

**XII INTERNATIONAL CONFERENCE ON GRAVITATION, ASTROPHYSICS AND
COSMOLOGY/ 15th ITALIAN-KOREAN SYMPOSIUM ON RELATIVISTIC
ASTROPHYSICS**

**A JOINT MEETING
EWA WOMANS UNIVERSITY
JULY 3-7, 2017, SEOUL, KOREA**

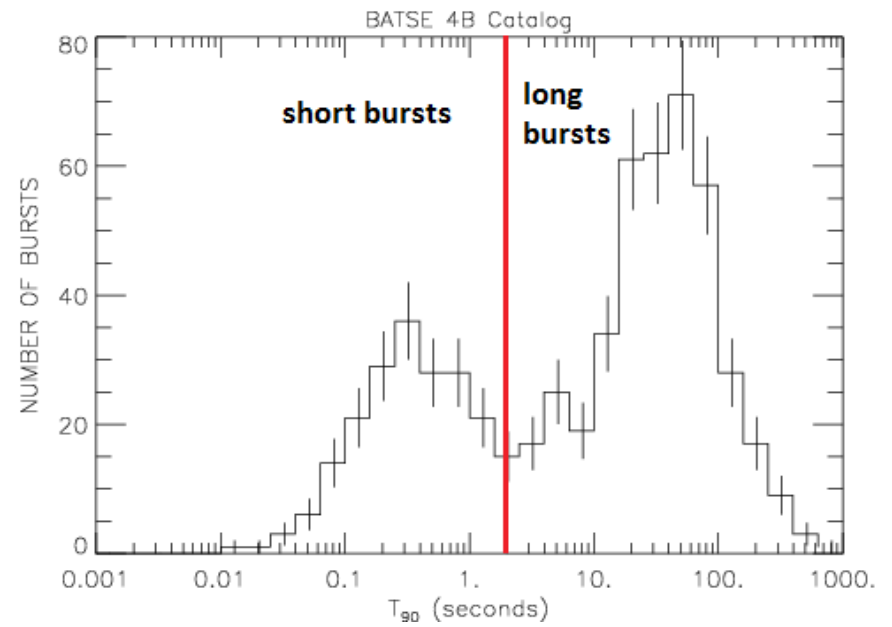
**GRB 110731A
within the IGC paradigm**

**Daria Primorac
University of Rome “Sapienza” & ICRA Net, Italy**

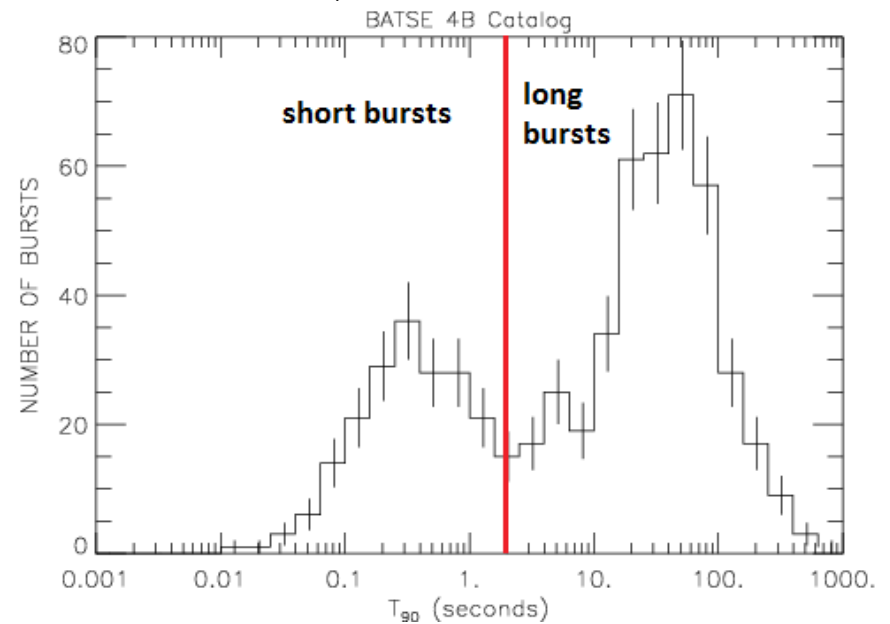
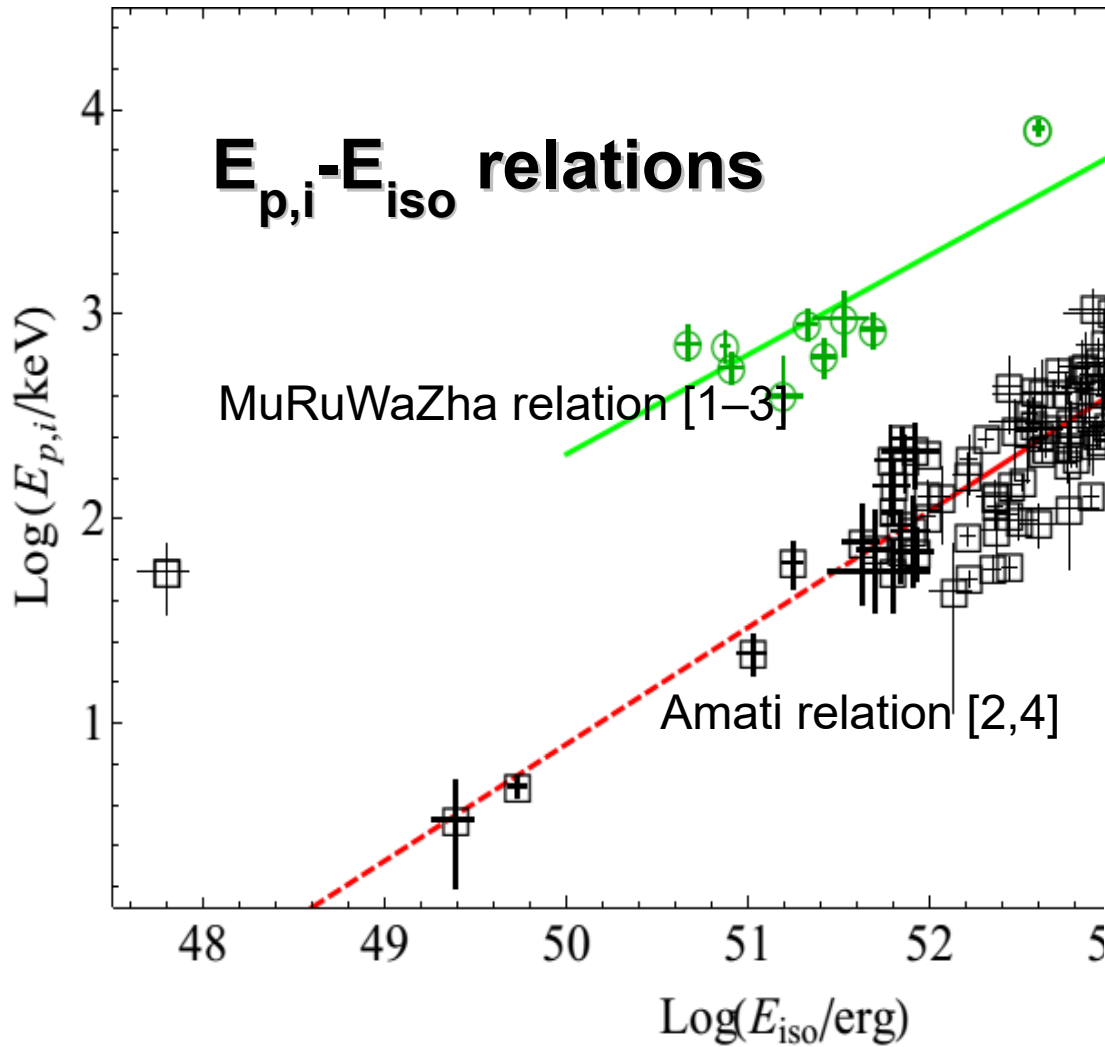
On behalf of a large collaboration

R. Ruffini, Y. Aimuratov, L.M. Becerra, C.L. Bianco, C. Cherubini, M. Della Valle, S. Filippi, C.L. Fryer, L. Izzo, M. Karlica, M. Kovacevic, DJ. Melon Fuksman, R. Moradi, A.V. Penacchioni, G.B. Pisani, D. Primorac, J.F. Rodriguez, J.A. Rueda, S. Shakeri, G. Vereshchagin, Y. Wang & S.-S. Xue

GRB classification

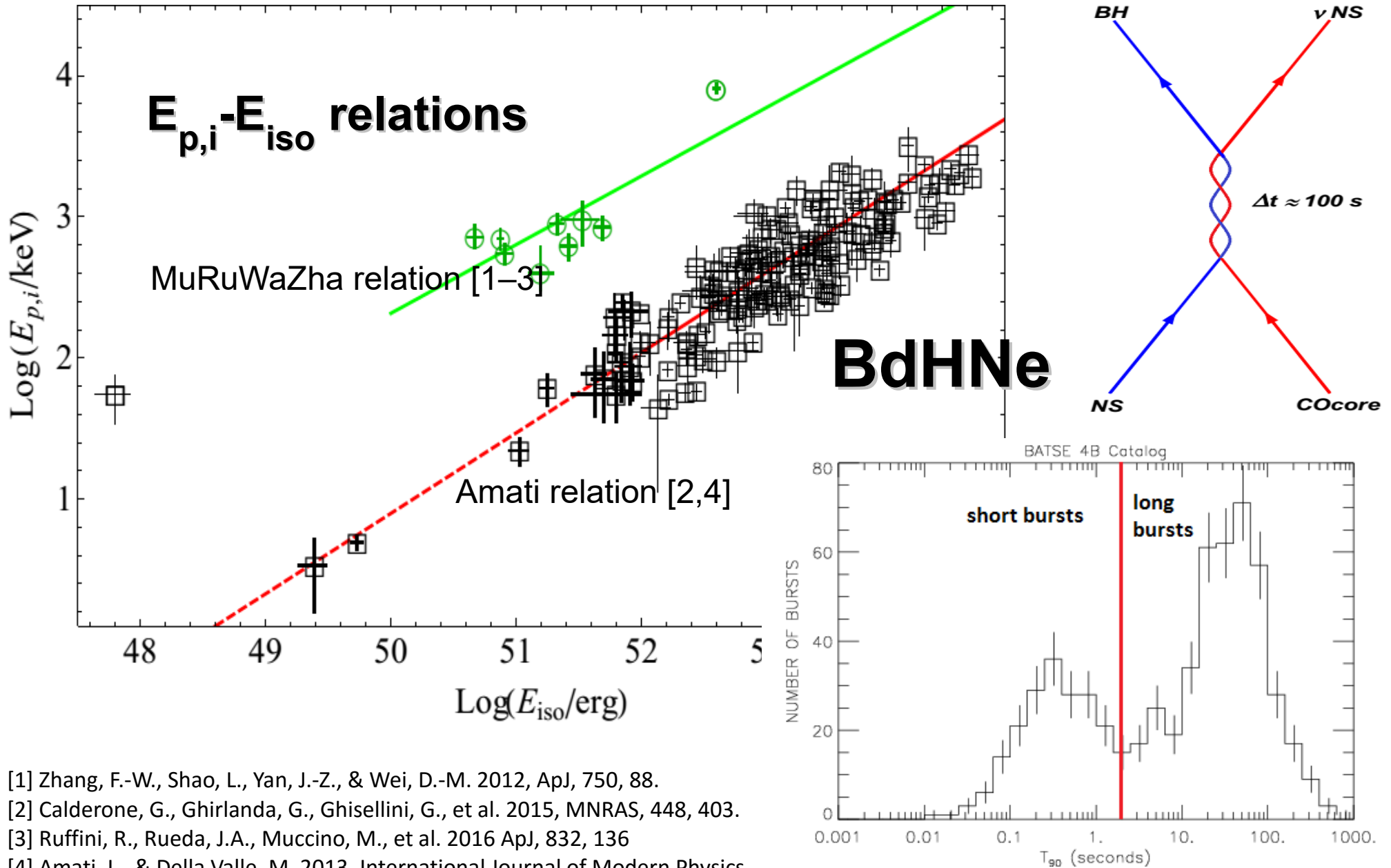


GRB classification



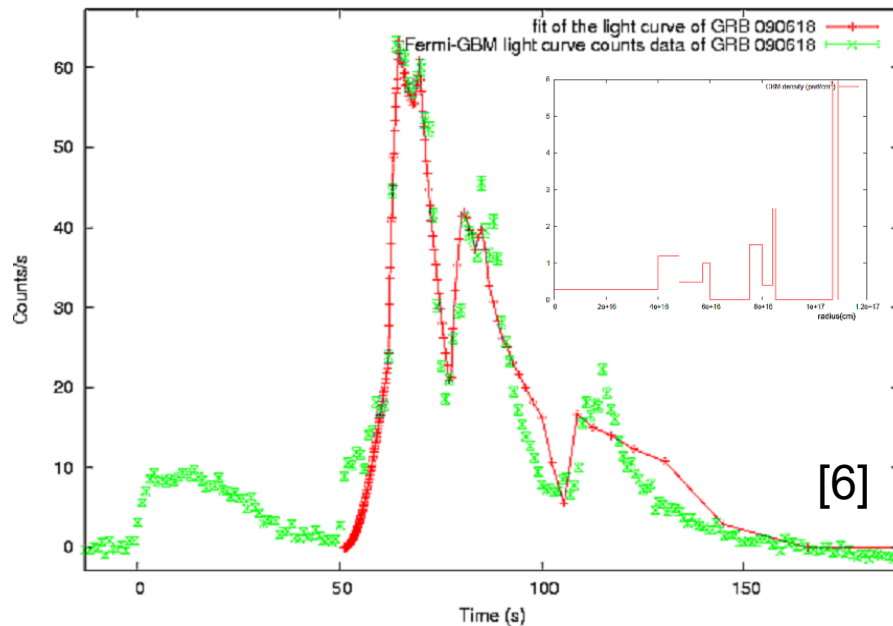
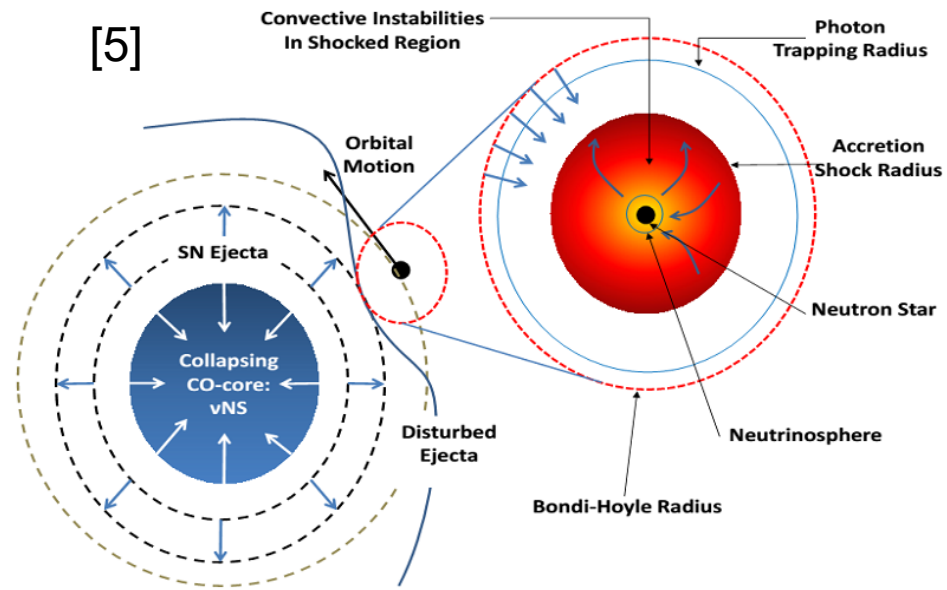
- [1] Zhang, F.-W., Shao, L., Yan, J.-Z., & Wei, D.-M. 2012, *ApJ*, 750, 88.
- [2] Calderone, G., Ghirlanda, G., Ghisellini, G., et al. 2015, *MNRAS*, 448, 403.
- [3] Ruffini, R., Rueda, J.A., Muccino, M., et al. 2016 *ApJ*, 832, 136
- [4] Amati, L., & Della Valle, M. 2013, *International Journal of Modern Physics*

GRB classification



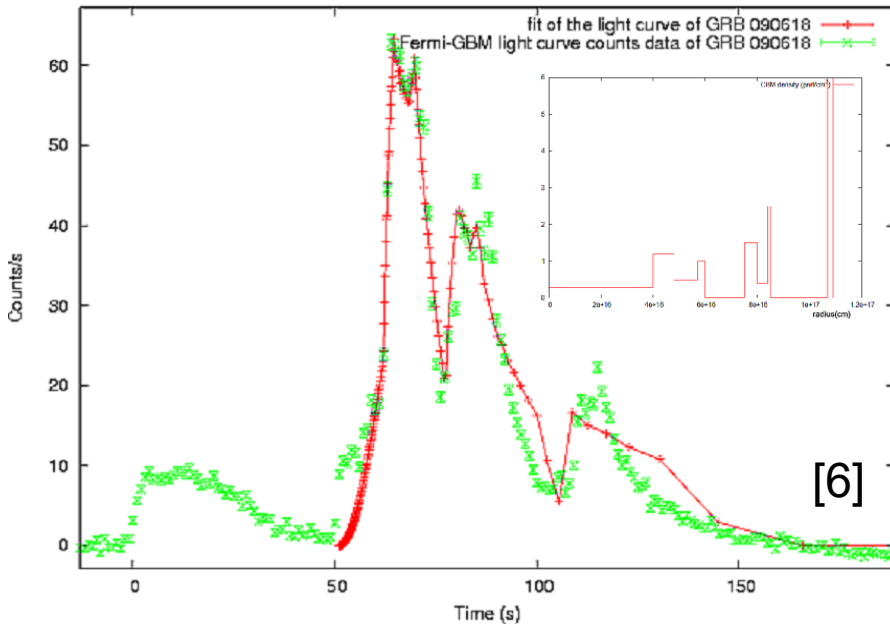
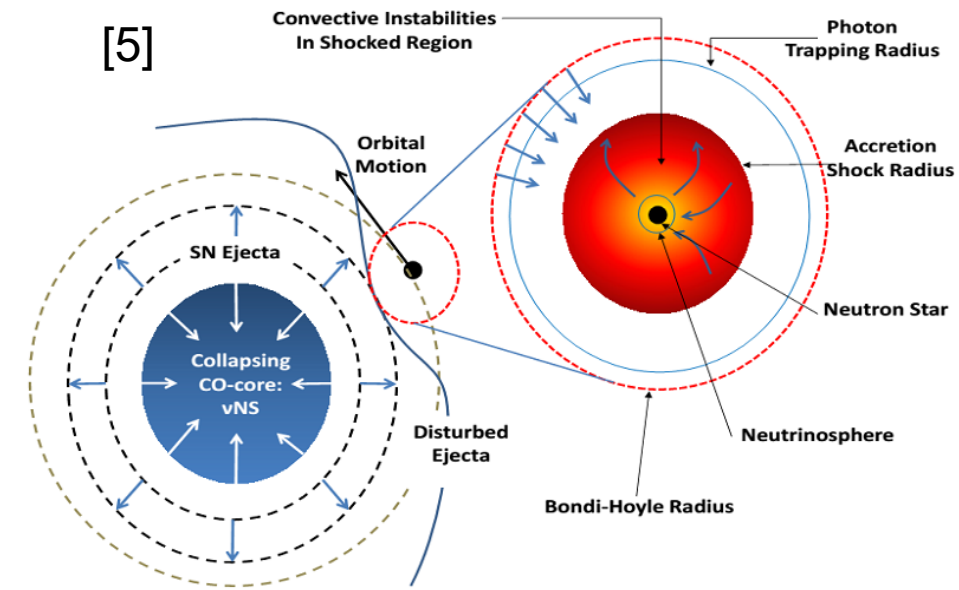
- [1] Zhang, F.-W., Shao, L., Yan, J.-Z., & Wei, D.-M. 2012, ApJ, 750, 88.
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Induced Gravitational Collapse paradigm



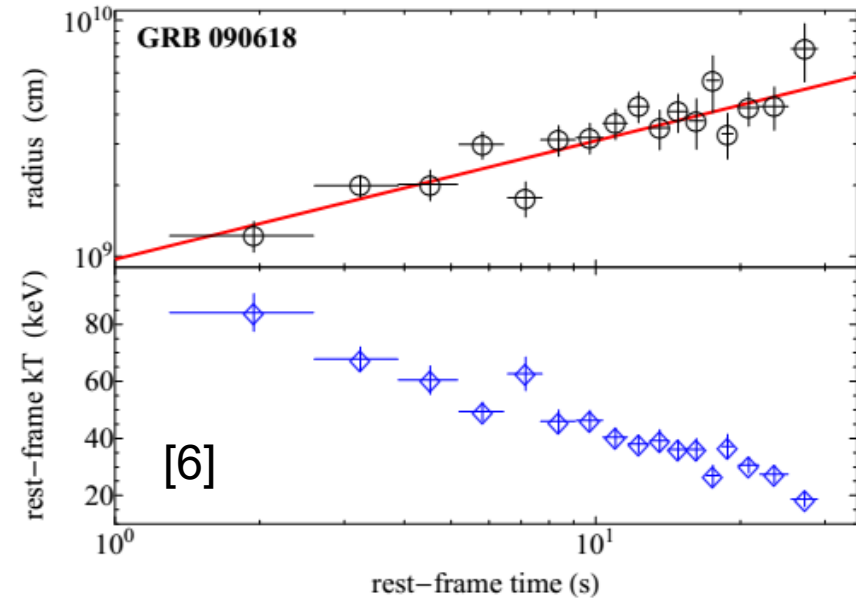
- [5] Fryer, C. L., Rueda, J. A., & Ruffini, R. 2014, ApJ, 793, L36
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Induced Gravitational Collapse paradigm



