STRONG CHANGES OF THE PHOTOMETRIC BEHAVIOUR OF CARBON MIRAS

V.I. Marsakova

Department of Astronomy Odessa State University,
T.G.Shevchenko Park, Odessa 65014 Ukraine
e-mail: astro@paco.odessa.ua

ABSTRACT. Analysis of variations of the light curves parameters of 16 Miras of spectral classes C and S has been made. A number of the peculiarities of these variations has been found. One of the most interesting results is the detection of the mean brightness variations: they are cyclic (with a superperiod of about $10 \cdot P_0$ and not stable cycle length) or secularly decreasing.

Key words: Stars: pulsating variables: Mira stars: carbon stars: light curves; stars: individual: R And, T Cam, V Cnc, S Cas, W Cas, S Cep, V CrB, χ Cyg, R Cyg, U Cyg, T Gem. R Lep, R Lyn, Y Per, S UMa.

1. Introduction

Strong irregularities in the photometric behaviour of carbon Miras were pointed out by many authors (e.g. Alksne et al., 1983)

Changes of the individual cycles characteristics (of carbon long-period variables) are also discussed by Mattei & Foster (1998), correlations between them and the characteristics of mean light curves (of long periodic stars) were studied by Harrington (1965) and Fruchter (1976).

The star S Cep was discussed separately (Marsakova, 1999) and it may be a prototype of the stars with strong quasiperiodic variations of the mean brightness. Isles & Saw (1989) noted the presence of correlation between the magnitudes of different points of cycle and variations of the mean brightness with a cycle length about 6000-9000 days. In the work by Marsakova (1999) was found the cyclicity of 1500-4000 days. But there are gaps in the middle of the observational interval and some cycles are lost. So the value 6000^d given by Isles & Saw (1989) may be an upper limit of the cycle length.

Changes of the mean brightness are probably a typical phenomena for C and S Miras and study of its variations character is an interesting problem.

Other problems related to the cycle-to-cycle changes of light curve parameters and correlations between them (typical for C and S stars) are discussed in this paper.

We have analyzed the variability of 16 Miras intensively observed by amateurs. There are 6 stars belonging to the spectral class C and 10 – to the spectral class S. Some of them belong to transitional types (MS, SC).

2. Methods of analysis

We have used the amateur observations from the AFOEV and VSOLJ databases (Schweitzer, 1998, Nogami, 1998) obtained during a 75-year interval to analyze the period changes and individual cycle characteristics variability of the stars.

The time series analysis was similar to that applied to U Her (Marsakova & Andronov, 1998a).

The mean phase light curves are fitted by using a trigonometrical polynomial fit. The statistically significant degree was determined by using the Fischer's criterion (Andronov, 1994).

Moments of extrema were determined by using a "running parabola" (RP) fit (Andronov, 1997), to avoid affect of humps on the shape of maxima.

Such values as the individual periods, amplitudes, mean brightness were calculated as two values in a cycle: periods are determined by using the moments of maxima and moments of minima, amplitudes of ascending and descending branches, mean brightness as the average between magnitude of maximum and magnitude of both (preceding and successive) minima.

To study long-term cyclicity of the variations of mean brightness, we have used the extension of the Morlet-type wavelet analysis for irregularly spaced data (Andronov, 1998).

To look for possible dependencies between characteristics of the individual cycles we have used the correlation analysis.

We take in consideration the correlations, for which the ratio of correlation coefficient (ρ) to its error estimate (σ_ρ) was more then 3.0. Here $\sigma_r^2 = (1-r^2)/(n-2)$ (e.g. Korn and Korn, 1961).

