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STUDYING STELLAR MAGNETIC ACTIVITY:
ASTEROSEISMIC MEASUREMENTS

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I-Introduction

I-STELLAR ACTIVITY

- Activity cycles are the consequence of:
  - Interaction between
    - Rotation, convection & magnetic fields
- There is a relation between:

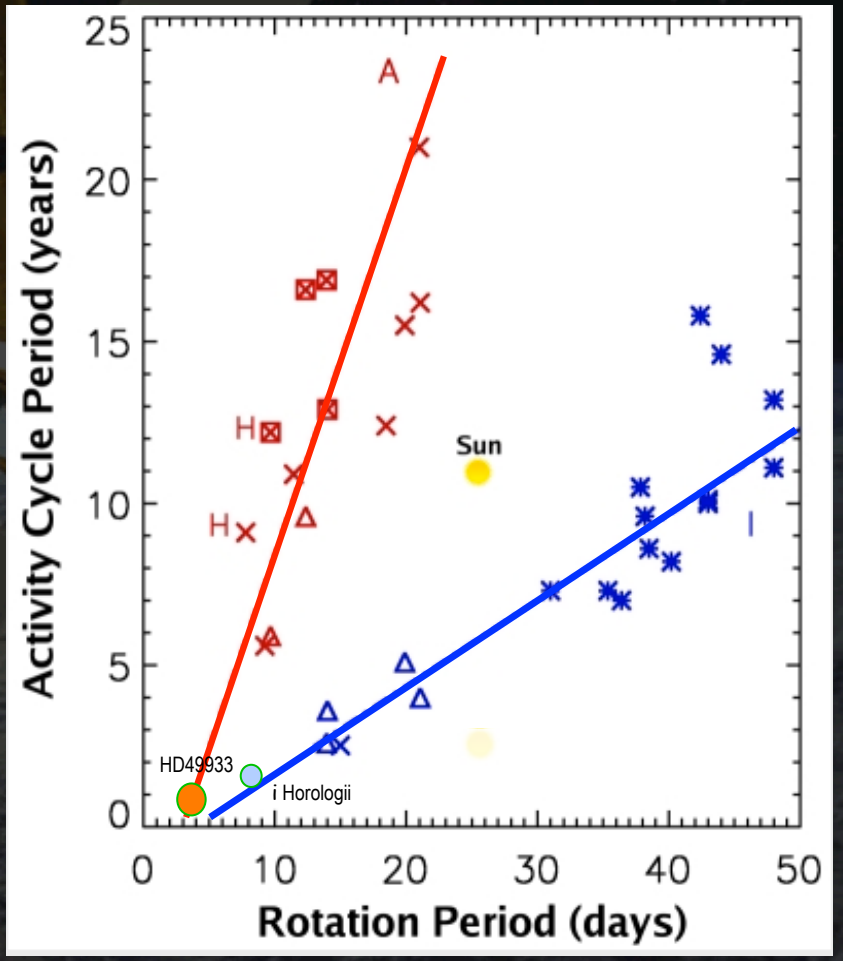
$$P_{cyc}/P_{rot} = \Omega/\Omega_{cyc} = CRo^{q}$$

[e.g. Thomas & Weiss 2008]

  - with $Ro = P_{rot}/\tau_c$, the Rosby number
  - τ_c the convective turnover time
  - q changing from 0.25 to 1

[e.g. Ossendrijver 1997; Saar 2002; Jouve et al. 2010]

- Stellar activity cycles:
  - Two branches
  - The position of the Sun
    - Between both branches
- Faster rotators
  - Stronger magnetic activity amplitudes
  - Rarely have regular cycles



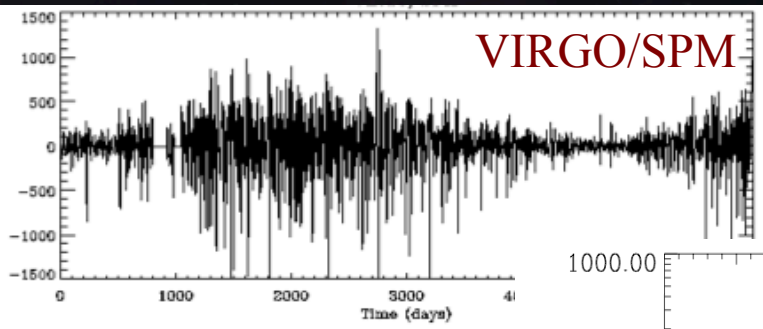
[Adapted from Bohm-Vitense, 2007]

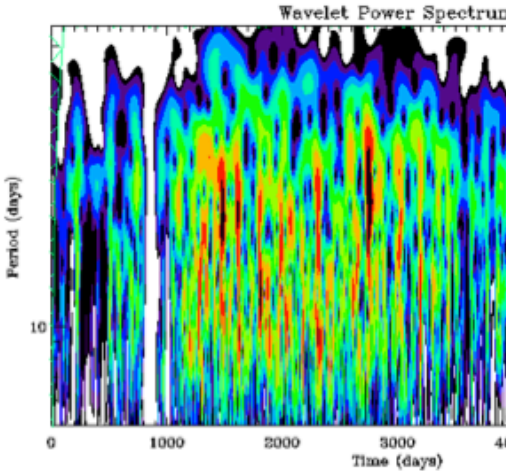
[Fletcher et al. 2010]

I-WHAT CAN SEISMOLOGY OFFER?

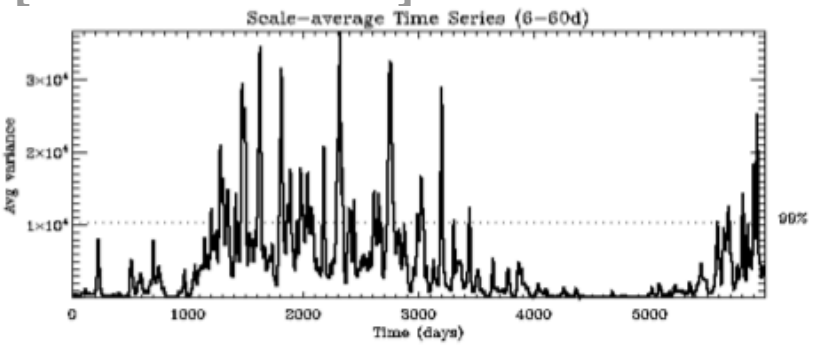
- Long, uninterrupted (stable?) photometric observations
  - CoRoT
    - Hundred days (2 or 3 times)
  - Kepler:
    - More than 3.5 years
- Convective properties
  - Characteristic time of the granulation
  - Depth of the convective zone
- New magnettic-activity cycle proxies:
  - Frequency shifts
  - Mode amplitudes

