

PROBING STELLAR DYNAMICS WITH SPACE PHOTOMETRY

RESULTS FROM COROT AND KEPLER

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Special thanks to:

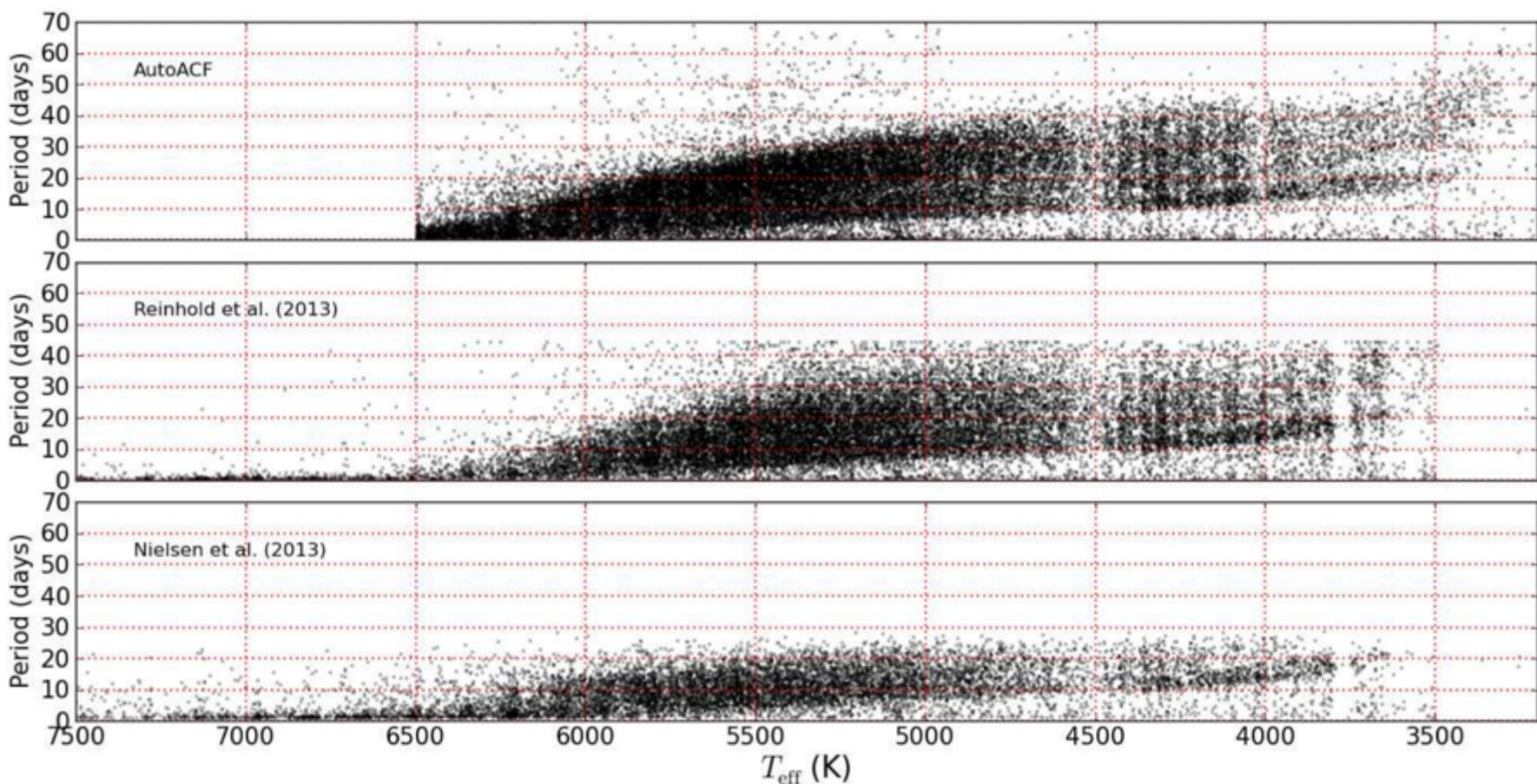
J. Ballot, P.G. Beck, O. Benomar, A. Bonanno, A.S. Brun, M. Cantiello, T. Ceillier, G.R. Davies, S. Deheuvels, R. Egeland, A. Lanza, S. Mathur, T. Metcalfe, J. Do Nascimento, and D. Salabert

- What can offer high-precision photometry (HPP) to better understand stellar dynamics, magnetism & dynamos ?
 - HPP observations can potentially give access to:
 - Surface (differential?) rotation of hundred to thousand stars [e.g. McQuillan et al. 2013, 2014; Nielsen et al. 2013; Reinhold & Reiners 2013, 2015; García et al. 2014]
 - Internal (differential?) rotation through seismology [e.g. Beck et al. 2012; Deheuvels et al. 2012, 2014, 2015; Mosser et al. 2012, Nielsen et al. 2014, Benomar et al. 2016, Pia di Mauro et al. 2016,
 - Convection properties
 - Characteristic time scale of convection (granulation) [e.g. Mathur et al. 2011; Kallinger et al. 2014, 2016]
 - other scales:
 - e.g. Faculae in active stars [e.g. Karoff et al. 2013]
 - Internal structure (through seismology)
 - Size of the convective envelope (through seismology (+ modelling)) [e.g. Mathur et al. 2012; Mazumdar et al. 2014; Metcalfe et al. 2014,...]
 - Constraining deep internal magnetic fields & convective core dynamos [Fuller et al. 2015.; Stello et al. 2016a,b]
 - Activity cycles & surface magnetism
 - Through the analysis of long time series (activity proxies)
 - Or asteroseismology [e.g. García et al. 2010; Mathur et al. 2013, 2014, Salabert et al. 2016]
 - [e.g. García et al. 2010; Régulo et al. submitted]

