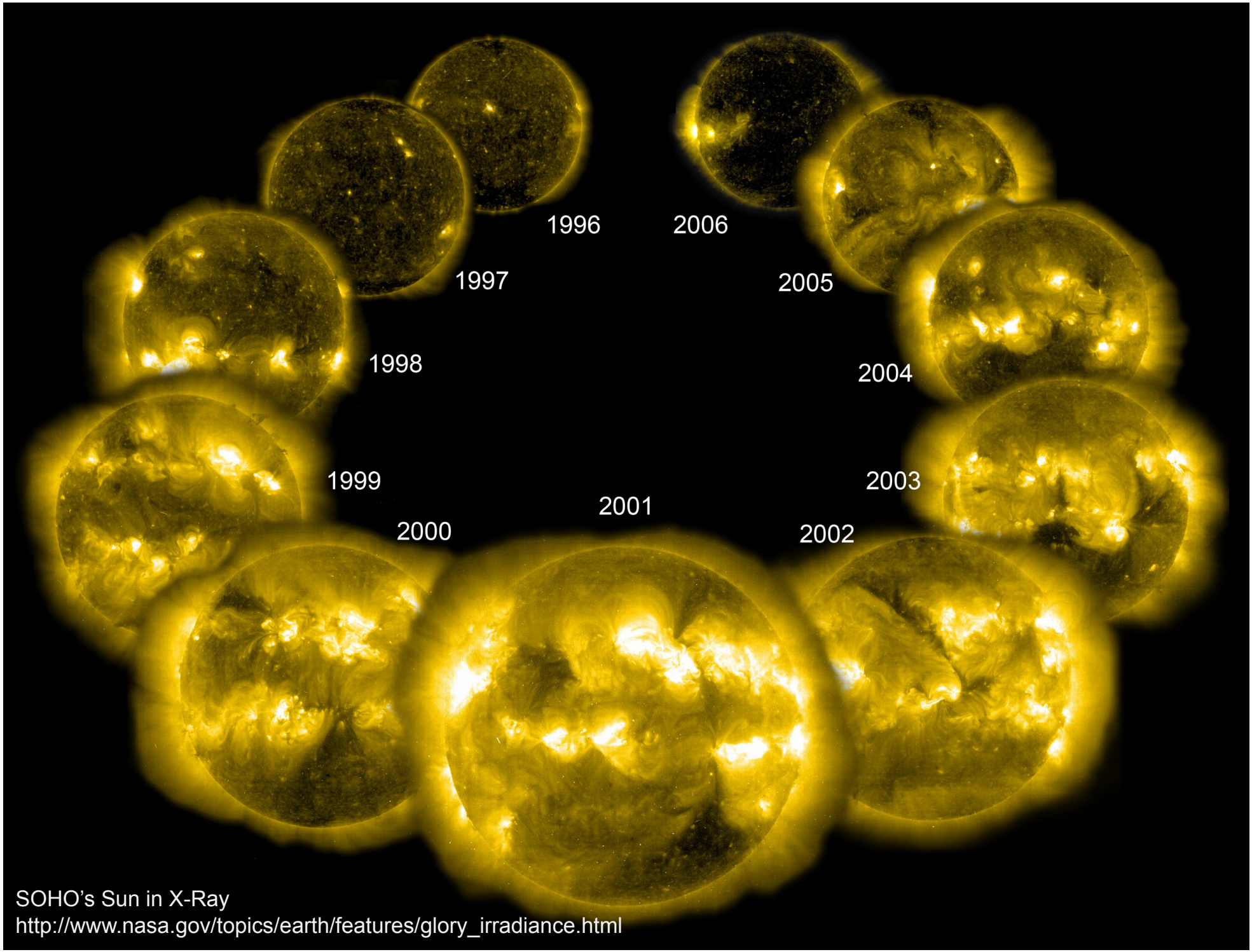
Automating the Characterization of Solar Flares

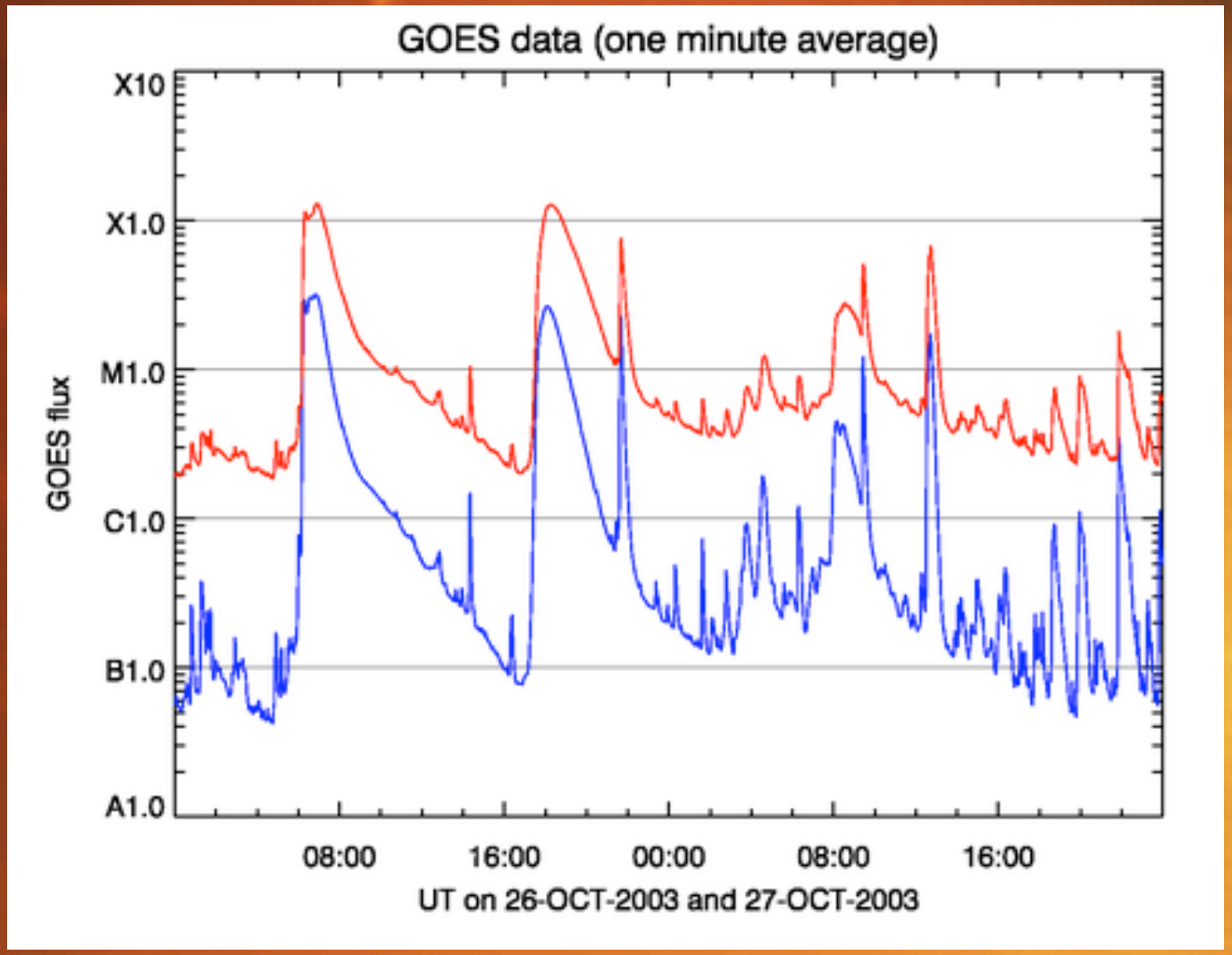
Jenny Goetz, Carleton College
Dr. Andrew Jones, LASP

What are solar flares?



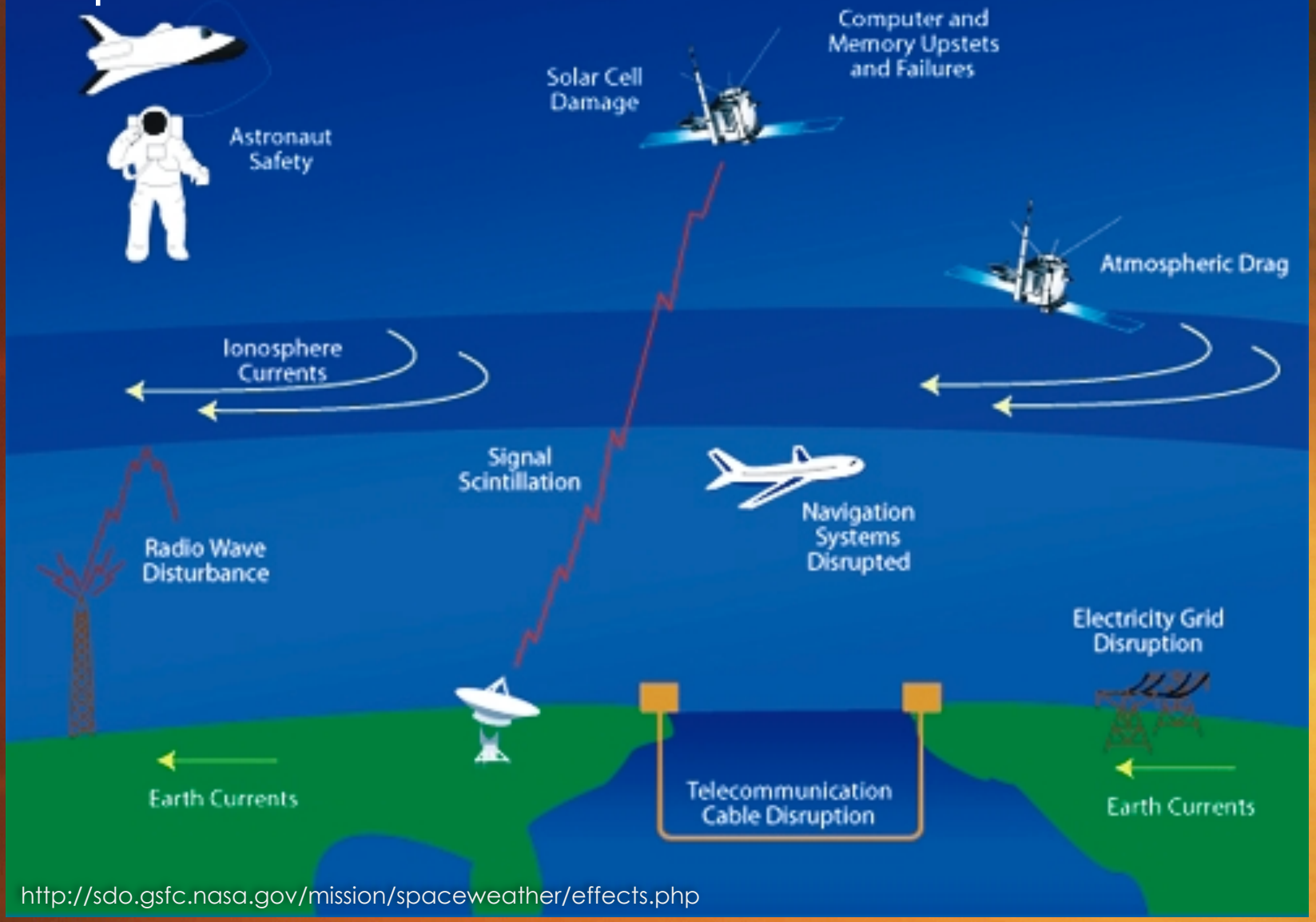
SOHO's Sun in X-Ray
http://www.nasa.gov/topics/earth/features/glory_irradiance.html

