The diversity of GRBs and their SNe: GRB-SNe, kilonovae and SN-less GRBs

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IAA-CSIC, Spain
Dark/NBI, Denmark

La Réunion – 21st February 2017

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Rubén Sánchez-Ramírez


Katarzyna Bensch

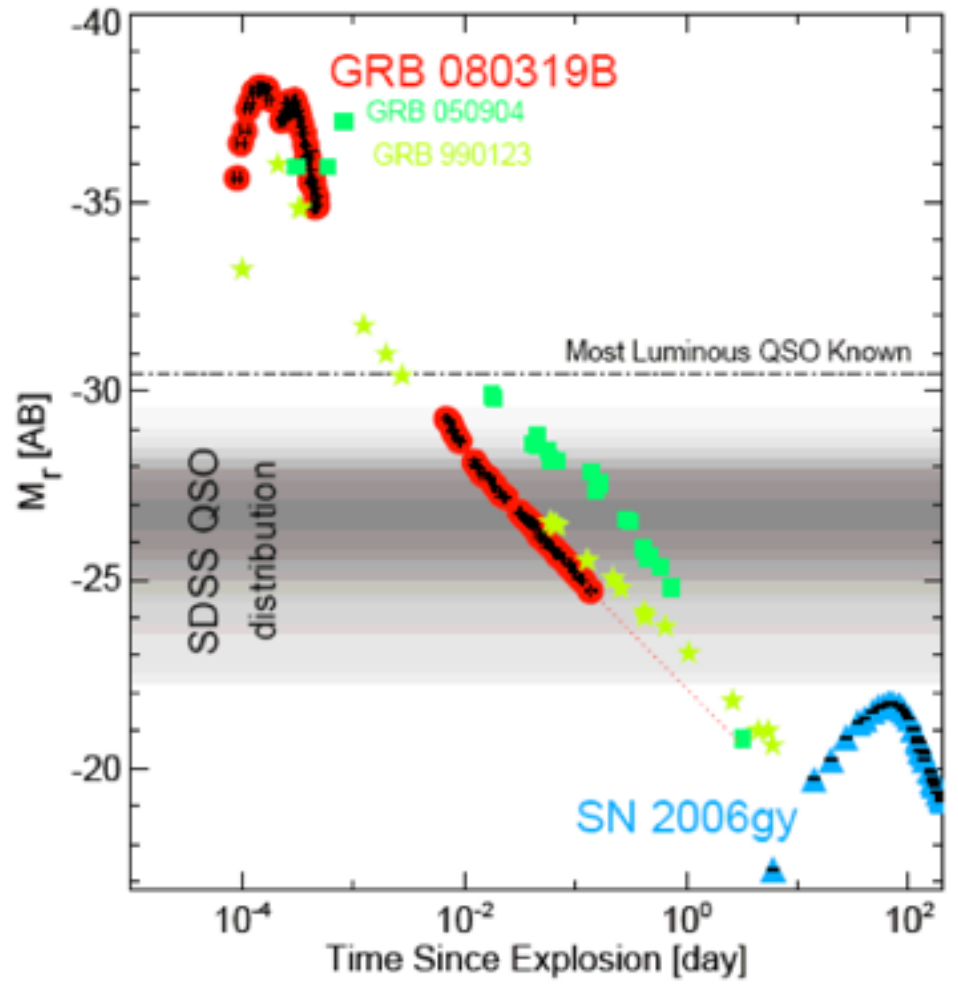
TRANSIENTS

- **Gamma-ray bursts**
- **Supernovae**
- Novae
- Fast Radio Bursts
- Tidal disruption events
- Magnetars
- X-Ray Binaries
- And their environments!

External Collaborators: Steve Schulze (Weizmann), Giorgos Leloudas (Weizmann, DARK/NBI), Daniele Malesani (DARK/NBI, DTU Space), Dong Xu (NAOC,CAS), Nial Tanvir (U. Leicester), …

Gamma ray bursts

- The most luminous explosions in the Universe
- Observable at any redshift
- Classified into soft-long and hard-short (perhaps others: intermediate, ultralong, ...)



Bloom et al. 2008

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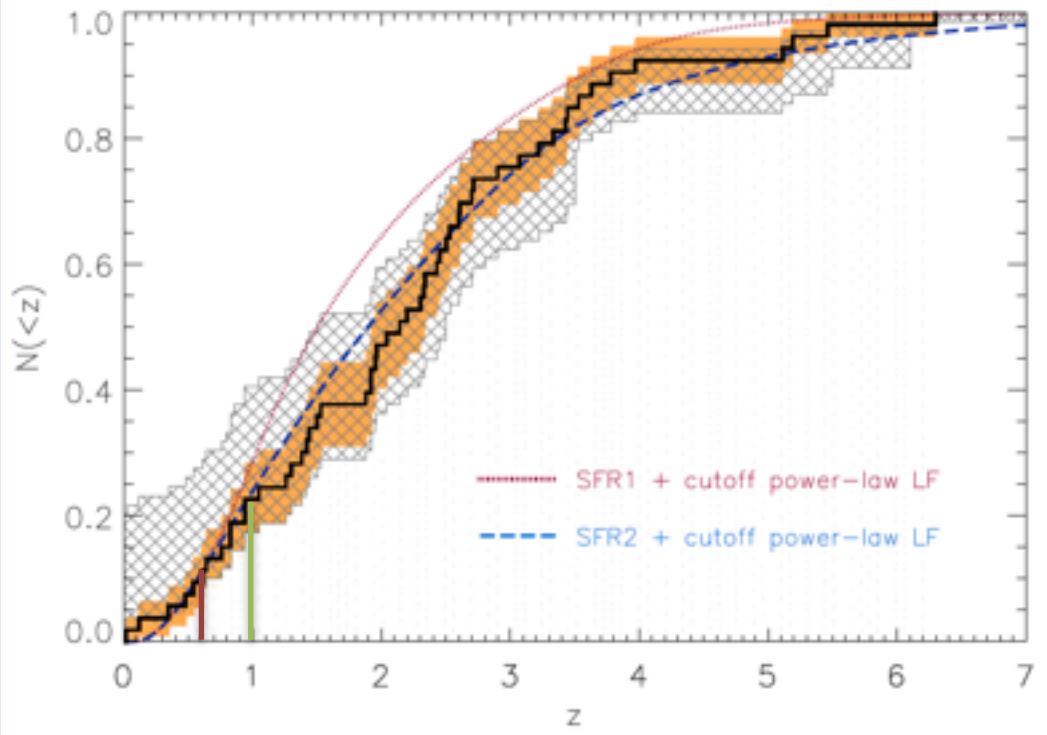

Jakobsson 2012

Gamma ray bursts

- Much rarer than other SNe types
- BUT:
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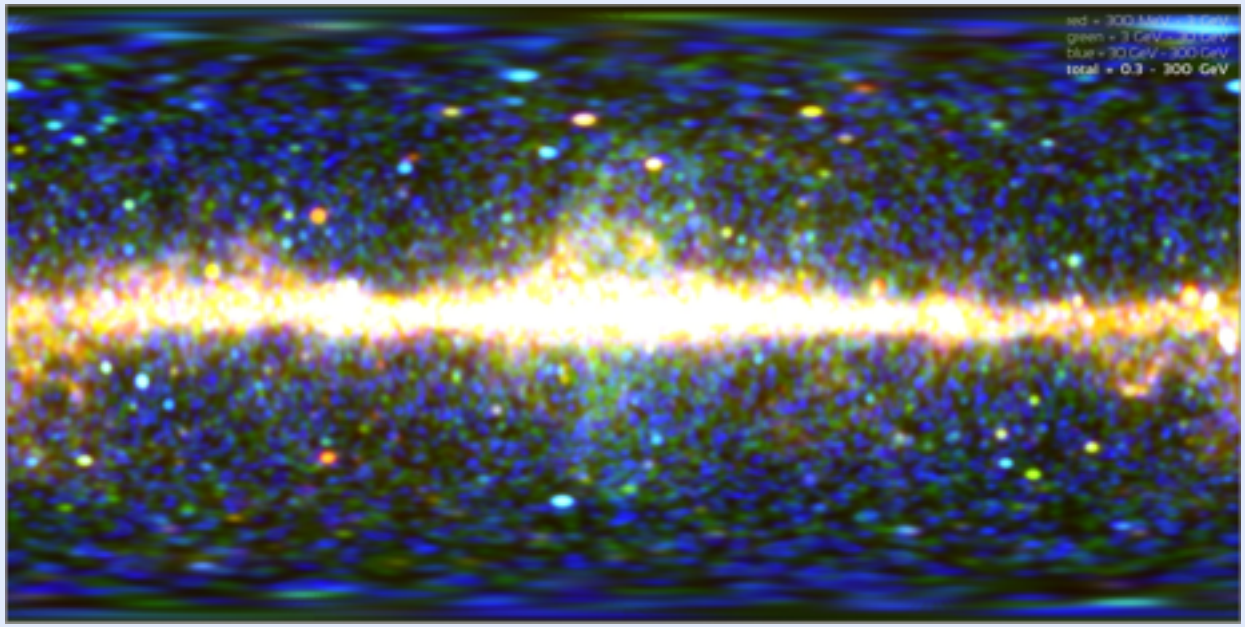
  - Well localised in X-rays within seconds
- We know when & where to search



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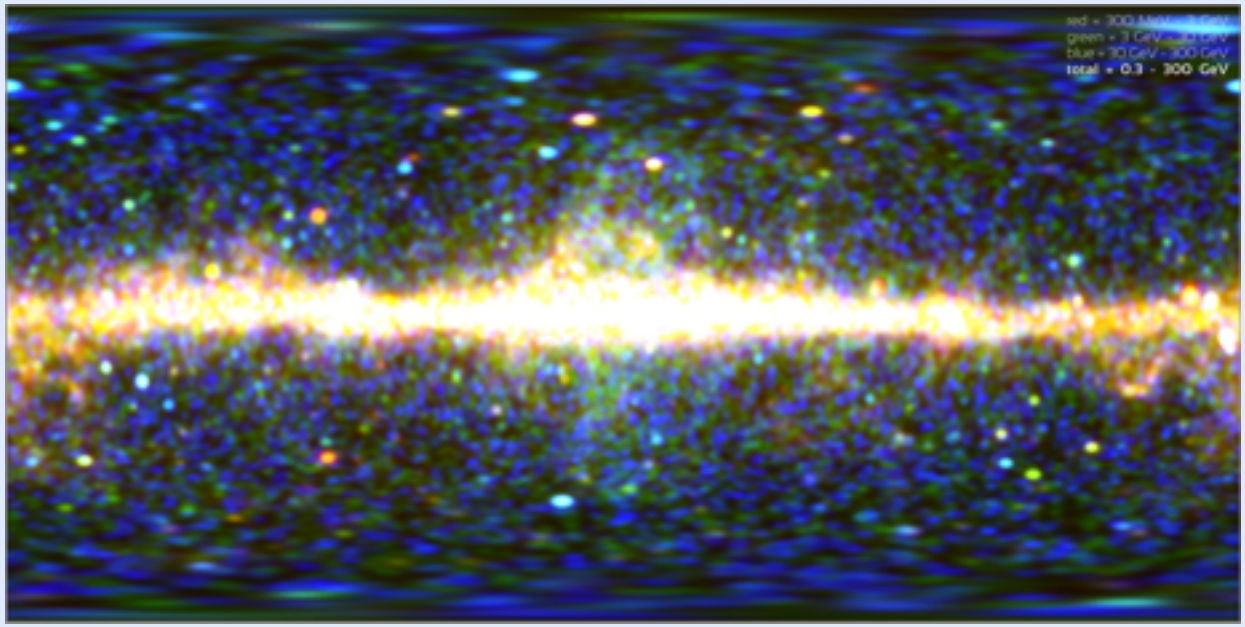

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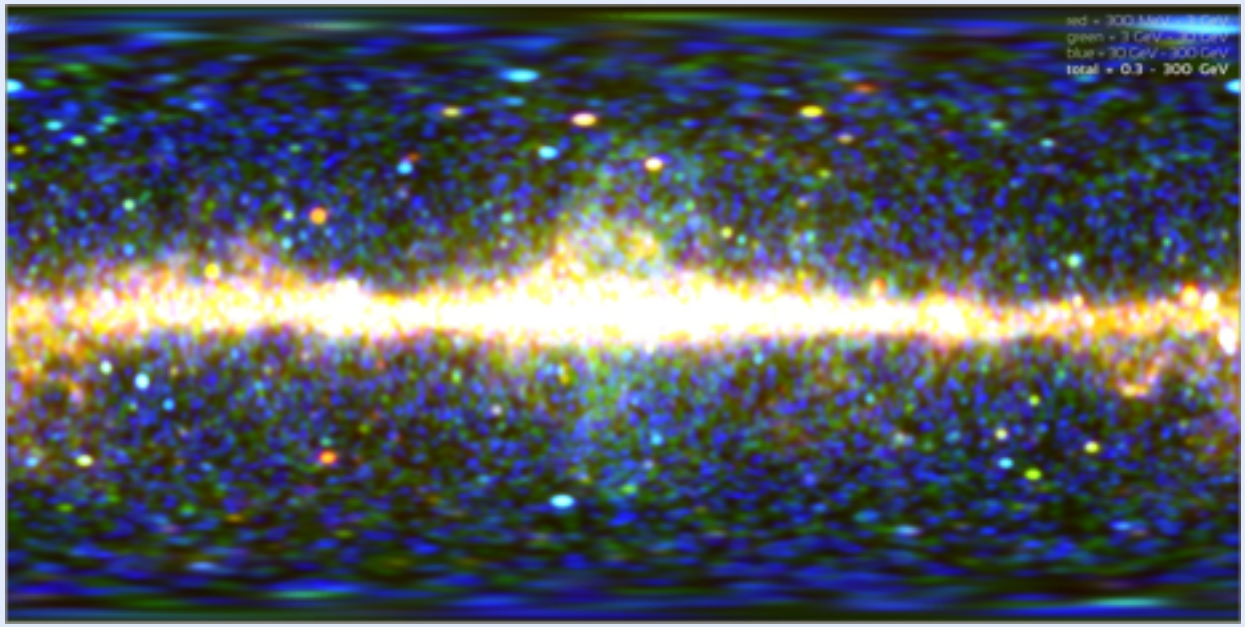

