TT ARIETIS: UNPRECEDENTED SWITCHING FROM NEGATIVE TO POSITIVE SUPERHUMPS

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ABSTRACT. Results of the international observational campaign "TT Ari–98" are presented. Altogether 11 336 observations have been obtained in the "positive superhump" state during 18 runs in 6 observatories, partially in UBV, UBVR (switching filters). During one night, 1027 simultaneous UBVRI data have been obtained. No significant shifts between the times of extrema in different colors have been found. The asymmetry is 0.44±0.01 is present showing more abrupt brightness increase than a decrease. The smoothed U-B color varies from $-0.^m65$ to $-0.^m86$, whereas the B-V=$0.^m03$ is remarkably constant. Sometimes the maxima have larger amplitude and a sharp shape corresponding to flares with a duration of $\sim$ 5 minutes. One may note a significant decrease of the mean magnitude by $0.^m35$ on JD 2251069. The moments of 21 maximum and 18 minima are listed. They correspond to the period for the 1997 data obtained by Skillman et al. (1998) showing no period change from one season to the next. The "test function - frequency" dependence in a double logarithmic scale has a linear trend in the range (90–370 c/d) and a very large slope 2.3–3.1 corresponding to QPOs rather than to the flickering.

Key words: Stars: cataclysmic, individual: TT Ari

Introduction

Photometric period of TT Ari has been recently switched from its usual "negative superhump" value from $0.^d1326$ to $0.^d1331$ (Andronov et al., 1999) to the "positive superhump" value $P = 0.^d14926$ (Skillman et al., 1998), which is in an excellent agreement (within 0.3%) with the value predicted by Tremko et al. (1996) based on the empirical "orbital period - superhump period" relation by Andronov (1990).

Such switch from a negative to a positive superhump without significant luminosity change is an unprecedented one, and the star should be carefully monitored to study details of such a process. Here we present some results of the international campaign "TT Ari-98". Owed to the paper size limitation, we will present the extrema timings based on the data from all observatories, whereas the fast variability will be discussed on the run of simultaneous UBVRI observations obtained in the Crimean observatory (fig. 1).

Characteristic time scales of the variability

Suggesting that the variability of TT Ari is not strictly periodic, the light curve was approximated by using the method of "running parabolae" (Andronov, 1997). Two maxima at the dependence of the signal/noise ratio vs. Δt were detected at $\approx 0.^d065$ (superhump variability) and $\approx 0.^d0054$ (quasi–periodic oscillations (QPOs) and flares).

Moments of extrema

By using the "running parabola" fit with the filter half-width $\Delta t = 0.^d065$, we have computed the mo-

