THE BAA OBSERVERS' WORKSHOPS

Cambridge	Winchester	York
2003 February 15	2003 April 26	2003 September 6

Karen Holland provides a summary of her talk at the first Observers' Workshop in Cambridge.

Why observe variable stars?

by Karen Holland

Workshop No. 1:
The Institute of Astronomy, Cambridge
2003 February 15

Introduction

For many of us, there is much pleasure to be gained from watching a star night after night, seeing its brightness change, and wondering about the reasons for that change. This activity becomes even more rewarding when professional astronomers request the data that we have collected, take it away for analysis, and from the data deduce amazing snippets of information regarding the system that we have monitored. Often, the brightness estimations that we have made on the star, may be the only observations that exist for *that* particular star at *that* specific time, making them extremely valuable.

Many stars are variable; even our own Sun is very slightly variable, but happily it is not variable enough to affect us on Earth to any great extent. We are very fortunate that the Sun doesn't go through some of the massive changes experienced by some of the systems we will look at today!

Variable star nomenclature can initially be somewhat confusing. By the beginning of the 17th century Bayer had designated the brightest stars in each constellation using Greek letters, e.g. γ Cas. At this time, lower case letters and the first part of the alphabet had already been used to designate many properties in astrophysics, but the end of the alphabet still remained unused. When Argelander decided to instigate a naming convention for variable stars, he didn't think that there would ever be any need to name more than nine variables in each constellation, so he started at the letter R, calling the first variable star that was discovered in a constellation (e.g. Andromeda) R Andromedae (R And), the second S And, and so on, all the way to Z And. However, it was not long before more than nine variable stars were discovered in a particular constellation, so he continued, by doubling up the letters to produce a new sequence e.g. RR And, RS And…. down to ZZ. Then when more letters were again required, capital letters from the beginning of the alphabet were used: AA to AZ, BB to BZ, through to QZ. Then finally in desperation, when yet more stars needed a designation, he turned to numbers, starting with V335 (as 334 variable stars would already have been numbered in the constellation using the letters). This was a wise move, as there are now thousands of known variable stars in some constellations.

What are variable stars?

Variable stars are stars whose light output, for some reason, varies. We often plot light curves showing the brightness (magnitude) of the star versus time, to see how the light output is changing. Where there is a regular periodicity to the variation, we can specify a period for the star, which is simply the length of time for the star to go through one cycle. The range of variation can be from barely detectable millimagnitudes to several whole magnitudes.

There are many different types of variable star, but for the purpose of this introductory talk, these many different types can be roughly grouped into three main classes: *pulsating variables*, *eclipsing variables* and *eruptive variables*. Within each main group, there are many sub-types, and the sub-types are usually named after the first star of that sub-type that was discovered. So, for example, Mira stars are so called after the first star, Mira, that was discovered to have what we now call Mira-type behaviour (see later section on pulsating stars).

Over the years, fashions change, and whereas years ago, meticulously following the luminosity changes of long period variables was trendy, nowadays there is great interest in cataclysmic variable stars. To see how the number of observations of different types of object has changed over the years, see the Web page of the BAA Variable Star Section.[1]

Pulsating stars

Why do stars pulsate, and what effect does this have on their light curve? Pulsating stars are stars that physically expand and contract; they pulsate. This pulsation causes the star to go through a heating and cooling cycle, which changes its luminosity. That's why we see the brightness of the star change; less noticeable to us visually is the change in colour that takes place as the star heats up and cools down. As the star cools down, the light becomes more red, and as it heats up the light shifts towards the bluer end of the spectrum. Some stars have different pulsation modes, so that rather than the whole star expanding and contracting, different parts of the star are affected, as if a

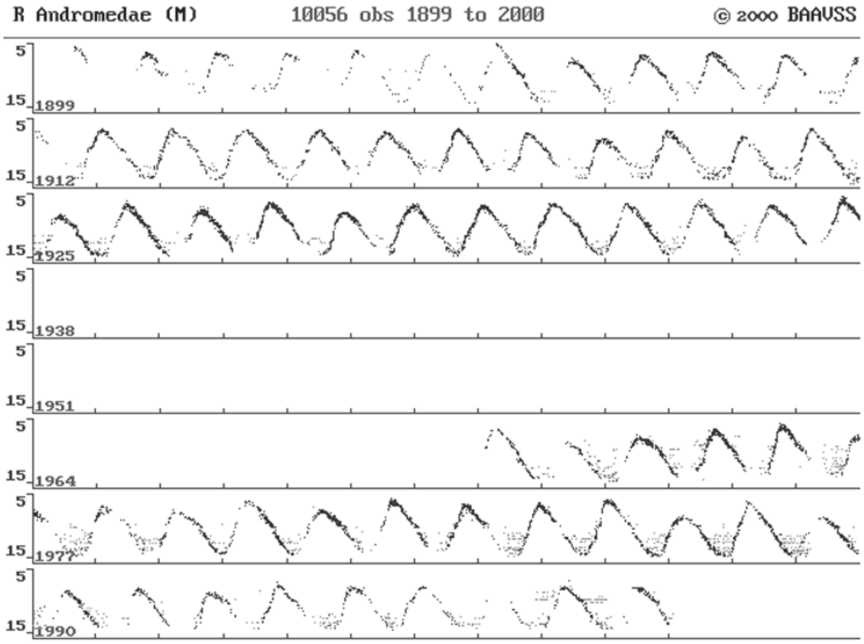


Figure 1. The light curve for R And, constructed from 10056 visual estimates made between 1899 and 2000. *BAAVSS archive*

wave were running around its surface; these are called *non-radial pulsators*, as opposed to the *radial pulsators* discussed above.

