How Swift transformed our view of short Gamma-Ray Bursts

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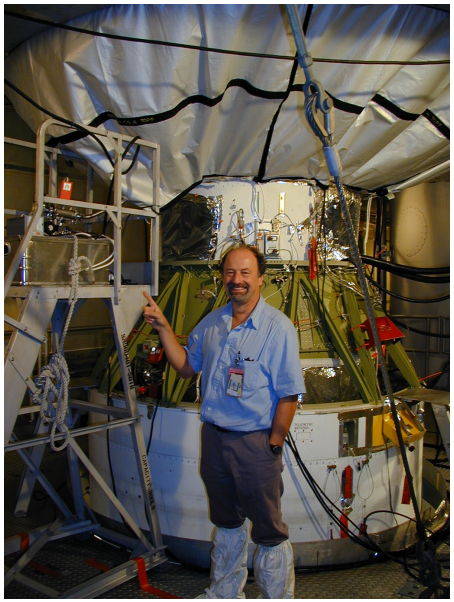
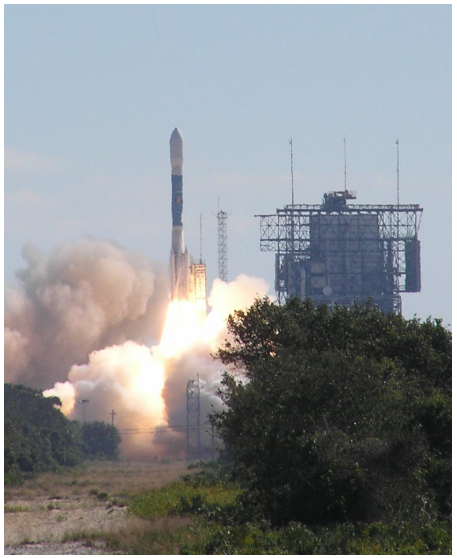
(with thanks to the entire Swift team who built this amazing observatory)





In orbit, but not yet free…

Thanks to Martin Ward

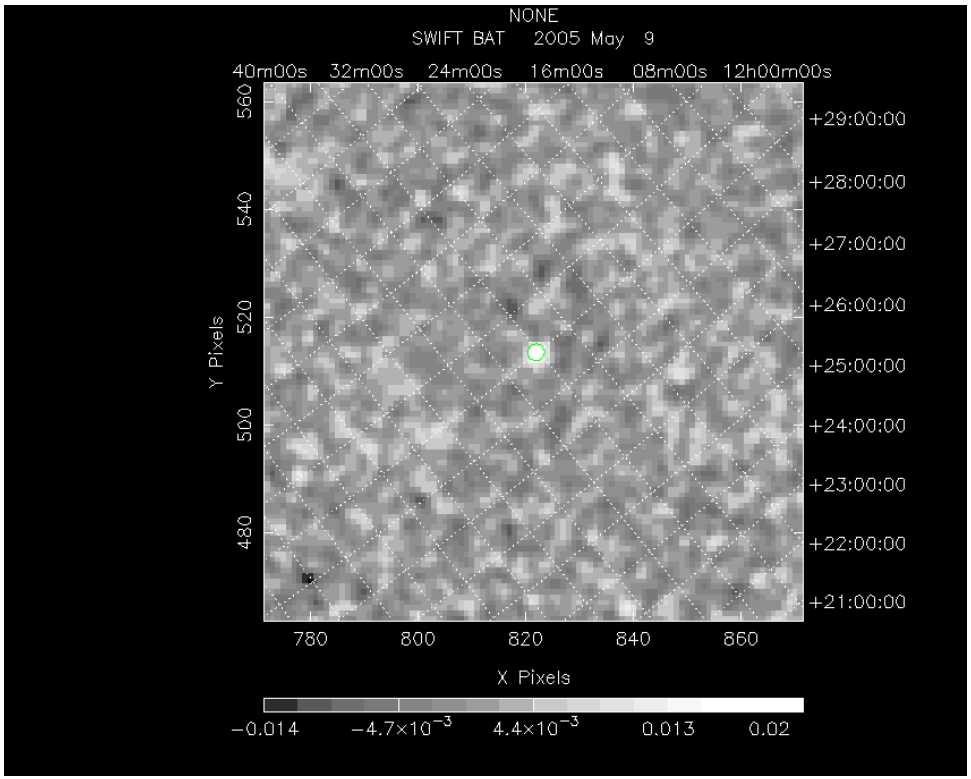
Swift proposal (August 1998)

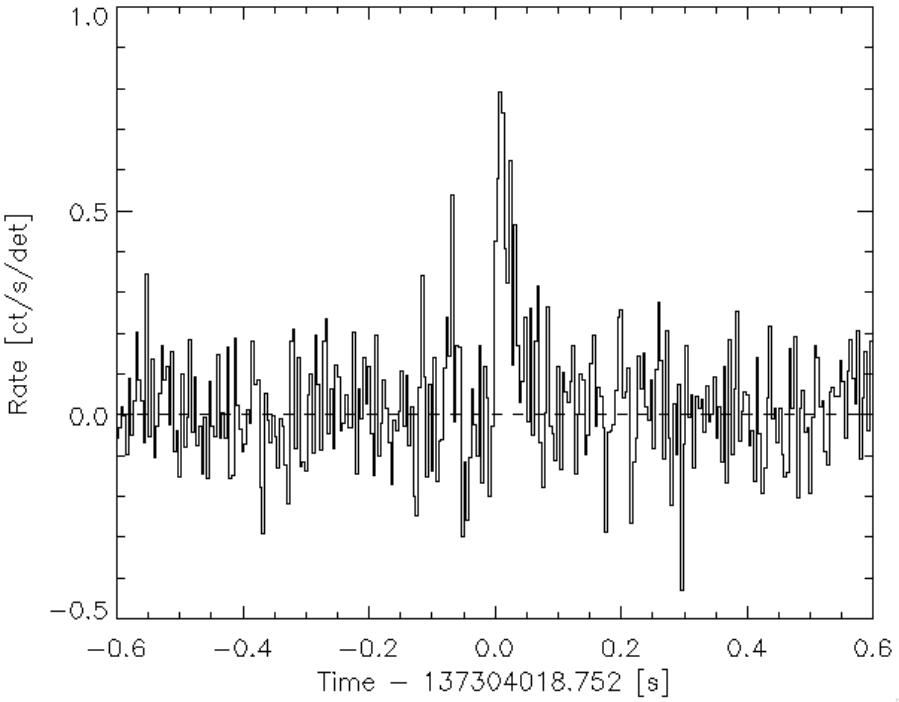
- Section 1.1.3
  - Q1 What are the progenitors of GRBs?
  - Q2 Are there different classes of bursts with different physical processes at work? (collapsars and mergers)

- Section 1.1.7
  - Swift will determine whether sub-classes of GRBs exist and what fundamental differences in the source physics causes the classes
  - Swift will be sensitive to the shortest events, and will provide far better coverage of these events than has been possible

