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The radio signatures of magnetar-driven SGRBs, and their detectability with the SKA

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Observed properties of GRBs

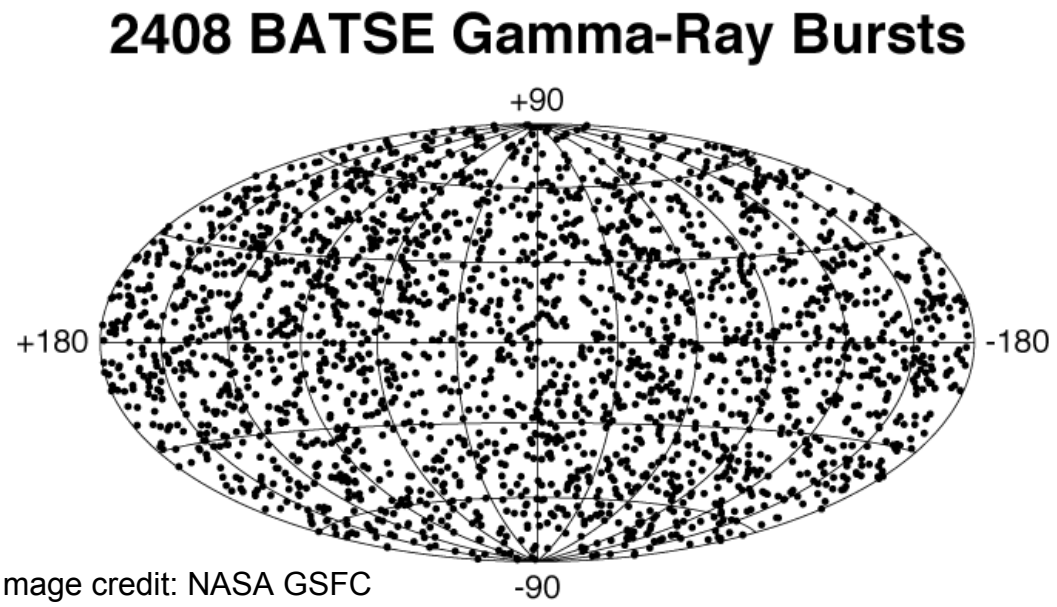
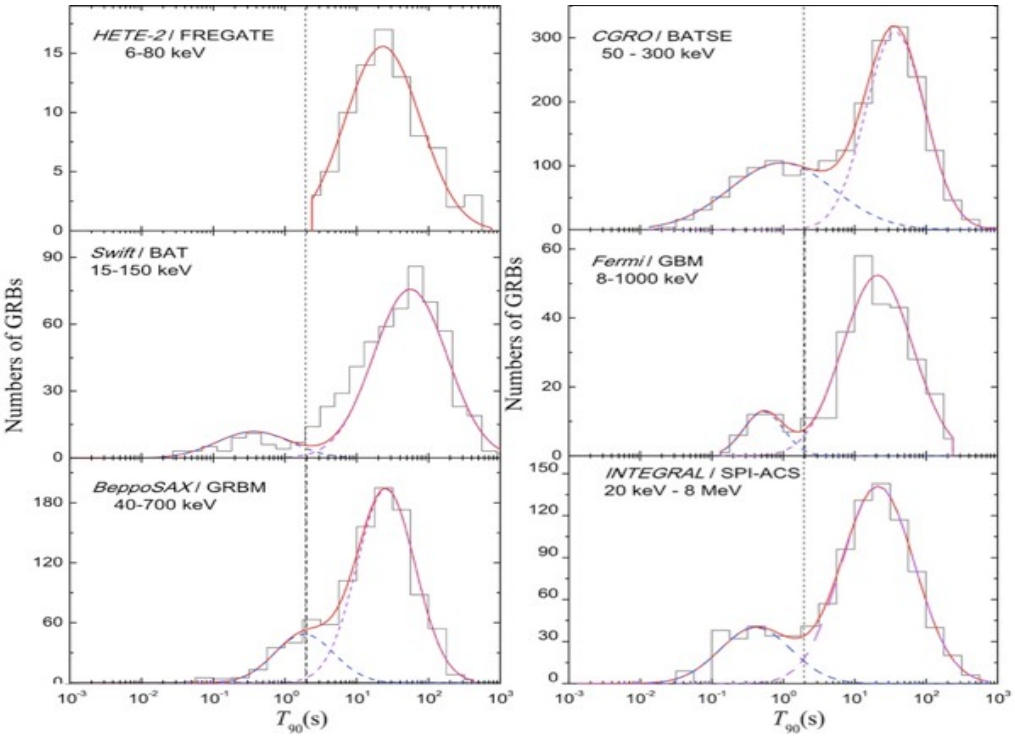


Image credit: NASA GSFC

- Short, intense bursts of EM radiation
- Isotropically distributed across the sky
- Cosmological distances
- Isotropic equivalent energy release up to the order of 10^{54} erg

- Two broad classes are apparent (Kouveliotou et al. 1993)
- Divided by duration (T_{90}) and spectral hardness
- Possible third class exists (Norris & Bonnell, 2006)

Qin et al. (2013)



