SN-less LGRBs with *SVOM* and GW interferometers

Extracted from Arcier et al. 2020

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Detection of short high-energy transients in the local universe with SVOM/ECLAIRs

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Outline

- The LGRBs – SNe connection
- SN-less LGRBs
- Detecting nearby LGRBs with *SVOM*/ECLAIRs
- Identifying SN-less LGRBs with *SVOM*
- The role of GW interferometers

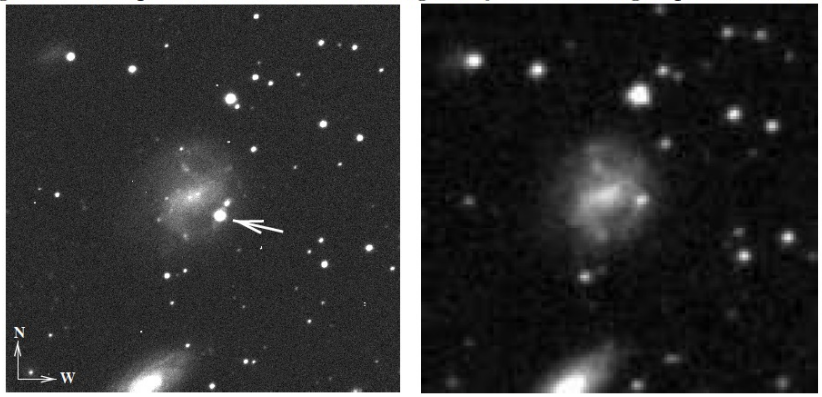
The LGRBs – SNe connection

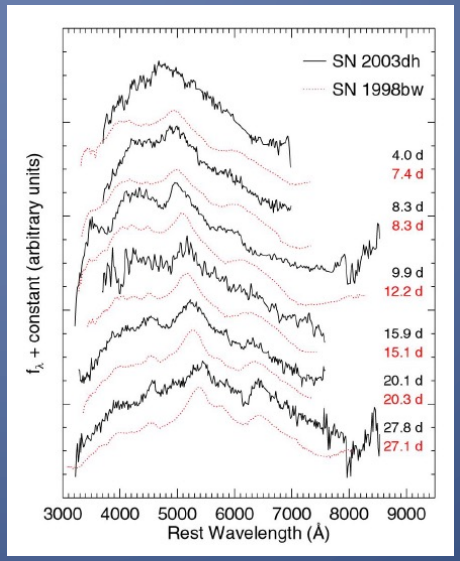
- The first GRB / SN link was the association of GRB 980425 with SN 1998bw at z=0.0085 (left, Galama et al. 1998). However…
  - GRB 980425 was unusual: ~10^4 fainter than classical GRBs.
  - SN 1998bw was unusual: a « hypernova », a very energetic supernova of type Ibc. It is often used as a template for GRB-Sne.

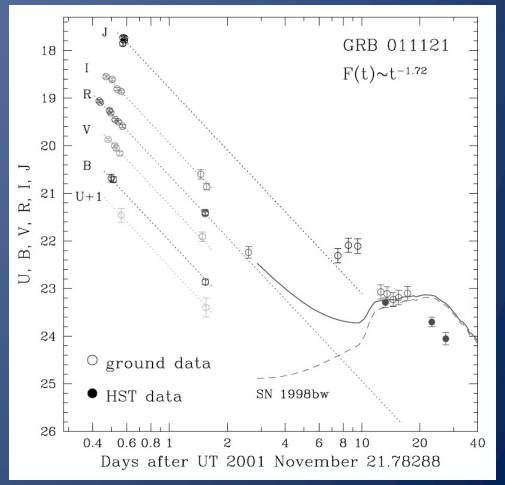
- The association was confirmed in 2003 with GRB 030329 and SN 2003dh at z = 0.1685 (middle, Hjorth et al. 2003).
  - GRB 030329 was a classical long GRB, with E_{iso} = 3 10^{52} erg.
  - SN 2003dh was an hypernova.

- A large fraction of nearbyL GRBs (z ≤ 0.5) show spectroscopic or photometric (right, Garnavich et al. 2003) evidence for SN emission.