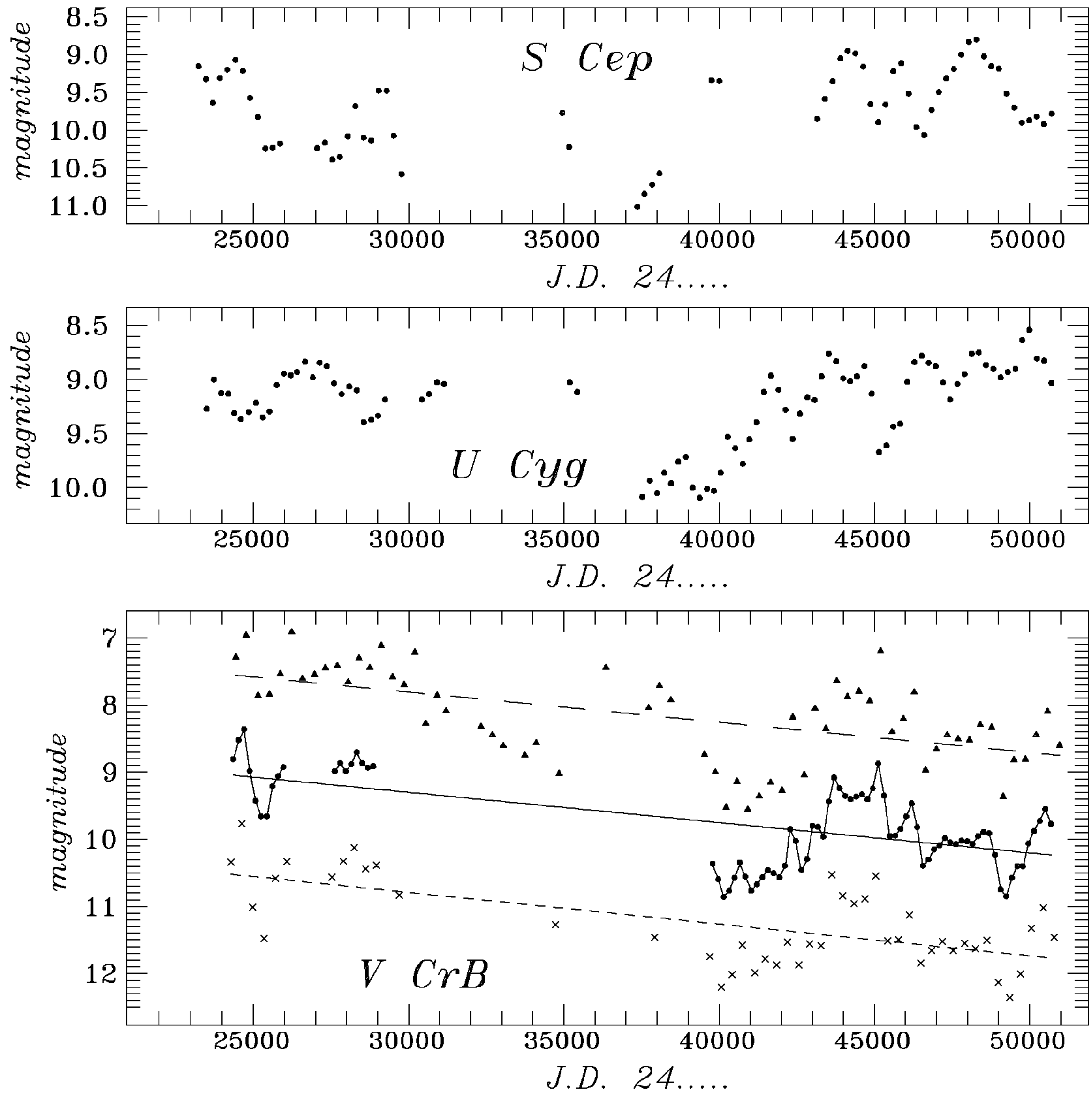

Fig. 1-4. Variations of mean brightness (points) or magnitude of maxima (triangles) and minima (crosses) for the some typical stars

3. Observational results

In the Table 1 the characteristics of 16 C and S Miras are listed. The periods and amplitudes are obtained by trigonometrical polynomial fits, spectral classes are listed according to GCVS (Kholopov et al., 1985). The types of variations of the mean brightness and some correlations obtained from our analysis and the quantities of the observed humps (relatively to the quantities of the observed maxima) are listed in the Table 2. The several periods correspond to the different peaks on the wavelet peiodogram. This swithing multiplicity appear because secondary cycles are unstable.

