

# The Sun and the Kepler Solar-Type Stars: Quiescence and Flaring

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- 1) Nature of solar variability
- 2) The quandary of the “superflare” stars
- 3) Extreme solar events
- 4) “Nanoflares”

# Solar Irradiance Variations

**Table 1** Identified variability mechanisms for solar total irradiance

Mechanism	Time scale	Amplitude	Reference
Oscillations	5 min	Few ppm	Woodard & Hudson 1983
Granulation	Tens of min	Tens of ppm	Hudson & Woodard 1983
Sunspots	Few days	<0.2% peak-to-peak	Willson et al. 1981
Faculae	Tens of days	<0.1% peak-to-peak	Willson et al. 1981
Rotation	27 days	Variable	Fröhlich 1984
Active Network	11 yr	~0.1% peak-to-peak	Foukal & Lean 1988

Hudson, 1988

Plus (in 2015):

Flares	Few min	Few hundred ppm	Woods et al. 2004
Secular	Cycle	150 ppm	Froehlich 2009

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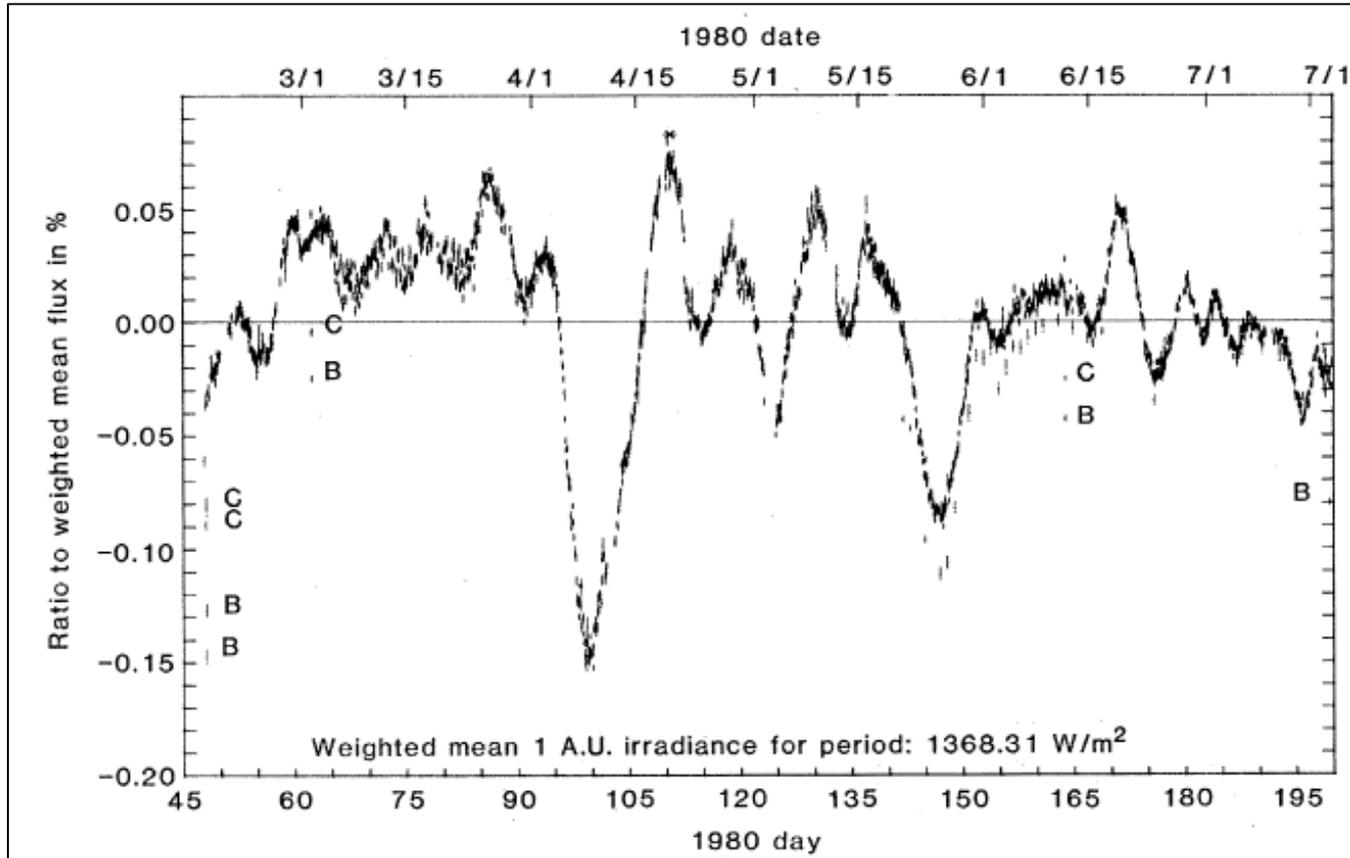
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# Flares and Irregular Magnetic Variability

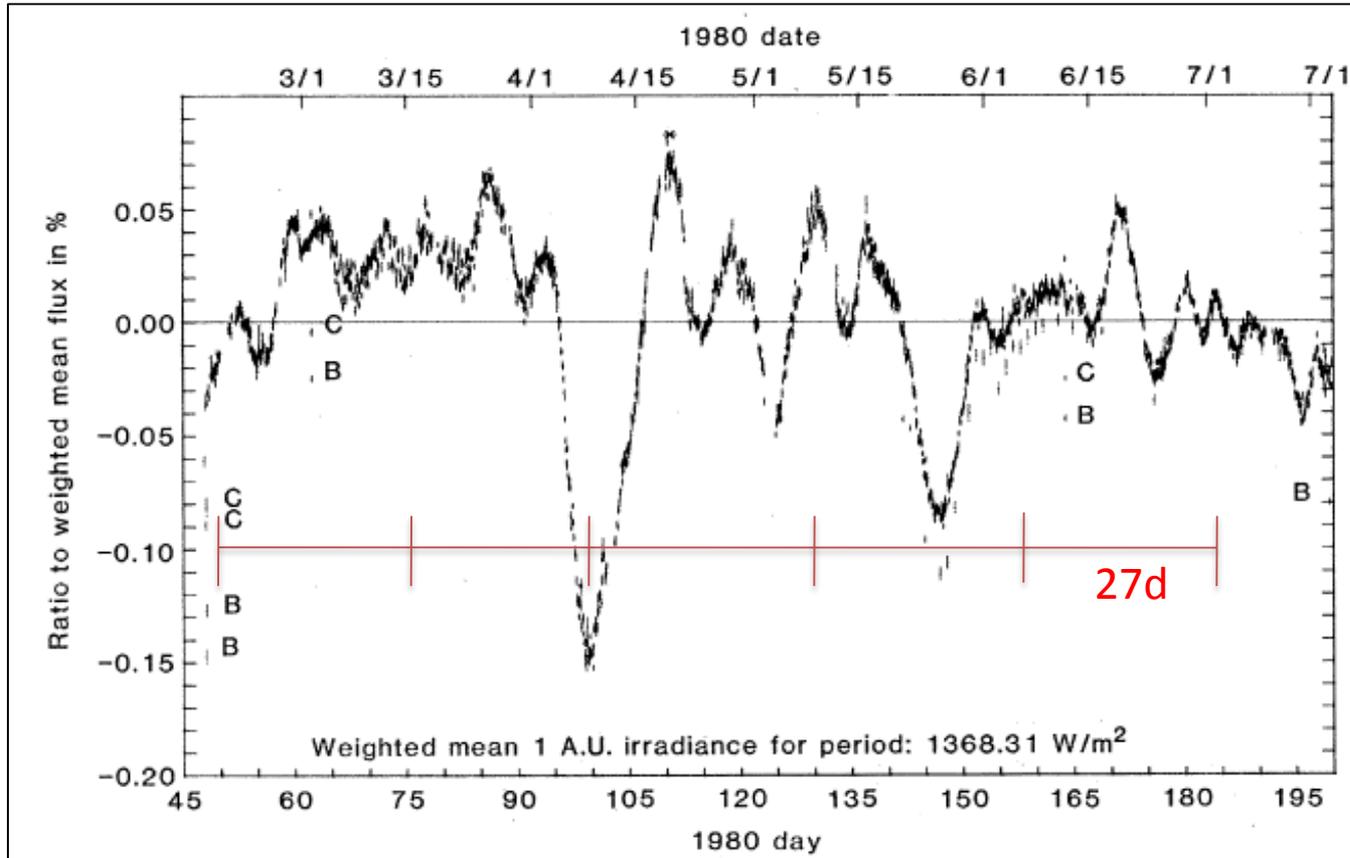
- Flares themselves are uniquely detectable, the background variation may appear to be chaotic.
- Something like Parker's nanoflares may connect these phenomena.
- Stars may differ from the Sun in the nature of the quiescent variability.
- I will discuss how the Kepler "superflare" stars behave in this respect.