Fig. 1.— Left panel: NTT R band image May 1.3 UT. Right panel: DSS image



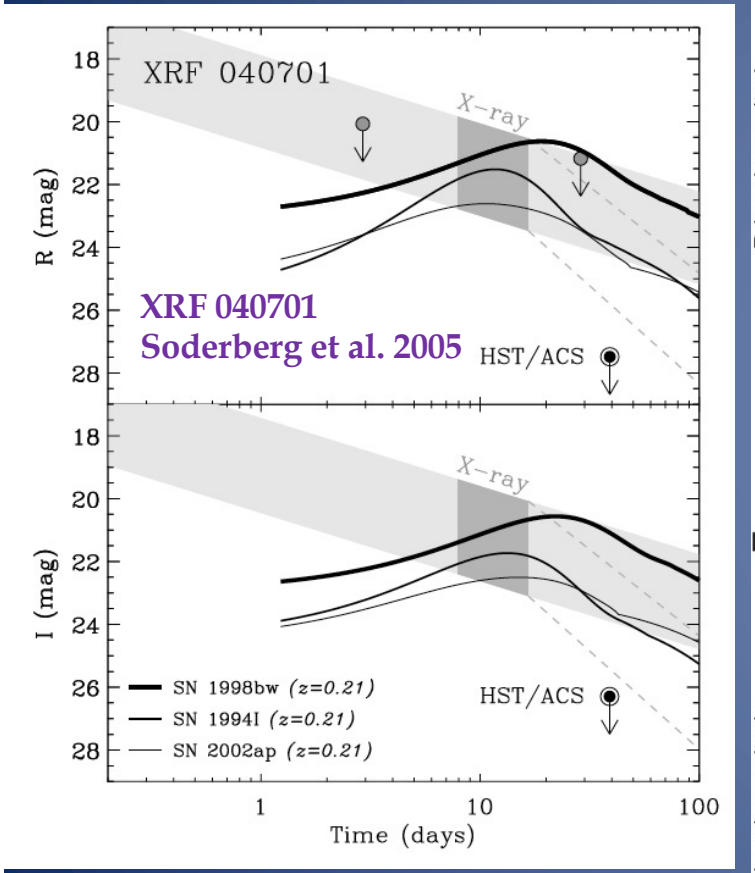




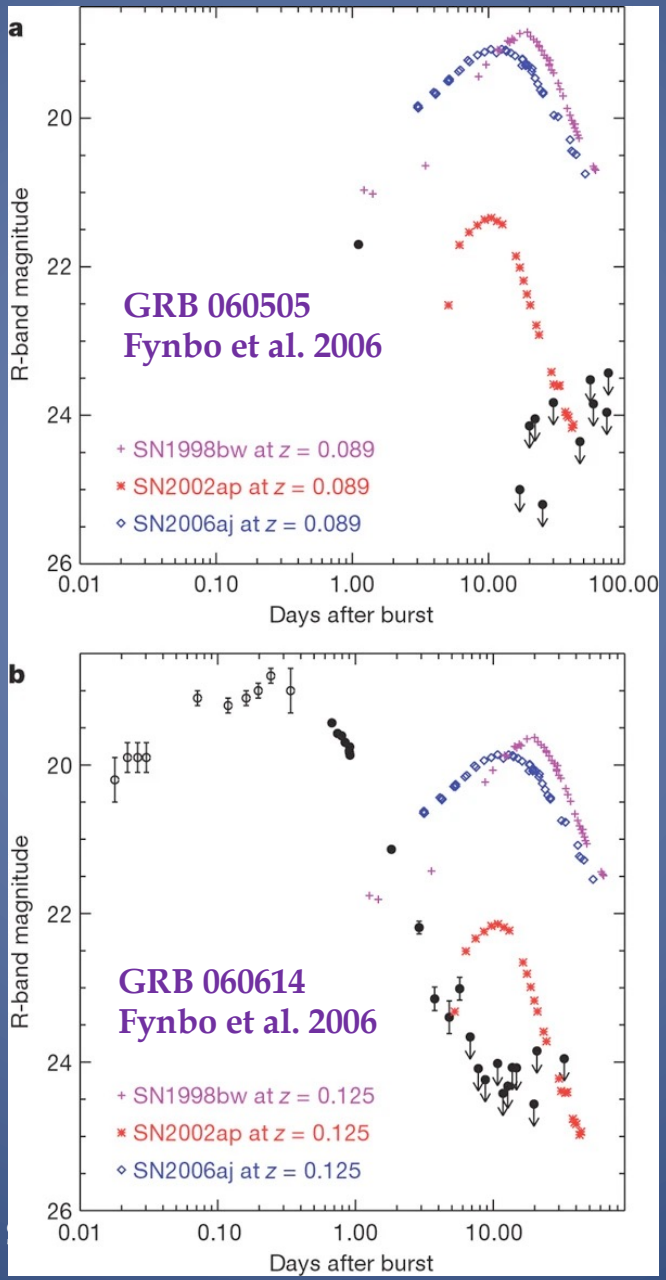
SN-less LGRBs

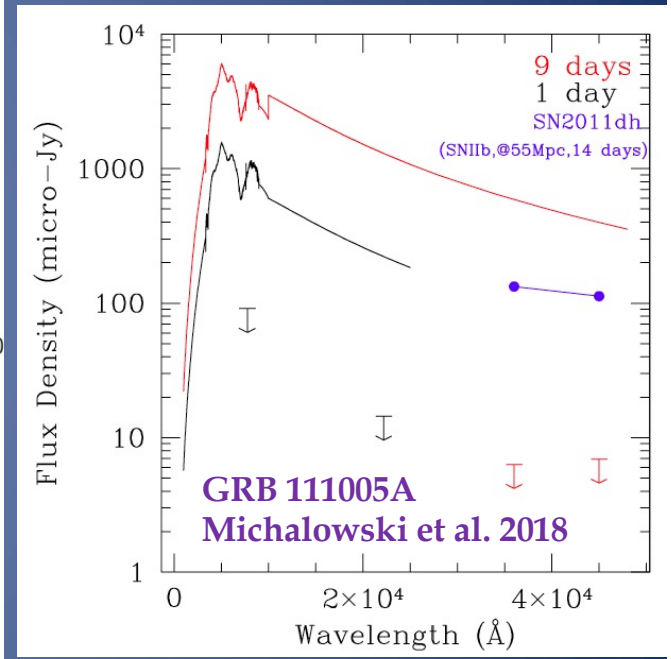
- By 2005, the connection between LGRBs and SNe was commonly admitted.
  - XRF 040701 at z = 0.2146 was the exception, with no evidence for a SN down to 3-6 magnitudes fainter than 1998bw (Soderberg et al. 2005). This was however the only example, and this was an X-Ray Flash…
- In May and June 2006, two nearby LGRBs (z = 0.089 & z=0.125) were localized by Swift. All searches for SNe were negative, raising the question of the nature of SN-less GRBs.
- One more in 2011: GRB 111005A (z=0.013)
- Possible explanations:
  - Failed or faint SN? (fallback?)
  - Merger?
  - Something new?

