T CEP, U UMI, Z SCO – MIRA-TYPE VARIABLES WITH CYCLIC PERIOD CHANGES

V.I. Marsakova

Department of Astronomy, Odessa National University
Shevchenko Park, 65014, Odessa, Ukraine
vmarsakova@mail.ru

ABSTRACT. Period and amplitude changes of three Mira-type variables have been analyzed. Characteristics of long-term cyclicity were obtained.

Key words: Stars: LPVs, Mira-type, period changes, individual: T Cep, U UMi, Z Sco.

Introduction. Many Mira-type variables show period changes. They may be small cycle-to-cycle scatter or significant secular or irregular variations. Zijlstra & Bedding (2002) mark out continuously changing periods; sudden changes and meandering Miras (their periods change form one value to another and then backwards). Some representatives of the last group have smooth nearby cyclic variations with cycle length about 20000 days. Three of them are discussed in this paper. They listed in the table 1 with range of period changes (obtained be individual cycle length) and spectral classes. Some results concerning T Cep was presented in Marsakova & Andronov (2000).

Table 1

Variable	P, days	Sp. class (Samus at al., 2012)
T Cep	381-410	M5.5e-M8.8e
U UMi	300-350	M6e-M8e
Z Sco	315-380	M5.5e:-M7e

Analysis. We have analyzed light curves of these stars obtained by amateur astronomers from the AFOEV and AAVSO databases of visual observations. Our analysis process was discribed by Andronov & Marsakova (2006). “Running parabola” Andronov (1997) fit has been used to determine parameters of the extrema. Some details of methods have been discussed by Andronov (2005). For each extremum, the following parameters were obtained: the deviation of the moment of extremum from a linear ephemeris *O-C*, amplitudes and mean brightness for both (ascending and descending) branches, individual cycle length using successive maxima and (alternatively) minima. The range of period changes (noted in Table 1) was obtained using successive maxima. The minima show bigger range of changes and sometimes bigger amplitude at the O-C diagrams (Fig 2, 5, 6). Variations of the parameters are shown in Fig 2-4 for T Cep, as the example. Variation of amplitude and mean brightness of U UMi and Z Sco are similar, but with smaller quantity of data points (the periods are close to 1 year, so the same parts of light curves are poorly observed). Mean light curves of T Cep for three seasons are shown in Fig 1. They have been obtained using a trigonometric polynomial fit. Characteristics of these approximations are listed in Table 2.

Than we have applied the periodogram analysis of *O-C* (for maxima and minima), individual amplitudes and mean brightness, taking into account the linear trend using program MCV (Andronov & Baklanov (2004)). Most statistically significant periods, which correspond to highest peaks, are listed in Table 3. The peaks are listed, if the corresponding values of the test-function exceed a limiting value of 0.1. Corresponding periodograms are shown at the Figures 7-9.

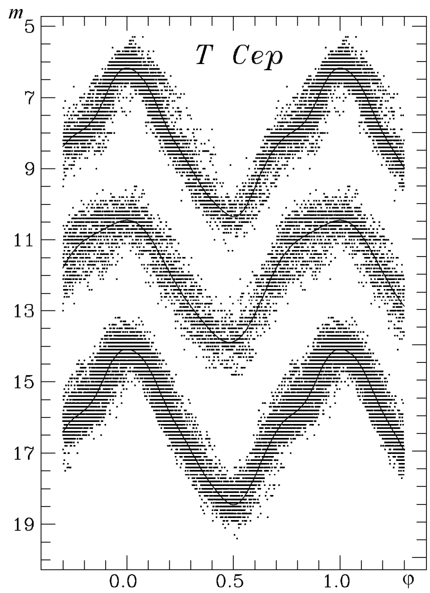

Fig.1. Phase light curves of T Cep during 3 seasons and statistically optimal trigonometric polynomial fits.