# Sunspot TSI dips



Willson et al. 1981

# Sunspot TSI dips

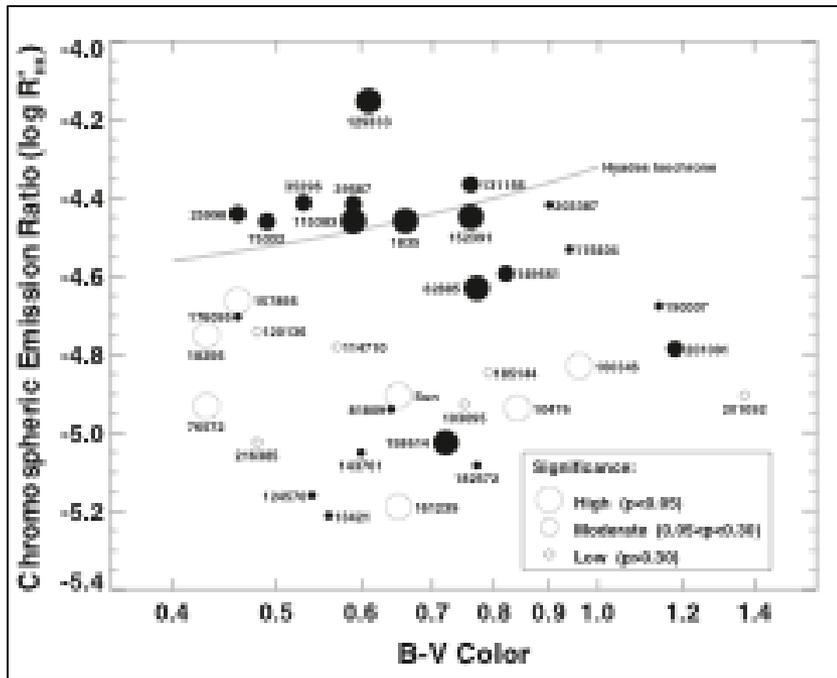


Willson et al. 1981

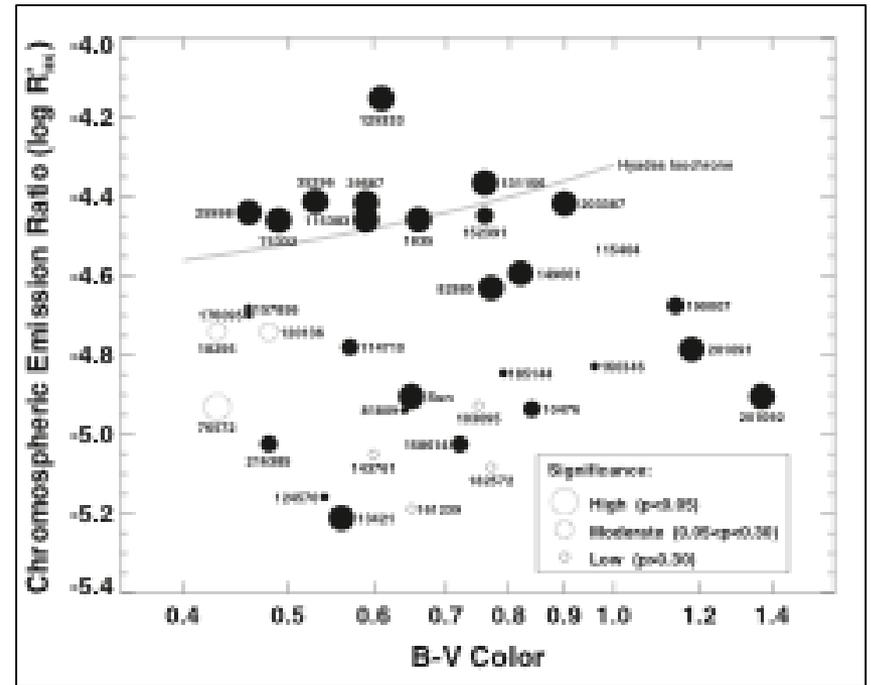
# The TSI dips

- Sunspots are darker than their faculae are bright, especially early in their life
- An individual dip lasts for about  $\frac{1}{4}$  rotation, since the projected spot area is foreshortened
- Facular excesses may dominate at the limb passages

