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METHODS FOR THE VISUAL OBSERVATION OF VARIABLE STARS

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The observation of variable stars (often called "variables") can be undertaken by amateurs for simple pleasure, as an educational exercise, as a contribution to serious scientific research, or all of these.

However, be warned. Many people over time and across the world have found the observation of variable stars to be addictive. Of course, the careful study of individual stars is not for everyone, but one of the great things about astronomy is the breadth of activities that an amateur can choose from. If you find that using you eyes to study variables is not attractive, you may consider the measurement of these stars using photoelectric instruments. These may be CCD cameras, or photoelectric photometers with photodiode or photomultiplier tube detectors such as those manufactured by Optec Inc. in the United States of America.

This document is intended to be a brief instruction manual for the visual observation of variables using binoculars and telescopes. Observations can also be made with the unaided eye, but these would be limited to the brightest stars, and the change in brightness of these objects is not great. Therefore, most observers use optical instruments.

Choice of an Optical Instrument

Binoculars are easy to use, there is almost no setup time, and of course you can only observe the brighter variables, but it is therefore easier to find your targets. Most observers use 7x50 or 10x50 instruments (7x or 10x magnification, with objective lenses – the big ones at the front of the binoculars – having a diameter of 50mm). Some observers use more powerful instruments for fainter targets, but binoculars which have a higher magnifying power are larger, and it will therefore be more difficult to hold the field of view steady, unless you use some form of mount.

Finding target stars is particularly easy with 7x50 binoculars, because of the wide field of view (in my instrument, 7.5 degrees). I bought a good quality pair a few years ago, and find using them to be particularly enjoyable. 10x50 binoculars have a narrower field of view, and it may therefore take a little more concentration to find your way around the sky, but you will be able to see and estimate the brightness of slightly fainter stars.

How faint ? That depends on how dark the sky is where you observe, and on your eyes. For a "senior" observer like me, in a suburban site near Brisbane, 7x50 binoculars will take me down to 6th magnitude stars, and at a dark sky site away from the city, 7th magnitude. However, a younger colleague with a good pair of 10x50 binoculars has observed down to 9th magnitude. I also have an 80mm refractor telescope, for observing down to 9th magnitude stars, and I use a 10inch Newtonian reflector on an alt-azimuth (Dobsonian) mount for fainter stars. The Dobsonian mount allows quick and easy slewing of the telescope to find your way around the sky, and to move quickly between variable and comparison stars.

If you have a choice of instruments, the most important thing is not to try to observe stars that are "very bright" for any one of them. It would not be a good idea to estimate the magnitude of a 6th magnitude star with a 10 inch telescope, for example. Your accuracy would suffer, (and bright comparison stars would very likely be outside the field of view). The usual recommendation is to observe stars 1 to 4 magnitudes brighter than the limiting magnitude (the magnitude of the faintest star that you can see) of the instrument. Experience will give you a feeling for what is comfortable.

Finding Variable Stars with “Go To” Computerized Telescopes

Many modern telescopes are computerized, with a “go to” function, allowing the user to key in the identity of the target, and then to sit back and watch as the telescope swings toward it. If you wish to find variable stars this way, I recommend that you create a chart with a reasonably bright “finder star” near the variable, and that you programme the telescope to go to that bright star first. Unless you have a very expensive setup, your target may not be in the centre of the field of view, and if that is the case, having a bright, easily recognizable target makes life easier. Once you are near the variable, consult your chart and find the variable by moving the telescope manually. The problem with trying to let the telescope slew to the variable itself is that the field may be crowded with stars, the variable will be of similar magnitude to surrounding stars (i.e., it won’t stand out), there may not necessarily be an easily recognizable pattern of stars (asterism) near the variable, and you may waste time trying (sometimes with no success) to reach your target. This advice comes from personal experience.

Finder and Comparison Star Charts

A finder chart allows you to identify a star, or, if it is faint, brighter stars in its vicinity to help you get orientated. For the brightest stars, the finder chart may also be the comparison star chart, which will show the variable and stars near the variable with numbers beside them, such as 59, 70 and 103. The stars so numbered are comparison stars (sometimes called "comp" stars), and the numbers refer to their magnitudes. The magnitudes are shown with the decimal places omitted, so that they cannot be confused with faint stars. Thus, 59 is magnitude 5.9, 70 is magnitude 7.0 and 103 is magnitude 10.3. If the variable is rather faint, more than one chart may be needed to allow easy "star hopping" to find it. In general, finder and comparison star charts for fainter variables will cover a smaller field of view. I usually print my own finder charts from one or other planetarium programme on my home computer, and find it a good idea to show stars on the charts as faint as the limiting magnitude of the instrument through which I observe that field.