Episode 1

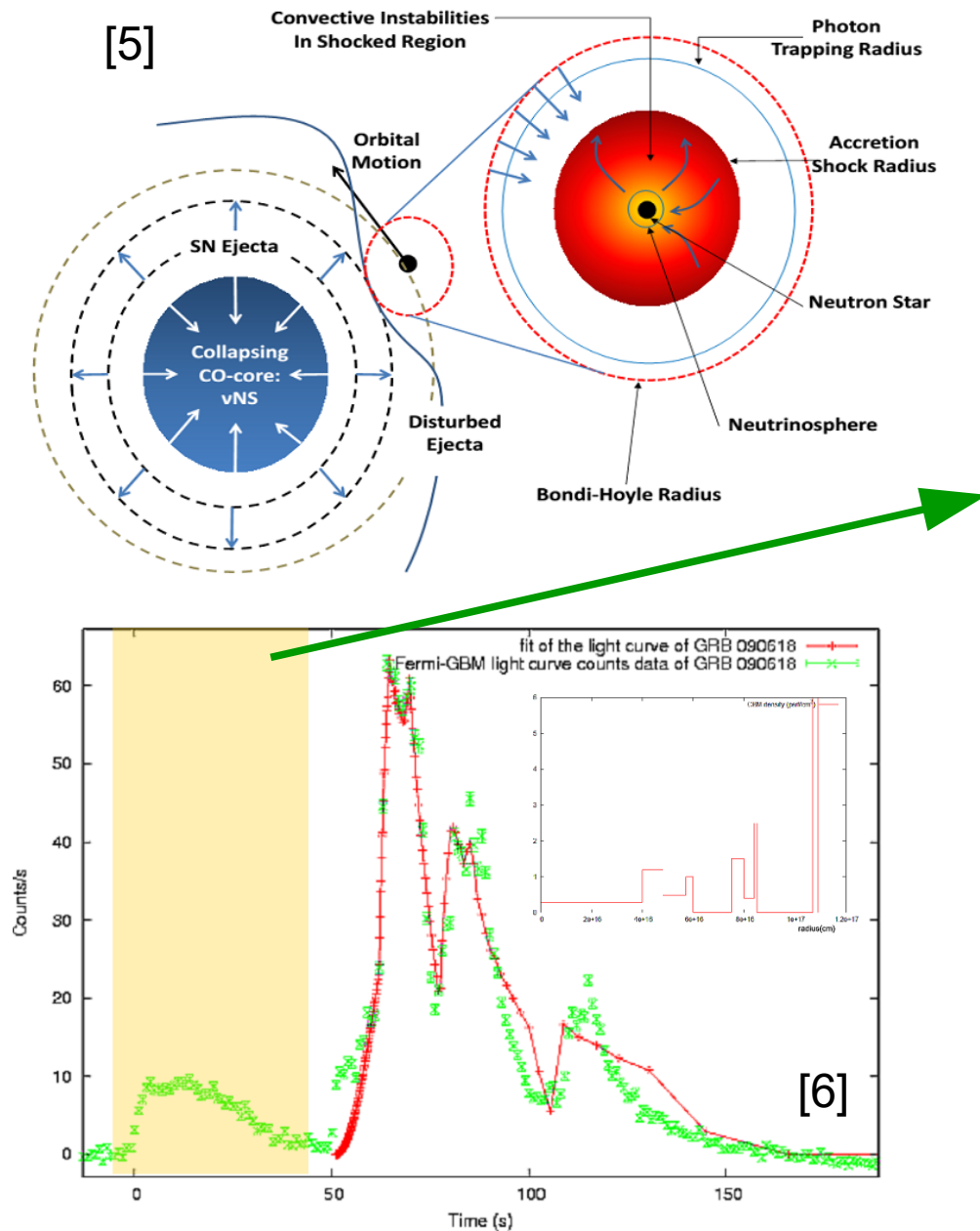
The hypercritical accretion phase



[5] Fryer, C. L., Rueda, J. A., & Ruffini, R. 2014, ApJ, 793, L36

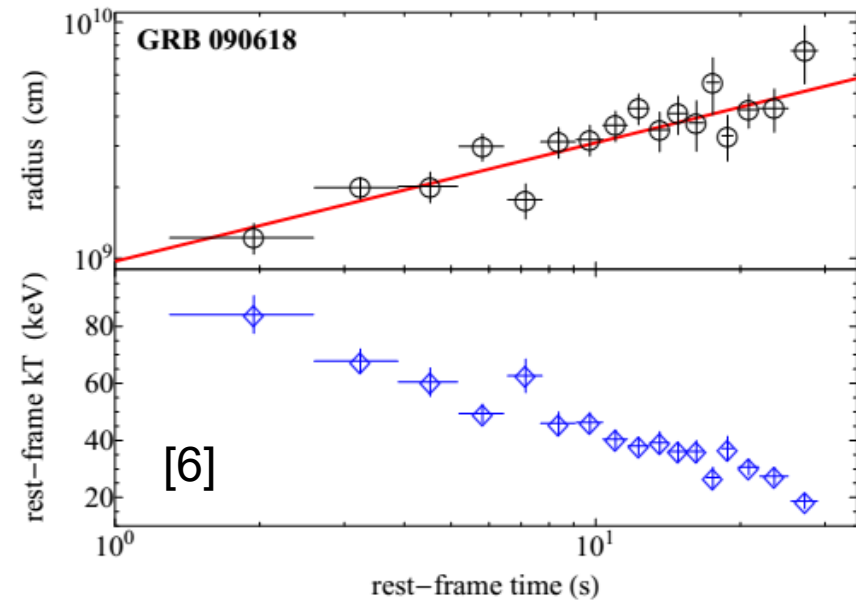
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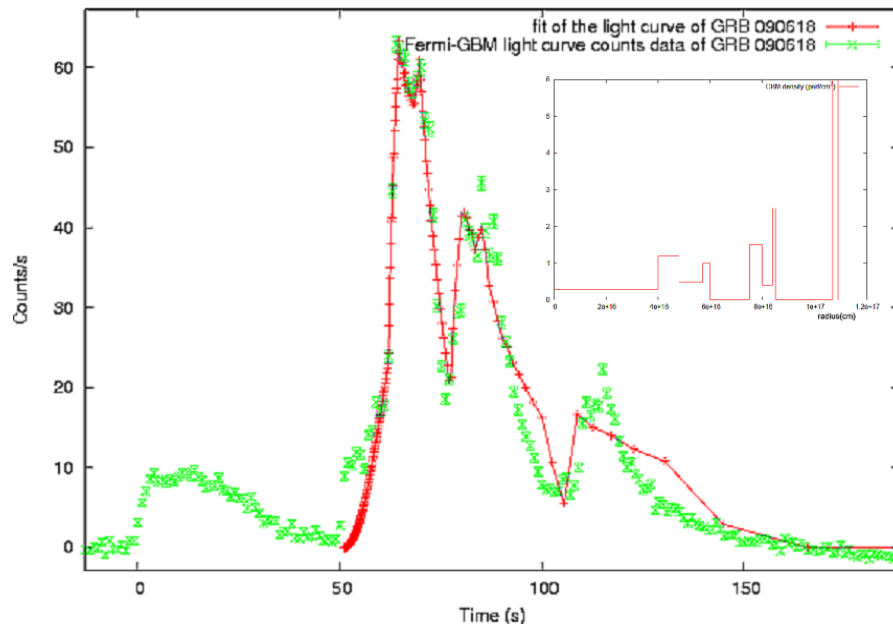
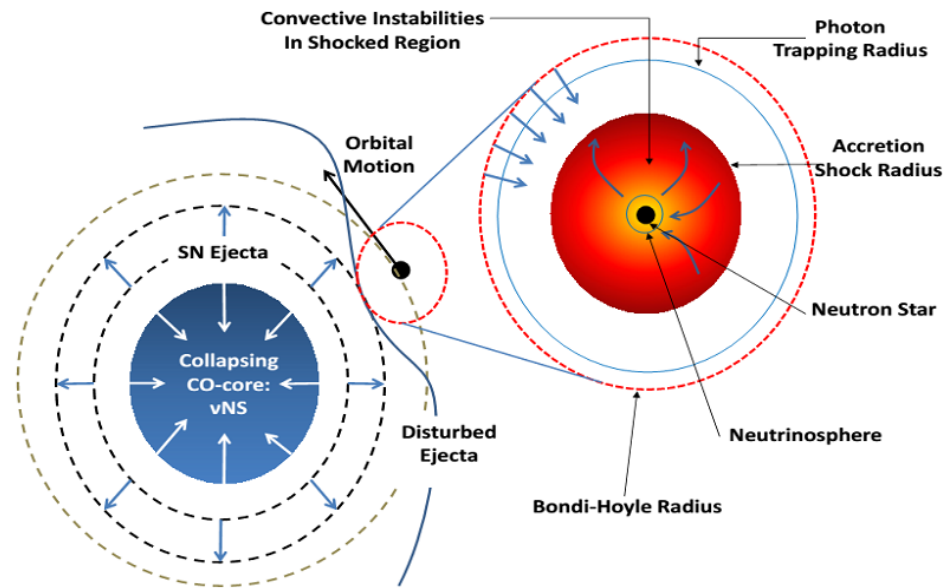
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Induced Gravitational Collapse paradigm



Fireshell model [7-9]

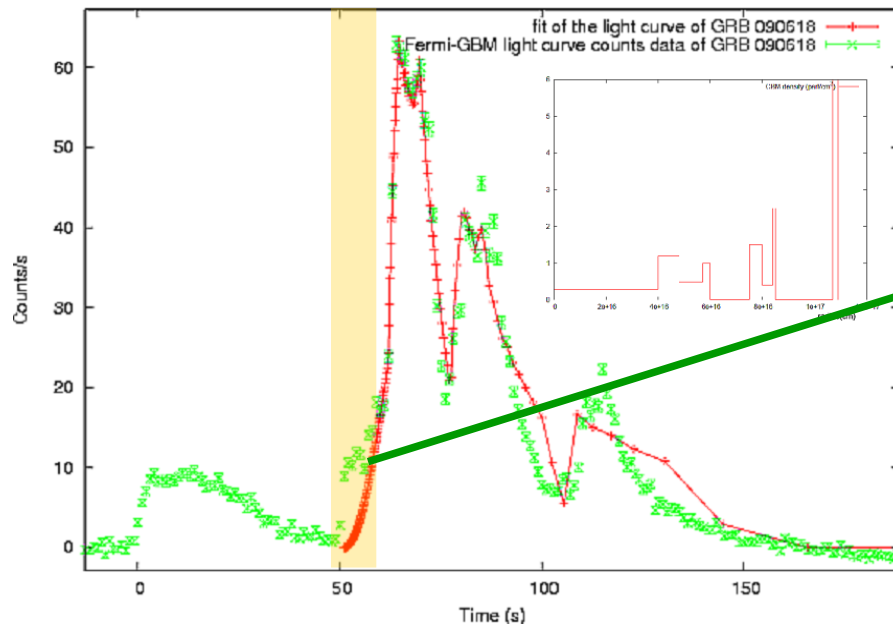
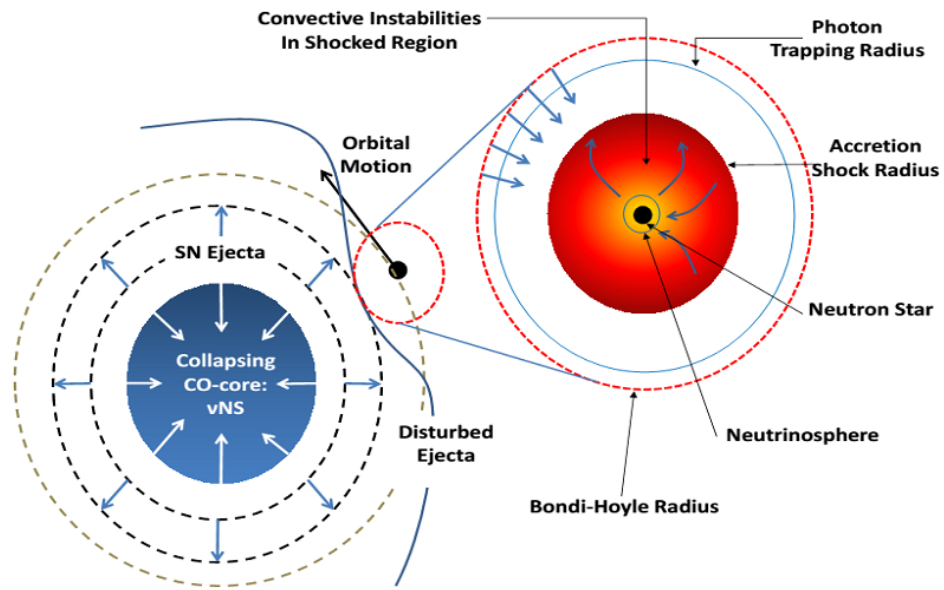
- An optically thick e^\pm plasma with energy E^{tot} is formed around a black hole (BH)
- The expanding e^\pm *fireshell* engulfs the baryons left over in the collapse to BH, described by the baryon load $B = M_{BC}^2 / E^{tot}$, and thermalizes with the baryons.
- The fireshell self-accelerates to ultra-relativistic velocities up to the transparency and the **Proper-GRB (P-GRB)**, characterized by a thermal spectrum, is emitted.
- The dynamics of the fireshell in the optically thick phase up to the transparency condition is fully described by E^{tot} and B

[7] Ruffini, R., Bianco, C. L., Fraschetti, F., et al. 2001, ApJ, 555, L117

[8] Ruffini, R., Bianco, C. L., Fraschetti, F., et al. 2001, ApJ, 555, L113

[9] Ruffini, R., Bianco, C. L., Fraschetti, F., et al. 2001, ApJ, 555, L107

Induced Gravitational Collapse paradigm



Fireshell model [7-9]

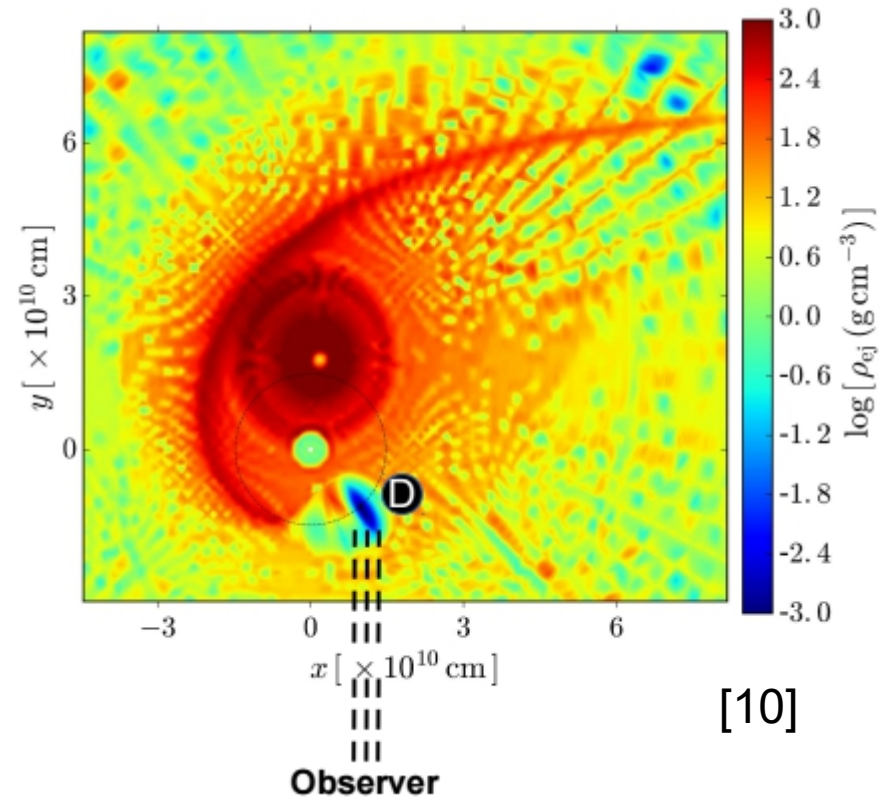
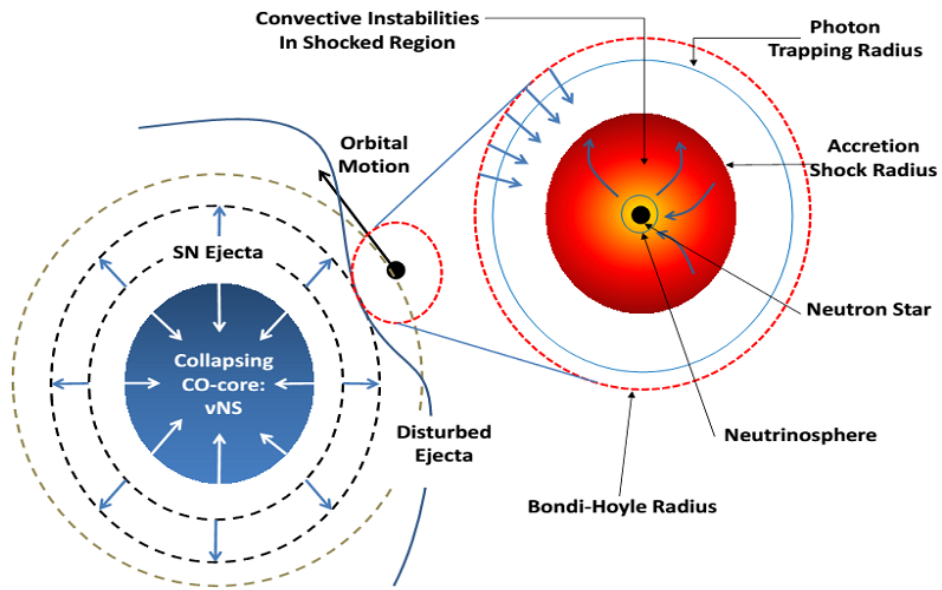
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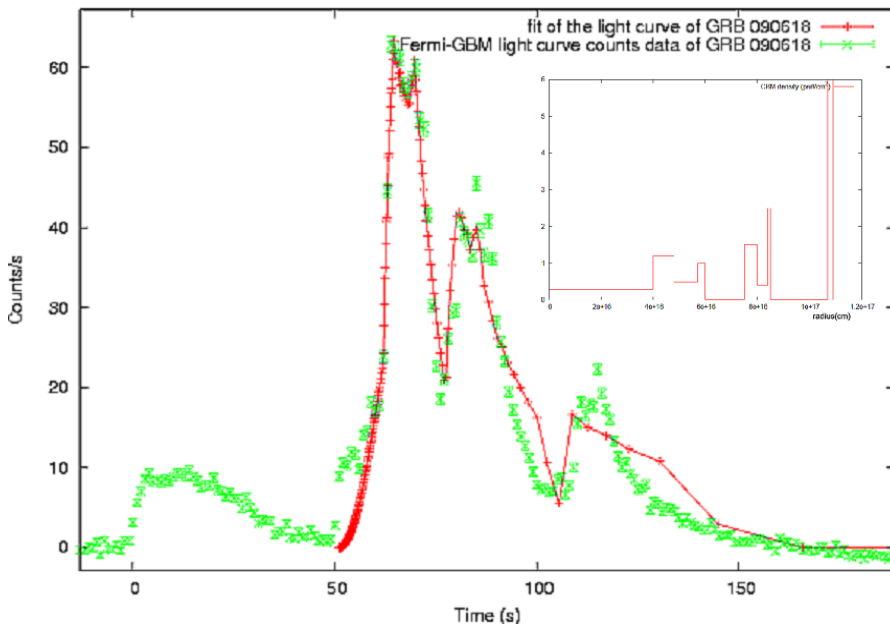
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Induced Gravitational Collapse paradigm



