Why should we care about small flares ?

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Because they can affect solar irradiance variations

(speculative answer)

Matthieu Kretzschmar
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Small flares contribute to irradiance variations if …

- ✓ They have a significant impact on irradiance
- ✓ They dominate the total radiative outputs caused by flares ($\alpha > 2$)
- ✓ The rate of small flares varies with time.

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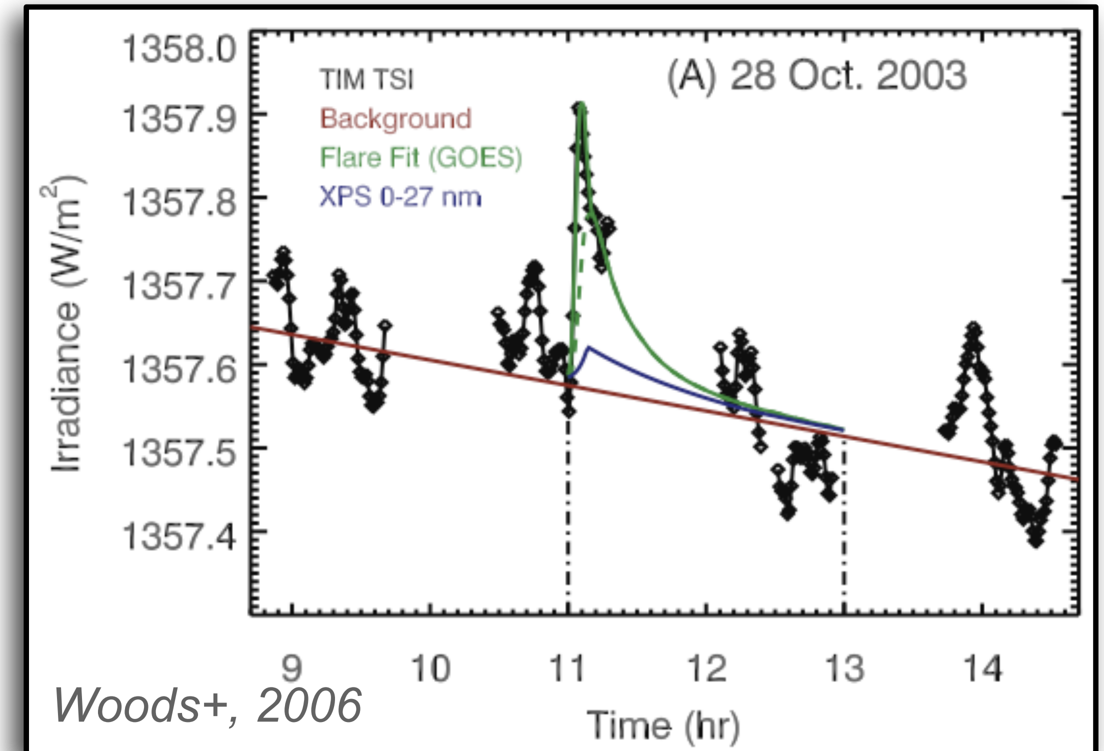
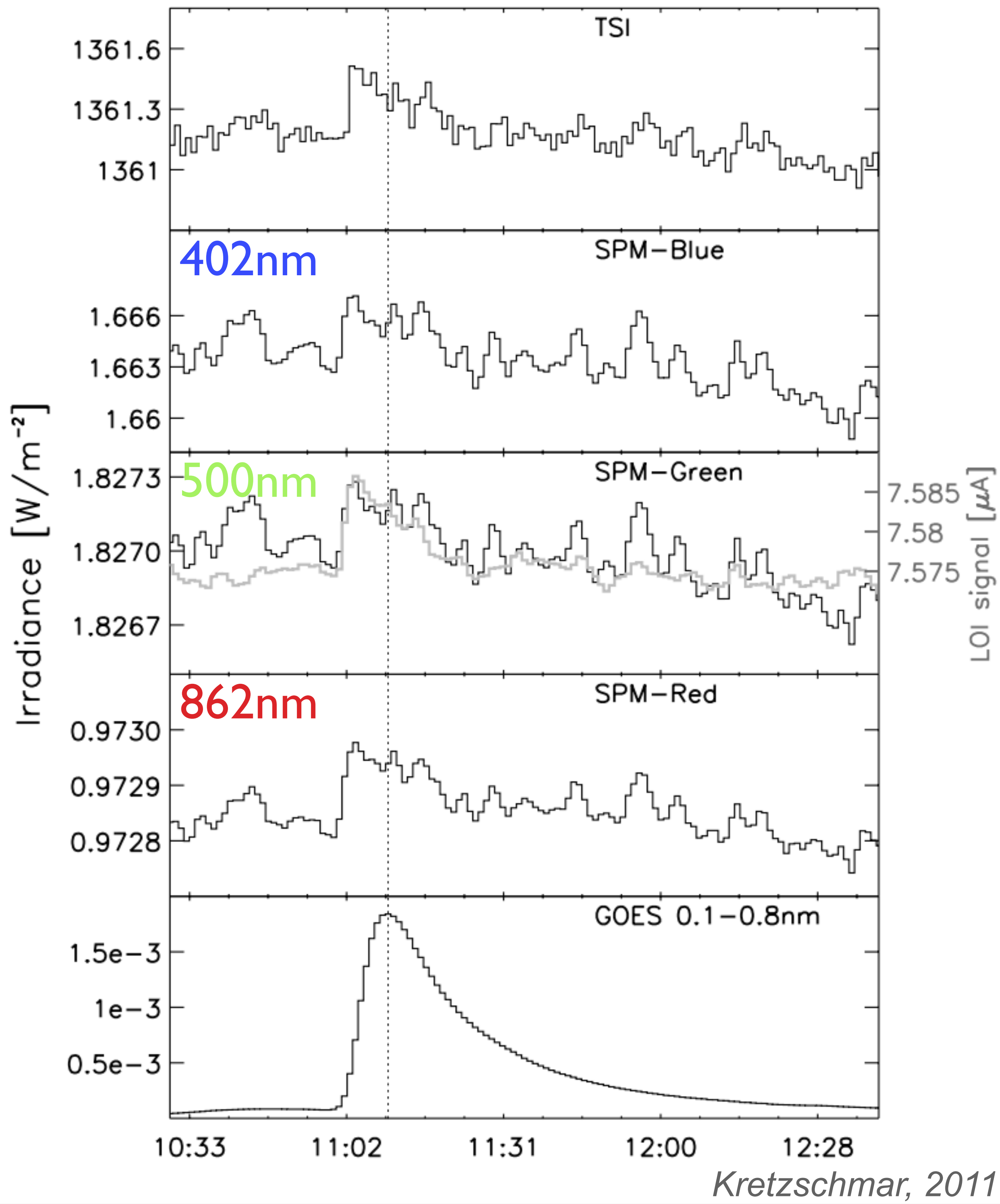
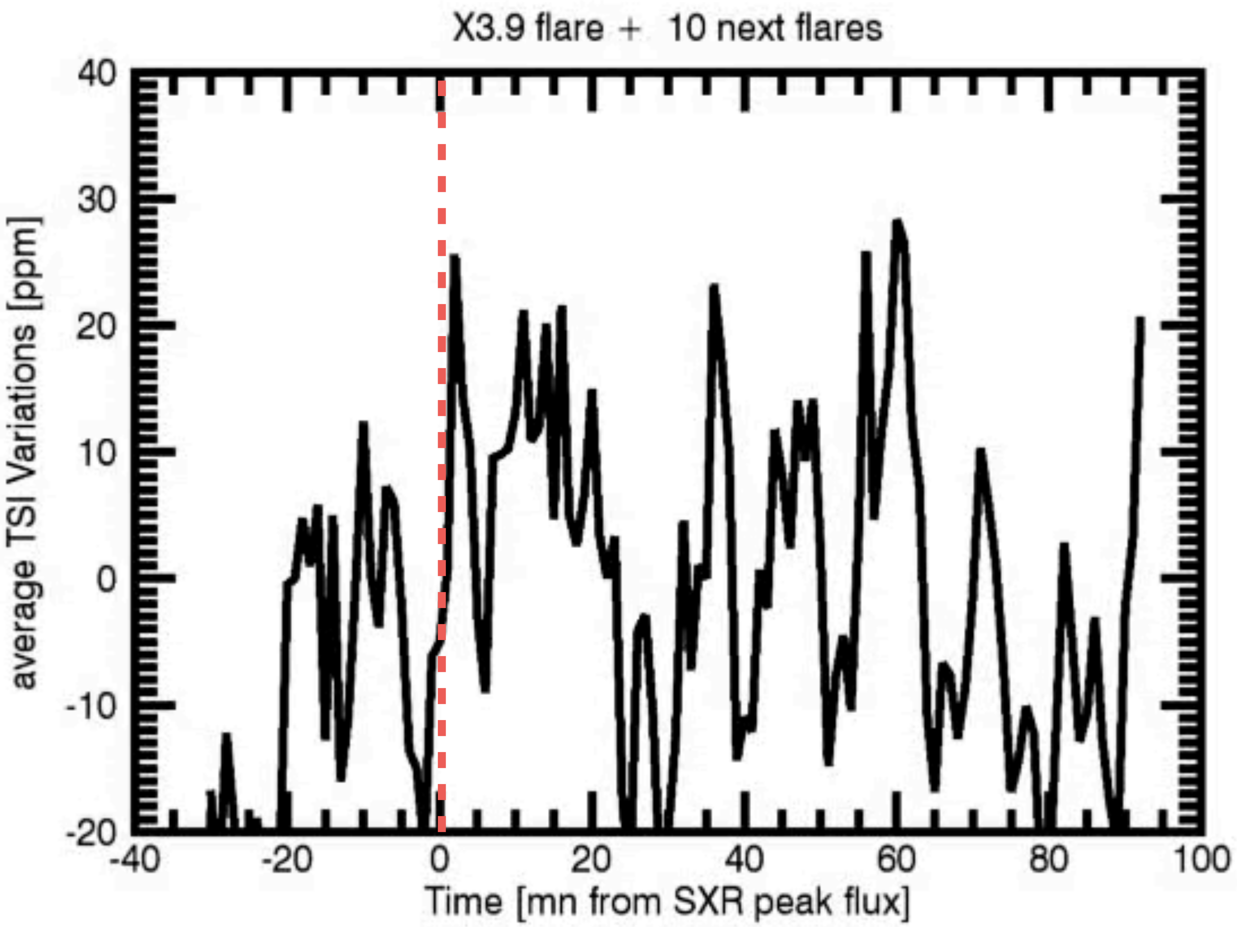
Big flares impact the solar irradiance



