Seismic signatures of magnetic activity in solar-type stars

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Collaborators:

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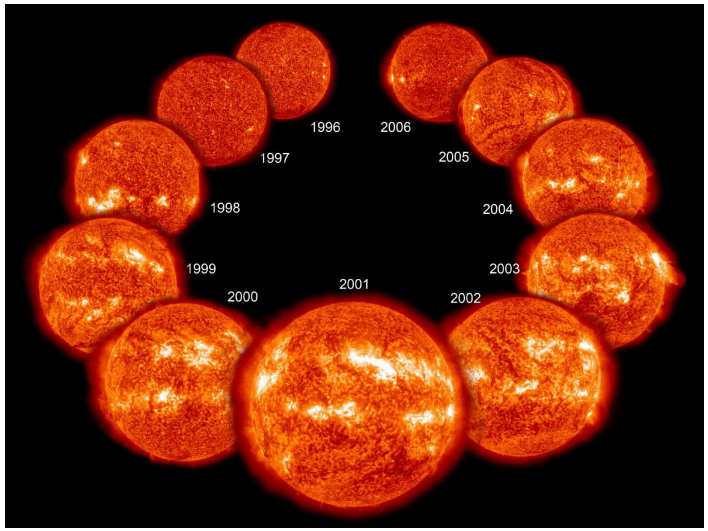
Planet-star connections in the era of TESS and Gaia
KITP, Santa Barbara, CA, US – May 20-24, 2019

Sun: seismic signatures of magnetic activity

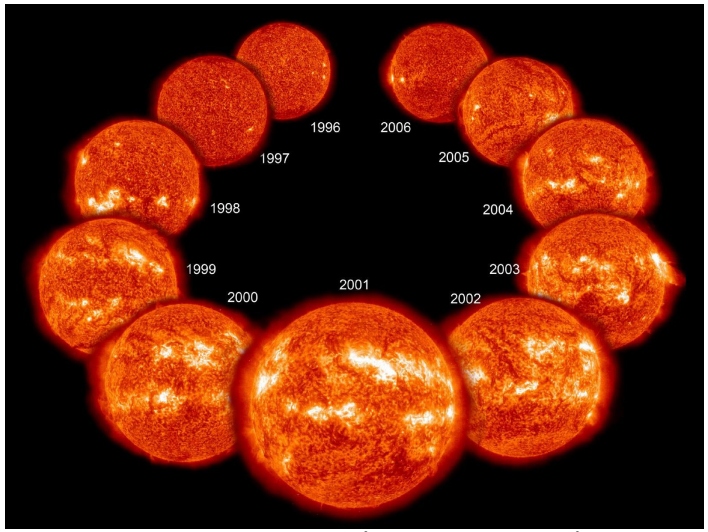
Magnetic Activity



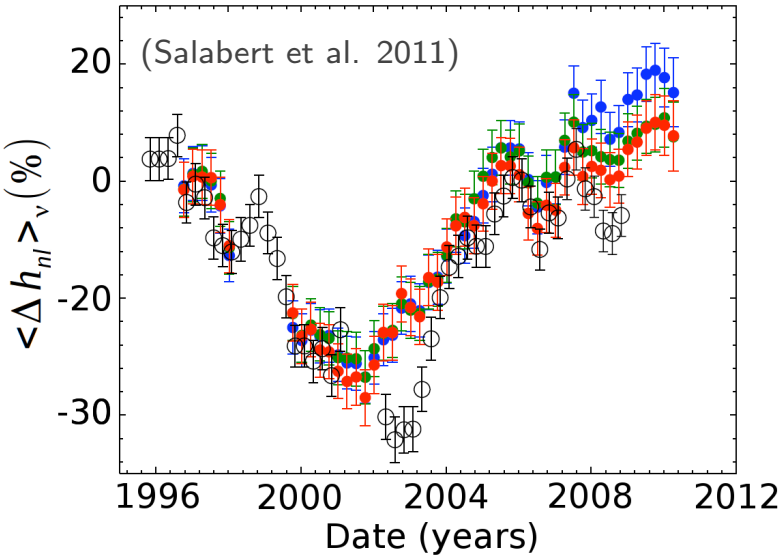
Credits: SOHO (ESA & NASA)

Sun: seismic signatures of magnetic activity

Magnetic Activity → *Cyclic variations of the oscillation properties*



Credits: SOHO (ESA & NASA)

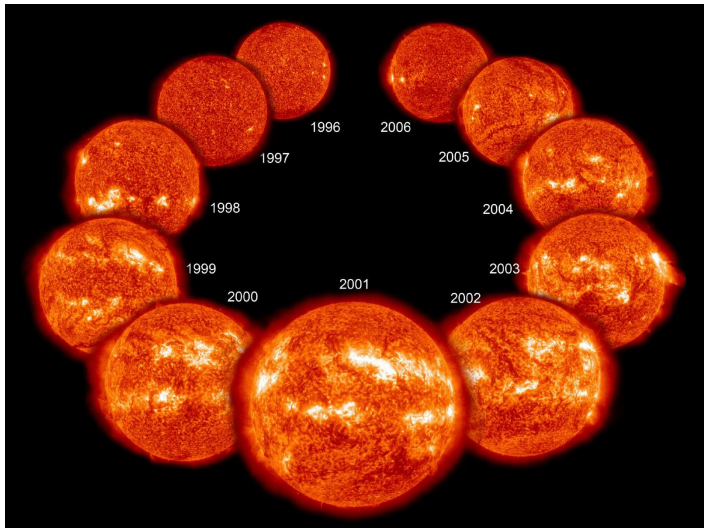


★ the mode amplitudes decrease with the activity level

(e.g. Pallé et al. 1990; Anguera Gubau et al. 1992; Jiménez et al. 2002; Howe et al. 2003; Jiménez-Reyes et al. 2004; Salabert et al. 2011; Howe et al. 2015)