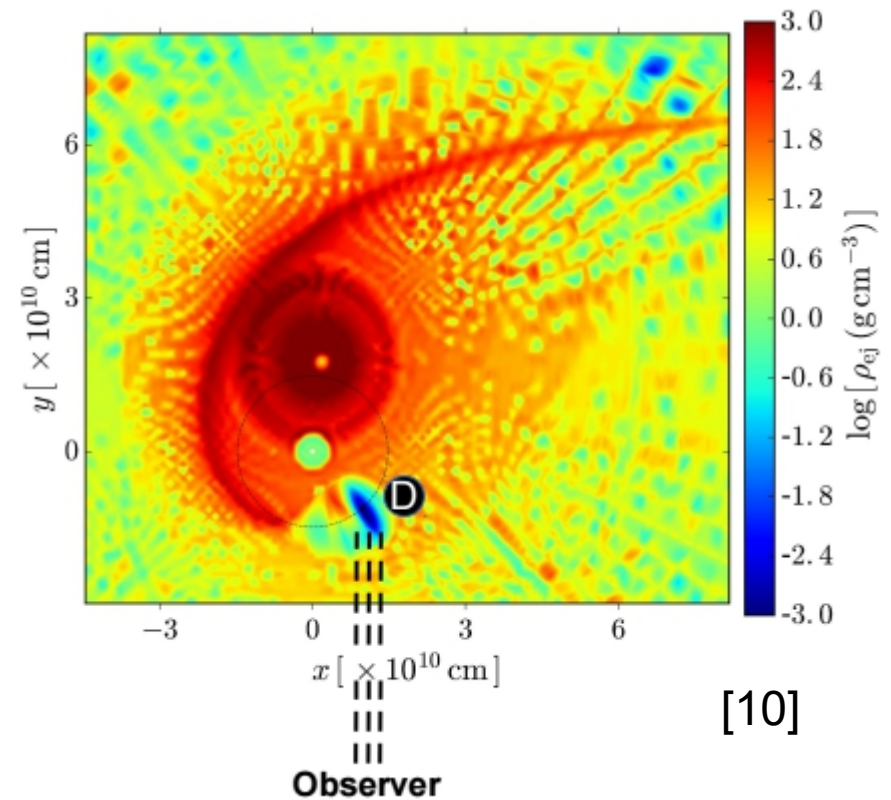
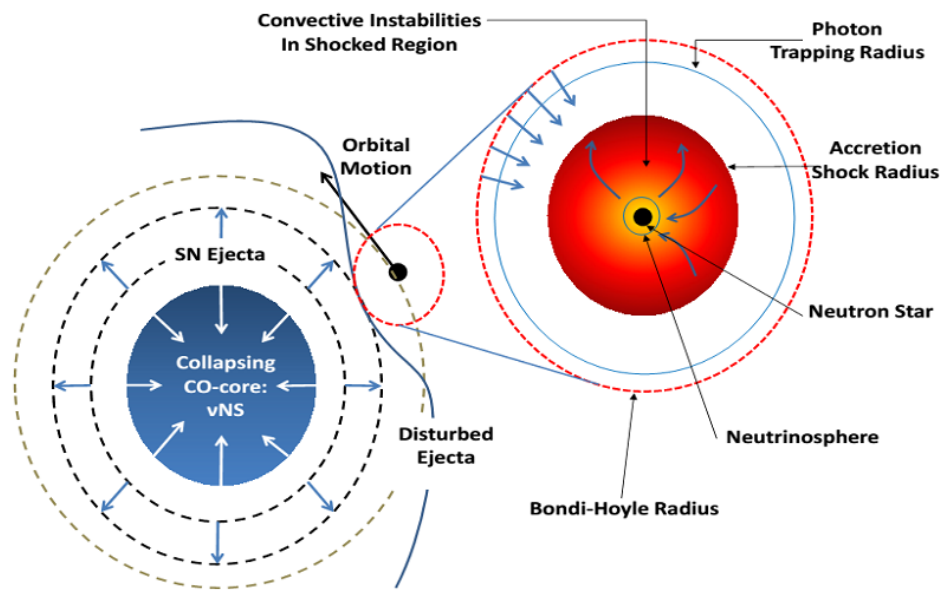
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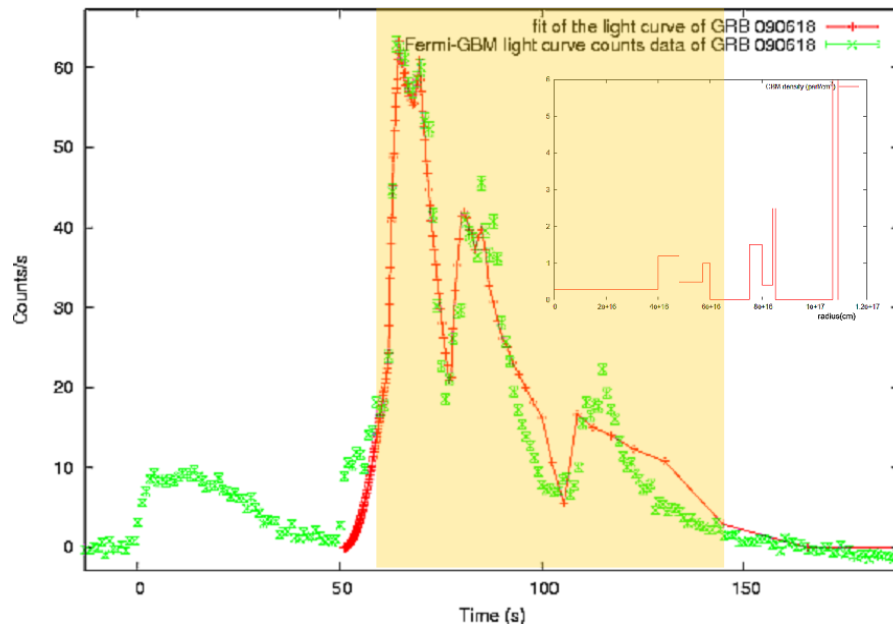
Prompt emission

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

Induced Gravitational Collapse paradigm



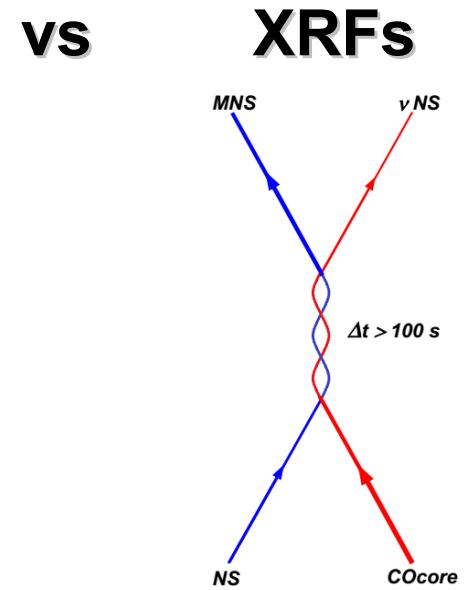
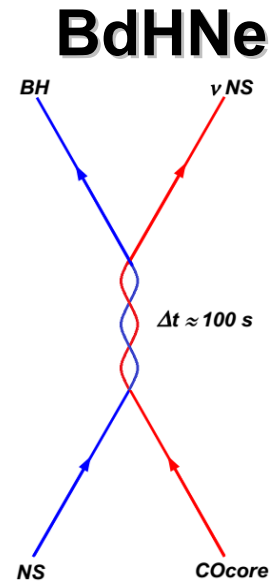
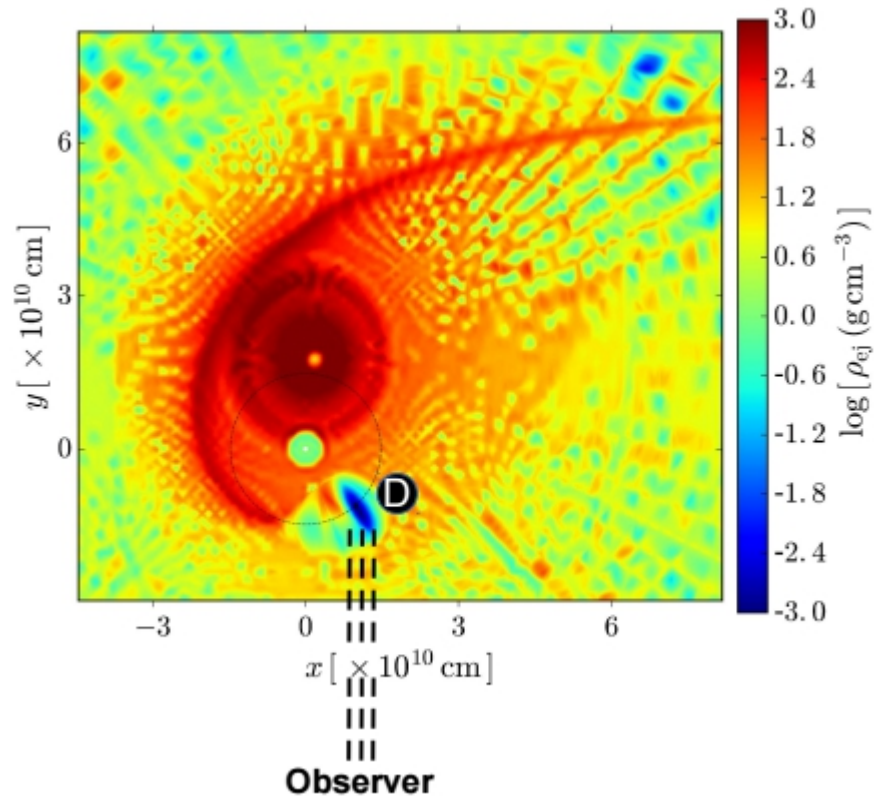
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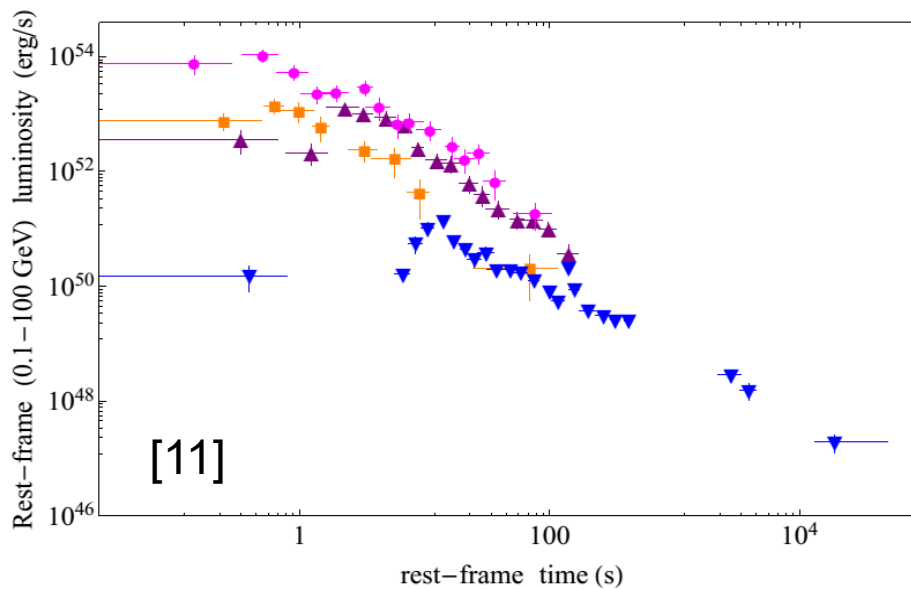
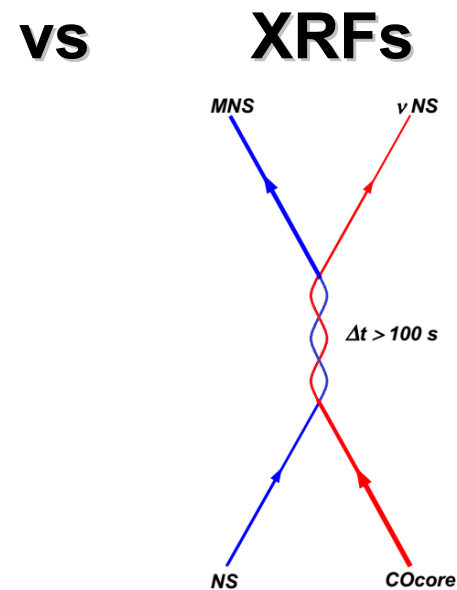
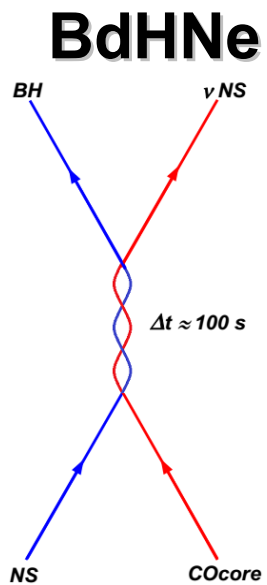
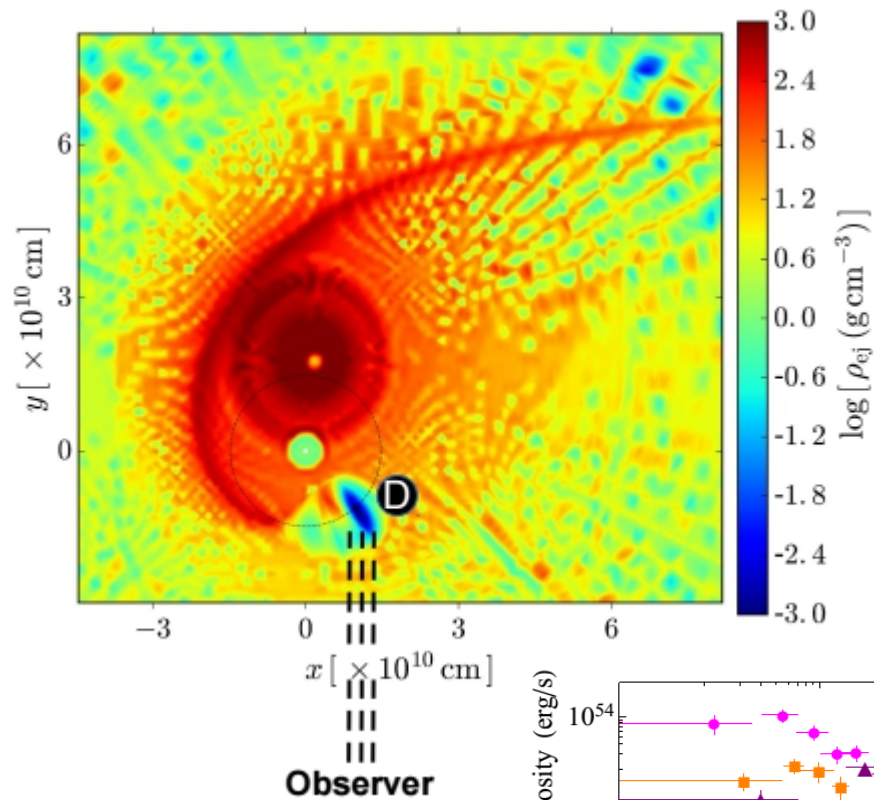
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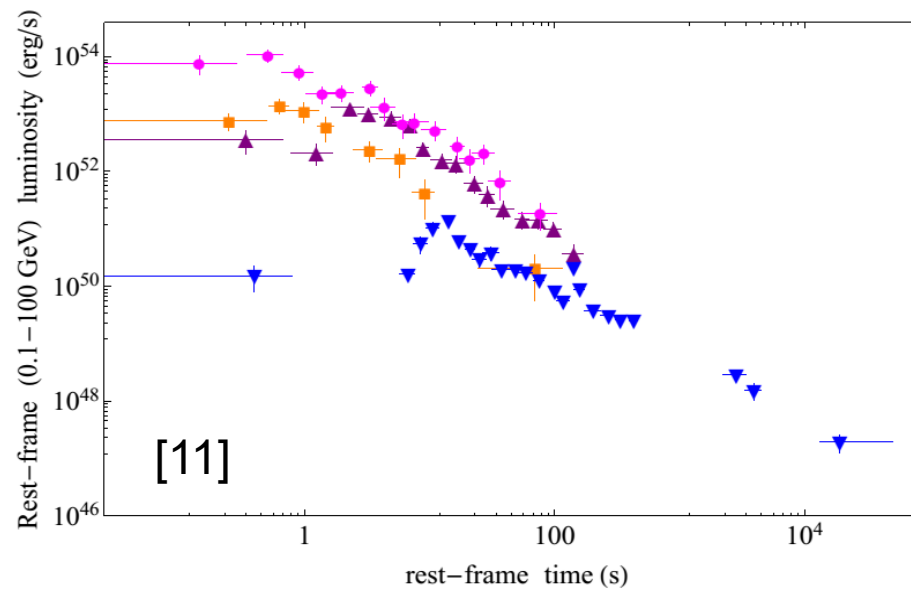
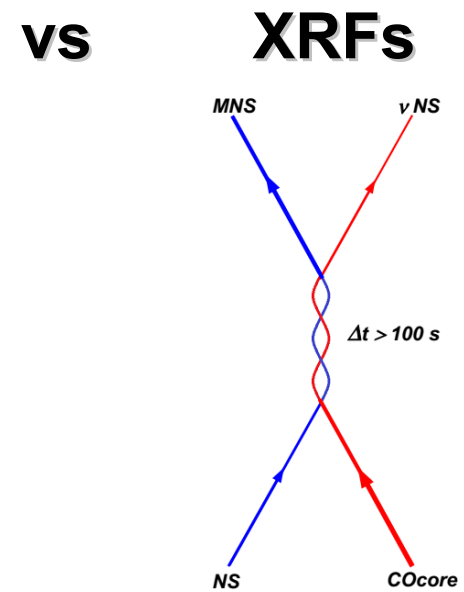
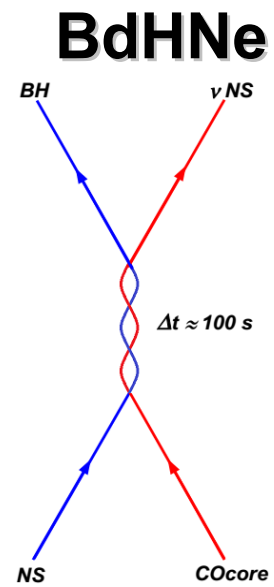
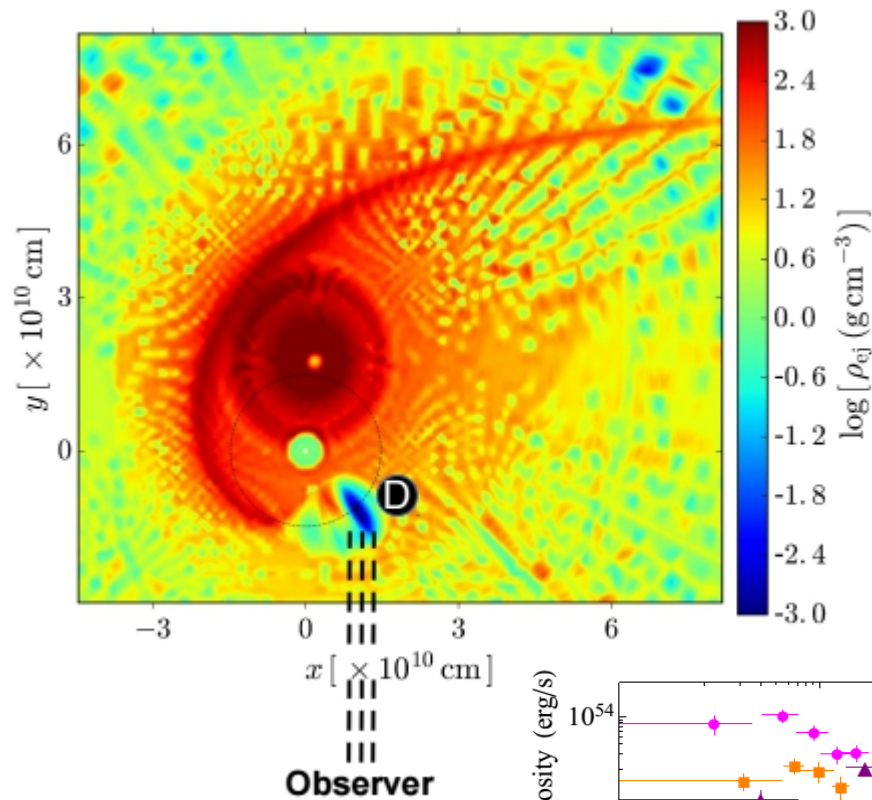
GeV emission – BH formation



