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Monitoring of the cool ZZ Ceti star PG 2303+243

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Abstract. Because PG 2303+243 had not been observed since 1992, we have arranged the mini-campaign of six observatories on PG 2303+243 in 2004 Sep. 5-21 for the more detailed frequency analysis of variations. The amplitudes of the most frequencies change even during the one night and some frequencies can disappear or appear in one year. Probably it is resonance effect. We have estimated 69 frequencies of pulsations and their amplitudes according the observations from 2004 and 36 frequencies and its amplitudes from 2005.

Keywords. Stars: oscillations, (stars:) white dwarfs, stars: individual (PG 2303+243)

1. Introduction

Pulsating hydrogen-atmosphere (DAV or ZZ Ceti) white dwarf stars are interesting objects for understanding in the structure of white dwarfs in general. The cooler DAV stars have more independent pulsation modes excited than hotter DAVs and are therefore potentially richer targets for seismology. Among the cooler DAVs, PG 2303+243 was discovered in 1986 (Vauclair *et al.* 1987, Vauclair *et al.* 1992). Its main pulsation period was 795 s with amplitude as large as 0.05 of the mean intensity. The large amplitude and number of frequencies identified makes PG 2303+243 a very interesting star to follow up for asteroseismological study.

2. Observations

The mini-campaign on PG 2303+243 was arranged in 2004 Sep. 5-21th. Five observatories (Observatory of Vienna University 80 cm telescope, Konkoly obs. 100 cm telescope, Molėtai AO 31/51 cm telescope, Baker obs. 40 cm and Teide obs. 80 cm) have got CCD observational data with duty cycle around 35.2% and FT spectrum resolution 0.76 μHz. The observations were repeated at Molėtai observatory in 2005 Sep. 5-9th. Got duty cycle was 27.7% and spectrum resolution 2.7 μHz. 69 frequencies were defined from prewhitening of reduced light curves for observations from 2004 and 36 from 2005 observations. The most of the detected pulsation frequencies have unstable amplitudes and change sometimes dramatically from night to night. That is intrinsic to cool ZZ Ceti stars. The mode around 1.622 mHz is most stable during all observations, although its amplitude changes from year to year too.

3. Amplitudes

The wavelet analysis of LC for separate nights confirms a short time scale associated with several regions of power, and periods which appear and disappear during the run (see Fig. 2, left panel). It can mean that the life time of these pulsations is quite short,

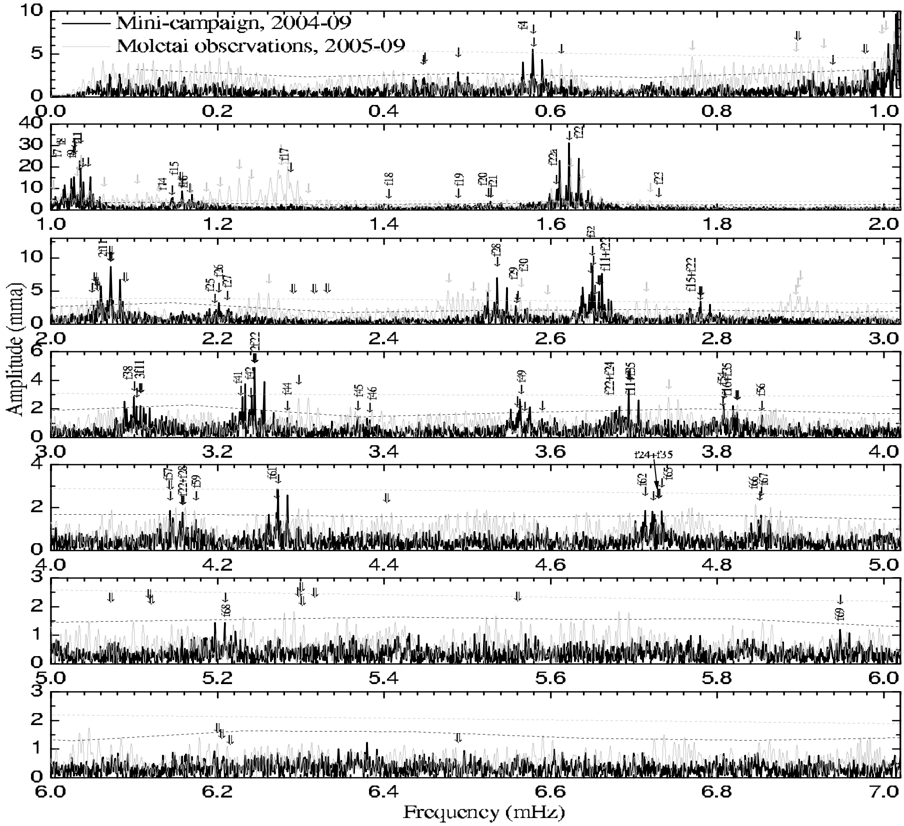

Figure 1. FT spectrums and spectral windows from 2004 and 2005. Black arrows show estimated frequencies in 2004, grey arrows in 2005, triple black arrows show linear frequencies combinations estimated using observations from 2004, double arrows possible locations of harmonics in FT for observations from 2004, which can be below the current noise limit. Black dashed line is significant curve for observations from 2004, and grey dashed line is significant curve for observations from 2005.

