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Photometric and Spectroscopic Investigation of the Dwarf Nova HS 0218+3229: A Short Review

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Abstract

This paper is devoted to the study of the cataclysmic variable HS 0218+3229 using the photometric and spectroscopic observations.

Keywords: cataclysmic variables - dwarf novae - optical photometry - spectroscopy - individual: HS 0218+3229.

1 Introduction

Cataclysmic variables (CVs) are highly evolved close binaries consisting of a white dwarf (WD) accreting matter from a red dwarf companion. This matter creates an accretion disc around the white dwarf. Dwarf novae (DNe) are a subclass of cataclysmic variables, whose members experience outbursts either caused by a thermal-viscous instability in the accretion disc (DI) or by a sudden increase in mass transfer rate. Outbursts of DNe last a few days. In GCVS (Samus et al., 2007-2012) DNe are described as stars of the type UGSS (U Gem–SS Cyg), with the recurrent time between outbursts lasting from days to several years.

HS 0218+3229 ($\alpha_{2000} = 02^h 21^m 34^s$; $\delta_{2000} = +32°$ 43' 24") was discovered spectroscopically during the large-scale search for CVs in the Hamburg quasar survey by Gänsicke et al. (2002). Rodriguez-Gil et al. (2009) carried out photometric and spectroscopic observations of HS 0218+3229 from 2000 to 2005 and determined its orbital period to be $0.^d297229661(1)$. The phase light curve (LC) in the R passband exhibits ellipsoidal modulation. The K5V secondary component gives a contribution of 80-85% to the R light. An analysis of the time-resolved optical spectroscopy and R passband photometry provided some parameters of HS 0218+3229: a mass ratio of 0.52< q <0.65, a white dwarf mass of 0.44< $M_1/M_\odot$ <0.65, a secondary component mass of 0.23< $M_2/M_\odot$ <0.44, the orbital inclination $i = 59^o \pm 3^o$. The distance to the system was estimated to be 0.87–1.0 kpc. HS 0218+3229 has been identified as the X-ray source 1RXS J022133.6+324343 and the 2MASS source J02213348+3243239.

2 Photometric Observations of HS 0218+3229

2.1 Optical outbursts

In 2006 the object was discovered independently by S. Antipin using the photo plates of the photographic archive at the Sternberg Astronomical Institute (SAI) and identified as a DN. One outburst with an amplitude of about 4.5 mag in the B_{ph} passband was detected in September 1980. Another outburst was detected in 2002 by Wills from NEAT database (2002). Golysheva et al. (2012, 2013) described photometric and spectroscopic observations of HS 0218+3229 from 2006 till 2010. CCD photometry in $UBVR_cI_c$ passbands was carried out at the Crimean laboratory of SAI (Nauchny) and at the Stará Lesná Observatory of the Astronomical Institute of the Slovak Academy of Sciences. The magnitudes of comparison stars were determined in Golysheva et al. (2012). In October 2007 they detected the outburst of HS 0218+3229 with an amplitude of 4 mag and duration of 15–16 days (JD 2454380–395). The shape of the outburst LC was more symmetric than for other DNe. Its asymmetry coefficient (the ratio of the duration of the ascending branch to the descending branch) was ∼0.22. A new ephemeris was calculated using the initial epoch of the minimum from Rodriguez-Gil et al. (2009). The epoch corresponds to the inferior conjunction (the secondary is in front of the WD):

$$HJD_{min} = 2453653.0286 + 0.2973559 \times E \qquad (1)$$

The orbital period of the object (7.13 h) largely exceeds the average orbital periods of DNe, which are in the range 1.5–4 hours. The maximum V magnitude of the 2007 outburst was determined as V_{max}=12.34±0.05 mag. The maximum magnitudes in other passbands were estimated by extrapolation as U=11.3±0.2 mag, B=12.3±0.2 mag, $R_J \simeq I_J$ =12.2±0.2 mag.

During 2011–13 we continued observations of the object. As seen from BVR_CI_C light curves (LCs) of the object, obtained in 2006-13 and presented in Fig. 1, a new outburst occurred in 2013. Its V-maximum magnitude was the same as in 2007 outburst. A sudden 0.5 mag increase of brightness in the B passband was detected on January 31, 2011. The BVR_CI_C plots in Fig. 1 show long-term brightness variations during quiescence with a characteristic timescale of a few tens of days and an amplitude of ∼0.2 mag, noted in Golysheva et al. (2012).

