

SPACE WEATHER INTRODUCTORY COURSE



Collaboration of



Solar-Terrestrial Centre of Excellence



Koninklijke luchtmacht



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu



SOLAR ERUPTIONS

Magnetic Reconnection

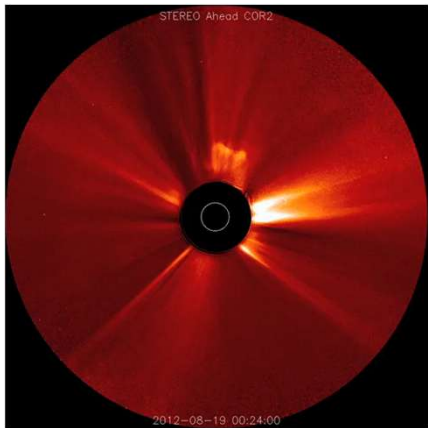
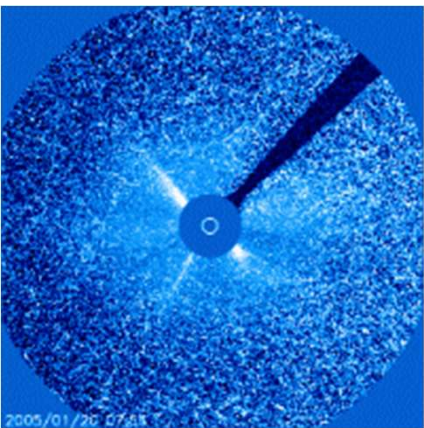
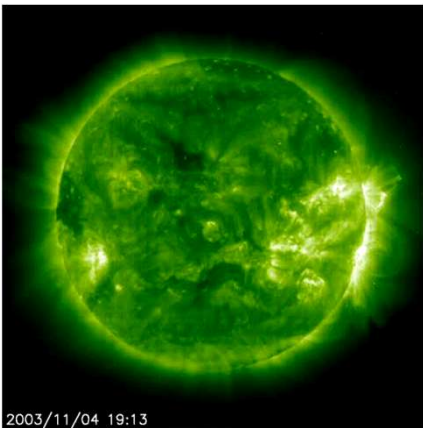
Radiation

Particles

Solar flares

Proton events

Coronal Mass Ejections



SOHO/EIT



SOHO/LASCO



SOHO/LASCO



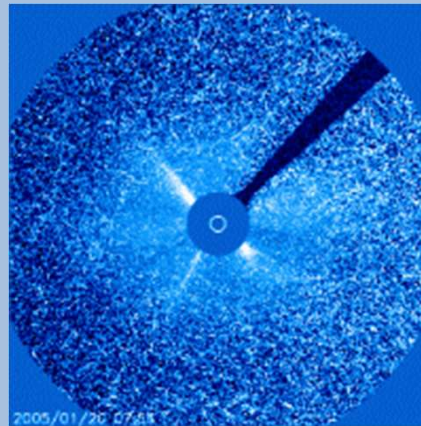


SOLAR ERUPTIONS

—Magnetic Reconnection

Particles

Proton events

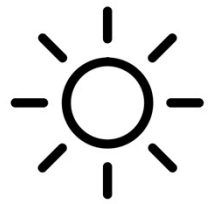
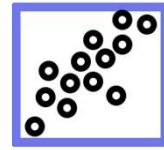


SOHO/LASCO

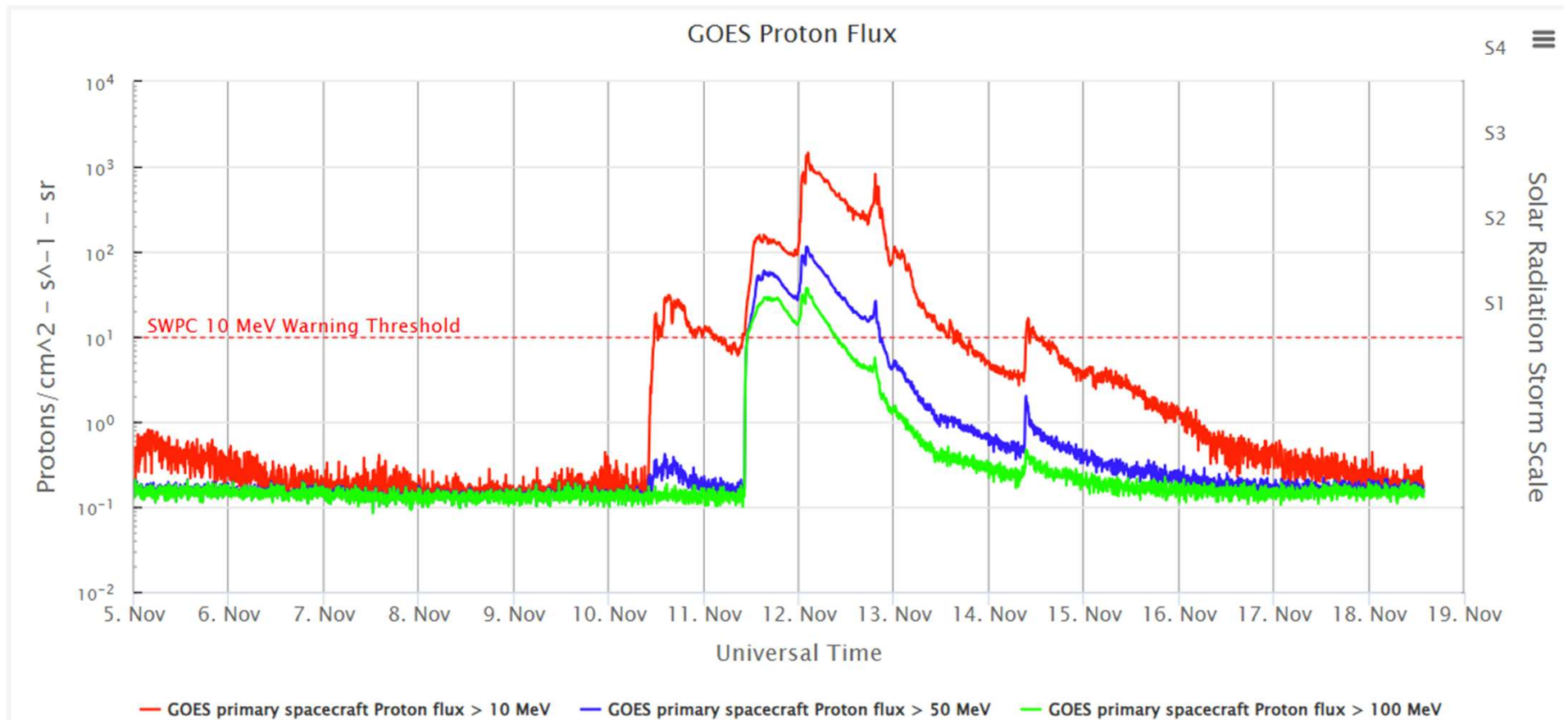


ENERGETIC PARTICLES

MEASURED by GOES



GOES

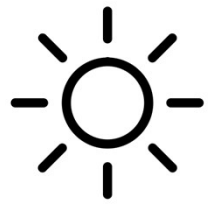
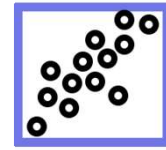


