GRB-SN connection: rate and missed opportunities

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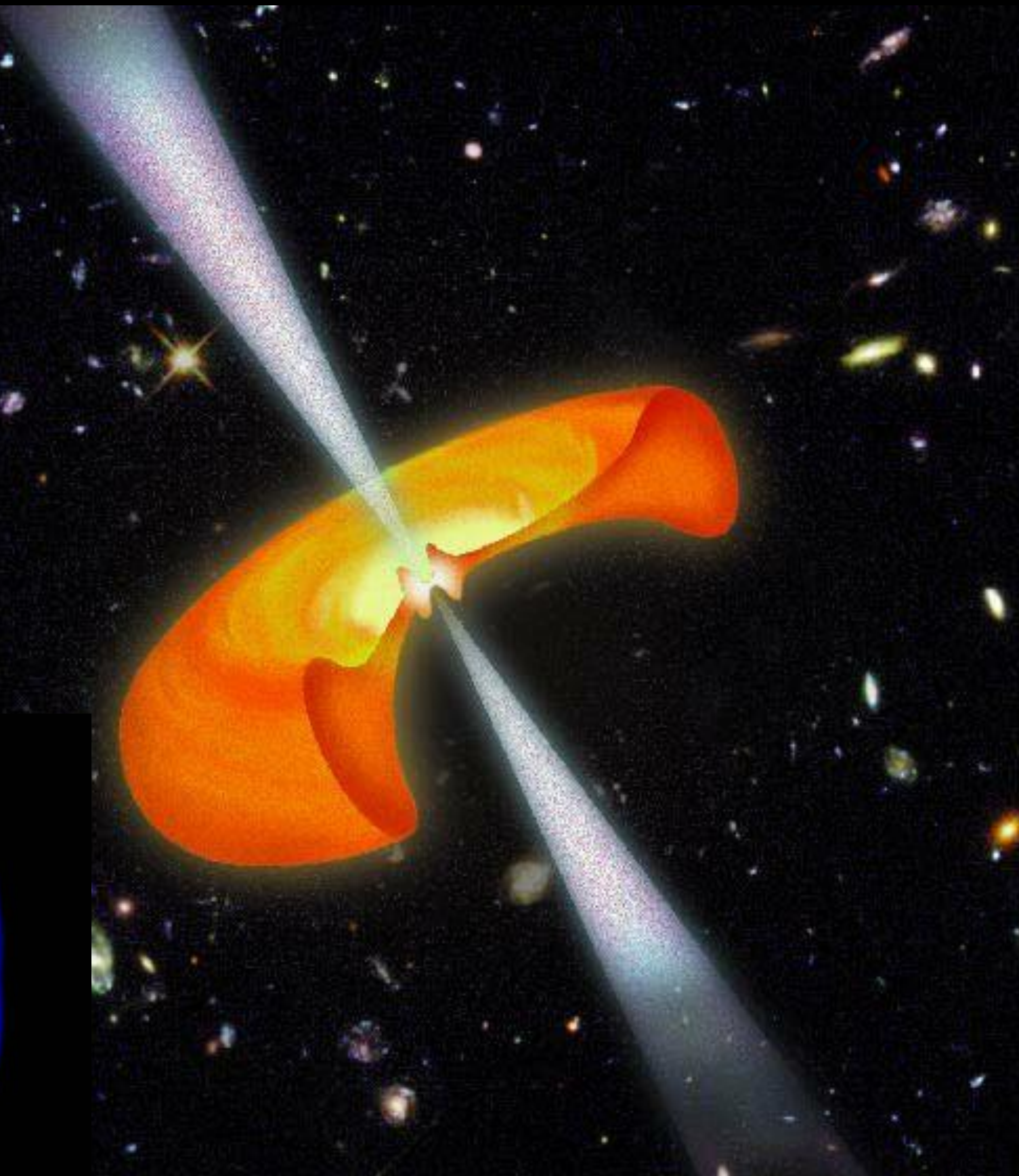
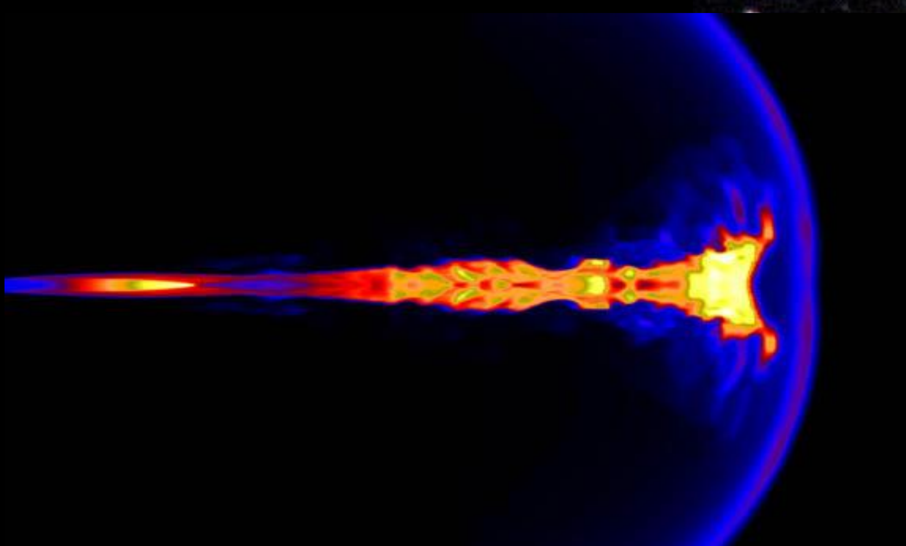
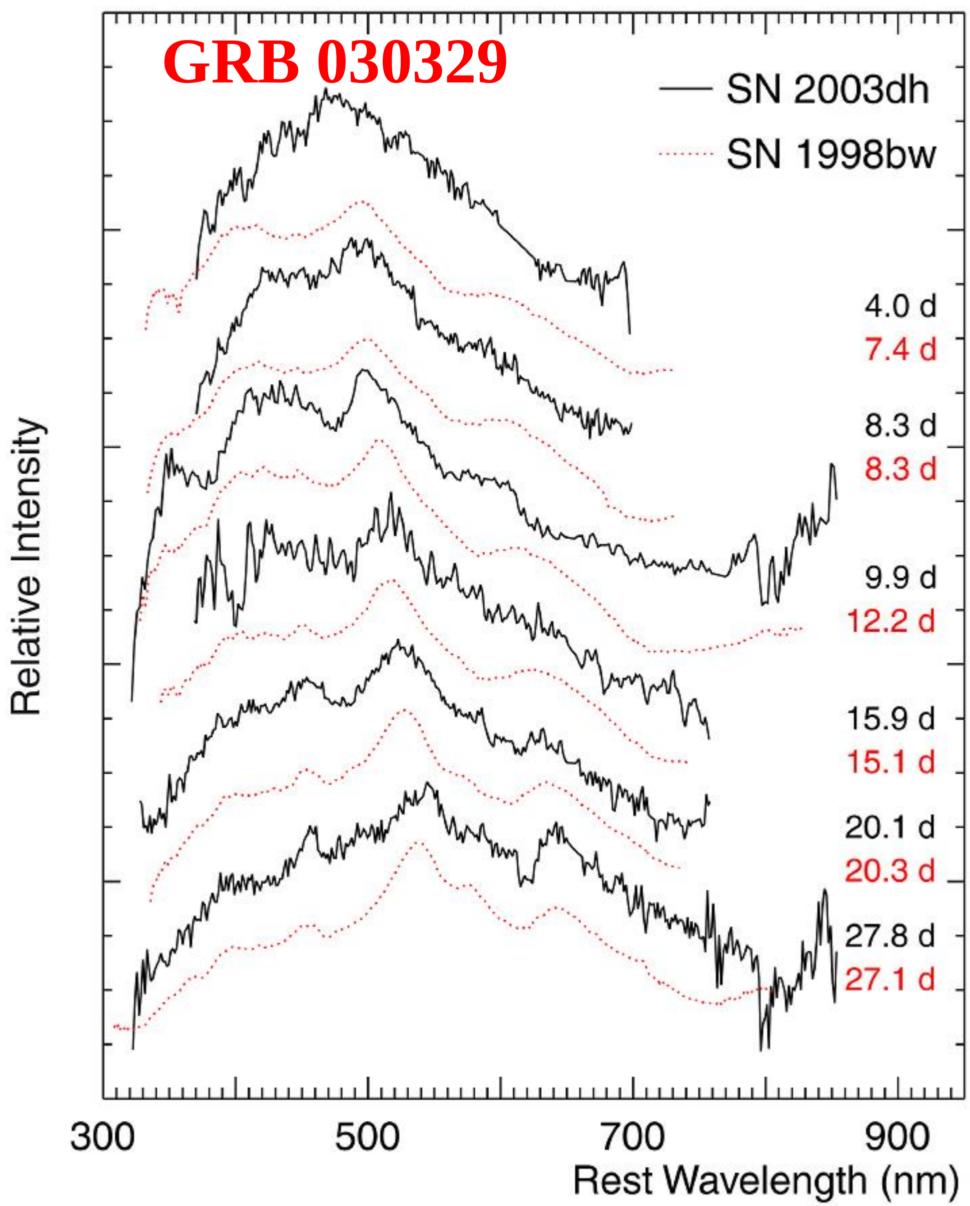
- ❖ **Why do we care?**
- ❖ **GRB-Supernovae detections**
- ❖ **Conclusion/Plea**

