Future Japanese X-ray missions and the cluster study --- NeXT ---

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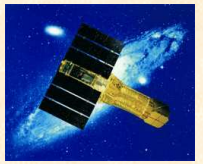
1. Japanese X-ray missions
2. NeXT mission: hardware design
3. Expected science on clusters

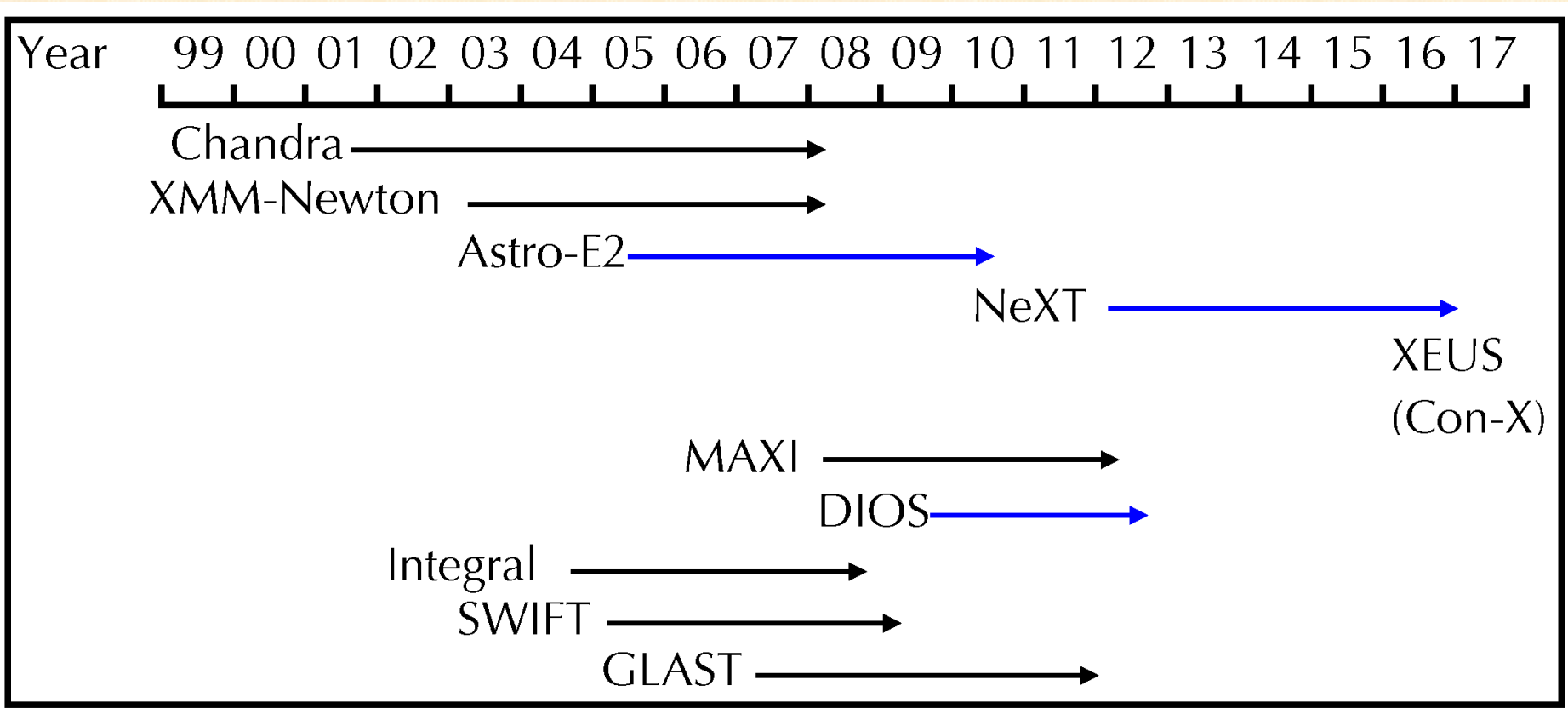
Japanese X-ray missions

- Hakucho (1979): X-ray bursts, Galactic binaries
- Tenma (1983): Fe line from Galactic sources
- Ginga (1987): Fe line from G. ridge, AGN, Clusters
- ASCA (1993): First imaging spectroscopy
- Astro-E2 (2005): Microcalorimeter (ΔE = 6 eV)
- DIOS (~2009): Missing baryon
- NeXT (~2012): Hard X-ray image & μ-calorimeter



Energy axis: resolution, dynamic range, image

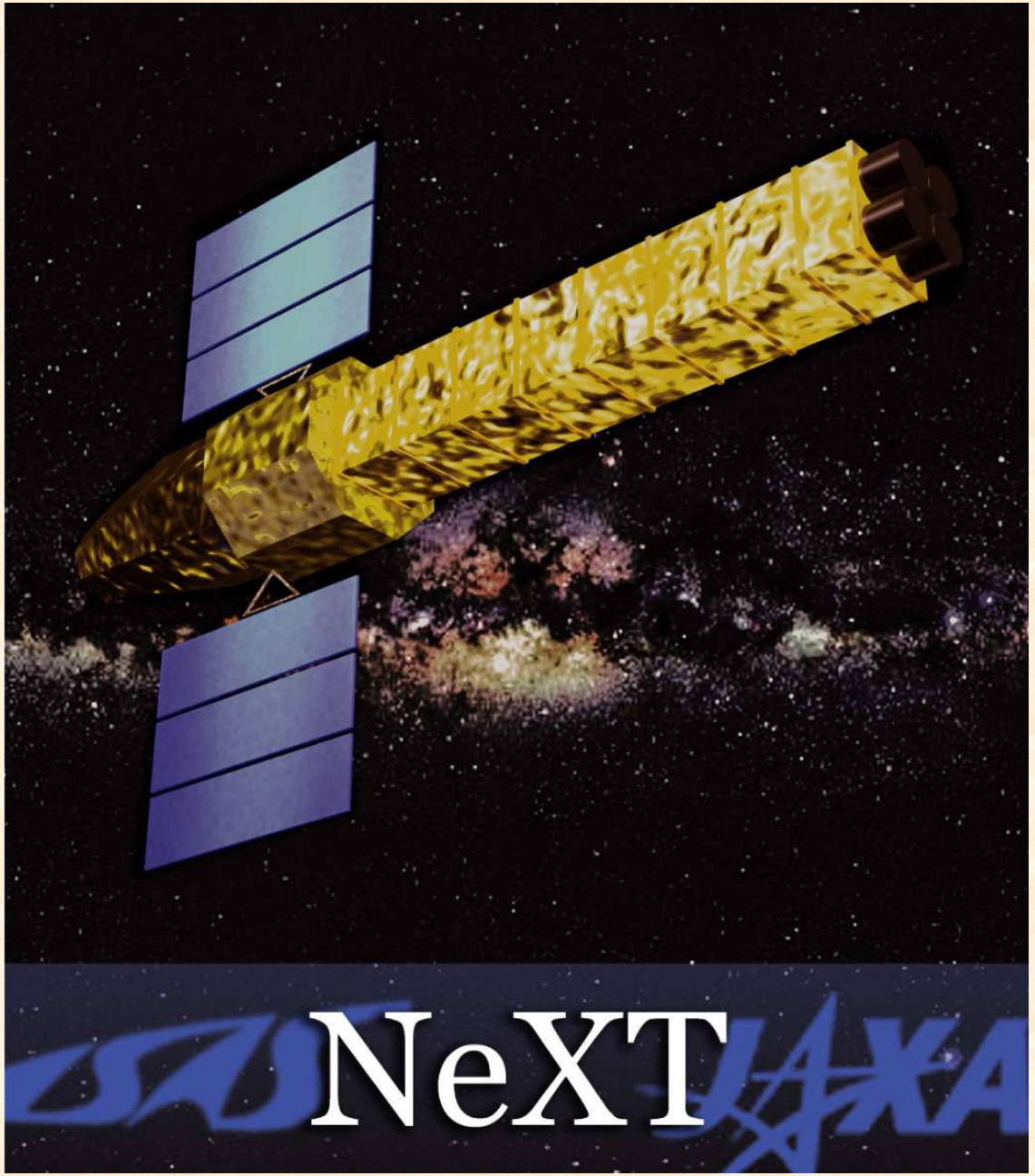
X-ray and γ-ray missions



NeXT

New X-ray Telescope

Length: 5 m →13 m
Diameter : < 2.2 m
Weight: 1700 kg
(Payload 860 kg)
Power: 1070 W
(2900 W generated)
Launch: 2012 Jan-Feb
M-V Rocket
Orbit: 550 km circular
Inclination: < 31°



