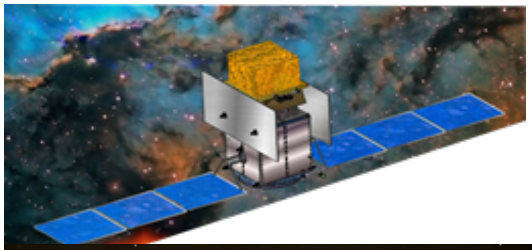


eASTROGAM

GRB physics with eASTROGAM

Jet collides with ambient medium (external shock wave)

Colliding shells emit low-energy gamma rays (internal shock wave)

High-energy gamma rays

X-rays

Visible light

Radio

Slower shell

Faster shell

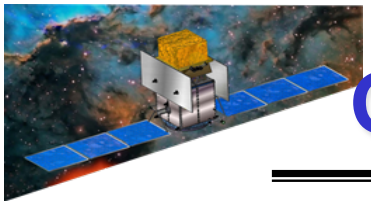
Low-energy gamma rays

Black hole engine

Prompt emission

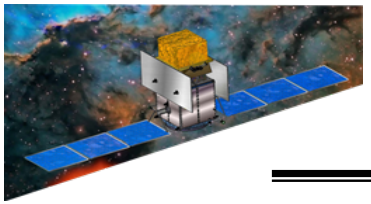
Afterglow

Francesco Longo
University of Trieste
INFN Trieste



GRB Physics Objectives for ASTROGAM

- **Spectral Measurement of the crucial 10 – 100 MeV Energy band**
- **Polarimetry in the Compton and Pair**
- **Triggering on HE-emitting GRB in the era of CTA …**

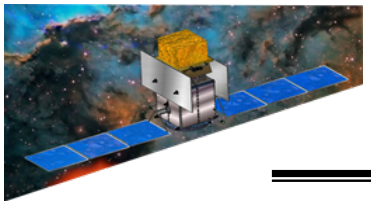


Overview of Past GRB presentations

ASTROGAM and GRBs
Strong points

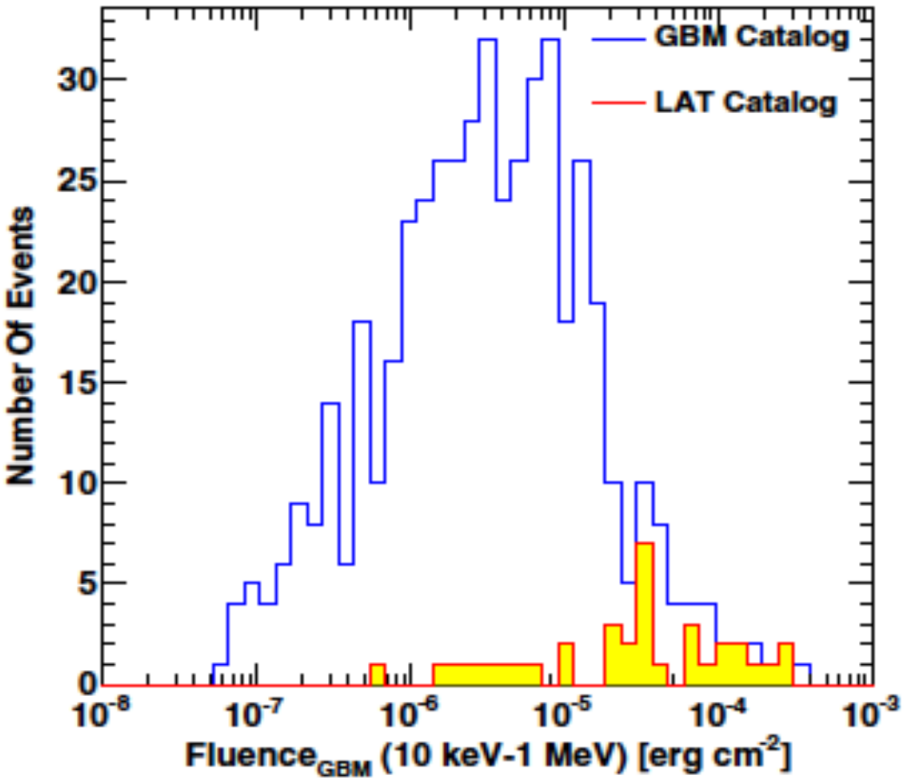
- Several GRB/yr in large FOV of ASTROGAM (→ spectroscopy, polarimetry)
- Very interesting energy range bridging the "classical GRB range" (Band function) with the >100 MeV range where extra components are required
- Calorimeter as independent detector (GRBs, SGRs, TGFs, …)

S.Mereghetti -- 2014

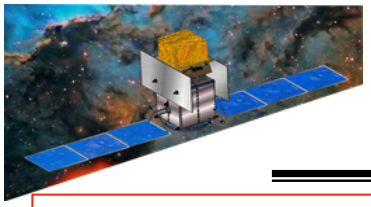


Overview of Past GRB presentations

- Only the highest fluence GRBs detected by LAT
  (~1 /month)
- Delayed onset and extended emission at E>100 MeV
- … and below 100 MeV ?



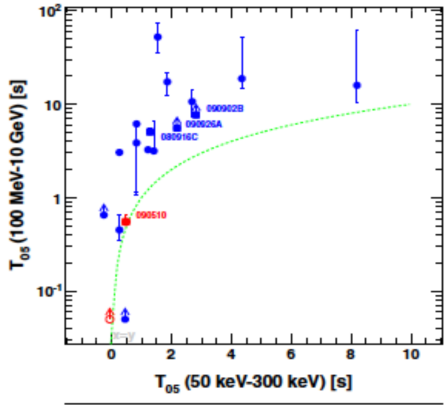
S.Mereghetti -- 2014

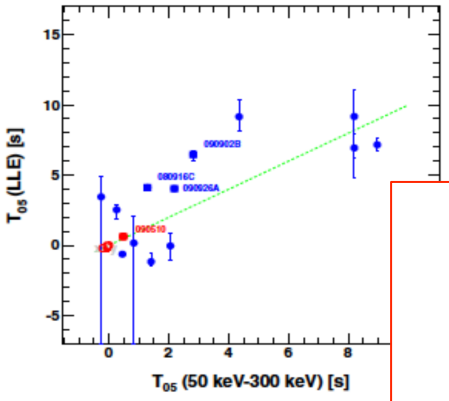


Overview of Past GRB presentations

GRB onset times

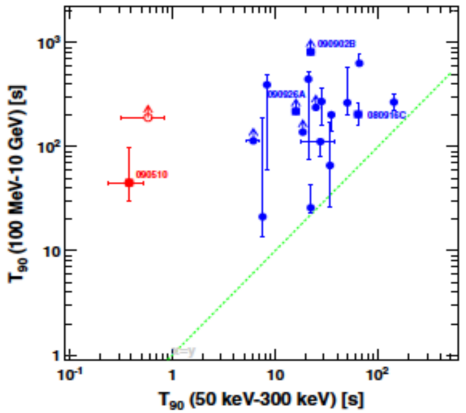
Ackerman etal 2013

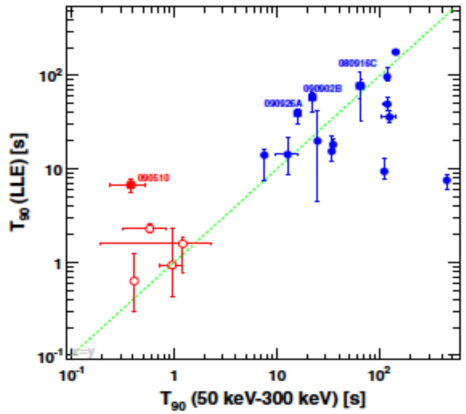




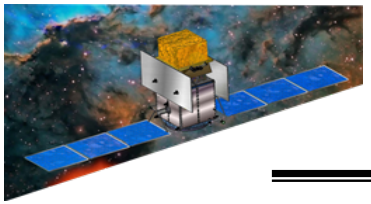
GRB durations

Ackerman etal 2013

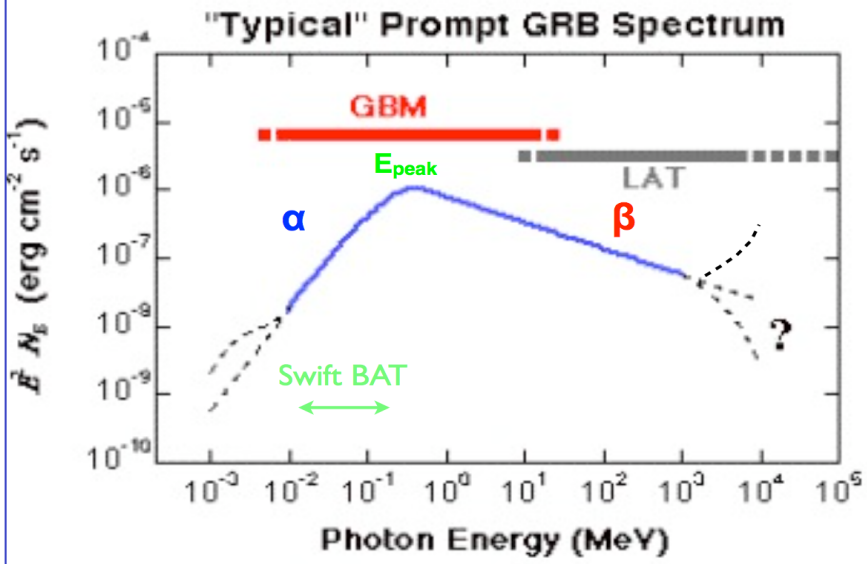




S.Mereghetti -- 2014



Overview of Past GRB presentations



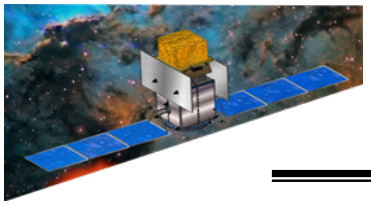
The Band function is a good enough fit to most GRB spectra

GRB spectra peak energies soften over time.

$$N(E) = \begin{cases} E^{\alpha} \exp\left(-\frac{E}{E_0}\right), & \text{if } E \leq (\alpha - \beta) E_0 \\ \left[(\alpha - \beta) E_0\right]^{(\alpha - \beta)} E^{\beta} \exp\left(\beta - \alpha\right), & \text{if } E > (\alpha - \beta) E_0 \end{cases}$$

