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"Hybrid" pulsators - fact or fiction?

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Abstract

We carried out a multi-colour time-series photometric study of six stars that were claimed as "hybrid" p- and g-mode pulsators in the literature. The β Cep/SPB star γ Peg was confirmed and revealed excellent asteroseismic potential. HD 8801 was confirmed as a "hybrid" δ Sct/γ Dor star; additional pulsation frequencies were detected. 53 Psc likely is an SPB star and the O-type star HD 13745 showed small-amplitude slow variability. No light variations were detected for HD 19374 and, surprisingly, ι Her.

Individual Objects: γ Peg, 53 Psc, HD 8801, HD 13745, HD 19374, ι Her

Introduction

Stars can self excite observable pulsations if an excitation mechanism operates in a resonant cavity in their interior or on their surface. Since this is only fulfilled under certain physical conditions, pulsating stars are located in different instability domains in the HR diagram. These instability strips are not necessarily distinct. Stars having two different sets of pulsational mode spectra excited simultaneously may therefore exist within overlapping instability strips. This is good news for asteroseismology, as both types of oscillation can be exploited to obtain a more complete picture of the stellar interior.

Following this idea, Handler et al. (2002) discovered a star that showed both γ Doradus type g modes and δ Scuti type p modes. However, at least some of the g modes may have been excited through tidal effects from a close companion in an eccentric orbit. Nevertheless, following this discovery several such "hybrid" pulsators were reported in the literature. Henry & Fekel (2005) discovered both γ Doradus and δ Scuti type pulsations in a single Am star, and the MOST satellite found two additional examples (King et al. 2006, Rowe et al. 2006), both of which are again Am stars.

Among the B type stars, "hybrid" SPB/β pulsations have been reported for several objects (e.g., see Jerzykiewicz et al. 2005, Handler et al. 2006, Chapellier et al. 2006, De Cat et al. 2007). In addition, two subdwarf B stars were also discovered to show "hybrid" oscillations (Oreiro et al. 2005, Baran et al. 2005, Schuh et al. 2006). The main physical difference between the B type and A/F type "hybrid" pulsators is that in the first group the same driving mechanism excites both types of oscillation, whereas in the δ Sct/γ Dor stars two different driving mechanisms are at work.

Besides all the exciting possibilities that "hybrid" pulsators offer for asteroseismology, the major observational problem that needs to be solved before arriving at a unique seismic model still remains the same - or is even more severe: a sufficiently large number of pulsation modes must be detected and identified - in *both* frequency domains. Consequently, the best targets for asteroseismic studies need to be identified before embarking on large-scale projects. To

this end, we have selected six stars that have been claimed as "hybrid" pulsators in the literature for such an exploratory study, comprising one main sequence A/F star and five O/B stars.

Observations and results

We carried out time-series (u)vy photometry of these six stars of the 0.75-m Automatic Photoelectric Telescope (APT) T6 at Fairborn Observatory in Arizona, between October 2007 and June 2008. An overview of the observations and the results is given in Table 1.

Table 1: Results of our photometric survey. ΔT is the time span of the data set, T_{tot} is the total number of hours observed, N_{tot} is the number of nights observed, and N_{obs} is the number of data points obtained.

Star	ΔT	T_{tot}	N_{tot}	N_{obs}	Filters	Classification
γ Peg	69	284	48	884	uvy	"hybrid" SPB/β Cep star
53 Psc	69	281	48	861	uvy	SPB star
HD 8801	69	272	48	737	vy	"hybrid" γ Dor/δ Sct star
HD 13745	69	243	47	616	uvy	slowly variable
53 Ari	69	283	48	927	uvy	not found to vary
ι Her	78	118	45	498	uvy	not found to vary

HD 8801 was confirmed as a "hybrid" γ Dor/δ Sct star, as were all frequencies found in the discovery data (Henry & Fekel 2005), allowing for some aliasing ambiguities. In particular, we confirm the presence of several frequencies intermediate between the γ Dor and δ Sct domains. Their origin remains to be understood; an explanation in terms of binarity is unlikely given that HD 8801 seems to be a single star. Additional pulsation frequencies were detected in the two lower-frequency domains in our data.

Our measurements of 53 Psc are consistent with two close frequencies around 0.87 cycles/day. Their uvy amplitudes are consistent with an interpretation in terms of low-order g-mode pulsation. No β Cep-type pulsations were detected within a limit of 0.8 mmag. We note that the presence of β Cep pulsation of 53 Psc has already been disputed in the literature (Le Contel et al. 2001, De Cat et al. 2007), but we observed it anyway due to its proximity to γ Peg in the sky.

The O-type star HD 13745 was claimed to be a "hybrid" β Cep/SPB star by De Cat et al. (2007), which would be particularly interesting given its spectral classification. However, our measurements only showed a complex, low-amplitude variation with a time scale of $\sim$ 3.2 d, and no evidence for β Cep pulsation within a limit of about 1 mmag.

The stars 53 Ari and ι Her showed no discernible variability in our measurements, within a (generous) 1.5 mmag limit. This is particularly surprising for ι Her because this star has repeatedly, and convincingly, been reported as variable in the literature (Chapellier et al. 2000 and references therein).

Our most encouraging result was the clear confirmation of the "hybrid" nature of γ Peg; four g modes and two (previously known) p modes were detected. We took this as a motivation for an extended observational effort on the star, involving high-precision photometry with the MOST satellite aided by high-resolution multisite spectroscopy and ground-based multicolour photometry to facilitate pulsational mode identification. Preliminary results indicate the presence of additional g modes and of a virtually complete set of $l = 0 - 2$ modes in the domain of excited β Cephei-type modes.

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