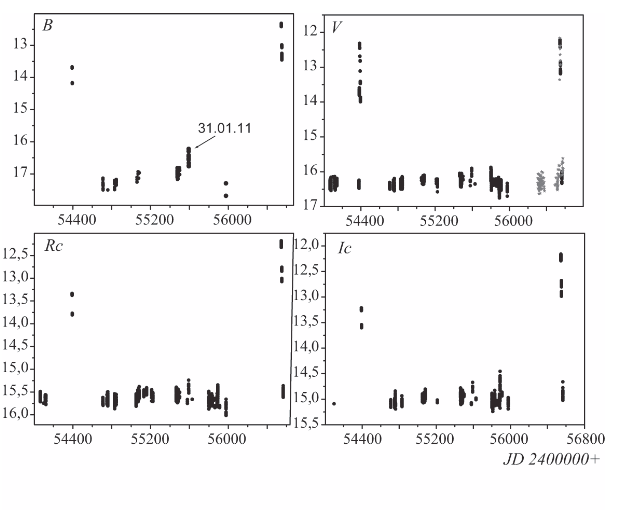

Figure 1: The BVR_CI_C LCs of HS 0218+3229 in 2006–2013. The AAVSO data are marked by grey circles.

Our observations of the last outburst of HS 0218+3229, detected on September 5, 2013 (VSNET, 2013), were obtained at the Stará Lesná Observatory. Taking into account that the object exhibited outbursts also in 2002 and 2007, it is possible to estimate the recurrent time between outburst to be 5–6 years. Fig. 2 shows the LCs of the outbursts in 2007 (upper panel) and 2013 (lower panel). The nightly LCs are inserted in separate panels. Left LC, obtained directly before the outburst in 2007, shows half of orbital wave with an ellipsoidal effect. This effect is not visible on the other nightly LCs because of the presence of the outbursting disk. In the framework of the DI model, the shape of the outburst LC of HS 0218+3229 can be explained by a low mass transfer rate in the system and "inside-out" outburst in accordance with Smak (1984). Outburst starts from the inner parts of the disk and extends outward. The 2013 outburst shape is similar to the previous one in 2007. The nightly BV LCs are shown in Fig. 2.

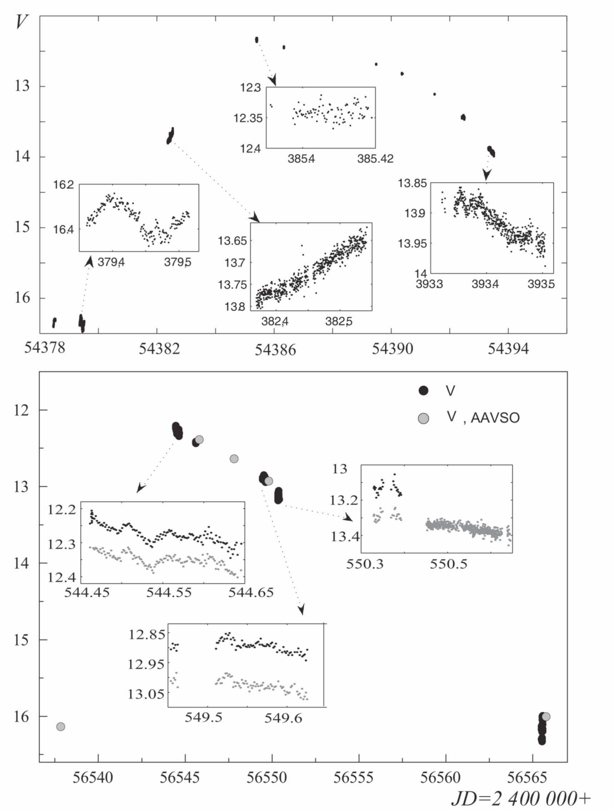

Figure 2: The outburst LCs in 2007 (top) and 2013 (bottom) in V (black points and circles) and B (grey points). The AAVSO V data are marked by grey circles.

The $\Delta UBVR_CI_C$ outburst LCs, near the maximum brightness, are presented in Fig. 3. All LCs look similar.

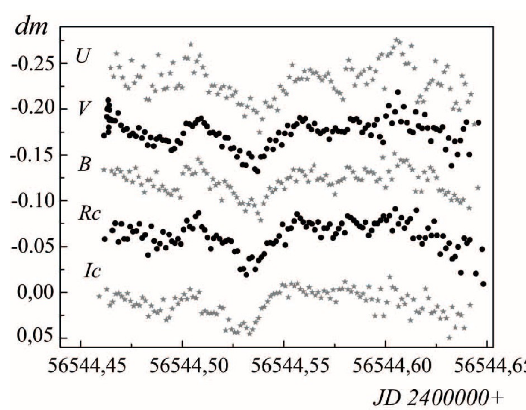

Figure 3: The LCs after removal of the declining trend in brightness during the outburst, on September, 8, 2013. The LCs are displaced by arbitrary magnitudes.

