清華大學天文系
Department of Astronomy, Tsinghua University

The Sun is less active than other solar-like stars

Reinhold et al., Science, 2020

Present by Hongjing Yang (杨弘靖)

Outline

1. How to define “activity”?

3. How did they make this conclusion?

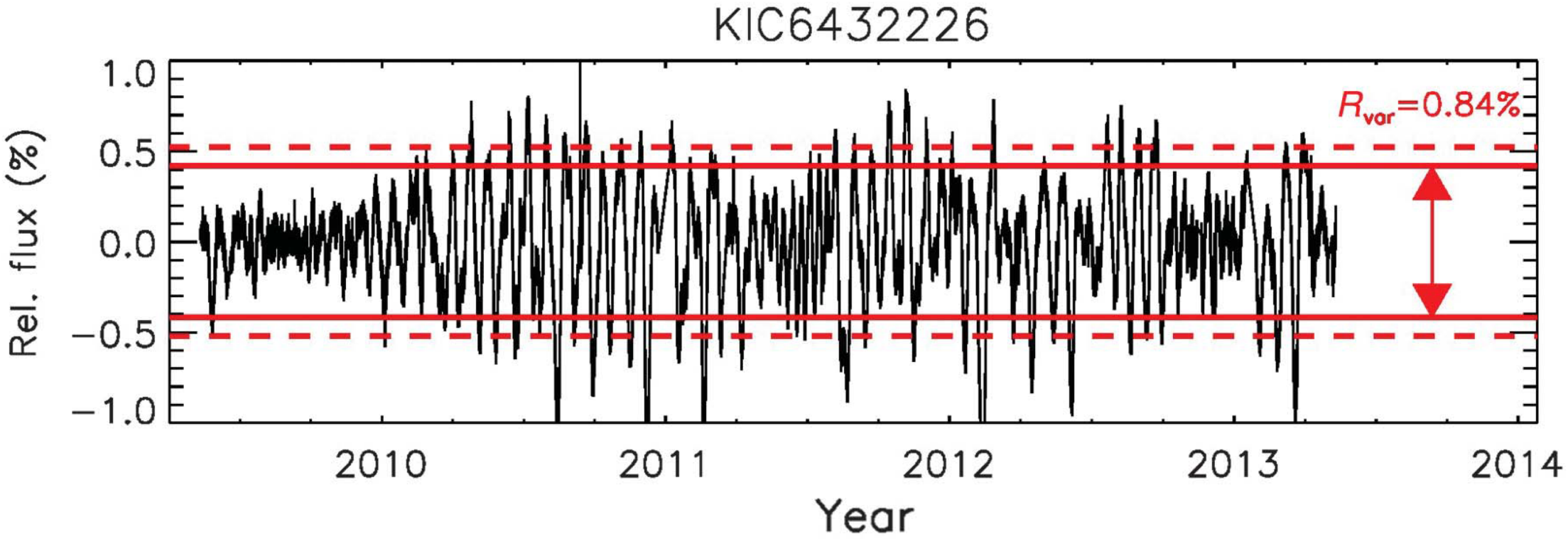
The Sun is less active than other solar-like stars

2. What are “solar-like” stars?

4. Why the Sun is less active?

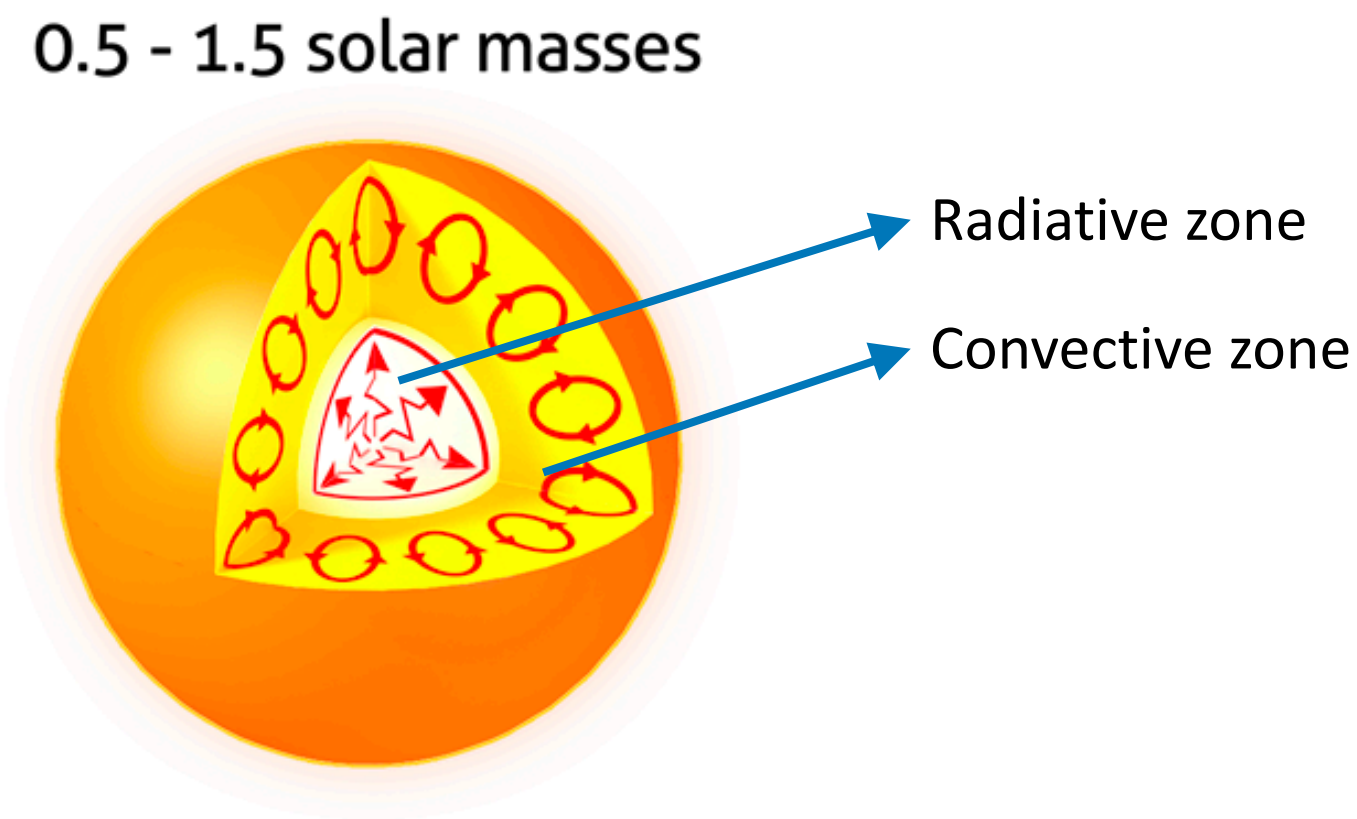
Definition of the “Activity” of a star

Observationally, from light curves



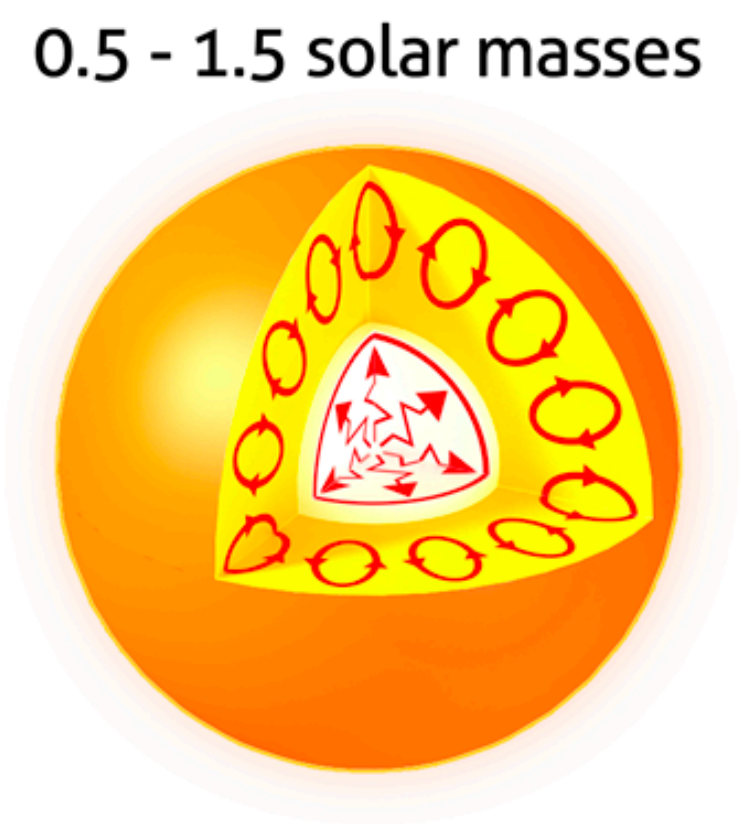
$$R_{\mathrm{var}} = \frac{F(95\text{th percentile}) - F(5\text{th percentile})}{F_{\mathrm{median}}}$$

