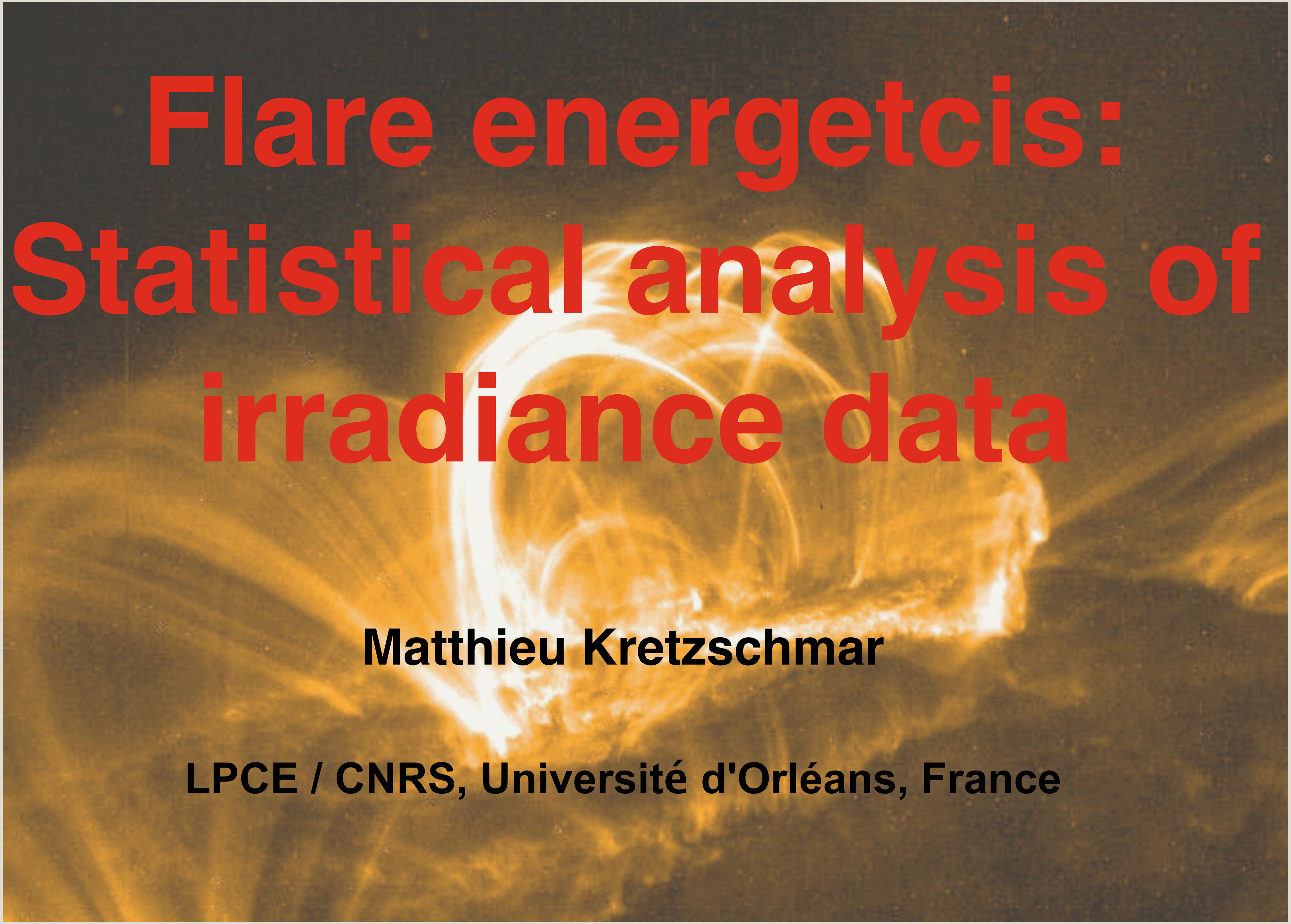

Flare energetcis: Statistical analysis of irradiance data

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✓ **What is the total amount of radiated energy ?**

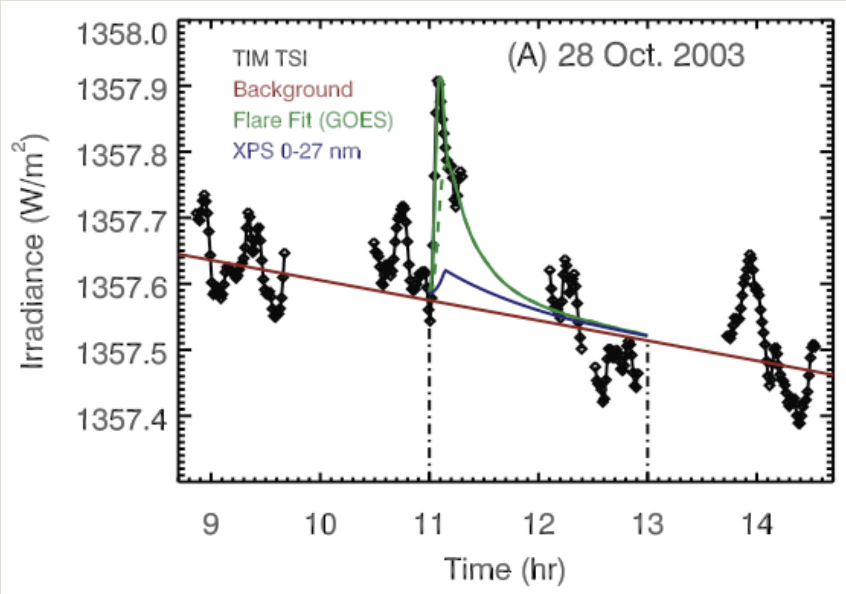
✓ TSI signature observed for only 4 flares. This is because the TSI fluctuations (due to p-modes and convection) are about ~70ppm=0.1W/m^2 and hide the emission increase due to flare.

