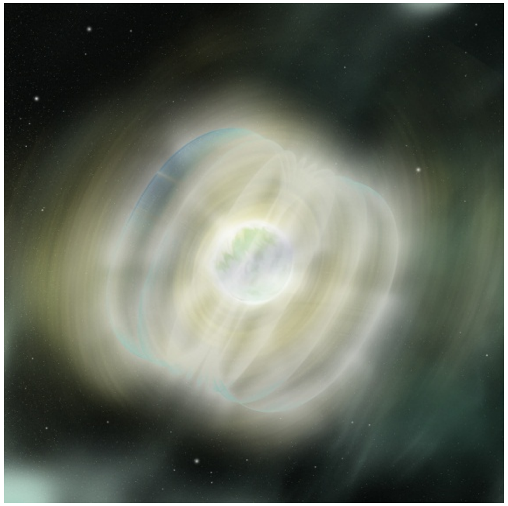
Energy injection in short GRBs and the role of magnetars



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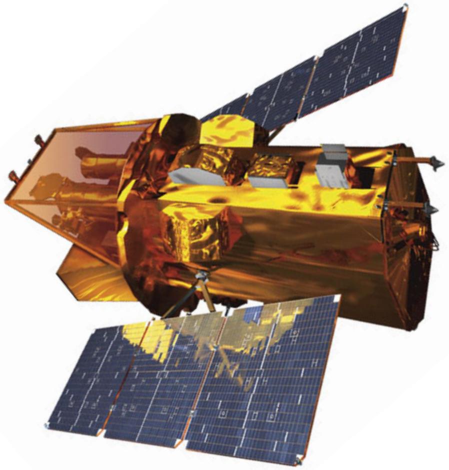
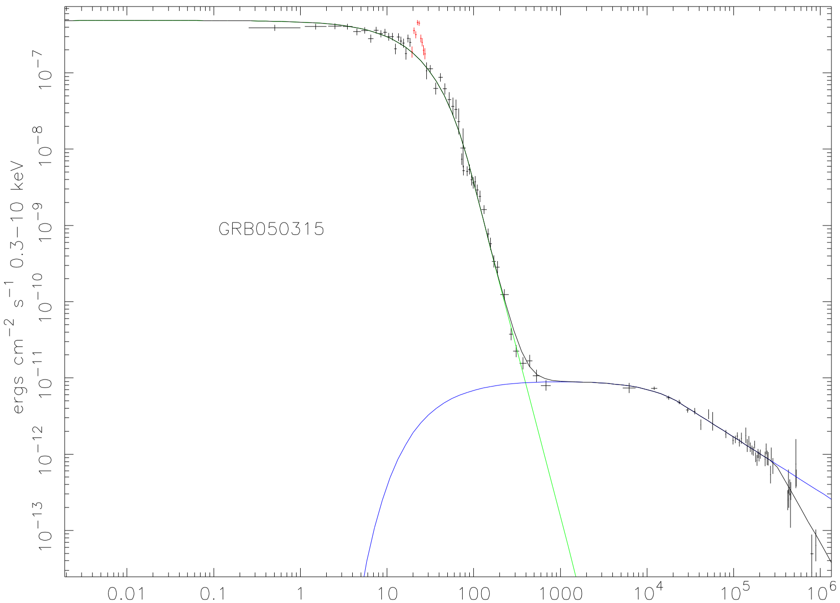
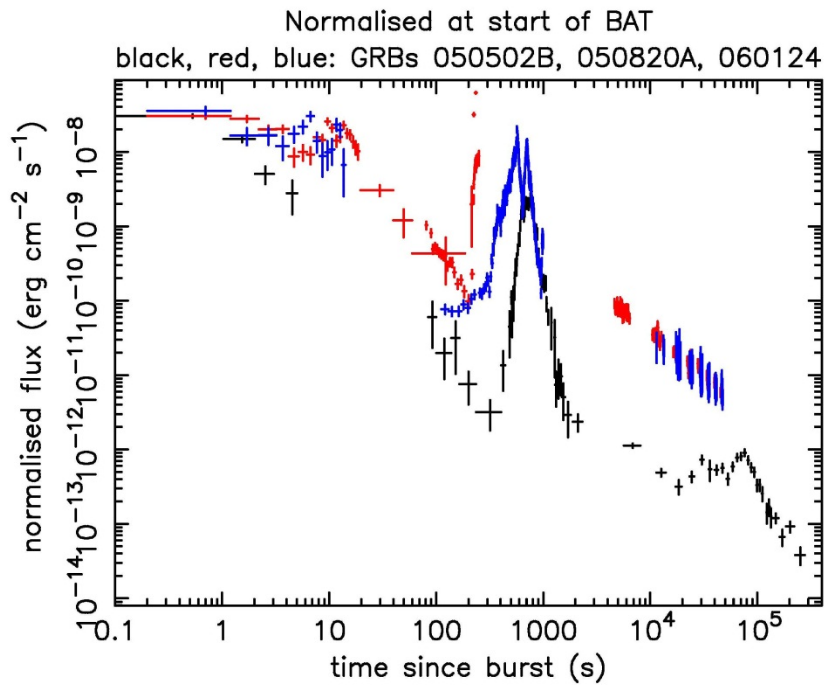


Example GRB X-ray "features"





See many examples of features thought to be due to adding energy, but where does that energy from?

