

The new challenges of the shortest-period eclipsing binary star GSC 2314-0530

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Abstract. The new photometric and spectral observations of the shortest-period eclipsing binary star (with nondegenerate components) GSC 2314-0530 led to detection of additional peculiarities of the target. Besides the first distant companion (the *Twin*) of the binary a second close companion (the *Neighbour*) at distance of only 1.2 arcsec was discovered. The low-dispersion spectrum of GSC 2314-0530 reveals that its components are M4.5 and M6 red dwarfs. The low-dispersion spectrum of the *Twin* corresponds to spectral subtype around M6.5. The same spectral subtype is supposed for the *Neighbour* on the base of the same brightness and colors as those of the *Twin*.

Key words: eclipsing stars, multiple stars

Новите предизвикателства на най-късопериодичната затъмнително-двойна звезда GSC 2314-0530

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Новите фотометрични и спектрални наблюдения на най-късопериодичната затъмнително двойна звезда (с неизродени компоненти) GSC 2314-0530 доведоха до установяване на допълнителни нейни пекулярности. Освен първият далечен спътник (*Близнакът*) бе открита втора близка компонента (*Съседът*) на разстояние само 1.2 arcsec. Нискодисперсният спектър на GSC 2314-0530 показва, че компонентите на двойката са червени джуджета, съответно M4.5 и M6. Нискодисперсният спектър на *Близнака* съответства на спектрален клас около M6.5. Предполагаме, че спектралният клас на *Съседа* е също M6.5 поради почти същия му блясък и същите цветове като тези на *Близнака*.

Introduction

Although the M dwarfs are the most numerous stars in our Galaxy, they are quite poorly investigated. The reason is the selection effect that plays against the detection of faint and small stars. Less than 20 binaries with low-mass dM components have empirically-determined masses, radii, luminosities and temperatures. This deficiency hindered the development of the models for the cool dense-atmospheres of the M dwarfs. On the other hand recently they became especially interesting as appropriate targets for planet searches due to the relatively deep transits.

Applying a multiparametric method for search for variable objects in large dataset (Dimitrov 2009) to the Northern Sky Variability Survey (NSVS, Wozniak et al. 2004) several hundred new short-period eclipsing stars were discovered. GSC 2314-0530 (NSVS 6550671 and SWASP J022050.85+332047.6, Pollacco et al. 2006) was one of them. Its period $P=0.192637$ d turned out to

be the shortest one for a binary with non-degenerate components (Dimitrov & Kjurkchieva 2010, further Paper I) and considerably below the cut-off limit of 0.22 d (Rucinski 2007). Norton et al. (2007) reported the coincidence of GSC 2314-0530 with the *ROSAT* X-ray source 1RXS J022050.7+332049.

Our CCD photometric observations in *VRI* colors and spectroscopic observations around the $H\alpha$ line of the newly discovered eclipsing binary GSC 2314-0530 in 2009-2010 allowed us to determine the global parameters of its components: temperatures $T_1 = 3735$ K and $T_2 = 3106$ K, masses $M_1 = 0.51 M_{\odot}$ and $M_2 = 0.26 M_{\odot}$, radii $R_1 = 0.55 R_{\odot}$ and $R_2 = 0.29 R_{\odot}$; luminosities $L_1 = 0.053 L_{\odot}$ and $L_2 = 0.007 L_{\odot}$. The orbital inclination, separation and the distance to the binary were estimated as $i = 72.5^{\circ}$, $a = 1.28 R_{\odot}$ and $d = 59$ pc (Paper I).

These parameters reveal that GSC 2314-0530 is interesting not only by the shortest orbital period but also by its components that are small dM stars. Moreover, we observed strong emission in the $H\alpha$ line (with mean $EW = 5$ Å) as well as several flares of GSC 2314-0530. The high chromospheric activity means that its components are dMe stars (Paper I).

Our interest to the "champion" GSC 2314-0530 continued and led to new interesting results.

1 The results from the new observations of GSC 2314-0530

The new photometric and spectroscopic observations were carried out by the 2-m RCC telescope and 60-cm Cassegrain telescope of the Rozhen National Astronomical Observatory.

