Gamma-ray Observation in Space

Synergy between X-ray and Gamma-ray Observation present and future

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Hiroshima Univ.

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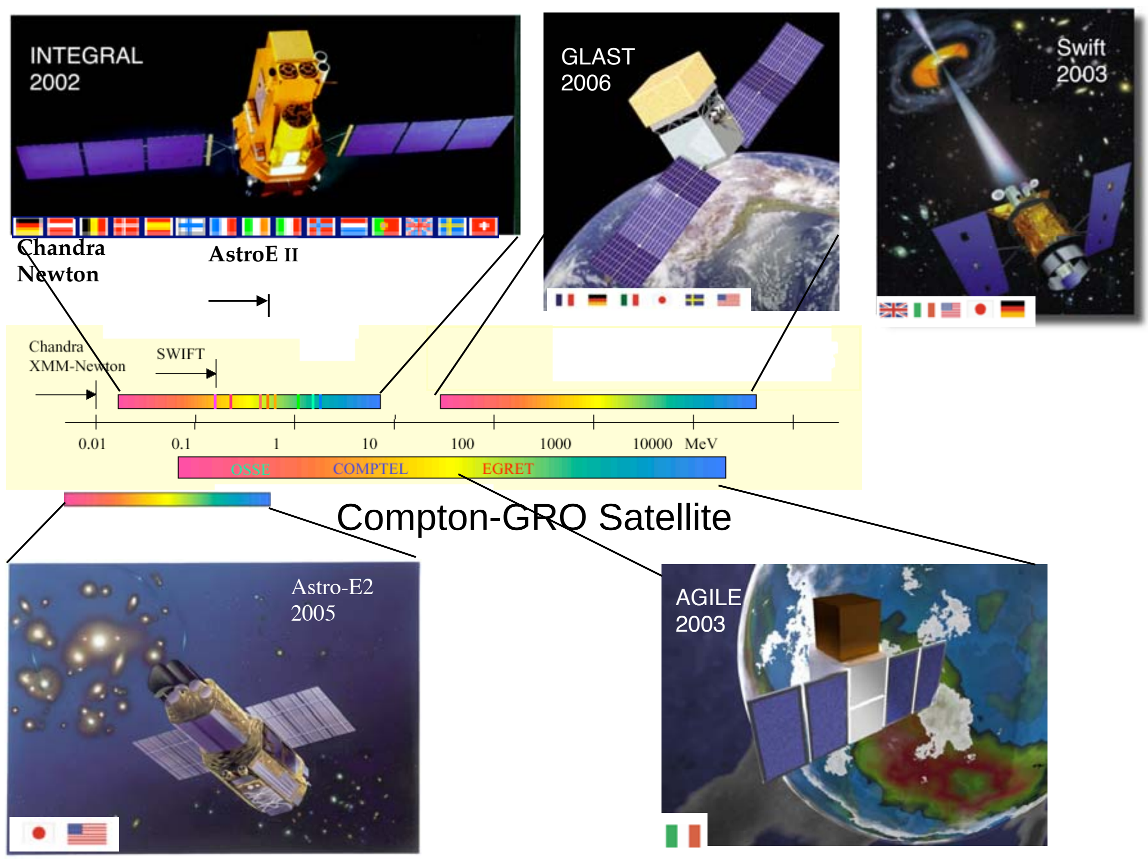
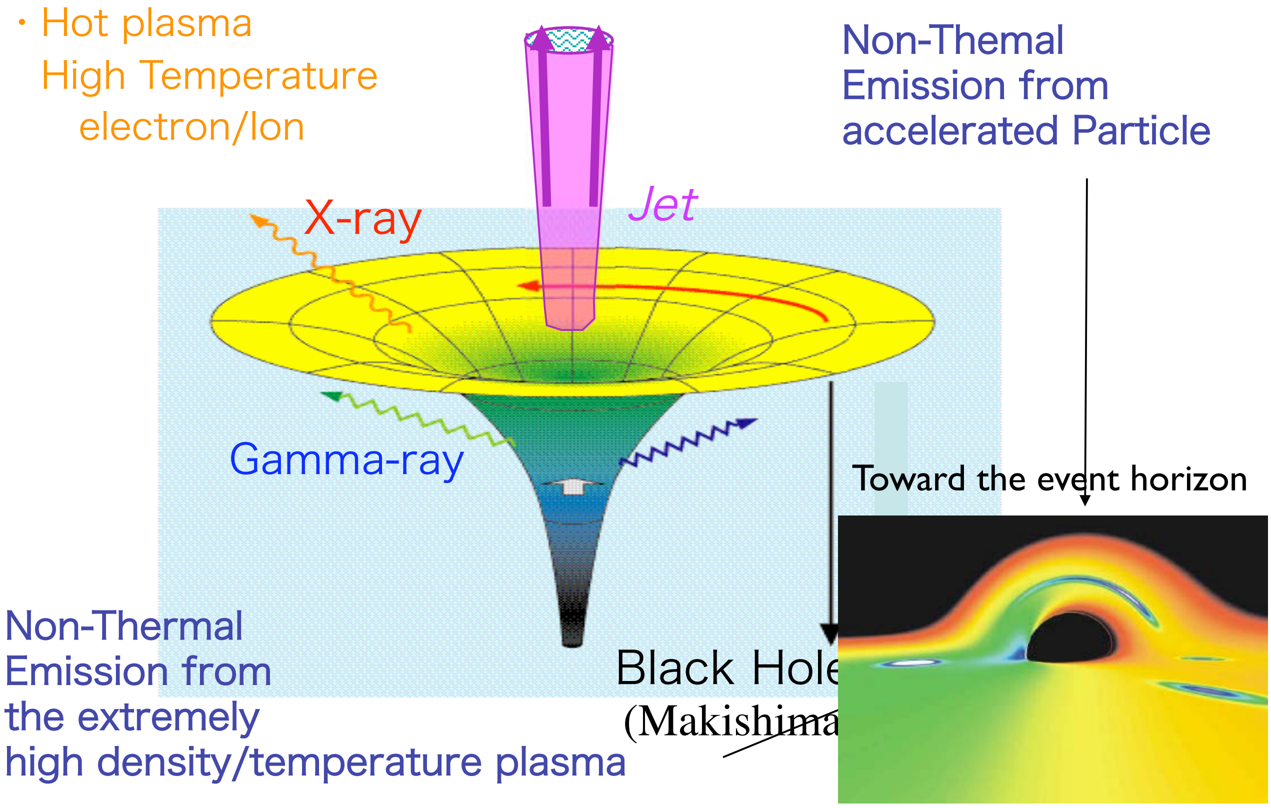
Saitama Univ.

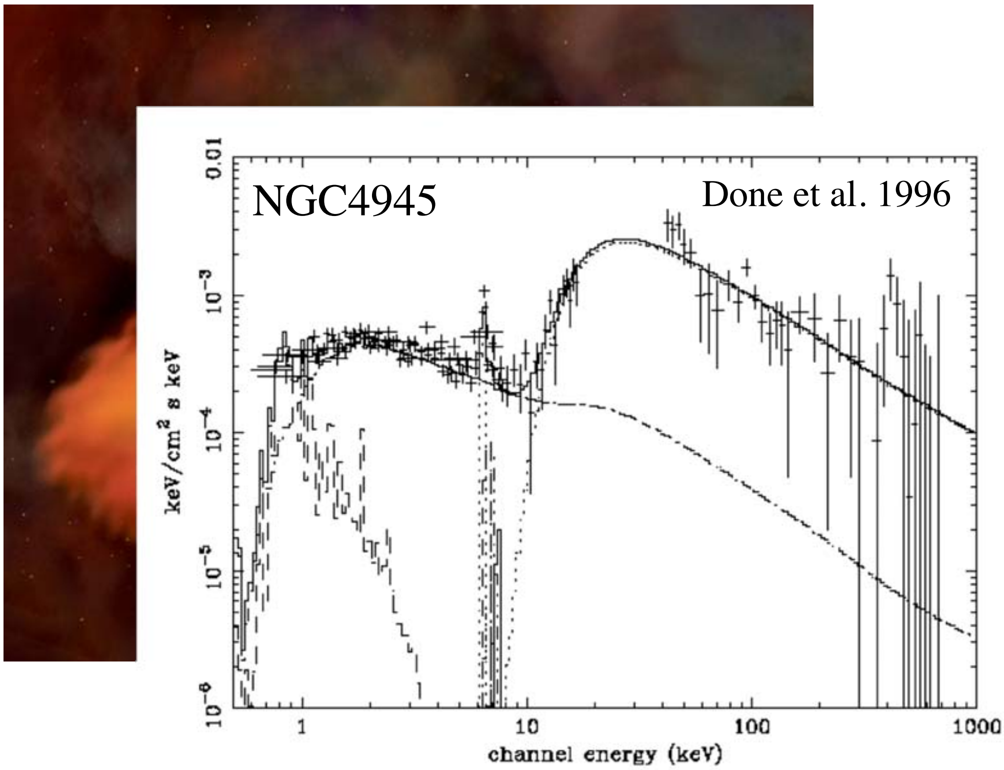
Gamma-ray Mission in 21st Century



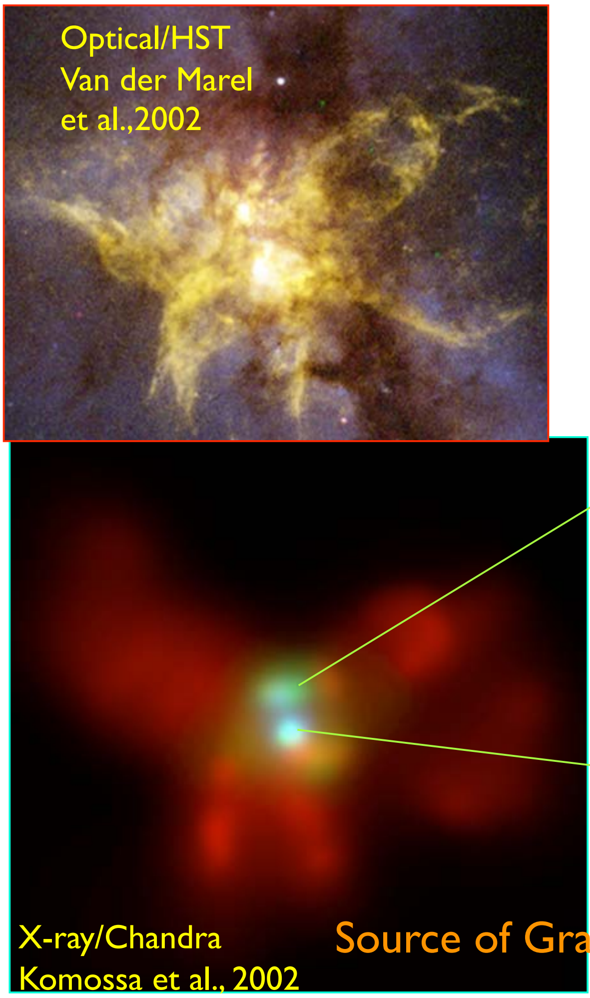
X-ray/Gamm-ray Observation is crucial to access Black Hole

