Observing variable stars with binoculars

by Melvyn D. Taylor

Workshop No. 3: York 2003 September 6

Introduction

One of the finest aspects of visual observing is freely roaming around a dark night sky picking out galactic and solar system bodies, noting patterns of stellar hues and brightness. The binocular is an ideal tool for this pursuit. Use of two eyes, the natural state, is relaxing, easy and relatively quick, although for optimum night-time observing the eyes have to adapt to the conditions which does take time.

Whether observing as a beginner or a more experienced astronomer, binoculars are useful in many areas; eclipses, lunar occultations, comets, meteors, asteroids, deep sky, artificial satellites, novae hunting and variable stars. The BAA Variable Star Section, formed in 1890, has in its database around 1.6 million observations available to amateur and professionals. Programmes of observation include long-standing telescopic and binocular variables, also a list of recurrent variables, a set of eclipsing binary stars and an important area called the 'new variables' based on those stars which Mike Collins has found and which require follow-up work.

Types of programme stars

Apart from some variables which defy being 'boxed' there are four major classification groups, described as eruptive, pulsating, cataclysmic and eclipsing. The subtypes are many and differing forms of variation may be occurring in a single star or a stellar system. The main classes and subtypes (abbreviated) of variable suggested for binocular use are: Eruptive (GCAS, RCB), Pulsating (M, SR, RV), Cataclysmic (N, NR, ZAND), Eclipsing (subtypes EA, EB, EW). The General Catalogue of Variable Stars (GCVS) and Information Bulletin on Variable Stars (IBVS) are the source for descriptions of the categories. Dependent on an individual's interests the longer period (interval between successive maxima) objects may be more appropriate for observers with limited time to spend. Those with lots of spare time available may choose eclipsing binaries that show an eclipse in one night; these objects require an estimation of the magnitude every 10 to 15 minutes around the time when an eclipse is predicted. In general the frequency of clear skies will also prove important in selecting the type and number of variables to follow. The basic visual observation is an estimate of the star's magnitude as compared with 'standard stars' at that time.

Time and magnitudes

Time to the nearest minute, from an accurate source, is normally required and it is useful to have a standard clock, for example, the Rugby MSF (60 kHz) receivers may be acquired as wall clocks or wrist watches. The signal from Mainflingen DCF77 on 77.5 kHz is also being used in similar timepieces. For most purposes time is best recorded in Universal Time, that is British Summer Time minus one hour. Universal Time abbreviated UT (or Greenwich Mean Time, GMT) beginning at midnight is used in nearly all astronomical records. Some observers specialising in eclipsing binaries use the Greenwich Mean Astronomical Time (GMAT) system that can be confusing in relation to the date, as it commences a new 'day' at noon.

In the 1850s Norman Pogson (1829–1891) instigated the modern definition of a stellar magnitude scale and a fixed ratio of 2.512 corresponding to one magnitude difference. Five magnitudes therefore relate to a ×100 change of brightness. Visual magnitude differences of the comparison 'standard stars' may be appreciated by habitual and systematic observing using a particular specification of binocular. In general, the naked eye under a very clear sky could detect stars to a magnitude of 6.2, a typical 50mm binocular with similar conditions may allow magnitude 10.5 objects to be seen but these values are unlikely in practice (Table 1).

Table 1. Theoretical limiting magnitude, resolution and magnification for different binocular apertures

Aperture (mm)	*Limiting magnitude (2+5logA)*	*Limiting magnitude (90% effic.)*	*Resolution (arcsec)*	*Magnification for exit pupil of 5mm*	*Magnification for exit pupil of 8mm*
20	8.5	7.6	5.8	4	2.5
25	8.9	8.1	4.6	5	3.1
30	9.4	8.5	3.9	6	3.7
40	10.0	9.0	2.9	8	5.0
50	10.5	9.4	2.3	10	6.2
60	10.8	9.8	1.9	12	7.5
70	11.2	10.1	1.7	14	8.7
80	11.5	10.4	1.5	16	10.0
100	12.0	10.8	1.2	20	12.5
125	12.4	11.2	0.9	25	15.6

Figure 1. Three low power binoculars. *Left to right:* 8×40 Swift Trilyte (roof prisms), 3×20 opera glass, 8×42 Opticron (porro prisms).