Band et al. 1993

V.Connaughton -- 2015

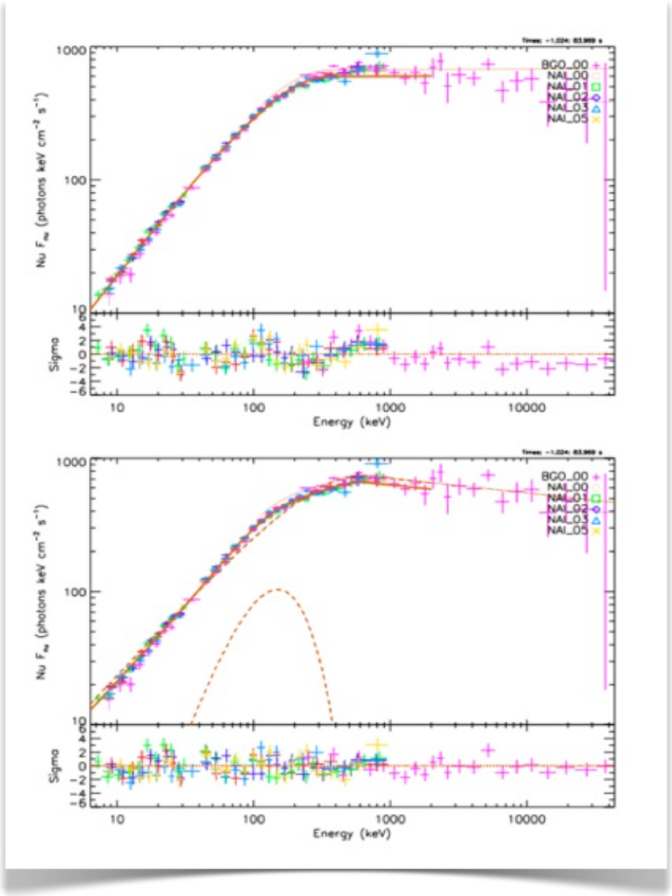


Overview of Past GRB presentations

Photospheric emission may show a signature above the Band function in bright GRBs

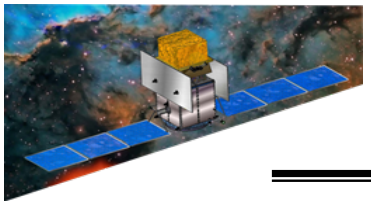
Models	Standard Model			
	Band			BB
Parameters	E_{peak}	α	β	kT
Band	352	−0.67	−1.99	
	±6	±0.01	±0.01	
Band+BB	615	−0.90	−2.11	38.14
	±29	±0.02	±0.02	±0.87

The thermal component steepens alpha



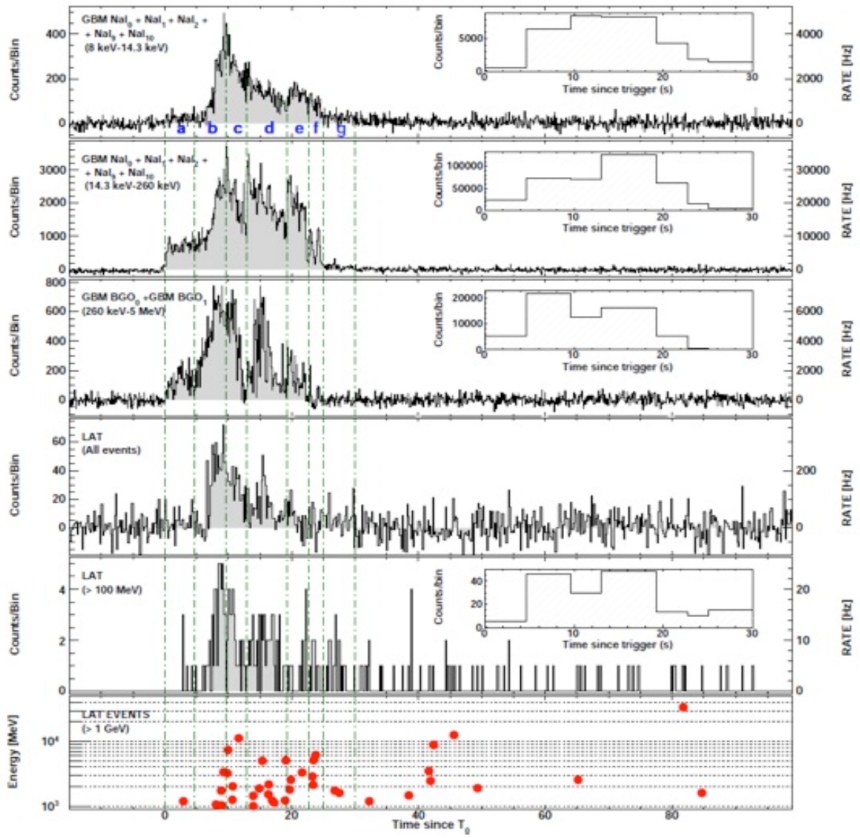
GRB 100724B
Guiriec et al. 2011

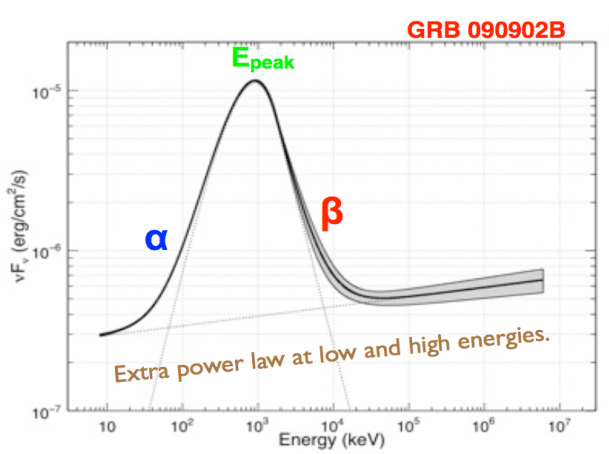
V.Connaughton -- 2015



Overview of Past GRB presentations

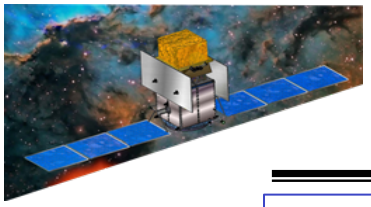
Spectral behavior at HE sometimes appears to have 2 components
Additional spectral component - sometimes also seen at LE





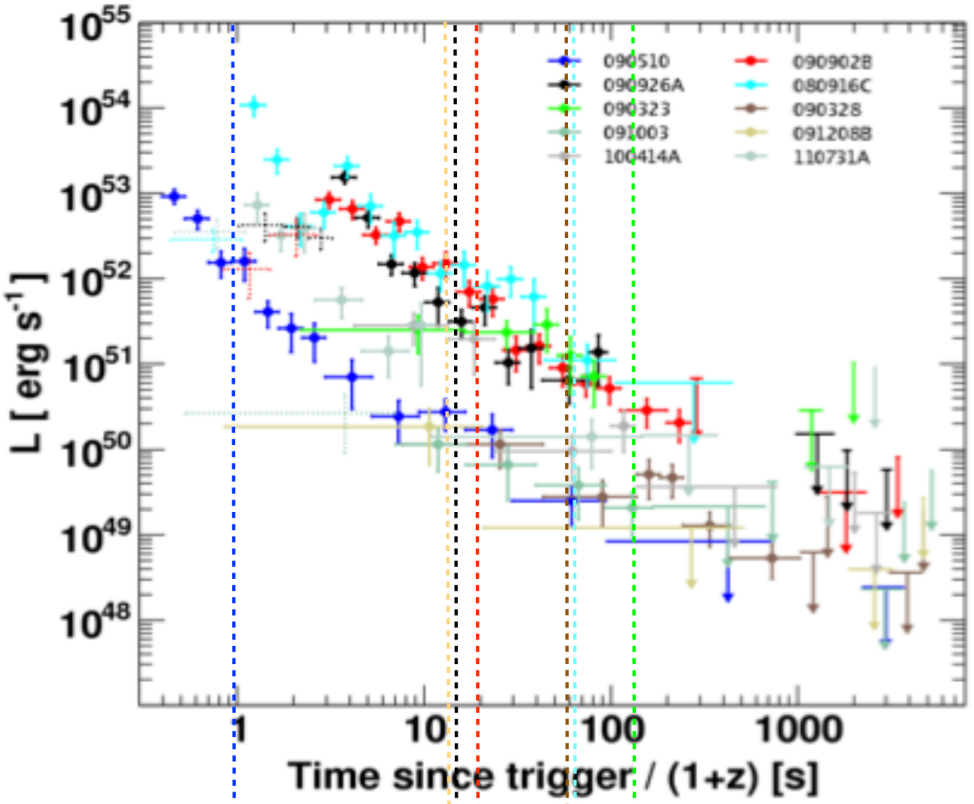
GRB 090902B
Abdo et al. 2009

V.Connaughton -- 2015



Overview of Past GRB presentations

Long-lived HE emission is common in GRBs seen > 100 MeV.
It appears to decay smoothly like afterglow emission.

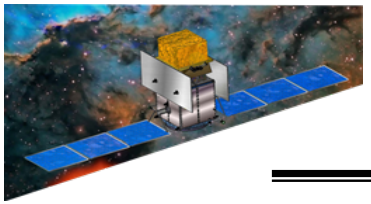


dashed lines are 50-300 keV t90s

More recently...
GRB 130427A 70ks
extended emission!

LAT GRB Catalog
Ackermann et al. 2013

V.Connaughton -- 2015

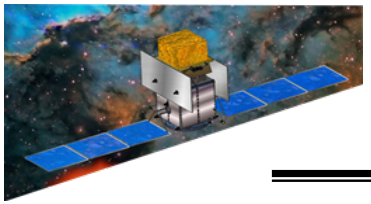


Overview of Past GRB presentations

What should motivate GRB observations for Astrogam?

