S02 / S03 :
Combining asteroseismology and interferometry : FGK stars in all evolution stages

Orlagh Creevey, Sébastien Deheuvels, Mathieu Vrard
and S02/S03 SPICA team

S02: astero+interfero, focus MS

- Participants : O. Creevey, R. Ligi, D. B. Palakkatharappil, T. Morel, R. M. Roettenbacher, R. Szabo, T. Boyajian, M. Bazot, N. Nardetto (D. Mourard, K. Belkacem, W. J. Chaplin) **+ Mathieu Vrard**

- Main scientific objectives :
  - S0: (a) calibrating the radius seismic scaling relation covering a range of masses and metallicities (b) model-independent masses using Delta nu and R_interferometric. ***Sample : stars with detected global seismic quantities***
  - S1: detailed seismic analysis for (a) high precision stellar parameters (b) testing of different physical ingredients in stellar models. ***Sample : stars with detected individual frequencies***
  - S2: "Butterfly diagrams" -> needs imaging (this point has not had moved forward much). ***Sample : stars with detected individual frequencies with enough precision to infer differential rotation***

- Work :
  - During 1-2 years (see next slide), and last worked on about one year ago with collaborators.

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Work :

- Target list created by the full team comprising northern seismo + PLATO targets. All contributed to this input catalogue. Searched literature for known parameters (R, M, Age), + identified type of target « S0,S1,... » + … + specific scientific cases in mind

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	ID_string	RA_float	Dec_float	Bibref_string	Seismic_integer	Activity_integer	Activit_type_strir	DataFile_string	Dnu_float	eDnu_float	Numax_float	eNumax_float	AmpNu_float	eAmpNu_float	Priority_integer
2	HIP 58093	178.7164989	-1.45151956:	https://ui.adsabs.harvard.edu/abs/2015	0				65.7	0.7	1176	58			
3	HIP 58191	179.0052387	-1.44221601!	https://ui.adsabs.harvard.edu/abs/2015	0				51.5	1.01	890	46			
4	HIP 55778	171.4289355	5.74789509	https://ui.adsabs.harvard.edu/abs/2015	0				66.6	0.8	1196	72			
5	HIP 57676	177.435715	6.523228357	https://ui.adsabs.harvard.edu/abs/2015	0				57.1	1.3	1000	46			
6	HD 89345	154.6710833	10.12903056	https://arxiv.org/pdf/1805.01860.pdf	1			HD89345_FreqData.txt	67	1.87	1300	58			0
7	KIC 6106415	285.4153333	41.49009167	https://iopscience.iop.org/article/10.108	1		high-proper moti	KIC6106415_FreqData.txt	10.4	0.5	2210	50			
8	KIC 12009504	289.4408333	50.480075	https://iopscience.iop.org/article/10.108	1	2	rotationaly variat	KIC12009504_FreqData.txt	88	0.6	1833	40			
9	KIC 10513837	280.8679333	47.70363456	https://iopscience.iop.org/article/10.108	1	1	red giant branch	BD+472682_FreqData.txt	14.6	0.2	191	7			
10	KIC 8006161	281.1463301	43.83327475	https://iopscience.iop.org/article/10.108	1		high proper-moti	HD173701_FreqData.txt	149.3	0.4	3570	96			
11	KIC 7940546	283.0687447	43.70994327	https://iopscience.iop.org/article/10.108	1			HD175226_FreqData.txt	58.9	0.2	1081	34			
12	KIC 5939450	283.5598312	41.22579437	https://iopscience.iop.org/article/10.108	1			HD175576_FreqData.txt	30.5	2.4	605	25			
13	KIC 9139151	284.0886021	45.51478694	https://iopscience.iop.org/article/10.108	1		high proper-moti	BD+452796_FreqData.txt	117.3	0.3	2695	74			
14	KIC 9139163	284.0921957	45.5070442	https://iopscience.iop.org/article/10.108	1	2	eruptive variable	HD176071_FreqData.txt	81.1	0.2	1685	45			
15	KIC 10454113	284.1526994	47.65643422	https://iopscience.iop.org/article/10.108	1	2	rotationally varia	HD176153_FreqData.txt	105.1	0.3	2310	68			
16	KIC 6106415	285.4153258	41.49009044	https://iopscience.iop.org/article/10.108	1		high proper-moti	HD177153_FreqData.txt	104.3	0.3	2219	60			
17	KIC 9206432	285.9380663	45.60838577	https://iopscience.iop.org/article/10.108	1			HD177723_FreqData.txt	84.7	0.3	1859	50			
18	KIC 5774694	286.0682393	41.00317867	https://iopscience.iop.org/article/10.108	1			HD177780_FreqData.txt	140.2	4	3442	274			

