GRBs and Supernovae: possible signatures of proto-magnetars

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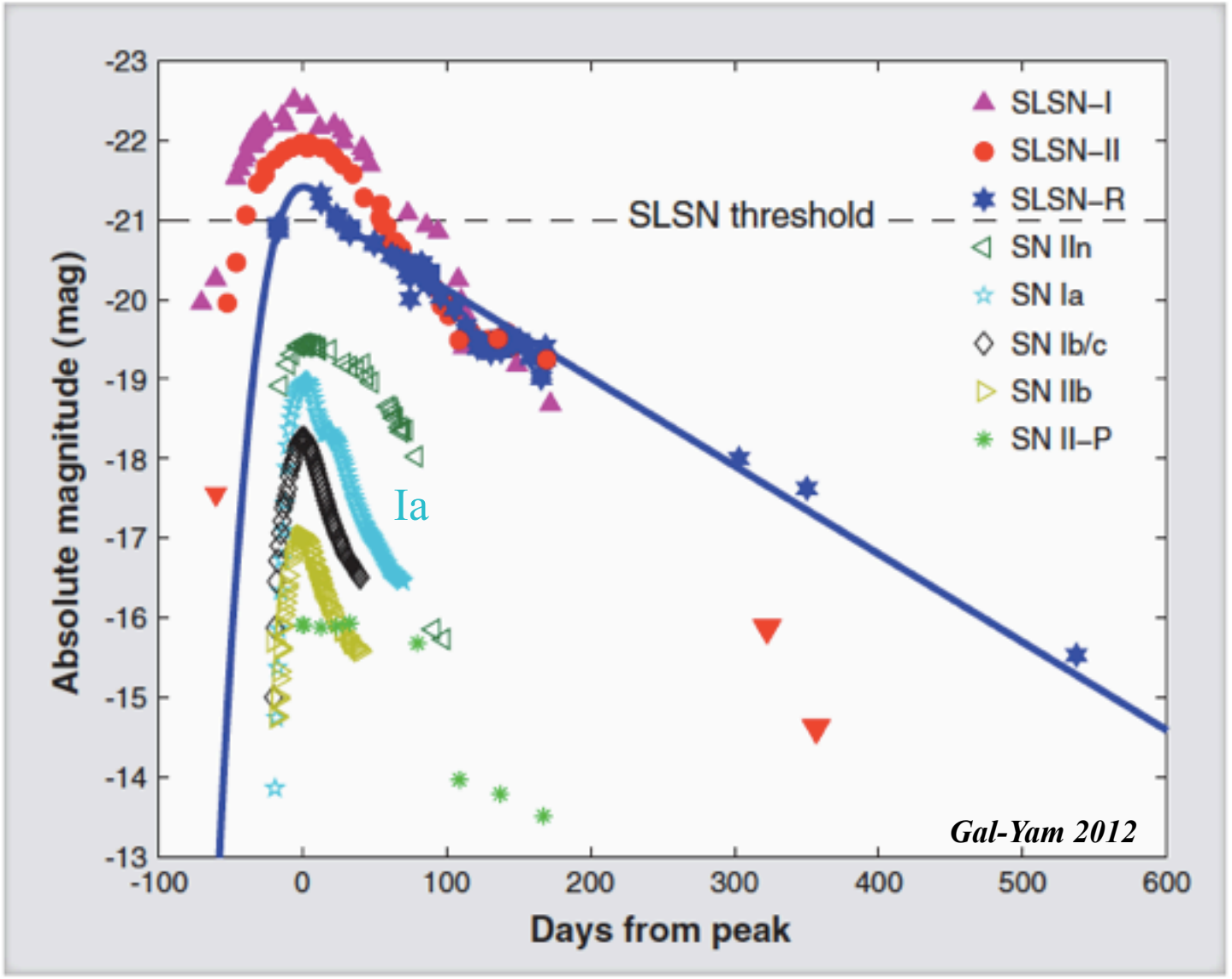
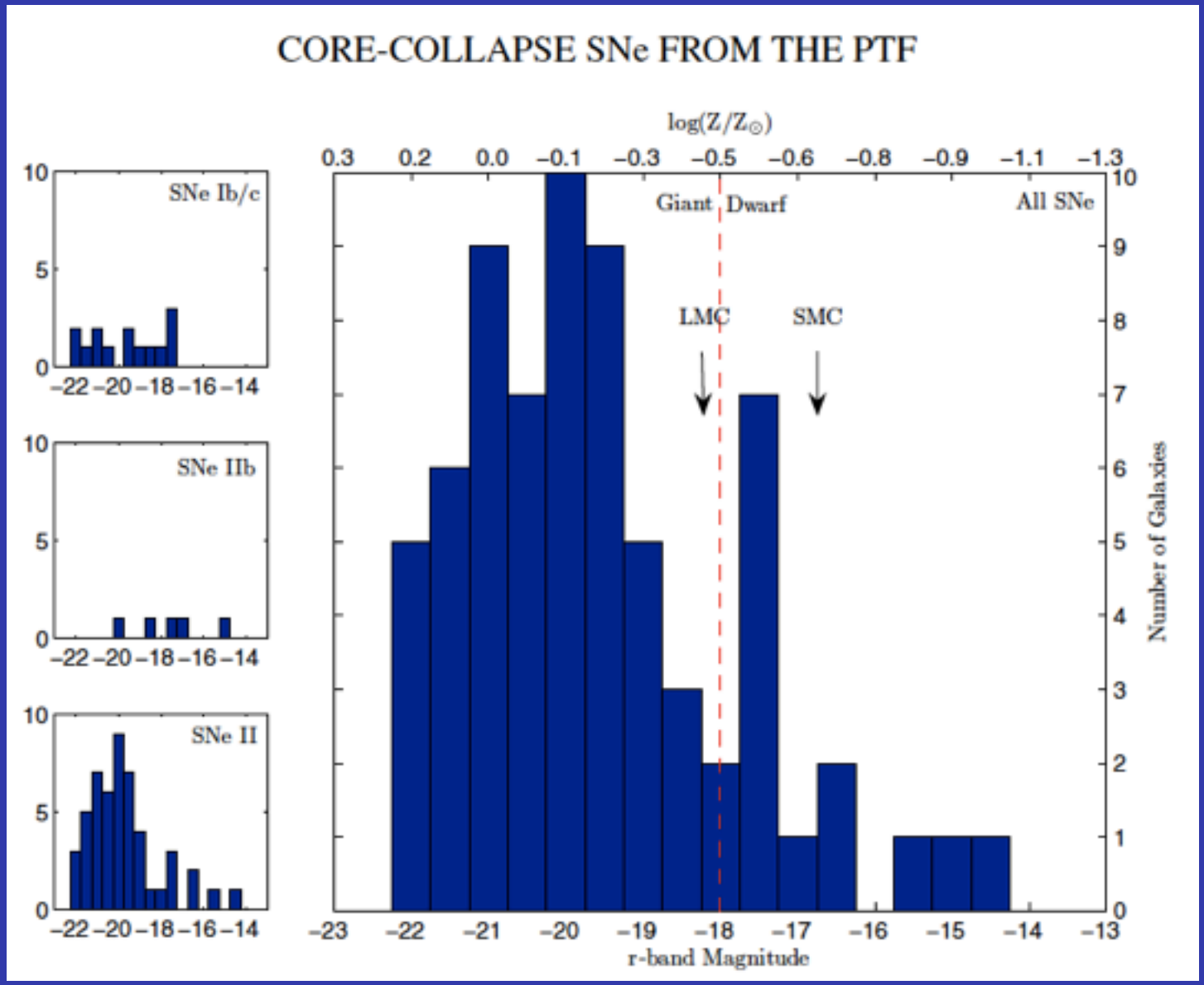
Supernova light curves