As the results of our research was found that photometric behaviour of C and S Miras (in the long time scale) show the following properties (in comparison with M-Miras (Marsakova & Andronov, 1997, 1998a):

- 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 ($< 0\stackrel{p}{.}5$) which is typical for other Miras (Marsakova & Andronov, 1997, 1998b);
- Absence of significant amplitude variations and that lead to:
- Correlation between magnitude of different points of the curves (especially typical for C-stars).

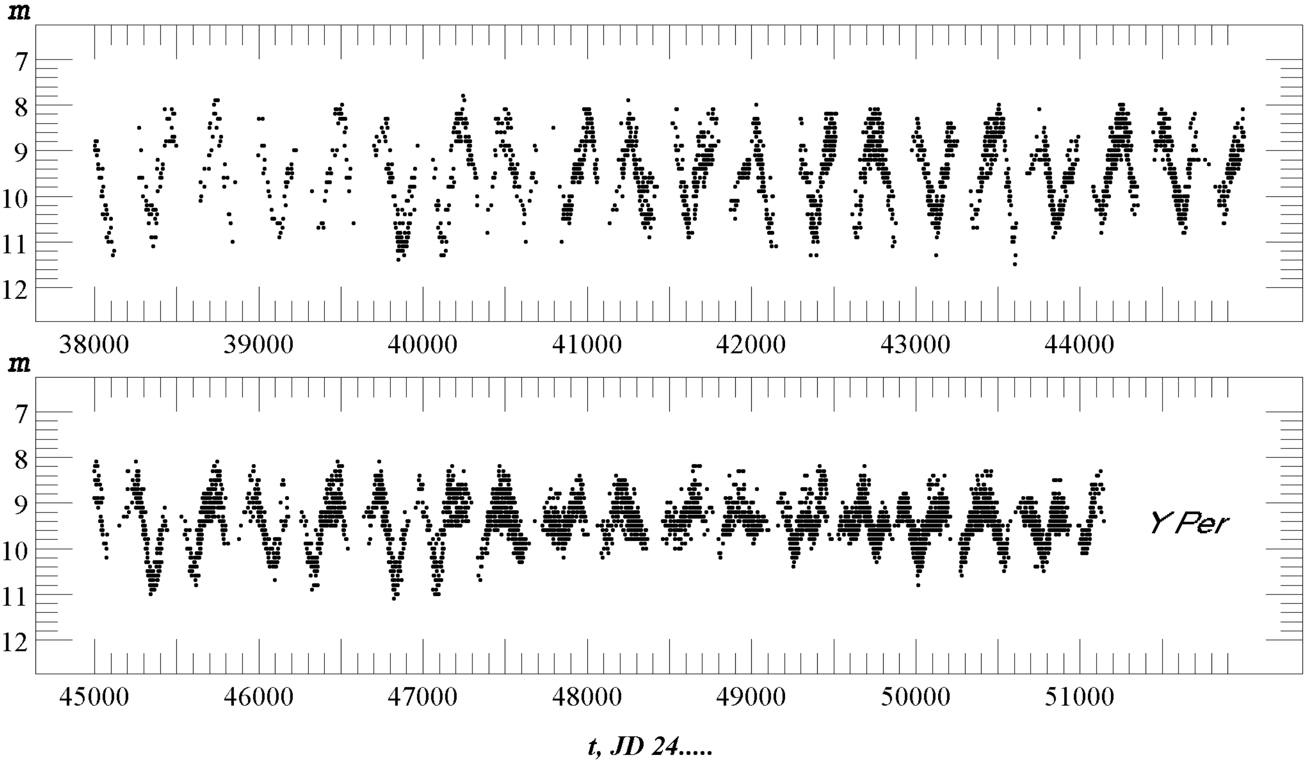

Fig. 5. Strong light curve changes in Y Per.

