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Mode identification from spectroscopy of gravity-mode pulsators

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Abstract. The gravity modes present in γ Doradus stars probe the deep stellar interiors and are thus of particular interest in asteroseismology. For the MUSICIAN programme at the University of Canterbury, we obtain extensive high-resolution echelle spectra of γ Dor stars from the Mt John University Observatory in New Zealand. We analyze these to obtain the pulsational frequencies and identify these with the multiple pulsational modes excited in the star. A summary of recent results from our spectroscopic mode-identification programme is given.

Keywords. line: profiles, techniques: spectroscopic, stars: oscillations (including pulsations)

1. Introduction: why are γ Dor stars interesting?

The γ Doradus stars are of particular interest in asteroseismology for a number of reasons. First, the γ Dor stars are defined as A-F type main sequence (or close to main sequence) stars that display gravity-modes (g-modes) of high radial order. These g-modes probe the deep interior of the stars and thus provide us with a probe of the structure and evolutionary changes that occur in regions as deep as the core. Second, some "hybrid" γ Dor/δ Scuti stars also undergo simultaneous pressure-mode pulsations which probe the outer convective envelopes of these stars. Finally, it is possible that solar-like oscillations may also occur in such stars, which would supply information about time and distance scales for convective processes. Although a star showing all three types of variability (g-modes, p-modes and solar-like variability) is yet to be discovered, it is intriguing that this region of the H-R diagram would allow such a star to exist.

2. Results from our extensive high-precision time series spectroscopy

For our MUSICIAN programme at the University of Canterbury, we have obtained extensive, high-resolution echelle spectra of the g-mode γ Dor pulsators and related stars, using the 1.0-m McLellan telescope and the high-resolution fibre-fed HERCULES spectrograph at the Mt John University Observatory. The observatory is at latitude 43°59.2′ S and longitude 170°27.9′ E and is thus at a useful longitude to obtain multi-site data in association with sites in Chile, Australia and South Africa. This is an ideal set-up for undertaking long time-series echelle spectra of bright stars ($V \lesssim 9$).

A description of our observational, reduction and analysis techniques is given in Brunsden *et al.* (these proceedings). Our intent is to obtain reliable mode identifications that can constrain the theoretical models of γ Dor stars. In particular we are looking at the way that g-modes differ from p-mode pulsations and the effects of stellar rotation on the mode identification. Rotational effects appear to be important since the rotational

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Table 1. A summary of our spectroscopic mode identifications of γ Dor stars.

Identifier	v sin i (km s^{-1})	Frequency (d^{-1})	Photometric	Spectroscopic	Reference
HD 12901	64	1.3959(2)	1	1,1	1, 3, 5
		1.1862(2)	1	1,1	1, 3, 5
		1.6812(2)	1	1,1	3, 5
		1.2156(2)	1	1,1	1, 3, 5
		1.5596(2)	1	1,1	3, 5
HD 27290 (γ Dor)	57	1.3641(2)		1,1	2, 5
		1.3209(2)		3,3 or 1,1	2, 5
		1.4712(3)		1,1 or 2,0	2, 5
		1.8783(2)		1,1	5
HD 40745	44	0.7523(5)		2,−1	8
		1.0863(7)		3,−3 or 2,−2	8
HD 55892 (QW Pup)	51	0.055972(4)		1,−1	6, 9
		0.064846(4)		4,−1	6, 9
		5.219398(2)		4, 2	6, 9
HD 65526	59	2.616		1,−1	7
		1.840		1,−1	7
HD 112429	116	0.0515(3)		1,−1	6
HD 135825	40	1.3150(3)		1,1	4, 5
		0.2902(4)		2,−2	4, 5
		1.4045(5)		4,0	4, 5
		1.8829(5)		1,1	4, 5
HD 139095	64	2.353		2±1,1±1	9
HD 189631	38	1.6774(2)		1,1	5, 7
		1.4172(2)		1,1	5, 7
		0.0714(2)		2,−2	5, 7
		1.8228(2)		1,1 or 1,1	5, 7

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and pulsational frequencies are of the same magnitude. We note that identification of modes as either p-mode or g-mode based purely on the observed frequency, rather than the co-rotating frequency, is uncertain unless the rotational frequency is known.

Table 1 summarises the significant number of γ Doradus stars spectroscopic pulsation mode identifications that we have obtained. This is credited to extensive, high-resolution datasets and sophisticated analysis techniques. We can contribute these, and further results, to constrain stellar structure and seismic models of γ Doradus stars. We hope to further refine our analysis methods, and thus our inputs to the stellar structure models, through a more thorough investigation and understanding of the effects of rotation on stellar pulsations.

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