Why solar-like stars' brightness vary



Convective envelope
Magnetic field activities

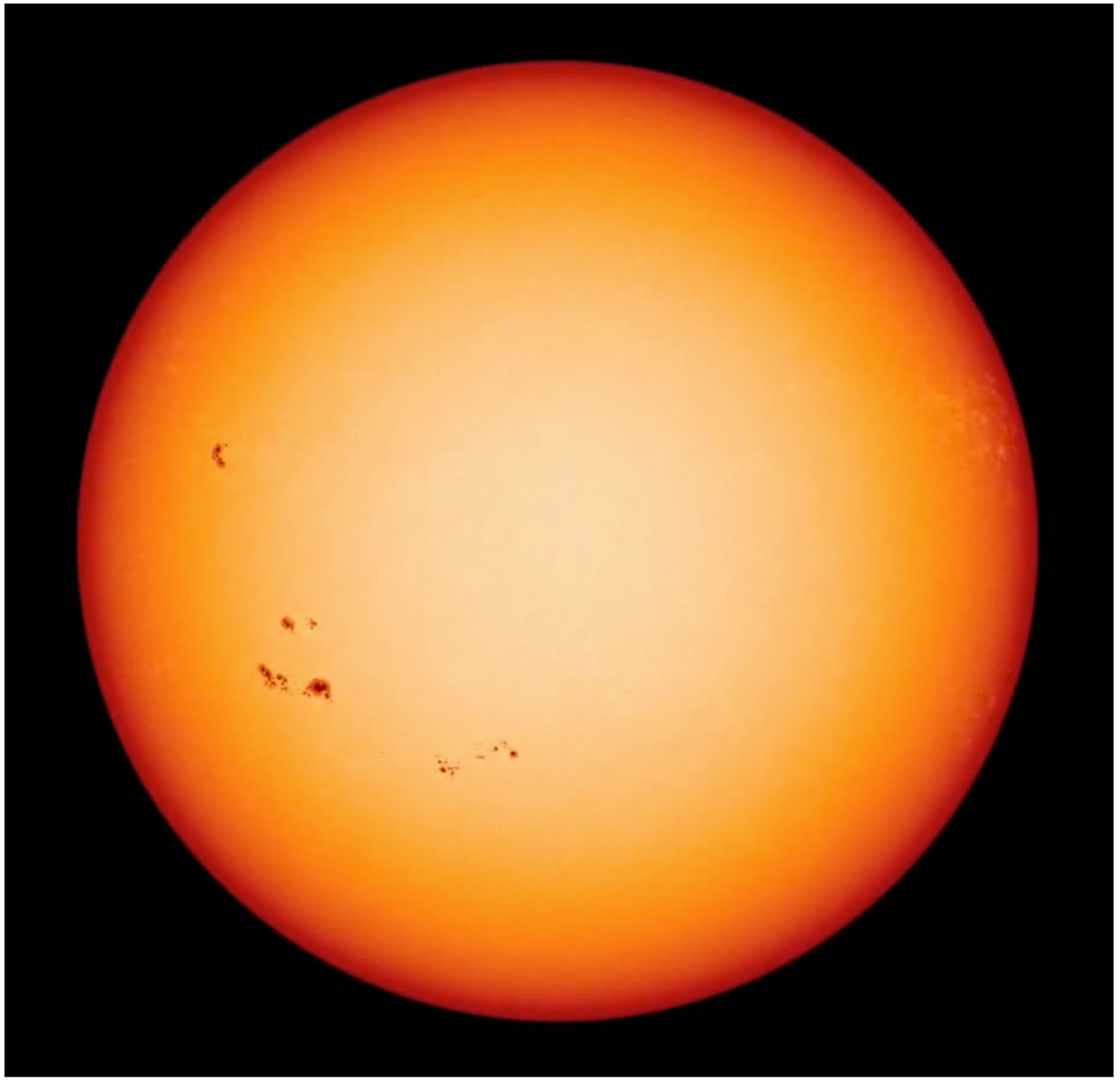
Why solar-like stars' brightness vary



Convective envelope
Magnetic field activities

Sun spots & flares

Why solar-like stars' brightness vary



Sun spots & flares

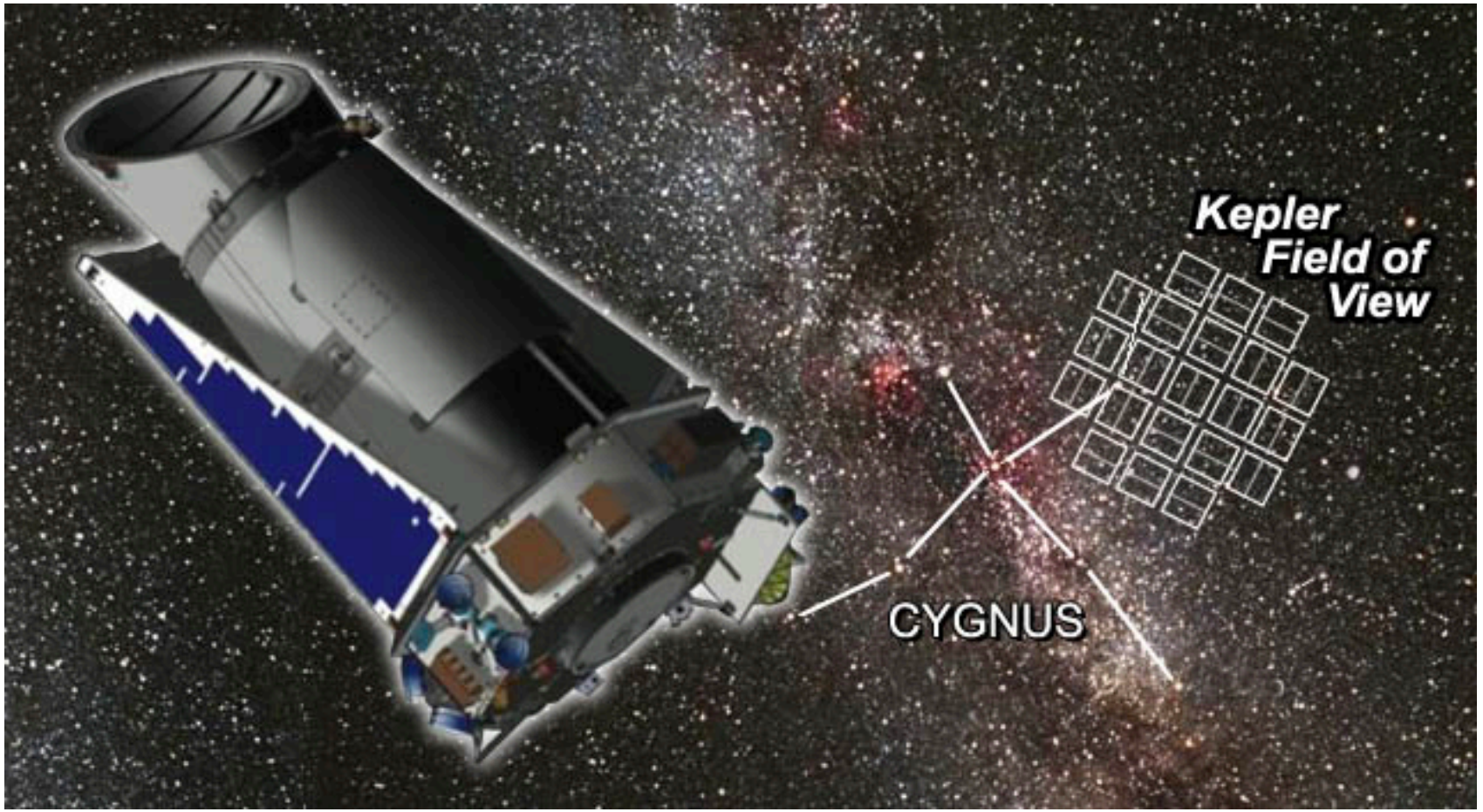
+

Evolution & Rotation

=> Variability

Measure the “Activity” for other stars

Kepler Mission



~4 yr observation

continuously light curve of 133,030 stars

$=>\ R_{\mathrm{var}}$

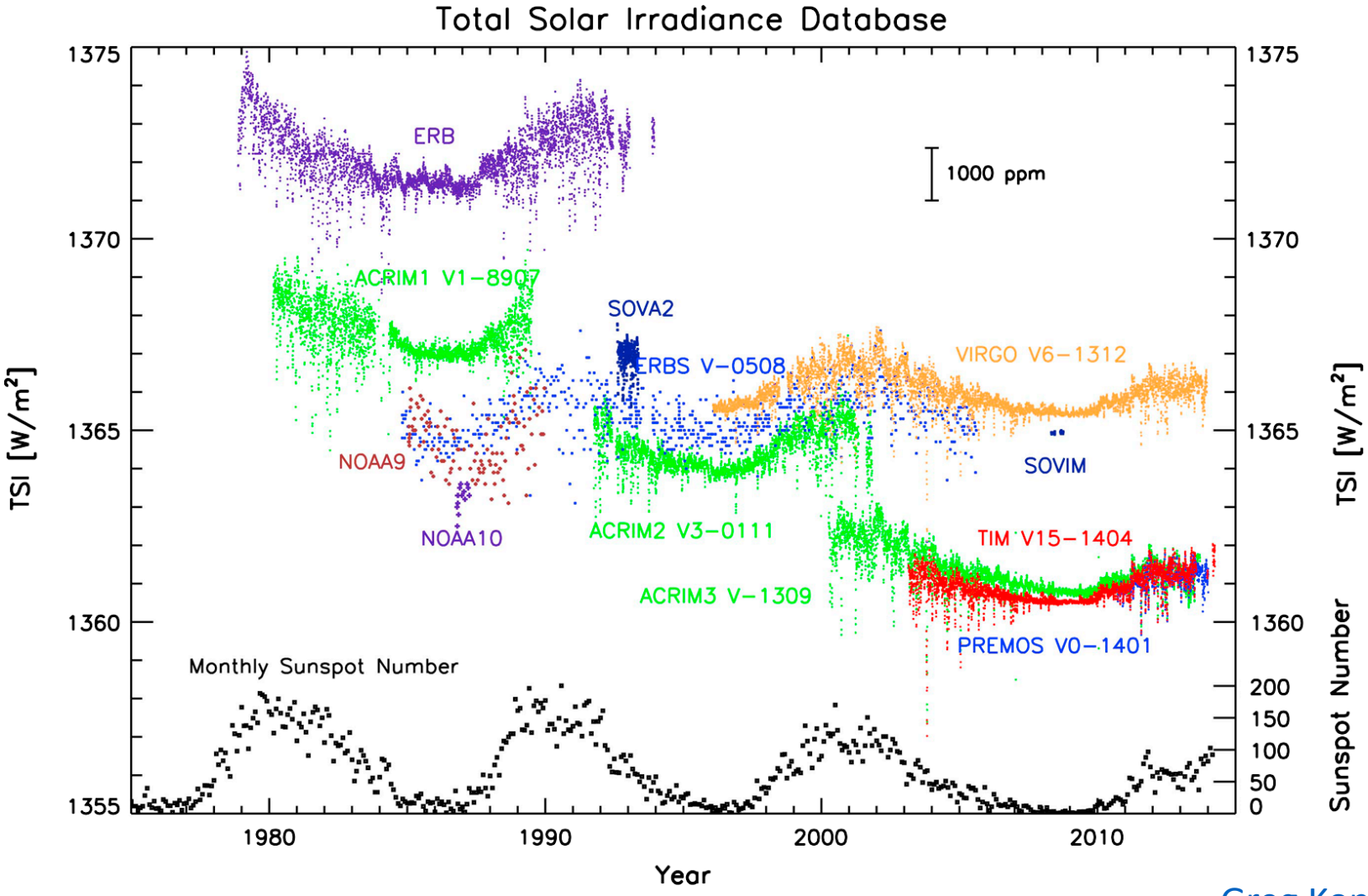
Measure the “Activity” for the Sun

The Sun is too BRIGHT and too BIG!

