A step to the side
F-type stars, solar-type stars, and the Sun

Besançon
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Hot suns ?

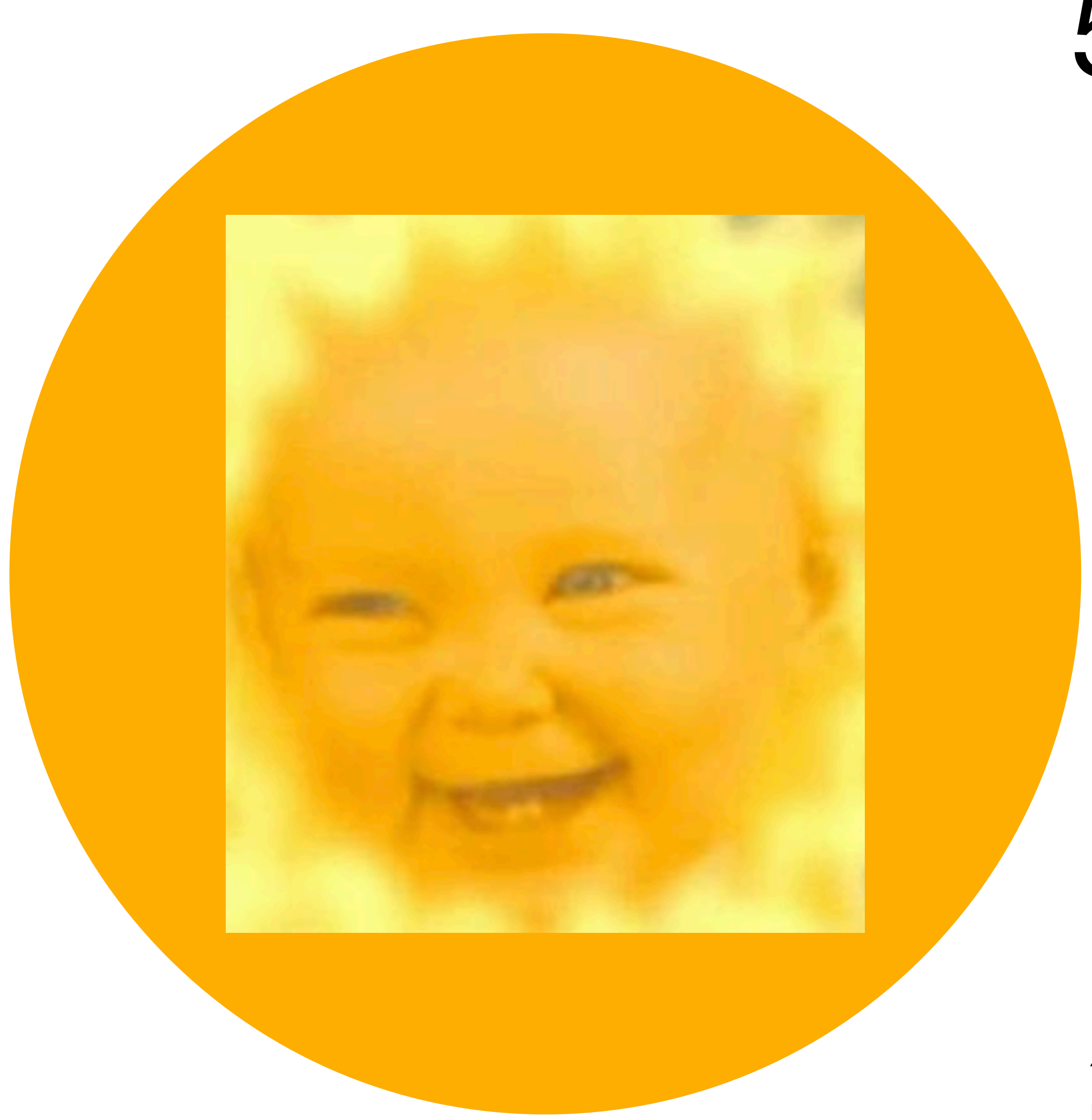
The Sun

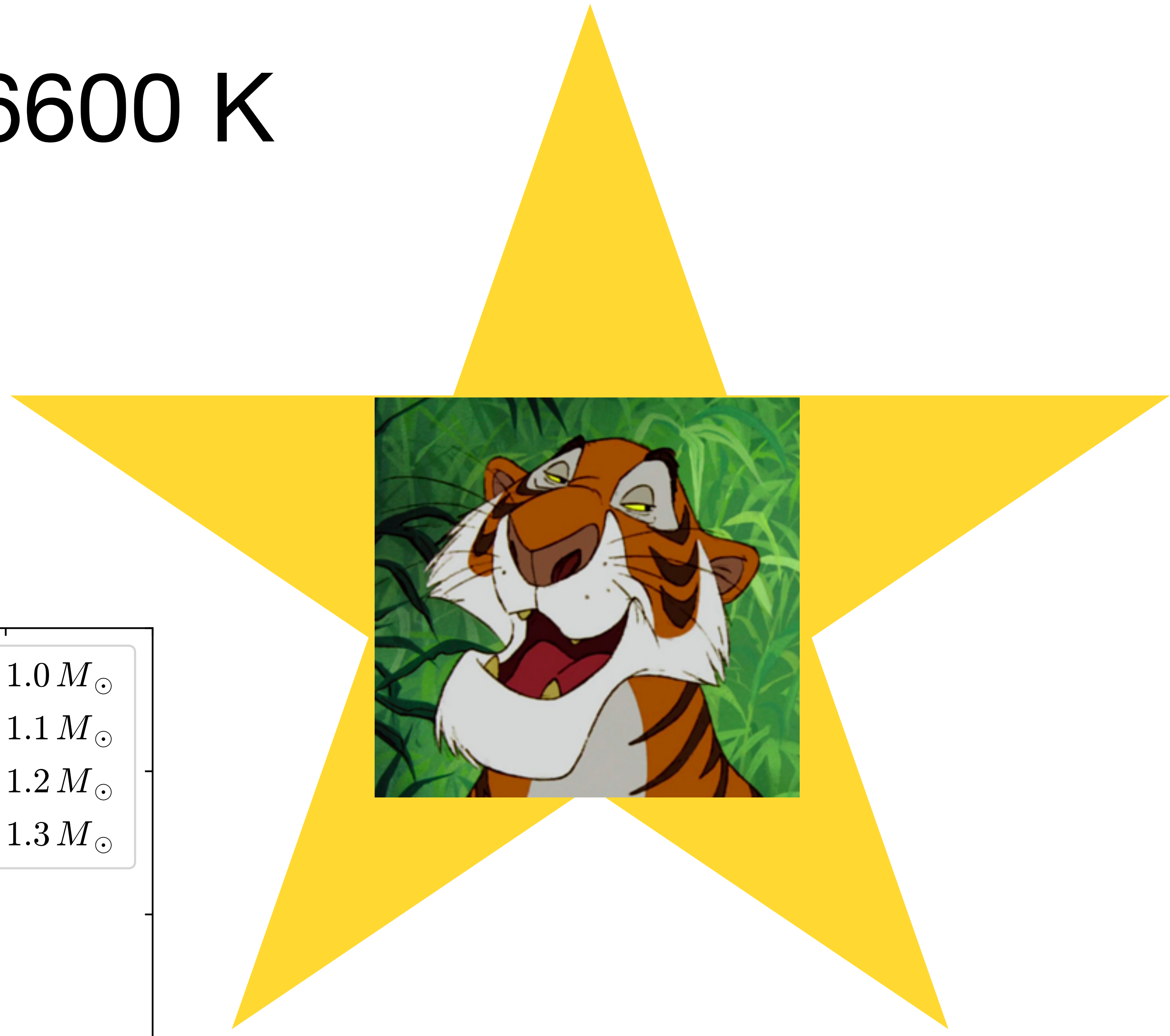
T_{eff}

Late F-type stars

5770 K

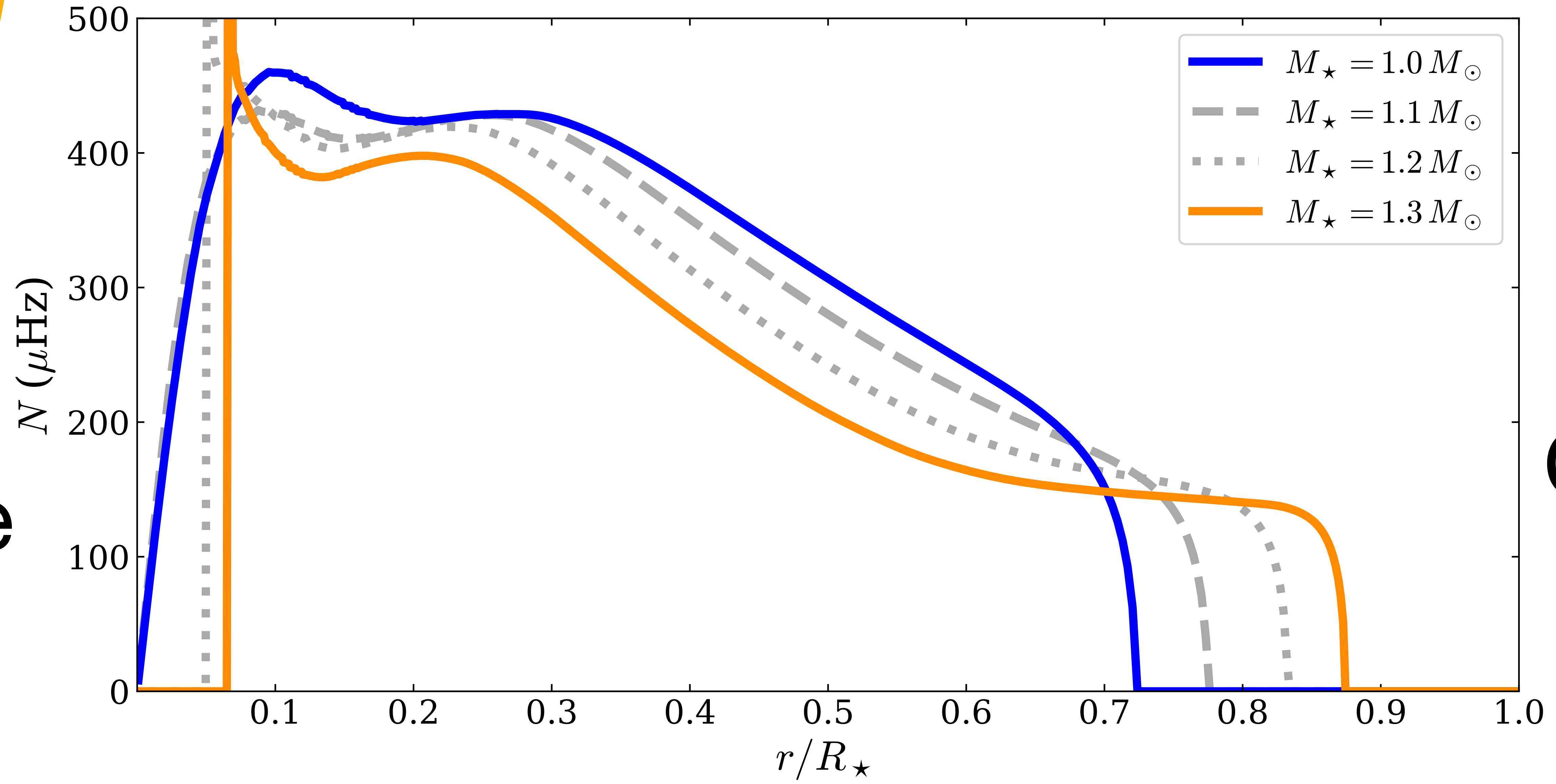
6000-6600 K





Convective envelope
Radiative core

$1\,\mathrm{M}_{\odot}$



Convective envelope
(but thinner)
Convective core
$\sim 1.2 - 1.5\,\mathrm{M}_{\odot}$

The quest for rotational constraints

