The High Energy Photons Emission from Solar Flares observed by SZ2-XD

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SZ2/XD data

XD1: 10~200 keV,

XD2: 40~800 keV,

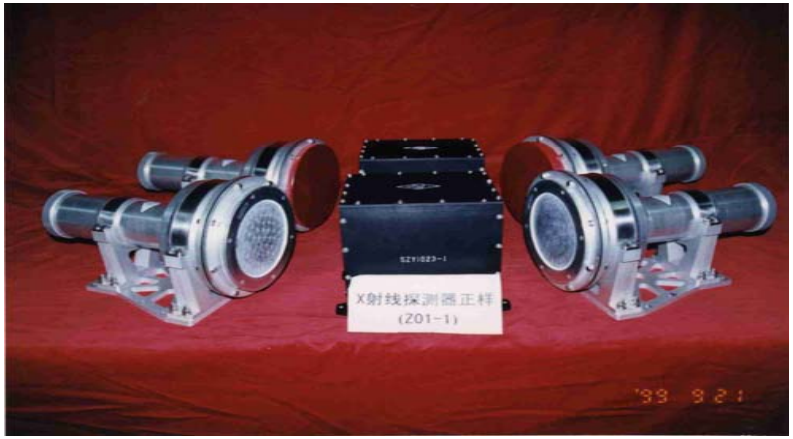
Trigger: 40ms, 200ms, 1s

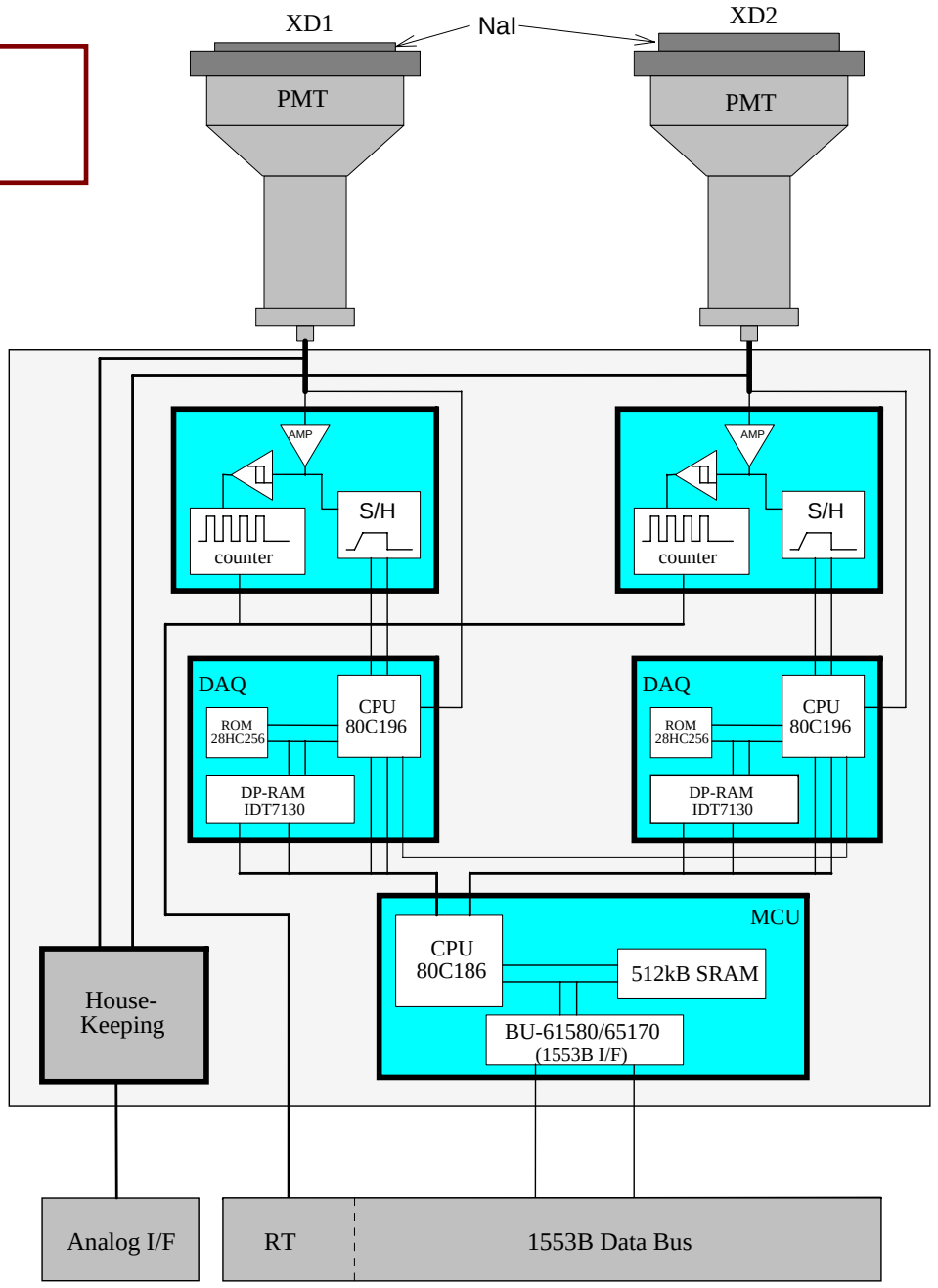
Burst Mode: 40s BG + 128s B

spectrum: 64 Chs/s, BG data

64chs/40ms B data

Accumulate Counting rate



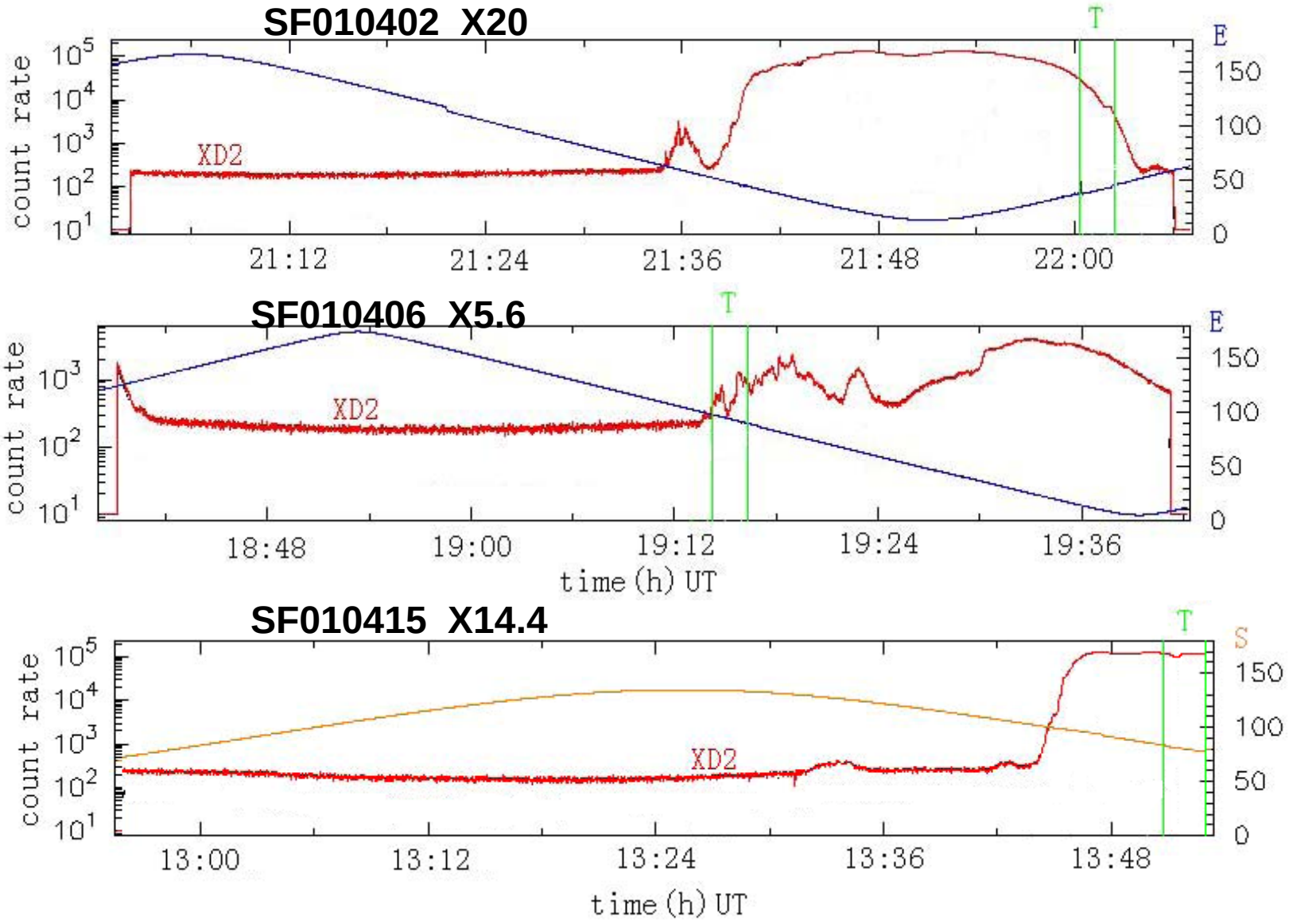


SZ2/XD Observations

- **SZ2:**
  - **Operated In 10 Jan – 25 June 2001,**
  - **Orbit: 400km, Period: ~92min.**
  - **Inclination : 42.2° ~ 42.7°**
  - **Attitude: 3 Axis stability**
  - **Two mode of pointing : to Sun; to Earth center**
- **XD:**
  - **Two mode of pointing: to Sun; to anti-earth center**
  - **Three working mode: BG mode, Burst Mode, SAA mode (HV off, no data)**
