"GRB 090510: a S-GRB from a binary neutron star coalescing into a Kerr black hole"

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On behalf of a large collaboration

The S-GRBs in the $E_{p,i}$-$E_{iso}$ plane [1–5]

The fireshell model [6–8] and the S-GRBs [9]

– An optically thick $e^\pm$ plasma with energy $E_{\text{tot}}^{\pm}$ is formed in the merger of two neutron stars (NS) leading to the birth of a black hole (BH).

– The expanding $e^\pm$ fireshell engulfs the baryons left over in the collapse to BH, described by the baryon load $B=M_{\text{bc}}^2/E_{\text{tot}}^{\pm}$ and thermalizes with the baryons.

– The fireshell self-accelerates to ultra-relativistic velocities up to the transparency and the Proper-GRB (P-GRB), characterized by a thermal spectrum, is emitted.

– The optically thin shell of baryons collides with a Circum Burst Medium (CBM) of density $n_{\text{CBM}}$, giving rise to the prompt emission. The CBM is modeled by the filling factor, which takes into account filamentary structures of the medium, $R=A_{\text{eff}}/A_{\text{vis}}$.

S-GRB space-time diagram [10]

Some canonical examples of S-GRBs

S-GRB 090227B

S-GRB 140619B

S-GRB 140402A
Aimuratov, Y., et al. in preparation

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An unusual(?) example of S-GRBs

S-GRB 090510

An unusual(?) example of S-GRBs

S-GRB 090510

The P-GRB, occurring before the on-set of the GeV emission does not exhibit the typical thermal spectral component...

...WHY?
A spinning BH for the S-GRB 090510?

The dyadosphere for a Reissner-Nordström BH
A spinning BH for the S-GRB 090510?

The dyadotorus for a Kerr(-Newman) BH
The $\gamma$-ray emission in the fireshell model [12]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>$B$</td>
<td>$(5.54 \pm 0.70) \times 10^{-5}$</td>
</tr>
<tr>
<td>$\gamma_{tr}$</td>
<td>$(1.04 \pm 0.07) \times 10^4$</td>
</tr>
<tr>
<td>$r_{tr}$</td>
<td>$(7.60 \pm 0.50) \times 10^{12}$ cm</td>
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<tr>
<td>$E_{e^+e^-}^{\text{tot}}$</td>
<td>$(3.95 \pm 0.21) \times 10^{52}$ erg</td>
</tr>
<tr>
<td>$kT_{\text{blue}}$</td>
<td>$(1.20 \pm 0.11) \times 10^3$ keV</td>
</tr>
<tr>
<td>$\langle n \rangle$</td>
<td>$(8.7 \pm 2.1) \times 10^{-6}$ cm$^{-3}$</td>
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Not a binary-driven hypernova (BdHN) [12]

Not a binary-driven hypernova (BdHN)

A bunch of BdHNe [5,13]

What do S-GRBs have in common that could give origin to the GeV emission (when LAT data are available), while S-GRFs do not?

An already formed BH!!

The origin of the LAT emission


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<table>
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<tr>
<th>GRB</th>
<th>$z$</th>
<th>$E_{p,i}$ (MeV)</th>
<th>$E_{iso}$ ($10^{52}$ erg)</th>
<th>$E_{LAT}$ ($10^{52}$ erg)</th>
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BdHN 130427A
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The accretion can explain in a simple way the GeV emission energy reservoir [12]

$$E_{LAT} = f_{b}^{-1} \eta_{\pm} M_{acc} c^2$$

where $f_{b} \equiv 1 - \cos \theta$ and $\eta_{+} = 42.3\%$ or $\eta_{-} = 3.8\%$ for a Kerr BH [13].

Two cases can be studied, e.g., for the case of the S-GRB 090510:

1) Isotropic emission $f_{b} \equiv 1 \implies M_{acc} \gtrsim 0.08 \, M_{\odot}$ for the co-rotating case

$\implies M_{acc} \gtrsim 0.86 \, M_{\odot}$ for the counter-rotating case

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Two cases can be studied, e.g., for the case of the S-GRB 090510:

2) Accretion from a 1.6+1.6 M$_\odot$ NS–NS merger crustal mass. In the NL3 nuclear model each globally neutral NS has a crustal mass of $M_c = 4.30 \times 10^{-5}$ M$_\odot$ [14] and part of it goes into the baryon load, $M_B \equiv E_{e^+ e^-}^{tot} B / c^2 = 1.22 \times 10^{-6}$ M$_\odot$. So, the total available mass for accretion is $M_{acc} \equiv 2M_c - M_B = 8.48 \times 10^{-5}$ M$_\odot$.

Thus a beaming is necessary $\Rightarrow \theta \gtrsim 2^\circ .70$ for the co-rotating case

$\Rightarrow \theta \gtrsim 0^\circ .81$ for the counter-rotating case

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Two cases can be studied, e.g., for the case of the S-GRB 090510:

2) Thus a beaming is necessary $\Rightarrow \theta \gtrsim 2^\circ.70$ for the co-rotating case $\Rightarrow \theta \gtrsim 0^\circ.81$ for the counter-rotating case

These beaming angles are larger than the relativistic beaming angle $\theta_r = \gamma_{LAT}^{-1} \approx 0^\circ.1$, where the lower limit on the Lorentz factor $\gamma_{LAT} \approx 550$ has been derived by applying the pair production optical depth formula [15] to the GeV luminosity light curve.

Conclusions

⇒ The $E_p$ and $E_{iso}$ values of GRB 090510 fulfill the MuRuWaZha relation.

⇒ The P-GRB spectrum of GRB 090510 is best-fitted by a Comptonized model and it is interpreted as a convolution of thermal spectra originating in a dyadotorus.

⇒ The prompt emission occurs after the P-GRB. The analysis within the fireshell model leads to an average value of the CBM density of $8.7 \times 10^{-6}$ cm$^{-3}$, typical of galactic halos where NS binaries are expected to migrate due to large natal kicks.

⇒ The GeV emission occurs after the P-GRB emission, in both S-GRBs and BdHNe, and originates from a Kerr(-Newman) BH dominated by its angular momentum, i.e., a Kerr BH, approximately. The energy of the GeV emission in GRB 090510 can be explained by matter accretion on co-rotating and counter-rotating orbits around an extreme Kerr BH. If the accretion involves the crustal mass from a $1.6+1.6$ M$_\odot$ NS–NS binary, fulfilling global charge neutrality, geometrical beaming angles of $0^\circ.81$, for co-rotating case, and $2^\circ.7$, for the counter-rotating case, are necessary. These angles are larger than the relativistic beaming from the initial Lorentz factor of the jetted material, $\gamma \approx 550$.

⇒ When GeV emission can be jetted, no beaming appears to be present both in the P-GRB and in the prompt emission.

⇒ The late X-ray emission of GRB 090510 does not follow the characteristic patterns expected in BdHN events.
Thank you