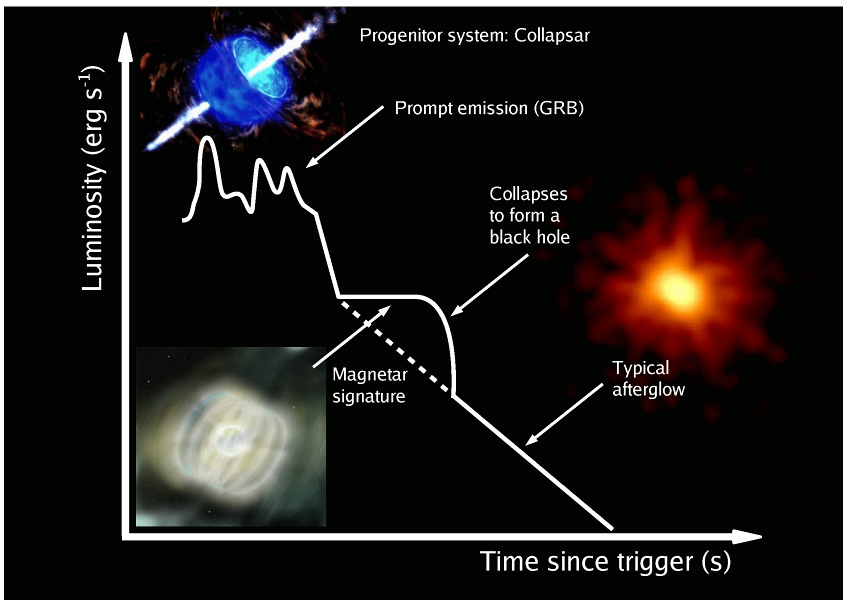
Many options (e.g. accretion), but here we look at one: a magnetar

GRB magnetar models

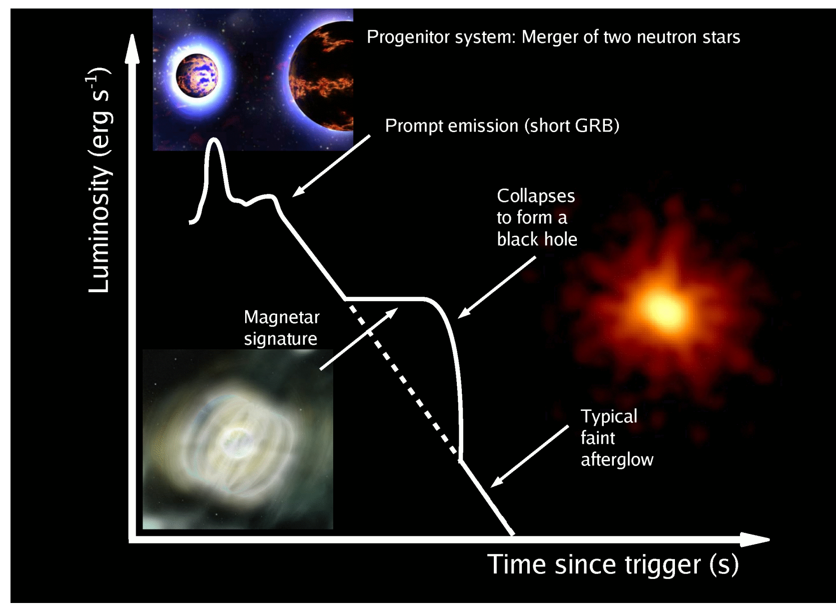
Some GRBs may be powered by an unstable, millisecond pulsar (a magnetar) (e.g., Usov 1992; Duncan & Thompson 1992; Dai et al. 2006; Metzger 2009; Ozel et al. 2010; Metzger et al. 2011; Dessart et al. 2012)