# Solar-Stellar Magnetic Variability



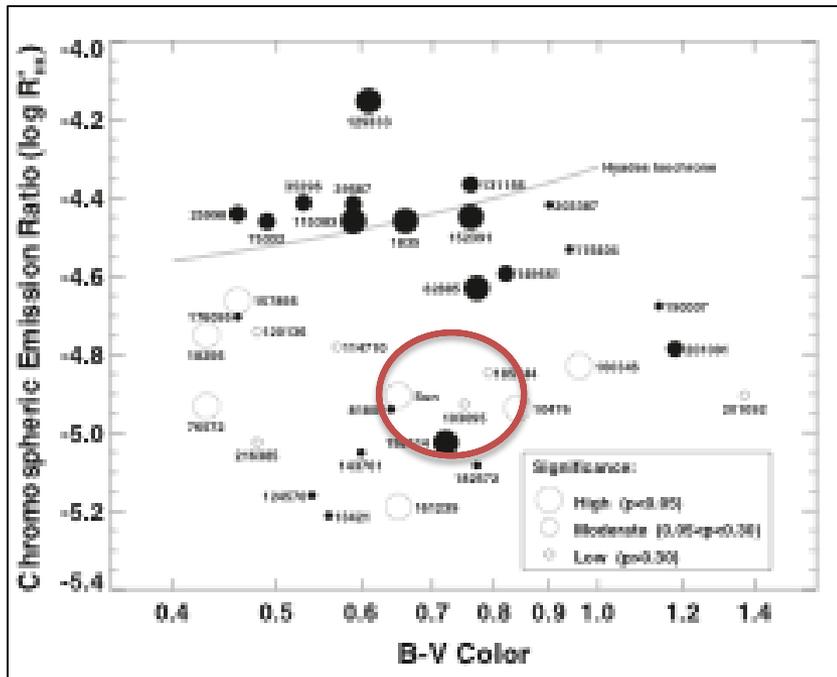
Short-term variation



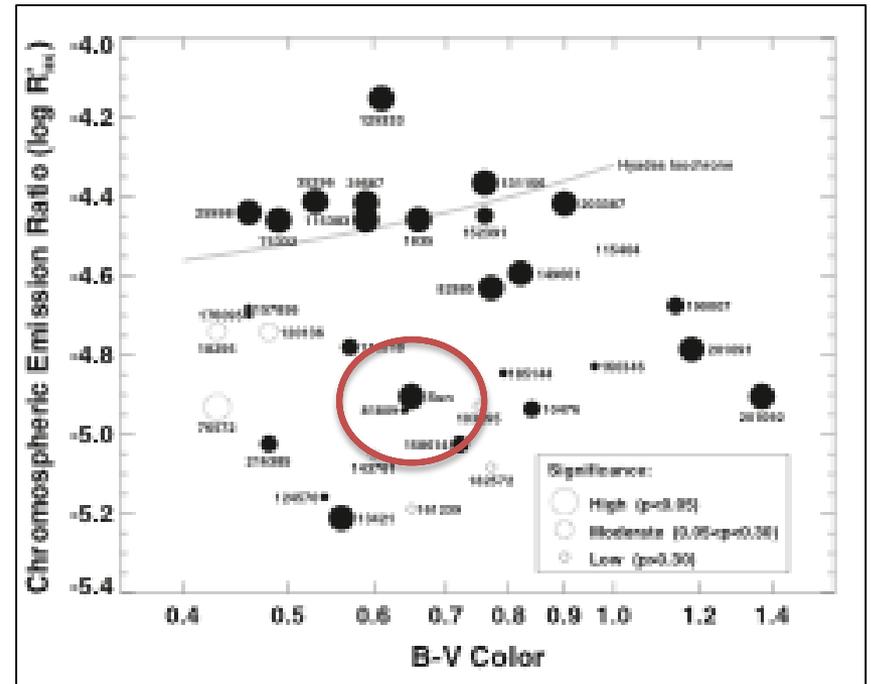
Cycle time scales

Solar TSI has maxima at sunspot maxima;  
other stars may not (e.g. Radick et al. 1998)