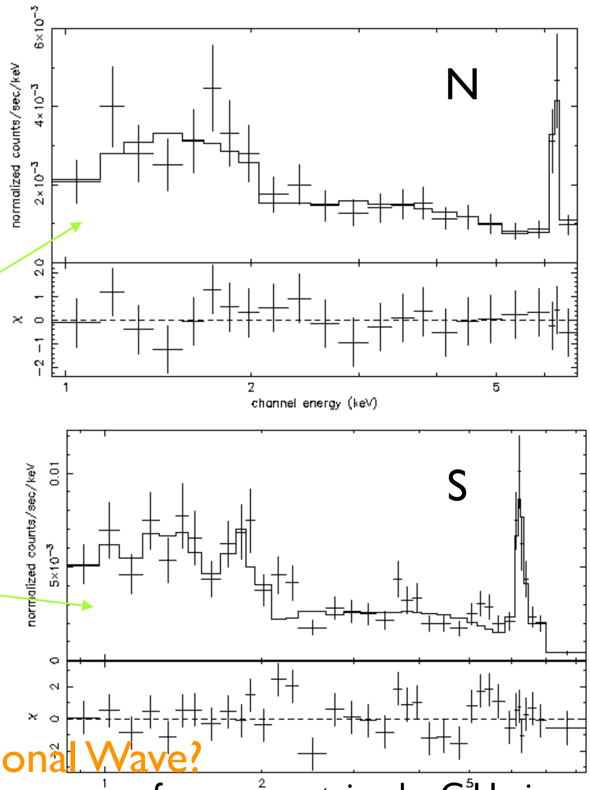


To Probe Obscured Black Hole



Binary BH in NGC 6240

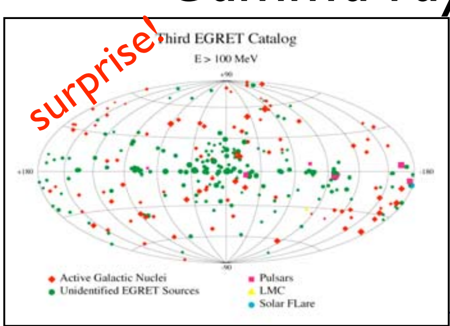


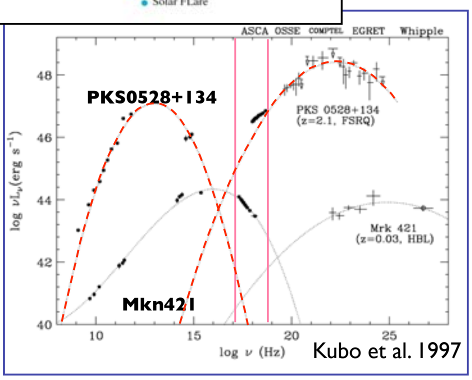


Source of Gravitational Wave?

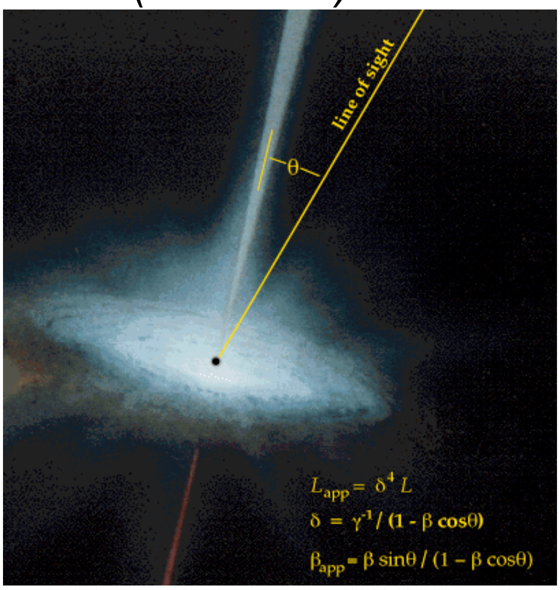
from presentaion by G.Hasinger

Gamma-ray Black Hole (Blazars)





Kubo et al. 1997



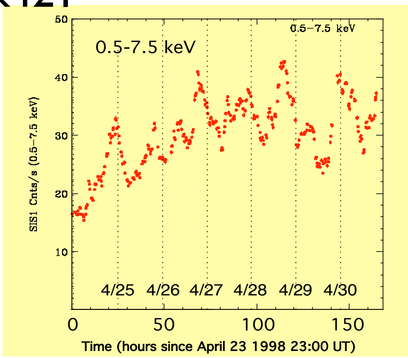
- Synchrotron,
  peak at IR-X ray energies
- Inverse Compton,
  peak at GeV-TeV energies

from the same electron distribution

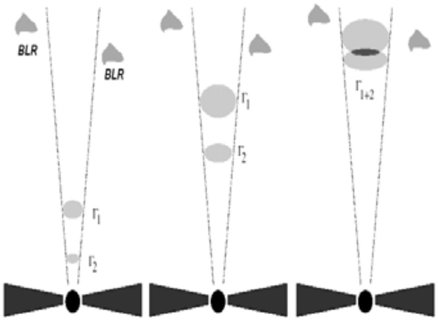
The relativistic jet points close to the observer. The non-thermal emission is Doppler boosted and greatly enhanced.

Blazar Variability & Internal Shocks

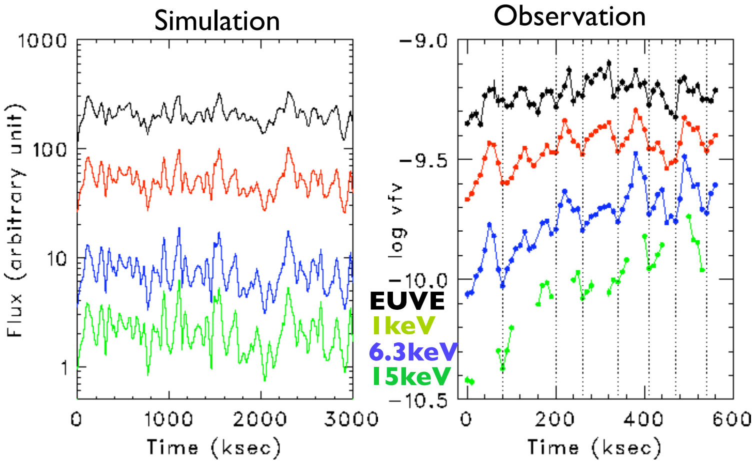
Mrk421



Takahashi et al. 2000



from G. Madejski, 2001



- R_{fo} =0.7, T_{chr} =40 ks⇒ D_0 =1x10^{13} cm
  s_G =0.015, G =15 (assumed)
- (Γ / σ_Γ =1,000

L_{kin} ~1,000 L_{jet}

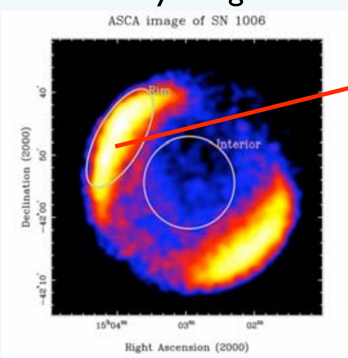
Tanihata, Takahashi, Kataoka et al. 2002,
Iwamoto, Takahara et al. 2003

Particle Accelerator in SNRs (1)

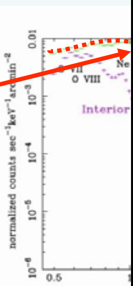
The remnant of SN 1006

Discovery of synchrotron X-ray emission by ASCA
(Koyama et al. 1995)

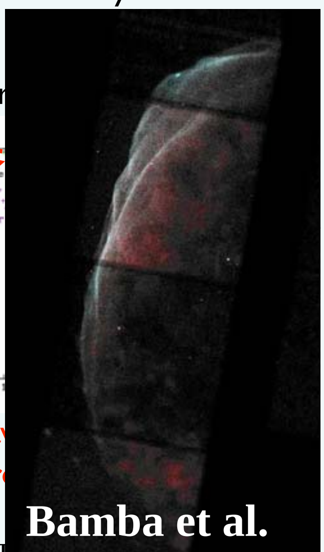
X-ray image



X-r

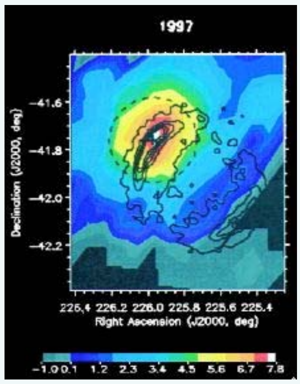


Power-la
= synchr



$h\nu_{synch} = 5.3\, E^{2}_{100\,TeV}$ $_{10\,\mu G}$ [ ]

CANGAROO
TeV Gamma-ray
(Tanimori et al. 1998)

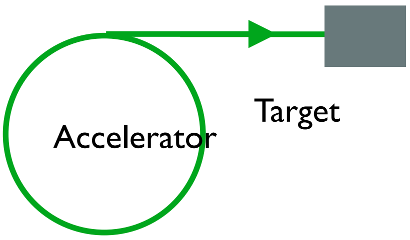


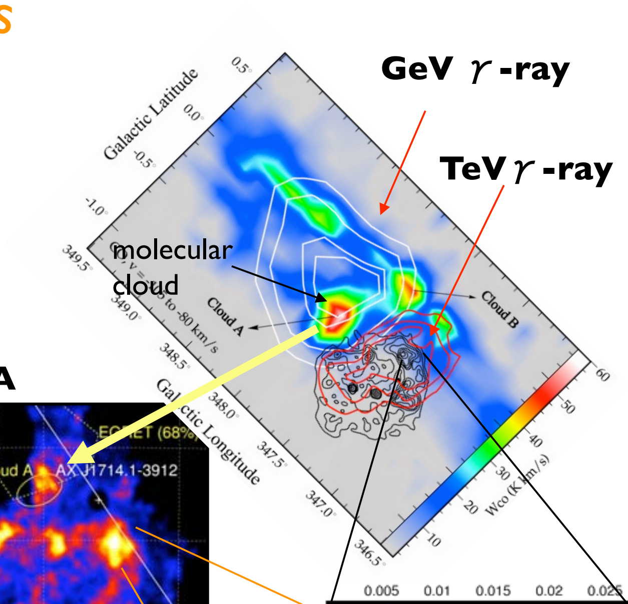
Direct evidence of > 10 TeV particles

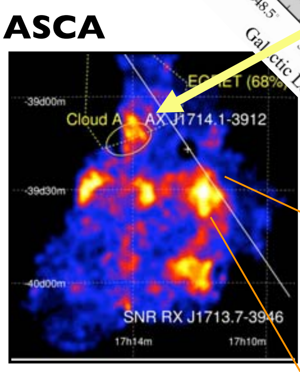
X-ray observation ⇒ highest energy electrons

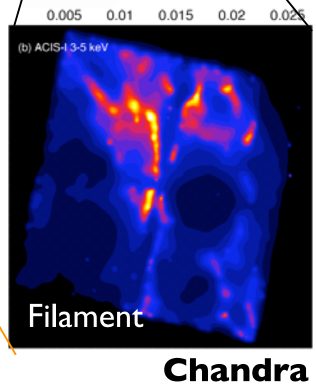
(from presentation by Uchiyama 2003)

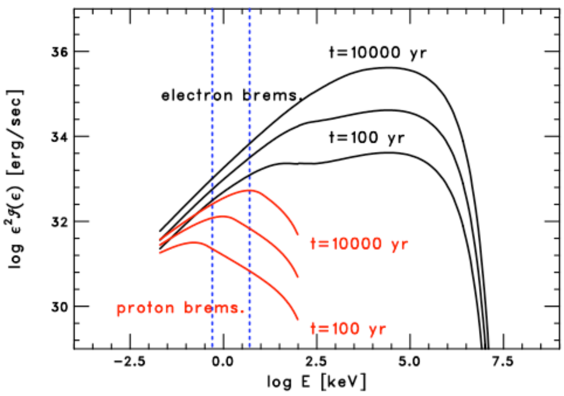
Particle Accelerator in SNRs (2)







