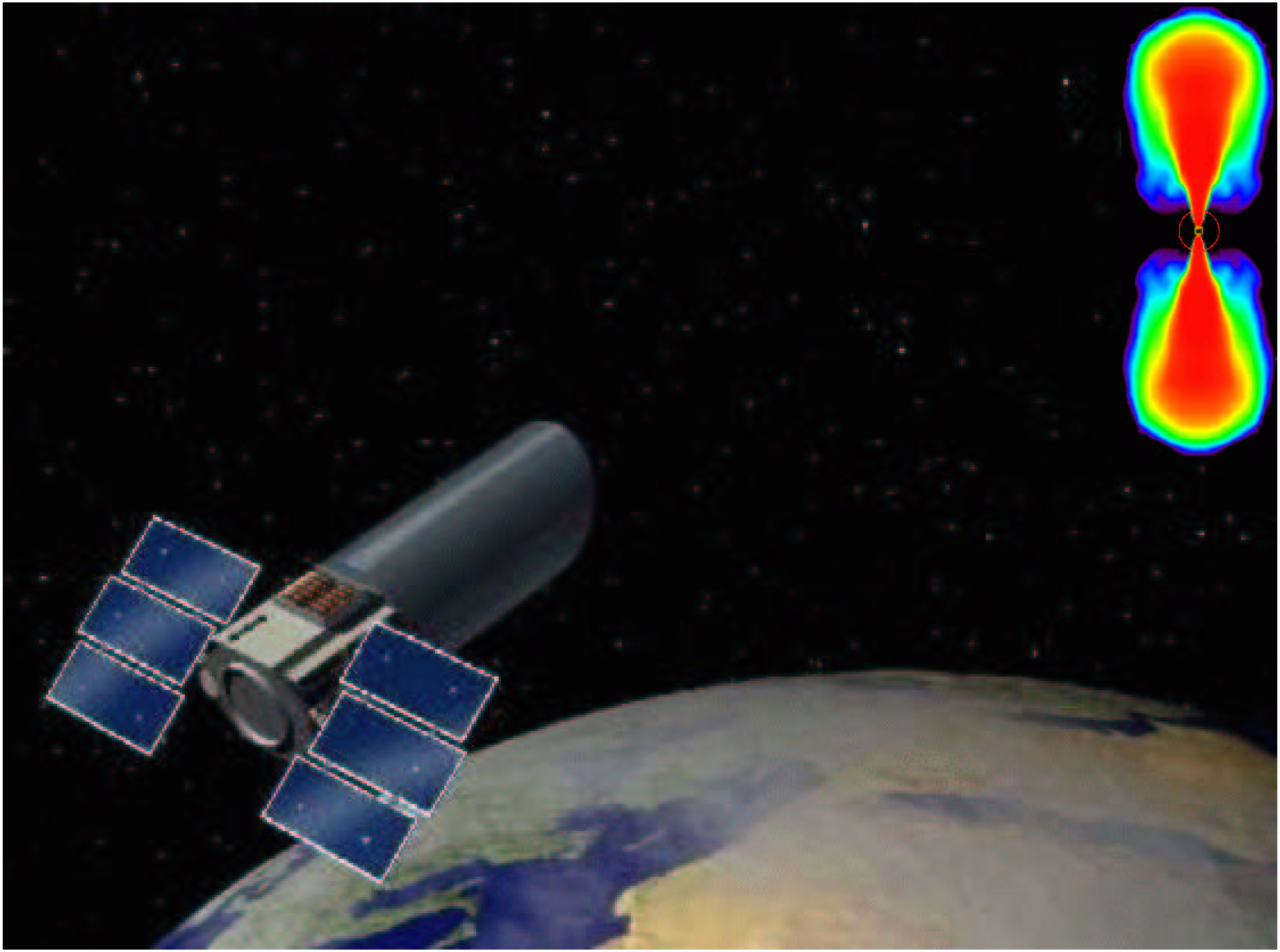
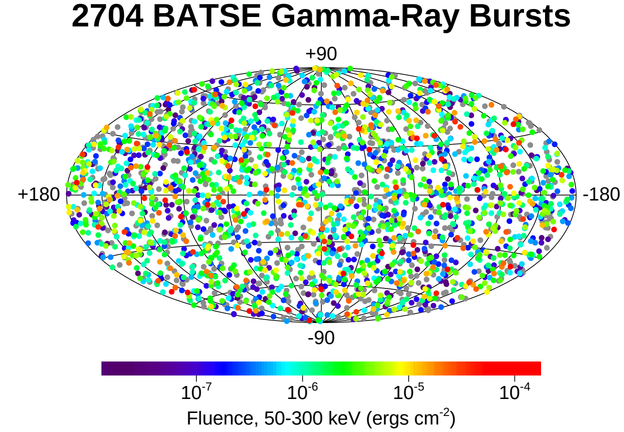
GRB Afterglows and SNAP



2003.03.29 Brian C. Lee (LBL)

GRB and their Afterglows

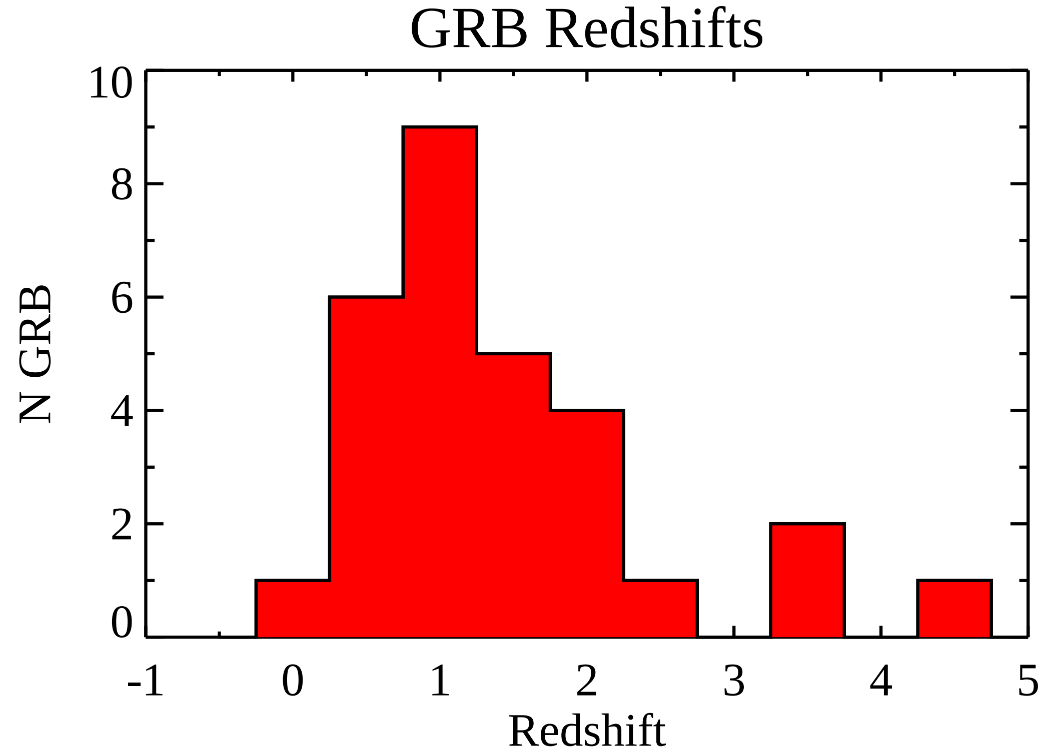
"The biggest bangs since the big bang"



RATE:

at least 1 per day (BATSE) somewhere in the universe
about half have afterglows
many orders of magnitude more rare than SNe.

