GeV radiation in short GRBs

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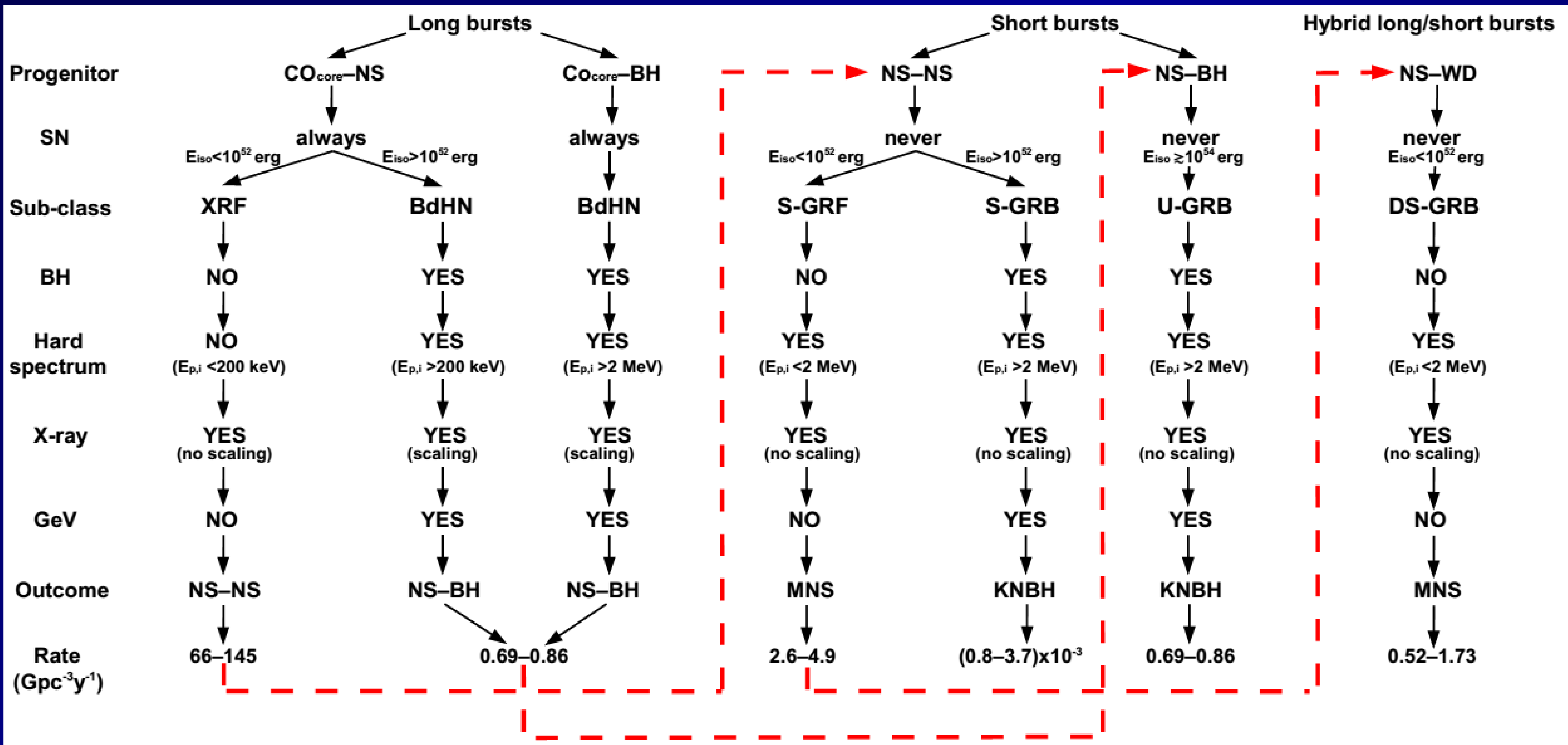
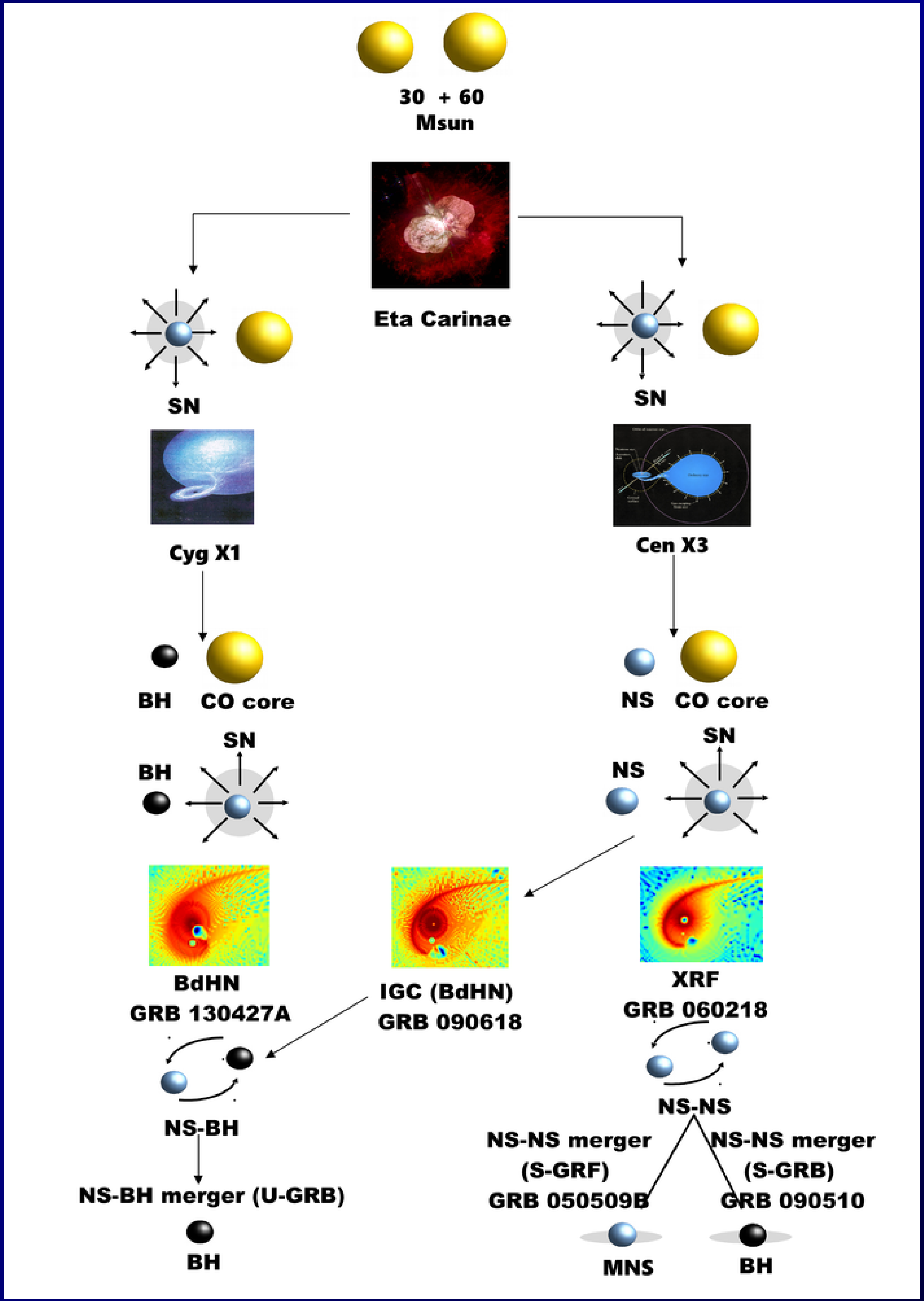
Summary: Seven Different GRB families



