Gamma-Ray Bursts

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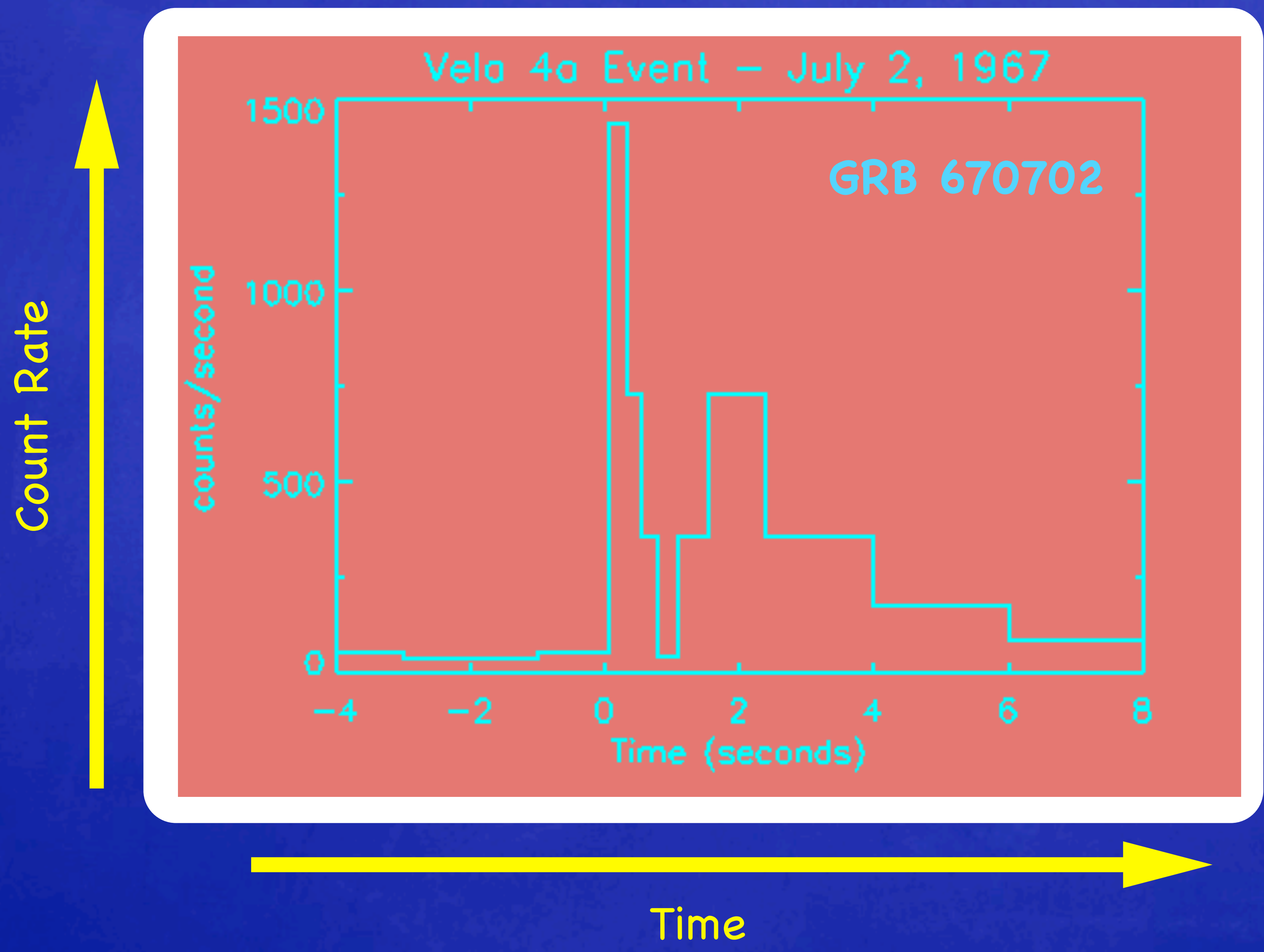
Overview

- Introduction to Gamma-Ray Bursts (GRBs)
- Recent results on prompt and afterglow emission
- Polarisation
- Hardware activities at UCD

First GRBs



Count Rate
Vela 4a Event – July 2, 1967
GRB 670702
counts/second
1500
1000
500
0
-4
-2
0
2
4
6
8
Time (seconds)
Time

How are they detected?

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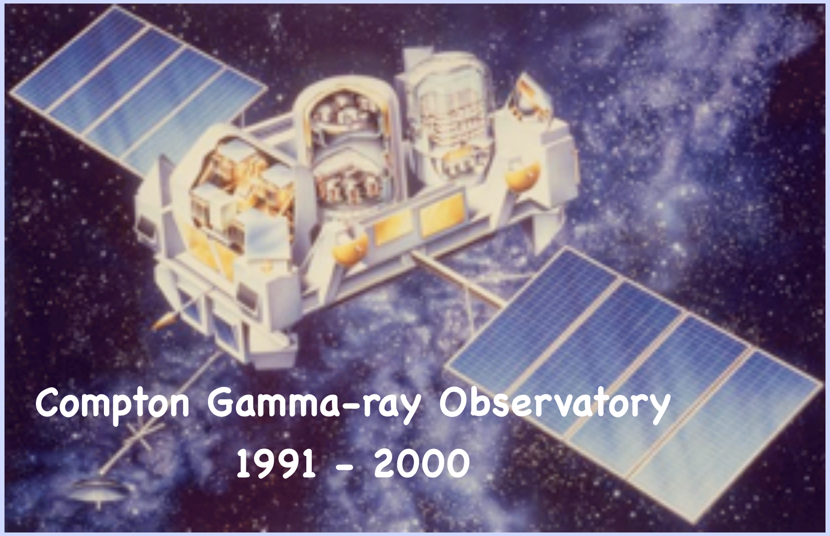

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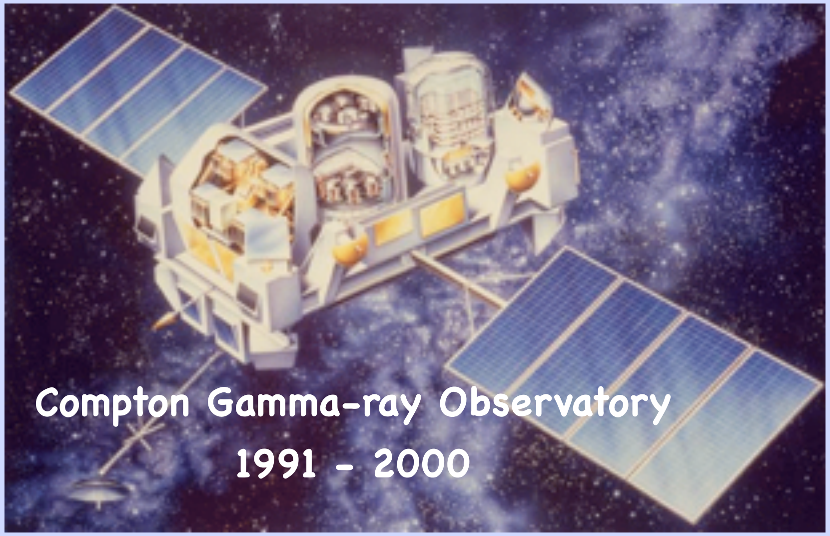

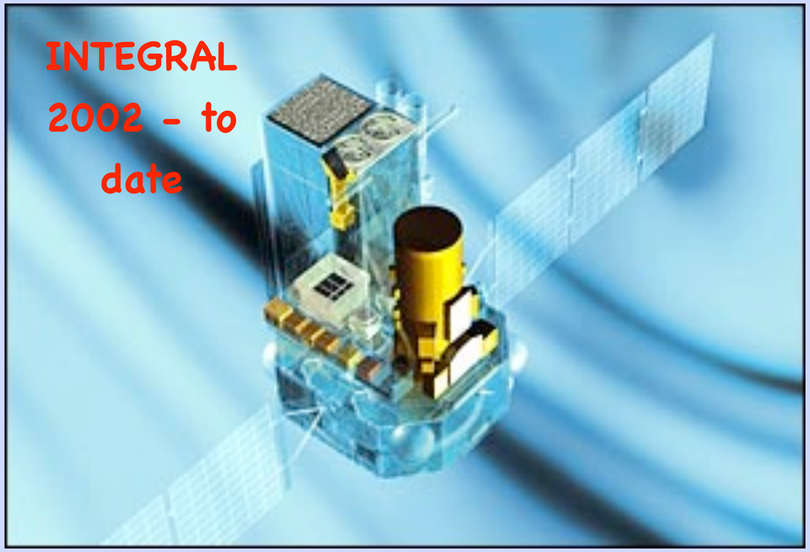

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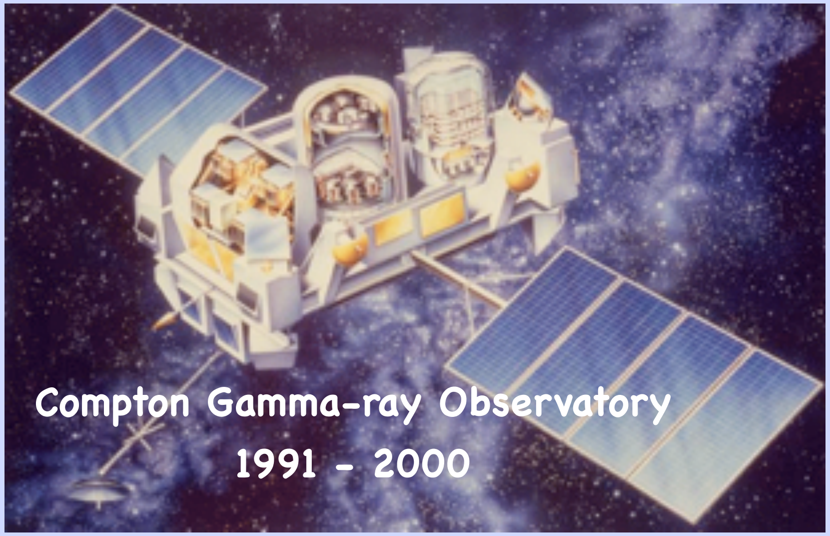

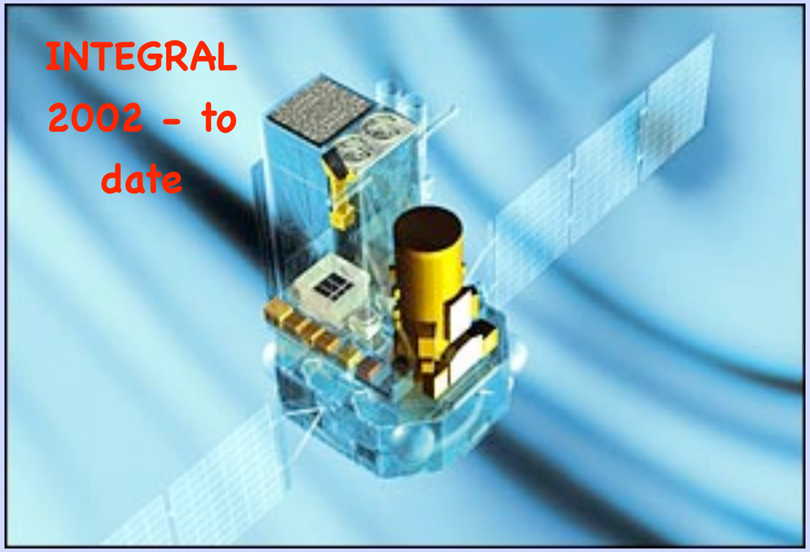

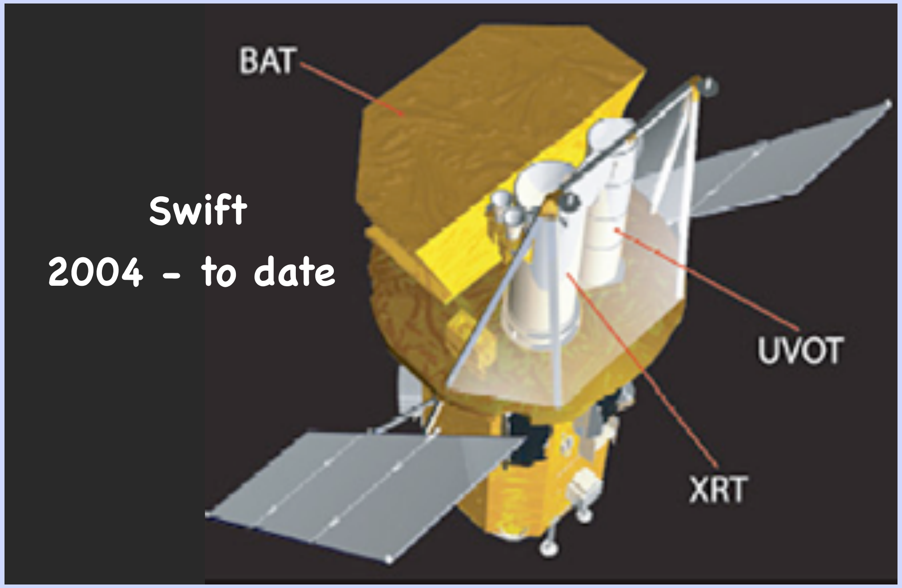

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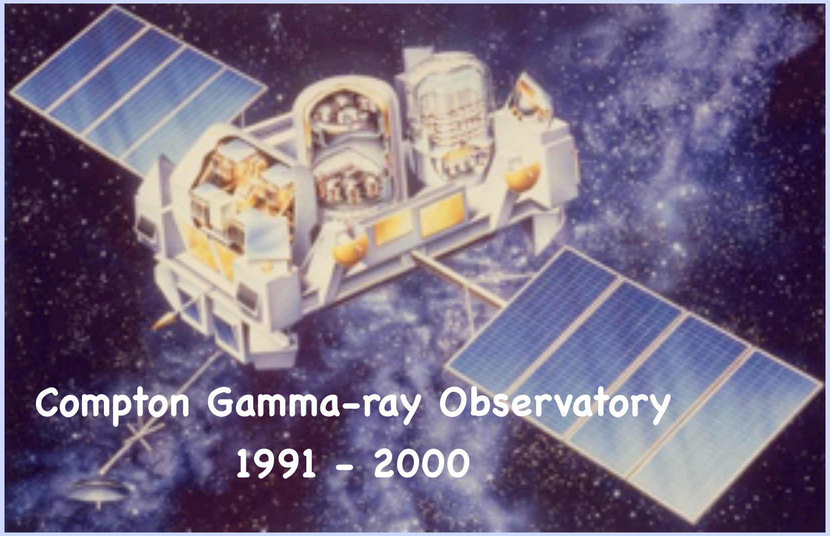

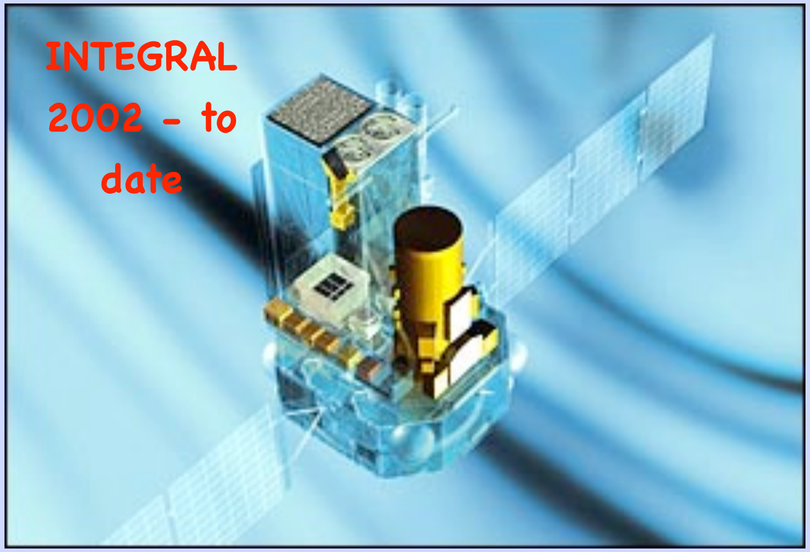

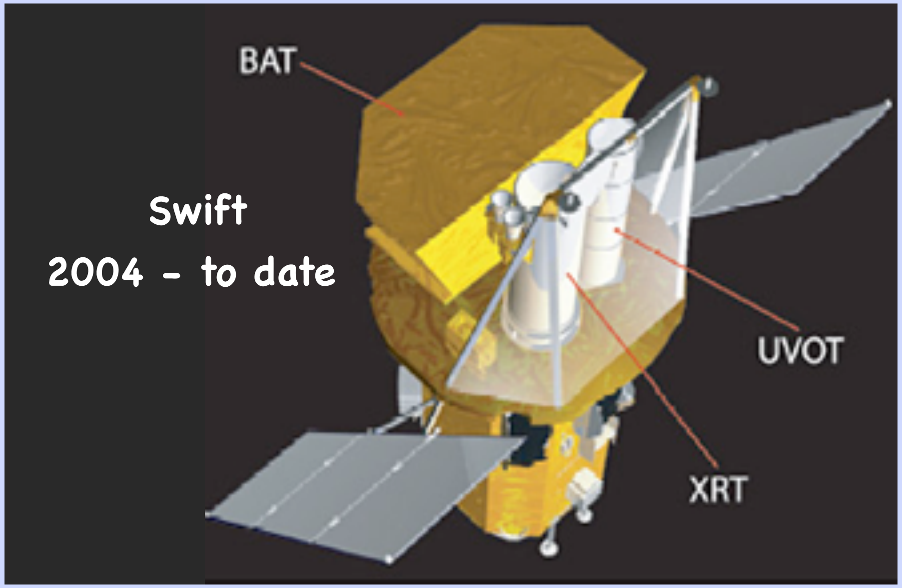

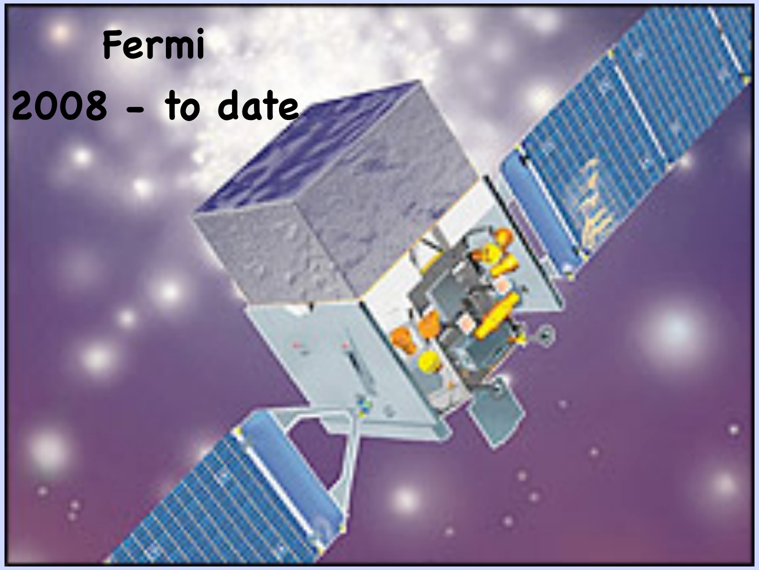

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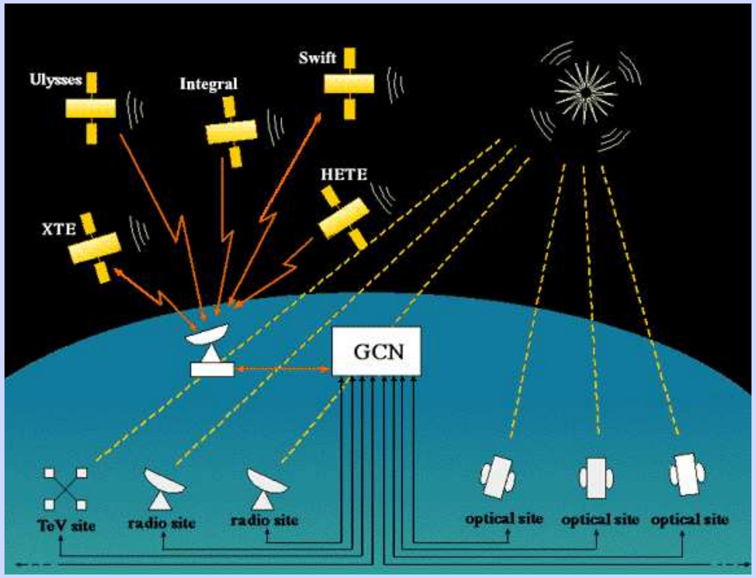