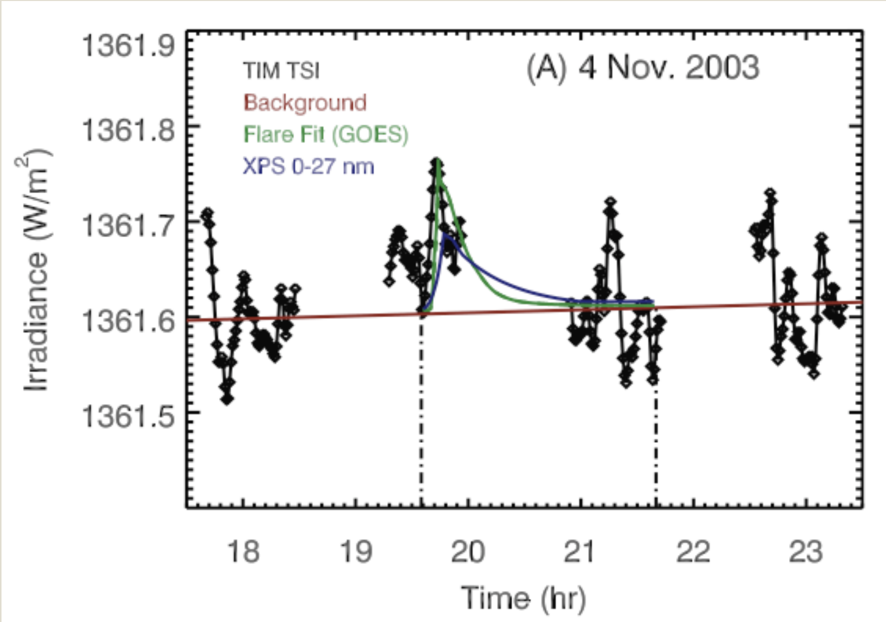
✓ **What is the spectral distribution of the radiated energy ?**

✓ In particular, what is the contribution of near visible and visible wavelengths ? Very small increases at these wavelengths contain easily as much energy than very large increases in X-ray.