Sun: seismic signatures of magnetic activity

Magnetic Activity → *Cyclic variations of the oscillation properties*



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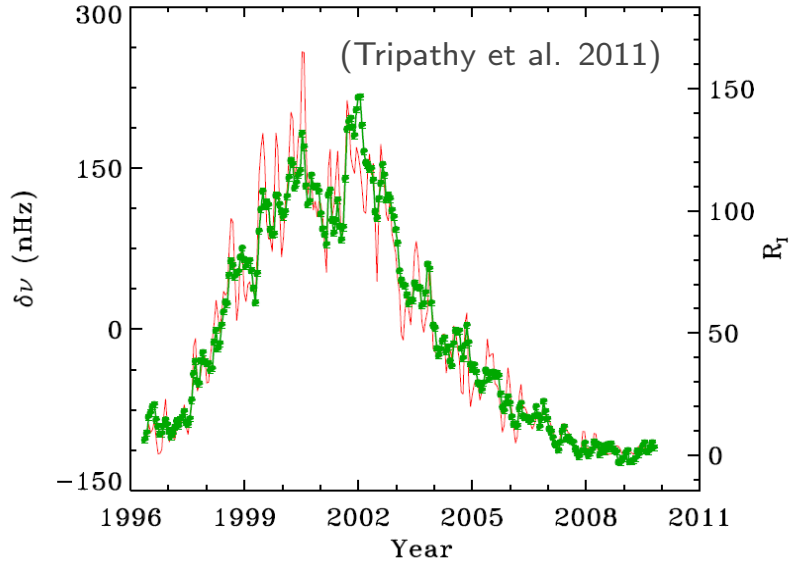
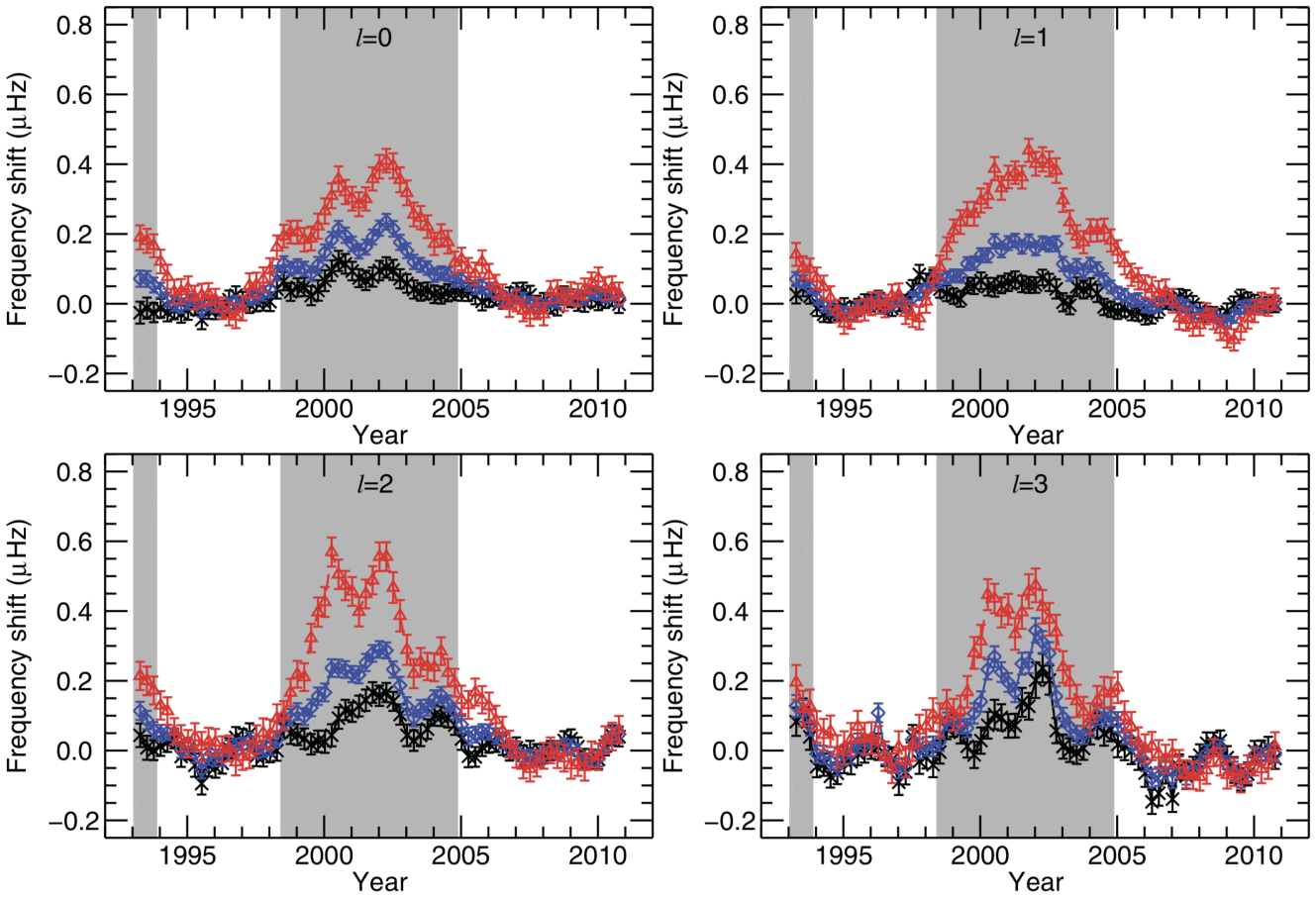


★ the acoustic frequencies increase with the activity level

(e.g. Woodard & Noyes 1985; Libbrecht & Woodard 1990; Elsworth et al. 1990; Chaplin et al. 1998; Dziembowski & Goode 2005; Tripathy et al. 2011; Salabert et al. 2015; Howe et al. 2015)

Sun: seismic signatures of magnetic activity

(Broomhall et al. 2012)



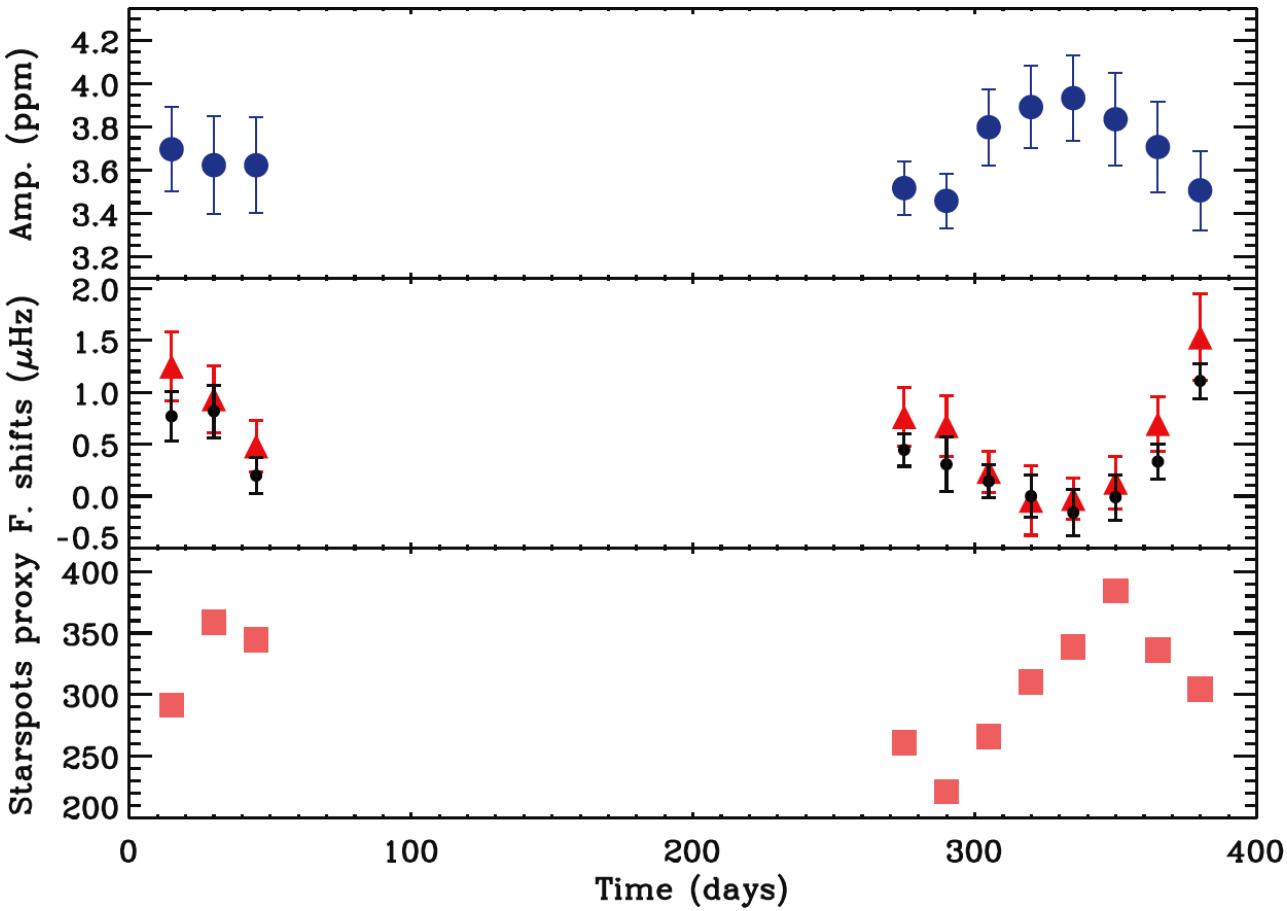
- ★ frequency-dependency → source located $> 0.996 R_\odot$
- ★ degree-dependency → active latitudes

(e.g. Libbrecht & Woodard 1990; Elsworth et al. 1994; Chaplin et al. 1998, 2001, 2004, 2007; Broomhall et al. 2012; Salabert et al. 2015; Howe et al. 2015)