What physically starts off this pulsation is still not well understood, but scientists do have a fair understanding of what happens during the pulsation cycle. Inside stars, the gravitational field due to the mass of the star acts to hold the star material together, but the pressure that is exerted by this same hot gas, tries to make the star expand. In a star that is non-variable, these two quantities are perfectly balanced, so the star remains a constant size. But what if something happens to upset this balance a little? Imagine that, for whatever reason, the star is compressed a little and therefore becomes slightly smaller; the pressure and temperature inside the star would increase. In stars that do not have a predisposition to become variable, the star would quickly return to its equilibrium position by expanding again. But in variable stars, there exists a layer of helium atoms at a crucial position in the star's structure, that act as a positive feedback mechanism, and instead of any disturbance being quickly damped out, this mechanism keeps the pulsation going.

So in such a variable star that has become a little contracted through some disturbance, as the temperature rises, the helium atoms in the star's outer layers become ionised. Ionised helium is a bit like the sunblock that we put on to stop the sun from getting to our skin and burning it – it stops light and heat from passing through it; remember that heat is simply a colour of light that we cannot see with our eyes (infrared light). The ionised helium therefore stops the heat and light from inside the star from escaping as easily as it did previously, and this means that the temperature and pressure rise even more rapidly inside the star. When the pressure becomes greater than the gravitational force holding it all together, then the star has to expand. But when the star reaches what was once the equilibrium position, it overshoots, and keeps on going. As it does so, the pressure drops, the gas cools, and the helium ions recombine to become whole atoms again; in this state, they become much more transparent to the heat that is inside the star trying to escape, so the star cools down even more rapidly. This means that the pressure of the gas drops sharply, and it isn't long until the gravitational force of the star wins again, and the star starts to contract. Once again, as it passes the equilibrium position, it overshoots, the star becomes contracted, and the cycle starts all over again. Without the helium ionisation mechanism providing positive feedback, the initial disturbance would have been quickly damped out, but with it, the pulsation is sustained.

The period of pulsation of a variable star can provide scientists with a wealth of information about its properties, arising from the fact that the period of pulsation is related to the density of the star. In fact the pulsation can be thought of as being similar to a sound wave travelling into the star and back out of it again.

There are many different classes of pulsating star. R And is a typical Mira-type star. Figure 1 shows a light curve for R And constructed from 10056 visual estimates that were made between 1899 and 2000. This is typical of Mira-type stars, which have a light range of greater than 2.5 magnitudes in the visual, and periods of between 80–1000 days.

Less regularly varying pulsating stars may be classified as semi-regular variables, and this group is further divided according to how regular their light curves are, with SRa type stars being the most regular, through to SRd type stars which are the most irregular. These stars generally have smaller amplitudes than Miras, and there is also a difference in the spectral classes of the various types of stars.

There are many other pulsating star types too numerous to list here. L type stars are slow, irregularly-varying stars, and it may be that many stars have been placed in this category simply because they have not been well enough studied to place them more appropriately. Figure 2 shows a light curve for BI Cyg, a slow irregular variable supergiant of late spectral class (LC class variability). For an up-to-

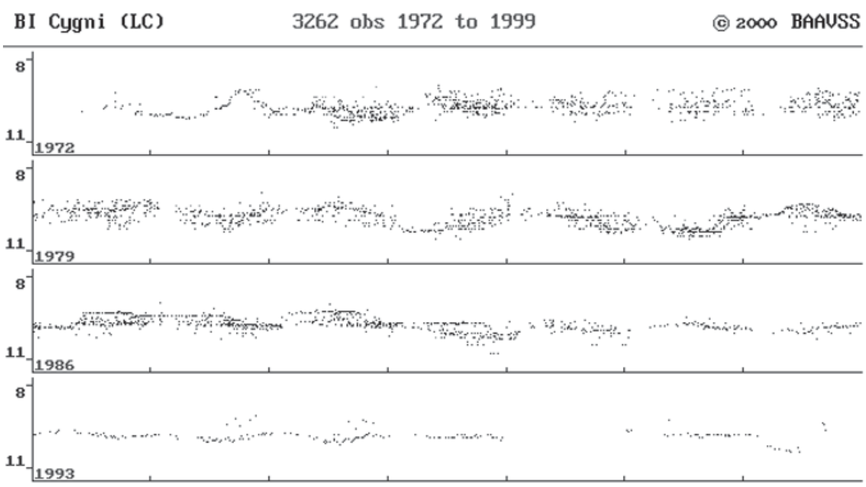


Figure 2. The light curve for BI Cyg, a slow irregular variable supergiant of late spectral class (LC class variability). *BAAVSS archive*

date reference section that lists all the many different types of pulsating variable stars, together with their respective subtypes, see Gerry Good's book *Observing Variable Stars*.[2]

Eclipsing binary stars

Eclipsing binary stars are binary systems which are inclined at an angle to the Earth such that periodically one of the stars *eclipses* the other star, blocking out a fraction (or all) of the light that we would have received from it. Then, when the system has progressed through half an orbit the stars may again eclipse each other, with their roles reversed. This only occurs if the system is at the correct angle of inclination to us on Earth, but when it does take place it allows us to learn a great deal more about the system properties[3] than would be the case for a single star. A visually-observed eclipse of RZ Cas is shown in Figure 3.