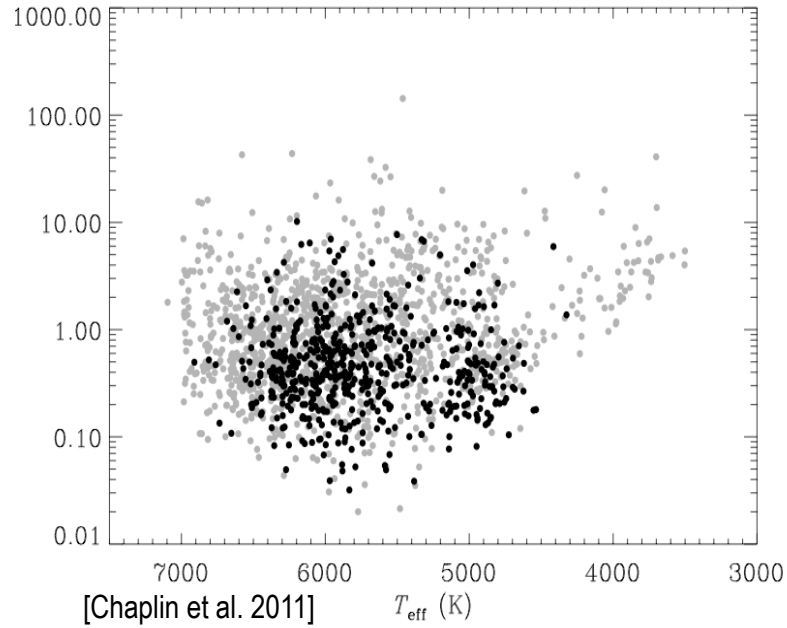
I-METHODOLOGY: THE SUN



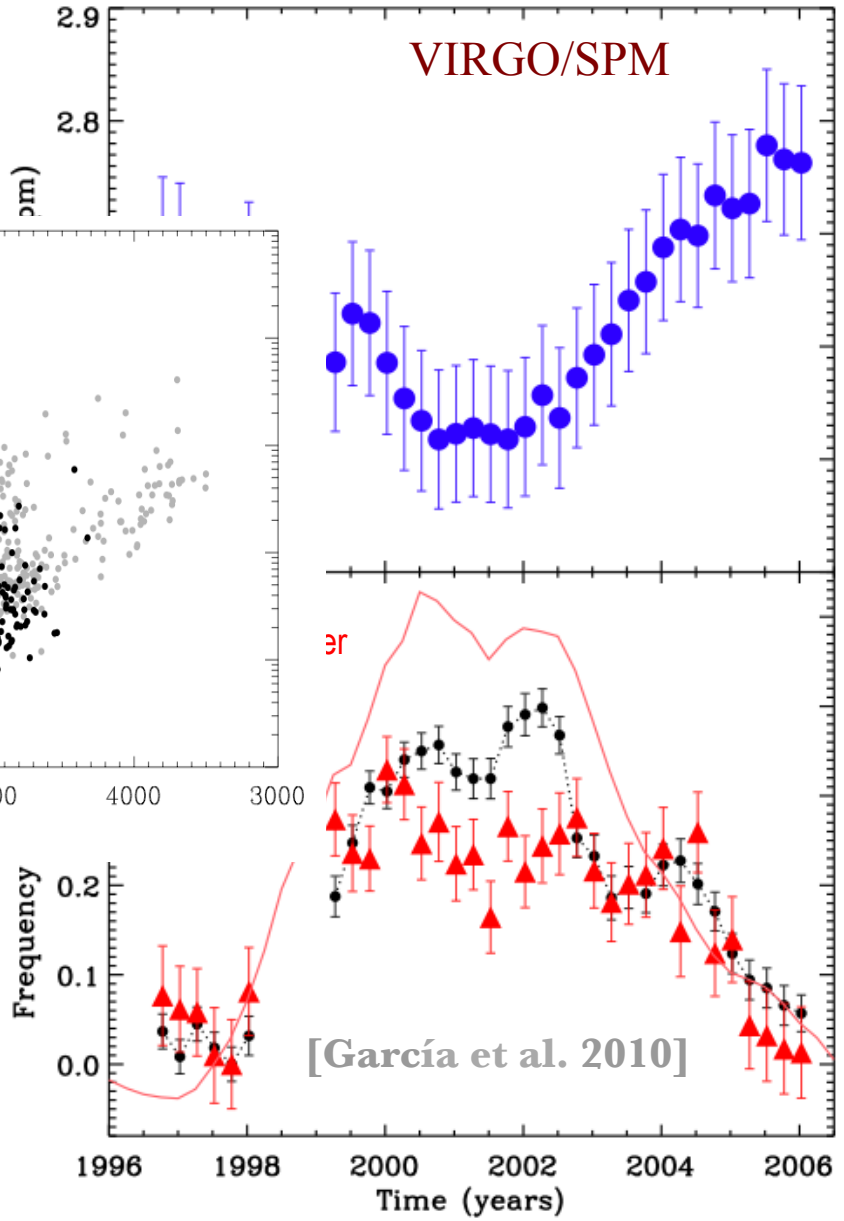


[Mathur et al. 2013]





[Chaplin et al. 2011]



[García et al. 2010]

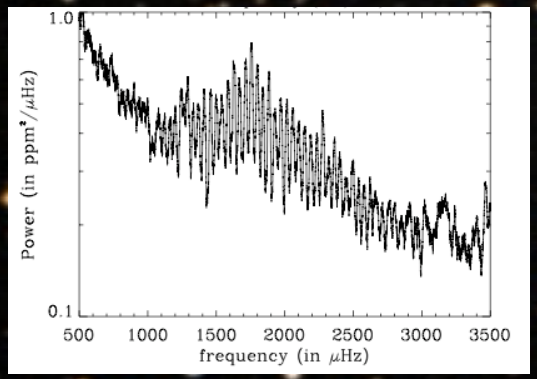
II- RESULTS:

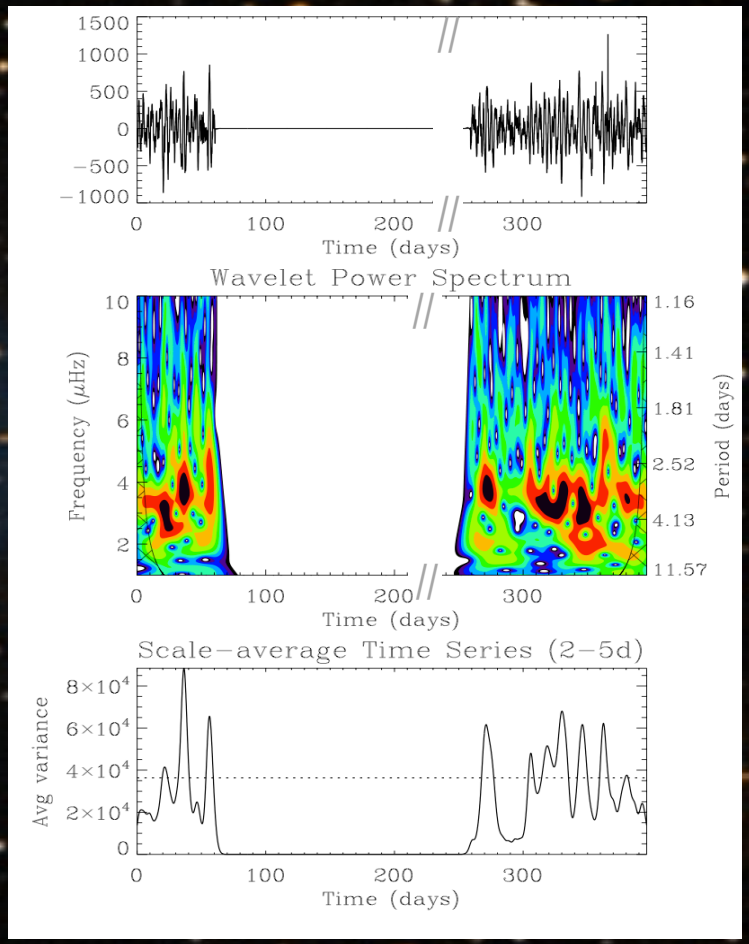
CoRoT

II-THE COROT TARGET: HD49933

Stellar parameters:

- F5V dwarf
  - 1.2 $M_\odot$; 1.3 $R_\odot$
- Observed by CoRoT during 60 + 137 days + 90 days
  - 50 oscillation modes measured
- P_{rot} = 3.4 days

