An Overview of Current Gamma-Ray Burst Experiments

AGILE
Fermi
INTEGRAL
RHESSI
MESSENGER
Swift
Suzaku
Odyssey
Wind

Kevin Hurley
UC Berkeley Space Sciences Laboratory
khurley@ssl.berkeley.edu
A Golden Age of GRB Experiments?

9 missions (13 experiments) are now operating in space which have the capability to detect the prompt emission of GRBs.

They cover 8 decades in energy (3 keV – 300 GeV).

They have up to arcminute localization capability.

Some of them can localize GRBs almost in real time.

They are detecting over 400 bursts per year.
The Missions and Experiments

1. AGILE (Super-AGILE, Mini-Calorimeter, and Gamma-Ray Imaging Detector)
2. Fermi (Gamma Burst Monitor\(^1\) and Large Area Telescope)
3. INTEGRAL (Imager on Board the INTEGRAL Satellite - IBIS, SPI Anticoincidence System\(^1\))
4. RHESSI (Ge spectrometer)
5. Mars Odyssey (High Energy Neutron Spectrometer)
6. MESSENGER (Gamma-Ray and Neutron Spectrometer)
7. Suzaku (Hard X-Ray Detector Wide Area Monitor\(^1\))
8. Swift\(^2\) (Burst Alert Telescope\(^1\))
9. Wind (Konus\(^1\))
   \(^1\) Dedicated GRB experiment (5)
   \(^2\) Dedicated GRB mission (1)
10. IKAROS (GRB Polarimeter) May 22 launch
Overview: Energy Ranges

- 3 keV
- 300 GeV
## Overview: Independent Precise Localization Capabilities

<table>
<thead>
<tr>
<th>Mission/Experiment</th>
<th>Initial localization accuracy</th>
<th>Speed</th>
<th>Number of bursts/year</th>
<th>Field of view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swift/BAT</td>
<td>3′</td>
<td>Real-time</td>
<td>140</td>
<td>100°x60° (.15 sky)</td>
</tr>
<tr>
<td>INTEGRAL/IBIS</td>
<td>1.5′</td>
<td>Real-time</td>
<td>10</td>
<td>8.3°x8° (.0016 sky)</td>
</tr>
<tr>
<td>Fermi/LAT</td>
<td>10′</td>
<td>Real-time</td>
<td>10</td>
<td>90°x90° (.20 sky)</td>
</tr>
<tr>
<td>AGILE/SuperAGILE</td>
<td>3′</td>
<td>Hours</td>
<td>6</td>
<td>107°x68° (.18 sky)</td>
</tr>
</tbody>
</table>

These are the bursts for which almost all X-ray, optical, and radio counterpart searches take place today
The 9 spacecraft together form the interplanetary network (IPN)
# Overview: Other localization capabilities

<table>
<thead>
<tr>
<th>Mission/Experiment</th>
<th>Localization accuracy</th>
<th>Speed</th>
<th>Number of bursts/year</th>
<th>Field of view</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPN</td>
<td>3’ and above</td>
<td>Hours and more</td>
<td>325</td>
<td>Whole sky</td>
</tr>
<tr>
<td>Fermi/GBM</td>
<td>3º and above</td>
<td>Real-time</td>
<td>250</td>
<td>Whole unocculted sky</td>
</tr>
<tr>
<td>Wind/Konus</td>
<td>Ecliptic latitude band 10º wide</td>
<td>Day</td>
<td>250</td>
<td>Whole sky</td>
</tr>
</tbody>
</table>
Overlap between Swift, Fermi, and IPN Bursts

- Swift: 140/yr
- Fermi: 250/yr
- IPN: 325/yr

Numbers:
- 6
- 31
- 53
- 79
Overview: Sensitivities

• Sensitivity is a function of GRB duration, spectrum, peak flux, and fluence, and the instrument energy range, and time resolution, among other things.