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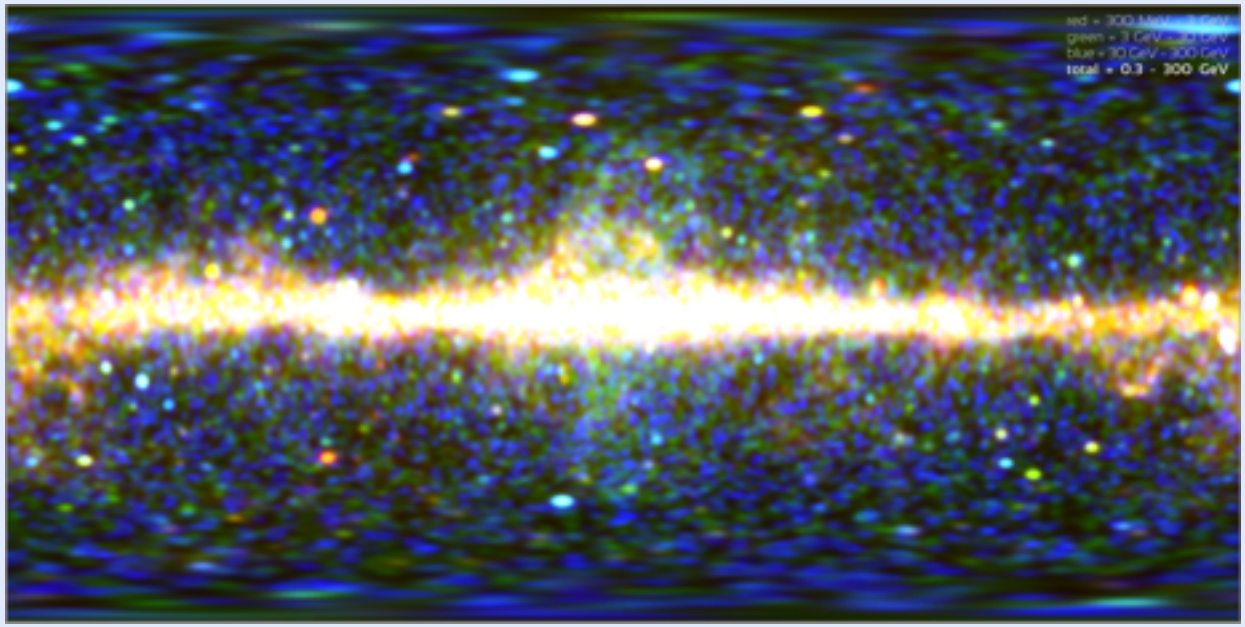

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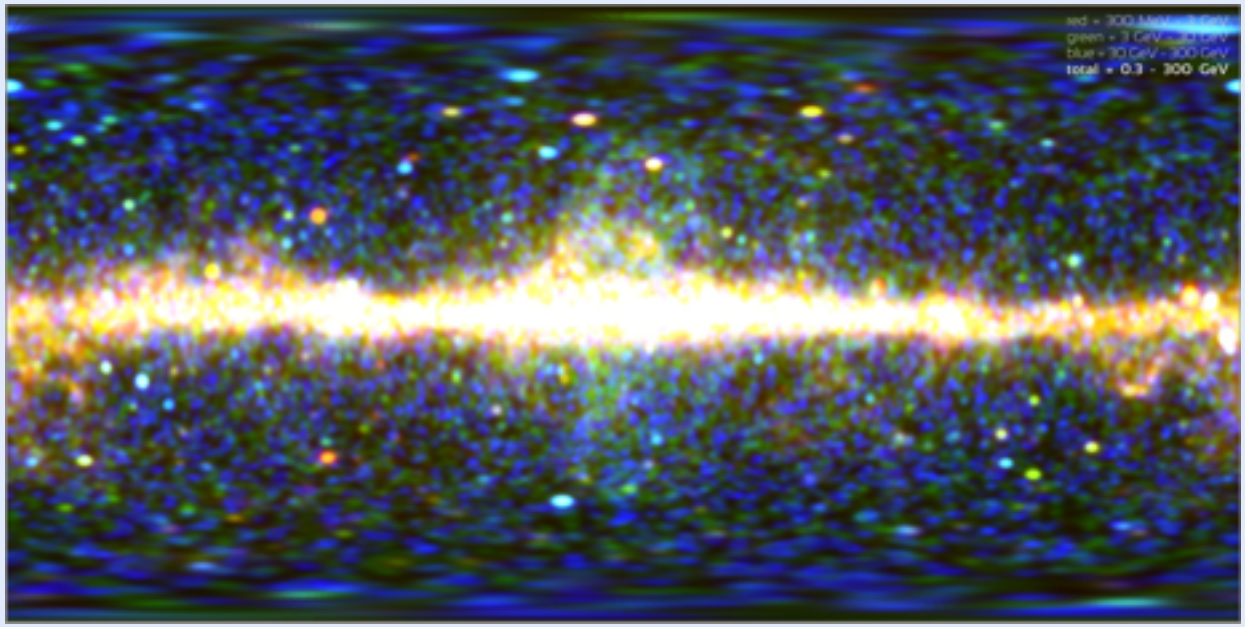

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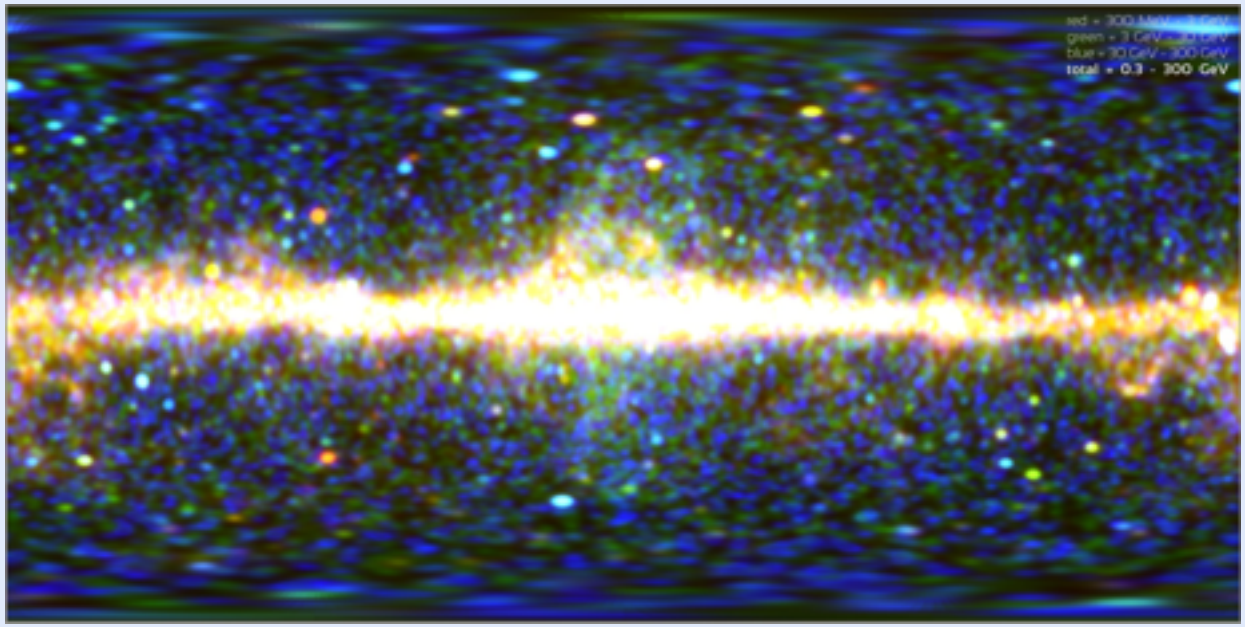

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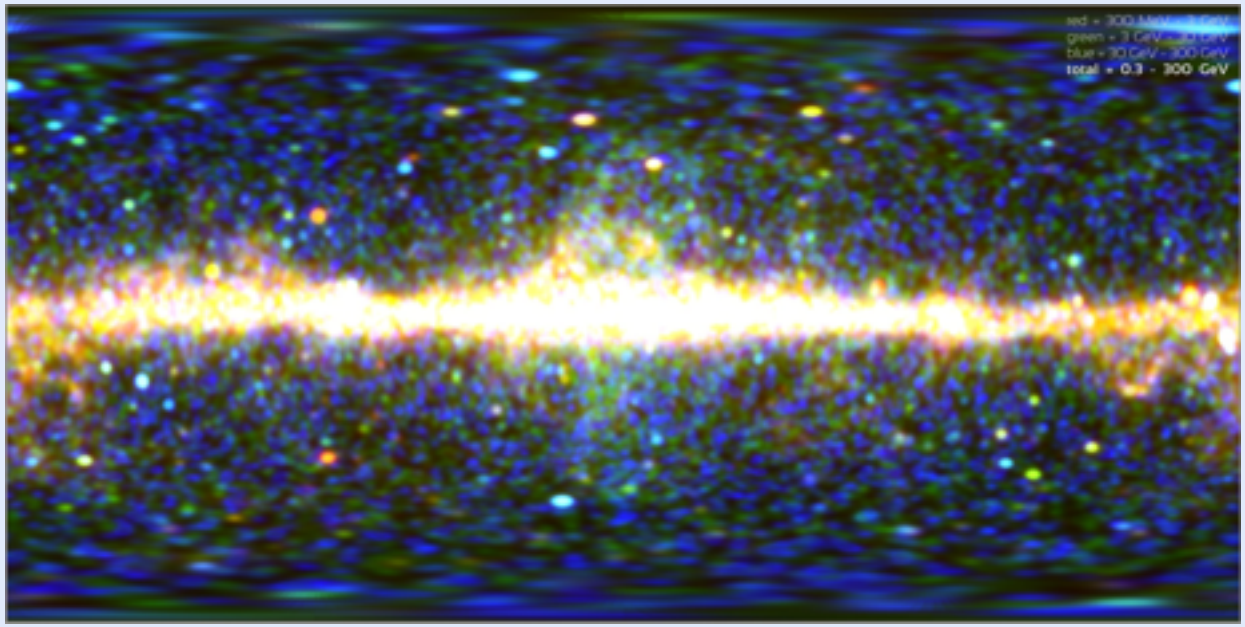

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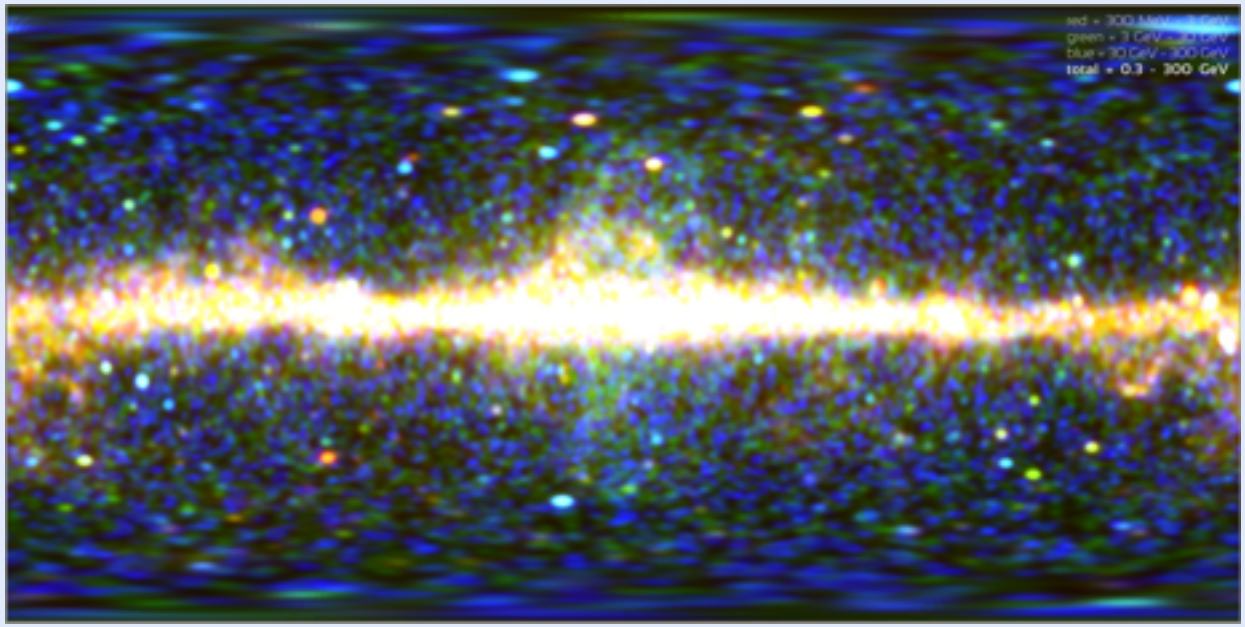

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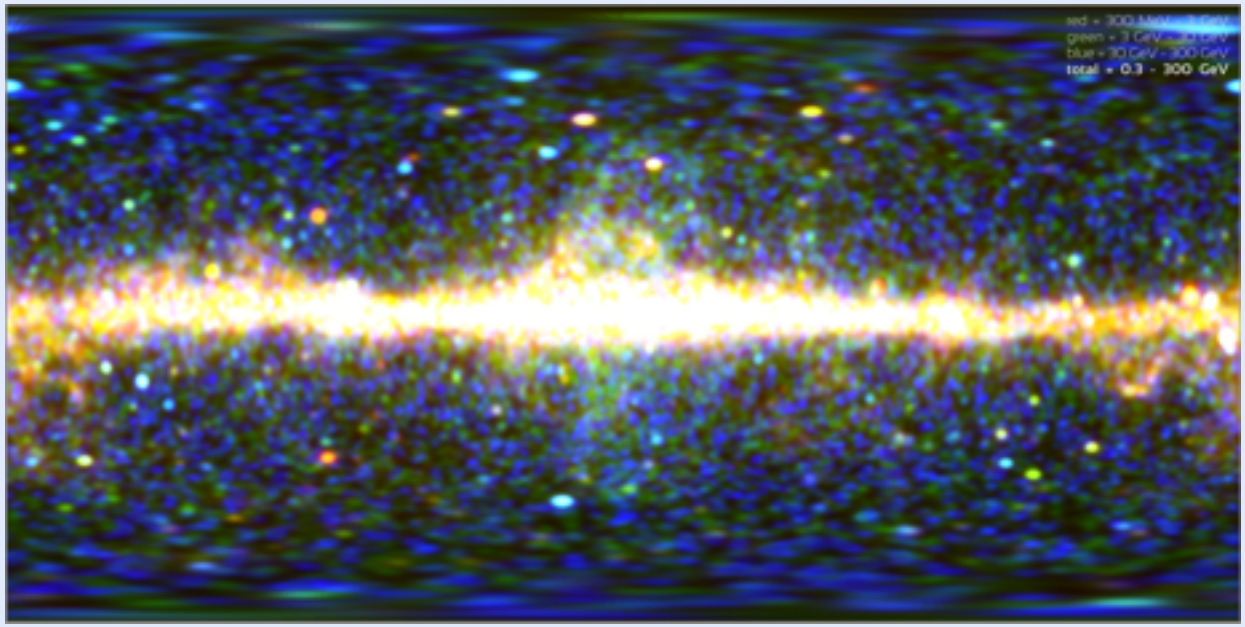

