NEGATIVE SUPERHUMPS AND RED NOISE IN THE CATACLYSMIC BINARY TT ARIETIS: THE INTERNATIONAL CAMPAIGN "TT ARI–94"

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ABSTRACT. Results obtained during the international observational campaign "TT Ari–94" are briefly discussed. During 258 hours, totally 51299 observations were obtained in 12 observatories. The moments of 68 individual maxima and 74 minima are tabulated. The linear ephemeris for the maximum is $MaxHJD = 2449645.4255 \pm 0.^d0003 + (0.^d133160 \pm 0.^d000004) \cdot E$ for our data obtained in JD 2 449 614–690. The period value is distinctly outside the interval $0.^d1326 - 0.^d13298$ obtained for previous years. It still corresponds to the 'negative superhump' state, whereas for a normal 'positive superhump' the value predicted by Tremko et al. (1996, As.Ap. 312, 121) is $P = 0.^d1426 \pm 0.^d00006$. The data prewhitened in respect to the superhump variations show the red noise power–law power spectrum with an index $\gamma = 1.3...2.6$.

Key words: Stars – binary – novalike – superhumps, red noise; Individual: TT Ari

TT Ari is the binary system exhibiting a variety of phenomena causing its variability. Thus the observations have been carried out occasionally since 1961. The main types of variability are the following:

- Spectral variations with phase of the orbital period $P_{orb} = 0.^{d}13755114$;
- Primary wave with a photometric period P_1 in the range $0.^{d}1326 - 0.^{d}13298$ prior to our observations;
- Possible beat between P_{orb} and P_1;
- Possible secondary photometric period of $P_2 \approx 0.^{d}1952$;
- Quasi–periodic oscillations with a cycle length of 14-20 minutes;
- Long-term variations of the mean brightness from 10 to 16 magnitude;
- Possible dips (brightness fadings at a minute time scale);
- Fast variability with a power–law power spectra.

Detailed overview and references one my find e.g. in Tremko et al. (1996). To study these phenomena, one should have observations from different observatories, if possible, overlapping and longitude - dispersed.

The international campaigns were organized in 1985 and 1988. Their results were summarized by Semeniuk et al. (1987) and Tremko et al. (1996). The present campaign "TT Ari – 94" is the first one with the observations obtained at very different longitudes - in Japan, Turkmenistan, Europe and USA.

The complete discussion of the results will be presented elsewhere (Andronov et al., *Astron. J.,* submitted). Here we only briefly describe the results and present the tables of the original timings of the extrema and the figure illustrating the night–to–night changes of the characteristics of the red noise, which will not be included in the final paper. The timings for the year 1988 are listed by Tremko et al. (1994).

As $P_1 < P_{orb}$, one may call such a phenomenon the "negative superhump", which is observed in few stars, but contradicts the theory of precessing elliptic accretion disk (cf. Patterson et al., 1997), if one suggests that the primary photometric period P_1 coincides with the synodical period of the disk P_d. One may suggest that $P_1 = P_d/2$, and thus P_d will be a 'true' photometric period consisting of two nearly equal cycles. This is in an agreement with the initial suggestion by Smak and Stępień (1969), who first derived the value of $0.^{d}2658$.

The 'expected' value of the superhump period is usually larger than P_{orb} and may be determined from an empirical relation by Andronov (1990):

$$\begin{array}{rcl} \lg P_{sh} & = & -0.0043 + 1.077 \cdot \lg P_{orb} \\ & & \pm\ 33 \quad \pm\ 6 \end{array} \qquad (1)$$

In this equation the periods are expressed in hours. For TT Ari, $P_{sh} = 0.^{d}1493 \pm 0.^{d}0007$, as was predicted by Andronov et al. (1992) by using the value P_{orb}=$0.^{d}13755114$ (Thorstensen et al., 1985).

The values of P_1 derived from the present observations are $0.^{d}133130$ (fit to the maxima) and $0.^{d}133118$ (fit to the minima). However, the sine fit to all data obtained at the Dushak-Eregdag station of the Odessa State University, corresponds to slightly other value $0.^{d}133160$ listed in the abstract. Such discrepancy exceeds the error estimates and may be interpreted by real relatively large phase shifts in different runs. In any case, the value of P_1 lies well outside the range of values previously determined.

Thus one may note, that during its study in 1961–1994, the normal positive superhump was never detected.