- Analyzing energy spectra to study the physics of GRBs
  - spectrally interesting behavior in GBM/LAT from keV to GeV
  - peak of many short GRB spectra lie in ~MeV range
  - temporally extended HE emission - how low in energy does it extend?
- Using GRBs as a tool for cosmology
  - Follow-ups of bright GRBs
- GRBs as multi-messenger beacons
  - Paucity of planned keV - MeV transient detectors for e/m counterpart observations
  - Bright GRBs provide context for neutrino detections/UL
- Polarization: evidence from INTEGRAL, IKAROS (Götz, Yonetoku 11, 12)
  - Toma (09): 100 GRBs to distinguish among models in which polarization is expected
  - Photospheric models - less polarization expected
- Poster by David Murphy on GRB observations by Astrogam: 50 - 120 GRB per year, MDP of 20% for 8 GRBs per year

V.Connaughton -- 2015



Overview of Past GRB presentations

"fireball" model: general framework

Source of energy

↓

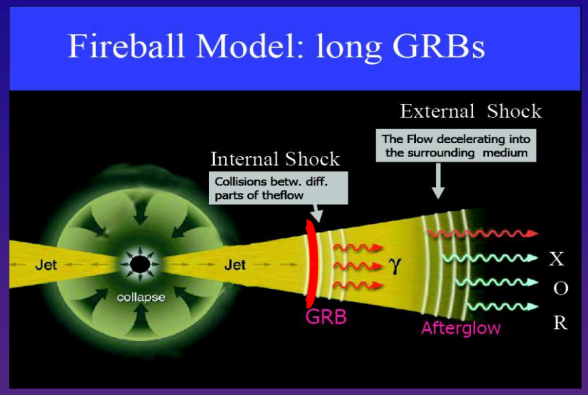
Kinetic energy (jet)

↓

Dissipation

↓

Radiation



What do we want to know ??

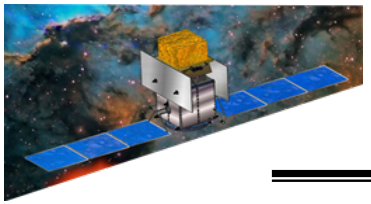
Basic (GRB) physics

1. Progenitor /Central engine
   Collapsar ? Magnetar ? Merger ?
2. Jet launching mechanism;
   Magnetic ? Neutrino heating ?
   - jet composition
   Leptonic? Hadronic?
3. Jet dynamics, dissipation & radiative processes
   Γ_{GRB} >~100, Γ_{AGN} <~30

4. How are GRBs connected to other objects ?
   Stellar evolution, star formation, host galaxies, pop-III stars, SNe, Binaries, GW, cosmic rays, ν's…

5. GRBs and basic physics:
   Cosmology, Lorentz violation,…

A.Peer -- 2015



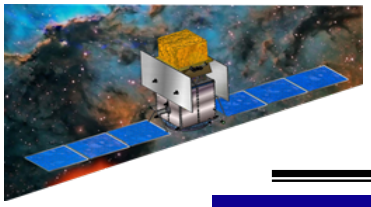
Overview of Past GRB presentations

The basic questions

Apart from the general framework:
E_G -> E_k -> E_γ + AG,
the details of the fireball model are highly uncertain !!

1. Nature of the progenitor:
   Collapsar ? Magnetar ? BH-BH / BH-NS / NS-NS Merger ?
2. Jet launching mechanism:
   photons ? magnetic (Blandford-Znajek) ? Neutrino heating ?
3. Why relativistic speeds ? Γ_{GRB} >~100, Γ_{AGN} <~30
4. Jet composition: Leptonic ? Hadronic ? Poynting – flux dominated ?
5. Dissipation mechanism: efficiency problem in internal shocks
6. Radiative processes: understanding the broad band spectrum
   -> particle acceleration

A.Peer -- 2015

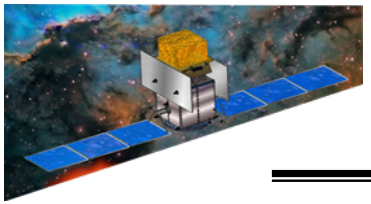


Overview of Past GRB presentations

The basic questions

	Where are we now
1. Nature of the progenitor:	Continuous works; further constraints by higher Γ
2. Jet launching mechanism:	Continuous works; **interest in magnetic models**
3. Why relativistic speeds ?	Still unclear
4. Jet composition:	Still unclear; many possibilities
5. Dissipation mechanism:	**More than a single region;** **Connection between prompt and early AG**
1. Radiative processes: -> particle acceleration	**Interest in photospheric models;** constraints by lack of LAT detection

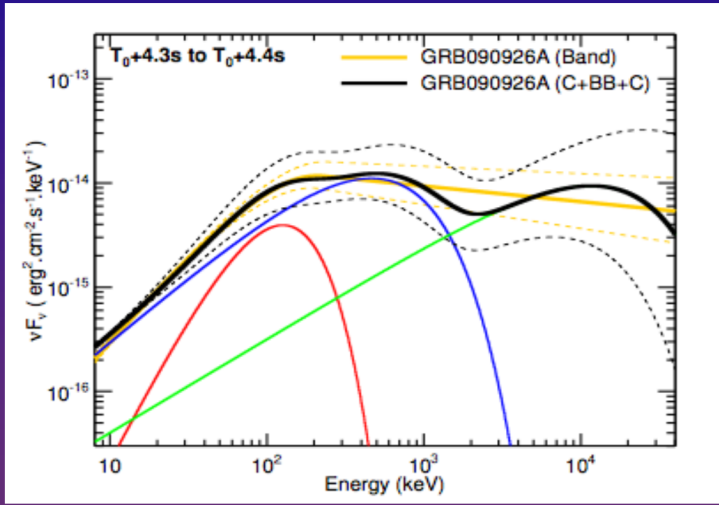
A.Peer -- 2015



Overview of Past GRB presentations

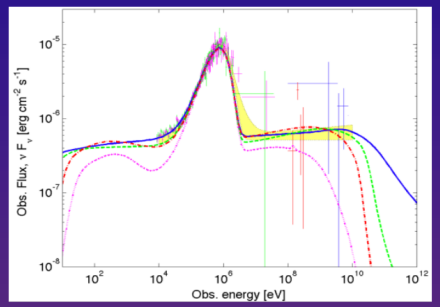
Three component model ?

"Band" + BB + power law **(Guiriec+15)**



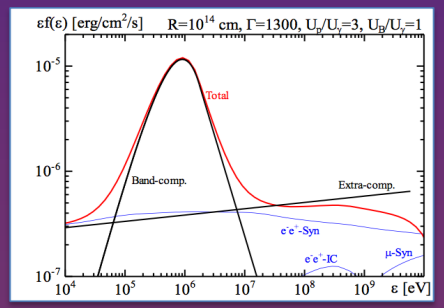
090902B

Leptonic **(AP + 12)**



Sync+SSC+Thermal Comptonization

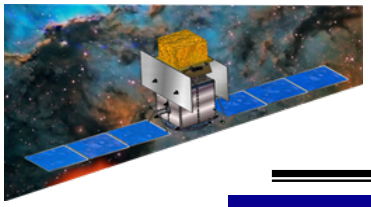
Confusing, rapidly changing picture !



Hadronic cascade **(Razzaque+09,**

Asano+ 10, Dermer & Razzaque 10 Meszaros & Rees 11)

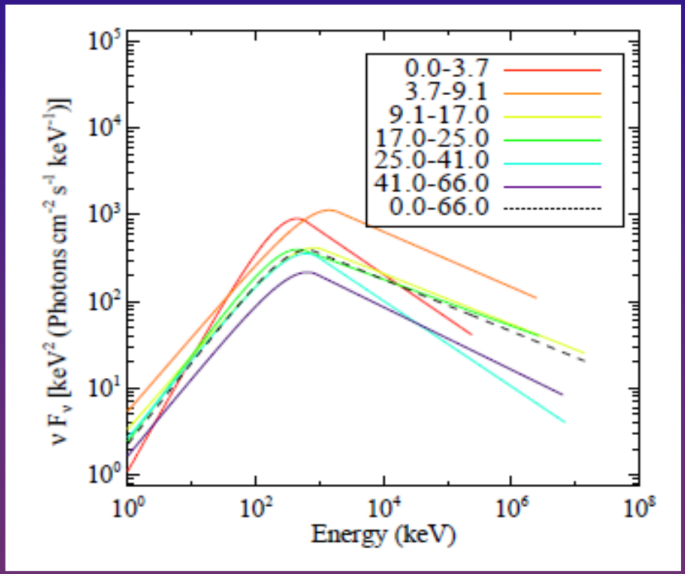
A.Peer -- 2015



Overview of Past GRB presentations

But in many cases no evidence for spectral break ?

080916C(Abdo+09)



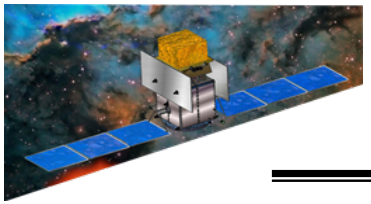
1. Need a refine data analysis: 'hidden' component - ?

2. Need a refine theory;
   Origin of emission mechanism – Still unclear !

   Evidence for magnetized outflow ?

Zhang & AP 09

A.Peer -- 2015

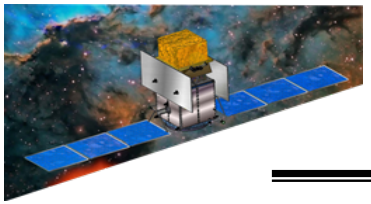


Overview of Past GRB presentations

Bottom line

- Despite major progress in recent years, a coherent picture of GRB physics is still lacking.
- New data: high energy & polarization may provide key information