Binocular basics and the eye

The basic binocular specification such as 8×30 or 10×50 has the power first, the number of times an object is magnified. The second number is the diameter in millimetres of the front lenses, the aperture. Large objectives are for fainter stars and more detailed views. Comparing a 10×40 with a 10×70 the larger collects 70×70/ 40×40 or 3.0 times more light, so objects appear 1.2 magnitudes brighter. A table of fairly common specifications is given as a guide only. The choice of binoculars will involve the observer's interest(s) and age, conditions of use (e.g. if from a dark or polluted site), aperture, magnification, body design (handling appeal), weight and the cost.

Size of the binocular exit pupil, that is, aperture in millimetres divided by the magnification, is likely to be the critical factor since it is important to try to match this with the observer's eye pupil under working conditions. The eyes will give the clearest detail operating in the range 2mm to 5mm, their normal size during daylight. Andrew Langley's comments (BAA *Journal*, 2004 April) on visual acuity in relation to the exit pupil are well worth noting. Maximum pupil size may be 7mm to 8mm but the aging process will reduce this to about 4mm or 5mm. There is an approximate relation of 0.35mm reduction per 10 years as suggested in *Sky & Telescope*, 1992 May. Sky Publications market a small device that allows the pupil size to be measured. Ten or more minutes after going outside the eyes will have adapted (but not fully) to darker conditions and faint objects and stars will be apparent. Shine a bright white light on a chart or open the 'fridge' door and this will immediately decrease the pupils' size – faint stars will now be lost to view. A dim red light will have a less dramatic effect since night-time response to this wavelength is not so adverse and dark adaptation can be restored without it being lost completely. A torch's white light covered with red paint or cellophane is an essential item for visual observers. Those troubled by stray lights often use a black cloth placed over the head and eyepieces to help cut down side reflections. Binocular eyepieces with rubberised side guards are particularly handy in these circumstances and may help larger apertures to be steadied.

Shape of the binocular for hand holding is important and before purchasing, different models should be compared and examined visually and mechanically. A one-piece (American styled) barrel design is inherently tough, a genuine Zeiss style (H profile) which has a two-piece body is also strong. Bird-watching and photographic suppliers of small telescopes and binoculars vary in their sympathy to an amateur astronomer keen to critically inspect their wares so it is probably wise to inform them of the quality expected.

Binocular parts and choices

Most binoculars have the angular field of view or its dimensional cotangent inscribed on the body housing as a number of feet seen at a distance of 1000 yards. (1 degree of arc or two lunar diameters approximately corresponds with 52ft at 3000ft). For a true binocular field of 5° on an 8×30, the apparent field is 40°. A simple check on the true field of view is useful and this may be simply done by finding two stars that fit across the circle diameter and then check the celestial spacing in degrees and minutes of arc from the scale of a star atlas.

The hinged bridge that gives the eyes access to the eyepiece centres should be smooth and capable of staying in the required position. The two circular fields of view should merge into one if both optical barrels are aligned correctly and for all positions around the hinge. Poor collimation is a bad sign and if used persistently without being properly recognised it could affect one's eyesight. It should be possible for an optical specialist to amend this fault but the cost may well be a large proportion of its original value. Large and heavier binoculars that have a long rod extending from the hinge base to a support bridge nearer the objectives are guarding against distortion and bad collimation.

Figure 3. Exit pupils (4mm) of a 20×80 binocular *(courtesy Leeds AS)*.