Total solar irradiance (TSI):
Sunlight integrated over the entire spectrum & surface

Measure the “Activity” for the Sun

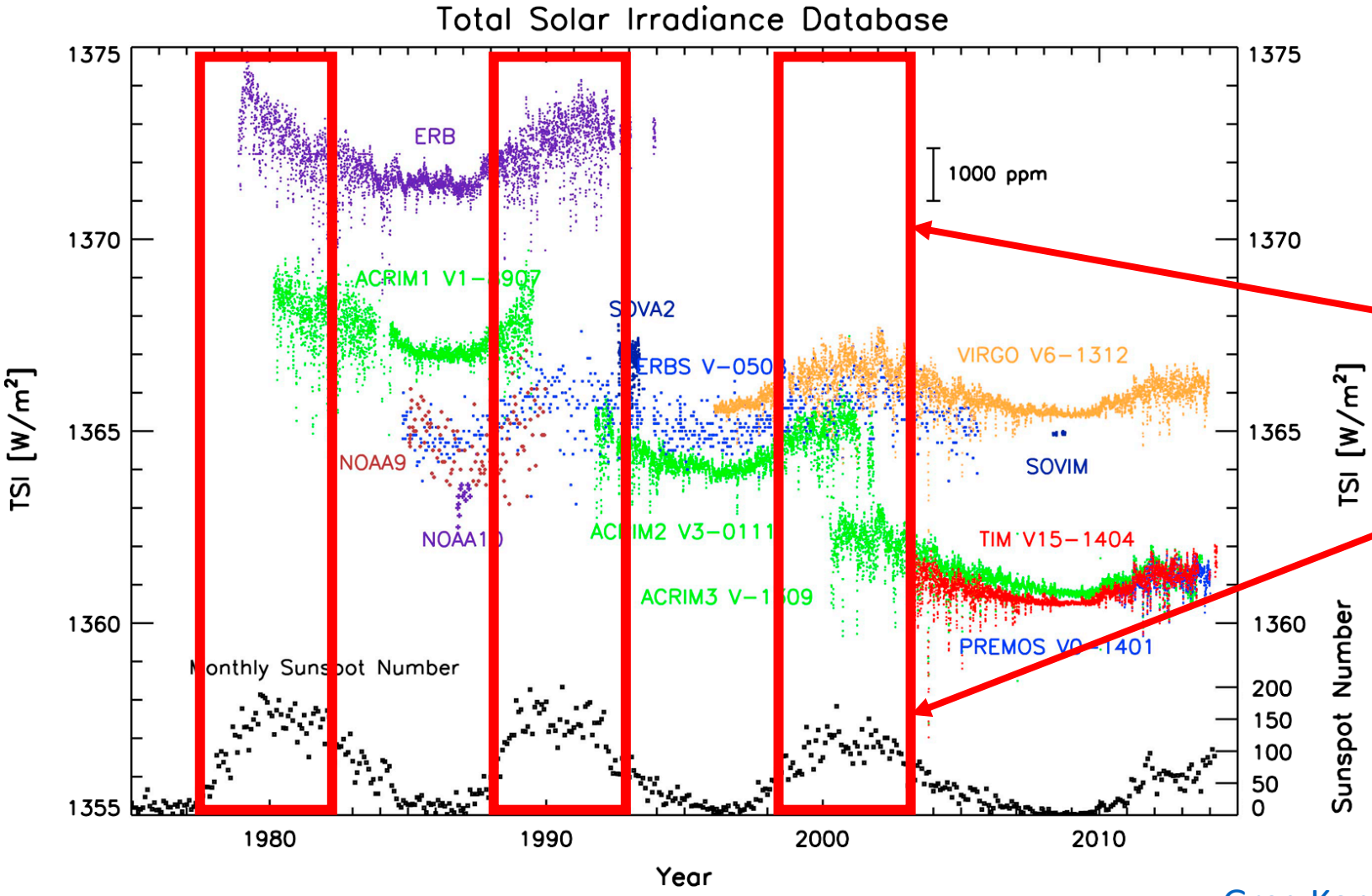
1978 - now: precise measurement from space mission



Greg Kopp (2014)

Measure the “Activity” for the Sun

1978 - 2014: precise measurement from space mission



Correlation

Sunspots
&
TSI variations

Greg Kopp (2014)

Measure the “Activity” for the Sun

1978 - 2014: precise measurement from space mission — Greg Kopp (2014)

1878 - 1987: Sunspot area & position + solar surface flux transport model — Dasi-Espuig et al. (2014)

1610 - 1878: Sunspot counts — Usoskin, Ilya G. (2017)

