Towards asteroseismology of main-sequence g-mode pulsators: Spectroscopic multi-site campaigns for slowly pulsating B stars and γ Doradus stars

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1. INTRODUCTION

In 2007, we started a project, dedicated to main-sequence g-mode pulsators to improve the mode identification techniques for g-mode pulsators and to study the relation between rotation and pulsation from an observational point of view. We therefore selected a sample of slowly pulsating B stars (SPB) and γ Doradus (γDor) stars with a large spread in projected rotational velocity as targets for dedicated spectroscopic multi-site campaigns (see Table 1). For these targets, photometric observations show multiperiodic variations and/or clear line profile variations (LPVs) have been observed, making them some of the best candidates available for total characterisation of the pulsation modes. With these multi-site campaigns, we aim to provide both a reliable identification of the strongest modes (degree *l* and azimuthal number *m*) and severe restrictions on stellar parameters (including the effective temperature, surface gravity, metallicity, inclination and rotation speed), allowing asteroseismic modelling to become possible for these types of stars. Currently, 11 observatories, including Okayama Astrophysical Observatory, which all have excellent high-resolution spectroscopic facilities, are involved in our observational efforts (see Table 2). In this poster, we introduce the sample of selected objects and give an overview of the multi-site campaigns that have been organised up to now.

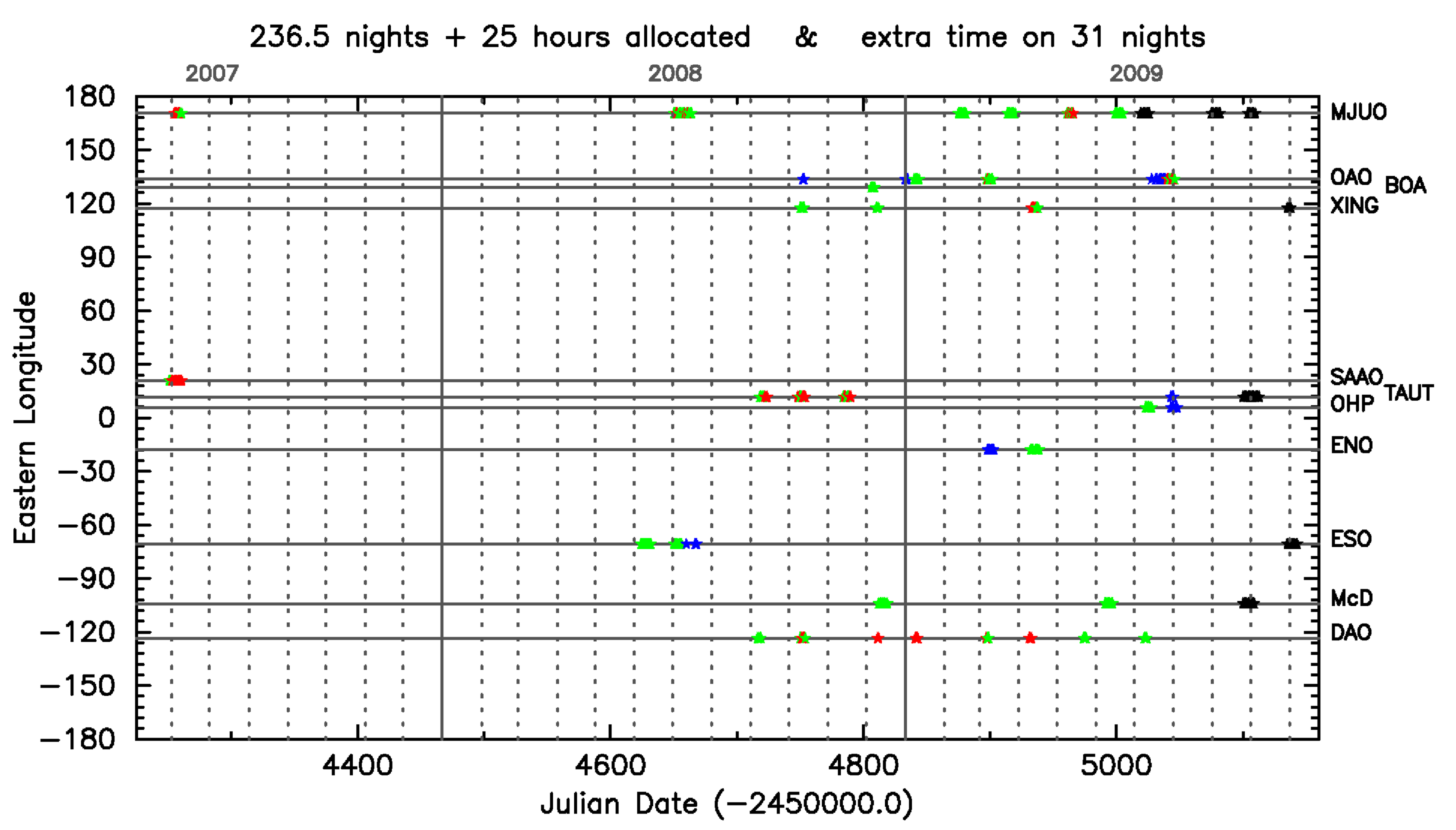

Figure 1. Overview of the nights allocated to our multi-site campaigns so far. Green denotes that at least one usable observation has been taken that night, red means that no observations could be done, blue denotes extra time obtained by our collaborators, and black is an upcoming allocated night.