Waterproofing of the binocular is an added bonus since repeated temperature and humidity changes cause condensation and mould to affect the internal parts. Over time with use and possibly the odd accident, optical degradation of stellar images will occur probably due to the prisms moving or coating corrosion. A suggestion for anyone with ideas about multiple use (daytime and night-time) would be to own two binoculars so the astronomical one is kept for that purpose only.

In quality binoculars all air-to-glass surfaces are fully multicoated, which means that ghost images and internal reflections are reduced. The technique of depositing optical coats on polished glass began in the 1930s. The best coatings can be judged by looking down on the objective with a hand over the eyepiece and examining reflections. A totally white reflection means an optical surface is not coated. Multi-coatings reveal reflections that are noticeably fainter. Checking for blemishes on the optics by turning the binocular around and inspecting the objectives against various lighting angles is a useful task. Looking at a thin vertical or horizontal element (a radio mast, or an aerial) through one barrel at a time should display minimal curvature and little false

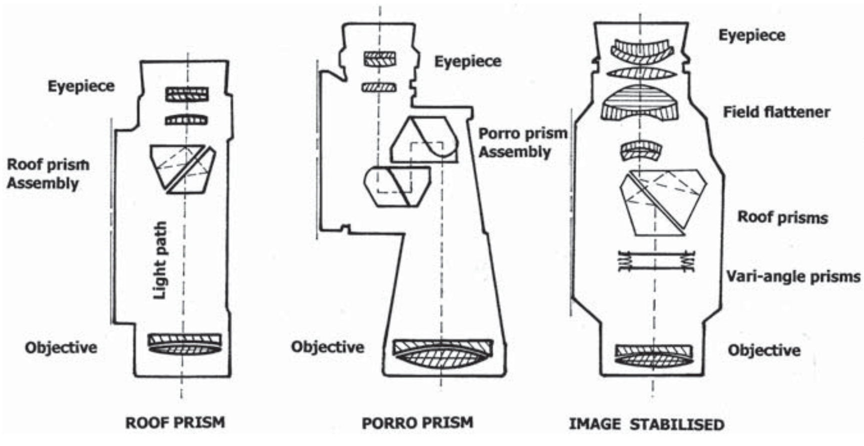

Figure 2. Cross sections and light paths of different binoculars *(Melvyn Taylor)*.

Figure 4. 16×70 Swift fixed to tripod head with angle bracket screwed to end of prism housing.

colour to its edges. The eyepiece coatings are also worth checking. Quality lenses including the eyepiece design and fully multi-coated optics with BAK-4 prisms (light crown) are superior to BK7 (borosilicate) prisms bearing in mind relative cost of the type and body style. If the binocular is aimed at a bright background and is held about a foot away the bright exit pupils should have a dark or black surround and no internal parts should be visible.

Eye relief relates to how far the eye may be from the eyepiece and still see the full field of view. Observers who have astigmatism and use spectacles will need a long eye relief; those who have near or far sight normally take spectacles off and focus without any thought. The modern focusing mechanism is to have the left eye adjusted first by the wheel, with this one then shut (or objective capped) the right eyepiece is turned on its housing and the focus refined. This technique also corrects for different eye strengths. However, a binocular that has individual eyepiece focus could be considered slighter superior mechanically

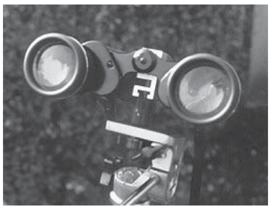

Figure 5. 8×40 Hoya fixed with a screw V-clamp around focusing spindle.

and optically. A wheel centre focus that turns both eyepieces at once is fast, individual ones a bit slower. Long dewshields extending from the objectives and large enough not to lessen the field of view will reduce reflections into the objective lenses, assist seeing faint objects and delay dew forming on the glass.

Figure 6. Modified car seat with steel bracket for binocular housing (courtesy *The Astronomer, John Hosty, Peter Madej*).