Check out: <https://www.swpc.noaa.gov/products/goes-proton-flux>



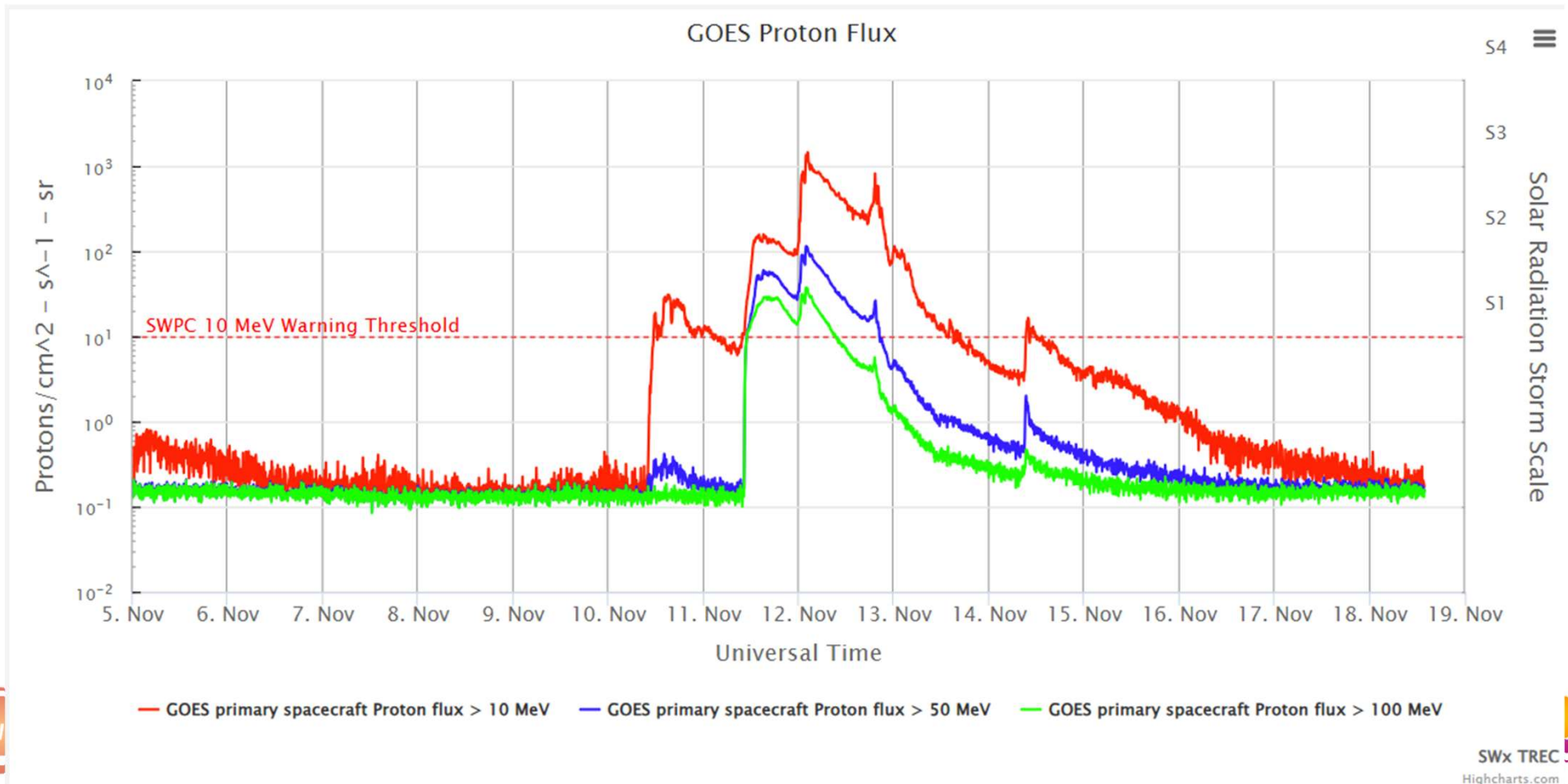
ENERGETIC PARTICLES

MEASURED by GOES



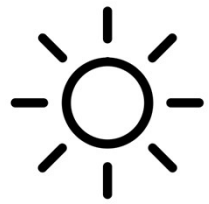
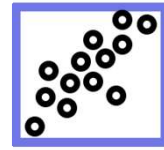
GOES

Proton flux : Number of protons on a given „surface“ per seconds
Unit : PFU = Particle Flux Unit



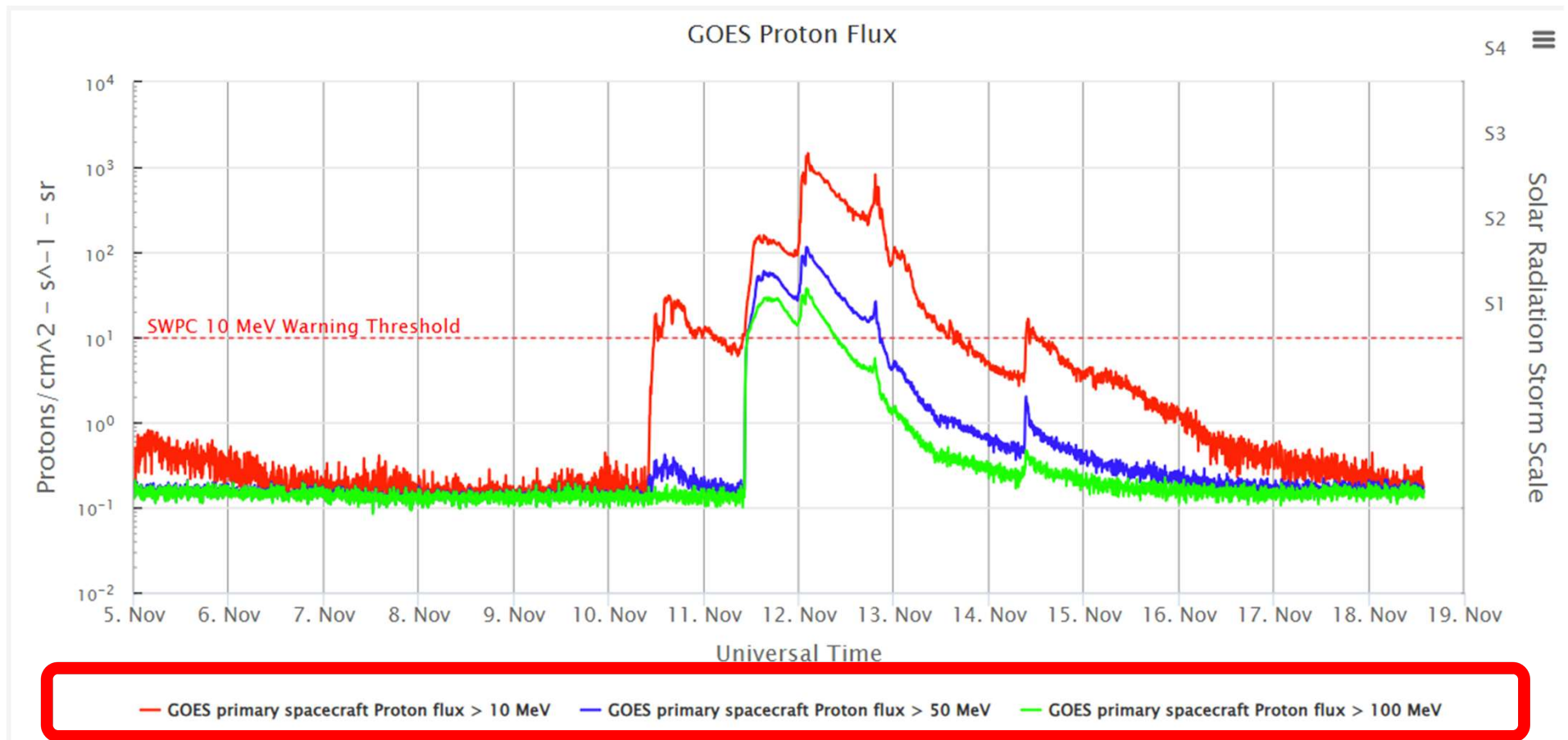
ENERGETIC PARTICLES

MEASURED by GOES



GOES

Different energies



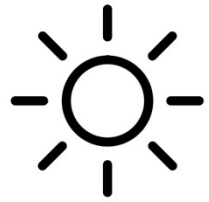
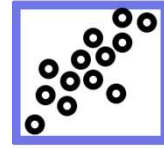
SWx TREC
Highcharts.com

