Service d'Astrophysique
Laboratoire AIM

MAIN SEQUENCE AND SUBGIANTS:

INTRODUCTION

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With the help of E. Michel

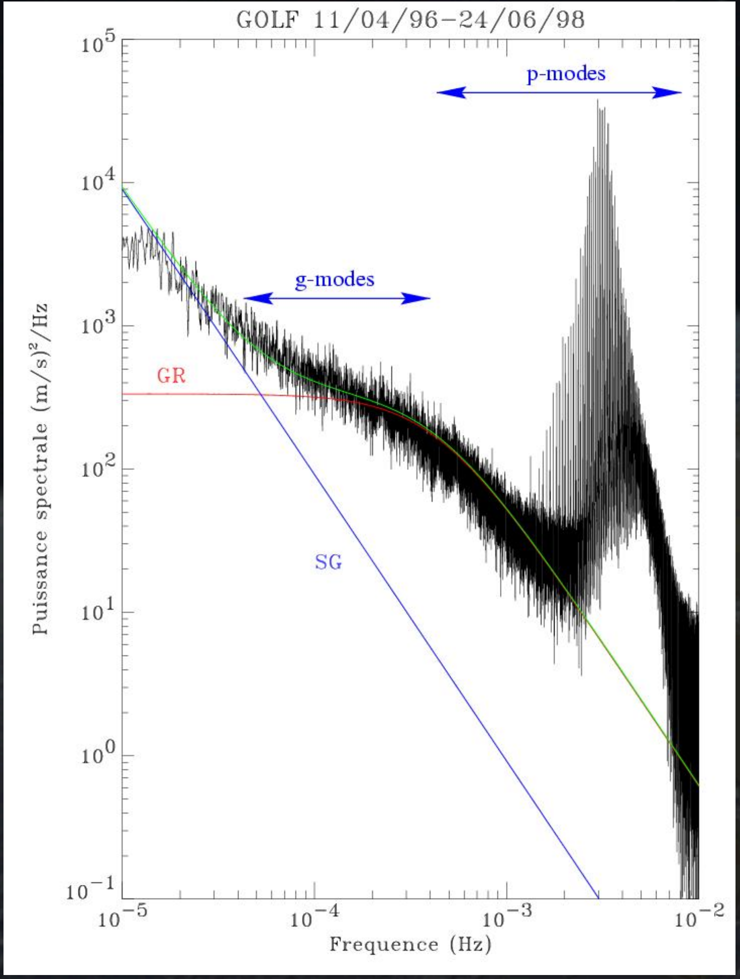
I-Introduction

I-INTRODUCTION

- What is a solar-like oscillating star?
  - Those in which oscillations are stochastically excited by turbulent convection
- **Oscillations are seated over a convective background**

[Goldreich & Keeley 1977]

[Harvey, 1985; Lefebvre et al. 2008; Mathur et al. 2011]

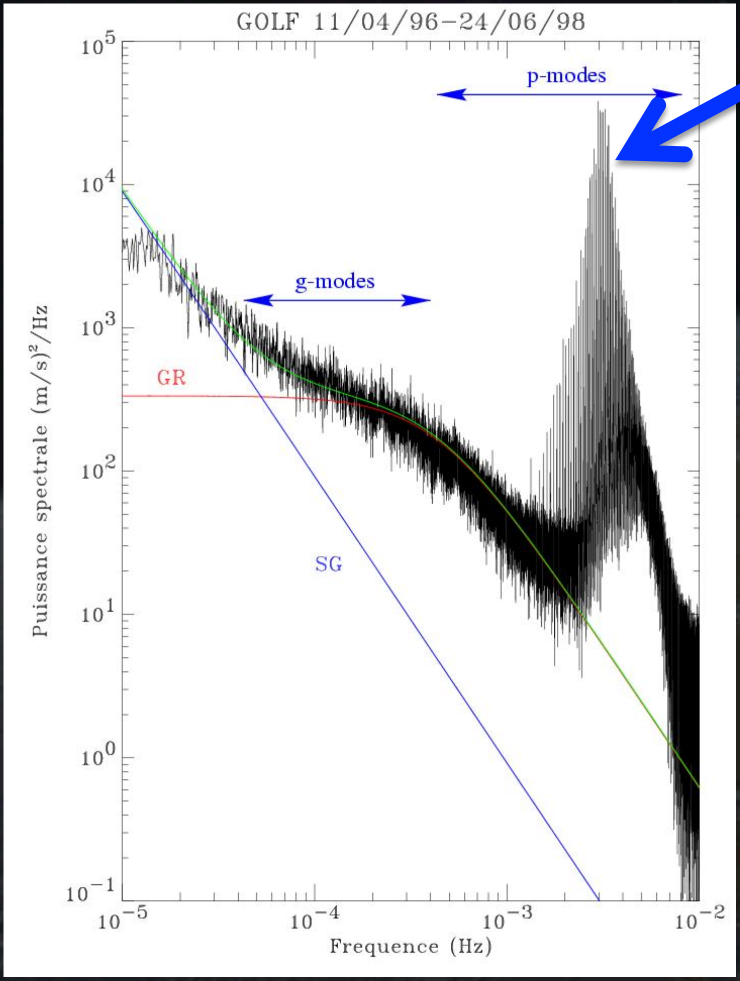


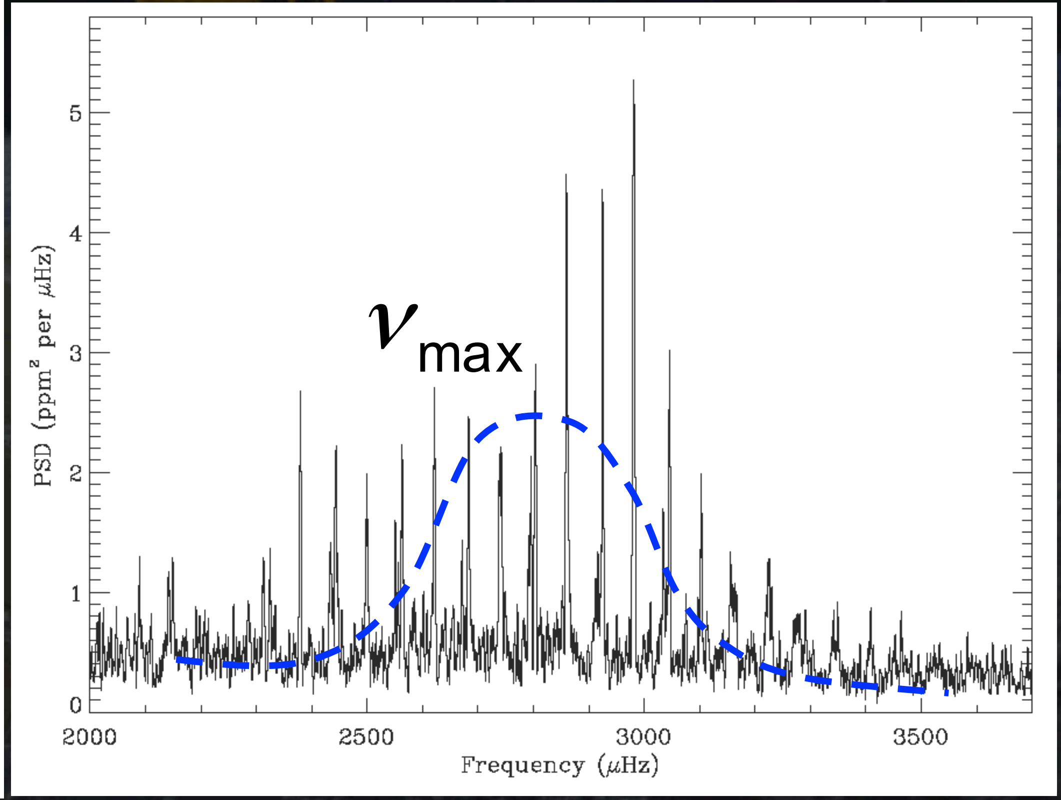
I-INTRODUCTION

- ν_{max} scales with the acoustic cut-off frequency

[Brown et al. 1991; Belkacem et al. 2012]