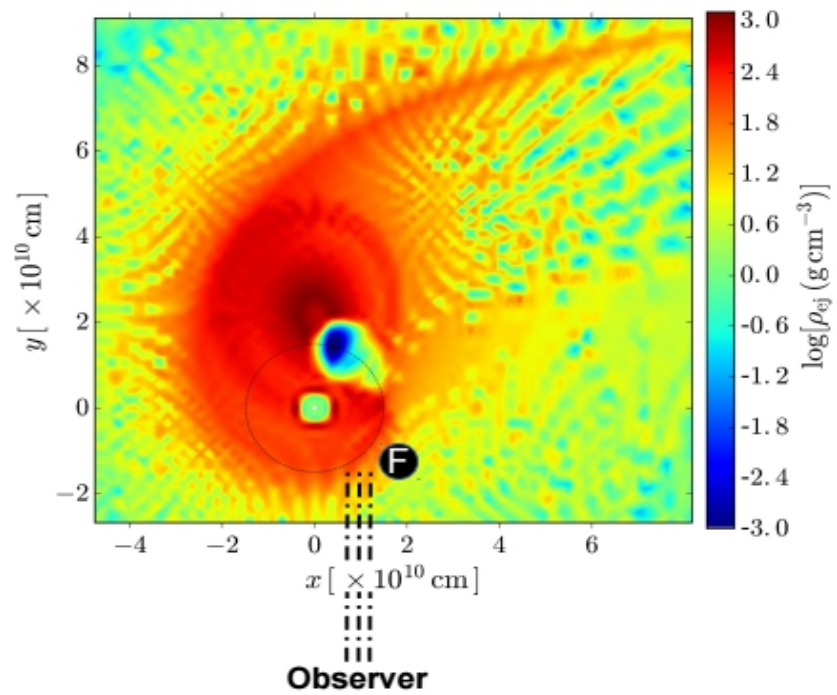
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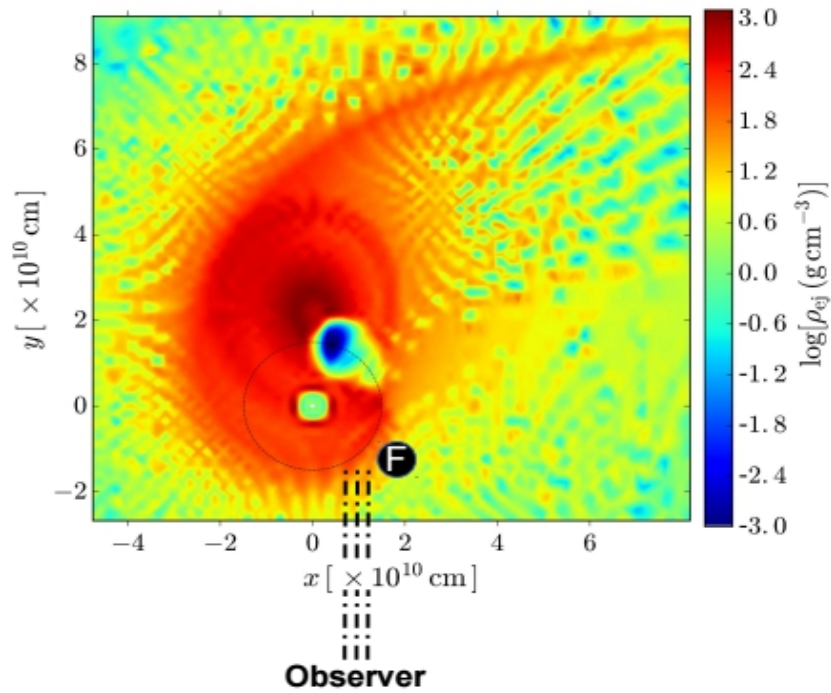
GeV emission – BH formation



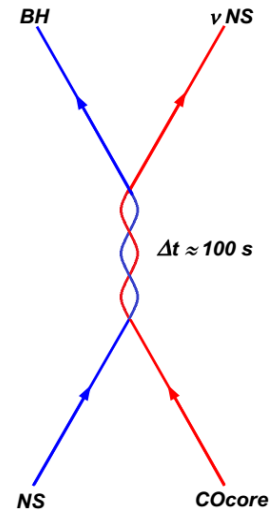
IGC and X-ray afterglow



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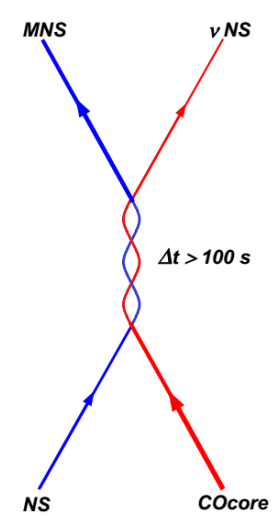


BdHNe

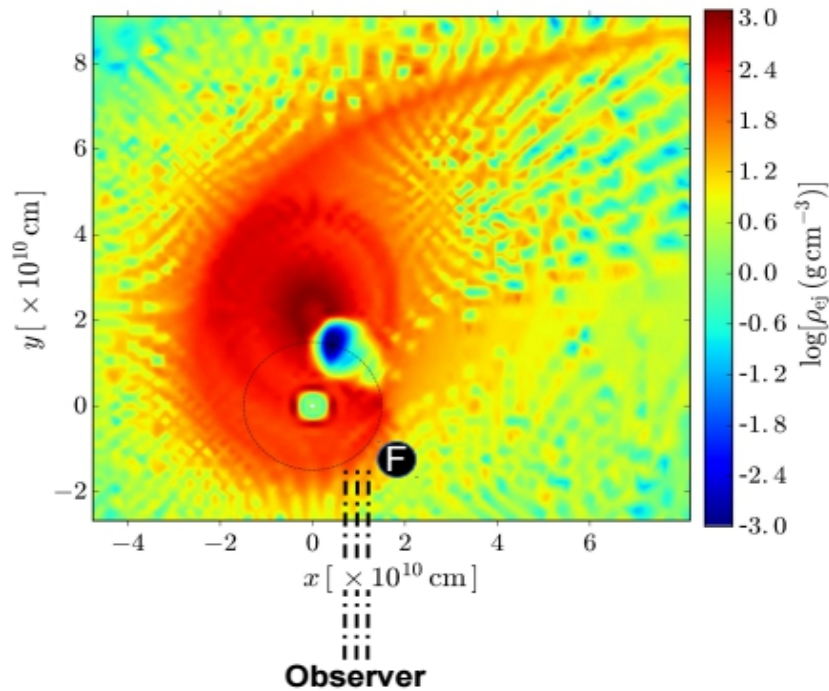


vs

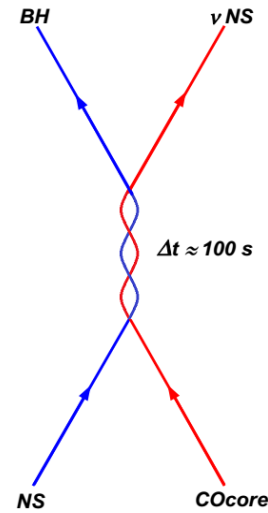
XRFs



IGC and X-ray afterglow

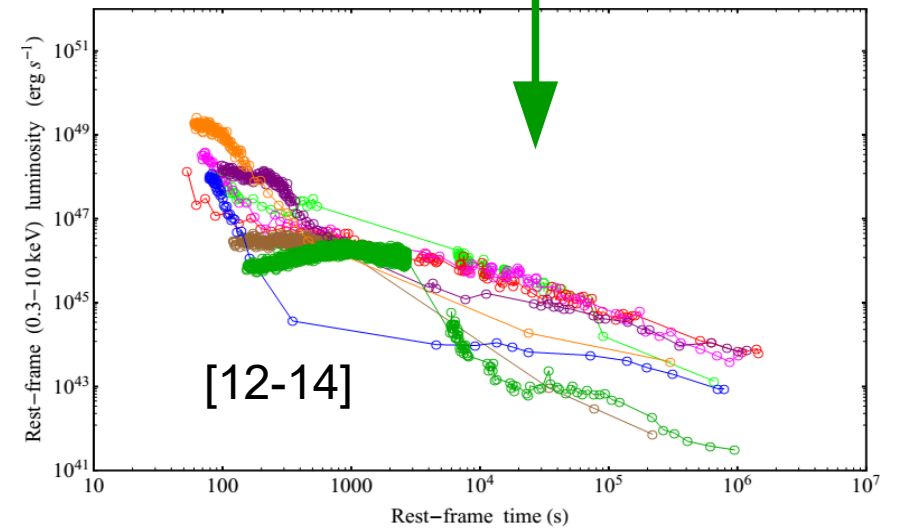
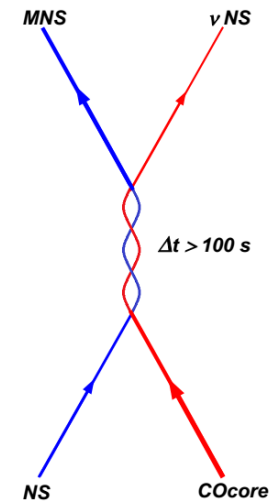


BdHNe



vs

XRFs



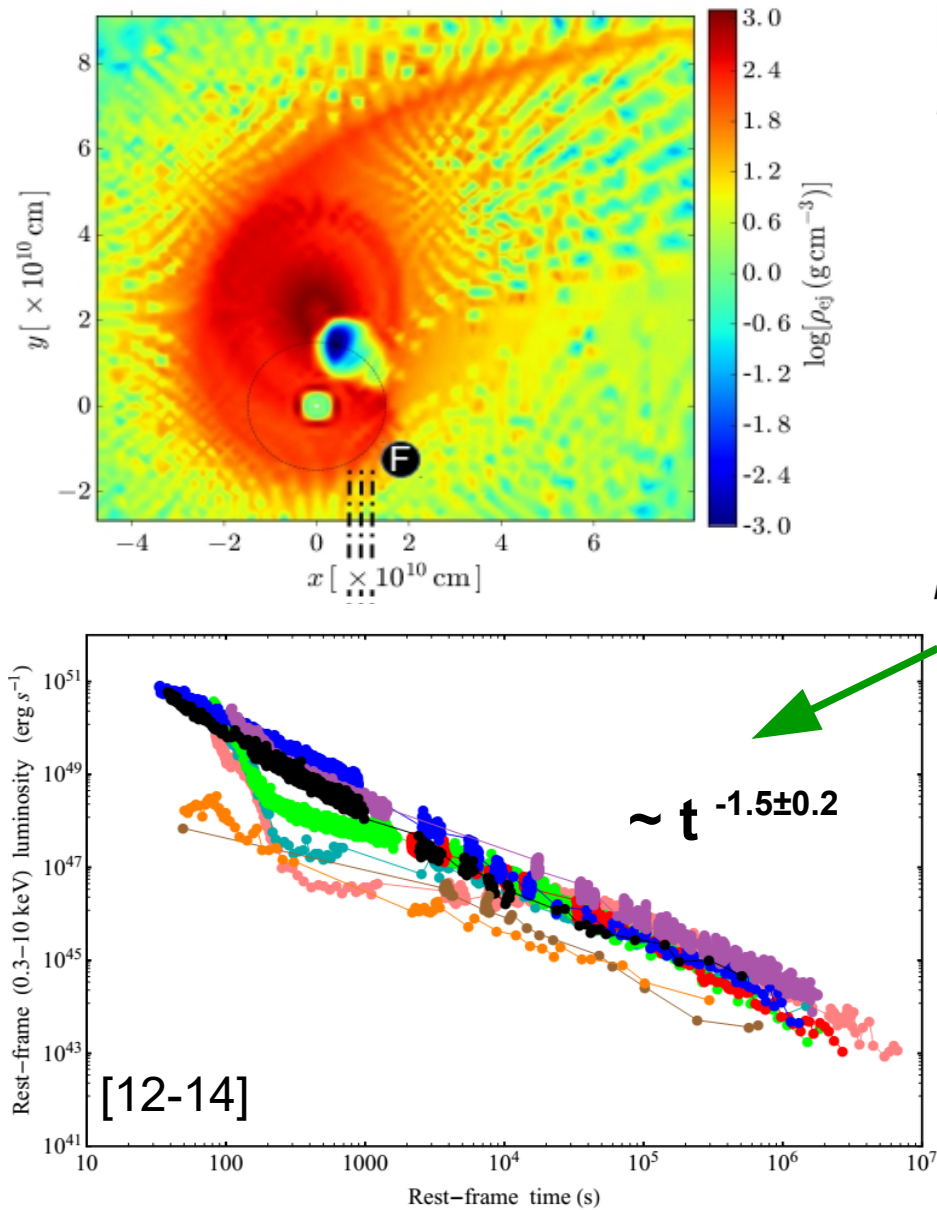
[12] Pisani, G. B., Izzo, L., Ruffini, R., et al. 2013, A&A, 552, L5

[13] Pisani, G. B., Ruffini, R., Aimuratov, Y., et al. 2016, ApJ, 833, 159

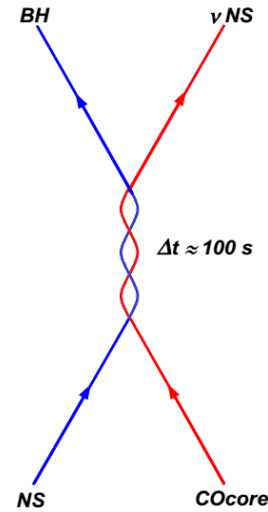
[14] Ruffini, R., Wang, Y., Aimuratov, Y., et al 2017, arXiv:170403821

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IGC and X-ray afterglow

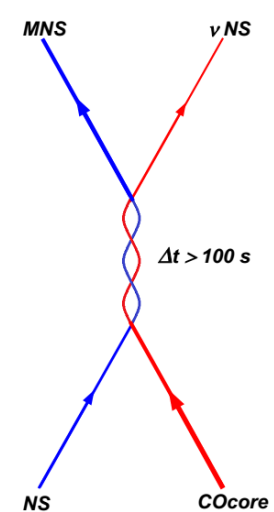


BdHNe



vs

XRFs

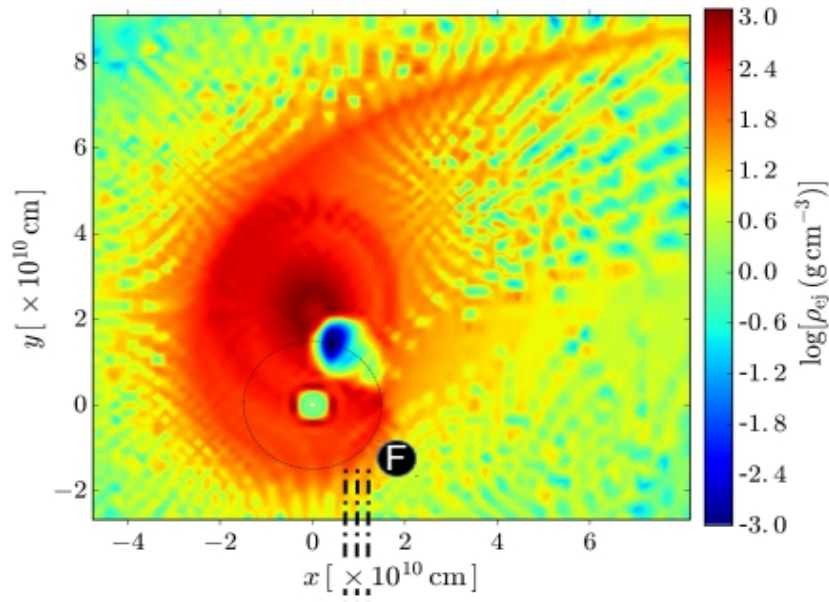


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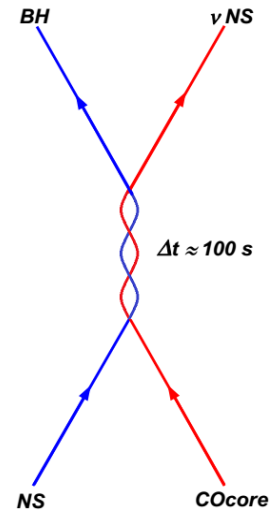
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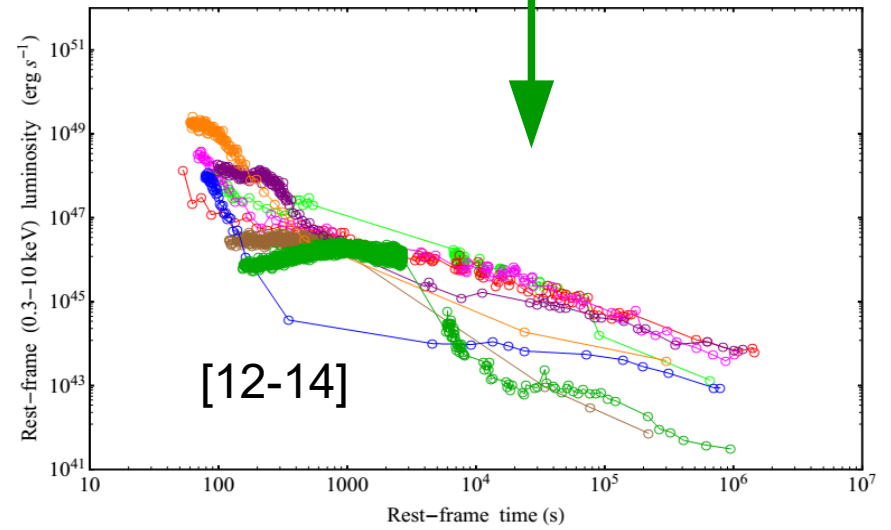
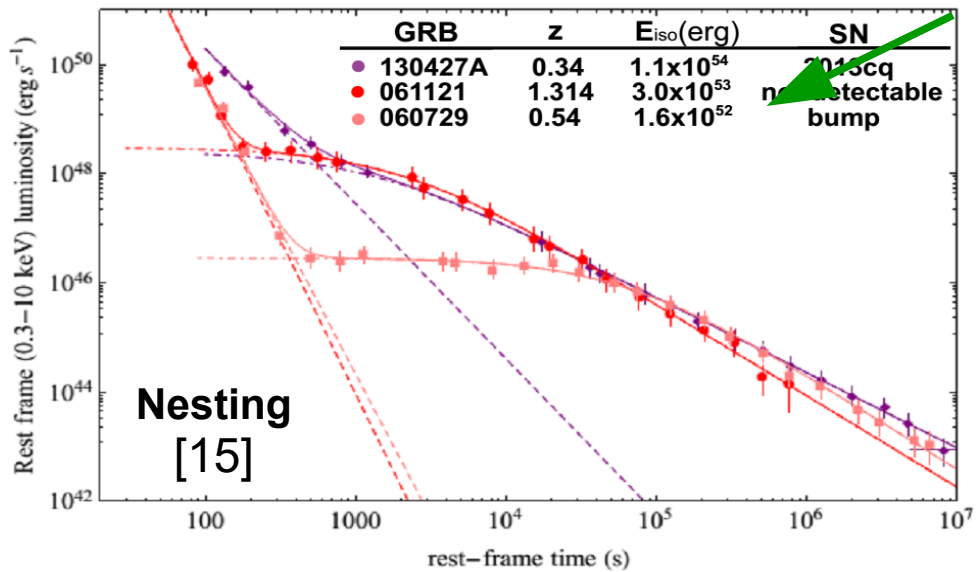
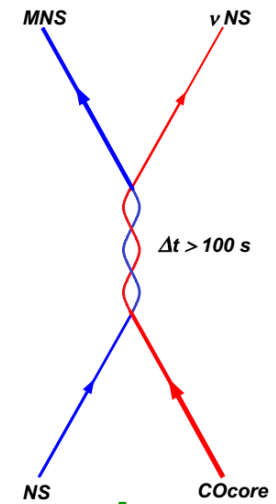