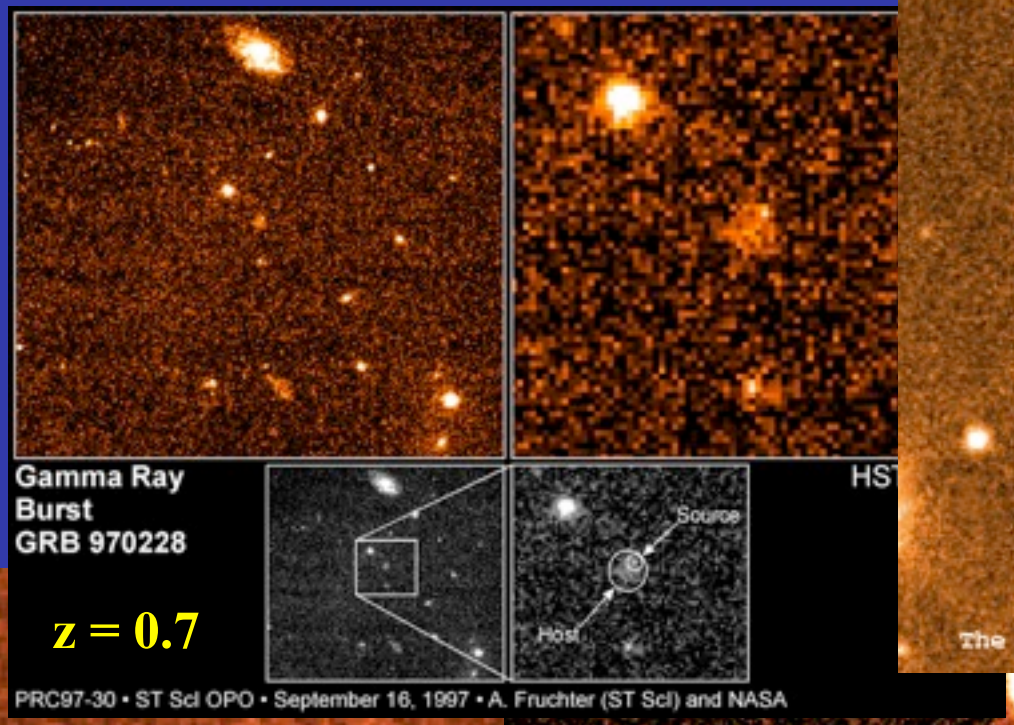


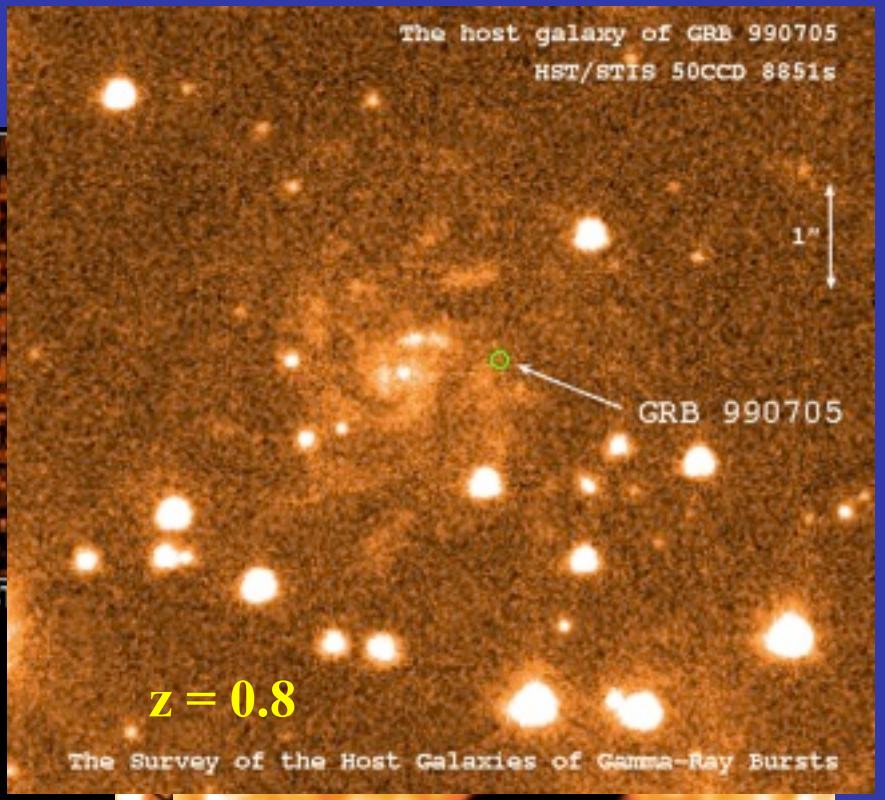
Host galaxies of CC-Sne span a wide range of properties

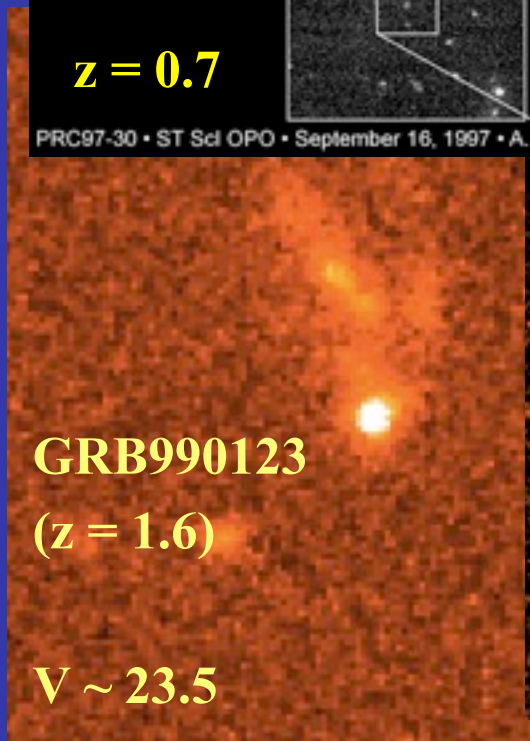


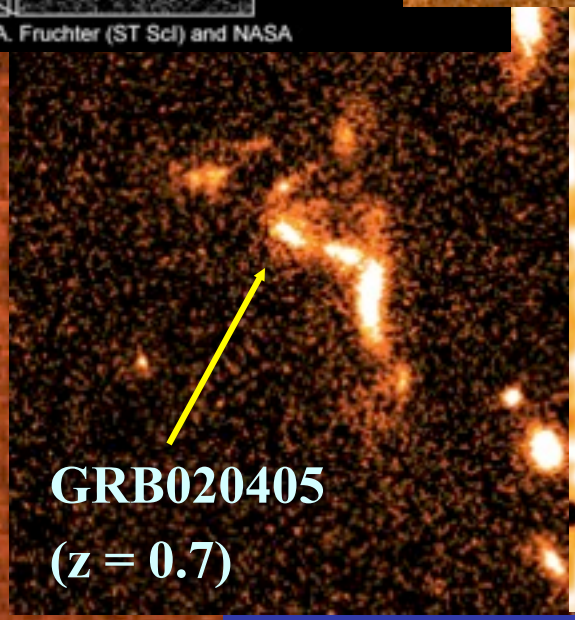
Arcavi et al. 2010

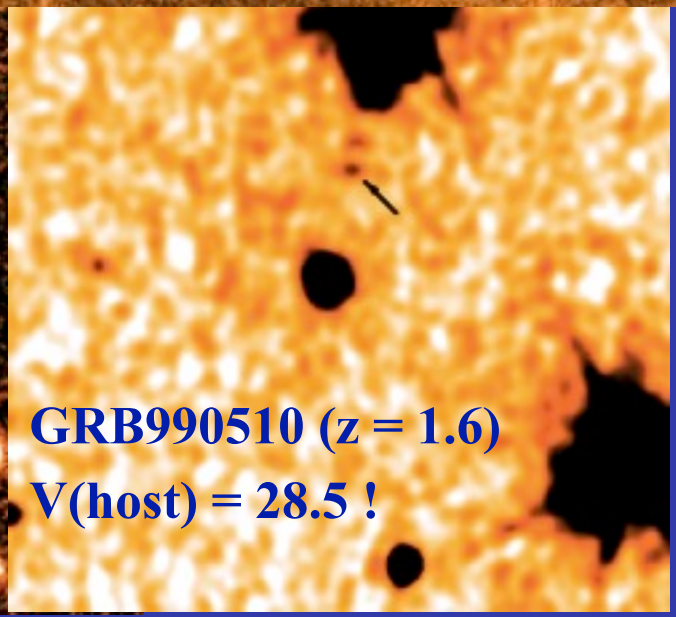
Host galaxies of GRBs



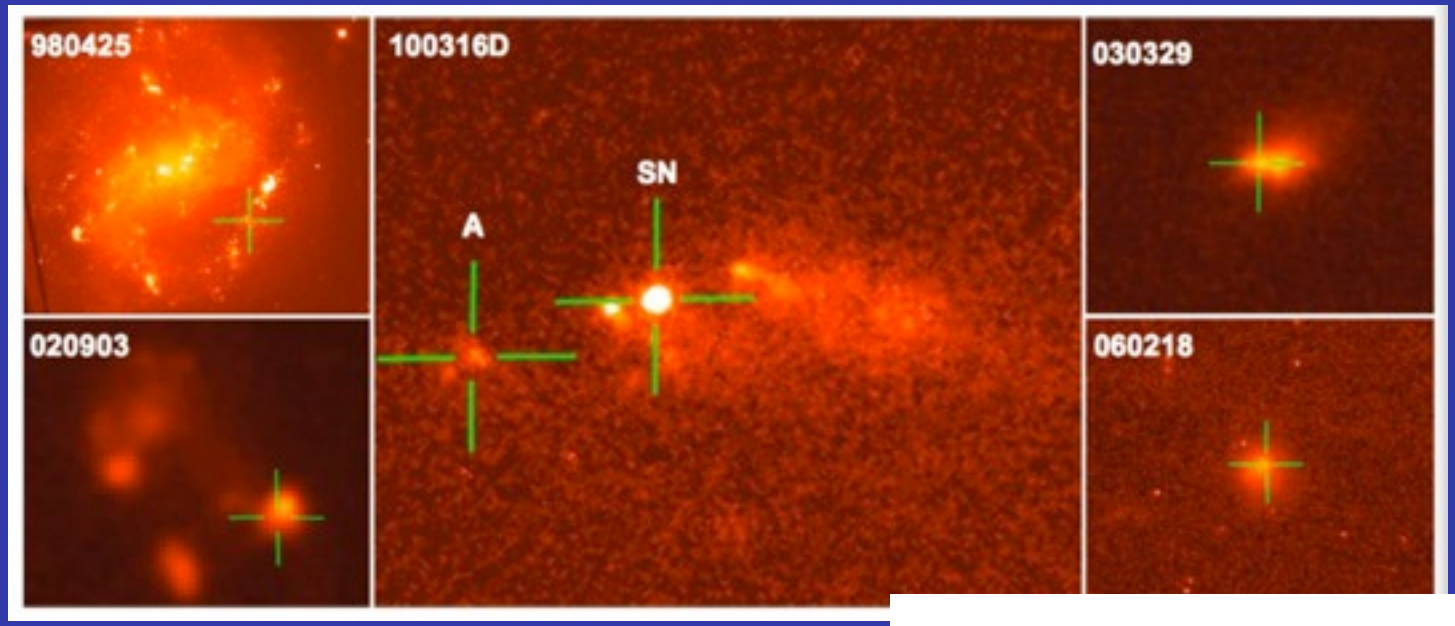






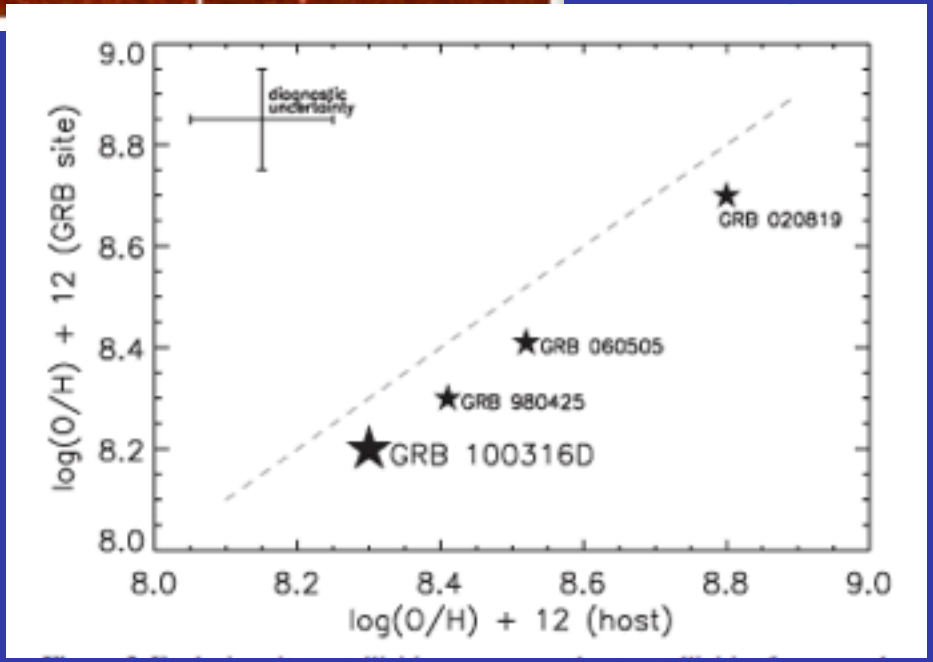


HST Fields of z < 0.2 GRBs
(physical scale across each image is about 7 kpc)

