Baltic Astronomy, vol. 9, 81–86, 2000.

FREQUENCY STABILITIES OF TWO PULSATING WHITE DWARFS

D. J. Sullivan and T. Sullivan

School of Chemical and Physical Sciences, Victoria University of Wellington, P.O. Box 600, Wellington, New Zealand

Received December 6, 1999

Abstract. A report on a New Zealand photometric observing campaign to monitor the frequency stability of specific modes of two pulsating white dwarfs is provided. In addition, the status of two WET campaigns carried out on the objects is summarized.

Key words: stars: pulsating white dwarfs – stars: individual: L 19-2, EC 20058–5234

1. INTRODUCTION

The pulsating white dwarfs have yielded in a variety of ways to the probing of asteroseismology. When a significant number of the rich spectrum of possible g-mode pulsations are detected in the high-speed photometry data, then many properties of the star can be deduced. This can be vividly seen by viewing the results of WET runs on the pre-white dwarf PG 1159–035 and the DBV white dwarf GD 358 (Winget et al. 1991, 1994, Bradley & Winget 1994). But, when few pulsation modes are evident the modelling process is not well constrained. This situation, however, does offer one distinct advantage: the presence of a relatively isolated frequency corresponding to a specific pulsation mode makes the task of measuring period stabilities that much easier. Ideally, if the frequency of the mode can be unambiguously identified from a few hours data, then regular single-site monitoring during successive observing seasons will suffice to track the period stability of the mode.

Kepler and collaborators (eg Kepler, Nather & Metcalfe 1998) have been monitoring a white dwarf for over 20 years that fits into the latter category. The DAV object G 117-B15A (WD 0921+354) has a dominant pulsation mode with a period near 215 *s*. The latest $O - C$ data set for this mode (Kepler et al. 1998, or see Fig. 2 in Sullivan 1999) shows a period (Π) stability that is close to the theoretical upper limit (Bradley, Winget & Wood 1992, Bradley 1996) of $d\Pi/dt = \dot{\Pi} \sim 10^{-15}\,\mathrm{ss}^{-1}$.

Anchored by recent WET runs, two objects have been part of a NZ campaign to monitor the stability of pulsating white dwarf pulsation modes. One of these is a southern hydrogen atmosphere white dwarf ($T_{\mathrm{eff}} \approx 12\,000$ K) that now has a data set that spans a period of over 20 years, and the other is a recently discovered (also southern) helium atmosphere white dwarf ($T_{\mathrm{eff}} \approx 25\,000$ K). Brief statements of the existing position follow.

2. THE DAV WHITE DWARF L 19–2

L 19–2 (MY Aps, WD 1425–811) was studied extensively over a period of six years up to 1985 by O'Donoghue & Warner (1987) using high-speed photometry techniques. Their asteroseismological analysis included a result that two of the pulsation modes had a period stability of $\dot{\Pi} < 2 \times 10^{-14}\,\mathrm{ss}^{-1}$.

In order to extend their analysis, including the monitoring of the period stability of these modes, a WET run (XCOV12) was undertaken on the object in 1995. Single-site photometry has been carried out at Mt. John University Observatory in NZ since the WET run, in order to further extend the time base for the stability analysis. Taken together, the discovery data (McGraw 1977, Hesser, Lasker & Neupert 1977), the O'Donoghue & Warner data, the WET data and the recent NZ work provide a time frame that rivals that for G 117–B15A. It is expected that the $\dot{\Pi}$ constraints will also be competitive.

To date, several brief summaries of the state of the analysis of the combined data set on this star have appeared in the literature (Sullivan 1995, 1998a, 1998b), but a comprehensive WET paper has not surfaced. This omission is currently being rectified (Sullivan et al. 2000a).

3. THE DBV WHITE DWARF EC 20058–5234

The helium atmosphere white dwarf EC 20058–5234 (QU Tel, WD 2006–523) was first identified by the Edinburgh–Cape survey of