NeXT Working Group

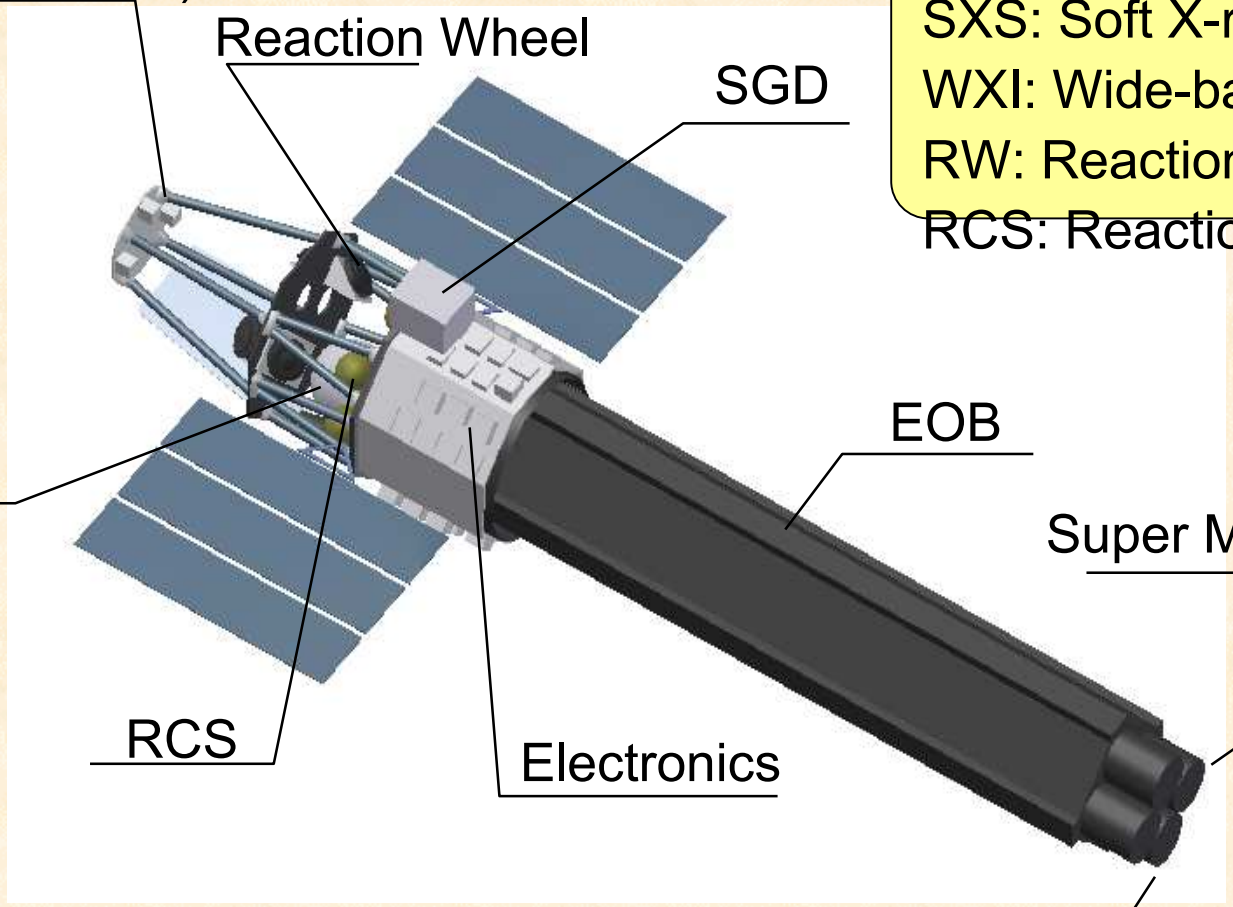
- ISAS/JAXA
- University of Tokyo
- Saitama University
- RIKEN
- Rikkyo University
- Kougakuin University
- Tokyo Metropolitan University
- Tokyo Institute of Technology
- Aoyama Gakuin University
- Nagoya University
- Kanazawa University
- Kyoto University
- Osaka University
- Ehime University
- Hiroshima University

Concept of NeXT

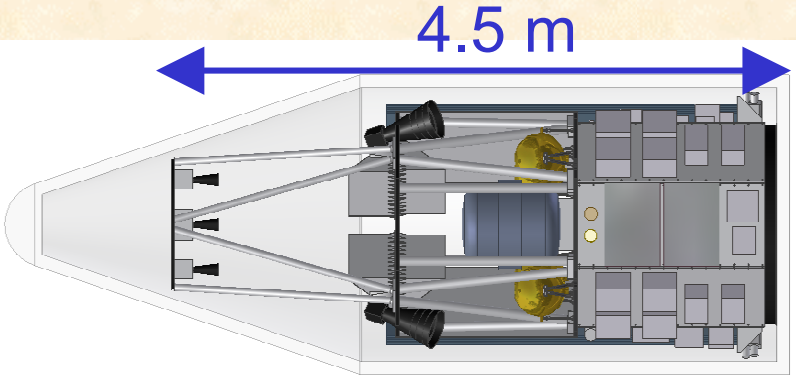
- Hard X-ray imaging of non-thermal emission
  - Supermirror hard X-ray telescope: 3 identical units, 750 cm^2 @ 30 keV, sensitive to 80 keV
  - Focal length = 12 m, ang. resolution = 30"--60"
- Broad band coverage
  - Soft γ-ray detector (Compton telescope): 10 keV -- 1 MeV
- High resolution spectroscopy
  - TES calorimeter array: ΔE = 2 eV, ~1000 pixels
  - 1 soft X mirror with focal length 9 m

