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On the Period of Mira Type Carbon Stars: A Discrete-dynamic Study

By

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Abstract

The period of 19 Mira type carbon stars are studied from a discrete-dynamic point of view to examine the results from SAIJO and WATANABE (1987). They found that Mira stars are classified into three types, to say, Type 1, Type 2 and Type 3, on the first-return maps of succeeding period length. They also noted that carbon stars belong to their Type 3 only. Analysis on Mira type carbon stars nearly confirm their results, which may come from some evolutionary effects.

1. Introduction

Mira stars belong to late-type pulsating variables of giant and supergiant stars characterized by periodic light variations of large amplitude in magnitude from 2.5 to more than 10 and long periods of 100 to 1000 days. Spectral class of Mira type stars are divided in M, S and C. Spectrum of S and C show anomaly on chemical abundance. Class S is characterized by overabundance of Zirukonium. Class C, so-called carbon star, is characterized by that of carbon. Over 90 parcent of Mira stars of known spectral class belong to M. According to PETIT (1987), for example, there are 1356 M stars, 69 S stars and 79 C stars. C and S stars have longer average periods than M stars. C stars have generally smaller amplitudes than M stars.

Recent theoretical studies on pulsating variables have very much succeded in explaining rather short period pulsating stars such as classical Cephids and RR Lyra stars. For Mira type pulsating stars, however, we can not have any satisfactory model as yet. Therefore, it is very useful to investigate observational features in Mira type pulsating variables.

SAIJO and WATANABE (1987) studied period changes of 60 Mira type stars for the first time from a discrete-dynamic point of view on the basis of observed quantities after theoretical considerations by TAKEUCHI (1987). They found that Mira stars are calssified into three types, to say, Type 1, Type 2 and Type 3. They also noted that Mira type carbon stars belong to their Type 3 only.

In this paper period changes of 19 Mira type carbon stars are investigated to examine the results from SAIJO and WATANABE (1987).

2. Observational data and first-return map

2.1 *Observational data*

CAMPBELL (1926) and CAMPBELL (1955) complied observed times of maximum and minimum light of long period variables from 1901 to 1949 obtained mainly from visual estimates of AAVSO. From those sources we can collect observed periods of 19 Mira type carbon stars except 5 stars discussed already in SAIJO and WATANABE (1987). Classification and characteristics of those stars are from the fourth edition of General Catalogue of Variable Stars (1985). Observed period length is defined as an interval of successive times of maximum light.

2.2 *First-return map*

Considering the period change from a discrete-dynamic point of view, SAIJO and WATANABE (1987) used "first-return" maps as a tool of analysis. A first-return map is obtained to plot successive sets of observed period (P_i, P_{i+1}) on P_i-P_{i+1} plane, where P_i is an interval of successive times of i-th and i+1-th light maximum counted from an arbitary maximum. The relation of successive periods may be described as a descrete-dynamic expression, $P_{i+1}=f(P_i)$, and the first-return map express the Poincare section.

3. Results and discussions

3.1 *Results*

First-return maps of 19 carbon stars have been obtained and statistical results are tabulated in Table 1 as well as characteristics of stars. The fifth column of table 1 shows the number of plots obtained. The sixth and seventh columns show correlation coefficients and their range of 95 parcent reliability. In the last column the type from the first-return map defined by SAIJO and WATANABE (1987) is shown. From them the pattern of the first-returen maps are classified into three types as Type 1, Type 2 and Type 3 according to the values of correlation coefficient. Type 1 has rather large positive coefficients, more than 0.35, Type 2 has negative ones, less than −0.35, and Type 3 does not show any remarkable correlation. Detailed expressions were given in SAIJO and WATANABE (1987).

All the stars except two stars, W Cas and RT Oph, may belong to Type 3. Plots of Type 3 stars, V Aur, T Dra and V Oph, for example, are shown in figure 1 to figure 3. WX Cyg indicates rather large negative value of correlation coefficient, −0.387, whose plots are shown in figure 4. However, the plots in figure 4 distribute randomly around the point of (410, 410) except two plots, (318, 436) and (423, 380), and the number of plots are so small. Therefore, WX Cyg seems to belong to Type 3 but Type 2. RZ Peg, whose correlation coefficient is −0.336, also seems to belong to Type 3. W Cas and RT Oph both belong to Type 2 and their plots are shown in figure 5 and figure 6, respectively.

Table 1. Characteristics and results of Mira type carbon stars.

