SOME GROUPS OF THE REGULARITIES IN THE CYCLE–TO–CYCLE CHANGES IN THE MIRA–LIKE VARIABLES

V. I. Marsakova, I. L. Andronov

Odesa National University, Department of Astronomy
T. G. Shevchenko Park, 65014 Odesa, Ukraine
e-mail: vlada@mail.od.ua, il-a@mail.ru

The analysis of different light curve variations based on the characteristics of large number of individual pulsational cycles of 53 LPVs was done. Six groups of regularities are described: 1) cyclic period and amplitude variations; 2) variations of light curves (period, amplitude and slopes) of stars at the stage of helium-shell flash; 3) variations of light curves of stars of C and S spectral classes (main result is the mean brightness variations); 4) various behaviour of objects which are transient between Miras and semiregular variables; 5) secular increase or decrease of amplitude; 6) variations of the hump at ascending branch.

DATA PROCESSING

Long period variables (LPVs) are the pulsating stars which characterized by significant changes of the light curves from one pulsating cycle to another. The research of long-term changes of period and light curves of the LPVs leads to the important information on their pulsation and evolution and can give new criteria of their classification. In our research, the characteristics of large quantity of individual pulsational cycles were obtained for 53 LPVs and the analysis of different light curve variations was done.

To study cycle-to-cycle changes in the Mira variables, the dense series of data during long time interval (about several dozens or hundreds of periods) are necessary. To study changes from one cycle to another in Mira variables and some Mira-like semiregular variables we used the data in the long interval of time (80 years) from the AFOEV and VSOLJ databases.

The "asymptotic parabola" (Marsakova & Andronov, 1996) and "running parabola" and (Andronov, 1990; Andronov, 1997) fits were applied to determine the characteristics of extrema. Thus, the "asymptotic parabola" method was applied for majority of the stars, but the "running parabola" method was applied in a case of strong irregularities or hump at the ascending branch.

We have obtained the following characteristics of individual cycles: moments and magnitudes of extrema, and differences between them – individual periods, amplitudes, *etc.* The asymmetry, magnitude of the hump on ascending branch, slopes of the ascending and descending branch, mean brightness of the branches were also calculated. Analysis of variations of these characteristics with time and correlation analysis of them have been done. Analysis is analogous to one described by (Andronov & Marsakova, 1996).

RESULTS

As the result of our research, several groups of the typical light curve variations of 53 LPVs were distinguished and their characteristic long-term behaviour is thoroughly analyzed:

1) Cyclic secondary variations of the period, amplitude and other characteristics.

Variations of a period and amplitude, which are cyclic ones in the observational interval were found in some stars. But there are some difficulties: characteristic times of this cyclisity is of about 15000–23000 days, so we can't study more than 2–3 long cycles. In the T Cep star these variations of period, amplitude and characteristics of the hump in ascending branch were the most prominent ones. The cross-correlation analysis for these characteristics was done. Correlation coefficient between period and amplitude changes is equal to 0.93 and shift is equal to 3 pulsational cycles. Correlation coefficient between changes of amplitude and magnitude of hump is equal to 0.85 without shift (Marsakova & Andronov, 2000).

2) Stars with progressive period changes

Two types of light curve transformation were pointed out (Marsakova, 2000): in R Aql and R Hya a period decrease is followed by very strong amplitude decreasing, in T UMi a fast period decreasing is followed by significant changes of curve sharpness. It is suggested (Wood & Zarro, 1980; Gal & Szatmary, 1995) that T UMi is in the beginning of helium shall flash, but R Aql and R Hya are in the more later stages of it.

3) Light curve changes of C- and S-Miras

As the result of our research (Marsakova & Andronov, 1999) we note the following:

— Strong chaotic cycle-to cycle changes of all parameters of the light curves;
— Absence of significant systematic changes of period or small abrupt changes of period ($< 0.5^P$) which is typical for other Miras;
— Absence of significant amplitude variations which leads to the following:

— Correlation between magnitude of different points of the curves (especially typical for C-stars).
— Light curves of C-stars are very noisy during one cycle;
— For the some stars a correlation between period and amplitude was obtained;

— A correlation between time between maxima and corresponding magnitude differences was obtained for the some stars;
— A correlations between period and magnitude in maximum was obtained for 5 from 10 S-stars;
— Strong variations of mean brightness:

— cyclic: S Cep, U Cyg, V CrB, probably some other stars,
— decreasing: V CrB, W Cas and probably T Cam, S Cas and V Cnc.
Cyclic variations are more clear in C-stars. Trends appear in both groups (C and S) of stars and they also are observed in two stars of M-type: R LMi, R Dra.

— There are some moments in some stars when the photometric behaviour changes abruptly. Y Per: at J.D. 2447700 the variability changes from the Mira to the semiregular with double maxima but with keeping the value of the mean period. S UMa: abrupt change of O-C behaviour was appeared near J.D. 2430000 (change of the mean period and its stability) and, simultaneously, the double maxima in the light curve was appeared.
— Low amplitudes of C-Miras and high amplitudes of S-Miras are the well known facts;

Characteristics times of mean brightness changes are close to ones obtained in models (Winters *et al.*, 1994) taking into account the influence of dust-shell on light curves of LPVs.

4) Mira-like SRa variables

There are some variables (10 stars were studied, 9 SRa and Mira Y Per – classification of GCVS (Kholopov *et al.*, 1985)) which are transient between Miras and SRa. They have relatively small amplitudes and their amplitudes are significantly being changed with time. Most of these stars show the light curve variations which are close to ones detected in C-Miras (mean brightness variations, small amplitudes of Mira-like variability less than 2^m) and keep the constant mean period during the observed interval. So, Miras and some SRa variables of the C spectral type may be distinguished in one close group. There are semiregular variables in this group which are different from Miras only by small (about 2^m) amplitudes. And there is a subgroup of stars for which Mira-type and semiregular variability changes in the different time intervals (Y Per also belongs to this group).

5) Stars with secular amplitude changes

Also we have found 7 stars with amplitude increasing or decreasing (except the stars with progressive period changes). Among them are only 2 stars with amplitude decreasing, they are sure classified as semiregular variables: V Boo and RU Cyg. The SS Vir star was classified as semiregular in GCVS, but amplitude of its pulsation had to be increased with time and become more than 2^m in recent time, so this star can be reclassified into Miras.

6) Stars with humps at ascending branch

It was found that hump in some variables is more correlated with magnitude of minimum, but in other stars – of maximum. Correlations between mean hump duration and asymmetry of mean light curves as well as anticorrelation between mean hump duration and amplitude of mean light curves have been found.

Some regularities in the cycle-to-cycle variations were found such as follows:

- period-amplitude relations,
- correlation between period and difference in maximal magnitudes,
- correlation between magnitudes and various points of curve,
- correlation between slope of the descending branch and magnitude of minimum, *etc.*

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

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