MCCP: Photometry Through Clouds!?

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1. Rapidly Variable Objects – a Challenge to Photometry

The investigation of cataclysmic variables (CV) has almost become a tradition at the Universitäts-Sternwarte München. CVs form a large group of close binary systems as for example novae, dwarf novae, X-ray bursters and polars. These objects normally exhibit orbital periods of up to a few hours, and some of them, additionally, show very rapid light variations at time scales of even less than seconds. In particular eclipse light curves of such systems offer a large amount of information allowing to derive fluxes and other relevant parameters separately for the individual components.

For years such photometric observations with the required high time resolution have been performed using conventional single-channel photometers which for this purpose suffer from essential disadvantages:

- Multiband measurements are fairly ineffective due to the sequential exchange of filters. The non-simultaneous measurements may seriously affect the calculation of colours (e.g. U–B, B–V). Additionally, large errors arise due to the unavoidable deadtime.
- Continuous photometric monitoring of variables could be done only during photometric nights, when comparison star and sky brightness had not to be checked too often. Non photometric nights caused considerable loss of observing time or resulted in annoying discussions about the reliability of data taken under poor weather conditions.

This inefficiency and inability of single-channel photometers after many useless nights initiated plans to develop a more appropriate photometric instrumentation.

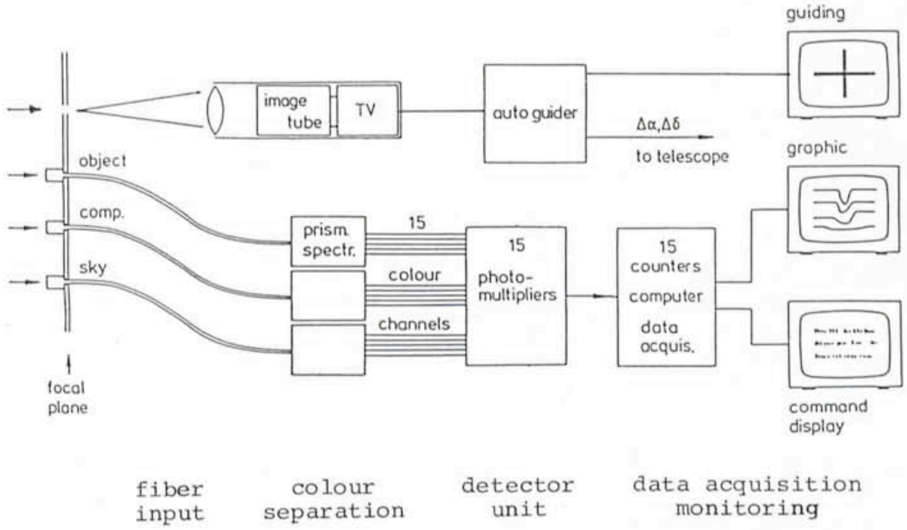

Figure 1: *Block diagram of the three-channel five-colour photometer (MCCP).*

2. MCCP – The New Photometer Concept

The instrumental development began in 1982. It ended with the prototype of the **M**ulti-**C**hannel Multi-**C**olour **P**hotometer (MCCP) schematically displayed in Figure 1. A detailed description is given by Barwig et al. (1987).

The instrument consists of 3 separate fiber optic input channels, each splitting the light into 5 colours by means of highly efficient prism spectrographs. 15 photomultiplier tubes are used as photon-counting detectors. Hence the MCCP allows to measure three sources (object, nearby comparison star and sky background) in 5 colours (UBVRI), all simultaneously and with high time resolution. Photometry relative to a calibrated comparison star can be performed with this instrument even during quite variable atmospheric conditions and spectral distributions can be measured even for erratic variable objects.

The instrument is equipped with a data-acquisition and monitoring system that is fully independent of other computer support. Furthermore, it contains power supplies, a cooling system and a meteorological station to measure the atmospheric conditions in the dome. The photometer has a built-in autoguider system which can be interfaced via the handset connectors to practically any telescope that offers offset facilities. For operation, the MCCP only needs 220 V, 50–60 Hz, 4 Amps stabilized power and a telescope which can support 100 kp at its Cassegrain focus. The instrument has now been used many times at La Silla and other observatories as well. Guest groups have also used the MCCP with success. In its present state at least one well-trained and experienced user must accompany the instrument to guarantee proper installation, operation and packing.