7000 B.C. - 1610: Cosmogenic isotopes (同位素) — Wu, C. -J. et al. (2018)

$=>$ R_{var} of the Sun

What is “Solar-like” stars

Fundamental parameters (from Kepler DR25):

$$5500\ \mathrm{K} < T_{\mathrm{eff}} < 6000\ \mathrm{K}$$
$$\log g > 4.2$$

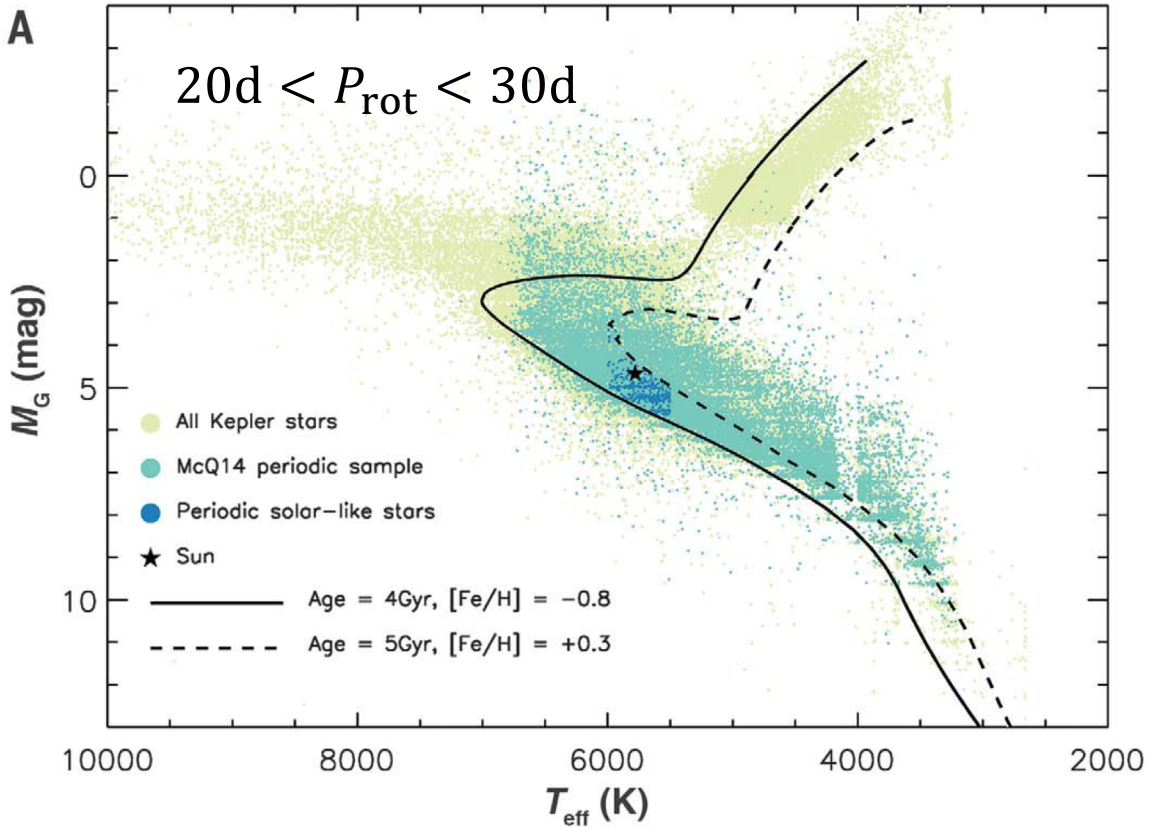
$$T_{\mathrm{eff},\odot} = 5780\mathrm{K}$$
$$\log g_{\odot} = 4.44$$

