Trying to Reduce Errors in Visual Estimates of Variable Star Magnitudes

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Introduction

The light-curves of many variables, prepared from a large number of individual estimates by many different observers, have a lot of scatter, ranges greater than one magnitude being common, although it is generally accepted that the eye can detect differences of roughly 0.1 magnitude, at least for stars of moderate brightness. The question arises whether these gross discrepancies can be reduced. We think that this is possible if observers make better use of their observational capabilities.

For certain types of variable stars, e.g. long-period ones, the lack of accuracy may often be balanced by the vast number of estimates available. But for other stars, especially those exhibiting small-amplitude fluctuations, this process of combining observations leads to broad light curves that completely hide any possible fluctuations. Variable-star observers are familiar with these problems, but it is desirable to try to improve the accuracy that can be obtained.

Observational Errors

Apart from purely accidental errors, such as wrong identification of the variable or of one or more comparison stars, there are several sources of error that affect the quality of any visual estimate. These fall into two categories: random errors, which are present in any scientific measurement, and systematic errors, introduced by the measuring device, in this case telescope plus observer.

Random errors tend to cancel out as one considers more and more independent measurements. The r.m.s. deviation is $1/\sqrt{(N)}$, N being the number of measurements made. The origin of systematic errors is less evident, and its reduction depends on a thorough study of the process of estimation. A further difficulty is introduced by the bias on the part of the observer.

These errors can be grouped as follows:

1. observers make estimates with different telescopes (different aperture, power, focal length, eyepiece),
2. observing conditions are different, from dark, clear skies to light-polluted ones,
3. observers use different comparison stars, or different charts with different magnitudes for the stars, and
4. the thoroughness, experience and sensitivity – especially to colour – of observers are not the same.

The most important errors come from points 3 and 4, and they can be removed or at least reduced by using additional pairs of comparison stars, re-assessment of the steps assigned to comparisons, and improvement of charts, along with the usual observational precautions.

Study of Errors

Additional Pairs. The Argelander method is the most popular for estimating magnitudes. By assigning a step to each comparison star in a pair that brackets the brightness of the variable, the magnitude of the latter can be inferred. The step is chosen from a universal scale of steps.

An obvious extension of the Argelander method, sometimes mentioned in the literature but not sufficiently stressed, is the use of additional pairs of comparisons. More observers now use this method because it leads to an improvement in the accuracy by reducing random errors, with little increase in effort and observing time. A more accurate value is obtained by averaging results for each pair of comparisons. This is apparent in the light-curve of SS Cygni in Fig. 1, where dots represent averaged results, but individual estimates lie within the error bars.

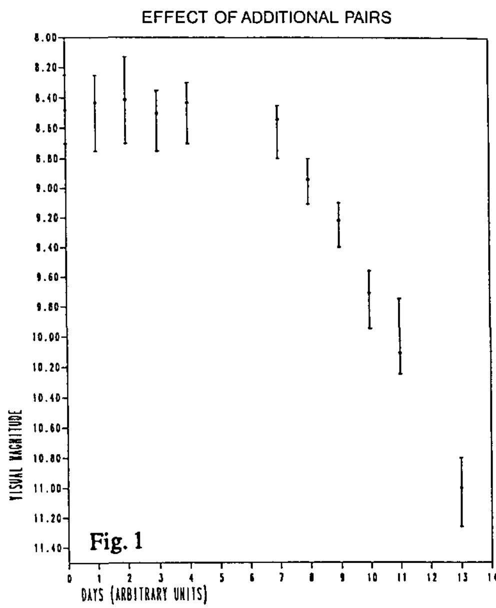

Fig. 1

In the light curve of Fig. 2, important oscillations seen by one observer, who used additional pairs, are missing for another person who did not. Another good light-curve, that of the 1985 fade of R Coronae Borealis, is shown in Fig. 3. Two observers were involved in the measurements, and small-scale departures from the mean curve could be detected.

But not only are random errors reduced with this practice. Sensitivity problems, for example if any of the comparison stars is red, are also diminished, as well as problems introduced by erroneous magnitudes.

