Bull. Natn. Sci. Mus., Tokyo, Ser. E, 13, December 22, 1990

Photoelectric Observation of ZZ Psc

By

Keiichi SAIJO

Department of Science and Engineering, National Science museum, Ueno Park, Tokyo

and

Hideo SATOH

Institute of Astronomy, The Tokyo University, Mitaka, Tokyo

Abstract

Photoelectric observation of ZZ Psc, one of the ZZ Cet variable stars, was carried out at Dodaira station of National Astronomical Observatory, Japan, on December 15, 1989. The major pulsation period on that day was obtained to be 668 seconds from PDS (Phase Dispersion Minimization) method with 80 data points.

1. Introduction

Since the first discovery of V441 Tau by LANDOLT (1968), the number of pulsating white dwarf variables, ZZ Cet type stars, has grown to about twenty. The spectrum type of these stars is DA and the colors are concentrated at about $B-V=0.2$ and $U-B=-0.5$.

The observed oscillation of ZZ Cet stars is interpreted as a nonradial g-mode pulsation. The amplitude of the luminosity variation is small, from 0.005 to 0.3 magnitude. The periods are from 100 to 1000 seconds and characterized by multi-periodicity, which shows several major periods. In addition to these major periods, many small secondary periods originated by combination of the major periods are shown. These frequency structures are rather stable in low-amplitude stars. In high-amplitude stars, however, those structures are not stable and variation of the period lengths and the amplitudes in major periods are observed even in one night.

MCGRAW and ROBINSON (1975) found out such variation for the first time in two high-amplitude ZZ Cet stars, ZZ Psc and V468 Per. Such phenomena has not been explained theoretically yet. Therefore, continuous observations are necessary to slove the phenomenon.

In the course of studying the irregularity of pulsating variable stars, photoelectric observation have been carried out continuously at Dodaira Station of National Astronomical Observatory by us. In this paper, we report the observation of ZZ Psc. ZZ Psc is the brightest, $V=13$, and has the largest amplitude, 0.3 magnitude, in ZZ

Table 1. Observation of ZZ Psc

N	HJD(2440000+)	V	B	U	B-V	U-B
1	7875.9550	12.875	12.980	12.489	0.105	-0.492
2	7875.9557	12.744	12.998	12.577	0.254	-0.422
3	7875.9575	12.750	12.997	12.370	0.247	-0.627
4	7875.9582	12.737	12.936	12.395	0.198	-0.541
5	7875.9589	12.819	13.024	12.525	0.204	-0.498
6	7875.9597	12.823	13.044	12.558	0.221	-0.486
7	7875.9604	12.862	13.049	12.497	0.187	-0.552
8	7875.9611	12.881	13.039	12.493	0.158	-0.546
9	7875.9618	12.766	13.068	12.584	0.303	-0.484
10	7875.9625	12.803	13.009	12.483	0.206	-0.526
11	7875.9633	12.737	12.974	12.372	0.237	-0.602
12	7875.9640	12.667	12.932	12.413	0.265	-0.519
13	7875.9651	12.847	12.998	12.423	0.151	-0.575
14	7875.9658	12.851	13.074	12.553	0.223	-0.521
15	7875.9665	12.852	13.033	12.470	0.180	-0.563
16	7875.9673	12.801	13.047	12.463	0.246	-0.584
17	7875.9680	12.822	13.073	12.590	0.250	-0.482
18	7875.9687	12.843	13.005	12.503	0.162	-0.502
19	7875.9694	12.804	13.075	12.582	0.272	-0.494
20	7875.9701	12.779	13.043	12.555	0.264	-0.488
21	7875.9709	12.799	13.024	12.478	0.225	-0.546
22	7875.9716	12.728	13.005	12.401	0.278	-0.604
23	7875.9723	12.856	12.933	12.481	0.077	-0.451
24	7875.9730	12.940	13.007	12.394	0.067	-0.613
25	7875.9737	12.807	13.039	12.440	0.232	-0.600
26	7875.9748	12.916	13.094	12.552	0.178	-0.542
27	7875.9756	12.771	12.964	12.471	0.193	-0.493
28	7875.9763	12.967	13.054	12.439	0.087	-0.616
29	7875.9770	12.672	12.949	12.636	0.277	-0.313
30	7875.9777	12.851	12.937	12.464	0.086	-0.474
31	7875.9784	12.765	12.893	12.386	0.128	-0.507
32	7875.9791	12.835	13.016	12.422	0.181	-0.594
33	7875.9799	12.850	12.977	12.460	0.127	-0.517
34	7875.9806	12.786	12.912	12.360	0.126	-0.552
35	7875.9813	12.865	13.025	12.447	0.160	-0.578
36	7875.9820	12.870	13.013	12.522	0.143	-0.491
37	7875.9827	12.782	13.012	12.460	0.230	-0.551
38	7875.9839	12.896	13.016	12.451	0.119	-0.565
39	7875.9846	12.822	13.068	12.483	0.247	-0.585
40	7875.9854	12.817	12.974	12.470	0.157	-0.504

