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Magnetars in extended emission GRBs

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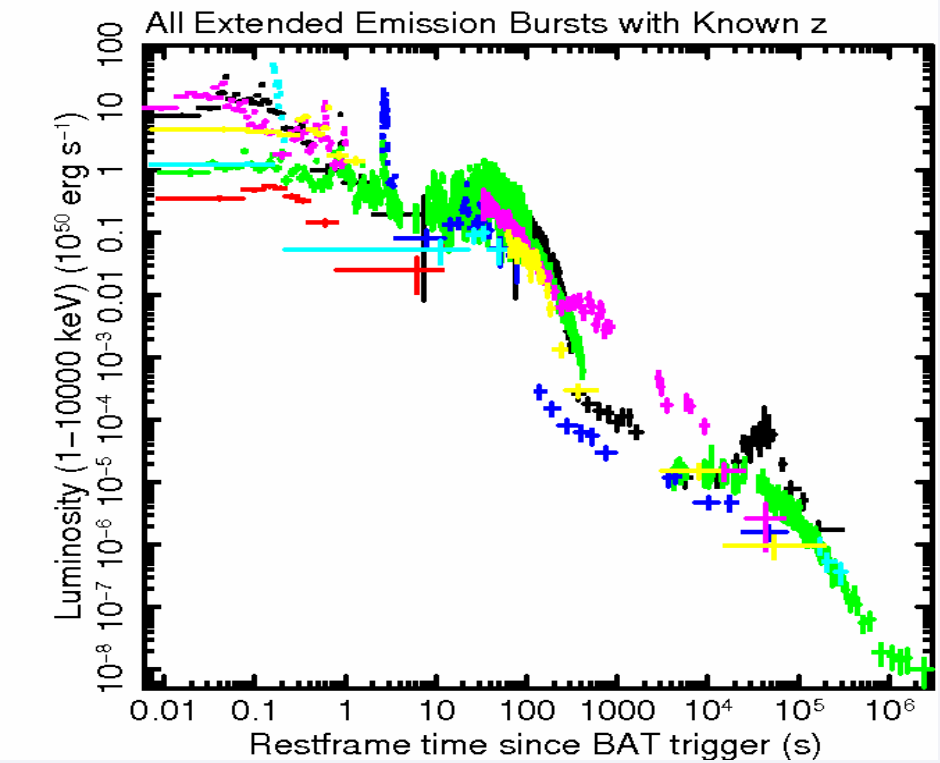
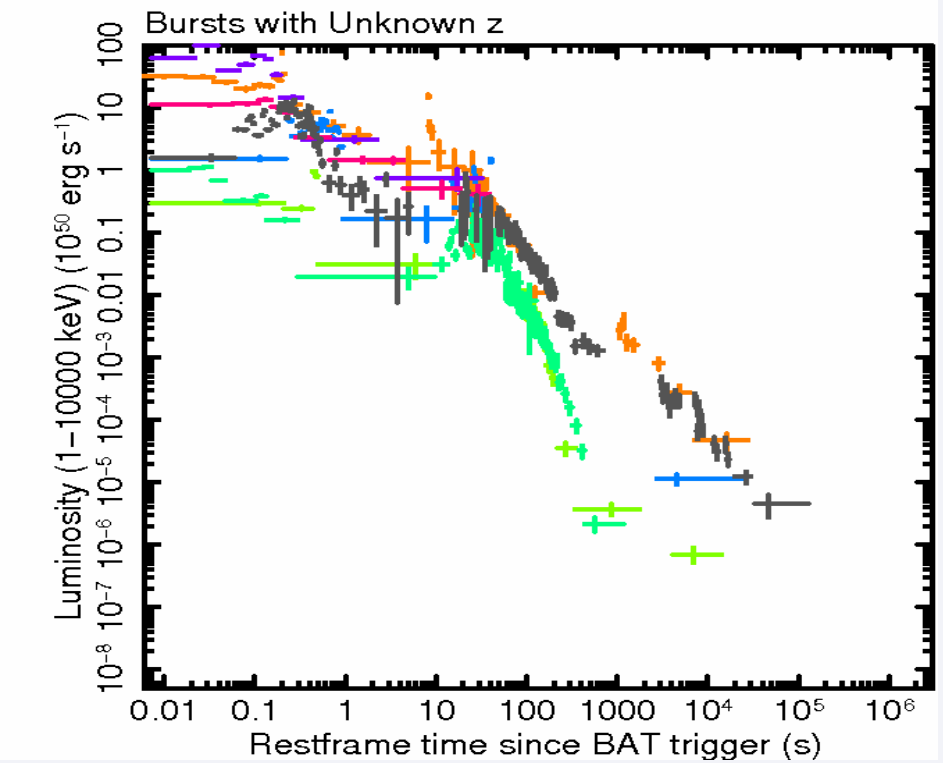
Extended emission bursts