The favored model for long-duration GRBs: shocks in relativistic jets emanating from the central collapsed core plus torus of an evolved **massive star**.





GRB-SN connection: massive star origin



Hjorth et al. 2003, Nat 423, 847
Stanek et al. 2003, ApJ 591, L17
Kosugi et al. 2004, PASJ 56, 61
Kawabata et al. 2003, ApJ 593, L19
Matheson et al. 2003, ApJ 599, 394

Long-duration GRBs are connected to explosion of massive stars

This star must have lost its H and He envelope before it died

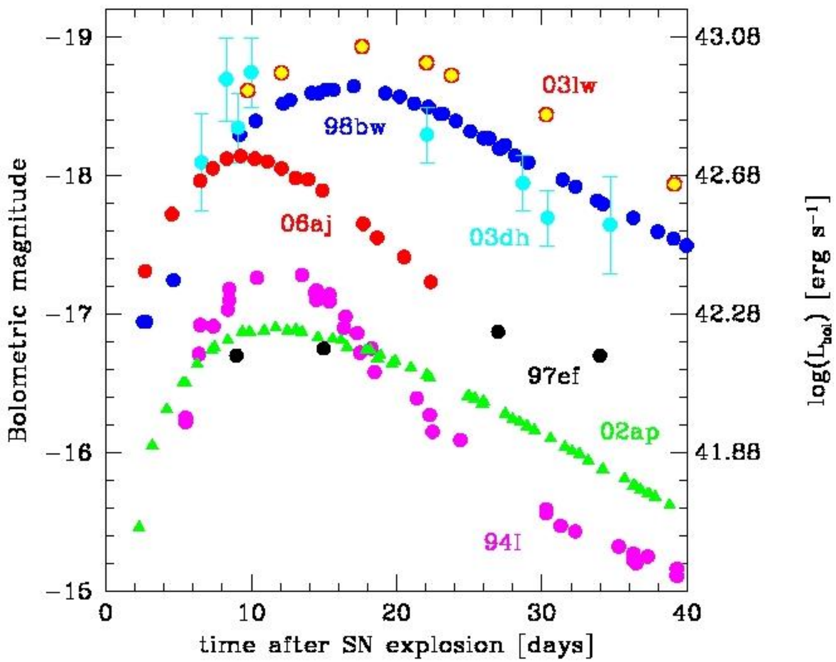
Only rare sub-types of SN Ibc produce GRBs

