Future Prospects for Space-Based Gamma-Ray Astronomy

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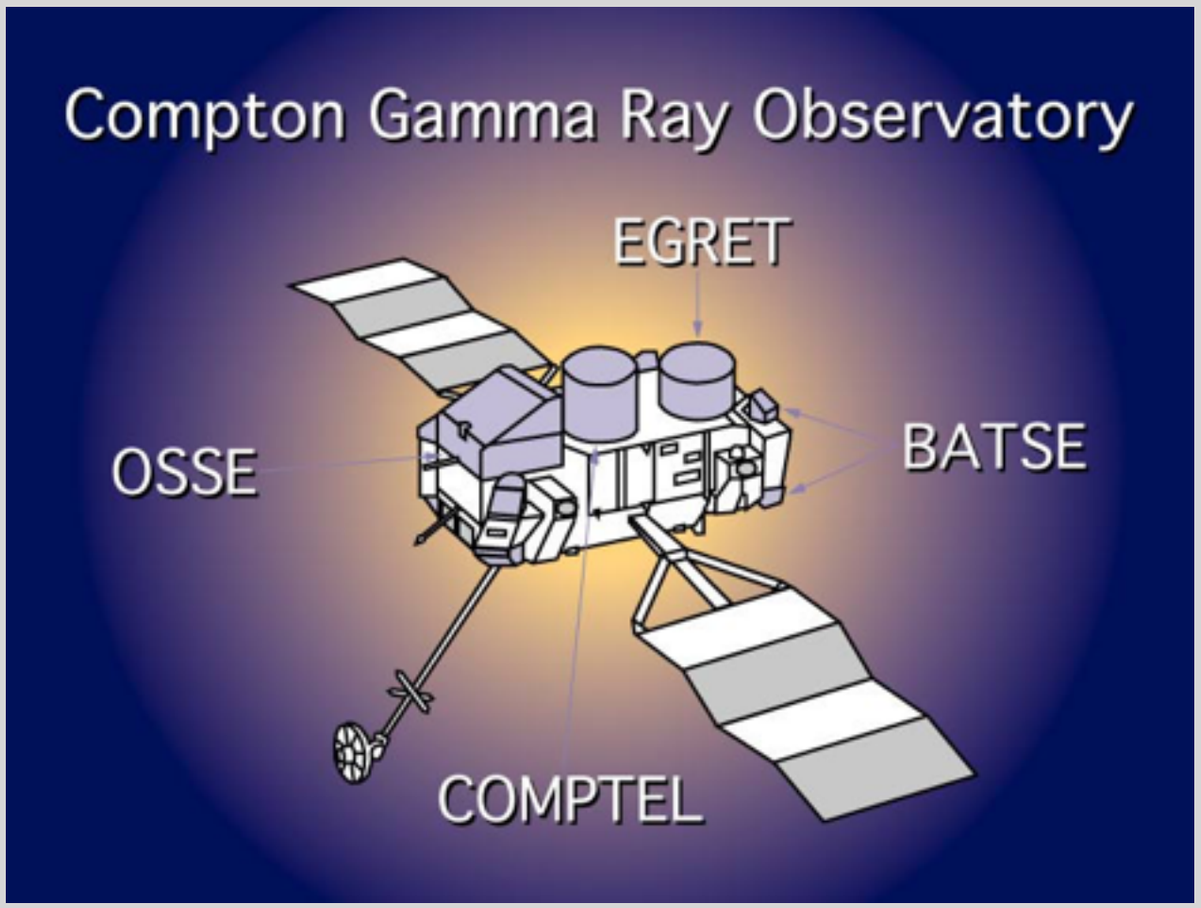
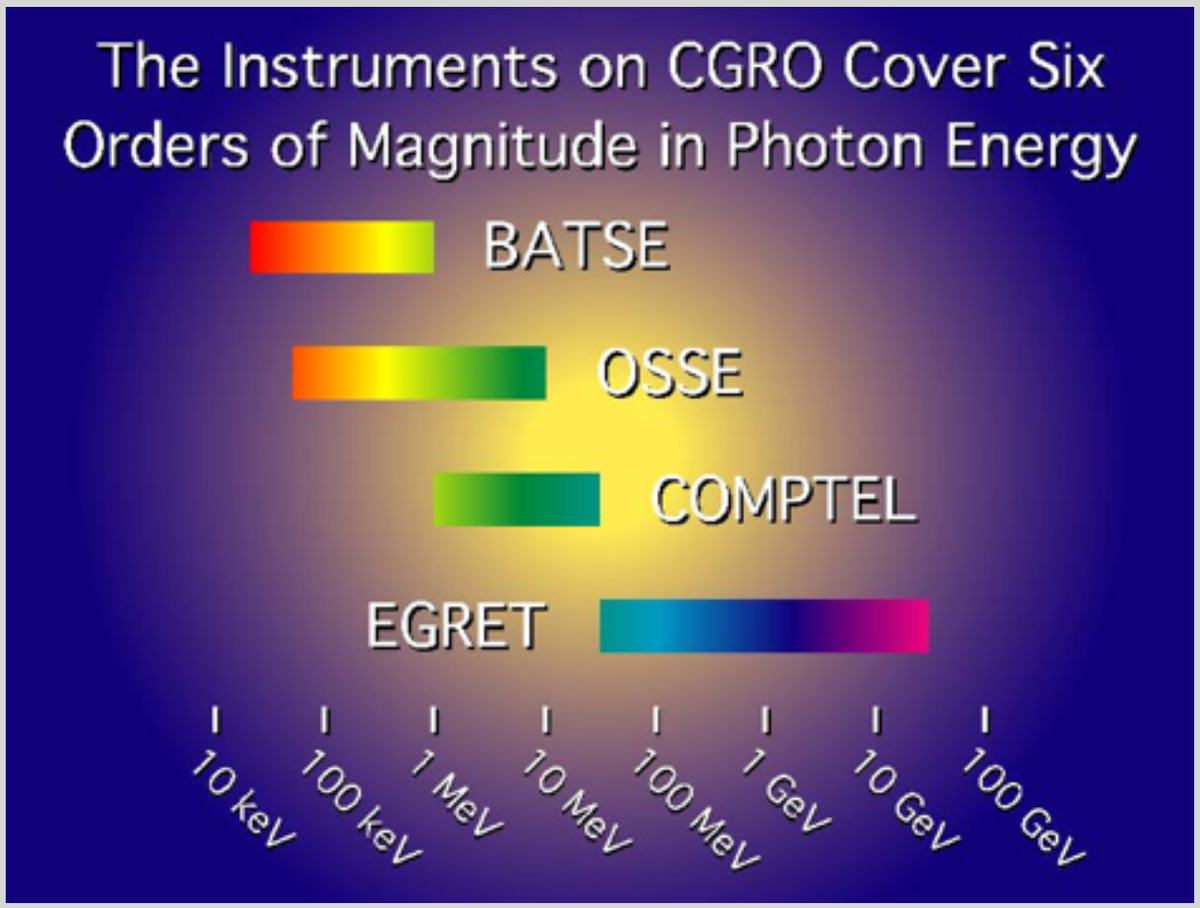
on behalf of the
Gamma-ray Science Interest Group (GammaSIG)