- Spectrally hard
- No associated supernovae
- T_{90} often greater than 2 seconds
- Remarkably uniform

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The magnetar model

- Formed by merger or collapse
- Produces a compact, rapidly spinning (P ~ 1 ms) NS
- Very high (10^{15} G) magnetic field
- Large energy reservoir
- Variety of potential energy extraction methods
- Previous examples: Metzger et al, 2008; Bucciantini et al, 2012; Rowlinson et al, 2013

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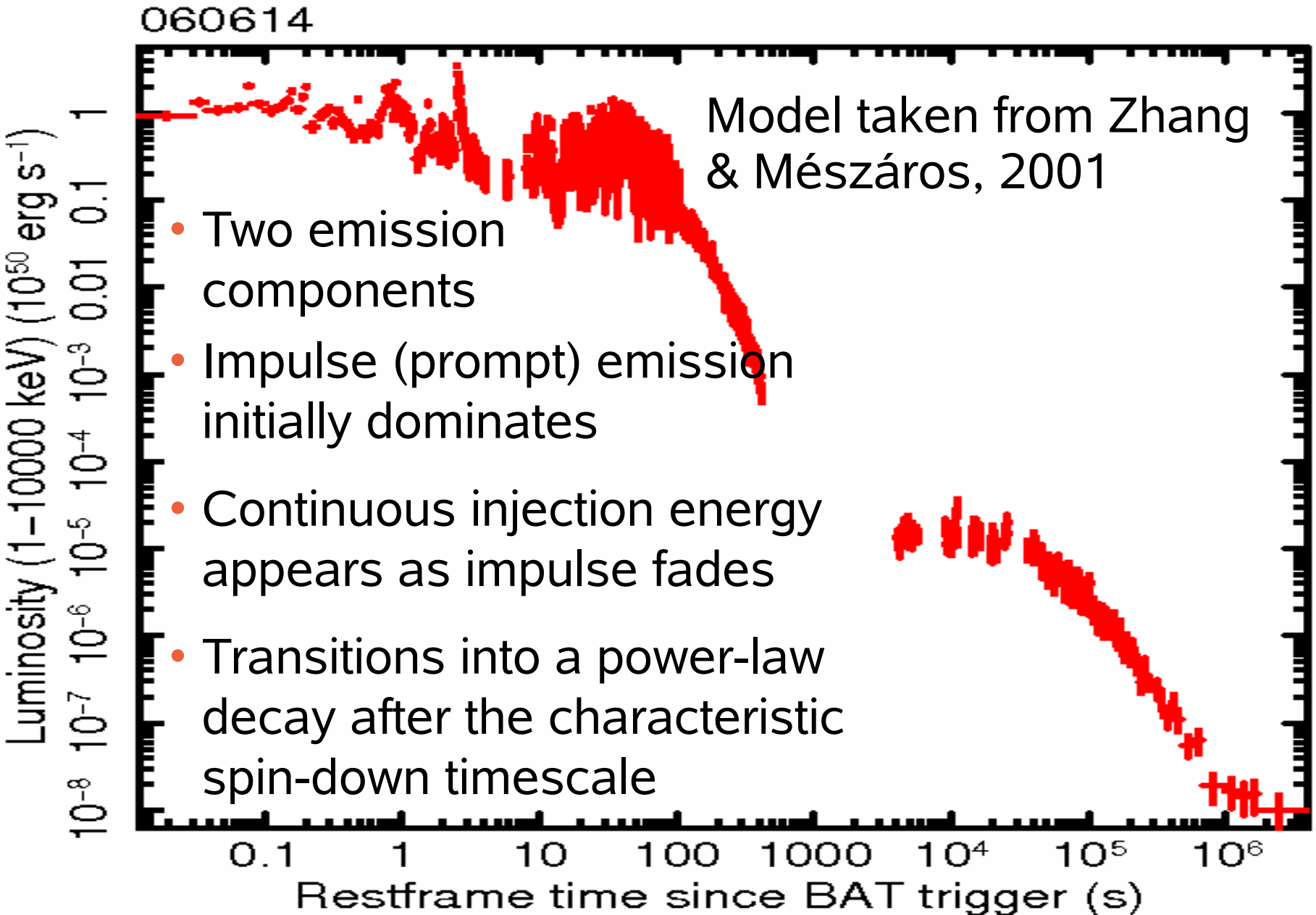
Dipole spin-down