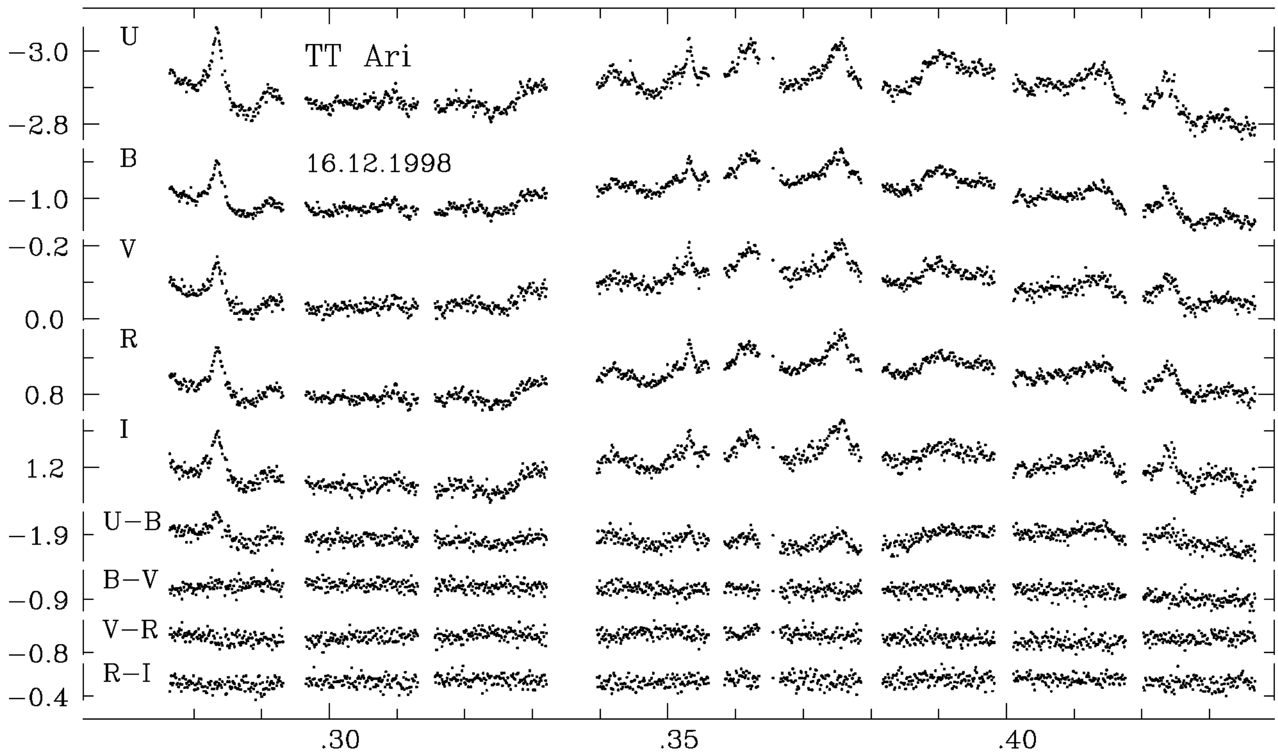

Figure 1. Instrumental UBVRI light curves of TT Ari (var-comp) and corresponding color differences. The vertical scale is the same for all graphs. The abscissa is decimal part of BJD.

Table 1. Moments of extrema

Max		Min	
BJD, 2451...	Obs	BJD, 2451...	Obs
066.4757 0.0018	Br W	051.5037 0.0010	Od B
069.5511 0.0011	Od B	051.5037 0.0010	Od B
069.5511 0.0011	Od B	066.5236 0.0036	Br W
097.4361 0.0029	Kr U	097.3786 0.0025	Kr B
097.4395 0.0025	Kr B	097.3793 0.0025	Kr V
097.4411 0.0024	Kr V	097.5183 0.0035	Kr U
100.4481 0.0009	Br V	097.5122 0.0048	Kr B
102.3859 0.0011	Br V	097.5244 0.0027	Kr V
104.4654 0.0043	Kr U	104.5588 0.0024	Kr U
104.4802 0.0036	Kr V	110.4165 0.0016	Bu B
104.4834 0.0031	Kr B	110.5574 0.0024	Bu B
110.3368 0.0023	Bu B	125.5303 0.0018	Br R
110.4770 0.0017	Bu B	125.6818 0.0012	Br R
125.4453 0.0014	Br R	164.3024 0.0005	Cr U
125.5984 0.0012	Br R	164.3025 0.0004	Cr B
125.7473 0.0023	Br R	164.3023 0.0005	Cr V
164.3696 0.0015	Cr U	164.3030 0.0004	Cr R
164.3670 0.0007	Cr B	164.3043 0.0004	Cr I
164.3677 0.0008	Cr V		
164.3684 0.0009	Cr I		
164.3714 0.0010	Cr R		

Here BJD is barycentric Julian date of the extremum and the corresponding error estimate. "Obs" marks the place of the institute/observatory, i.e. "Od" (Odessa), "Br" (Brno), "Bu" (Budapest), "Cr" (CrAO), "Kr" (Kryonerion), and the filter UBVRI or "W" (white, unfiltered).

ments of maxima and minima which are listed in Table 1.

No statistically significant difference between the times of extrema in different spectral bands was detected. The period derived from these extrema is in an excellent agreement with that published by Skillman et al. (1998).

"Red noise"

The periodograms in the double logarithmic scale show linear parts corresponding to the "red noise" fit $\lg S(f) = -a - \gamma(\lg f - \langle \lg f \rangle)$, where $\langle \lg f \rangle = 2.63$. To make a direct comparison with the results presented for the "negative superhump" state (Tremko et al., 1996; Andronov et al., 1998), we have used the same frequency interval 90-900 c/d. However, for the present data, the linear part finishes at the frequency $f \approx 370$c/d with a corresponding change of the best fit parameters. The values of a_{900}, γ_{900} and γ_{370} and the mean error estimate σ are listed in the following table:

filter	U	B	V	R	I	σ
a_{900}	2.95	2.95	2.99	2.92	2.92	0.008
γ_{900}	1.82	1.69	1.56	1.58	1.42	0.024
γ_{370}	2.40	2.32	2.67	2.64	3.13	0.063

Thus one may conclude that the coefficients γ_{900} are very similiar to that obtained during another state of the "negative superhump", whereas the maximal slope in the narrower range 90–370 c/d is much more larger and even exceeds 3.