Free or fixed binoculars

A magnification of up to about ×10 if hand held and steadied may give suitable views, but over ×12 a stellar image will be 'jittery' and it is advisable to have the binocular secured to a mounting for critical observations. There are two commercially made clamps that connect a binocular to a photographic tripod, the view will then be superior to a hand held one, fainter objects will be seen better and you are hands free. A screw connection in the base of the hinged bridge is a better position than one to either of the barrels. Several large binoculars use a centre bar with sliding clamp that is screwed into the tripod mount.

There have been a number of mountings devised on an individual basis by binocular specialists with balanced/stabilised ones available from instrument suppliers. A sturdy tripod with fittings to mount the instrument in alt-azimuth mode is one method, but for real comfort a chair or recliner with a binocular attachment is potentially ideal. Urban observers hounded by permanently bright night skies may find that a higher magnification will show fainter stars, and in this respect large, custom-mounted instruments with interchangeable eyepieces would be an option. Charts, atlas and a torch or logbook can be used more easily if the binoculars are mounted. Some observers dispense with a record book and use a voice record, thereafter writing the observations directly into a log book or on a computer file for personal use and/or sending to a variable star organisation.

The ultimate test for the casual observer is on focused stars. The changing aspect of a focused star image as the observer takes it across the field of view will make for interesting comparisons – higher quality instruments should show these tiny circlets of light to near the field edge. The technique of bringing variable star and comparisons to the optical centre is a standard method that tends to offset the mercenary comment that follows. Image stabilised binoculars have a reputation for producing virtual pinpoint images from edge to edge, however their higher cost has to be considered in relation to a conventional instrument of larger aperture mounted firmly. Resolving close stellar pairs is an interesting pastime and another check on the binocular performance.

Variable star names

The system started by F. W. Argelander (1799–1875) has, for example, the first-named variable star in Scutum as R Scuti, then proceeding with additional ones to Z Scuti. There were hundreds or thousands more found in particular constellations so after Z, RR, RS to RZ came about.

Figure 7. Orion Telescopes parallelogram binocular mount.

Thereafter SS to SZ, and so on. From ZZ the formation went to double form AA to AZ and so on but J was not used because of its similar character shape to I. The double lettering to QZ provided for 334 designated variables. Identifying and naming additional objects then started at V335, in every case followed by the genitive form of the constellation or its accepted abbreviation. The 88 constellations have standard short forms using three letters, for example, V465 Cas (or in full Cassiopeiae).

Charts and sky scale

The Variable Star Section observing charts use an analogy of stellar magnitude differences by the commonly used procedure of showing brighter stars with a larger diameter in comparison to fainter ones. Night-time stellar observers are looking at the smallest of tiny circles of light as defined by the diffraction of light across the objective's clear diameter. By placing the

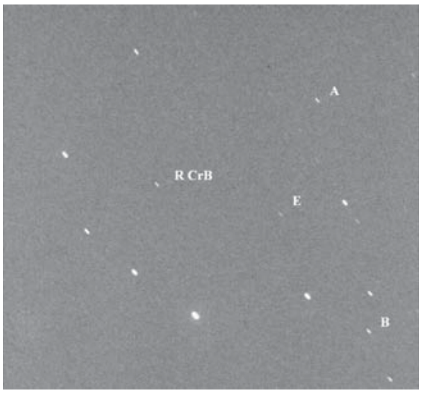

Figure 8. 5° square field (long exposure) of Corona Borealis with R CrB and three comparison stars.

comparisons and variable into a brightness order sets of observations made at differing times allow a light curve to be drawn. By plotting a series of magnitude estimates with smaller values (bright) at the top of the y-axis and time on the x-axis the basic properties of the star's period, maximum and minimum brightness are displayed. With many light estimates from a team of observers the analyst is able with suitable data to confirm or refine these values making the results available to other scientific users. Period analyses on VSS programme stars UU Aur, U Boo, RX Boo, ST Cam, W Cyg, VY UMa have appeared in the BAA *Journal*.

