THE UTRECHT PHOTOMETRIC SYSTEM (≡ UPS) AND SOME RESULTS WITH IT

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1. Definition

The Utrecht Photometric System (≡ UPS) is a narrow-band photometric system ($\Delta\lambda < 10$ nm) characterized by wavelength regions in which no telluric lines and nearly no stellar/interstellar spectral lines are present. Because in the near-infra red the density of spectral lines is much less than in the visible and blue, filters with transmission as far as possible into the near-infra red are necessary. Photomultipliers with GaAs cathodes, which have a high sensitivity up to 900 nm have enabled the design of the UPS. In Figure 1 the absolute

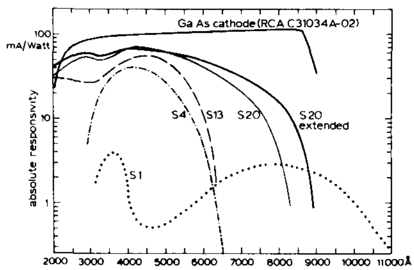

Figure 1. Comparison of responsivities of several cathodes.

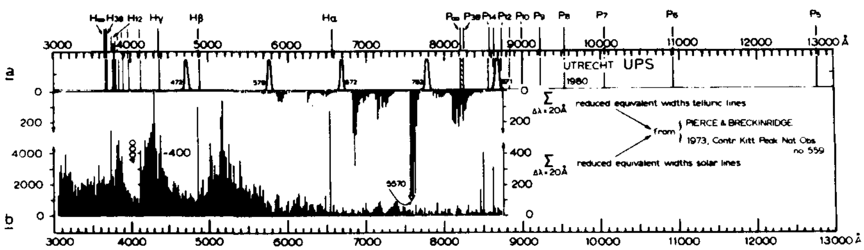

Figure 2. The positions of the UPS filters with respect to solar and telluric lines.

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responsivity of the GaAs cathode is compared with S1, S4, S13, S20 and S20 extended cathodes. In Figure 2a the transmission curves of the UPS (474, 579, 672, 781 and 871 nm) are given as a function of wavelength (Provoost (1980) gives larger graphs for the transmissions). Figure 2b shows in the lower part over 20 Å summed up equivalent widths of solar lines as a function of wavelength. In the upper part of Figure 2b the same is done for the telluric lines.

2. Motivation

2.1 For the interpretation of lightcurves of eclipsing binaries, centre to limb variations (≡ CLV) at the observed wavelengths are necessary. Theoretical CLV are available for stellar continua but not CLV which are a superposition of the CLV of the spectral lines present in the passband and that of the stellar continuum. This is the reason why passbands were chosen which are as much as possible uncontaminated by spectral lines.

2.2 As a result better dimensions of the components of eclipsing binaries should be attained. These dimensions should be independent of wavelength, which especially in short-wavelength broad band photometry is not always the case.

2.3 With respect to Algols the UPS is particularly useful as secondary minima are much more pronounced in the near-infra red than in the visible wavelength region. Nice examples are the light curves of U CrB of which the UPS lightcurves are shown in the corresponding paper of Van Gent in these proceedings. It is obvious that more pronounced secondary minima provide better dimensions and temperatures.

2.4 With the GaAs tubes it is possible to cover a rather large wavelength region. The UPS has a base of nearly 400 nm (from 474 to 871 nm), which should provide a better T_{eff} of the secondary relative to that adopted for the primary.

2.5 A further advantage of UPS lightcurves is the relative absence of distortions of the lightcurves by transient emission features or changes in spectral line strengths.

2.6 Finally, due to the narrow band widths the effective wavelengths of the filters do not depend on spectral type.

3. A photometer for GaAs tubes

A photometer suitable for photomultipliers with GaAs tubes (RCA C31034A and Hamamatsu R943-02) has been built and is attached to a 40 cm telescope (F/5) operational at the moment in Switzerland (λ = +8° 08' 04.8, ϕ = 46° 23' 44.8, heigth = 1350 meters).

Because the RCA tubes have an off-axis rectangular cathode of about 4 x 10 mm^2, the image of the main telescope mirror is transformed into an ellipse with axes of 3 and 9 mm by cylindrical optics.

Two equal diaphragms (7 pairs) and a chopper allow for chopping against the night sky. The difference of the count rates of the two diaphragms is proportional to the luminosity of the star. From these differences the actual S/N ratio is determined during the observations and compared with √(total amount of counts).

The GaAs tubes are cooled to a constant temperature of - 25° C.

Our experience is, that quite some of these photomultipliers are not stable enough to be used for absolute photometry. We used them for differential photometry alone. Between successive high and low count rates a "recovery" time of about 4 ms is necessary.