GRB050509B

Touchdown: BAT trigger on 2005 May 9, 04:00:19.23 UT

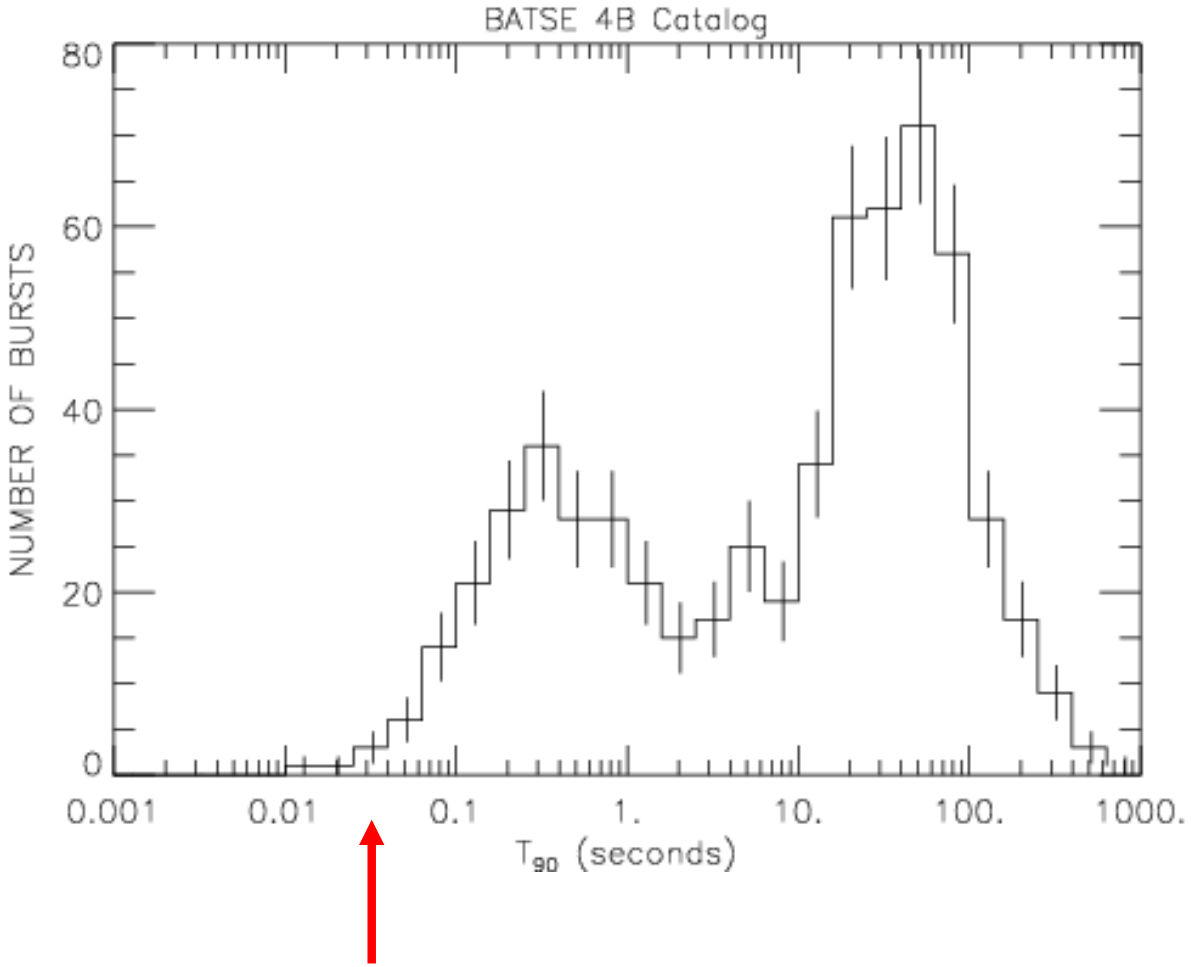




Short burst: T90=40±4 ms

Fluence (15-150 keV) = 9.5±2.5 x 10^{-9} erg cm^{-2}

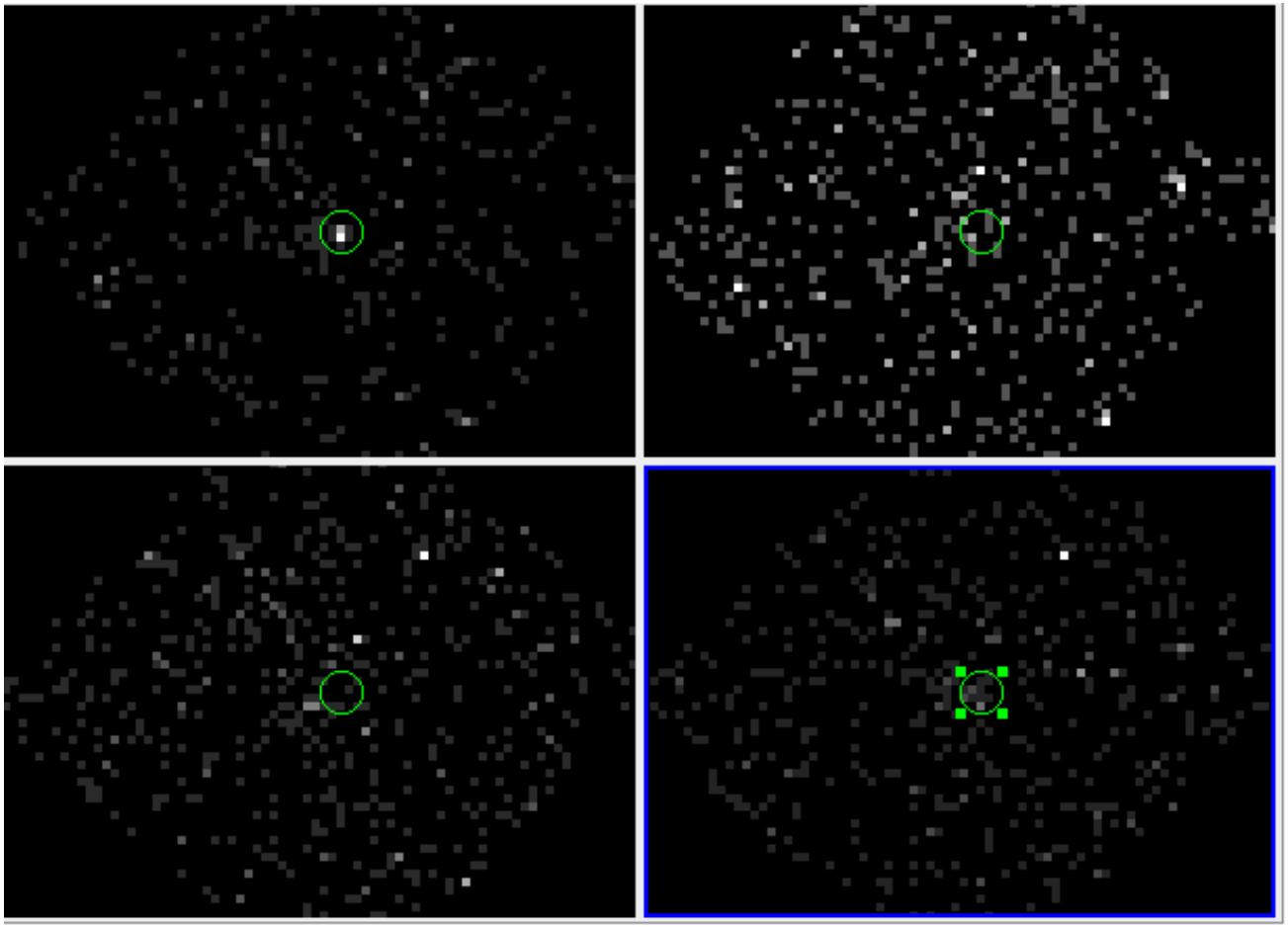
GRB duration distribution



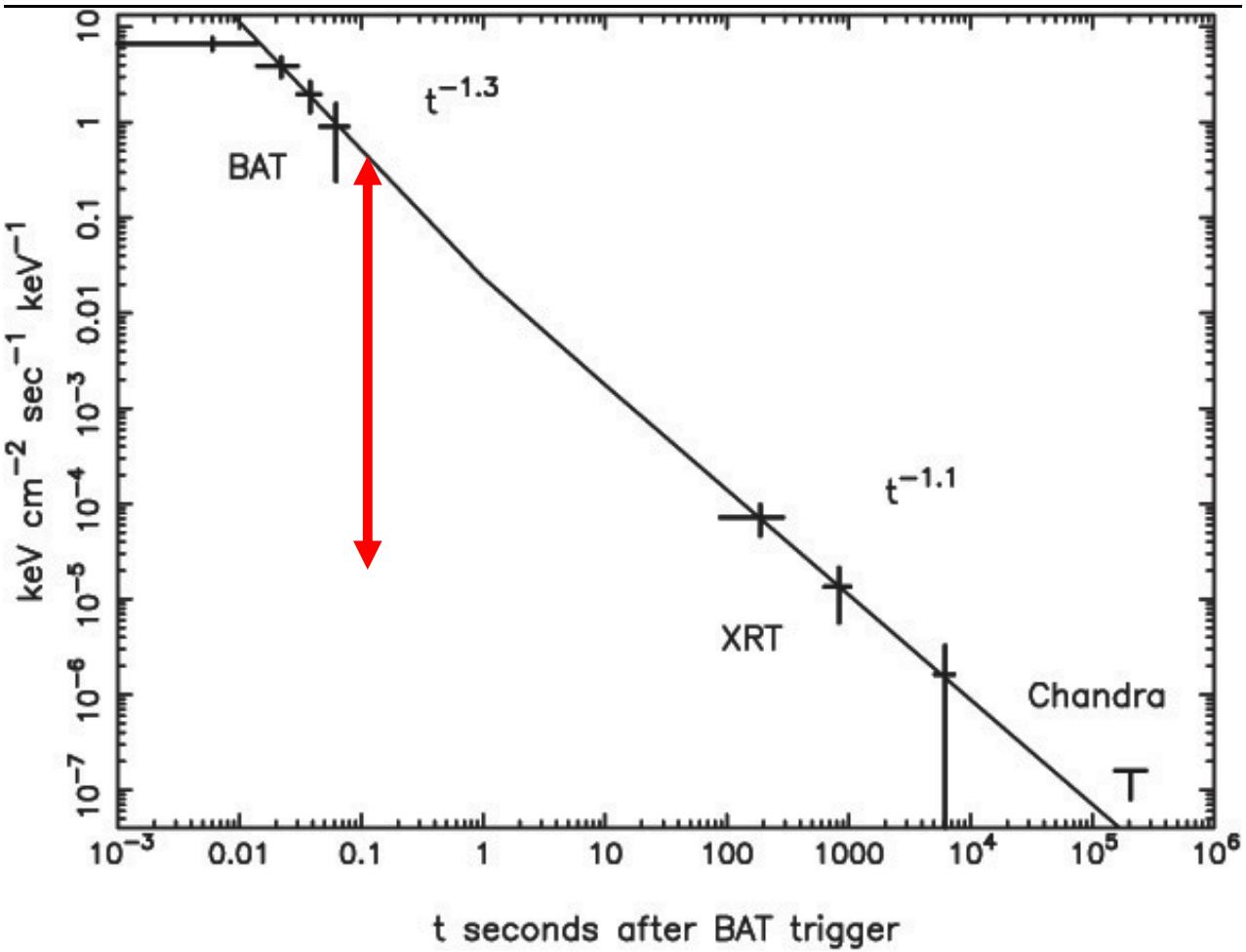
GRB050509B (it's a short burst!)