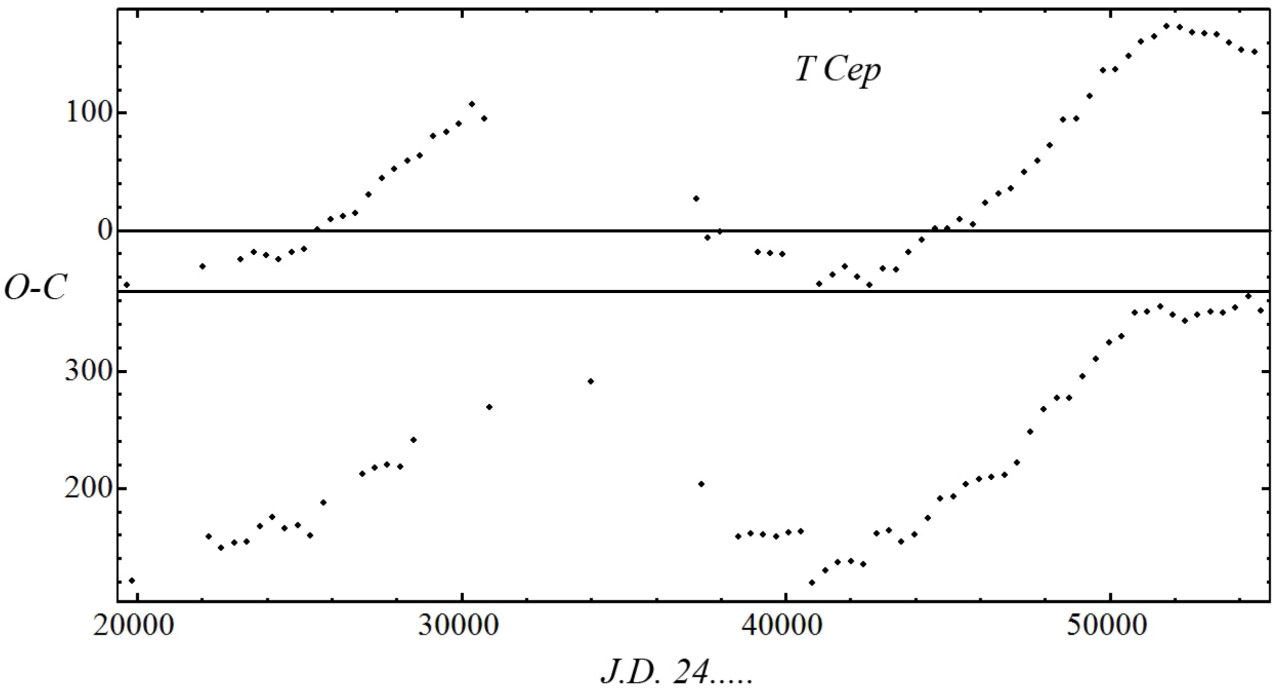

Fig. 2. O-C curves for T Cep. Top curve is O-C obtained for maxima, bottom one is O-C obtained for minima.

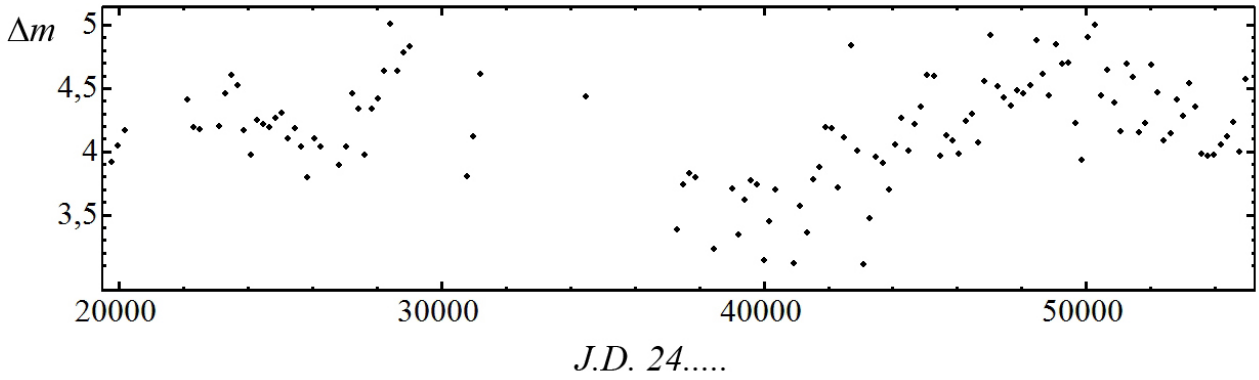

Fig. 3. Amplitude variations for T Cep.