CoRoT: seismic signatures of magnetic activity

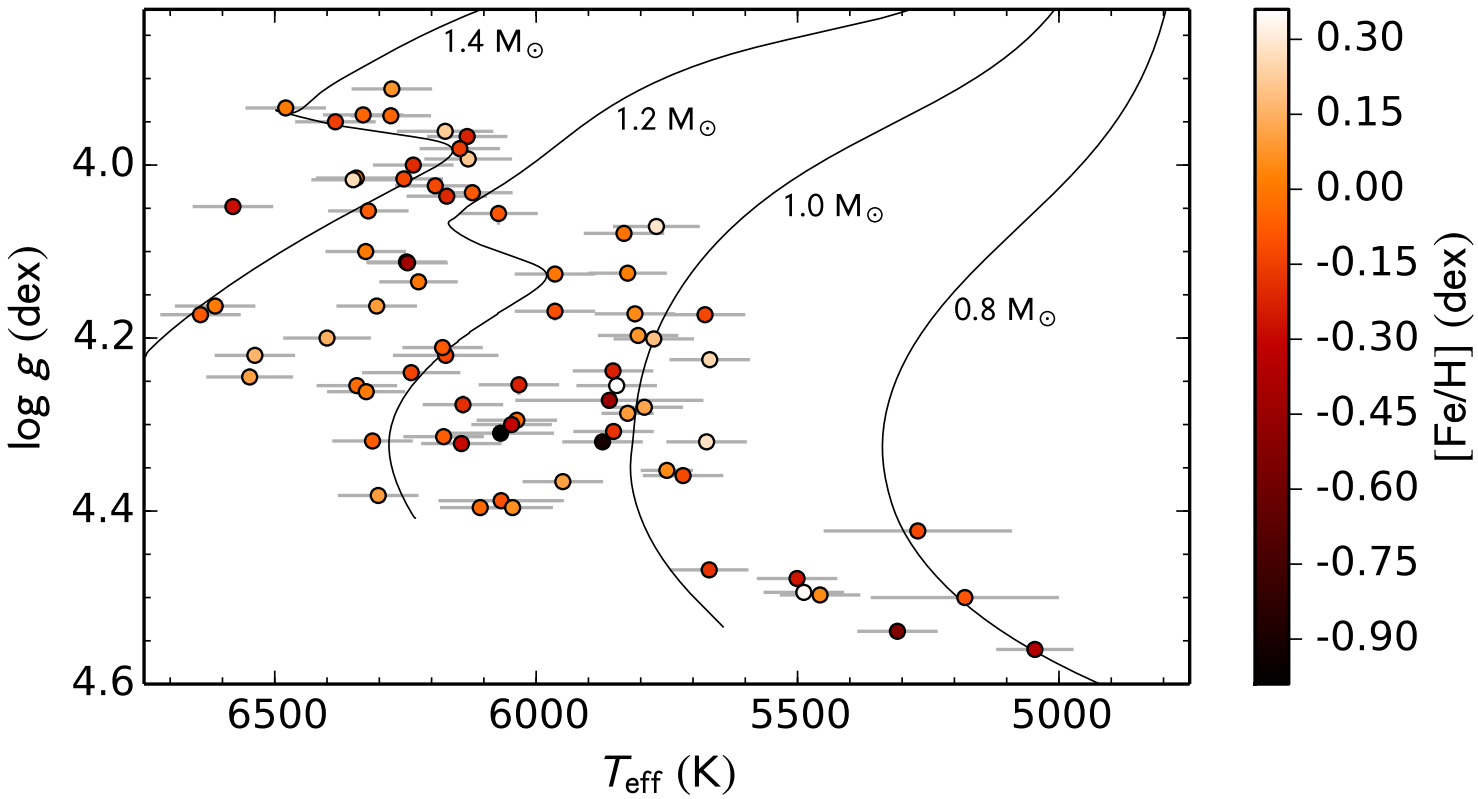
Solar-type star HD 49933 observed by CoRoT

(García et al. 2010)



Target sample and data

(Santos et al. 2018)

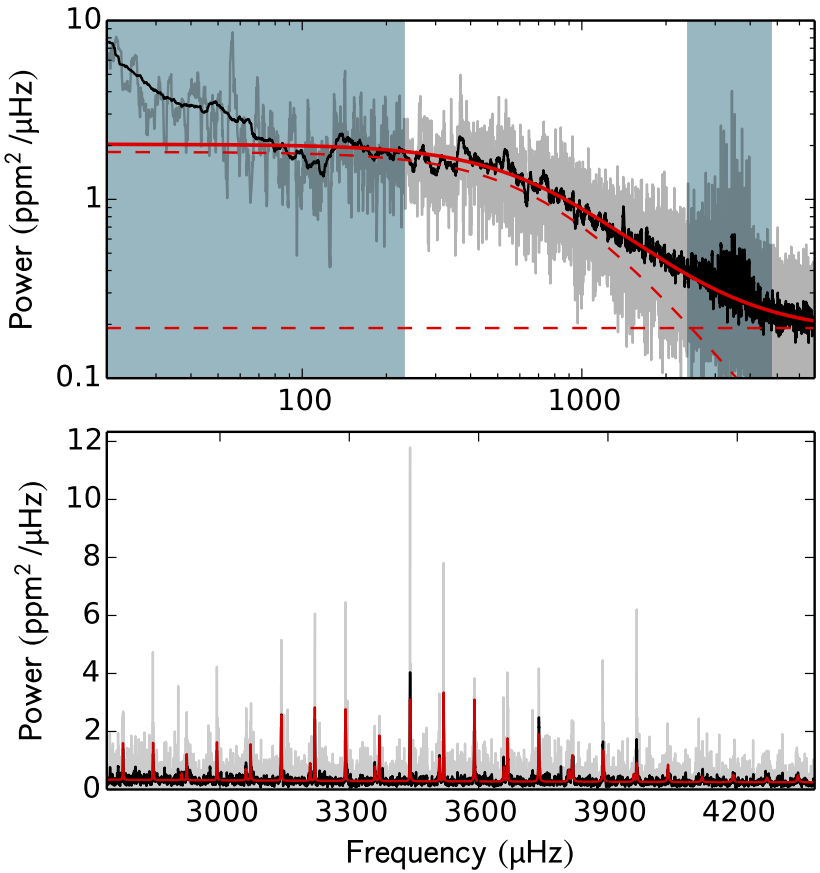


★ 87 Kepler solar-type stars
- Legacy Sample (Lund et al. 2017, Silva-Aguirre et al. 2017)
- 25 KOIs (Silva-Aguirre et al. 2015, Davies et al. 2016, Campante et al. 2016)

Target sample and data

- short-cadence KASOC light curves
  (Handberg & Lund 2014)
- 90-d subseries
- background fit
- Bayesian peak-bagging for the global fit to the p-modes
  - Fitting method: `emcee`
    (Goodman & Weare 2010,
    Foreman-Mackey et al. 2013)
- prior knowledge on the mode parameters

(Santos et al. 2018)

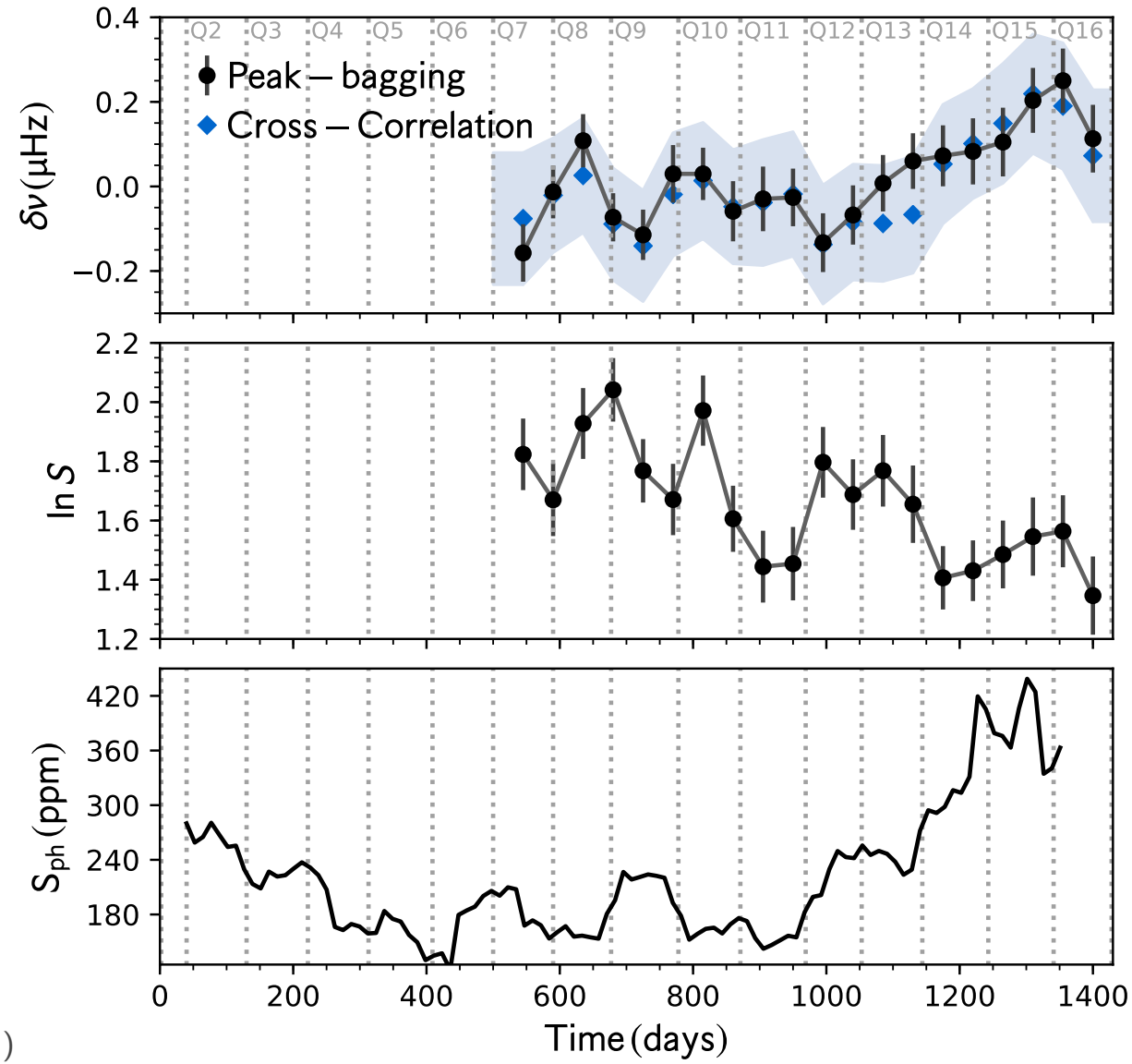


Kepler: seismic signatures of magnetic activity

KIC 5184732

(Kitty)