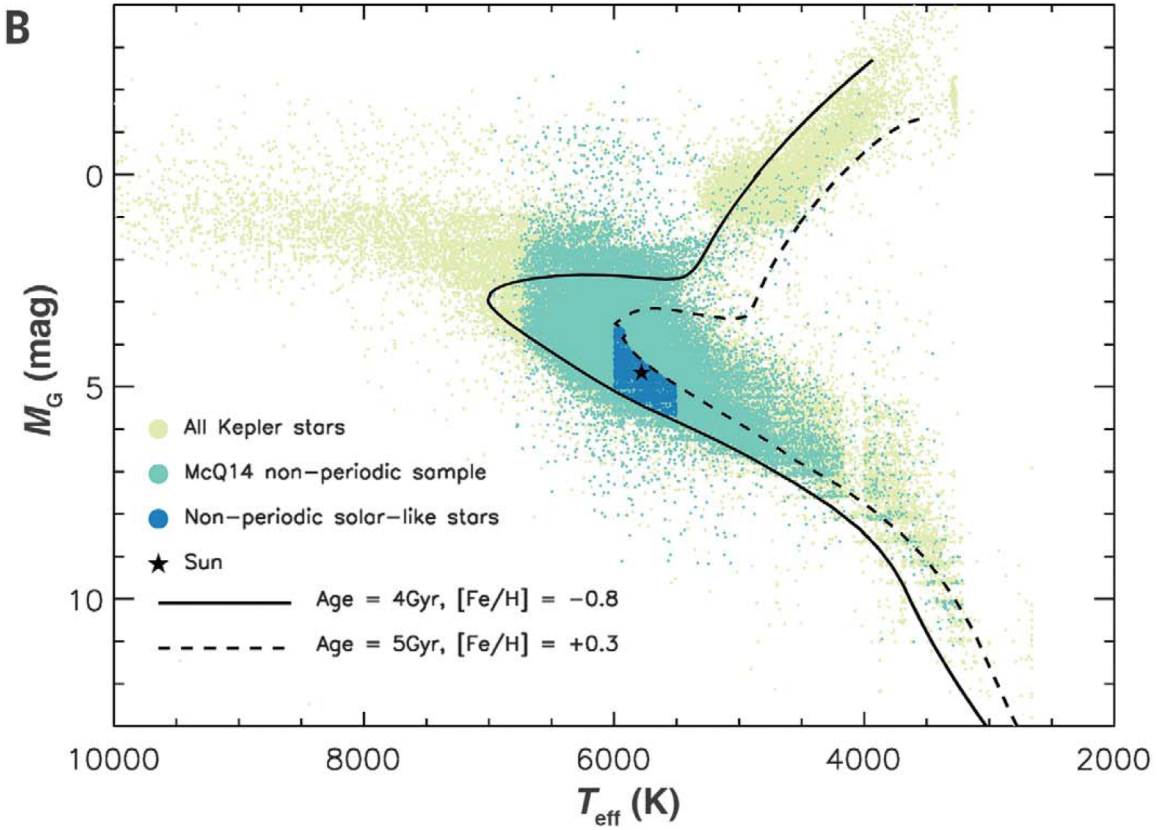
What is “Solar-like” stars

M_G from Gaia DR2

$-0.8 < [\mathrm{Fe/H}] < 0.3$

$4\ \mathrm{Gyr} < t_{\mathrm{age}} < 5\ \mathrm{Gyr}$



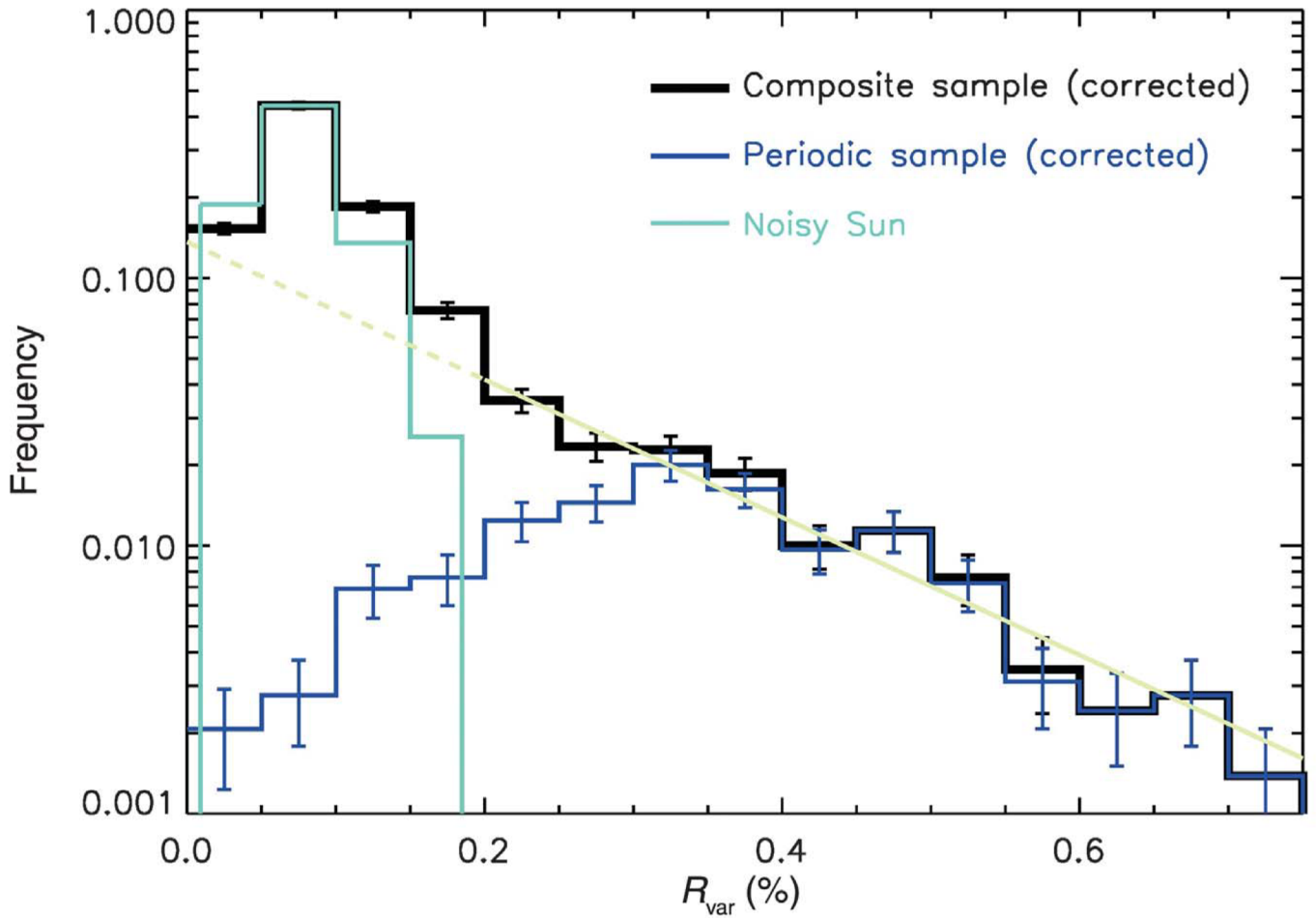


periodic sample
(rotation period identified)

Sun should be here

non-periodic sample
(rotation period unidentified)

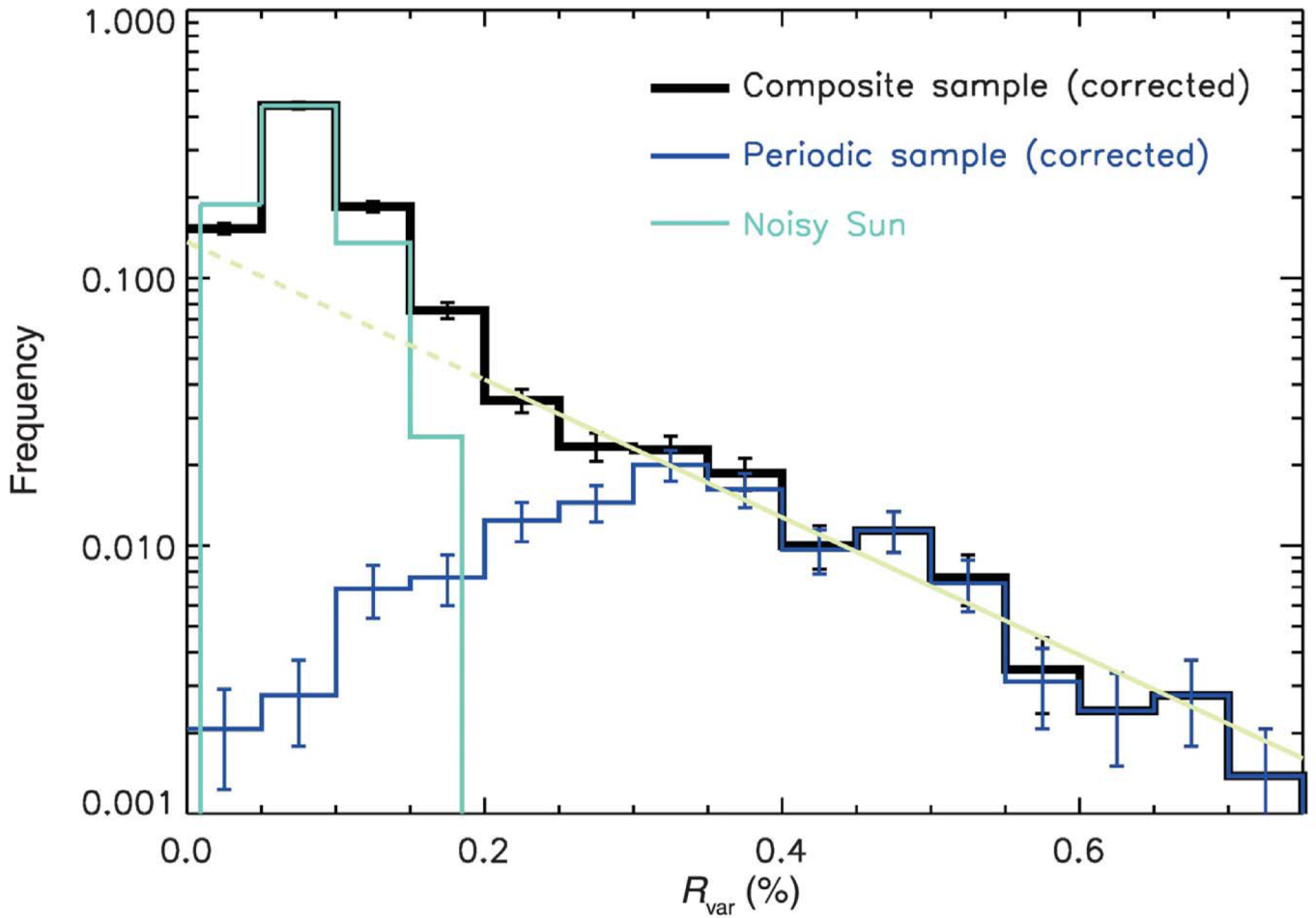
The Sun is less active than other solar-like stars



R_{var} of Sun is typical non-periodic stars

But is smaller than typical periodic stars

Interpretations



1. The Sun is in it's "quiet phase" for at least 9,000 years.

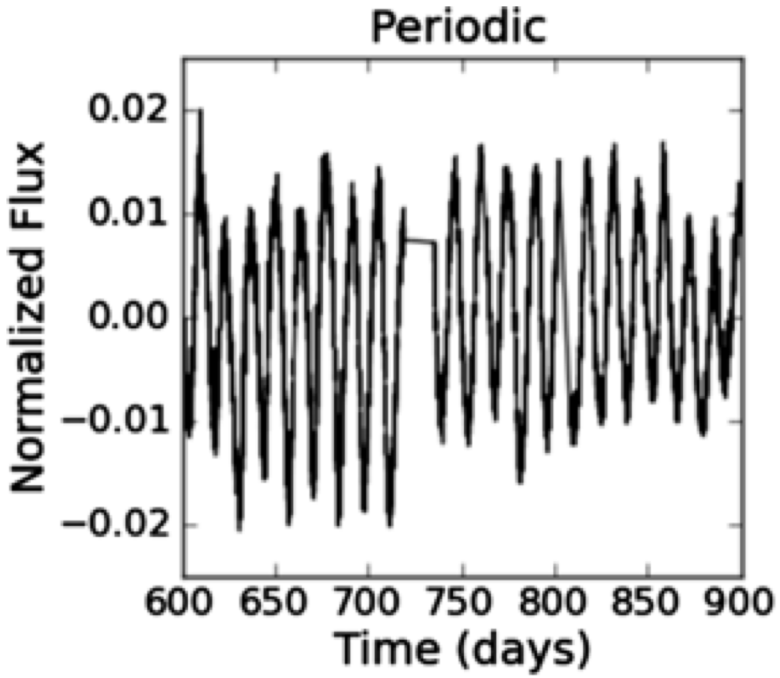
2. There are unidentified, intrinsic difference between periodic and non-periodic sample.