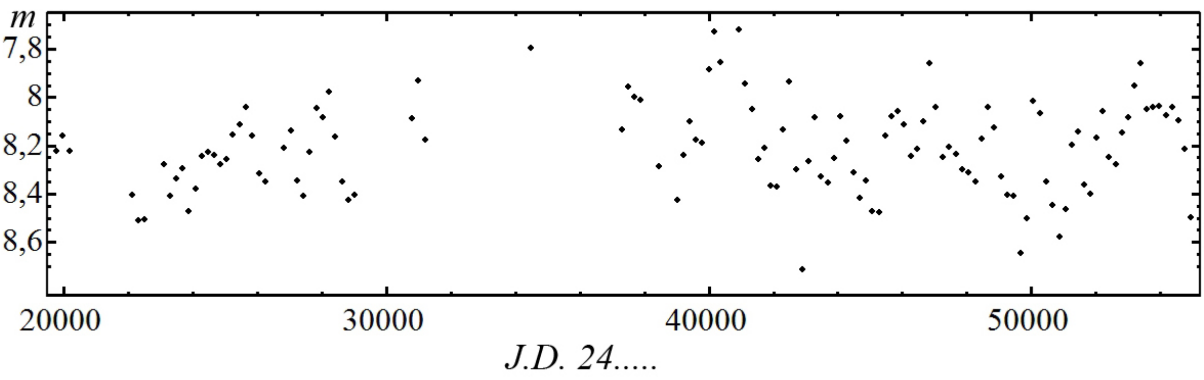

Fig. 4. Mean brightness variations for T Cep.

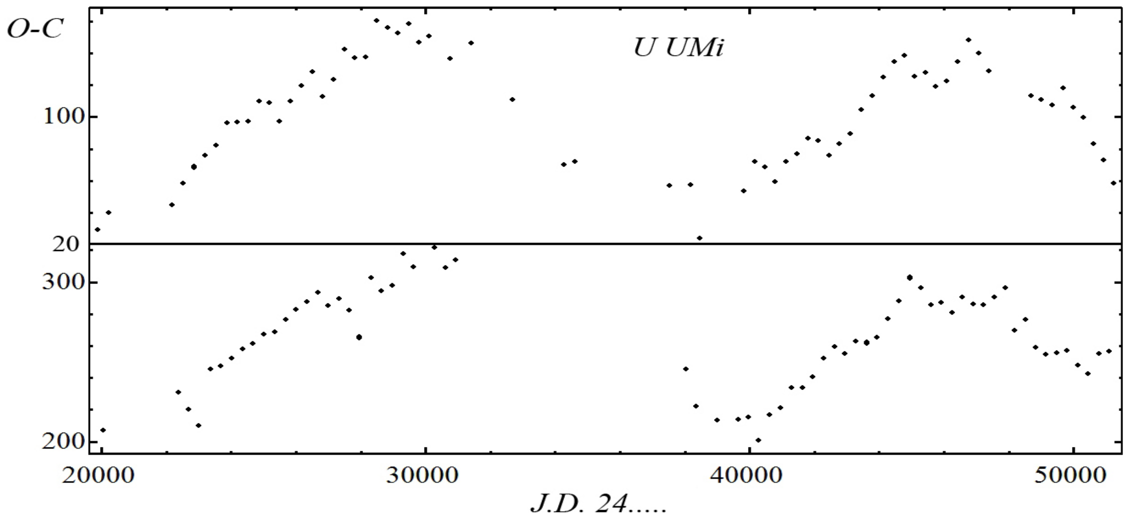

Fig. 5. O-C curves for U UMi. Top curve is O-C obtained for maxima, the bottom one is O-C obtained for minima.

