Prompt optical observations of GRB 080319B


„π of the Sky”

Swift UVOT

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The night 2008.03.18/19

- Swift satellite as usually hunts for GRBs
- „Pi of the Sky” telescope routinely monitors Swift FoV with 10s exposures
- Image started 6:12:47 UT shows new object
- \( t_0 = 6:12:49 \) UT Swift receives the first \( \gamma \)-rays
- \( t_0 + 2 \) s – RAPTOR telescope takes image
- \( t_0 + 8 \) s – object became visible to TORTORA telescope which makes movie of the peak
- \( t_0 + 17 \) s – Swift sends out GCN alert
- \( t_0 + 51/68 \) s – REM & Swift UVOT telescope start imaging
- \( t_0 + 1 \) h – VLT, Gemini-N & Hobby-Eberly telescopes measured the distance \( z=0.937 \)
"Pi of the Sky" observation of GRB 080319B

Automaticaly detected by flash recognition algorithm
GRB 080319B prompt optical data

„white” data (400-700 nm) normalised to V
Spectral energy distribution of the prompt emission

Wind-Konus data

π of the Sky data

$t_0 - 2s$, $t_0 + 8s$
$t_0 + 12s$, $t_0 + 22s$
$t_0 + 27s$, $t_0 + 37s$
GRB 080319B – setting records

The brightest explosion ever observed
◆ 5.3 magnitudo at 7.5 Gy (z=0.937)
◆ 2.6·10^6 brighter than SN2005ap
◆ unprecedented X-ray flux

The best measured GRB
◆ Optical and γ limits before t₀
◆ Flux changed 10⁹ over 1 month
◆ Spectrum covered from radio to γ-rays (11 orders)

Optical measurements with highest temporal resolution
◆ Δt<1s for t₀+8–95s (TORTORA) ⇒ detailed study of correlation with γ emission
◆ Δt=10s for t≤t₀ – t₀+400s („π of the Sky”) ⇒ optical and γ emissions starts simultaneously ±5s
The brightest GRBs missed?

Observed very late:
- GRB 030329 >t₀+1.2h
- GRB 050603A >t₀+3.4h
Hunting for prompt optical emission

GRB 990123 and GRB 041219 triggered by precursors

GRB 080319B triggered by GRB 080319A

Who will trigger the next? And when?

New approach needed!
Observing prompt optical emission

No one knows where the next GRB will happen.

**Standard approach:**
- wait for GRB alert and move there quickly
  - robotic telescopes listening to GCN:
  - BOOTES, (SUPER)LOTIS, MASTERS, RAPTOR, REM, ROTSE, TAROT, ... 

**New approach proposed:**
- look everywhere, all the time
  - wide field of view ($\pi$ steradians ?)
  - self-triggering

$\Rightarrow$ „$\pi$ of the Sky“
π of the Sky

- Soltan Institute for Nuclear Studies, Warsaw
- Center for Theoretical Physics PAS, Warsaw
- Warsaw University, Warsaw University of Technology
- Space Research Center PAS, Warsaw

Special thanks to ASAS and LCO staff
π of the Sky

Concept:
• continuous ~all sky survey (32×3000 images / night)
• large data stream (1 Terabyte / night)
• real time analysis (multilevel trigger)

Project:
• 2×16 CCD cameras, each 2000×2000 pixels
• Canon lenses f=85mm, f/d=1.2
• field of view = 2 steradians = GLAST LAT > Swift BAT

Observing strategy:
• follows SWIFT or INTEGRAL or GLAST field of view
• detects independently optical flashes
• all sky survey twice a night (2×30min)
• follows targets of GCN alerts
„π of the Sky” – prototype

Las Campanas Observatory, Chile

In ASAS dome from 6.2004

OGLE
“π of the Sky” – prototype

- 2 CCD cameras 2000×2000 pixels
- Canon lenses f=85mm, d=f /1.2
- common field of view 20°×20°

- paralactic mount
  design by G.Pojmański / ASAS
- autonomic operation
- internet controlled
Flash recognition in real time

**multilevel trigger concept** *(a’la particle physics exp.)*

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**Graph Description**

- **Y-axis:** Number of objects after selection
- **X-axis:** Selection criteria

- **Categories:**
  - Total
  - Tn
  - Tv
  - MinPrev
  - Overlap
  - Black
  - Hot
  - Coinc
  - If_more
  - Track
  - Sat
  - Stars
  - Shape

- **Colors:**
  - Blue: Camera 1
  - Red: Camera 2

- **Legend:**
  - All pixels
  - Stars
  - Coincidence
  - Bad pixels
  - Cosmosics
  - Planes
  - Satellites

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**One night**

- Bar chart showing the number of objects after selection for different criteria and cameras.
Search for cosmic flashes

„π of the Sky” prototype at LCO from July 2004

- ~200 flashes seen by both cameras, in one frame only (could be satellites reflecting sunlight)
- 8 flashes seen in >1 frame (not confirmed/excluded by others)
- Several outbursts of flare stars detected

**CN Leo**

**EQ Peg**

![Graphs showing magnitude over time for CN Leo and EQ Peg]
Flare star GJ 3331A / GJ 3332

Outburst detected 2006.11.28 06:03 UT
"π of the Sky": GRB observations

89+212 GRB’s seen by satellites 7.2004-7.2005 & >6.2006:

5+24 – clouds (4+11) or apparatus off (1+13)
64+153 – daytime or below horizon
16+33 – outside field of view, 4+3 limits published:

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<thead>
<tr>
<th>GRB</th>
<th>Limit (m)</th>
<th>GCN</th>
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<tr>
<td>040916B</td>
<td>&gt;13.0</td>
<td>2725</td>
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<td>041217</td>
<td>&gt;11.5</td>
<td>2862</td>
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<td>050123</td>
<td>&gt;12.0</td>
<td>2970</td>
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<td>&gt;12.8</td>
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<td>061202</td>
<td>&gt;14.3</td>
<td>5891</td>
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2+2 – within FOV: limits before / during / after $t_0$

<table>
<thead>
<tr>
<th>GRB</th>
<th>Limit (m)</th>
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<td>040825A</td>
<td>&gt;10.0 / &gt;12.0 / &gt;9.5</td>
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<td>&gt;11.5 / &gt;11.0 / &gt;11.5</td>
</tr>
<tr>
<td>070521</td>
<td>&gt;12.2 / &gt;12.6 / &gt;12.5</td>
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**Final system**
Near completion – we are looking for suitable sites

Parralax measurement to reject close to Earth sources
π of the Sky