It is very useful to have access to a star chart or software to print large areas of sky with bright stars that are then used in conjunction with a variable star chart. The charts include the right ascension and declination of the variable, and a guide to the scale of the chart, usually either 18°, 9°, 3° or 1° size plots. In order to assist in finding objects the chart has an arrowed marker to the north-south axis.

One of the first steps is to hold the chart so that its north-south marker is approximately aligned with the north pole star, to appreciate the chart's orientation. How large or small things appear on the sky, the scale, is not easy to grasp at first. A degree of arc, about twice the lunar size, is shown as a bar on the chart so it may be compared with the observed field size. A typical 10×50 binocular field of view is 5° across the diameter, so ten Moons will fit in the circle. Finding an object for the first time may take some effort but it is essential to identify it with certainty so it is worthwhile cross-checking, going back and forth between the chart and sky.

Estimating brightness – the basic methods

The variable is compared in brightness with usually at least two of the (fixed brightness) comparison stars, one brighter and the other a little fainter than the variable. Glance from one comparison to the variable centring each in turn until a brighter and fainter one are definitely found. The process of light estimation may go as follows using what is known as the fractional method. The brightness of the variable is placed mentally between that of the two comparisons, labeled, say A and C. This difference is divided into small number fractions such as 1/2, 1/3 and 1/4. If the variable's brightness looks 1/3rd of the way from A to C then the light estimate is placed in the observer's log as A(1)V(2)C. The brighter comparison is always written first as a matter of convention, with V being the variable. It may be that the variable looks equal in brightness to comparison B and so it is written, simply =B. Leaving nothing to memory light estimates are recorded in an observing log dedicated to variables, or an audio recorder could be used. For the visual observer it has become standard practice to record the full estimate as a means of insurance and possible maintenance of the observational data. A comparison star may be found to vary, even on a small scale, so the observation will require amendment if that is possible. Otherwise the work of the observer will be inappropriate to use in further analysis or research.

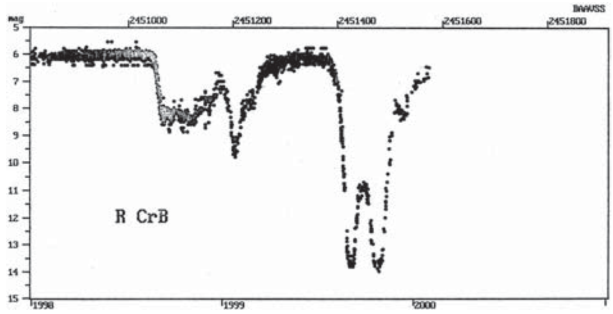

Figure 9. BAAVSS lightcurve for R CrB, 1998 to 1999.

Pogson devised an alternative method of light estimation that in principle requires only one comparison, yet it is always good practice to use another or a third. The variable is compared with brighter and fainter comparisons but with one at a time. By checking the magnitude difference of the comparisons shown on the chart the observer has to judge a difference of tenths of a magnitude. The number of tenths fainter than A and brighter than C are estimated. Say the variable looks 0.2 fainter than A and 0.3 brighter than C, then the observation is recorded as A–2, C+3 with the convention that minus means 0.2 is added (fainter than) to A's value. The plus 3 means 0.3 is subtracted (brighter than) from C's value. The variable's magnitude is deduced as [(7.0+0.2)+(7.6–0.3)]/2 = 7.25, and this is rounded to 7.3.

Observers have used many in-situ experiments to train their appreciation of brightness differences, even assessing differing street lamps at large distances as an exercise(!). A meteor observer may use a set of stars of magnitude 0.0, 1.0 to 5.0 in order to gauge the brightest part of an event seen for a fraction of a second. Variable star observers at least have the object in view for as long as may be required and are required to round the estimated magnitude to a tenth of a magnitude.