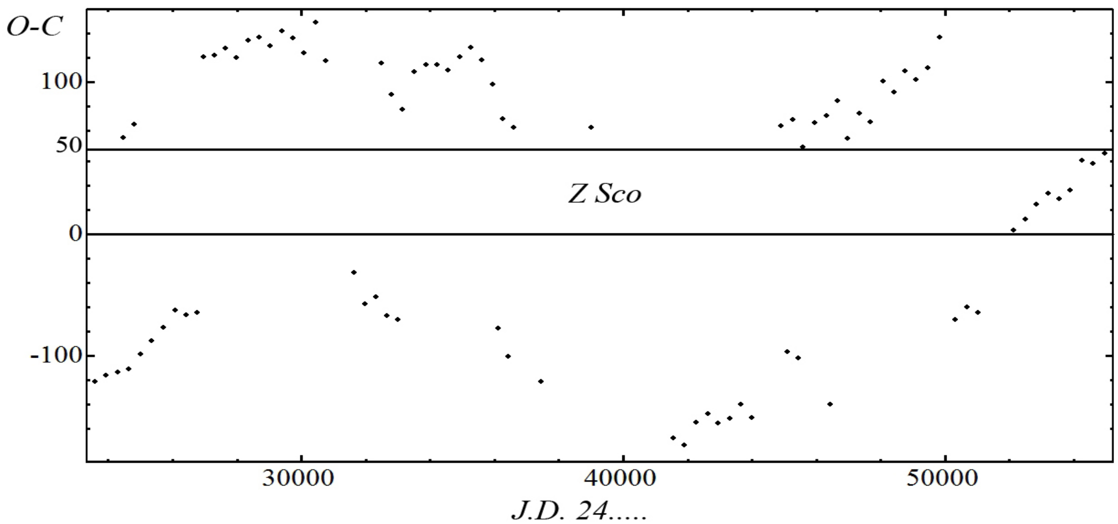

Fig. 6. O-C curves for Z Sco. Top curve is O-C obtained for maxima, the bottom one is O-C obtained for minima.

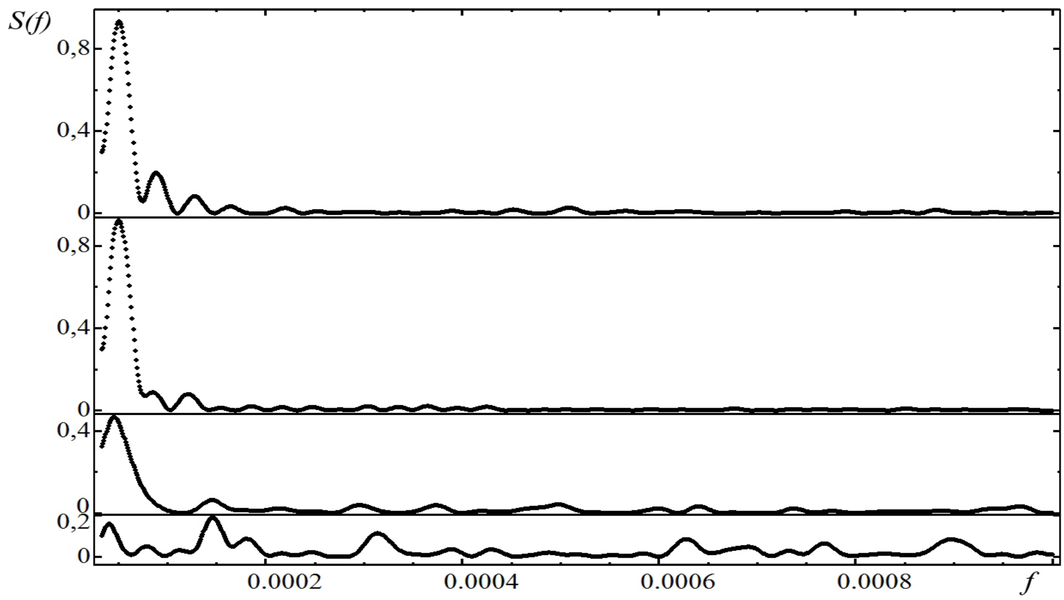

Fig. 7. Periodograms for T Cep. Top curve correspond to O-C obtained for maxima, next one correspond to O-C obtained for minima, next one correspond to amplitude variations and the bottom one corresponds to mean brightness variations.

