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Photometric Study of Three Variable Stars: YY Men, YZ Men and UX Men from the Bamberg Observatory Southern Sky Survey*

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Abstract. The Bamberg Observatory Southern Sky Survey provided 67 photographic plates in the field 5^h -77° and 62 plates in the field 4^h -77° which include the variable stars YY Men, YZ Men and UX Men on them. The plates were taken in the period 1963–1971. Fifty five of them were scanned with the Epson Expression 1640 XL flatbed scanner and aperture photometry performed. For each plate a transformation of plate magnitudes to the Tycho-2 magnitudes in B photographic band was found for selected reference stars, and was used for deriving B magnitudes of the target stars. The analysis of the photometric behavior of YY Men, YZ Men and UX Men is presented.

1 Introduction

We have selected three stars: YY Men, YZ Men and UX Men, with different type of variability, to test the aperture photometry method [1] and to look for long-term brightness variations, using the Bamberg Observatory Southern Sky Survey (BOSSS).

YY Men, ($HD32918$, $\alpha_{2000} = 4^h58^m18^s$, $\delta_{2000} = -75^\circ16'38''$, V = 9.60 - 9.89, $(B-V)$ = 1.04-1.12) is a single, late type active giant ($K1-2\,IIIp$) with period $9^d.55$ and amplitude of 0.3 mag in V and is classified as $FKComae$ type star by Collier [2]. The star shows $RS\,CVn$-like rotational light curve, and also intense flares in radio and optical bands with B amplitude about 0.1 mag [3, 4]. The spectral observations during the flare peak show that the star has a very active chromosphere with strong $CaII\ H$ and K emission and inverse $P\,Cyg$ profile in H_α.

YZ Men ($HD34802$, $\alpha_{2000} = 5^h10^m27^s$ $\delta_{2000} = -77^\circ13'0''$, V = 7.57–7.67, $(B-V)$ = 1.08, $K1III$) is a typical $RS\,CVn$ type star, $SB1$ spectral binary

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with an orbital period of $19^d.310$ [5]. The star has weak $CaII$ H and K emission and is an X-ray source [6]. A long-term variability with weak brightness decrease of about 0.1 mag (V) for the period 1978–1990 is also detected.

UX Men ($HD37513$, α_{2000} = $5^h30^m03^s$ δ_{2000} = $-76°15'55''$, V=8.26, ($B-V$)= 0.5, P=$4^d.18$) is a well studied $F8V$ double-lined eclipsing binary, with well determined spectroscopic orbit [7]. The star is detected as variable with amplitude of 0.3 mag (pg) and period of $\sim$ $2^d.09$ in the BOSSS [8, 9]. It appears to be a deep eclipsing, well detached system, with no indication of period changes and it makes the star an interesting test to see how well the light curve and time of minima could be derived, using the aperture photometry method.

2 Bamberg Observatory Southern Sky Survey

The BOSSS was performed in the interval 1963–1976, and is unique for this period, as the Harvard Observatory Southern Sky Survey had been stopped, and there was no other operational southern sky survey programme. The survey was carried out with 22 cameras (each one with aperture $d = 10$ cm), Zeiss camera ($d = 7$ cm), and the Harvard telescopes: Metcalf ($10''$) and Ross B ($3''$). The plates were obtained at three stations: Boyden Observatory (South Africa), Mount John University Observatory – Lake Tekapo (New Zealand) and San Miguel Observatory (Argentina). The main goals of the survey were variable stars discovery and their monitoring. More than 22 000 monitoring plates covering the whole southern sky were obtained, now well stored in the Bamberg Observatory, Germany. The survey plate size is 16×16 cm (field $13° \times 13°$), the typical exposure is 1 hour and the limiting magnitude is 14 (B). At present the on-line access to the BOSSS, as well as to the preview images of selected plates is provided by Sofia Sky Archive Data Center (`ttp://www.skyarcive.org`).