NeXT

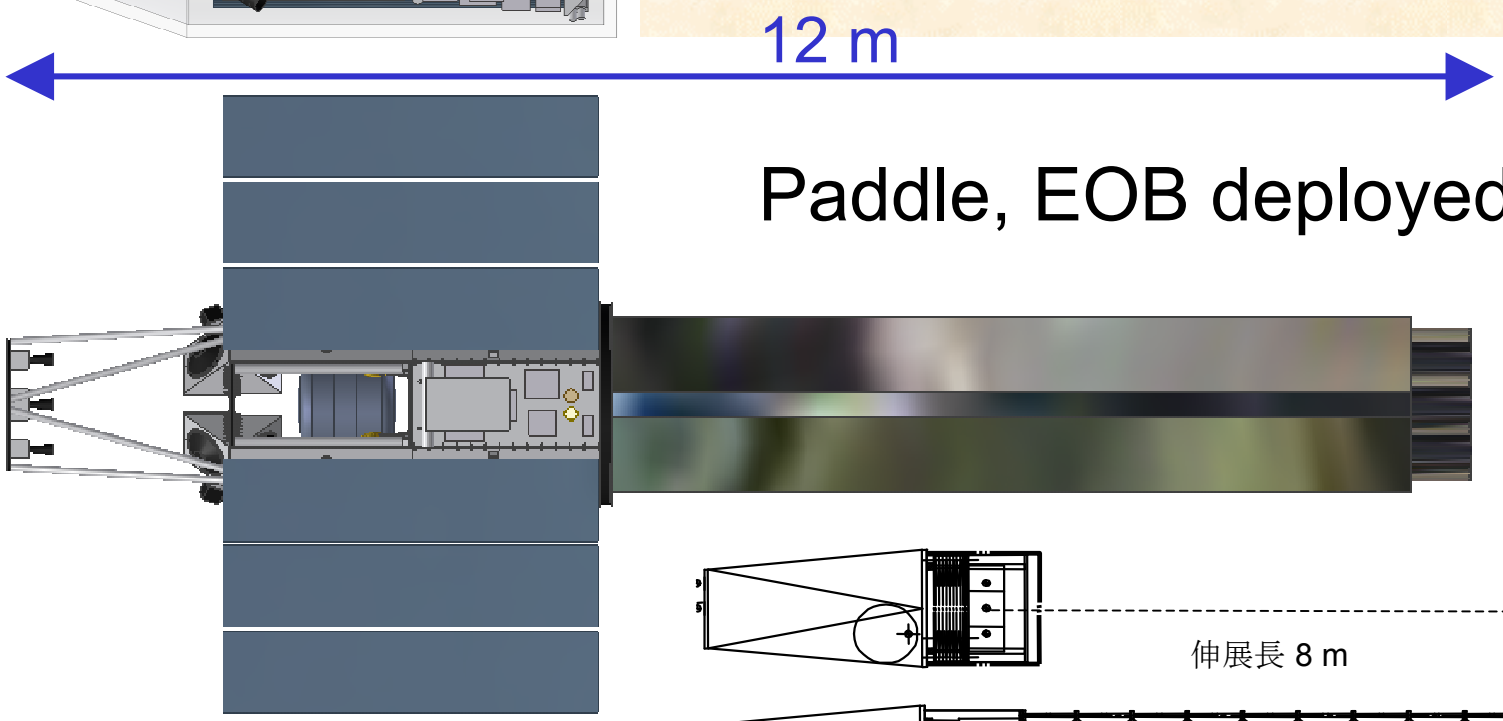
HXT/SXT: Hard/Soft X telescope
EOB: Extensible optical bench
SGD: Soft γ-ray detector
SXS: Soft X-ray spectrometer
WXI: Wide-band X-ray imager
RW: Reaction wheel
RCS: Reaction control system



