Stellar Magnetic Activity and Extreme Events*

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1) Kepler superflares and solar flares
2) Kepler quiescent variability and the solar paradigm

*http://arxiv.org/abs/1504.04755

Literature

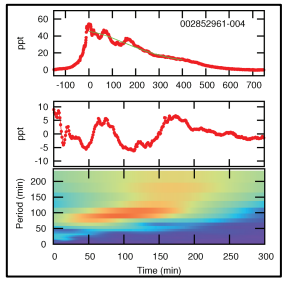
- There are 12 papers in ADS, searching on “Shibata + Kepler – Keplerian” since 2012
- But zero papers on “- Shibata + Kepler – Keplerian”
- Most recent is Maehara et al. (arXiv 1504.0074M): “Statistical properties of superflares on solar-type stars based on 1-min cadence data”

Shibata group papers thus far

\cite{2015arXiv1504.00074M}: 1-min cadence
\cite{2014arXiv1412.8245N}: Spectroscopy II
\cite{2014arXiv1412.8243N}: Spectroscopy I
\cite{2014PASJ...66L...4N}: Two slow rotators
\cite{2014IAUS..293..393M}: Superflares
\cite{2014ApJ...792...67C}: G-, K-, M-stars
\cite{2013PASJ...65..112N}: KIC 6934317
\cite{2013ApJS..209....5S}: Statistics
\cite{2013PASJ...65...49S}: Can they occur?
\cite{2013ApJ...771..127N}: Rotation and starspots
\cite{2012Natur.485..478M}: Nature paper
\cite{2012cosp...39.1786S}: Will they occur?

The non-Shibata papers

\item \cite{2015MNRAS.450..956B}: QPP; faint hope of seeing seismic waves



\item \cite{2015MNRAS.447.2714B}: ``Flare stars across the HR Diagram'' (no evidence for reconnective duplicity)

\item \cite{2015Ap.....58...62A}: Distribution functions; something about piecewise Poisson, but otherwise...

\item \cite{2015csss...18..389W}: Some vain X-ray searches

\item \cite{2015ApJ...798...92W}: Variability of distribution functions

\item \cite{2014MNRAS.442.3769K}: Two slow rotators... KIC10524994 and KIC07133671 and a shifted photocenter for the latter

\item \cite{2014IAUS..302..212R}: Kepler + CHARA and spots

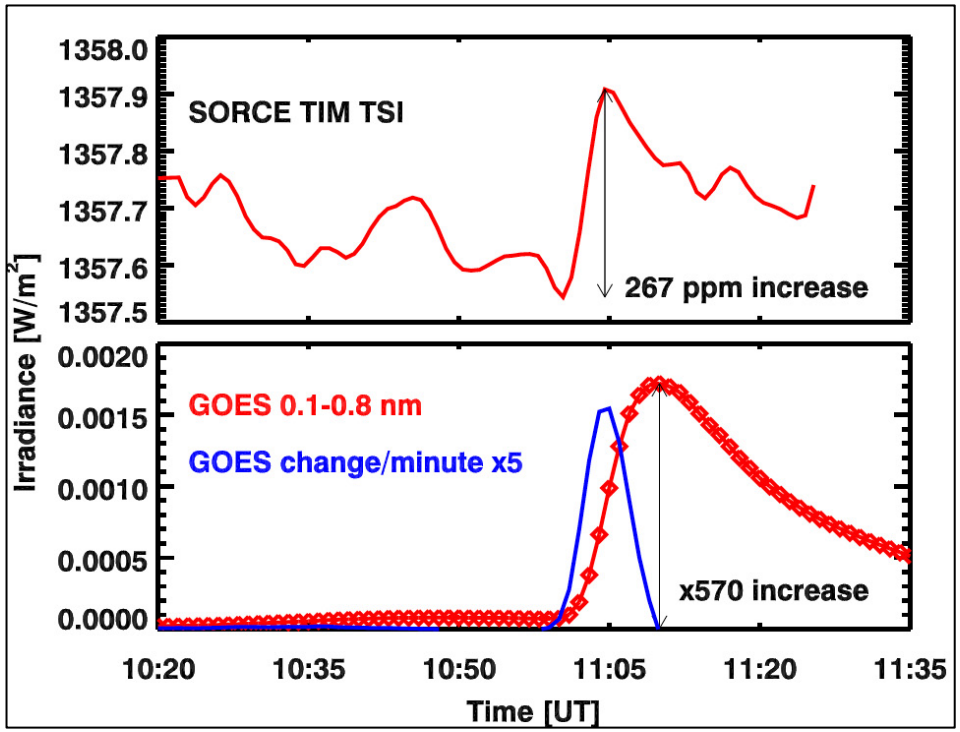
\item \cite{2014ApJ...781L..22K}: Followup on \cite{2008ApJ...678L..73K} but for Kepler -- but is it any more plausible here?

\item \cite{2013A&A...549A..66A}: ``Give me a big spot, and I can give you a big flare''

