The Sun as a proxy for stellar variability

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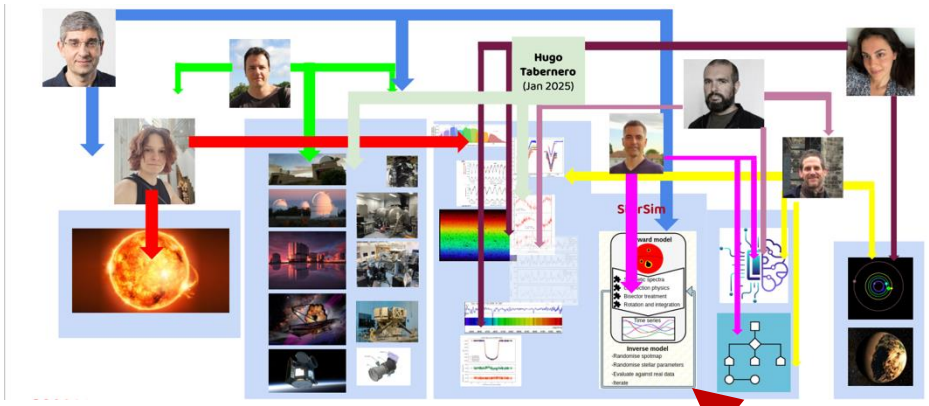
EXCELENCIA MARÍA DE MAEZTU

“From solar physicist to exoplanet hunter”