Santos et al. 2018



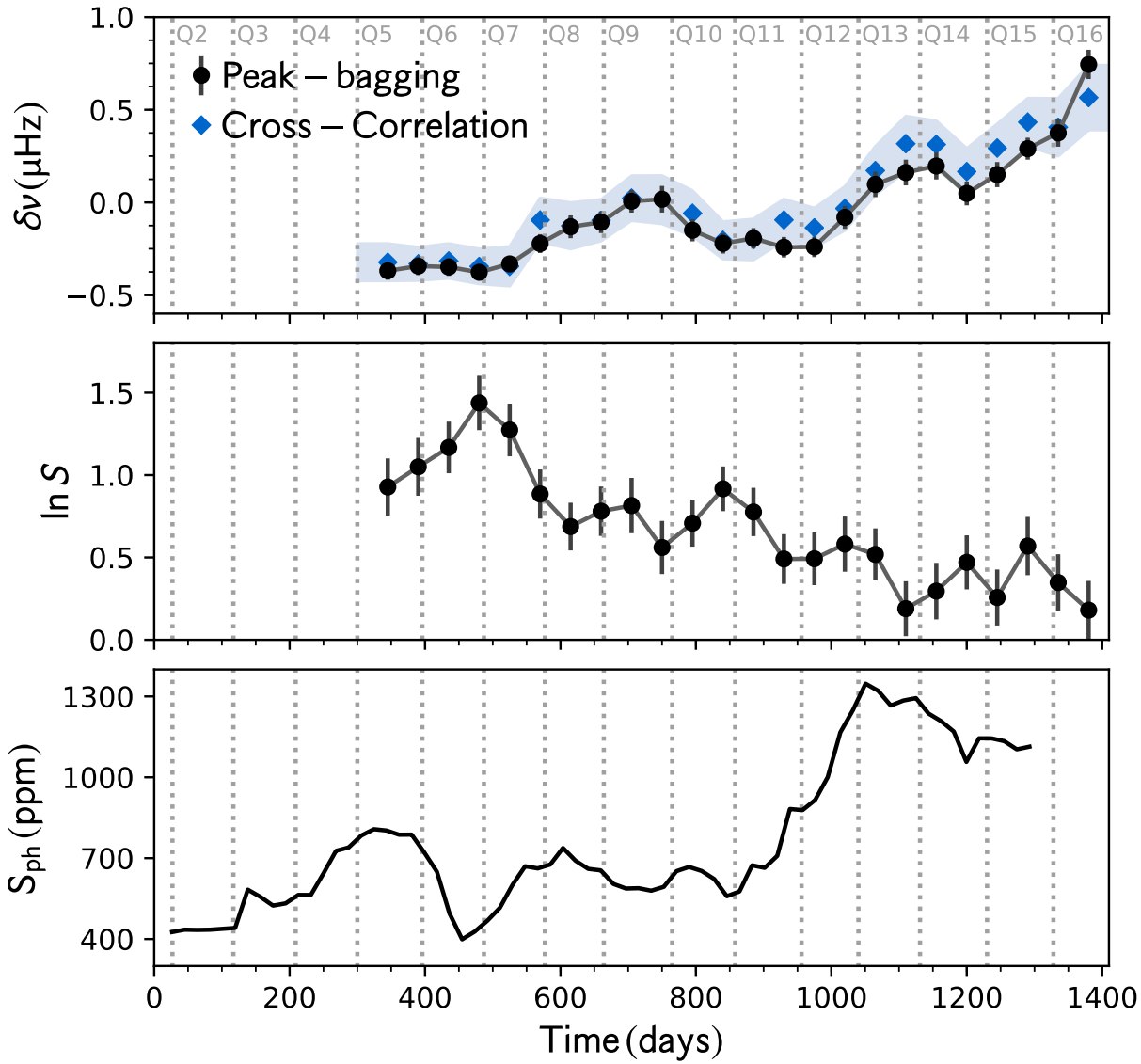
(S_{ph} - poster by Santos et al.)

Kepler: seismic signatures of magnetic activity

KIC 8006161

(Doris)

Santos et al. 2018



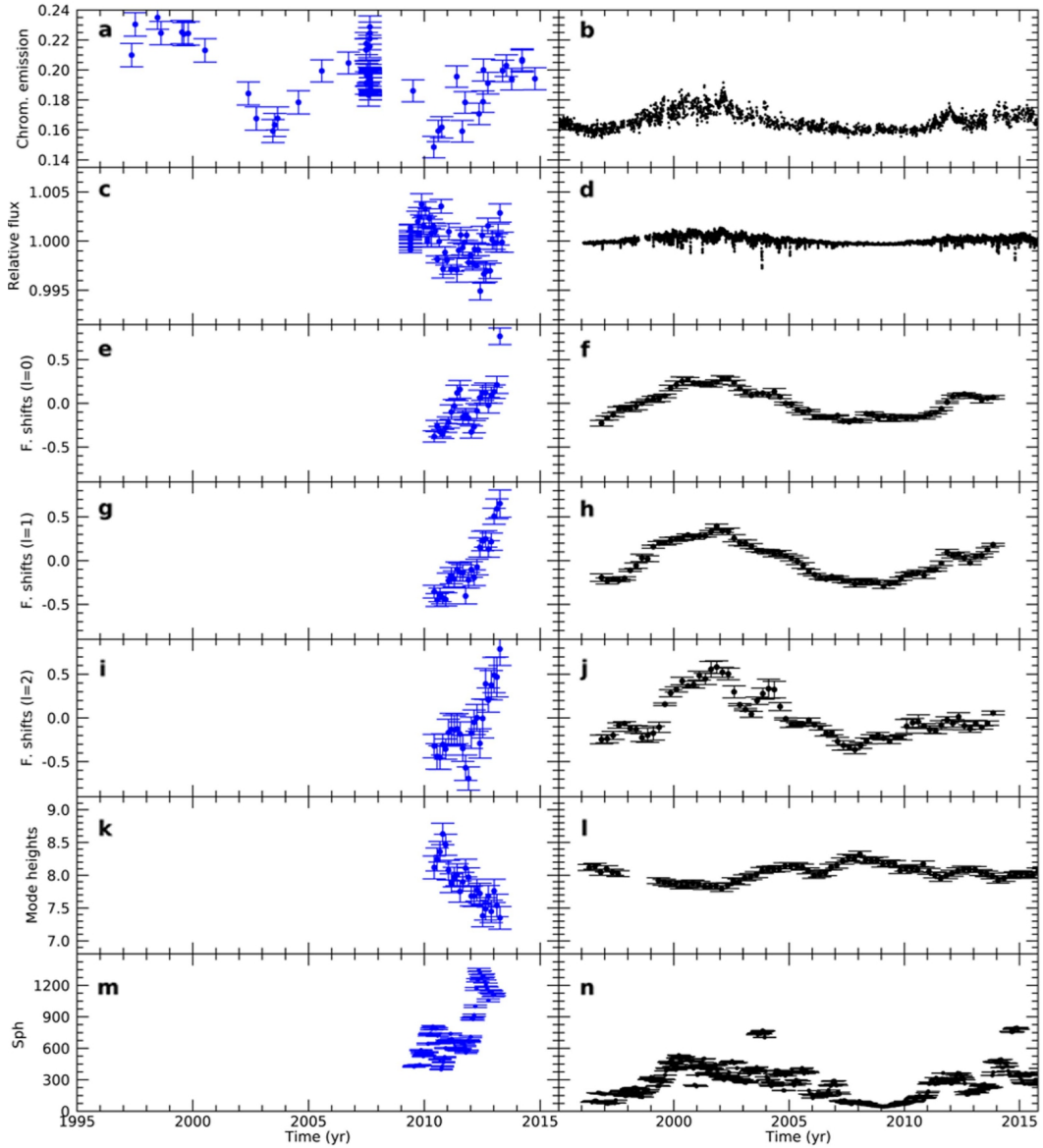
(S_{ph} - poster by Santos et al.)

