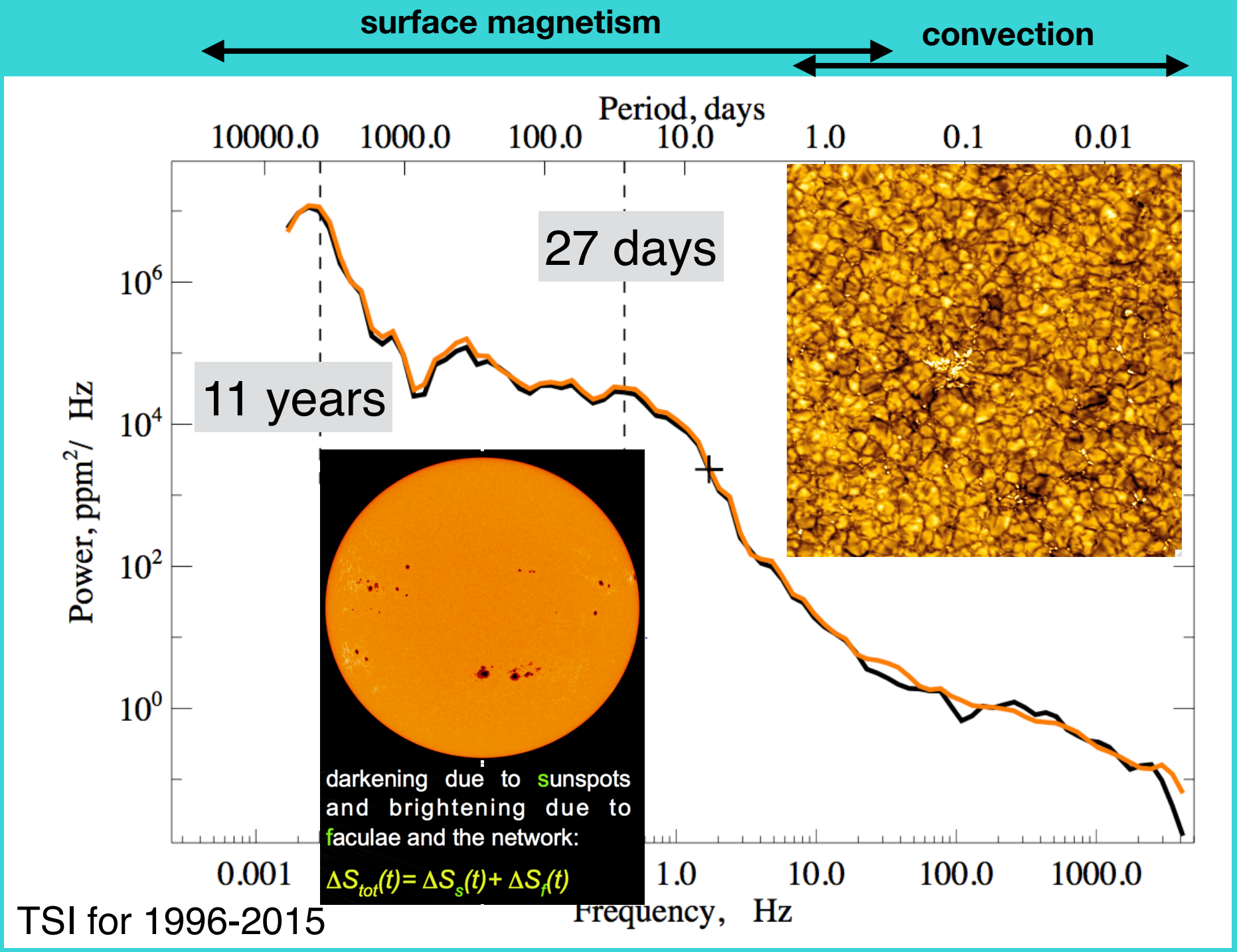
Solar Activity over the Last Four Billion Years

1. Satellite-era
2. Centuries
3. Thousands & Millions of years
4. Evolutionary timescales

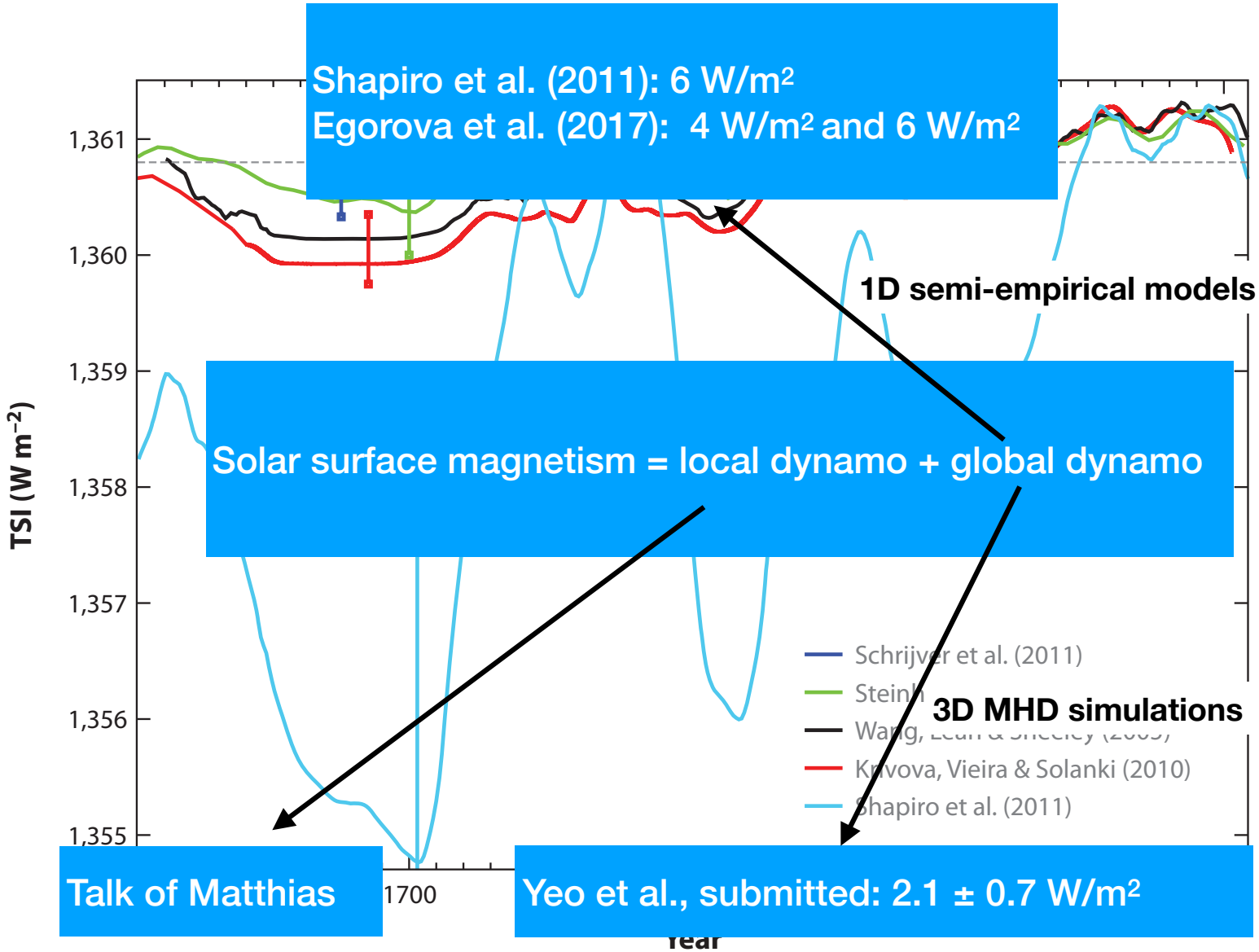
TSI variability at timescales from minutes to decades