The quiescence LCs in the BVR_CI_C passbands, folded with the ephemeris (1), are shown in Fig. 4. Double wave is clearly seen in the VRI passbands, and less clearly in the B passband. It should be noted that the heights of the maxima (in phases 0.25 and 0.75) and depth of the minima (in phases 0 and 0.5) can change from night to night. The displacement of the second minimum around phase 0.5 is clearly seen. This feature was noted also by Rodriguez-Gil et al. (2009).

Golysheva et al. (2012, 2013) noted a large UV-excess in quiescence in 2010. During the 2007 outburst the position of the star in the two-colour diagram was close to that of an absolute black body with a temperature of about 15000 K. At the minimum brightness the position of the variable corresponded to a star of spectral class K5V-K6V. More detailed information about two-colour diagrams can be found in the paper of Golysheva et al. (2012).

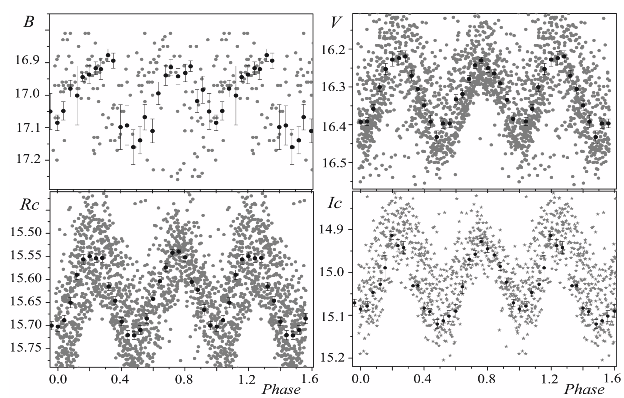

Figure 4: The average orbital phase BVR_CI_C LCs in 2006–2012, folded with ephemeris (1). Individual observations are marked by grey points, mean values by black points.

2.2 The analysis of the AAVSO data

We also present data by the American Association of Variable Star Observers (AAVSO), whose observers were asked to observe the object to support the Hubble observations (HST/COS, the AAVSO "alert 471" (2012) about monitoring of HST targets). The HST/COS observations were obtained in December 2012.

The main bulk of AAVSO observations were carried out in a clear filter. Because of a very good time coverage, the orbital LCs were very well covered by observations in some nights from September 17, 2012 till January 2, 2013. We reduced the data to heliocentric values. The nightly LCs in September and October 2012 are presented in Fig. 5 and folded LCs are shown in Fig. 6. In spite of the error 0.02–0.03 mag, the shape of the nightly LCs is distinctive. The depth of the primary minimum (marked by 1) is smaller than the depth of the secondary minimum (marked by 2) and the hump after the primary minimum is brighter than the hump after the secondary minimum. This phenomenon is especially evident in the orbital folded phase LCs (Fig. 6).

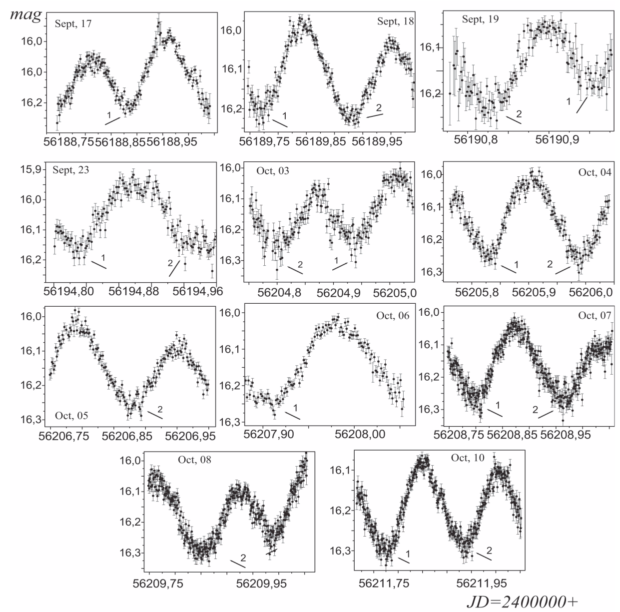

Figure 5: The AAVSO LCs obtained in September and October 2012. The primary and secondary minimum are marked by 1 and 2, respectively.