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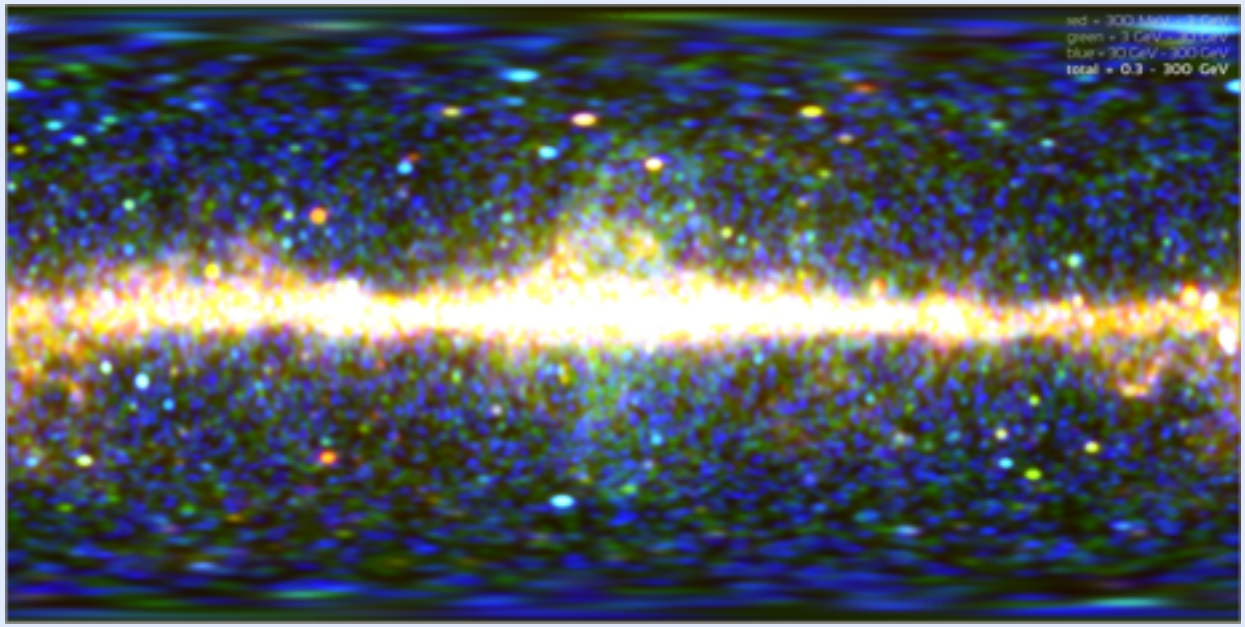

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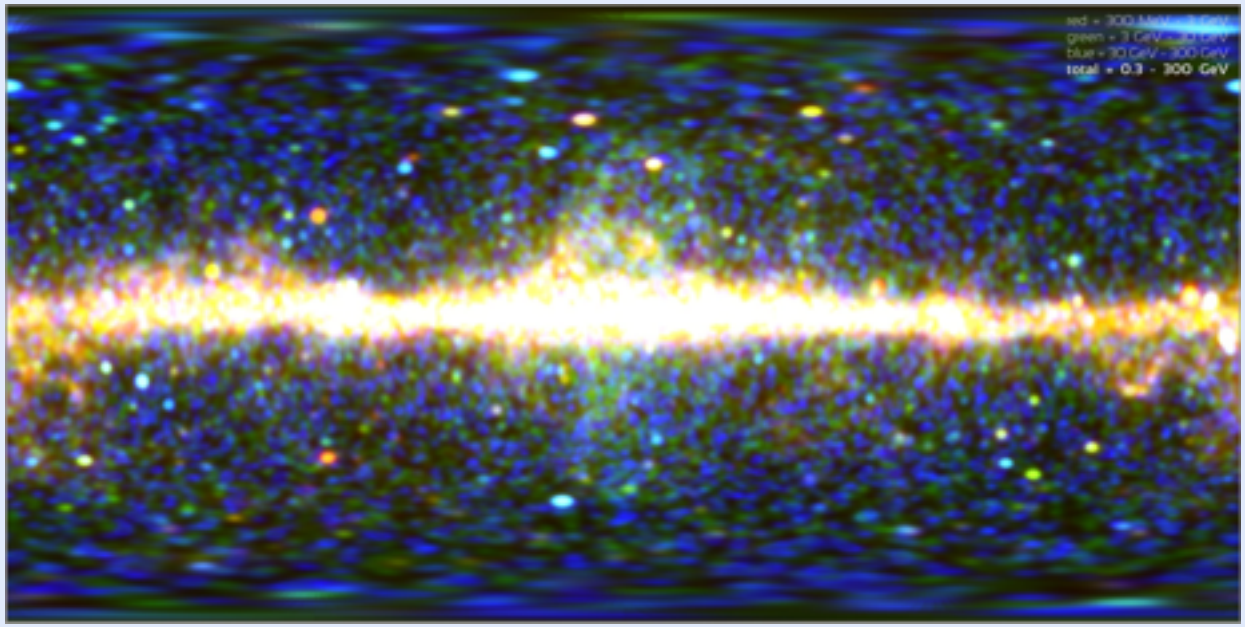

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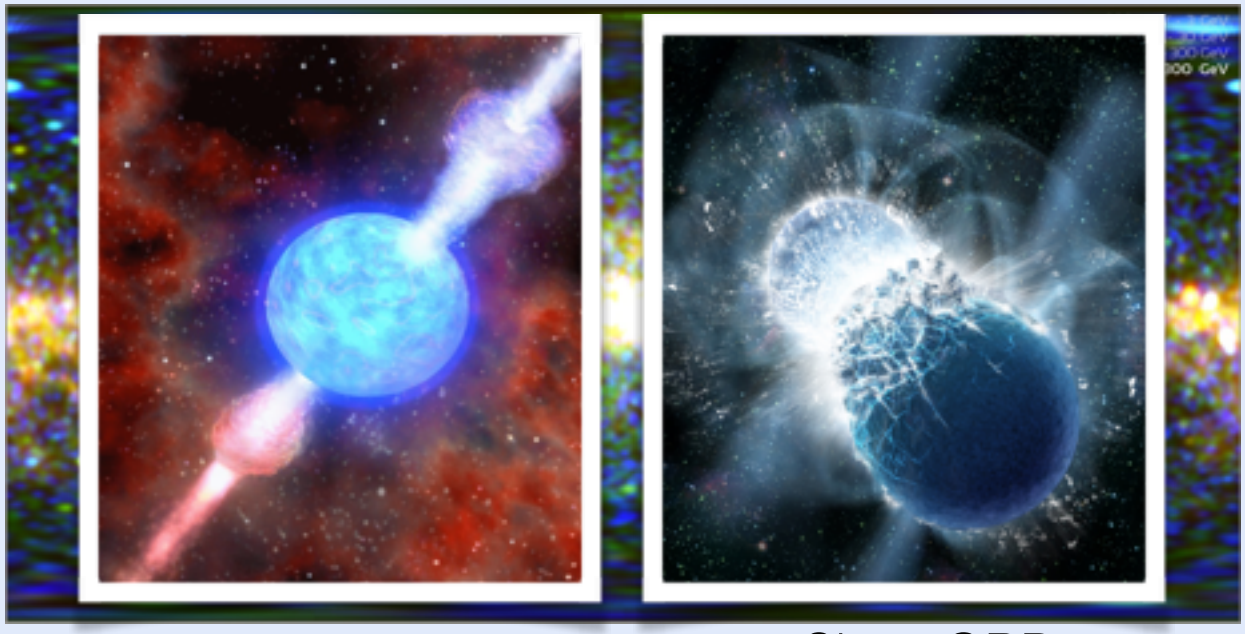

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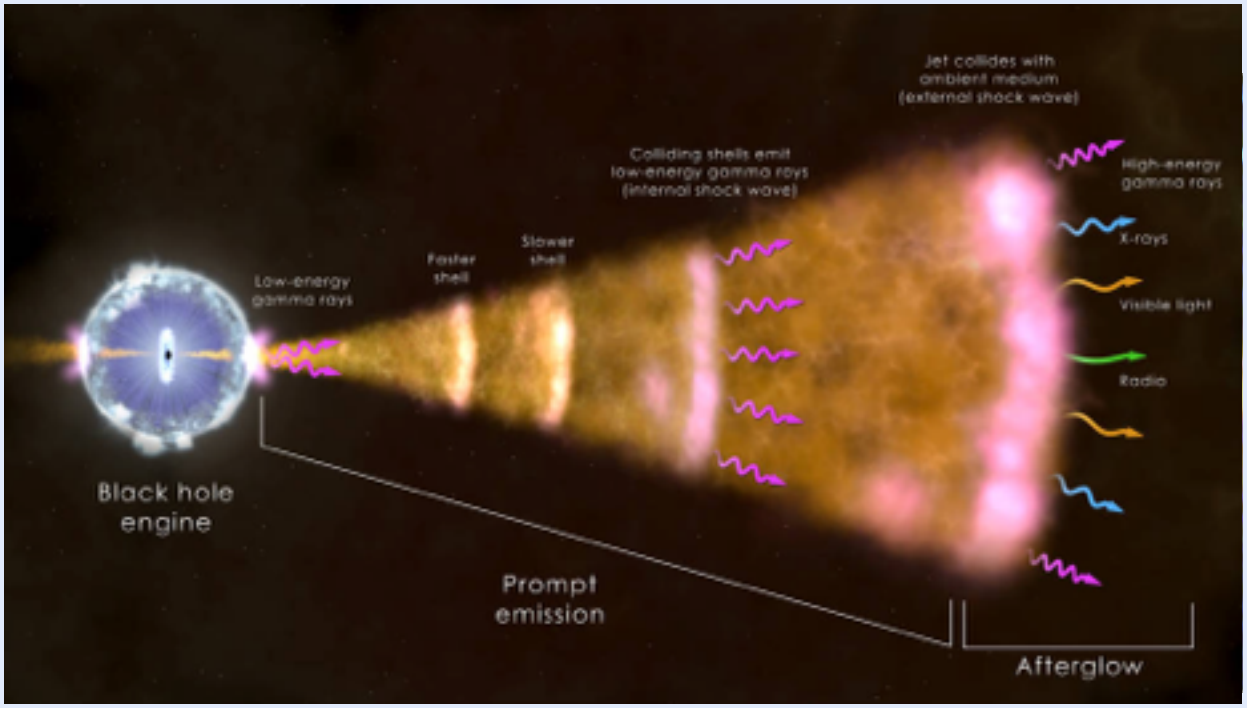
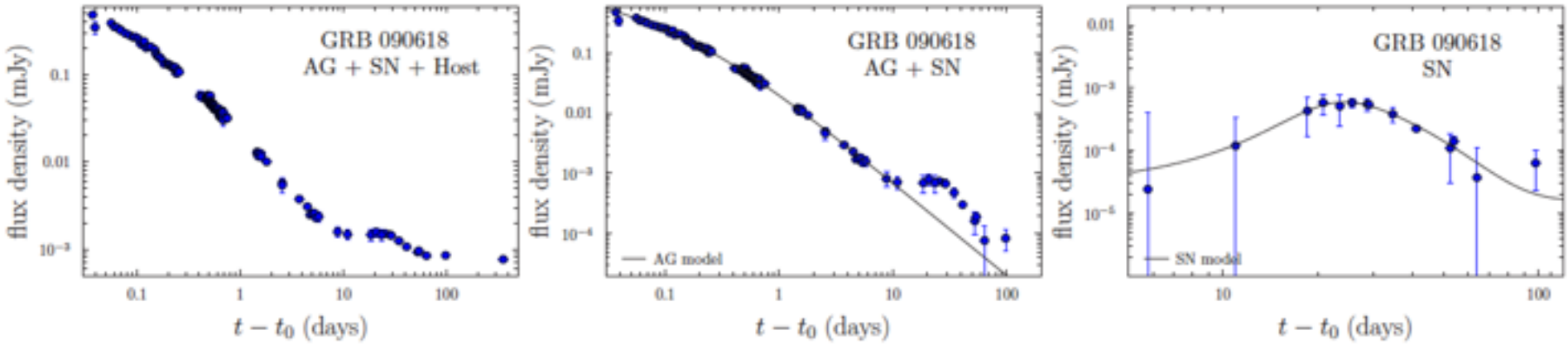


Typical GRB-SN light curve

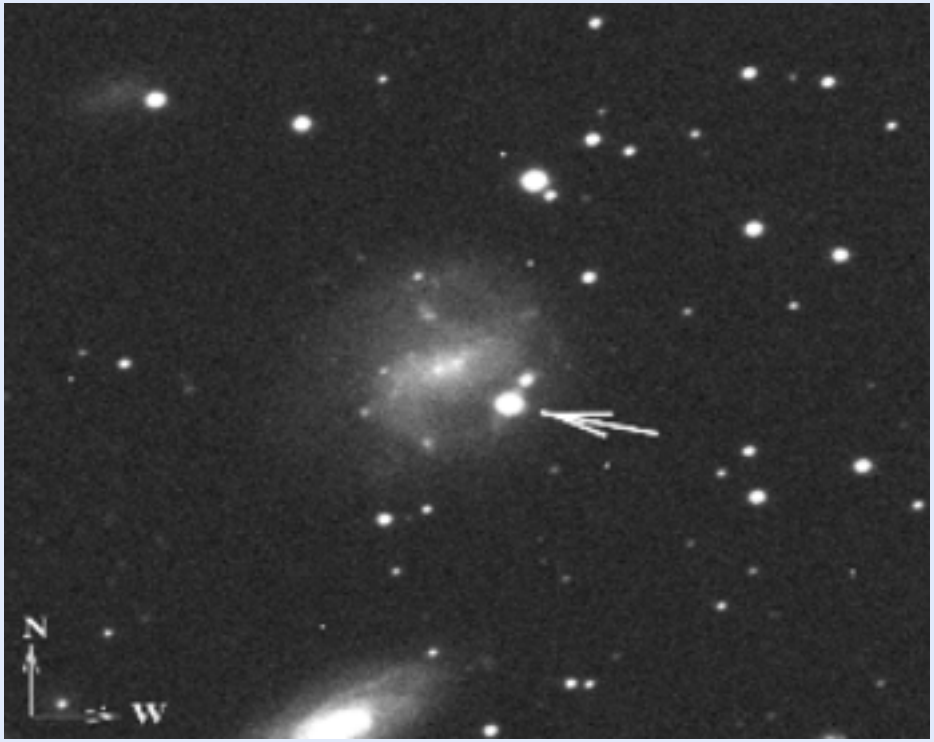


Cano et al. 2016

- 1st week: Light curve dominated by afterglow
- 2nd - 4th week: Supernova bump
- > 1 month: Host galaxy dominates

The GRB-SN connection (long GRBs!)