Table 1. Observation of ZZ Psc (Continued)

N	HJD(2440000+)	V	B	U	B-V	U-B
41	7875.9861	12.808	12.894	12.240	0.086	-0.654
42	7875.9868	12.714	13.040	12.703	0.326	-0.337
43	7875.9875	12.766	12.878	12.289	0.112	-0.589
44	7875.9882	12.895	12.977	12.456	0.082	-0.521
45	7875.9890	12.873	13.004	12.450	0.131	-0.554
46	7875.9897	12.842	13.030	12.577	0.188	-0.453
47	7875.9904	12.813	13.023	12.537	0.210	-0.485
48	7875.9911	12.806	12.991	12.396	0.185	-0.596
49	7875.9918	12.827	13.034	12.591	0.207	-0.442
50	7875.9926	12.805	13.010	12.527	0.205	-0.482
51	7876.0142	12.788	12.907	12.418	0.119	-0.490
52	7876.0149	12.863	12.945	12.425	0.083	-0.521
53	7876.0157	12.772	12.994	12.426	0.221	-0.567
54	7876.0164	12.780	12.982	12.473	0.202	-0.509
55	7876.0171	12.635	12.989	12.500	0.354	-0.489
56	7876.0178	12.751	12.837	12.353	0.086	-0.484
57	7876.0185	12.739	12.874	12.533	0.135	-0.341
58	7876.0193	12.650	12.866	12.308	0.216	-0.558
59	7876.0200	12.686	13.021	12.360	0.335	-0.661
60	7876.0207	12.727	12.886	12.375	0.159	-0.511
61	7876.0214	12.855	12.956	12.490	0.102	-0.466
62	7876.0221	12.820	12.962	12.721	0.142	-0.241
63	7876.0228	12.873	12.974	12.559	0.101	-0.415
64	7876.0236	12.625	12.904	12.285	0.278	-0.618
65	7876.0243	12.796	12.946	12.306	0.149	-0.639
66	7876.0250	12.690	12.874	12.246	0.184	-0.628
67	7876.0257	12.775	12.970	12.412	0.196	-0.559
68	7876.0264	12.803	12.999	12.435	0.195	-0.563
69	7876.0272	12.756	12.902	12.342	0.147	-0.560
70	7876.0279	12.656	12.871	12.349	0.214	-0.522
71	7876.0286	12.736	12.973	12.369	0.236	-0.604
72	7876.0293	12.778	12.908	12.353	0.129	-0.554
73	7876.0300	12.848	12.879	12.350	0.031	-0.529
74	7876.0308	12.746	12.910	12.311	0.165	-0.599
75	7876.0315	12.824	12.841	12.322	0.016	-0.519
76	7876.0322	12.784	12.876	12.391	0.091	-0.484
77	7876.0329	12.713	12.846	12.503	0.133	-0.343
78	7876.0336	12.739	12.822	12.273	0.083	-0.548
79	7876.0344	12.753	12.788	12.250	0.035	-0.538
80	7876.0351	12.657	12.825	12.183	0.168	-0.642

Cet stars. According to MCGRAW and ROBINSON (1975), ZZ Psc has five major periods, which are arranged in decreasing order in seconds, $f_1 \sim 1000$, $f_2 \sim 930$, $f_3 \sim 820$, $f_4 \sim 670$ and $f_5 \sim 620$.