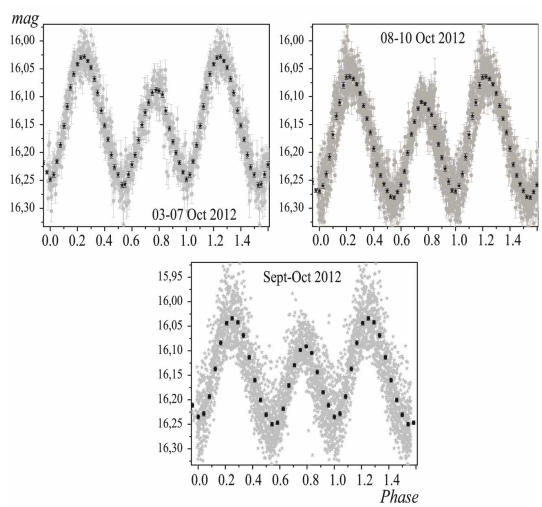

Figure 6: The average LCs in September–October 2012, folded with ephemeris (1). The notation is the same as in Fig. 4.

3 Spectroscopic Observations

Our spectroscopic observations of HS 0218+3229 was taken in 2010 and 2012, when the object was in quiescence. Golysheva et al. (2013) obtained two spectra of HS 0218+3229 on September 17/18, 2010 in the prime focus of the Russian 6-m telescope BTA of the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS) at the spectroscopic mode of the SCORPIO multi-mode focal reducer (Afanasiev, Moiseev, 2005) with the long slit and CCD-camera EEV CCD 42-40 (2048×2048 pixels) with the exposures of 300 sec. Our new spectroscopic observations of the objects were carried out on November 5, 2012 with the same reducer at the 6-m BTA telescope. The VPHG1200g grating (1200 grooves/mm) were used in both cases. The spectroscopic resolution $\Delta\lambda = 5.0$ Å in the wavelength interval 3950–5700 Å was achieved. The spectra were reduced with sky and bias substraction and division by a flat-field frame.

The discovery spectrum of the object obtained in 2000 (Rodriguez-Gil et al., 2009) revealed the absorption-line spectrum of the K5 V secondary, accompanying by the Balmer and He I emission lines, arising in the accretion disk of the white dwarf primary. The 2010 spectrum was different.

Emission line of neutral helium λ5875 Å became stronger, emission Balmer decrement more flat and the features of the red companion became less pronounced (Golysheva et al., 2012, 2013). These changes were probably caused by enhancing of a mass transfer rate and veiling of the spectrum of the secondary component. Our spectrum obtained on November 5, 2012 is similar to the spectrum taken in 2000. The red star manifested itself again.

4 Discussion and Conclusions

Four outbursts of HS 0218+3229 in 1980, 2002, 2007, 2013 were detected up to now. The 2002 outburst (Wills, 2002) was found in the database NEAT. The duration of 2007 outburst was 15–16 days and its asymmetry coefficient ~0.22. The maximal amplitudes were 5 mag in the *U, B* passbands and 4 mag, 3.5 mag, 3 mag in the *V, R, I* passbands, respectively. It is possible to estimate the recurrence time of the outbursts to 5–6 years. We determined the orbital period to be $0.^{d}2973559(10)$ and updated the ephemeris of the object.

Two-colour diagrams, presented in Golysheva et al. (2012, 2013), showed that the object was bluer during its outburst than in quiescence. It was caused by cthe additional ontribution of a bright accretion disk to the total luminosity. Outburst colour temperature was about 15 000 K. Colour indices in quiescence correspond to a star K5 V. As a result, this cataclysmic variable was classified as a very rare subtype of UGSS-type DN with a low accretion rate and sparse and more symmetric (”inside-out”) outbursts than it is usual in U Gem-type and SS Cyg-type of DNe.

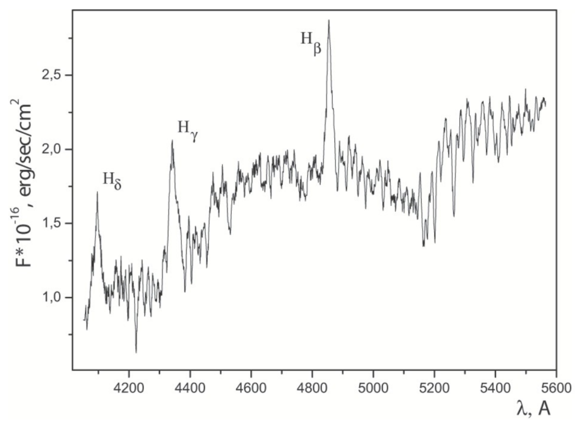

Figure 7: The spectrum of HS 0218+3229 on November 5, 2012.

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