There are several subgroups of eclipsing binaries and many stars of other types are also eclipsing; for example, cataclysmic variables, which are classed as eruptive variables, may also be eclipsing. Eclipsing binary systems are classified largely according to the form of their light curves, which may differ depending on whether the two stars in the system are detached from each other, are semi-detached, or are in contact. EA (Algol) type eclipsing binary systems are systems that are detached, producing a characteristic light curve, in which the start and end of eclipses are well-defined. EB (Beta Lyrae) type binaries exhibit light curves that vary more continuously throughout eclipses, due to the ellipsoidal shape of one or both of the components. W UMa type systems have extremely short orbital periods of less than one day, and it is thought that the two stars in such systems are likely to be in contact, with mass transfer taking place.

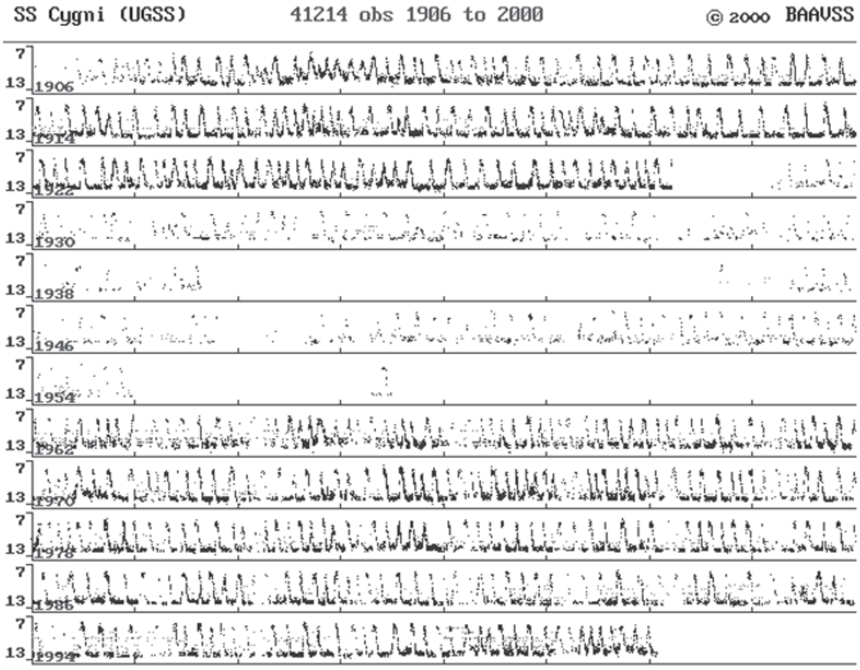


Figure 4. A light curve for SS Cyg. *BAAVSS archive*

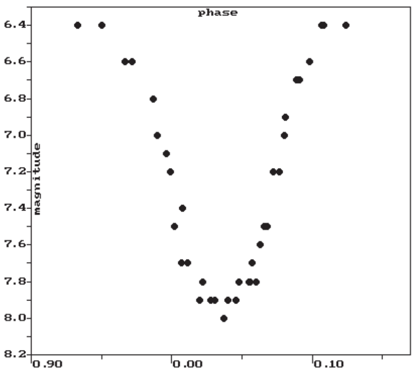


Figure 3. The light curve of an eclipse of RZ Cas. This is based on observations of several eclipses observed and estimated by Des Loughney in February to March 2003.

Eruptive stars

Eruptive stars are by far the most disparate group of objects. Within this group are a host of categories of stars that vary for very different reasons. Incorporated in this group are classes such as Wolf–Rayet stars, R Corona Borealis stars, symbiotic stars, X-ray Binaries, supernovae, T Tauri stars, flare stars, gamma-ray bursters, pulsars, S Doradus type variable supergiants, Gamma Cas type stars, variable planetary nebulae… the list is seemingly endless. Discussion of these many types of eruptive star is beyond the scope of this talk, and for a description of each of these types, again, consult Gerry Good's book.[2] There is however one group of objects within this class, with its own set of subtypes, that deserves particular mention, as it is one of the most widely studied groups of stars in current times. These are the *cataclysmic variable stars*, which include *dwarf novae*, *novae* and *recurrent objects*.

Cataclysmic variables are binary systems in which matter is transferred from one star (the secondary star) to the other (the primary); the transferred matter forms an accretion disc of material around the primary star. Periodically, the accretion disc flips between a dimmer, cooler state, to a hotter, brighter state, which we observe as a sudden increase in the brightness of the system. After a period of time, the disc returns to its quiescent state.

The reason that there is such interest in these objects at this time is that discs form in many astrophysical situations: they exist around black holes, and in star formation regions; planets form from protoplanetary discs. Dwarf novae, in particular, are so interesting because the timescales involved in the change in state between the dim state to the hot state are relatively short, ranging from just a few days, to a few years or more. This means that individual observers have an opportunity to study these systems in both states, and particularly during the transitions from one state to another.

An example of such a dwarf nova is SS Cygni. A light curve for SS Cyg is shown in Figure 4. In SS Cyg the two components orbit around each other once every 6 hours or so, and you can see that the disc goes into outburst every month or two. It is also nice and bright at around magnitude 12 in quiescence, and in outburst it almost becomes a binocular object.

Another interesting object of this type is RS Ophuichi, which is classed as a recurrent nova. A light curve for this object is shown in Figure 5. Outbursts have been detected for this system in 1933, 1958, 1967 and 1985, so another outburst is expected any time now.