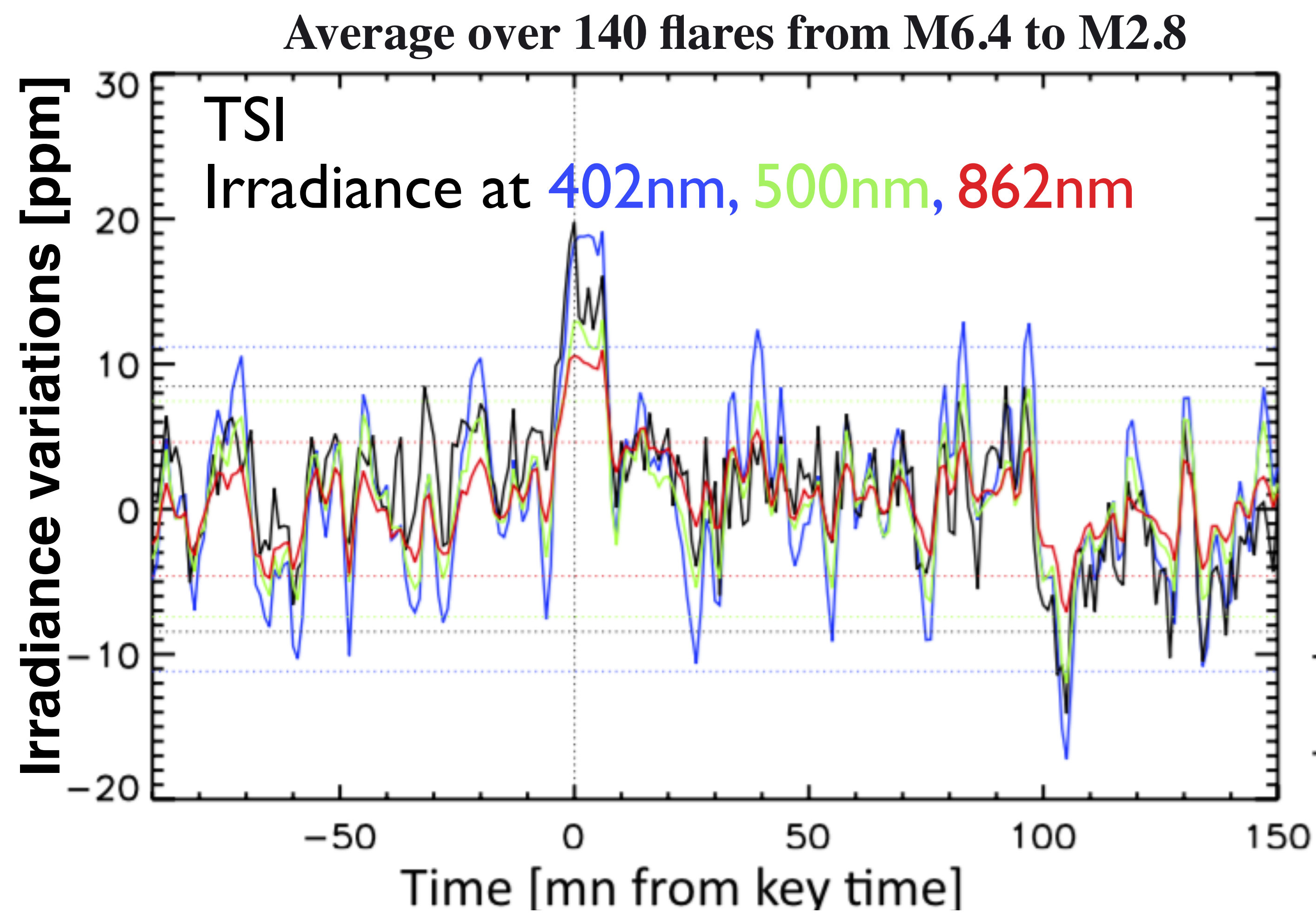
- ★ 264ppm increase for the TSI observed by VIRGO (268 by TIM)
- ★ Increase of the visible channel as well

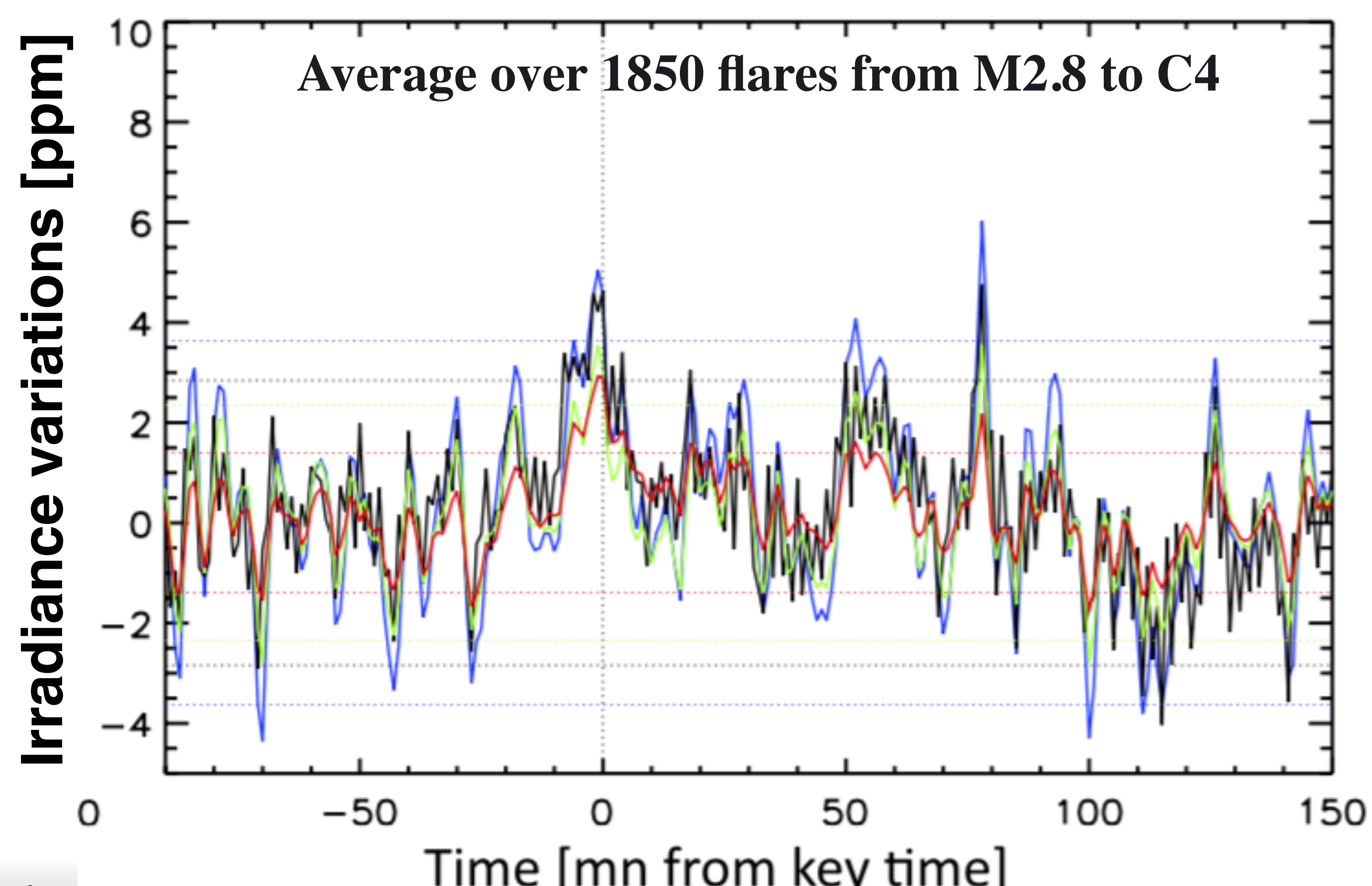


Smaller flares impact the solar irradiance



★ Both TSI and visible irradiance increase during flares.





Should we care about small flares ?, Kretzs

Kretzschmar, 2011

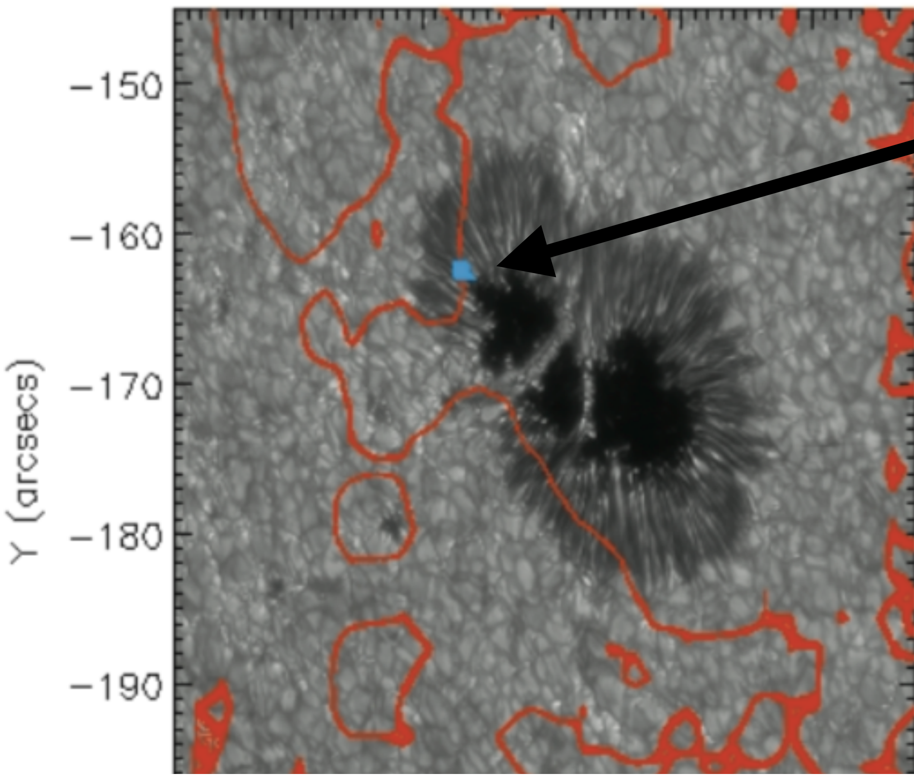
Smaller flares impact the solar irradiance

DO ALL FLARES HAVE WHITE-LIGHT EMISSION?