- GRB 980425 / SN1998bw
- $z = 0.0086$ (40 Mpc)
- Very low luminosity GRB
- No optical afterglow
- Is this a normal GRB?
- Confirmation in 2003 with GRB 030329 / SN2003dh



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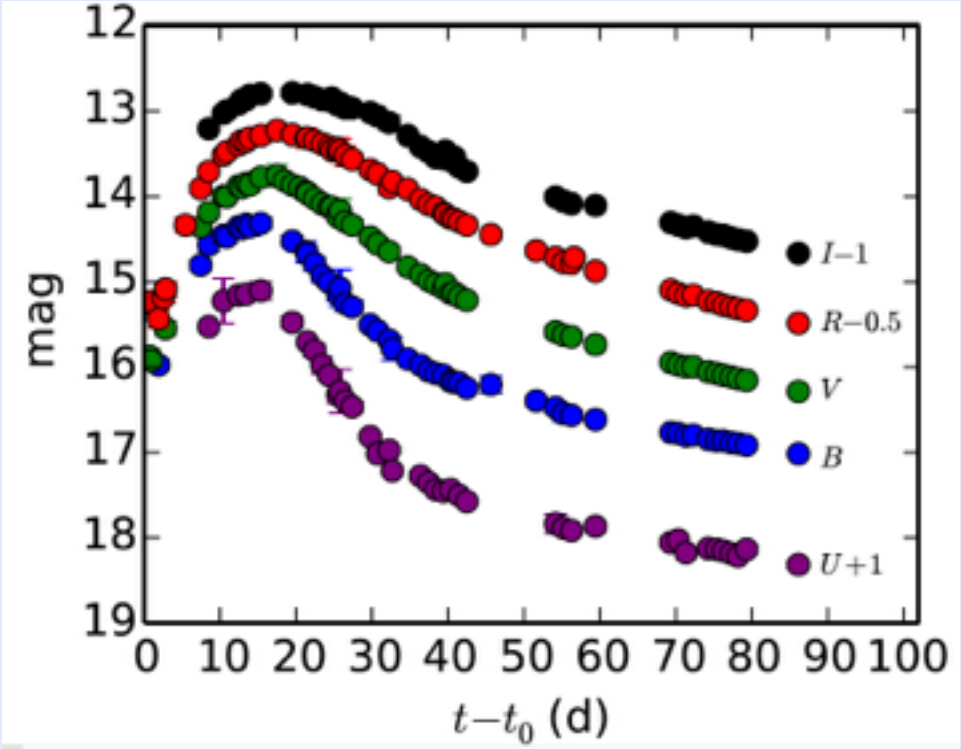

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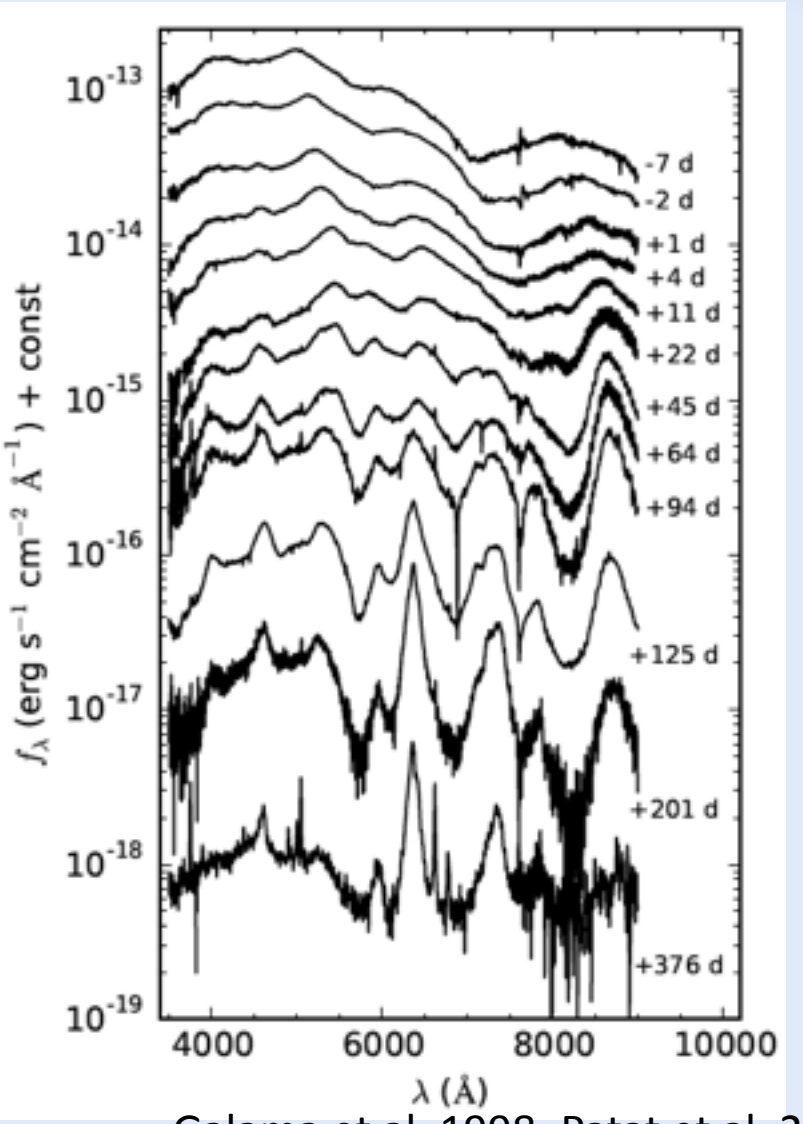

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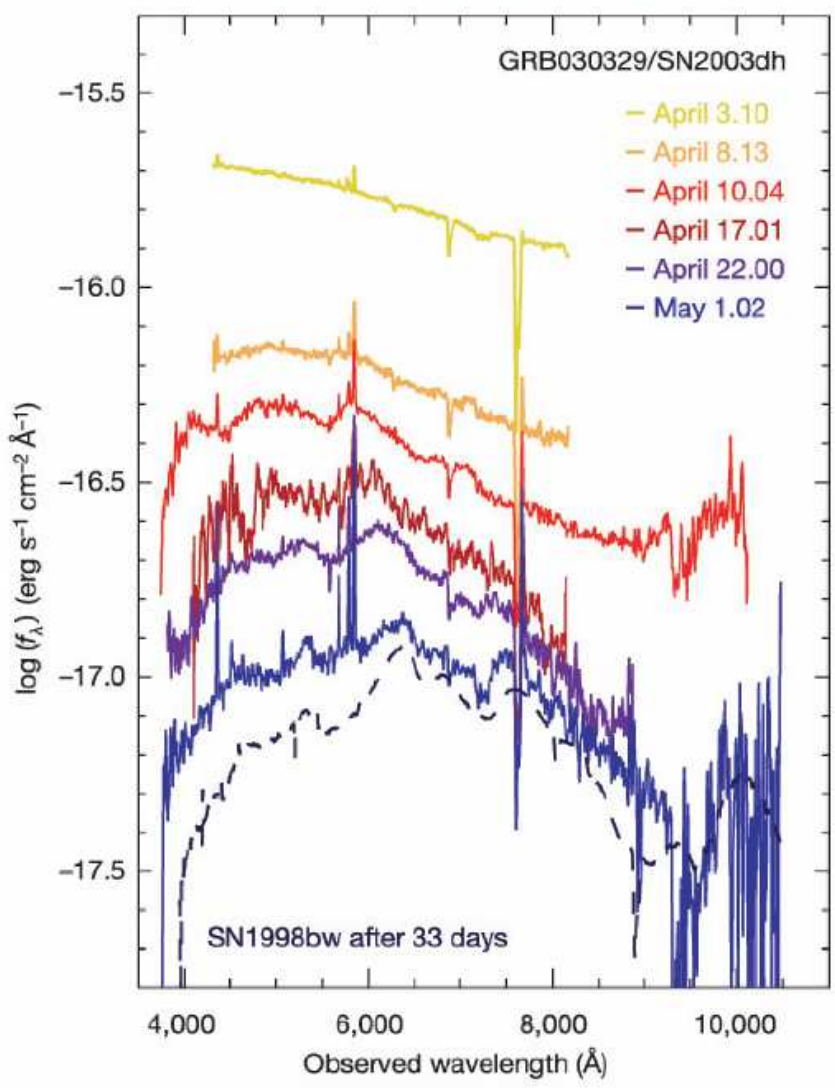

Hjorth et al. 2003

Biased and limited studies

- Follow-up of GRB-SN was biased towards nearby, peculiar events
- Most GRB-SN are low-luminosity GRBs that may not represent the GRB population
- No systematic studies for short, intermediate or ultra-long GRBs
- Good spectroscopic studies for only 4 GRBs, all at $z < 0.17$
- No component detected for short GRBs
- Two SN-less GRBs discovered in 2006. No further cases confirmed later

The GTC GRB-SN programme

- In 2010 the 10.4m GTC programme starts
- Systematic search for all GRB-SNe at $z < 1.0$
- Spectroscopic follow-up at $z < 0.6$
- All types of GRBs (including short)
- Support from smaller telescopes
- Still some biases (e.g. dust extinction)

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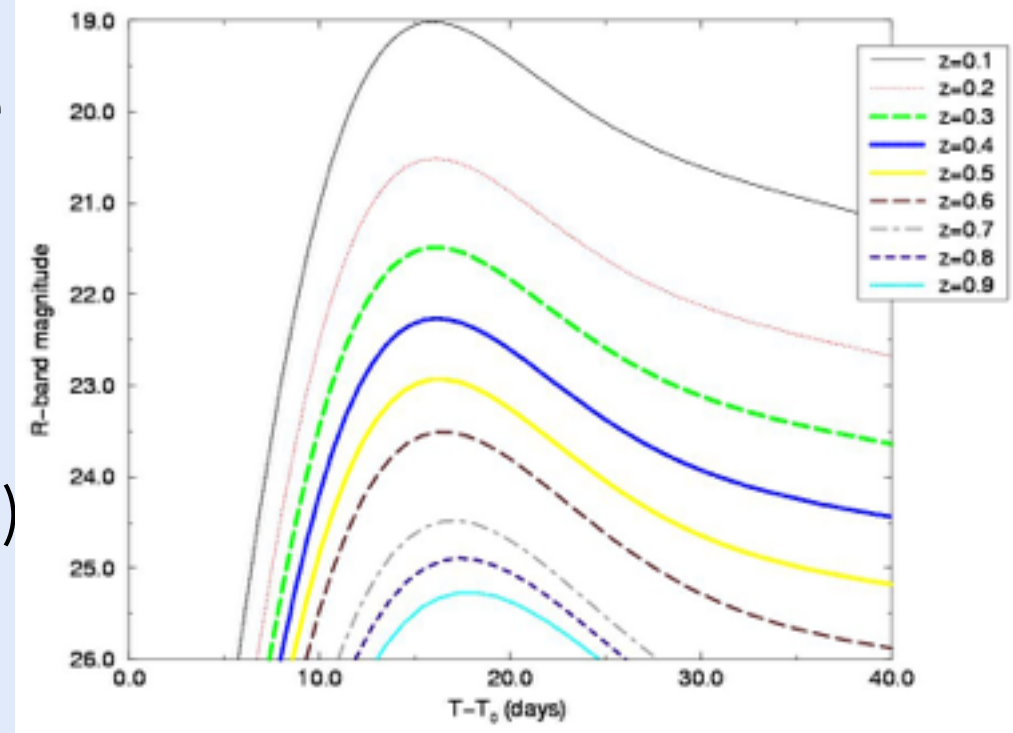

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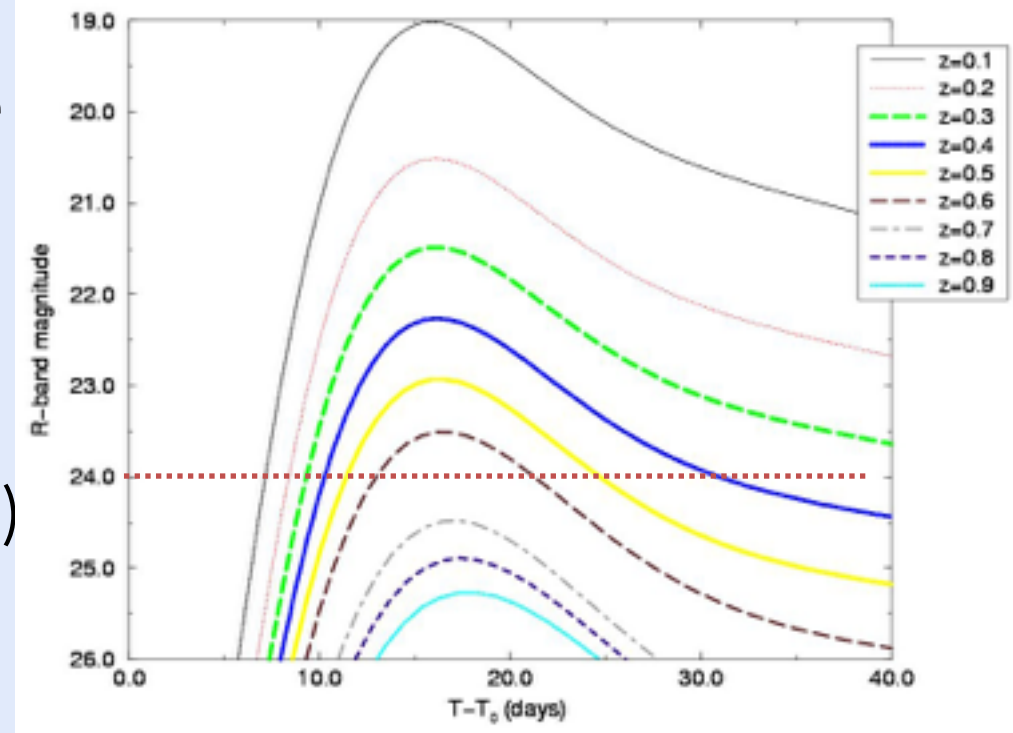

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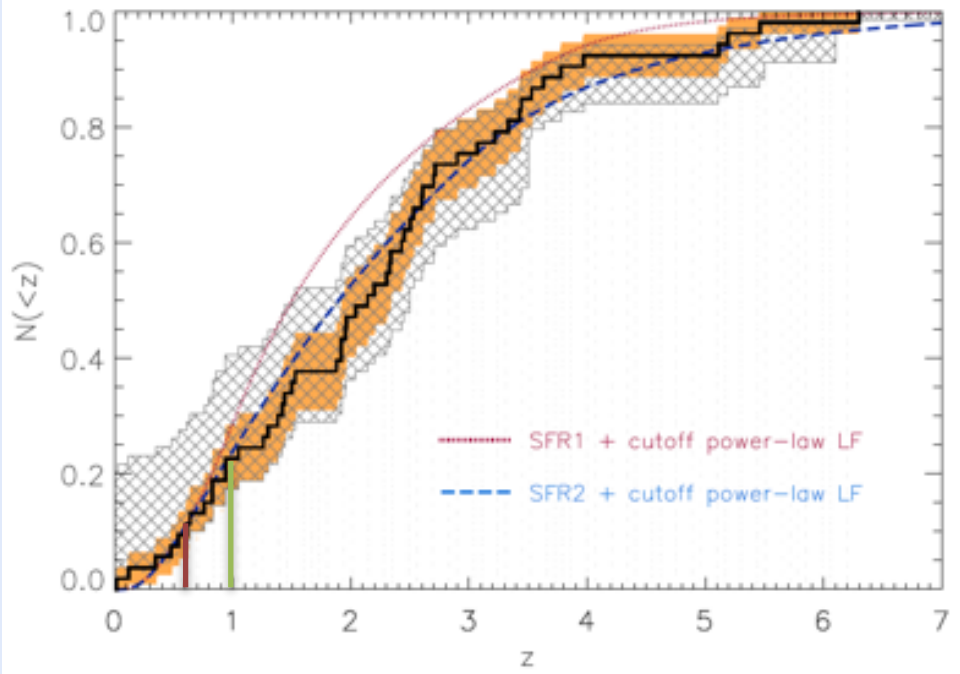