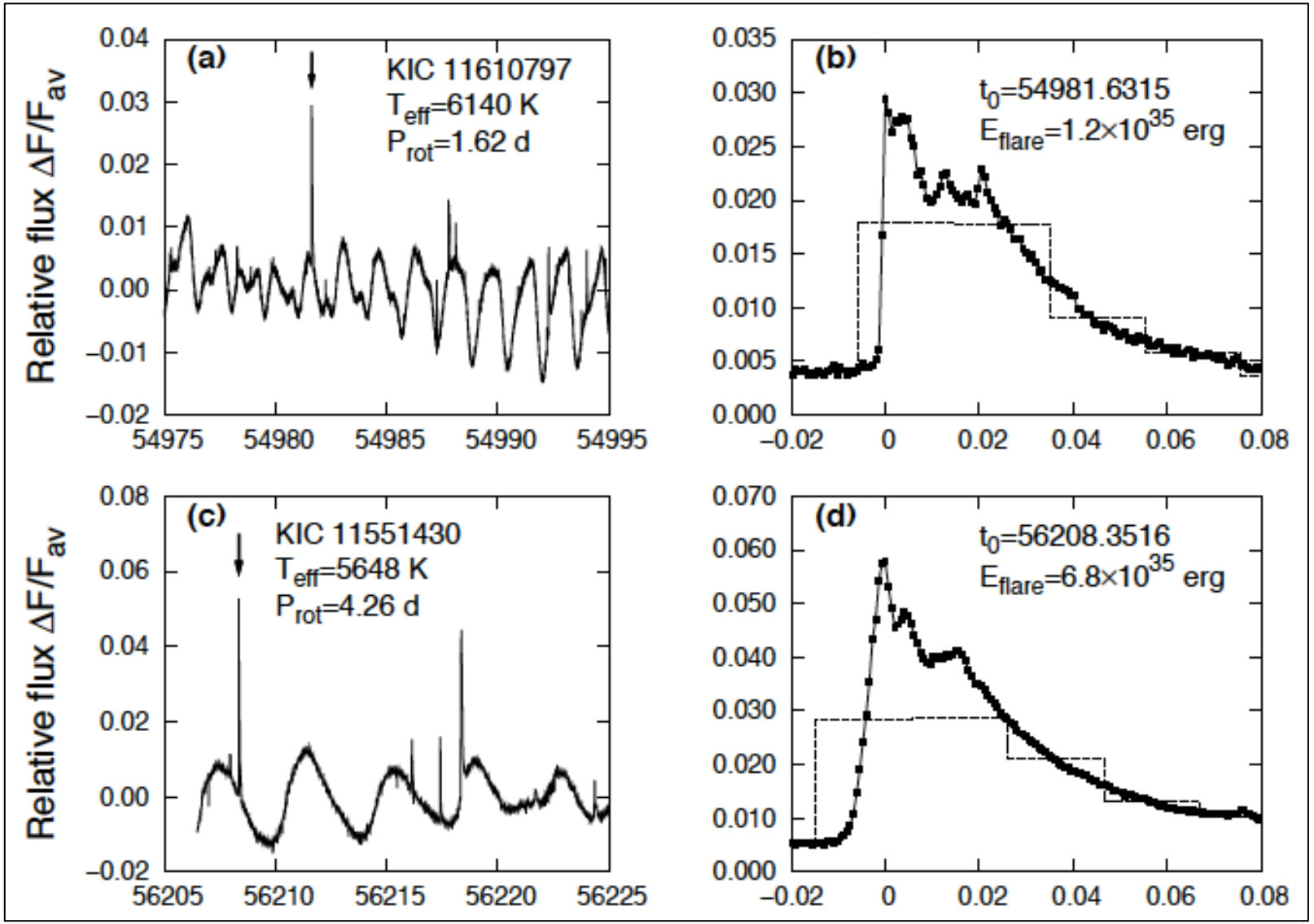
\item \cite{2011AJ....141...50W}: Kepler introductory flares paper (Walkowicz)

The TSI literature

- Hudson & Willson (1983SoPh...86..123H), “Upper limits on the total radiant energy of solar flares”
- Woods et al. (2006JGRA..11110S14W), “Contributions of the solar ultraviolet irradiance to the total solar irradiance during large flares”
- Kretzschmar 2011A&A...530A..84K), “The Sun as a star: observations of white-light flares”
- Moore et al. (2014ApJ...787...32M), “Measurements and Modeling of Total Solar Irradiance in X-class Solar Flares”



Maehara et al. (2015)