D. B. Jess,[1,2] M. Mathioudakis,[1] P. J. Crockett,[1] and F. P. Keenan[1]

Received 2008 September 10; accepted 2008 October 8; published 2008 November 3

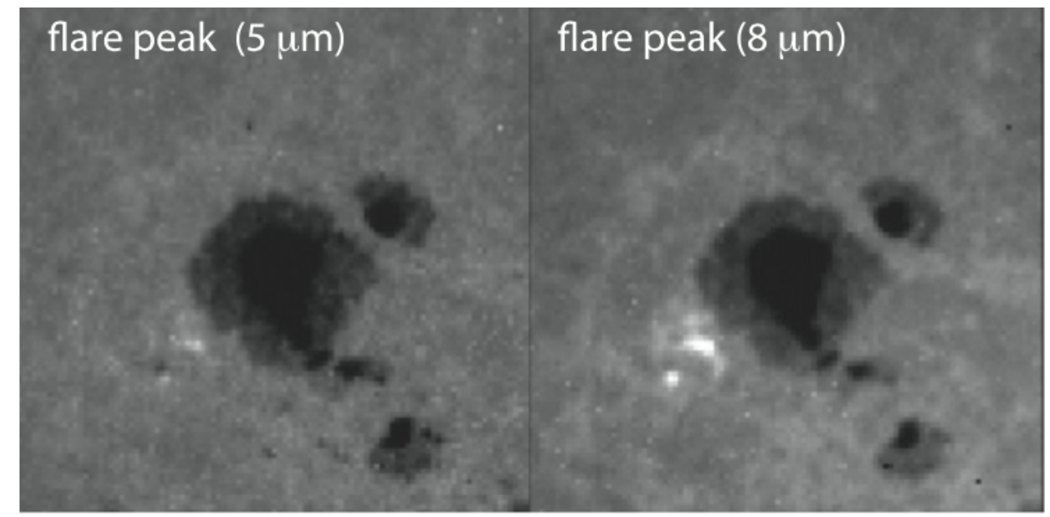
ApJ, 2008

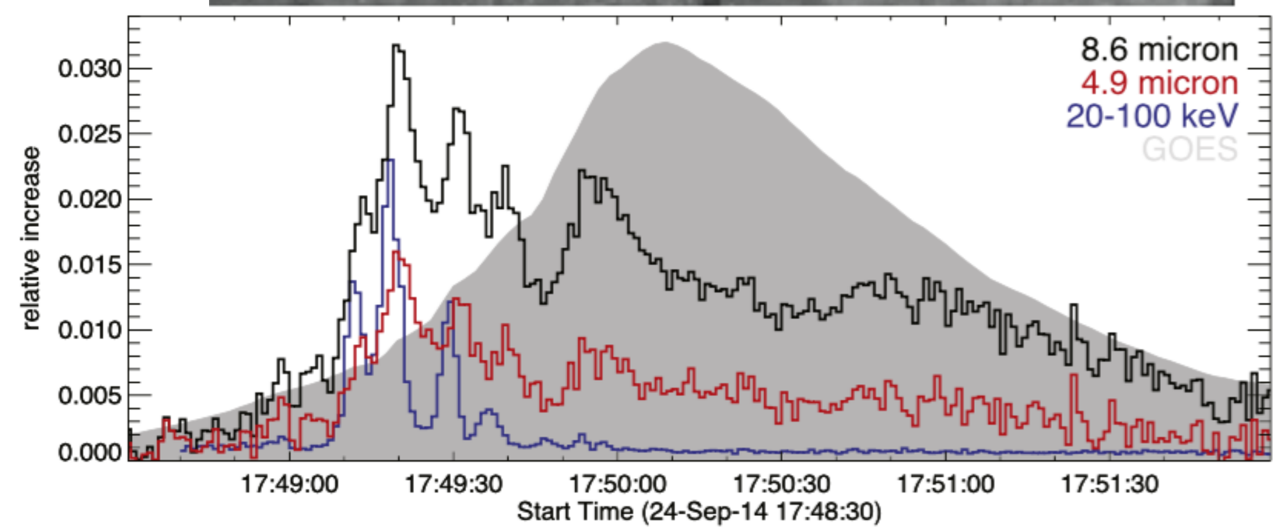


A WLF in a C2 X-ray class flare

Size: 300km

C7 class flare *Penn+, 2016*





- ★ Smaller flares have smaller size and smaller contrast, which make then hardly detectable.
- ★ Yet, they are there and contribute to total and visible irradiance.
- ★ Roughly one can assume that 50% of the flare emission goes into the visible and near UV (continua + lines)

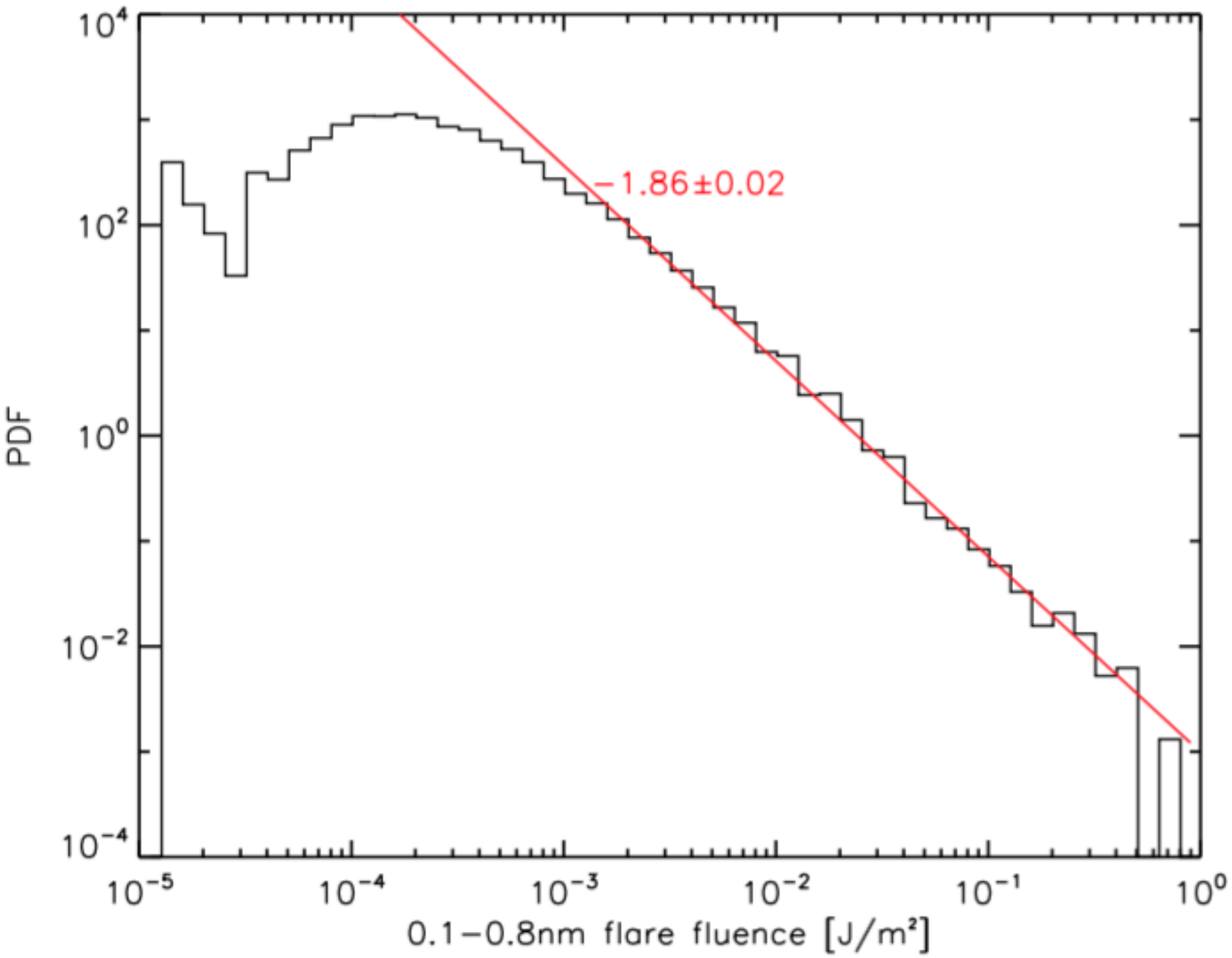
see: Kretzschmar 2011, Kleint+ 2016, Warmuth+2016

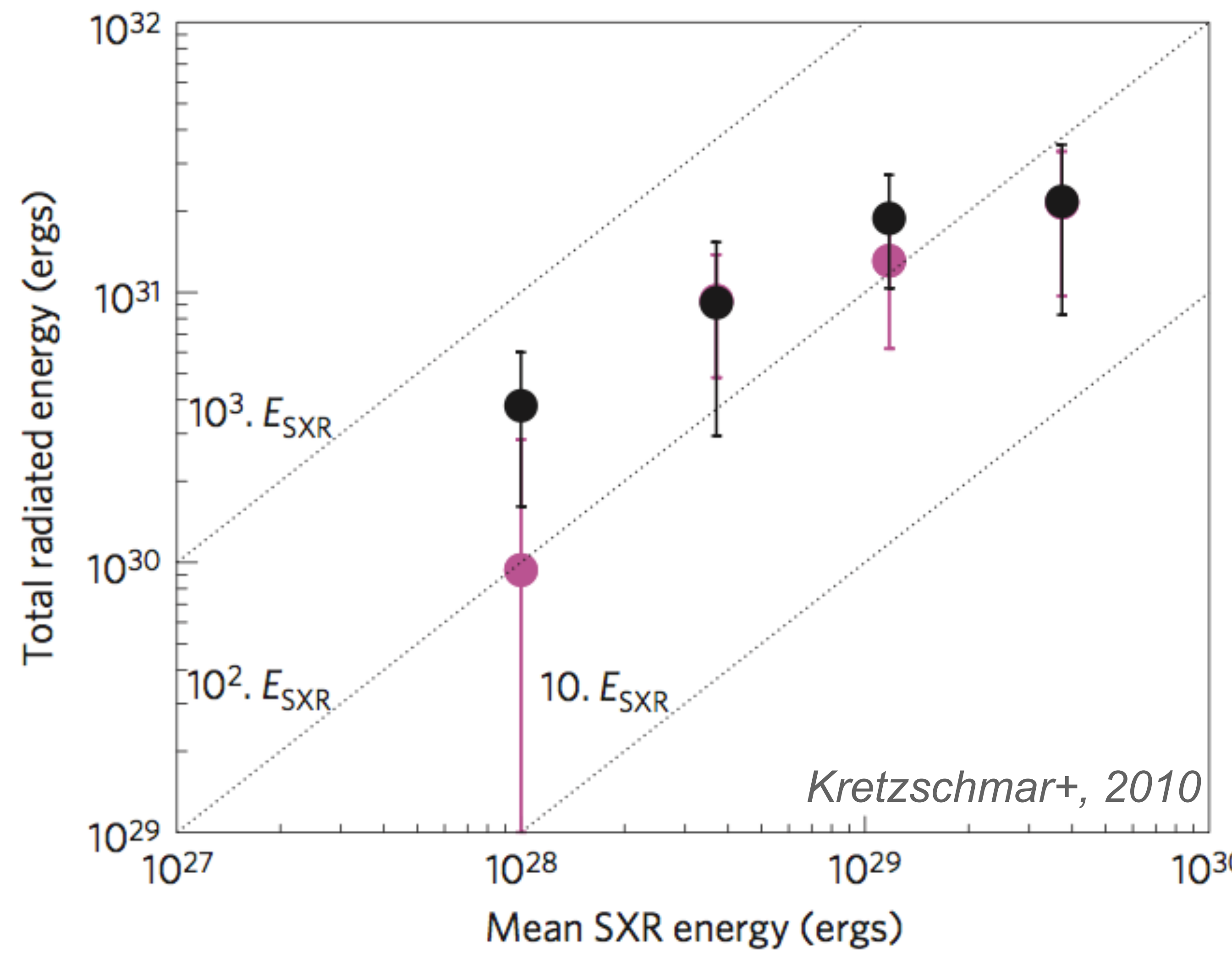
Small flares contribute to irradiance variations if …

✓ **They have a significant impact on irradiance**

Are small flares dominating ?

★ The total flare emission is dominated by small flares if the slope exponent is larger than 2.