Jakobsson 2012

7 years of follow-up

- 20 objects followed
  - 4 short
  - 11 long
  - 4 intermediate
  - 1 ultralong
- $0.14 < z < 0.97$
- $\gtrsim$ 7 spectroscopic detections
- GRB 120422A (z=0.28)
- GRB 140606B (z=0.38)
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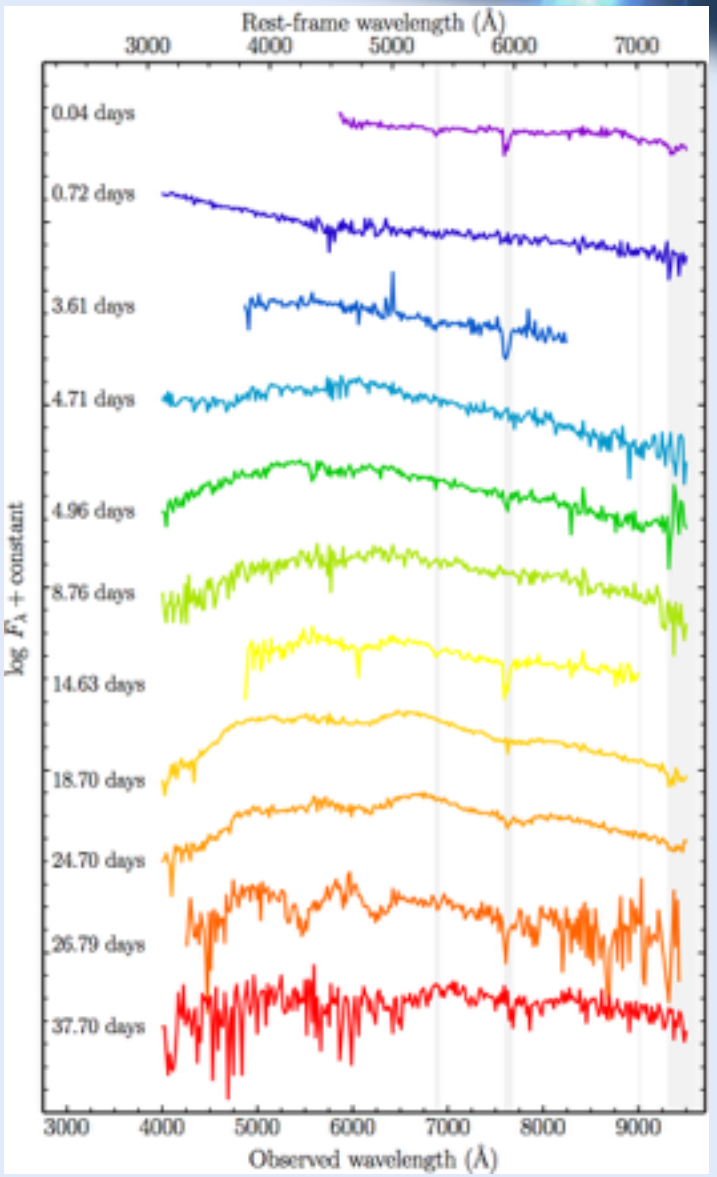

Schulze, et al. 2014, A&A 556, 102

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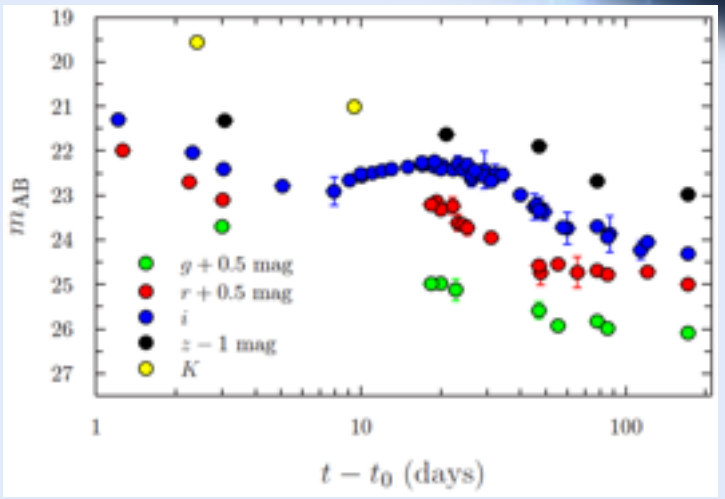

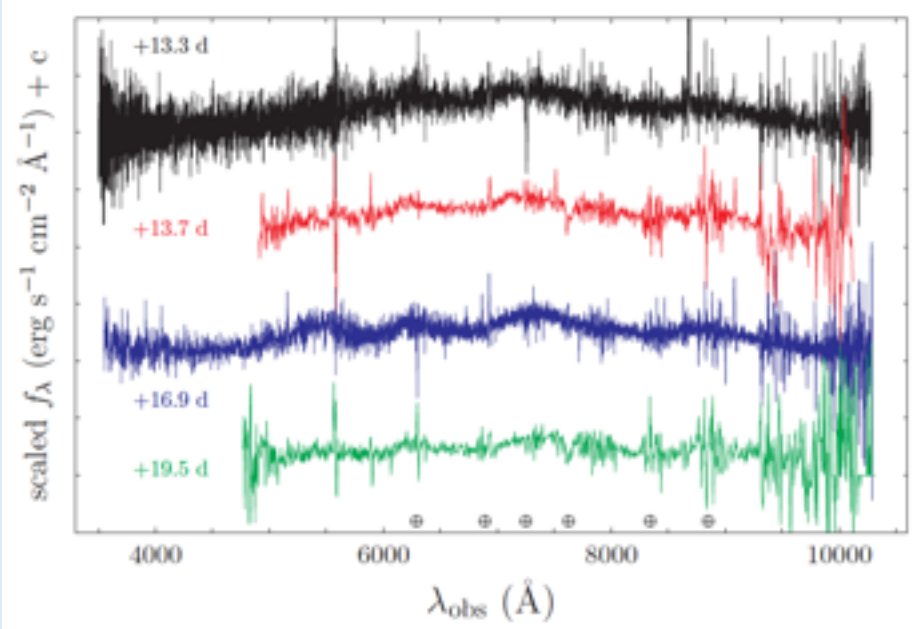

Cano, de Ugarte Postigo, et al. 2015

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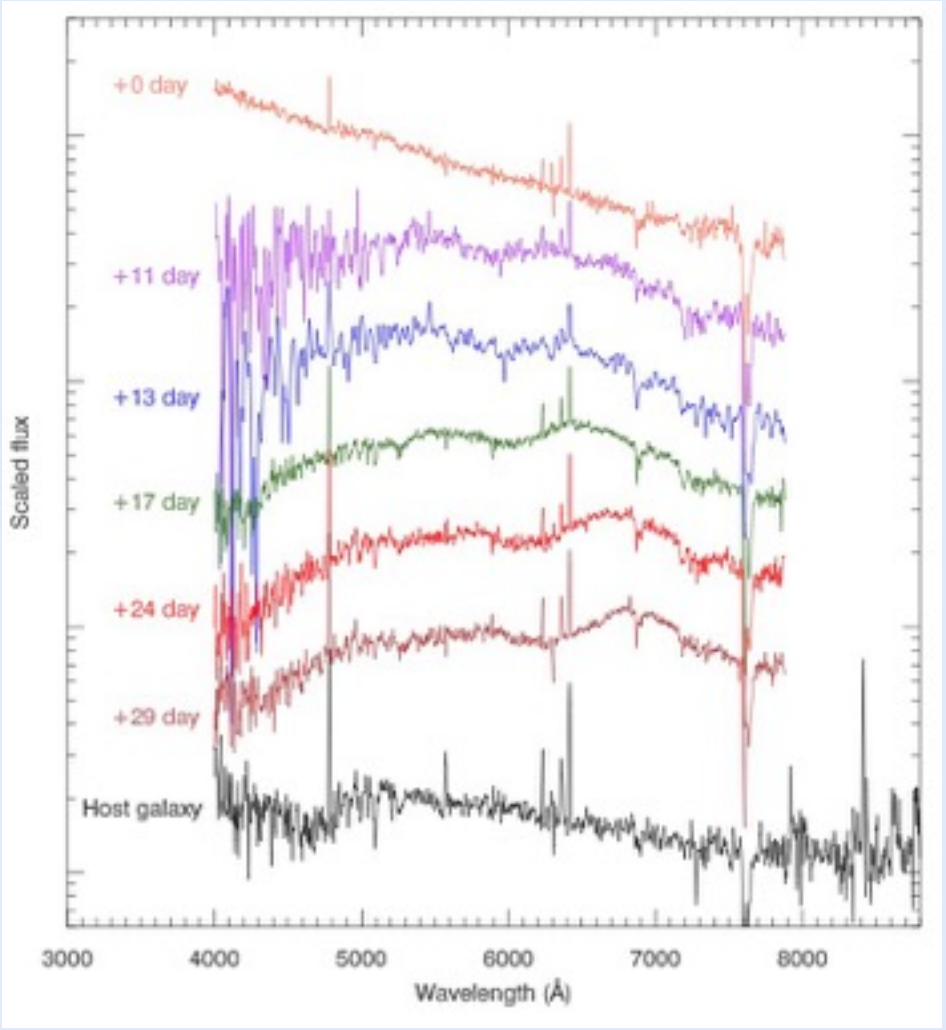

de Ugarte Postigo, in prep

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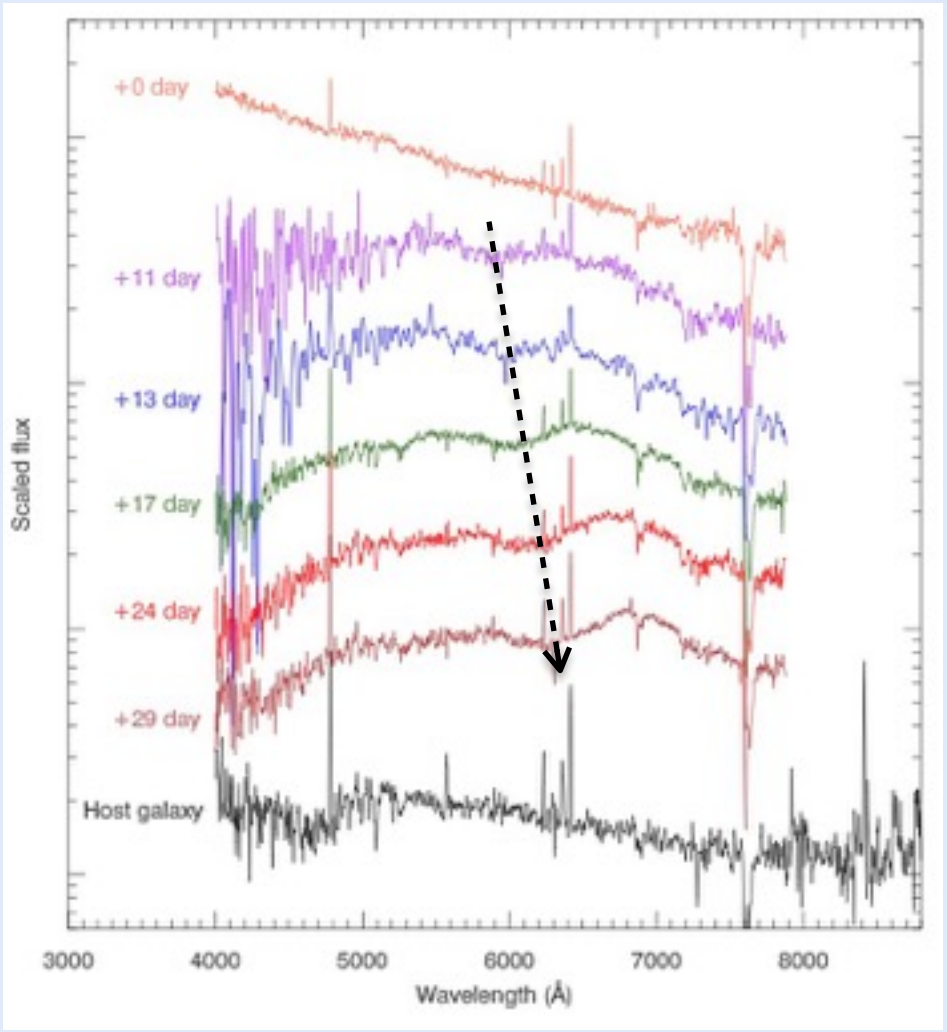

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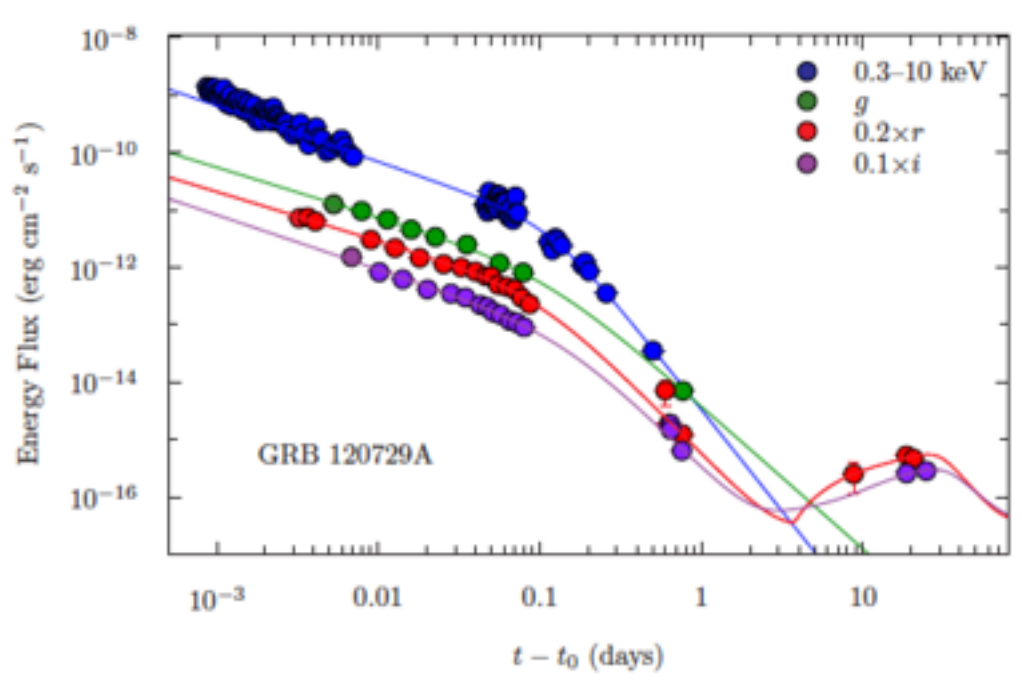

