CHARACTERISTICS OF THE PERIOD CHANGES IN MIRA-TYPE VARIABLES

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ABSTRACT. The period changes in a sample of Mira-type variables were analysed and classified. Characteristics of the long-term cyclicity in the period changes were obtained.

Key words: Stars: LPVs, Mira-type, period changes.

Introduction

The Mira Ceti stars are long-period variables whose light curves are not only distinguished by the periods of variability, but also exhibit significant cycle-to-cycle alterations as opposed to the corresponding light curves of classical pulsating stars (e.g., δ Cephei or RR Lyrae variables). The comprehensive survey of the properties of Mira variables and similar long-period variables was conducted by Kudashkina (2003). In particular, it was reported that many Mira-type variables exhibited changes in their periods. Zijlstra & Bedding (2002) defined continuously changing periods, sudden changes, and meandering Miras (whose periods change to some extent with time, followed by a return to the previous period). Our study resulted in more detailed classification of the period changes.

We used observation data taken from the French Association of Variable Star Observers (AFOEV), Variable Star Observers League of Japan (VSOLJ) and American Association of Variable Star Observers (AAVSO), which enabled us to study the target stars' variability over a period of about 100 years.

The methods and detailed procedures applied in our analysis are given in Andronov & Marsakova (2006). Some methods had been discussed earlier in other studies, in particular: "asymptotic parabolae" and "running parabolae" fittings were applied for determination of the characteristics of extrema (Andronov, 1997; Marsakova & Andronov, 1996); trigonometric polynomial was employed to obtain parameters of the mean light curves (Kudashkina & Andronov, 1996); the light curves were subjected to wavelet analysis and running sine approximation to study the period and amplitude stability (Andronov, 2003; Chinarova, 2010; Andronov & Chinarova, 2013).

To obtain variations in individual cycle parameters with time, in this research we have analysed a sample of 56 variables classified as either the Mira type or intermediate type which is between semi-regular (SRa) and Mira classes. We examined variations in such parameters as periods, amplitudes, the light curve asymmetry, the mean luminosity (averaged over individual pulsation cycles), parameters of humps on the ascending branches, etc. as described in Andronov & Marsakova (2006). To analyse and classify the period changes, we used the O-C curves obtained using moments of maxima. The individual cycle characteristics for the majority of target stars are listed in catalogues (Marsakova & Andronov, 1998; Marsakova & Andronov, 2000c).

The research results allow us to define the following types of period changes:

1. Small irregular period changes. Small and moderate amplitudes of the O-C curve can be seen in Fig. 1.

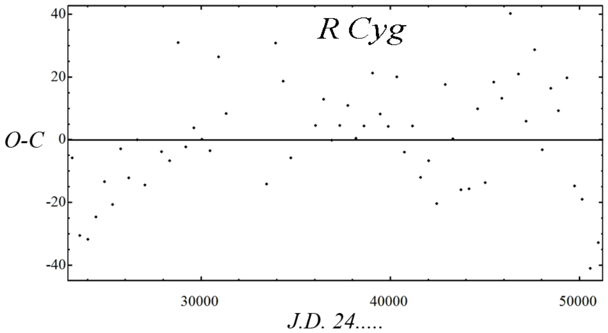

Figure 1: The R Cyg O-C curve (small irregular period changes)

2. Switchover between similar period lengths producing the saw-tooth O-C curve. Many Mira variables show such period changes all the time or just over certain time intervals. Such evolution is cyclic rather than strongly periodic. The corresponding O-C curve is shown in Fig. 2. Characteristics of these period changes (including mean pulsation periods, as well as the O-C variation periods and amplitudes) are given in Table 1. Accounting for the findings of the study by Marsakova & Andronov (2007), it can be noted that there are no humps on the ascending branches of the light curves of the indicated variable stars; and the proportion of pulsation cycles with short increments on the ascending branches are rather small.