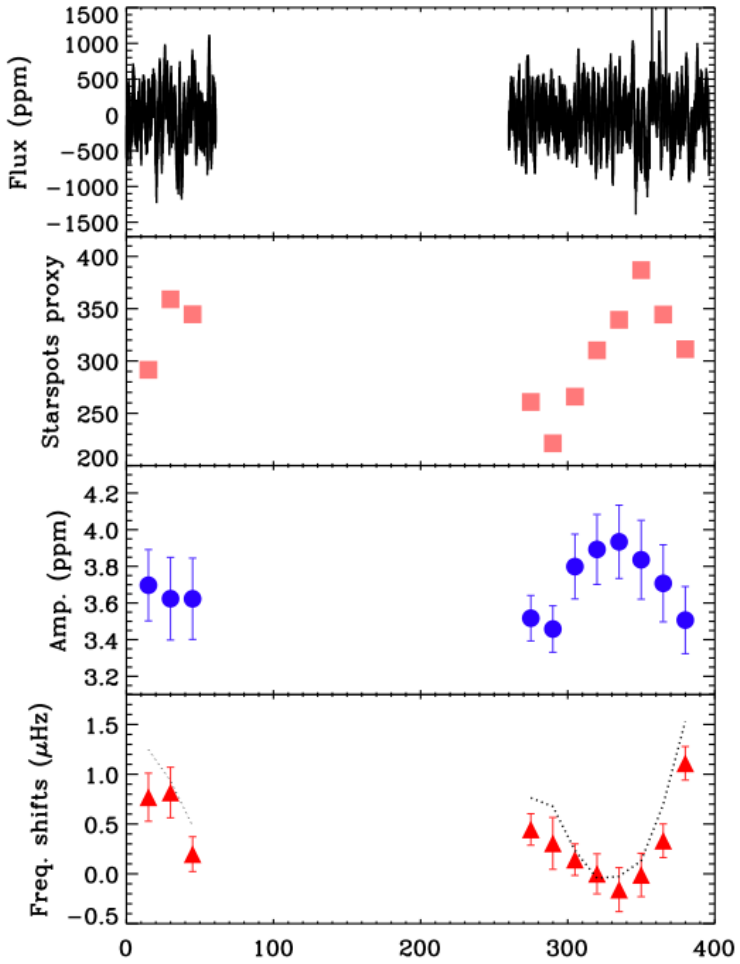




[Appourchaux et al. 2008; Benomar et al. 2009]

HINTS OF A MAGNETIC-ACTIVITY CYCLE

Seismology



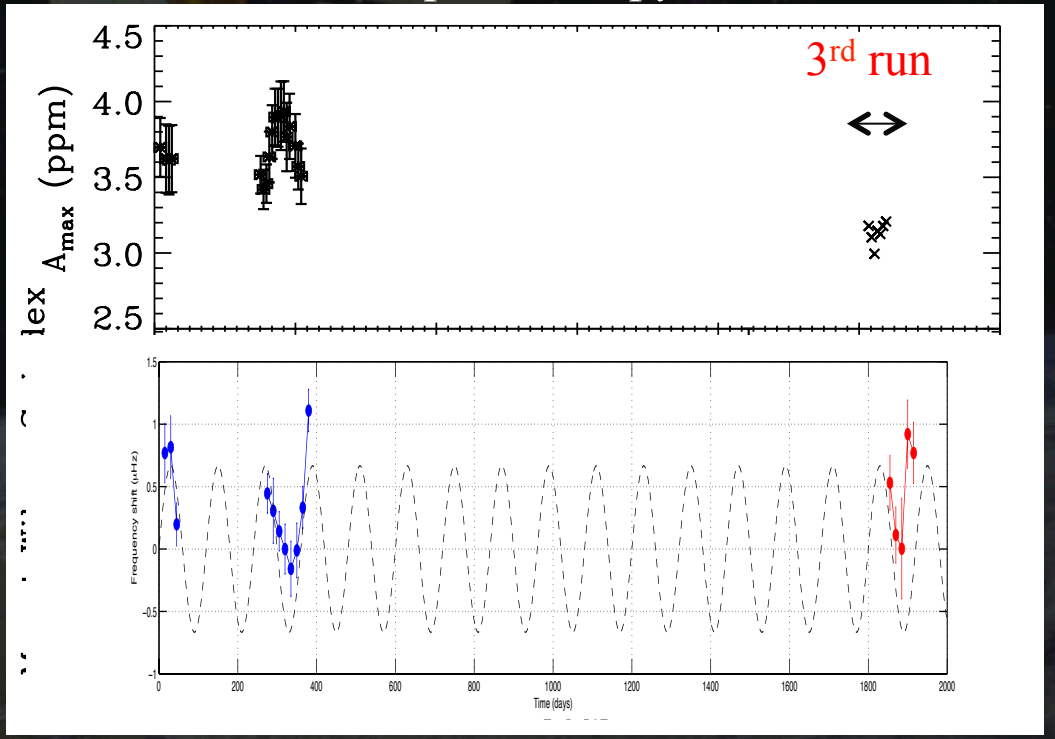
[García et al. 2010]

Anticorrelation between amplitude variation and frequency shifts

P_{cyc}>120days

HD49933

Spectroscopy



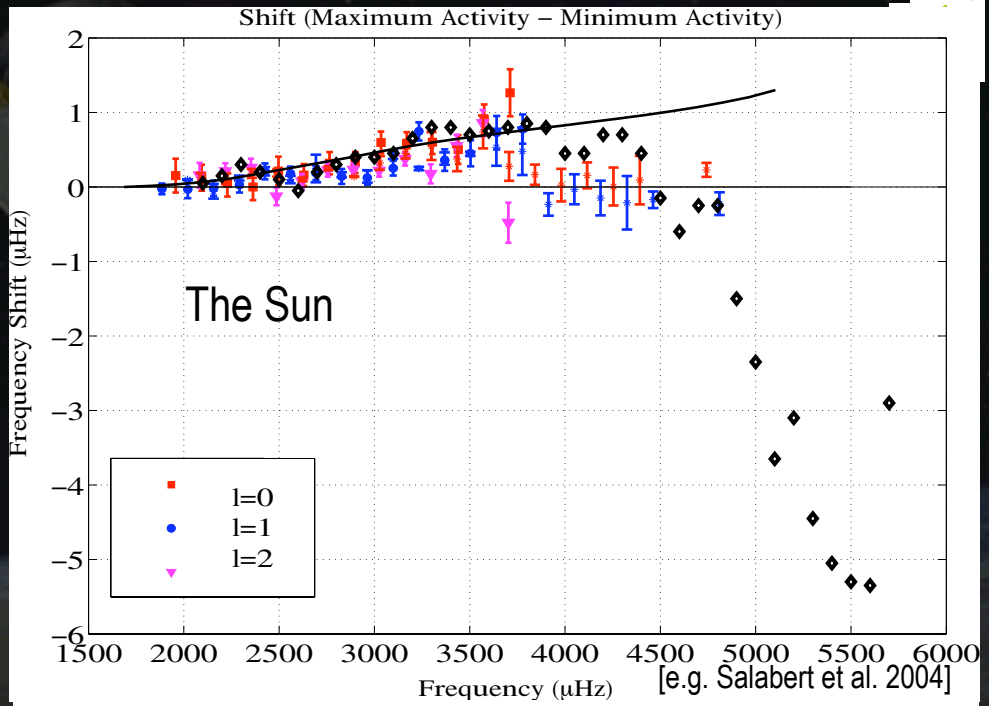
- Complementary observations
  - ✓ Ca HK: Mount Wilson index of 0.31
    Active star

