Flare, Irradiance, and PICARD.

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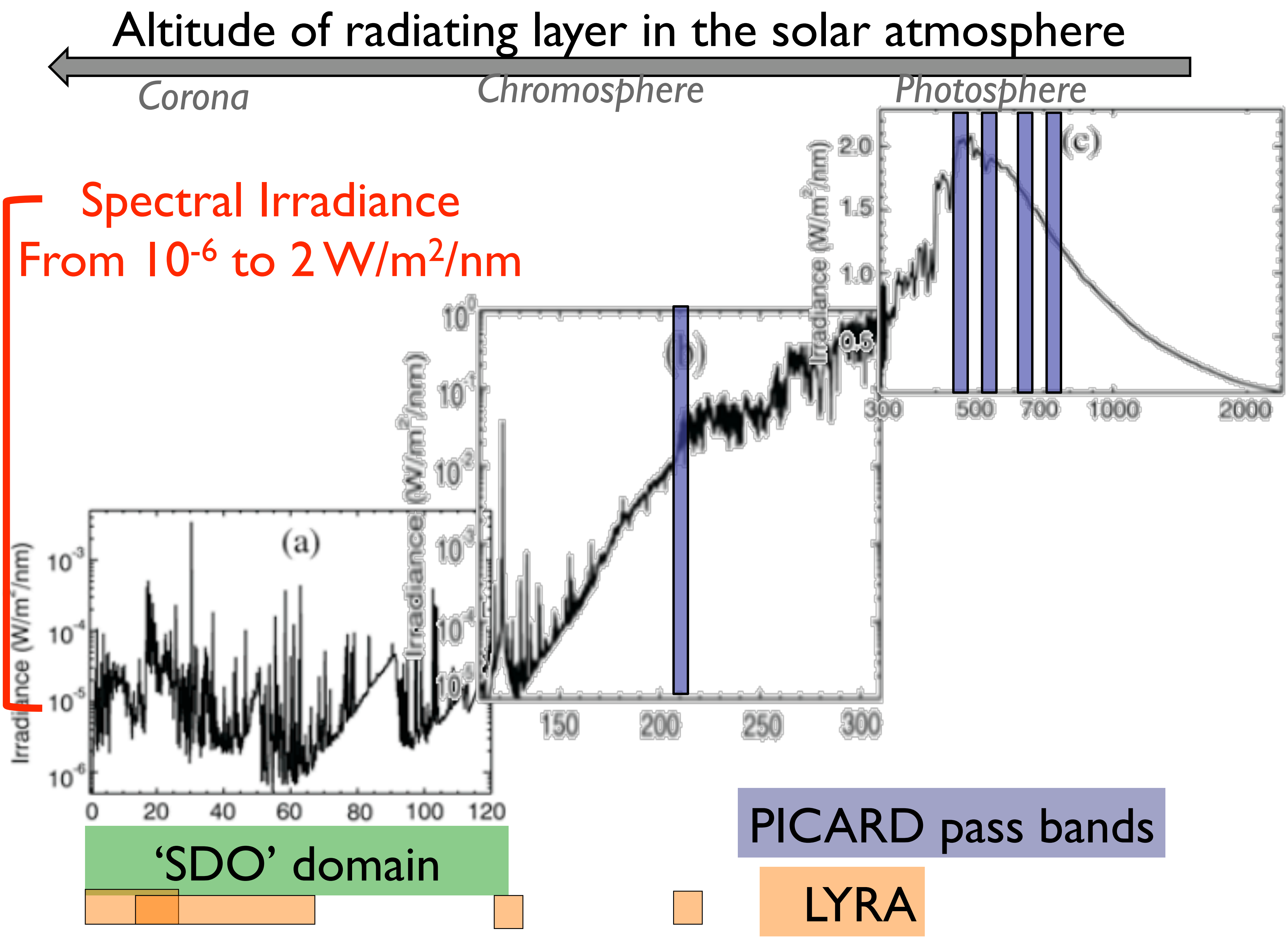
Why should PICARD care about flares ?

- *Flares will affect the PICARD data !*
  - Flares impact total and visible irradiance
  - Flares are present in helioseismology time series

- *Flares are within the scientific objectives of PICARD !*
  - Contribution of flares to TSI variability