Pandey et al 2006

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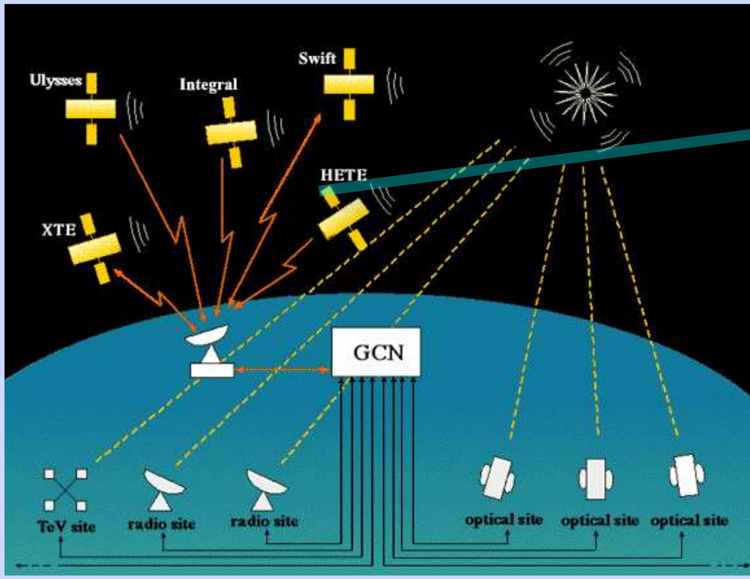
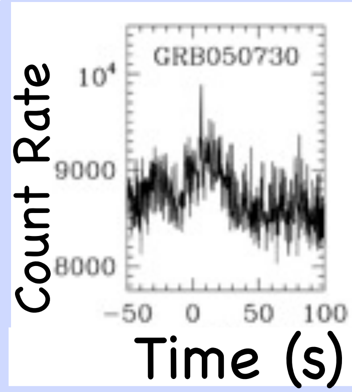
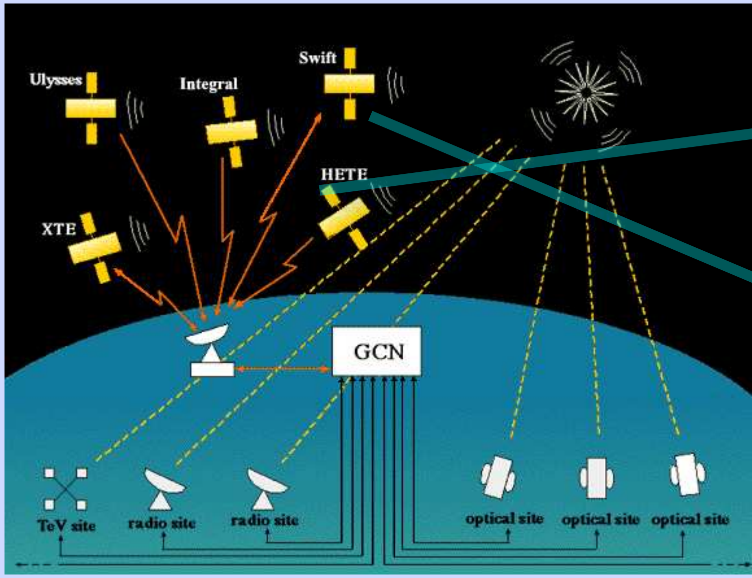


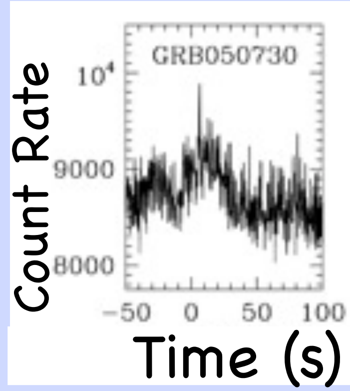


Prompt Emission: GRB 050730
30 s

Pandey et al 2006

How are they located?





Prompt
Emission:
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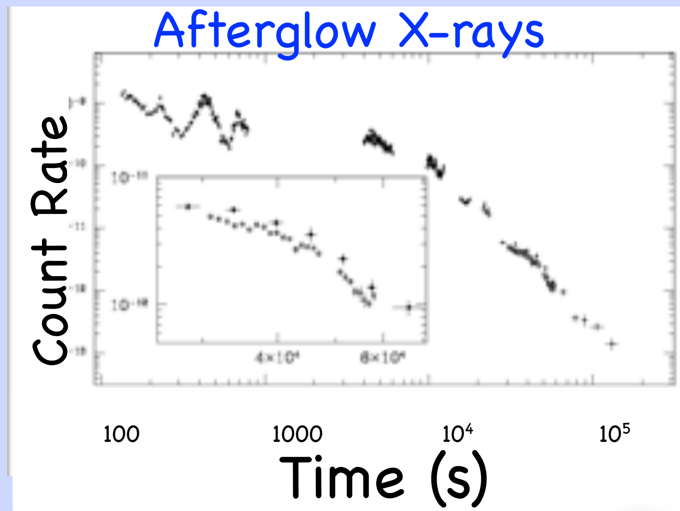
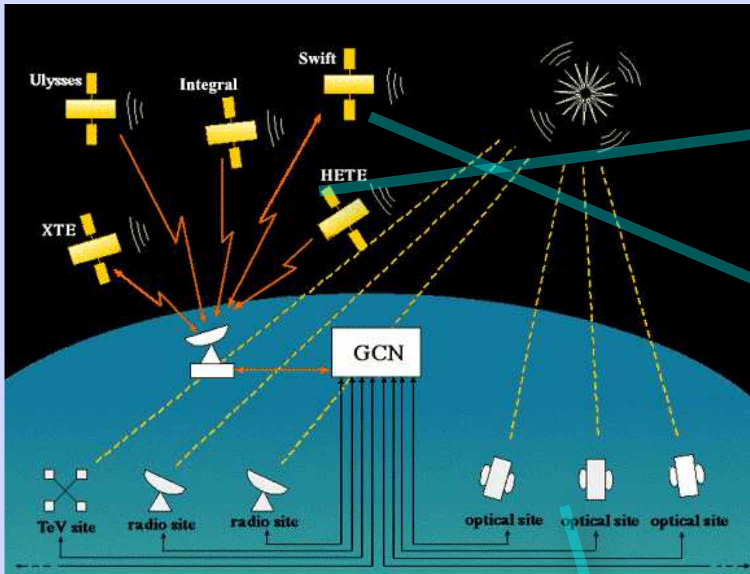
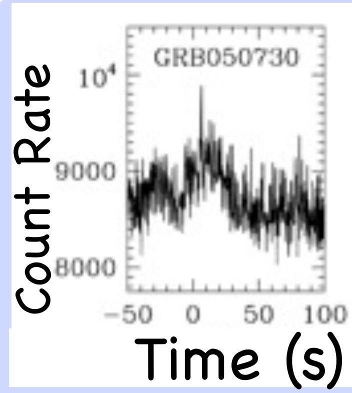


0.03h 0.3h 3h 30h

Pandey et al 2006

How are they located?





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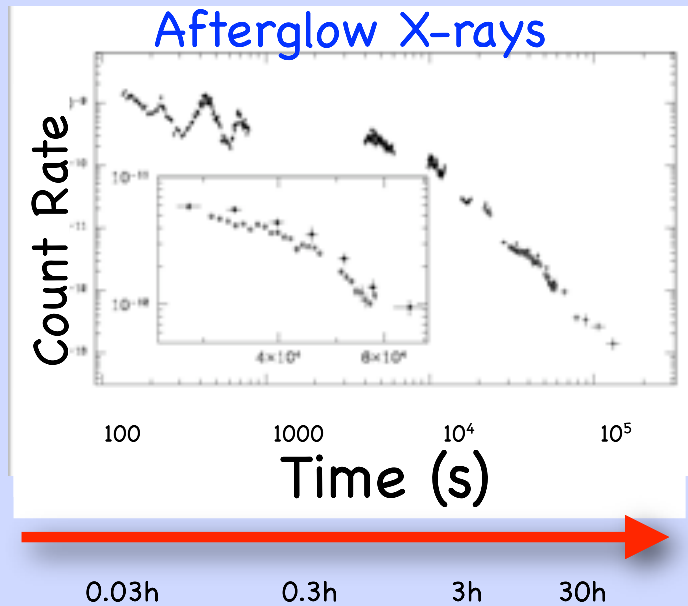
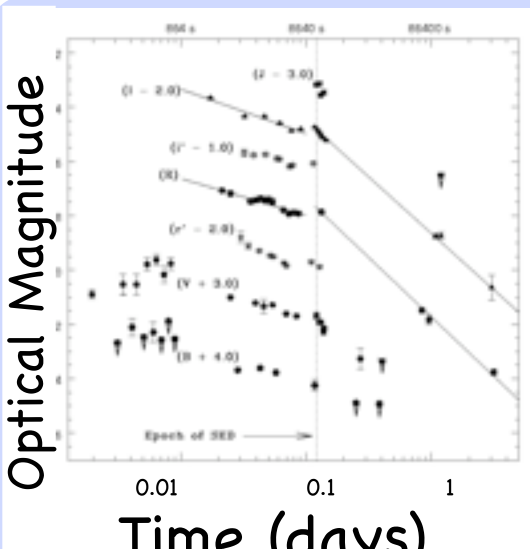


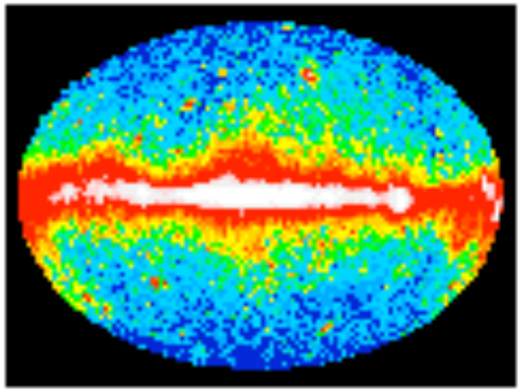


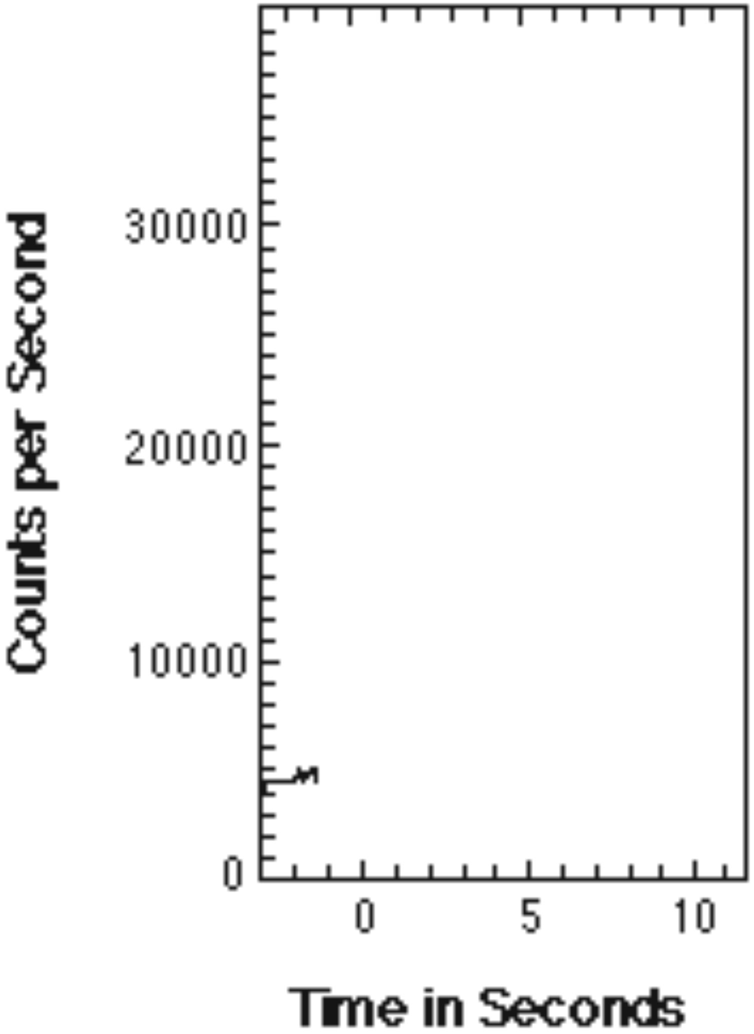
Afterglow Optical/NIR 100s to days post GRB

Pandey et al 2006

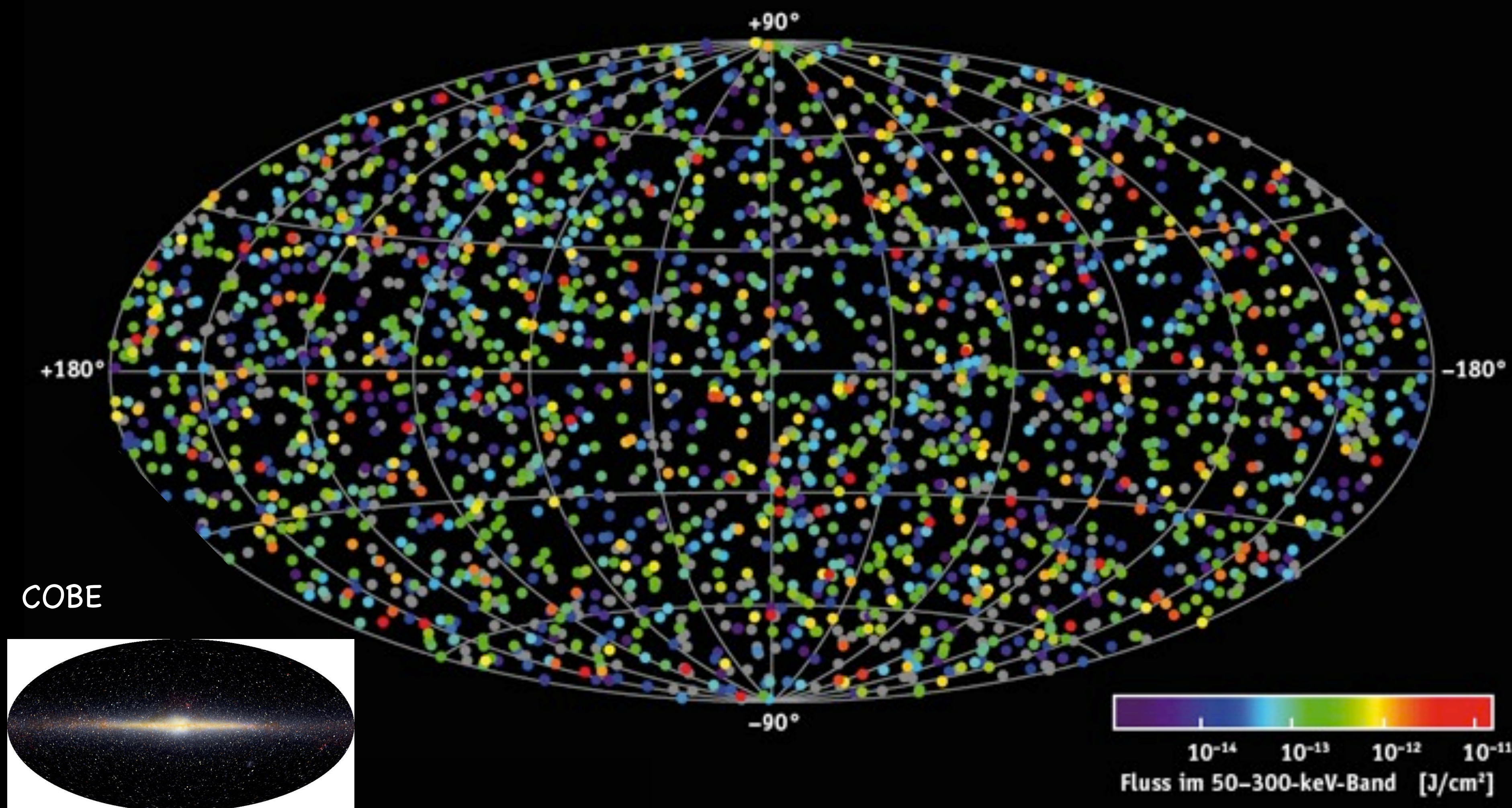
Brightness

Brightness



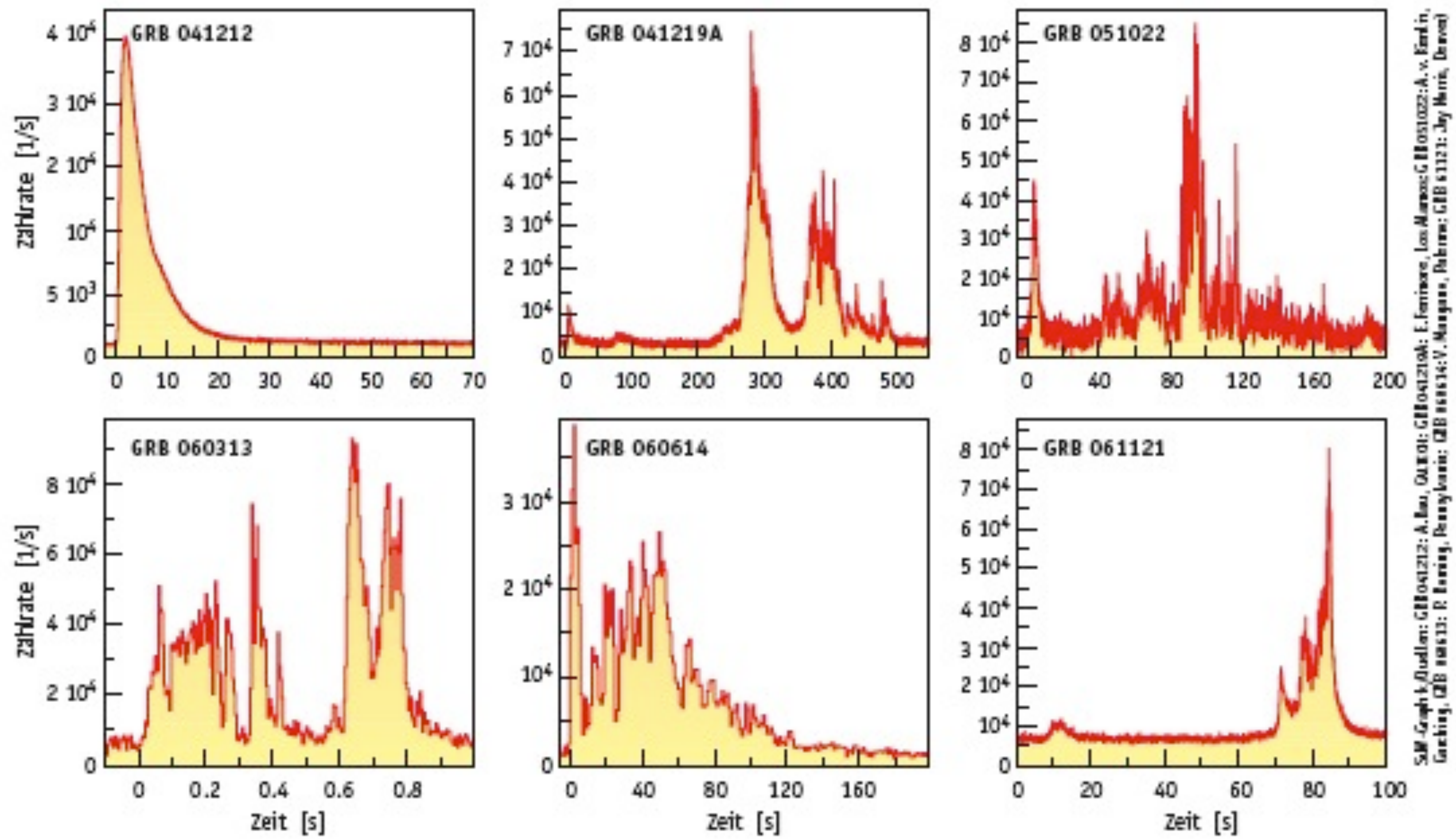


Where?



