A SIMULTANEOUS X-RAY AND OPTICAL STUDY OF TT ARIETIS

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ABSTRACT. Prelimary results of an extended program of coordinated X-ray and optical observations of TT Ari are presented. The object was observed on August 21/22 1985 both in X-rays (EXOSAT) and optical range, about 100 days after the return to the active state. The first detailed simultaneous study of TT Ari in active state indicates the presence of strongly absorbing structure in the system.

1. INTRODUCTION

The cataclysmic variable TT Ari, an object close to intermediate polars, is known to undergo high ($B \sim 10.6$) and low ($B \sim 11.5 - 13$) states, the first lasting several times longer (in mean) than the second (Hudec, Huth and Fuhrmann, 1984). However, a quite exceptional 'superlow' state with decline down to 16.5 mag. superimposed by rather large variations occured between 1979 and 1985, resulting in the fact that the active (A) state measurements are 'rarer' than the inactive (I) ones. Actually, no previous X-ray detection of TT Ari in the A state exists (Hudec et al., 1986).

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An extended optical program was established within the Intercosmos program in order to monitor the behaviour of TT Ari, to wait for the next transition to the A state and to allow coordinated X-ray and detailed optical observations after the return to the high state. 10 professional as well as numerous small and amateur observatories participated.

Here we present preliminary optical and X-ray results obtained not long after the final return of TT Ari to the A state. A final and more detailed discussion will be published elsewhere (Wenzel et al., 1986, Hudec et al., 1986).

2. THE LONG-TERM LIGHT CURVE

In Figure 1 the continuation of the long-term curve of TT Ari by Hudec, Huth and Fuhrmann (1984) is given.

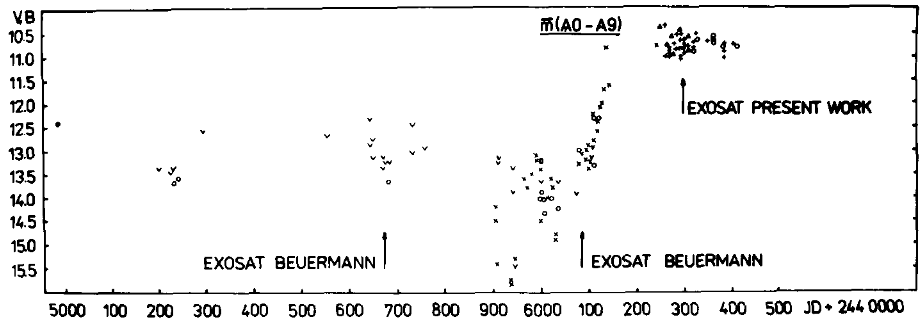

Figure 1. The optical long-term light curve of TT Ari showing the I9 to A10 transition and the times of EXOSAT observations. The average A state brightness derived from A0 to A9 is indicated by a line at mag. 10.55. Open circles = Sonneberg sky patrol data (v are upper limits), + = Sonneberg astrograph, x = visual observations by Bortle and Verdenet (1984a, 1984b, 1985a, 1985b), Verdenet (1985) and Mattei et al. (1985), triangles are estimations of small observatories and amateurs, square measurement by Beuermann and Weissieker (1985).

The object has been in the very low I9 state (for numbering of states see Hudec, Huth and Fuhrmann, 1984) from ~ JD 244 4116 to ~ JD 244 6120. The transition to the A10 state proceeded in a rather unusual way, starting at ~ JD 244 5950 and increasing the brightness from m ~ 16 to m ~ 13.2 in ≤ 50 days and then fading again to m ~ 14.8 in ~ 40 days. The final rise to activity started ~ JD 244 6050 at a average brightening rate of ~ 0.04 mag day^{-1} resulting in the brightening from m ~ 14.5 to ~ 10.75 in ~ 100 days. It should be noted that a possible final rise from ~ 10.75 to the average brightness derived from the A0 to A9 states occured since JD 244 6480.

3. THE COORDINATED OPTICAL OBSERVATIONS

A great amount of simultaneous and quasisimultaneous optical photometric and partly spectroscopic data was obtained at participating observatories.

