Introducing Variable Stars Without Using Sophisticated Technology

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Abstract Photographs of TV Cas and U Cep taken by students equipped with conventional cameras and mobile, self-made mountings are used to introduce variable stars and, in particular, eclipsing binaries. The first step—by making a simple visual comparison—is to discover that variable stars do exist. The star's brightness change is then estimated by visual comparison with surrounding stars and measured by means of digitized photographs. Plots of luminosity versus time produce a light curve that can be discussed in terms of the star's regularity and periodicity.

1. Introduction

As a science teacher at a high school (7th–9th grade) in Switzerland, there is little chance of plunging into Astronomy, and the vast field of studying observations made by amateur astronomers has to be all but neglected. Nevertheless, there are some occasions where one could do some practical astronomy in workshops freely chosen by interested students. I had the opportunity to introduce the visual observing of binary stars (and Miras) some years ago, and the following is a presentation of my experiences.

2. Is the sky as unchanging as it seems?

The students taking my class were urged to observe the sky visually on a regular basis throughout the semester and hopefully note some changes. Besides the changing view of the night sky due to the revolution around our sun, the moon, and in some cases, the planets, were also recognized as variable elements in the sky. Since the weather in mid-Europe is greatly variable too, there was no chance to observe a certain area of sky frequently enough to actually note variable stars. There was one exception: Mira! It's nearly impossible to match all the criteria for a successful observation of a minimum of an eclipsing binary, however. First of all, you need a fairly bright object (to be observed with binoculars) with a notable amplitude and a short period (students tend to get impatient, too), and a minimum occurring preferably before midnight. Second, you look for a day that most of the involved people—including the teacher!—do not need to attend a sports event, a choir rehearsal, a public meeting, and so on. And last, but not least, there has to be a fairly clear sky in order to be able to find the object every fifteen minutes over a period of four hours! After several attempts I gave up on this.

3. Minima observing in the classroom

Considering these criteria, I came up with the idea to take photos with a 35mm camera and a 200mm telelens, and show the results to my students. On a clear but moonlit sky, I took two-minute exposures of U Cep every twenty minutes on ASA 125 black and white film. The paper copies were presented to the students, and the first task was to discover any changes (Figure 1). After a while I focused on the relevant spot by covering the rest of the picture with a mask. Very soon they noted a single star to be different on the various copies. The next step included the attempt to sort the frames by any useful criterion. Naturally they started to compare the different stars in the vicinity of the variable and they ended up with different solutions since they worked in pairs. After telling them that the brightest state is normal virtually everyone concluded a temporarily dimming of the star. I gave the times of exposure for every single frame so that a light curve could be plotted (Figure 2). The importance of tracking the brightness of a variable star versus time was made clear when we now tried to interpret the data.

4. Attempts of interpretation

What mechanism could be responsible for a huge gas-ball like our sun to change its brightness in this apparently symmetrical manner in such a short time? After hearing about Mira stars that change their brightness vastly due to internal energy problems, the first ideas were similar: a small star with shorter period. Adding the unobserved part of the period (there had to be a period, otherwise we wouldn't have had the problem of organizing an observing run!) and giving the hint that many stars are pairs or groups, it wasn't long before the idea of eclipses was born. We then tried to model some different binaries and found out about the changing light curves and what they could tell us.

5. From visual to instrumental reduction of data

After showing quite an interest in the beginning, students soon felt their data were not important since the period had to be known in advance and therefore they only could confirm well-known things. I then introduced the goal of keeping track of the very many binaries there are, in order to note changes in their period. There is a need to determine the exact time of minimum brightness in the data to achieve this objective. Since an eclipse is a symmetrical event, the "slopes" of the dip in the light curve are symmetrical as well; and with simply trying to match a given light curve with its mirror image, one can estimate a minimum quite accurately. This so-called tracing paper method was used to determine the different minima obtained by the different student groups. A discussion about the accuracy of their data lead to the question of how to obtain even better results. Instead of explaining all the various devices for measuring a star's brightness, I decided to scan our photos and measure the brightness in terms of the grayscale value. This procedure contains some elements of modern CCD technology, but is still within the range of the students' ability.

6. Computer-aided brightness estimates

Each student group had to scan four images. This used up quite a bit of disk space, but by saving only the relevant portion we managed to load every scan on each computer. The next task incorporated the measurement of the star's brightness. As used in the visual method, the students decided on a set of comparison stars. Soon they found out about the variability of these comparisons and wondered whether they had measured the same star. This lead to a fruitful discussion about the problems of this kind of brightness measurement. We ended up with an independent measurement of three comparison stars, the variable, and the sky background per image and obtained light curves for all of these (Figure 3). You clearly can recognize that all of the stars seem to be variable in a random fashion, except that U Cep shows the expected dip, with a distinct minimum. Smoothing the curves by getting the mean value finally shows a state-of-the-art light curve. The next step would be to introduce a statistical method (Kwee van Woerden, least square, etc.) to deduce the time of minimum brightness—but this wasn't carried out in this course.

7. Conclusions and acknowledgements

Despite the facts of poor weather, little time, and missing equipment, it has been shown that there are ways by which to lead students to work in the field of variable stars. The whole process of realizing that there are stars that vary in brightness, that one can follow an eclipse of a pair by comparing the total light output to surrounding steady stars, and obtaining a useful result in terms of a minimum timing, can be done without the use of high technology and sophisticated instruments. It was a new and exciting experience for me as a teacher and for the students, of course, and I'd like to encourage others to try taking a similar path.