Model taken from Zhang & Mészáros, 2001

- Two emission components
- Impulse (prompt) emission initially dominates
- Continuous injection energy appears as impulse fades
- Transitions into a power-law decay after the characteristic spin-down timescale

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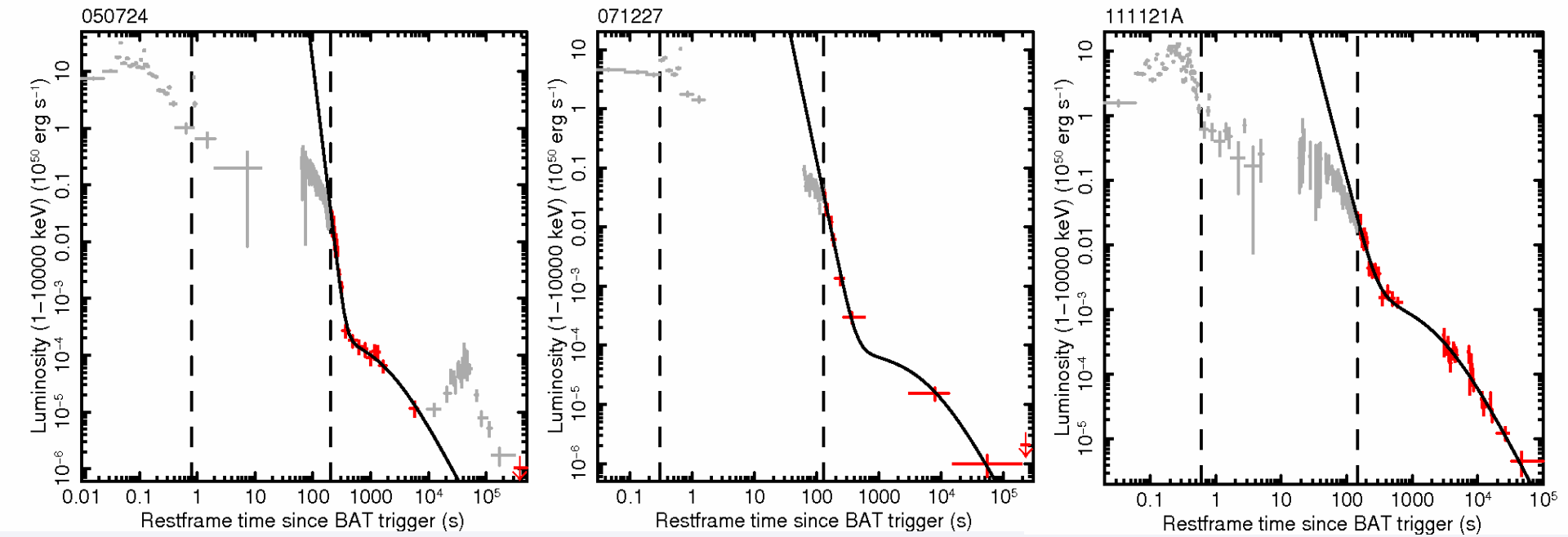
Fitting the dipole plateau

