Polarimetric observations of GRB afterglows

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What is GRB?

Gamma-ray Burst; GRB

- Most energetic explosion in the universe (~ $10^{52}$ erg)
- Occurring at cosmological distance
- Gamma-ray arises in the form of relativistic jet. We observe it along the axis of the jet.
- Long GRB (> 2s) and short GRB (< 2s)
- A part of long GRBs associate with SNe Ic

http://www.batse.msfc.nasa.gov/batse/grb/duration/ (Hjorth+ 03)
A considerable fraction of GRBs show afterglows, in X-ray, optical, NIR, and radio wavelength.

GRBs are relativistic events. “jetbreak” ~1d after the burst.

http://spiff.rit.edu/classes/phys240/lectures/grb_pres/grb_pres.html
Synchrotron Radiation is most likely as prompt and afterglow reasons:
- consistent with non-thermal SED
- easy to explain γ-ray LC
Basic ideas of GRB polarization

- P.D. ~ max 70%
- no time variability

- local P.D. ~ max 70%
- P.D. become smaller with time
Important model 1

Random $B$-field in micro-scale + off-axis jet beaming effect

(Sari +99; Rossi +04; Granot +99 etc.)

From jet edge
- P.D. becomes zero at early time
- large P.D. amplitude

P.D. once becomes zero with jetbreak (at $\sim$ 1day?)
Important model 2

Group of independent patches having coherent $B$-field

(Gruzinov & Waxman +99)

Many coherent patches ($N \sim 50$)

$$P = \frac{70\%}{\sqrt{N}} \sim 10\%$$

not canceled out completely

Possible to produce complicated P.D.

Independent from jetbreak

→ high P.D. at early epoch?

Locally Polarized
Kanata telescope + HOWPol

Kanata telescope
- Located Higashi-Hiroshima
- Effective aperture 1.5 m
- Fair weather ratio ~50%
- Moving speed
  - Azimuth axis 5 degree / s
  - Altitude axis 2 degree / s
  - Extremely fast as 1m-class

HOWPol
(Hiroshima One-shot Wide-field Polarimeter)

Polarization obs. with one exposure

Tertiary mirror makes polarization
→ HA-depending model correction
  \((\sigma \sim 0.5\% )\)
**GRB auto-observation system**

- Auto observation system
- High moving speed

**Kanata telescope**

**HOWPol**

- Only one exposure

**Appropriate for GRB polarization observation**

Since 2009, ~60 GRB with auto-observation system

<table>
<thead>
<tr>
<th>ID</th>
<th>Time [s]</th>
<th>Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRB 091208B</td>
<td>149 ~ 1286</td>
<td>Uehara +12, ApJL</td>
</tr>
<tr>
<td>GRB 111228A</td>
<td>163 ~ 19000</td>
<td>Takaki+ in prep.</td>
</tr>
<tr>
<td>GRB 121011A</td>
<td>92 ~ 5241</td>
<td></td>
</tr>
<tr>
<td>GRB 130427A</td>
<td>10000 ~ 30000</td>
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</tr>
<tr>
<td>GRB 130505A</td>
<td>~10000</td>
<td></td>
</tr>
<tr>
<td>GRB 140629A</td>
<td>73 ~ 12000</td>
<td>Takaki+ in prep.</td>
</tr>
</tbody>
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GRB 091208B  \( z = 1.063, T_{90} = 14.9 \pm 3.7 \) s

- Standard Afterglow
- Forward shock emission
- High PD is inconsistent with model 1

See Uehara et al. 2012 for detail.
GRB 111228A

$z = 0.714$, $T_{90} = 101.2 \pm 5.4$ s

- PD evolution
  - $>20\%$ at $\sim 500$ s
  - $\sim0\%$ at $\sim 6000$ s
  - $>10\%$ at $\sim 15000$ s

- PA rotated 90d
  (across origin in QU-plane)

(Takaki+ in prep.)
GRB 111228A Discussion

- Prompt emission?
- Reverse shock?

Possible? Hard? to explain with model 1

- Zero-PD at very fast timing
  Most possible due to jetbreak
  Viewing angle? Jet surface size?
  Not standard optical LC shape → More complicated?

- X-ray shallow decay is just geometric effect?
GRB 121011A  \( z = \text{unknown}, \ T_{90} = 75.6 \pm 12.7 \text{ s} \)

- Started observation from very early (\( t = 92 \text{ s} \))
- Standard Afterglow
- Nearly zero PD (< 4%)

\[ R_C \text{ magnitude} \]
\[ P (\%) \]

Time since GRB (sec)
GRB 130427A & 130505A

GRB 130427A

\(z = 0.34, T_{90} = 162.8 \pm 1.4\) s

GRB 130505A

\(z = 2.27, T_{90} = 88 \pm 10\) s

Both GRBs are small PD at \(\sim 10^4\) s
GRB 140629A

- $z$ = unknown
- $T_{90} = 75.6 \pm 12.7$ s

- Multi-band LC
- Very standard AG
- Small PD

**Obtained with “OISTER”**

**Nearly zero-PD**

(Takaki+ in prep.)
GRB polarization: 1 event / yr
Still unclear, no uniformed picture
More observation samples, especially early phase.