



# Modelling of the SSI and TSI variability

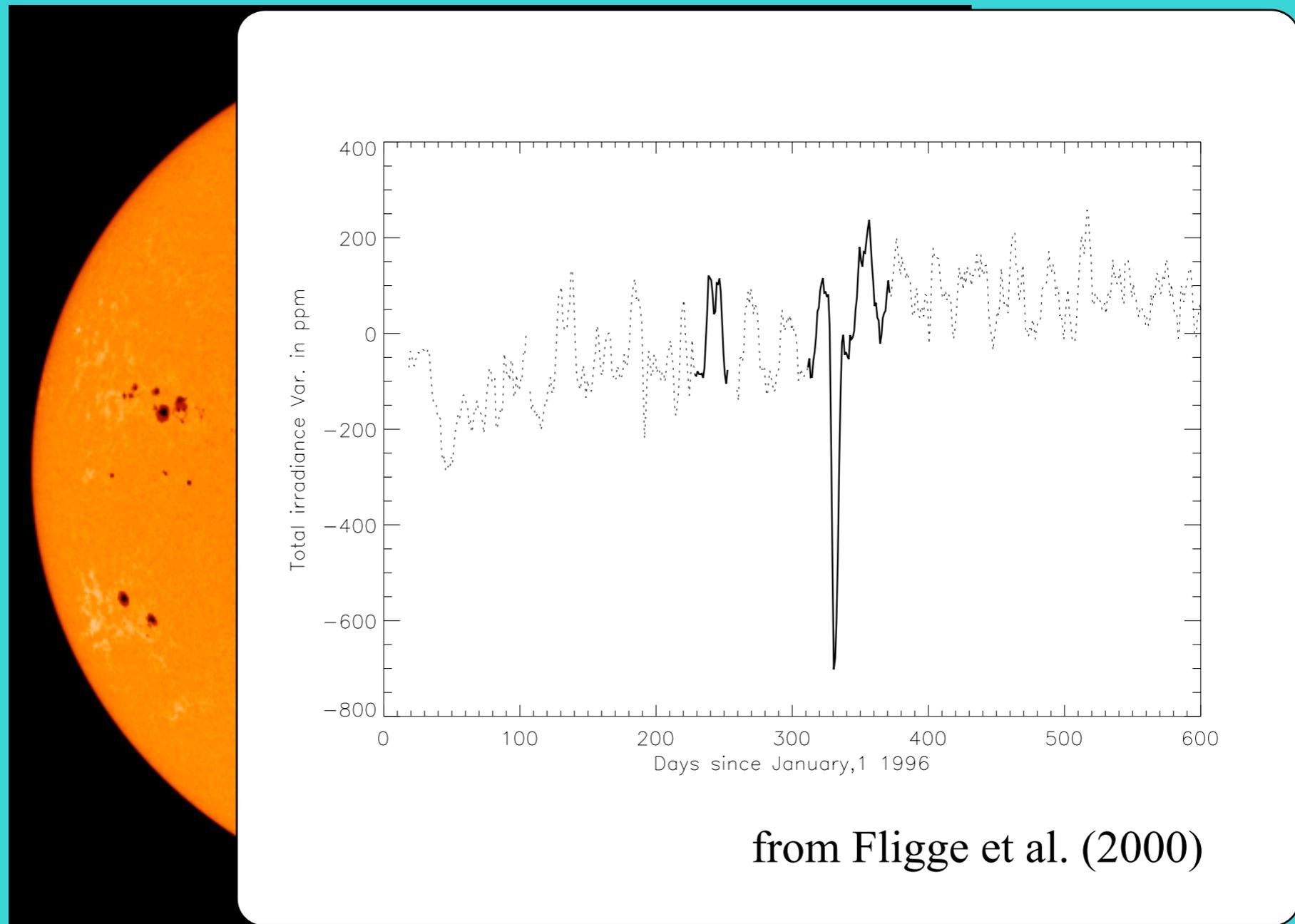
What we **do** and **do not** know

Current limitations: who is to blame and what to do?

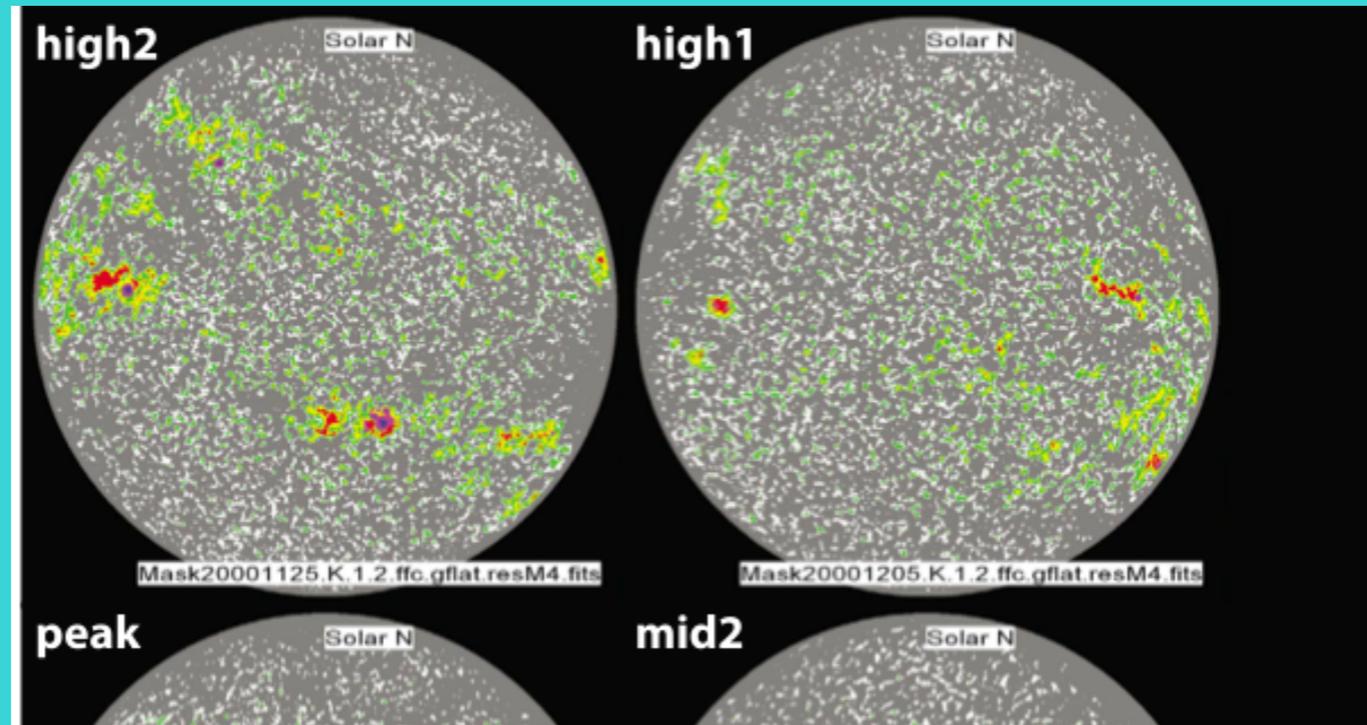


# Modelling of the solar irradiance variability

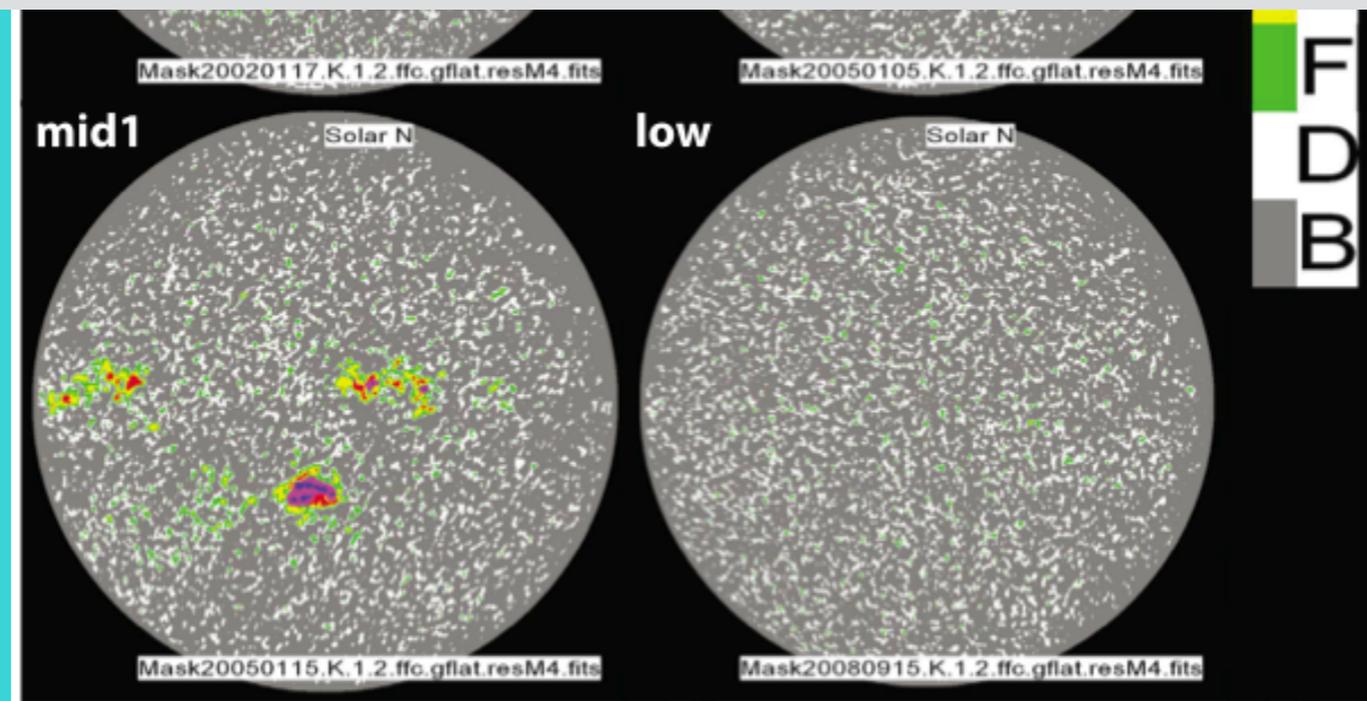
**Main assumption.** Variations in the solar irradiance are directly related to the evolution of surface magnetic flux



from Fligge et al. (2000)



**Irradiance reconstruction = surface coverages + spectra of the individual components**



from Fontenla et al. (2011)

Solar Radiation Physical Modelling (SRPM)

Fontenla et al. (2011)

Naval Research Laboratory Solar Spectral Irradiance (NRLSSI)

Lean et al. (1997, 2000)

COde for Solar Irradiance (COSI)

Shapiro et al. (2011), Cessateur et al. (2014)

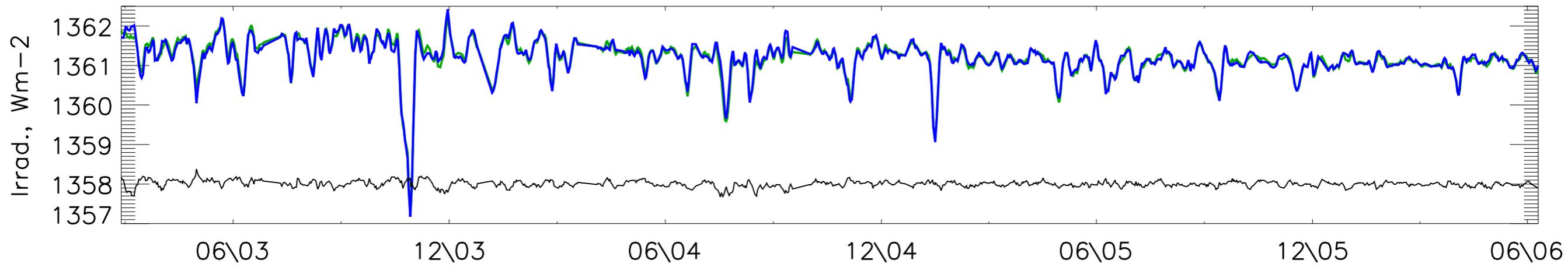
Spectral And Total Irradiance REconstructions (SATIRE)

Krivova et al. (2006), Ball et al. (2012)

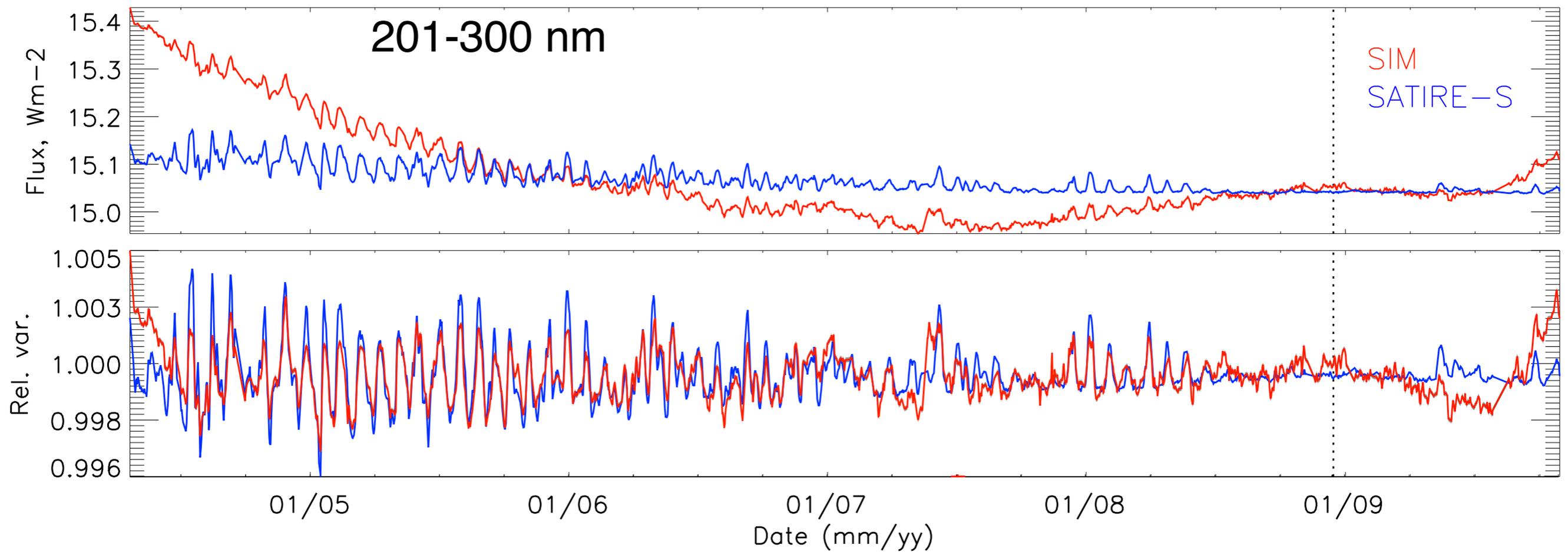
# Modelling of the solar rotational variability



# TSI



from Ball et al. (2011)