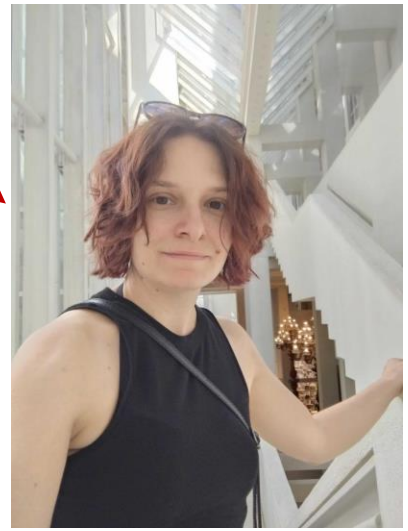


ERC Advanced SPOTLESS

Ignasi/ICE/SPOTLESS as host for fellowship

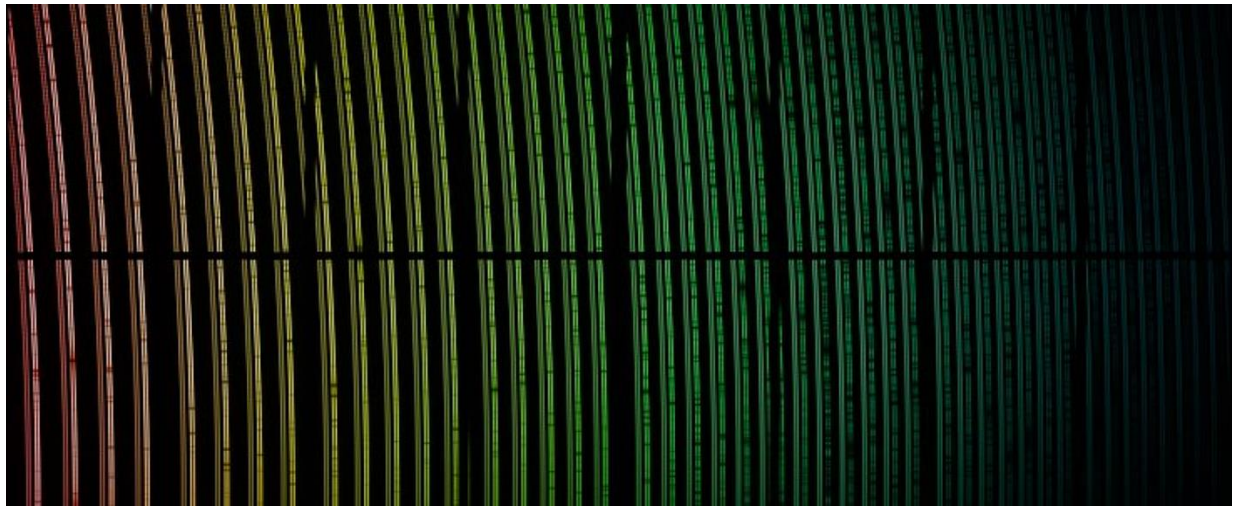
ERC Synergy REVEAL

PhD under supervision of Sasha and the ERC Starting Grant SOLVe



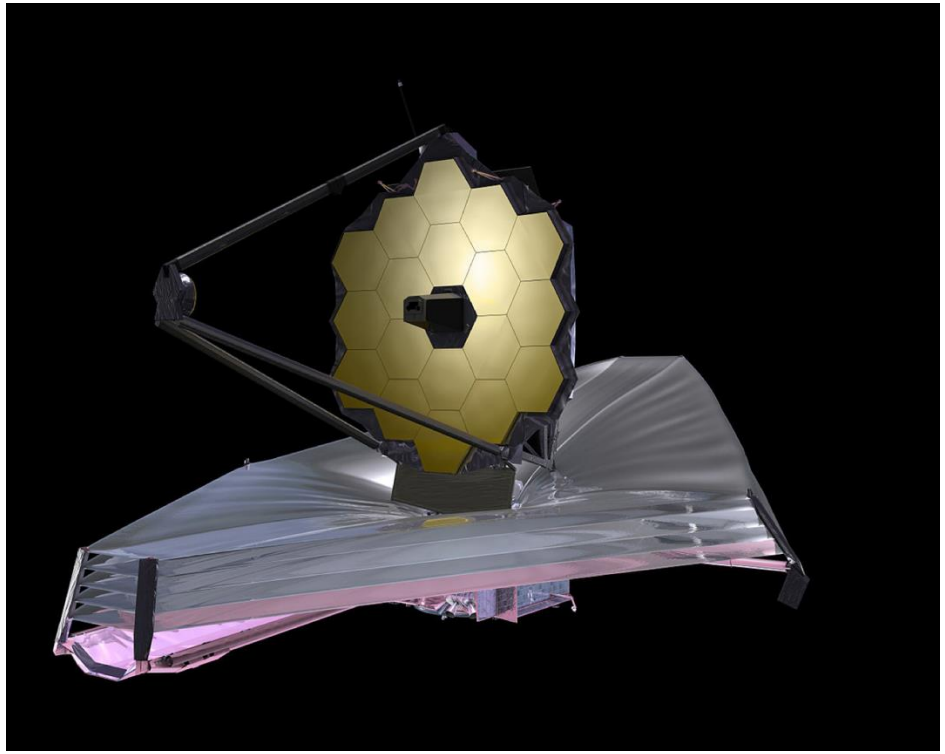
MSCA European Fellowship INCITE

Exciting times of high precision measurements

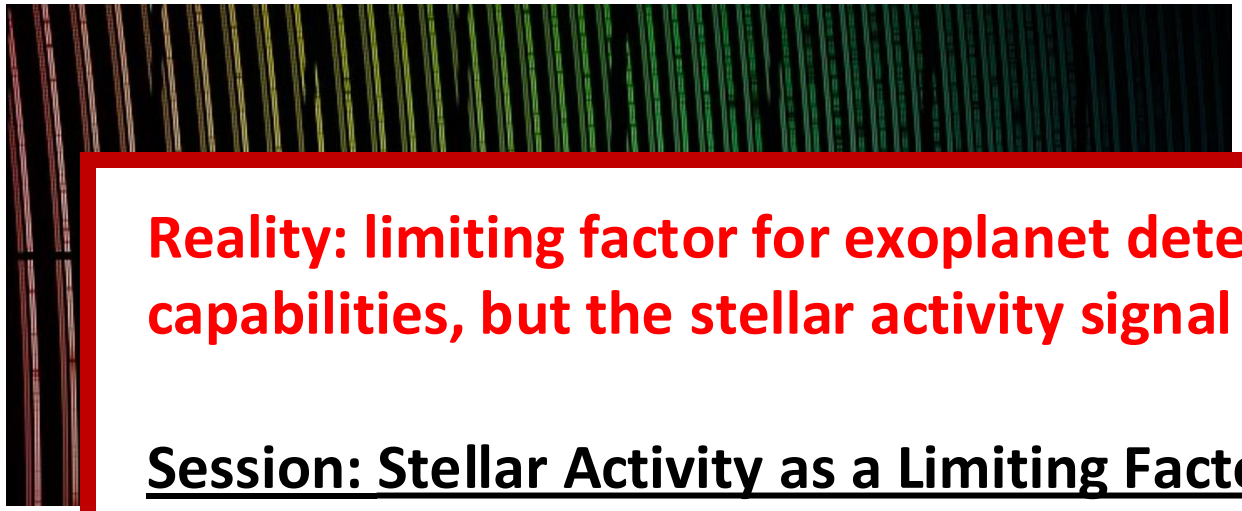


Spectroscopy: ESO's ESPRESSO: 10 cm/s stability

Transmission spectroscopy: JWST: 10 ppm



Exciting times of high precision measurements

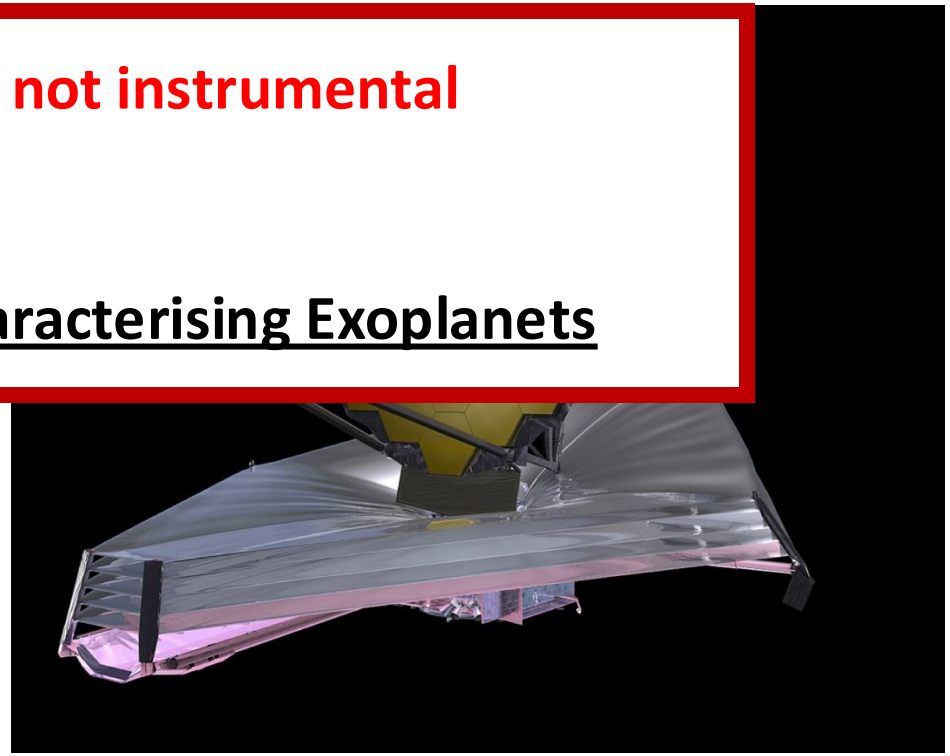


Transmission spectroscopy: JWST: 10 ppm

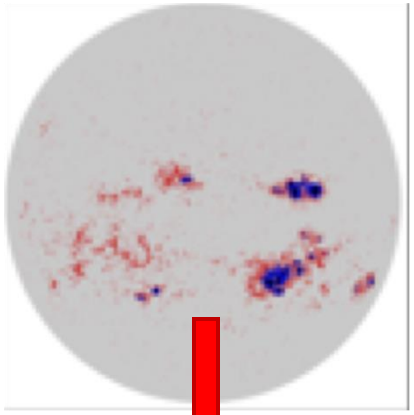
Reality: limiting factor for exoplanet detection are not instrumental capabilities, but the stellar activity signal

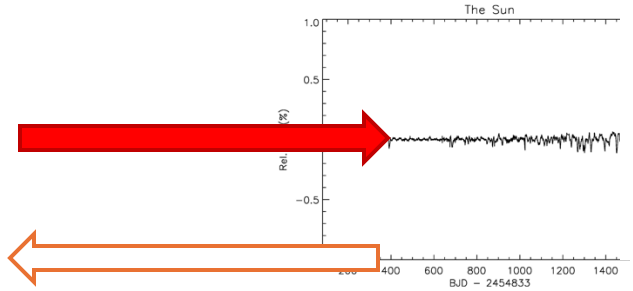
Session: Stellar Activity as a Limiting Factor for Characterising Exoplanets