# Solar-Stellar Magnetic Variability



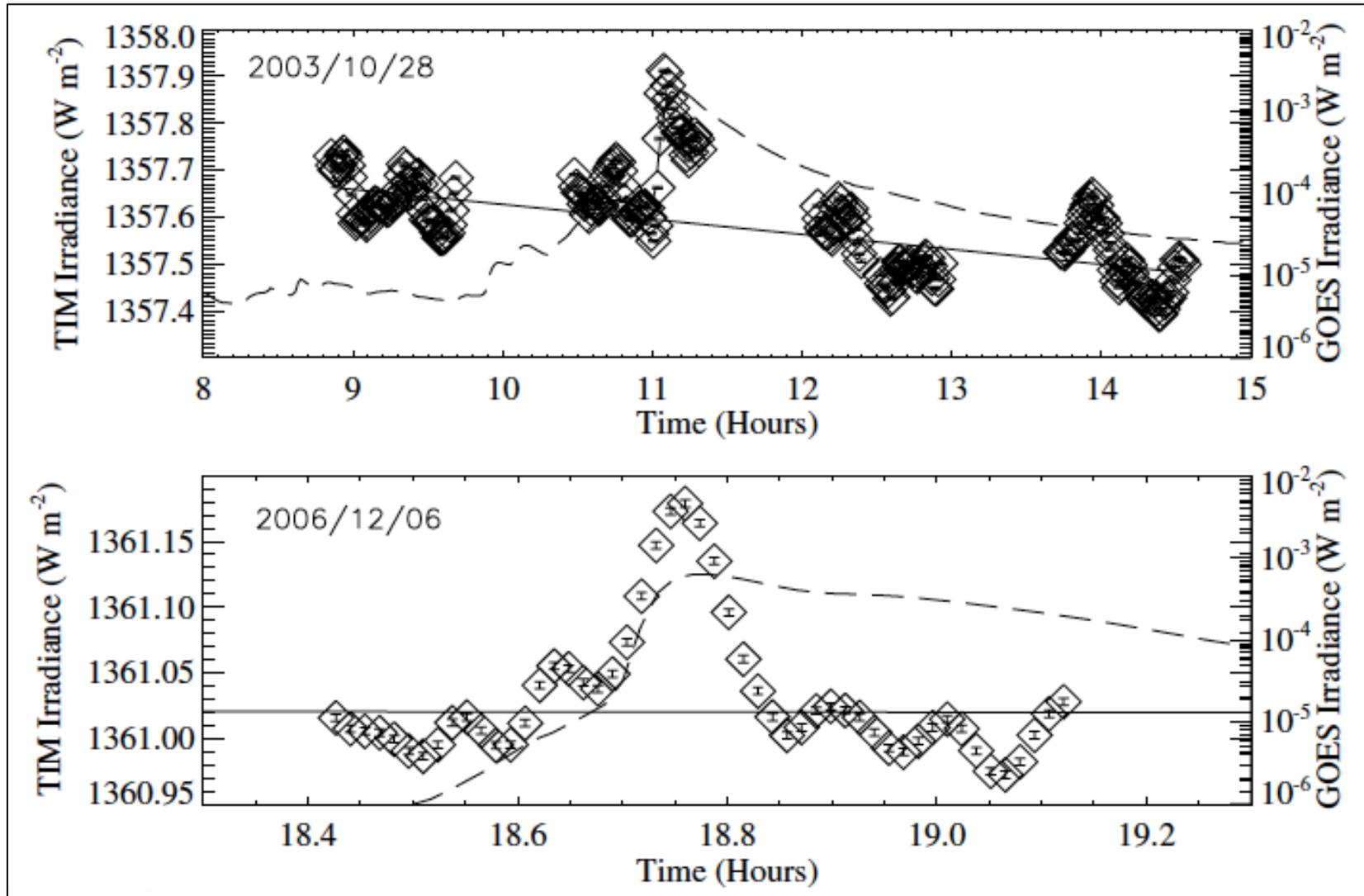
Short-term variation



Cycle time scales

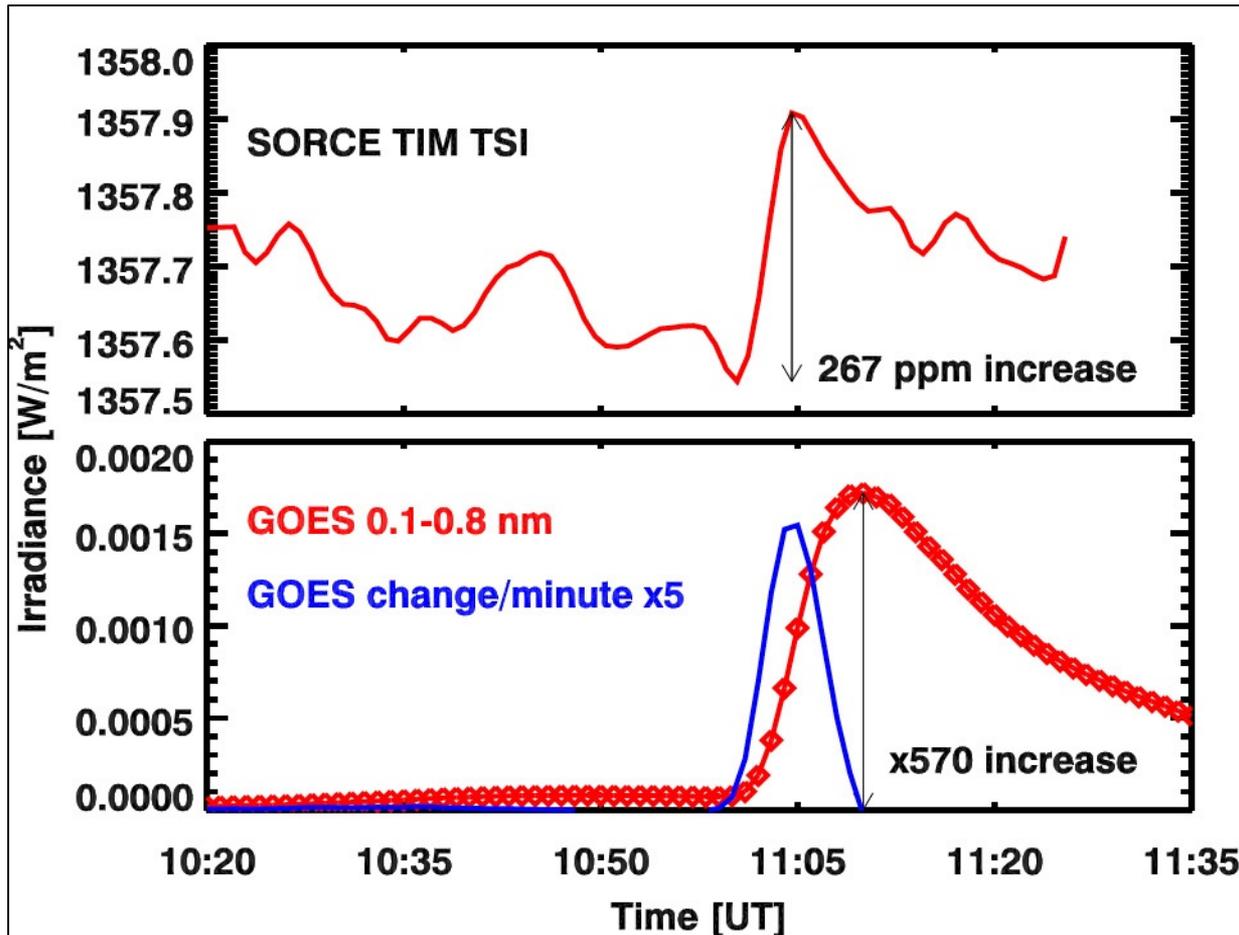
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# Flares in the TSI



Moore et al. 2014

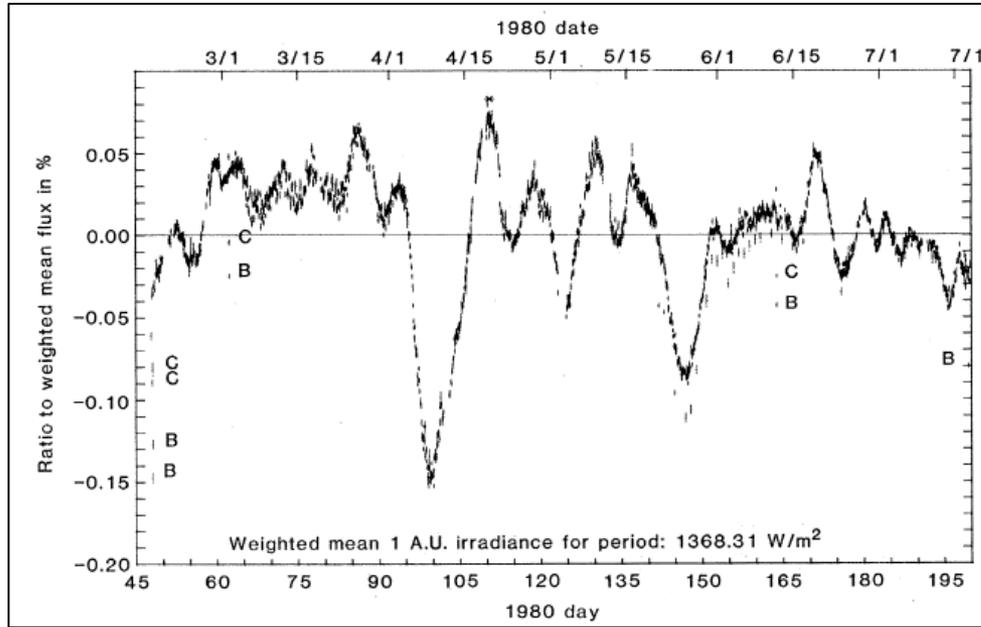
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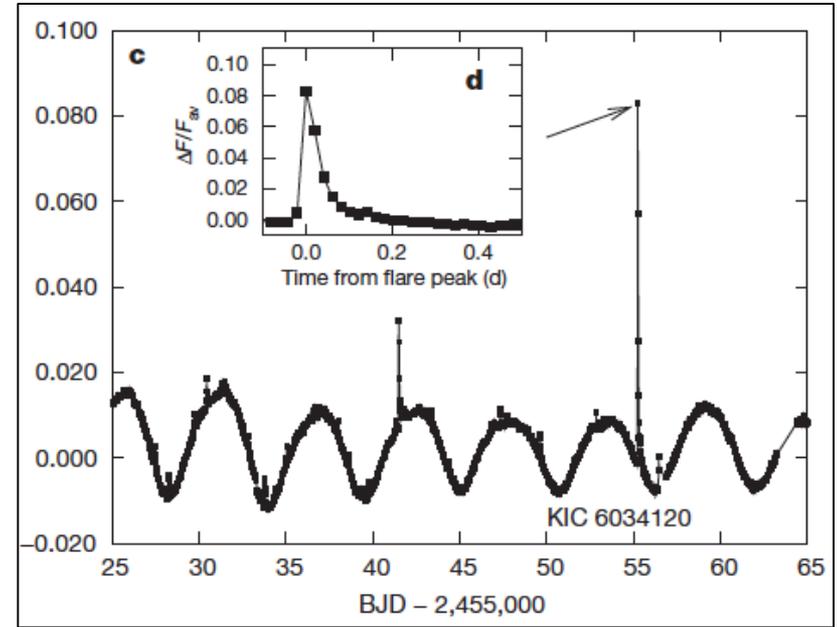
Woods et al. 2004

- Note the clear association with the impulsive phase (cf. Kretzschmar, 2011): flares are *nonthermal*