$$T_{em,3} = 2.05(I_{45} B_{p,15}^{-2} P_{0,-3}^{2} R_6^{-6})$$

$$L_{0,49} \sim (B_{p,15}^{2} P_{0,-3}^{-4} R_6^{6})$$



$$\Delta E = 2\pi^2 I(P_i^{-2} - P_0^{-2})$$

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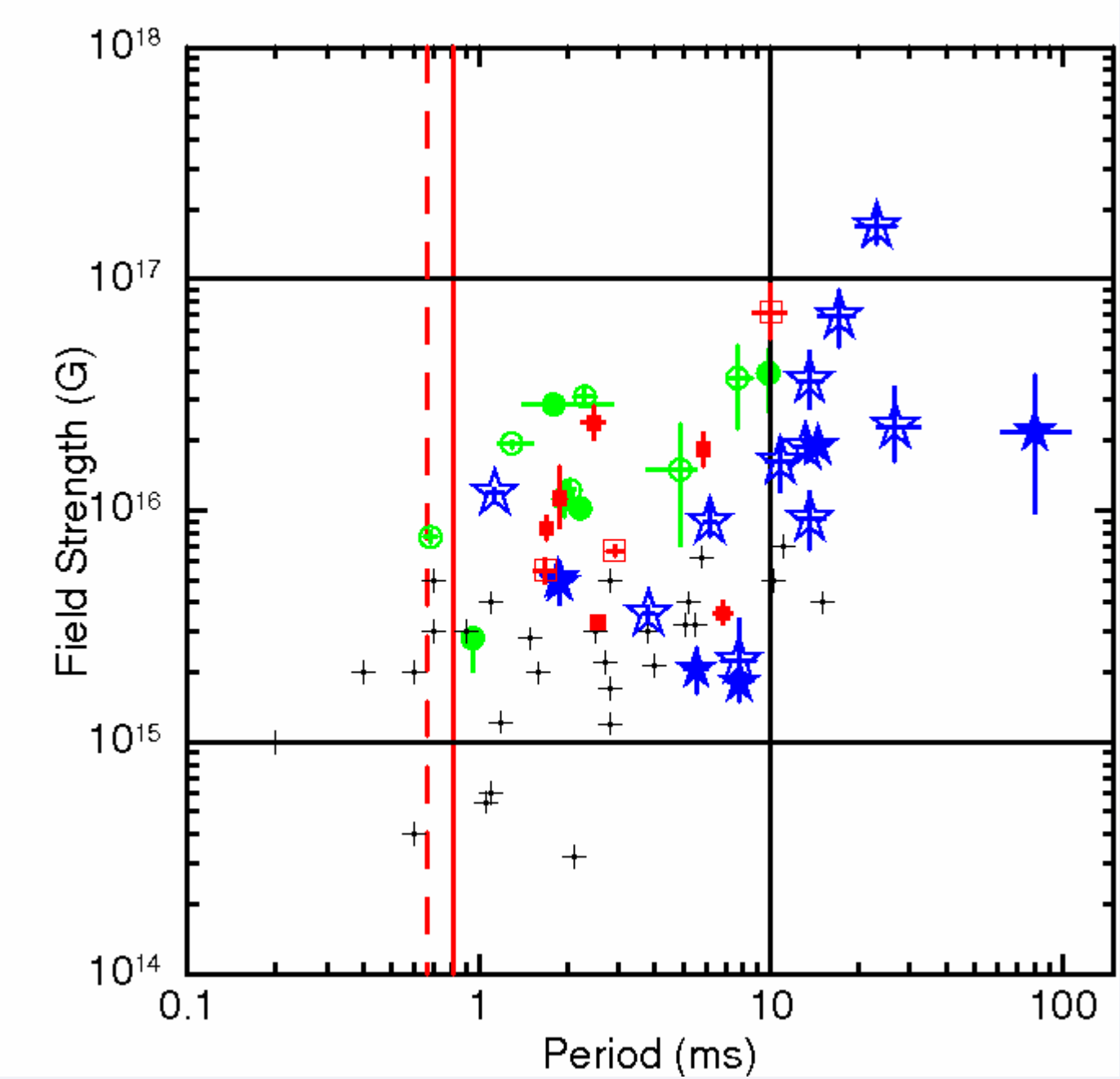
Results