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Work :

- Target list created by the full team comprising northern seismo + PLATO targets. All contributed to this input catalogue. Searched literature for known parameters (R, M, Age), + identified type of target « S0,S1,... » + … + specific scientific cases in mind
- Notebook developed (courtesy of Dinil's expertise) to crossmatch targets with several external catalogues [extinction, simbad, gaia, …]
- Assuming 1 % angular diameters (SPICA criteria) → calculate sigma Radius. Selection and priority on sigma Radius + Vmag + declination + coverage HR diagram

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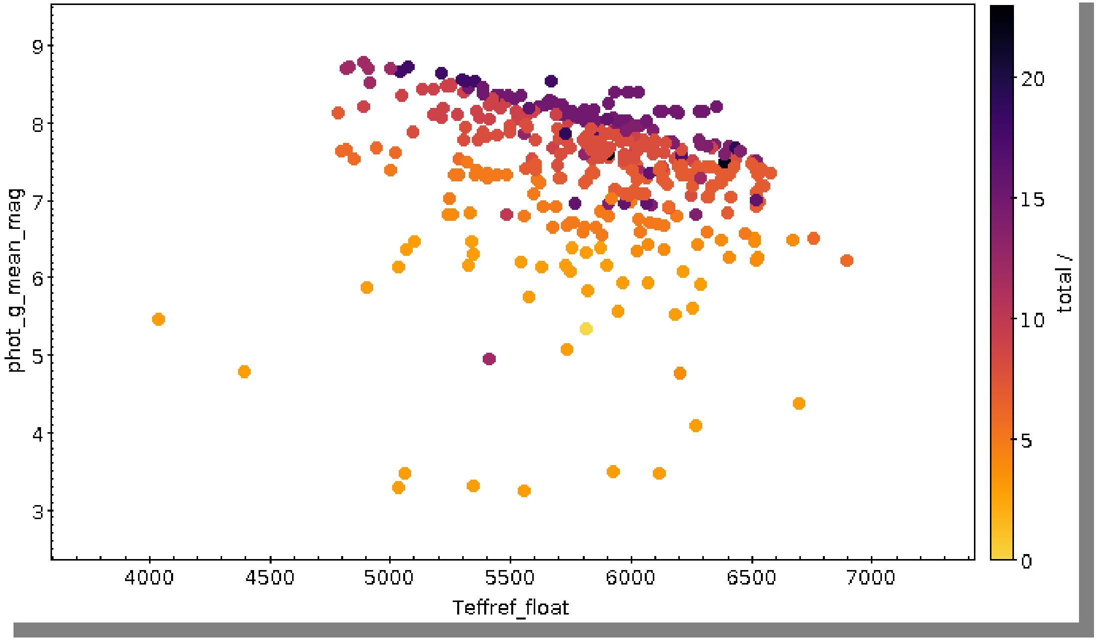
- List → SpicaTarget List with

  P0 and P1
- Next steps → Mathieu et al.