3 Plate digitization and data reduction

We obtained information for 129 plates containing the images of the three variables: YY Men, YZ Men and UX Men. They were taken in two sky zones: 4^h $-77°$ and 5^h $-77°$ on Agfa Gevaert 67 A50 emulsion (blue sensitive, close to B photographic band). The plates are not of the best quality: 14 plates have scratches and high noise level, 25 are overexposed, about 35 plates are not available, which means that 55 plates can be used for this photometry research. The Bamberg Observatory offers opportunity for plate digitization with flatbed scanner – Epson Expression 1640XL with resolution of 16μ (about 5 arcsec/pix), maximal plate size of A3 standard paper format, with data written in 14bit FITS file format. The file header includes information for telescope type, plate identifier according to the Wide-Field Plate Database (WFPDB), coordinates and plate equinox. Also by the use of IRAF astrometric reduction tasks and Aladin sky

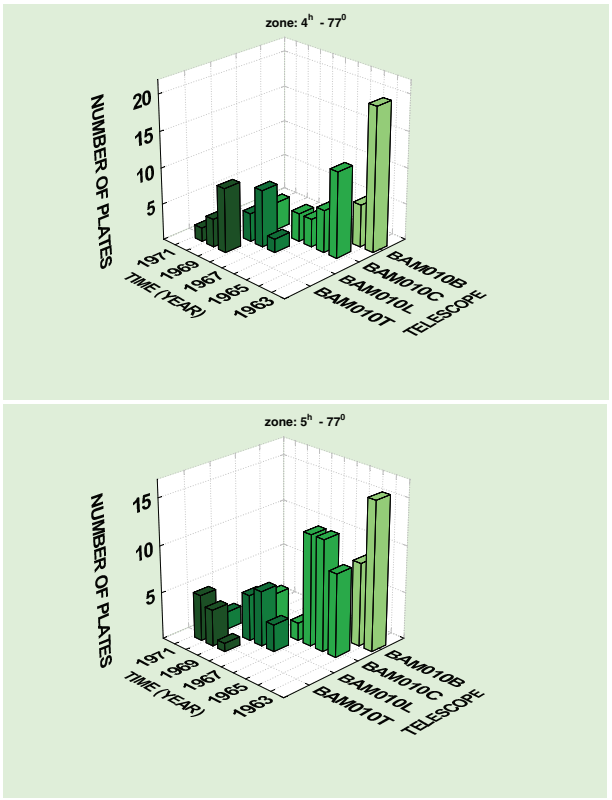

Figure 1. Distribution of available plates by time and telescope for zones $4^h\ -77^\circ$ and $5^h\ -77^\circ$.

atlas, provided by CDS in Strasbourg, a tangential coordinate system ($J2000$) is added in standard wcs fits form. A typical characteristic of the star profile of the scanned photographic plates is the saturated, flat-topped core in the central part of star image (Figure 2). The reason is the limited dynamical range of the photographic emulsion, as well as the scanning device with up to 16383 gray scale levels, which is significant for the brighter stars. The saturation radius depends of star magnitude, exposure time, noise level, and scanning adjustment. The aperture photometry method, using standard IRAF photometry tasks, is described in detail in [1]. Here we applied the same technique with typical star aperture radius of 20 pixels chosen to include the star signal (by the brightest star profile inspection) and to avoid the contribution from nearby stars to derive instrumental star magnitudes. For deriving B magnitudes of the selected variables we also measured 15 (non-variable) stars in the fields close to the variables, with B magnitudes in the range from ~ 8.7 to ~ 11.10.

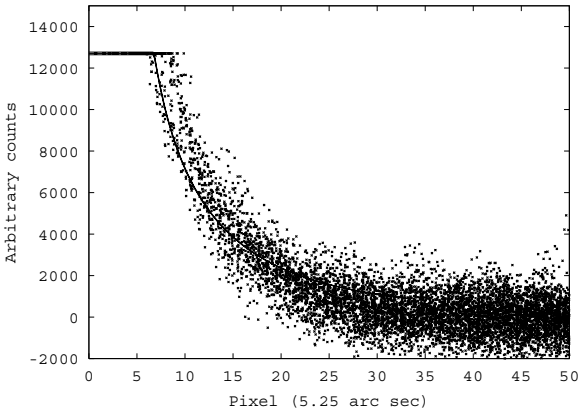

Figure 2. Typical star profile of scanned plates from the BOSSS.