Solar Flare Classification



Why look at solar flares?

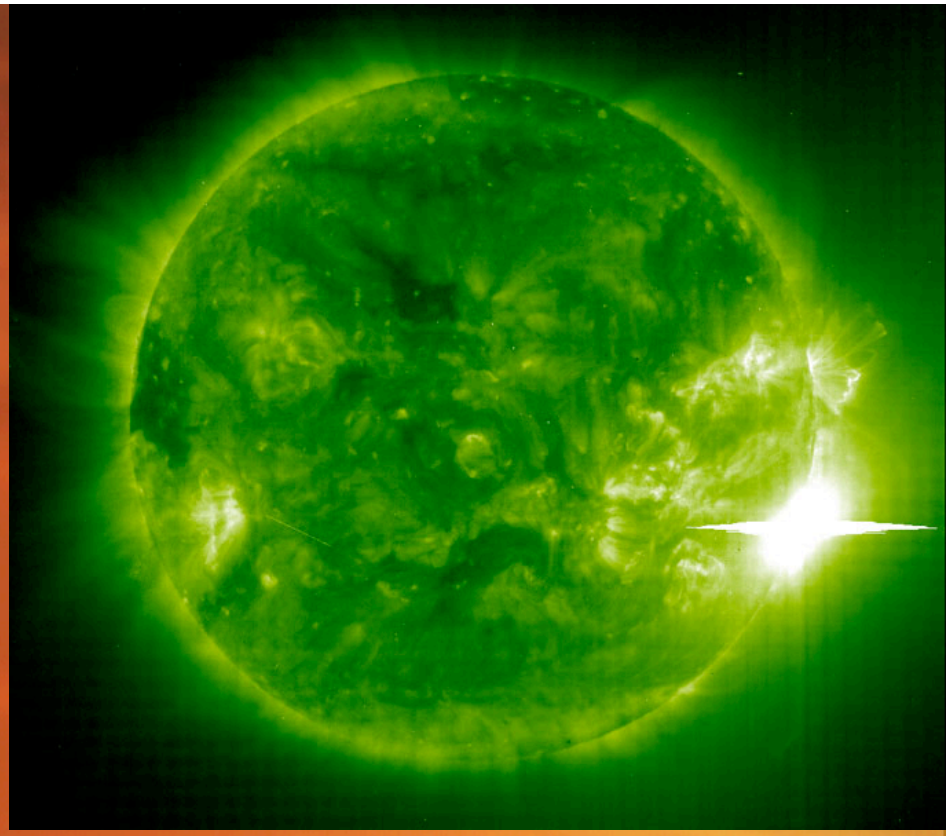
Space Weather…



http://sdo.gsfc.nasa.gov/mission/spaceweather/effects.php

Why..

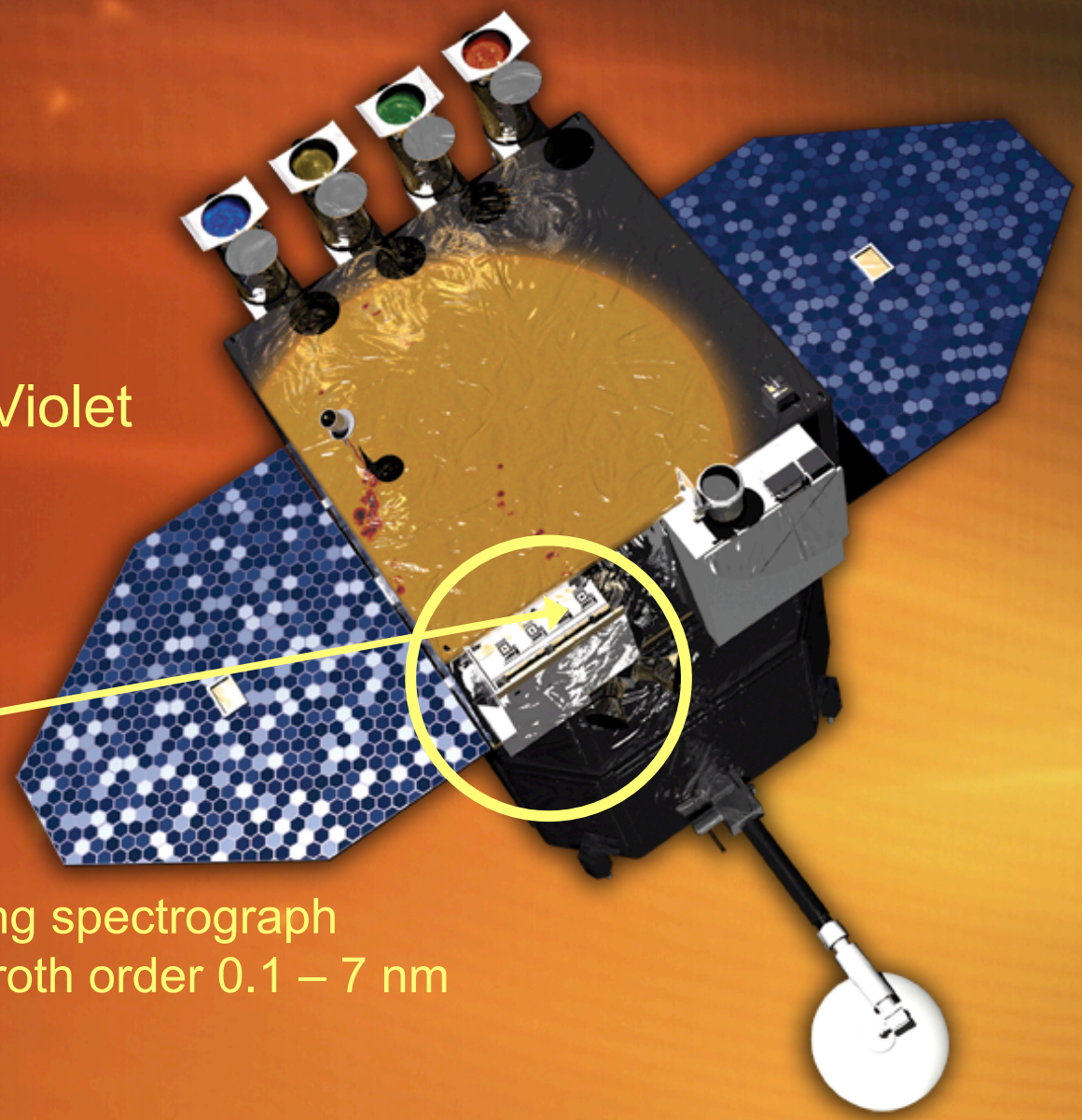
- Understand our sun!
  - Solar and plasma physics
  - Magnetic fields
- High energy interactions (giant particle accelerator)
- Other cosmic events, pulsars, quasars, and flare stars…



Research Goals

- Algorithms for GOES EXIS x-ray sensor
  - Next generation space weather – 2015
  - Quadrant photodiode – location!
- Flare - finder and flare prediction (C, M, X?)
- Conveniently already a similar device pointed at the sun! (SDO…)
- Catalogue of recent flares