Different energies: > 10 MeV proton but also higher energies



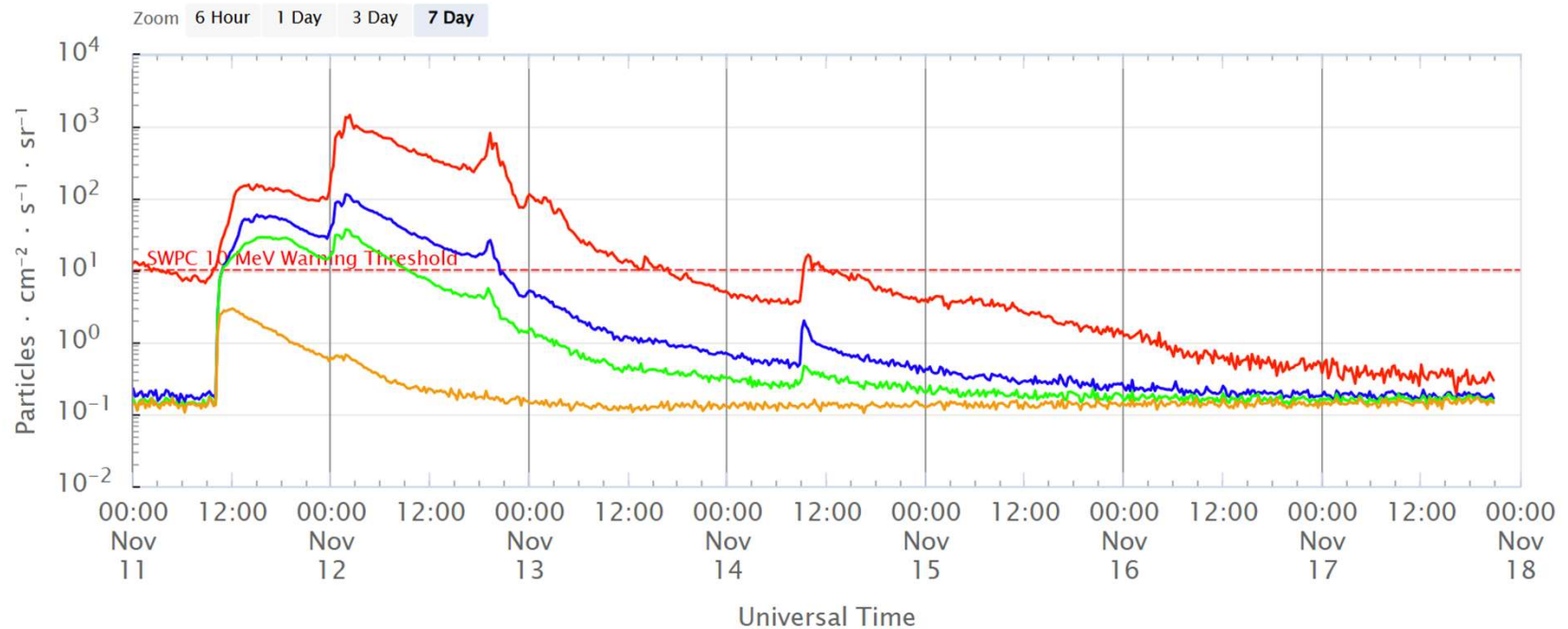
ENERGETIC PARTICLES

MEASURED by GOES



GOES

GOES Proton Flux (5-minute data)



— GOES-18 ≥ 10 MeV — GOES-18 ≥ 50 MeV — GOES-18 ≥ 100 MeV — GOES-18 ≥ 500 MeV

Updated 2025-11-17 20:50 UTC

Space Weather Prediction Center

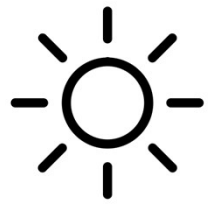
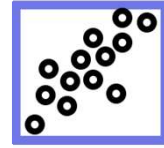
Proton flux >500MeV protons: Very rare...



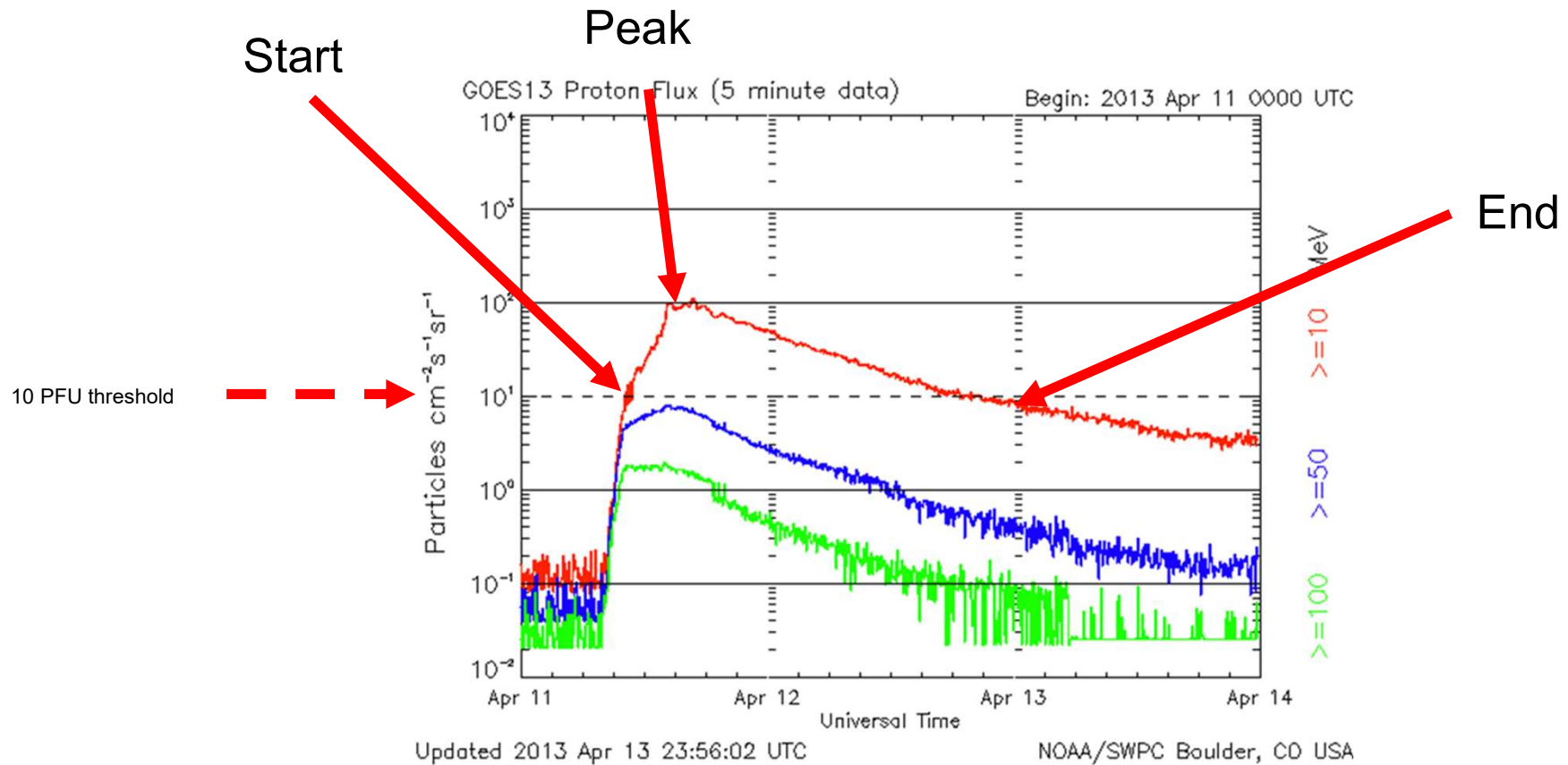
ENERGETIC PARTICLES

Proton Event

Some definitions



GOES



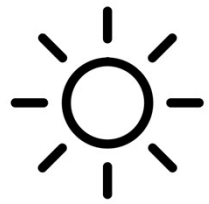
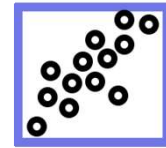
10 MEV Proton flux > 10 PFU



