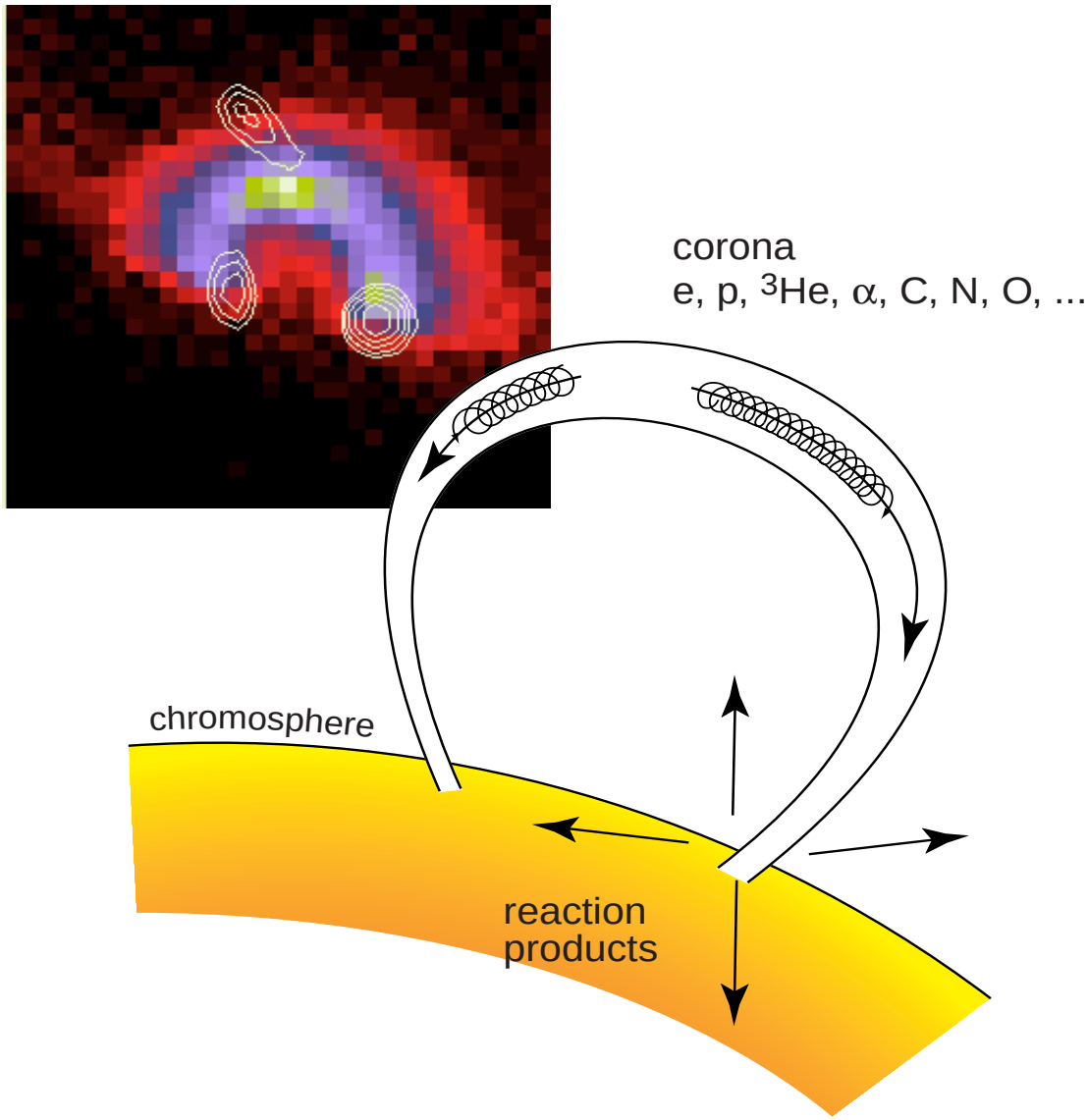
SOLAR-FLARE SCIENCE

- INTRODUCTION
- SUMMARY OF RECENT ADVANCES (*SMM*, *CGRO*, *Yohkoh*)
- EXPECTATIONS FOR HESSI
- THE NEXT SOLAR CYCLE

GAMMA-RAYS and NEUTRONS FROM SOLAR FLARES



electrons: X- and γ-ray bremsstrahlung

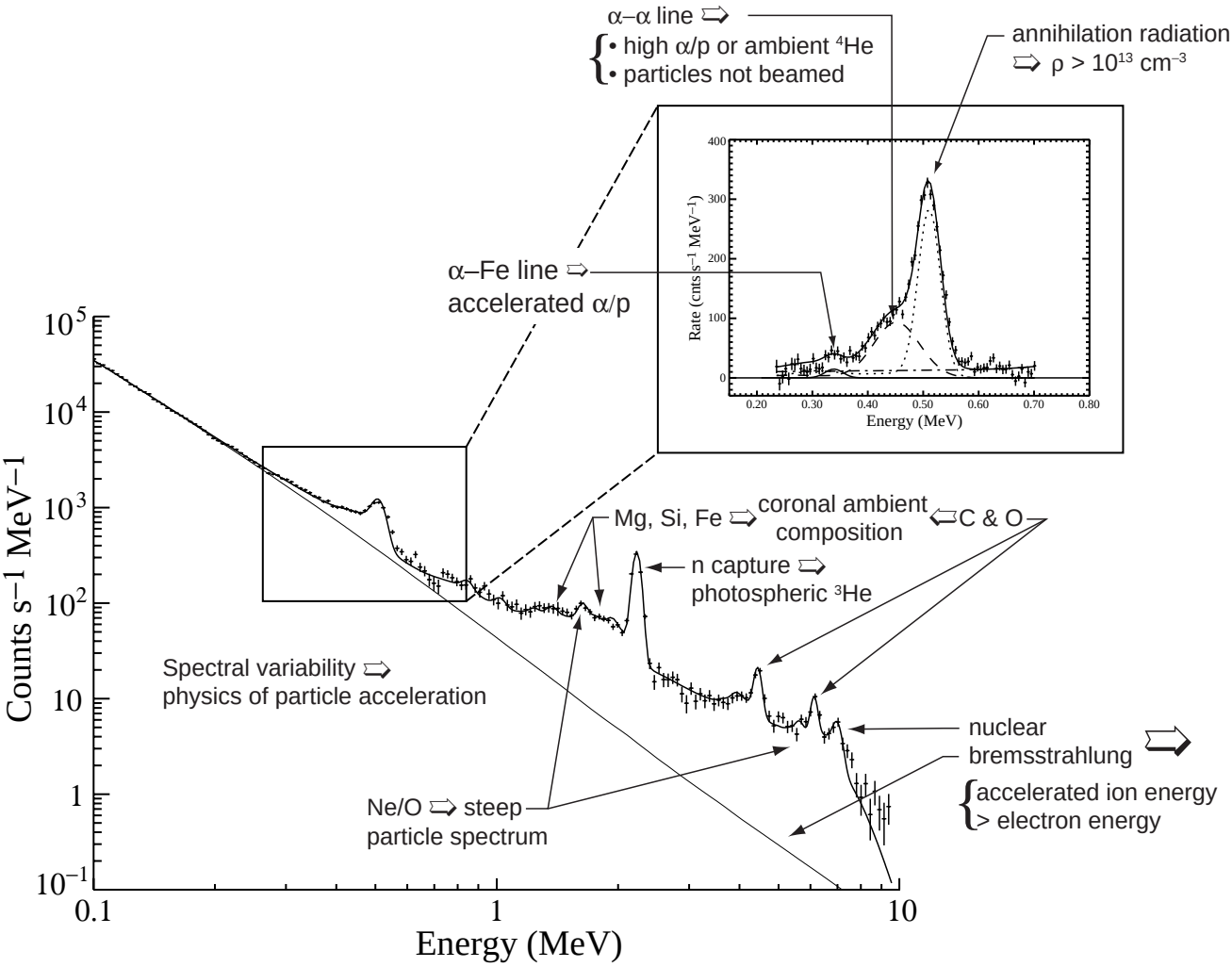
ions: radioactive nuclei $\rightarrow e^+ \rightarrow \gamma_{511}$

$\pi \rightarrow \gamma$ (decay, $e^{\pm}$ bremsstrahlung)

excited nuclei $\rightarrow \gamma$–ray line radiation

neutrons $\rightarrow \begin{cases} \text{escape to space} \\ \text{2.223 MeV capture line} \end{cases}$

