Exploring the Universe with Gamma-Ray Burst Afterglows

Andrea Melandri (INAF-OAB)

on behalf of the CIBO collaboration

L. Amati (INAF-OAS), L. A. Antonelli (INAF-OAR), M.G. Bernardini (INAF-OAB), S. Campana (INAF-OAB), S. Covino (INAF OAB), P. D'Avanzo (INAF-OAB), V. D'Elia (ASI-SSDC/INAF-OAR), M. Della Valle (INAF-OAC), M. De Pasquale (Uni. Messina), A. Fernandez-Soto (CSIC), F. Fiore (INAF-OATs), D. Fugazza (INAF-OAB), C. Guidorzi (UNIFE), L. Hunt (INAF-OA Arcetri), E. Maiorano (INAF-OAS), D. B. Malesani (Radboud Univ.), F. Mannucci (INAF-OA Arcetri), N. Masetti (INAF-OAS), L. Nicastro (INAF-OAS), E. Palazzi (INAF-OAS), E. Pian (INAF-OAS), S. Piranomonte (INAF-OAR), A. Rossi (INAF-OAS), R. Salvaterra (INAF-IASF Mi), S. Savaglio (Calabria Univ.), L. Stella (INAF-OAR), G. Stratta (INAF-OAS), G. Tagliaferri (INAF-OAB), V. Testa (INAF-OAR), S. D. Vergani (Obs. Paris)

TNG 1996-2021

Hotel Taburiente a Los Cancajos, 19-21 October 2021

Coordinamento **I**taliano **B**urst **O**ttici

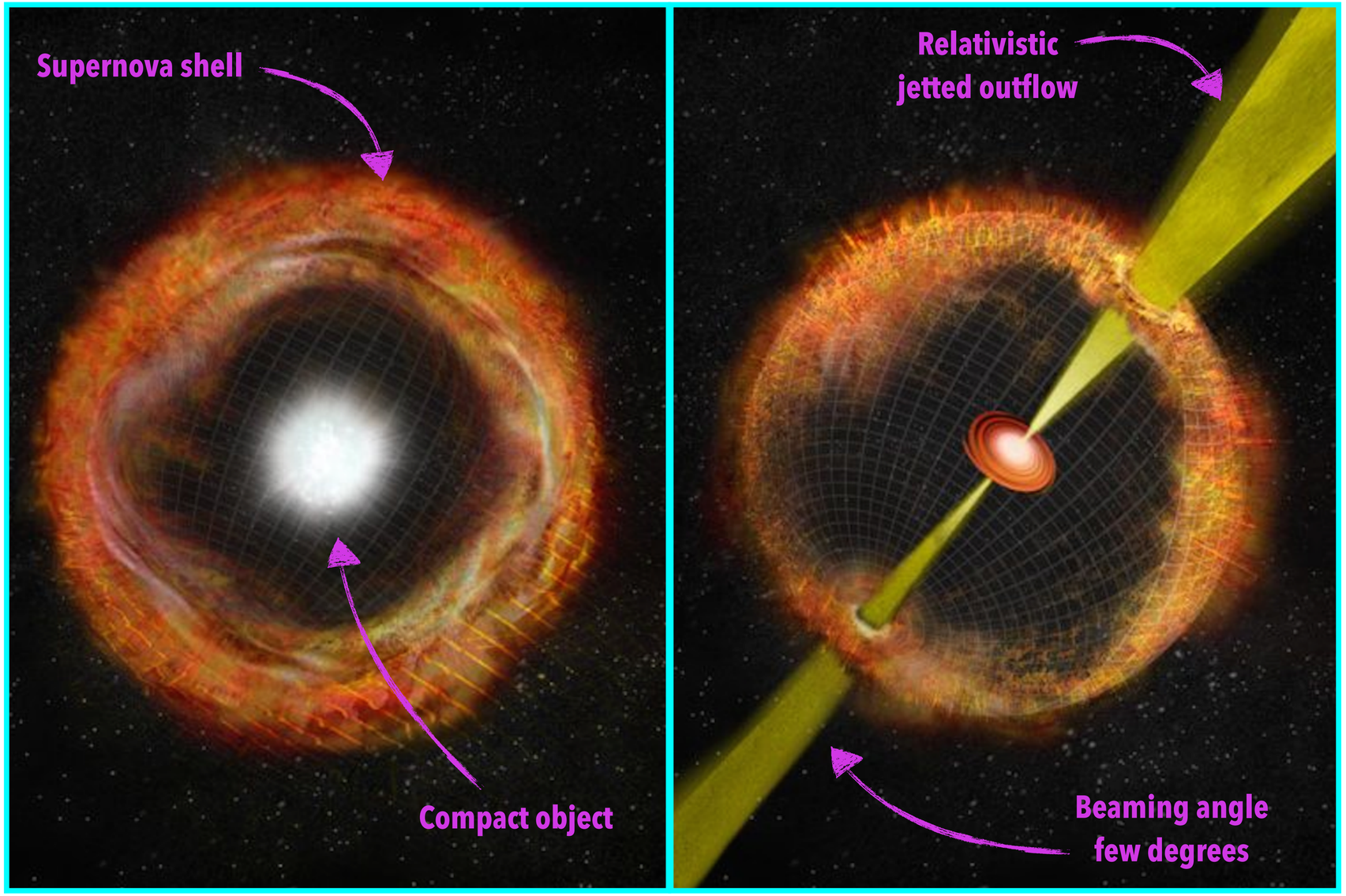
The **C.I.B.O.** collaboration, formed in 2000, involves most of the Italian astronomers interested in optical and infrared observations of the GRB afterglows and their host galaxies (HGs). Many members of the collaboration are also part of the Italian *Swift* team.