Flare signature in the TSI

Woods et al., 2006



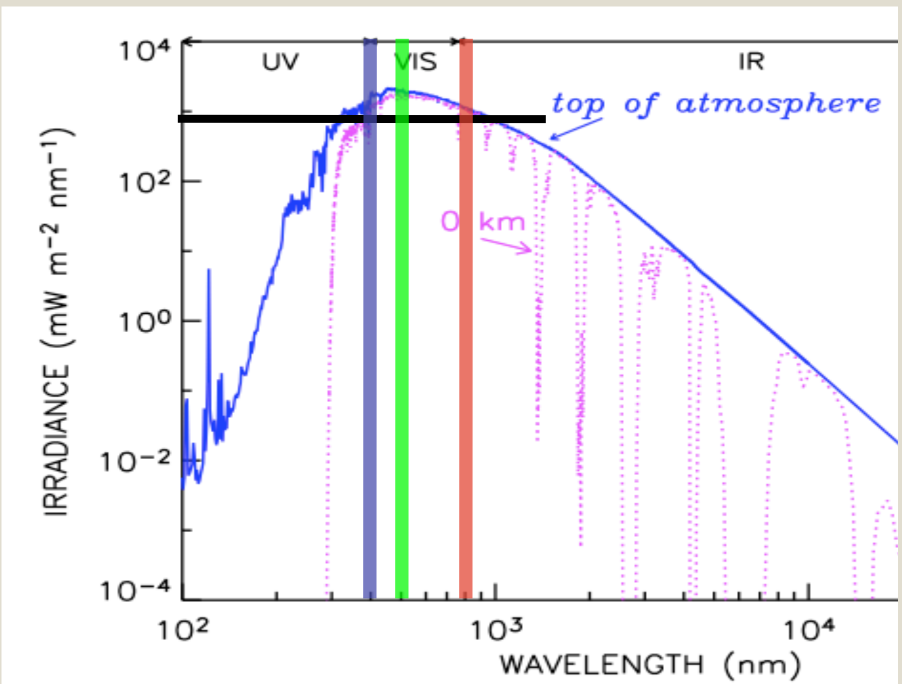


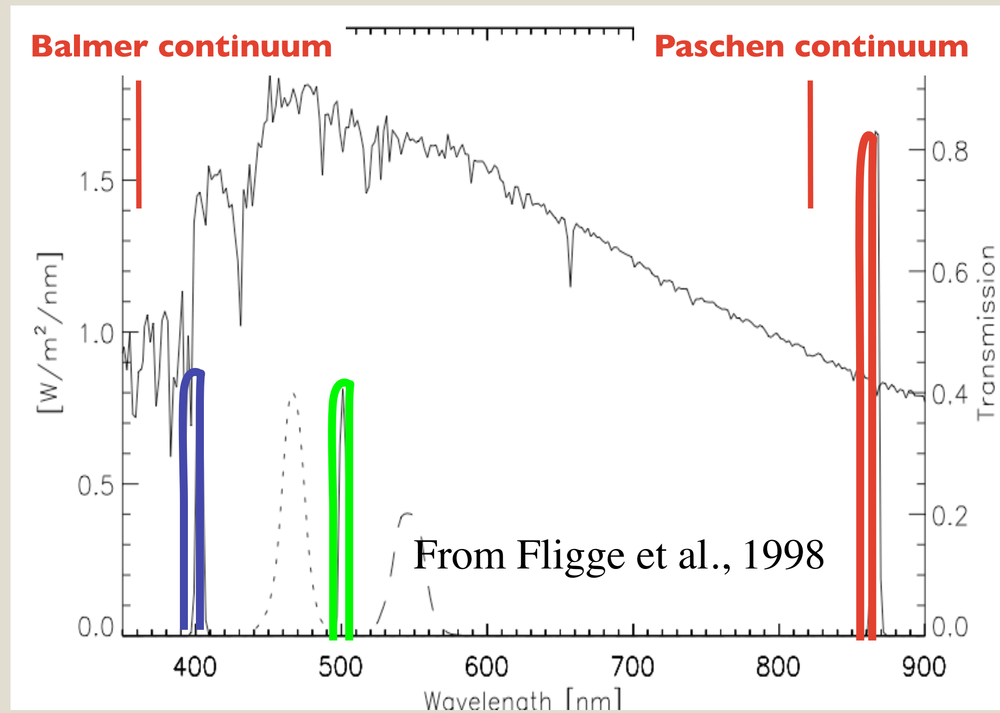
Observation Date	GOES Class	Total Flare Energy for TSI, 10^{32} ergs	Ratio $\frac{TSI}{0.1-0.8\ nm}$	Ratio $\frac{0.1-27\ nm}{TSI}$	Ratio $\frac{0-190\ nm}{TSI}$	Total Flare Energy Uncertainty
10/28/03	X17	6.0	162	0.22	0.43	39%
10/29/03	X10	2.4	126	0.38	0.50	86%
11/04/03	X28	2.6	49	0.85	0.69	65%
9/7/05	X17	3.0	64	0.67	1.00	71%

We want more !

VIRGO data

We use the high temporal resolution irradiance data from the VIRGO experiment onboard SoHO. Two sensors measure the TSI (PMO and DIARAD), and SPM measures the visible irradiance in three channels of about 5nm centered around 402nm (blue), 500nm(green), and 862 (red). Period from 1996 to 2007.





NB: The red channel includes the Ca II line at 866.22nm

Data analysis

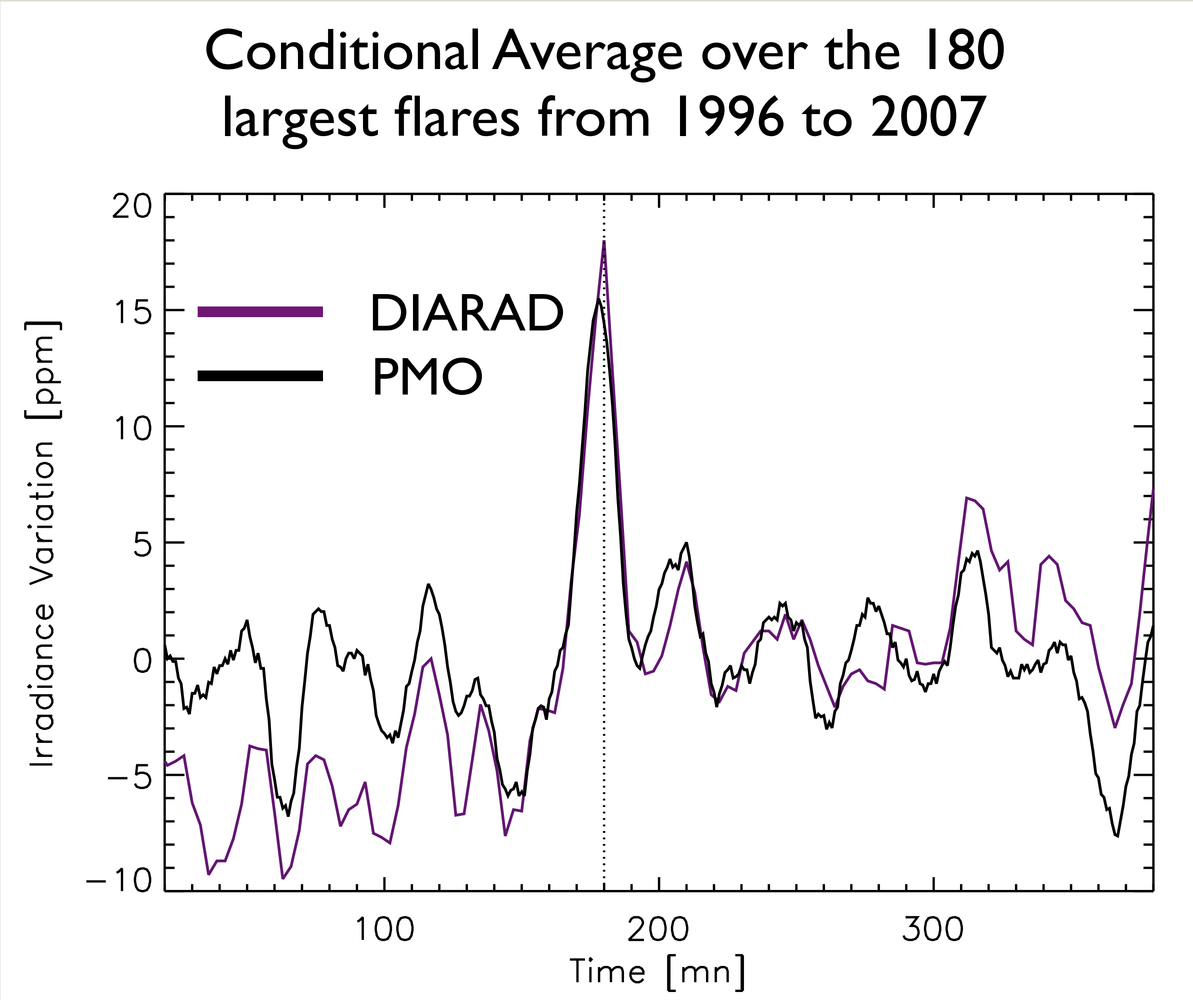
✓ Direct observations of flare signal not very clear because its amplitude is less than or of the order of the fluctuation level.