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vs

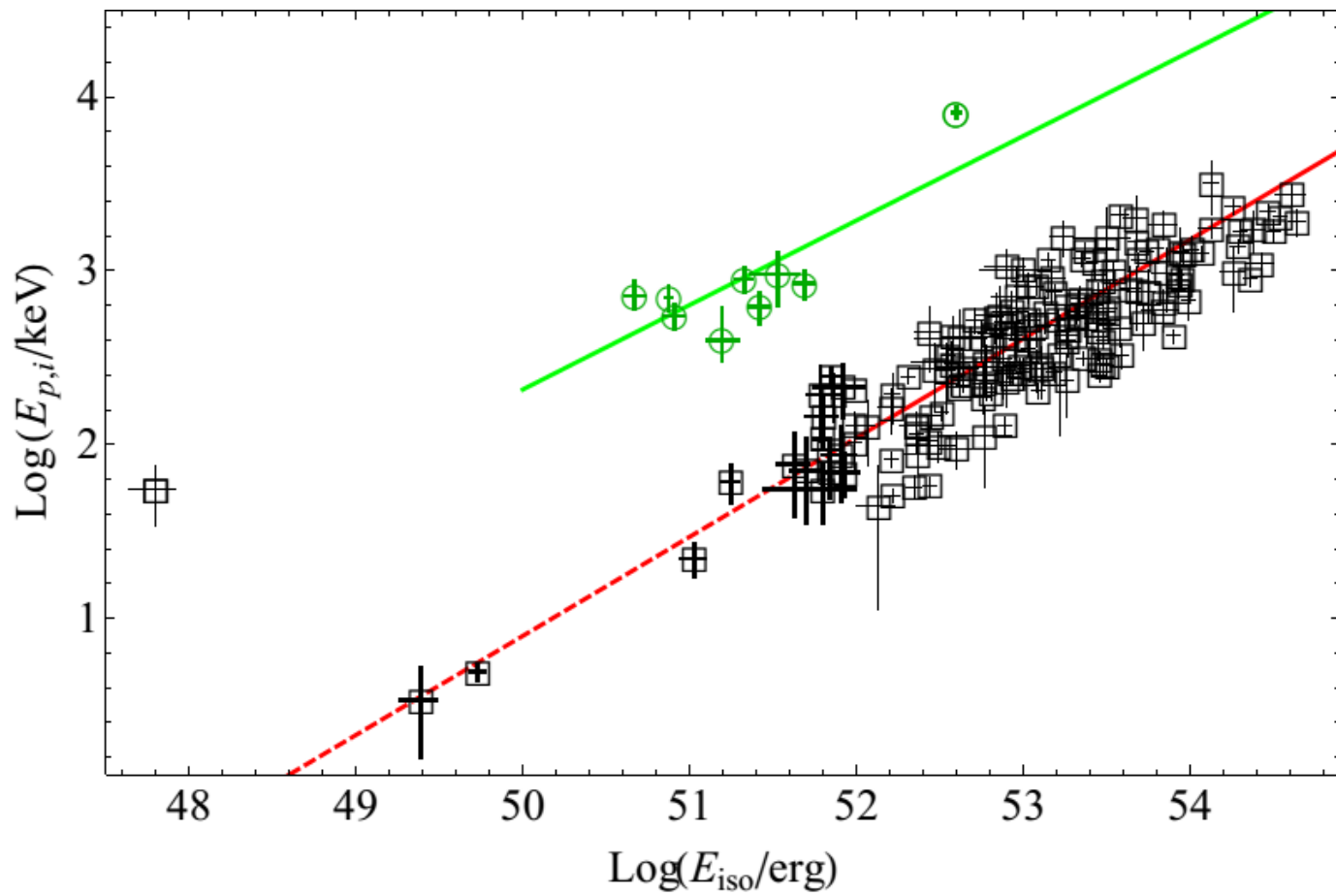
XRFs



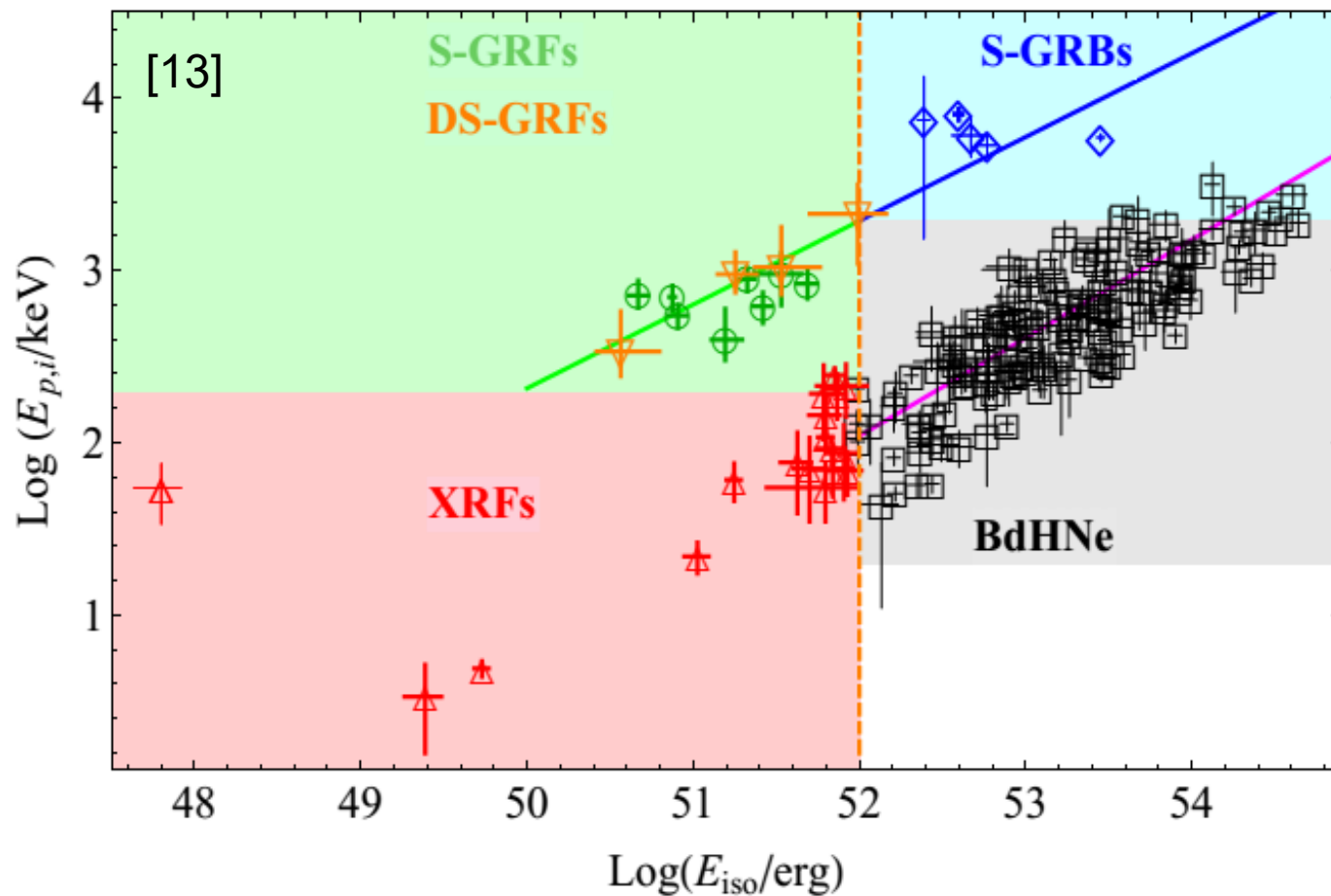
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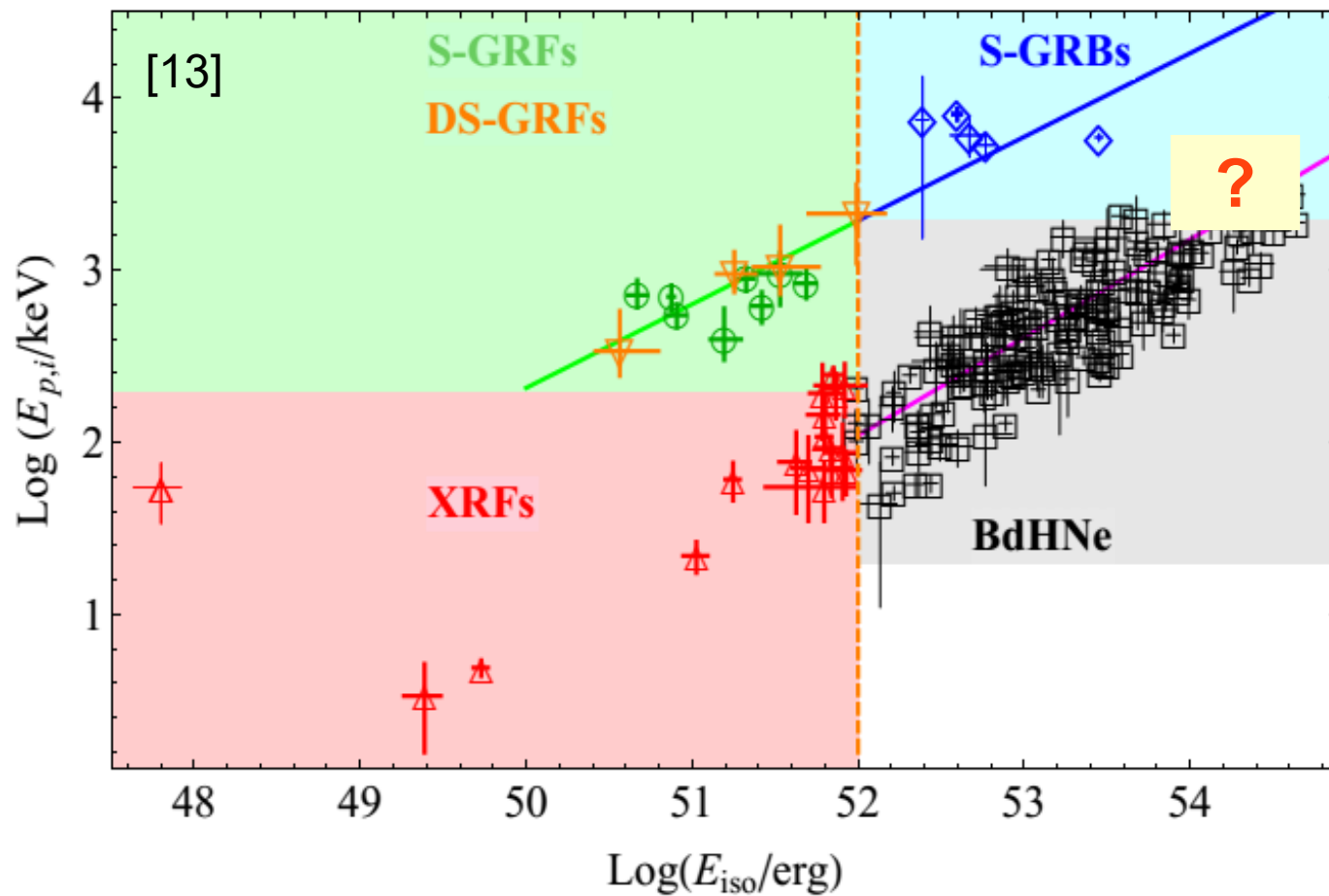
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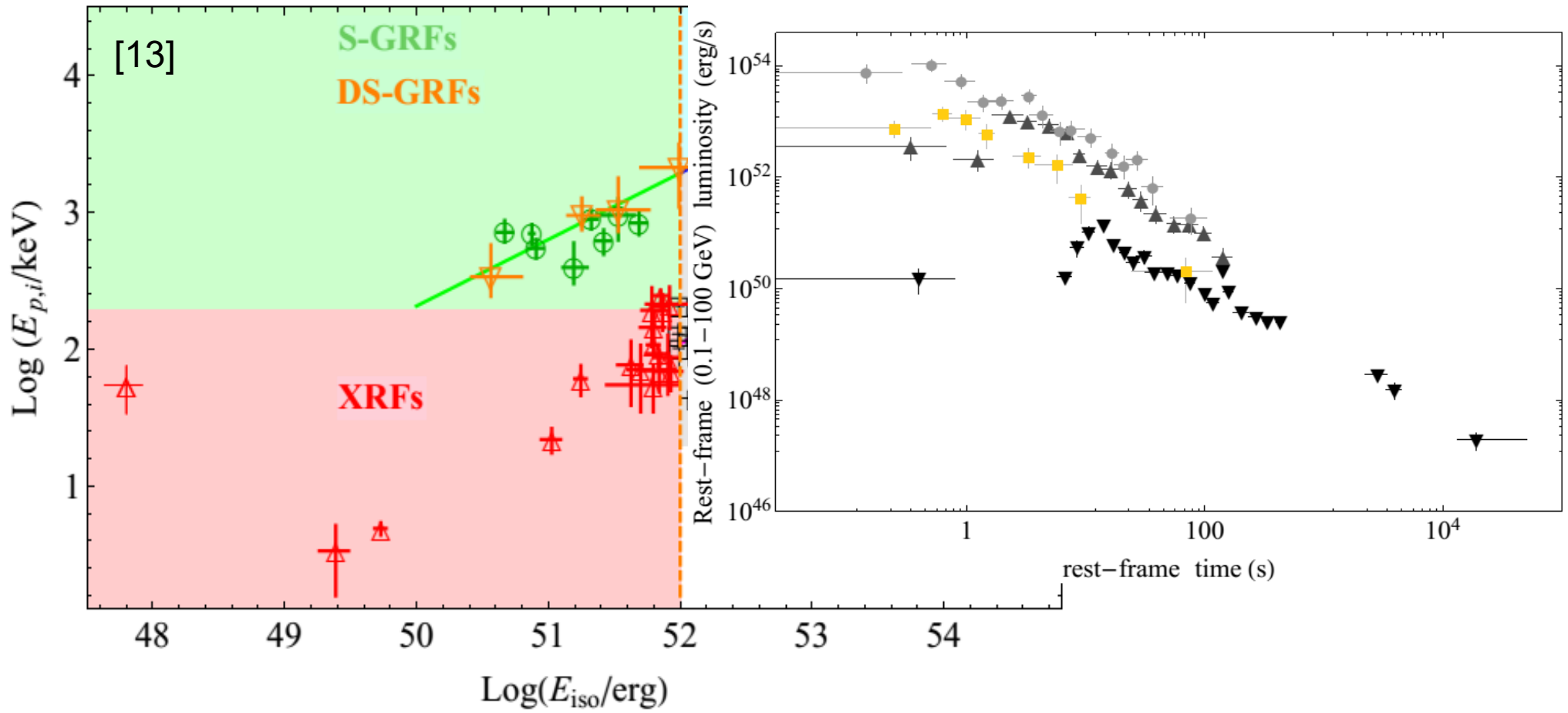
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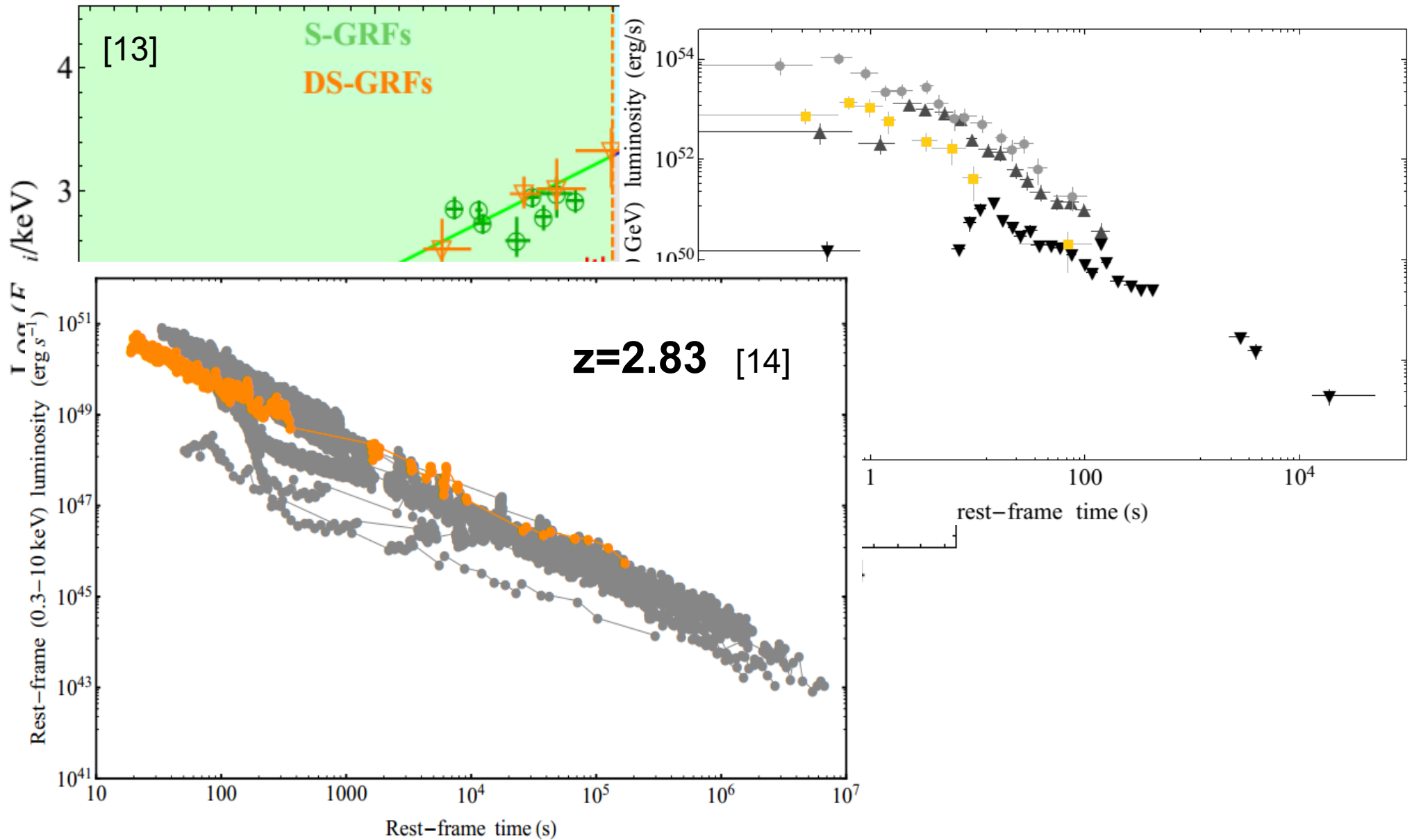
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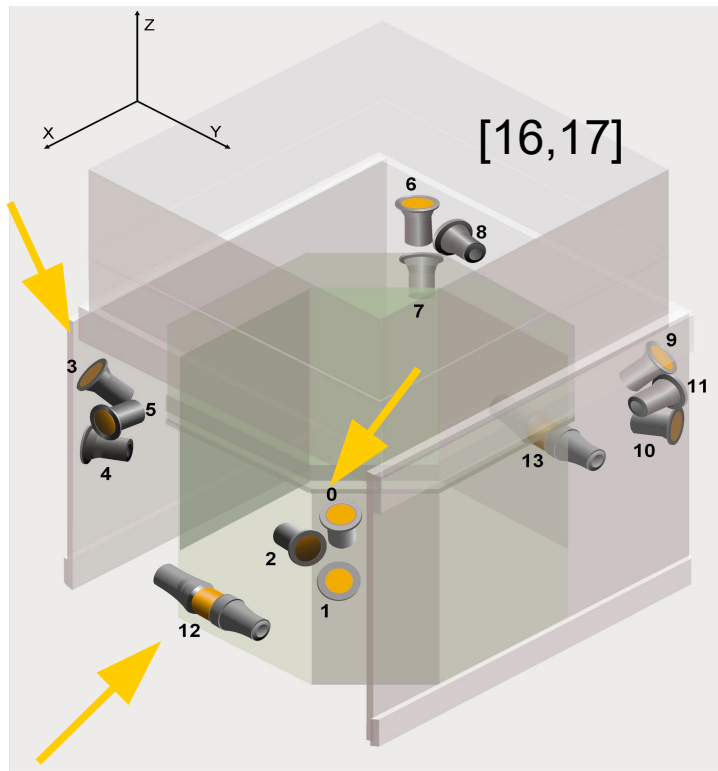
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[13] Ruffini, R., Rueda, J.A., Muccino, M., et al. 2016 ApJ, 832, 136

[14] Tanvir, N.R., et al. 2011, GRB Coordinates Network, 12225

RMFIT [15] & Data Analysis

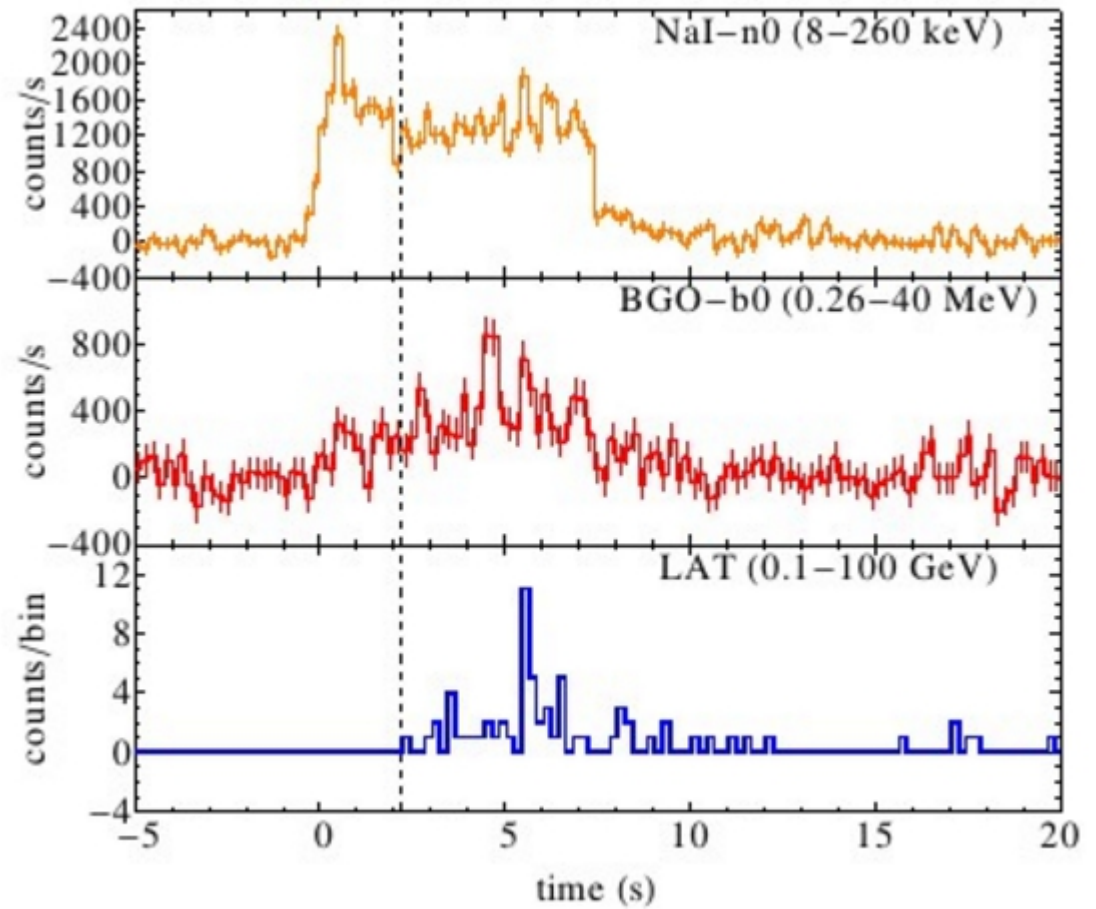
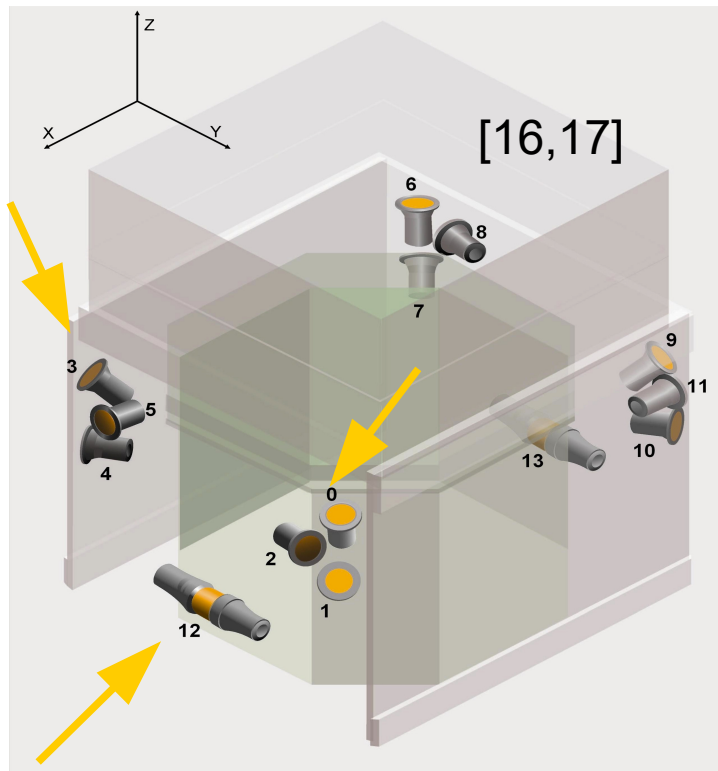