Recurrent novae are an unusual class of eruptive star. They are a subclass of the cataclysmic variable stars: dwarf novae

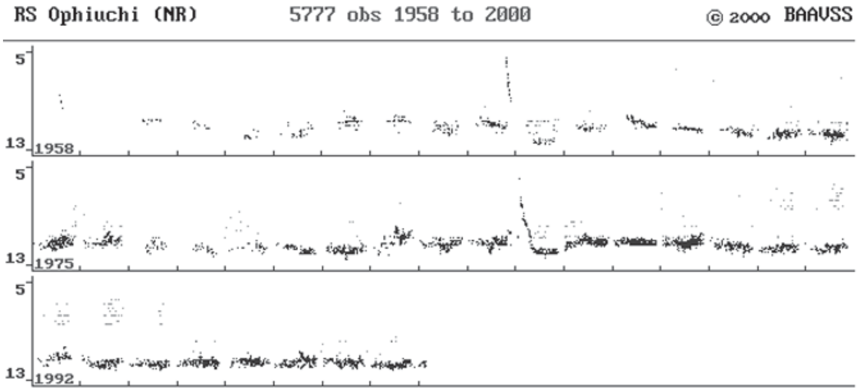


Figure 5. The light curve for RS Oph. *BAAVSS archive*

exhibit outbursts perhaps every few months to a few years, and their outbursts are of the order of 2–6 magnitudes; classical novae exhibit bigger outbursts (8–15 magnitudes) that have only been seen once; recurrent objects form a class between these two. Although this may sound entirely reasonable, current theories suggest that dwarf nova-type outbursts are different in nature to nova-type outbursts, so to have systems (and there are *very few* confirmed members of this class) that exhibit behaviour in between the two is exciting, and a great opportunity for learning. Dwarf nova outbursts are thought to be due to the accretion disc flipping into a hotter state. Nova outbursts, on the other hand are thought to occur when enough of the disc material has been accreted on to the white dwarf's surface; this leads to an increase in the gravitational forces exerted, and the base of the material becomes compressed and hot, and triggers a thermonuclear reaction, resulting in a shell of material being ejected from the white dwarf's surface. So what happens in recurrent objects? This is why we need to observe these objects well.

For more on cataclysmic variables, see Coel Hellier's book *Cataclysmic Variable Stars*,[4] and also Brian Warner's definitive professional-level volume of the same name.[5]

So, why observe variable stars?

There are many reasons why the collection of data on variable stars is an important and useful activity.

Research on these stars provides a wealth of information about stellar properties, such as mass, radius, luminosity, temperature, internal and external structure, composition, and evolution. This information can also be used to understand other stars.

Variable stars need to be observed over decades to determine their long-term behaviour; some variables have periods of many years. Traditionally, professionals have not had the time, or the telescope access, to monitor stars over such long periods. If a star does begin to exhibit unusual behaviour, we can alert professionals to changes, possibly resulting in time allocation on world-class telescopes.

Professionals often request that correlated data is obtained from ground-based optical observations at the same time as their observations are made at other wavelengths.

Determination of periods can lead to a better understanding of the pulsation mechanism of stars. Albert Zijlstra and Tim Bedding are doing a great deal of work in this area, and made a specific request recently to the Variable Star Section that we monitor particular bright stars in an effort to determine their, as yet, unknown periods, so that they can add further points to their period–luminosity relationship graph, and further their research.[6]

O–C diagrams (Observed–Calculated diagrams)[7] can tell us about systems that are changing. These diagrams chart the differences between the expected time of minimum of a system, and the actual time of minimum that is observed in a new observation. Often the period of a system changes, and much can be learnt about the system by monitoring this change.

Observation of previously unclassified systems can throw up surprises, and even result in new classes of variable star. For many years now, Mike Collins has been discovering new variable stars, about which nothing is yet known.[8,9]

Eclipse monitoring can teach us a great deal about binary systems.[3]

Data is sometimes needed to test professionals' theoretical models of some systems. This is the case for the SS Cyg project that is part of the BAA Variable Star Section's (hereafter VSS) CCD Target List.[10]

How do we make visual observations of variable stars?

You have decided that you'd like to have a go at observing some variable stars. How do you get started?

Paper documentation available from the VSS

- The *Guide to Making Visual Observations*; this is currently in the process of being updated and will be available shortly
- *Observation report forms* are available, but the sending of observations by e-mail is strongly encouraged (see section later), to reduce the need for manual entry of paper reports
- A *Chart Catalogue* is available which lists all the charts that are available from the Section
- *Charts* and *sample charts* are available for binoculars, smaller telescopes and larger telescopes. These are available from the Chart Secretary (Eclipsing binary charts from the Eclipsing Binary Secretary). Charts that have recently been revised are also included in the Variable Star *Circulars*. Sample charts are provided if you are new to observing variable stars and just want a taster pack! Charts are also freely available from the VSS Web page.

Documentation available on the VSS Web page[11]

There is a vast resource of additional information available on the Web page; this is an invaluable source of up-to-date material, as its contents can be so quickly updated. I summarise this information below for those who may not have easy internet access, as all of it can be provided by the officers of the Section on request.

- Details of the telescopic, binocular, recurrent object, eclipsing dwarf nova, CCD and eclipsing binary programmes
- A complete list of all objects for which there is data in the database, with links to files including details of period, type, magnitude range, sequence, total number of observations made so far, links to articles on the stars, details of charts and lightcurves to view
- PDF versions of past VSS *Circulars* (including many finder charts)

- Predictions of the time of minimum for eclipsing binary stars for the next three months
- A list of Mike Collins' discoveries (TAV and TASV stars) which need further observation
- Details of special observing campaigns, in which professionals have asked us to monitor a particular object at a certain time
- The most up-to-date charts are freely available on the Web page for download.