$$\nu_{max} \propto g T_{eff}^{-1/2} \propto M R^{-2} T_{eff}^{-1/2}$$

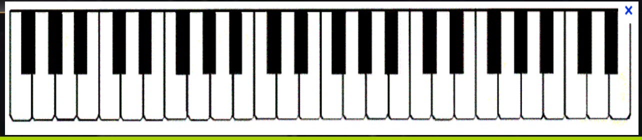


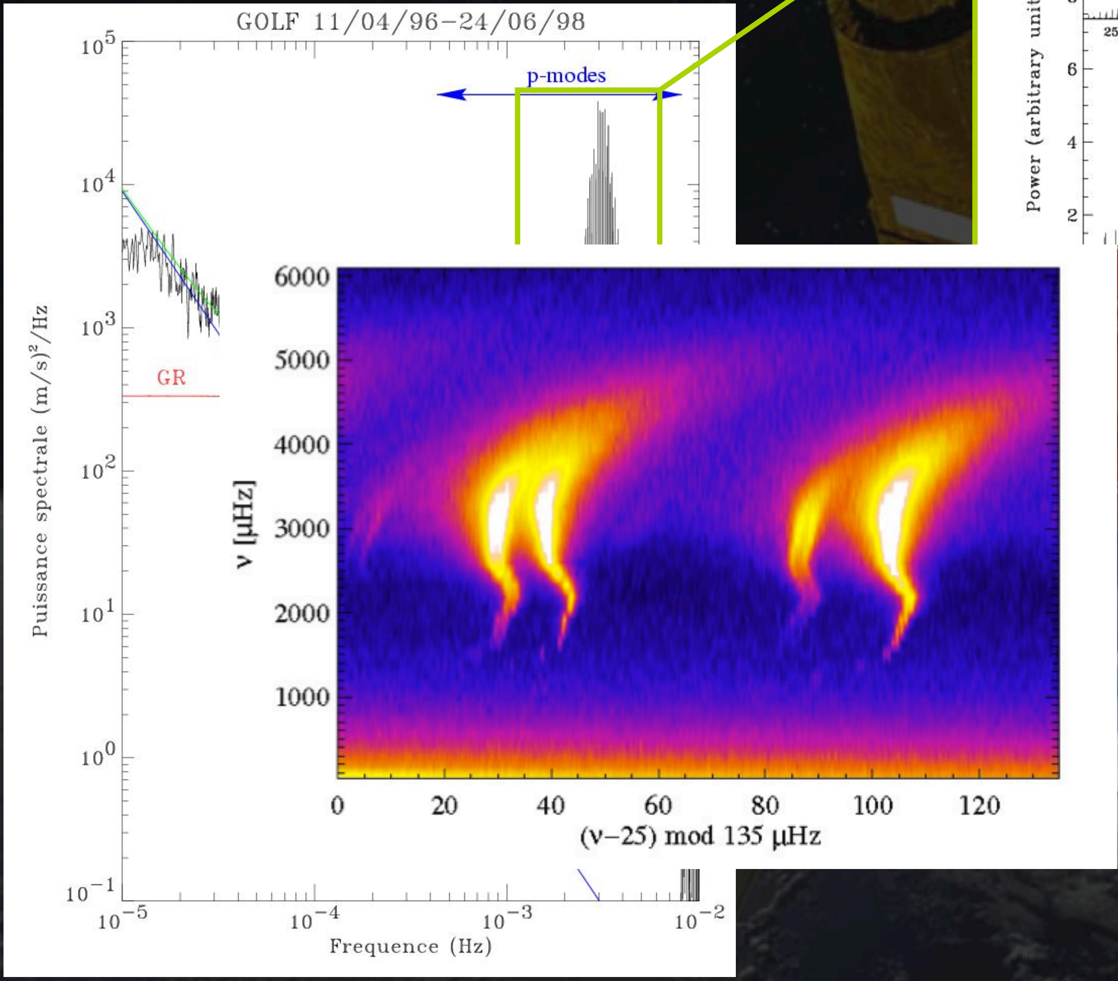


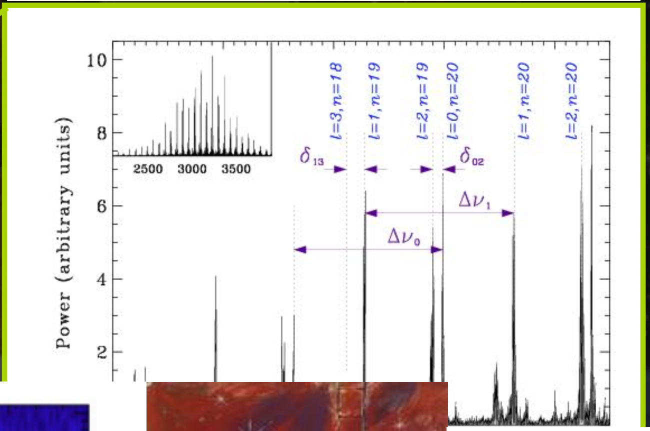
I-INTRODUCTION

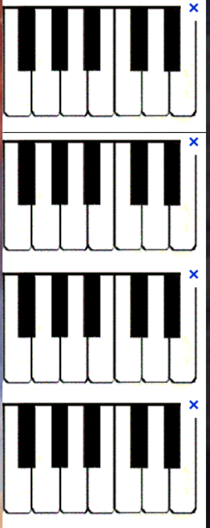
- ***Large separation:*** $\Delta\nu = \nu_{n,\ell} - \nu_{n-1,\ell}$
  - **Average properties of the star:**

$$\langle \Delta\nu \rangle \propto \langle \rho \rangle^{1/2} \propto M^{1/2} R^{-3/2}$$









I - EXTRACTING GLOBAL PROPERTIES

$$\langle \Delta\nu \rangle \propto \langle \rho \rangle^{1/2} \propto M^{1/2} R^{-3/2}$$

$$\nu_{\max} \propto g T_{\text{eff}}^{-1/2} \propto M R^{-2} T_{\text{eff}}^{-1/2}$$

- Use of scaling relations
  - From global asteroseismic parameters and a good estimation of T_{eff}
  - Tested both theoretically and observationally

$$\frac{R}{R_\odot} = \left(\frac{135}{\langle\Delta\nu\rangle}\right)^2 \left(\frac{\nu_{\max}}{3050}\right) \left(\frac{T_{\text{eff}}}{5777}\right)^{1/2}$$

$$\frac{M}{M_\odot} = \left(\frac{135}{\langle\Delta\nu\rangle}\right)^4 \left(\frac{\nu_{\max}}{3050}\right)^3 \left(\frac{T_{\text{eff}}}{5777}\right)^{3/2}$$

[Kjeldsen & Bedding 1995; Bedding & Kjeldsen 2003; Stello et al. 2008; Belkacen et al. 2011…]

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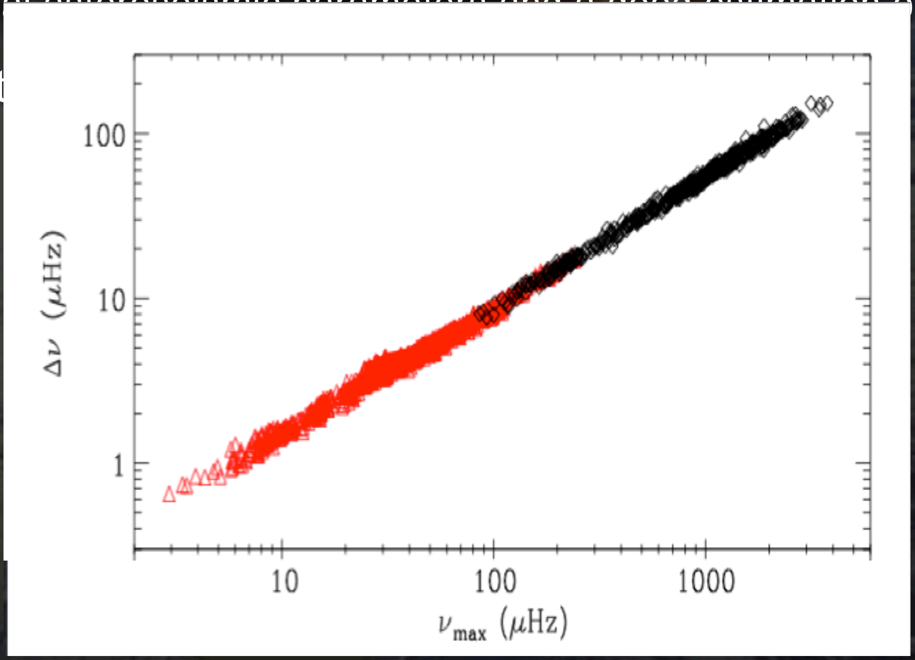
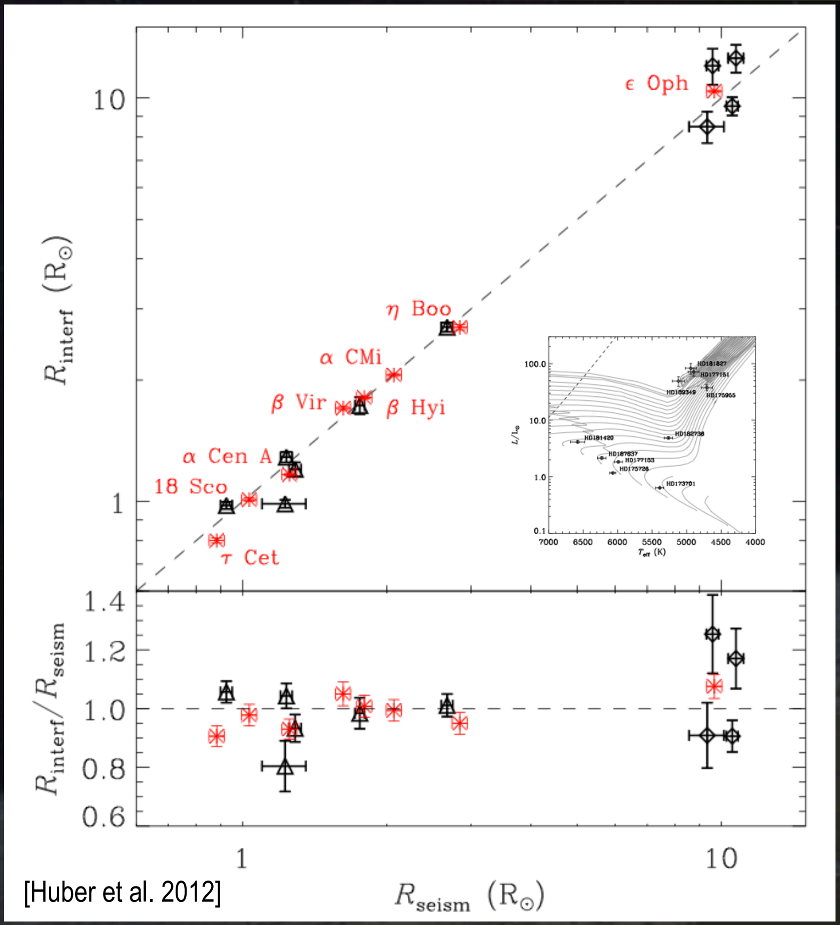
$$\nu_{\max} \propto g T_{\rm eff}^{-1/2} \propto M R^{-2} T_{\rm eff}^{-1/2}$$

