Prospects in space-based Gamma-Ray Astronomy

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The unique Gamma-Ray sky

- Specific emission processes

	Radio	IR	Vis	UV	X	Gamma-rays
Relativistic particles	Synchrotron					Inverse Compton
Nuclear processes	-	-	-	-	-	Lines and continuum
Particle interactions	-	-	-	-	-	Continuum
Antimatter annihilation	-	-	-	-	-	Lines and continuum
Dark matter	Sync	-	-	-	-	Annihilation signatures

The non-thermal, nuclear and particle Universe

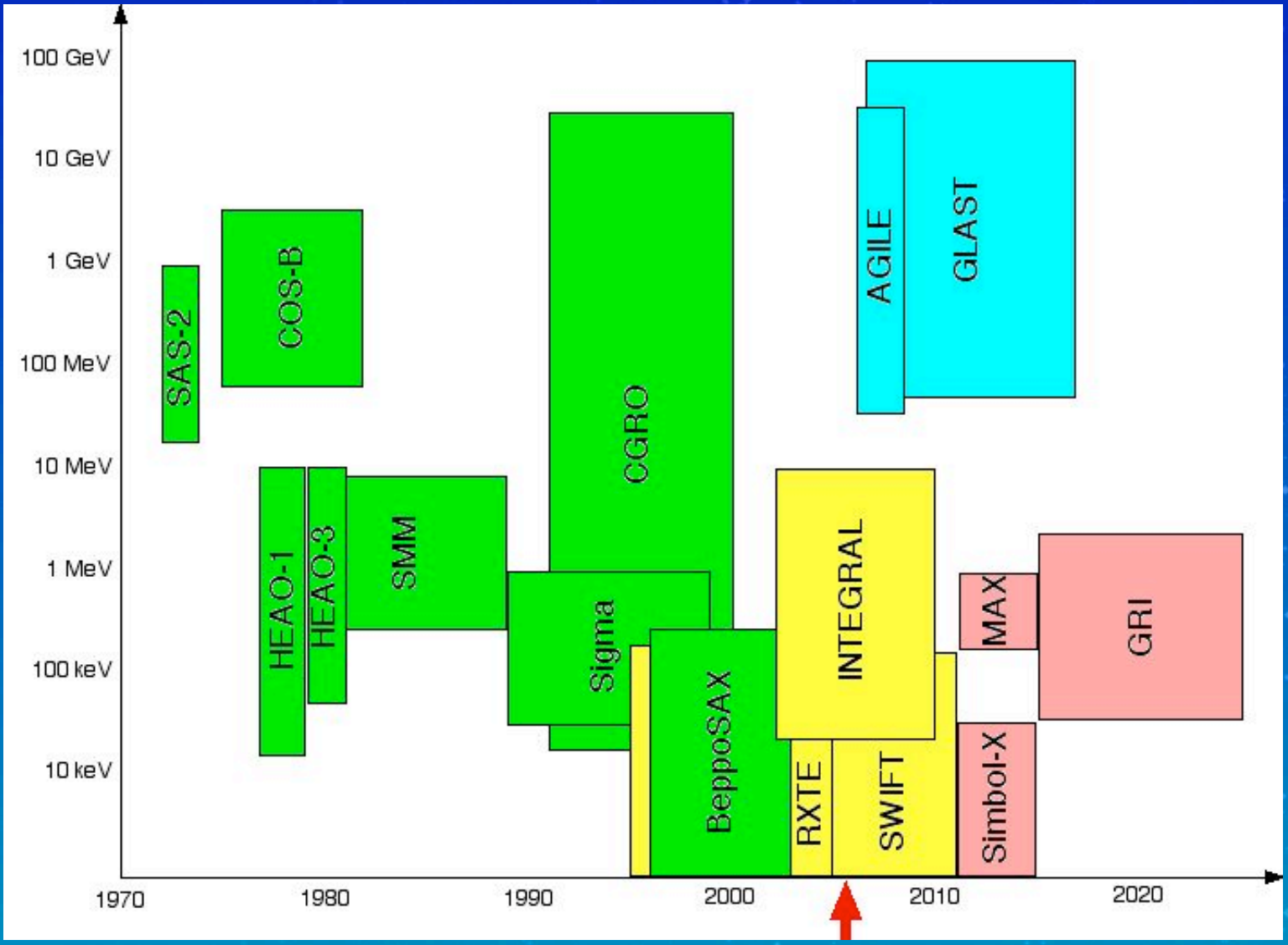
- Diversity of emission sites

  Sun, black holes, neutron stars, pulsars, SNRs, galaxies, AGNs, GRB, CB

- Penetrating power of gamma-ray photons

  Probe the central engines

Observing the Gamma-Ray sky



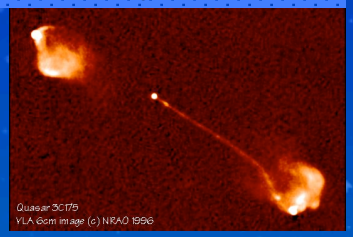
(Selected) science themes

Cosmic accelerators

The most dynamic and powerful sites in the Universe

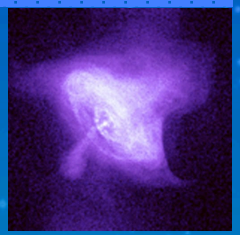
- **Accretion on compact objects**

  Binaries