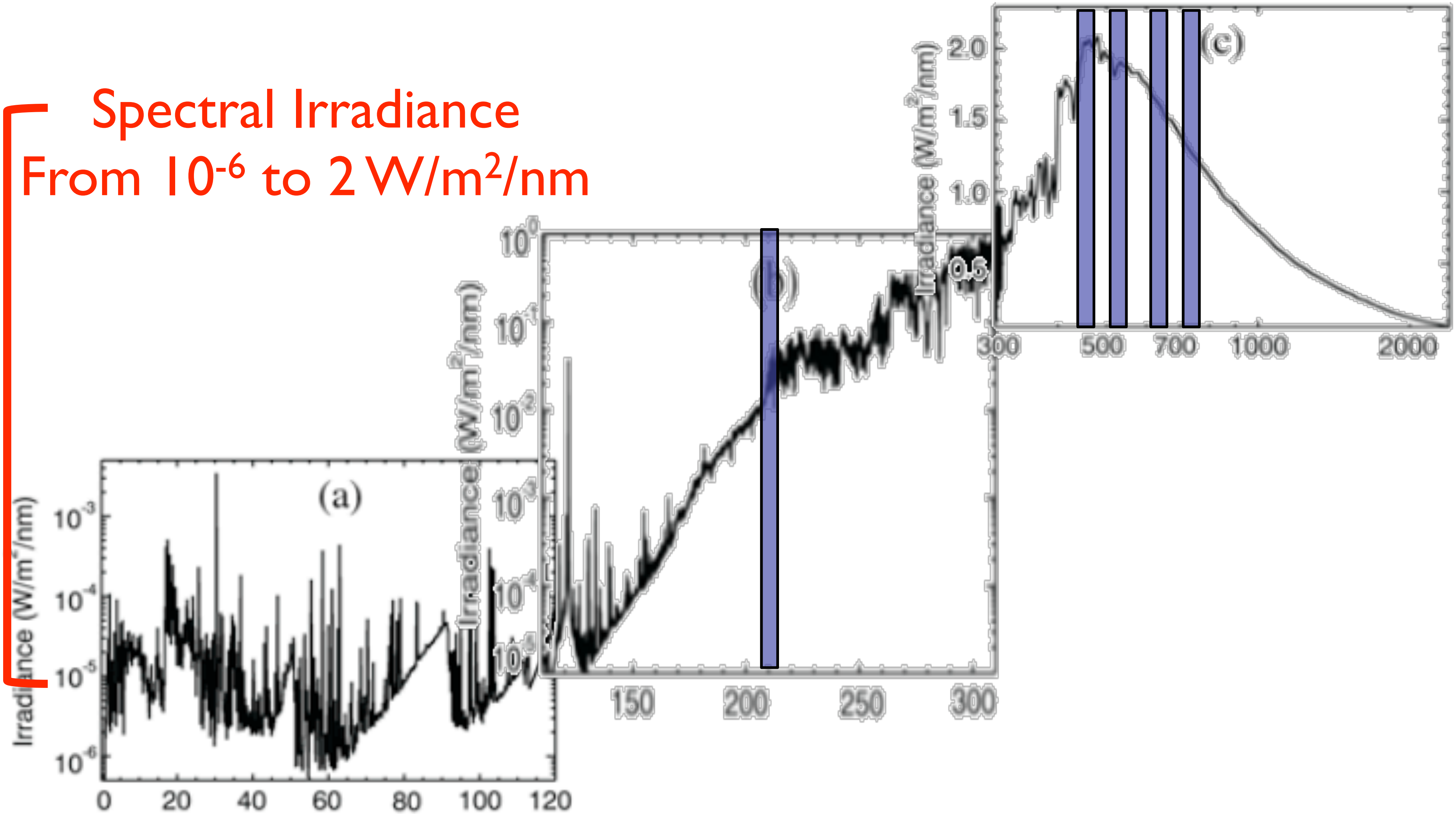
- *PICARD can provide flare observations than no other spacecraft can !*
  - Space quality images of flare at various visible wavelength (flare spectrum, flare physics, flare contribution to TSI variability)



Altitude of radiating layer in the solar atmosphere
