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The symbiotic star YY Herculis

I. Photometric history over 1890-1996*

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Abstract. The lightcurve of the symbiotic star YY Her extending from 1890 to 1996 is presented and discussed.

YY Her underwent four outbursts in the last century, in 1914-19, 1930-33, 1981-82 and 1993-96, with additional bright phases in 1890, 1903, 1942, 1954, 1965 and 1974. The absolute magnitude reached at peak brightness is adequate for mild thermonuclear flashes with no mass loss induced by super-Eddington luminosities.

An orbital period of 590 days is inferred from the quiescence $\triangle V$=0.3 mag modulation ascribed to a heating effect. Four enigmatic deep minima in 1952, 1965, 1971 and 1992 appeared at the right phase for an eclipse to occur, but such an explanation encounters severe difficulties. At least two of these minima occurred right at the onset of an active phase or outburst and this suggests an alternative interpretation to the eclipse hypothesis.

YY Her appears to belong to the Bulge/thick-Disk population of the Galaxy, with D = 3.2 kpc, z = 950 pc and E_{B-V}=0.41

Key words: symbiotic binaries – individual stars: YY Her

1. Introduction

Much of the current understanding of symbiotic stars is unfortunately still based on a mere handful of well studied cases, far from properly tracing the variegated zoo of symbiotic binaries. Enlarging the set of template systems against which to test models and evolutionary scenarios seems a mandatory step forward. With this paper on 107-years long photometric history of YY Her, we intend to begin a long term project aimed to provide detailed photometric and spectroscopic documentation as well as model investigation of several symbiotic stars suitable to expand the set of template systems.

The photometric variability of YY Her was discovered by Wolf (1919) and additional observations by Plaut (1932) and Bohme (1938) led to a classification as an irregular variable, varying in the range 10.5< m_{pg} <14. No devoted investigation followed these early reports. Comparison with visual estimates by amateur astronomers allowed Welty (1983) to recognize a "bright phase" in 1981 and Munari *et al*. (1993) to document a major outburst in 1993.

Herbig (1950) was the first to describe in detail the spectrum of YY Her (= AS 297 = MHα 352-34, *cf.* Merrill & Burwell 1950) and to associate the object with the symbiotic stars. His observations were secured in quiescence and revealed a strong emission line spectrum superimposed on a M2 giant absorption continuum. Emission lines from H I, He I, He II and [O III] were reported, with He II 4686 Å as bright as Hβ, which suggests the companion to the M2 giant to be very hot and luminous at the time of Herbig's observations. Quiescence spectra with similar features were secured in 1978 and 1980 by Allen (1984) and Blair *et al*. (1983) respectively. The very high ionization conditions in YY Her were further confirmed by the IUE spectra obtained in 1980 by Michalitsianos *et al*. (1982), which are

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* Tables 5 and 6 are only available in electronic form at the CDS via anonymous ftp 130.79.128.5
** Late (1992)

Table 1. Comparison stars marked in Fig. 1. α = our m_{pg} sequence, β = m_{pg} sequence used by Plaut (1932), γ = AAVSO comparison stars, δ = AFOEV comparison stars.

star	U	B	V	m_{pg} (α)	m_{pg} (β)	m_{vis} (γ)	m_{vis} (δ)
A	11.73	11.70	11.21	11.36	11.45	11.3	11.3
B	12.05	12.07	11.60	12.16	11.90	11.8	11.8
C	12.82	12.66	12.06	12.65	12.23	12.2	12.0
D	13.98	13.33	12.40				12.3
E	13.89	13.37	12.42			12.7	12.5
F		13.21	12.18	13.35			
G	13.69	13.72	13.07	13.56			12.9
H	13.54	13.62	12.94			13.0	
I	15.52	14.36	13.13			13.4	13.5
J	14.94	14.55	13.61				13.7
K	14.55	14.11	13.24	14.03			
L	14.80	14.84	14.17	14.52			13.9
M	15.25	15.29	14.75				14.2