Constraints on SN emission

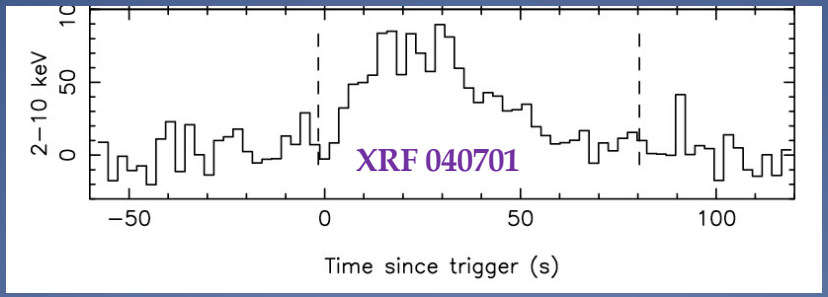


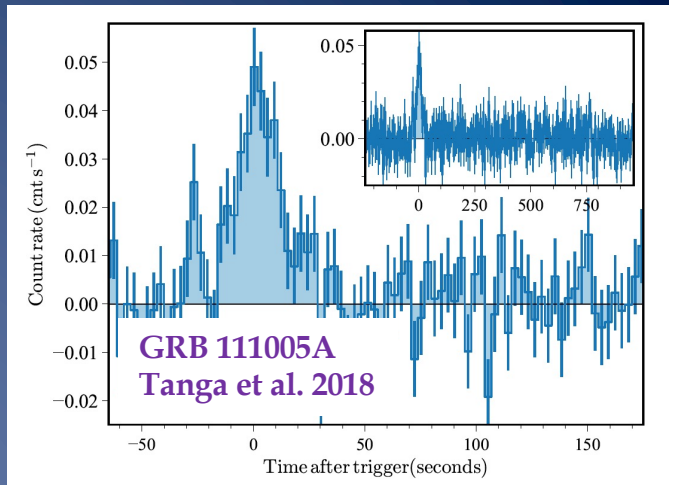
XRF 040701
Soderberg et al. 2005



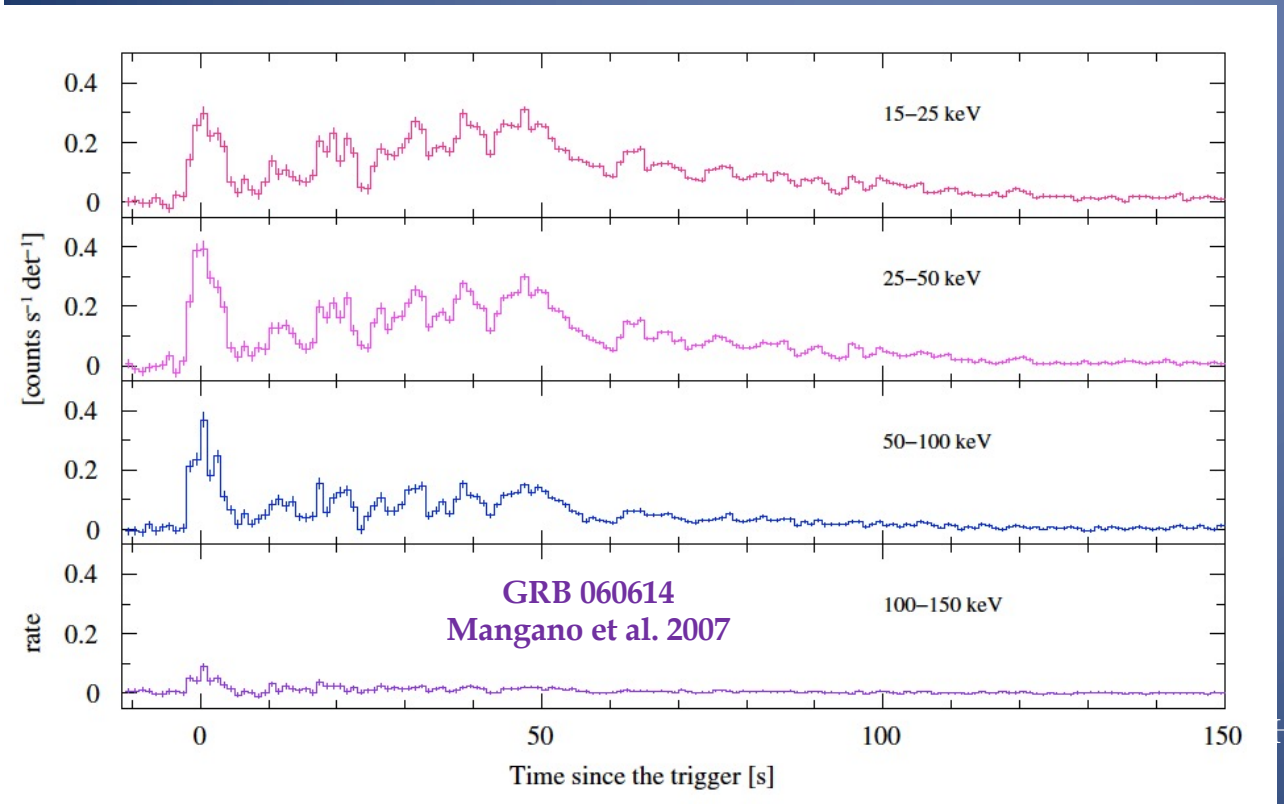


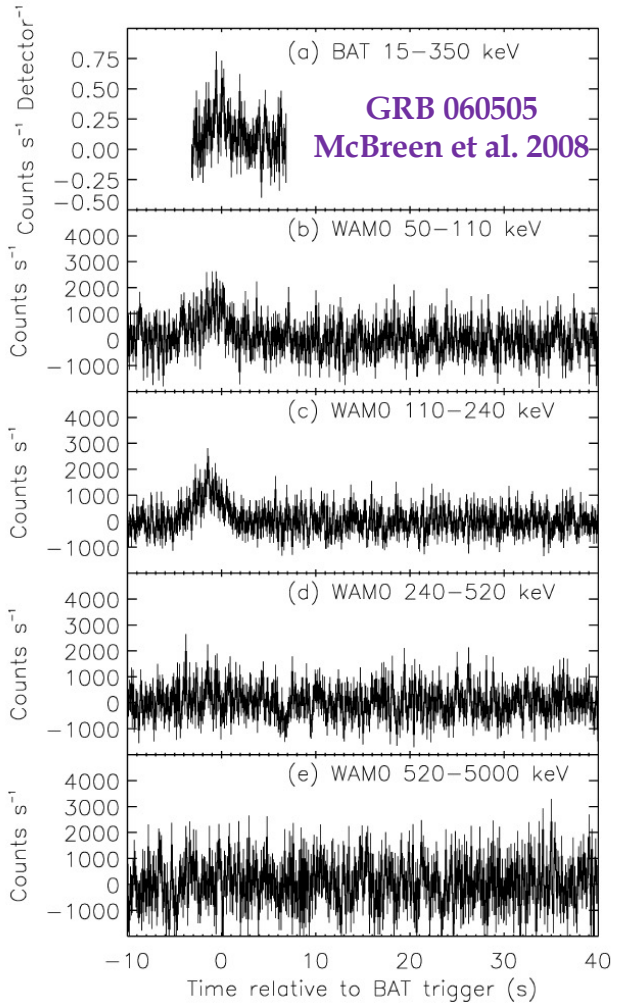
Light-curves of SN-less LGRBs





- GRB 040701, GRB 060505 and GRB 111005A have featureless single peaks.
- GRB 060614 (below) has a highly structured light-curve.





Summary of 4 SN-less LGRBs

GRB Name	z	Eiso (10^{52} erg)	T90 (s)	AG (X/O/R)	Host mag.*	SN limit wrt 1998bw	Comment
GRB 040701[a]	0.2146	0.008	11.7	X	R~17.9	÷ 15 - 200	XRF, E_p≈4 keV
GRB 060505[b]	0.089	0.0057	4	XO	B=18.5	÷ 80 - 100	
GRB 060614[c]	0.125	0.20	109	XO	B=23.6	÷ 80 - 100	
GRB 111005A[d]	0.013	0.00005	27	R	R=14	÷ 50	10 years old

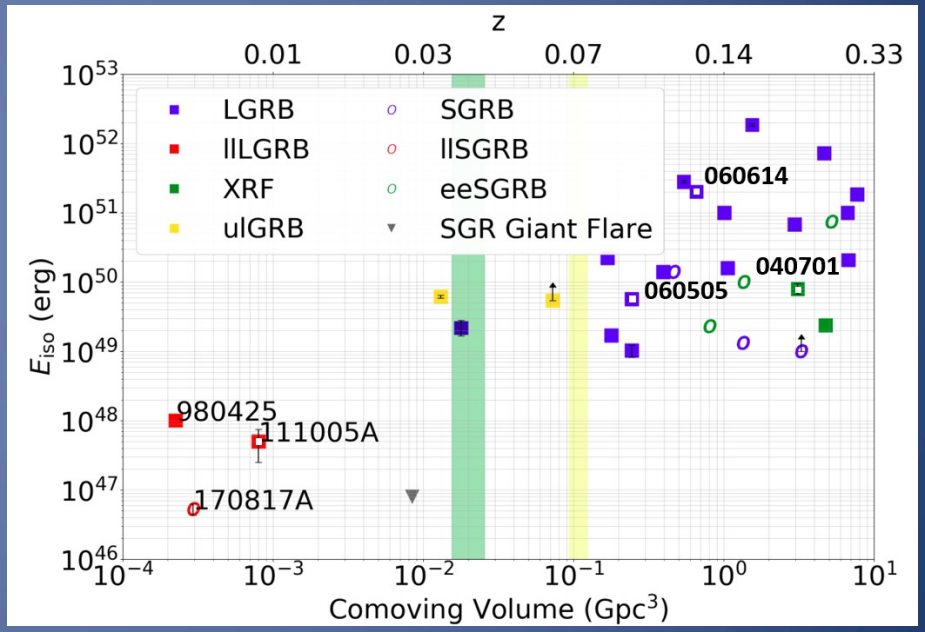
* Approximate calculation, to be taken with caution!

- Non-comprehensive reference list:
  a. Soderberg et al. (2005) ; Pélangeon et al. (2008)
  b. Fynbo et al. (2006) ; Levesque et al. (2007) ; Ofek et al. (2007) ; McBreen et al. (2008) ; Thöne et al. (2014) ; Xu et al. (2009)
  c. Della Valle et al. (2006) ; Fynbo et al. (2006) ; Gehrels et al. (2006) ; Mangano et al. (2007) ; Zhang et al. (2007) ; Lu et al. (2008) ; Jin et al. (2015)
  d. Wang et al. (2017) ; Michalowski et al. (2018) ; Tanga et al. (2018)

SN-less LGRBs in the *SVOM* and GW interferometers era

2021, a status:

- The origin of SN-less GRBs remains mysterious.
- The advent of GW interferometers is a significant asset to distinguish mergers from collapsars.
- SN-less GRBs may represent ~20% of detected long GRBs.
- SN-less GRBs are found among local GRBs, which are rare!