Solar Dynamics Observatory

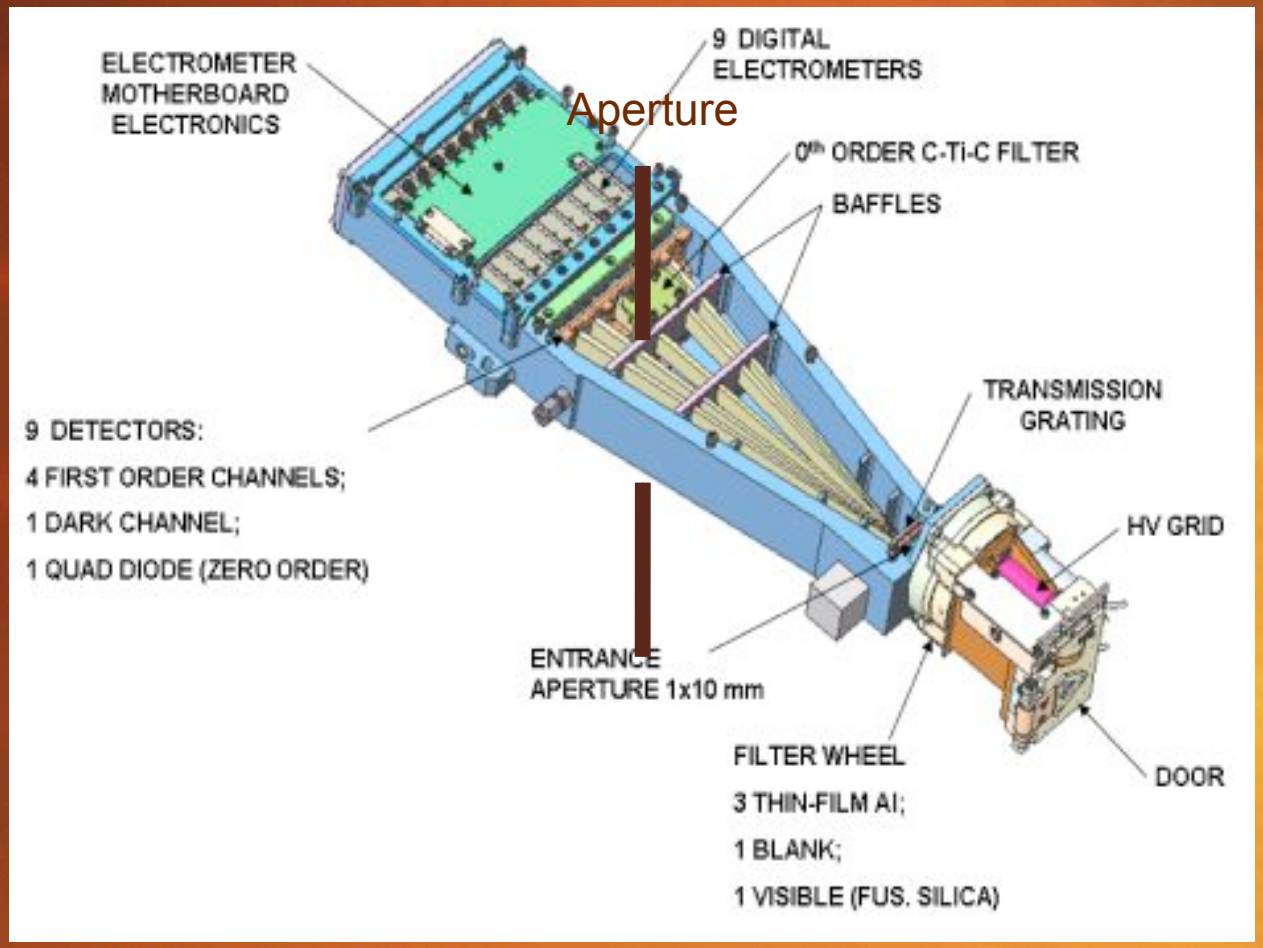


EVE - Extreme ultraViolet Experiment

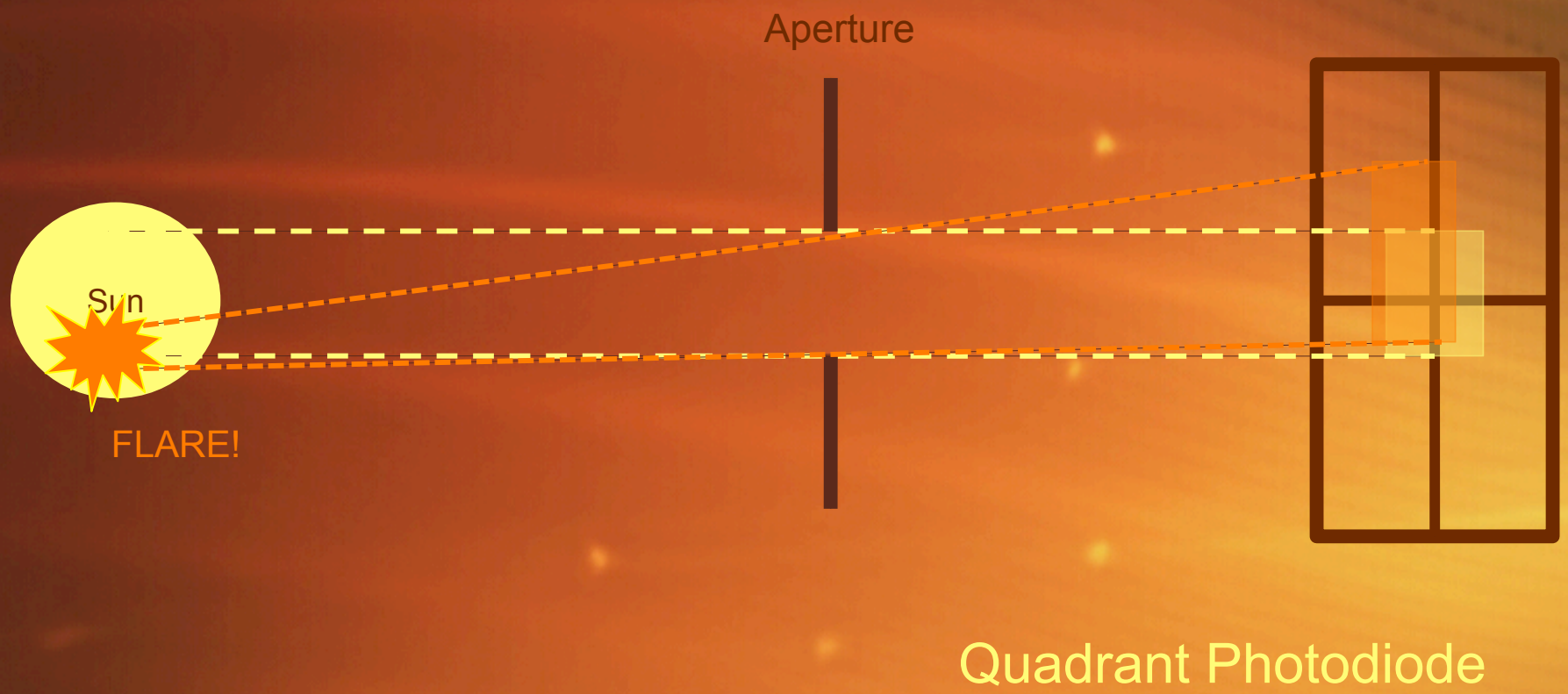
ESP – EUV SpectroPhotometer

Transmission grating spectrograph