- Use of scaling relations
  - From global asteroseismic parameters and a good estimation of $T_{\rm eff}$
  - Tested bot



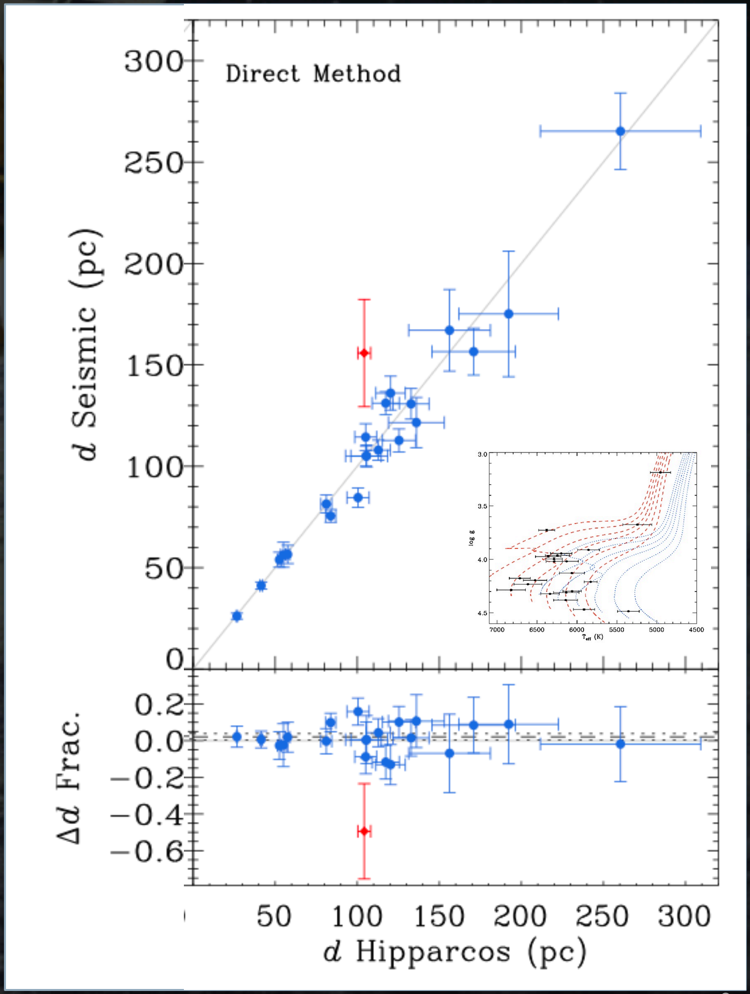
[Huber et al. 2012]

I-SCALING-RELATION COMPARISON



[Huber et al. 2012]

- Validation of the scaling relations using:
  - Interferometric measurements
    - G. based, CoRoT & *Kepler* targets



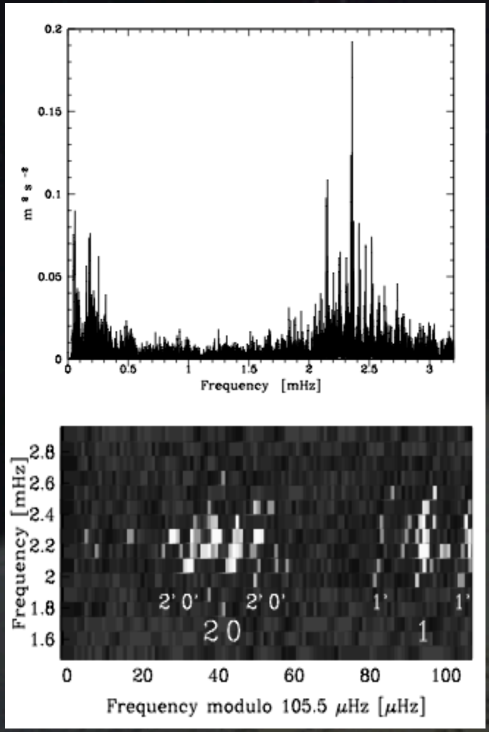
- Seismic and IRFM distances compared to Hipparcos
  - Interferometric measurements
    - G. based, CoRoT & *Kepler* targets
- Also compared to theoretical predictions (*Kepler* stars)

[Mathur et al. 2012]

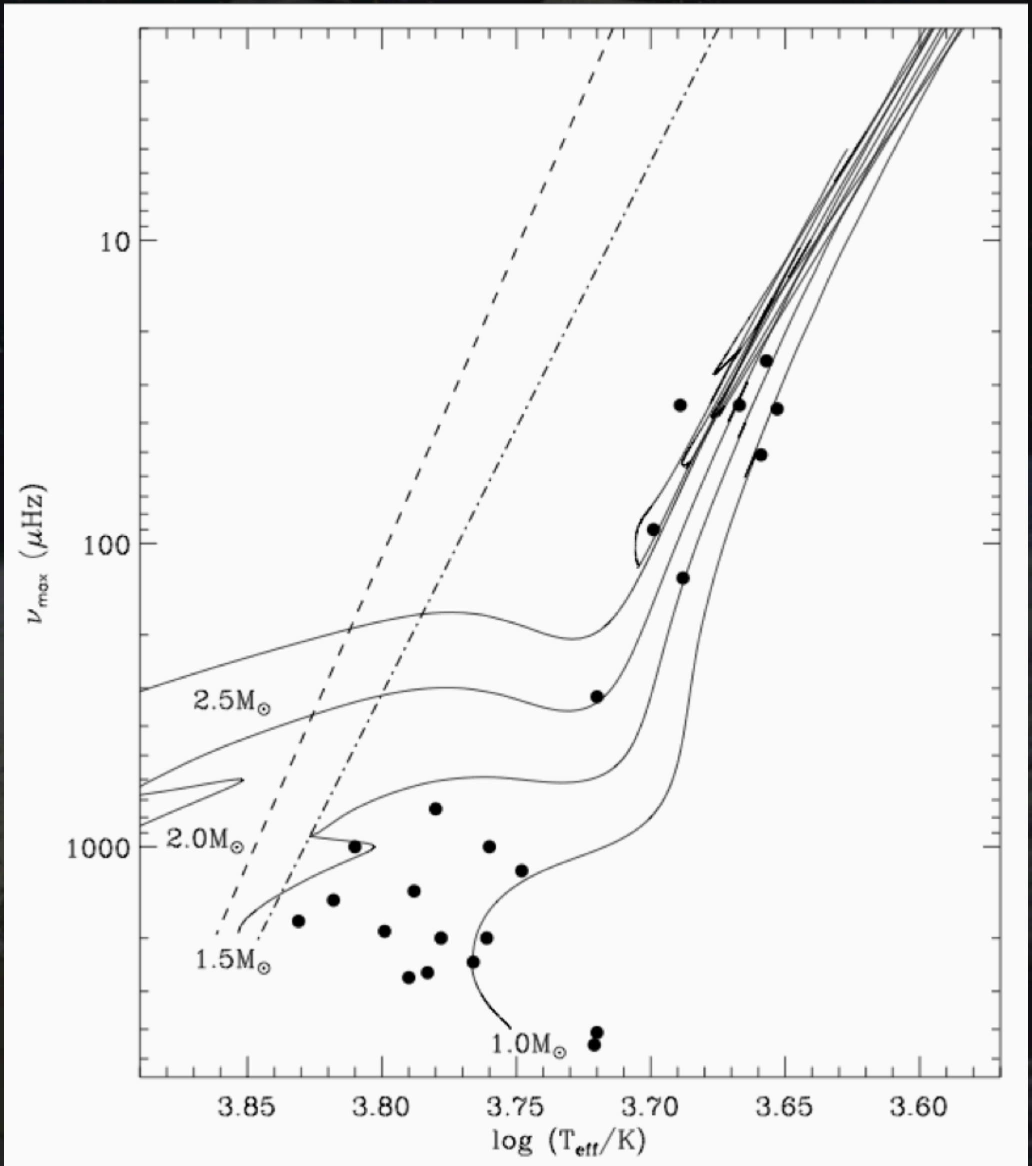
[Silva-Aguirre et al. 2012]