SGRBs (Green, blue): Rowlinson et al. 2013

LGRBs (Black): Lyons et al. 2010; Dall'Osso et al. 2011; Bernardini et al. 2012

(Gompertz et al. 2013, MNRAS, 431, 1745)



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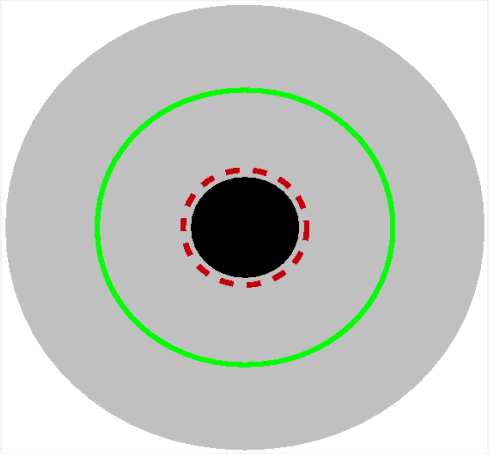
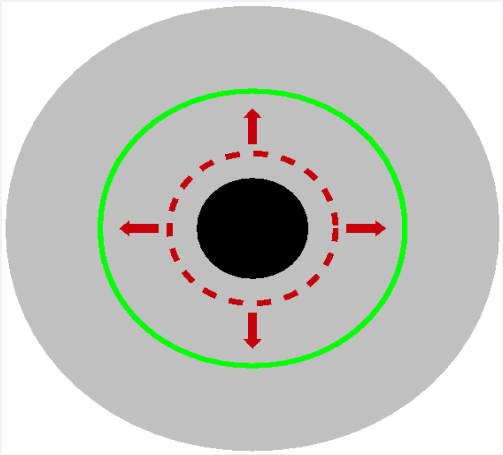
Magnetic propulsion

Previous application in LGRBs: Piro & Ott, 2011; Bernardini et al. 2013

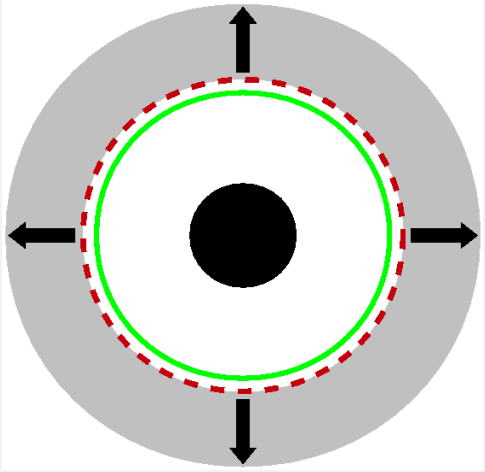
ADepends on 2 key radii: Alfvén (R_M) and co-rotation



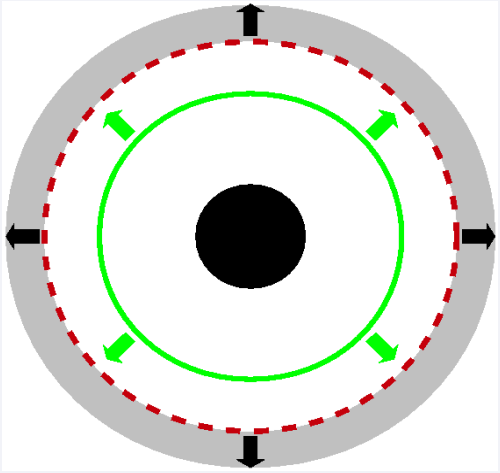
1. Accretion rate is high (and/or P is high and/or B is low)



