Newborn magnetars from the merger of neutron star binaries

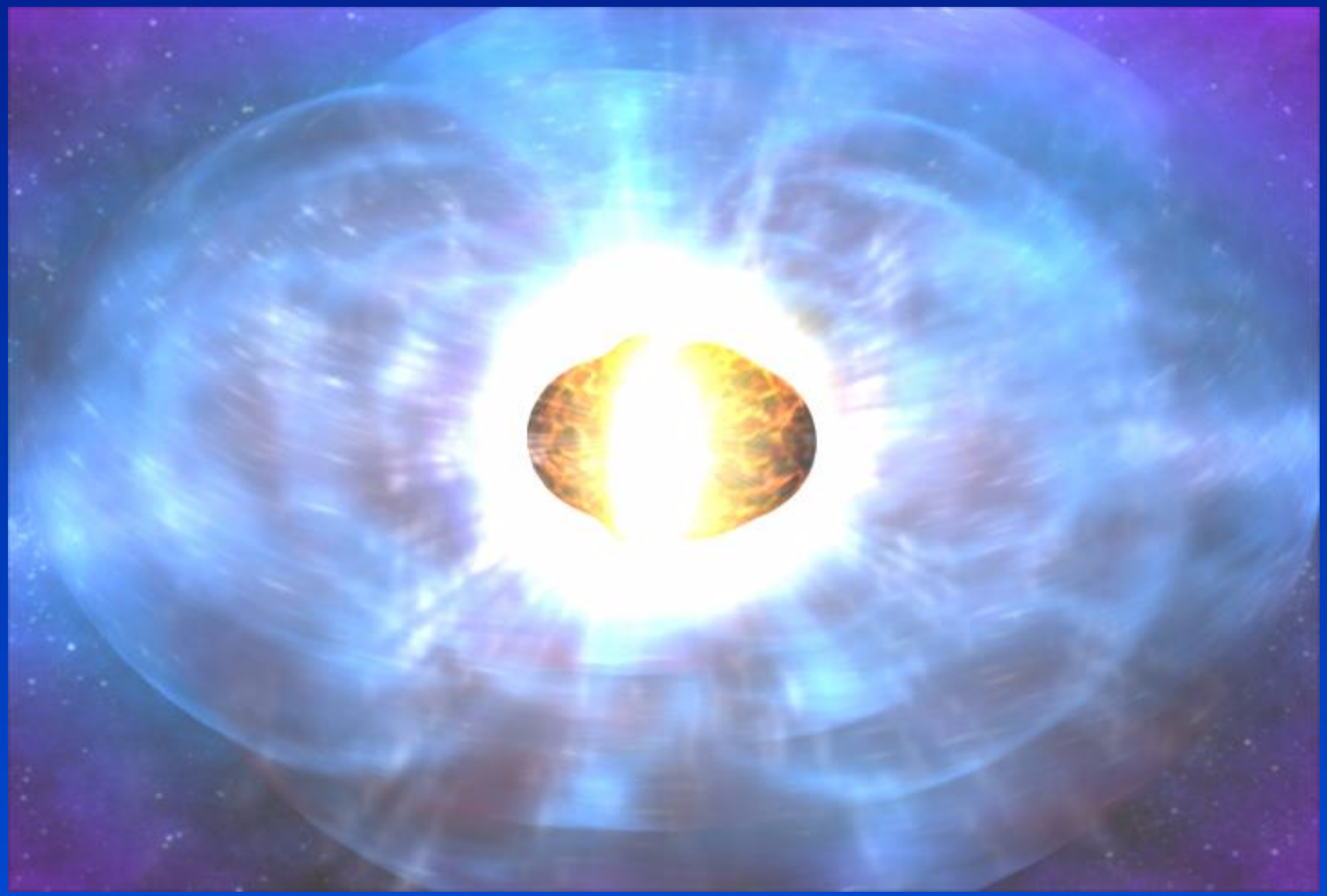

Image credit: NASA/Goddard Space Flight Center

Antonia Rowlinson

29th November 2013

erc European Research Council

ASTRONOMICAL INSTITUTE ANTON PANNEKOEK

UNIVERSITEIT VAN AMSTERDAM

Summary:

- Electromagnetic counterparts to neutron star binary mergers
- Recent observational developments
- Nature of the remnant following the merger
- Looking to the future

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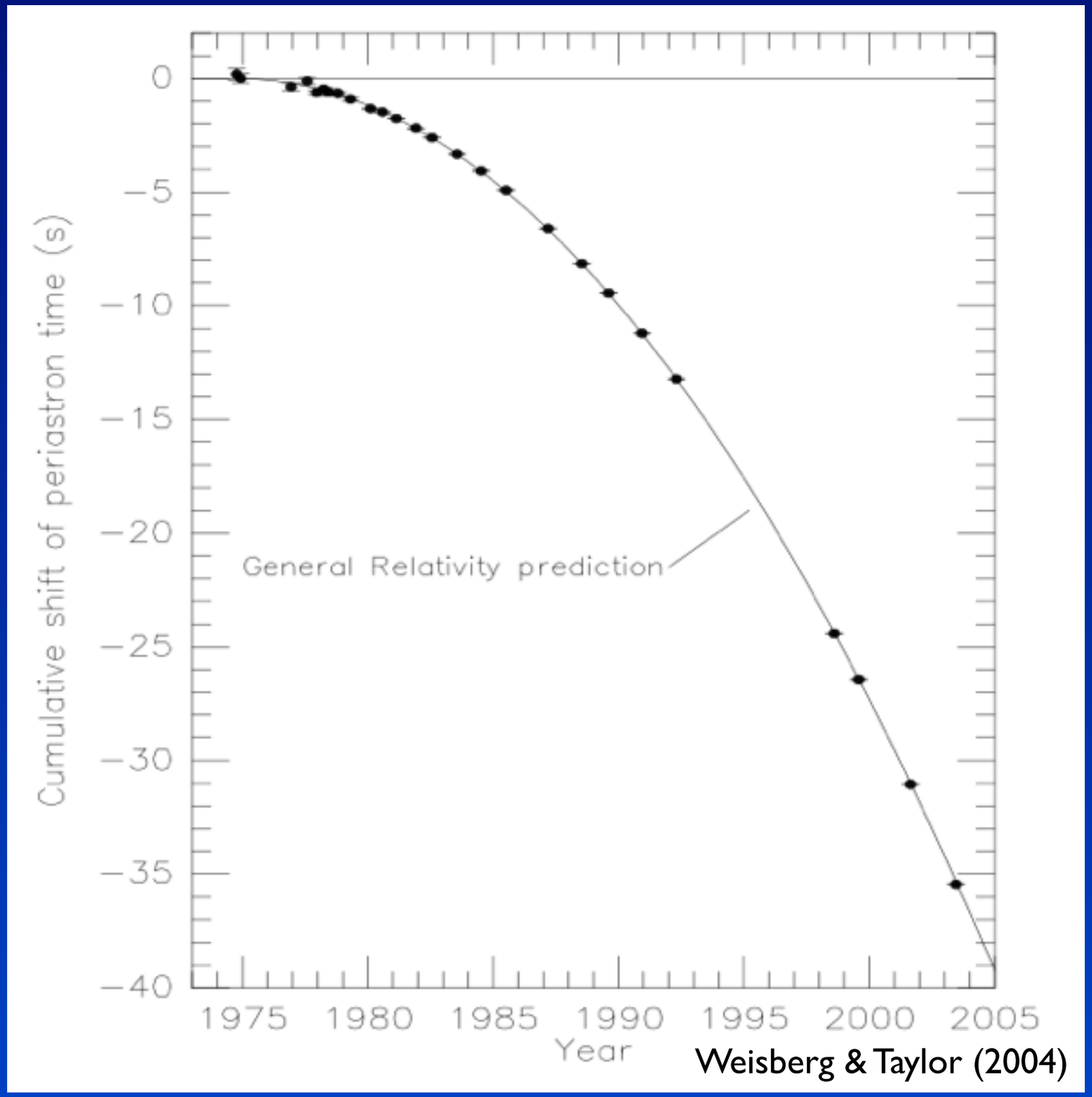

Weisberg & Taylor (2004)

- First binary neutron star system discovered in 1974: Hulse-Taylor binary pulsar system
- Timing analysis of orbit proved existence of gravitational waves
- This binary will merge in ~300 million years

What will happen then?

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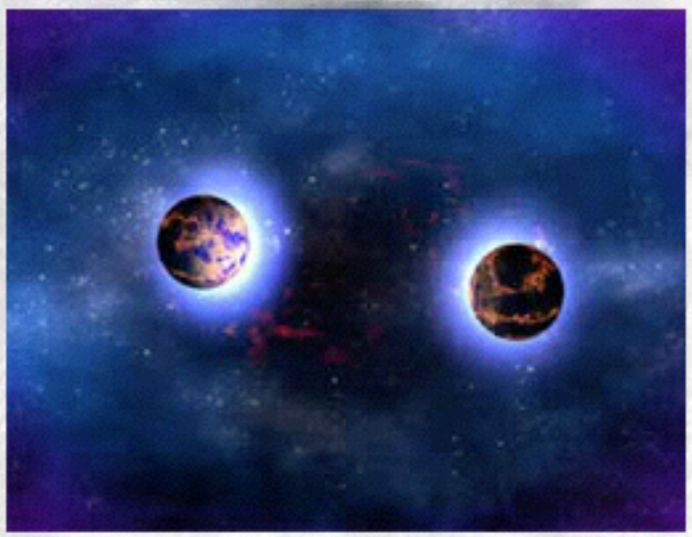
SWIFT NEUTRON STAR
COLLISION V. 2



ANIMATION: DANA BERRY
310-441-1735
PRODUCED BY ERICA DREZEK

Electromagnetic signals

Gravitational wave burst

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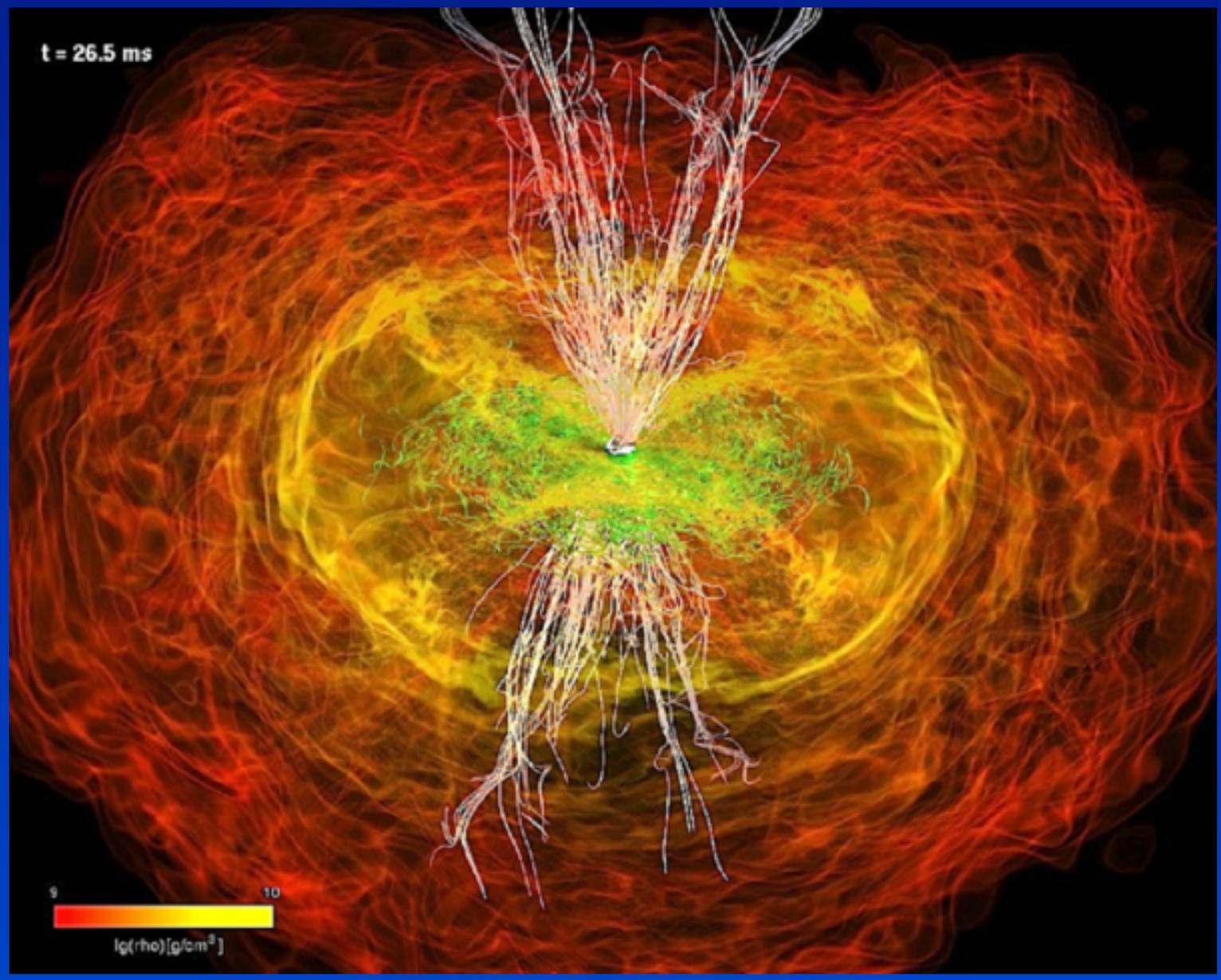
Expected signals: Short GRB

- Short GRBs are predicted to form via the merger of a compact binary system such as 2 neutron stars or a neutron star and a black hole (Lattimer & Schramm 1976, Eichler et al. 1989, Narayan et al. 1992)
- Accretion takes << 2 s



Rezzolla et al. (2011)

