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STELLAR ROTATION AND MAGNETIC ACTIVITY:

USING ASTEROSEISMOLOGY

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Special thanks to:

S. Mathur, K. Auguston, J. Ballot, T. Ceillier, T. Metcalfe, and D. Salabert,

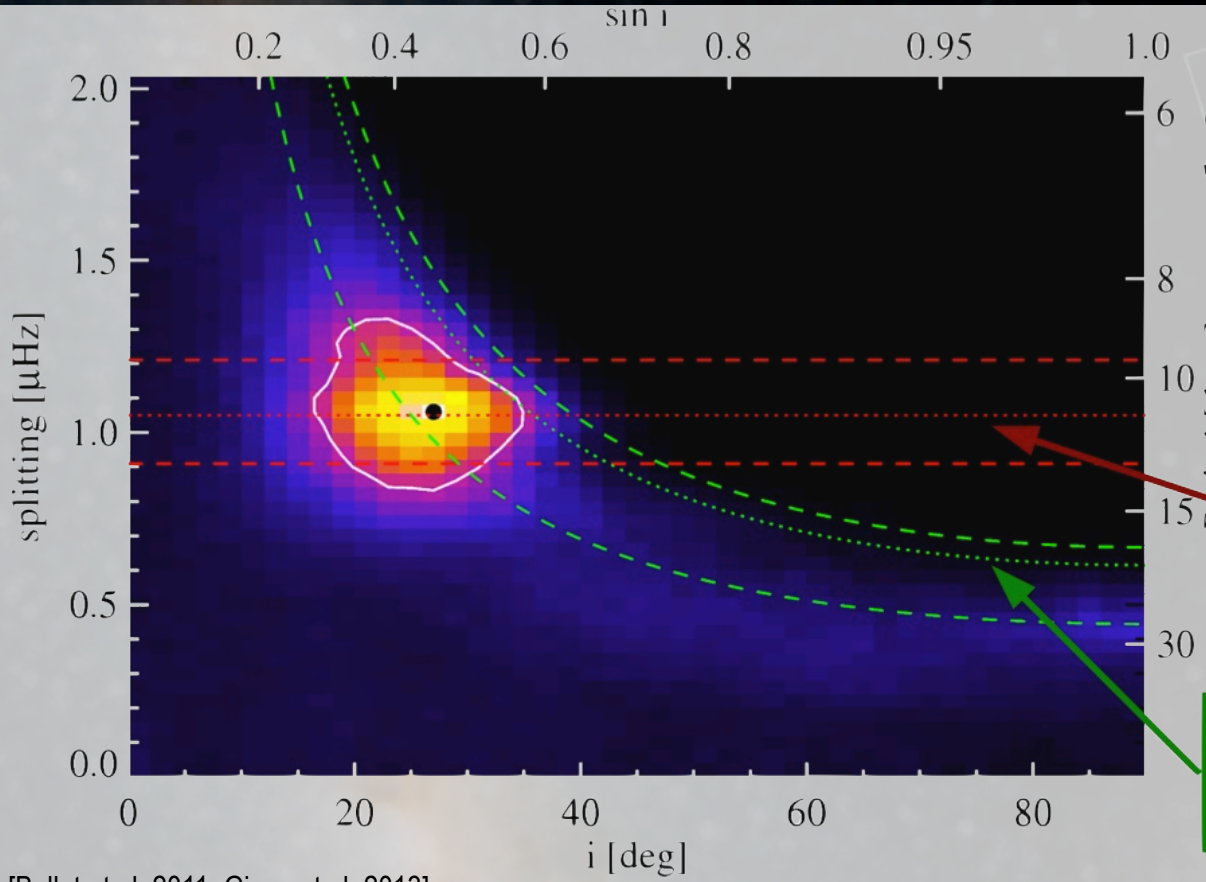
I-INTRODUCTION

- The study of stellar dynamics is a challenge
  - Internal rotation
    - Modify stellar structure and evolution
      - e.g. increasing the mixing in radiative zones
        - Modify the determination of the age
  - Surface rotation
    - Gyrochronology:
      - Validation of the age-rotation relation
        - Universal law (stars harbouring planets)?
  - Magnetic Activity
    - In which conditions stars develop magnetic cycles
      - When are they regular?
      - Study of magnetic activity (history) on stars harbouring plants in the habitable zone

II-Determining the rotation rate of stars:

Internal

II-INTERNAL ROTATION (MS)



HD52265

Colored map: mode fitting
White: high probability
Black: low probability

spots

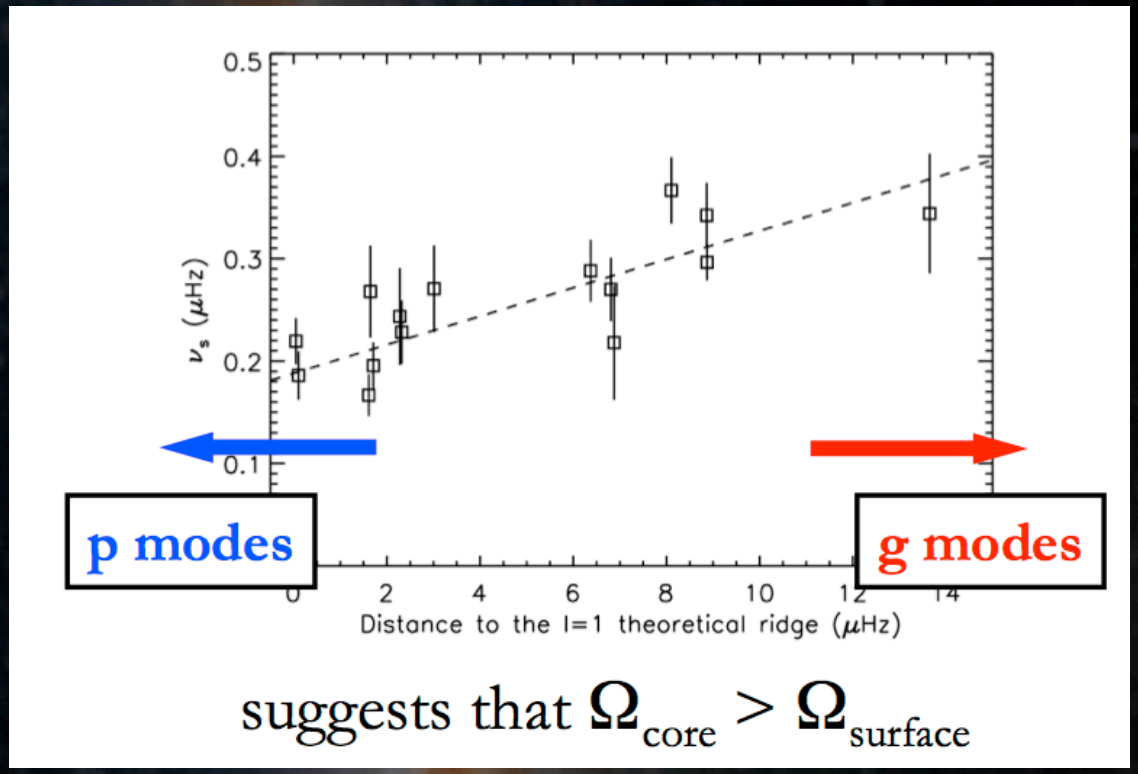
Spectro. Constraints (vsini) + R from seismo.