  μ-blazars
  AGN



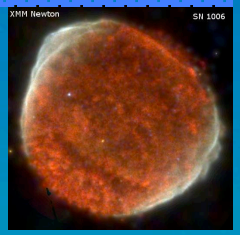
- **Rotation of neutron stars**

  Pulsars
  Magnetars



- **Explosions and shocks**

  GRB
  SNR
  Stellar winds



Cosmic explosions

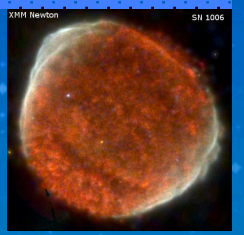
The most violent events in the Universe

- **Gravitational collapse**

  Core-collapse SN
  GRB

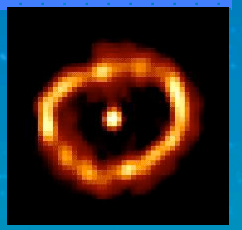
- **Thermonuclear explosions**

  Type Ia SN



- **Thermonuclear runaways**

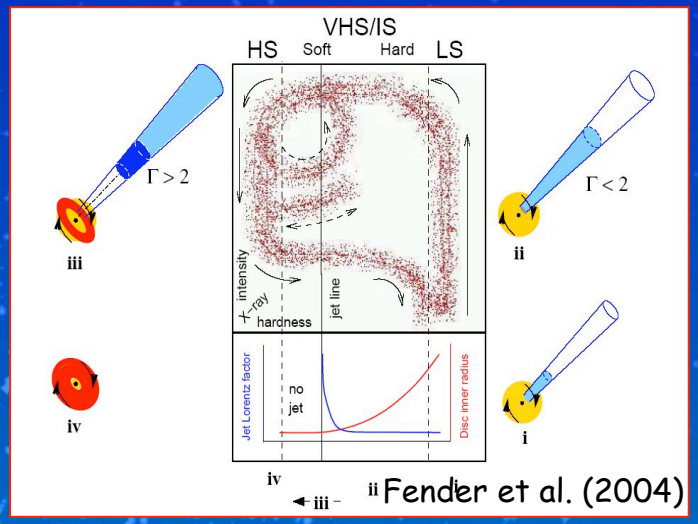
  Novae
  X-ray bursts



Cosmic accelerators

Black holes : understanding the accretion-ejection physics

- How is the energy reservoir transformed into relativistic particles ?
- Jet formation and collimation ?
- What triggers the outbursts ?
- Composition of accelerated plasmas ?
- Nature of the radiation process ?

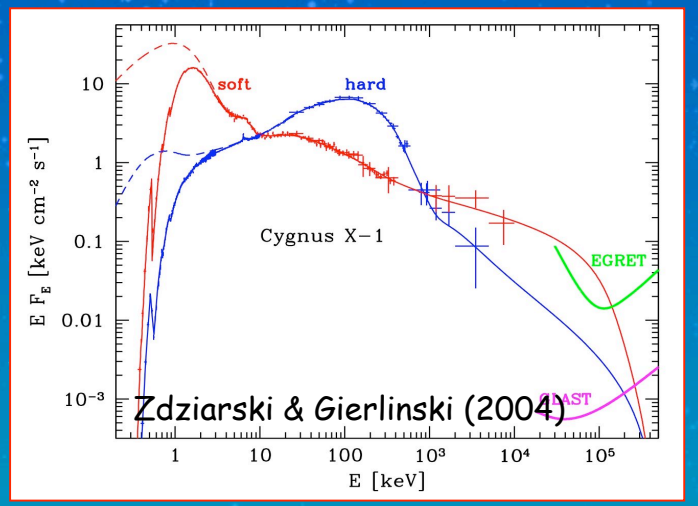


Fender et al. (2004)

Study broad-band SED in various states ; probe the universality of hard powerlaw tails