2. Photoelectric Observation

Photoelectric observation was made on 15, December, 1989 at Dodaira station with 91 cm reflecting telescope attached the multi-channel polarimeter, whose details are described in KIKUCHI (1988). Intergration time was about 55 seconds and the number of data obtained were 80. The analysis is carried out to transform the intrinsic system of the multi-channel polarimeter to Johnson's standard UBV system. B-magnitude is given from the mean of the second and the third channel of the intrinsic system.

Equations for the reduction are given below as a usual manner,

$$V=v-k_v'X-k_v''(b-v)X+\varepsilon(B-V)+\zeta_v$$
$$B-V=\mu(b-v)-\mu k_{bv}'X-\mu k_b''(b-v)X+\zeta_{bv}$$
$$U-B=\phi(u-b)-\phi k_{ub}'X-\phi k_{ub}''(u-b)X+\zeta_{ub},$$

and the coefficients meant as a usual manner are,

$$k_v'=0.268, \quad k_v''=0.035,$$
$$k_{bv}'=0.155, \quad k_{bv}''=-0.019,$$
$$k_{ub}'=0.261, \quad k_{ub}''=0.058,$$
$$\varepsilon=-0.044, \quad \mu=1.073, \quad \phi=1.065,$$
$$\zeta_v=-0.516, \quad \zeta_{bv}=0.769, \quad \zeta_{ub}=-0.937.$$