DISTANCE: at least z = 4.5
(photo−z's above 5)



ENERGY:

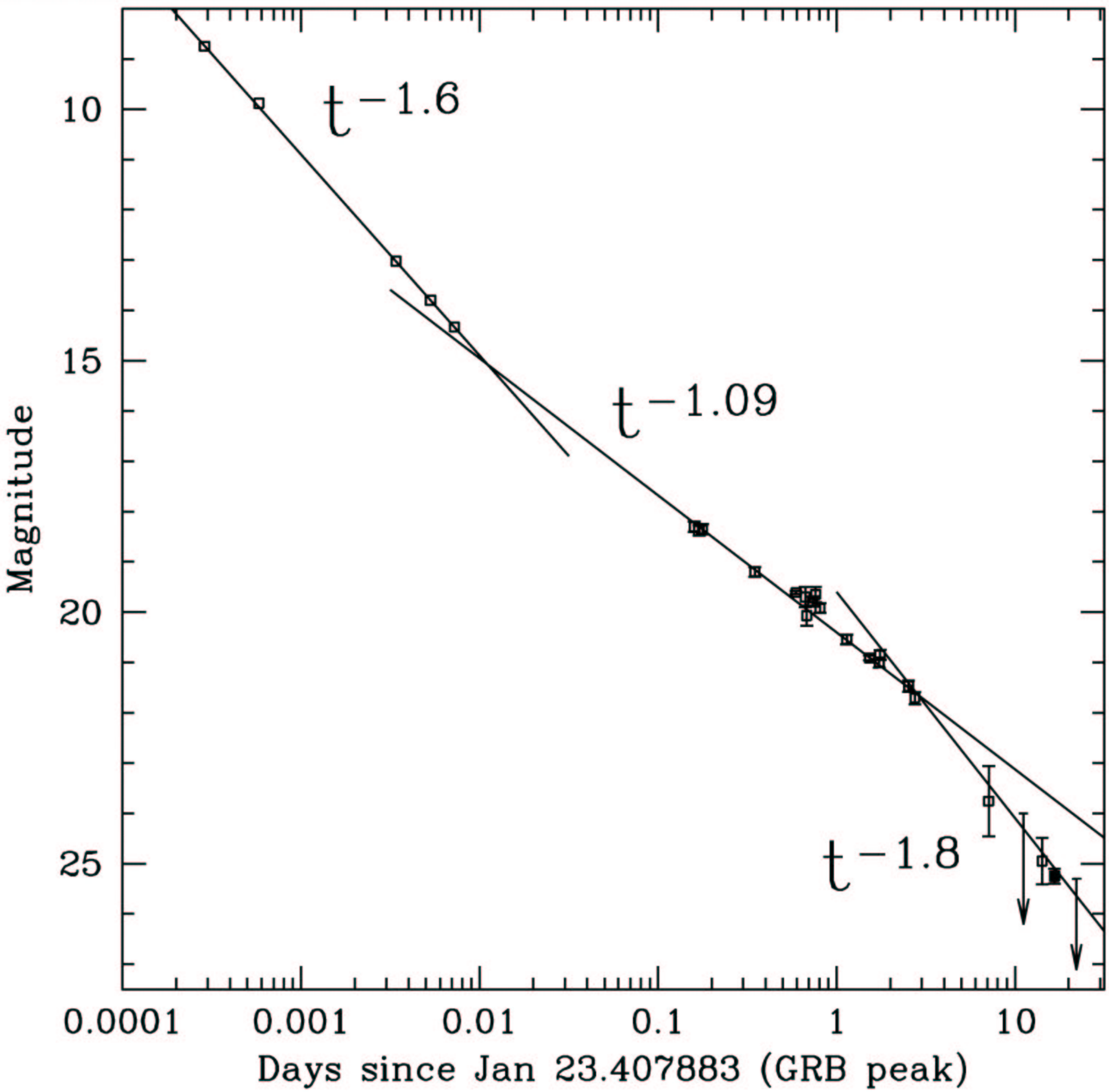
an isotropic explosion would require
$>10^{54}$ ergs total (> solar rest mass)
and $>10^{51}$ ergs/sec

TIME:

optical flux decays as t^{-1} or faster
for space telescopes, visible for weeks or months

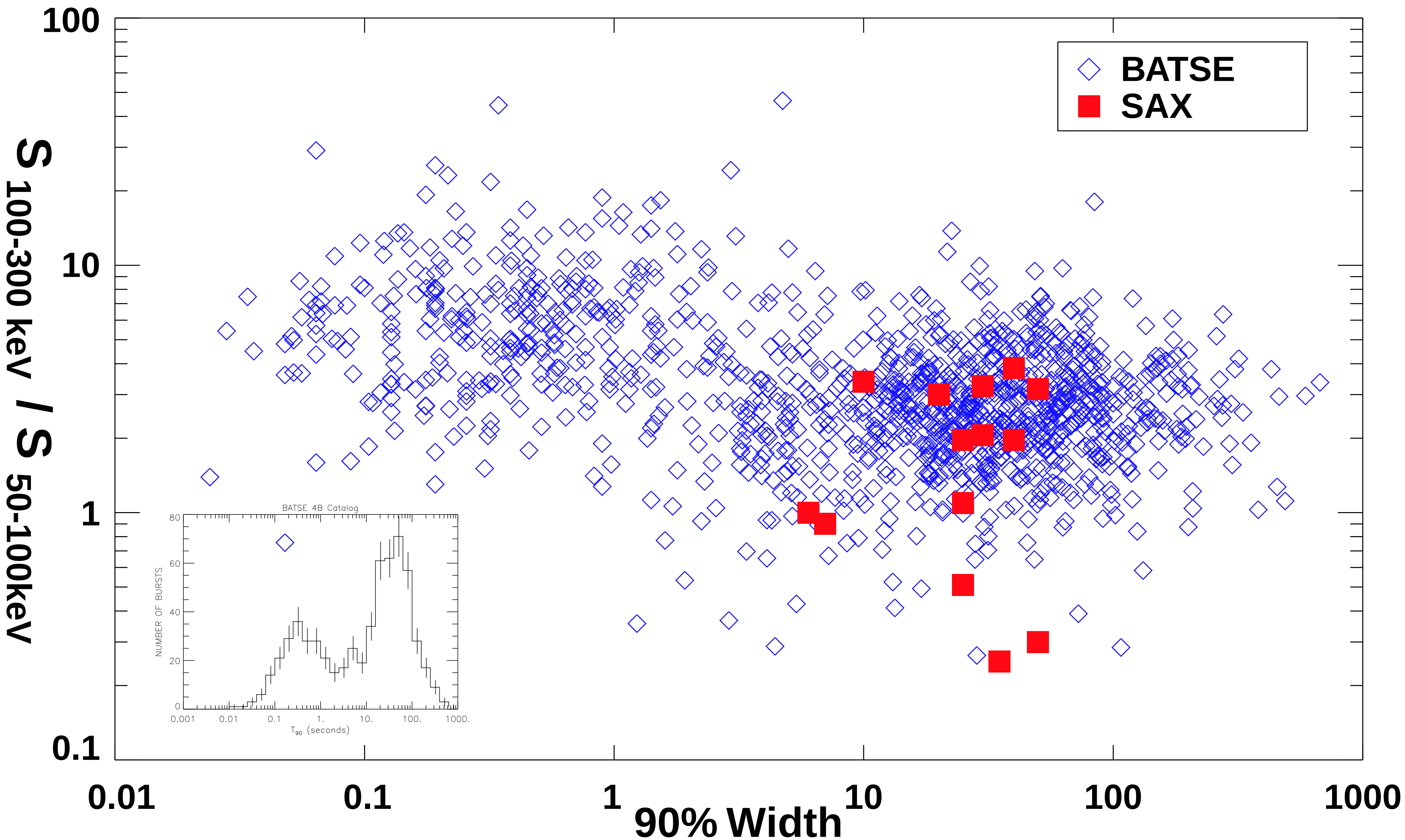
COLOR: flux is also a power law in frequency, roughly ν^{-1}

