

# Prospects in space-based Gamma-Ray Astronomy

On behalf of the European Gamma-Ray community

Jürgen Knödlseder

Centre d'Etude Spatiale des Rayonnements, Toulouse, France

# Gamma-Ray Astronomy in Europe

- Europe has a long tradition in gamma-ray astronomy and is actually the world leader in the field (INTEGRAL)  
Maintain Europe's leading role in gamma-ray astronomy
- Why Gamma-Ray Astronomy ?  
Specific character of emission processes w/r to other wavebands  
(non-thermal, particle acceleration, particle & nuclear physics)  
Diversity of emission sites  
(Sun, compact binaries, pulsars, SNRs, Galaxy/ISM, AGNs, GRBs, CB)  
Penetrating power of gamma-ray photons
- Seminar : Prospects in space-based Gamma-Ray Astronomy for Europe  
March 18th, 2005 (Rome) <http://www.cesr.fr/~jurgen/rome2005/>  
Presentation of the conclusions

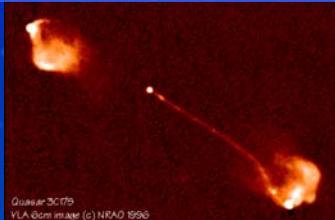
# Science themes

## Cosmic accelerators

The most dynamic and powerful sites in the Universe

- Accretion on compact objects

Binaries  
 $\mu$ -blazars  
AGN



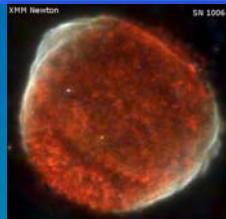
- Rotation of neutron stars

Pulsars  
Magnetars



- Explosions and shocks

GRB  
SNR  
Stellar winds



## Cosmic explosions

The most violent events in the Universe