Spectroscopy: ESO's ESPRESSO: 10 cm/s stability

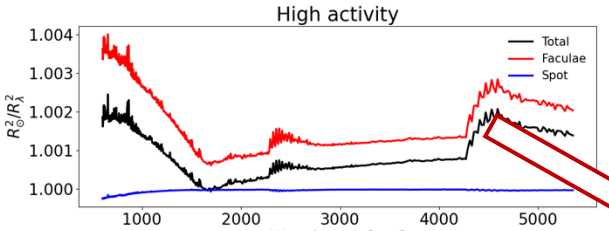


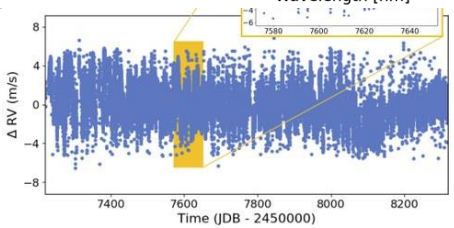
Stellar activity conundrum

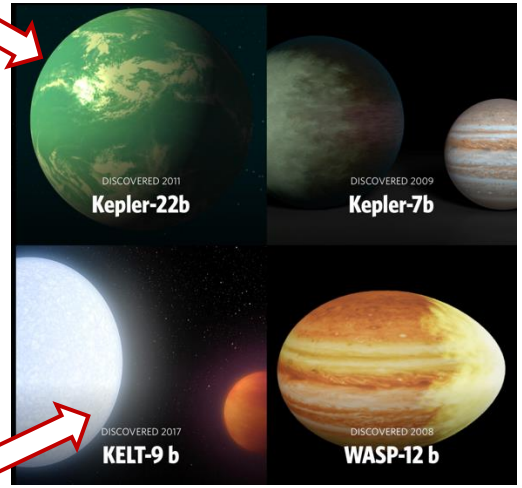


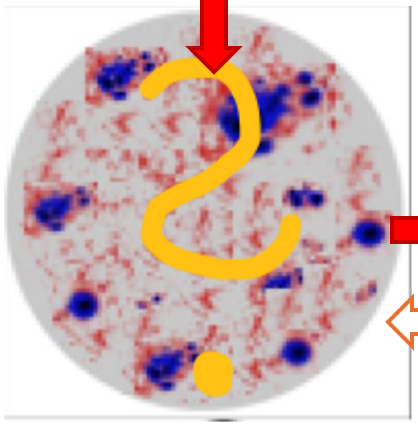


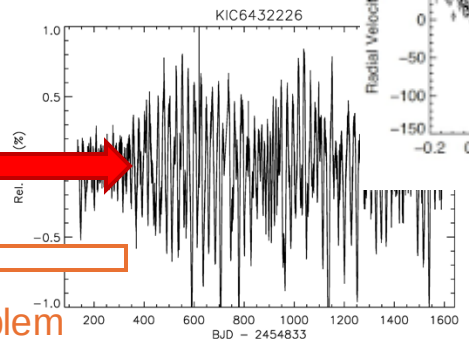
Inverse problem
generally ill-posed

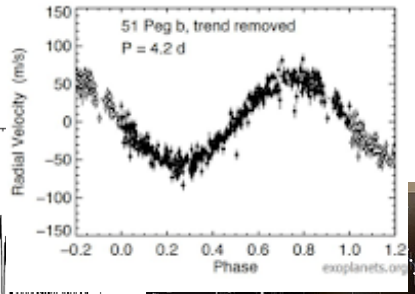


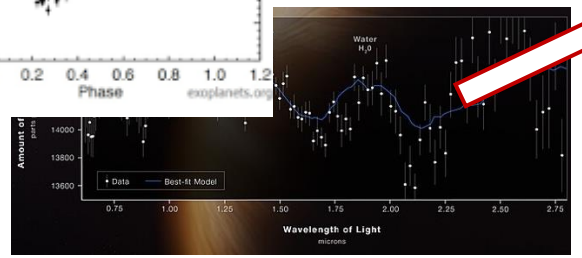






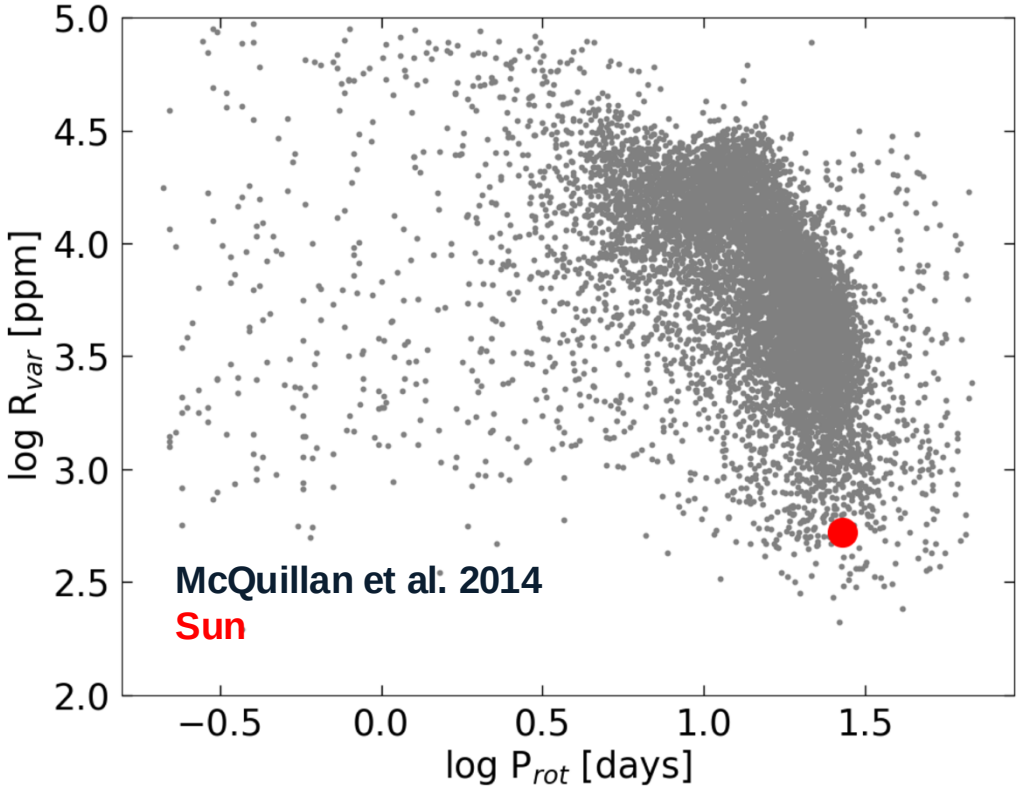




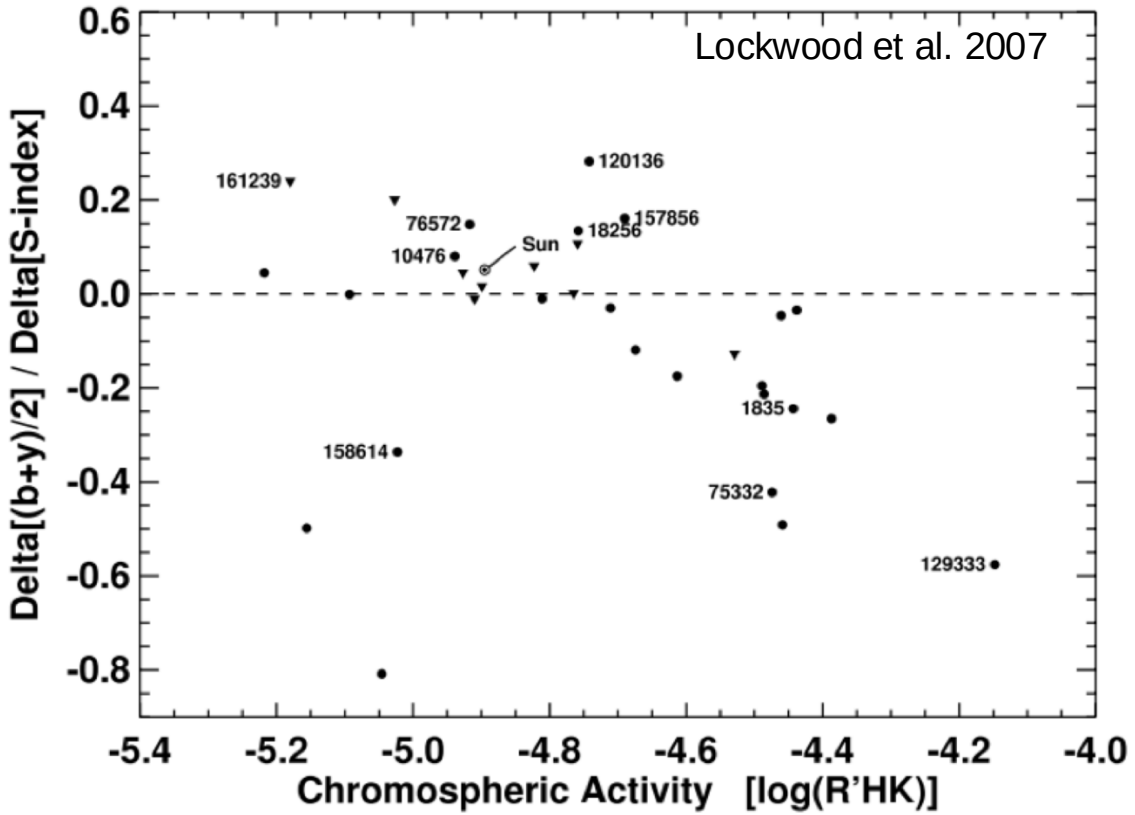