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

[Chaplin et al. 2013 for some Kepler results on Kepler-50 and Kepler-65]

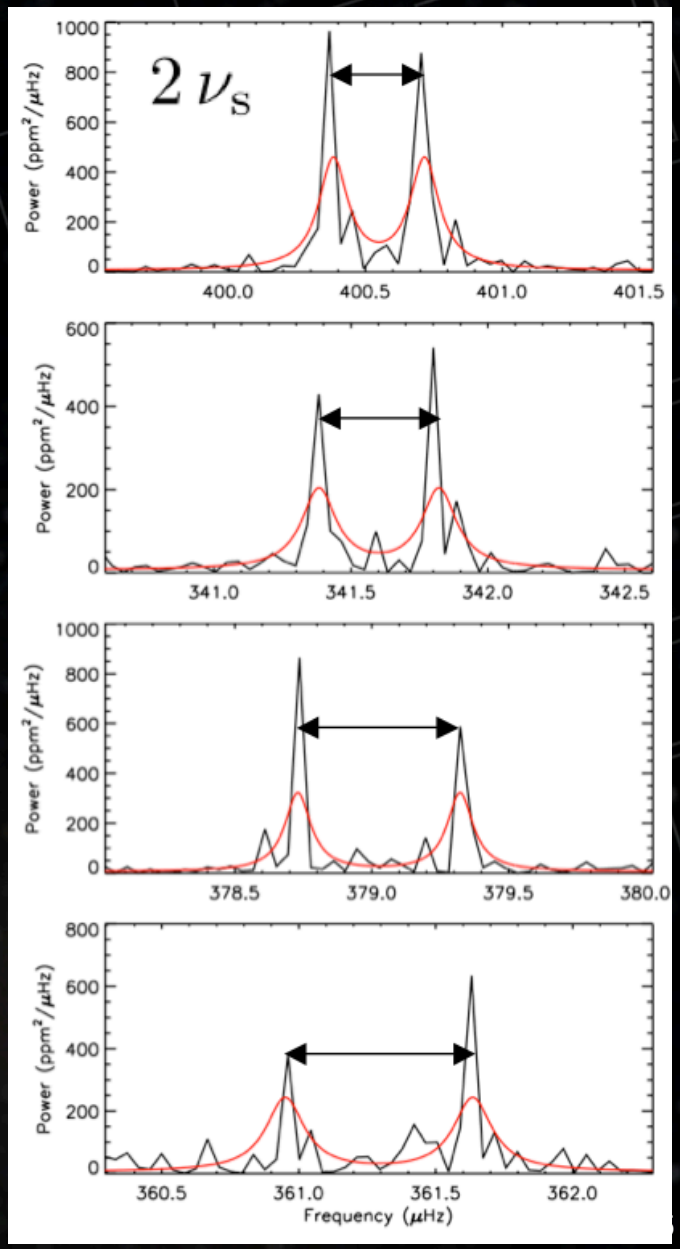
II-INTERNAL ROTATION

- Mixed modes allow us to study the internal dynamics
  - g-dominated mixed modes:
    - Sensitive to the deep radiative interior
  - P-dominated modes
    - Sensibility weighted towards the outer layers



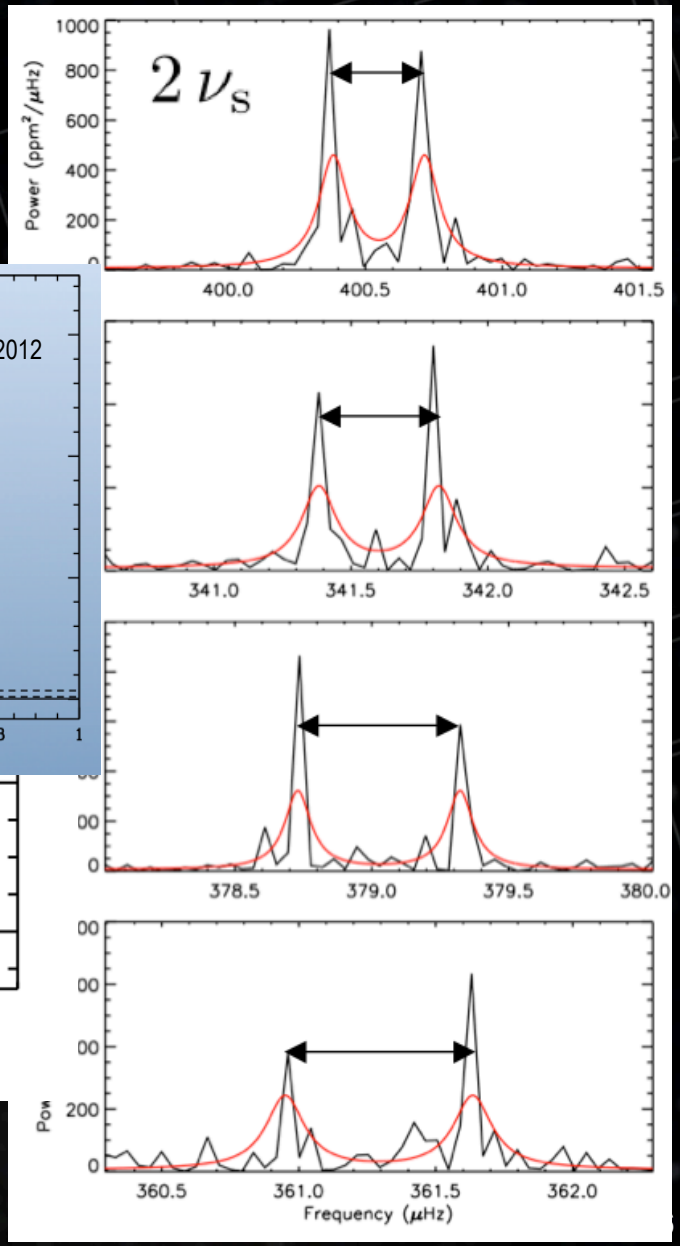
[Deheuvels, Garcia, et al. 2012]