FLARE SCIENCE from GAMMA-RAY OBSERVATIONS



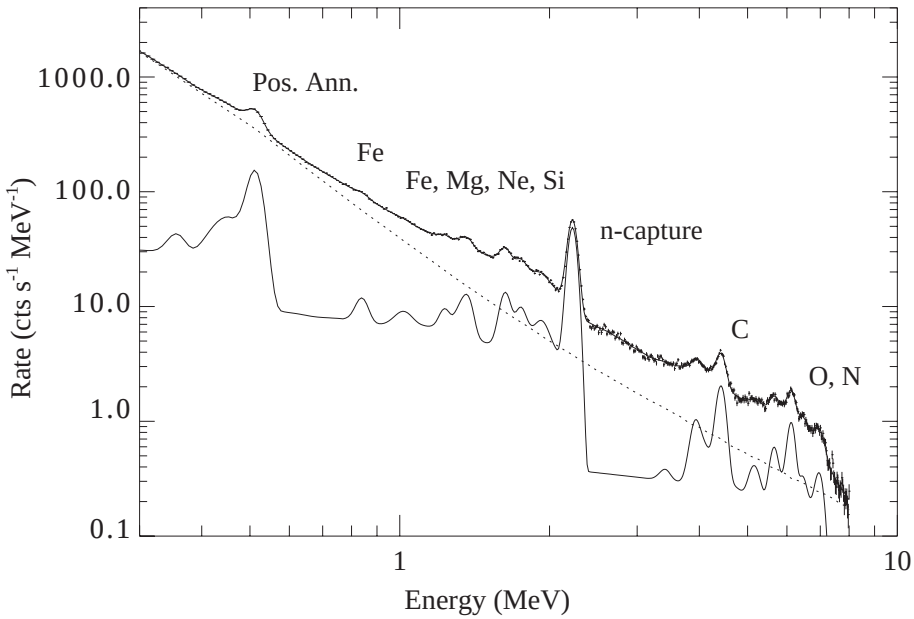
$(p,\alpha) + {}^{12}C \rightarrow {}^{12}C^* \rightarrow \gamma$ (prompt & delayed)

${}^{12}C + (H,He) \rightarrow {}^{12}C^* \rightarrow \gamma$ (prompt & delayed)

$(p,\alpha) + {}^{12}C \rightarrow {}^{11}C^*$ (20 min) $\rightarrow e^+ \rightarrow \gamma$ (0.511 MeV)

$(p,\alpha) + (He,H) \rightarrow n \rightarrow \gamma$ (2.223 MeV, delayed)