GRB 990123 Optical Lightcurve



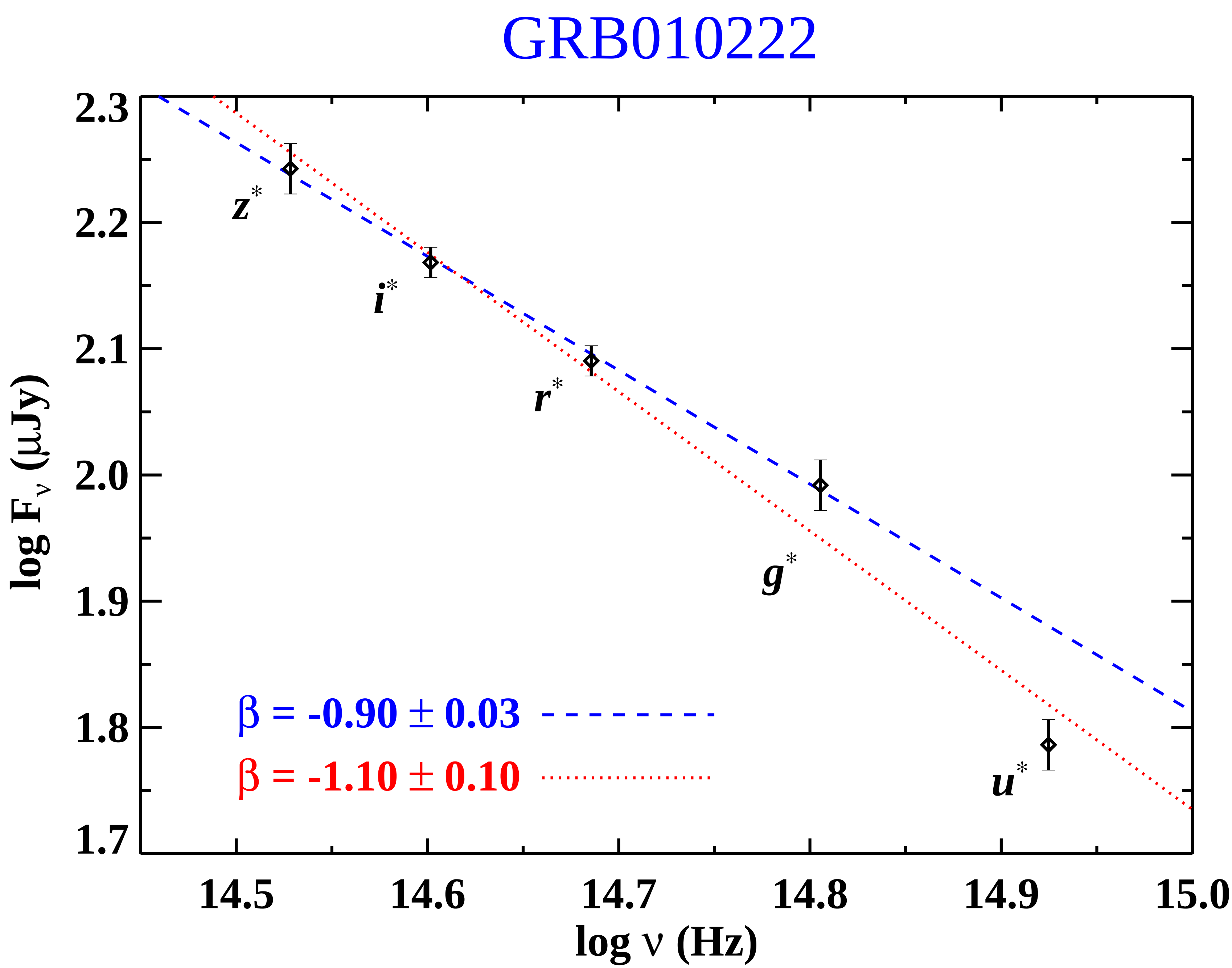
R−band light curve of the OT associated with GRB 990123. All points, except for the HST point (rightmost filled square), were taken from the literature as discussed in the text and reduced to a common flux standard with the galaxy flux subtracted. Error bars are shown where available (1 sigma), and arrows indicate 95% confidence upper limits.

