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Photometric analysis of TT Arietis in the high and low states during 2004 – 2013

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Abstract. We announce a study of photometric behaviour of TT Ari in the time interval between 2004 and 2013, including its last low state that occurred in 2009 – 2010. We used data of the VSNET Collaboration, AAVSO and ASAS databases. We found that negative superhumps in TT Ari take place only if the brightness of the object is larger than 11.5 mag. Here we also claim the first detection of co-existense of negative and positive superhumps in TT Ari and present a refined orbital ephemeris.

1. Introduction

TT Ari is one of the brightest cataclysmic variables, showing photometric variations on timescales from seconds to years, together with X-ray flikering. It was classified as a nova-like star belonging to the VY Scl group. Its brightness is normally about 10–11 mag, with a sudden fall down to a “low state” of about 16.5 mag. The duration of the latter varies from weeks to years. The only low-state before the one discussed in this paper was observed around 1980 – 1985. A bibliographical review can be found in Andronov et al. (1999), Smak (2013).

2. Observation and data analysis

The data were obtained under the campaigns led by the Variable Star Network (VSNET) Collaboration (Kato et al., 2004) and American Association of Variable Star Observers (AAVSO) International Database and ASAS database as a supplement. The majority of the data were obtained by means of time-resolved CCD photometry with 30-cm class telescopes. The public data in Kim et al. (2009) were also included. After the corrections of systematic zero-points differences between observers we obtained the long-term light curve. For the periodic analysis we combined all the B, V, Rc, Ic and unfiltered observations together and subtracted the general trend by fitting low-order (typically three-five) polynomials for each seasonal segment and used phase dispersion minimization (PDM: Stellingwerf, 1978) for determining the mean photometric period.

The error in the period estimate in the PDM method is based on Fernie (1989). We also present a new method, a least absolute shrinkage and selection operator (Lasso) analysis (Kato, Uemura, 2012). Light curves of TT Ari are presented in the left panel of figure 1.

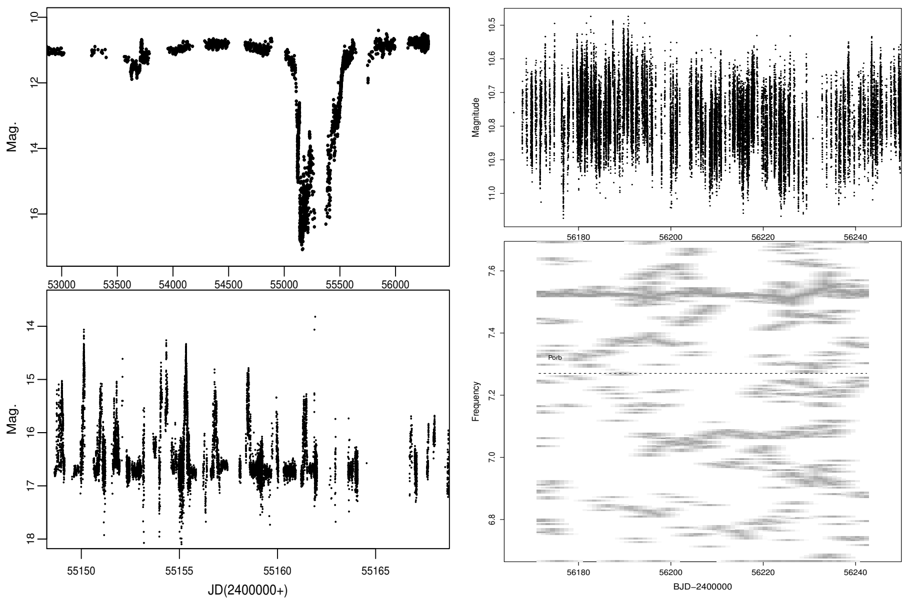

Figure 1. Left: Long-term light curve (2004 – 2013) and flares during the low state (bottom). Right: Two-dimensional power spectrum (bottom plot) and light curve of TT Ari for the time interval JD 2455160–2456305.

3. Results

The brightness of the object varied slightly near the value of $\sim$ 11 mag. until the first shallow decline started in 2005 March. The next fading episode started at the very beginning of 2009 and in October 2009 the object reached the minimum brightness. This low state lasted until 2010 August 4. Initial brightness was reached in 2011 March.

Our analysis revealed that negative superhumps in TT Ari take place only if the brightness of the object is larger than 11.5 mag. This fact shows a strong relation between the presence of negative superhumps and $\dot{m}$. The period of negative superhumps varied slightly, reflecting the changes of the accretion disk radius. Variations of the superhump amplitude and profiles can be seen in figure 2.

During the low state remarkable flares were observed with amplitudes up to 2.5 mag that lasted for several hours. Between such flares, a clear orbital modulation sometimes could be seen. The phase folded orbital wave is presented in the right-first line figure of plot 2 together with the refined orbital ephemeris.

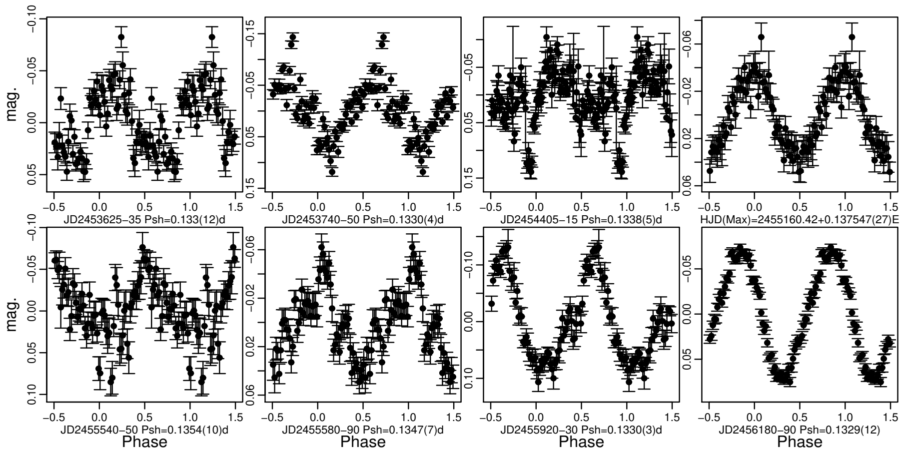

Figure 2. Folded light curves for the different time intervals, presenting negative superhumps. The time interval and period of modulation are marked below each plot.

In the right panel of figure 1 we present a Lasso two-dimentional power spectrum of the 2012 – 2013 season. At the end of the season, there was clear presence of negative and positive superhumps at the same time. This detection supports a disk tilt model for the negative superhumps. Positive superhumps showed an unstable period, probably, affected by the pressure effects.

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