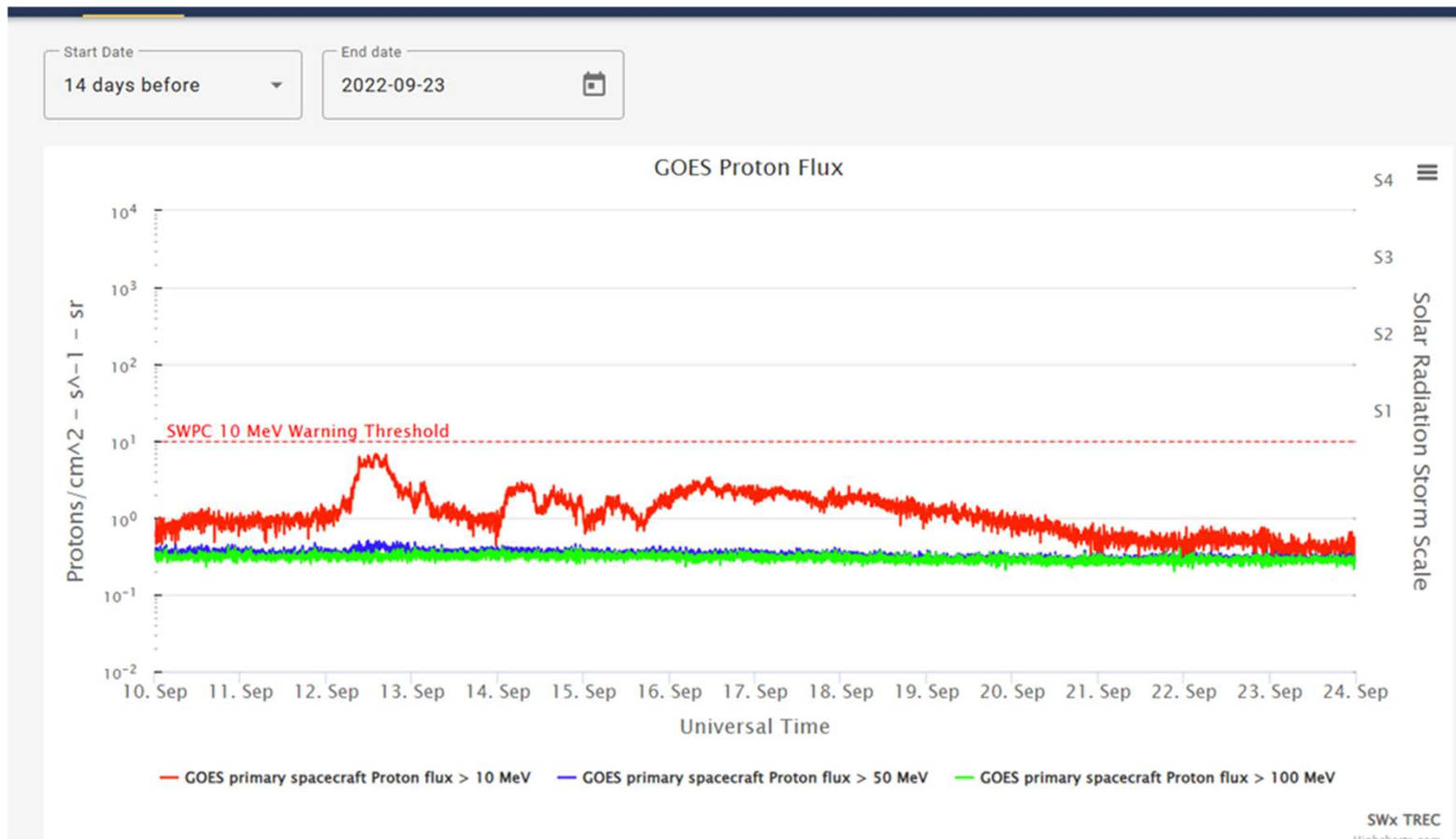
ENERGETIC PARTICLES

Proton Enhancement

Not a “proton event” per definition

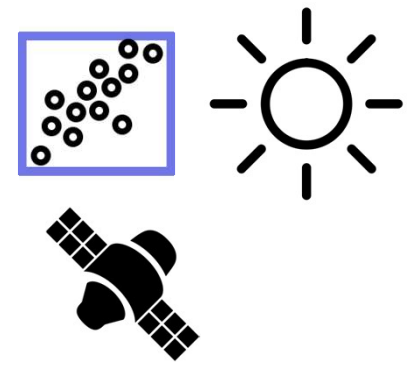


GOES

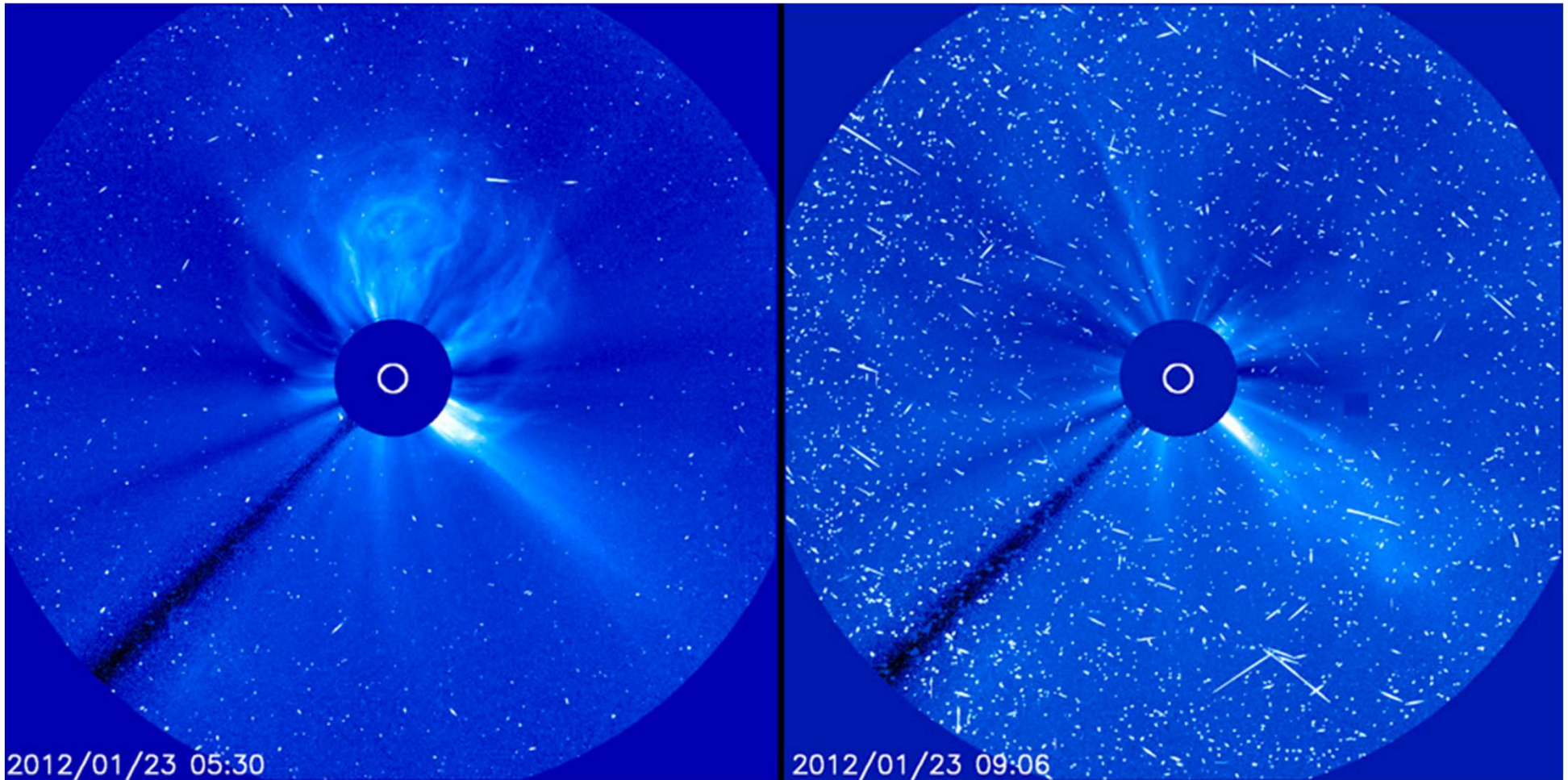


ENERGETIC PARTICLES

SEEN by SOHO/LASCO C3



SOHO/LASCO C3





PROTON EVENT CLASSIFICATION

NOAA-scales: S-scale (Solar Radiation Storm)

Scale	Description	Effect	Physical measure (Flux level of ≥ 10 MeV particles)	Average Frequency (1 cycle = 11 years)
S 5	Extreme		10^5	Fewer than 1 per cycle
S 4	Severe		10^4	3 per cycle
S 3	Strong		10^3	10 per cycle
S 2	Moderate		10^2	25 per cycle
S 1	Minor		10	50 per cycle