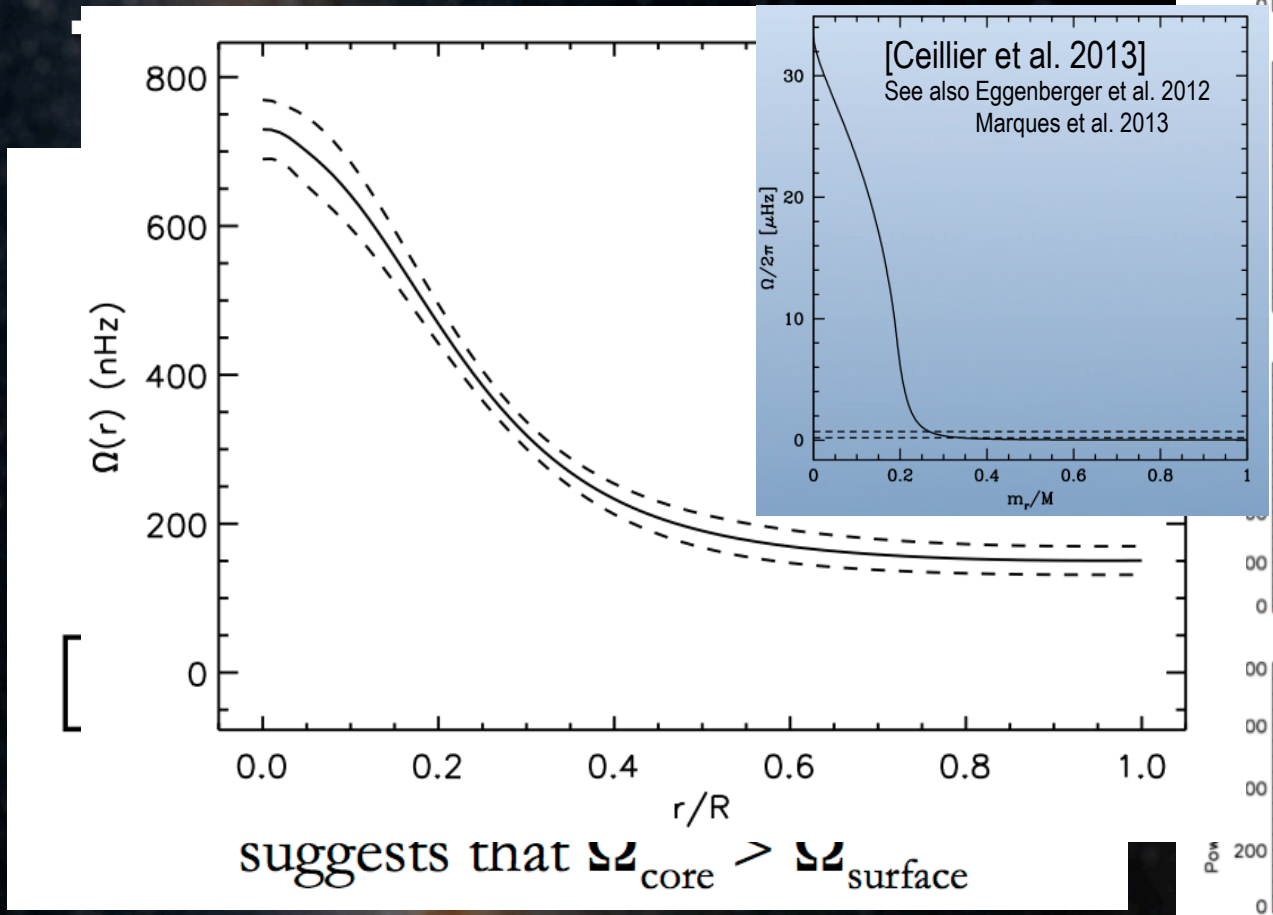
[see also Beck et al. 2012 for the analysis of 3 Rg]



II-INTERNAL ROTATION (SUBGIANTS)

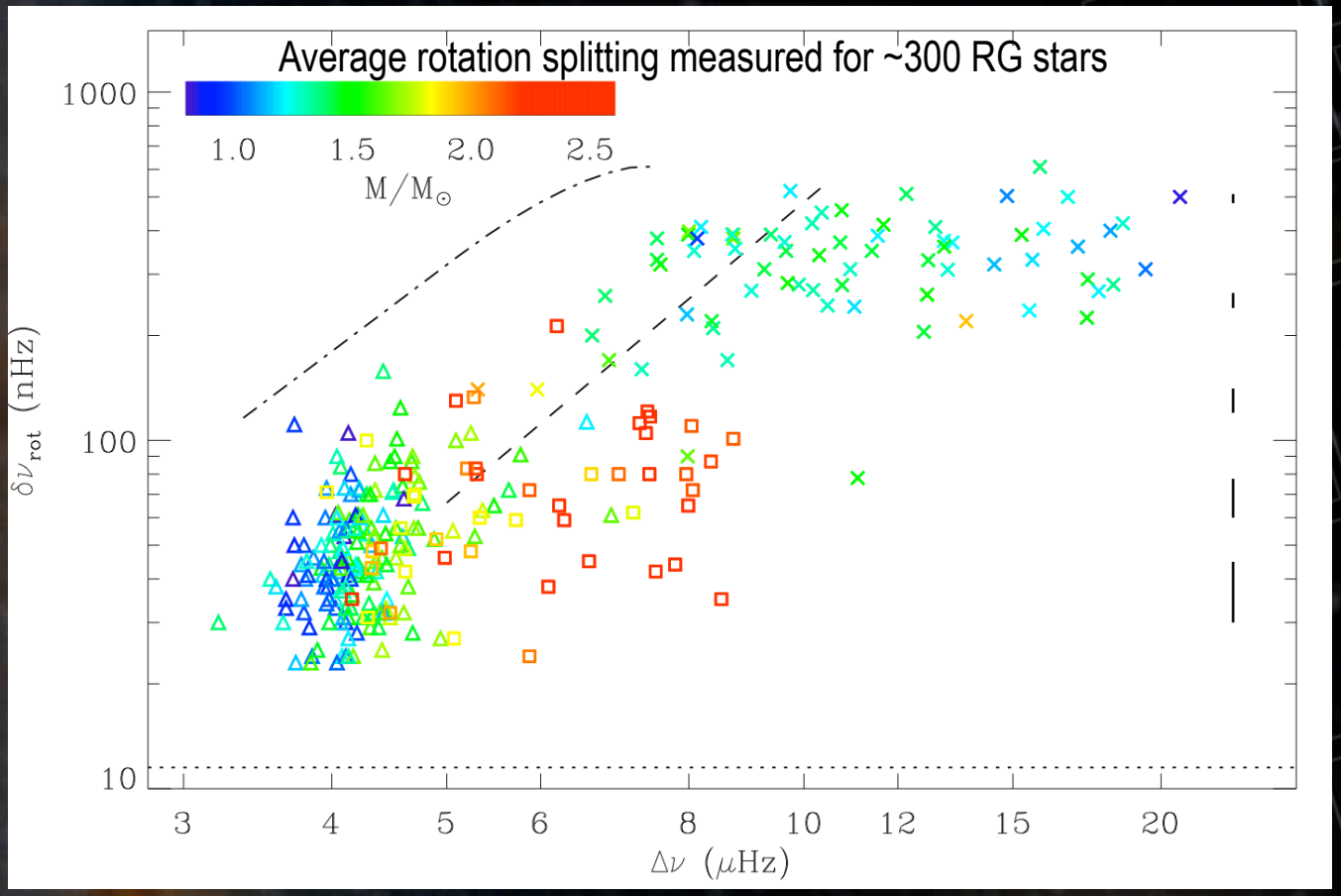
- Mixed modes allow us to study the internal dynamics
  - g-dominated mixed modes:
    - Sensitive to the deep radiative interior





