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A Return-map Study of Semiregular Variable Stars: Period and Magnitude

By

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Abstract In order to develop our previous works for Mira type variables (SAIJO and WATANABE, 1987; SAIJO, 1988), the period and magnitude of 21 semiregular variable stars are studied by using return maps. According to our previous works, return maps are classified into three types, Type 1, Type 2 and Type 3. Analysis on the period shows similar result to Mira type stars, which means that nearly all the semiregular stars belong to Type 3. Analysis on the magnitude shows that semiregular stars belong to two Types, Type 1 and Type 3. Discussion is also given.

1. Introduction

Recent theoretical studies of nonlinear and nonadiabatic treatments of stellar oscillation have been developed to investigate the irregularity of late type pulsating variables as chaotic phenomena. However, because of difficulty of estimation of the effect of convection in late type stars, we do not have fully satisfactory model which describe the properties of late type pulsating variables as yet.

In the course of theoretical development, TAKEUCHI (1987) proposed the usefulness of the return maps to compare theoretical models with observational properties of late type variables. From the dynamical point of view, return map express the Poincare section. Therefore, comparison of return maps given from theoretical models with those from observations may give important informations and may help to construct more realistic models. Moreover, return maps from observational data may expect to reveal the difference among various types of late type pulsating variables, to say, Mira type, semiregular, RV Tauri type and irregular.

In our previous works (SAIJO and WATANABE, 1987; SAIJO, 1988), we investigated the period of Mira type variable stars from the discrete-dynamic point of view. Using the return maps as a tool of the analysis, we derived that Mira stars are classified into three types, Type 1, Type 2 and Type 3, according to the value of correlation coefficient and that nearly all the Mira type carbon stars belong to Type 3 only. SAITOU, TAKEUCHI and TANAKA (1989) compared theoretical return maps of one-zone nonlinear oscillation models with observed return maps of luminosity for about 30 semiregular and RV Tauri stars. They found that complexity of the pattern of return maps develops according as the decrease of the effective temperatures of both models and stars.

Table 1. Characteristics of 21 semiregular stars.

Star	Subtype	Sp	Amplitude	Period (Day)
RU And	SRA	M5–6e	9.9 –14.5	238.3
ST And	SRA	C4, 3–6, 4e	7.7 –11.8	328.34
S Aql	SRA	M3–5.5e	8.9 –12.8	146.45
T Ari	SRA	M6–8e	7.5 –11.3	316.6
Z Aur	SRD	G0–6e	9.2 –11.7	
U Boo	SRB	M4e	9.8 –13.0	201.3
V Boo	SRA	M6e	7.0 –12.0	258.01
S Cam	SRA	C7, 3e	7.7 –11.6	327.26
V CVn	SRA	M4–6e	6.52– 8.56	191.89
T Cen	SRA	K0–M4e	5.5 – 9.0	90.44
RS Cyg	SRA	C8, 2e	6.5 – 9.5	417.39
RS Dra	SRA	M5e	9.0 –12.0	282.72
RT Hya	SRB	M6–8e	7.0 –10.2	290
RS Lac	SRD	K0	9.6 –12.5	237.26
U LMi	SRA	M6e	10.0 –13.3	272.2
X Mon	SRA	M1–6ep	6.8 –10.2	155.8
S Pav	SRA	M7–8e	6.6 –10.4	380.86
RW Sgr	SRA	M4–6e	9.0 –11.7	186.82
W Tau	SRB	M4–6.5	8.2 –13.0	264.6
R UMi	SRB	M7e	8.5 –11.5	325.7
RU Vul	SRA	M3–4e	8.1 –12.7	173.6

Table 2. Characteristics of return maps.