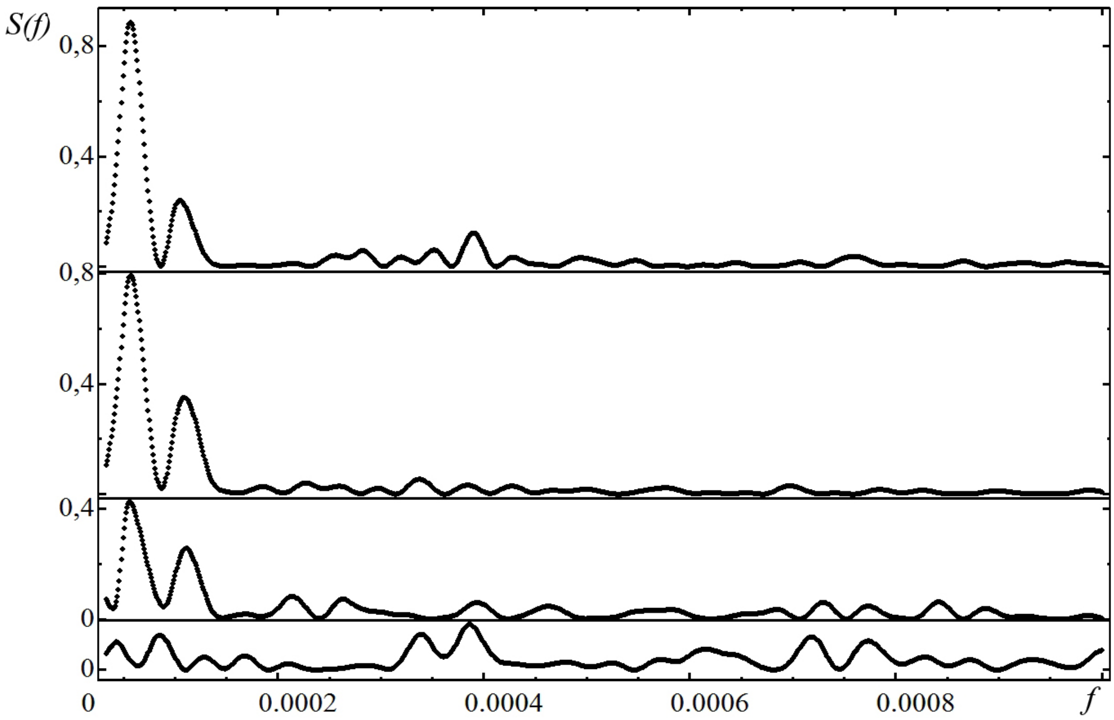

Fig. 8. Periodograms for U UMi (see explanation to Fig 7 for details).