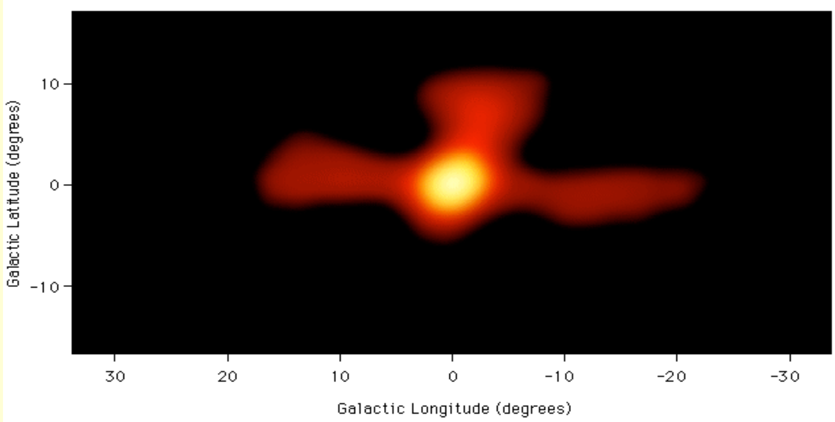




Characteristic 1/ε Spectrum (Uchiyama, Takahashi and Aharonian, 2002)

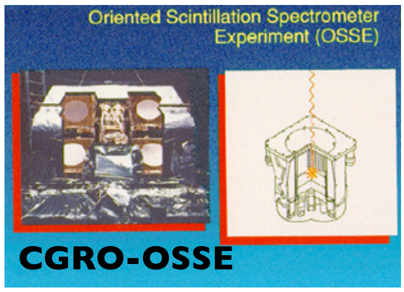
Emission due to electron/proton interaction in the dense molecular cloud

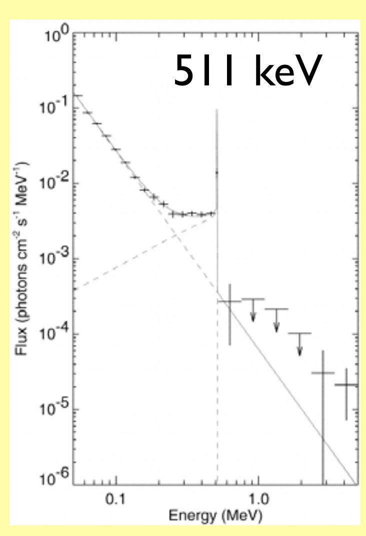
Annihilation Fountain in the Center of Milky Way



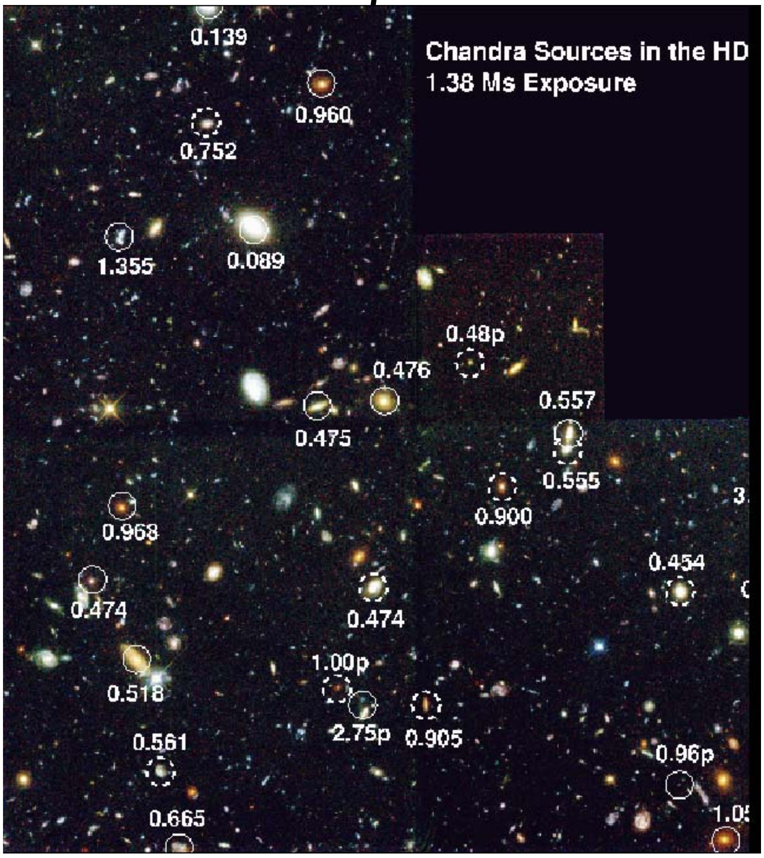
Caption: Map of the distribution of positrons towards the center of the Milky Way Galaxy, including the newly discovered antimatter "cloud". The brightest feature corresponds to the nucleus of the Galaxy. The horizontal structure lies along the plane of the Galaxy. The antimatter "cloud" is located above the Galactic center.

Courtesy of D. D. Dixon (University of California, Riverside) and W. R. Purcell (Northwestern University)



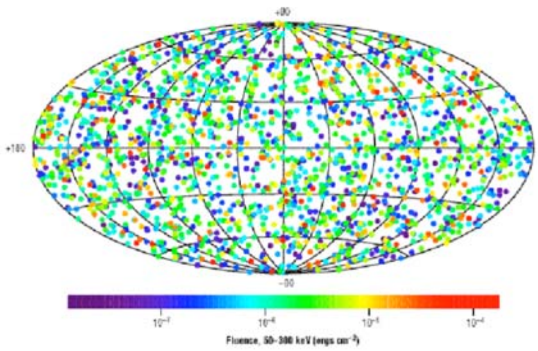


Deep Sky:
Black holes are ubiquitous in the Universe

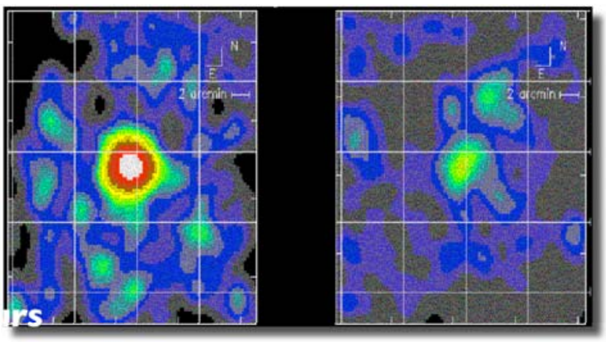


Gamma-ray Burst

BASTE



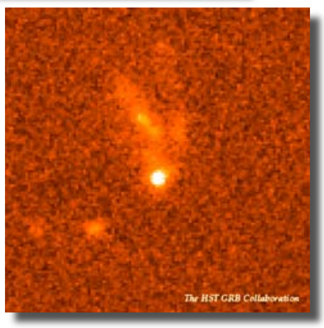
Afrerglow:
X-ray Images from BeppoSax



Optical discoveries of host galaxies and measurements of spectroscopic redshift distances

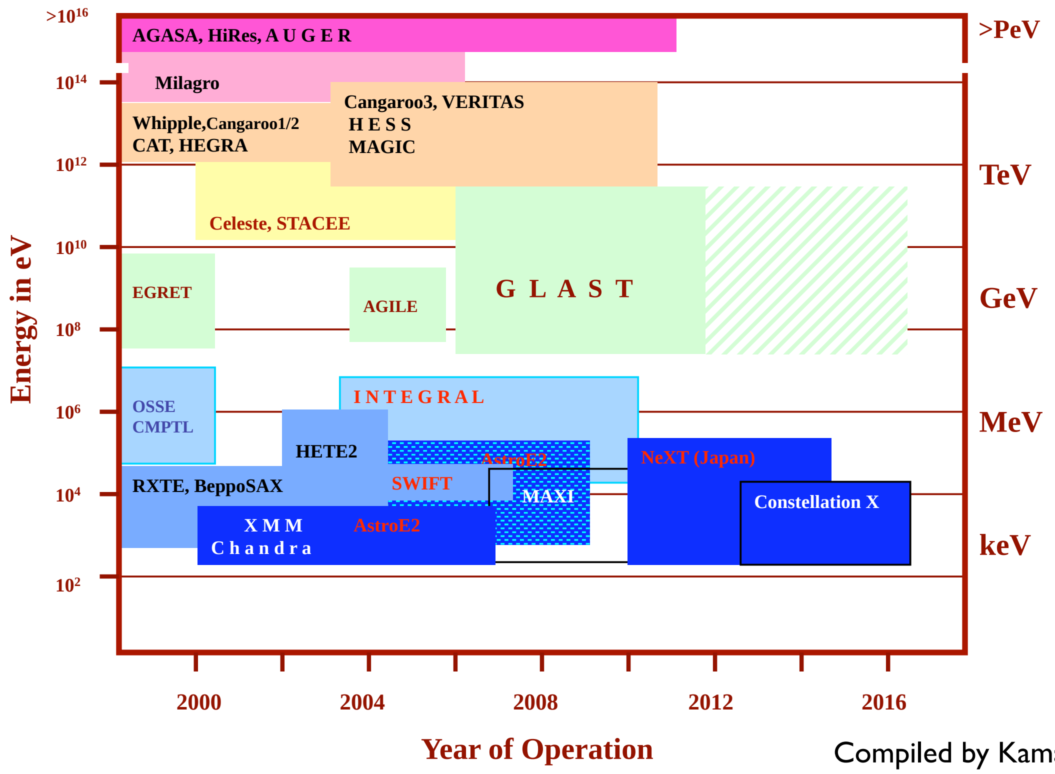
Gamma Ray bursts are occuring in distant (z = 1-3) galaxies

HST



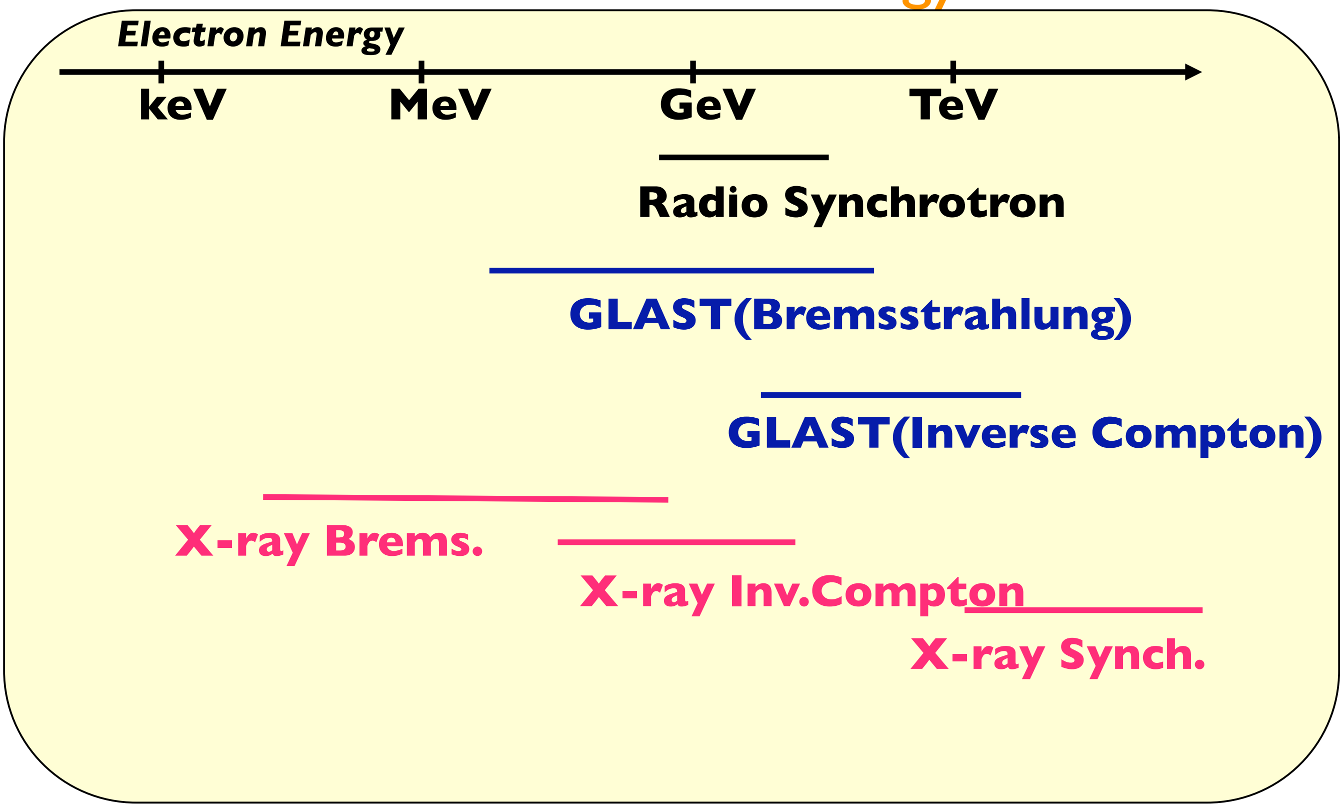
Most powerful and relativistic phenomena known (10^{52}-10^{54} ergs)