Fruchter et al 1999



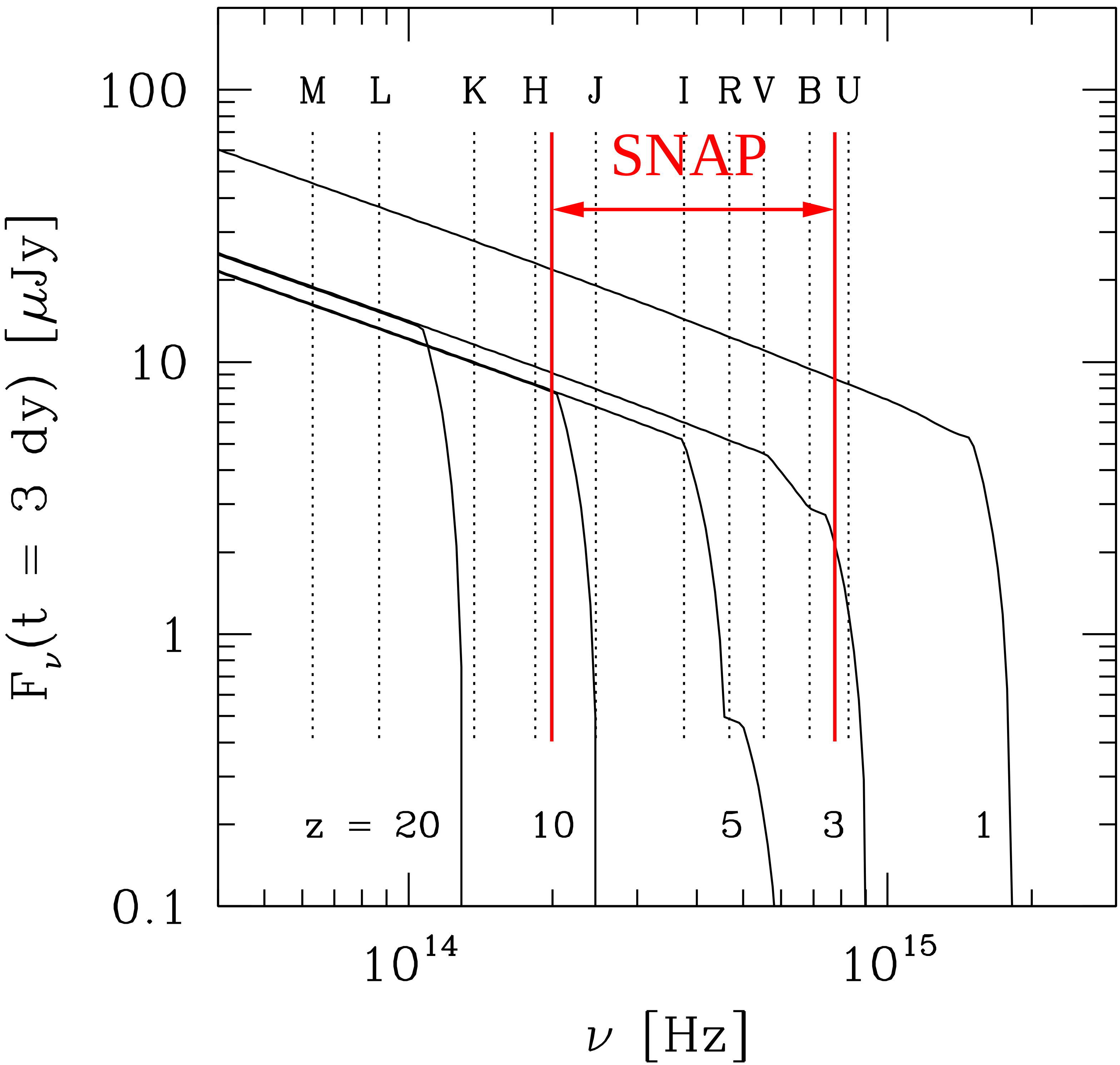
Distribution of duration (T90) vs. spectral hardness for BATSE bursts (diamonds) from the 4B catalogue. There is a clear suggestion of two groups of GRBs: short/hard and long/soft events. Events localized by BeppoSAX (solid squares) appear to belong to the long duration class.

Kulkarni et al. 2000 Inset: Paciesas et al. 1999



SDSS 2.5m multiband observations of GRB010222 at a single epoch. The best fit to F(nu) proportional to nu^beta with all five bands is beta = −1.10 +/− 0.10, shown in red. Excluding u−band produces a fit of beta = −0.90 +/− 0.03, shown in blue.

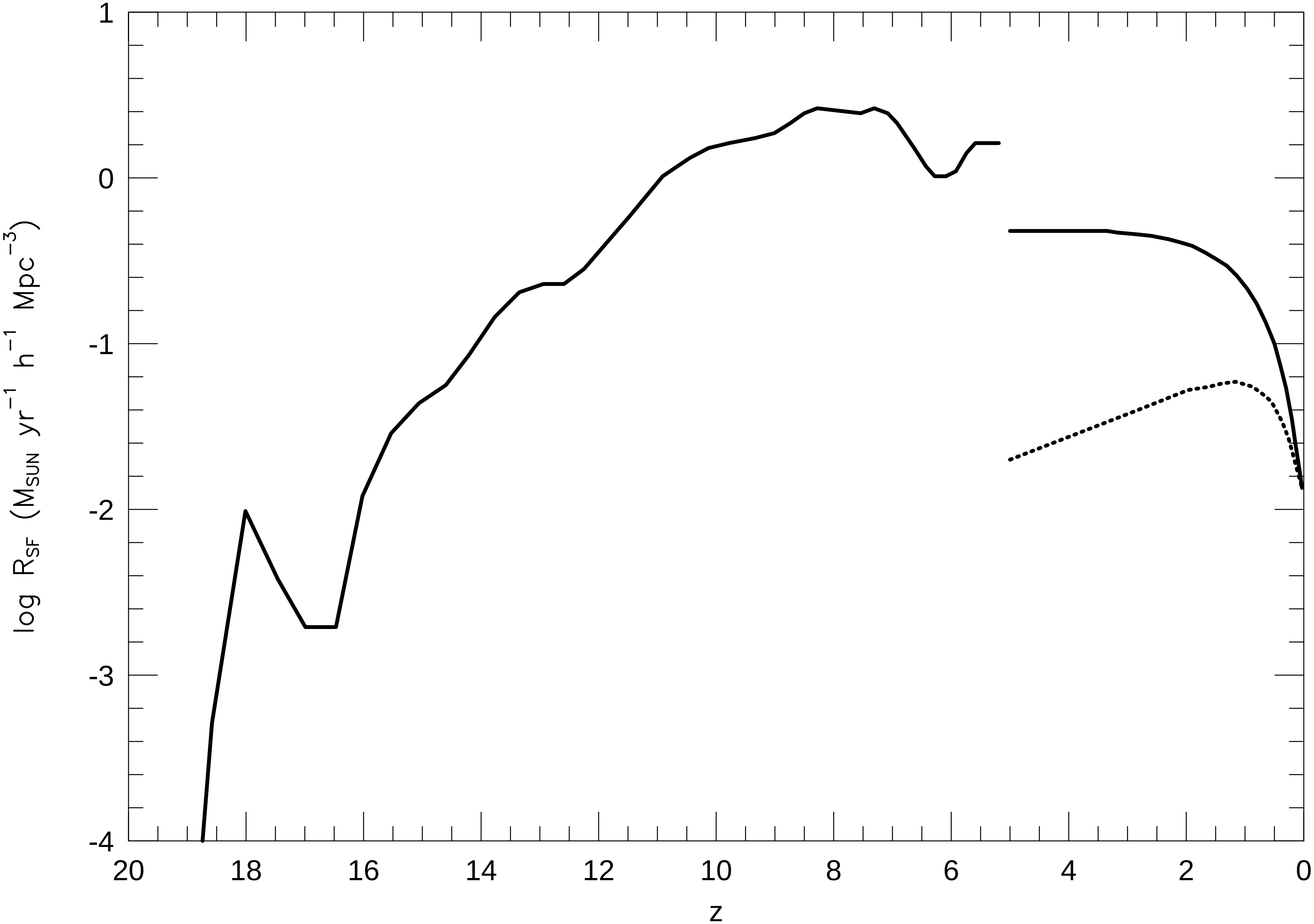
Lee, Tucker, Vanden Berk, Yanny, Reichart et al. 2001



The best−fit spectral flux distribution of the early afterglow of GRB 000131, as observed one day after the burst, after transforming it to various redshifts, and extinguishing it with a model of the Lyman−alpha forest. From Lamb 2002.