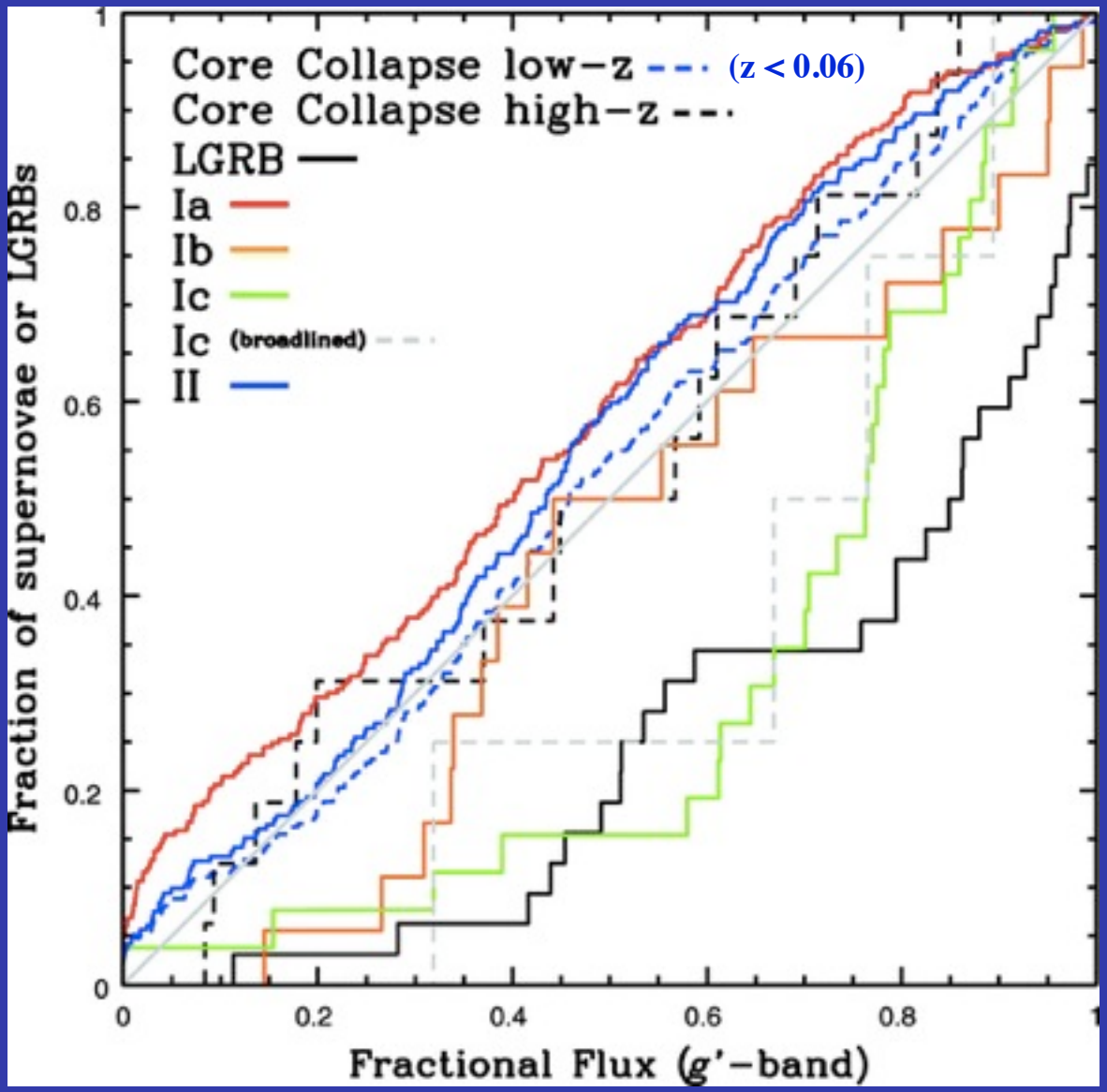


Starling et al. 2011

Host vs circumburst metallicity of GRBs
Levesque et al. 2010



Location vs stellar light distribution: GRBs are similar to Ic SNe



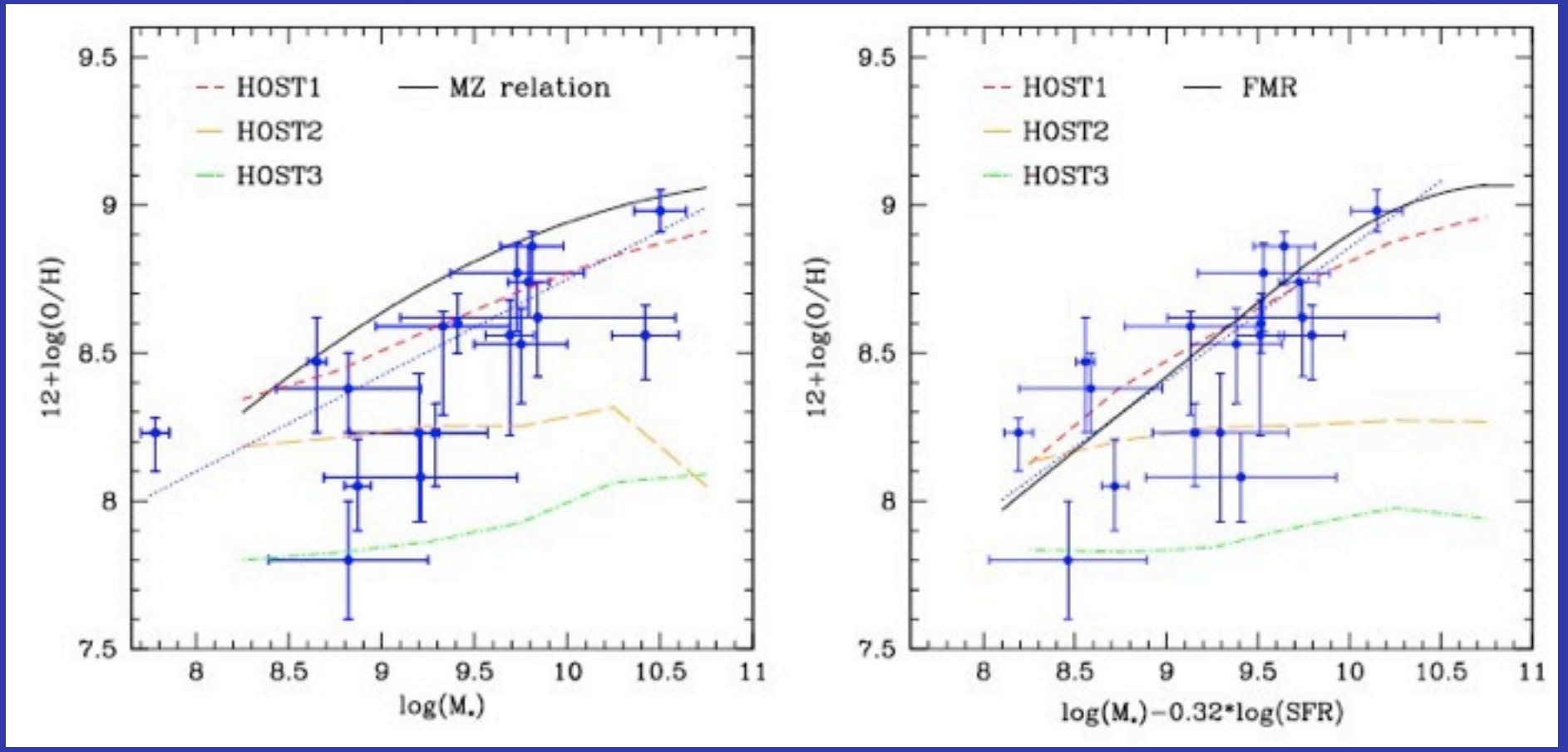
Kelly, Kirshner & Pahre 2008

Mass-metallicity and Fundamental Metallicity Relation of LGRB hosts

The star formation rate appears to be the primary parameter to generate a GRB

The low metallicity of observed long GRB hosts is a consequence of the high

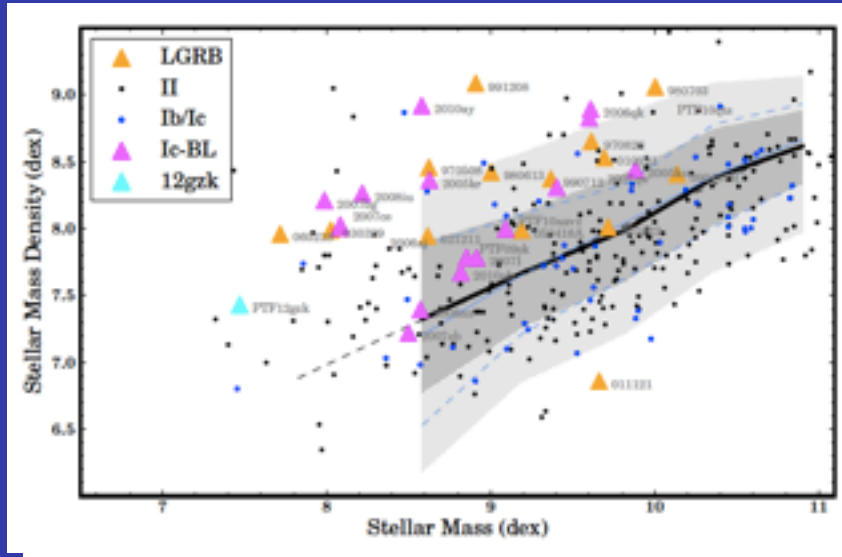
Star formation environment (see however Graham & Fruchter 2013)