Present and Future X-ray/Gamma-ray Missions



Compiled by Kamae (2002)

Electro-Magnetic Radiation and Electron Energy



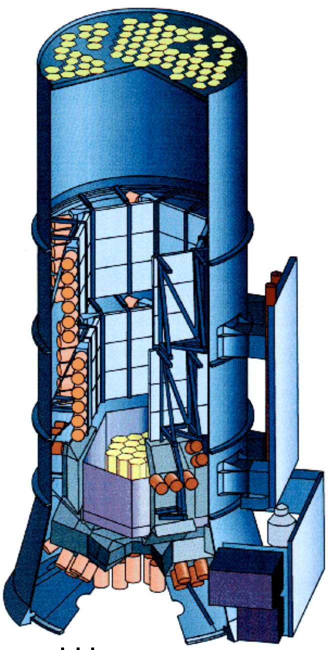
Integral Mission (2002-)

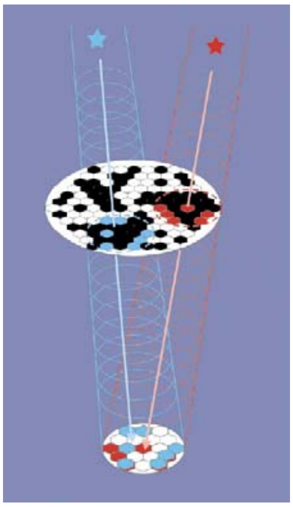
Big Gamma-ray Mission After CGRO
(15 keV 10 MeV)
Imaging (Coded Mask)
High Energy Resolution
X-ray Detector (JEM-X)

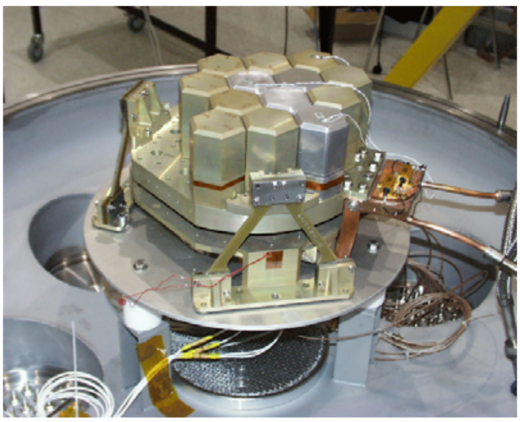
from Integral Homepage

High resolution Gamma-ray detector (SPI)

19 Cooled Ge detector (each 6x7 cm)
FWHM : 2keV @ 1.3 MeV

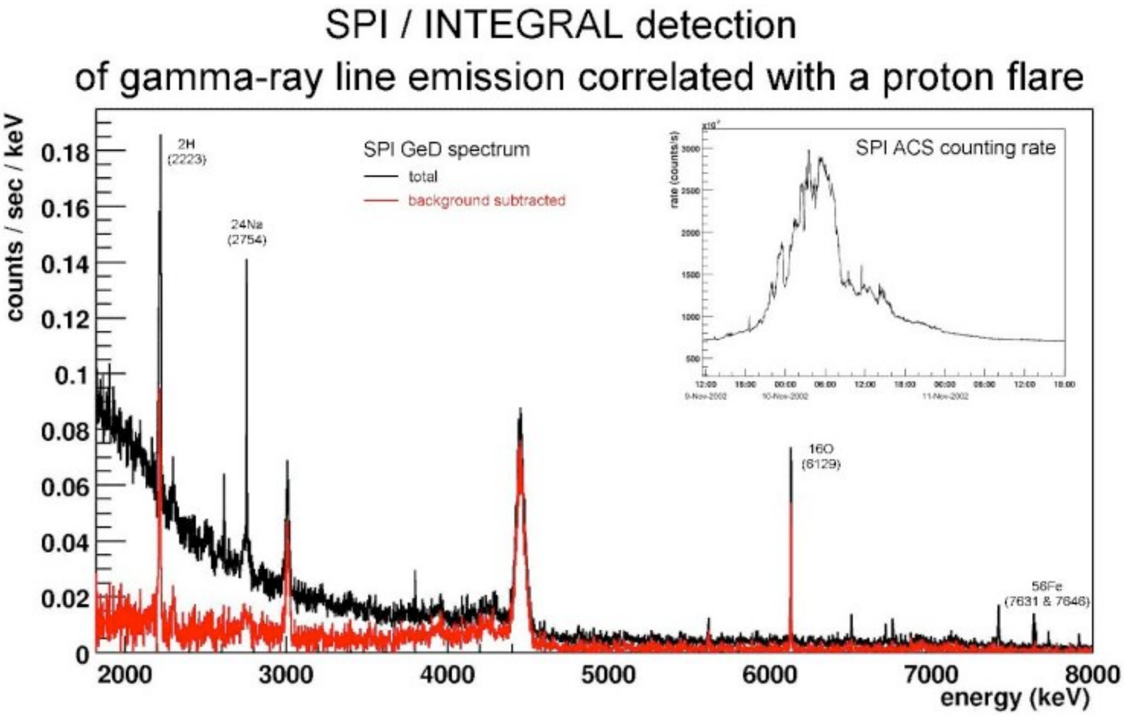






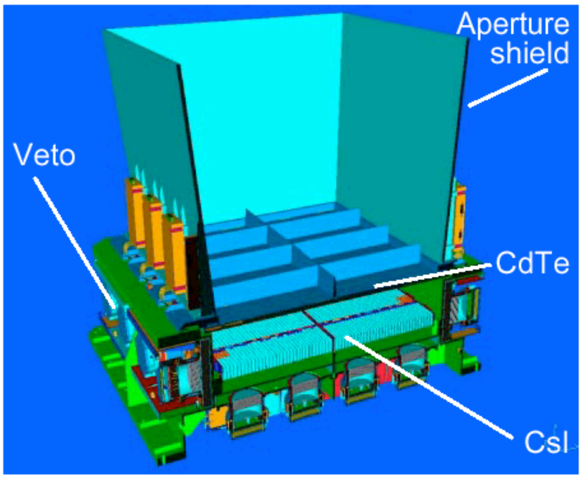
from Integral Homepage

Solar Flare Spectrum by SPI



from Integral Homepage

IBIS (CdTe + CsI(Tl))
7 keV @ 100 keV



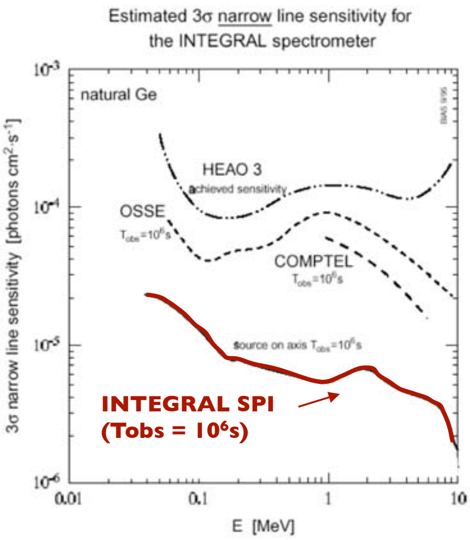
16384 CdTe detectors
total area 2620 cm^2
with 4x4 mm^2 x2mm^t detector

from Integral Homepage

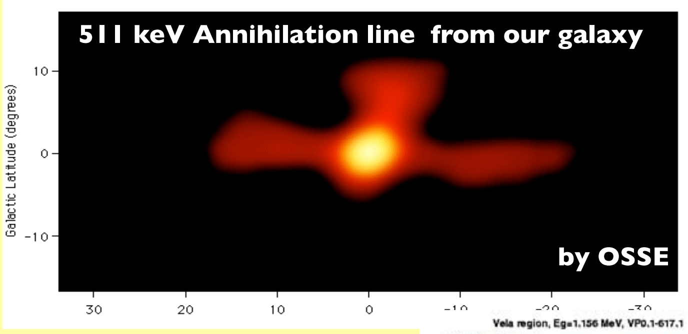
Integral Science

INTEGRAL

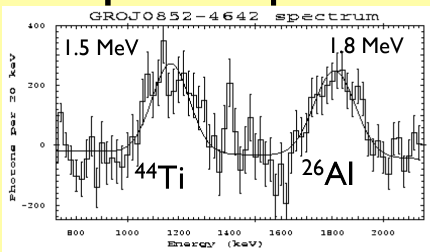
High Energy and Spatial Resolution

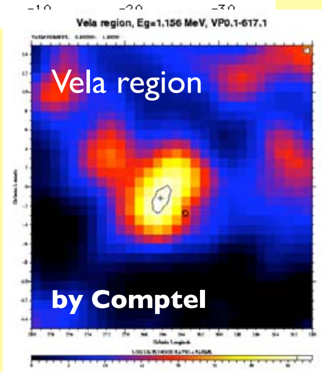


Line Gamma-ray from Nuclear Decay



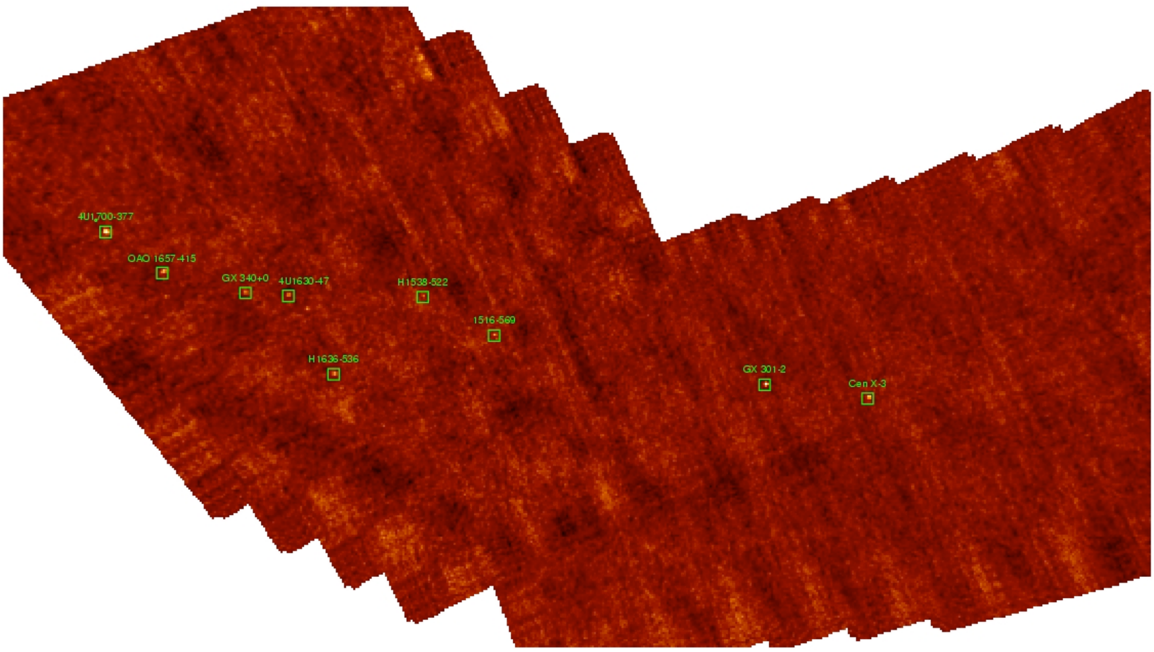
^{44}Ti and ^{26}Al (and more) from past SN explosions





