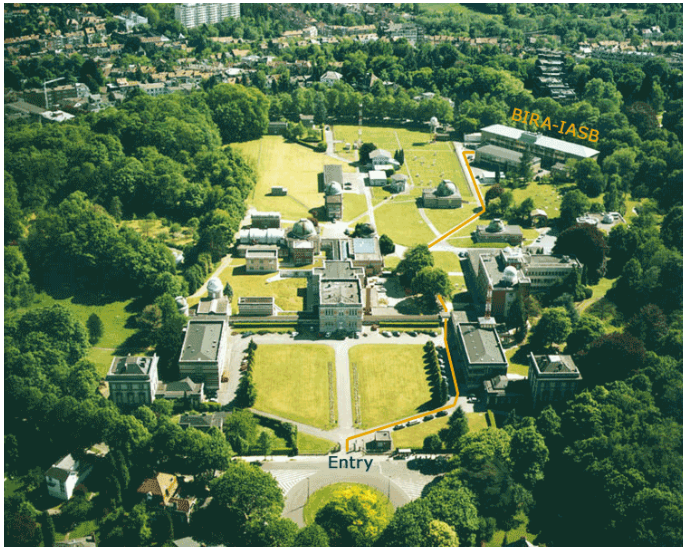
SOC Behavior: How Important is the State of the Dataset ?

Norma B. Crosby

Belgian Institute for Space Aeronomy
Ringlaan-3-Avenue Circulaire, 1180 Brussels, Belgium



Self-Organized Criticality and Turbulence, ISSI Team Meeting 1, Bern, Switzerland, 16-20 Sept. 2013

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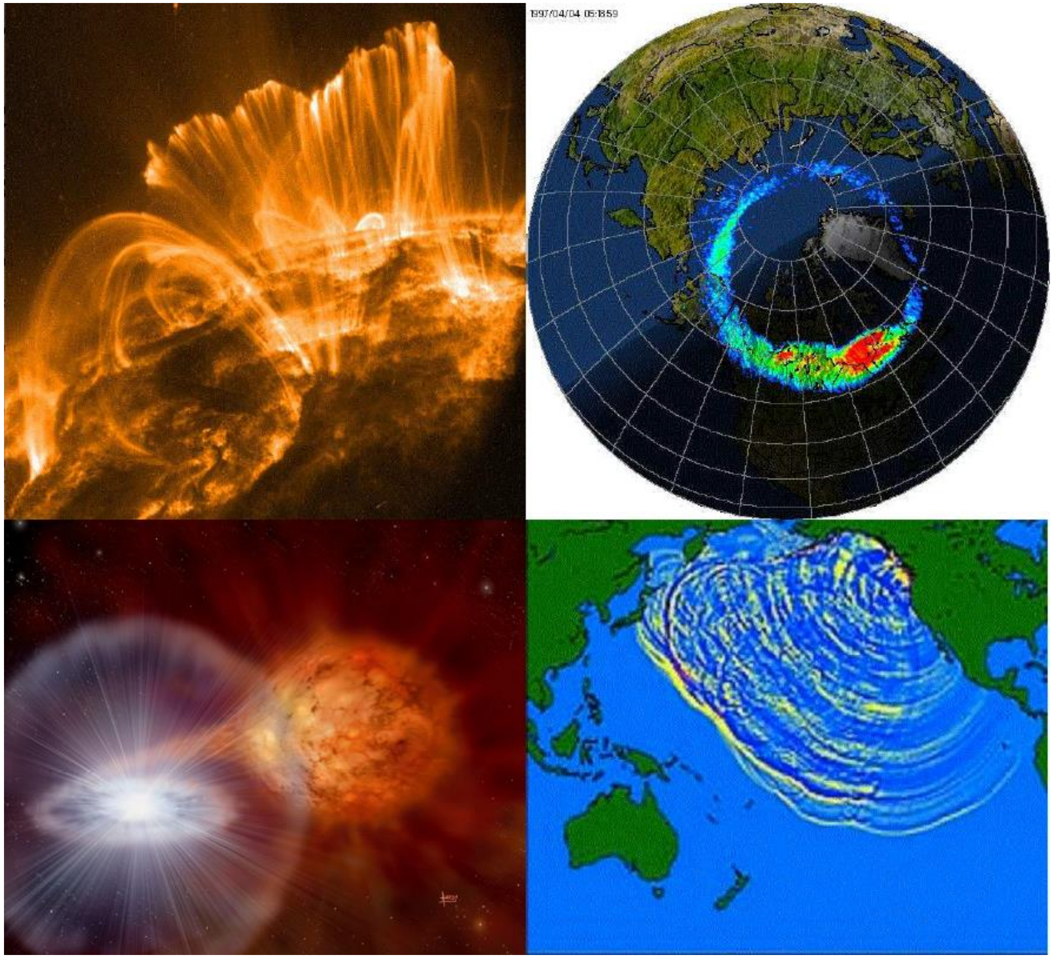


Upper left-hand corner: Solar flare of 2000 Nov. 9 observed in EUV with the TRACE spacecraft in 171 Å (credit: NASA, TRACE). Upper right-hand corner: Global image of the auroral oval observed by the Ultraviolet Imager (UVI) onboard the NASA satellite “Polar” (credit: NASA, Polar/UVI Team, George Parks)

Lower left-hand corner: Artistic rendering of the cataclysmic variable star RS Ophiuchi, which exhibits a nova outburst about every 20 years. This binary system contains a white dwarf and a red giant with mass transfer (credit: PPARC, David A. Hardy). Lower right-hand corner: Satellite recording of tsunami waves produced by one of the 10 largest earthquakes, originating in North America (credit: NOAA).

What do all these natural dynamic phenomena have in common?

1. They cover a large range of temporal, as well as spatial scales.
2. The most extreme events, known as “black swans” (Taleb 2007), are of concern to society.
3. There are large databases so that statistical approaches can be used for interpreting the data characterizing the phenomena.
4. Size distributions (on log-scale) of parameters describing the phenomena (volumes, energies, etc.) cover many orders of magnitude.
5. Powerlaw-like behavior has been found to be a universal characteristic of such phenomena.

In summary,

Phenomena that display “avalanche” behavior display in most instances powerlaw behavior.

Does there exist a common “avalanche” signature?

However,

Each type of phenomenon is observed to have a range of powerlaw slope values as a function of the parameter describing it.

The difference in value is also observed on measured parameters of the same type of “avalanche” suggesting that the slope may be detector dependent.

OUTLINE

PART 1. How sensitive is the slope value is in regard to the dataset being used?

PART 2. Powerlaw scaling.

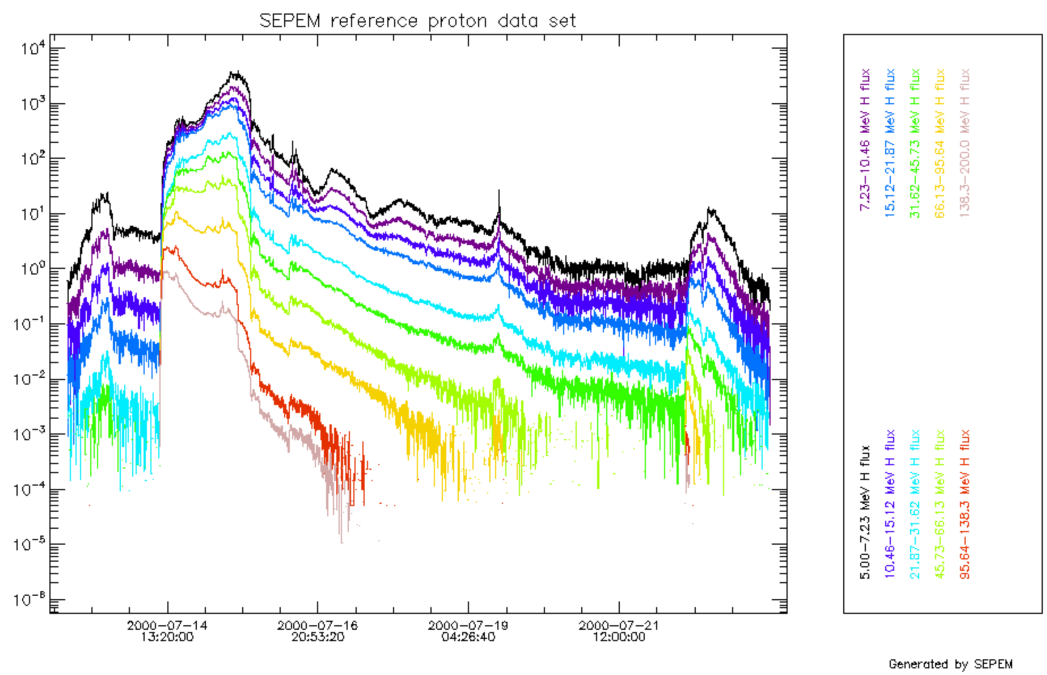
- Have the largest events been observed?
- What about the outliers that have been observed?

PART 3. Discussion

PART 1. How sensitive is the slope value is in regard to the dataset being used?

Solar Energetic Particles [SEP] Events

- SEPs are <u>protons</u>, electrons & heavy ions, up to the iron mass (and even beyond)
- Energy Range: dozen of keVs to a few GeVs
- Temporal Range: Sporadic [minutes to days]
- Very difficult to predict.



SEP Frequency Distribution Studies

- Van Hollebeke et al. (1975), proton events have a powerlaw behavior with a slope of −1.15±0.05.
- Cliver et al. (1991), peak differential fluxes of the proton events have a slope of −1.30±0.07, for the electrons it was −1.42±0.04.
- Gabriel and Feynman (1996), powerlaw slopes range between −1.2 and −1.4 depending on the integral energy (>10, 30, 60 MeV) over three to four orders of magnitude in fluence.
- Miroshnichenko et al. (2001) found that a subset of sudden storm commencement associated events have a double powerlaw distribution with two exponents (−1.00±0.04 and −1.53±0.03), whereas the overall distribution has a slope value of −1.37±0.05.
- Gerontidou et al. (2002) and references in the above mentioned SEP event studies.

SEPEM Application Server
http://dev.sepem.oma.be/

SEPEM

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  - Event spectra
  - Fluence and peak flux
- My SEPEM

Welcome to ESA's Solar Energetic Particle Environment Modelling (SEPEM) application server, a WWW interface to solar energetic particle data and a range of modelling tools and functionalities intended to support space mission design.

The system provides an implementation of several well known modelling methodologies, built on cleaned datasets. A large number of datasets have been combined into an SQL database for easy access. SEPEM also gives the user increased flexibility in his/her analysis and allows generation of mission integrated fluence statistics, peak flux statistics and other functionalities. It also integrates effects tools that calculate single event upset rates and radiation doses for a variety of scenarios; the statistical methods can further be applied to these effects parameters.

Furthermore, SEPEM makes use of a newly developed physics-based shock-and-particle model to simulate particle flux profiles of gradual SEP events from Mercury to Mars orbits [SOLPENCO2].

A contiguous reference proton data set was constructed using data ranging from 1973 to 2013, by means of data cleaning and processing tools available on the server. Using this dataset, a reference event list was constructed and also made available on the server.

An extensive set of help pages is available, including background material, information on the datasets and processing, and context sensitive help for each application page. Please consult the help pages before using the system!

Use of SEPEM is free of charge, but registration is required and can be done from the homepage using the link at the bottom of the left-hand menu. For further information please contact **N. Crosby**. Please consult the **server usage** help page before registering for an account: registration implies acceptance of the terms and conditions outlined there.

