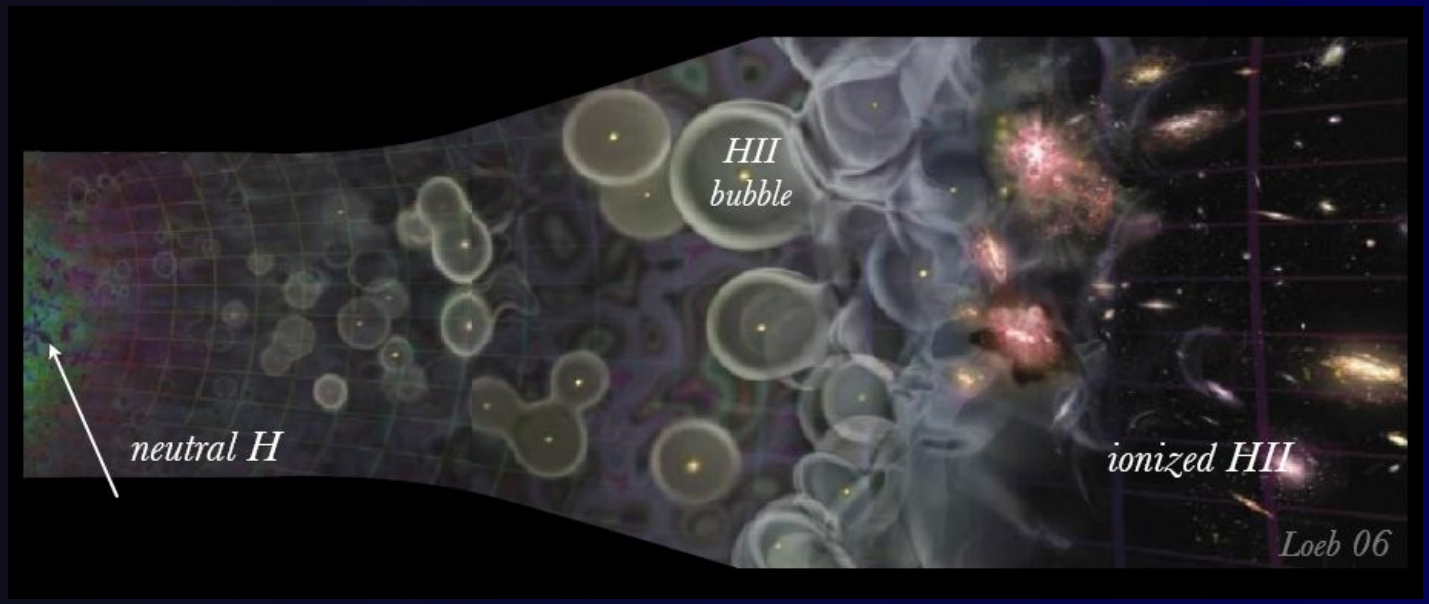
High Redshift Rate Constraints and Demographics



Nat Butler (UC Berkeley)

GRBs as Cosmological Lighthouses

I. DIRECT

Standard Candles?

High-Energy Observables
+ Redshift
→ Cosmology

II. INDIRECT

Backlights at Edge of Universe [FUTURE MISSIONS]