  - **Formal data collection:**
    Total 145 days Duration **16 Jan ~ 25 June**

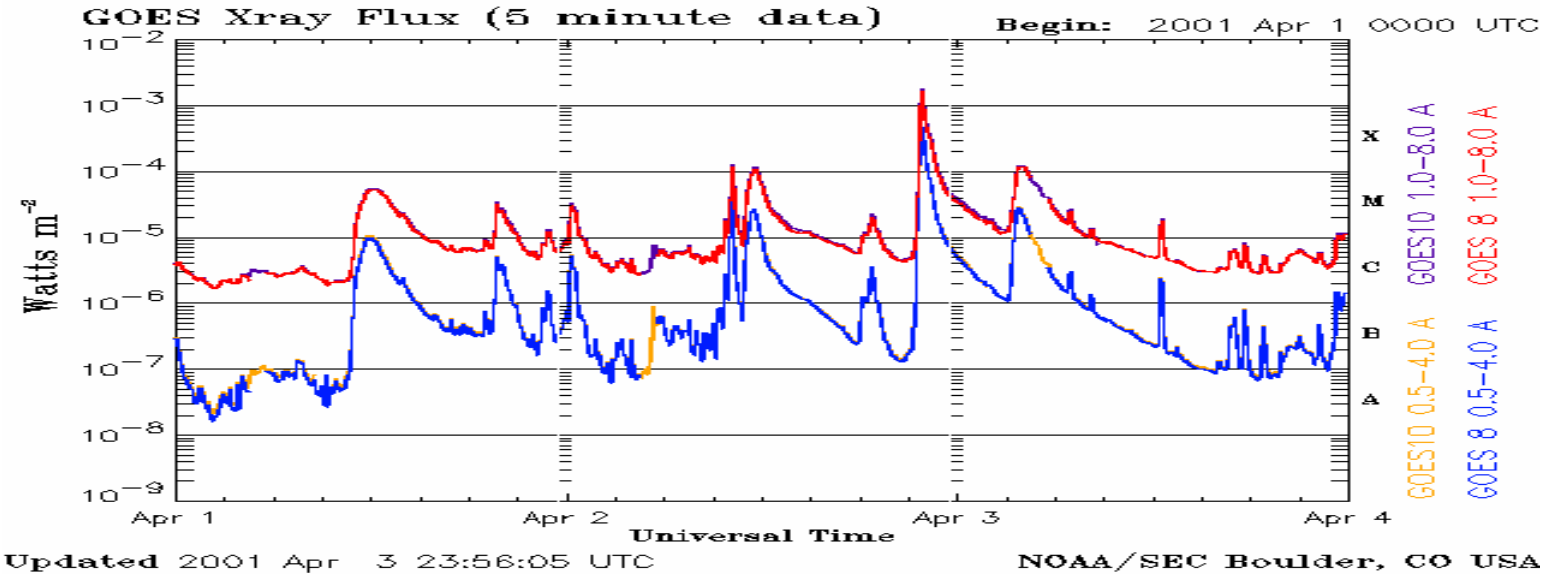
SZ2/XD Achievement in SF obs.

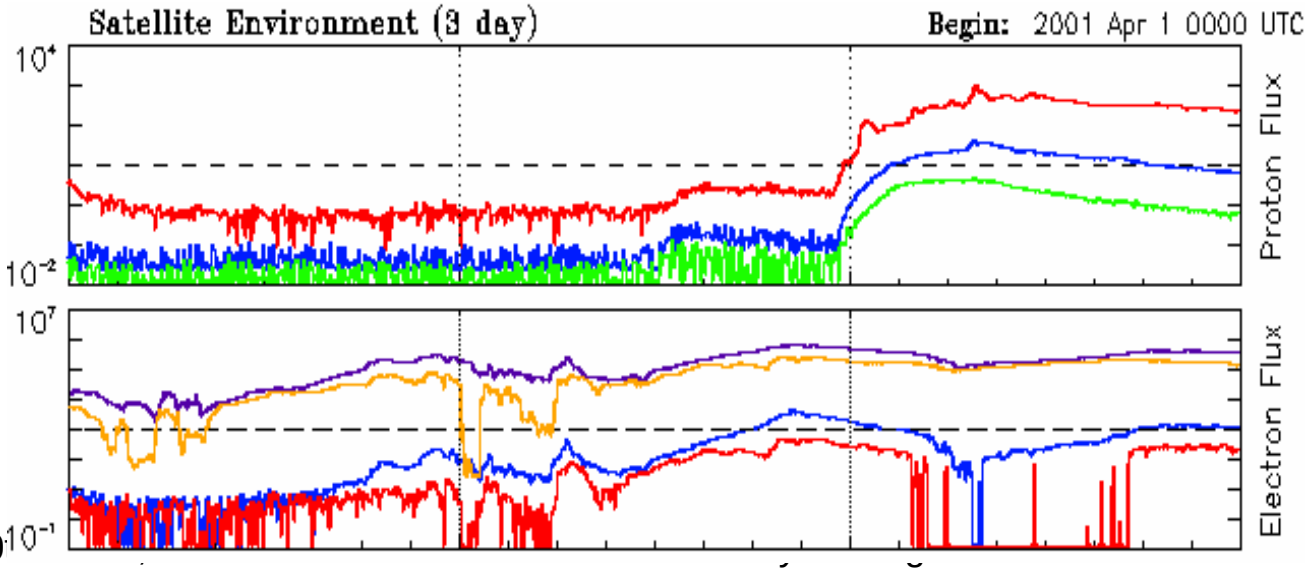
- Total 664 set of spectrum data in BG mode,
  281 trigger events in trigger mode
- Data of counting rates: 145 day, 5~10 hopus/day.
- XD met the peak time of 23th solar cycle, about 136 solar flares with GOES class above B7.5 were observed, including:
  - 68 events in trigger mode, coincident with 43 GOES-8 X-ray events and 14 Yokhoh events. 70% happened in March and April, mainly C class in March and more M, X class in April.
  - 3 X-class events were recorded.
- A special event at special time period showing the SEP developing and its relation with CME. – 15 April event.



