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Research Note

A search for pulsations among low-mass DAO white dwarfs

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Abstract. We performed a search for periodic light variations among low-mass DAO white dwarfs. These objects have theoretically been predicted to exhibit low-order g-mode pulsations due to a potent ϵ mechanism in hydrogen-burning shells according to model calculations of Charpinet et al. (1997).

No pulsations were detected in any of our nine candidate stars. This can be attributed to the very narrow instability strip predicted or to the fact that pulsationally unstable modes are not necessarily excited, a common phenomenon among pulsating stars. It may also be the case that hydrogen-burning shells in the stars are too small to drive pulsations or not present.

Key words: white dwarfs – stars: oscillations

1. Introduction

Pulsational driving via nuclear burning (the ϵ-mechanism) has been suspected to be present in a number of different classes of star. Some examples are Wolf-Rayet stars (Maeder 1985), where the driving region is located in the stellar core, or hot central stars of Planetary Nebulae and hot white dwarfs with hydrogen surface layers (Kawaler et al. 1986, Kawaler 1988), whose pulsations are to be powered by nuclear-burning shell sources.

For the latter objects Kawaler (1988) theoretically predicted pulsationally unstable nonradial g-modes under the condition that the stars still contain an active hydrogen-burning shell. Hine (1988) carried out an extensive optical search for such pulsators and did not find any. Kawaler (1988) suggested that this may be due to a fundamental problem in the standard hydrogen-burning models of central stars of Planetary Nebulae. In any case, no class of star whose pulsations are driven by the ϵ mechanism has been observationally detected yet.

Recently, Charpinet et al. (1997) discovered a potent ϵ mechanism operating in their models of post-extreme horizontal branch stars with active hydrogen-burning shells. They predicted luminosity variations with periods in the range 40–125 s in low-mass DAO white dwarfs, suggested to search for such pulsations in these objects and particularly recommended six objects which seem to be the most promising candidates.

In an effort to discover pulsations in low-mass DAO white dwarfs, we photometrically observed five of the stars recommended by Charpinet et al. (1997) plus four further DAO white dwarfs (partly of presently unknown mass). The results of this survey are reported below.

2. Observations, reductions and analysis

Time-series photometric measurements of our targets were acquired during two observing runs at McDonald Observatory, Fort Davis, Texas. Both the 2.1m and 0.9m telescopes were used together with a standard two-channel photoelectric photometer. Continuous integrations on the target star and a comparison star in the field were obtained, only interrupted by sky measurements. No filter was used to maximize the number of photons counted.

Reductions were started with sky subtraction using a piecewise linear or spline fit to our background measurements. Then the data were corrected for extinction. The mean magnitude of each run was set to zero. Remaining long-period variations in the data were removed by low-order polynomial fits, since we were only interested in variations occurring on time scales of 10 minutes and less. Finally, the HJD of each observation was calculated.

These reduced data were subjected to frequency analysis using a modified version of the program PERIOD (Breger 1990). Amplitude spectra of each run were calculated out to the Nyquist frequency of the respective data set, and are shown in Fig. 1 together with some further information.

3. Interpretation of results

We did not detect any coherent periodic variations in the light curves of any of our targets. The detection levels we achieved are generally between 0.7 and 1.5 mmag for each star except for PG 0134+181, where it is about 5 mmag. This star should be reobserved, but its faintness (V=16.12 mag) requires a long run on a fairly large telescope. Ton 353 is the only object suggested to be observed (Charpinet et al. 1997), where we could not acquire