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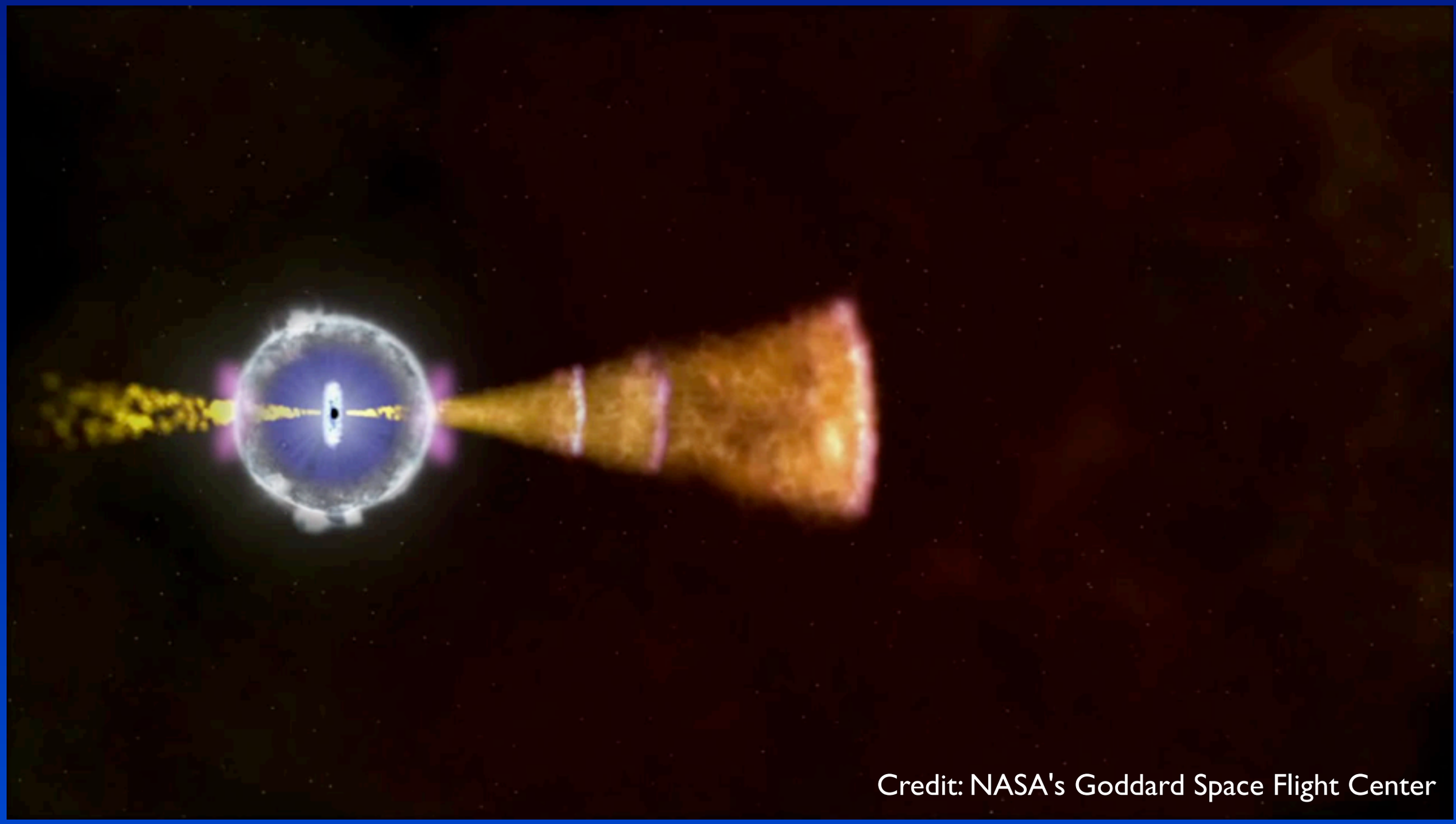
GRB Fireball Model



Credit: NASA's Goddard Space Flight Center

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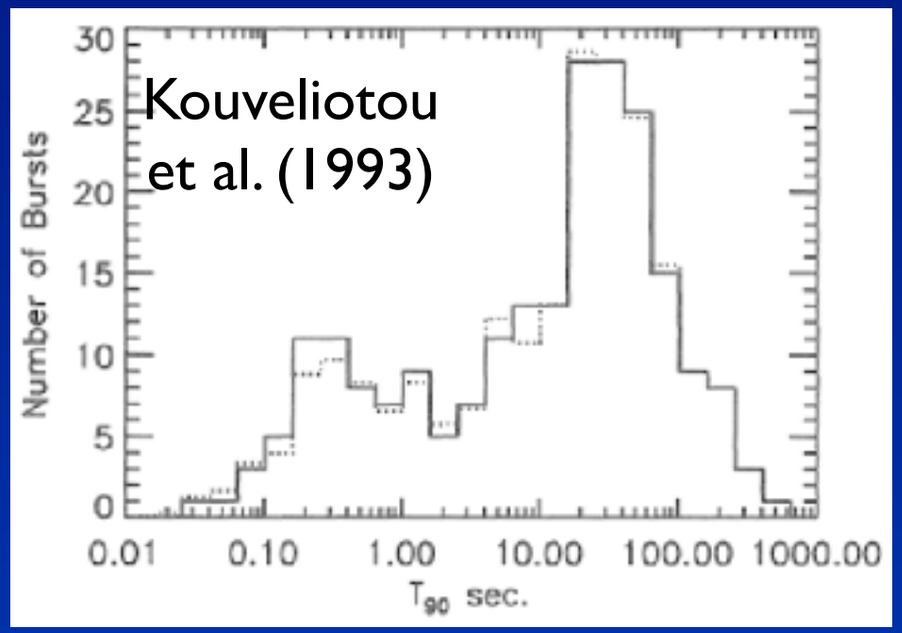
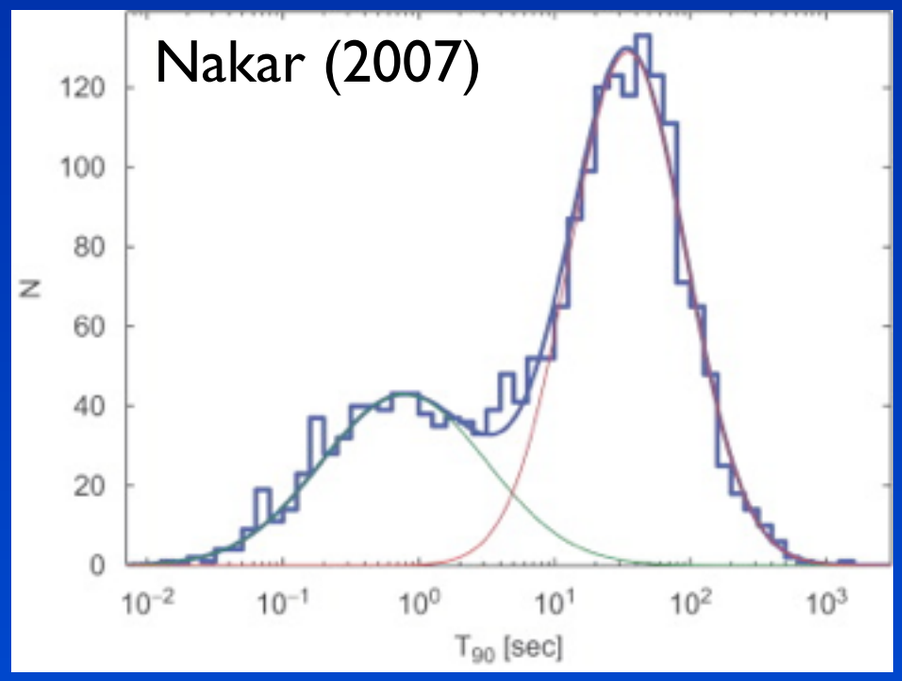
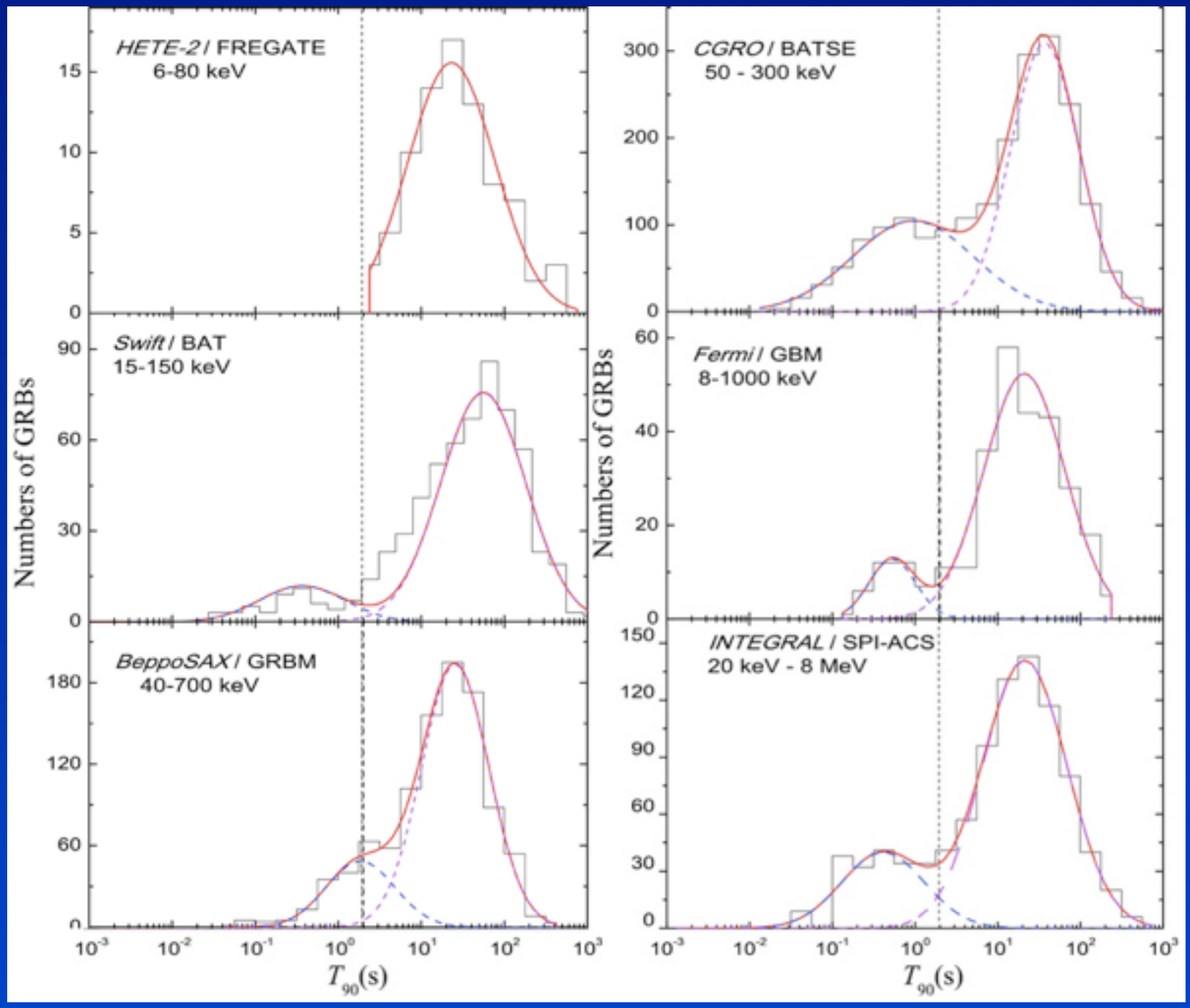
Identification of Short GRBs



BATSE





Qin et al. (2013) (see also work by Bromberg et al. 2013)

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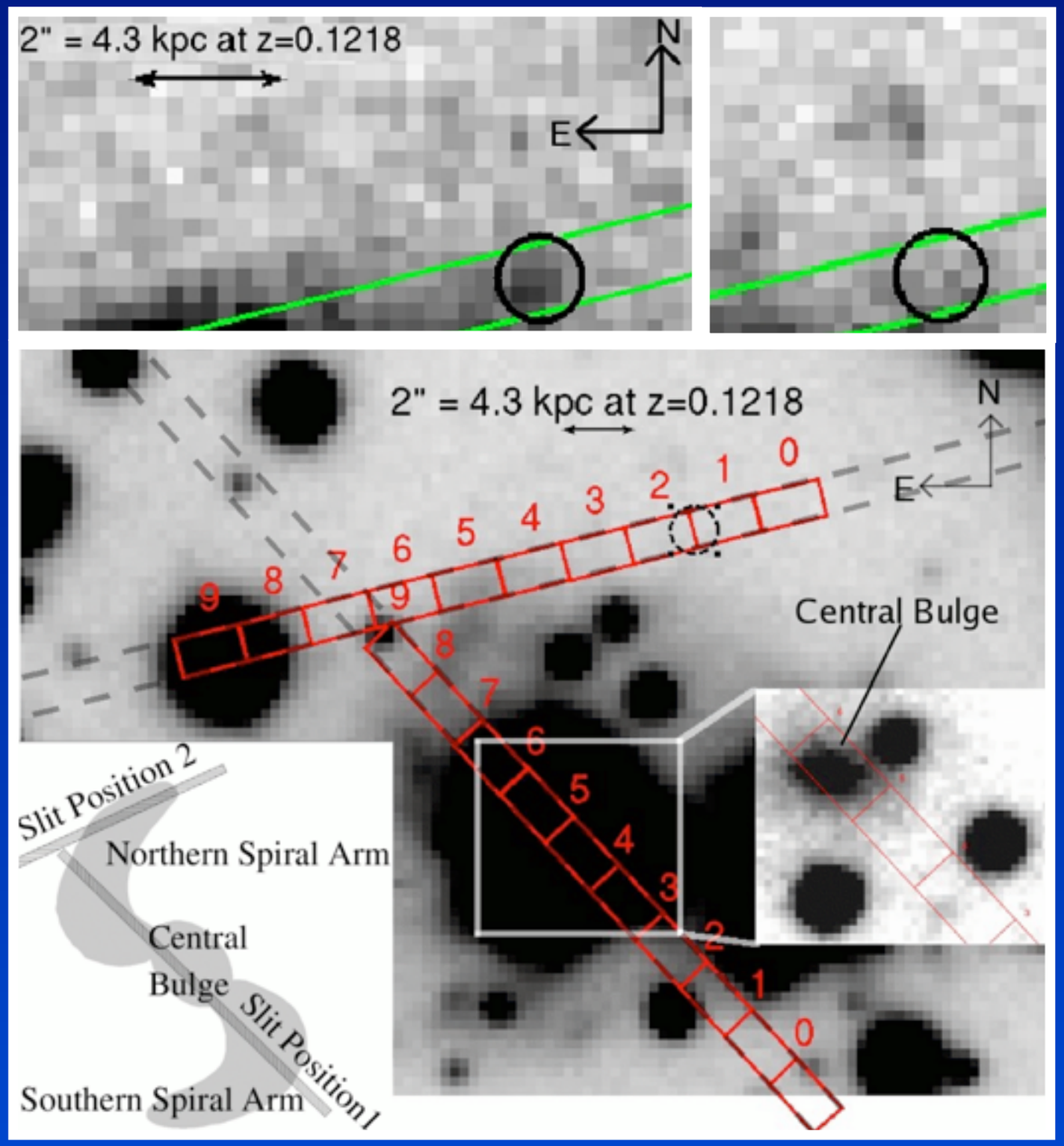
Kicked out of birth place?