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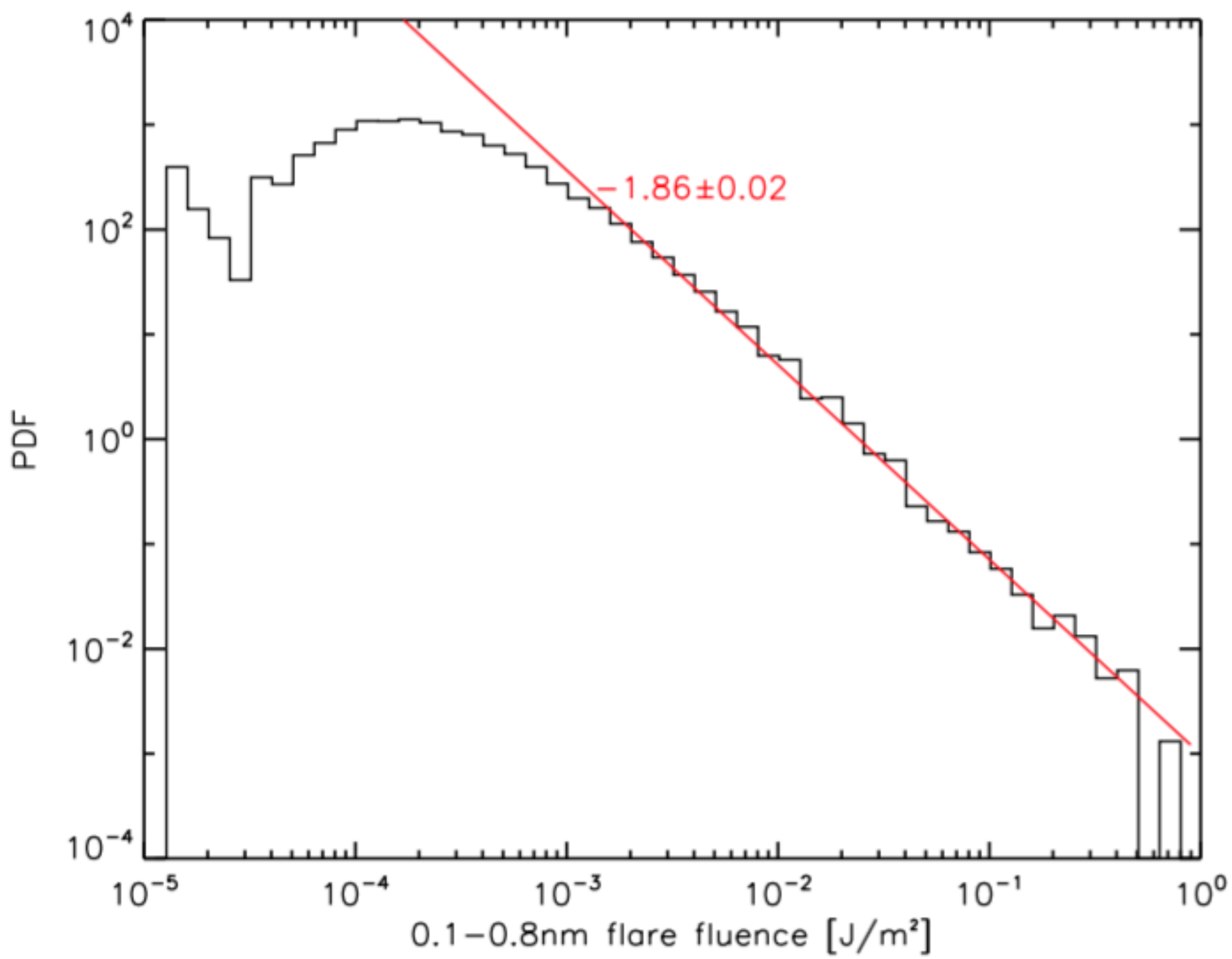
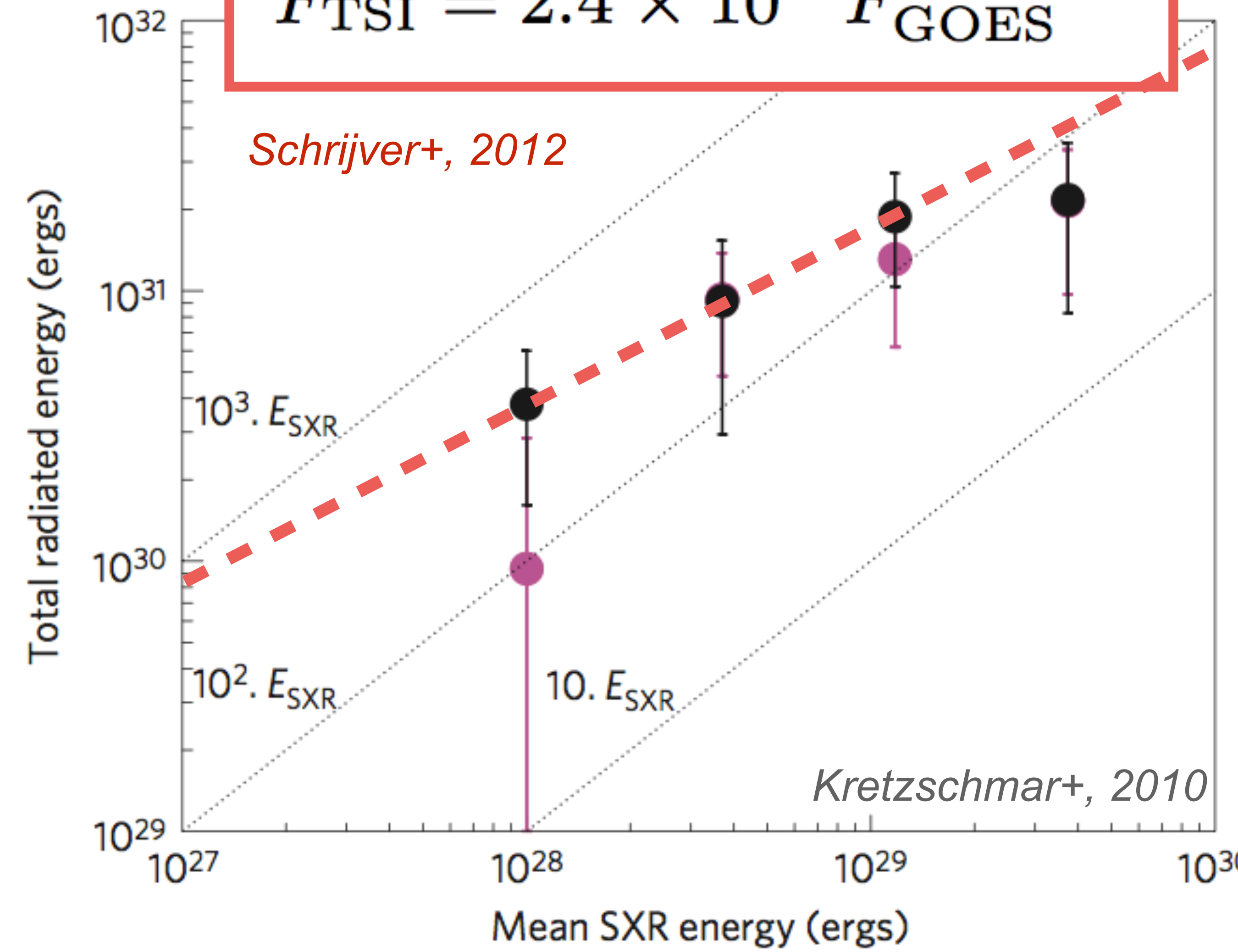


$$F_{\mathrm{TSI}} = 2.4 \times 10^{12} F_{\mathrm{GOES}}^{0.65 \pm 0.05}$$



★ It looks to be the case of the total emission: $\alpha_{\mathrm{TSI}} = 2.3$

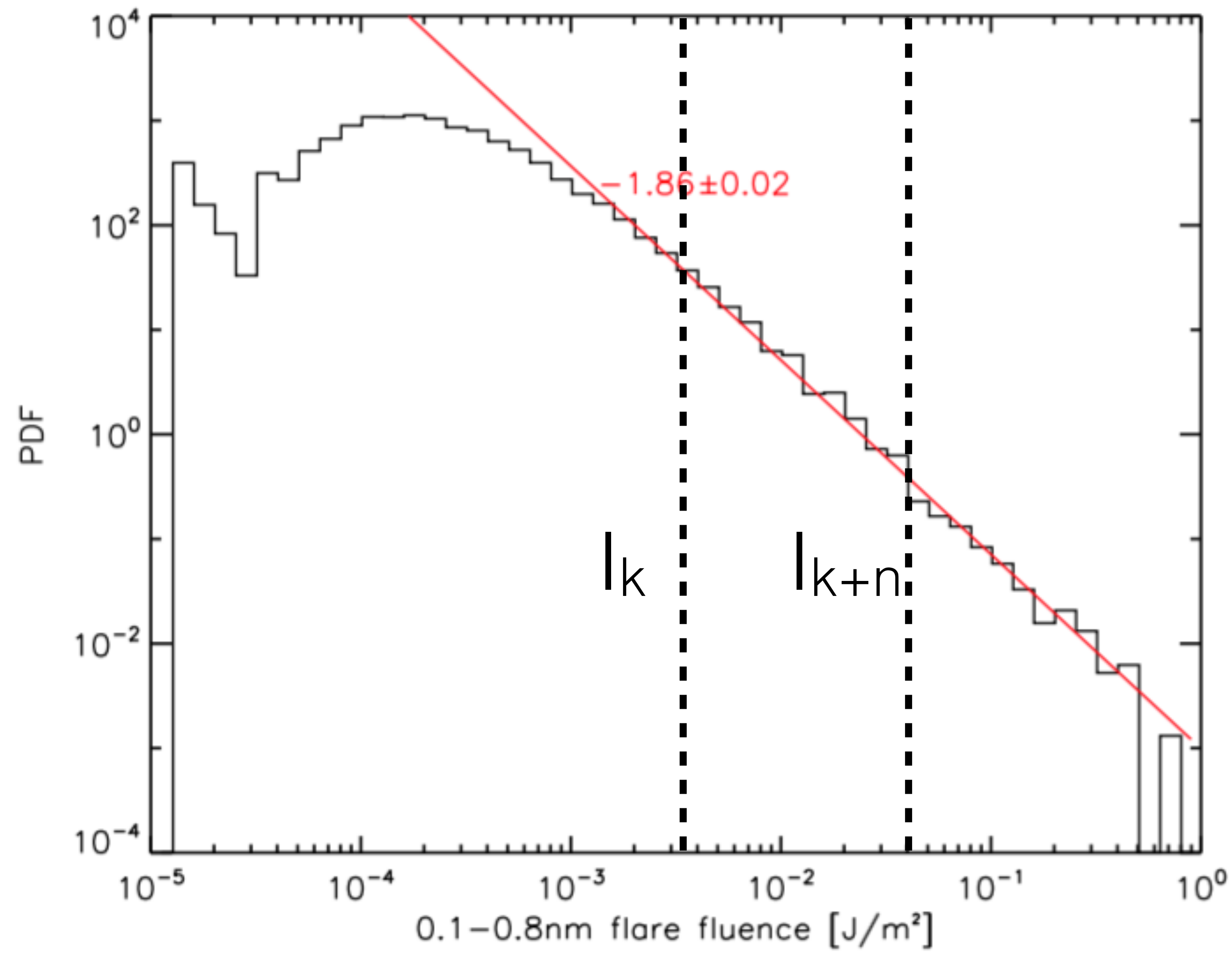
$P(x) = C_1 x^{-\alpha_x}$ and $y \sim x^{\gamma}$ ➡ $P(y) = C_2 y^{-\alpha_y}$ and $\alpha_y = \dfrac{\alpha_x + \gamma - 1}{\gamma}$