C.I.B.O. activities:

- Follow-up observations of GRBs & HGs with **TNG** since 2000
- Follow-up observations of GRBs with small Italian Telescopes since 2000
- Follow-up observations of GRBs with REM since 2004
- Follow up observations of GRBs & HGs with LBT since 2008

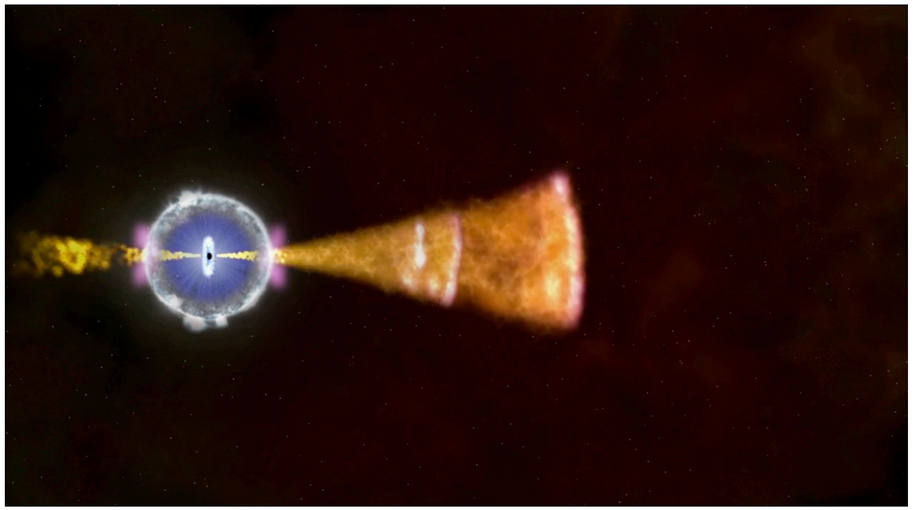
Gamma-Ray Bursts

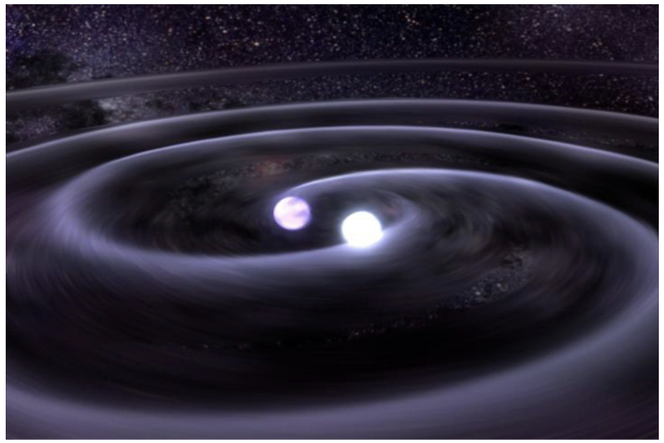
Brief intense (short or long) pulses of gamma-rays - Most energetic events (in the EM regime) in the Universe



Science with Gamma-Ray Bursts

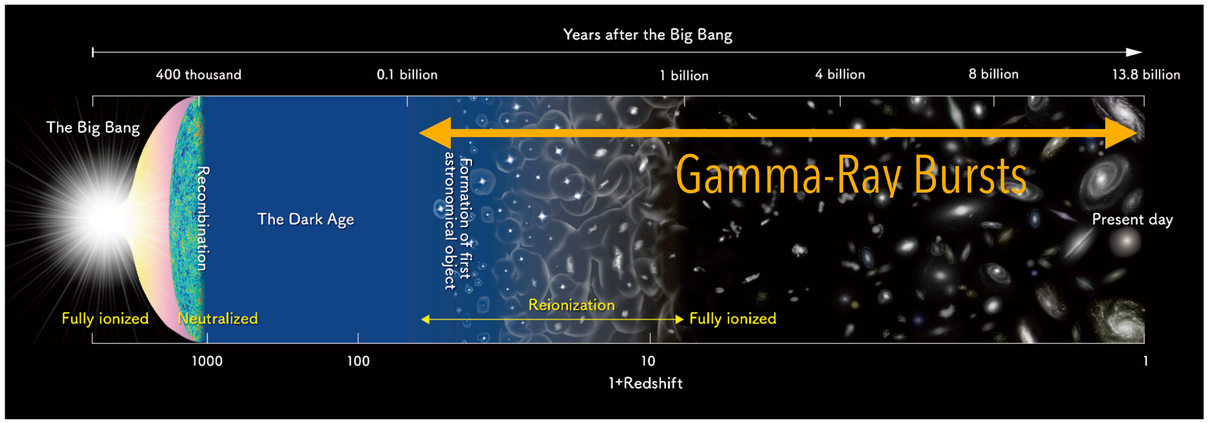
- GRBs Physics
  1. Shocks
  2. The role of magnetic field
  3. Jets
  4. Accretion/ejection: extreme regimes





- Progenitors
  1. Long GRBs: GRB-SN connection
  2. Short GRBs: compact objects merging (GW)

- Long GRBs as cosmological probes
  1. Connection with massive star formation
  2. From the local Universe to the re-ionisation era
  3. Circumburst environment / IGM
  4. Chemical history of the Universe

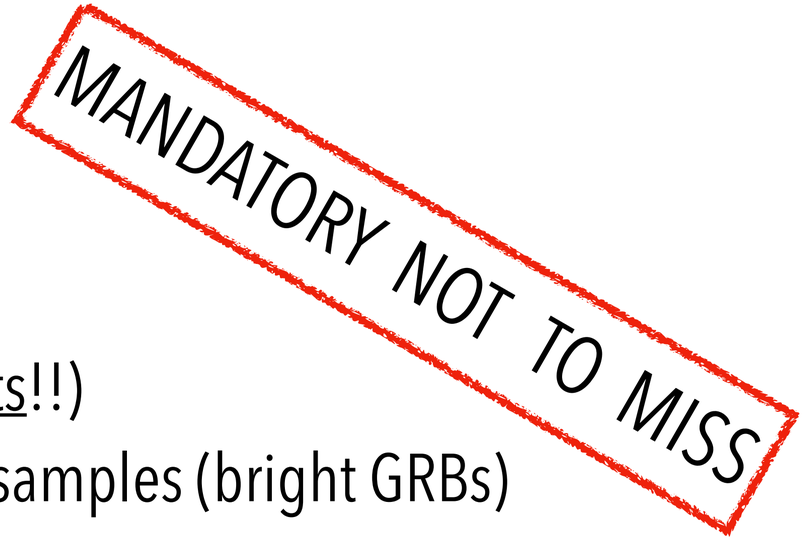


Since 2004 *Swift* observed 1499 GRBs: legacy/statistical approach to tackle the above science cases

Gamma-Ray Bursts with TNG: a legacy approach

Since AOT22 (2010) we started a series of Long Term Programs focused on well defined scientific topics (ensure a proper follow-up of rare but flagship events):