Star	Period			Magnitude		
	Number of plot	Correlation coefficient	Type	Number of plot	Correlation coefficient	Type
RU And	64	−0.115	3	41	0.364	1
ST And	43	−0.207	3	35	0.494	1
S Aql	87	0.016	3	66	0.121	3
T Ari	25	0.030	3	19	0.381	1
Z Aur	127	0.553	1	97	0.569	1
U Boo	66	0.088	3	33	0.574	1
V Boo	62	−0.023	3	60	0.312	3
S Cam	46	−0.129	3	46	0.146	3
V CVn	20	−0.150	3	12	0.349	3
T Cen	105	−0.457	2	90	−0.036	3
RS Cyg	39	−0.036	3	37	0.511	1
RS Dra	13	−0.182	3	8	0.145	3
RT Hya	30	−0.042	3	19	0.384	1
RS Lac	19	−0.095	3	13	0.850	1
U LMi	16	−0.147	3	15	0.506	1
X Mon	84	−0.093	3	44	0.114	3
S Pav	22	−0.250	3	18	0.545	1
RW Sgr	49	−0.247	3	39	0.455	1
W Tau	62	0.100	3	41	0.759	1
R UMi	28	0.089	3	29	0.286	3
RU Vul	15	−0.391	2	11	−0.059	3

Table 3. Type distribution of period return map.

Type	Number of Stars
1	1
2	2
3	18

Table 4. Type distribution of magnitude return map.

Type	Number of Stars
1	12
2	0
3	9

Table 5. Period-Magnitude type distribution.

Type Period-Magnitude	Number of Stars
1–1	1
1–2	0
1–3	0
2–1	0
2–2	0
2–3	2
3–1	11
3–2	0
3–3	7

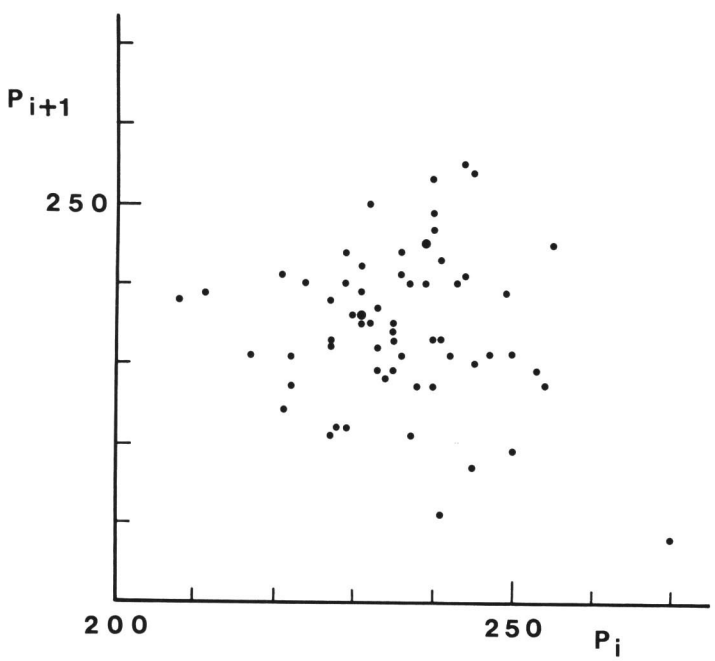

Fig. 1. A first-return map of successive observed period for RU And. Larger dot means two plots at the same place.

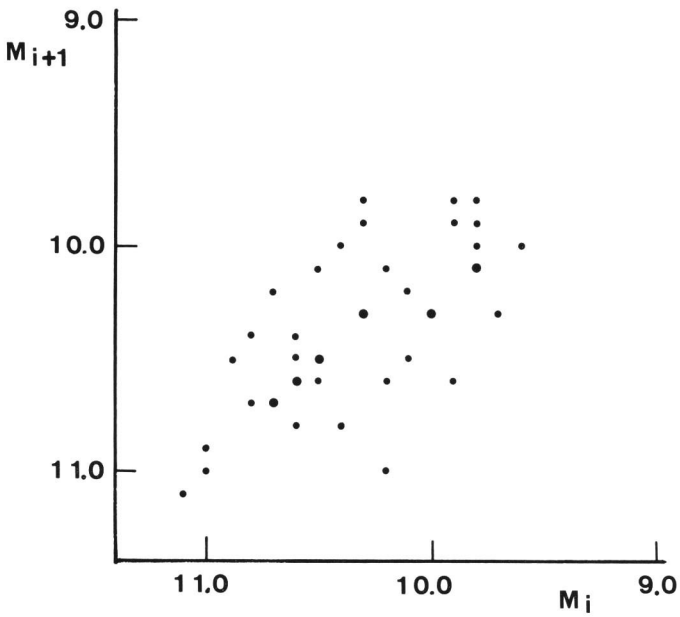

Fig. 2. A first-return map of successive observed magnitude maximum for RU And. Larger dot means two plots at the same place.