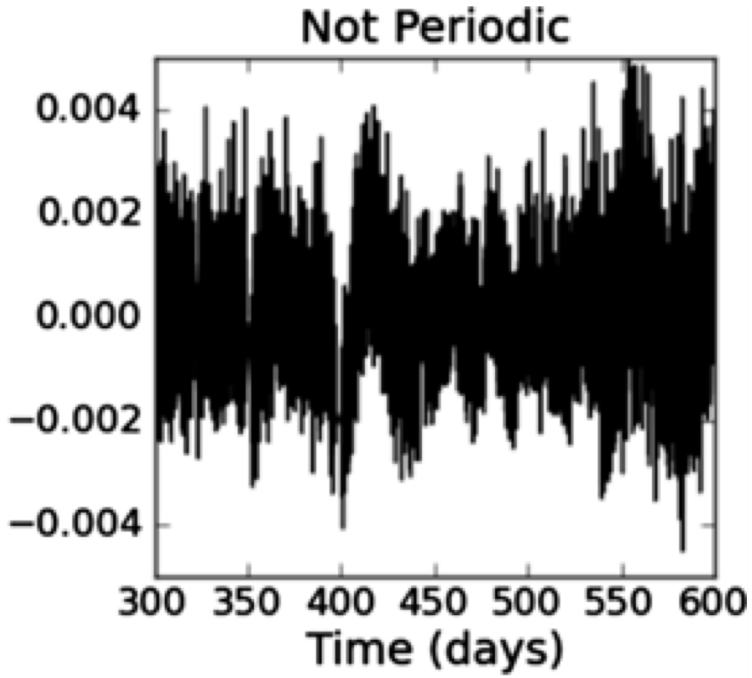
Interpretations: stellar evolution

Metcalfe, Travis S. & van Saders, Jennifer

Interpretations: stellar evolution

There are intrinsic difference between periodic and non-periodic stars

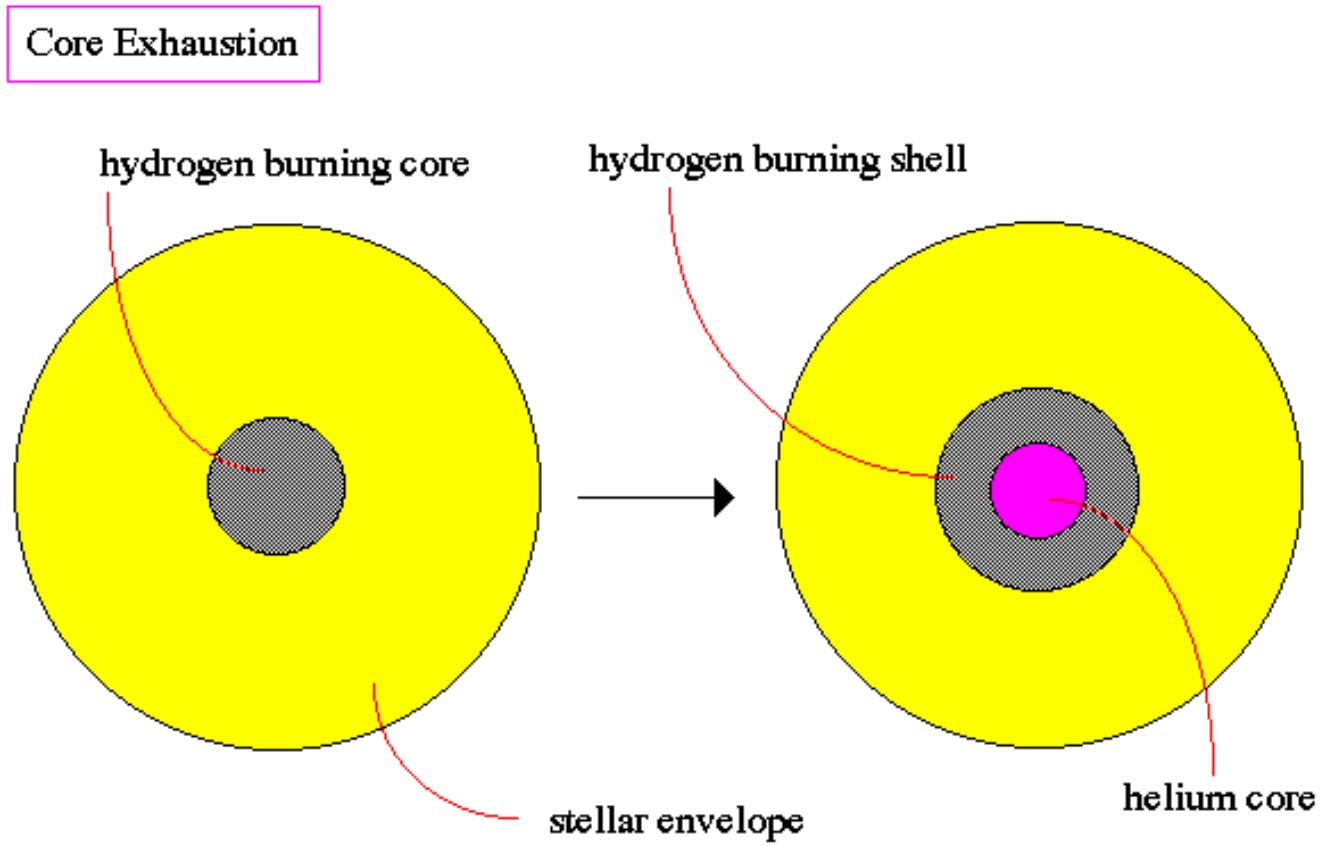




cooler
mental-rich
deeper convective envelope

hotter
mental-poor
shallower convective envelope

Interpretations: stellar evolution



Convective envelope:
-> shallower

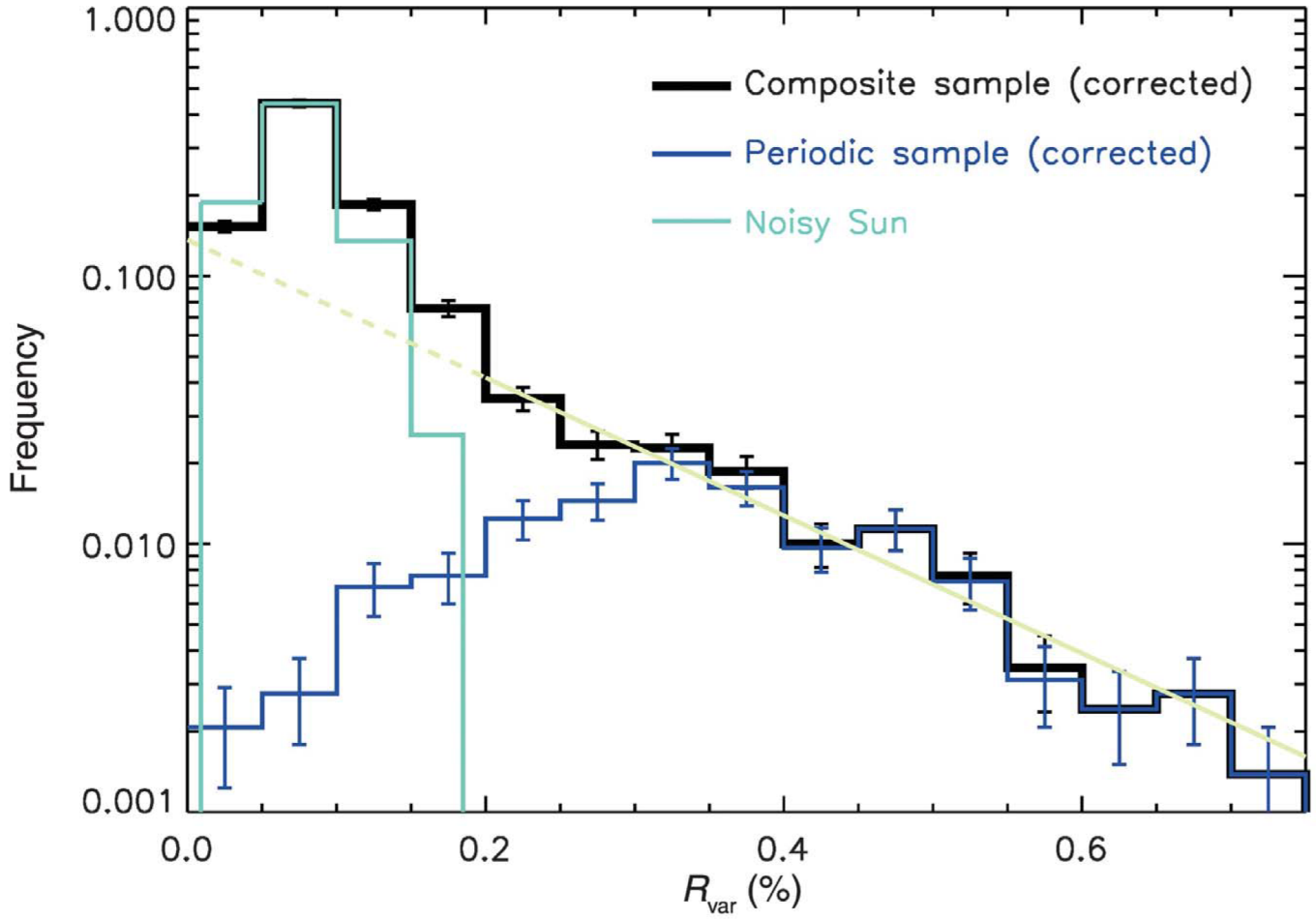
Magnetic activities:
-> weaker

Spots number:
-> fewer

Spots lifetime:
-> shorter

Transition time for $1M_{sun}$ star: ~5Gyr!

Interpretations: stellar evolution



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Transition time for $1M_{sun}$ star: ~5Gyr!

Summary

From the paper:

- The Sun is less active than other solar-like **periodic** stars;
- Periodic and non-periodic stars may have intrinsic difference.