The quest of the secondary period suggested by Wenzel et al. (1986) on the data from 1985 year remains opened. Tremko et al. (1992) argued for a secondary 5–7 hour wave, but have failed to choose the best peak from the 4 candidates at the periodogram. This suggested period is longer than the usual observational run and thus the aliases at the periodogram are very strong. In the present data, in the range from 2.5 to 5.5 cycles/day there may be a wave with a frequency 3.2895 cycles/day and an amplitude of 25 mmag. There is no mechanism to make this wave coherent, thus possibly the amplitude of the wave is underestimated owed to the night-to-night phase shifts.

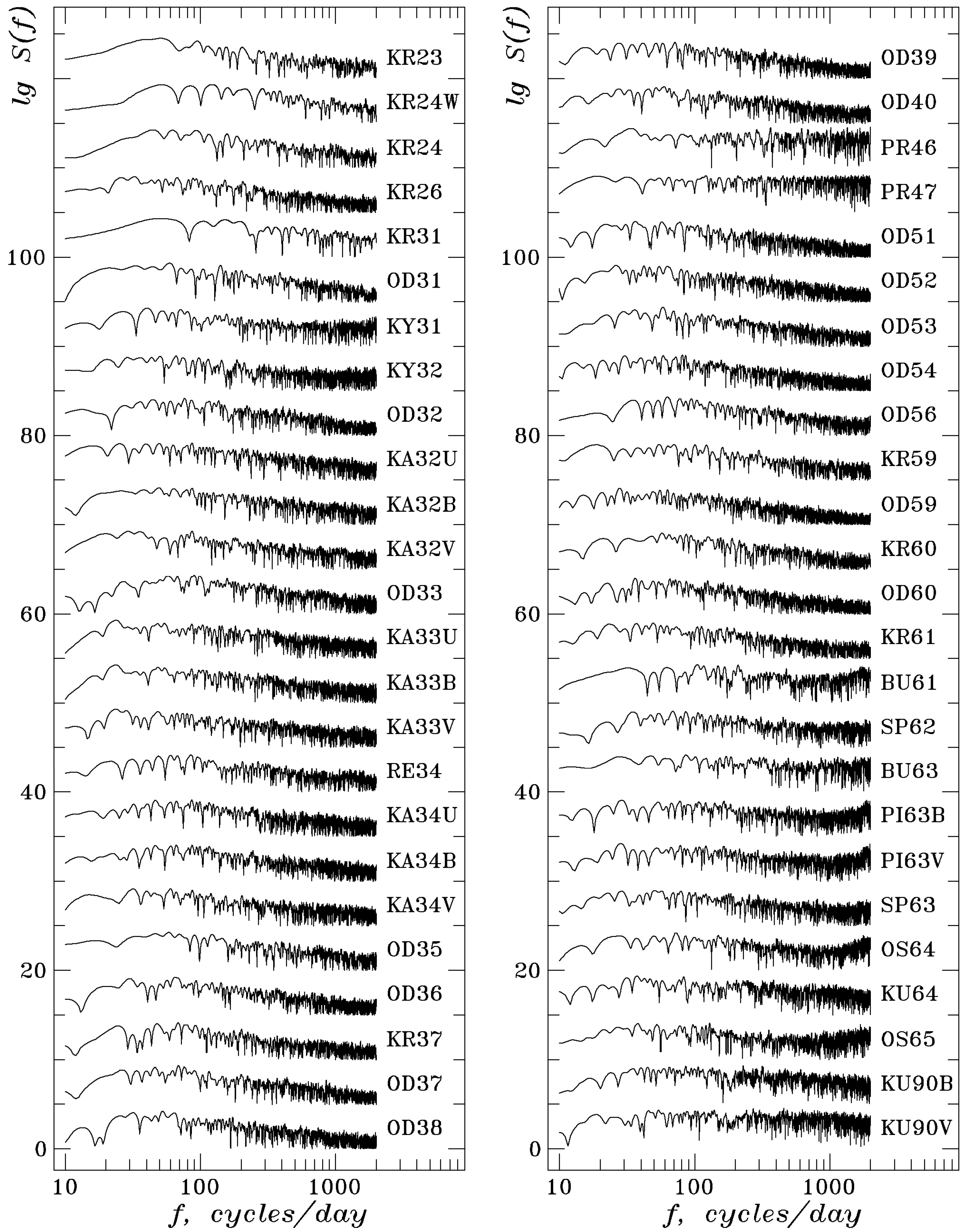

Figure 1. The periodograms for individual runs of TT Ari in a double logarithmic scale. The shift between the subsequent lines is set to 5. The runs are marked in the following way: two first letters correspond to the city or observatory then two last digits of JD. The data are usually in the B system, otherwise noted. The test function $S(f)$ is used (Andronov, 1994).

