A Four Star Photometer

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Abstract

A new photometer is presently being developed at the O.C.A. Observatory. It consists of four arms and a CCD camera situated in the focal plane of the telescope. Each arm can move in both directions and support a diaphragm and a liquid optic guide that directs the light to a photomultiplier. The simultaneous acquisition of the four signals enables to obtain magnitude differences between the objects in real time. A typical use of this photometer is to observe at the same time one or two variables, comparison stars and the sky background.

Introduction

Differential photometry is usually performed on bright stars using a single telescope which is pointed sequentially at the variable, the sky and at one or two comparison stars. This operating mode is time-consuming and assumes that the sky does not vary during the movement of the telescope : that point is one of the major sources of errors in precise differential photometry (there are a lot of other ones !). A first solution is to observe in good photometric sites where atmosphere is very stable. In Europe such sites are few, although many telescopes are operating in different countries.

So, how could we improve the efficiency of the photometers in order to reach the millimagnitude level of precision in poor sites?

It is evident that, for every one, if we can measure simultaneously the program star, two comparison stars and the sky background, we should obtain data from which the atmospheric fluctuations could be easily removed. Different solutions have been proposed to solve this problem at least partially : use of two telescopes to point simultaneously at two different objects (Querci et al, 1990), two channel photometer (Piccioni et al 1979), three or four channel photometer (Barwig et al, 1987, Mantel et al, this conference).

As part of a project to install a photometric automatic telescope at the south pole, we have been studying a four channel comparative photometer in collaboration with N. Walker. The South Pole project was stopped because of funding problems but we could develop and build the photometer. We present here a description of that prototype and the results of preliminary observational tests.

https://doi.org/10.1017/S0252921100007545 Published online by Cambridge University Press

Description

We can divide the four star photometer into three distinct parts : a "focal plane" part mounted on the telescope, for collecting the light, a "driving" part, essentially electronics and software, these two parts are now complete, finally an "acquisition" part, with filters, cooling box, optical switching, etc, which is currently in design phase.

The basic principle of the instrument is the following : Four arms, driven by step by step motors move in the focal plane of the telescope. On each arm a liquid optic guide coupled with a diaphragm collects and transmits the light to four photomultipliers. In addition an intensified CCD camera on its own arm is used to recognize the observed field and if necessary for telescope guiding. The photometer is completely automatic and fully controlled by a micro-computer.

The observing schedule is the following :

The observer first chooses the field by entering the corresponding coordinates and the characteristics of the telescope in the computer. The computer then displays the field (SAO catalogue is included in the software) and allows the observer to identify stars to be observed and to choose the best mechanical positions of the arms and of the CCD camera in the focal plane. Then the telescope is pointed and the real field controlled by means of the CCD camera. The arms are sent to the positions of the stars. Automatic centering is then performed for each of them. After this, the data acquisition program is run and the different signals are registered and displayed in real time on the computer screen.

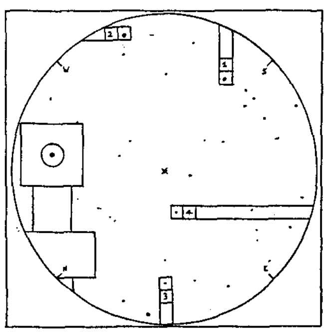

Figure 1 : Picture of the focal plane part of the photometer.

Technical Characteristics

The linear dimension of the field is 200 mm, the precision on each arm position is 10 microns, each arm can move in two directions in half of the field, the minimal distance between arms being 4 mm.

The diaphragms in front of the light guides have a 0.6mm diameter, the fluid optic

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guides are 2 meters long and 3 mm large (useful diameter of 2 mm) with a numerical aperture of 0.47. The CCD camera is a light-amplified one (figure 1).

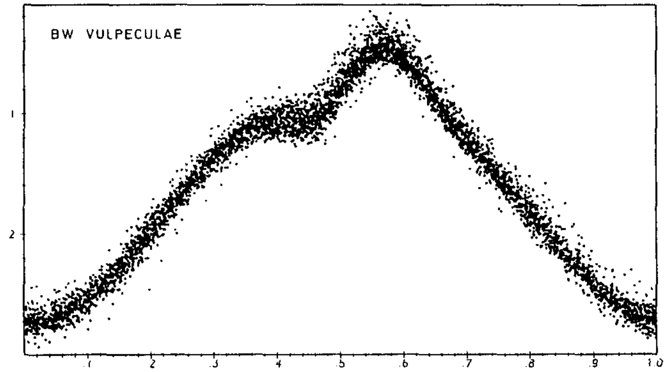

Figure 2 : Mean light curve of BW Vul obtained from international campaign.