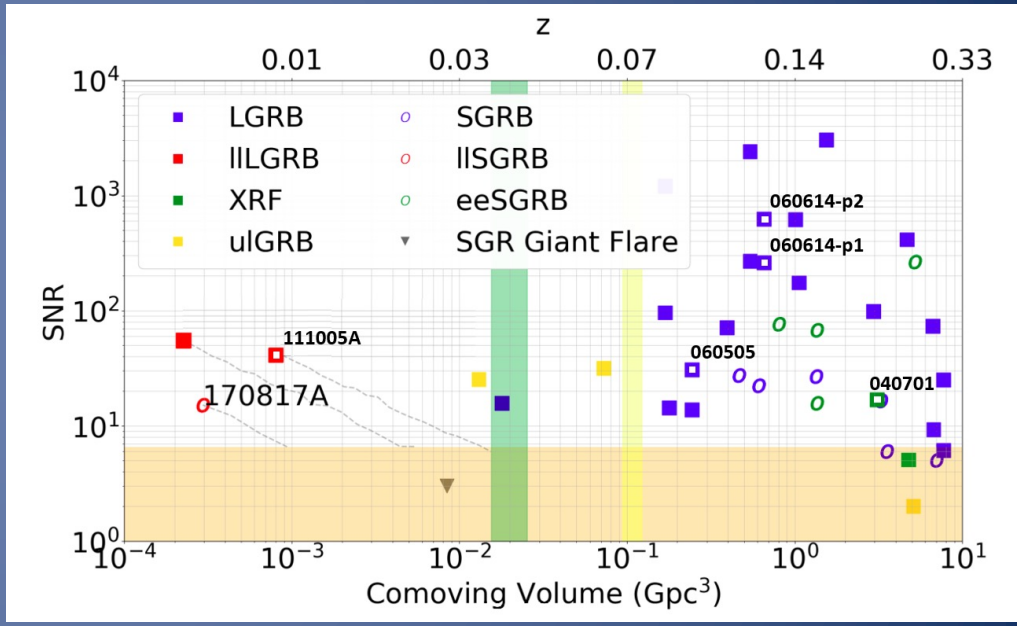
Identifying SN-less LGRBs with *SVOM*

- Confirming the detection of a SN-less LGRB requires several steps:
  1. Detect a nearby LGRB (typically $z \leq 0.3 - 0.5$) (ECLAIRs/GRM).
  2. Measure its distance:
     1. Identify the host galaxy. This requires sub-arcminute localization (MXT/VT/GFT).
     2. Find an optical afterglow (GFT/VT) and measure its spectrum (large telescopes).
  3. Look for the SN with sufficient sensitivity at late times (VT).

- ***SVOM can effectively contribute to steps 1, 2.1 and 3.***

Detecting nearby LGRBs with *SVOM*/ECLAIRs

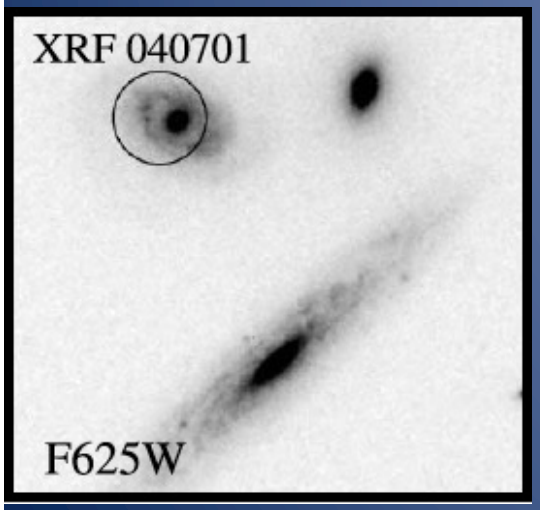
- The sample of Arcier et al. contains 24 LGRBs closer than z = 0.3.
  - 14 with a SN (~4/5).
  - 4 without a SN (~1/5).
  - 6 with no data.
- 21/24 are detectable with ECLAIRs.
- The 4 SN-less LGRBs are detectable with good SNR.