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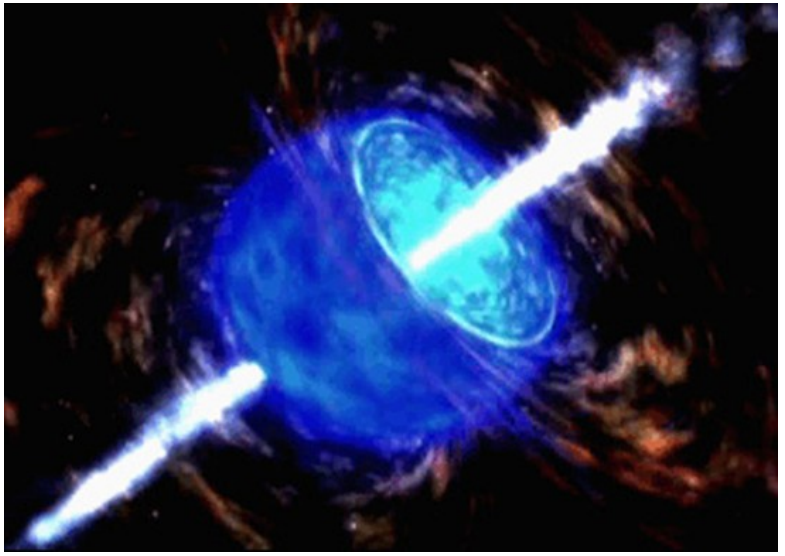
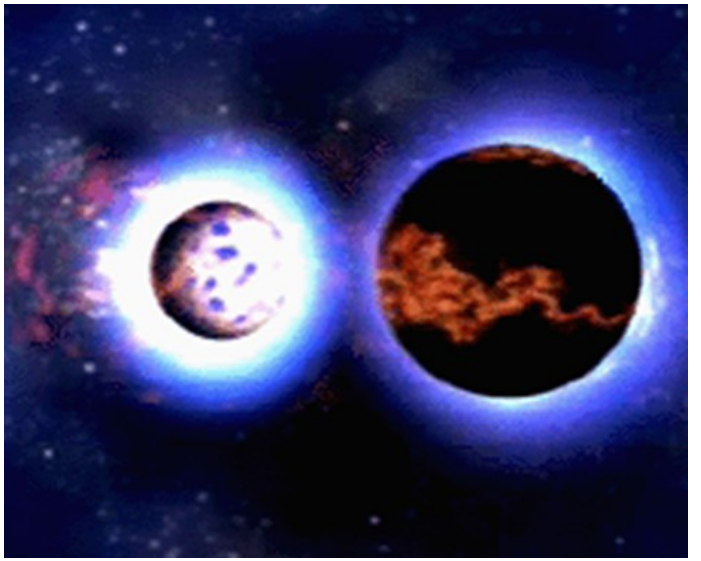
GRB progenitors

Collapsar – LGRBs



Binary Merger – SGRBs



LGRB: Collapsar model – occurs in region of massive (hence recent) star formation. Several examples known of associated super/hypernova signature

SGRB: Merger model (e.g. NS-NS) – can occur in any type of galaxy, and also off of a galaxy due to natal dynamic kick and long merger time

Other models are available…

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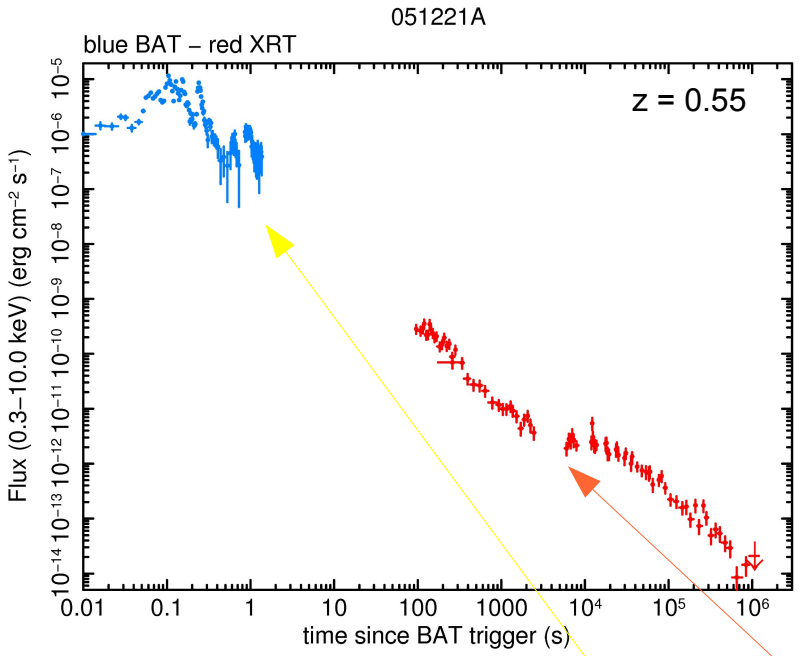
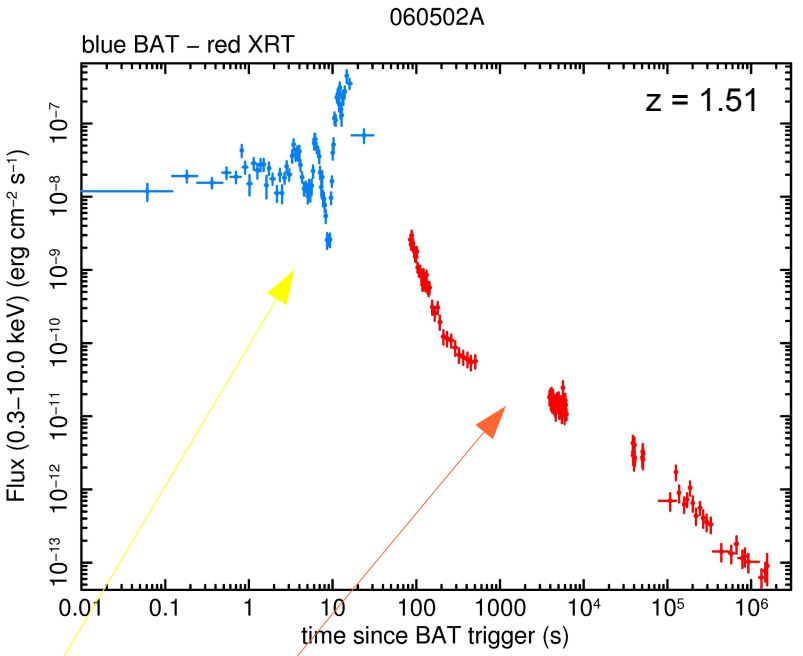
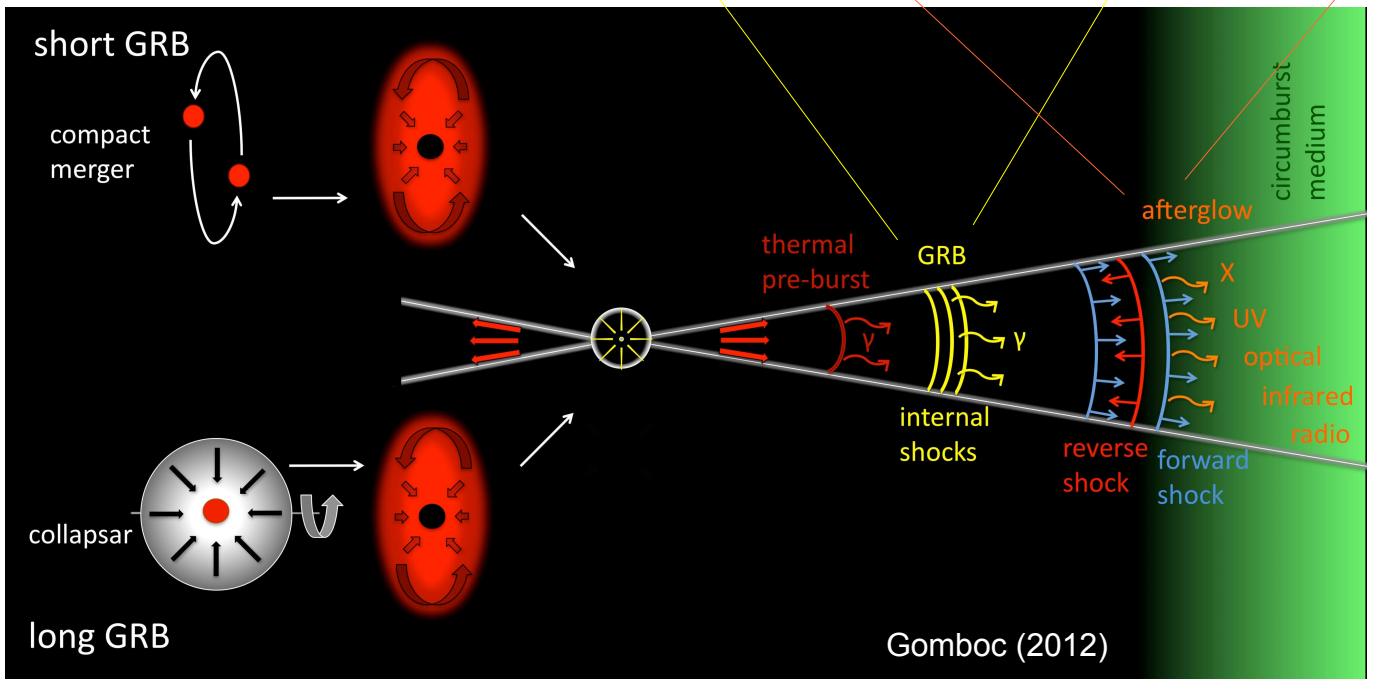
The decelerating fireball model







