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UBV(RI)$_C$ photometric sequences for symbiotic stars. III⋆

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ABSTRACT

We present accurate $UBV(RI)_C$ photometric sequences and astrometric positions for a final set of 41 symbiotic stars. In a similar manner to the 40 targets of Papers I and II, these sequences extend over wide brightness and color ranges and are suited to covering both quiescence and outburst phases. They are intended to assist both the CCD photometric monitoring of current variability and exploitation of old photographic plates from historical archives.

Key words. binaries: symbiotic – atlases – standards

1. Introduction

In Paper I (Henden & Munari 2000), we discussed the need for extended, accurate, and homogeneous photometric sequences around symbiotic stars and how their lack has contributed to our currently poor photometric knowledge of these interacting binaries. The basic types of variability for symbiotic stars and their causes were reviewed, and $UBV(RI)_C$ sequences for a first sample of 20 objects were provided. Paper II (Henden & Munari 2001) presented similar $UBV(RI)_C$ photometric sequences for an additional 20 symbiotic stars.

This paper presents accurate $UBV(RI)_C$ photometric comparison sequences for the final set of 41 symbiotic stars that complete our program. The observed symbiotic stars are listed in Table 1. The sequences are intended to allow a general observer to capture the following on a single CCD frame or to have them in the same eyepiece field of view when inspecting archival photographic plates: (*a*) enough stars to cover the whole range of known or expected variability for the given symbiotic star, (*b*) stars of enough different colors to be able to calibrate the instrumental color equations and therefore reduce the collected data to the standard $UBV(RI)_C$ system, and (*c*) stars well separated from surrounding ones to avoid blending at all but the shortest telescope focal lengths. As the photometric sequences of previous papers have been used in the extensive reconstruction of historical light-curves from inspecting of Asiago archival photographic plates (Munari et al. 2001; Munari & Jurdana-Šepić 2002), a similar effort is underway for this final set of additional 41 symbiotic stars (Jurdana-Šepić & Munari, in preparation).

2. Observations

We used observing strategies and data reduction methodologies strictly similar to those of Papers I and II (to which the reader is referred for all details). All observations were made with the telescopes of the US Naval Observatory at Flagstaff Station. The reported photometry only uses data collected on photometric nights (transformation errors under 0.02 mag). For each night, symbiotic field observations were interspersed with observations of Landolt (1983, 1992) standard fields, selected for wide color and airmass ranges. Our sequences are therefore placed accurately on the Landolt $UBV(RI)_C$ system.

Astrometry was performed using SLALIB (Wallace 1994) linear plate transformation routines in conjunction with the USNO–A2.0 and UCAC2 reference catalogs. Errors in coordinates were typically under 0.1 arcsec in both coordinates, referred to the mean coordinate zero point of the reference stars in each field. Astrometric positions for the program symbiotic stars are given in Table 1 for the mean epoch of 2000.3, all observations having been collected within a few months of the mean epoch.

The finding charts (built from our observations) and the photometric sequences are presented in Figs. 1–41 (available at the CDS).

3. Notes on individual symbiotic stars

CH Cyg. The comparison star "*a*" is SAO 31628, the one traditionally used in photoelectric photometry. It has been reported by Sokoloski & Stone (2000) to be an eclipsing binary star characterized by $\Delta B = 0.2$ mag, 5 h duration for the eclipse and ephemeris for primary minimum

$$\begin{aligned}\text{Min } I &= \text{HJD } 2\,451\,717.8150\,(\pm 0.0005)\\ &+ E \times 3.747833(\pm 0.000007).\end{aligned}$$

The star is retained in our comparison sequence (*a*) for historical reasons and its commonality with literature photoelectric data, (*b*) for being the brightest star in the field, and (*c*) for its usefulness outside of eclipse phases.

UV Aur. This carbon symbiotic Mira has a close companion of similar magnitude ∼3.3 arcsec to the north (plotted on the finding chart), at position RA = 80.4538820 (±0.046 arcsec)

⋆ Finding charts and photometric sequences are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/458/339 or http://ulisse.pd.astro.it/symbio_comp_seq/

Table 1. List of the program symbiotic stars. The coordinates for the symbiotic stars are from our observations (equinox J2000.0, mean epoch 2000.3). The e_α and e_δ columns list errors in arcsec for right ascension and declination, respectively. l and b are the galactic coordinates.