AAS - January, 2016

Compton Gamma Ray Observatory

Broad range of energies.
Several different photon interactions.
Need several different instruments.





Pair Production Telescopes (> 20 MeV)

SAS-II (1972) / COS-B (1975)
25 sources

↓

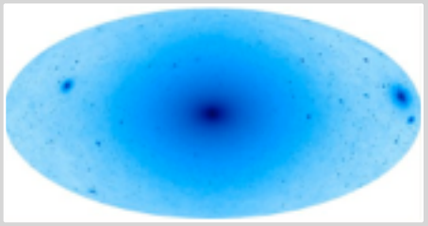
CGRO/EGRET (1991)
271 sources

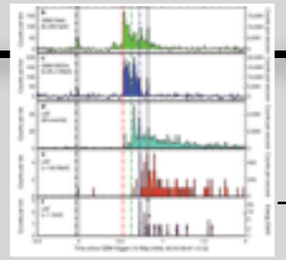
↓

Fermi (2008)
3033 sources

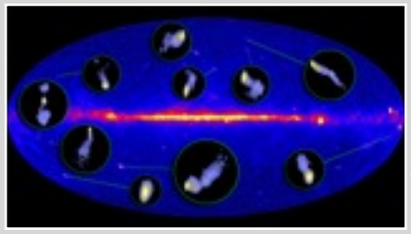
Fermi Highlights and Discoveries

Dark Matter

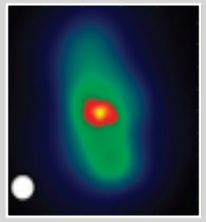




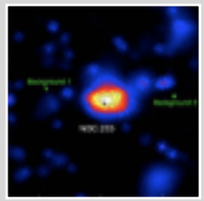
GRBs



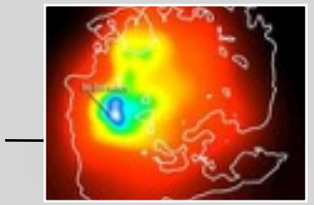
Blazars



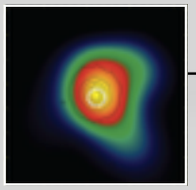
Radio Galaxies



Starburst Galaxies

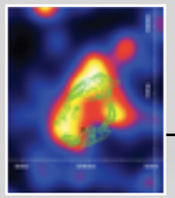


LMC & SMC

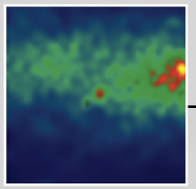


Globular Clusters

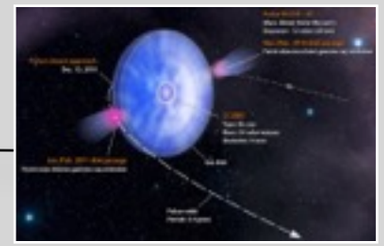
Fermi Bubbles



SNRs & PWN

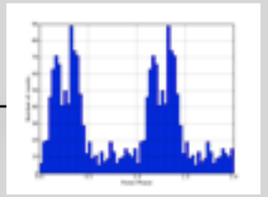


Novae



γ-ray Binaries

Pulsars: isolated, binaries, & MSPs



Sun: flares & CR interactions

Terrestrial γ-ray Flashes

Extragalactic

Galactic

What Next?

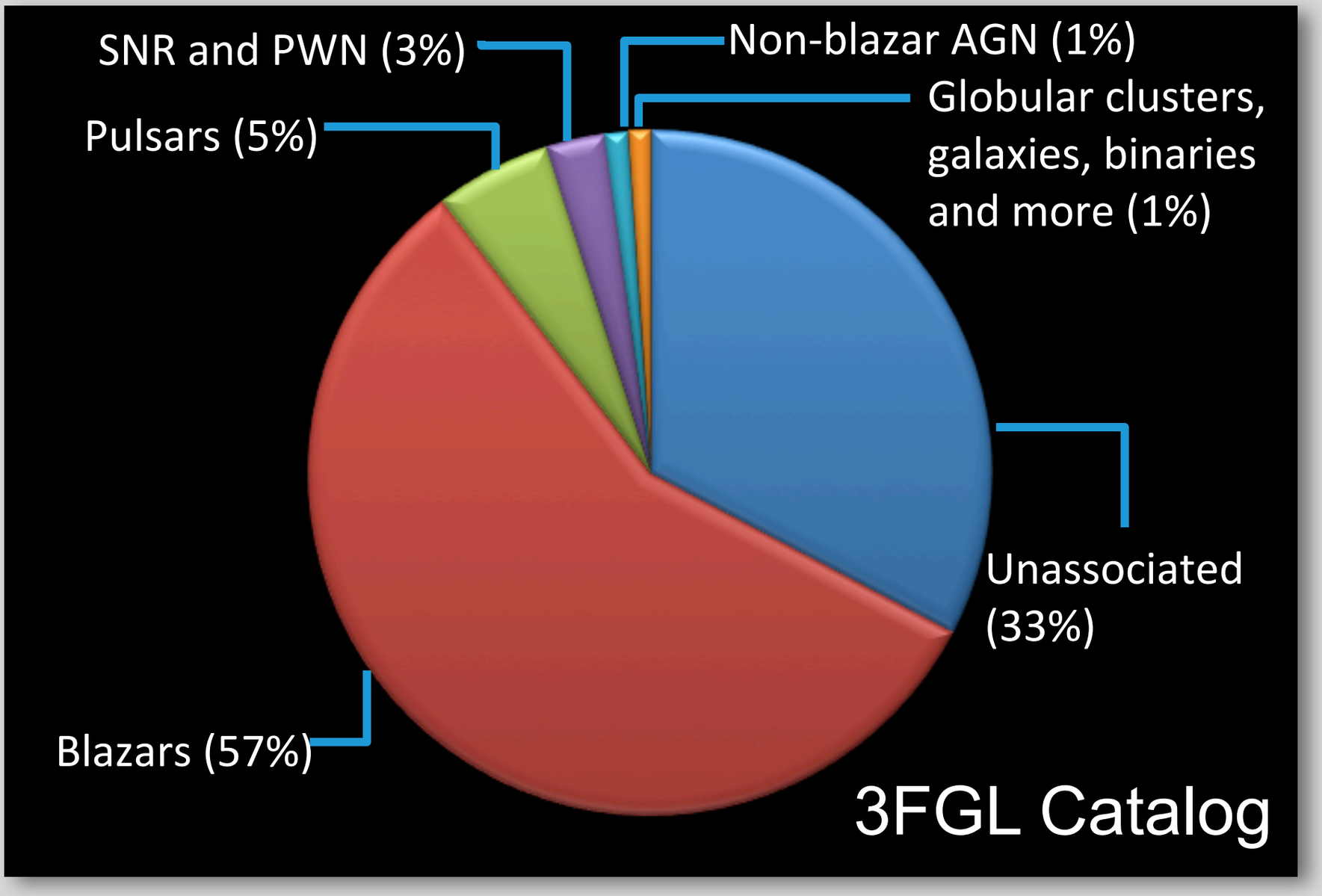
As we look beyond 2016, what are the next steps for space-based gamma-ray astronomy?