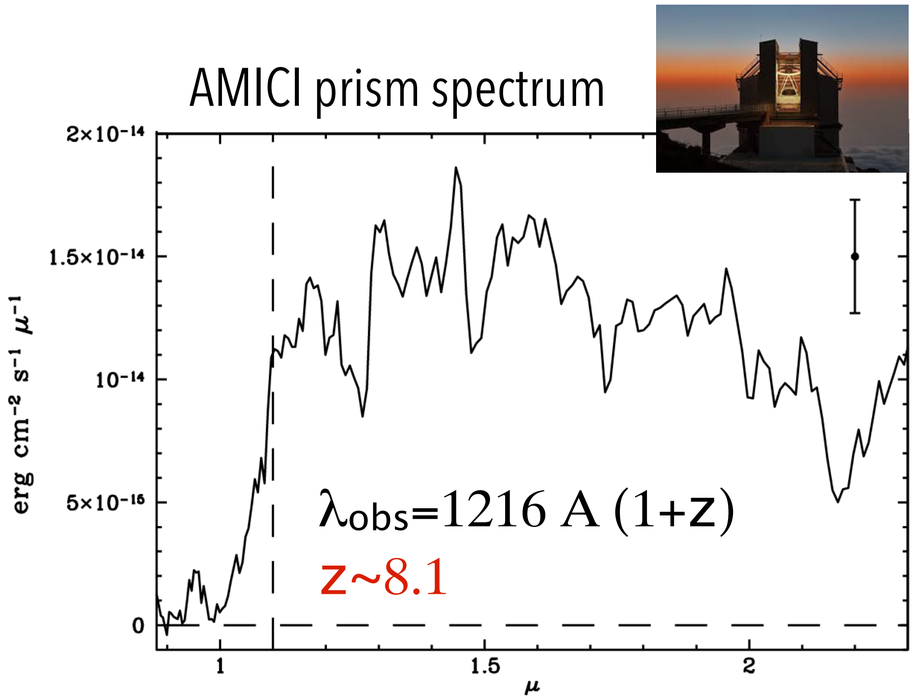
- candidate high redshift GRBs
- GRB–SN association
- short GRBs (strong connection with GW events!!)
- events belonging to complete (flux–limited) samples (bright GRBs)

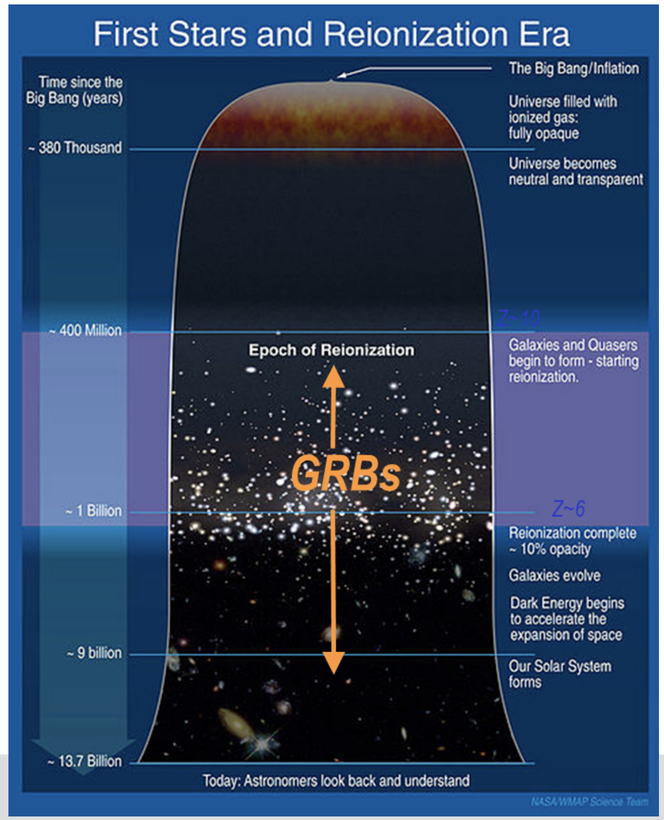


GRBs as cosmic probes: GRB090423

Long GRBs are detectable from the local Universe to very high redshifts:

- cosmic star formation history
- metallicity & dust evolution
- properties of faint galaxies (missed by 'traditional' surveys)





nature

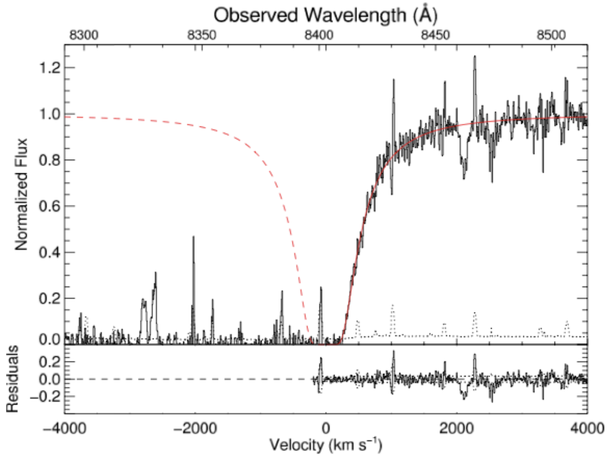
LETTERS

GRB 090423 at a redshift of $z \approx 8.1$

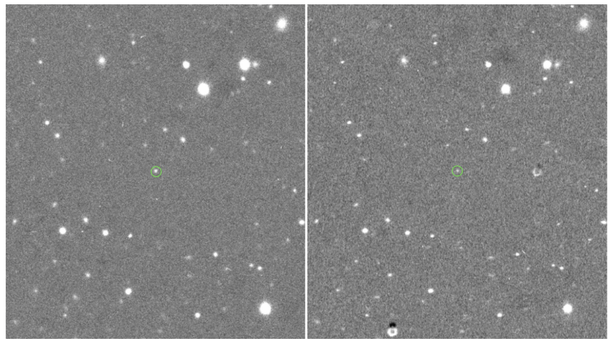
R. Salvaterra[1], M. Della Valle[2,3,4], S. Campana[1], G. Chincarini[1,5], S. Covino[1], P. D'Avanzo[1,5], A. Fernández-Soto[6], C. Guidorzi[7], F. Mannucci[8], R. Margutti[1,5], C. C. Thöne[1], L. A. Antonelli[9], S. D. Barthelmy[10], M. De Pasquale[11], V. D'Elia[9], F. Fiore[9], D. Fugazza[1], L. K. Hunt[8], E. Maiorano[12], S. Marinoni[13,14], F. E. Marshall[10], E. Molinari[1,13], J. Nousek[15], E. Pian[16,17], J. L. Racusin[15], L. Stella[9], L. Amati[12], G. Andreuzzi[13], G. Cusumano[18], E. E. Fenimore[19], P. Ferrero[20], P. Giommi[21], D. Guetta[9], S. T. Holland[10,22,23], K. Hurley[24], G. L. Israel[9], J. Mao[1], C. B. Markwardt[10,23,25], N. Masetti[12], C. Pagani[15], E. Palazzi[12], D. M. Palmer[18], S. Piranomonte[9], G. Tagliaferri[1] & V. Testa[9]