- Neutron stars get a 'kick' when formed - binary gets a kick (e.g. 100 kms^{-1})
- Binaries can take ~10^8 years to merge
- GRB 080905A was 9" (18 kpc) offset from host

Rowlinson et al. (2010a)

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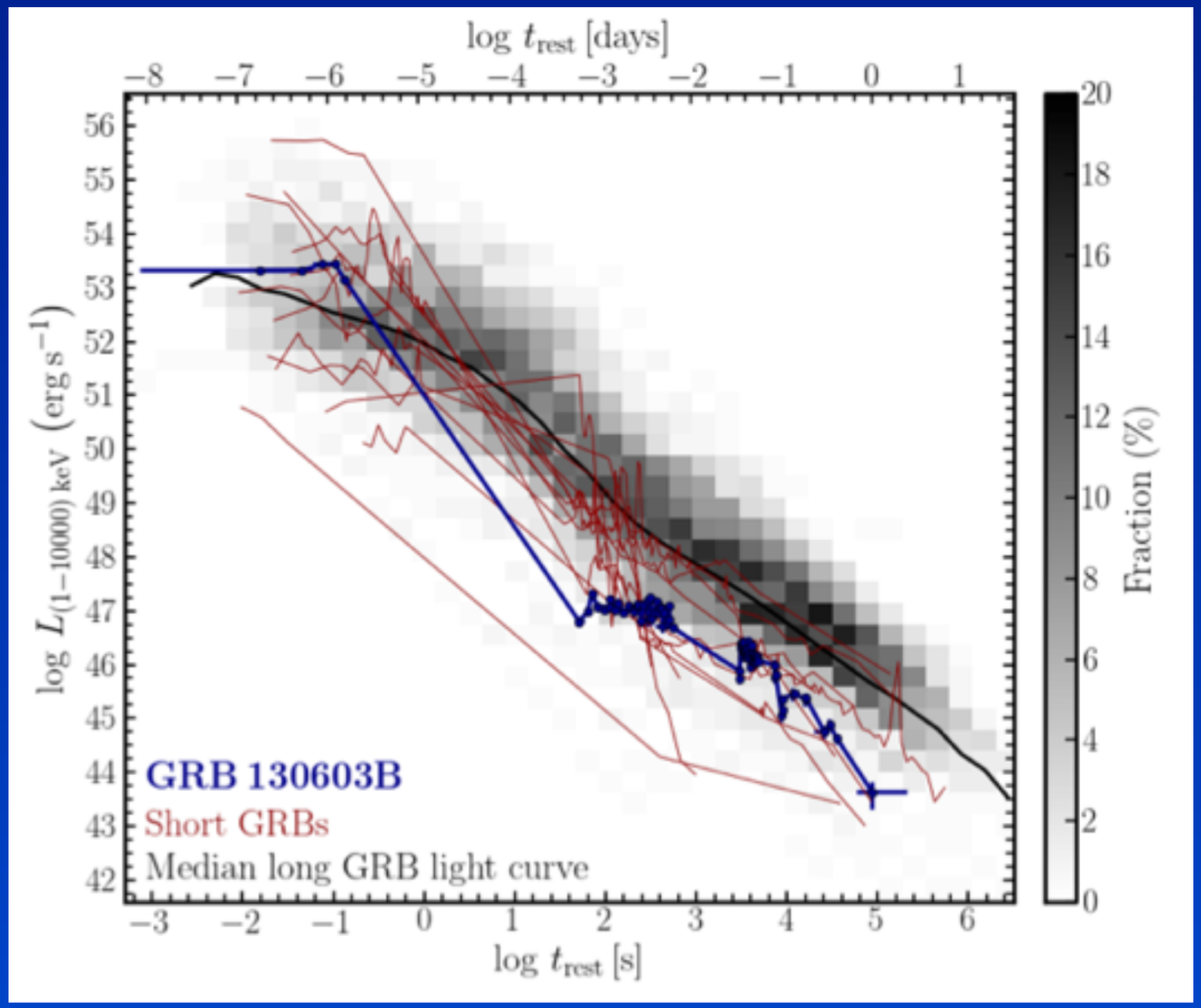
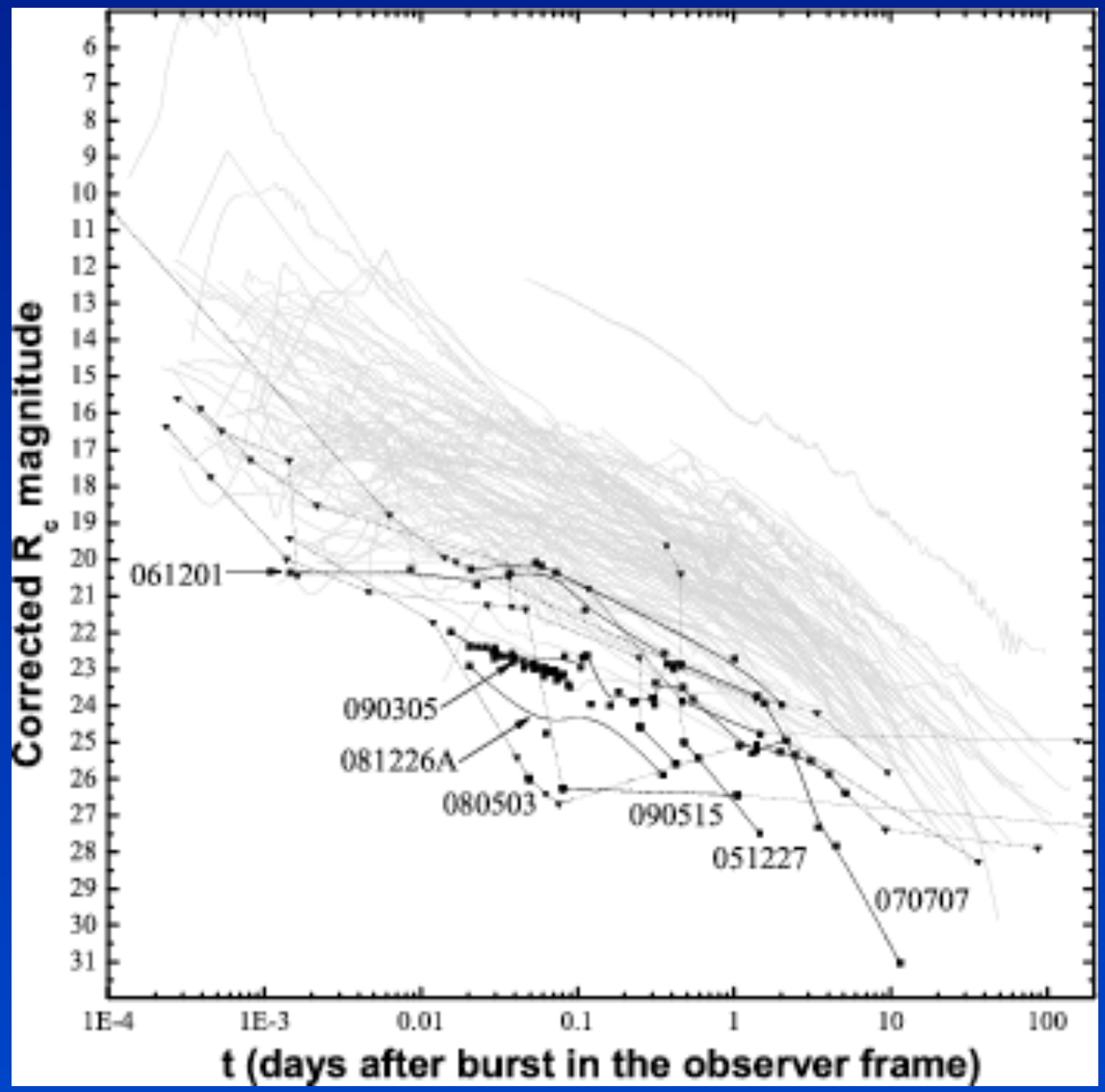
Expected signals: Faint Afterglow

X-ray



de Ugarte Postigo et al. (2013)

Optical



Kann et al. (2011)

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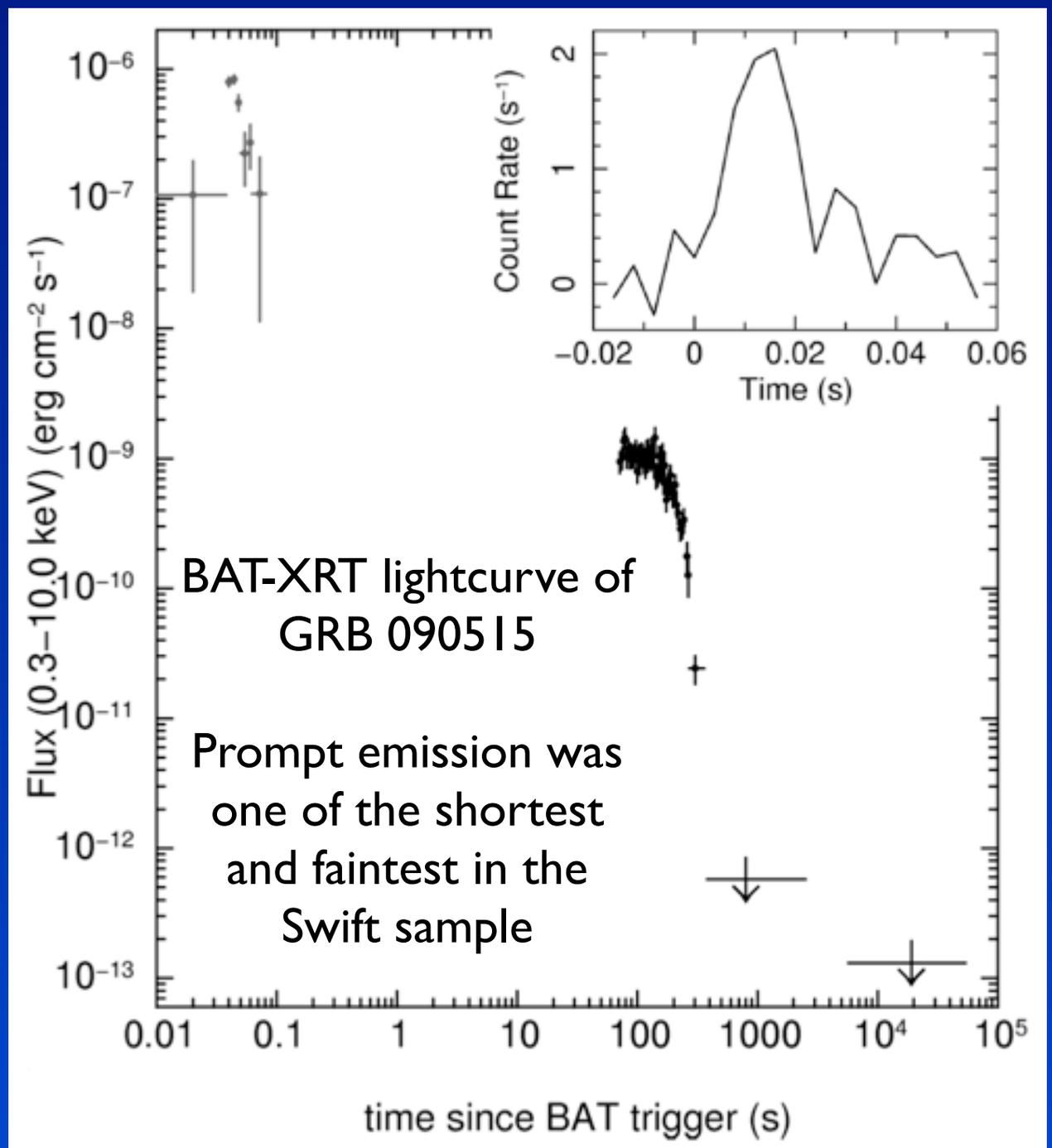
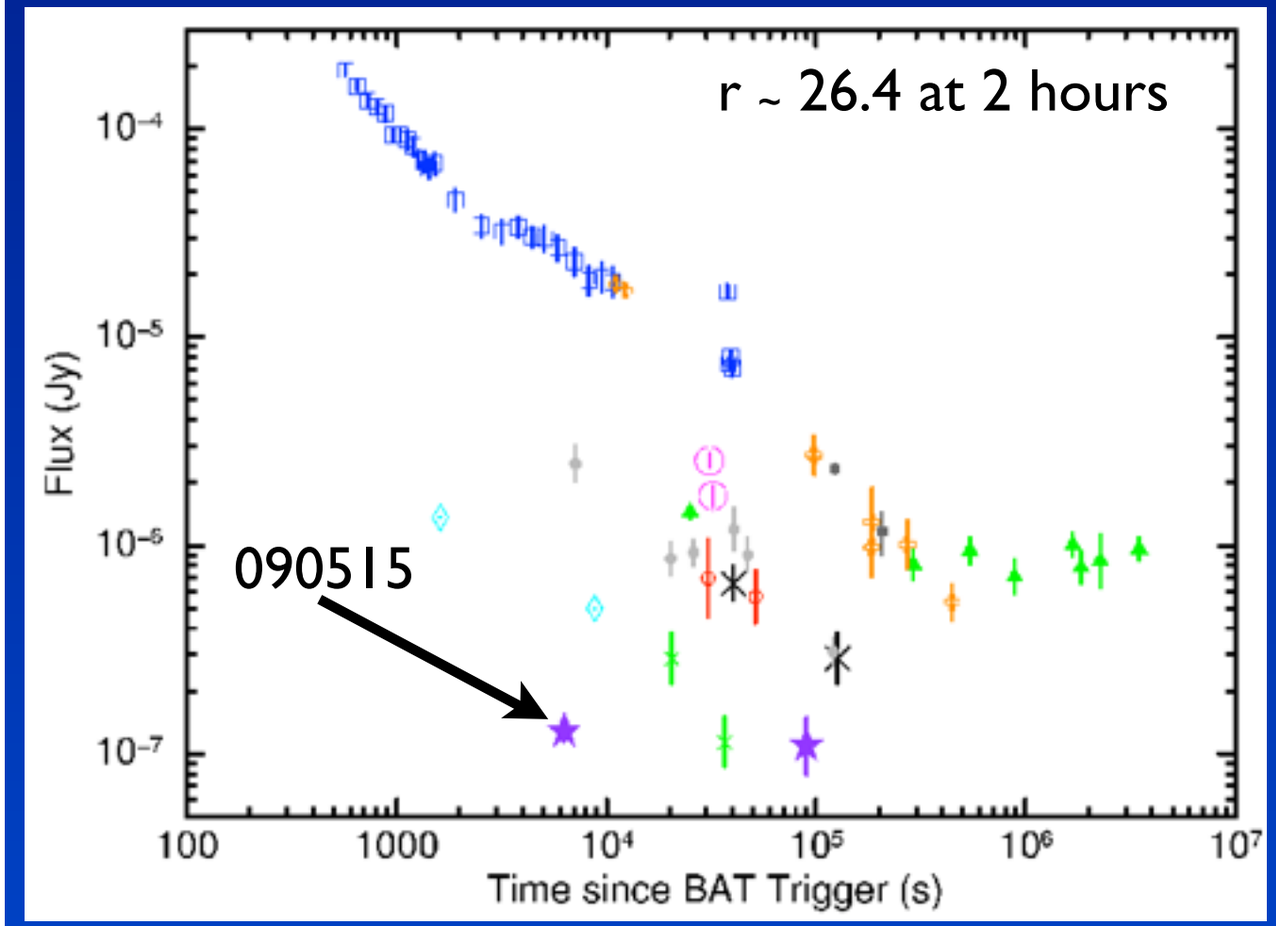
GRB 090515: An unusual short GRB?