A prism spectrogram was obtained at Abastumani observatory 16 h prior to the X-ray measurements showing a typical spectrum of TT Ari in the A state (Voychanskaya, 1983) with weak hydrogen lines with emission components.

Photoelectric light curves were obtained in more than 20 nights close to the time of the X-ray measurement or coinciding with it, with integration times from 8 to 16 s.

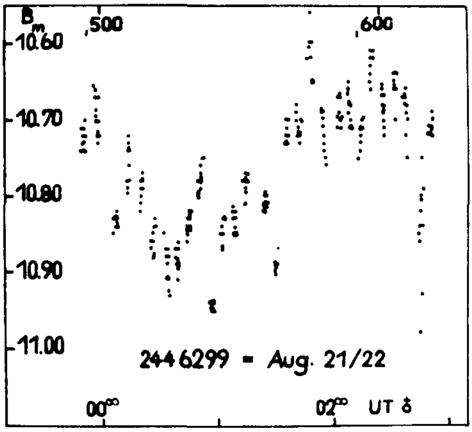

Figure 2. Photoelectric light curve for August 21/22 1985 (coinciding with EXOSAT observation) obtained at Jena-Grossschwabhausen Observatory. The star 'c' according to Shafter et al. (1985) served as comparison star.

Five components of variability were revealed in the curves: (a) a wave-shaped variation of .2 to .4 in B with a period 0.005° shorter than the orbital one, (b) a variation of the shape of this wave, (c) day-to-day variations by .1 to .2 in B, (d) quasiperiodic flickering (P ~~ 10 ± 5 min) with an amplitude up to .2 in B, and (e) fast periodic and quasi-periodic (9.6 s, 18.3 s) variations in the milli-mag range.

The flickering intensity was found to be variable. During the EXOSAT observation, a high level of flickering activity was revealed. The shape of the maximum was found to be steep (B-V= +0.06) during the period of X-ray measurement in contrast to the second possible flat shape (B-V~-0.02).

The main photometric period of $0^{d}.13277100$ was found to be stable between 1961 and 1985, but at some intervals displacements of maxima up to $0^{d}.05$ occur (Wenzel et al., 1986). Besides the most stable frequency at f_o = 7.534 cpd a possible second frequency at f_1

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= 5.12 was revealed in the data. The synthetic light curve for f_o, $2f_o$, f_1, $2f_1$ repeats exactly after $3\overset{d}{.}02$: this period can possibly be seen as a hint for the physical description of the system (beat period or disk precession).

4. THE X-RAY OBSERVATIONS

We observed TT Ari using the LE2 telescope with CMA as focal detector and the ME experiment on the EXOSAT observatory for a total of 11 hours on Aug 21/22, 1985. The source was surprisingly faint, resulting in some difficulties in evaluating and analysing of the data.

4.1. X-ray fluxes

The LE (0.05 - 2 keV) data are available using both 3000 lexan (16:40 to 19:53 UT, Obs. 1 and 23:19 to 02:59 UT, Obs. 3) and Al-Parylene filter (19:57 to 23:19 UT, Obs. 2). The use of 3000 lexan represents the wavelength range 6.5-210 A, of Al-Parylene filter the 6.9-95 and 155-310 A range.

The analysis yields corrected count rates 0.016 ± 0.002, 0.010 ± 0.001 and 0.014 ± 0.001 cts s^{-1} for observations 1, 2 and 3. The corresponding mean source flux at earth is ~ 1 x 10^{-11} erg $cm^{-2}s^{-1}$ in the 0.05-2 keV range considering thermal bremsstrahlung + Gaunt spectrum with T ~ 10 keV and N_H ~ 10^{21} cm^{-2}. To make correlations with previous data possible, the flux was estimated ~ 1.9 x 10^{-11} erg $cm^{-2}s^{-1}$ in the 0.2-4 keV range. TT Ari was also detected by the ME experiment at a mean (2-20) keV count rate of 0.8 ± 0.1 cts s^{-1} in the 4 argon detectors pointed to the source.