Therefore, in this paper, in order to develop our previous works, the period and magnitude of 21 semiregular variable stars are studied by using return maps.

2. Observational Data and First-return Map

Semiregular variables are giants or supergiants of intermediate and late spectral types characterized by showing noticeable periodicity of light changes accompanied or sometimes interrupted by different irregularities (KHOLPOV, 1985). Periods are from 20 to 2000 days and the amplitudes are from several hundredths to several magnitudes. Semiregular (SR) stars are not homogeneous group and subdivided into four types, SRA, SRB, SRC and SRD, according mainly as decrease of periodicity. The difference between semiregular and Mira type stars is not valid too and the stars whose amplitudes are less than 2.5 magnitude tend to be classified as semiregular type, in particular SRA and SRB.

Observed periods and magnitudes of light maximum of 21 semiregular stars are collected from CAMPBELL (1926) and CAMPBELL (1955), which compiled observed times and magnitudes of maximum and minimum light of long period variables from 1901 to 1949 obtained mainly from visual estimates of AAVSO. Classification and characteristics of those stars are shown in Table 1 from the fourth edition of General Catalogue of Variable Stars (KHOLPOV, 1985).

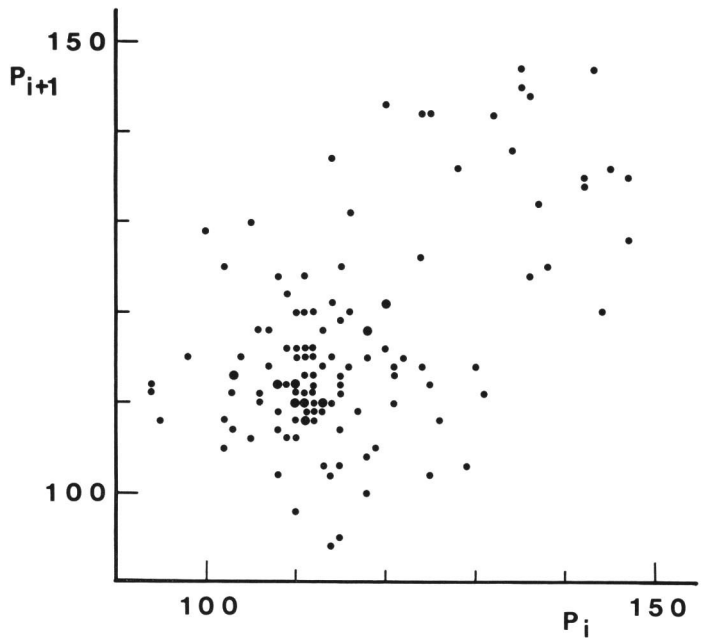

Fig. 3. A first-return map of period for Z Aur. Larger dot means two plots at the same place.

From those observational data, first-return maps of period and magnitude of maximum light are obtained to plot successive sets of observed period, (P_i, P_{i+1}) on $P_i - P_{i+1}$ plane and of observed magnitude of maximum light, (M_i, M_{i+1}) on $M_i - M_{i+1}$ plane, where i is counted from an arbitrary maximum.

3. Results and discussion

3.1. *Results*

SAIJO and WATANABE (1987) classified the pattern of first-return maps of period into three types as Typel, Type 2 and Type 3 according to the values of correlation coefficients. For simplicity, we adopt the same classification to the return maps of magnitude maxima. Type 1 has rather large positive correlation coefficients, more than 0.35. Type 2 has negative ones, less than -0.35. Type 3 does not show any remarkable correlation, from -0.35 to 0.35. Detailed expressions were given in SAIJO and WATANABE (1987).