✓ However, the random (i.e. non in phase) fluctuations can be removed by averaging over many samples. We use a conditional average, or superposed epoch analysis:

1) Detect flares (We use the GOES flare catalog)
2) Extract the irradiance time-series around peak time of each flare.
3) Average (or superpose) the curves.

We order the time-series in decreasing order of the X-ray class, and we average them from the n_0^{th} event to the $(n_0+n)^{th}$ event.

The TSI response to flares

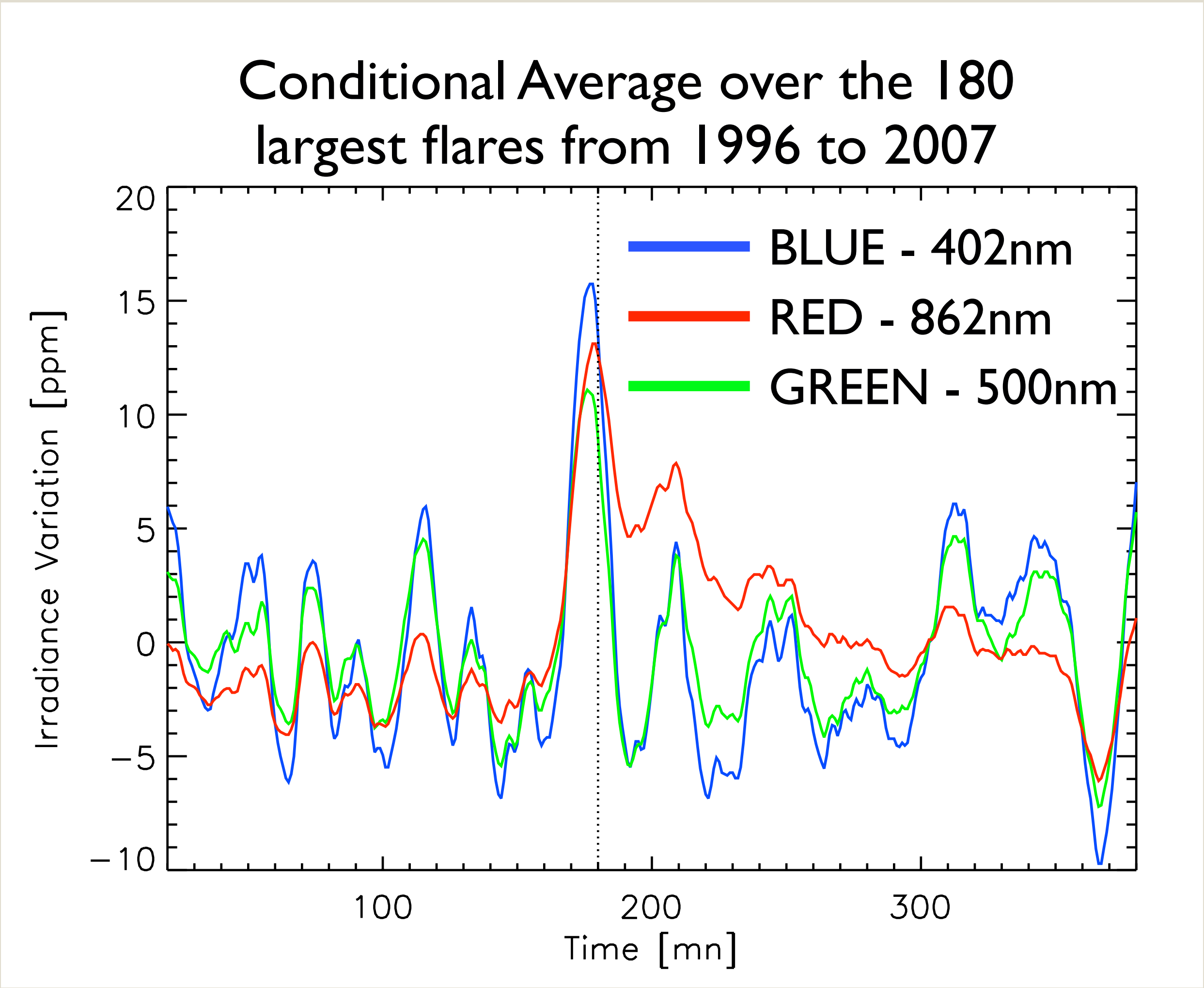


✓ Fluctuations level goes as 1/sqrt(n):

5 ppm ≈ 70/sqrt(180) ppm !