3. Scene of Action: La Silla

Whenever the MCCP has arrived at La Silla after a long journey from Europe, it

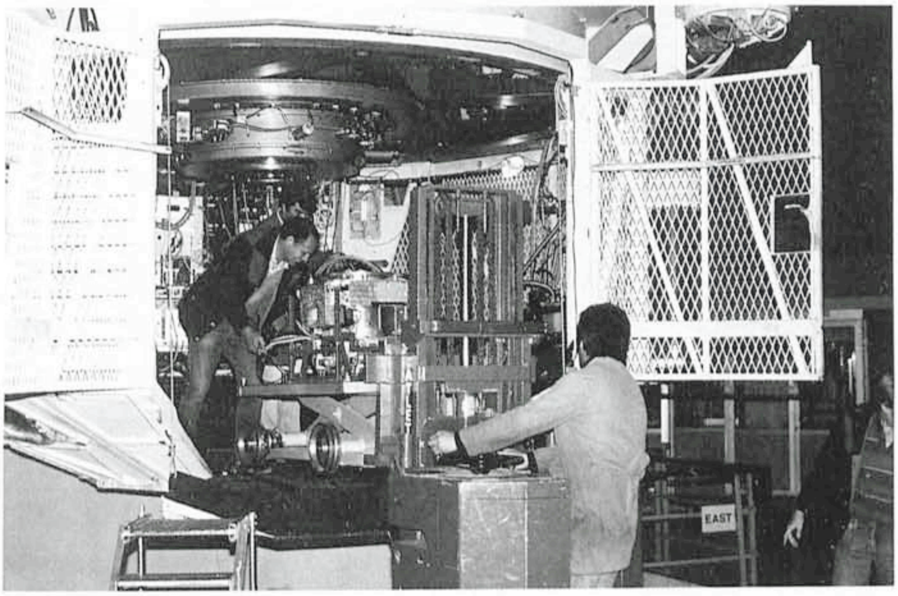

Figure 2: *ESO experts mounting the MCCP at the 3.6-m telescope.*

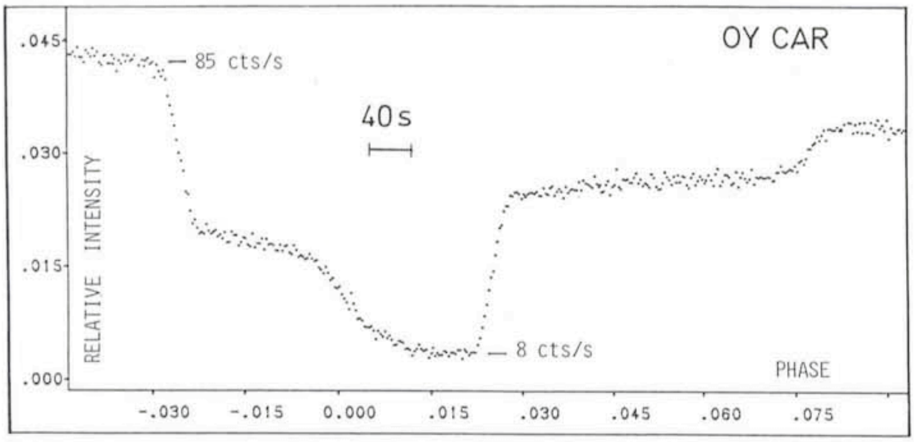

Figure 3: *Averaged eclipse lightcurve in B of the short period (P = 91 min) cataclysmic binary OY Car, showing ingress and egress of white dwarf and hot spot. The data were obtained from 25 orbital cycles observed with the MCCP during 7 nights at the ESO 1-m telescope. Time resolution: 2 s. The indicated count rate of the very eclipse minimum corresponds to approximatively 18 mag.*

is generally stored in the telescope building, waiting for the observers to drop in well in advance for operational tests and preparation. They start with the installation of a laboratory setup to check the complete system. First a calibration measurement is performed by means of artificial light sources simulating star and sky radiation. For comparison the same tests had run before shipment. The consistency of the results, proper storage of the data, proper reading, plotting and reduction of them together with a 24-hour stability test of dark current and sensitivity guarantee the readiness for mounting at the telescope.