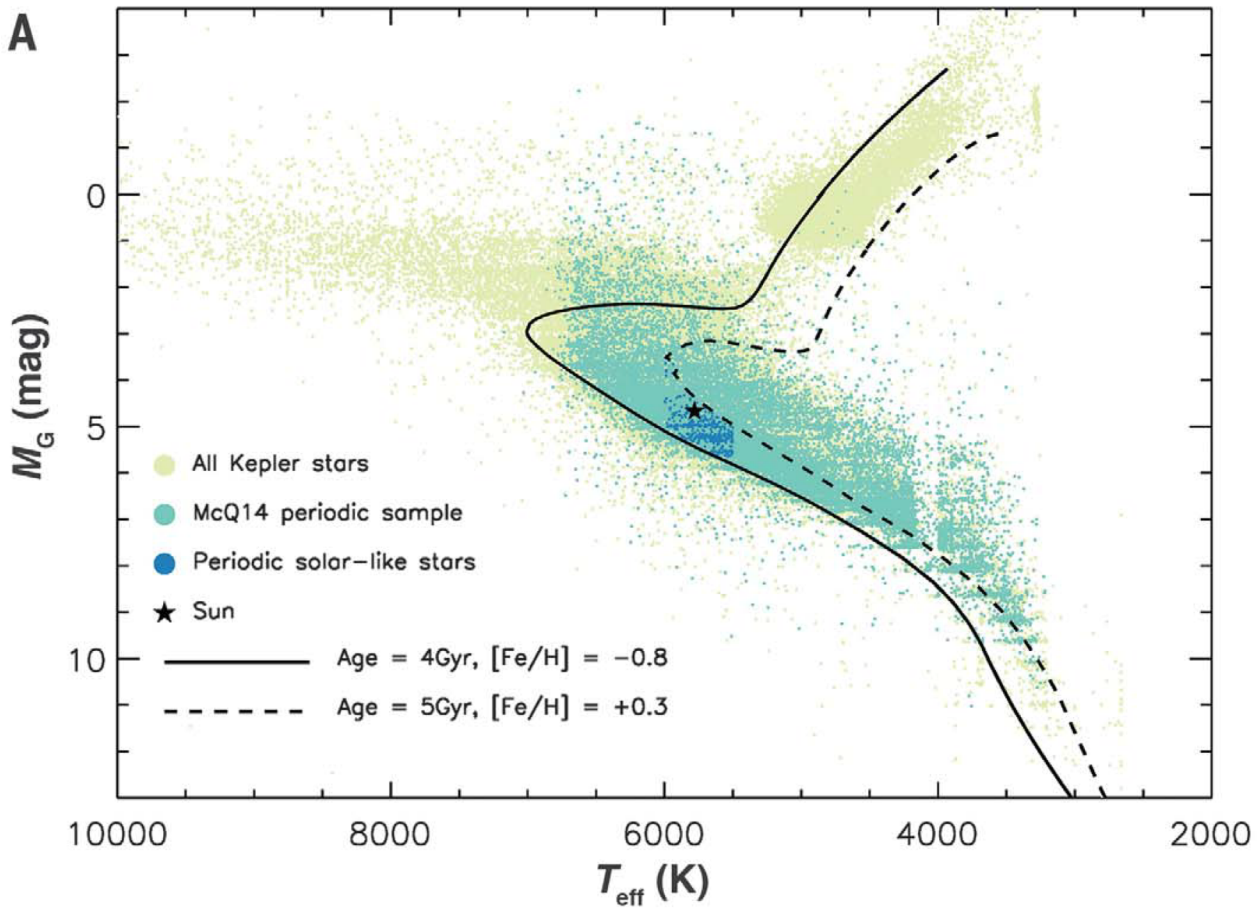
From the comment paper:

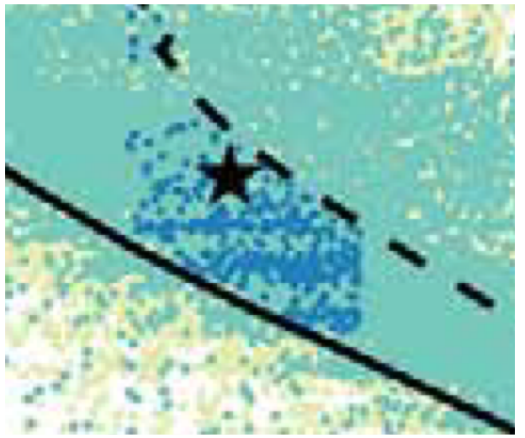
- As time evolve, solar-like stars tend to be less active;
- Our Sun is undergoing the transition.

Questions

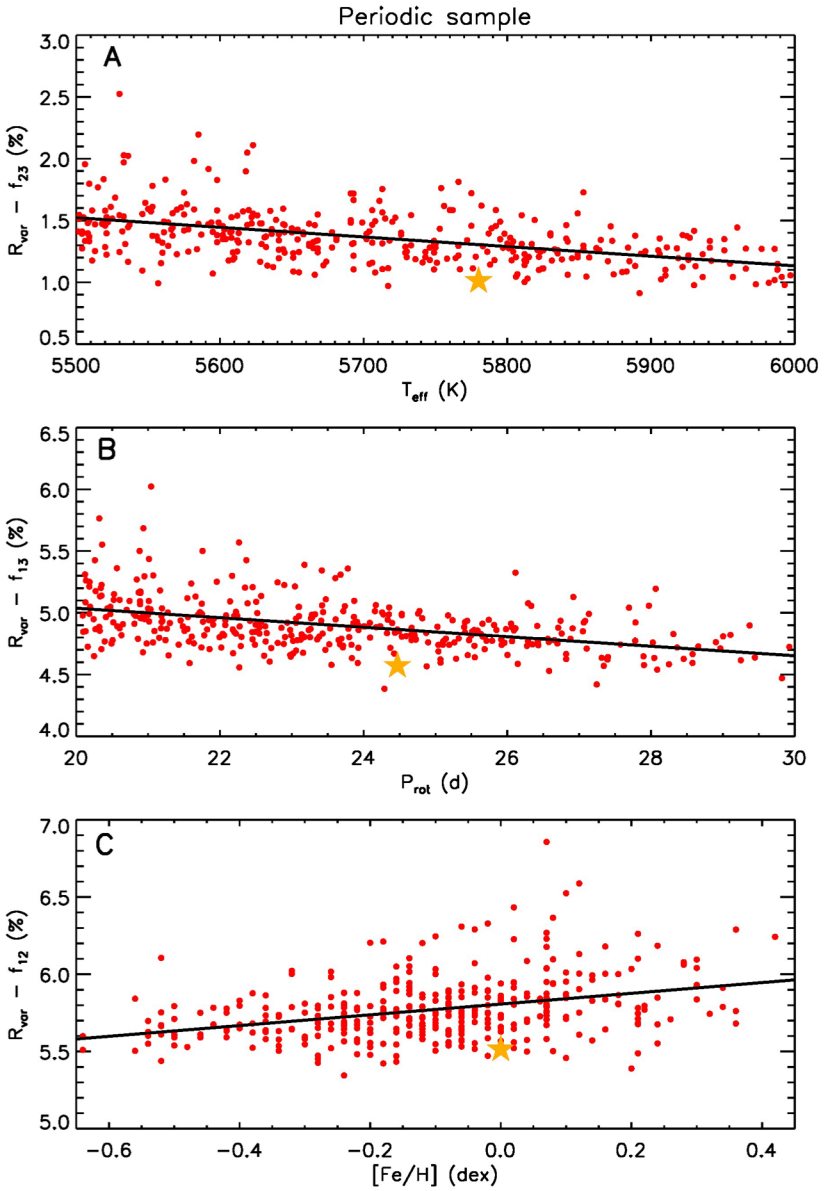
1. Why the solar R_var value is not a point, but a distribution?
2. Selection bias?
3. TSI vs Kepler bandpass?
4. Inclination?