If you use binoculars or a Newtonian reflector telescope, use charts in which north is up, and west is to the right (i.e., west is 90 degrees clockwise from north) - the same orientation that you see in those instruments, and with your unaided eyes. Of course, the view in the telescope will be inverted (upside down), but otherwise the orientation is as stated.

If you use a refracting telescope or a Schmidt-Cassegrain telescope, use charts in which north is up, and east is to the right (i.e., east is 90 degrees clockwise from north).

If you use a refracting telescope or a Schmidt-Cassegran telescope, and your eyepiece is inserted into an erecting prism, use charts in which north is up, and west is to the right.

Organizations that foster the observation of variable stars (see below) produce comparison star charts. The use of these charts standardizes the comparison stars that are used to make estimates of the magnitudes of the variables. The use of these charts, with "official" comparison stars, is encouraged.

Making Estimates of the Brightness (Magnitudes) of Variable Stars
1. Variable Stars and Comparison Stars

The principle is to compare the variable with two comparison stars, one slightly fainter (preferably no more than a few tenths of a magnitude) and one slightly brighter than the variable. Then, try to estimate if the brightness of the variable is about half way between those of the comparison stars, or if it seems to be closer in brightness to one comparison star than the other. Figure 1. below is a cartoon depicting three "stars". A is the brighter comparison star, B the variable, and C the fainter comparison star. The diameters of the black circles represents the relative brightness of the stars.

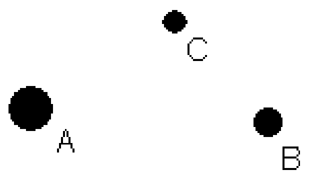

Figure 1. Cartoon to illustrate the comparative visual brightness of a variable star (B) with a brighter comparison star (A) and a fainter comparison star (C).

B looks fainter than A, but brighter than C. The thing is, how much fainter than A, and how much brighter than C? To answer this question, it may be useful to imagine the brighter comparison star, the variable and the fainter comparison star on a straight line. Then imagine that the differences in magnitude between the bright comparison star and the variable, and the variable and the faint comparison star can be expressed as one or more steps. For example, suppose that we think that the following is the situation:

COMP1 (1 STEP) V (1 STEP) COMP2

That is, we think that the difference in brightness between COMP1 and the variable is the same as the difference in brightness between the variable and COMP2.

This is better illustrated with an example, in which the magnitude of COMP1 is 5.1, and the magnitude of COMP2 is 5.5. Application of the above expression yields:

5.1 (1 STEP) V (1 STEP) 5.5

But the usual way to express this is:

5.1 (1) V (1) 5.5

We calculate the magnitude of the variable as follows:

There are two brightness “steps” between COMP1 and COMP2. The ratio of the steps is 1:1, and the brightness of the variable is ½ of the way (1 step) between the brightnesses of COMP1 and COMP2 (which are 2 steps apart). So, with the COMP1 magnitude being 5.1 and the COMP2 magnitude 5.5, the difference is 5.5 – 5.1 = 0.4 magnitude. The magnitude of the variable is ½ of that difference fainter than COMP1 (remember that the higher the magnitude figure, the fainter the star – a 5.5 magnitude star is fainter than a 5.1 magnitude star). The calculation is therefore as follows:

Variable = 5.1 + (1/2x0.4) = 5.1 + 0.2 = 5.3

This is probably easier to understand on a visual analogue scale, where 5.1 is the magnitude of COMP1, 5.3 is the magnitude of the variable V, and 5.5 is the magnitude of COMP2:

5.1 5.2 **5.3** 5.4 **5.5**

This example can also be used to illustrate the principle that each “step” can be of any magnitude range, and therefore can be defined however you wish. So, the “step” from 5.1 to 5.3 can be thought of as 2 steps, each of 0.1 magnitude. Similarly, 5.3 to 5.5 can be 2 steps of 0.1 magnitude. When magnitude differences are small, using 0.1 magnitude as a step can sometimes be convenient.

Lets look at another example.