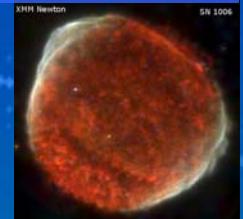
- Gravitational collapse

Core-collapse SN  
GRB



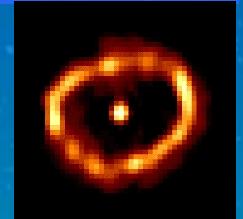
- Thermonuclear explosions

Type Ia SN



- Thermonuclear runaways

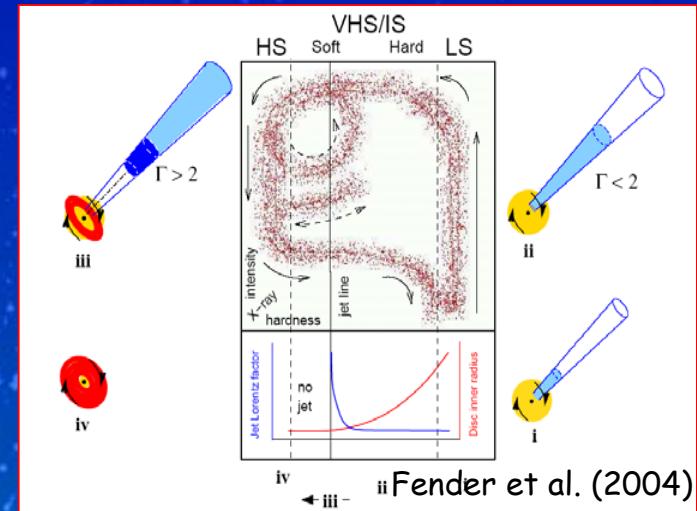
Nova  
X-ray bursts



# Cosmic accelerators

Black holes : understanding the accretion-ejection physics

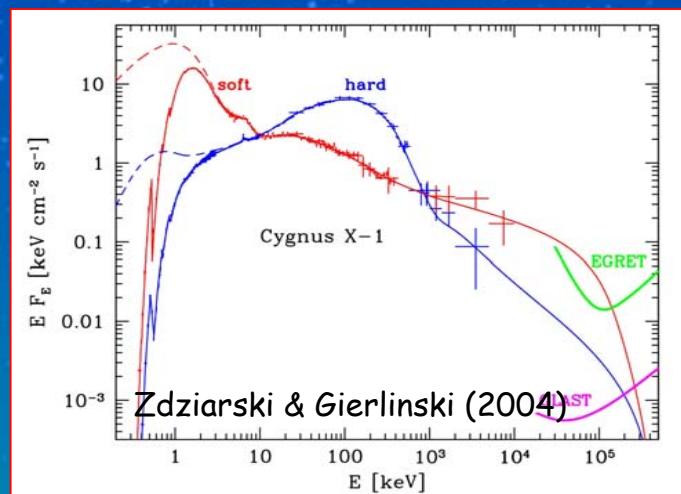
- How is the energy reservoir transformed into relativistic particles ?
- Jet formation and collimation ?
- What triggers the outbursts ?
- Composition of accelerated plasmas ?
- Nature of the radiation process ?



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



# Cosmic accelerators

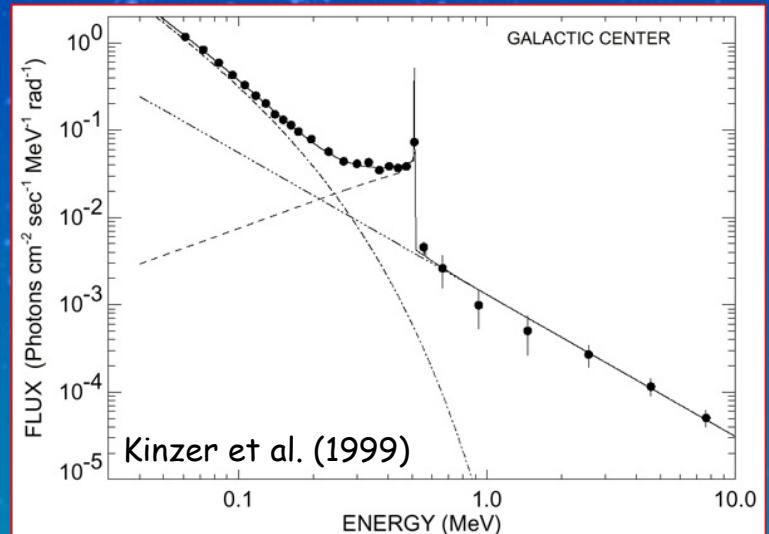
The origin of galactic soft  $\gamma$ -ray emission

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



Search for hard tails in soft  $\gamma$ -ray sources

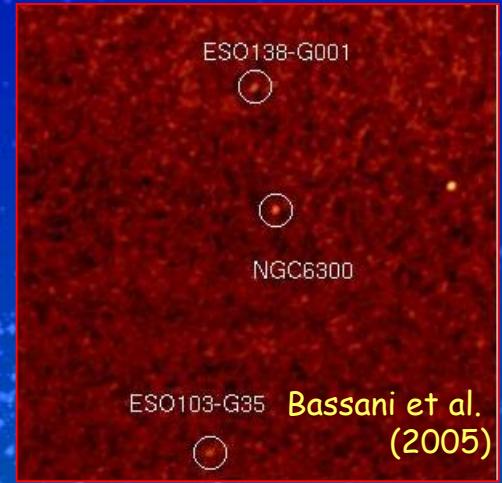
Resolve the 'diffuse' galactic soft  $\gamma$ -ray emission



# Cosmic accelerators

## The origin of the cosmic soft $\gamma$ -ray background

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



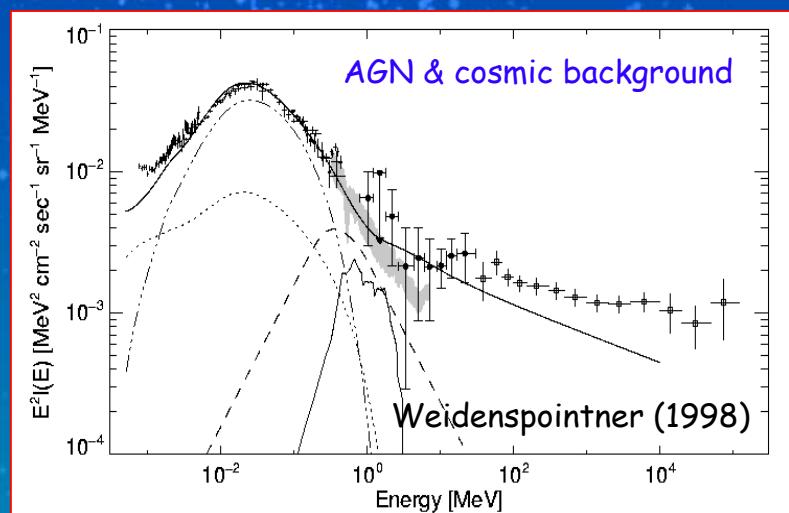
Measure the soft  $\gamma$ -ray SED of AGN