17 – 38 nm and zeroth order 0.1 – 7 nm

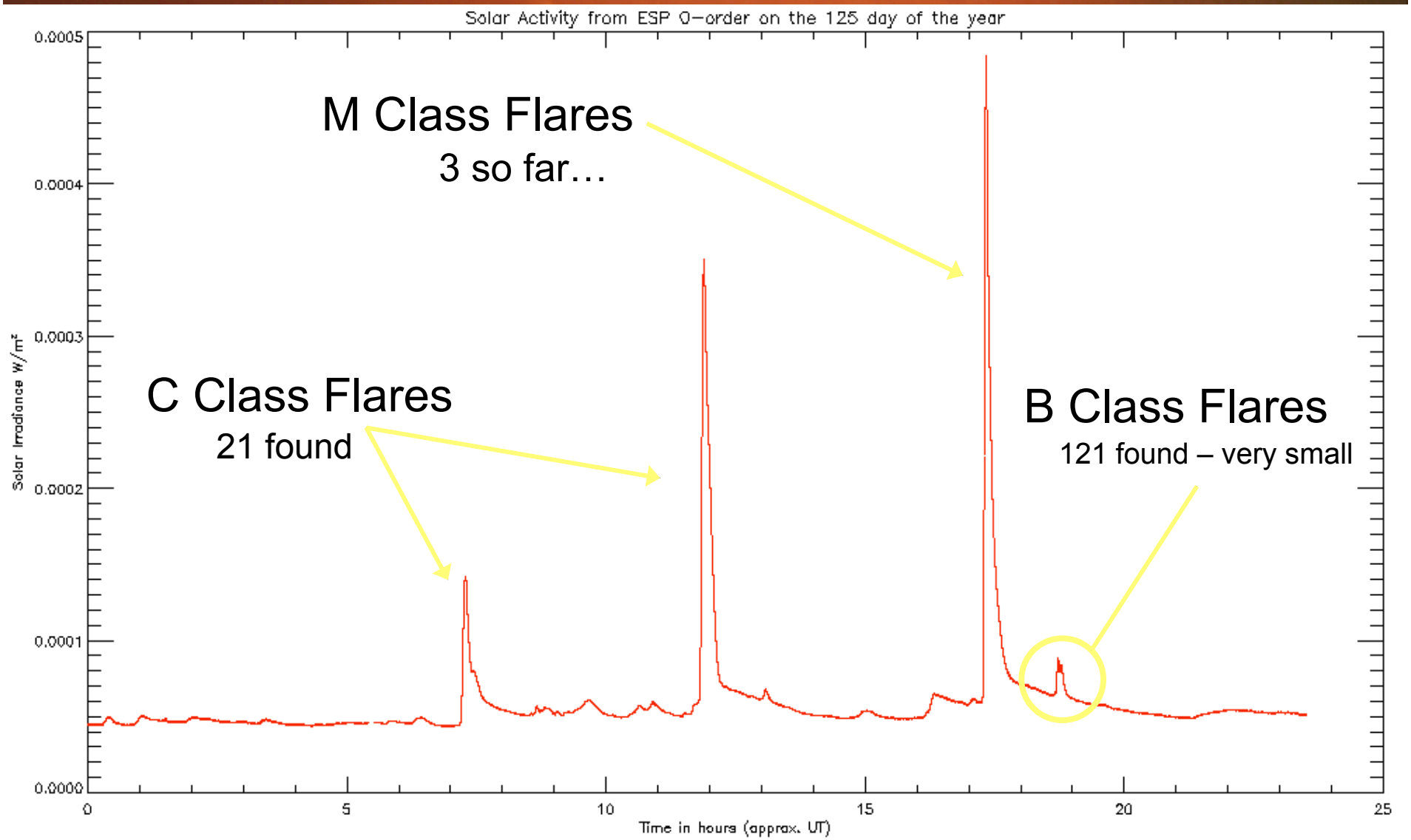
EUV SpectroPhotomete – 0th order



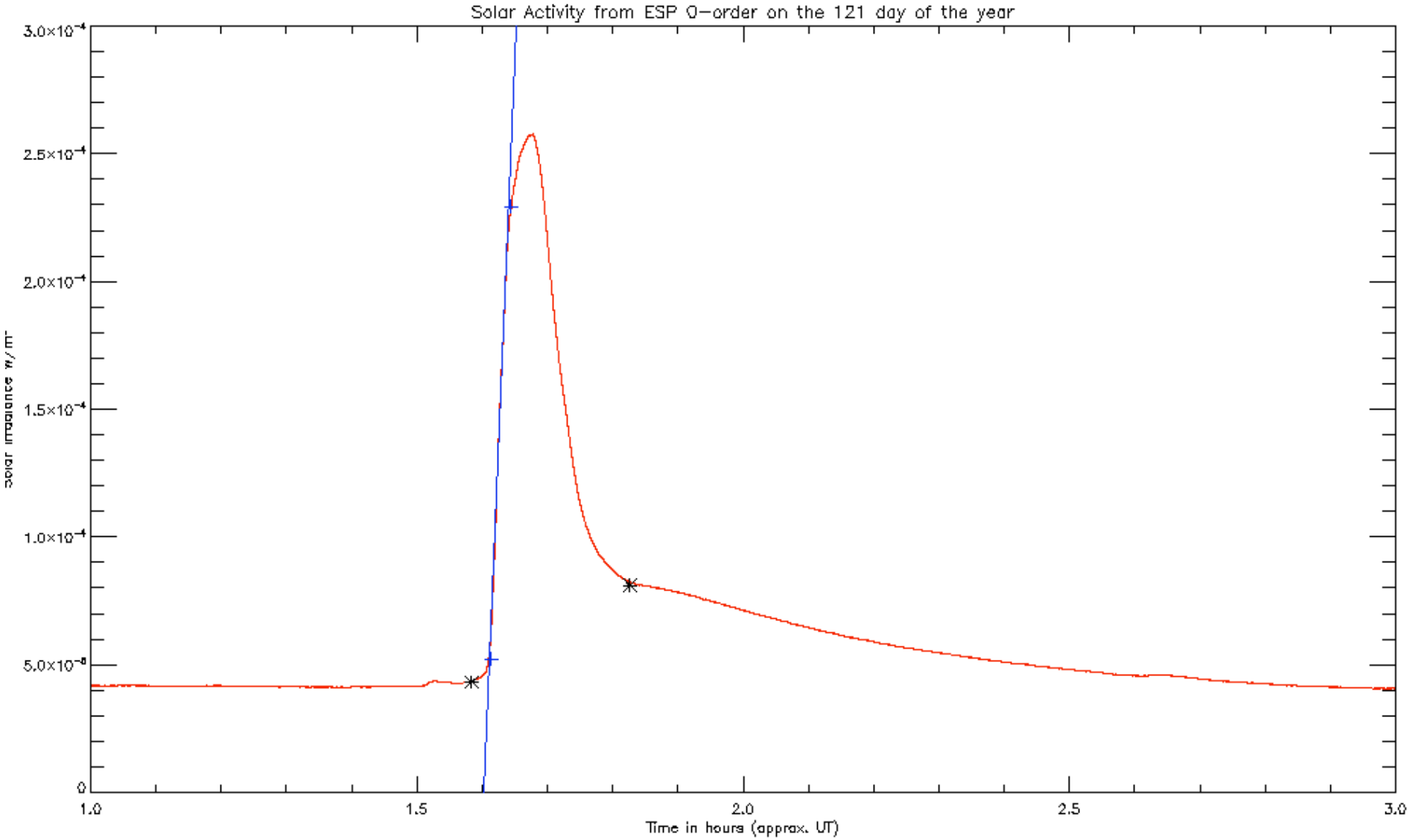
EUV SpectroPhotomete – 0th order



A day in the life of the Sun!

