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# FOUR RAPIDLY PULSATING sdB STARS REVISITED

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**Abstract.**
We have re-observed four rapidly-pulsating sdB stars during 2003 and 2004 and compared the results to earlier observations. The class prototype, EC 14026–2647, had a weak frequency which has apparently disappeared, whilst a new frequency has appeared. In EC 20338–1925, the strongest frequency (6806 $\mu$Hz; ampl. 0.026 mag) has reduced to about 0.004 mag, and weaker frequencies have come and gone. Between 1997 and 2004, the complex pulsator, PG 1605+072, has had its strongest frequency ($f_1$) halve in amplitude, $f_3$ and $f_4$ double in amplitude, whilst $f_2$ has remained essentially constant. Finally, HS 2149+0847 shows no significant change between 2003 and 2004, but we have increased the number of known frequencies from two to six.

**Key words:** stars: oscillations – stars: horizontal-branch

## 1. INTRODUCTION

The existence of a new class of variable star – the rapidly pulsating sdB stars – was reported by Kilkenny et al. (1997). These stars have been called EC 14026 stars, after the prototype, though they are also referred to as sdBV stars and the prototype is now designated V361 Hya. They pulsate with very short periods (typically $\sim$ 2 to 3 minutes); they usually have several oscillation frequencies; they have surface temperatures around $28000 < \mathrm{T_{eff}} < 35000$ K and surface gravities $5.2 < \log g < 6.1$. Reviews of pulsating sdB stars have been given by Kilkenny (2002) and Charpinet, Fontaine & Brassard (2001) for example.

The EC 14026 stars provide potential for examination of the internal structure of hot subdwarfs via the identification of pulsation modes. In addition, it is clear that the rapidly pulsating sdB stars can undergo quite significant changes in their pulsational behaviour. For example, a comparison of the 1996 data for PG 1336–018, with the 1999 data from the "Whole Earth Telescope" campaign (Xcov17), shows that the main pulsation frequencies in that star had changed substantially – and were changing from day to day (see Figs 7 – 9 of Kilkenny et al. 2003)

The South African Astronomical Observatory (SAAO), in collaboration with several South African Universities, has set up a programme – the National Astrophysics and Space Science Programme (NASSP) – to provide training at graduate level in Astronomy and Astrophysics for students from Africa. Part of the honours course is a practical project and some students opt to do this at the Sutherland site of the SAAO. So far, students have carried out observational projects on four pulsating sdB stars, obtaining data sets with baselines up to 14 days – comparable in length to a "WET" campaign but with only one site. Some results are presented below and compared to earlier data.

## 2. OBSERVATIONS

Observations were made with the University of Cape Town's frame-transfer CCD on the 1.9m and 1.0m telescopes at the Sutherland site of the SAAO. Where possible, target stars were diffferentially corrected using other stars on each frame. The frequency analyses described in this paper were all carried out using software which produces periodogram analysis following the Fourier transform method of Deeming (1975).

## 3. RESULTS

### *3.1. EC 14026–2647*

EC 14026–2647 is the class prototype, but is somewhat atypical. It is dominated by a single frequency and appears at times to show only that frequency. Periodograms from the discovery paper (Kilkenny et al. 1997) reveal a frequency at 6930 $\mu$Hz (144.3 s) with an amplitude of $\sim$ 0.012 mag but, on a few nights, a clear frequency at 7485 $\mu$Hz (133.6 s; 0.004 mag) is also visible.

The more recent data (2003 July) again shows the 144s variation, except that the amplitude is only about 0.007 mag – half that previously seen – and two nights show a frequency near 7265 $\mu$Hz (P $\sim$ 137.6s). The previously seen frequency near 7485 $\mu$Hz is not detected.

### *3.2. EC 20338–1925*

EC 20338–1925 was discovered to be a pulsator in 1998 (paper in preparation). At that time, the variability was dominated by a very strong frequency near 6806 $\mu$Hz (146.9 sec; 0.026 mag) but four other much weaker frequencies were clearly present. The same five frequencies were found from data obtained in 1998 July and September, although there is some indication of changes in amplitude in some frequencies.

In 2003 July, two runs of just over 6 hours each were obtained on successive nights. The most obvious change is that the very strong frequency near 6806 $\mu$Hz has decreased in amplitude from 0.026 mag to 0.004 mag. It is also apparent that a frequency near 7425 $\mu$Hz (135 sec; 0.002 mag) has disappeared in the 2003 data and a new frequency near 7913 $\mu$Hz (126 sec; 0.004 mag) has appeared.