- high-energy cut-offs
- hard tails

Resolve the soft  $\gamma$ -ray background

Determine the nature of the radiation process

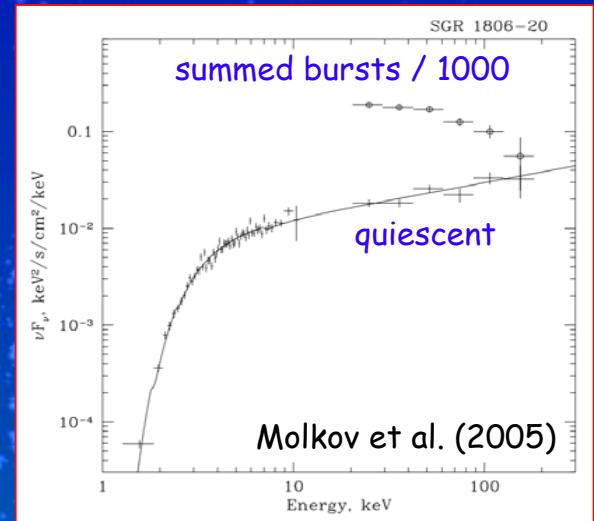
- polarisation measurements
- annihilation features



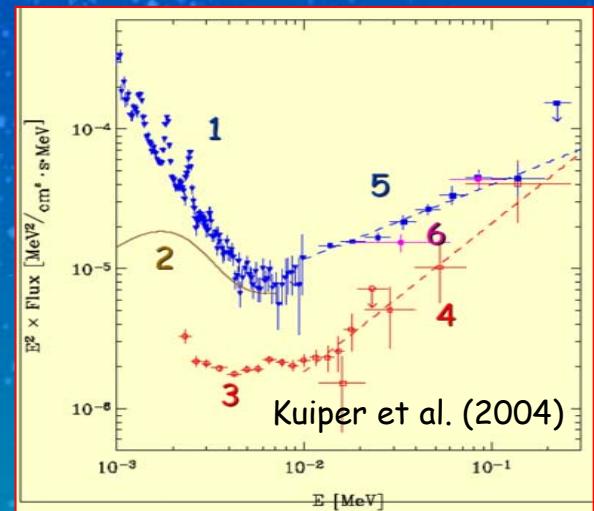
# Cosmic accelerators

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 ?



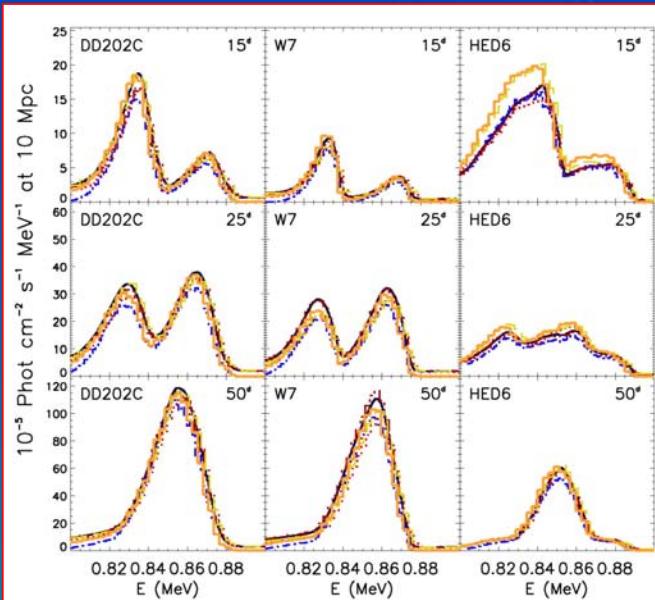
Measure the soft  $\gamma$ -ray SED of magnetars  
- high-energy cut-off  
- cyclotron features