4. Results

4.1 With respect to 2.2, it is found that the dimensions of the components of eclipsing binaries as obtained from light curves in the UPS filters at 672, 781 and 871 nm are practically the same (within 0.5%) whereas those obtained with the filter at 472 nm differ by about 2.5% from the near-infra red results. The same is true for the T_{eff} of the secondary (assuming that of the primary as fixed). The light curve interpretation is always done with the latest Wilson & Devinney program (Wilson, 1979) as refined by Van Gent (see his paper "some modifications to the Wilson-Devinney program" in these proceedings).

4.2 All Algols for which we have long term observations (QS Aql, TV Cas, U CrB, u Her and λ Tau) show symmetric minima. Often light curves in 5 different colours are available. The time differences between descending or ascending branches provide reliable instantaneous periods, together of course with O-C values.

4.3 It is obvious that final results can only be obtained by combination with other observations, in particular IUE measurements and measurements of radial velocities (≡ RV's). With respect to Algols, energy distributions as obtained from low dispersion IUE spectra often provide a reliable T_{eff} for the primary and a distance of the system to Earth. Regarding RVC's, we try to get a solution by imposing $\gamma_1 = \gamma_2$ and by allowing a possible phase shift, $\Delta\phi$, to account for possible differences between the ephemeris as used (often taken from light curve observations) and the real instantaneous ephemeris. As is well known, hydrogen lines can only be used for the determination of RV's if these RV's can be determined from the wings of the H lines. The central parts of these lines are often distorted by gas streams around the component(s). An example of all this is given in the paper together with Van Gent concerning U Cep. The new results for the primary of U Cep are plotted in a (M, R) diagram (see Figure 3) together with those as found by Tomkin (1981). In the same diagram are also plotted the results for the primary of YZ Cas, a wide eclipsing binary [De Landtsheer et al. (1984)], of TV Cas, an Algol [De Grève et al., 1985] and of U CrB, also an Algol (see the paper by Van Gent in these proceedings). In this diagram the primary of YZ Cas lies above the (M, R) relation for luminosity class V stars of Strayzis and Kuriliene (1981). This is a normal evolutionary effect of a single star. The primary of TV Cas also lies above this relation. However in this case mass transfer effects have taken place. The primaries of U Cep and U CrB (these components have also received mass from the secondary) lie close to Strayzis & Kuriliene's ZAMS. The spectral types of the primaries of TV Cas, U Cep and U CrB (B9V, B8V and B6V respectively) are too late by 0.5, 2.2 and 1.7 subclasses respectively with respect to the spectral type indications of Strayzis and Kuriliene.

4.4 Whenever accurate dimensions, masses and temperatures of the components of a binary are found it makes sense to try to find the evolutionary history of such a system. Results for YZ Cas and TV Cas are given below:

	$M_1/M_\odot$	$R_1/R_\odot$	$M_2/M_\odot$	$R_2/R_\odot$	age(years)
YZ Cas (a "wide" EB)	2.31(1)	2.60(1)	1.35(1)	1.37(1)	4.47 E8
TV Cas (an Algol)	2.8(3)	2.8(1)	1.3(1)	3.1(1)	3.24 E8

In the case of YZ Cas: T_{eff} = (10 300 ± 290) K if T_{eff} = 7200 K is assumed (De Landtsheer, 1983) X = 0.65; Z = 0.015 while $Z_{photosphere}$ = 0.030; (De Landtsheer & De Grève, 1984).
In the case of TV Cas: T_{eff} = (5250 ± 120) K if T_{eff} = 11 000 K is assumed. The initial mass of the gainer was 2.45 $M_\odot$. 25% of the total initial mass together with 40% of the total angular momentum is lost from the system.

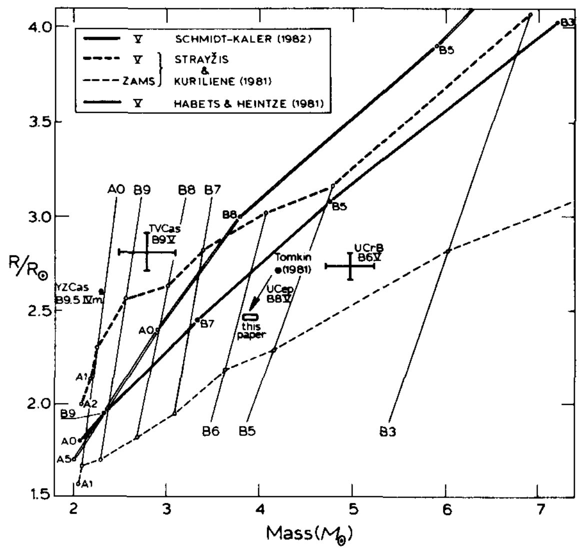

Figure 3. The (M.R) diagram with the primaries of YZ Cas, TV Cas, U Cep and U CrB in it.

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