BAT-XRT lightcurve of GRB 090515

Prompt emission was one of the shortest and faintest in the Swift sample

Optical afterglows of short GRBs



Rowlinson et al. (2010b)

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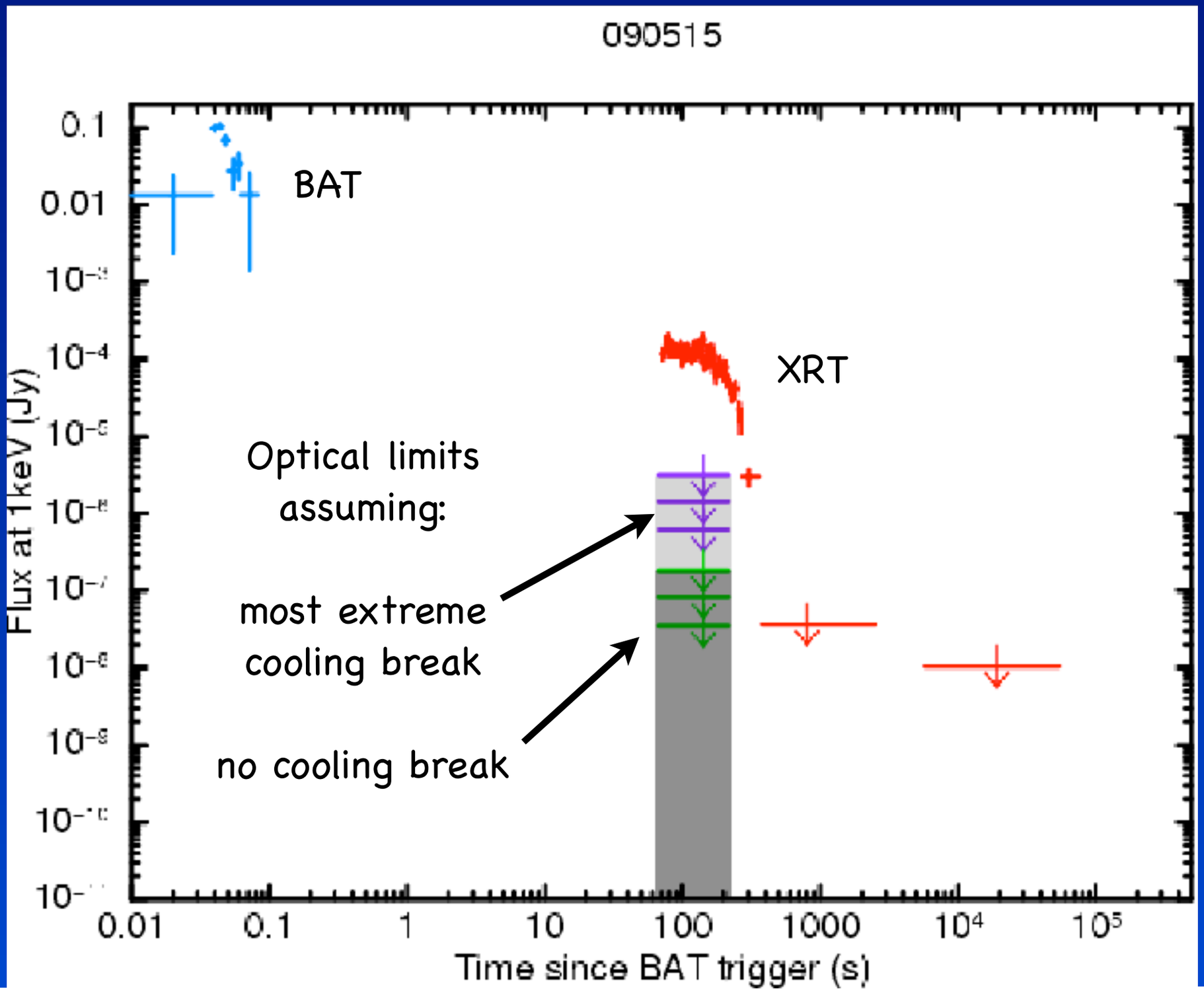
Optical Afterglow



Rowlinson et al. (2013)

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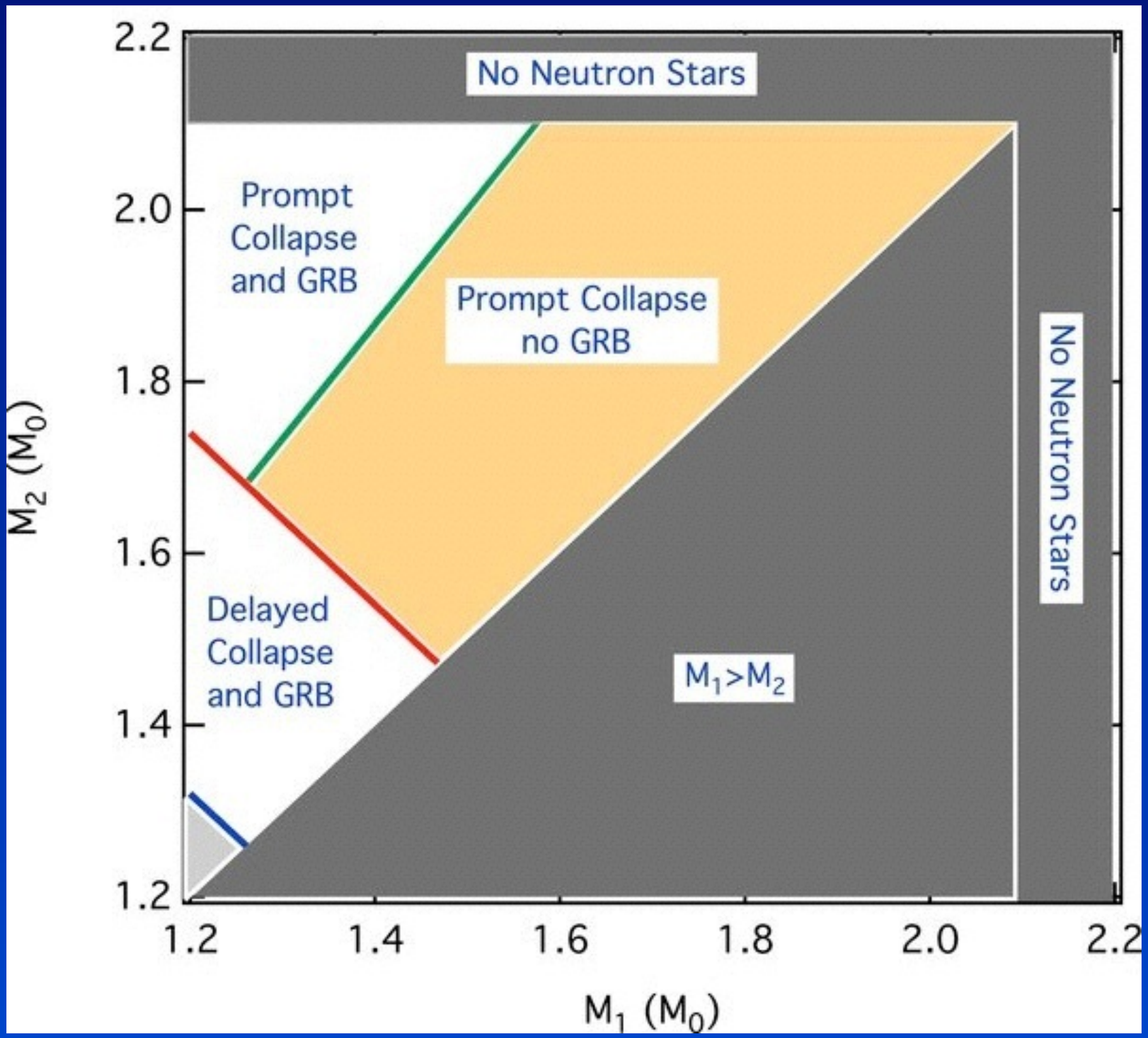

The outcome of a binary merger of 2 Neutron Stars assuming the maximum stable Neutron Star mass is

$$\sim 2.1 M_\odot$$

Demorest et al. (2010)
Ozel et al. (2010)

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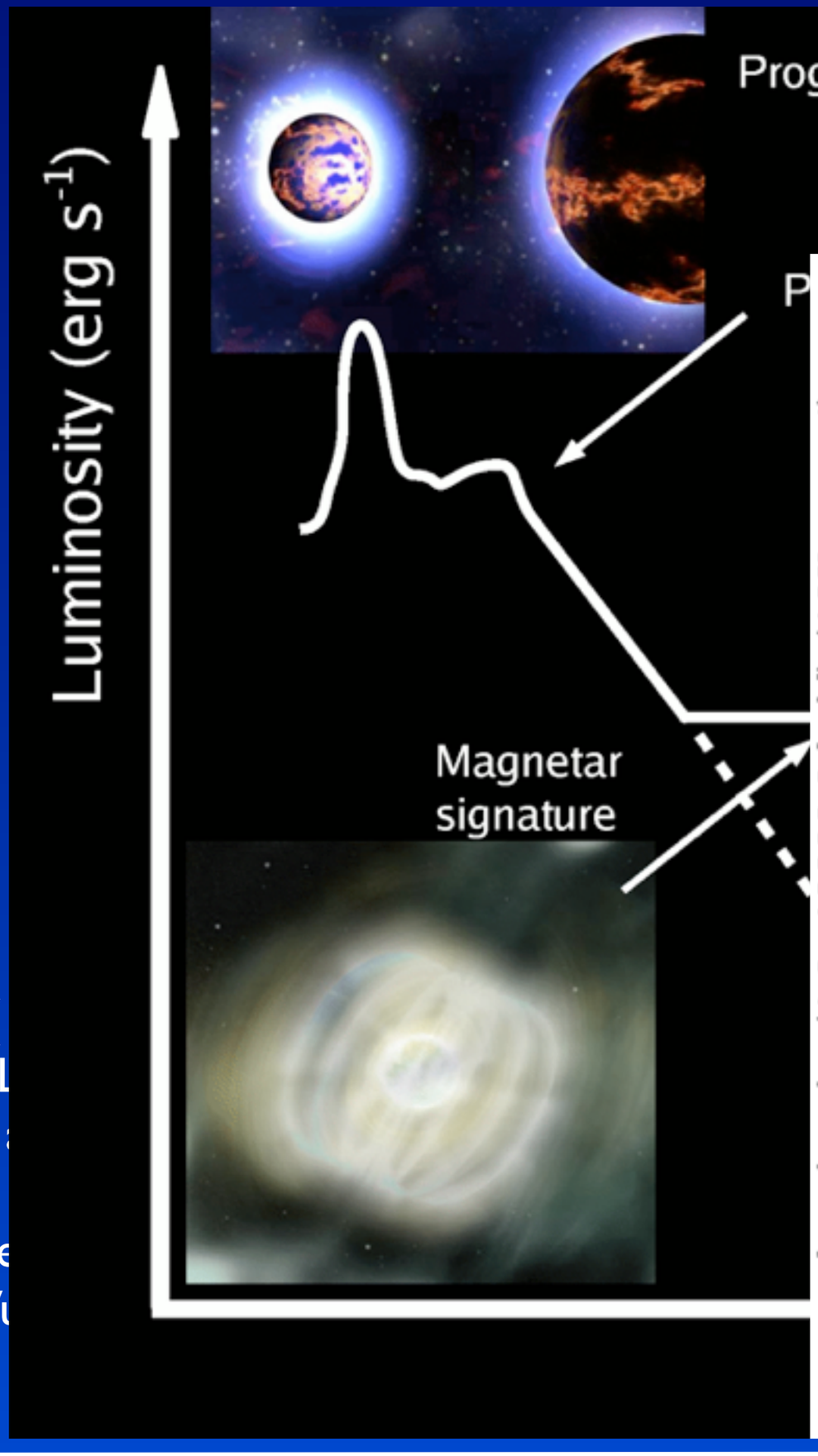

