Stars*, produced as a companion to the Moscow *General Catalog of Variable Stars* (GCVS) by B.V. Kukarkin et al. All stars in the NSV have reported but unconfirmed variability, in particular, lacking complete lightcurves. Some NSV stars will eventually prove truly variable; others will be spurious. Information about this and the *General Catalog of Variable Stars* can be found at: http://www.sai.msu.su/gcvs/gcvs/intr.htm.

Many stars and variable objects are assigned prefixes based on astronomer, survey or project names. Many are temporary designations until they are assigned a conventional name in the GCVS.

3C xxx - These are objects from the Third Cambridge (3C) catalog (Edge et al. 1959), based on radio-wavelength observations at 158 MHz. There are 471 3C sources, numbered sequentially by right ascension. All 3C sources are north of -22 declination. The 3C objects of interest to variable star observers are all active galaxies (quasars, BL Lacs, etc.).

Antipin xx- Variable stars discovered by Sergej V. Antipin, a junior researcher working for the General Catalogue of Variable Stars Group.

HadVxxx - This represents variables discovered by Katsumi Haseda. One of Haseda’s discoveries was Nova 2002 in Ophiuchus, V2540 Oph.

He-3 xxxx - Variables from Henize, K. G. 1976, “Observations of Southern Emission-Line Stars”, Ap.J. Suppl. 30, 491.

HVxxxxx - Preliminary designations of variables discovered at Harvard Observatory.

Lanning xx - Discoveries of UV-bright stellar objects by H. H. Lanning from Schmidt plates centered primarily on the galactic plane. In all, seven papers entitled “A finding list of faint UV-bright stars in the galactic plane” were published.

LD xxx - Variables discovered by Lennart Dahlmark, a Swedish retiree living in southern France are given this prefix. Dahlmark has been conducting a photographic search for new variable stars; discovering several hundred to date.

Markarian xxxx - TThe widely used abbreviation for Markarian objects is Mrk. These are active galaxies from lists published by the Soviet Armenian astrophysicist B.E. Markarian (1913-1985). Markarian looked for galaxies that emit unusually strong UV radiation, which comes from either pervasive star-formation HII regions or from active nuclei. In 1966, Markarian published ‘Galaxies With UV Continua’. Around that time, he started the First Byurakan Spectral Sky Survey (FBS), which is now completed. In 1975, Markarian initiated a Second Byurkan Survey (SBS). The SBS was continued by his collaborators after his death. For more information see ‘Active Galactic Nuclei’, by Don Osterbrock.

MisVxxxx - The stars are named MisV after MISAO Project Variable stars. The MISAO Project makes use of images taken from all over the world, searching for and tracking astronomically remarkable objects. The number of variables discovered so far reached 1449 on May 18, 2014. Few of these stars have lightcurves, and the type and range of many are still undetermined. The project website url is: http://www.aerith.net/misao/

MDV xxx - Preliminary names MDV (Moscow Digital Variable) are given to variable stars discovered semi-automatically using scans of photographic plates from the collection of Sternberg Astronomical Institute, Lomonosov Moscow University. By 2014, studies were published for 595 stars of the MDV series.

OX xxx - Another group of objects is labeled with the prefix O, then a letter, then a number (OJ 287 for example). These objects were detected by the Ohio StateUniversity radio telescope "Big Ear" in a series of surveys known as the Ohio Surveys.

S xxxxx - These are preliminary designations of variables discovered at Sonneberg Observatory.

SVS xxxx - Soviet Variable Stars, indicates preliminary designations of 2887 Soviet-discovered variables. This series was discontinued in 1991.

Many variables are named with prefixes associated with surveys or satellites, combined with the coordinates of the object. Here are some examples:

2QZ Jhhmmss.s-ddmmss - Objects discovered by the 2-degree field QSO Redshift Survey. The aim is to obtain spectra of QSOs out to redshifts so high the visible light emitted by these objects has shifted into the far infrared. The observations are actually of the ultra-violet part of the spectrum that has been redshifted into the visible. As with most QSO surveys, a serendipitous byproduct is the discovery of CVs and other blue stars. A description and awesome pictures of the equipment can be found here: http://www.2dfquasar.org/Spec_Cat/basic.html Home site: http://www.2dfquasar.org/index.html

ASAS hhmmss+ddmm.m - This is the acronym for All Sky Automated Survey, which is an ongoing survey monitoring millions of stars down to magnitude 14. The survey cameras are located at the Las Campanas Observatory in Chile, so it covers the southern sky from the pole to about +28 degrees declination.

ASASSN-yyxx - The All Sky Automated Survey for SuperNovae is an automated program to search for new supernovae. It has robotic telescopes in both the northern and southern hemispheres and can survey the entire sky every two days. The main goal of the project is to look for bright supernovae, however other transient objects including variable stars are frequently discovered

CRTS Jhhmmss.s-ddmmss - The Catalina Real-Time Transient Survey is a synoptic survey that covers thirty three thousand square degrees of the sky in order discover rare and interesting transient phenomina. The survey utilizes data taken by the three dedicated telescopes of the highly successful Catalina Sky Survey (CSS) NEO project. CRTS detects and openly publishes all transients within minutes of observation so that all astronomers may follow ongoing events.