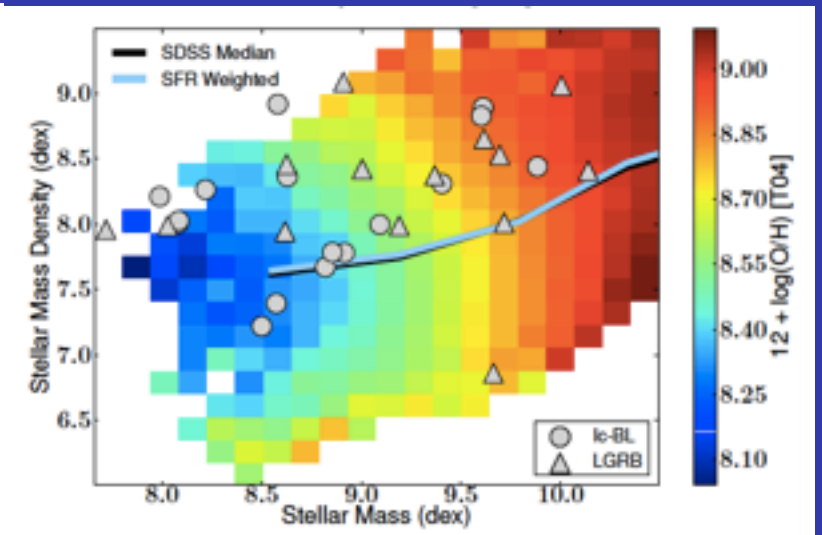


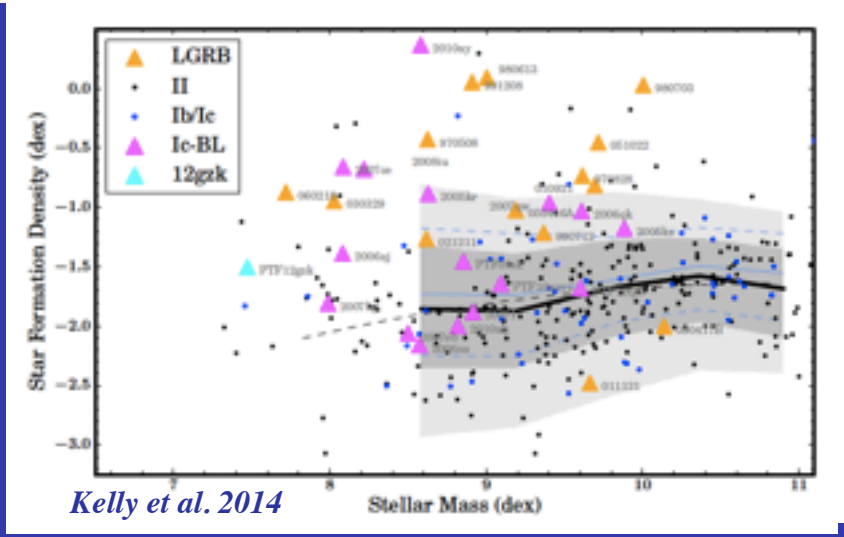
Campisi et al. 2011

Host galaxies of 245 z < 0.2 CC-Sne and 15 z < 1.2 LGRBs

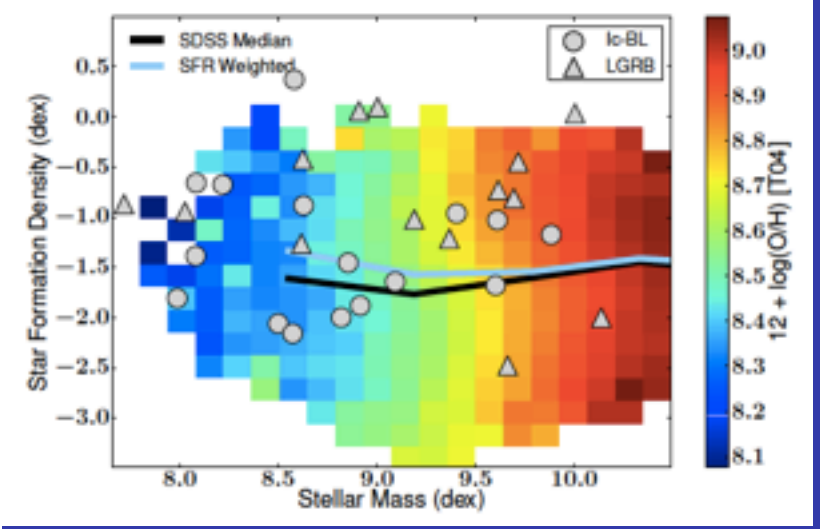
High stellar-mass density suggests binary progenitor systems are favored. Moreover, the preference of SN Ic-BL and LGRBs for galaxies with high stellar-mass and star-formation-rate densities cannot be attributed to a preference for low metal abundances but must reflect the influence of a separate environmental factor.





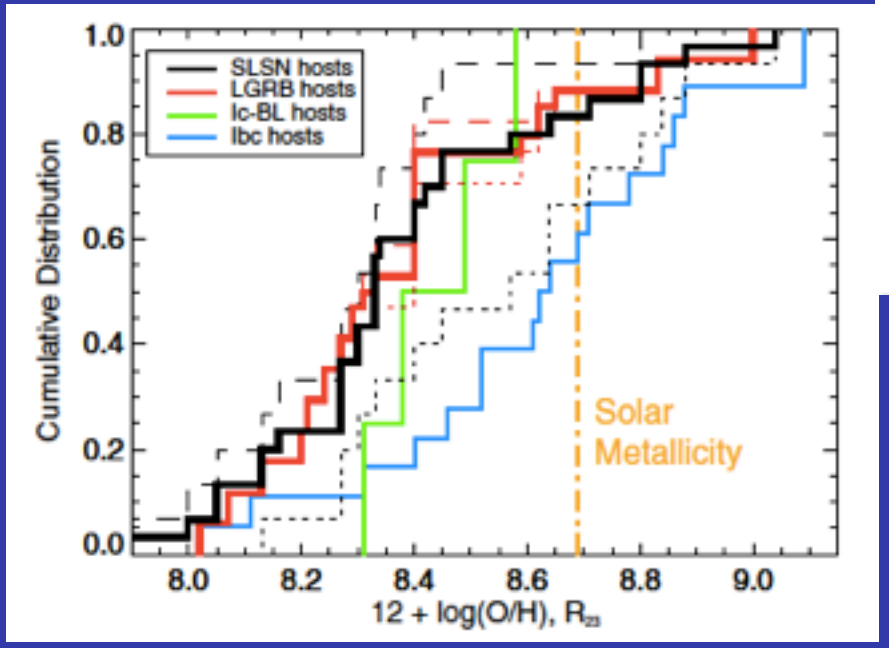


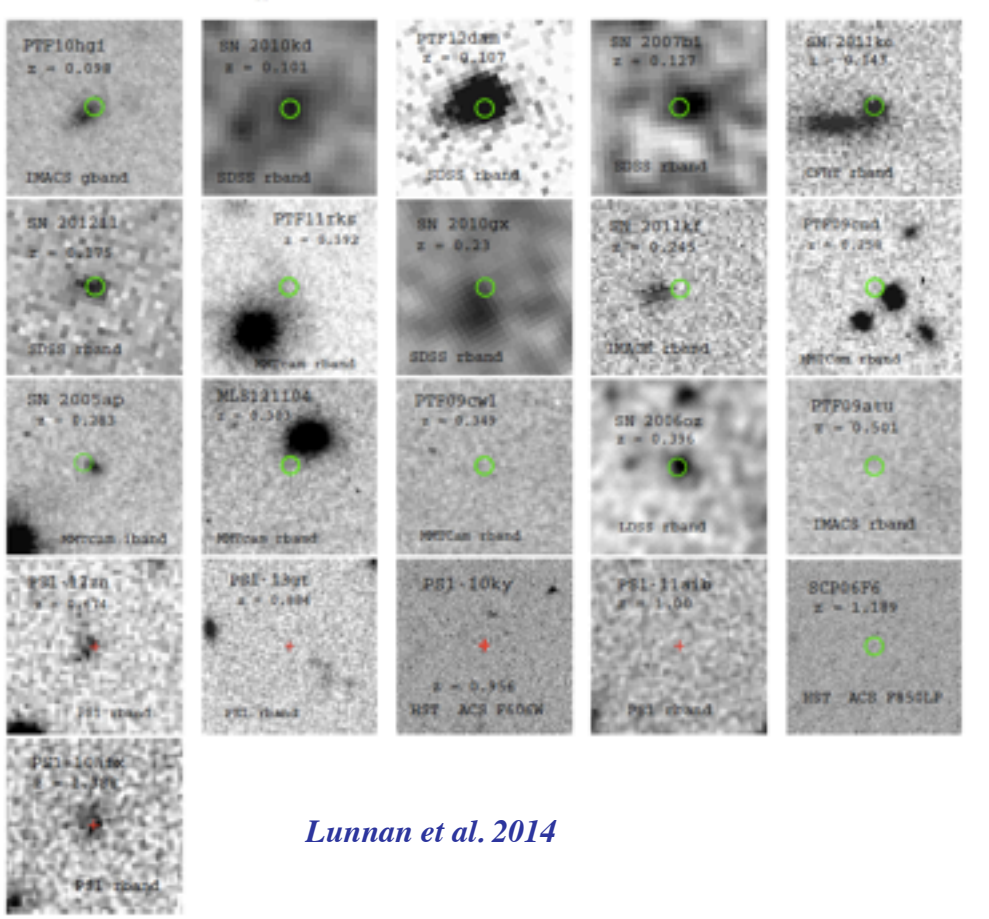
Kelly et al. 2014



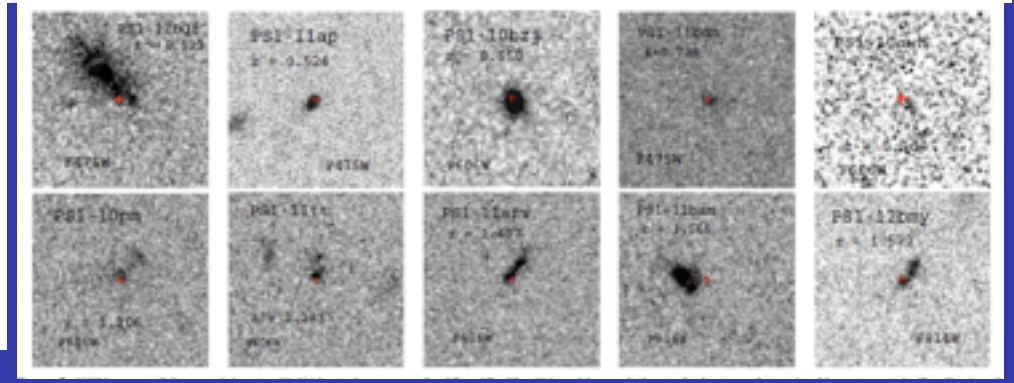
Host galaxies of super-luminous supernovae