- Prompt emission from shocks between shells of expanding ejecta
- Afterglow from blast wave deceleration in CBM
- Late plateau suggests long-lived central engine activity

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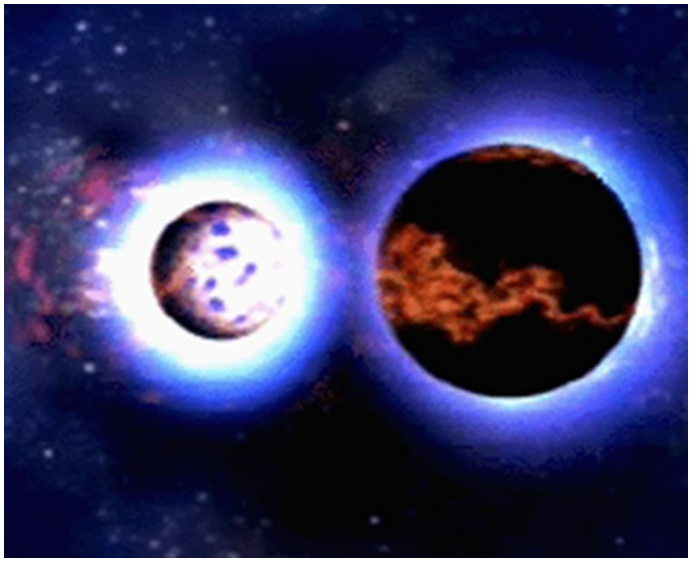
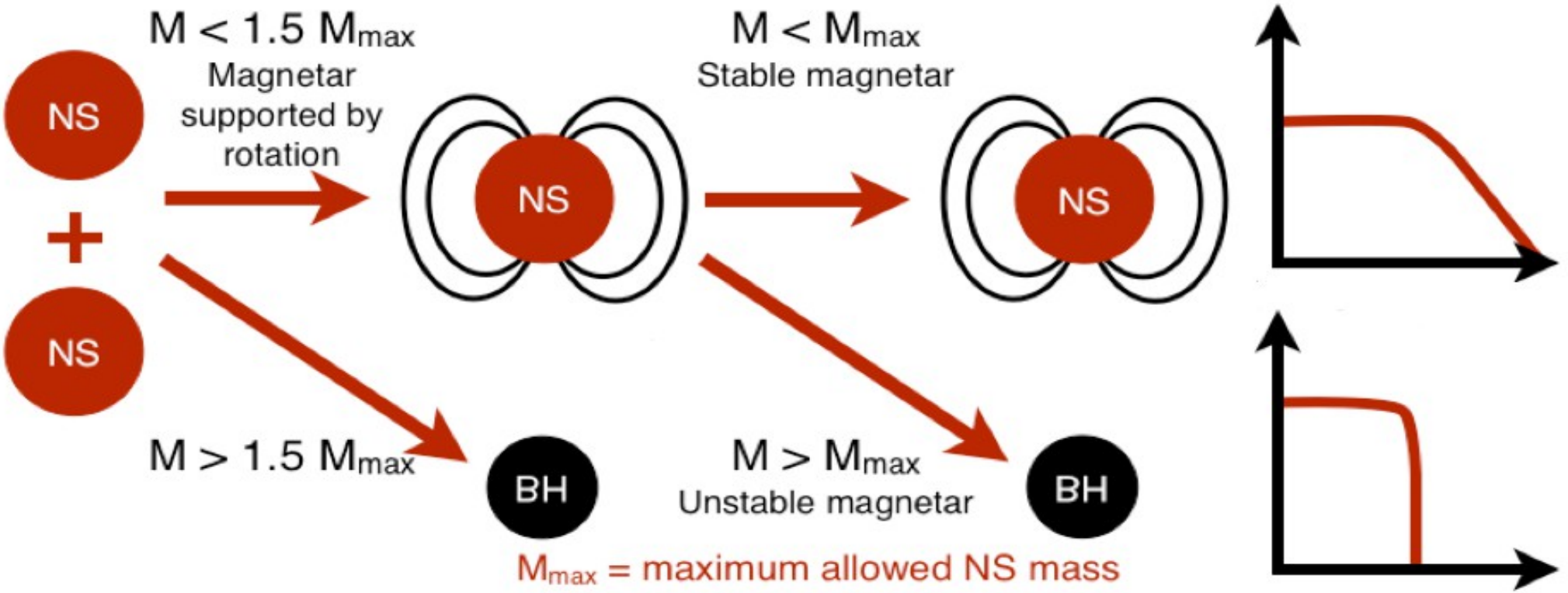
Magnetar central engine