Ruffini, Rueda, et al., *ApJ*, 832 (2016) 136
Ruffini, Wang, et al., *ApJ*, 852 (2018) 53

A common evolutionary scenario for short and long GRBs



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Ruffini, Rueda, et al., *ApJ*, 832 (2016) 136

GeV emission in the seven families

	Sub-class	Number	*In-state*	*Out-state*	$E_{\rm p,i}$ (MeV)	$E_{\rm iso}$ (erg)	$E_{\rm iso,Gev}$ (erg)
I	S-GRFs	18	NS-NS	MNS	~ 0.2–2	$\sim 10^{49}$–10^{52}	–
II	S-GRBs	6	NS-NS	BH	~ 2–8	$\sim 10^{52}$–10^{53}	$\gtrsim 10^{52}$
III	XRFs	48	$CO_{\rm core}$-NS	νNS-NS	~ 0.004–0.2	$\sim 10^{48}$–10^{52}	–
IV	BdHNe	327	$CO_{\rm core}$-NS	νNS-BH	~ 0.2–2	$\sim 10^{52}$–10^{54}	$\gtrsim 10^{52}$
V	BH-SN	4	$CO_{\rm core}$-BH	νNS-BH	$\gtrsim 2$	$> 10^{54}$	$\gtrsim 10^{53}$
VI	U-GRBs	0	νNS-BH	BH	$\gtrsim 2$	$> 10^{52}$	–
VII	GRFs	1	NS-WD	MNS	~ 0.2–2	$\sim 10^{51}$–10^{52}	–

Table 2
Summary of the GRB subclasses from (Ruffini et al. 2016b). In addition to the subclass name, we list the number of GRBs for each subclass updated by the end of 2016. We also summarize the "in-state" representing the progenitors and the "out-state", as well as the $E_{\rm p,i}$ and $E_{\rm iso}$ for each subclass. We indicate the GeV emission in the last column, which is uniquely for the BdHNe and BH-SN (in the case of long GRBs) and for the S-GRBs (in the case of short GRBs). In all of these events the GeV emission is greater than 10^{52}erg.

Ruffini, et al. arXiv:1802.07552

Short Gamma-Ray Flashes (S-GRFs) (E_{iso}<10^{52} erg, no BH formed)

Group	S-GRF	z	E_p keV	E_{iso} (10^{50} erg)	Fermi GCN	θ (deg)	GeV observed	Comments
No *Fermi* Observation	090426	2.609		44.5 ± 6.6	–	–	no	
	090515	0.403		0.094 ± 0.014	–	–	no	
	100724A	1.288		16.4 ± 2.4	–	–	no	
	101219A	0.718		48.8 ± 6.8	–	–	no	
	120804A	1.3		70.0 ± 15.0	–	–	no	46^{day} x-ray (GCN 13841)
	130603B	0.356		21.2 ± 2.3	–	–	no	**kilonova** (GCN 14893, 14895, 14913)
	140622A	0.959		0.70 ± 0.13	–	–	no	
	140903A	0.351		1.41 ± 0.11	–	–	no	
Outside Boresight Angle	090927	1.37	408.64	7.6 ± 3.5	GCN 9974	85.0	no	
	100117A	0.915	625.73	78.0 ± 10.0	GCN 10345	86.0	no	
	100625A	0.453	701.81	7.50 ± 0.30	GCN 10912	125.0	no	
	131004A	0.717	202.45	12.7 ± 0.9	GCN 15315	93.0	no	
	141004A	0.573	268.99	21.0 ± 1.9	GCN 16900	100.4	no	
Inside Boresight Angle	080905A	0.122	443.12	6.58 ± 0.96	GCN 8204	28.0	no	
	100206A	0.408	748.34	4.67 ± 0.61	GCN 10381	44.7	no	
	111117A	1.31	857.40	34.0 ± 13.0	GCN 12573	12.0	no	
	150101B	0.134	141.88	0.4	GCN 17276	44.0	no	Fong et al. (2015), 39^{day} x-ray (GCN 17431)
	160821B	0.16	97.44	1.2	GCN 19843	61.0	no	**kilonova**