The host galaxies of H-poor SLSNe resemble the host galaxies of long GRBs in terms of stellar mass, SFR, sSFR, and metallicity. This indicates that the environmental causes leading to massive stars forming either SLSNe or LGRBs are similar, and in particular that SLSNe are more effectively formed in low metallicity environments: ***large core angular momentum***

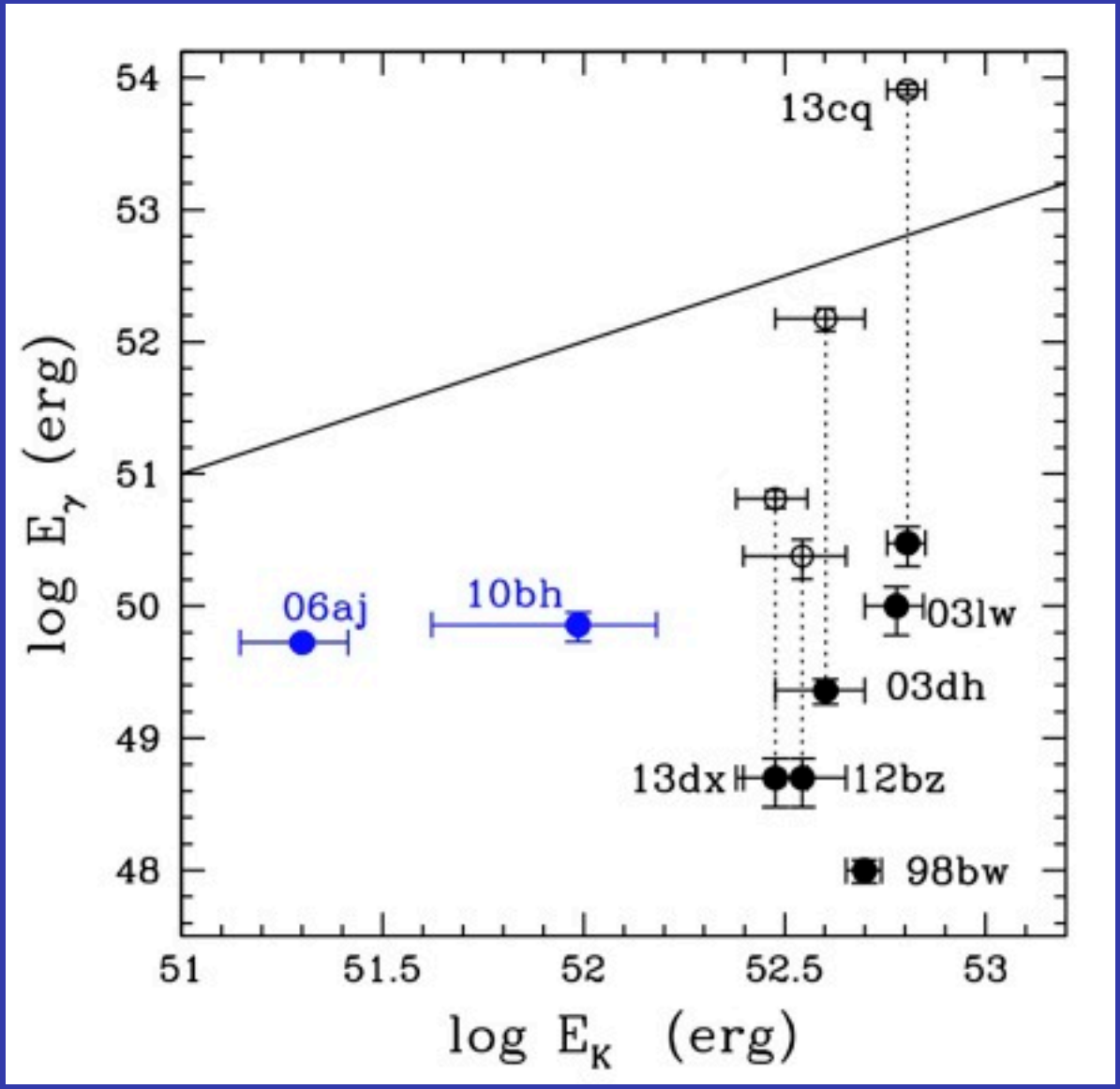




Lunnan et al. 2014



GRB energy output is small fraction of SN kinetic energy

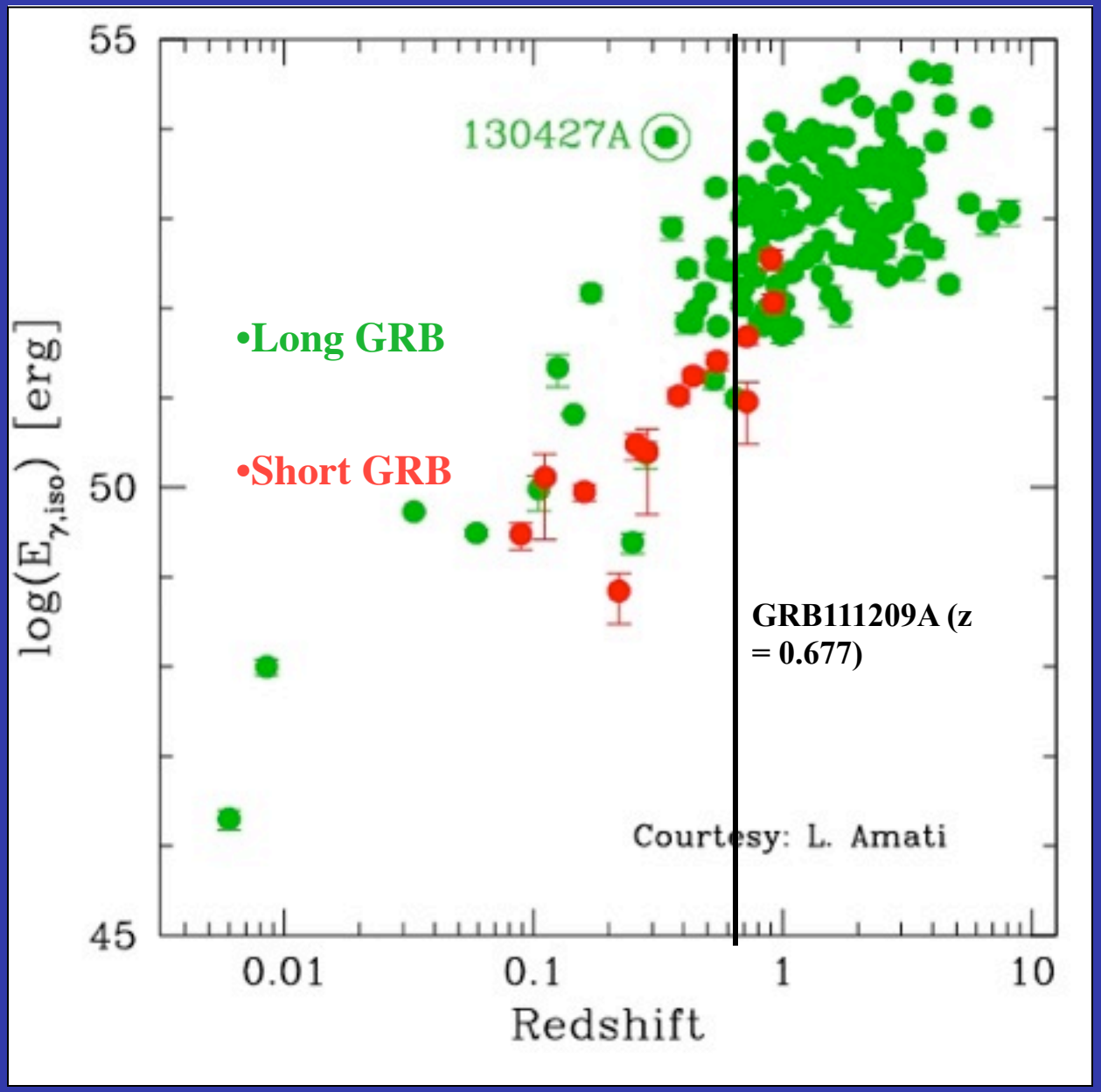


Mazzali, MacFadyen, Woosley, EP, Tanaka 2014

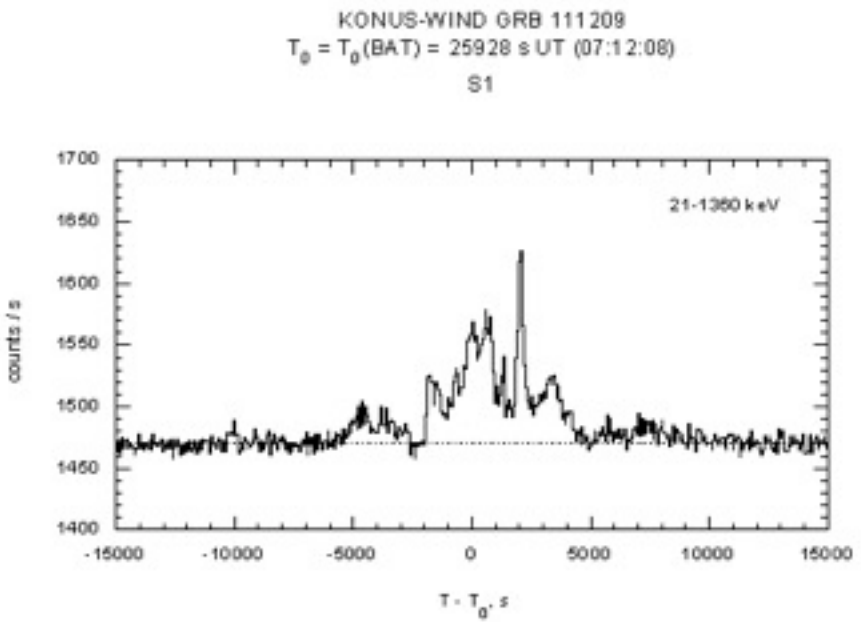
The missing link between GRBs And SLSNe:

