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Wide-Field Variability Surveys: A 21st Century Perspective

Asteroseismology of the ZZ Ceti and DAZ GD 133

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Abstract. GD 133 is a DAZ white dwarf with an atmosphere polluted by heavy elements accreted from a debris disk, which is formed by the disruption of rocky planetesimals with orbits bringing them at the white dwarf tidal radius. To reach such orbits implies the potential presence of a perturbing planet. GD 133 is a ZZ Ceti pulsator close to the blue edge of the instability strip. The presence of a planet could be revealed by the periodical variation of the observed pulsation periods induced by the orbital motion of the white dwarf. We started a multi-site photometric follow-up aimed at detecting the signature of this potential planet. As a partial result of this work in progress, we give the parameters of a preliminary best-fit model derived from asteroseismology.

1 Context: GD 133, an accreting DA white dwarf and ZZ Ceti pulsator

GD 133 is one of the increasing number of white dwarf stars surrounded by debris disks resulting from the tidal disruption of rocky planetesimals ([2–4]). Part of the matter of the disk falls onto the white dwarf surface, polluting the chemical composition of its outer layers. The spectrum of GD 133 shows the lines of a number of heavy elements (Ca, O, Mg, Si). The derived abundance ratios are quite similar to the bulk Earth composition ([10]). GD 133 is a ZZ Ceti pulsator ([9]) close to the blue edge of the instability strip.

The scenarii for the formation of the debris disks by the tidal disruption of rocky planetesimals suggest that one (or more) undetected planet(s) could be orbiting the white dwarfs. Through gravitational interactions the planet(s) perturbs their orbit so that they may come close enough to the white dwarf tidal radius.

GD 133 is a good candidate to search for the signature of such a potential planet through the effect of the orbital motion on the observed pulsation periods.

2 Observations

We started a photometric follow-up of GD 133 in 2011. A multisite campaign including the 1.5 m telescope of the San Pedro Martir observatory (Mexico), the 2.4 m telescope of the Lijiang observatory (Yunnan, China), and the 1 m telescope of Pic-du-Midi observatory (France) was organized in March 2011 during which we obtained 106 hours of photometric data. Table 1 gives the list of the identified frequencies and their amplitudes. As a preliminary result of this work in progress we used these data to determine the parameters of GD 133 from asteroseismology.

Table 1. Frequencies of GD 133 during the 2011 campaign. The frequencies and their uncertainties are given in units of μHz; the amplitude and their uncertainties are given in mmag.

$\nu(\mu\text{Hz})$	$\sigma(\nu)(\mu\text{Hz})$	A (mmag)	$\sigma(A)$(mmag)
2821.74	0.34	0.47	0.15
5106.04	0.31	0.55	0.20
6818.48	0.14	1.33	0.51
6821.89	0.14	1.24	0.38
8308.81	0.16	1.95	0.43
8310.28	0.12	2.24	0.58
8625.25	0.15	0.72	0.25
8628.57	0.15	0.62	0.19

3 Modelling GD 133

We use MESA ([6–8]) to obtain a set of white dwarf models in the range $0.45 - 0.9\,M_\odot$ from initial main-sequence stellar models with masses between 0.8 and $8\,M_\odot$. DA white dwarf models were then obtained with an updated version of WDEC ([1, 5]) by adjusting and relaxing the C-O core models prepared with MESA. The spectroscopic analysis by [10] leads to the atmospheric parameters of GD 133 as $T_{\rm eff}$ = 12600 K (200 K) and $\log(g)$ = 8.10 (0.10) from which they derive a mass of 0.65 (0.05) $M_\odot$. We built a grid of models exploring the space of stellar parameters: $0.60 \le M/M_\odot \le 0.70$; $12400 \le T_{\rm eff}(\text{K}) \le 12800$; $-4 \le \log(M_{\rm He}/M) \le -2$; $-10 \le \log(M_{\rm H}/M) \le -4$.

We computed the adiabatic ℓ=1 and ℓ=2 non-radial oscillation modes for all these models. By comparing their periods with the observed periods through a χ^2 method, we derived a preliminary best-fit model for GD 133 with parameters: $M/M_\odot$ = 0.63; $T_{\rm eff}$ = 12400 K; $\log(M_{\rm He}/M) = -2$; $\log(M_{\rm H}/M) = -4.5$.

4 Conclusions

We have undertaken a photometric follow-up of the ZZ Ceti and DAZ GD 133, which we consider as a promising candidate for the search of a potential planet. As a preliminary result we used the data obtained during the 2011 first multisite campaign to derive preliminary values of the star main parameters. This is a work in progress and the follow-up of GD 133 is going on.

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