IIa-Stellar Dynamics: Surface Rotation

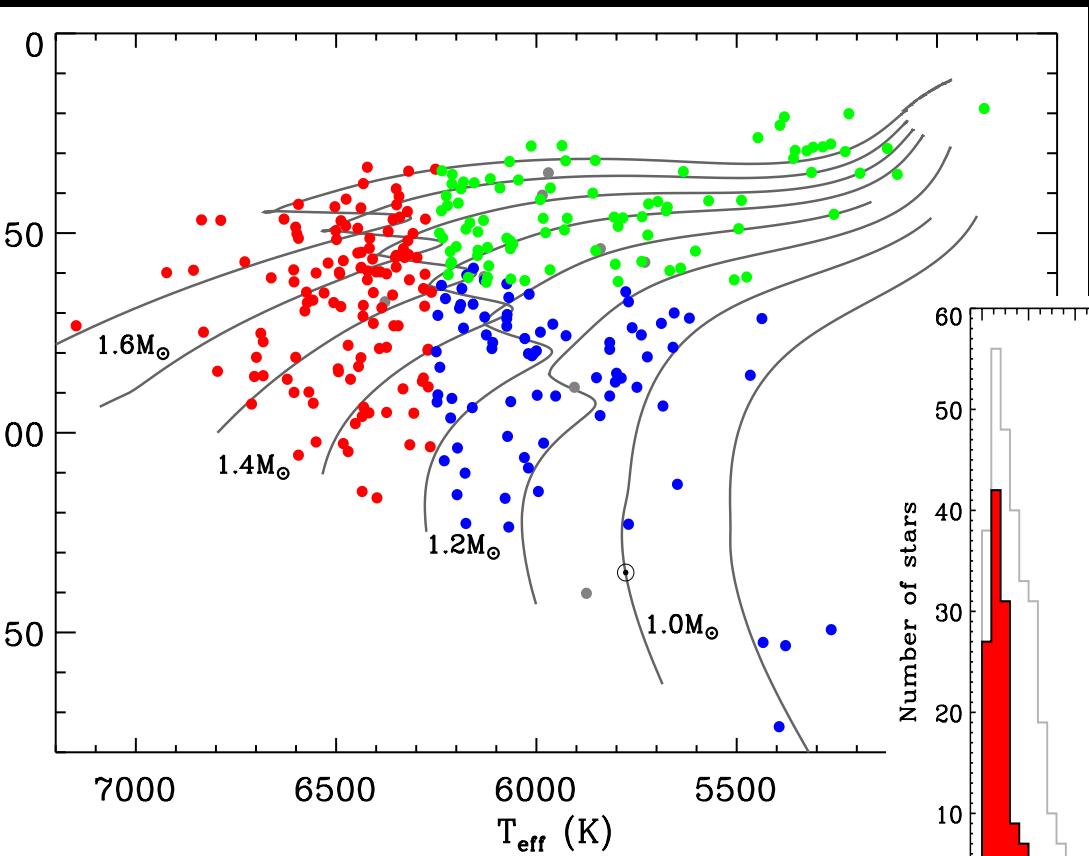
II-SURFACE ROTATION

	AutoACF	Reinhold et al. (2013)	Nielsen et al. (2013)
Total Number	34,030	24,124	12,515
AND AutoACF	—	20,009	10,381
AND Reinhold et al. (2013)	20,009	—	9,292
AND Nielsen et al. (2013)	10,381	9,292	—

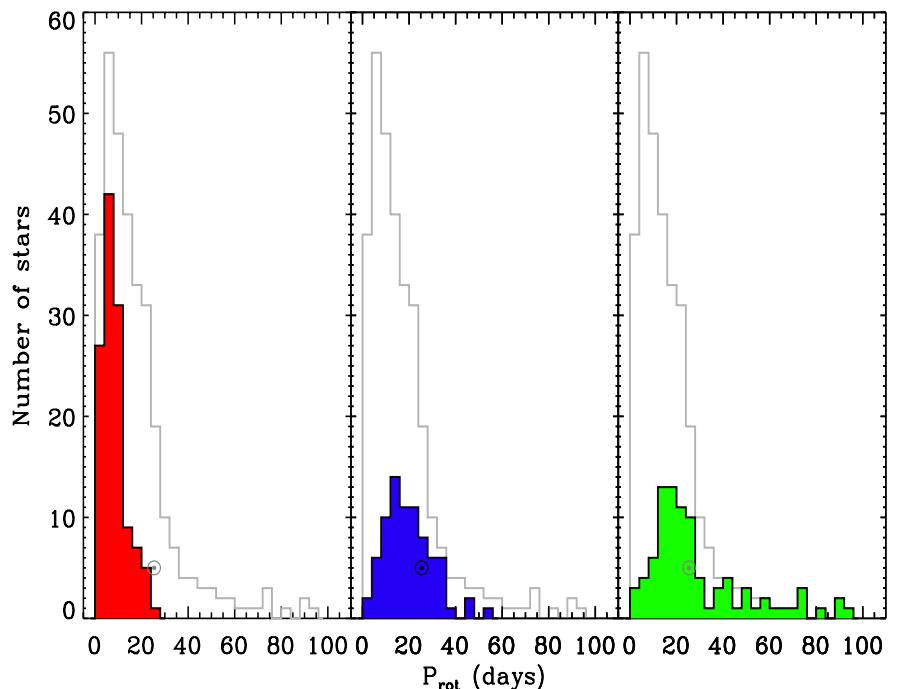


II-SURFACE ROTATION (M-S & SUB-RG)

- ~540 solar-like stars showing p-mode oscillations have been measured (1 month) [Chaplin et al. 2014]
 - Reliable surface rotation rates and photospheric magnetic index obtained for 310 stars
- Stars in which pulsations are measured => Low surface activity (biased sample) [Garcia et al. 2010; Chaplin et al. 2011]



[García et al 2014]



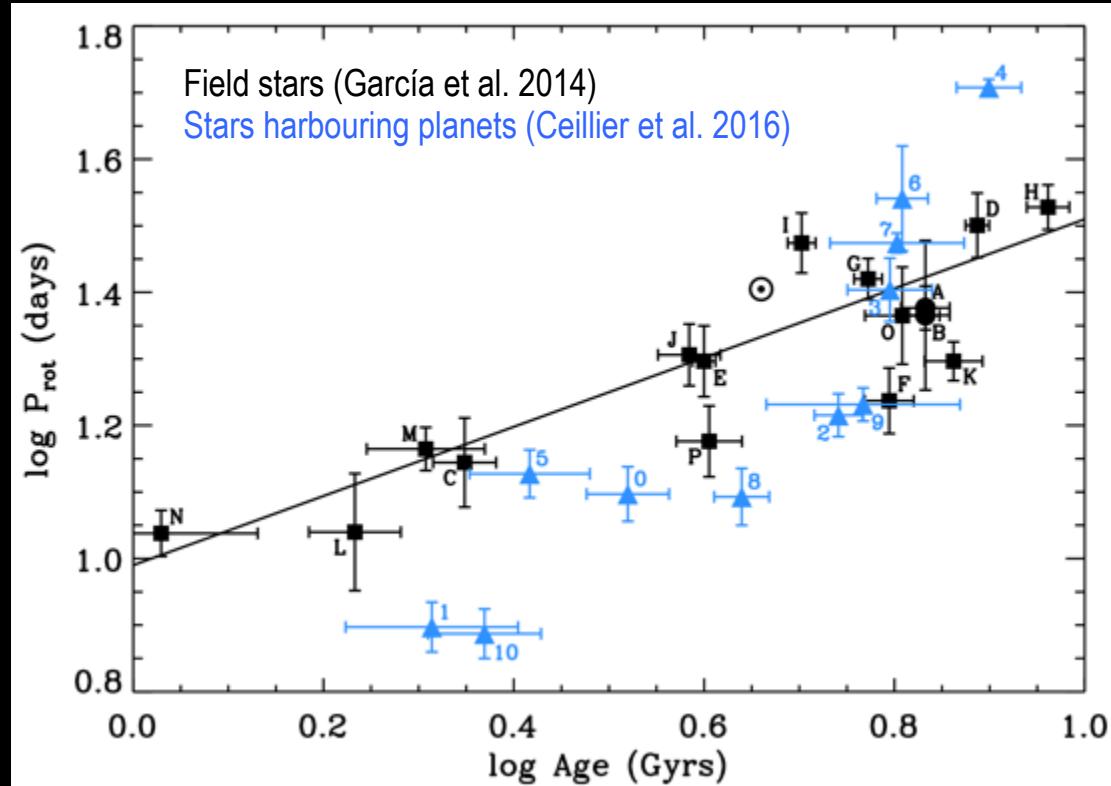
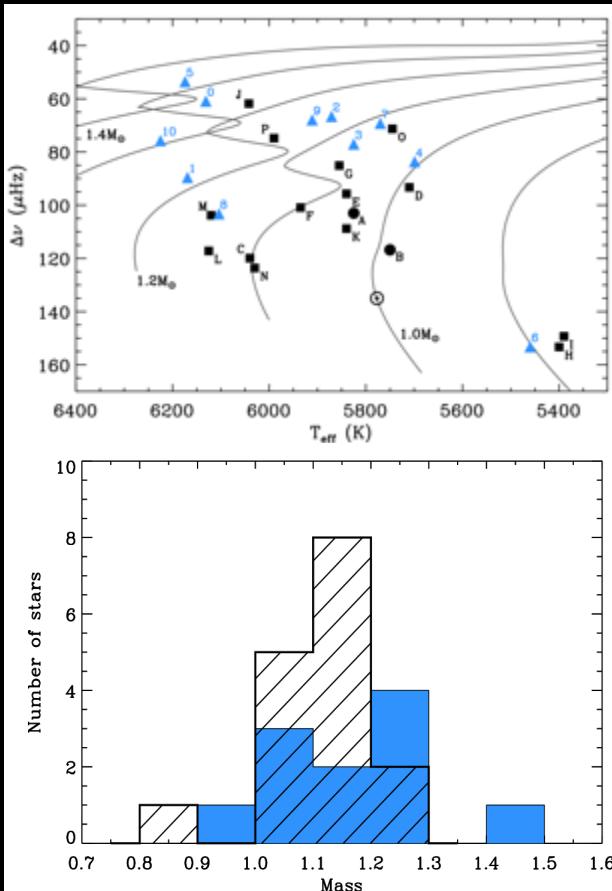
➤ Gyrochronology