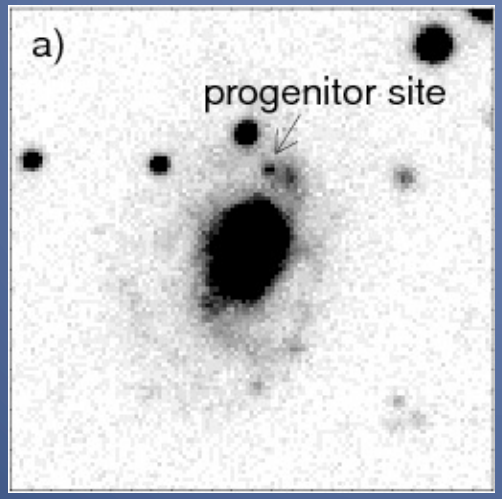
Host galaxies of 4 SN-less LGRBs

- Host galaxies are usually rather bright, but not always. We cannot rely on the presence of a bright galaxy in the MXT error box to identify all nearby GRBs.

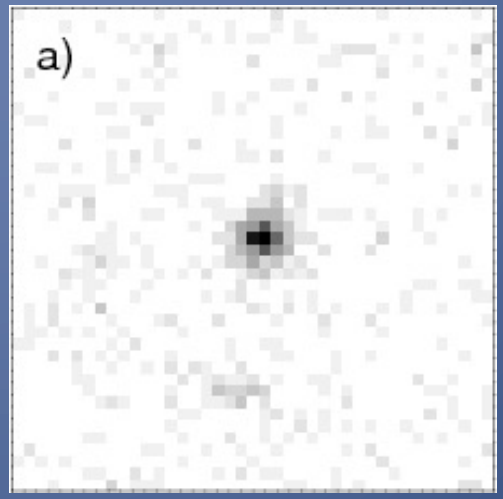
GRB 040701
HST -- 12" side
Soderberg et al. 2005



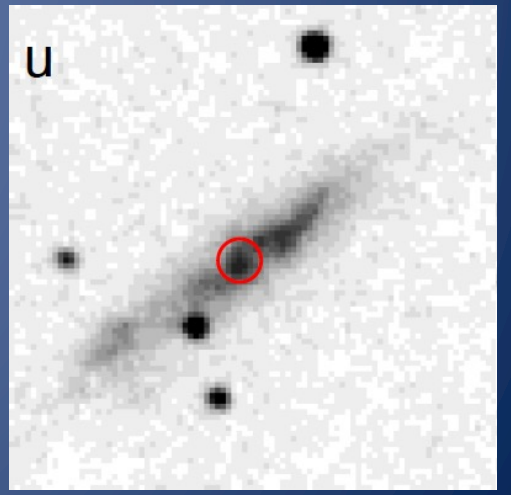
GRB 060505
VLT -- 24" side
Fynbo et al. 2006