The light curve of Three X-class of Solar Flare (T is spectrum range)

The flare in 2nd April is a big SEP event

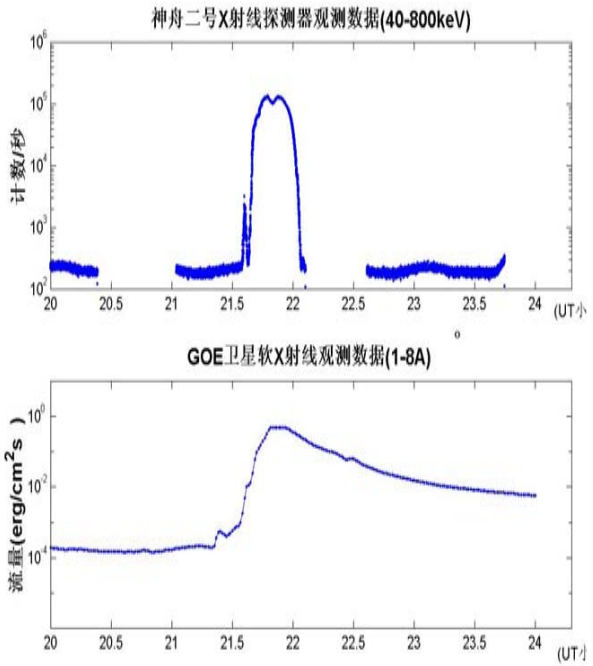




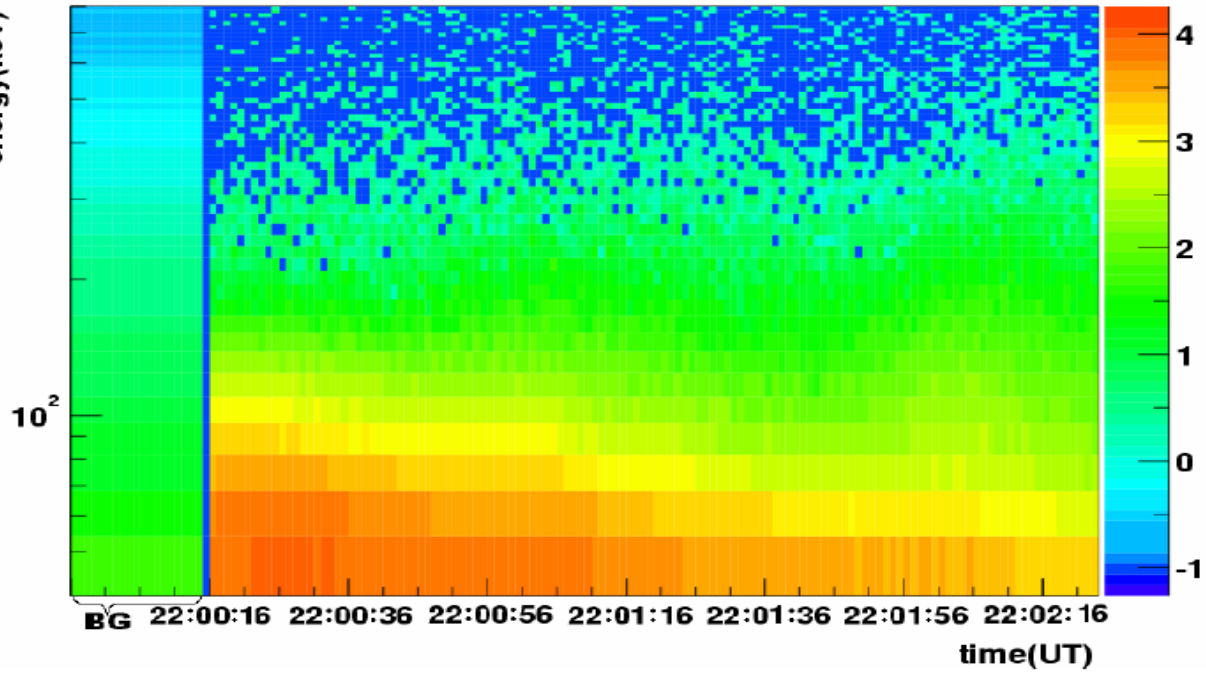
Proton Flux in gradual increase

X20 Flare in 2 Apr 2001

-- The Most Intense Solar Flare Since 1989



Spectrogram of SF010402

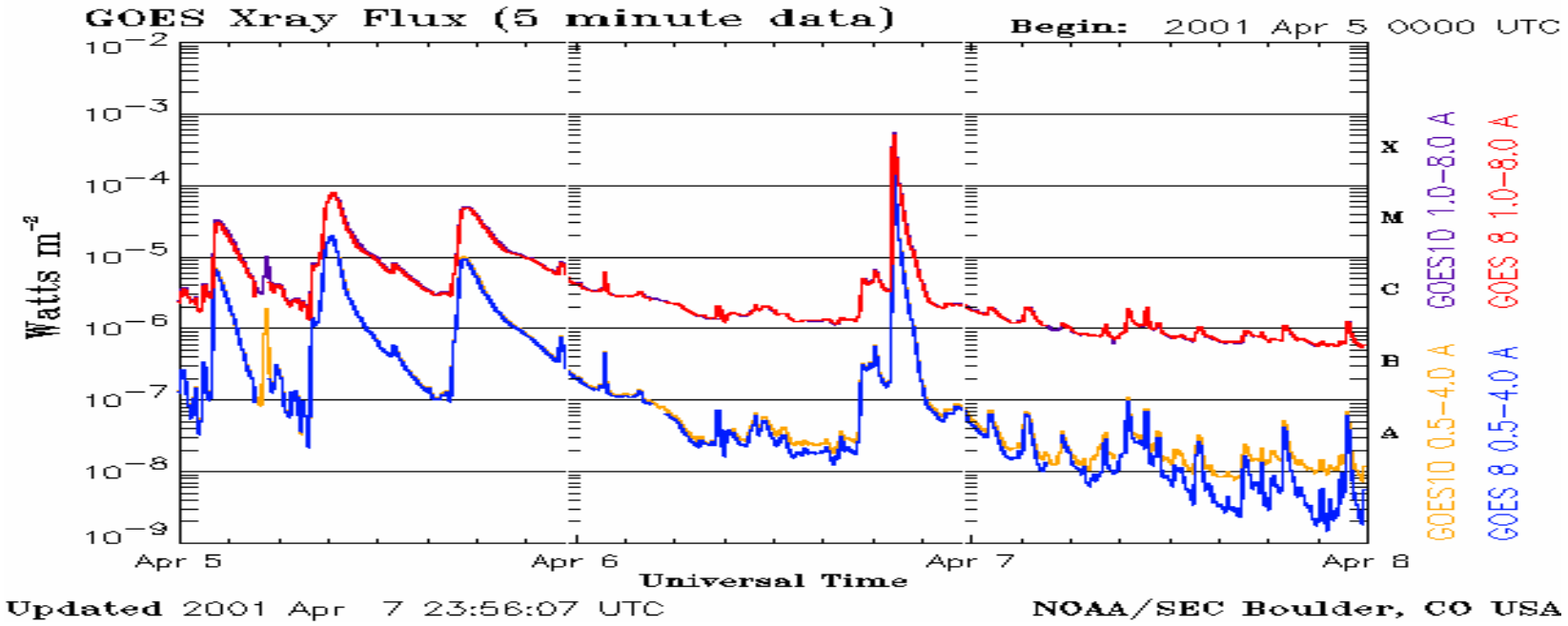


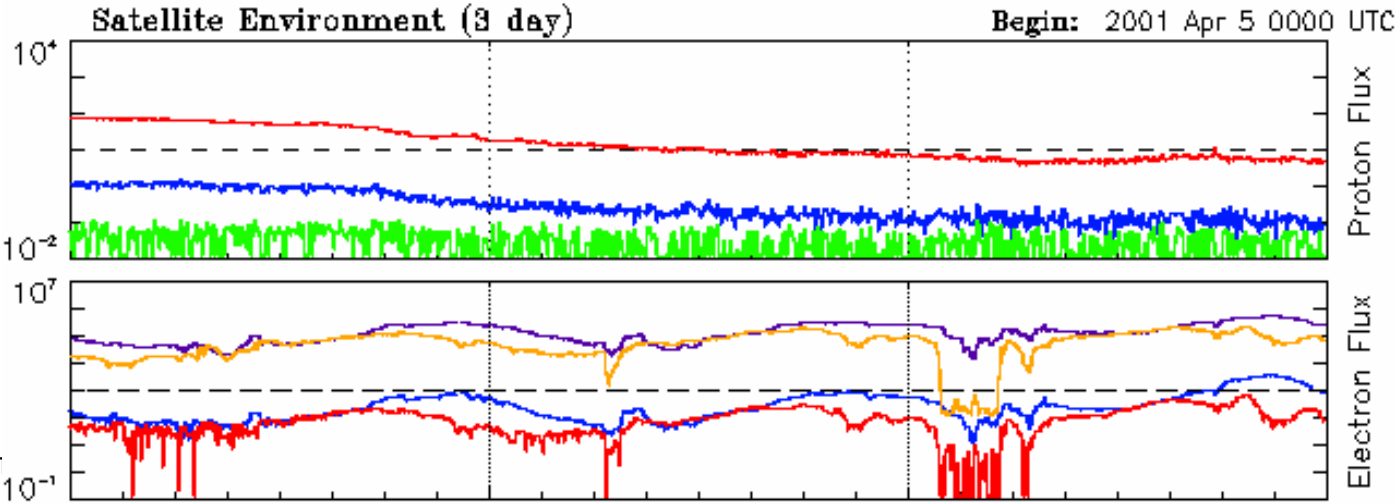
时间(s)	λ	K	χ^2/ndf
0-50	6.13±0.03	(3.2E+11)±(3.9E+10)	3.6
50-90	4.40±0.03	(3.7E+07)±(5.4E+06)	2.7
90-128	4.7±0.1	(3.5E+07)±(2.1E+07)	3.0

Power Law Spectrum fitting of SF010402 in its weaken Phase, time start from 22:00:16, the spectrum become hard.