- must be calibrated using stars of known age (published relations mostly employ open cluster stars and the Sun).
- Until now, gyrochronology has simply extrapolated these trends to stars older than the Sun.

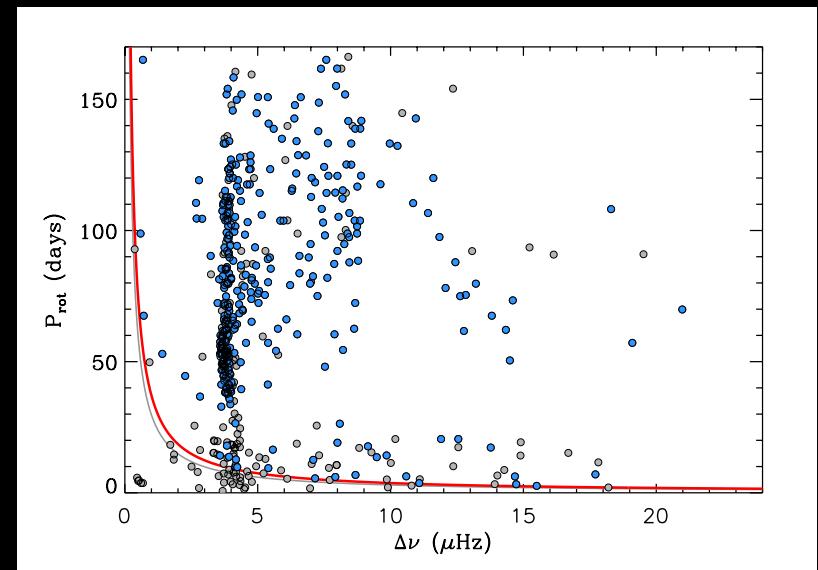
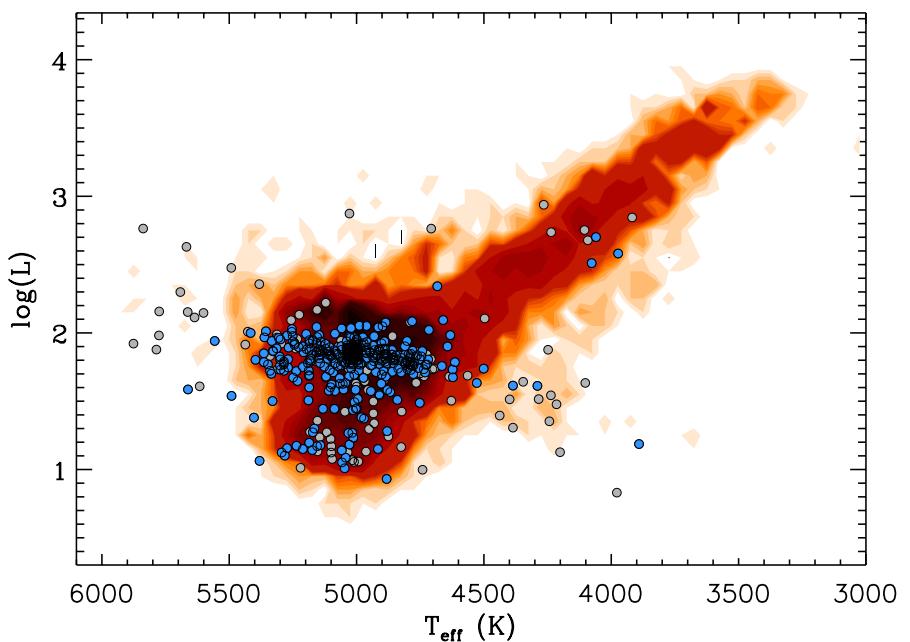
➤ Using also confirmed stars holding planets

- Small planets in the range 0.7 to $3.94 R_{\oplus}$ with semi-major axes range from 0.035 to 0.392 AU
- Differences are due to a difference mass distribution

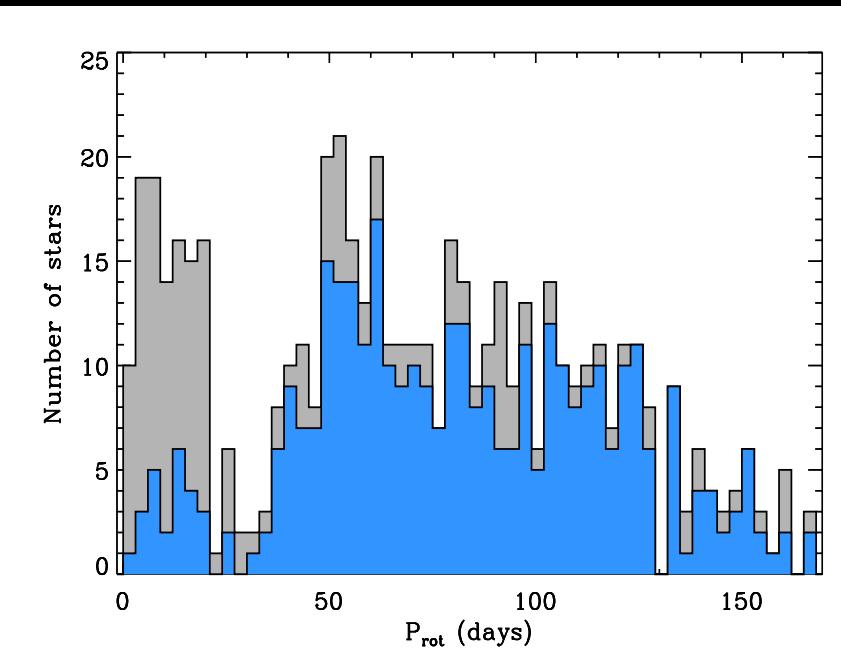
[See Van Saders presentation tomorrow]



II-SURFACE ROTATION (RGB-RC)



