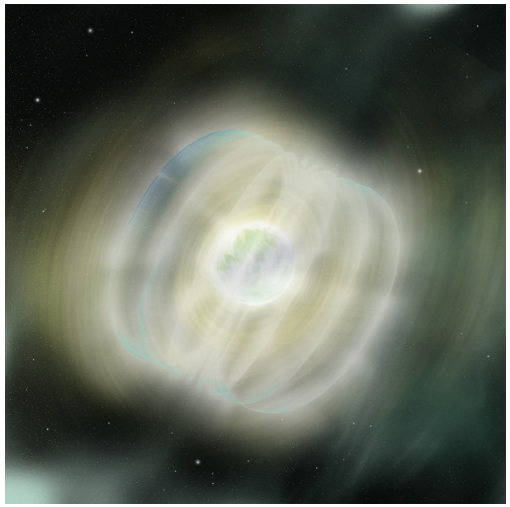
Are short GRBs powered by magnetars?



Paul O'Brien

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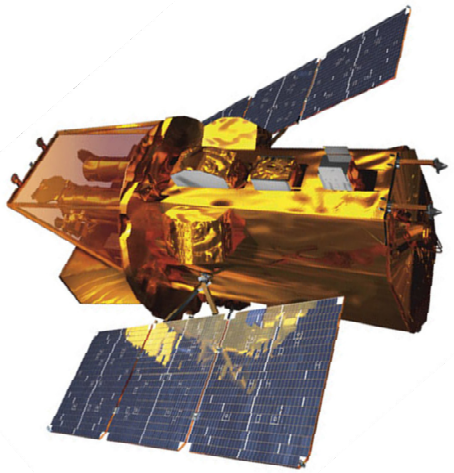


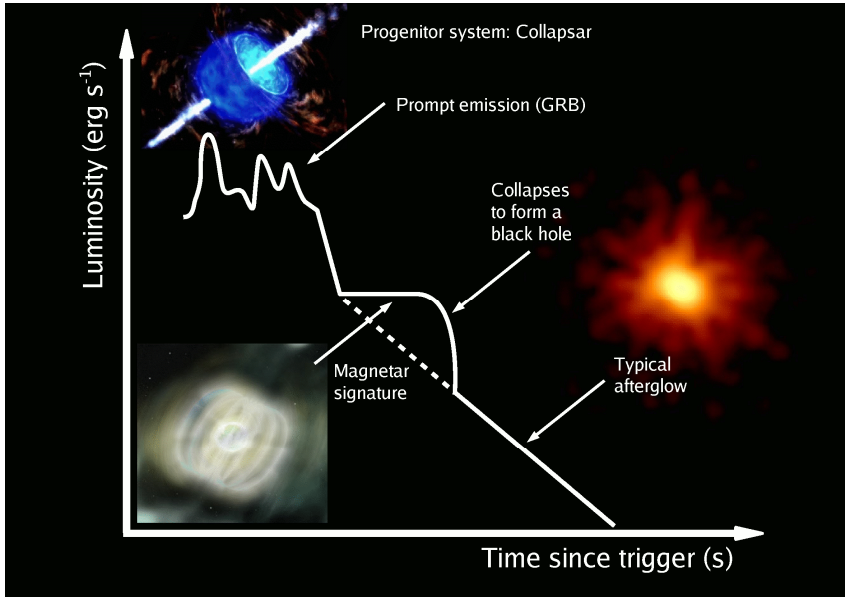
with thanks to Antonia Rowlinson, Nicola Lyons, Brian Metzger & Bing Zhang

GRB magnetar models

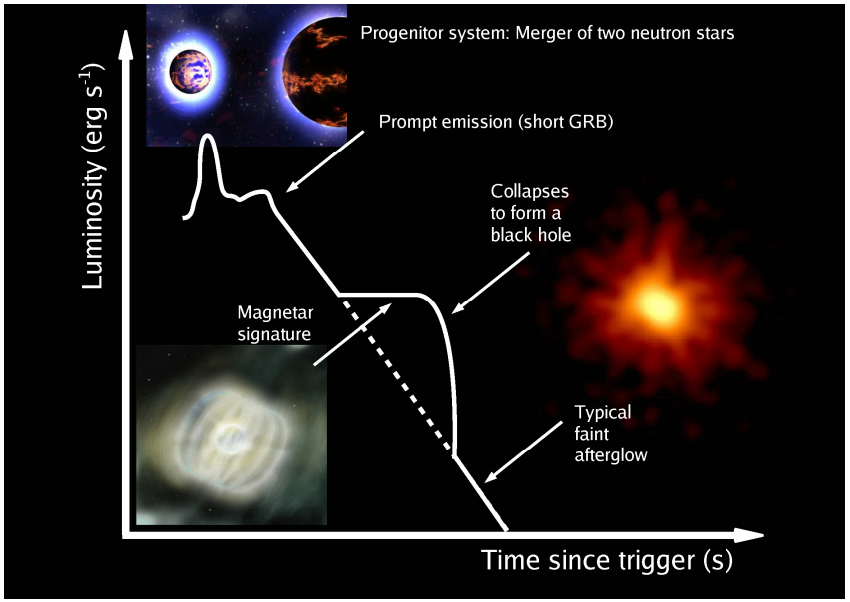
Some GRBs may be powered by an unstable, millisecond pulsar (a magnetar) (e.g., Usov 1992; Duncan & Thompson 1992; Dai et al. 2006 Metzger 2009; Metzger et al. 2011; Ozel et al 2010 – high mass merger remnant)