Inverse problem
generally ill-posed

Explaining observed patterns in stellar variability on different timescales



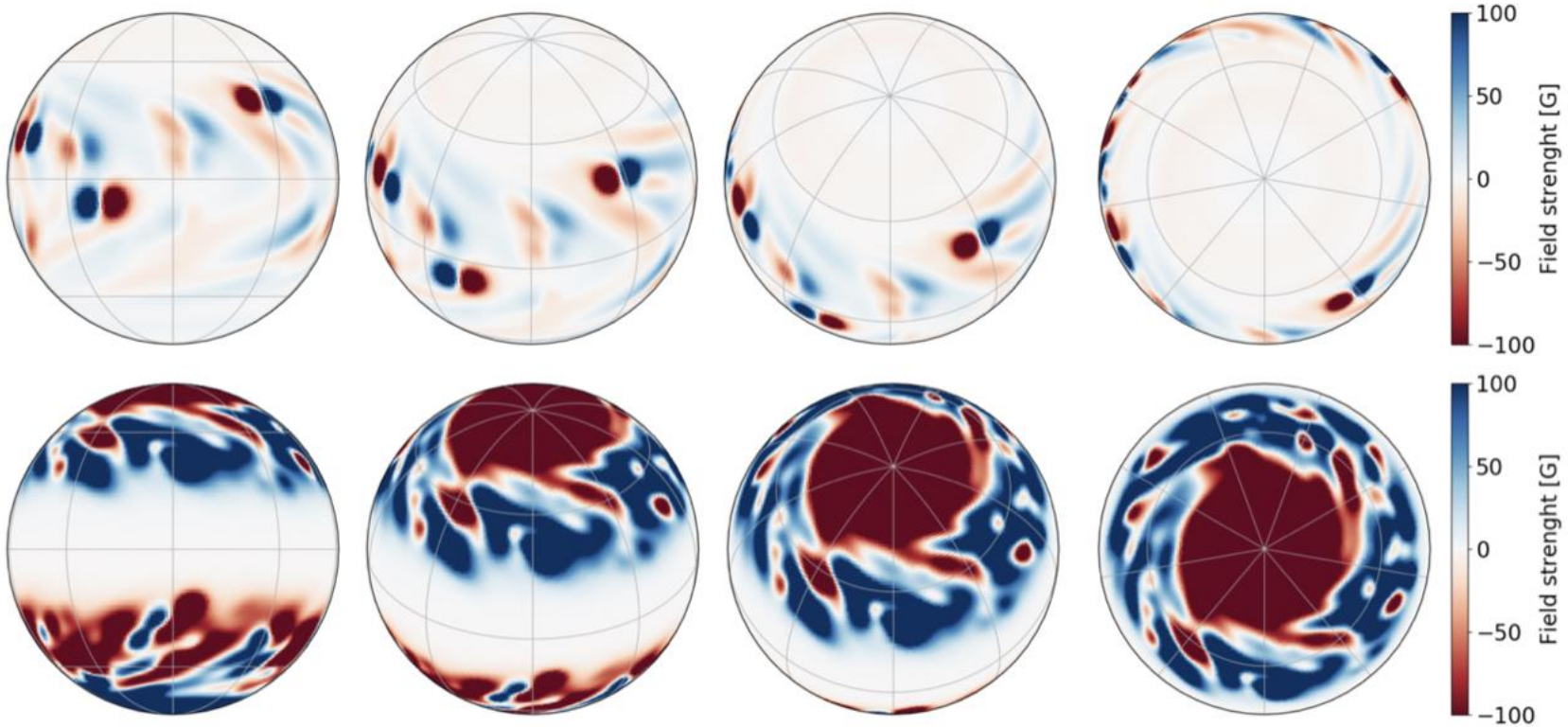
Kepler: rotational timescale



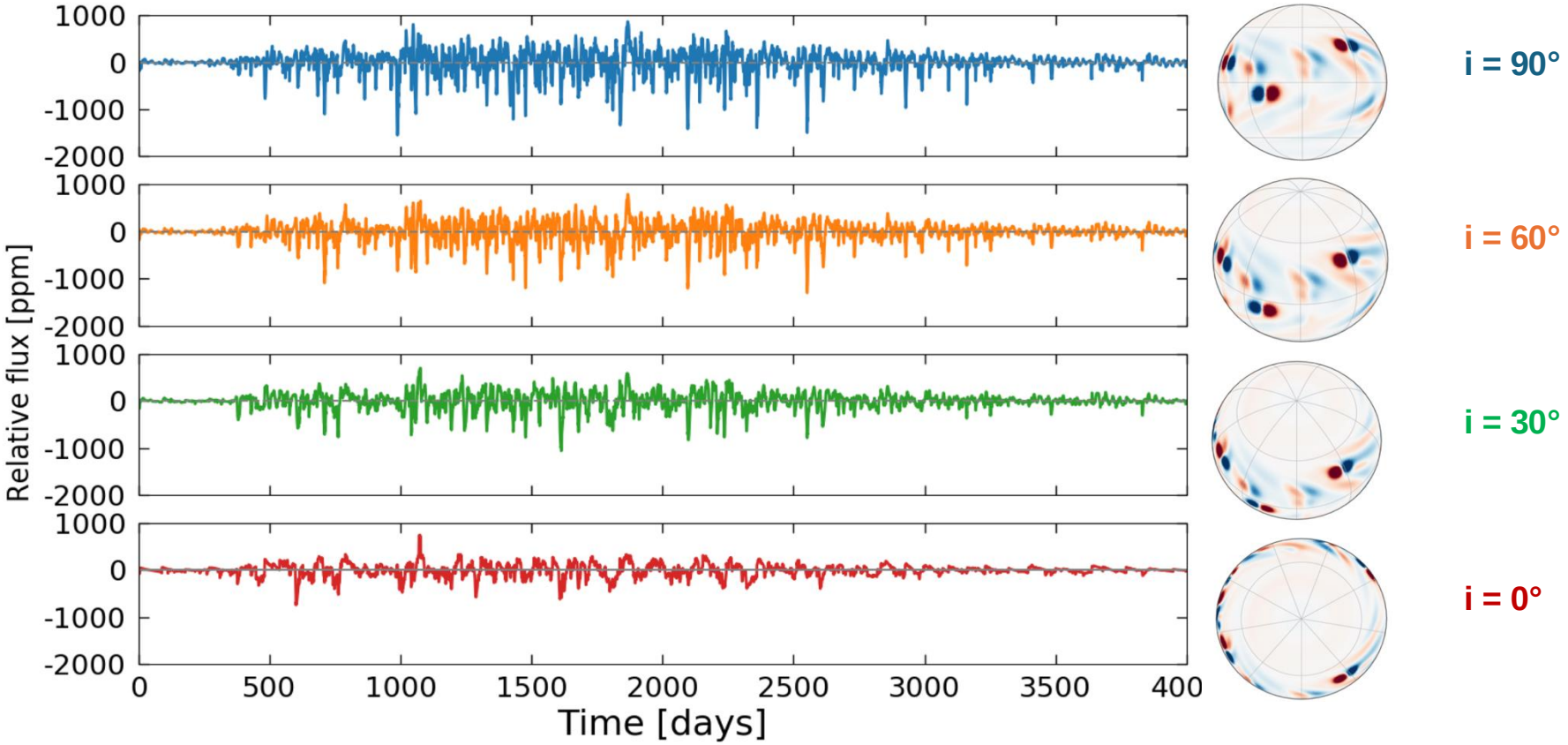
Strömgren b+y and Ca II H&K: decadal/cycle timescale

SATIRE

$$\Delta S_{tot}(t) = \Delta S_{spots}(t) + \Delta S_{faculae}(t)$$



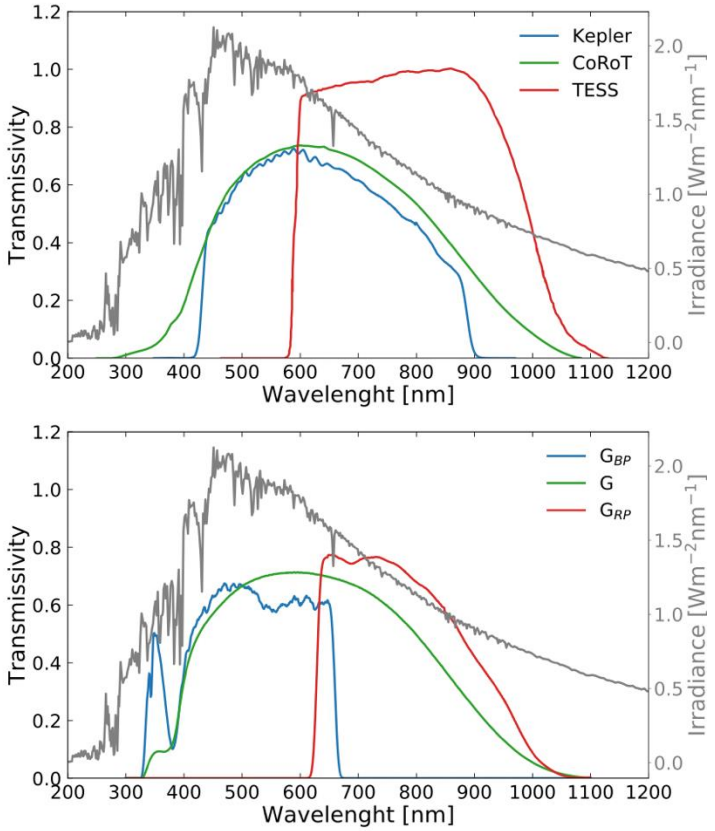
Synthetic lightcurves of a star with solar like distribution of magnetic features as seen by *Kepler*