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ESA Contract No: 20162/06/NL/JD
Project Manager: Norma B. Crosby
IT Development and Data Processing: Daniel Heynderickx
ESA Technical Officer: Piers Jiggens (formerly Alexi Glover)
ESA Technical Responsible: Alain Hilgers, **ESA Space Environments and Effects**
SEPEM Team Members and Names of the Consortium

- **Background material**
  - Overview
  - SEP events
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- **Tips and tricks**
  - Browser timeouts
- **Data information**
  - Data sources
  - SEPEM reference proton dataset
  - SEPEM reference event list
- **Help page authors**
  - A. Aran,
  - N. Crosby,
  - D. Heynderickx,
  - P. Jiggens,
  - B. Sanahuja,

SEPEM Reference Proton Dataset

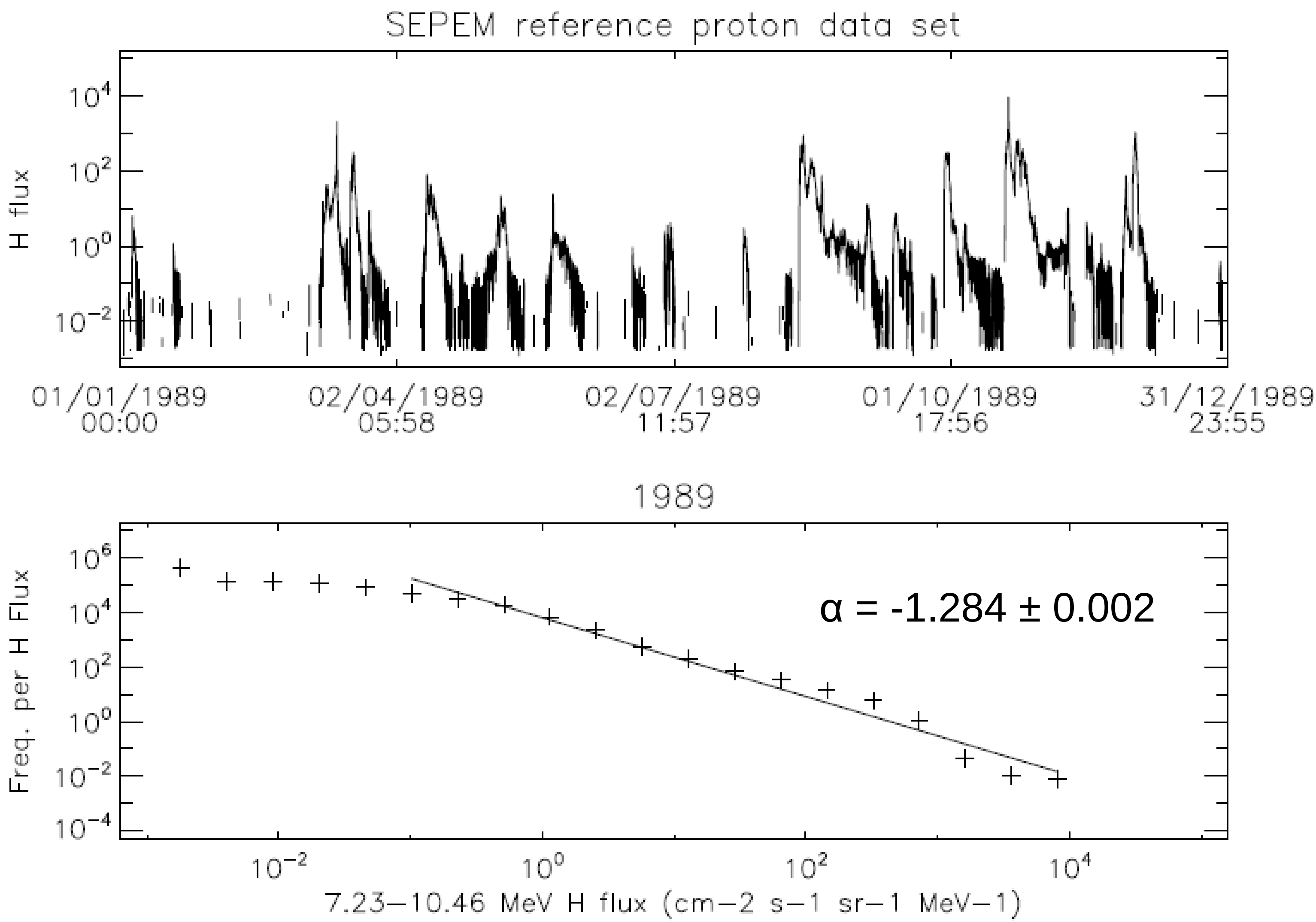
1973 – 2013

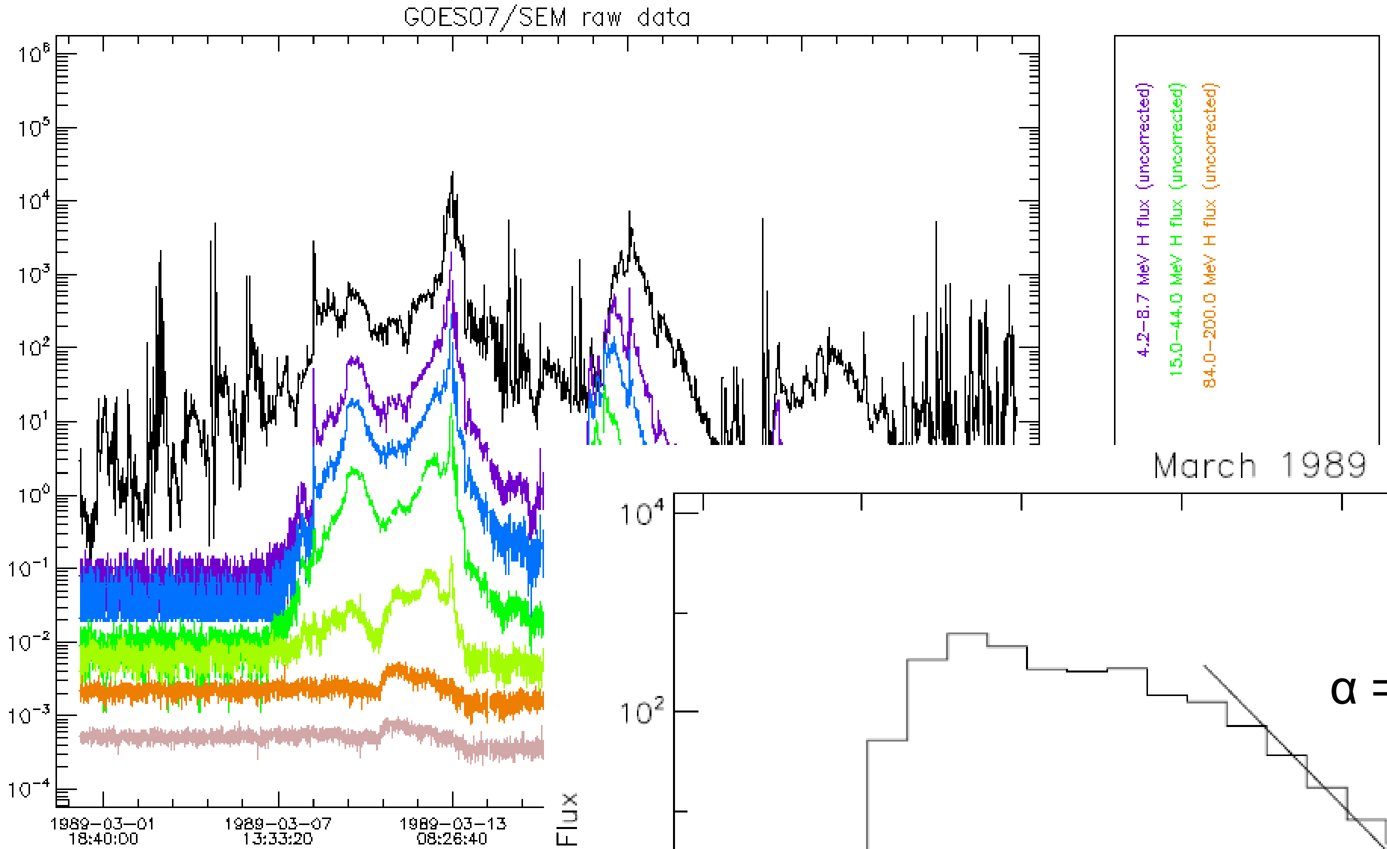
(comprised of 10 reference energy channels exponentially distributed in range from 5 to 200 MeV)