Fast rotation plus very strong magnetic field may power a jet (and hypernova)

Extraction of rotational energy ⇒ inject energy into the light curve ⇒ rapid decline when the magnetar collapses to a BH (Zhang & Mészáros 2001)



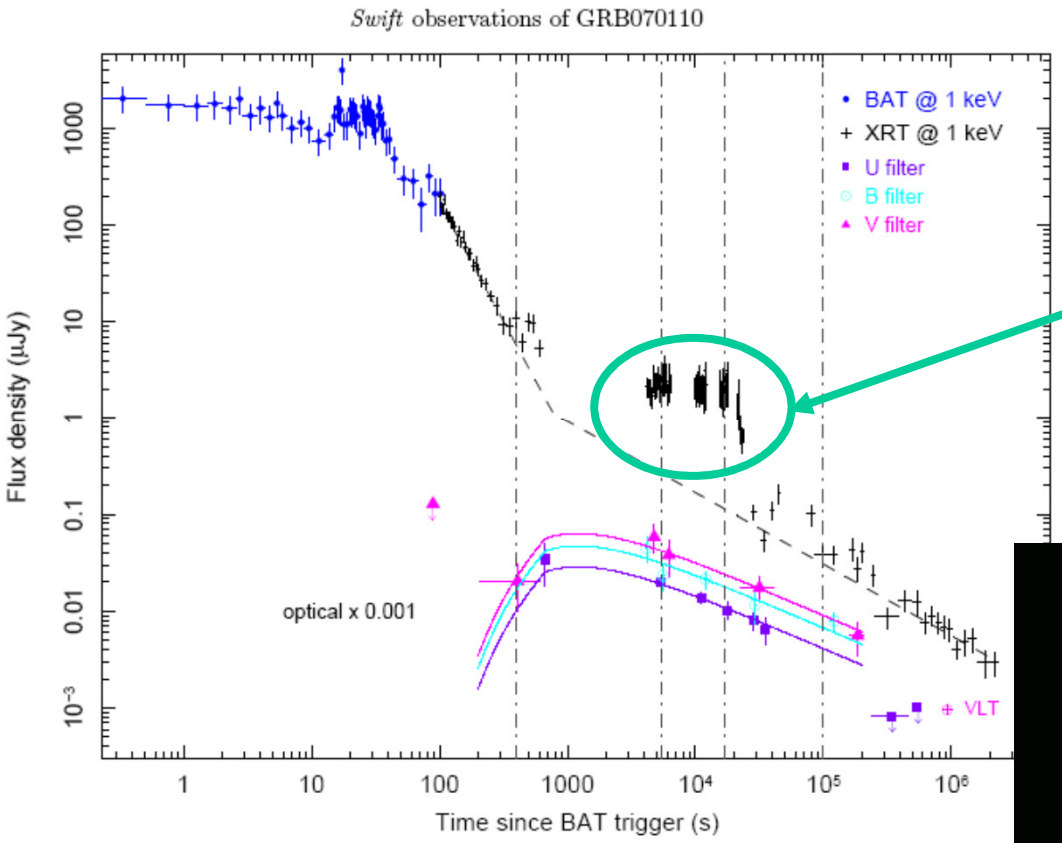
Collapsar – LGRBs



Binary Merger – SGRBs