There are several technical options being discussed…

Next Generation Pair Production Telescope

50 MeV - 300 GeV

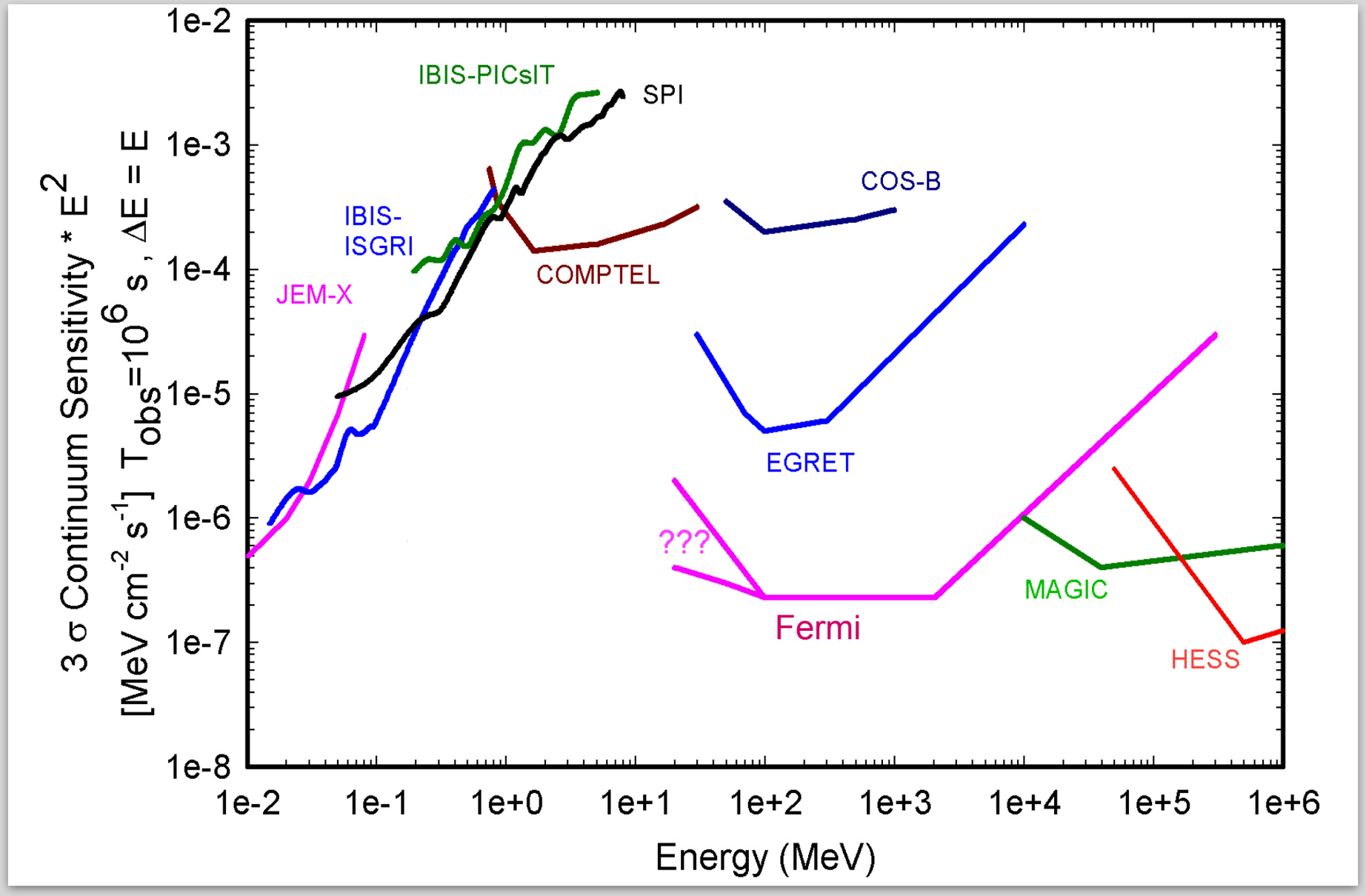
Utilizes latest technology and lessons learned from Fermi.