GRBs trace evolution of star formation rate

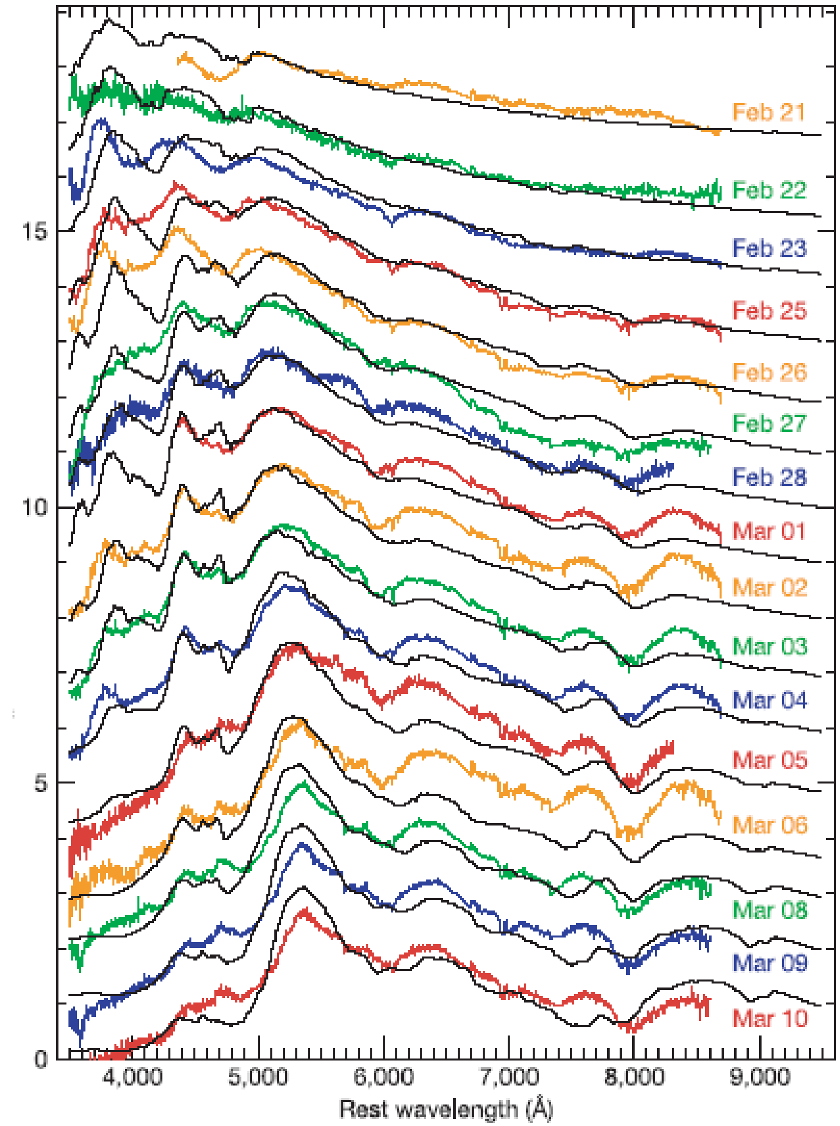
Many open questions

- what kind of progenitor? Different sub-classes, i.e. BHs vs. magnetars?
- what determines production of a GRB(-jet) in one out of hundreds of SN?
- are GRB-SNe standard candles?"
- why are most discovered GRB/SN among the low-luminosity GRBs?
- asphericity of explosions? is there any impact of a jet on the SN?
- …

Modelling of GRB/XRF 060218 / SN 2006aj



Pian et al. 2006, Mazzali et al. 2006



- Progenitor mass ~20 $M_\odot$:
  $M \sim 2\ M_\odot$, $E_{kin} \sim 2 \times 10^{51}$ erg
  ➔ no BH, but NS forms!
- In contrast:
  SNe 1998bw, 2003dh, 2003lw:
  $M \sim 8–13\ M_\odot$, $E_{kin} \sim 3–7 \times 10^{52}$ erg

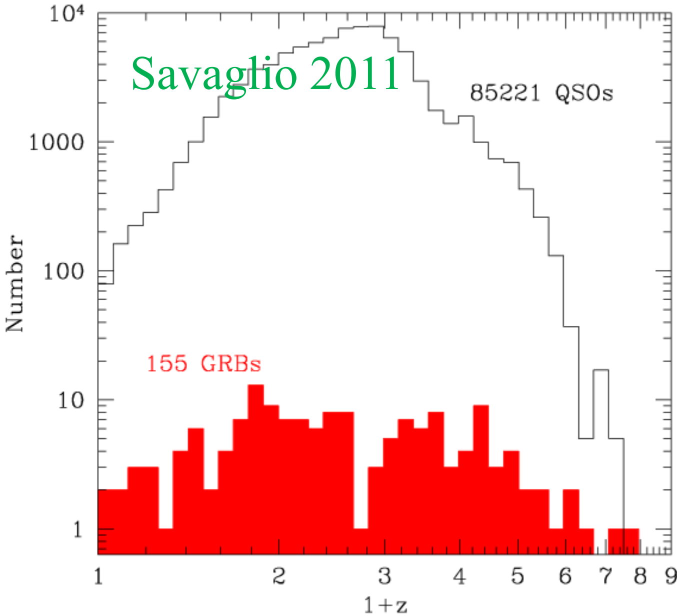
GRB/SN statistics

~ 4000 GRBs
~ 850 GRB X-ray afterglows
~ 530 GRB optical afterglows
~ 330 GRBs with redshifts (some only through host)
~ 10 spectroscopically confirmed GRB-SN

➔ Pretty low success rate!

➔ Do we miss some GRB/SN, or is the rate intrinsically so low?

Redshift distribution suggests ~15% of GRBs at z<0.5 compared to the above 3%!



Improving searches

- TACs force us to pre-select few "interesting" GRBs for ground-based follow-up, but this pre-selection is often illusive/misleading

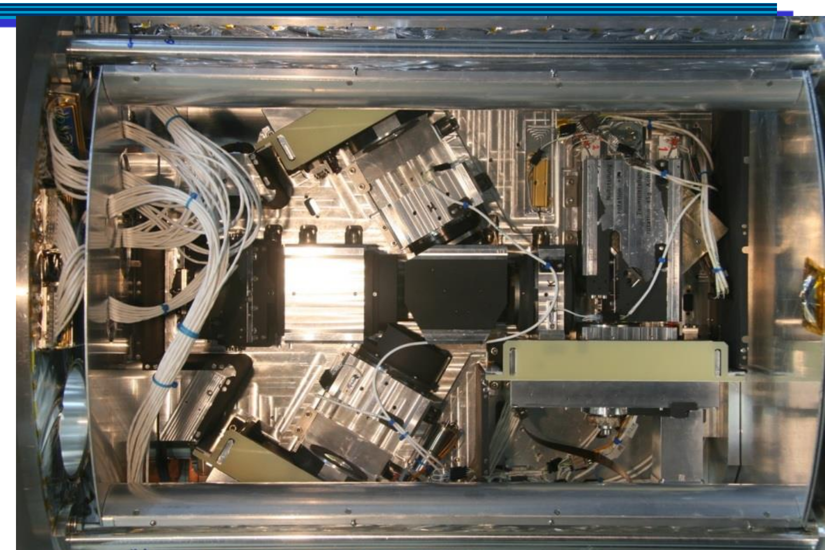
- also selections based in prompt-emission "indicators" (most notably redshift) is very often wrong

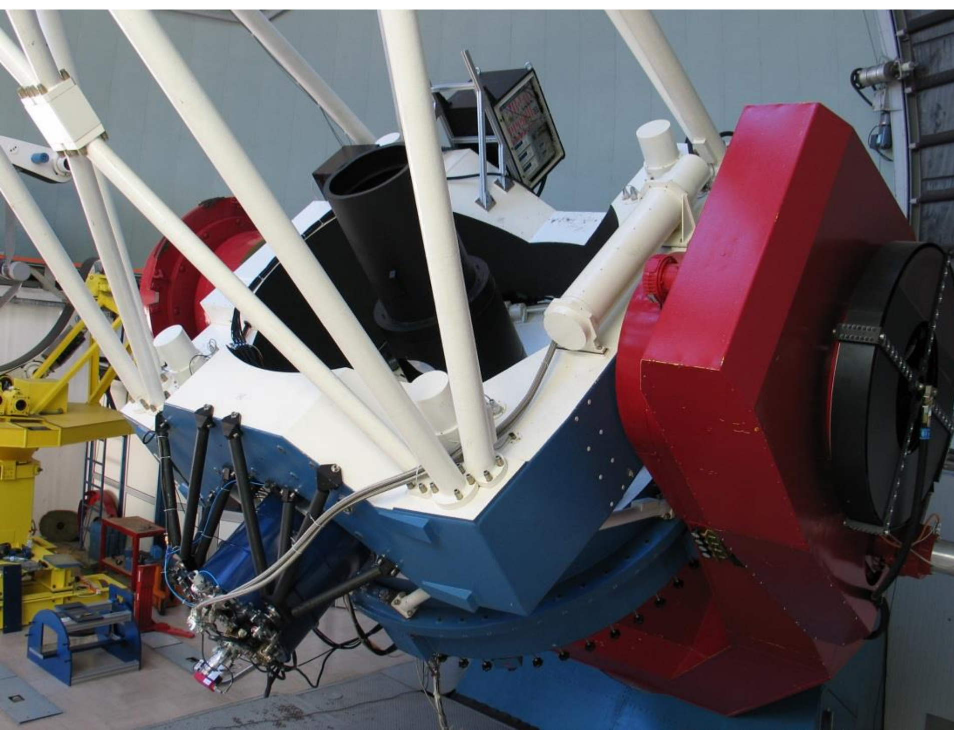
- we need to MUCH more systematically observe all optical afterglows down to at least 25th mag – this needs 3-4m class telescopes (which get out of fashion these days)

