



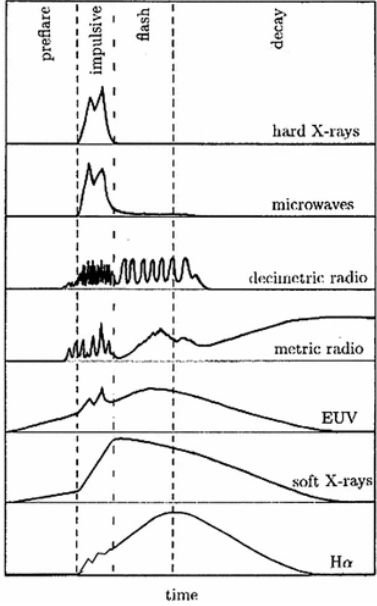
16° European Solar Physics Meeting

Signal processing for the automatic detection of flare events in the Soft-X GOES signal in the period 1986-2020

N. Plutino, F. Berrilli, D. Del Moro, L. Giovannelli

Department of Physics -University of Rome "Tor Vergata" – Physics Department





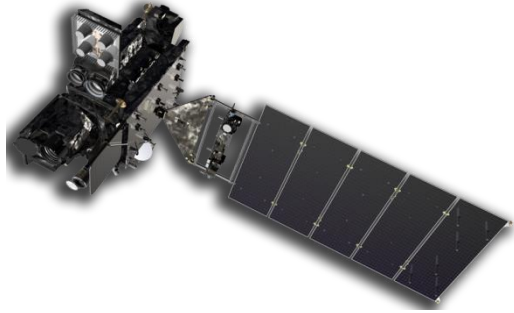
Sudden and intense variation in brightening, with manifestations across most of the electromagnetic spectrum

Solar plasma near region interested by flares reaches $2 \cdot 10^7$ K (X-rays emission)

Soft-X observation make different flare stages clearly distinguishable

Solar flares classification make use of the peak flux measured in the soft-X range (0.1 – 0.8 nm), as measured by GOES spacecrafts

Soft-X Flare Class	Flux [Wm^{-2}]
A	10^{-8}
B	10^{-7}
C	10^{-6}
M	10^{-5}
X	10^{-4}



Geostationary Operational Environmental Satellite Program – NASA and the NOAA - Meteorological observation and space weather data
Space Environment Monitor (SEM) – Energetic Particle Sensor, Magnetometer and **X-ray sensor** → soft-X channel (0.1-0.8 nm) + hard-X channel (0.05-0.4 nm)

GOES Flare List Algorithm:

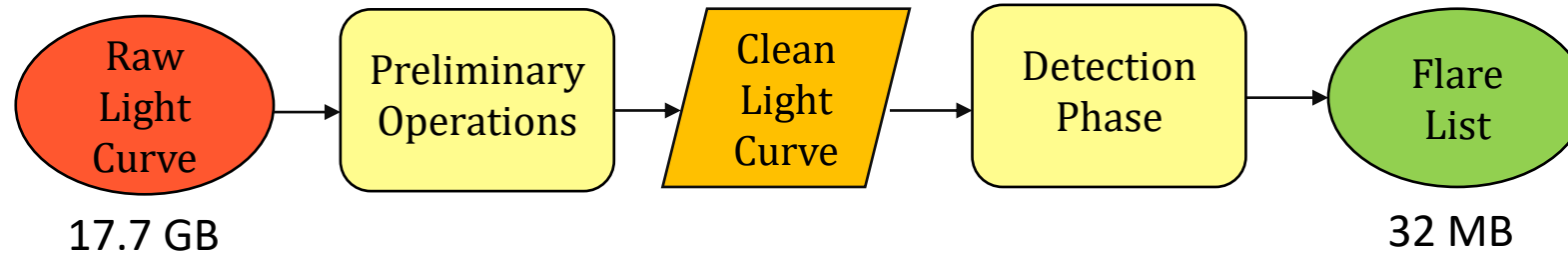
1. Given a sequence of 4 flux values (spaced by 1 minute)
2. *Flare start* when all 4 values are strictly increasing and above the B1 threshold ($10^{-7} Wm^{-2}$) and the last value must be at least 1.4 times the first one
3. *Flare peak* is fixed at the maximum
4. *Flare ends* when the flux goes back to half the peak

Main Goals:

1. Production of an **alternative to** standard solar flare lists by NOAA/NASA (GOES catalogs), including a **bigger number of low energy solar flare events** and **information about preflares background**
2. **Improve data to be used in statistical analysis** of solar flares and the quality of **warning and forecasting systems**

GOES Detection Algorithm	New Detection Algorithm
Low time resolution	12s time resolution
The B1 threshold is a lower limit on flare intensities detected	The A2 class as new lower limit
Rise times and duration times are greatly underestimated	Flare start and end points can be estimated more accurately
No information about preflare background	The preflare background is computed and stored

New solar flare list (1986-2020)



The algorithm was implemented using **Python 2.7** on a **Linux Mint 18.2 Cinnamon** operative system. *NumPy*, *SunPy*, *Pandas*, *powerlaw* and *Matplotlib* are the main Python packages used.