5.1 (2) V (1) 5.8

Here there are 2 + 1 = 3 steps between COMP1 and COMP2
The ratio between the two steps is 2:1
The variable is thus estimated to be 2/3 (i.e., 2 steps over 2+1=3 steps) of the way between the brightness of COMP1 and the brightness of COMP2.
Magnitude of COMP2 – magnitude of COMP1 = 5.8 – 5.1 = 0.7
2/3 of 0.7 = 0.46
Magnitude of variable = 5.1 + 0.46 = 5.56
After rounding up, the magnitude of the variable is reported as 5.6, since it is usual practice to report a visual estimate of magnitude to the nearest 0.1 magnitude.

If the result of a calculation yields a figure such as 6.55, simply round off, and report the magnitude as 6.5.

In practice, if the magnitude differences between the variable and the comparison stars are quite small, I simply conjure up a mental image of a visual analogue scale, and estimate the magnitude of the variable directly.

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2. Observational Techniques

It is obvious that you need to look at the variable star, and look at each of the comparison stars that are relevant to a particular estimate. Start by comparing the variable quickly with nearby comparison stars. You will soon realize which of the comparison stars are brighter, and which are fainter than the variable. Don't try to make any quantitative estimates at this point, as the aim is to select two comparison stars, one which you can see is just brighter and one which you can see is just fainter than the variable. You may at this point find that the variable star is indistinguishable in brightness from one of the comparison stars. If that is the case, find two more comparison stars, one fainter and one brighter than the first one, just to check that the variable is indeed between these two. But if you are confident that the variable looks identical to one of the comparison stars, then the magnitude of that comparison star becomes your estimate of the magnitude of the variable.

However, you will often have to study the variable and two comparison stars, one brighter and one fainter than the variable, and at this point you must now do this carefully. If the variable and the comparison stars are in the same field of view, you can, if you wish, hold the binoculars or telescope steady, and move your eye(s) from one star to another. If you do this, it is recommended that you draw an imaginary line between the two stars that you are comparing at any one moment, and make that line parallel with a line joining your two eyes. This procedure will result in some gymnastics if you try to carry it out properly, so be careful if you need to use a ladder to reach the eyepiece of your telescope! Start with one of the comparison stars and the variable, and flick your eyes from one to the other and back again, looking at each star for only 1 to 2 seconds. You will gain an impression of the difference between the two stars. Now, do the same thing with the other comparison star and the variable. After doing this, you may be able to judge if the variable is closer in brightness to one of the comparison stars than the other. You may have to repeat the observing sequence until you are confident about your observations. I have personally found this method to be awkward to apply rigidly, because of the necessity to twist my head around to line up the stars as described. Therefore, I usually use the another method – which is to bring each star into the centre of the field in turn to observe it.

When I first read about the latter method, I thought that it would be very difficult to carry out. In fact, I found that it allowed me more easily to distinguish between stars that differed by only a small part of a magnitude (e.g., 0.2 magnitude). What I do is this. Bring the variable into the centre of your field of view, look at it for 1 to 2 seconds, look away to the dark sky for a second, look at the variable for 1 to 2 second, and repeat this sequence several times until you feel that you have a "visual memory" of the brightness of the star. Now bring a comparison star into the centre of the field and repeat the procedure of alternately looking at the star and at the nearby sky. You should be able to detect a difference. After repeating this with the variable and the other comparison star, you may be able to judge if the variable is closer in brightness to one of the comparison stars than the other. You may have to repeat the observing sequence until you are confident about your observations.

My personal experience is that it requires some persistence and practice to feel reasonably confident with your estimates. Don't be discouraged if you don't make perfect estimates on your first night out. Keep trying, and I think that you will find that your skill will develop.

Optimizing the Accuracy of Your Estimates

First of all, avoid errors. Ensure that you identify the variable and the comparison stars correctly, that your judgment of the relative brightness of the variable and the comparison stars is as good as you can make it, and that you take care with calculations of the type we have just described above.

Accuracy of estimates will be improved if the magnitude difference between the relevant comparison stars is small, ideally only a few tenths of a magnitude. If the difference is greater than one magnitude, it will be more difficult for most observers to make accurate estimates. It is not always possible to achieve the ideal, particularly in parts of the sky away from the plane of the Milky Way, where the numbers of stars of any magnitude that you could see in the field of view of your instrument may be quite small.