less than one hour. analogical analysis was made on the synthetic light curves. The result was surprising, in the sense that the wavelet analysis of the simulated data set looks very much like the real observed data set. That tells us that there are no extra pulses of short lived character in the data and amplitudes change because frequency resonance. So, the Brickhill (1992), Wu (2001) and Montgomery (2005) models for convection can be used to further PG2303+243 data analysis.

We have found a lot of 2-4 frequencies combinations, among them 3 harmonics and 7 two frequency linear combinations (see Fig. 1).

4. Mode identification from combination frequency

Having identified and measured the amplitudes of the combination frequencies allows us to calculate the ratio of combination to parent mode amplitudes R_c and compare it to the theoretical prediction by Yeates *et al.* (2005), assuming θ_0=6 deg for different spherical degree l and azimuthal order m=0 to individual Eigen frequencies (Fig. 2, right panel). We have estimated the inclination angle (Pesnel 1985) of PG 2303+243

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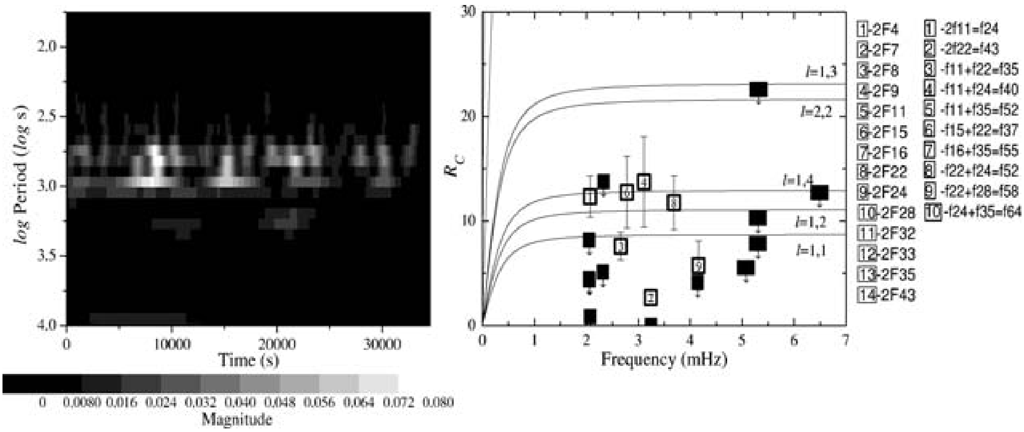

Figure 2. *Left panel*: The result of wavelet analysis for light curve observed in Teide Obs. in 14th Sept. of 2004. *Right panel*: The observed R_c for all of detected two-mode combination frequencies in PG 2303+243 (thicken squares) and not detected harmonics for some modes (normal squares), what correspond to upper limit of ratio R_c. The solid lines show the theoretical prediction.

by frequency splitting at 1.6223 mHz. If the highest peak is l=1,m=0 mode, then we can say that inclination angle of PG 2303+243 is less than 12 deg. The closest peak at 1.606 mHz the most believable is independent frequency and doesn't contain information about star inclination angle, but in case the peak at 1.606 mHz is the mode l=1,m=1 with amplitude 2.5 mma, then maximal inclination angel can be only 6 deg or even less. It means that theoretical R_c dependence on frequency is not sensitive to small uncertainty of inclination (Yeates *et al.* 2005).

Using Yeates *et al.* (2005) method we didn't find any harmonic with higher l value than 2. We have estimated, that only modes f4 and f35 can be l=2 modes, and all others can be only l=1 modes. Using trapping modes theory (Brassard *et al.* 1992) we have found that l values can be equal 3 or even 4, but we were not able to find unambiguous l values for every frequency because of plenty observed frequencies.

5. Conclusions

PG2303+243 is very rich of pulsating modes ZZ Ceti star (69 frequencies are detected). The amplitudes of many pulsations change because frequency resonance. The most stable frequency around 1.622 mHz allowed us to estimate star inclination less than 12 deg. It is difficult to identify modes because of reach pulsation spectrum and changeable amplitudes.

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