Kepler: seismic signatures of magnetic activity

KIC 8006161
(Doris)

Karoff et al. 2018

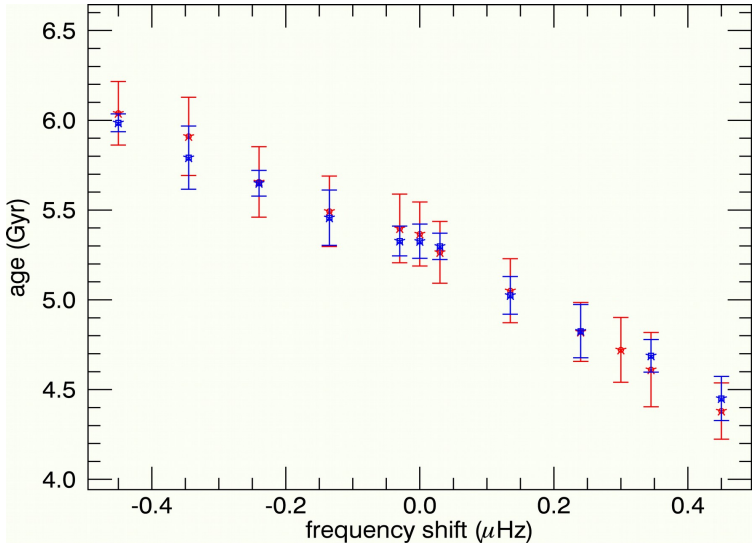
(S_{ph} - poster by Santos et al.)

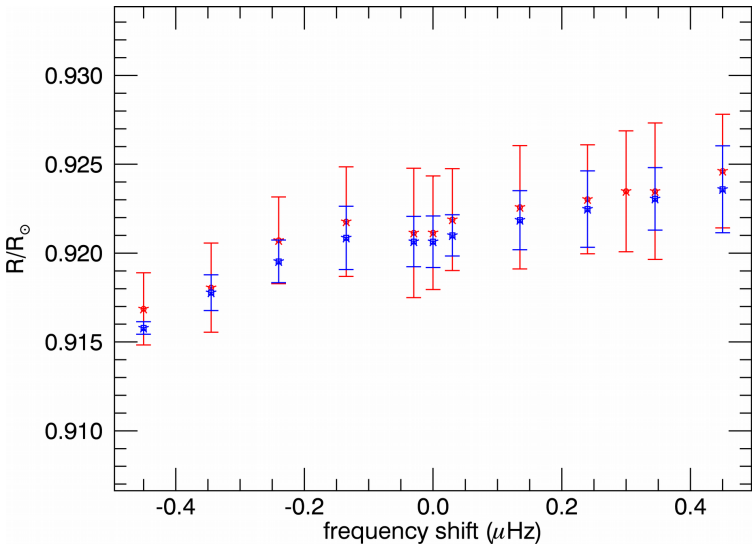


Kepler: seismic signatures of magnetic activity

KIC 8006161
(Doris)

Pérez Hernández et al. (in press)

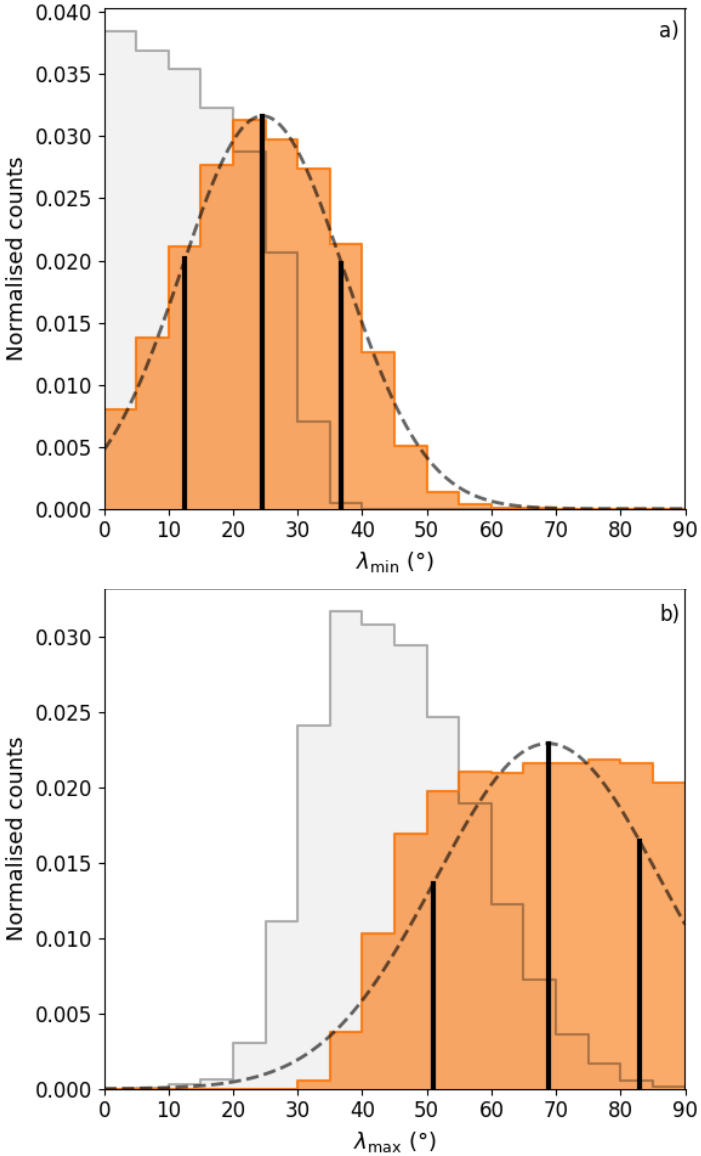




Kepler: seismic signatures of magnetic activity

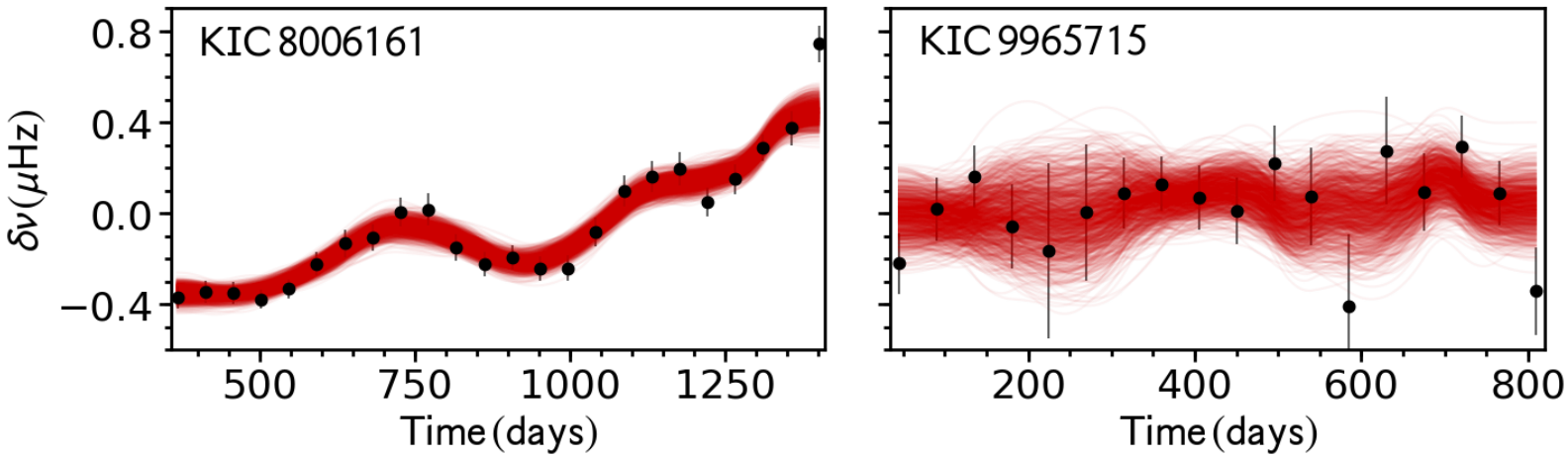
KIC 8006161
(Doris)