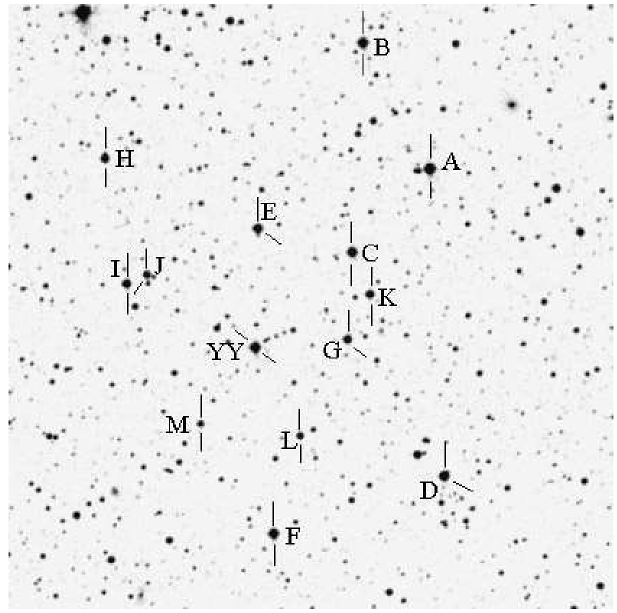

Fig. 1. Identification of the comparison stars in Table 1 (chart from the digitized version of the Palomar Observatory Sky Survey; field 12 arc min).

dominated by extremely strong N V 1240 and He II 1640 Å emission lines.

Highly sensitive VLA radio observations by Seaquist & Taylor (1984) and Seaquist *et al.* (1993) failed to detect YY Her, confirming the absence of significant amount of circumstellar material already inferable from the negative detection by the IRAS satellite and the results of the ground-based *JHK* photometry presented by Swings & Allen (1972), Taranova & Yudin (1982), Kenyon (1988) and Munari *et al.* (1992).

Kenyon & Webbink (1984) modelled the ultraviolet continuum of YY Her in terms of a main sequence star accreting from the M2 giant companion. Mürset *et al.* (1991) using the same data set concluded instead the hot component to be a WD without a detectable accretion disk.

The peculiarity of YY Her among the symbiotic stars became evident during the major outburst it underwent in 1993 (Bortle *et al.* 1993). Contrary to the behaviour of classical symbiotic stars (*cf.* Ciatti 1982), IUE and optical spectra secured by Munari *et al.* (1993) showed that at maximum light, when a blue continuum overwhelmed the TiO absorption bands of the M giant, the high ionization lines largely increased in their integrated absolute flux. Unaware they were observing YY Her during an outburst in 1981, the spectra described by Gravina (1981) and Huang (1984) well match the peculiarities described by Munari *et al.* (1993) for the 1993 outburst.

This paper presents and discusses the lightcurve of YY Her over the last 107 years. Forthcoming papers (collectively referred to as Paper II in the following) will deal with our tight spectrophotometric monitoring in high and low resolution mode since 1986, as well as finally to a comprehensive physical model of YY Her. In the present paper therefore the data discussion will be kept at a minimum.

2. Observations

In order to map in the most complete way the lightcurve of YY Her, we assembled data from a wide set of sources. This obviously comes together with some systematic offsets due to instrumental diversities and differences in the adopted comparison sequences. We have tried to overcome and/or correct these offsets in a fair way (see below). For reader's convenience, the various comparison star sequences are summarized in Table 1 and identified in Fig. 1. To assess their accuracy, UBV photoelectric photometry has been obtained for all comparison stars with the 1.25 m telescope operated in Crimea by the Sternberg Astronomical Institute (SAI).

2.1. Photographic blue data

Given the unknown instrumental color terms, all data (from literature or our own measurements) derived from blue sensitive plates or prints (filtered or unfiltered, taken with an astrograph or a Schmidt telescope) have been collectively assumed to match the m_{pg} system. This is quite fair because their main use is to assess the mean quiescence brightness and the occurrence of outbursts at historical times. A total of 618 plates (dating back to 1890) imaging YY Her have been located at several plate archives. They have been measured against the same comparison sequence (marked α in Table 1) to ensure the highest internal consistency. Additional 33 m_{pg} values have been found in literature (Wolf 1919, Plaut 1932, Herbig 1950). A complete listing of the so gathered 651 m_{pg} data of YY Her is given in Table 6. The typical external error of our m_{pg} determinations is 0.2 mag.

Table 2. UBV photoelectric photometry of YY Her (MJD = JD-2400000). af=AFAM, st=Crimean Astronomical Observatory (Sternberg Astronomical Institute), son=Sonneberg Observatory, cr=Crimean Astrophysical Observatory (Ukraine Academy of Sciences). A colon indicates internal errors exceeding 0.03 mag.