The periodogram S(f) shows a peak at $f = 85.5$ c/d which is very close to the edge of the interval 90 c/d, contrary to the "negative superhump" data (Tremko et al., 1996; Andronov et al., 1999). Thus the "linear part" may be a "wing" of the peak rather than a "continuum" at the power spectrum. Such behaviour may be interpreted by a relatively small flickering as compared with the quasiperiodic oscillations and flares.

Scalegram analysis

The "scalegram" test function $\sigma_{O-C}(\Delta t)$ (Andronov, 1997) is an effective tool to study aperiodic "red noise"- like and chaotic processes, as it may be representer in some intervals by a power law $\sigma_{O-C}(\Delta t) \propto (\Delta t)^{\gamma_\sigma}$. E.g. for the magnetic cataclysmic variable AM Her, this fit is valid for the range differing by 7.5 orders of magnitude (Andronov et al., 1997).

Contrary to this, the scalegram for TT Ari is very complicated, showing branches of rapid increase with Δt corresponding to increasing systematic differences between the variability at ≈ 17 minutes and ≈ 3.6 hours and the fit.

Variability excess in the ultraviolet

The amplitude of ≈ 17 min variability is much larger in U than in other colors, in qualitative agreement with the the "negative superhump" data (Tremko et al., 1996; Efimov et al., 1998). This type of variability seems to be originated from the hotter inner parts of the accretion disk.

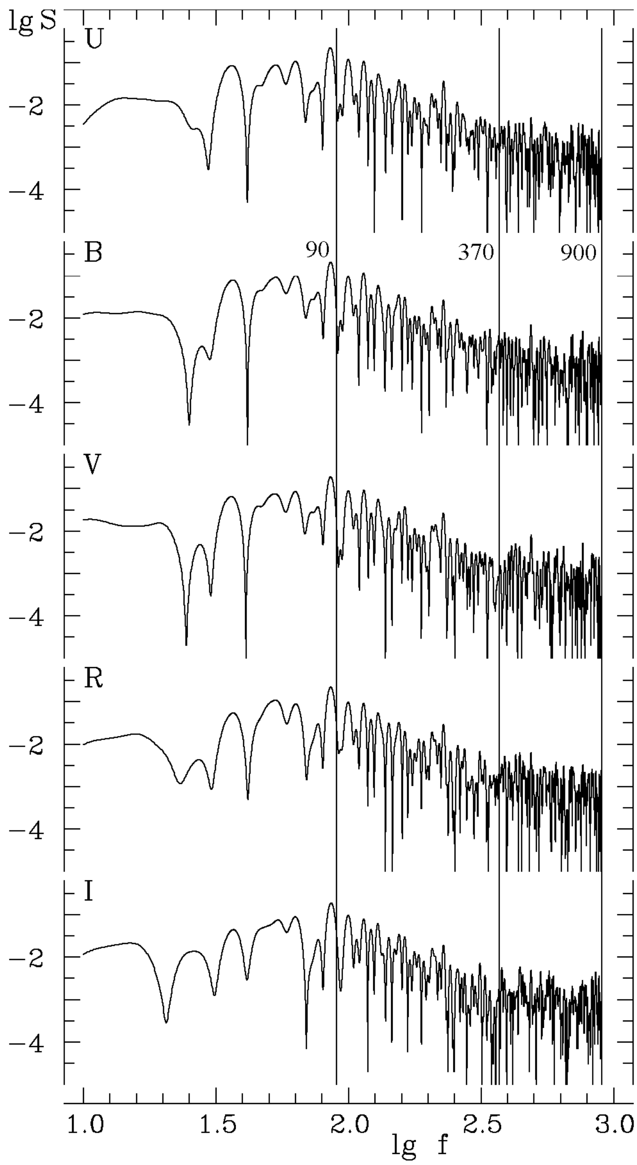

Figure 2. The periodograms for the residuals of the instrumental UBVRI observations of TT Ari from the smoothed superhump curve fitted by using the method of "running parabolae" with the filter half-width $\Delta t = 0^{d}.065$. A double logarithmic scale is used. Vertical lines mark the border frequencies f =90, 370 and 900 cycles/day corresponding to the linear branches of the $\lg S - \lg f$ dependence. The range was 90–900 c/d for the "negative superhump" state (Tremko et al., 1996; Andronov et al., 1998) and seems to be much smaller 90–370 c/d for the present data. The highest peak at the periodogram occurs at the frequency $f = 85.5 \pm 0.2$ c/d corresponding to the "period" $P = 16.84 \pm 0.04$ minutes. The frequency estimates are coinciding within the accuracy estimates. The mean semiamplitudes of the variations are 22 (U), 15 (B,V) and 16 (R,I) mmag (± 1 mmag), i.e. significantly larger in U than in other colors.

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