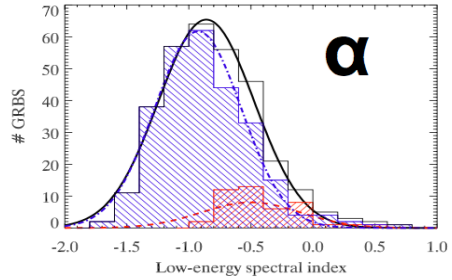
A.Peer -- 2015

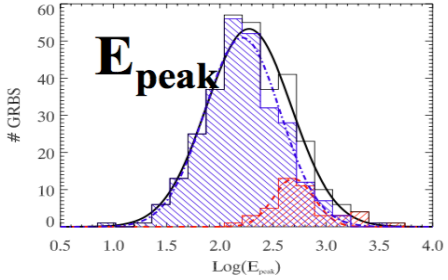


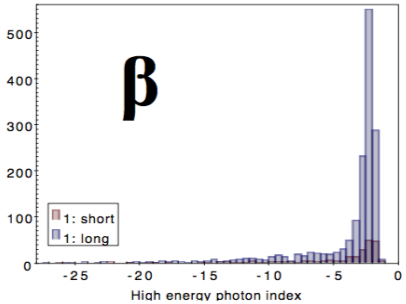
Overview of Past GRB presentations

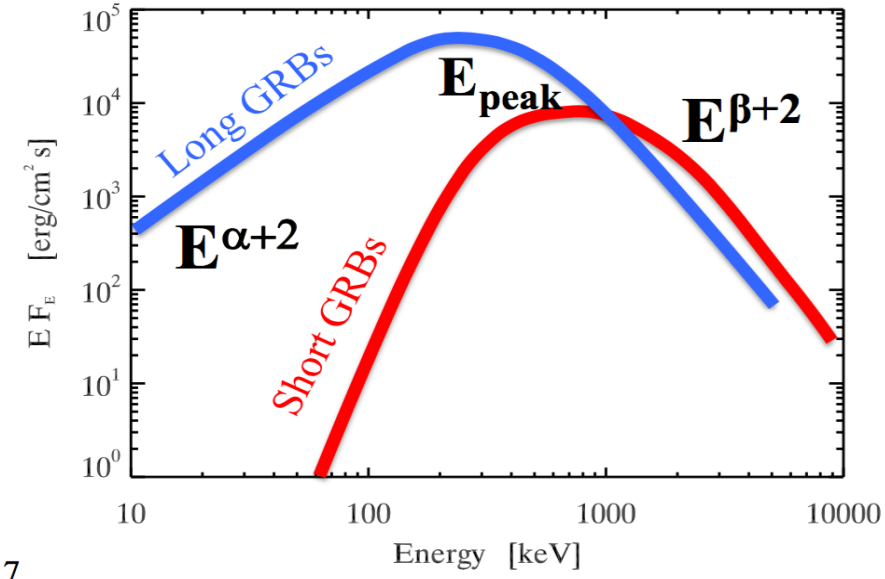
MeV emission of GRBs

BATSE-CGRO [Band+1998;Preece+2000; GG+2003], **BeppoSAX** [Frontera+2006]; **Fermi** [Goldstein+2010; GG+2011; Nava+2011]; **Integral** [Vianello 2008]; **Swift** [Sakamoto 2013]



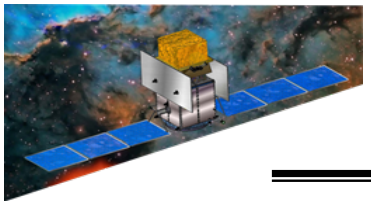






G. Ghirlanda – PD 2017

G.Ghirlanda -- 2017



Overview of Past GRB presentations

MeV emission of GRBs

β > -2 (no peak) → 20%

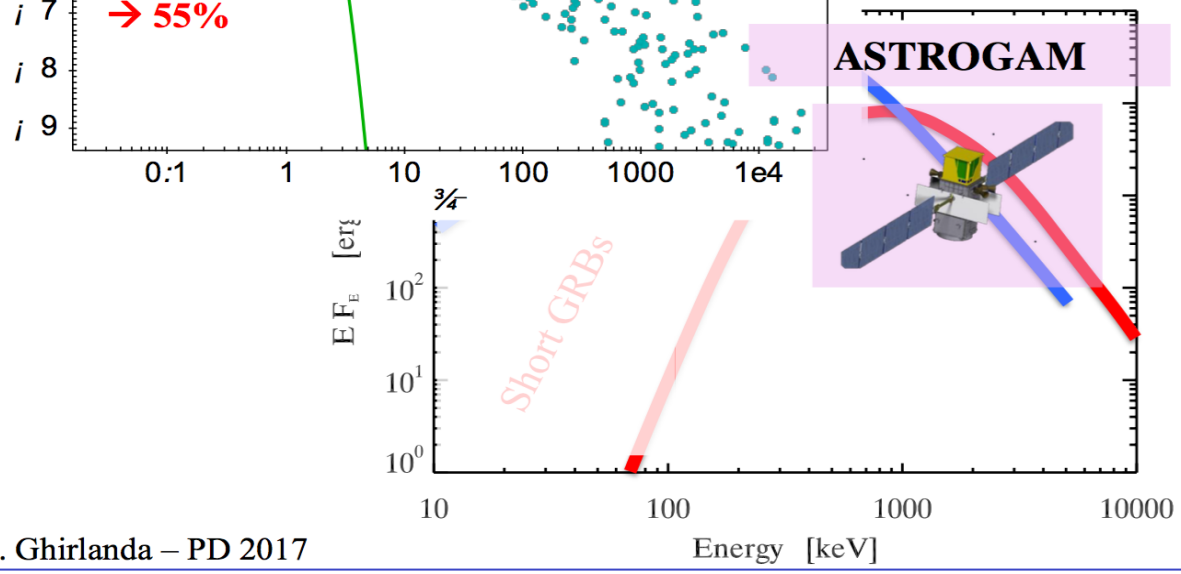
β undetermined → 25%

Decreasing MeV spectral tail → 55%

Powerlaw vs Exp cutoff?

Time evolution?

- Different emission mechanisms?
- Internal absorption?
- Contamination by higher energy component?



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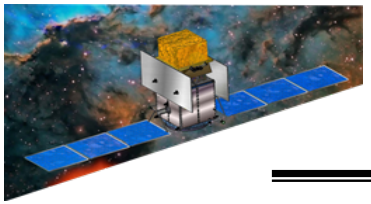
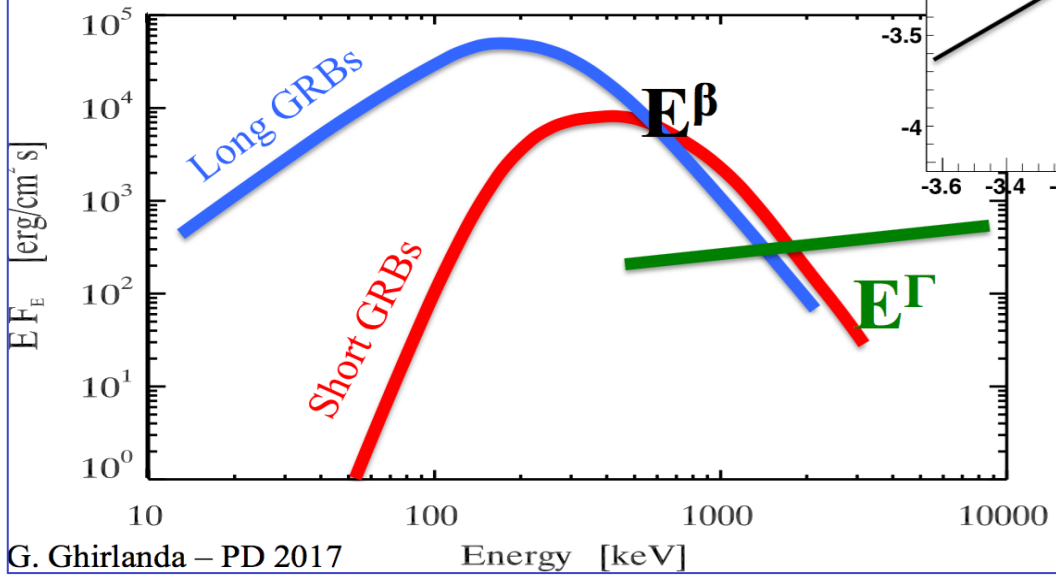


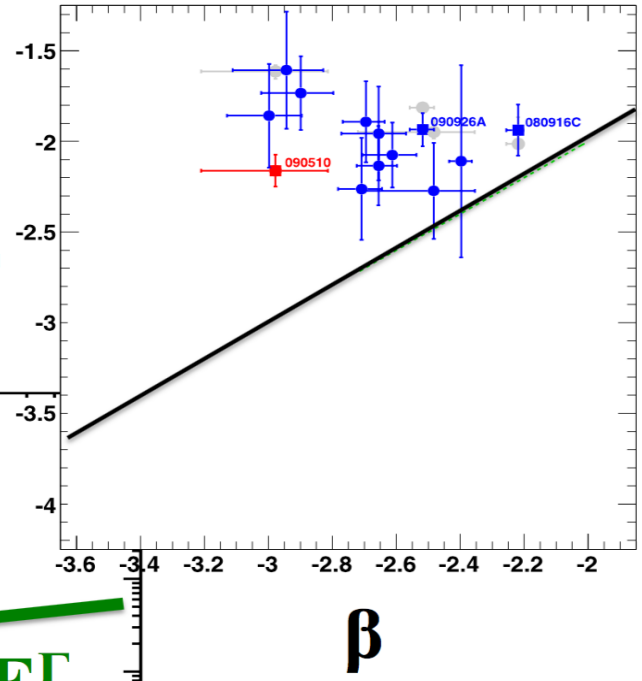
Overview of Past GRB presentations

GeV emission: (III) Spectrum

GeV component is spectrally harder than the tail of the MeV

GeV component delayed wrt MeV





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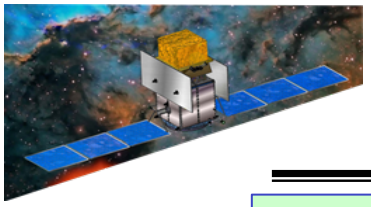
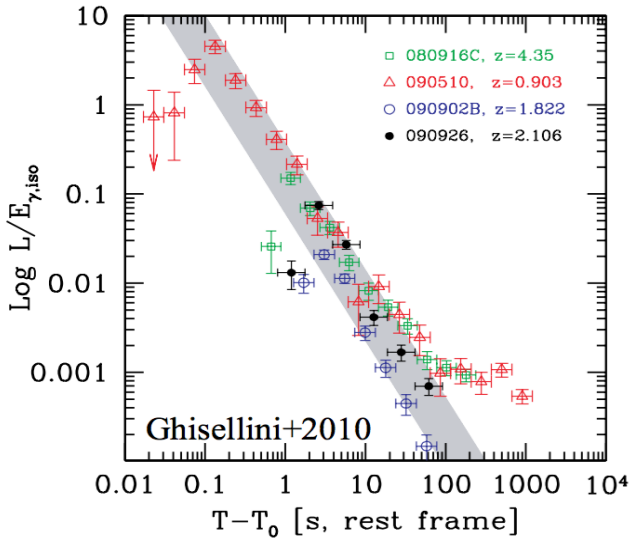