Binned XRT image – first 4 orbits

GRB 050509B, faint point source seen only in first orbit



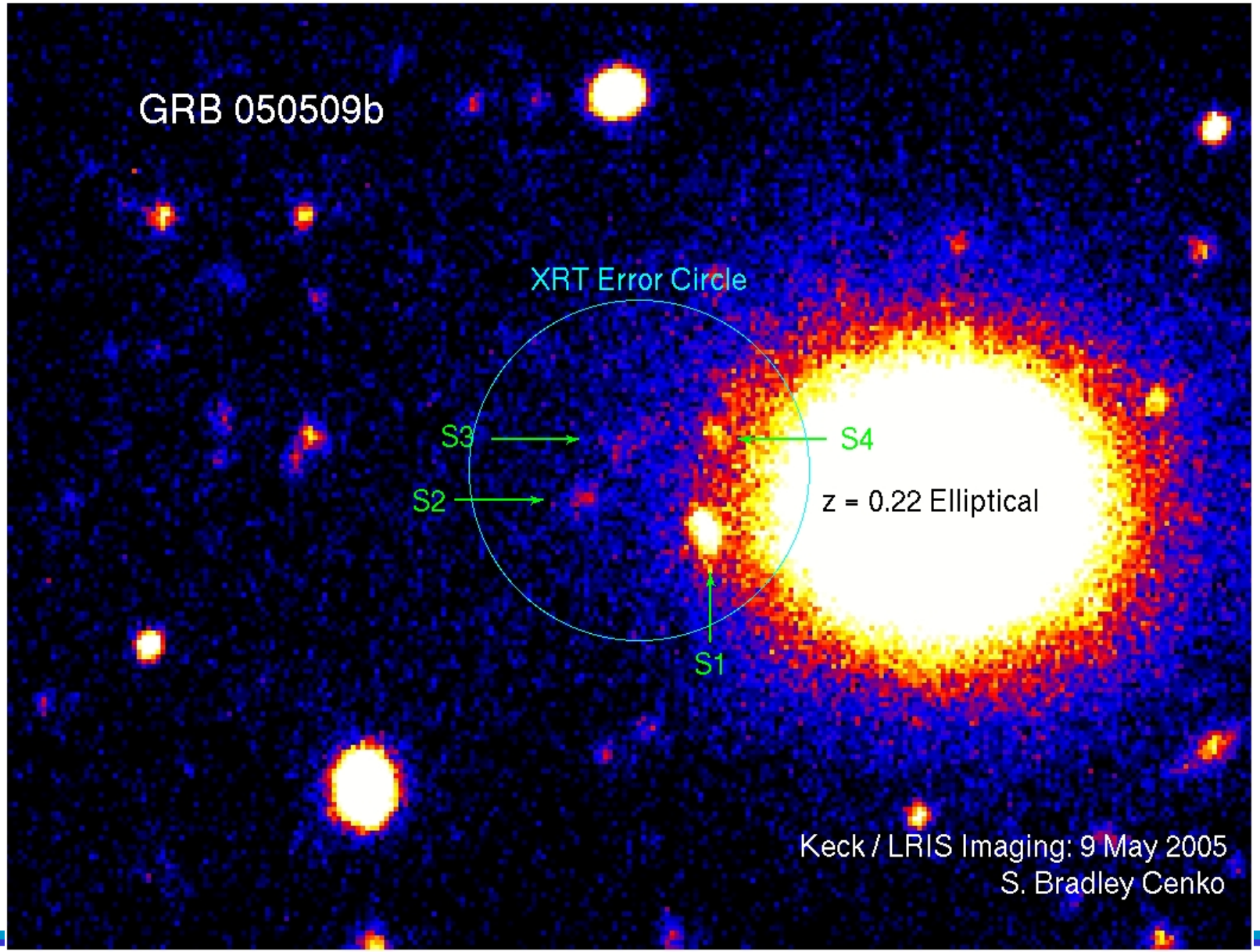
GRB 050509B 1 keV light curve



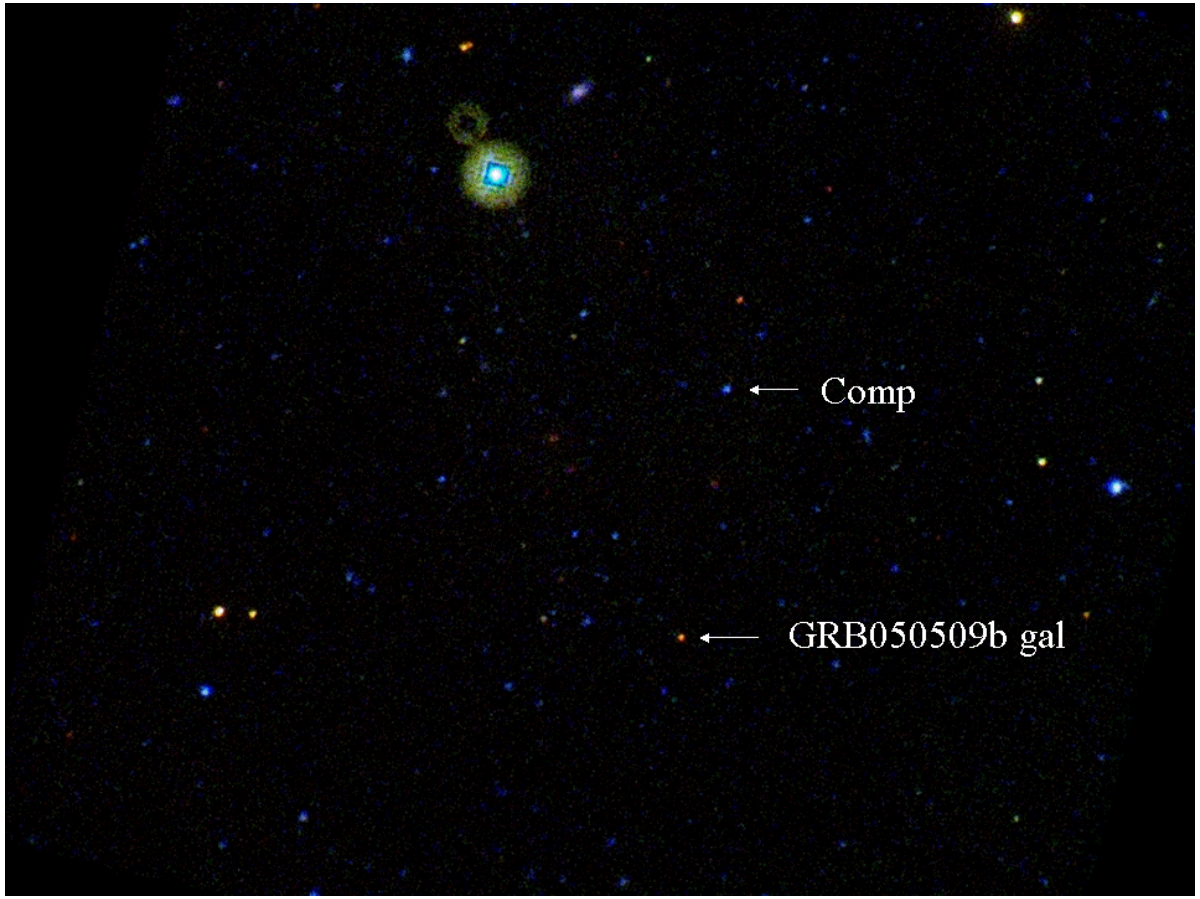
Very faint X-ray afterglow (4 orders of mag drop in ~100s)

Chandra image helped register XRT location

GRB 050509B Host Galaxy



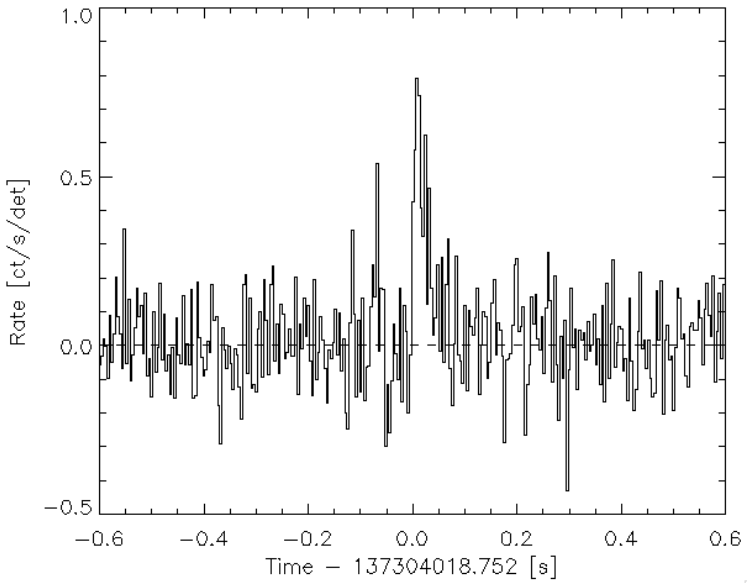
GRB050509B host UVOT image



Not detected in the UV: SFR < 0.2 $M_{\odot}$ yr^{-1}

First Swift short GRB 050509B

Gehrels, Sarazin, O'Brien et al. (2005) + Bloom et al.