# Modelling of the solar variability with COSI

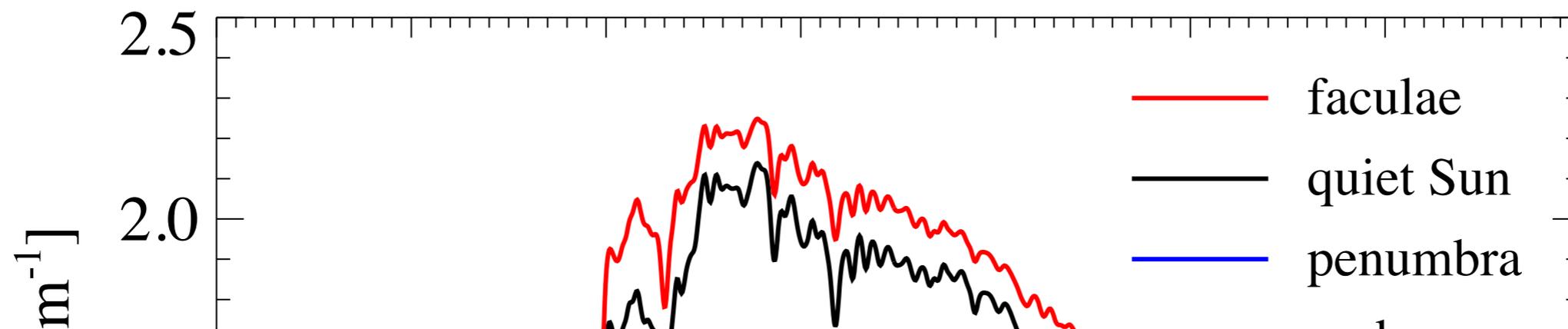


**Sunspot (umbra + penumbra)**

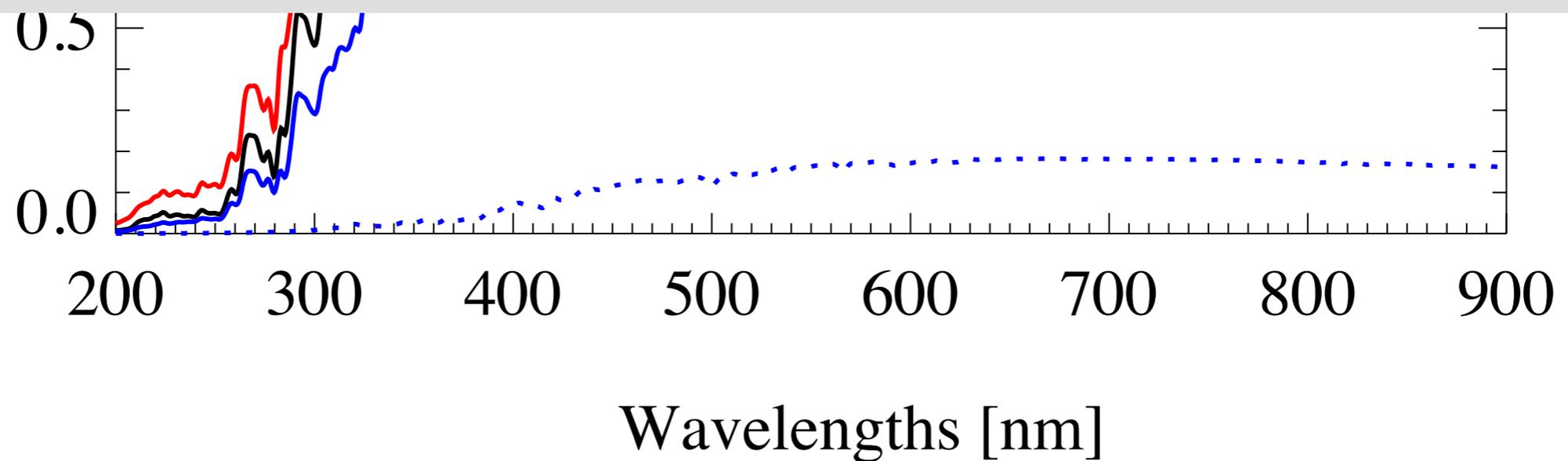
**Faculae**

**Bright network**

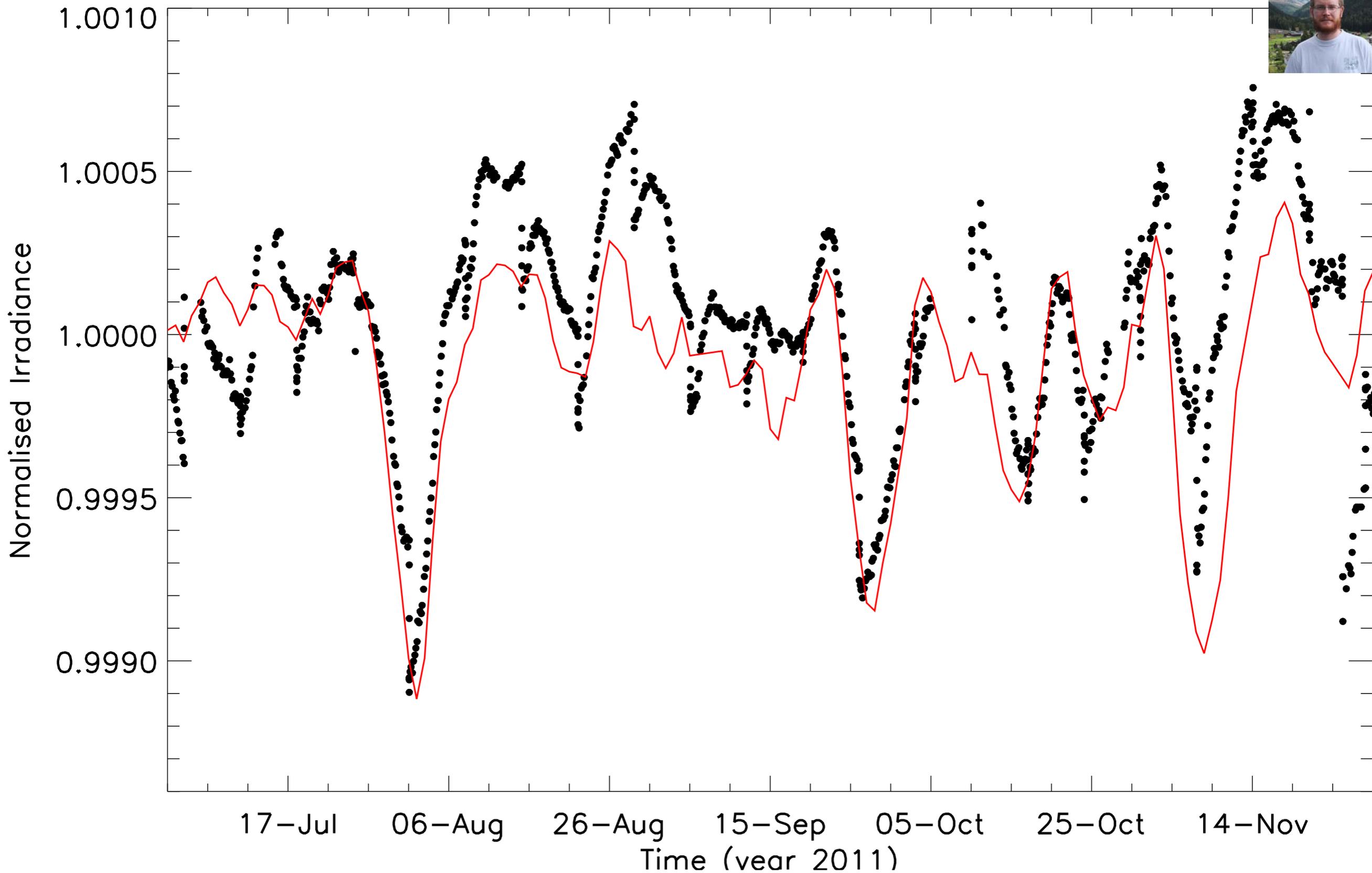
**Quiet Sun**



surface coverages from HMI/SDO (Yeo et al. 2013)