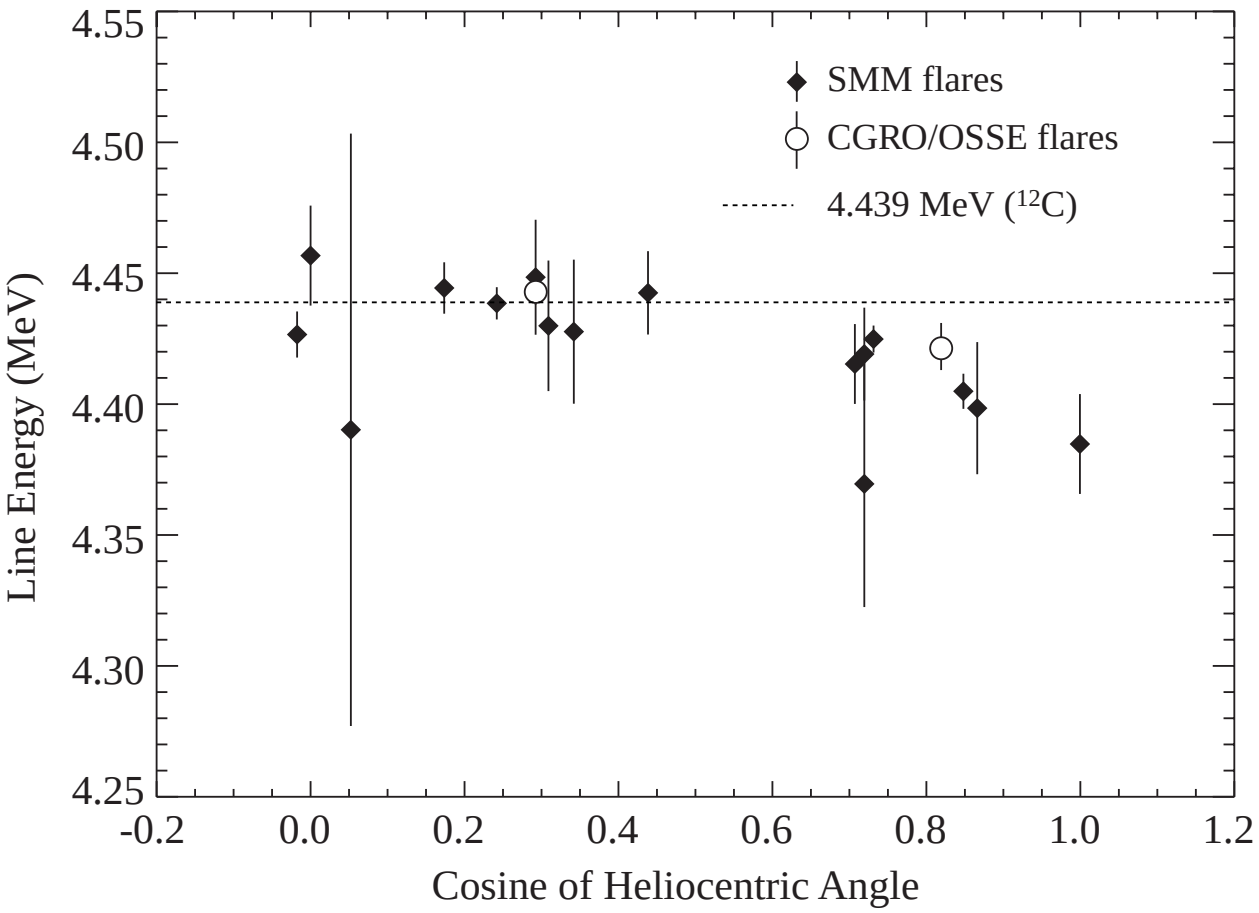
GAMMA-RAY LINES



Narrow Lines Observed in Solar Flare gamma-Ray Spectra

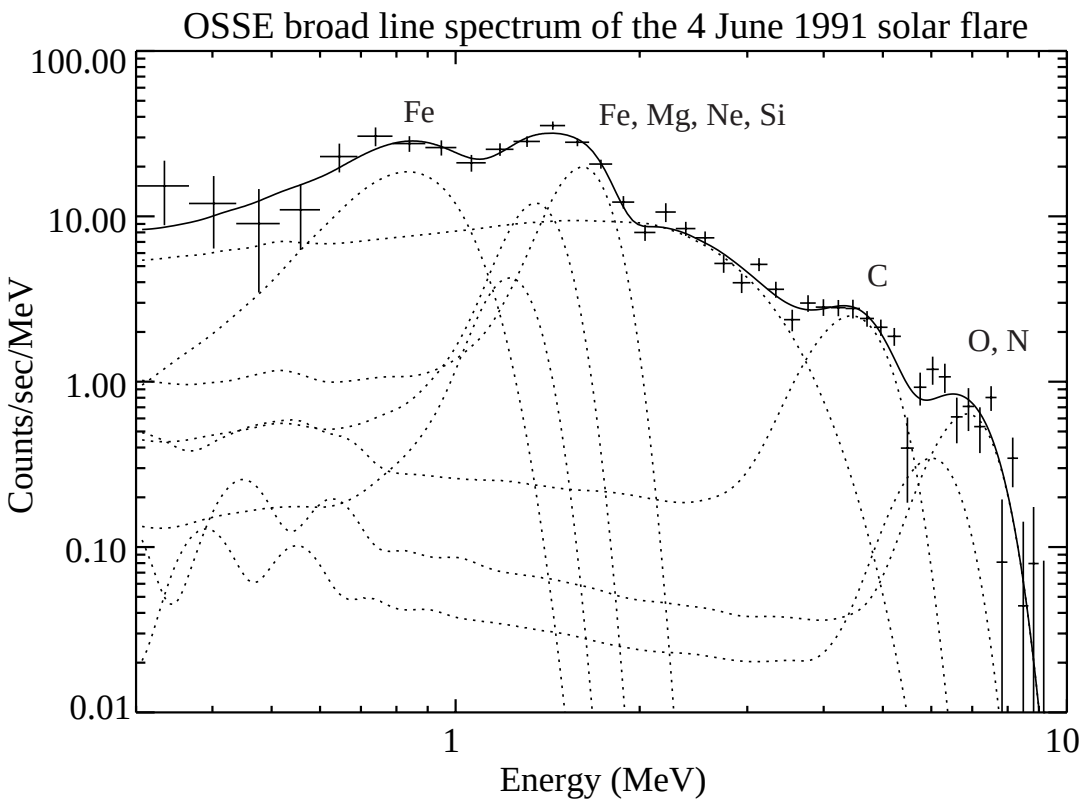
Energy (MeV)	Width (%FWHM)	Identification (Energy, MeV)
~0.35	---	^{59}Ni (0.339)
0.452 ± 0.003	17 ± 2	^{7}Be,^{7}Li (0.429, 0.478)
0.513 ± 0.002	<2	e^{+}-e^{-} annihilation (0.511)
~0.841	---	^{56}Fe (0.847)
0.937	---	^{18}F (0.937)
1.03 ± 0.01	7 ± 3	^{18}F,^{58}Co,^{58}Ni,^{59}Ni (1.00/4/5/8)
1.234	---	^{56}Fe (1.238)
1.317	---	^{55}Fe (1.317)
1.371 ± 0.005	1.9 ± 2.0	^{24}Mg (1.369)
1.630 ± 0.002	2.8 ± 0.5	^{20}Ne (1.633)
1.781 ± 0.005	3.0 ± 1.4	^{28}Si (1.779)
2.221 ± 0.001	<1.5	n-capture on H (2.223)
2.27	---	^{14}N,^{32}S (2.313, 2.230)
3.332	---	^{20}Ne (3.334)
4.429 ± 0.003	3.5 ± 0.3	^{12}C (4.439)
5.300	---	^{14}N,^{15}N,15O
6.134 ± 0.005	2.3 ± 0.3	^{16}O (6.130)
6.43	---	^{11}C (6.337, 6.476)
6.981 ± 0.012	4.1 ± 0.4	^{14}N,^{16}O (7.028, 6.919)