Next Generation Compton Telescope

200 keV - 50 MeV

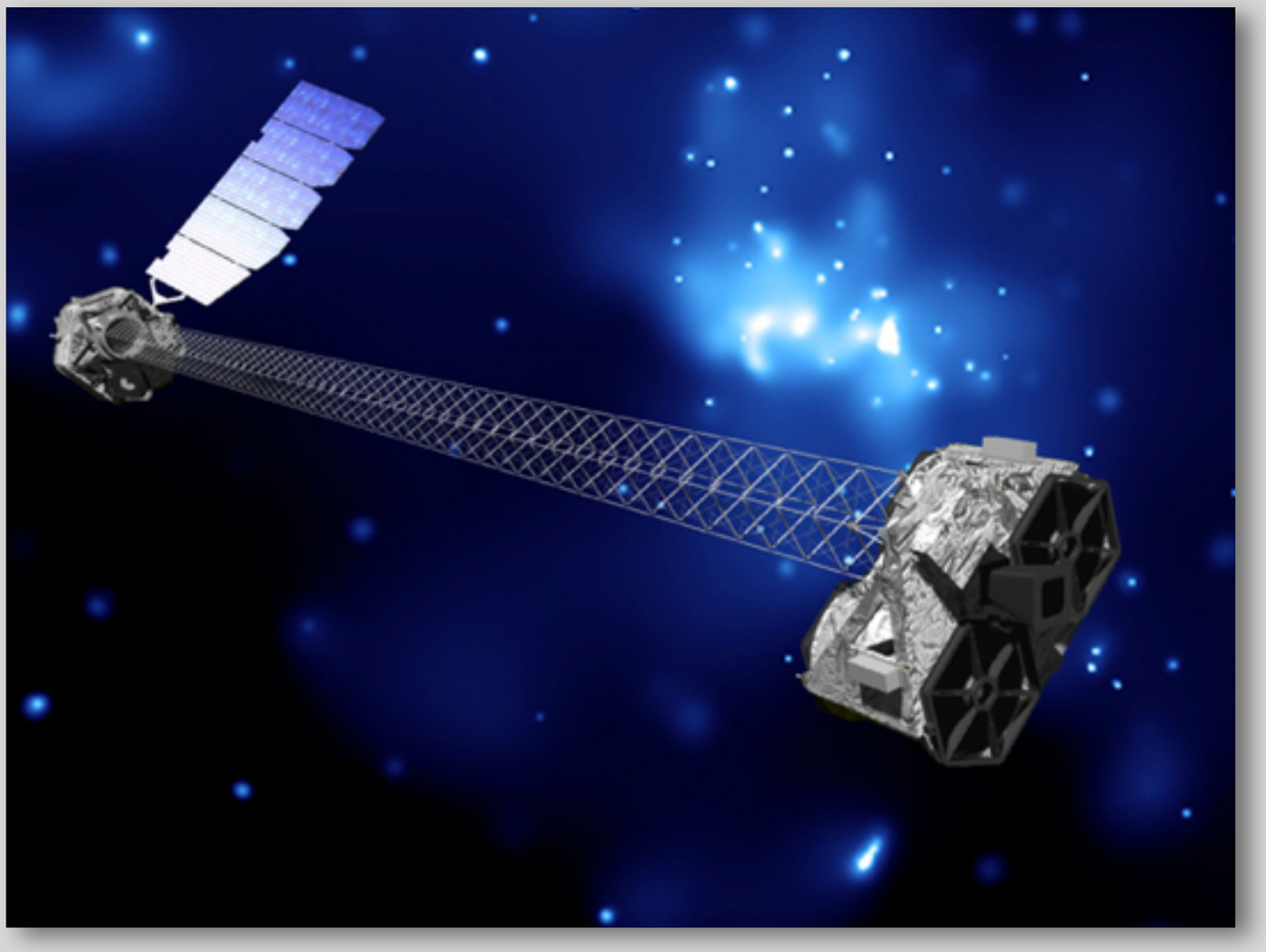
Utilizes latest technology and lessons learned from CGRO/COMPTEL.

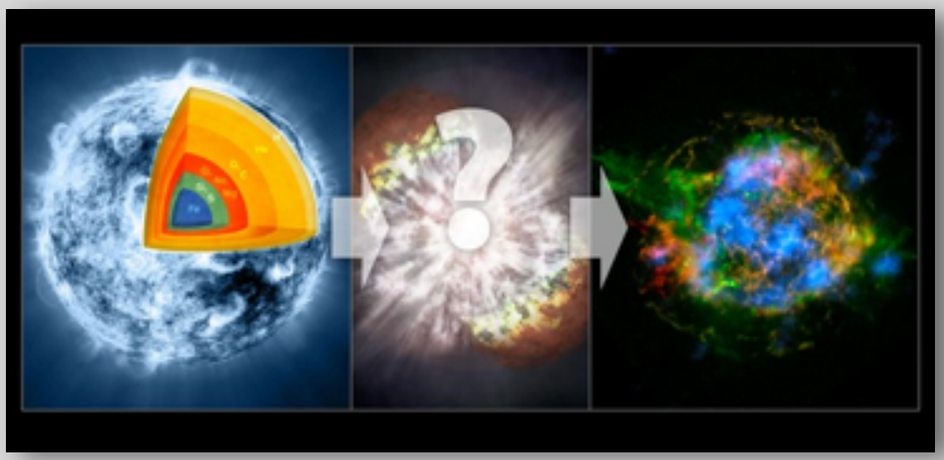


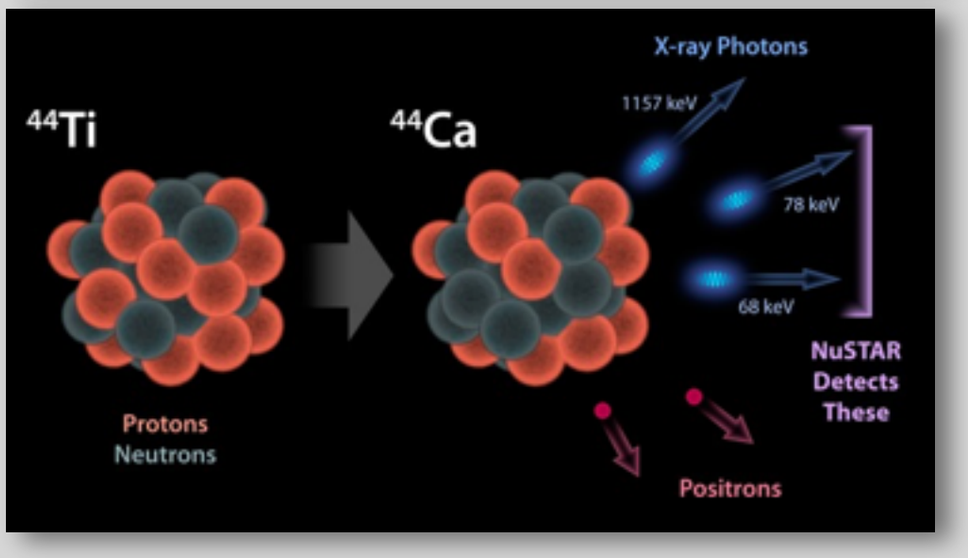
Next Generation Grazing Incidence Telescope