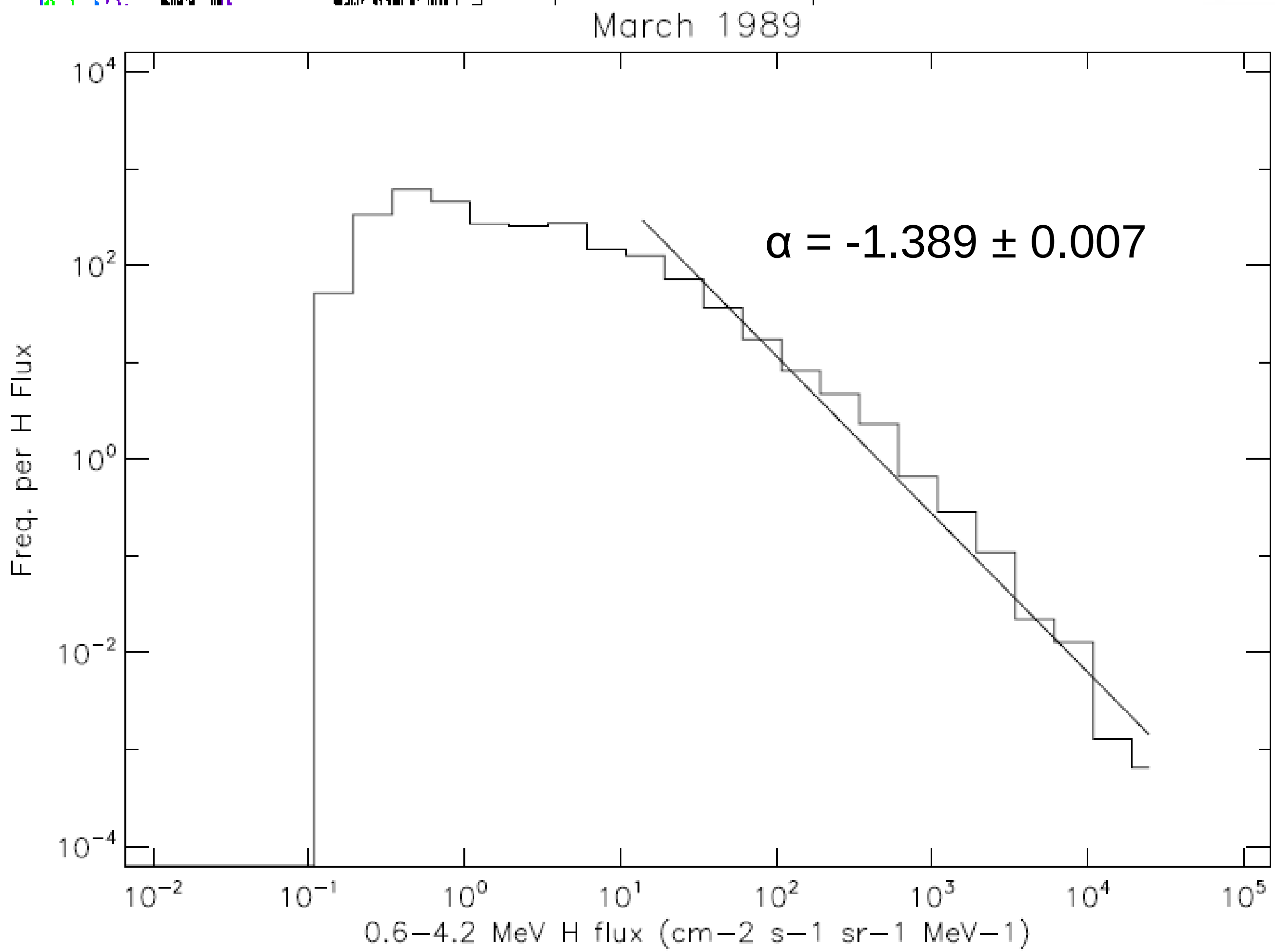
DATA PROCESSING

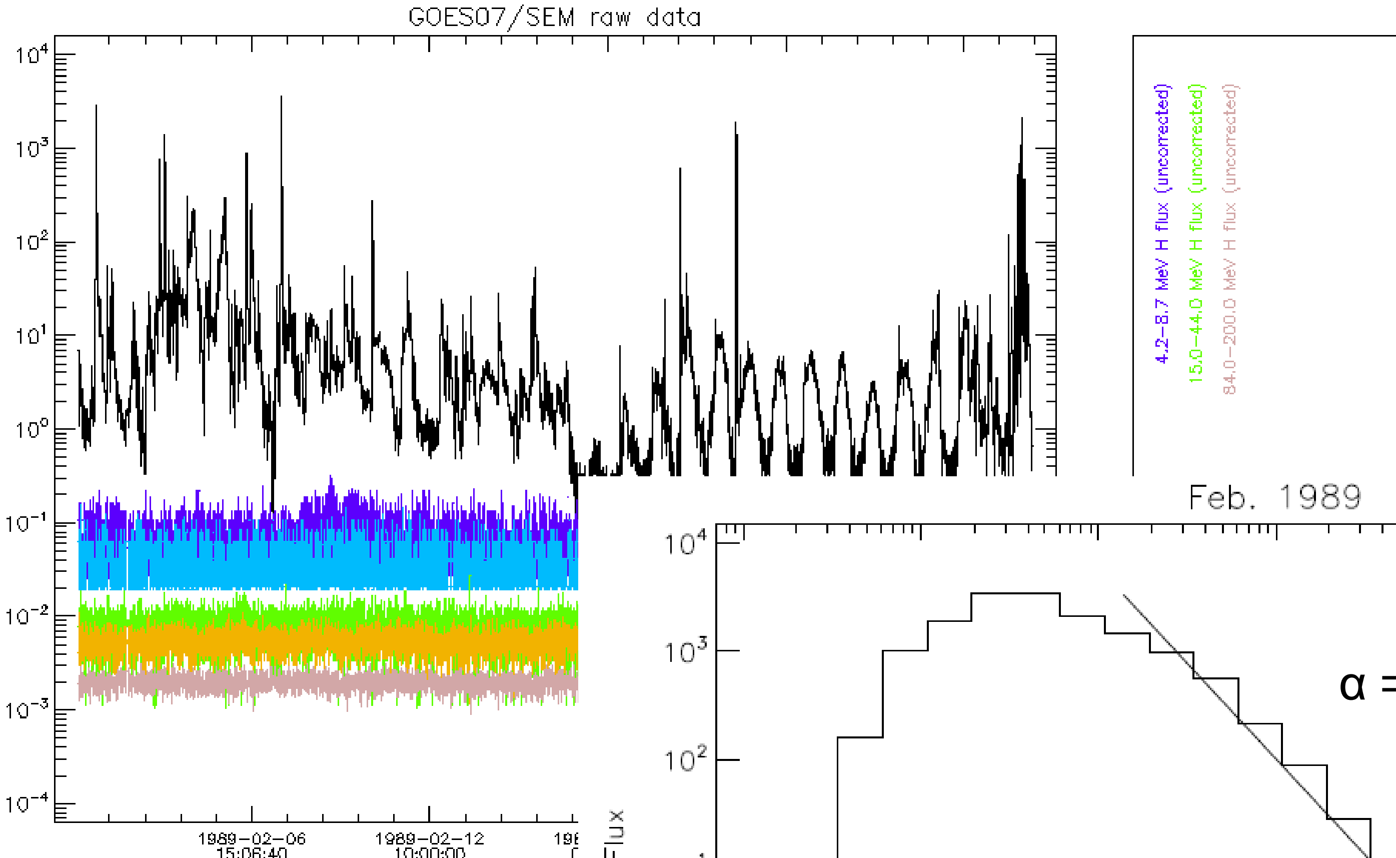
STEP 1: Removing data spikes, correcting (or otherwise removing episodes) where problems such as saturation, pulse pile-up, contamination etc. occur, and filling in where possible data gaps (including gaps introduced by removing bad data).

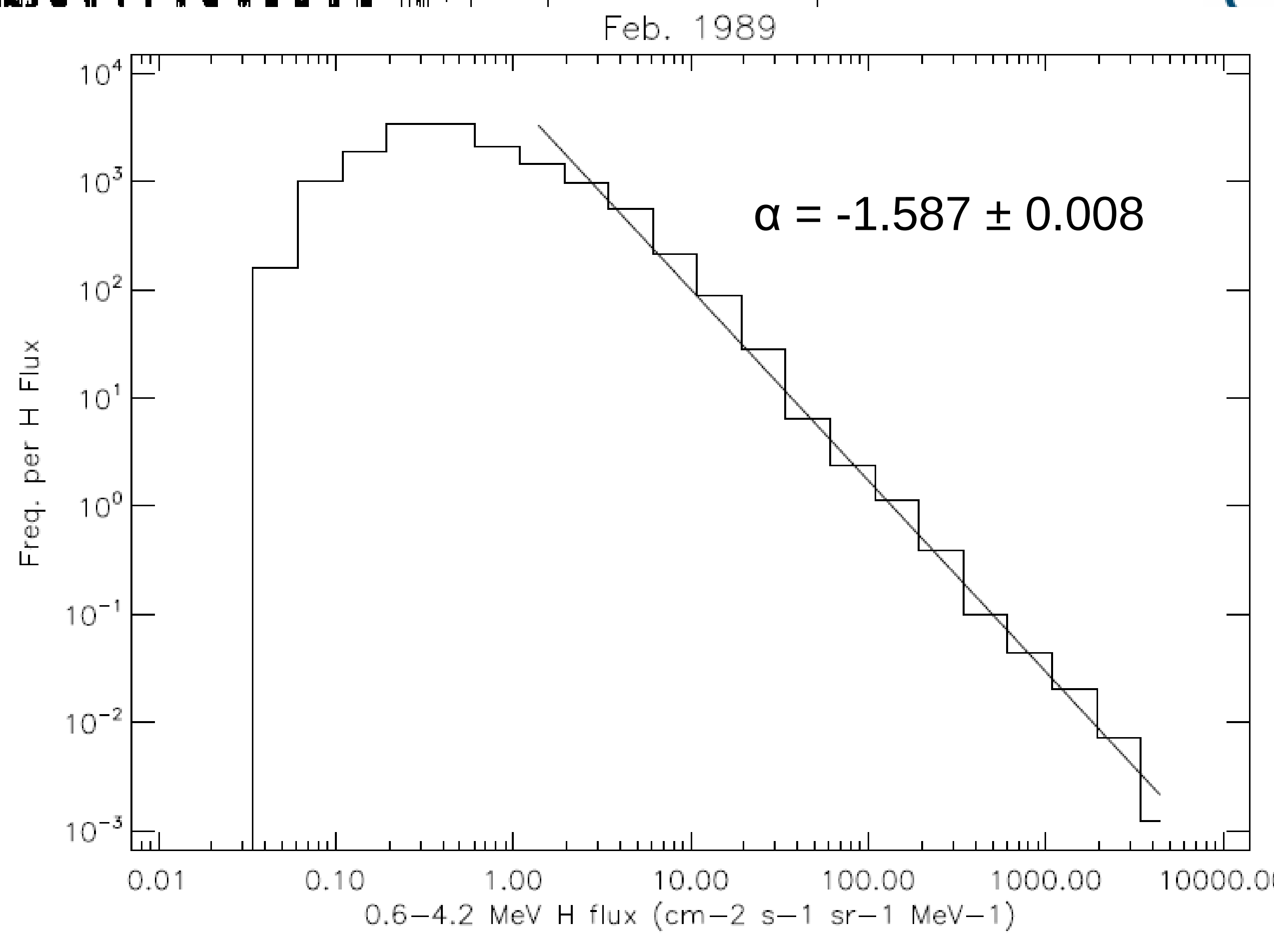
STEP 2: After correcting and completing the data, there still remained the issue of differences in the energy channels between different instruments, so the data cannot easily be combined. This required additional processing of the data: re-binning of the individual data point spectra into a reference energy spectrum, cross-calibration of the re-binned data, and merging of the individual datasets without overlaps in time.

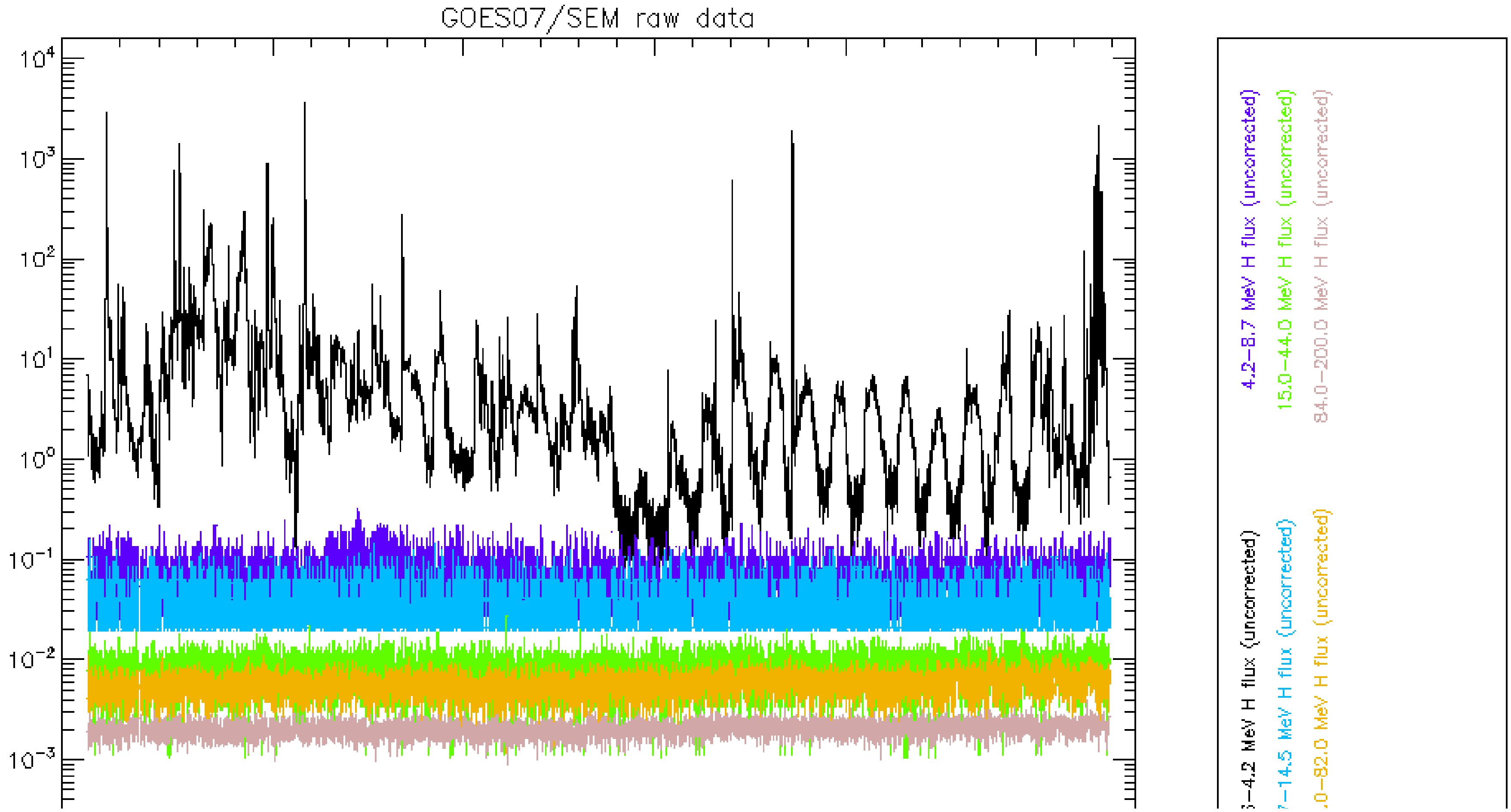

SEPEM reference proton data set
H flux
10^4
10^2
10^0
10^-2
01/01/1989 00:00
02/04/1989 05:58
02/07/1989 11:57
01/10/1989 17:56
31/12/1989 23:55
1989
Freq. per H Flux
10^6
10^4
10^2
10^0
10^-2
10^-4
α = -1.284 ± 0.002
10^-2
10^0
10^2
10^4
7.23–10.46 MeV H flux (cm–2 s–1 sr–1 MeV–1)