DOPPLER SHIFTS of GAMMA-RAY LINES



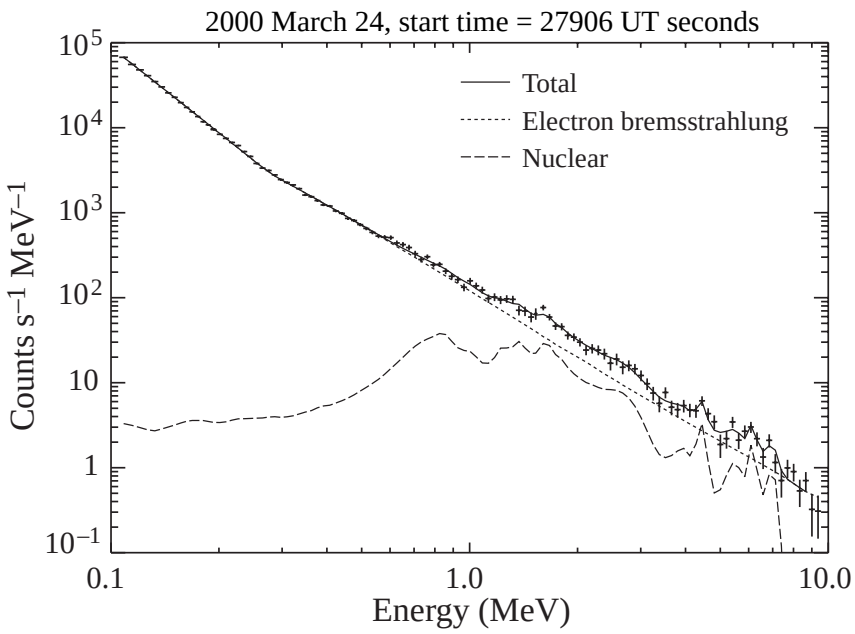
- Downward-directed distribution
- Imhomogeneous interaction region