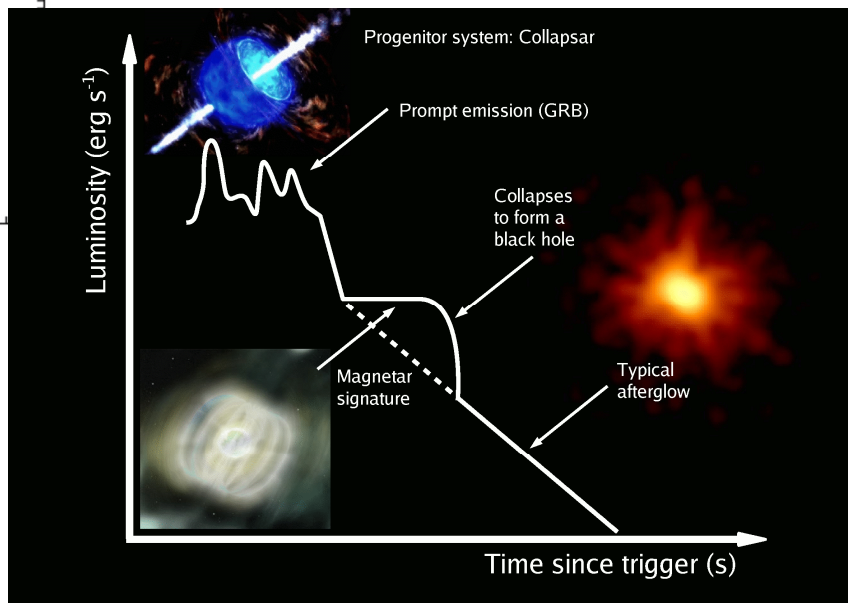
GRB 070110: magnetar l.c.?

(Troja et al. 2007)



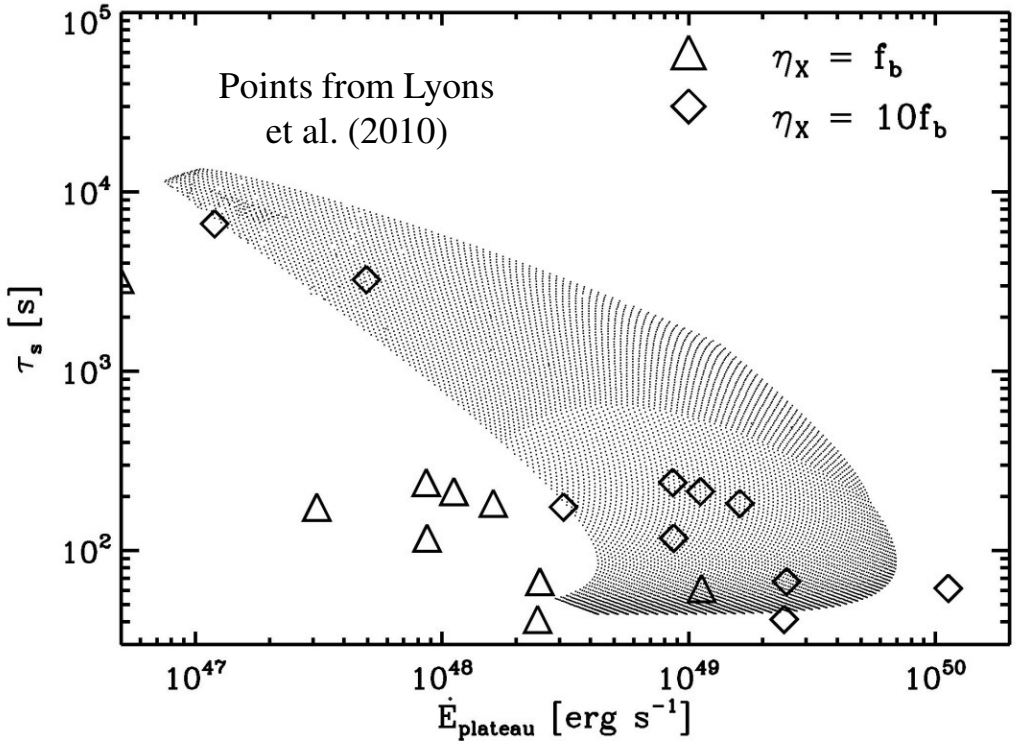
See a late excess or "internal plateau" followed by a very steep decay in X-rays.

Not seen in the optical.



Lyons, O'Brien et al. (2010) found 10 such candidates (LGRBs) to end 2008.