I would like to thank my father and my teachers that led me to observe variable stars for many years now, and I also would like to thank the AAVSO for the support and organization of meetings like the one in Sion.

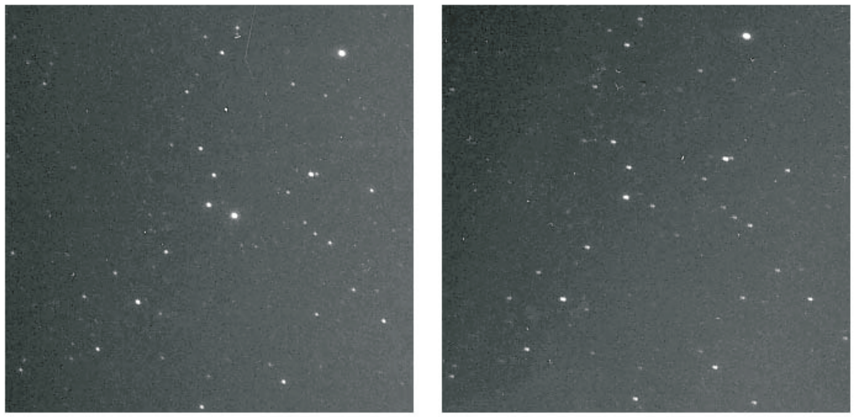

Figure 1. U Cep during an eclipse.

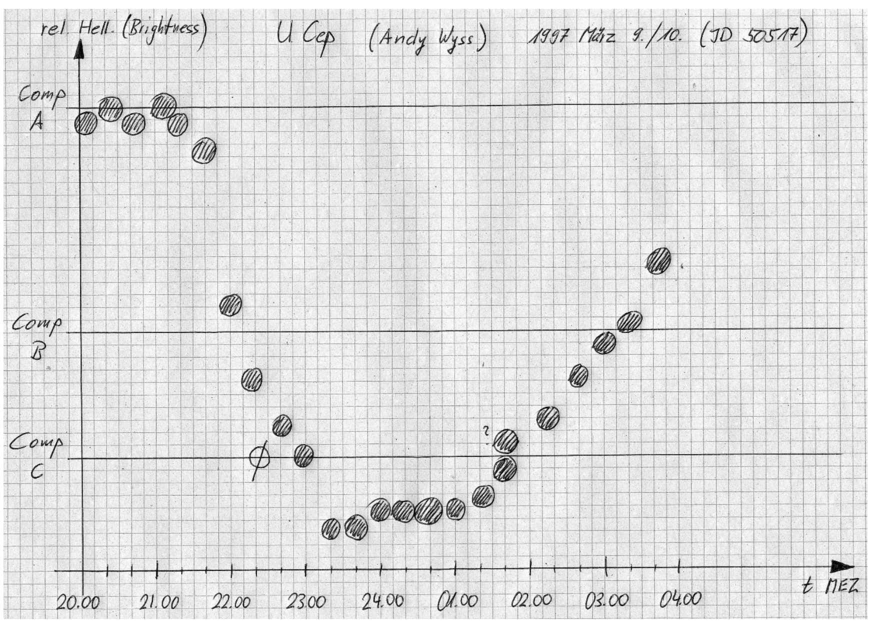

Figure 2. An example of the first visual estimates and a lightcurve (by A. Wyss).

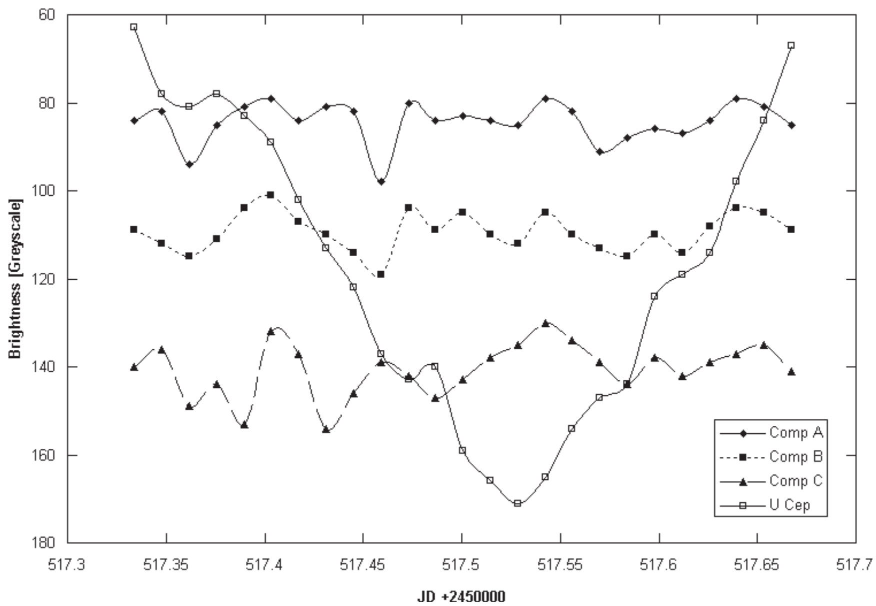

Figure 3. Raw data of the "grayscale" light curves.