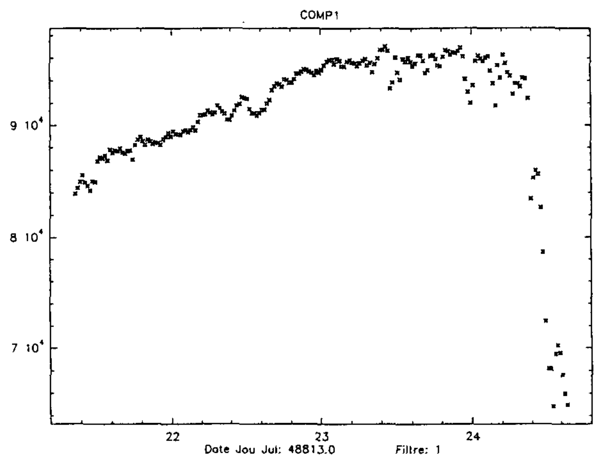

Figure 3 : Raw signal of HD 198820 on July 9.

Initial Tests

These were performed in July 92 at Nice observatory on an old 40cm astrograph with a two meter focal distance. That corresponds to a total field of 5° and 40' and diaphragm diameters of 1'. Four I.P.21 uncooled photomultipliers mounted in a single copper box were used with Johnson B filters.

The external temperature was 25°C. Due to that high temperature and sea proximity, the sky was foggy and the absorption highly variable. Due to the light pollution of the city and moonlight during some nights, the sky background was almost as bright as the second comparison star (a 7th mag star).

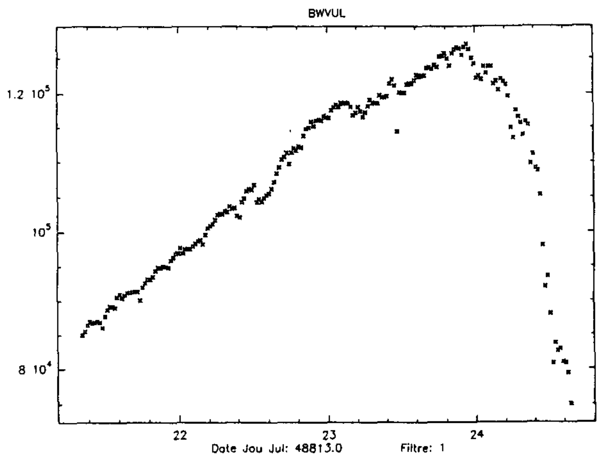

Figure 4 : Raw signal of BW Vul on July 9.

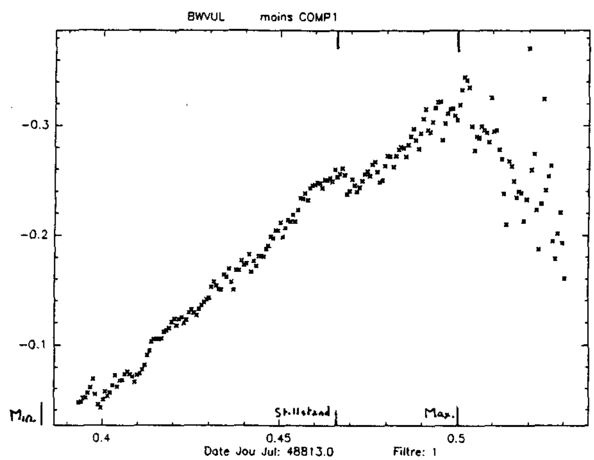

Figure 5 : Magnitude differences BW Vul - HD 198820 on July 9.

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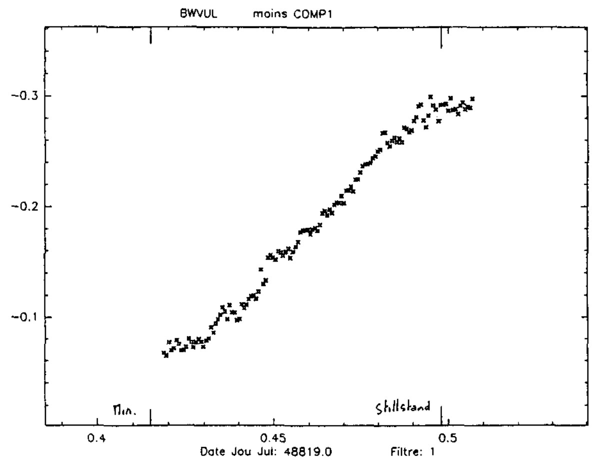

Figure 6 : Magnitude differences BW Vul - HD 198820 on July 15.