Table 3

List of 18 *short gamma-ray flashes (S-GRFs)* divided in three different groups: 1) without *Fermi*-LAT observation (upper group); 2) with the *Fermi*-LAT observation but the boresight $\theta \geq 75°$, and 3) those within the *Fermi*-LAT boresight angle (lower group, $\theta < 75°$). None of the S-GRFs have associated GeV emission detected. In the first column we indicate the name of the source, in the second their redshift, in the third column the $E_{p,i}$ deducible from the *Fermi* data, in the fourth column we estimate the E_{iso} which is systematically lower than the 10^{52} erg. For the convenience we also add both the specific GCN of the *Fermi* source as well as the boresight angle of the LAT observation. We also note the non-observation of the Gev emission. The last column contains comments about Kilonova emission. The symbol "–" indicates no information on the LAT boresight angle due to the lack of GBM observation.

Ruffini, et al. arXiv:1802.07552

Short Gamma-Ray Bursts (S-GRBs) (E_{iso}>10^{52} erg, BH formed)

Source	z	$E_{p,i}$ (MeV)	E_{iso} (10^{52} erg)	Fermi GCN	E_{LAT} (10^{52} erg)	θ (deg)	TS	*comments*
081024B	3.12	9.56 ± 4.94	2.64 ± 1.00	8407, 8408	$\gtrsim 2.79 \pm 0.98$	18.7	111	
090227B	1.61	5.89 ± 0.30	28.3 ± 1.5	8921	< 2.56	71	30	
090510A	0.903	7.89 ± 0.76	3.95 ± 0.21	9334, 9336	$\gtrsim 5.78 \pm 0.60$	13.6	1897	possible **kilonova**
140402A	5.52	6.1 ± 1.6	4.7 ± 1.1	16069, 16070	$\gtrsim 4.5 \pm 2.2$	13	45	
140619B	2.67	5.34 ± 0.79	6.03 ± 0.79	16419, 16420	$\gtrsim 2.34 \pm 0.91$	32	149	
160829A	4.373	0.92 ± 0.34	2.56 ± 0.22	19879	$\gtrsim 3.39 \pm 2.95$	14.8	30.5	

Table 5

List of 6 S-GRBs within the Fermi-LAT boresight angle. All of these events have associated GeV photons: prompt and GeV emission properties of S-GRBs. In the first column we indicate the name of these sources. The second column gives their redshift. The third column gives the $E_{p,i}$ deduced from the best fit model of the *Fermi*-GBM and remarkably different from those observed in S-GRFs. The fourth column gives the associated *Fermi* GCN number. In 5 column we estimate the characteristic E_{iso}, which is systematically larger than the lower limit of 10^{52} erg. Column 6 shows the value of E_{LAT} deduced from the *Fermi*-LAT. Column 7 shows the position of the source from the LAT boresight θ. Column 8 is the likelihood test statistic (TS).