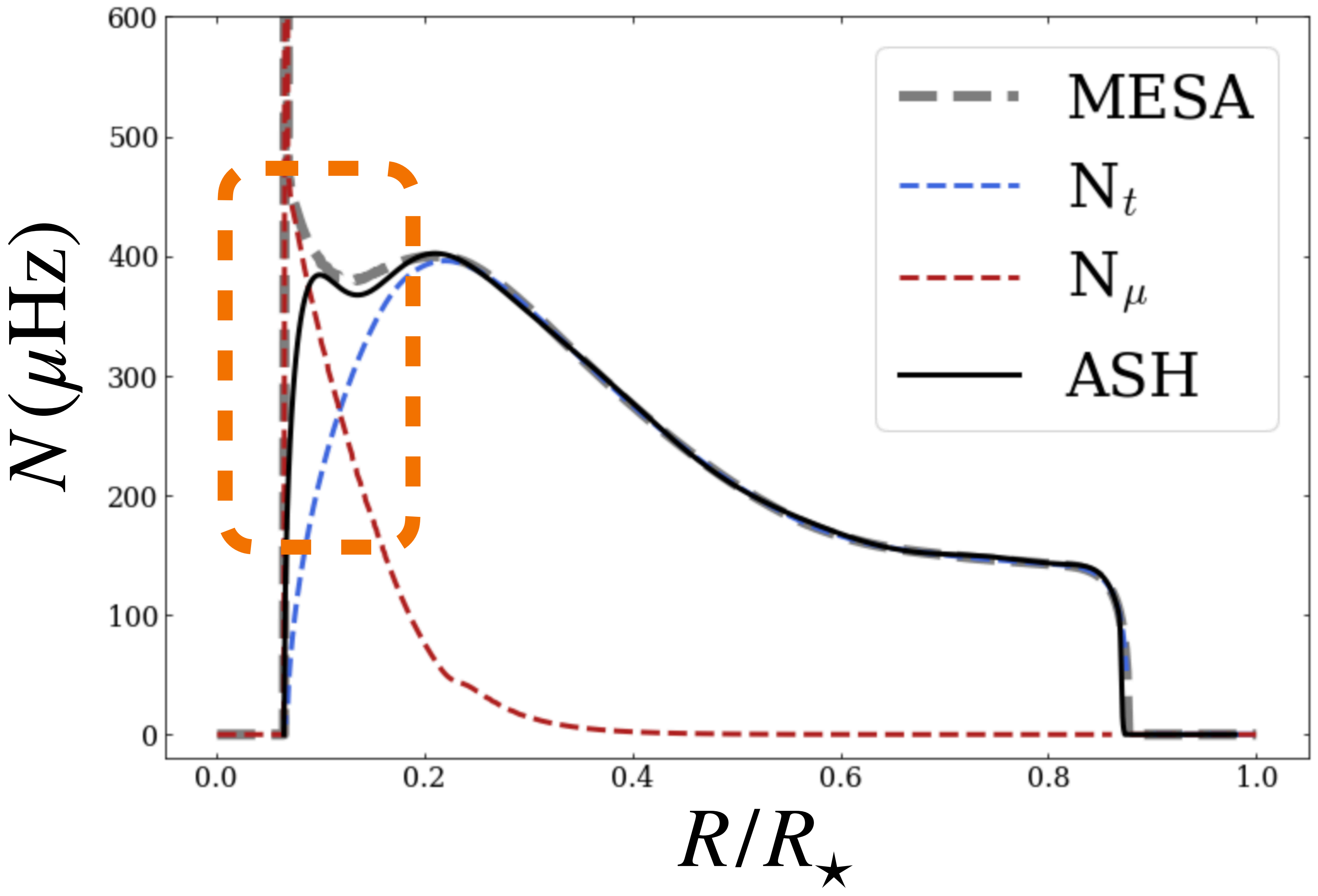
What about F-type stars ?

Late F-type stars have **fast convective flows and are « fast » rotators** : **stochastic wave excitation should be enhanced compared to the Sun**

(Neiner et al. 2012, 2020, Mathis et al. 2014, Augustson et al. 2020, Aerts et al. 2021)

Therefore, what are the **g-mode surface amplitudes** we can expect for late F-type stars ?

F-type star modelling in 3D simulations



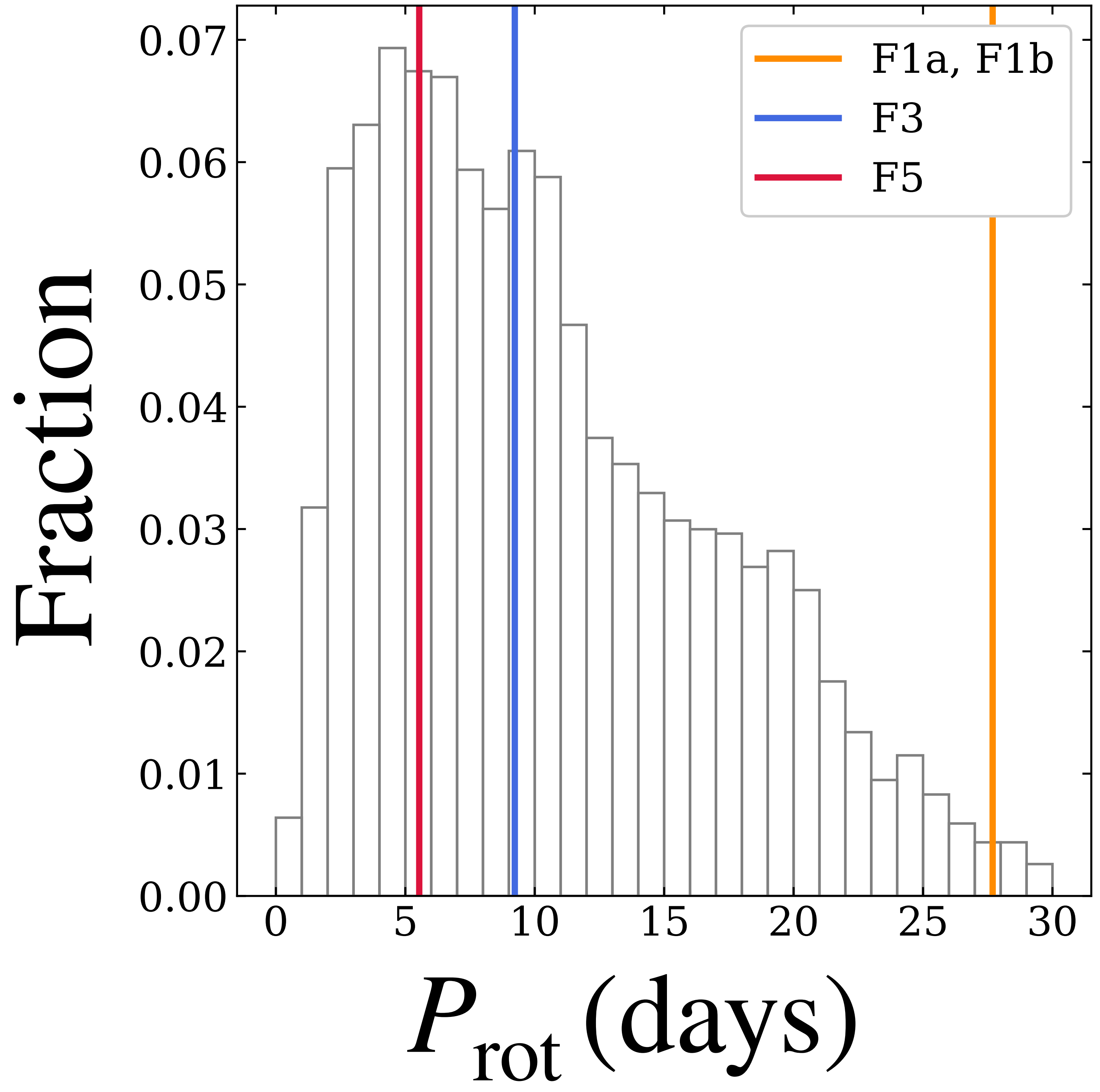
M = 1.3 $M_\odot$
T_{eff} = 6340 K
log g = 4.2