I-INTRODUCTION

- Before 2007



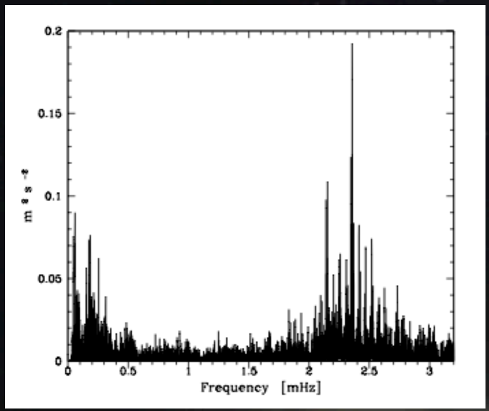
[Bouchy & Carrier 2002]

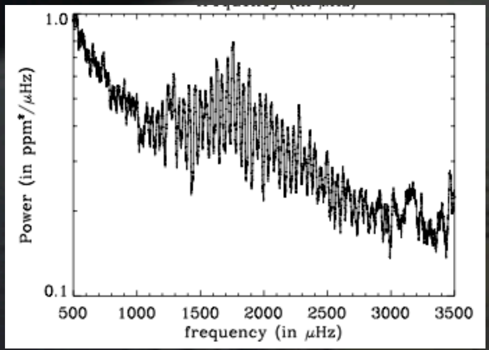


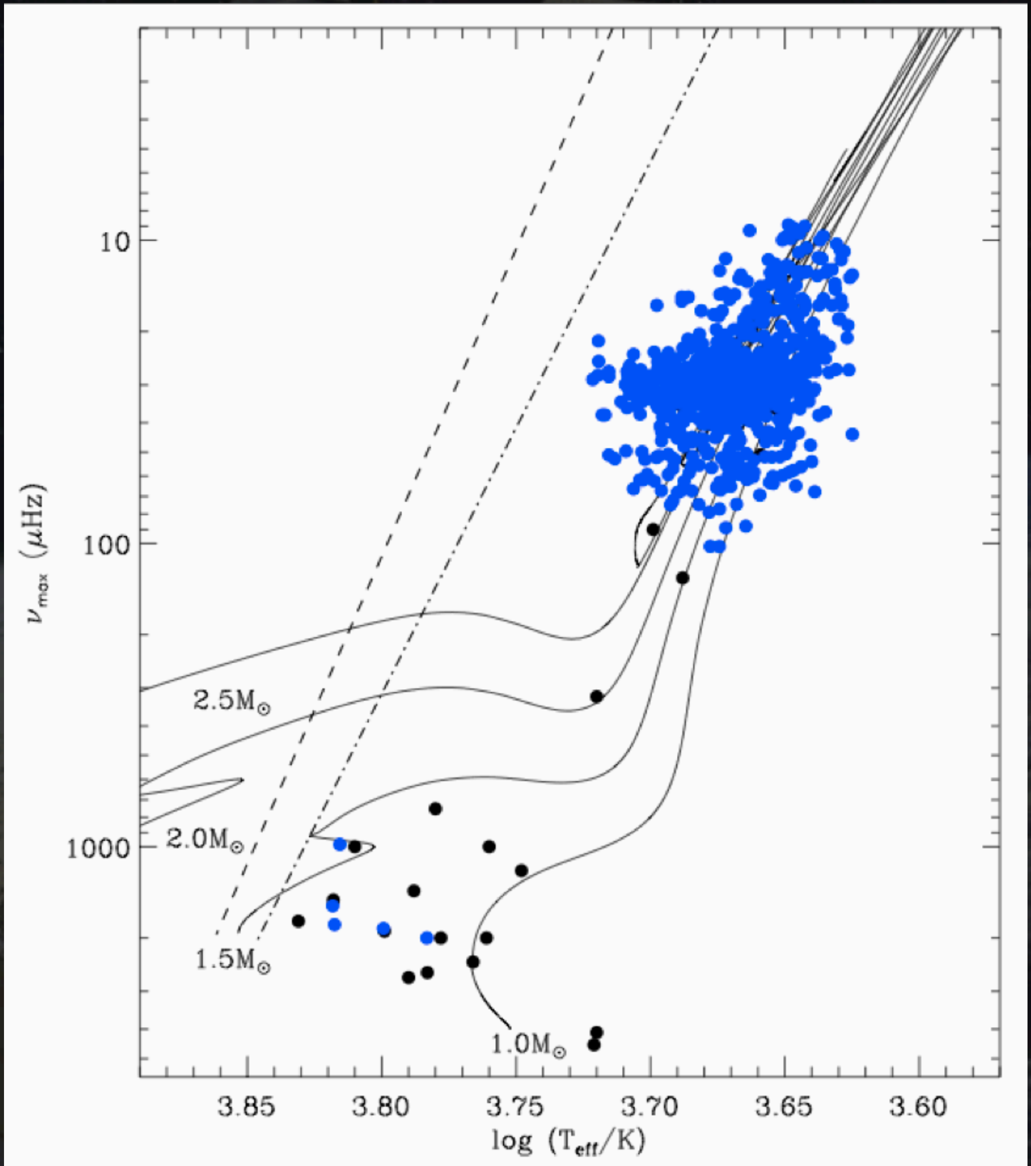
[D. Huber, KASK-II Conference, 2011]

I-INTRODUCTION

- Before 2007
- CoRoT



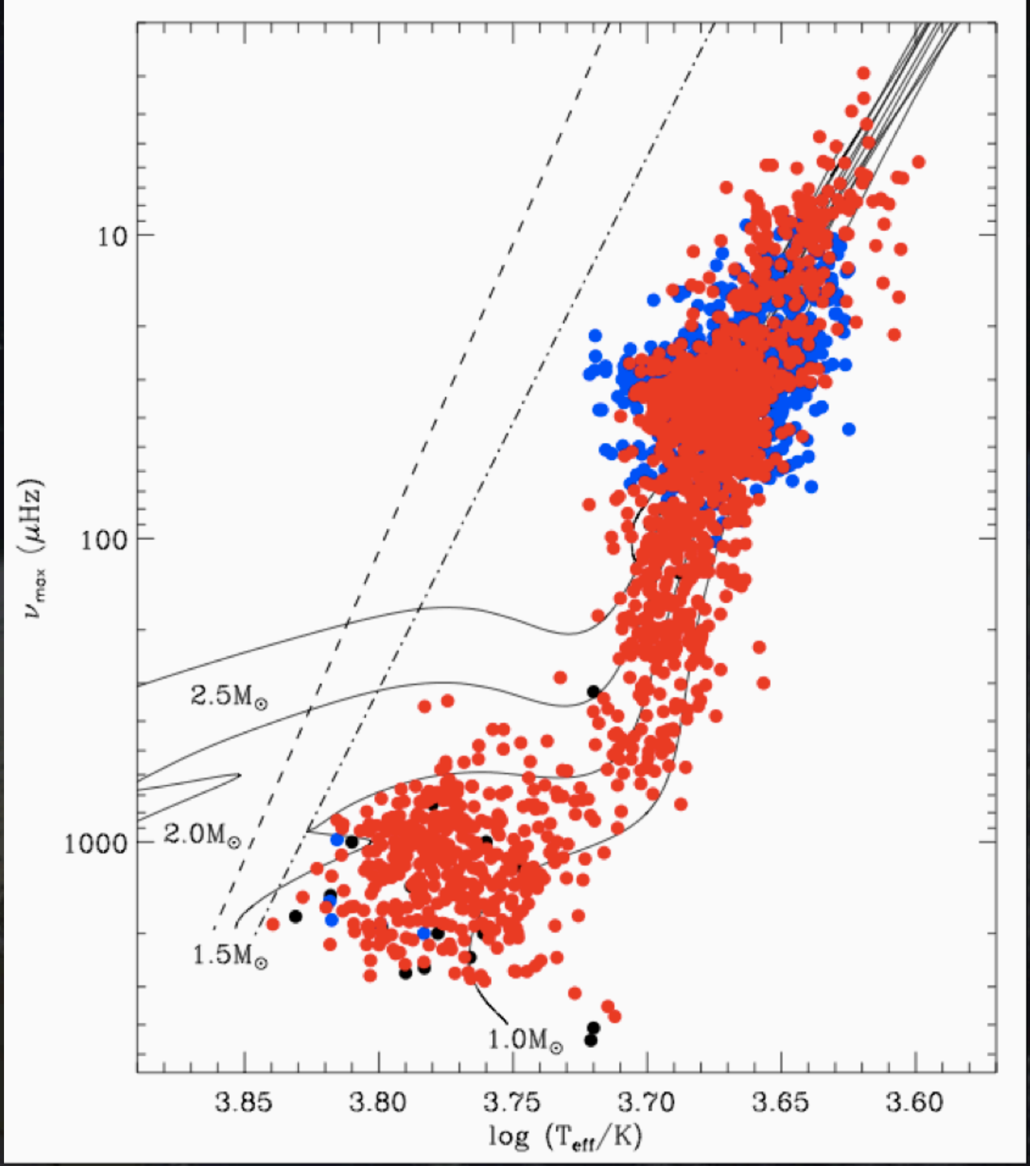




[D. Huber, KASK-II Conference, 2011]