Ruffini, et al. arXiv:1802.07552

GeV Emission in S-GRBs

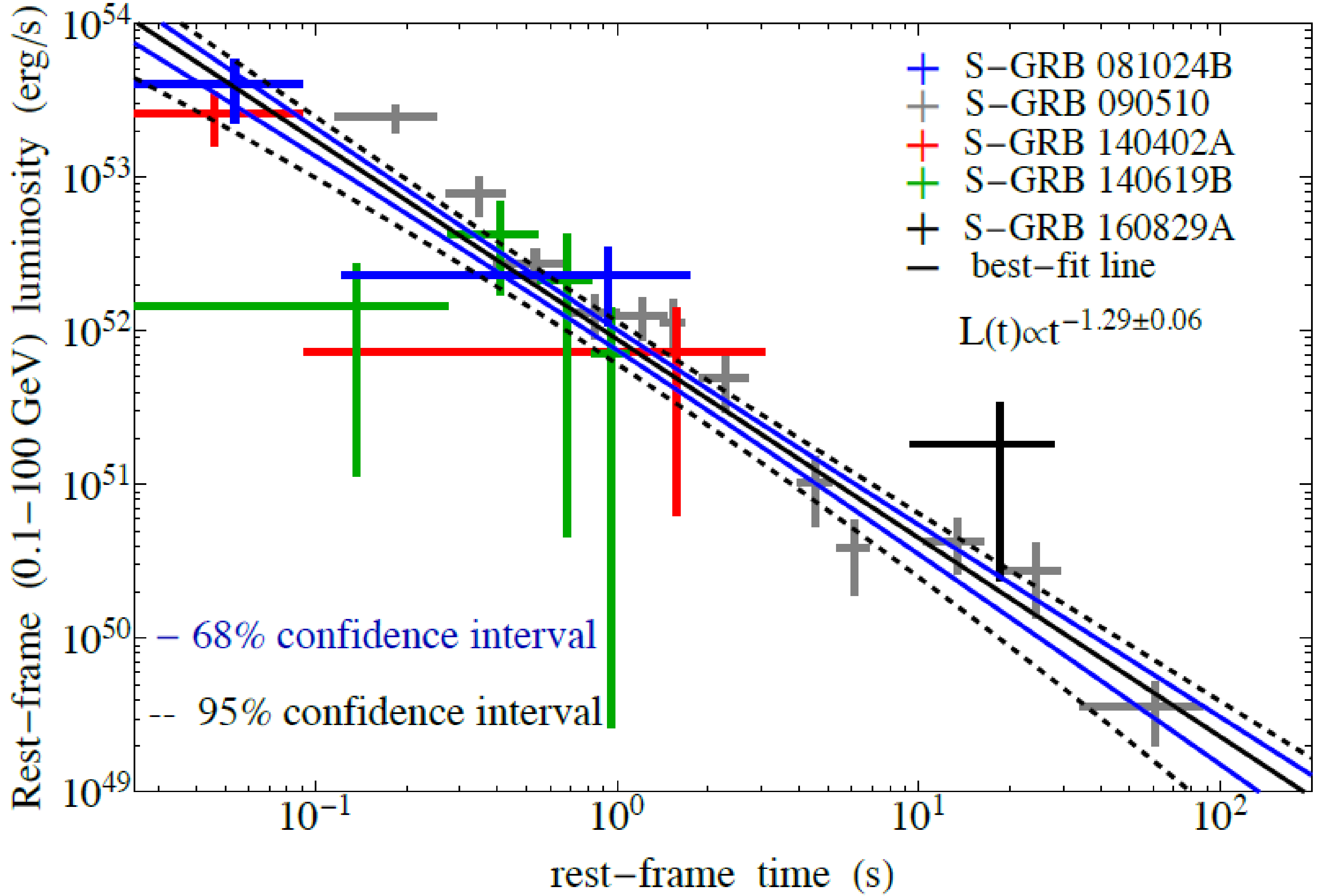


Figure 2. The rest-frame 0.1–100 GeV isotropic luminosity light-curves of all S-GRBs with LAT emission. The black line indicate the common power-law behavior of the GeV emission with the slope of $\gamma = -1.29 \pm 0.06$.