Daily Solar Light Curves from **1986 to 2020** (three solar cycles) have been analysed, producing a list of **270857 flares**.

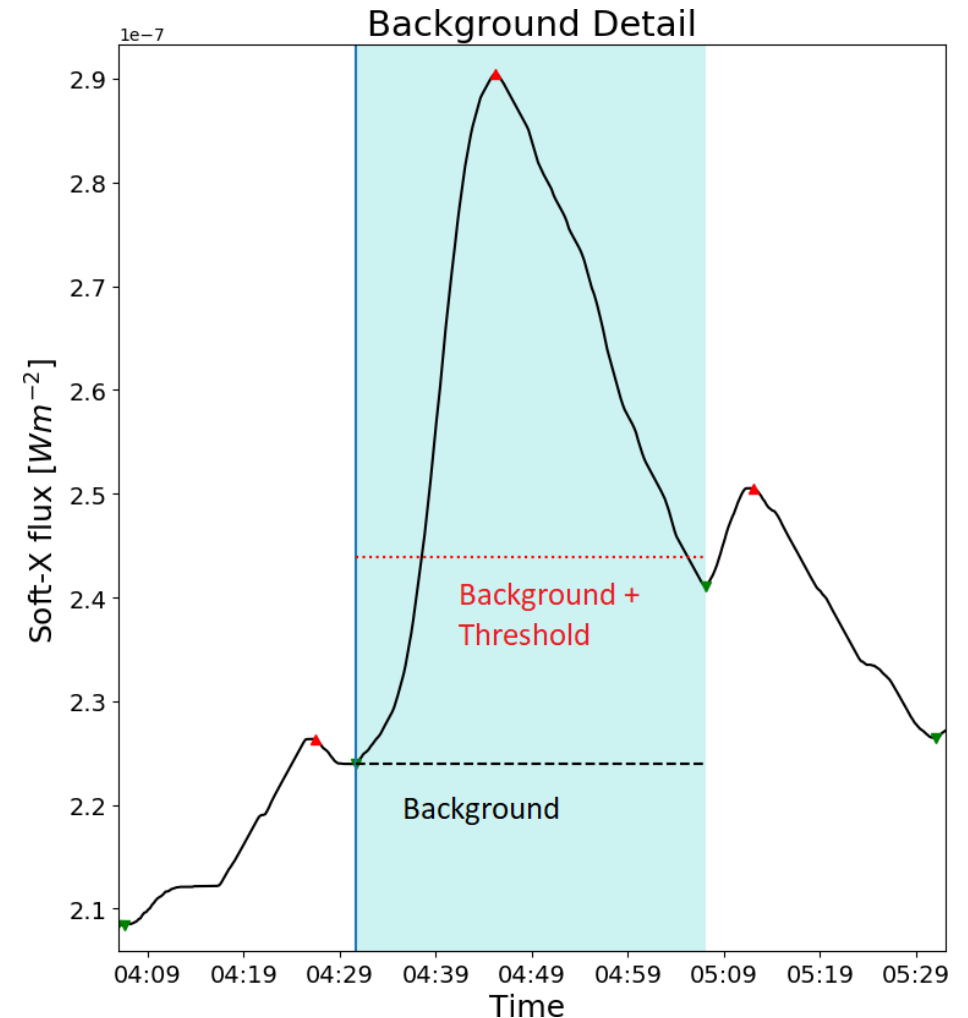
NDA number	start_time	end_time	peak_time	peak_flux	fclass	background	ID
1409	1986-09-15 10:03:52	1986-09-15 10:18:28	1986-09-15 10:11:04	5.1154E-08	A5.1	1.0082E-08	0
1410	1986-09-15 10:43:28	1986-09-15 11:08:16	1986-09-15 10:50:40	8.8172E-08	A8.8	1.0071E-08	0
1411	1986-09-15 13:31:28	1986-09-15 14:10:04	1986-09-15 13:43:40	8.5327E-08	A8.5	1.0068E-08	0
1412	1986-09-15 14:28:40	1986-09-15 14:51:52	1986-09-15 14:42:40	7.2779E-08	A7.3	1.0066E-08	0
1413	1986-09-15 19:24:40	1986-09-15 20:25:52	1986-09-15 20:15:52	5.6578E-08	A5.7	1.0065E-08	0
1414	1986-09-15 22:28:16	1986-09-15 22:47:04	1986-09-15 22:45:40	8.7102E-08	A8.7	1.0064E-08	0
1415	1986-09-16 00:57:04	1986-09-16 01:37:28	1986-09-16 01:09:28	1.7643E-07	B1.8	5.4589E-08	0
1416	1986-09-16 01:38:04	1986-09-16 03:16:16	1986-09-16 02:19:40	2.0694E-07	B2.1	5.6162E-08	0
1417	1986-09-16 07:08:40	1986-09-16 09:09:28	1986-09-16 07:15:28	8.6323E-08	A8.6	5.3502E-08	0
1418	1986-09-16 09:09:28	1986-09-16 11:04:16	1986-09-16 09:29:04	8.3770E-07	B8.4	5.3497E-08	1

Information about flare *start*, *peak* and *end time*, the *peak flux* value (and *soft-X classification*) with its associated *background*. In addition each flare is labelled with a *series number* (NDA number) and an *ID* related to consecutive flares.

