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PROCESSING OF AMATEUR OBSERVATIONS OF MIRA-TYPE STARS FROM LARGE DATABASES: PROBLEMS AND RESULTS

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Abstract. The problems of finding light curve characteristics of long-period variables (LPVs) and methods of light curve fit are discussed. A new "asymptotic parabolae" method is proposed for this task. The catalogue of individual cycle characteristics of LPVs is compiled. The results concerning long-term variability of these stars and their classification are listed.

Key words: methods: data analysis – stars: Mira variables

1. INTRODUCTION

LPVs are pulsating stars characterized by significant changes of their light curves from one pulsating cycle to another. The search for long-term changes of period and light curves of the LPVs may lead to important information on their pulsation and evolution and to new criteria for their classification. To study cycle-to-cycle changes in the Mira variables, the dense series of data obtained during long time intervals (about several dozens or hundreds of periods) are needed. The periods of these stars are from one hundred to several hundred days, so it is impossible to study the long-time behavior of the light curves using data of the same instrument or observer. One of the ways of solving this problem is the usage of amateur observations from large international databases.

2. DATA AND METHODS OF THEIR PROCESSING

We use the AFOEV and VSOLJ databases for this research. But there are some problems concerning the data from these databases:

(1) large scatter of the data caused by different systems of many observers,

(2) gaps in the data, which appear when the pulsation period is close to one year,

(3) lack of data (this problem appears at JD 24300000–2440000 and in some cases in more early interval of time).

A number of methods for data fitting were applied and compared. As a result, two methods were chosen: the "asymptotic parabola" (AP) and "running parabola" (RP) fits. These methods were developed by the authors, and they show minimum errors in the determination of moments and magnitudes of extrema. The descriptions of these methods are given by Marsakova & Andronov (1996) and Andronov (1997). The comparison of errors of individual extremum parameters obtained by using different methods (including AP and RP fits) is given by Marsakova & Andronov (1996).

The AP fit has a fixed shape (parabola with linear asymptotic branches) and needs at least five points for an approximation. So the AP fit allows to determine the characteristics of extrema using a relatively small number of points and, in some cases, allows to decrease the effect of season gaps. But it needs a previously chosen interval of data near the extremum for approximation. The RP fit is more sensitive to instabilities of the light curve which often appear in the Mira variables. Table 1 lists the mean errors (for one typical Mira-type star, W Lyr) of extrema obtained by using AP and RP fits. They have been calculated by the following formula:

$$\overline{\sigma} = \sqrt{n/\sum_{i=1}^{n}(1/\sigma_i^2)},$$

where n is the number of extrema. Thus the AP fit shows smaller errors in moments of extrema but larger errors of magnitude. Larger error of moments of extrema in the RP fit may be connected with the sensitivity of this method to small irregularities at the branches of the light curves.

Thus, the AP method was applied for the majority of the stars. However, in cases of strong irregularities or of a hump on the ascending branch, the RP method was applied.

We have obtained the following characteristics of each individual cycle: moments and magnitudes of extrema and hump at the ascending branch, amplitude, asymmetry, slopes of the ascending and descending branches, mean brightness of the branches. Analyses of variations of these characteristics with time and correlation analysis of them have been made. This algorithm is described by Andronov & Marsakova (1998). We also applied the periodogram, Fourier and wavelet analysis to study the periodicities and their stabilities.

Table 1. Mean error estimates of moments ($\overline{\sigma_t}$) and magnitudes ($\overline{\sigma_m}$) of extrema in the AP and RP fits for W Lyr. n is the number of extrema.

	RP			AP		
	n	$\overline{\sigma_t}$ (d)	$\overline{\sigma_m}$ (mag)	n	$\overline{\sigma_t}$, d	$\overline{\sigma_m}$ (mag)
Max	83	2.09	0.038	83	0.30	0.063
Min	70	2.07	0.075	67	0.16	0.142

3. RESULTS

Our research allowed to obtain the catalogue of the individual cycle characteristics of 53 long-period variables (the first part of the catalogue is published by Marsakova & Andronov 1999) and the correlations between these characteristics have been calculated.

Several groups of Miras with typical light curve variations were identified and their characteristic long-term behavior thoroughly analyzed:

(1) in the stars with progressive period changes (R Aql, R Hya, W Dra, T UMi) the two types of light curve transformation were pointed out: amplitude changes and changes of the curve form and sharpness of the extrema (Marsakova 2000);

(2) the cyclic secondary variations of the period, amplitude and other characteristics in some stars (especially T Cep and U UMi) are interrelated (Marsakova & Andronov 2000);

(3) Light curve changes of C- and S-Miras are characterized by significant variations of the mean brightness, correlations between magnitudes for different points of the curve and some other properties;

(4) In some Miras and SRa variables (10 stars were studied) Mira-type and semiregular variability exchange each other in different time intervals. Many of these stars show the light curve variations which are close to those detected in C-Miras (mean brightness variations, small amplitudes of Mira-like variability (less than 2 mag) and keep the constant mean period during the observing interval. In some stars different amplitude variations were found.

Also we have found seven stars with amplitude changes (the amplitude decreases only in two stars – the semiregular variables V Boo and RU Cyg); a decrease of the mean brightness was found in three stars (R LMi, R Dra, V CrB).

Some correlations were found between the cycle-to-cycle parameters, such as period-amplitude correlations, correlations between magnitudes at different points of the light curve, etc. These correlations are different for different stars.

We have also analyzed the relations between the numerical characteristics of cycle-to-cycle changes, the parameters of the mean light curves and the spectral class. We have obtained a sequence of diagrams such as spectral class – arbitrary amplitude scatter, spectral class – arbitrary mean brightness scatter, arbitrary period scatter – arbitrary amplitude scatter, etc. These diagrams allow to introduce new criteria of the classification of LPVs into Miras and semiregular variables.

Using these diagrams and the character of amplitude, period and mean brightness variations, we propose the additions to the classification of these 53 LPVs. We join to one class of periodic carbon LPVs the Miras and semiregular variables of spectral class C. Only four stars were classified as semiregular and two stars as the transient ones between Miras and semiregular variables (Y Per and S Aql). Also two stars were called "the small amplitude Miras", because they show the typical variability for Miras, but with mean amplitudes less than 2 mag (X Oph, T Ari). So the long-term light curve changes may serve as an additional criterion of classification of LPVs.

Some papers are available at http://ila.webjump.com

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