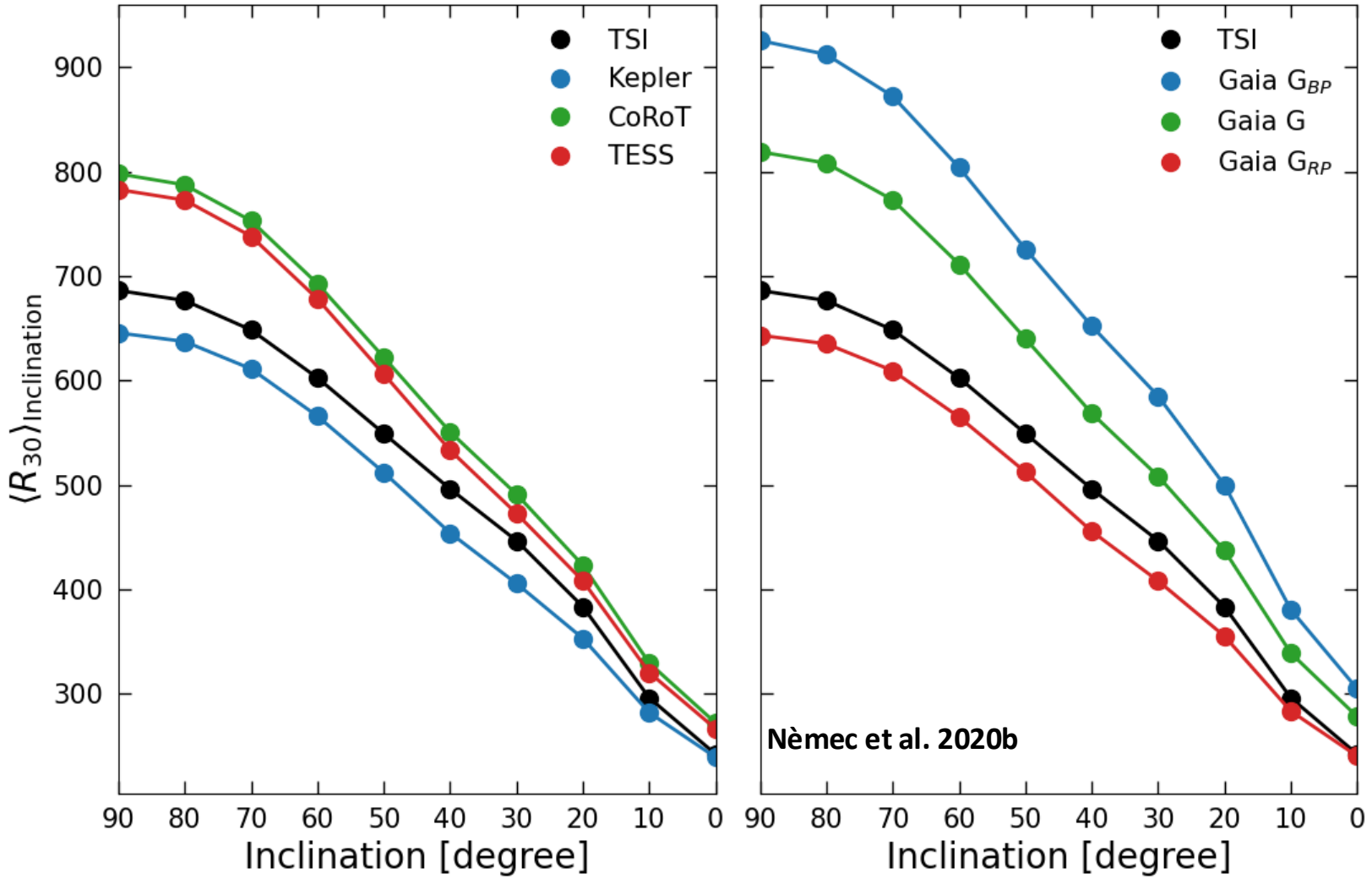


Nèmec et al. 2020b

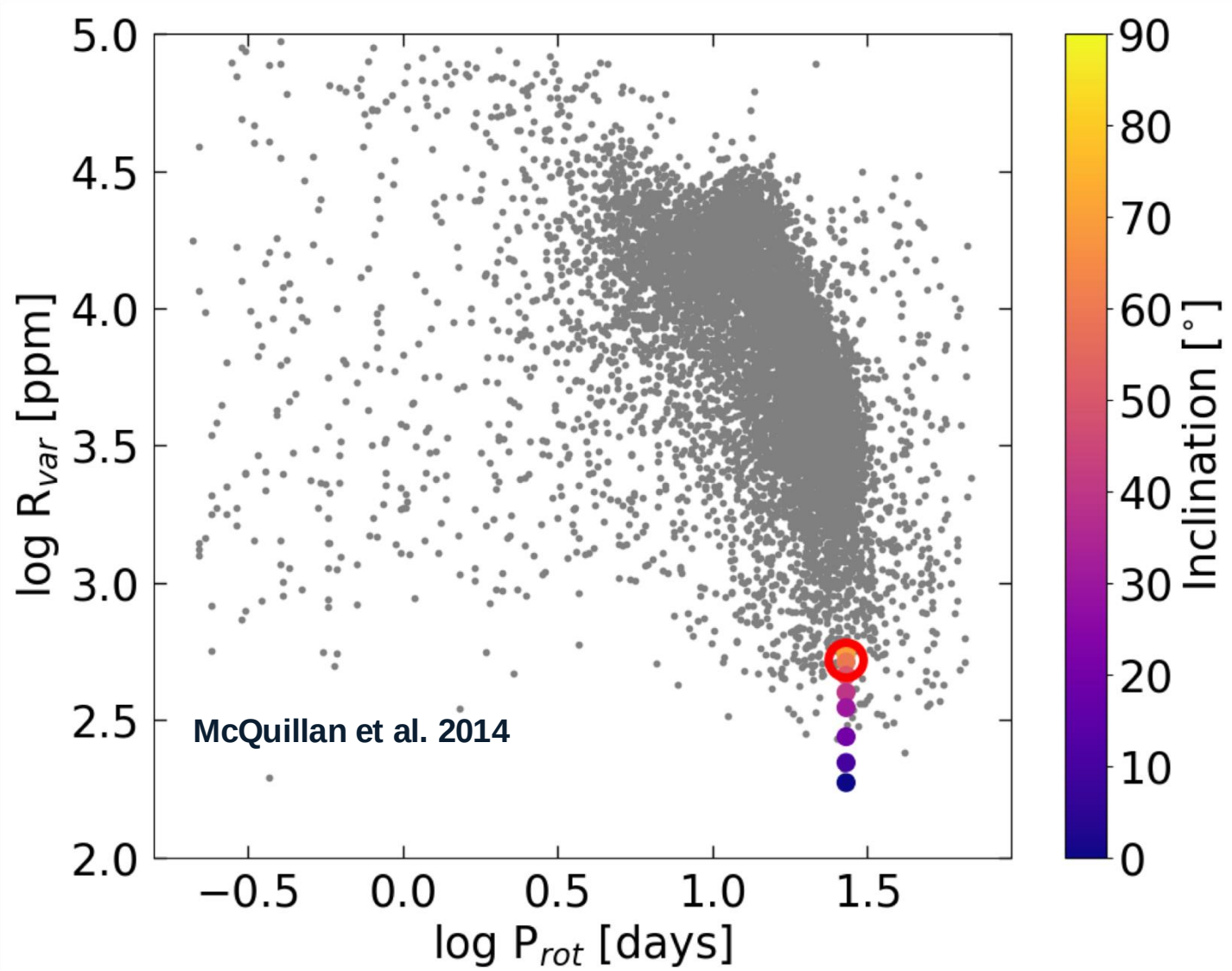
Equatorial bound observer: transit + evolution of magnetic features

Pole bound observer: evolution of magnetic features





- Visibility of magnetic features strongly depends on the passband
- On average, out-of-ecliptic observers will observe 15% less variability



Nèmec et al. 2020b

Reinhold et al. (2020): stars with detected near-solar rotation periods show more regular LCs

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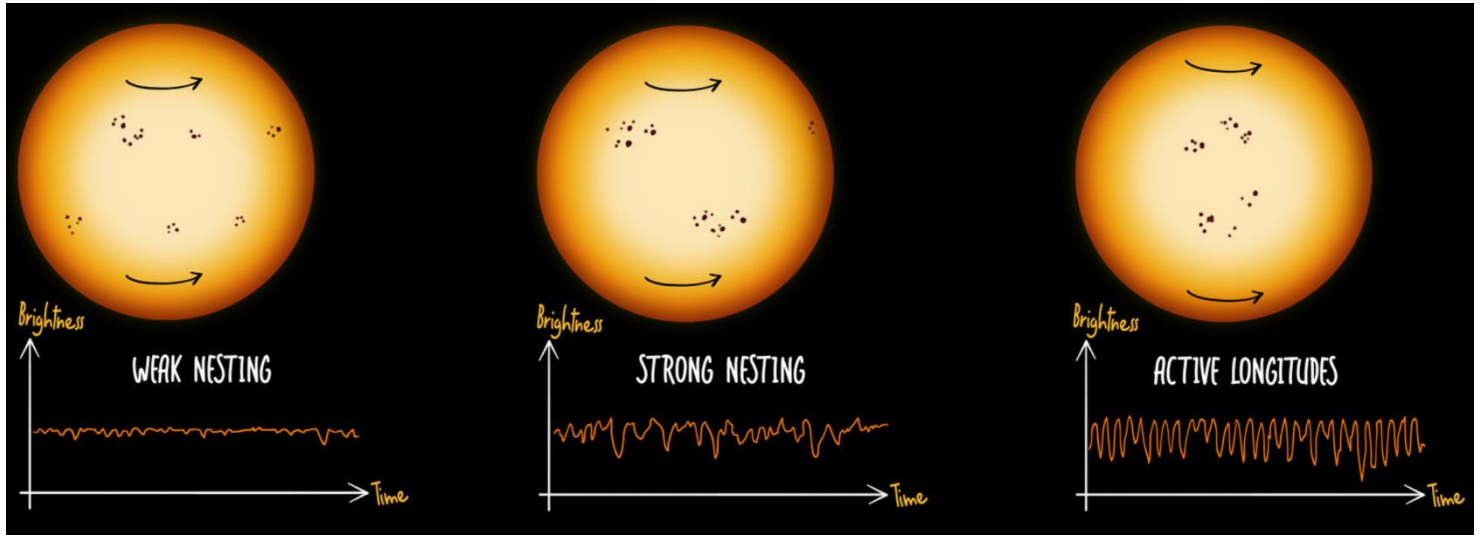
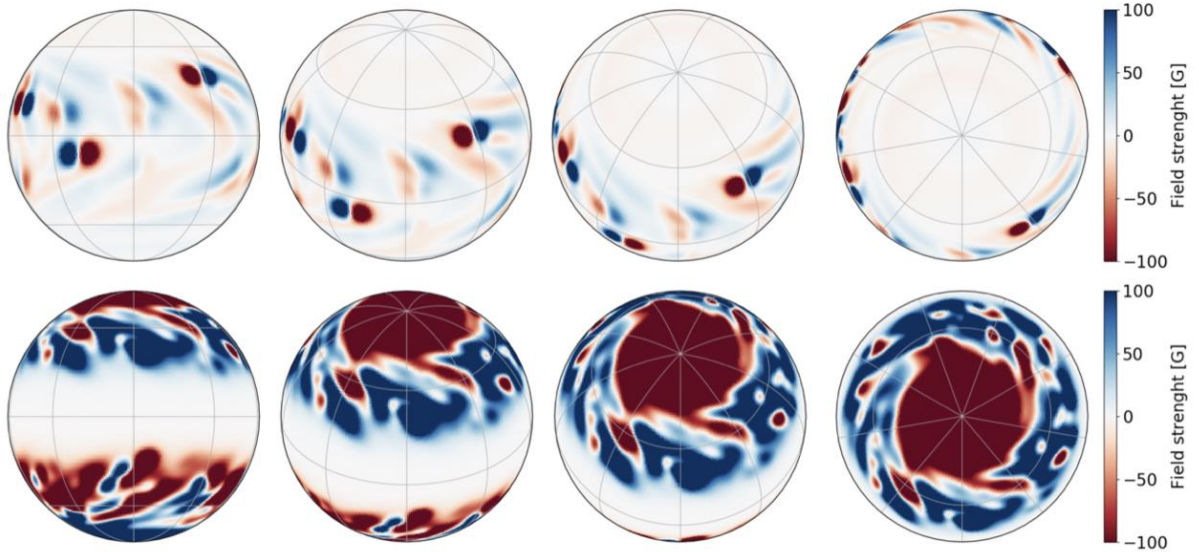


Isik et al. (ApJ, 2020): higher amplitude of variability and regularity can be explained by nesting of regions for solar rotators

Nèmec et al. (2023): Extended the nesting approach to faster rotators using the Surface Flux Transport Model