✓ Clear flare signature in both sensors

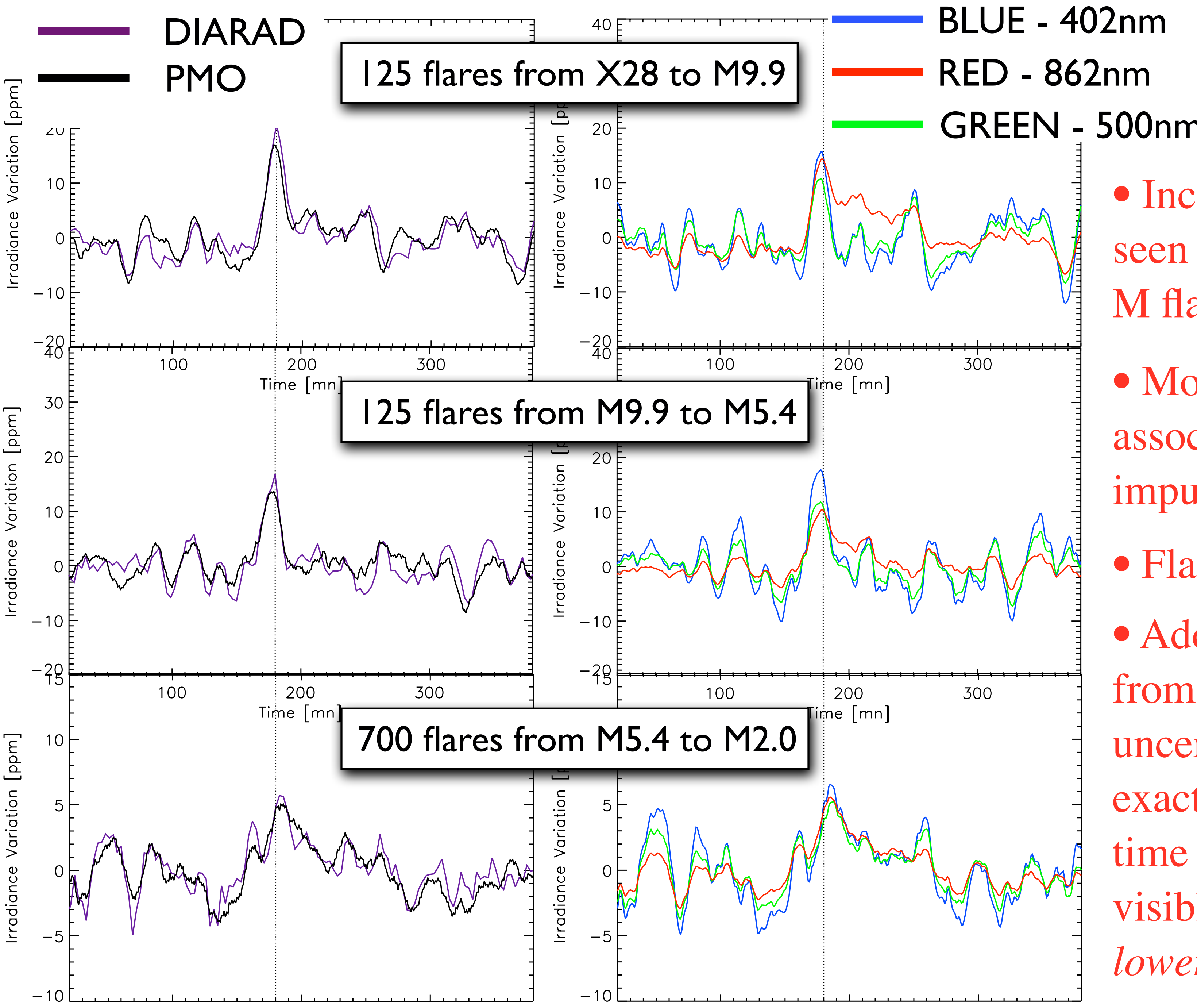
The visible irradiance response to flares



✓ Even in visible !!

✓ Note the gradual phase in the red channel (Ca II)