The Variable Star Section mentoring scheme

The mentoring scheme was set up recently,[12] in order to provide assistance and encouragement to those who are new to variable star observing. Under this scheme, beginners can be allocated a mentor, who will act as a friendly adviser throughout the early stages of learning. A number of experienced observers have offered to act as mentors; some will communicate by e-mail only, and some are willing to assist by sharing observing sessions with their observing partner, as well as being in contact by e-mail. In either case, an effort will be made to link students with a mentor who is as local to them as possible.

It is intended that a mentor will provide support with all those little difficulties and questions that arise during the early stages of a variable star observing career. Most of these problems can be solved without assistance, of course, but they are often answered far more quickly by an experienced observer, who can pass on useful techniques and know-how. Even more importantly, a common fear amongst beginners is that they may not be estimating the star's brightness correctly; this can often stop an observer from contributing the results to the Section's valuable archive, and in doing so, both robs a future analyst of the data, and deprives the observer from contributing to a potentially important project.

One key way in which it is envisaged that a mentor might assist, is to observe a few of the same stars as the student, to enable a comparison to be made between the mentor's estimation and the student's estimation. In this way, the new observer will start to gain confidence in the results, and is more likely to submit them to the Section's archive; any problems encountered in making the estimation will be picked up and corrected at an early stage.

A map showing the locations of the mentors can be seen on the Web page,[13] or a copy obtained from one of the officers of the Section.

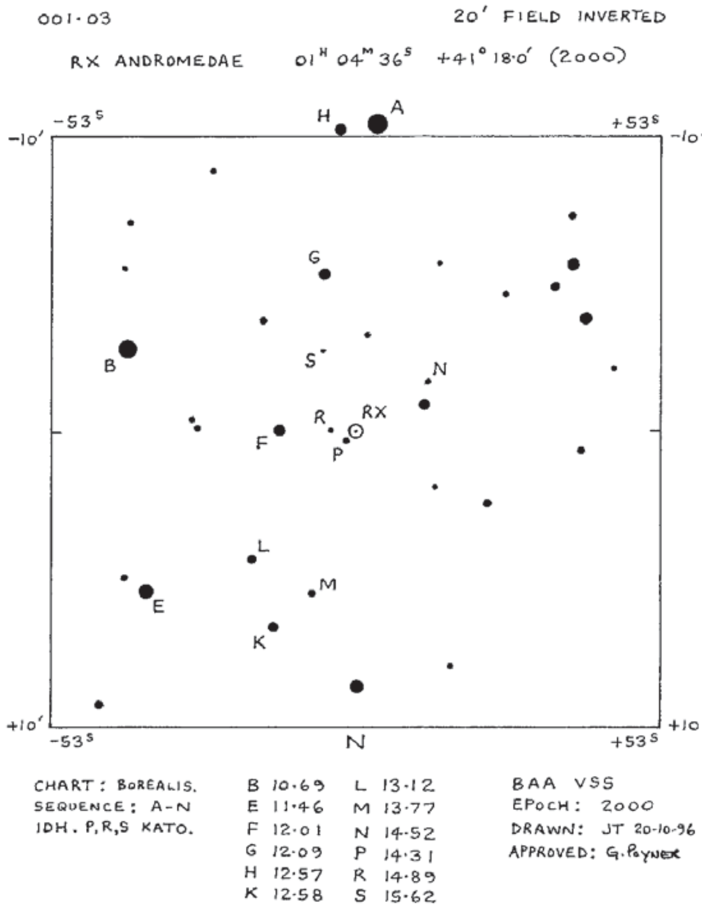


Figure 6. The BAA 'C' chart for RX And.

Choice of equipment

Naked eye

Whilst the VSS doesn't have a formal naked eye programme, there are a few stars in the database with observations that are bright enough to be observed by the naked eye, like Epsilon Aurigae. Unfortunately, this varies by a fairly small amount (about magnitude 2.8 to 3.5), so it is not ideal for observers new to this field. This is an eclipsing binary, that has a period of nearly 9000 days! Gamma Cas is another interesting star, but it too, only varies from 1.78 to 2.6; this is the prototype star of its class.

Binoculars

Binoculars are good for observing stars in the 4 to 8 magnitude range if hand-held, and down to magnitude 9 if mounted securely. With a pair of binoculars the whole binocular programme opens up to you. Many observers find that stars are easier to find with binoculars than with a telescope, and they are therefore a very good way to start practising variable star observing.

Telescope

A telescope offers the opportunity to observe a different set of objects, but also makes life a little more complicated as you need to start to consider what is the upper magnitude limit to which you should estimate. Each target star has its own ideal instrument combination (telescope and eyepiece). The general rule is only to use enough power and magnification so that you can see the variable clearly, but not so much that it is so bright that it is difficult to estimate. In an ideal world, the target star should be a couple of magnitudes brighter than the faintest star that you can see with your telescope. Of course, in practice we do try to estimate stars that are near the limit of what we can see, out of necessity, but try to follow the above rule when possible. You will find that there are some stars that at minimum you will barely see with a 300mm telescope, but at maximum you can observe with binoculars!

Effective approximate magnitude limits for some common telescope sizes are listed below:

Aperture (mm)	60	150	200	300
Brightest (mag)	6.4	8.5	9.0	10.0
Faintest (mag)	11.0	13.0	13.5	14.5

Use an eyepiece that gives the widest available field of view, so that you can see as many of the comparison stars as possible in the same field of view as the target star.

You will also need a notebook, a pen or pencil, a loose-leaf binder for holding charts, a watch for noting the time, a dim red light and warm clothes!