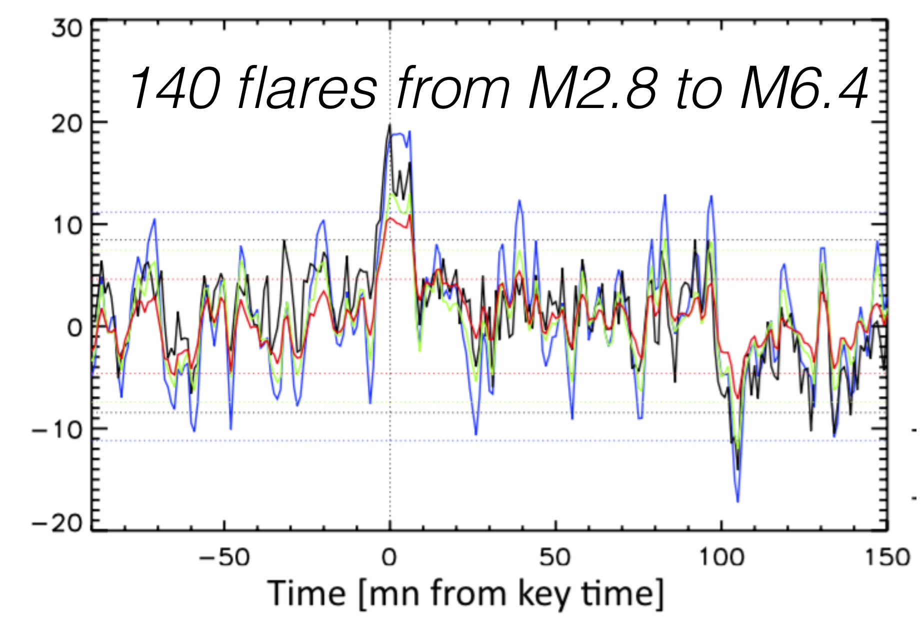
Should we care about small flares ?, Kretzschmar M., Space Climate 6, Finland, 2016

The slope α of the PDF for TSI flare emission

The result of the superposed epoch analysis can be predicted as :

$$\bar{I}_{k,n} = \int_{I_k}^{I_{k+n}} I f(I) dI \quad \text{where} \qquad I_1 > I_2 > \ldots > I_N$$





The slope of the TSI flare emission

The result of the superposed epoch analysis can be predicted as :

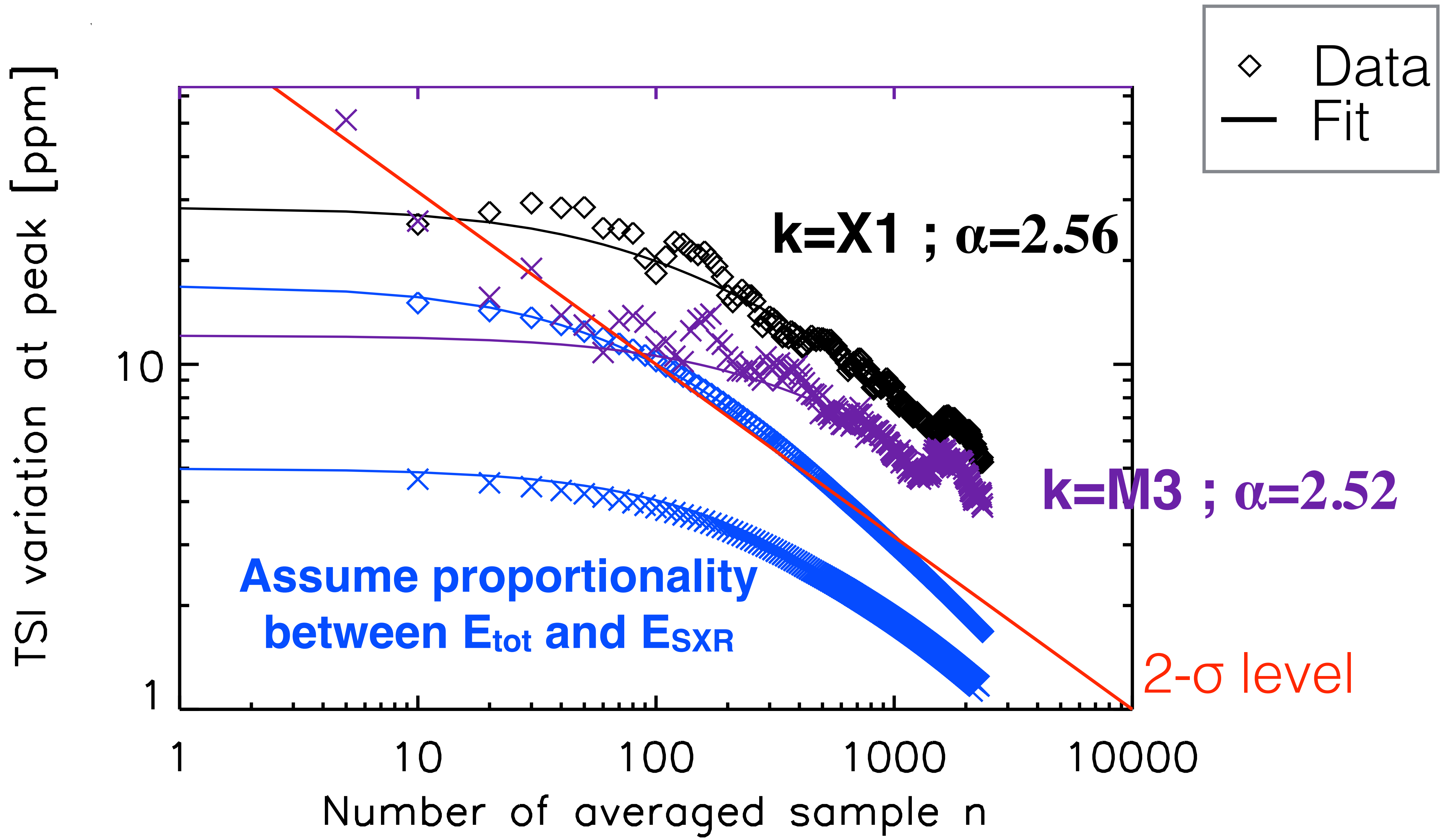
$$\bar{I}_{k,n} = \int_{I_k}^{I_{k+n}} I f(I) dI \quad \text{where} \quad I_1 > I_2 > \ldots > I_N$$

For $f(I) = C I^{-\alpha}$ and $I_i^{mp} = \left[\frac{C[(\alpha-1)N+1]}{(\alpha-1)i+1} \right]^{1/\alpha-1}$ *Sornette, 2000*

leads to :

$$\overline{I^f}(k,n) = \frac{C'}{(2-\alpha)n} \left\{ [(\alpha-1)k+1]^{\frac{2-\alpha}{1-\alpha}} - [(\alpha-1)(k+n-1)+1]^{\frac{2-\alpha}{1-\alpha}} \right\}$$