GRB111209A/SN2011kl: a very luminous supernova associated with an ultra-long GRB

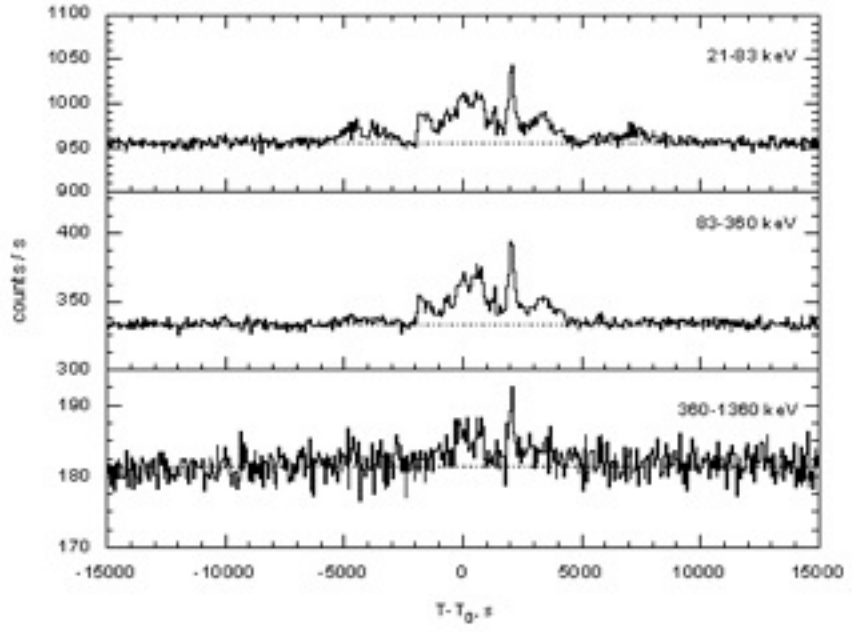
Isotropic irradiated γ–ray energy vs redshift



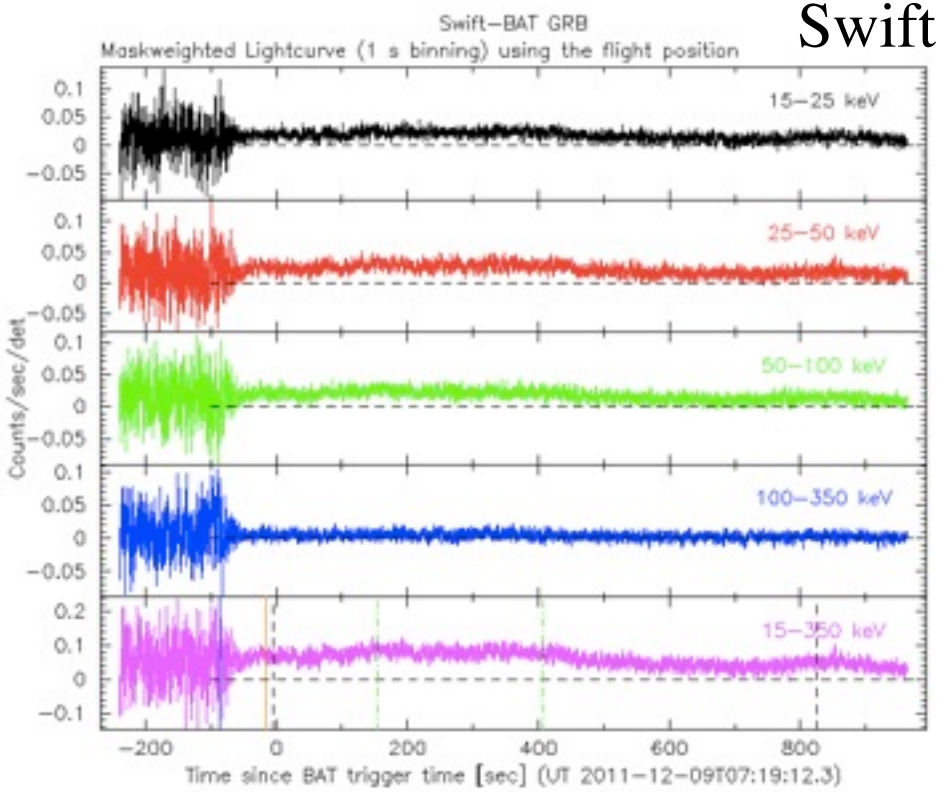
GRB 111209A (z = 0.677)
prompt light curve



