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Absolute and geometric parameters of contact binary GW Cnc

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HIGHLIGHTS

- We present the analysis of spectroscopic and new photometric observations of GW Cnc.
- The period changes in the Observed–Calculated (O–C) diagram were analyzed.
- The orbital and physical parameters of the system were derived.
- Our model describes GW Cnc as a W-type overcontact binary.

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ABSTRACT

We present the results of our investigation on the geometrical and physical parameters of the W UMa type binary system GW Cnc. We analyzed the photometric data obtained in 2010 and 2011 at Ankara University Observatory (AUO) and the spectroscopic data obtained in 2010 at TUBITAK National Observatory (TUG) by using the Wilson–Devinney (2013 revision) code to obtain the absolute and geometrical parameters. We derived masses and radii of the eclipsing system to be $M_1 = 0.257\,M_\odot$, $M_2 = 0.971\,M_\odot$, $R_1 = 0.526\,R_\odot$ and $R_2 = 0.961\,R_\odot$ with an orbital inclination $i(^\circ) = 83.38 \pm 0.25$ and we determined the GW Cnc system to be a W-type W UMa over-contact binary with a mass ratio of $q = 3.773 \pm 0.007$.

1. Introduction

The short-period ($P \sim 0^d.2814$) binary system GW Cnc (ASAS 084813+2107.2, $V = 12^m.595$, $\alpha_{2000} = 08^h48^m12^s.693$, $\delta_{2000} = +21^\circ07'13''.86$) was reported as an *L*: type variable by Takamizawa (2000) in the GCVS. Thereafter, Khruslov (2005) identified the system as W UMa (EW) type eclipsing binary by using ASAS3 and ROTSE data and gave the light elements as follows:

$$HJD(Min.I) = 2451554.023 + 0^d.281415 \times E. \quad (1)$$

The first photometric analysis of the system was made by Terrell et al. (2005) which gives the mass ratio of the system as 4.15 and the orbital inclination as 83°.4. The $(B-V)$ color was obtained by the same authors as $0^m.68$ during the total eclipse and also at the phase of 0.75. The spectral type of the system and distance are given as *G8V* and 319 pc, respectively in the catalogue of "All-sky spectrally-matched Tycho2 stars" (Pickles and Depagne, 2010).

In this study, we derive the physical and geometrical parameters of the eclipsing binary system using photometric data obtained at the Ankara University Observatory (AUO) between 2010 October and 2011 March and radial velocity data obtained at the TUBITAK National Observatory (TUG) in 2010 November. We revised the light elements by using the published minima times given in the literature within the framework of the well-known (O-C) method.

2. Observations

Observations of GW Cnc in *VRI* bands were carried out with an Apogee ALTA-U47 (1024 × 1024) CCD photometric system attached to the 0.40 m Meade-LX200GPS telescope at the AUO in 2010 and 2011. The telescope was equipped with a standard Johnson *UBVRI* filter set with a field of view of 11′.3 × 11′.3. The exposure time for each image was varied according to the filter used.

TYC1399-1572-1 ($V = 11^m.43$, $\alpha_{2000} = 08^h48^m38^s.353$, $\delta_{2000} = +21^\circ05'10''.68$), GSC1399-1348 ($V = 12^m.96$, $\alpha_{2000} = 08^h48^m22^s.10$, $\delta_{2000} = +20^\circ59'58''.00$) and GSC1399-2073 ($V = 12^m.84$, $\alpha_{2000} = 08^h48^m29^s.70$, $\delta_{2000} = +21^\circ00'36''.7$) were used as comparison and check stars which are located on the same frame of the CCD camera as GW Cnc. The coordinates were obtained from SIMBAD database.

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Table 1
Observation log and standard errors of the observations of GW Cnc.

Obs. date	Number of obs.				Observers
	$(V+R+I)$	$\pm\sigma(V)$	$\pm\sigma(R)$	$\pm\sigma(I)$	
2010-10-30	56	0.013	0.016	0.015	YD-TO
2010-11-01	315	0.013	0.010	0.015	AO-SC
2010-11-02	270	0.017	0.012	0.015	GG-YK
2010-11-07	438	0.016	0.012	0.015	ZT-AB
2010-11-10	353	0.018	0.014	0.020	GG-HA
2010-11-14	393	0.017	0.020	0.025	HG-GV
2010-11-18	85	0.011	0.012	0.011	HG
2011-03-14	291	0.015	0.010	0.011	AO-YŞ
2011-03-15	292	0.017	0.016	0.016	GG-YK
	Mean	0.015	0.014	0.016	

Observers: YD: Y. Demircan, TO: T. Ozun, AO: A. Okan, SC: S. Cerit, GG: G. Gökay, YK: Y. Kılıç, ZT: Z. Terzioğlu, AB: A. Baykal, HA: H. Arslan, HG: H. Gürsoytrak, GV: G. Varol, YS: Y. Şendağ.

We give the information about the observations in Table 1 showing the date, the number of observations, nightly standard deviation of observations and observers. In total, 2493 filtered observations were obtained between the years 2010 and 2011.