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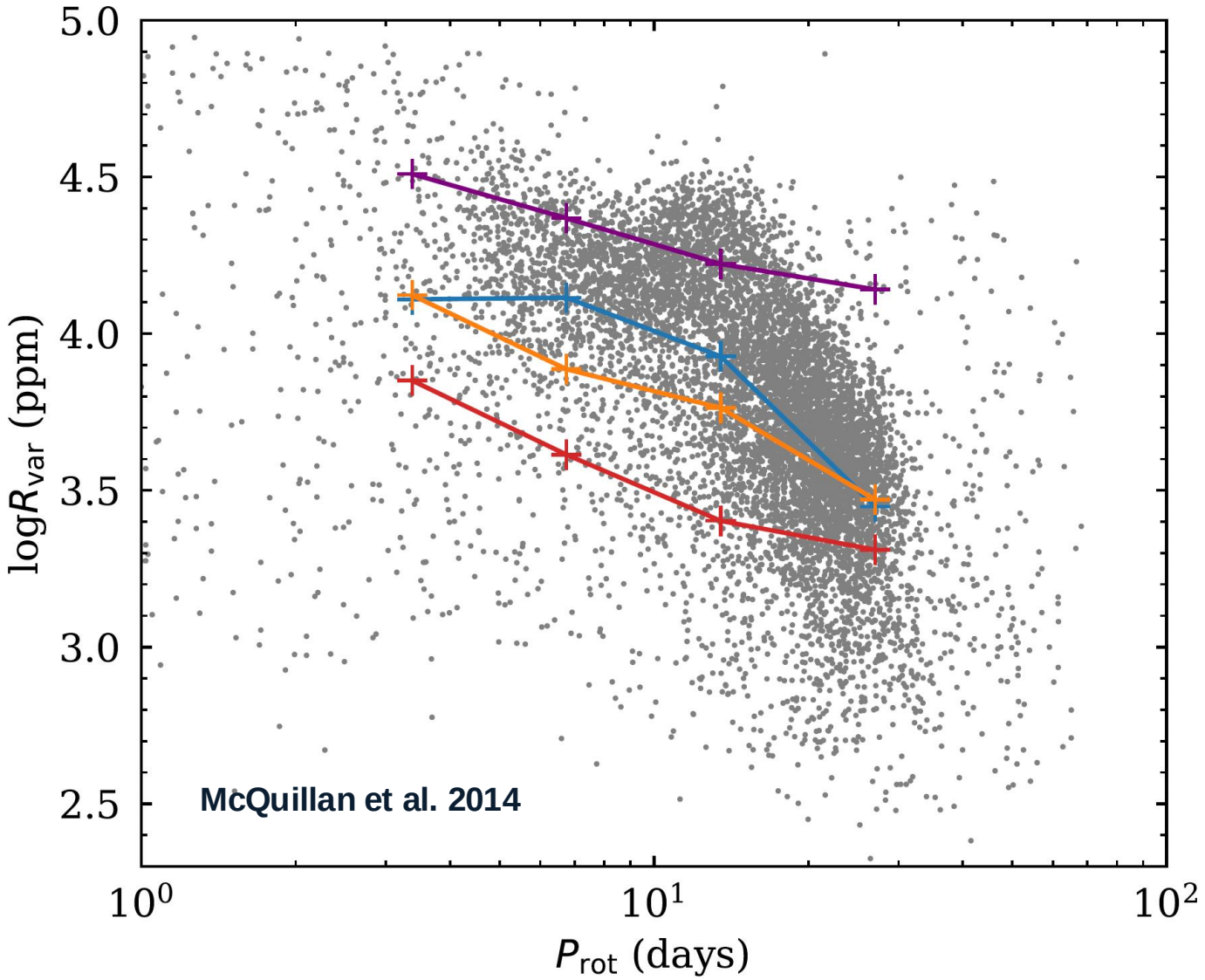


Somwya, Nèmec, et al. 2022

99% Free Nesting

mean of the observations

100% Active Longitude Nesting

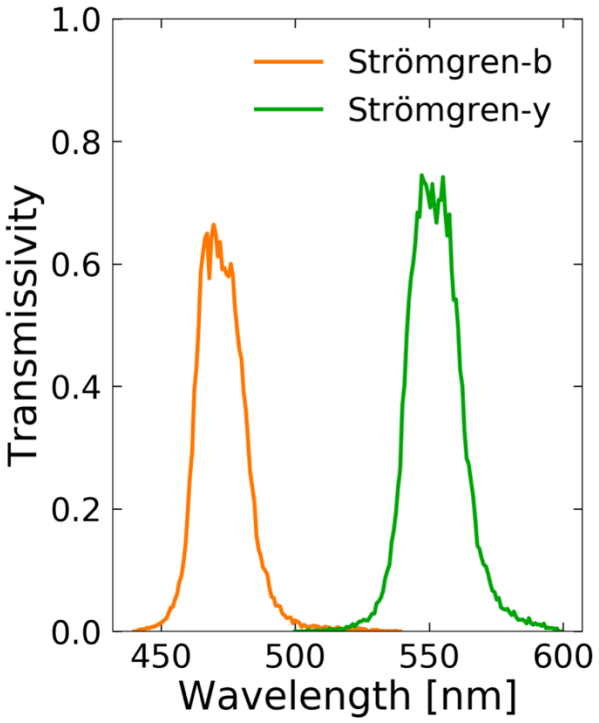
No Nesting

Dependence of rotational variability on the rotation period can be explained by increasing nesting of active regions