Thomas et al. 2019



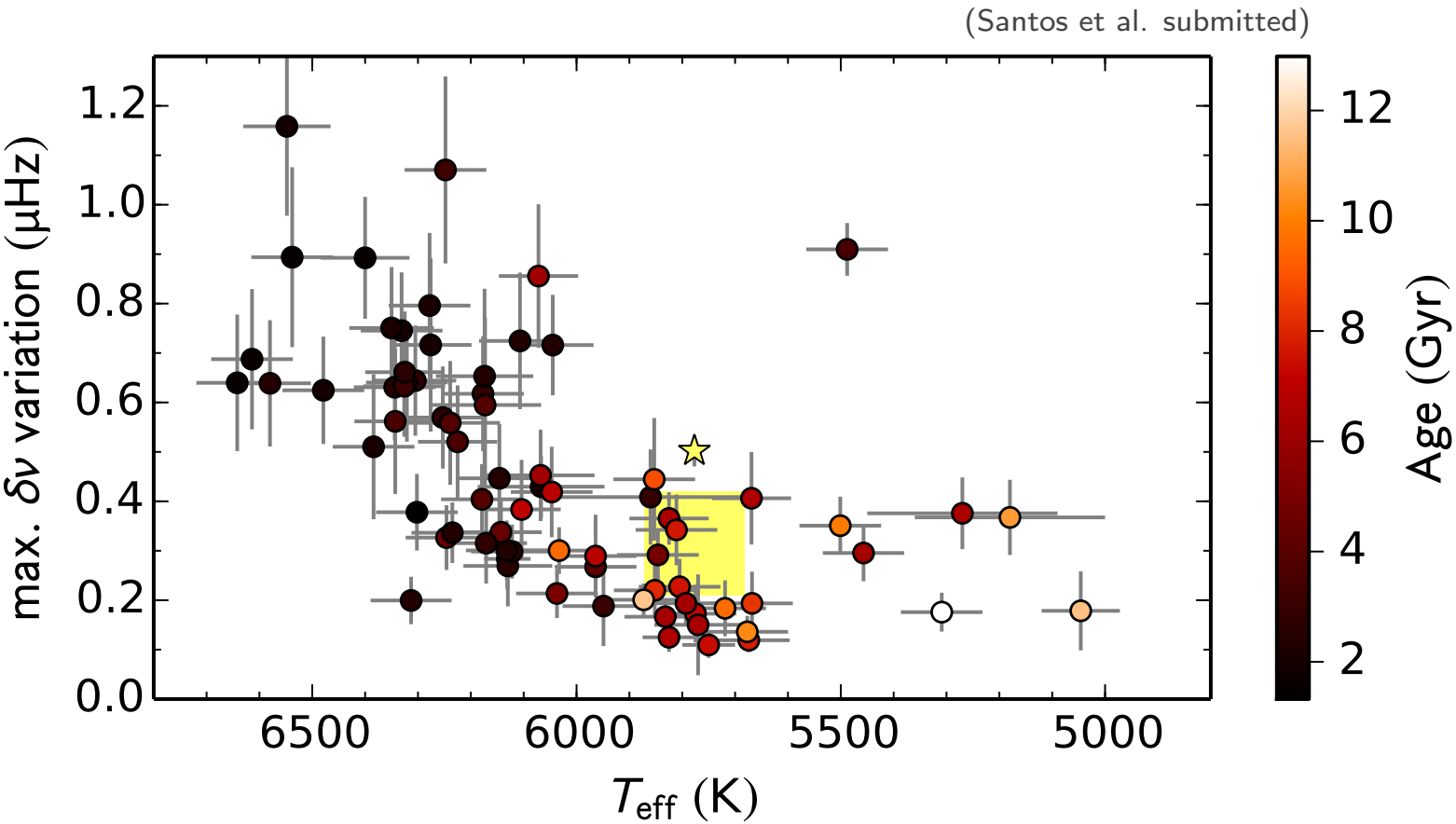
Maximum frequency variation

- ⋆ Significant $\delta\nu$ are found in more of 60% of the stars
- ⋆ To ensure that the measure $\delta\nu$ are not noise-related
  - 75 with highest SNR
  - smoothing processes



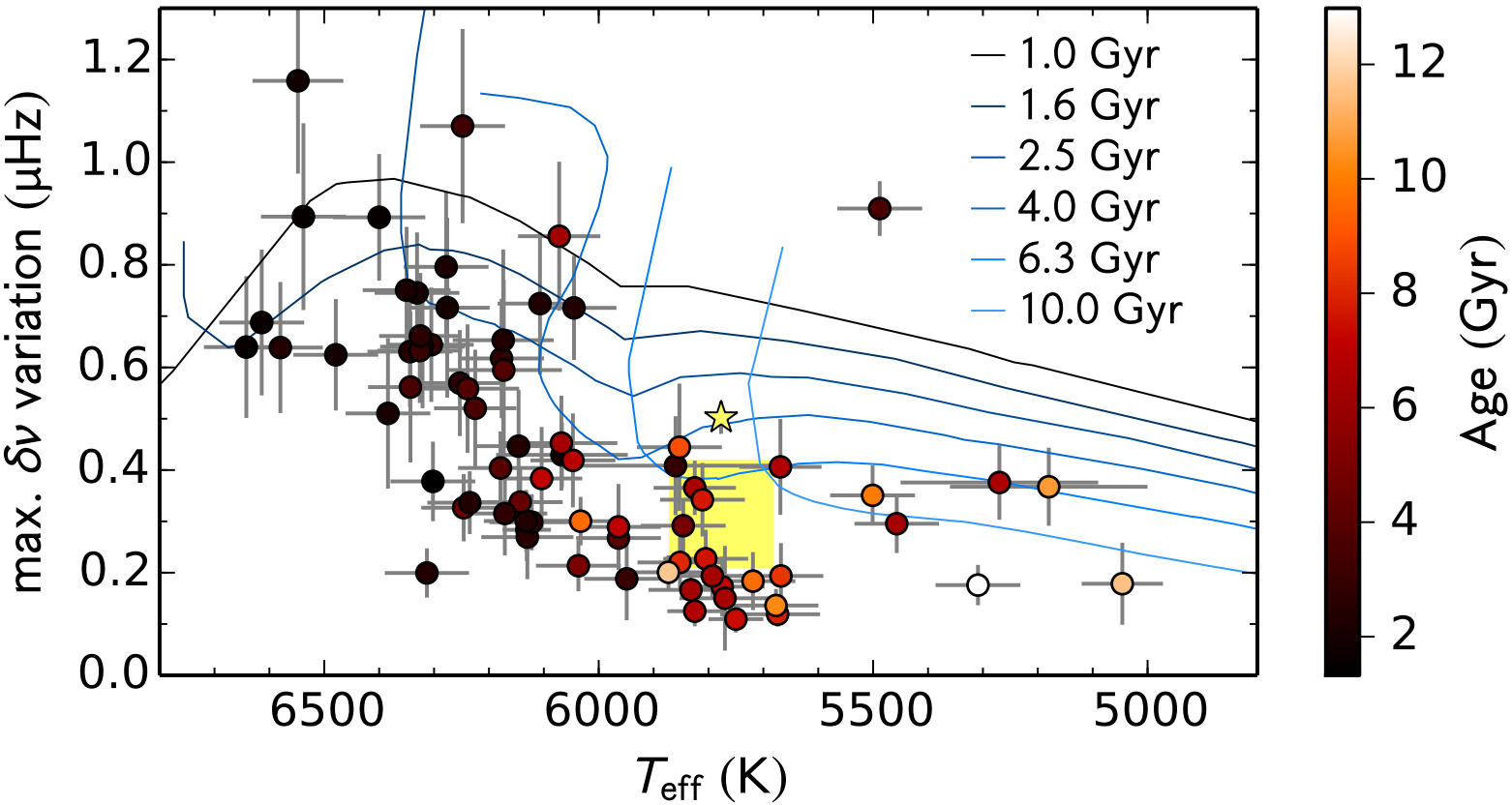
- ⋆ How $\delta\nu$ depend on stellar properties?
- ⋆ Are those consistent with an activity-related origin?