[15] *rmfit* for GBM and LAT analysis was developed by the GBM Team and is publicly available at fermi.gsfc.nasa.gov/ssc/data/analysis/

[16] Meegan, C., et al. 2009, *ApJ*, 702, 791

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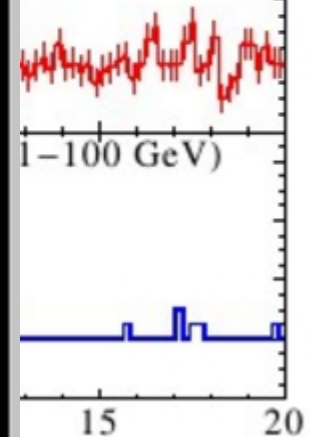
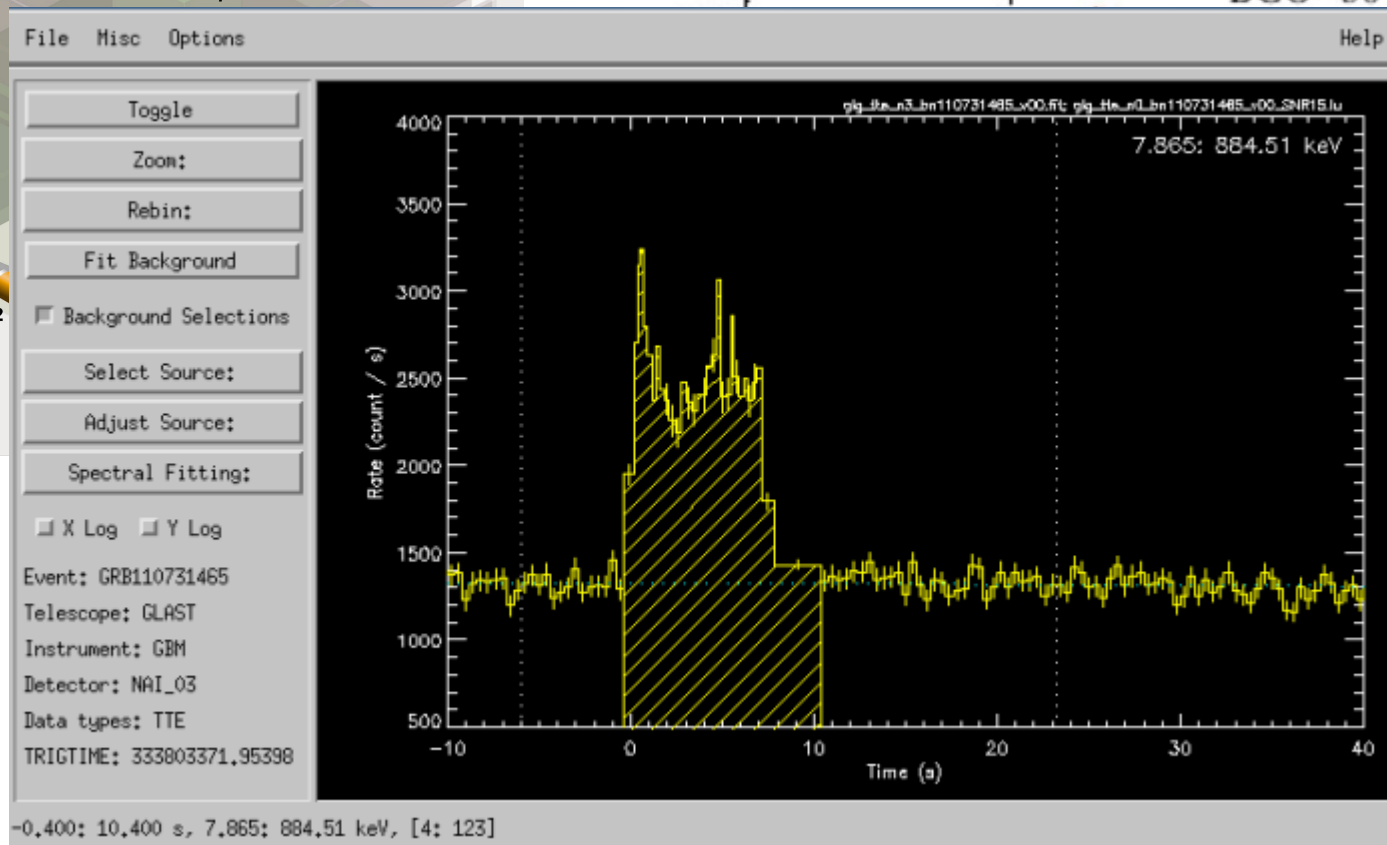
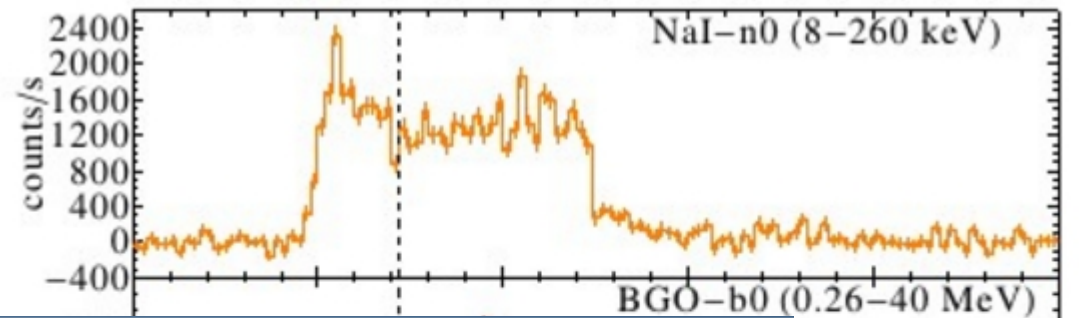
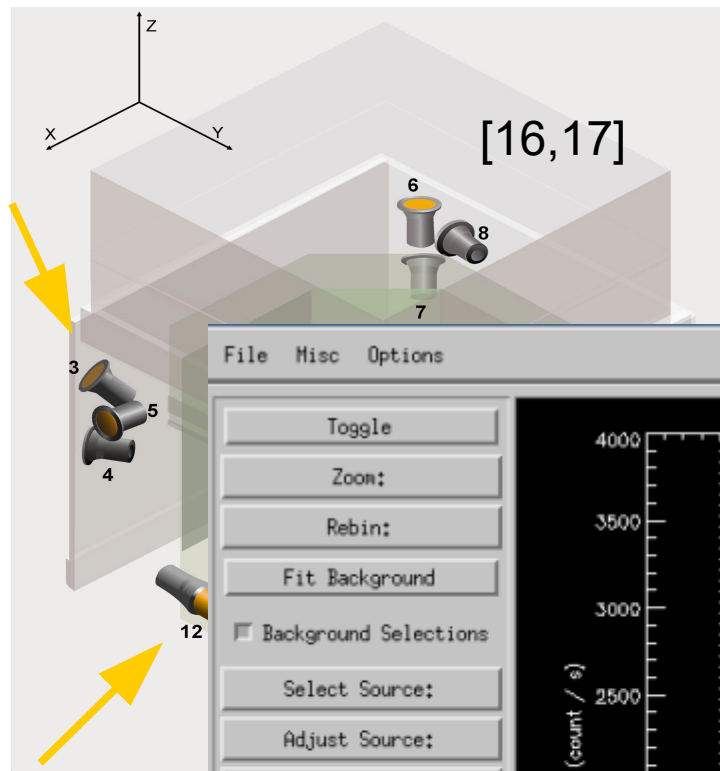


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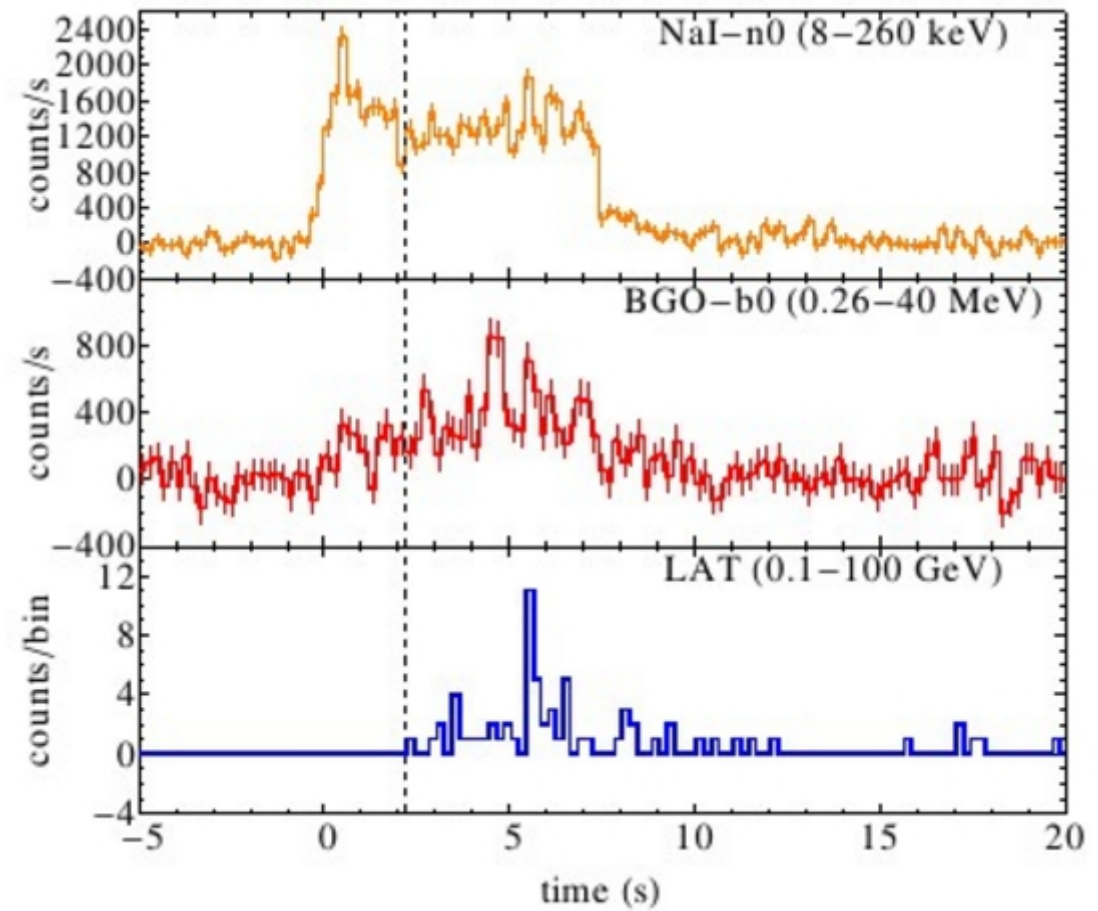


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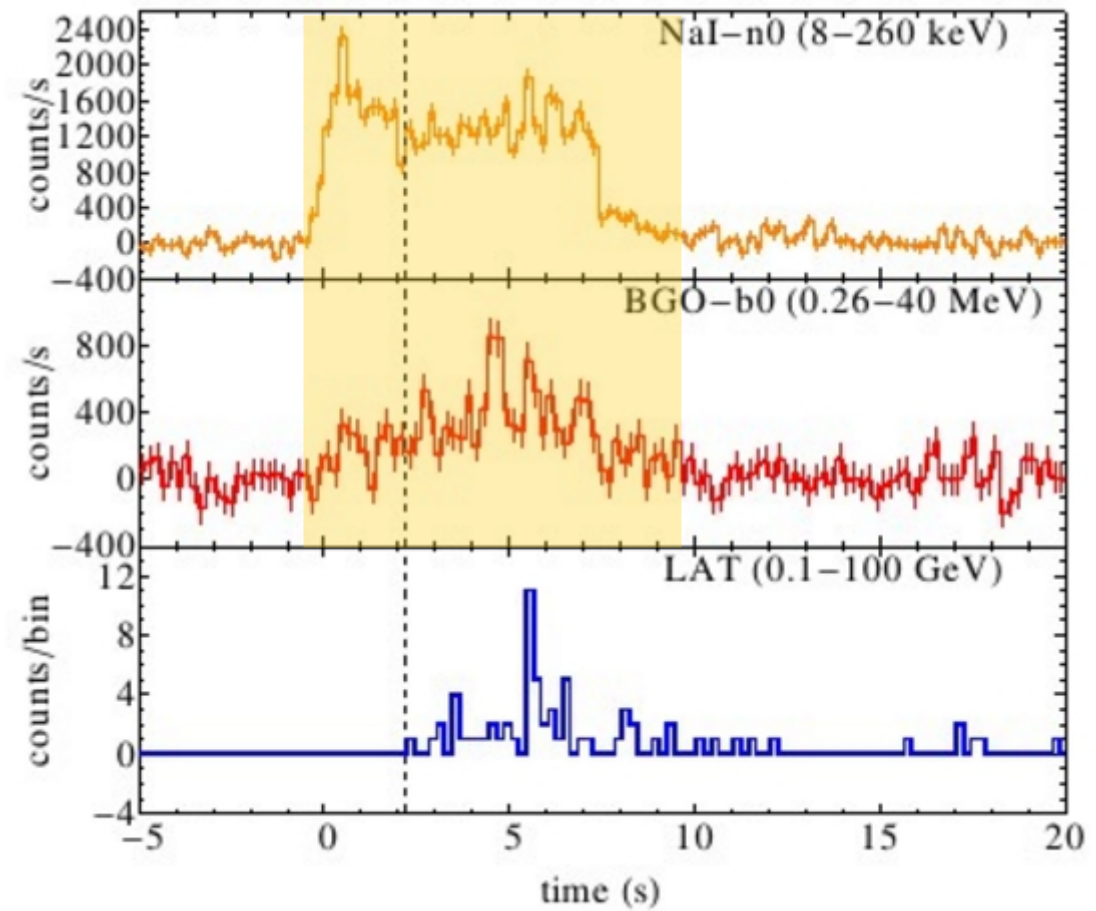
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Prompt emission and P-GRB identification



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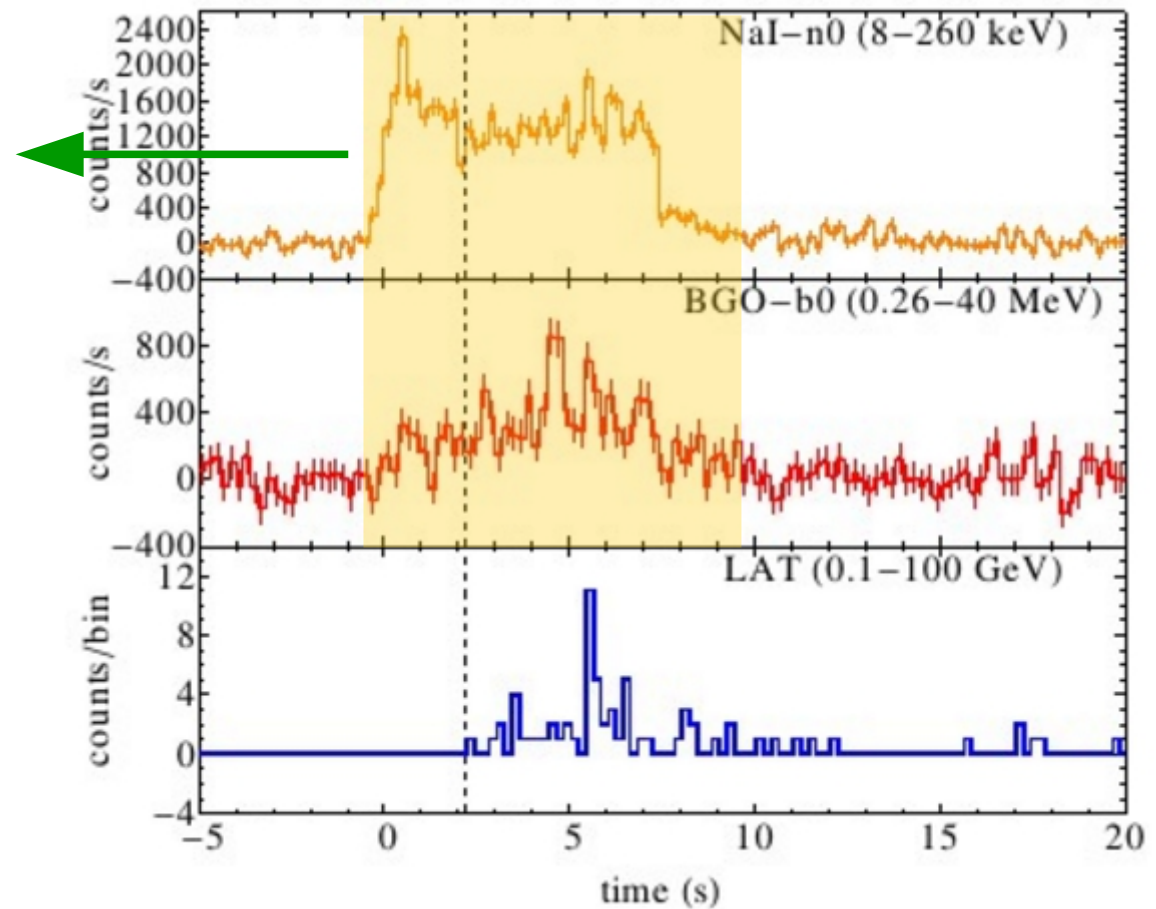