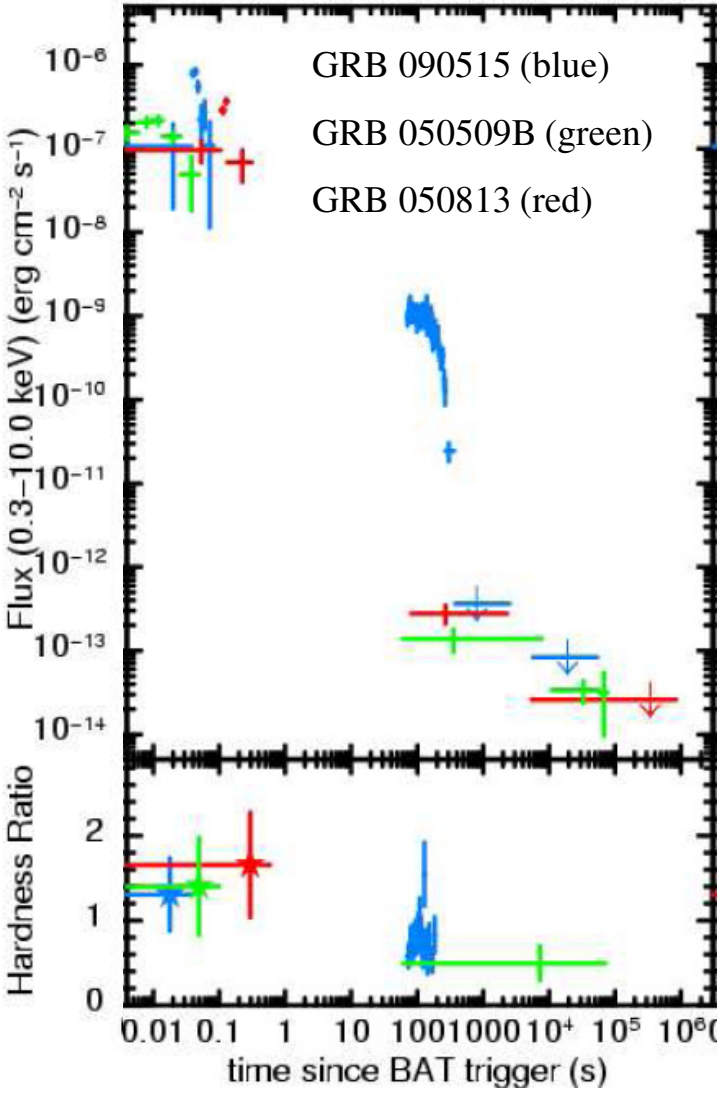
Compare with magnetar model



Observed LGRB internal plateaus are broadly consistent with the magnetar model wind power as presented by Metzger et al. (2011)

GRB 090515 – a short magnetar?

(Rowlinson, O'Brien et al. 2010)



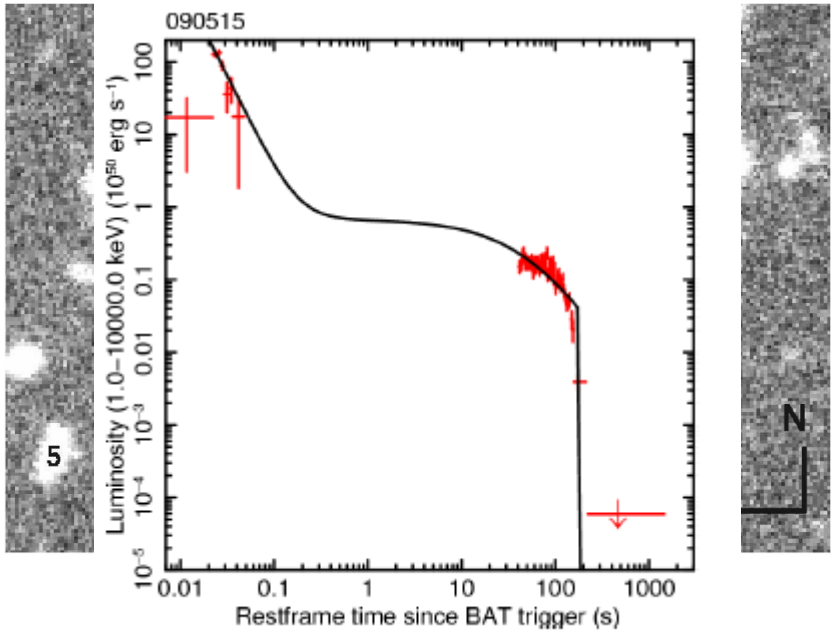
T90 = 0.036s

Fluence = 2×10^{-8} erg s^{-1} (15-150 keV)