TSI for 1996-2015

Shapiro et al. 2017, Nature Astronomy

TSI variability over centuries



from Solanki et al. (2013)

1. ~~Satellite-era~~

2. ~~Centuries~~

3. Thousands & Millions of years

4. Evolutionary timescales

↓

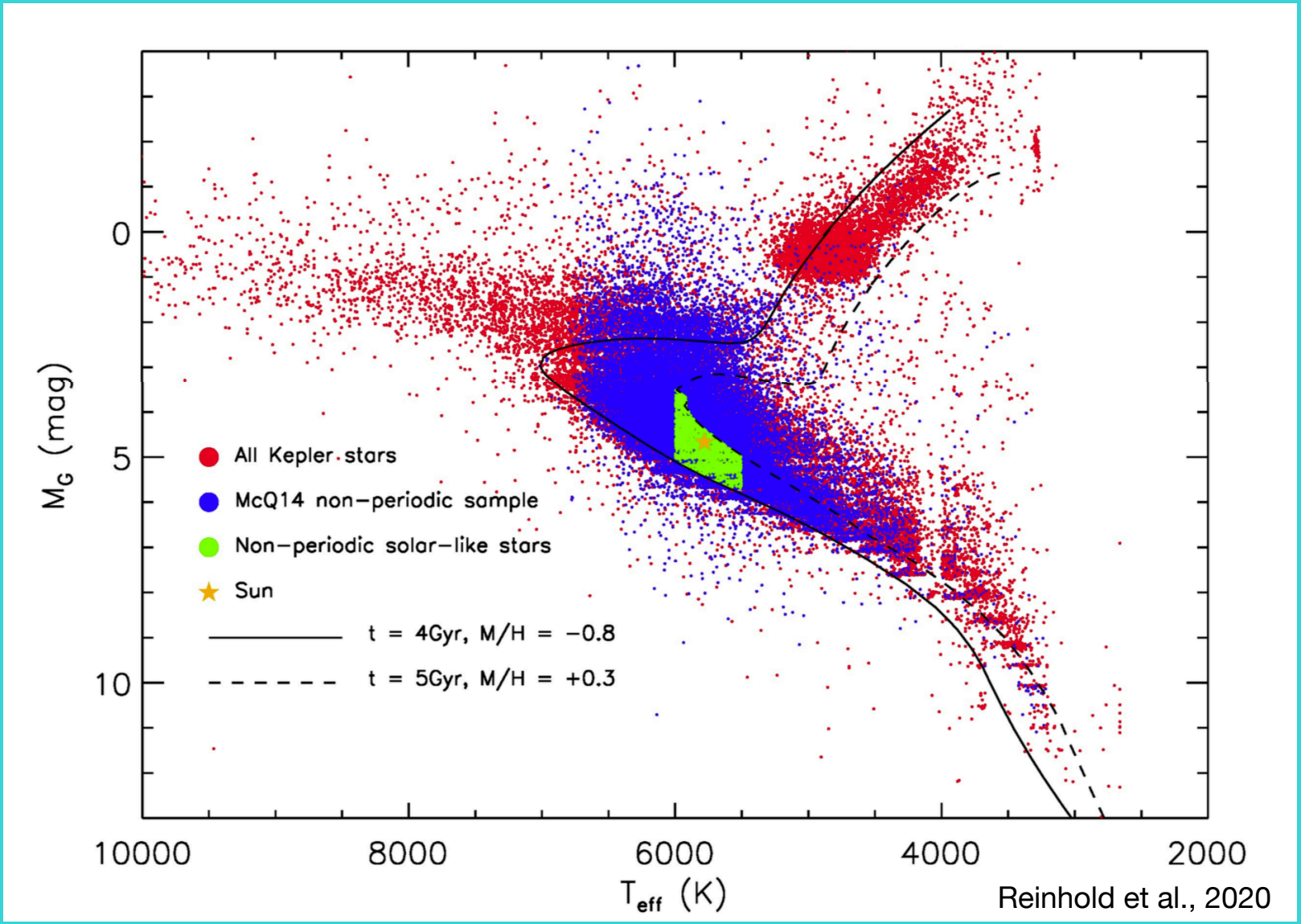
Observations of solar-like stars

Sample of solar-like stars

Kepler: variability

Gaia: brightness and distances

LAMOST: better constraints on the fundamental parameters + some information about Ca II index



