GRB Observations and GLAST

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Outline
- Latest results on GRBs
- High energy emission from GRBs
- Capabilities of GLAST
Compton Observatory Era

Hurley et al. 1994

Extended/Delayed emission
Beppo-SAX & HETE-2 Era

GRB 970228 - BeppoSAX

⇒ GRBs in distant galaxies
⇒ Collimated outflows with $\Gamma > 100$
⇒ Energy $\sim 10^{51}$ ergs in $\gamma$-ray flash
⇒ Origin related to black hole birth

GRB 971214 - Keck
Swift - GLAST Era

Swift & GLAST likely will be simultaneously in orbit for >10 years

Follow-up:
- Swift XRT & UVOT
- 10's of dedicated telescopes
- 8 m telescopes with rapid response
- IR coverage
- HST, Chandra, XMM, Spitzer
- radio: VLA upgrade, ALMA coming
- neutrino detectors coming on-line
- grav. wave interferometers on-line

Prompt:
- hundreds of GRBs
- 10 keV - 100 GeV
- Versatile GRB triggers
- Accurate rapid positions
Classes of GRBs

Kouveliotou et al.

Short GRBs

Long GRBs

$T_{90}/(1+z)$ (s)

$E_{\text{iso}}$ (ergs)

SN GRBs

short GRBs

long GRBs
Long GRB Hosts

- Associated with SF galaxies
- Concentrated in regions of most massive stars
- Hosts are sub-luminous irregular galaxies
- Average redshift $z \sim 2.5$ (Swift)

Fruchter et al. 2006
Spectroscopy of Swift GRB 050505

Berger et al. 2005

$z = 4.275$

Damped Ly$\alpha$

$N(\text{HI}) = 10^{22} \text{ cm}^{-2}$

$n \sim 10^2 \text{ cm}^{-3}$

$Z = 0.06 \ Z_{\odot}$

$M_{\text{progenitor}} < 25 \ M_{\odot}$
Long GRB Summary

1) Massive star with core collapse to BH
2) Rotation required for jet escape
3) Low metallicity may be indicated
   - Tighter binding energy
   - Low winds to maintain rotation

Collapsar Jet Emergence

MacFadyen & Woosley
**Short GRBs**

- Associated with SF and non-SF galaxies
- Average redshift $\sim 0.7$
- Weaker X-ray afterglows than long GRBs (at $t_o+90s$)
  
  $<F_{\text{short}}>$ = $7\times10^{-10}$ erg cm$^{-2}$ s$^{-1}$
  
  $<F_{\text{long}}>$ = $3\times10^{-9}$ erg cm$^{-2}$ s$^{-1}$
1) Detections in non-SF galaxies ruled out hypernova model and support NS-NS merger model

2) Weak afterglow consistent with rarified medium around NS-NS merger

3) Lots of work remains to understand short burst population
Supernova GRBs

Four nearby \((z<0.1)\) GRBs have coincident SNe
- GRB 980425 - SN 1998bw \(z=0.0085\)
- GRB 030329 - SN 2003dh \(z=0.168\)
- GRB 031203 - SN 2003lw \(z=0.105\)
- GRB 060218 - SN 2006aj \(z=0.0331\)

Underluminous GRBs \((E \sim 10^{49} \text{ erg})\)
SN I b/c type of supernovae
GRB trigger provides SN early warning

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Rates ((1/\text{Gpc}^3\text{-yr}))</th>
<th>Comments</th>
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<tbody>
<tr>
<td>SN II</td>
<td>200,000</td>
<td></td>
</tr>
<tr>
<td>SN Ib/c</td>
<td>(~20,000)</td>
<td>(Guetta &amp; della Valle)</td>
</tr>
<tr>
<td>GRBs</td>
<td>(~100)</td>
<td>(1000 yr(^{-1}) to (z=4, \theta_b=5^\circ))</td>
</tr>
<tr>
<td>Underluminous GRBs</td>
<td>700</td>
<td>(Soderberg et al.)</td>
</tr>
<tr>
<td>Short GRBs no beaming</td>
<td>10</td>
<td>(250 yr(^{-1}) to (z=0.5, \theta_b=4\pi))</td>
</tr>
<tr>
<td>Short GRBs with beaming</td>
<td>300</td>
<td>(250 yr(^{-1}) to (z=0.5, \theta_b=15^\circ))</td>
</tr>
<tr>
<td>Short GRBs with logN-logS</td>
<td>100,000</td>
<td>(Nakar et al.)</td>
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High Energy Gamma Ray Emission

