TT ARI–94: A STUDY OF 1.6...60 MINUTE VARIABILITY

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We report photometric results from 44 runs at 11 observatories during the international campaign 'TT Ari–94'. No coherent oscillations in the frequency range 10...900 cycle d^{-1} are found. The highest peaks in the power spectrum cover the wide range of 28...139 cycle d^{-1}. Variations occur at a few preferred time-scales rather than at one cycle length, with

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a possible secular decrease. In the frequency range 90...900 cycle d^{-1} the power spectrum obeys a power law with slope γ ranging from 0.8 to 2.6 for different runs.

TT Ari is one of the brightest cataclysmic variables and remains one of the most interesting objects of this class. It exhibits a variety of phenomena observed at time-scales from seconds to months. A recent detailed photometric study of this object and a bibliographical overview may be found in Tremko et al. (1996). Tremko et al. (1992, 1993, 1994) discuss aspects of the TT Ari–88 campaign. Our campaign TT Ari–94 was unprecedented, as the observations were longitude–dispersed, from Japan through Turkmenia, to Europe and the American continent. Moreover, our optical data on October 7 partially overlap with the HST observations obtained by Horne & Welsh (1995, private communication). The numerical results of observations obtained during these nights are shown in Table 1.

During TT Ari–94 we tried to obtain as many nights as possible at different observatories. Most successful were the observations obtained at the Dushak mountain station of the Odessa State University located in Turkmenia. A total of 16 nights containing 13 879 observations with mainly 20 s integrations were gathered. At the Mt. Suhora station near Krakow 8 nights with 19 355 observations with mainly 5 s integrations were obtained.

To study variability on time-scales shorter than the primary '3–h period' and a possible longer secondary wave (see Tremko et al. 1992, 1995 for discussion), we have computed a low–frequency trend by using the method of 'running parabolae' (Andronov 1990) with a filter half-width $\Delta t = 0.05$ d. The $(O - C)$ deviations from this fit were used for further analysis.

Periodograms were computed by the program FOUR-1 (Andronov 1994) using a one–frequency harmonic fit with unknown mean. In Table 1 the following parameters of the individual runs are listed: observatory O (numbered as per affiliation on title page, 8 means 8 and 11), filter F (W = white light, i.e. unfiltered); Julian date (JD – 2 449 600), number of points N; r.m.s. deviation in mmag σ_O of the signal from the mean, and σ_{O-C} from the running parabolae fit; the Nyquist frequency F_N in cycle d^{-1}; the 'best- fit' amplitude r in mmag and frequency f in the range 10...200 cycle d^{-1}; the value $LP = -\ln(Pr)$, where Pr is the 'false alarm probability'; and the best-fit slope γ.

Tremko et al. (1993, 1995) and Efimov et al. (1995) have found that the power spectrum obeys the power law $S(f) \propto f^{-\gamma}$ in the frequency range 90...900 cycle d^{-1}. It may be noted that the values of γ for the runs with $f_N < 900$ cycle d^{-1} are to be neglected because the interval being fit extends beyond the Nyquist frequency. For these runs the apparent values are closer to zero than those data-sets with a time resolution of 1...20 s. For some runs we have binned the counts to obtain 20–s resolution. The