[Deheuvels, Garcia, et al. 2012]

II-INTERNAL ROTATION



[Mosser et al. 2012]

- Ensemble analysis used to obtain a proxy of the rotation rate of the deep radiative interior
- During RGB: (Assuming local conservation of ang. Momentum)
  - contradiction with core contraction
- Change from RGB to the clump can be related to the expansion of the non-degenerate helium burning core.
  - It can not explain all the reduction

[Iben 1971; Sills & Pinsonneault 2000]

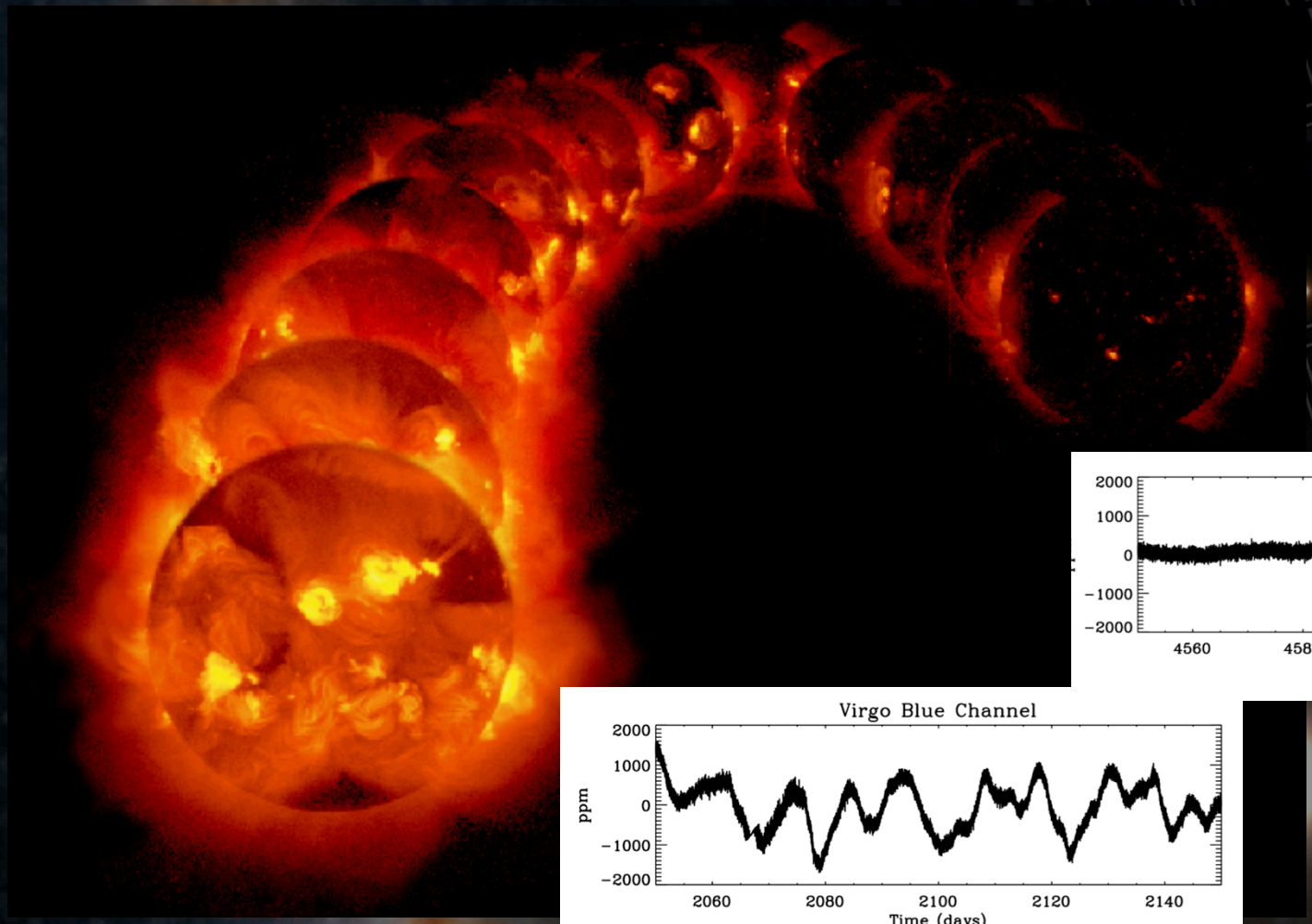
    - significant transfer of internal angular momentum from the inner to the outer layers.