Compiling your personal observing list, and maximising the value of your observations

Once you have selected your equipment, you are ready to choose some stars that you will begin to observe. In theory, you can choose to observe any stars you like; the VSS accepts observations of any star into its archive. However, because there are only a limited number of observers, the VSS selects a number of stars for its various programmes. These programmes are a kind of *preferred* observing list, that if we all were to concentrate our efforts on, would allow sufficient data to be obtained for a sensible analysis of the data to be made. Each programme is updated regularly, at which time stars are added or removed from the list. In practice it makes sense initially to choose stars that are on one of the VSS programmes; in addition to adding your data to a valuable database along with that of other observers, you will be able to compare the results of your estimations with those of others.

As a first step to compiling your list establish the following:

- What is your possible magnitude range as dictated by your equipment?
- What type of stars are you interested in, or do you want to sample many types?
- How often do you want to observe, weather permitting? A short period eclipsing system will need intensive monitoring throughout a single night; irregular stars and those that erupt unpredictably may need observing every clear night; long period stars will probably need observing less frequently. You should plan to observe a star no more frequently than is necessary to show its most rapid variations.
- What area of the sky is available to you? Do you have restricted views in any direction?
- What time do you prefer to observe? The most poorly-observed stars are those that are only visible in the later hours of the night, just before dawn, and observations of these stars are particularly valuable.
- Try to select stars that are not already grossly over-observed. The information provided on the Web pages may prove valuable in this respect, particularly the archive statistics which demonstrate which stars have been the most widely observed to date.
- If you have a large telescope, then you should concentrate on observing stars that are relatively faint.

Once you have all this information, consult the list of stars for each of the VSS programmes: telescopic, binocular, recurrent objects, eclipsing binary, CCD, Mike Collins discoveries (TAV and TASV), and choose your targets!

Charts

You will need to obtain a chart for every star that you want to observe, although some charts cover more than one star. For some stars there may be an A, B and a C chart, as is the case for RX And. The A chart, in this case, covers an area of 9° squared; the B chart covers 1° squared, and the C chart (Figure 6) covers 20 arcminutes squared. I like to draw a circle on the chart that I will be using at the telescope, that represents my field of view through the eyepiece so that I know exactly which stars should fit into my view.

On the chart is also printed the sequence. This is a list of stars in the field that are given letters as identification, and their magnitudes are listed. These stars, which are called comparison stars, have been chosen to provide a graduated brightness sequence that you can use to help you to measure the brightness of the variable star at the time that you are observing. You might need to refer to a star atlas or chart software to find the area covered by the chart initially. On the charts of widest sky coverage, there will usually be at least one star identified that you can locate on your star chart or using star chart software.

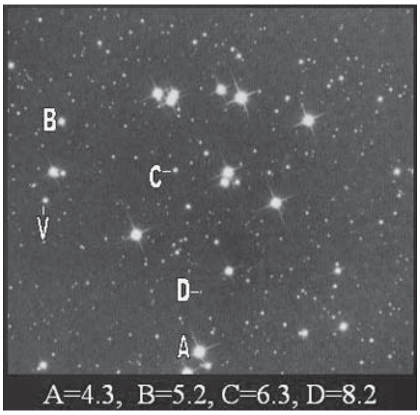


Figure 7. An image for the demonstration of the fractional method of estimation.

Because there is a real art to good chart generation, it is vitally important that you use BAA charts wherever they exist. Comparison stars are chosen taking many factors into consideration. Clearly it is important that as far as possible they are known to be non-variable, but good comparison stars are also selected by their colour, and a star that is a good comparison star for one variable, may not necessarily make a good choice as a comparison star for a different variable star. The VSS Chart Secretary, assisted by many other people, has built a wealth of experience in this field, and is now working with international variable star organisations to integrate the combined knowledge and expertise of all concerned, and to standardise as many sequences internationally as possible.

Estimating magnitudes by the fractional method

Imagine that for the image shown in Figure 7, with the stars labelled as shown, we are given the following sequence: A=4.3, B=5.2, C=6.3, D=8.2.

In order to estimate the brightness of our variable star, marked V on the image, then we need to compare the brightness of the variable (V) with the brightness of the comparison stars. If we do this with each of the stars in turn, you can see from the image that it is clear that star A is much brighter than the variable, V; star B is a bit brighter; star C is slightly fainter than V; and star D is much fainter. In this case, we would choose to use stars B and C to compare the variable against, because one is a little brighter, and one is a little fainter than the variable.

You then need to look alternately at the stars, B, V and C, and try to determine the ratio of the brightness differences. I like to imagine the brightness scale as a line drawn on paper, in this

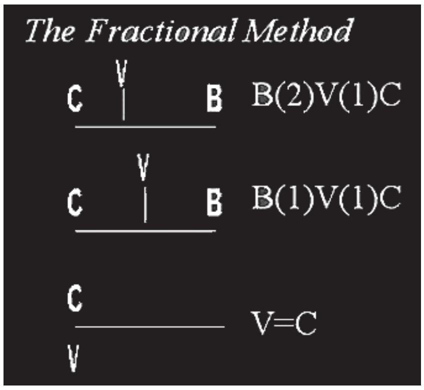


Figure 8. Imagine the comparison stars' brightnessess on a scale, and try to position the variable star some way between the two.

case with star C's brightness as the faint end of the line, and star B's brightness as the bright end of the line.

Then you need to try to decide where on the line, the brightness of V should be positioned. I believe the trick here is to try not to think too hard about this, or analyse what you're doing too much; just make a decision based on your instinct. Humans can do this surprisingly well. The main thing is to find out how this process best works for you, and then stick to it. Then you need to translate what you have drawn into words that will record your observation. If you think that the variable star brightness is one third nearer to C than to B then write B(2)V(1)C; if you think that the variable's brightness is exactly mid-placed between B and C write B(1)V(1)C; and if you think that V is the same brightness as C then just write V=C.