I-INTRODUCTION

- Before 2007
- CoRoT
- Kepler



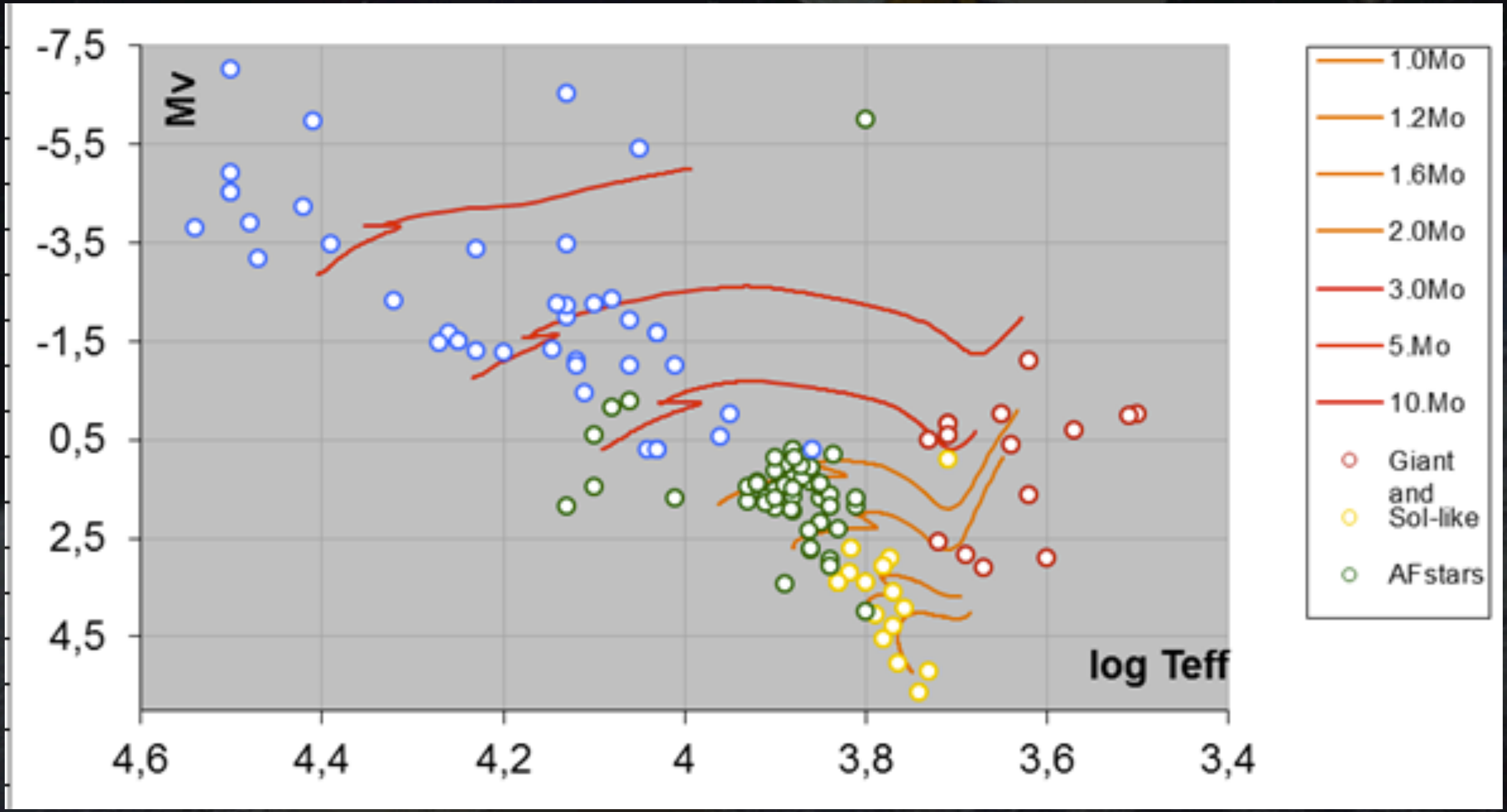
[D. Huber, KASK-II Conference, 2011]

II- What have we learnt ?

Some selected results

II-WHICH DATA DO WE HAVE?

- Corot IS a success for the study of oscillating stars
  - Main sequence, Subgiants and giants

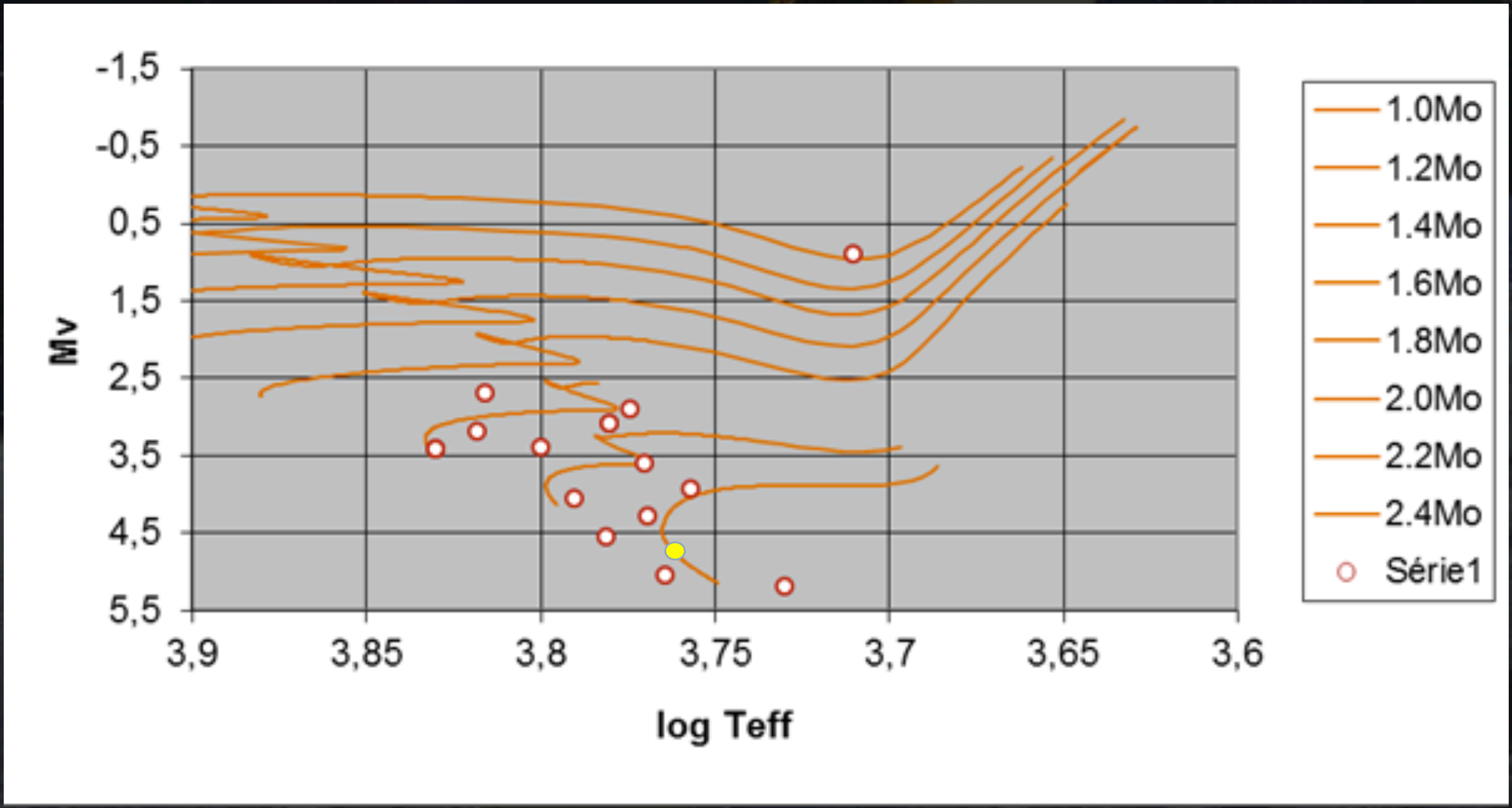


[http://www.lesia.obspm.fr/projets/corotswg/targetssismoEM.htm]

II-WHICH DATA DO WE HAVE?