M. Kretzschmar, Solar activity during the onset of Solar Cycle 24, Global event energetics workgroup.

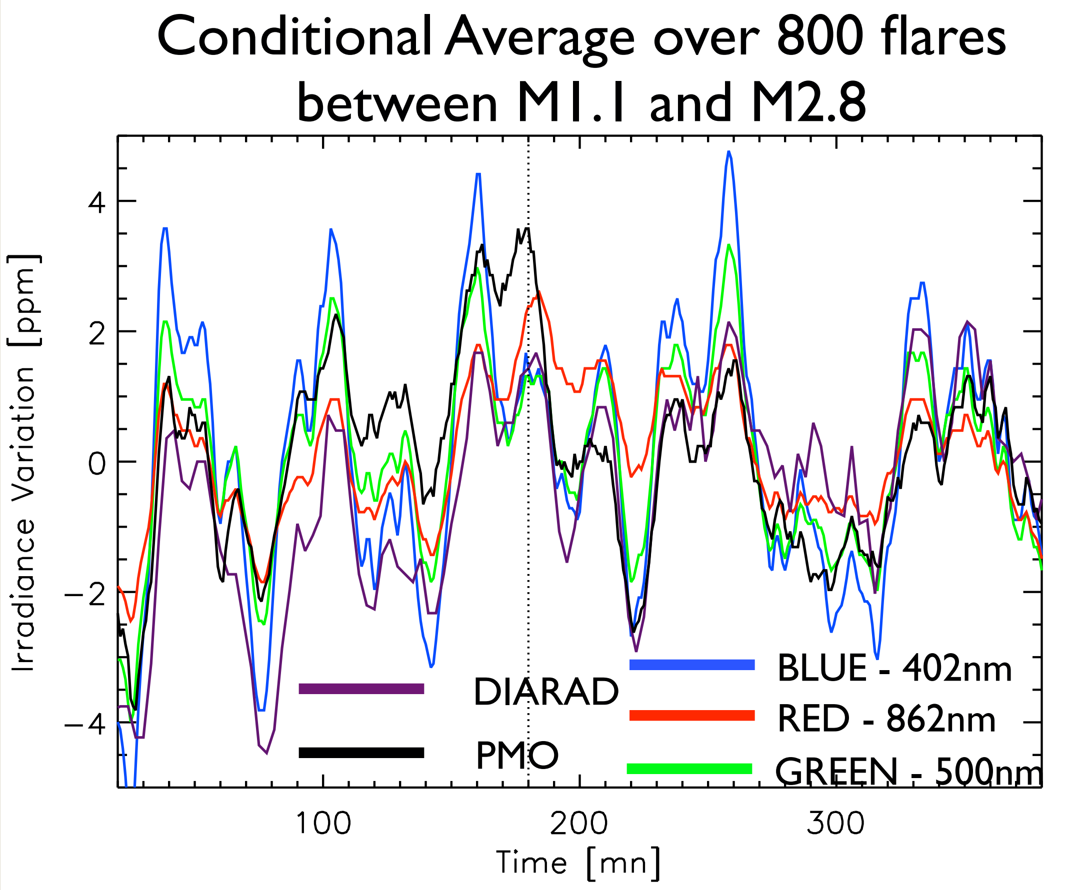


- Increase well seen down to small M flares
- Mostly associated to the impulsive phase
- Flares are “Blue”
- Additional noise from the uncertainty on the exact flare peak time in TSI and visible: these are *lower* estimate.

Irradiance response to flares

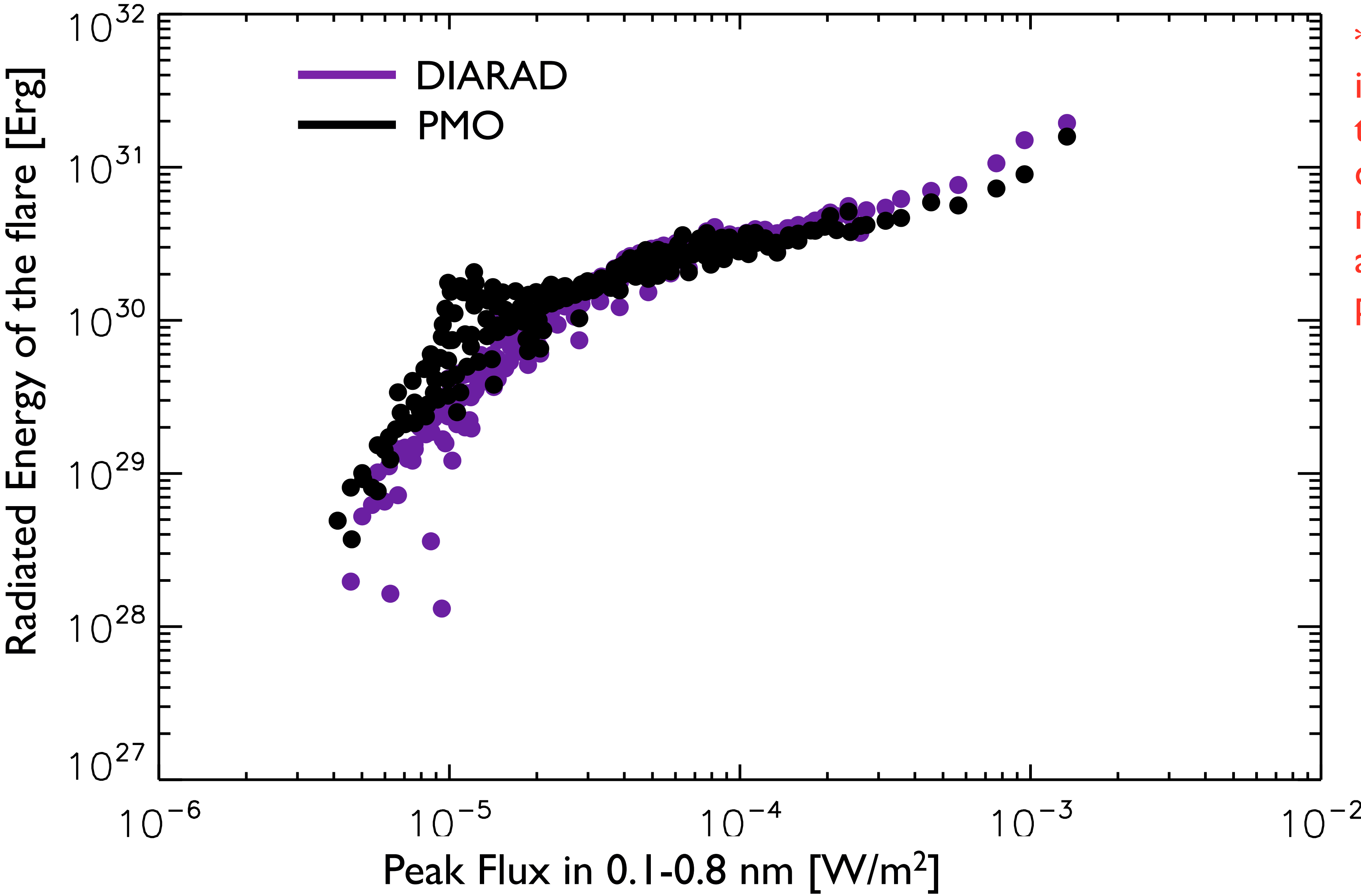
✓ However, by looking at flare of still smaller amplitude, signature become less clear/more ambigus.