B magnitudes of reference stars were determined by transforming Tycho-2 B_T and V_T data [10] using interpolation tables of Bessell [11]. For each plate a transformation equation:

$$B_i = b_1 M_i + b_2 M_i^2 + b_3 (B-V)_i + b_4$$

was found by the less-squares method. Applying the transformation equa-

Table 1. Reference stars and the transformed Tycho-2 magnitudes.

HD or CD star number	B	$(B-V)$
HD 29922	9.66	0.20
HD 31175	9.83	0.51
HD 34851	8.96	1.10
HD 36480	9.52	1.15
CD-76207	10.38	0.51
HD 33747	9.71	0.95
CD-76200	11.08	1.15
HD 37069	10.03	0.44
CD-78198	10.93	0.63
HD 34665	9.43	1.03
CD-76177	10.18	0.43
HD 31378	9.22	0.43
HD 39490	9.40	0.70
HD 27222	9.09	0.22
HD 33245	8.73	0.41

tion with the b_i coefficients determined for each plate to instrumental magnitudes for target variable stars we determined B magnitudes. We also used $(B-V)$ color indices of 1.04 for YY Men, 1.08 for YZ Men and 0.5 for UX Men, published respectively by Collier [2], Cutispoto [5] and Simbad database (`http://simbad.u-strasbg.fr/`). Changes in color indices of YY Men and YZ Men are observed but they could be neglected in view of the size of the observational errors in the instrumental magnitudes. With the method described here the magnitudes of field stars and selected variables could be determined with the typical 1-standard deviation of the fit of 0.15 mag, so we may consider accuracy of 0.15 in the B interval 8.7–11.10.

4 Results

Our observations can contribute to the construction of the optical light curve and help in solving the question of long-term brightness variations over the time frame of years, for YY Men. Usually the previous published observations of the star were spread over one rotation period (about 20 days), but not enough to study the long-term photometric variability. The variations within one cycle have wave-like form with an amplitude of about 0.2 (B) to 0.4 (B) for the long time scale (several years). Such amplitude changes are common for $FKComae$ type stars (for the $FKComae$ itself the amplitude varies from 0.06 – up to 0.12). The derived B magnitudes for YY Men are presented in Figure 3. For composing light curves the ephemeris $JD = 2444155.64 + 9.5476E$ given by Collier [2] are used. According to the BOSSS the star shows B changes with amplitude of 0.55 mag with the mean magnitude 9.41. We clearly observe a nice rotational modulation for YY Men for 1964. Compared with the previous published photometry [2] the star is brighter by ~ 0.23 mag, and the amplitude of the B light variations is bigger by ~ 0.2 mag. The observational history suggests a rapidly rotating hot giant with massive outflows coupled with intense optical and radio flares and existence of a cool spot-region. Earlier photometry suggests that the equatorial spots might have been permanent during 7 year at the same longitude – active region. Our data are not evenly distributed over the years. For instance for 1967 we have at disposal only few points, but long-term behavior of the star shows changes in the amplitude and mean magnitude. This is typical for stars with rotational activity and is also reported by Grewing [12].

The star $YZ\ Men$ is relatively bright and on the most of the plates it is near the non-linear part of the characteristic curve, for these reasons we could not get a full coverage of the seasonal light curves (Figure 4). Our data are too sparse to judge the shape of the light curve. However the variations in the mean stellar magnitude, due to the degree of spottedness in the period 1963–1969, can easily be seen. Our photometry results, plotted with the ephemerides $JD = 24447869.0 + 19.31E$ given by Cutispoto [5] are presented in Figure 4. For the observed period the star shows changes in B with amplitude of 0.54 mag with