Measure polarisation of emission components

Search for pair annihilation and nuclear line features



Zdziarski & Gierlinski (2004)

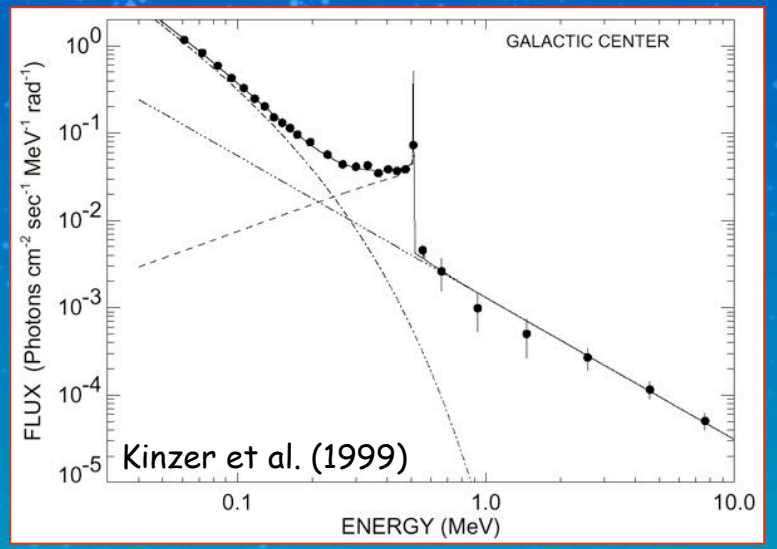
Cosmic accelerators

The origin of galactic soft γ-ray emission

- *INTEGRAL* : ~ 90% of the galactic hard X-ray emission is resolved
- Spectral change around ~ 300 keV (Comptonisation ⇨ powerlaw)
- What is the origin of the emission at soft γ-ray energies ?

Search for hard tails in soft γ-ray sources

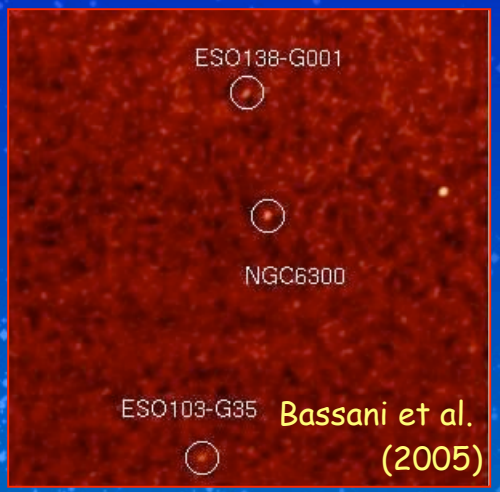
Resolve the 'diffuse' galactic soft γ-ray emission



Cosmic accelerators

The origin of the cosmic soft γ-ray background

- *INTEGRAL* : ~ 20% of the sources in the 2nd IBIS catalogue are of extragalactic origin
  24 Seyferts, 5 Blazars, 5 AGN, 3 clusters
- So far, only ~ 1 % of the cosmic soft γ-ray background is resolved

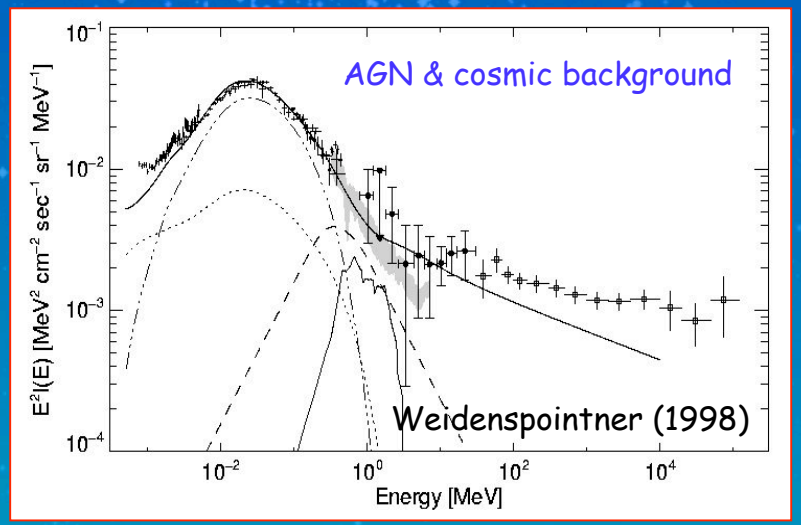


Bassani et al. (2005)