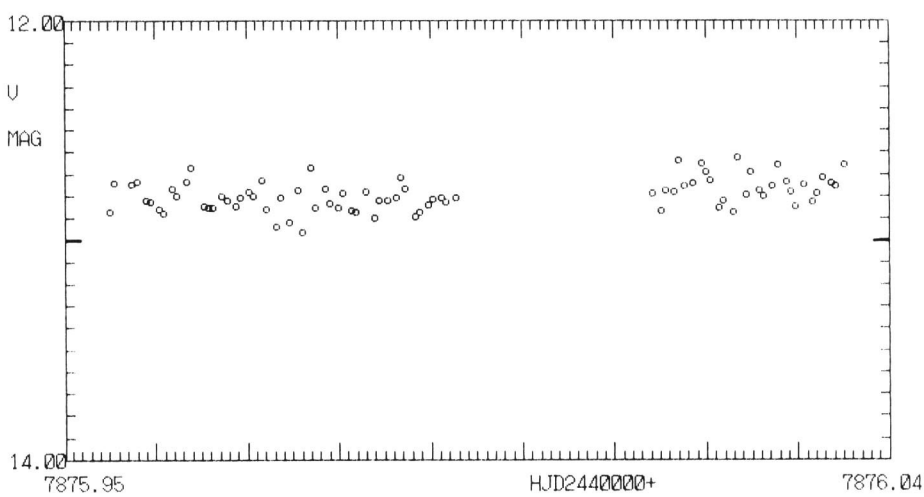

Figure 1. Light curve in V

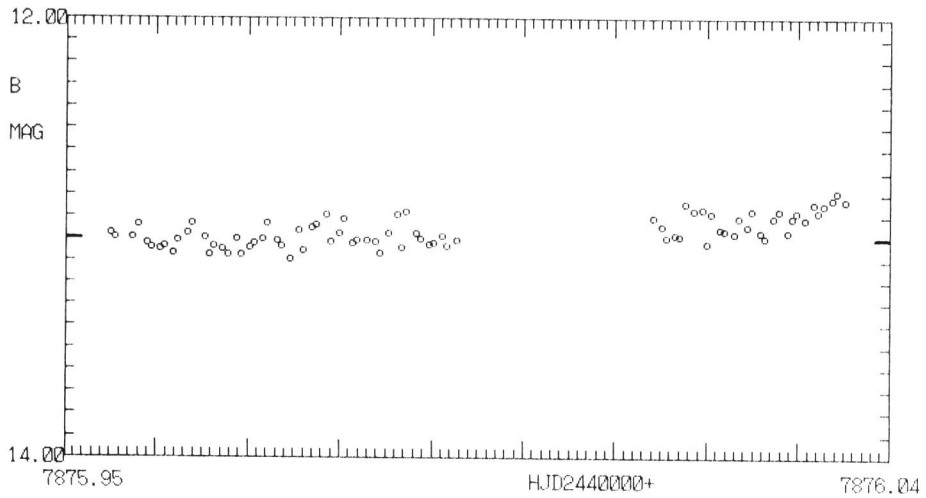

Figure 2. Light curve in B

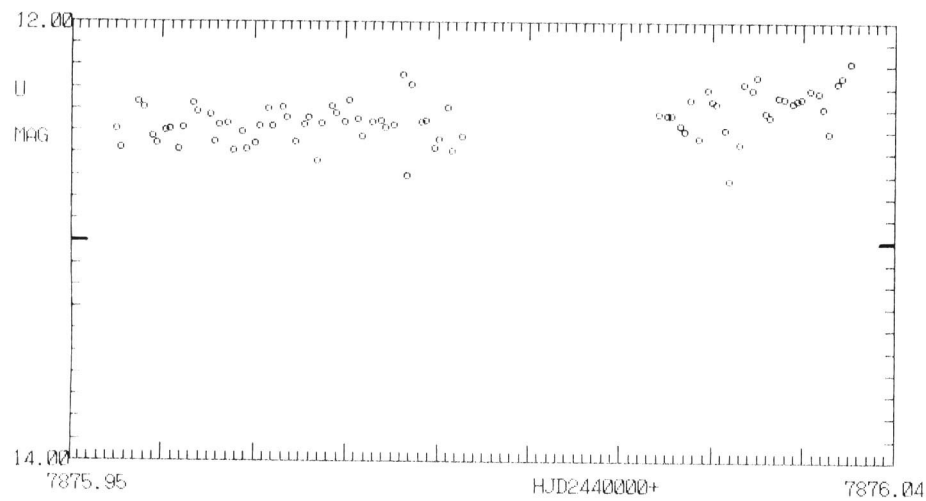

Figure 3. Light curve in U

The observed results are tabulated in table 1 and the light and color curves in V, B, U, $B-V$ and $U-B$ are shown in figures 1 to 5, respectively.

The light amplitudes are 0.3 in V, 0.3 in B and 0.4 in U, and the mean magnitudes and colors are, $V=12.79$, $B=12.97$, $U=12.44$, $B-V=0.18$ and $U-B=-0.53$.