The photometric calibration of the raw CCD images was performed according to the standard method using the program package C-Munipack (MuniWin, Version 2.0.10) programmed by Motl (2012). All CCD images were reduced by means of the " Advanced Calibration Scheme" using bias, scalable dark and flat files. The standard errors of the observations were estimated by using the difference between the magnitude of the check and comparison star which are constant within $\pm\,0^m.015$, $\pm\,0^m.014$ and $\pm\,0^m.016$ for V, R and I bands, respectively for all of the observations. Differential extinction corrections were found to be negligible, since the comparison stars are very close to the variable star. The data may be obtained from authors upon request.

The magnitude and color values for variable and comparison stars are listed in Table 2. The values were obtained from the " All-sky spectrally matched Tycho2 stars" catalogue which were calculated by fitting $UBVRI-ZY$ and $u'g'r'i'z'$ magnitudes, spectral types, and distances for 2.4 million stars, derived from synthetic photometry of a library spectrum that best matches the Tycho2 B_T, V_T, NOMAD RN, and 2MASS JHK2/S catalogue magnitudes (Pickles and Depagne, 2010).

3. Light elements

We determined new light elements for the eclipsing system since the orbital period of the system and period variations are important for the remaining analysis. First, we collected a total of 21 timings of minimum light given in Table 3 and calculated the O–C variation as shown in Fig. 1 by using the light elements given by Khruslov (2005).

Essentially, we used a total of 19 minima times to revise the ephemeris given by the author. Two timings of minima light are excluded from the fit and marked in Fig. 1. Because of the limited minima times and small time spans, we were able to do only a linear fit on the O–C variation to obtain the corrections on the epoch and period of the eclipsing system. The derived coefficients of the fit are $(O-C)=-3.602352539\cdot10^{-6}\times E+0.02094661412$. Using these fit parameters, we revised the ephemeris as,

$$HJD(Min.I)=2451554.0439(18)+0^d2814114(1)\times E, \quad (2)$$

where the uncertainties are given in parenthesis. The improved ephemeris was used for the rest of the calculations in this study.

Table 2
Magnitudes and color values of the variable and comparison stars from "All-sky spectrally matched Tycho2 stars" by Pickles and Depagne (2010).

Star	B	V	R	I	J	H	K	$B-V$	Sp. type
GW Cnc	13.47	12.716	12.28	11.89	11.35	11.04	10.96	0.754	G8V
TYC1399-1572-1	12.96	11.629	10.96	10.43	9.31	8.68	8.51	1.331	rK3III
GSC1399-1348	13.02	12.501	12.19	11.90	11.51	11.25	11.20	0.519	wF8
GSC1399-2073	13.41	12.841	12.49	12.15	11.76	11.49	11.43	0.569	rF8V

Table 3
Times of minimum light and (O–C) residuals of GW Cnc calculated by using the light elements given by Khruslov (2005).

HJD+2400000	$\pm\sigma$	Ecl. type	Method	E	O–C	Ref.
51554.0230	–	p	Survey	0	0.00000	1
54172.2949	0.0044	p	pe-Ir	9304	−0.01326	2
54172.4346	0.0019	s	pe-Ir	9304.5	−0.01427	2
54172.5766	0.0019	p	pe-Ir	9305	−0.01297	2
54506.3336	0.0006	p	pe-Ir	10491	−0.01417	3
54523.4952	0.0004	p	ccd c	10552	−0.01893	4
54831.9258	0.0004	p	ccd	11648	−0.01912	5
54869.0690	–	p	pe V	11780	−0.02270	6
55502.5278	0.0001	p	ccd BVRI	14031	−0.02906	7
55508.5771	0.0001	s	ccd BVRI	14052.5	−0.03019	7
55515.6124	0.0002	s	ccd BVRI	14077.5	−0.03026	7
55571.8950	0.0002	s	pe V	14277.5	−0.03066	8
55635.3537	0.0003	p	ccd BVRI	14503	−0.03105	7
55636.3383	0.0007	s	ccd BVRI	14506.5	−0.03140	7
55656.7408	0.0002	p	pe V	14579	−0.03148	8
55932.9471	0.0005	s	ccd	15560.5	−0.03401	9
56007.3788	0.0002	p	ccd R	15825	−0.03658	10
56007.3793	0.0001	p	ccd I	15825	−0.03608	10
56007.3796	0.0002	p	ccd V	15825	−0.03578	10
56021.7252	0.0012	p	ccd V	15876	−0.04234	11
56359.7073	0.0004	p	ccd c	17077	−0.03966	12

References: 1: Khruslov (2005), 2: Hübscher (2007), 3: Hübscher et al. (2010), 4: Brat et al. (2008), 5: Diethelm (2009), 6: Kazuo (2010), 7: Gökay et al. (2012), 8: Diethelm (2011), 9: Diethelm (2012a), 10: Honková et al. (2013), 11: Diethelm (2012b), 12: Nelson (2014).