Reinhold et al., 2020

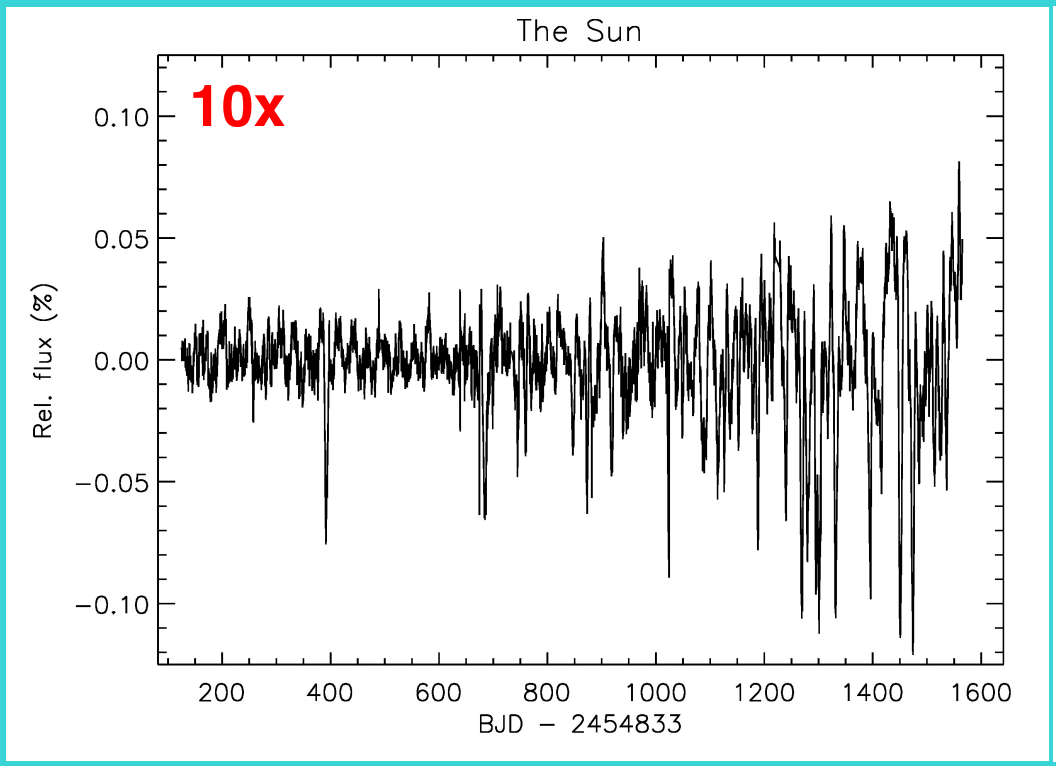
2898 stars with 5500 K<T_{eff}<6000 K

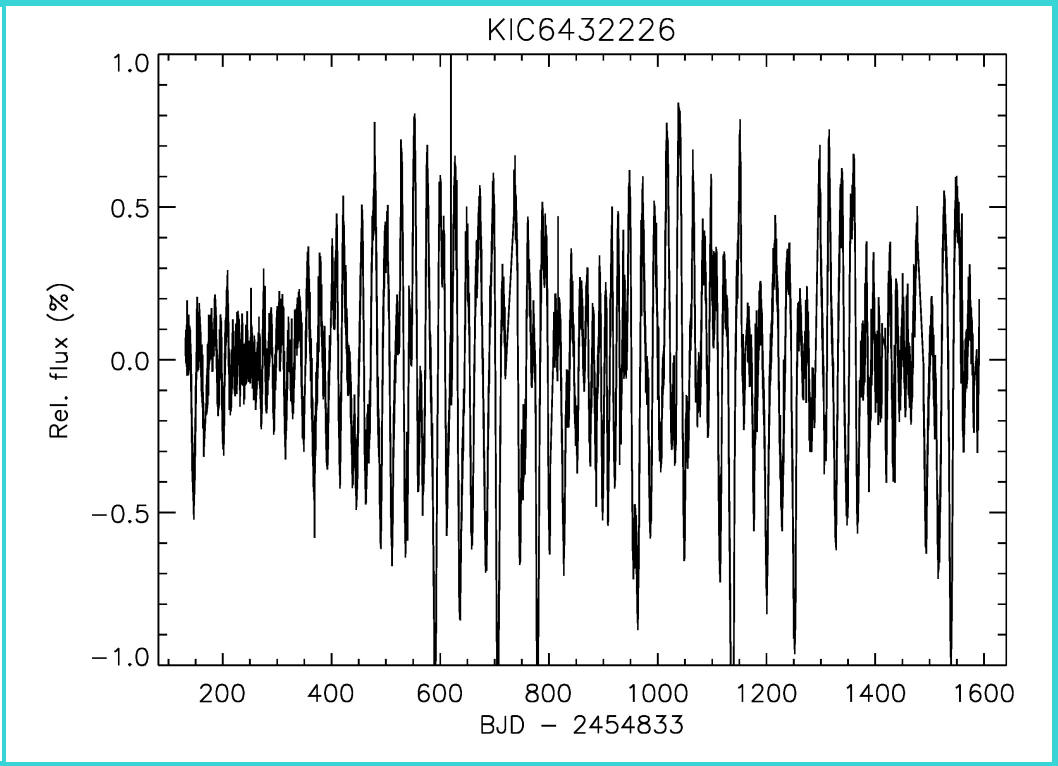
369 stars with 20 d<P_{rot}< 30 d (periodic stars)