SNAP will be able to see GRB afterglows out to **z~10** (if they are there!)

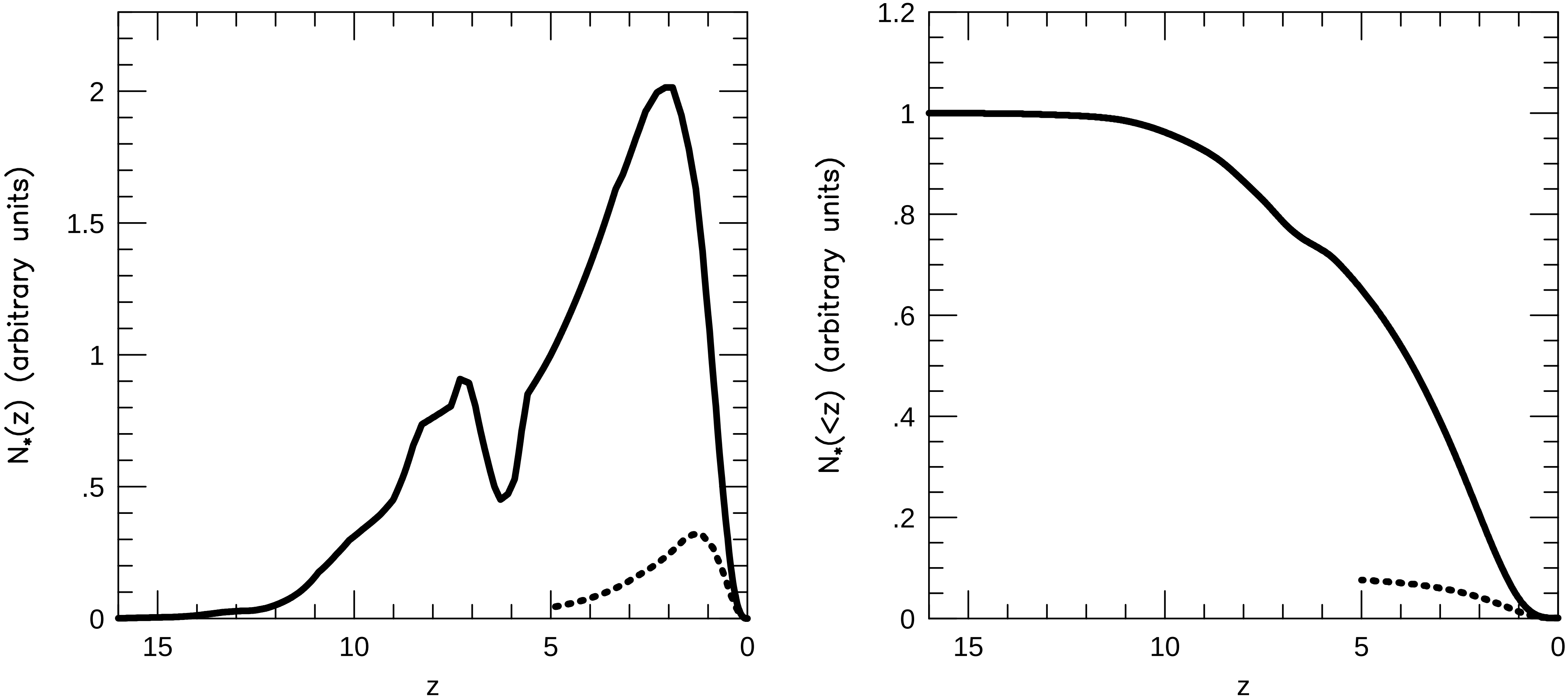
STAR FORMATION RATE: little known past z=2



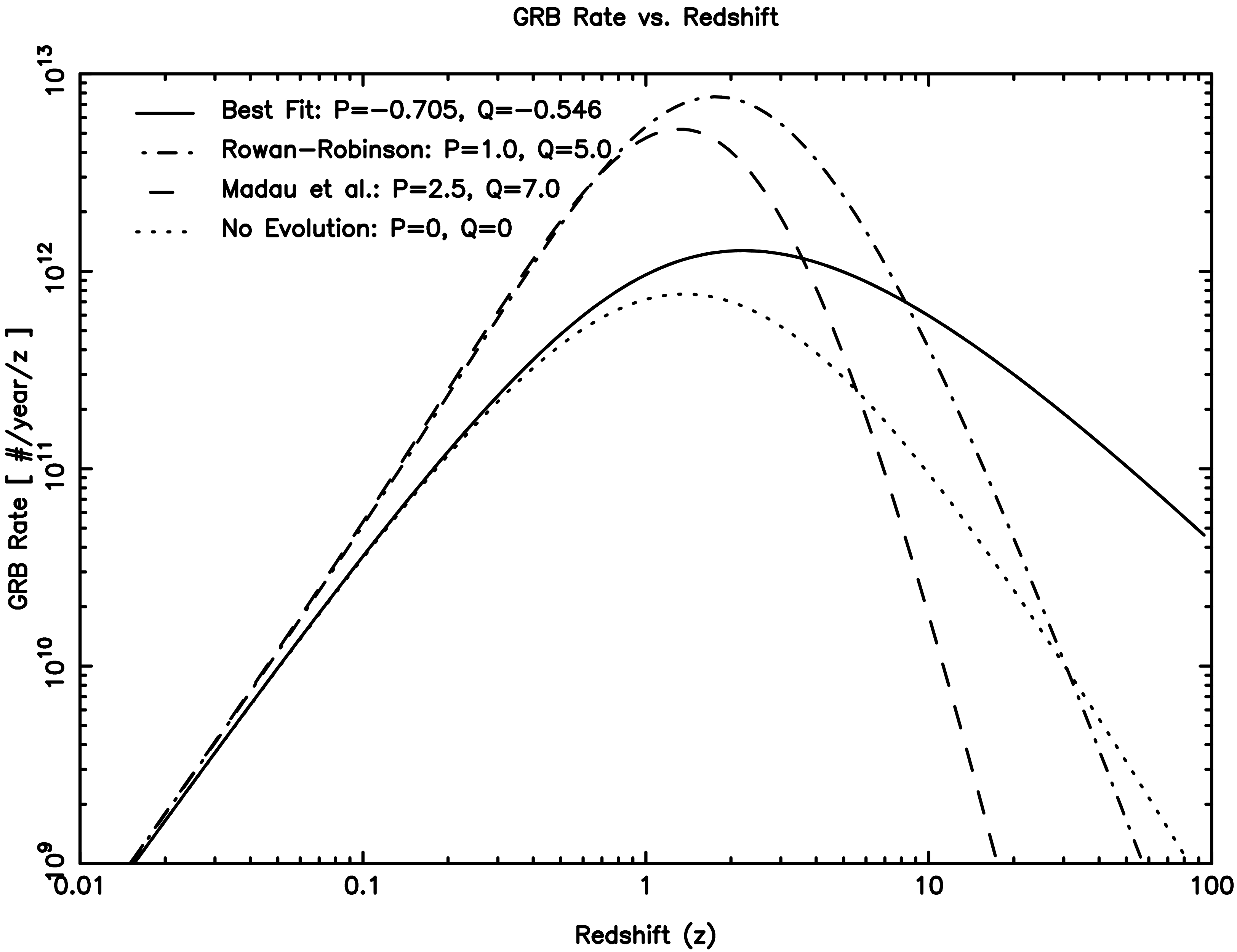
The cosmic SFR as a function of redshift z. The solid curve at z <5 is the SFR derived by Rowan−Robinson 1999; the solid curve at z >= 5 is the SFR calculated by Ostriker & Gnedin 1996 (the dip in this curve at z ~ 6 is an artifact of their numerical simulation). The dotted curve is the SFR derived by Madau, Pozzetti, & Dickinson 1998.