II-DEPTH OF THE PERTURBATION

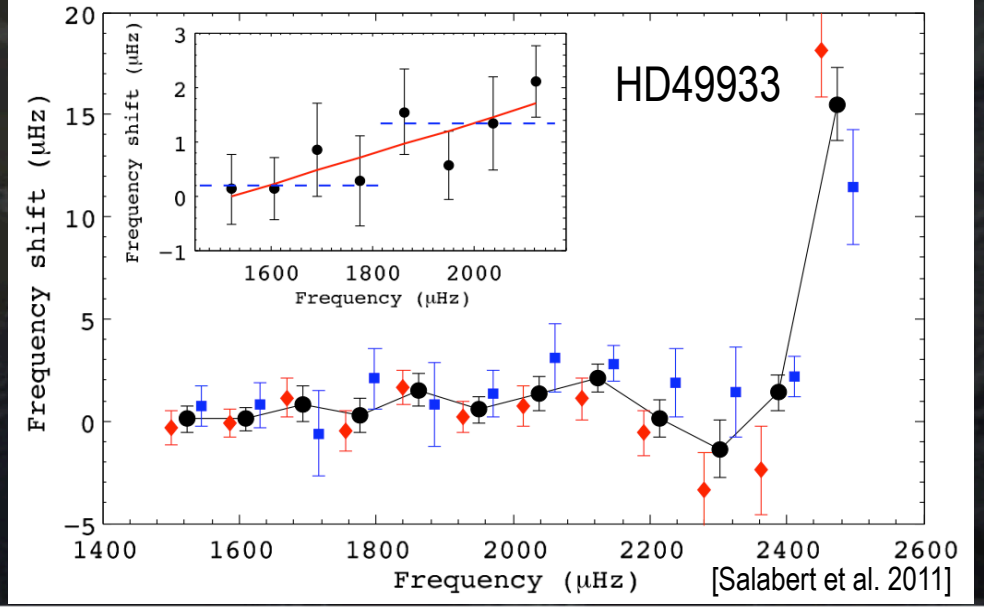
- The frequency shifts only affect:
  - Modes > 2 mHz
    - Surface effect
    - Modes <2 mHz
      - External turning point
      - Deeper as frequency decreases

- Similar dependence of $\Delta\nu(\nu)$:
  - Found in HD49933
  - Surface effect

[Ceillier et al. 2011]



[e.g. Salabert et al. 2004]



[Salabert et al. 2011]

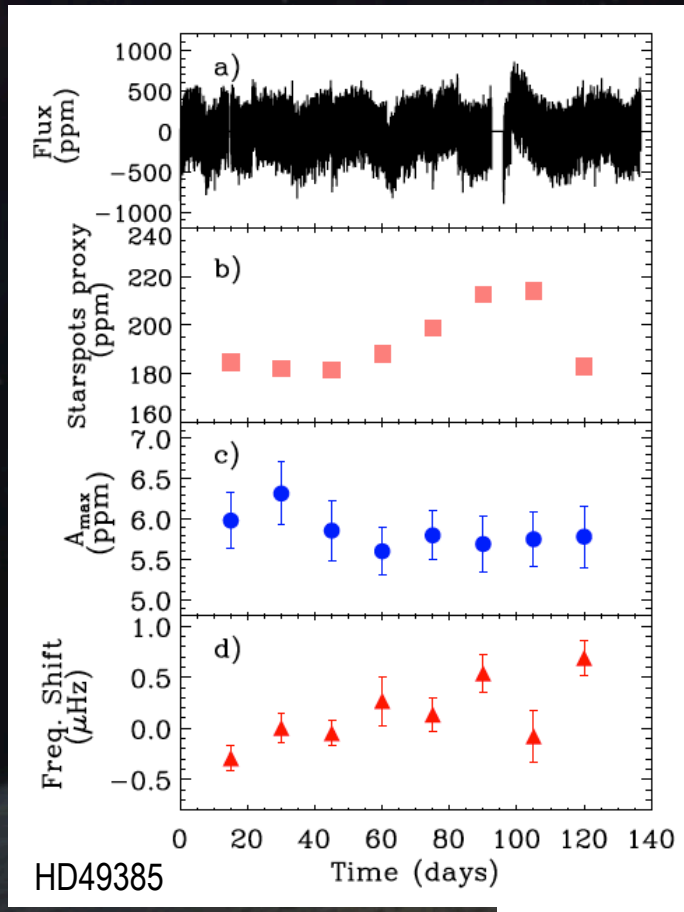
II-ANALYSE OF 3 OTHER STARS

➢ Using CoRoT and NARVAL:

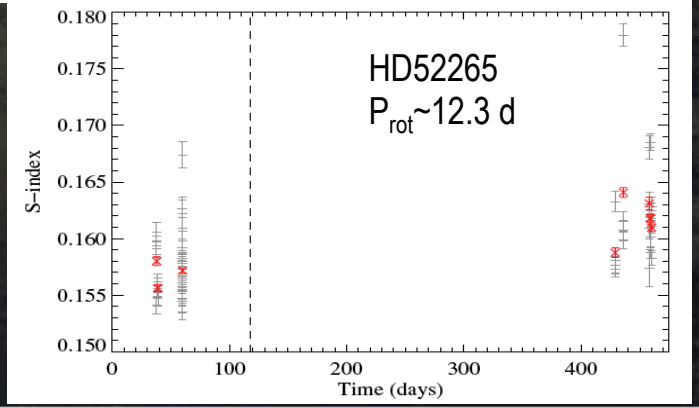
[Mathur et al. 2013]

Star	S-index
HD 49385	0.139
HD 52265	0.159
HD 181420	0.245
Sun	[0.16–0.2]

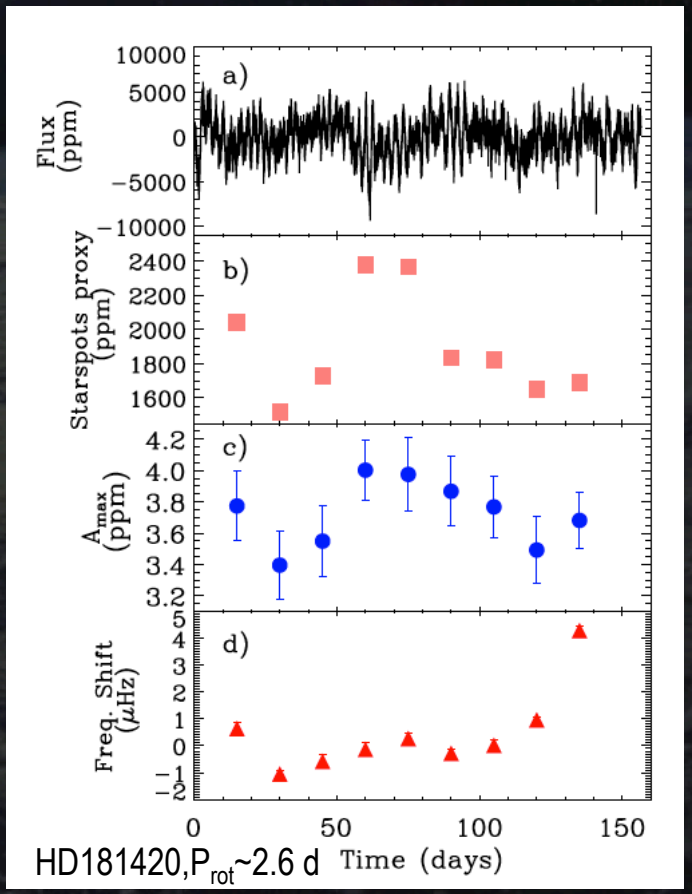
Star	Correlation coefficient	False alarm probability
HD 49385	−0.4	48.9%
HD 52265	0.4	48.9%
HD 181420	0.3	59.9%