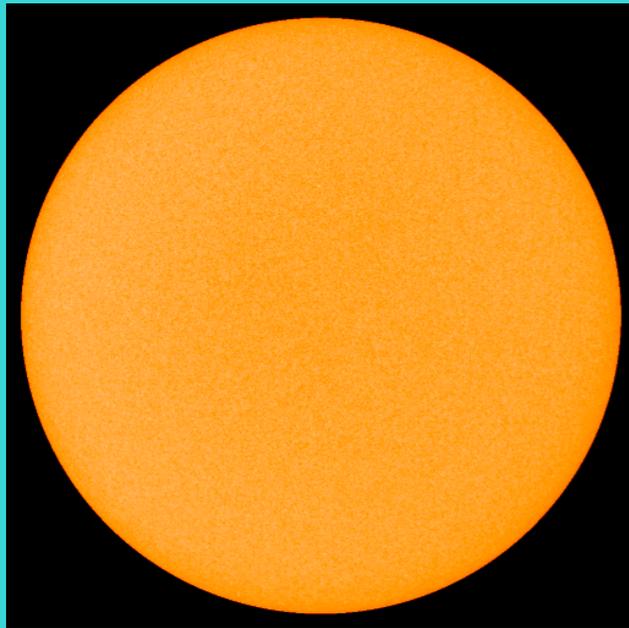


# Irradiance at 607 nm

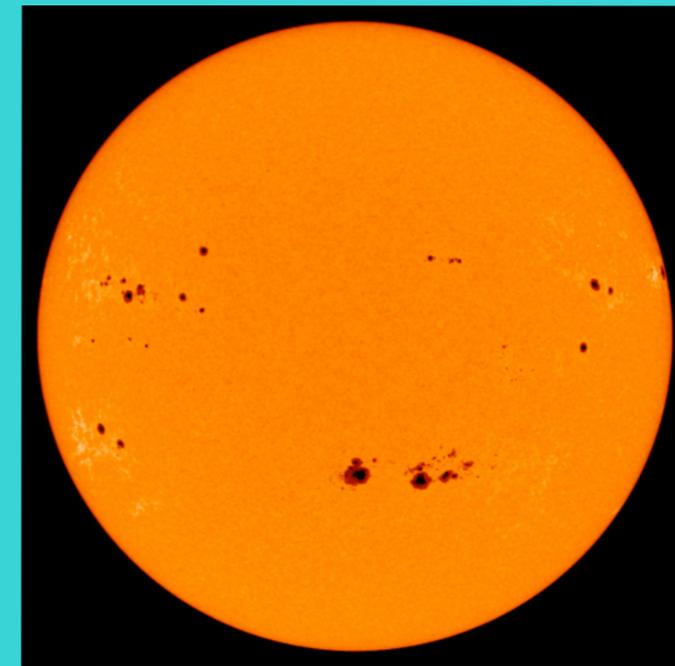


# Modelling of the solar 11-year variability

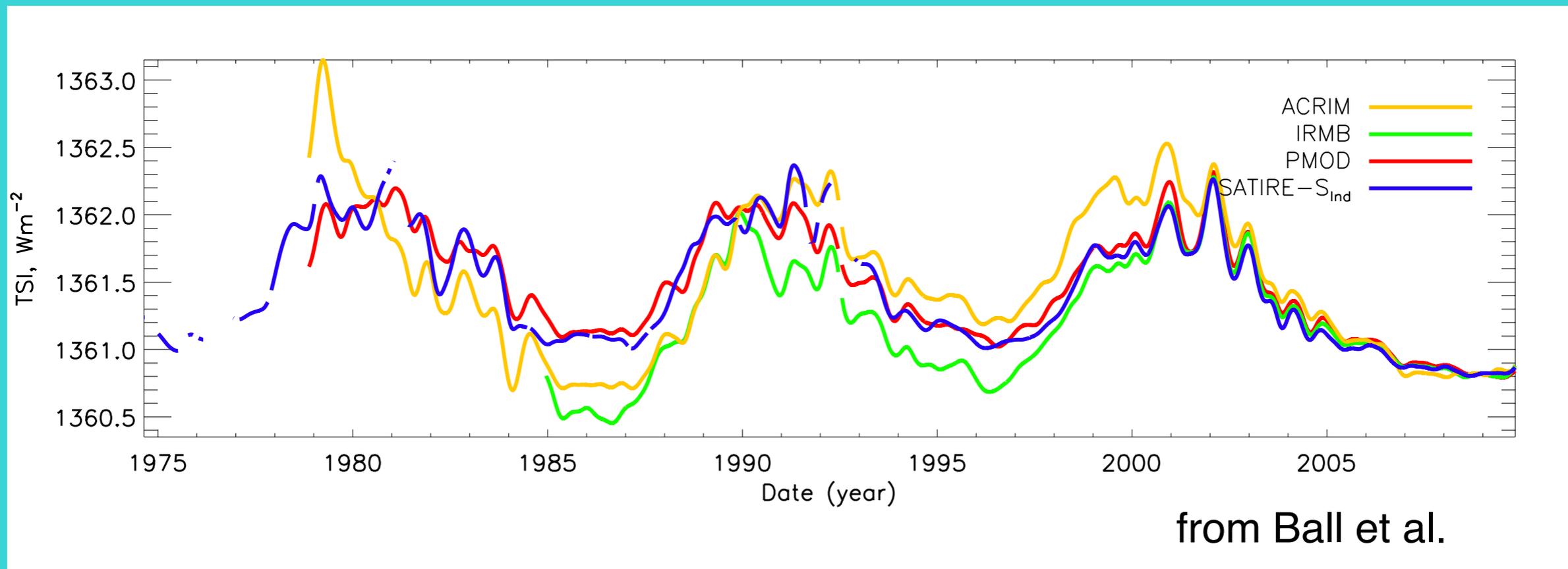
solar min

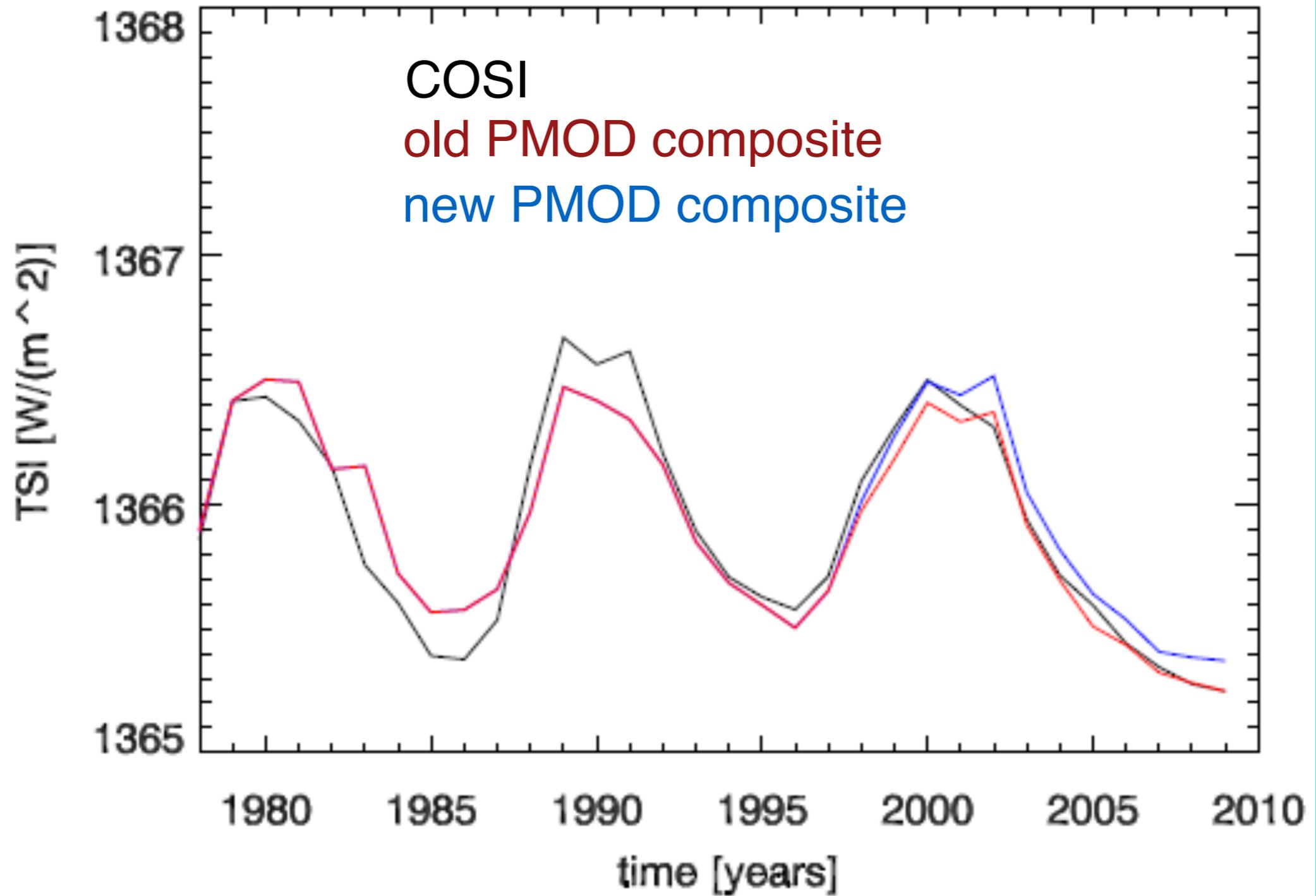


solar max



TSI



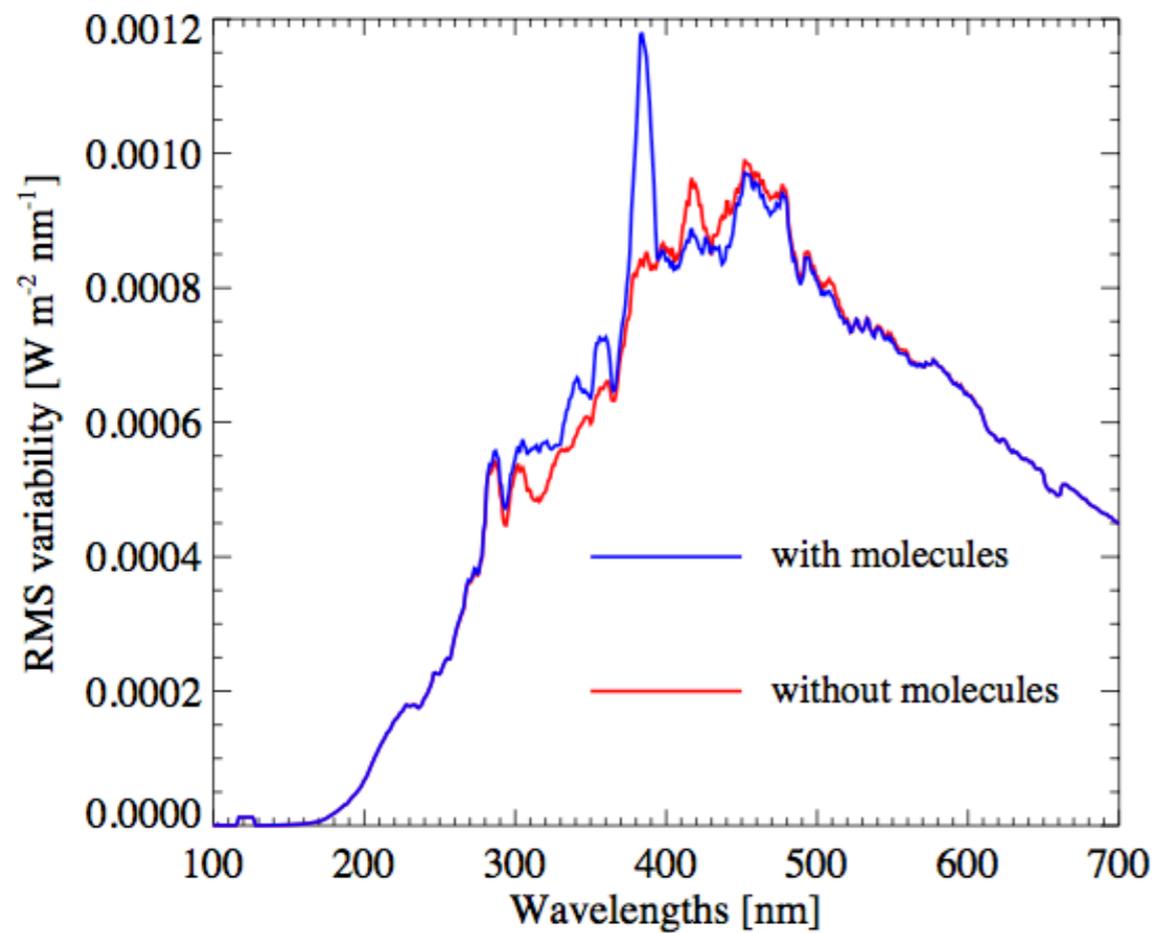


thanks to W. Adams

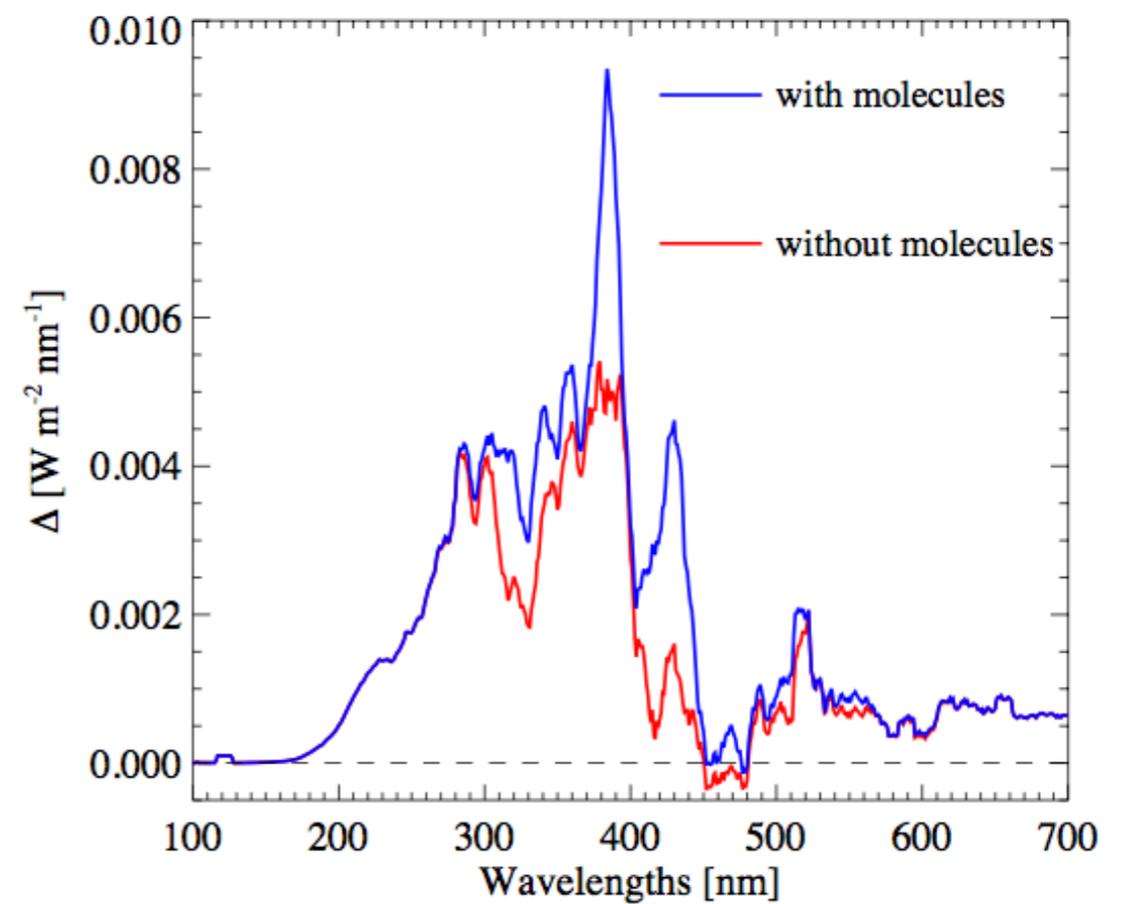


# One possible complication

27-day



11-year

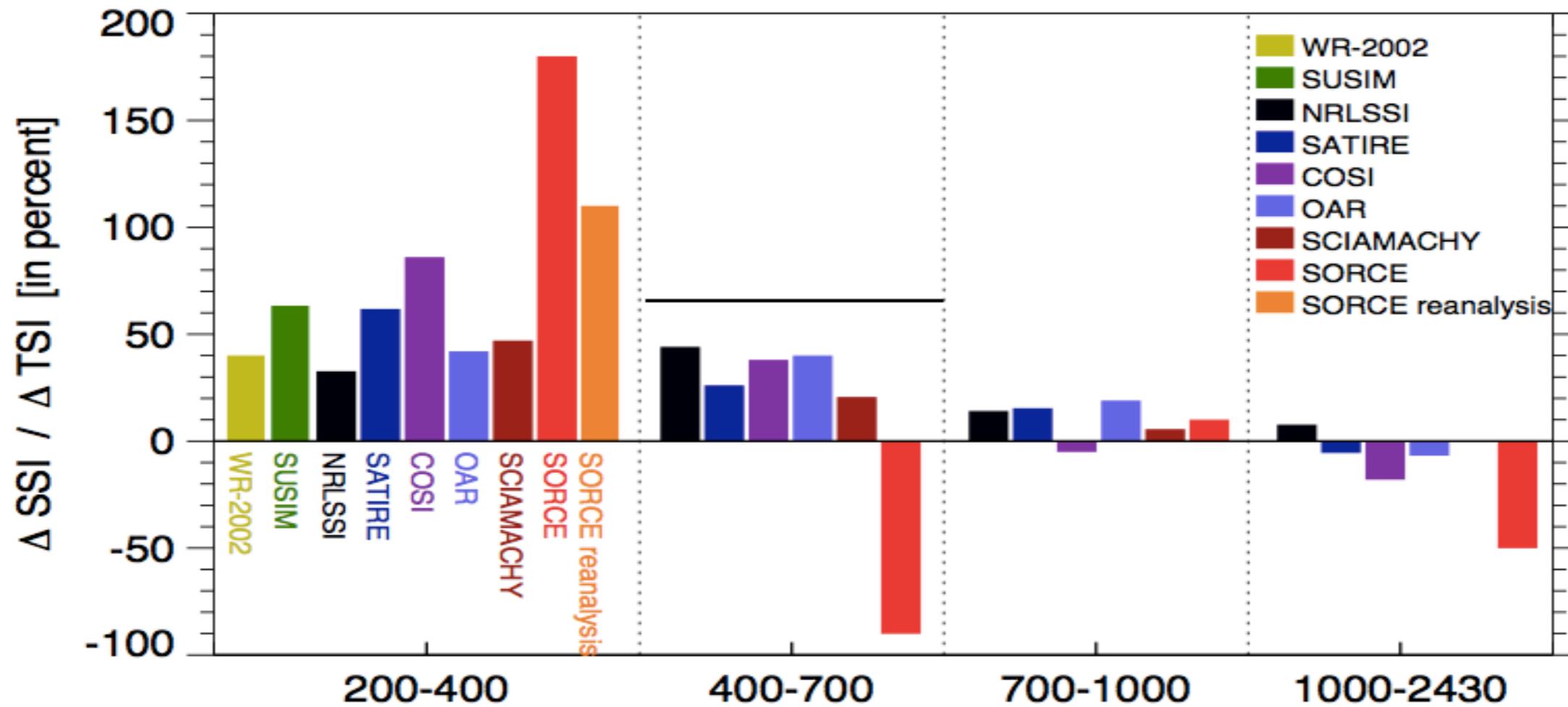


COSI

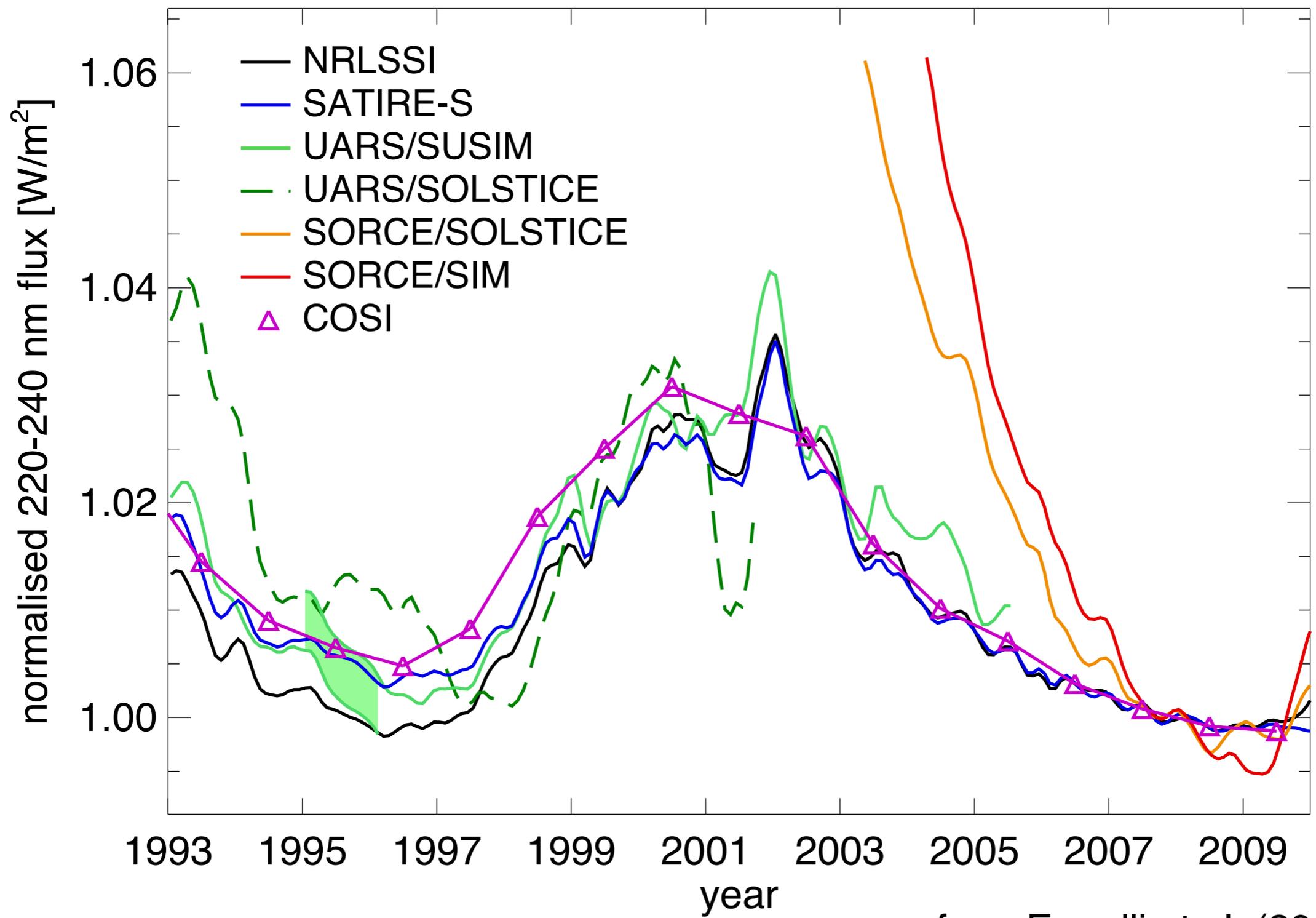


SATIRE

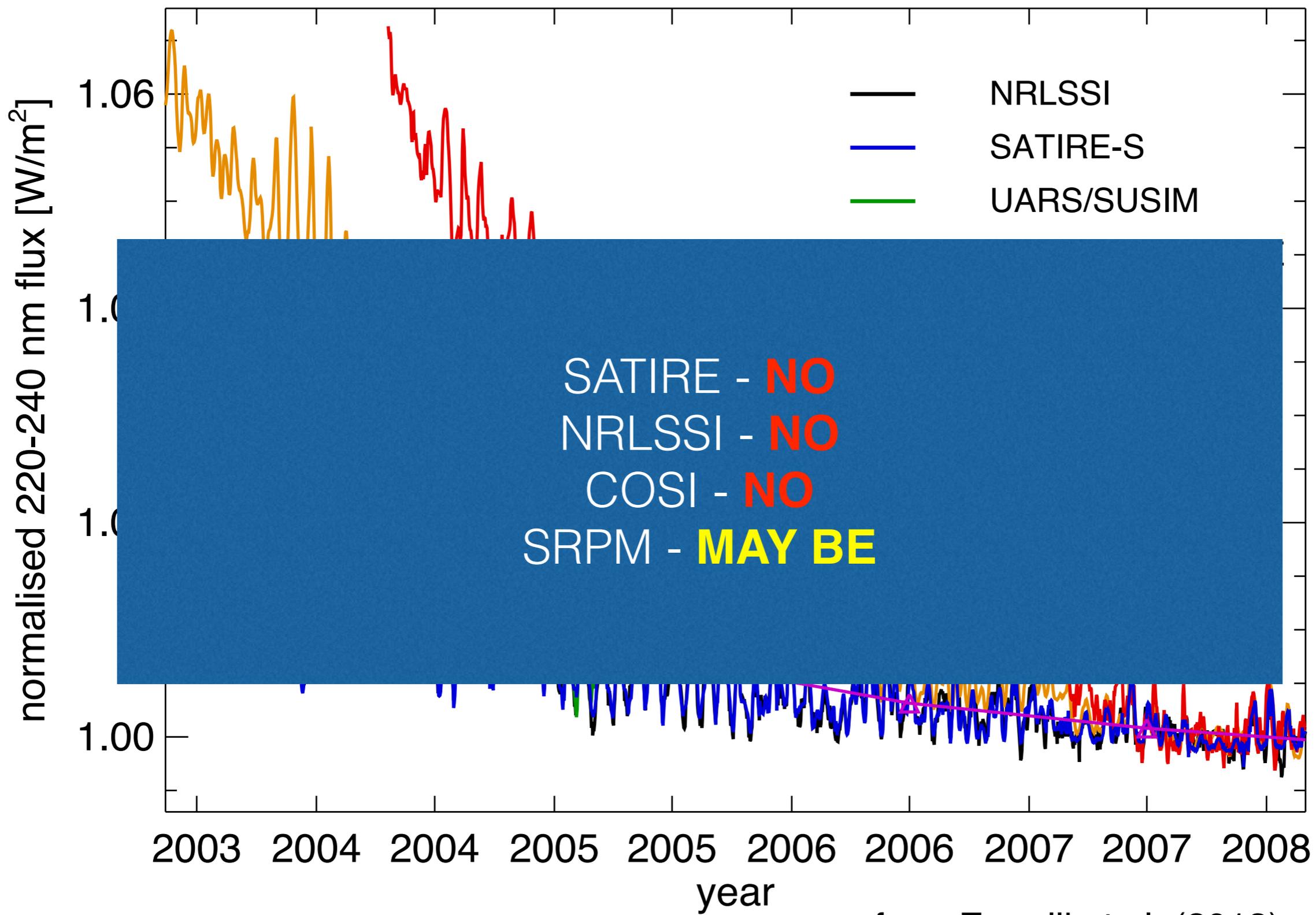
# What about SSI?



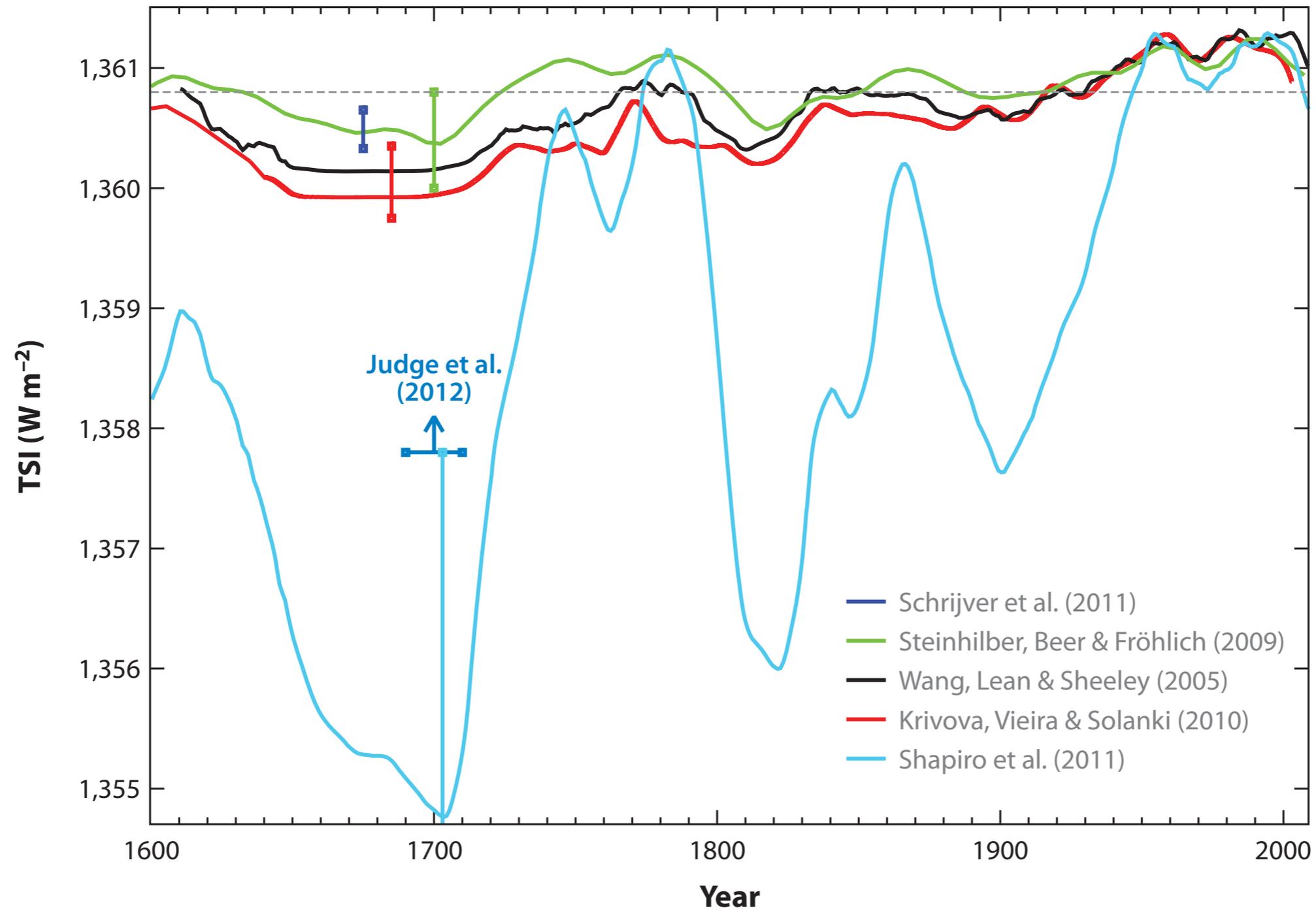
from Ermolli et al. (2013)



from Ermolli et al. (2013)



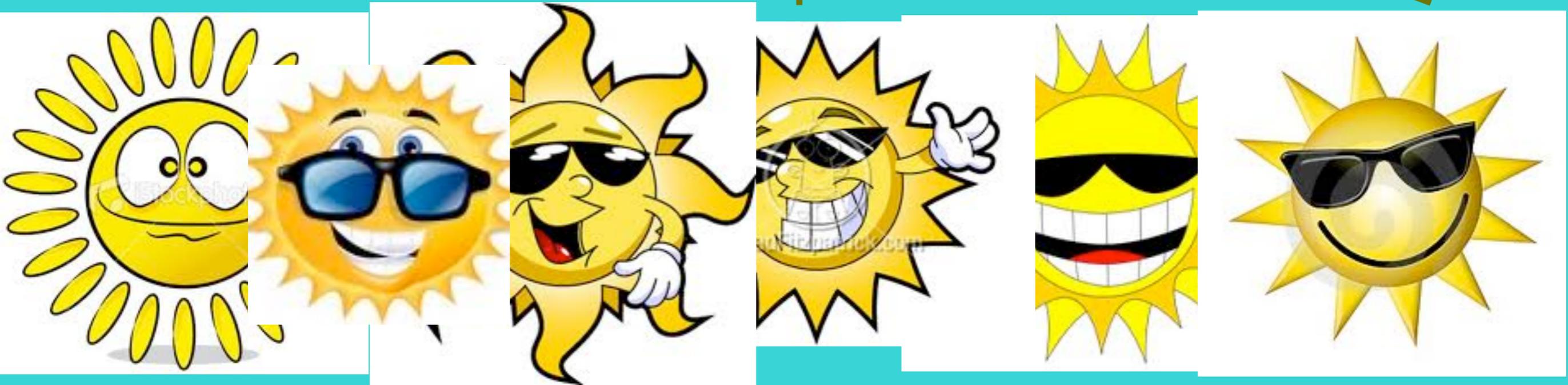
# Modelling of the long-term solar variability



from Solanki et al. (2013)