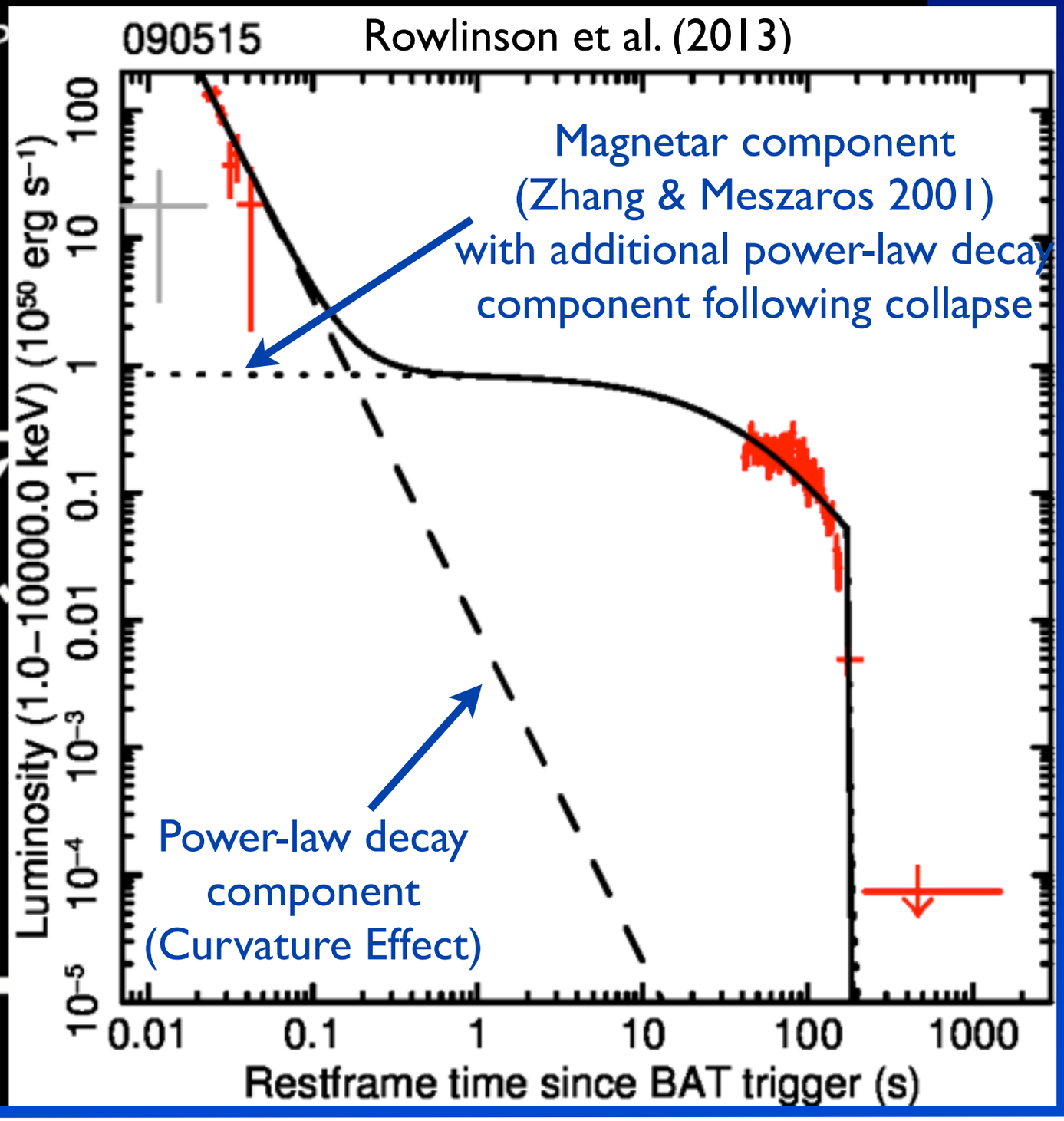

Usov (
Dai & L
Dai et
Huang
Gompe
Fan, Wu

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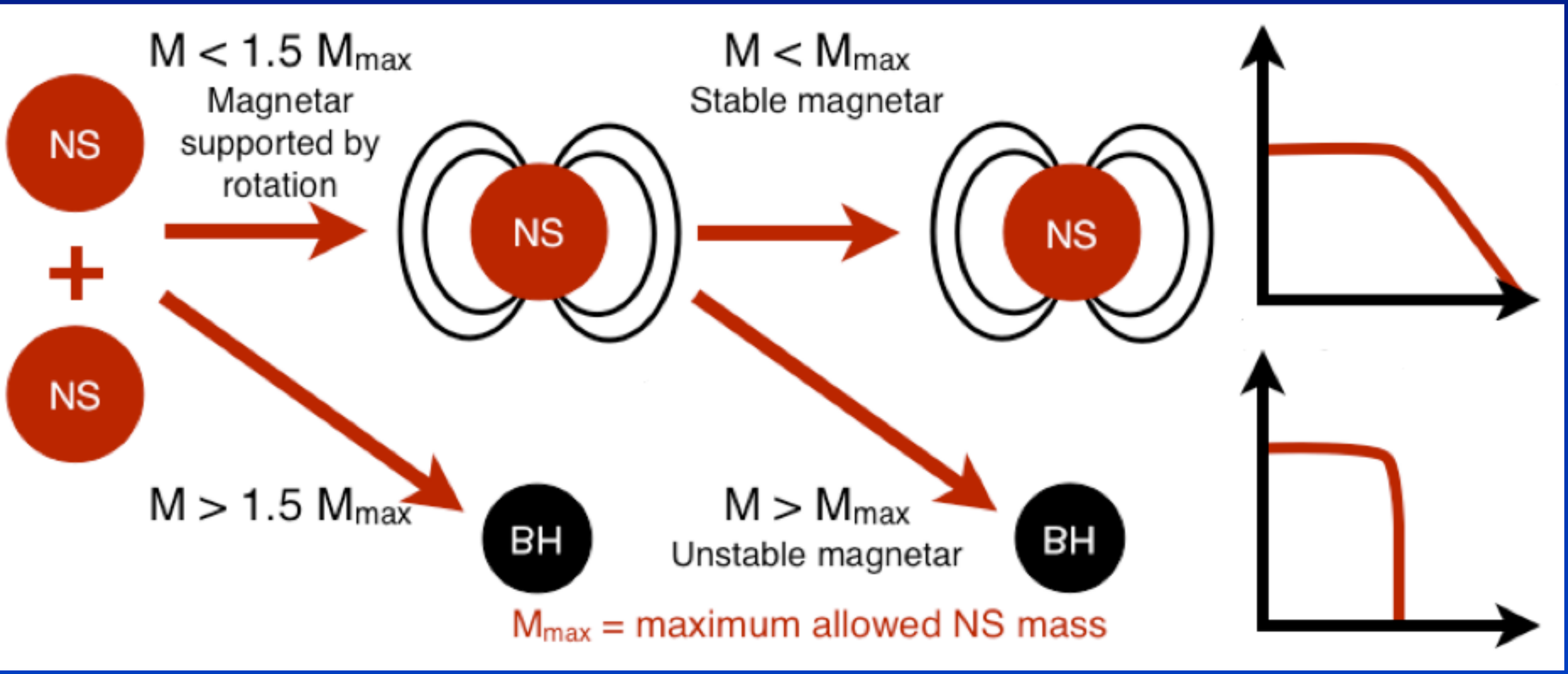
Outcomes from merging neutron stars



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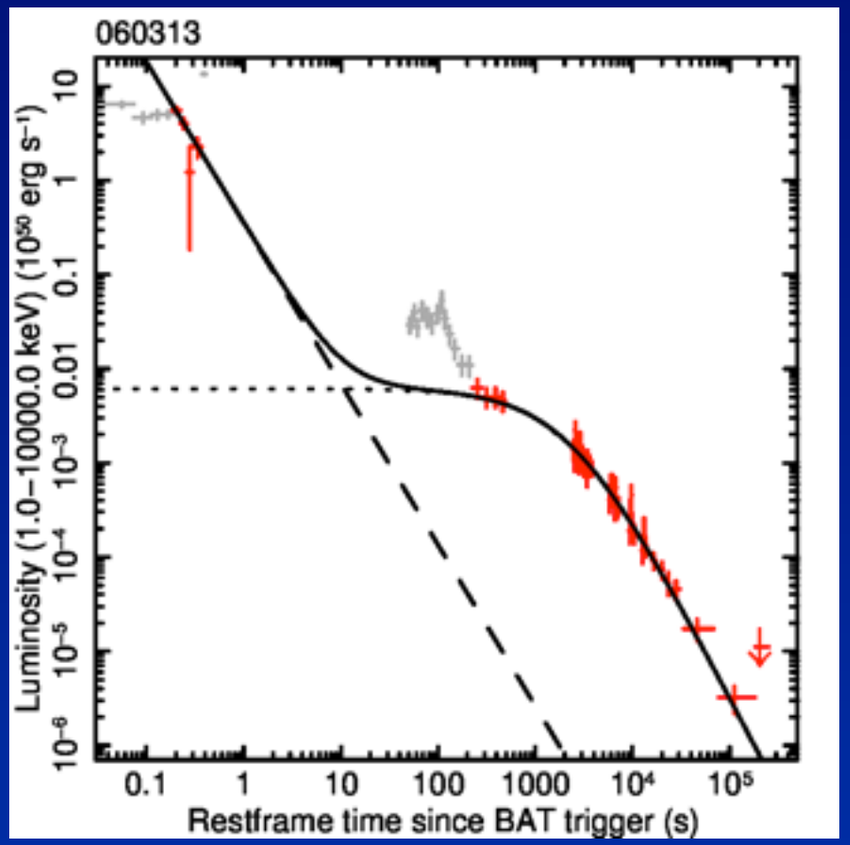
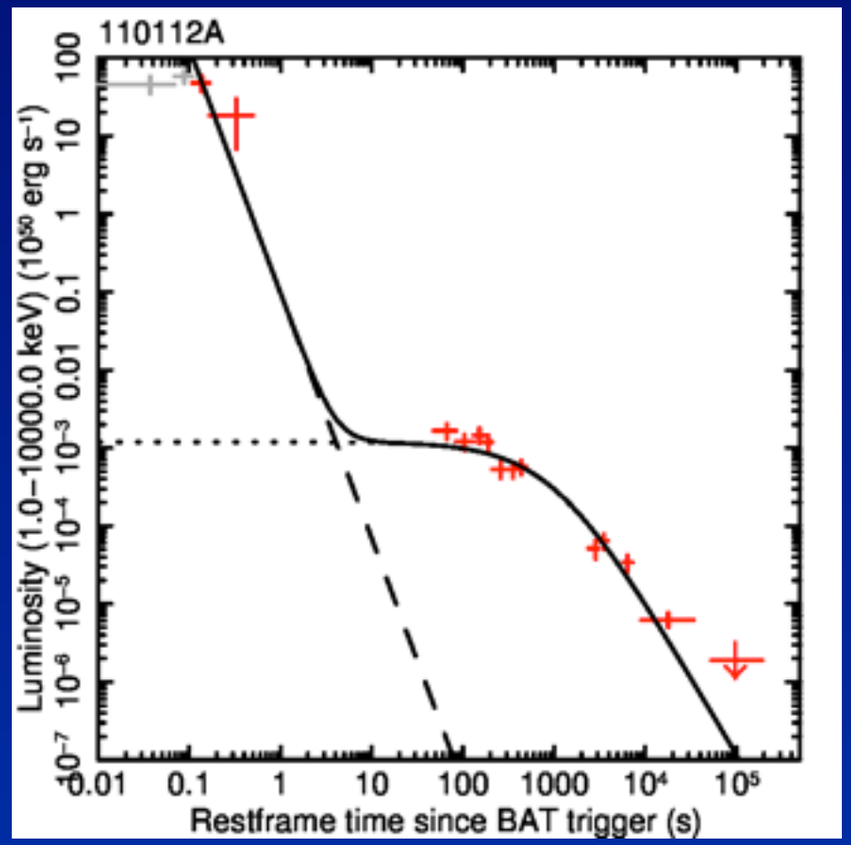
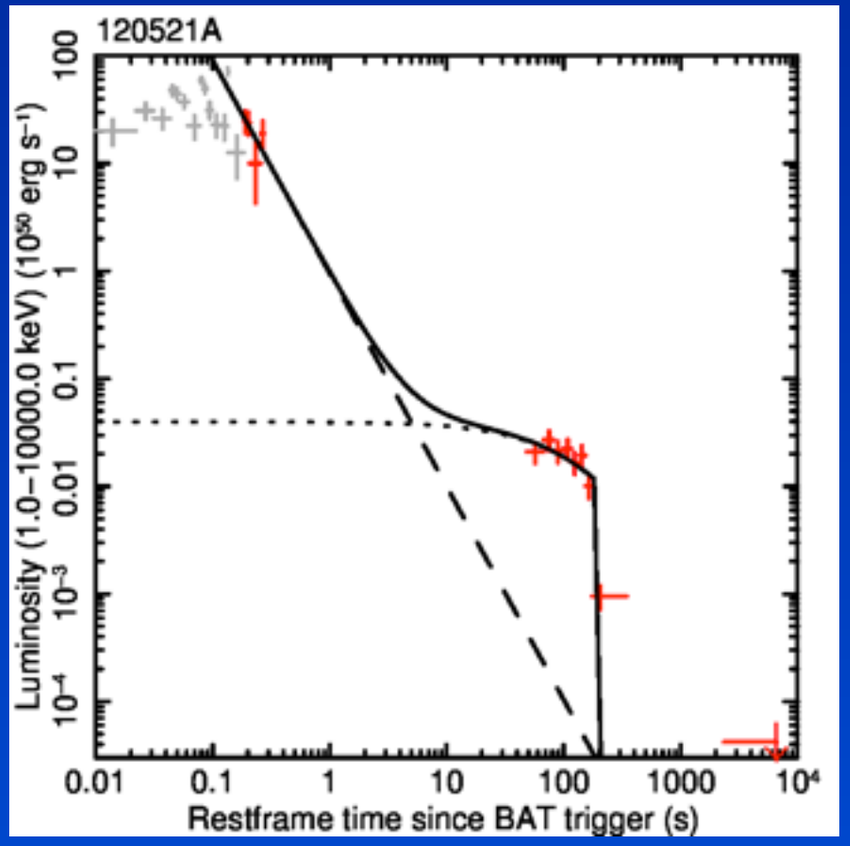
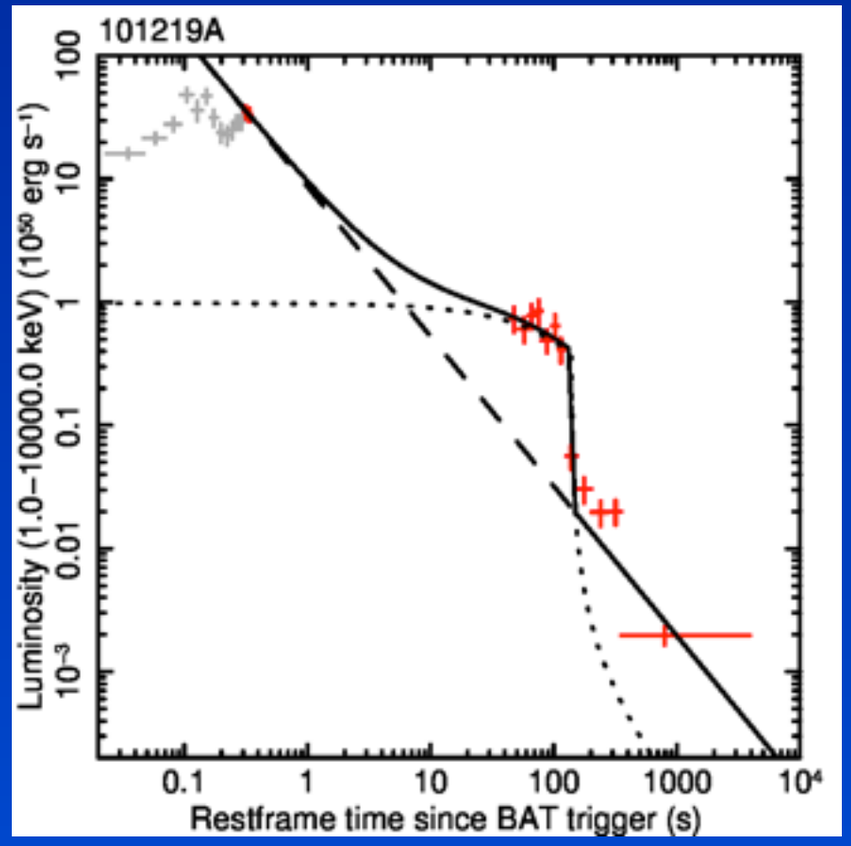




Stable





Unstable

Rowlinson et al. (2013)