MJD	V	$B-V$	$U-B$		MJD	V	$B-V$	$U-B$		MJD	V	$B-V$	$U-B$	
44035	12.66	1.35	0.25	st	48127	12.85	1.24		son	49260	11.75	0.51	-0.42	af
45124	12.84	1.14	-0.27	st	48499	12.85	1.38	0.12	cr	49290	12.26:			af
45513	12.96	0.74	-0.06	st	48500	12.72	1.40		son	49308	12.16:			af
46175	12.76	1.11		son	48523	12.74	1.38	-0.11	cr	49310	12.26:	0.90:		af
46552	12.91	1.11		son	48804	12.82	1.26		son	49445	12.2:	0.4:		af
46554	12.97	1.26		son	49154	11.94	0.31		af	49479	12.4:	1.0:		af
46592	13.32	1.00		son	49156	11.92	0.19	-0.59:	af	49509	12.6:	1.3:		af
46597	13.33	1.12		son	49157	11.81	0.31	-0.62	af	49563	12.2:	1.4:		af
46607	13.41	1.13		son	49176	11.66	0.43	-0.55	af	49886	12.61	0.96	-0.79	st
46990	12.74	1.10		son	49177	11.72	0.31	-0.66	af	49887	12.55	0.84	-0.72	st
47038	12.74	1.22		son	49199	11.26	0.38	-0.42	af	49903	12.67	0.87	-0.67	st
47616	12.81	1.28		son	49201	11.25:	0.29:	-0.40:	af	49917	12.71	0.90	-0.82	st
47669	12.89	1.31		son	49202	11.31	0.42	-0.44	af	49921	12.67	0.90	-0.76	st
47671	12.91	1.32		son	49209	11.78	0.33	-0.55	af	49924	12.69	0.88	-0.69	st
47703	12.90			son	49210	11.77	0.38		af	49944	12.67	0.96	-0.74	st
47943	12.82	1.41	-0.09	cr	49212	11.66:			af	50005	12.92	1.01	-0.73	st
47958	12.78	1.39	-0.05	cr	49213	11.73	0.42		af	50015	12.96	0.91	-0.71	st
47987	12.75	1.38	-0.08	cr	49214	11.74	0.51		af	50194	12.77	1.02	-0.63	st
47988	12.76	1.44	-0.18	cr	49215	11.85	0.35	-0.56	af	50199	12.85	0.97	-0.57	st
47995	12.80	1.37	-0.13	cr	49216	11.77	0.40	-0.58	af	50199	12.71	1.03	-0.59	st
48012	12.65	1.30		son	49218	11.64	0.56		af	50200	12.73	1.03	-0.56	st
48016	12.77	1.41	-0.19	cr	49220	11.70	0.60	-0.51	af	50222	12.88	1.01	-0.64	st
48024	12.74	1.33	-0.07	cr	49221	11.64	0.76:	-0.86	af	50224	12.84	1.02	-0.58	st
48032	12.66	1.21		son	49229	11.66:	0.41:	-0.51	af	50233	12.76	0.97	-0.50	st
48038	12.59	1.20		son	49232	11.78	0.44	-0.49	af	50245	12.83	1.02	-0.60	st
48053	12.86	1.30	-0.31	cr	49236	11.99	0.48	-0.61	af	50269	12.82	1.02	-0.58	st
48071	12.84	1.25	-0.22	cr	49242	11.84	0.58		af	50270	12.93	0.95	-0.61	st
48073	12.87	1.26	-0.33	cr	49249	11.94	0.68	-0.58	af	50301	12.88	1.05	-0.63	st
48090	12.94	1.28	-0.31	cr	49250	11.89	0.64	-0.46	af	50304	12.84	0.96	-0.69	st
48093	12.93	1.30	-0.33	cr	49251	11.45	0.67	-0.23	af	50362	12.91	0.86	-0.81	st
48099	12.99	1.30	-0.32	cr	49252	11.56	0.58	-0.32	af					

In particular, a total of 351 plates containing YY Her have been found in the Harvard plate collection (spanning the time interval 1890-1974). They have been exposed with a wide assortment of refractors (details in Table 6). The magnitude of YY Her has been eye-estimated at a microscope.

In the SAI plate archives we recovered 41 blue sensitive plates exposed unfiltered through different astrographs in the time interval 1899-1971. The magnitude of YY Her has been measured with a microphotometer.

Additional 223 plates (covering the period 1952-1965) have been found in the Sonneberg Sky Patrol archive. The magnitude of YY Her has been eye-estimated at a microscope.

Finally, we have also eye-estimated the YY Her brightness on the Carte du Ciel and on two POSS blue prints.

2.2. Visual estimates

The AAVSO and AFOEV databanks of visual estimates from amateur astronomers contain a copious amount of data on YY Her which are particularly suited to document the photometric evolution over the last three decades.