Long term monitoring

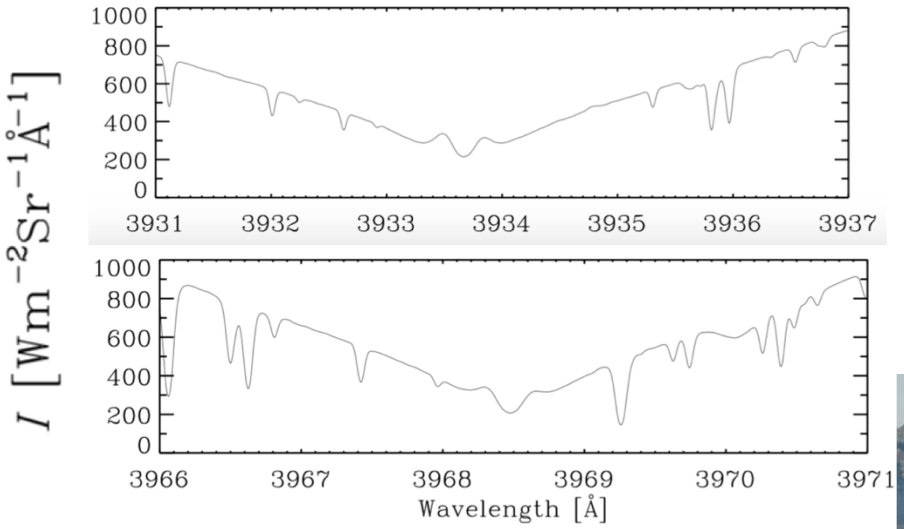
Photometry

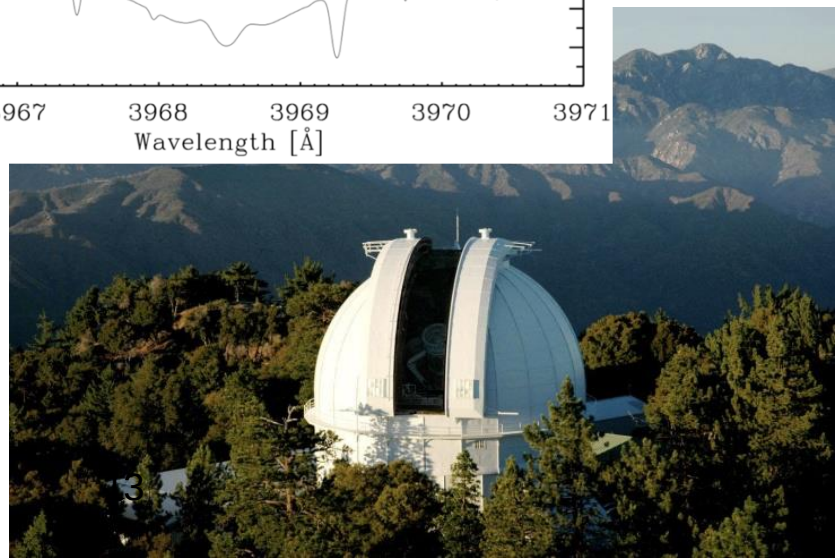
Lowell Observatory

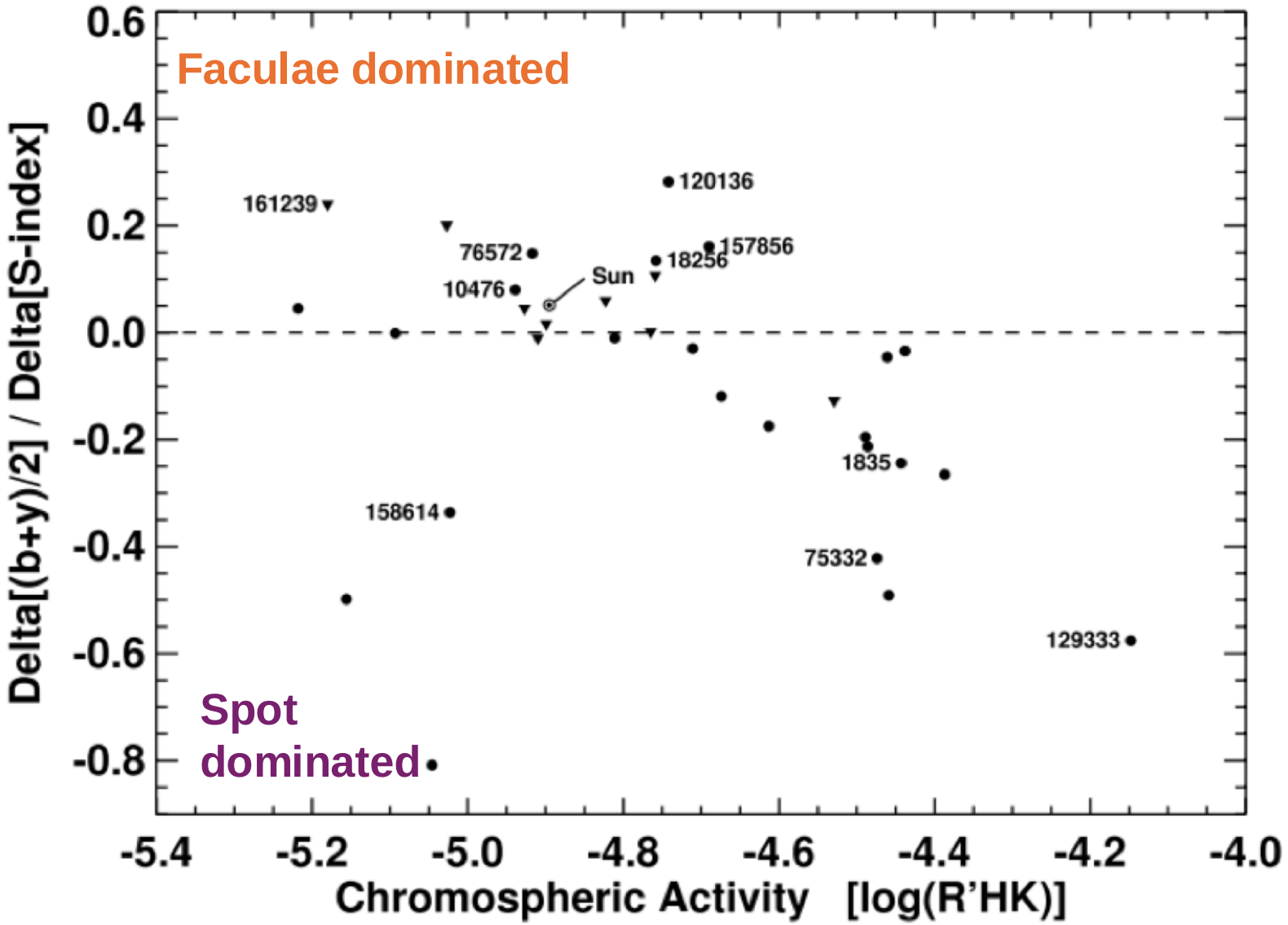


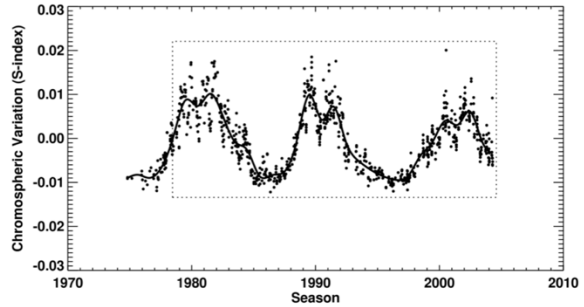
Calcium II H&K

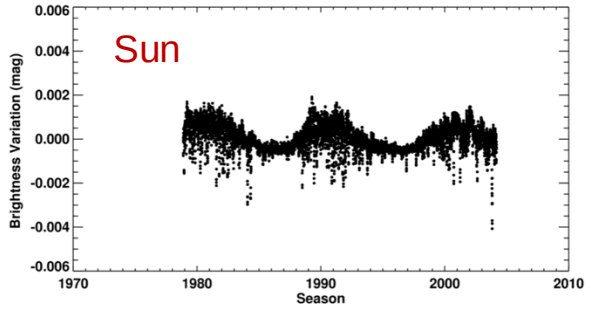
Mount Wilson observatory

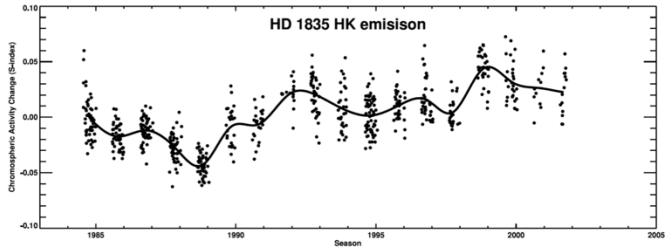


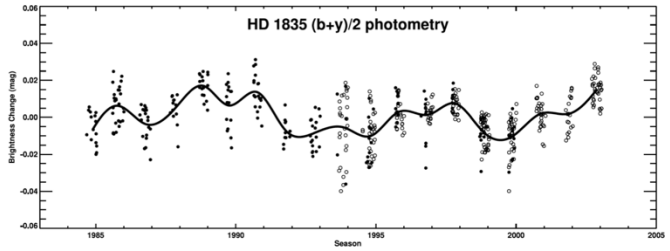












Lockwood et al. 2007

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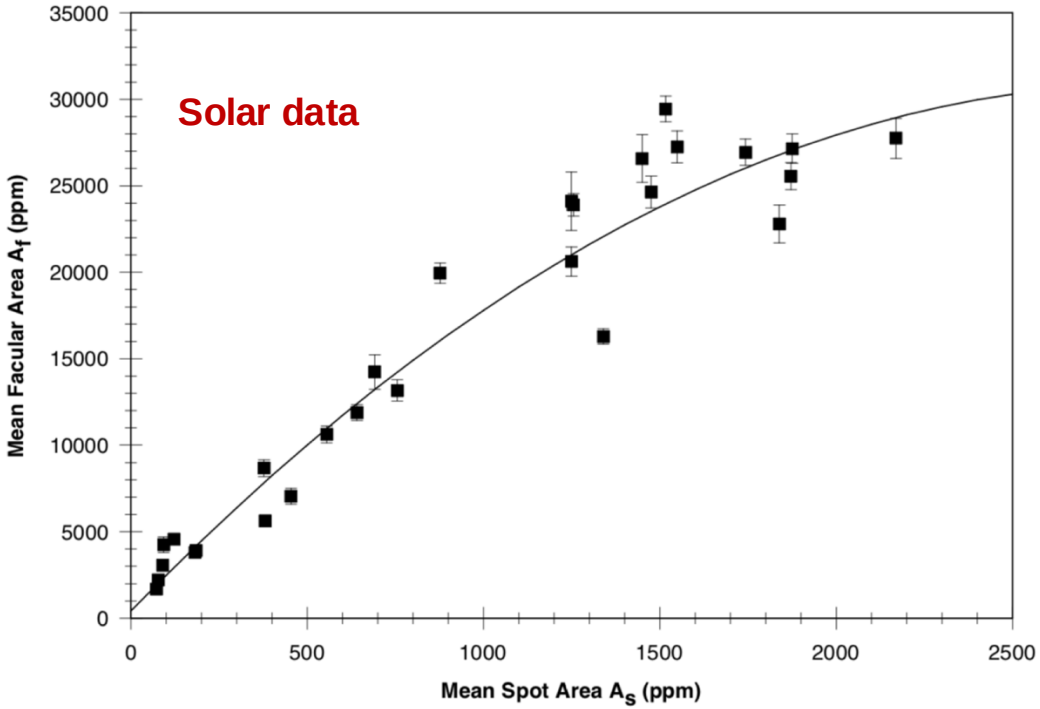
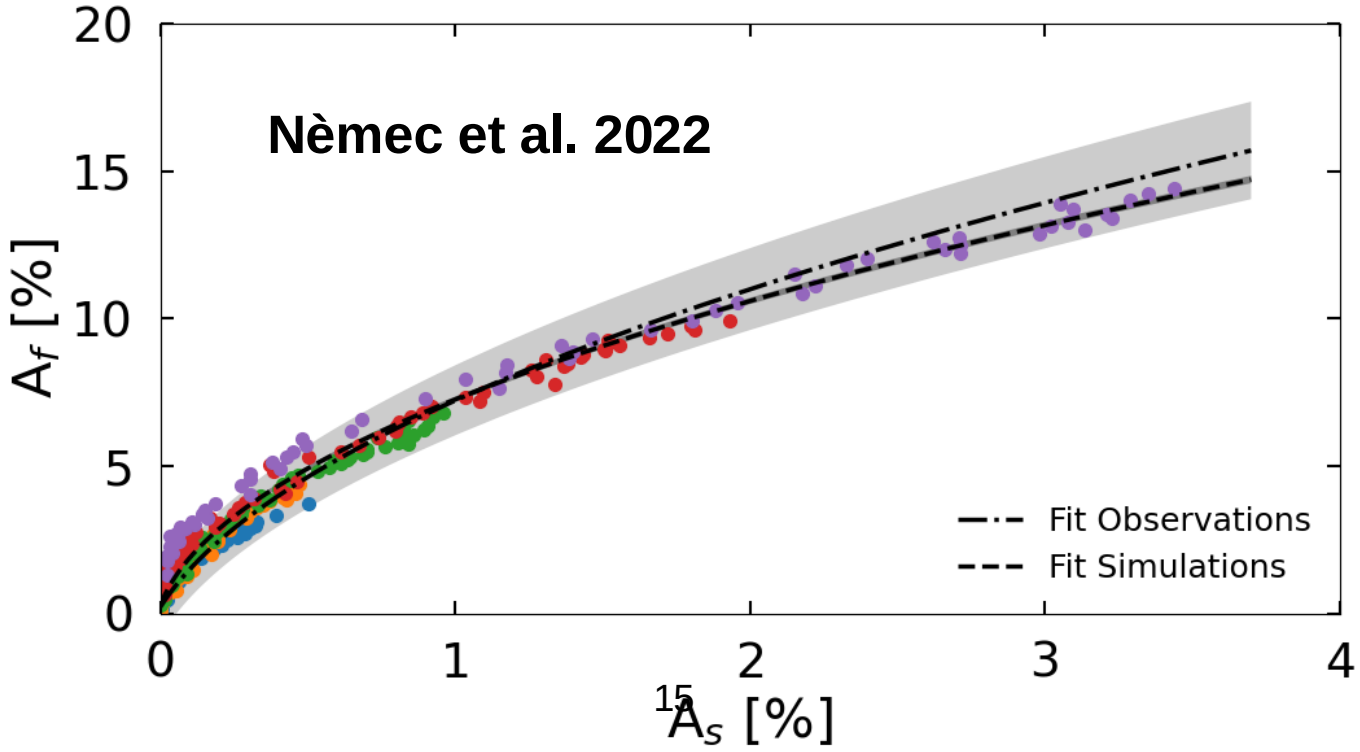
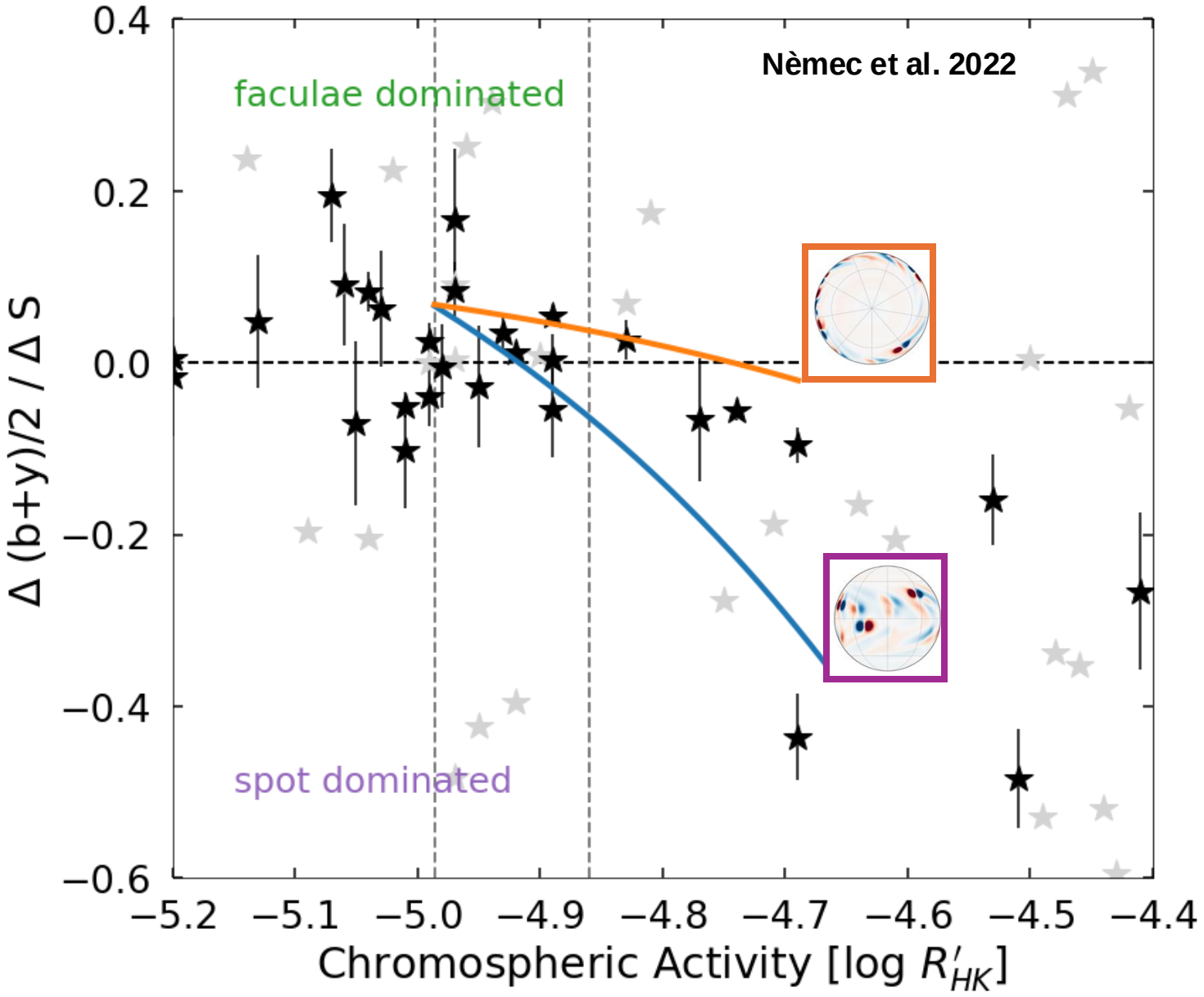