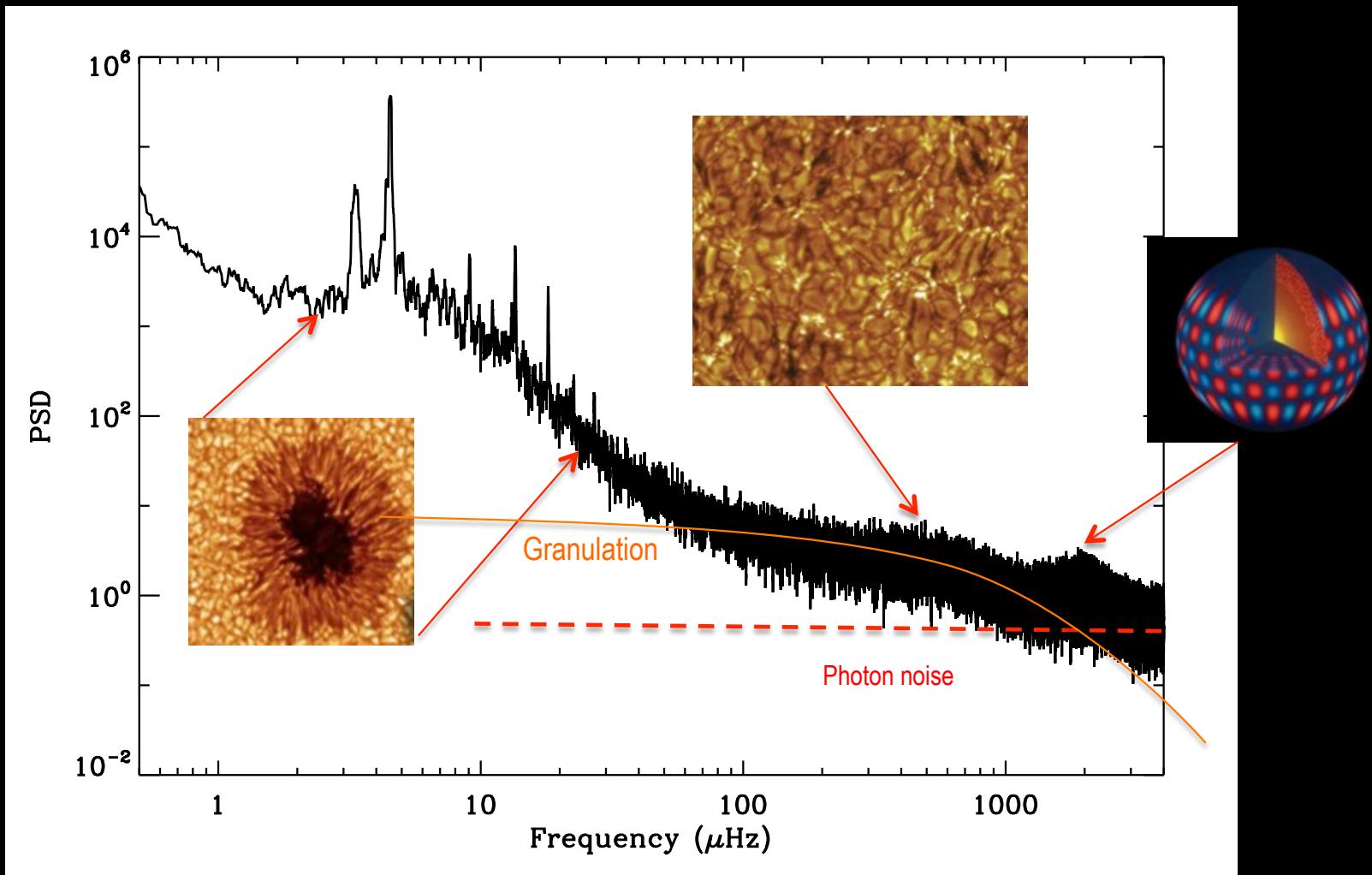
- Ensemble analysis of 17,000 Kepler pulsating RGs
 - ~361 shows reliable surface rotation (blue)
 - 171 that could be due to pollution (grey)
- As expected
 - Most are RC stars
 - Some possible mergers detected