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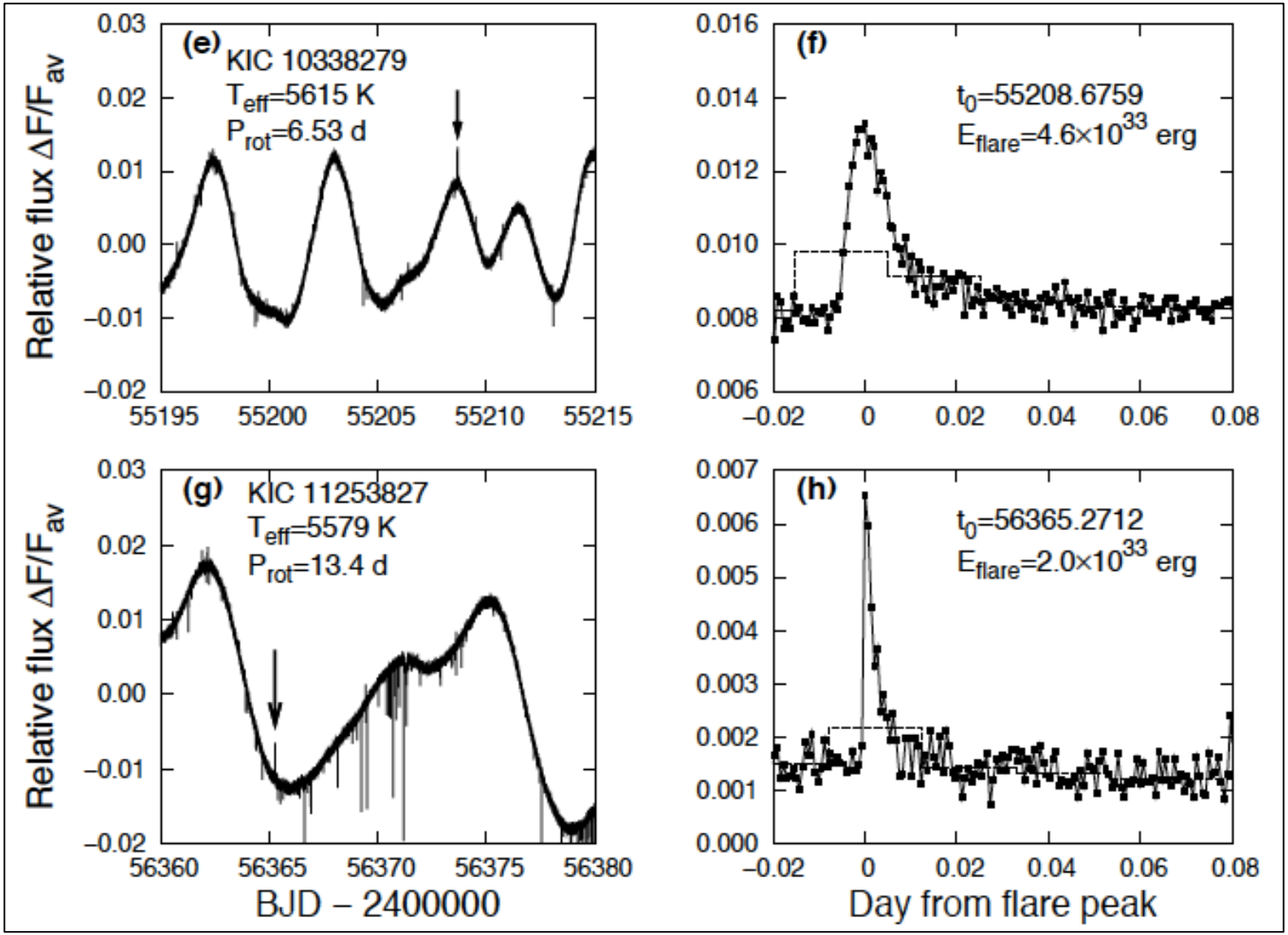
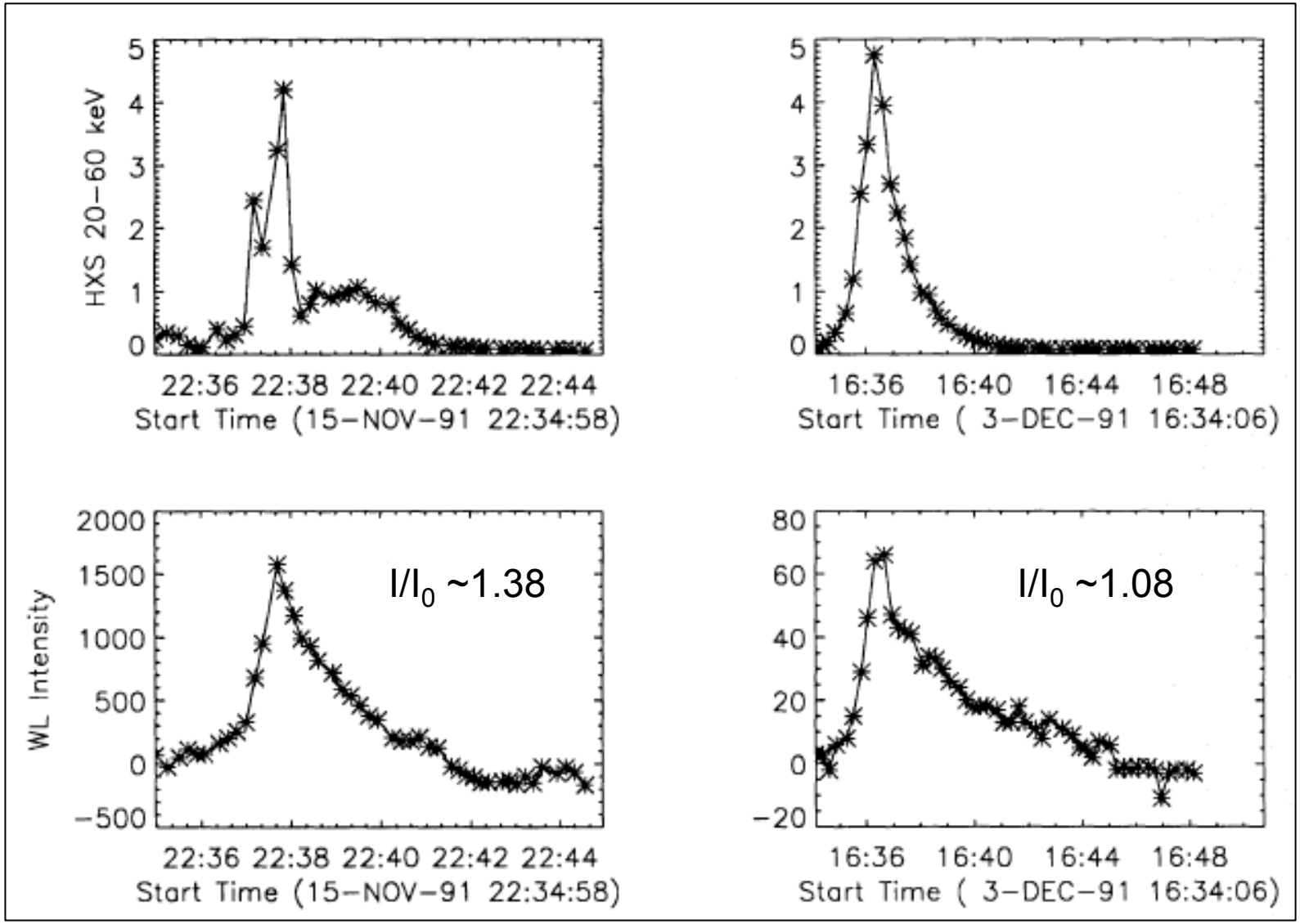


The stellar flares

- Generally, the light curves at 1-min cadence look very similar to the solar ones (next slide)
- The quiescent variations look very different (next topic)