Table 1. Moments of the individual maxima from the running parabolae fits. The times are expressed as HJD-2449600.

Run	t	ϕ	m
CCD14	14.5207±0.0070	-0.087±0.053	0.129±0.011
CCD14C	14.5234±0.0062	-0.068±0.047	-0.048±0.009
KR24	24.5384±0.0022	0.143±0.017	1.073±0.002
KR26	26.4088±0.0015	0.189±0.011	1.115±0.002
KR26	26.5047±0.0017	-0.091±0.013	1.115±0.002
KY31	31.2106±0.0051	0.249±0.038	-1.963±0.006
OD31	31.4355±0.0020	-0.061±0.015	-1.203±0.004
KY32	32.1261±0.0060	0.124±0.045	-1.977±0.008
KY32	32.2333±0.0018	-0.071±0.014	-1.976±0.005
OD32	32.3860±0.0053	0.077±0.040	-1.159±0.002
KA33U	33.4393±0.0055	-0.014±0.041	-3.793±0.005
KA33B	33.4470±0.0021	0.044±0.016	-1.612±0.004
KA34V	34.3580±0.0015	-0.115±0.011	-0.239±0.004
KA34B	34.3875±0.0020	0.107±0.015	-1.602±0.003
KA34U	34.4080±0.0024	0.261±0.018	-3.789±0.005
KA34U	34.4881±0.0017	-0.137±0.013	-3.832±0.005
KA34V	34.4894±0.0009	-0.128±0.007	-0.351±0.005
RE34	34.4975±0.0087	-0.067±0.065	-1.227±0.004
KA34B	34.5001±0.0046	-0.047±0.035	-1.647±0.004
OD35	35.4188±0.0016	-0.148±0.012	-1.193±0.003
OD36	36.4081±0.0046	0.281±0.035	-1.114±0.004
OD36	36.5216±0.0028	0.134±0.021	-1.182±0.005
OD37	37.4442±0.0028	0.062±0.021	-1.258±0.003
KR37	37.4464±0.0023	0.079±0.018	1.210±0.002
OD38	38.3541±0.0041	-0.105±0.031	-1.164±0.004
OD38	38.4957±0.0064	-0.041±0.048	-1.207±0.005
OD39	39.4077±0.0022	-0.193±0.016	-1.116±0.004
OD39	39.4728±0.0024	0.297±0.018	-1.113±0.004
OD40	40.3485±0.0027	-0.127±0.021	-1.184±0.003
OD40	40.4135±0.0052	0.361±0.039	-1.189±0.006
OD40	40.4928±0.0033	-0.044±0.025	-1.264±0.005
PR46	46.6293±0.0061	0.040±0.046	0.115±0.009
PR46	46.7700±0.0048	0.097±0.036	0.094±0.008
PR47	47.9189±0.0060	-0.275±0.045	0.046±0.013
OD51	51.4309±0.0036	0.099±0.027	-1.207±0.005
OD51	51.5190±0.0033	-0.240±0.025	-1.133±0.003
OD52	52.3421±0.0031	-0.058±0.023	-1.225±0.006
OD52	52.4857±0.0023	0.021±0.018	-1.218±0.005
OD53	53.4274±0.0013	0.092±0.010	-1.156±0.004
OD54	54.2597±0.0014	0.343±0.011	-1.160±0.006
OD54	54.3411±0.0040	-0.046±0.030	-1.135±0.004
OD54	54.4801±0.0039	-0.002±0.029	-1.206±0.005
OD56	56.3434±0.0031	-0.009±0.023	-1.132±0.004
OD59	59.1593±0.0049	0.137±0.037	-1.064±0.005
OD59	59.2839±0.0040	0.073±0.030	-1.062±0.004
KR59	59.3858±0.0015	-0.162±0.011	1.225±0.002
OD59	59.5245±0.0018	-0.120±0.014	-1.131±0.004
OD60	60.2099±0.0038	0.027±0.028	-1.150±0.003
OD60	60.3316±0.0030	-0.059±0.022	-1.158±0.005
KR60	60.3354±0.0019	-0.030±0.015	1.127±0.002
KR60	60.4484±0.0015	-0.181±0.011	1.113±0.002
OD60	60.4753±0.0026	0.020±0.019	-1.188±0.005
KR61	61.4111±0.0021	0.048±0.016	1.161±0.002
SP62	62.3248±0.0065	-0.091±0.049	1.330±0.007
BU61	62.4442±0.0041	-0.193±0.031	1.336±0.009
SP63	63.3697±0.0086	-0.243±0.065	1.353±0.007
OS64	64.1966±0.0202	-0.034±0.152	0.329±0.006