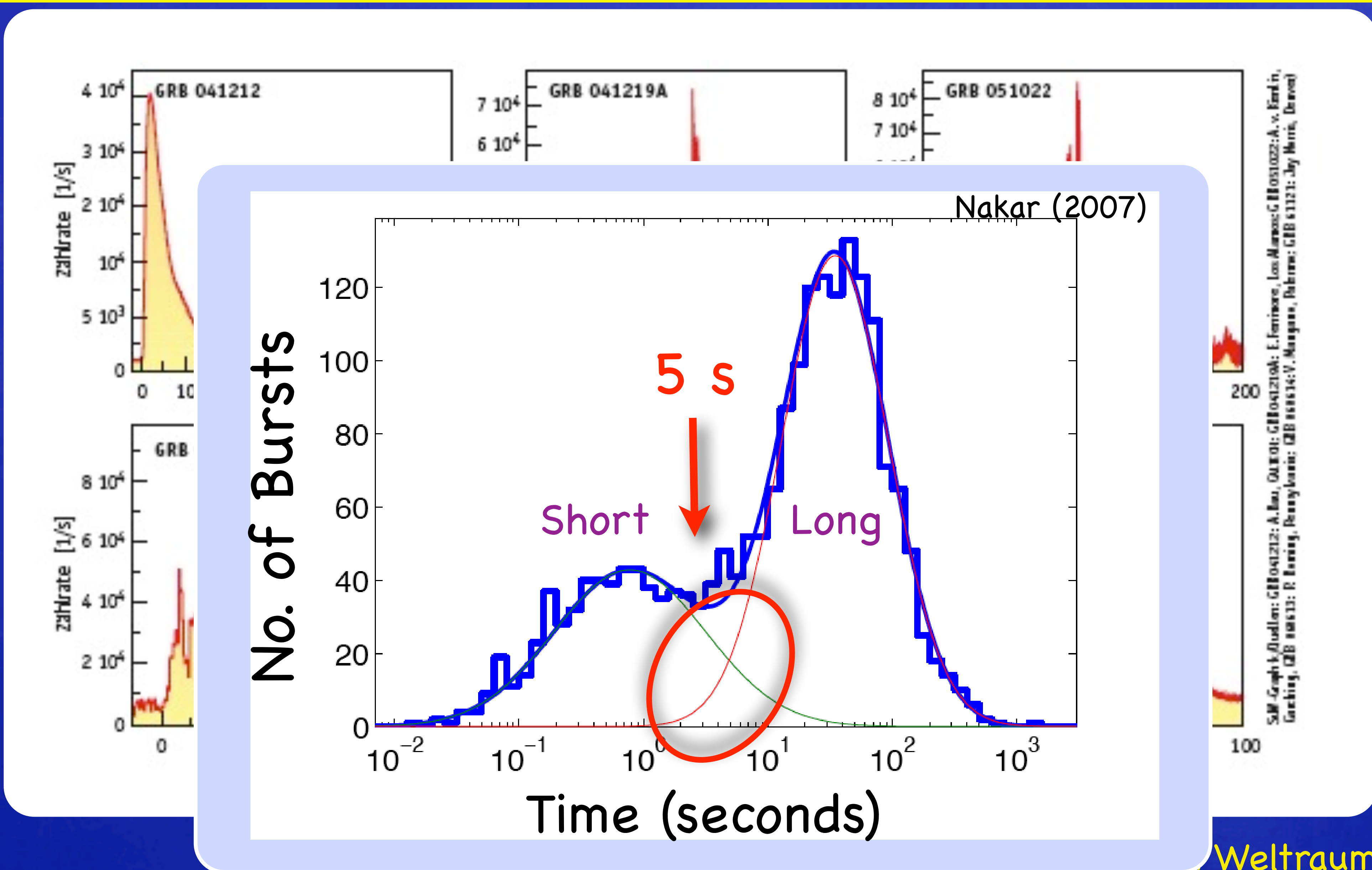
2704 GRBs. Credit: BATSE team.

Morphology



Kann et al 2007, Sterne und Weltraum.

Morphology



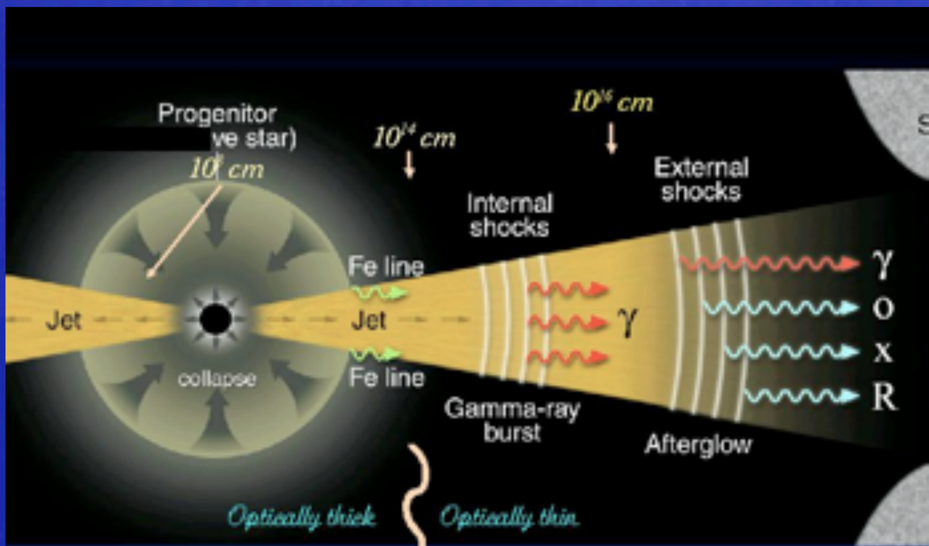
Weltraum.

Progenitors

Progenitors

<u>Long GRBs</u>

- Collapsar Model - massive star progenitors (Woosely)



Evidence : Energy, Supernovae, host galaxies with active star formation

Progenitors

Long GRBs

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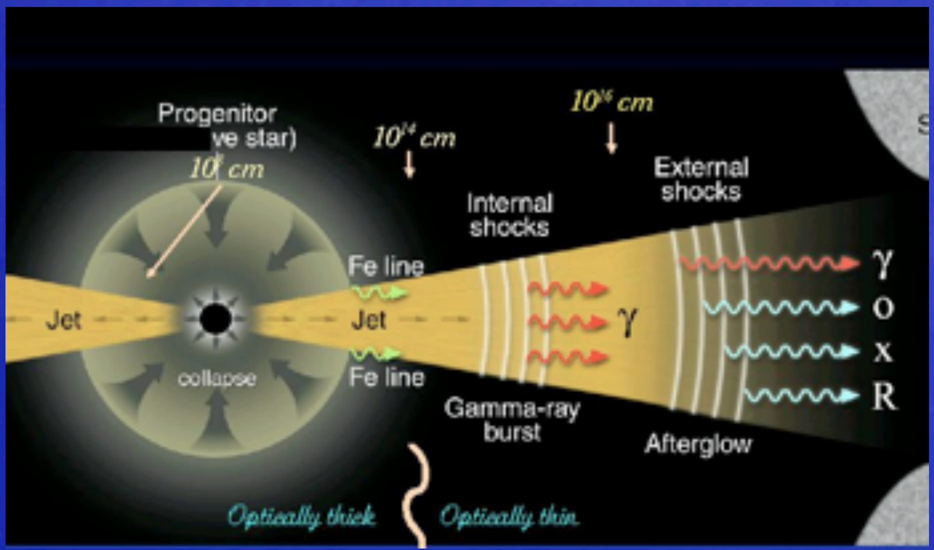
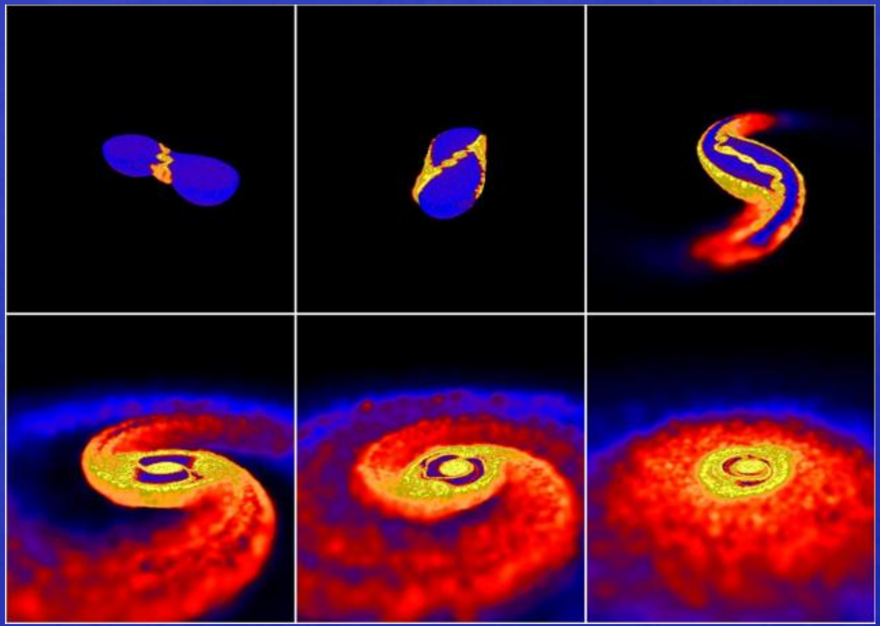


Evidence : Energy, Supernovae, host galaxies with active star formation

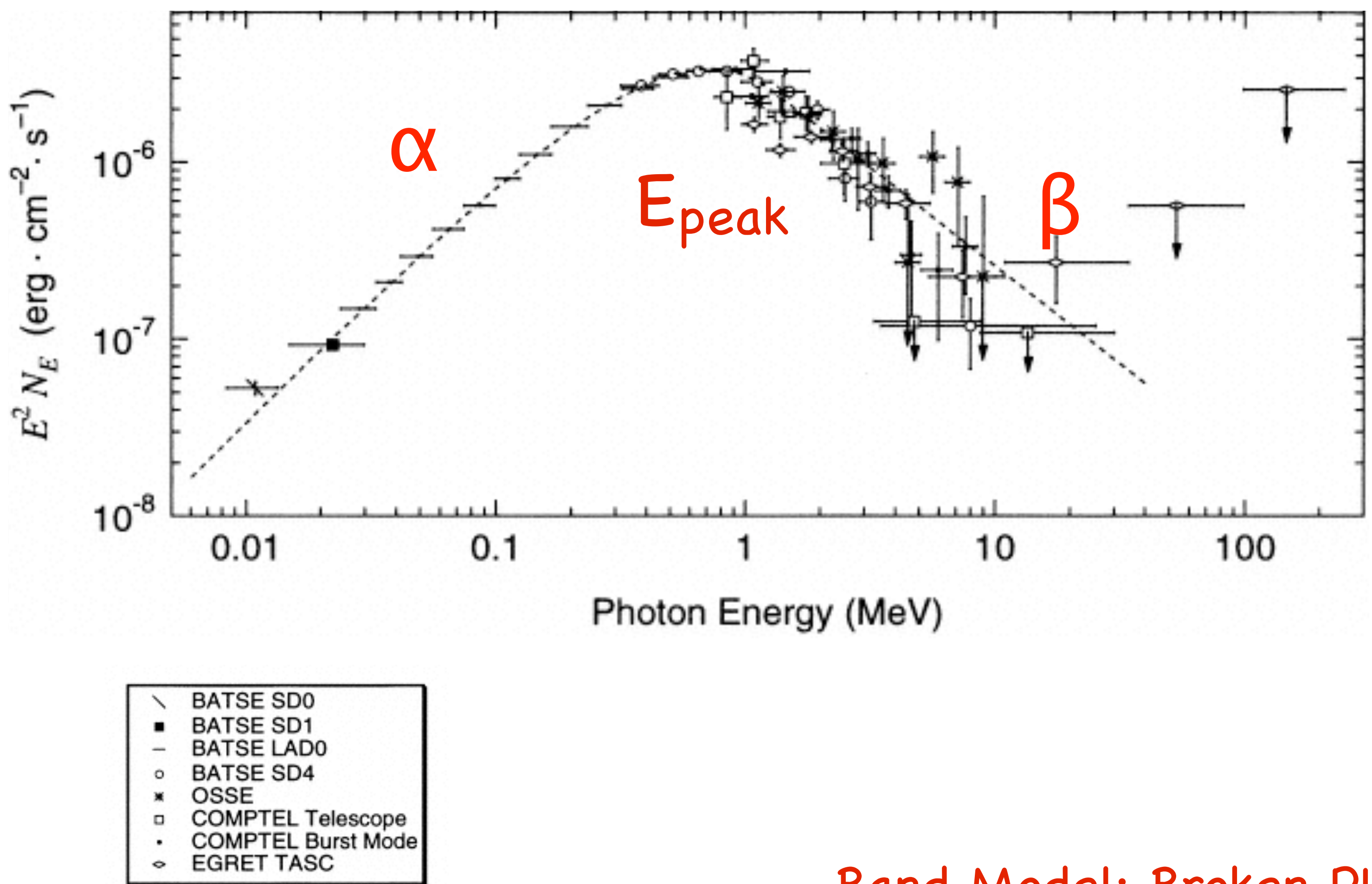
Short GRBs

- Compact Objects (eg Rosswog et al 2003)



Evidence : Timescales, Absence of Supernovae, host galaxies with old stars

Spectra



Band Model: Broken PL

Briggs et al, ApJ, 524, 82, (1999)

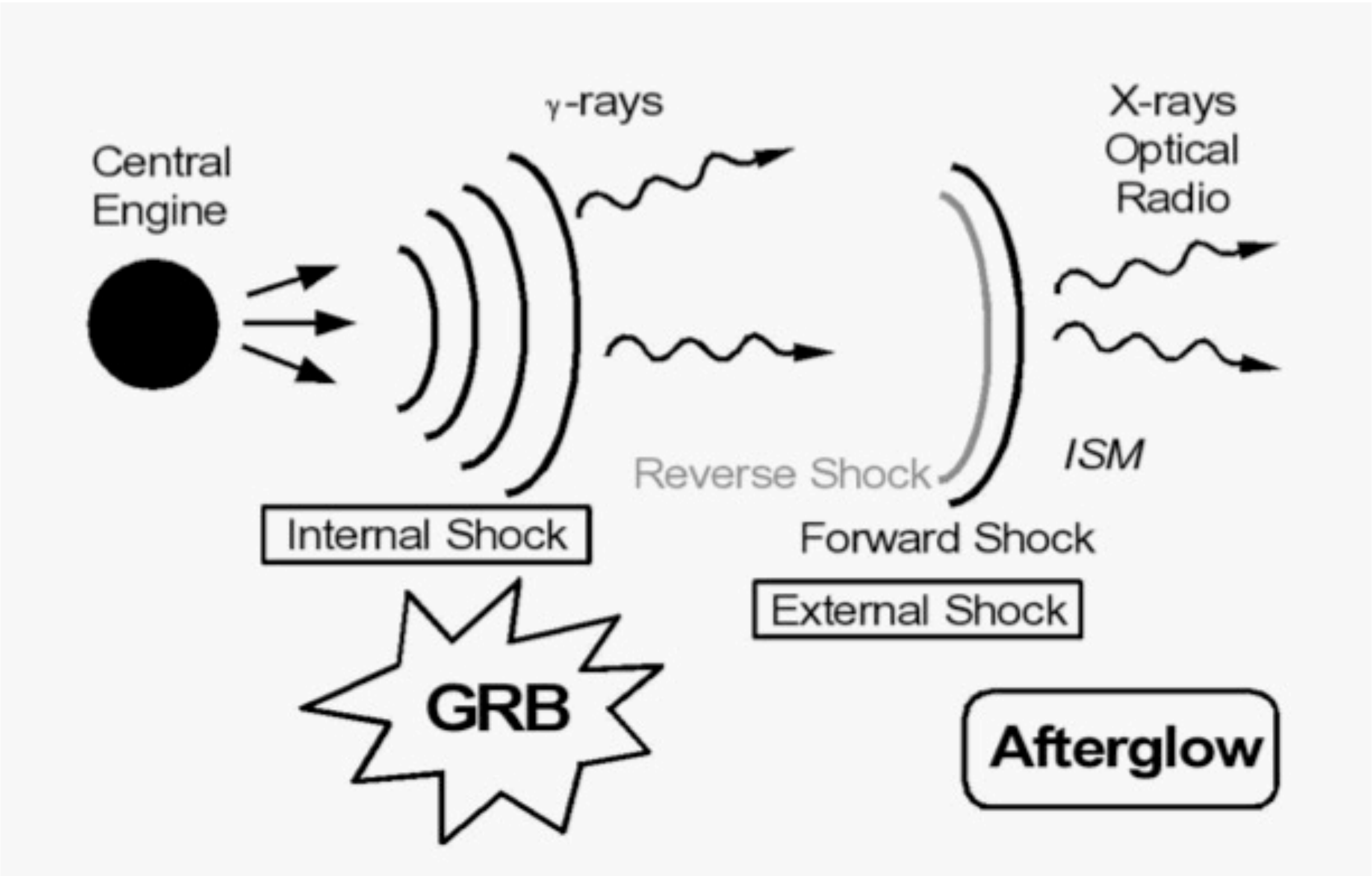
Compactness Problem

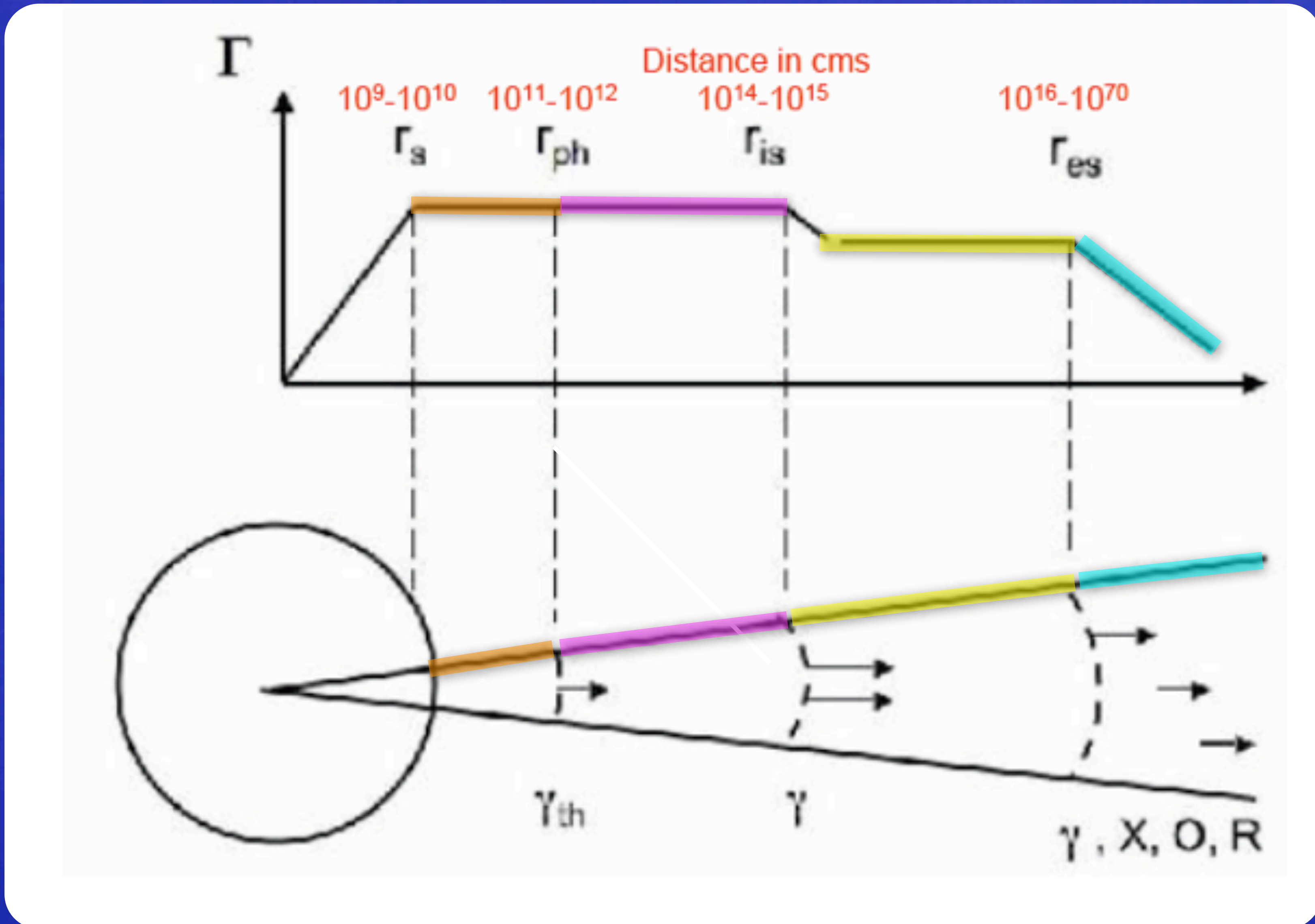
- Variability of GRBs on a millisec timescale
- Region ~ 100 km Radius ($r \sim c\Delta t$)
- Fireball -> many Photons / small Volume
- Optically thick (~10^{14}) -> $\gamma\gamma$ -> e^+e^-
- Thermal spectrum with cutoff