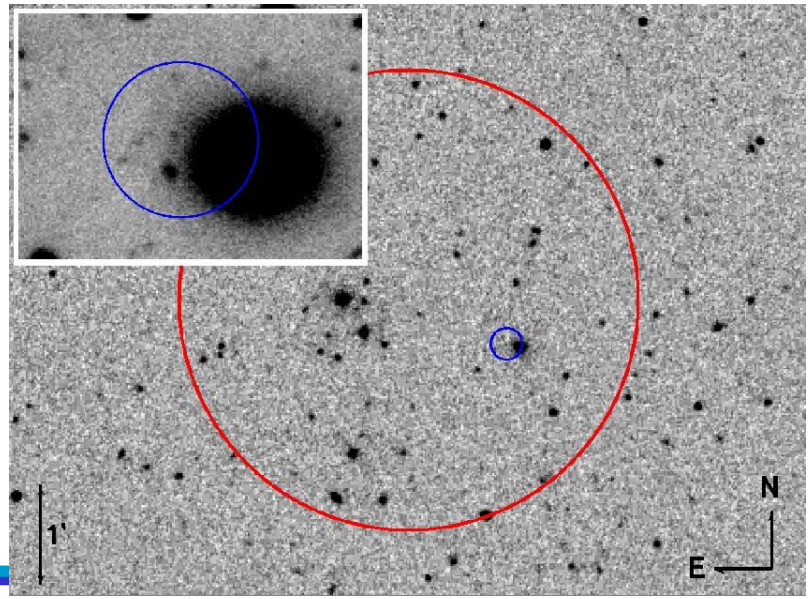
BAT
- 30 ms duration
- spectrum is medium hard
- very weak, 2×10^{-8} erg/cm^2

Spacecraft slew in 52 sec

XRT
- faint source, fading
- 11 cnts = 1×10^{-12} erg/cm^2/s

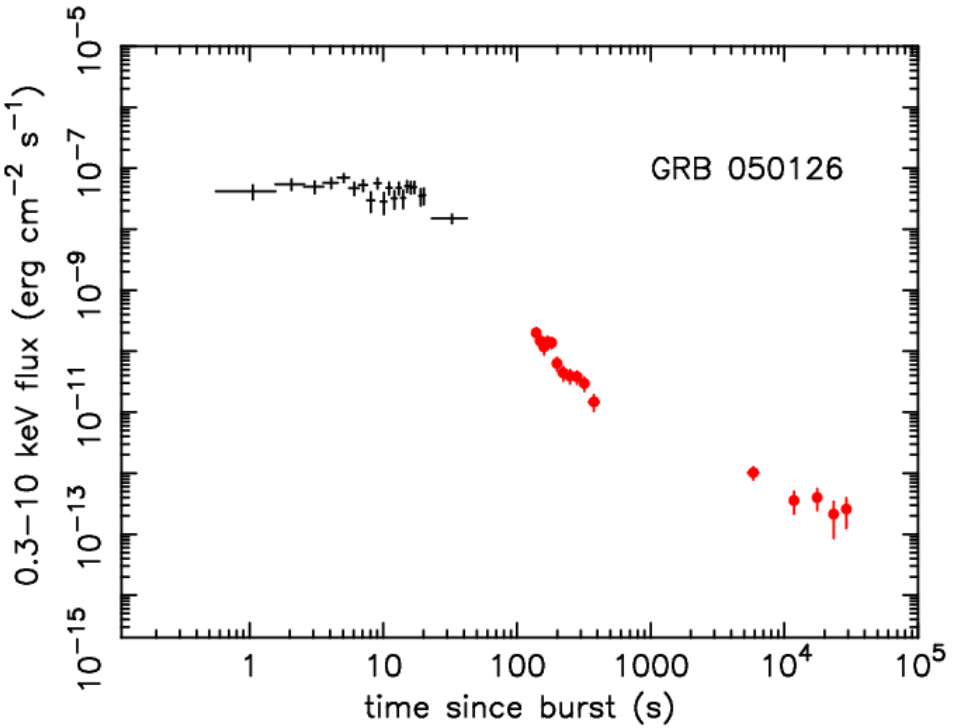
Proposed host:
- cD Elliptical in cluster
- K = 14.1
- L = 3 L*
- z = 0.225
- SFR < 0.2 M_O yr^{-1}

VLT image
Hjorth et al.



See talk by Wen-fei

Swift era long GRB light curves

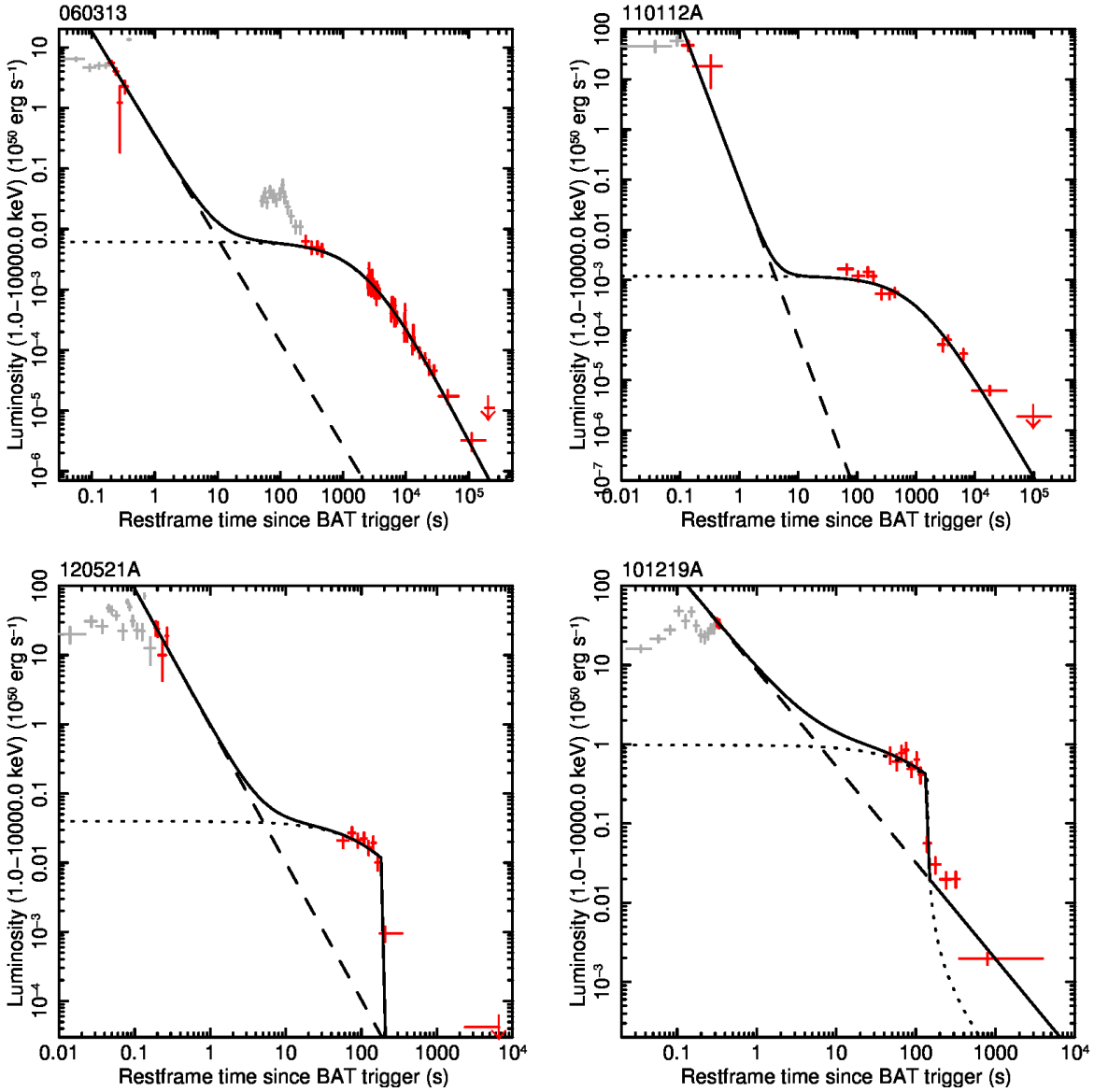


Range in shapes implies a mixture of internal and external processes (Tagliaferri et al. (2005); Nousek et al. (2006); O'Brien et al. (2006)…)
True for both long and short GRBs.