GRBs as cosmic probes: rareness (17 events with z>5)

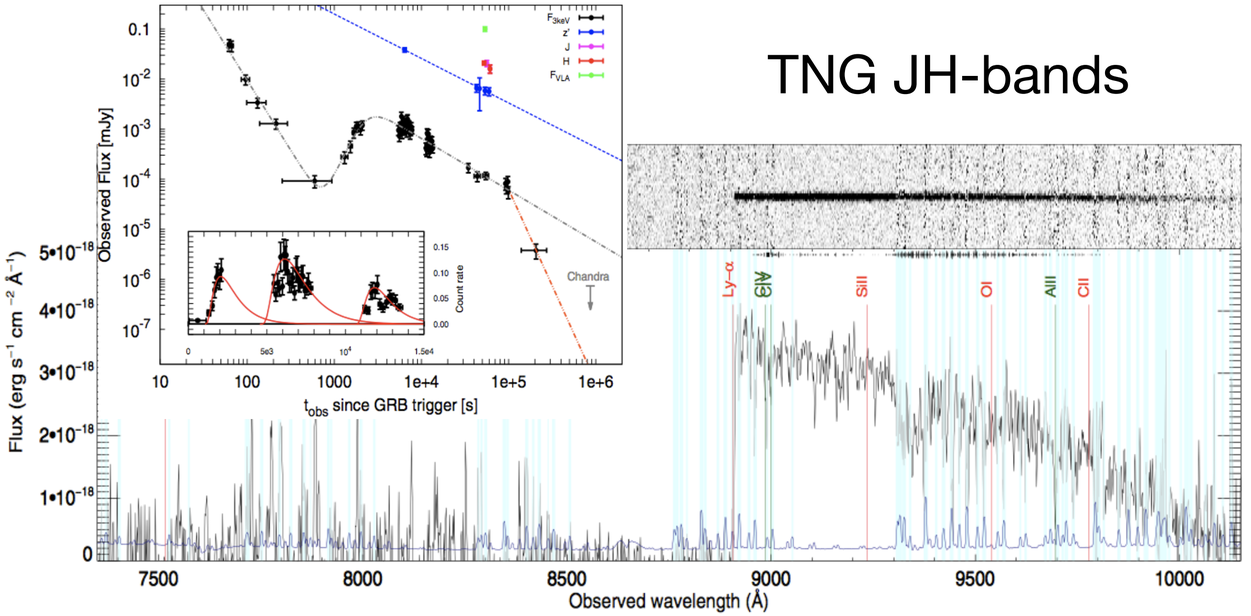
GRB 130606A (z = 5.913)
Hartoog et al. 2015

TNG z-band



GRB 140515A (z = 6.32)
Melandri et al. 2015

TNG JH-bands

GRB	Redshift
050904	6.29
080913	6.695
090423	8.2
090429B	9.4ph
100905A	7.9ph
120521C	6.0ph
120923A	7.8
140515A	6.32
210905A	6.318

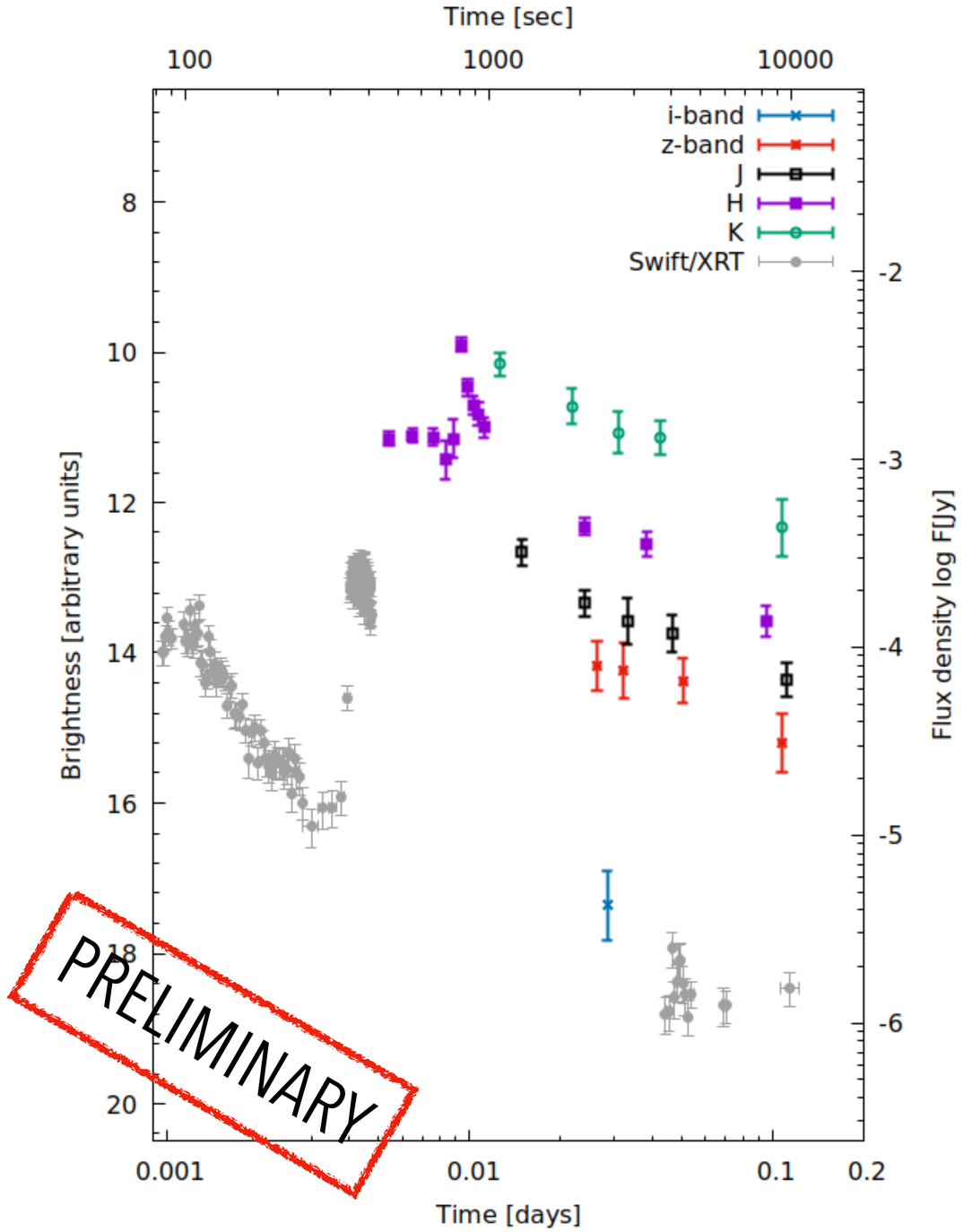
GRBs as cosmic probes: rareness

GRB 210905A (z = 6.318)
Rossi et al. 2021 in preparation


REM *izJHK* light curve continuous observations for the first 2 hr after the GRB event