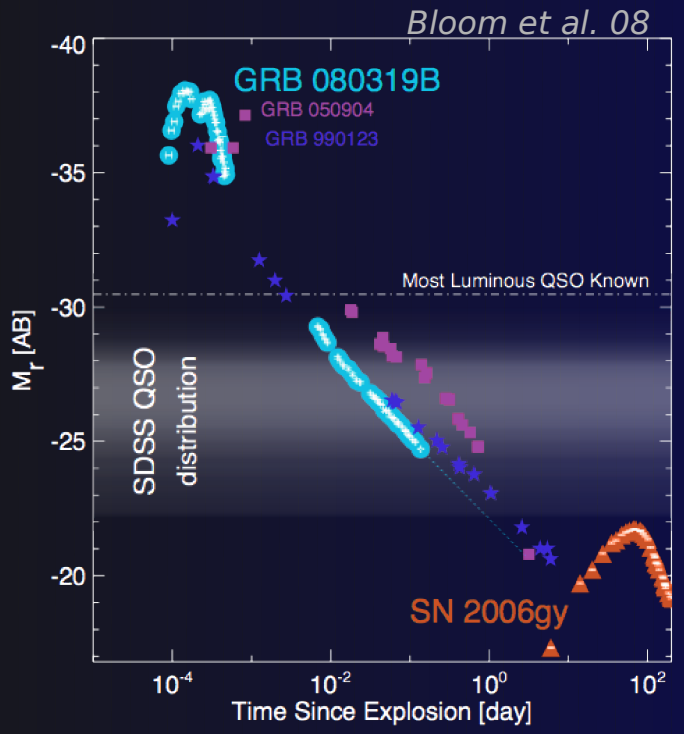
Optical/IR/X-ray Absorption
→ Gas/Dust in Distant Galaxies, IGM

Using Our Swift Catalog:

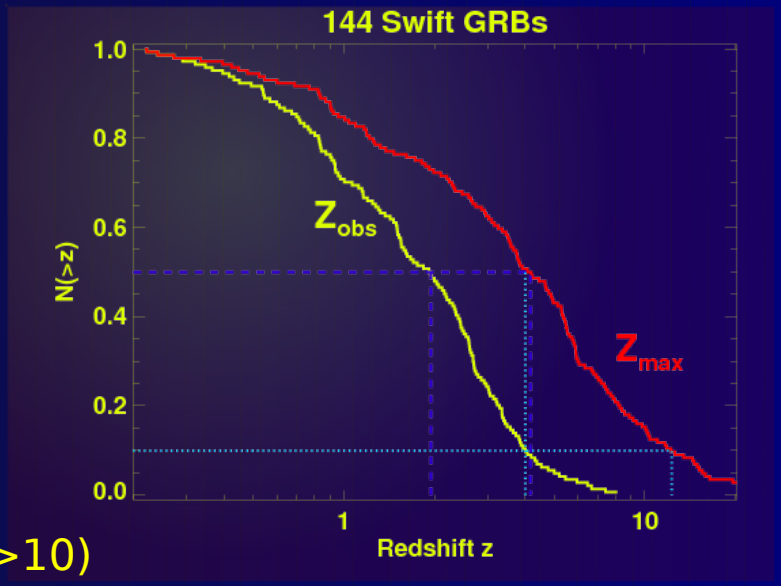
Butler+ 2007 (218 GRBs → 070509, 77 w/ z)
Butler+ 2010 (425 GRBs → 090813, 147 w/ z)

APOD 11/26/07

Extremely Distant & Piercing



1000x brighter than
brightest Quasar



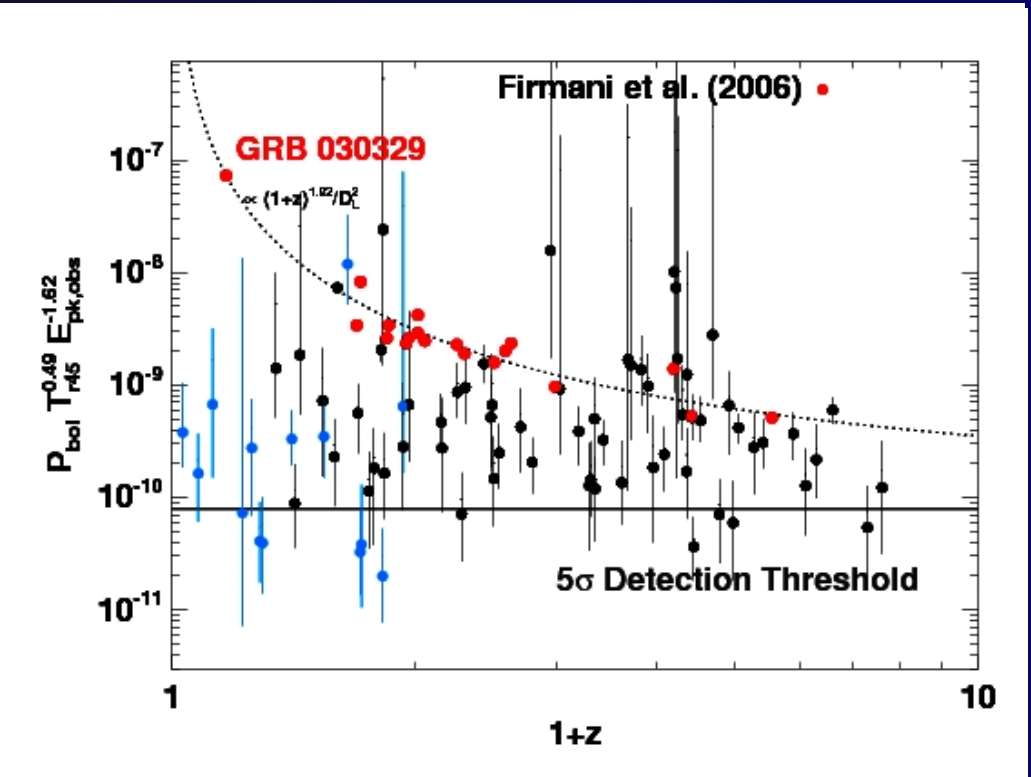
Median (Swift) z ~ 2.
(Detectable z=4)