2. As the accretion rate drops, R_M increases



3. Propeller regime begins when $R_M > R_C$



4. As P increases, R_C also expands

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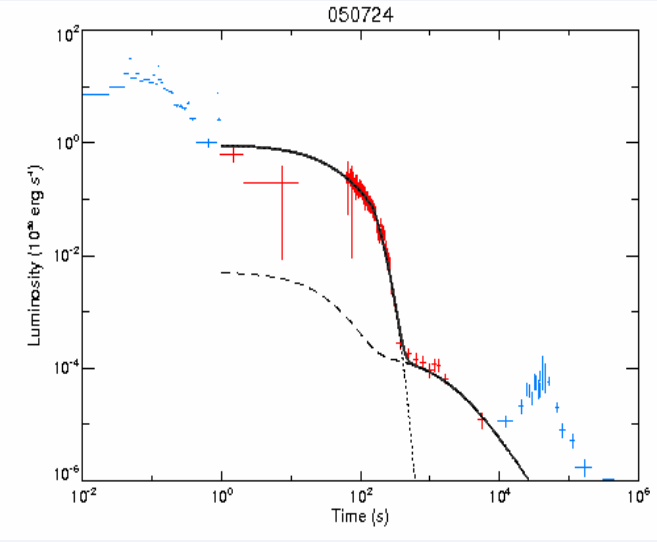
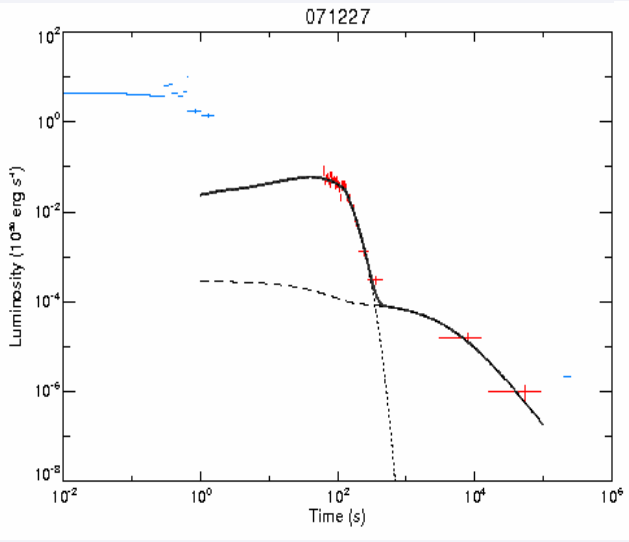
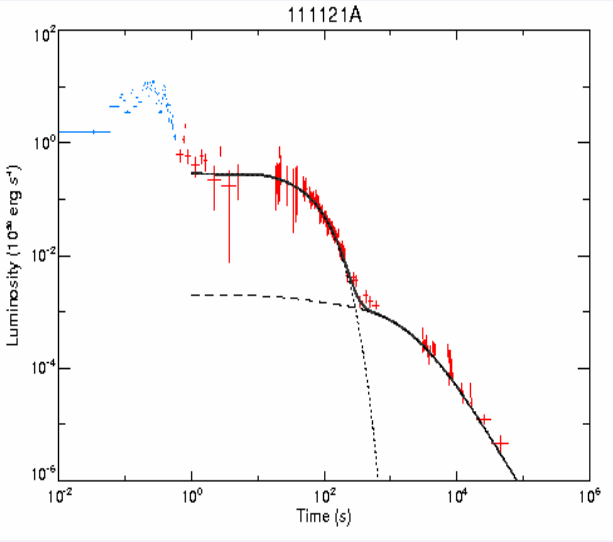
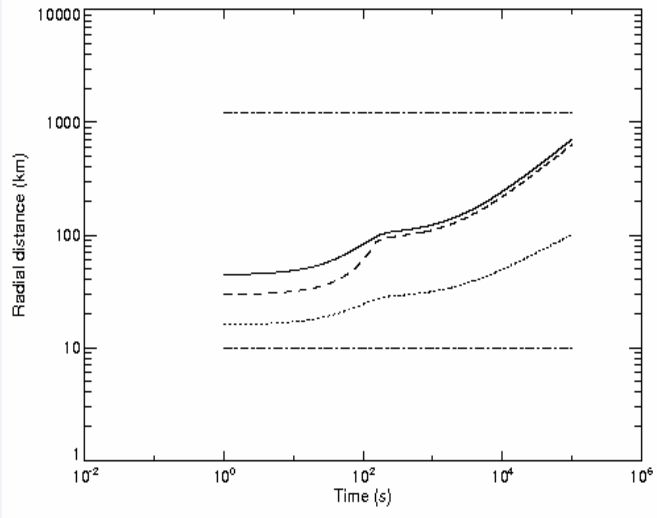
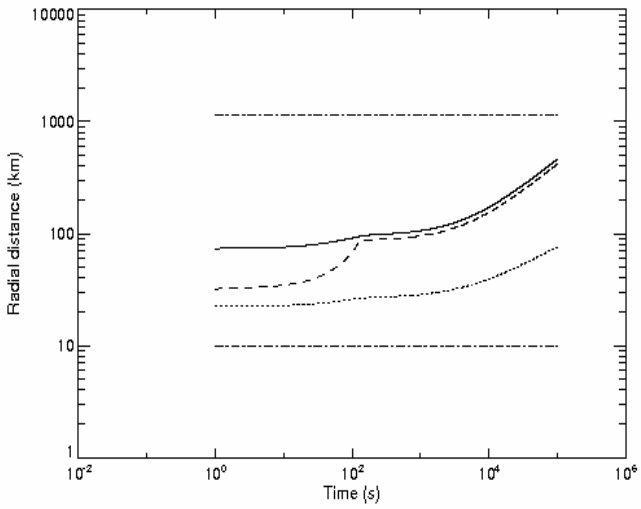
Fitting