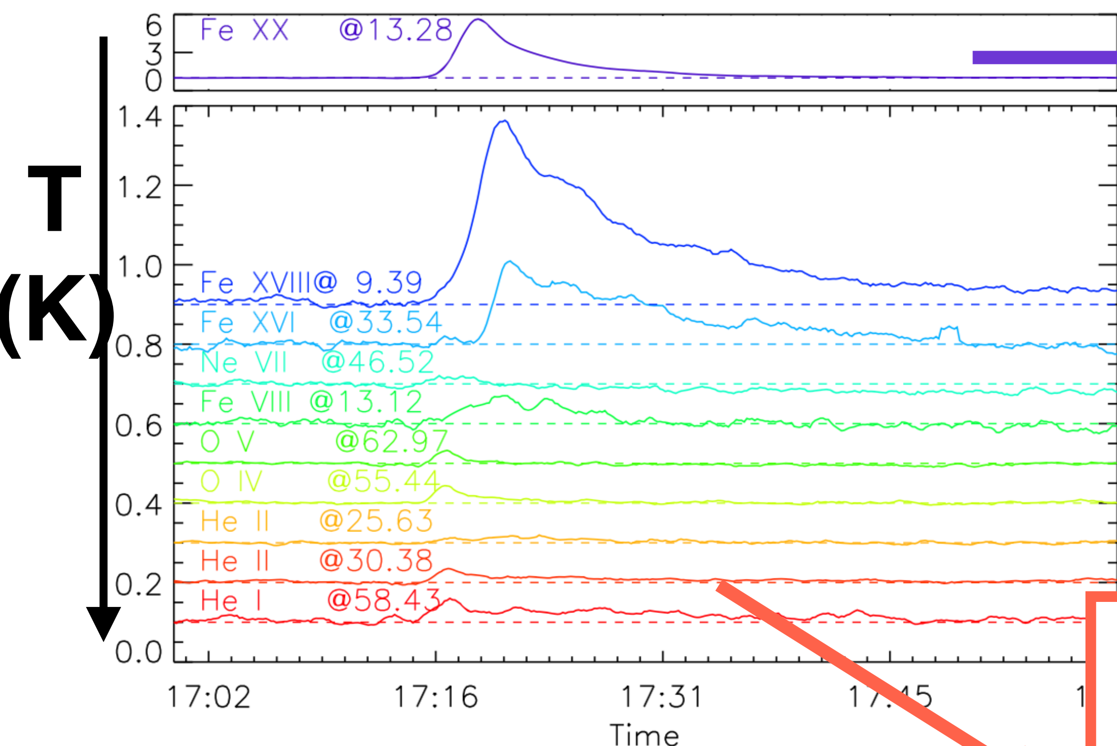
The slope of the TSI flare emission

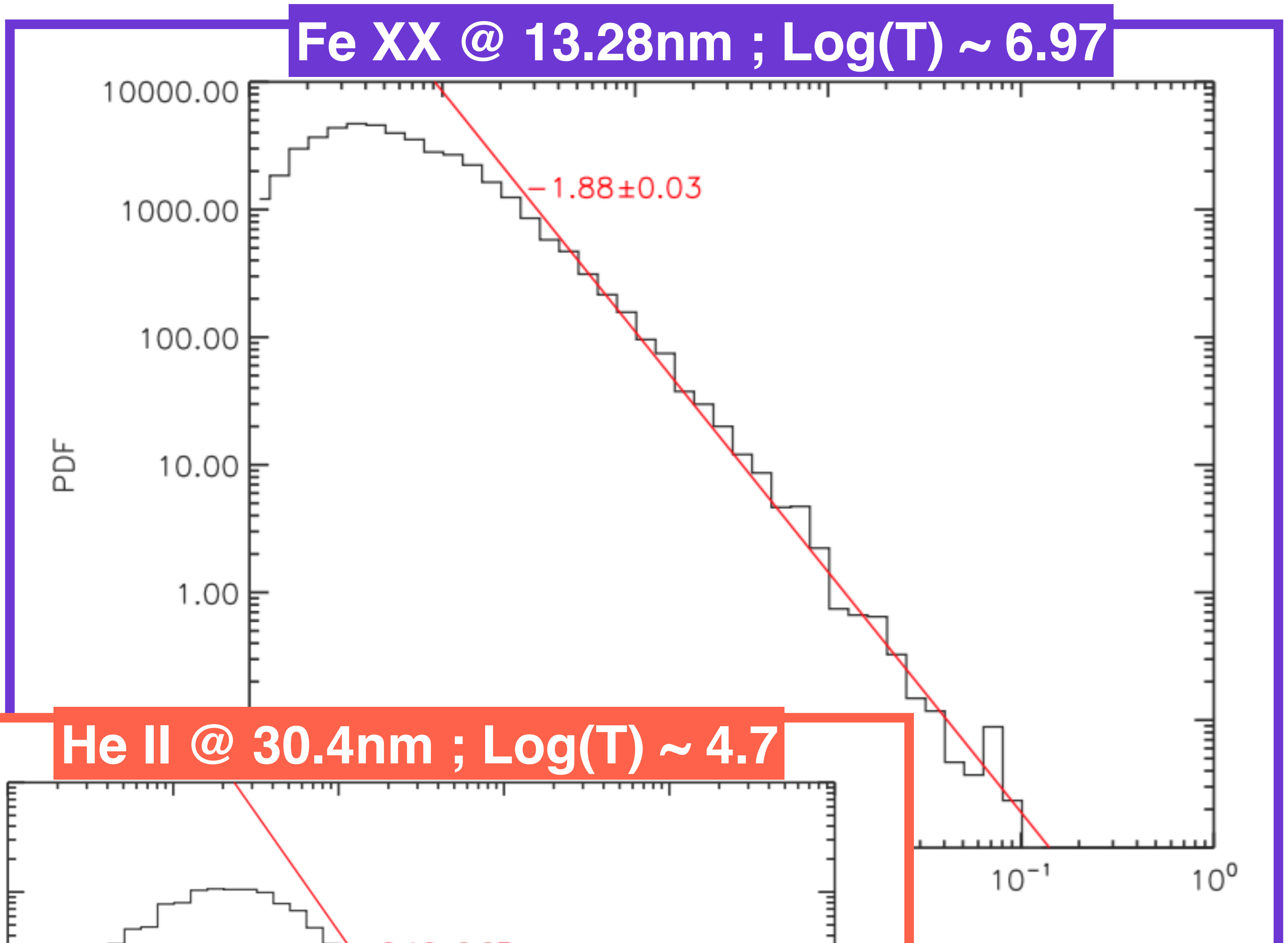


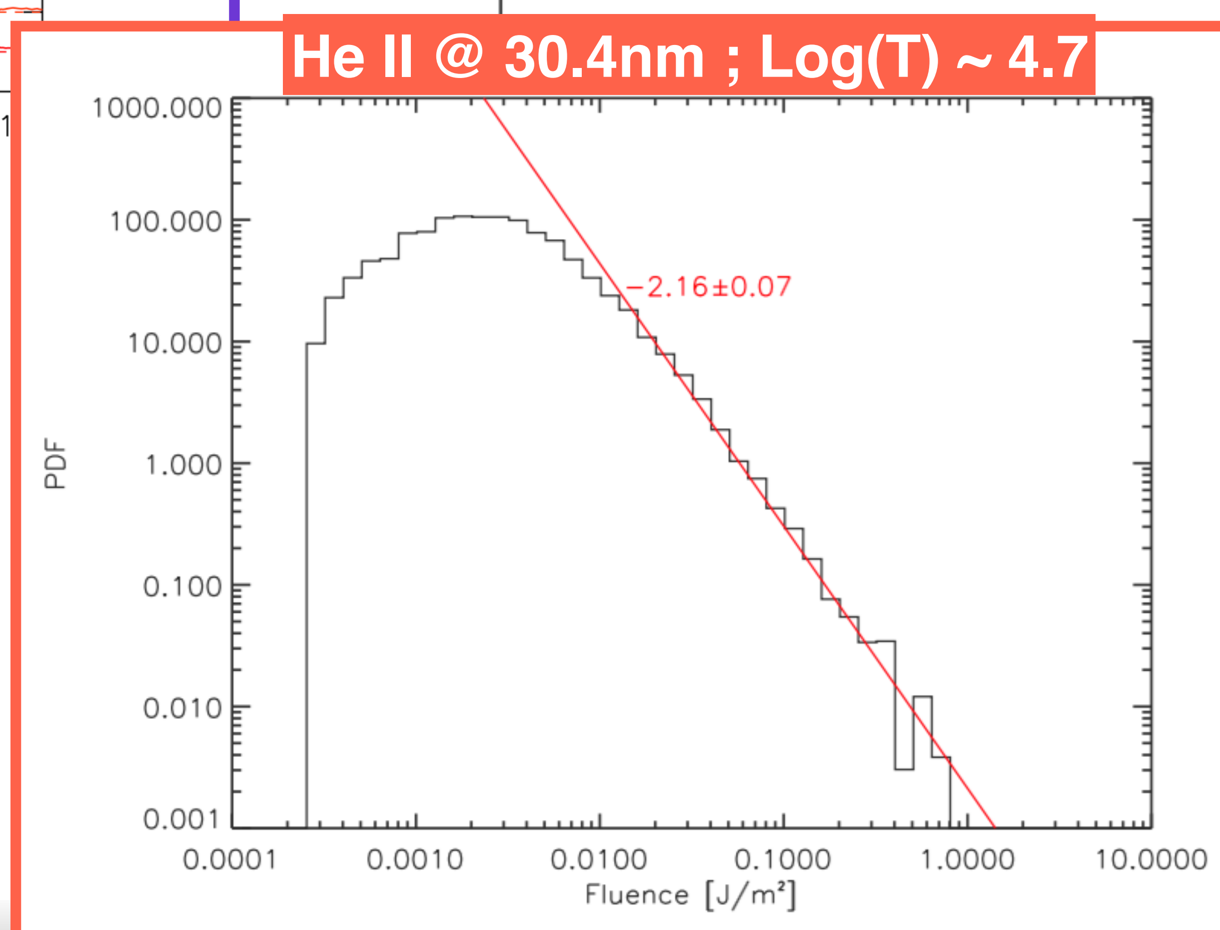
➡ **Is that true ?**

Flare fluence distribution vs λ

M1 flare on 5 May 2010



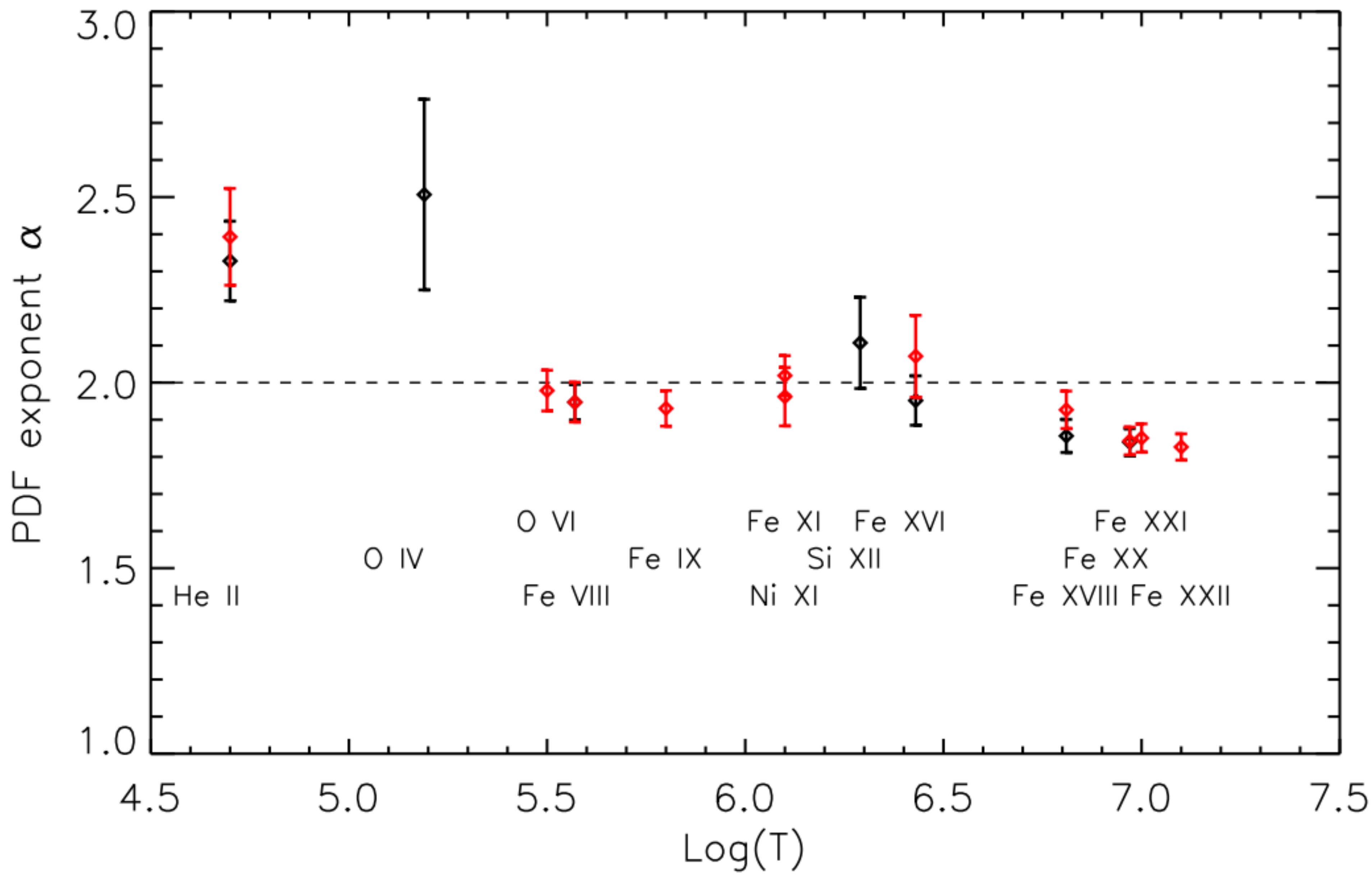




- SDO/EVE data
- All flares above the C1 level
- Check the influence of background and start and end times

Should we care about small flares ?, Kretzschmar M., Space Climate 6, Finland, 2016