Galactic Plane Scan

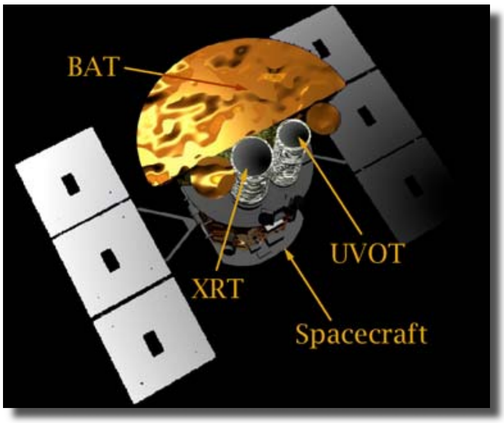
Cen region with ISGR (CdTe Imager)



from Integral Homepage

Swift Mission (2003-)

- ***Multi-wavelength observatory***



– Burst Alert Telescope (BAT): *10-150 keV*
  - *detect ~ 300 gamma ray bursts per year*
  - onboard computation of positions
  - arc-minute positional accuracy

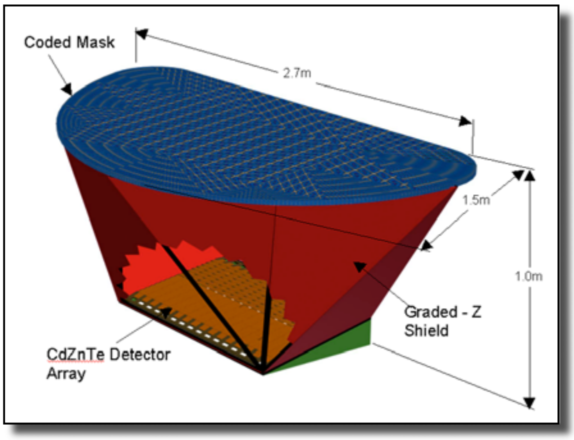
– Dedicated telescopes for X-rays, UV, and optical afterglow follow up:
  - 0.3-10 keV X-ray Telescope (XRT)
  - 170-650 nm UV/Optical Telescope (UVOT)
  - 0.3-2.5 *arc-second* locations
  - existing hardware from JET-X and XMM
  - determine redshifts from X-ray absorption, lines, and Lyman-α cutoff

Rapid response satellite

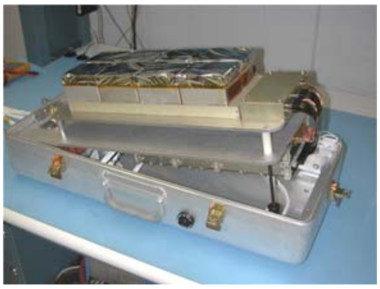
! 20 - 70 sec to slew within FOV of BAT

" ***autonomous operations***
" ***factor 100 improved response time***
" ***continue monitoring of fading afterglow***

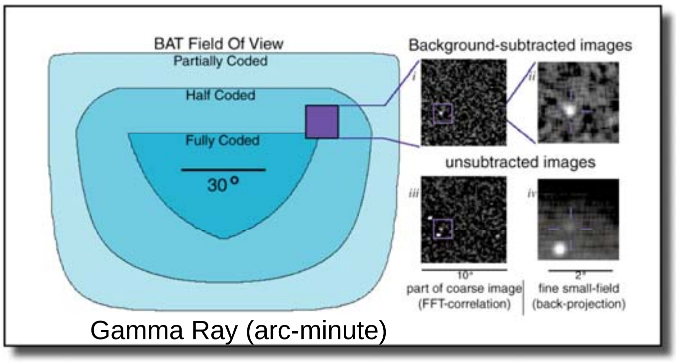
BAT Imager on Swift

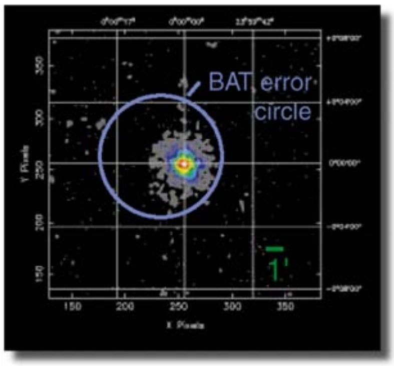


•32768 CdZnTe detectors
(4x4 mm^2 x2mm^t detector)
• Japanese Contribution to Calibration/Software (ISAS/Saitama U./ U.Tokyo)



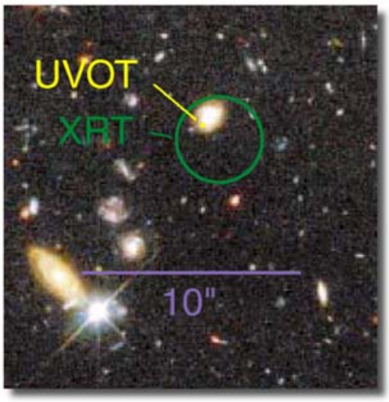
Multiwavelength Cascade of Images

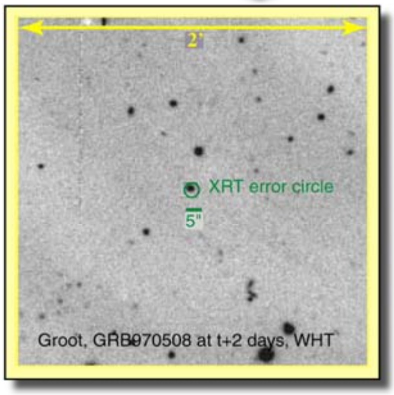




X-ray (2.5 arc-second)

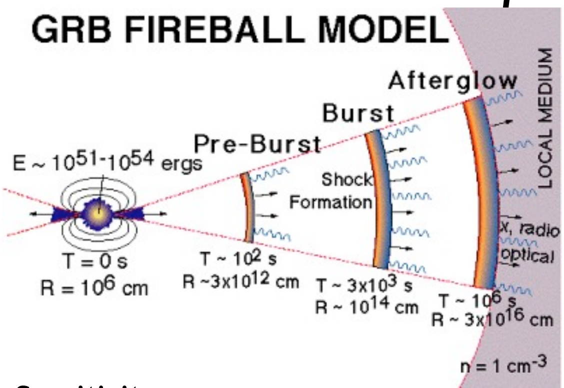
HST, Keck, etc.





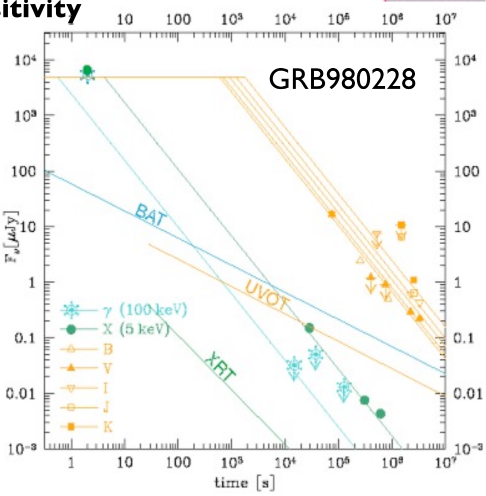
UVOT (0.3 arc-second)

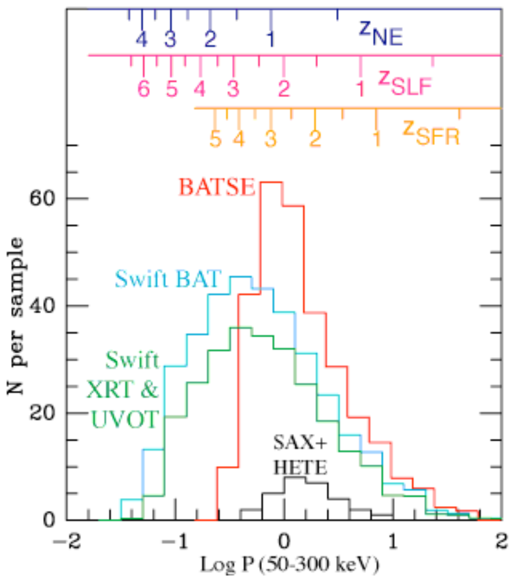
Swift Performance



- Location in host galaxies
- Probe the surrounding environment
- Use gamma-ray bursts as cosmological probes

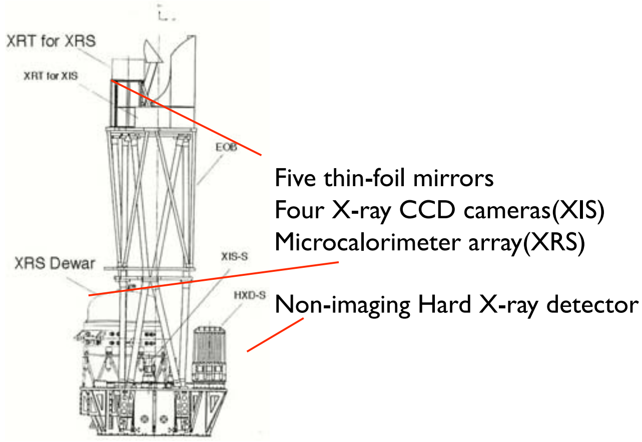
Sensitivity

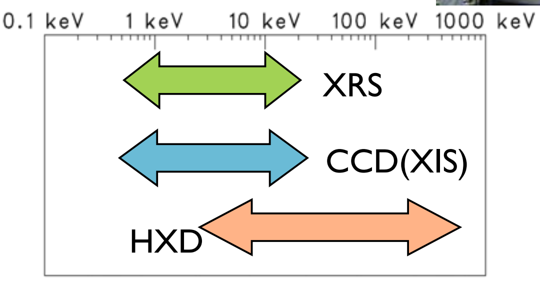




AstroE2 Multi-band Mission

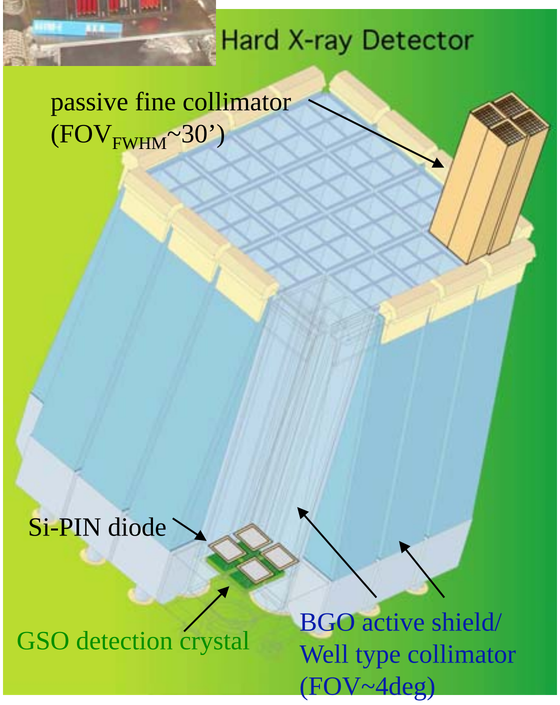
- Recovery Mission of Astro-E
- Launch in 2005
- Design almost identical to Astro-E