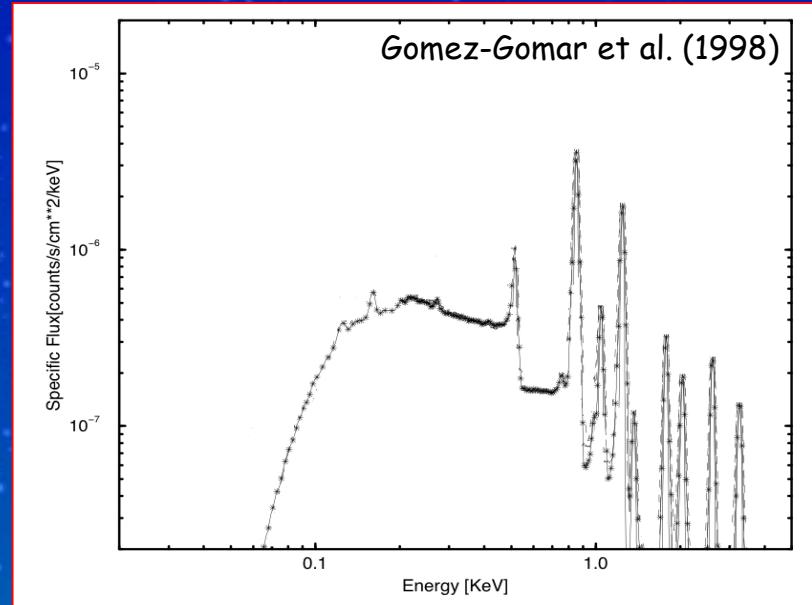
# Cosmic explosions

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

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



Milne et al. (2004)



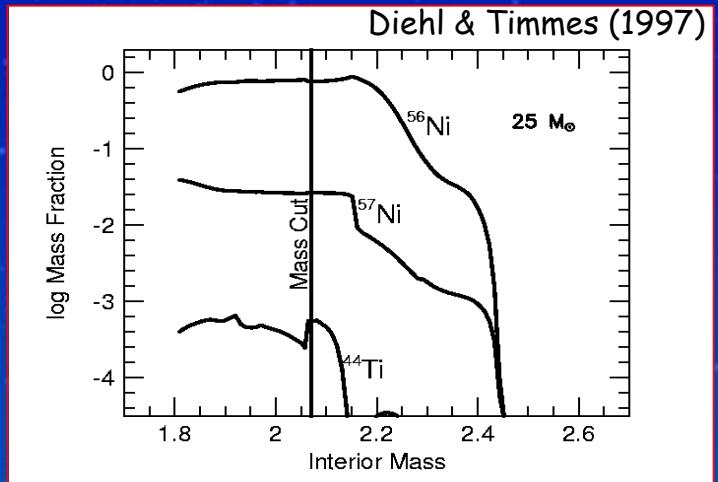
Measure  $\gamma$ -ray line lightcurves and profiles in nearby (< 100 Mpc) SN Ia

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

# Cosmic explosions

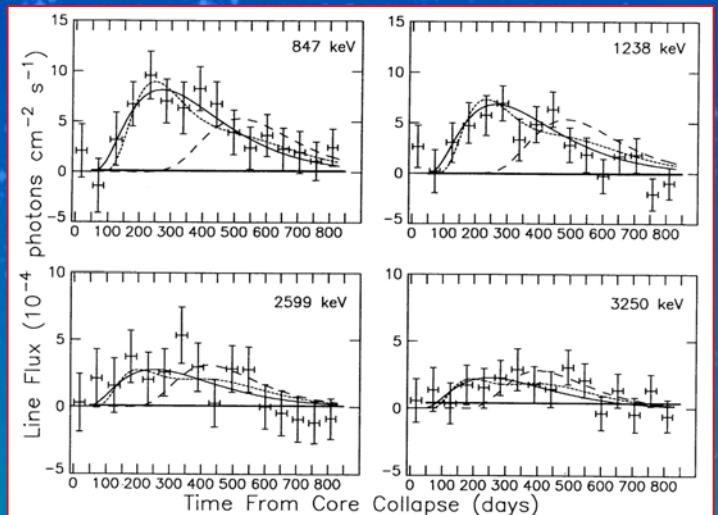
From stars to compact objects : understanding core collapse explosions