10% z>4 (Detectable z>10)

Standard Candles?

Essentially 3 Observables: Duration, Flux, Hardness

Assume Cosmology, Observables → Distance (or z)

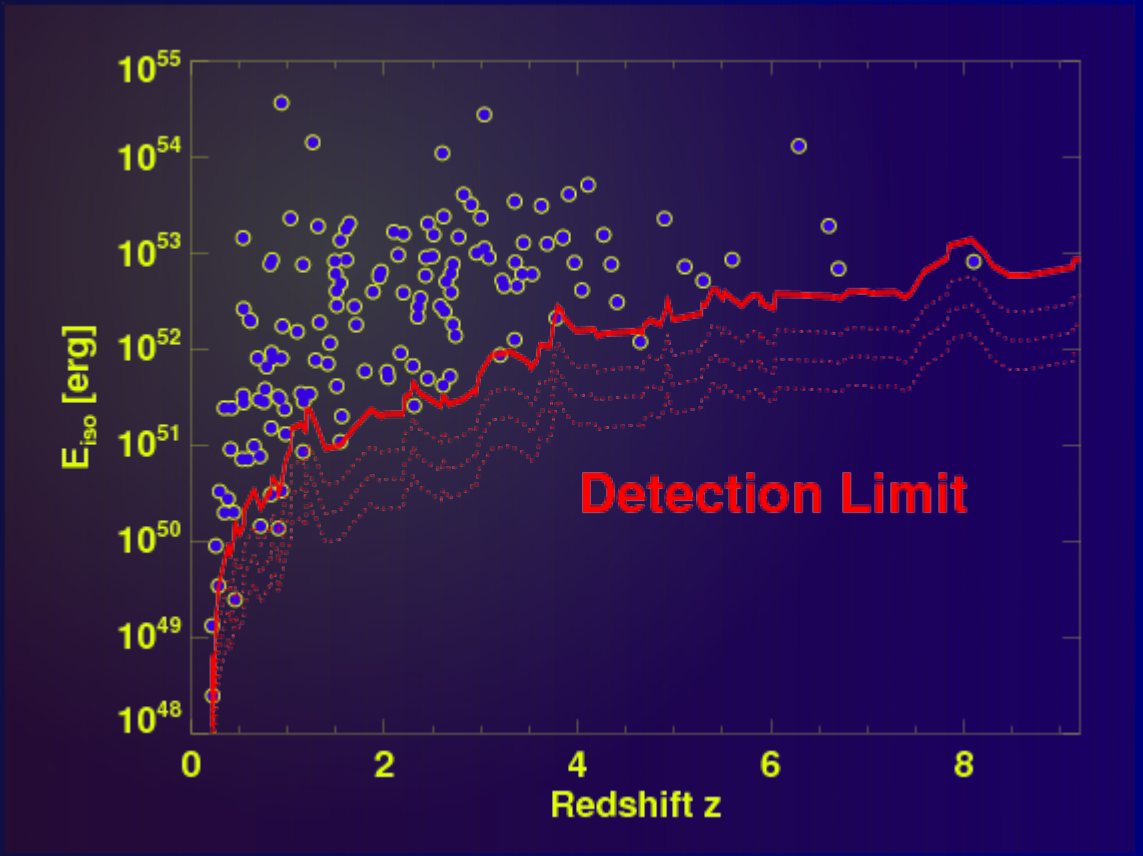


Pernicious Statistics! (*Butler et al. 07,09,10*)

Limited by Detector Sensitivity

Observed bright GRBs at high-z :

Due to Malmquist bias
+
Luminosity Evolution?
+
Number Evolution?



GRB World Model

Observed Rates

$$r_{\rm true} = \tilde{\phi}(L) P_E(E_{\rm pk}) P_T(T_{r45,z}) \frac{r_0 \dot{\rho}(z) dV/dz}{(1+z)}$$

=

Luminosity Function

x

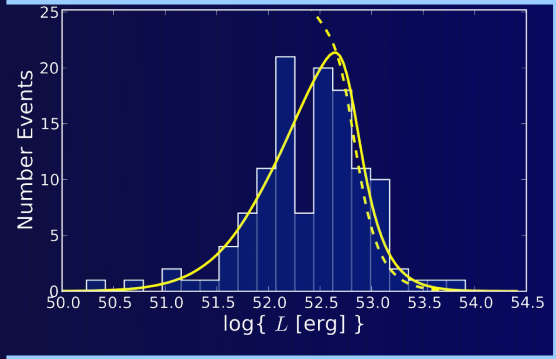
Rate Density

x

Detector

Most Important for Cosmology

Effective Luminosity L, (*corrected for hardness, duration, etc.*)



Standard Candle?

Butler, Bloom, & Poznanski (2010)

GRB Correlations

Shortcuts to Cosmology?