	S(cm²)	ΔE(eV) Fe 6.7KeV	Δθ (arcsec)	E_{rage}(keV)
Chandra	800	120	0.5	0.3~10
Newton	10,000	120	10	0.3~12
Astro-E	5,000	10	100	0.5~600

Hard X-ray Detector (HXD)



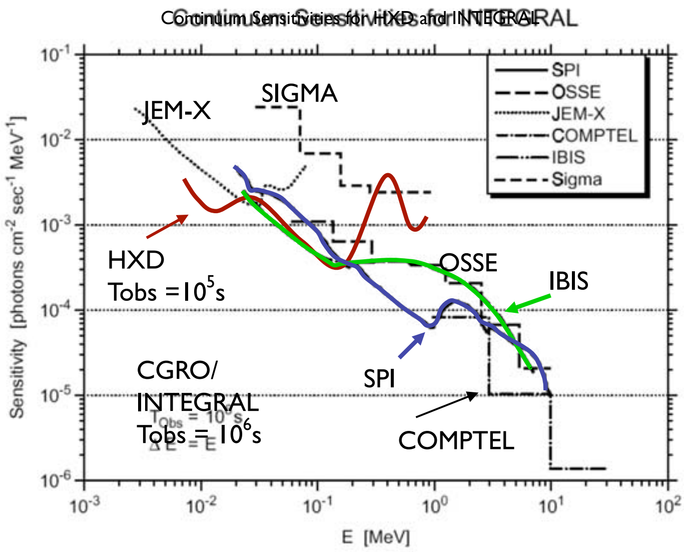
- Narrow FOV
  by well type (phoswitch) active shield
  & passive fine collimator (<100keV)
- Wide energy band (10 – 600 keV)
  w/ 64 Si-PIN (2mm thick) diodes
- Background rejection
  w/ LSI pulse shape discrimination
  anti-coincidence with 36 detector units
  & onboard CPU software

Low Background & High sensitivity are expected

ISAS, U.Tokyo, Hiroshima, Saitama, Kanazawa, SLAC

Astro-E2 HXD & Integral

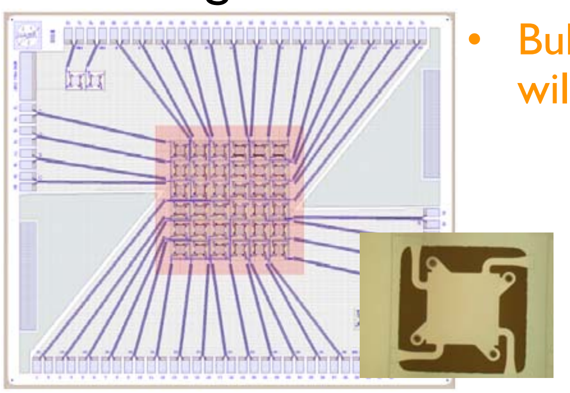
Continuum Spectrum



HXD-II has much narrower FOV and thus Background is lower and the sensitivity is higher.

Simultaneous observation with highly sensitive X-ray instruments gives us very unique opportunities to study gamma-ray sources.

High Resolution Detector (XRS) on AstroE2

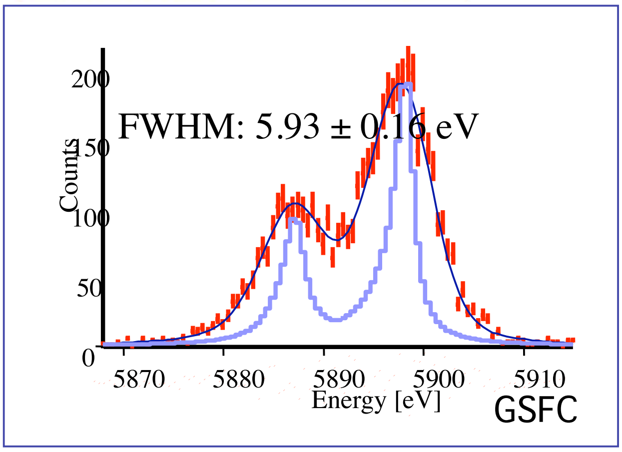


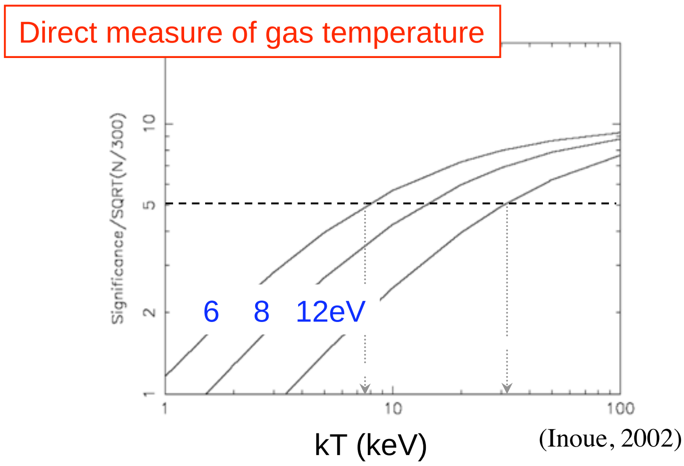
- Bulk motions of ICM in cluster mergers will be detected for the first time

Detection of a thermal Doppler width of an iron K-line:

for kT=10 keV, E_{line}=6.7 keV σ_L = 2.9eV and the intrinsic line width is 6.9 eV:

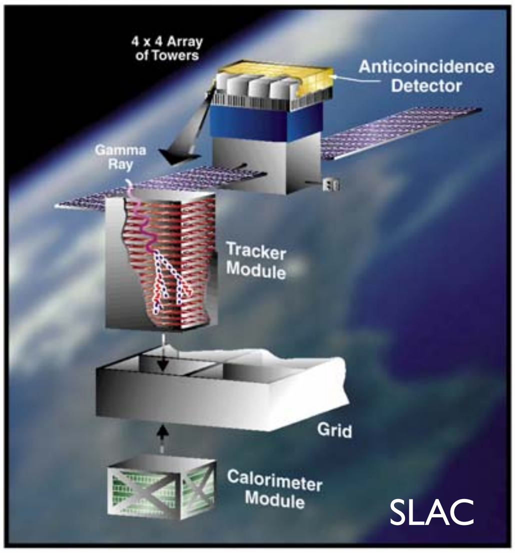
if we have 6 eV resolution···

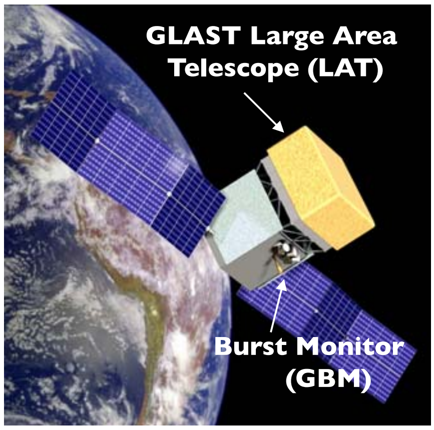




(Inoue, 2002)

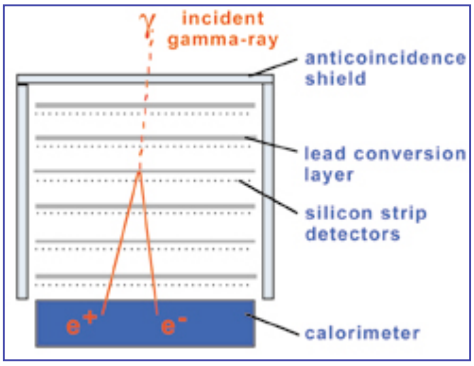
Glast Mission



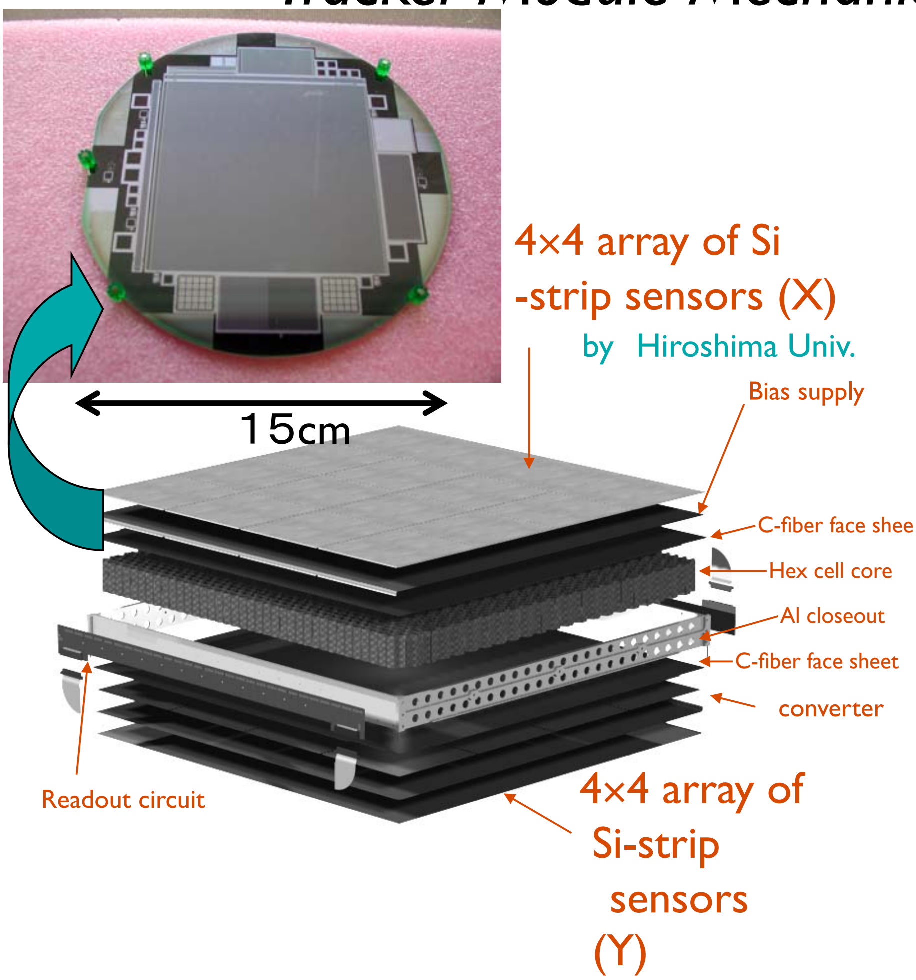


- •International Mission
- •Japanese Contribution (Hiroshima, ISAS, RIKEN, Titech)
- • <u>Wide FOV, Survey Operatiom</u>
- • 20MeV - 300 GeV
- • Large Area Silicon Strips.