Solar-like stars with non-solar variability

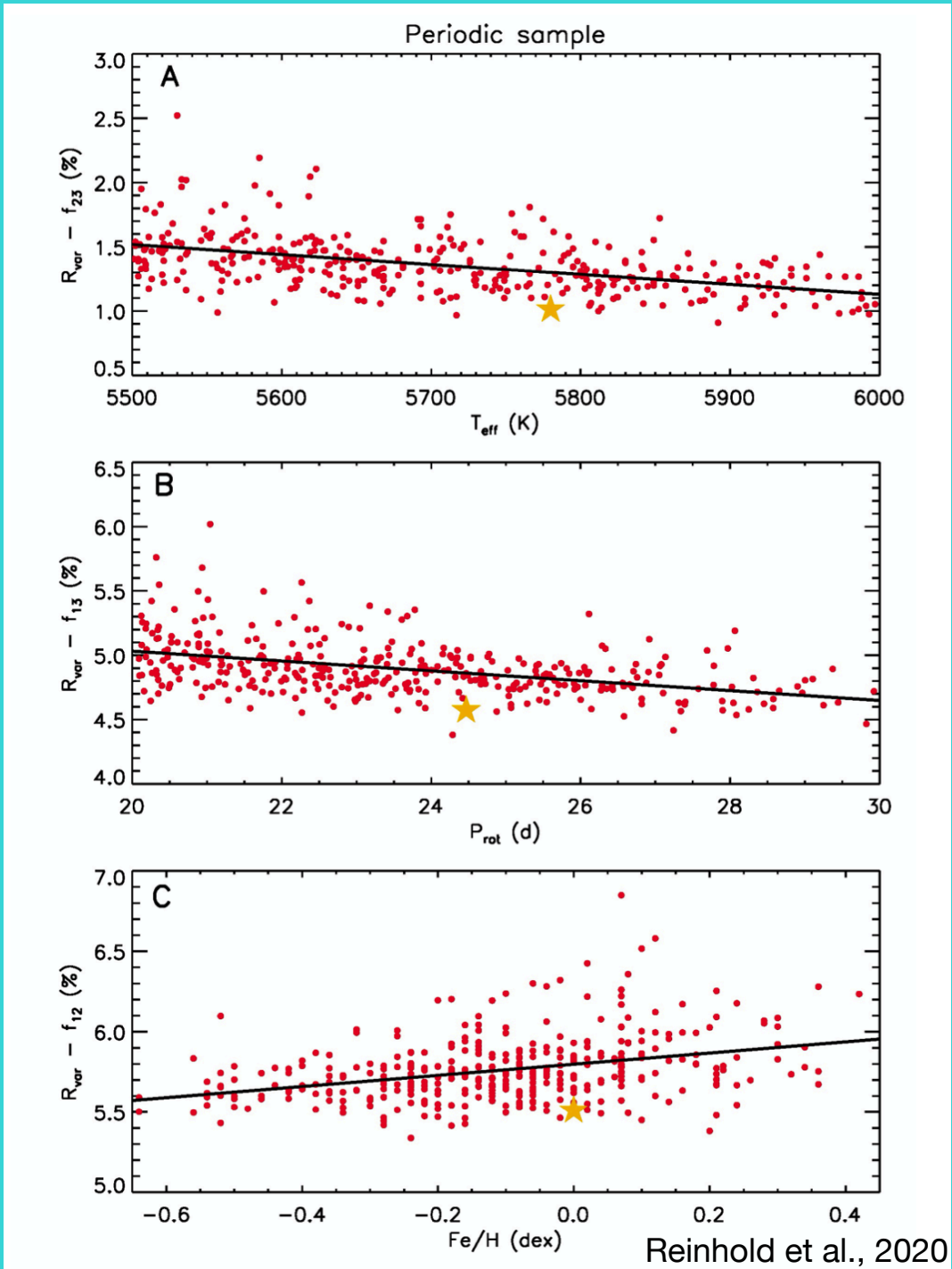
pretty chaotic

quite regular





Variability vs. stellar fundamental parameters



Reinhold et al., 2020

Temperature

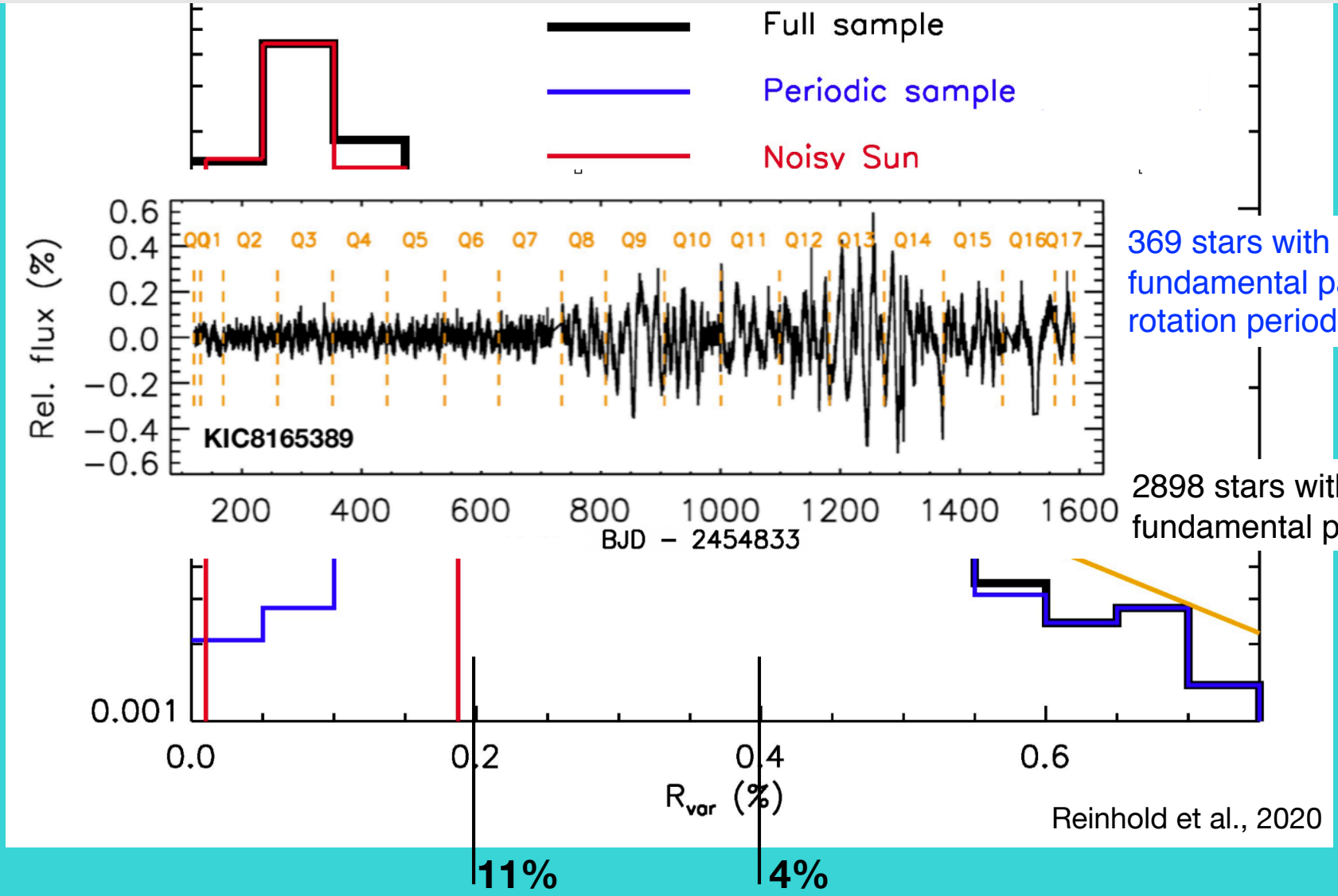
Rotation period

Metallicity

Distribution of stellar variabilities

Subtle, yet unidentified, differences between the periodic stars on the one hand and non-periodic stars (like the Sun) on the other

Solar-like stars allow us to see the entire distribution of possible activity values the Sun and stars with near solar fundamental parameters and rotational periods can achieve.