GROND @ 2.2m MPG telescope La Silla

History:

First light: Apr 30, 2007
First GRB: May 21, 2007
Photometric calibration: Jul 2007
Routine observations: since Sep 2007
fastest response time: 2 min





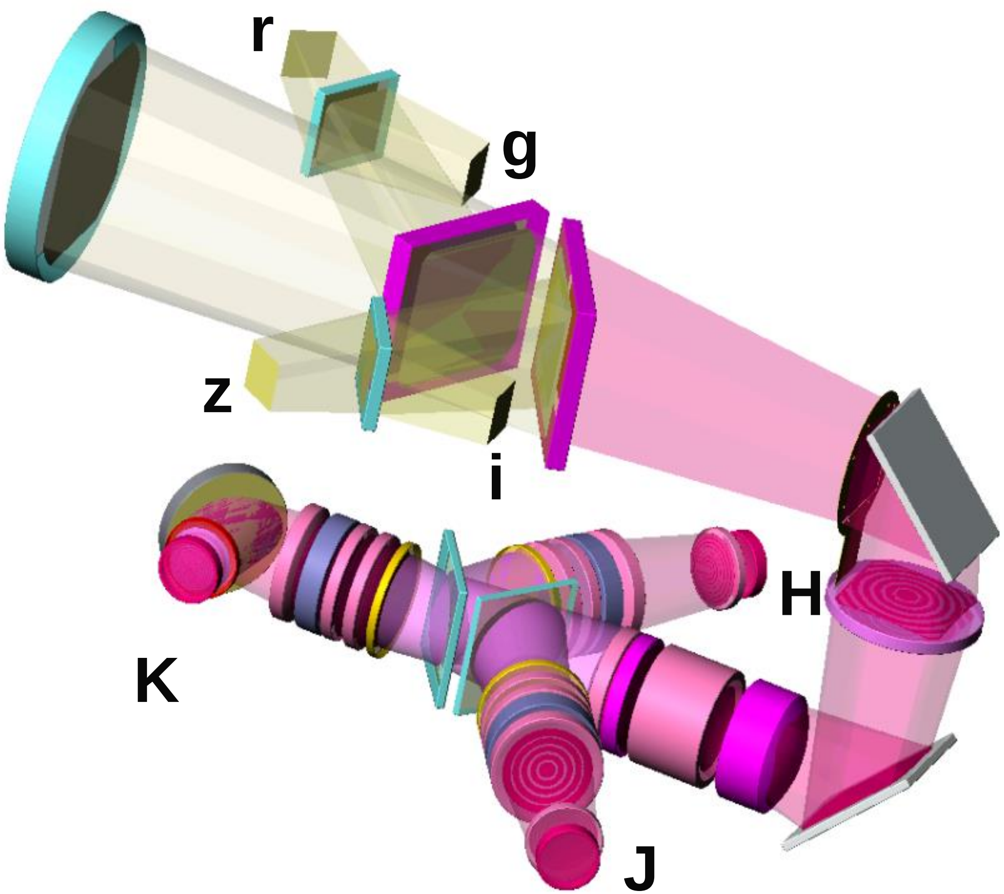
GROND: General Design

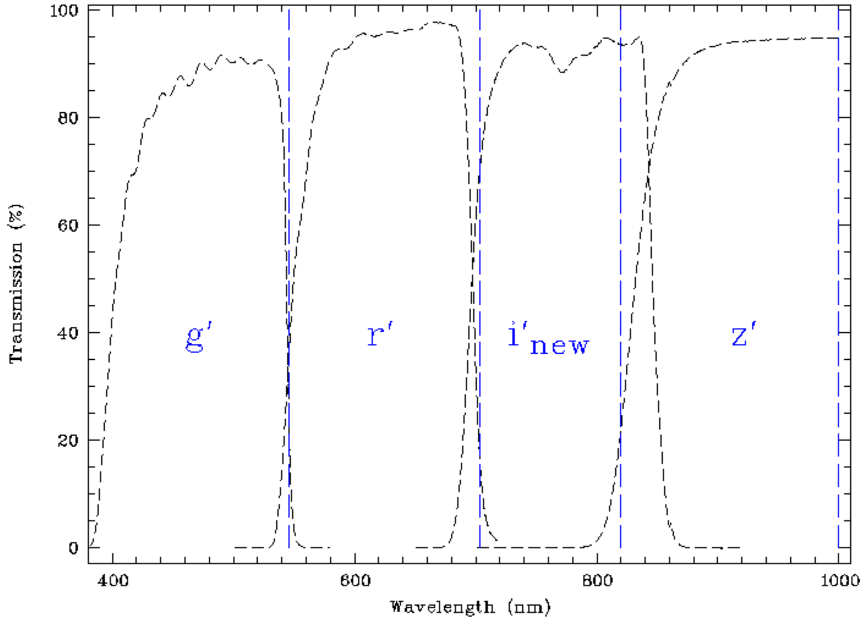
- 7 bands: Sloan g', r', i', z' and J, H, K
  One detector for one filter band (no movable filters!)
  3 HAWAII 1K*1K Arrays + 4 E2V 2K*2K CCDs
- Field-of-view: Visual: 5.4´x5.4´ (0.16´´/pixel)
  NIR: 10´x10´ (0.59´´/pixel)
- Dichroics tuned to minimize intrinsic polarization effects
- 2 shutters, i.e. g'r' and i'z' pairs of CCDs have same exposure
- Combined telescope and intrinsic mirror (K-band) dithering
- Sensitivity (AB):

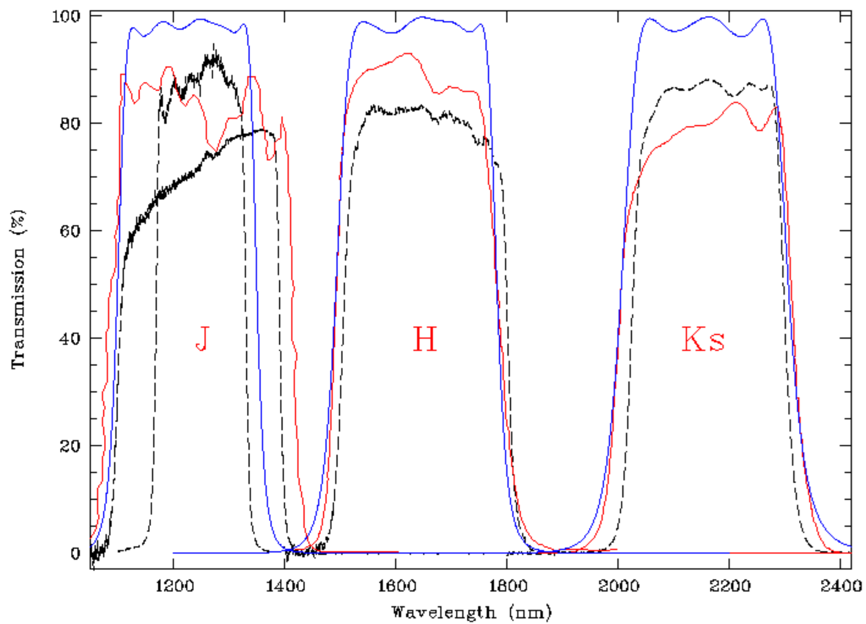
	4 min	1 hr
gr	21.5 mag	24.5 mag
iz	21.0 mag	24.0 mag
J/H/K	19/18/17 mag	22/21/20 mag