Frequency shifts vs. stellar properties



Frequency shifts vs. stellar properties

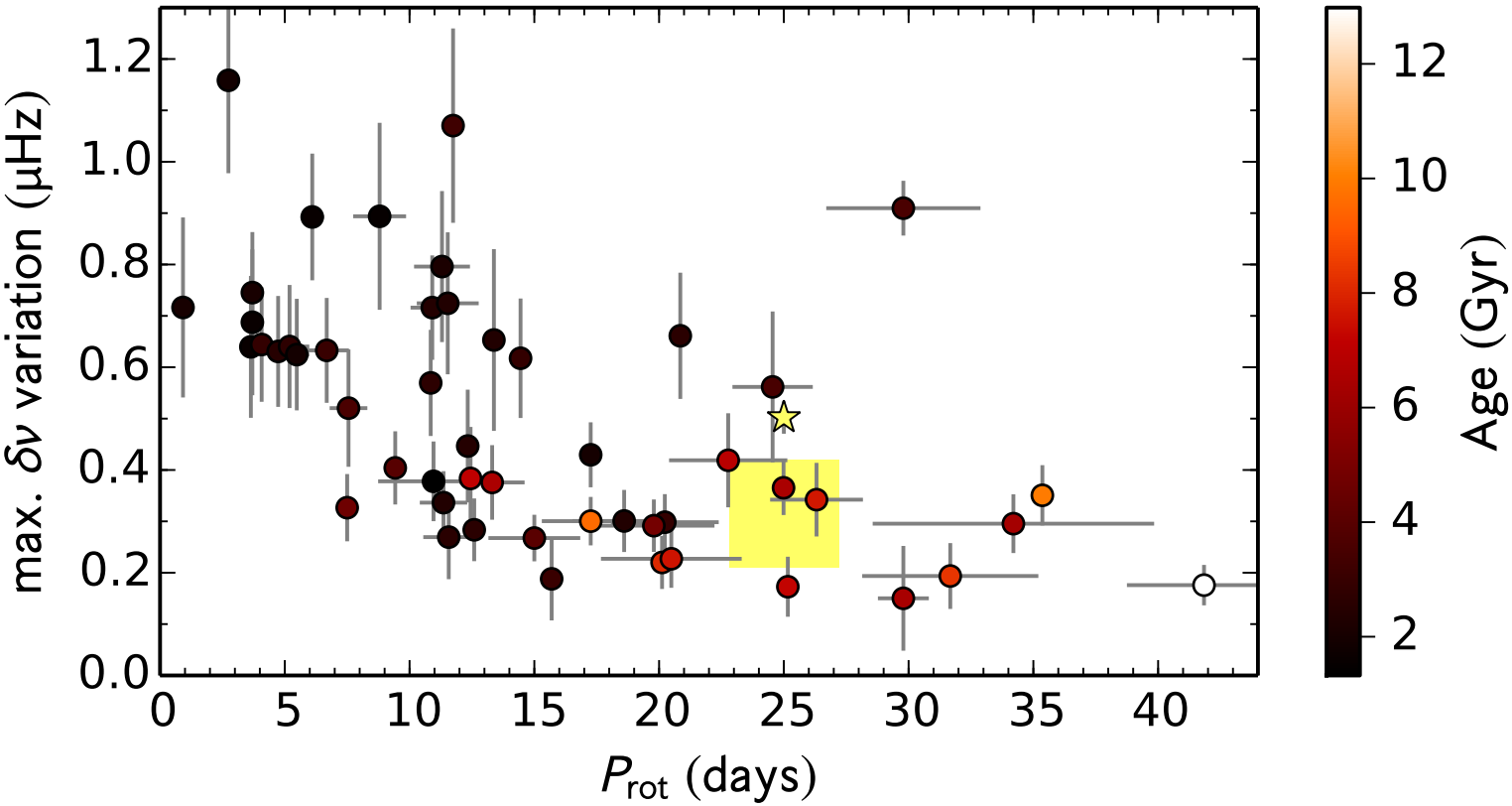
(Santos et al. submitted)



- Theoretical prediction: $\delta\nu$ increases with effective temperature
  (Metcalfe et al. 2007)
- Magnetic activity decreases as stars evolve
  (e.g. Wilson 1963; Wilson & Skumanich 1964)

Frequency shifts vs. stellar properties

(Santos et al. submitted)

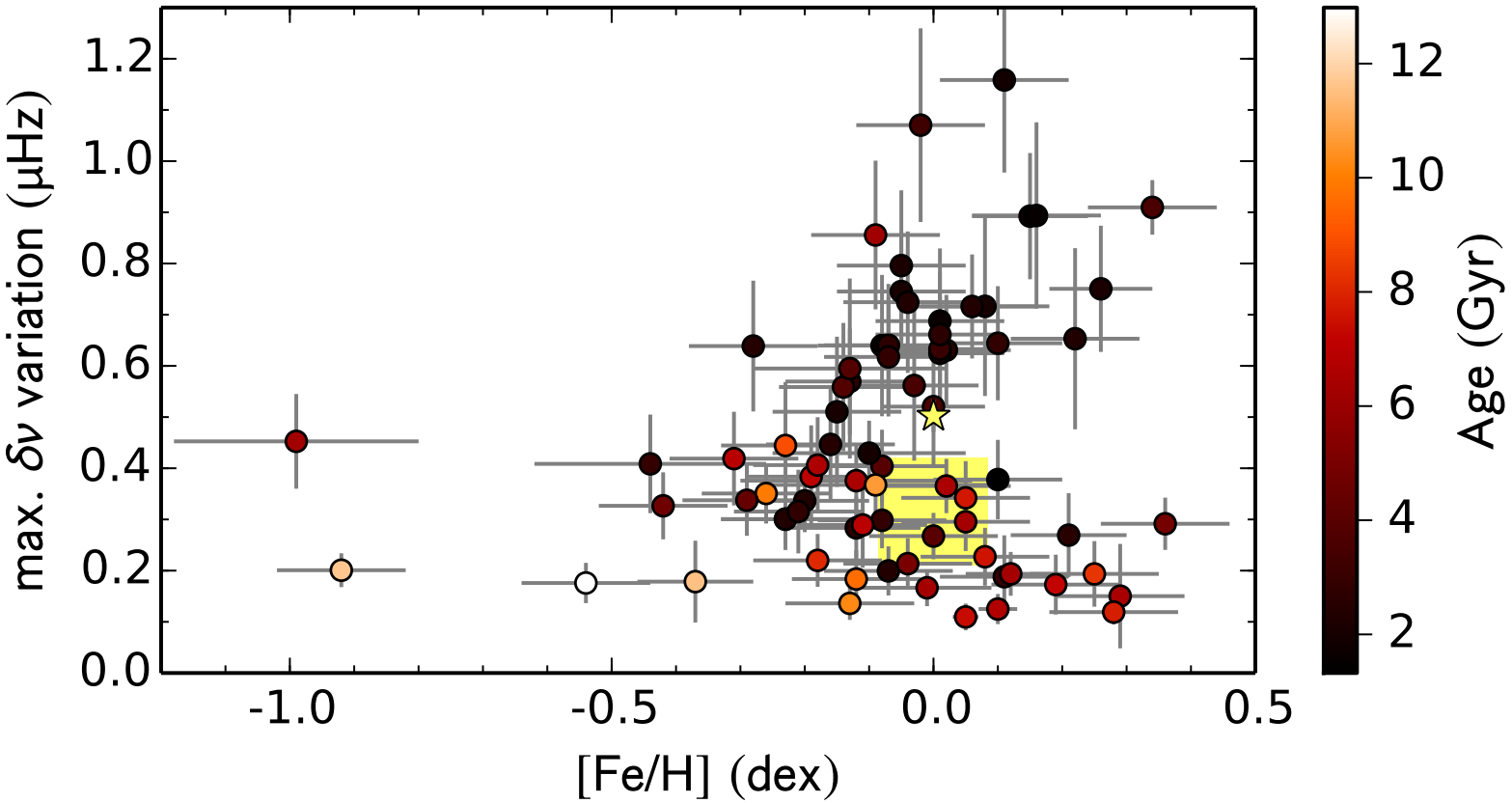


★ Magnetic activity decreases as stars spin-down

(e.g. Vaughan et al. 1981; Baliunas et al. 1983; Noyes et al. 1984; P_{rot} - poster by Santos et al.)