Ruffini, et al. arXiv:1802.07552

NS Critical Mass for different EOSs

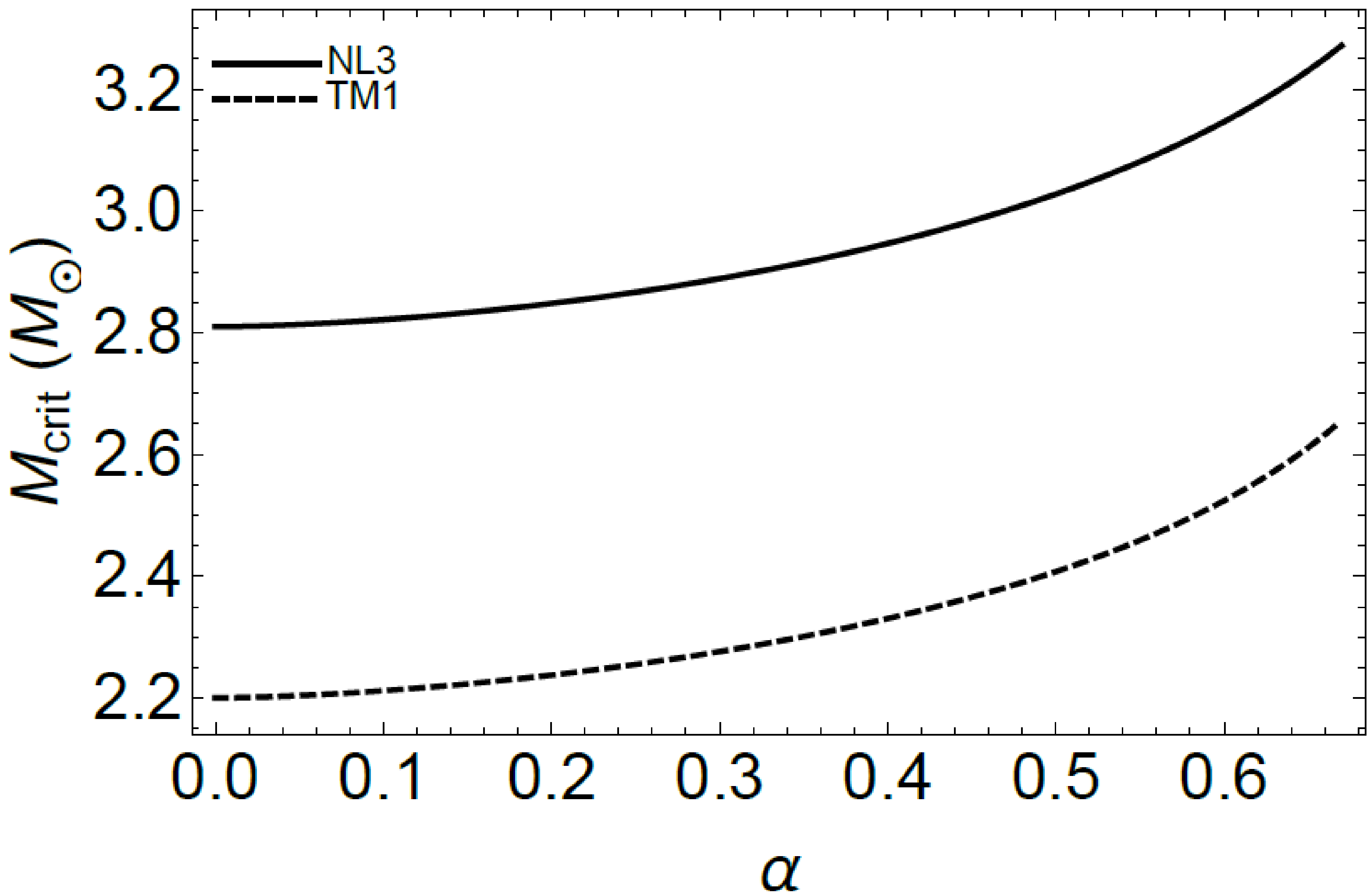


Figure 3. NS critical mass as a function of the spin parameter α for the NL3 and TM1 EOS. We recall that the maximum spin parameter of a uniformly rotating NS is $\alpha_{max} \approx 0.7$, independently of the NS EOS; see e.g. Cipolletta et al. (2015).