HD49385



HD52265
P_{rot}~12.3 d



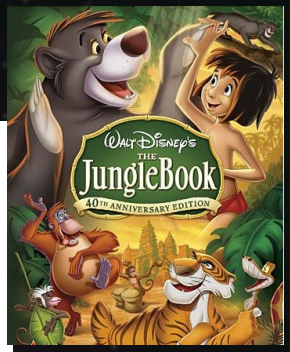
HD181420, P_{rot}~2.6 d

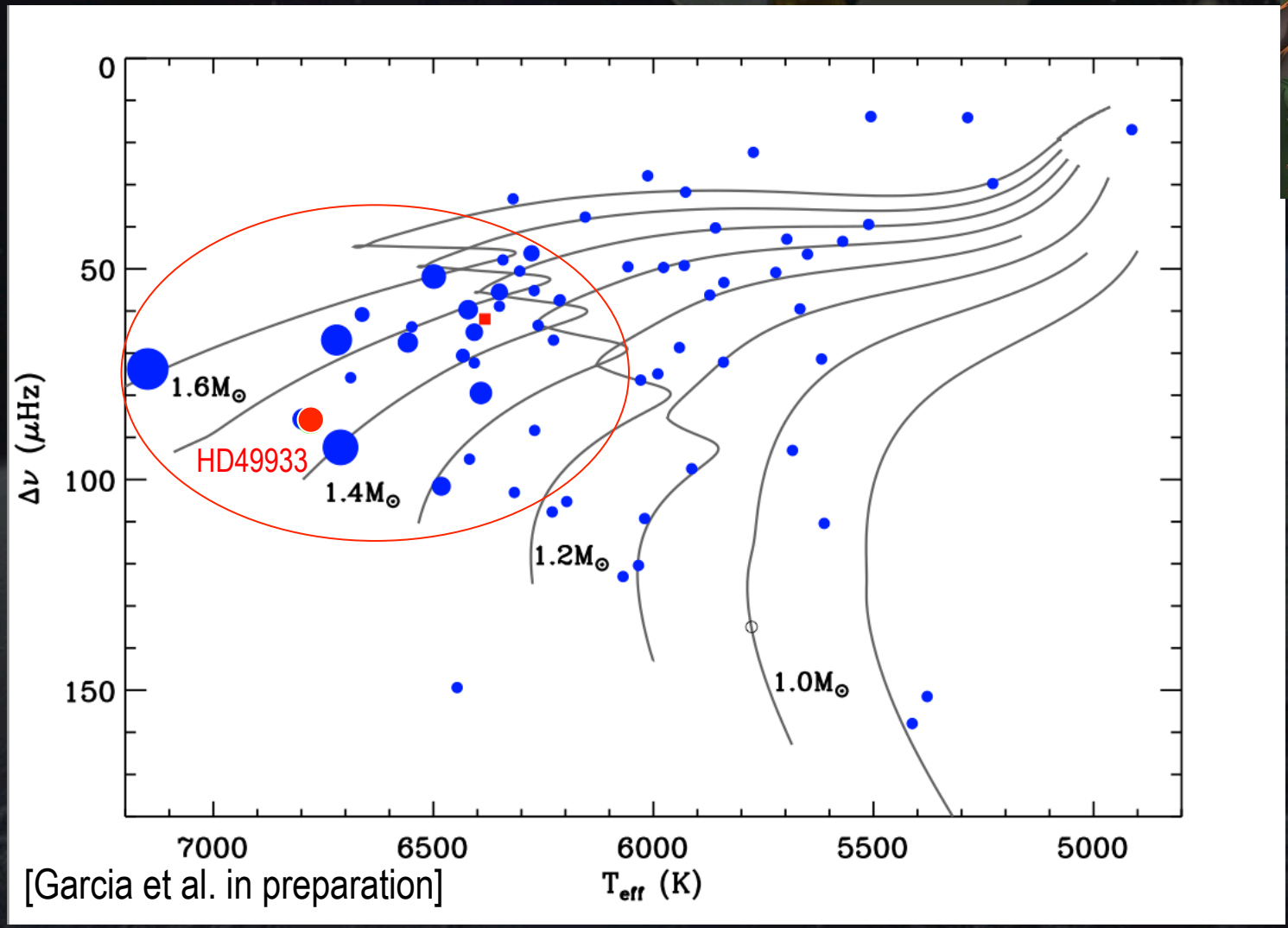
III- RESULTS:

Kepler

III-ROTATION (SURFACE)

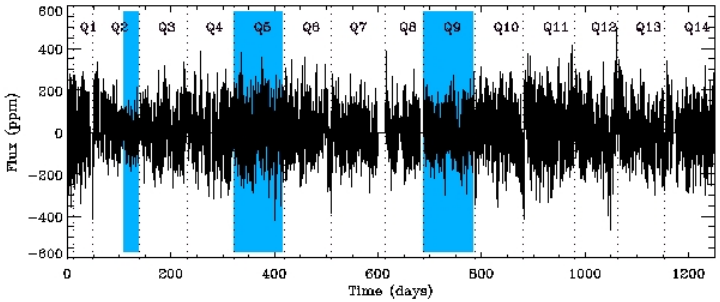
- Around 190 stars observed since Q5 for at least 3 months (short cadence)
  - 3.5 years of data available for surface rotation studies

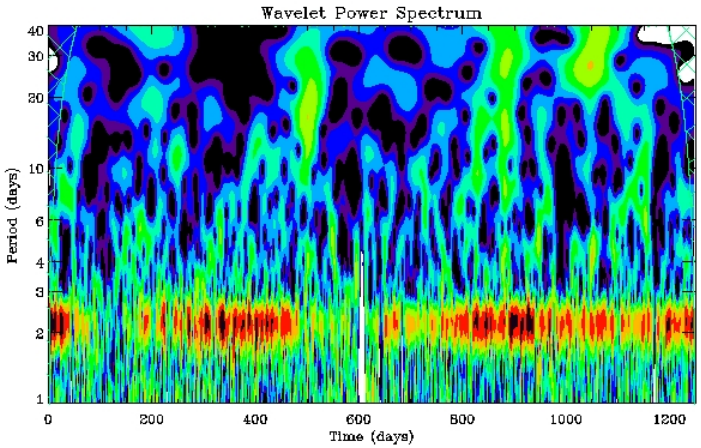


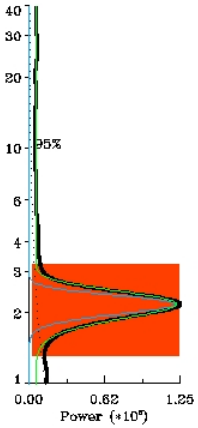


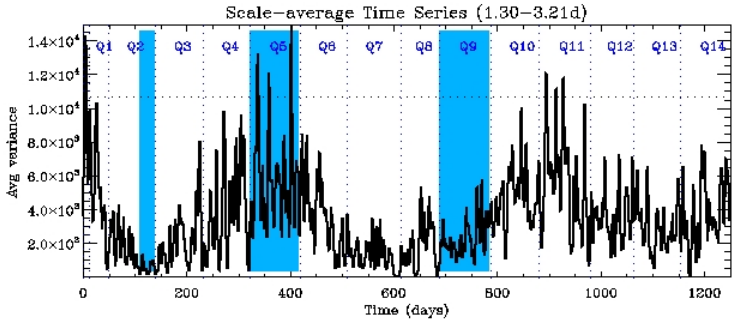
[Garcia et al. in preparation]