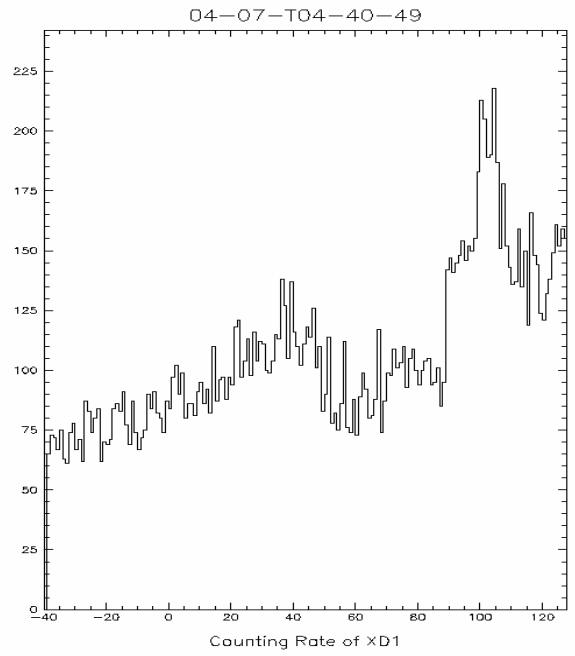
K in unit of photons/cm^2 s at 1 KeV

SF010406 occurred in 9415 range. It is not a SEP event

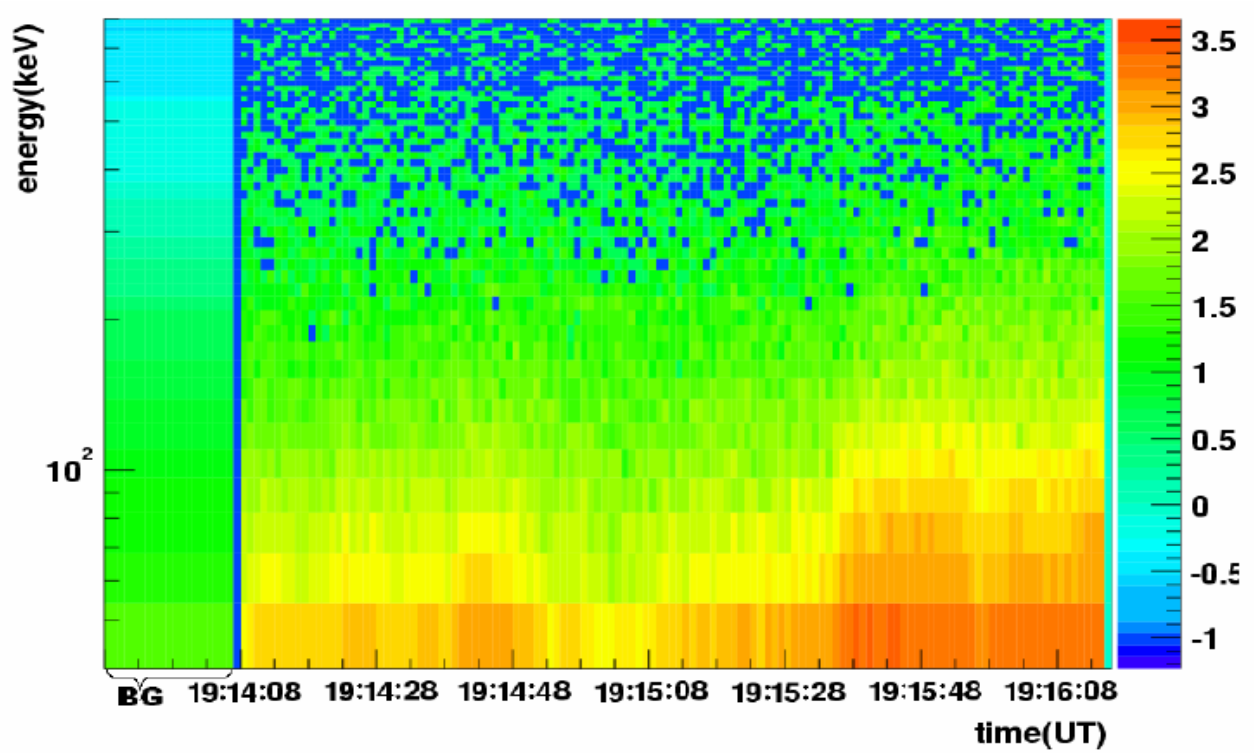




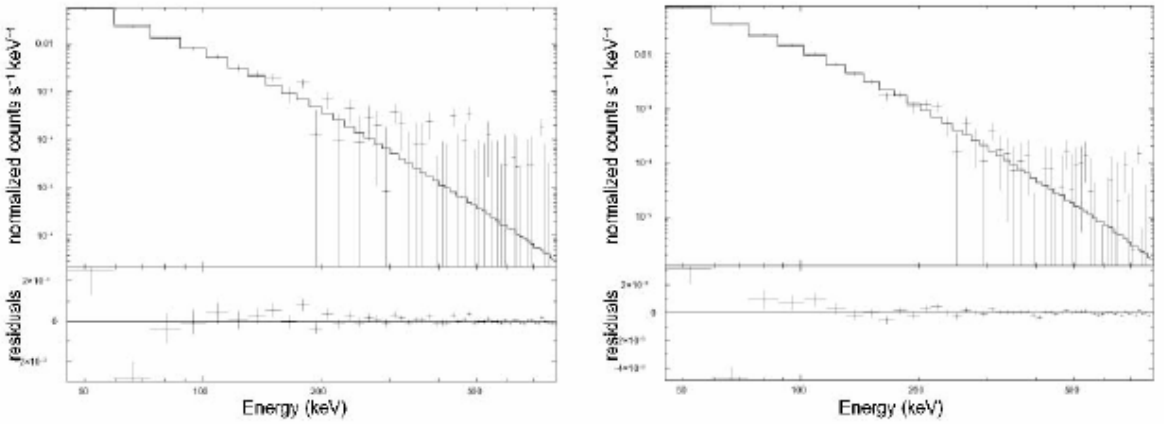
X5.6 flare spectrum and light curve



Light curve after triggered

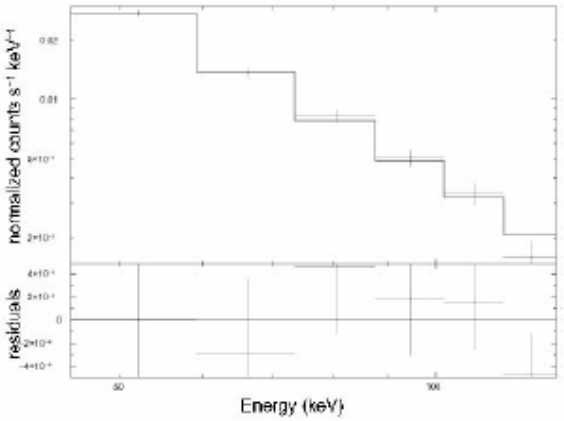


Spectrogram of SF010406

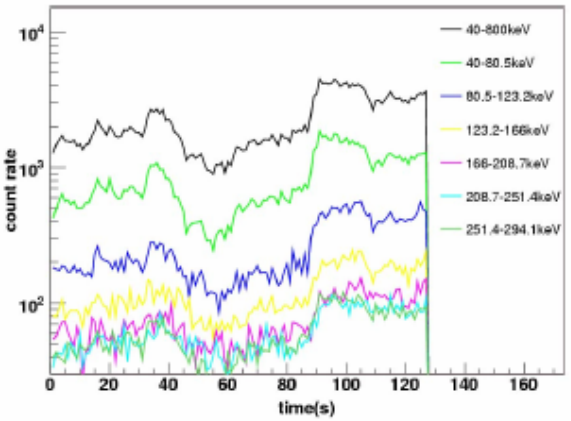


(a) 0-50s

(b) 50-87s



(c) 87-128s



(d) 128s各个能段入射光变