GOES07/SEM raw data
4.2–8.7 MeV H flux (uncorrected)
15.0–44.0 MeV H flux (uncorrected)
84.0–200.0 MeV H flux (uncorrected)
1989–03–01 18:40:00
1989–03–07 13:33:20
1989–03–13 08:26:40


March 1989
α = -1.389 ± 0.007
Freq. per H Flux
0.6–4.2 MeV H flux (cm–2 s–1 sr–1 MeV–1)

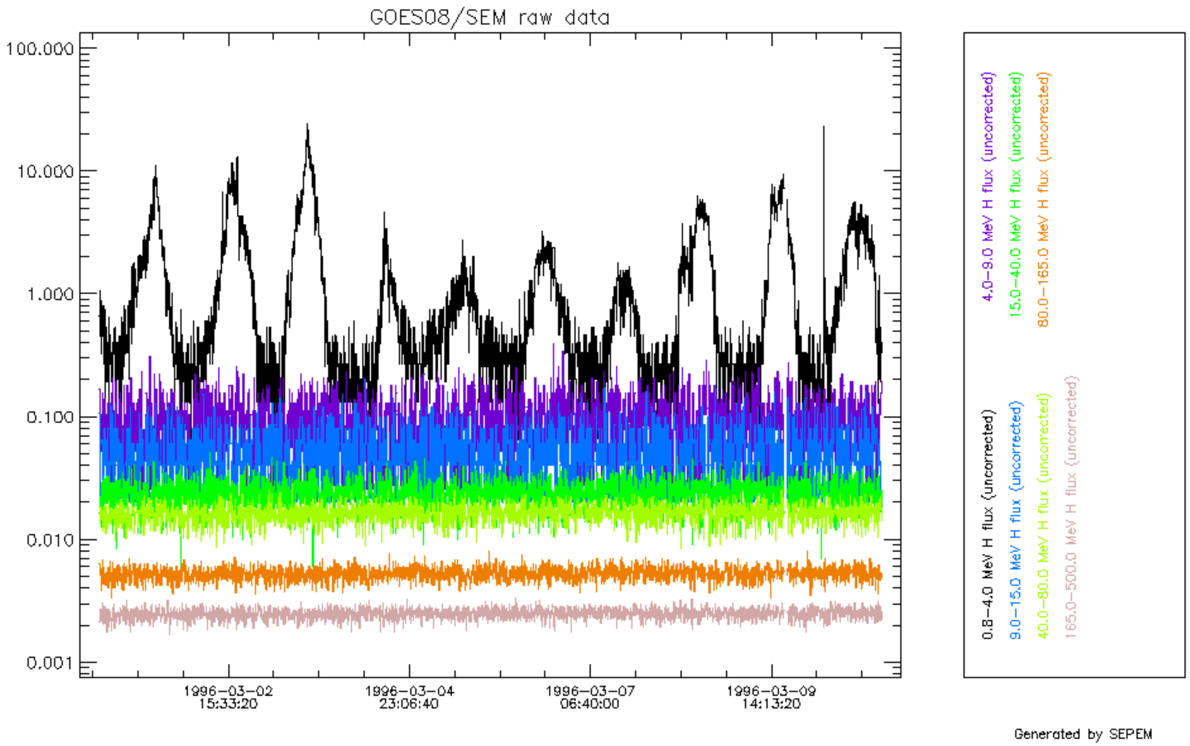

GOES07/SEM raw data
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
1989−02−06 15:06:40
1989−02−12 10:00:00
4.2−8.7 MeV H flux (uncorrected)
15.0−44.0 MeV H flux (uncorrected)
84.0−200.0 MeV H flux (uncorrected)

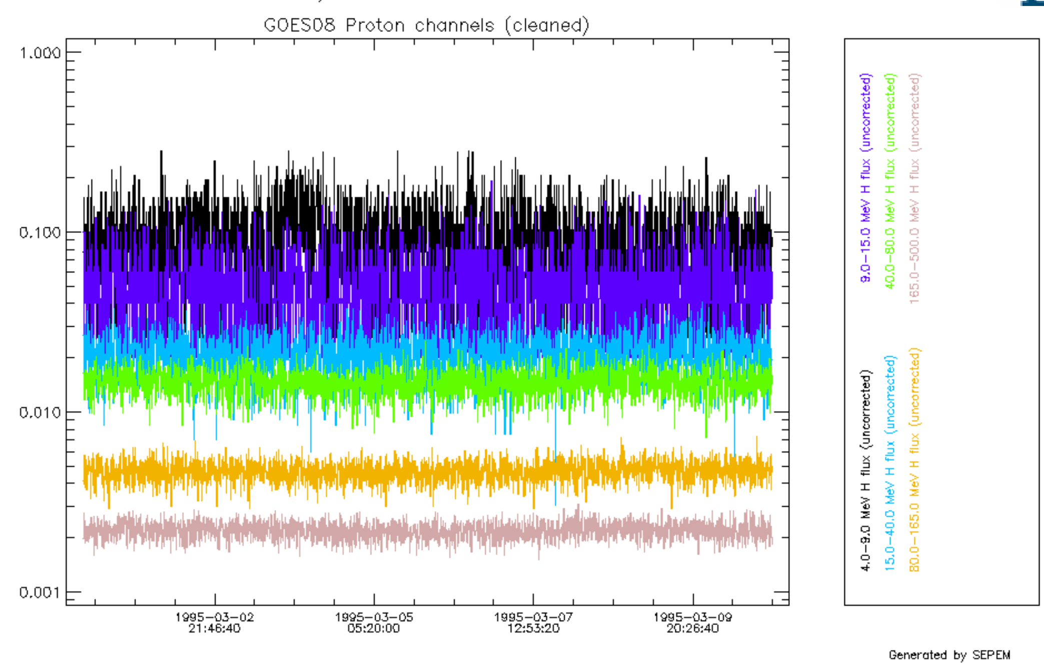

Feb. 1989
α = -1.587 ± 0.008
Freq. per H Flux
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
0.6−4.2 MeV H flux (cm−2 s−1 sr−1 MeV−1)

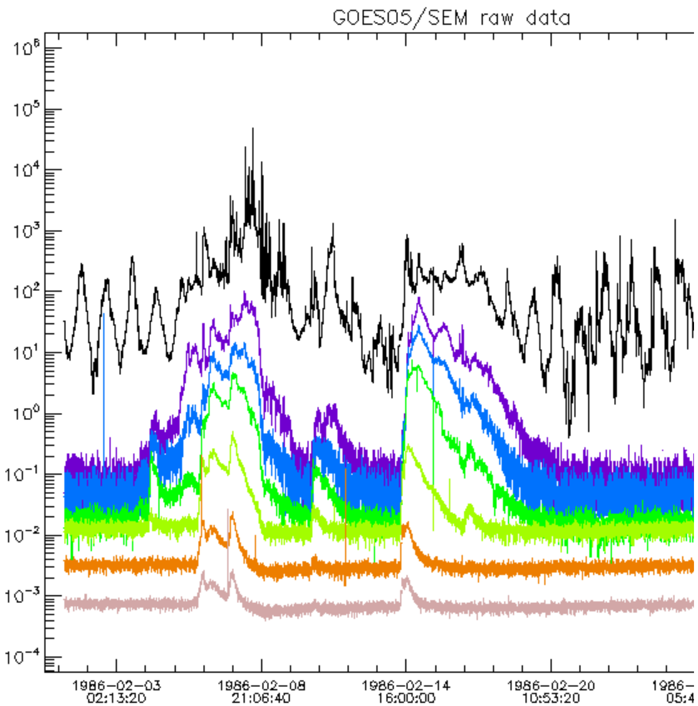


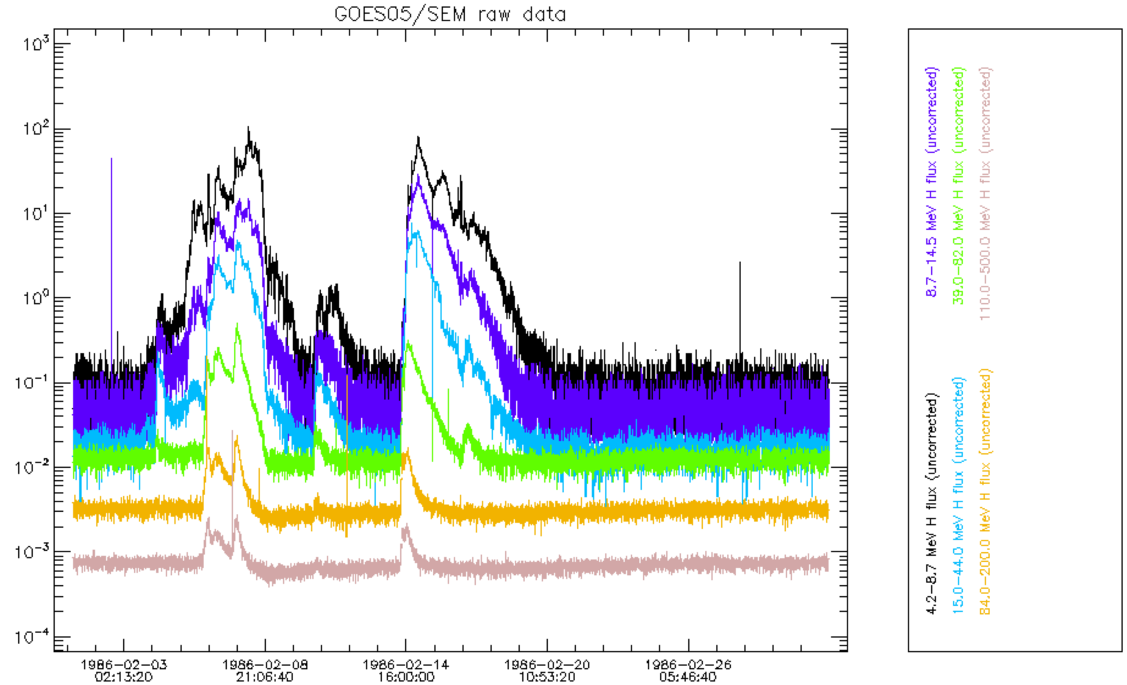
[1.] As reported in the online “SWPC GOES readme file” (2007) and on the “SPIDR GOES Data webpage”, the cutoff energy at geo-stationary orbit is typically of the order of several MeV, and therefore the P1 proton channel response is primarily due to trapped protons of the outer zone of the magnetosphere.