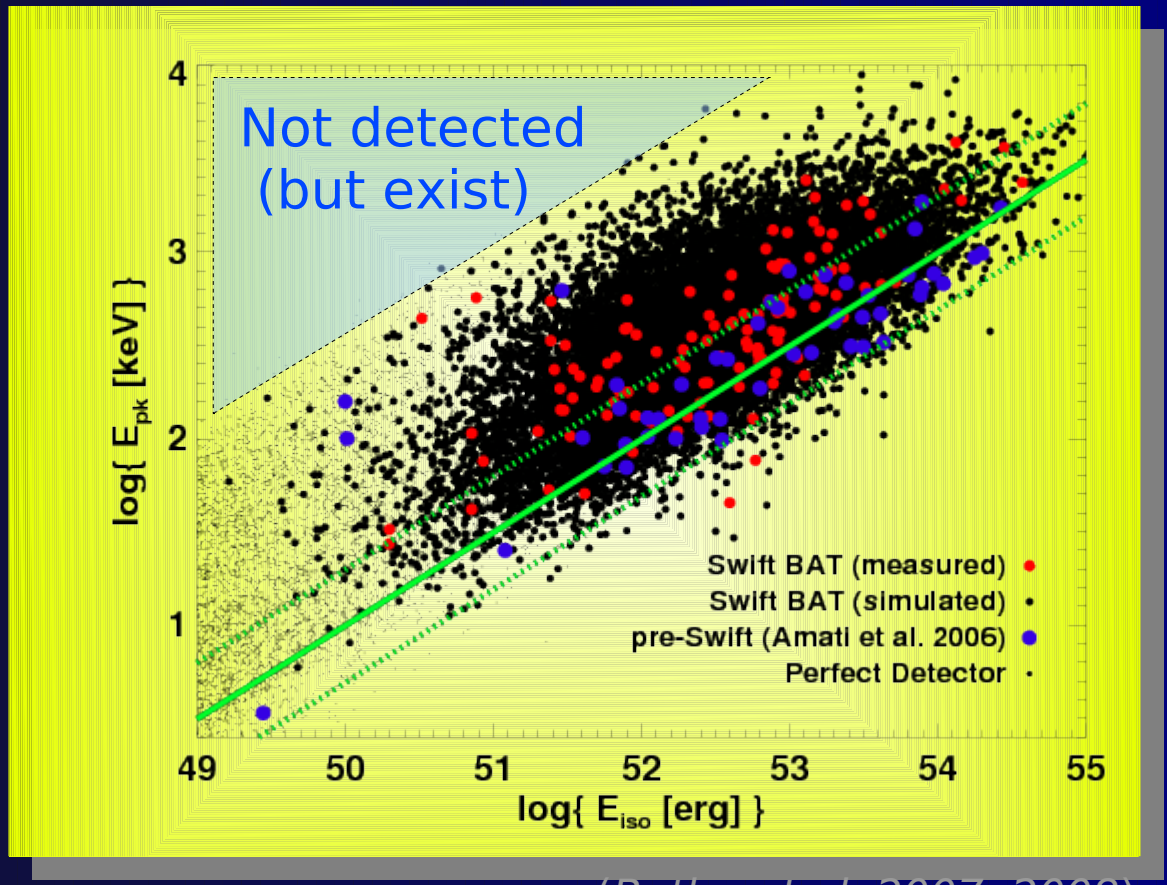
* NO

Clues to Intrinsic processes?