Since 1969 AAVSO and AFOEV have collected 3,238 and 986 visual estimates of YY Her, respectively. 389 estimates appear in both datasets and have been counted only once in the analysis. 96 AAVSO and 45 AFOEV data are reported as upper limits or uncertain values and have not been further used. Additional 176 AAVSO and 86 AFOEV estimates were ignored because provided by observers contributing a total number of estimates < 10: their scatter around the mean is much larger than the rest of the sample and computation of a zero-point offset is not statistically meaningful for them. Their exclusion from further analysis did not produce any loss of information and instead quite helped to suppress the overall noise. Thus, a total of 3,432 visual estimates were used to derive the recent photometric history of YY Her.

To obtain a clean lightcurve from the so selected 3,432 visual estimates while preserving the maximum of information, we proceeded in an iterative way: (a) first, the data from all

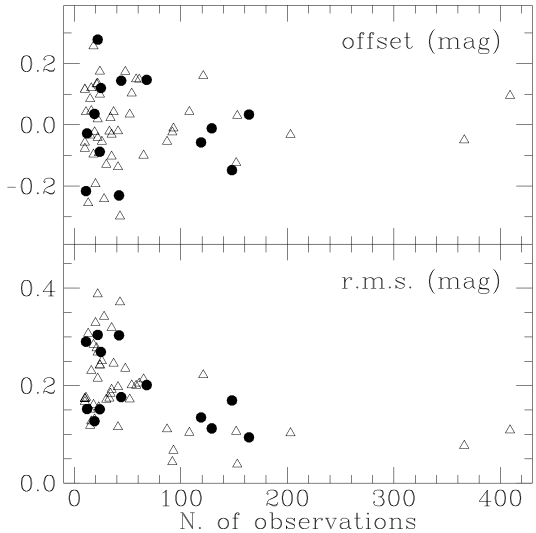

Fig. 2. Offset and rms. from the mean visual lightcurve of YY Her in quiescence for the AAVSO (open triangles) and AFOEV (filled circles) observers with more than 10 recorded observations.

AAVSO members with at least 80 estimates were averaged into 30-day consecutive, non-overlapping bins; (b) the starting date for the binning was chosen in order to have both the observations evenly distributed among all bins and to preserve the maximum of details in the resulting lightcurve; (c) the offsets from the averaged lightcurve were calculated for all observers with at least 80 estimates and were applied to their data. A new 30-day binned lightcurve was then computed, thus suppressing the noise due to systematic zero-point offsets between the most prolific observers; (d) with respect to this lightcurve, the offsets of all other observers contributing less than 80 estimates were computed and applied to their data; (e) with all individual offsets removed a new 30-day binned lightcurve for AAVSO data was calculated; (f) against it the offsets of all AFOEV observers were computed and applied to their data (in this way accounting and suppressing the small differences in the comparison sequences used by the two Organizations; cf. Table 1); and finally (g) the ultimate, 30-day binned lightcurve was obtained by merging all cleaned AAVSO and AFOEV data. Hereafter when discussing visual estimates we shall always refer to this ultimate lightcurve which is tabulated in Table 5.

The offset and rms from the final lightcurve for all observers with at least 10 estimates are shown in Fig. 2. It is quite clear how the larger the number of estimates, the lower the scatter and the offset. The way in which offset and scatter rapidly increase with decreasing number of estimates fully justifies the above described decision to ignore data coming from observers who provided less then 10 data.

2.3. $UBVR_J JHKL$ photoelectric photometry

Photoelectric photometry has been secured at four different sites:

Table 3. Crimean Astronomical Observatory $R_J JHKL$ photoelectric photometry of YY Her (MJD=JD-2400000).

MJD	R_J	J	H	K	L
44035	11.05	9.18		8.06	
44039				7.94	
44042		8.88		7.99	
45124	11.37	9.07	8.20	7.99	
45513	11.55	9.14	8.15	8.01	
45841		9.26			
45874		9.27	8.42	8.05	
46196		8.91			8.1
46225		8.95	8.33	7.91	7.7
46330		9.13	8.21	8.08	
46617		9.12	8.19	7.93	8.0
47041		9.10	8.21	7.99	7.7