Overview of Past GRB presentations

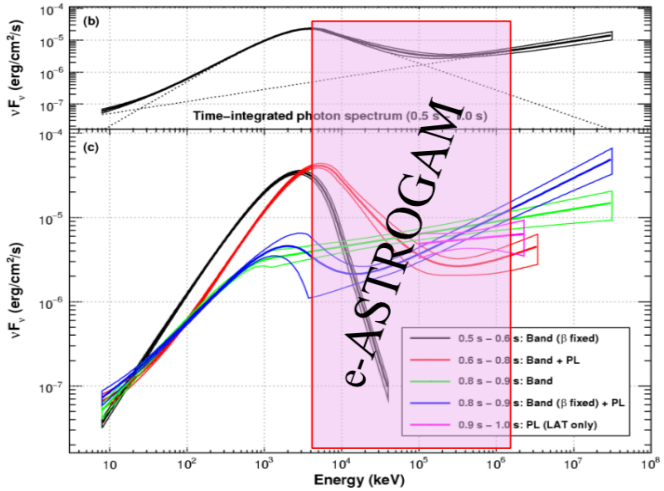
GeV emission origin

> GeV flux decays ~ $t^{-1.5}$



+

Spectral diversity of GeV wrt to MeV



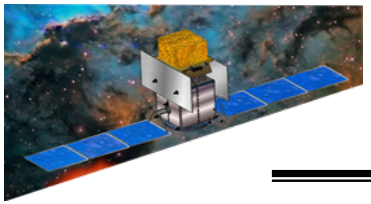
External origin → SYNCH. [Kumar+2009; Ghisellini+2010]

External origin → IC [Beloborodov+2014]

Internal origin [e.g. Toma+2011]

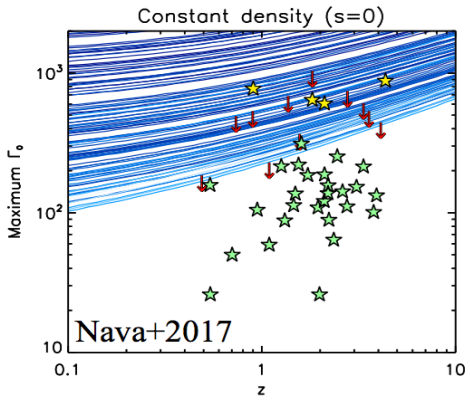
G. Ghirlanda – PD 2017

G.Ghirlanda -- 2017

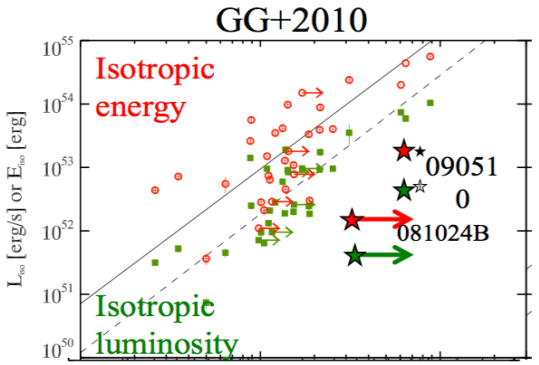


Overview of Past GRB presentations

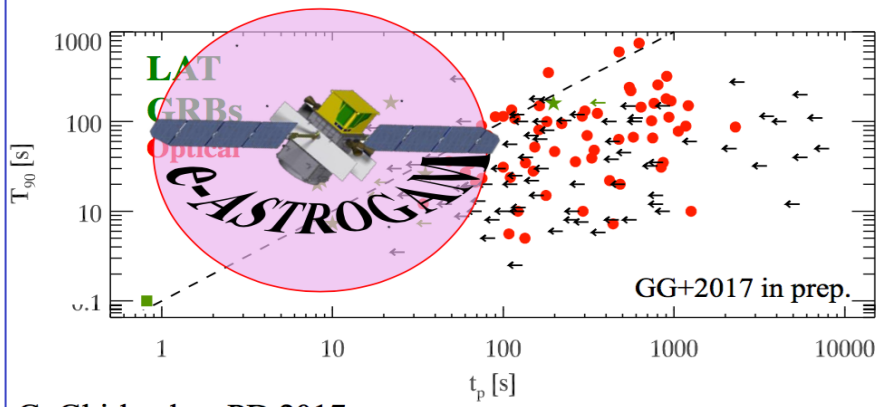
Bulk Lorentz factor

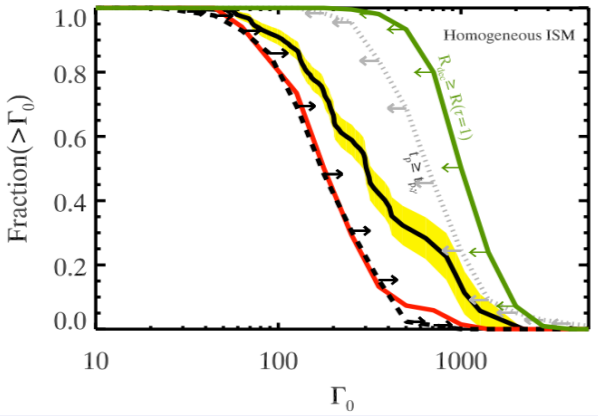


Bulk Lorentz factor and Jet opening angle could be related [e.g. McKinney 2009]
[GG+2011] $\vartheta^2\Gamma$=const



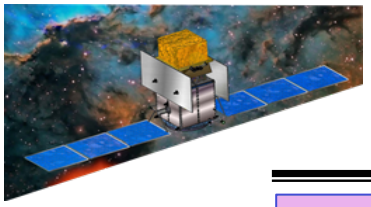
Estimate of Γ_0 from the peak of the afterglow





G. Ghirlanda – PD 2017

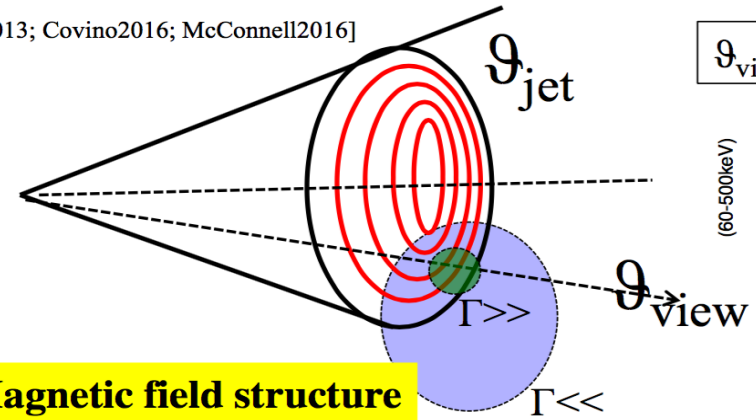
G.Ghirlanda -- 2017

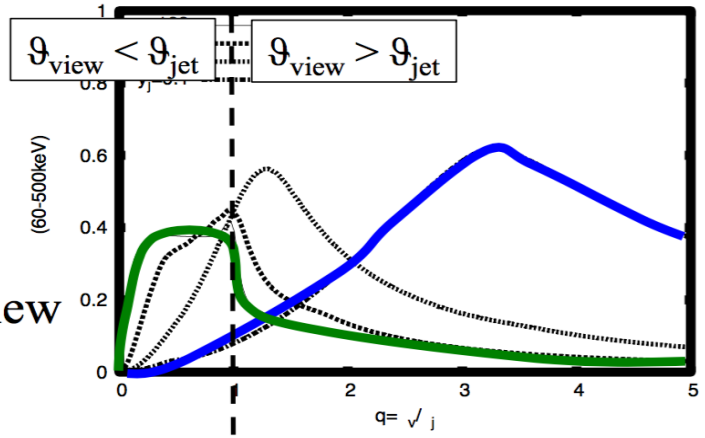


Overview of Past GRB presentations

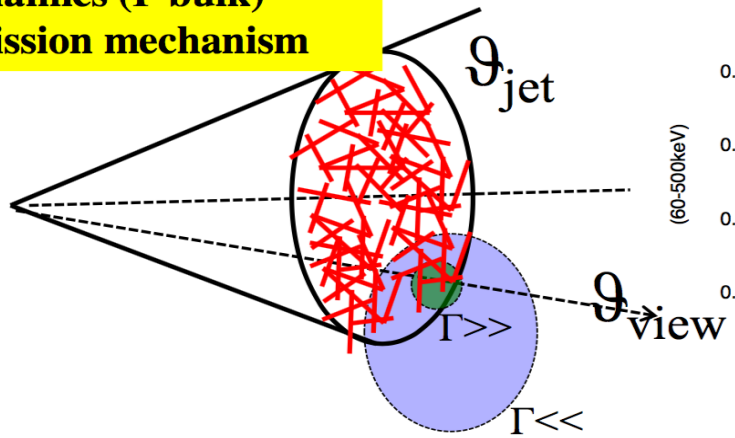
Polarization

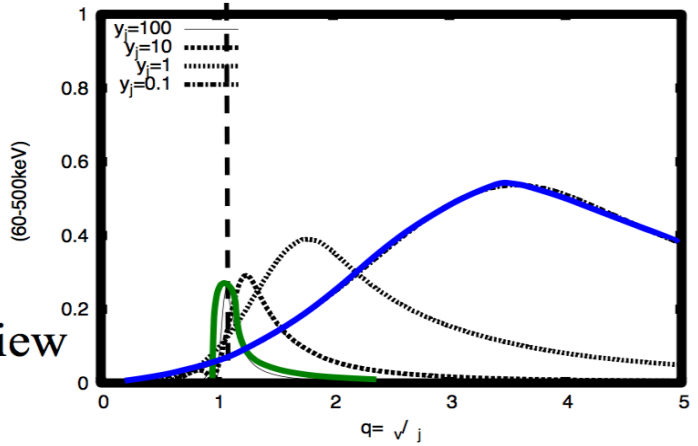
[Toma2013; Covino2016; McConnell2016]





1. **Magnetic field structure**
2. **Geometry (ϑ_{jet} ; ϑ_{view})**
3. **Dynamics (Γ bulk)**
4. **Emission mechanism**