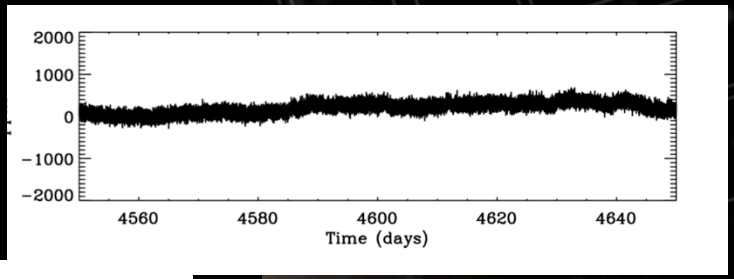
III-Determining the rotation rate of stars:

Surface

III SURFACE ROTATION

- When a star is magnetically active
  - Starspots crossing the visible disk of stars induce a modulation in the light curve



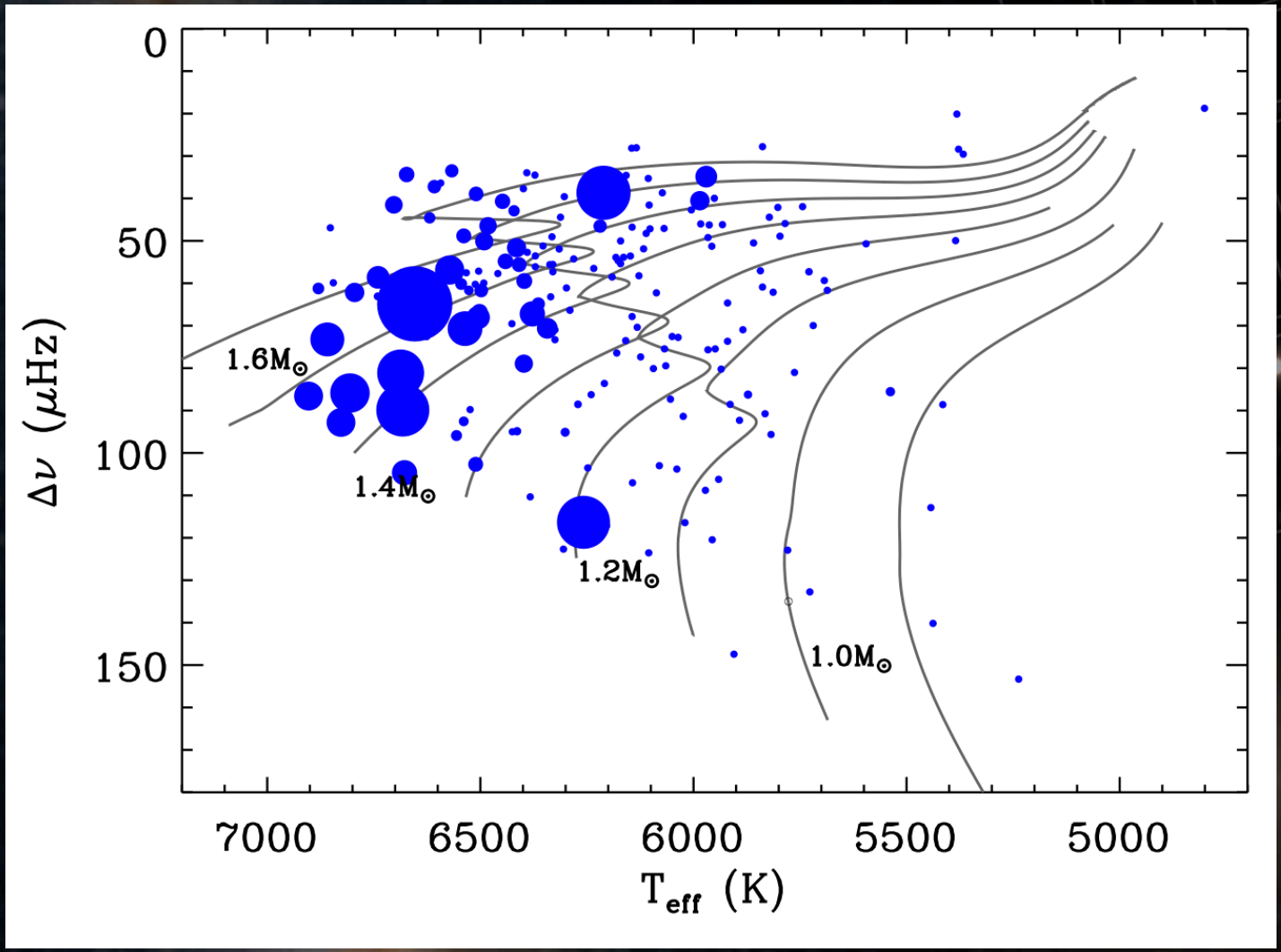


Solar Activity Minimum

Solar Activity Maximum

III-SURFACE ROTATION (F-G, S-L STARS)

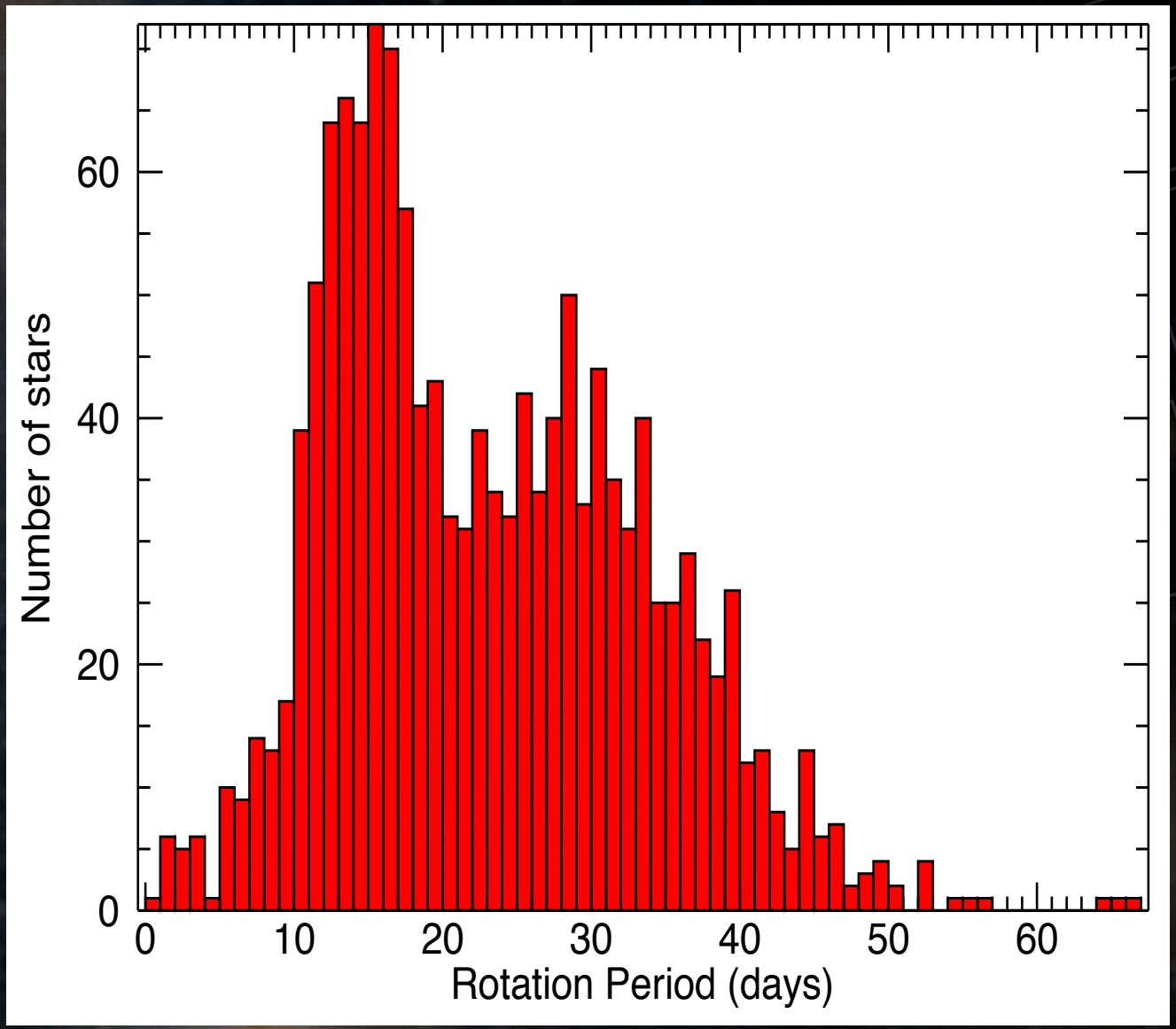
- ~540 solar-like stars showing p-mode oscillations have been measured (1 month) [Chaplin et al. submitted]
  - After solving Kepler calibration issues : On going extraction of the surface rotation rate