Ruffini, et al. arXiv:1802.07552

Inferring BH Mass and spin in S-GRBs from their GeV emission

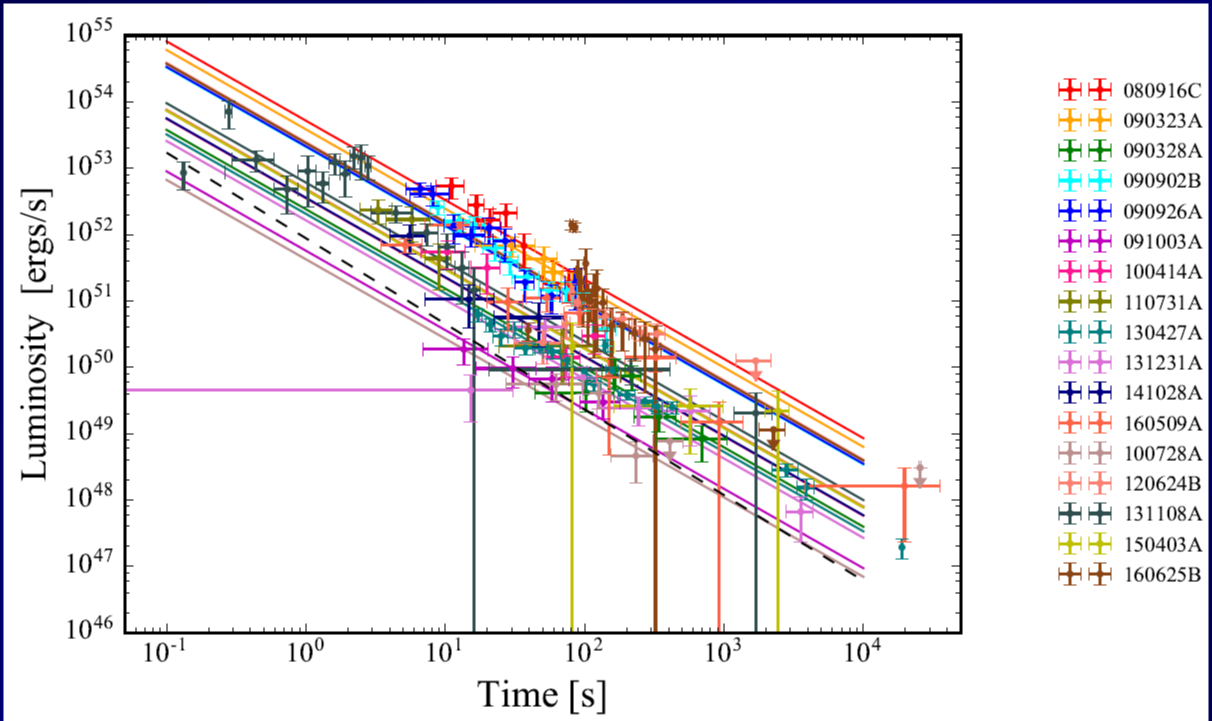
Source	TM1 α	TM1 $M(\alpha)$ ($M_\odot$)	NL3 α	NL3 $M(\alpha)$ ($M_\odot$)
S-GRB 081024B	$0.23^{+0.04}_{-0.04}$	$2.25^{+0.01}_{-0.01}$	$0.21^{+0.03}_{-0.04}$	$2.85^{+0.01}_{-0.01}$
S-GRB 090227B	–	–	–	–
S-GRB 090510A	$0.33^{+0.02}_{-0.02}$	$2.29^{+0.01}_{-0.01}$	$0.30^{+0.01}_{-0.01}$	$2.89^{+0.01}_{-0.01}$
S-GRB 140402A	$0.29^{+0.06}_{-0.08}$	$2.27^{+0.03}_{-0.03}$	$0.26^{+0.05}_{-0.07}$	$2.87^{+0.03}_{-0.03}$
S-GRB 140619B	$0.21^{+0.04}_{-0.05}$	$2.24^{+0.01}_{-0.02}$	$0.19^{+0.04}_{-0.05}$	$2.85^{+0.01}_{-0.01}$
S-GRB 160829A	$0.29^{+0.10}_{-0.18}$	$2.27^{+0.05}_{-0.06}$	$0.26^{+0.09}_{-0.17}$	$2.87^{+0.04}_{-0.05}$