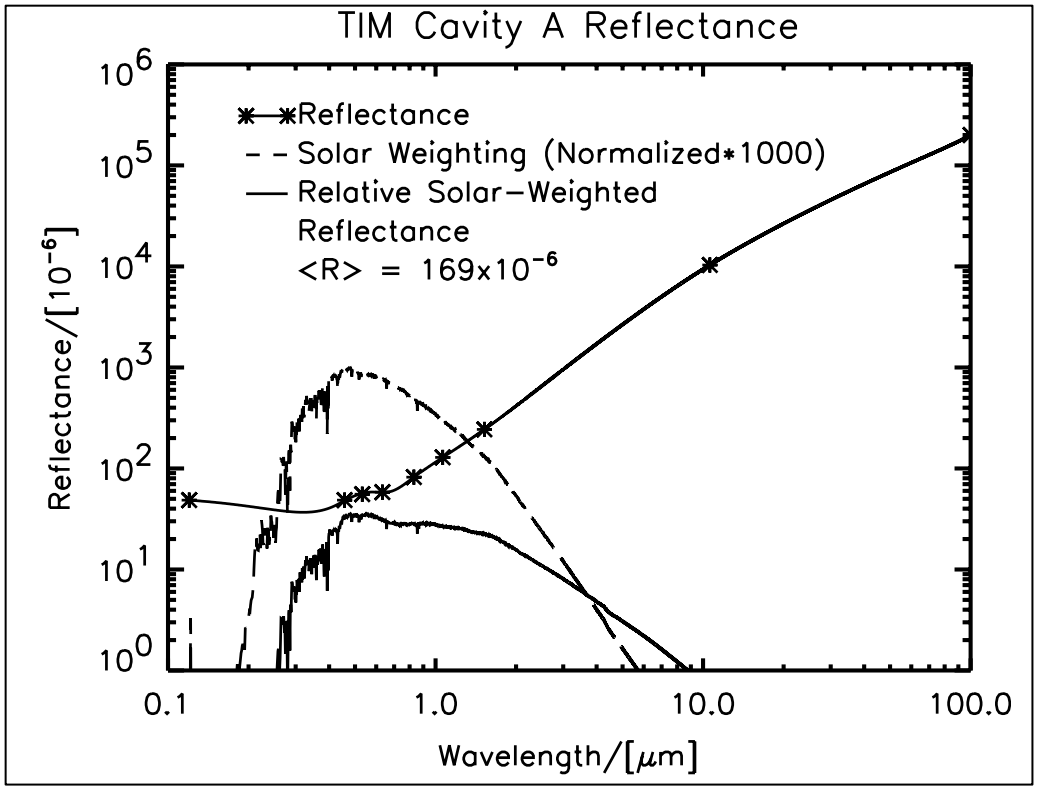
Yohkoh G-band and HXR



Hudson et al. 1992

Relative photometry

- Yohkoh 4308 Å CN band: perhaps 3x the 6550 Å contrast
- Kepler photometry: 4000-9000 Å
- TSI: very broadband



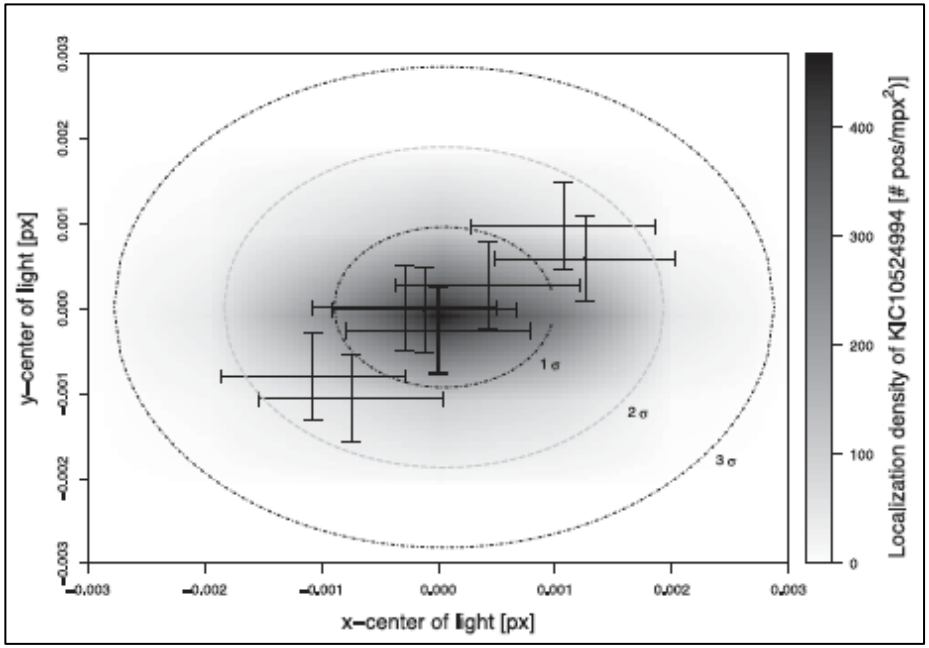
Lawrence et al. 2003

How to measure energy?