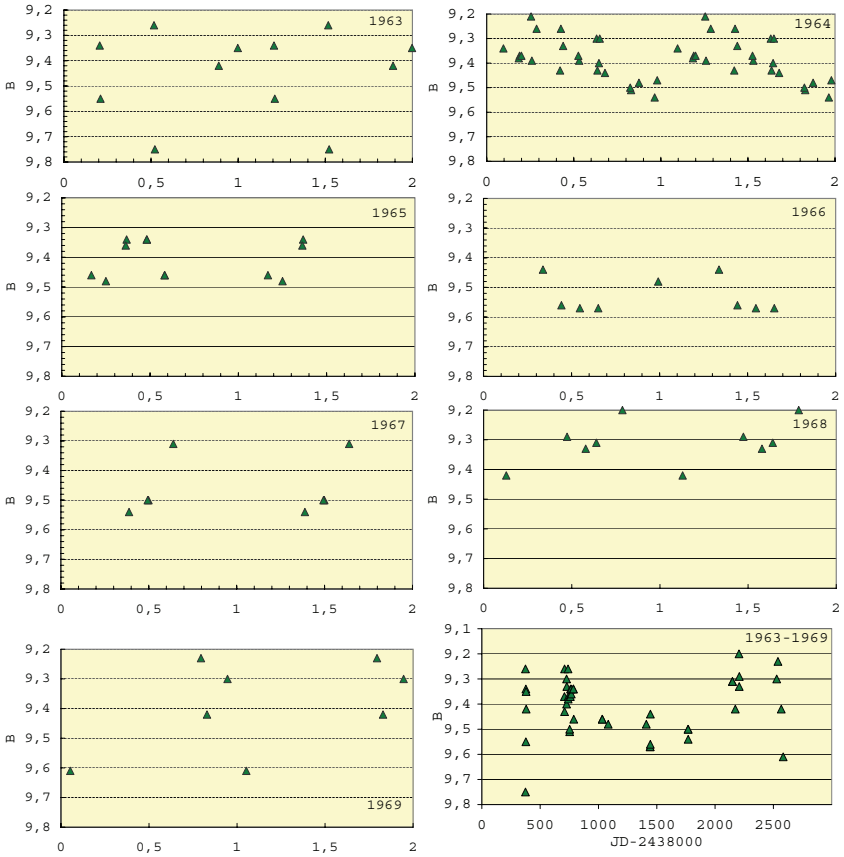

Figure 3. B light curve for YY Men versus rotational phase with the period used $9^d.55$, top-to-bottom, left-to-right: 1963, 1964, 1965, 1966, 1967, 1968, 1969, long-term B variations for the observed period.

mean $B = 8.86$. There is also a noticeable long-term brightness decrease with ~ 0.3 mag for the observed period. Similar changes are also reported for the period 1978–1990 [5].

According to the derived B magnitudes, the amplitude of the variability of star UX Men is 1.58 mag and its maximal brightness is 8.69 mag. The seasonal light curves and long-term variability for the observed period for $UXMen$ are presented in Figure 5. We have one data point in the eclipse of the star at phase $\sim 0,4890$ ($JD = 2438767,333$) and it is in a good agreement with phases of secondary eclipse given in [13].