Measure the soft γ-ray SED of AGN
- high-energy cut-offs
- hard tails

Resolve the soft γ-ray background

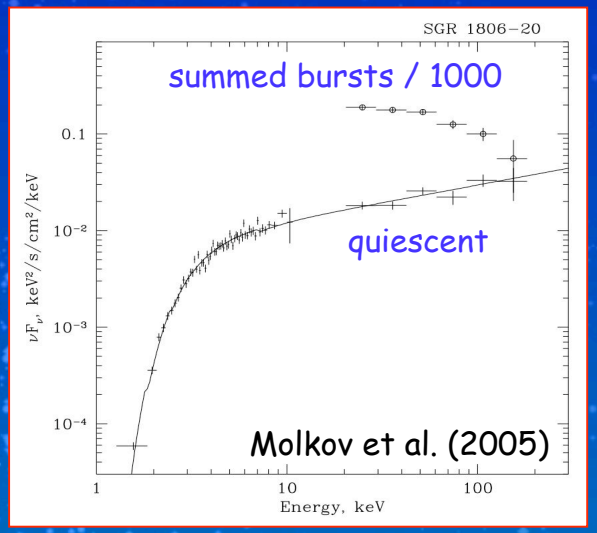
Determine the nature of the radiation process
- polarisation measurements
- annihilation features



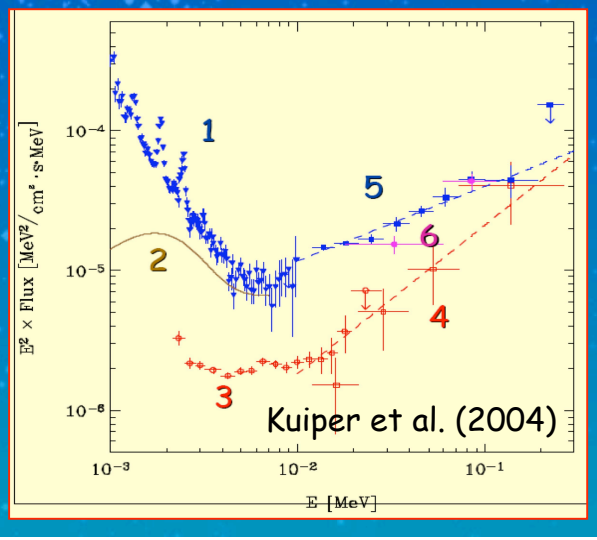
Cosmic accelerators

Probing particle acceleration in the most extreme magnetic fields

- *INTEGRAL* : discovery of hard emission tails in SGR 1806-20 and AXPs
- Emission mechanism ?
- Energy cut-off ?
  QED effects (photon splitting)
- Cyclotron features ?



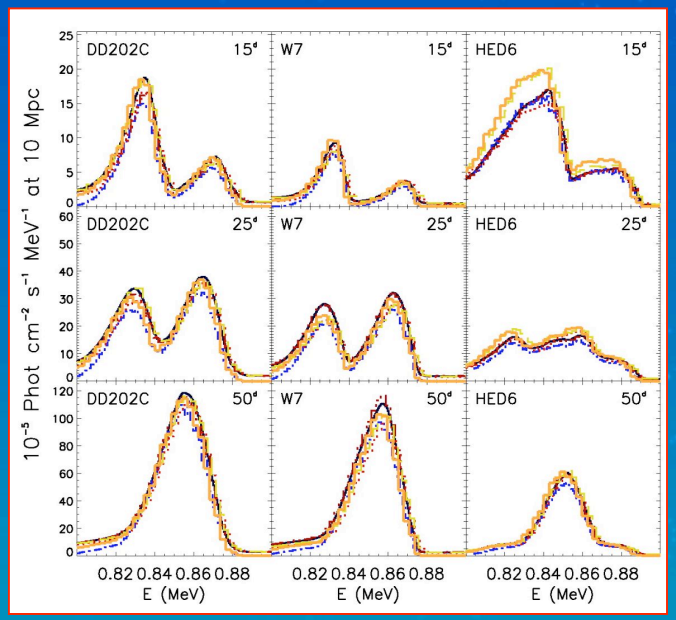
Measure the soft γ-ray SED of magnetars
- high-energy cut-off
- cyclotron features