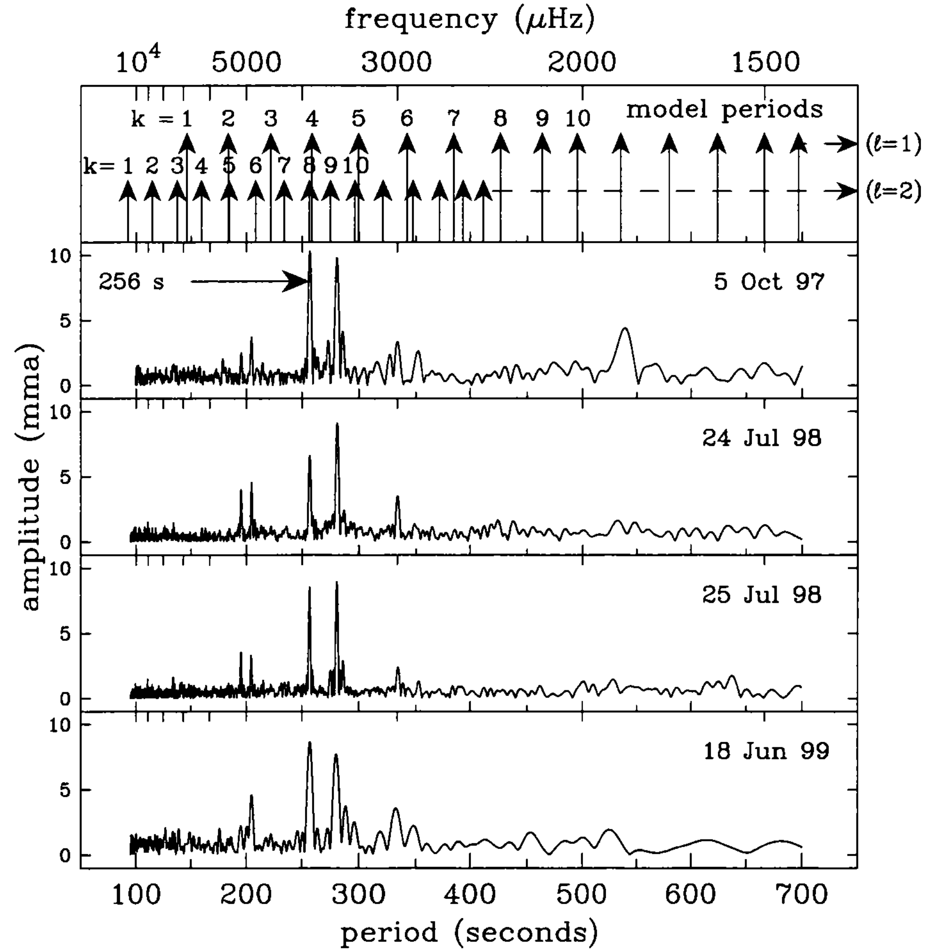

Fig. 1. DFT amplitude spectra of the observed pulsation behaviour of the DBV white dwarf EC 20058-5234, together with model predictions. The observational data derives from single-site photometry obtained at Mt. John University Observatory in NZ, while the model frequencies were obtained from the work of Bradley (1993, 1996).

faint blue stars (Stobie et al. 1997), and its classification and properties were first reported by Koen et al. (1995). High-speed photometry revealed the presence of a number of frequencies in the mHz region, but the limited single-site data set restricted the asteroseismological analysis of the star. With the aim of furthering this analysis, a WET run was undertaken in July 1997, and four southern sites obtained high-speed photometry on the object. The superior multi-site

WET data substantially improved the frequency specification of the pulsation behaviour of the star. In particular, one of the dominant pulsation modes (with a period near 256 s), was shown to be sufficiently isolated in frequency space that it was fully resolvable with high-speed photometry of only several hours duration. Following this discovery, a NZ observing programme was established in order to monitor the freqency stability of this mode.

Fig. 1 shows the DFT amplitude spectra of a number of EC 20058–5234 runs obtained at Mt. John Observatory since the WET run. For comparison purposes, a set of model periods from the work of Bradley (1993, 1996) have been included. No attempt has been made to optimise the model choice in the light of the experimental data, but the plot does reveal that additional observed periods will be required to reasonably constrain models of the star.

Theoretical predictions of the $\dot{\Pi}$ for pulsation modes of the DBV white dwarfs are a factor of 10 larger than the expected DAV rate, largely because of the much higher $T_{\rm eff}$, but partly due to the non-negligible neutrino energy loss. These $\dot{\Pi}$ estimates range from $10^{-13}\,{\rm ss}^{-1}$ to $10^{-14}\,{\rm ss}^{-1}$ (Bradley, Winget & Wood 1993, Bradley 1993). The existing EC 20058–5234 data set now spans 5 years, and it is anticipated the $O-C$ values will be challenging these theoretical predictions.

A full WET paper reporting on both the WET data and the current state of the frequency stability analysis is in preparation (Sullivan et al. 2000b).

4. DISCUSSION

The currently accepted theories of the nucleosynthesis that occurred in the big bang (Bernstein et al. 1989, Schramm & Turner 1998), and continually occurs in stellar interiors (e.g. Wallerstein et al. 1997), predicts that the the cores of white dwarfs all contain a combination of ^{12}C and ^{16}O nuclei. This prediction is a triumph for the field of nuclear astrophysics and, as the great majority of stars pass through the white dwarf stage on their way to oblivion, it deserves to be tested.