G. Ghirlanda – PD 2017

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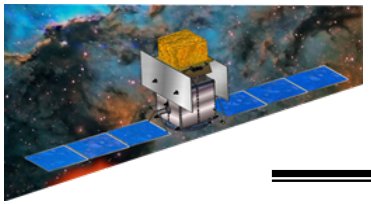
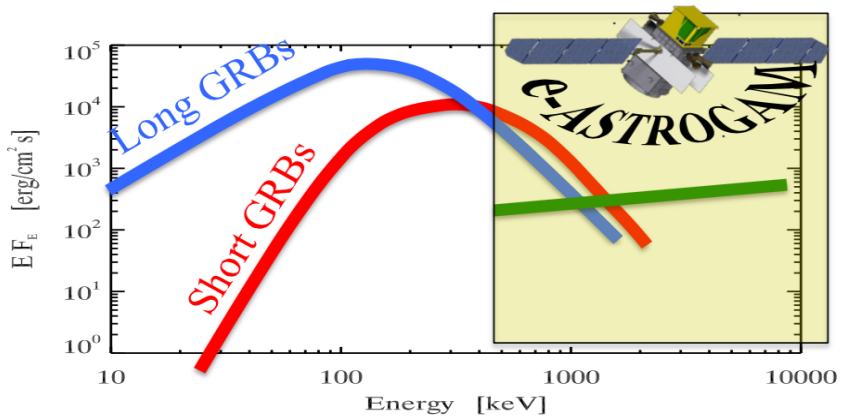


Overview of Past GRB presentations

CONCLUSIONS

Question	Key obs → e-ASTROGAM	How?(suggestions) → simulations
Origin of prompt emission	• Spectra (1MeV – 3GeV) ✓ Energy resolution ✓ Temporal resolution • Sensitivity (hundreds yr^{-1}) • Polarization	GRB detection rates (short and long)
Origin of GeV emission		Properties of detected population (prompt + afterglow)
Role of magnetic field Geometry (ϑ_{jet} ;ϑ_{view})		Include viewing angle effects (relevant for some polarization mechanisms)
Jet acceleration (Γ)		Population – extend earliest onset

