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HT Cas - eclipsing dwarf nova during its superoutburst in 2010

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Abstract. We present results of a world-wide observing campaign of the eclipsing dwarf nova HT Cas during its superoutburst in November 2010. Using collected data we were able to conduct an analysis of the light curves and we calculated $O - C$ diagrams.

The CCD photometric observations enabled us to derive the superhump period and with the timings of eclipses the orbital period was calculated. Based on superhump and orbital period estimations, the period excess and mass ratio of the system were obtained.

Key words: Stars: individual: HT Cas - binaries: close - novae, cataclysmic variables

1. Introduction

Among close binary stars there are cataclysmic variables containing a white dwarf (the primary) and a main-sequence star (the secondary or the donor). The primary accretes matter from the donor star through the inner Lagrangian point. In non-magnetic systems the material forms an accretion disk around the primary.

One of the subclasses of cataclysmic variables are dwarf novae and among them there are SU UMa type stars. They can be characterized by a short orbital period ($P_{orb} < 2.5$ h) and in their light curves we see two types of outbursts: normal and superoutbursts. Outbursts are about one magnitude fainter and last shorter than superoutbursts. Tooth-shaped oscillations, called superhumps, manifest their presence during superoutburts (Hellier 2001).

HT Cas was discovered 70 years ago and classified as a variable star (Hoffmeister 1943). Unfortunately, for 35 years this object did not receive any attention, until the eclipses of HT Cas were noticed (discovery made by Bond in 1978, private communication with Patterson) and this amazing dwarf nova became a top priority object for an observing season organized in 1978. Patterson called HT Cas "a Rosetta stone among dwarf novae" because of a variety of manifested features presented in light curves (Patterson 1981). Over 30 years since this statement literature concerning HT Cas is still growing, reaching several dozens of publications.

2. Observations

We present observations of the superoutburst in HT Cas made during 21 nights. Data were collected between 2nd and 27th of November. During this world-wide campagin five observers were gathering observations in four countries: Poland, Turkey, Spain and USA, and eight telescopes with diameters ranging from 10 to 100 cm were used simultaneously. Moreover, data collected by the AAVSO[1] organization were used for this analysis.

HT Cas was monitored in a clear filter ("white" light). Bias, dark current and flat-field corrections were made using the IRAF[2] package. Profile photometry was obtained with DAOPHOTII (Stetson 1987). Relative manitudes were transformed to the standard Johnson V manitudes using data published by Henden and Honeycutt (1997). In Fig. 1 there are presented resulting light curves from our observing campaign.

The superoutburst lasted 11 nights (3rd-13th Nov) and we gathered data covering almost the whole period except for the last night of the superoutburst. HT Cas reached maximum brightness of $V \approx 12$ mag and the amplitude of this superoutburst was about $A \approx 4$ mag.

3. Results

The $O-C$ diagram is an excellent tool to check the stability of the superhump or the orbital period and to determine their values. We analyzed light curves from 10 subsequent nights where superhumps clearly manifested their presence and we identified 69 moments of maxima. The least squares linear fit to the gathered data gave the following ephemeris for the maxima:

$$\mathrm{HJD}_{\max} = 2455504.5132(8) + 0.07608(1) \cdot E. \tag{1}$$

[1]American Association of Variable Star Observers, www.aavso.org.

[2]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation.

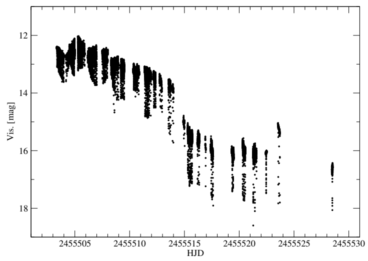

Figure 1. The photometric behavior of HT Cas in November 2010. During that time one can observe an outburst precursor, developed later into a full superoutburst. At the end of November the star came back to its quiescence level.

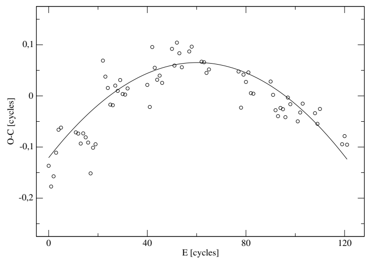

Figure 2. The $O-C$ diagram of the superhumps maxima. The solid line corresponds to the fit given by Eq. 2.