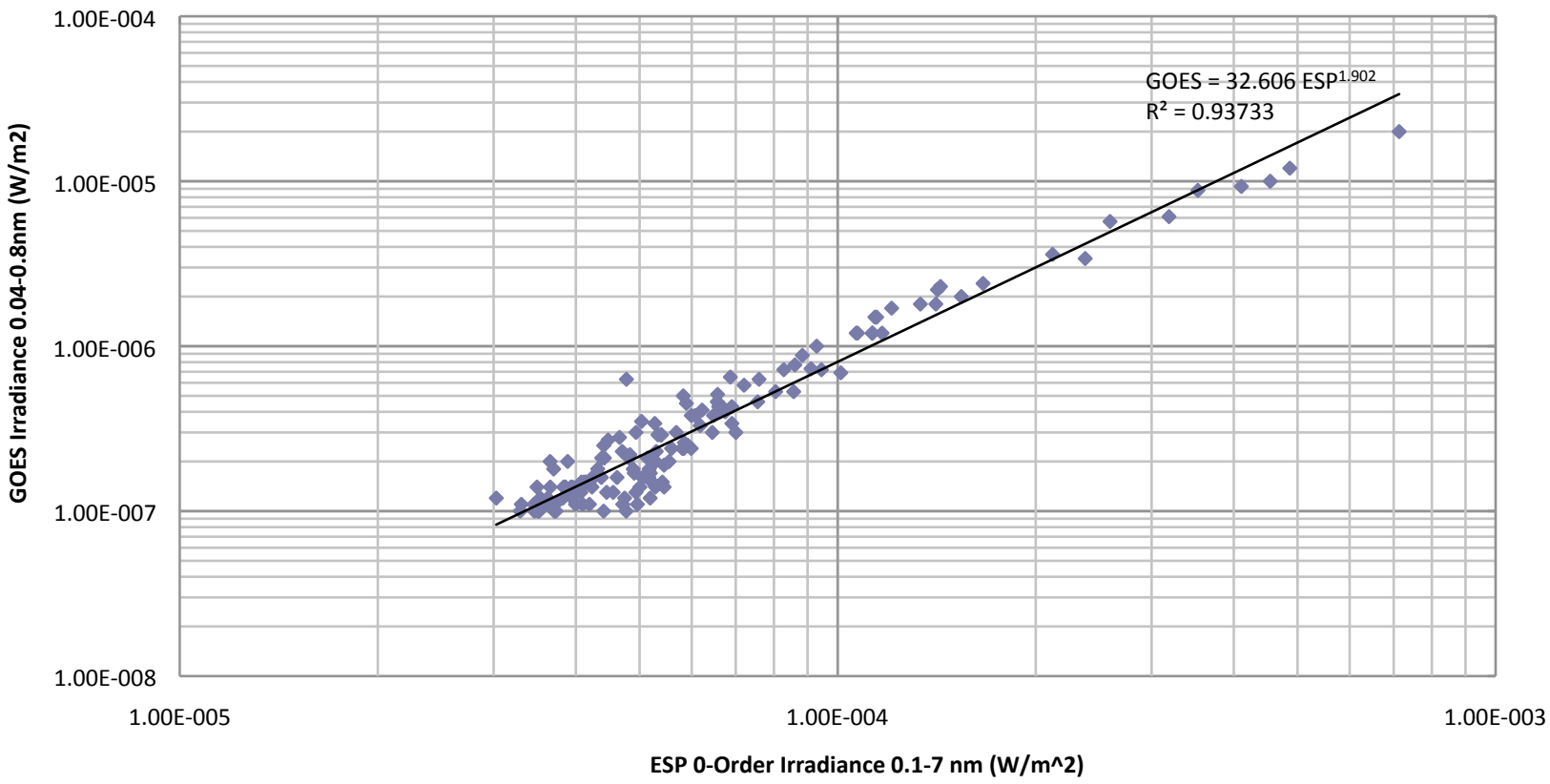


Flare Measurements



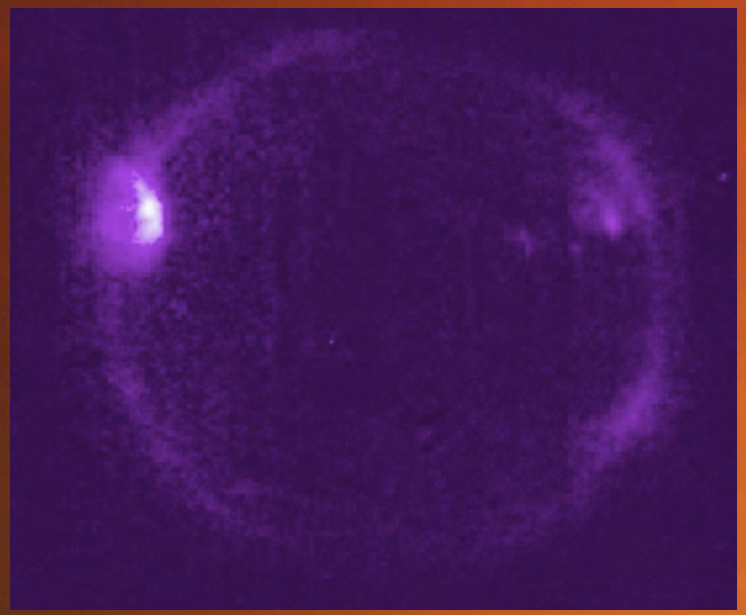
ESP and XRS Flare Comparison
Linear Fit

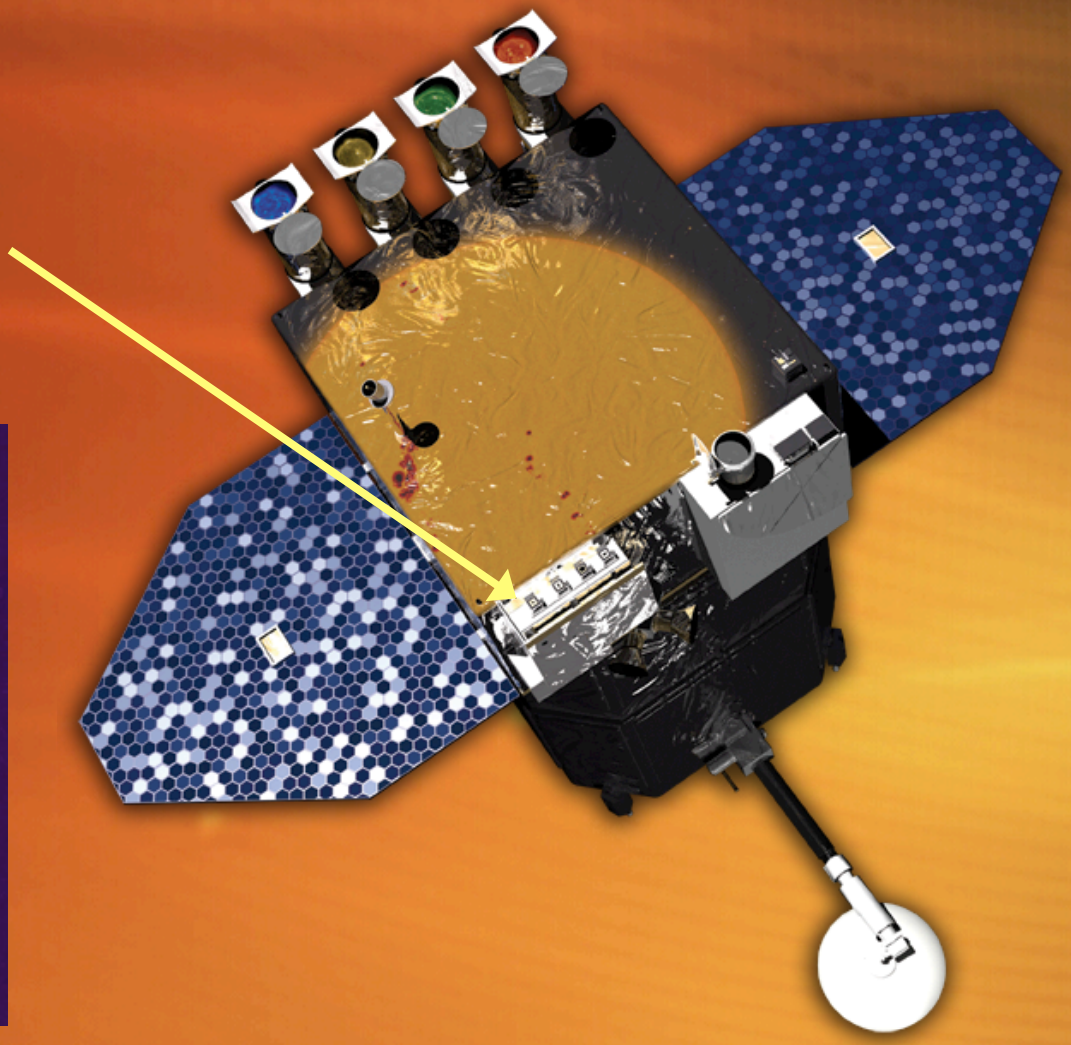
Jenny Goetz, Carleton College

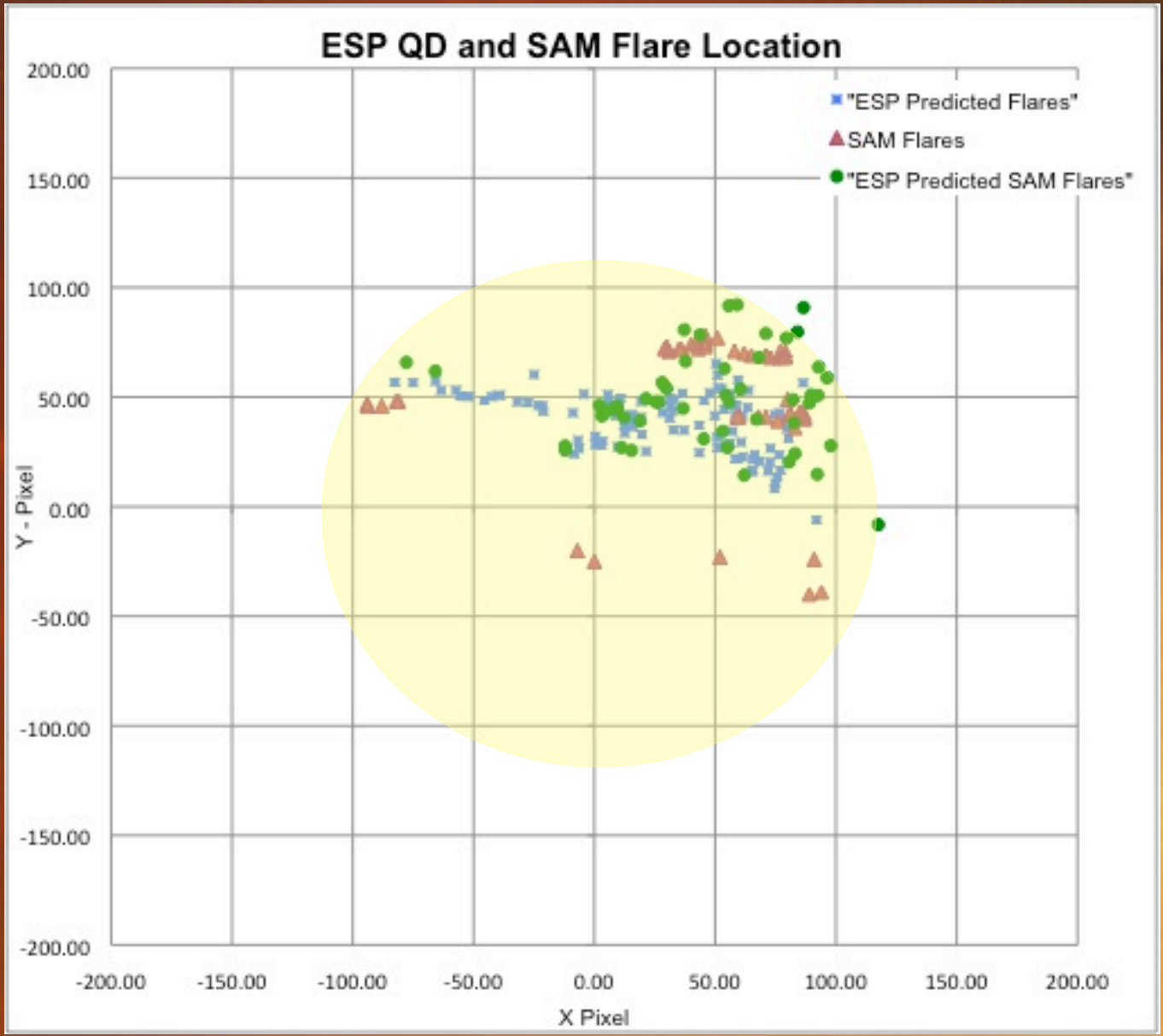


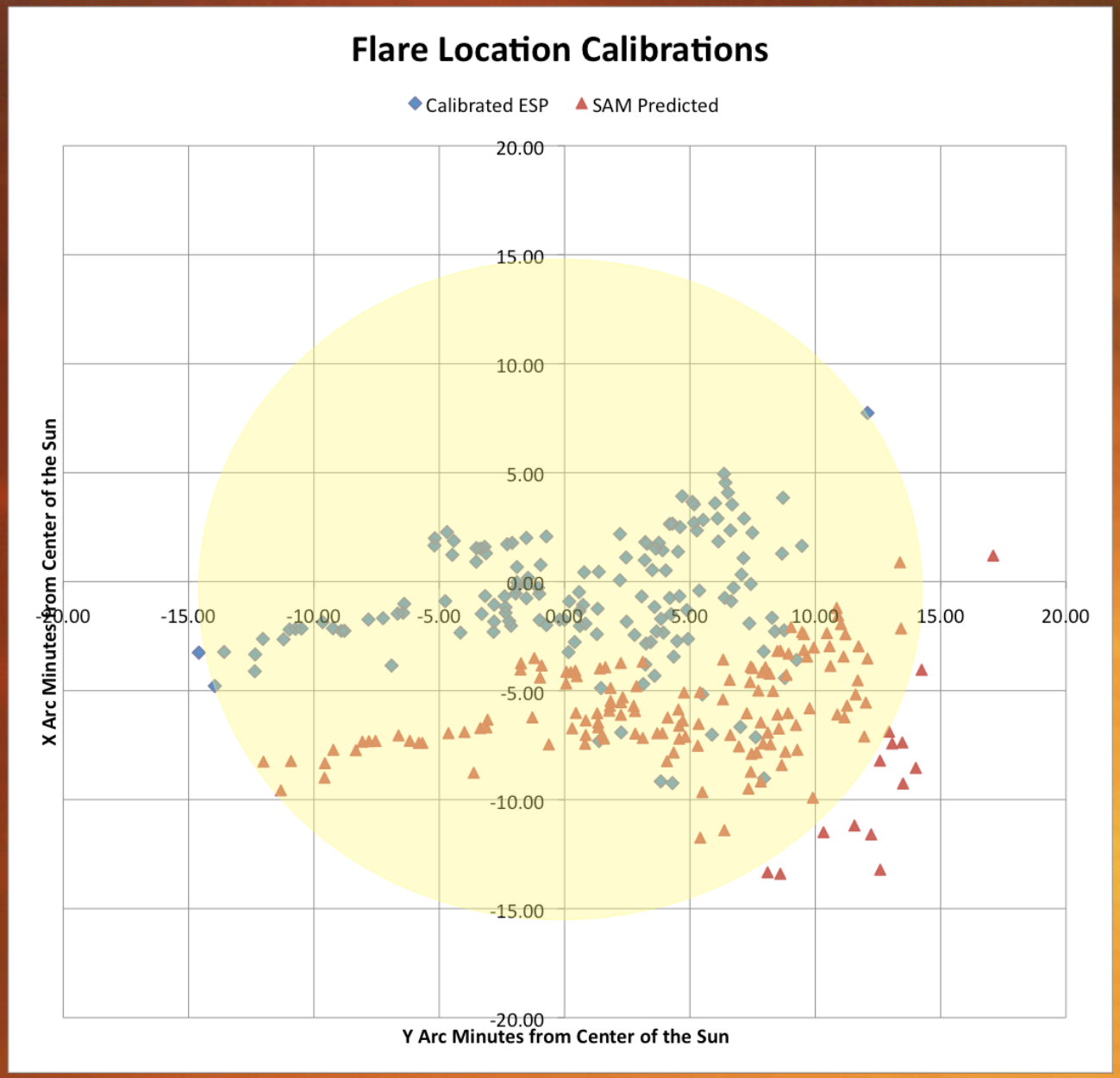
MEGS - SAM

SAM – pinhole camera on MEGS A in soft x-ray

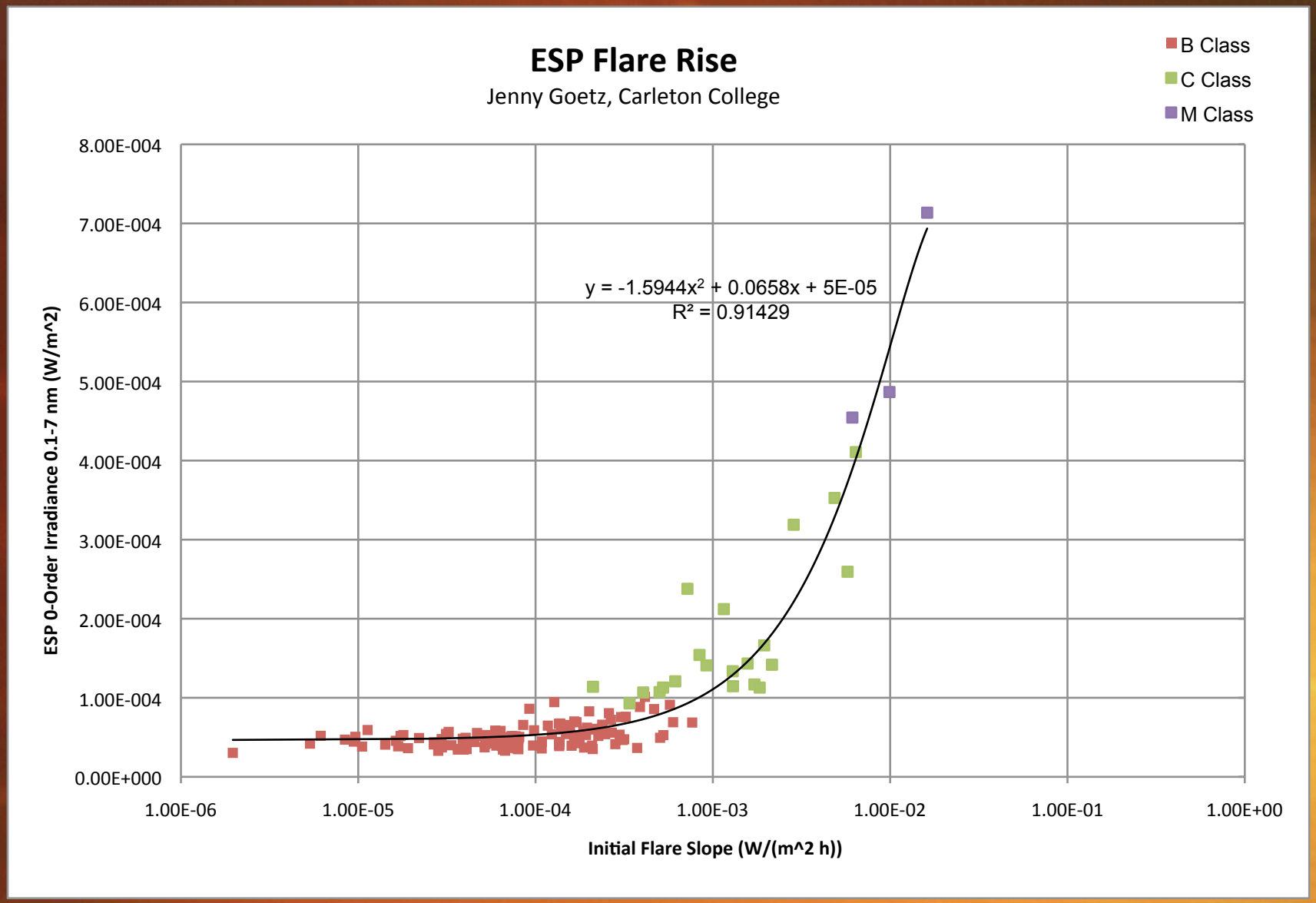





ESP QD and SAM Flare Location
"ESP Predicted Flares"