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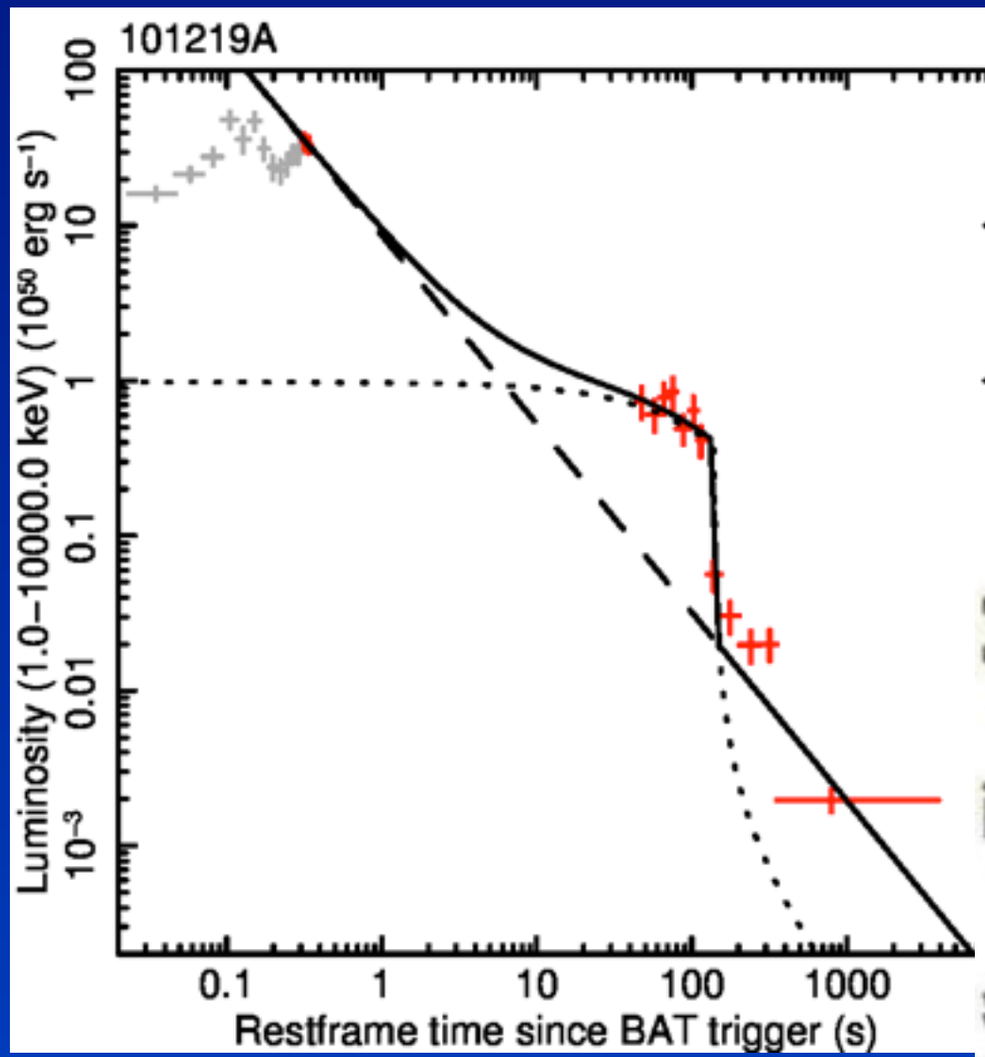
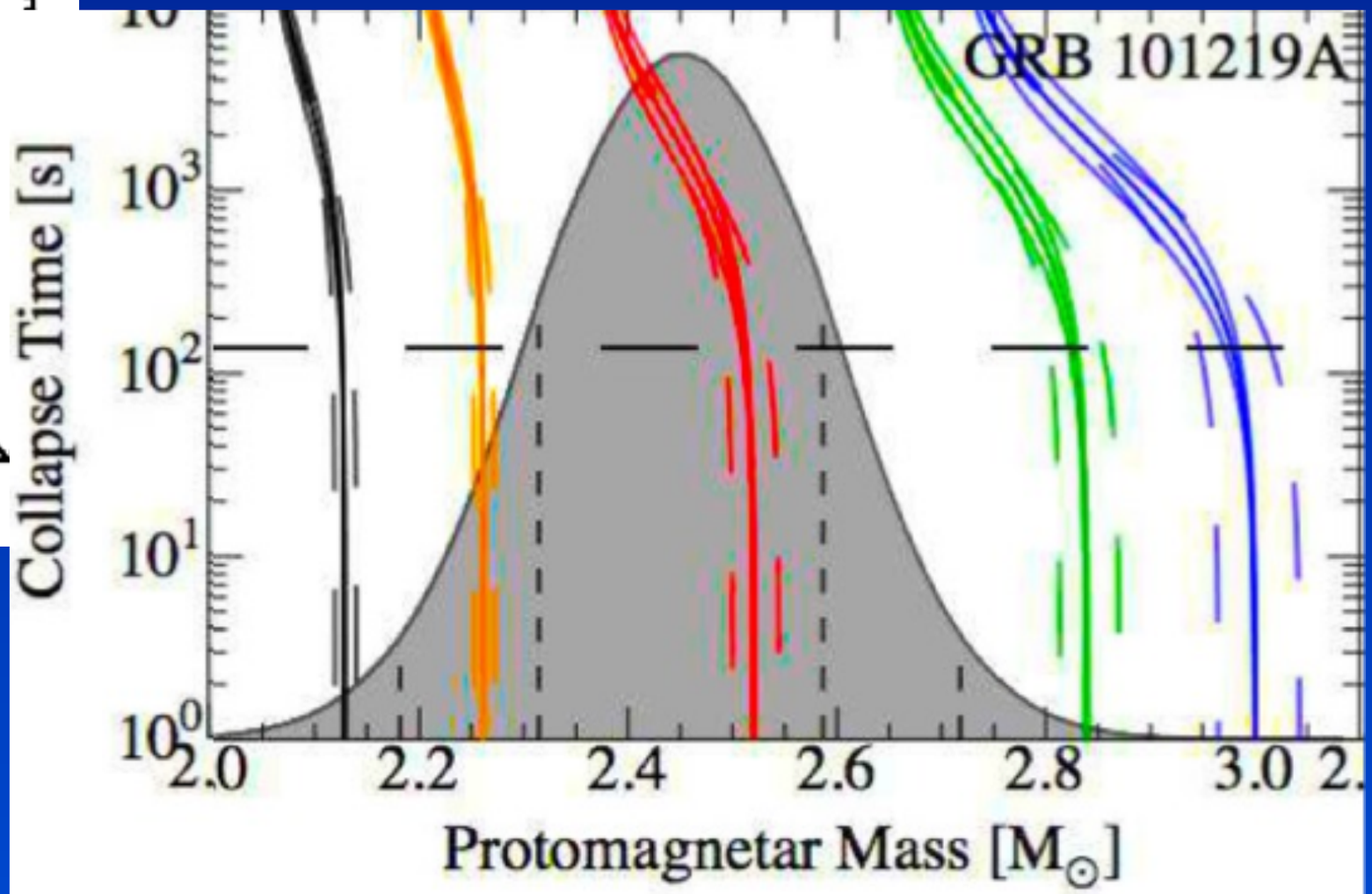
Constraining equation of state



Lasky et al. (2013)



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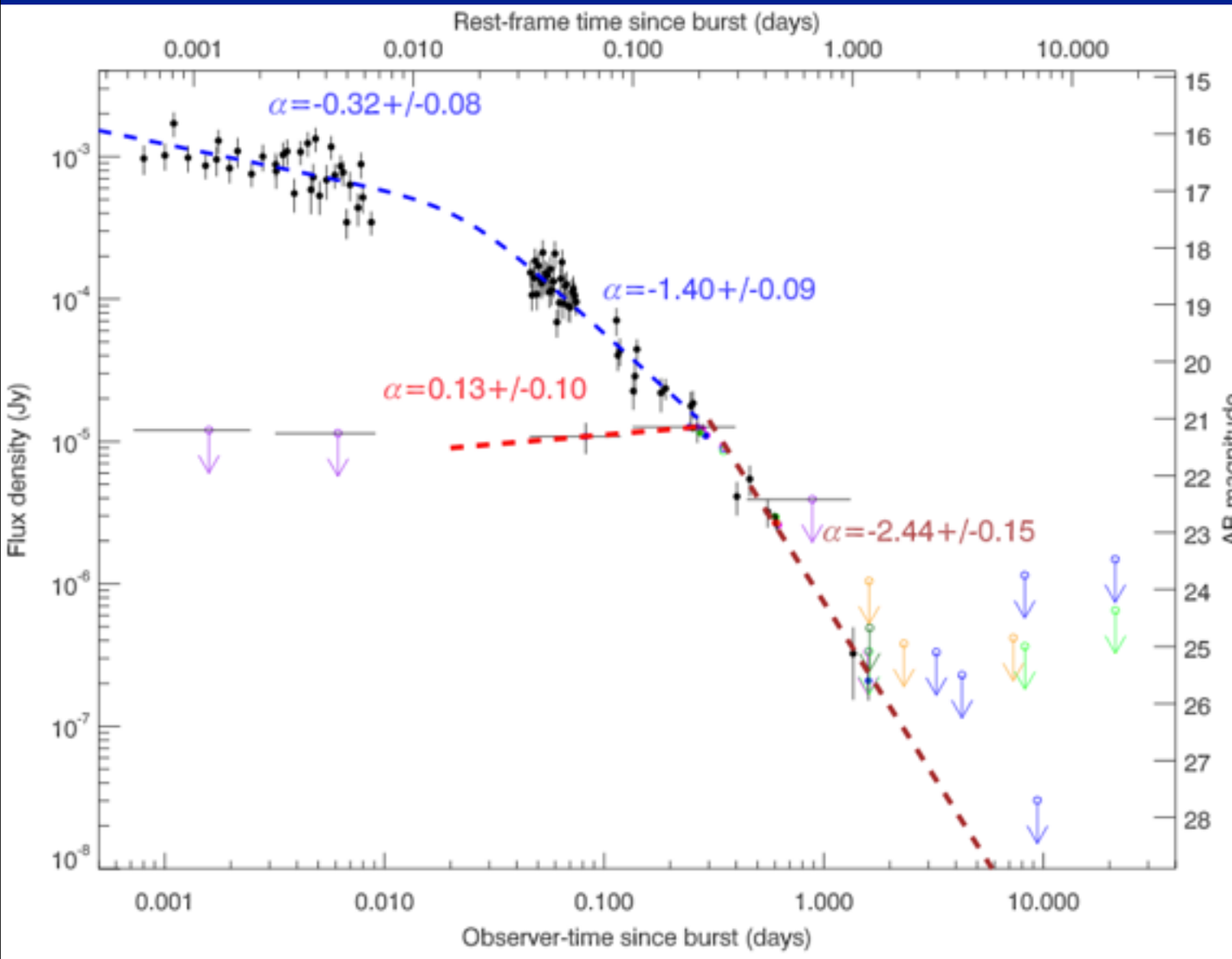
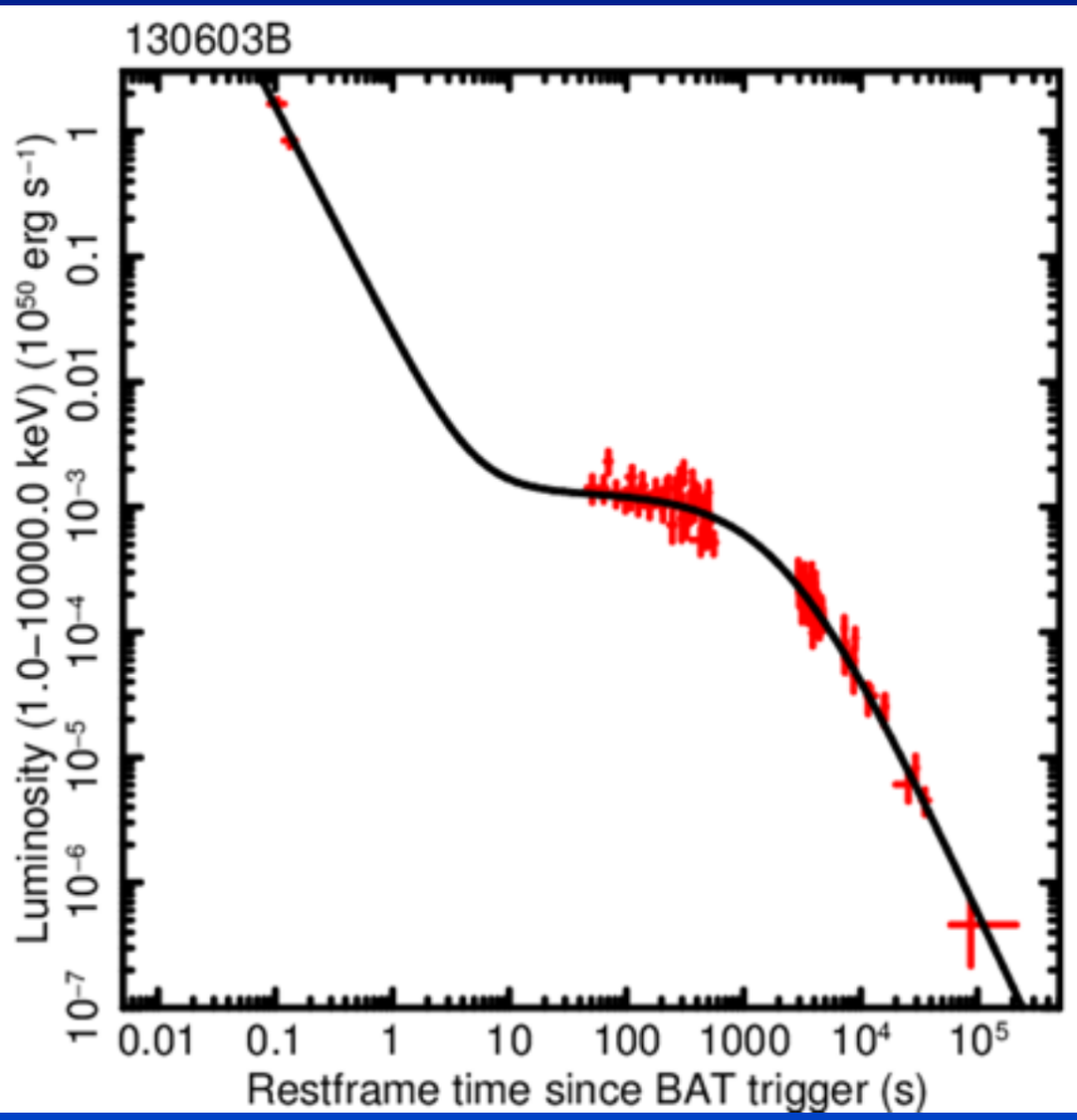
GRB 130603B:

an unambiguously short GRB at a known redshift





de Ugarte Postigo et al. (2013)