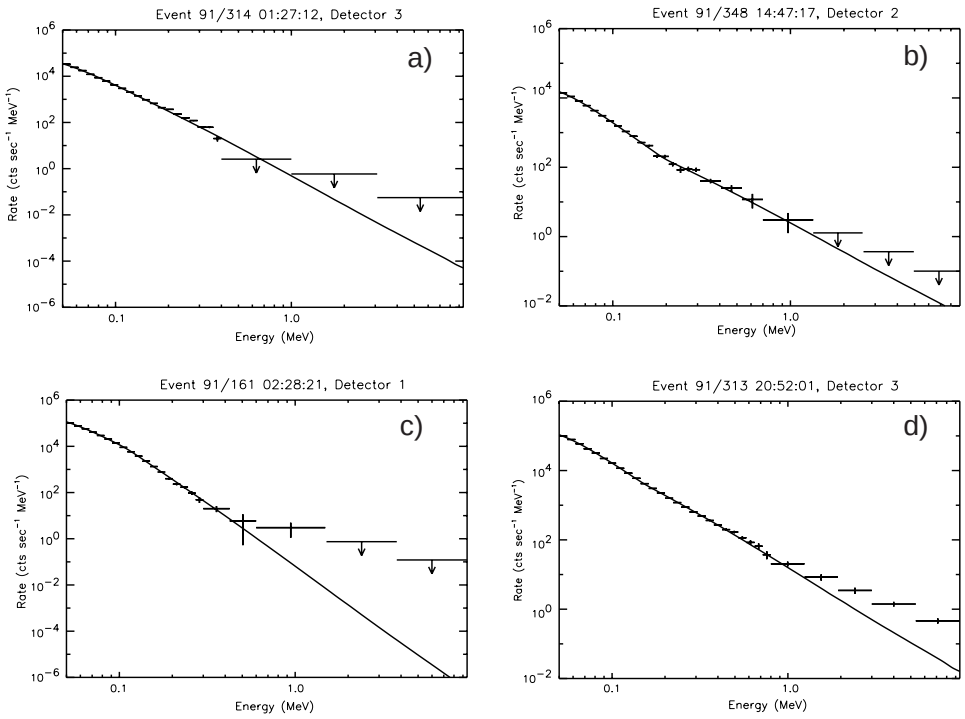
BROAD LINES from ACCELERATED HEAVY IONS



➠ Accelerated Fe/C abundance is enhanced relative to that found in the corona

ELECTRON BREMSSTRAHLUNG





HIGH ENERGY SOLAR SPECTROSCOPIC IMAGER (HESSI)

Energy range: ~5 keV–8 MeV

Energy resolution: 3–5 keV @ few MeV

Angular resolution: ~2 arcsec for hard X rays (up to 200 keV)
3 arcmin at few MeV

Will do well with narrow line such as 0.511 keV, 2.223 MeV, radioactive lines and capture lines

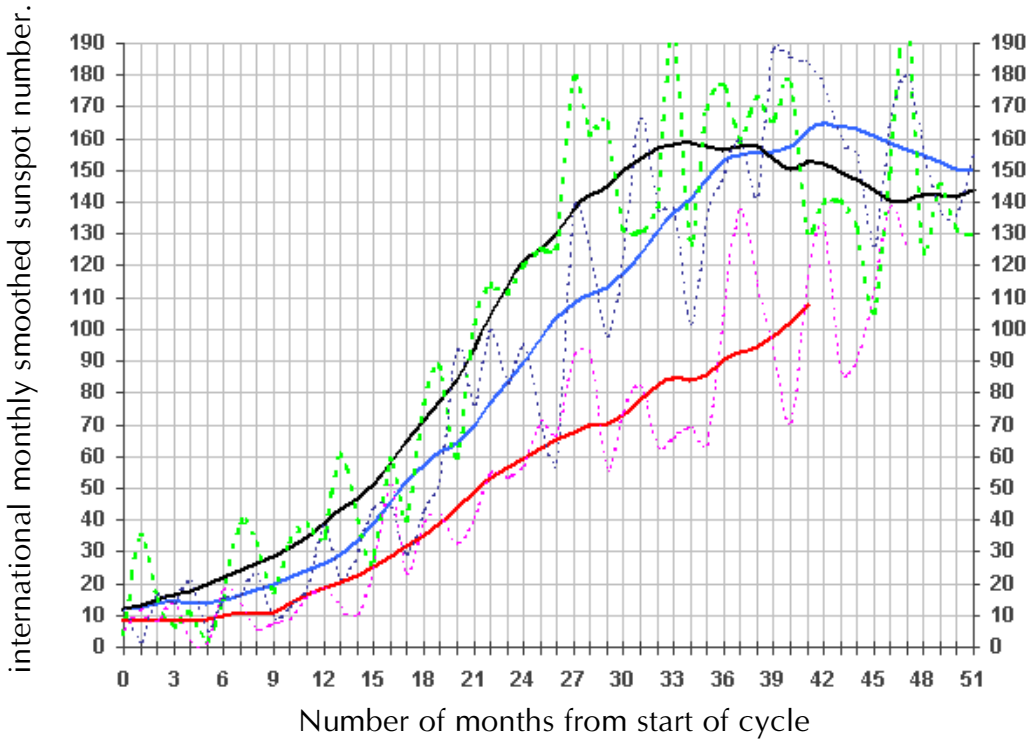
But no Compton rejection — poor determination of broad lines and continua