FBS hhmm+dd.d - Stands for First Byurakan Survey and the coordinates of the object. The First Byurakan Survey (FBS), also known as the Markarian survey, covers about 17,000 square degrees.

EUVE Jhhmm+ddmm - These are objects detected by NASA's Extreme Ultraviolet Explorer, a satellite dedicated to studying objects in far ultraviolet wavelengths. The first part of the mission was dedicated to an all-sky survey using the imaging instruments that cataloged 801 objects. Phase two involved pointed observations, mainly with the spectroscopic instruments. One of the highlights of the mission was the detection of Quasi Periodic Oscillations (QPOs) in SS Cyg.

FSVS Jhhmm+ddmm - Discoveries from the Faint Sky Variability Survey, the first deep wide-field, multi-color, time-sampled CCD photometry survey. It was specifically aimed at detecting point sources as faint as 25th magnitude in V and I and 24.2 in B. Targets were faint CVs, other interacting binaries, brown dwarfs and low mass stars and Kuiper Belt Objects.

HS hhmm+ddmm- The Hamburg Quasar Survey is a wide-angle objective prism survey searching for quasars in the northern sky, avoiding the Milky Way. The limiting magnitude is approximately 17.5B. The taking of the plates was completed in 1997.

PG hhmm+DDd- Palomar Green Survey conducted to search for blue objects covering 10714 square degrees from 266 fields taken on the Palomar 18-inch Schmidt telescope. Limiting magnitudes vary from field to field, ranging from 15.49 to 16.67. The blue objects detected tend to be quasars and cataclysmic variables. The CVs were documented in Green, R. F., et al. 1986, "Cataclysmic Variable Candidates from the Palomar Green Survey", Ap. J. Suppl. 61, 305.

PKS hhmm+ddd - This was an extensive radio survey (Ekers 1969) of the southern sky undertaken at Parkes (PKS), Australia, originally at 408 MHz and later at 1410 MHz and 2650 MHz. These sources are designated by their truncated 1950 position. For example 3C 273 = PKS 1226+023. This is still the most common, and useful, system of naming quasars.

ROTSE1 thru 3 Jhhmmss.ss+ddmmss.s - The Robotic Optical Transient Search Experiment (ROTSE) is dedicated to the observation and detection of optical transients on time scales of seconds to days. The emphasis is on gamma-ray bursts (GRBs). Objects detected by this survey are designated with positions to 0".1 precision.

ROSAT is an acronym for the ROentgen SATellite. ROSAT was an X-ray observatory developed through a cooperative program between Germany, the United States, and the United Kingdom. The satellite was designed and operated by Germany, and was launched by the United States on June 1, 1990. It was turned off on February 12, 1999.

Prefixes for x-ray sources detected by ROSAT include, **1RXS**, **RXS** and **RX**. The J2000 coordinates for the source are then stated according to the accuracy of the X-ray position and the density of stars in the field.

arcsecond accuracy ---> RX J012345.6-765432
tenth-arcmin accuracy ---> RX J012345-7654.6
arcmin accuracy ---> RX J0123.7-7654

Distressingly, these can all refer to a single object!

Rosino xxx or N xx - Variables discovered by Italian astronomer L. Rosino, primarily in clusters and galaxies through photographic surveys.

SBS hhmm+dd.d - Indicates objects discovered by the Second Byurakan Sky Survey, plus the coordinates of the object.

SDSSp Jhhmmss.ss+ddmmss.s - These are discoveries from the Sloan Digital Sky Survey. The positions of the objects are given in the names. SDSS- (Sloan Digital Sky Survey), p- (preliminary astrometry), Jhhmmss.ss+ddmmss.s (the equinox J2000 coordinates). In subsequent papers on CVs detected by SDSS (Szkody et al) the p was dropped and the names became simply SDSS Jhhmmss.ss+ddmmss.s.

TAV hhmm+dd - The Astronomer Magazine, in England, has a program that monitors variable stars and suspected variable stars. TAV stands for The Astronomer Variable, plus the 1950 coordinates.

TASV hhmm+dd - TASV stands for The Astronomer Suspected Variable, plus the 1950 coordinates. The Astronomer Variable star page can be found at this url: http://www.theastronomer.org/variables.html

XTE Jhhmm+dd - These are objects detected by the Rossi X-Ray Timing Explorer Mission. The primary objective of the mission is the study of stellar and galactic systems containing compact objects. These systems include white dwarfs, neutron stars, and possibly black holes.

With more and more surveys being conducted, and more new variables being discovered, this list of non-conventional names will undoubtedly grow. I hope this explanation has helped to demystify the existing names and prepares you for the onslaught of names yet to come.

There is a CDS webpage (http://cdsarc.u-strasbg.fr/viz-bin/Cat) where you can find details about specific acronyms. The GCVS also has a list of catalog abbreviations.

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