From Lamb & Reichart 2000, Lamb 2002.

Number of stars as a function of redshift

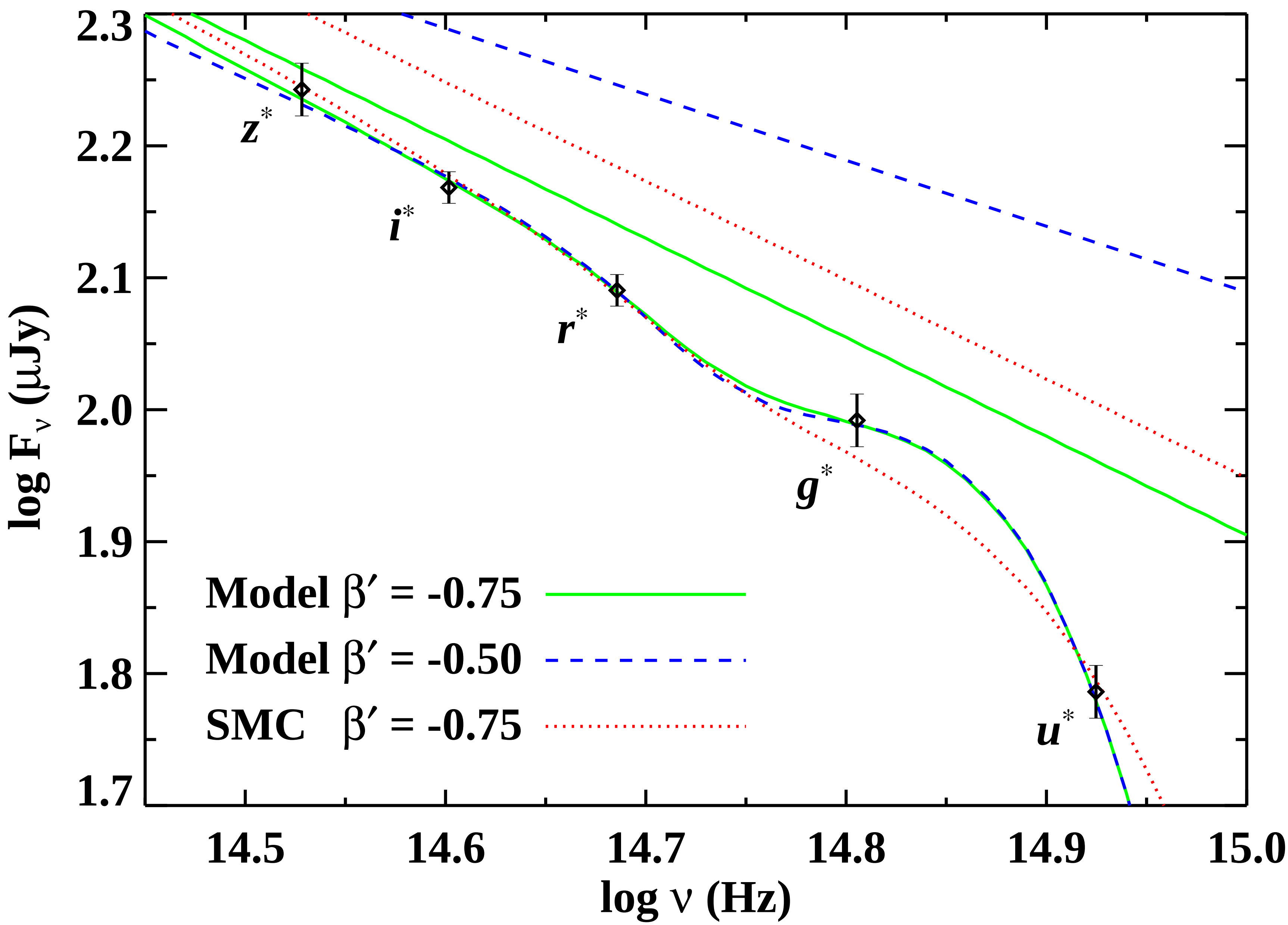


Left panel: The number of stars expected as a function of redshift z (i.e., the SFR from the previous figure, weighted by the differential comoving volume, and time−dilated) assuming that Omega_M = 0.3 and Omega_Lambda = 0.7. Right panel: The cumulative distribution of the number of stars expected as a function of redshift z. Note that approximately 40% of all stars have redshifts z > 5. The solid and dashed curves in both panels have the same meanings as in the previous figure.
From Lamb & Reichart 2000, Lamb 2002.