1) with a 2-channel photometer mounted on the 1.25 m reflector at the Crimean Astronomical Observatory, operated by SAI. For $UBVR_J$ bands a S-20 photomultiplier has been used, while an PbS photoconductor was the detector for *JHKL* bands before 1983 when it was replaced by a InSb diode. The comparison stars adopted have been HD 168957 (U=6.35, B=6.91, V=7.01, R_J=7.05) and HR 6895 (J=1.92, H=1.26, K=1.16, L=1.02);
2) with the 0.45 m reflector of the Associazione Friulana di Astronomia e Meteorologia (hereafter AFAM) and a UBV photoelectric photometer housing an uncooled 1P21 photomultiplier. The comparison star was HD 164922 (V=7.28, B=7.82, U=8.28);
3) with a single channel UBV photometer at the 60 cm reflector of the Sonneberg Observatory. The comparison star was again HD 164922;
4) with the $UBV(RI)_J$ photoelectric photometer at the 1.25 m Cassegrain telescope of the Crimean Astrophysical Observatory (CAO; Ukraine Academy of Sciences). Further details on the adopted comparison star cannot be recovered because the observer (P.V.Chugainov, co-author of the present paper), passed away in 1992.

We did not carry out any attempt to derive detailed transformation equations between these four reproductions of the international $UBV(RI)_J$ photometric system, because the possible systematic differences are very small compared with the great range of variation in brightness exhibited by YY Her.

The photoelectric data are summarized in Tables 2, 3 and 4. The internal errors do not exceeded 0.03 mag in $UBV(RI)_J JHK$ bands and 0.1 mag in L except where noted in the tables.

3. The lightcurve

The lightcurve of YY Her covering the period 1890-1996 is presented in Fig. 3, with m_{pg} data documenting the evolution to 1970 and m_{vis} later on.