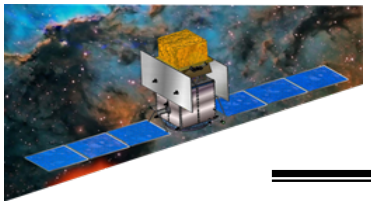


High sensitivity
Spectral resolution
Polarization

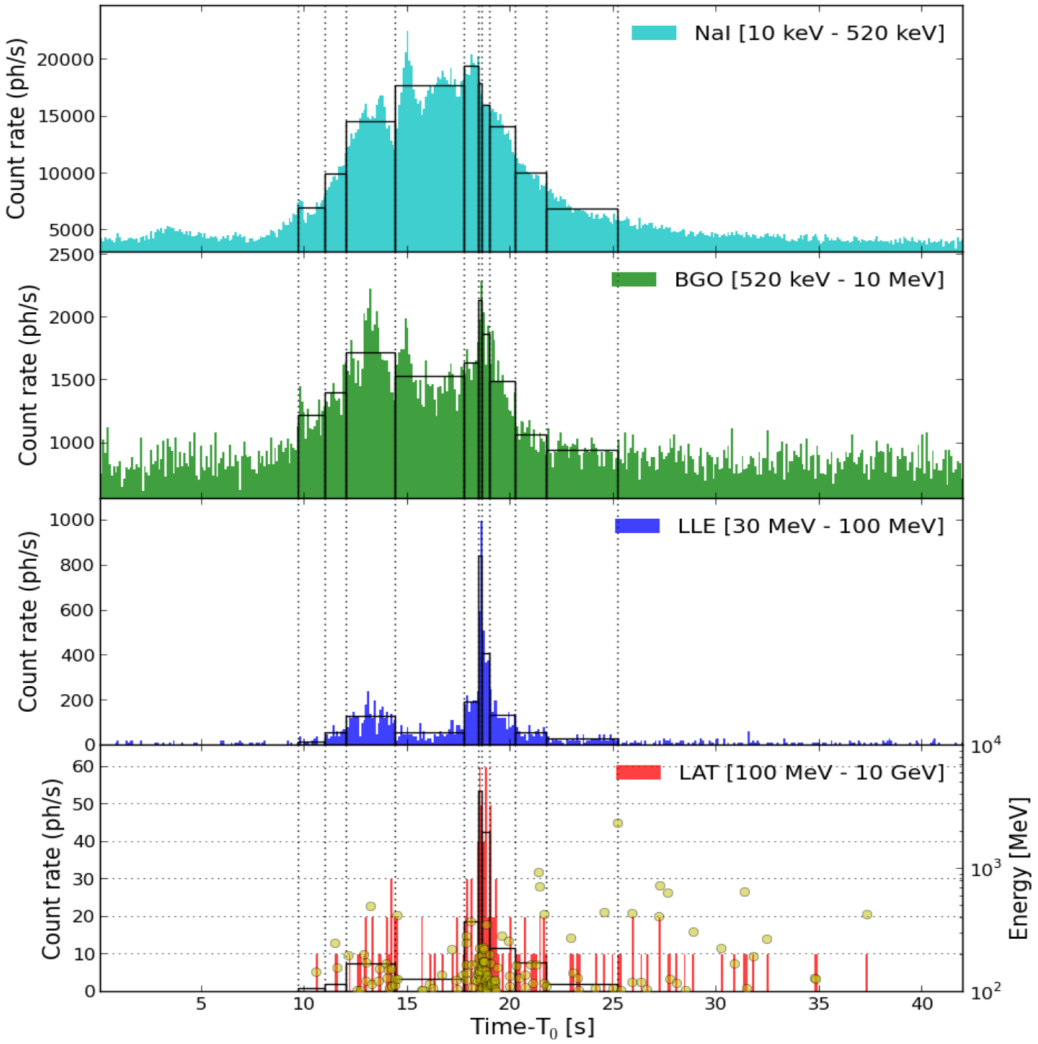
Thank you

G. Ghirlanda – PD 2017

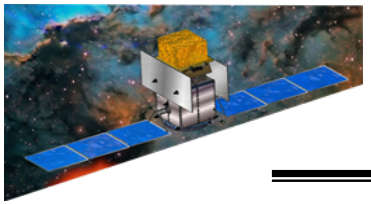
G.Ghirlanda -- 2017



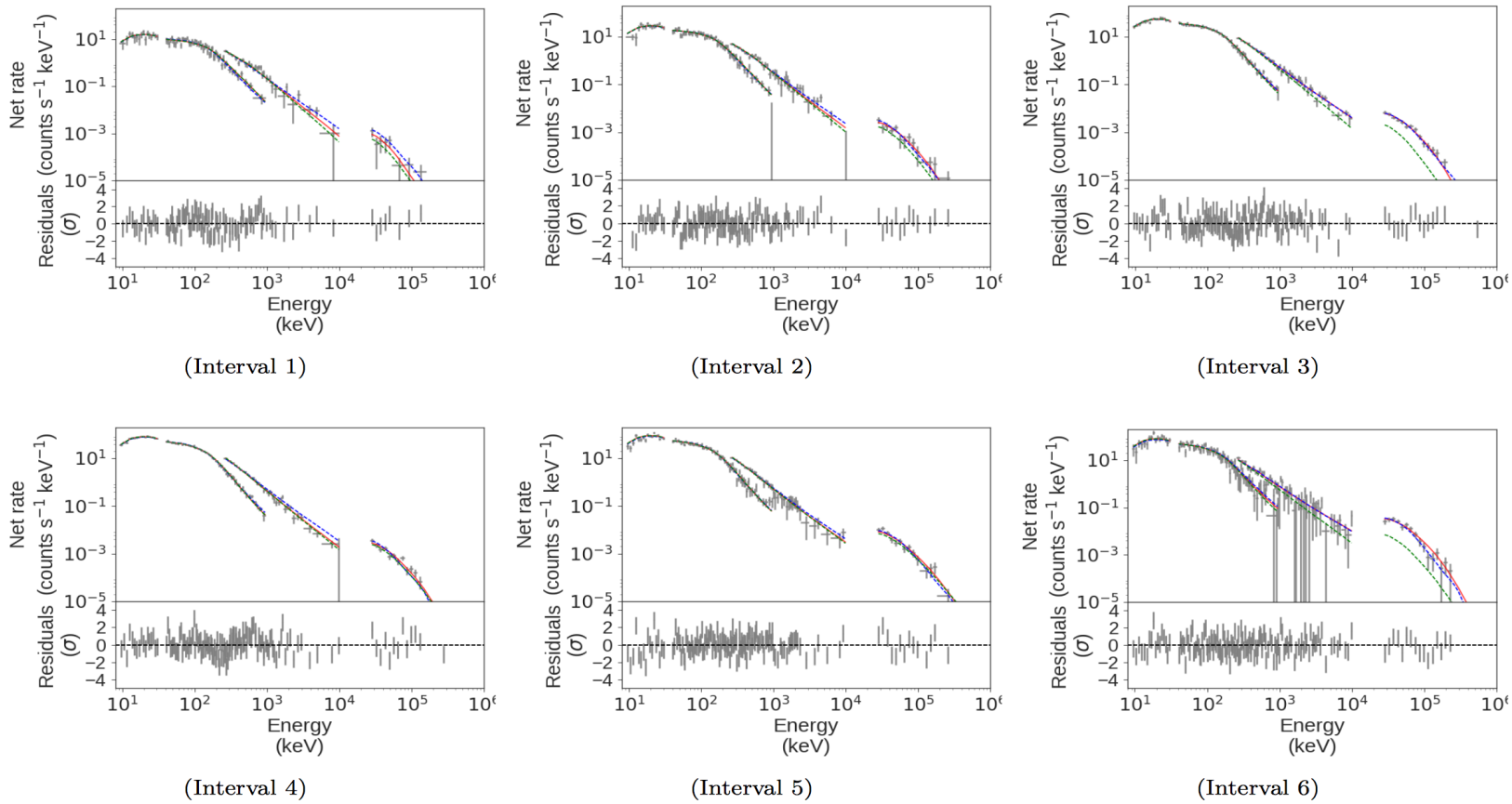
GRB cutoff in prompt emission



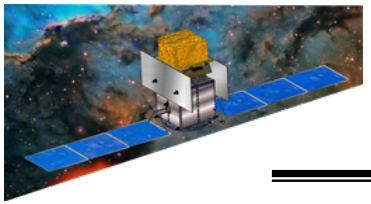
G.Vianello et al. -- 2017



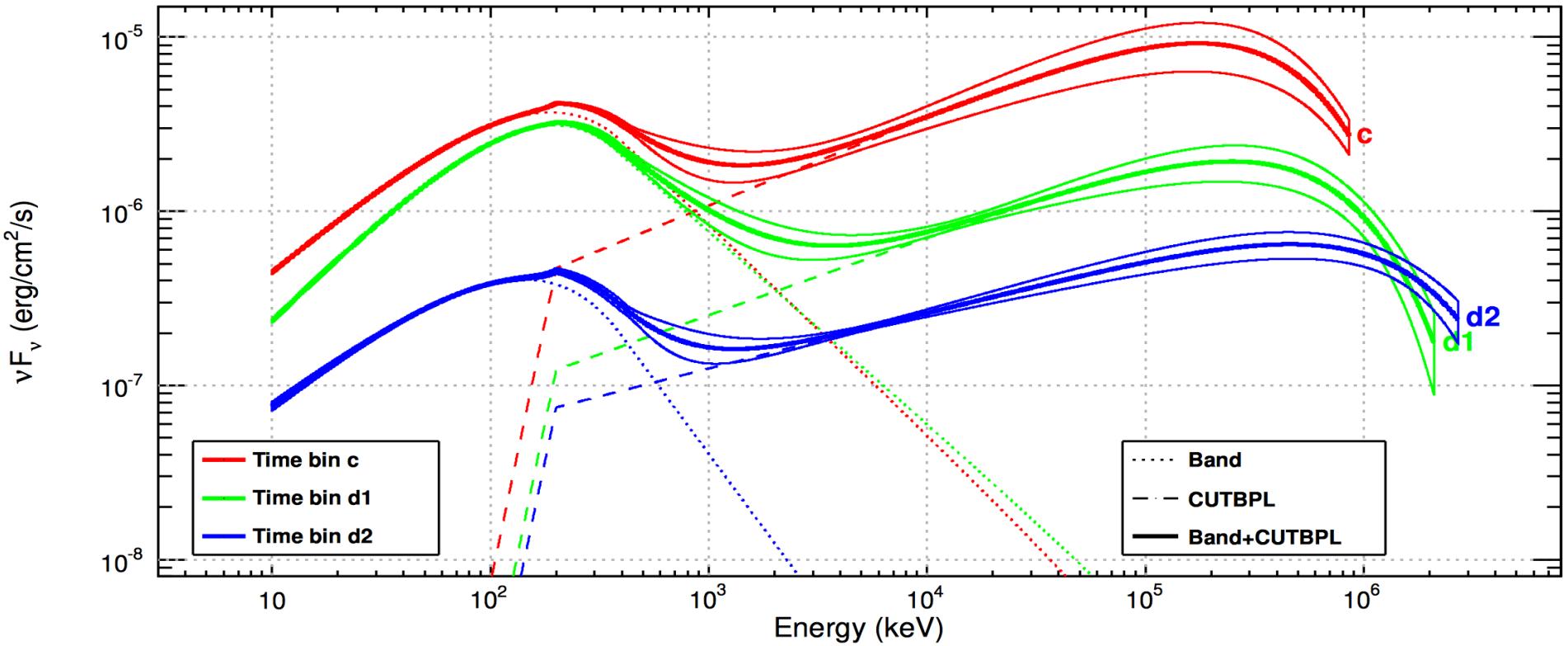
GRB cutoff in prompt emission



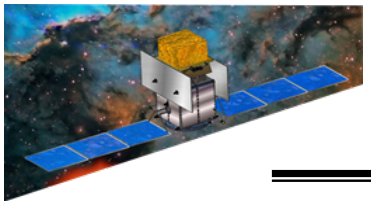
G.Vianello et al. -- 2017



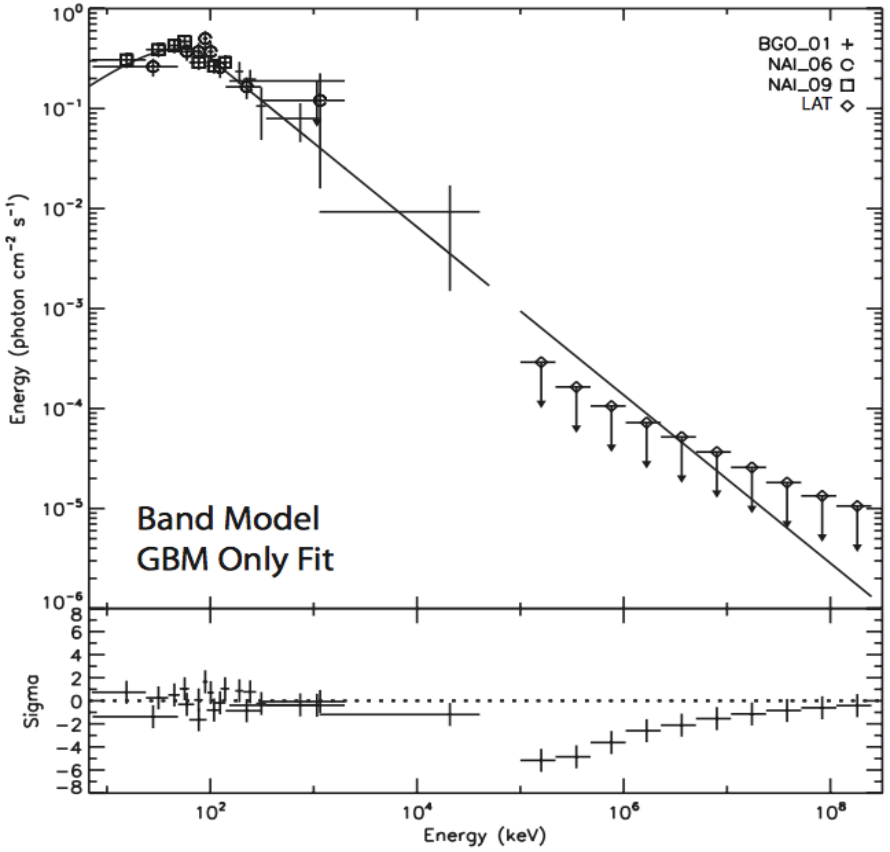
GRB cutoff in prompt emission

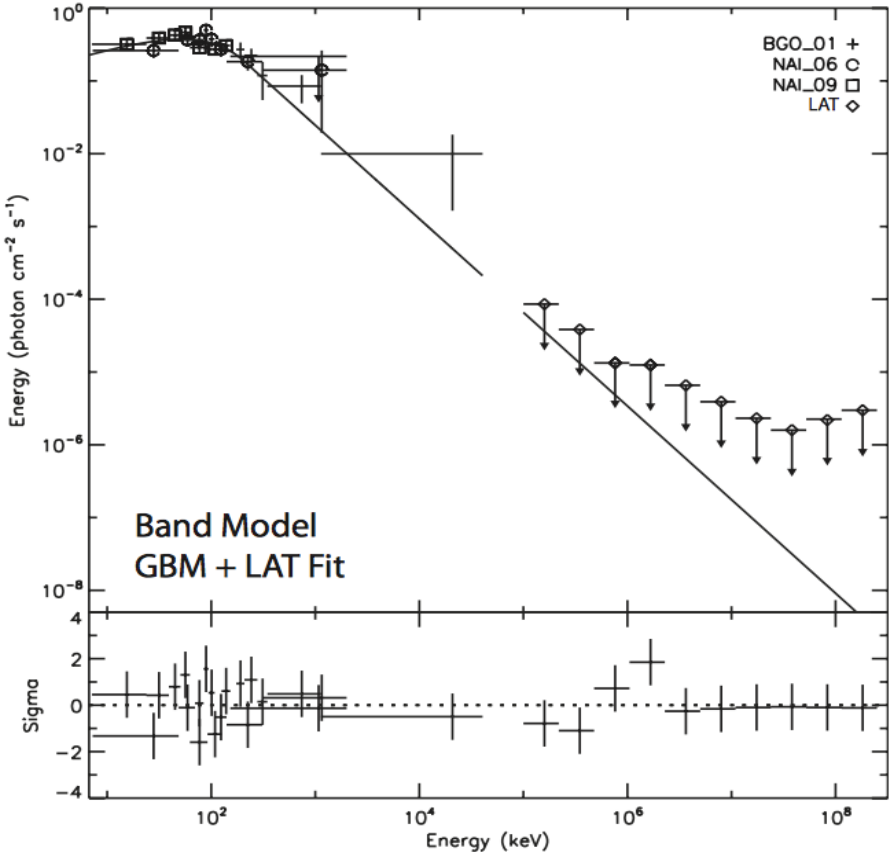


M. Yassine et al. -- 2017

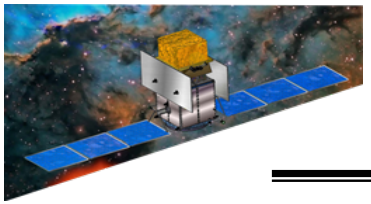


GRB cutoff in prompt emission





M.Ackermann et al. -- 2012

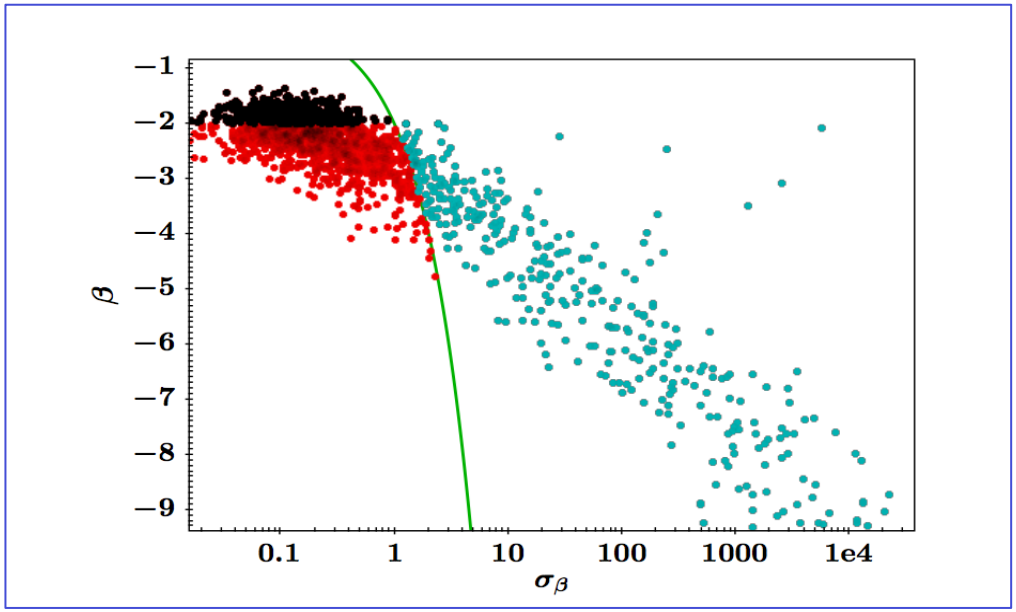


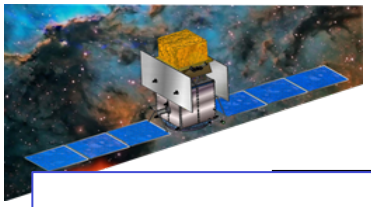
WB contributions

eASTROGAM contribution to the understanding of GRB prompt emission

G. Ghirlanda[1,2] and L. Nava[1,3]

[1] *INAF – Osservatorio Astronomico di Brera, via E. Bianchi 46, I-23807 Merate, Italy.*
[2] *Dipartimento di Fisica G. Occhialini, University Milano Bicocca, Piazza della Scienza 3, I-20126 Milano, Italy.*
[3] *INAF – Osservatorio Astronomico di Trieste, via G. B. Tiepolo 11, I-34143 Trieste, Italy.*