✓ There is still an increase at the time of the flare, but it is of the same order of the remaining fluctuations.



✓ To go further, we look at the behavior of the irradiance value supposed to be influenced by the flare (values for t~180mn).

Flare radiated Energy vs Xray Energy*



* Estimated by integration of the averaged curve over 24 minutes around the peak time

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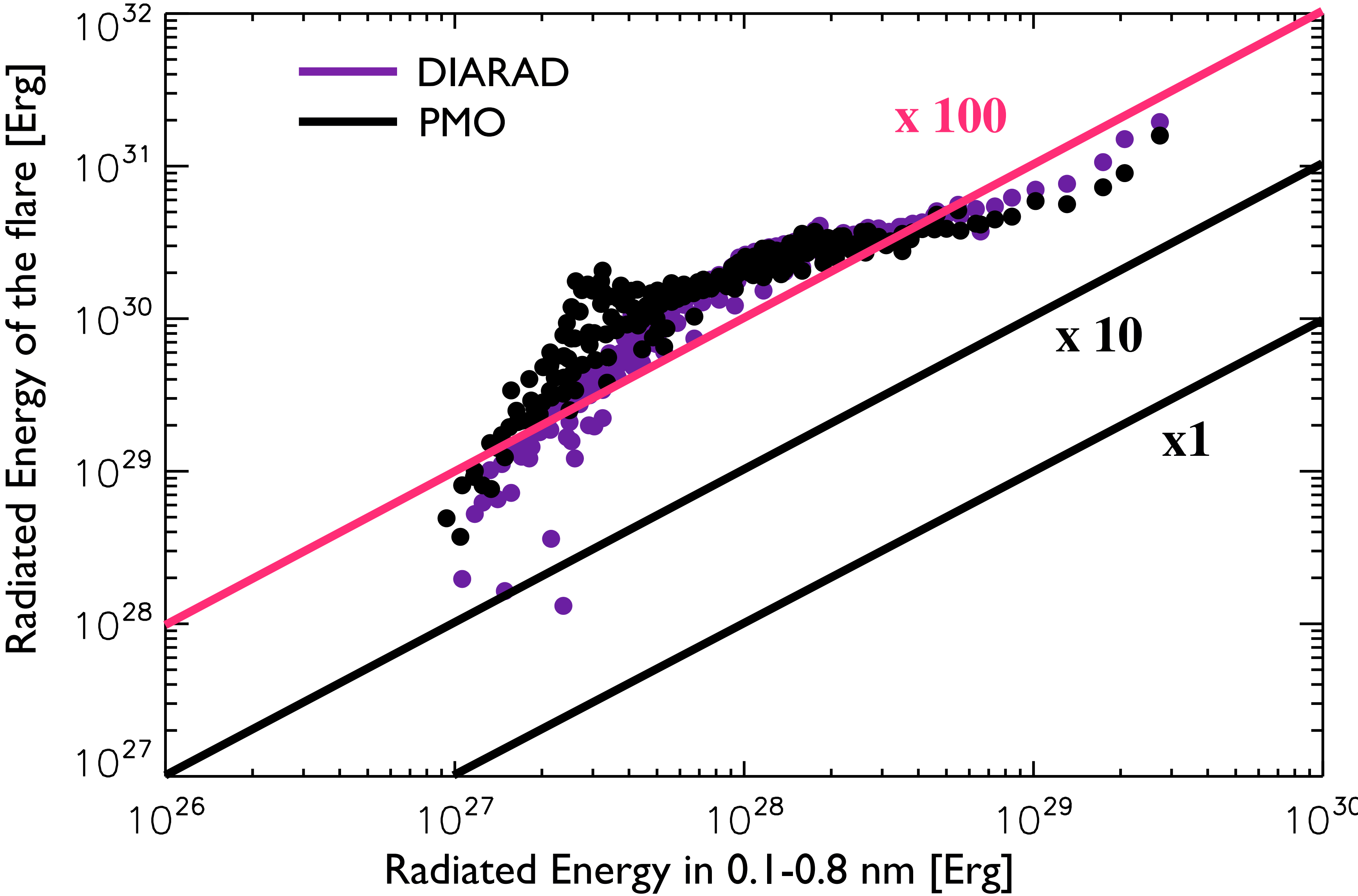
Flare radiated Energy vs Xray Energy*



* Estimated by integration of the averaged curve over 24 minutes around the peak time