GROND=GRB Optical/NIR Detector

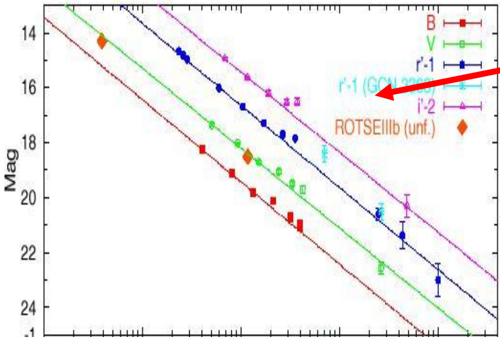
Imaging in 7 channels simultaneously

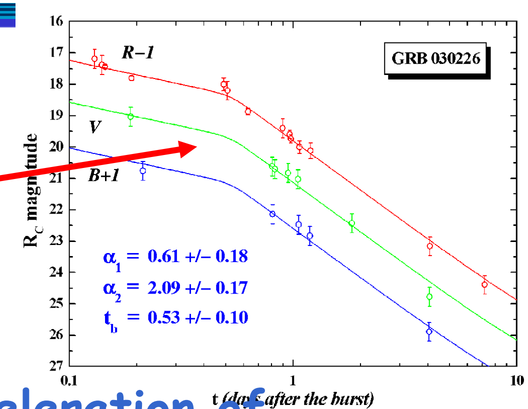




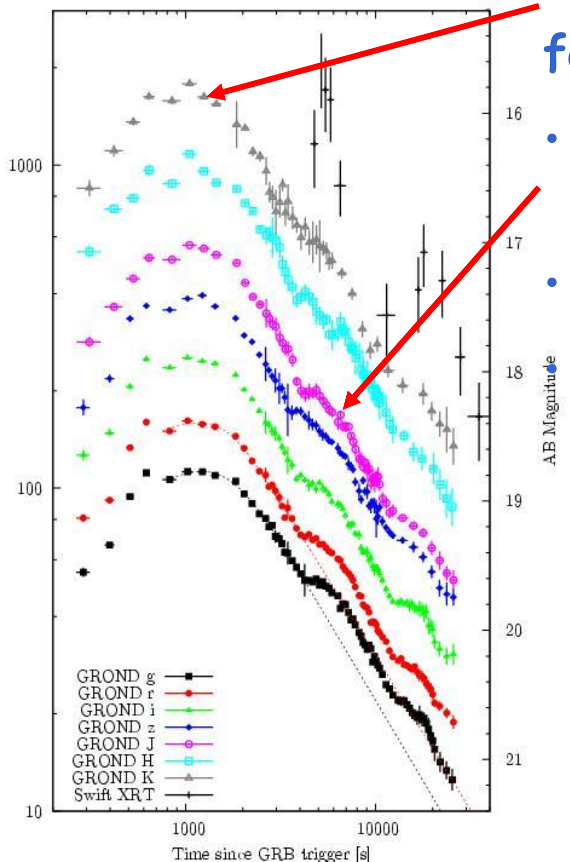


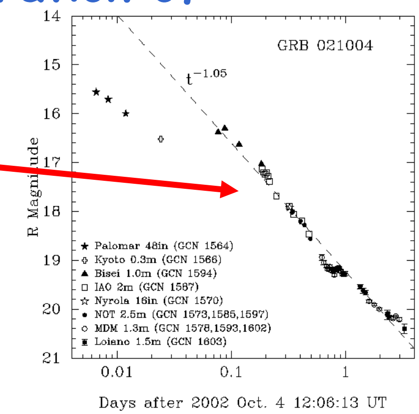
Optial/NIR Afterglow light curves in a nutshell

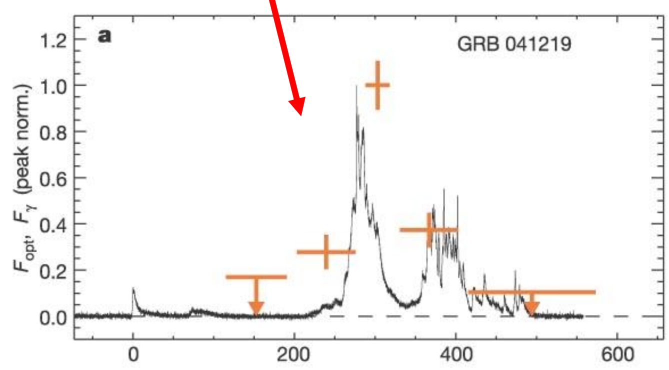


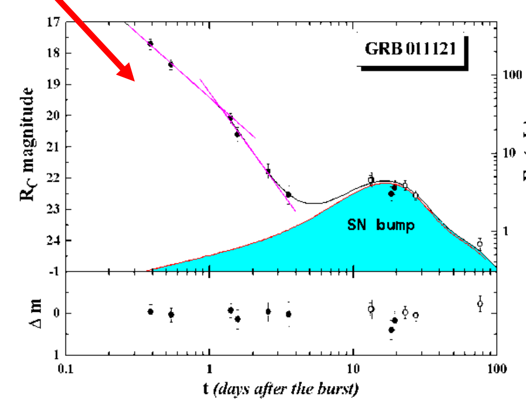


- power law decay
- jet breaks (0.5-2.0 d)
- Early peaks: reverse shocks
- gently rising early emission: deceleration of forward-shock -> Γ-determination
- bumps and wiggles on decaying lc: "riding on density waves"
- SN bumps at (1+z)*(8-20) days
- Correlated prompt emission