GRB	Redshift
060522	5.11
050502B	5.2 ph
140304A	5.283
050814	5.3
131227A	5.3
060927	5.467
201221A	5.7
130606A	5.913
120521C	6.0 ph
050904	6.295
210905A	6.318
140515A	6.327
080913	6.695
100905A	7.9 ph
090423	8.26
120923A	7.8
090429B	9.4 ph

only 12 (5) events with z_spec > 5 (6)



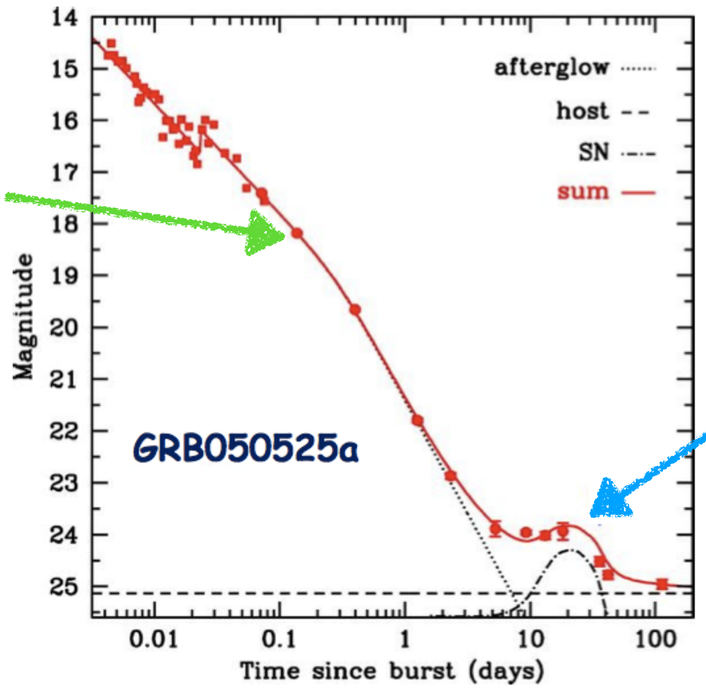
GRB-SN connection (observed for about 20 events)

Nearby Long GRBs are usually associated with broad lined Type Ib-c SN:

- powering mechanism and progenitor features
- properties of the circumstellar medium and host-galaxies

GRB 050525A/SN2005nc (z = 0.606)
Della Valle et al. 2006

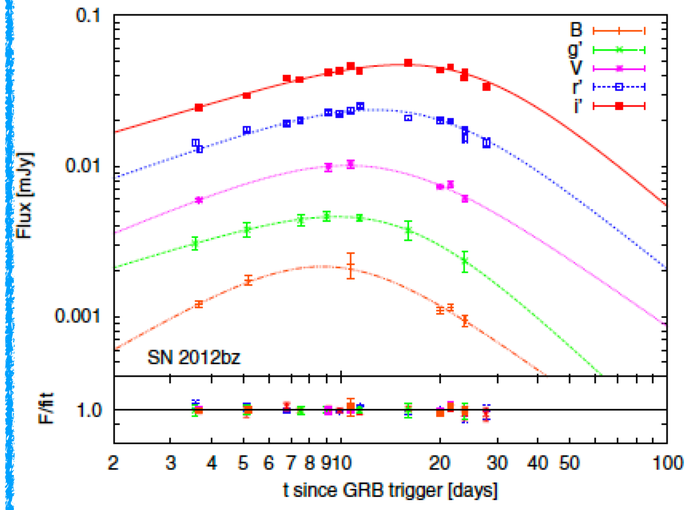
TNG optical light curve



VLT spectrum near maximum light

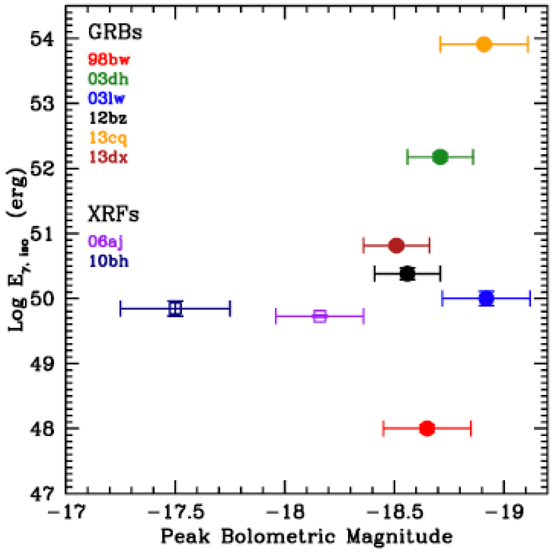
GRB-SN connection: ordinary events, ordinary monsters and real monsters

GRB 120422A/SN2012bz (z = 0.283)
Melandri et al. 2012

TNG *griz* obs.

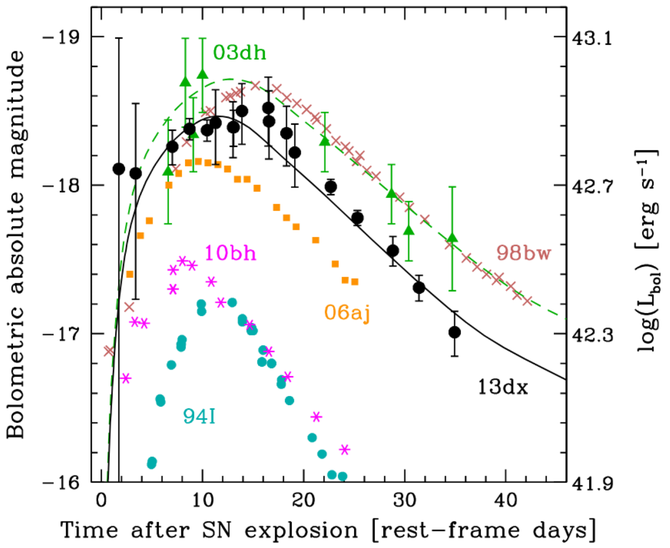
GRB 130427A/SN2013cq (z = 0.3399)
Melandri et al. 2014

TNG *gri* obs.