[García et al. in preparation]

III-SURFACE ROTATION

- *Kepler* analysis of 2483 M-type stars



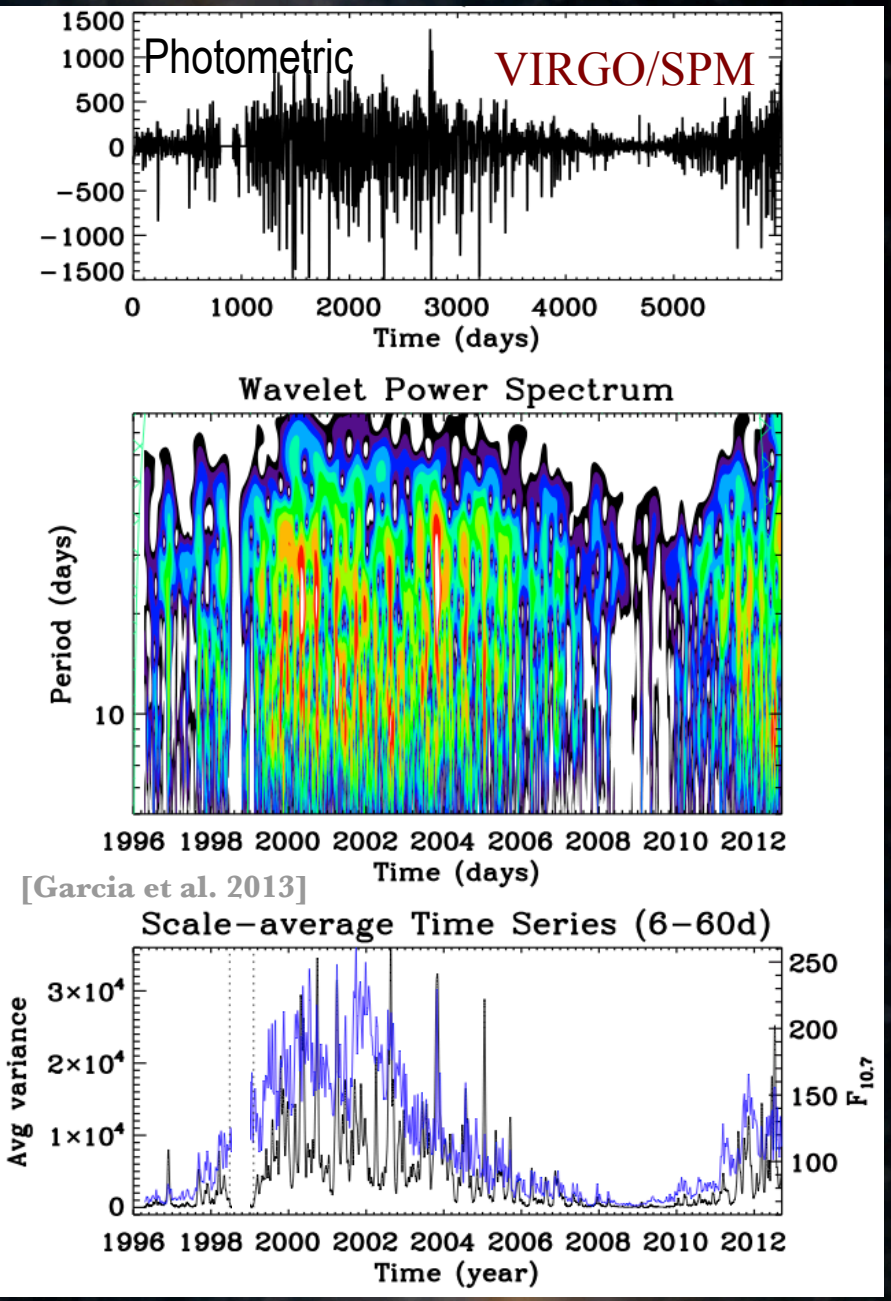
[McQuillan et al. 2013]