• Using only the GRB fluence, in various energy ranges between \( \sim 15 \) and \( \sim 1000 \) keV:
  - Swift BAT \( 1.2 \times 10^{-8} \) erg cm\(^{-2}\)
  - Fermi – GBM \( 4.0 \times 10^{-8} \) erg cm\(^{-2}\)
  - INTEGRAL – IBIS \( 5.7 \times 10^{-8} \) erg cm\(^{-2}\)
  - AGILE – SuperAGILE \( 1.0 \times 10^{-7} \) erg cm\(^{-2}\)
  - IPN \( 5.0 \times 10^{-7} \) erg cm\(^{-2}\)
Overview: Redshifts Sampled by Various Missions

- Swift
- IPN
- Fermi
- INTEGRAL
- AGILE

Redshift, z
**Swift (Repetita Juvant)**

- **Burst Alert Telescope (BAT)**
  - 3' positions for GRBs in real-time
  - 15-150 keV

- **X-Ray Telescope (XRT)**
  - Arcsecond positions for GRB afterglows
  - .2 – 10 keV

- **UV/Optical Telescope (UVOT)**
  - Sub-arcsecond imaging for GRB afterglows
  - 22.3 mag sensitivity (1000 sec)
  - Finding chart for other observers

- **Autonomous re-pointing in ~ 1 minute**
**Swift**

- The Swift Burst Alert Telescope detects about as many GRBs which are outside its field of view as inside it (140/year); positions can’t be obtained for them onboard.

- These can often be localized by the Interplanetary Network.

- The spacecraft can then repoint to observe the afterglows of these bursts and obtain arcsecond positions for them.

- It can do the same for GRBs which are localized by Fermi, AGILE, and INTEGRAL, provided that the error box fits within the 24’ FoV of the XRT.
Fermi

- Large Area Telescope (LAT)
  - 20 MeV – 300 GeV
  - 90°x90° FoV
  - 10′ localization in real-time

- Gamma Burst Monitor (GBM)
  - NSSTC/MPE
  - 8 keV – 40 MeV
  - All the unocculted sky
  - 3° localization in real-time
Fermi

- Nominally points 45° from orbital plane zenith, in survey mode

- Autonomous repointing to GRB positions within ~5 minutes
  - Positions determined by the LAT, or
  - Positions determined by the GBM, outside the LAT FoV

- High energy GRB emission is often delayed
How They Work Together – Energy Spectra

GRB 100423A
How They Work Together – Energy Spectra

GRB 100423A
How They Work Together – Energy Spectra
GRB 100423A

[Diagram showing energy spectra with labels Konus, BAT, and Suzaku]
How They Work Together – Follow-up Observations

- Swift slews to BAT burst positions and follows up with X-ray and optical observations using the XRT and UVOT.

- It also slews to the positions of bursts observed and localized by AGILE, Fermi, INTEGRAL, and the IPN, and obtains arcsecond positions for them from their fading X-ray counterparts.

- This leads to ground-based observations, and measurements of redshifts.
How They Work Together - Localizations

• IPN localizations can be used to refine AGILE, Fermi, and occasionally INTEGRAL and Swift GRB positions
47 IPN/Fermi GBM localizations (there are more)
How They Work Together - Localizations

- IPN localizations can be used to refine AGILE, Fermi, and occasionally INTEGRAL and Swift GRB positions.

- Refined Fermi GBM/IPN localizations can be searched more efficiently by the Fermi LAT for evidence of high energy emission because their areas are smaller by orders of magnitude.
<table>
<thead>
<tr>
<th>If you’re interested in:</th>
<th>You should look at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Redshifts, host galaxies, IGM, source mechanisms</td>
<td>• Swift GRBs, or bursts followed up by Swift</td>
</tr>
<tr>
<td>• Broadband energy spectra</td>
<td>• Swift/Konus, Swift/Suzaku, Swift/RHESSI, Fermi GRBs</td>
</tr>
<tr>
<td>• VHE $\gamma$ radiation, Lorentz invariance, jet $\Gamma$ factor, EBL</td>
<td>• Fermi LAT, AGILE GRID GRBs</td>
</tr>
<tr>
<td>• Gravitational radiation, $\nu$, GRB/SN connection, ground-based VHE searches, your birthday burst</td>
<td>• IPN, Swift, Fermi GRBs</td>
</tr>
</tbody>
</table>
A New Approach: Polarimetry

- Polarization of GRB prompt emission has been reported in several cases
- The evidence for it is either controversial, or statistically at the limit
- None of the experiments was a dedicated polarimeter
- The GRB Polarimeter aboard IKAROS may resolve this issue
GRB Polarimeter aboard IKAROS

- IKAROS is a solar-sail spacecraft to Venus built by JAXA
- Launch was May 22
- The mission has a dedicated Compton-scatter GRB polarimeter built by T. Murakami and collaborators
- Over the 6 month mission lifetime, definitive polarization measurements of several GRBs are expected
Golden Ages Don’t Last Forever