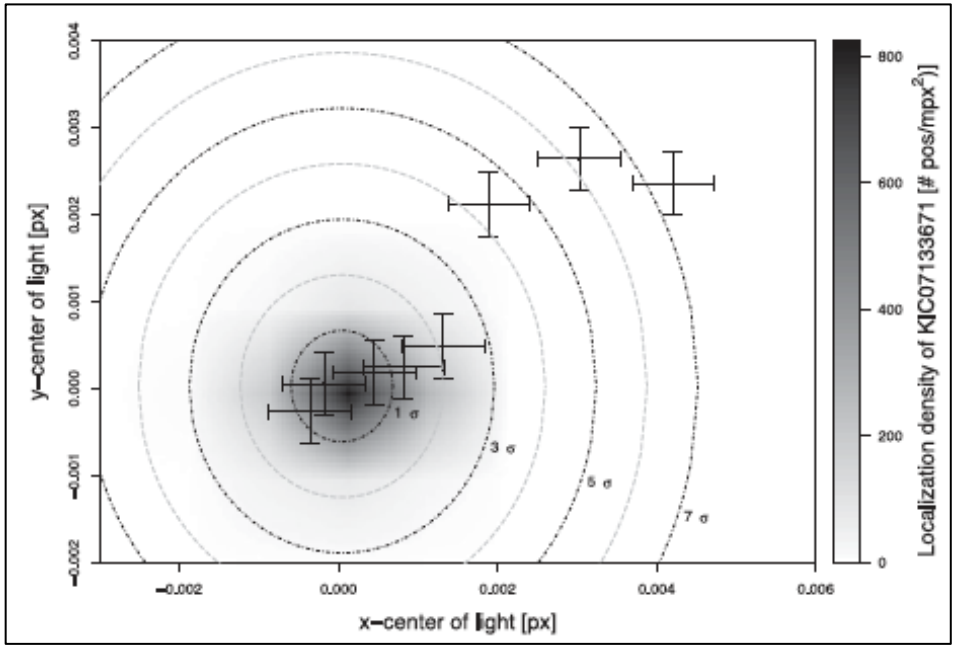
- The stellar-flare spectrum is not too well known; the assumption in the Shibata group's work is that the WLF spectrum has a 10^4 K blackbody form. ???

- Assessing the solar-flare energy has always been difficult because of the lack of spectroscopic observations. A 10^4 K blackbody form might be OK, but could be way off.

The “random dMe star” peril



KIC10524994



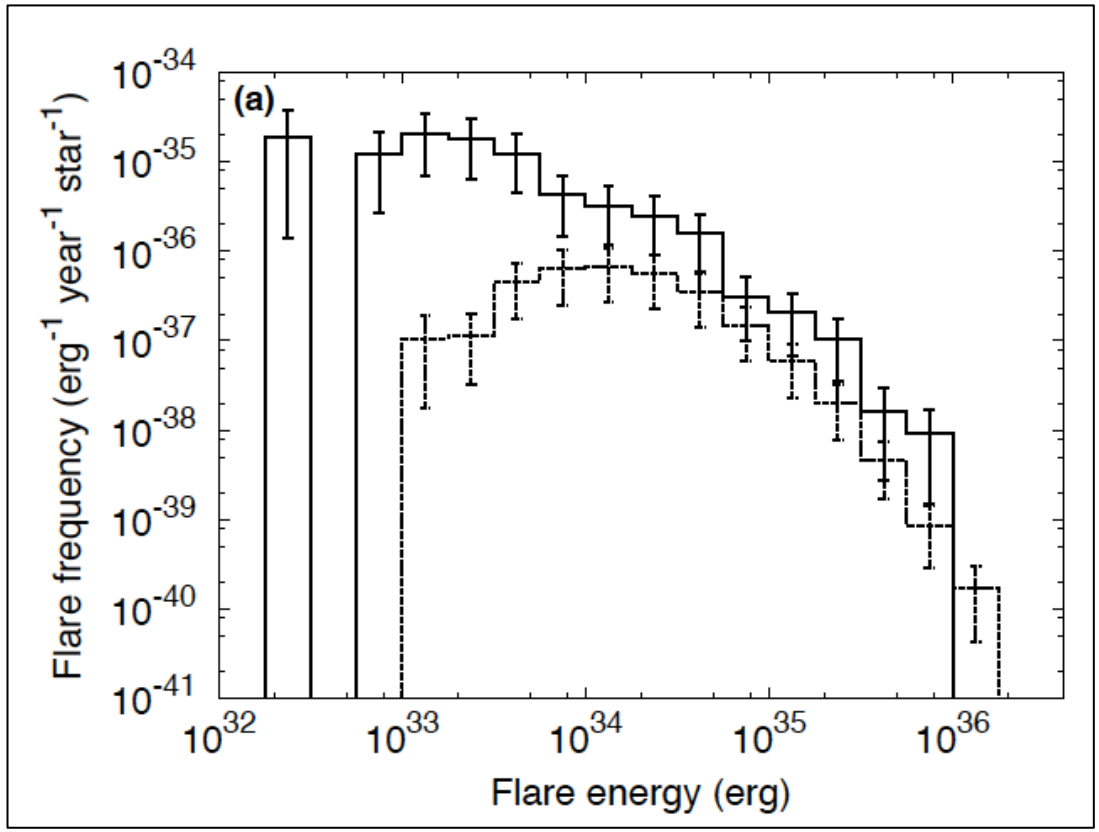
KIC07133671

From Kitze et al. 2014

Do starspot sizes correlate?