We observed the field around GSC 2314-0530 with the 60-cm telescope (exposure time 60 sec, *I* filter) using the CCD camera FLI ProLine 09000 under very good atmospheric conditions on Sept 2 2010. They led us to the supposition about the existence of near (unseparated) star to GSC 2314-0530. That is why we carried out follow-up observations with the 2-m RCC telescope (exposure time 30 sec, *V* and *I* filters) using the CCD camera VersArray 1300 on Sept 15 2010 and obtained several direct images. The standard IDL procedures (adapted from DAOPHOT) were used for reduction of these photometric data.

Moreover, we obtained six low-resolution spectra (four of GSC 2314-0530 and two of the distant companion called by us the *Twin*) with exposure time 300 sec on Feb 13 2011. We used the focal reducer FoReRo-2 attached to the 2-m telescope, CCD camera VersArray 512, grism with 300 lines/mm and slit with width 0.11 mm. The spectra cover the range 5000-7000 Å. Night-sky emission lines were used for wavelength calibration. The mean ratio S/N of the FoReRo2 spectra was around 50. The reduction of the spectra was performed using IRAF packages by bias subtraction, flat fielding, cosmic ray removal, one-dimensional spectrum extraction and wavelength calibration. The spectra were normalized to 1 for the range around 6100 Å.

The analysis of our new observations led to finding of additional peculiarities of GSC 2314-530.

(1) The higher space resolution of the 2-m telescope images as well as the excellent atmospheric conditions during the photometric observations allowed

to discover a star at distance of only 1.2 arcsec from GSC 2314-530 (Fig. 1). That is why we called it the *Neighbour*.

Thus our new observations revealed presence of second companion around the binary GSC 2314-530. Let's remember that the first detected companion was the weak red star (identified as USNO-B1 1233-0046425 and) at distance 61 arcsec (corresponding to linear separation around 3500 AU for a distance of 59 pc) from GSC 2314-530 called by us the *Twin* (see Fig. 2, Paper I). Our supposition that the *Twin* is a visual companion of the binary GSC 2314-0530 was based on their equal proper motion (Table 1).

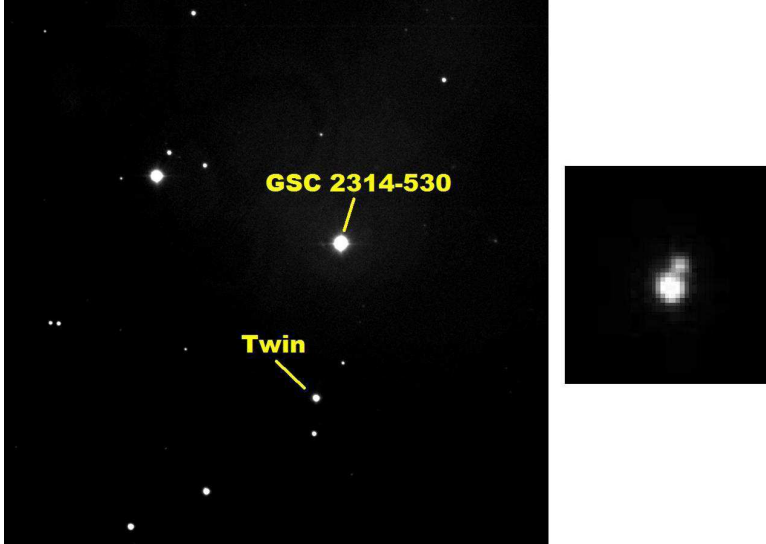


Fig. 1. On the right: the observed field (by 2-m telescope) of the variable star with sizes 3.75 x 3.75 arcmin; On the left: detailed sight of the vicinity of GSC 2314-530

Table 1. Proper motion of the variable star, standard stars and the *Twin*

	ID	V	$B - V$	pmRA	pmDE
	GSC/USNO-B1	[mag]	[mag]	[mas yr ⁻¹]	[mas yr ⁻¹]
Var	2314-0530	13.36	1.18	144.0	-112.0
The Twin	1233-0046425	16.91	1.41	140.0	-112.0