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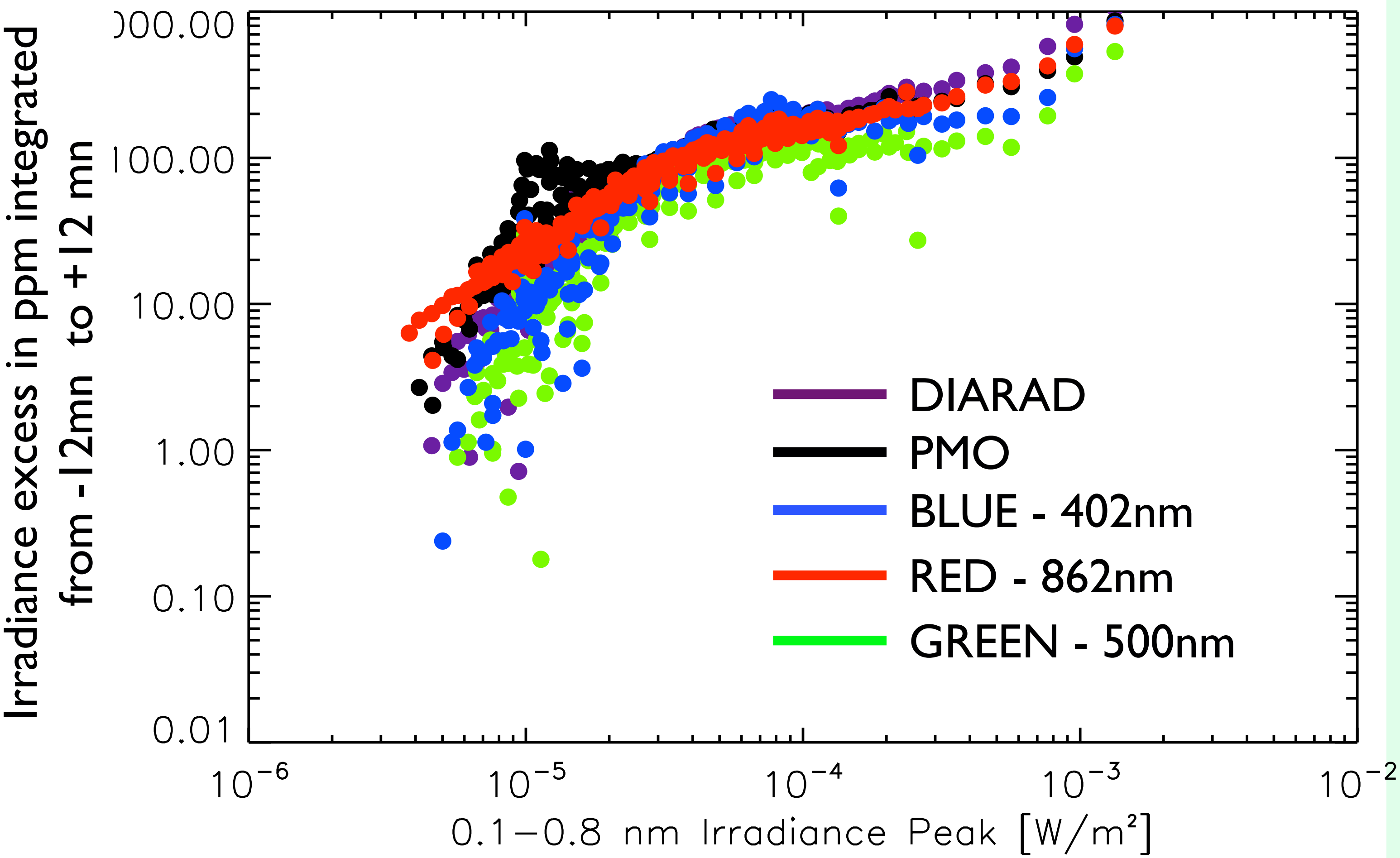
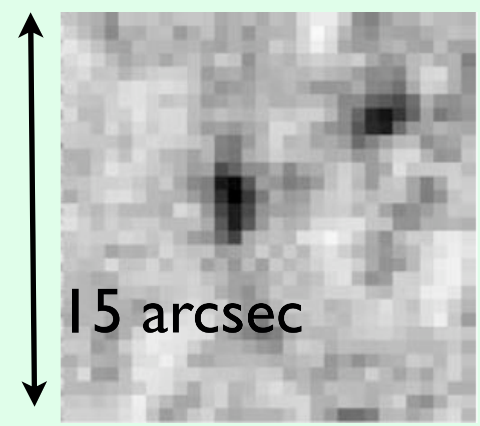
Relative Excess at peak: total and visible



- Trend and amplitude similar for TSI and all visible channels.
- 1ppm in visible irradiance ~ 20% contrast in 5 arcsec². This agrees with other observations (Hudson, 2006)



Conclusion

✓ Flare emission influences irradiance data at all wavelength.

✓ The total radiated energy is about 100 times the energy radiated in the SXR (0.1-0.8nm). Largest flare have $E{\sim}10^{32}$ erg. It agrees with Woods et al. (2006) and extends to smaller flares, with respect to the previously thought factor fo 10-15.

✓ Most of the increase seems to be in the *impulsive* phase (but too much noise to investigate properly the gradual phase)

✓ Visible emission seems ubiquitous (even for small flares), and to be a very significant part of the total radiated energy.