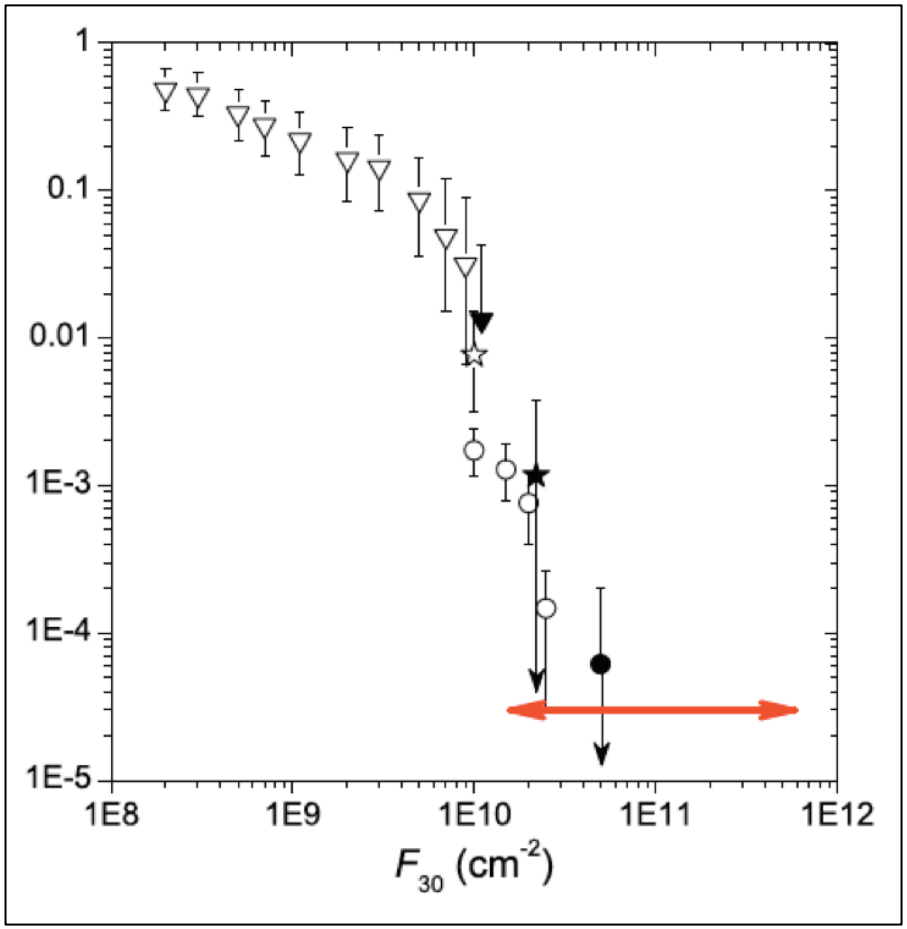
$$E_{\rm flare} \sim 7 \times 10^{32} ({\rm erg}) \left(\frac{f}{0.1}\right) \left(\frac{B}{1000{\rm G}}\right)^2 \left[\frac{A_{\rm spot}/2\pi R_\odot^2}{0.001}\right]^{3/2}$$

???

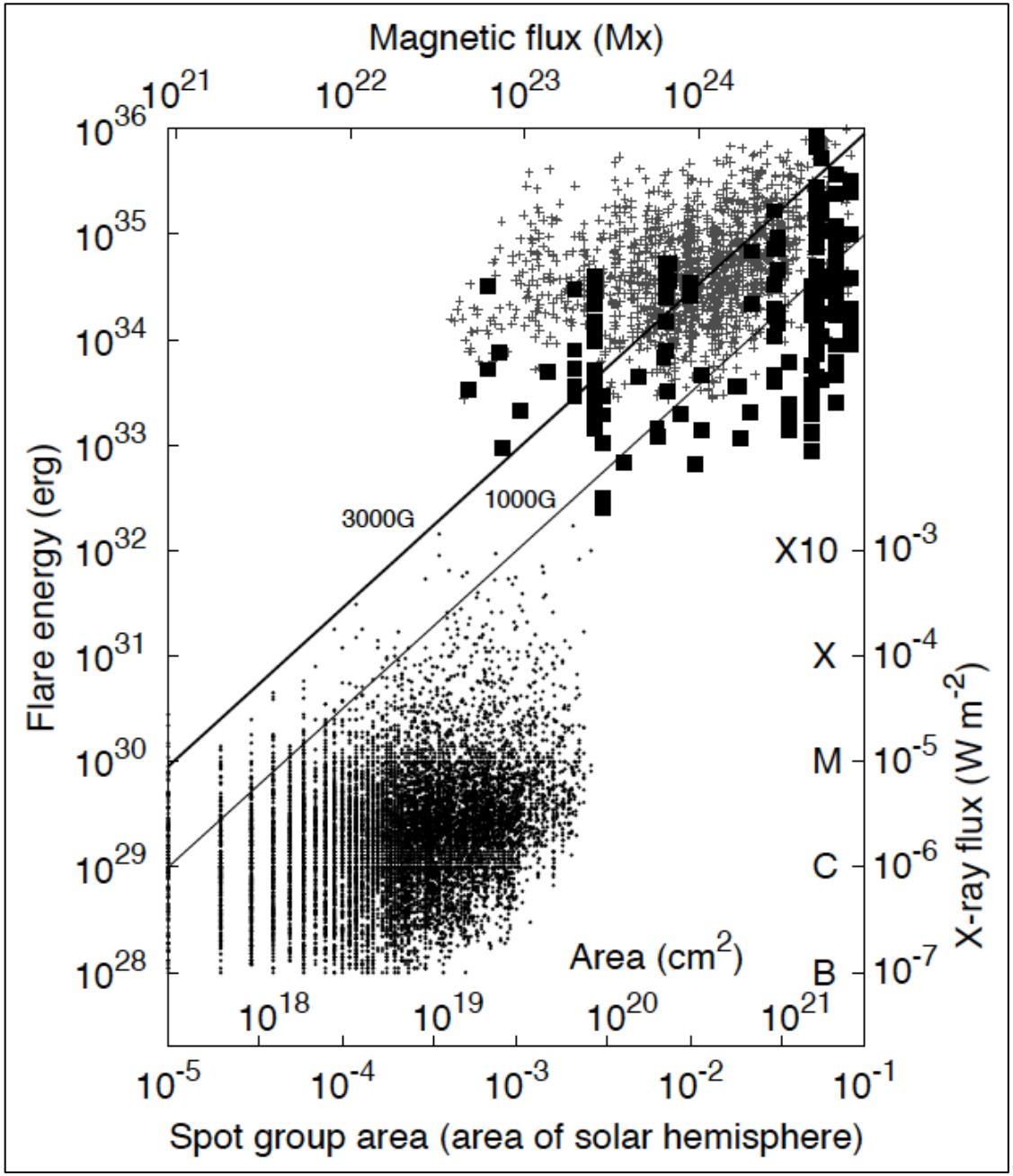


From Maehara et al. (2015); bold from 1-min data

Are there solar “Black Swans”?