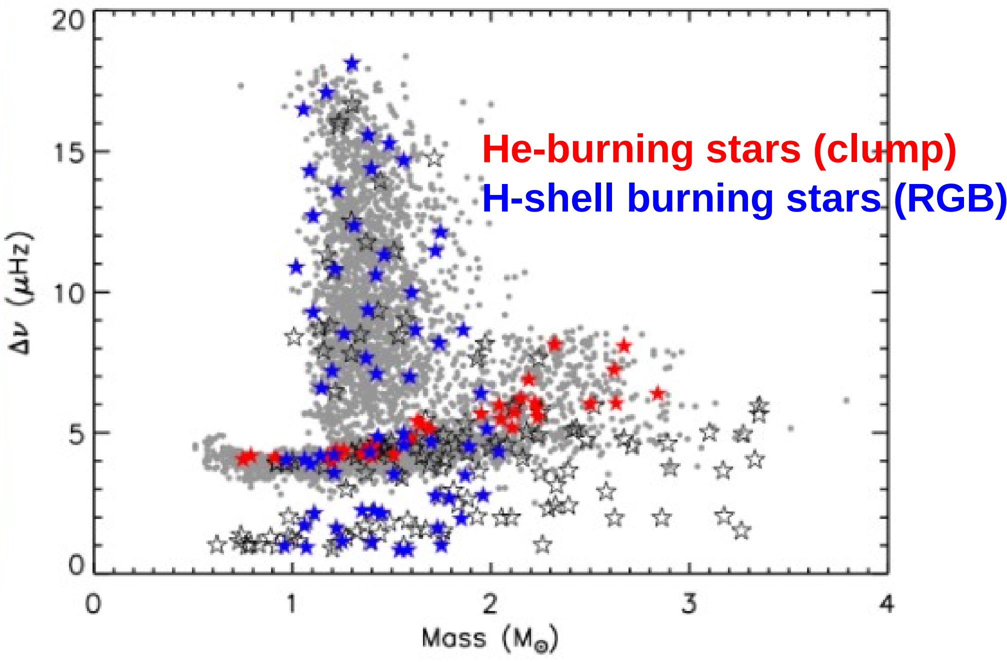


S03: astero+interfero, subgiants and red giants

-Subgiants and red giants with excellent seismic data and large enough predicted angular diameter

-236 stars in *Kepler* and CoRoT data that corresponds to those criteriums

-60 P0 targets selected following evolutionary stages, masses and $\Delta\nu$



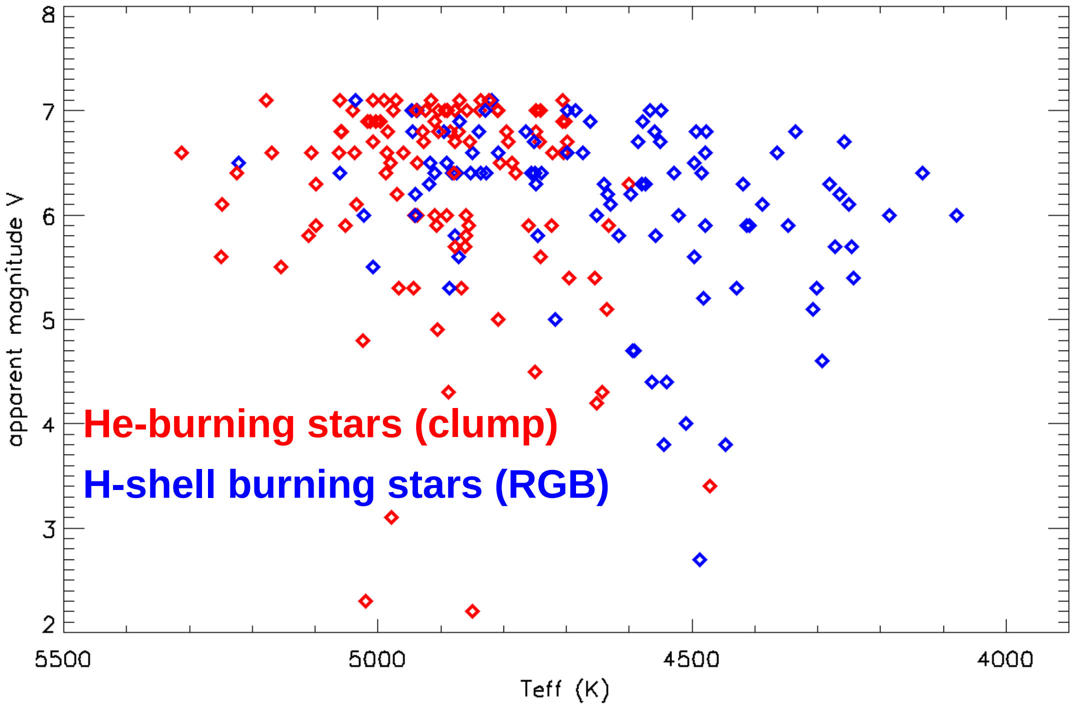
$\Delta\nu$-Mass plane for P0 red giants and red clump targets (courtesy of Romina Ibañez-Bustos)

Sample completion with TESS data

-New red giant sample from the TESS bright star sample (Hon et al., 2022)
Selected with V<8, θ>0.2, δ>-20°

-211 red giant targets with measured seismic quantities (Δν, ν_{max})