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

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



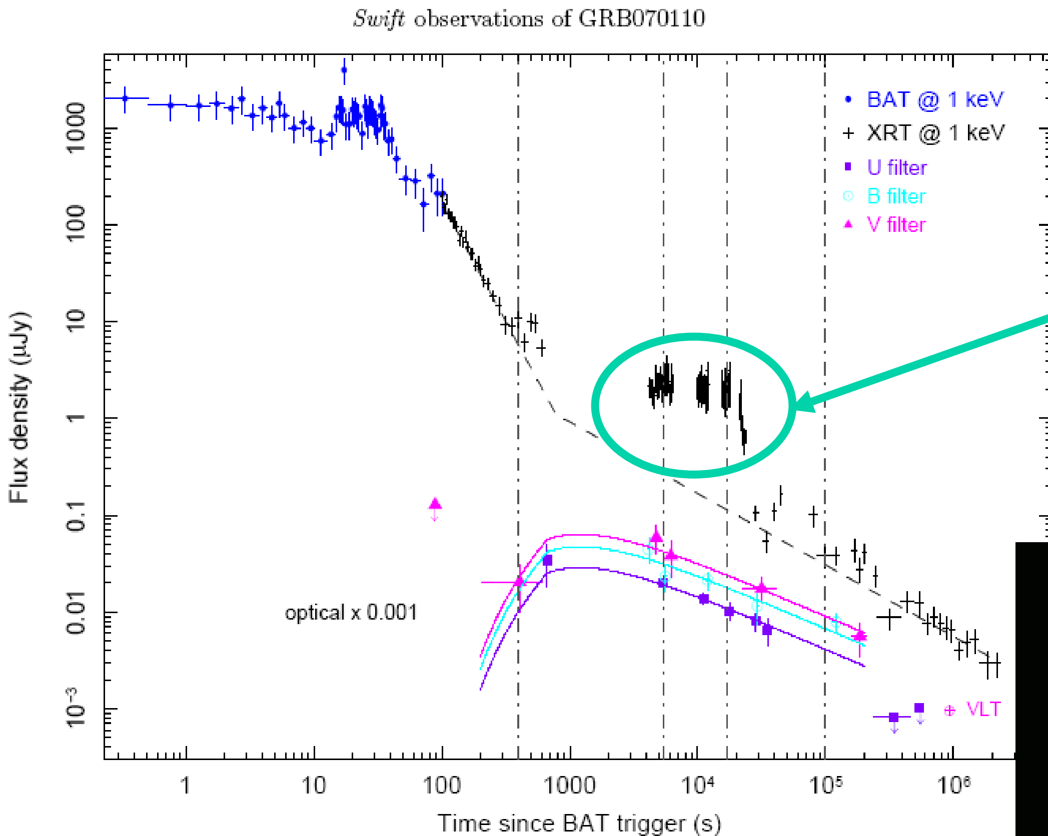
Collapsar – LGRBs



Binary Merger – SGRBs

GRB 070110: a magnetar l.c.?

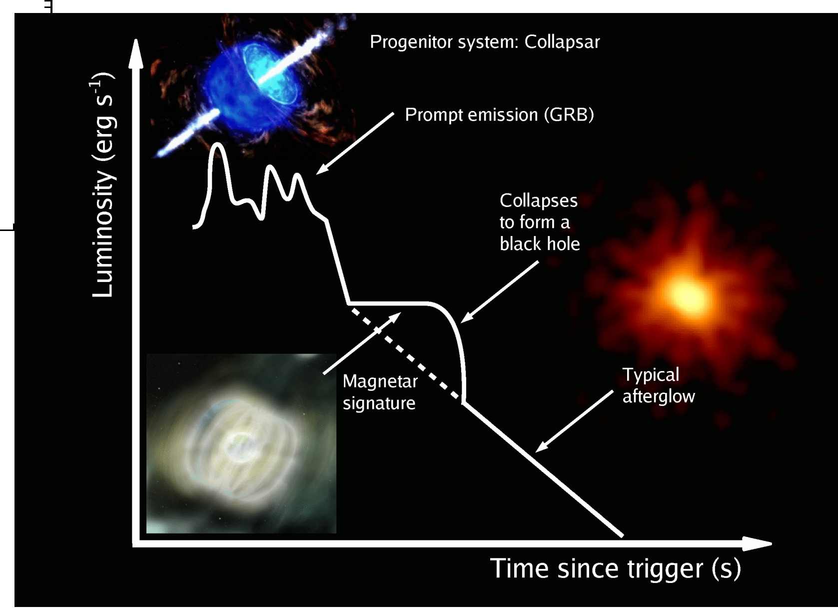
(Troja et al. 2007)



See a late plateau followed by a very steep decay in X-rays.

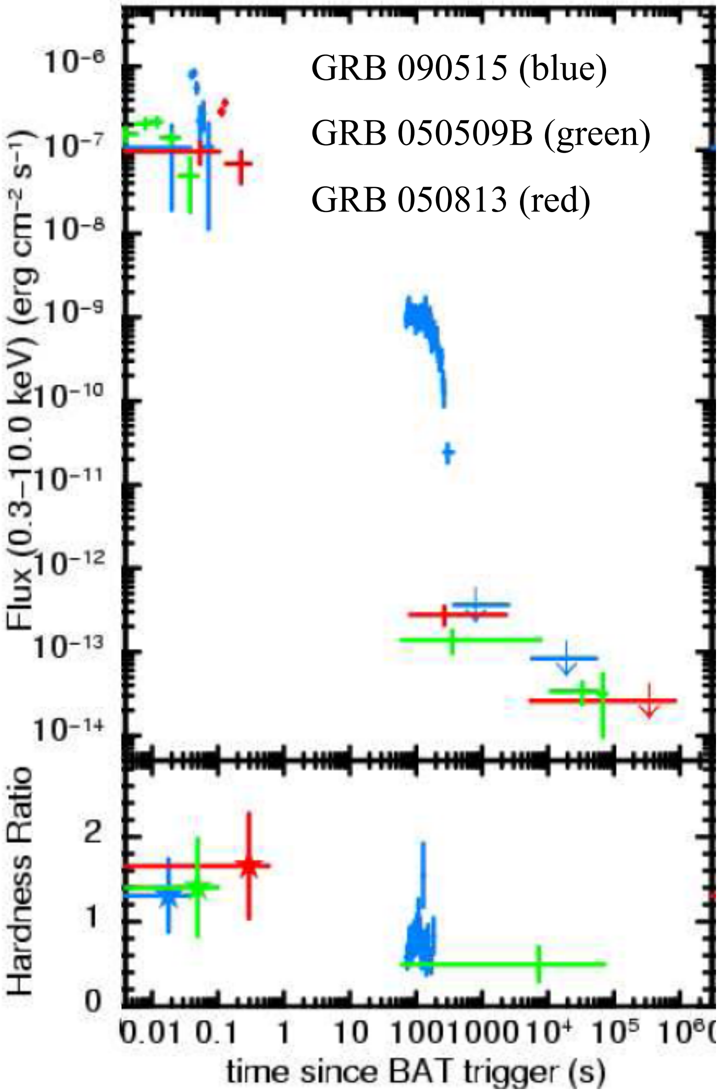
Not seen in the optical, which instead suggests a common multi-wavelength underlying "canonical" plateau

Lyons et al. (2010) found 10 such candidates LGRBs up to 2008



GRB 090515 – a short magnetar?