GRB 060614
D1.5m -- 16" side
Fynbo et al. 2006

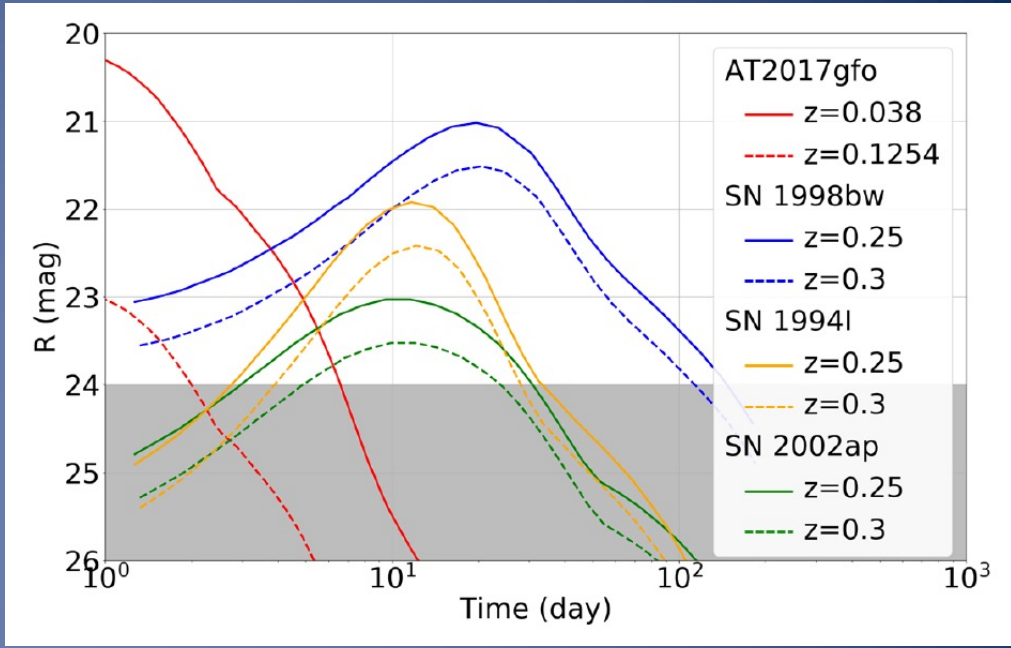


GRB 111005A
UVOT -- 90" side
Michalowski et al. 2006



Identifying SN-less long GRBs with *SVOM*

- The VT is sensitive enough to detect most core-collapse SNe at z = 0.3.
- This requires few orbit observations taking place 10-20 days after the GRB.

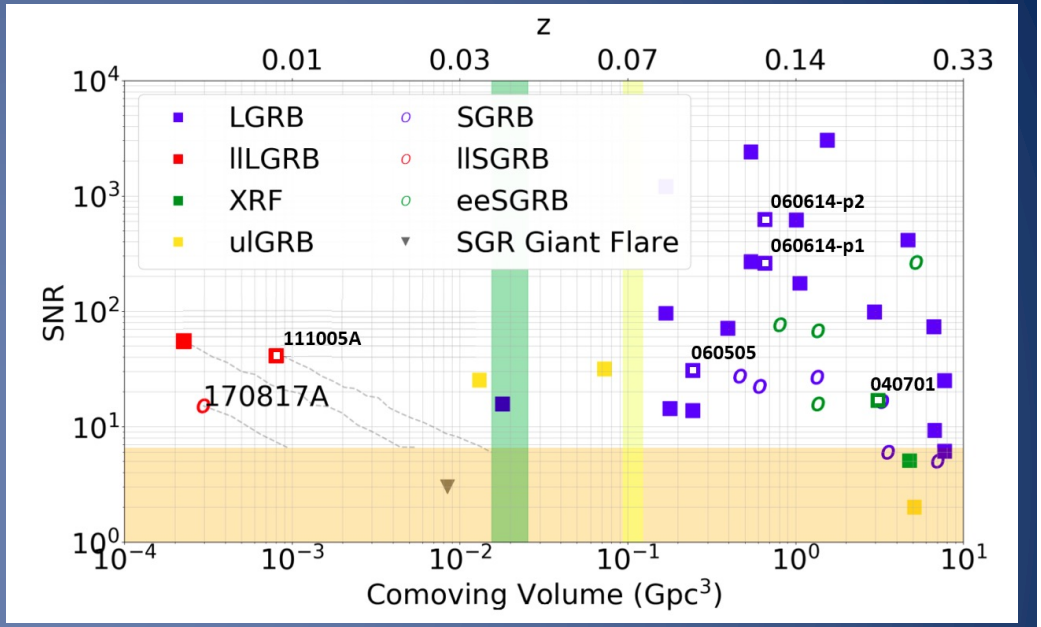


Light-curves of typical SNe at z = 0.3, and the sensitivity of the VT for an observation lasting ≈2 orbits (4800 s).

The role of GW interferometers

- GRBs (long or short) due to mergers are expected to be accompanied by transient signal of GWs, if they take place within the horizon of GW interferometers (see figure).
- For the moment, we must consider all possibilities…

Local LGRB with…	GW Transient	SN	Comment
	No	Yes	Expected
	No	No	Failed SN?
	Yes	No	Merger!
	Yes	Yes	Mystery



Predicted sensitivity limits of ECLAIRs (orange horizontal band) and GW I/F (green and yellow vertical bars). The green bar shows the horizon for the detection of BNS mergers and the yellow bar the horizon for the detection of BHNS mergers during the O4 run.

Conclusions

- SN-less LGRBS are very interesting events for *SVOM*.
- We must do our best to identify nearby LGRBs quickly.
  - Bright host galaxy, but not only…
- We must be ready to spend some orbits to look for the SN signal with the VT (or mid-size ground-based telescopes), 10-20 days post-GRB.
- GW interferometers may bring crucial new information to constrain the nature of these events.
- Since nearby LGRBs are rare, the best opportunity for joint *SVOM*/ LVK operation will probably happen during O5. Nevertheless, having *SVOM* launched during O4 would be extremely valuable to start working on this topic.
- 1 additional comment by F. Daigne: radio calorimetry of nearby GRBs could bring a complementary diagnostic on the nature of the progenitors of SN- and SN-less LGRBs.

The end