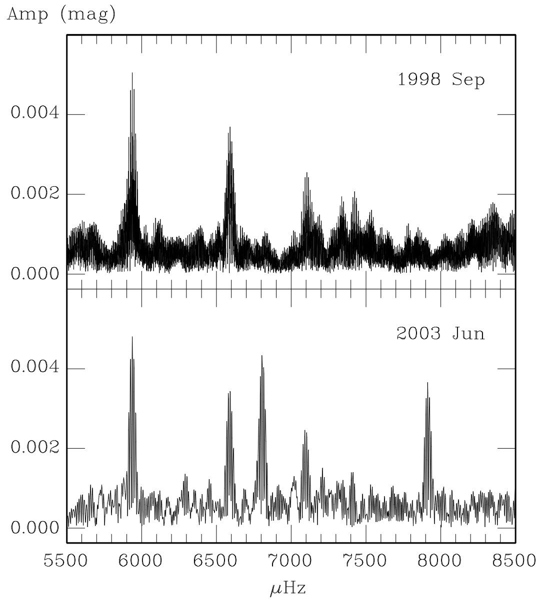


**Fig. 1.** Peridograms for EC 20338-1925 for 1998 Sep and 2003 July. The strong frequency (0.026 mag) near 6805 $\mu$Hz has been removed from the 1998 Sep data to allow other frequencies to be seen. The most dramatic difference between 1998 and 2003 is that this frequency has dropped to an amplitude of 0.004 mag in 2003. The frequency near 7425 $\mu$Hz has disappeared from the 2003 data and a completely new frequncy near 7913 $\mu$Hz has appeared.

### *3.3. HS 2149+0847*

HS 2149+0847 was discovered to be a pulsating sdB star by Østensen et al., (2001). Two short runs showed two clear frequencies near 6.3 mHz (0.011 mag) and 7.1 mHz (0.007 mag) with a possible third frequency near 6.7 mHz (0.002 mag). We obtained 4 runs on HS 2149+0847 during 2003 July and 10 runs during 2004 June. In both sets of data, we find the same six frequencies (see Fig 2) and there seems little evidence for any significant changes between the two dates.

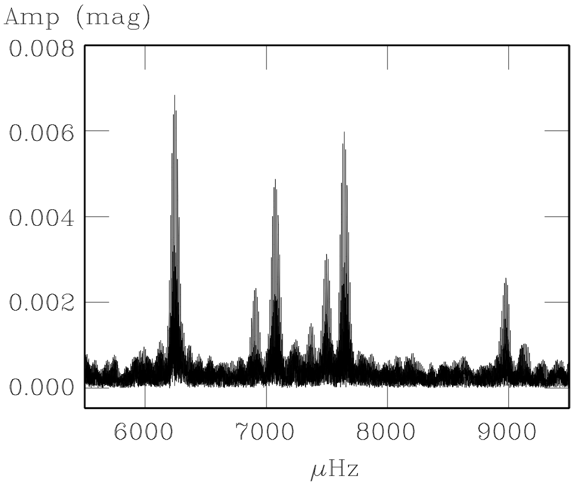


**Fig. 2.** Periodogram for HS 2149+0847 for @004 June (10 nights).

### *3.4. PG 1605+072*

PG 1605+072 was discovered to be an sdB pulsator by Koen et al. (1998). It is the largest amplitude pulsator known and has a remarkable number of frequencies resolved ($> 40$) as was shown in both the discovery paper and in 1997 by Kilkenny et al. (1999). It is also unusual in that most of its pulsation modes are of rather longer period than in the other rapidly pulsating sdB stars ($\sim 350 - 550$ seconds) – probably due to the lower surface gravity.

During the 2004 NASSP student project, PG 1605+072 was observed on twelve nights out of two weeks. The 1997 data – split into two separate weeks – seem consistent between the two weeks, but significant changes are obvious between the two weeks in 2004 and between 2004 and 1997. Such changes are not unexpected – they were noted between the discovery data of Koen et al. (1998) and the campaign reported by Kilkenny et al. (1999).

Between 1997 and 2004, the four strongest frequencies are still the strongest, but their "rank" is reversed. Using the Kilkenny et al. (1999) nomenclature, $f_3$ and $f_4$ have more than doubled in amplitude; $f_1$ has more than halved, while $f_2$ is about the same. Many of the strongest remaining frequencies from 1997 are still found in the top twenty, though $f_7$ is absent and a number of "new" frequencies have appeared.

## 4. CONCLUSIONS

The phenomenon described above is not new – several authors have noted changing amplitudes – but these raise some questions:

- Are these changes related to the growth and decay of normal modes ? This seems likely, but why does this happen ?
- On what sort of time scale(s) are the changes happening ?
- If these are normal modes, will repeated observation of the stars enable us to map out a more substantial frequency set for analysis ?

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