To Synchrotron or Not to Synchrotron

The First Pulse of GRB 130427A

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on behalf of the Fermi GBM team
**GRB 130427A**

**Context:**
Fluence: \((2.4 \pm 0.1) \times 10^{-3}\) erg cm\(^{-2}\)
Duration: \(\sim 35\) s
Most fluent GRB ever detected

First Pulse: \(\sim 2.5\) s
Brighter than most GRBs!

**many synchrotron**

**so saturation**

**wow**

**very fluence**
Time-Resolved Spectral Analysis

Two-component spectrum: Synchrotron + blackbody

Band function is able to fit the spectrum, but does not call for a significant blackbody.


Synchrotron $E_p$ follows a broken power law in time.

Preece & Burgess et al (2014)
Time-Resolved Spectral Analysis

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J. Michael Burgess : Fifth Fermi Symposium : Nagoya Japan 2014
Slow cooling synchrotron??
Slow cooling

\[ \gamma_{\text{min}} \ll \gamma_{\text{cool}} \]

\[ \alpha \simeq -2/3 \]
Slow cooling

\[ \gamma_{\text{min}} \ll \gamma_{\text{cool}} \]

\[ \alpha \approx -2/3 \]

Marginally fast cooling

\[ \gamma_{\text{min}} \simeq \gamma_{\text{cool}} \]

see Beniamini & Piran (2013)

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Slow cooling

$\gamma_{\text{min}} \ll \gamma_{\text{cool}}$

$\alpha \simeq -2/3$

Marginally fast cooling

$\gamma_{\text{min}} \approx \gamma_{\text{cool}}$

see Beniamini & Piran (2013)

Fast cooling

$\gamma_{\text{cool}} \ll \gamma_{\text{min}}$

$\alpha \simeq -3/2$
Slow cooling and marginally fast cooling are indistinguishable via their photon spectra…

However, the one must explain either scenario in a self-consistent manner.
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see Beniamini & Piran (2013)
### Time-Resolved Spectral Analysis

<table>
<thead>
<tr>
<th>GRB</th>
<th>Peak$_{\text{syn}}$</th>
<th>Peak$_{\text{bb}}$</th>
<th>$E_p$ brk [s]</th>
<th>$kT$ brk [s]</th>
<th>$kT$ indx$_1$</th>
<th>$kT$ indx$_2$</th>
<th>$E_p$ indx$_1$</th>
<th>$E_p$ indx$_2$</th>
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<tbody>
<tr>
<td>081224A</td>
<td>1.40</td>
<td>0.59</td>
<td>1.59</td>
<td>2.51</td>
<td>-0.21</td>
<td>-1.38</td>
<td>-0.21</td>
<td>-1.05</td>
</tr>
<tr>
<td>090719A</td>
<td>5.04</td>
<td>5.04</td>
<td>4.74</td>
<td>7.36</td>
<td>-0.07</td>
<td>-2.02</td>
<td>0.41</td>
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<td>110920A</td>
<td>11.65</td>
<td>5.9</td>
<td>15.53</td>
<td>45.30</td>
<td>-0.14</td>
<td>-1.13</td>
<td>-0.01</td>
<td>-1.35</td>
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<tr>
<td>110721A</td>
<td>0.28</td>
<td>2.03</td>
<td>0.54</td>
<td>1.85</td>
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<td>-0.26</td>
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<tr>
<td>130427A</td>
<td>0.45</td>
<td>0.15</td>
<td>0.36</td>
<td>0.22</td>
<td>-0.67</td>
<td>-1.15</td>
<td>-0.49</td>
<td>-1.18</td>
</tr>
</tbody>
</table>

**Graphs and Data:**

- **Graph 1:** $E_p$ vs. Time (sec), data points and trend line for 081224A.
- **Graph 2:** $E_p$ vs. Time (sec), data points and trend line for 090719A.
- **Graph 3:** $E_p$ vs. Time (sec), data points and trend line for 110920A.
- **Graph 4:** $E_p$ vs. Time (sec), data points and trend line for 110721A.
- **Graph 5:** $E_p$ vs. Time (sec), data points and trend line for 130427A.

**Remarks:**

- Preliminary data and analysis.
Time-Resolved Spectral Analysis

Blackbody kT and synchrotron $E_p$ are correlated. Consistent with a larger sample of GRBs (see talk by Peter Veres)

Burgess et al. 2014b

Lots of common behavior in resolved, single pulses!
L-E_p Correlation
L-E_p Correlation

$L \propto E_p^{1.4}$

Rise phase
L-E\textsubscript{p} Correlation

\begin{align*}
E_p &\propto \Gamma B \gamma_{\text{min}}^2 \\
L &\propto \Gamma^2 B^2 \gamma_{\text{min}}^2
\end{align*}

BR\textsuperscript{2} \propto \text{constant} \Rightarrow B \propto R^{-2}

\gamma_{\text{min}} \propto R^{-1}

\begin{align*}
E_p &\propto \Gamma R^{-4} \\
L &\propto \Gamma^2 R^{-6}
\end{align*}

L_{\text{synch}} \propto E_{p}^{3/2}

Burgess et al 2014a
Outflow Parameters

Using the blackbody $kT$ and flux, outflow parameters are calculated.

A decreasing bulk Lorentz factor with time!

via Pe'er et al (2007)
Pulse width and lag analysis consistent with predictions of Daigne & Machkovitch (1998)

Indicative of synchrotron from internal shocks.

Cross correlation of LAT LLE and GBM detectors
Pulse Width Evolution

Cross correlation of LAT LLE and GBM detectors

Indicative of synchrotron from internal shocks.

Consistent with predictions of Daigne & Machkovitch (1998)

and lag analysis.
Puzzles...
Puzzles...
Puzzles...

Summary:

- Two-component spectrum:
  - Consistent with synchrotron+blackbody
  - Best solution?
- Spectral evolution could imply flux-freezing
- Pulse width evolution matches well with simulations of Daigne & Mochkovitch (1998)
- Explaining spectrum, pulse width, and L-Ep curve simultaneously is very difficult!
Puzzles...

However:

- These simple synchrotron models seem to work for some pulses (Burgess et al. 2014), now we can test sub-photospheric dissipation models (see poster of Björn [9.01])
- Recent findings indicate that synchrotron + blackbody cannot explain over the half the detected GRBs (see my poster [9.03] and talk by Magnus Axelsson)
- Band (or Band+blackbody) fits to spectra should be interpreted with **caution**!