Corona
Chromosphere
Photosphere
Spectral Irradiance
From 10-6 to 2 W/m2/nm
(a)
(b)
(c)
Irradiance (W/m2/nm)
0 20 40 60 80 100 120
150 200 250 300
300 500 700 1000 2000
'SDO' domain
PICARD pass bands
LYRA

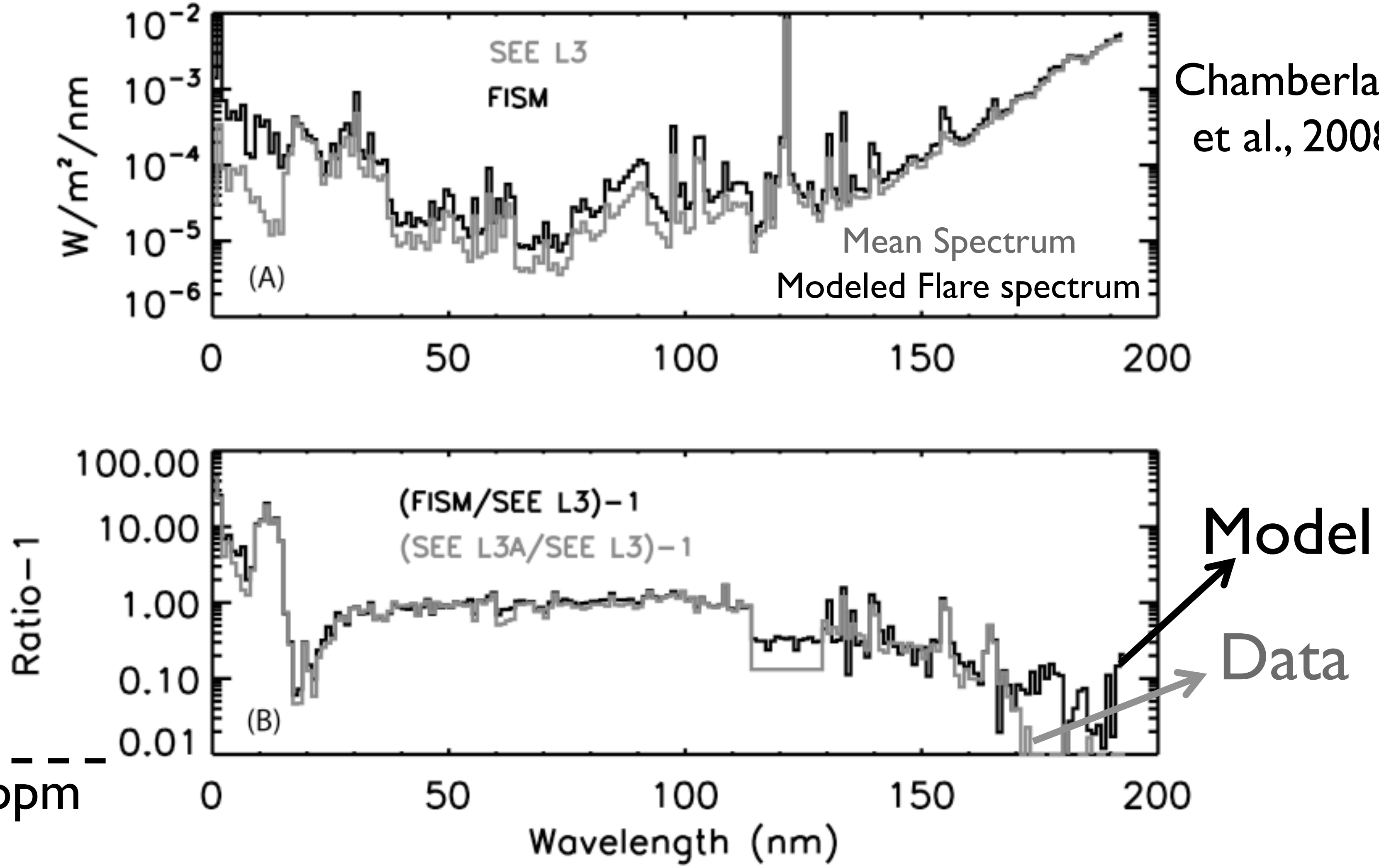
Relative variability (contrast)