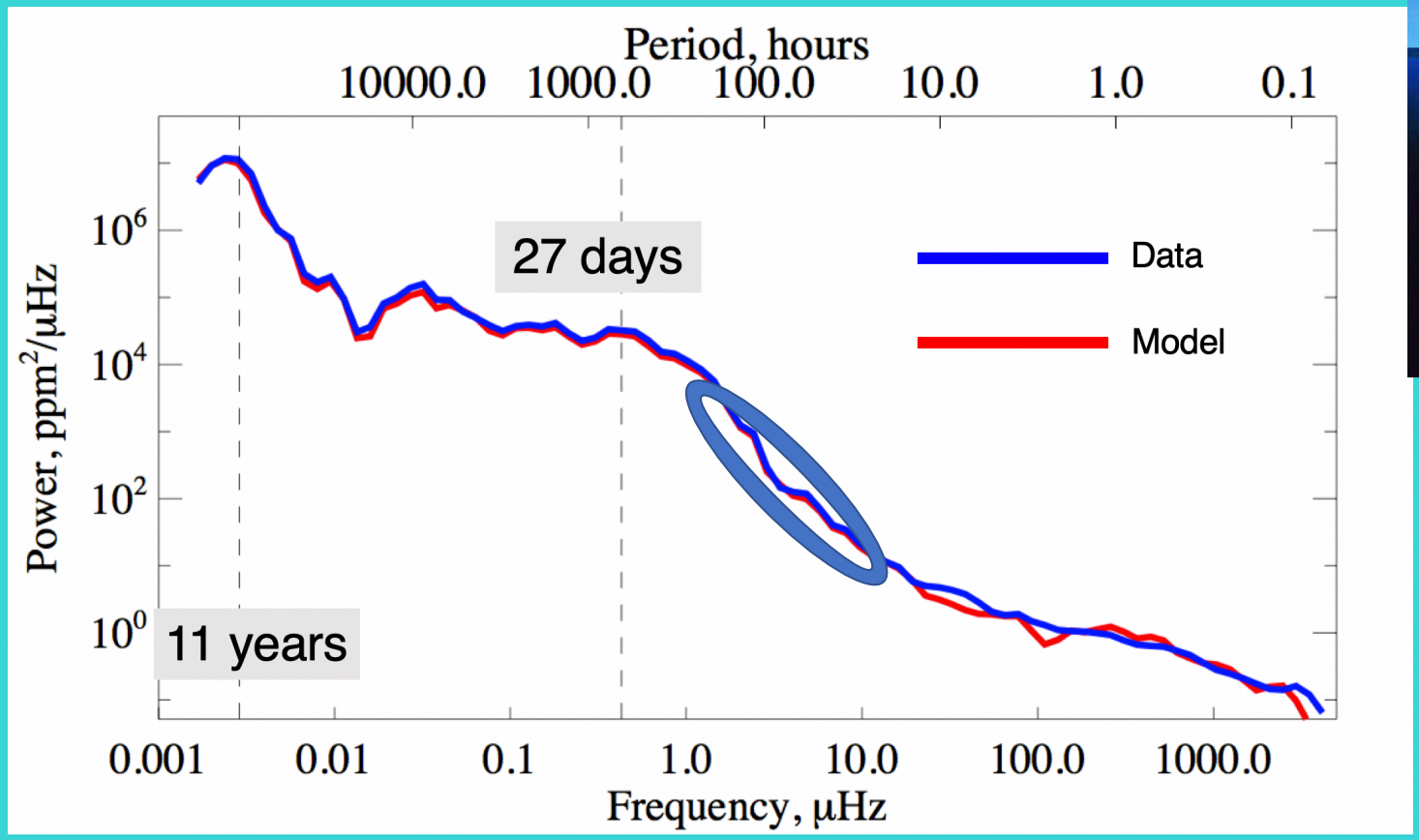


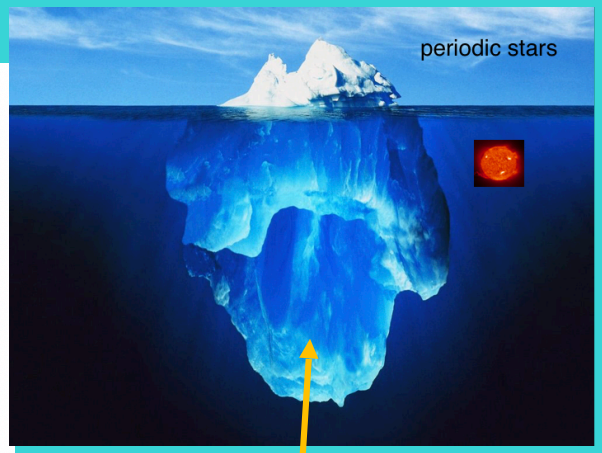
369 stars with near-solar fundamental parameters and rotation periods