# Secular variability

$$SSI(\lambda, t)$$

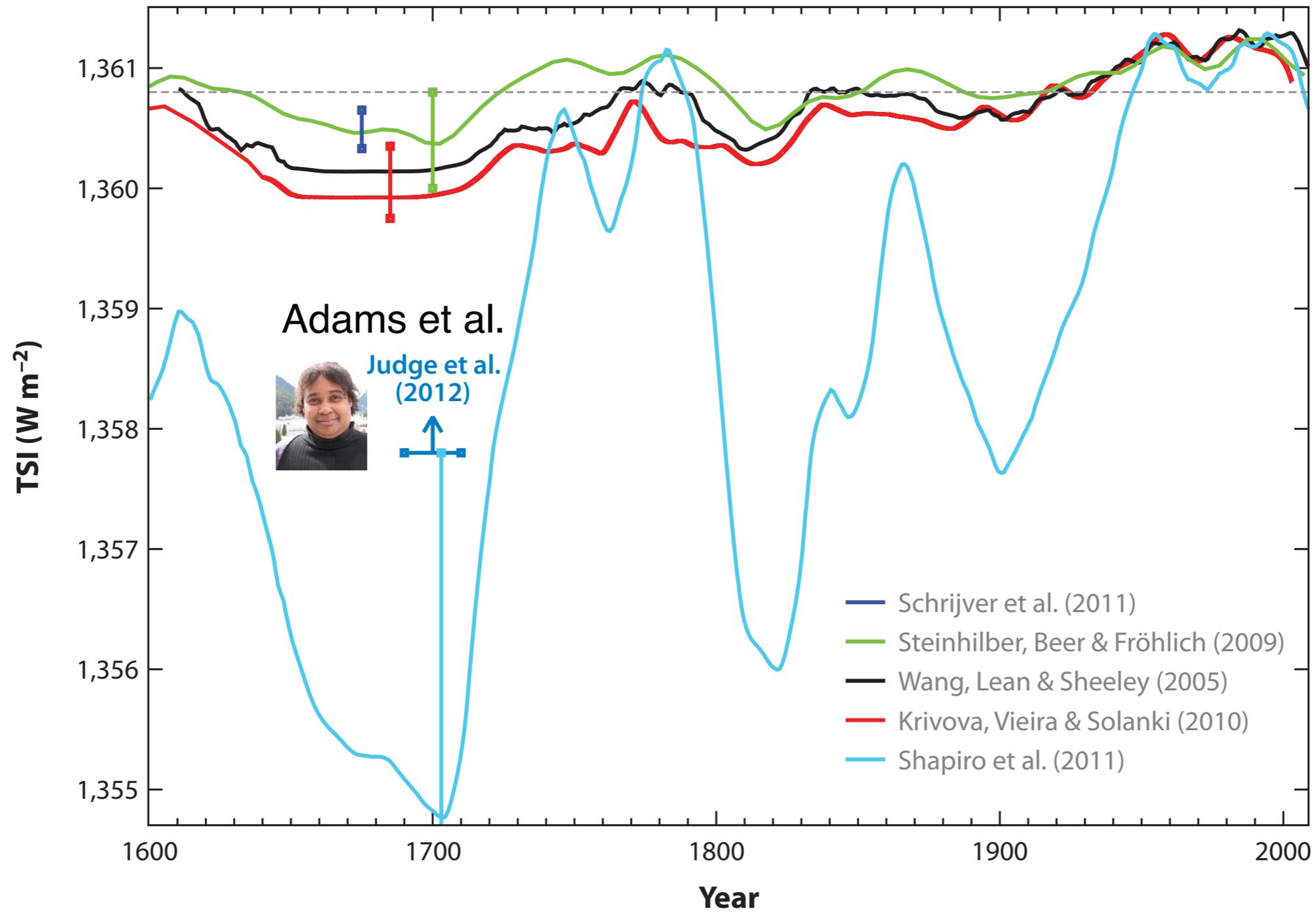


Minimum Sun

Present Sun

Linear interpolation using available proxies of the solar activity

# Modelling of the long-term solar variability



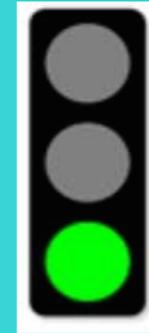
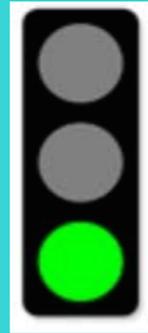
from Solanki et al. (2013)