III-RESULTS: *KEPLER*







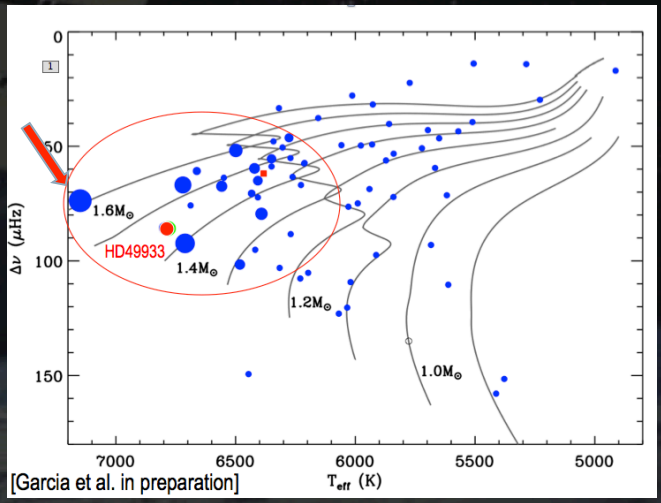


ν_{rot} =5.3μHz

P_{rot} =2.16days

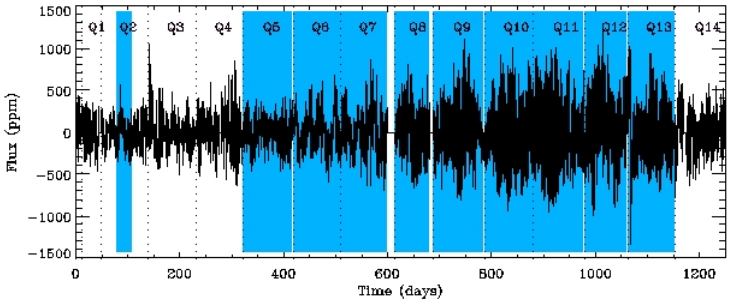
P^1_{rot} =2.17 ± 0.14days

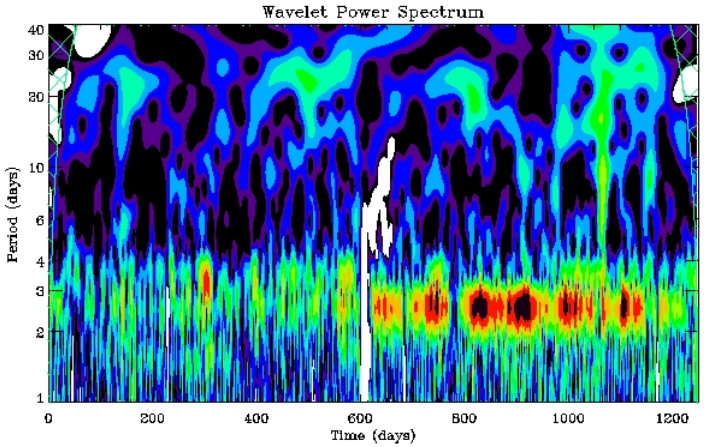
- Kaa

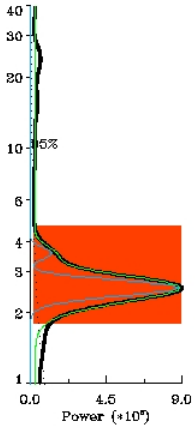


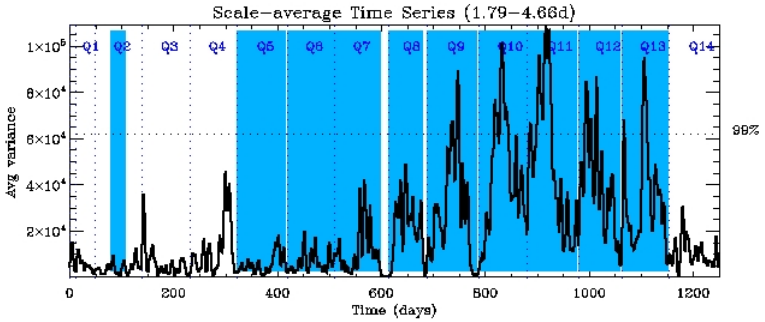
[Mathur et al. to be submitted]

III-RESULTS: *KEPLER*



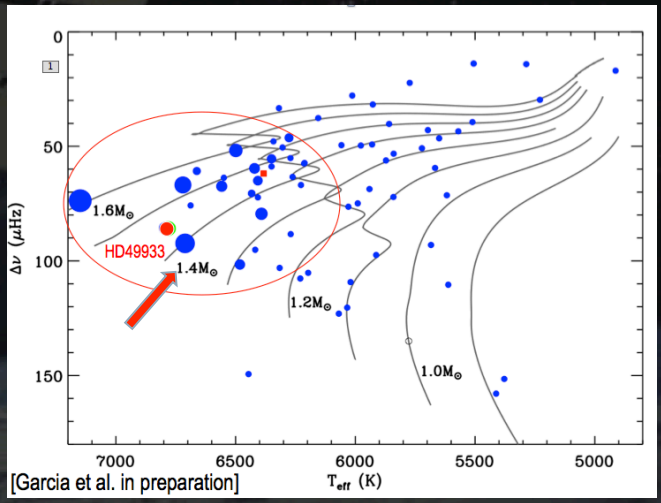






ν_{rot} =4.55μHz
P_{rot} =2.54days
P^1_{rot} =2.54 ± 0.16days
P^3_{rot} =3.5 ± 0.16days

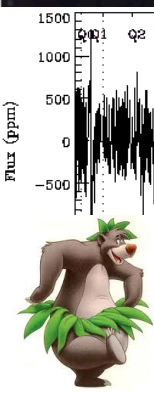
➢ Shere-Khan

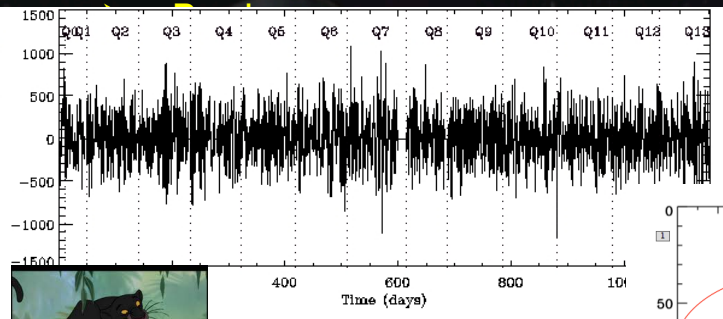


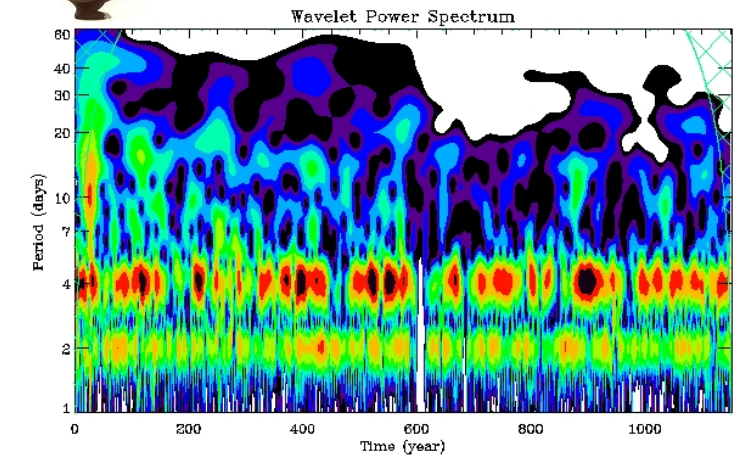
[Mathur et al. to be submitted]