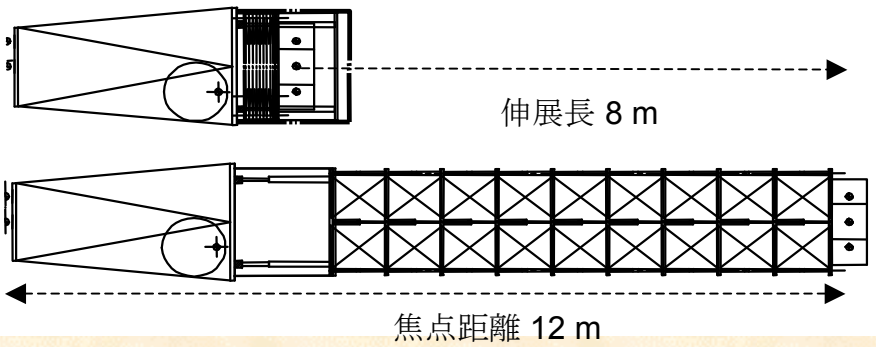
Extensible optical bench



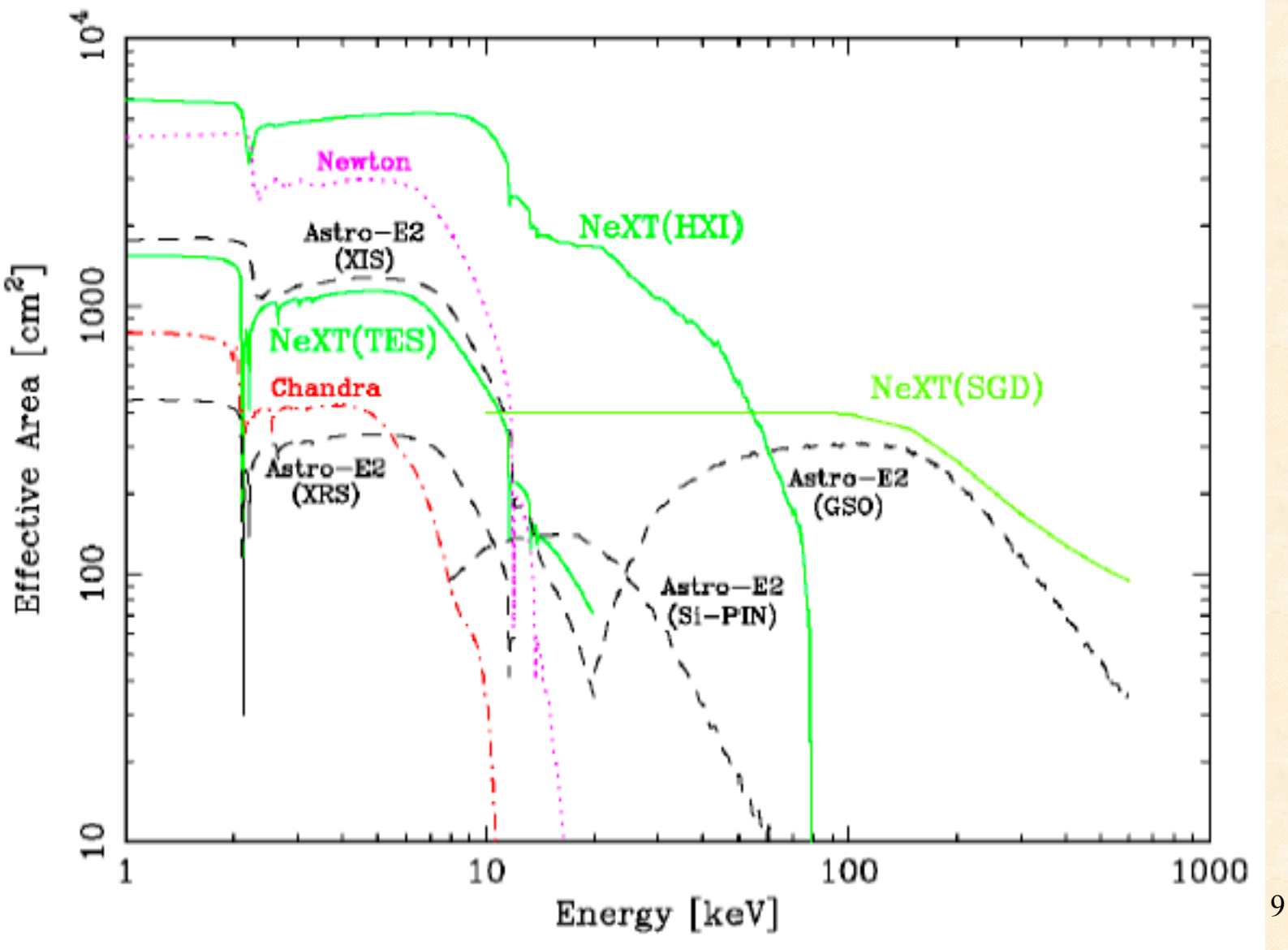
Launch configuration



Paddle, EOB deployed



Effective area vs energy

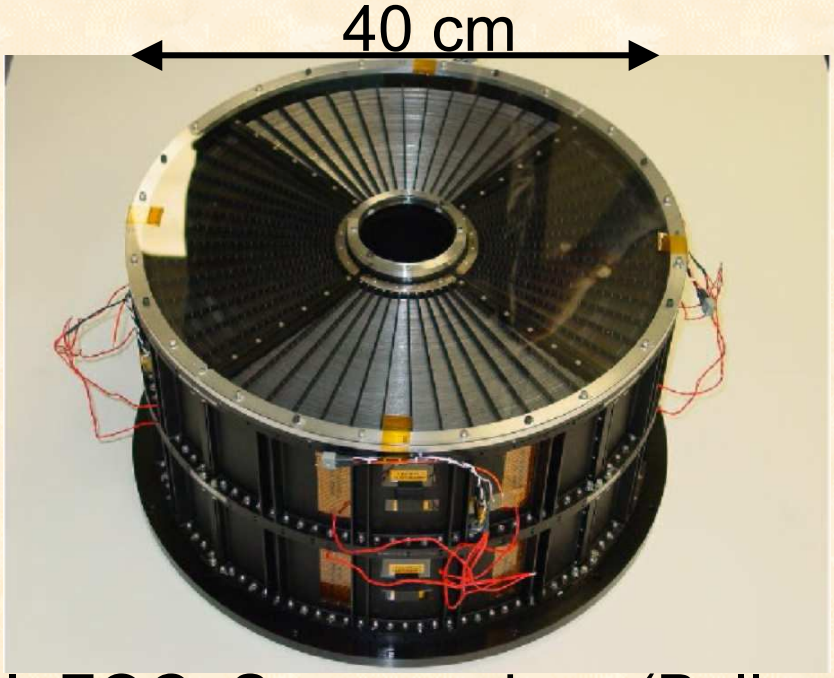


Hard X-ray telescope

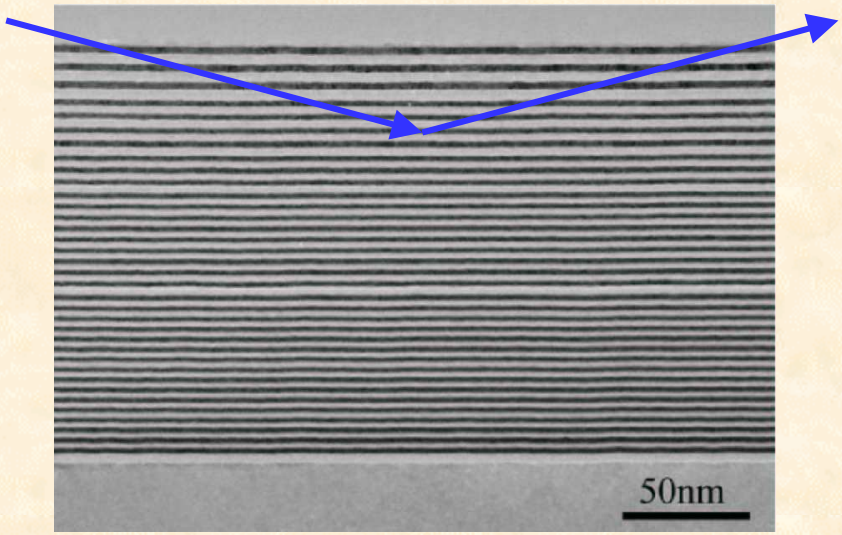
Supermirror multilayer coating
True imaging up to 80 keV
50 cm dia x 3 units

(at 30 keV)	Goal
Effective Area	750 cm^2
Energy range	0.5 - 80 keV
Angular resolution	30-60 arcsec
Field of view	8 arcmin
Focal length	12m (3 HXT) 9m (1 SXT)

Pt -K edge = 78 keV



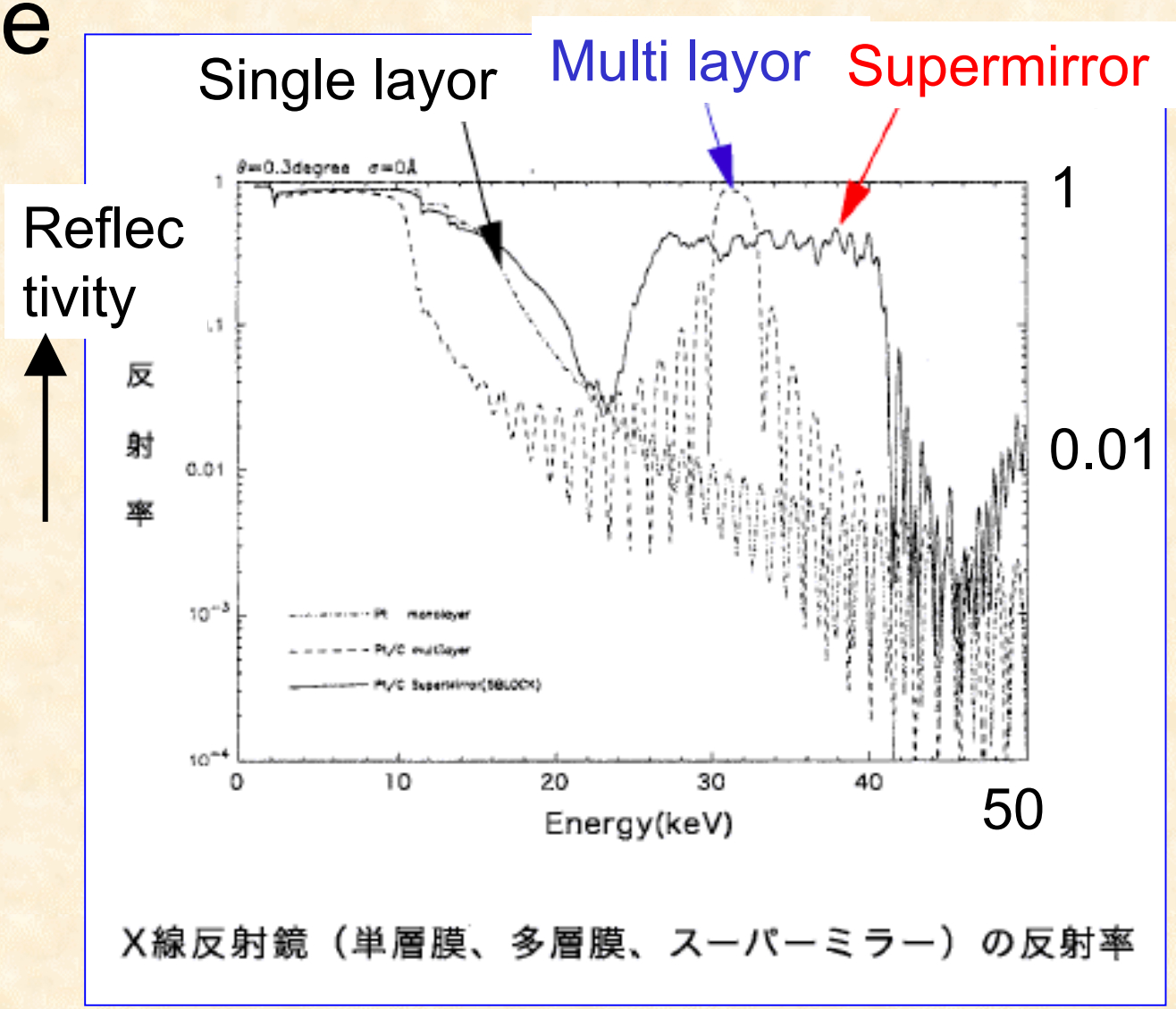
InFOCμS supermirror (Balloon)