Star modelled from r = 0.06 to 0.98 $R_\star$

Edge of the convective core taken as an impenetrable boundary

IGWs excitation only by the convective envelope

$\Omega_0 = 1\,\Omega_\odot$ (F1a, F1b)
$\Omega_0 = 3\,\Omega_\odot$ (F3)
$\Omega_0 = 5\,\Omega_\odot$ (F5)



Model resolution
1205 x 512 x 1024 (F1a)
1205 x1024 x 2048 (F1b, F3, F5)

Surface rotation of main-sequence *Kepler* F-type stars

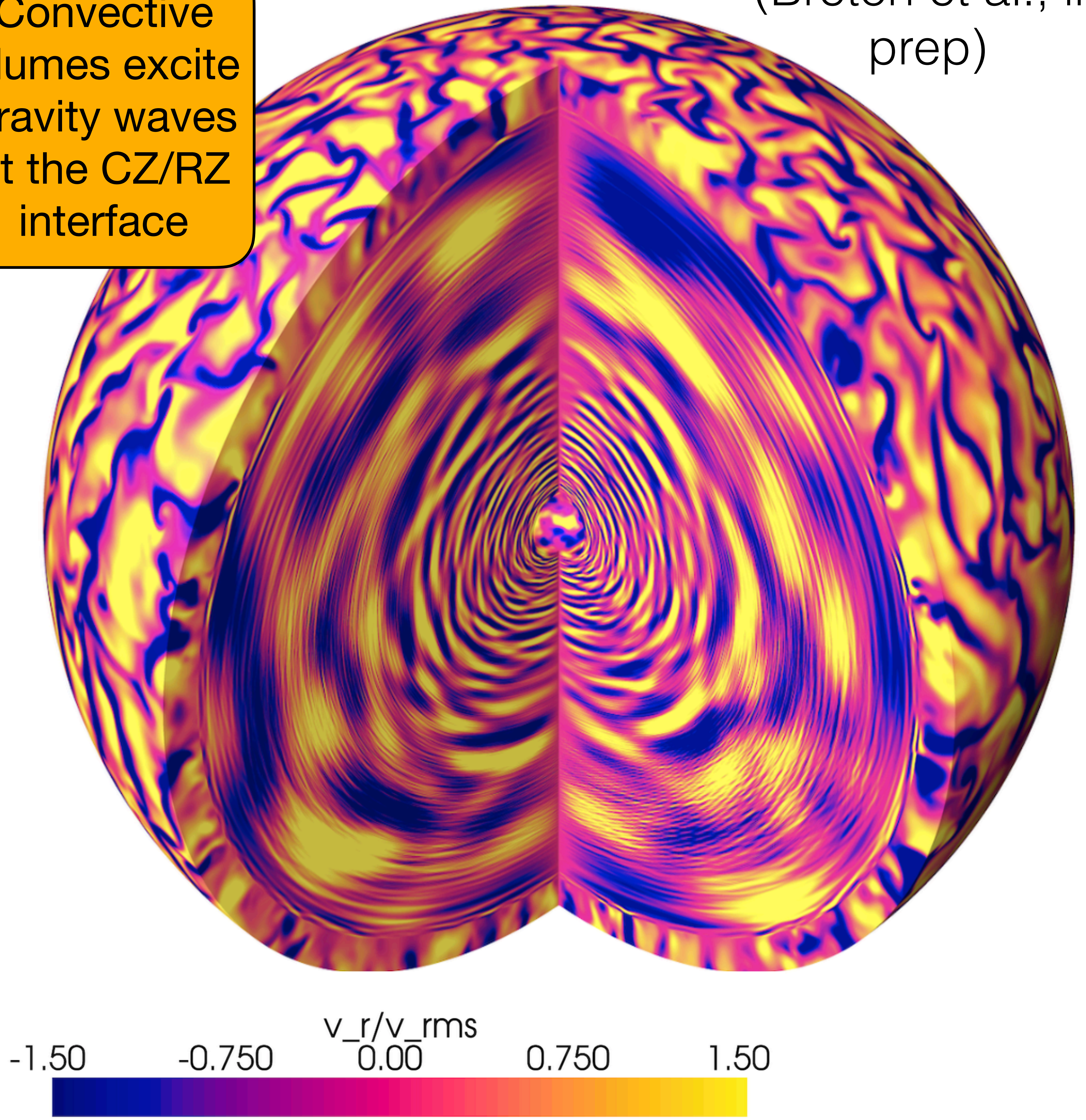
(Santos, Breton et al. 2021, Breton et al. in prep)

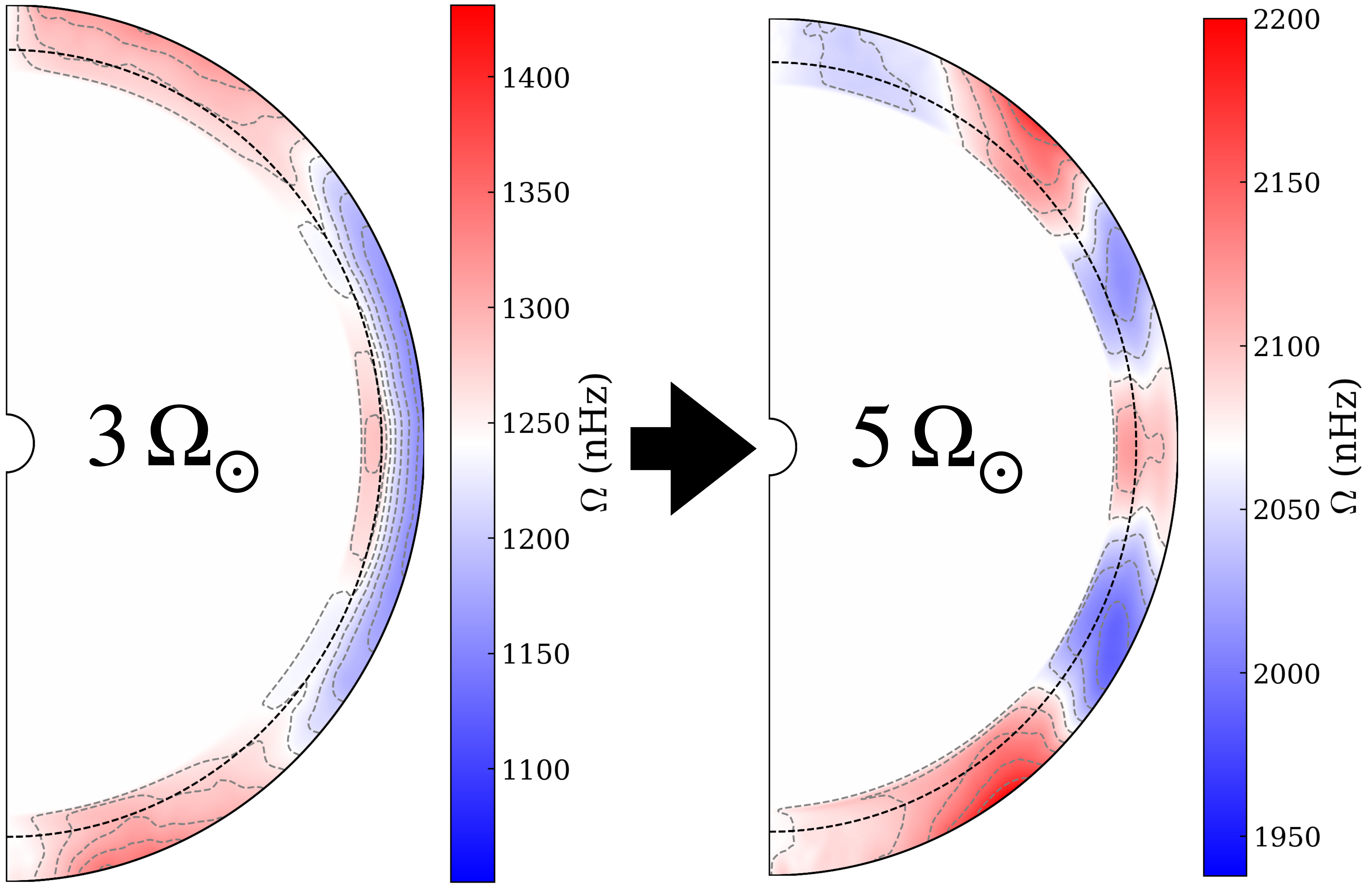
3D simulations with the ASH code

(Clune et al. 1999, Brun et al. 2004)

Convective plumes excite gravity waves at the CZ/RZ interface

(Breton et al., in prep)