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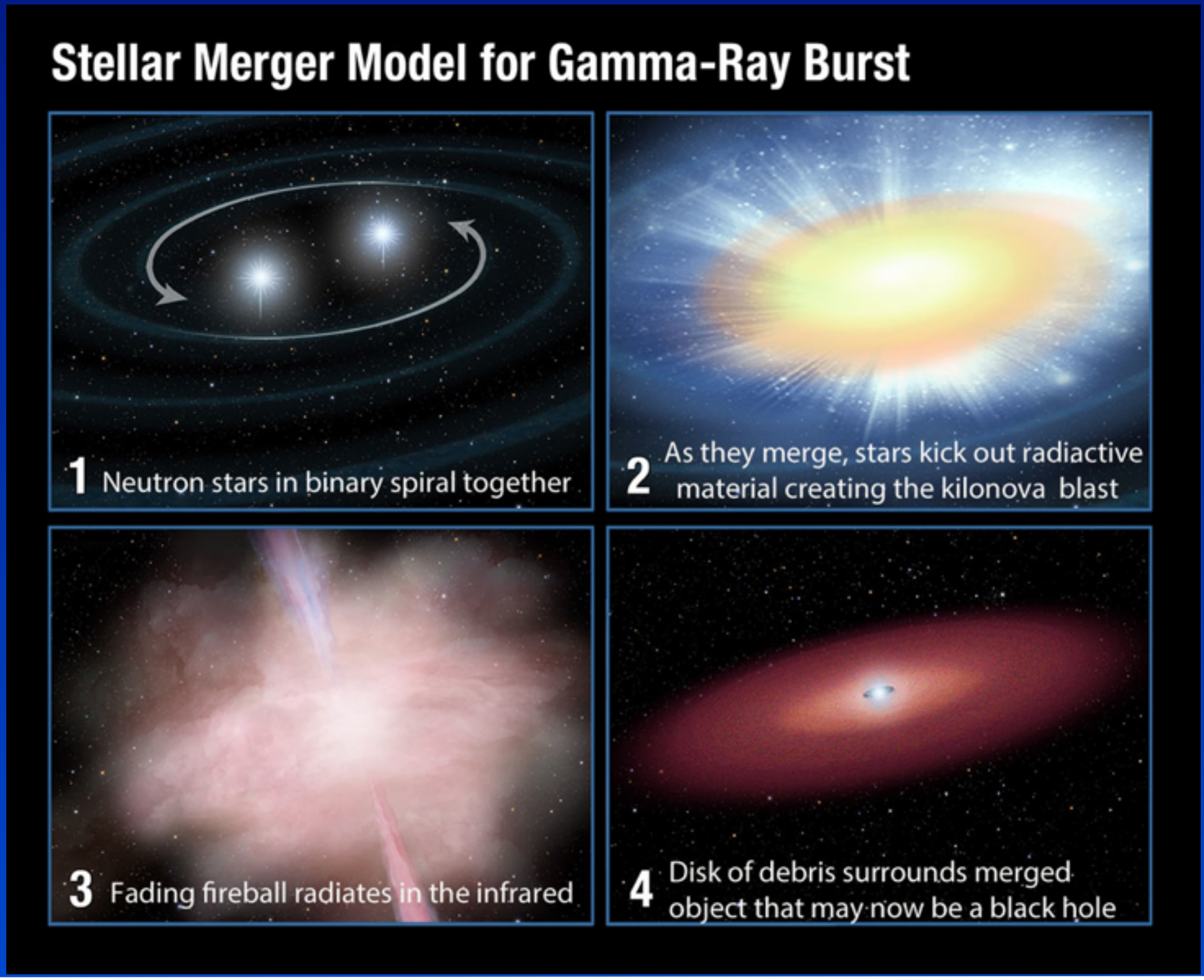
Kilonovae: (a.k.a. Macronova, Mini-Supernova)



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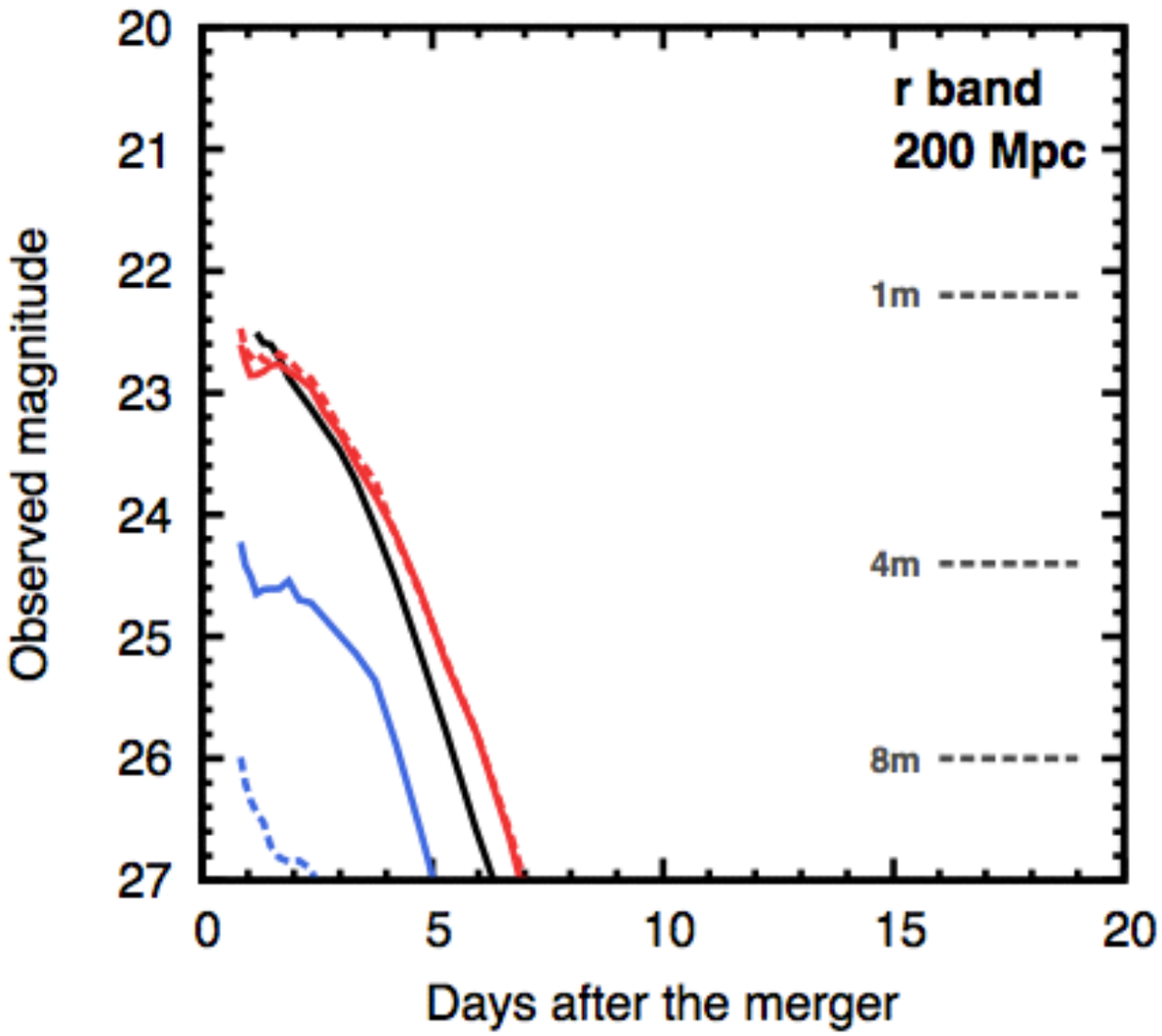
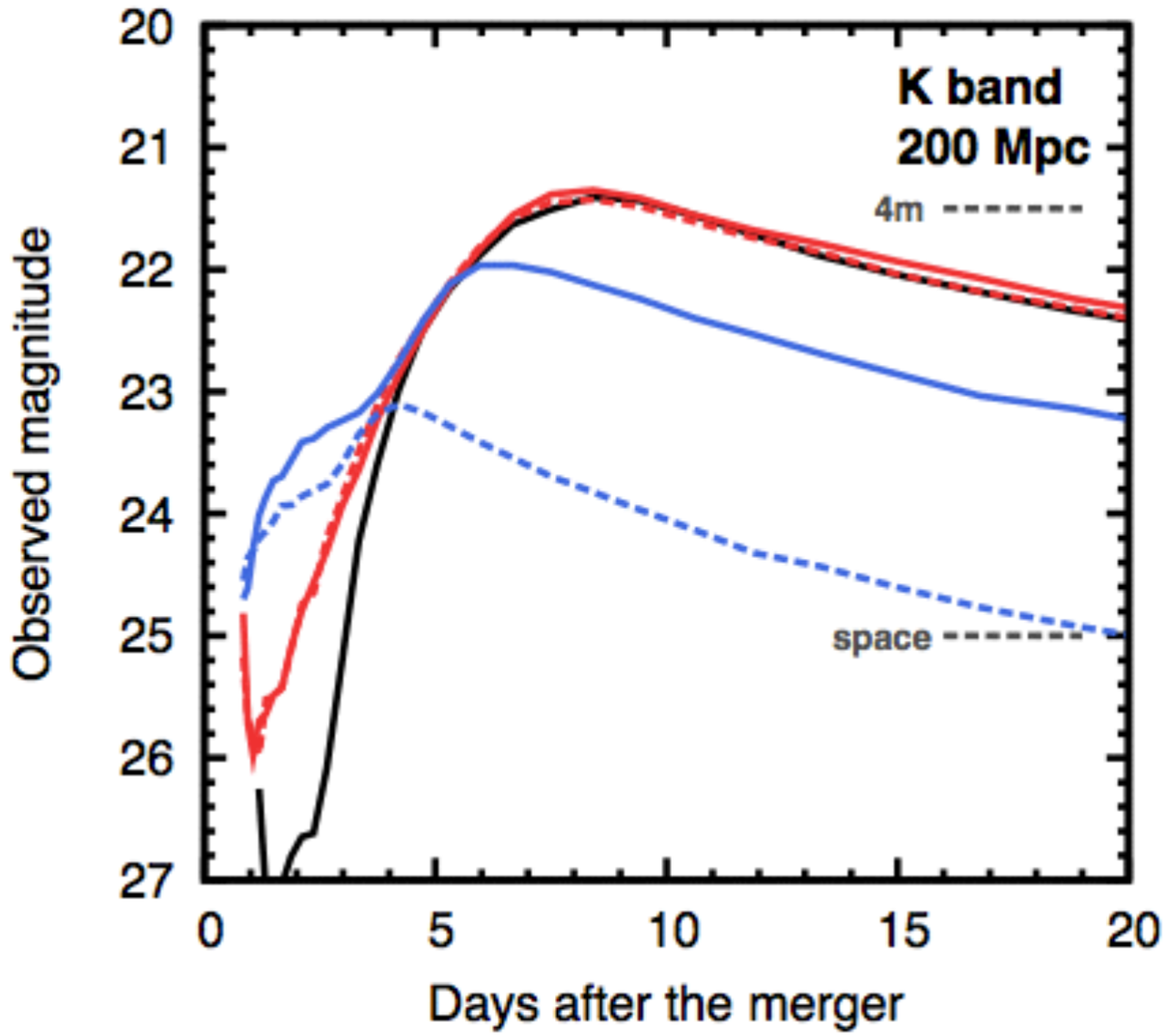
Kilonova Predictions:





Tanaka & Hotokezaka 2013

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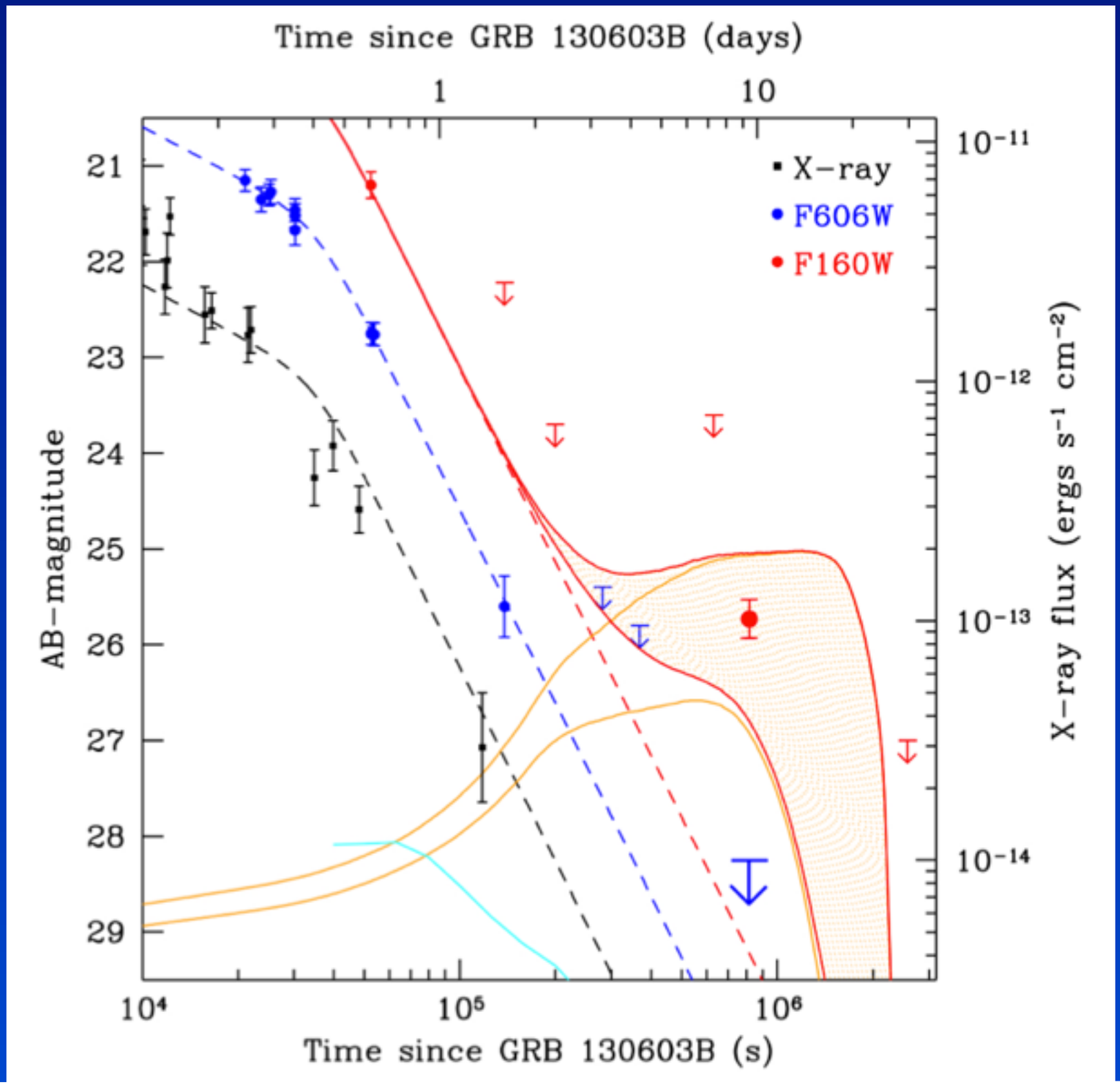
GRB 130603B - Kilonova detection