# Solar-stellar quandary



Willson et al. 1971



Maehara et al. 2012

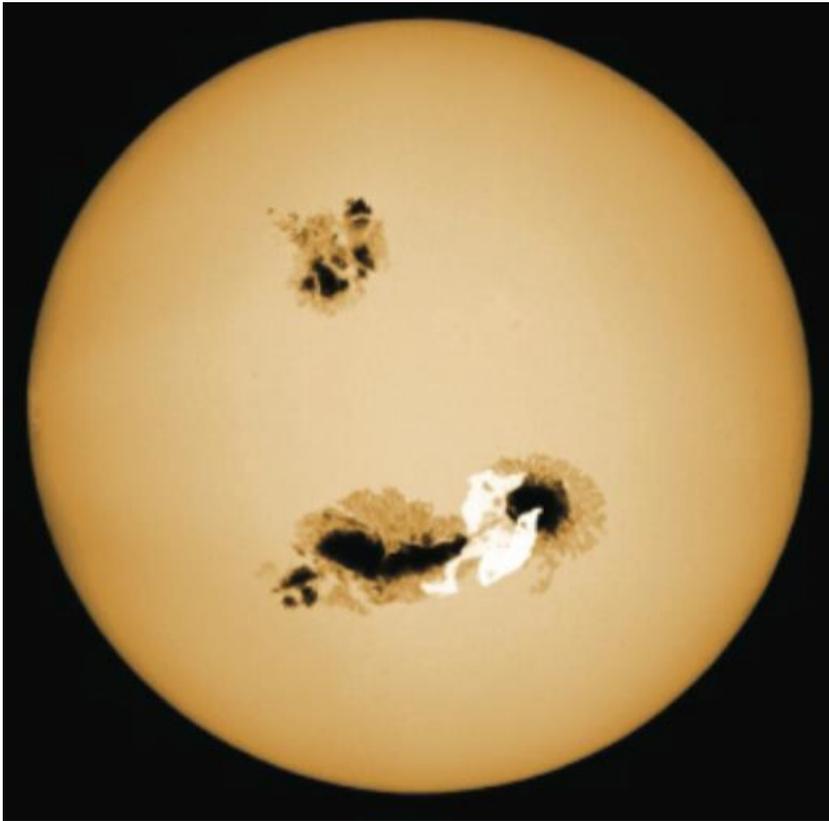
- Faculae are important for solar variability, but *not* for the stellar quiescent variations
- There are toy models to explain this, but a lot of unknowns get glossed over

# Solar-stellar quandary

- The Sun has short-term weak chaotic variability, *with dips.*
- These Kepler stars have nearly sinusoidal variations, *with flares.*

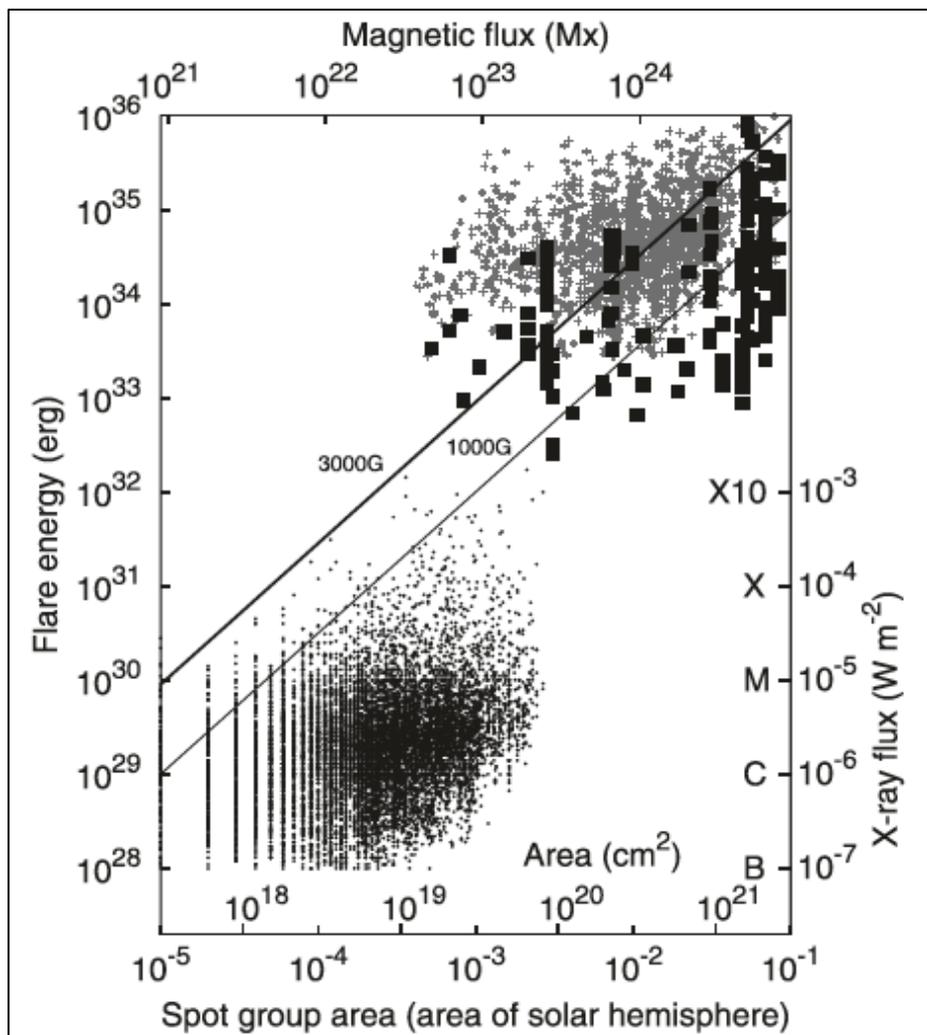
These light curves could not be more different; where's the paradigm?

# The Kepler “superflares”

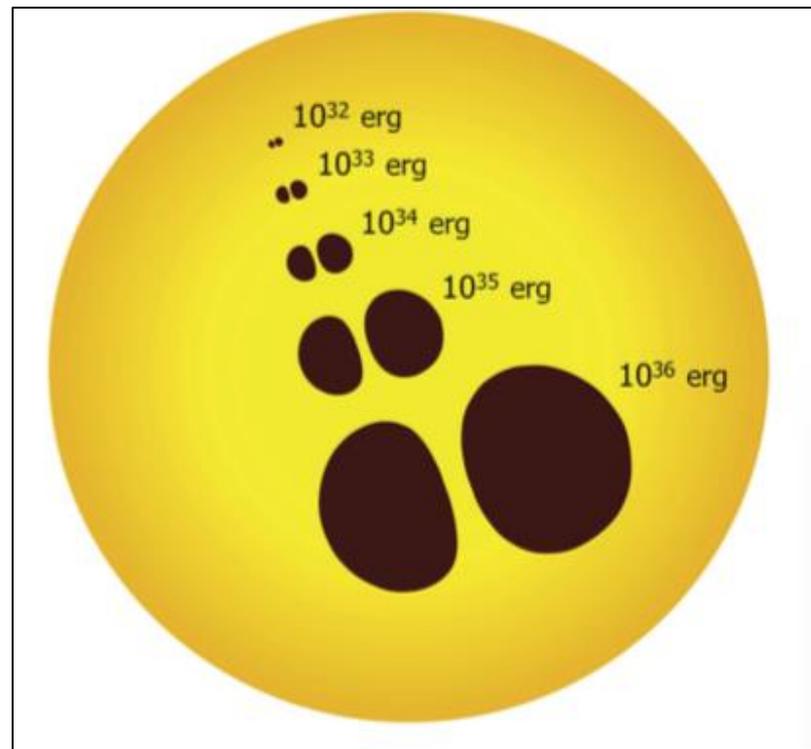


- Where are the faculae?
- How can such spots produce so sinusoidal a rotation modulation?