Konus-Wind

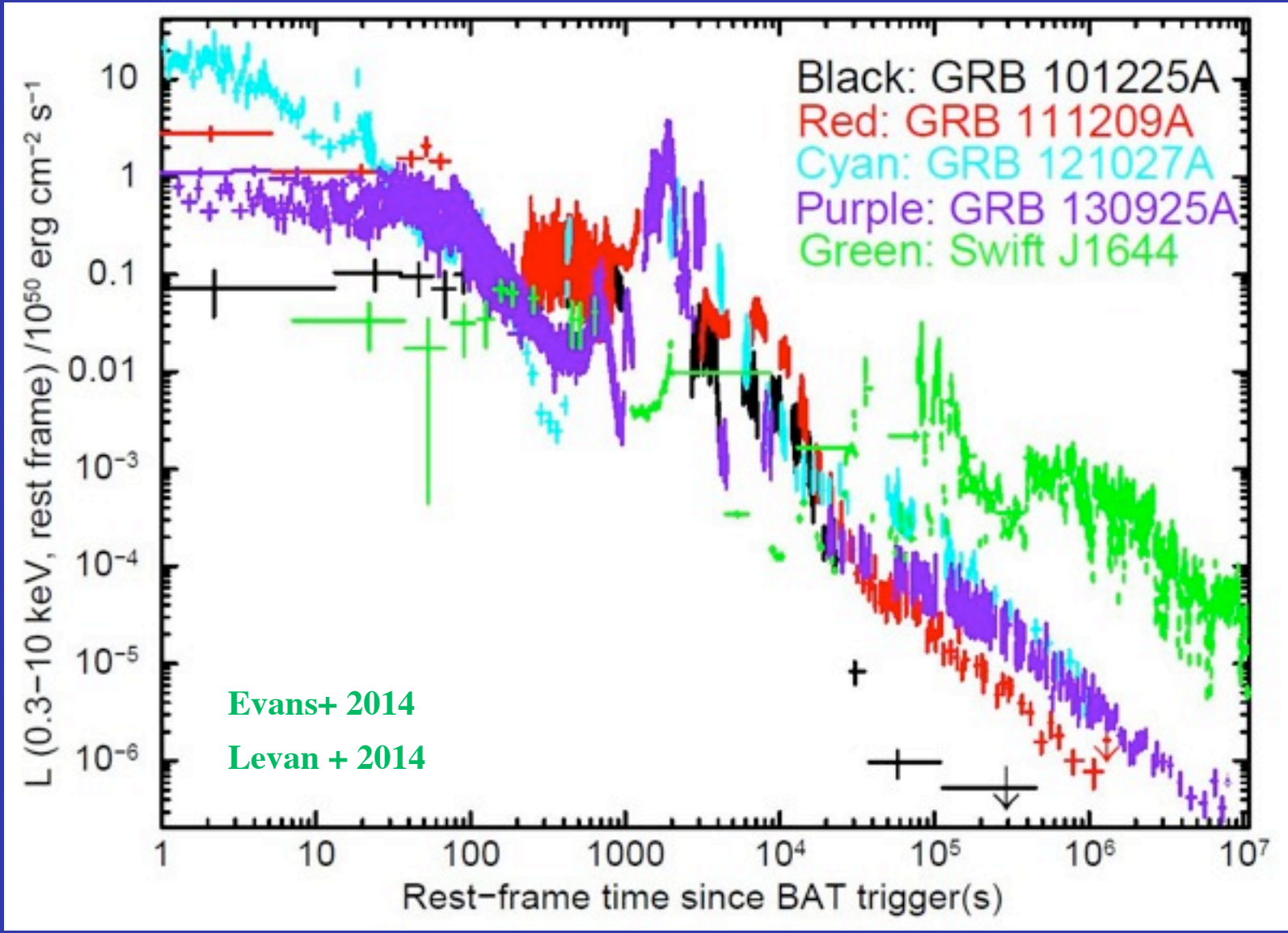


Swift



Ultra-long duration can be properly recognized only by interplanetary satellites

Ultra-long GRBs

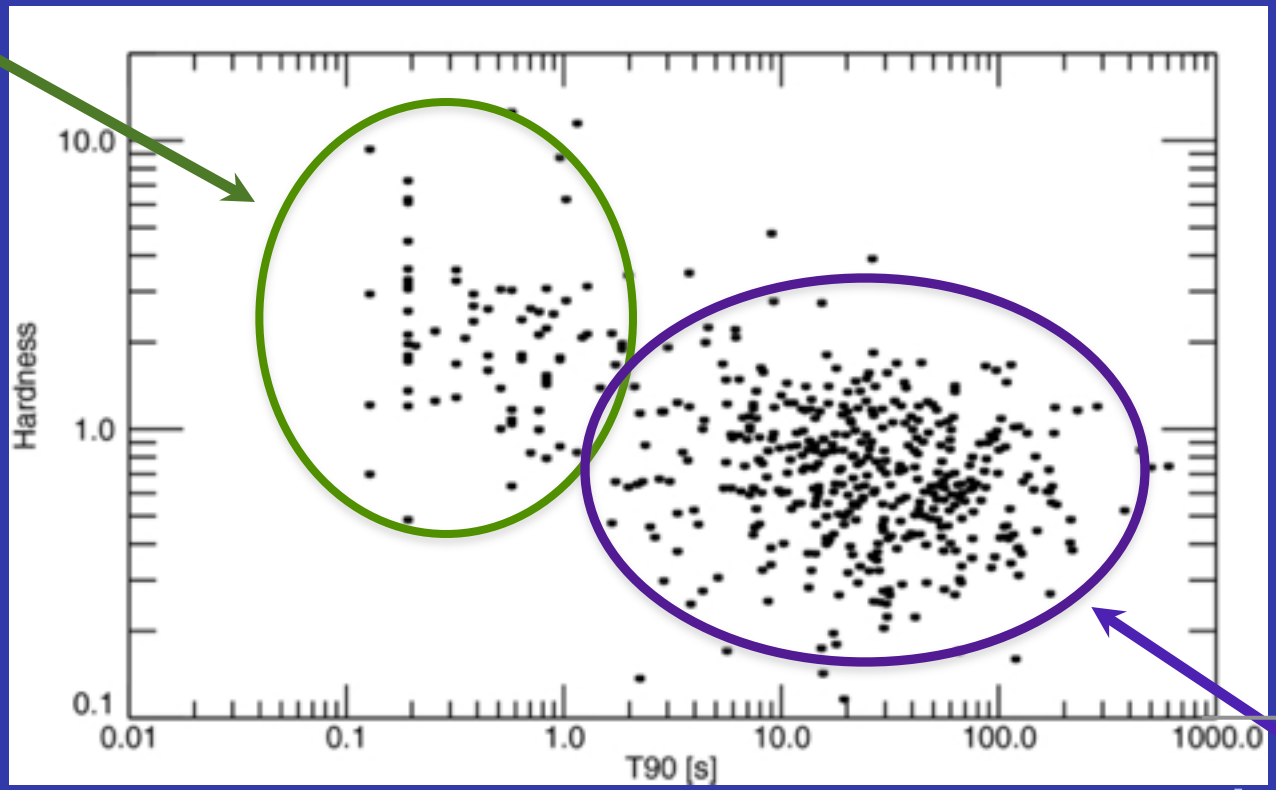


Hardness-Duration Classification

$$H = \frac{\text{50 - 300 keV flux}}{\text{10 - 50 keV flux}}$$

Four GRBs with duration $>10^4$ s

Short/Hard



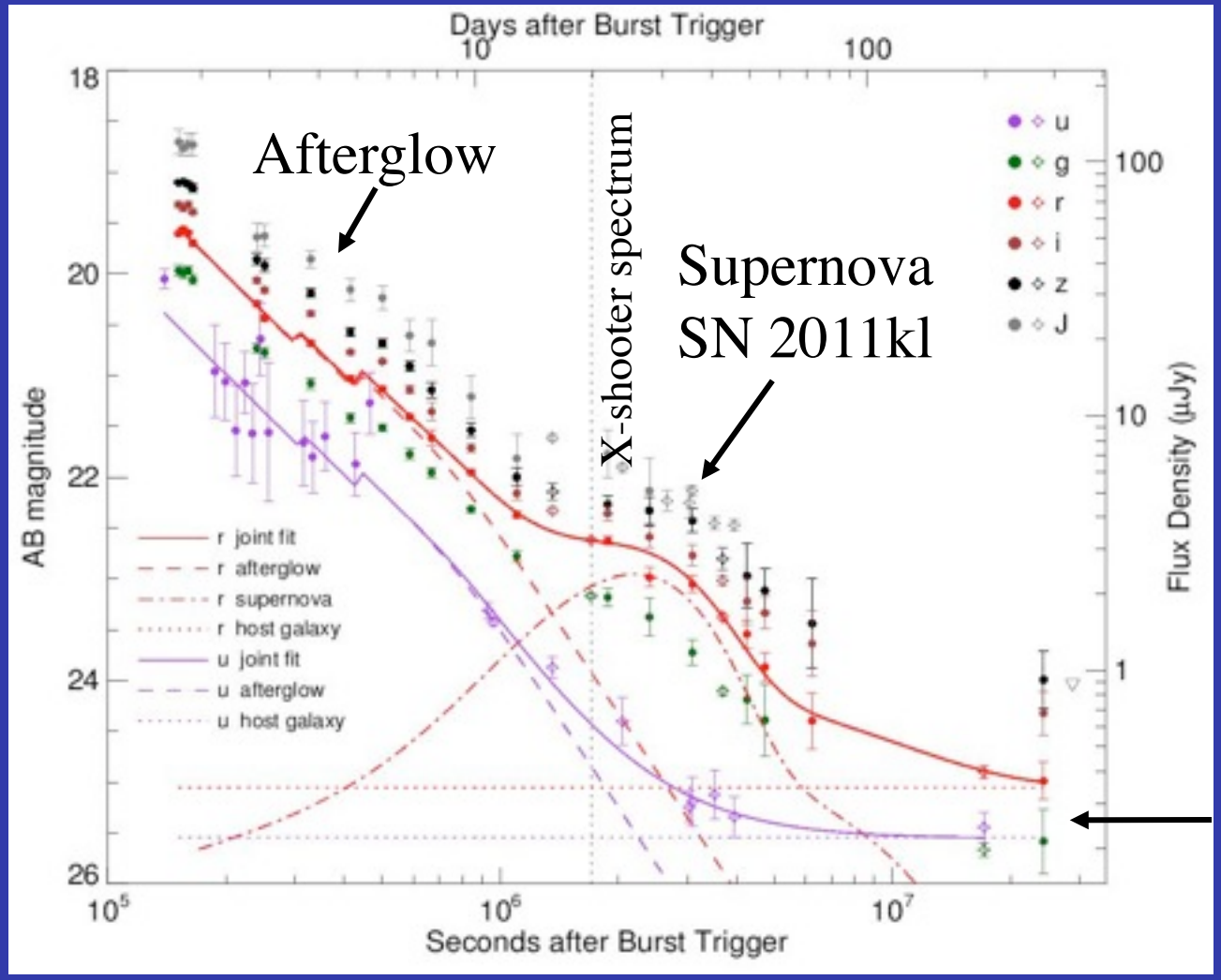
Long/Soft

Kouveliotou+1993; von Kienlin+2014

Ultra-long GRB 111209A (z = 0.677) & its SN

7-channel GROND@2.2m observations over 70 days

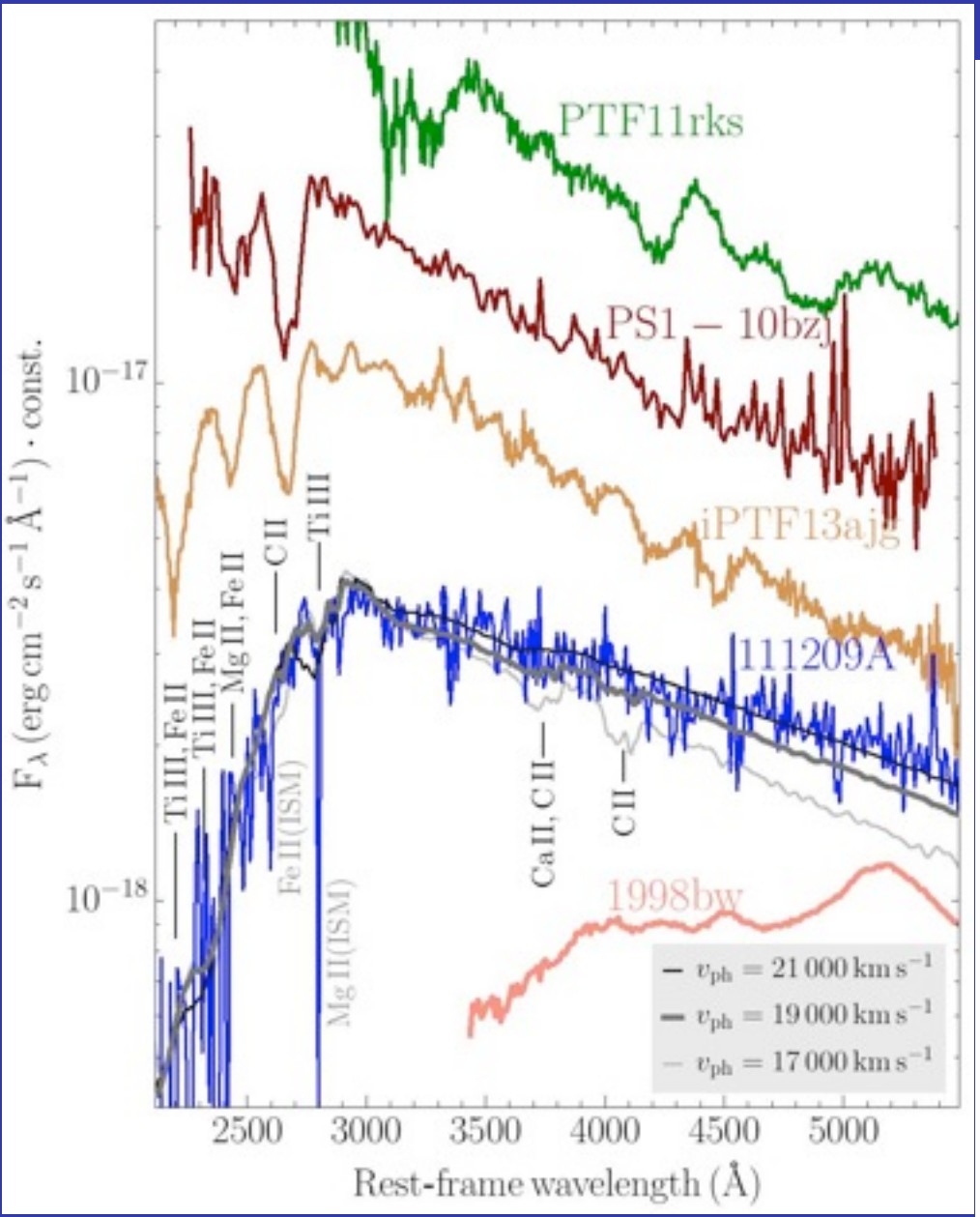
Added Swift/UVOT + publ. HST data (from Levan et al. 2014)