EGRET discovered >30 MeV emission from GRBs

Five GRBs found with spark chamber EGRET events in coincidence with a BATSE GRB
- GRB 910503
- GRB 910601
- GRB 930131 - Queen Beatrix GRB
- GRB 940217 - Hurley et al. extended emission
- GRB 940301

4 long GRBs
perhaps, 1 short GRB
Famous GRB 940217

\[
T_{90} = 150 \text{ s}
\]

\[
S = 1.2 \times 10^{-4} \text{ erg cm}^{-2}
\]

100 MeV \( \gamma \)'s for >1 hr

Hurley et al. 1994
Queen Beatrix GRB 930131

$T_{90} = 14$ s
(but short-hard main emission of $\sim 1$ s - short GRB?)

$S = 1.2 \times 10^{-5}$ erg cm$^{-2}$
100 MeV $\gamma$'s past main prompt phase
Late X-ray Flares

Late X-ray flares likely due to central engine activity on hour time scales
GRB941017 High Energy Component

BATSE + EGRET/TASC spectra show high-E component

Different time evolution

Opportunities for GLAST

Key Questions:

• What is the nature of the fireball explosion?
  - Observations of GRBs with prompt and extended high energy emission
  - Overall SED

• What is the origin of short GRBs?
  - Time profile of high energy emission
  - Variability of prompt and extended emission

• What can be learned about universe from GLAST (+Swift) GRB observations?
  - EBL studies with GRB spectra
  - Quantum gravity tests using photon dispersion (e.g., Scargle, Norris & Bonnell)

Requirements:

- Hundreds of GRBs
- GBM plus LAT observations of prompt emission
- Repointing to search for extended emission
- Swift and ground follow-up to measure afterglows and determine redshifts
GLAST Performance

~50 GRBs/yr with LAT
~200 GRBs/yr with GBM
15° (<5° on gnd) GBM
~arcmin-degree LAT

LAT - 27 μs deadtime
EGRET - 100 ms deadtime
Queen Beatrix GRB 930131

$T_{90} = 14 \text{ s}$
(but short-hard main emission of $\sim 1\text{ s}$ - short GRB?)

$S = 1.2 \times 10^{-5} \text{ erg cm}^{-2}$

100 MeV $\gamma$'s past main prompt phase
GLAST Repoint Capability

Repointing to keep GRB in LAT field of view as much as possible

Purpose is continued coverage of prompt emission and search for extended emission

For GRBs in LAT field of view
  - Repoint to keep GRB in LAT field ~ once per week
  - Will do this for every GRB trigger in early mission

For GRBs detected by GBM
  - Repoint for most interesting GRBs
  - Will do this few times per year
Two Wide-Field Instruments

Swift/BAT

FOV \sim 1.4\text{sr}

Mask

CZT

GLAST/LAT

FOV \sim 2\text{sr}

Tracker

Calorimeter
Swift - LAT Joint GRB Operations

**BAT - LAT Joint Pointing**

Assumes: Swift = 21° x 600 km & GLAST = 28° x 550 km (out of date)

**XRT/UVOT Follow-up**

- Rapid follow-up by Swift will give arc-sec locations and redshifts
- ~1 LAT GRB per month will fit in XRT FOV

25% of time BAT & LAT field of view overlap
GLAST MISSION ELEMENTS

- DELTA 7920H
- GPS
- TDRSS
- White Sands
- Mission Operations Center (MOC)
- GLAST Science Support Center
- LAT Instrument Science Operations Center
- GBM Instrument Operations Center
- HEASARC GSFC
- GRB Coordinates Network
- Telemetry 1 kbps
- Alerts Data, Command Loads Schedules

GLAST - Swift GRBs
Conclusion

New GRB capabilities of GLAST combined with Swift combine with ground-based facilities

⇒ A golden age of GRB research is upon us
Soft Gamma Ray Component

GRB 050709

Time (sec)

GRB 050911

Time (sec)

GRB 050724

Time (sec)

GRB 051227

Time (sec)
Norris & Bonnell (2006)

BATSE long GRBs with short-hard episode and long softer hump
Non-GRB Joint Science Opportunities

BAT & LAT both monitors sky daily for blazar flares
(15 blazars in BAT survey out to z=3)

Joint campaigns of active sources  opt + UV + X-ray + gamma-ray

XRT & UVOT searches of LAT unidentified sources

XRT & UVOT observations of LAT pulsars

LAT observations of galactic transients found by BAT

New sources found by LAT can be rapidly observed by Swift
(>200 Swift ToO's performed in 2 years)