Now we need to convert this record into a magnitude. Take the estimate B(2)V(1)C: V is one third nearer to C than B, so we need to work out the difference between B and C, and split this into thirds. The difference between B and C is $6.3 - 5.2 = 1.1$. One third of this is 0.37. So V is estimated to be $6.3 - 0.37 = 5.93$. Instead, we could have worked this out by adding two thirds of the difference between B and C from the brightness of B $[5.2 + (2 \times 0.37)] = 5.94$, and we would have got the same answer. Magnitudes should be rounded off to the nearest whole fraction.

The Pogson method

This is a different method of estimation in which you compare the variable against only one comparison star, and try to judge the brightness difference between the variable and just one comparison star in steps of tenths of a magnitude. It is an essential technique for occasions when the variable star has become fainter than the faintest star that is on its sequence, for example.

So if the variable were judged to be two tenths of a magnitude fainter than a comparison star A, for example, then we would write this down as A–2. If the variable was one tenth of a magnitude brighter than B, we would write B+1. Again, we can write =B, if we think the variable has the same brightness as comparison star B.

If you find it difficult to judge tenths of a magnitude steps, try using a variation on this method called the Herschel–Argelander method, which is very similar, but instead of using steps of 0.1 magnitude, you use the smallest step that you can confidently detect instead.

Negative observations

Remember that if you cannot see the variable star on a particular night, it is important to make, and report, a negative observation. You do this by recording the faintest comparison star that you can see, and recording that the variable star is fainter than that star: e.g. V < F, where the magnitude of the variable is less than that of comparison star F. This provides an important upper bound on the brightness of the star at the time of observation, so that if the star is seen at a much brighter magnitude the following night, in outburst, more precise limits on the time of onset of outburst can be calculated using your negative observation, together with any others that were made.

Minimising errors

There are a number of important factors that you should remember, in order to minimise the number of errors that are made:

- Allow 15–20 minutes for your eyes to become fully dark adapted before observing. This is important because the spectral response of your eye when fully lit, is very different to that when dark, so that estimating a variable that has a different colour to the comparison star that you are using whilst your eye is not dark-adapted, may result in a different estimated value to that which you would obtain once the eye is fully dark-adapted.
- Take care to correctly identify the variable and comparison stars; estimating the wrong star is one of the commonest errors that is made in variable star observation.
- Take care to record observations correctly.
- Try to avoid plotting light curves or learning of others' estimations of the same star on the night you go out to observe, as this may bias your results.
- Avoid observing when tired or ill, or after a few pints!
- Make multiple estimations using different sets of comparison stars if you are keen to be very precise, and take the mean of the result. This is particularly useful when using the Pogson method.
- Avoid making estimations at low altitude, or through cloud or haze.
- Bring each star, variable and comparison to the centre of the field of view to minimise errors that depend upon the star's position in the field of view.

Factors that affect your estimation

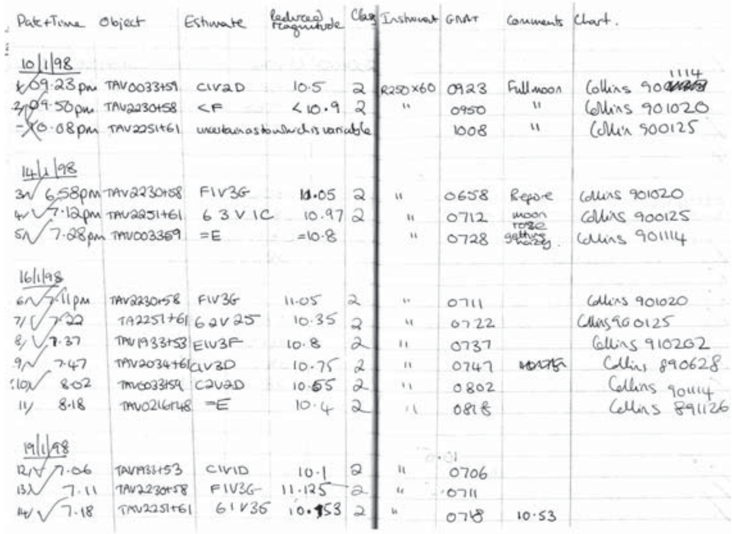
There are many factors that may affect your estimation, and whilst you may not be able to do anything about some of these, it is as well to be aware of them:

- The Purkinje effect is a tendency for observers to estimate red stars at brighter magnitudes than bluer stars of the same brightness; try using quick glances instead of long stares, so that the red light has less opportunity to build up on the retina; try defocusing the stars so that they are fuzzy balls of light instead of sharply focused points; try using averted vision, as the edge of the retina is more sensitive to differences in light. Whatever you do, don't try to correct your estimations, just make the best estimate that you can.
- Moonlight affects observations, as it is scattered like sunlight to give the impression of a bluer sky, making red stars look brighter. If possible try to avoid estimating red stars during moonlit nights, if not, just do your best!
- Light pollution may affect estimations; do not use light pollution or other filters, as these filters change the relative brightnesses of the stars depending on their colours. Just make a note on the observation report form, of the fact that light pollution may have affected your estimation.
- Low altitude affects different colours of light differently, and so may affect your variable and comparison differently if they are not exactly the same colour. Try to observe stars at as high an altitude as possible to avoid low altitude effects, and plan your observing session so that as objects come to the zenith they are observed.
- High cirrus clouds can effect your estimation without you being aware that they are there; try to be careful and be aware of such problems.