-Next step: modify the P0 sample taking these new data into account



Apparent magnitude as a function of T_{eff} for the selected 211 stars

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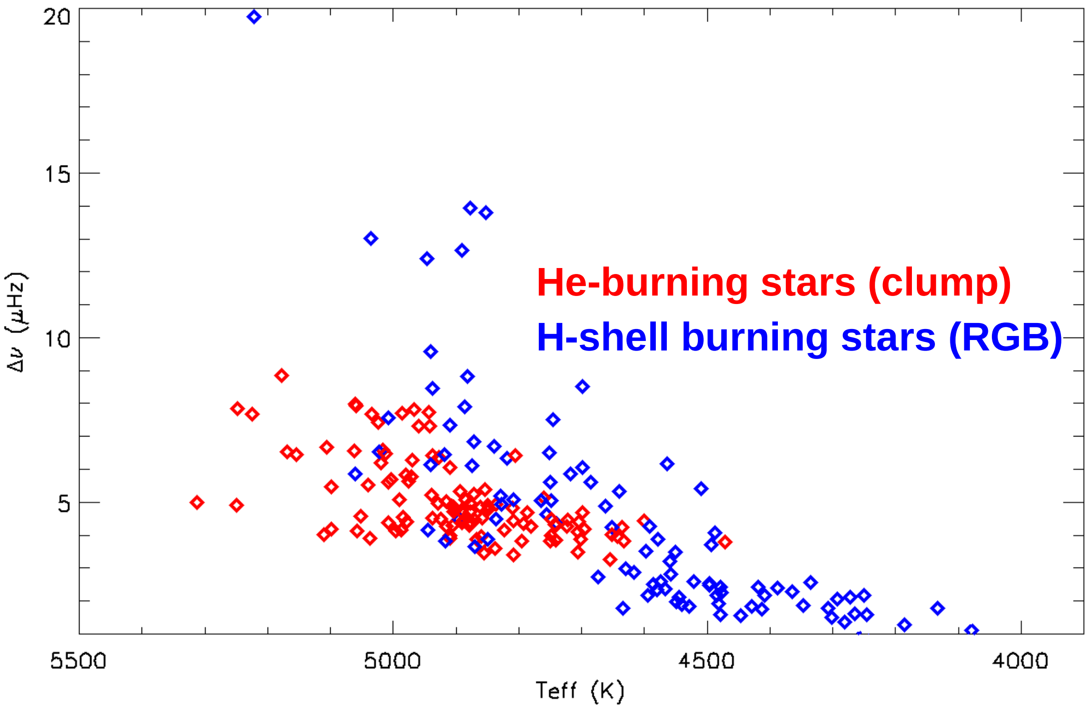

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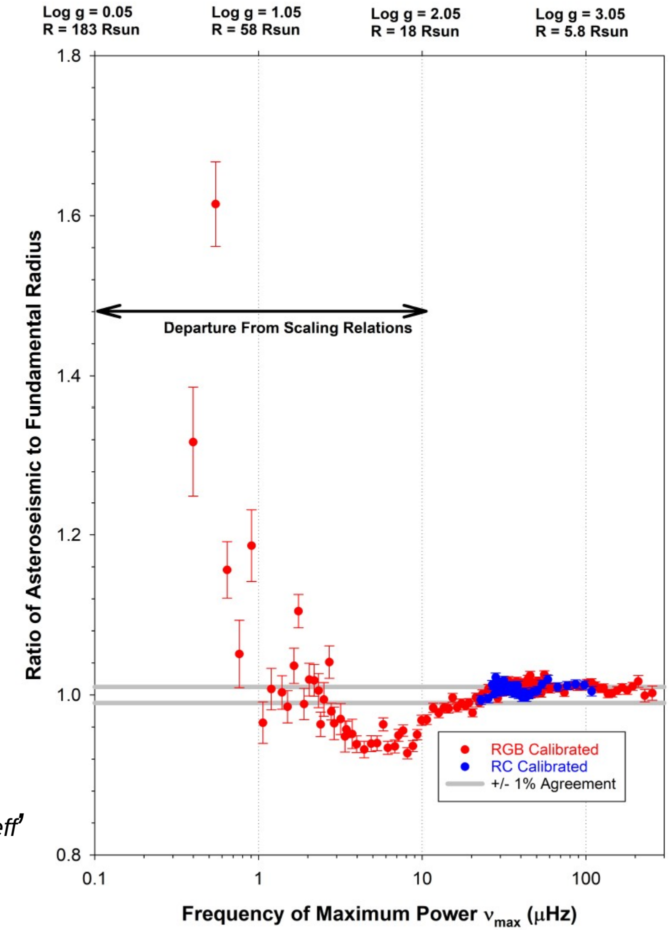
Scientific objectives

Main objectives:

1-Testing the seismic scaling relations (determination of radius R and mass M)



Ratio between asteroseismic R and fundamental R (obtained with T_{eff}, Luminosity L and Gaïa parallax) as a function of ν_{max} (courtesy of Marc Pinsonneault)