Be aware of the colours of the stars that you observe. The Johnson-Morgan B-V colour index is most widely used. Blue stars have negative indices (e.g., Rigel has a colour index of -0.03), and orange to red stars have a much higher colour index (e.g., 2.5 or higher). It is ideal if the colour of your comparison stars is close to the colour of the variable. This is possible for some variables, such as eclipsing binaries, but it is not possible, for example, for Mira-type long period variable. By their very nature, Mira variable are red, and most very red stars are variable! Therefore, comparison stars for most long period variables will be bluer than the variable.. Why is this important? The response of the human eye to the red end of the visual spectrum differs considerably among visual observers. Two observers with different red responses may differ in their estimates of the same star by several tenths of a magnitude. In my personal experience of observing V Crucis, another observer and I differed by up to one magnitude.

How accurate can you be? With practice, your estimates may differ by no more than 0.2 magnitude from the actual figure. How can you determine this? A good way is to choose some star fields, select stars that are NOT variable, make observations of the sort described above, then go to your planetarium programme and note the measured magnitudes of the stars. The magnitudes in the Bright Star Catalogue (stars down to 6th magnitude), and the Tycho-2 Catalogue (for stars down to 10th or 11th magnitude) are generally good enough for checking visual estimates, and for assigning magnitudes to comparison stars.

Organizations that Foster the Study of Variable Stars

There are organizations around the world that have members and contributors who submit the results of the study of variable stars, and these results are archived in databases. The two organizations I wish to note here are the American Association of Variable Star Observers (AAVSO) and the Variable Star Section of the Royal Astronomical Society of New Zealand (VSS of the RASNZ).

The URLs of these two organizations are:

http://www.aavso.org

http://www.rasnz.org.nz

On the RASNZ web site follow the link to “RASNZ Sections” and then the link to “Variable Star”.

Both of these organizations provide comparison star charts for variable star observers, and have very large databases of variable star observations, which can be accessed by interested observers. In general, the AAVSO has more content online, including a facility to create light curves in real time from stored data (including very recently submitted data), and a facility to download validated data on any variable star in the database. One particularly fascinating aspect of the AAVSO light curve generator is that you can instruct the interface to highlight the observations that you have submitted to the AAVSO, so that you can see how your observations compare with those of others. If you submit your own observations online through the interface known as Web Obs, they will be available for you to see often within 15 minutes. An example of output from the AAVSO light curve generator, with a user-selected format, is shown below in Figure 2.

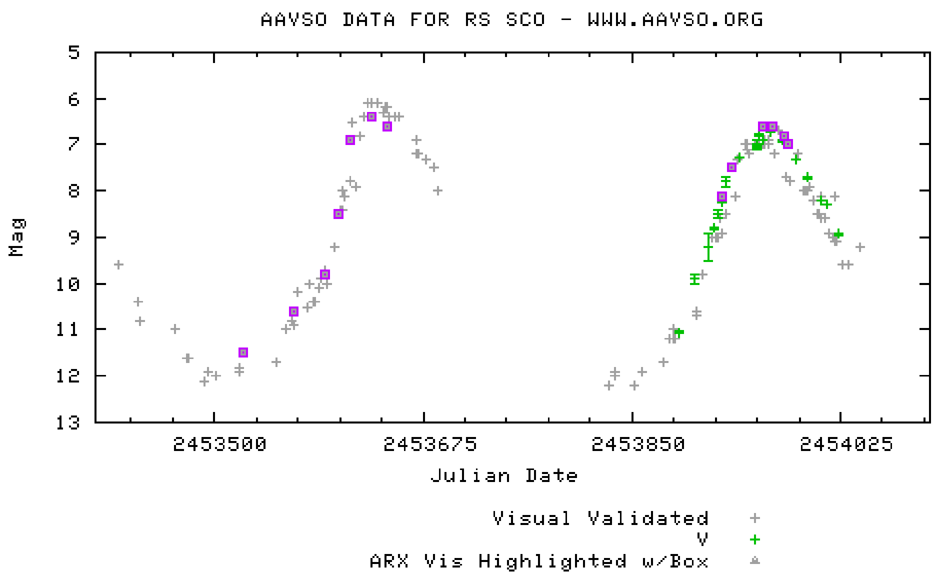

Figure 2. Example of output from the AAVSO light curve generator. Visual observations are grey plus signs, photometric observations are green plus signs. My visual observations are highlighted by purple boxes.

Conclusion

I have found considerable pleasure in making estimates of the magnitudes of variable stars, and plotting light curves of my own observations. I think it is amazing that we can see, with our own eyes, using small optical instruments, the effects in the visible part of the electromagnetic spectrum of complex astrophysical phenomena in immense bodies of gas enormous distances from this planet.

Clear skies!

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