This procedure essentially depends on the effective cooperation between astronomers and observatory staff: During the laboratory test the 15 detectors had to be cooled, and as known to all users of photomultiplier tubes, they don't like changes very much and easily get unstable when temperature or high voltage variations occur. Thus the aim is to restart cooling as fast as possible (within less than 5 minutes) after switching off in the lab and moving to the telescope floor. This problem has always been solved, thanks to the efforts of the experienced ESO staff (Fig. 2). After mounting and balancing, the whole equipment is rechecked. In the following, all electrical operations eventually necessary during observations at night must be tested for electric pickup (e.g. dome rotation, light switches in the dome building, shutters, elevator and platform operations, radio transmitters, etc.). When satisfying results are obtained, the time until start of observations is used to continuously monitor the dark currents of all 15 multipliers running an appropriate test programme.

First-night observing activities generally are quite stressing: For this special instrumentation usually the telescope

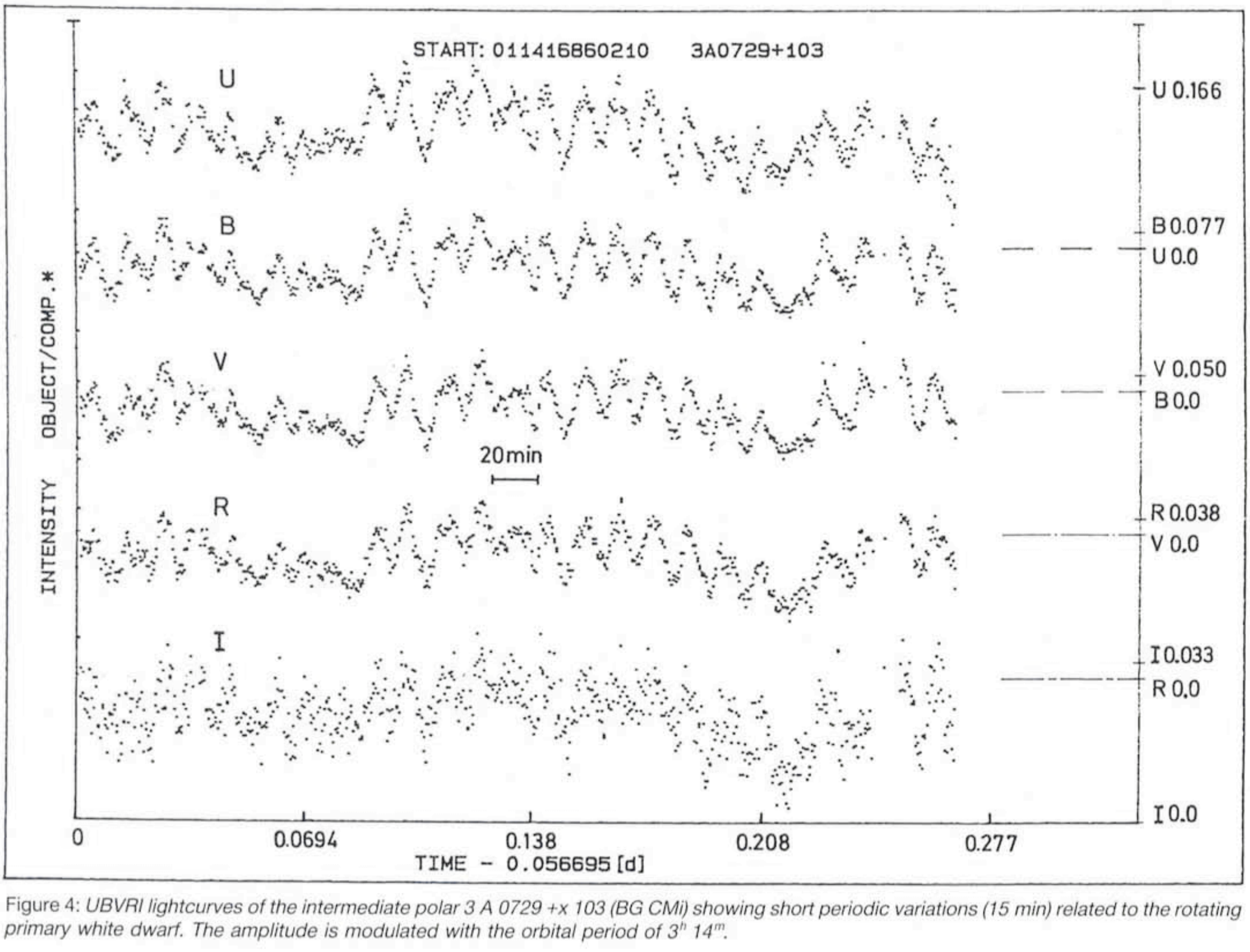

Figure 4: *UBVRI lightcurves of the intermediate polar 3 A 0729 +x 103 (BG CMi) showing short periodic variations (15 min) related to the rotating primary white dwarf. The amplitude is modulated with the orbital period of $3^h 14^m$.*

focus is completely off at the beginning, and the photometer coordinate system does not match to the local star acquisition system. Consequently, initialization takes more time. Then with dome lights off and photometer shutters open, the amount of straylight from indicator lamps, Cermet clock, TV displays, etc. be checked.