* POSSIBLY

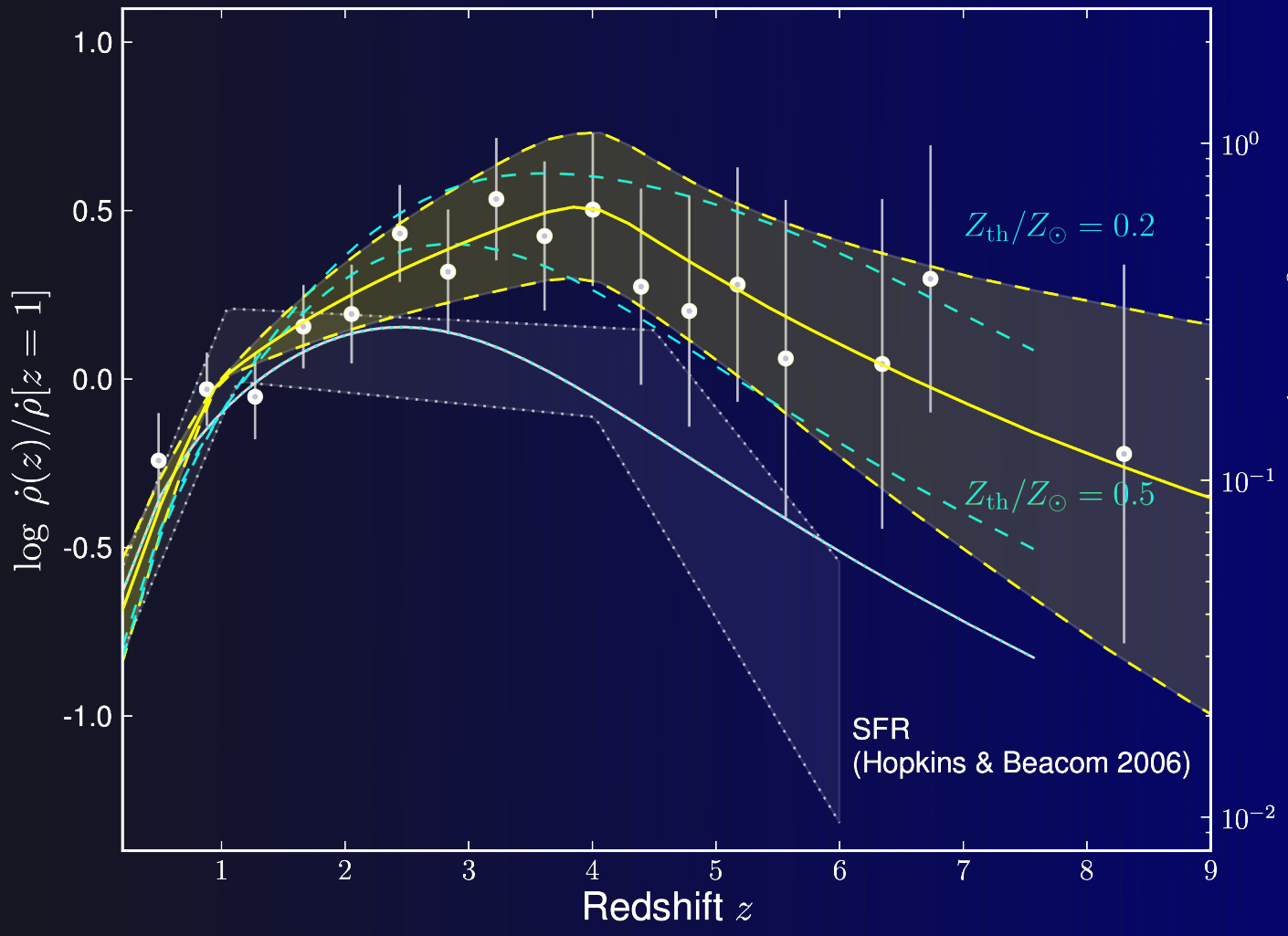
Selection Effects?