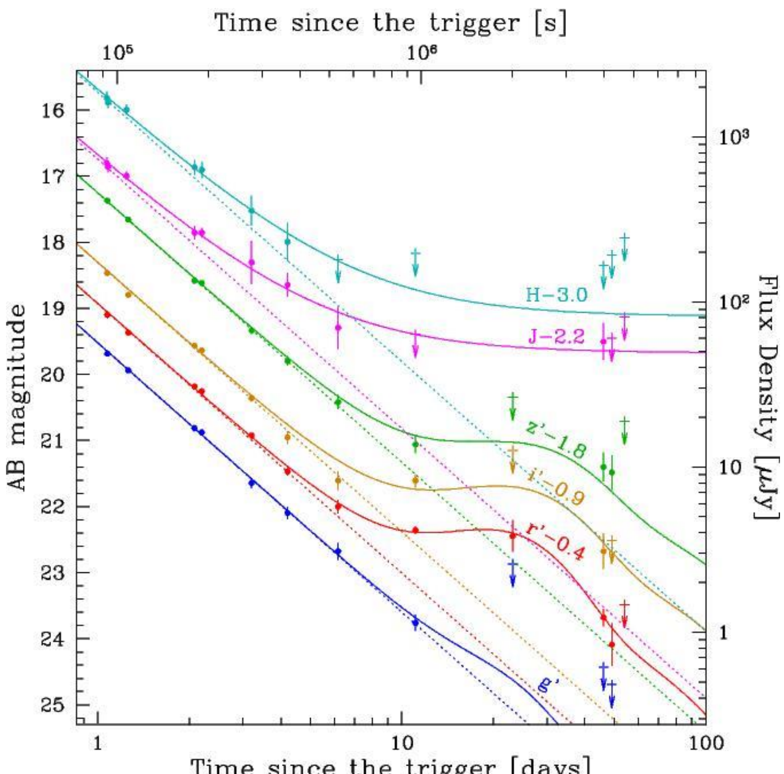


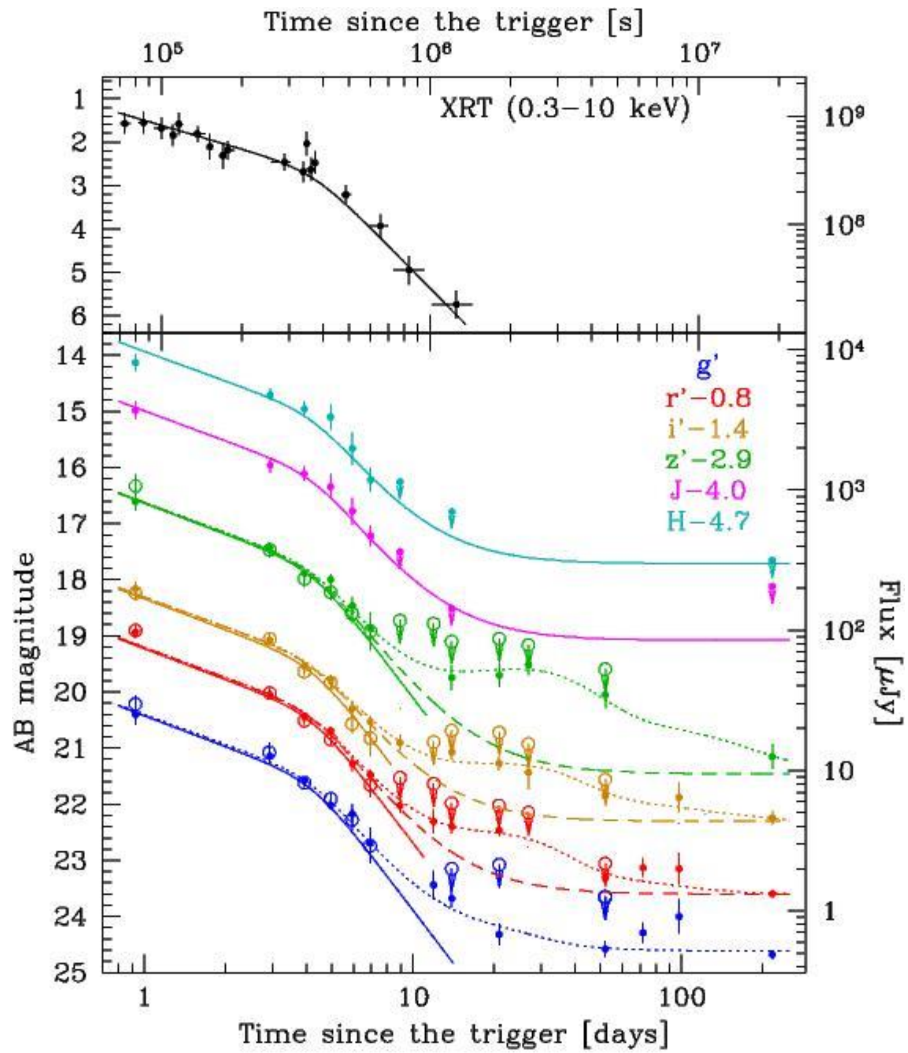
GROND examples: I

a clear case from 2009

a poor S/N case from 2011

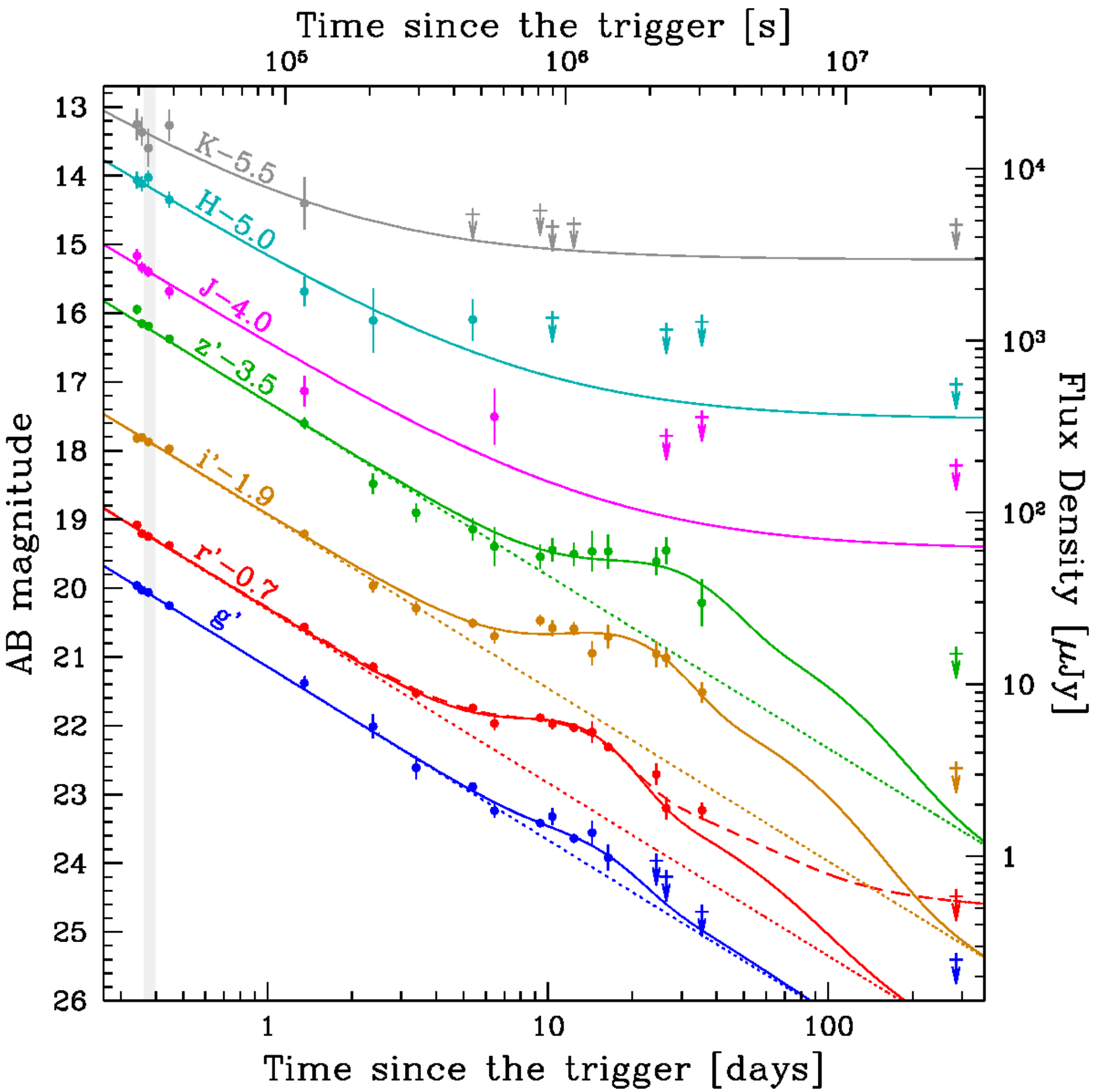
Olivares (talk next week)