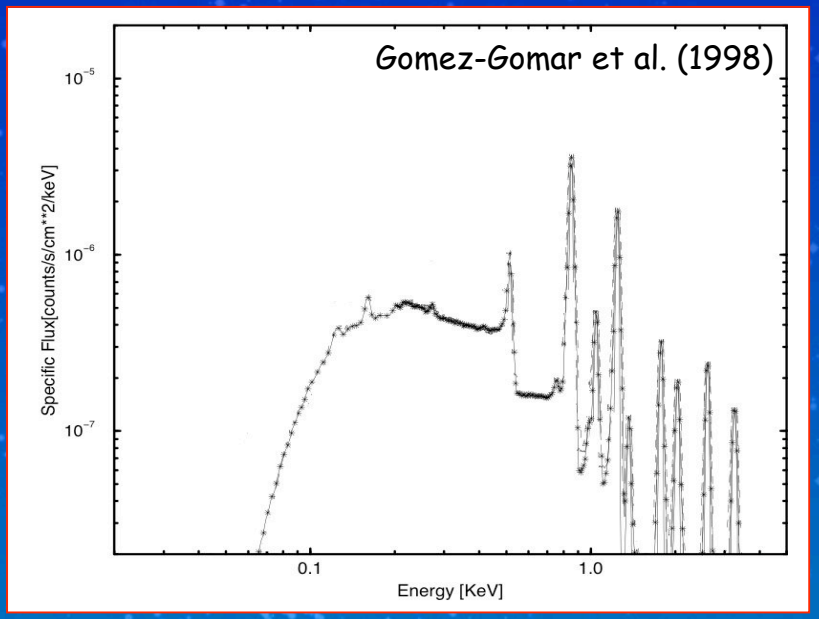
Cosmic explosions

Type Ia SN : Identifying the progenitors and probing the explosion physics

- Distinguish progenitor scenarios
  direct measurement of ^{56}Ni mass
  (single / double degenerate)
- Distinguish explosion scenarios
  measure line shape evolution



Milne et al. (2004)



Measure γ-ray line lightcurves and profiles in nearby (< 100 Mpc) SN Ia

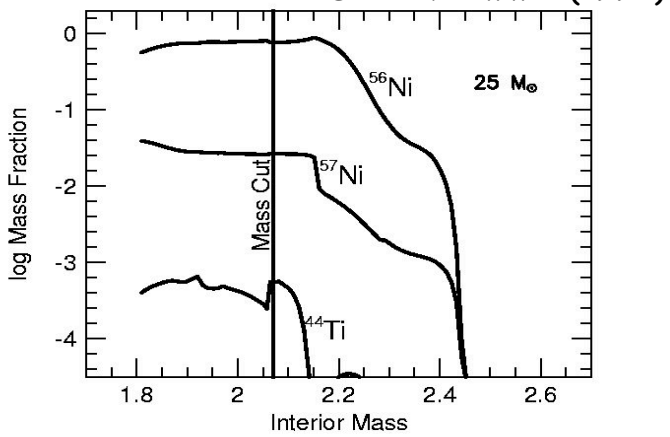
Search for radioactive decay signatures in galactic SNR (incl. e^+)

Cosmic explosions

From stars to compact objects : understanding core collapse explosions

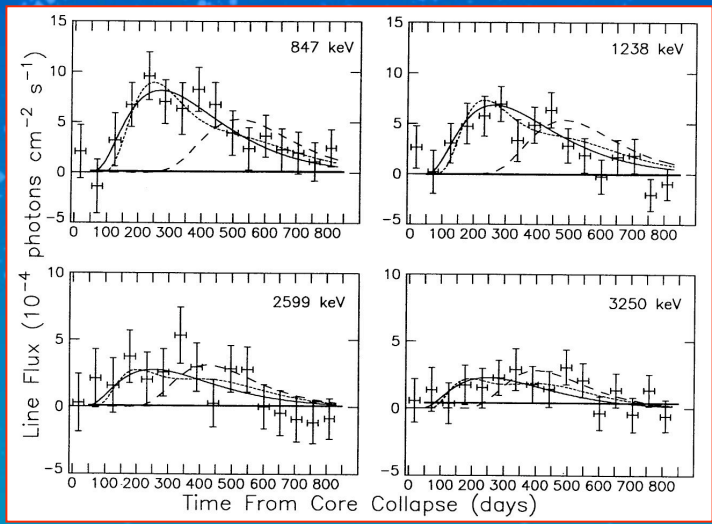
- *INTEGRAL* : ^{44}Ti ejection velocity in Cas A v_e > 1000 km s^{-1}
- Fe-core material acceleration ?
- Jet formation ?
- What drives the supernova explosion ?