- Corot IS a success in the study of S-L oscillating stars

Star type	All Runs	LR	IR	SR
FG Sol-like	19	8	8	3



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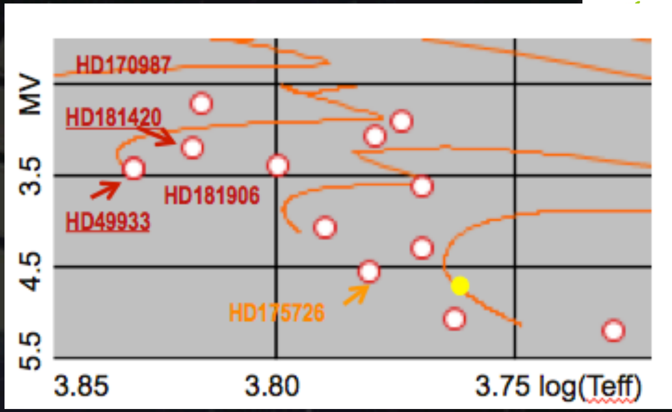
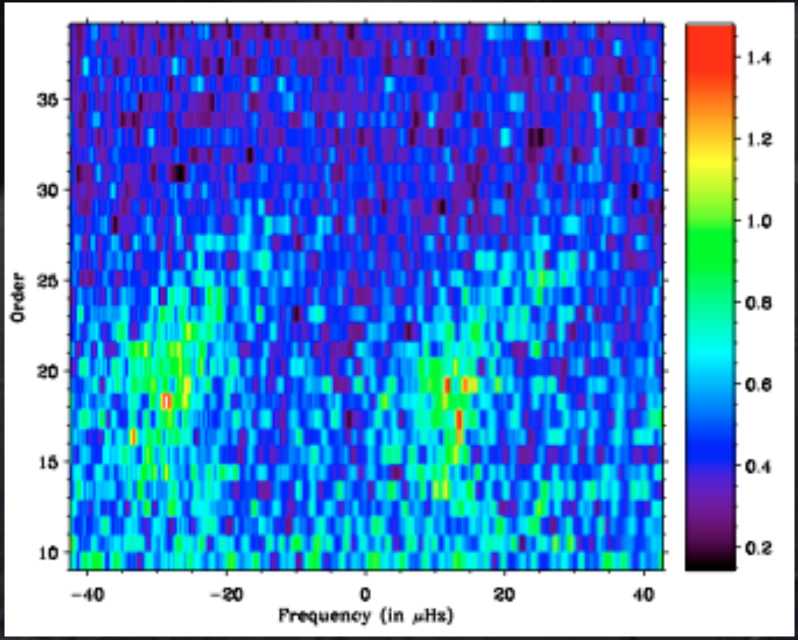
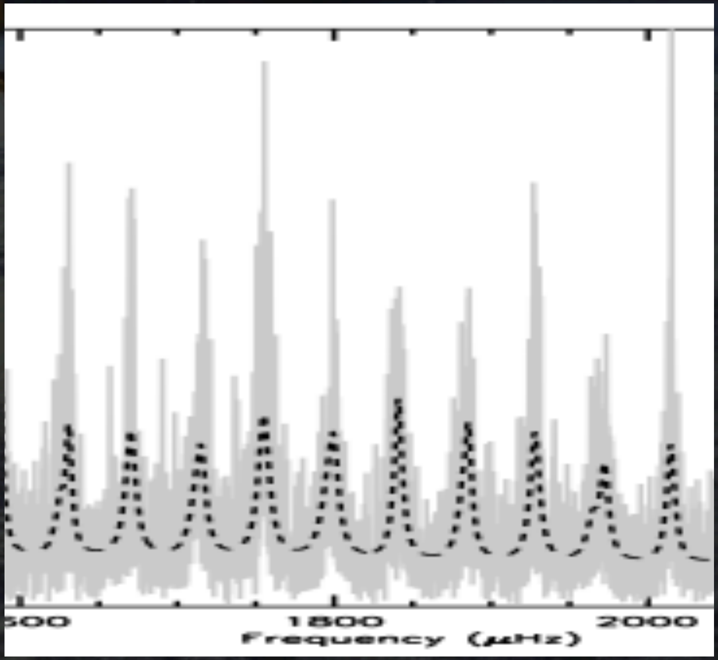
II- THE PROBLEM OF THE F-TYPE STARS

- First stars to be observed: Main sequence F-Type stars
  - Higher expected Amplitudes than G–type stars
  - Problem: Linewidths > δν
  - How to identify the modes ?
- Set up the "modern" procedure to:
  - Obtain global seismic parameters: $\Delta\nu$ and ν_{max}
  - identify and extract individual mode frequencies





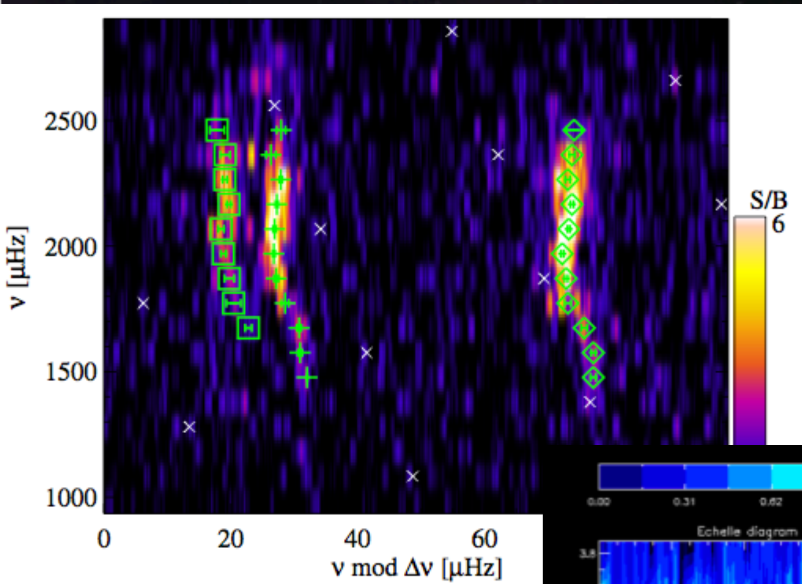
[Appourchaux et al. 2008]



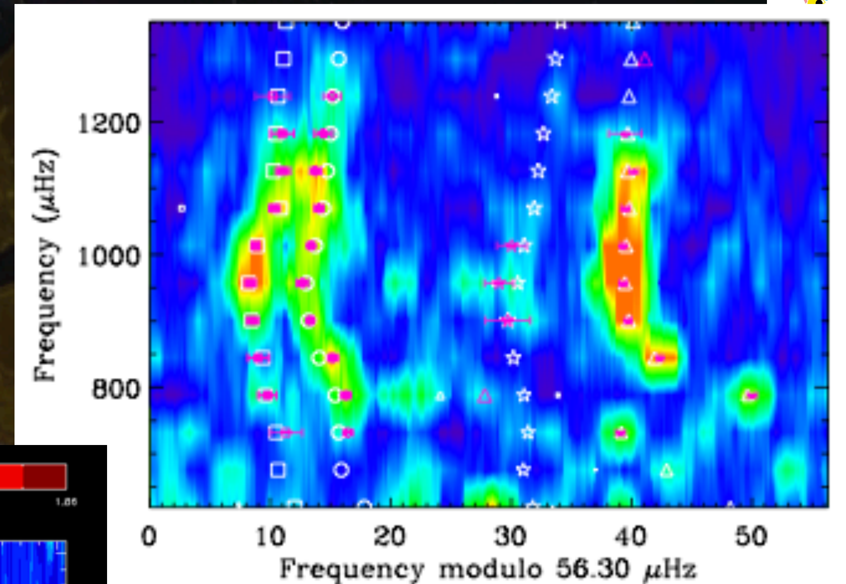
[Benomar et al. 2009]

II- G-TYPE STARS

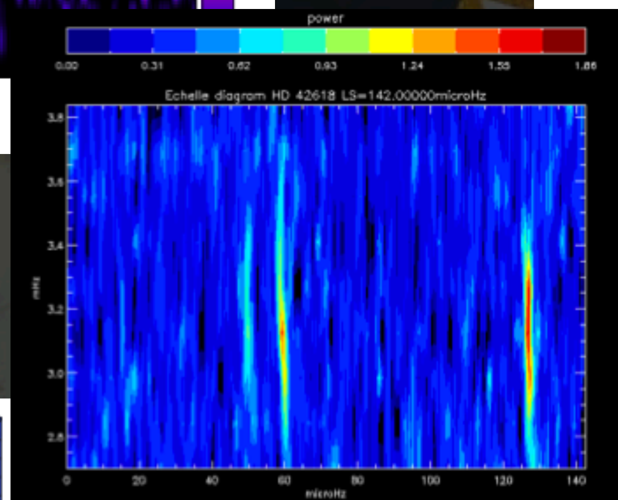
HD52265



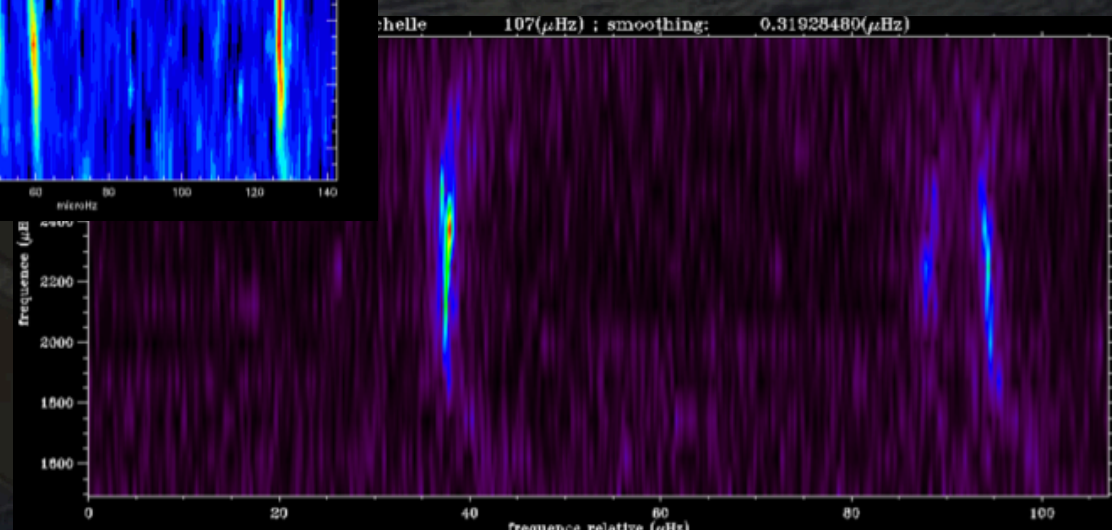
HD169392



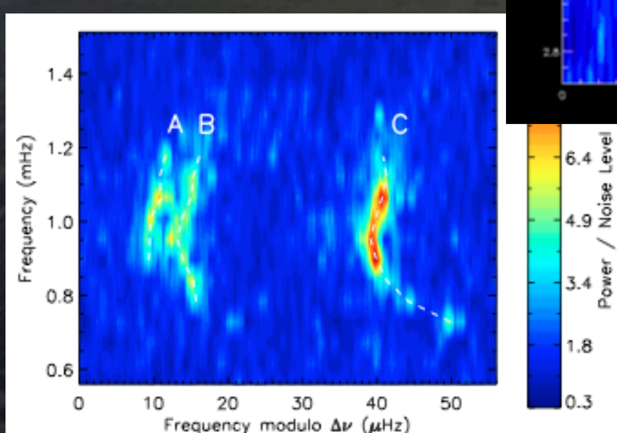
HD42618



HD43587



HD49385



SURFACE AND INTERNAL ROTATION

- Surface rotation:
  - For active stars only (see presentations by F. Baudin, J.D. do Nascimento Jr.)