# The Kepler “superflares”



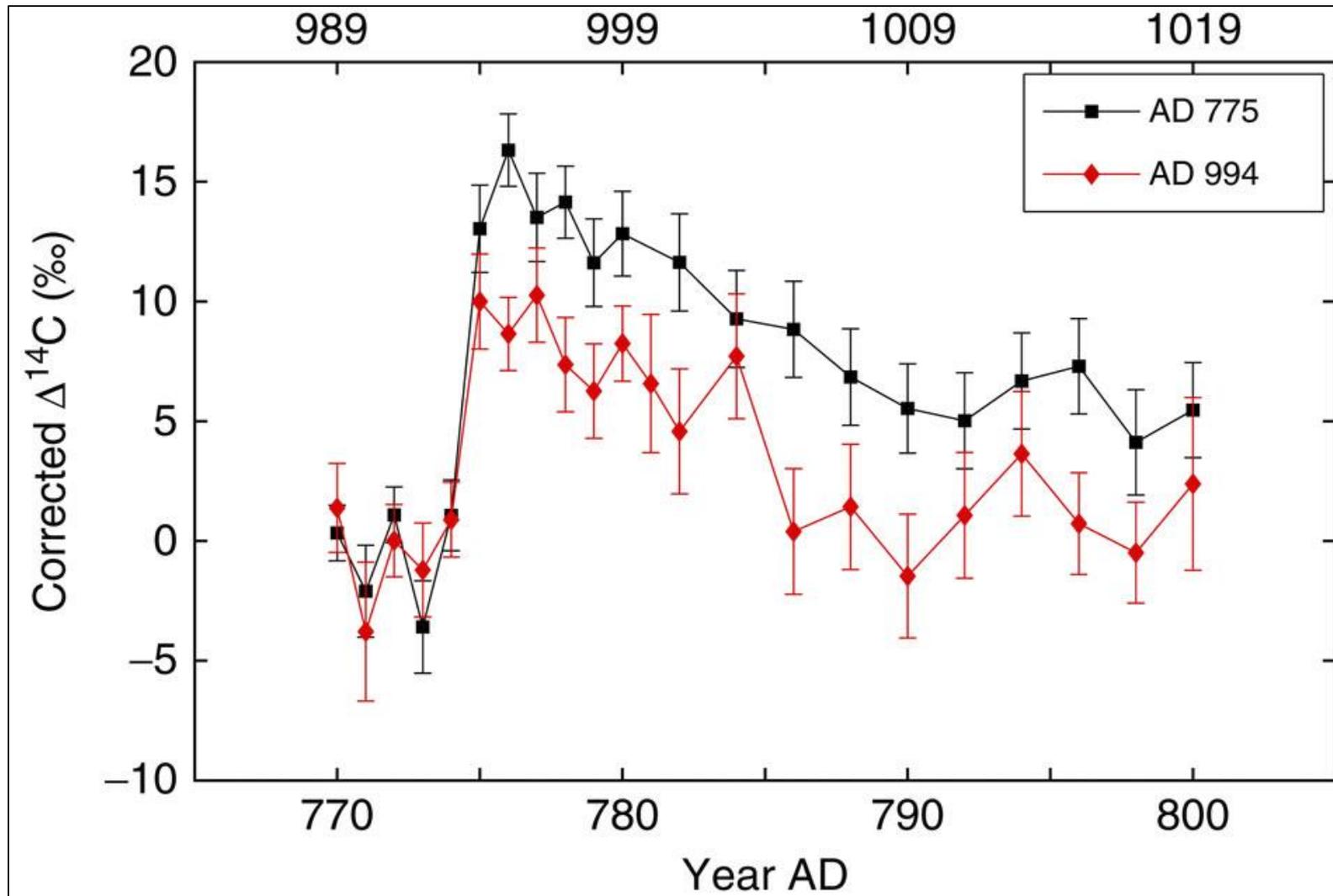
Maehara et al. 2015

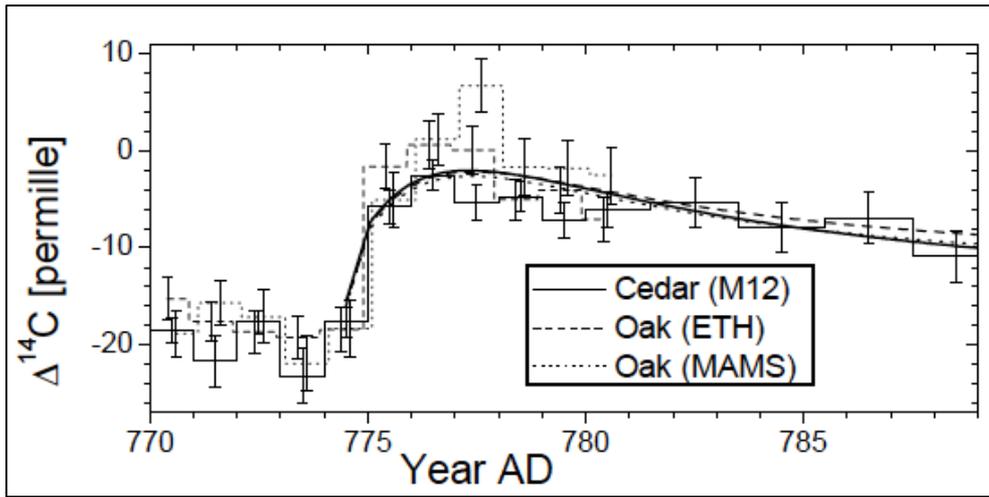


Aulanier et al. 2014

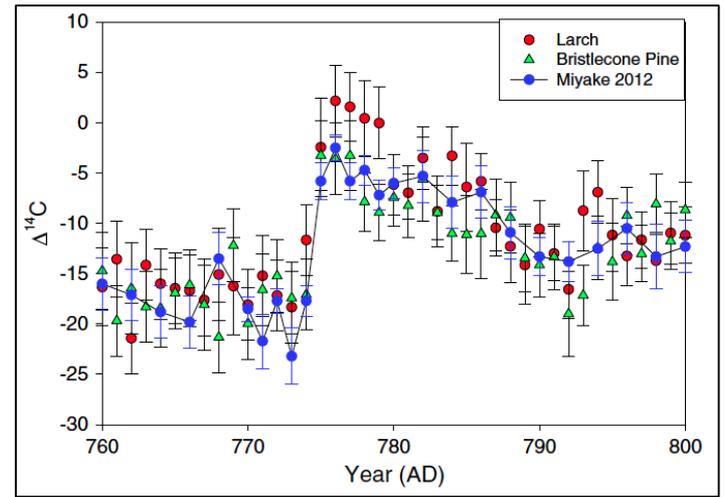
“Give me a big spot, and I can give you a big flare.”