- Prompt emission from relativistic jets, launched by initial merger
- Initial decay from the 'curvature effect,' created by high latitude emission
- Plateau created by energy injection into the forward shock from spin-down of a highly-magnetized, rapidly-rotating neutron star (magnetar)



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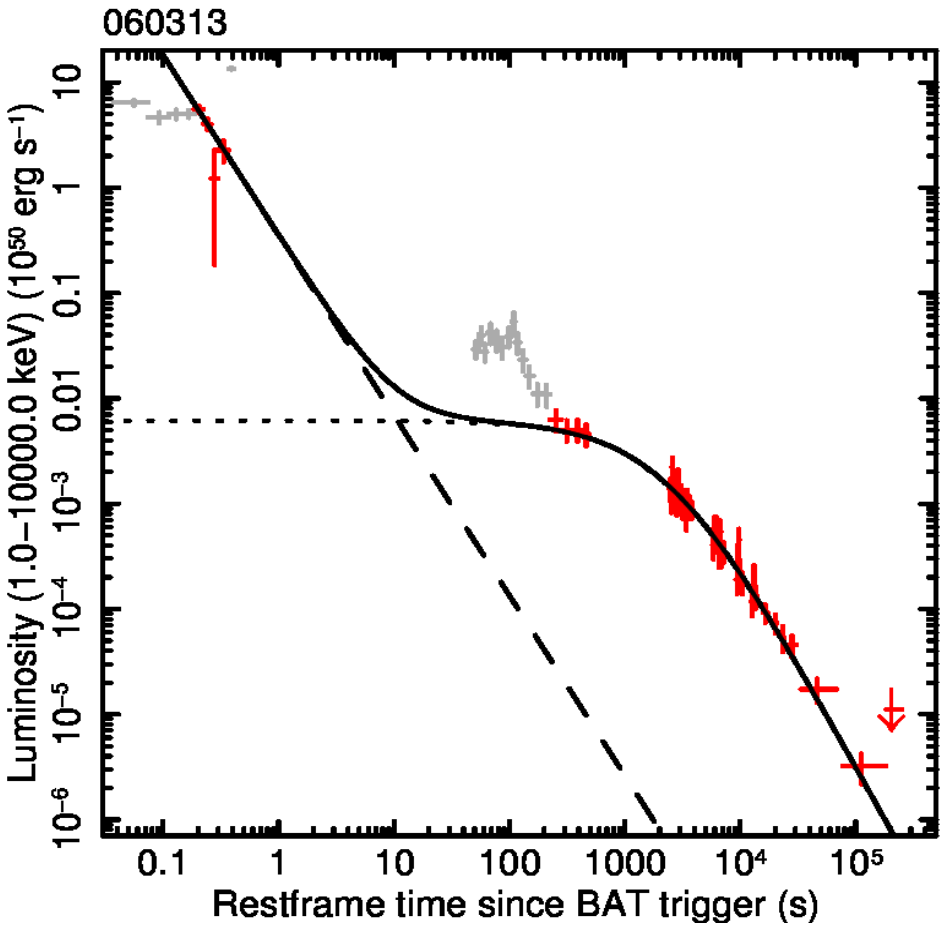
Magnetar central engine

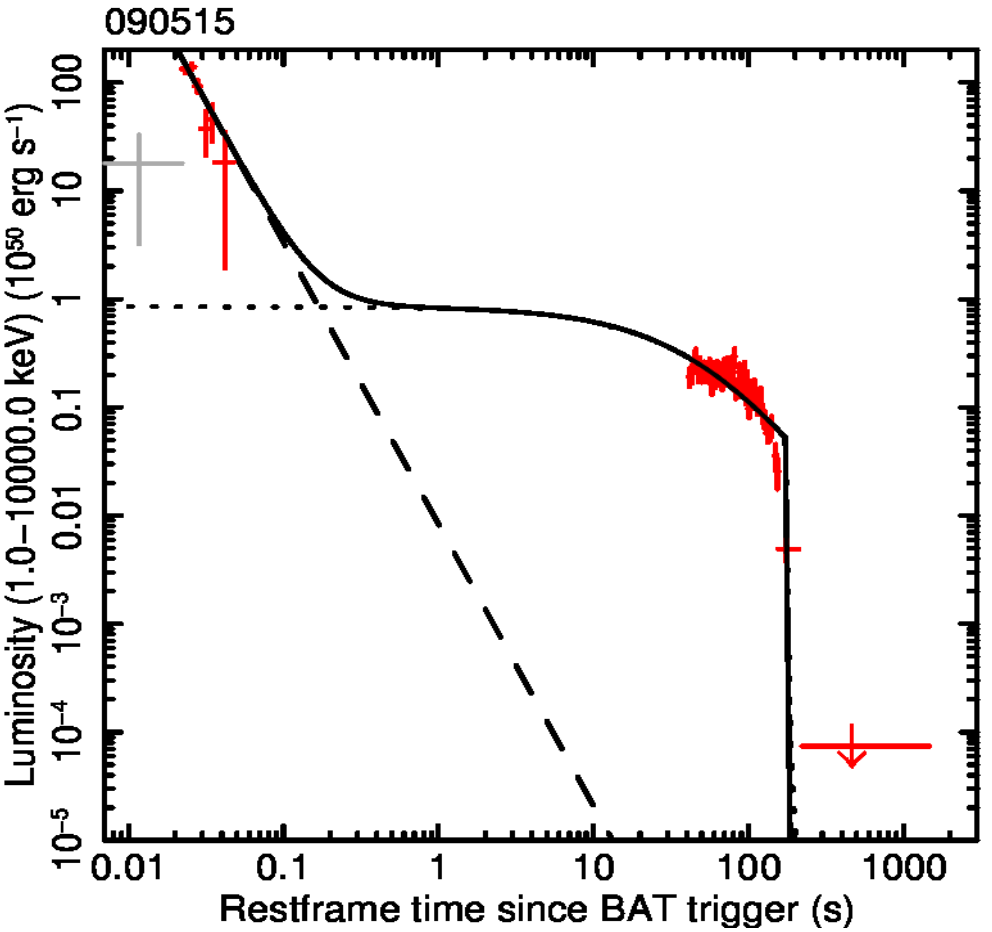
$$T_{em,3} = 2.05(I_{45}B_{p,15}^{-2}P_{0,-3}^{2}R_{6}^{-6})$$