Solution

- Fireball expands with ultra-relativistic speeds
- Material moves with Lorentz factor towards us $\Gamma = (1-(v/c)^2)^{-1/2}$
- **1)** Emission region is bigger
- **2)** Photons are less energetic
- **3)** Photon angle
- Γ=100 -> v = 0.99995c

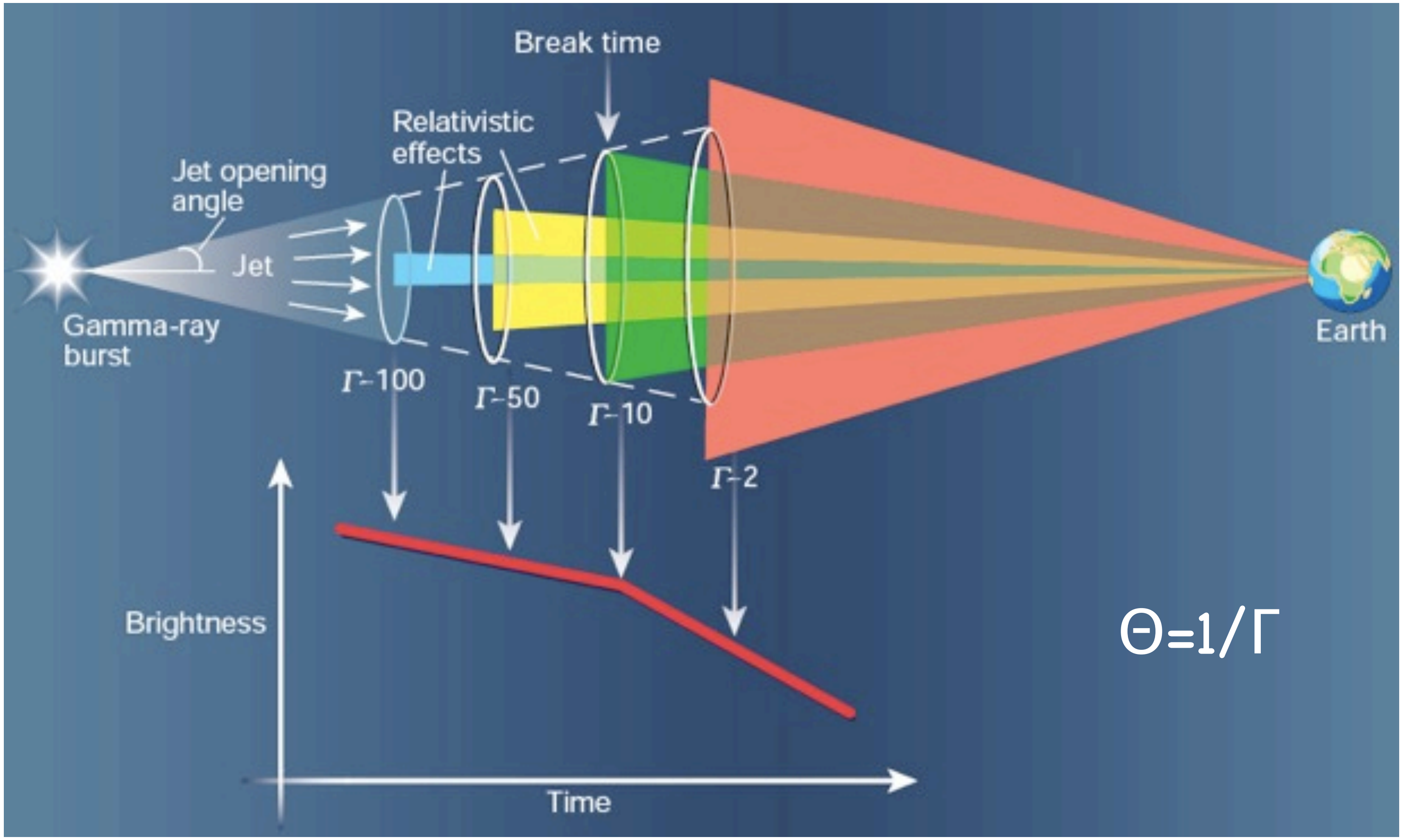
Fireball


γ-rays
Central
Engine
X-rays
Optical
Radio
ISM
Reverse Shock
Internal Shock
Forward Shock
External Shock
GRB
Afterglow



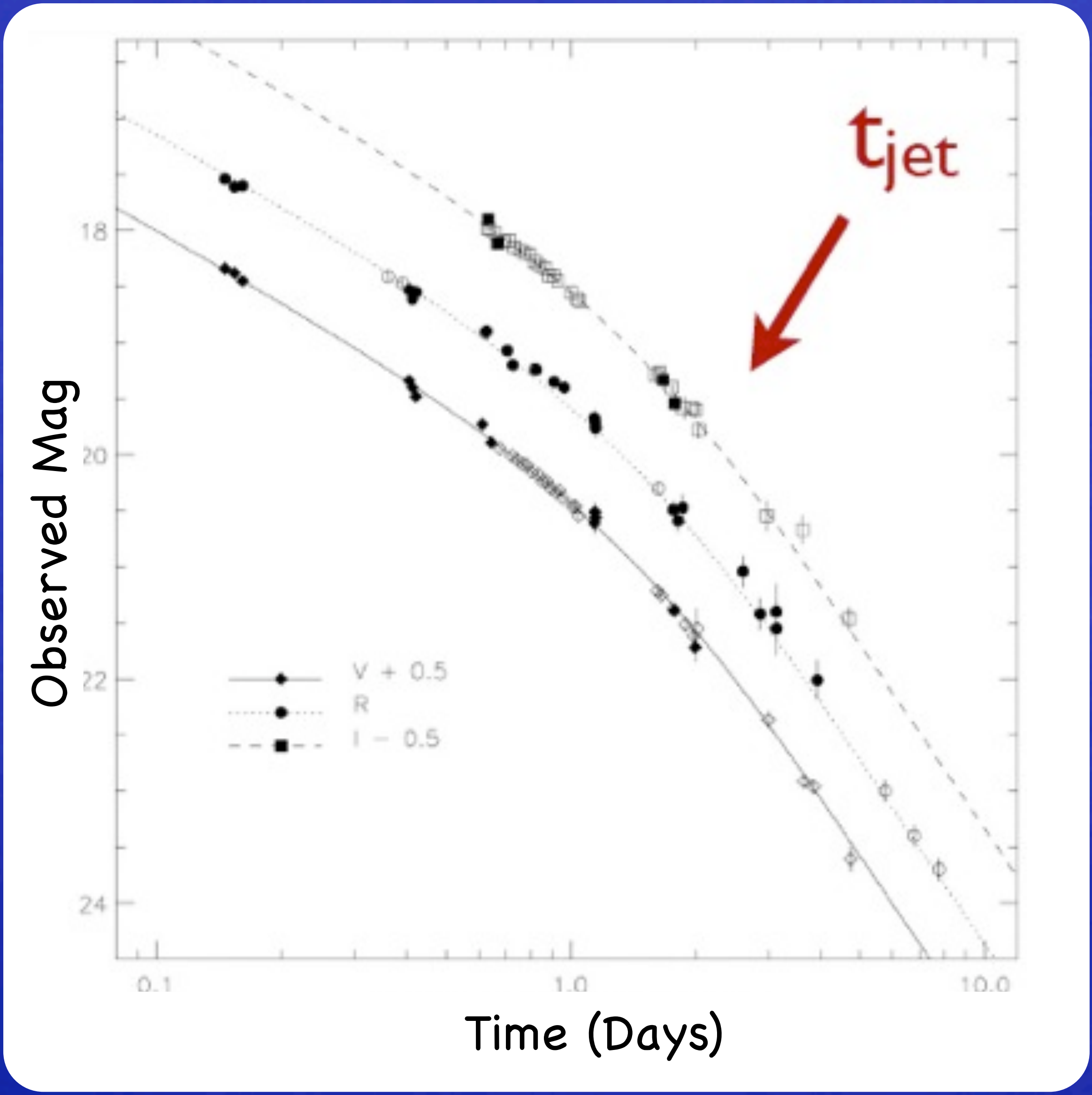
Saturation radius r_s , photospheric radius r_{ph} , internal shock radius r_{is} ,external shock r_{es}.
The photosphere produces thermal γ -rays, the internal shock/dissipation region produces the non-thermal γ -rays, the external shock region produces the afterglow.

Jets



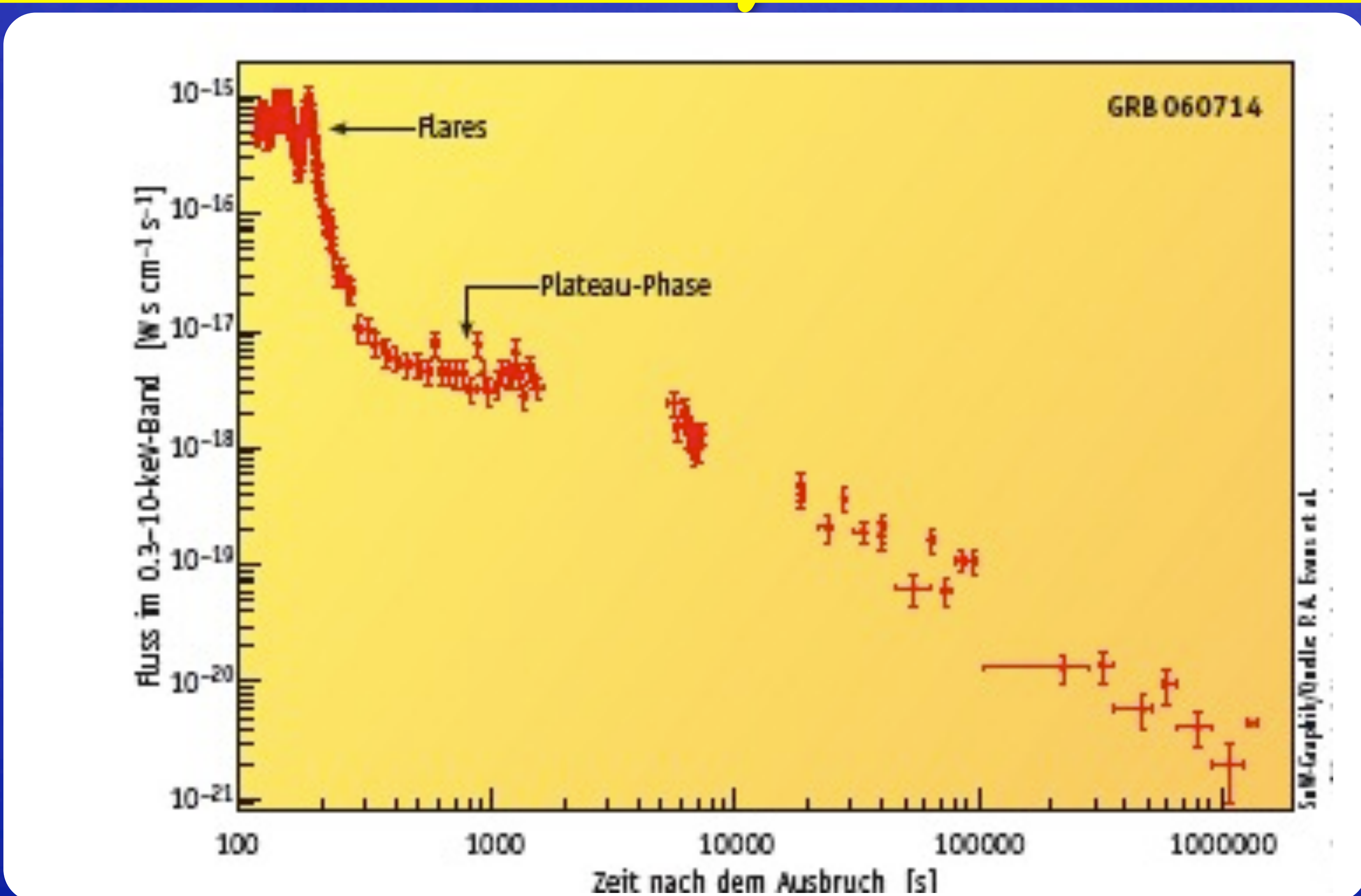
Woosley, Nature, News and Views, 2001.

Jets



Harrison et al., The Astrophysical Journal, 523, L121.

X-rays



Kann, Schlutze, Klose, Sterne & Weltraum (2007)

Breaks?

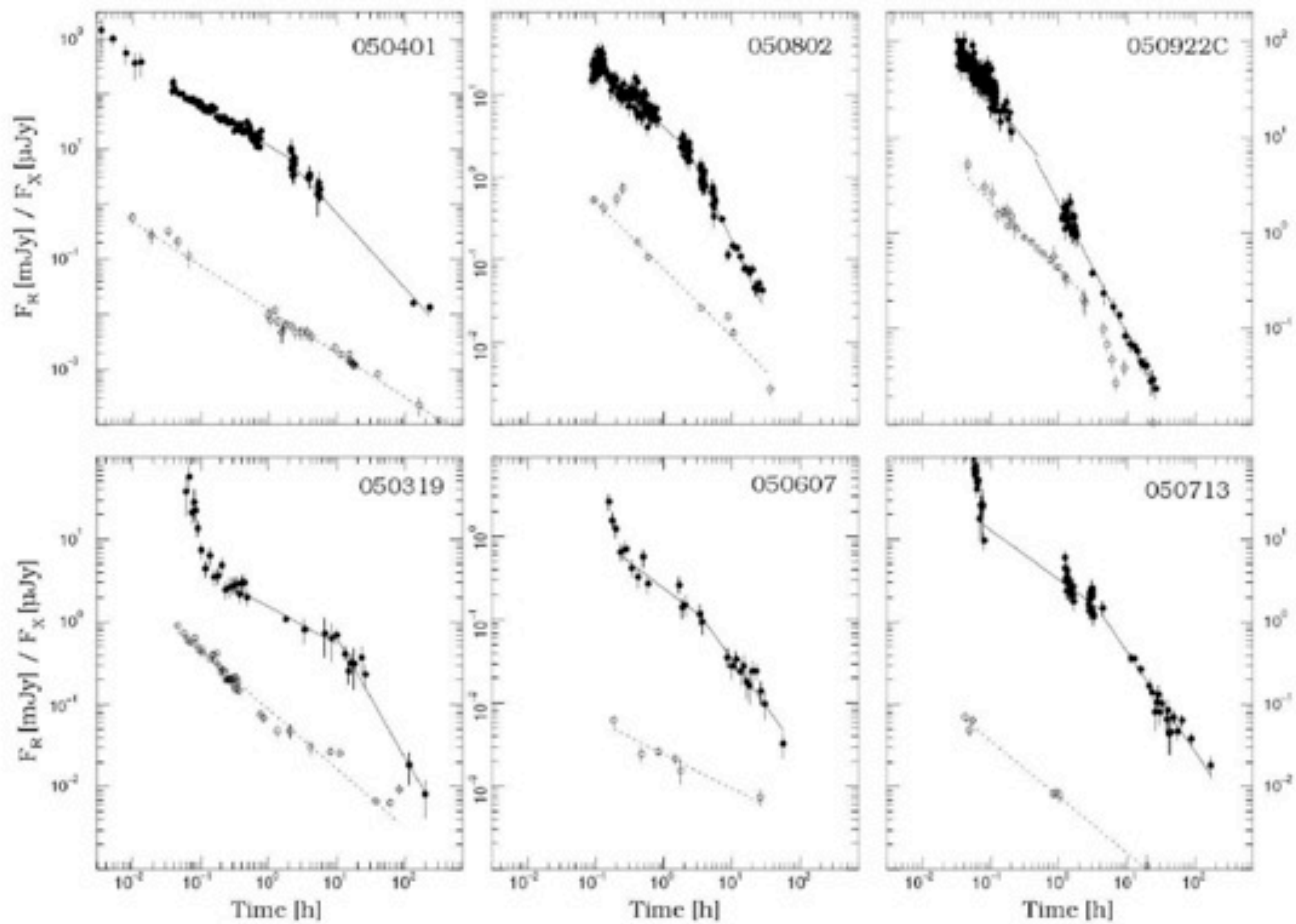
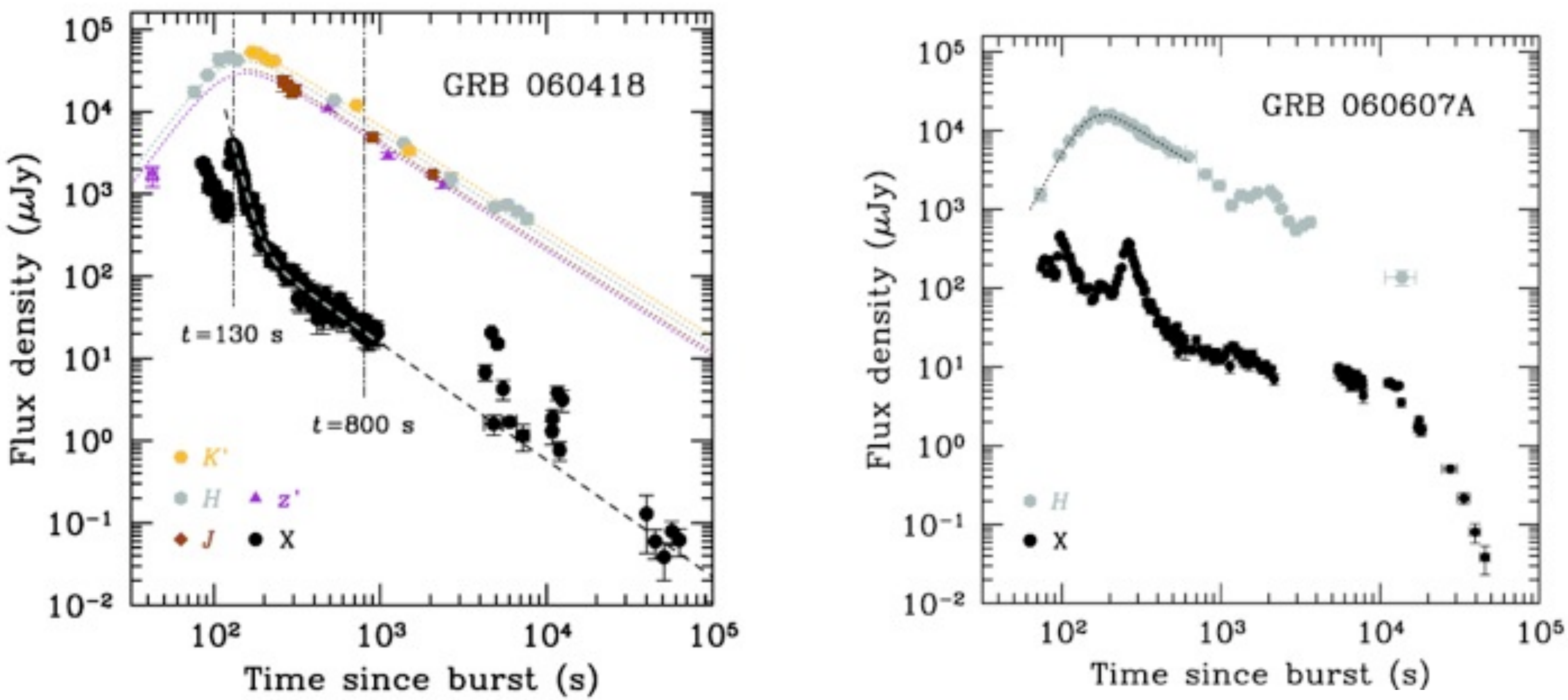