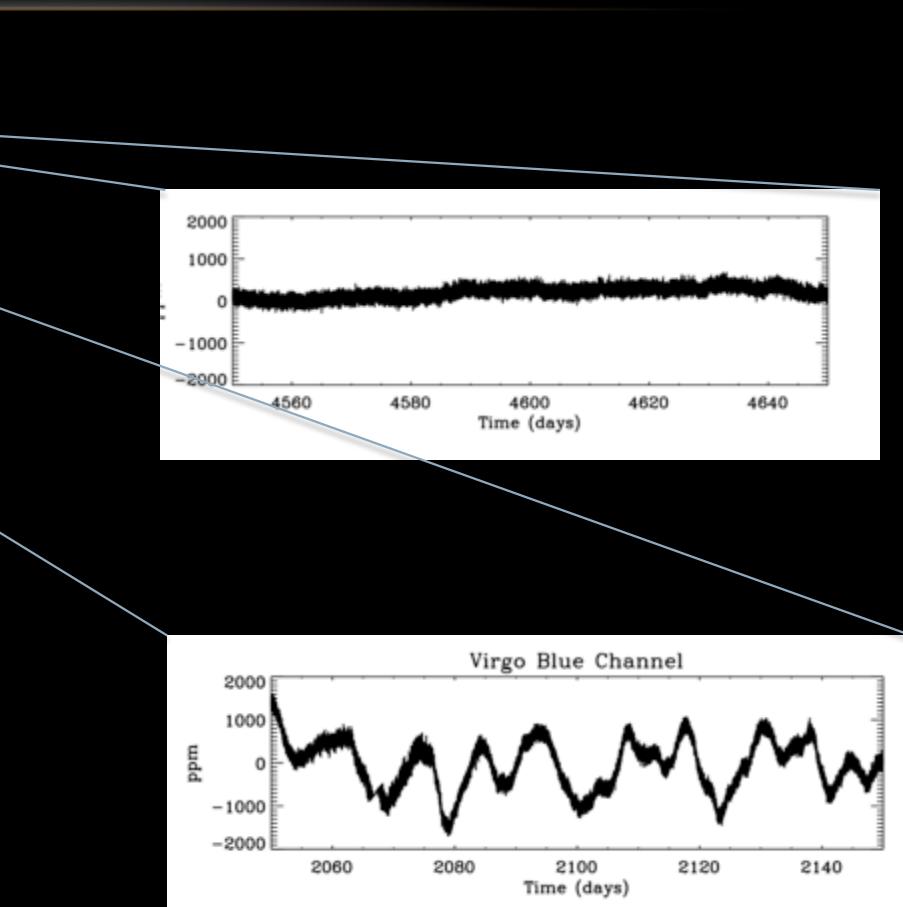
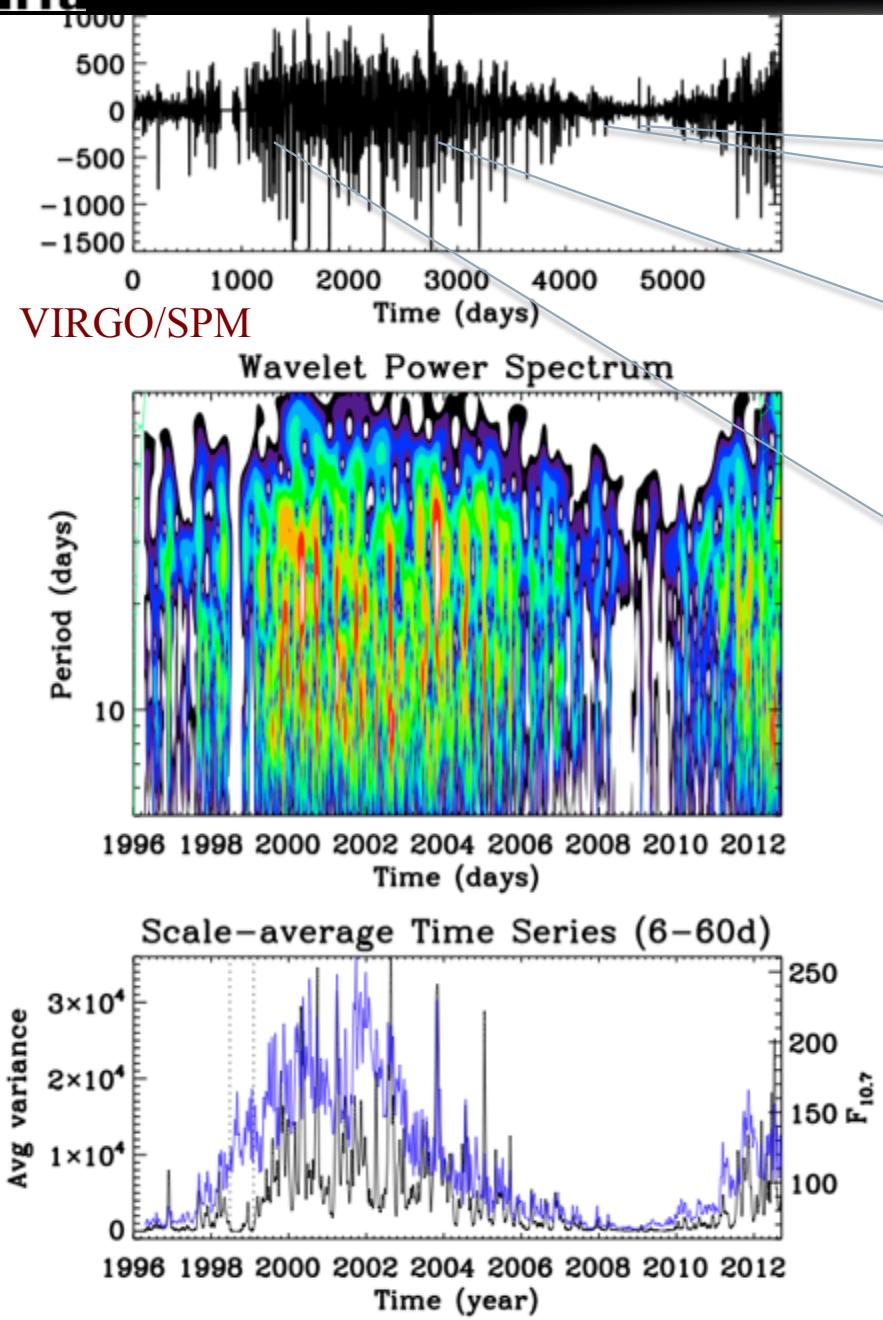
III-Stellar Dynamics: Surface magnetism

III-STELLAR VARIABILITY

- Example of the PSD of a Solar-Like star

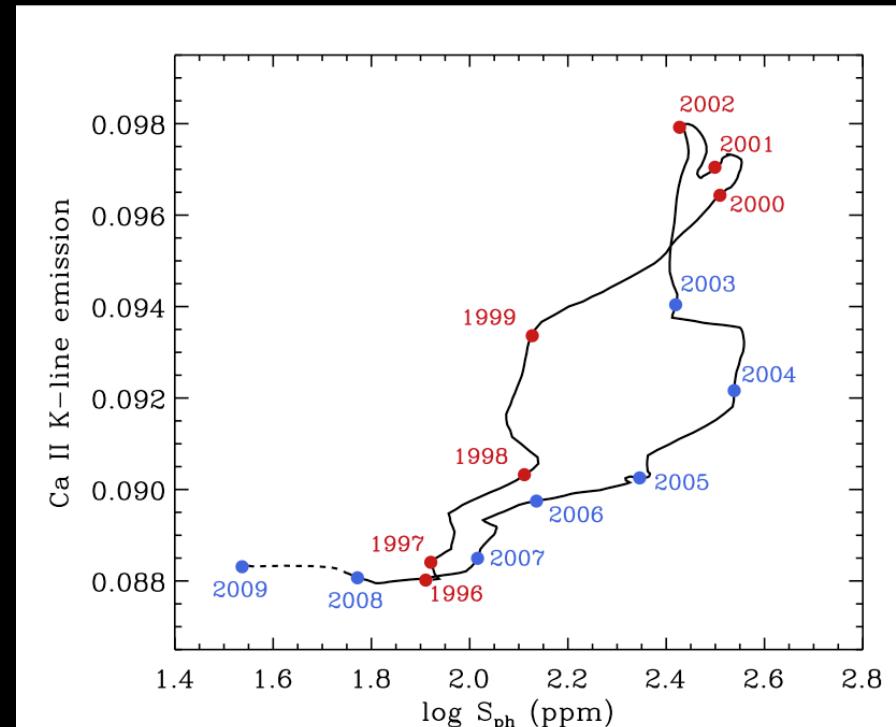
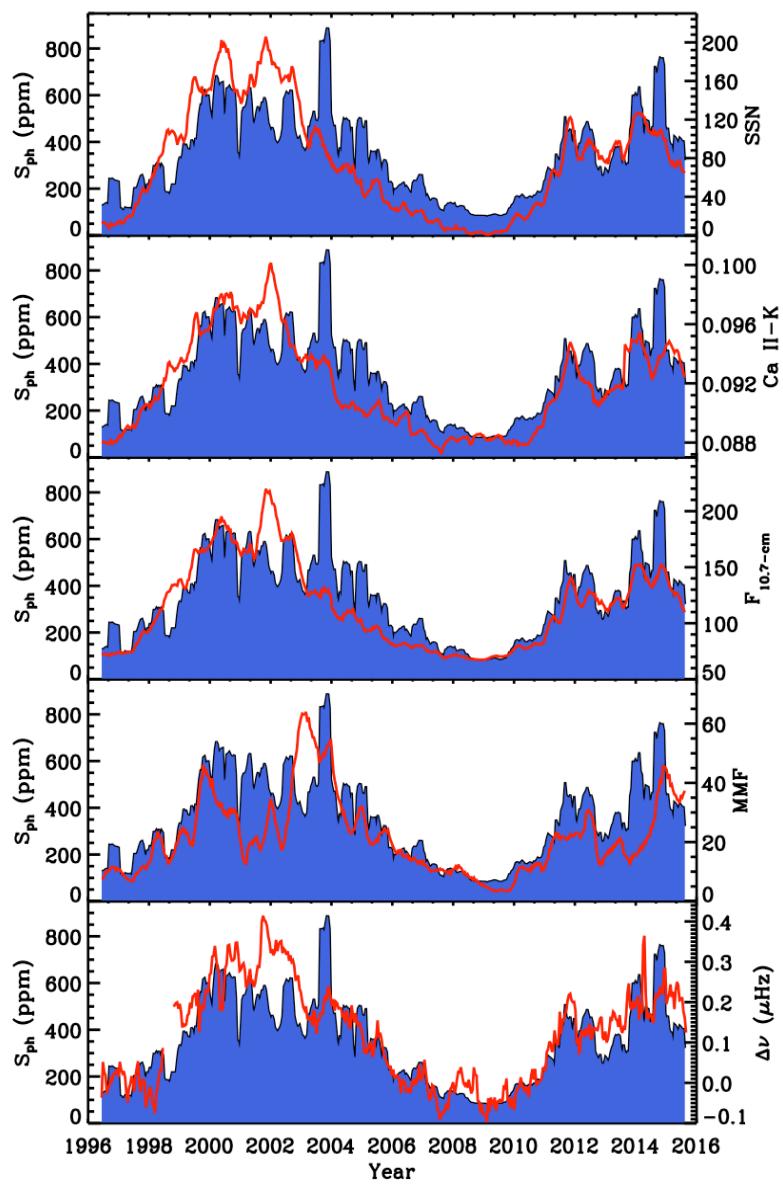