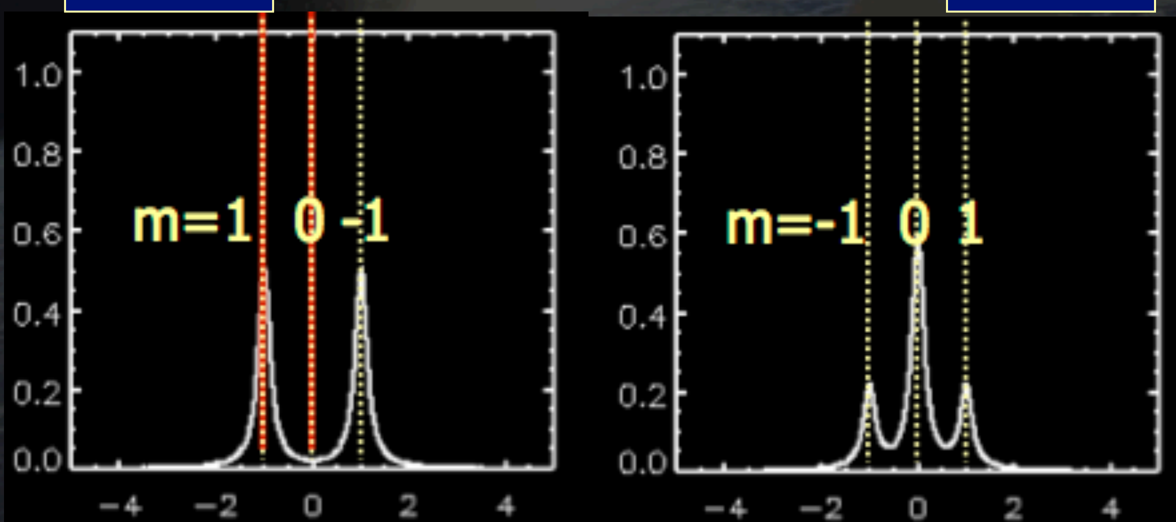
[Mosser et al. 2009, do Nascimento et al. 2012]

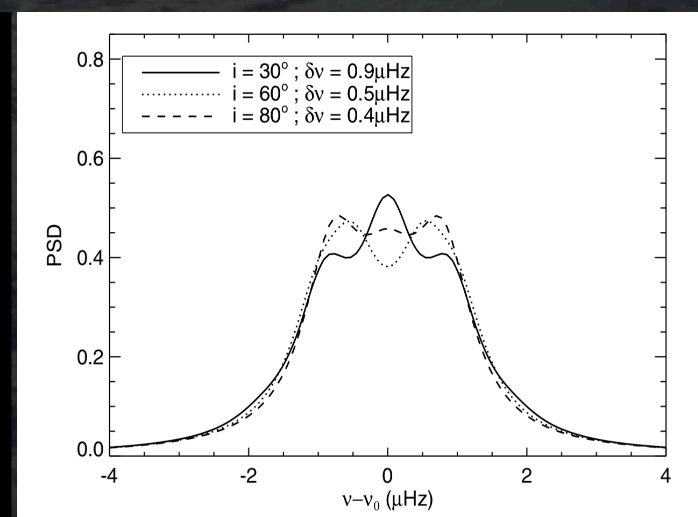
[Appourchaux et al. 2008; Barban et al. 2009. Garcia et al. 2009, Mathur et al. 2010,2013…]

- Internal rotation:
  - Measuring rotational splittings
  - Complicate measurement:
    - Inclination angle of the star
    - lifetime of the modes

i = 90°

i = 40°





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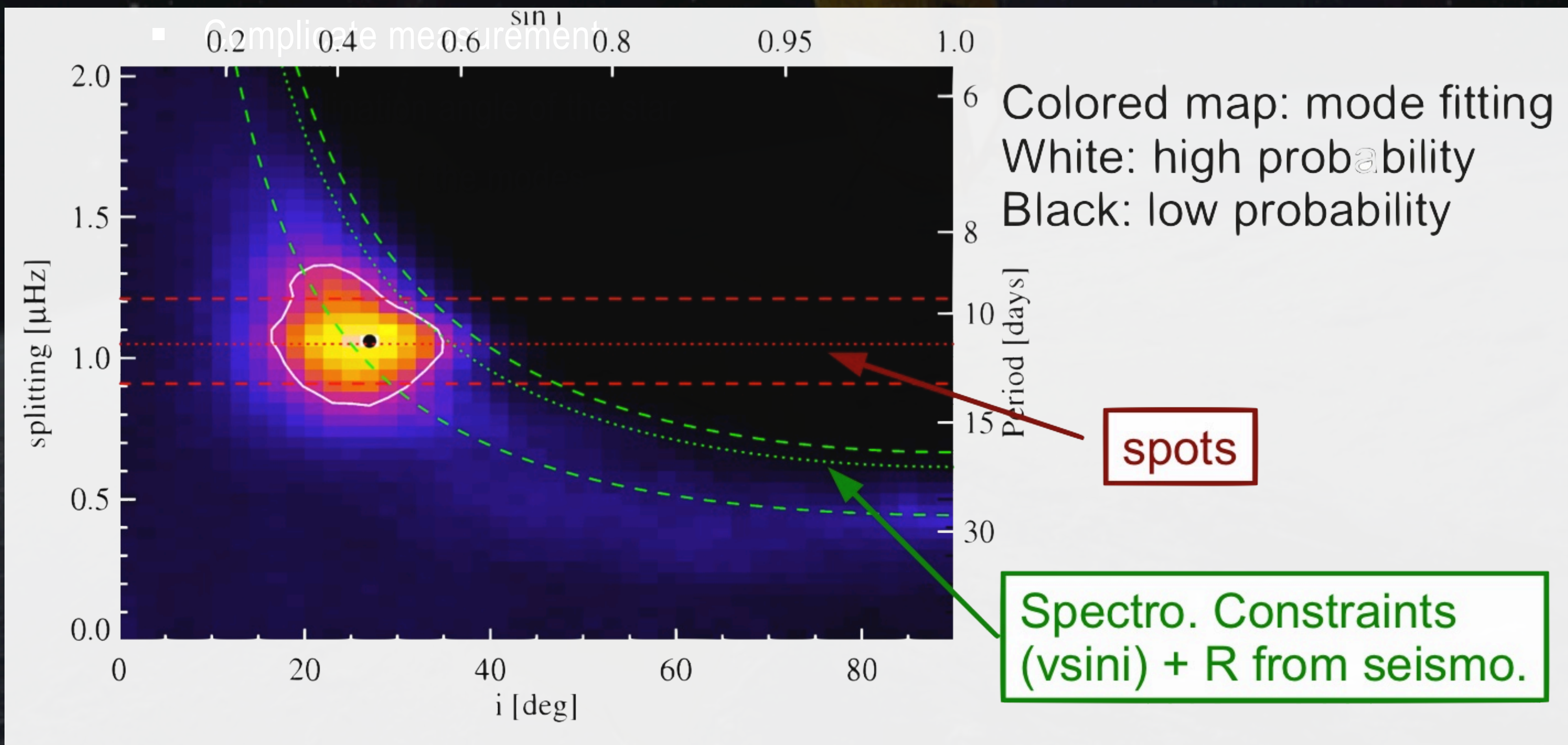
HD52265



[Ballot et al. 2011; Gizon et al. 2013 in press]