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



Study  $\gamma$ -ray lines in galactic SNR  
( $^{44}\text{Ti}$ ,  $^{26}\text{Al}$ ,  $^{60}\text{Fe}$ )

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

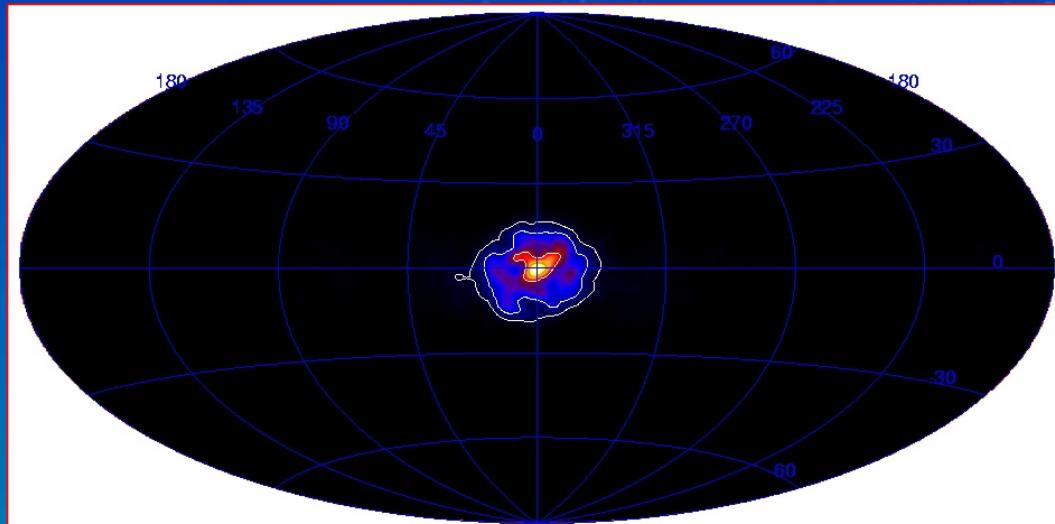


Leising & Share (1990)

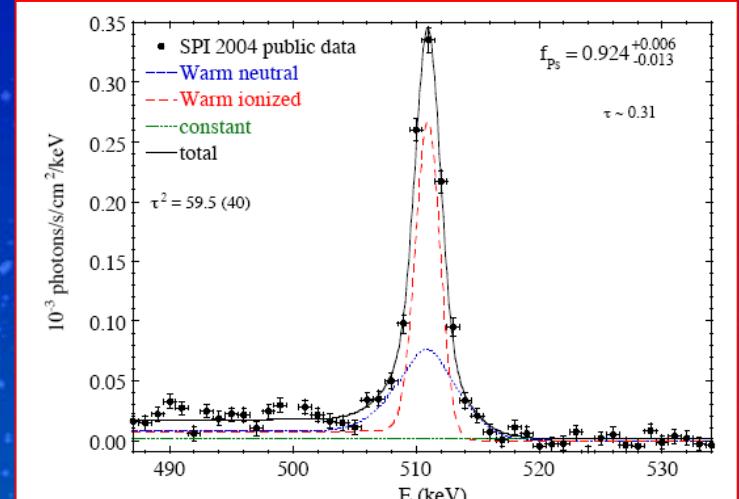
# Cosmic explosions

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 ?



Knölseder 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	$10^{-8} \text{ ph cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1}$ ( $10^6$ s, $3\sigma$ )
• Narrow line sensitivity	$5 \times 10^{-7} \text{ ph cm}^{-2} \text{ s}^{-1}$ ( $10^6$ s, $3\sigma$ )
• Energy resolution	2 keV @ 600 keV
• Angular resolution	arcmin
• Polarisation	1 % @ 10 mCrab ( $10^6$ s, $3\sigma$ )

# The Gamma-Ray Imager