# *Brief summary*

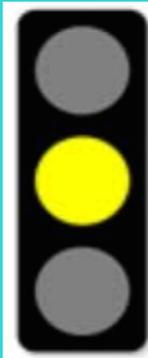
TSI

SSI

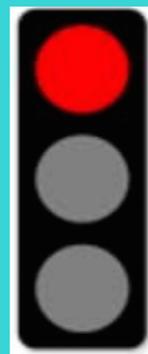
27-day



11-year



long-term



*What to do?*

# Modelling of the solar variability



**Sunspot (umbra + penumbra)**

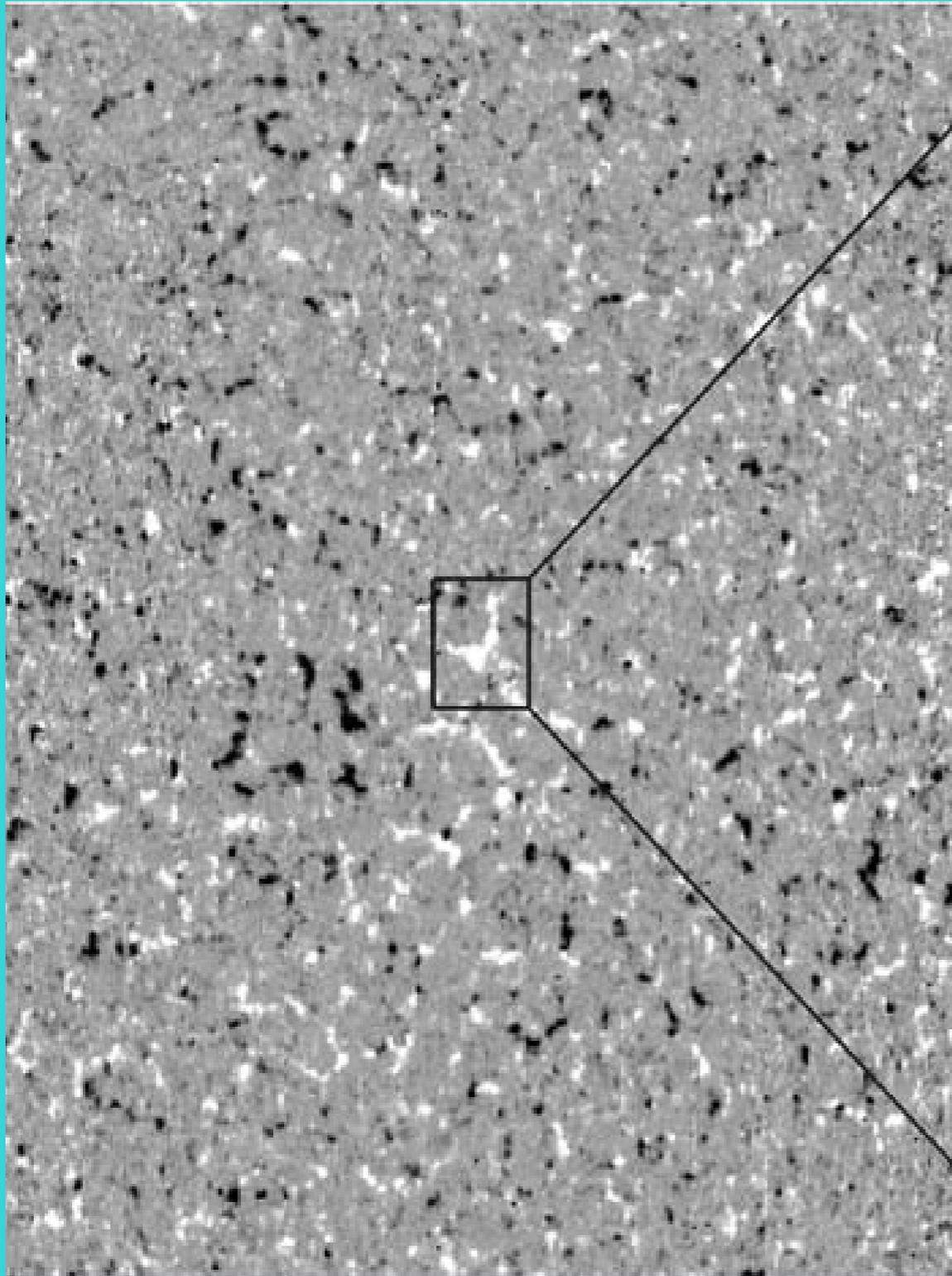
**Faculae**

**Bright network**

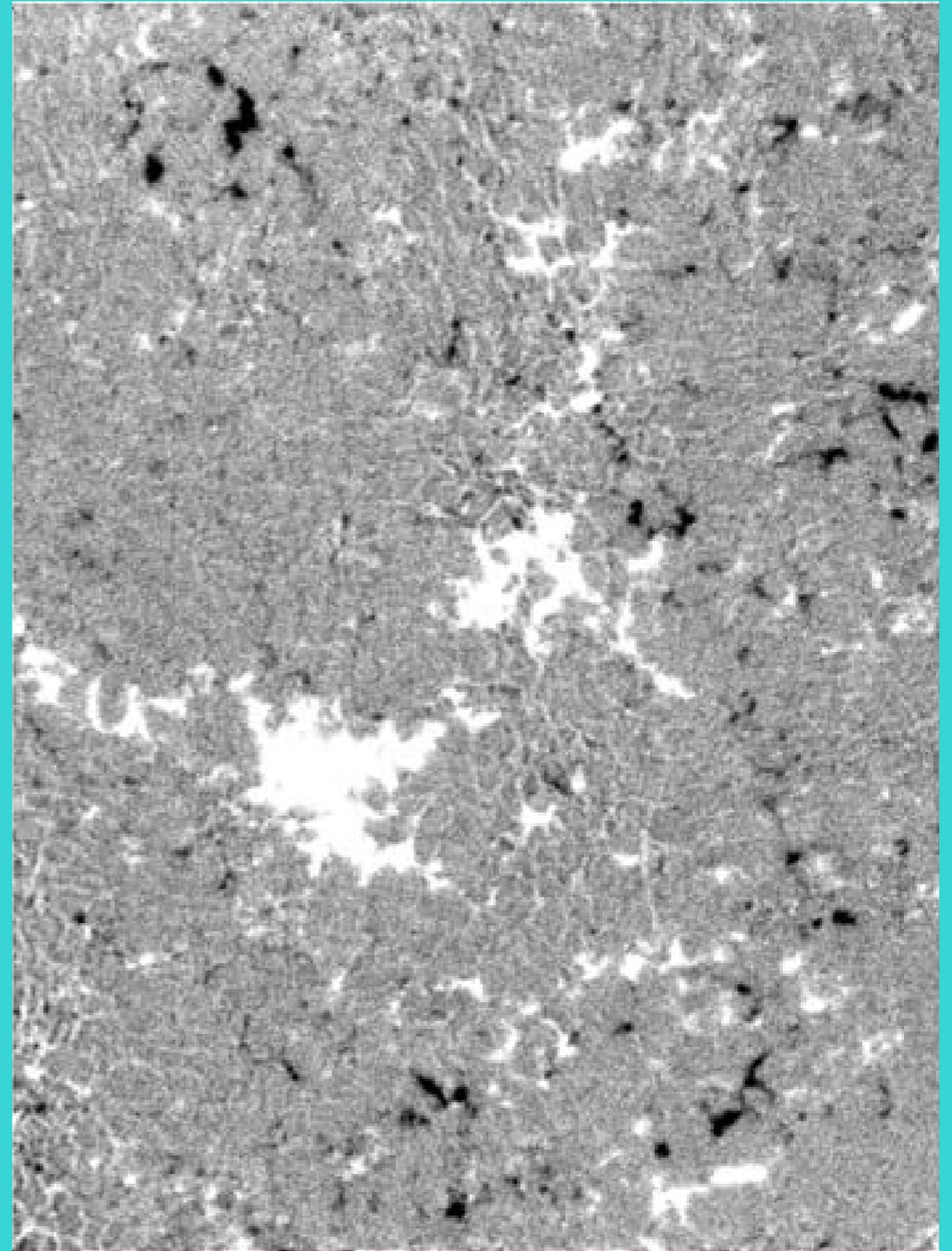
**Quiet Sun**

# Solar magnetism

15 % of the solar disk



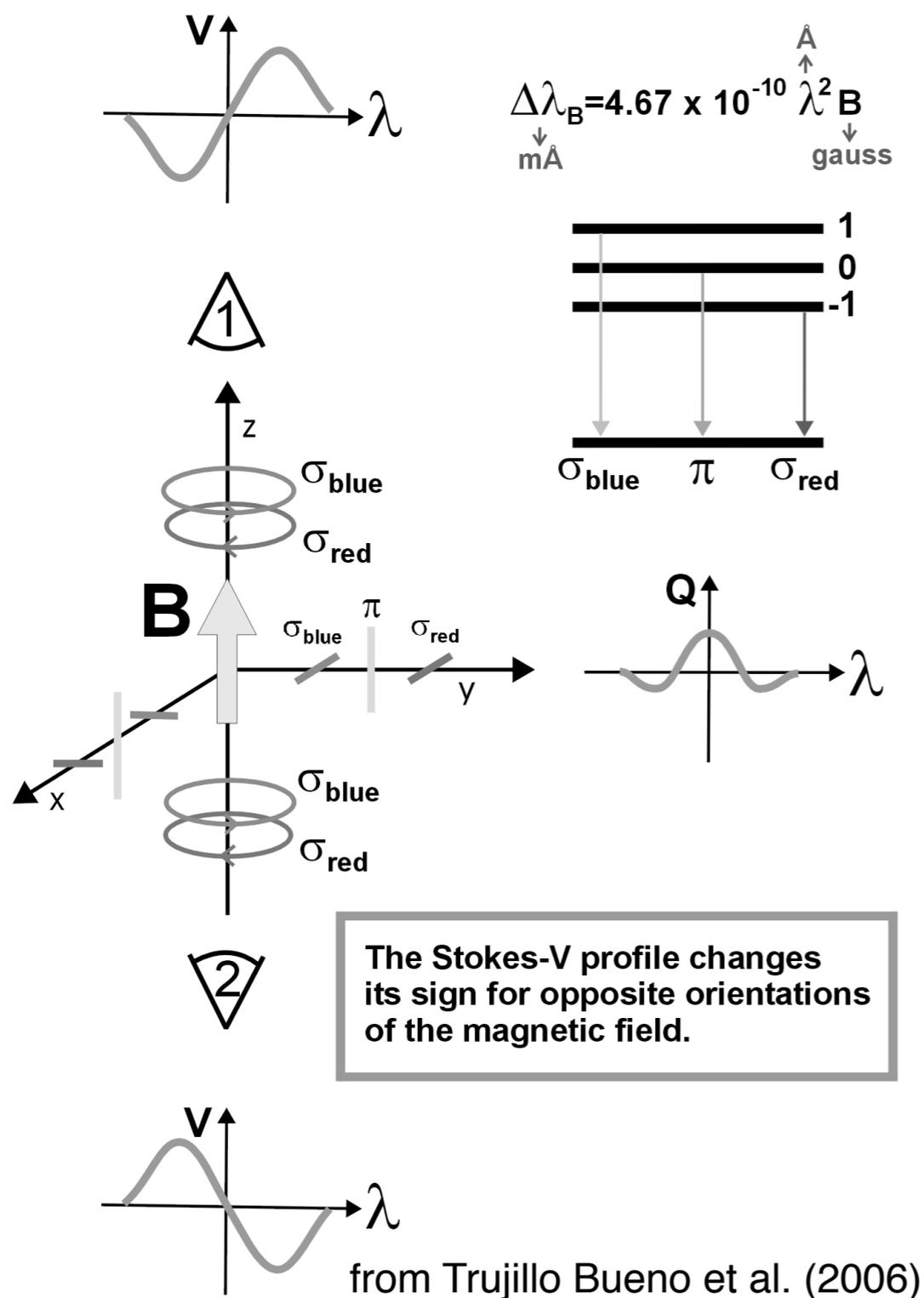
Kitt Peak



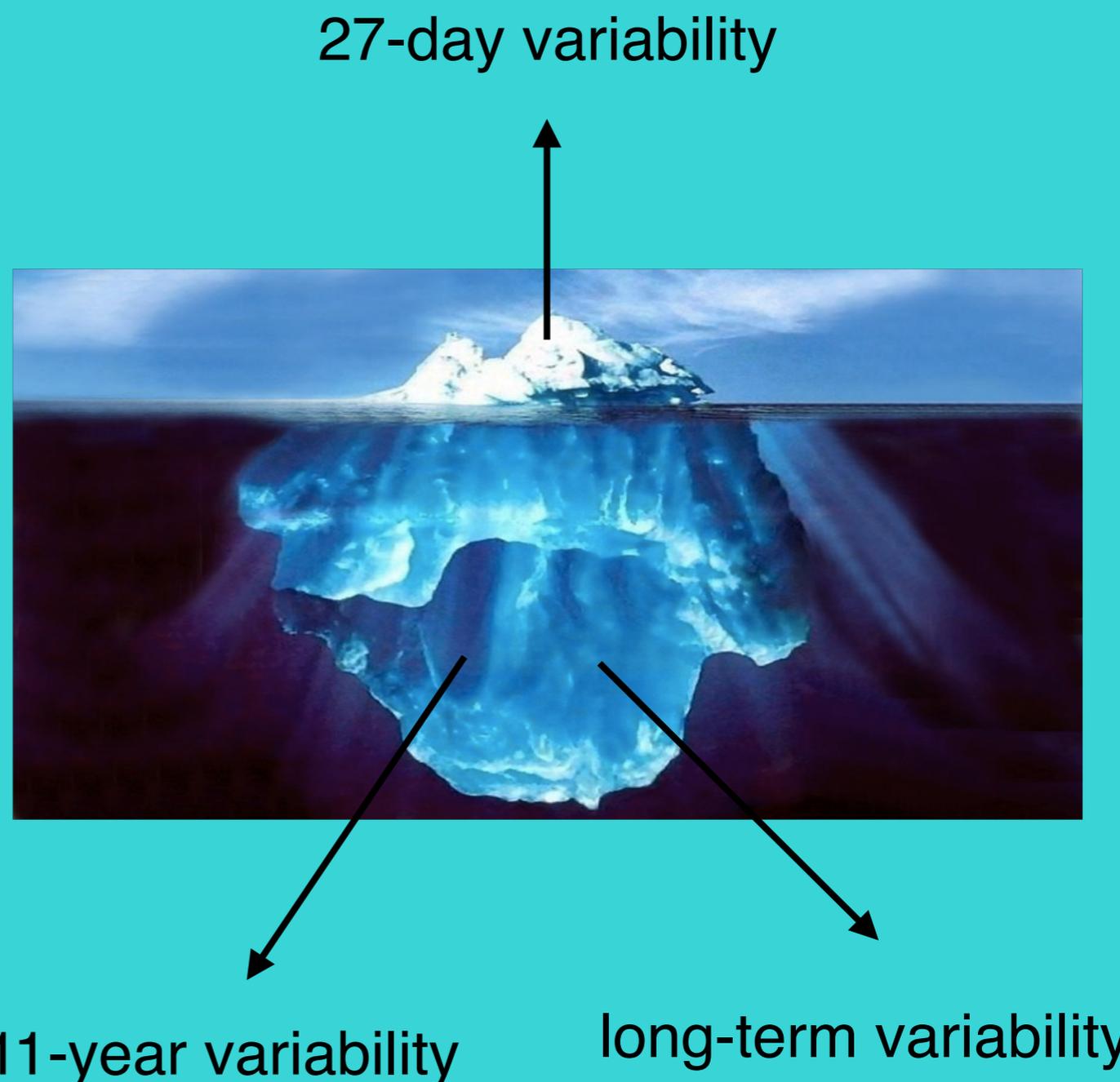
SST

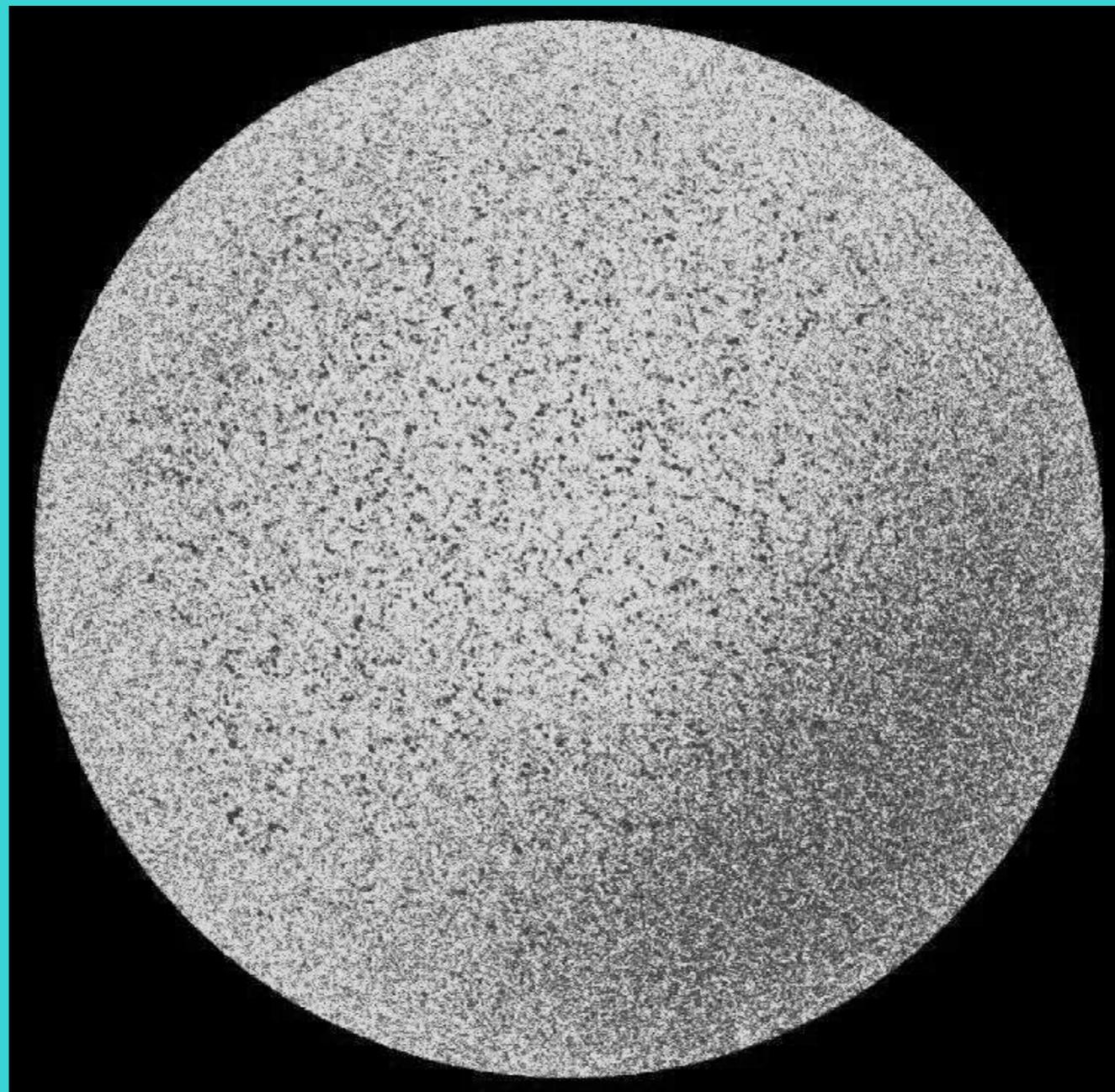
from Stenflo et al. (2008)

### The Zeeman Effect



The resolved magnetic field is just “tip of the iceberg”





from Ball et al. (2012)

NO contribution to the rotational variability

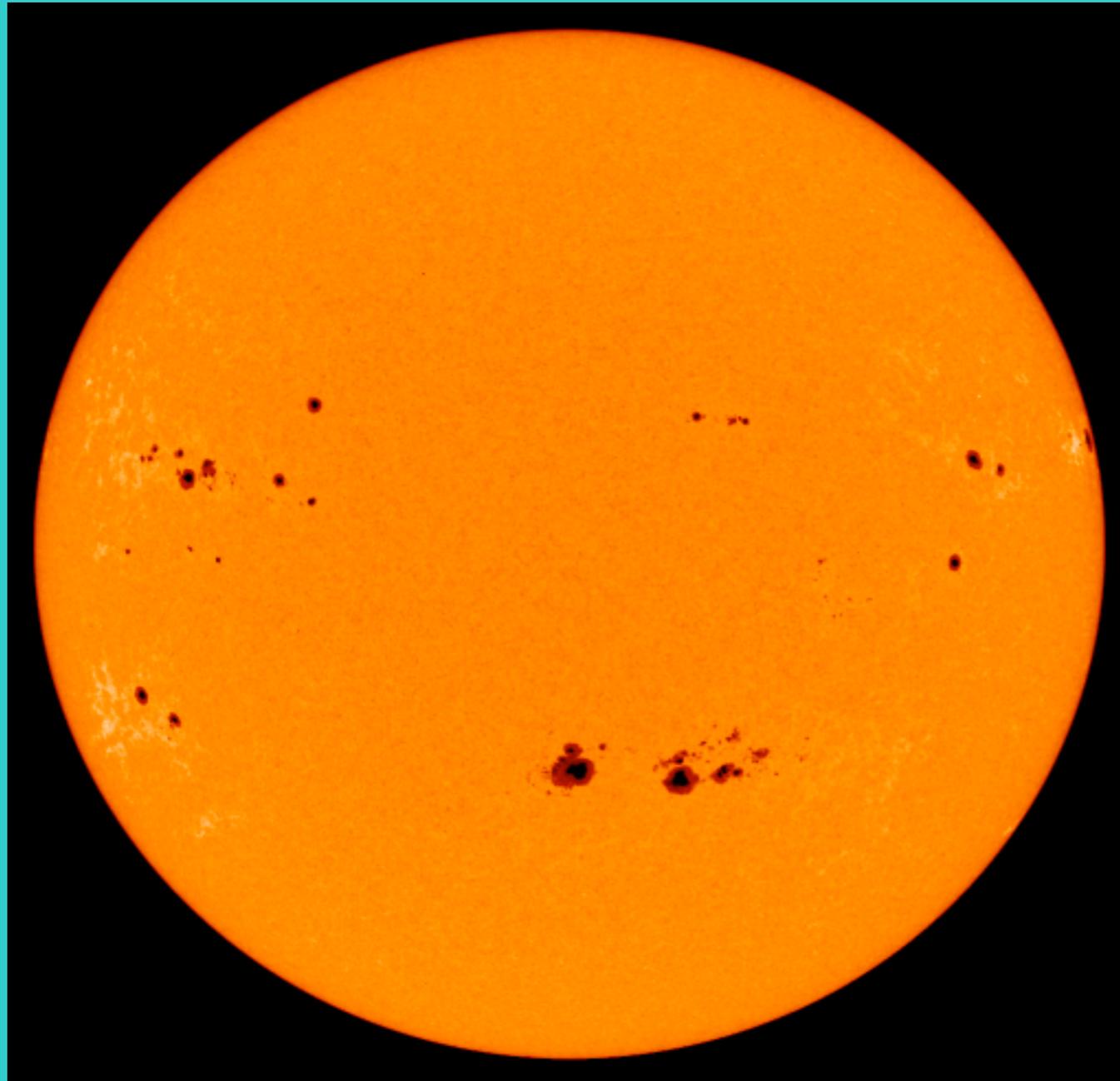
Strong contribution to the 11-year and possibly long-term variability

???

$I(\lambda, \mu)$



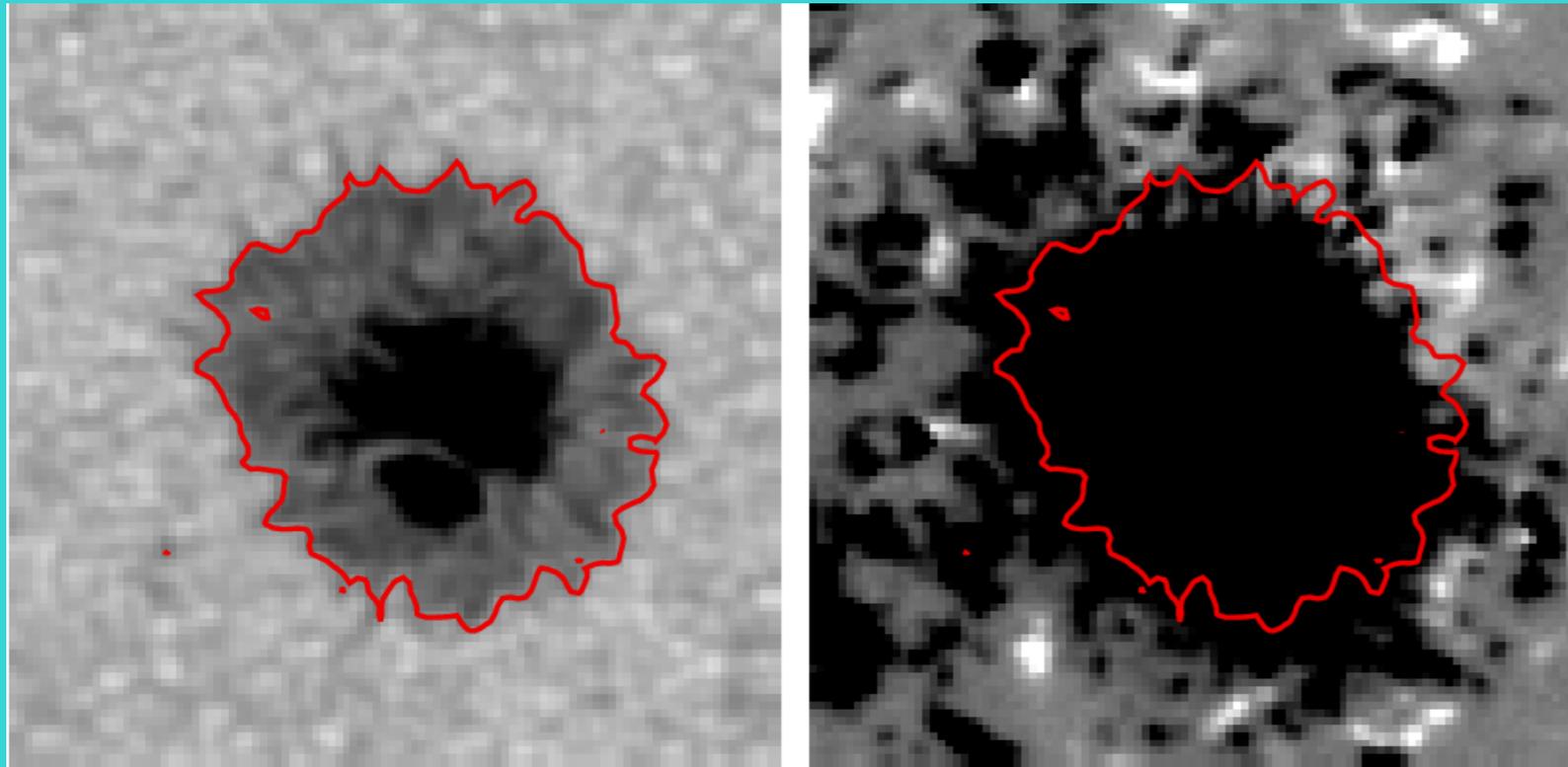
**B**



***What to do?***

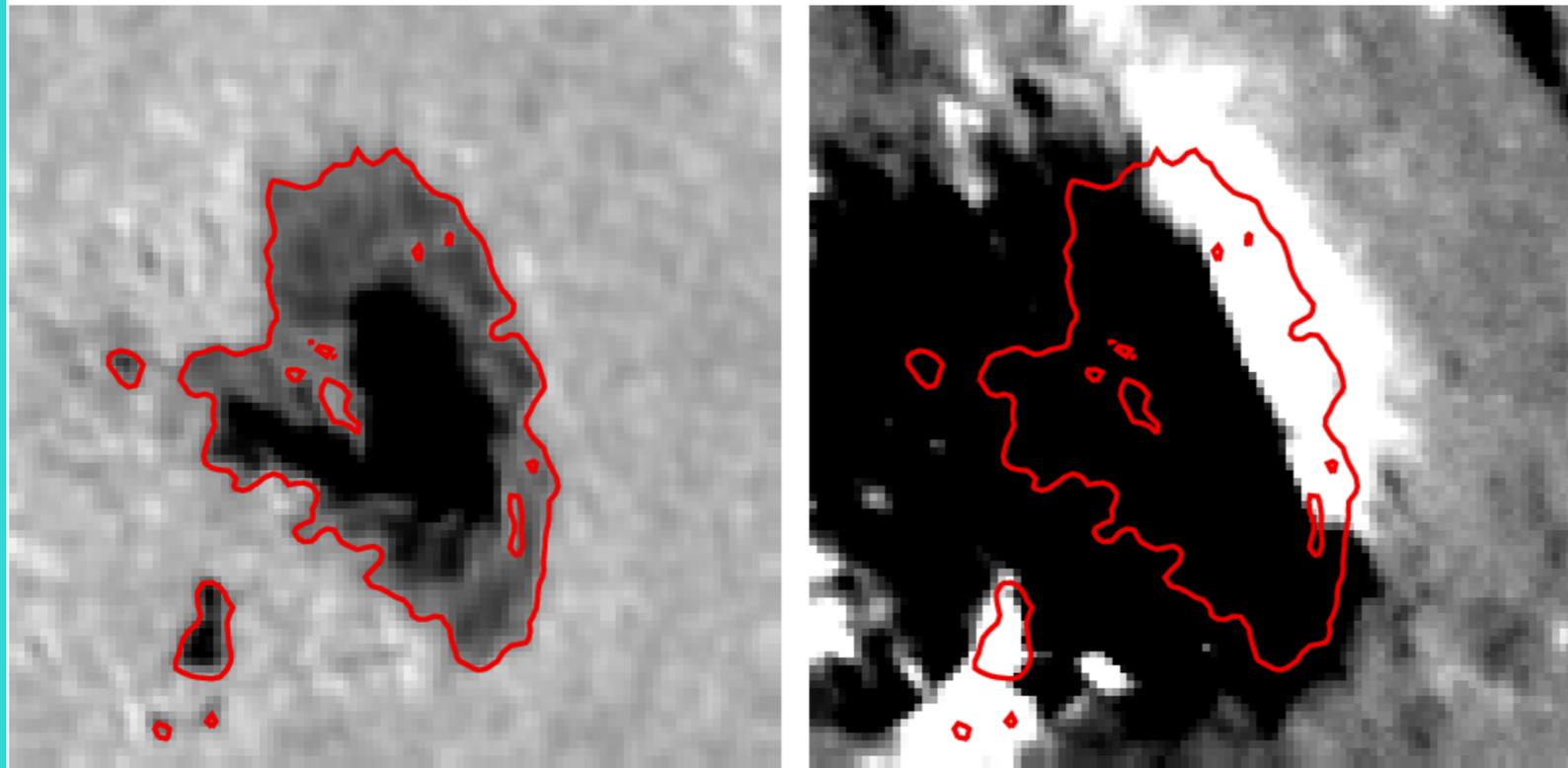
# Helioseismic and Magnetic Imager on-board the Solar Dynamics Observatory

800 km resolution



Secular changes in solar irradiance may be considerably larger than what some models of solar irradiance variations have suggested, given the variation in the number of small-scale magnetic elements on the solar disc is a prime candidate driver of secular changes

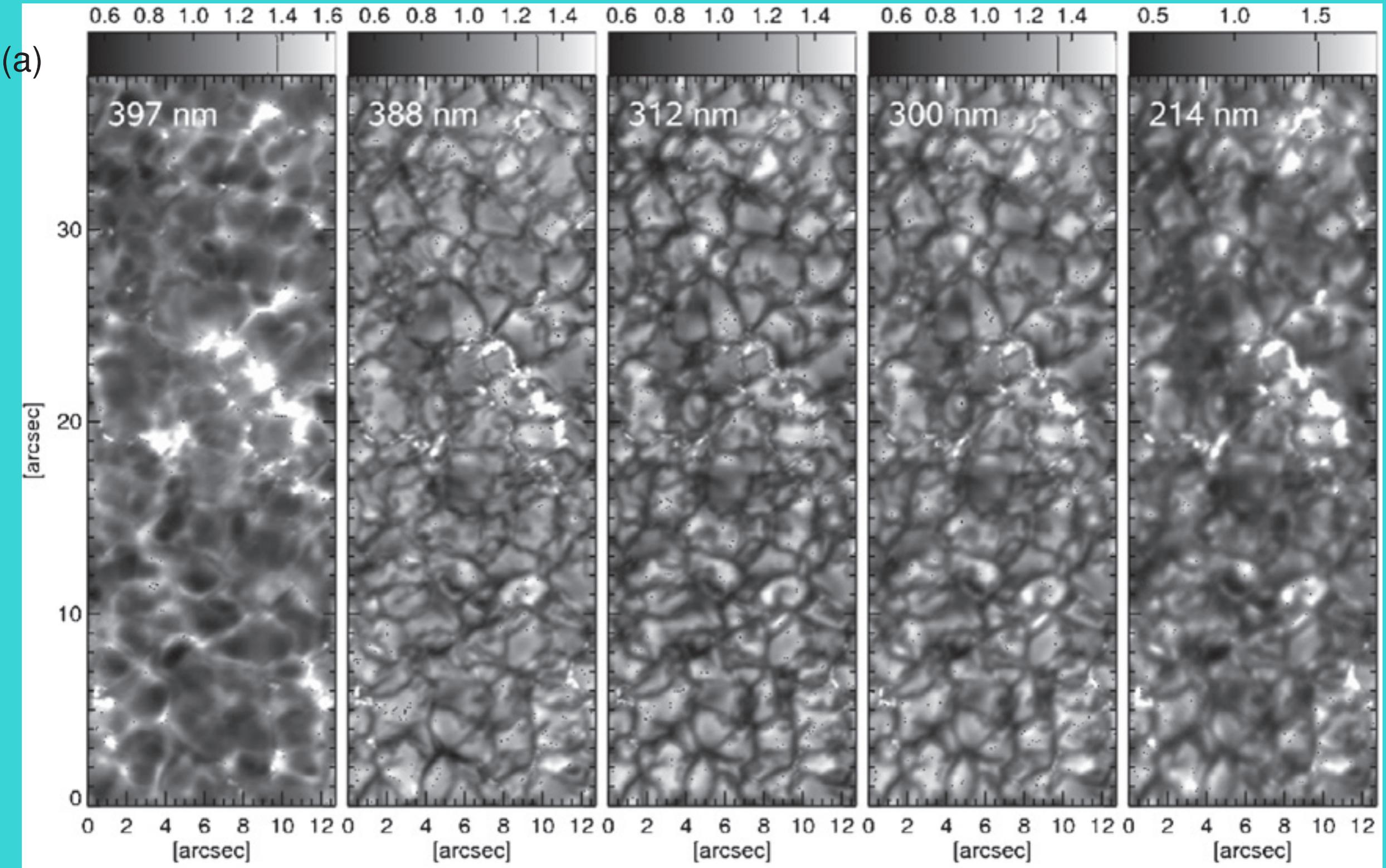
Yeo, Solanki, and Krivova (2013)