Greiner et al. 2015, Nature, in press

Host

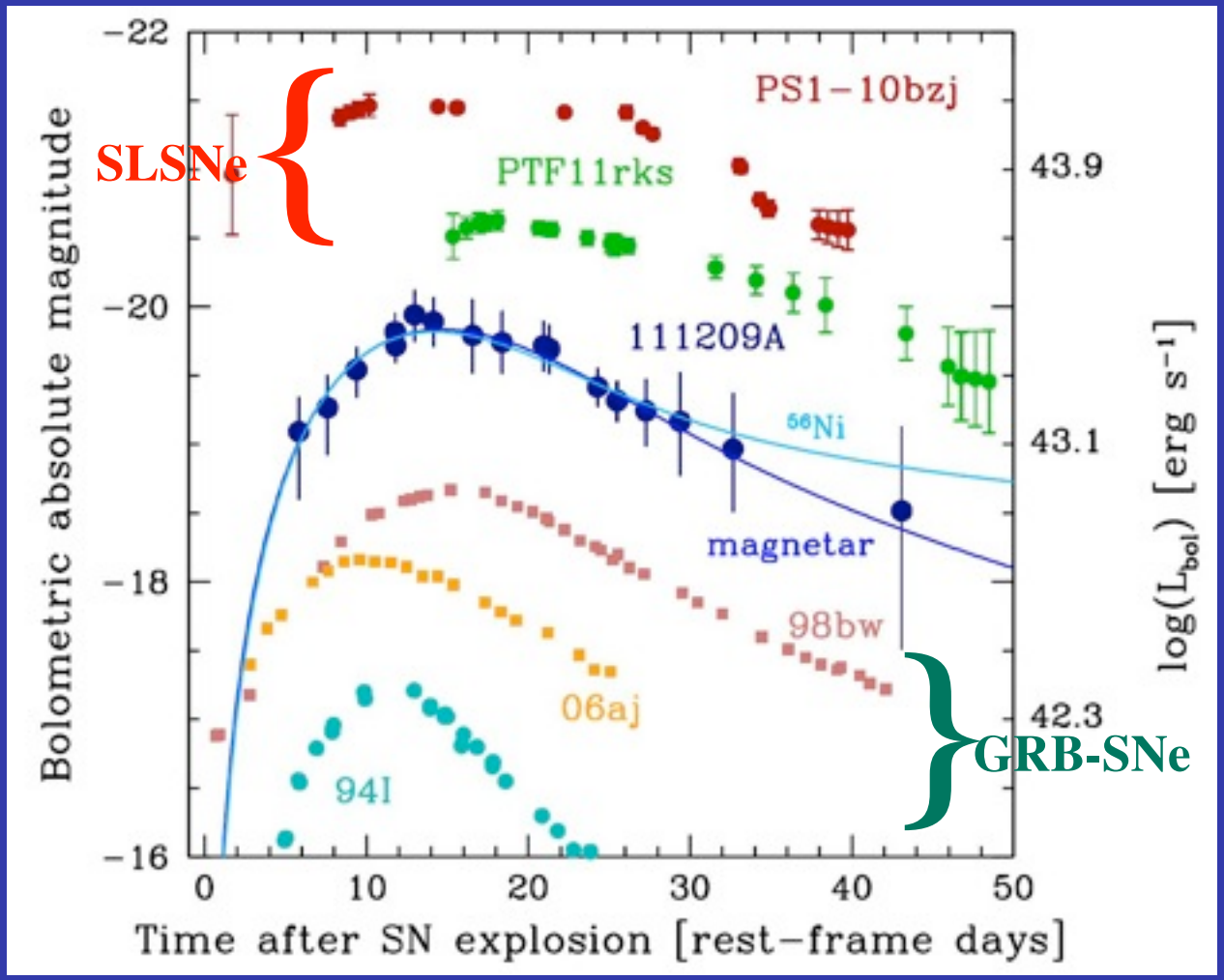
SN 2011kl spectrum (z = 0.677)



- SN 2011kl X-shooter spectrum reminiscent of SLSN
- Spectrum very blue and (nearly) no absorption lines:
  ➔ little ejecta
  ➔ high velocity
- Spectrum reproduced with radiation transport code (Mazzali+00) and a density profile $\varrho \sim r^{-7}$
- featureless spectrum due to line blending ($v_{ph} \sim 20{,}000$ km/s)
- no evidence of freshly synthesized material mixed-in, unlike in GRB-SNe

SN 2011kl light curve

- Bolometric light curve: brighter than any previous GRB/SN, but somewhat fainter than superluminous SN



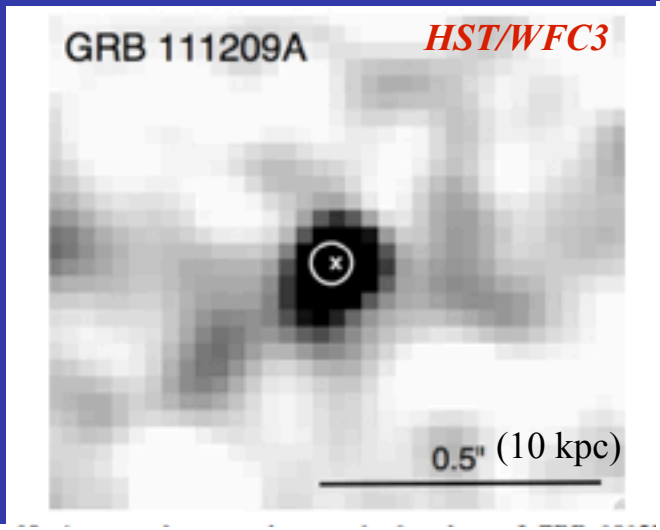
- Luminosity implies $1M_{\odot}$ ^{56}Ni, which is incompatible with the blue UV spectrum
- Needs new explanation: magnetar (spinning, magnetized NS)

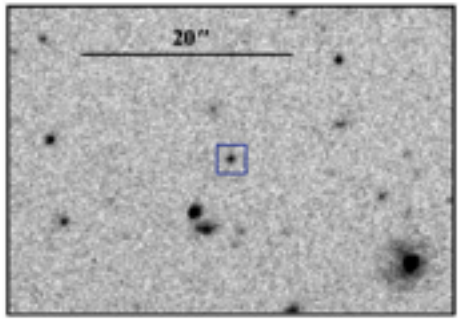
Woosley 2010

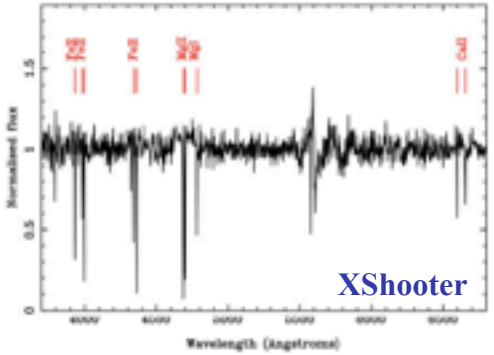
Kasen & Bildsten 2010

- Would also naturally explain ultra-long

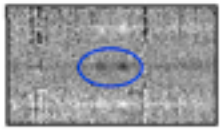
GRB111209A host: Low-extinction, highly star-forming, low Z

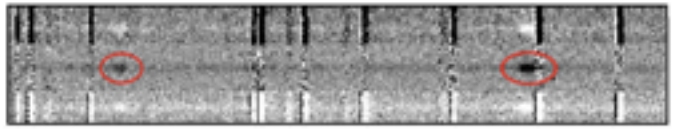


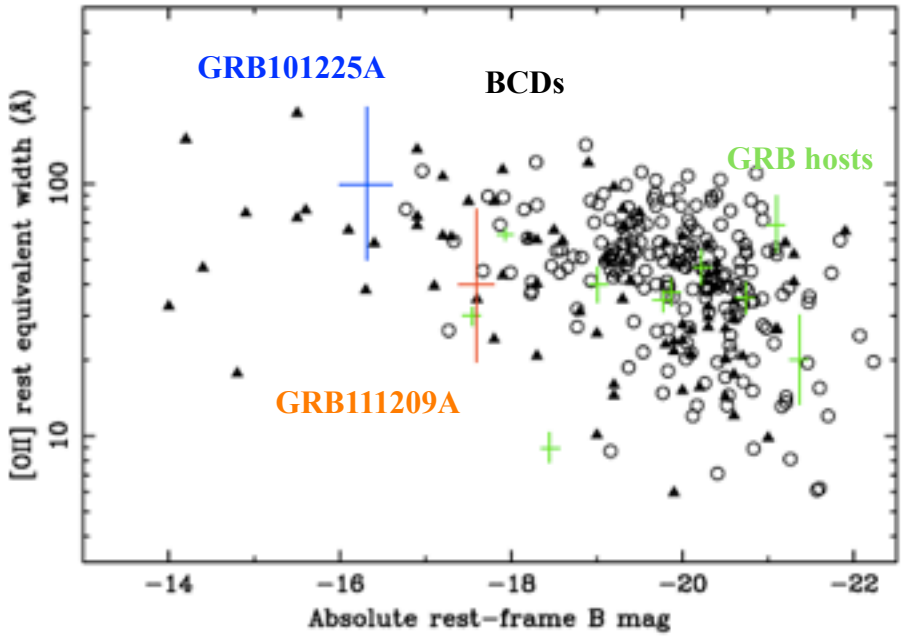


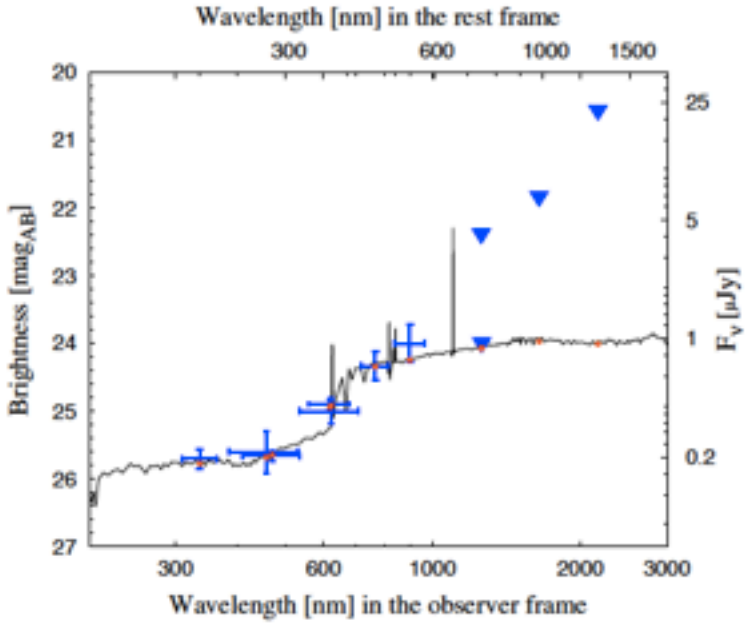


XShooter









Levan et al. 2014

Kann et al. 2014

Conclusions

CC-Sne host galaxies have a wide range of properties. Ic-BL Sne have most similar hosts to LGRBs: low-metallicity seems to be implied, but not in the sense that GRBs favor it. It is probably rather a consequence of other circumstances

SLSNe hosts are similar to those of LGRBs. A common ingredient is inferred and a similar mechanism: a magnetar?

A possible hint comes from the Ultra-long GRB111209A, that is associated with SN 2011kl: 3x more luminous than brightest GRB-SN and intermediate between GRB-Sne and SLSNe

UV spectrum disfavours too high production of 56Nickel: another mechanism must power the LC: a magnetar?

Outstanding questions:

are all LGRBs (and ULGRBs) produced by magnetars?

What is the condition for magnetar and GRB formation in SN explosion?