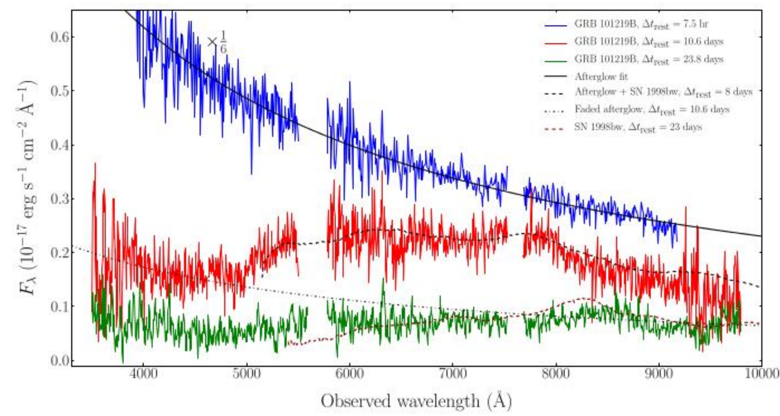
GROND examples: II

Olivares et al. 2014 (in press)



GRB 101219B: clear case X-Shooter team informed for spectroscopy

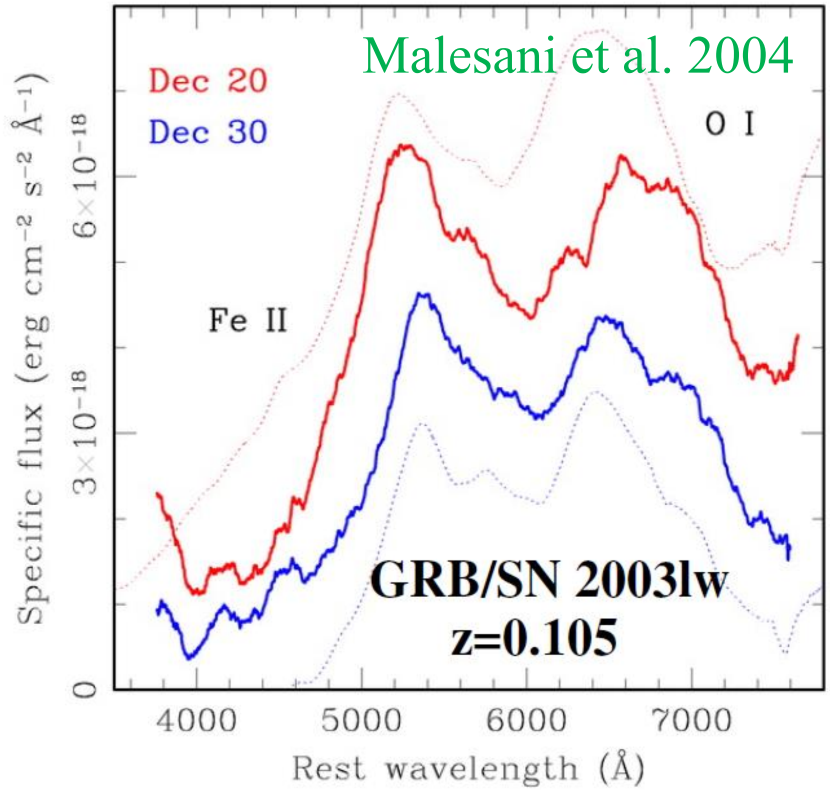
➔ Sparre et al 2011



GRB 120714B / SN 2012eb (z=0.3984)

Klose et al. 2012, GCN 13613 / CBET 3200

Figure will be published in Klose et al 2014



- at t=18.5 days (obs) = 13.2 d (host frame)

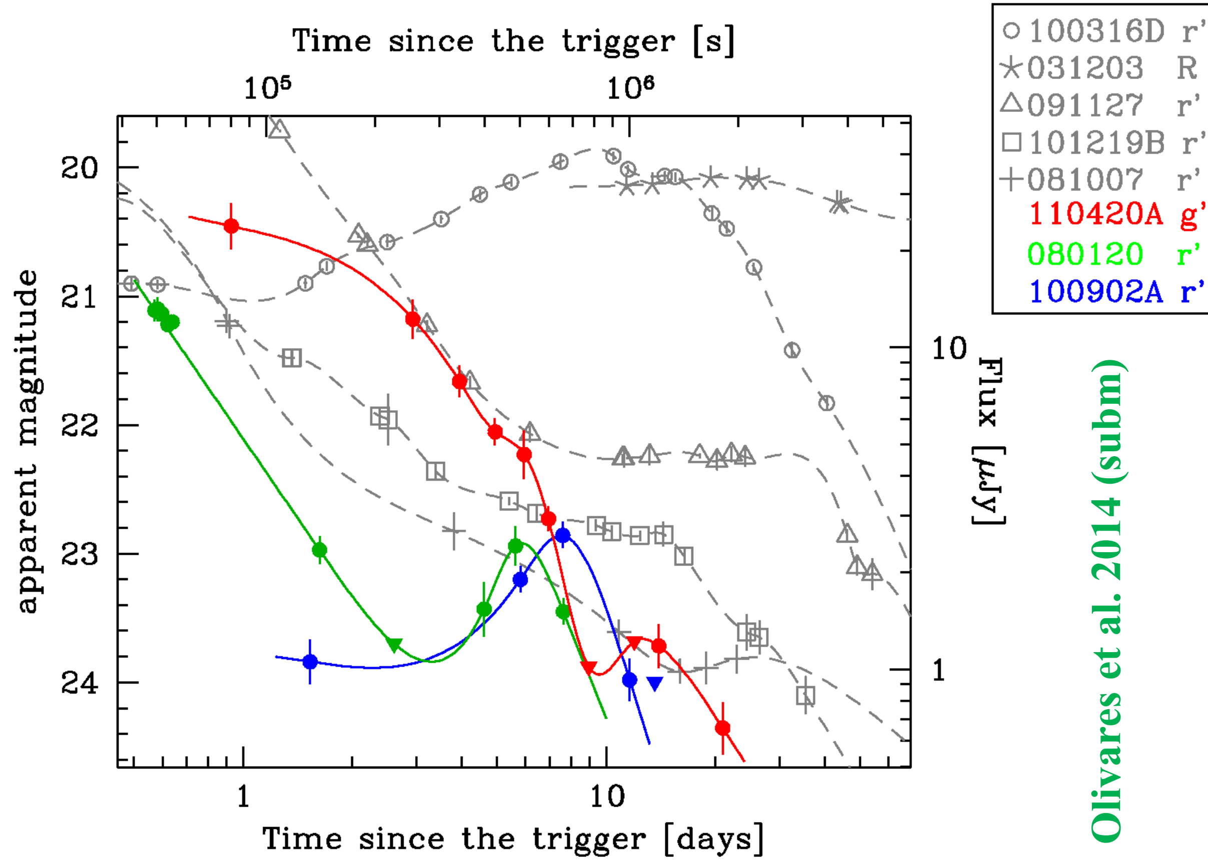
GRB 130831A / SN 2013fu (z=0.478)