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

Zhang & Mészáros (2001)



Stable



Unstable

Fits from Rowlinson et al. (2013)

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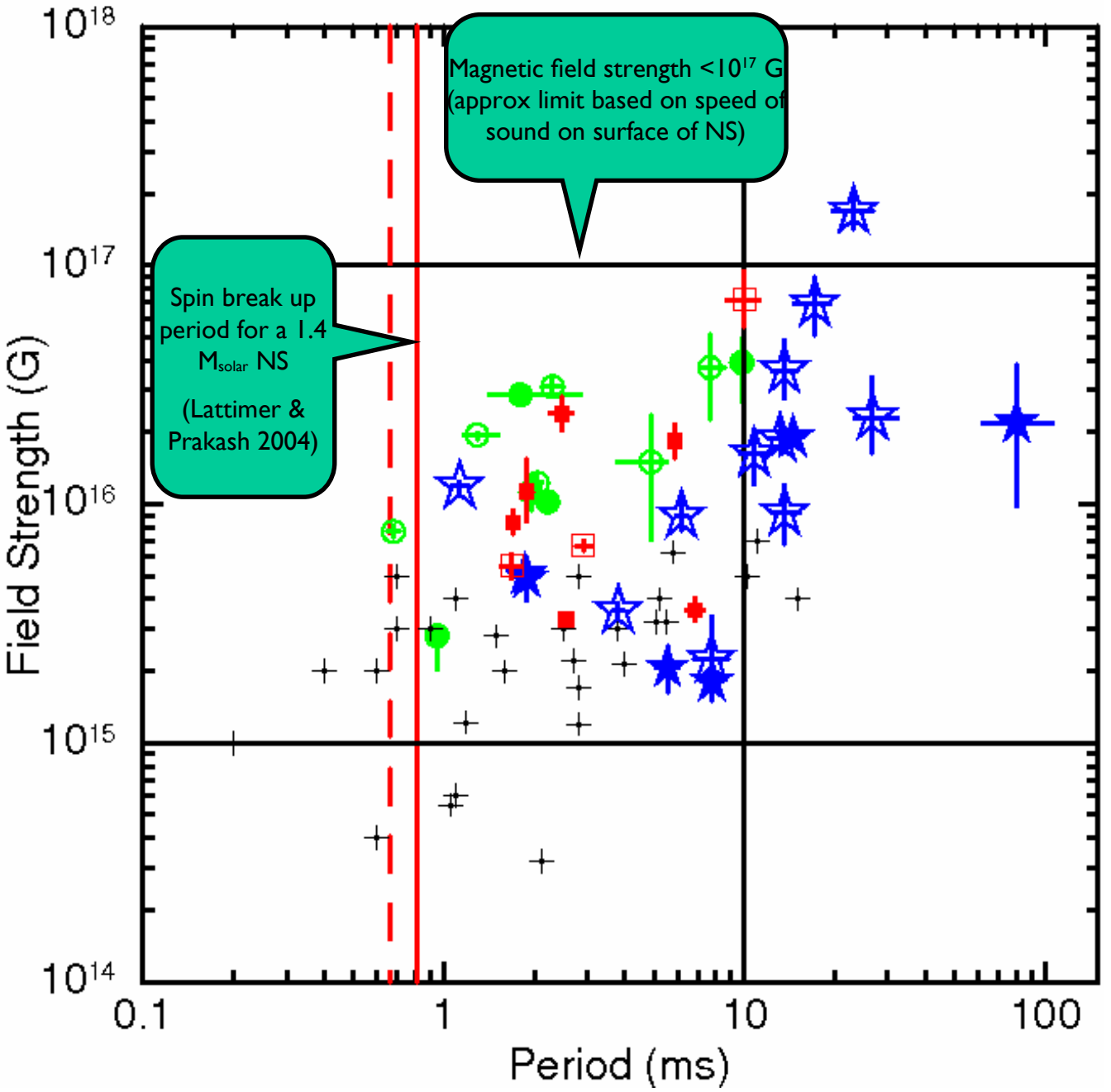
Wider GRB context