Records, errors and reporting

A typical observational record with deduced magnitudes using differing methods is shown below (Figure 11). Often there is no point in reducing the observation to a final magnitude whilst out observing, since this may be done indoors. If there are any other items that may have affected the observation like a nearby Moon, haze/thin cloud or bad sky pollution then a note should be added after

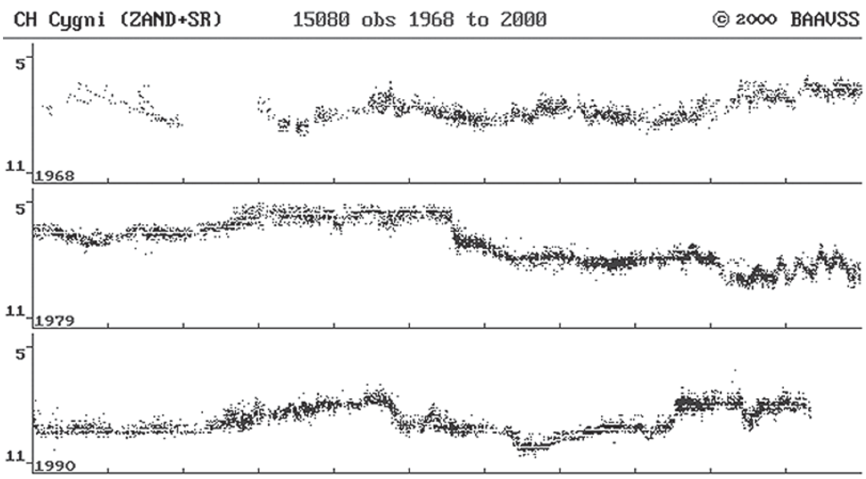

Figure 10. BAAVSS light curve for CH Cygni, 1968 to 2000.

VARIABLE		TIME	LIGHT ESTIMATE	Ded. Mag.	Class	Inst.	YEAR m. d.d.
Des.	Const.	UT/GMAT h. m.					
R	CrB	09 25	C-3	6.1	2	16x70B	2004 AUG 13/14
V	CVn	09 27	G (3) V (4) H	7.4	1	"	
Y	CVn	09 28	=C	5.7	2	8x40B	
V	UMi	09 30	D (1) V (2) E	7.9	2	16x70B	
V1293	Aql	09 33	3 (1) V (4) 4	6.9	1	8x40B	
R	Sct	09 35	H-2 K+3	7.3	2	"	
UW	Dra	09 40	C+4	7.4	3	H "	
Mira	Cet	13 30	G (3) V (1) P	5.2	2	"	
CH	Cyg	13 32	B (2) V (3) F	7.8	1	16x70B	
X	Per	13 35	=A, B+1	6.1	3	H,C "	

Figure 11. A record/log of binocular variable observations with deduced magnitudes *(Melvyn Taylor)*.

the instrument code. Class of an observation refers to the quality an observer gives to it at the time. A Class 1 suggests it was made under the best observing conditions for your site and that it seemed a reliable estimate. A Class 3 means it was just about worth recording, possibly due to being pressured by cloud, light pollution, a nearby Moon or bright planet. Class 2 is obviously in between. Errors are many but a biased estimate is a common one: this is the effect of recalling the last observation of the same star and possibly making a similar light estimate.

A very useful guide to observational errors in variable star observing is seen in *Variable Stars*, Webb Society Handbook vol. 8 by J. E. Isles. Overall advice to guard against errors is to be systematic and consistent in the making of light estimates. Reporting to the VSS is done either on paper reports on a 6-monthly basis or by electronic means to the Computer Secretary on a more regular timescale. The VSS web pages at **http://www.britastro. org/vss** give observers assistance and advice in many areas of variable star observing.

Address: 17 Cross Lane, Wakefield, West Yorkshire WF2 8DA. [melvyn.taylor @breathemail.net]