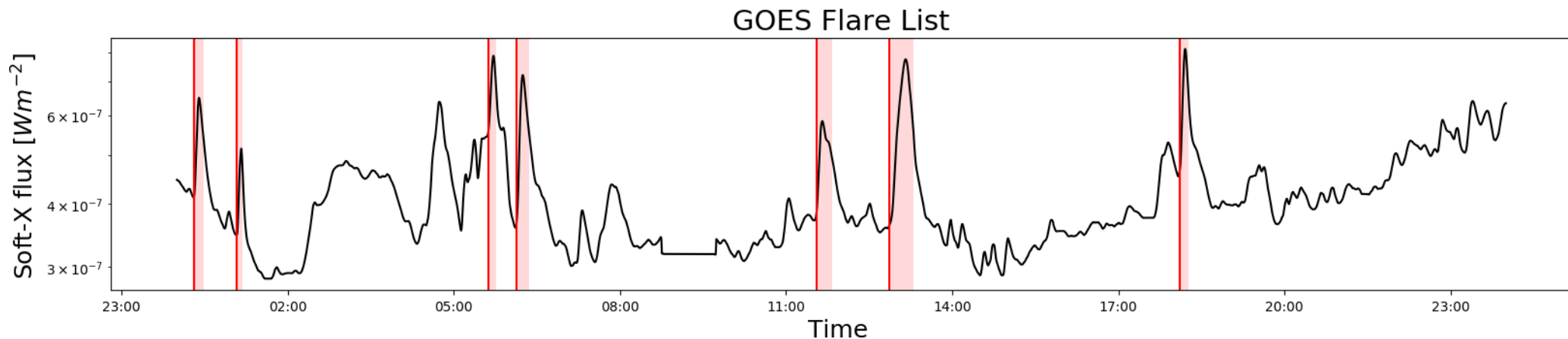
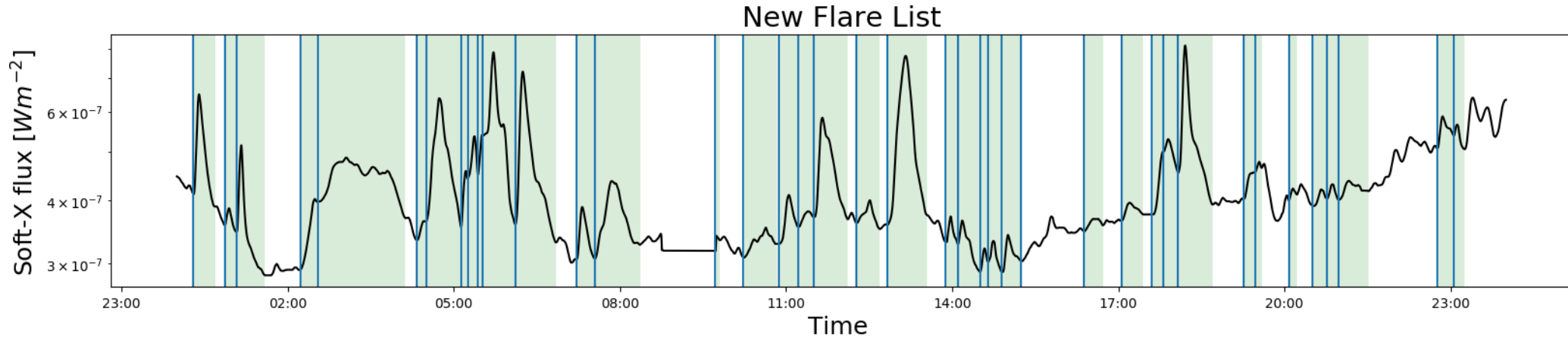
- **Background** = 1 minute average of the flux preceding the starting minimum
[$t_{min} - 60s, t_{min}$]

From the mean and standard deviation of typical GOES fluxes during quiescent time periods, we find a noise level of $f_{noise} \approx 2 \cdot 10^{-8} Wm^{-2}$ and define a corresponding threshold level $f_{tresh} = f_{noise}$
[Aschwanden, M. J., & Freeland, S. L. (2012)]

- **Flares ends** when $f_e < f_{BG} + f_{tresh}$
- **Flare Peak Condition:** $f_{max} > f_{min} + f_{tresh}$



Comparison with GOES flare list



Peak Flux Power Law Index Analysis