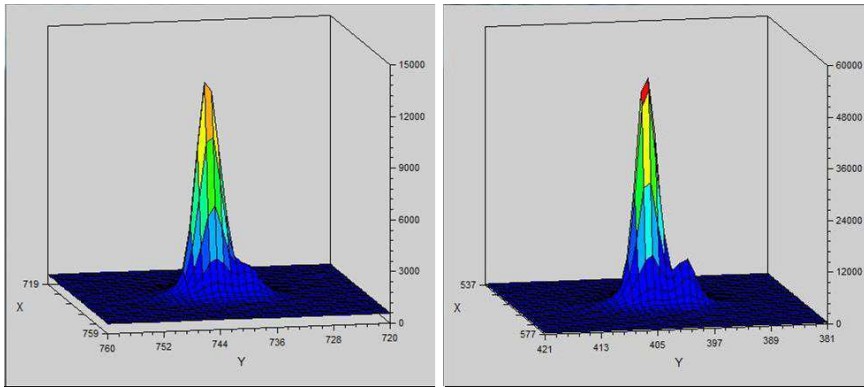


Fig. 2. 3D images of the close vicinity of GSC 2314-530 in V color (on the left) and in I color (on the right) obtained by 2 m telescope that confirm the presence of the *Neighbour* and its stronger emission at longer wavelengths

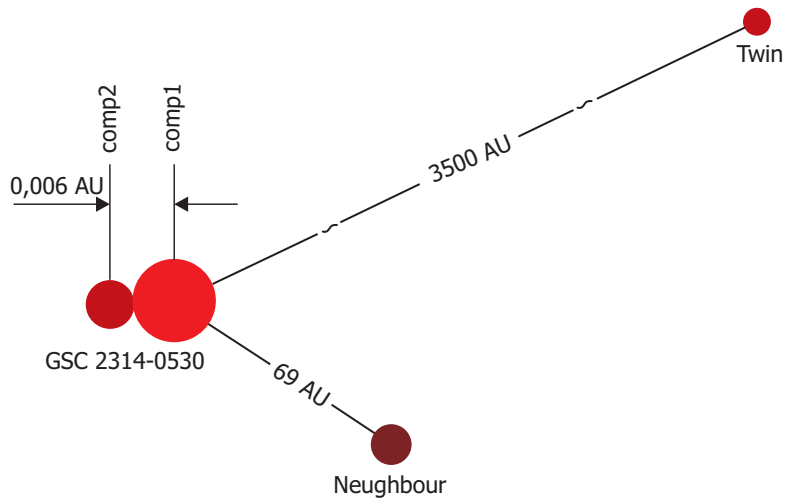


Fig. 3. The multiple system with 4 components

It should be noted that the 3D image of the target in V filter (left frame in Fig. 2) is obtained under seeing of 0.85 arcsec while the 3D image in I filter (right frame in Fig. 2) is taken under seeing of 0.78 arcsec. These images obtained by 2 m telescope as well as the previous ones obtained by the 60-cm telescope mean that the *Neighbour* would be unresolved on the frames taken under seeing above 1.0 arcsec, i.e. only the excellent observational conditions on Sept 15, 2010 have gave us a chance to discover this close companion.

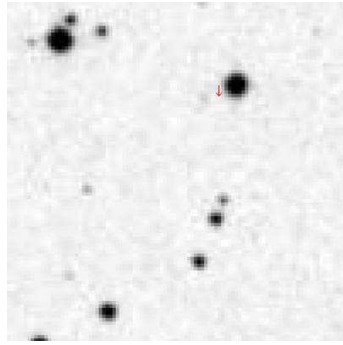


Fig. 4. The old (1952) POSS I image of the GSC 2314-0530 region, the arrow marks the present position of the *Neighbour*

A confirmation of the supposition about the connection of the *Neighbour* and GSC 2314-0530 is the archival POSS I image of the field (Fig. 3). It does not reveal any star at the present position of the *Neighbour* (marked with arrow). Hence, the *Neighbour* is not a field star but moves together with GSC 2314-0530.

Thus, as a result of both old and new observations we may conclude that our target is multiple system containing 4 stars (Fig. 4).

The multiplicity of the shortest-period binary GSC 2314-0530 may explain the exclusive small value of its angular momentum (Paper I). Recently the supposition about the multiplicity of the short-period close binaries is widely assumed as a reasonable explanation for their small angular momenta (Pribulla & Rucinski 2006).