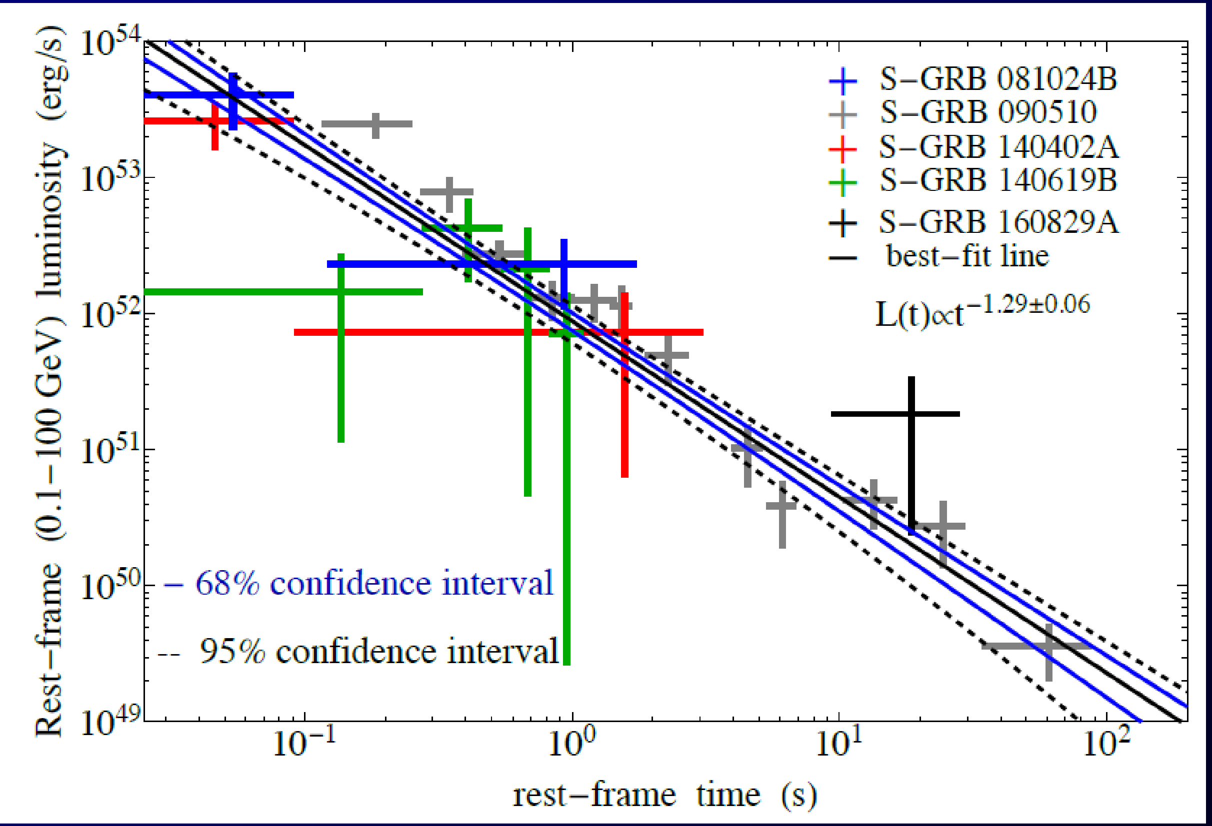
Table 6

Minimum mass and corresponding maximum spin parameters of the newly-formed BH, as inferred from the values of $E_{\rm LAT}$ for all S-GRBs in Fig. 2, and for the TM1 and the NL3 nuclear equations of state.

Ruffini, et al. arXiv:1802.07552

GeV emission in BdHNe and S-GRBs





Ruffini, Rueda, et al., *ApJ*, 832 (2016) 136
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