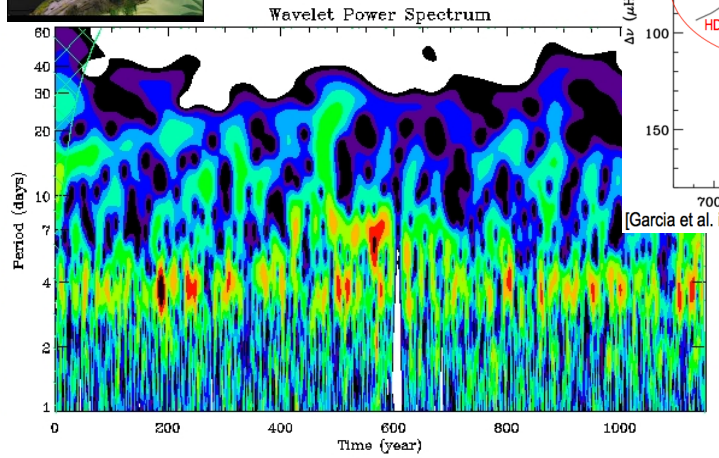
III-RESULTS: *KEPLER*

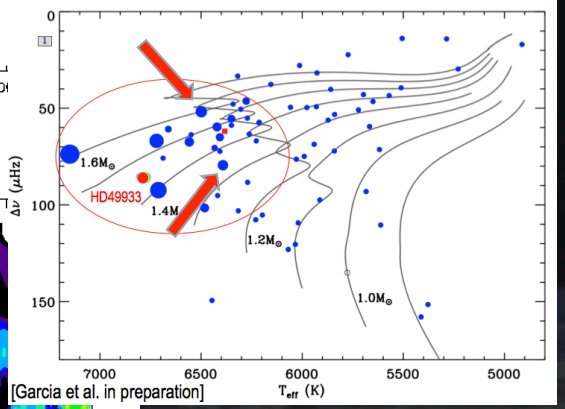
- Baloo
- Bagheera



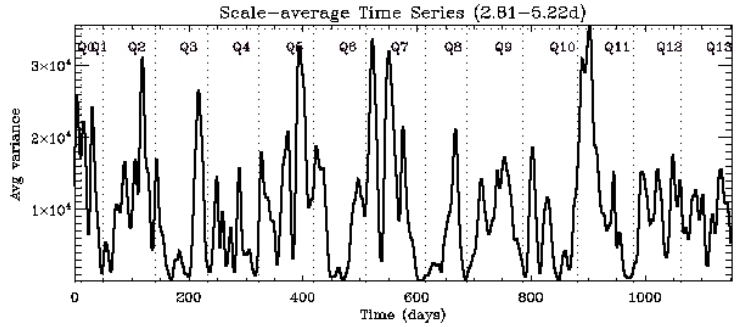




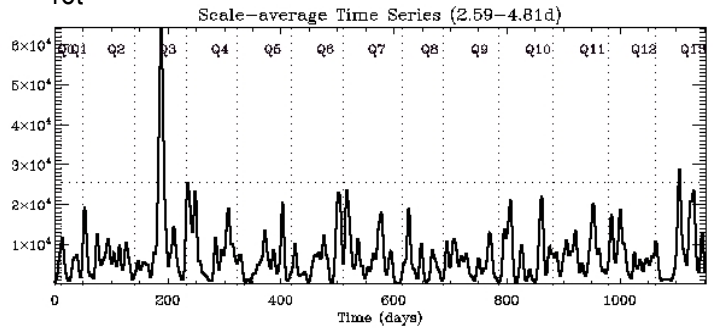




P_{rot}=3.7d



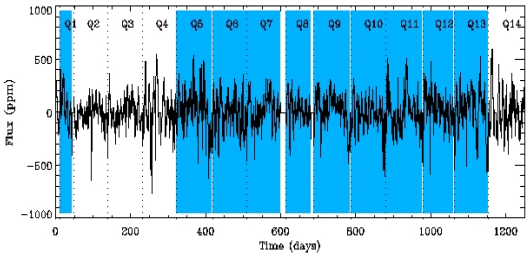
P_{rot}=4.0d

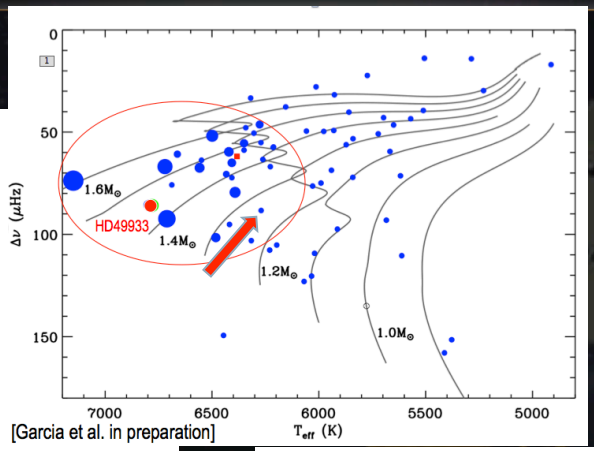


[Mathur et al. to be submitted]

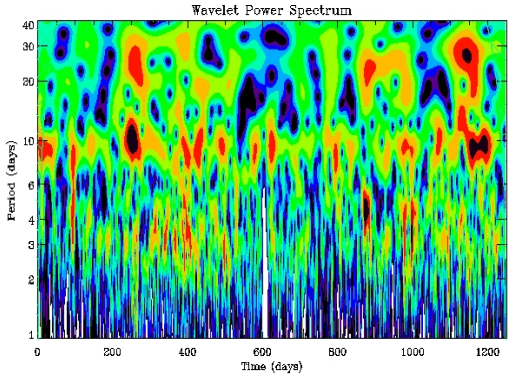
III-NEXT STEP: 3D MODELS

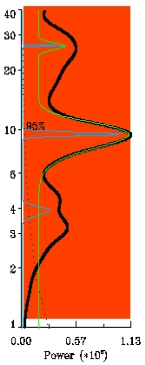
- 1D Seismic model
- 3D Model by ASH

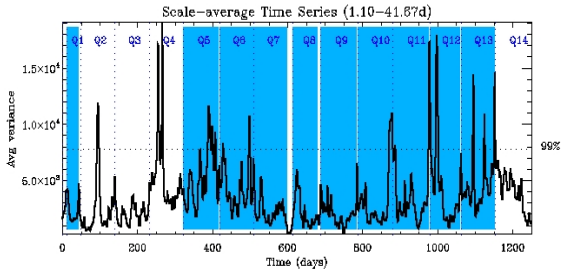




[Garcia et al. in preparation]