Figure 1.11 A sample of *Swift* bursts with chromatic breaks. The break is either absent in one of the X-ray or optical bands, or not simultaneous. From (Panaitescu et al., 2006a)

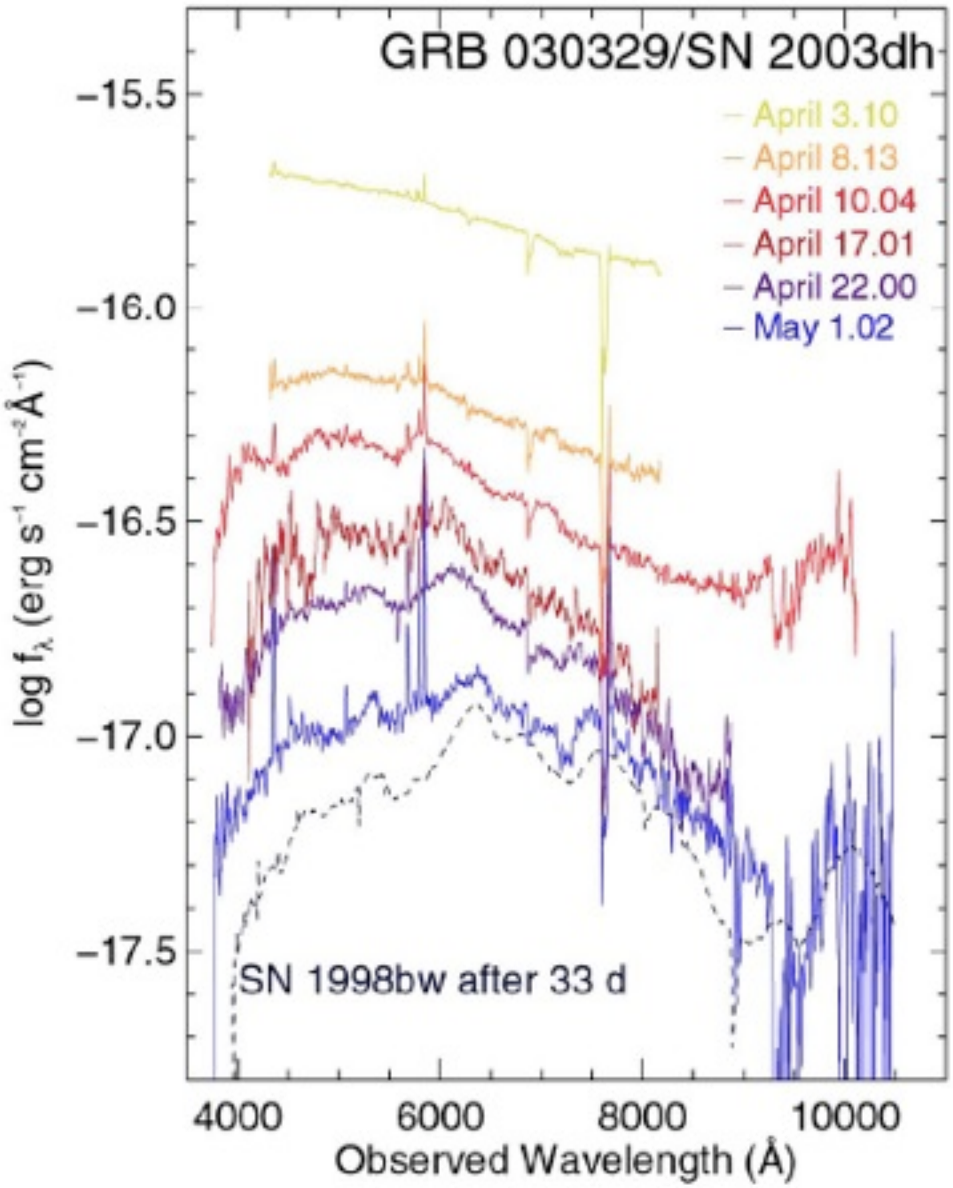
Rising AG



$\Gamma_0 \sim 400$

Molinari et al, Astronomy and Astrophysics, 469, L13, (2007)

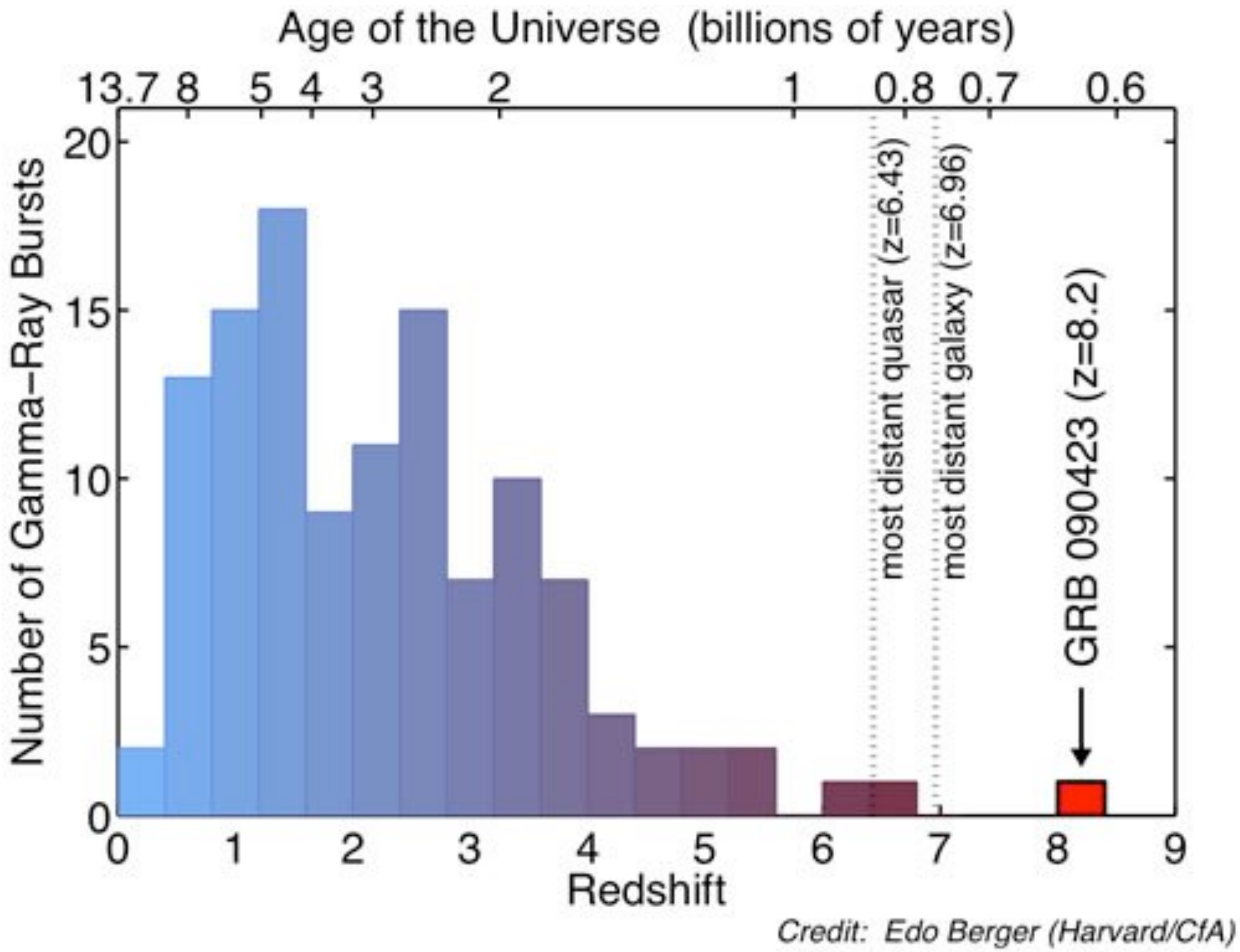
SN2003dh



Typ Ic
36,000 km/s

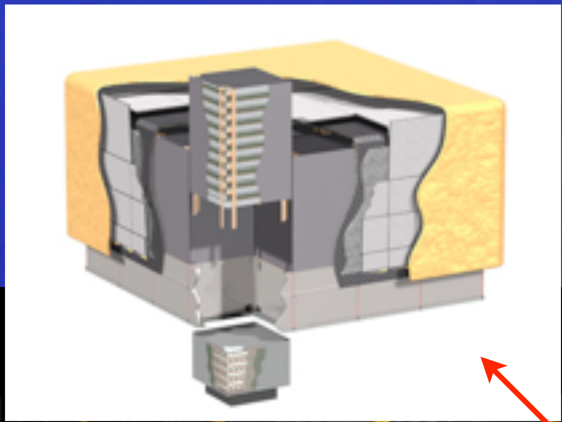
Hjorth et al, Nature, 423, Issue 6942, pp. 847-850 (2003)

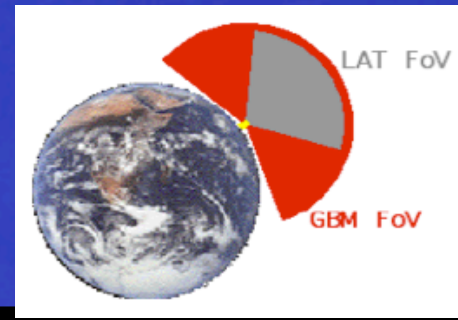
Redshifts

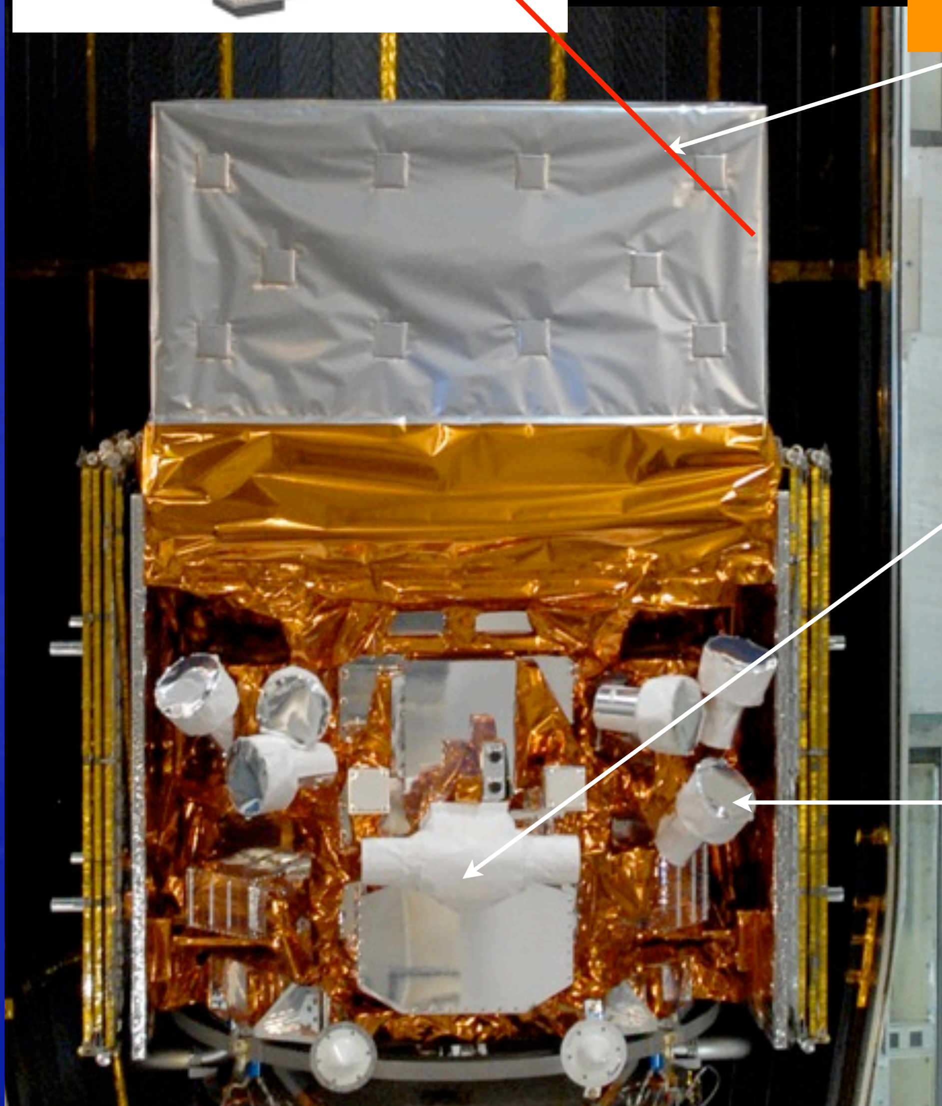


Mean redshift Swift GRBs z~2.3

Fermi







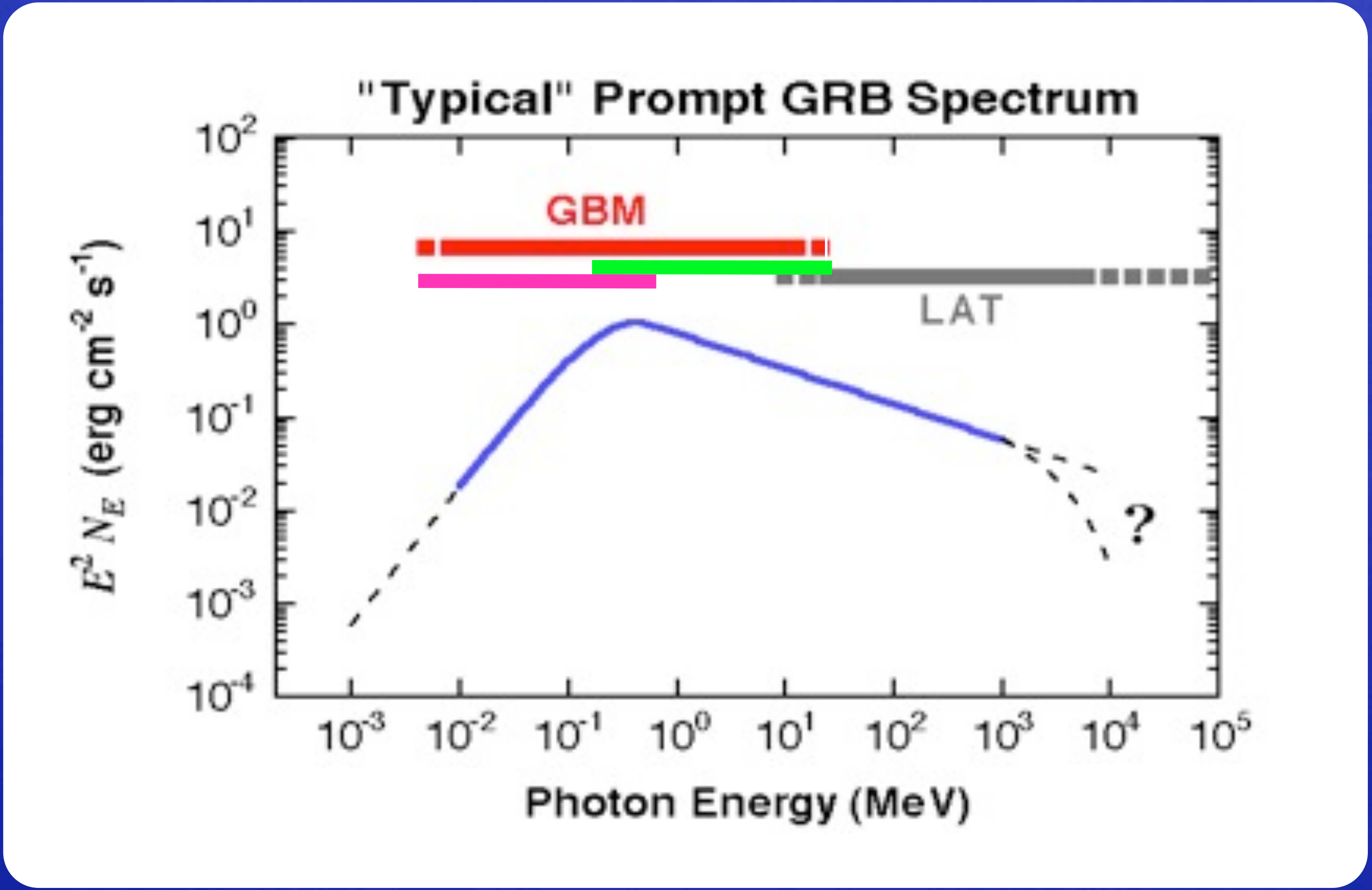
The Large Area Telescope (LAT)

Pair Telescope: 100 MeV to 300 GeV

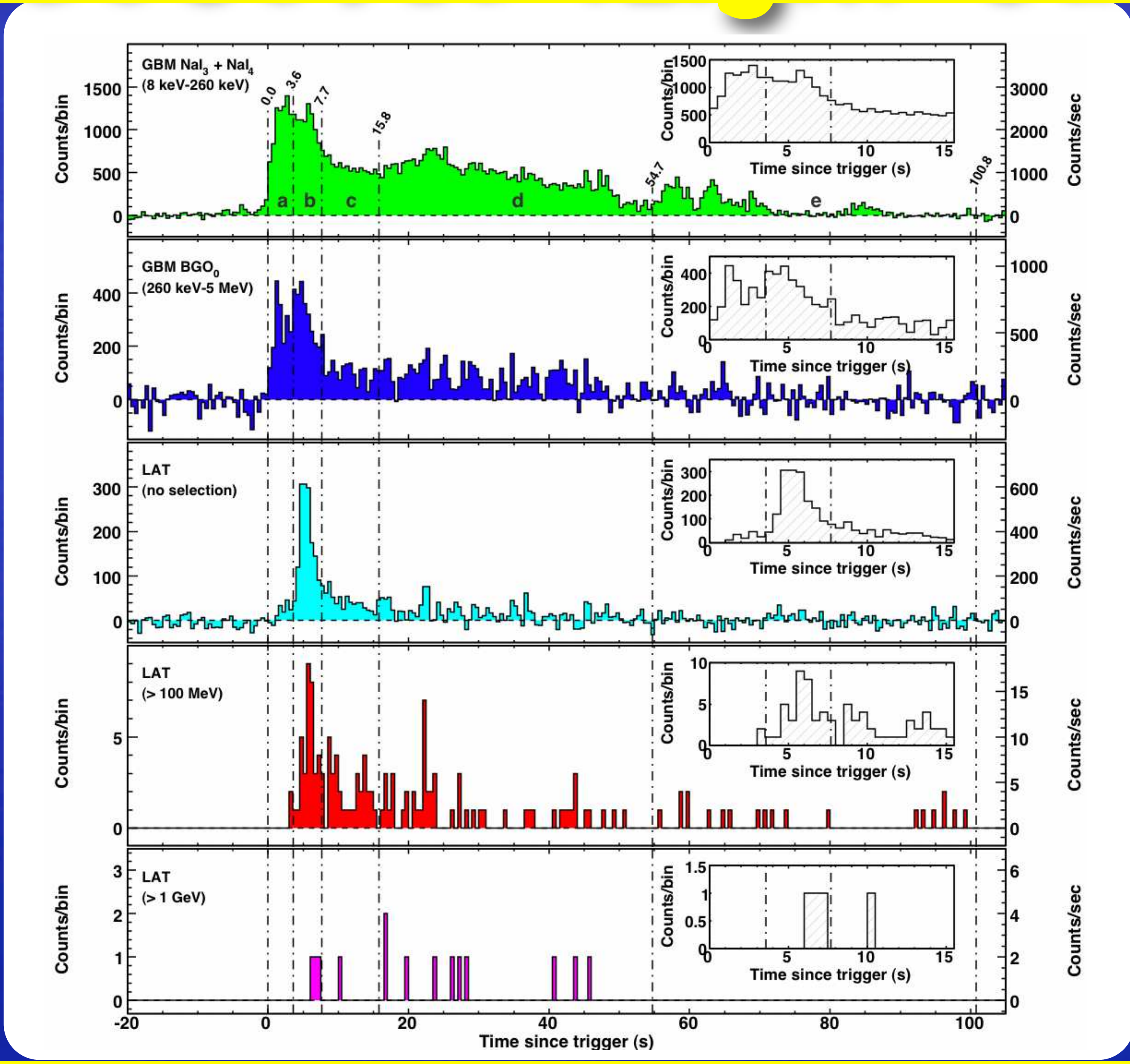
GBM BGO detector.
200 keV -- 40 MeV
126 cm^2, 12.7 cm
Spectroscopy
Bridges gap between NaI and LAT.