[2.] As reported in the online “SWPC GOES readme file” (2007), and on the “SPIDR GOES Data webpage”, during moderate compressions of the magnetosphere, the P2 proton channel may also ‘see’ magnetospherically trapped protons, while during extreme compressions (magnetopause crossings), GOES will find itself in the magnetosheath.

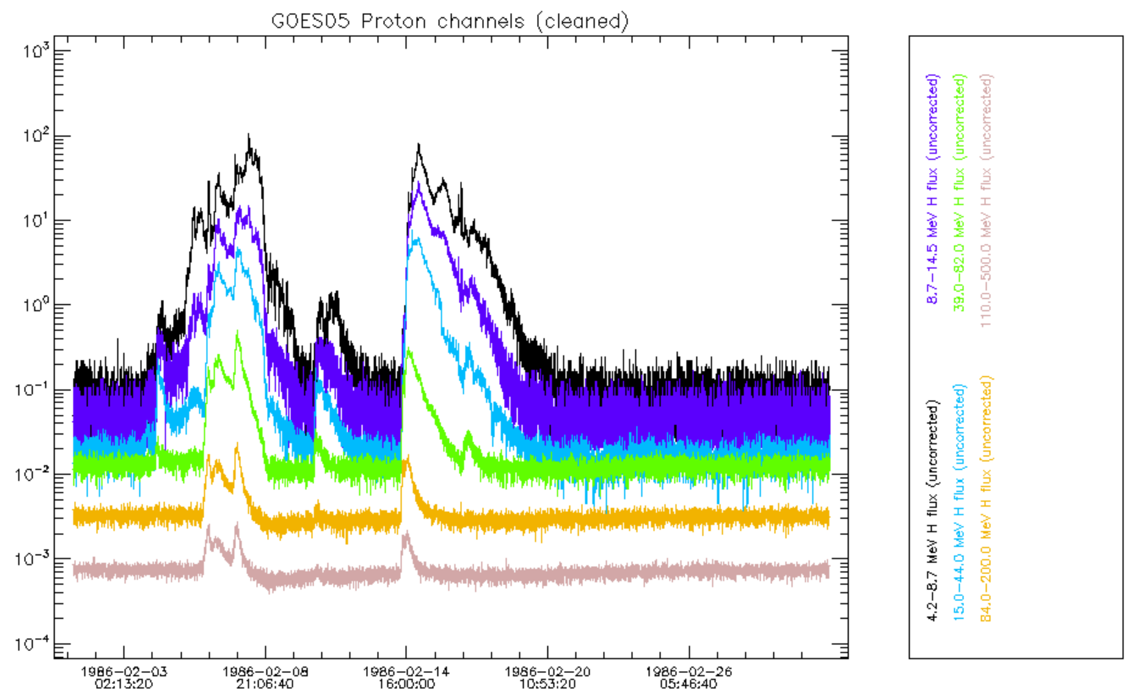

GOES08/SEM raw data
100.000
10.000
1.000
0.100
0.010
0.001
1996-03-02 15:33:20
1996-03-04 23:06:40
1996-03-07 06:40:00
1996-03-09 14:13:20
4.0-9.0 MeV H flux (uncorrected)
15.0-40.0 MeV H flux (uncorrected)
80.0-165.0 MeV H flux (uncorrected)
0.8-4.0 MeV H flux (uncorrected)
9.0-15.0 MeV H flux (uncorrected)
40.0-80.0 MeV H flux (uncorrected)
165.0-500.0 MeV H flux (uncorrected)
Generated by SEPEM


GOES08 Proton channels (cleaned)
1.000
0.100
0.010
0.001
1995-03-02 21:46:40
1995-03-05 05:20:00
1995-03-07 12:53:20
1995-03-09 20:26:40
9.0-15.0 MeV H flux (uncorrected)
40.0-80.0 MeV H flux (uncorrected)
165.0-500.0 MeV H flux (uncorrected)
4.0-9.0 MeV H flux (uncorrected)
15.0-40.0 MeV H flux (uncorrected)
80.0-165.0 MeV H flux (uncorrected)
Generated by SEPEM