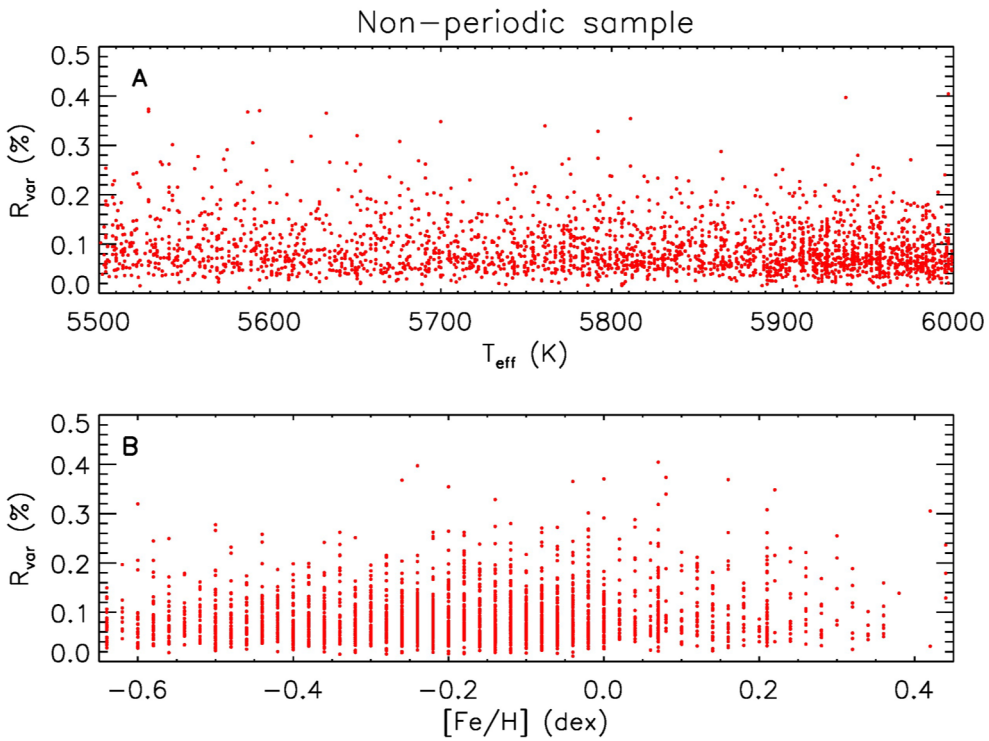
Question: selection bias?





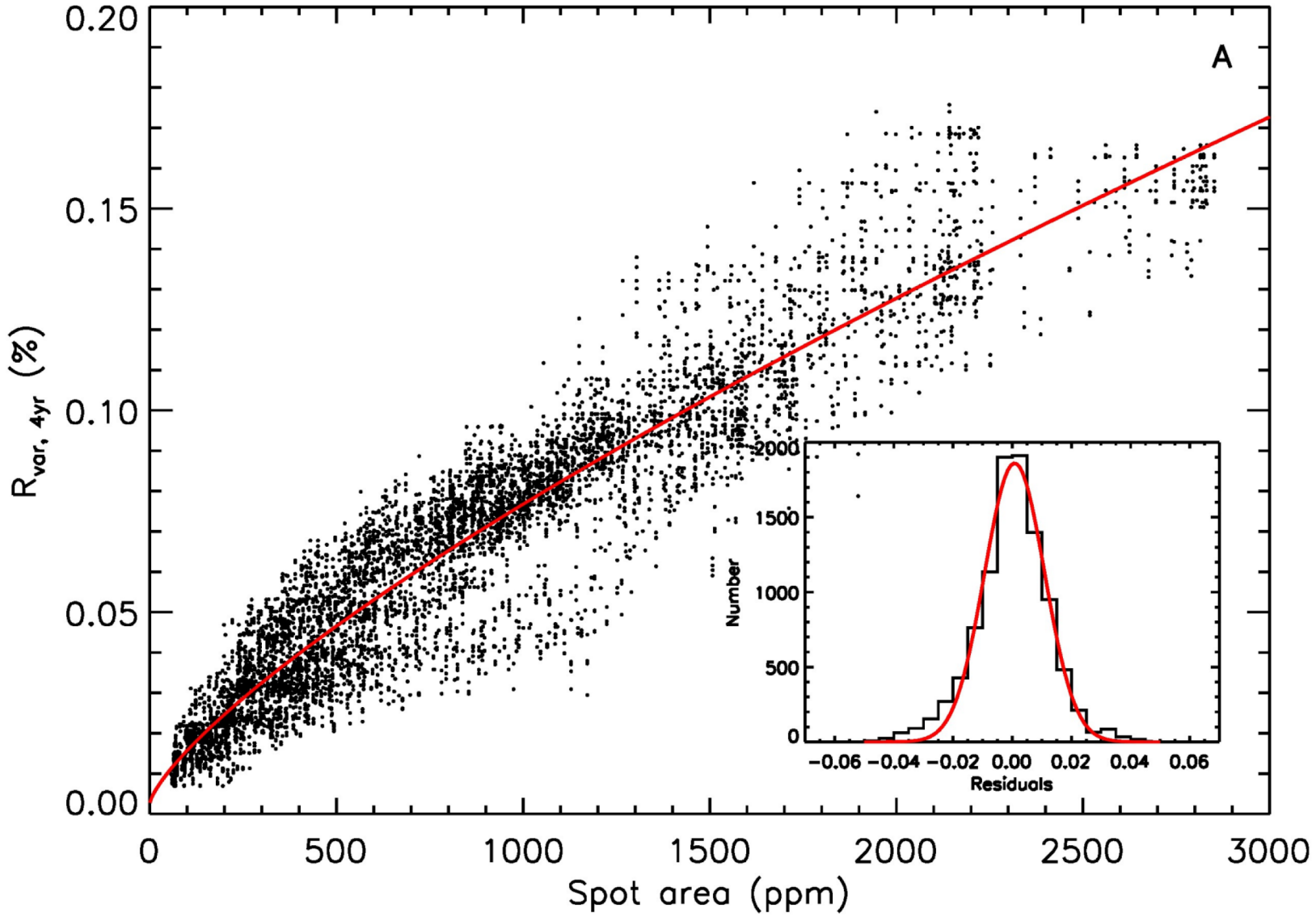
Measure the “Activity” for the Sun





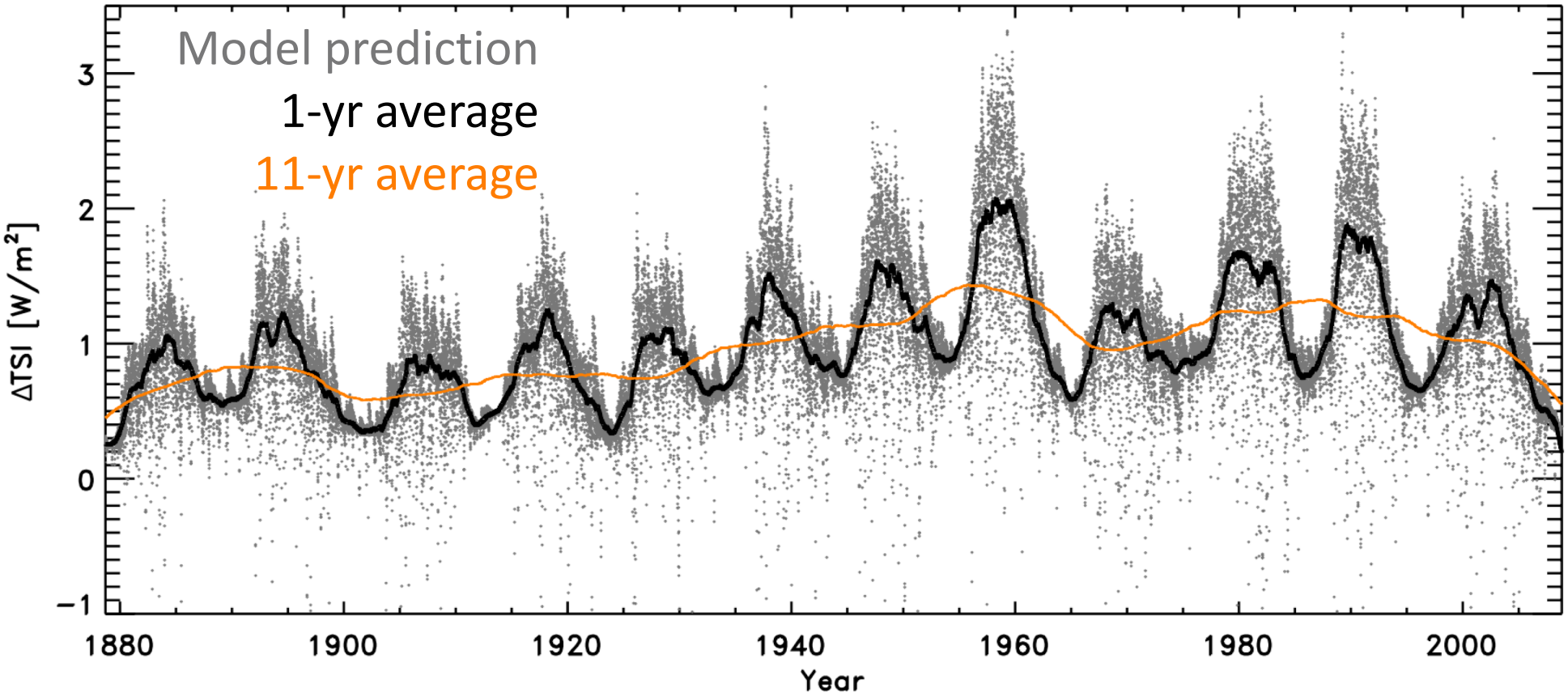
Measure the “Activity” for the Sun

Spot area vs R_{var}



Measure the “Activity” for the Sun

1878 - 1987: Sunspot area & position + solar surface flux transport model



Dasi-Espuig et al. (2014)