Diehl & Timmes (1997)



Study γ-ray lines in galactic SNR (^{44}Ti, ^{26}Al, ^{60}Fe)

Measure γ-ray line lightcurves and profiles in nearby (< 10 Mpc) core-collapse supernovae

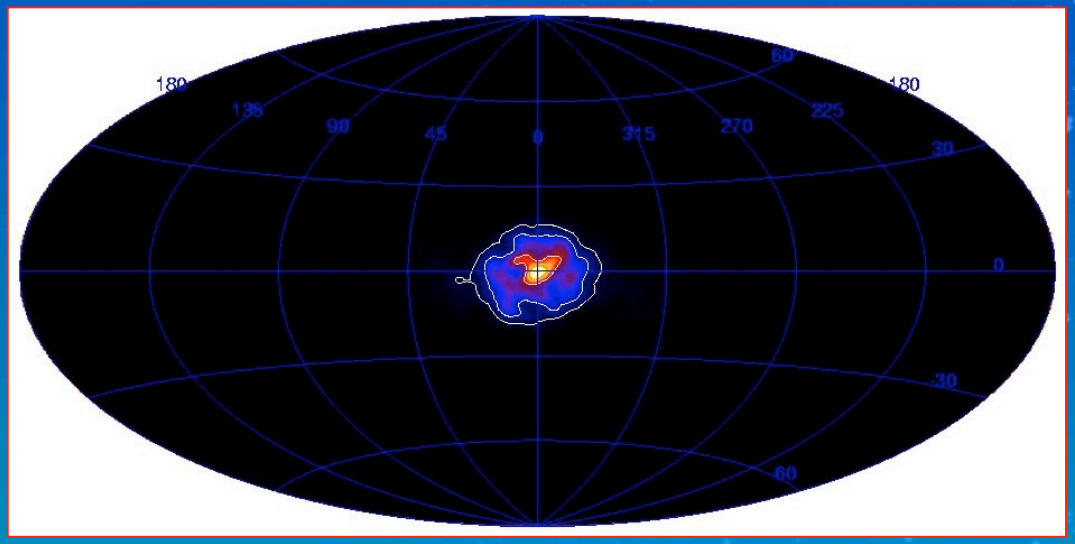


Leising & Share (1990)

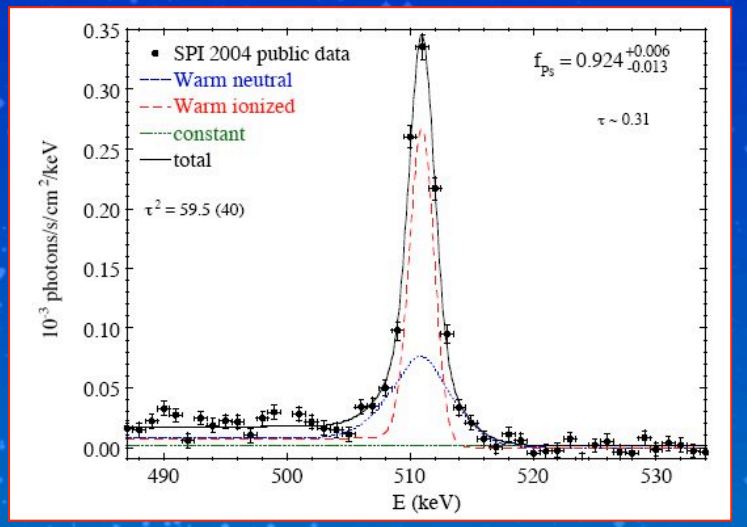
Cosmic explosions

Unveiling the origin of galactic positrons

- *INTEGRAL* : the bulk of positrons originates from a pure bulge population ; they annihilate in a warm and partially ionised ISM
- What is this mysterious bulge source ?



Knödlseder et al. (2005)



Jean et al. (2005)