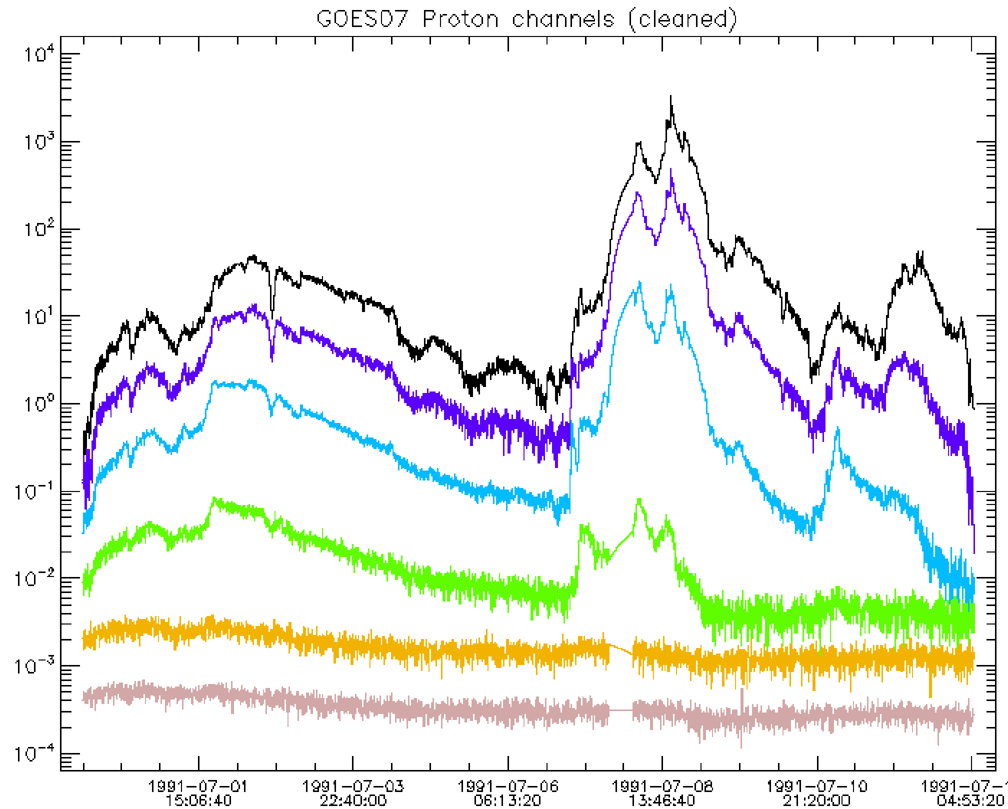


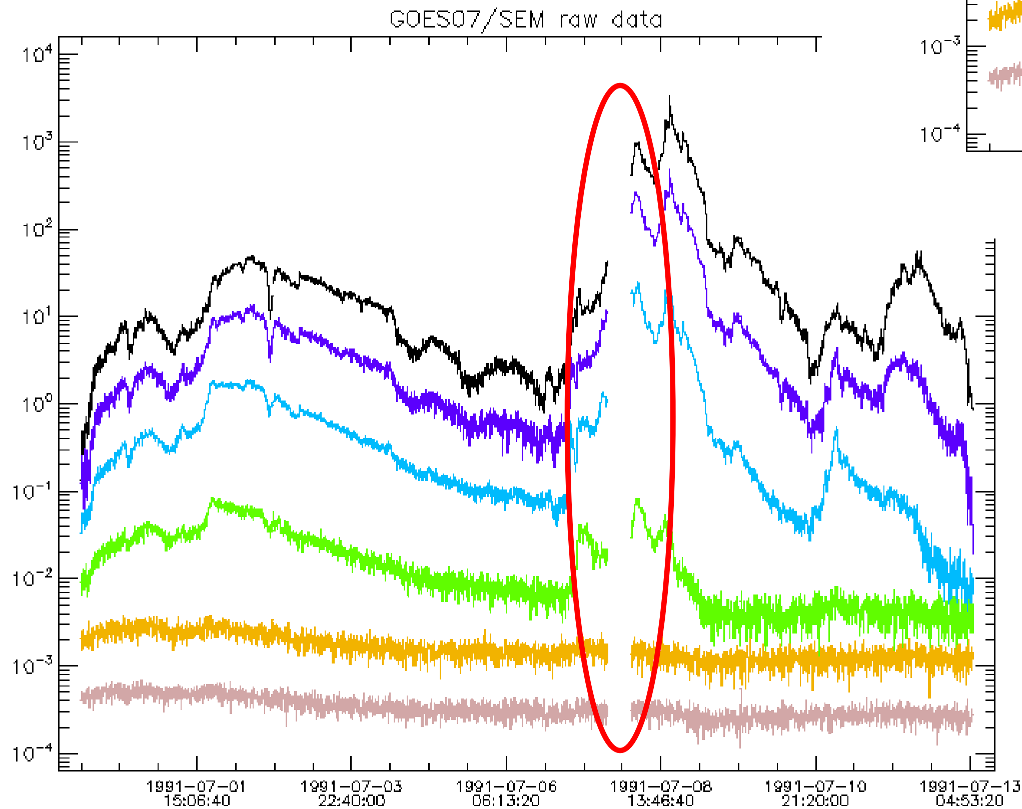


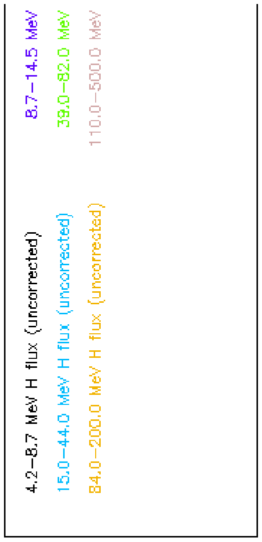
Generated by SEPEM



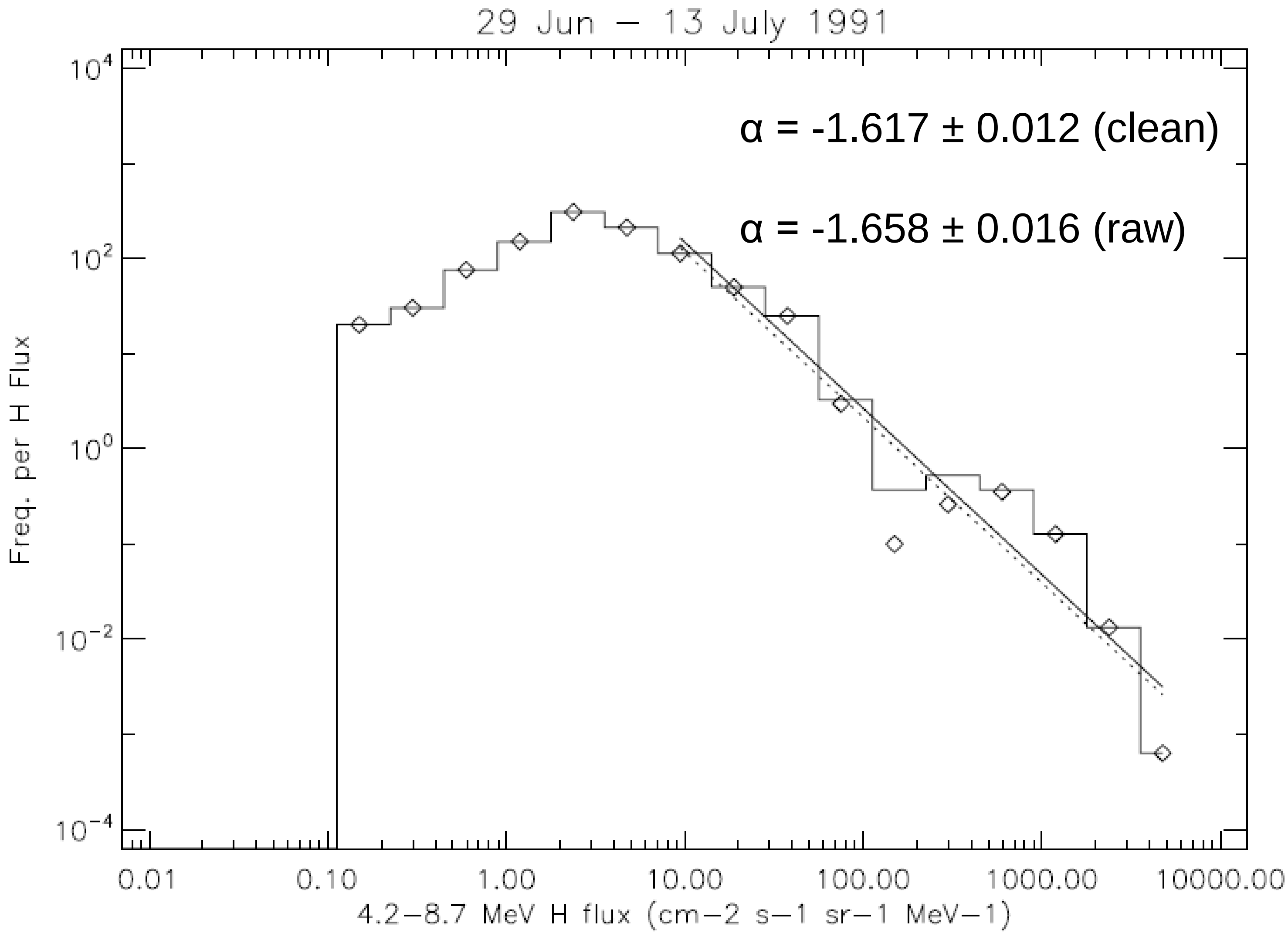
Generated by SEPEM

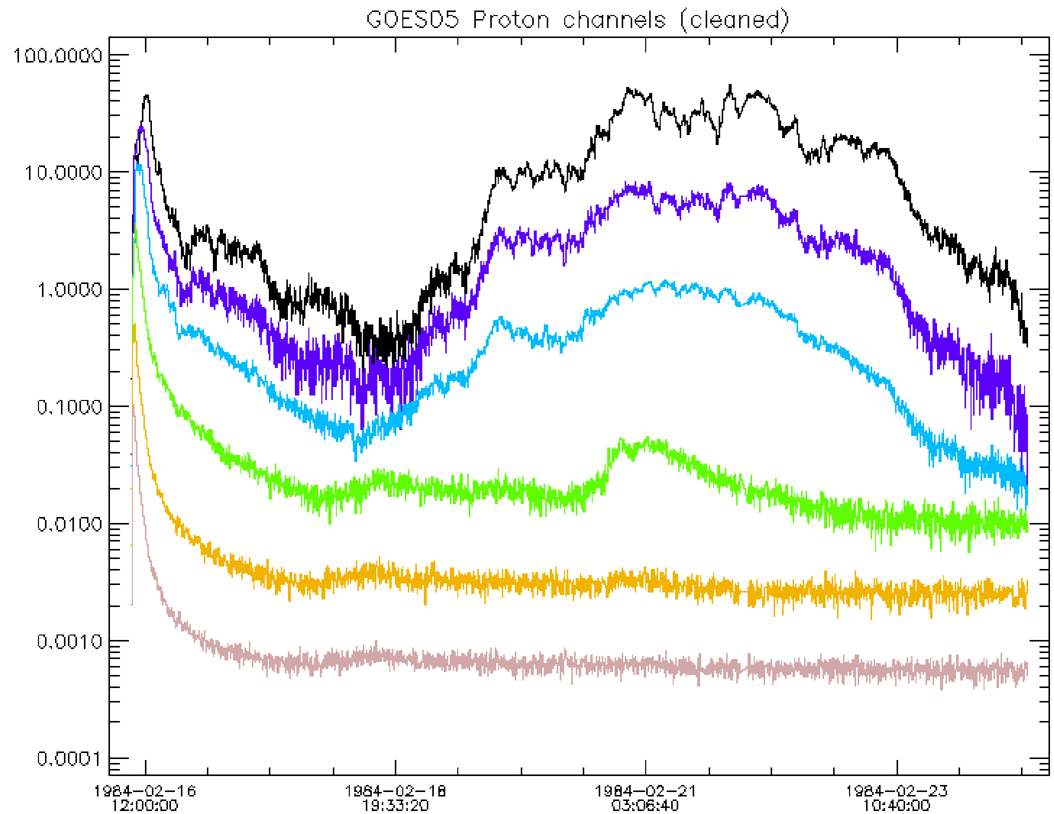

GOES07 Proton channels (cleaned)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
1991-07-01 15:06:40
1991-07-03 22:40:00
1991-07-06 06:13:20
1991-07-08 13:46:40
1991-07-10 21:20:00
1991-07-1 04:53:20

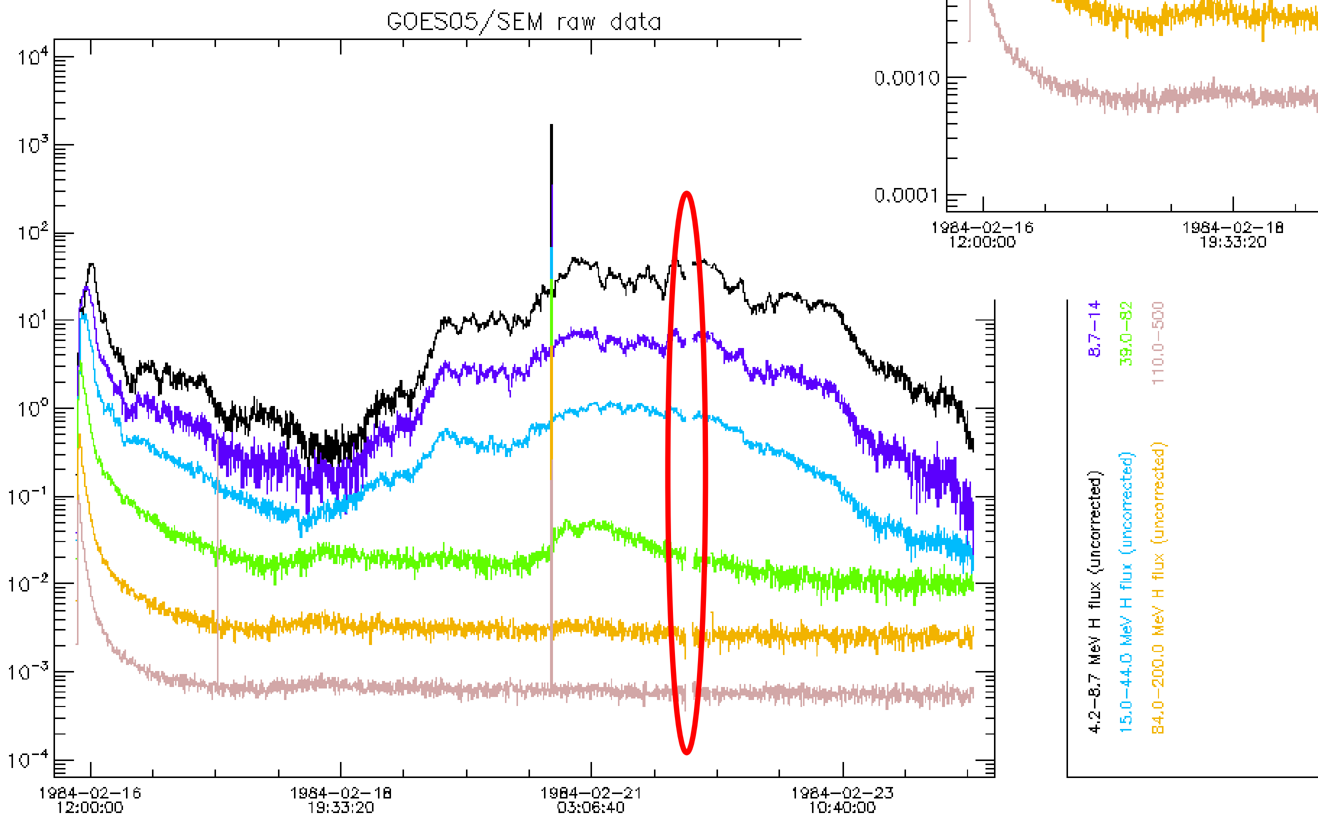

GOES07/SEM raw data
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
1991-07-01 15:06:40
1991-07-03 22:40:00
1991-07-06 06:13:20
1991-07-08 13:46:40
1991-07-10 21:20:00
1991-07-13 04:53:20


4.2–8.7 MeV H flux (uncorrected)
8.7–14.5 MeV
15.0–44.0 MeV H flux (uncorrected)
39.0–82.0 MeV
84.0–200.0 MeV H flux (uncorrected)
110.0–500.0 MeV

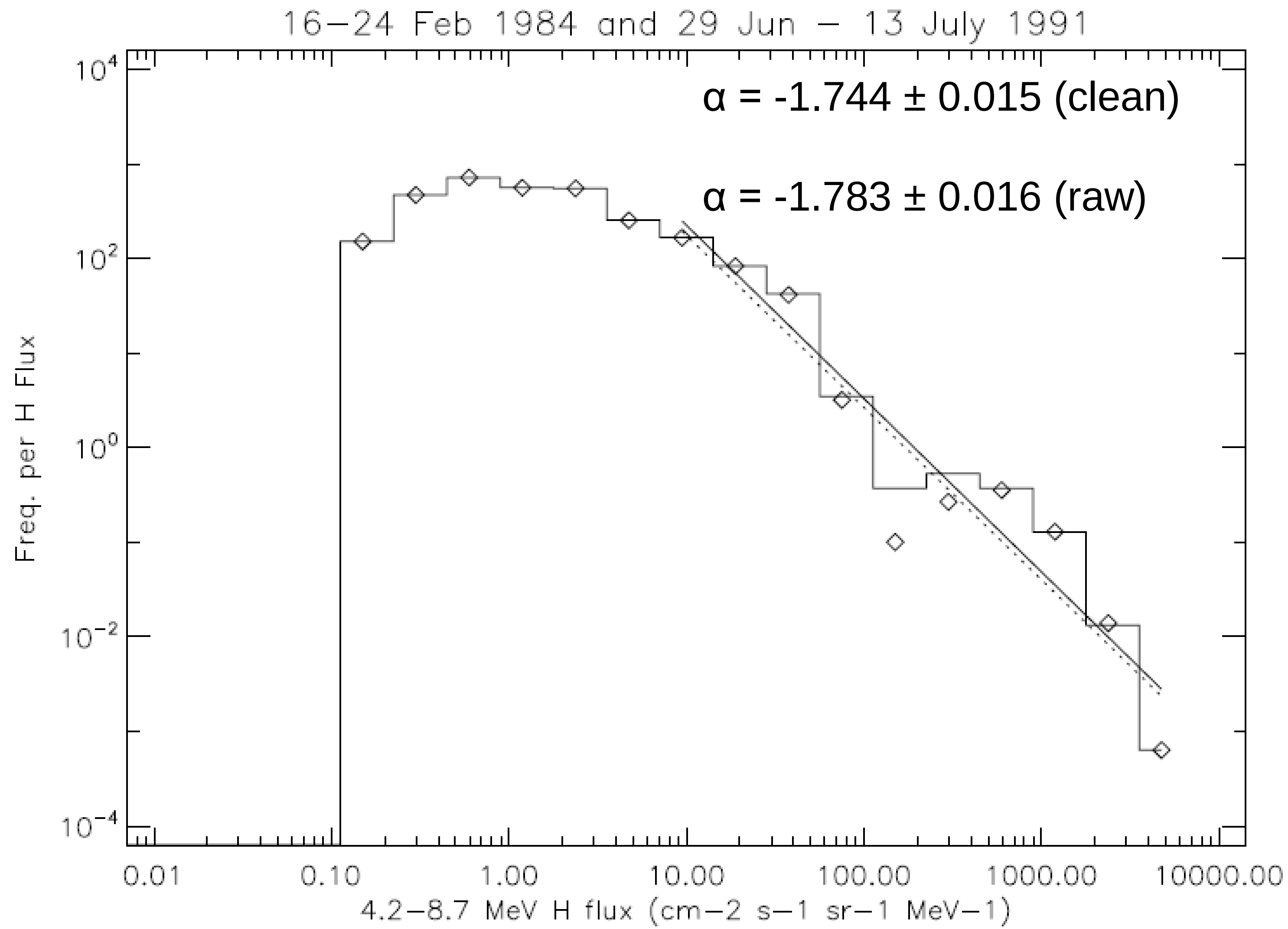
288 datapoints per day







Generated by SEPEM



16−24 Feb 1984 and 29 Jun − 13 July 1991
α = -1.744 ± 0.015 (clean)
α = -1.783 ± 0.016 (raw)
Freq. per H Flux
4.2−8.7 MeV H flux (cm−2 s−1 sr−1 MeV−1)