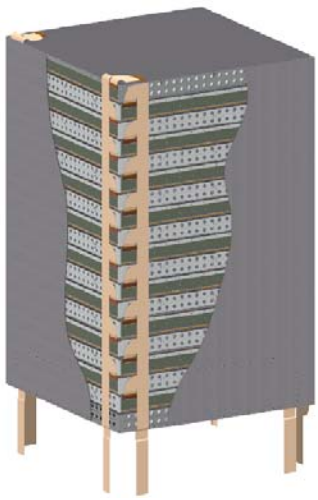
Utilize Pair-production



Tracker Module Mechanical Design

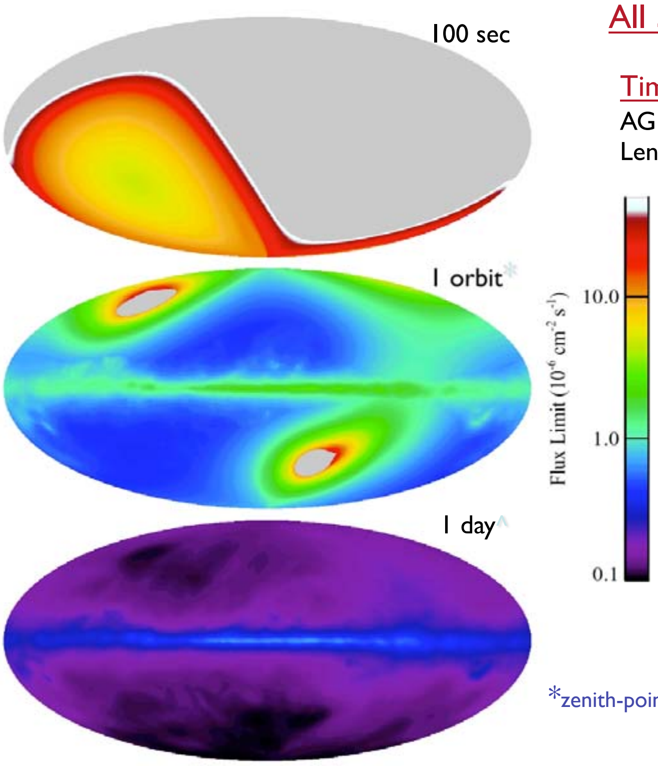


16 Towers



New approach GLAST will bring forth

- EGRET's 3rd Catalog in 2 days -



All 3EG sources + ~ 80 new in 2 days

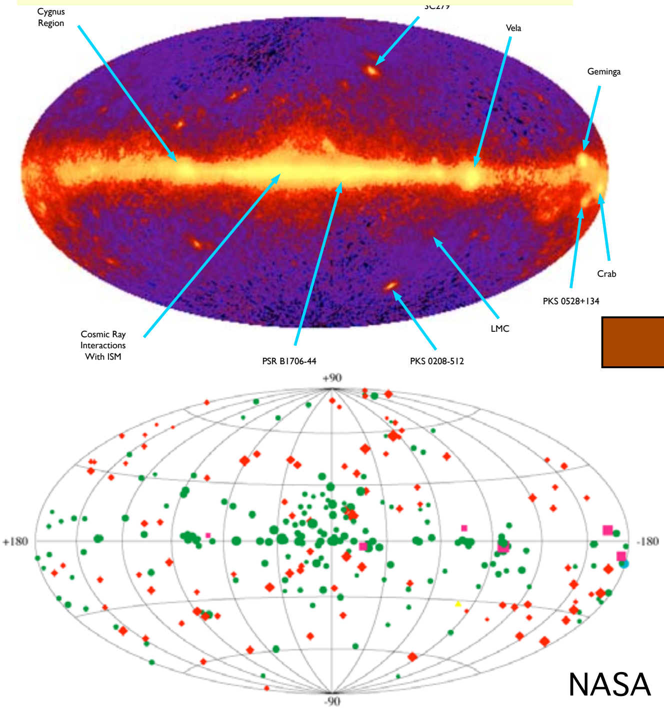
Time Variability Monitoring: Flares (Blazars, AGNs, Coronas), Precessions and Glitches (Pulsars), Lensing (AGNs)

- GRB940217 (100sec)
- PKS 1622-287 flare
- 3C279 flare
- Vela Pulsar
- Crab Pulsar
- 3EG 2020+40 (SNR g Cygni?)
- 3EG 1835+59
- 3C279 lowest 5s detection
- 3EG 1911-2000 (AGN)
- Mrk 421
- Weakest 5s EGRET source

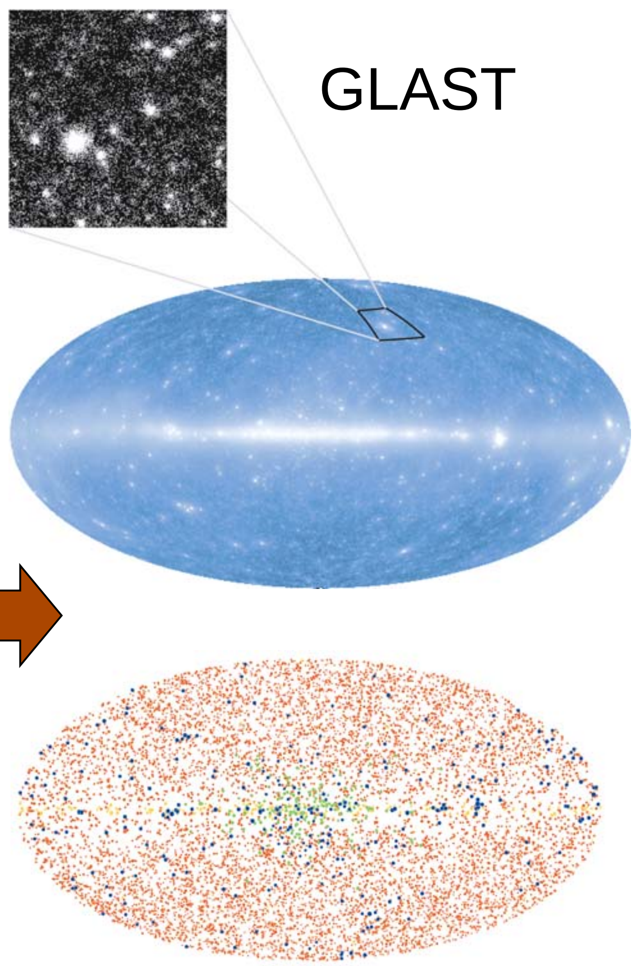
*zenith-pointed, ^"rocking" all-sky scan

Sensitvity of GLAST

CGRO-EGRET (1991-2000)



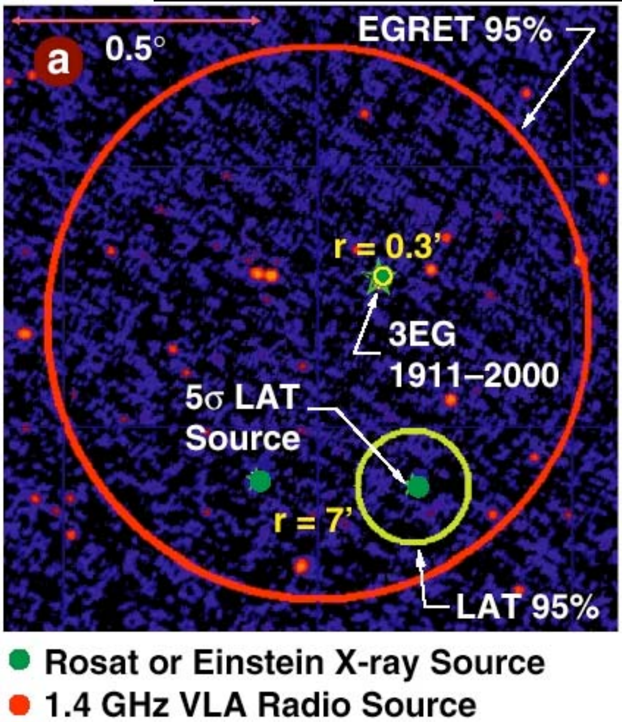
GLAST



NASA

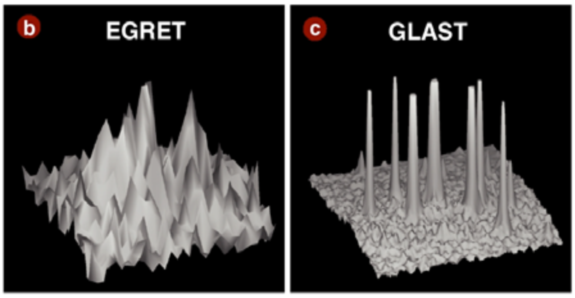
Unidentified Source

172 of the 271 sources in the EGRET 3rd catalog are "unidentified"



EGRET source position error circles are ~0.5°, resulting in counterpart confusion.

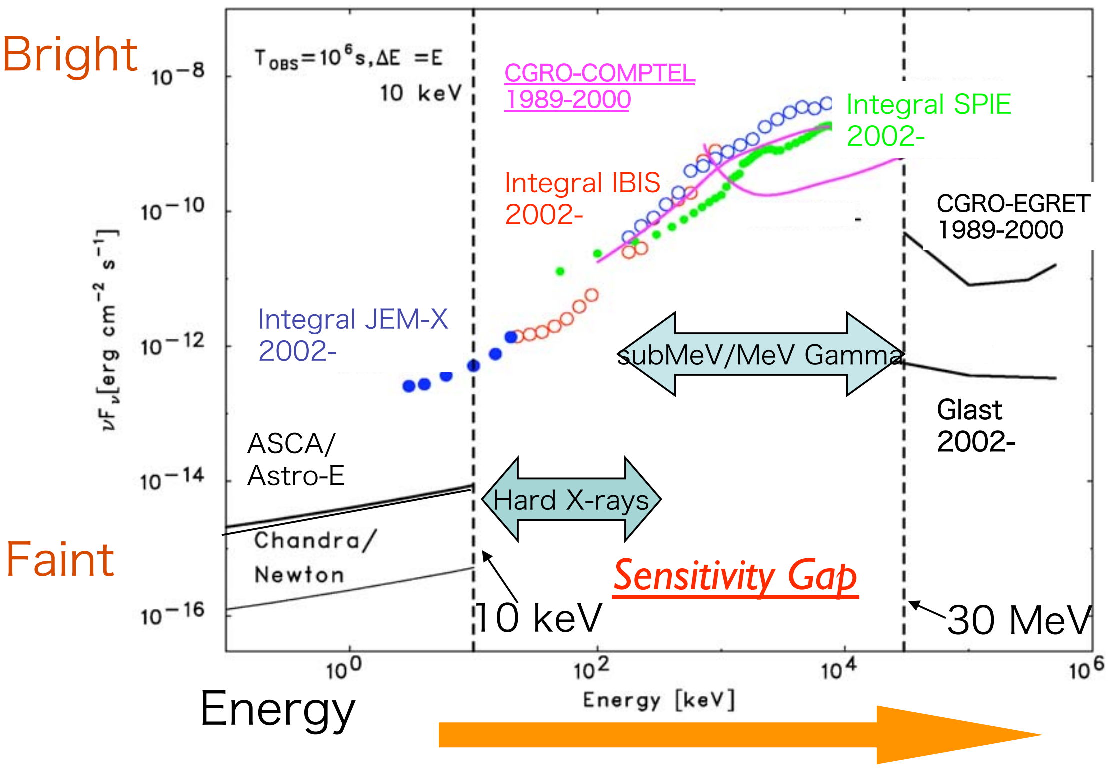
GLAST will provide much more accurate positions, with ~30 arcsec - ~5 arcmin localizations, depending on brightness.