Cano, de Ugarte Postigo, et al. 2014, A&A 568, 19

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- $z = 0.1475$
- Amongst the closest GRB/ SN to date
- SN discovered by GTC (de Ugarte Postigo et al. 2016)
- Well detected 2 months after the GRB
- Host galaxy well resolved
- HST observations

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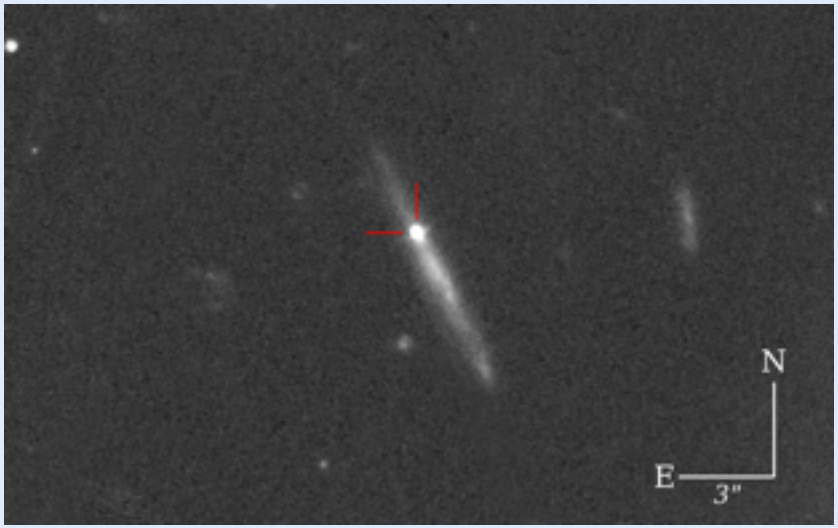

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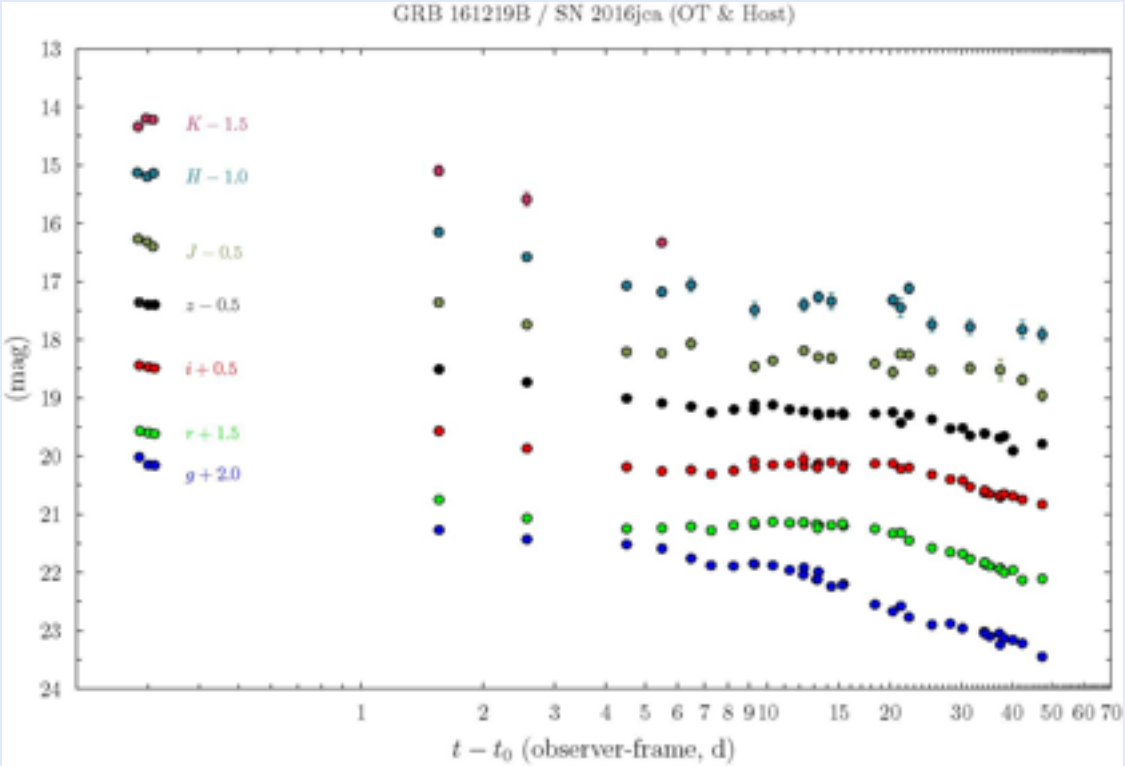

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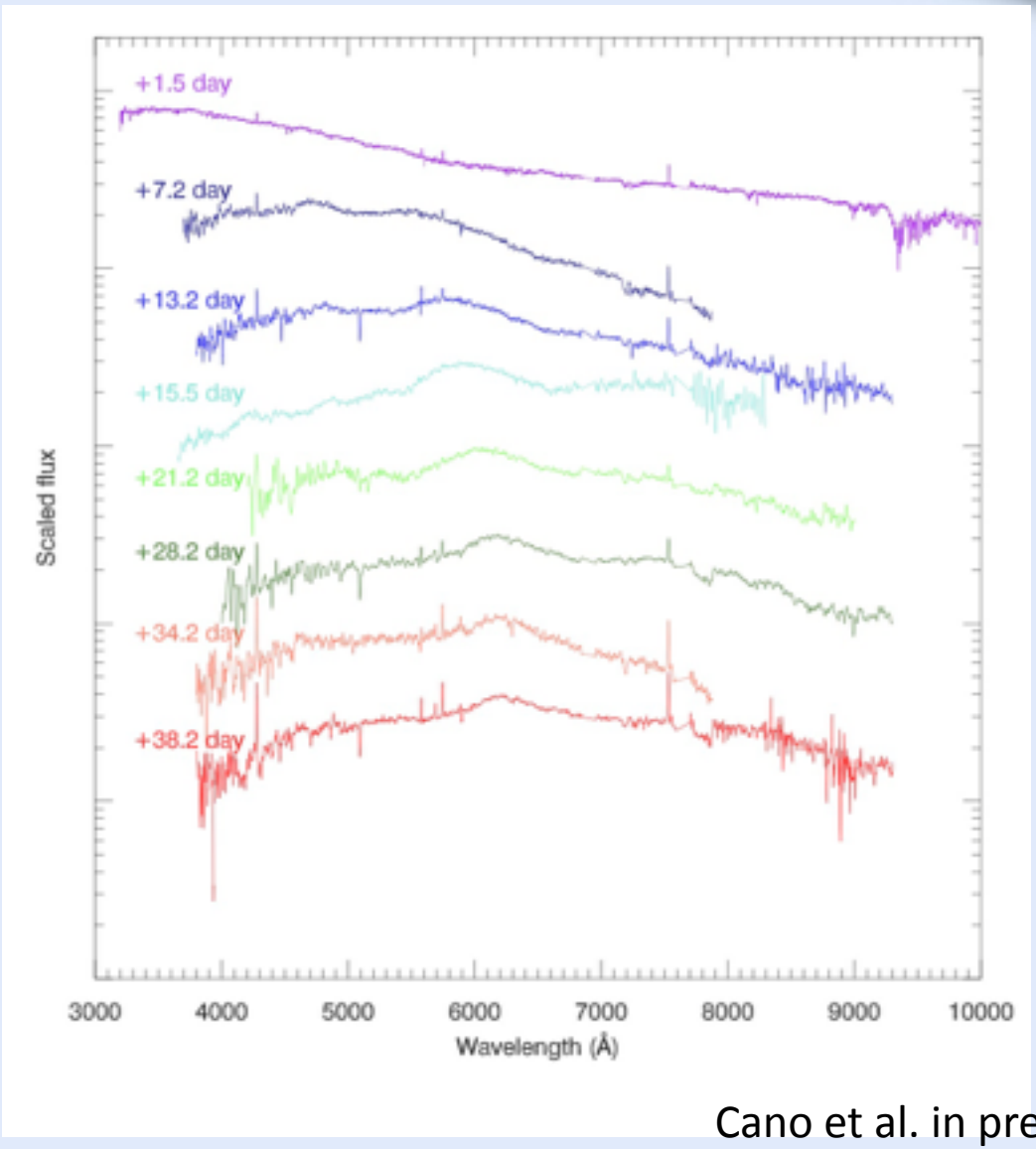

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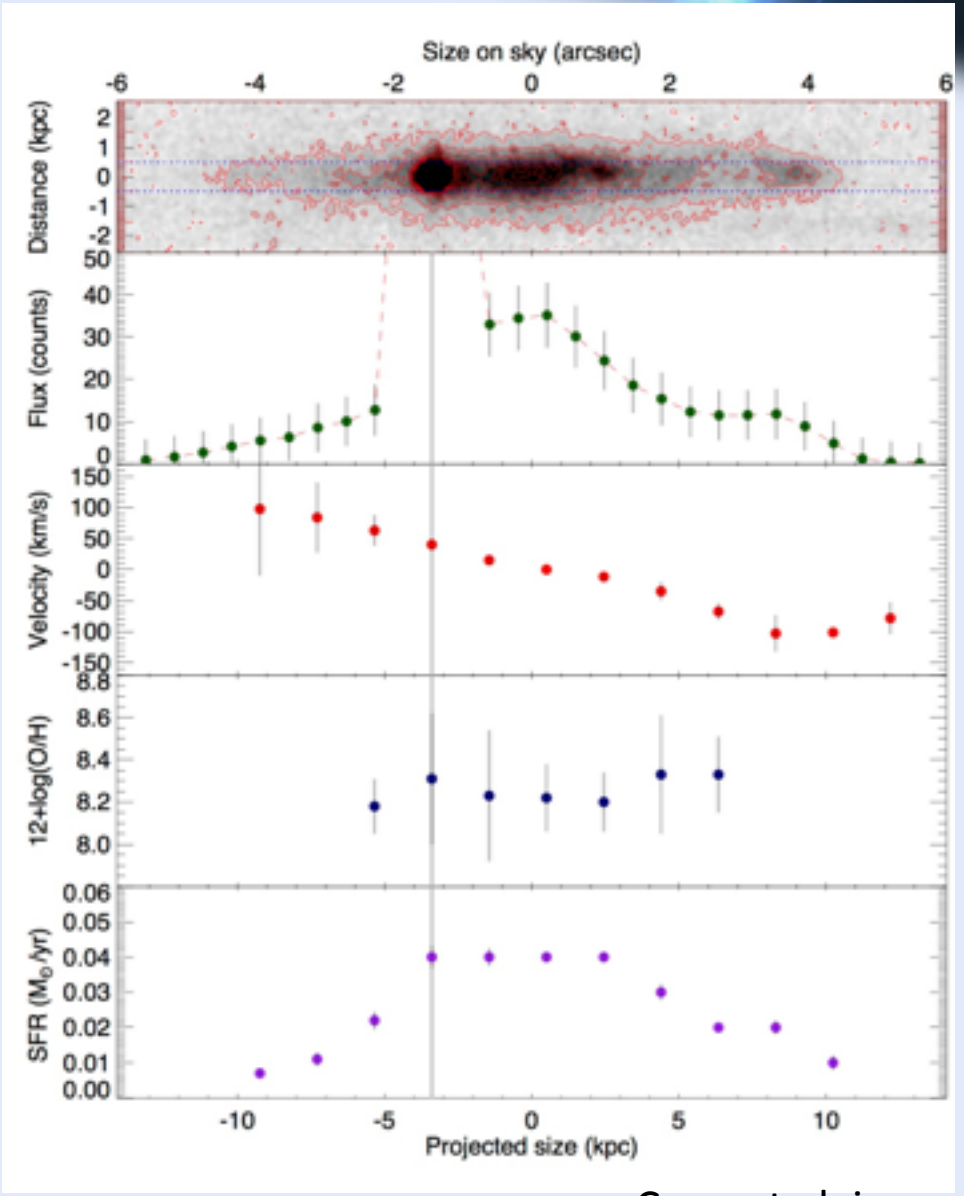

Cano et al. in prep

GRB 100418A: An underluminous SN

- Intermediate duration GRB at $z = 0.63$
- Luminous afterglow and host galaxy
- Host magnitude r = 22.1 mag
- Image subtraction reveals SN at r = 24.8 mag
- Supernova component peaking at $M_r \sim$ -17.0 mag (1998bw reached -18.7 mag)

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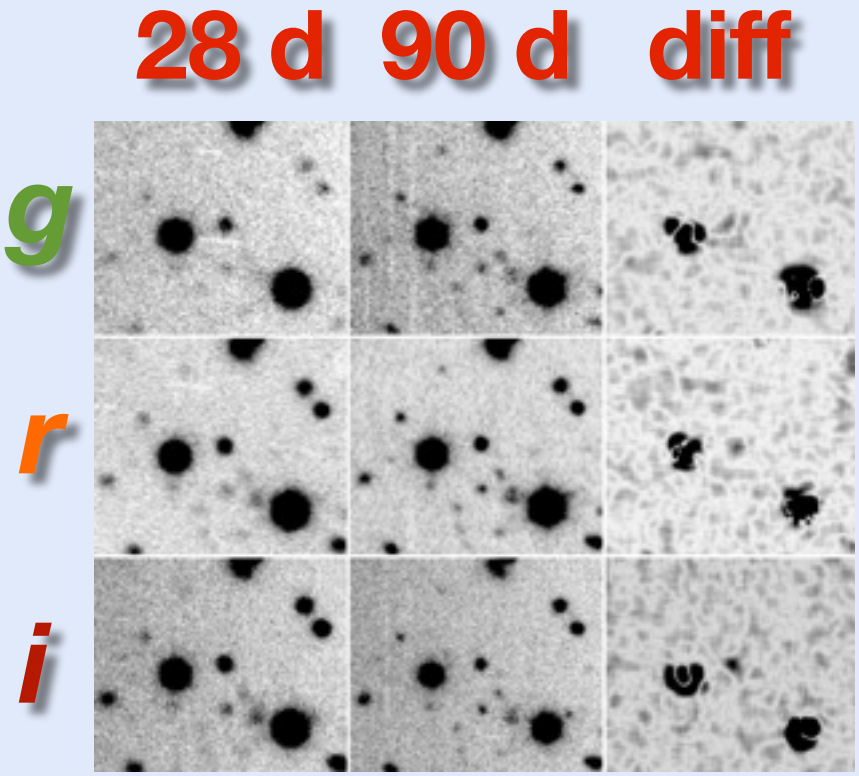
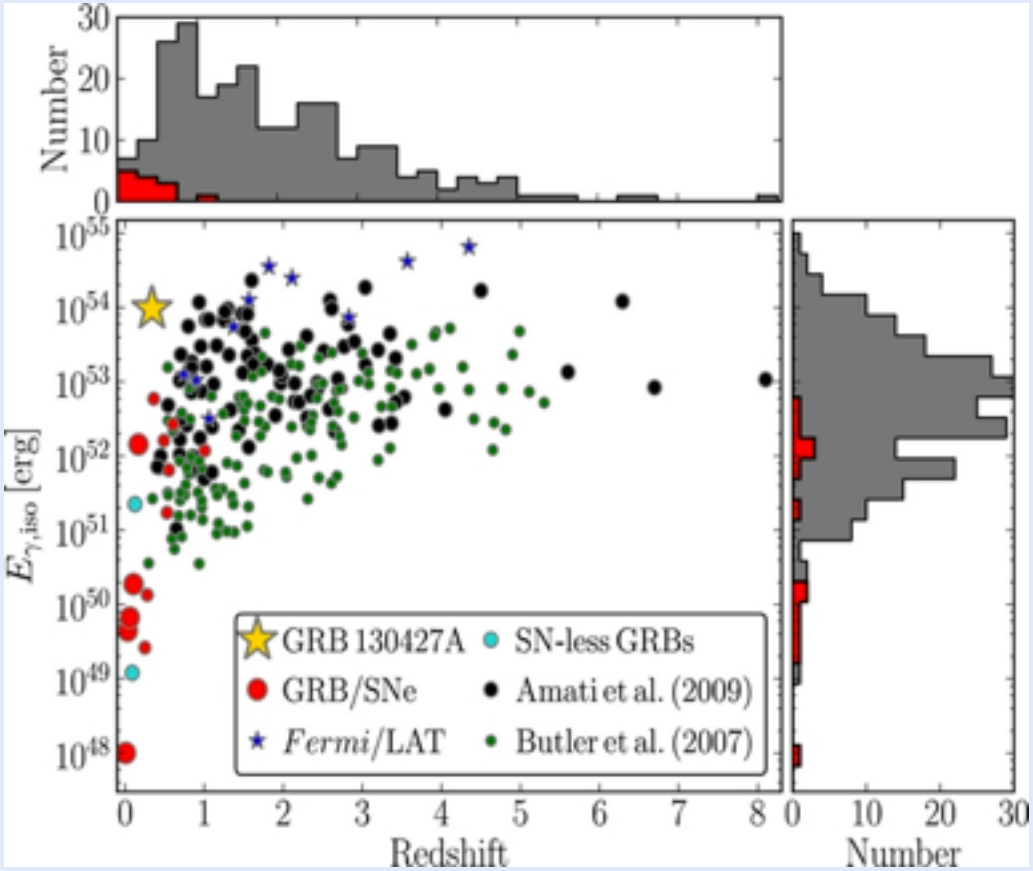