2898 stars with near-solar fundamental parameters

Reinhold et al., 2020

Novel method for the detection of stellar rotation periods

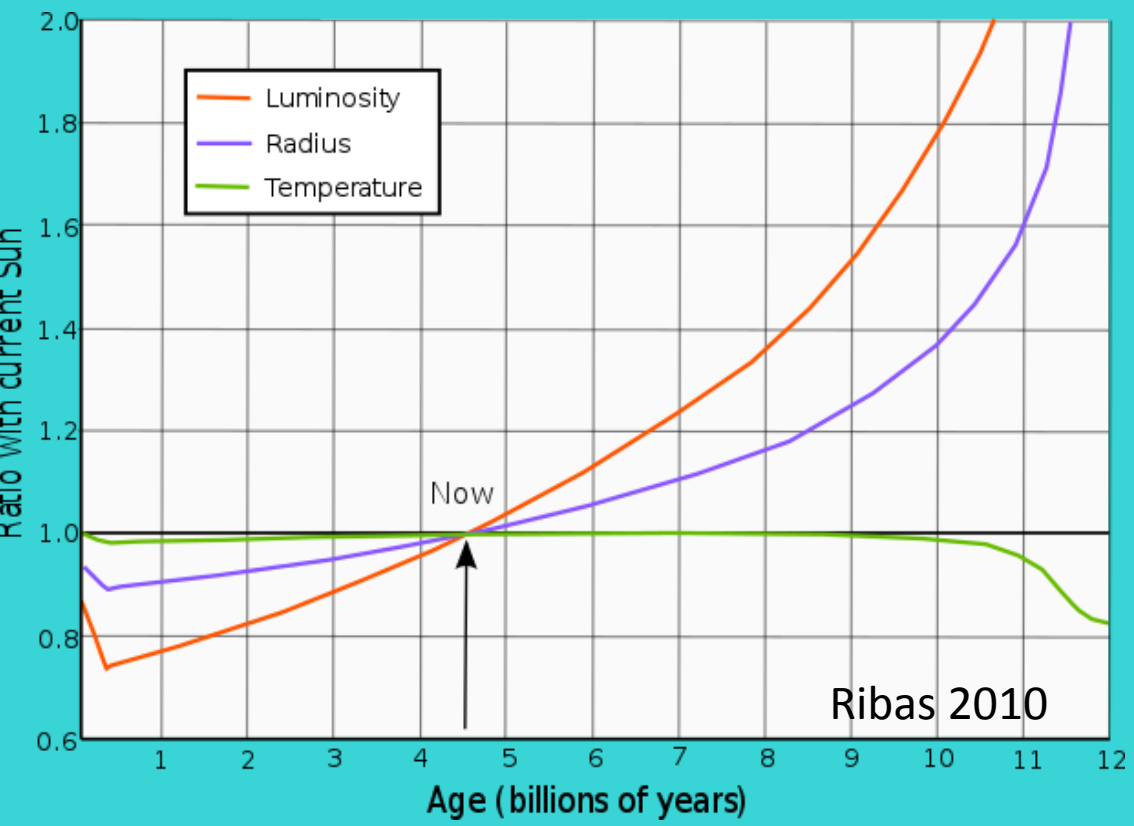


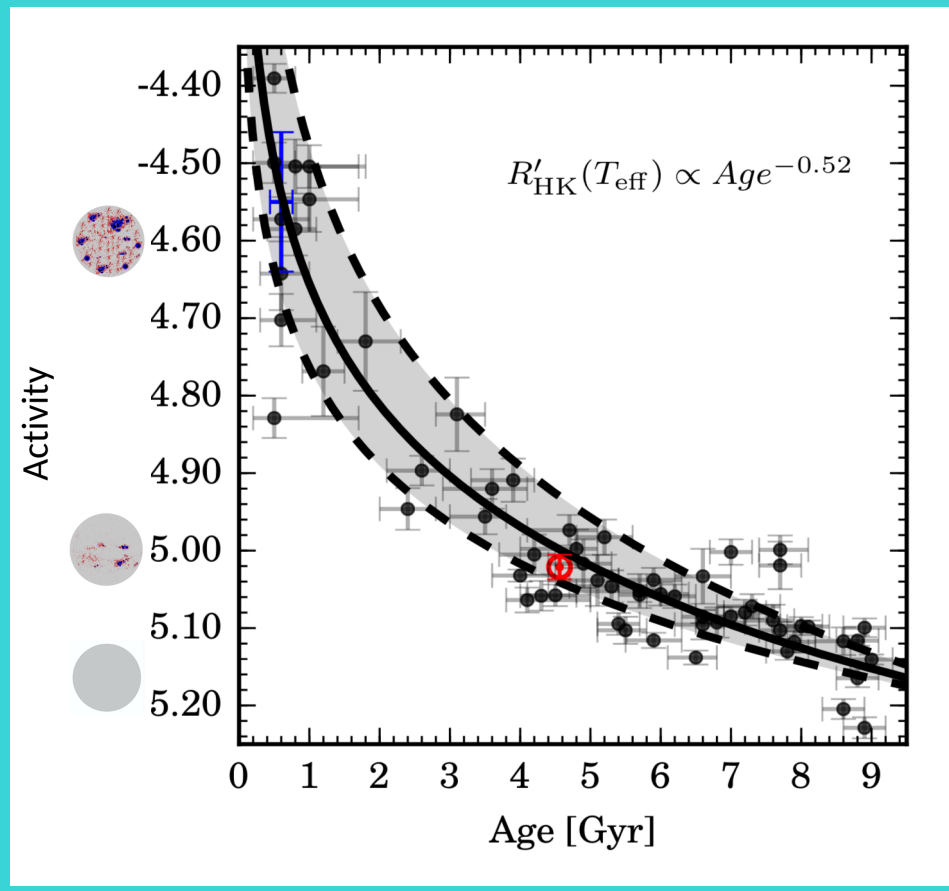


Shapiro et al. 2020

Amazo-Gomez et al., 2020

Evolutionary timescales



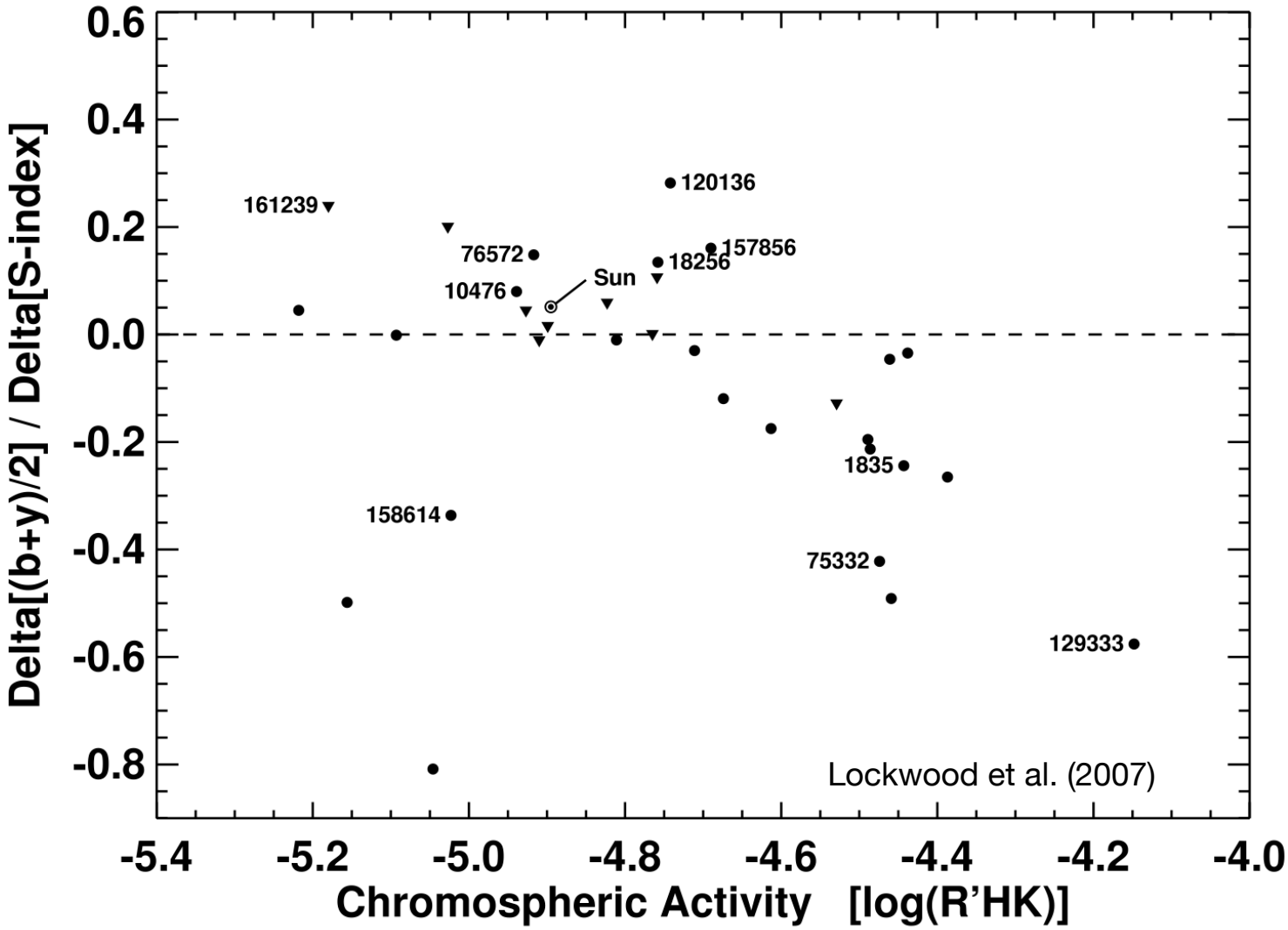


SATIRE-based model
(Shapiro et al. 2014)