GBM NaI detector.
8 keV -- 1000 keV
126 cm^2, 1.27 cm
Triggering, localization, spectroscopy.

Energy Range



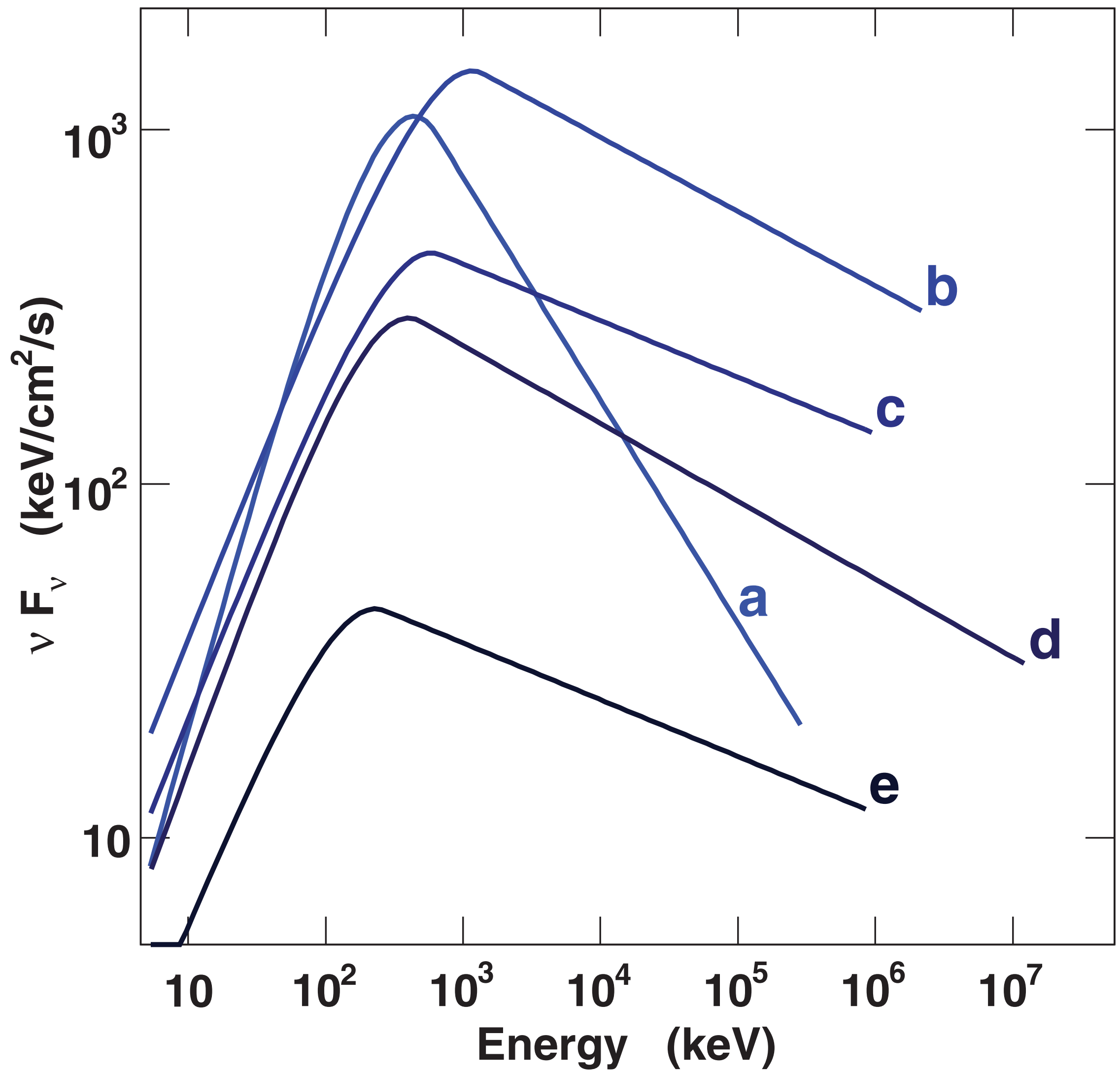
GRB080916 :Light Curves



Abdo+, Science, 2009

Spectrum

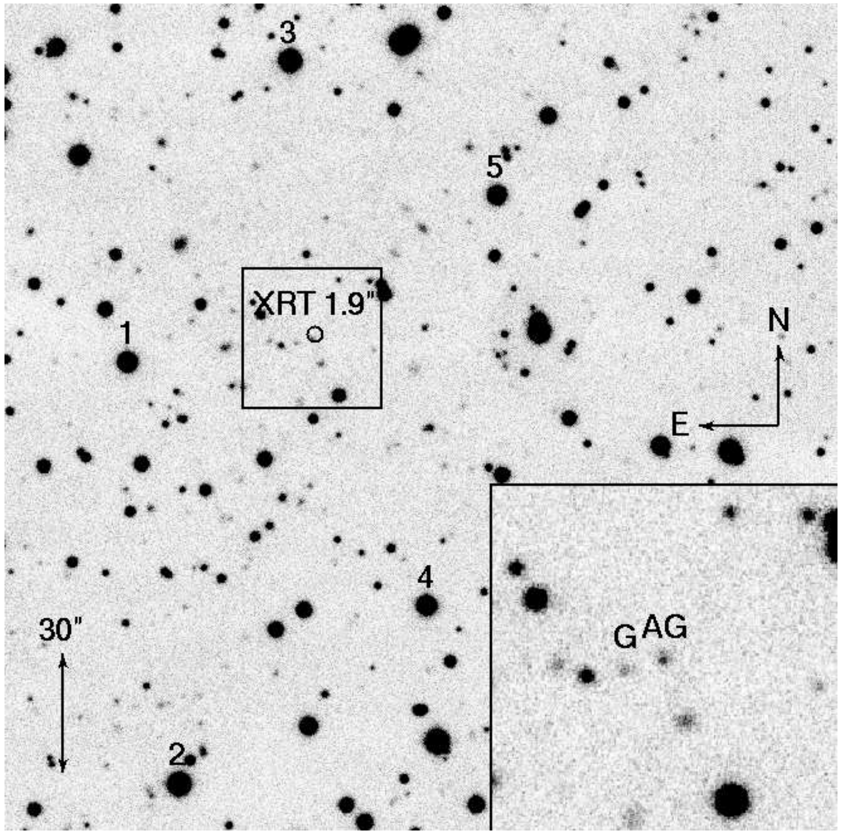
Abdo+, Science,2009

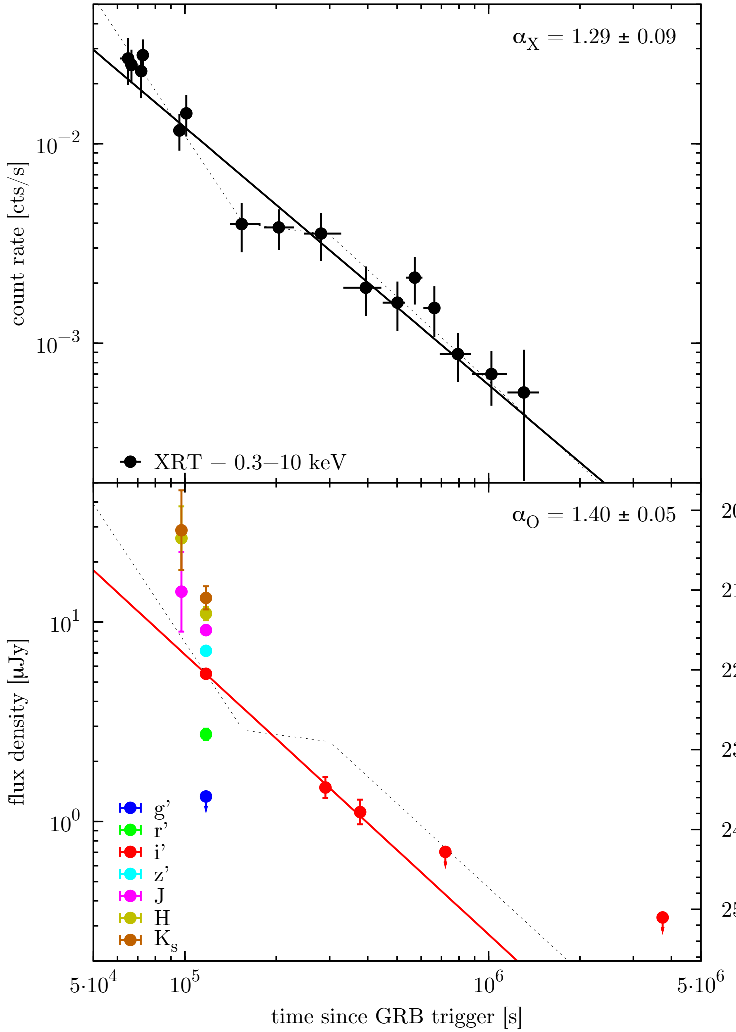


Light curve

Afterglow discovery

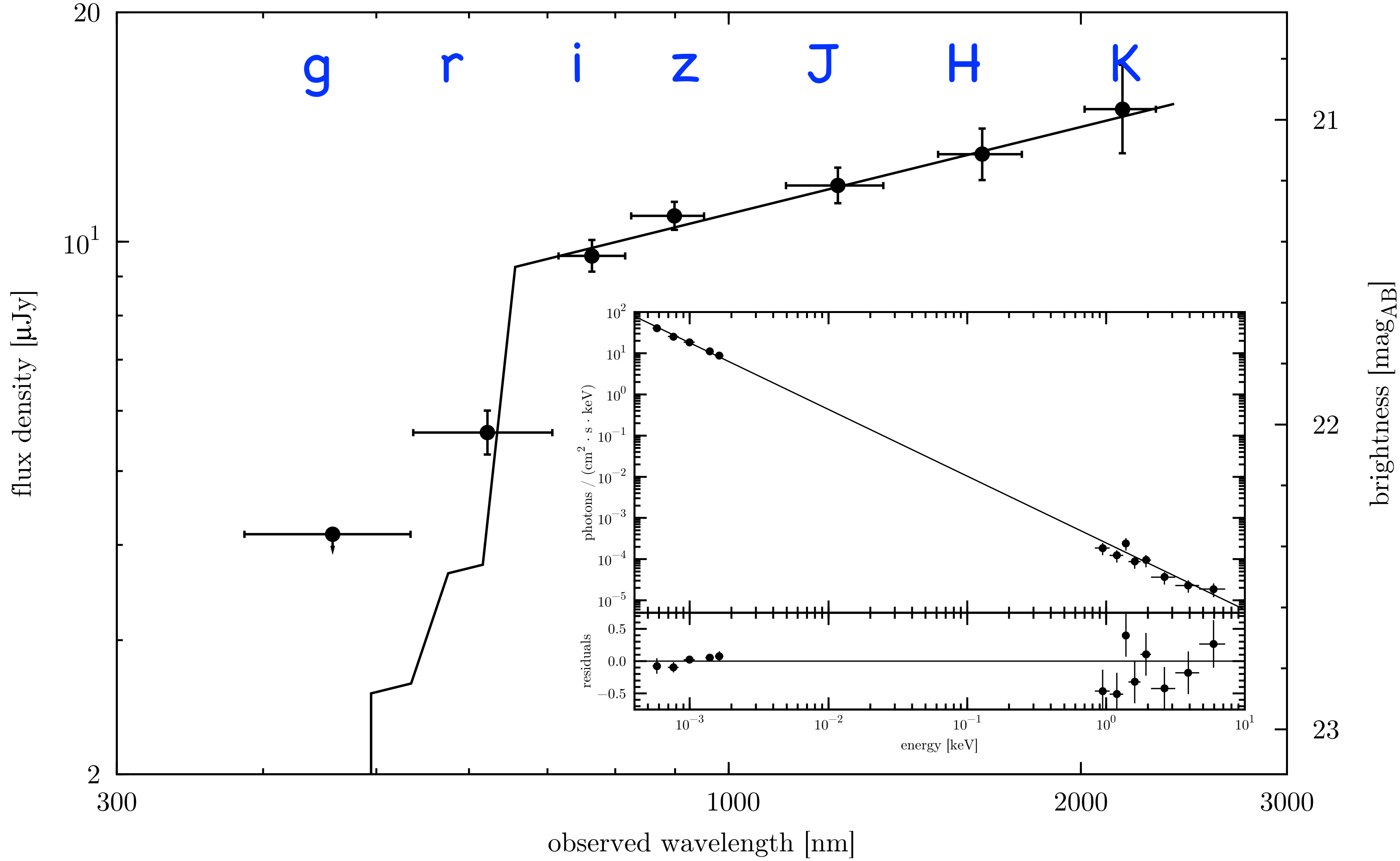
X-ray position -> optical.





Greiner+2009

080916C @ 4.35±0.15

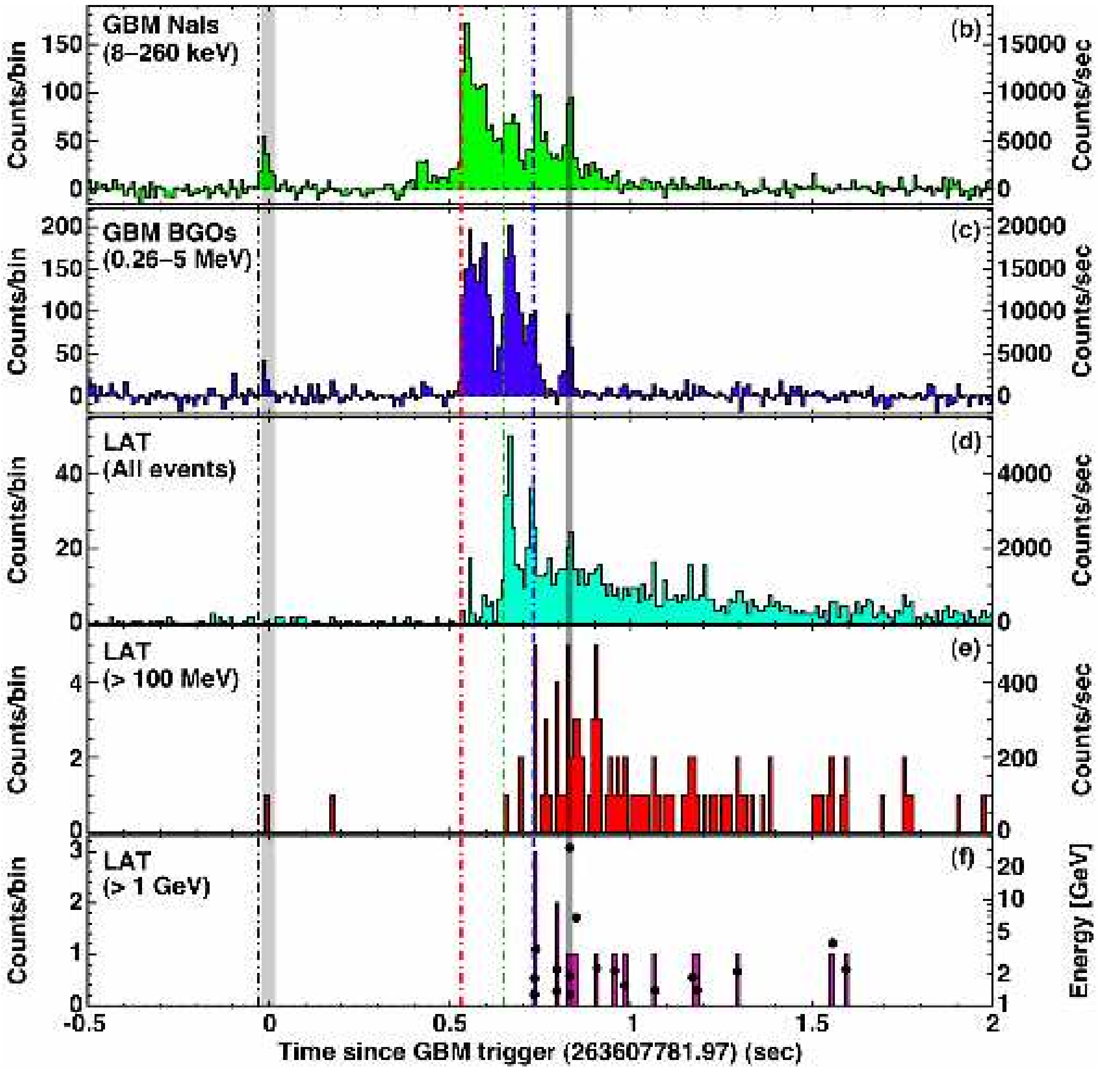


Greiner+2009

Other Results

- E_{ISO} ~ 9×10^{54} erg
- $E_{\gamma} > 5 \times 10^{52}$ erg
- Γ_{MIN} ~ 800 based on highest energy photon & variability
- Test photon dispersion relation $\Delta t \; \alpha \; (\Delta E/(M_{QG}c^2))\, D/c$ (Amelino-Camelia+98)
- Lower limit on $M_{QG} > 0.1\, M_{Planck}$ (Abdo+)