# Extreme events in tree rings

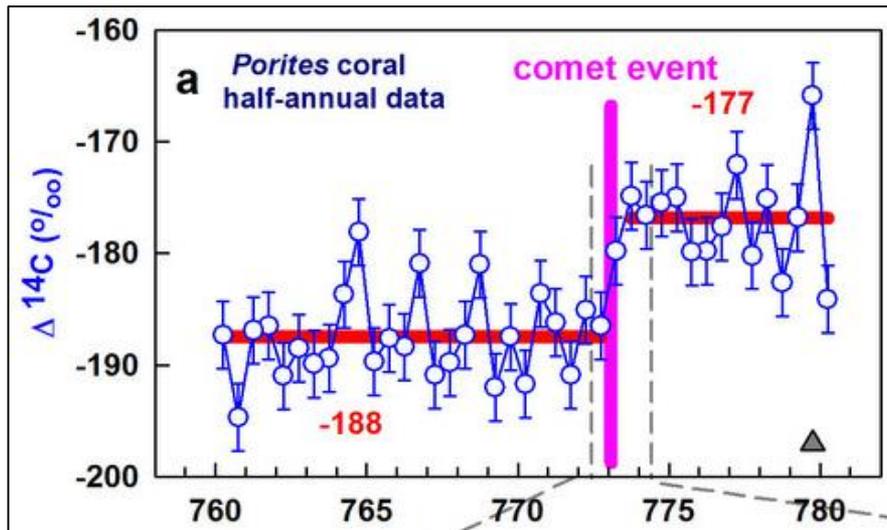




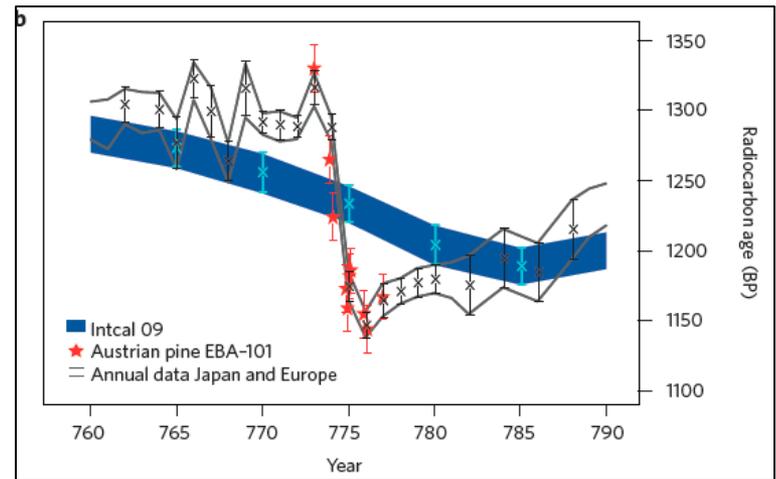
Usoskin & Kovaltsev 2013



Jull et al. 2014



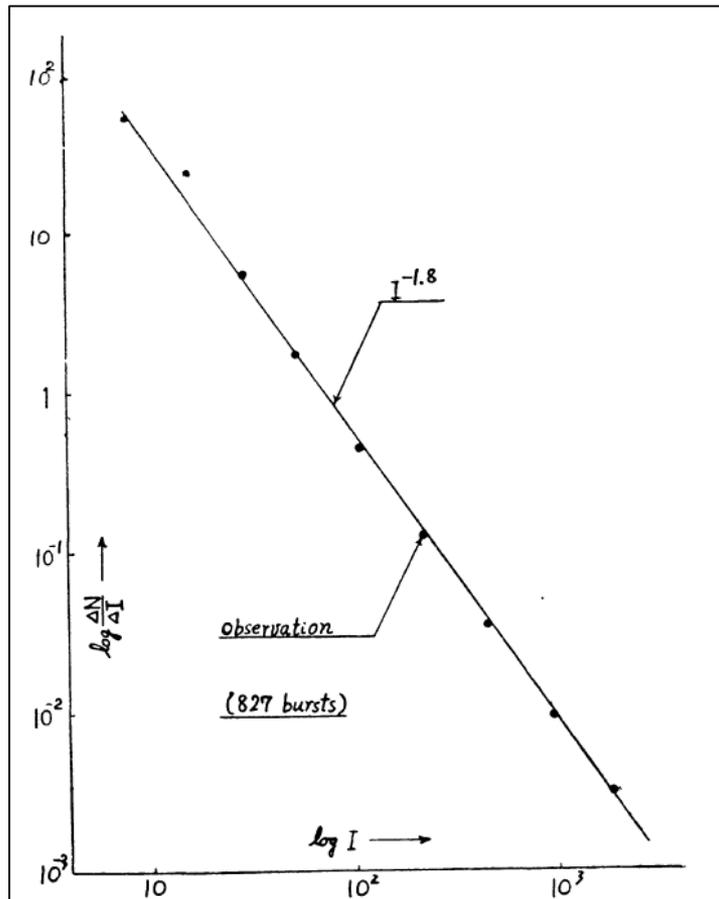
Liu et al. 2014



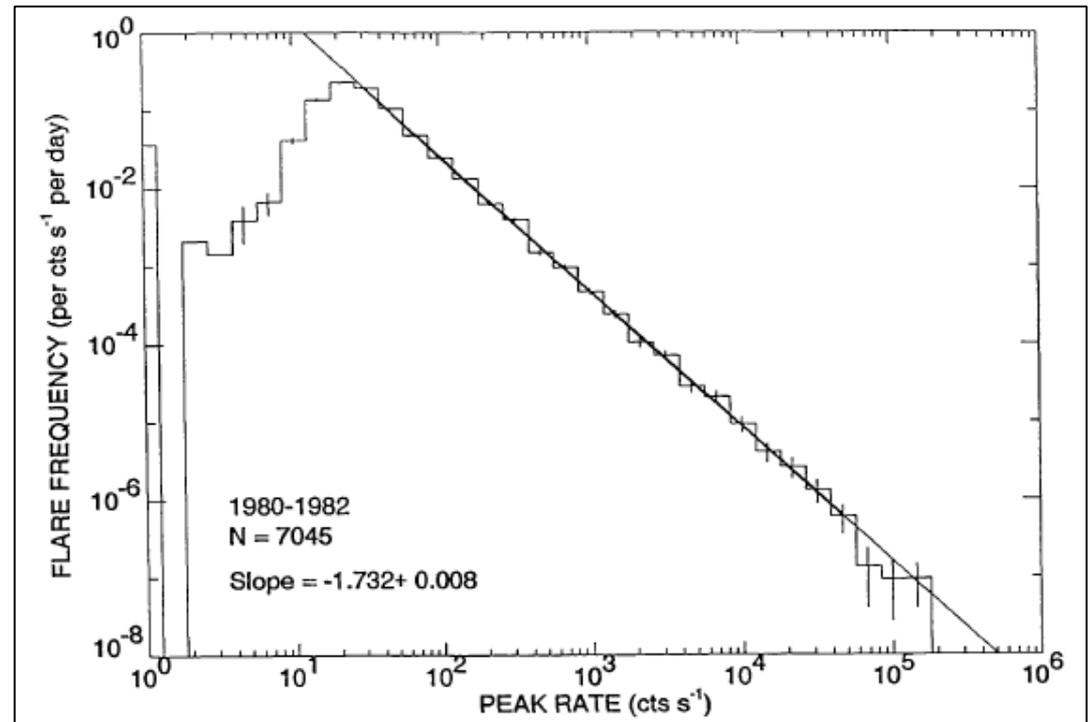
Büntgen et al. 2014

# The problem of the power law:

*a **break** is required*

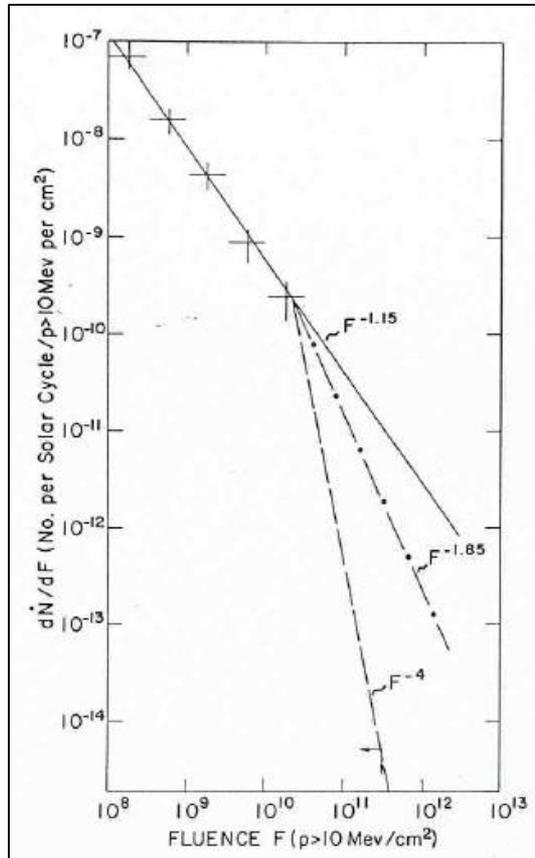


Akabane, 1956

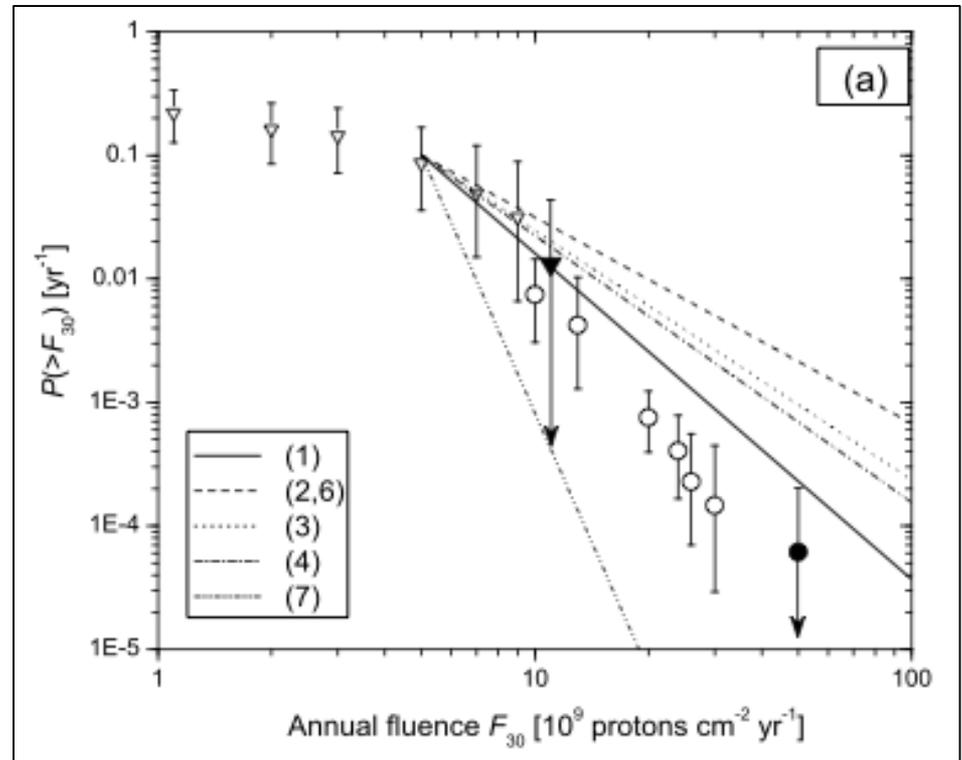


Crosby et al., 1993

# Can we see the break in SEPs?



Lingenfelter & Hudson 1980

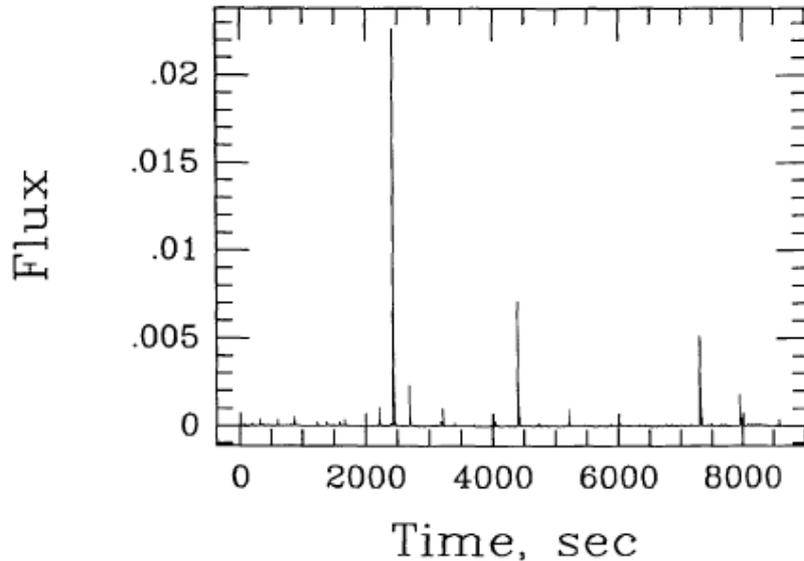


Kovaltsov & Usoskin 2014

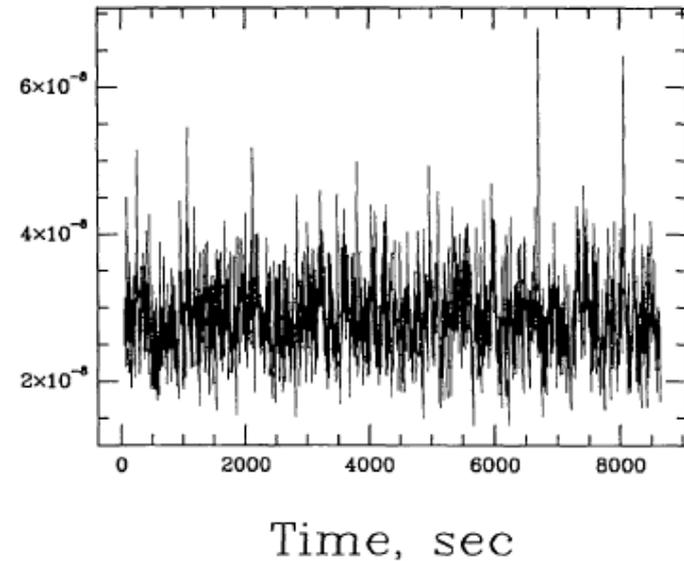
# Extreme events

- The Kepler superflares and the radiisotope events suggest that powerful solar flares might occur
- The weight of evidence for the radiisotopes leans away from the Sun
- To locate the break for solar flares, we need more TSI observations at *higher time resolution*

# Nanoflares



Power-law  $\delta = 1.8$



Power-law  $\delta = 4$

- Toy model of shot noise distinguishes flares and nanoflares (Hudson, 1991)
- The noise-like component of weak stellar variability may well conceal the presence of episodic heating
- Many searches for nanoflare signatures continue

# Conclusions

- Flares also contribute to TSI (a SORCE result)
- Recent tree-ring data and Kepler photometry reveal “extreme events” \*
- Parker’s nanoflares may be lurking in the quiescent variability

\* <http://arxiv.org/abs/1504.04755>