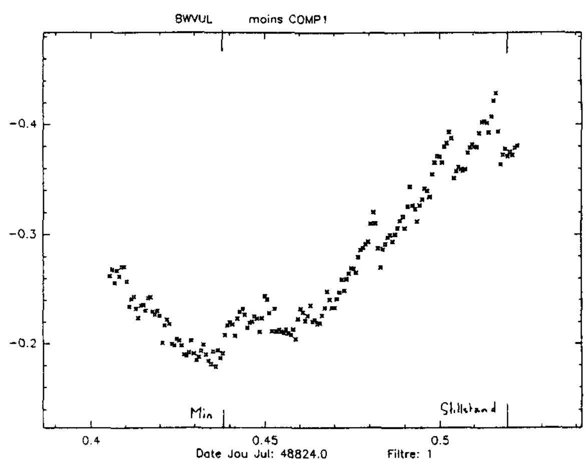

Figure 7 : Magnitude differences BW Vul - HD 198820 on July 20.

In brief, the observing conditions were worse than anything that an Astronomer could imagine in his worst nightmares.

We chose to observe the well-known Beta Cephei star BWVul (B2 III, V = 6.44), with the comparison stars C1 = HD 198820 (B3 III, V = 6.34) and C2 = HD 199102 (B9, V = 7). A very well defined mean light curve for this variable had been previously derived from an international campaign (Sterken et al, 1986) (figure 2).

It is important to note that the C1 star is situated 4° 20' south of the variable. The chosen integration time was 10 sec.

Figures 3, 4 and 5 show respectively the raw signals of C1 and BWVul and the final magnitude differences with the theoretical corresponding ephemeris (Chapellier and Garrido, 1990) obtained on July 9. Figures 6 and 7 show the same as figure 5 for the 15th and 20th of July. One can note that on night 9 the bump (so called "stillstand") in the lightcurve is clearly seen.

Discussion and Conclusion

These figures clearly show that the four star photometer enables us to obtain interesting results on variable objects even in extremely poor conditions. In addition, the possibility of moving arms independently enables us to use this instrument to carry out photometry on extended or moving objects (asteroids for instance).

We now need to perform complete tests on this prototype, particularly on fiber stability and response with defocusing, changing temperature, etc.

We also plan to finish the acquisition system quickly that should have eight cooled photomultipliers, at least two filters and an optic switching system in order to have a self-calibration of the instrument. We also plan to check new receptors, such as AP diodes for instance, that could be mounted directly on the arms in the focal plane.

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Discussion

C. Sterken: *Tinbergen, this morning, said that in the past all money was put into the telescope, and none into the photometer to be attached to it. You seem to do it the other way round. You put a lot of effort into the design and construction of the photometer, but where is the telescope on which the photometer will be mounted. It also seems to me that the photometer is of a complex and fragile design, and that it most likely will need to be mounted permanently on a dedicated instrument.*

J. C. Valtier: The photometer now is not so fragile and can be changed from one telescope to another without great difficulty. It should be installed on a one meter telescope in the south of Spain.

G. Szecsenyi-Nagy: *As you told us the four star photometer just has been tested on a 40 cm refractor. Was it an astrograph of the type made by Carl Zeiss Jena? If you definitely intend to use the device to measure stars with angular distances of 4-5 degrees you may*

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evaluate the possible use of Schmidt type cameras. Do the weight and dimensions of the photometer allow it to be mounted at the prime focus of telescopes or Schmidt cameras?

J. C. Valtier: No, the photometer is to be installed at the cassegrain focus of a telescope.

K.H. Mantel: *What is the transmission of your liquid optical fibre?*

J. C. Valtier: The transmission given by the maker between 3500Å and 6000Å varies from 60% to 80%.

How do you make sure you are observing in the same passband with each of the four channels?

J. C. Valtier: It is just the problem of choosing the same filters - but anyway it is a problem. It is the reason planning to switch between the P.M.

W. Tobin: *Why are you using eight PMTs for four channels?*

J. C. Valtier: Because in the 'switching' configuration we need one P.M. per filter and we plan to observe with two filters.

Gordon Herries Davies and Patrick Wayman at the Banquet

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