- Stable magnetars
- Unstable magnetars
- Long GRB candidates
- EE GRBs

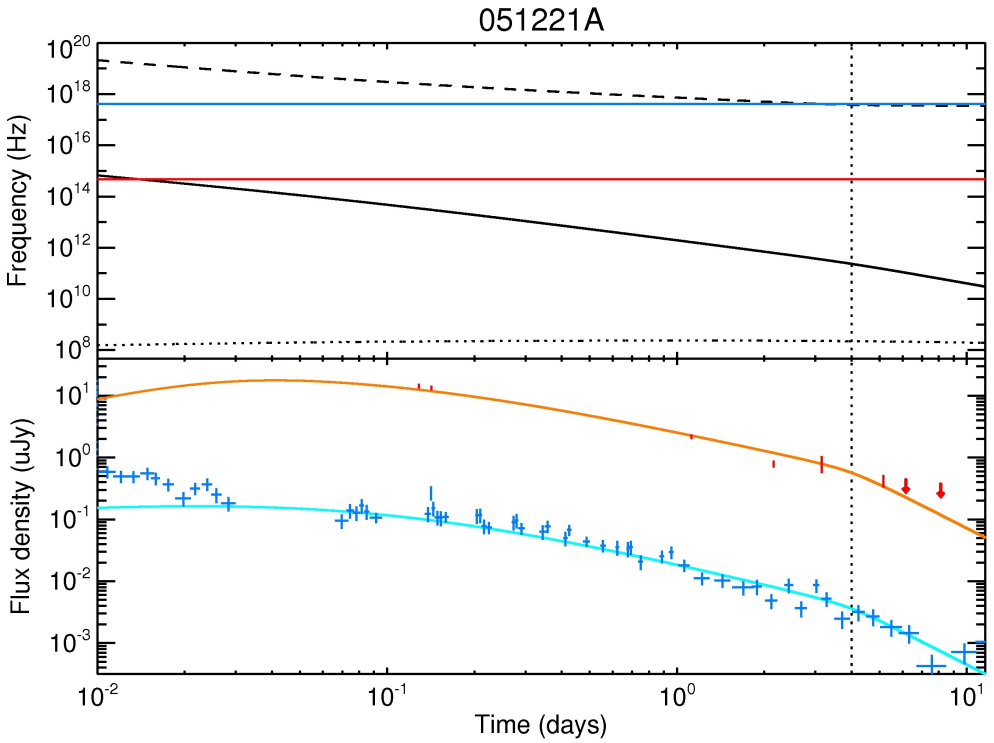
- GRB light curves energetically compatible with a magnetar central engine
- Magnetar parameters in the short and EE samples consistent with theory
- Some long GRBs are consistent, but violations of theoretical limits are more common

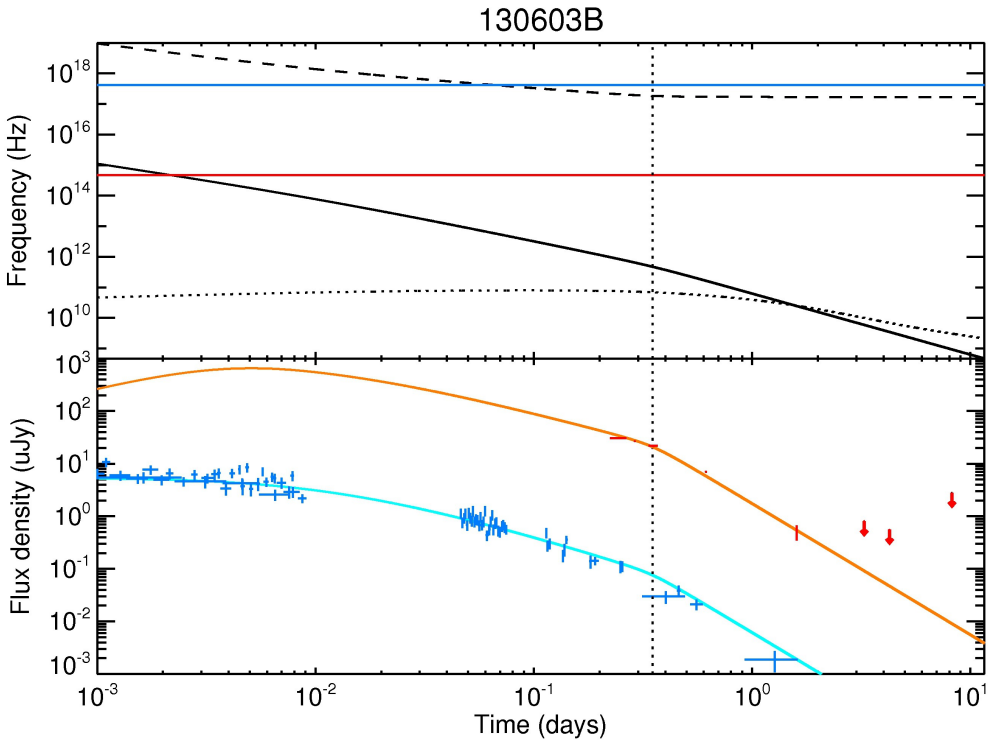


Gompertz et al. 2013, MNRAS, 431, 1745

The broadband view

- Standard dipole fitting assumes certain conversion efficiency from X-ray light curves.
- Gives no information on emission at longer wavelengths.
- Perform broadband modelling of forward shock emission with dipole (and EE) profile as time-varying energy injection.
- Available data is not constraining to self-absorption break (very few radio observations, even fewer detections) or cooling break (if above X-ray frequency).
- Many combinations of physical parameters can match available data.