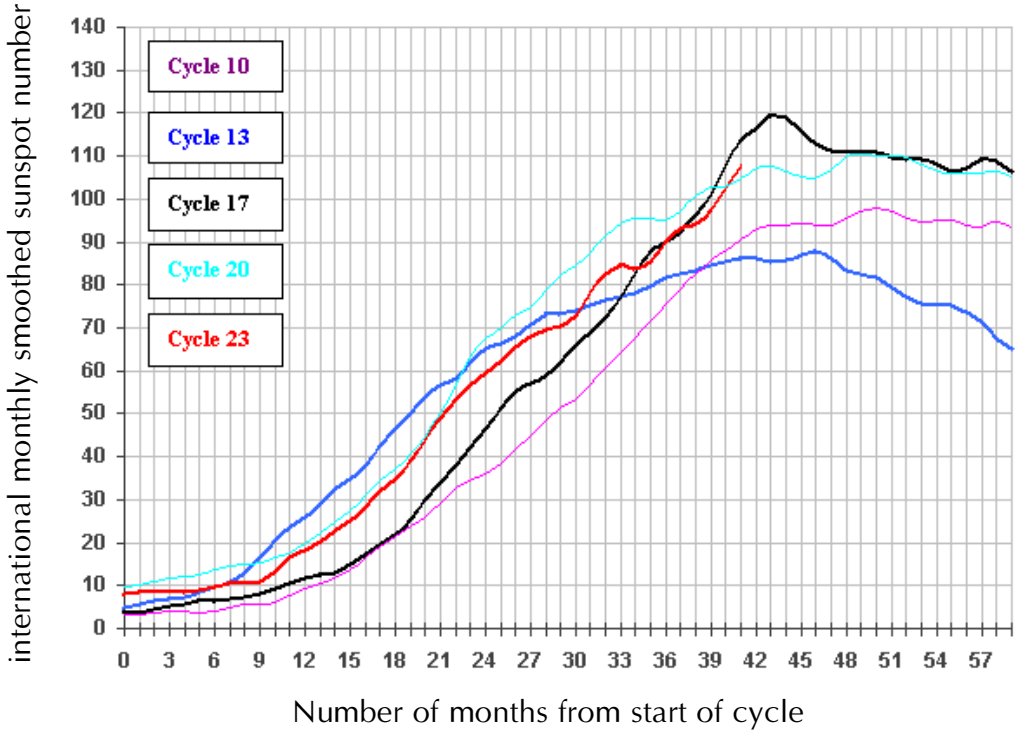
Launch is postponed until January 2001

Comparison of Photopeak Areas

Energy (MeV)	HESSI (cm^2)	OSSE On-axis (cm^2)	OSSE Off-axis (cm^2)	SMM (cm^2)
0.339	177	1088	—	160
0.511	107	994	—	148
1.369	61.5	682	102	85
2.223	44.7	524	114	61
4.439	17.7	378	87	38
6.129	9.5	324	71	31

CYCLE 23 PROGRESS





NEXT SOLAR MAXIMUM (2010)

PROPOSED

Place a HESSI-like detector at 0.2 AU
⇒ without advance in technology, achieve:
25× improvement in effective area
5× improvement in angular resolution

REQUIREMENTS FOR LEO MISSION

Effective Area: at least several hundred cm^2 at a few MeV (comparable to OSSE, not HESSI)

Energy resolution: 3–5 keV

Angular resolution: ~5 arcsec at several MeV

Continuous spectroscopy from 10 keV to 10 MeV

Diagonal response: want to be able to use photopeak only for measurement of continuum and also total response to maximize effective area

Polarization

Advantages of spatially-sensitive detectors + mask
(vs. rotating collimator + "bolometer"):
More effective area
Close-pack detectors (square geometry) to improve photopeak fraction

Disadvantages
Added complexity
To achieve few-arcsec resolution with a standard 3-m boom will require ~30-μ spatial sensitivity (comparable to HESSI 30-μ grid pitch)