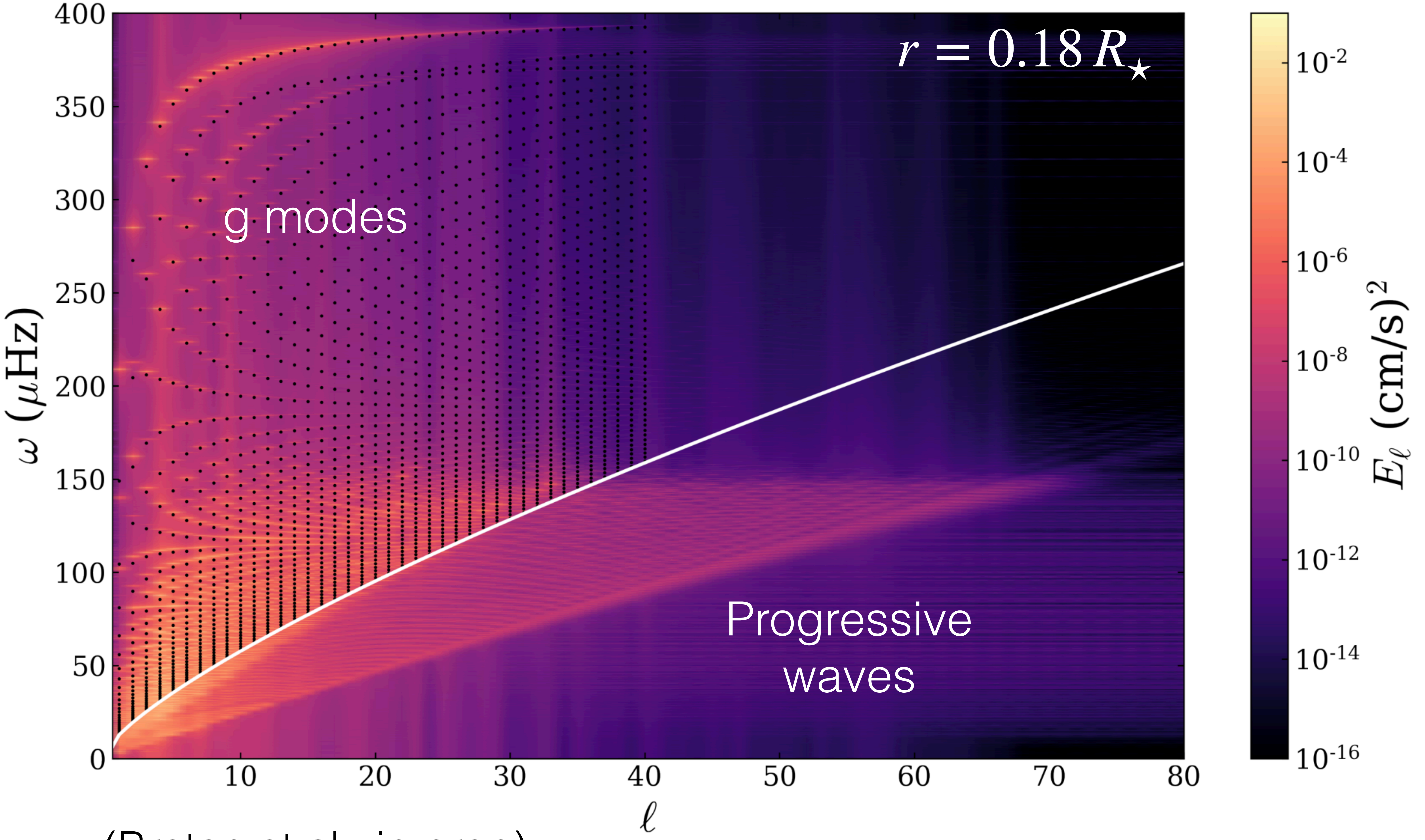
Transition towards a solar regime as Rossby number decreases

(Augustson et al. 2012, Brun et al. 2017, 2022, Noraz, Breton et al., submitted)

Gravity-waves power spectrum

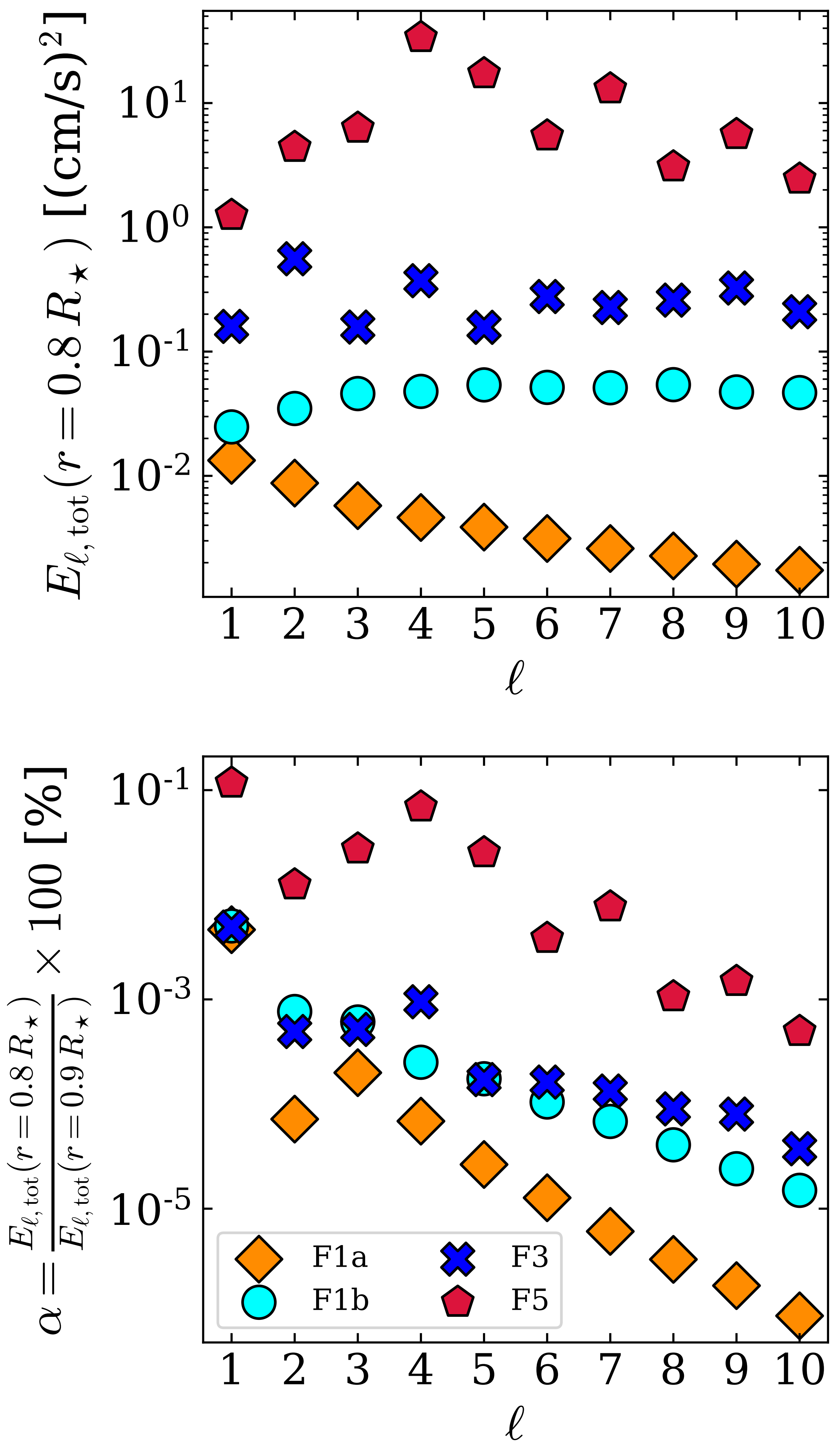
Power spectrum from ASH vs mode frequencies computed with GYRE.

(Townsend & Teitler 2013, Townsend et al. 2018, Goldstein & Townsend 2020)