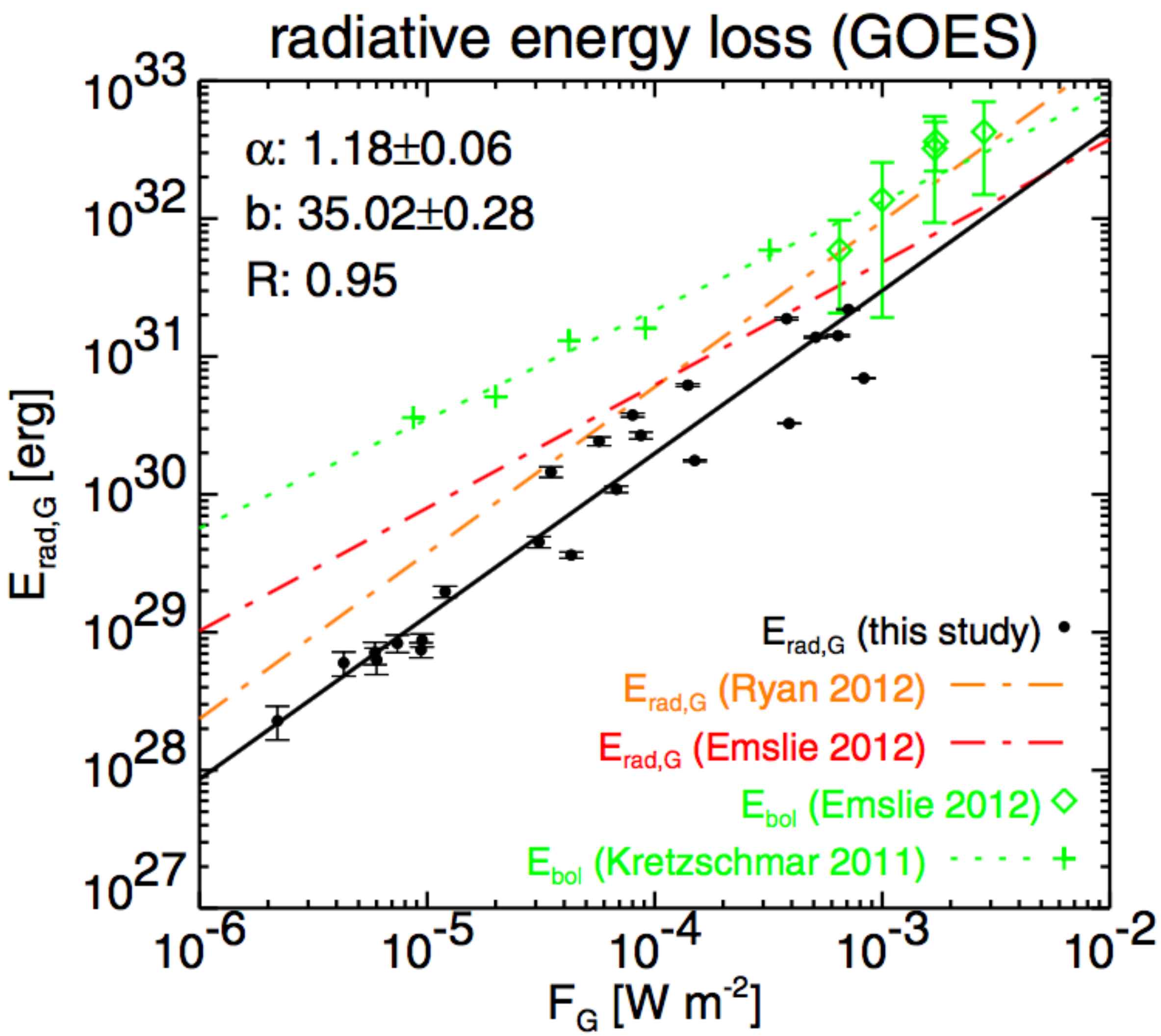
α's dependence on T ?

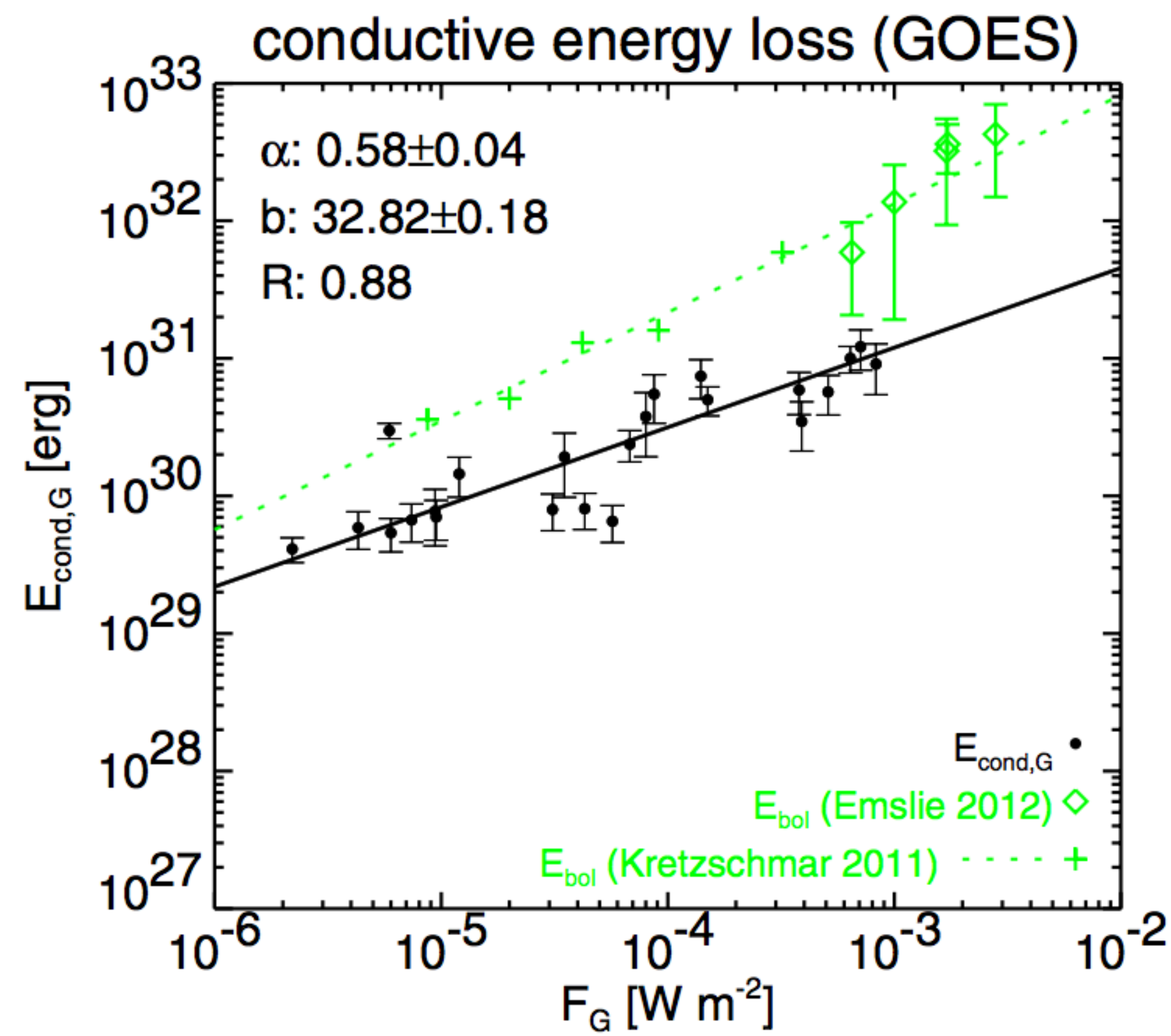


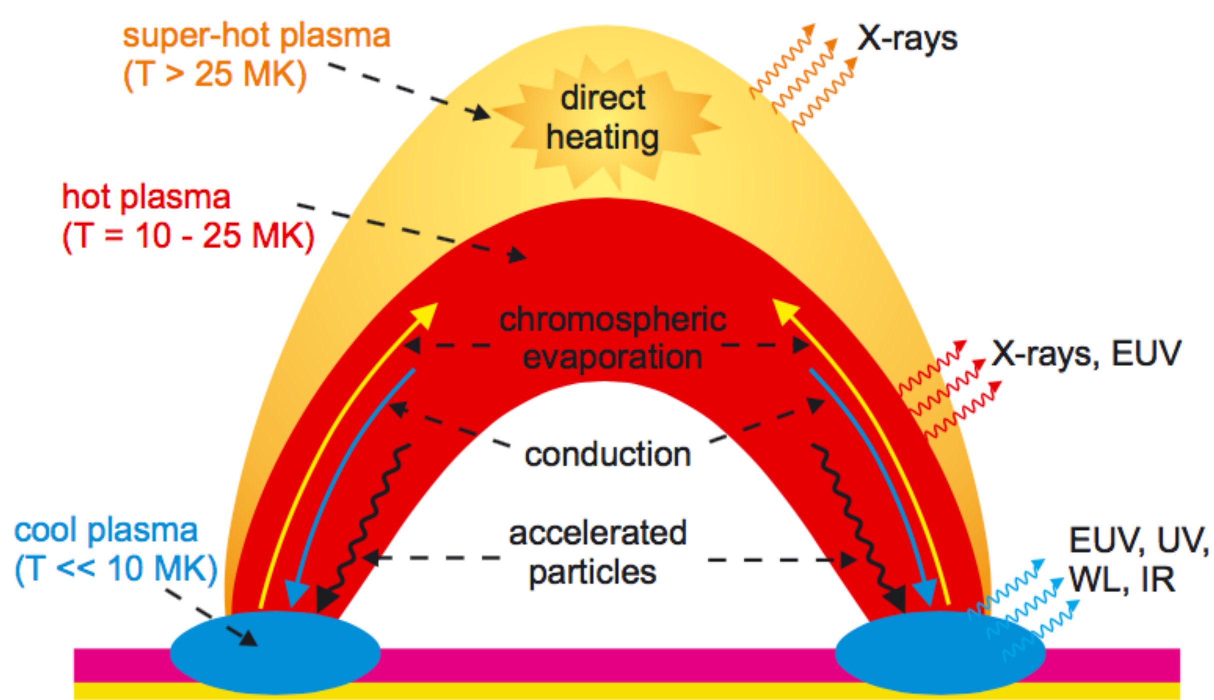
Kretzschmar, 2015

★ Tendency for chromospheric emission to have an exponent greater than 2.

Why is chromospheric and coronal flare emission scaling differently ?







Warmuth+, 2016

Small flares contribute to irradiance variations if …

- ✓ We can estimate their impact on irradiance (and assume it remains true for yet smaller flare)
- ✓ They dominate the total radiative outputs due by flares ($\alpha > 2$) (and assume the distribution does not change for yet smaller flares).
- ✓ The rate of small flares varies with time. **?**

Variations due to active regions

(A toy model)

- Assume ARs are heated by nano flares and that each of them produce also an emission at longer wavelength (visible, near UV, IR).