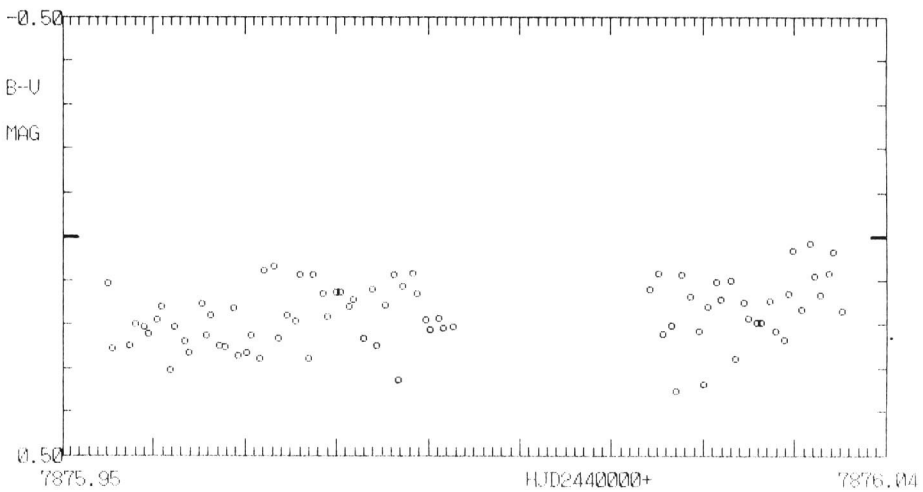

Figure 4. Color curve in $B-V$

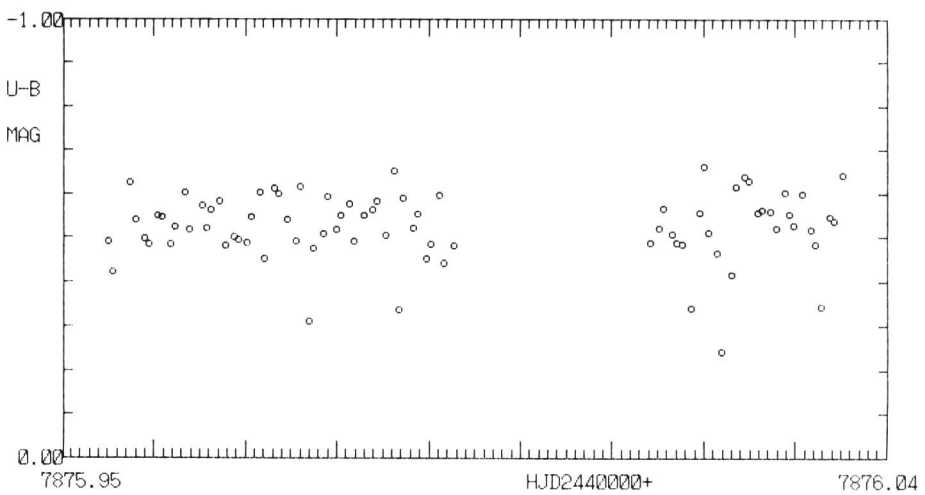

Figure 5. Color curve in $U-B$

3. Period Analysis

Period analysis is made using the phase dispersion minimization method (PDM-method) introduced by STELLINGWERF (1978), which is suit for the small number of observations. PDM-method gives the best-fitting period, which minimzes the ratio of the sum of the variance of sample subsets to the variance of all data from assumed periods. It use bin structure, (N_b, N_c), whose samle number is $M=N_bN_c$. Detailed meanings are shown in STELLINGERF (1978).

We calculated with 29 bin structures, (N_b, N_c), that is to say: for $N_b=4$ and 5 with $N_c=2$, 3, 4, 5, 6, 8 and 10, for $N_b=6$ with $N_c=2$, 3, 4, 5, 6 and 8, for $N_b=8$ with $N_c=2$, 3, 4, 5 and 6 and for $N_b=10$ with $N_c=2$, 3, 4 and 5. The mean period from 29 bin structures for each color is considered as the real period.

Periods obtained are 678 seconds for V, 665 seconds for B and 661 seconds for U. Therefore, we conclude that the period was 668 seconds, which is the same as $f_4 \sim 670$ seconds obtained by McGraw and Robinson (1975).

4. Discussion and Conclusion

As cited in section 1, McGraw and Robinson (1975) found out five major period by Fourier analysis of the observational data on October 16, 17 and 21, 1974. The number of observation is from 3000 to 7000 in each night. From their results, we find the variation of the frequency structure of pulsation periods; On October 17, the period f_1 did not exist and the period f_2 was very weak. The largest frequency on October 16 is f_2 but, on the contrary, on October 17 is f_3.

These variation seems to be controlled by nonlinear combination of major periods and/or conditions of excitation, which favor a specific frequency, although the origin is unknown yet. In low-amplitude ZZ Cet stars, similar variations are rarely seen. But, in the case of PT Vul, which has two periods, 252 seconds and 564 seconds, and whose amplitude is 0.03 magnitude, showed only one period of 256 seconds over 80 days in 1979. Therefore, continuous observations on ZZ Cet stars seem to be important to examine the cause of the variation.

Photoelectric observation on ZZ Psc was carried out on December 15, 1989, and we obtained $V=12.79$, $B=12.97$, $U=12.44$, $B-V=0.18$ and $U-B=-0.53$. The amplitudes of light variation are 0.3 in V, 0.3 in B and 0.4 in U. Period analysis shows that the major pulsation period on December 15, 1989, is 668 seconds, which indicates f_4 was the largest of five major period then. However, the more observation is need for the study of the variation of the frequency structure of pulsation on this star.

Acknowledgement

The authors express their hearty thanks to Mr M. Saitou and Dr T. Ishida of Tohoku University for providing us the computer programme of PDM-methods and are grateful to Professor M. Takeuchi, Tohoku University, and Dr. Y. Nakada, Tokyo University, for useful discussions. They also thank the staff of Dodaira station of National Astronomical Observatory.

References

Kikuchi, S. 1988, The Present Status of the Multi-channel Polarimeter at Dodaira, *Tokyo Astronomical Bulletin, 2nd Series*, No. 281.

LANDOLT, A. U. 1968, A new short-period blue variable, *Astrophys. J.*, **153**: 151.
MCGRAW, J. T., and ROBINSON, E. L. 1975, G29–38 and G38–29: Two new large-amplitude variable white dwarfs, *Astrophys. J.*, **200**: L89.
STELLINGWERF, R. F. 1978, Period determination using phase dispersion minimization, *Astrophys. J.*, **224**: 953.