2. OBSERVATION STRATEGY

To study the **g-modes** in full detail (expected periods between 0.3 and 3 days), we need a long timebase covered with observations every few hours. To additionally check if short-term **p-mode** like variations are present (expected periods of a few hours), we need groups of consecutive exposures with short integration times. Therefore we currently observe in two modes:

Low cadence mode for spectrographs with small wavelength coverage where a single exposure has S/N ≥ 200 and exposure time ≤ 1 hour. Bright targets with exposure times ≤ 10 min are observed in groups of 5 consecutive spectra to search for **p-modes**.

High cadence mode for spectrographs with a large wavelength coverage where groups of five S/N ≥ 90 spectra are taken each with exposure time ≤ 10 min. LSD profiles (Donati et al., 1997, MNRAS 291, 658) are used to study the high **p-mode** frequencies and individual lines are used to study the lower **g-mode** frequencies.

In Table 1, we list the number observations obtained so far in the low cadence mode are given in column #LC, and those in high cadence mode in column #HC., we also list the number of HIDES spectra taken in column #HIDES to highlight the large contribution made to the project by the OAO.

Table 1. Overview of all the targets that were selected for our spectroscopic multi-site campaigns. For each target, we give the HD number, right ascension, declination, spectral type, the mean magnitude in the Johnson V filter, the projected rotational velocity, pulsational classification, starting year of the multi-site campaign, the number of observed spectra in the high and low cadence mode and the number of spectra taken with HIDES. The targets marked with * are observable with an airmass below 2.0 from all the involved observatories.

HDnr	$alpha_{2000}$	$delta_{2000}$	SpT	V	Bin	*v*sin*i*	class	year	#LC	#HC	#HIDES
12901	02 06 10.7	-10 16 34	F0	6.7		64	γDor	2009	3	45	
40745	06 00 17.7	-12 54 00	F2IV	6.2		40	γDor	2008	250	44	
55892	07 12 33.6	-46 45 33	F0IV	4.5		54	γDor	earlier	273		
65526*	07 59 03.0	-04 20 00	A3	7.0		56	γDor	2009	6	93	
112429	12 55 28.5	+65 26 19	F0IV-V	5.2		101	γDor	2009	33	464	185
135825	15 15 32.2	-10 30 02	F0	7.3		38	γDor	2009	10	368	
139095	15 37 16.9	-32 03 26	F0V	7.9		65	γDor	earlier	85	5	
147787	16 27 57.3	-64 03 29	F4IV	5.3	SB2	8+25	γDor	2007	300	5	
167858*	18 17 04.9	+01 00 21	F2V	6.6	SB1	5	γDor	2007	27	1067	
182640*	19 25 29.9	+03 06 53	F0IV	3.4		85	γDor	2009	22	330	
189631	20 02 40.8	-41 25 04	F0V	7.5		44	γDor	2007	98	278	
218396	23 07 28.7	+21 08 03	A5V	6.0		38	γDor	2008	131	313	74
21071	03 25 57.4	+49 07 15	B7V	6.1		62	SPB	2008	159	128	92
25558*	04 03 44.6	+05 26 08	B3V	5.3		22	SPB	2008	170	99	59
28114*	04 26 21.1	+08 35 25	B6IV	6.1		11	SPB	2009	21	25	25
182255	19 22 50.9	+26 15 45	B6III	5.2	SB1	14	SPB	2009	70	242	51

Table 2. Overview of the high-resolution spectrographs involved in our multi-site campaigns so far. For each spectrograph, we give a reference of the form 'instrument@observatory/telescope' used in the text, the resolution (R) and wavelength coverage (Δλ in nm) of the spectra, and the name of the observatory (country, eastern longitude in degrees, northern latitude in degrees, altitude in m).

Reference	R / Δλ	Observatory (country, long, lat, alt)
9682M@DAO/1.2-m	60,000 / 625-645	Dominion Astronomical Observatory (Canada, -123, 49, 230)
RA2@McD/2.1-m	60,000 / 540-660	McDonald Observatory (Texas USA, -104, 31, 2026)
HARPS@ESO/3.6-m	120,000 / 378-691	European Southern Observatory (La Silla Chile, -71,-29, 2347)
FEROS@ESO/2.2-m	48,000 / 370-900	European Southern Observatory (La Silla Chile, -71,-29, 2347)
HERMES@ENO/1.2-m	85,000 / 377-900	Roque de los Muchachos Observatory (La Palma, -18, 29, 2326)
SOPHIE@OHP/1.93-m	40,000 / 388-694	Observatory de Haute Provence (France, 6, 44, 665)
CES@TAUT/2.0-m	67,000 / 472-740	Karl Schwarzchild Observatory (Germany, 12, 51, 331)
GIRAFFE@SAAO/1.9-m	35,000 / 380-1050	South African Astronomical Observatory (South Africa, 21,-32, 1771)
COUDE@XING/2.16-m	35,000 / 560-900	Xinglong Observatory (China, 118, 40, 950)
BOES@BOA/1.8-m	90,000 / 381-810	Bohyunsan Optical Astronomical Observatory (Korea, 129, 36, 1127)
HIDES@OAO/1.88-m	50,000 / 400-775	Okayama Astrophysical Observatory (Japan, 134, 35, 372)
HERCULES@MJUO/1.0-m	45,000 / 380-900	Mount John University Observatory (New Zealand, 170,-44, 1027)