- Fast decay and flares appear internal – "central engine dominated"?
- Slow decays and late plateau external – "afterglow dominated"?

Complex SGRB light curves

(Rowlinson, O'Brien et al. 2010)

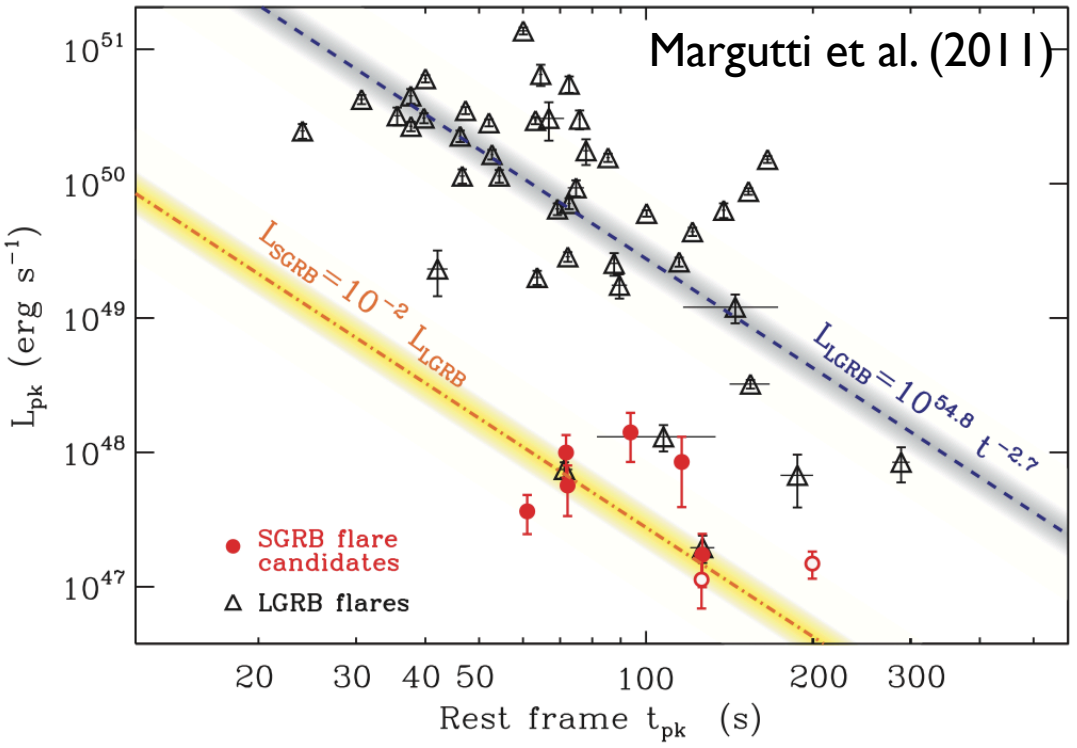


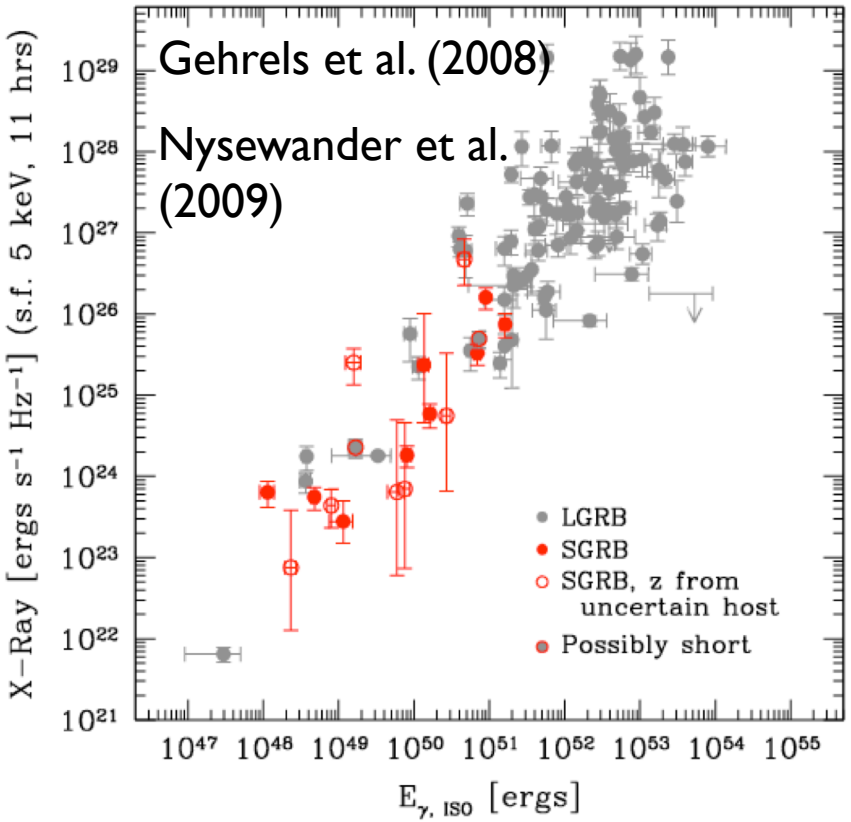
See flares, plateaus, steep decays, similar to those seen in long GRBs

The central engine "causes stuff" at late times

SGRB X-ray Afterglows

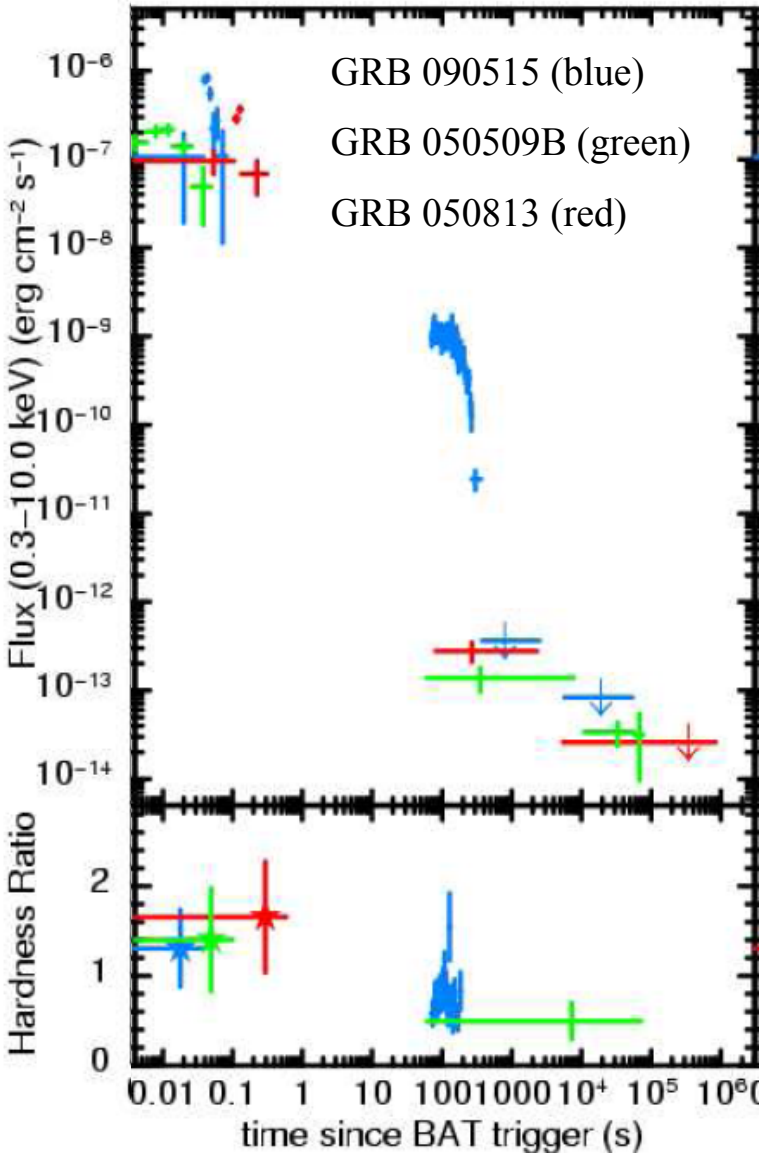
Short GRBs exhibit similar X-ray flares to long GRBs, but with significantly lower luminosities





X-ray afterglows are fainter and less luminous than those of long GRBs.