Spot coverages ~S^2
Facular coverages ~S

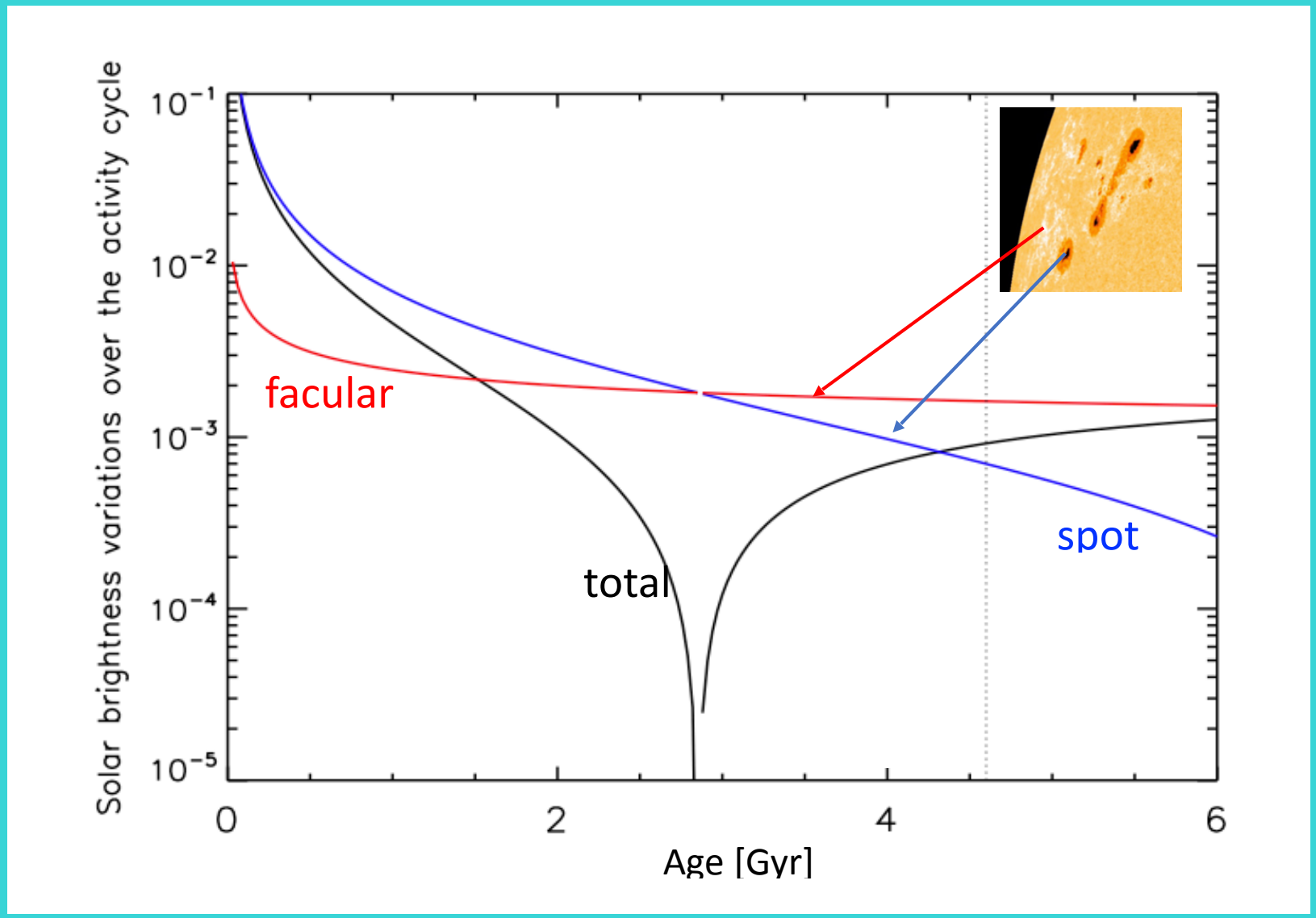
Lorenzo-Oliveira et al., 2018

Amplitude of the TSI variability back in time



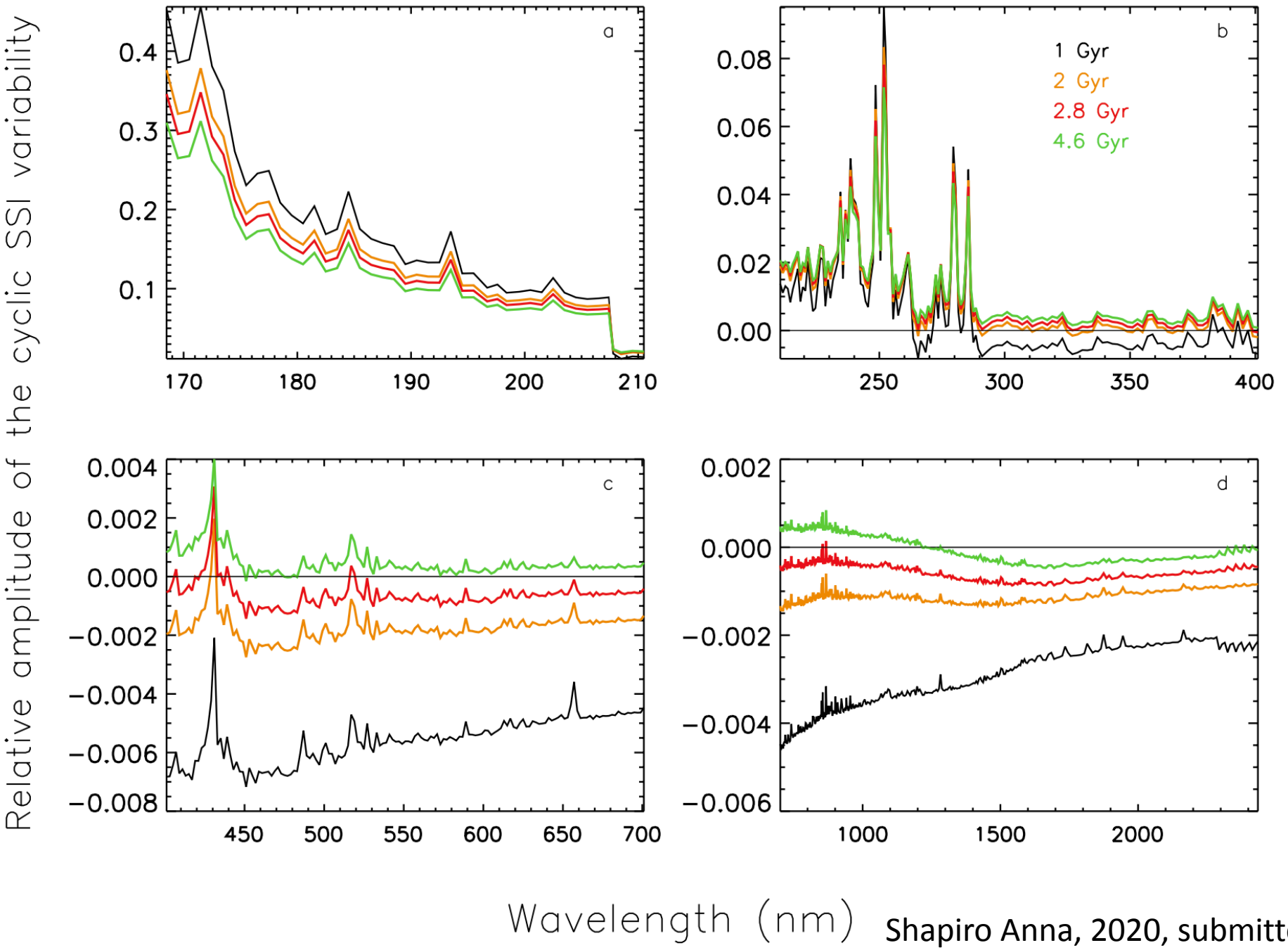
Shapiro Anna, 2020, submitted

Out of phase vs. in phase

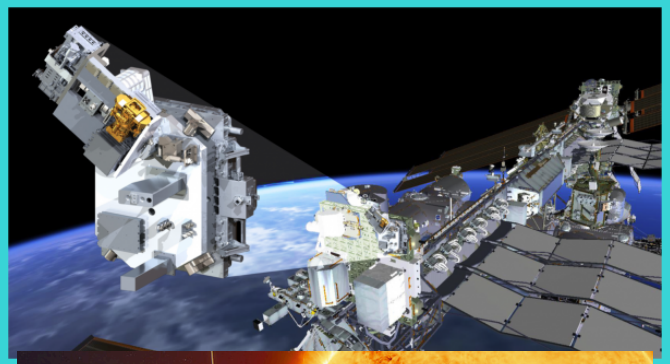


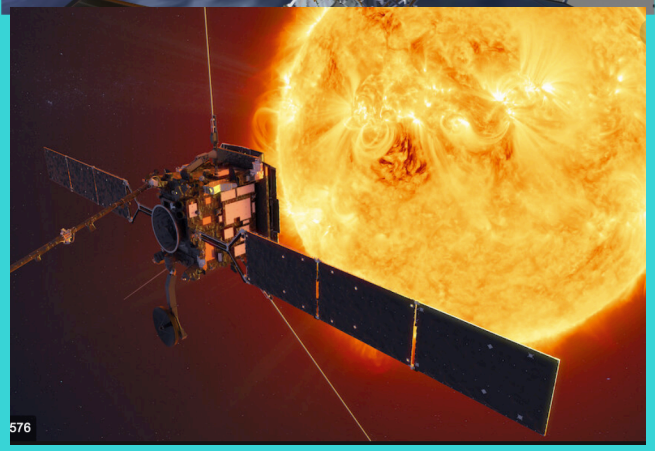
Shapiro Anna, 2020, submitted

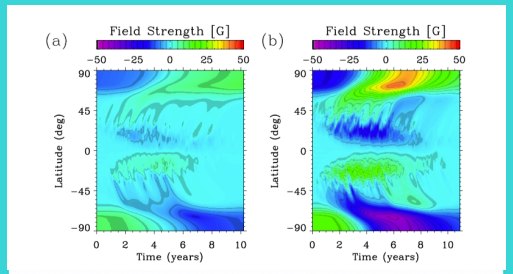