One can observe the decreasing trend of the superhump period presented in Fig. 2. Due to this fact the second-order polynomial fit to the moments of maxima was derived and the following ephemeris was obtained:

$$\mathrm{HJD}_{\mathrm{max}} = 2455504.504(1) + 0.07655(6) \times E - 3.9(5)10^{-6} \times E^2. \qquad (2)$$

Based on those calculations, we can confirm that the period of superhumps was not stable and can be described by a decreasing trend with a rate of $\dot{P}{=}{-}10.2(1.3) \times 10^{-5}$.

To obtain the value of the orbital period we constructed the $O-C$ diagram for the moments of minima. In total the timings of 70 eclipses from November 2010 superoutburst were used to calculate the following ephemeris of the minima:

$$\mathrm{HJD}_{\mathrm{min}} = 2455504.49185(3) + 0.0736469(5) \times E. \qquad (3)$$

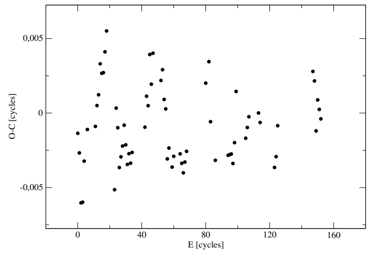

Figure 3. The $O - C$ diagram for eclipses observed during the superoutburst of HT Cas in November 2010. Regular humps are the manifestation of the beat period - composition of the orbital and superhump periods.

There is a relation between the superhump and orbital periods (Osaki 1985):

$$\frac{1}{P_{sh}} = \frac{1}{P_{orb}} - \frac{1}{P_{beat}}, \tag{4}$$

and we used Eq. 4 to calculate the beat period of $P_{beat} = 2.30 \pm 0.01$ days. This value is in full agreement with previous results presented by Zhang et al. (1986) for the superoutburst in HT Cas in 1985. In Fig. 3 one can observe regular humps near cycles: 18, 47 and 80, we checked those features and this is beat period manifestation.

We used values of superhump P_{sh} and orbital P_{orb} periods to calculate the period excess ε which can be obtained based on the formula:

$$\varepsilon = \frac{\Delta P}{P_{orb}} = \frac{P_{sh} - P_{orb}}{P_{orb}}. \tag{5}$$

Based on Eq. 5, the value of the period excess for HT Cas is $\varepsilon = 3.30\% \pm 0.01\%$ and this is a typical value for SU UMa-type stars.

There is an empirical formula for the relation between the period excess and mass ratio of the binary $q = M_2/M_1$ (Patterson 1998):

$$\varepsilon = \frac{0.23q}{1 + 0.27q}. \tag{6}$$

Based on Eq. 6, the mass ratio of HT Cas with the value of $q = 0.149$ was obtained.

4. Summary

To summarize the results of the autumn 2010 observations of the HT Cas we can confirm:

– After 25 years of quiescence or normal outbursts in November 2010 the superoutburst in HT Cas was detected. This rare phenomenon had an amplitude of about $A = 4$ mag, lasted 11 nights and was triggered by an outburst precursor.

- During the superoutburst mesmerizing superhumps manifested their presence and based on them the superhump period with a value of $P_{sh} = 0.07608(1)$ days and decreasing with a rate of $\dot{P} = -10.2(1.3) \times 10^{-5}$ was calculated.
- Based on the timings of eclipses observed during the superoutburst, an orbital period with a value of $P_{orb} = 0.0736469(5)$ days was obtained and its value is in full accordance with results presented by other authors from earlier observations (Horne et al. 1991, Feline et al. 1998, Ioannou et al. 1999, Borges et al. 2008). No anomalies in the orbital period were detected as it was mentioned by Ioannou et al. (1999) or Borges et al. (2008).
- From the November 2010 superoutburst the period excess with a value of $\varepsilon = 3.30\% \pm 0.01\%$ was obtained and it has a typical value for SU UMa type stars. The same value of the period excess was derived from the superoutburst in 1985 (Zhang et al. 1986).
- The mass ratio with the value of $q = 0.149$ was calculated and it confirms the result obtained by Horne et al. (1991) where a different method and set of observations were used.

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