GRB 090515
(Rowlinson, O'Brien et al. 2010)

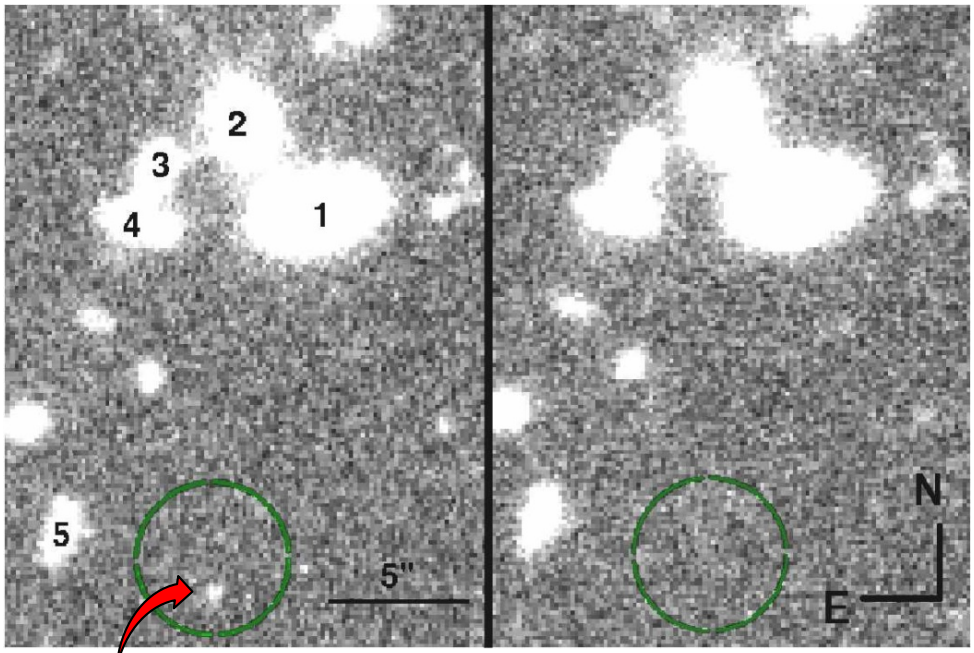


T90 = 0.036s

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

Highest short GRB X-ray flux at100s

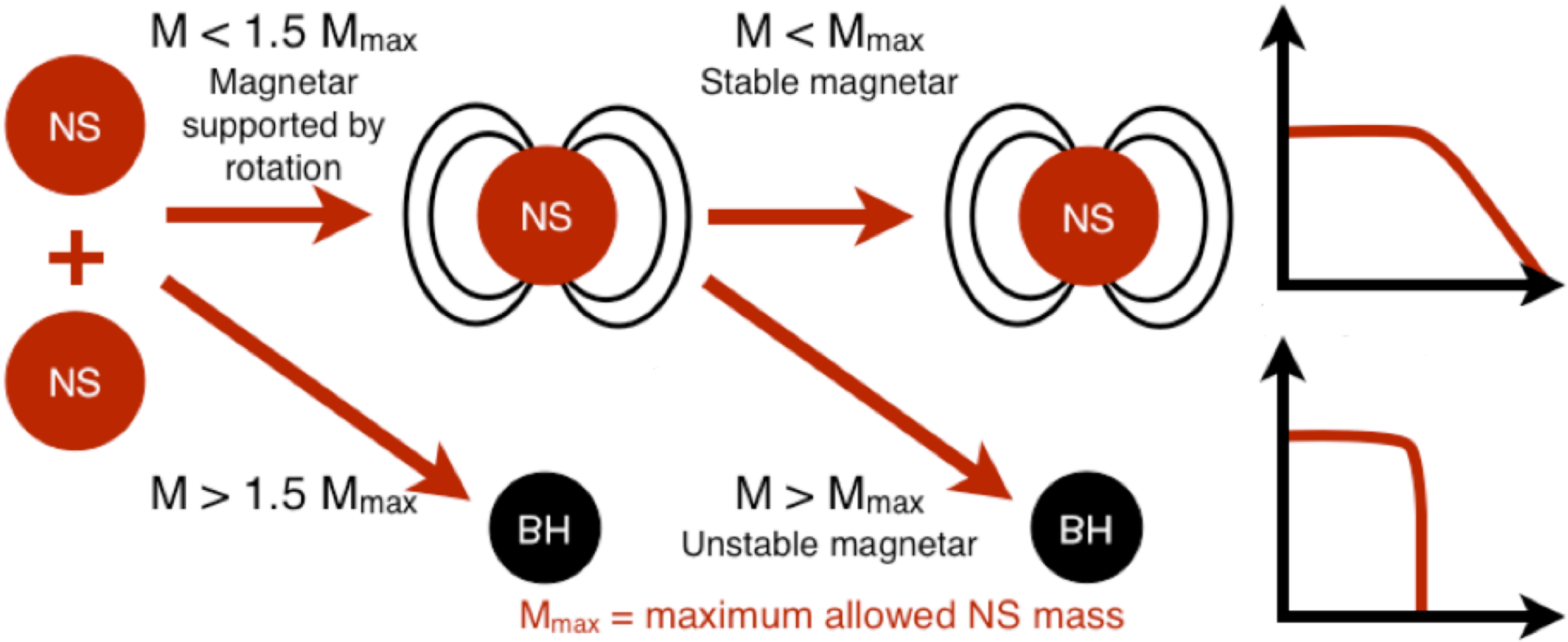
Very unusual given low γ-ray fluence



Gemini-N, r-band at 6300s

See a (fading) r=26.4 source

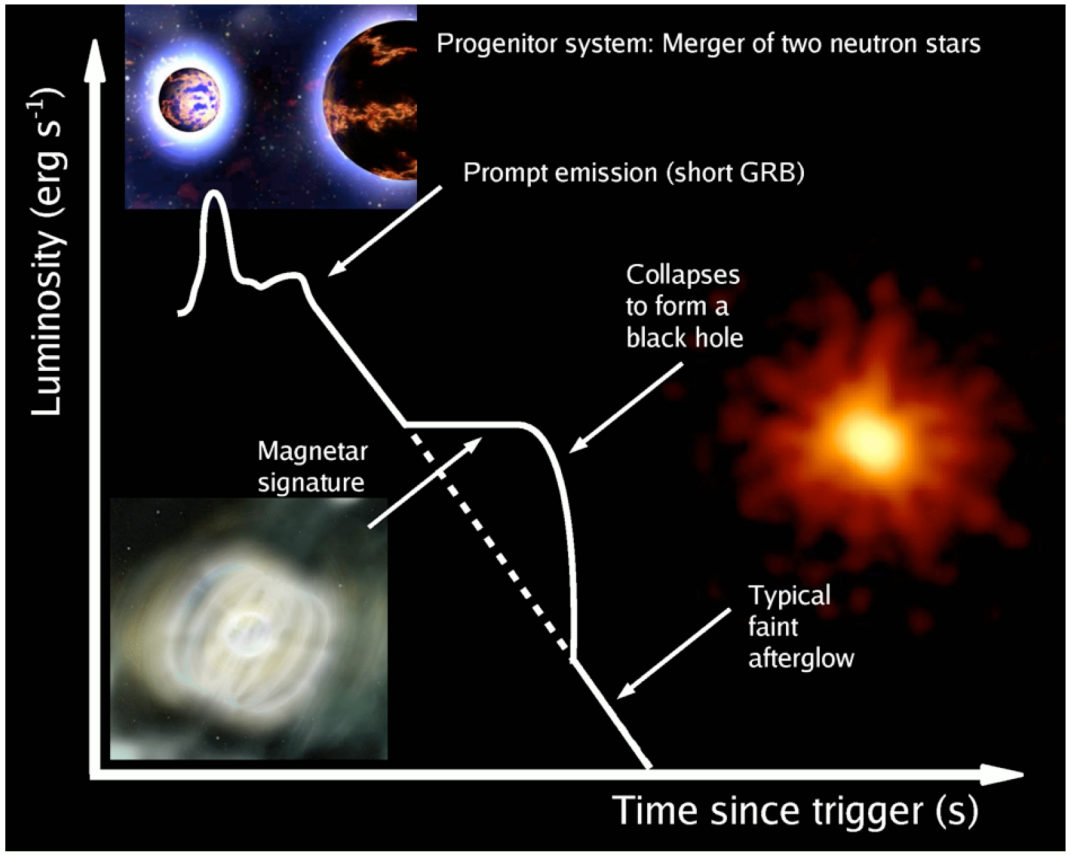
Outcomes from NS-NS merger

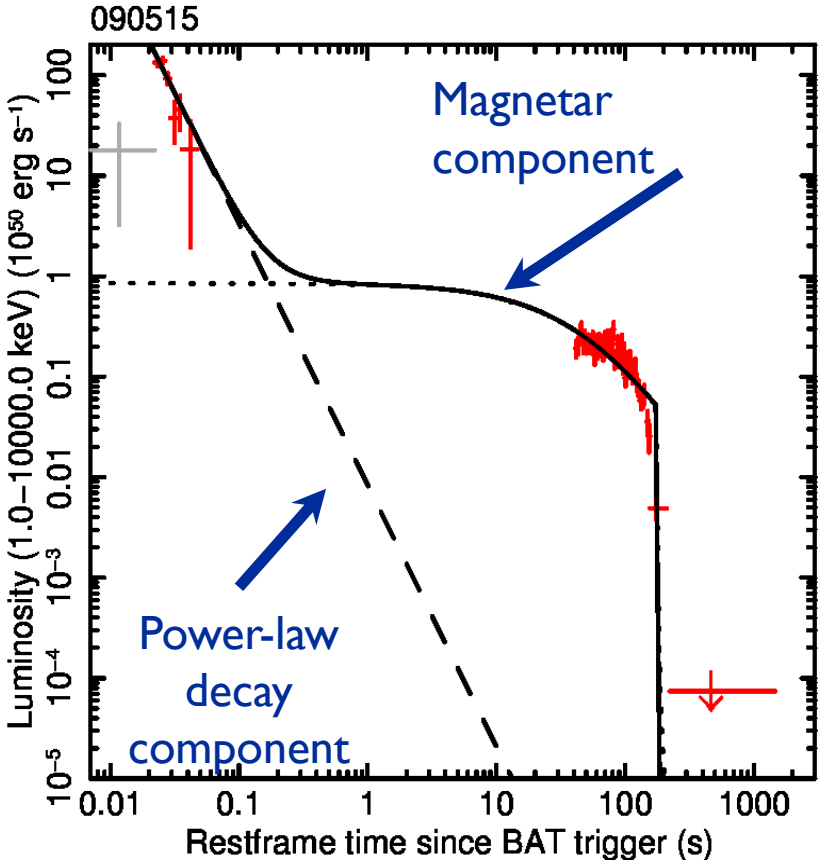


Rowlinson