High-resolution mapping of the galactic bulge region

Probe annihilation medium around positron sources

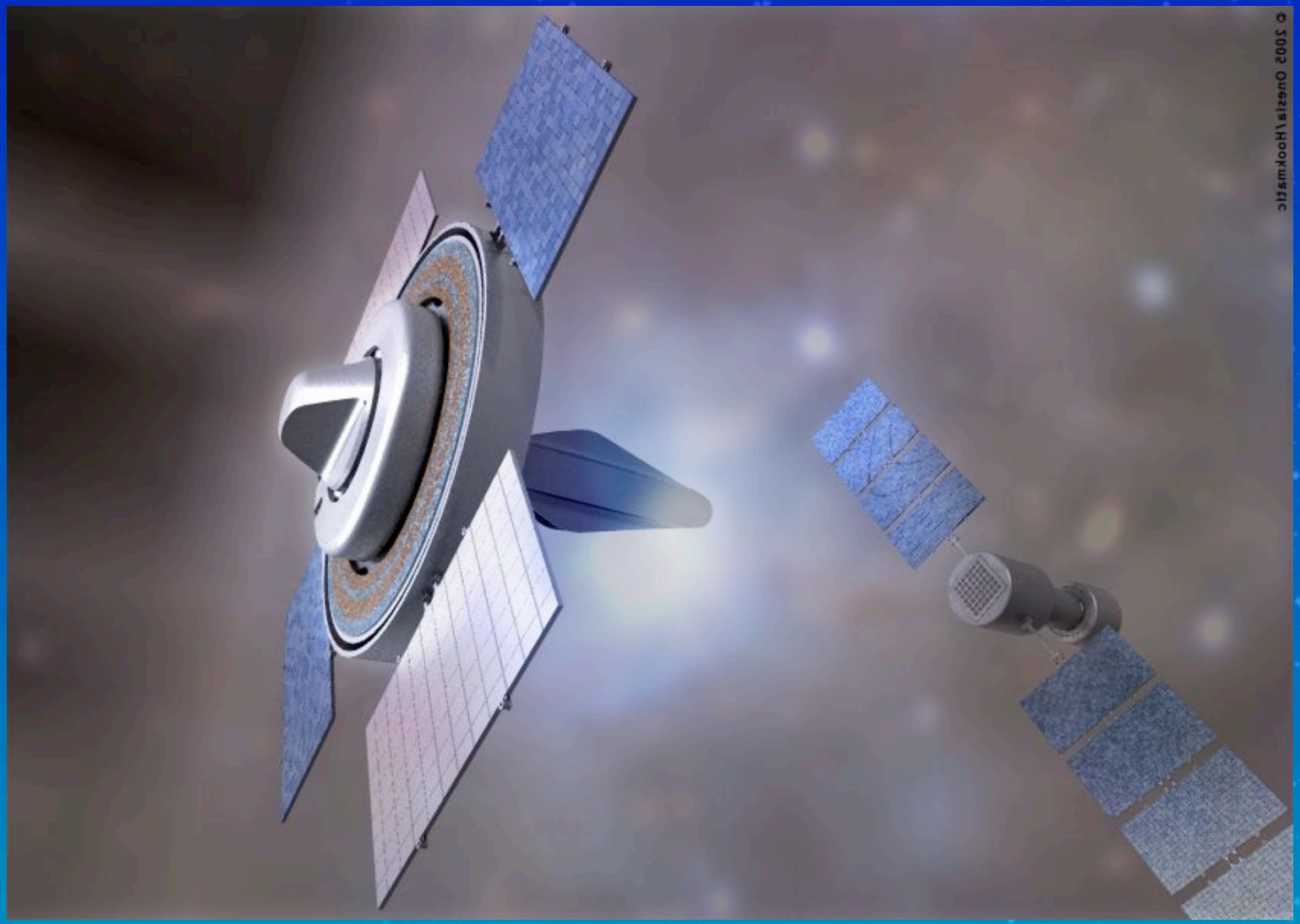
Mission requirements

- Sensitivity leap in the soft gamma-ray band
- Adequate angular resolution for counterpart identification
- Capability to measure polarisation