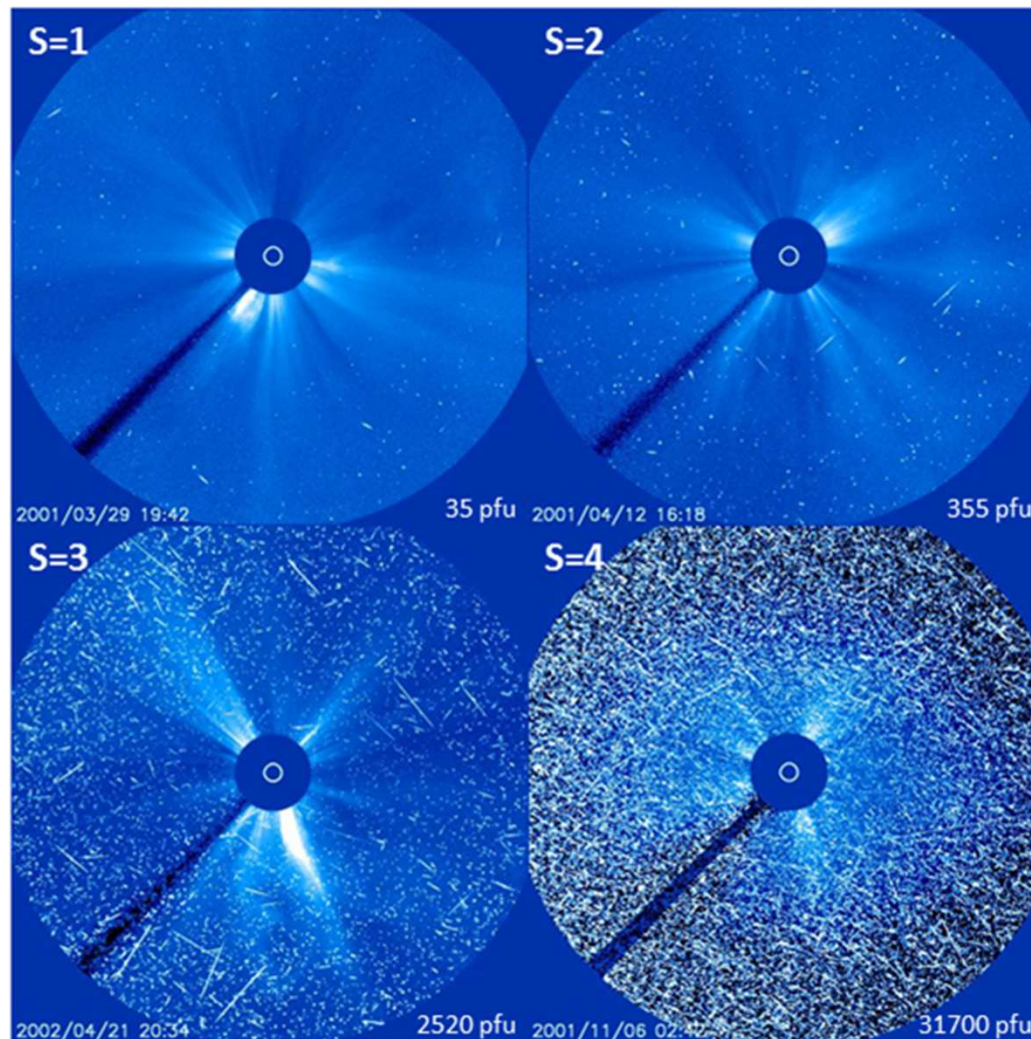


PROTON EVENT CLASSIFICATION

NOAA-scales: S-scale



SOHO/LASCO



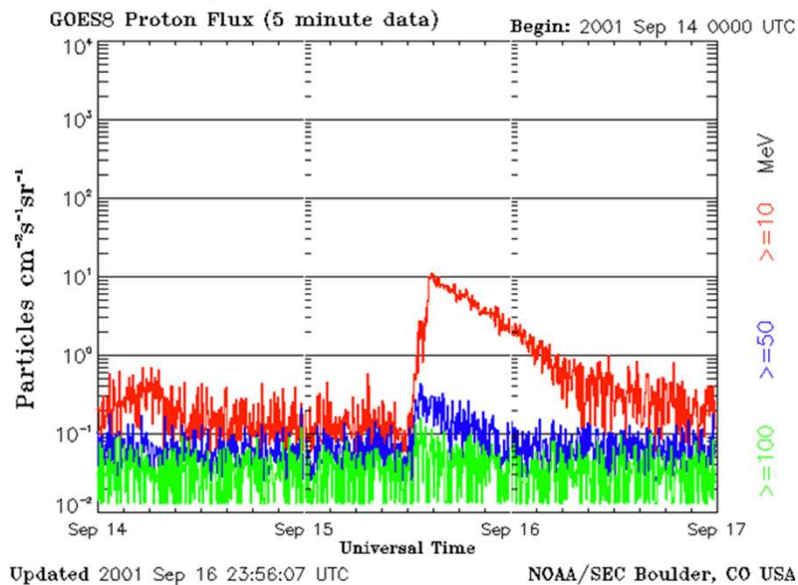


PROTON EVENTS

DRIVERS



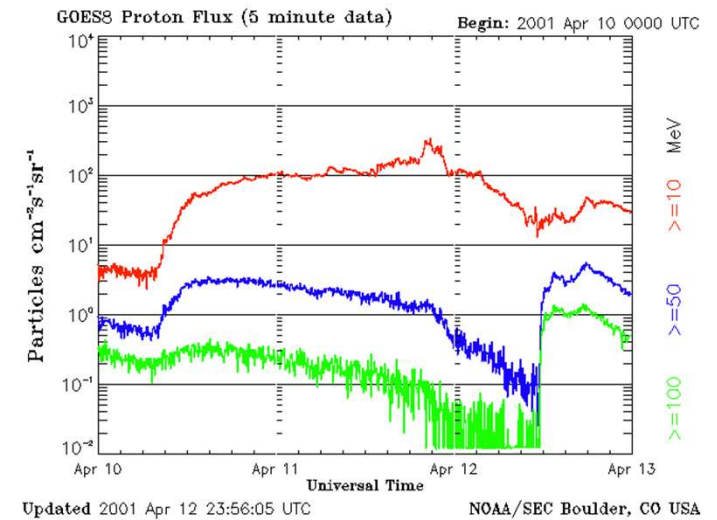
Impulsive



Impulsive solar flares



Gradual



CME-driven shocks

- Wide and fast shocks
- Type II and IV radio bursts





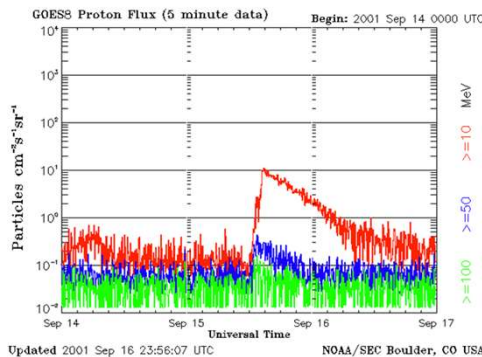
PROTON EVENTS

DRIVERS

**STRONG
FLARES**



Impulsive



The onsets are not necessarily fast, but the events are of rather **short** duration (1 to 20 hours)

Rather narrow propagation cones

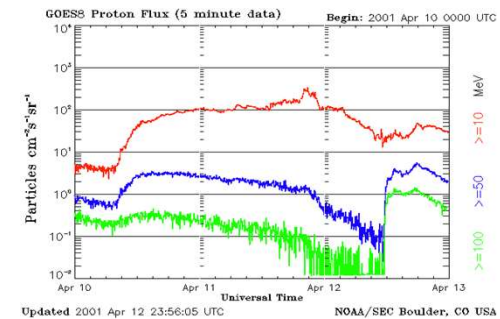
Events from eastern hemisphere may not be observed



**Shock of CME
(Fast & Wide)**



Gradual



The onsets are not necessarily gradual, but the events are of **long** duration

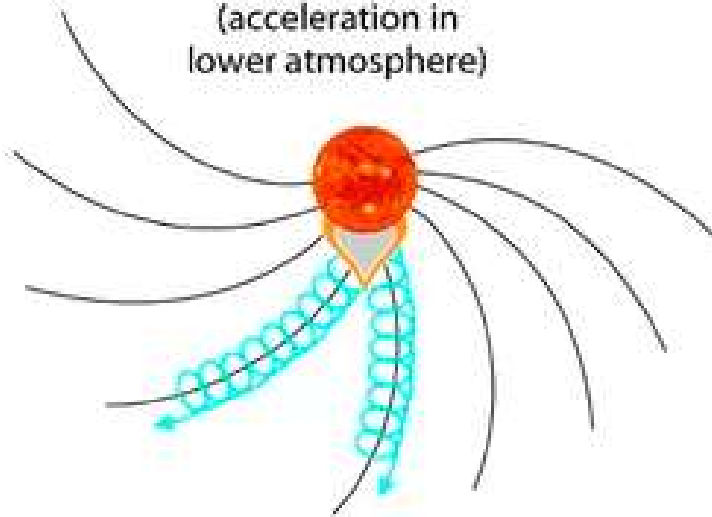
- 1 to 3 days
- Partly due to continuing acceleration of shock