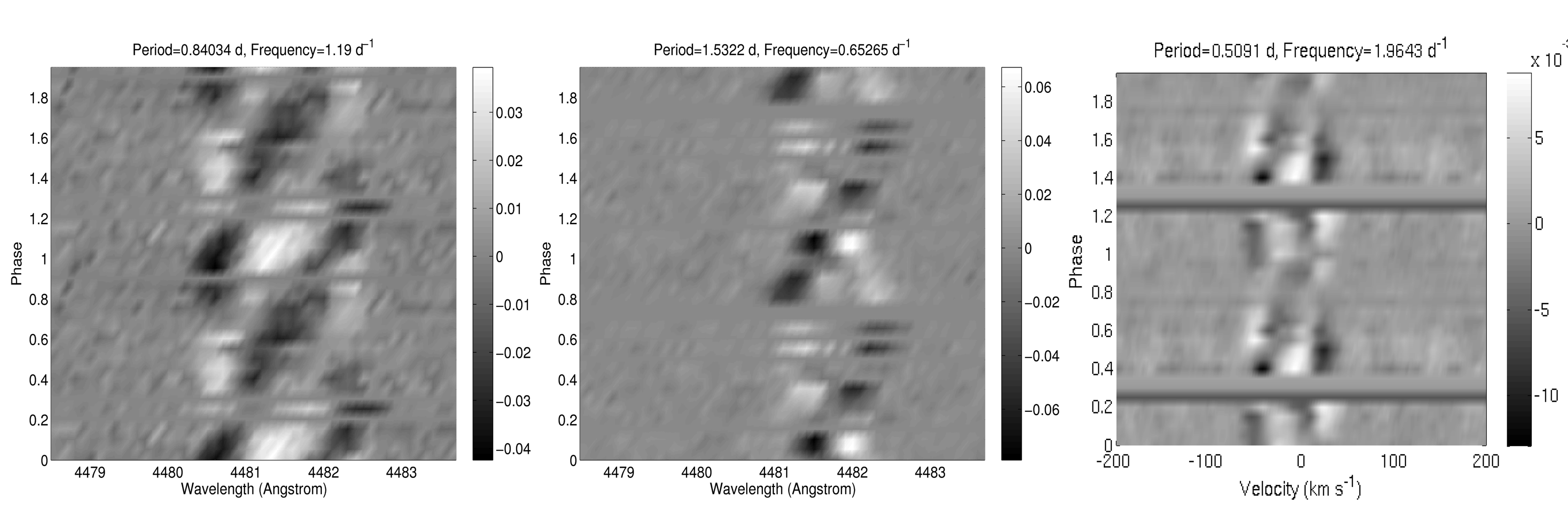

Figure 2. To demonstrate the variability of some of our targets, and the quality of the data we are able to collect we show the Si II 6347Å profiles for HD21071 (left) and HD25558 (middle) and the LSD profiles for HD218396 (right) all taken from HIDES@OAO/1.88-m, phased to each stars strongest photometric frequency.

3. ORGANISED MULTI-SITE CAMPAIGNS

Our first aim is to focus on each selected target (Table 1) initially for one year and to analyse the obtained data with already existing older data. The most promising targets will be selected for very long-term monitoring. So far, we have organised 3 multi-site campaigns: campaign 1 in spring of 2007 and 2008 for 3 γDor stars (HD147787, HD167858, HD189631), campaign 2 in fall 2008 for 2 SPB stars (HD21071, HD25558) and the planet hosting γDor star HD218396, and campaign 3 in 2009 for 2 SPB stars (HD28114, HD182255) and 6 γDor stars (HD12901, HD40745, HD65526, HD112429, HD135825, HD182640). An overview of the nights allocated to our multi-site campaign is given in Fig. 1. The analysed HIDES@OAO/1.88-m observations obtained during campaign 2 are presented in Fig. 2, showing clear line profile variations for all objects. For each of the stars, the visible variations appear consistent with one of the frequencies known from photometry.

CONCLUSIONS & FUTURE

So far, we have collected 150+ spectra for 8 stars. We are now analysing these data and will use the results to establish a few well characterised stars for both the γDor and SPB classes, which are sorely needed. We also hope to better understand the problems encountered thus far with mode identification of these g-mode pulsations, and will to try to improve on the current mode identification methods for these stars.