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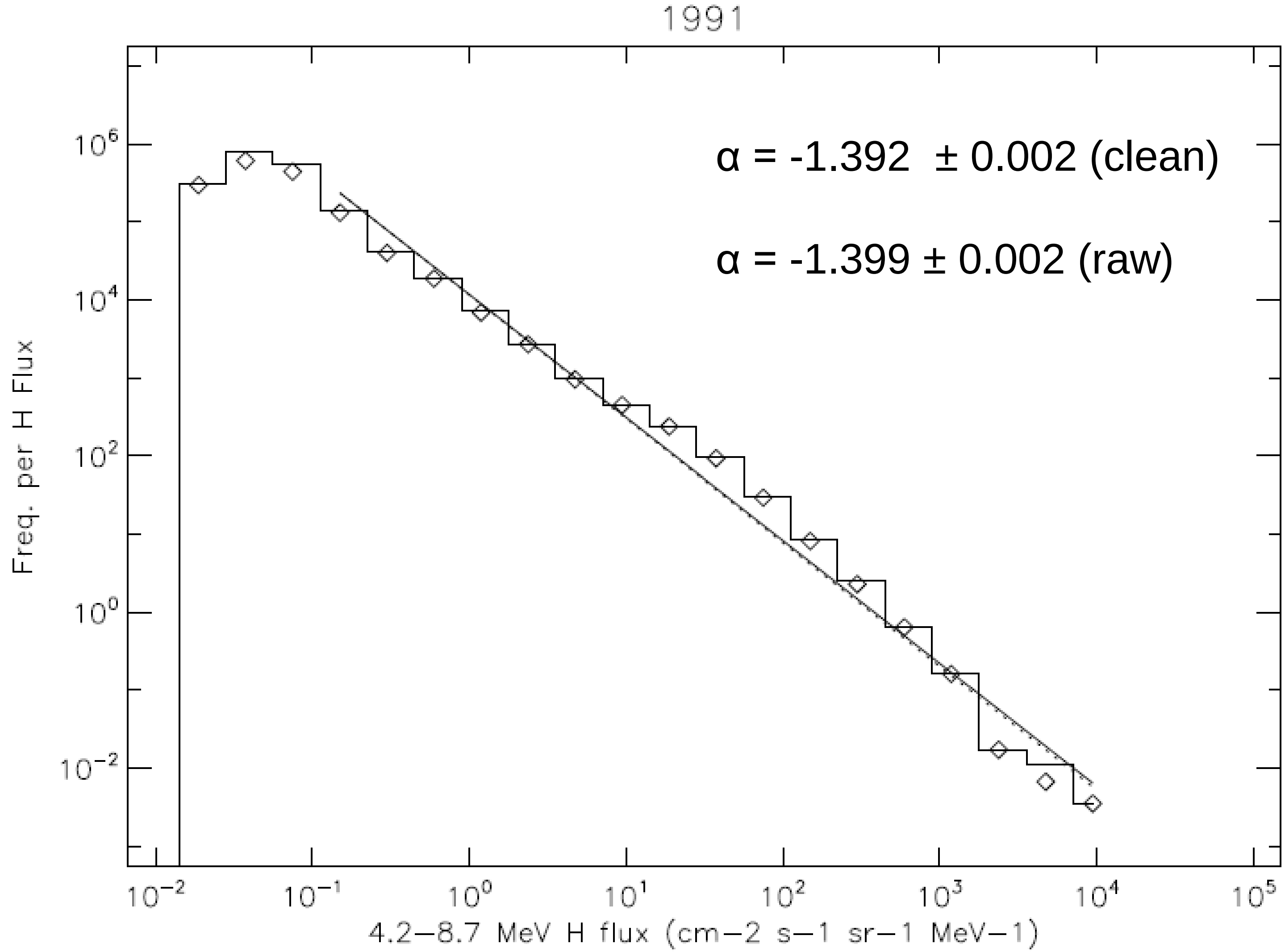
105120 datapoints per year
(datapoints “ne” NULL: 93159)



	4.2 - 8.7 MeV H Flux	
Year	CLEAN DATA	RAW DATA
1989	-1.377 ± 0.002	-1.379 ± 0.002
1991	-1.392 ± 0.002	- 1.399 ± 0.002

	8.7 - 14.5 MeV H Flux	
Year	CLEAN DATA	RAW DATA
1989	-1.400 ± 0.002	-1.400 ± 0.002
1991	-1.426 ± 0.002	-1.438 ± 0.002

PART 2. Powerlaw scaling.

- Have the largest events been observed?
- What about the outliers that have been observed?

Have we yet observed the largest solar energetic particle event ?

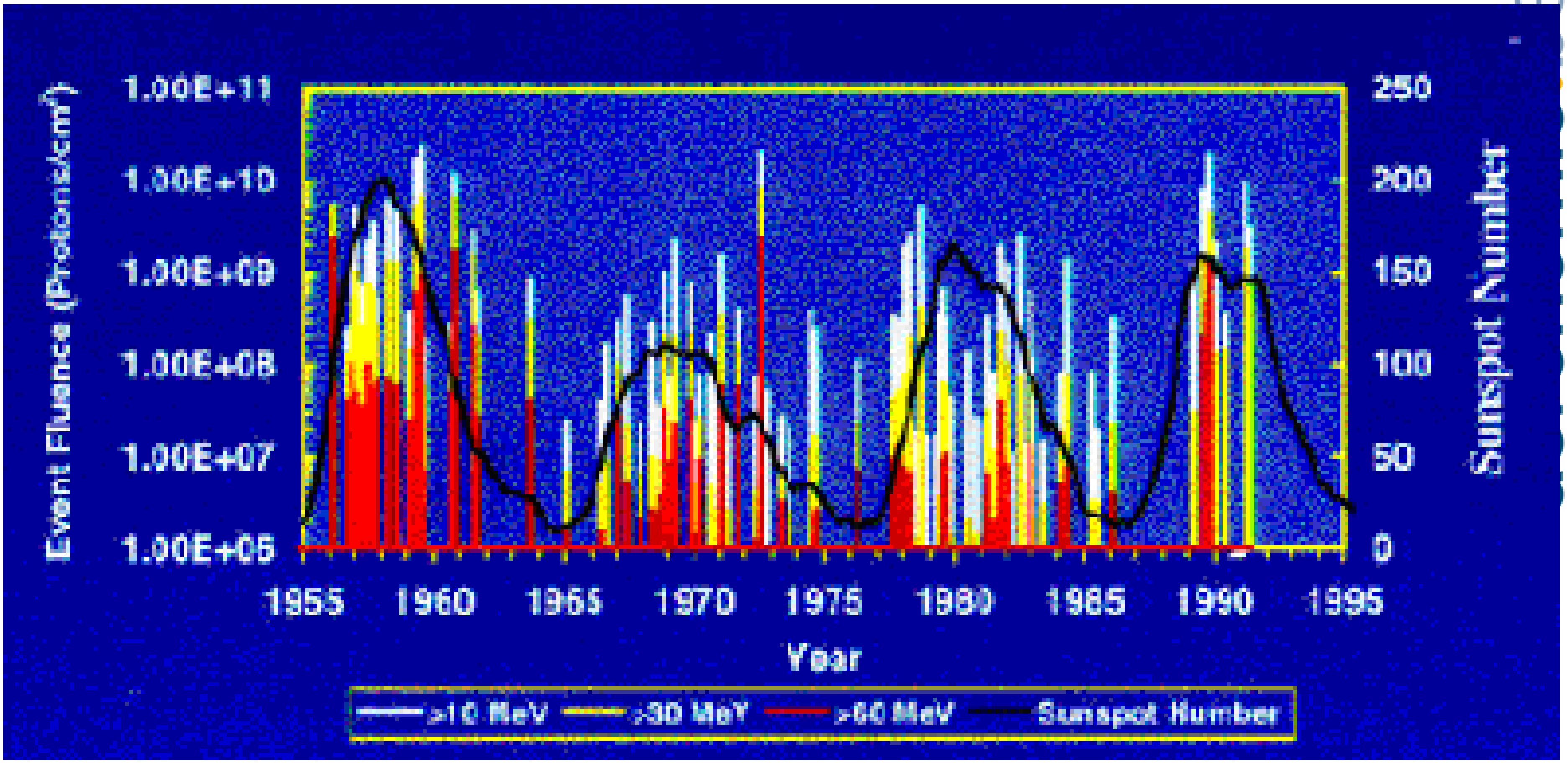
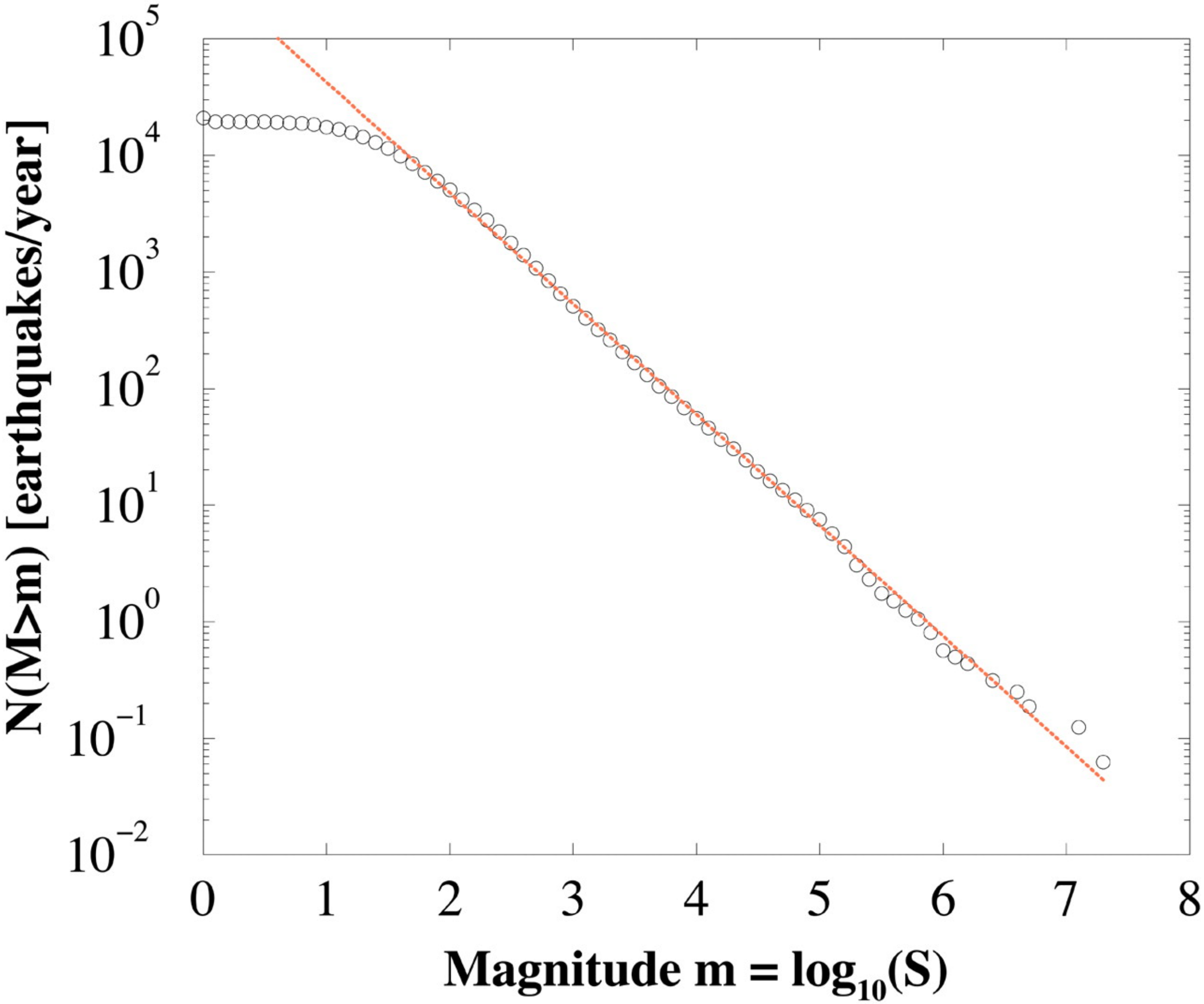