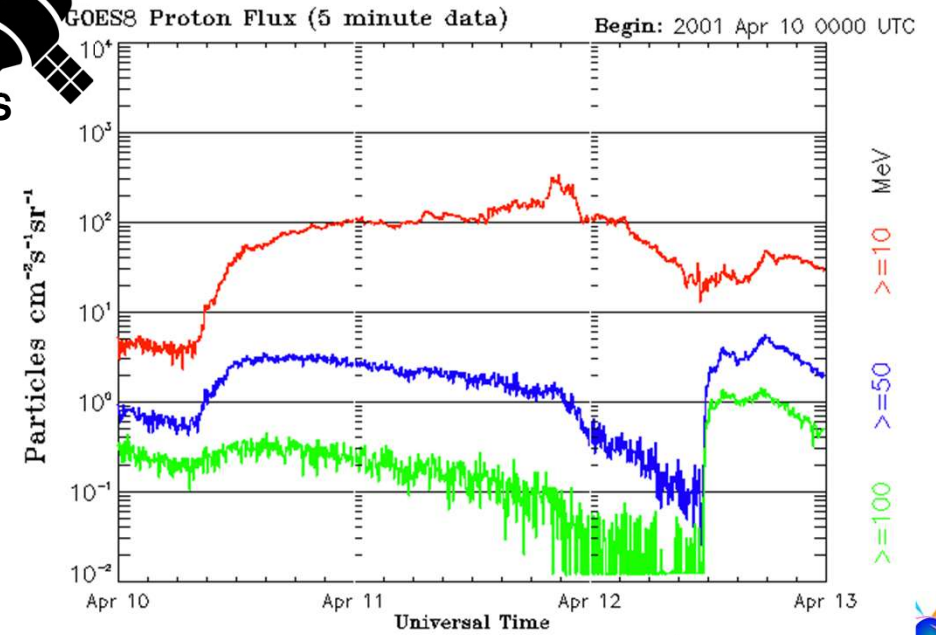
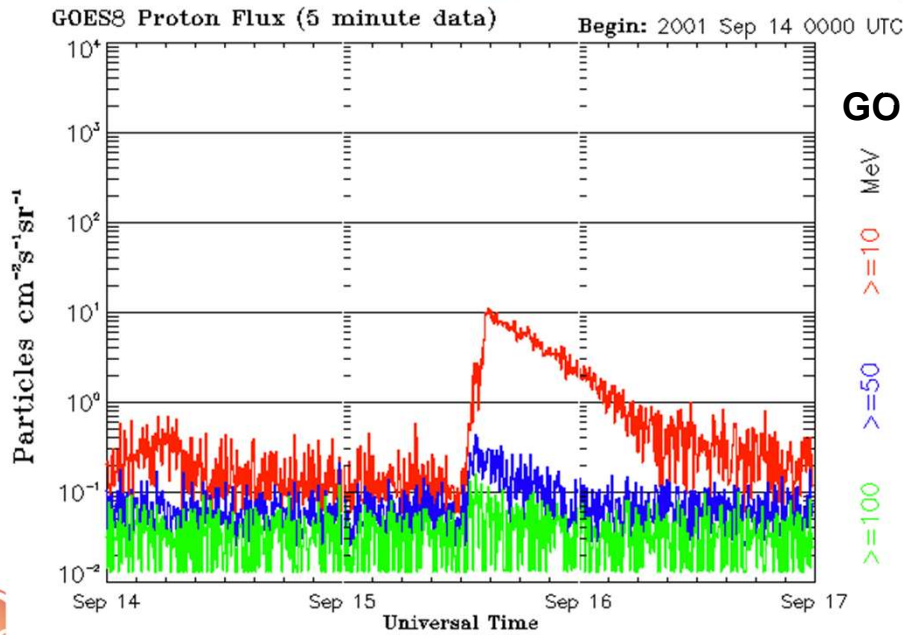
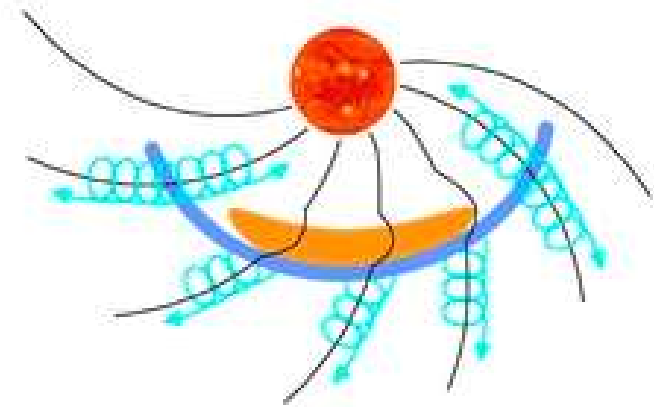


PROTON EVENTS

Impulsive SEP events
(acceleration in
lower atmosphere)



Gradual SEP events
(CME shocks in corona
and IP space)



Updated 2001 Sep 16 23:56:07 UTC

NOAA/SEC Boulder, CO USA

Updated 2001 Apr 12 23:56:05 UTC

NOAA/SEC Boulder, CO USA

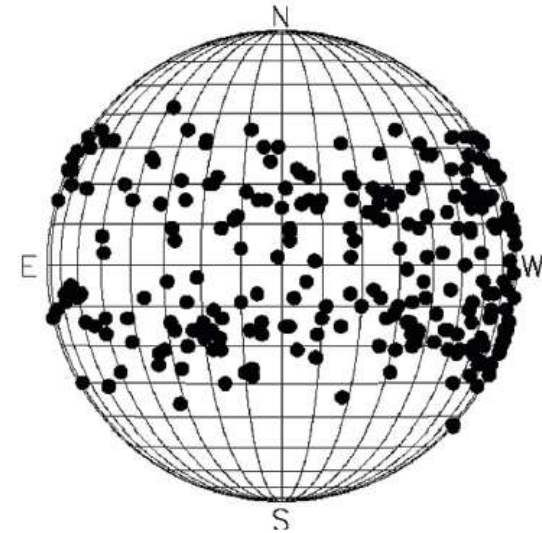




FORCASTING PROTON EVENTS

1. LOCATION

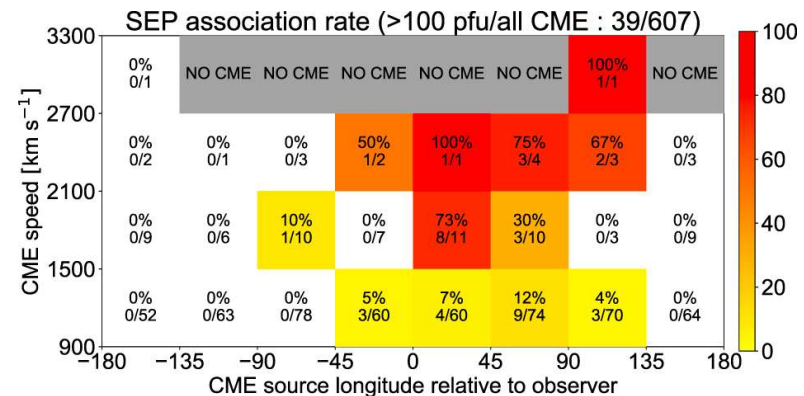
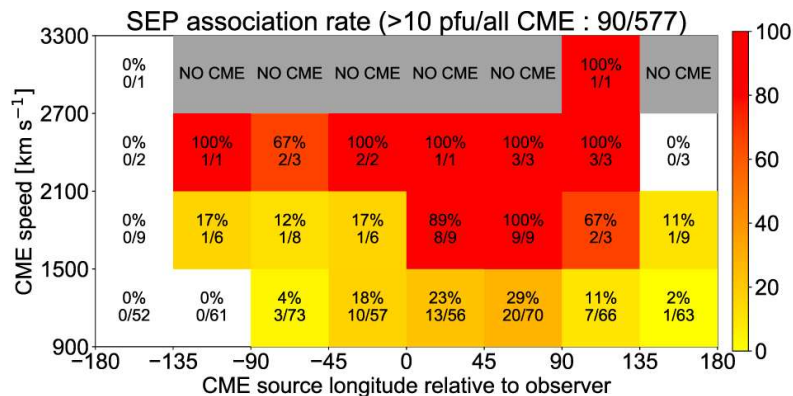
Higher likelihood for SEP events from the regions on **western** hemisphere



Does not exclude SEPs from the eastern hemisphere or even from the Sun's backside!

- E.g. Major flare on 23 July 2012
- Mechanism?