Continuum Intensity

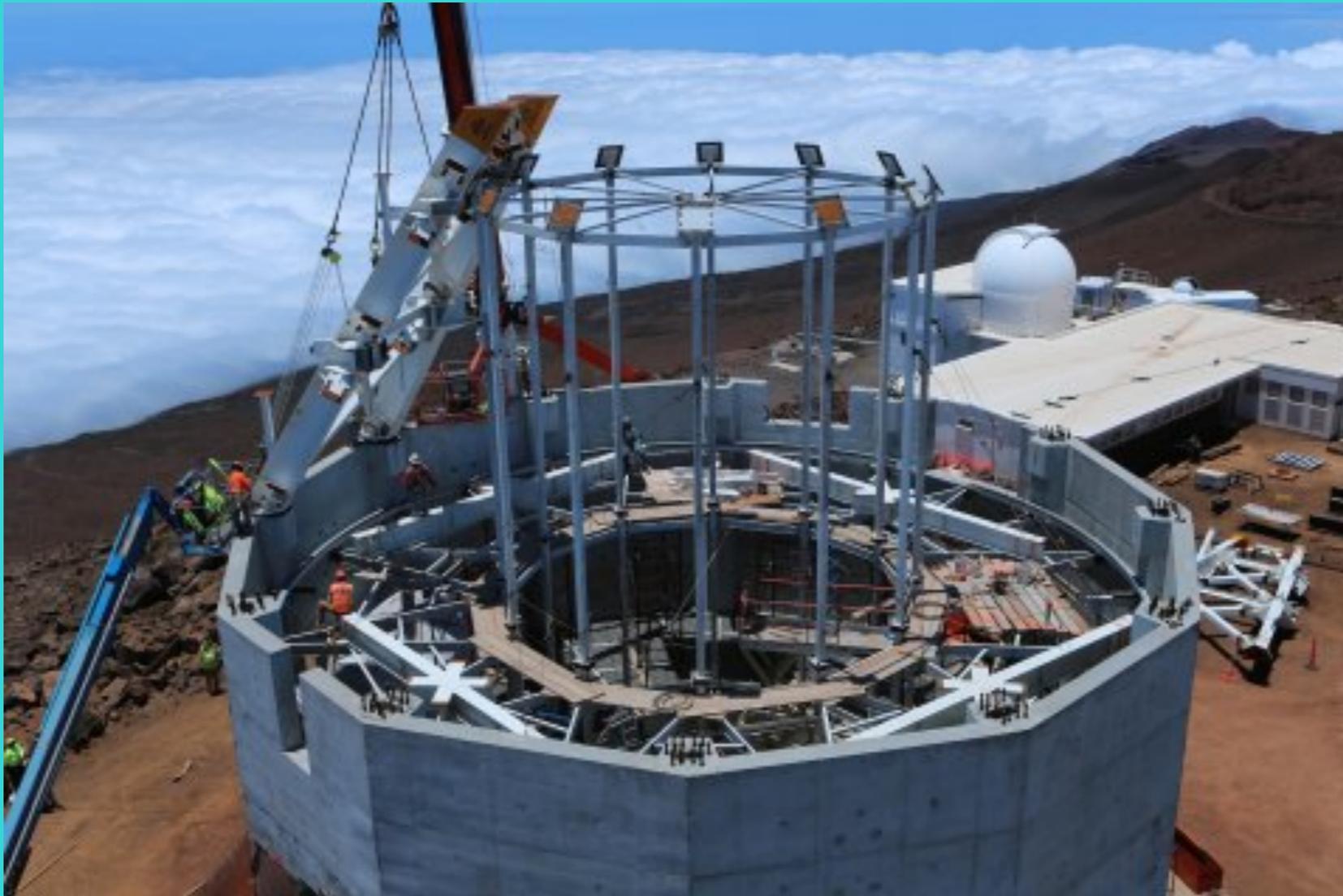
# SUNRISE flights

100 km resolution



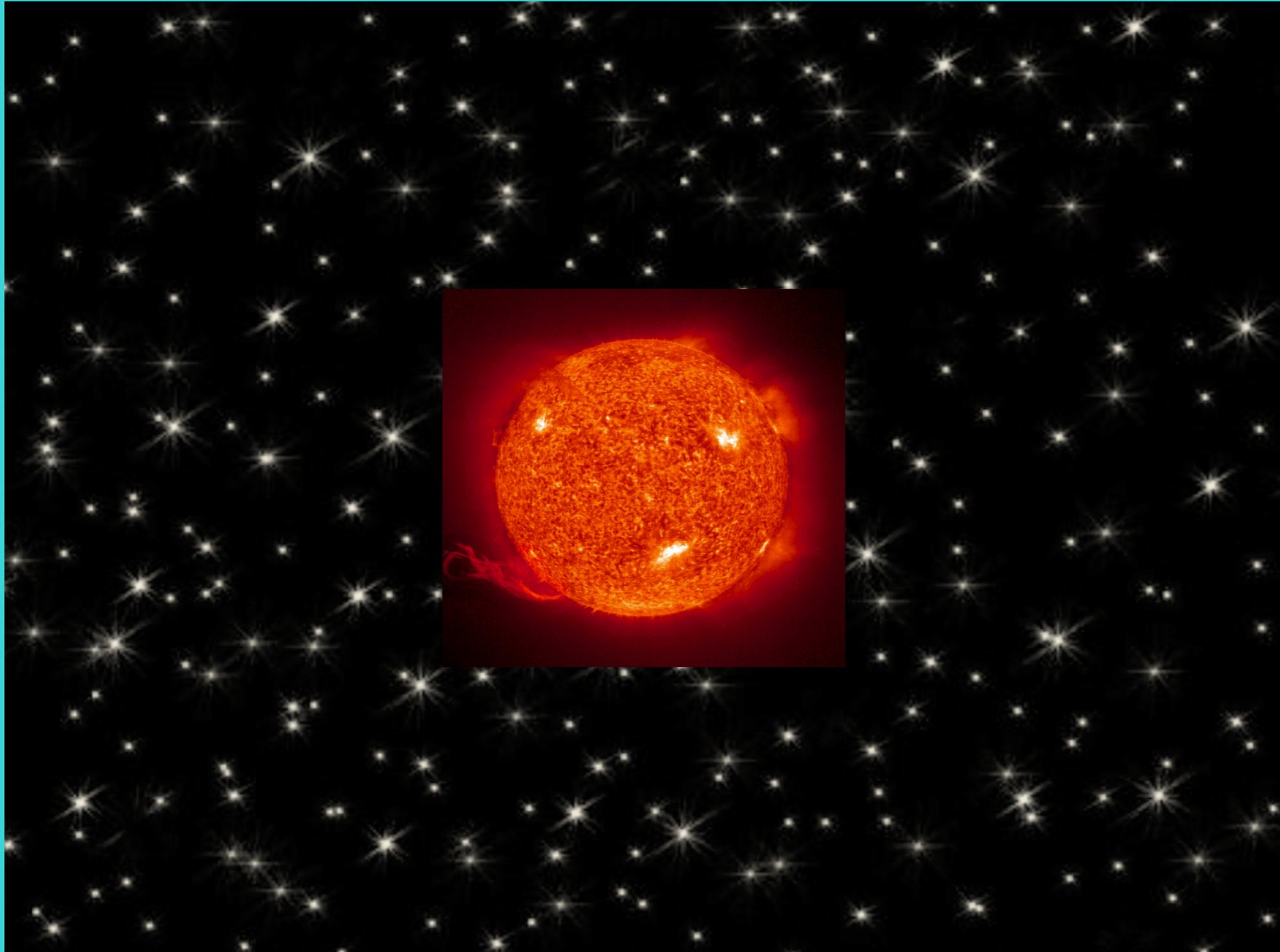
# DANIEL K. INOUE SOLAR TELESCOPE (Advanced Technology Solar Telescope, ATST)

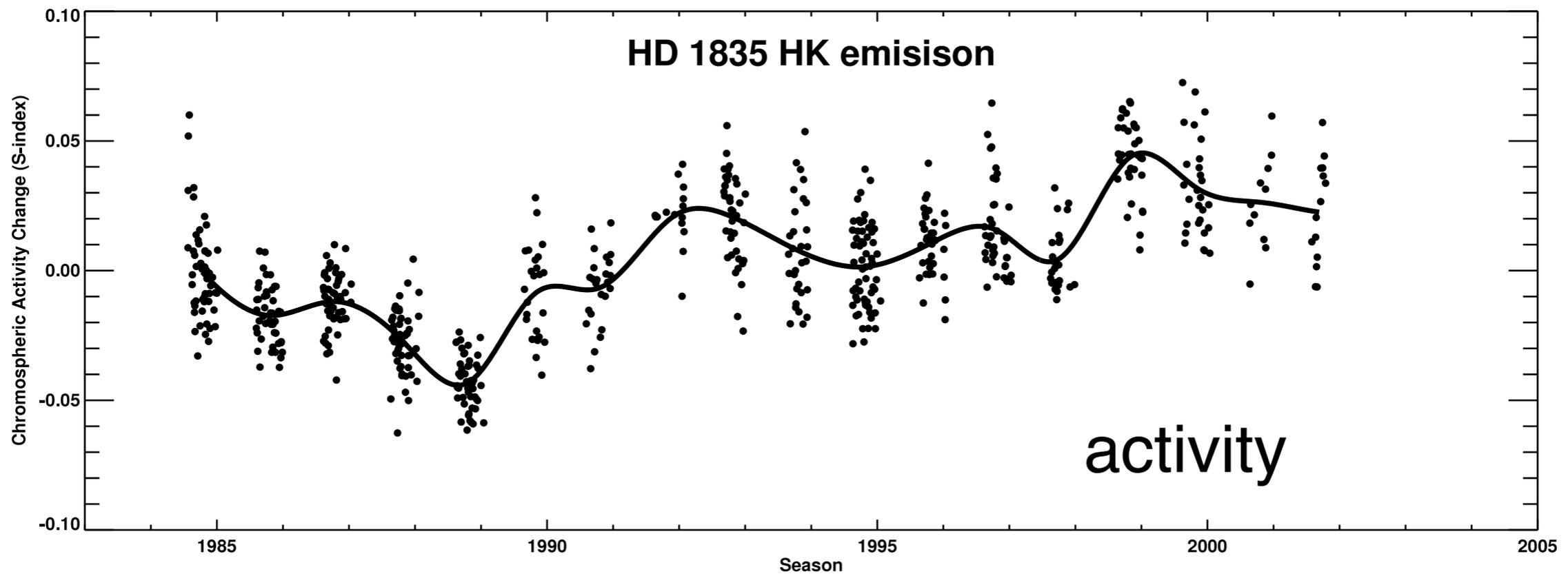
up to 30 km resolution



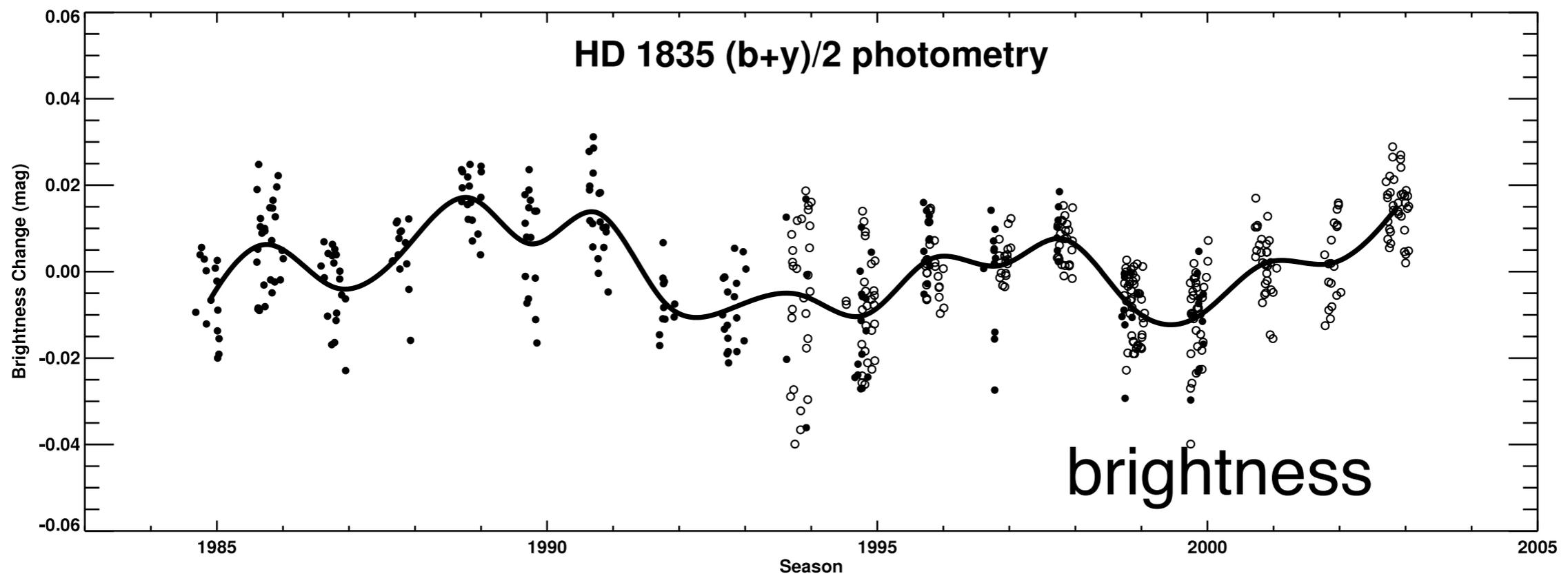
**An alternative way...**

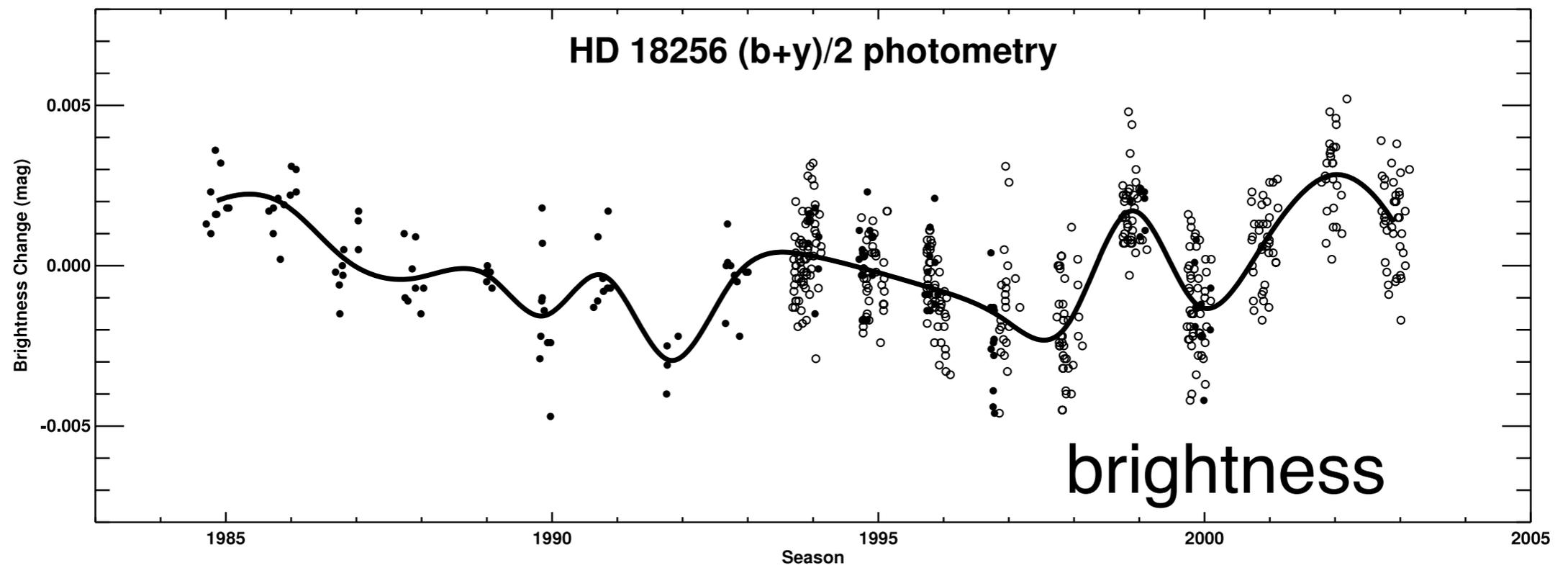
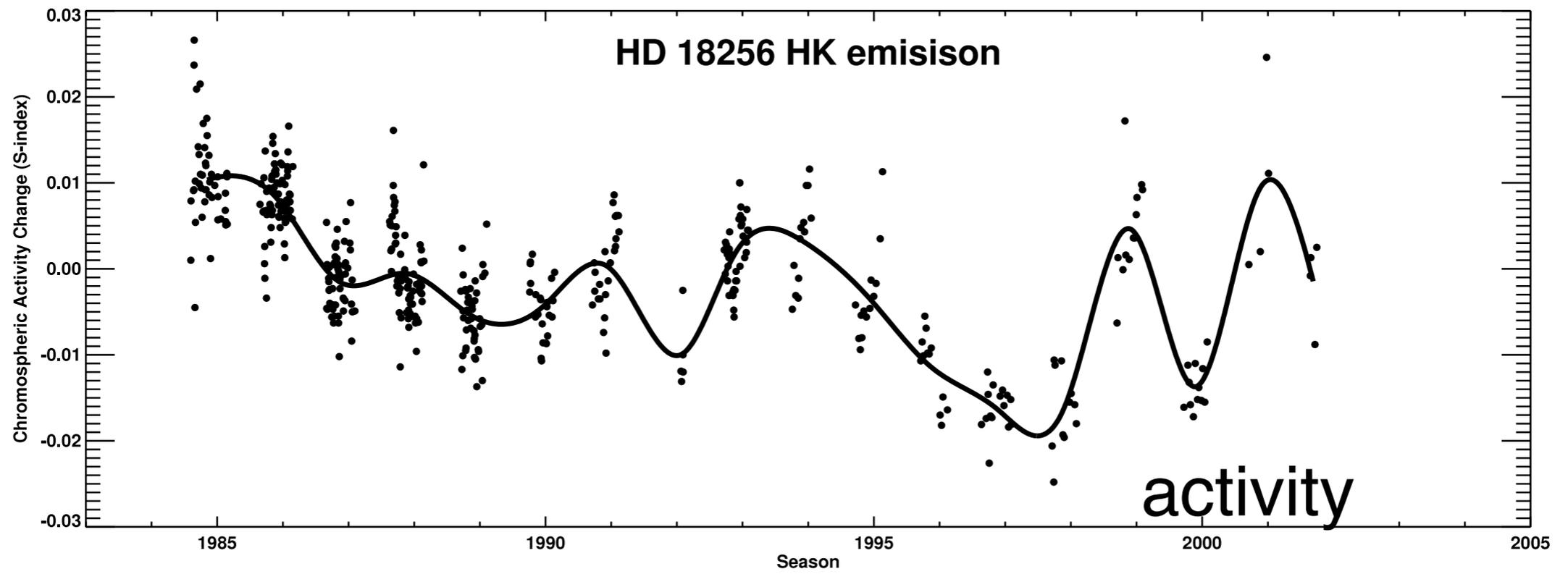
**Let us look at stars...**