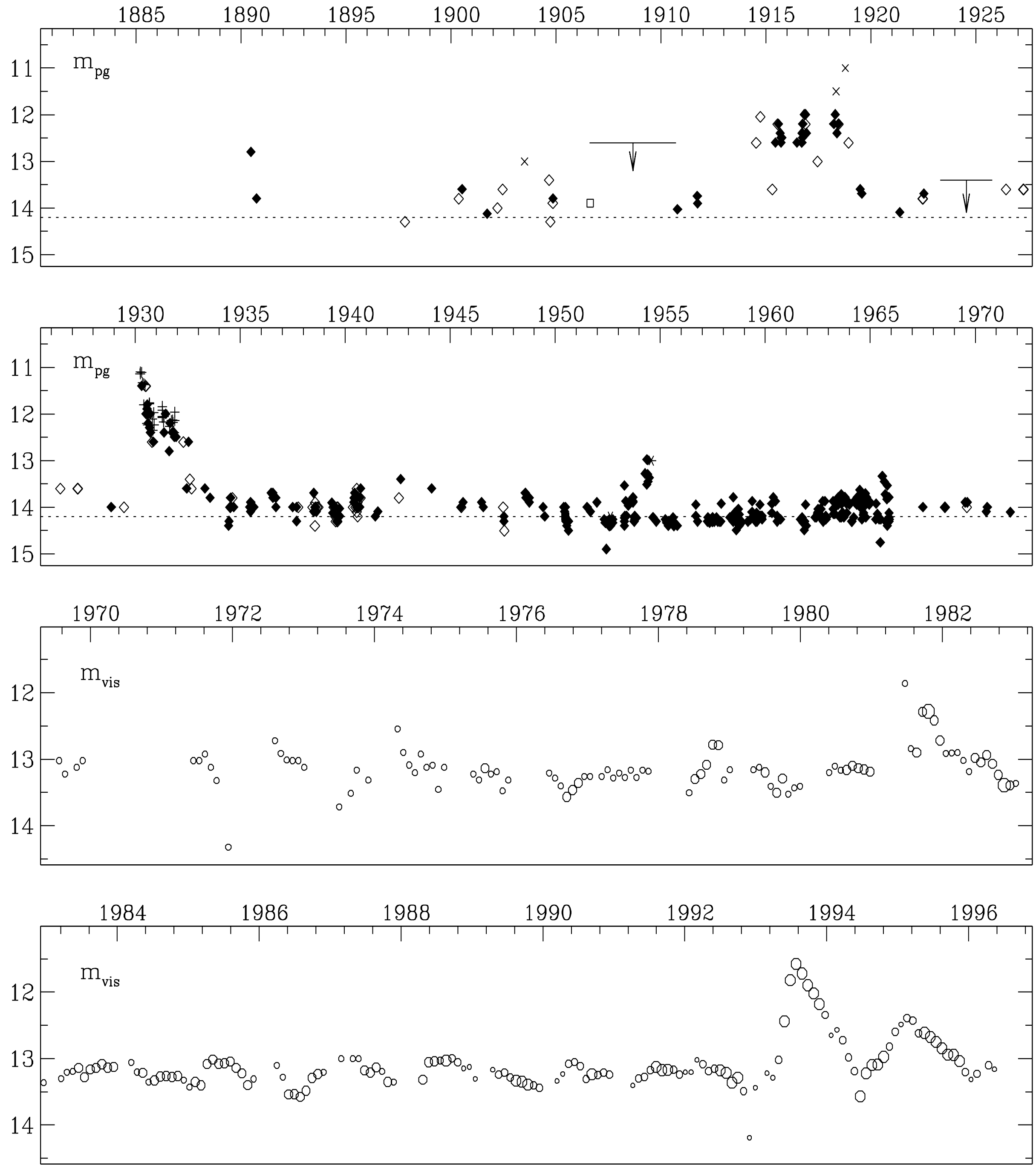

Fig. 3. The 1890-1996 lightcurve of YY Her. m_{pg} *Panels*. The dotted line is the quiescence B magnitude from photoelectric photometry in Table 2. Upper limits from Table 6 are omitted for plot clarity. *Filled rhombs*: our data from Table 6; *Open rhombs*: uncertain values from Table 6; *Crosses:* from Wolf (1919); *Plus signs:* from Plaut (1932); *Asterisks*: estimates on the POSS blue prints; *Filled squares:* from Herbig (1950); *Open square*: estimate on the Carte du Ciel. m_{vis} *Panels*. The circle dimension is proportional to the number N of individual estimates in the given 30-day bin. Smallest circles refer to N≤5, intermediate to 5<N<30, and the largest one to N≥30.

Table 4. Crimean Astrophysical Observatory $R_J I_J$ photoelectric photometry of YY Her (MJD=JD - 24000000).

MJD	R_J	I_J	MJD	R_J	I_J
47943	11.17	9.94	48071	11.20	10.00
47958	11.18	9.98	48073	11.25	10.08
47987	11.12	9.92	48090	11.29	10.08
47988	11.14	10.00	48093	11.30	10.07
47995	11.16	9.97	48099	11.34	10.10
48016	11.07	9.91	48499	11.21	9.87
48024	11.11	9.92	48523	11.17	9.66
48053	11.19	10.00			

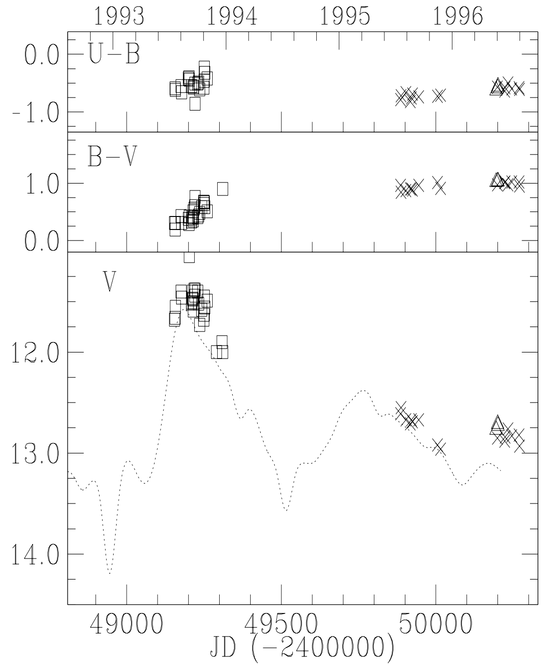

Fig. 4. *UBV* photoelectric photometry during the 1993-95 outburst. The dotted line is plotted for reference purposes and shows a spline fit to the binned AAVSO+AFOEV lightcurve. *Open squares*: AFAM; *Crosses*: Crimean Astronomical Observatory

3.1. Quiescence

During the last century YY Her has experienced long periods of flat quiescence, during which the mean brightness has remained fairly constant.

The photoelectric photometry during recent quiescence phases in Table 2 gives $< B >$=14.2 mag, a value closely fitting old m_{pg} data as the dashed line in Fig. 3 shows. A least square fit to the visual quiescence data during the period 1969-1993 (cf. Table 5) does not support evidence for a significant trend with time:

$$\triangle V = +0.003 \pm 0.002 \ \ mag\ yr^{-1} \qquad (1)$$

In this respect, symbiotic stars display a range of behaviours. V443 Her is known to have a remarkably constant mean brightness in quiescence (Kolotilov *et al.* 1995), while AS 296 = FG Ser has shown a steady and marked trend during the long quiescence prior the nova eruption in 1988 (Munari *et al.* 1995).

