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Exciting new features in the frequency spectrum of the EC 14026 star HS 0702+6043

Simultaneous g-modes and p-modes in a sdB pulsator

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Abstract. The discovery of a long-period g-mode oscillation in the previously known short-period p-mode sdB pulsator HS 0702+6043 makes this star an extraordinary object, unique as a member of the family of sdB pulsators, and one of the very few known pulsating stars overall exhibiting excited modes along both the acoustic and gravity branches of the nonradial pulsation spectrum. Because p-modes and g-modes probe different regions of a pulsating star, HS 0702+6043 holds a tremendous potential for asteroseismological investigations. We present preliminary results from the first extended campaign on this object.

Key words. stars: oscillations – stars: subdwarfs – stars: individual: HS 0702+6043

1. The two classes of sdB pulsators

Subdwarf B stars populate the extreme horizontal branch (EHB) in the effective temperature range of 22 000 to 40 000 K and have surface gravity values from $\log g$=5.0 to 6.2 in cgs units. The masses of these hot, evolved objects cluster around 0.5 $M_{\odot}$. They are believed to be core helium-burning but with hydrogen envelopes too thin to sustain H-shell burning. Standard tracks of stellar evolution do not cross the EHB region since they do not produce inert hydrogen envelopes; the evolutionary history of sdBs largely remains a puzzle.

SdB internal structure might be investigated through the multi-mode oscillations exhibited by a fraction of sdB stars. One sdBV group known as EC 14026 variables shows short-period p-mode pulsations with periods of a few minutes and amplitudes of a few tens mmag. The more recently discovered lpsdBV (long-period sdB variables, the prototype is PG 1716+426) pulsate in g-modes of about 30-80 min at mmag amplitudes. A κ mechanism drives the low-order p-modes, where the required opacity bump is due to iron accumulated by diffusion. The same κ mechanism can also drive high-order g-modes, so that the sdBV / lpsdBV groups might have a main sequence analogy in the β Cep / [SPB] variables

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(high / low frequency, high / low temperature). Theoretical aspects are discussed in more detail by Charpinet et al.; Fontaine et al.; and Randall et al. (all these proceedings).

2. The hybrid object HS 0702+6043

In a 1998 / 1999 search program for sdB variables, we discovered the m_B=15 star HS 0702+6043 as one of the coolest, high-amplitude sdBV pulsators (Dreizler et al., 2002). Its stellar parameters (28 400 K, $\log g$=5.35) place HS 0702+6043 at the cool end of the EC 14026 instability region.

We subsequently demonstrated the existence of an additional photometric variation at a much longer time-scale of 1 h. This initial discovery was confirmed by further data obtained under excellent observing conditions during two nights in February 2004. The detection suggested a complex nature of the amplitude structure in the low-frequency range, excluding alternative explanations such as binarity or rotation at a high level of confidence. Due to this clear pulsational character of the variations, HS 0702+6043 must be regarded as a member of both classes and represents the first hybrid object that exhibits both p- and g-mode pulsations (Schuh et al., 2005). To resolve the sub-structure in the low-frequency range, a dedicated 10-day coordinated campaign was organised in January 2005 at the 2.2 m Calar Alto (Spain) and the 1.55 m Steward telescope on Mount Bigelow (U.S.A.).

The dominant feature in the frequency spectrum is a 2754 μHz (363 s, f_1) pulsation at an amplitude of $\approx$22-29 mmag. A second short period at 2606 μHz (383 s, f_2) at a much smaller amplitude of $\approx$4 mmag was suspected in the 1999 data, and confirmed in the 2004 and 2005 data. The value published for f_2 in Dreizler et al. (2002) is separated by one daily alias from the current determination.

In the longer-period range, a peak near $\approx$ 1 h is marginally significant in the 1999 data, and clearly detected in the 2004 data. There is residual power above the 3σ detection level, determined from false alarm probability analysis, after prewhitening of one sinusoidal period in the low-frequency range from the 2004 data. This complex structure can either be attributed to the phase discontinuities and amplitude variability (a quasi-periodic behaviour characterstic of many of the known long-period sdB pulsators) or, when the amplitude variability is interpreted as beating, suggests the presence of unresolved frequencies. In the 2005 data, the highest peak in the low-frequency range (f_3=271μHz, or 3690 s) is consistent with the previous detection, and it is, at the better frequency resolution now available, *no longer consistent* with a value of $2(f_1 - f_2)$, as suggested previously. The new data are generally much noisier, with significant very-low frequency contributions due to atmospheric instability complicating the analysis, and require further work.

3. Overlapping instability regions

The identification of HS 0702+6043 as a member of *both* classes of sdB pulsators simultaneously implies that the instability regions overlap. One important consequence of this is that other such hybrid objects, which are of considerable interest in asteroseismology since the different modes probe different regions of a pulsating star, might exist. And indeed, following the initial announcement of HS 0702+6043 (Schuh et al., 2005), a second such object has been published (Balloon 090100001: Oreiro et al. 2004 / Baran et al. 2005).

It is interesting to note that a hybrid δ Sct and γ Dor object has also been found, following the prediction of the likely existence of such stars with both δ Sct p-modes and γ Dor g-modes oscillations by Dupret et al. (these proceedings).

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