Spectral Irradiance
From 10^{-6} to 2 W/m^2/nm



Amount of solar energy radiated

Flare spectrum

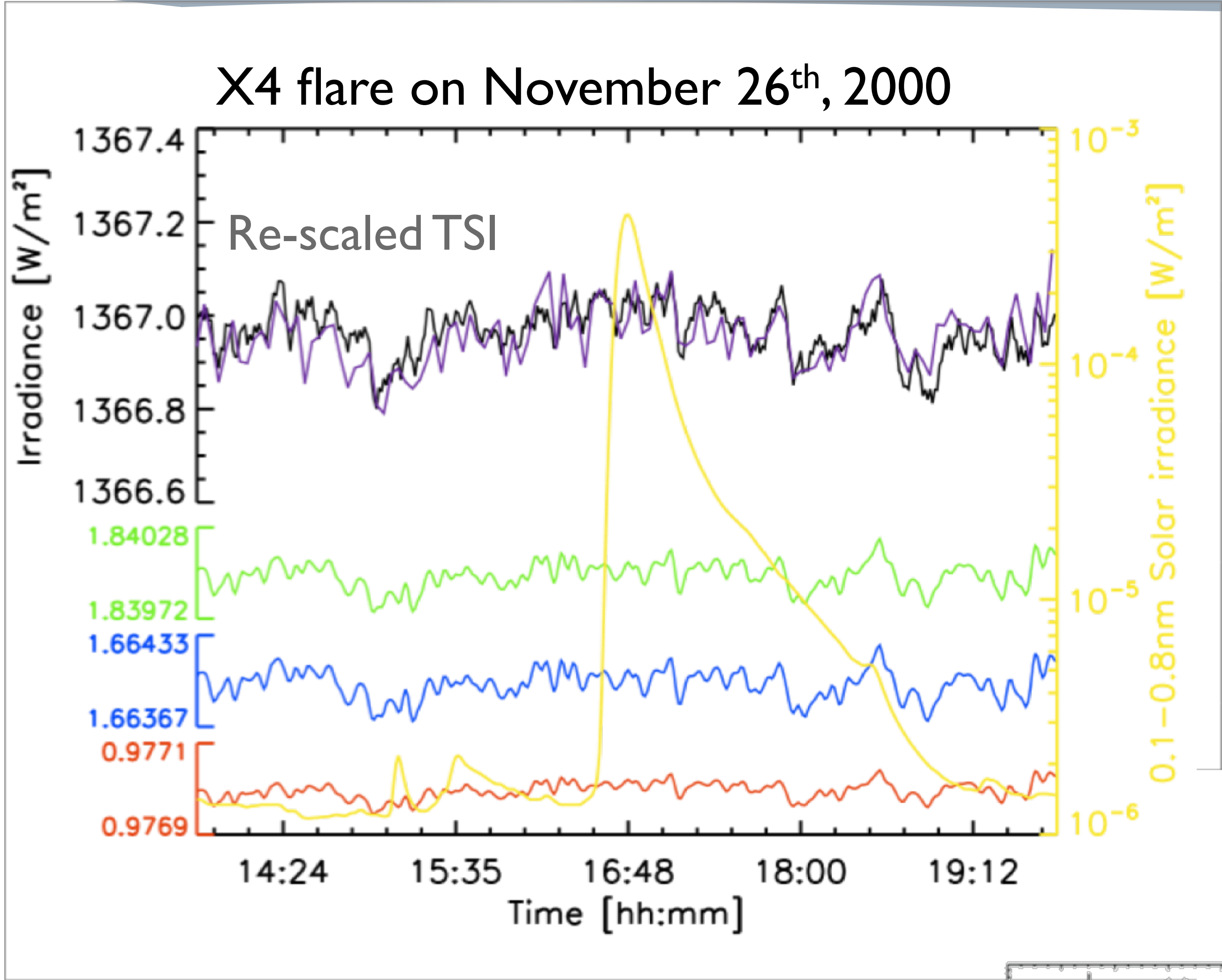


Chamberlain et al., 2008

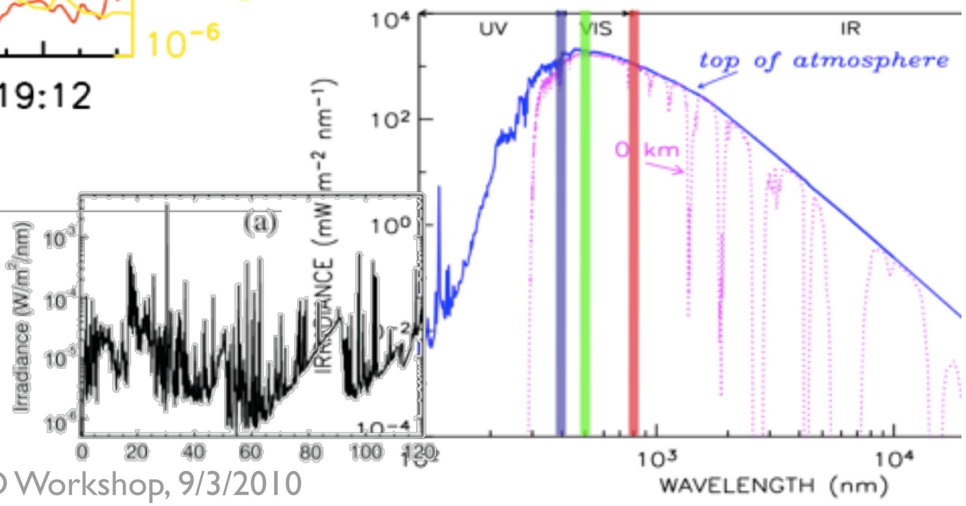
1%=10^4 ppm

- ***Very low contrast at long wavelength but potentially most of the flare energy.***
- ***Information is missing in the near UV, visible, and IR.***