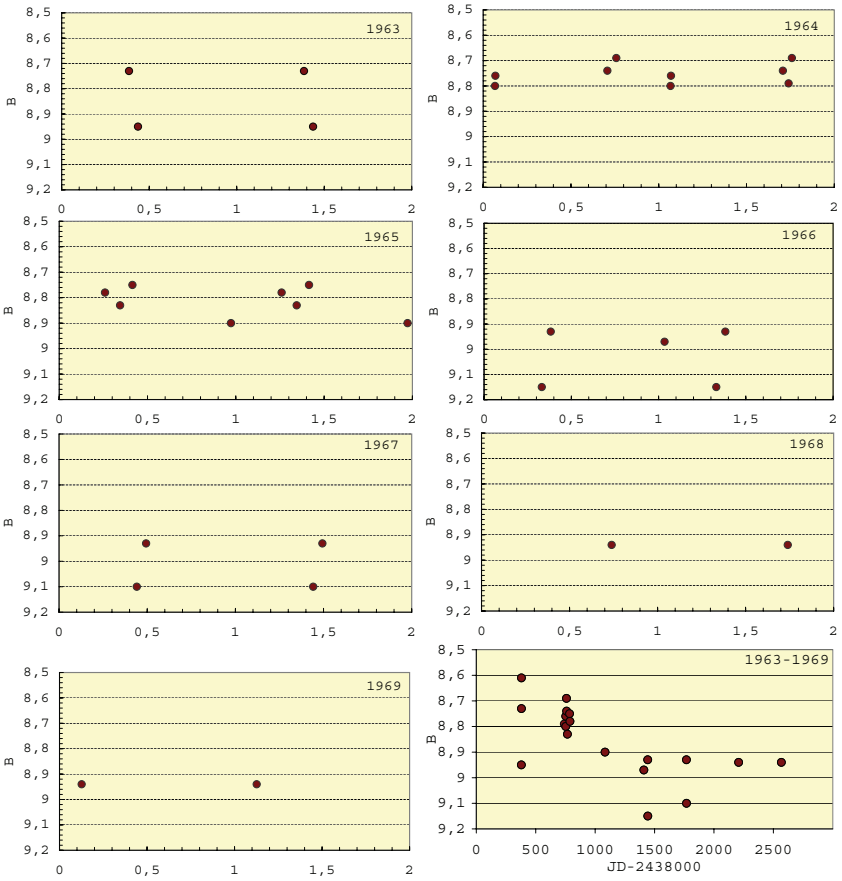

Figure 4. B light curve for YZ Men versus rotational phase with the period used $19^d.310$, top-to-bottom, left-to-right: 1963, 1964, 1965, 1966, 1967, 1968, 1969, long-term B variations for the observed period.

5 Conclusions

Our observations of the three variable stars YY Men, YZ Men, UX Men contribute to the construction of the optical light curves and help address the question of long-term brightness variations over several years. For all target stars we derived long-term variability curves and also some seasonal light curves with quite a good phase coverage. For the bright stars ($B \leq \sim 8.7$ mag) plate characteristic curve should be checked for non-linear saturation effect. This research shows that detailed study of different types variable stars and also the digitization and analysis of other plates archives is worth-while.

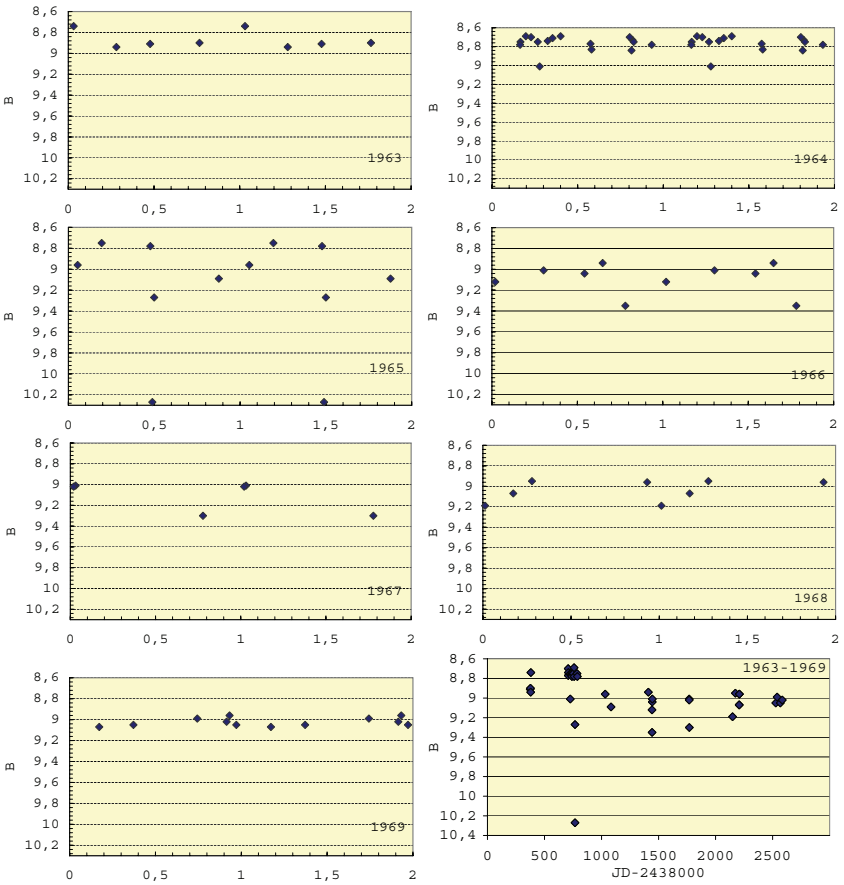

Figure 5. B light curve for UX Men versus rotational phase with the period used $4^d.18$, top-to-bottom, left-to-right: 1963, 1964, 1965, 1966, 1967, 1968, 1969, long-term B variations for the observed period.

Acknowledgments

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