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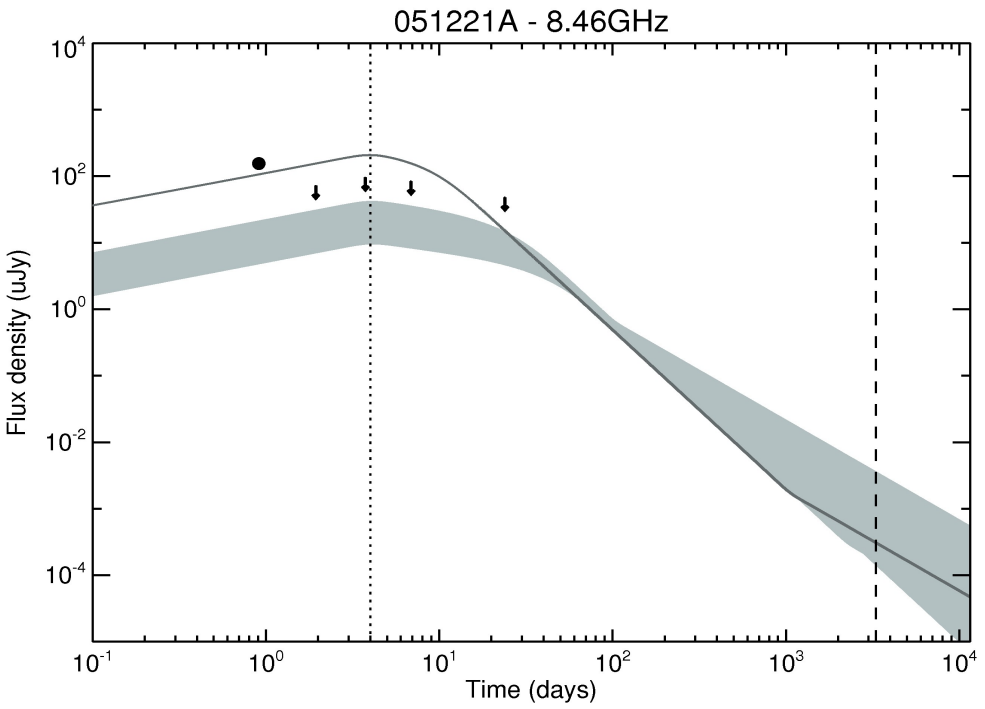
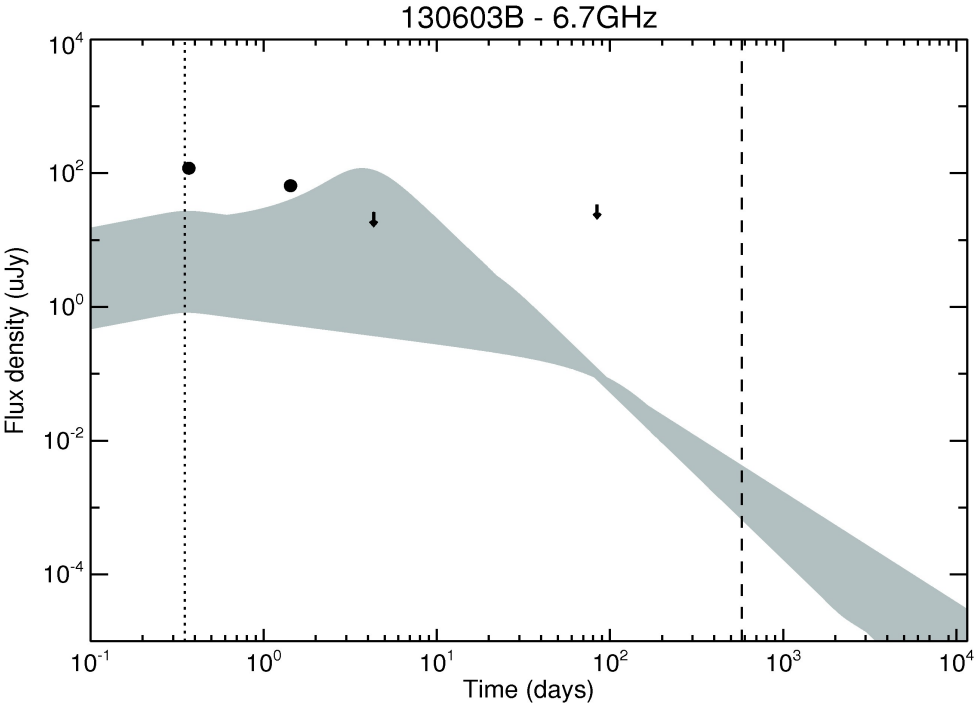
Radio signature

- Order of magnitude parameter space search for 3 physical parameters (ε_e, ε_B and n) and 3 energy terms (prompt, EE and dipole contributions).
- Each successful match provides a family of parameters that are self-consistent within the magnetar model.
- Can be used to create the expected radio signature for a magnetar injecting energy into a forward shock.
- Difficult to reproduce early-time radio observations with forward shock alone. Evidence for reverse shock?