Recording observations

It is important to make a note of your observation *whilst at the telescope*, together with all pertinent information. Figure 9 shows a copy of an entry in my log book. It gives an idea of the bare minimum of information that you should note down at the telescope. Remember, also, to keep a note of which chart you are using for each star, and to note if your observing location changes for any reason. You should add any comments that you think might be relevant such as the method that you have used to make the estimation, noting if you have used averted vision or defocused to make the estimation, together with any notes relating to bad light pollution, haze, mist or a bright moon. You should also try to judge what class you would give to the estimation that you have made, labelling it as a class 1 observation if it is of the best quality that you can achieve, class 2 for a mediocre estimation, and class 3 for a poorer attempt.

I would suggest, therefore, that the minimum to note in your log book would be the time and date of observation, star name, magnitude estimate, the class of observation, the instrument used, and any comments relating to the observation. Then additionally, you will want to keep track of the chart used, and have somewhere to note the reduced magnitude.



Date+Time	Object	Estimate	Reduced magnitude	Class	Instrument	GMT	Comments	Chart.
10/1/98								
1 ✓ 09·23pm	TAV0033+59	C1V2D	10·5	2	R250×60	0923	Full moon	Collins 90[illegible] 1114
2 ✓ 09·50pm	TAV2230+58	<F	<10·9	2	"	0950	"	Collins 901020
– ✗ 10·08pm	TAV2251+61	unsure as to which is variable				1008	"	Collins 900125
14/1/98								
3 ✓ 6.58pm	TAV2230+58	F1V3G	11·05	2	"	0658	Repore	Collins 901020
4 ✓ 7·12pm	TAV2251+61	6 3 V 1C	10.97	2	"	0712	moon rose	Collins 900125
5 ✓ 7·28pm	TAV003369	=E	=10·8		"	0728	getting hazy.	Collins 901114
16/1/98								
6 ✓ 7·11pm	TAV2230+58	F1V3G	11·05	2	"	0711		Collins 901020
7 ✓ 7·22	TA2251+61	6 2 V 25	10·35	2	"	0722		Collins 900125
8 ✓ 7·37	TAV1933+53	E1V3F	10·8	2	"	0737		Collins 910202
9 ✓ 7·47	TAV2034+61	C1V3D	10·75	2	"	0747	[illegible]	Collins 890628
10 ✓ 8·02	TAV0033+59	C2V2D	10·55	2	"	0802		Collins 901114
11 ✓ 8·18	TAV0216+48	=E	10·4	2	"	0818		Collins 891126
19/1/98								
12 ✓ 7·06	TAV1933+53	C1V1D	10·1	2	"	0706		
13 ✓ 7·11	TAV2230+58	F1V3G	11·125	2	"	0711		
14 ✓ 7·18	TAV2251+61	6 1 V 36	10·153	2	"	0718	10·53	

Figure 9. A copy of a page of the author's log book.

Submitting observations

You then need to convert your log into a record to e-mail to the Computer Secretary (or send it on a disk), so that your information can be added to the VSS archive. You can still send records on paper if you do not have access to a computer, although there are still thousands of paper observations awaiting typing into the archive, so your results will reach the archive more quickly if you can persuade a friend to help you out here!

Before sending your first set of data, you should contact the Computer Secretary who will advise you of the format to be used. He can supply an Excel spreadsheet which greatly speeds up data entry if you have the necessary equipment, but there is also a standard format for manual typing if required.

The data archive

The VSS archive contains over 1½ million visual observations of over a thousand variable stars, with many more observations on paper still to be entered. There are over thirty stars that have more than ten thousand observations each. All this data has been collected by over 940 observers to date. You can view these statistics, and see how the type of object being observed has changed over the years by looking at the VSS Web pages.

Both amateurs and professionals find this data extremely useful. In many cases, these observations are the only measurements that exist of a given star at a particular time, and the data is frequently used for analysis, resulting in publication in professional journals or in the *JBAA*.

Sources of more information

The *VSS Circular* is a quarterly publication which is the newsletter of the Variable Star Section. It is now also available in electronic form, as a PDF file, saving postage costs for our many overseas members. PDF versions of the *Circulars* are made available on the VSS Web pages approximately six months after they have been sent to subscribers.

Circulars include vital information on Section activities such as news about upcoming meetings (as well as summaries of meetings for those who were unable to attend), Pro-Am observing campaigns, and schemes such as the mentoring scheme and CCD Photometry programmes amongst others. It is also a useful medium in which members can share their experiences with others. There have been articles recounting complete beginners' introductory experiences; descriptions of experiments attempting to use standard digital cameras at the eyepiece for photometry, through to articles about spectroscopy and precision photometry. There is an occasional letters page, and regular 'Observer Profiles' articles recounting how members got started in their field, as well as regular news on charts, recurrent objects, and topical thoughts *From the Director*.

In conclusion… Why observe variable stars?

There are so many reasons to observe variable stars. It is simply fascinating to watch stars that are millions of miles away changing, and to learn about these systems from data that is obtained using your own eyes. Your data, when combined with other observers' data can be valuable and unique, and can make a real contribution to science.

Finally, you can hope to make many good friends all over the world through variable star observing. Some years ago, I was fortunate to visit a Japanese observatory for a tour with a keen VS observer. After a short while of struggling, as I did not speak any Japanese, and my host had very little English, I happened to mention a star that I was interested in by name – HT Cas. My host's eye's lit up, and he became very animated; he almost seemed to jump up and down a little as he excitedly repeated 'HT Cas, yes, HT Cas!' And with the aid of a pen and paper, we finally managed to start to communicate a little, comparing notes on our favourite stars.

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