de Ugarte Postigo, in prep.

GRB 130427A: A hyper-energetic GRB

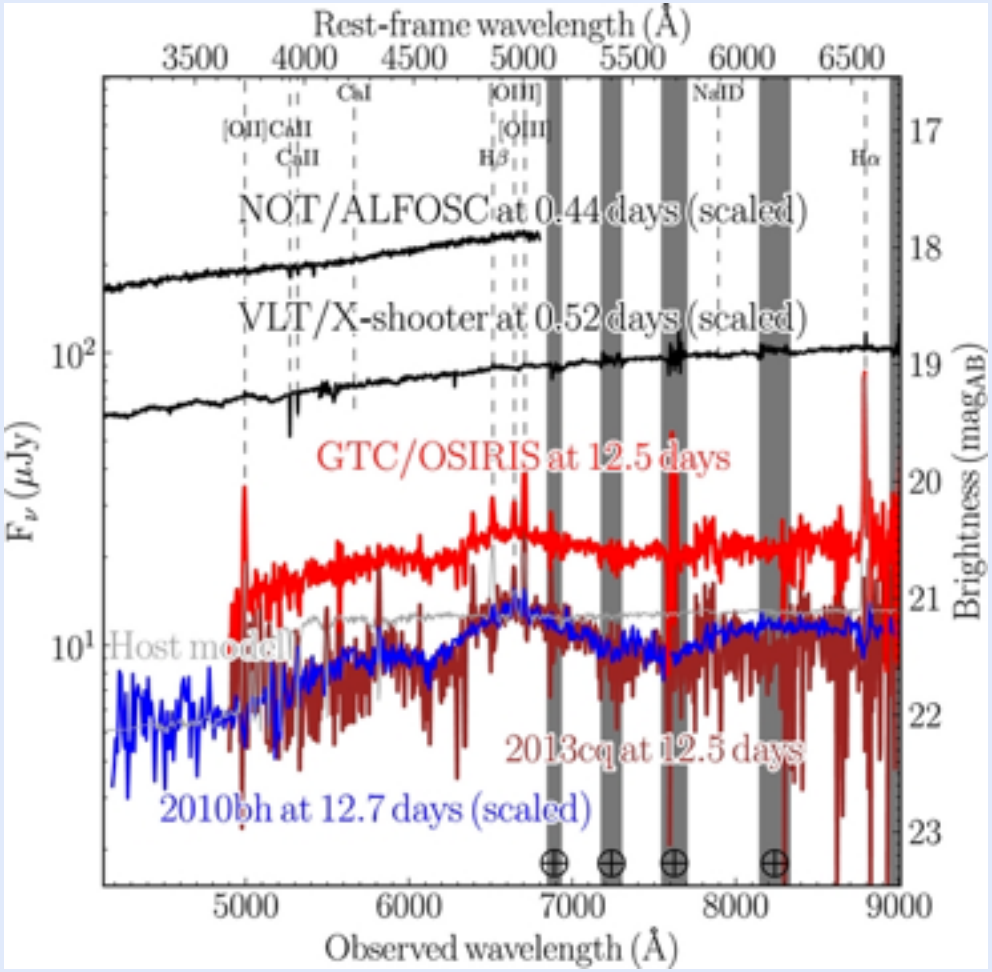
- GRB130427A / SN2013cq
- $z = 0.34$
- $E_{iso,\gamma} = 9.6 \cdot 10^{53}$ erg
- SN was a typical BL-Ic, as for other GRBs



Xu, de Ugarte Postigo et al. 2013, ApJ 776, 98

GRB 130427A: A hyper-energetic GRB

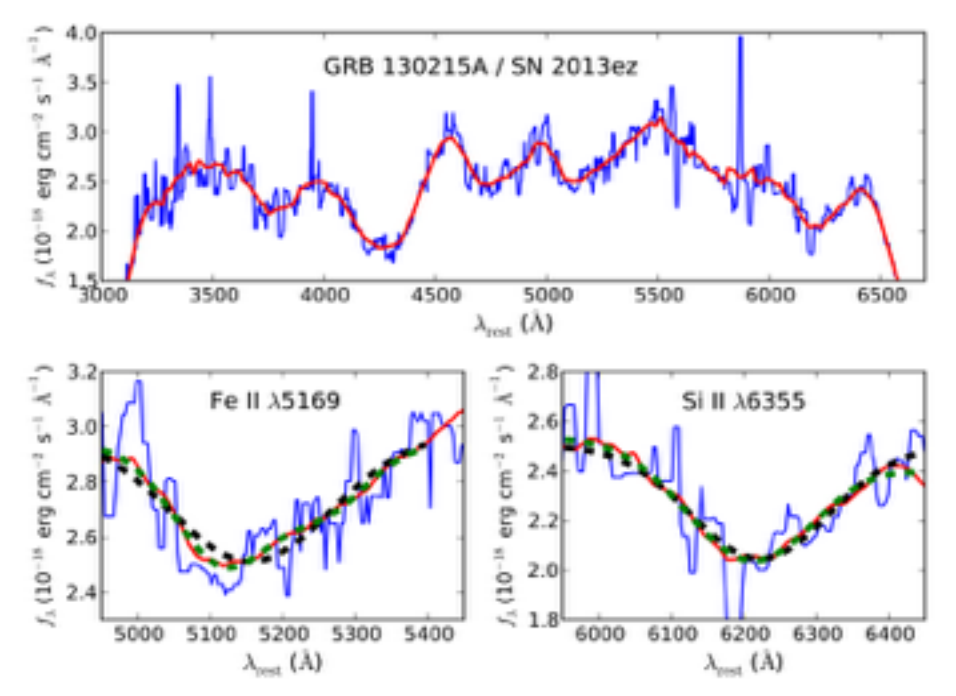
- GRB130427A / SN2013cq
- $z = 0.34$
- $E_{iso,\gamma} = 9.6 \cdot 10^{53}$ erg
- SN was a typical BL-Ic, as for other GRBs



Xu, de Ugarte Postigo et al. 2013, ApJ 776, 98

GRB130215A: "Slow" ejecta

- $z = 0.597$ (at the limit of our spectroscopy)
- Ejecta at ~5000 km s^{-1}
- Slowest GRB-SN ejecta to date
- Non broad-line Ic
- Possible millisecond magnetar powering the afterglow



Cano, de Ugarte Postigo, et al. 2014, A&A 568, 19

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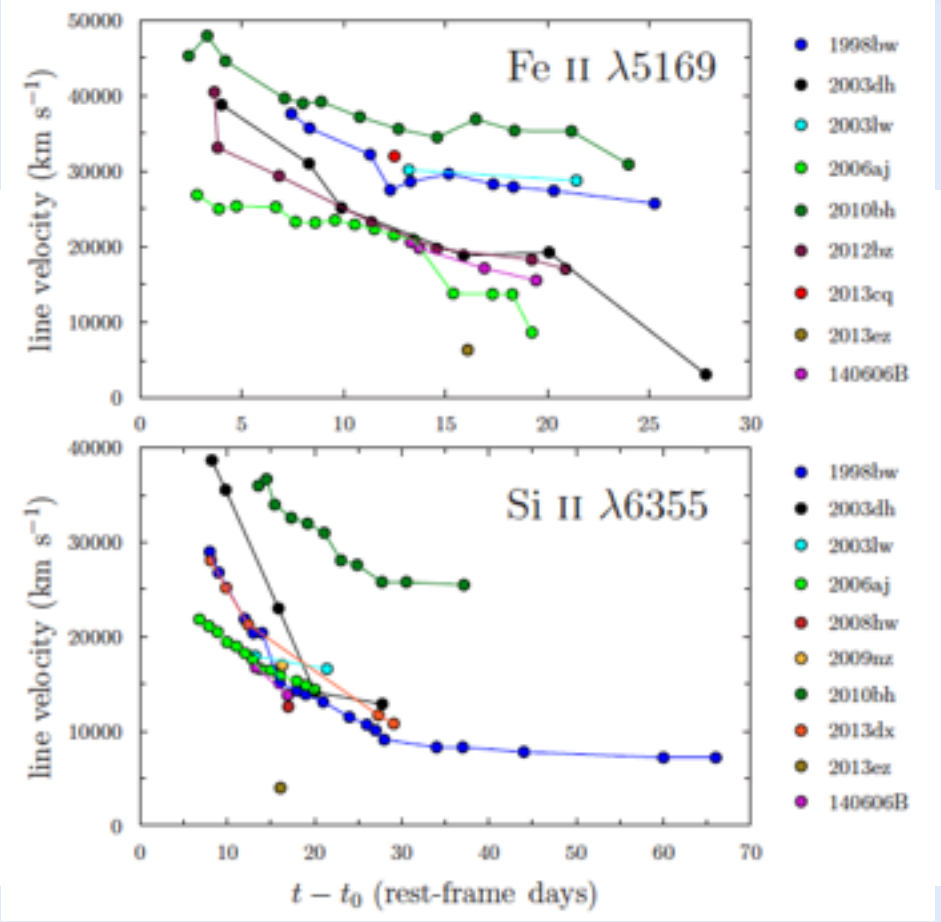
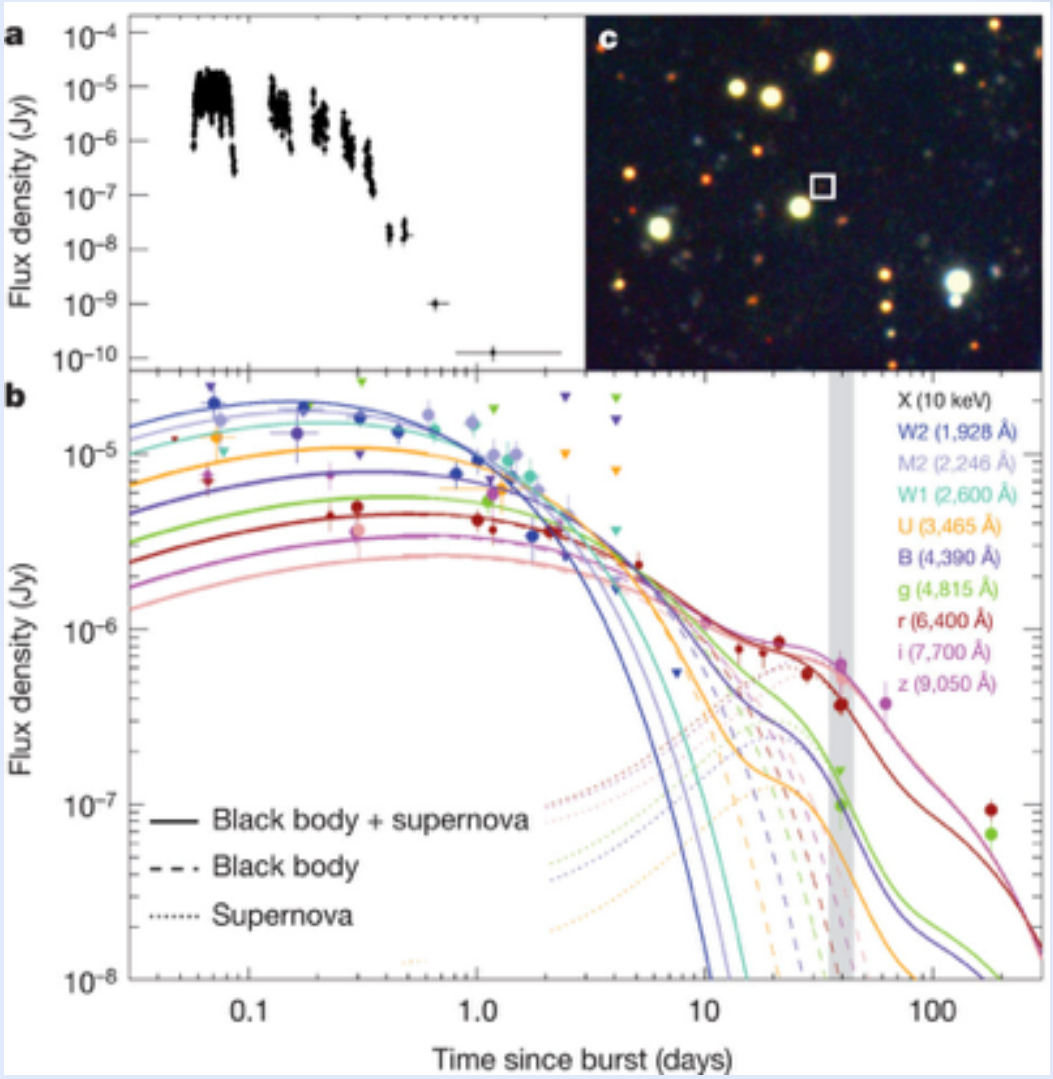