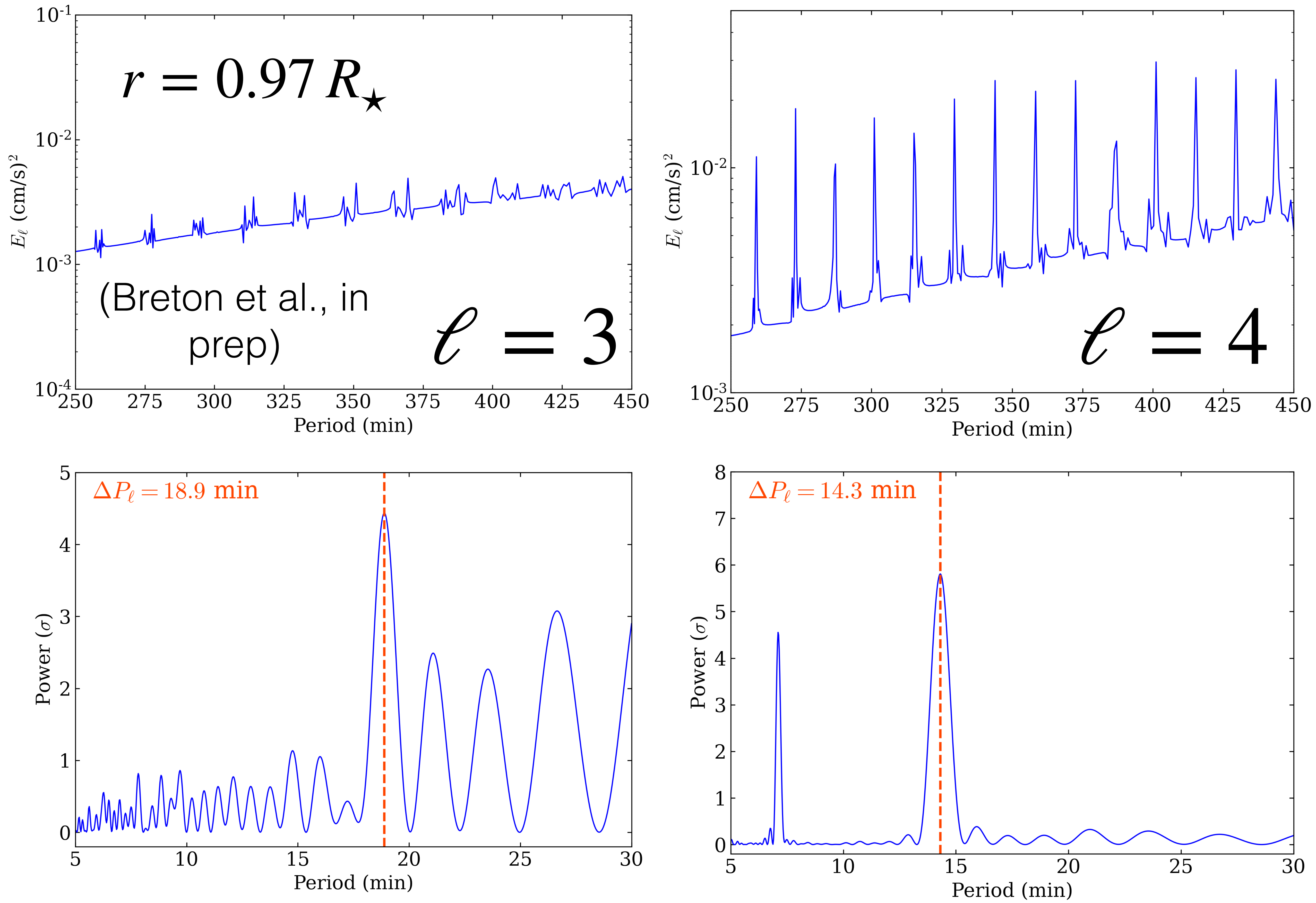


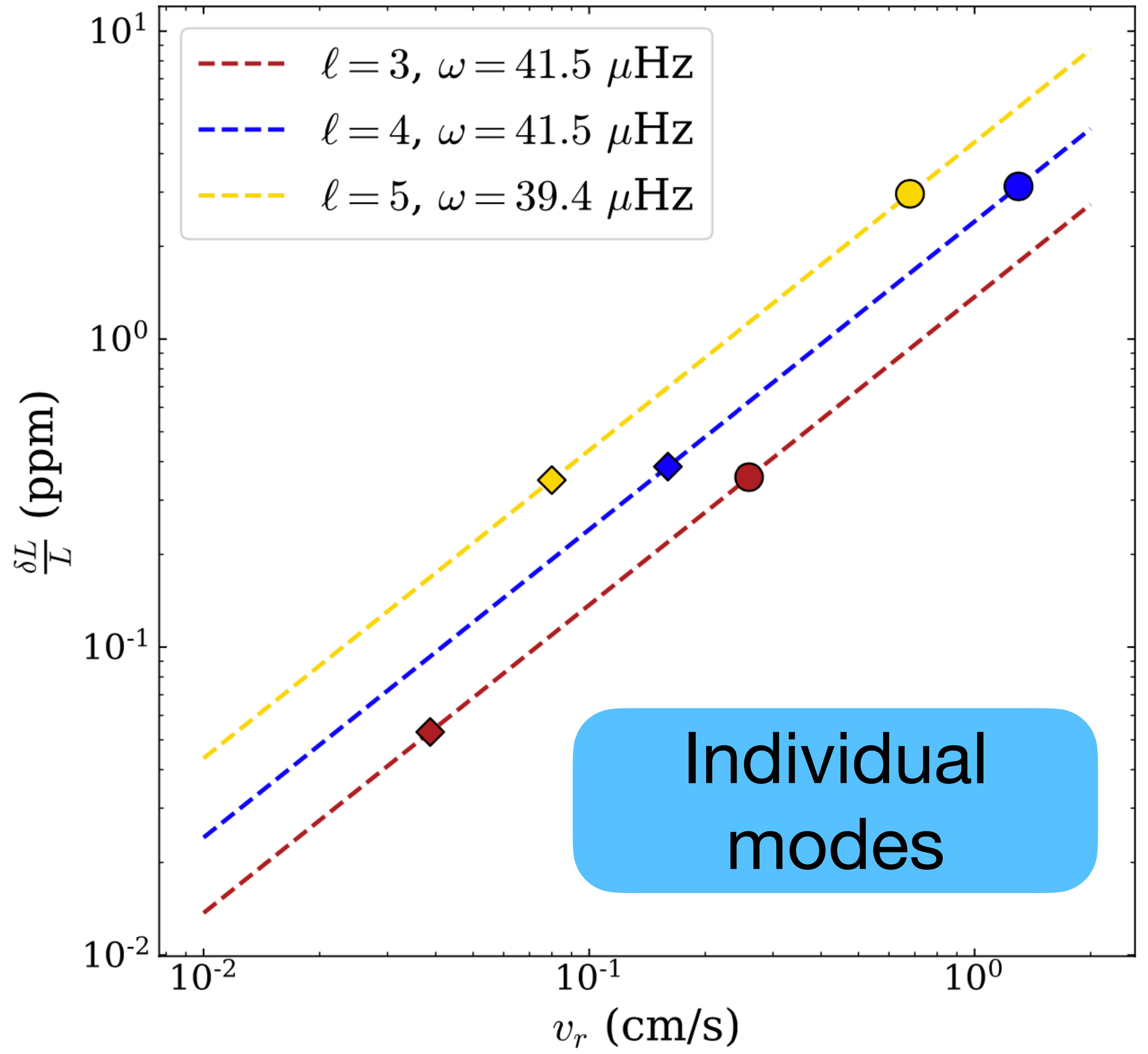
(Breton et al., in prep)

Rotation and mode excitation



Mode visibility near the surface





Modes signatures are detected at the top of the F5 simulation for ℓ = 3 to 7.

(e.g. García et al. 2007 for mode signature detection method)

Modes amplitude compared to the Sun

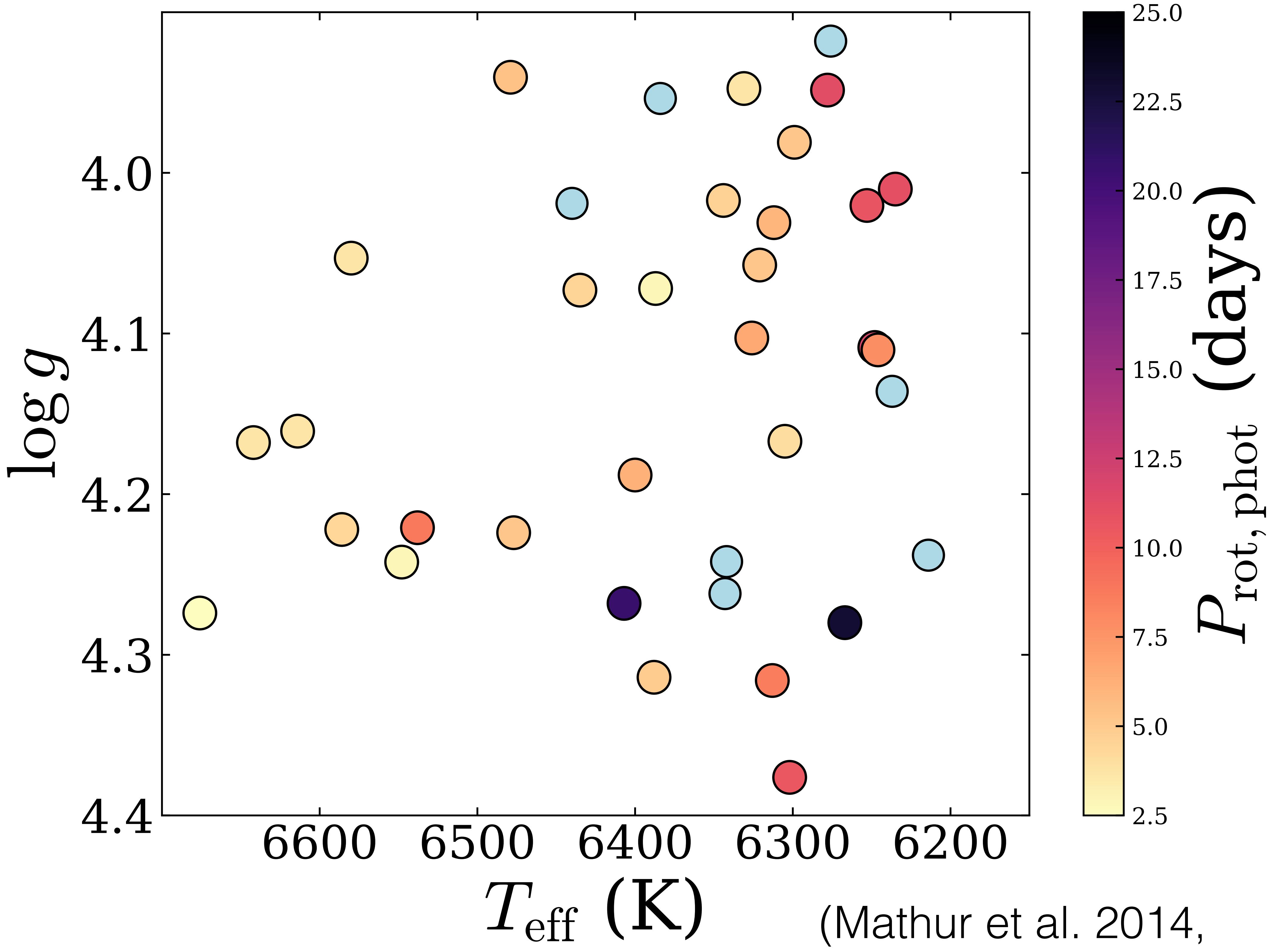
2 orders of magnitude at $1\ \Omega_\odot$
6 orders of magnitudes at $5\ \Omega_\odot$ (!!!)

(Alvan et al. 2014)

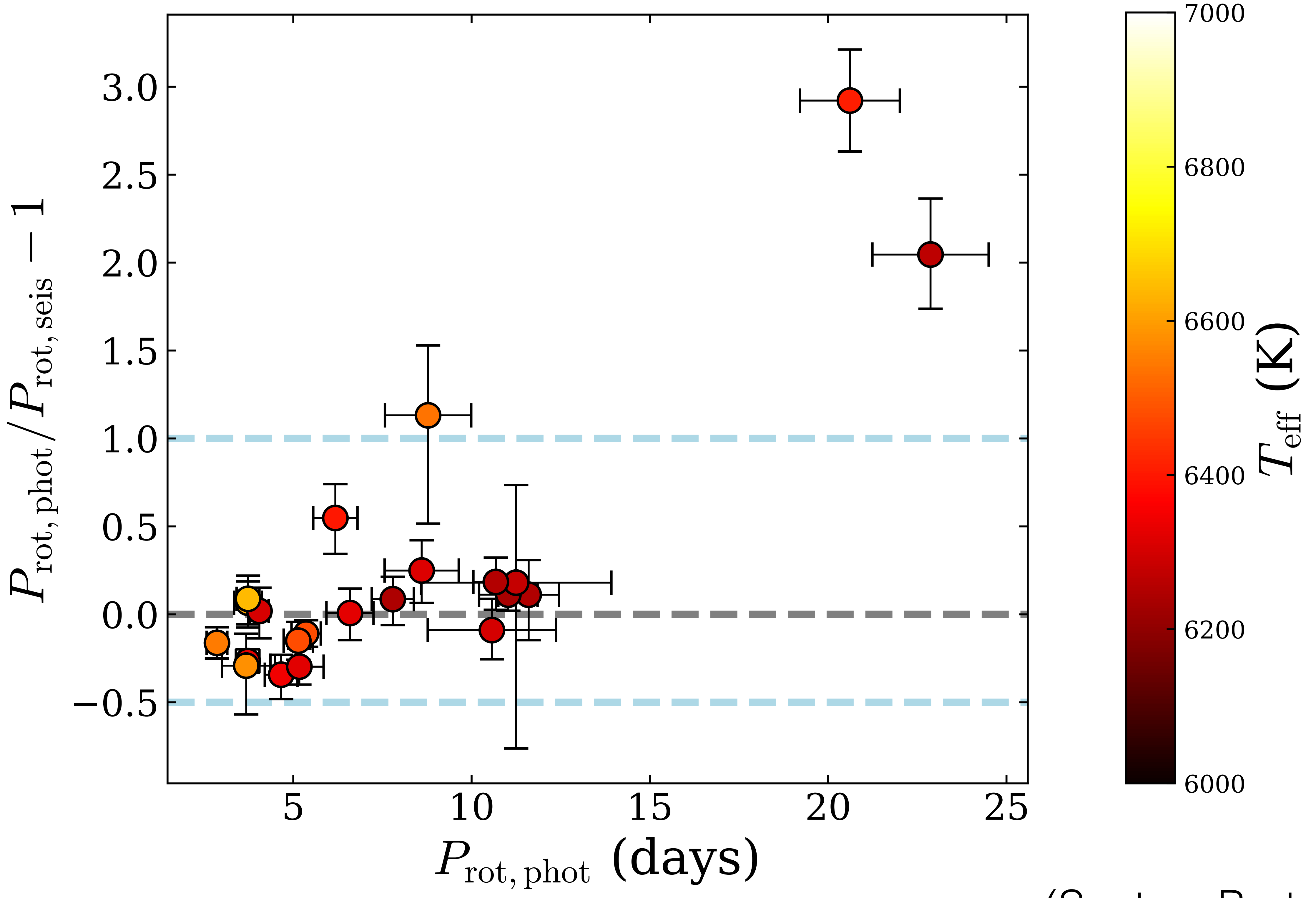
Looking for tigers: *Kepler,* a reliable ally