Cross section of (235) multi-

Hard X-ray telescope

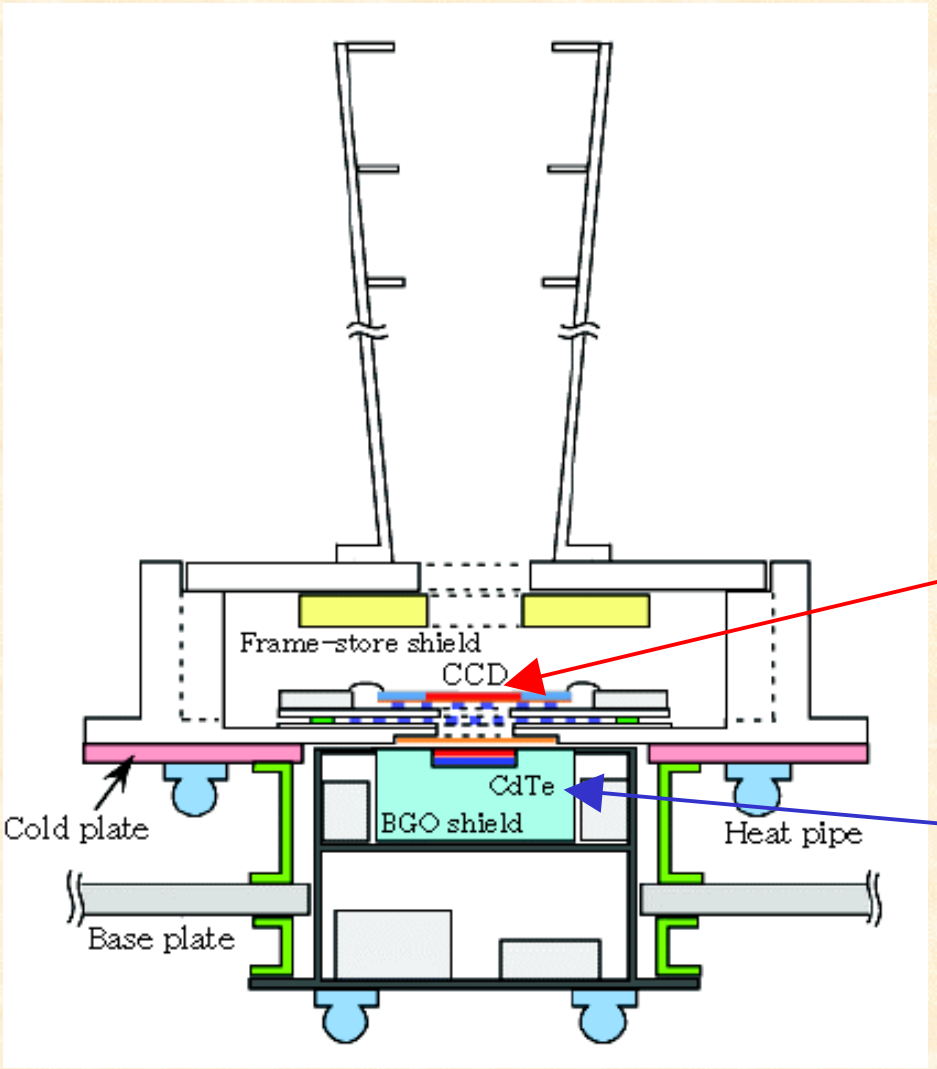
High throughput mirror
+
Supermirror coating

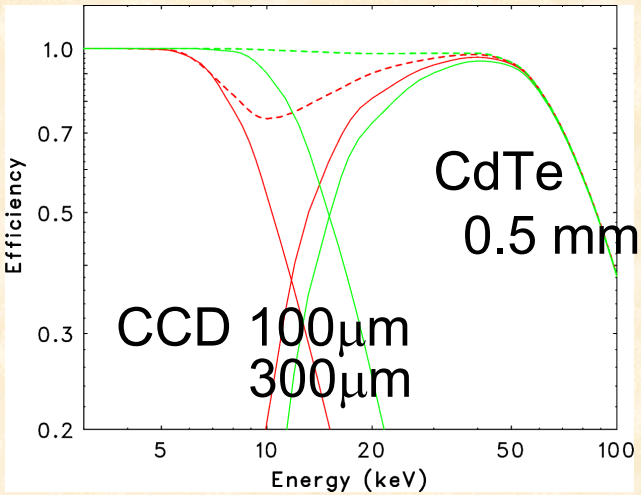


X線反射鏡（単層膜、多層膜、スーパーミラー）の反射率

Wide-band X-ray Imager

Hybrid concept



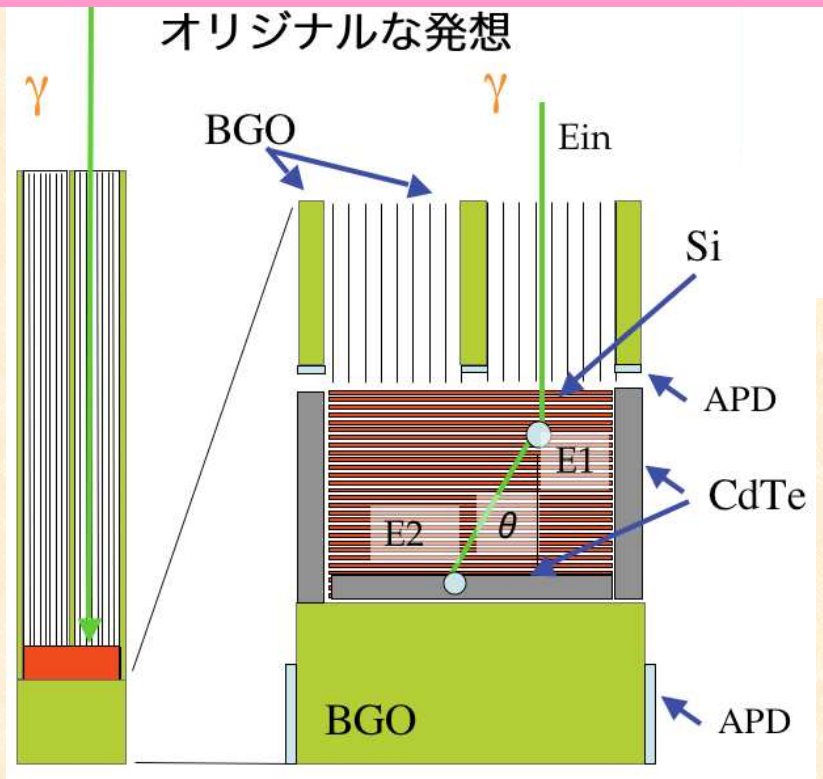


Soft-X (< 20 keV)
Half transparent CCD
~50 x 50 mm (14')