Cano, de Ugarte Postigo, et al. 2014, A&A 568, 19

GRB 101225A: Ultra-long & peculiar

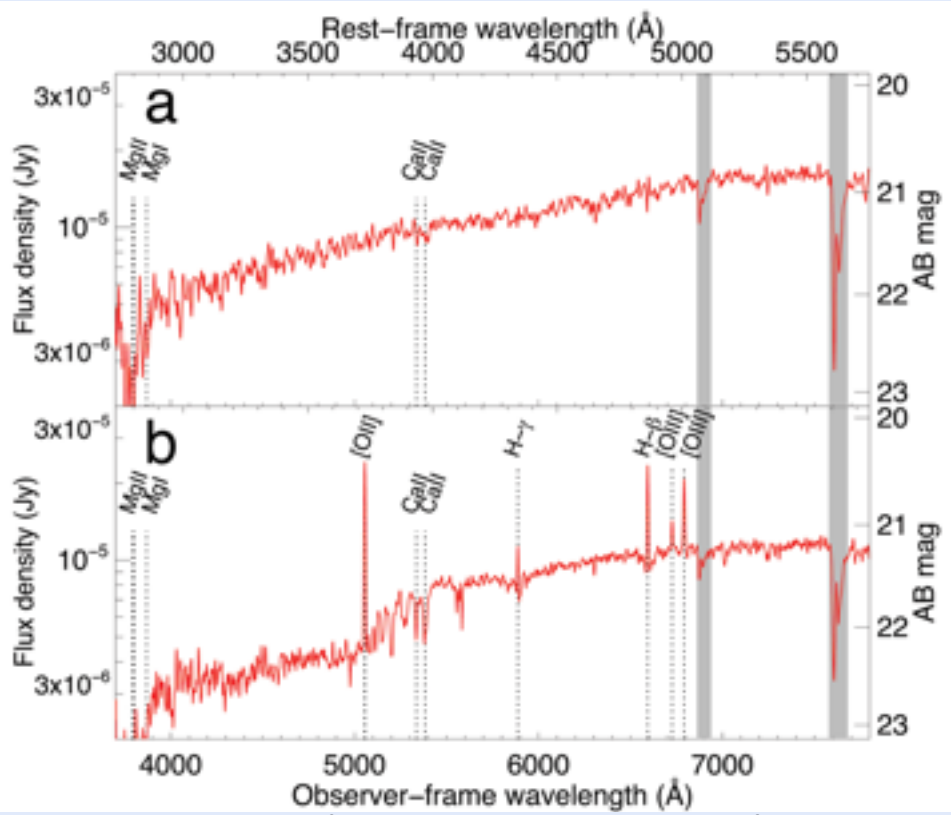
- Ultralong GRB
- Thermal emission instead of synchrotron afterglow
- Luminous blue supernova component
- $z = 0.847$
- GRB111209A, ULGRB had also a blue SN, but even brighter



Thöne et al. 2011, Nature 480, 72

GRB130603B: First kilonova detection

- First short GRB with an afterglow spectrum
- $z = 0.36$
- HST observations show NIR excess
- First kilonova detection
- Possible new, faint detection for GRB160821B at z=0.16



de Ugarte Postigo, et al. 2014

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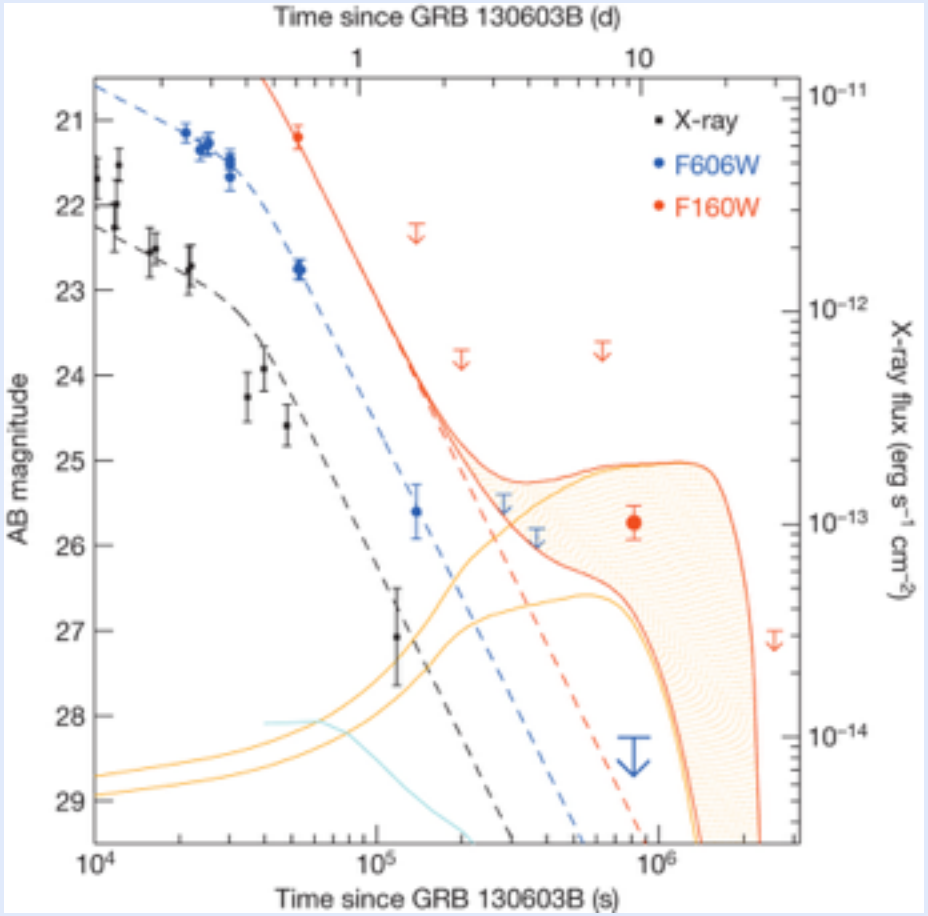

Tanvir, et al. 2013

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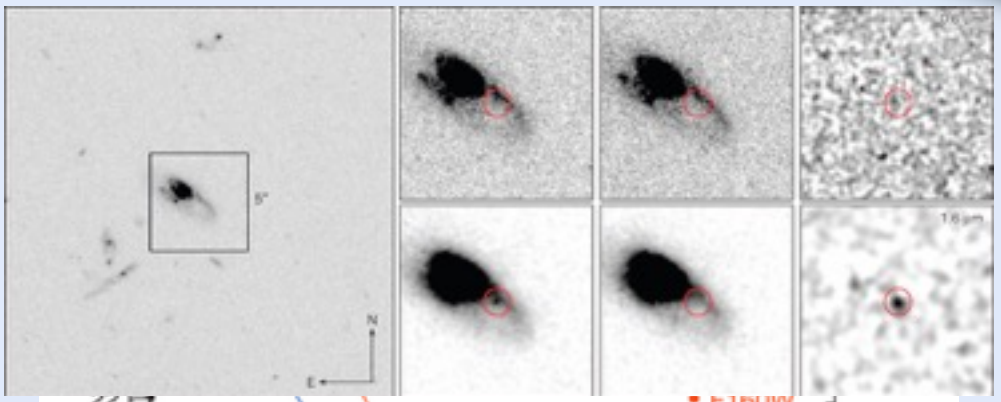

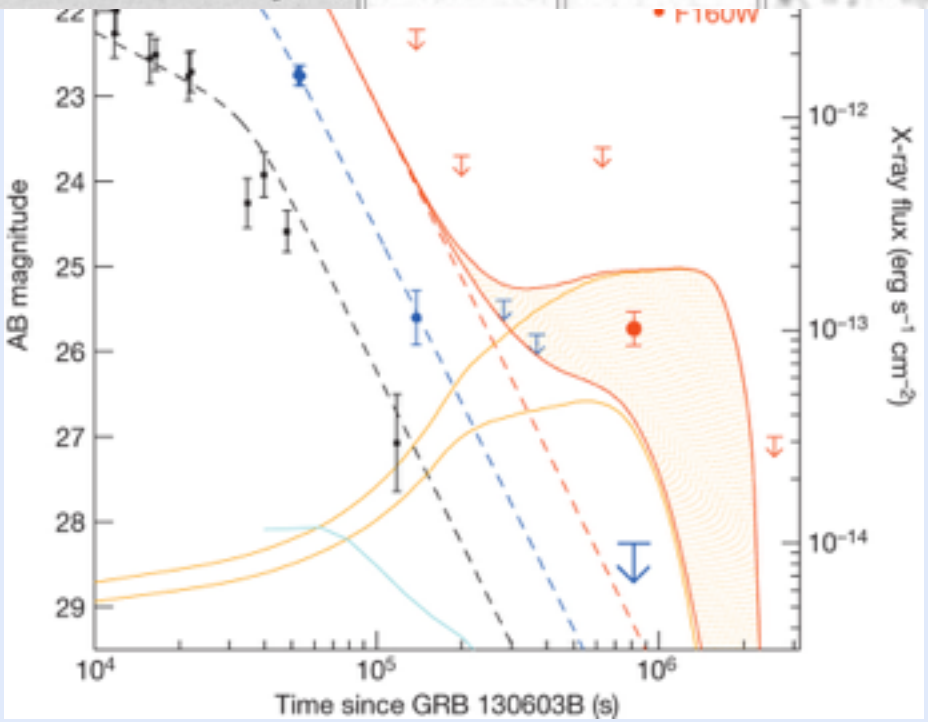

Tanvir, et al. 2013

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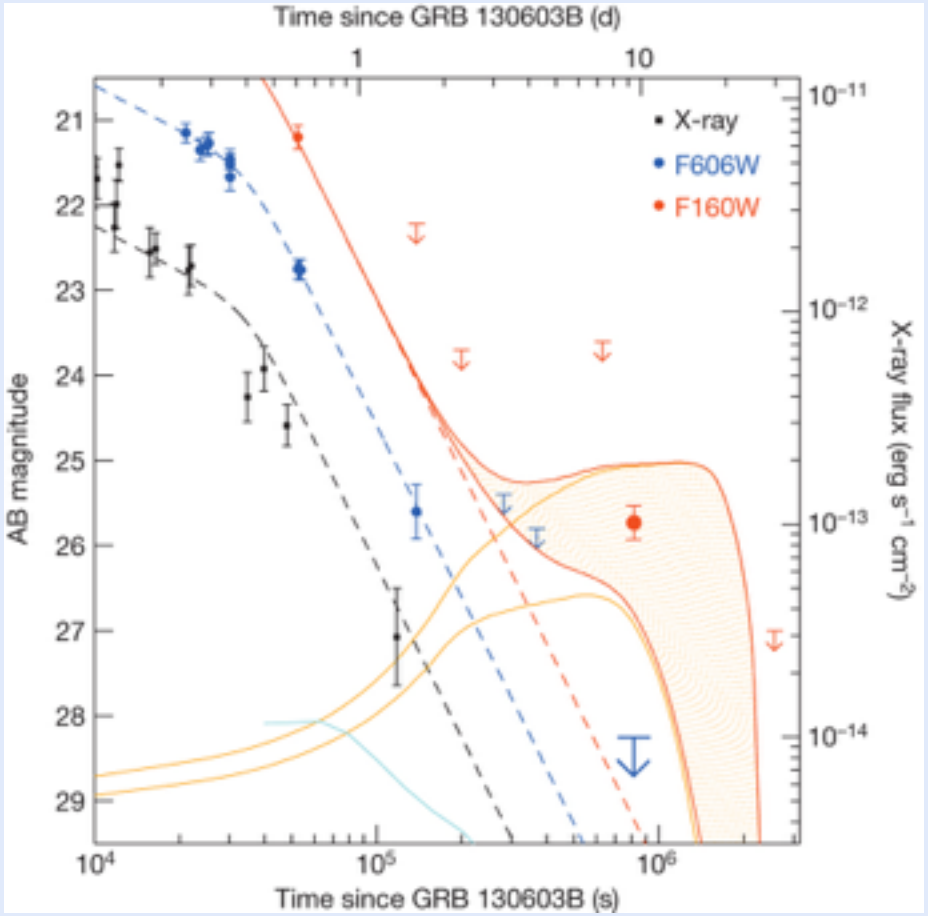

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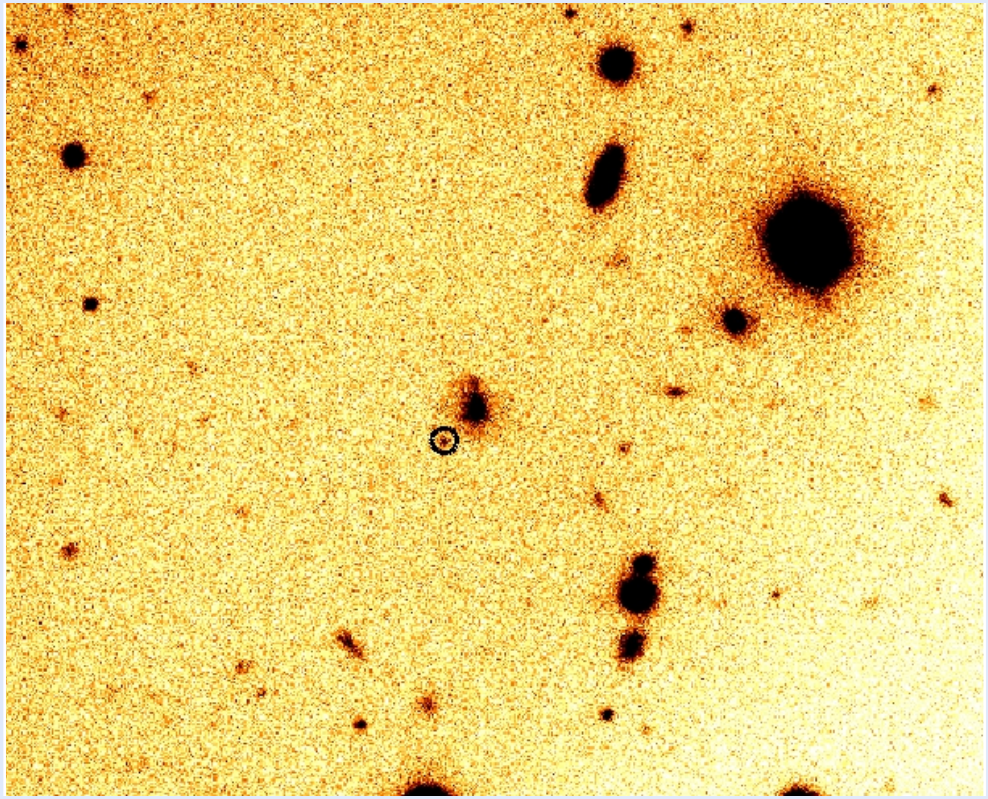

Conclusions

- Early observations focused on peculiar GRB-SNe
- Systematic surveys begin to allow statistical studies
- Our GRB-SN programme at GTC has followed ~20 objects (11 long, 4 intermediate, 1 ultra-long, 4 short), with spectroscopic detection of 7 GRB-SNe
- First SN for an ultra-long GRB
- First SN for an hyper-energetic GRB
- Under-luminous SN for GRB 100418A
- Slow ejecta for GRB 130215A


Thanks!