SAM Flares
"ESP Predicted SAM Flares"
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Y - Pixel
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
X Pixel

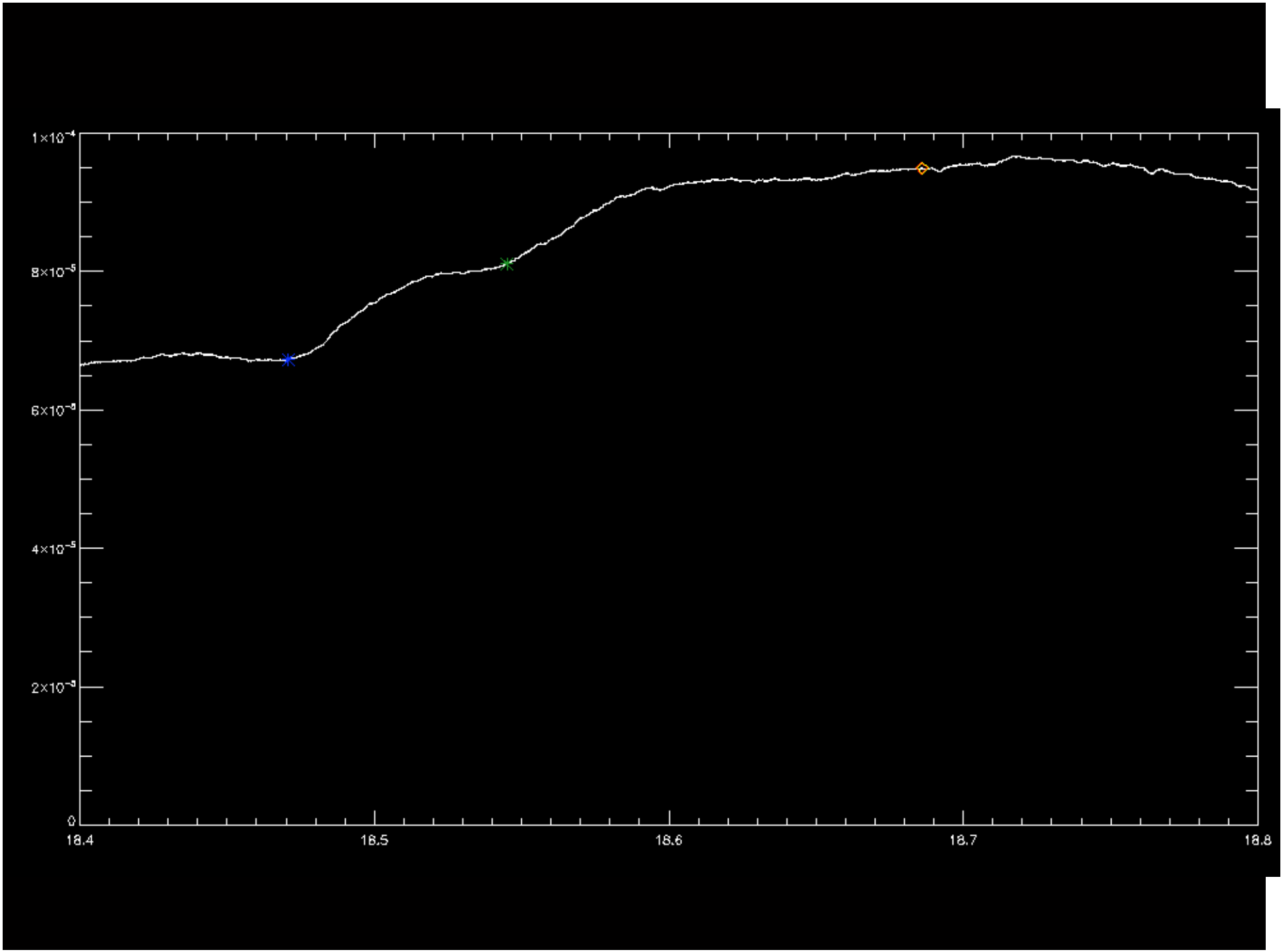

Flare Location Calibrations
Calibrated ESP
SAM Predicted
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-20.00
-15.00
-10.00
-5.00
0.00
5.00
10.00
15.00
20.00
X Arc Minutes from Center of the Sun
Y Arc Minutes from Center of the Sun

