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LONG TERM BVR_CI_C PHOTOMETRY OF CARBON AND SYMBIOTIC STARS IN THE DRACO DWARF GALAXY

MUNARI, U.[1]; SIVIERO, A.[1]; OCHNER, P.[2]; TOMASONI, S.[2]; MOSCHINI, F.[2]; FRIGO, A.[2]; MORETTI, S.[2]; TOMASELLI, S.[2]; BALDINELLI, L.[2]; MAITAN, A.[2]; VAGNOZZI, A.[2]; BACCI, S.[2]

[1] INAF Osservatorio Astronomico di Padova, Sede di Asiago, I-36032 Asiago (VI), Italy

[2] ANS Collaboration, c/o Osservatorio Astronomico, I-36032 Asiago (VI), Italy

The Draco dwarf galaxy (Ddg) is a satellite of the Milky Way Galaxy, characterized by low reddening ($E_{B-V} = 0.03$), low metallicity ($[\mathrm{Fe/H}] \approx -2$), high velocity dispersion ($\sigma_V = 10.5\,\mathrm{km\,sec^{-1}}$), a tidal radius of 40 arcmin ($\approx 0.83\,\mathrm{kpc}$), a total mass within the tidal radius of $3.5 \times 10^7 M_\odot$, and a distance modulus of $m - M = 19.3\,\mathrm{mag}$. The overall light-to-mass ratio is $M/L = 146 \pm 42$ (in solar units), indicating a strongly dark-matter dominated, bound stellar system (Odenkirchen et al. 2001).

The first three carbon stars (named C1, C2, C3) were discovered in Ddg by Aaronson et al. (1982). Since then, other three were found (cf. Kinemuchi et al. 2008, and references therein). One of the carbon stars, C1, is a symbiotic binary (Belczynski et al. 2000). It displays a rich and high ionization emission line spectrum (Aaronson et al. 1982, Munari and Buson 1994) and it is a super-soft X-ray source (Bickert et al. 1996).

An extensive search for variable stars in Ddg was carried out by Baade and Swope (1961), during which they found 260 variables. They did not notice any of the carbon stars as a variable star, in spite the mean brightness of the variables they discovered and characterized (mainly RR Lyr) was three whole magnitudes fainter than the carbon stars themselves. Should any of the carbon stars have varied by more than 0.2 mag, Baade and Swope's survey would have detected them. The issue if any of the carbon stars in Ddg is indeed variable, of very low amplitude, is still an open issue given the contradicting results reported in the literature (see Kinemuchi et al. 2008 for a partial summary).

Over the last three years we have carried out a surveillance monitoring of C1, looking for active phases of this highly interacting and energetic binary.

Our $BVR_\mathrm{C}I_\mathrm{C}$ CCD photometric surveillance extended from 2006.30 to 2008.68. Together with C1, in the same field of view our CCD observations, we recorded also C2 and C3. We observed with several telescopes, all located in Italy: the 0.5 m of Museo Civico di Rovereto (Trento), the 0.5 m of Osservatorio Astronomico S. Lucia di Stroncone (Terni), the 0.4 m of Associazione Ravennate Astrofili Rheyta in Bastia (Ravenna), the 0.4 m of Osservatorio Astronomico Pizzinato (Bologna), and a 0.3 m located in Folgaria (Trento). All instruments were equipped with either Schuler, Optec, Custom Scientific or Omega standard $BVR_\mathrm{C}I_\mathrm{C}$ filters. All observations were reduced and corrected for color equations using the same photometric comparison sequence calibrated around C1 by Henden and

Table 1: Median values (and errors) of our $BVR_\mathrm{C}I_\mathrm{C}$ photometry of Draco C1, C2 and C3 covering the period from 2006.30 to 2008.68. Median values (and errors) from Skopal et al. (2007, coded *b*) and mean values (and errors) from Kinemuchi et al. (2008, coded *a*) are given for comparison.

	$< V >$		$< I_\mathrm{C} >$		$< B-V >$		$< V-I_\mathrm{C} >$		$< R_\mathrm{C}-I_\mathrm{C} >$		
C1	17.17	0.08	15.68	0.05	1.49	0.14	1.49	0.06	0.63	0.06	
C2	17.36	0.06	16.03	0.05	1.59	0.25	1.31	0.07	0.63	0.05	
C3	17.53	0.09	16.23	0.08	1.47	0.29	1.31	0.10	0.59	0.06	
C1	17.15	0.08	15.66	0.04			1.49	0.09			*a*
C2	17.30	0.05	15.99	0.04			1.31	0.06			*a*
C1	17.19	0.05	15.82	0.07	1.45	0.03	1.41	0.05	0.65	0.02	*b*

Munari (2000). A total 121 $VR_\mathrm{C}I_\mathrm{C}$ runs were collected in separate nights, 33 of which included also observations in the B band.

Even if no outburst or bright phase of C1 has been recorded, the collected data allow to put constraints on the variability of C1, C2 and C3. Table 1 lists the median values of our observations, and for comparison the median values obtained by Skopal et al. (2007), who monitored C1 from 2003.9 to 2007.2, and by Kinemuchi et al. (2008), who monitored C1 and C2 from 1993 to 1996. The values in Table 1 agree well within the errors, indicating the absence of any long term trend affecting C1 and C2 over the last 15 years.