Selecting interesting stars from different catalogs

Photometry vs. Seismology

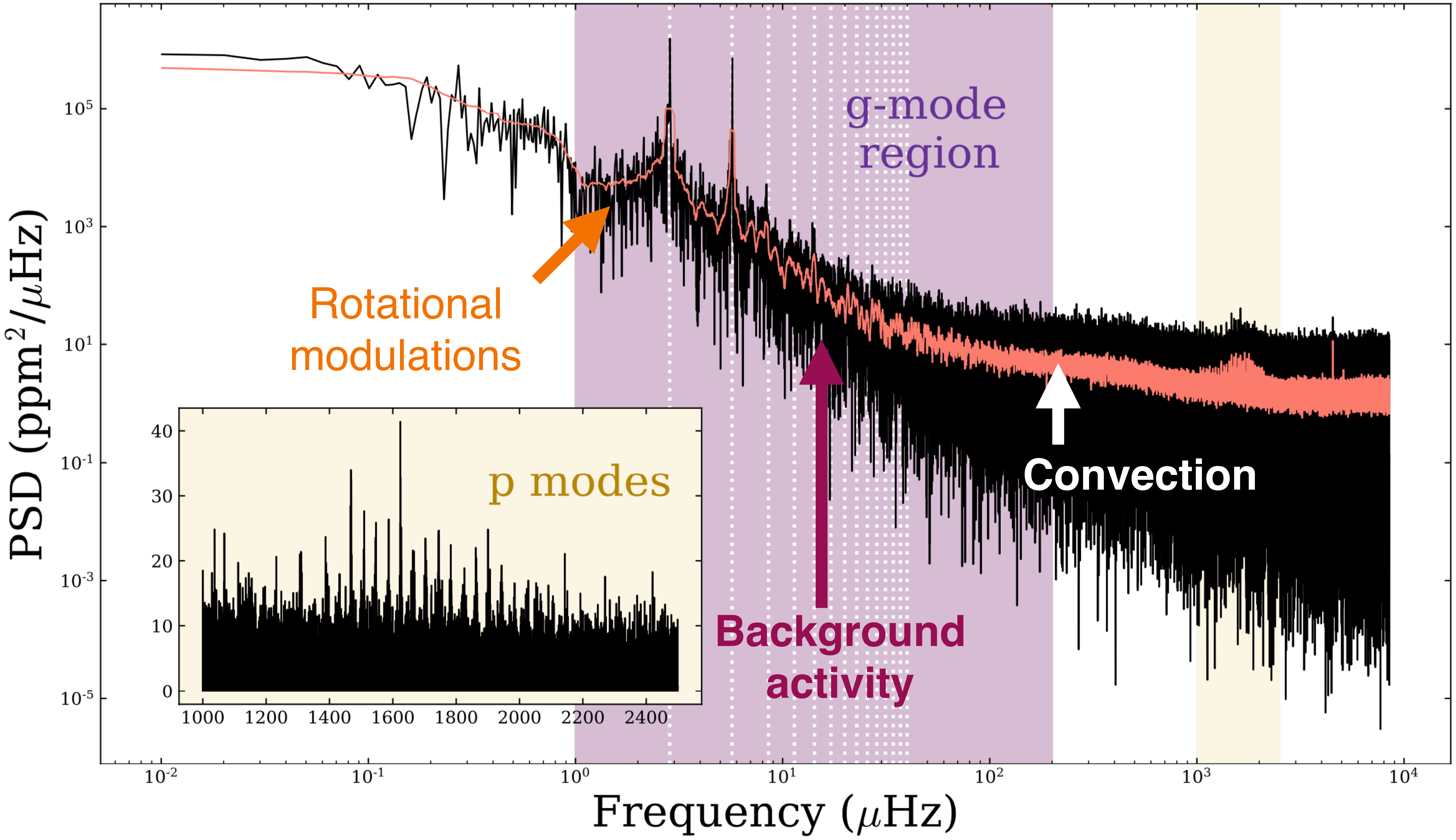


(Mathur et al. 2014, Lund et al. 2017, Hall et al. 2021)



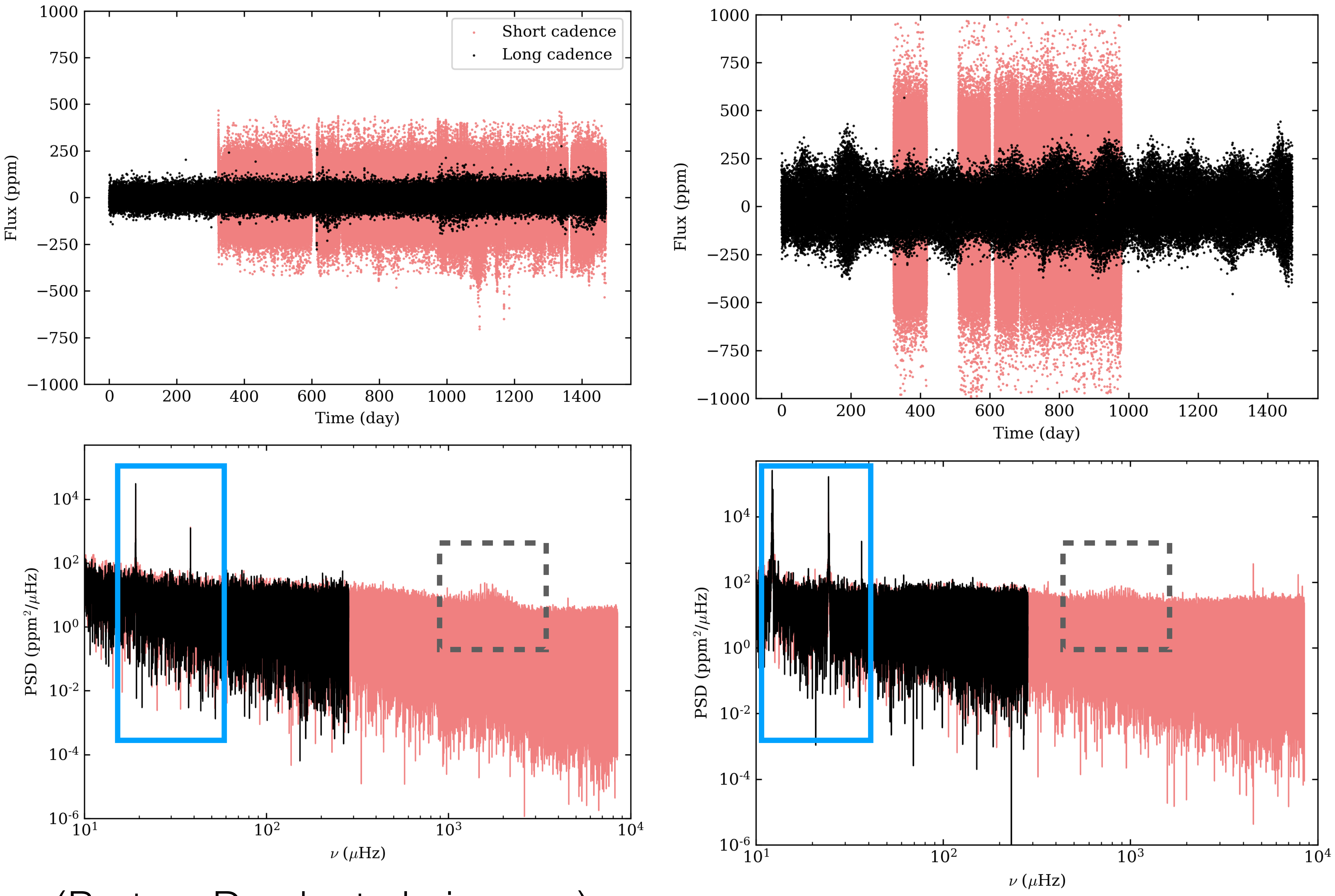
(Santos, Breton et al. 2021, Hall et al. 2021)

Roaring tigers with velvet paws



(This one is a panther actually)