name	α	e_α	δ	e_δ	$l(^\circ)$	$b(^\circ)$
EG And	00 44 37.1894	0.027	+40 40 45.721	0.052	121.54	−22.17
AX Per	01 36 22.7057	0.046	+54 15 02.545	0.017	129.53	−8.04
BD Cam	03 42 09.3072	0.236	+63 13 00.707	0.350	140.84	6.44
CI Cam	04 19 42.1536	0.051	+55 59 57.851	0.041	149.18	4.13
UV Aur	05 21 48.9084	0.024	+32 30 40.219	0.043	174.22	−2.35
V1261 Ori	05 22 18.6365	0.151	−08 39 57.841	0.009	210.63	−23.72
ZZ CMi	07 24 14.0035	0.131	+08 53 51.983	0.010	208.64	11.30
NQ Gem	07 31 54.5318	0.035	+24 30 12.953	0.250	194.63	19.35
Wray 15-157	08 06 34.8708	0.080	−28 32 01.226	0.102	246.60	1.95
AS 201	08 31 42.8885	0.122	−27 45 31.482	0.047	249.08	6.97
RW Hya	13 34 18.1277	0.039	−25 22 48.860	0.056	314.99	36.49
T CrB	15 59 30.1601	0.000	+25 55 12.619	0.026	42.37	48.16
AG Dra	16 01 41.0537	0.105	+66 48 10.134	0.018	100.29	40.97
Wray 15-1470	16 23 21.6470	0.013	−27 40 10.366	0.056	350.06	15.24
AS 210	16 51 20.4031	0.029	−26 00 26.687	0.025	355.51	11.55
V934 Her	17 06 34.5190	0.079	+23 58 18.610	0.025	45.15	32.99
Hen 3-1341	17 08 36.5710	0.030	−17 26 30.066	0.055	5.02	13.39
Hen 3-1342	17 08 54.9641	0.045	−23 23 36.467	0.027	0.08	9.92
M 1-21	17 34 17.2270	0.008	−19 09 22.867	0.025	6.96	7.36
Pt 1	17 38 49.5442	0.016	−23 54 06.275	0.054	3.48	3.94
RT Ser	17 39 51.9972	0.016	−11 56 38.519	0.008	13.90	9.97
RS Oph	17 50 13.1611	0.027	−06 42 28.472	0.016	19.80	10.37
Hen 3-1591	18 07 32.0220	0.029	−25 53 43.357	0.029	5.07	−2.68
AS 289	18 12 22.1513	0.016	−11 40 06.823	0.019	18.09	3.19
V4074 Sgr	18 16 05.5500	0.024	−30 51 13.799	0.049	1.59	−6.69
V4018 Sgr	18 25 26.8418	0.027	−28 35 57.368	0.030	4.55	−7.46
AS 327	18 53 16.6534	0.014	−24 22 58.724	0.011	11.14	−11.23
Pe 2-16	18 54 10.0327	0.030	−04 38 51.810	0.141	29.10	−2.72
MaC 1-17	19 12 57.2748	0.027	−05 21 20.293	0.023	30.59	−7.22
V352 Aql	19 13 33.7073	0.167	+02 18 13.252	0.037	37.51	−3.86
BF Cyg	19 23 53.5068	0.041	+29 40 29.496	0.025	62.93	6.70
CH Cyg	19 24 33.0838	0.014	+50 14 29.440	0.267	81.86	15.58
Hen 2-442	19 39 43.3680	0.015	+26 29 33.324	0.012	61.79	2.11
HM Sge	19 41 57.0958	0.024	+16 44 40.204	0.022	53.57	−3.15
StHα 169	19 49 57.6137	0.087	+46 15 20.855	0.096	80.14	10.02
CI Cyg	19 50 11.8435	0.055	+35 41 03.239	0.021	70.90	4.74
V1016 Cyg	19 57 05.0345	0.114	+39 49 36.401	0.022	75.17	5.68
PU Vul	20 21 13.3279	0.049	+21 34 18.926	0.034	62.58	−8.53
V1329 Cyg	20 51 01.2737	0.015	+35 34 54.390	0.021	77.84	−5.48
AG Peg	21 51 01.9891	0.049	+12 37 32.567	0.015	69.28	−30.89
Z And	23 33 39.9516	0.117	+48 49 06.139	0.031	109.98	−12.09

and Dec = +32.5121112 (±0.031 arcsec). Its spectral type is given as O9II by the Hipparcos catalog. Our photometry lists for the companion U = 10.799 (±0.027), B = 11.114 (±0.036), V = 10.937 (±0.027), R_C = 10.887 (±0.041), and I_C = 10.768 (±0.061). The light of the hotter component of the optical pair dominates that of the combined pair at $\lambda \leq 5000$ Å when the Mira is at minimum, while the Mira overwhelms the hotter component when it is at maximum. The interplay is clearly visible in the spectra of Munari & Zwitter (2002) for Oct. 15, 1995 (Mira at minimum according to AAVSO database) and Feb. 7, 1996 (Mira at maximum). The disappearance of emission lines on the Oct. 15, 1995 spectrum, combined with emergence of a hot supergiant spectrum in the blue, could have been straightforwardly interpreted as evidence of an outburst state of the symbiotic star. Actually, the disappearance of emission lines at the minima of pulsation light-curves is a widespread property of Carbon Miras and it is a well-documented process, as in the multi-epoch spectroscopic atlas of Mikulášek & Gráf (2005).

V4074 Sgr. Merrill & Burwell (1950) found an emission line spectrum for AS 295. Herbig & Hoffleit (1975) discovered that the emission lines instead originate in a fainter star about 3 arcsec to the south, which they named AS 295B. The finding chart for this symbiotic star as provided by Allen (1984) is in error. Our finding chart points to the correct AS 295B star as originally identified by Herbig & Hoffleit (1975) and confirmed by the $U-B = -0.89$ color index in our observations (compared to the $U-B = +1.43$ of the object identified in Allen's finding chart, which is typical of field stars).

RS Oph. This star went into outburst on Feb. 13, 2006; the first outburst in 21 years. It peaked at V = 4.8 and has been followed extensively by the AAVSO (see `http://www.aavso.org/news/rsoph.shtml`), as well as many professional observatories and satellites (cf. Eyres et al. 2006; Bode et al. 2006; Rudy et al. 2006).

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