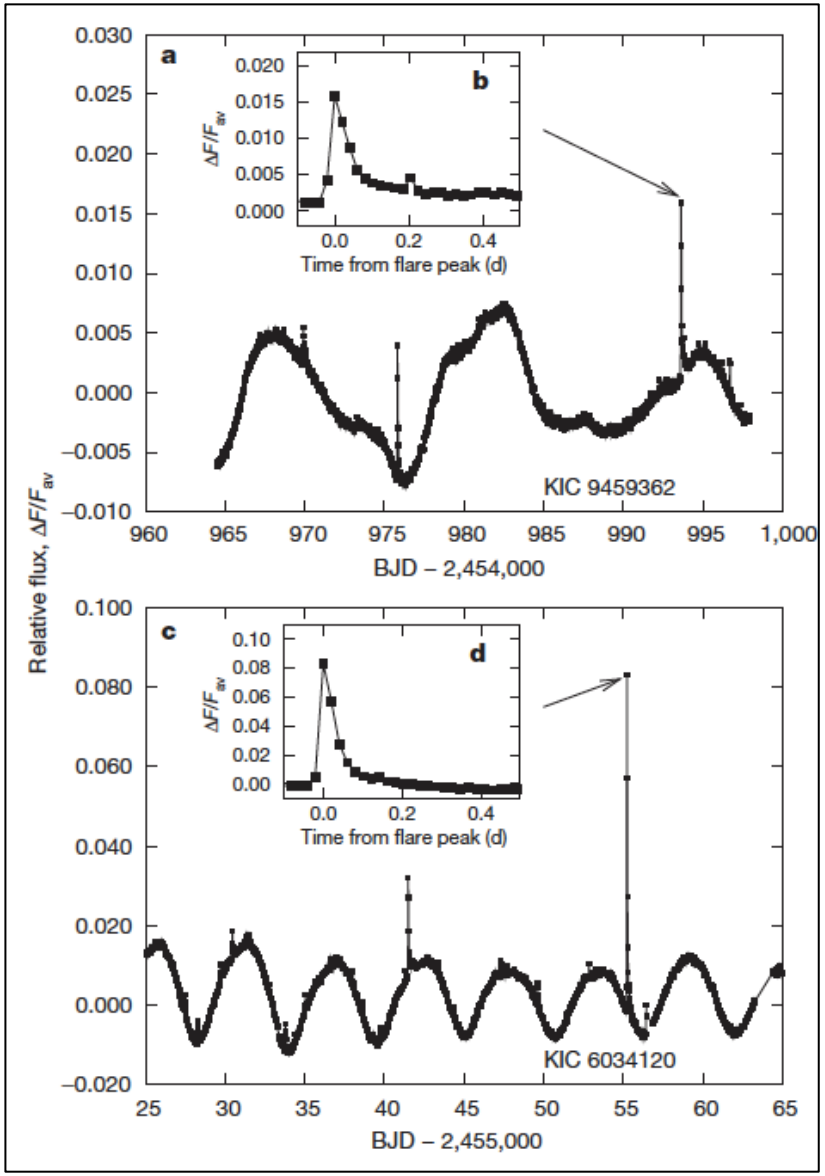


Kovaltsov et al. 2012

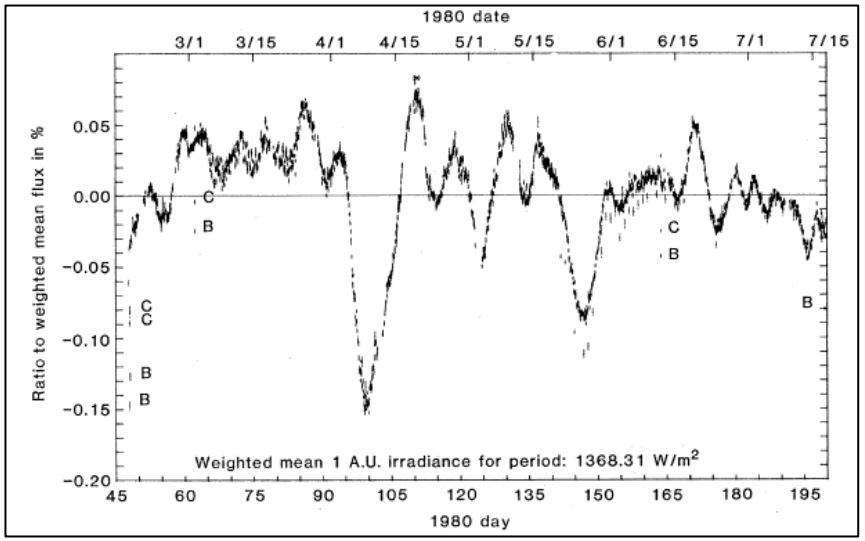


Maehara et al. 2015

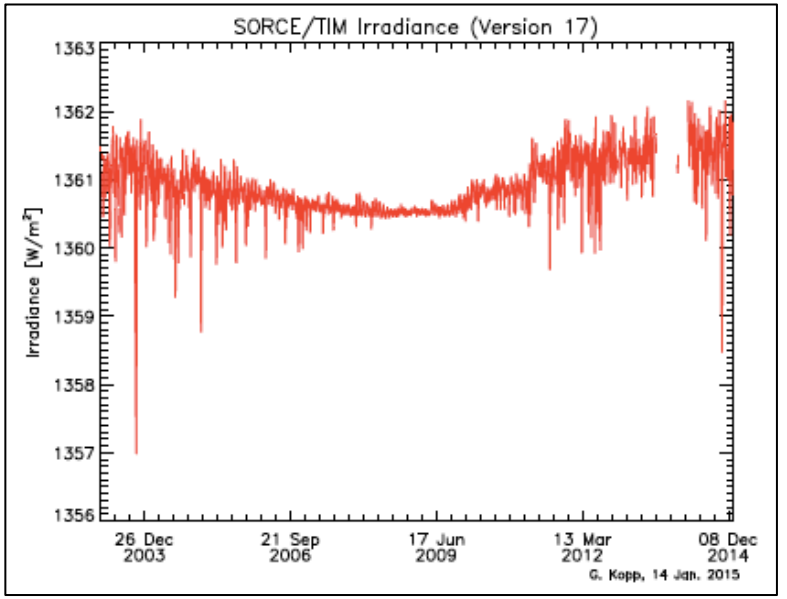
Kepler and solar light curves



Maehara et al. 2013



Willson et al. 1981



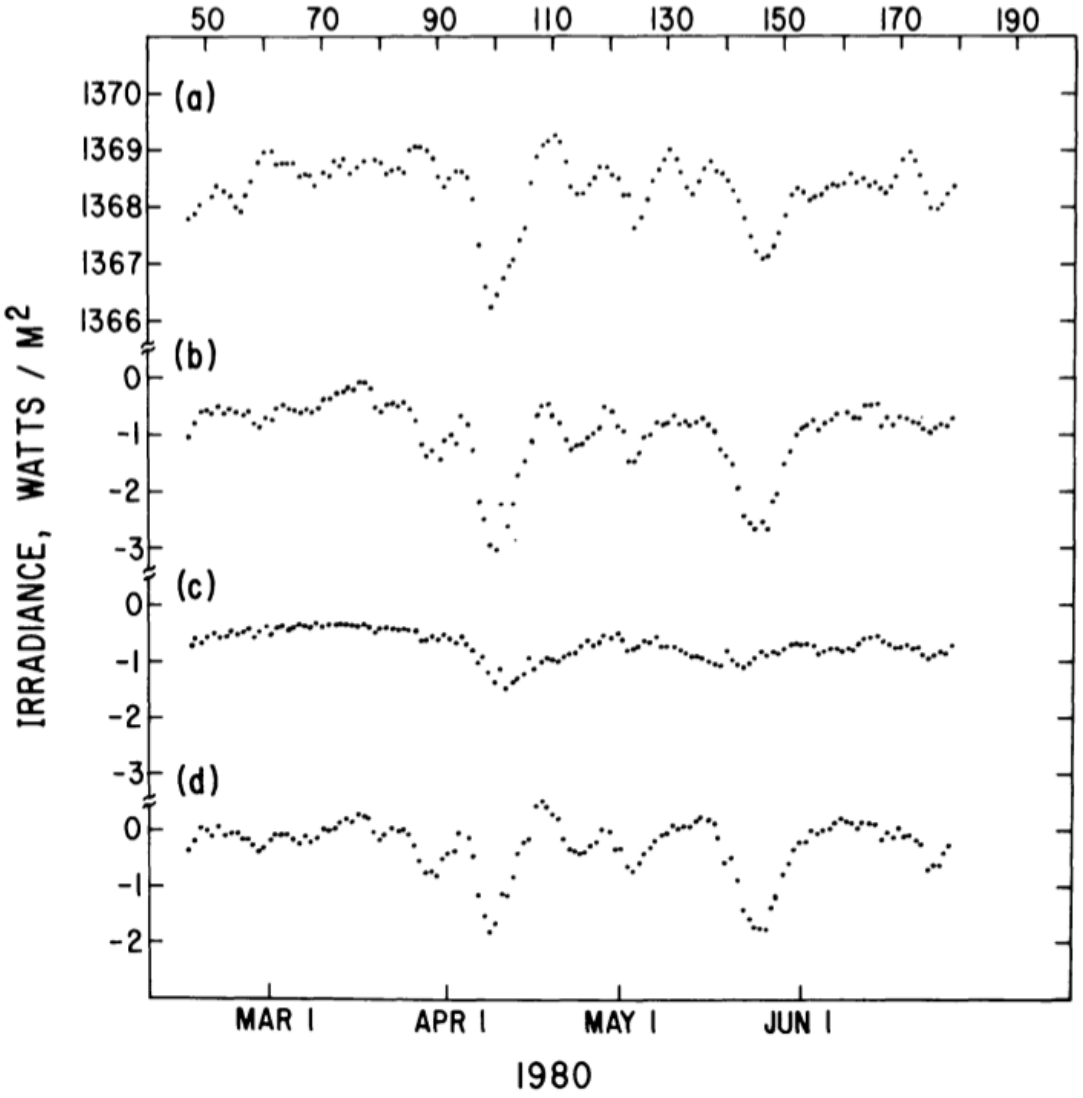
Kepler and solar light curves

- The variability patterns could not be more different:

  - Kepler superflare stars show large nearly sinusoidal variations, plus flares

  - The Sun shows erratic small variations, plus “dips”
- The solar sunspot dips are ¼ rotation in length because of foreshortening; they are not sinusoidal at all
- The solar variability models are well characterized in terms of spots and faculae, roughly equal contributors
- Stellar variability models typically don’t include faculae

Global solar model (Hudson et al. 1982)



This model of the 1980 ACRIM data incorporated spots and plage-based faculae including the invisible hemisphere. The resultant (c) should be like the luminosity.

Modern approaches might make luminosity estimates more realistic.

Conclusions

- The solar paradigms may or may not be appropriate for Kepler “superflare” stars
- The Kepler and solar time series look quite inconsistent – do we understand what a “starspot” is?
- Solar TSI models are complete and precise, but are frequently ignored
- We cannot safely use the Kepler statistics for prediction of solar extreme events