How to detect flares…

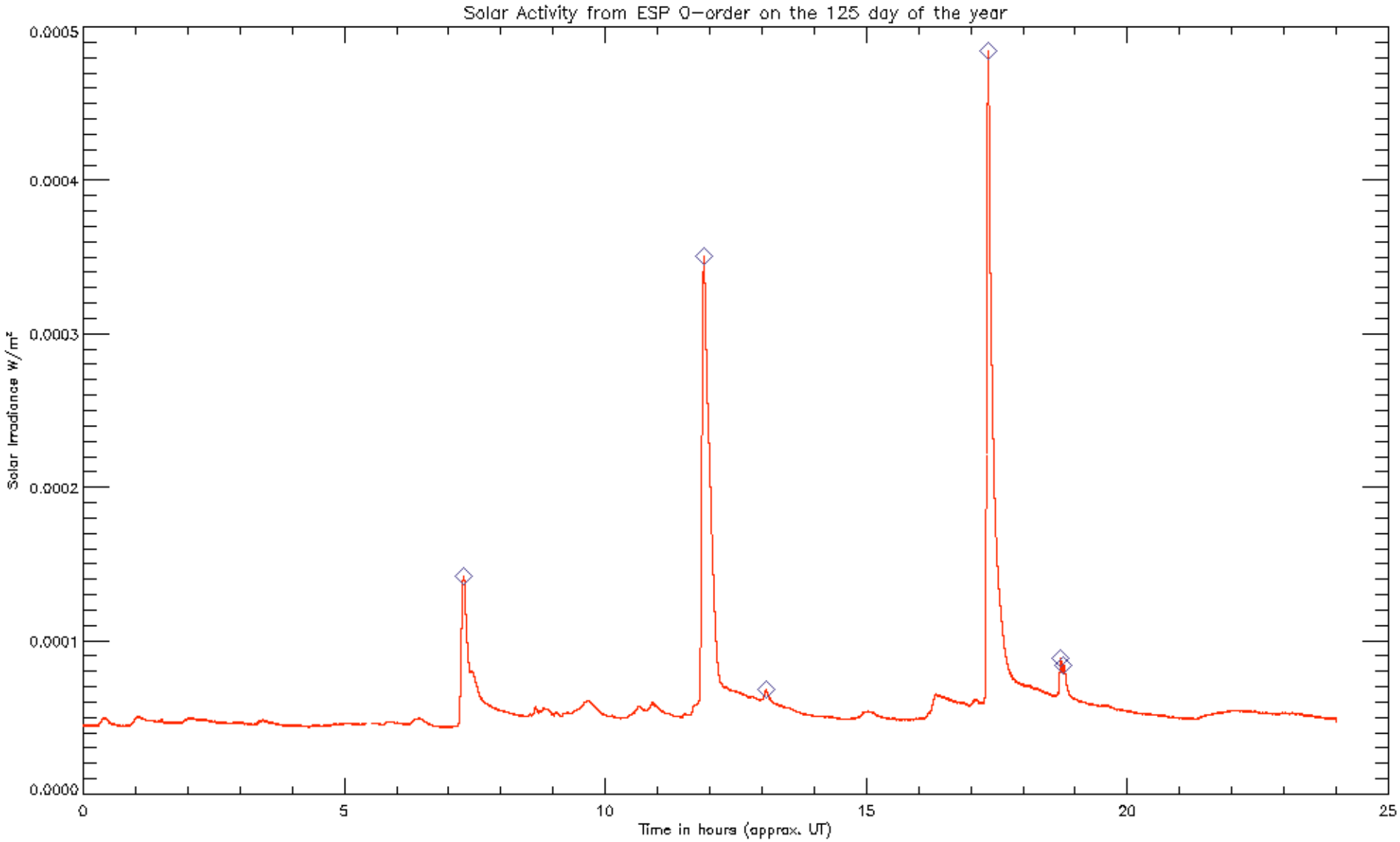

ESP Flare Rise
Jenny Goetz, Carleton College
B Class
C Class
M Class
y = -1.5944x² + 0.0658x + 5E-05
R² = 0.91429
ESP 0-Order Irradiance 0.1-7 nm (W/m^2)
8.00E-004
7.00E-004
6.00E-004
5.00E-004
4.00E-004
3.00E-004
2.00E-004
1.00E-004
0.00E+000
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
Initial Flare Slope (W/(m^2 h))

Flare Finder

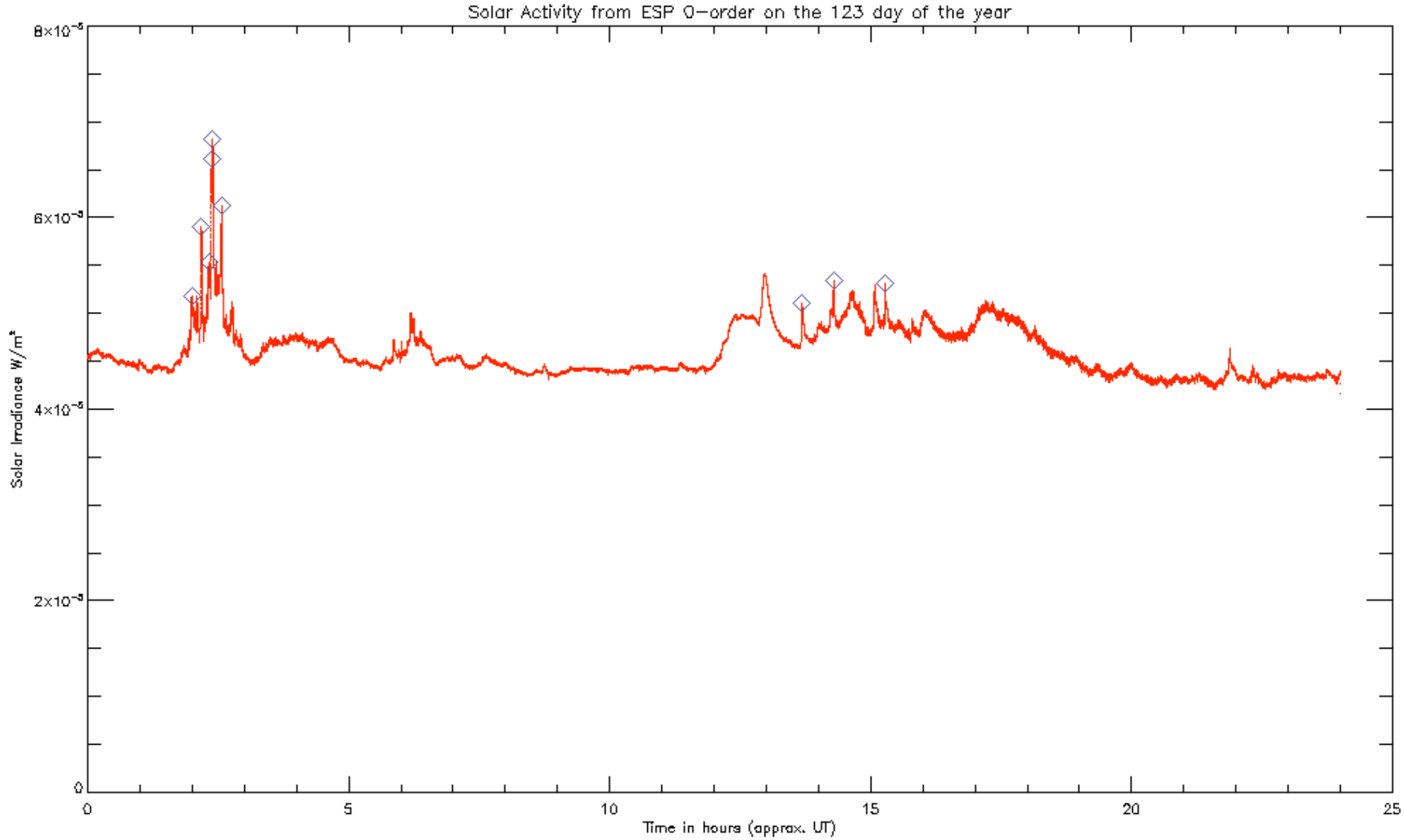
- Detection based on linear fit of a timed section
  - Slope larger than threshold – flare here!
- Use of the derivative to determine flare peak
- Max slope – derivative
- Notes of irregularities


1×10⁻⁴
8×10⁻⁵
6×10⁻⁵
4×10⁻⁵
2×10⁻⁵
0
18.4
18.5
18.6
18.7
18.8

Sometimes pretty good



Other times…


Solar Activity from ESP 0-order on the 123 day of the year
8x10⁻⁵
6x10⁻⁵
4x10⁻⁵
2x10⁻⁵
0
Solar Irradiance W/m²
0
5
10
15
20
25
Time in hours (approx. UT)

Additions for FlareFinder

- Record slopes over longer period
  - Initial slopes mostly the same…

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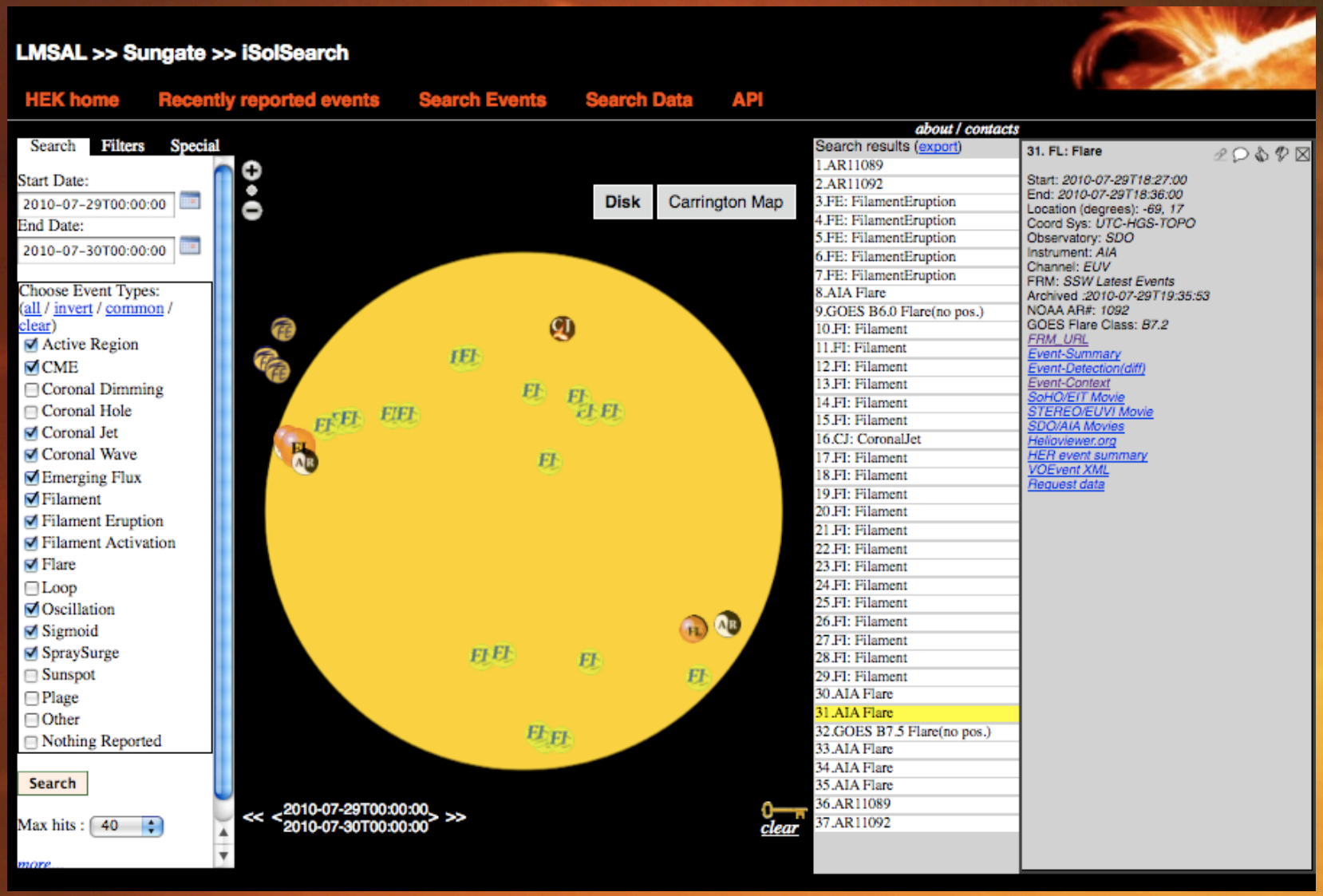