(*The parallel evolution* of magnitudes of maxima and minima in the Carbon LPVs was also found by (Mattei & Foster (1998));

- Light curves of C-stars are very noisy during one cycle;

- For the some (4) stars a correlation between period and amplitude was obtained ;

- For the some stars a correlation between time between maxima and corresponding magnitude differences was obtained (see discussion below);

- For 5 from 10 S-stars a correlations between period and magnitude in maximum was obtained;

- 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.

  (Mattei & Foster (1998) also pointed out that in their sample *about half of the stars are getting fainter, especially in maximum, none shows a brightening*);

- In some stars there are some moments 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 appeared near J.D. 2430000 (change of the mean period and its stability) and simultaneously double maxima in the light curve appeared.

- Low amplitudes of C-Miras and high amplitudes of S-Miras are a well known facts (Alksne et al., 1983);

The shape of light curve and quantities and strength of the humps at the ascending branch do not depend on the spectral type. Similar humps also appear in some M-type stars. Correlation analysis with the hump characteristics have not been applied for all stars: the noised light curves and superimposing of the humps and maxima significantly hindered from this analysis. So it was applied for the 5 stars in this sample only. R Lyn shows a correlation between the magnitudes of minima and hump, χ Cyg – between the magnitudes of minima and hump, and S Cep – both these correlations. In the some M-Miras also appear humps at the ascending branch, but this problem needs a separate discussion.

In the case of faint minima it is impossible to calculate sufficient number of values of the amplitudes and mean brightness. So in R Cyg small correlation bet-

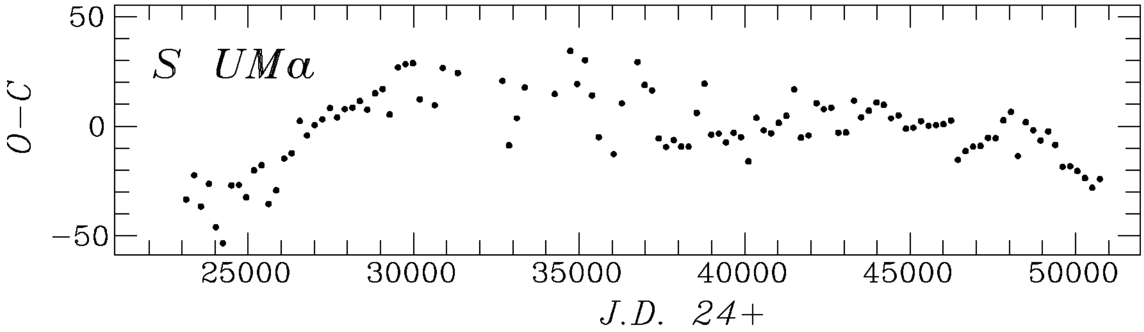

Fig. 6. O-C curve for S UMa.

Table 1. Mean light curve characteristics.