50% of the total necessary energy as emission in the visible, near UV, etc.. :

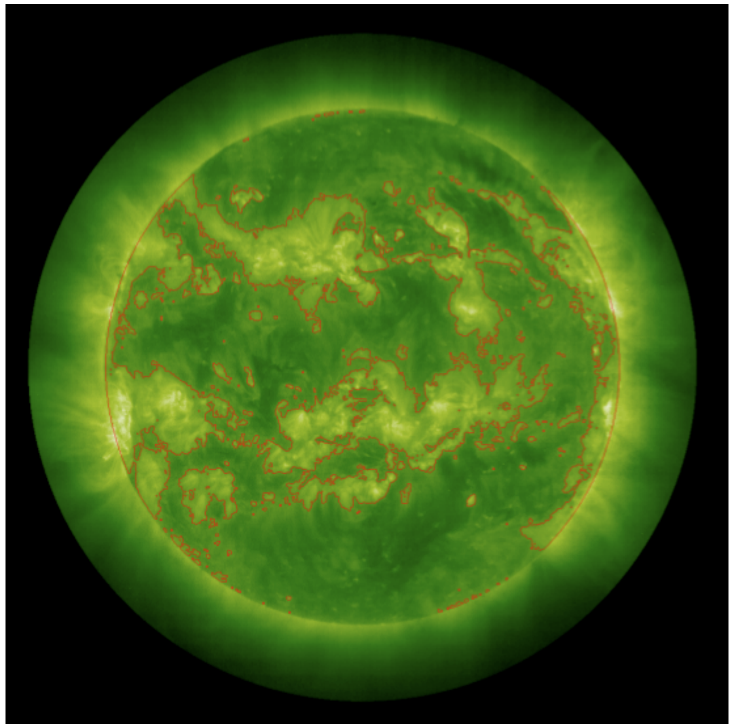
$$\int_{W_1}^{W_2} W N(W) dW = W_{tot}$$

$W_1 = 10^{24}$ erg
$W_{2,AR} \sim 10^{32}$ erg
$W_{tot,AR} \sim 10^7$ erg.cm^{-2}.s^{-1}

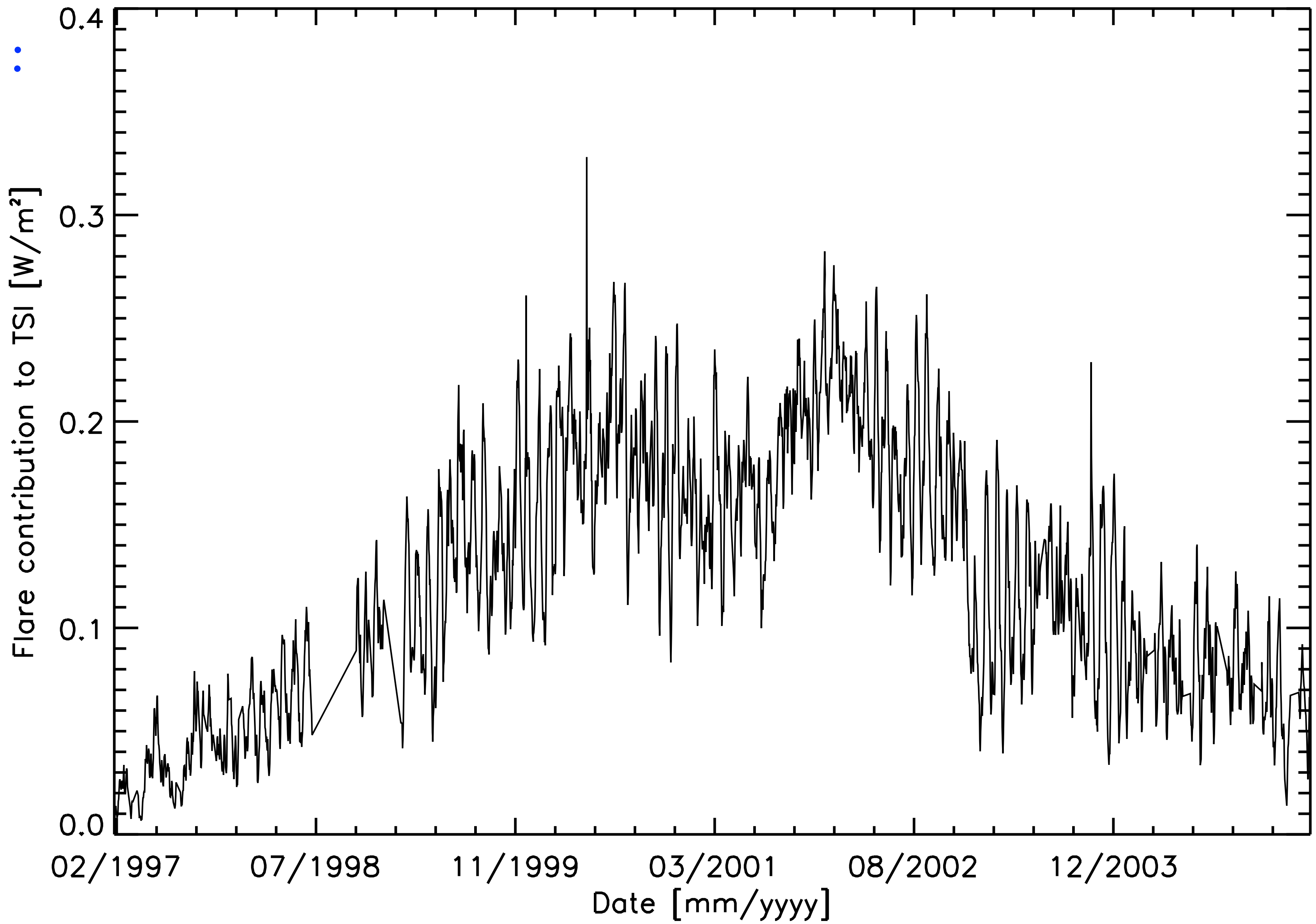
✓ With the active region we have a modulation of the energy:

$$f(W_{tot} * \sigma_{AR}(t))$$

✓Use EIT/195 AR area from segmentation (Barra+ 2009)



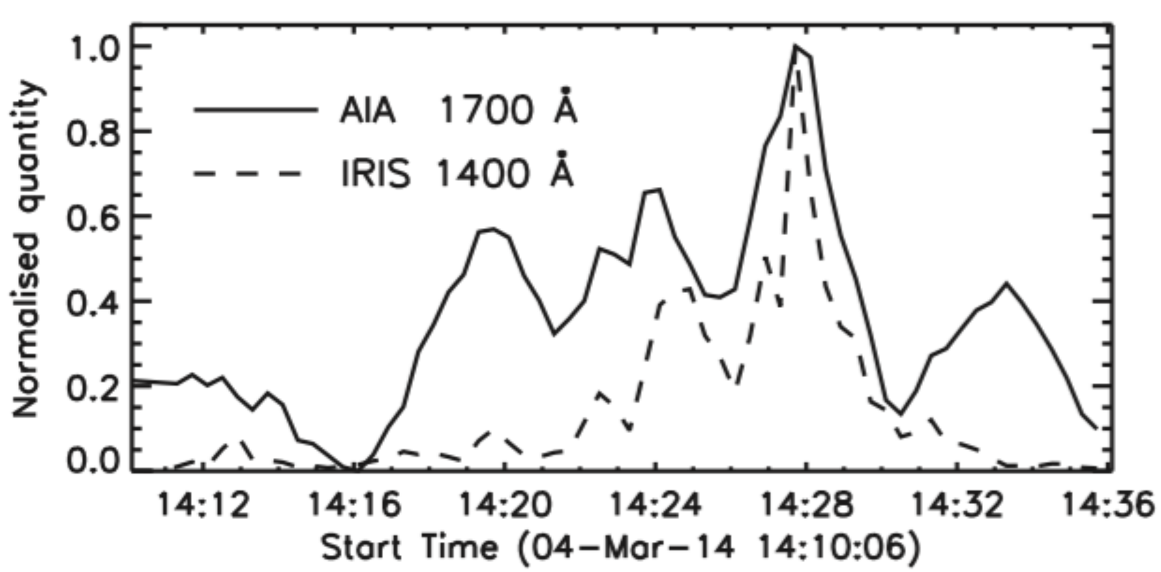
- Results :



✓ This is about 20% of the 1W TSI variation with the cycle.

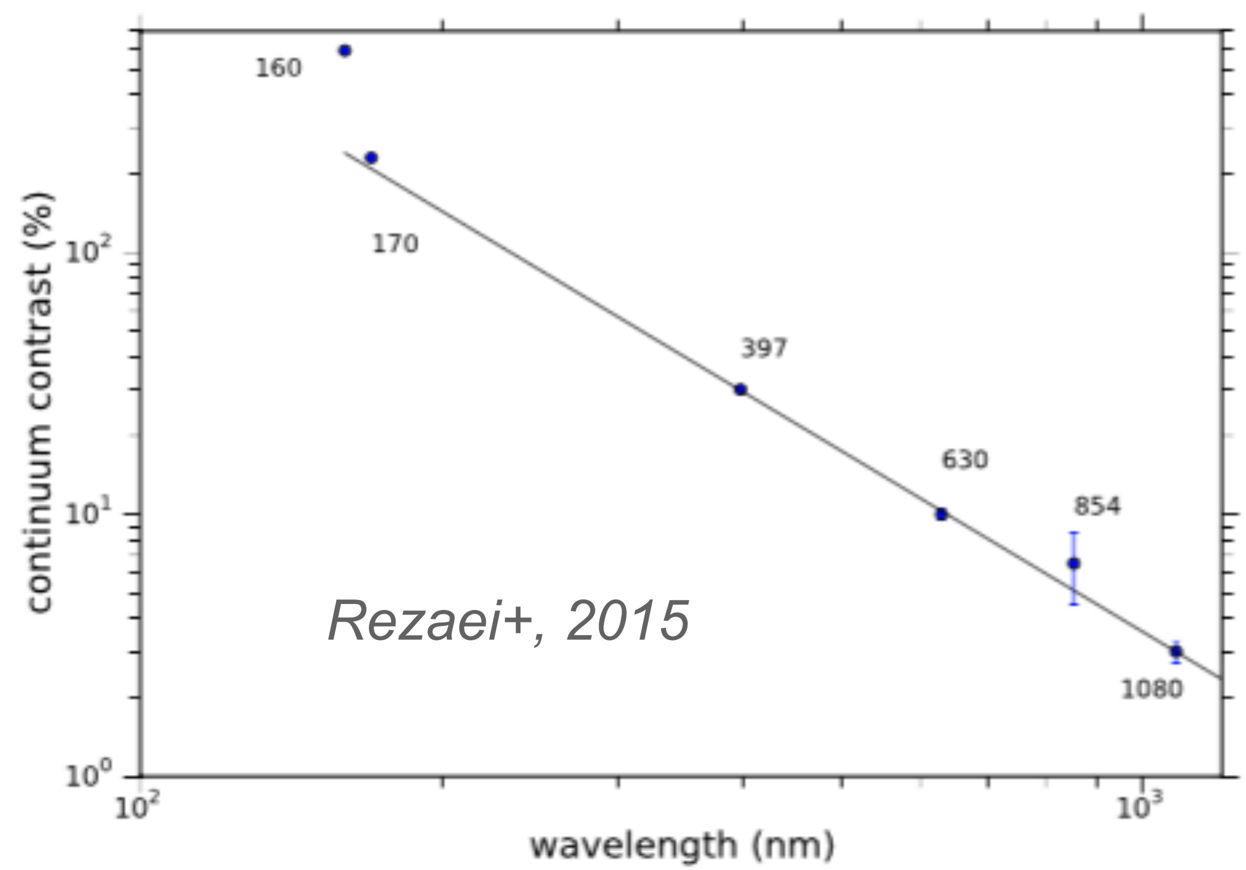
Related topics

- Cycle variation of chromospheric network size (talk by A. Pevtsov)
- Ellerman Bombs, Explosive events, Hot low atmosphere Bombs ..:



Gugpta+, 2015

Peter+, 2014
Judge 2015



Continuum contrast of Ellerman Bombs
10^{27} Erg

- What is the statistics ? Does it vary in time ?

Take home

- ✓ Flares impact irradiance even at wavelengths where the contrast is small: near UV, visible, TSI
- ✓ At these wavelengths, the distribution of the flare fluence differs from the coronal one and have an exponent larger than 2. Small flares dominates.
- ✓ How small are the smallest flares belonging to this distribution ?
- ✓ Do the rate of small flares varies with time
  - ✓ with the cycle ?
  - ✓ from minimum to minimum ?