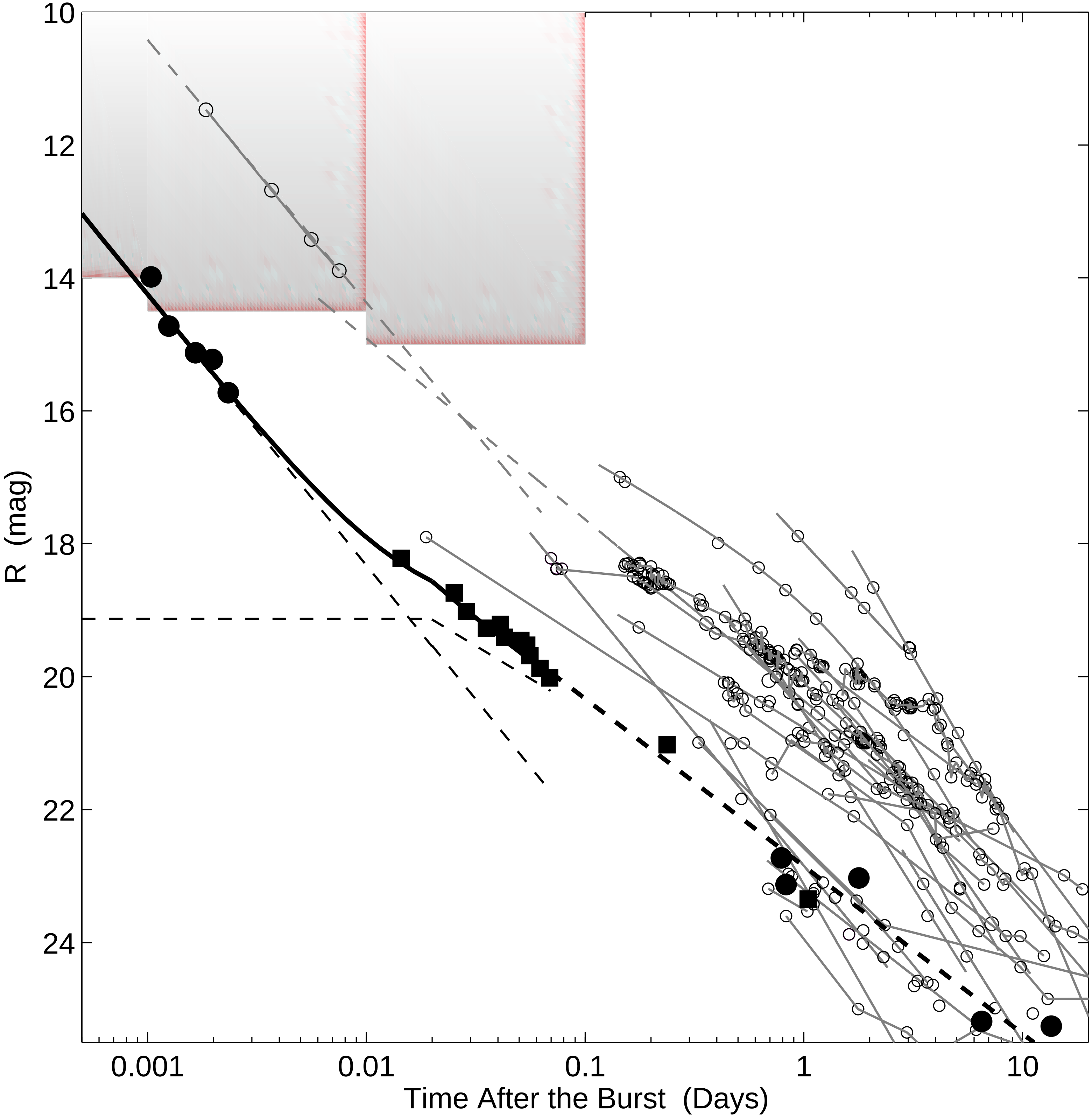


The GRB rate per unit redshift z (estimated using GRB variability, Reichart et al. 2000). Estimates of the star formation rate as a function of redshift z made by Madau et al. (1998) and Rowan−Robinson (1999) are shown in both panels for comparison, as is the no evolution with redshift z model (P=Q=0). We emphasize that we have not taken into account the statistical and systematic errors in the redshifts z and intrinsic peak photon luminosities L derived from the variability measure V, and therefore cannot quote meaningful confidence regions for our best−fit parameters. From Donaghy et al. 2002.

GRB010222: Extinction by Host Galaxy



Host galaxy extinction fits at z = 1.477 for GRB010222. The two best fit extinction models from Reichart 2001 as well as an SMC curve are presented here. The best fits indicate this burst was in a star forming region which may have been modified by the burst itself. From Lee, Tucker, Vanden Berk, Yanny, Reichart et al. 2001



Light curves of many GRB afterglows, from Fox et al. 2003.

At mag=27−28, afterglows remain visible for ~40 days or more.

Afterglow rates in the SNAP surveys

Afterglow rate (conservative): from BATSE, 0.5/day

Duration: with ABmag limits ~27−28, typically visible for at least 40 days

Probability of seeing a particular afterglow

SNe survey: 7.5 of 40,000 sq. deg. every 4 days ~ 1 in 5000

number of afterglows in 16 x 2 months ~ 0.1 afterglow

Weak Lens survey: ~2 sq.deg. per day, 40 days ~ 1 in 500

number of afterglows in 5 months ~ 0.15 afterglow

TOTAL: **approx. 25% chance of seeing 1 afterglow in 3 years**

What if we take a less conservative rate?

Visible for months: ~ few (<10) afterglows

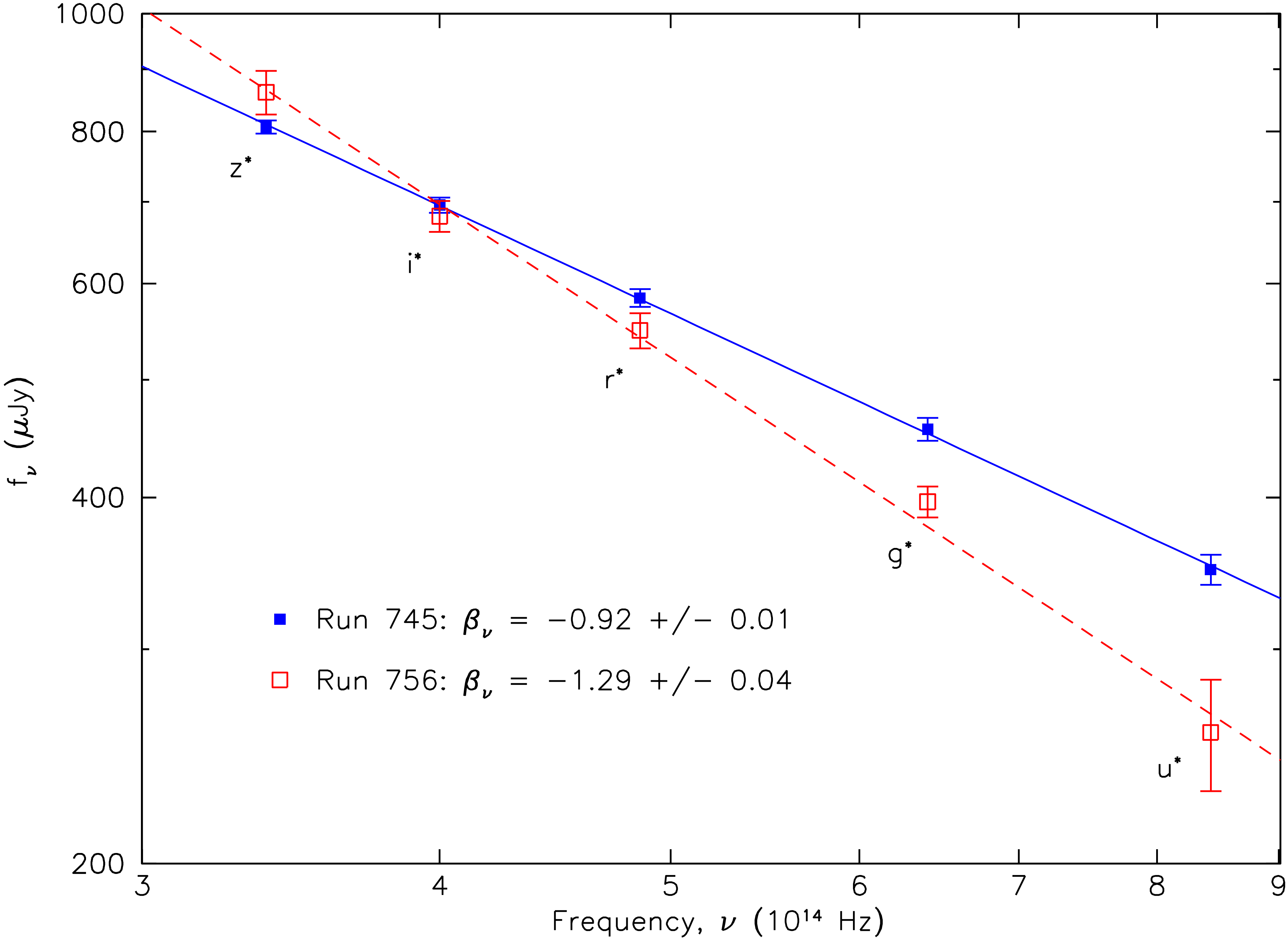
High early massive star SFR + hypernova/collapsar: 1 or a few afterglows