Brightest short GRB in X-rays at 100s

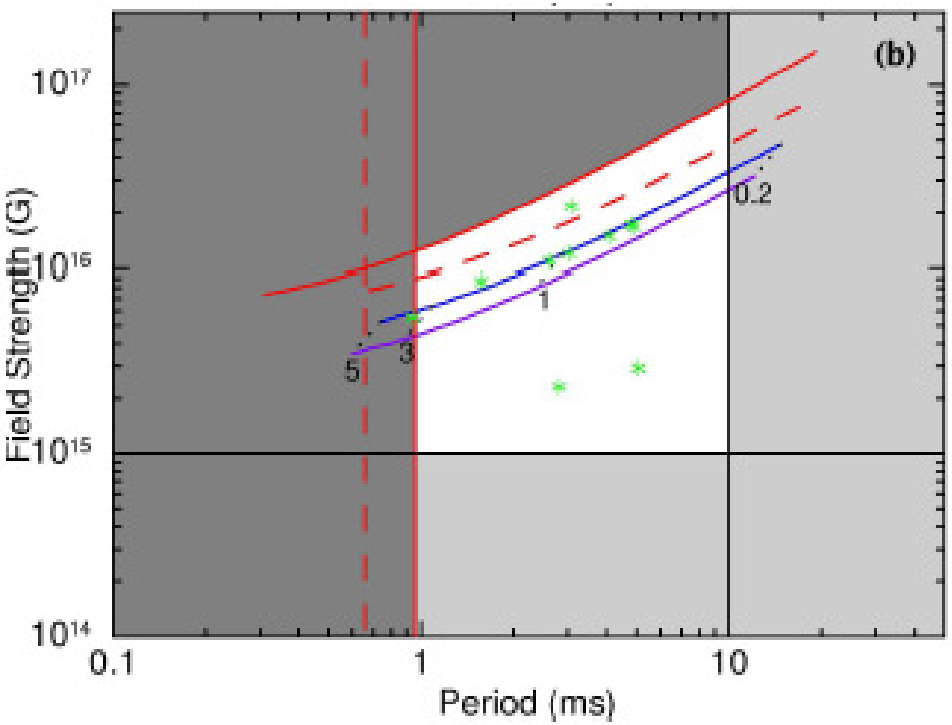
Very unusual given low γ-ray fluence

Very faint optical transient seen (r=26.4 at ~2hr)



Magnetar model fit assuming z~0.7

GRB 090515 and the long GRBs



Blue and purple lines: 090515 at various z for a neutron star of 1.4 or 2.1 $M_{\odot}$.

Red lines: impose causality limit

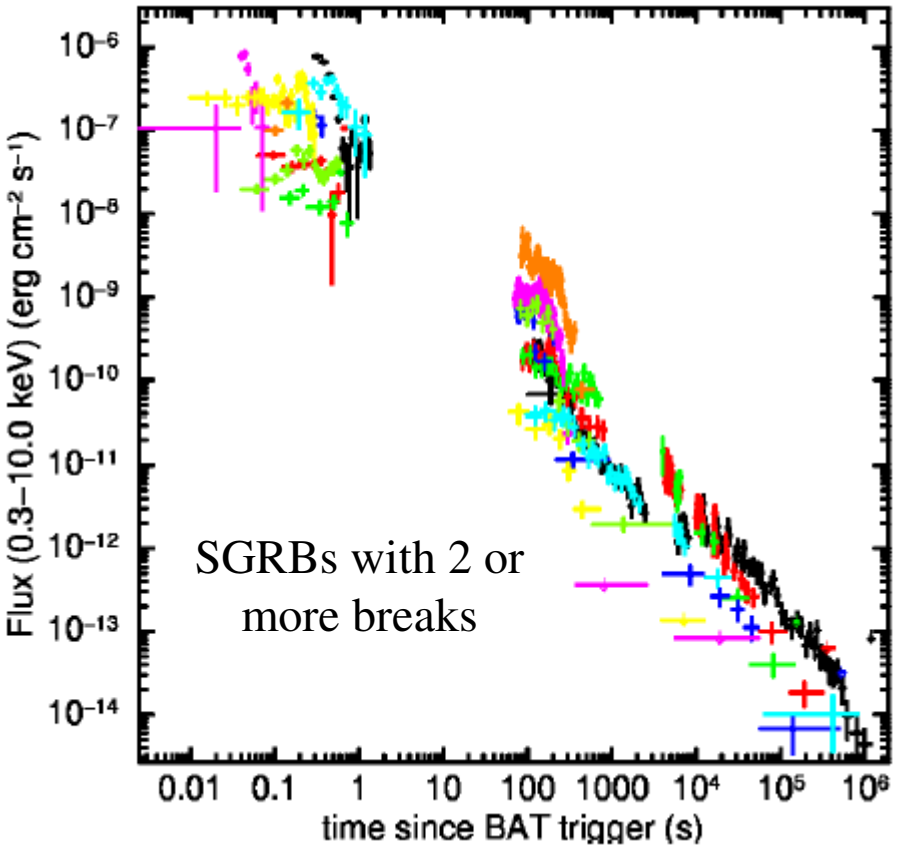
Green points: LGRBs (Lyons et al. 2010)