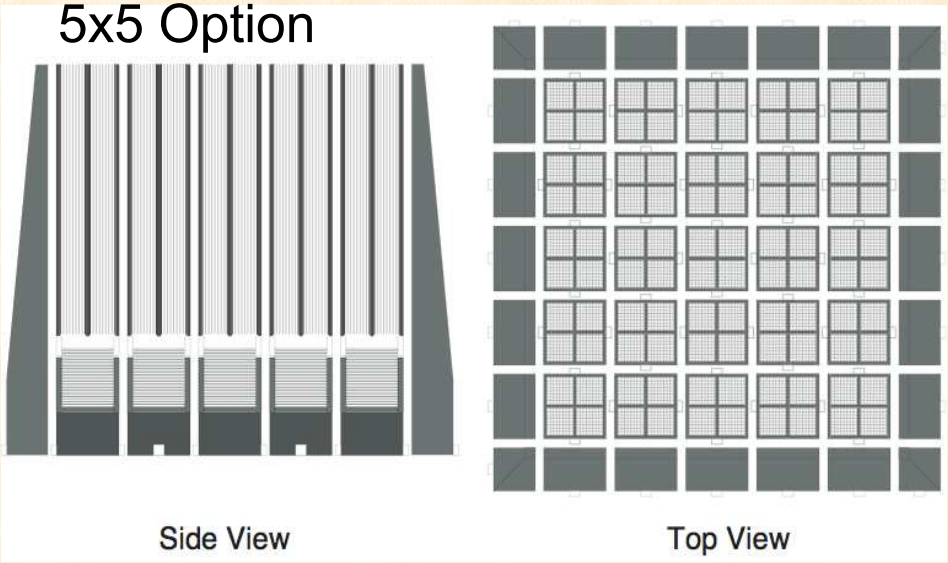
Hard-X (> 10 keV)
CdTe Pixel detector
(100x150 pix), 20 x 30 mm

Soft γ-ray detector

Narrow field Compton camera



5x5 Option



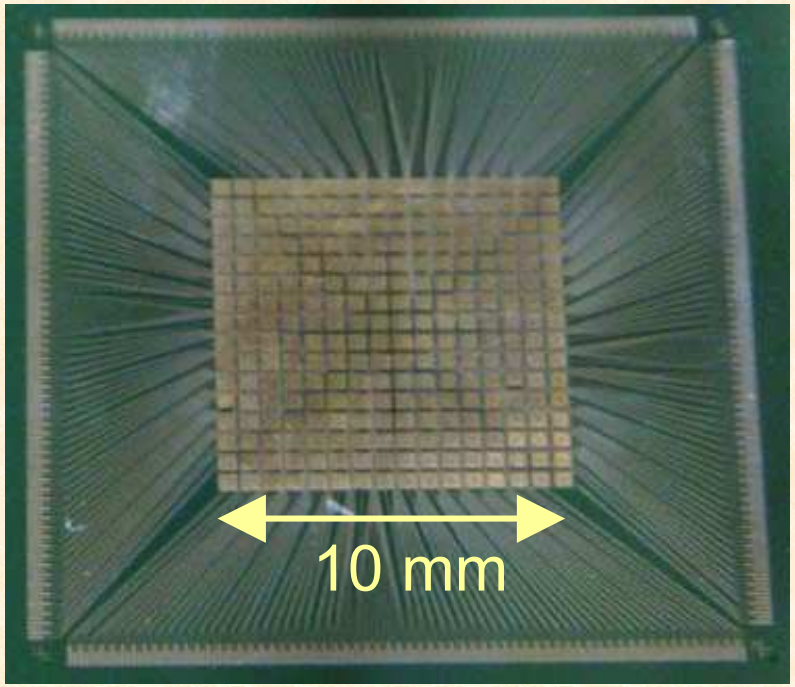
Energy range	10 keV – 1 MeV
ΔE	2 keV (FWHM, @40keV)
Eff area	625 cm^2
Field of view	0.6x0.6 – 4x4 deg^2
Ang resol	1.5° (Compton mode, 500 keV)