"Orphan" afterglows: possibly a few to 10's of afterglows

If nature smiles on SNAP, it might see a few or even 10's, but probably not 100's, of (mostly orphan) afterglows in the planned surveys.

→ SNAP will need to point to find afterglows (Guest Observer program?)

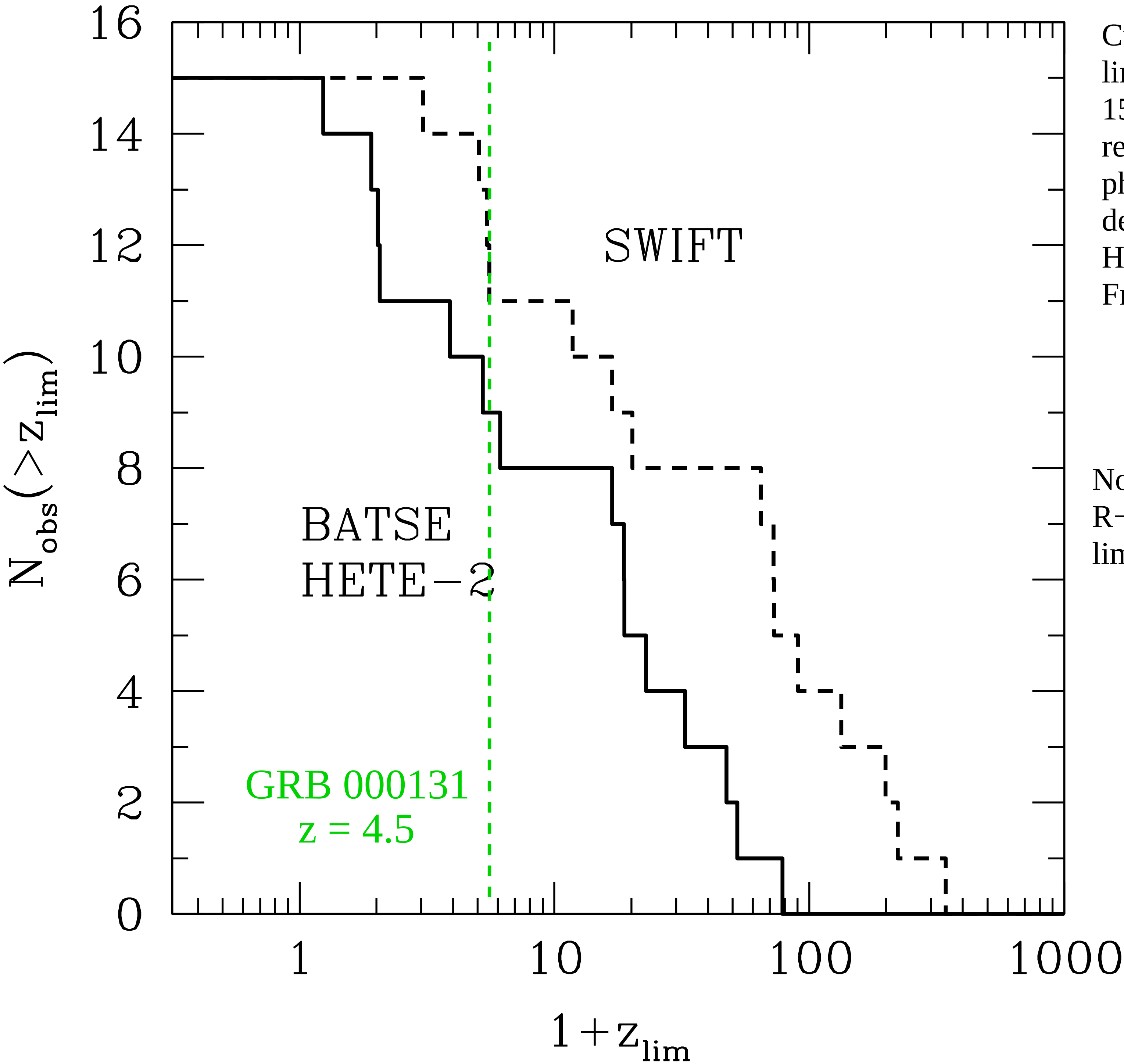
AGN



Some AGNs look like better GRB afterglows than real afterglows do!

Figure from Vanden Berk, Lee, Wilhite, Beacom, Lamb et al. 2002

GRB detection limits as a function of z for Swift



Cumulative distributions of the limiting redshifts at which the 15 GRBs with well−determined redshifts and published peak photon number fluxes would be detectable by BATSE and HETE−2, and by Swift. From Lamb 2002.

Note that typical ground based R−band afterglow searches are limited to a redshift of z < 5.

SUMMARY: SNAP and GRB Afterglows

PROS:

- A probe of the universe out to $z \sim 10$
  - QSO−like probe (epoch of reionization)
  - SFR of early universe (possibly the first stars)
  - Properties of early galaxies
  - Cosmological "standard candle" to $z=10$?
- And as a bonus: GRB physics/burst environment

CONS:

- You wont get many (if any) unless you point
- What you do get (if you get many) will be orphans (followup)
  - If you want to point
    - Swift and/or GLAST will be able to tell you where and you’ll have weeks to get around to it.