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Extreme Amplitude Variations of the Pulsating DB White Dwarf Star PG 1456+103 Traced with the Whole Earth Telescope

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Abstract. PG 1456+103 was chosen as a WET target because it exhibited a complicated pulsation pattern not resolvable with a two-site photometric campaign. Pre-WET observations however showed that the pulsations had almost completely disappeared. They grew back in amplitude during the WET run to reach their "normal" values one month after the global network observations. We document the amplitude changes and discuss them along with possible asteroseismic inferences. We suggest that the total power in the oscillations of pulsating white dwarfs is not conserved when amplitude and frequency changes occur.

1. Introduction and observations

After extensive two-site CCD photometric observations of the pulsating DB white dwarf star PG 1456+103 (Handler et al. 2002) it was deemed worthwhile to devote a large observing effort to it. The reason was that the star's pulsation spectrum could not be resolved with the published measurements, and that evidence for amplitude variations was found. The top panel of Fig. 1 shows the corresponding amplitude spectrum.

However, two weeks before the global observing campaign took place, the pulsation spectrum of the star had considerably changed. The amplitudes had dropped so dramatically that the oscillations were not visible in the light curves, but could only be recovered in the Fourier Transform (second panel of Fig. 1)!

Whole Earth Telescope (WET, Nather et al. 1990) observations of PG 1456+103 were carried out in May 2002 and resulted in over 230 hr of data with a duty cycle of 57%. During the WET run, the pulsations grew back (central panels of Fig. 1). Post-WET measurements (lowest panel of Fig. 1) imply that the pulsation spectrum had stabilized, but...

2. Temporal changes of the individual modes

As a rough general trend, one can state that the lower the frequency, the faster an amplitude change would happen. Particularly remarkable is a fivefold growth of a mode at 1270 μHz within only five days. There are also changes in pulsational phase (or, mathematically indistinguishable, frequency).

In general, whenever there is amplitude variation, there is also phase/frequency variation. This statement is not be reversible, for two reasons. The pulsation amplitudes in the two-site observations by Handler et al. (2002) and those in the post-WET measurements are not explicable with pulsation frequencies found in the WET data alone,

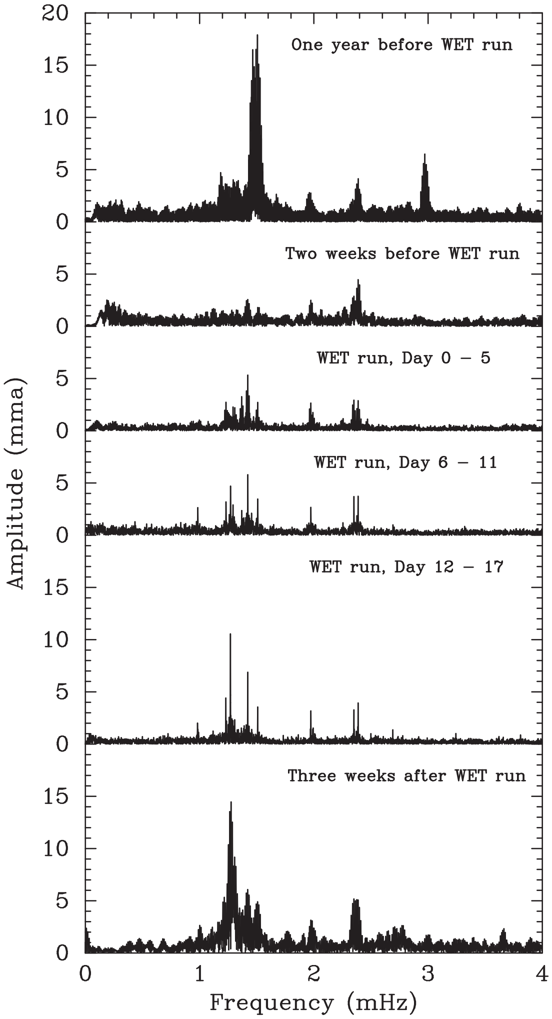

Figure 1. Temporal evolution of the amplitude spectrum of PG 1456+103 in 2001 and 2002. The pulsation modes have frequencies between 0.9 and 2.5 mHz, the other signals are combination frequencies. Whereas the modes above 2 mHz are fairly stable, considerable amplitude changes in the lower-frequency domain occur.

even when allowing for some small frequency variations. In fact, in the post-WET measurements the dominant signal is at $1275\,\mu$Hz, but there is no signal at $1270\,\mu$Hz, which was the strongest mode at the end of the WET run, at about the same amplitude. Postulating a $\sim 5\mu$Hz frequency "jump" of a pulsation mode is unphysical.