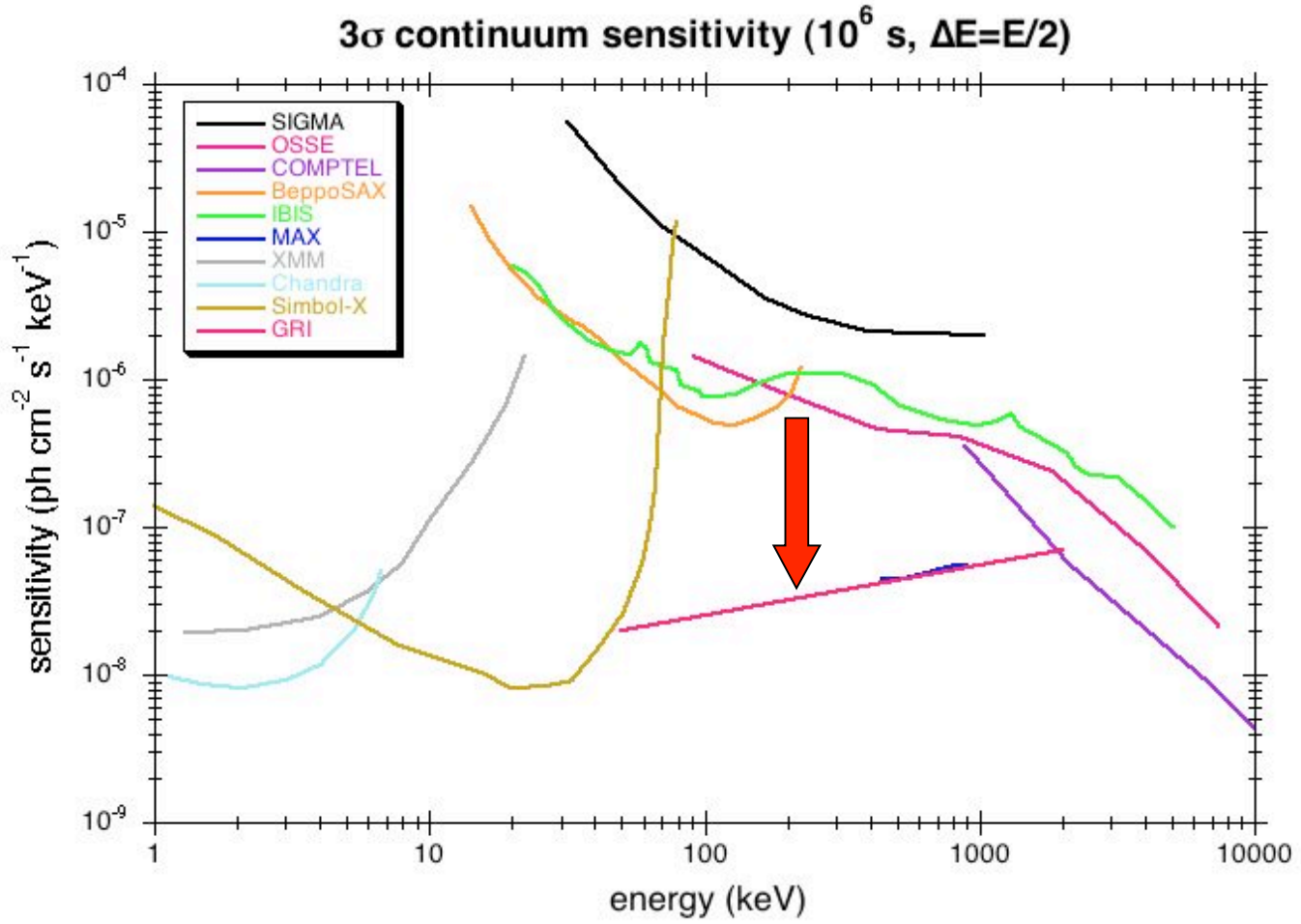
Mission parameters

• Energy band	50 keV - 2 MeV
• FOV	30 arcmin
• Continuum sensitivity	10^{-8} ph cm^{-2} s^{-1} keV^{-1} (10^6 s, 3σ)
• Narrow line sensitivity	5×10^{-7} ph cm^{-2} s^{-1} (10^6 s, 3σ)
• Energy resolution	2 keV @ 600 keV
• Angular resolution	arcmin
• Polarisation	1 % @ 10 mCrab (10^6 s, 3σ)

The Gamma-Ray Imager

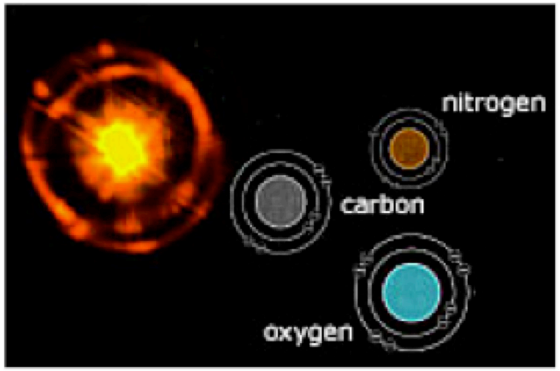


The Gamma-Ray sensitivity leap



ESA's Cosmic Vision 2015 - 2025

- ESA is currently defining the space program for 2015 - 2025
  - april 2004 : call for themes
  - autumn 2005 : final report
  - early 2006 (?) : first AO (3 expected)



Looking at the Universe with gamma-ray eyes

These observatories would be joined by more missions, such as an Optical/Near-infrared Wide Field Imager to provide clues to the understanding of the elusive dark energy through the study of distant supernovae. An All-sky Cosmic Microwave Background Mapper would chart the details of the early accelerated expansion of the Universe.

An Ultra-high Precision Astrometry Optical/UV Spectroscopy mission could conduct a census of terrestrial exoplanets within 326 light years, a MeV Gamma Ray Imager would study the physics of supernovae at the origin of heavy nuclei and find the true origin of antimatter, and a High-resolution UV Spectroscopy mission would investigate the warm/hot intergalactic medium and distant supernovae.

http://www.esa.int/esaSC/SEM8OJ2IU7E_index_0.html

- GRI consortium works towards detailed mission design
  http://gri.cesr.fr

GRI science working group

GRI kick-off meeting (Toulouse, June 2005)