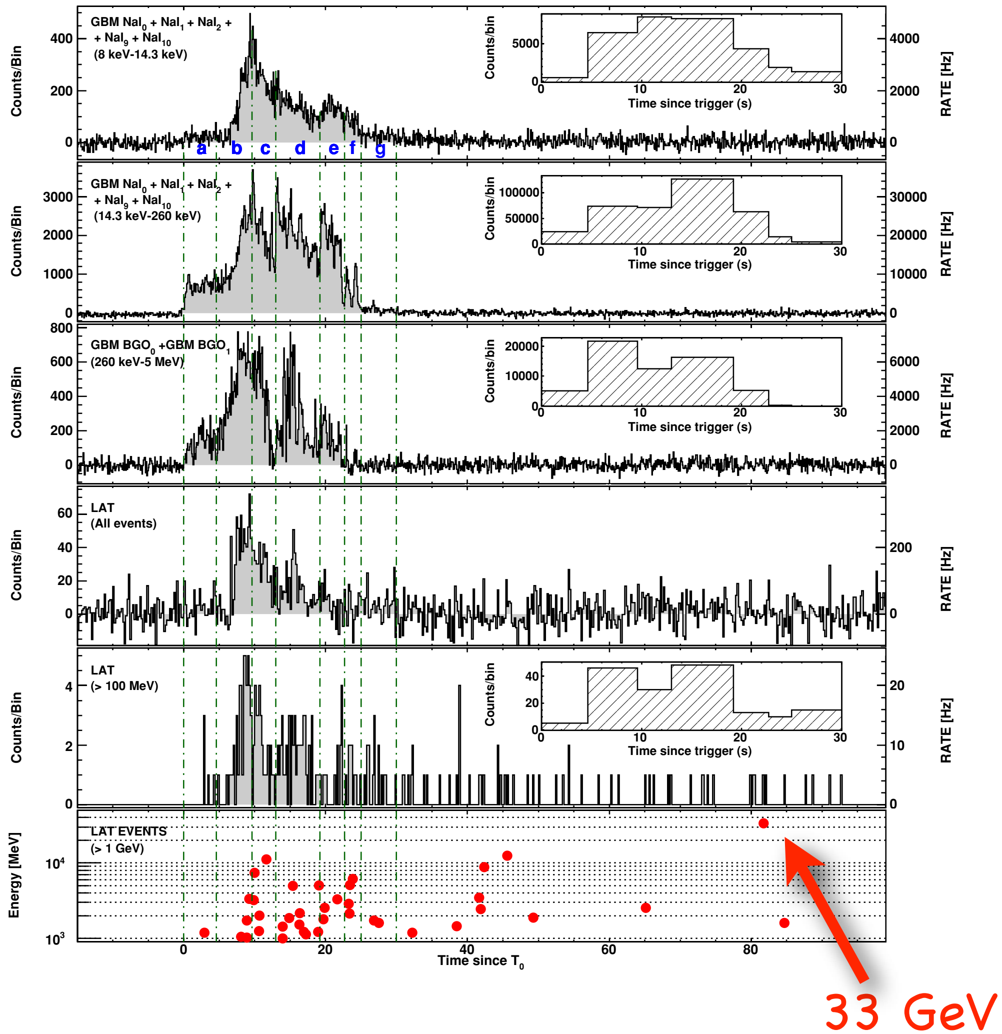
GRB090510

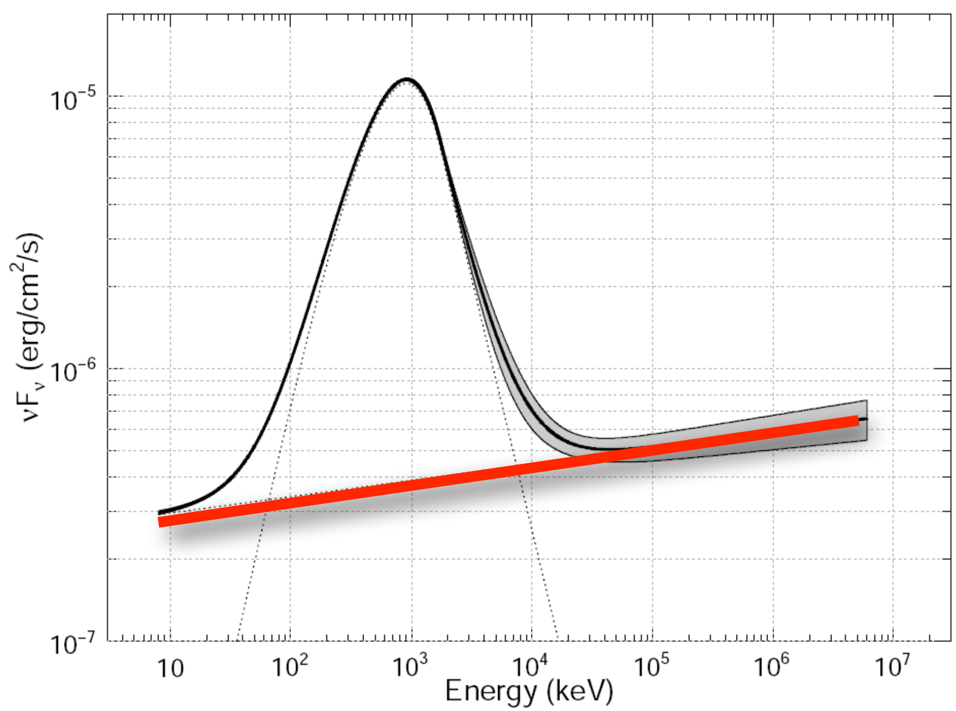


- Highest energy photon at 0.83 s -> 31 GeV
- Redshift 0.903 (McBreen+, 10)
- Photon Dispersion :
- M_{QG} > 1.22 M_{PLANCK}

Abdo+, Nature, 10

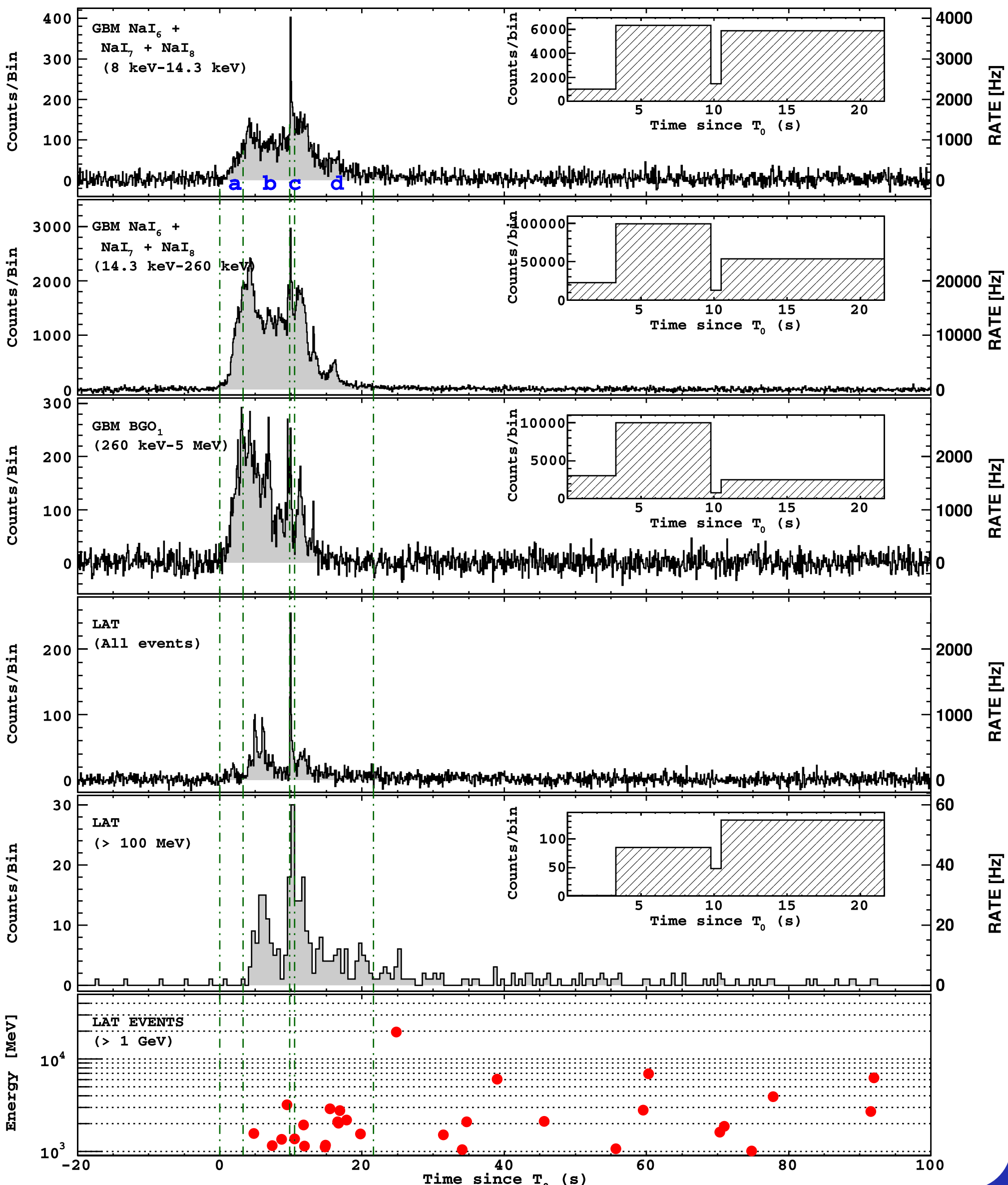
GRB09092B

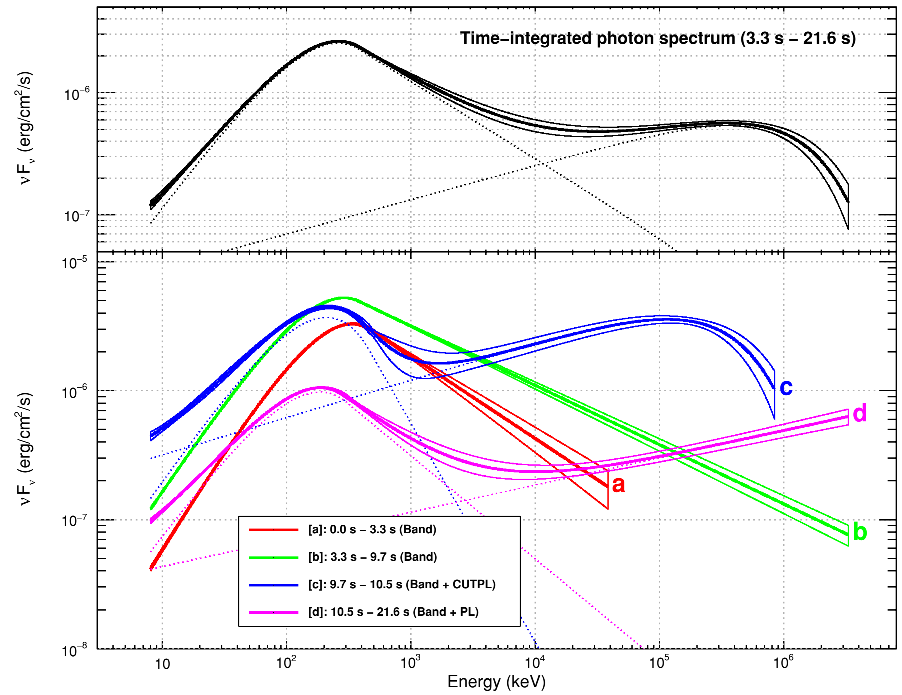




Abdo+, ApJL, 09

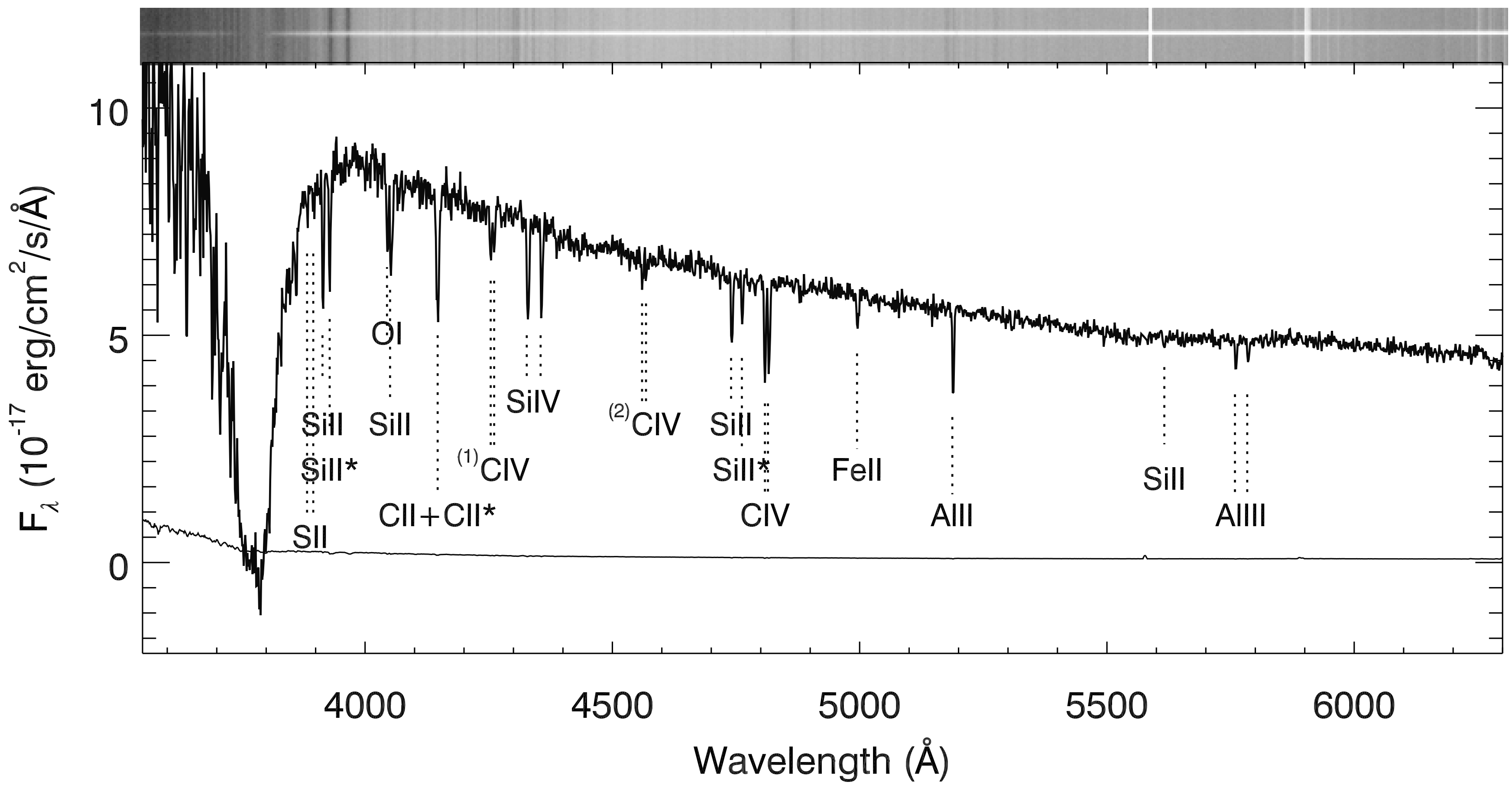
GRB09026A





Ackermann et al., ApJ, 11

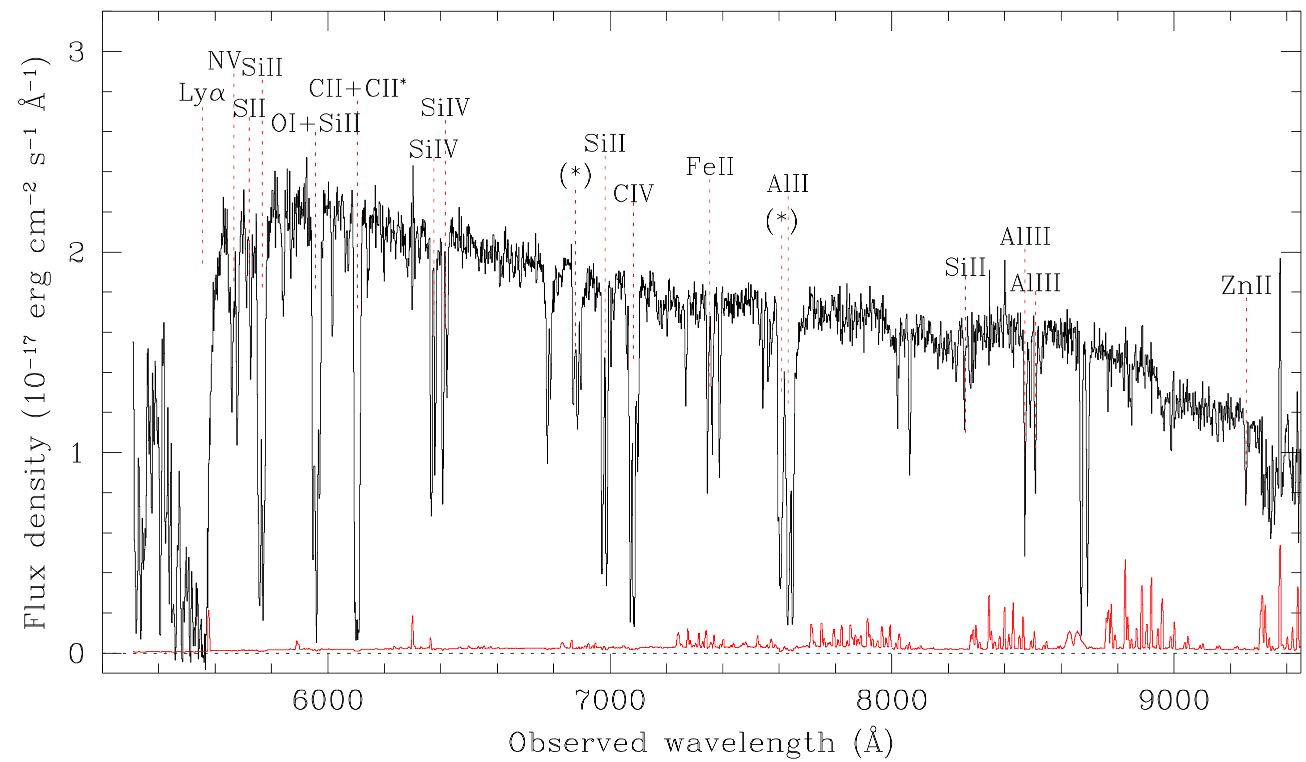
GRB09026A



Rau et al., A&A, 11

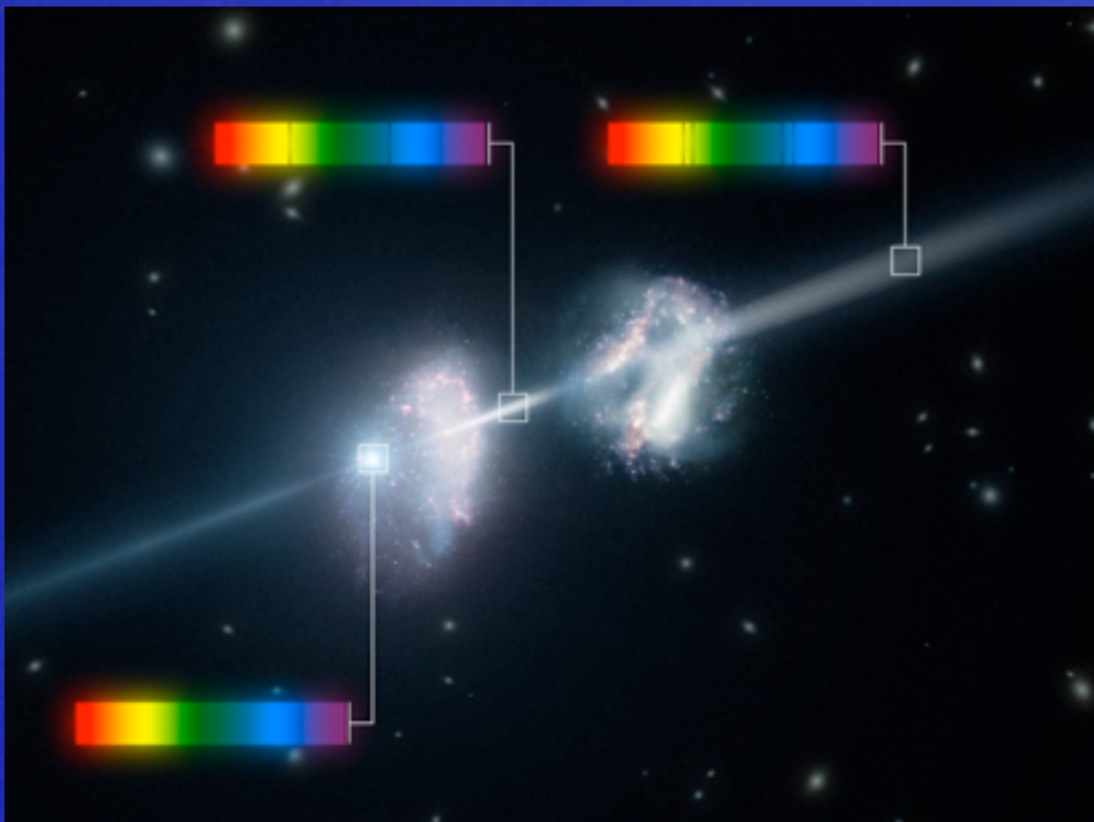
GRB090323

Super-Solar metallicity at z=3.57.
[Zn/H] =+0.29+/-0.10 and [S/H] = +0.67+/- 0.34
Star-formation rate ~ 6 M_{Sun}