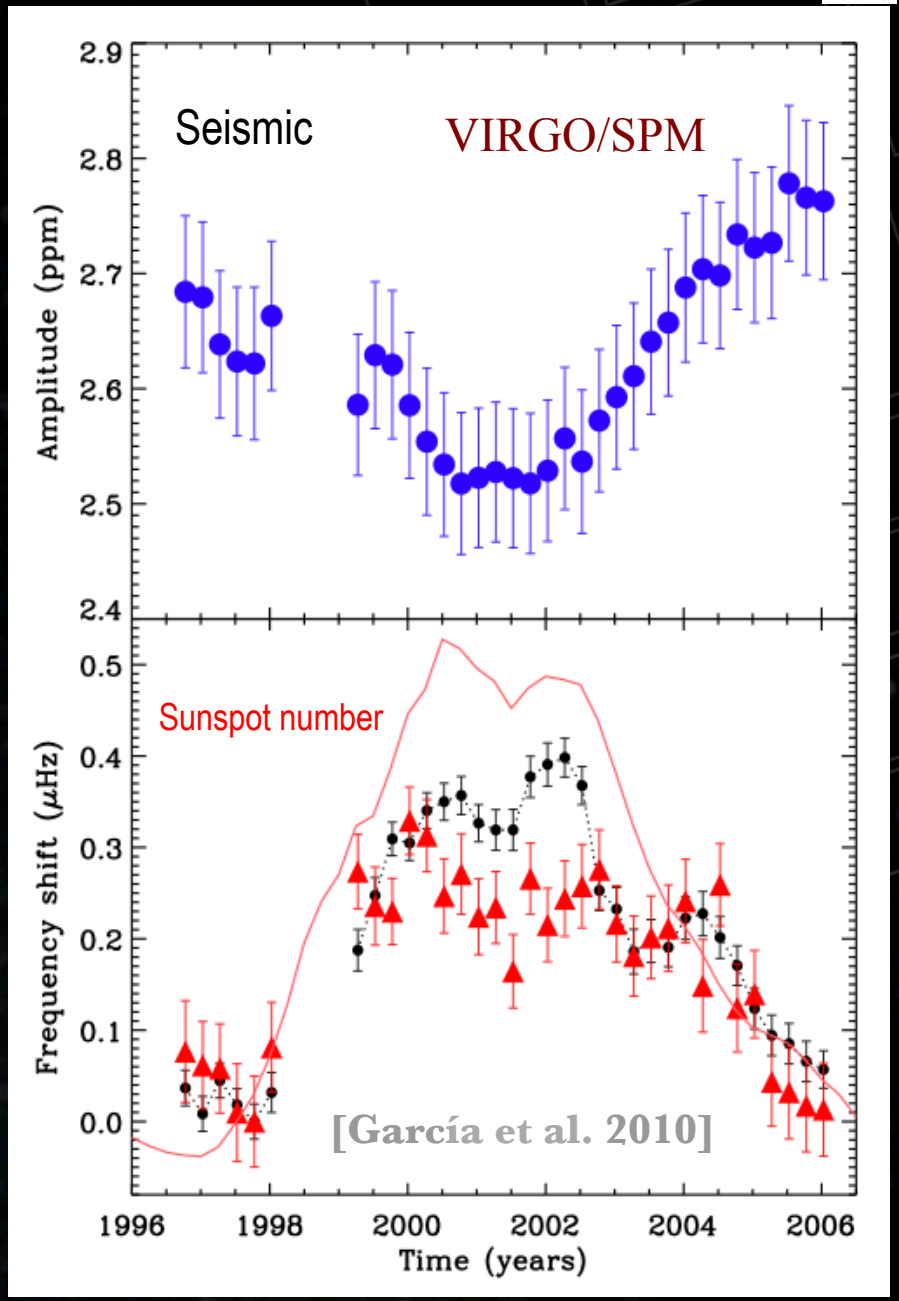
IV-Magnetic activity cycles

IV-MAGNETIC ACTIVITY CYCLES

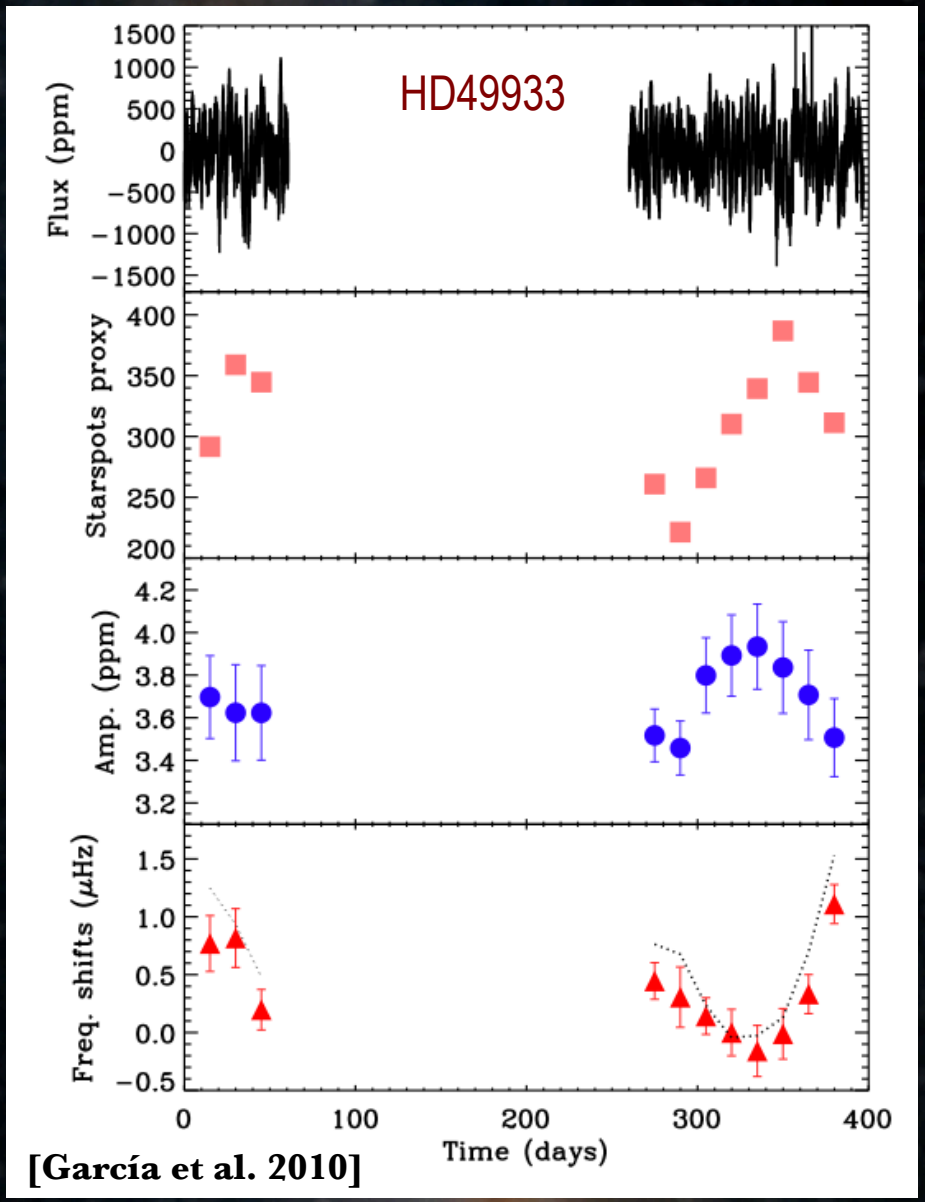
- Magnetic activity in stars:
  - Combination of Convection-Rotation-Magnetic Fields
- What can offer asteroseismic observations to better understand stellar dynamics ?
  - Asteroseismic observations can potentially give access to:
    - Surface (differential rotation)
    - Internal (differential rotation)
  - Convection properties
    - Characteristic time and sigma of the granulation
  - Internal structure
    - Size of the convective envelope
    - Probing (or not) the existence of internal magnetic fields
  - Activity cycles
    - Through the light curves or with seismic activity proxies