GRB 130702A/SN2013dx (z = 0.145)
D'Elia et al. 2015



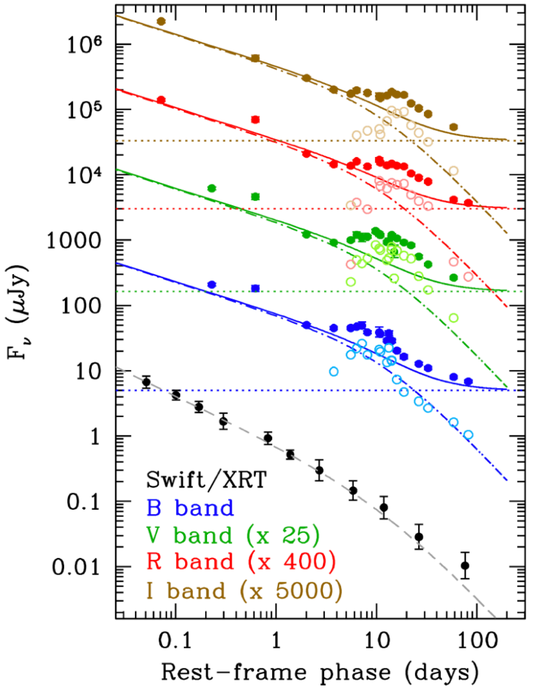


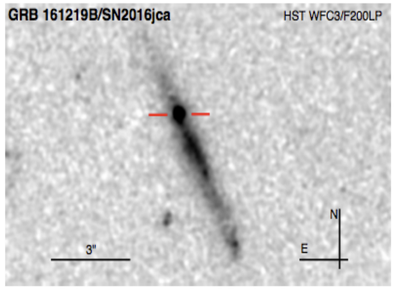
TNG U*griz* (+5 spectra)+ REM *gr* obs.

GRB-SN connection: ordinary events, ordinary monsters and real monsters

GRB 161219B/SN2016jca (z = 0.148)
Ashall et al. 2019



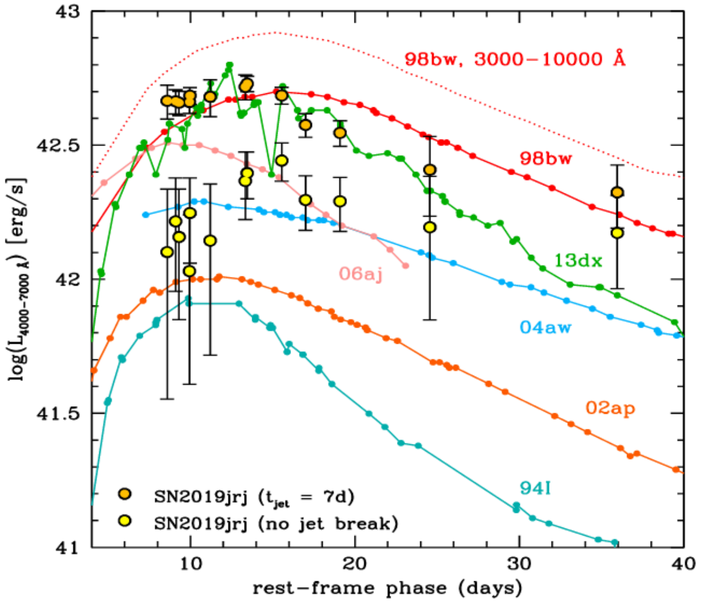




TNG *BVRI* obs.

GRB 190114C/SN2019jrj (z = 0.4245)
Melandri et al. 2021 submitted



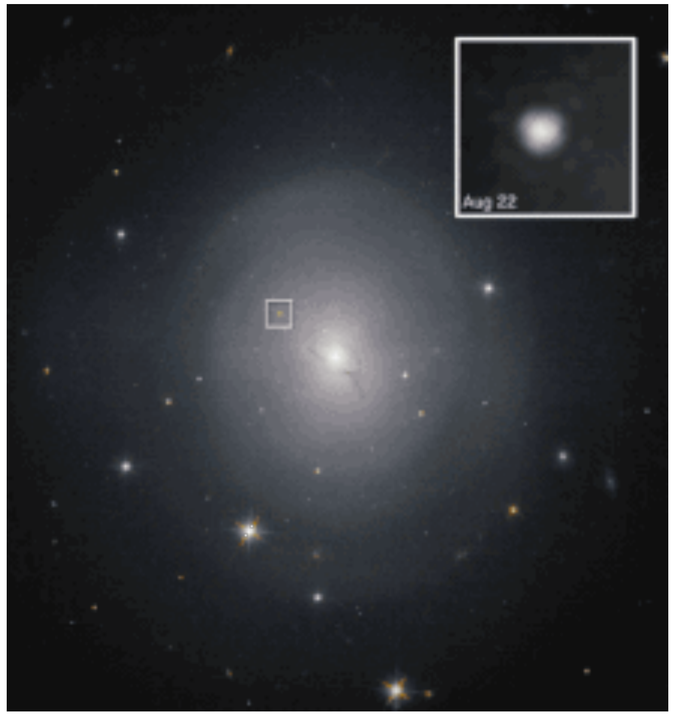


TNG *griz* + LBT *gri* obs. (+others)