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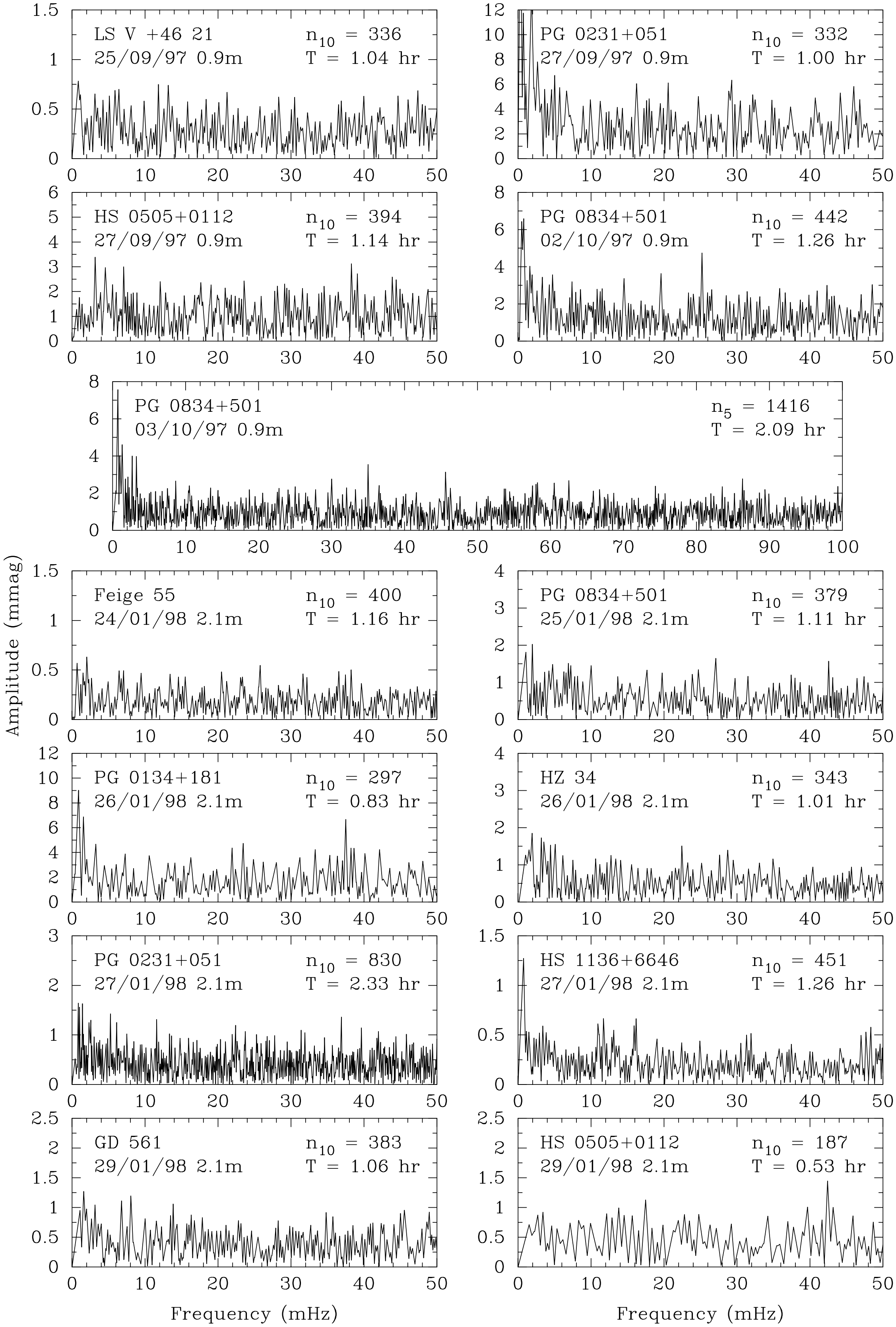

Fig. 1. Amplitude spectra for all our runs in chronological order. They are calculated out to the corresponding Nyquist frequency. The latter is usually 50 mHz, except for the October 3, 1997 observations of PG 0834+501, where it is 100 mHz. Informations about the targets, the telescope, the number of k-second integrations (n_k) on the stars themselves and about the run lengths (T) are also given.

any data. This faint, southern object should be examined for light variations as well.

The only star where one could suspect periodic light variations in the frequency region of interest is PG 0834+501, whose amplitude spectrum of the first run showed some higher peaks. There are also higher peaks in the amplitude spectrum of the second run, but at different frequencies. A combined analysis of both runs (which were taken in consecutive nights) does not show any significant peak. The third run taken on the 2.1m telescope confirms this conclusion.

We can think of three possible explanations of this absence of observed pulsations. First, the instability strip determined by Charpinet et al. (1997) is very narrow. It may simply be the case that all our target stars do not fall into the predicted instability region and hence cannot pulsate. Second, it is a well-known fact that not all stars inside a given instability strip are necessarily pulsators; only a small number of promising objects was available. Mode-selection mechanisms may be at work or our noise levels were too high that we would be able to detect the light variations.

Third, and astrophysically most interesting, it is possible that the evolutionary history of the models used by Charpinet et al. (1997) is different from that of the real stars. The hydrogen layer masses of the progenitors may be too small for a driving region being efficient enough to generate pulsational instabilities. Furthermore, no model is perfect. As an example, stellar winds which may be present in the stars might be sufficient to remove enough hydrogen that a driving region cannot develop.

To conclude, still no class of pulsating star definitely being driven by an ϵ mechanism is known. Pulsating low-mass DAO white dwarfs may exist, but the number of promising objects is still small. Spectroscopic observations will reveal further candidates to be examined for pulsational light variations. This will both increase the chances to find pulsators and contribute to a better understanding of this phase of stellar evolution, even if no variables are found.

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