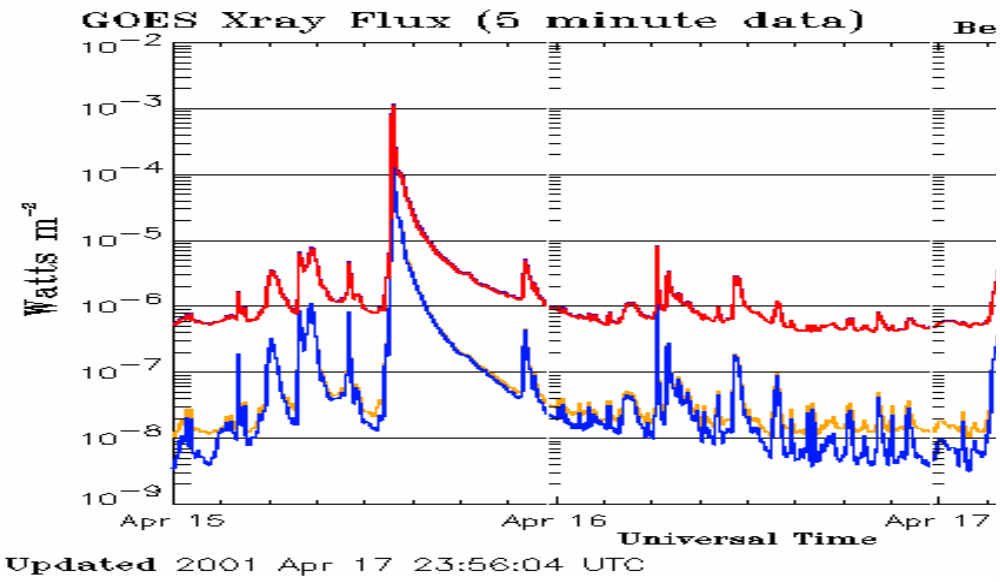
表 7.2: 耀斑SF010406由power能谱拟合参数

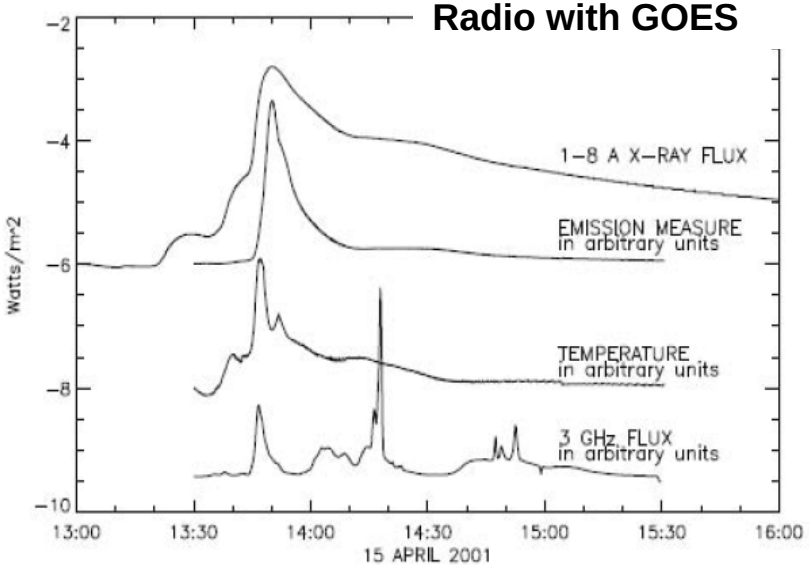
时间(s)	λ	K	χ^2/ndf
0-50	4.16±0.08	(8.49E+05)±(3.04E+05)	1.5
50-87	3.62±0.04	(1.25E+05)±(2.24E+04)	2.2
87-128	3.84±0.12	(1.17E+05)±(6.50E+04)	0.7

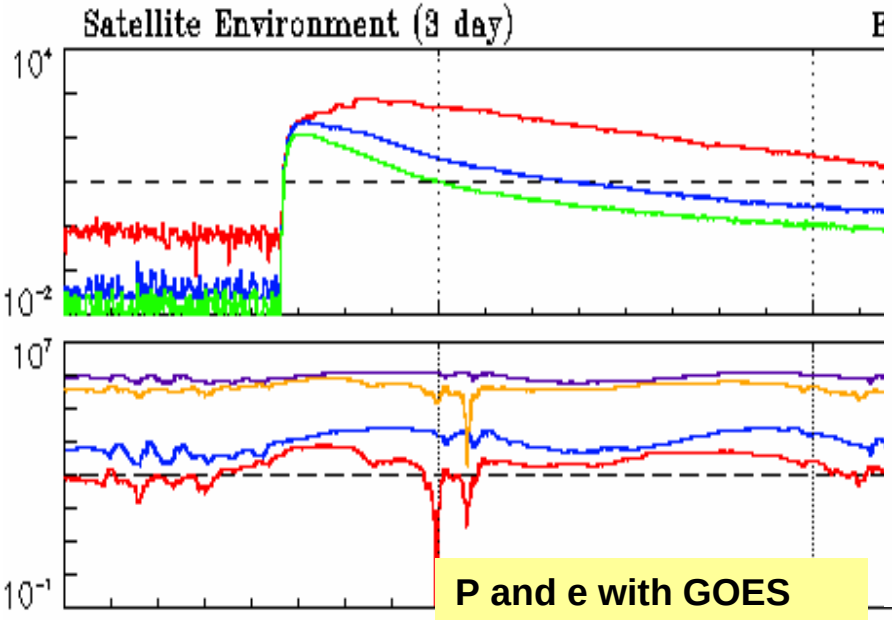
SF 010406 spectrum fitting

In mode “towards to Earth”, Sun is just moving in to the FOV. The geometric area correction has not been included.