Hint, what causes the transition from faculae to spot dominated, is already in the solar data

Model explains solar data and indicates that solar dependence can be extrapolated to more active stars





Model captures the area, at which the transition occurs very well

Most importantly: a simple relationship between S-index and spot/faculae is valid!

Summary

- Sun is the proxy of (Sun-like) stellar variability

- Rotational timescale
  - Active region distribution needs to be altered to explain the observed variability distribution
  - with increasing rotation rate, nesting degree needs to be increased

- Cycle timescale
  - Small scale flux cancels out on active stars, leading to the switch from faculae to spot dominated on the stellar activity cycle timescale

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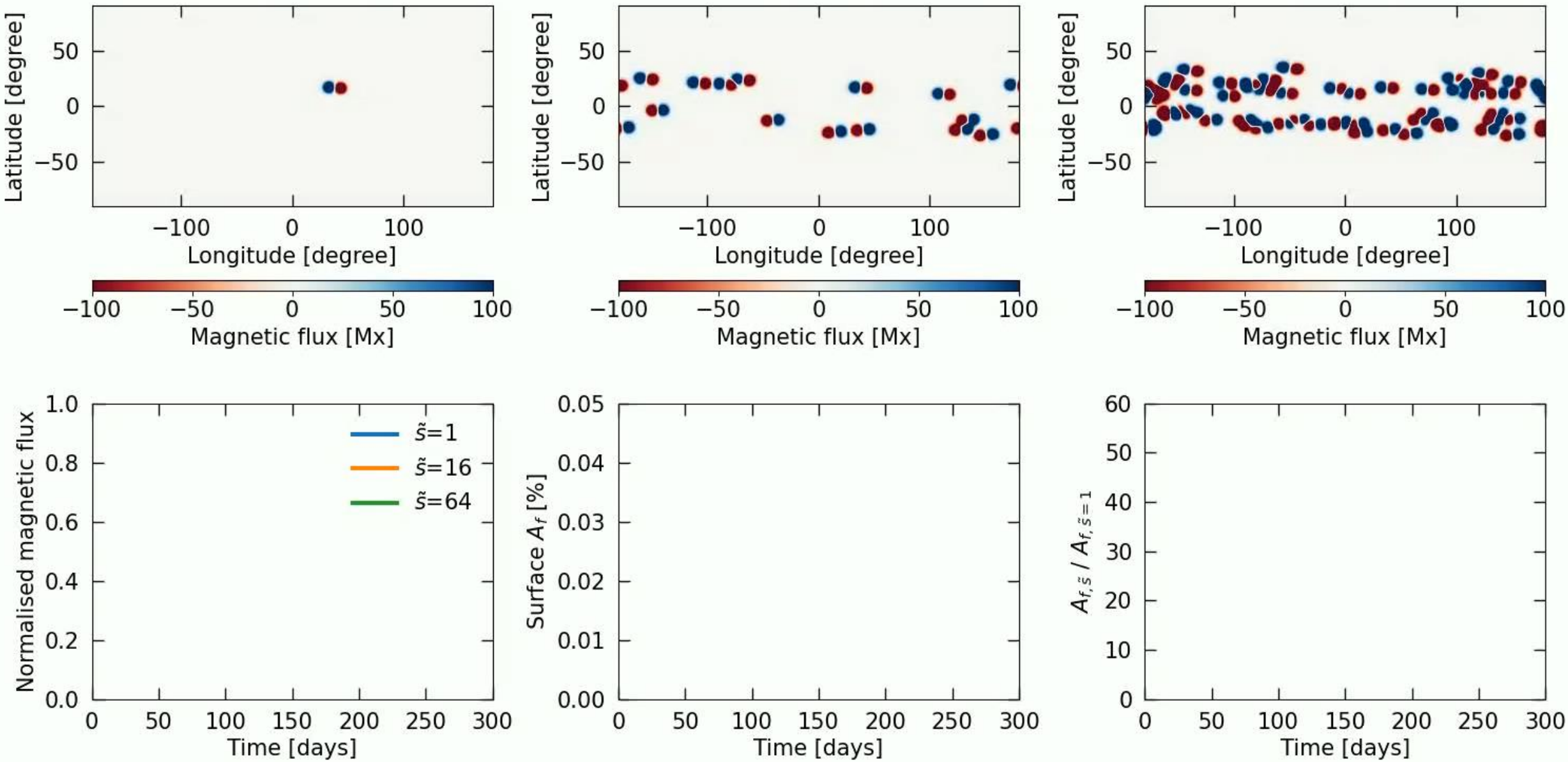
Latitude [degree]
50
0
−50
−100
0
100
Longitude [degree]
−100
−50
0
50
100
Magnetic flux [Mx]
Normalised magnetic flux
1.0
0.8
0.6
0.4
0.2
0.0
$\tilde{s}$=1
$\tilde{s}$=16
$\tilde{s}$=64
0
50
100
150
200
250
300
Time [days]
Surface A_f [%]
0.05
0.04
0.03
0.02
0.01
0.00
$A_{f,\tilde{s}}$ / $A_{f,\tilde{s}=1}$
60
50
40
30
20
10
0