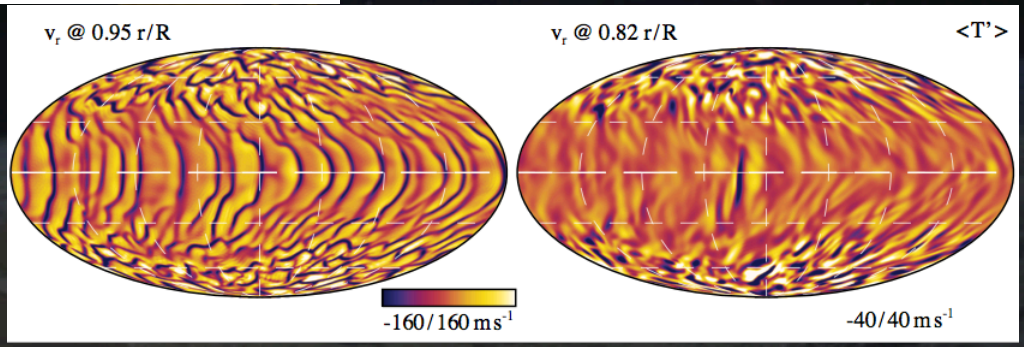


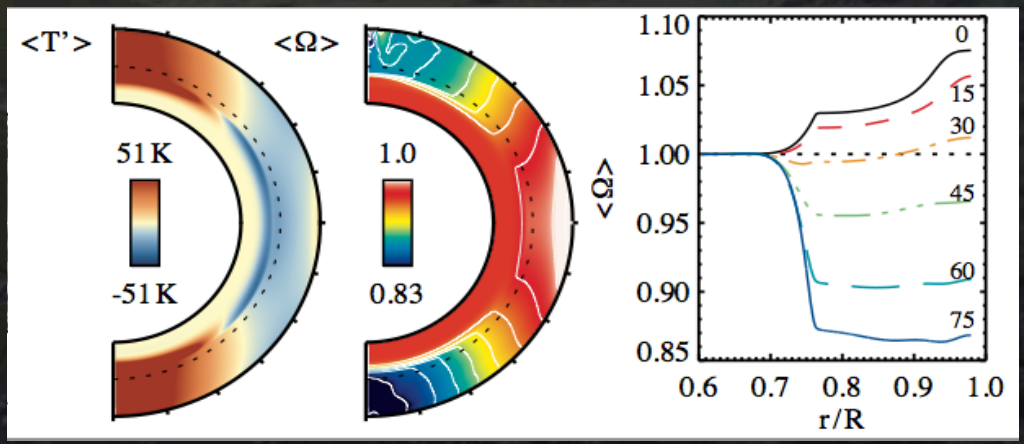


ν_{rot} =1.23μHz
P_{rot} =9.4days
P^1_{rot} =9.4 ± 0.7days
P^3_{rot} =26.3 ± 0.5days
P^6_{rot} =42.4 ± 0.14days

[Mathur et al. to be submitted]

Hidrodynamical models





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

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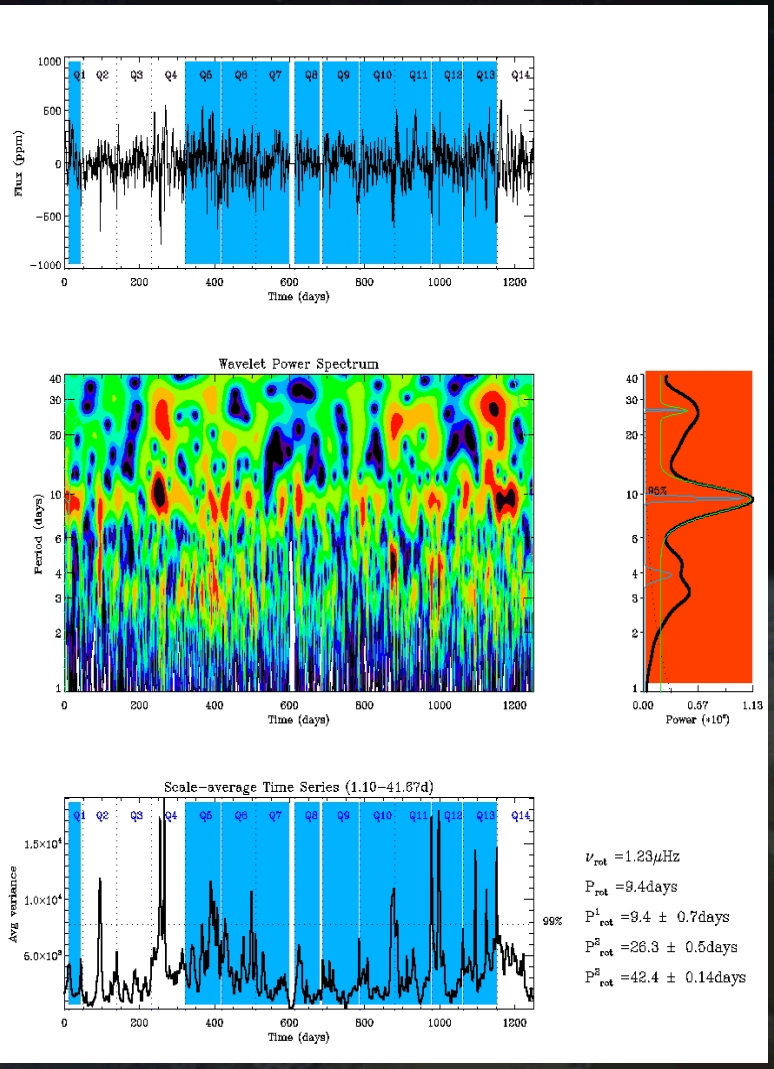

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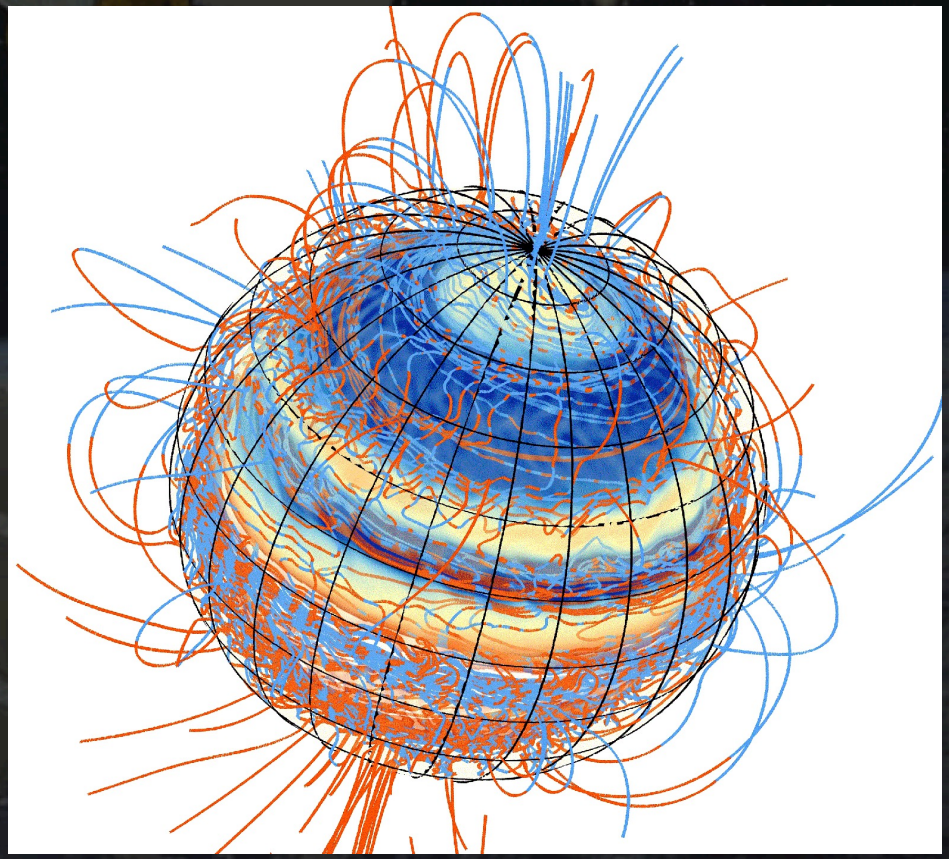
MHD Model



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

Preliminary results: a regular cycle has been established


Thanks
¡¡Gracias!!