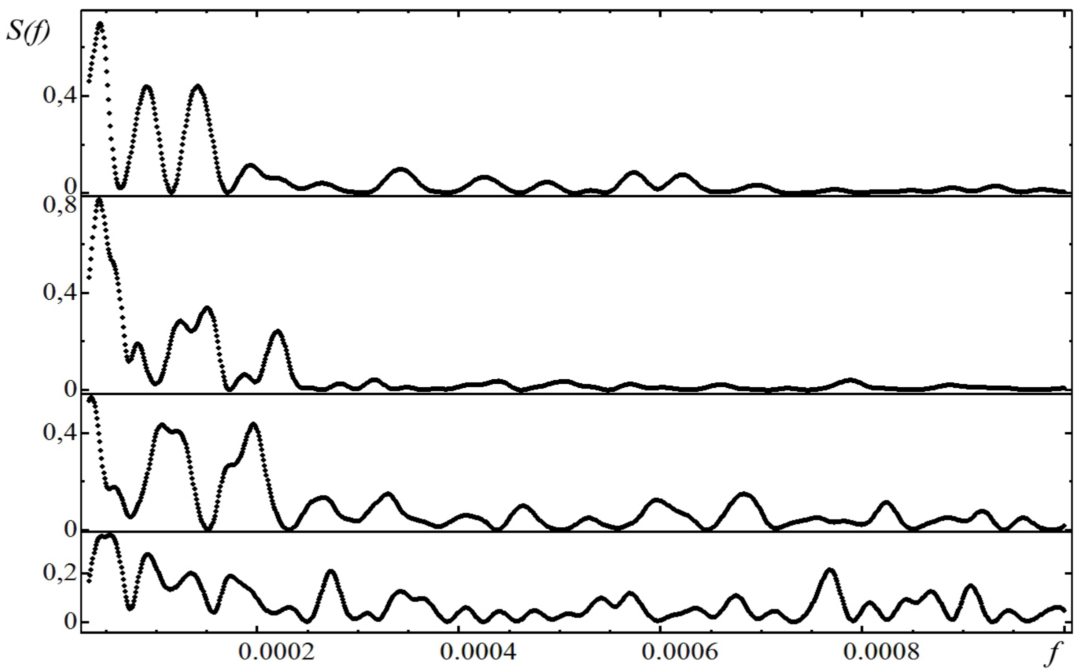

Fig. 9. Periodograms for Z Sco (see explanation to Fig 7 for details).

Table 2

Interval J.D. 24….	Period	T_0	s	*As.*	*Am.*
23100-33430	394.98 ±0.03	26331 ±1	6	0.497 ±0.006	4.18 ±0.02
33430-41820	379.94 ±0.08	38368 ±3	4	0.519 ±0.004	3.44 ±0.03
41820-50600	398.68 ±0.02	47354 ±6	6	0.500 ±0.004	4.36 ±0.02

Here T_0 is the initial epoch, s is the degree of the statistically optimal trigonometric polynomial approximation, *As* is the asymmetry, *Am* is the amplitude of light curve.

Table 3

T Cep			
parameter	cyclicity		
	P_1	P_2	P_3
O-C (maxima)	19700	11300	
O-C (minima)	19700	11700	8250
amplitude	21800	6900	
Mean brightness	6900	24350	3200
U UMi			
parameter	cyclicity		
	P_1	P_2	P_3
O-C (maxima)	17700	9550	2550
O-C (minima)	17700	9200	
amplitude	17700	9050	
Mean brightness	2600	2950	11700
Z Sco			
parameter	cyclicity		
	P_1	P_2	P_3
O-C (maxima)	22750	7100	11050
O-C (minima)	22750	6600	8100
amplitude	28350	5100	9550
Mean brightness	18645, 21800	10950	1302

Results. As we can see from the O-C diagrams, the changes of period are not strongly cyclic. They are smooth transitions between extreme values, which are not very different. Maximal long-term cycle length is exhibited by Z Sco, the mean pulsational period of which is not the biggest among these variables. But as the period variations are not strongly periodical, and the observations cover only 2 long “periods”, so we can conclude that the long “periods” are close to each other. It looks like similar variations may be present in other Mira-type variables, such as W Lyr (Marsakova & Andronov (1997).

Periods of amplitude variations are close to the O-C periods, but oscillations with smaller characteristic time are also evident. In general, smaller period corresponds to smaller amplitude, but in Marsakova & Andronov (2000), where the cross-correlation analysis of individual cycles characteristics of T Cep were presented, it was mentioned that there is a shift for about 3 cycles between the variations of period and amplitude.

Some Mira-type variables have humps at the ascending branches of their light curves. Their general characteristics were discussed in Kudashkina & Rudnitskij (1995) and Marsakova & Andronov (2007). T Cep and U UMi also have humps. In the Fig. 1 one may see that in season with smaller period, the hump transforms into a double-peak maximum (at individual curves) or flat (at the mean phase curve) maximum. For U UMi, the variations of parameters of hump are not so clear and Z Sco has a not detectable hump at the ascending branch.

Some carbon Miras and semiregular variables have significant changes of the mean brightness (Marsakova, 1999; Marsakova & Andronov, 2006). Some of these changes are sudden or linear trends and some changes are approximately cyclic with a cyclicity from 1500 to 10000 days. Similar cyclicities one may see in the Table 3, they are often more appreciable than the period close to 20000 d. Some of these peaks are also visible (Fig. 7-8) at periodograms for amplitude variations.

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