Frequency shifts vs. stellar properties

(Santos et al. submitted)

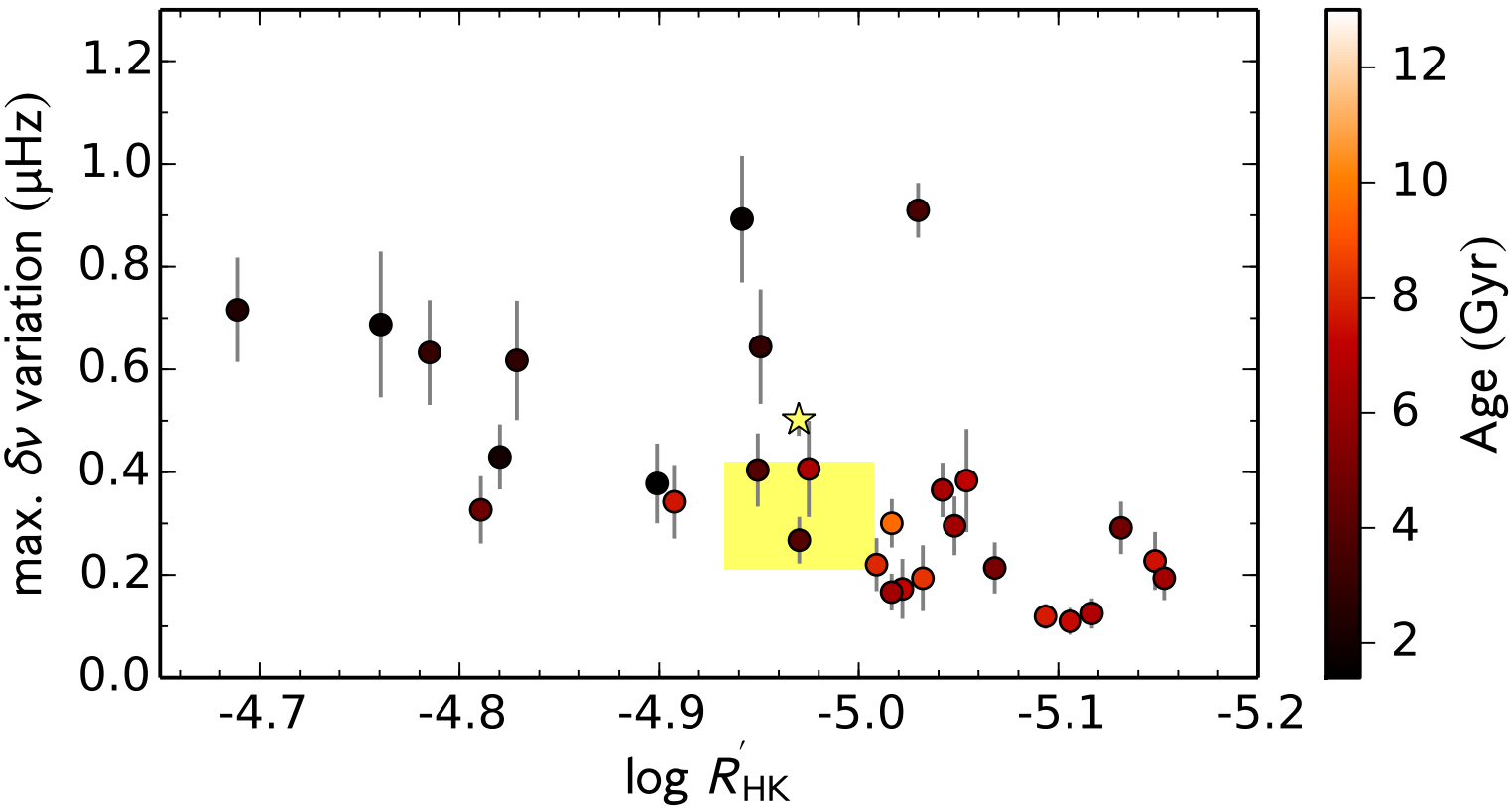


★ Stronger cycle related to deeper CZ due to high metallicity

(Karoff et al. 2018)

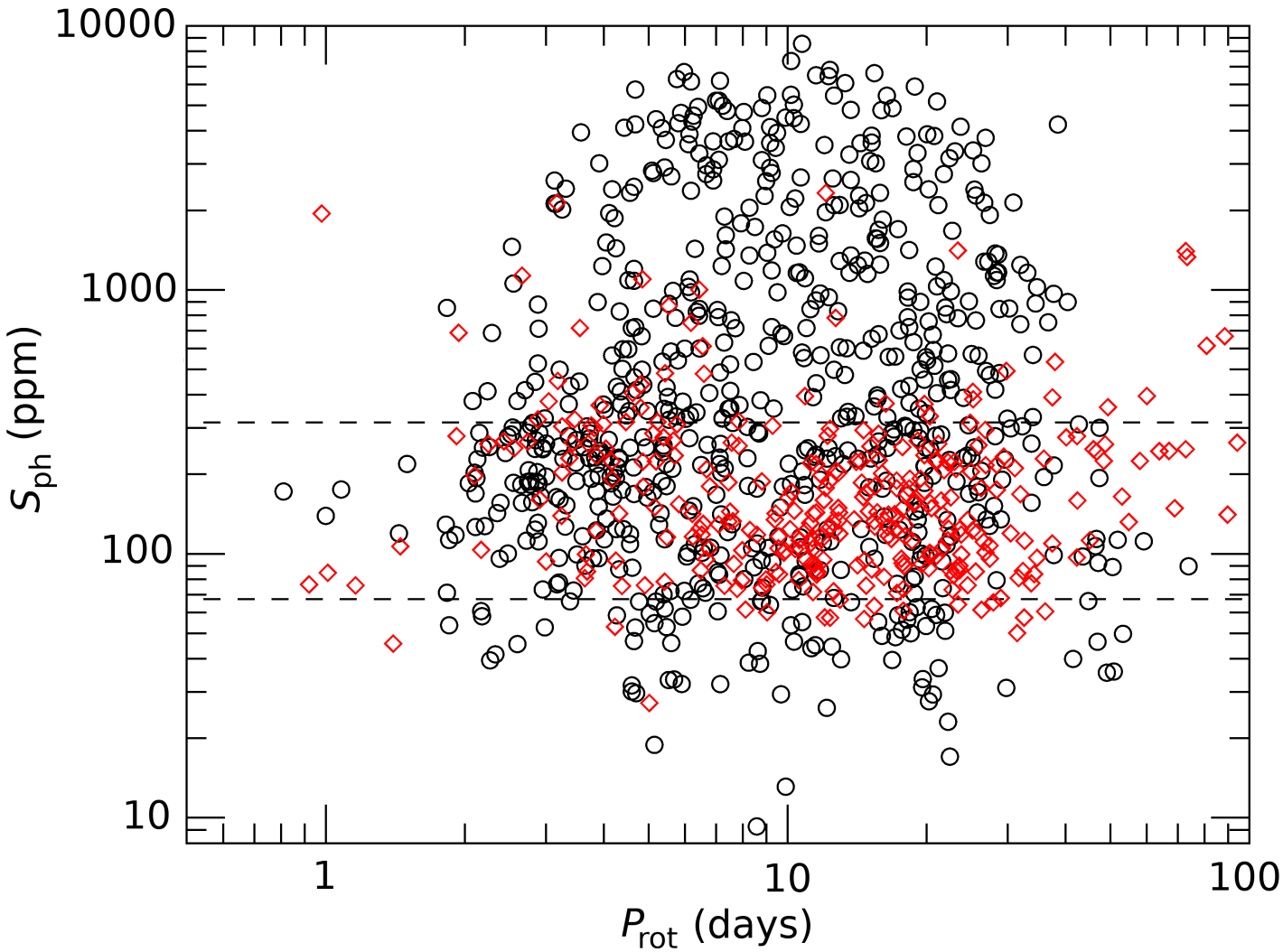
Frequency shifts vs. stellar properties

(Santos et al. submitted)



Magnetic activity and detection of oscillations

(Mathur et al. submitted; see also Chaplin et al. 2011)



(S_{ph} - poster by Santos et al.)

Summary

- ⋆ Kepler provides a unique opportunity to learn about stellar magnetism through asteroseismology
- ⋆ 60% of stars with significant frequency shifts
- ⋆ ensemble study supports an activity-related origin of the frequency shifts
  - $\delta\nu$ increases with $T_{\rm eff}$
  - $\delta\nu$ decreases with stellar age
  - $\delta\nu$ are largest for fast rotators
  - $\delta\nu$ seem to depend on metallicity
  - $\delta\nu$ increases with chromospheric activity
  - $\delta\nu$ decreases with Rossby Number
- ⋆ asteroseismology allow us to study magnetic activity and constraint activity-related properties of stars

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