Star		Sp	Amplitude	Period	Number of Plot	Correlation Coefficient	Range of 95 parcent Reliability	Type
V	Aur	C6,2e	8.5 -13.0	353.00	41	−0.107	0.207– −0.402	3
W	Cas	C7,1e	7.8 -12.5	405.57	41	−0.465	−0.183– −0.676	2
X	Cas	C5,4e	9.45–13.2	422.84	37	0.017	0.339– −0.309	3
RV	Cen	N3e	7.0 -10.8	446.0	22	−0.065	0.367– −0.474	3
S	Cep	C7,4e	7.4 -12.9	486.84	31	0.028	0.387– −0.330	3
V	CrB	C6,2e	6.9 -12.6	357.63	40	−0.294	0.019– −0.555	3
V	Cyg	C5,3–7,4e	7.7 -13.9	421.27	35	−0.002	0.332– −0.335	3
WX	Cyg	C8,2JLi	8.8 -13.2	410.45	26	−0.386	0.001– −0.673	3
T	Dra	C6,2–8,3e	7.2 -13.5	421.62	34	0.126	0.445– −0.222	3
R	For	C4,3e	7.5 -13.0	388.73	22	0.053	0.464– −0.377	3
S	Lyr	SCe	9.8 -15.6	438.40	32	−0.111	0.247– −0.442	3
U	Lyr	C4,5e	8.3 -13.5	451.72	34	0.226	0.524– −0.122	3
V	Oph	C5,2–7,4e	7.3 -11.6	297.21	53	0.056	0.321– −0.218	3
RT	Oph	M7e(C)	8.6 -15.5	426.34	36	−0.464	−0.160– −0.688	2
R	Ori	C8,2e	9.05–13.4	377.1	41	−0.212	0.102– −0.487	3
RZ	Peg	C9,1e/CSe	7.6 -13.6	438.7	21	−0.336	0.111– −0.671	3
Y	Per	C4,3e	8.1 -11.3	248.60	58	−0.208	0.053– −0.443	3
RU	Vir	C8,1e	9.0 -14.2	433.2	32	−0.047	0.307– −0.389	3
R	Vol	Ce	8.7 -13.9	453.60	21	−0.258	0.198– −0.619	3

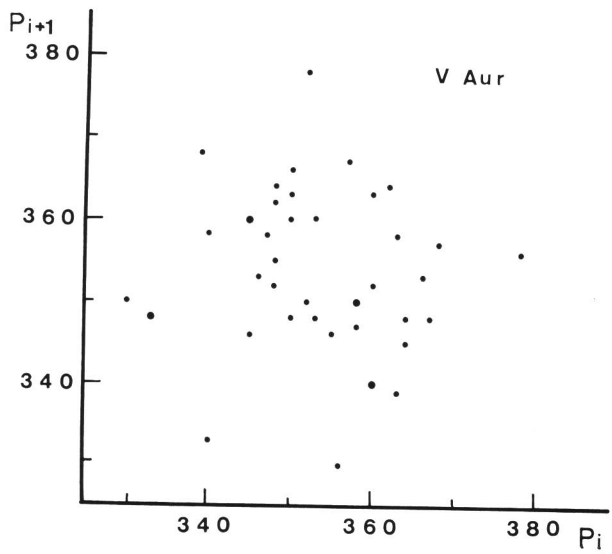

Fig. 1. First-return map of V Aur. Larger and largest dots show two and three dots are at the same place, respectively. Hereinafter large dots in figures indicate the same meaning.

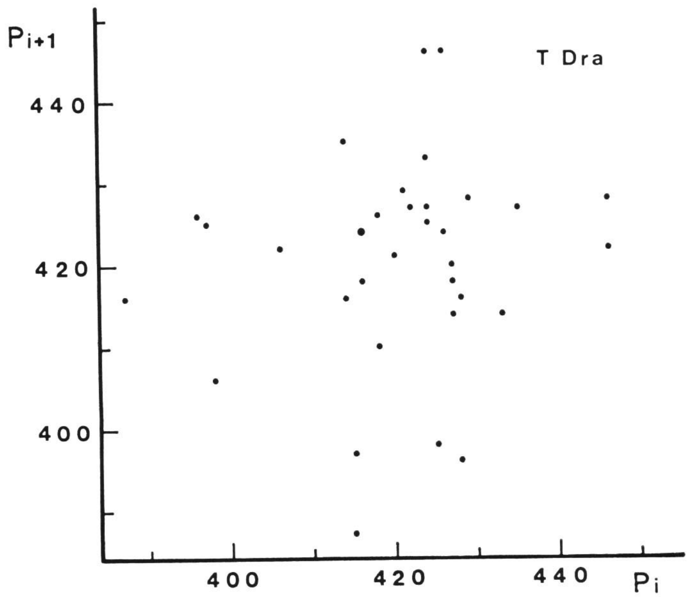

Fig. 2. First-return map of T Dra.