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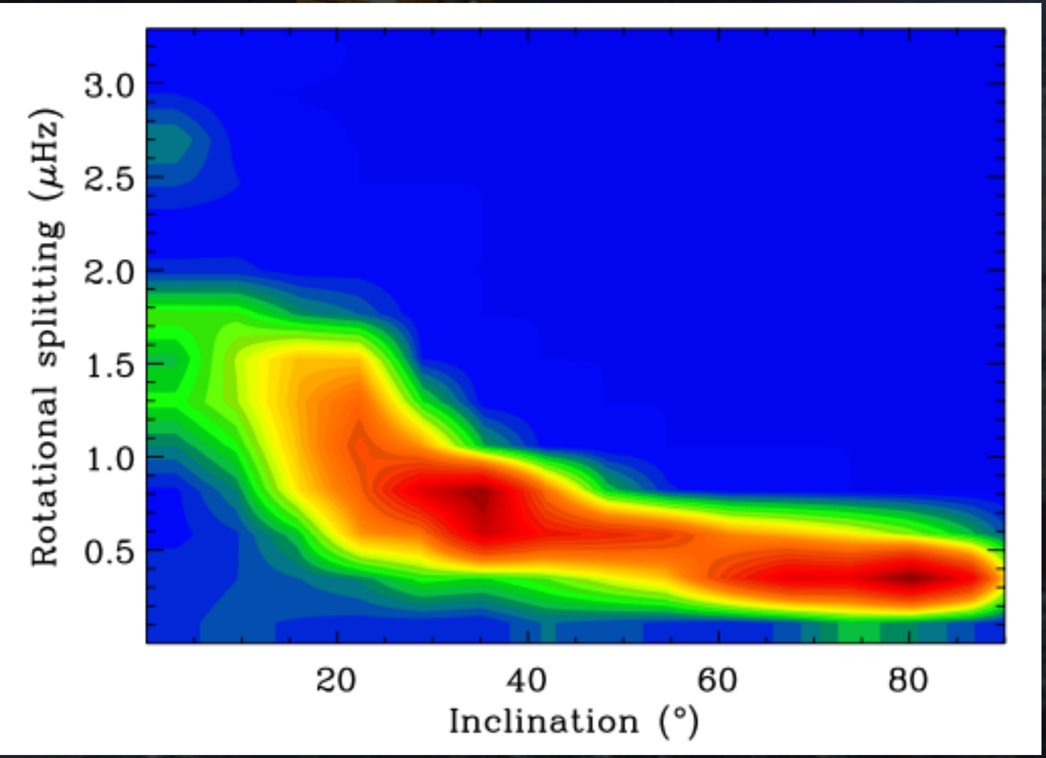
HD169392



[Mathur et al. 2013]

STARS IN MULTIPLE SYSTEMS

- Two S-L main targets belongs to multiple systems:
  - HD 169392
    - weakly bound binary system

      [Mathur et al. 2013]
  - HD 43587
    - quadruple system composed of two distant main sequence visual binaries

      [Boumier et al. in preparation]

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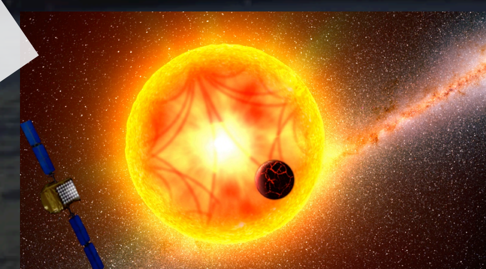
      [Mathur et al. 2013]
  - HD 43587
    - quadruple system composed of two distant main sequence visual binaries

      [Boumier et al. in preparation]
- Two host of non-transiting planets
  - HD 46375
    - Determination of the global stellar parameters
      - Re-estimation of the projected mass of the planet (a factor 2 better accuracy)

        [Gaulme et al. 2010]
  - HD 52265
    - Determination of the global stellar parameters and the inclination of the star
      - The companion is more likely a planet and not a brown dwarf

        [Gizon et al. 2013]
- Also new *Kepler* results

  [Huber et al. 2013; Chaplin et al. 2013]



PLATO-like Science

STARS IN MULTIPLE SYSTEMS

- Highlights on some results based on *Kepler* targets

[Huber et al. 2013]

  - 66 seismic targets (107 planet candidates)
    - Complete different planetary solution for 4% of them
- Surface gravities in Batalha et al. (2013) based on high-resolution spectroscopy
  - Subgiants and giants are systematically overestimated,
    - underestimated stellar radii (and hence planet-candidate radii) by up to a factor of 1.5
  - Unevolved stars are in good agreement
    - But greatly improved when seismology is taken into account

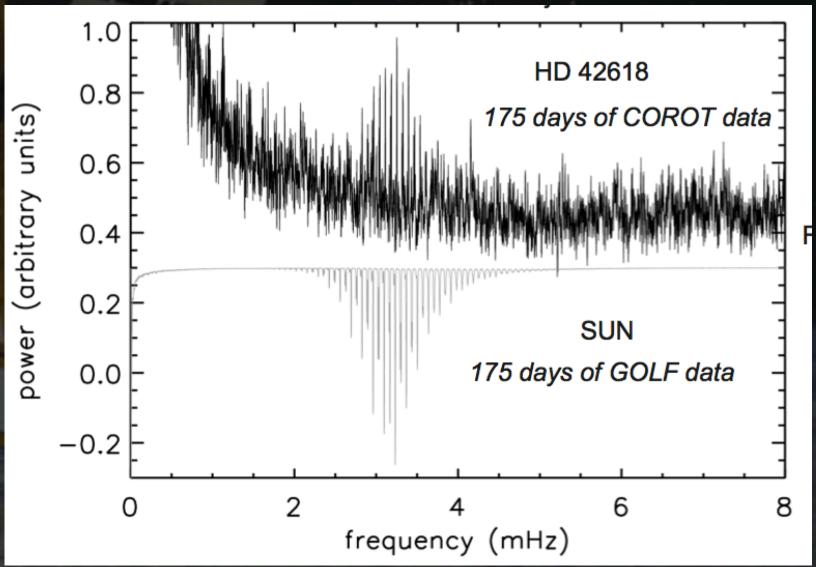
- Identification of misclassified stars (sub giants and giants instead of M dwrfs)
- Stellar densities compared with those derived from transit models (circular orbits)
  - significant disagreement for > 50%
    - systematics in the modeled impact parameters, or due to planet candidates which may be in eccentric orbits.
- Re-derived radii and semi-major axes for the 107 planet candidates

PLATO-like Science

STARS AS A PHYSICS LAB.

- Looking to other solar analogues to better understand the Sun : HD42618
  - A solar analogue $R=0.91\pm0.001\ R_{\odot}$; $M=0.85\pm 0.01\ M_{\odot}$

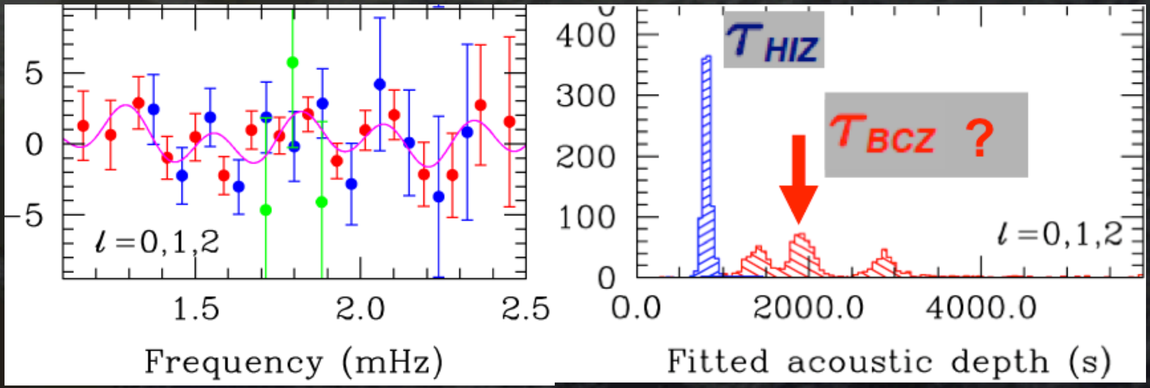
[Barban et al. in preparation]



- Sounding the cores:
  - Through mixed modes
    - Very precise dating tool
      - HD49385 [Deheuvels & Michel 2010, 2011]
  - Existence of core overshoot
    - HD49933 [Benomar et al. 2010; Goupil et al. 2011]
      - Core overshoot needed
- Tracking the HeII partial ionisation zone and BCZ:
  - HD49933

    [Mazumdar & Michel 2010]
  - HD181907 (RG)

    [Miglio et al. 2010]



- Constraining stellar Tachoclines:
  - HD52265:
    - Larger than the Sun

    [Lebreton & Goupil 2012]

OTHER ON-GOING WORKS

- On Amplitudes and linewidths + global seismic parameters
  - Mosser/Belkacem talk
- Comparing Models and Observations:
  - The Surface effects
    - I. Roxburgh talk + Poster
- Surface rotation extracted from the light curves:
  - Already seen yesterday ☺
    - J.D. do Nascimento Jr.
- Stellar activity
  - Already seen yesterday ☺
    - F. Baudin, J. Weingrill
  - Talk by Mathur/Garcia
- + everything else that I could not mention

WHAT ABOUT THE FUTURE?

- CoRoT mid-term S-L future is bright
  - With still some new data not yet analysed and archive datasets
- Legacy catalogue of stellar parameters
  - Masses, Ratios, logg…
    - Stars in the sismo and exo field showing S-L pulsations

[Fp7-SPACEINN Project]

- Statistical analysis of stars as a function of the evolutionary state:
  - (Surface) Rotation
  - Magnetic induced variability
  - Background (granulation) properties
- Constraints on stellar physics
  - New physics to be tested:
    - Core overshoot
    - Tachoclines + glitches…
  - Properties of stars in the clump vs. RGB
    - E.g. Mass loss during RGB

PLATO


¡¡Gracias
CoRoT!!
And all the crew
that makes this possible

After CW11

There's new hope…

Welcome to

CoRoT Symposium 3 + KASC-7

To be held in Summer 2014

TOULOUSE