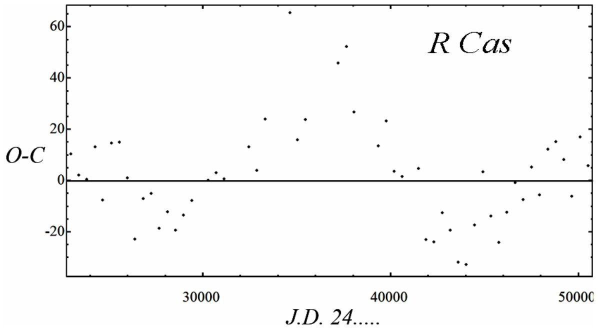

Figure 2: The R Cas saw-tooth O-C curve

Table 1: The period changes' characteristics for the variables with the most distinct saw-tooth O-C curves.

Variable	Pulsation period	Periods of the O-C variation	Amplitude of the O-C main wave
X Aur	164	20520±400	32±2
T Her	165	9000±200	10±1
RS Her	219	12600±260	17±1
R Boo	224	11340±195	11±1
R Dra	246	12500±260	11±1
X Oph	332	16000±500	24±3
χ Cyg	409	15400±350	15±2
R Cas	430	16600±300	20±2

3. Smooth cyclic period changes on the timescale of ~17000–22000 days.

These changes were discussed in Marsakova & Andronov (2013) by the example of three Mira variables. The most evident smooth cyclic changes in period were reported in T Cephei (also see Marsakova & Andronov, 2000b). Alternative example is shown in Fig. 3. These period changes are similar to those described in the previous paragraph, but generally they have comparatively longer mean cycle length and higher amplitude of the O-C variations (see Table 2). Moreover, for some variables there are noticeable humps on the light curve ascending branches, which can transform to double-peak maxima over the period evolution course (Marsakova & Andronov, 2013).

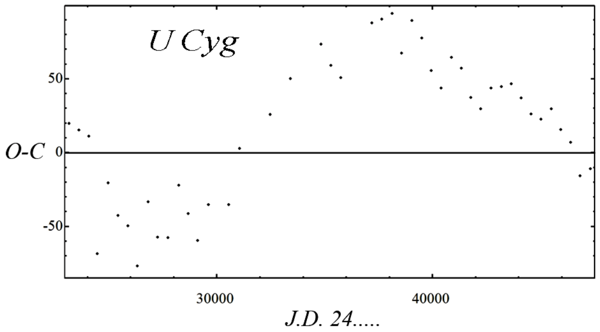

Figure 3: The U Cyg smooth cyclic O-C curve

Table 2: The period changes' characteristics for the variables with the most distinct smooth cyclic changes.

Variable	Pulsation period	Period of the O-C variation	Amplitude of the O-C main wave	Presence of humps on the ascending branch
W Lyr	197	23900±1400	25±3	
V Cas	229	22600±230	52±1	
R UMA	302	23000±540	25±1	
S UMi	328	14600±440 20600±500	29±3 26±2	+
U UMi	331	17600±200	50±2	+
Z Sco	348	22500±700	48±5	
T Cam	374	22500±550	52±4	+
T Cep	388	19000±180	82±2	+
T Cas	445	18700±600	25±3	+
U Cyg	466	23200±800	60±4	

General characteristics of humps on the ascending branches were discussed in Kudashkina & Rudnitskij (1995) and Marsakova & Andronov (2007). The results of the cross-correlation analysis of variations of the T Cep light curve parameters were presented in Marsakova & Andronov (2000b). It was reported that the light curve amplitude and period are strongly correlated while their variations are shifted by 3 cycles; moreover, the amplitude and hump magnitude variations are synchronous.

In Tables 2 and 3, the variables are listed in increasing order of the main pulsation period, but it is clear that the O-C wave cyclicity does no depend on the main period of pulsation.

However, as is obvious, these period changes are not strongly periodic either, and the cyclicity may be disrupted with time.

4. Progressive period changes (continuous ones of the same sign) were found in R Aql, R Hya, W Dra and T UMi (Marsakova & Andronov, 2000a; Marsakova & Andronov, 2006). Such period changes are illustrated with the R Aql O-C curve in Fig. 4. R Aql and R Hya exhibit constantly decreasing periods while W Dra shows slowly increasing period. T UMi has been undergoing abrupt decrease in period since about J.D. 2443000. There are different types of the period changes according to the classification by Zijlstra & Bedding (2002); meanwhile, Wood & Zarro (1981) introduced a helium - shell flash model that explains all such period changes at various stellar core masses and helium - shell flash phases.