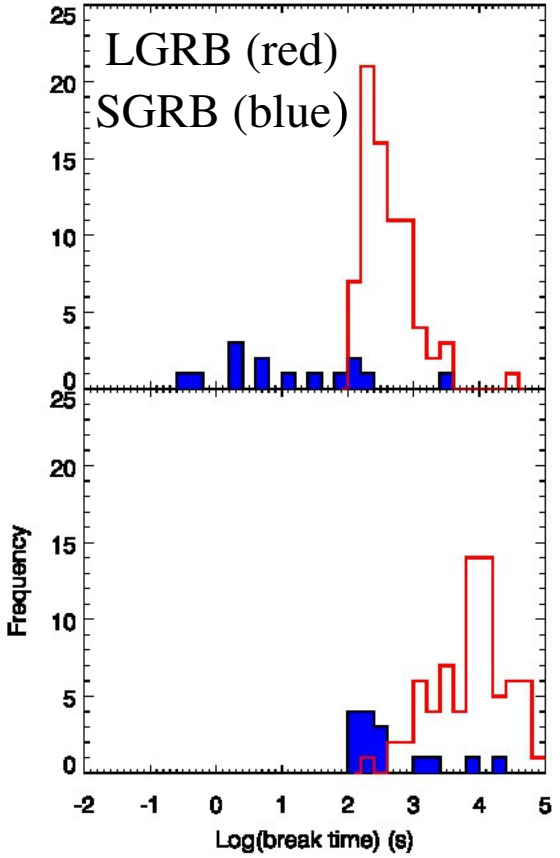
$$L \propto B_p^2 / P_0^4 \quad \text{and} \quad T_{em} \propto P_0^2 / B_p^2$$

Expected relation between the pulsar initial spin period (P_0), dipole field strength (B_p), luminosity (L) and the characteristic timescale (T_{em}) for spin-down

SGRB sample
(Rowlinson, O'Brien, Metzger, 2012,)

- 41 SGRBs up to January 2012, 37 of which were detected
- 27/37 have sufficient data to try a magnetar model fit





Example magnetar fits

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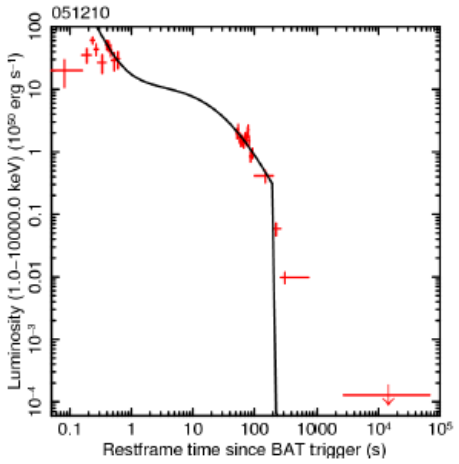
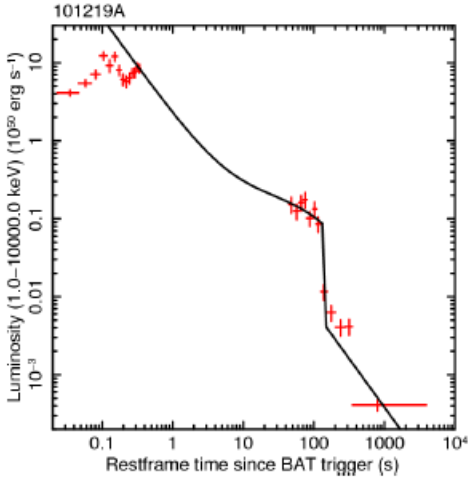
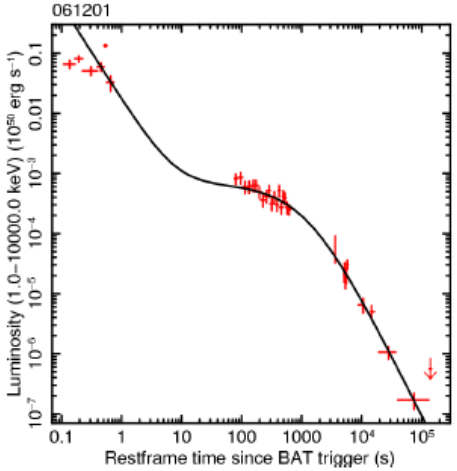
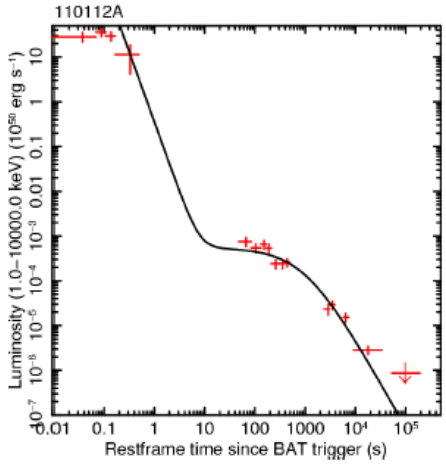
Collapse to BH