3.2. Orbital period

The dominant feature in the m_{vis} quiescence lightcurve of YY Her in Fig. 3 is a small amplitude, regular variation which is not visible in the m_{pg} section of the lightcurve due to the much higher noise there. The quiescence m_{vis} data have been searched with a Fourier code which has revealed a strong periodicity at 590 $\pm$ 3 days. A phase plot of the data is presented in Fig. 5. Separate analysis of the m_{vis} data before the 1981-82 outburst tends to support a shorter period $\sim$570 days, with acceptable lightcurves over the interval 555-600 days. For data between the 1981-82 and 1993-96 outbursts the values modify into $\sim$600 day period and 570-610 day range, respectively.

The sinusoidal shape suggests that the light modulation is due to the *heating effect* (a common feature of symbiotic stars; cf. Kenyon 1986, Munari 1989, Kolotilov *et al.* 1995): the hard radiation field of the hot component heats the facing side of the cool giant which is brought into and out of view periodically by the orbital motion. The 590 days is therefore taken as the orbital period of the YY Her. Instants of minimum brightness obey the ephemeris:

$$Min(V) = 2448945(\pm 10) + 590(\pm 3) \times E \qquad (2)$$

They trace the passages at inferior conjunction of the cool giant. Compared to other symbiotic stars showing the heating effect, the large amplitude of the modulation ($\triangle V$ = 0.3 mag) suggests YY Her to have a significantly large orbital inclination.

As the Allen (1984) and Blair *et al.* (1983) spectra clearly show, the quiescence V band emission of YY Her is vastly dominated by the cool giant. Could the $\triangle V$ = 0.3 mag modulation be related to intrinsic variability of the latter ? The following considerations argue negatively and reinforce the interpretation of the 590 days periodicity in terms of orbital period. The modulation repeats strictly identically over all recorded cycles, while low amplitude variability of cool giants (particularly at periods comparable to the derived 590 days) looses coherence over few cycles. The K infrared magnitudes in Table 3 show a spread of just 0.05 mag, comparable to the measurement errors and therefore exclude any significant intrinsic variability of the cool giant.

Given the significant orbital inclination of YY Her as inferred by the $\triangle V$ = 0.3 mag amplitude of the heating effect and the absence of any double-sine infrared variability (cf. Yudin & Munari 1993 for the T CrB case), it may be concluded that the cool giant is well inside its Roche lobe.

3.3. Deep minima

The lightcurve in Fig. 3 displays a few strange, deep and sharp minima. The m_{pg} depth of the 1952 and 1965 events is $\sim$0.6,

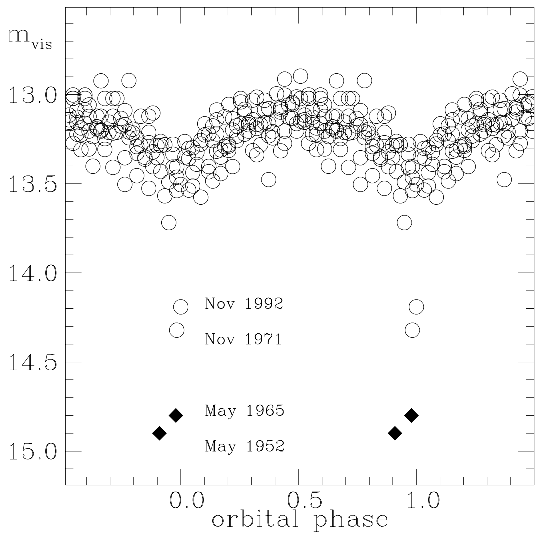

Fig. 5. Phase plot of the quiescence visual lightcurve of YY Her according to ephemeris (2). The solid diamonds are the two minima in the m_{pg} lightcurve of Fig. 3 at JD=2434141 and 2438902 are plotted for reference purposes.

and $\sim$1.1 mag in m_{vis} for those in 1971 and 1992. Amazingly, they appear near phase 0.0 (cf. eq. 2 and Fig. 5).

Are they related to eclipses of the hot component by the cool giant ? Such an interpretation is tempting given the strong orbital phase coincidence of the events (right at the time when eclipses *could* occur), however other arguments do not support it: (a) the amplitude does not increase toward shorter wavelengths as expected when the hot companion is eclipsed by the cool giant (as generally observed in eclipsing symbiotic stars). The very small number statistics could however play oddly here; (b) the quiescence V brightness of YY Her is vastly dominated by the cool giant, and therefore any eclipse of the hot companion ought pass undetected; (c) there are too many *missing eclipses* in the lightcurve of Fig. 3. If the four events are indeed eclipses, we do not see any straightforward explanation for the absence of other similar events in the m_{vis} lightcurve between 1971 and 1992 (cf. Figs. 3 and 5).