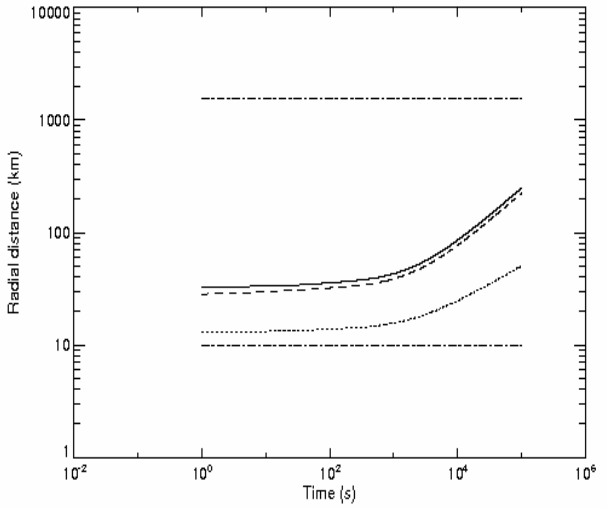












*Uses MPFIT (Markwardt 2009)

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Results

- Kinetic to EM conversion efficiency set to 40% for the propeller
- Dipole efficiency set to 5%
- Maximum ejection velocity is 0.9c
- Initial spin period ~ 0.69ms – 4ms
- Magnetic field ~ 10^{14}G – 4 x 10^{15}G
- Disc mass ~ $10^{-3}M_{sol}$ – $10^{-2}M_{sol}$
- Disc radius ~ 400km – 1500km
- Parameters are consistent with theoretical predictions for fallback discs (Lee et al. 2009)

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Summary

- Unable to disprove magnetic propulsion as the cause of extended emission, HOWEVER:
- Required efficiency is high (≥ 10%)
- Results cannot be confidently compared with previous works, since disc presence enhances dipole spin-down
- EE may be present to some degree in bursts not readily identified as extended; the class may be even more complex than currently realised