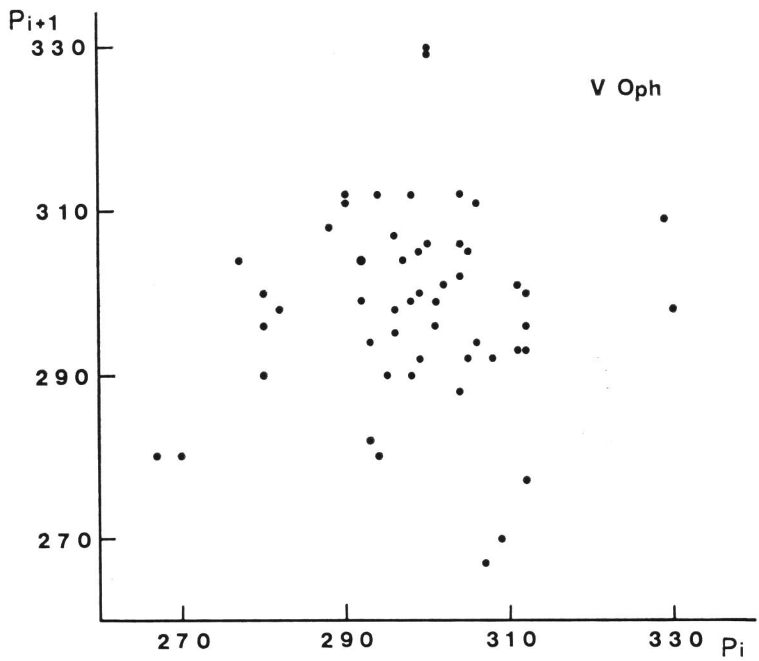

Fig. 3. First-return map of V Oph.

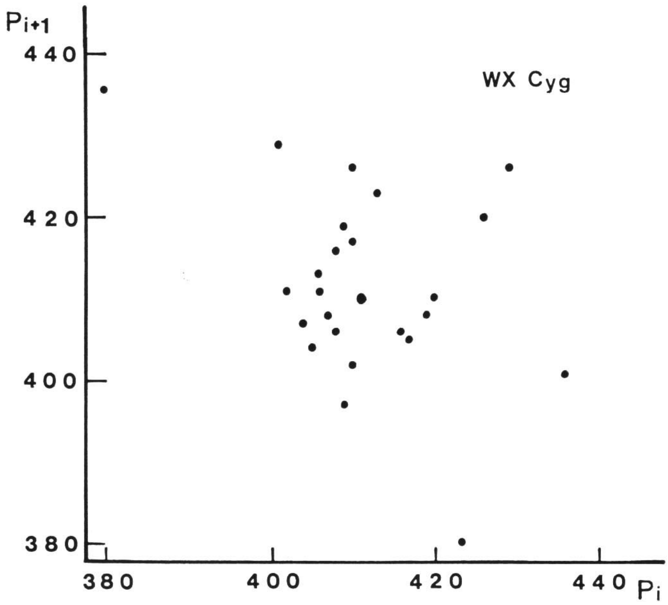

Fig. 4. First-return map of WX Cyg.