TABLE 1. Results of the periodogram analysis

O	F	JD	N	σ_O	σ_{O-C}	$r \pm \sigma_r$		$f \pm \sigma_f$		f_N	LP	$\gamma \pm \sigma_\gamma$	
8	B	23	1116	77	70	57	2	50.8	.3	7377	94	1.81	.17
8	W	24	715	52	32	21	2	122.7	.9	8171	35	2.56	.48
8	B	24	1394	55	51	31	2	44.5	.4	8387	57	2.01	.17
8	B	26	3204	62	53	25	1	32.4	.1	8111	75	2.01	.12
8	B	31	498	50	39	25	2	50.2	1.7	8387	24	1.71	.32
1	B	31	501	71	44	29	2	59.1	.4	2009	24	2.17	.22
4	B	31	294	72	64	40	5	40.3	.5	942	11	0.94	.12
4	B	31	639	75	58	24	3	66.0	.3	924	10	1.52	.10
1	B	32	1429	67	43	22	1	76.2	.2	3680	42	1.86	.16
1	B	33	353	62	49	43	3	91.1	.8	3849	35	1.80	.17
1	B	33	6218	72	63	36	1	95.1	.1	25205	231	1.32	.13
5	B	34	1203	72	61	32	2	85.2	.2	3272	39	1.81	.15
1	B	35	847	66	52	32	2	58.1	.3	3697	34	1.56	.15
1	B	36	765	61	50	29	2	64.9	.2	1862	27	1.70	.12
8	B	37	3560	80	59	31	1	68.4	.1	8331	110	1.79	.10
1	B	37	1529	95	58	38	2	68.7	.1	3885	77	1.41	.13
1	B	38	950	62	50	29	2	52.4	.2	1834	34	1.78	.11
1	B	39	106	55	48	45	5	74.3	2.3	1812	10	1.66	.33
1	B	39	738	59	47	23	2	58.8	.3	1815	17	1.88	.15
1	B	40	917	67	54	27	2	59.4	.2	1775	23	1.83	.17
6	R	46	58	62	34	25	5	33.9	.9	160	1	-0.32	.17
6	R	47	49	48	39	20	7	121.1	1.6	160	0	-0.06	.17
1	B	51	1096	66	53	24	2	36.2	.2	1872	22	1.80	.11
1	B	52	1116	84	57	27	2	26.2	.2	1830	27	1.76	.13
1	B	53	776	63	50	35	2	58.1	.2	1838	44	1.60	.12
1	B	54	112	74	58	57	6	58.6	2.0	1815	13	1.90	.28
1	B	54	1052	77	55	27	2	30.5	.2	1849	26	1.83	.11
1	B	56	534	60	48	30	3	62.7	.4	1860	23	1.87	.15
8	B	59	2501	64	47	21	1	70.5	.2	8343	52	2.03	.16
1	B	59	1476	70	47	23	2	27.8	.1	1877	37	2.06	.11
8	B	60	3199	65	53	24	1	57.3	.2	8452	74	1.87	.13
1	B	60	1409	73	48	21	2	36.3	.1	1832	28	1.97	.08
8	B	61	3883	62	46	20	1	49.4	.1	8383	76	1.93	.11
3	B	61	134	74	62	38	7	104.2	.7	485	4	1.46	.18
10	B	62	338	62	53	26	4	68.8	.4	832	7	1.35	.14
9	B	63	265	63	48	22	4	28.8	.4	509	4	1.11	.11
9	V	63	266	58	50	28	4	28.3	.3	511	7	1.14	.10
3	B	63	118	67	54	30	7	85.9	.9	435	2	0.51	.16
10	B	63	451	59	50	19	3	79.0	.4	890	5	1.23	.11
7	V	64	248	65	47	26	4	72.5	.5	641	6	1.45	.16
7	V	64	358	61	42	20	3	128.8	.3	618	7	1.11	.09
2	B	64	440	75	50	34	3	37.4	.2	846	22	0.81	.16
2	V	90	95	106	63	45	7	139.2	.4	178	2	0.16	.13
2	B	90	320	100	53	30	4	85.9	.2	606	10	0.96	.20

corresponding values of γ changed by only 0.02, i.e. much below the error estimate. The values for B, V obtained quasi–simultaneously at JD 63 are very close, similar to the results of the *UBVRI* photometry by Efimov et al. (1995).

The periodograms often show a few peaks of comparable height, arguing for a set of preferred time-scales, rather than a secular decrease like the change from 27 m in 1962 to 17 m in 1985 suggested by Semeniuk et al. (1987). Characteristics of the highest peaks for 45 runs obtained in 1988 are presented by Tremko et al. (1994). Our present results support their suggestion that, in TT Ari, we observe contributions from several instability mechanisms with similar time-scales. It will be very fruitful to obtain spectra with time resolution sufficient to study 20–m variability and to locate the source of its origin.

On 1994 October 7, observations with 1–s resolution were carried out at the 80 cm telescope of the Odessa State University. The best fit cycle length was equal to 15.80 ± 0.14 m with the extremely low 'false alarm probability' 10^{-241}. Such low false alarm probabilities are an indication that that the noise might be dominated by red power-law shot-noise rather than white noise. For a discussion of red noise modeling, see van der Klis (1989). The apparently low value $\gamma = 1.32$ listed in Table 1 is due to lower signal-to-noise ratio for shorter exposures. Reduced to a standard 20–s resolution we find a corresponding $\gamma = 1.85 \pm 0.16$, which is very consistent within error estimates with the values obtained on the days before and after.

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