– Eastern SEPs: slower rise

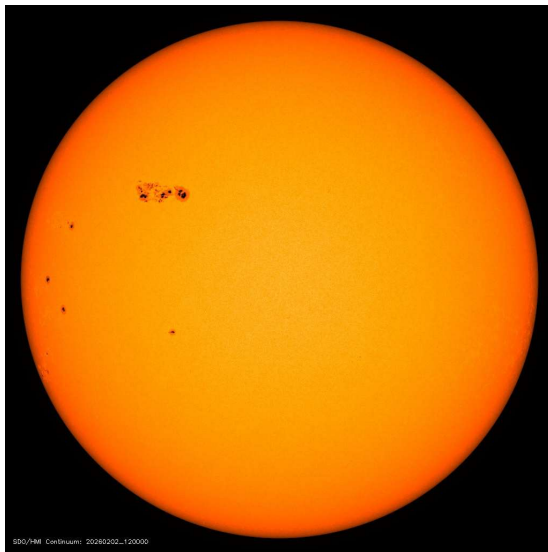
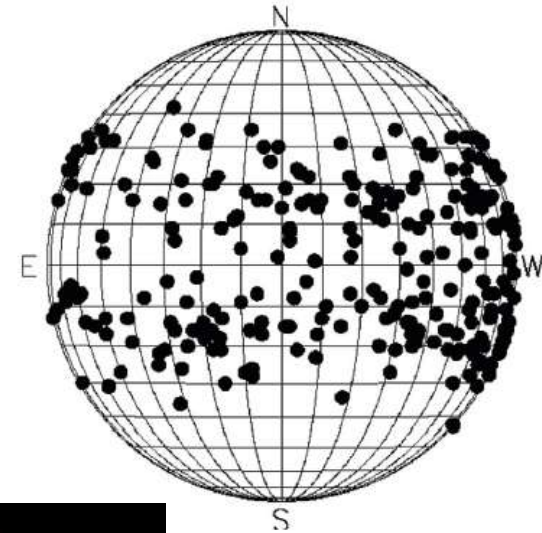




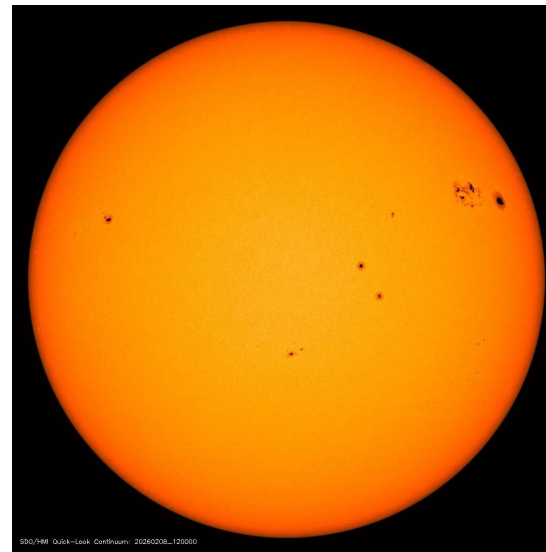
FORCASTING PROTON EVENTS

1. LOCATION

Higher likelihood for SEP events from the regions on **western** hemisphere



Beginning of this Week:
Active Flaring region on eastern hemisphere: lower probability for proton event given by forecaster



End of this Week:
Active Flaring region on western hemisphere: higher probability for proton event given by forecaster



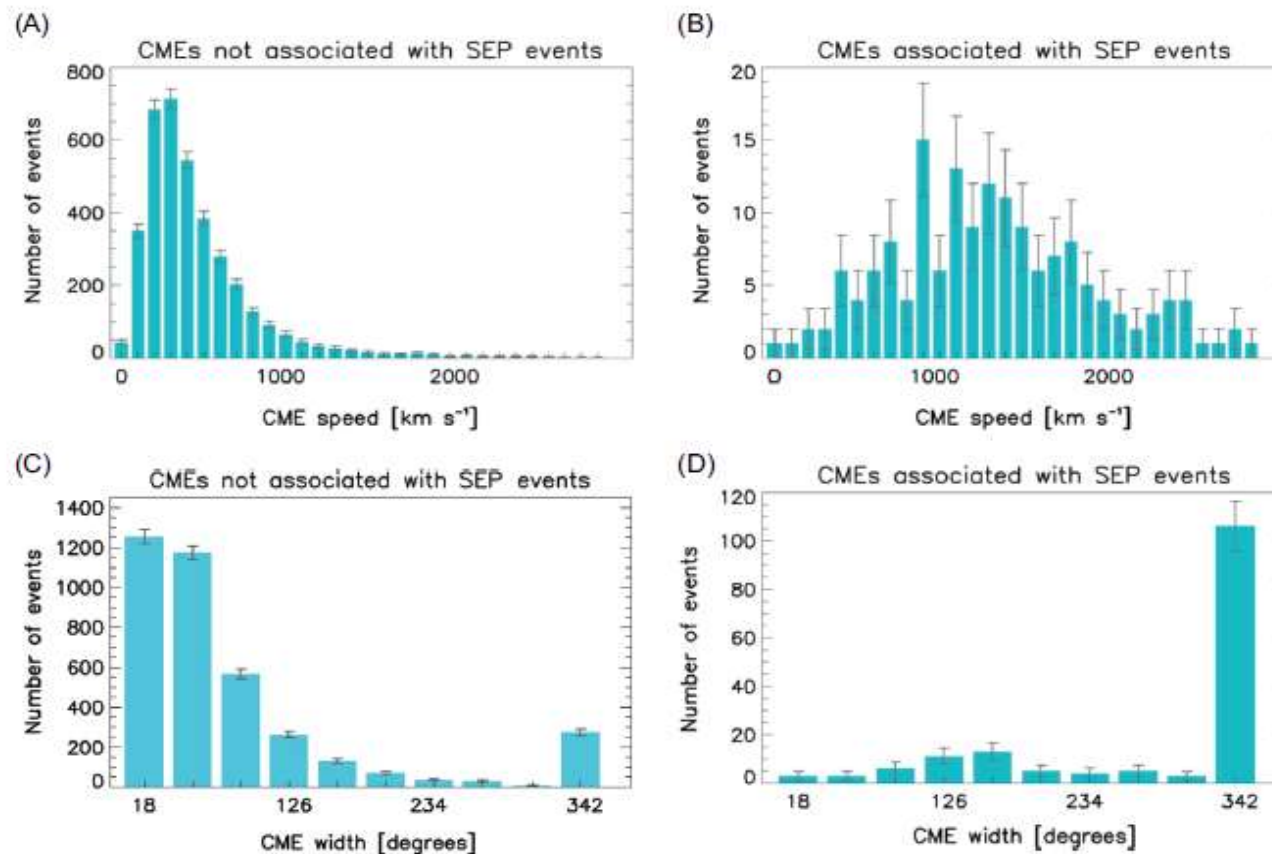


FORECASTING PROTON EVENTS

- 2. CME Speed
- 3. CME width

A. Papaioannou et al.: SEP events and their parent solar sources

Fast CMEs



wide CMEs

Fig. 6. Distribution of the CME velocity (in km s^{-1}) for all 3535 CMEs not associated with SEP events in our sample from 1997–2013 (A) and for the 158 SEP events, within the same time period (B). Distribution of the CME width (in degrees) for all 3535 CMEs not associated with SEP events in our sample from 1997–2013 (C) and for the 158 SEP events, within the same time period (D). The error bars denote the statistical error.