0.1 - 200 keV

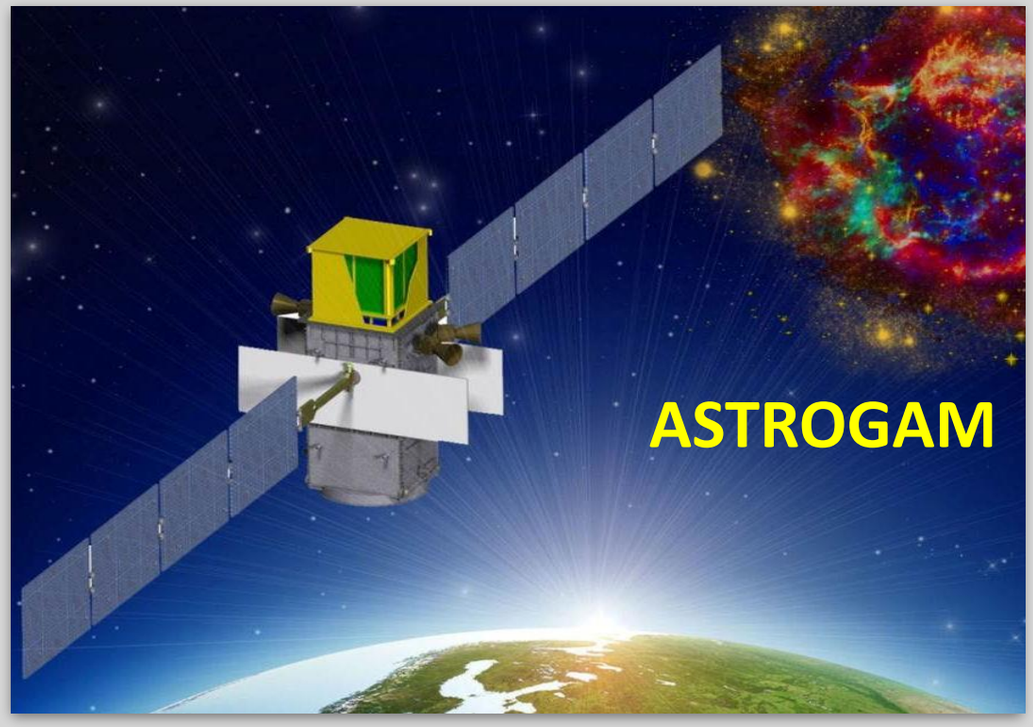
Utilizes latest technology and lessons learned from NuStar.







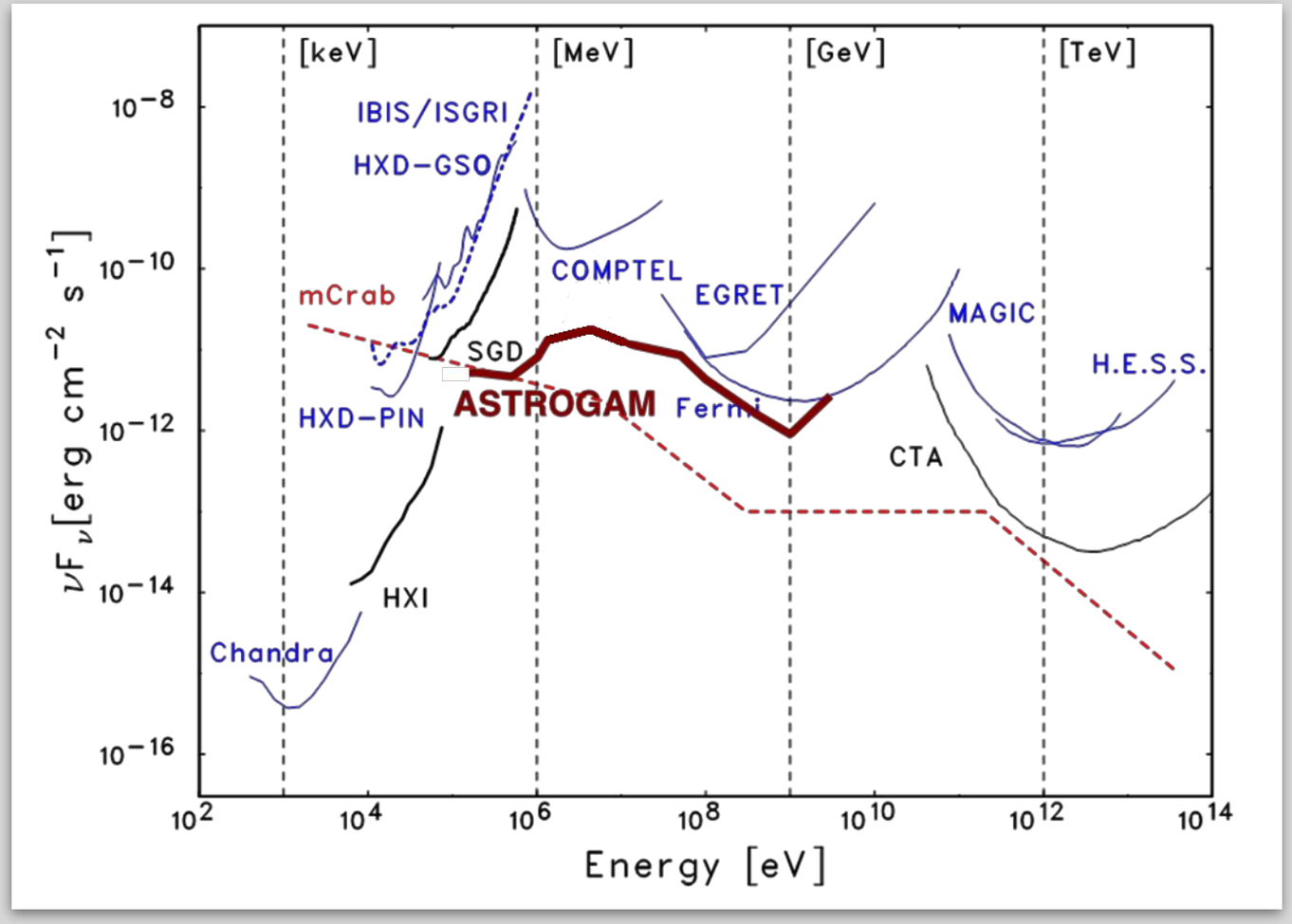
ASTROGAM - The Next Step?