Prompt emission and P-GRB identification

Comptonized Epeak	
Amp	0.06099 ± 0.00190

Epeak	354.6 ± 13.1 keV
3σ	-34.8, 42.8
2σ	-23.9, 27.5
1σ	-12.3, 13.2

Index	-0.7816 ± 0.0278

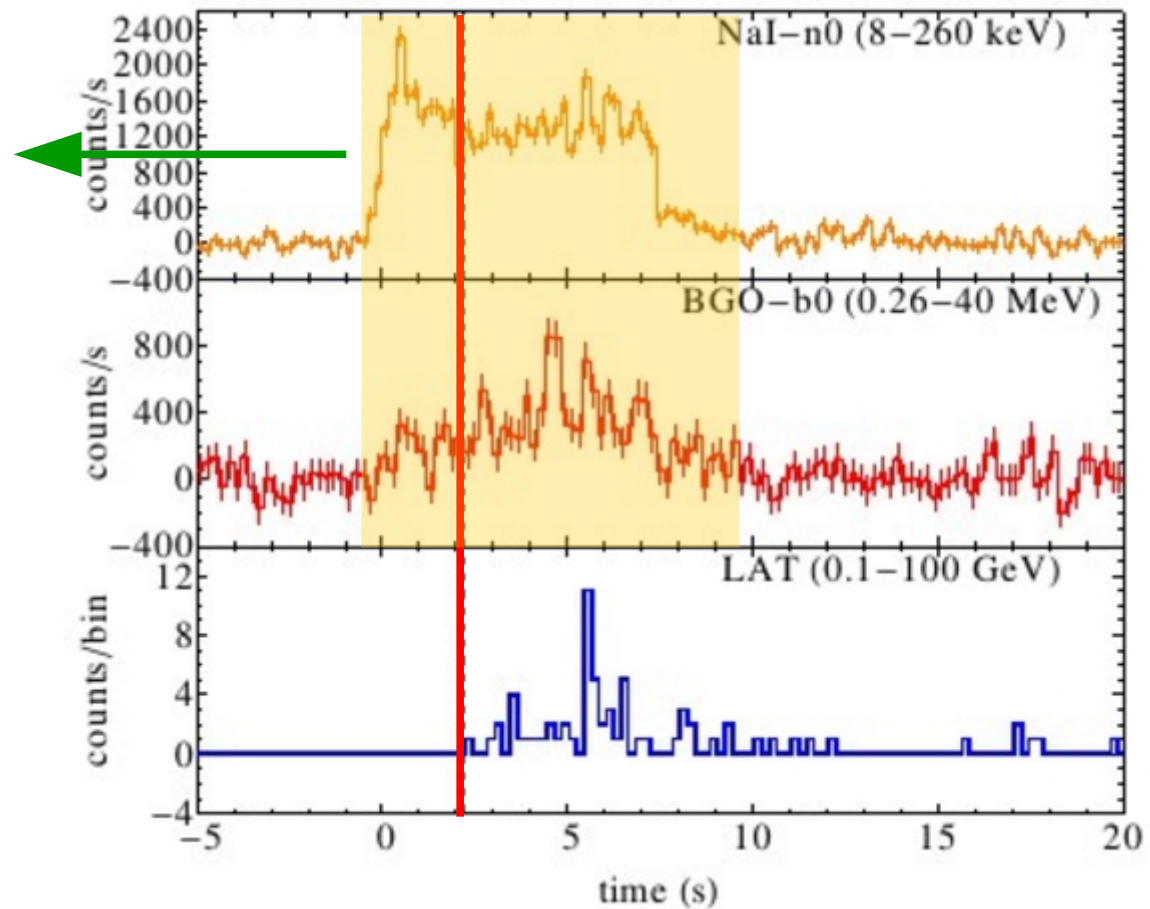


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Index	-0.7816 ± 0.0278

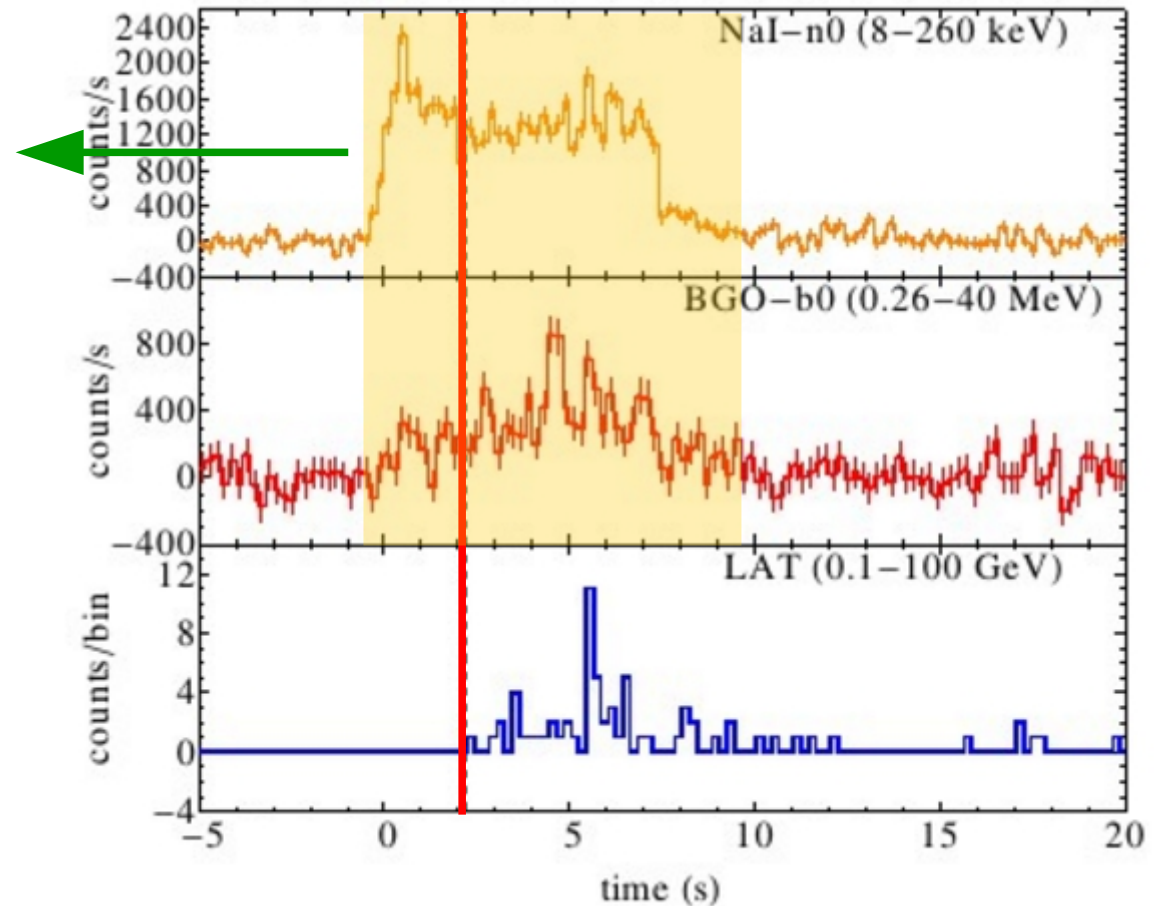


Prompt emission and P-GRB identification

Comptonized Epeak	
Amp	0.06099 ± 0.00190

Epeak	354.6 ± 13.1 keV
3σ	-34.8, 42.8
2σ	-23.9, 27.5
1σ	-12.3, 13.2

Index	-0.7816 ± 0.0278



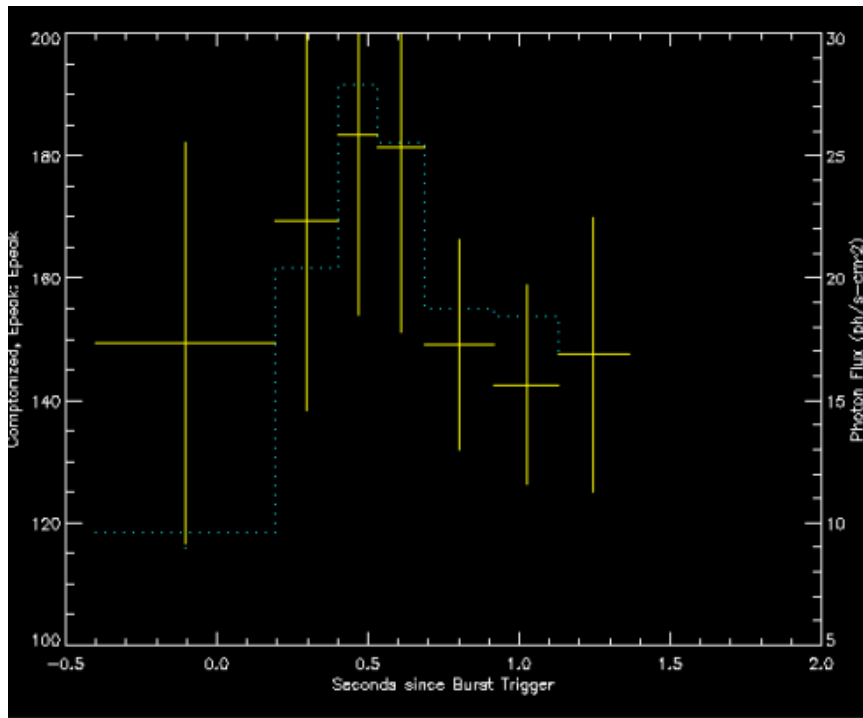
S/N = 15

MODELS: PL, PL+BB, Compt,
Compt+BB, Band, Band+BB

No single BB component

P-GRB ends around 0.7s

Prompt emission and P-GRB identification

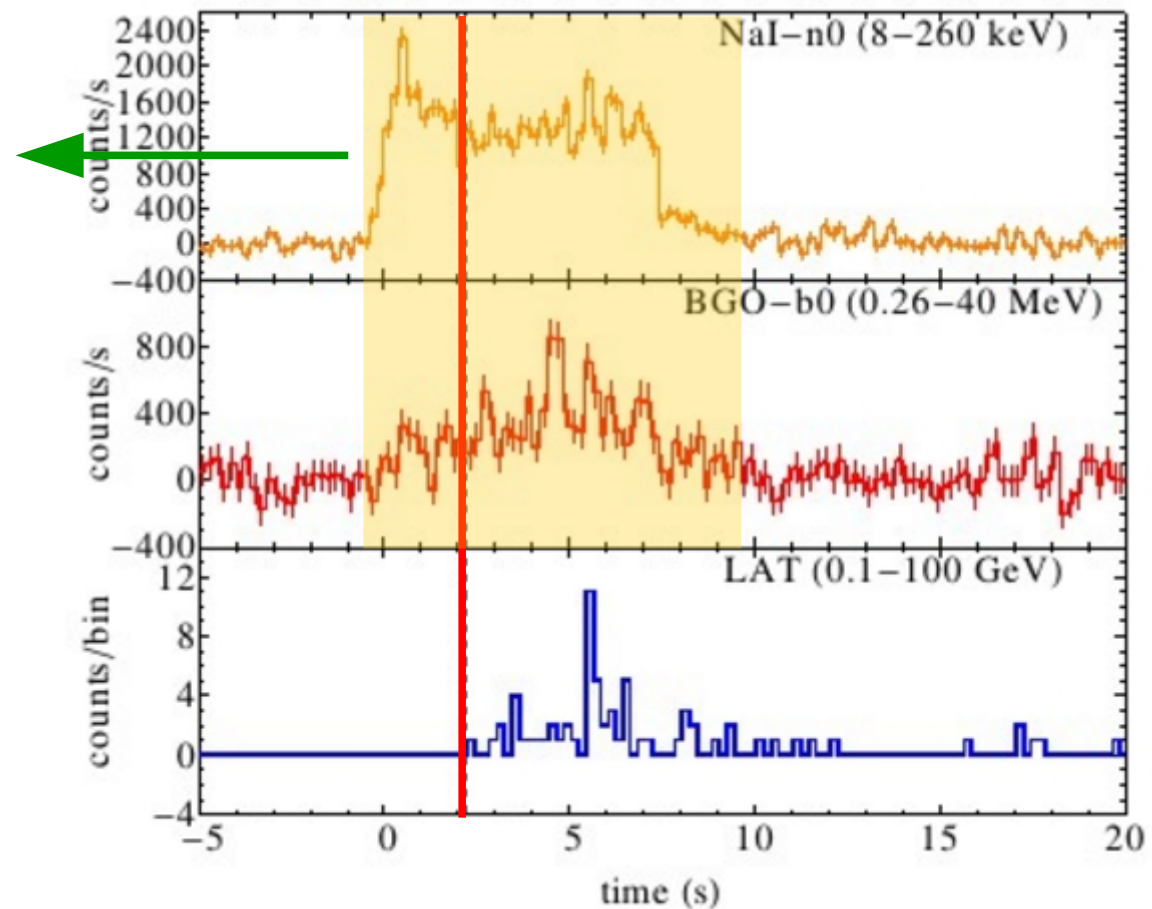


S/N = 15

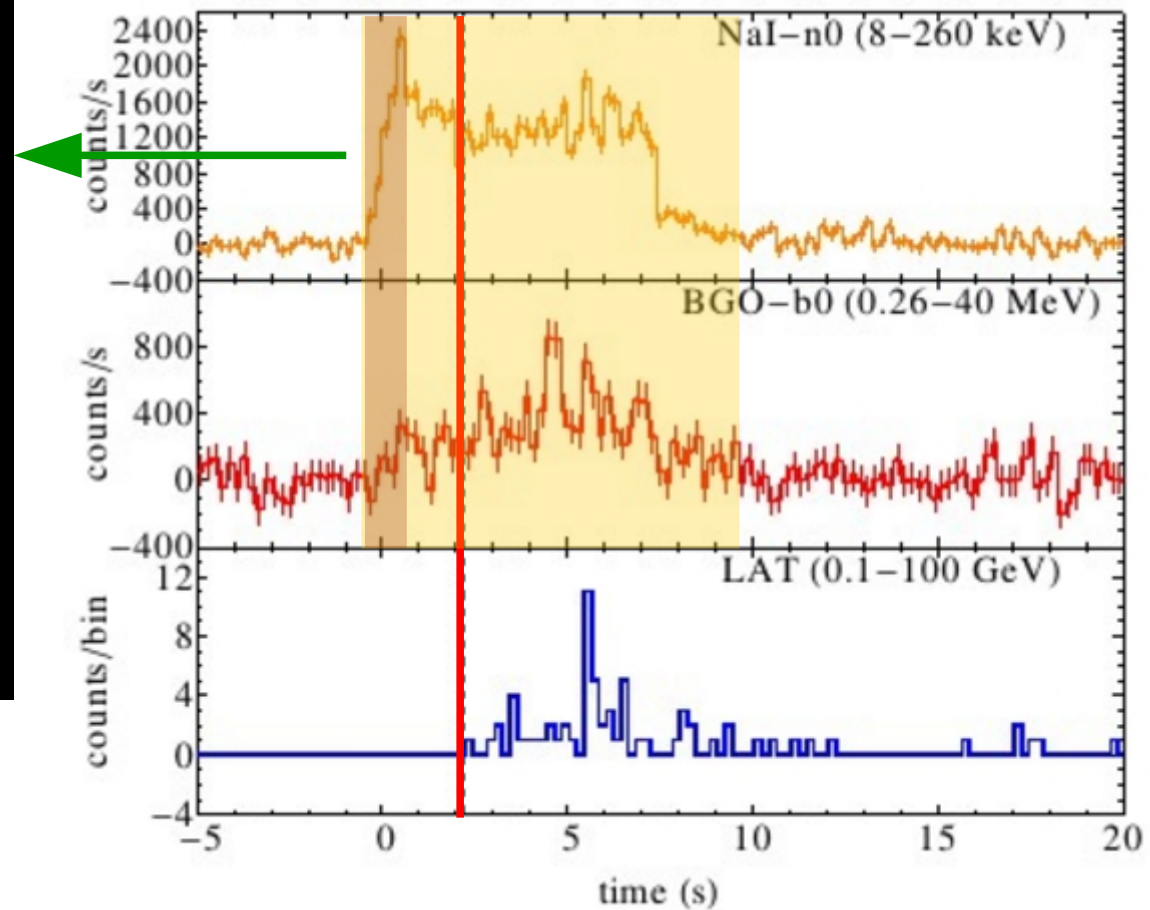
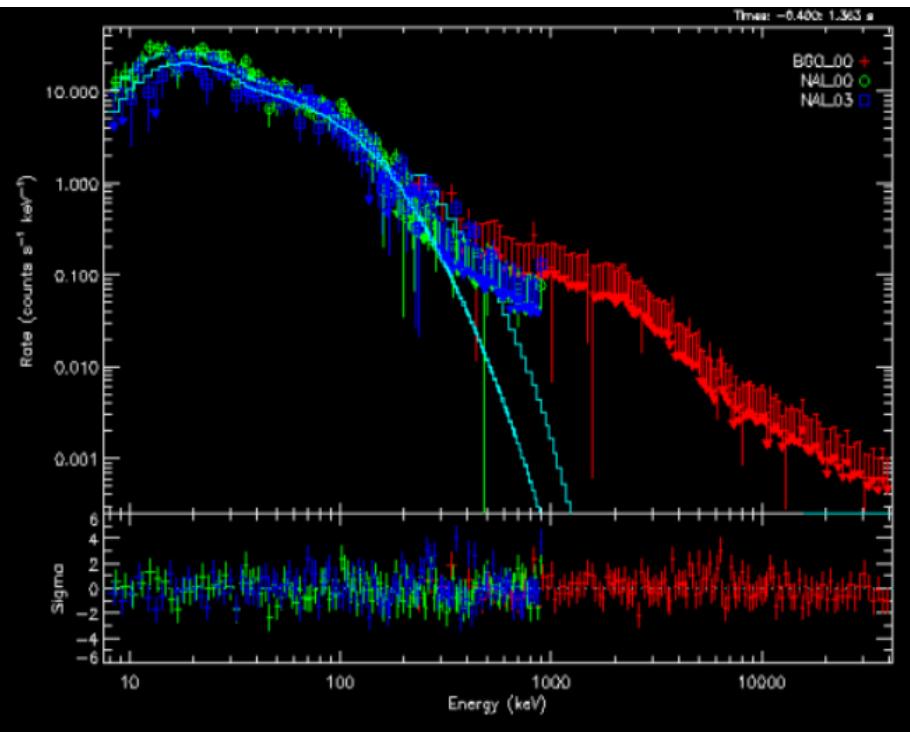
MODELS: PL, PL+BB, Compt,
Compt+BB, Band, Band+BB

No single BB component

P-GRB ends around 0.7s



Prompt emission and P-GRB identification



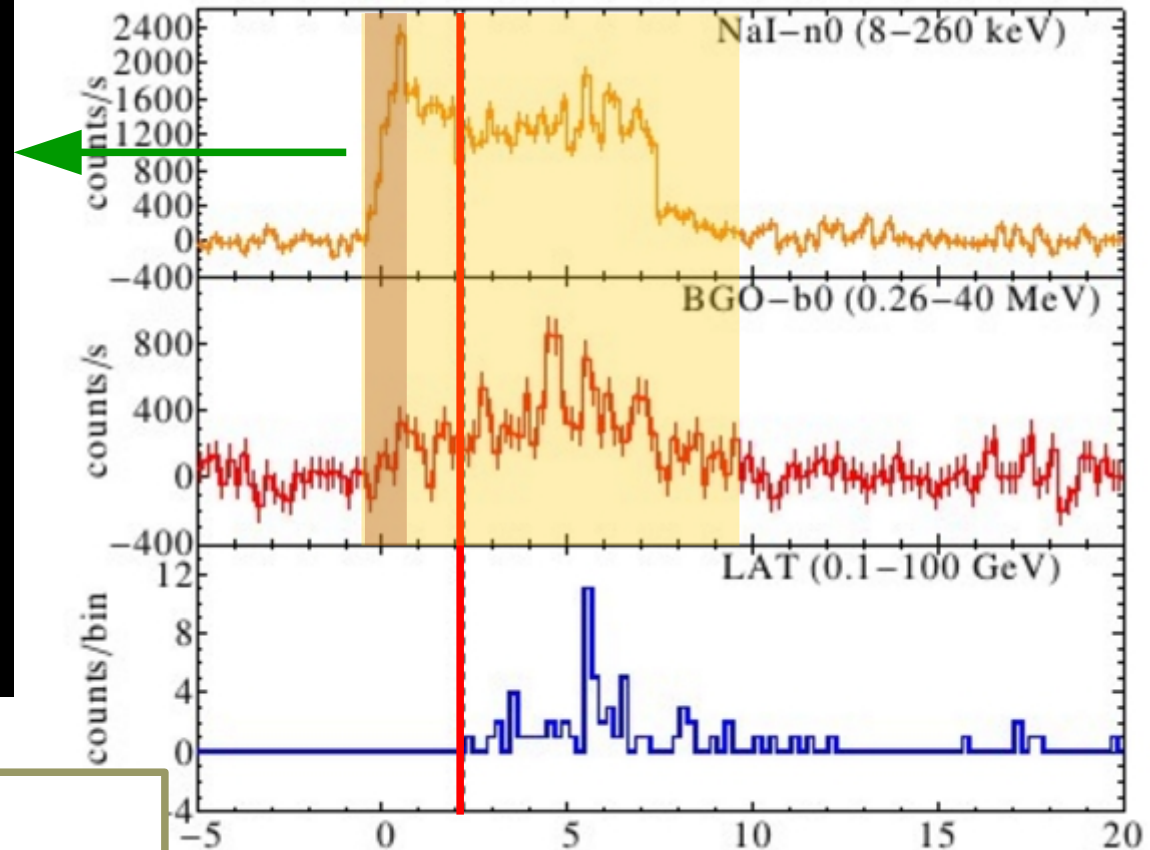
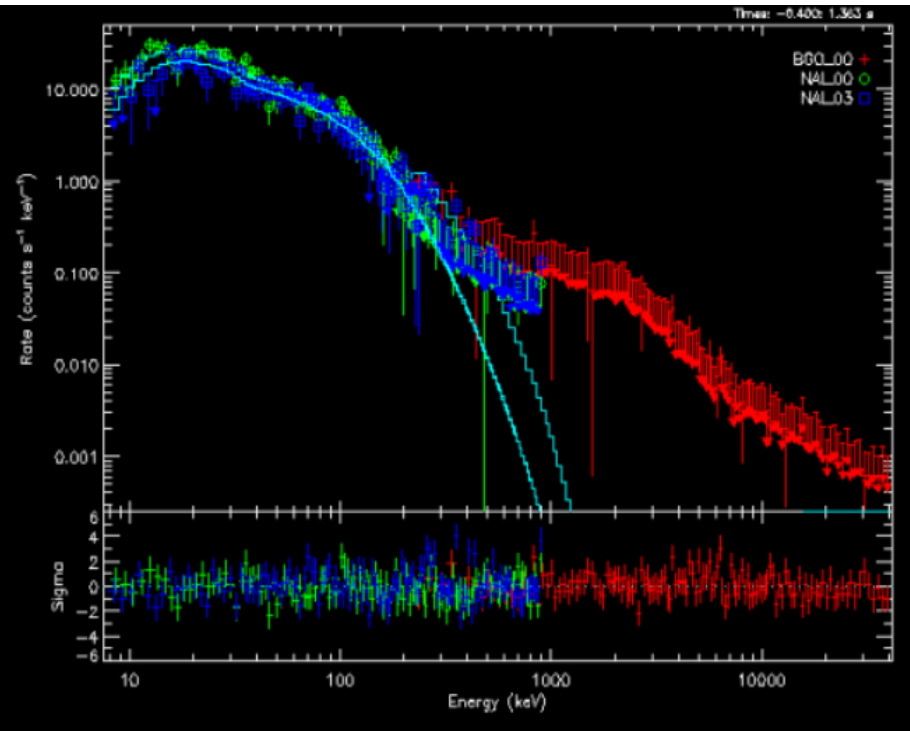
S/N = 15