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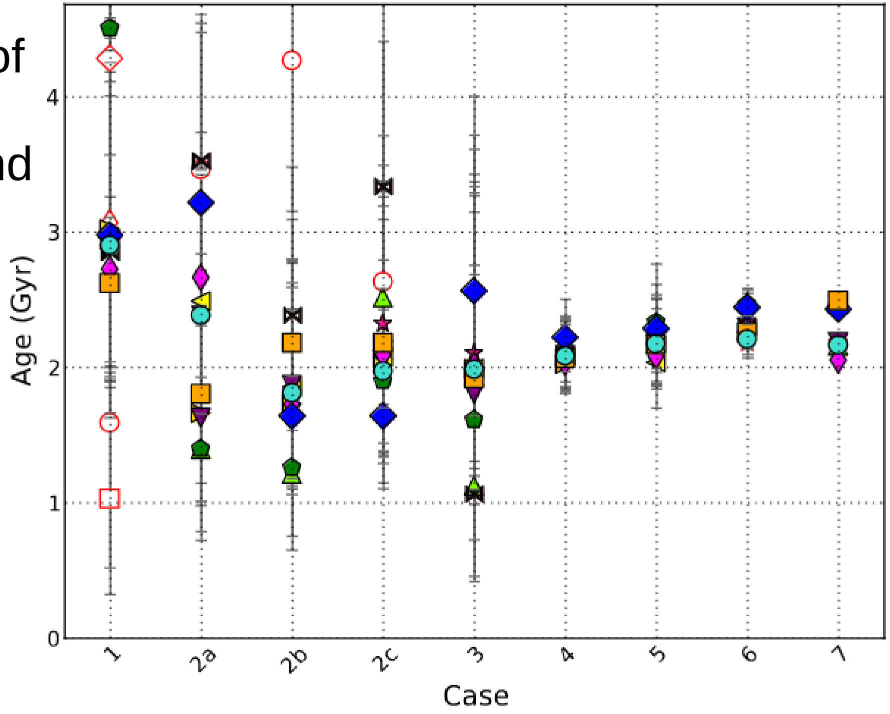
2-Obtaining more precise and accurate ages with R and models



Age determination of HD 52265 with different models as a function of different input parameters (Lebreton & Goupil, 2014)

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Additional objectives:

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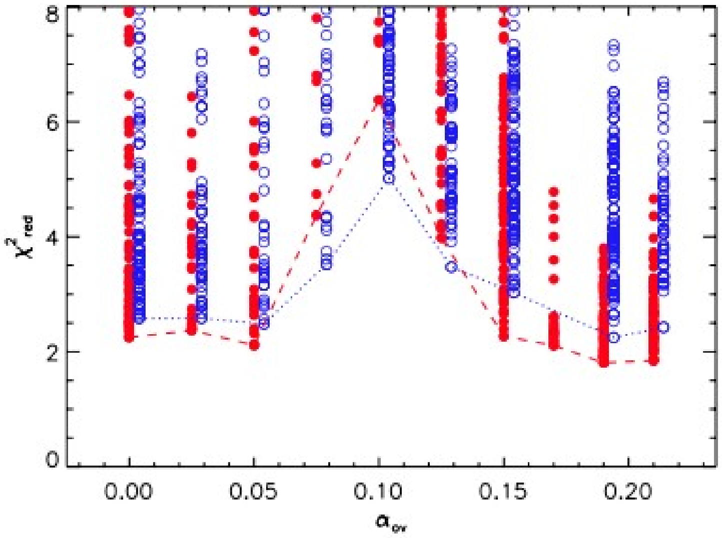

Deheuvels & Michel (2011)

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Project completion steps :

Specific objectives (3,4,5,6) can begin as soon as the first observations will be available

Objective 1 is possible to achieve if we obtain data for a representative sample of stars in Δν and M space

Objective 2 needs thorough precise modelisation and is therefore a more long-term objective to be completed during the 3 years of the project

Important discussion points

-No specific aspects to consider for the observations

-For data analysis, one specific point that needs to be adressed: **modelisation**
- -What type of models ? Codes ?
- -Use of code or a grid ?
- -Several codes or one main ?
- -Which entree parameters do we need ?

-For publications : focus on publications that concerns global data analysis (point **1,2**)
Also possibility to publish on specific star work, not necessary led by S02/S03 PI

-Publication of an observation catalog

Conclusion

-340 S02 targets and 446 S03 targets, 128 P0 targets among them

-An improvement of the S03 P0 sample is ongoing

-Additional objectives can be achieved with a small target sample
However, testing seismic scaling relations and improving the stellar age determination will necessitate a more important observation sample

-The most important technical difficulty will be to perform appropriate modelisation for age determination and individual target analysis

-The publication of an observation catalog is a necessity