(Rowlinson, O'Brien et al. 2010)



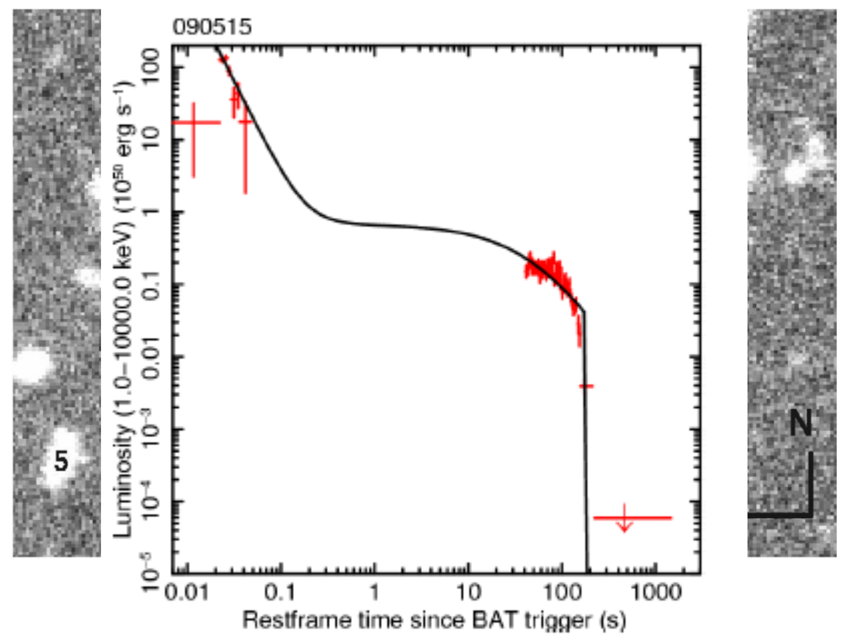
T90 = 0.036s

Fluence = 2x10^{-8} erg s^{-1} (15-150 keV)