Savaglio et al. 11

GRB090323



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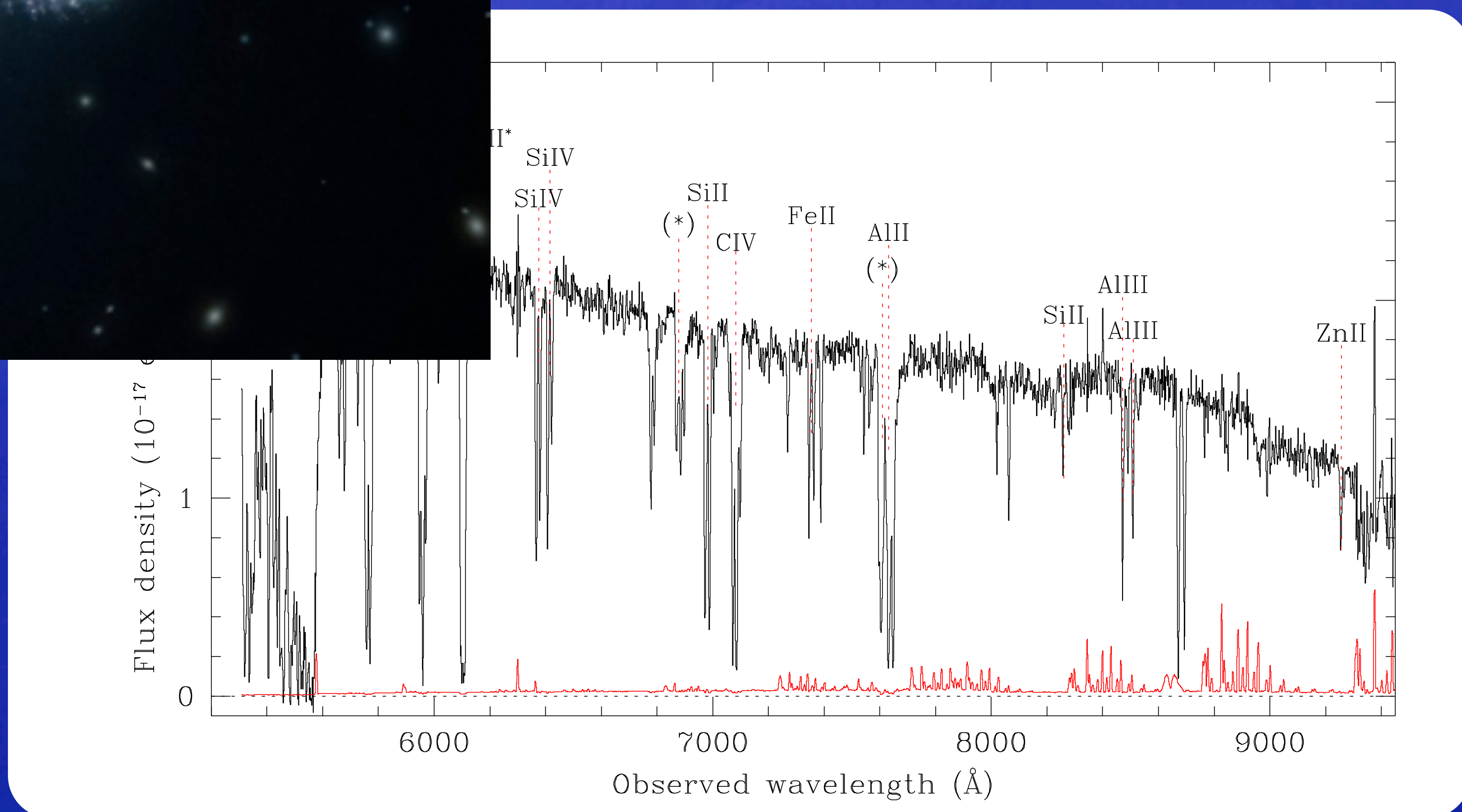


Savaglio et al. 11

Summary of Fermi Results

- Delayed on-set of the > 100 MeV emission
- Extra components, cut-off detected
- Long lived emission in GeV
- Afterglows yield distances, energetics, galaxies
- Estimate minimum Lorentz factor
- Lorentz Invariance Limits
- EBL constraints

Polarisation

- Excellent diagnostic tool for the emission process at low energies
- Progress limited by instrumentation
- Recent progress with GAP

Polarisation

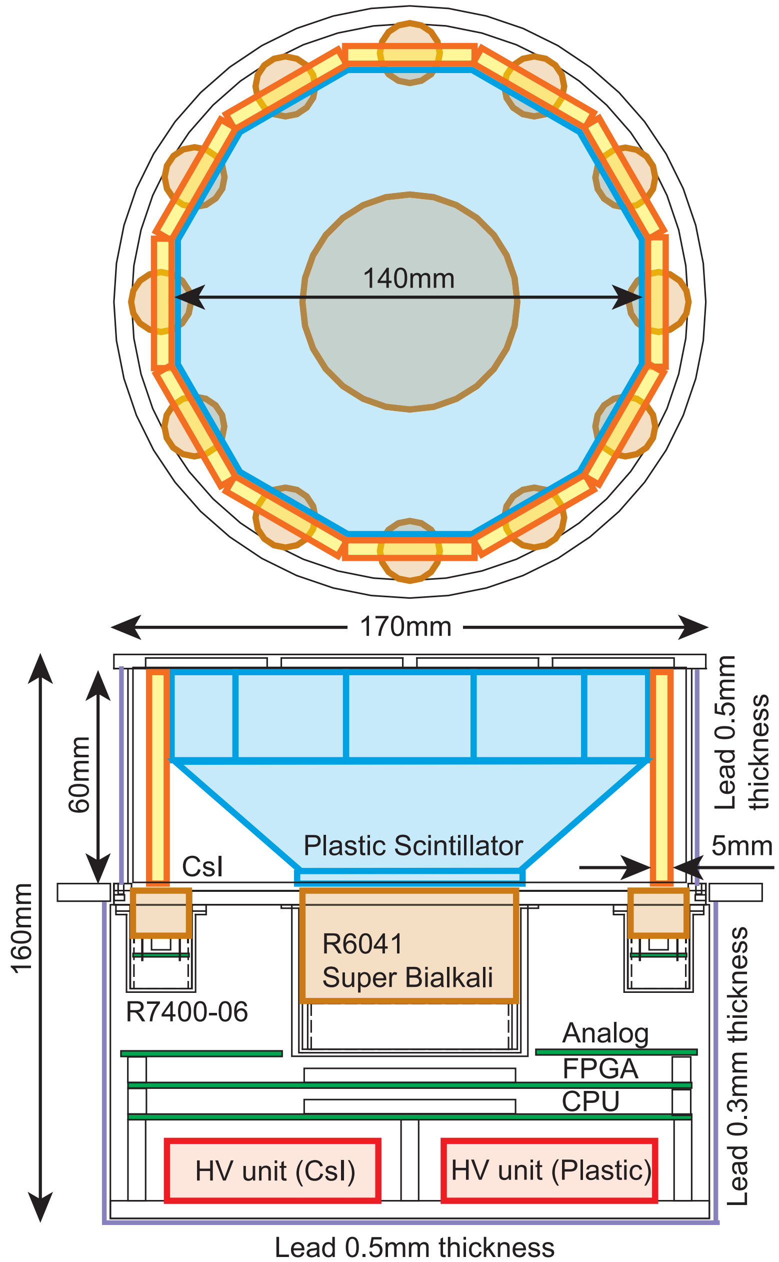
- Synchrotron Radiation from relativistic jet
- Expect high polarisation there is a large scale B-field ~ 40%
- Expect low value in absence of ordered field.
- Compton drag can get up to 80% near the jet edge
- Measurements/time resolved can give indications of the process.

Polarisation

- **RHESSI**: GRB021206 Π = 80 ± 20 % at > 5.7 σ (Coburn & Boggs, 2003). Not reproduced by Wigger + 2004, or Rutledge & Fox, 2004).
- **INTEGRAL/SPI**: GRB041219A Π = 93 ± 33 % (Kalemçi+ 2007) and Π = 66 ± 30 % (McGlynn+ 2007).
- **INTEGRAL/IBIS:** GRB041210A Time resolved analysis found varying Π and angle. (Goetz+ 2010)
- **IKAROS/GAP:** GRB 100826A Changing angle at 3.5 σ . Average level Π = 27 ± 11% at 3.5 σ (Yonetoku+2011)

GAP

- Gamma-Ray Burst Polarimeter (Yonetoku + 11).
- Solar sail demonstrator IKAROS (Kawaguchi+08, Mori +09) launched May 2010 by JAXA.
- Continue to 2 AU in 2 years.
- 50-300 keV



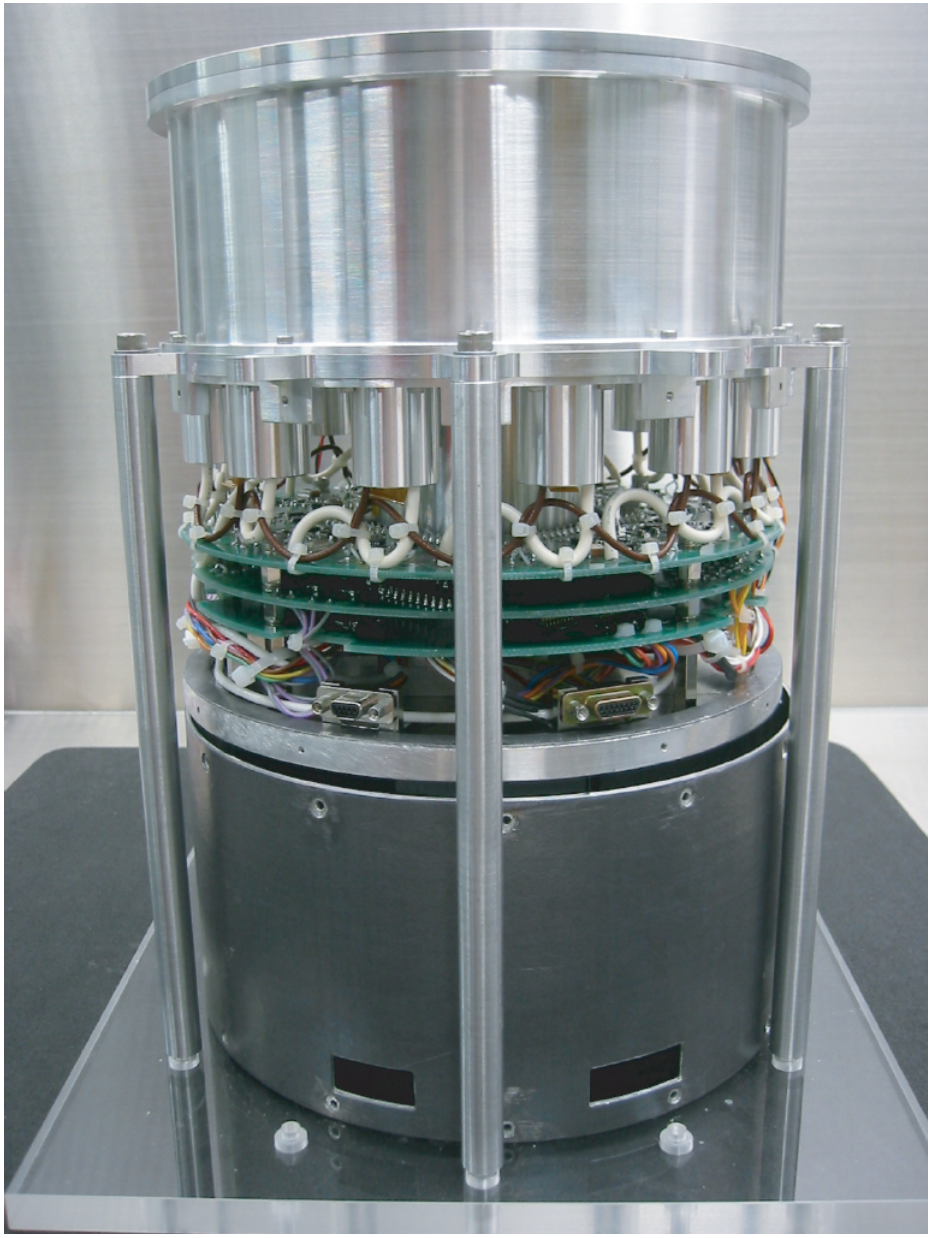
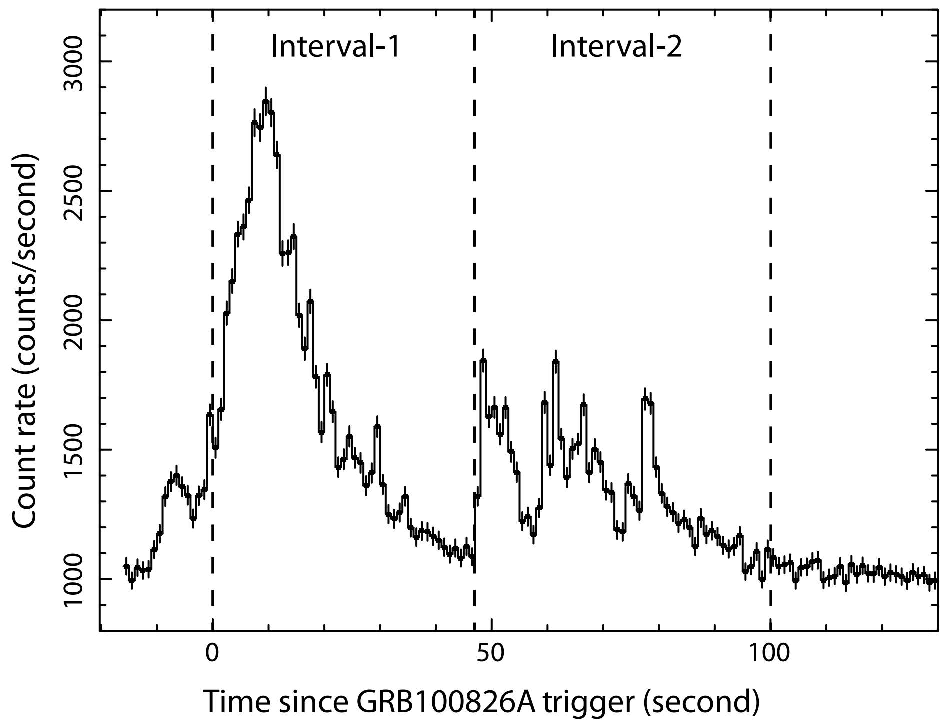
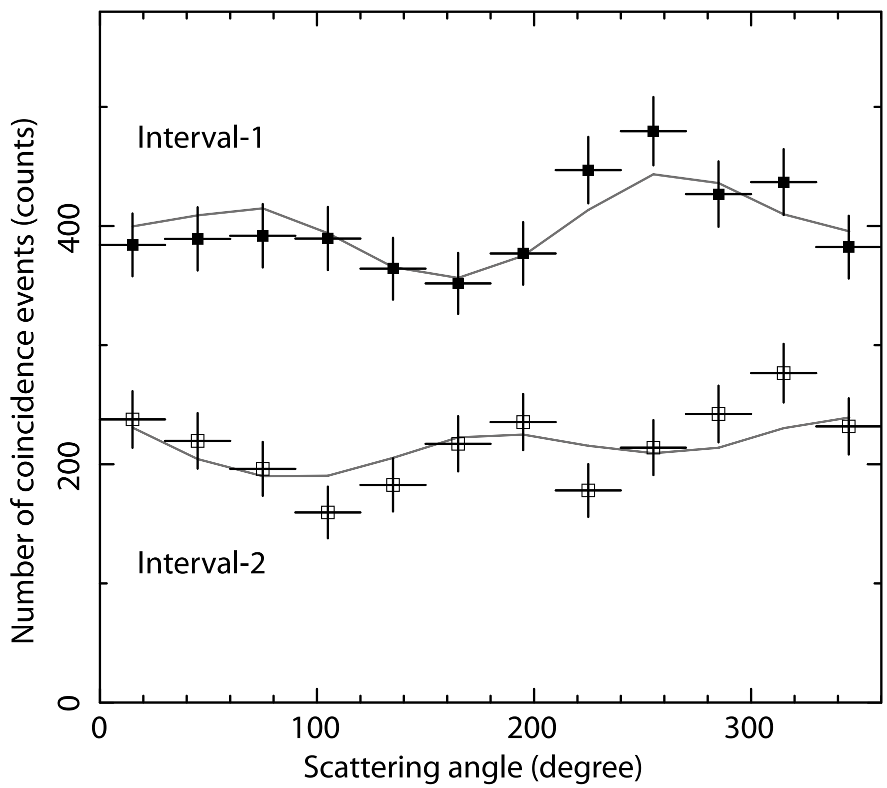


Fig. 3. Left: Schematic view of the GAP sensor. A large plastic scintillator with a super bialkali cathode of PMT (R6041) is attached at the center, and 12 CsI scintillators with small PMTs (R7400-06) are set around it. Right: The photo of GAP whose lead shield is opened.

(Yonetoku+2011)

GAP





- **IKAROS/GAP:** GRB 100826A Changing angle at 3.5 σ .
  Average level Π = 27 ± 11% at 3.5 σ
- (Yonetoku+2011)

Wednesday, December 7, 2011

Polarisation

- N_m/N_d : Number of measurements/Number of detections
- N_m/N_d > 30% & Π ~ 0.2 to 0.7 ->SO
- N_m/N_d < 15% & Π low -> SR/CD
- Several with Π > 0.8 -> CD

Toma+ 2009

Hardware Project

- ESA Strategic Initiative for Ireland
- 2 year project
- Develop 2 demonstration modules of LaBr3 + SiPMTs
- Test spectral and timing performance
- SensL & ACRA control

Thanks for your attention