A different possibility is R CrB-like events in the atmosphere of the cool giant. The fact that these minima seem to precede outbursts or bright phases could support this interpretation (this is clearly the case for the 1952 and 1992 events, possibly also for the 1965 one. Nothing can be said for the 1971 one, because it was immediately followed by the period of seasonal invisibility of the star). The increased atmospheric opacity during the R CrB events may lead to an expansion of the cool giant atmosphere and hence to a larger filling of the Roche lobe and eventually to a higher mass accretion onto the hot component. The increased mass accretion rate could trigger the onset of an outburst or bright phase if the conditions in the hot component accreted envelope are already critical. However, such an interpretation faces at least two problems. R CrB stars are not first red-giant branch like the bulk of cool giant in symbiotic stars (cf. Whitelock & Munari 1992). The occurrence of R CrB-like events always at the same orbital phase is also strange, unless they are triggered by changing orbital separation in an eccentric orbit.

3.4. Distance, reddening and cool giant variability

Final values for the adopted distance and reddening of YY Her have to wait the analysis of the spectrophotometry in Paper II. Preliminary values, useful to assess the energetics of the outbursts, may however be derived here.

Herbig (1950) derived a spectral type M2 III for the cool giant in YY Her from observations in the blue part of the spectrum, where contamination from the nebular continuum may play some role. Kenyon & Fernandez-Castro (1987) obtained a M3 III classification from observations in the near-IR. We therefore adopt here a M3 III type, and note that galactic latitude of YY Her is b = +17° and from Table 3 it is $< K >$= 8.00$\pm$0.02 and $< J - K >$= 1.09 $\pm$ 0.03

Assuming that YY Her shares the properties of the galactic thin-Disk M giants, from Lee (1970) tabular values a distance D = 5.5 kpc and a reddening E_{B-V}=0.0 mag are derived. The distance from the galactic plane would therefore result in z = 1.6 kpc, which is really too large for a star supposedly a member of the young stellar population of the Galaxy, for which the scale hight is z_h = 350 pc (Freeman 1987). Also the E_{B-V}=0.0 seems unrealistically low.

On the other hand, Whitelock & Munari (1992) and Munari (1994) have shown that the symbiotic stars with non-variable M giants belong to the Bulge/thick-Disk population of the Galaxy. In this case, using tabular data from Frogel & Whitford (1987), the distance and reddening of YY Her change to D = 3.2 kpc and E_{B-V} =0.41, and the height above the galactic plane lowers to z = 950 pc, in agreement with the z_h = 1.0 kpc scale height derived by Freeman (1987) for the Bulge/thick-Disk population of the Galaxy.

Photometric data therefore strongly argue for YY Her to belong to the Bulge/thick-Disk of the Galaxy.

3.5. Outbursts and bright phases

Four outburst phases in 1914-19, 1930-33, 1981-82 and 1993-96 are evident in the lightcurve of Fig. 3, and a few additional bright phases in 1890, 1903, 1942, 1954, 1965 and 1974 add up. The distinction between outbursts and bright phases is somewhat arbitrary given the splinted coverage in m_{vis} and m_{pg} and the different amplitude in the two photometric bands.

Integrating the flux over a smoothed lightcurve for each of the four outbursts gives the following values for the released energy in the given photometric band (adopting the above derived D = 3.2 Kpc and E_{B-V}=0.41):

$$1914-1919: \quad L_B = 1 \times 10^{43} \quad erg\ sec^{-1}$$
$$1930-1933: \quad L_B = 5 \times 10^{42} \quad erg\ sec^{-1}$$
$$1981-1982: \quad L_V = 3 \times 10^{42} \quad erg\ sec^{-1}$$
$$1993-1996: \quad L_V = 7 \times 10^{42} \quad erg\ sec^{-1}$$

To estimate from these values L_{bol} requires inputs from wide $\lambda-$range spectrophotometric data, and this will be attempted in Paper II. The peak B brightness reached during the 1931 and 1993 outbursts translates into:

$$M_B \simeq -3.0\, mag \tag{3}$$

which is adequate for a mild intensity thermonuclear event far from reaching Eddington luminosities and associated mass loss (cf. Iben 1982). Similar values are attained by Duschl's (1986) models of symbiotic star outbursts governed by the evolution of accretion disks around main sequence stars.

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