WB contributions

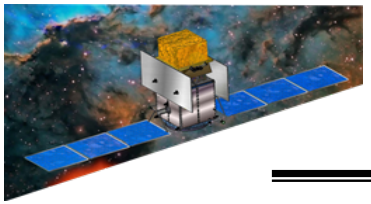
Detection of Very Short Gamma-Ray Bursts in exotic stellar transitions with e-ASTROGAM

M. Angéles Pérez-García[1], *Conrado Albertus*[1], *José M. Álvarez*[2], *Luis Roso*[3]

[1] *Department of Fundamental Physics and IUFFyM University of Salamanca, Plaza de la Merced s/n 37008 Spain*
[2] *Spanish Center for Pulsed Lasers (CLPU), M5 Bldg. Science Park, Villamayor, Salamanca (Spain)*
[3] *University of Salamanca (USAL), Plaza de la Merced s/n, 37008, Salamanca (Spain)*

Science questions – Gamma-ray Bursts (GRBs) are highly energetic fenomena than remain without a definite explanation [1]. Its origin is believed to be triggered by cataclysmic events linked to large changes in the internal structure of stellar compact objecs of mass $M \sim 1.5 M_{\odot}$ and radius $R \sim 12$ km releasing gravitational energies $\Delta E \approx GM^2/R \approx 10^{53} - 10^{55}$ erg.

One of the possible situations where GRBs may be emitted involve neutron stars (NSs) transitioning to more compact stars. In particular, the possible formation of stars where the quark component has been deconfined out of the the nucleons has been studied in the literature [2]. Such an scenario is often referred to as quark stars (QS). In a NS to QS transition part of the outer stellar crust in the origininal star can be expelled to relativistic speeds leading to a transient episode of high-energy emission. In those cases the expected duration of the gamma-ray signal is much smaller than that typically predicted for short GRBs at about ~ 2 s. The mechanism behind the hipothesized transition is not yet clear but has been considered to be due either to a rise in the central density for slowly rotating old NS or due to the accretion of an exotic dark component [3]. This latter possibility [4] links two types of matter (standard and dark) present in our Universe as experimentally determined from complementary indications [5] and constitute itself another key aspect of the Physics motivation driving the e-ASTROGAM mission.

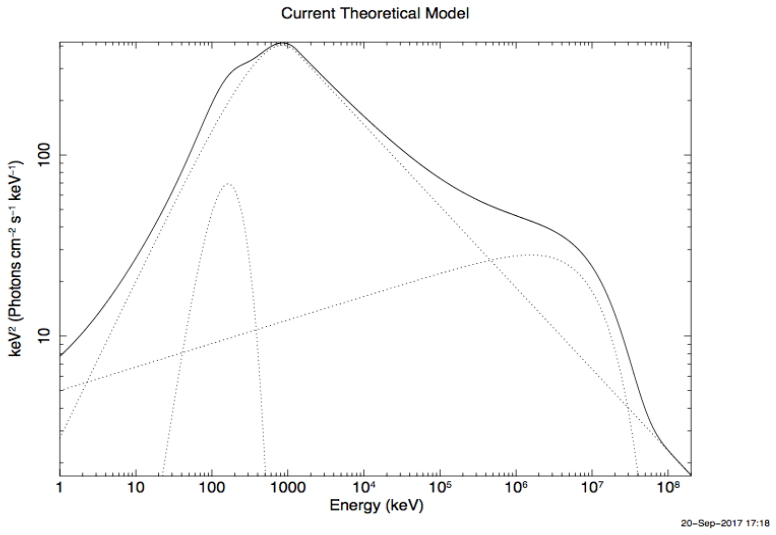


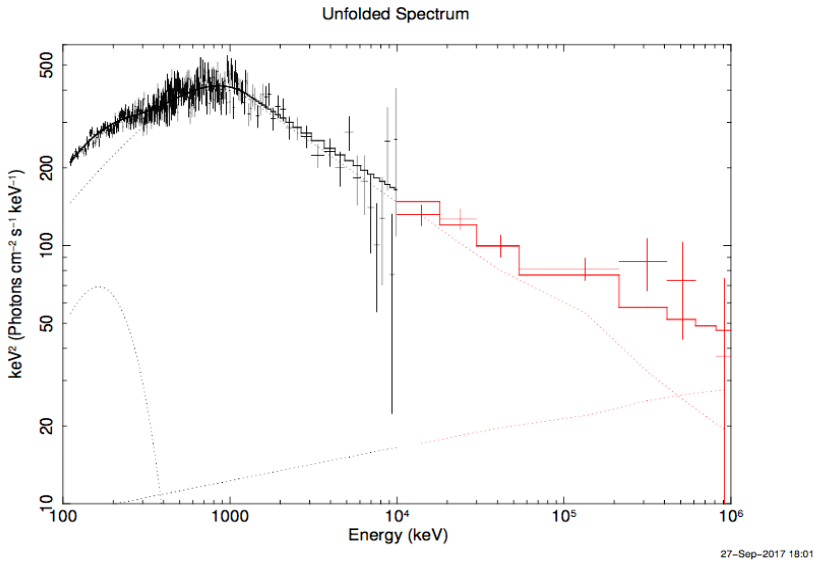
WB contributions

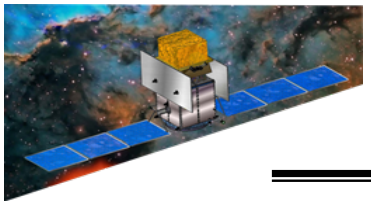
The physics of Gamma Ray Bursts through the polarized eyes of e-ASTROGAM

Tancredi Bernasconi, Merlin Kole, Nicolas Produit, Roland Walter

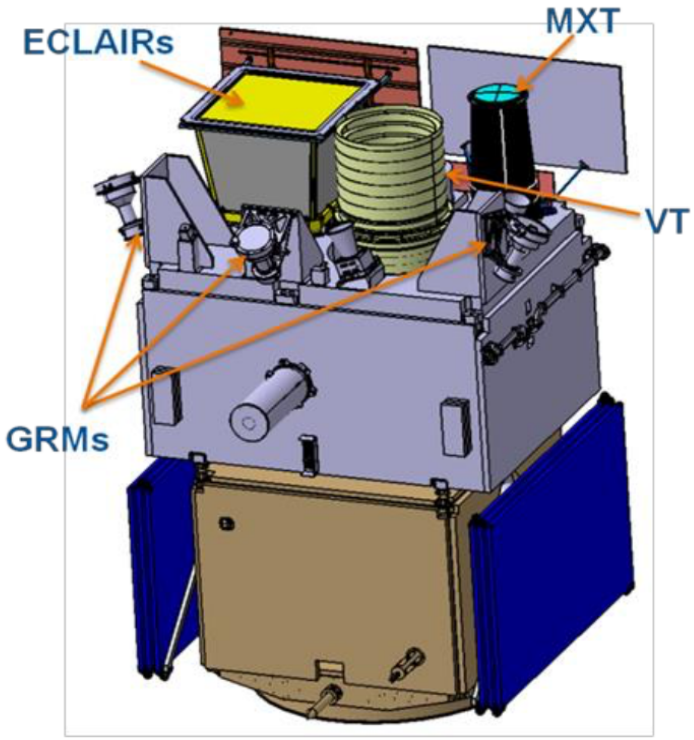
University of Geneva, Switzerland

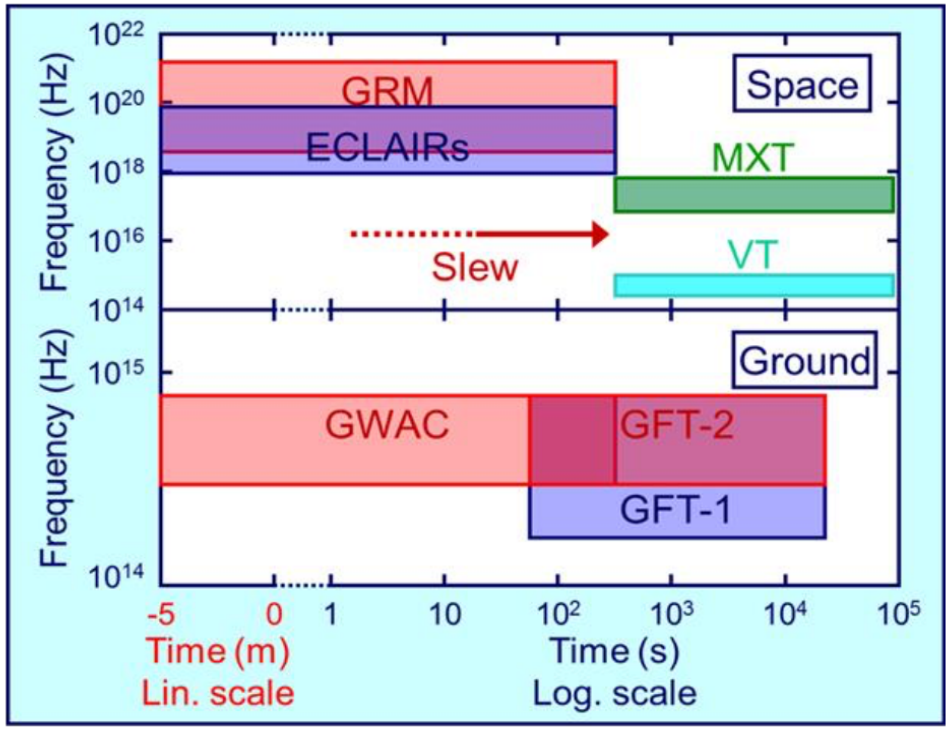






Connection to Low Energy





SVOM mission