Si strip + CdTe pixel detector

Compton requirmnt → low backgnd

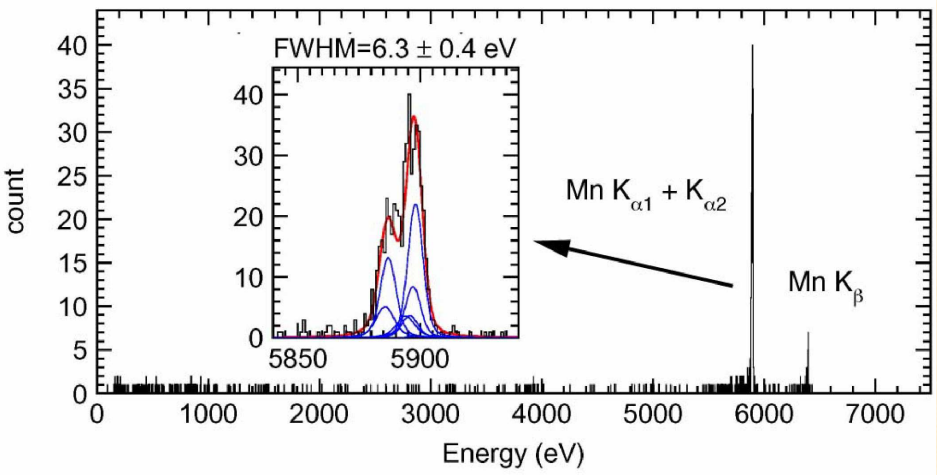
Soft X-ray spectrometer

TES calorimeters
256 pixel test model

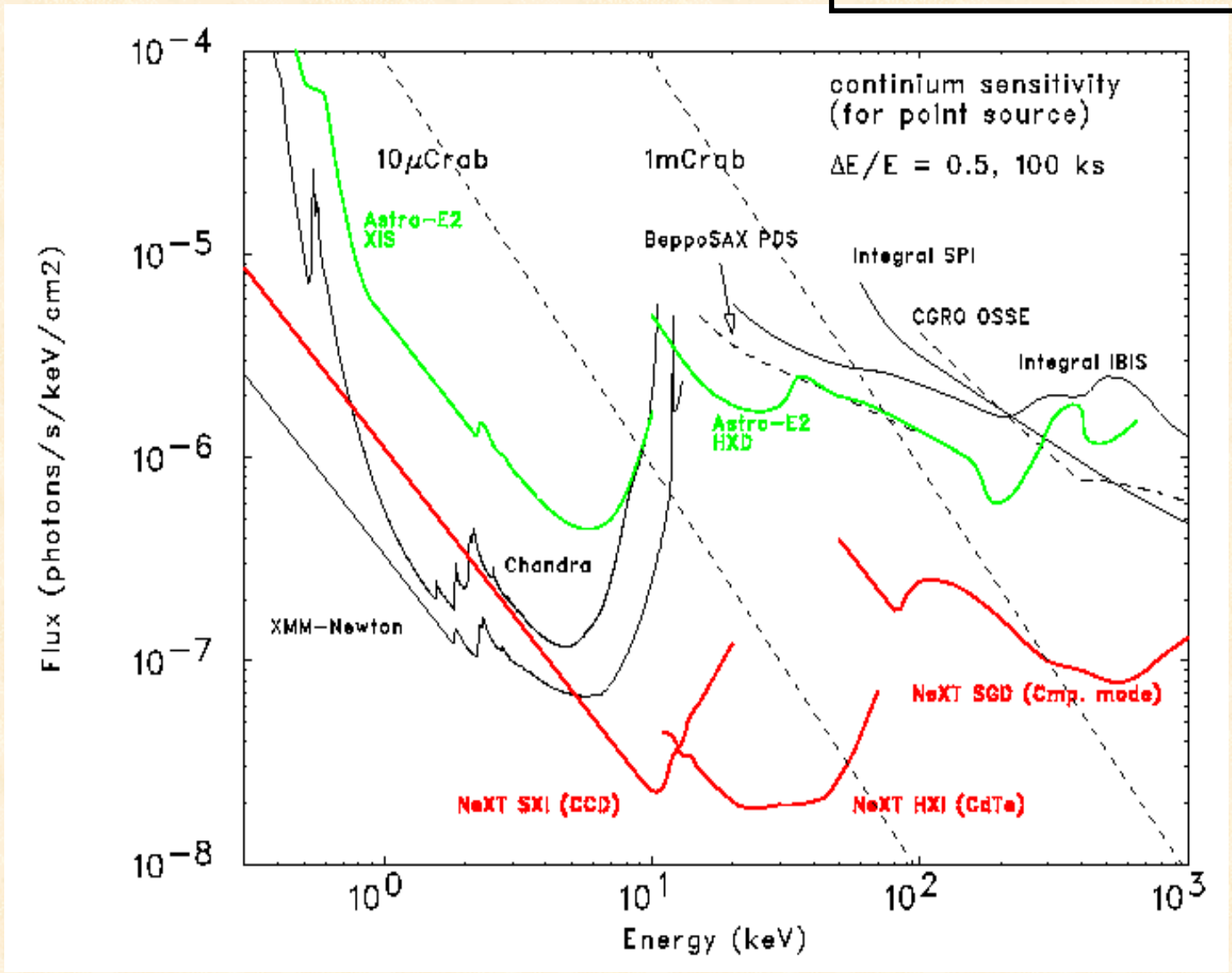


Energy range	0.3-10 keV
Resolution	2eV (FWHM @6keV)
Size	12~16 mm square
FOV	6 ~ 8 arcmin
SΩ	7~13 deg^{2}cm^2 (7 keV)
Count rate	100 c/s/pixel
Life	> 5 yr

ΔE=6 eV with single pixel



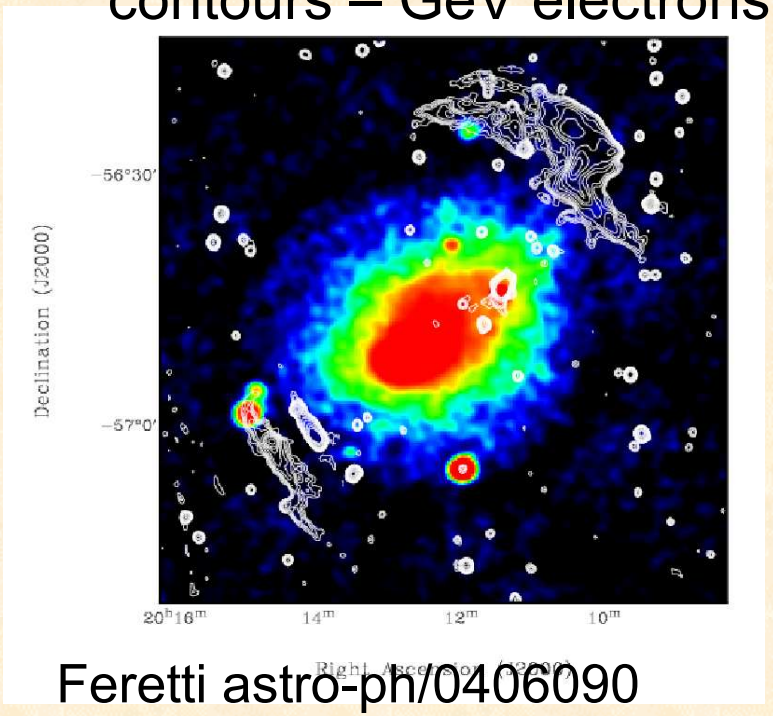
Sensitivity



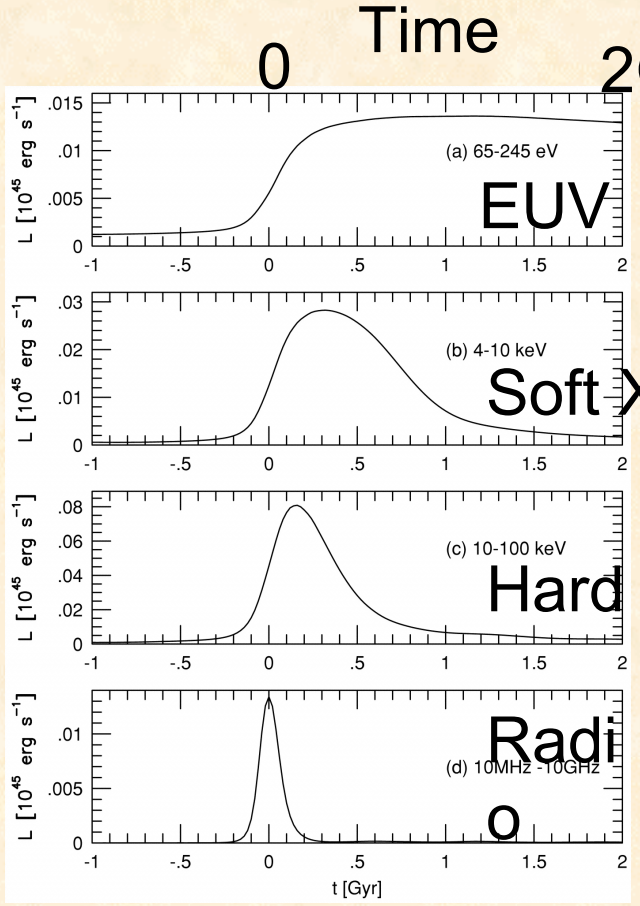
Cluster Science from NeXT

Non-thermal electrons

A3667: X-ray & 843 MHz contours – GeV electrons



Feretti astro-ph/0406090



- $L_{\text{Hard-X}} / L_{\text{Radio}} = U_{\text{MWB}} / U_B \sim 1$

  $\Rightarrow \; L_{\text{Hard-X}} \sim L_{\text{Radio}} \sim 10^{41}$ erg s^{-1}

… achievable with NeXT

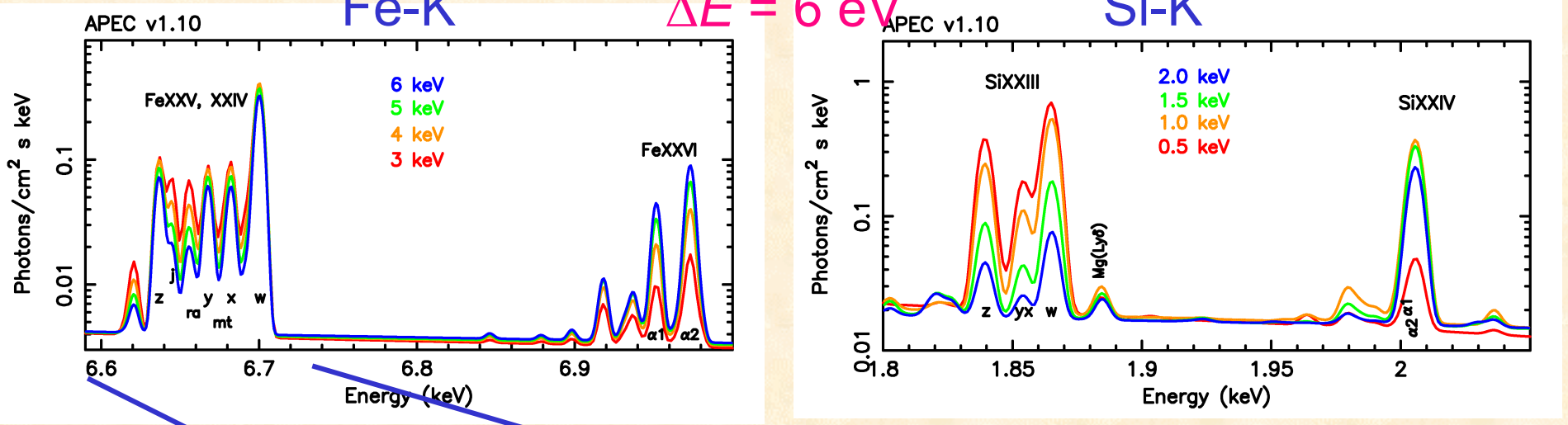
Acceleration in merger
Takizawa & Naito 00,
ApJ 535, 586