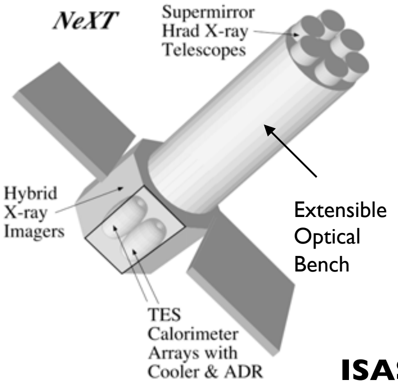
Cygnus region (15x15 deg)

From presentaion by S.Ritz, 2001

Future Perspectives



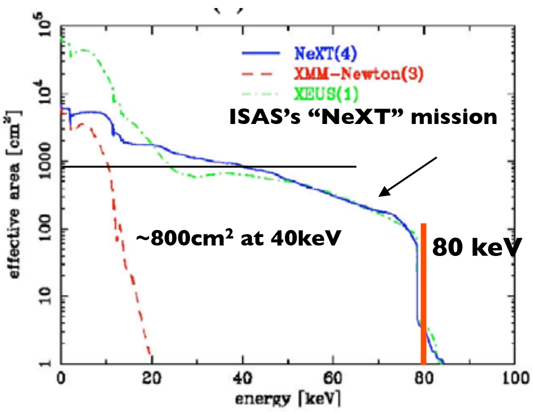
Future Mission
-- Focusing Hard X-ray Experiments --

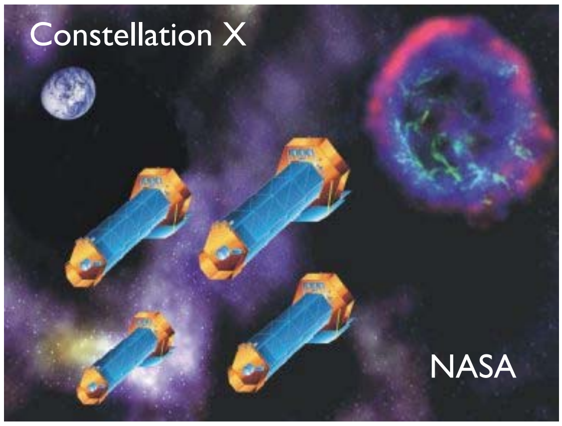


Key technology: Super Mirror & γ-ray Imager

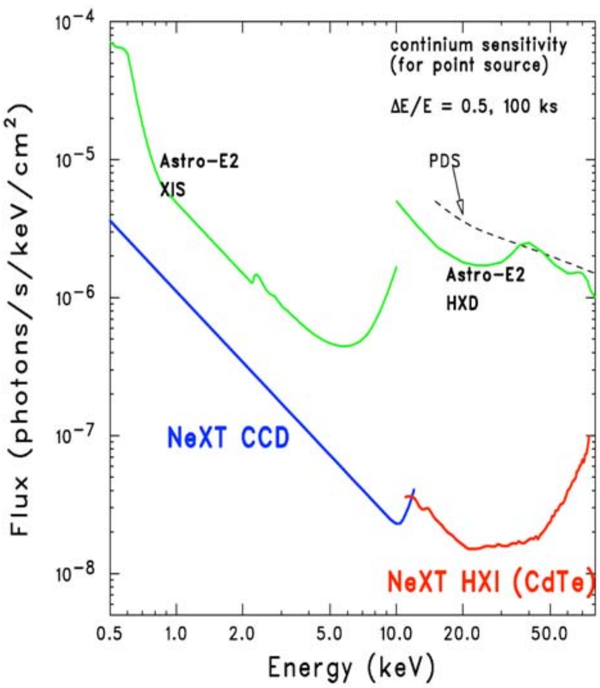
Focusing Telescope is
not only for the equipment to take pictures
but also for the key to achieve high sensitivity.
Because,
a mirror concentrates the incoming flux onto a small spot of the detector, greatly reduce background.

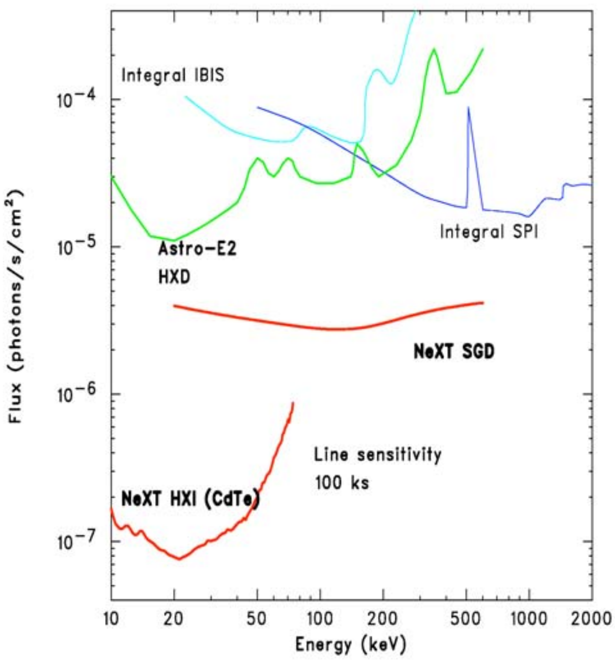
ISAS, Japan





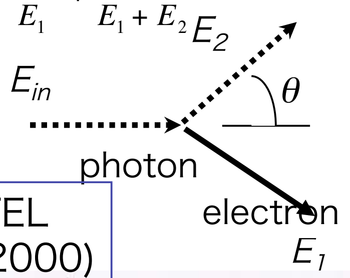
NeXT Mission



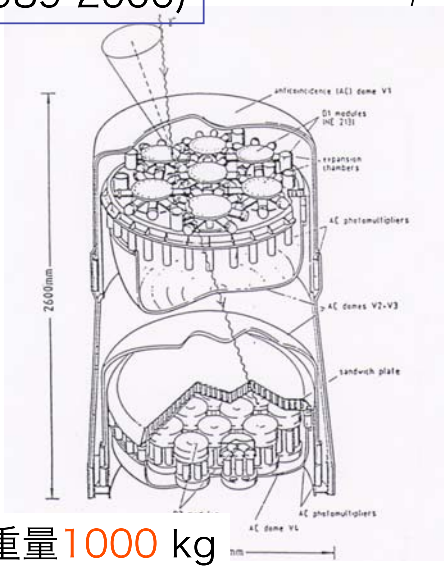


Beyond COMPTEL

$$\cos\theta = 1 - \frac{m_e c^2}{E_1} + \frac{m_e c^2}{E_1 + E_2}$$



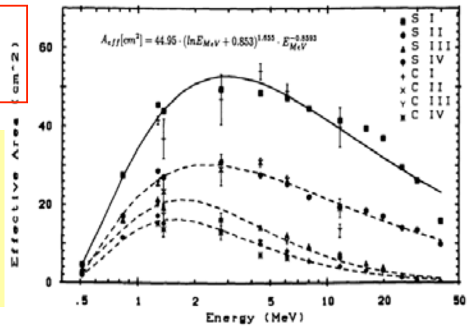
COMPTEL (1989-2000)



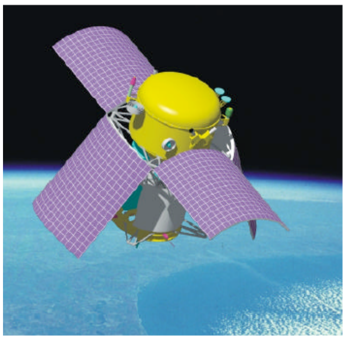
総重量1000 kg

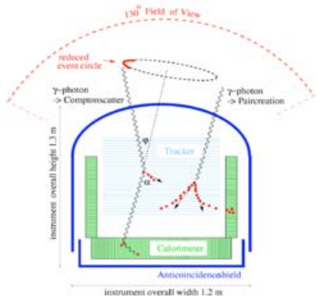
Compton-Dominant Region

COMPTEL has an effective area of ONLY 30~40 cm^2



MEGA Mission (proposed by COMPTEL Team)



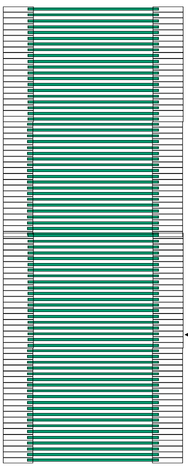


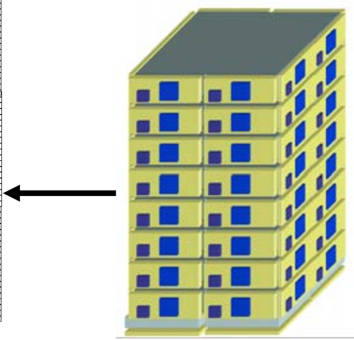
Weight 650kg

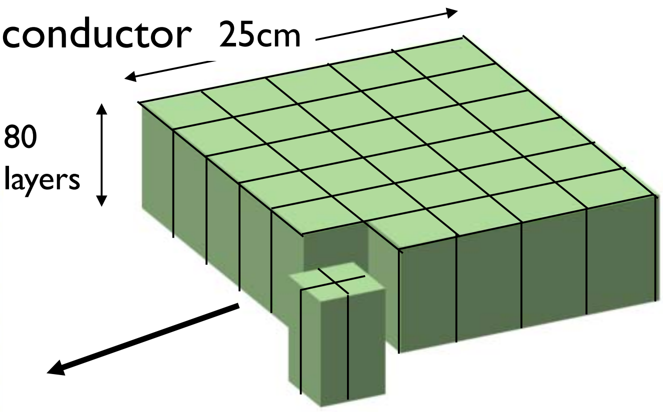
Next generation Compton Telescope in Japan

- Semiconductor Multi Compton Telescope (SMCT) (ISAS)

with high Z semiconductor (CdTe)







80 layers of 0.5 mm thick CdTe strip detectors

625 cm^2 ×4cm CdTe Detector:

ISAS/SLAC/Osaka U. Hiroshima U./ U.Tokyo

Compact BUT Detection Efficiency at 1 MeV becomes 10 times higher than COMPTEL (weight 1 ton) on CGRO

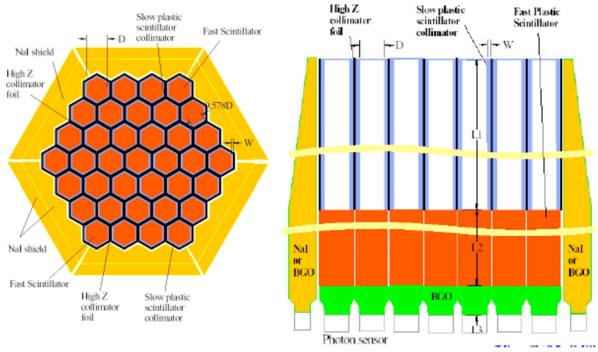
- Compton telescope based on Micro Gas Pixel Chamber (Kyoto Univ.)

Polarization

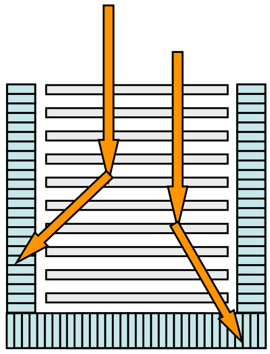
- Polarization in X-ray/Gamma-ray
  is the only remaining parameter to be measured.
- Expected from Jet Sources/Pulsars/Accretion Disk/GRB
- Development of New and Sensitive Instruments are crucial

Gamma-ray

by Newly Desined Gamma-ray Polarimeter
(Kamae et al. 2003)



by Compton Telescope



(INTEGRAL, SMCT, MEGA…)

Summary

- X-ray and Gamma-ray energy band in space are very important window to study high energy particles (cosmic rays) in the universe
- By combining information from X-ray and Gamma-ray observations, we can deepen our understandings of "Accelerator" in the universe