(2) The visual magnitude of the *Neighbour* is 15.5 mag and respectively its absolute magnitude is 11.65 mag (at distance of 59 pc). The brightness of the *Neighbour* in V color is weaker than in I color in respect to the binary GSC 2314-530. This means that the *Neighbour* is red dwarf which spectral type is later (probably M6 V) than those of the components of GSC 2314-530.

(3) The comparison of the FoReRo spectra (in the range 5000-7000 Å) of GSC 2314-0530 and the *Twin* with those of three M spectral standards reveals that the energy distributions of GSC 2314-0530 and the *Twin* are typical for M stars (Fig. 5).

The FoReRo spectrum of GSC 2314-0530 confirmed its H α emission. Its energy distribution corresponds to average M5 spectral subtype of the binary that means its components are M4.5 and M6 red dwarfs. The new result slightly differs from the previous estimate for the mean spectral type M2-3 of GSC 2314-0530 that was based on its (V-I) color.

The FoReRo spectrum of the *Twin* imply that it is also source of H α emission while its spectral subtype is around M6.5.

The spectral subtype of the *Neighbour* should be also around M6.5 because its brightness and colors are almost the same as those of the *Twin*.

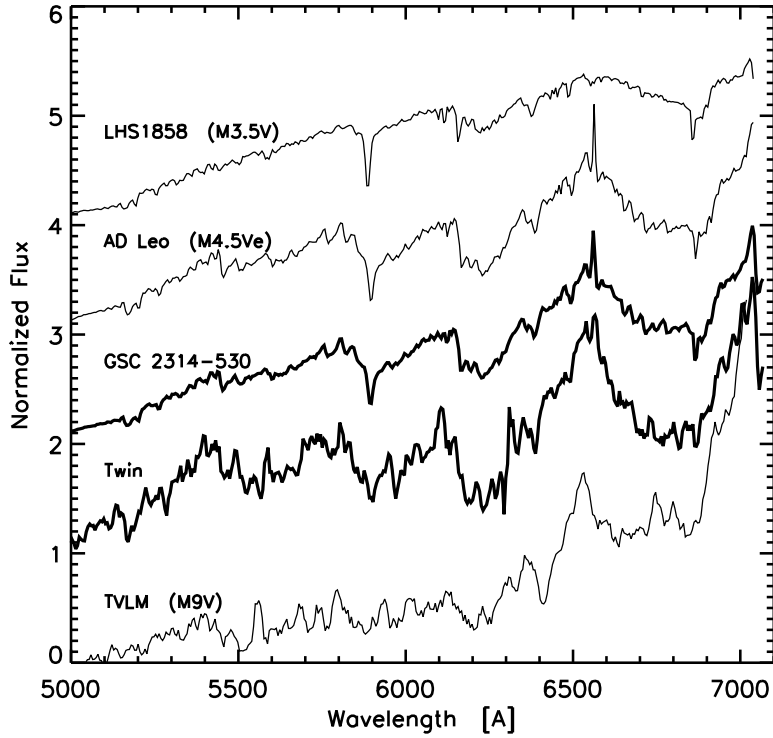


Fig. 5. FoReRo spectrum of GSC 2314-0530 (combined from 4 spectra); the spectrum of the *Twin* (combined from 2 spectra); the spectra of three M-type standard stars

2 Conclusion

The main results of the new observations of the shortest-period eclipsing binary star GSC 2314-0530 are:

1. A close companion (called by us the *Neighbour*) at distance 1.2 arcsec (69 AU) from GSC 2314-0530 was discovered. Thus our target turned out to be a multiple system with 4 components;
2. The FoReRo spectrum of GSC 2314-0530 confirmed its H α emission. Its energy distribution in the range 5000-7000 Å reveals that its components are M4.5 and M6 red dwarfs.
3. The FoReRo spectrum of the *Twin* imply that it is also source of H α emission and its spectral subtype is around M6.5. We suppose the same spectral subtype for the *Neighbour* on the base of the same brightness and colors as those of the *Twin*.

The new results from the study of the shortest-period eclipsing binary GSC 2314-0530 support supposition that the exclusive small values of the

angular momenta of the short-period binaries may be explained by the presence of close companions. Another contribution of this investigation is that it enriches the poor statistics of the M dwarfs.

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