Cosmic rays in clusters

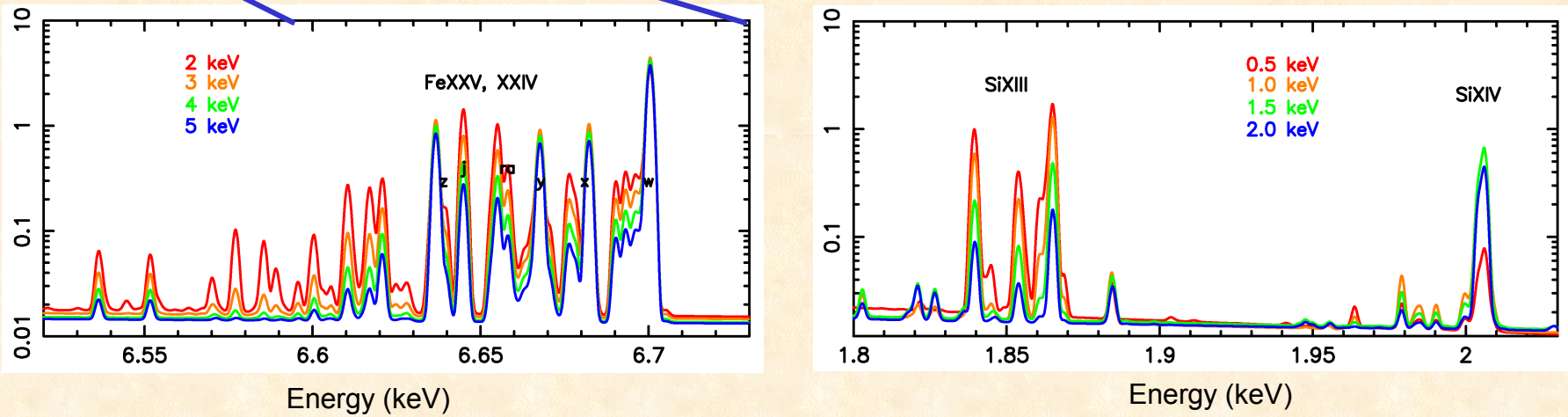
- Diffusive shock acceleration: $E_{max} \sim 10^{15}$ eV
  Cosmic-ray pressure: $P_{CR} \sim 0.2\, P_{therm}$
  (Miniati et al. 2001)
- Larmor radius ρ :
  $E \cong 10^{19}$ eV $(\rho/100$ kpc$)(B/0.1\ \mu$G$)$
- Diffusion loss: $E > 10^{16\text{-}18}$ eV $(D \sim c\rho/3)$
- Observational signatures:
  - Excess cosmic-rays toward Virgo cluster (?)
  - π_0 decay ⇒ ~135 MeV hump ⇒ GLAST
  - Proton-electron bremsstrahlung ⇒ Hard X-rays from widespread regions in a cluster ⇒ NeXT

Spectroscopy with ΔE=2eV

Fe-K ΔE = 6 eV Si-K



ΔE = 2 eV



Study of gas bulk motion, turbulence, ion temperature …

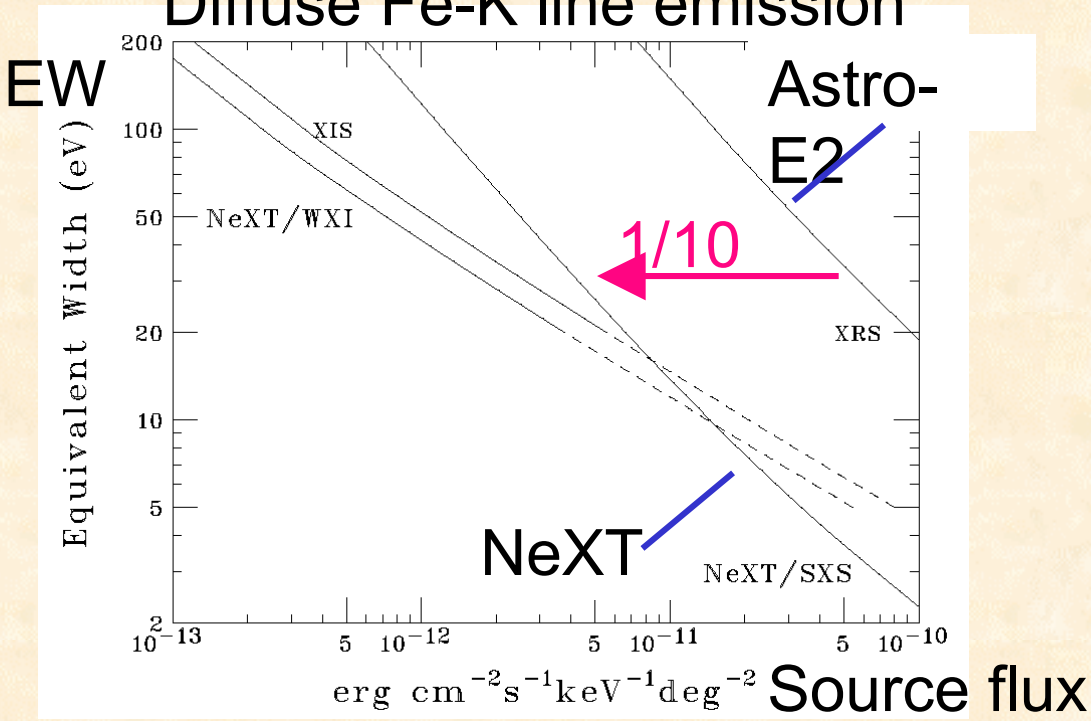
Microcalorimeter performance		
	Astro-E2	NeXT
ΔE	6 eV	2 eV (Goal)
Area	300 cm^2	900 cm^2
Ω	9 min^2	~64 min^2

Finding distant iron

NeXT is 10 times more sensitive than Astro-E2 for diffuse Fe-K line

Fe line from distant clusters and groups of galaxies can be studied out to $z \sim 1$

Diffuse Fe-K line emission



Summary

- NeXT (~ 2011) will fill the gap in the continuation of X-ray study
- First true image of the non-thermal universe at ~ 80 keV by supermirror technique
- With high sensitivity spectrum up to 1 MeV with narrow-field Compton camera
- Doppler spectroscopy with large-area micro-calorimeters: probing gas motion in the acceleration region
- Line spectra from distant clusters and groups of galaxies