II-MAGNETIC ACTIVITY & ROTATION

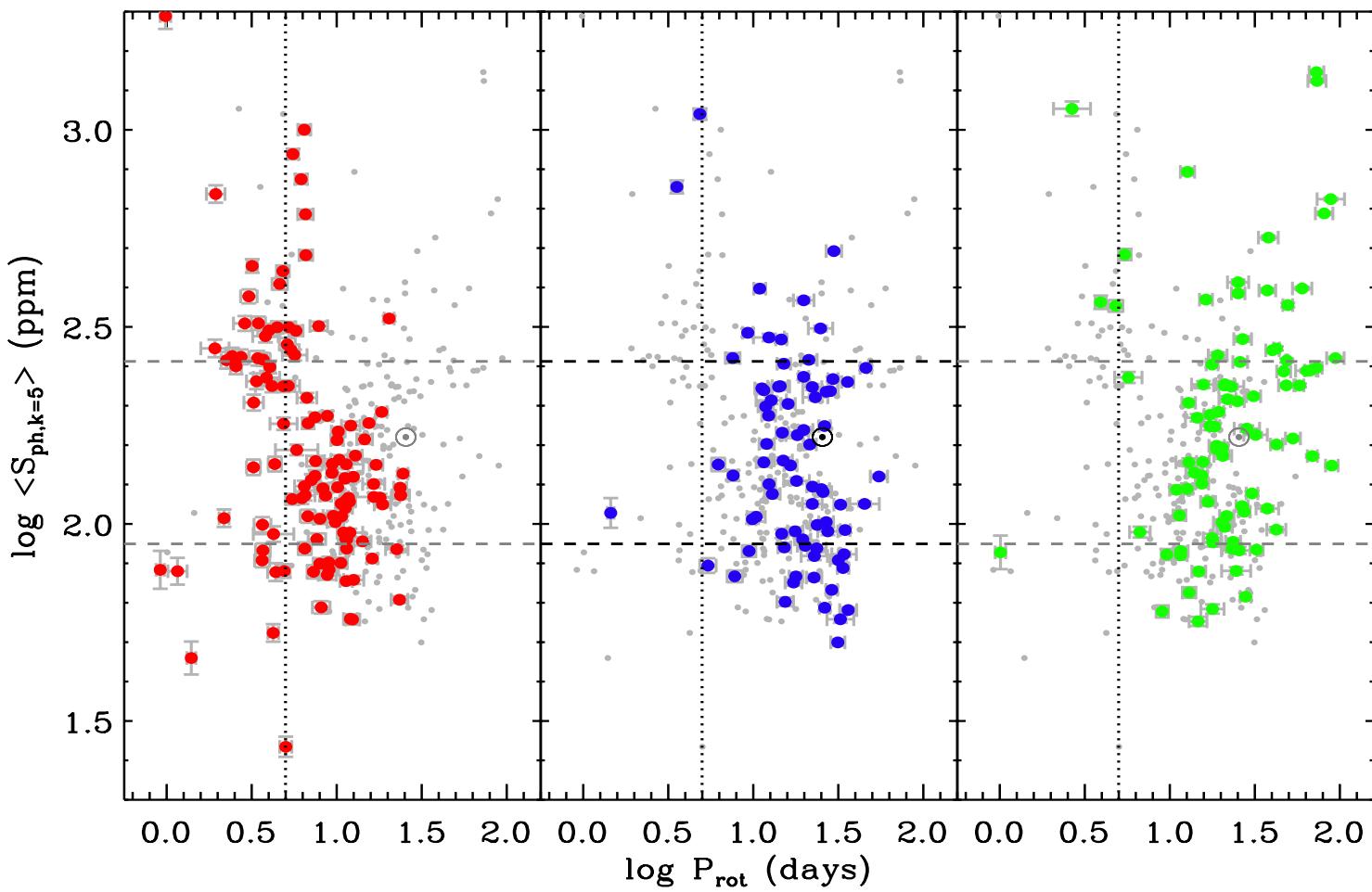


[García, Salabert, Mathur et al. 2013]