Two known cases of "massive" NS, ~2 $M_\odot$ indicate a fairly stiff EOS (Demorest et al. 2010; Ozel et al. 2010; Antoniadis et al. 2013)

SGRB magnetar concept

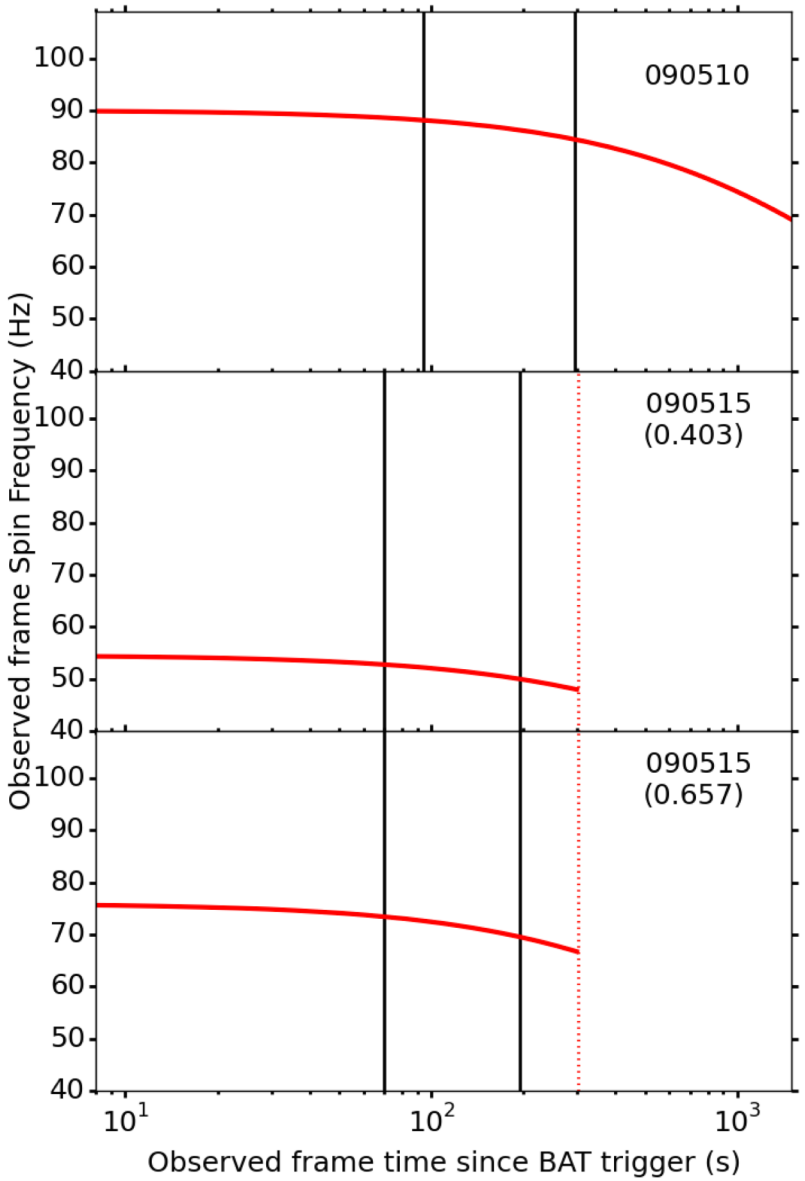




Expect a relation between the pulsar initial spin period (P_0), dipole field strength (B_p), luminosity (L) and the characteristic timescale (T_{em}) for spin-down:

$$\mathbf{L \propto B_p^2 / P_0^4 \quad and \quad T_{em} \propto P_0^2 / B_p^2}$$ (Zhang & Mészáros 2001)

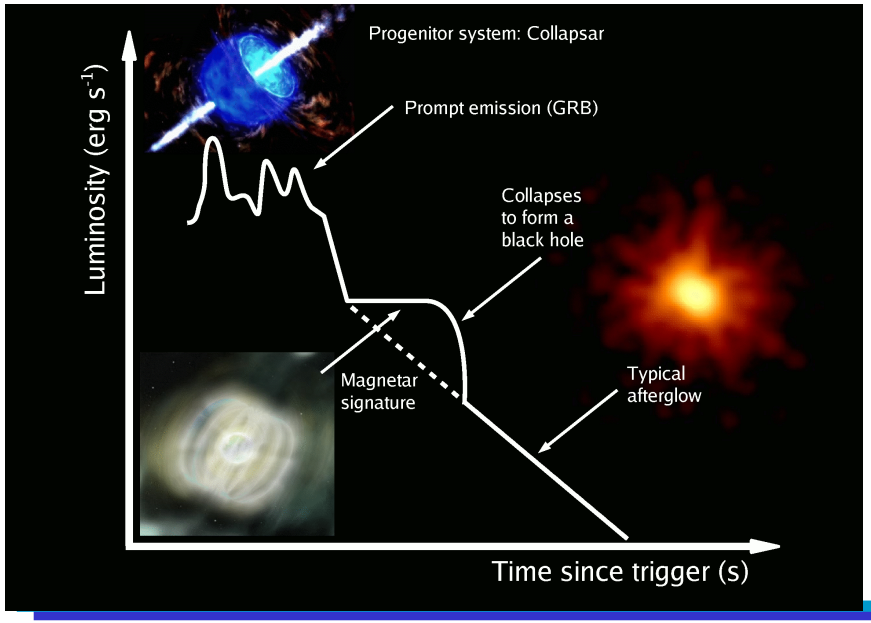
Test: X-ray Pulse Fraction
(Rowlinson, Patruno, O'Brien 2017)