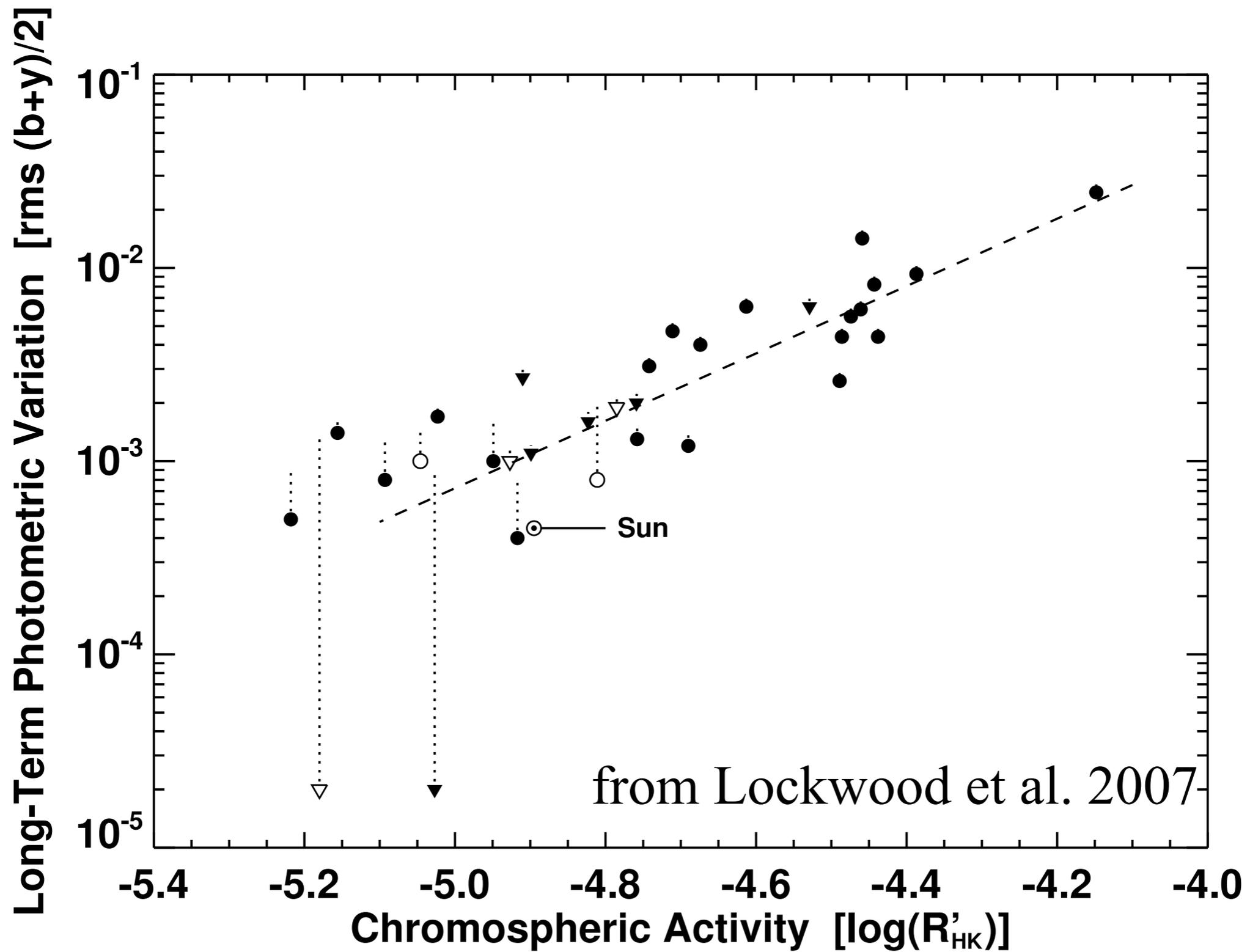


**solar variability 0.0002 mag**

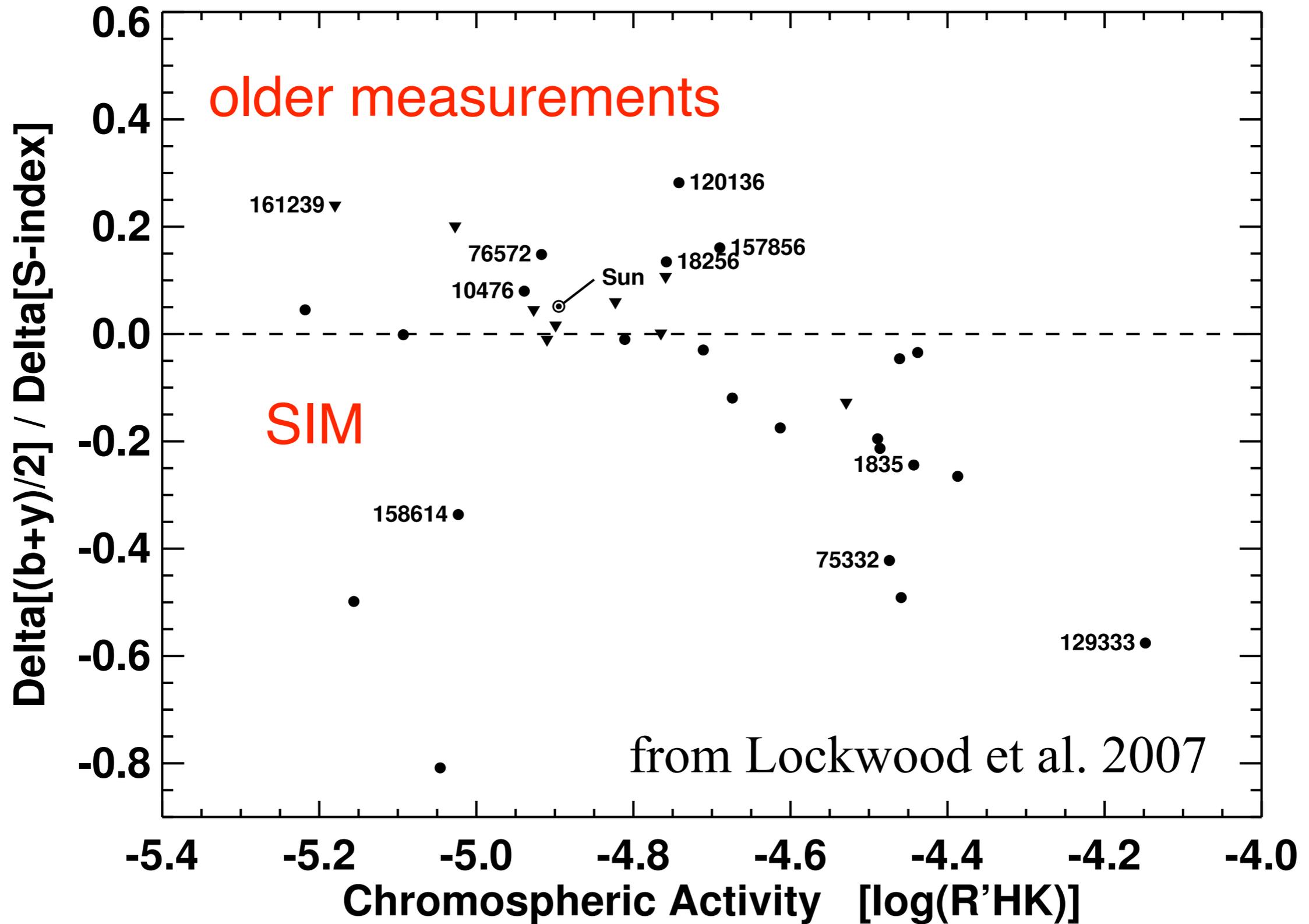




# Variability as a function of activity



# Spot and faculae dominated variability

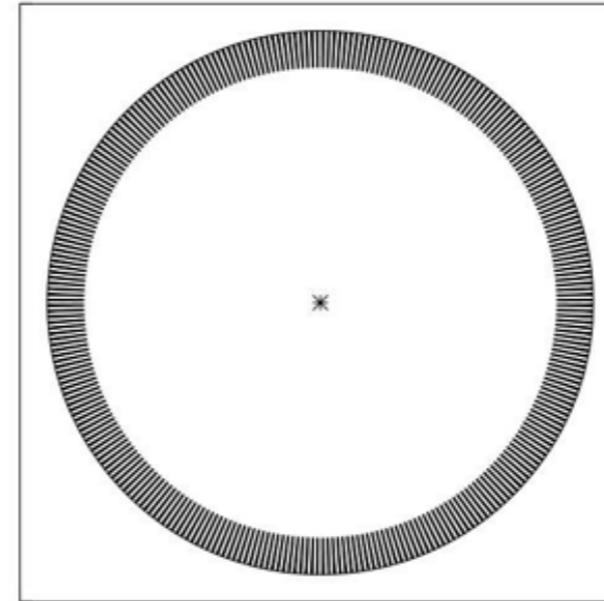
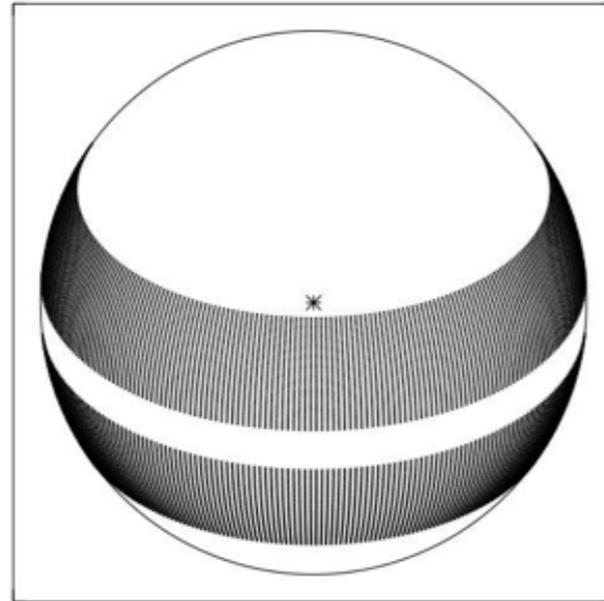
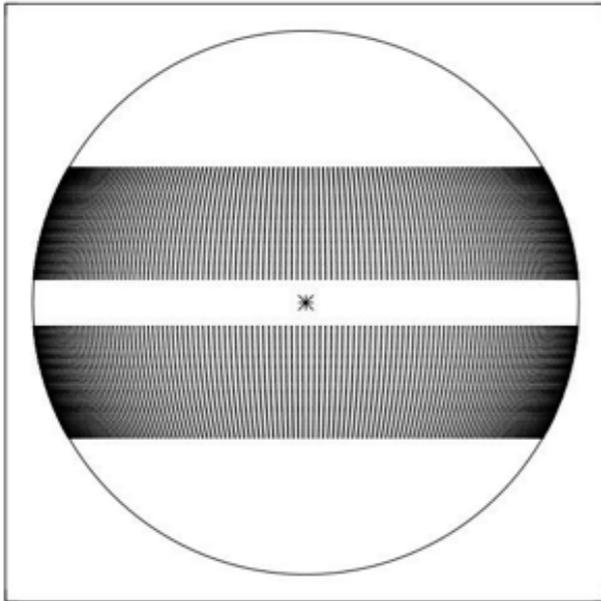


# SATIRE: treats stars as hypothetical Suns with coverage by magnetic features different from that of the Sun

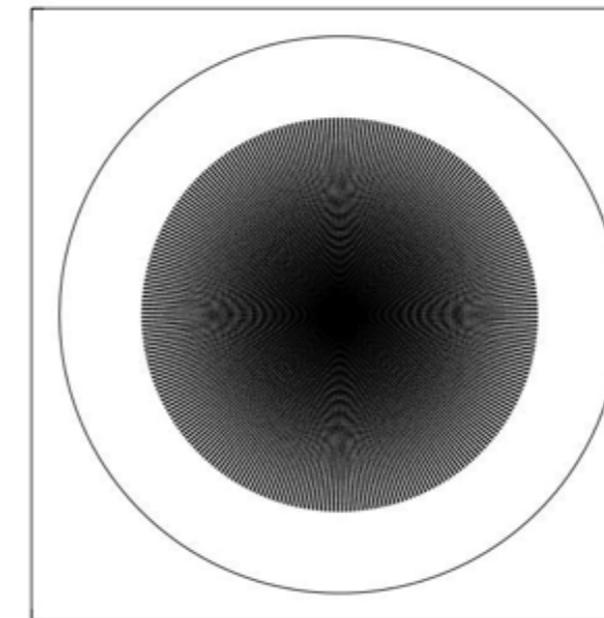
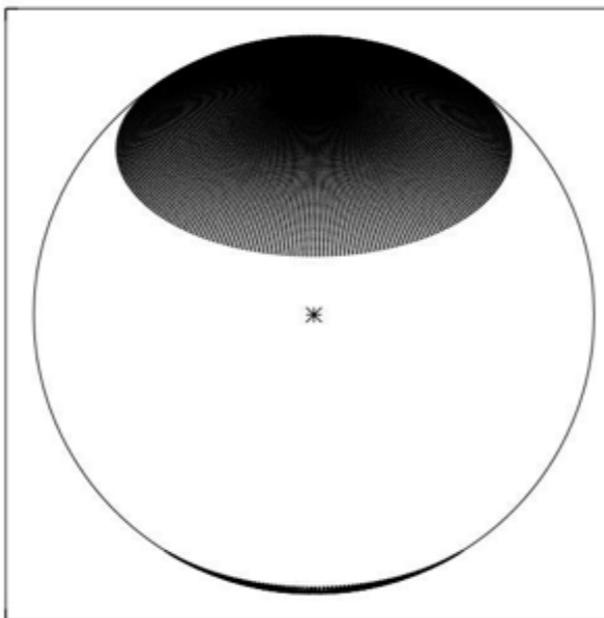
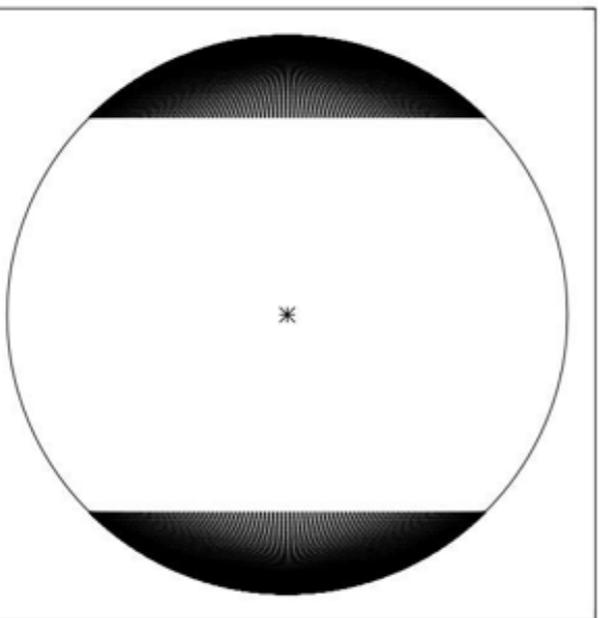
equator