3. Mode typing

Despite the variable pulsation spectrum of PG 1456+103, the WET observations allowed the extraction of apparent independent mode frequencies. These are schematically displayed (with their mean amplitudes over the run) in Fig. 2.

As opposed to white dwarf pulsators with secure mode identifications, no mode groupings reveal themselves immediately. The only obvious pattern is a frequency

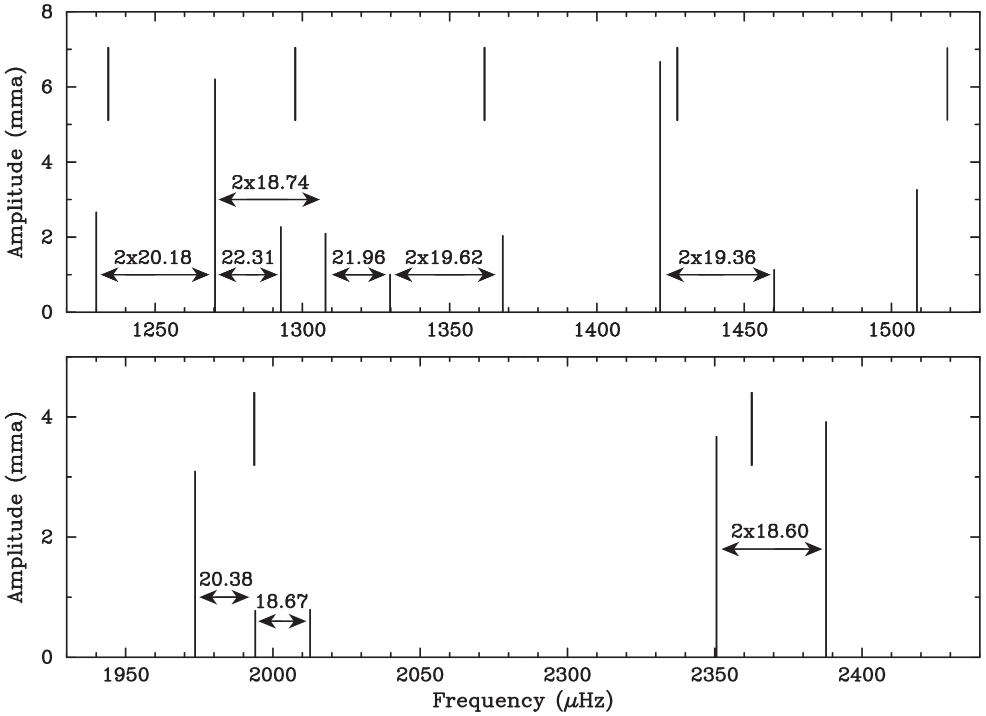

Figure 2. Schematic amplitude spectrum of PG 1456+103 from the WET data. The short lines mark the $l = 1$ mode frequencies of the prototype DB pulsator GD 358.

spacing of about $20\,\mu$Hz, as illustrated in Fig. 2. As the interior structure of white dwarf stars is often alike, one may want to compare the oscillation frequencies of PG 1456+103 to that of other DB pulsators, because their eigenmode spectra should then also be alike. This has been demonstrated for ZZ Ceti stars by Clemens (1994), for instance. Therefore, Fig. 2 also compares the oscillation frequencies of PG 1456+103 to the $m = 0$ frequencies of the prototype DB pulsator GD 358, as derived, amongst others, by Winget et al. (1994) and Provencal et al. (2009).

All independent frequencies of PG 1456+103 are explicable with the pattern provided by GD!358 and the $\approx 20\,\mu$Hz spacing, and are consistent with a purely rotationally split $l = 1$ mode spectrum. If this interpretation was correct, PG 1456+103 would be among the fastest rotating pulsating single white dwarf stars known to date.

4. Concluding remarks

PG 1456+103 joins the ranks of pulsating DB white dwarf stars with rich, but temporally highly unstable pulsation spectra. Given these complications, a full mode identification required for in-depth asteroseismic modeling may only result from further time-resolved measurements with good temporal coverage – or the use of UV (spectro)photometry, even considering our attempt towards an interpretation using an analogy to GD 358. If the oscillation modes of PG 1456+103 were predominantly of low spherical degree – and there is no reason why they should not – the idea that the total pulsation power in white dwarf oscillators is conserved during amplitude changes (Kepler et al. 2003) can no longer be maintained. The amplitude changes are most pronounced for modes of higher radial overtone; less energy is required to affect such modes compared to oscillations of low radial order.

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