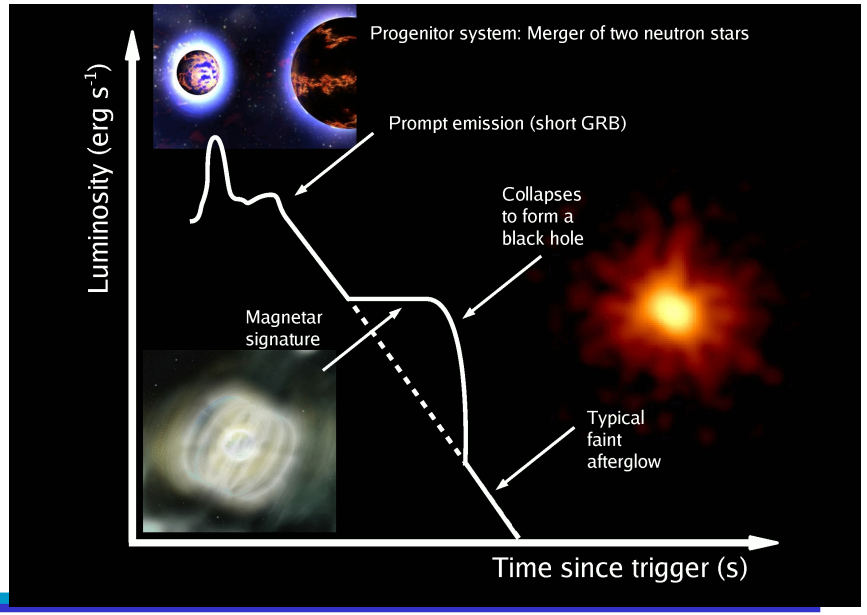


For the 4 SGRBs tested, the pulsed fraction upper limit is 15-30%

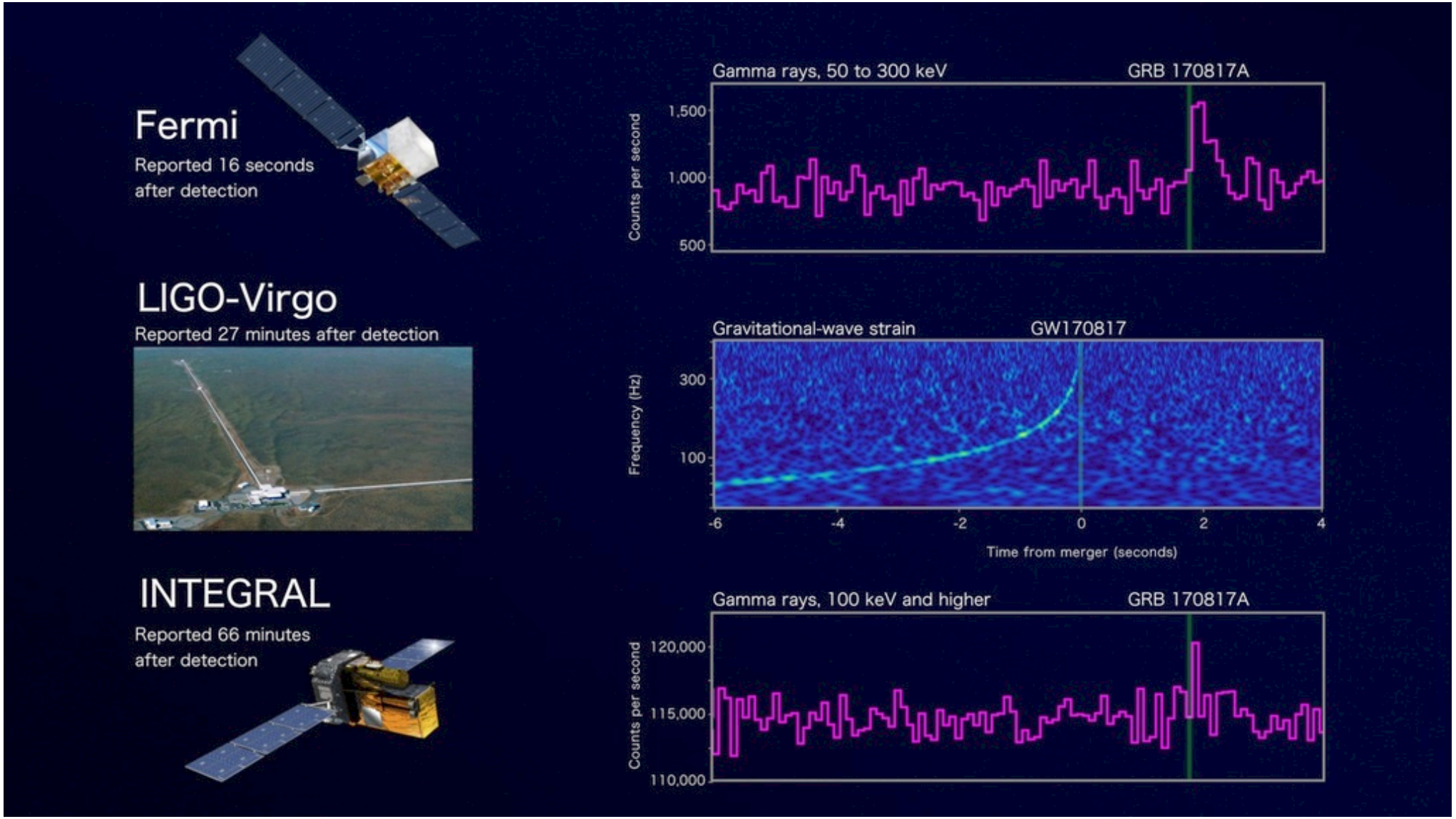
Test: Gravitational waves

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





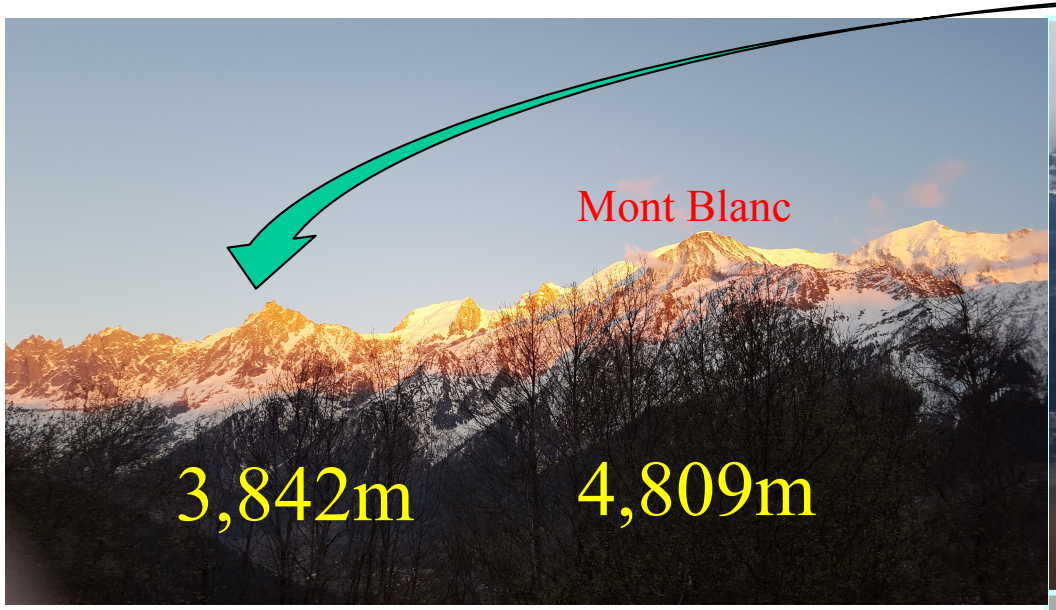
GW 170817 – closer to the answer



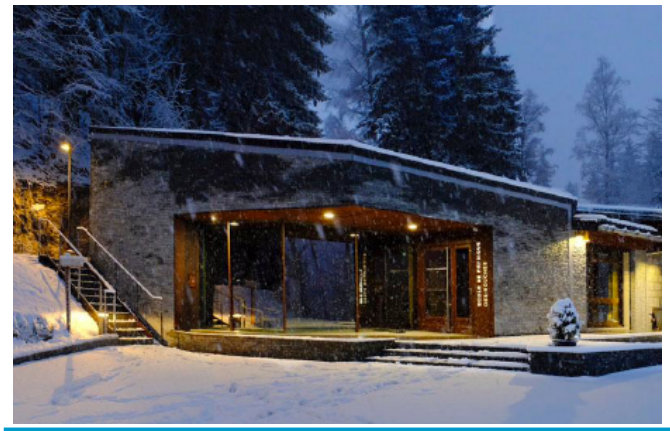
Some evidence, e.g. high ejecta mass, for not being direct collapse to BH


SVOM
Space-based multi-band astronomical Variable Objects Monitor
cnes
CENTRE NATIONAL
D'ÉTUDES SPATIALES
CHINESE ACADEMY OF SCIENCES
CNSA

For many astrophysicists of the *SVOM* collaboration, the 2016 workshop in *Les Houches, France* was the last opportunity for fruitful discussions with Neil.



On top of l'*Aiguille du Midi*



All members of the *SVOM* collaboration, will miss him greatly…

Jaques Paul

(SVOM team meeting, Les Houches, 18 May 2018)

Summary

- Neil was right. Being ‘swift’ is the key – a lesson learned for THESEUS
- Swift has localised many SGRBs, led to redshift determination, constraints on progenitors, host galaxy studies, etc.
- Swift met the design goals and answered the questions in the proposal
- Many unsolved issues:
  - What causes the burst – is it always a NS-NS merger?
  - What engine is left over (BH or NS)?
  - What causes the late-time variability (also in LGRBs)?
- Now we a have GW detection of a BNS merger, in which Swift played a key role – discovered early UV emission and constrained early X-ray emission (see later)
- We now await a joint GW – Swift trigger