Brightest short GRB in X-rays at 100s

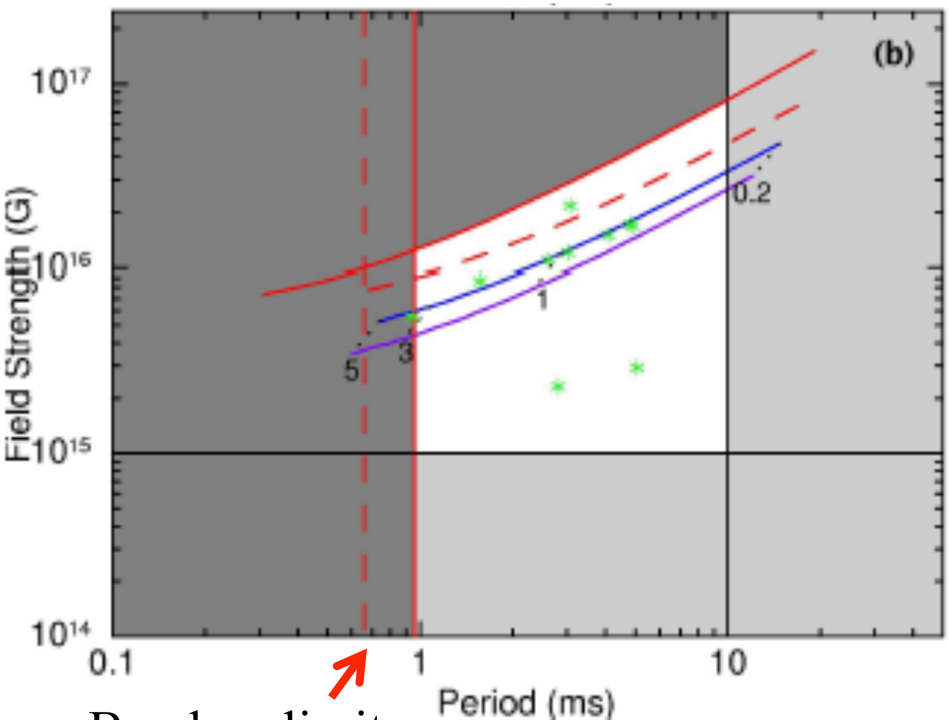
Very unusual given low γ-ray fluence

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



Magnetar model fit assuming z~0.7

GRB 090515 and the long GRBs



Breakup limit

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

Red upper lines: impose causality limit

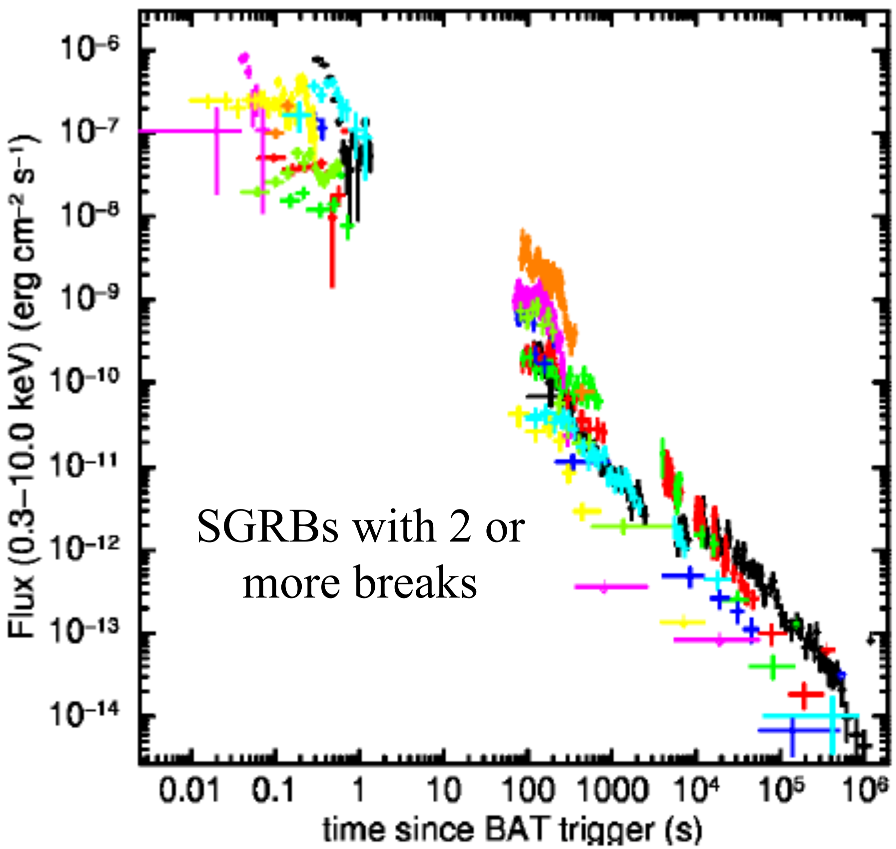
Green points: LGRBs (Lyons et al. 2010)

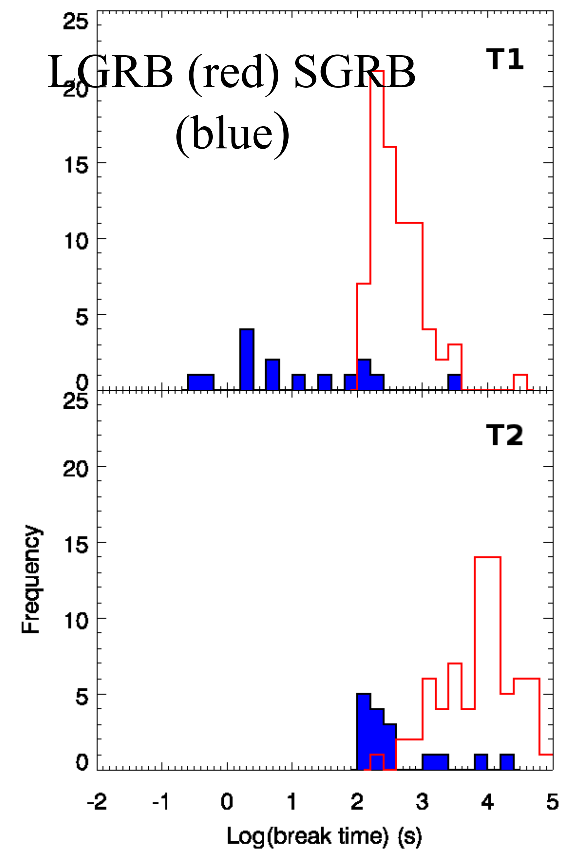
$$L \propto B_p^2 / P_0^4 \quad \text{and } T_{em} \propto P_0^2 / B_p^2$$

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

Swift SGRB sample
(Rowlinson et al., 2012)

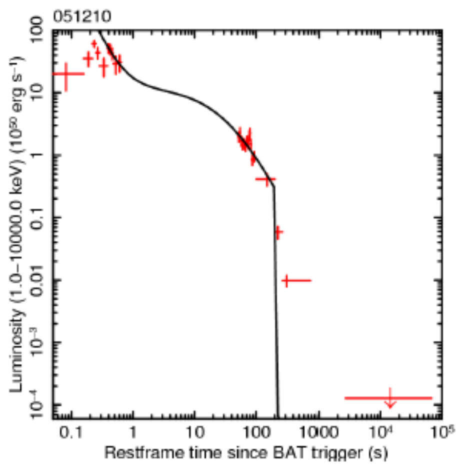
- 43 SGRBs up to March 2012, 37 of which were detected with the XRT
- Significant fraction of SGRBs are not well fitted by a single PL decay in the XRT data (see also Margutti et al. 2012)
- 28/37 have sufficient data to try a magnetar model fit to BAT+XRT