Proposed to ESA as new M4 mission.

Compton / Pair telescope optimized for 1-100 MeV, including line emissions.

Improved performance up to a few hundred MeV.



Filling the Gap

For any astrophysical source, we cannot expect to have a full understanding of its properties without observing the part of the spectrum where it has its peak energy output.

- *Without such a measurement, any estimate of source energetics is just an approximation.*
- *Without such a measurement, spectral modeling of the source physics will be incomplete.*

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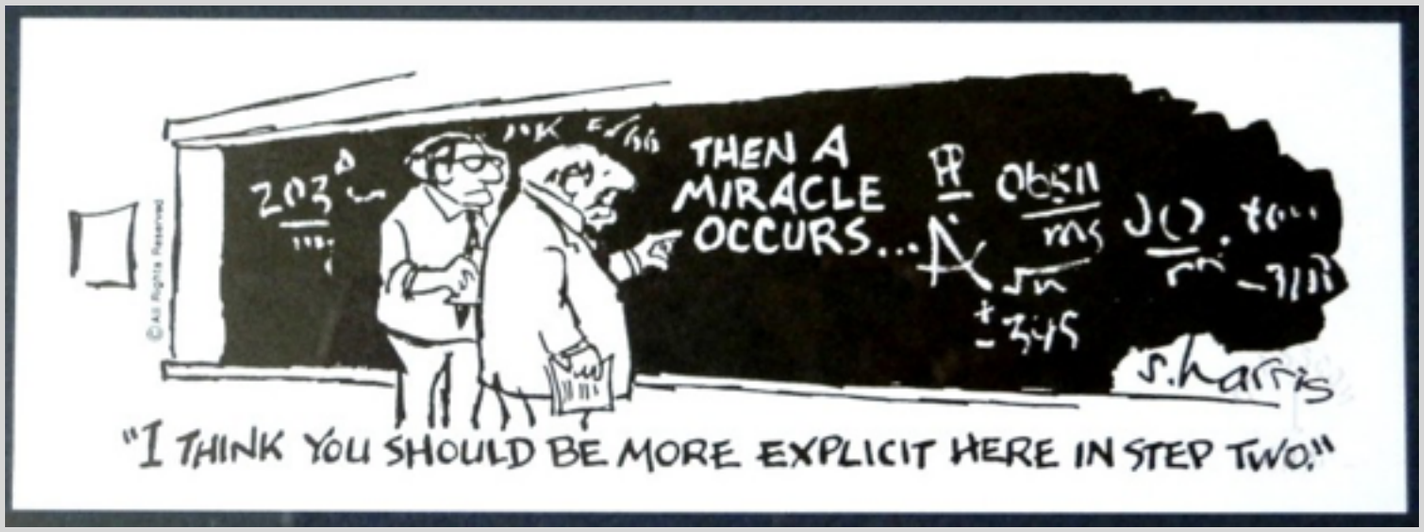
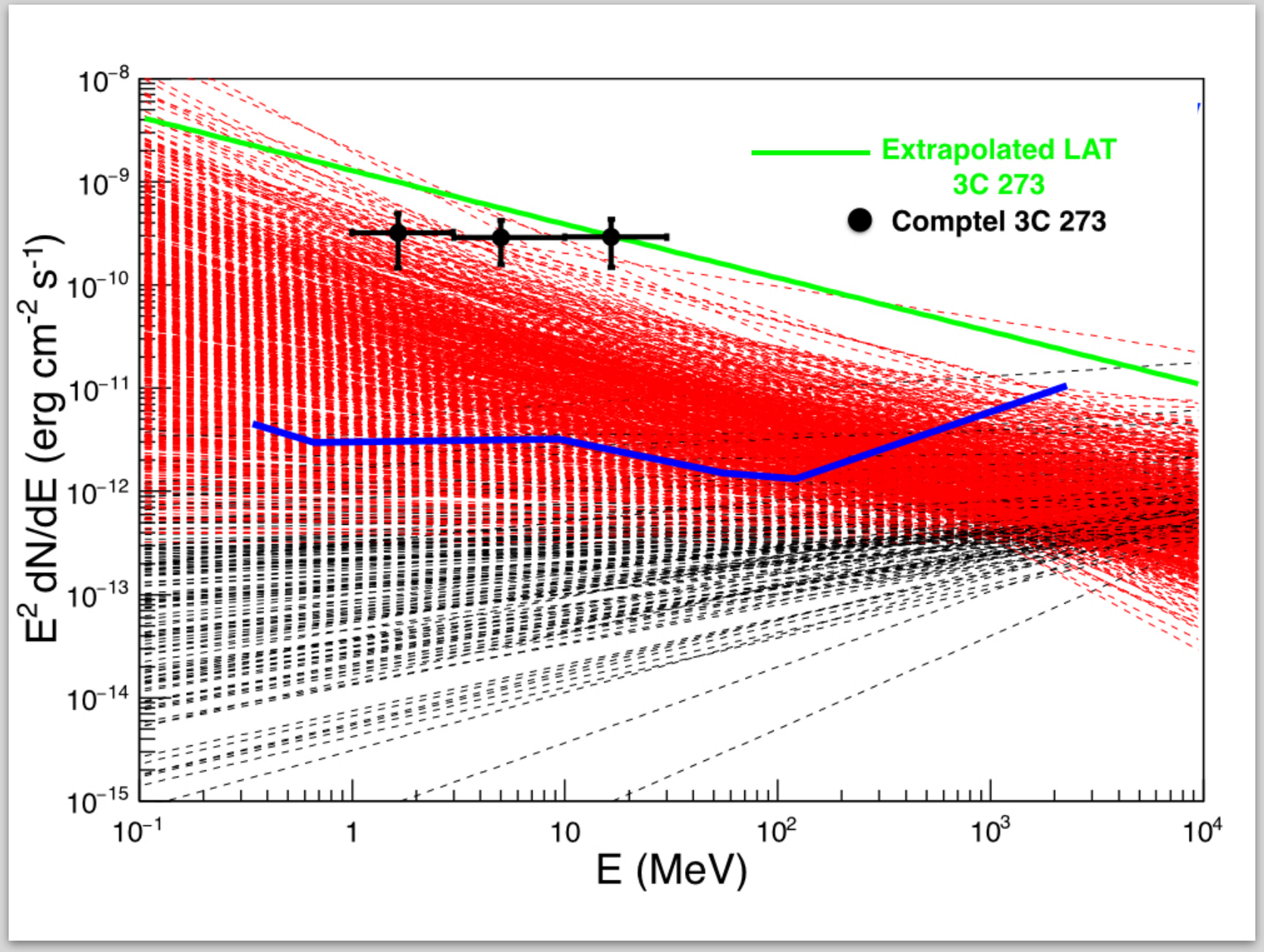