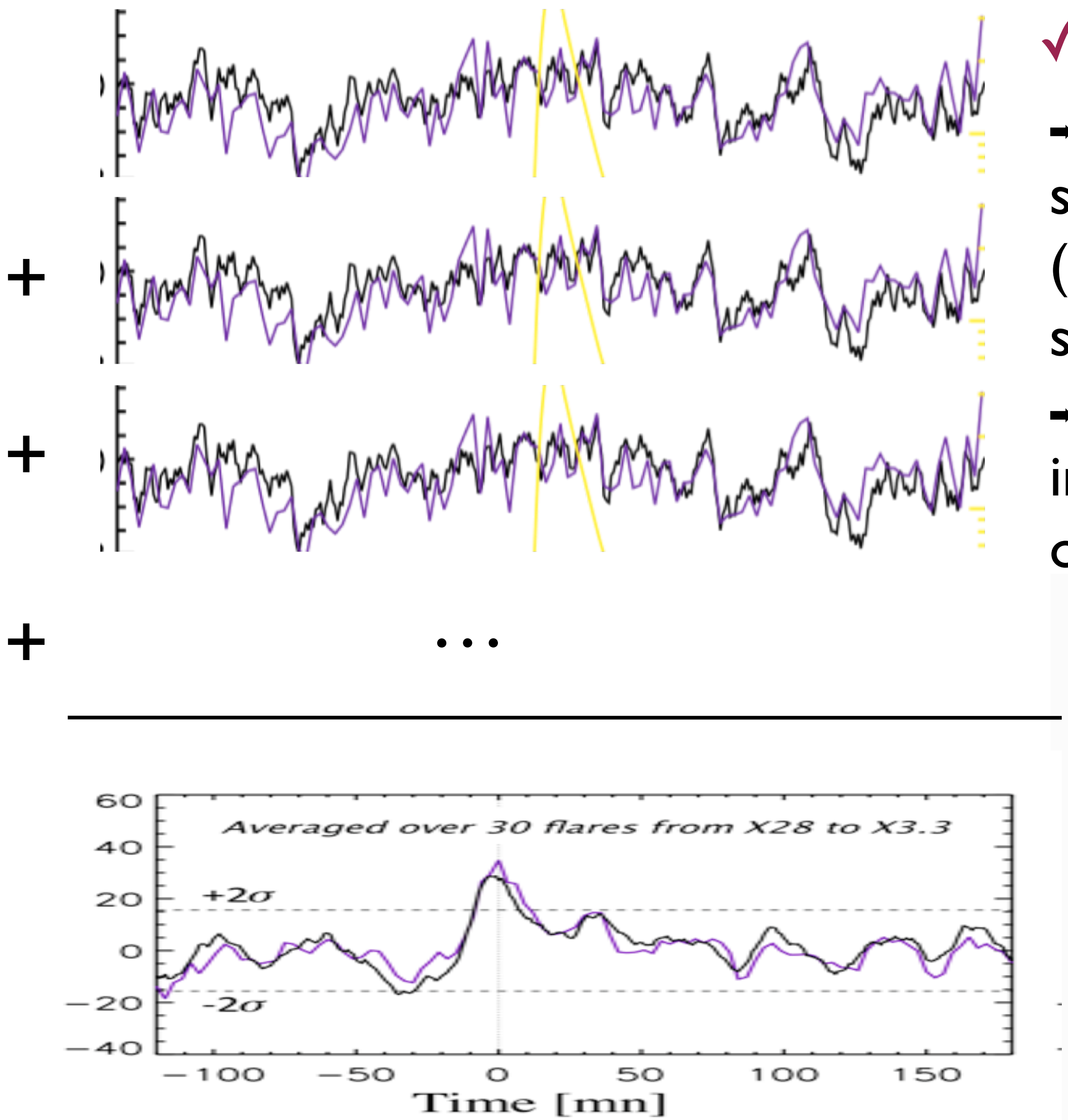
Flare will affect the PICARD data



- ✓Really ?
- ✓Eruptions seen in irradiance only at very short (X-ray) and long (radio) wavelength. (but see Woods et al, 2006.)



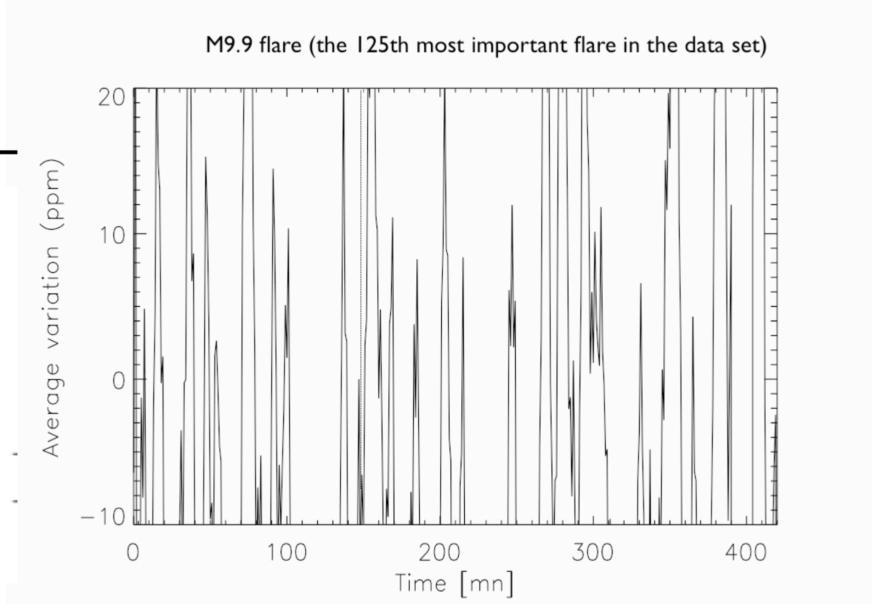
Flare detection in Irradiance



✓ Superposed epoch analysis:

➡ Spectral and total irradiance time series have fluctuations (1σ=50ppm) that hides the flare signal.

➡ Superposed epoch analysis: incoherent fluctuations averaged out.