Table 1 (continued)

Run	t	ϕ	m
BU63	64.3557±0.0128	0.161±0.096	1.344±0.009
BU63	64.4492±0.0041	-0.137±0.030	1.353±0.009
KU64	65.0130±0.0037	0.097±0.028	1.329±0.007
OS65	65.0115±0.0027	0.086±0.021	0.298±0.006
OS65	65.1186±0.0022	-0.109±0.017	0.337±0.007
KU64	65.1400±0.0027	0.051±0.020	1.297±0.008
OS65	65.2575±0.0070	-0.066±0.052	0.340±0.009
KU90B	90.9478±0.0049	-0.138±0.037	1.243±0.011
KU90V	90.9707±0.0061	0.034±0.046	1.578±0.021
KU90B	91.0770±0.0022	-0.168±0.017	1.320±0.007
KU90V	91.0826±0.0031	-0.126±0.023	1.631±0.010

Table 2. Moments of the individual minima from the running parabolae fits.

Run	t	ϕ	m
CCD14	14.6076±0.0072	-0.435±0.054	0.266±0.007
CCD14C	14.6143±0.0071	-0.385±0.053	0.068±0.007
KR23	23.5359±0.0025	-0.386±0.019	1.394±0.004
KR26	26.4588±0.0008	-0.435±0.006	1.024±0.002
KY31	31.2596±0.0050	-0.383±0.038	-1.872±0.009
KY32	32.0385±0.0059	0.466±0.044	-1.788±0.013
KY32	32.1875±0.0032	-0.405±0.024	-1.849±0.007
OD32	32.4447±0.0009	-0.482±0.007	-1.018±0.002
KA32B	32.4452±0.0012	-0.479±0.009	-1.470±0.003
KA32V	32.4491±0.0015	-0.450±0.011	-0.100±0.004
KA32U	32.4503±0.0008	-0.441±0.006	-3.585±0.005
KA33V	33.5038±0.0034	0.471±0.025	-0.095±0.006
KA33U	33.5145±0.0015	-0.449±0.011	-3.544±0.007
KA33B	33.5158±0.0010	-0.439±0.008	-1.474±0.005
RE34	34.4417±0.0012	-0.486±0.009	-1.354±0.004
KA34B	34.4446±0.0019	-0.464±0.015	-1.488±0.005
KA34U	34.4477±0.0024	-0.440±0.018	-3.694±0.007
KA34V	34.4493±0.0020	-0.429±0.015	-0.116±0.007
KA34U	34.5519±0.0019	0.342±0.014	-3.653±0.006
RE34	34.5565±0.0052	0.376±0.039	-1.299±0.004
OD35	35.3735±0.0014	-0.488±0.011	-1.092±0.004
OD36	36.4469±0.0030	-0.427±0.022	-1.081±0.005
OD37	37.3665±0.0019	0.479±0.014	-1.039±0.003
KR37	37.3707±0.0019	-0.489±0.014	1.053±0.003
KR37	37.5069±0.0019	-0.467±0.014	1.079±0.003
OD37	37.5138±0.0022	-0.415±0.017	-1.095±0.004
OD38	38.3050±0.0036	-0.473±0.027	-1.109±0.003
OD38	38.4392±0.0038	-0.465±0.029	-1.104±0.006
OD39	39.3713±0.0018	-0.466±0.013	-1.034±0.005
OD39	39.4403:±0.0023	0.052±0.017	-1.084±0.004
OD40	40.3078±0.0042	-0.433±0.032	-1.142±0.005
OD40	40.3806:±0.0022	0.114±0.016	-1.151±0.004
OD40	40.4404±0.0029	-0.437±0.022	-1.169±0.006
OD40	40.5306:±0.0032	0.240±0.024	-1.206±0.006
PR46	46.6850±0.0064	0.459±0.048	0.249±0.012
PR47	47.8842±0.0076	0.464±0.057	0.101±0.012
PR47	47.9541:±0.0107	-0.011±0.080	0.119±0.014
OD51	51.3335±0.0037	0.368±0.028	-1.083±0.005
OD51	51.4781±0.0028	0.453±0.021	-1.089±0.004
OD52	52.2966±0.0016	-0.400±0.012	-1.114±0.005
OD52	52.4229±0.0037	-0.451±0.028	-1.122±0.006
OD53	53.3486±0.0033	-0.499±0.025	-1.035±0.009
OD53	53.4876±0.0035	-0.456±0.027	-1.050±0.005