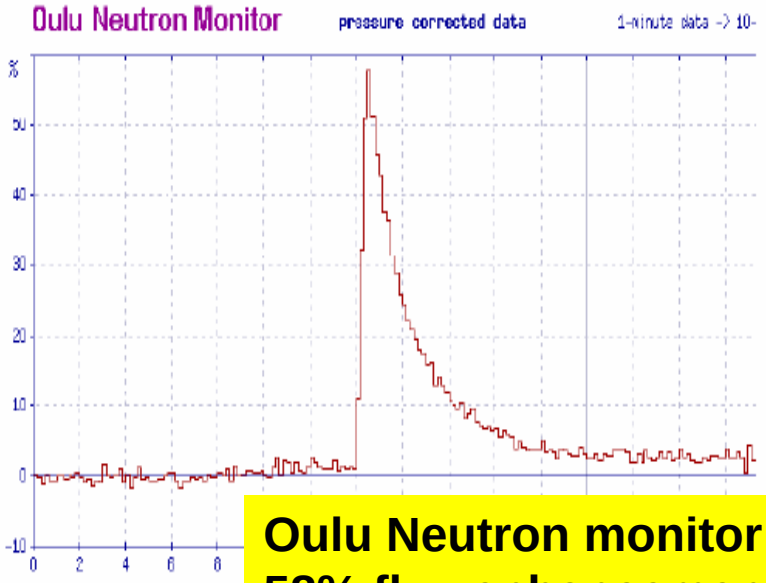
15 April flare has strong blast proton emission, a big GLE







P and e with GOES



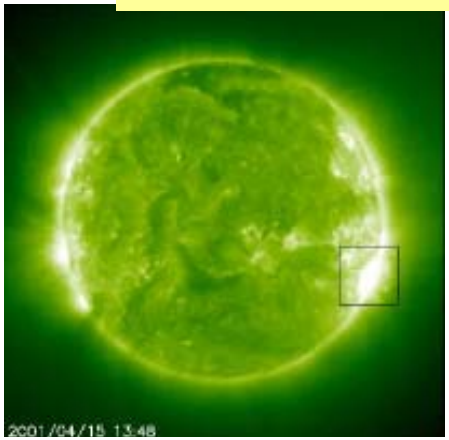
Oulu Neutron monitor
58% flux enhancement

SF 010415 Timing overview

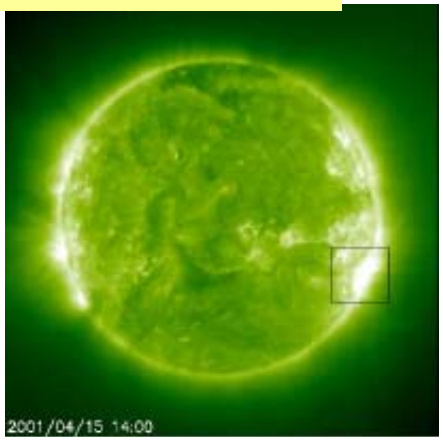
- Occurred at NOAA 9415 close to the edge (S20,W85), the same region with SF 010406 in (S21,E31).

	ST	Peak	End	(Time in UT)
GOES	13:19	13:50	15:30	
H_α	13:36	13:49	15:35	
SZ/XD	13:44	13:47	13:51[s]	[s]Spectrum data started
Neutron	14:00			Oulu CR station
3 GHz radio		14:17		
0.8-1.3 GHz	13:37	13:45		-4.7NHz/s, TRACE 1st CME
0.8-2.0 GHz	13:44	-13:54:20		-10 MHz/s, TRACE 2st CME
LASCO-C2		[a]14:30	[b]16:00	[a]Big CME, [b]Particle peak
LASCO-C2				
EIT 195 Å	13:48	14:00		