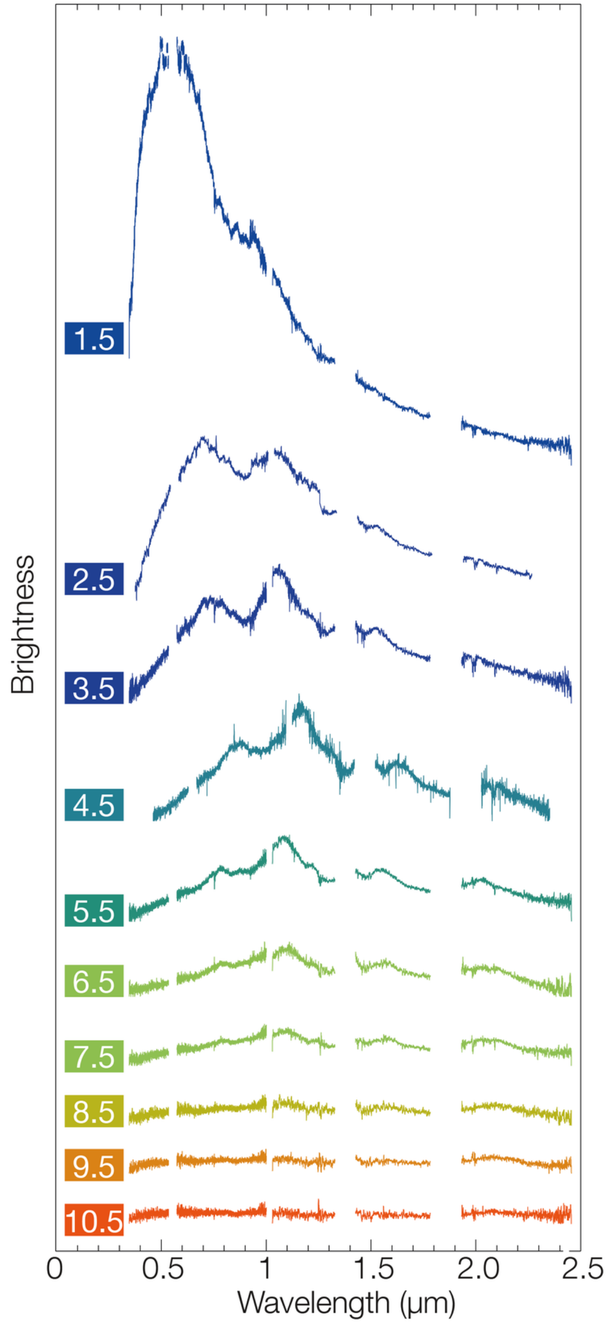
Short GRBs

Short GRBs are tricky to observe because fainter (even in the X-rays):

- *z* determination is critical
- different environment and energetics
- <u>strong link with GW</u> (progenitors)



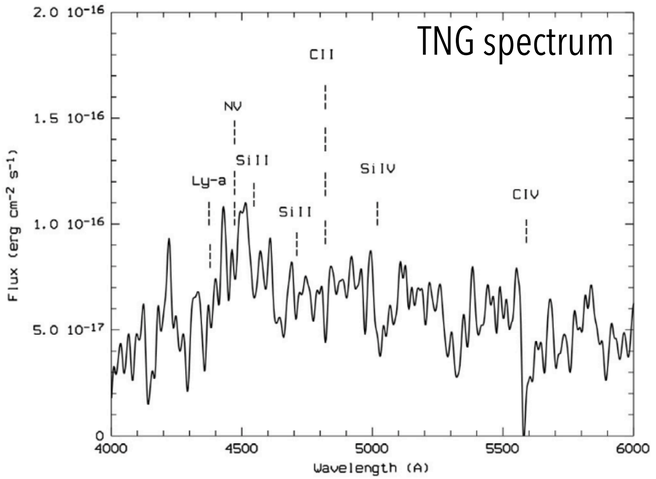
Credits: ESO



Credits: Pian, D'Avanzo +17, Smartt +17

Short GRBs

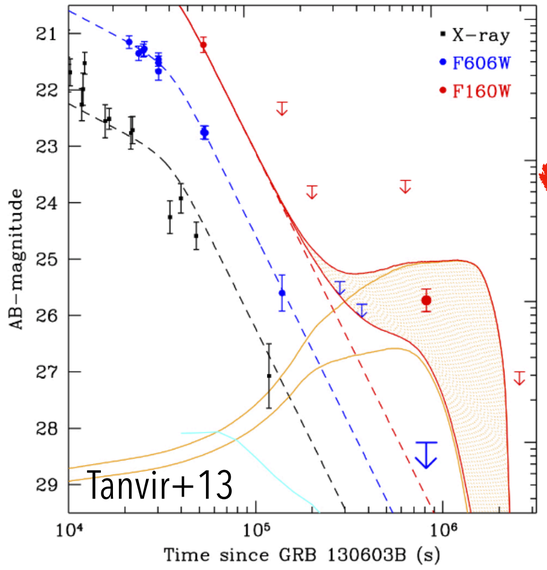
GRB 090426 (z = 2.609)
Antonelli et al. 2009

TNG *BVRI* + LBT g*riz*

GRB 130606B (z = 0.3565)
de Ugarte Postigo et al. 2014

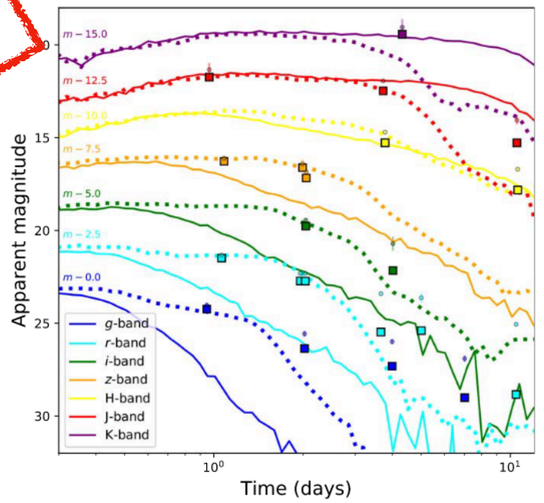




TNG *ri* obs.

KN indication

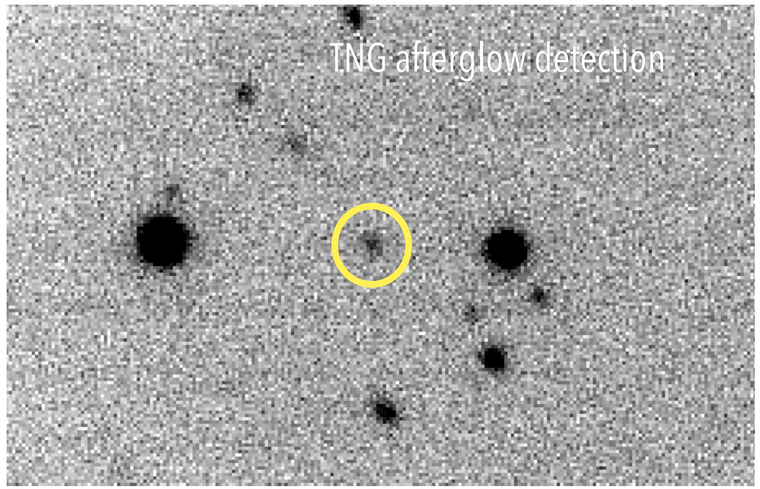
GRB 160821B (z = 0.162)
Lamb et al. 2019

TNG *r* obs.