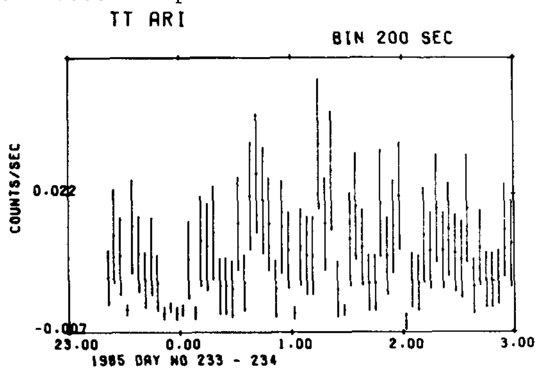

Figure 3. The X-ray light curve for Observation 3 (EXOSAT LE/CMA with 3000 lexan filter. A possible absorption feature is seen around 0^h UT.

4.2. X-ray Light Curves

The obtained soft X-ray light curves (Figure 3) are rather complicated, far from what would be expected from the varying aspect

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of the hot spot or hot polar cap. The preliminary analysis indicate
a) no obvious modulation with the spectroscopic or photometric period. The X-ray curve resembles the optical one after substracting the main photometric wave.
b) intensive X-ray flickering related to optical fluctuations, the delay between X and optical events being in mean ~ 1 min but not stable.
c) changes between non-flickering variations from cycle to cycle.
d) possible absorption events (dips) lasting 5-15 min suggesting possible recurrence period of ~3^h33^m. Analogous features were found also in ME data, but being less pronounced at higher energies. One analogy was found in optical light.
Besides the possible dip recurrence period of ~3^h33^m, no other strict periods were found in the data. Quasiperiodic variations have periods close to 3600 and 1800 s (non-flickering changes) and ~1200, 500 and 100 s (flickering).

4.3. X-ray Spectra

No significant soft X-ray excess was found in our data, in line with results expected for intermediate polars with high absorption. Both the multispectral analysis for LE data and spectral fits for the ME data indicate the thermal bremsstrahlung + Gaunt factor spectrum with kT = 4 to 8 keV and N_H of order of $10^{21}cm^{-2}$. The results of the spectral analysis will be in detail presented elsewhere (Hudec et al., 1986).

5. DISCUSSION AND CONCLUSION

The mean X-ray flux was found to be surprisingly (if compared e.g. with AM Her) stable over long time intervals, not changing by more than several tens of per cent and not reflecting the large optical intensity changes between the I and A states, the only exception being the superlow state where the mean flux seems to decline below ~ 25% of the average value (Beuermann, 1985).

The physical structure of the X-ray emitting and absorbing structures in the systems seems to be rather complicated. Of special interest are the possible absorption dips, probably due to photoelectric absorption or scattering because they are most pronounced at lowest X-ray energies. Unfortunately, no confirmation of dips recurrence using measurements by Jensen et al. (1983) was possible because of many gaps in their data coinciding with the expected times of minima. On the other hand, the optical curve from the Sonneberg Observatory for Aug 21/22. reveals that the decrease near 0^h UT, probably coinciding with one of the dips, is not simply a minimum between two flares.

We conclude that probably (at least) two hot X-ray emitting regions and (at least) two cold absorbing or scattering regions exist in the system in the A state. The first emitting region (hot spot, boundary layer or hot polar cap responsible for 'steady' flux) is probably more compact than the second (corona-like or cloud structure responsible for flicker) one. If the dips reported here are real, there exist hints that the flickering may occur also during the decrease, confirming the reality of two sources. The first absorbing region is responsible for the absorption of the 'steady' hard X-rays as well as the soft component from the central source in the A state, and is closely related to the enhanced mass flow activity. The second absorbing region is responsible for the dips. In the I state, we detect both the modulated (changing viewing) 'steady' X-ray emission from the central source together with the flaring emission from the extended source. In the A state, the enhanced X-ray emission from the central source seems to be blocked from direct viewing and only a small portion of the energy released in the disk is transported to the corona-like structure resulting in no significant change of the average X-ray flux. Another alternative would be the presence of both accreting column and disk in the system, the disk structure being more pronounced in the A state. In superminimum, no mass flow and, consequently, no X-ray production occur for some intervals.

A more detailed spectral data would be necessary to confirm the existence and character of two X-ray emitting regions.

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