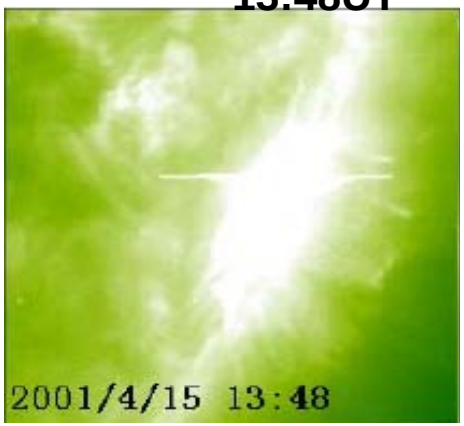
SOHO EIT 195 Å & LASCO C2

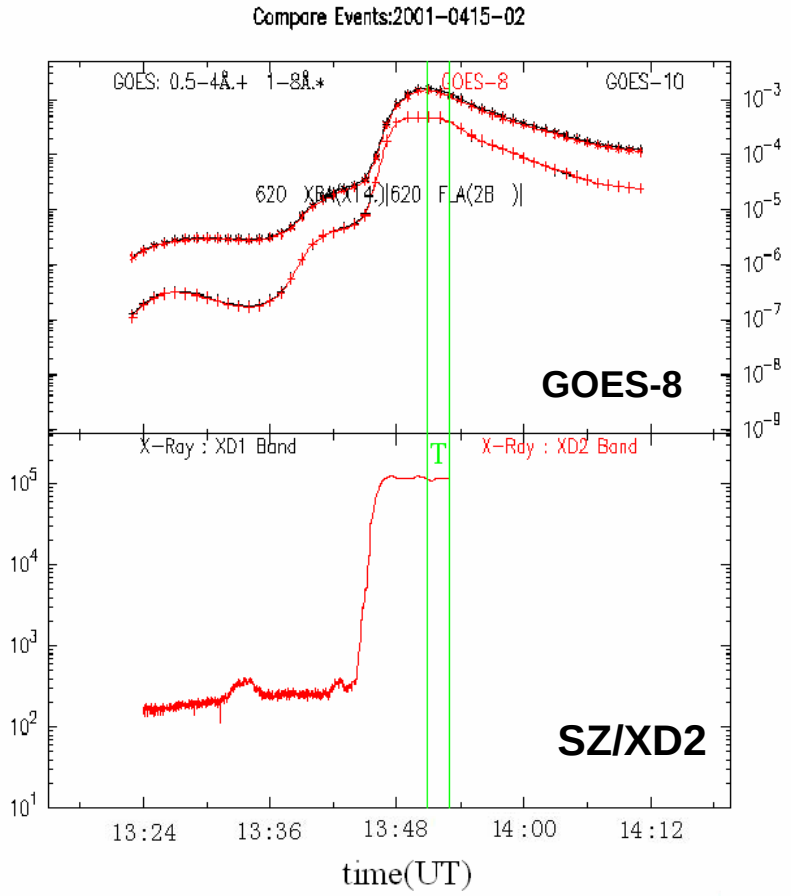


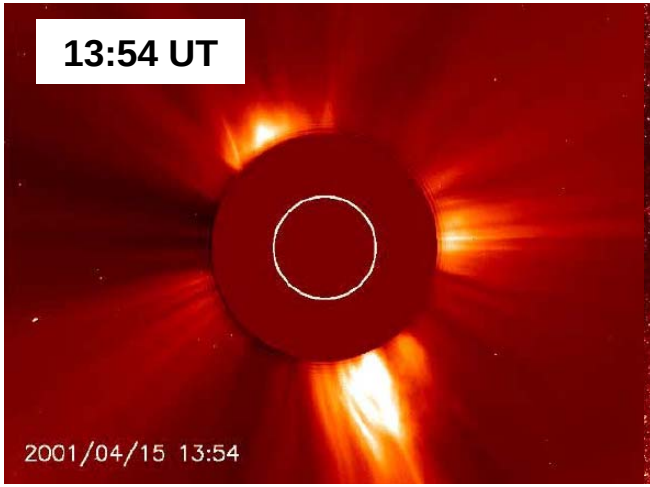
13:48UT

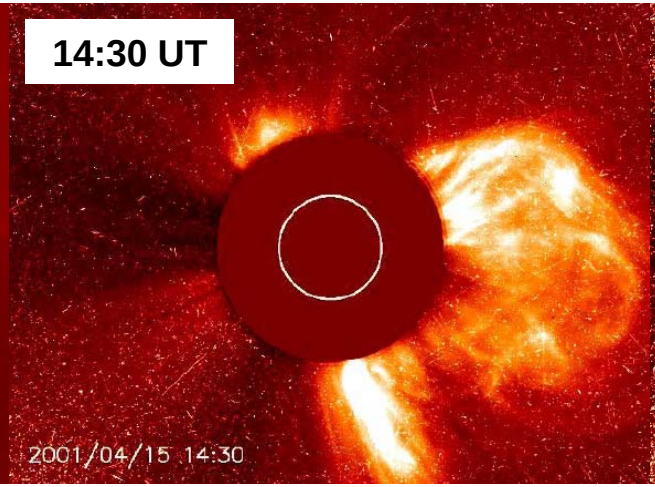


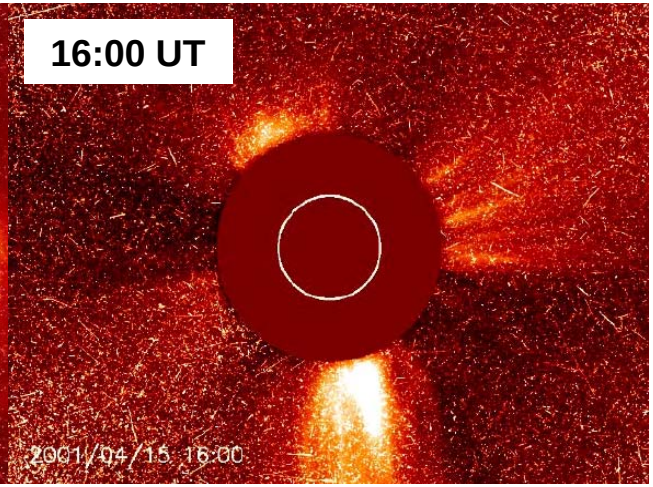
14:00UT



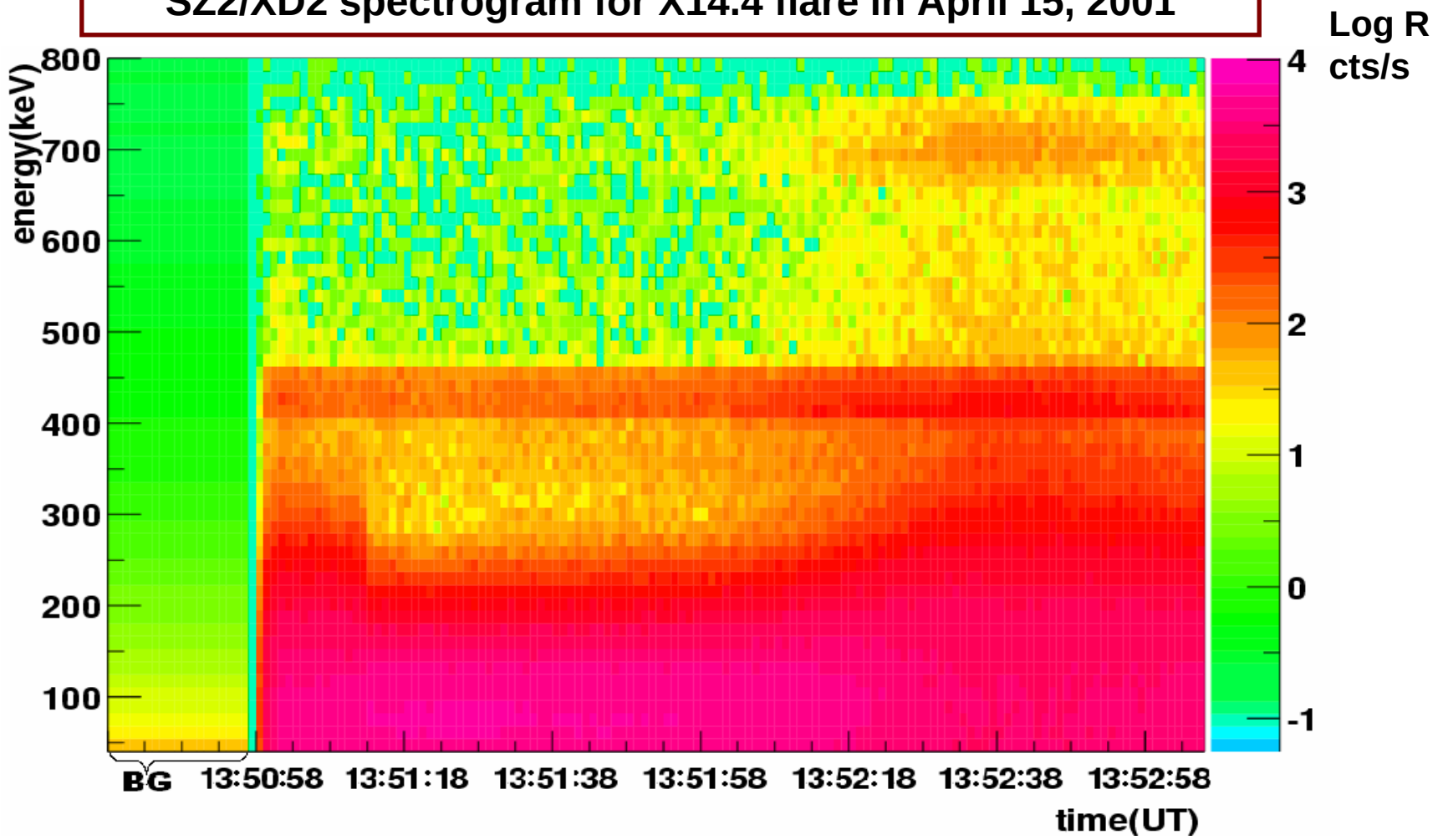






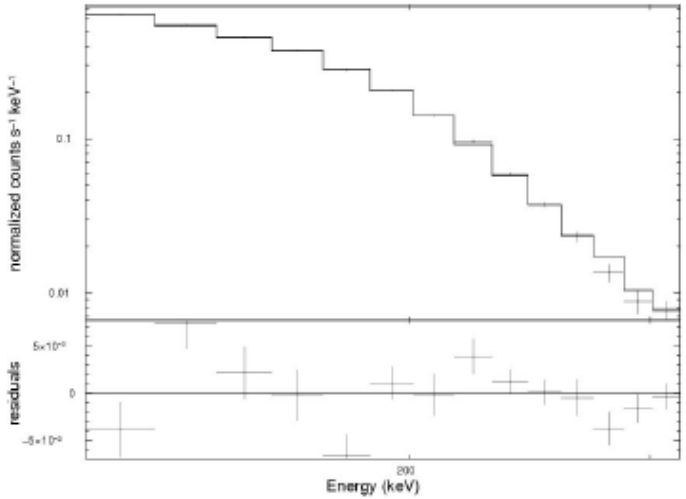


SZ2/XD2 spectrogram for X14.4 flare in April 15, 2001

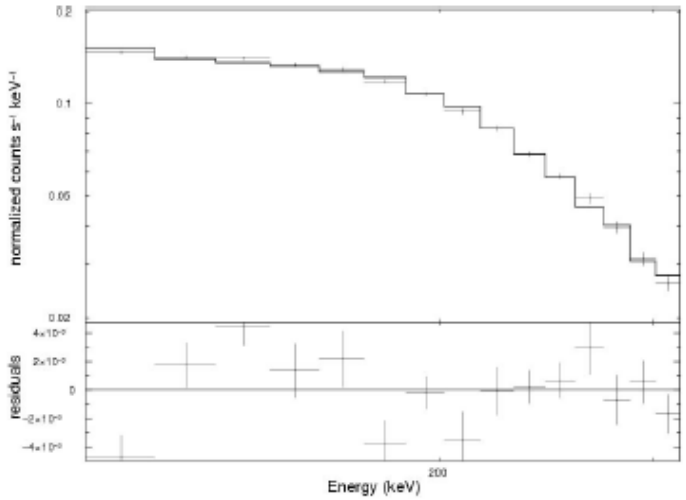


1), Shown three independent components (HX, and lines)
2) in 15-80s, a process of ions being accelerated can be seen, then a stable nuclear γ -ray spectrum occurred.