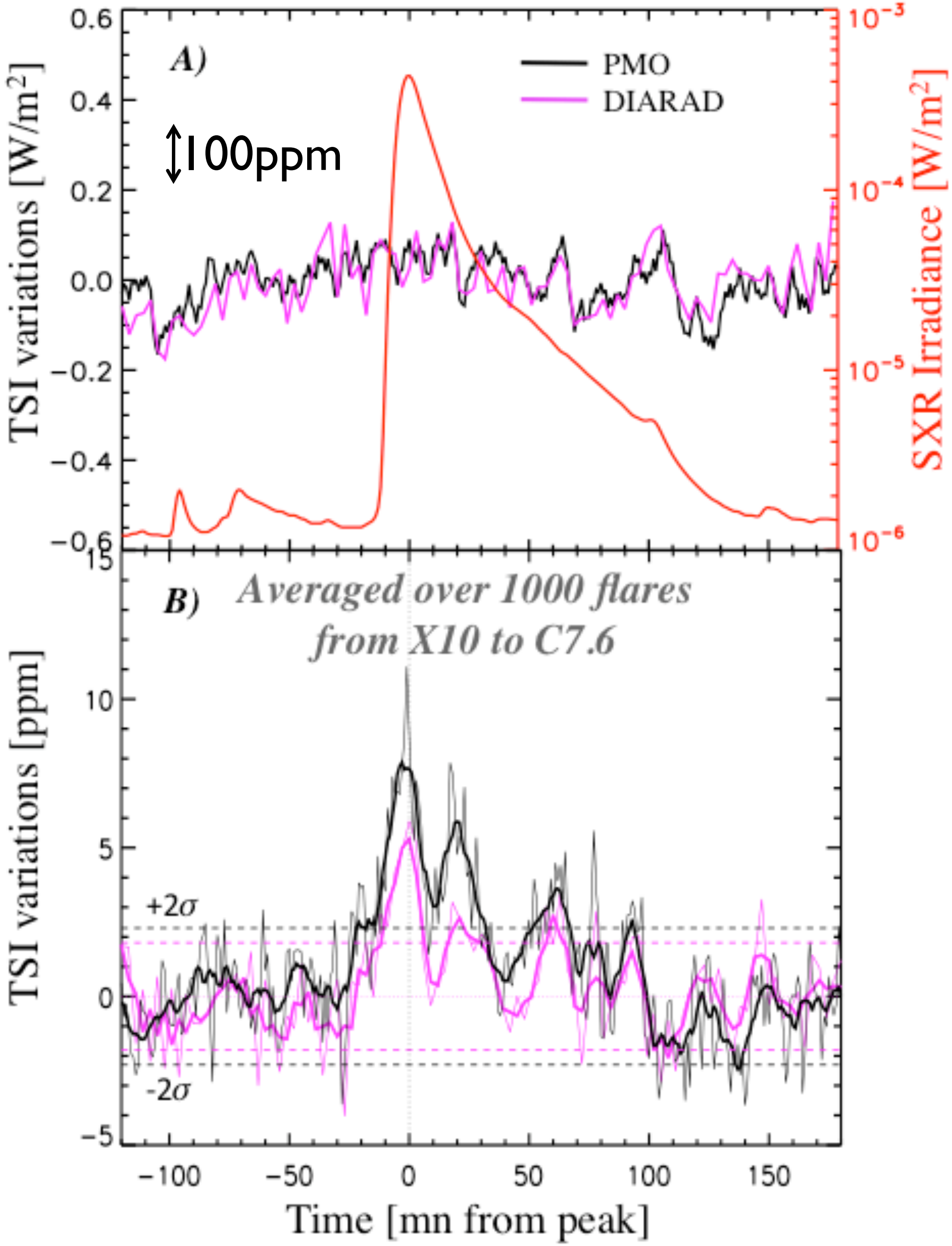
Flare detection in Irradiance

✓ Superposed epoch analysis:

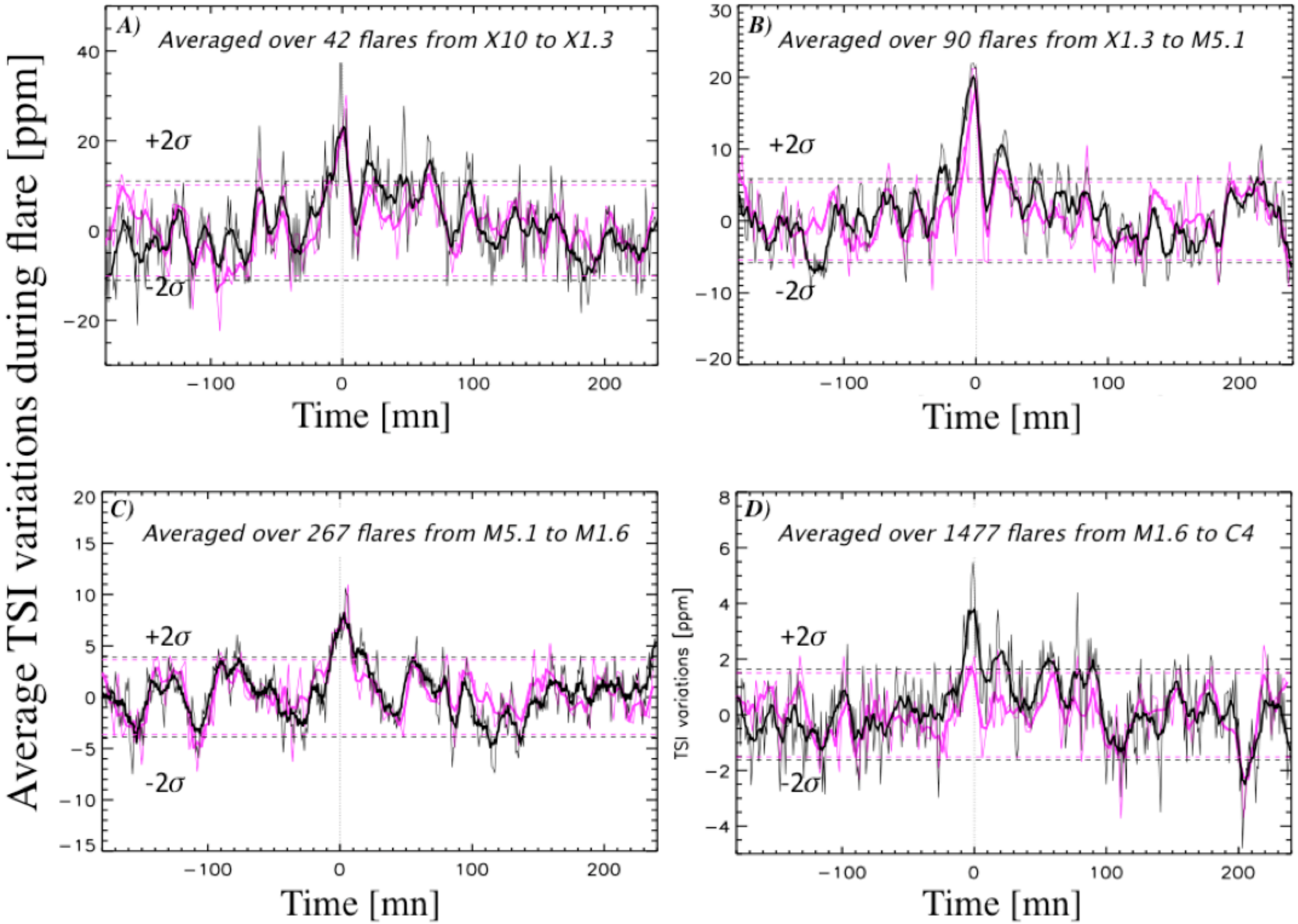
- We retrieve the « Flare knowledge » from GOES SXR observations.
- We sort the flares from the larger to the smaller:

$$F_1 > F_2 > \ldots > F_k > \ldots > F_{k+n} > \ldots > F_N$$

- We superpose (= average) the time series from rank k to rank $k+n$



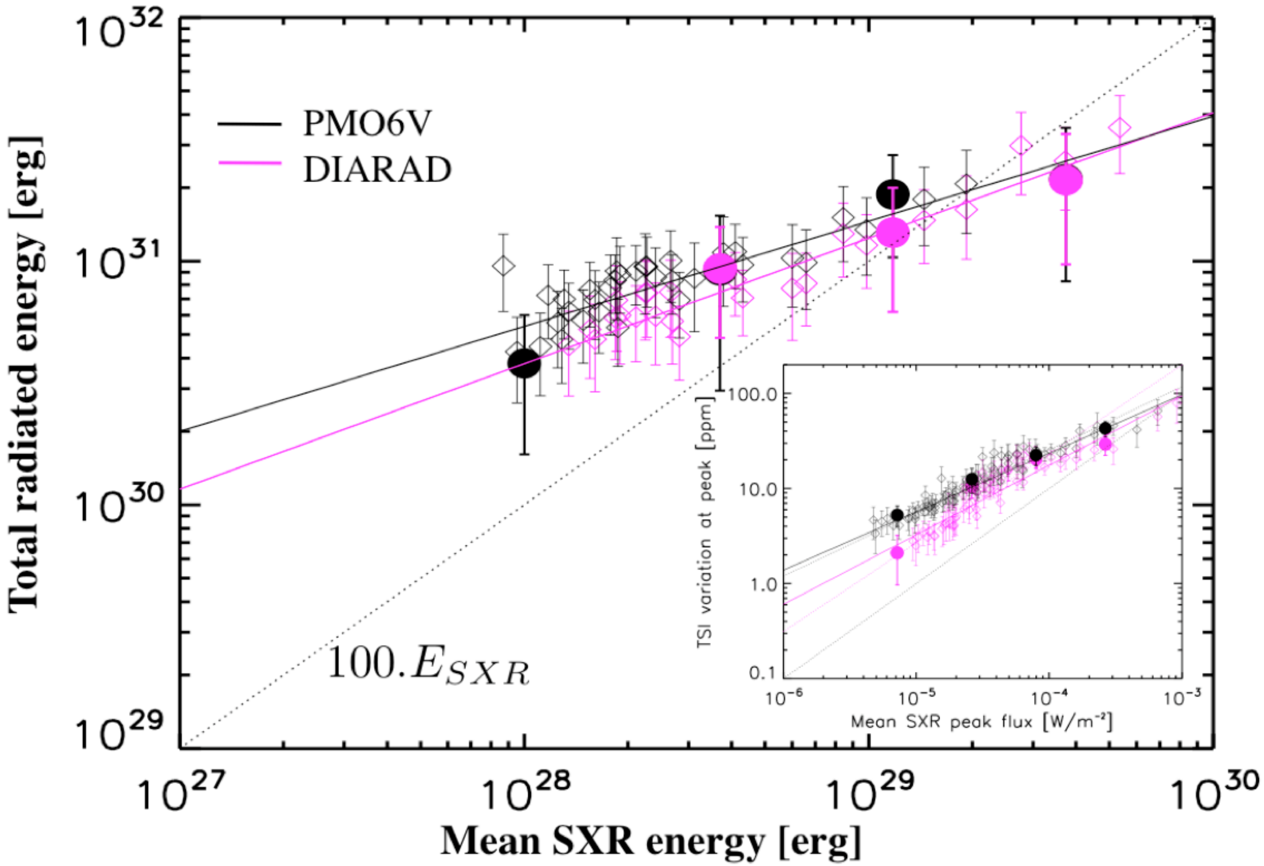
Kretzschmar
et al., 2010



➡ Flares as small as C-class ones have a quantitative effect on the TSI.

Kretzschmar et al., 2010

Flare total emission



Kretzschmar et al., 2010

- The total radiated energy decreases slower than SXR emission.
- The total energy radiated is more than the SXR energy by two order of magnitude. **Contribution of the *whole* spectrum to flare emission.**

Flare contribution to TSI variations

✓There are a lot of brightenings everywhere on the Sun at any time (included unresolved one).

✓Their total contribution:

$$L_f = \int_{I_{\min}}^{I_{\max}} N(I) I dI \qquad \text{(with } I = \int_\lambda I(\lambda) d\lambda \text{ et } N(I) = C \cdot I^{-\alpha} \text{)}$$

is not taken into account in the present TSI models (only large photospheric structures).

It should be taken into account *if*:

1. L_f is not constant in time.
2. and $\alpha > 2$

Flare energy distribution

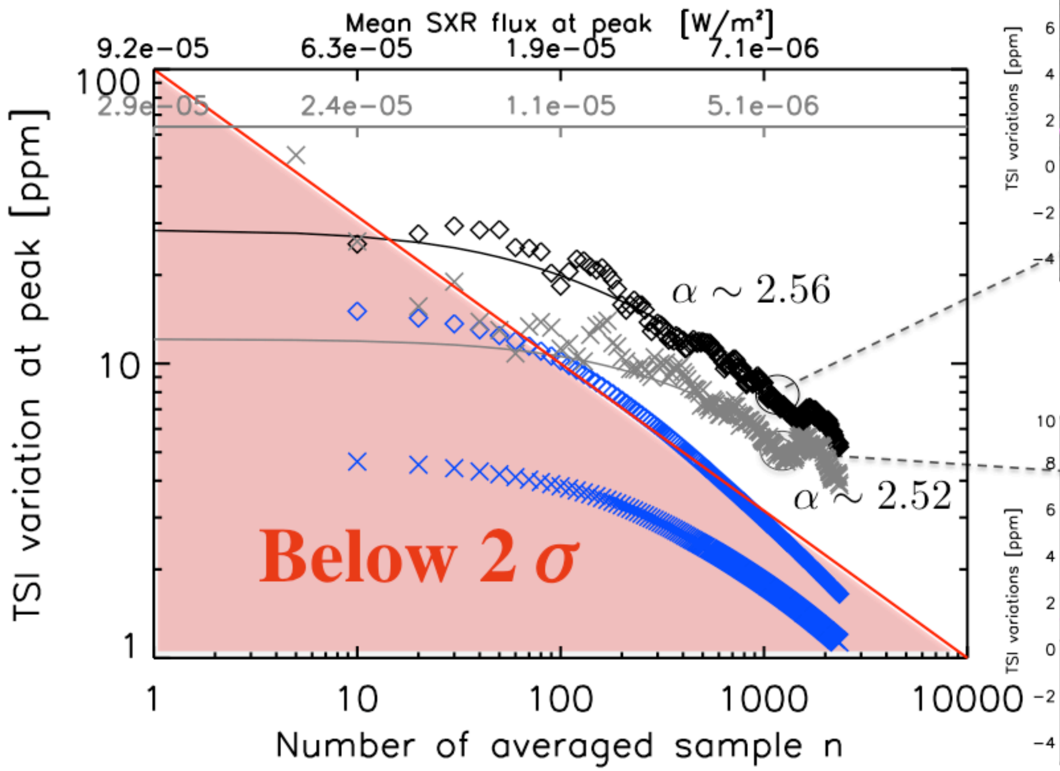
➡ The average flare signal is $\overline{I^f}(k,n) = \int_{I^f_{k+n-1}}^{I^f_k} f(I) I dI$

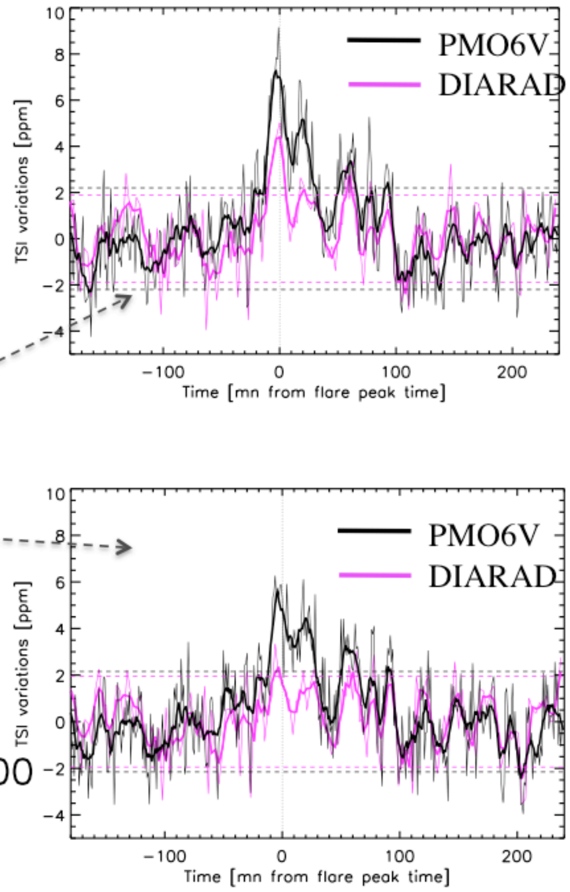
with: $$f(I) = C \cdot I^{-\alpha}$$

➡ We can then get the analytical expression:

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

Kretzschmar et al., 2010





In Black and grey: TSI measurements by PMO

Diamonds and crosses are for flare average starting from X1 and M3 respectively

Blue: Assuming $I^f_{TSI} \sim k\, I^f_{SXR}$ with k such that:

$dI^f_{TSI} = 228$ppm for the X17 flare of Oct. 2003.

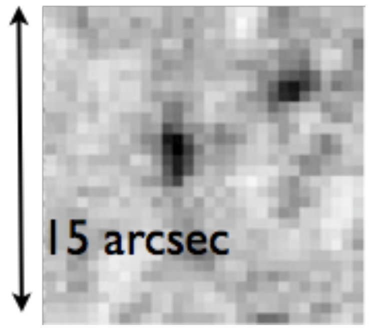
Thick curves are non-linear fit.

→ α > 2: small flares dominate the total emission due to flares. *Is their rate constant ?*

Why should PICARD care about flares ?

- *Flare & PICARD irradiance*
  - Flare in TSI (SOVAP and PREMOS)
  - Flare in visible irradiance (PREMOS)

- *Flares & PICARD images*
  - PICARD could observe flare dynamics in the visible domain !
  1ppm in visible irradiance ~ 20% contrast in 5 arcsec2. This agrees with WLF observations (Hudson, 2006; Jess, 2009). No dedicated instrument in space. *Can SODISM image flare ??? At limb ?*



  - Flare are present in heliosismology time series (in GOLF data, see Cessateur et al., Solar Physics, 2010). Could be seen in macro pixel images (current investigation with VIRGO/LOI).

- *Contribution of flares to TSI variability*

The end