Filling the Gap

- Any Fermi/LAT source (E>100 MeV) with a photon power-law spectrum steeper than E^{-2} has its peak energy output < 100 MeV.
- About 2000 of the 3FGL sources have power-law spectra steeper than E^{-2}. Over 600 of these have spectra steeper than $E^{-2.5}$.
- These include many Flat Spectrum Radio Quasars (the most distant and most energetic LAT sources) as well as many unidentified sources.
- These results guarantee a significant scientific return for any lower-energy instrument with reasonable sensitivity.

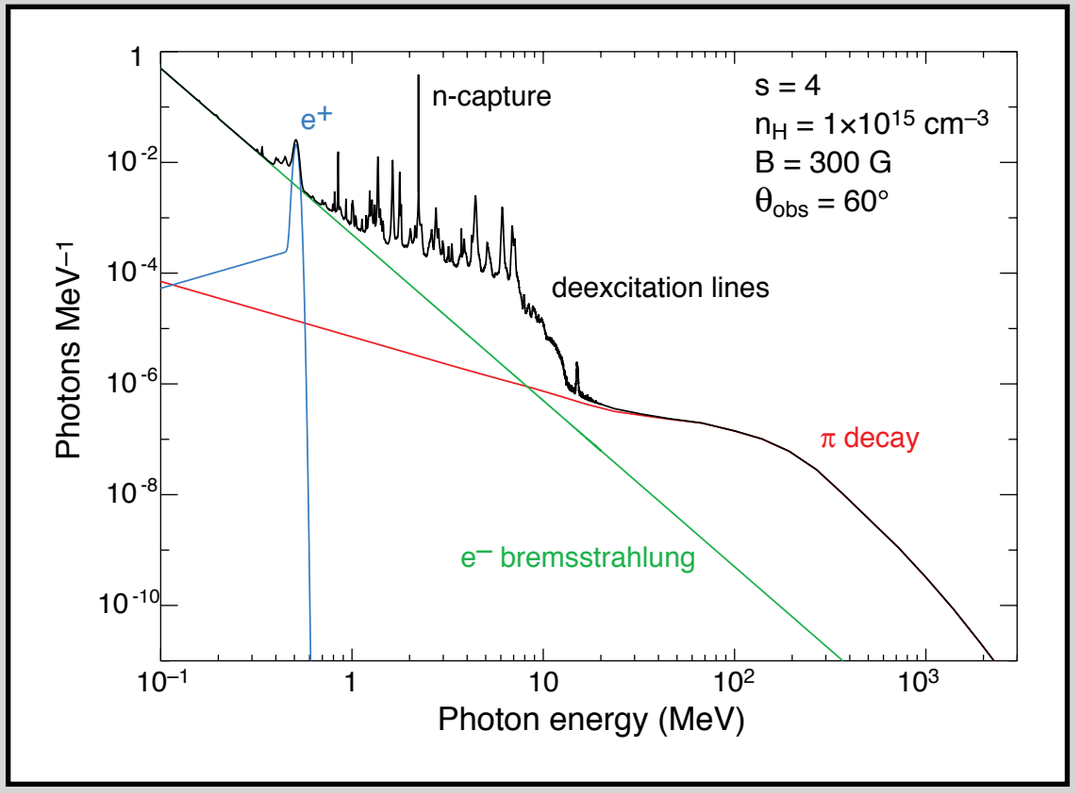
Filling the Gap



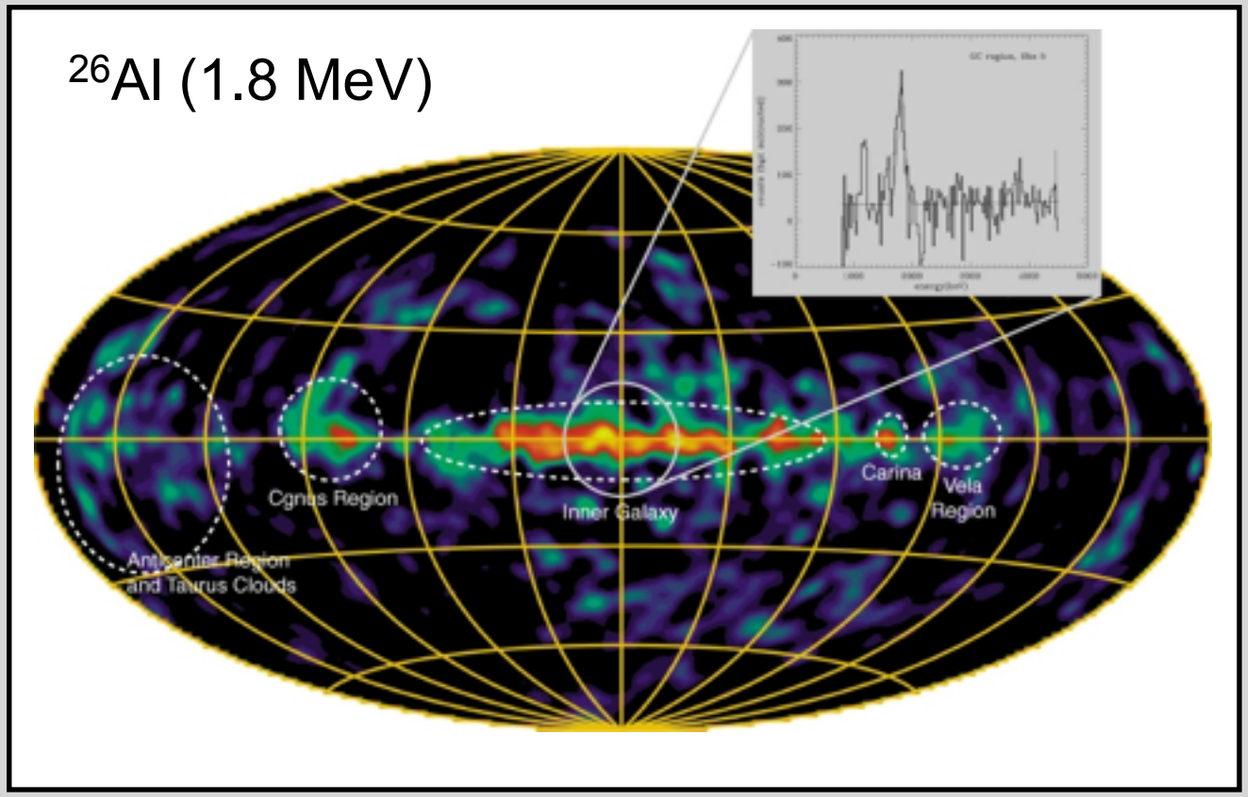
Extrapolated spectra of 3FGL unassociated sources