	Period	Amplitude	Asymmetry	Spectral Class	Relative quantity of humps
			C-Miras		
Y Per	248.60 ± 0.09	1.70 ± 0.05	0.40 ± 0.02	C4.3e	0.07
V CrB	358.08 ± 0.02	3.02 ± 0.03	0.39 ± 0.01	C6.2e	0.10
W Cas	405.42 ± 0.04	2.61 ± 0.02	0.490 ±0.006	C7e	0.30
R Lep	427.10 ± 0.09	1.44 ± 0.03	0.43 ± 0.02	C7e	0.19
U Cyg	465.56 ± 0.04	2.57 ± 0.02	0.48 ± 0.01	C7–C9	0.25
S Cep	487.35 ± 0.04	2.28 ± 0.02	0.552 ±0.005	C7.4e	0.57
			S-Miras		
S UMa	226.143±0.004	3.37 ± 0.01	0.506 ±0.005	S0e-S9e	0.70
V Cnc	272.100±0.008	4.85 ± 0.02	0.438 ±0.004	S0e-S7.9e	0.10
T Gem	287.21 ± 0.01	4.93 ± 0.05	0.505 ±0.007	S1.5e-S9.5e	0.36
T Cam	374.05 ± 0.01	4.51 ± 0.03	0.476 ±0.005	S4.7e-S8.5e C3.9E-C6.4E	0.68
R Lyn	378.61 ± 0.01	5.53 ± 0.03	0.441 ±0.004	S2.5e-S6.8e	0.33
W And	395.46 ± 0.01	7.61 ± 0.03	0.42 ± 0.01	S6.1e-S9.2e(M7e) M4-M10	0.25
χ Cyg	408.861± 0.008	7.75 ±0.008	0.447 ±0.004	S6.2e-S10.4e(MSe)	0.29
R And	410.28 ± 0.02	6.49 ± 0.04	0.482 ±0.001	S3.5e-S8.8e	0.06
R Cyg	428.15 ± 0.01	5.80 ± 0.03	0.421 ±0.004	S2.5e-S6.9e	0.07
S Cas	612.74 ± 0.06	4.84 ± 0.09	0.51 ±0.02	S3.4e-S5.8e	0.23

Table 2. Results of the light curves parameters variations and correlation analysis

	Variations of the meam brightness	Wavelet periods	Correlations coefficients between			
			magnitudes of maximum and minimum	amplitude and period	magnitude of maximum and period	magnitude and time differences between successive maxima
			C-Miras			
Y Per	?		–	–	–	–
V CrB	3000-8000, trend	1140, 7180, 9430	0.89	0.58	–	–
W Cas	trend max.		0.60	0.75	–	–
R Lep	?		0.90	–	–	–
U Cyg	2000-7000	1460, 4080, 4860	0.54	–	–	–
S Cep	1500-6000	1600, 4070, 7540	0.70	–	–	–
			S-Miras			
S UMa	–		–	0.50	–	–
V Cnc	trend min?		–	–	–	–
T Gem	?		0.89	–	–	–
T Cam	trend max.		0.64	–	–	–
R Lyn	?		–	–	–	0.57
W And	?		–	0.57	-0.64	–
χ Cyg	?		–	0.54	-0.55	–
R And	?		–	–	-0.47	0.65
R Cyg	–		–	0.69	-0.56	0.69
S Cas	trend		0.89	–	–	0.61

ween period and magnitude of maxima is present but there is not correlation between the period and amplitude. This mechanism may explain also a trend of maximum magnitude without trend of mean brightness.

4. Discussion

Miras and semiregular behaviour of Y Per also was discussed by Kiss & Szatmary (1999). They have pointed out that there is a similar star R Dor which in the GCVS was classified as a semiregular variable. But it has intervals of regular and semiregular pulsations likewise Y Per (Bedding et al., 1998). These authors suggest a mode switching for both these stars.

Harrington (1965) and Fruchter (1967) pointed out a correlation between time between maxima and corresponding magnitude differences $(m_i - m_{i-1})$ that appear in some LPVs. Harrington (1965) wrote that *"such an effect may be explained if we postulate that the light changes of these stars are associated with the outward propagation of disturbances taking more or less time to reach the surface depending upon the energy they carry"*.

In the our sample this correlation is present in four stars. Also in some stars an anticorrelation between $(m_i - m_{i-2})$ and time between two preceding maxima is present and in V CrB and V Cnc this correlation appears without the "usual" correlation between $(m_i - m_{i-1})$ and the time between *the same* maxima.

One of the most significant results concerns in the mean brightness variations. It is quite certain that many of carbon stars have dust envelopes (Wallerstein & Knapp G.R., 1998; Alksne et al., 1983 etc). So these cyclic variations of the mean brightness may be connected with irregularity in their density or opacity.