intermediate

polar

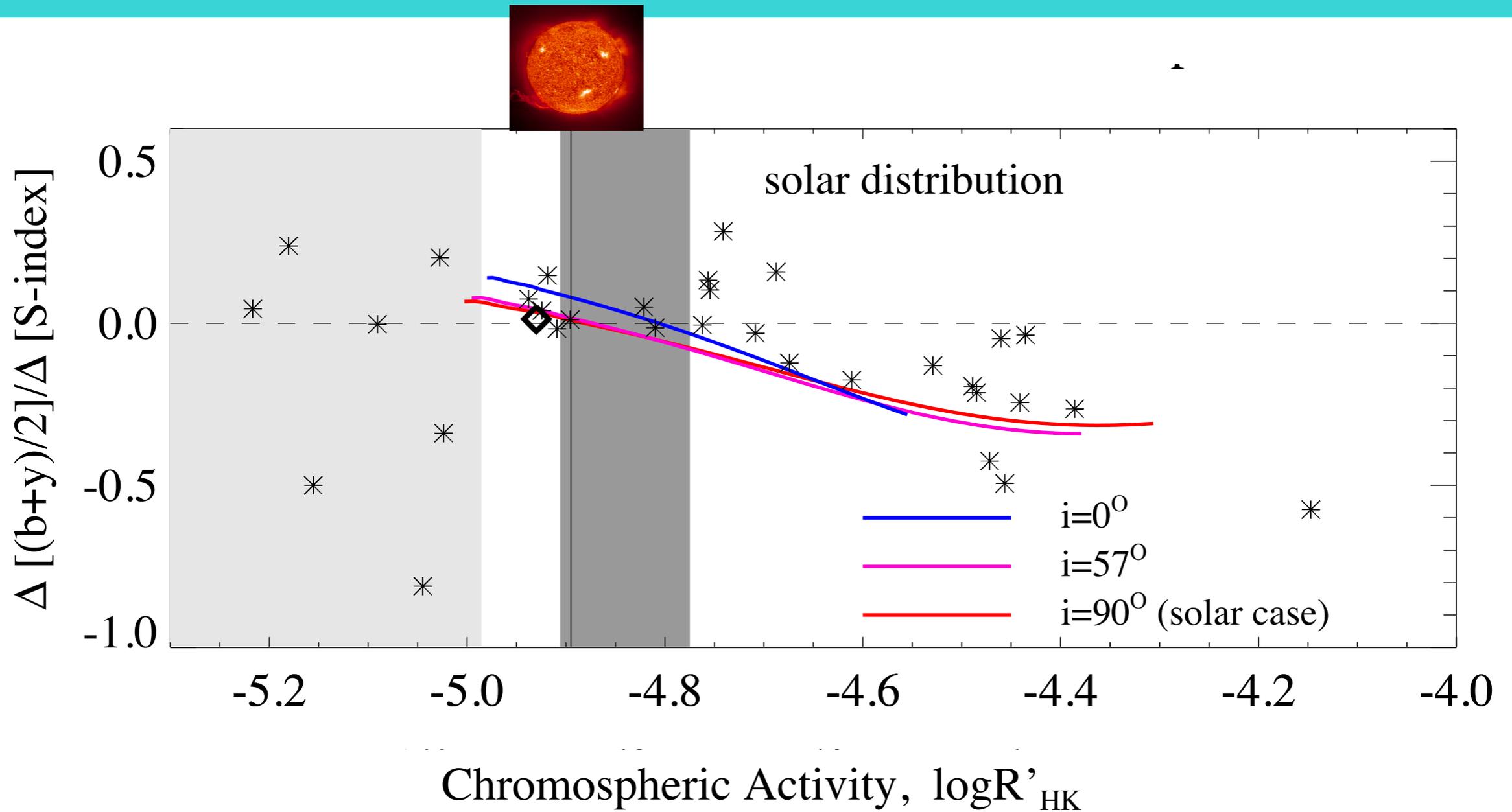


slow-rotator

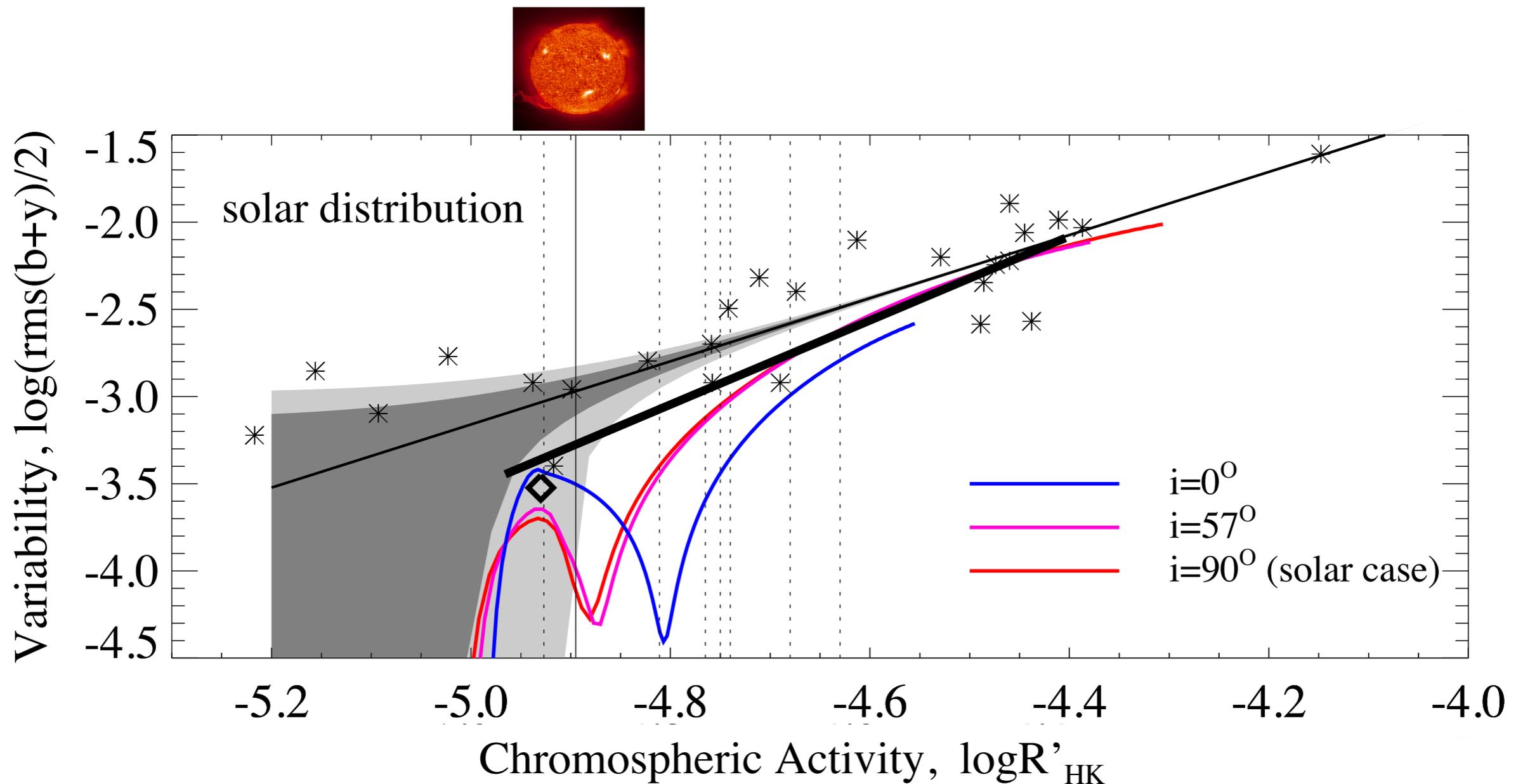


fast-rotator

# Spot- vs faculae- dominated regimes

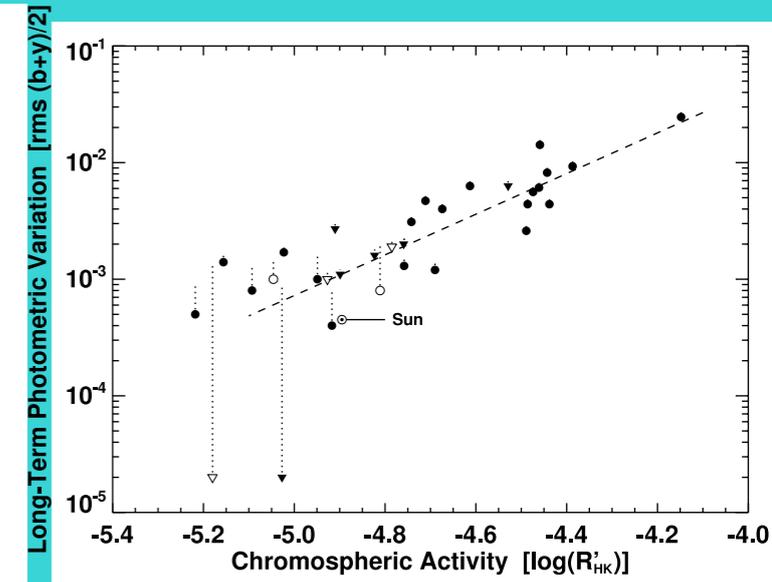
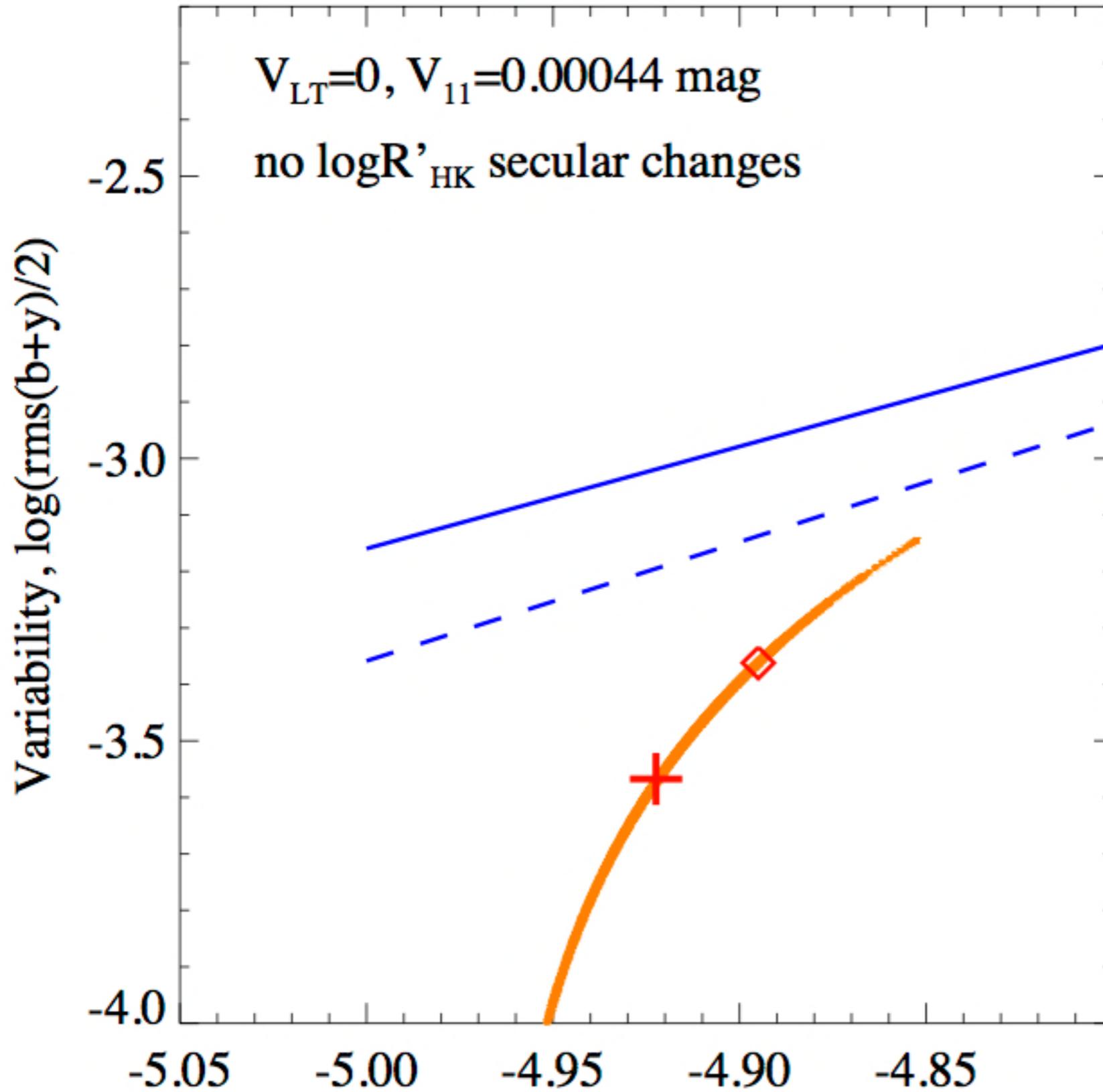


# Variability vs. magnetic activity

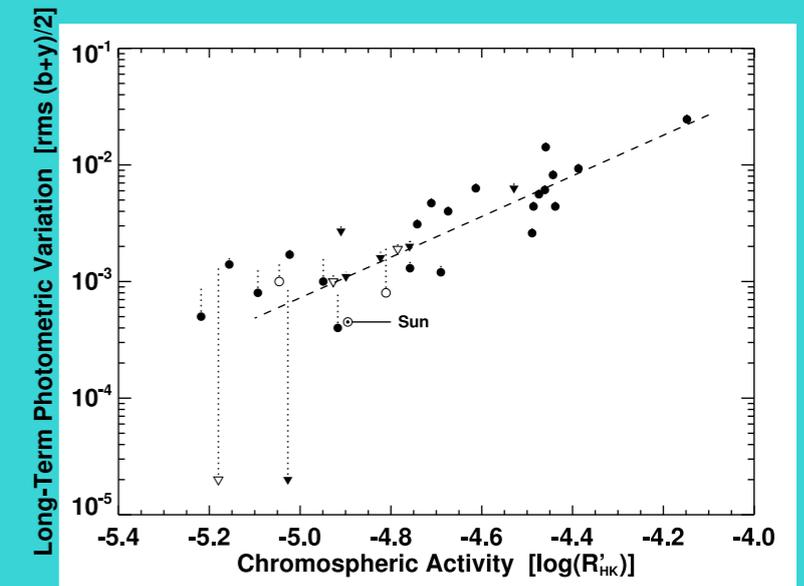
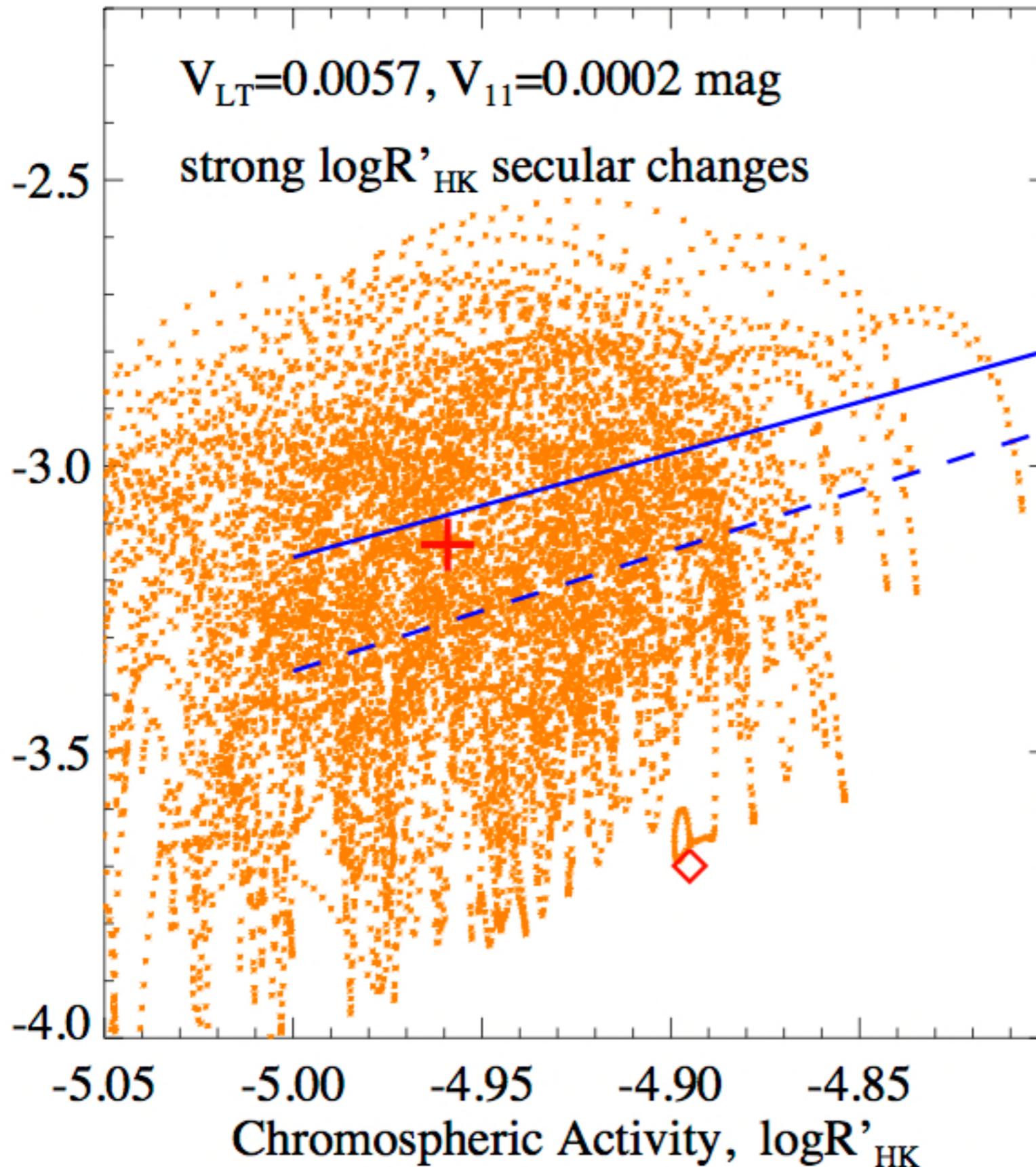


no variability gap in stellar data

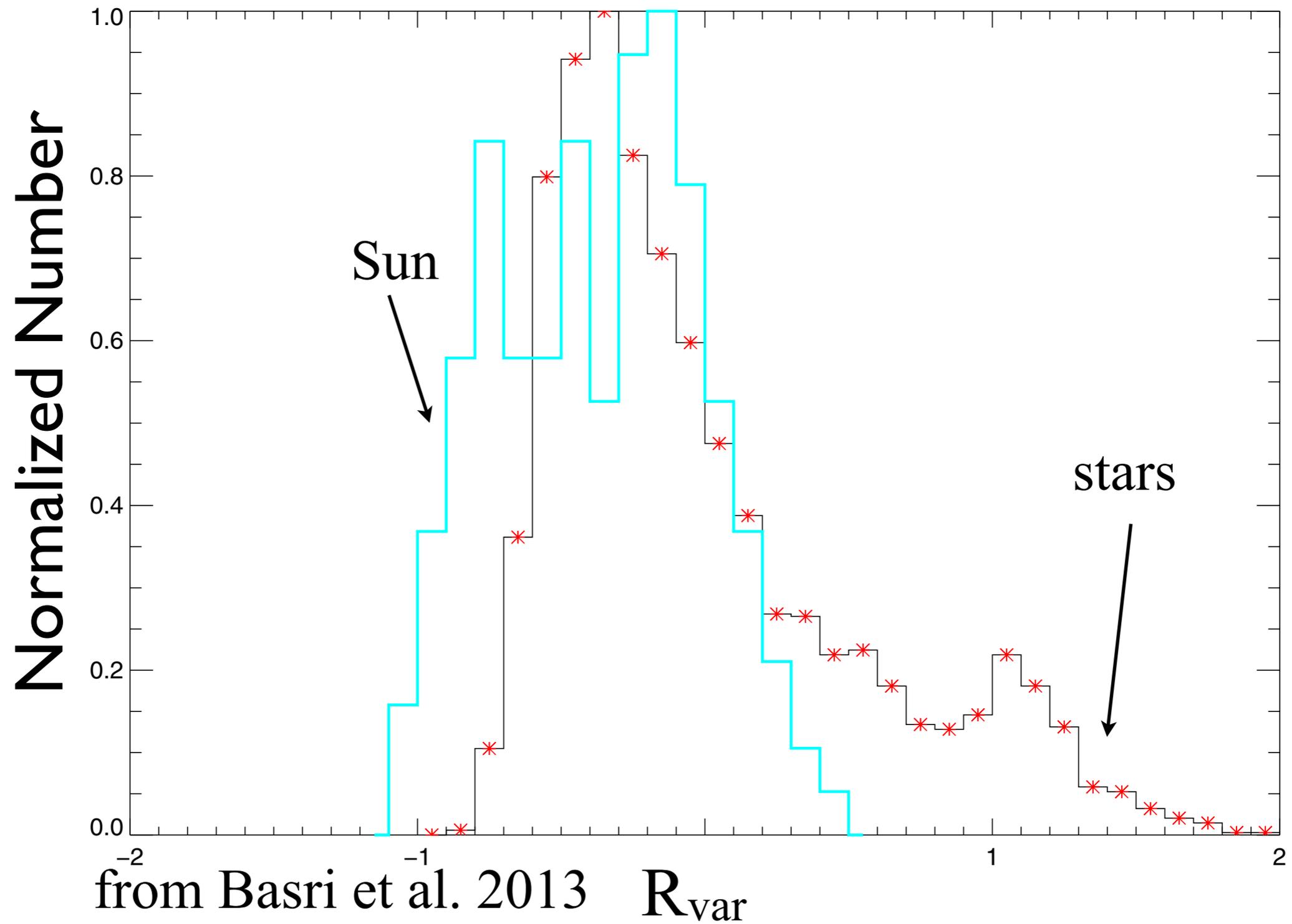
# Different scenarios for the solar trajectory



# Different scenarios for the solar trajectory



# KEPLER results





**THANK YOU!**