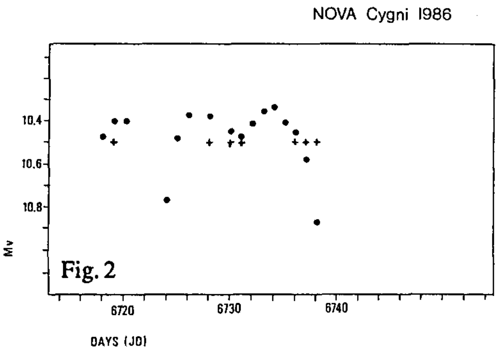

Fig. 2

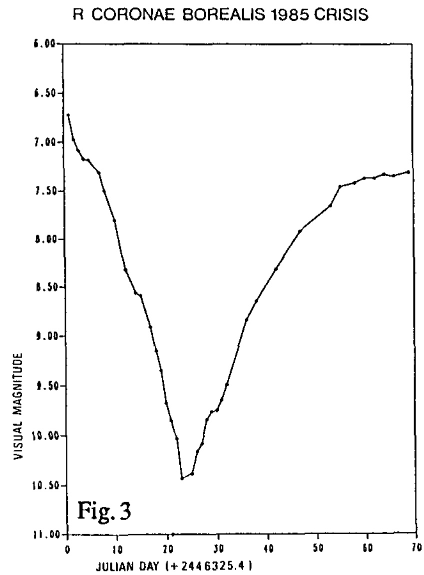

Fig. 3

Re-Assessment of Steps. The Argelander scale of steps is, in principle, universal, but each observer applies it in a different way. No problem arises if this personal interpretation amounts to a simple renormalisation of all steps. However, an observer may like to give large steps only when the difference in brightness between a comparison star and the variable is very large, but that may not apply to other observers. The result is that for that particular observer the estimated magnitude will be lower or greater than the average.

We have devised a simple procedure for performing this personal re-assessment of steps, and we think that every observer should do likewise, looking for consistency between his scale of steps and the scale of magnitudes, which are assumed to be linearly related in the Argelander interpolation formula. If this consistency is not fulfilled, bad results will be obtained.

Comparison Star Charts. The use of comparison star charts with wrong magnitudes contributes in an important way to obtaining false light-curves. Observers often find inconsistencies between magnitudes and observations. This is not strange taking into account that sometimes they use charts drawn decades ago. When inconsistencies appear, and lacking recent photoelectric measurements, estimates of the magnitudes of the comparison stars should be made visually. This can be done from any two or more comparison stars whose magnitudes are known. When measurements from different observing sessions are averaged and the new magnitudes used from then on, better individual light-curves are obtained simply because compatibility between the observer's eye and magnitudes has been reached. For an observer sensitive to red, the use of a red comparison star makes the variable appear fainter than it really is, and therefore it seems convenient to use a magnitude for that comparison star that agrees with what the observer sees. From this point of view each observer is a particular "photometer" and the question arises as to whether it makes sense, strictly speaking, to collect data from slightly different "photometers"

Limiting Magnitude. Finally, there are the effects related to different instruments and observing conditions. These effects are less important than those just mentioned. Some time ago, however, we and other members of our astronomical association observed a possible aperture-dependence. Such a dependence seems established for comets, thanks to the work of Bobrovnikoff and Morris. (Earlier in this Colloquium, however, S. Edberg pointed out some possible flaws in this aperture-correction for comets). Recent studies by Bateson, presented at the 46th Colloquium of the IAU in 1979, did not confirm this for variables.