The program stars were faint, our telescopes of limited diameter and the observations were carried out in surveillance, short-exposure mode. Therefore, the error affecting the single photometric point is significant. To obtain meaningful light-curves is necessary to bin the data. A bi-monthly binning proved to be the most convenient in term of noise suppression and preservation of light-curve details. Such a bi-monthly binning provides the following results for the three program stars.

C3 is not variable, at least not with an amplitude larger than 0.05 mag.

C2 is a border-line case. The amplitude of any actual variability should not exceed 0.1 mag. Shetrone et al. (2001) listed C2 as a definite photometric variable, but they did not provide supporting details. An amplitude around 0.2 mag is listed for C2 by Kinemuchi et al. (2008), again with not details.

C1 is more confidently a true variable, as illustrated by Figure 1 which could also support feeble hints of an anti-correlation of brightness and color (C1 redder when fainter, bluer when brighter), as observed in pulsating stars. The amplitude is ≈ 0.2 mag, with a possible periodicity of the order of one year. Amplitude and period would be appropriate for either a reflection effect or an ellipsoidal distortion of the carbon star. It is worth noticing that Shetrone et al. (2001) asserted C1 to be not variable, while it is definitively a variable according to Kinemuchi et al. (2008).

The reflection effect is quite common in symbiotic binaries and it is caused by the very hot and luminous white dwarf illuminating the facing side of the cool giant companion. In this case the period of the reflection effect is also the orbital period. The ellipsoidal distortion of the mass donor cool giant is also frequently observed in symbiotic binaries, where the high mass transfer rate necessary to sustain the stable H-burning conditions on the white dwarf, requires Roche lobe filling conditions. In this case, the orbital period is twice longer than the period of photometric variability. Given its super-soft X-ray nature, both a reflection effect and the Roche lobe filling are highly probable to occur in C1, and the light-curve in Figure 1 could result from the combination of the two. The high-resolution spectroscopic observations by Munari (1991) proved C1 to be variable in both radial velocity and emission line profiles. Clearly, C1 is worth further observations, which we plan to carry out.

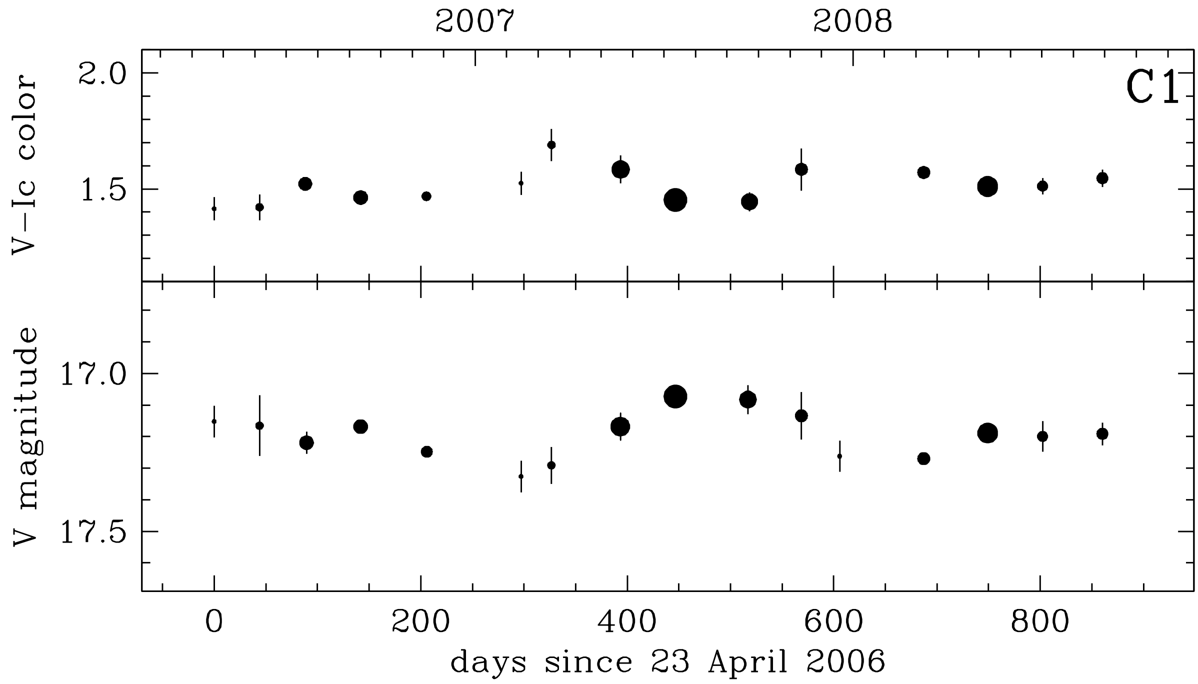

Figure 1. V, $V - I_C$ light-curve of carbon symbiotic binary C1 from our observations, binned into bi-monthly means. The size of the dots is proportional to the number of observations in that bin. The error bars are the errors of the mean.

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