MODELS: PL, PL+BB, Compt,
Compt+BB, Band, Band+BB

No single BB component

P-GRB ends around 0.7s

Prompt emission and P-GRB identification



Comptonized Epeak:

Amplitude: $0.06311 (\pm 0.00768)$ p/s-cm²-keV

E_{peak} : $171.9 (\pm 17.1)$ keV

Index: $-1.083 (\pm 0.080)$

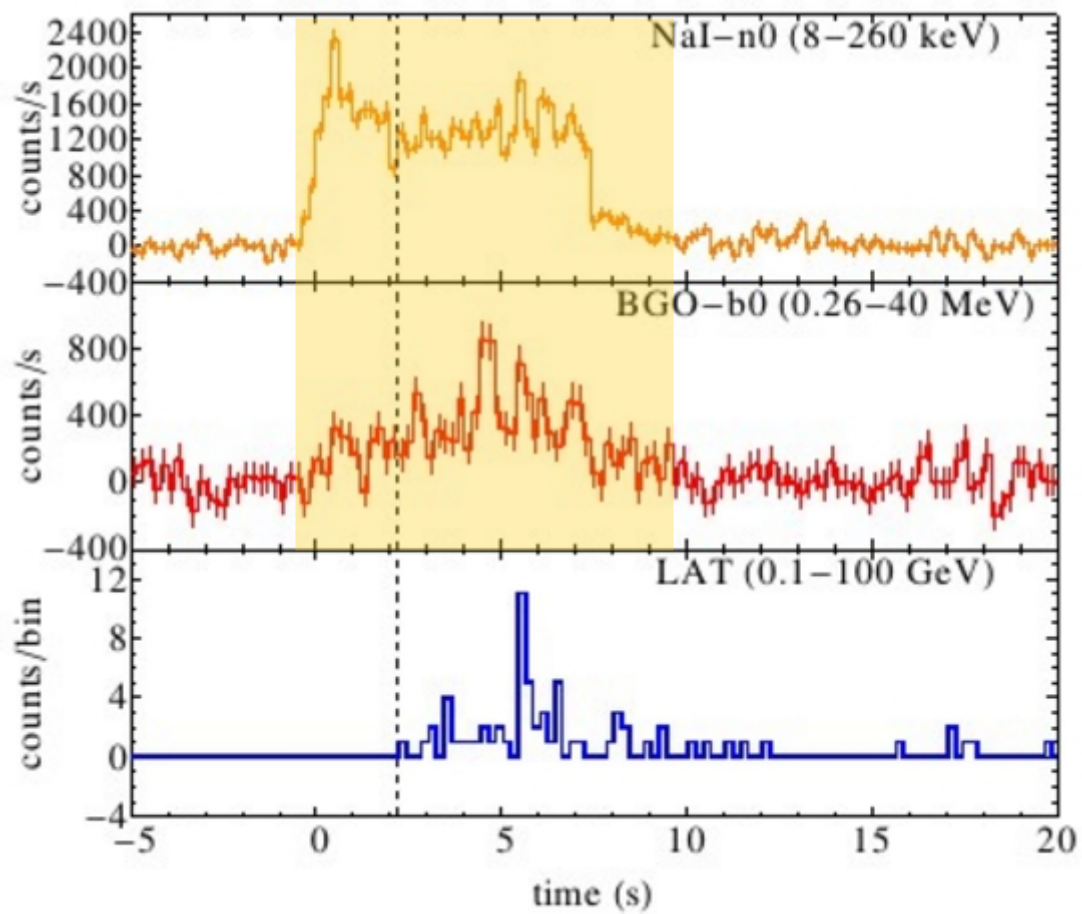
Cstat/DOF: 439.85/359

En.FLUX: $1.761 \text{ E-}06 (\pm 8.9\text{E-}08)$ erg/s-cm²

$$kT^{\text{RF}} = kT^{\text{OBS}} (1+z) = E_{\text{peak}} (1+z) / 3.92$$

$$kT^{\text{RF}} = 167.9 (\pm 16.7) \text{ keV}$$

Calculating E_{iso}



Calculating E_{iso}

Band:

Amplitude: 0.04263 (\pm 0.00191)

E_{peak} : 321.4 (\pm 21.7) keV

α : -0.910 (\pm 0.034)

B: -2.197 (\pm 0.081)

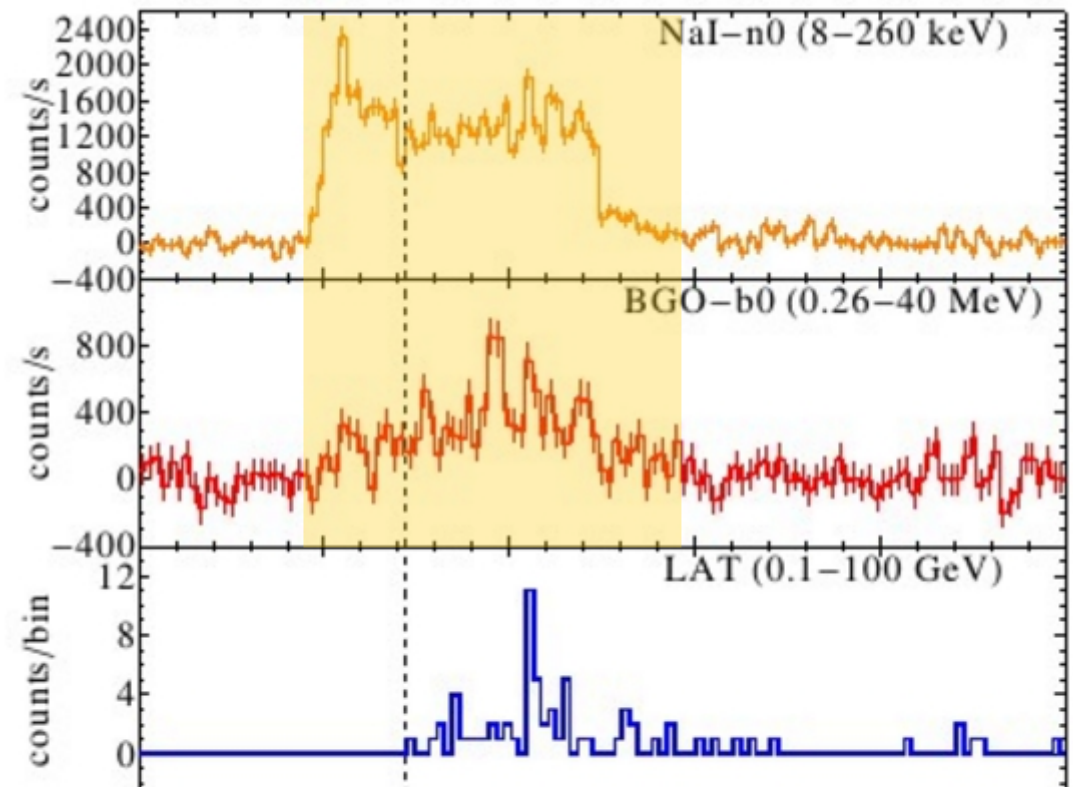
Cstat/DOF: 770.91/358

En.FLux: 2.122 E-06 (\pm 3.1E-08)

$$E_{\text{iso}} = \frac{4\pi d_L^2}{(1+z)} S_{\text{bol}},$$

$$S_{\text{bol}} = S_{\text{obs}} \frac{\int_{1/(1+z)}^{10^4/(1+z)} E\phi(E)dE}{\int_{E_{\text{min}}}^{E_{\text{max}}} E\phi(E)dE}.$$

$$E_{p,i} = E_p(1+z)$$



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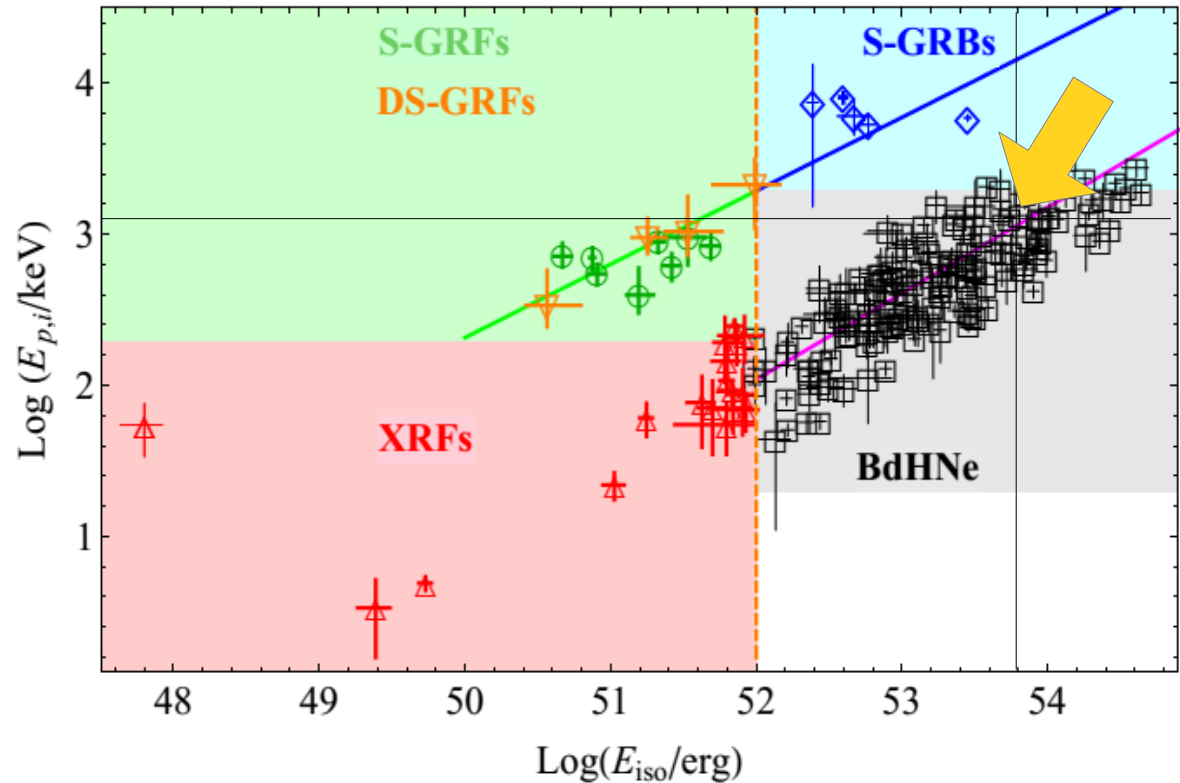
Cstat/DOF: 770.91/358

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$$E_{p,i} = E_p(1+z)$$



$$E_{\text{iso}} = 6.04917 (\pm 0.08836) 10^{53} \text{ erg}$$

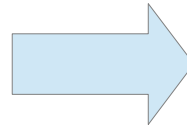
$$E_{p,i} = 1231 \text{ keV}$$

$$E_{\text{P-GRB}} = 3.6711 (\pm 0.1855) 10^{52} \text{ erg}$$

$$R = 0.060688 (\pm 0.003193)$$

Simulation - light curve - prompt emission

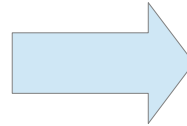
$$E_{\text{iso}} = 6.04917(\pm 0.08836) 10^{53} \text{ erg}$$
$$B = 4.35 10^{-4}$$



$$R = 0.05636$$
$$R_{+} = 0.06135$$
$$R_{-} = 0.05169$$
$$kT = 167.5 \text{ keV}$$

Simulation - light curve - prompt emission

$E_{\text{iso}} = 6.04917(\pm 0.08836) 10^{53} \text{ erg}$
 $B = 4.35 10^{-4}$



$R = 0.05636$
 $R_+ = 0.06135$
 $R_- = 0.05169$
 $kT = 167.5 \text{ keV}$

cost_max = 0.99999975d0

jmaxx = 500

nBin = 2500

nrhoism=10

0.00d00 2.25d-01

2.30d16 3.3d-02

3.85d16 0.45d-01

5.15d16 5.9d-03

8.05d16 2.7d-02

9.15d16 1.0d-03

10.50d16 1.8d-02

12.30d16 1.5d00

12.38d16 9.5d01

12.39d16 1.0d-06

ndr = 1

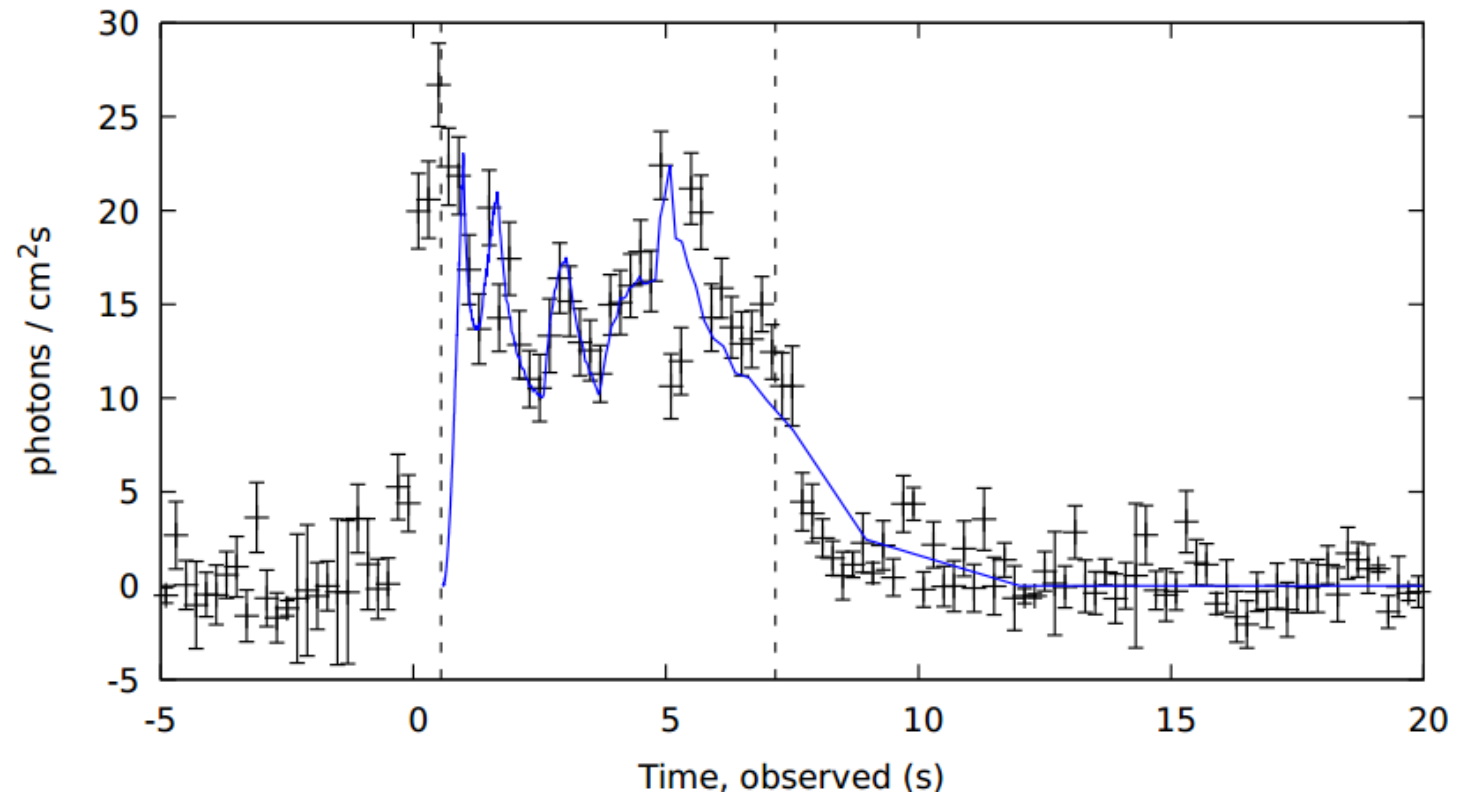
0.0 d0 1.002d0

nR = 2

0.00d00 3.5d-10

10.00d16 1.5d-9

GRB110731A



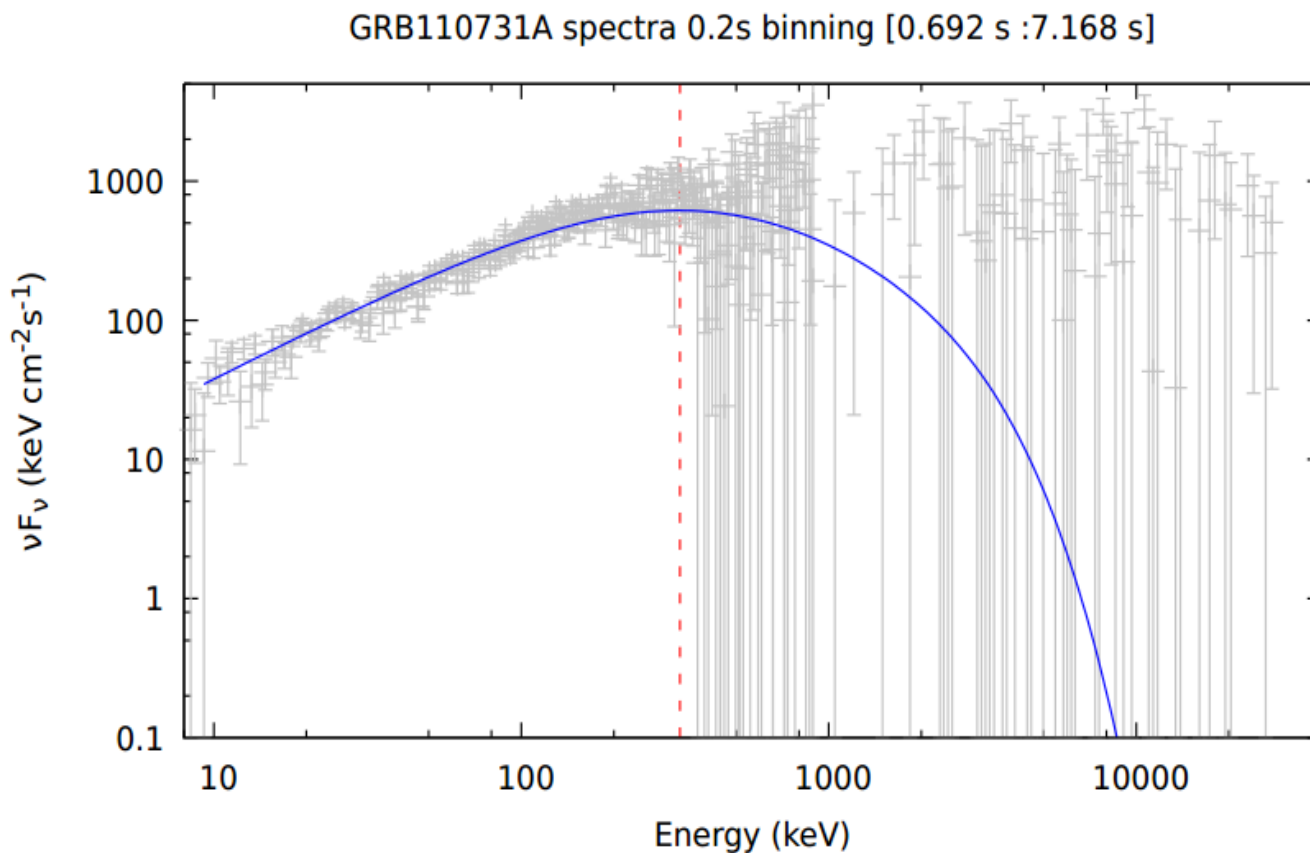
Simulated spectra

RMFIT model spectra	
Fit interval	
0.692 : 7.168	
Binning SNR 20	
Model	
Comptonized Epeak	
Amp	0.06099 ± 0.00190

Epeak	354.6 ± 13.1 keV
3σ	-34.8, 42.8
2σ	-23.9, 27.5
1σ	-12.3, 13.2

Index	-0.7816 ± 0.0278
Pivot E	100
EAC	fixed
CSTAT	578.14
DOF	359

SIMULATION	
Simulation time (s) (-0.55 s)	
Aimed	0.142 : 6.618
Achieved	0.141 : 6.447
Simulation Epeak	
327.9 keV	



Conclusion and future perspectives

- GRB 110731A is another interesting case of BdHN, exhibiting no early X-ray flare or plateau as in typical BdHNe (Ruffini et al. 2017 submitted to ApJ), suggesting that the system is very compact
- Study the GeV and X-ray emission in more detail – infer the parameters of the binary progenitor within the IGC paradigm
- Compare the observed and simulated E_{peak} evolution, determine the impact of arbitrary chosen background intervals ...
- Continue the search for new BdHNe

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THANK YOU!