The orientation and scale of the telescope field in the photometer guiding system must be verified, the limiting magnitude of the autoguider must be checked as well as its proper adaption to the telescope control system to avoid guiding oscillations.

After all this, a mask plate has to be produced which holds the three fibers and a guiding diaphragm at their precise positions in the focal field. Of course, the preparation of the mask could also be done at home, but due to uncertainties of the correct scale and orientation of the focal field it has proven safer to use an option of the photometer which allows to drill a precise mask, live on the telescope.

Finally: Fibers are inserted – calibration – start measuring object – autoguiding on. Now everything goes automatic, for hours, since this photometer is mainly used for variables which are monitored normally the whole night. When the results are looking good, the observer has time to go through a checklist to make sure that everything is really o.k.: Data are well presented on the graphic screen, there is regular storage on disk, autoguider regulation holds the star image within the errorbox indicated at the TV monitor, no oscillation, no drift, actual counts of object and comparison are consistent, programme parameter o.k.? . . . Yes! Observer can relax and watch the growing light curves on the monitor, check the transparency of the sky by following the comparison star on the graphic . . .

4. Performance – Present and Future

A large amount of photometric data could be gathered at La Silla until now, data that could have never been obtained with classical photometers. One example, presented by Schömbs et al. (1987a), concerns the monitoring of the short-period CV system OY Car during primary eclipse. The ingress and egress phases of the white dwarf last some 30 seconds only (Fig. 3). From colour variations within similar short time intervals the spatial temperature distribution of the eclipsed accretion disk can be derived. Another example is demonstrated in Figure 4, where the light variations of the intermediate polar 3 A 0729 + 103 are displayed. The MCCP has also been successfully applied to the investigation of optical pulses (timescale of milliseconds) from the X-ray burster MXB 1636 + 53. For this purpose the multichannel photometer had been attached to the 3.6-m telescope (See also Fig. 2). In order to investigate the extremely fast events produced by the neutron star of this object, a time resolution of 40 ms had to be used. Preliminary results are given by Schömbs et al. (1987b). Figure 5 finally displays the lightcurve of the eclipsing cataclysmic binary BD Pav, observed during a night so cloudy that even spectroscopists discontinued observation. BD Pav was measured as long as we could see our guiding star and as long as the observatory regulations permitted open domes. After reduction we found that for atmospheric absorptions of less than 80 % the accuracy of the reduced data was only degraded according to the photon statistics.

In the near future the MCCP will be sent to La Silla for several additional observing programmes while at its home institute work has already started for a next generation instrument: Equipped with computer-controlled positioning of the fiber optic channels it will offer 3 observing modes:

- *4-star multicolour photometry* which allows to simulate different photometric systems (Strömgren uvby, Geneva system, etc.) by means of software;
- *8-channel spectral photometry* with resolution of about 500;
- *Multistar spectroscopy* of up to 20 objects.

Each mode can be applied with a time resolution of 1 ms. A sophisticated software package shall optimize the observing routine in accordance with actual atmospheric conditions while complete reduction and preliminary analysis may be performed automatically during daytime, when the astronomer hopefully has already fallen asleep.

References

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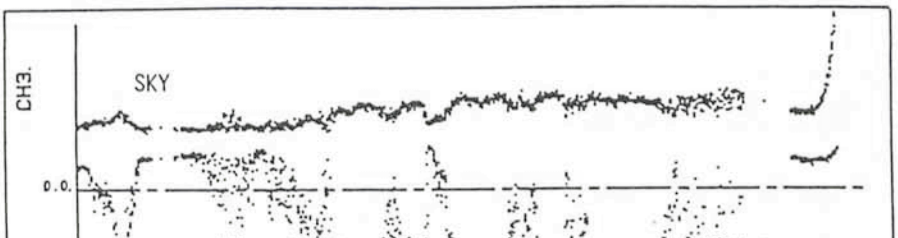

Figure 5: *Simultaneous observations of BD Pav, nearby comparison star and sky during a non-photometric night. The reduced lightcurve (V-colour channels displayed only) demonstrates the ability to compensate highly variable atmospheric absorption.*