It is remarkable that residuals from parabolic approximation of the R Aql O-C curve (the so-called O-C curve of the second order) produce a saw-tooth curve with the period of 18500±260 days (Fig. 5).

Slow decrease in the period was expected by the O-C curve in Y Per, but there is also some influence of the multi-periodicity.

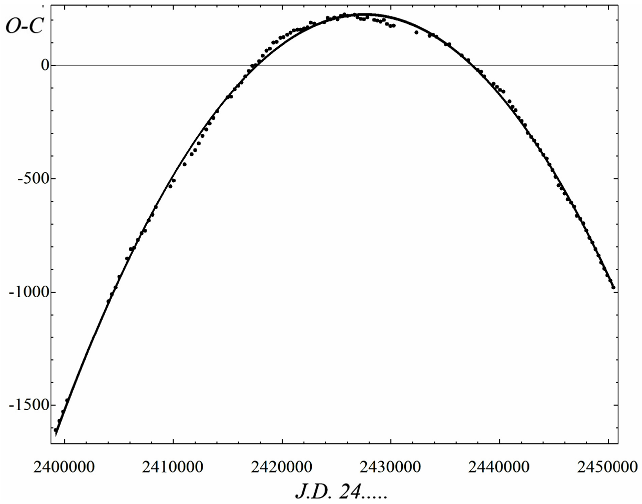

Figure 4: The R Aql O-C curve and its parabolic approximation
(O-C = –13568300 + 11.1786·t – 0.00000230241·t2, where t is measured in J.D.)

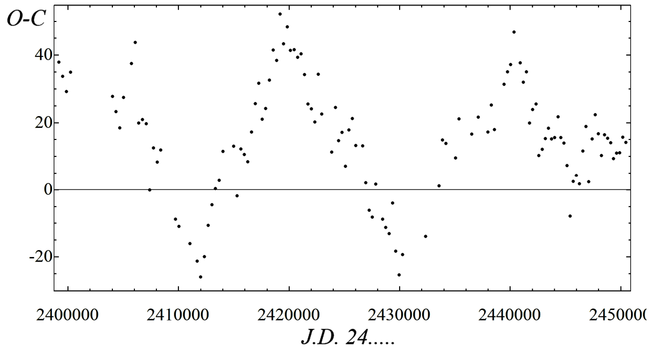

Figure 5: The residuals from parabolic approximation of the R Aql O-C curve (the so-called O-C curve of the second order)

5. Effects of multi-periodicity were discussed in Marsakova (2012), Marsakova & Andronov (2013) and Chinarova (2010). Such influence results in noisy O-C curves and significant decrease in the pulsation amplitude in some time intervals. To detect these effects, it is necessary to carry out thorough analysis of the light curves using various mathematical methods.

Conclusions

Among our sample 56 variable stars 16 variables exhibit small irregular period changes; smooth cyclic period changes are shown in 14 variables; and 11 variables produce saw-tooth O-C curves. There are also 4 variables with progressive period changes and 6 variables subjected to the multi-periodicity effects. We did not succeed in classifying period changes in 5 variables due to poor observation data.

Two critical aspects should be emphasised. Firstly, the effects of multi-periodicity may superimpose on period changes of one of the types (namely, saw-tooth, cyclic or even progressive ones as in Y Per) causing some distortion. Secondly, for the data acquired at the moments of maxima over a very long time interval (as it was made, for instance, by SVO; http://var.astronet.se/mirainfooc.php), it is evident that the O-C curve type may alter with time (but in this case we employed data obtained by different techniques). Thus, the suggested classification is applied to effects rather than variable stars.

The present study is a part of two projects, namely “Inter-Longitude Astronomy” (Andronov et al., 2010) and “Ukrainian Virtual Observatory” (Vavilova et al., 2012).

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