Table 2 (continued)

Run	t	ϕ	m
OD54	54.2950±0.0021	-0.392±0.016	-1.042±0.005
OD54	54.5307±0.0015	0.378±0.012	-1.053±0.006
OD56	56.2830±0.0039	-0.463±0.029	-1.034±0.005
OD59	59.2108±0.0021	-0.476±0.016	-0.937±0.006
OD59	59.3413±0.0021	-0.496±0.015	-0.983±0.004
KR59	59.4694±0.0009	0.467±0.007	1.115±0.002
OD59	59.4716±0.0016	0.483±0.012	-0.975±0.004
OD60	60.2660±0.0017	0.449±0.013	-1.031±0.003
OD60	60.3976±0.0025	0.437±0.019	-0.992±0.005
KR60	60.4025±0.0014	0.473±0.010	1.021±0.002
KR61	61.3297±0.0014	0.436±0.011	1.095±0.002
KR61	61.4700±0.0008	0.491±0.006	1.019±0.002
SP62	62.3869±0.0131	0.376±0.098	1.404±0.008
BU61	62.3930±0.0084	0.422±0.063	1.448±0.013
PI63B	63.3211±0.0035	0.392±0.027	1.527±0.007
PI63V	63.3244±0.0055	0.417±0.042	1.719±0.007
SP63	63.3256±0.0058	0.426±0.043	1.427±0.006
SP63	63.4435±0.0028	0.311±0.021	1.445±0.006
PI63B	63.4578±0.0143	0.418±0.107	1.464±0.008
PI63V	63.4786±0.0095	-0.425±0.072	1.673±0.009
OS64	64.1301±0.0031	0.467±0.023	0.190±0.009
OS64	64.2658±0.0062	0.486±0.047	0.242±0.008
BU63	64.4084±0.0049	-0.443±0.037	1.446±0.012
KU64	65.0639±0.0027	0.479±0.020	1.496±0.008
OS65	65.0587±0.0044	0.441±0.033	0.183±0.007
OS65	65.1909±0.0060	0.433±0.045	0.233±0.006
KU64	65.2009±0.0040	-0.492±0.030	1.462±0.006
KU90B	91.0200±0.0049	0.404±0.037	1.466±0.006
KU90V	91.0256±0.0105	0.446±0.079	1.773±0.021
KU90V	91.1626±0.0094	0.474±0.071	1.827±0.019
KU90B	91.1646±0.0158	0.490±0.118	1.549±0.008

The beat period of $3\overset{d}{.}8$ was suggested by Semeniuk et al. (1987) but was not justified by the data from other years; from the 16 nights obtained in Dushak-Erekdag, one may assume a period of $2\overset{d}{.}916$ which is by a factor of 1.43 smaller than that expected ($4\overset{d}{.}171$) for the current values of P_1 and P_{orb}.

The quasi-periodic oscillations are still present at frequencies from 46 to 95 cycles/day. Most often the QPOs occurred at 59 cycles/day, i.e. 24 minutes. The drastic run-to-run changes of the best fit frequency may be explained by the wavelet-like model by Tremko et al. (1996), when the 'shot noise' consists of pulses occurring randomly and resembling dumping sines rather than decaying exponents.

To study QPOs and more fast the flicker activity, we have removed the primary photometric wave by using the running parabola fit with $\Delta t = 0\overset{d}{.}05$. The power spectra of the detrended data show a linear branch in a double logarithmic scale, as one may see in Fig.1. The duration of this branch is dependent on the quality of runs (the "signal/noise" ratio), the duration of run and the time resolution. The slope varies from 1.3 to 2.6.

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