Supernova prediction and multi-wavelength observation of GRB 130427A

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• Induced Gravitational Collapse (IGC) Model

• Four episodes and examples

• GRB 130427A in the first 3 episodes

• Prediction of supernova (4th episode)
Episode 1: Initial Massive Star - Neutron Star

Induced Gravitational Collapse (IGC) Gamma-ray Burst

Massive Star

NS
Emission from the onset of a Supernova (SN), in a close binary system with a companion neutron star (NS). The initial SN expansion, at non-relativistic velocities, induces a strong matter accretion onto the NS, which reaches the critical mass and then collapses to a black hole.
The ejecta density:

\[ \rho_{ej} = \frac{3M_{ej}}{4\pi\sigma^3 t^3 n} \]

\( \sigma \) and \( n \) are constants

Accretion rate:

\[ \dot{M} = \frac{\pi \zeta \rho_{ej} (2GM_{NS})^2}{(v_{ej}^2 + v_{orb}^2)^{3/2}} \]

\( (\frac{1}{2} \leq \zeta \leq 1) \)

Episode 1: Expansion

Induced Gravitational Collapse (IGC) Gamma-ray Burst

Ref: Izzo et al 2012
Episode 2: GRB sweeps ISM

*Induced Gravitational Collapse (IGC) Gamma-ray Burst*

The accelerated baryonic matter and electron-positron pairs, ballistically expands and then collides at ultra-relativistic velocities with the ISM and filaments, giving origin to the GRB.
Vacuum polarization process occurs in an already formed Riessner-Nordstrom black hole. The pairs plasma expands away from the dyadosphere.

The accelerated baryonic matter and electron-positron pairs, ballistically expands and collides at ultra-relativistic velocities with the ISM and filaments, giving origin to the GRB.
Episode 2: Simulation of GRB

Induced Gravitational Collapse (IGC) Gamma-ray Burst

Episode 3, in soft X-rays, occurs when the prompt emission from the GRB fades away and an additional component emerges, different mechanism from prompt emission.
GRB 130427A : Episode 3 : Overlapping

Supernova Prediction

![Graph showing luminosity decay over time for different GRBs]
GRB 130427A : Episode 3 : Same Slope

Supernova Prediction

GRB 130427A MULTIWAVELENGTH OBSERVATIONS

Luminosity of GRB 130247A

<table>
<thead>
<tr>
<th>Energy (KeV)</th>
<th>Count Rate (counts s$^{-1}$ cm$^{-2}$)</th>
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<tbody>
<tr>
<td>10$^{-9}$</td>
<td></td>
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<tr>
<td>10$^{-7}$</td>
<td></td>
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<tr>
<td>10$^{-5}$</td>
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<tr>
<td>10$^{-3}$</td>
<td></td>
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<tr>
<td>10$^{-1}$</td>
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GRB 130427A (461s - 750s) - 378 counts/s
(196s - 461s after GBM trigger)
The late x-ray observations of GRB 130427A by Swift-XRT clearly evidence a pattern typical of a family of GRBs associated to supernova (SN) following the Induce Gravitational Collapse (IGC) paradigm (Rueda & Ruffini 2012; Pisani et al. 2013). We assume that the luminosity of the possible SN associated to GRB 130427A would be the one of 1998bw, as found in the IGC sample described in Pisani et al. 2013. Assuming the intergalactic absorption in the I-band (which corresponds to the R-band rest-frame) and the intrinsic one, assuming a Milky Way type for the host galaxy, we obtain a magnitude expected for the peak of the SN of $I = 22 - 23$ occurring 13-15 days after the GRB trigger, namely between the 10th and the 12th of May 2013.

Further optical and radio observations are encouraged.
Episode 4: SN appears in optical observation

Induced Gravitational Collapse Gamma-ray Burst

Ejecta
Optical luminosity of supernova due to nuclear decay of the ejecta:

\[
L(t) = M_{\text{Ni}} e^{-\left(\frac{t}{\tau_m}\right)^2} \left( (\epsilon_{\text{Ni}} - \epsilon_{\text{Co}}) \left( \int_0^{\frac{t}{\tau_m}} A(z) \, dz \right) + \epsilon_{\text{Co}} \left( \int_0^{\frac{t}{\tau_m}} B(z) \, dz \right) \right)
\]

\[
A(z) = 2ze^{z^2 - \frac{z\tau_m}{\tau_{Ni}}} \quad B(z) = 2ze^{z\left(z - \frac{\tau_m}{\tau_{Co}}\right)} \quad \tau_m = \sqrt{\frac{\kappa}{\beta c}} \sqrt{\frac{M_{\text{ej}}}{\lambda v_{\text{ph}}}}
\]

GRB 130427 / SN 2013cq

\[M_{\text{ejecta}} \sim 6 \text{ solar masses} \quad E_k \sim 6 \times 10^{52} \text{erg}\]

1) We have found that the features of this GRB comply to our IGC golden sample. In our GCN on 2nd May 2013 we predicted a SN to occur in about 13 days, confirmed by GTC, VLT and HST, starting from 13th May 2013.

2) GRB 130427A is the second most luminous GRB ever observed, of which energy exceeds 1054 erg, one of the few GRBs with optical, X-ray and GeV spectra for hundreds of seconds.

3) Our data analysis from the Swift and Fermi satellites indicates the same decay index in the optical, X-ray (0.3 keV – 10 keV) and in high energy (100 MeV – 100 GeV) light curves with a common power-law spectrum. In agreement with the papers published in Science Express on 21st Nov 2013 and in ApJ Letters on 10th Dec 2013.

Thank You