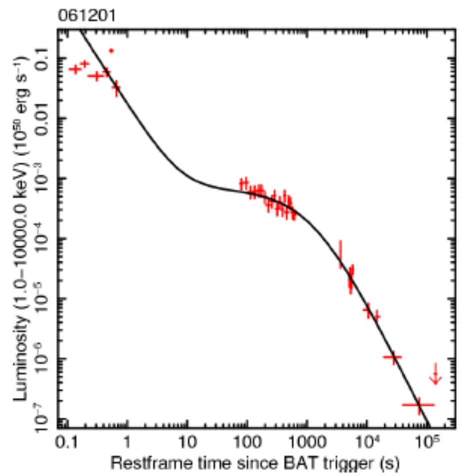


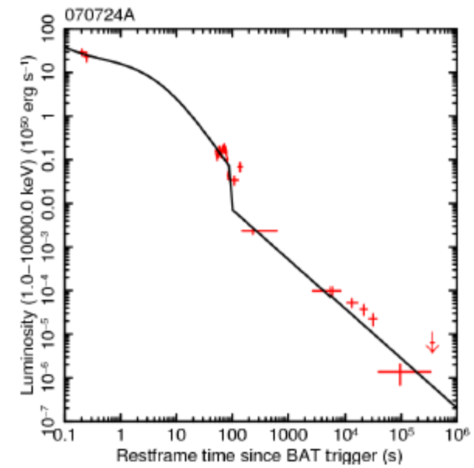


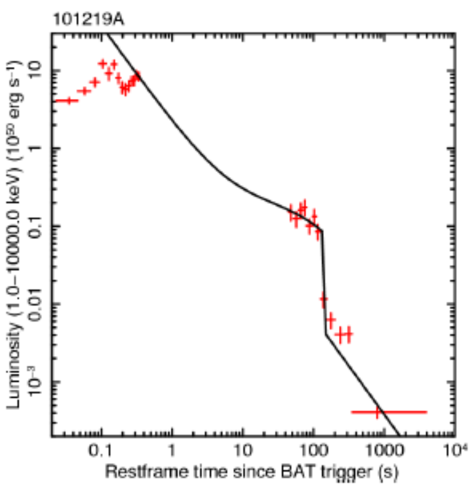
Example magnetar model fits (fit magnetar+underlying PL)

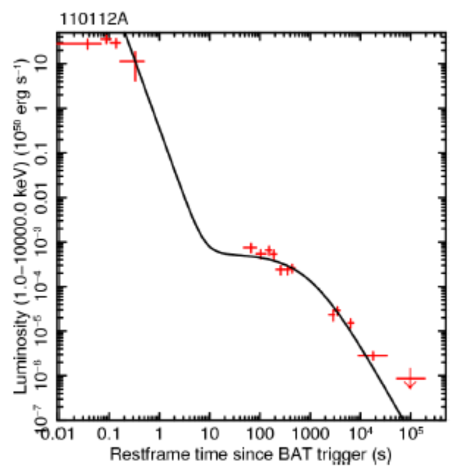
Collapse to BH	Magnetar survives	Unclear