Statistical characteristics and type classification of period and magnitude return maps for each star are given in Table 2. Type distribution of the period and the magnitude return maps are given in Table 3 and Table 4, respectively. Concerning to the period return map, the majority of the semiregular stars including all the three

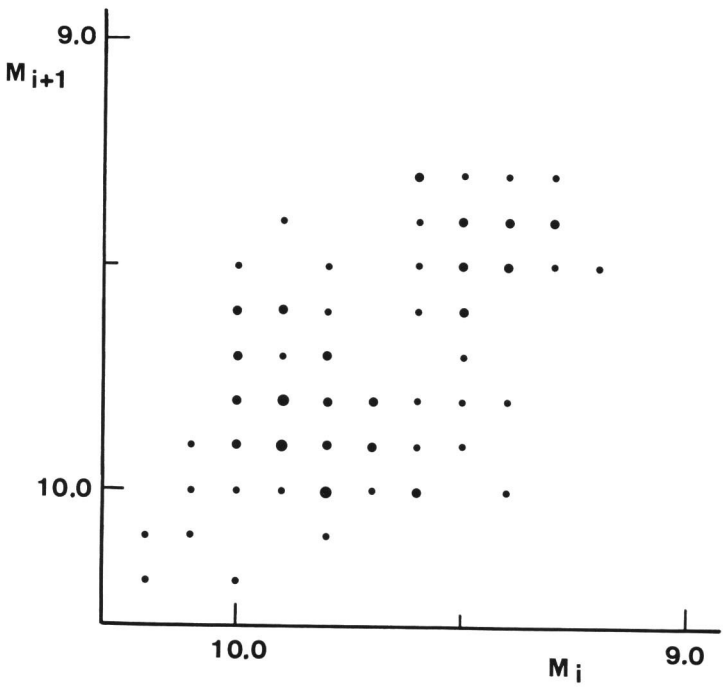

Fig. 4. A first-return map of magnitude for Z Aur. Larger dot means 2–4 plots at the same place and the largest dot is over 5 plots at the same place.

carbon stars belong to Type 3, which is similar to the previous results for Mira type stars (SAIJO and WATANABE, 1987; SAIJO, 1988). As to the magnitude return map, it is noted that the stars are found to belong to type 1 and type 3 only. Therefore, Period-magnitude type distribution given in table 5 concentrate Type 3–1 and Type 3–3. For example, return maps of RU And are shown in Fig. 1 and Fig. 2.

Subtype SRD means the highest irregularity of all the subtypes of semiregular variables. Z Aur, one of two SRD stars, is classified only one Type 1–1 star of Period-magnitude types. The star has the earliest spectral class, G, in Table 1 and is known to show remarkable period changes and irregular variability. In Figs. 3 and 4, period and magnitude return maps of Z Aur are shown respectively. The other SRD star, RS Lac, is Type 3–1, whose spectral type is K.

3.2. *Discussion*

SAITOU, TAKEUCHI and TANAKA (1989) calculated one-zone nonlinear stellar oscillation models and compare with return maps of observed luminosity maxima of about 30 semiregular and RV Tau type stars. They found that development of the pattern of return maps as to decrease of the effective temperature shows in good accordance with the calculated ones. They also expected that the irregularity shown

in those stars are considered as deterministic chaos. Their results are very important although the number of stars which coincide the computed sequence are very limited and some of the stars cannot be fully described as yet. Therefore, in order to develop the comprehension of the late type pulsating variables, the more wide study of return maps for those stars is needed.

4. Conclusion

Return maps of observed period and magnitude maximum of 21 semiregular stars are studied by using the classification introduced by our previous works. For the return maps of period, it is found that the majority of the stars belong Type 3 including three carbon stars. For the return maps of magnitude maximum, the stars are found to belong to Type 1 and Type 3 only. The more wide study of return map for late type pulsating variable stars is needed.

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