Ejected mass obtained from model: 10^{-1}-10^{-2} solar masses
(Tanvir et al. 2013)

If there is energy injection from a magnetar central engine, this signal could be boosted - requiring less ejected mass
(e.g Metzger & Piro 2013,)

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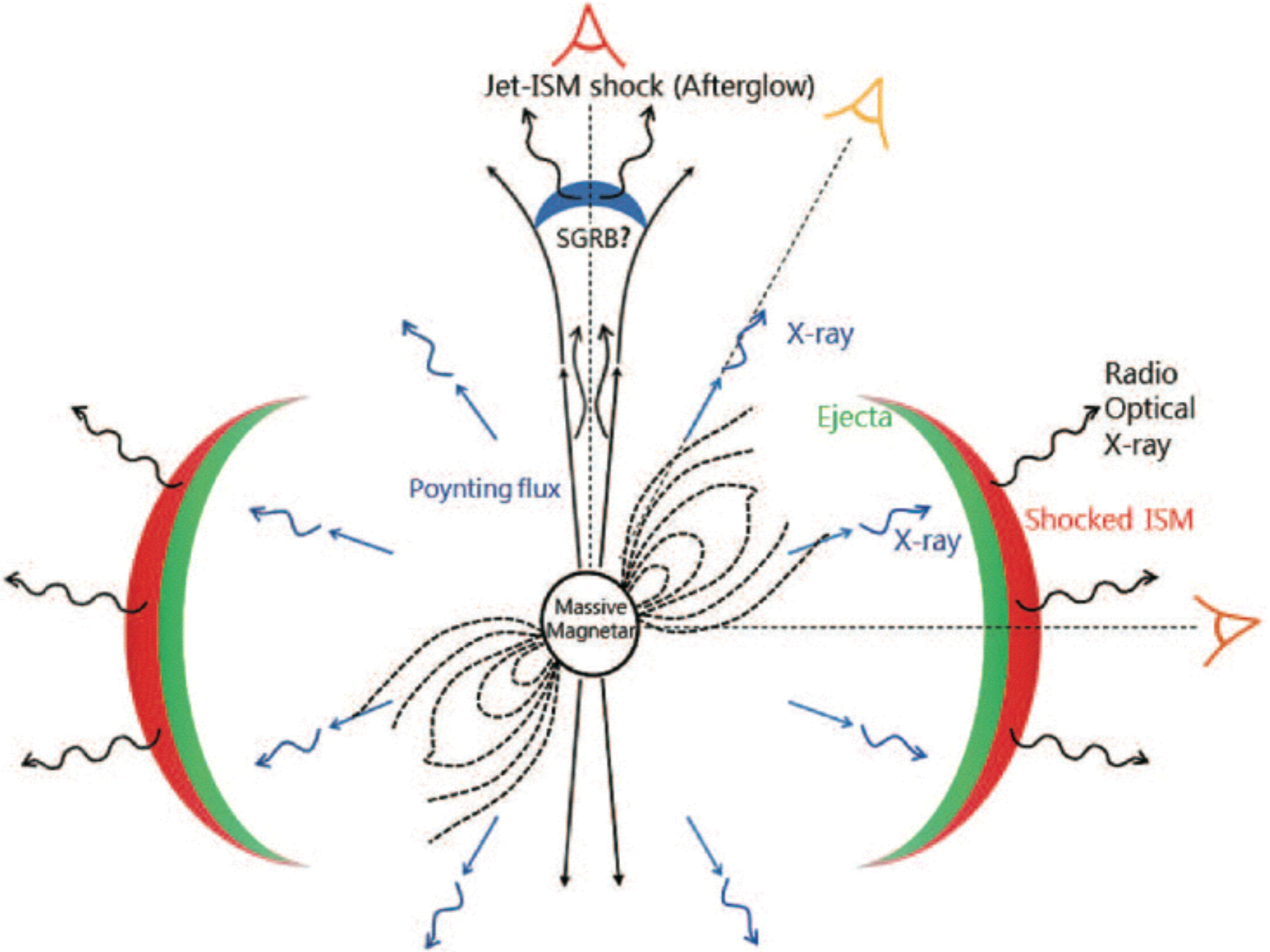
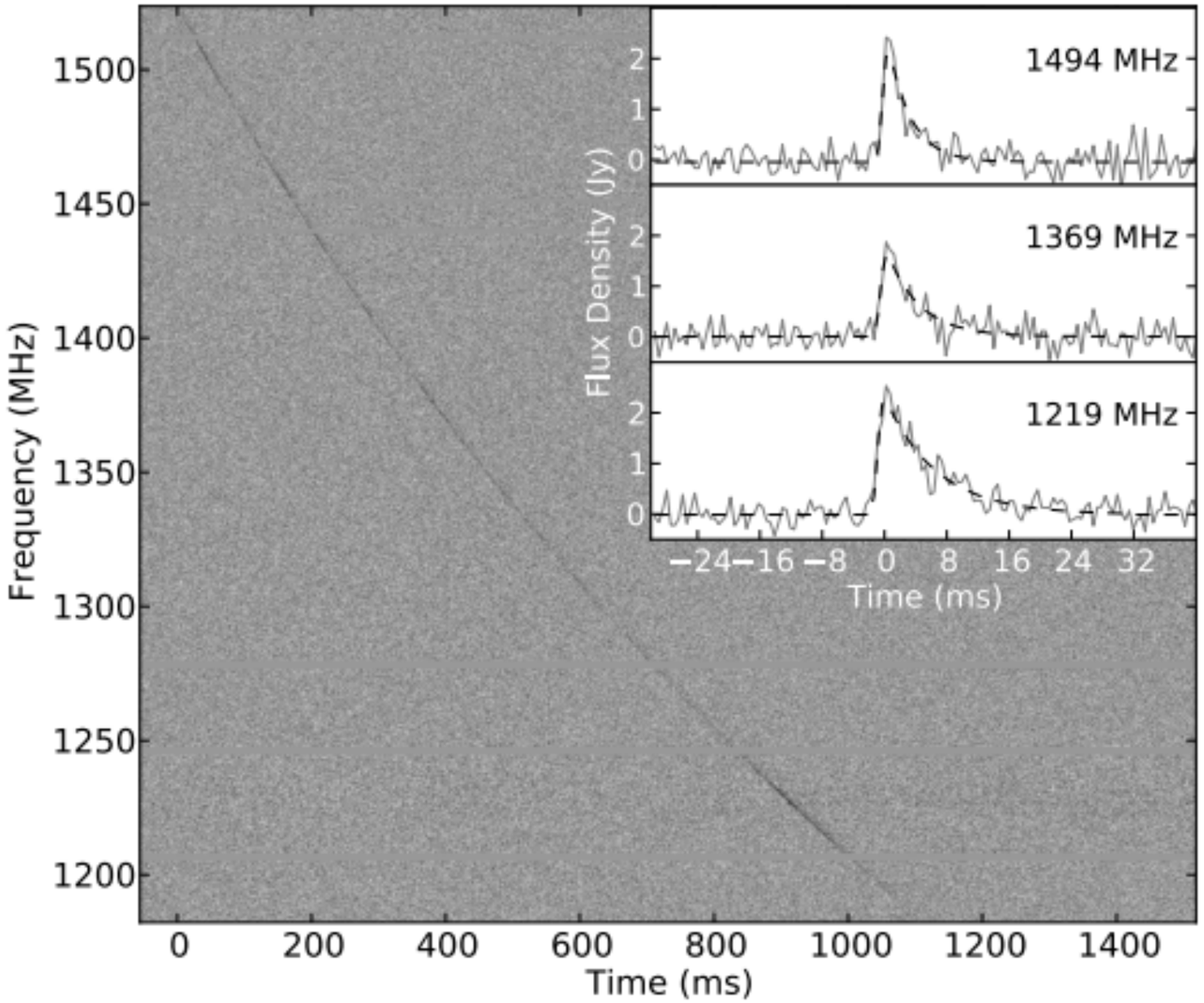


Gao et al. (2013)

Fast Radio Bursts

Thornton et al. 2013

- A cosmological population of radio transients
- 6 detected to date
  (Lorimer et al. 2007, Keane et al. 2011, Thornton et al. 2013)
- Very short in duration and high energy (10^{31}-10^{33} erg)
- Rate: 1000 sky^{-1} day^{-1}



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Theories aplenty

- Merger of neutron stars with misaligned magnetic fields
  (e.g. Totani 2013, Lyutikov 2013)
- Collapse of a magnetar (e.g. Falcke & Rezzolla 2013, Zhang 2013)
- Merger of magnetised white dwarves (e.g. Kashiyama et al. 2013)
- Magnetar flares (e.g. Popov & Postnov 2013)
- …

LOFAR Stations Across Europe

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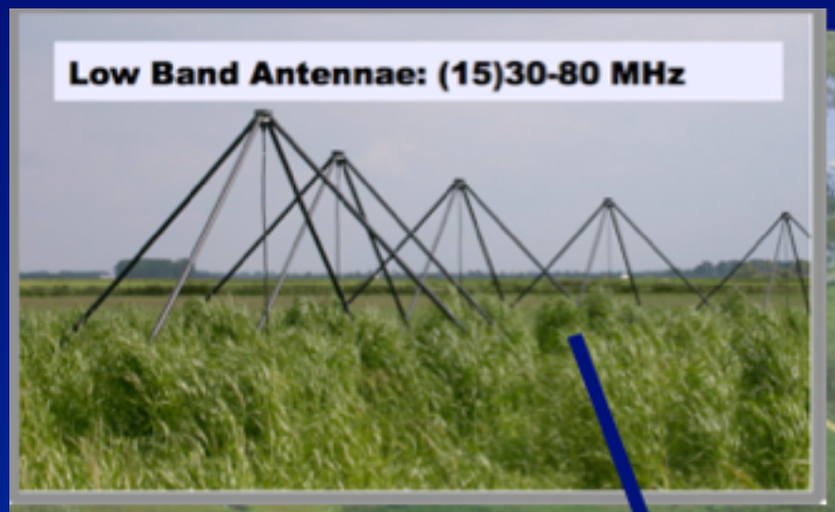

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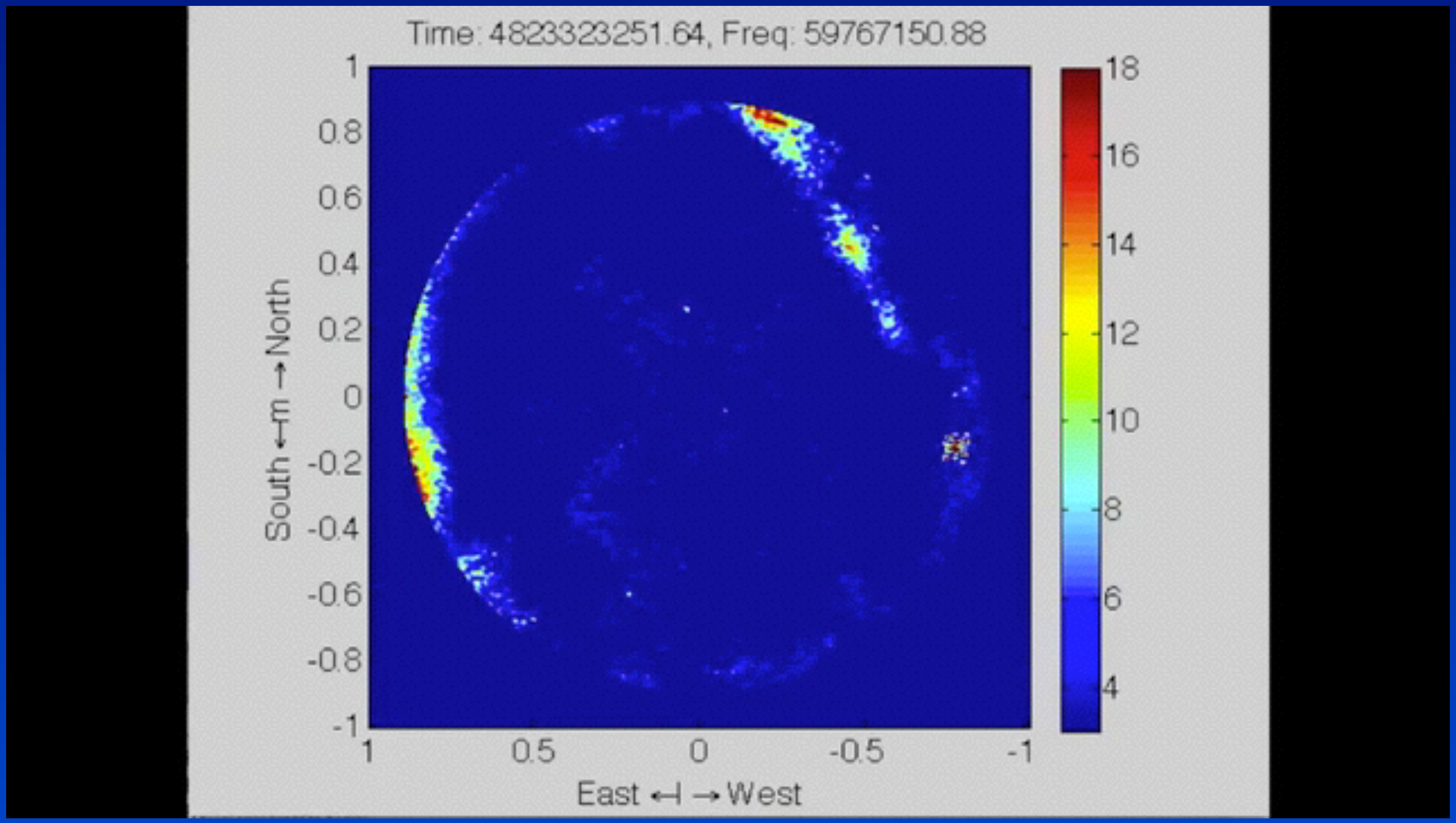
AARTFAAC: A whole sky monitor



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Summary:

- Neutron star binary mergers are multi-messenger events
- More data = more questions
- The next 5 years look very exciting (Advanced-LIGO, Kilonovae, Fast Radio Bursts…)

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"We were playing a detective game, gathering clues and solving logical puzzles as they presented themselves."

Joseph Taylor, Nobel Banquet, December 10, 1993

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