Klose et al. 2013, CBET 3677

Figure will be published
in Klose et al 2014

How many GRB/SN do we miss?

- from simple statistics it is clear we miss a good fraction: ~5x
- how many could we realistically re-cover? (brightness, host, …)
- previous examples were the secure cases; but there are others as well, like 100902A
- problem: to be safe, we only trigger AFTER maximum, so it is definitely not the host: ➔ we also miss some
- just with our GROND secure cases we double the present rate



Olivares et al. 2014 (subm)

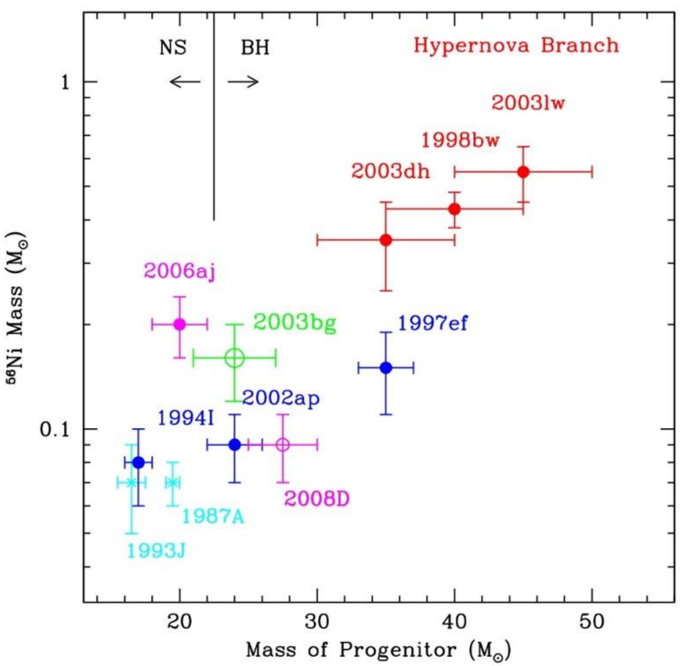
- previous discovery rate of spectr.-confirmed SN: ~0.5/yr
- ➔ but could be 1-2/yr with more aggressive ground-based follow-up

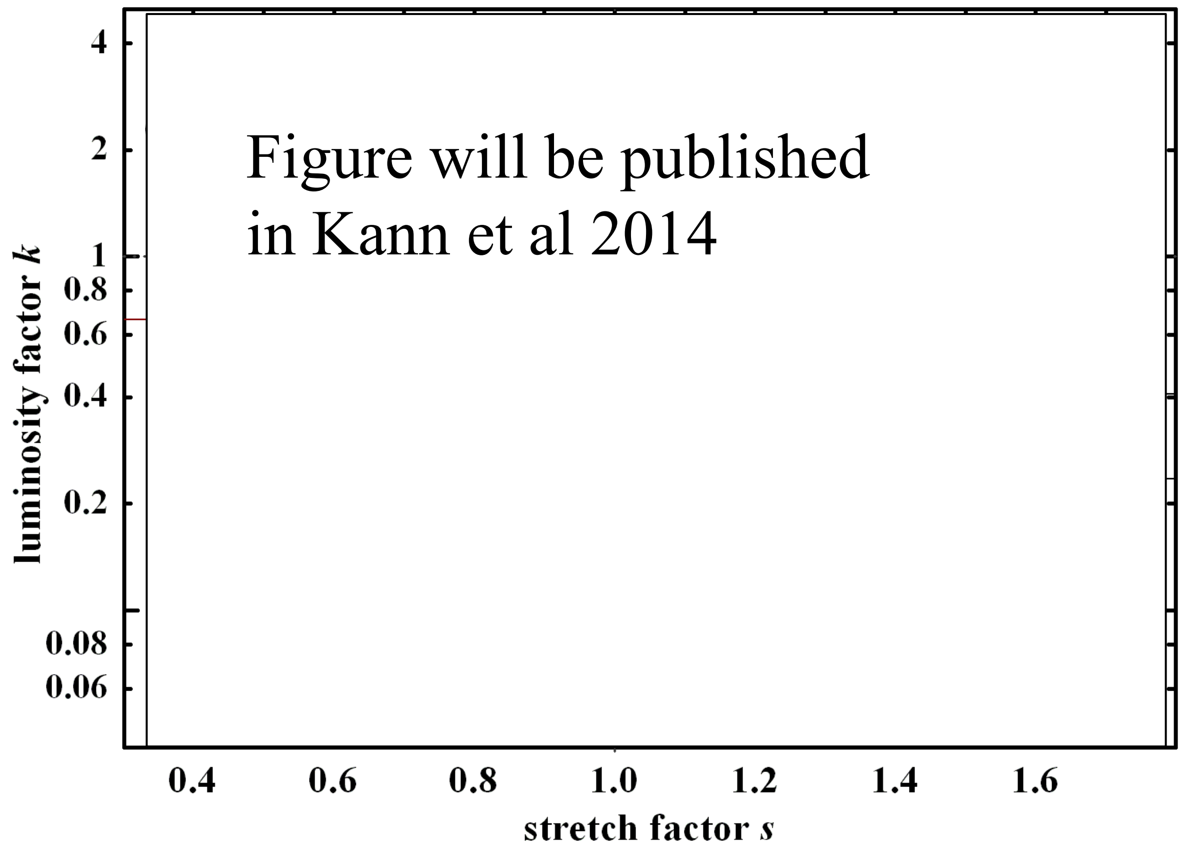
GRB/SN without spectra

- better than nothing?
- One would like to get physical parameters, but those require spectroscopy
  ➔ poor man's version is k vs. s

Kann et al. 2014

Mazzali et al. 2011





Conclusions

- GRB-SN are not as rare as we might deduce from the existing sample

- suggestions/pleas:
  - to optical astronomers: observe whenever you can; even better if you can organize systematic follow-up at a 3-4m telescope
  - to TAC members: don't enforce 'optimisation'
  - to Senior Review (USA): Swift/BAT triggers and XRT(/UVOT) follow-up are crucially needed to move from few single cases to a sample which allows to draw some statistics

  ➔ We should use the present availability of Swift!