The secondary periods were found also by Fritzova et al. (1954) for Miras and long-periodic semiregular variables (2000-3000^d), by Wood (1999) for semiregular variables in the LMC (8-10 pulsating periods), Houk (1963), Alksnis et al. (1997) (Miras) etc. Rudnitskii et al. (1999) have found a superperiod of 15-16 yr. (13-15 pulsating periods) of H_2O maser emission of semiregular variable W Hya. Stothers & Leung (1971) have interpreted long secondary periods as the *convective turnover time giant convection cells in the stellar envelope.* One may suggest that similar maechanism is present in the majority of LPVs, but there are favourable conditions to see these secondary periods in carbon Miras and semiregular variables.

It is difficult to explain trends. As they are not followed by period trends so they cannot be an evolutionary effect. Probably they also connected with changes of the envelope properties.

Acknowledgements. Author is thankfull to I.L. Andronov and L.S. Kudashkina for helpfull discussions and to the members of AFOEV and VSOLJ for their visual observations.

References:

Alksne Z., Alksnis A., Dzervitis U.: 1983, *Properties of carbon stars of the Galaxy,* Riga, "Zinatne" Publishing House (in Russian).

Alksnis A., Larionov V.M., Larionova L.V.: 1997, *Baltic Astron.,* **6**, 377.

Andronov I.L.: 1994, *Odessa Astron. Publ.*, **7**, 49.

Andronov I.L.: 1997, *As. Ap. Suppl.*, **125**, 207.

Andronov I.L.: 1998, *Kinem. Fiz. Neb. Tel,* **14**, 490.

Bedding T.R., Zijistra A.A., Jones A., Foster G.: 1998, *Mon. Not. R. Astron. Soc.*, **301**, 1073.

Fritzová L., Pěkný L., Švestka Z.: 1954, *Bull. Astr. Inst. Czechosl.,* **5**, N 3, 49.

Fruchter C.A.: 1967, *Astron. J.,* **72**, 702.

Harrington J.P., 1965: *Astron. J.,* **70**, 569.

Isles J.E., Saw D.R.B.: 1989: *J. Brit. Astron. Assoc.,* **99**, 121.

Houk N.: 1963, *Astron J.,* **68**, 253.

Kiss L.L., Szatmary K. : 1999, *Proc. IAU Coll. 176 "The Impact of Large-Scale Surveys on Pulsating Star Research"*, in press.

Khopolov P.N. et al.: 1985, *General Catalogue of Variable Stars 4-th ed.*

Korn G.A., Korn T.M.: 1961, *Mathematical Handbook for Scientists and engneers,* McGraw-Hill Book Comp., New York, Toronto, London.

Marsakova V.I.: 1999, *J. AAVSO*, **27**, 141.

Marsakova V.I., Andronov I.L.: 1997, *Kinem. Phys. Cel. Bodies*, **13**, N 6, 49.

Marsakova V.I., Andronov I.L.: 1998a, *Ap. Space Sci.*, **257**, 49.

Marsakova V.I., Andronov I.L.: 1998, *Proc. 29th Conf. Variable Star Res.*, Brno, 130.

Mattei J.A., Foster G.: 1998, *Proc. of IAU Symp. 177, "Carbon star Phenomena", Kluwer Acad. Publ.*, in press.

Nogami D.: 1998, http://www.kusastro.kyoto-u.ac.jp

Rudnitskii G.M., Lekht E.E., Berulis I.I., 1999: *Astronomy Letters*, **25**, N 6, 398.

Schweitzer E.: 1998, ftp://cdsarc.u-strasbbg.fr/pub/afoev/

Stothers R., Leung K.-C.: 1971, *Astron. Astrophys.,* **10**, 290.

Wallerstein G., Knapp G.R.: 1998, *Annu. Rev. Astron. Astrophys.*, **36**, 369.

Wood P.R.: 1999, *Proc. IAU Coll. 176 "The Impact of Large-Scale Surveys on Pulsating Star Research"*, in press.