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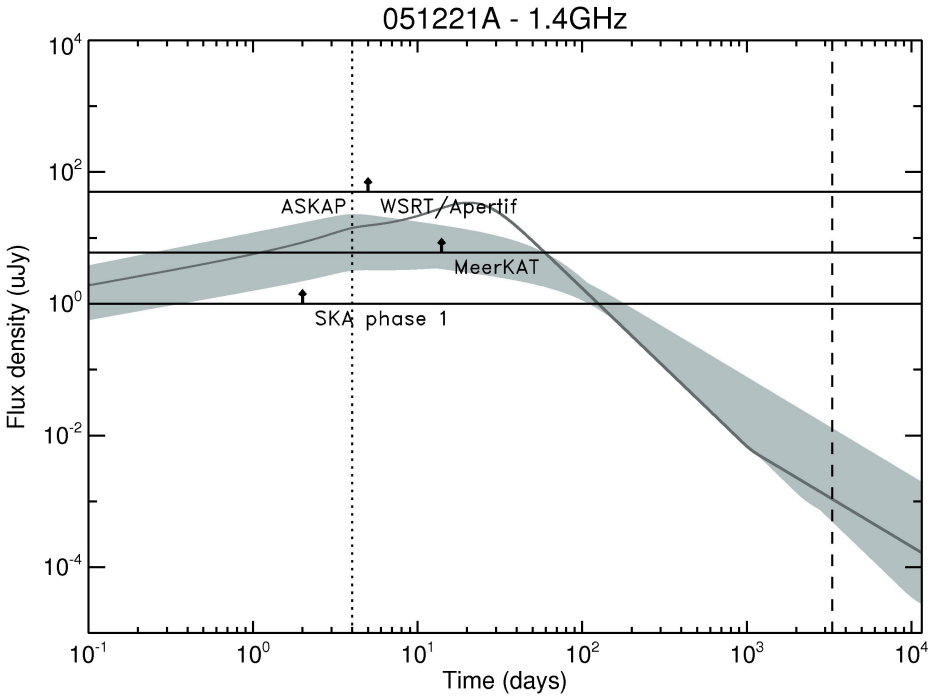
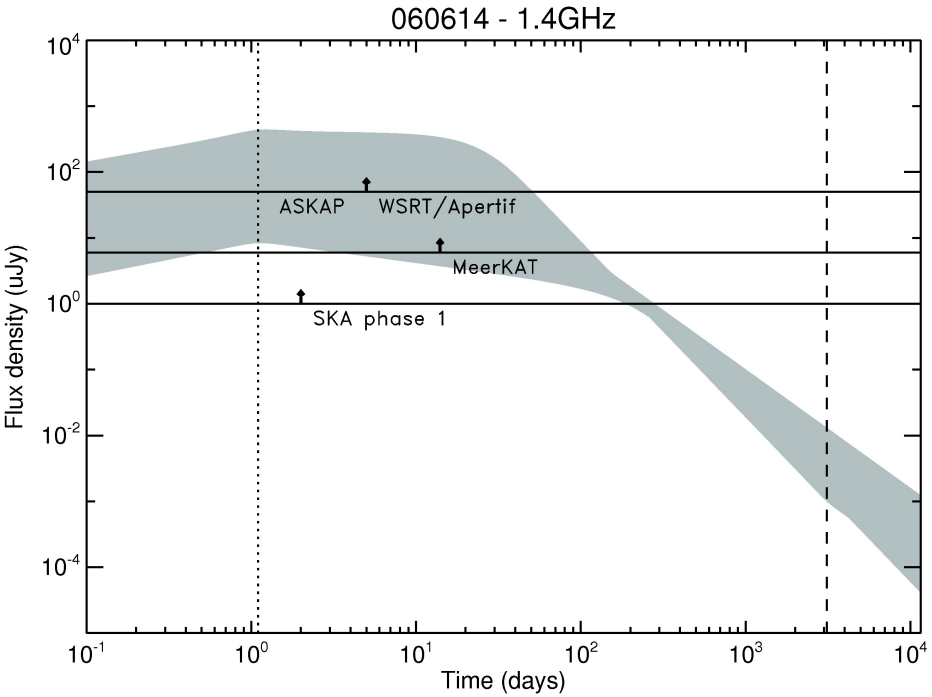
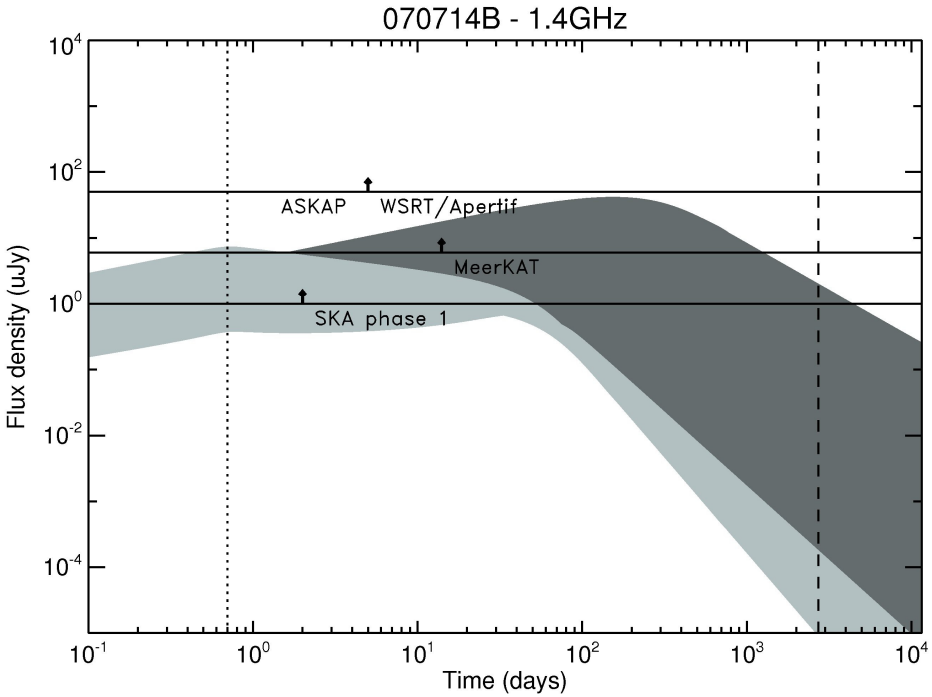
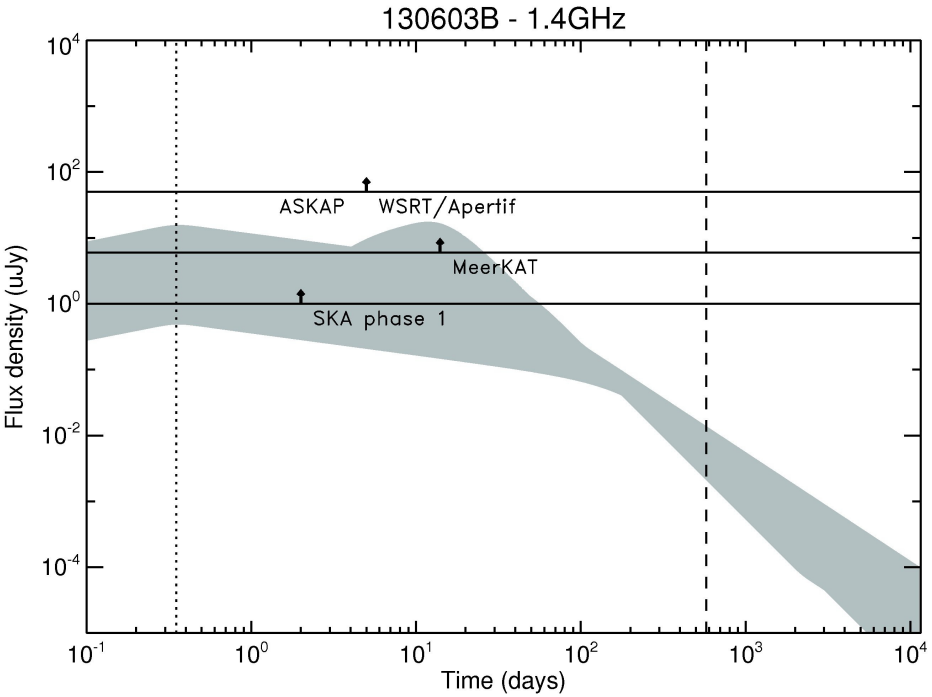
Detectability

Gompertz et al. (2015)
MNRAS, 448, 629









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Summary

- SGRB light curves are consistent with energy injection from a magnetar central engine.

- The magnetar model implies a great deal of energy injection, resulting in a brighter radio signature than the black hole scenario.

- Broadband observations are consistent with forward shock energy injection, but reverse shocks required at early times

- Paucity of observations means a wide range of potential physical parameters

- Previous radio observations provide some constraints to parameter space, but have not yet fully probed the model. Detections are likely to be from reverse shocks.

- Phase 1 of the SKA will have sufficient sensitivity to test the predicted radio signature of magnetar energy injection in most cases.

- SKA phase 2 will be able to go deeper than our lowest prediction for around a year after trigger!