* YES



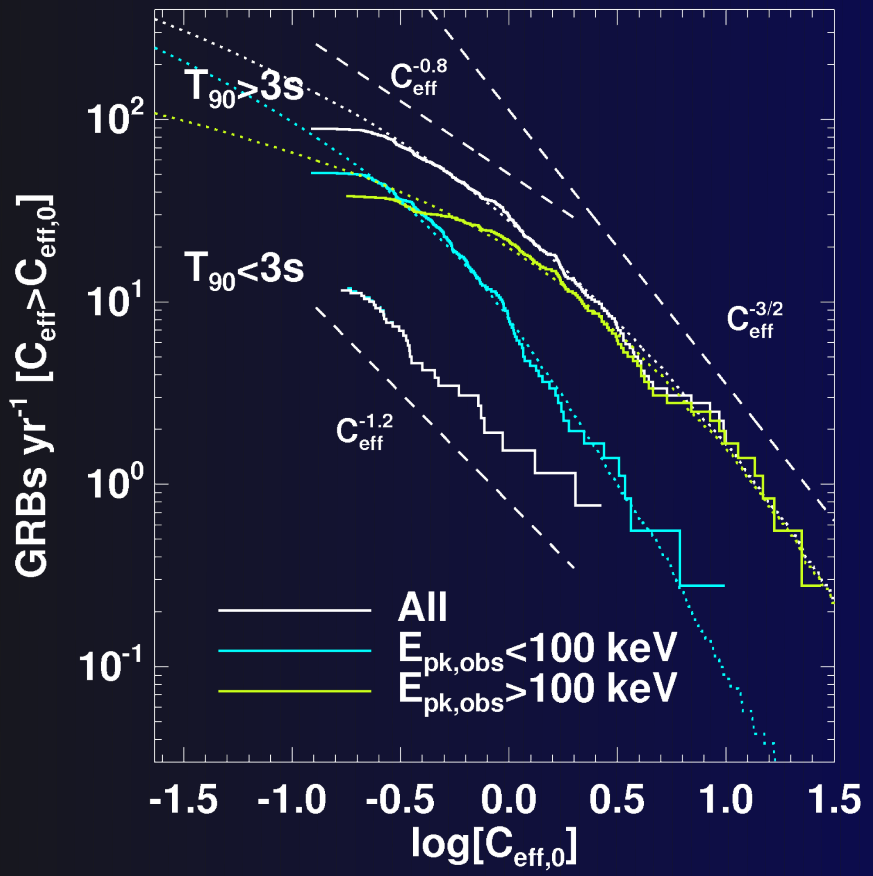
(*Butler et al. 2007, 2008*)

Rates Relative to Star Formation



also, Kistler et al. (2007, 2008); Salvaterra et al. (2007, 2008, 2009). Wanderman & Piran (2010); etc.