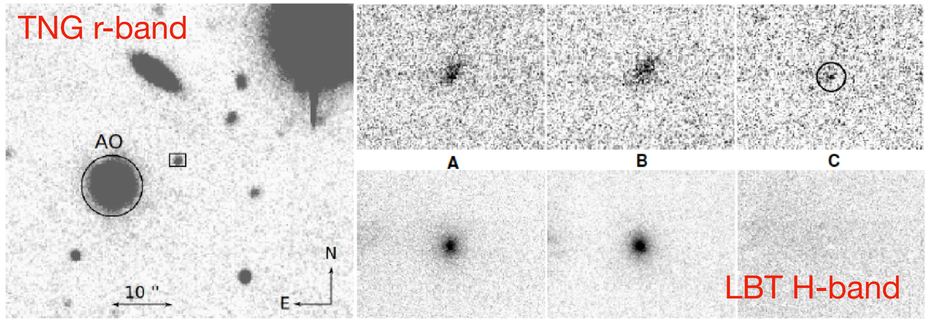
Short GRBs

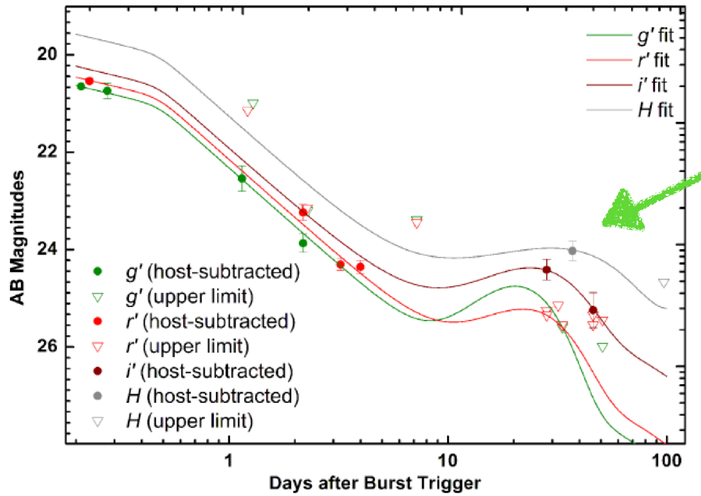
GRB 160927A (z = ??)
GCN with TNG OA detection



TNG *r* obs.

GRB 200826A (z = 0.748)
Rossi et al. 2021





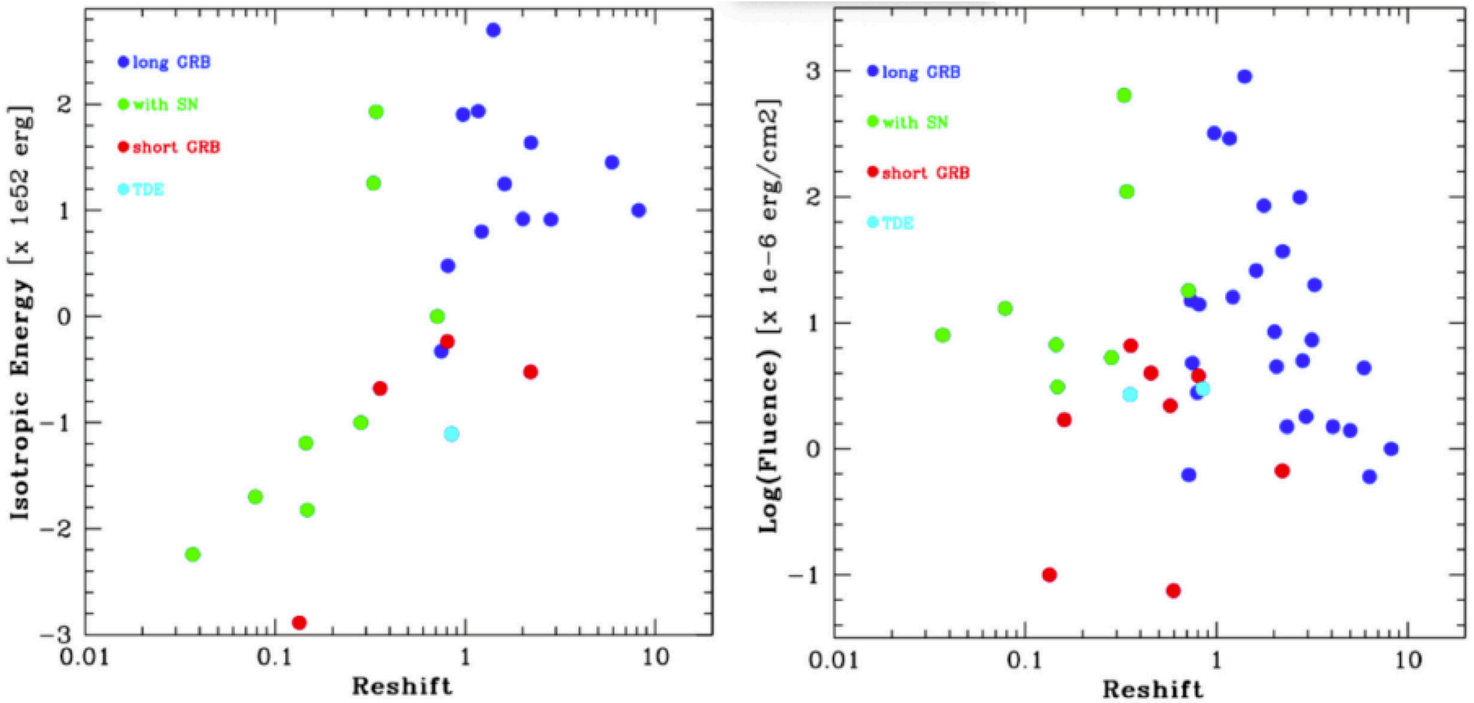
SN Bump?

TNG *r* +
LBT g*rH* obs.

Conclusions: legacy value

Some numbers (since 2010)

- observed ~3 GRB/semester that met our four criteria (~65 overall)
- 62 GCN circulars
- 36 peer-reviewed papers, 1915 citations (~3 papers/year with 52 citations/paper on average)
- 1 Nature, 1 Nat. Co.
- average time request of less than 30 hours/ semester (now 17.5 hr)



Conclusions: the future of GRBs @ TNG

- GRBs have a high science impact in many astrophysical fields
- The use of TNG in GRB studies played (and is playing) a fundamental role in keeping the Italian community in a leading position (LTP approach and synergy with other facilities)
- **Unpredictable events**: for a promptly visible afterglow, geographic location can give an edge to TNG, also compared to larger telescopes, provided observations can be scheduled flexibly and rapidly
- **New science** in the time-domain astronomy era (*Swift*, SVOM, SOXS, ZTF, BlackGEM, LSST)
- Focus on **rare events**:
    - GW sources emit **short GRBs** (GW 170817A), hence their study is of paramount importance to guide the (much more difficult) observations of binary neutron star mergers
    - **high-*z* GRBs** (as already demonstrated with AMICI)
    - nearby GRBs with **associated SN**

- **High visibility and scientific return with relatively small time investment**