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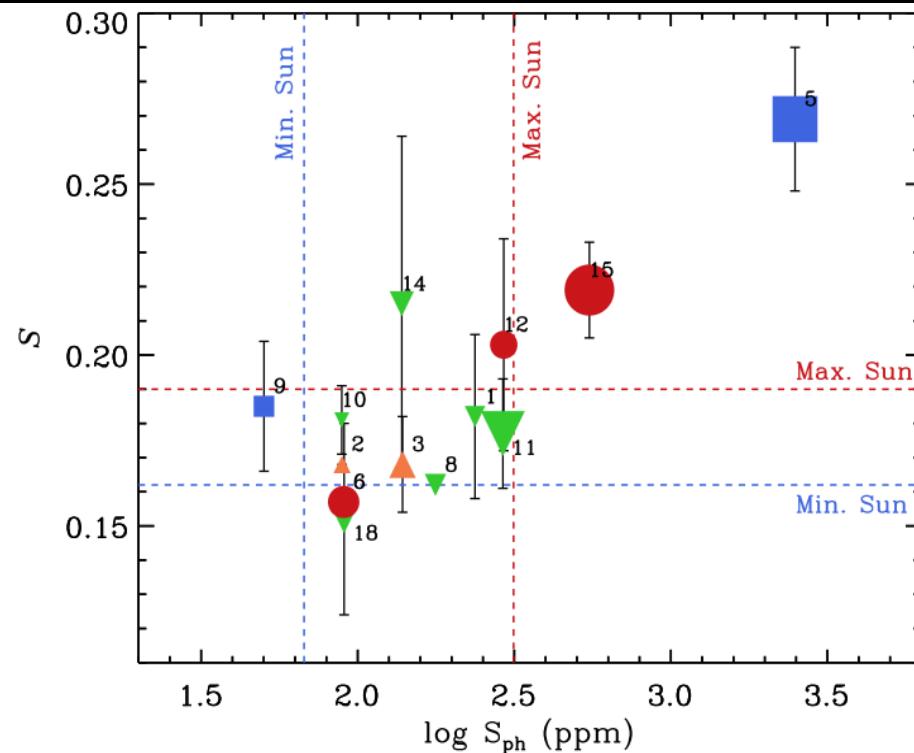
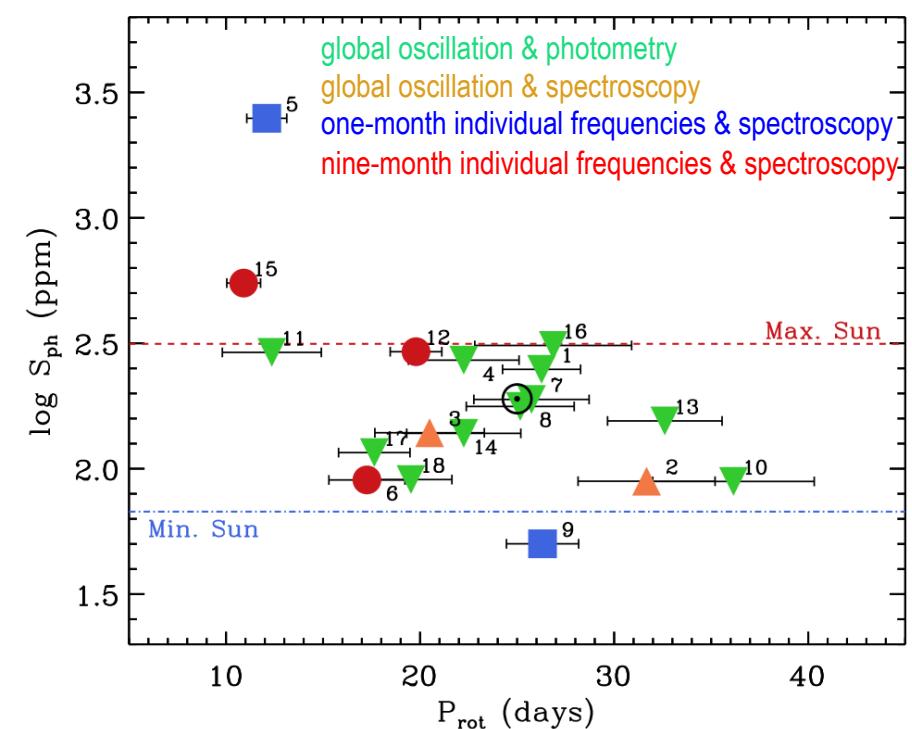
[Salabert et al. in preparation]



- The photospheric magnetic activity of the pulsating solar-like stars

[García et al. 2014]

- Compatible with the solar magnetic activity during the solar cycle (61.5%)
- But large range of inclination angles and position in an on-going long activity cycle

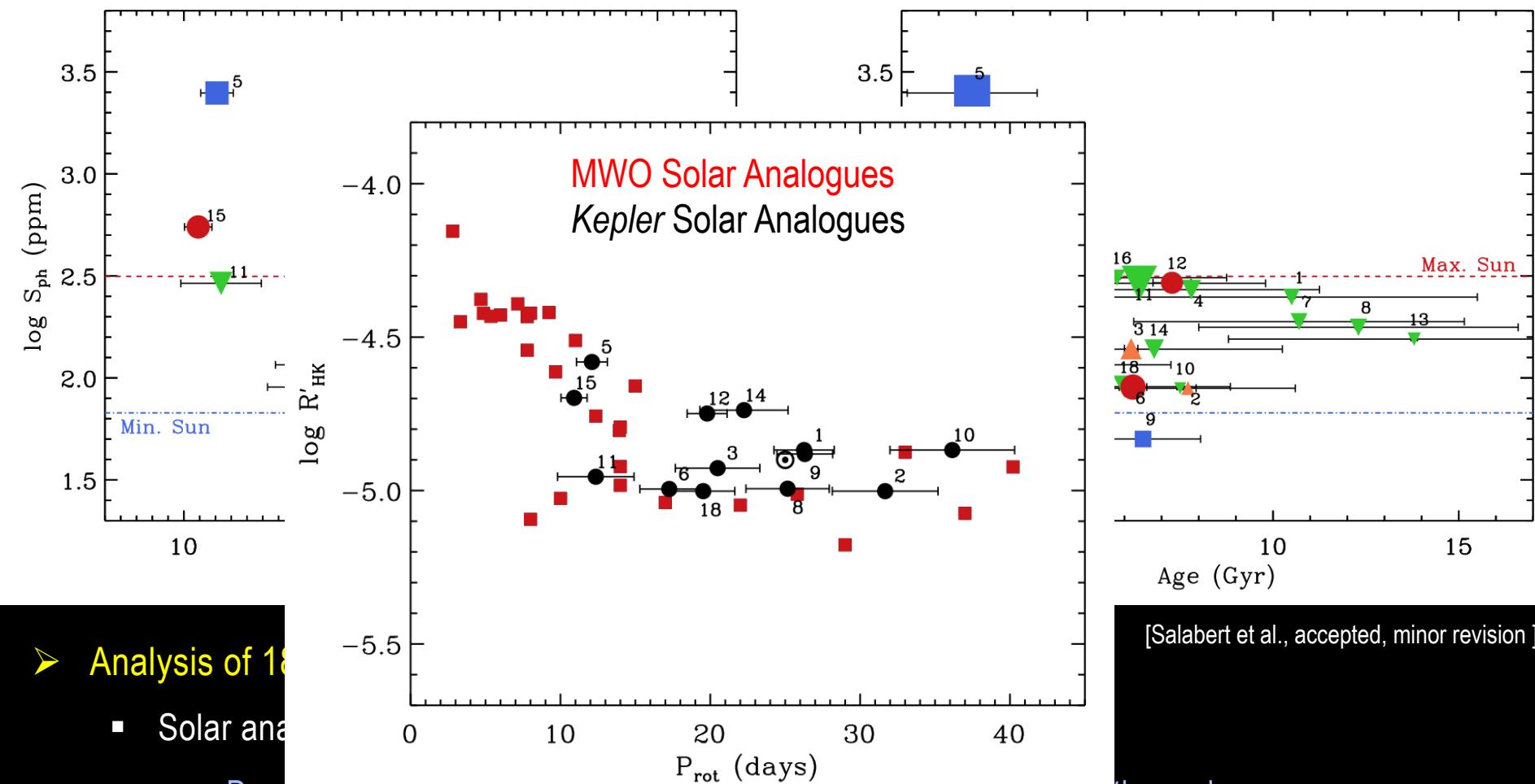


➤ Analysis of 18 seismic solar analogues observed by *Kepler*

- Solar analogs in Teff and Mass [see also Do Nascimento et al. 2014]
 - Degeneracy because of the unknown inclination axis and period of the cycle.
- The surface magnetic activity of the pulsating solar analogues is similar to the Sun

[Salabert et al., accepted, minor revision]

[For the variability of KOIs see: McQuillan et al. 2013; Walkowicz & Basri 2013]