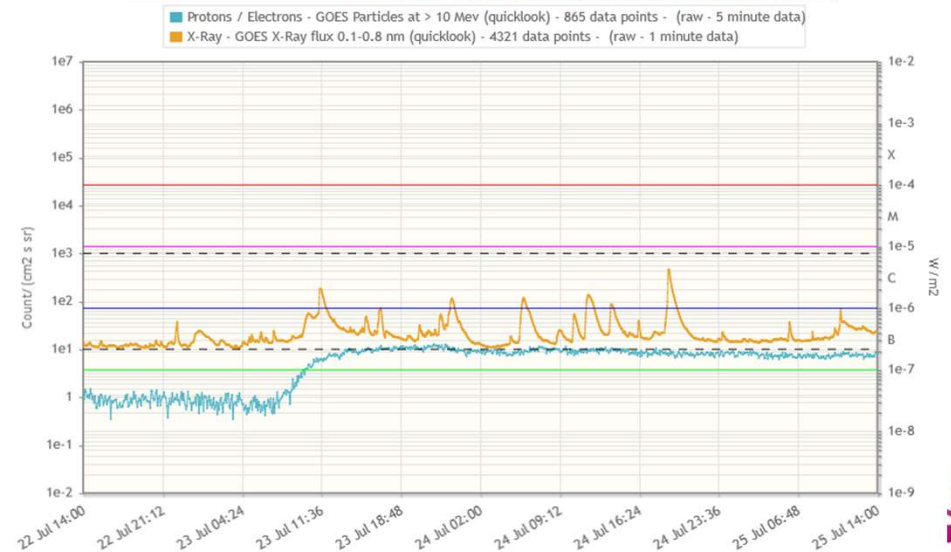
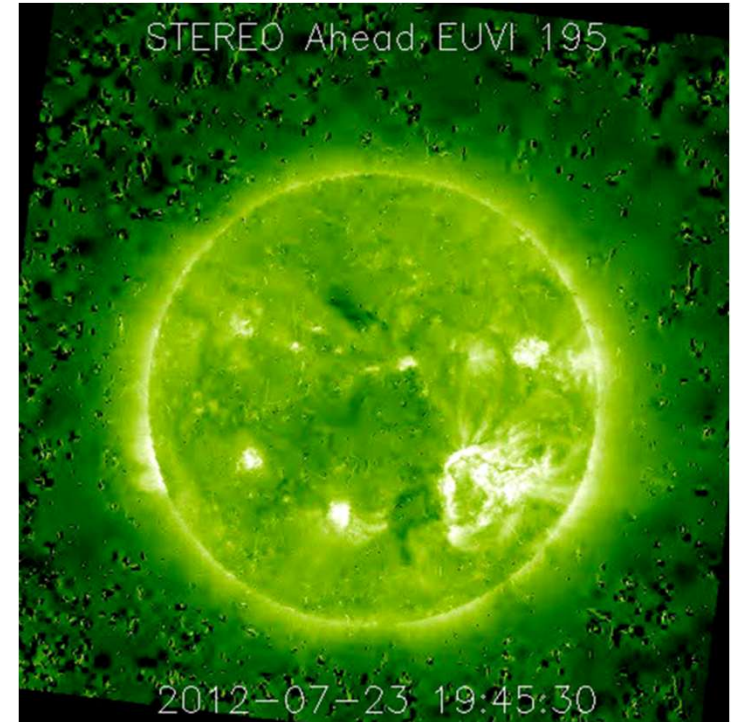


FORECASTING PROTON EVENTS

Look for active regions & filaments that can:

- Produce strong x-ray flares
- Fast CMEs (~ 1000 km/s or more)
- Wide CMEs (partial or full halo CMEs)
- Preferably on the western solar hemisphere

Finetune from history on farside/eastern hemisphere





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:Issued: 2023 Mar 18 1231 UTC
:Product: documentation at http://www.sidc.be/products/meu
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
# (RWC Belgium) #
#-----#

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SIDC URSIGRAM 30318
SIDC SOLAR BULLETIN 18 Mar 2023, 1230UT
SIDC FORECAST (valid from 1230UT, 18 Mar 2023 until 20 Mar 2023)
SOLAR FLARES : C-class flares expected, (probability >=50%)
GEOMAGNETISM : Quiet (A<20 and K<4)

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SOLAR PROTONS : Quiet

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PREDICTIONS FOR 18 Mar 2023 10CM FLUX: 138 / AP: 007
PREDICTIONS FOR 19 Mar 2023 10CM FLUX: 140 / AP: 019
PREDICTIONS FOR 20 Mar 2023 10CM FLUX: 138 / AP: 029

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COMMENT: The solar flaring activity was at moderate levels during the last 24 hours with one M-class flare and several C-class flares detected, with the most frequent sources being NOAA active regions 3254 and 3256. The largest flare was a M1.1 flare, peaking at 15:07 UTC on March 17, associated with active region NOAA 3254 (beta class). NOAA active region 3256 produced an impulsive C9.4 flare at 07:10 UTC on March 18. This event was also associated with Type IV radio emission. Other regions on the disc did not show any significant flaring activity. Further M-class flare activity is possible but not probable, while frequently C-class activity is expected in the next 24 hours.

A filament eruption in the southwestern quadrant was observed on March 17 from around 09:20UTC. The associated CME appears in SoHO/LASCO C2 coronagraph data from 10:23UTC onwards. The CME is directed to the south-west and the bulk of the CME is not expected to be Earth directed. However, a glancing blow of the shock may impact Earth at around 19:00 UTC on March 19. Another small filament eruptions occurred in the northwestern quadrant from around 17:09UTC and 20:09UTC on March 17. We are awaiting corresponding coronagraph data for further analysis. During the last 24 hours there were no other potentially Earth-directed CMEs detected in the available coronagraph observations.

The greater than 10 MeV proton flux was at almost nominal levels over the past 24 hours and is expected to remain so for the next 24 hours. The greater than 2 MeV electron flux remained below the 1000 pfu alert threshold and is expected to remain below this threshold during the next 24 hours. The 24h electron fluence was at normal levels and is expected to remain so.

Over the past 24 hours the solar wind parameters (ACE and DSCOVR) have been indicative of slow solar wind conditions. The solar wind speed ranged between 400 km/s and 450 km/s. The interplanetary magnetic field magnitude was about 6 nT. The magnetic field orientation was predominantly in the positive sector (field directed away from the Sun). Similar slow solar wind regime is expected on March 18 with a slight wind speed enhancement possible for late on March 19, due to expected influence of the small equatorial coronal hole of positive polarity with a chance of being mixed with glancing blow from a CME which left the solar surface around 10 UTC on March 17th.

The geomagnetic conditions over the past 24 hours were globally and locally quiet to unsettled (NOAA Kp and K Bel 1-3). Quiet conditions are expected for March 18 with active to minor storm conditions possible for late on March 19 and March 20, due to expected arrival of the high speed stream and a possible glancing blow from a CME.

TODAY'S ESTIMATED ISN : 044, BASED ON 14 STATIONS.

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SOLAR INDICES FOR 17 Mar 2023
WOLF NUMBER CATANIA : 110
10CM SOLAR FLUX : 134
AK CHAMBON LA FORET : 014
AK WINGST : 007
ESTIMATED AP : 007
ESTIMATED ISN : 073, BASED ON 18 STATIONS.

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NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
17 1504 1507 1511 S22W65 M1.0 SN 12/3247
END

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*Finding your way
in the
URSIgram*

Proton flux / events

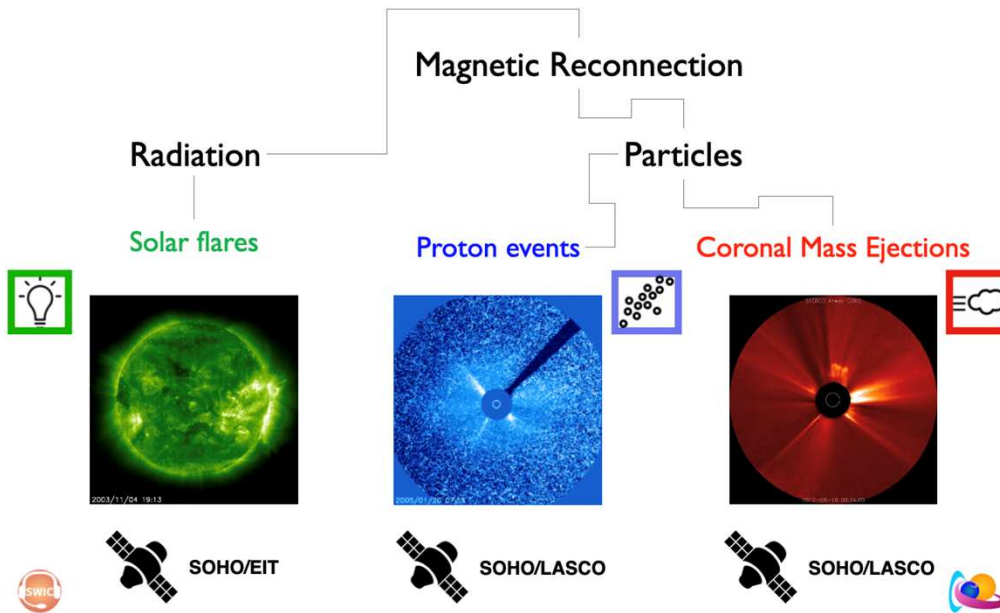




SUMMARY 1/2

Solar flares

- Standard model
- Classification
 - $H\alpha$, x-ray, NOAA scale (R)
- Flare predictions
 - McIntosh, Hale





SUMMARY 2/2

Proton events

- ≥10 MeV proton flux ≥ 10 pfu
- Classification
 - Impulsive vs. Gradual
 - NOAA Scale (S)
- Forecasting
 - Strong flare
 - Wide and fast CME
 - Western solar hemisphere

Coronal Mass Ejection

- Model
- On-disk signatures
- Classification & Terminology
 - Stealth, Cannibalism, Deflection
- True vs. Plane-of-the-Sky speed
- Interplanetary CME & Bz