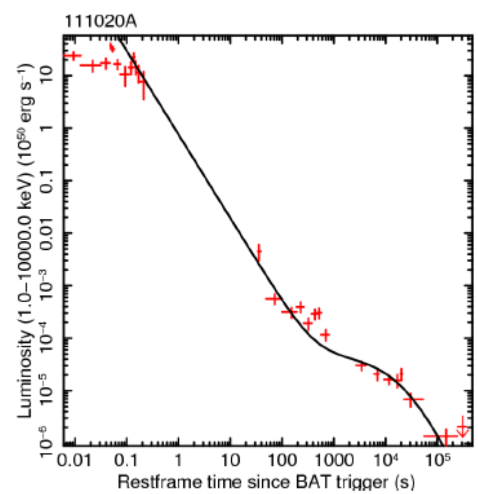




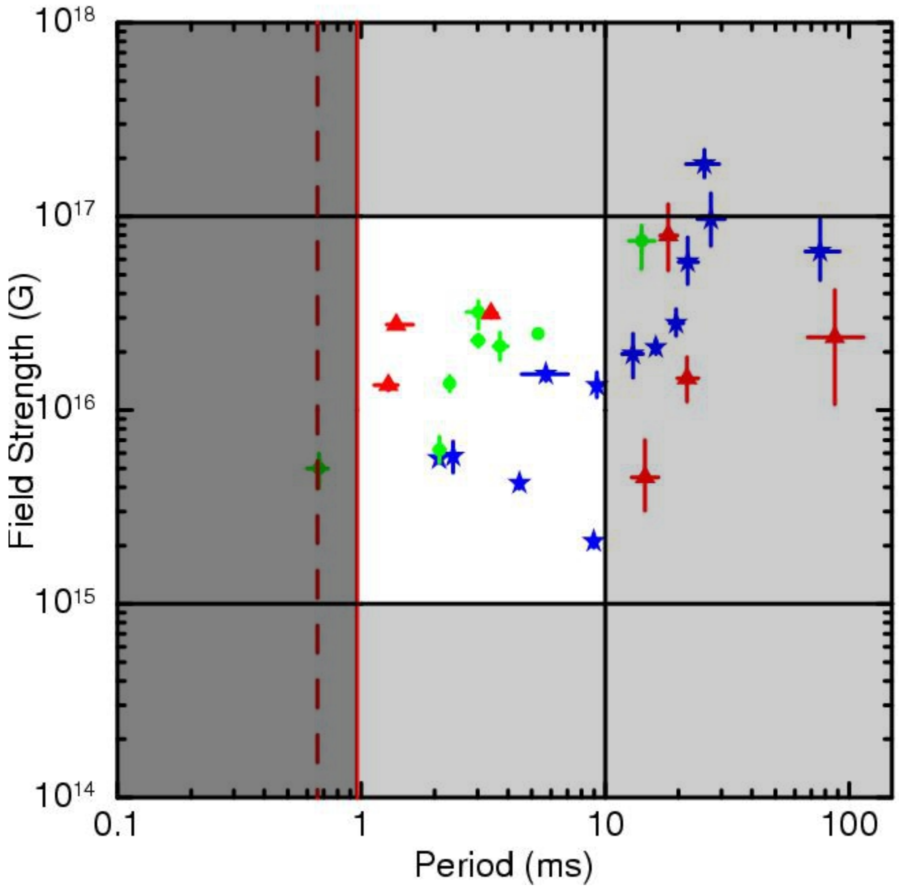








Derived magnetar parameters



Green: unstable magnetar
Blue: stable magnetar
} 21/28 = 75%

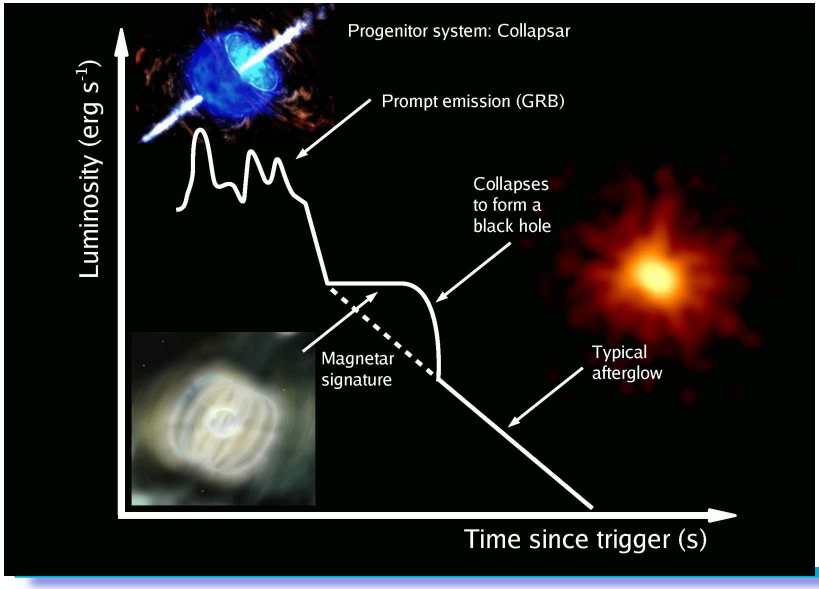
Red: poor/uncertain fit

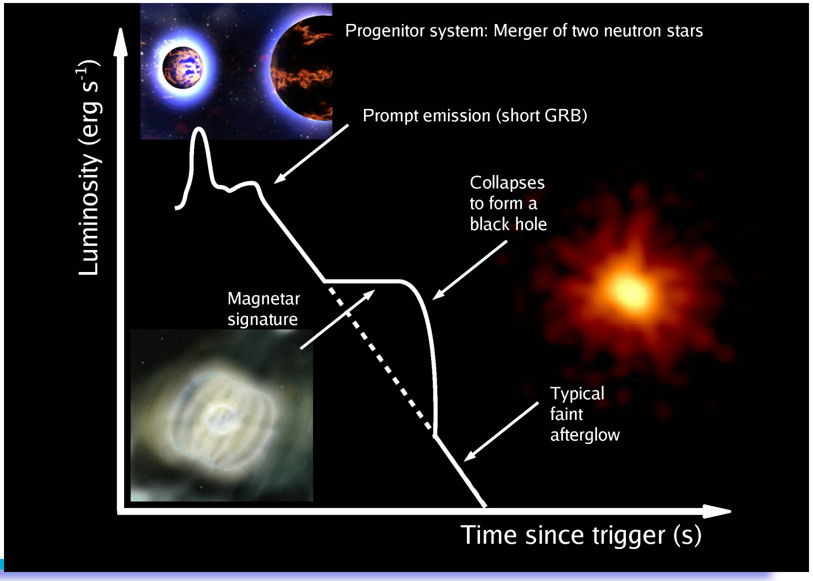
Typical B ~ few 10^{16} G, period ~few msec

(NB. Assume mean z for those without one)

Test model using gravity waves?

Phase	Amplitude (h)	A-LIGO limit (Mpc)	ET 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