spectra <-2 are red
spectra >-2 are black

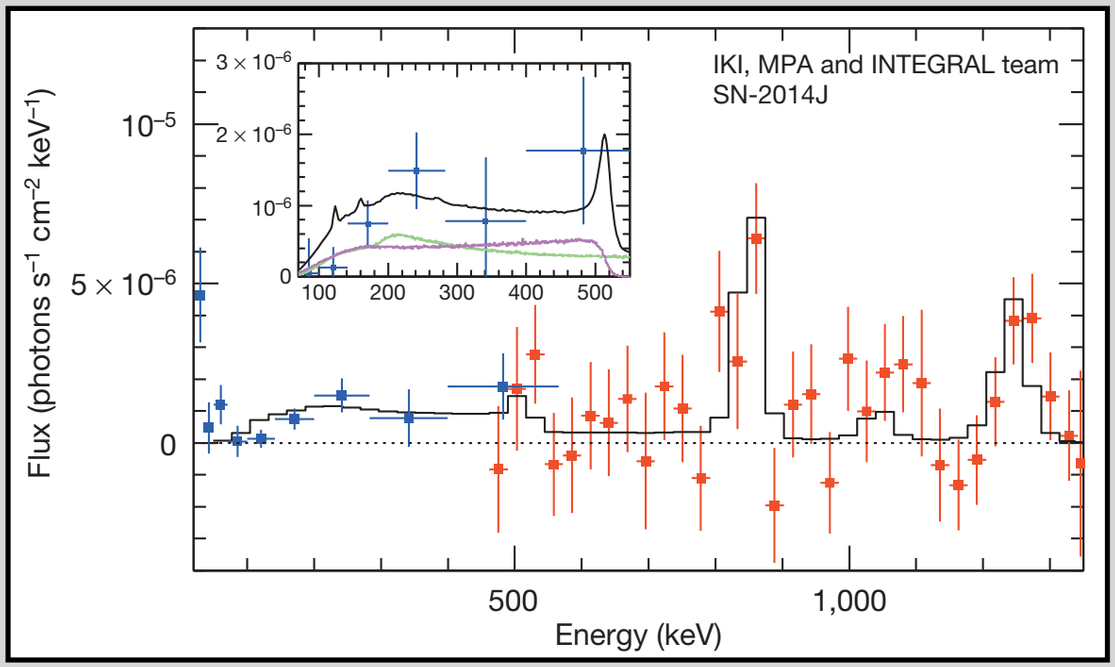
Specific Physics Examples



Model Solar Flare Spectrum



Diffuse Galactic Nucleosynthesis



^{56}Co decay lines from SN2014J (Churazov et al. 2014)

Science Questions

Matter and Antimatter in our Galaxy and Beyond

- What is the physics of thermonuclear and core-collapse supernovae?
- How is nuclear enrichment in our Galaxy related to SN activity and star formation?
- Are supernova remnants responsible for cosmic-ray acceleration up to PeV energies?
- How is the central black hole in the Galactic Center powering the surrounding regions?
- What is the source of the puzzling antimatter in the Galactic Center?

Accelerators in the Nearby & Distant Universe

- How are relativistic jets launched?
- How does the disk/jet transition occur?
- Is magnetic field reconnection at work in high-energy sources?
- How is the MeV extragalactic background produced?
- Where do ultra-high-energy cosmic rays (UHECRs) originate?
- What is the physics of acceleration and transient nuclear spectroscopy in solar flares?
- How are Terrestrial Gamma Ray Flashes (TGFs) generated?

Fundamental Physics and New Messengers

- What is the nature of Dark Matter?
- Are MeV-GeV sources related to the emission of gravitational waves and neutrinos?
- What is the connection of gamma-ray bursts (GRBs) to gravitational collapse?

Gamma Ray Science Interest Group

Our goal for this year is to develop a community roadmap for the future of space-based gamma ray astronomy in the US.

A major result of this effort will be to provide input to the next decadal survey.

GammaSIG Website
(http://pcos.gsfc.nasa.gov/sags/gammasag.php)

Mailing List
(http://pcos.gsfc.nasa.gov/sags/gammasag/gammasag-maillist.php)

Recent and Upcoming Events

Future Space-Based Gamma-Ray Observatories

Feb 5-7 workshop @ NASA/GSFC

http://asd.gsfc.nasa.gov/conferences/future_gamma_obs/

The Gamma-Ray Sky with ASTROGAM

Mar 26-27 workshop @ Paris

http://astrogam.iaps.inaf.it/Program_Astrogam2.html

Mini-Symposium on Future Gamma-Ray Missions

April APS Meeting @ Baltimore

PCOS Mini-Symposium

April APS Meeting @ Baltimore

High Energy Large and Medium-class Space Missions in the 2020s

Jun 29 - Jul 1, HEAD Meeting @ Chicago