The nuclear physics that leads to the white dwarf core prediction is beautiful to behold (e.g. see Rolfs & Rodney 1988), and is essentially based on the relative rates of 3 important reactions: the triple–α formation of ^{12}C, the ^{12}C$(\alpha,\gamma)^{16}$O reaction, and the ^{16}O$(\alpha,\gamma)^{20}$Ne reaction. Due to the well-understood ^{20}Ne energy level structure at the $^{16}O+\alpha$ entrance channel, corresponding to stellar interior energies, there is little doubt that oxygen α–burning is effectively blocked in the typical red giant interior. But, the relative amounts of ^{12}C and ^{16}O that remain is critically dependent on the $^{12}C+\alpha$ capture rate relative to the triple–α capture rate. To quote Wallerstein et al. "The rate of this reaction is responsible for one of the most important uncertainties in nuclear astrophysics today".

What has white dwarf asteroseismology got to do with this? In fact, the best hope of measuring the interior chemical composition of white dwarfs is by comparing observed period time derivatives with model predictions. The physics is appealingly simple: the nuclear species in the stellar core have a direct impact on the heat capacity of the object which affects the cooling time. A change in this timescale impacts on $\dot{\Pi}$. We are not really there yet, and as always, there are complications, such as the contribution of (a perhaps) uncertain total mass. Nevertheless, $\dot{\Pi}$ measurements are really the only way of probing the chemical compositions. As time progresses, measured constraints on white dwarf core compositions are improving.

And of course, as members of the white dwarf community have been saying for years: measure white dwarf cooling times and identify the oldest white dwarfs, and then you can contribute to the debate about the age of the galactic disk (e.g. Wood 1992) and the age of the universe itself.

ACKNOWLEDGMENTS. We thank the International Institute for Theoretical & Applied Physics (IITAP), based at Iowa State University, for generous financial support enabling both of us to attend the 5th WET Workshop, and the conference organisers (Gerard Vauclair, Noel Dolez and their team) for underpinning a most successful and enjoyable meeting. We would also like to thank Mt. John University Observatory, which is operated by the University of Canterbury in New Zealand, for the generous allocation of telescope observing time to this work, and the VUW Science Faculty Grants Committee for financial support.

REFERENCES

Bernstein J., Brown L. S., Feinberg G. 1989, Rev. Mod. Phys., 61, 25
Bradley P. A. 1993, PhD Thesis, The University of Texas at Austin
Bradley P. A. 1996, ApJ, 468, 350
Bradley P. A., Winget D. E. 1994, ApJ, 430, 850

Bradley P. A., Winget D. E., Wood M. A. 1992, ApJ, 391, L33.
Bradley P. A., Winget D. E., Wood M. A. 1993, ApJ, 406, 661.
Hesser J. E., Lasker B. M., Neupert H. E. 1977, ApJ, 215, L75
Kepler S. O., Nather R. E., Metcalfe T. S. 1998, in *The Fourth WET Workshop Proceedings*, eds. E. G. Meištas & P. Moskalik, Baltic Astronomy, 7, 175
Koen C., O'Donoghue D., Stobie R. S., Kilkenny D., Ashley R. 1995, MNRAS, 277, 913
McGraw J. T. 1977, ApJ, 214, L123
O'Donoghue D., Warner B. 1987, MNRAS, 228, 949.
Rolfs C. E., Rodney W. S. 1988, Cauldrons in the Cosmos: Nuclear Astrophysics, University of Chicago Press
Schramm D. N., Turner M. S. 1998, Rev. Mod. Phys., 70, 303
Stobie R. S. et al. 1997, MNRAS, 287, 848
Sullivan D. J. 1995, in *The Third WET Workshop Proceedings*, eds. E. G. Meištas & J.-E. Solheim, Baltic Astronomy, 4, 261
Sullivan D. J. 1998a, *A Half Century of Stellar Pulsation Interpretations*, ASP Conference Series 135, 62
Sullivan D. J. 1998b, in *The Fourth WET Workshop Proceedings*, eds. E. G. Meištas & P. Moskalik, Baltic Astronomy, 7, 159
Sullivan D. J. 1999, in *11th European Workshop on White Dwarfs*, eds. J.-E. Solheim & E. G. Meištas, ASP Conference Series 169, 85
Sullivan D. J. et al. (the WET collaboration) 2000a (in preparation)
Sullivan D. J. et al. (the WET collaboration) 2000b (in preparation)
Wallerstein G., Iben I., Parker P. et al. 1997, Rev. Mod. Phys., 69, 995
Winget D. E. et al. (the WET collaboration) 1991, ApJ, 378, 326
Winget D. E. et al. (the WET collaboration) 1994, ApJ, 430, 839
Wood M. A. 1992, ApJ, 386, 539