We undertook a study with telescopes of different apertures. The observing method included the techniques outlined above and also the out-of-focus technique, which is useful in estimating stars that are close in brightness or red. To avoid position-angle problems as much as possible, it is also good observational practice to observe from one side of the telescope and then the other – if using a reflector – to compensate for the uneven response of the retina. The results of our work are shown in Fig. 4. Borrowing an idea from Bobrovnikoff, a linear relation between observed magnitude and aperture was assumed,

$$m_{\text{obs}} = m_{\text{stand}} + \alpha(A - 5)$$

where m_{obs} is the estimated magnitude, m_{stand} is the standard magnitude, defined to be the magnitude corresponding to a previously chosen standard aperture, which in this case was 5 cm. A is the aperture of the instrument in cm. The parameter α is obtained from a least-squares fit. The Figure plots magnitude correction – that is, estimated magnitude minus standard magnitude – versus aperture. A definite trend is apparent: the larger the telescope, the fainter the star. This diagram incorporated several hundred observations made by the authors, spanning about a year. Some observations were taken from the authors' observing programme, not at first intended for use in this particular study. We ruled out red stars in order to avoid colour problems, and used the observational techniques quoted above.

However, we think that a more sensible parameter is the limiting magnitude of the telescope, which depends on both aperture and observing conditions, thus

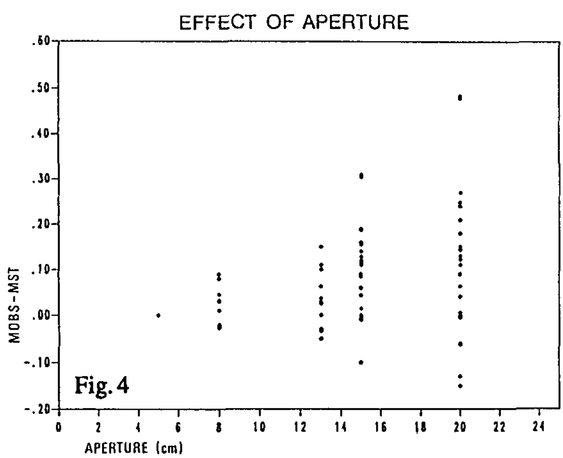

Fig. 4

including several factors in a single parameter. The limiting magnitude is a barrier near which stars are more difficult to observe, but at the same time differences in brightness are more easily detected. Much brighter stars may not be so clearly distinguished. This effect can be seen in Fig. 5, which plots Argelander step versus distance [= Δm − Eds.] from limiting magnitude. For a given difference in brightness between a pair of stars, say 0.5 magnitude, the step assigned to this separation tends to be higher as we approach the limiting magnitude. In theory, at the limiting magnitude, the step would be infinite if one of the stars were to lie on the border and the other below it. Furthermore, a straight line with non-zero slope is seen for values less than four magnitudes above the limiting magnitude, while a plateau is reached for values greater than four.

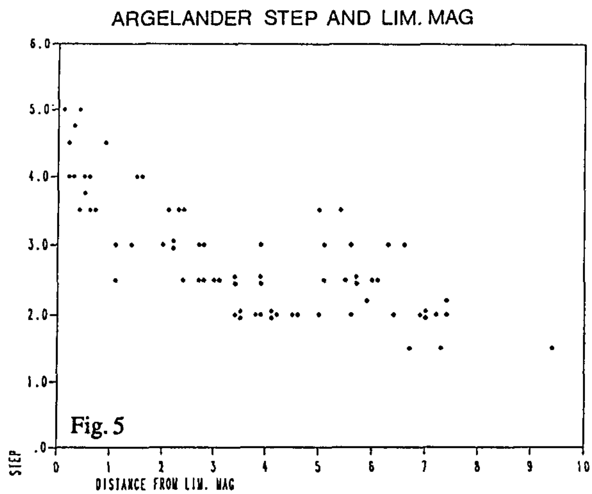

Fig. 5

We are continuing research along these lines in order to see if quantitative information, useful in the reduction of data, can be extracted.

Conclusions

In summary, we would advise observers to make an effort to imporve their estimates. Only in this way will large-scale collection of data be more significant. We speculated that a possible correlation existed between instrumentation plus observing conditions, and observational errors. Careful visual measurements were made to check this hypothesis, but no distinction was made between type of telescope, i.e. reflector or refractor, because we wanted to emphasise the important role played by the limiting magnitude parameter. Special care was taken with the colour of the stars, an aspect that was outside the scope of our study. This work is not free from shortcomings, of course, such as poor statistics, and further study will be needed to clarify the issue.

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