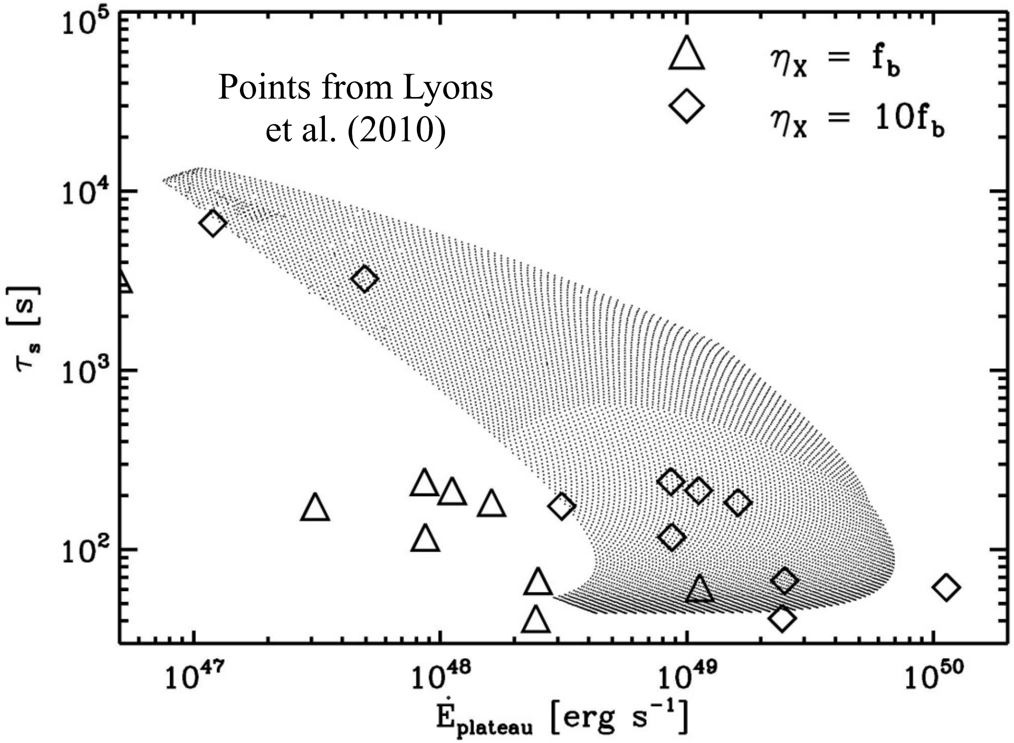
Summary

- 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 75% can be fitted by a magnetar model.
- Around a third or more of these magnetars eventually collapse to a BH while the rest may survive.
- Could see 2 or 3 GW signals for these models – rate very low for A-LIGO but good for ET

To test any progenitor model we need a functioning GRB trigger satellite in the era of A-LIGO, IceCube, CTA, LOFAR, E-ELT, ET, SKA etc., etc.

(e.g. SVOM, Lobster, Janus, UFFO, LOFT…)

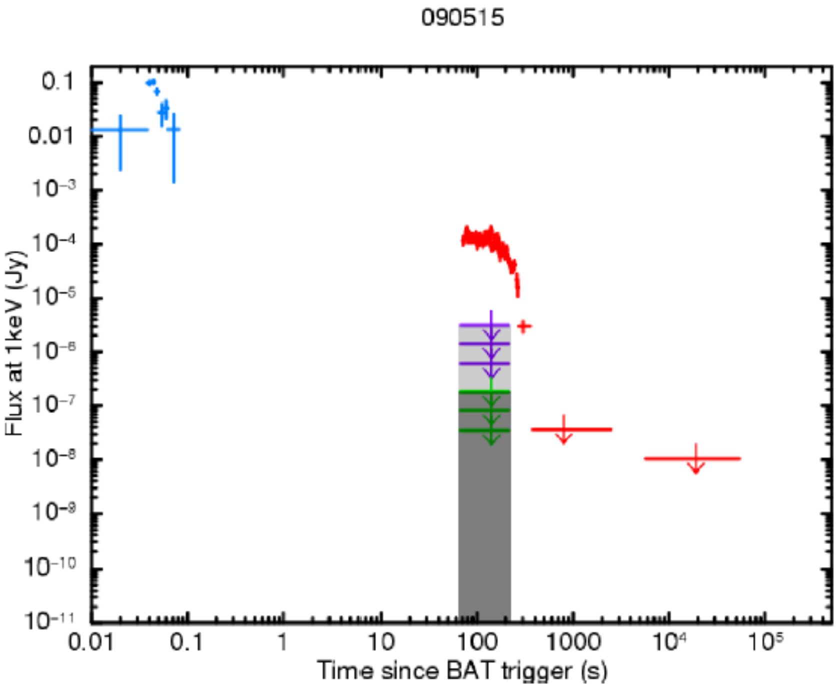
Compare with magnetar model



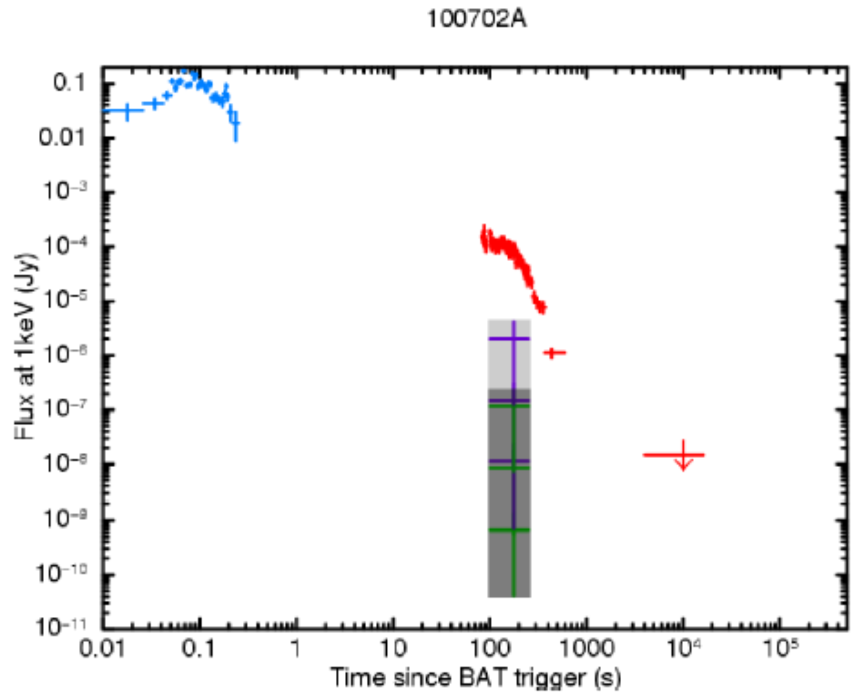
Observed LGRB internal plateaus are broadly consistent with the magnetar model wind power as presented by Metzger et al. (2011)

X-ray vs. optical emission for magnetar candidates

GRB 090515



GRB 100702A



Magnetar candidates tend to show an X-ray excess relative to optical where we have deep early optical data