Spectrum fitting – HX part

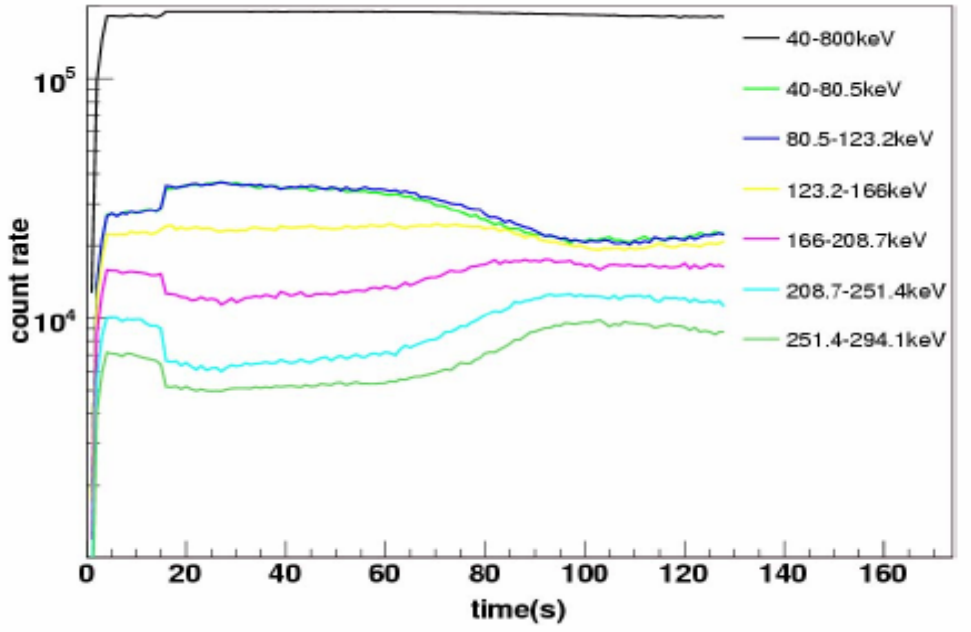


(a) 15-55s，110-320keV



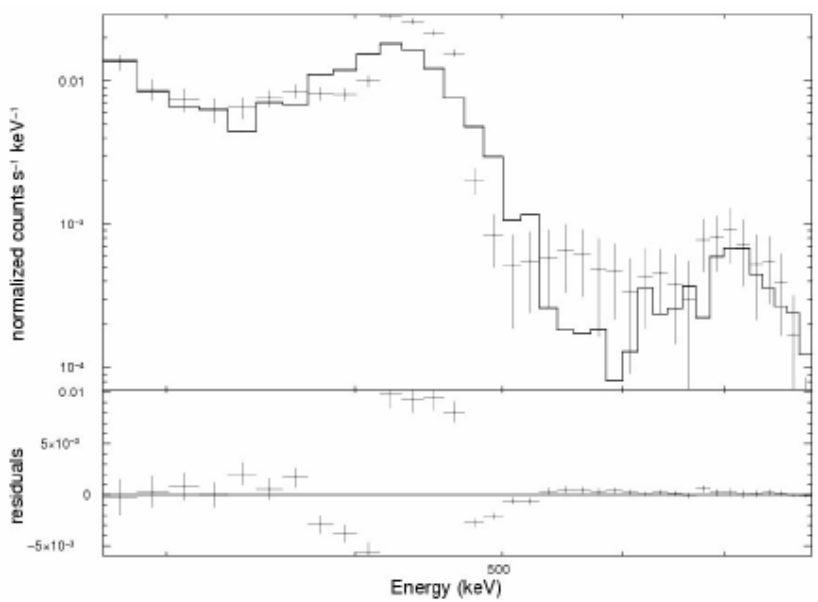
Fitted by broken power law

时间(s)	能段	λ_1	E_0	λ_2	K	χ^2/ndf
15-55	110-320	1.52±0.04	211±1.7	7.3±0.2	3224	3.0
85-128	100-320	-0.49±0.04	244±3.5	3.1±0.2	0.025	3.2

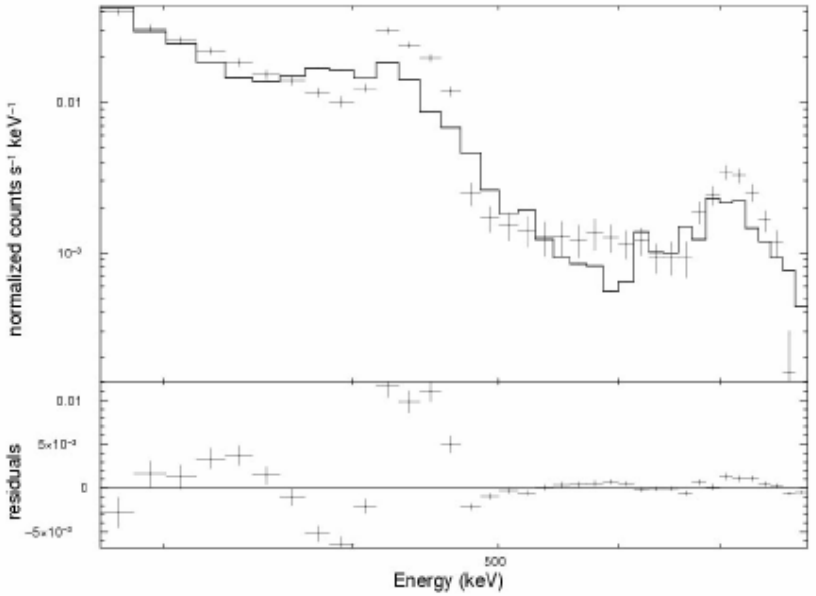


40-300 keV, light curve of incident counts

Spectrum fitting – the line part



(b) 15-55s，260-800keV



(d) 85-128s，260-800keV

时间(s)	能段	λ	Gauss Mean E1	Gauss Mean E2	K	χ^2/ndf
15-55	260-800	3.1±0.5	449±1.4	744±12.7	1.4E+06	15.2
85-128	260-800	4.92±0.04	441±9.6	729±4.9	3.0E+11	18.4

Fitted by power law + two lines

The spectrum show both the continuous and the line emissions

Where are the lines come from?

Time (sec)	E keV	λ	Gauss Mean E1	Gauss Mean E2	K	χ^2/ndf
15-55	260-800	3.1±0.5	449±1.4	744±12.7	1.4E+06	15.2
85-128	260-800	4.92±0.04	441±9.6	729±4.9	3.0E+11	18.4

1, From de-excited ion line:

line around 440 keV:

by (α α) interaction: accelerated α interacted with α in corona (rich helium ion)

or **by: excited ions of ^{7}Be* (439 keV), ^{7}Li* (478 keV)**

line around 730 keV: **by excited ions of ^{10}B* (717keV)**

2, From electron positron annihilation (511keV) and de-excited ^{56}Fe* (847keV). It need about (12~14)% red shift, which implicate the electrons and irons are all running away in a high speed reach to ~40k km. – From LASCO movie, it does in the duration with the maters running away.

---- both are only partially supported.

Summary

- We analyzed three X-class Solar flares during April 2001 which had been observed by SZ2/XD, and the result shown different light curve and spectrum characters.
- SZ2/XD observation traced an accelerate process of ion particles during the 14.4X class of flares in 15 April. Its γ -ray spectrum and two line feature may be the evidence of the particles running away in very high speed, or a possible abundant ions ejection.