Spectral variability back in time

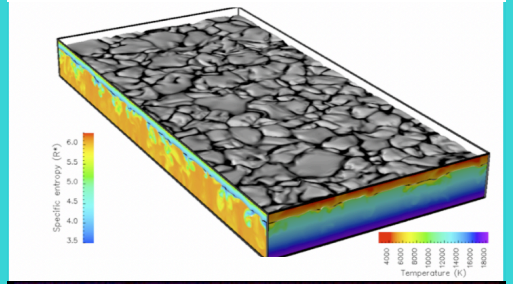


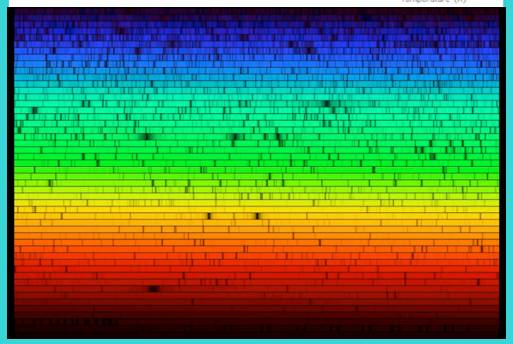
Shapiro Anna, 2020, submitted






(a)
Field Strength [G]
−50 −25 0 25 50
Latitude (deg)
90 45 0 −45 −90
0 2 4 6 8 10
Time (years)
(b)
Field Strength [G]
−50 −25 0 25 50
Latitude (deg)
90 45 0 −45 −90
0 2 4 6 8 10
Time (years)


Specific entropy (R*)
6.0
5.5
5.0
4.5
4.0
3.5
Temperature (K)



THANK YOU!