http://www.lmsal.com/hek/

Additions for FlareFinder

- Record slopes over longer period
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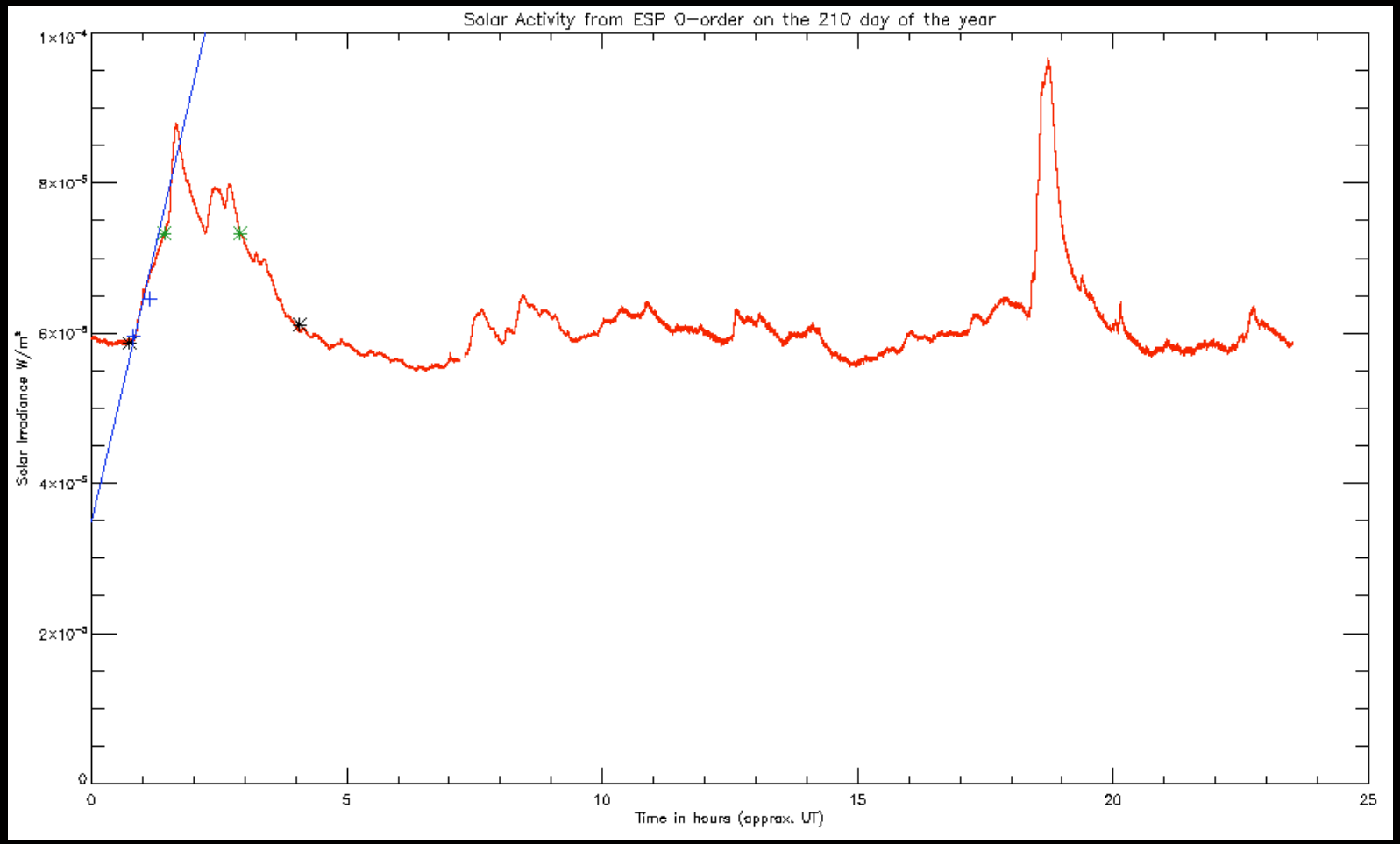
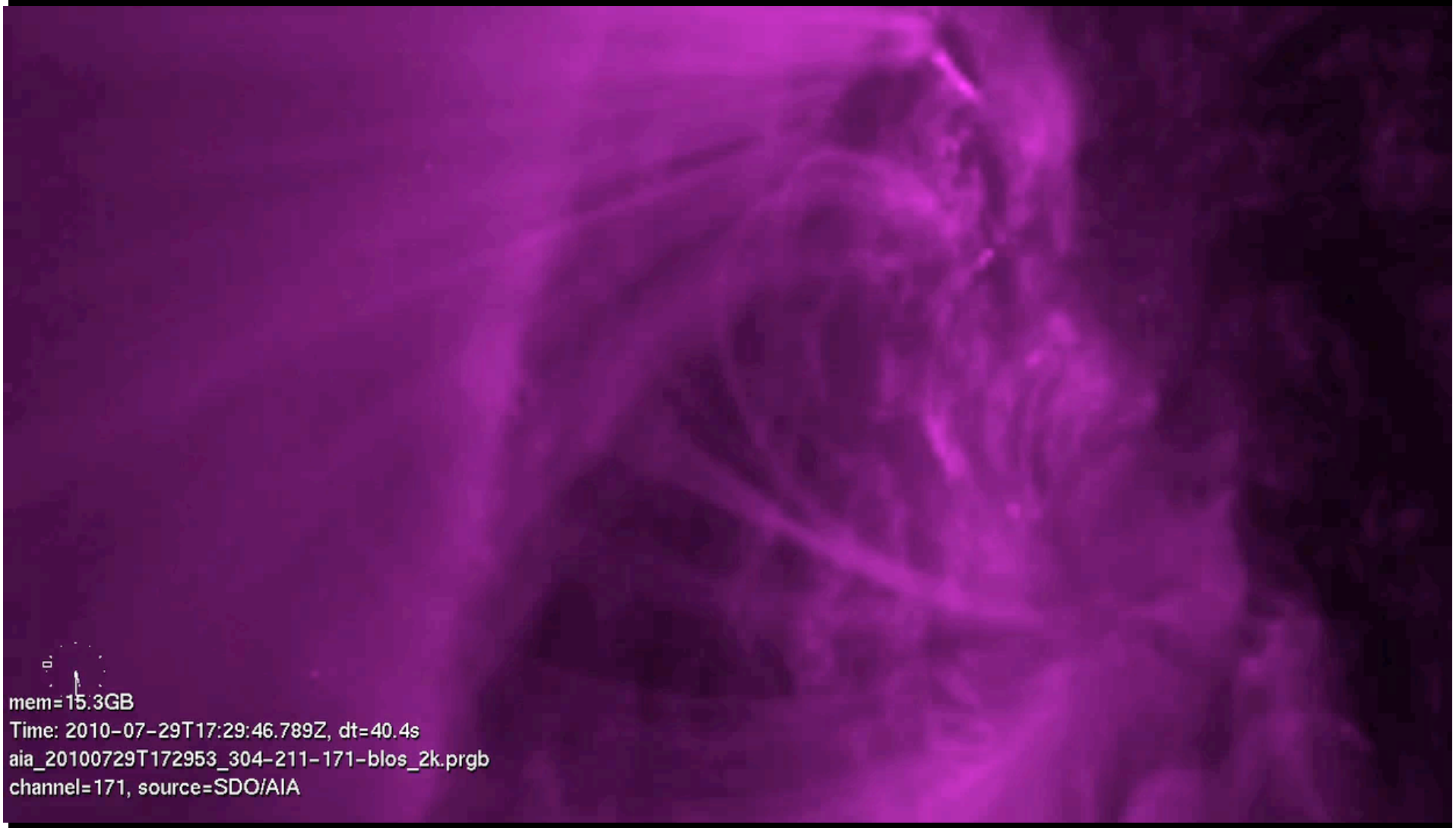
- Deal with ‘fast’ background
- Heliophsyics knowledgebase (HEK)
  - Link the flares to movies – why are they happening
- Small flares – missing flares

Additions for FlareFinder

- Record slopes over longer period
  - Initial slopes mostly the same…
- Deal with ‘fast’ background
- Heliophsyics knowledgebase (HEK)
  - Link the flares to movies – why are they happening
- Small flares – missing flares
- Correlate to GOES recorded flares


Solar Activity from ESP 0-order on the 210 day of the year
Solar Irradiance W/m²
1×10⁻⁴
8×10⁻⁵
6×10⁻⁵
4×10⁻⁵
2×10⁻⁵
0
0
5
10
15
20
25
Time in hours (approx. UT)


mem=15.3GB
Time: 2010-07-29T17:29:46.789Z, dt=40.4s
aia_20100729T172953_304-211-171-blos_2k.prgb
channel=171, source=SDO/AIA

Conclusions

- Autonomous detection program
  - Very accurate on large flares (C and up)
  - Fast flare statistics – can be programmed to any number of variables
- Flare location – flares smaller than SAM
  - High correlation
  - Nearly instant location
    - Is the flare coming towards us?!

References

L. Didkovsky, D. Judge, S. Wieman, T. Woord and A. Jones, Solar Phys. (2009).

L. Didkovsky et al., SDO ESP Radiometric Calibration, (2009).

T. Woods, et al., Solar Phys. (2010).

W. Tobiska, AIA, **69** (2005).

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