IV-STELLAR ACTIVITY





IV-MAGNETIC ACTIVITY CYCLES



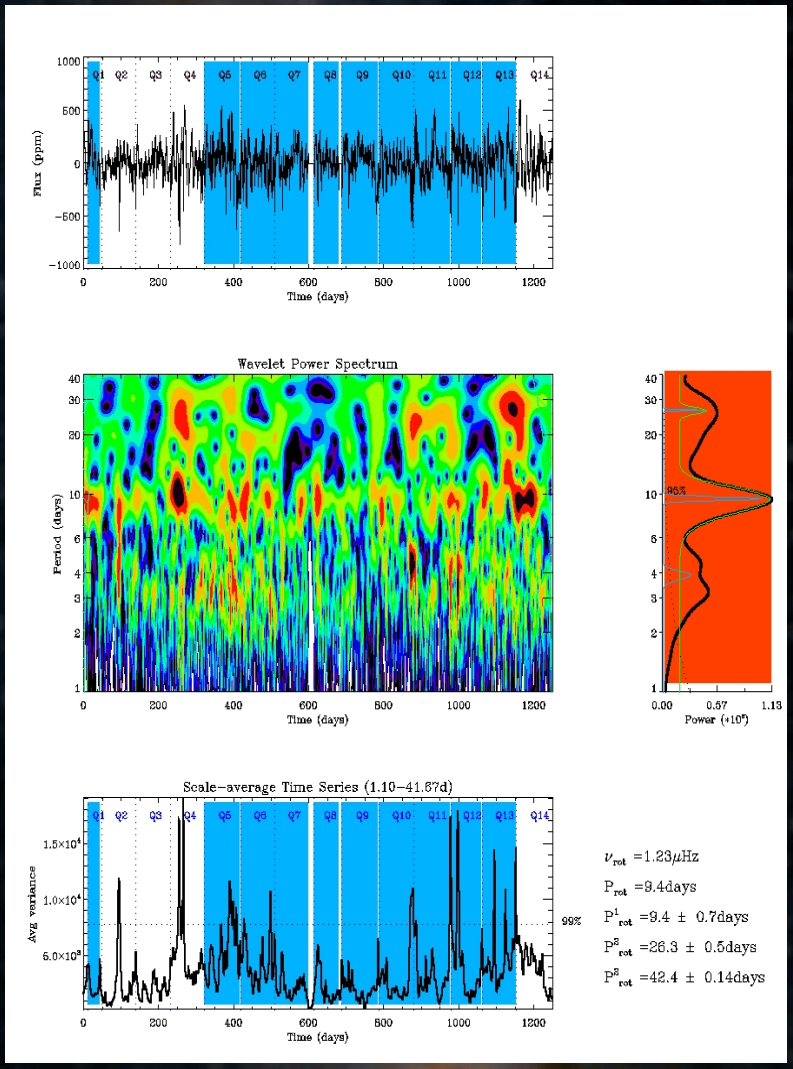
Anticorrelation between amplitude variation and frequency shifts

P_{cyc}>120days

- Complementary observations
  - ✓ Ca HK: Mount Wilson index
    - ✓ 0.31 (Active star)
  - ✓ See a modulation indication of an activity cycle

[Mathur, Metcalfe et al. in preparation]

IV-STARS AS MHD LABS



[Mathur et al. to be submitted]

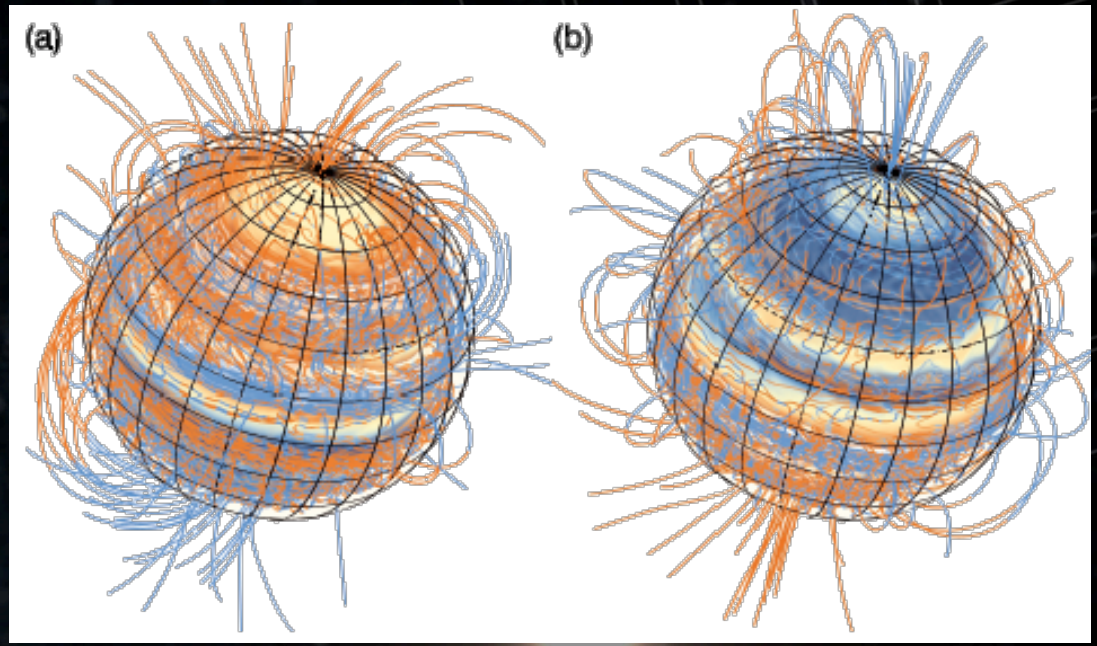
a.k.a Dushera

- 1D Seismic model by AMP

Coupled to

- 3D MHD Model by ASH

Preliminary results: a cycle has been established



[Augustson, Mathur, Brun et al. in prep.]

CONCLUSIONS (1)

Understand stellar dynamics

Is required

to better constraint exoplanet parameters

PLATO will be the only projected mission to address these scientific questions

For a large sample of solar-like stars

Joint 3rd CoRoT Symposium & 7th *Kepler* KASC Workshop

The Space Photometry Revolution

Espace Vanel, Toulouse (France)
6 – 11 July 2014

http://corot3-kasc7.sciencesconf.org