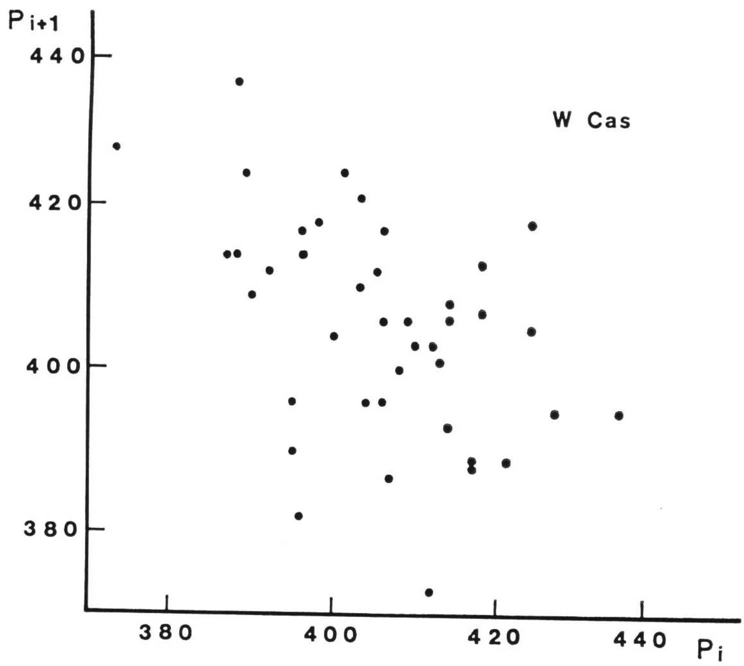

Fig. 5. First-return map of W Cas.

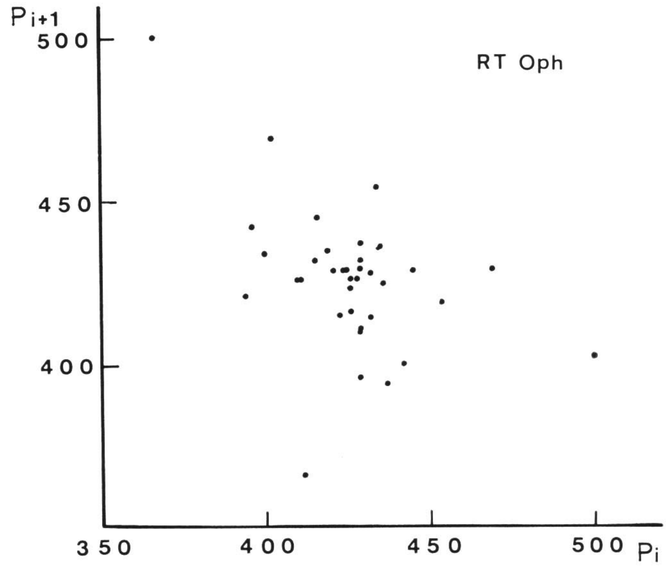

Fig. 6. First-return map of RT Oph.

3.2 Discussions

SAIJO and WATANABE (1987) noted that 5 carbon stars in their analysis belong to Type 3 only. Analysis in this paper nearly confirm their result. Seventeen of 19 stars are found to belong to Type 3. Only two stars, W Cas and RT Oph, belong to Type 2. Spectral type of RT Oph is rather different from the others. RT Oph does not seem to belong to pure carbon star because C type designation in brakets shows former classification. Therefore, RT Oph may be excluded from consideration. Then, only one star is found to belong to Type 2 and 22 stars of 23 Mira type carbon stars including 5 stars analyzed by SAIJO and WATANABE (1987) are found to belong to Type 3. This means that an overwhelmingly large proportion of carbon stars belong to Type 3. SAIJO and WATANABE (1987) found, on the contrary, that 18 and 27 of 47 M stars are Type 2 and Type 3, respectively, and that among 8 S stars, 5 stars are Type 2 and 3 stars are Type 3.

From an evolutionary point of view, Mira stars are low mass (about one solar mass) objects of latest stage of evolution and are located on the so-called asymptotic giant branch (AGB) on the HR diagram. Theoretical models of WOOD and CHAN (1977) and TUCHMAN, SACK and BARKAT (1979), for example, indicated that a typical low mass star evolving up the AGB eventually becomes luminous enough to pulsate as a Mira variable. However, the variables of C and S type spectral class are not clearly understood yet from the evolutionary point of view. Carbon stars are made from some kind of mixing process dredging up matters from carbon rich core to the surface. This process also still remains a theoretical problem.

Nearly all the Mira type carbon stars are found to belong to Type 3, which SAIJO and WATANABE (1987) thought that Type 3 feature is a result of limit cycle pulsation. This may come from some evolutionary effects characterized commonly in the Mira type carbon stars.

4. Conclusion

Period change of 19 Mira type carbon stars are studied from a discrete-dynamic method. Seventeen of 19 stars are found to belong to Type 3. Only two stars belong to Type 2. One of the Type 2 stars, RT Oph, may be excluded from pure carbon stars. Overwhelmingly large proportion of Type 3 in the Mira type carbon stars compared with the Mira stars of M and S pectral class may come from some evolutionary effects.

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