Tale of two balls of yarn



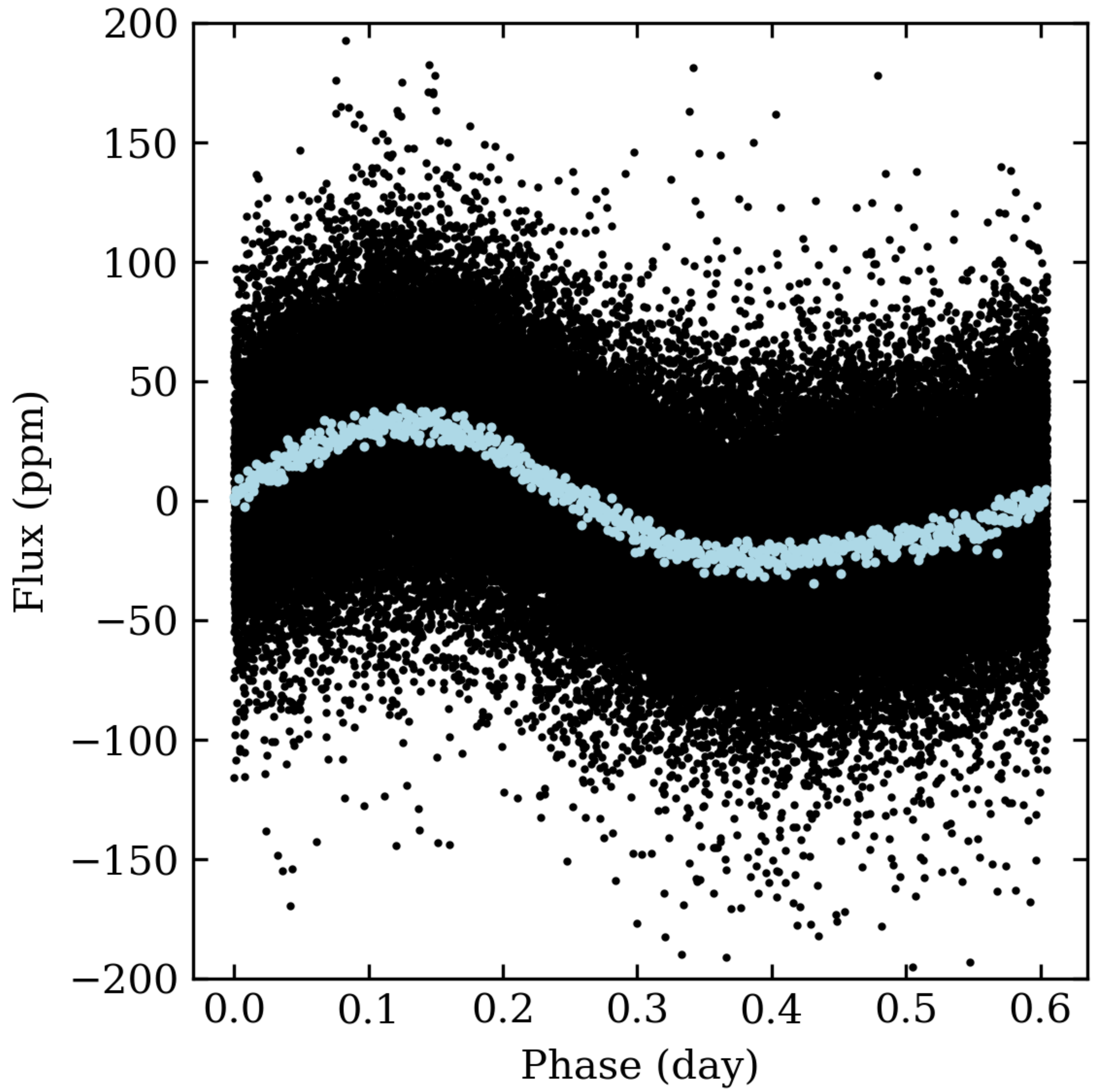
(Breton, Dyrek et al., in prep)

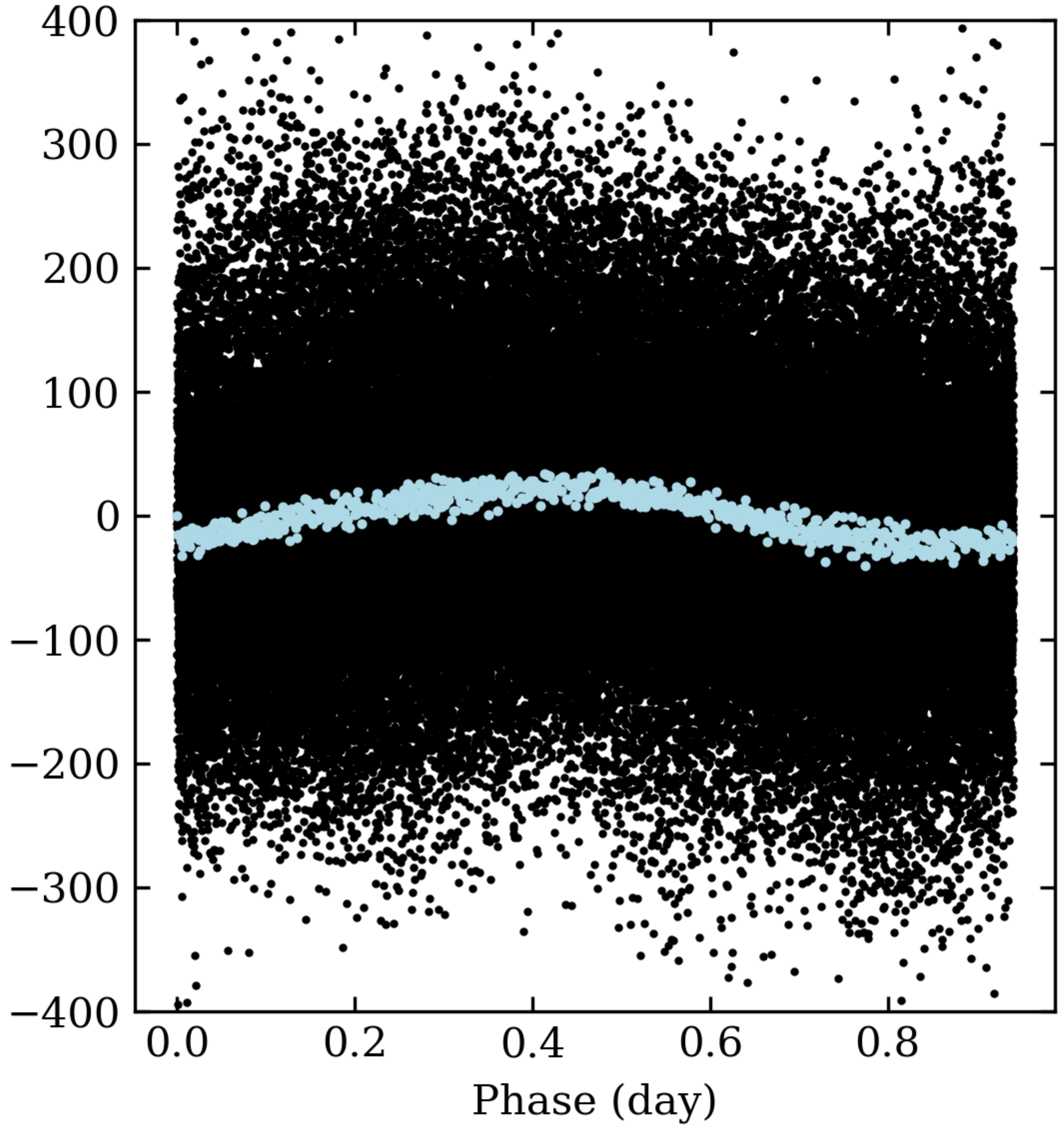
Evidence for non-transiting objects modulations in the light curves of two stars.

(Faigler & Mazeh 2011, Shporer et al. 2011, Shporer 2017, Millholland & Laughlin 2017, Lillo-Box et al. 2021)

How precisely can we characterise these systems ?

