Observations of the Extraordinarily Bright, Long, Nearby GRB 130427A

Judy Racusin
(NASA/GSFC)
On behalf of the Fermi-LAT and Fermi-GBM Collaborations
(especially Sylvia Zhu, Giacomo Vianello, Chuck Dermer, Jim Chiang, Nicola Omodei, Shaolin Xiong, Dan Kocevski)
Remarkable Features of GRB 130427A

- **Bright!** - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

**Prompt γ-ray emission detected by:**
- Fermi
- Swift
- Konus-Wind
- IPN
- RHESSI
- AGILE
- INTEGRAL
- MAXI

**Fermi-GBM**

Fine timescale (TTE) buffer filled-up + Photon pile-up

More on GBM Observations in Talk by Michael Burgess
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Only GBM fluence shown, but has also been compared to BATSE and other archives
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Autonomous repoint led to burst centered exposure
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Ackermann et al. 2013, Science
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Ackermann et al. 2013, Science
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (\(>100\) MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Ackermann et al. 2013, Science
Remarkable Features of GRB 130427A

• Bright! - Highest GRB fluence ever recorded
• LAT (>100 MeV) emission was extremely bright and long-lasting
• Relatively low redshift, but not subluminous
• Bright prompt optical flash and afterglow
• Long lived broadband radio – X-ray afterglow
• Most Luminous SN-GRB association – SN2013cq
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Not under-luminous like most nearby GRBs
Remarkable Features of GRB 130427A

• Bright! - Highest GRB fluence ever recorded
• LAT (>100 MeV) emission was extremely bright and long-lasting
• Relatively low redshift, but not subluminous
• Bright prompt optical flash and afterglow
• Long lived broadband radio – X-ray afterglow
• Most Luminous SN-GRB association – SN2013cq

Vestrand et al. 2013, Science

7th magnitude optical flash (2nd brightest ever recorded)
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Perley et al. 2014
Remarkable Features of GRB 130427A

- **Bright! - Highest GRB fluence ever recorded**
- **LAT (>100 MeV) emission was extremely bright and long-lasting**
- **Relatively low redshift, but not subluminous**
- **Bright prompt optical flash and afterglow**
- **Long lived broadband radio – X-ray afterglow**
- **Most Luminous SN-GRB association – SN2013cq**

Follow-up observations by many ground- and space-based observatories including Swift-UVOT, RAPTOR, Liverpool Telescope, P60, RATIR, Gemini-N, Faulkes-N, MITSuME, HST, Chandra, NuSTAR, VLA, CARMA…
Remarkable Features of GRB 130427A

- Bright! - Highest GRB fluence ever recorded
- LAT (>100 MeV) emission was extremely bright and long-lasting
- Relatively low redshift, but not subluminous
- Bright prompt optical flash and afterglow
- Long lived broadband radio – X-ray afterglow
- Most Luminous SN-GRB association – SN2013cq

Perley et al. 2014

Similarity between SNe associated with most and least luminous GRBs suggests similar progenitor star

Levan et al. 2014
The Nearby Ordinary Monster

- Nearby
  - But not subluminous
  - Similar to cosmological cousins
- Once in a decade (or more) sort of event
• Similar afterglow power-law decay slopes from Optical-X-ray-GeV
• Same component?
  – Additional inverse Compton component (Fan et al. 2013, Liu et al. 2013)
Spectral Evolution

Broadband Modeling
- Wind-like environment, or somewhere between constant density ISM and Wind
- Appears to be a single component

- First late-time hard X-ray (3-80 keV) afterglow ever observed
- Single smoothly broken power law from optical - GeV

Perley et al. 2014

Kouveliotou et al. 2013
GRB 130427A Challenges
Synchrotron Shock Physics?

- The high-energy LAT-detected photons violate maximum synchrotron energy for even the most extreme models

-Requires modifications to standard Synchrotron shock physics or alternative model (Non-uniform magnetic field, Diffusive shock acceleration, magnetic reconnection, Electromagnetic cascades)

-See poster #9.08 by Jeremy Perkins on limits set by VERITAS TeV observations of GRB 130427A

\[ t_{\text{acc}} \sim \frac{t_{\text{Larmor}}}{2\pi} \]

\[ t_{\text{acc}} \sim t_{\text{Larmor}} \]

<table>
<thead>
<tr>
<th>Model</th>
<th>( \Gamma_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind, adiabatic</td>
<td>2000</td>
</tr>
<tr>
<td>Wind, adiabatic</td>
<td>1000</td>
</tr>
<tr>
<td>Wind, adiabatic</td>
<td>500</td>
</tr>
<tr>
<td>ISM, adiabatic</td>
<td>1000</td>
</tr>
<tr>
<td>ISM, radiative</td>
<td>1000</td>
</tr>
</tbody>
</table>

\[ E [\text{GeV}] \]

\[ \text{Time Since Trigger [sec]} \]
Conclusions

- GRB 130427A was a rare and well-observed event that is teaching us about GRB emission mechanisms and shock physics.
- Pass 8 adds ~30% more photons (source class), including several new high energy photons with $E > 10$ GeV.
- Future TeV observations could help solve the Synchrotron puzzle:
  - HAWC has limits on GRB 130427A (Abeysekara et al., arXiv: 1410:1536), but will be more constraining with the full array.
- Current array of observatories (ground and space-based) are ideal for studying these rare and bright objects.