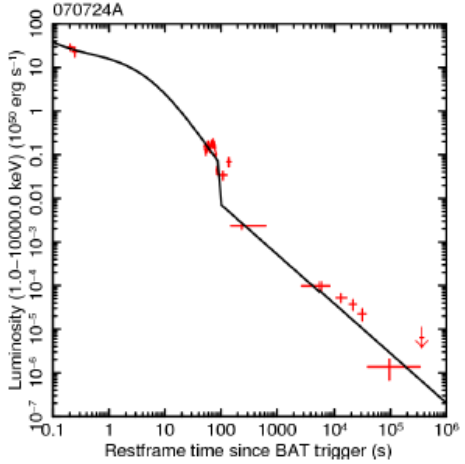


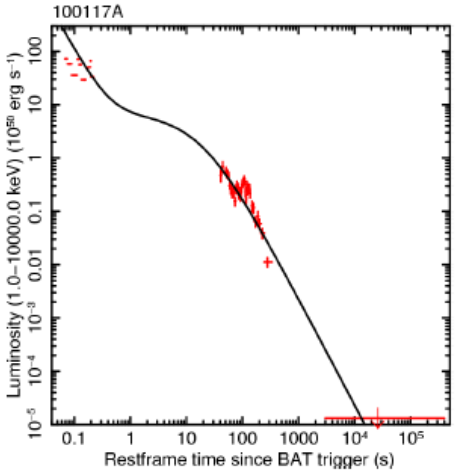
Magnetar survives



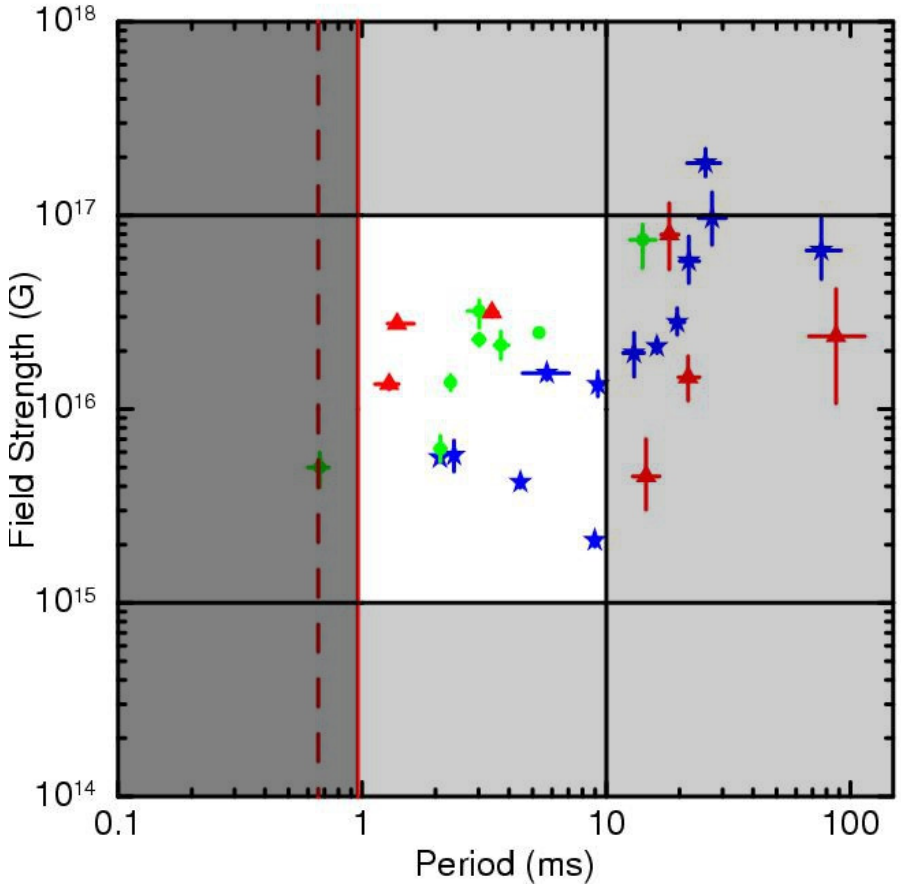


Unclear





Derived magnetar parameters



Blue: stable magnetar

Green: unstable magnetar

} 20/27 = 74%

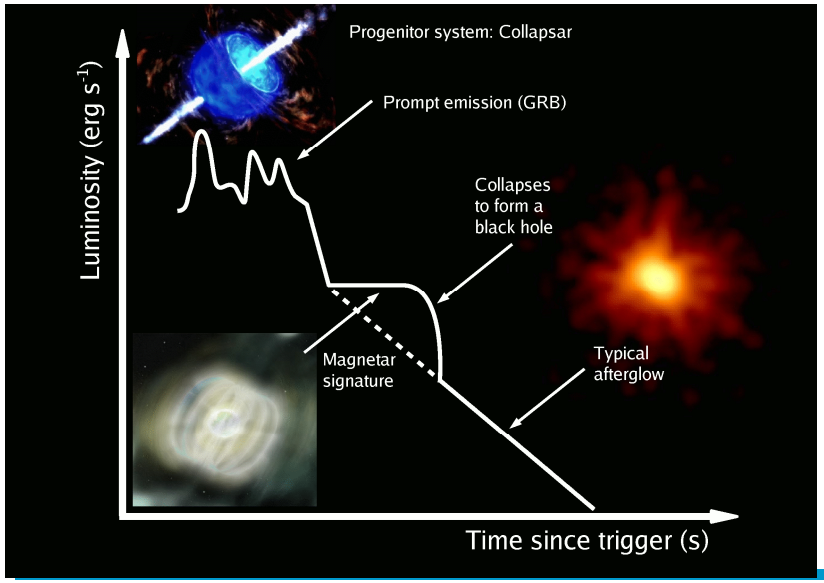
Red: poor/uncertain fit

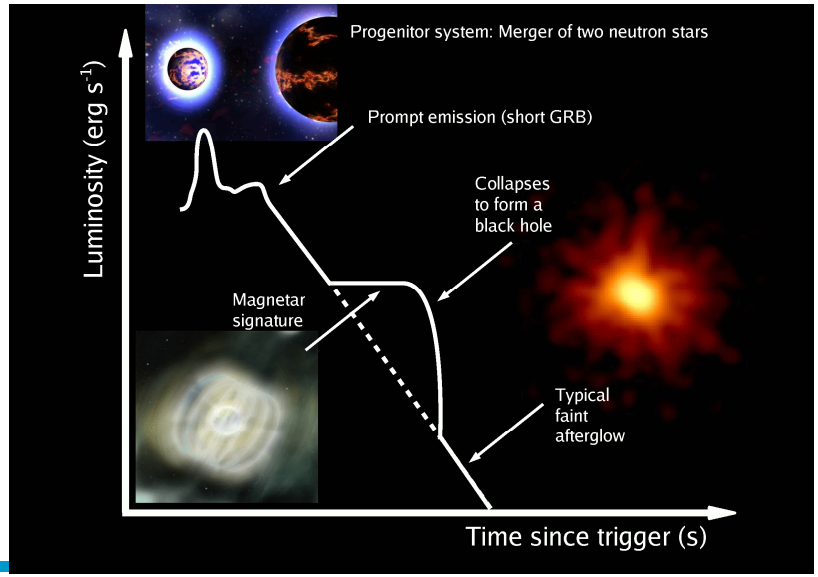
Derive B ~10^{16} G and periods ~few msec

Extreme values and unclear if they can be achieved theoretically, but…

Test model using gravity waves?

Phase	Amplitude (h)	A-LIGO limit (Mpc)	Einstein limit (Mpc)
NS-NS Inspiral	4×10^{-24} (Abadie et al 2010)	445	5900
Magnetar (spin down)	$<1.7 \times 10^{-23}$ (Corsi & Mezsaros 2009)	<85	<570
Collapse to BH	4×10^{-23} (Novak 1998)	100	1300





Summary

- SGRBs show many features in their X-ray light curves similar to those seen in LGRBs, but SGRBs do it earlier.
- For the SGRBs with good X-ray data available, up to 74% can be fitted by a magnetar model.
- Around a third or more collapse to a BH while the rest may survive as magnetars.
- Could see 2 or 3 GW signals in these models

To test any progenitor model we need a functioning GRB mission in the era of A-LIGO, IceCube, E-ELT etc.

(e.g. SVOM, Lobster, Janus, UFFO…)