Light curves phase folding and RVs

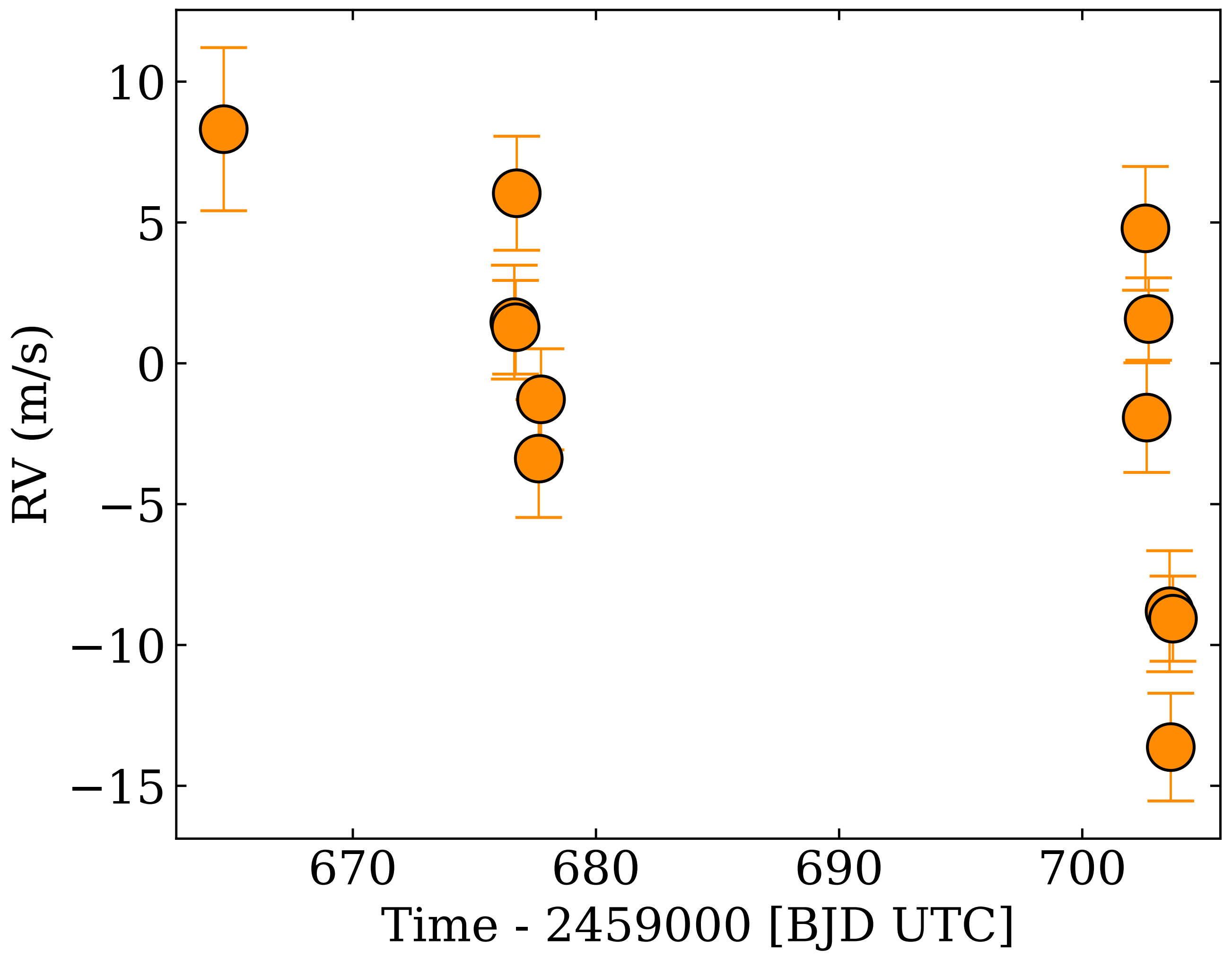




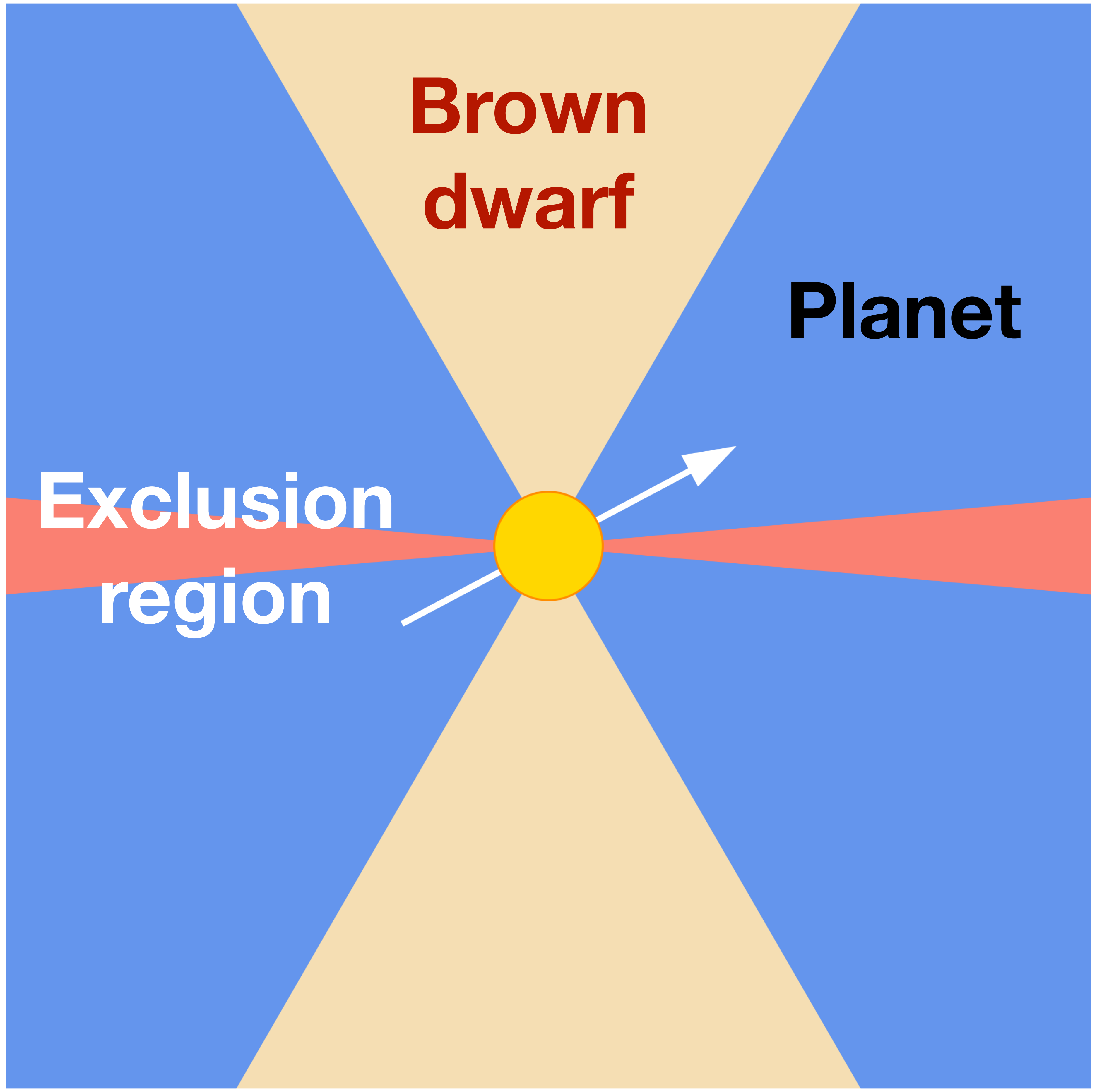
- Reflection
- Tides (ellipsoidal deformation)
- Doppler beaming

(Breton, Dyrek et al., in prep)

HARPS-N current follow-up

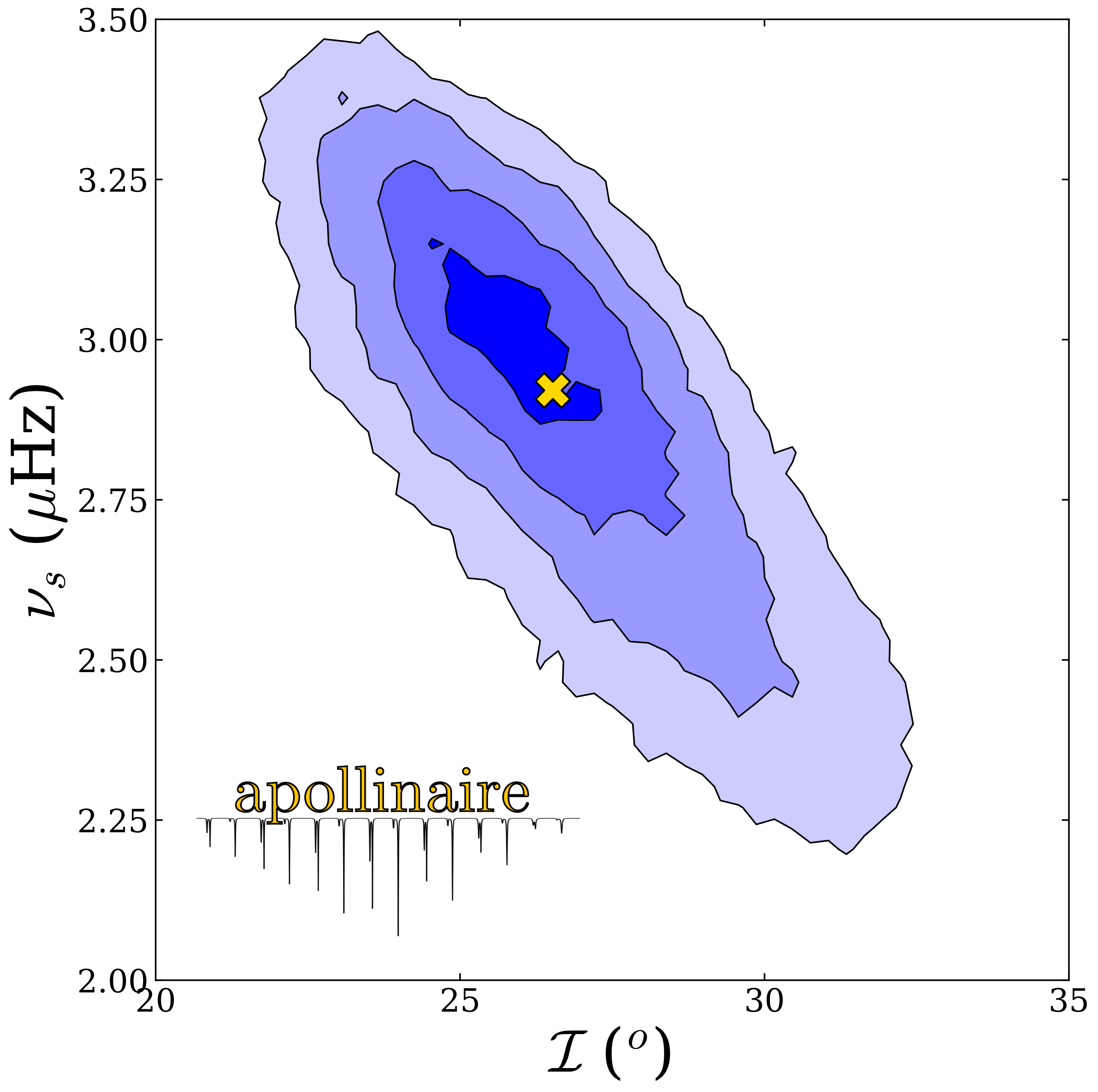


Perspectives for star-companion characterisation



Well constrained stellar inclination

How to constrain orbital inclination without any transit ?



[Check out **apollinaire** for your asteroseismic needs ! - it is documented and open source]

(Breton et al. 2022)

- Tidal and magnetic interactions
- Possible scenarios for the system dynamical evolution

(Bolmont et al. 2015, Fuller 2017, Ahuir et al. 2021, Lanza 2022)

Conclusion and perspectives

Simulations

- As expected, rotation has an important effect on the properties of low-frequency g modes (qua).
- We were able to detect g-mode signatures near the top of the simulation domain, from intermediate ℓ.

Observations

- Low-frequency signal is difficult to disentangle in these stars.
- Evidence for non-transiting companions around two F-type solar pulsators. Opportunities to study how close companions and hot solar pulsators behave together.

→ **Understanding these stars, their similarities and differences with solar analogs will help us to better characterise both populations**