Image courtesy of Ron Turner of ANSER and Robert C. Reedy of Los Alamos National Lab.

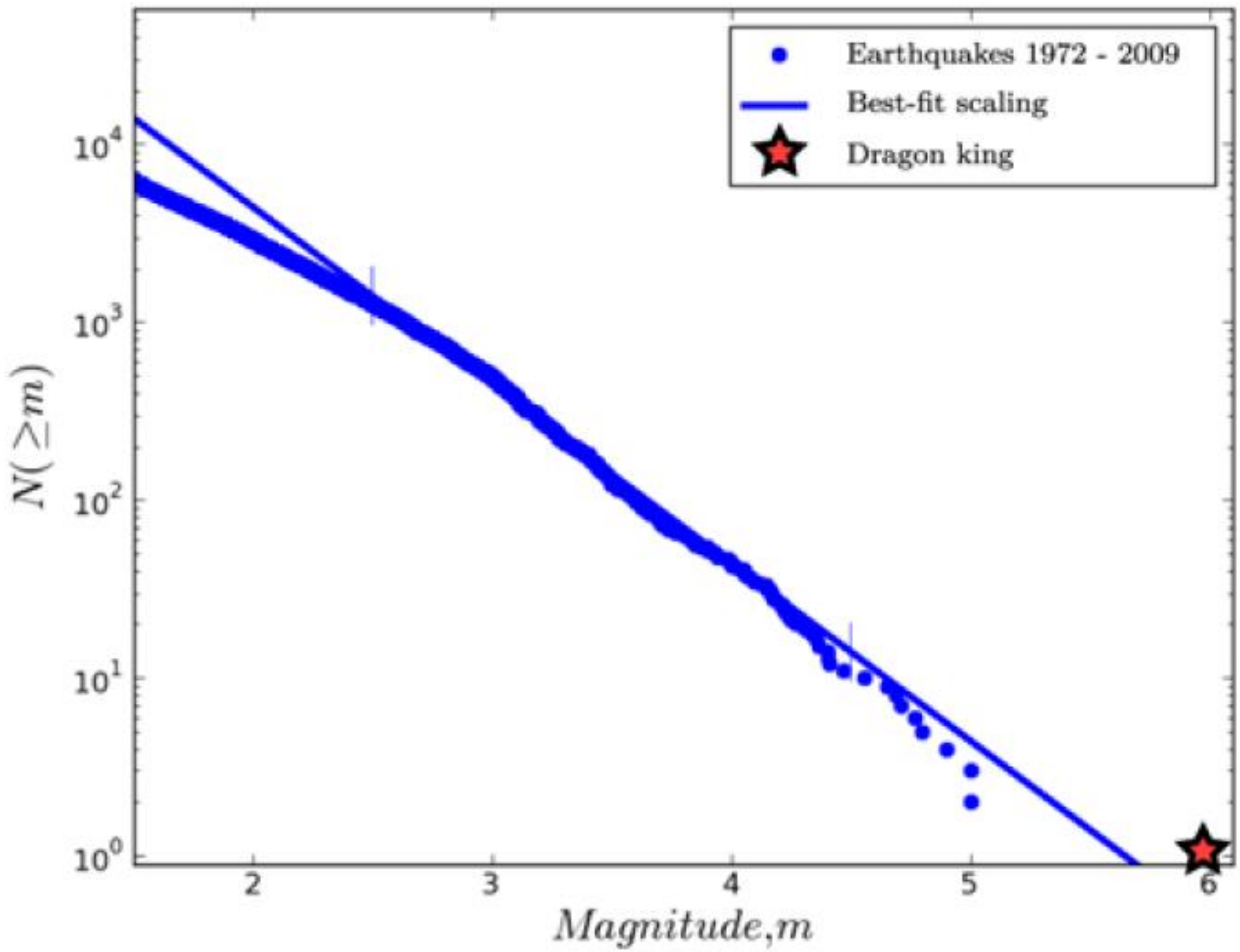
Dragon-Kings

Sornette (2009) developed the concept of the unexpected "dragon-kings" to describe this class of extreme events that are significantly larger than the extrapolation of the powerlaw scaling of their smaller counterparts.



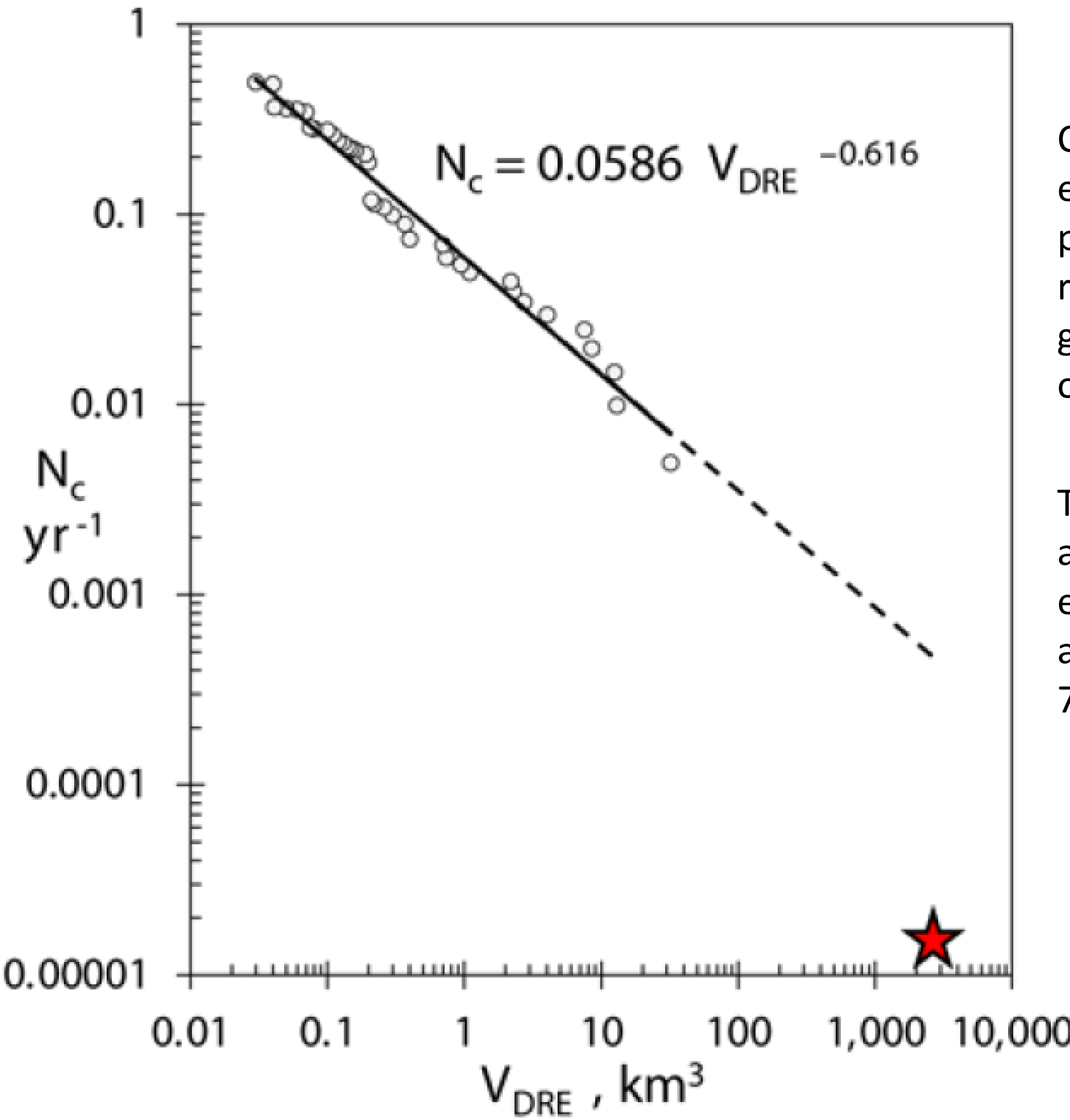
Earthquake magnitude distribution showing a powerlaw behavior over six decades. The graph follows log10 N(M > m) - bm, where b is the Gutenberg-Richter exponent b = 1 (dashed red line has a slope value of -0.95).

Christensen et al. (2002)



Cumulative number of earthquakes with magnitude greater than m as a function of m for the Parkfield earthquake cycle 1972 to 2009. The best-fit scaling is shown as the blue line. The m = 5.95 Parkfield earthquake is shown as a “dragon-king” (identified as the red star).

Sachs et al. (2012)



Cumulative number of volcanic eruptions (Nc) during the period 1800-2002 with dense rock equivalent volume (V_{DRE}) greater than V_{DRE} as a function of V_{DRE}.

The best-fit powerlaw scaling is also shown along with the Toba eruption in Sumatra (identified as the red star) occurring 73,500 +/ 500 years ago.

Sachs et al. (2012)

PART 3. Discussion

- Understanding the dataset is important
  - Are the data caveats clearly understood? Readme files are very important!

- Sufficient statistics is important.
  - What is the time resolution of the phenomenon being studied?
  - Is the dynamic range of the phenomenon being studied sufficient?
  - Is the largest possible event based not only on observations but also on the ongoing physics (limit to the size of the phenomenon) known?

- Why are there so many slope values in the literature?
  - Is this caused by the limit of the dataset being used or is this real?
  - Function of parameter (peak count rate, total duration, …); selection effects.
  - Function of instrument measuring the same parameter.
- Is it always a powerlaw? What about powerlaws with exponential roll-overs?
- Putting the statistical aspects and physics into the slope value.
  - What does the slope value mean?