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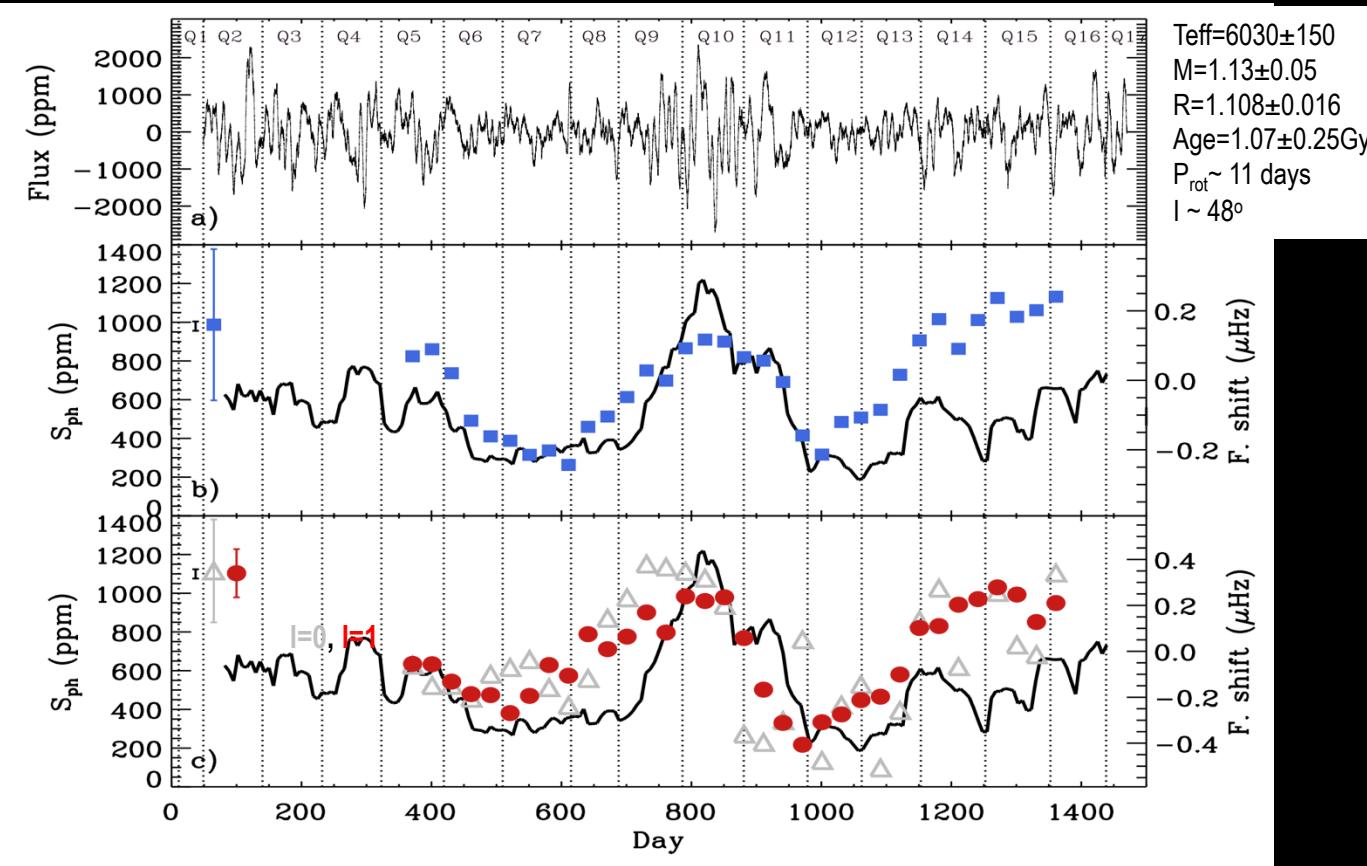
HINTS OF A MAGNETIC-ACTIVITY CYCLE

➤ KIC 10644253: a Solar analogue

Kepler

- Correlation between S_{ph} and p-mode frequency shifts

[Bruntt et al. 2012; Metcalfe et al. 2014; García et al. 2014, Salabert et al. 2016]



[Salabert et al. 2016]

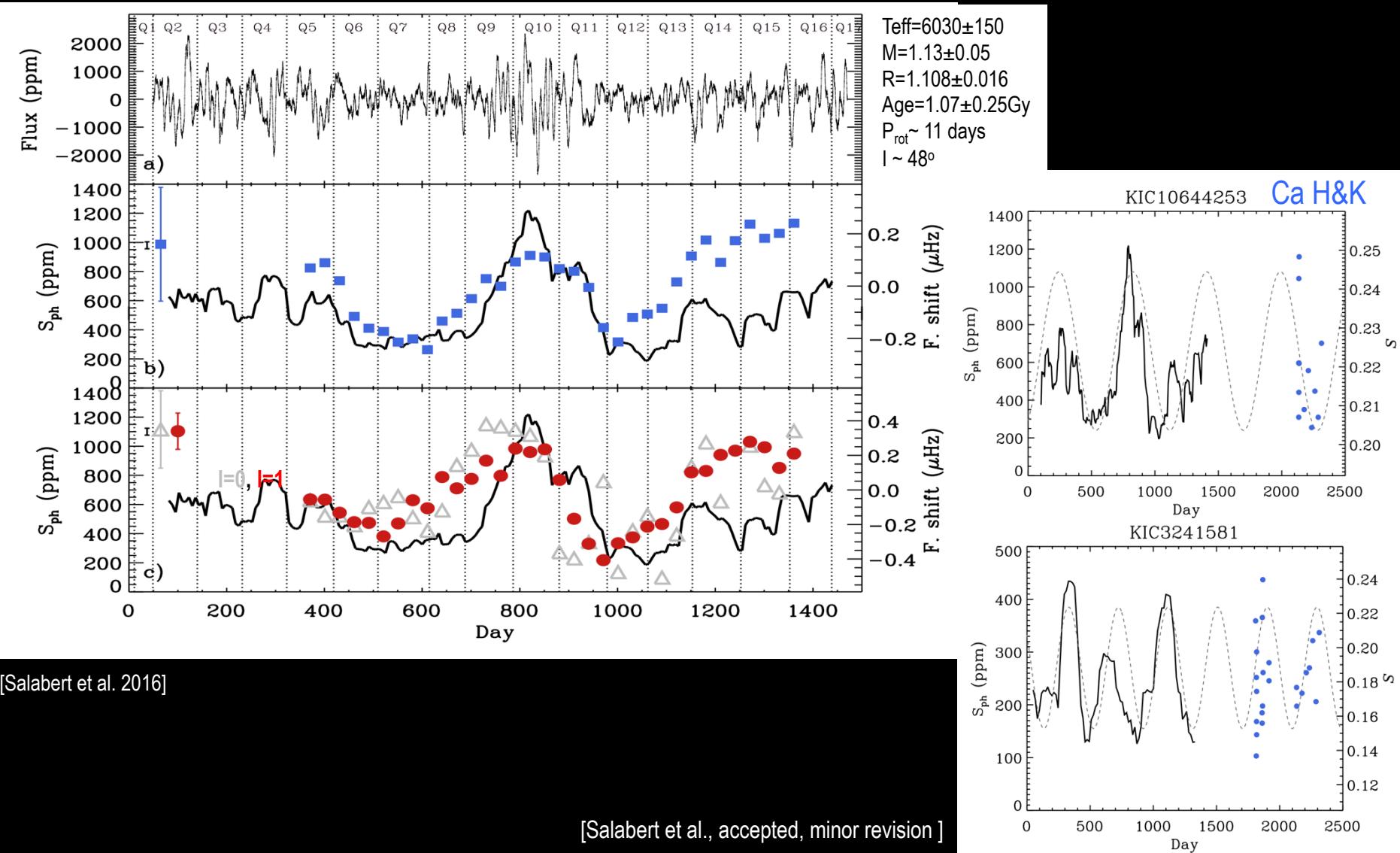
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Thanks