GRB World Model



Reproduces Prior Satellite Observations well.

Predicts large number of faint/soft GRBs.

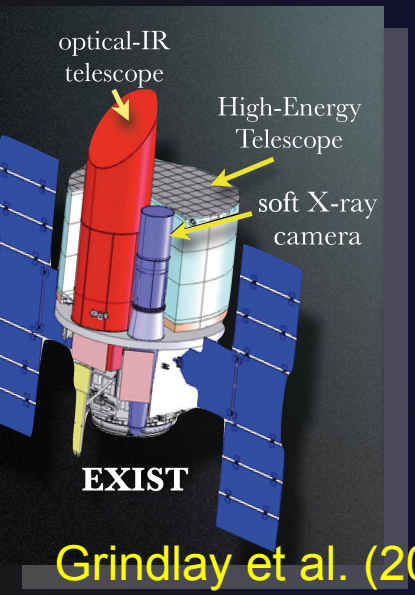
(*e.g., Strohmayer 98, Lamb 05*)

Fraction at High-z

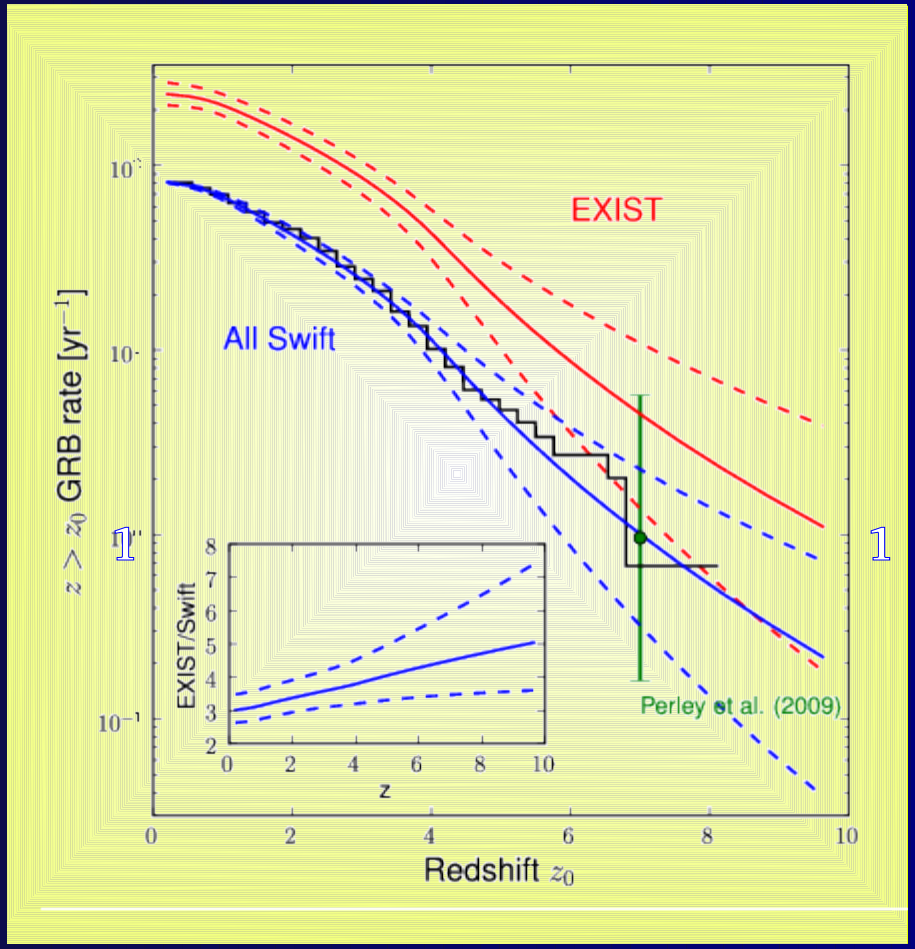
5±3 Swift GRBs/yr @ z>5

1±1 Swift GRB/yr @ z>7

(see, also, Perley...Butler et al. 2009, Fynbo et al. 2009)



Grindlay et al. (2009)



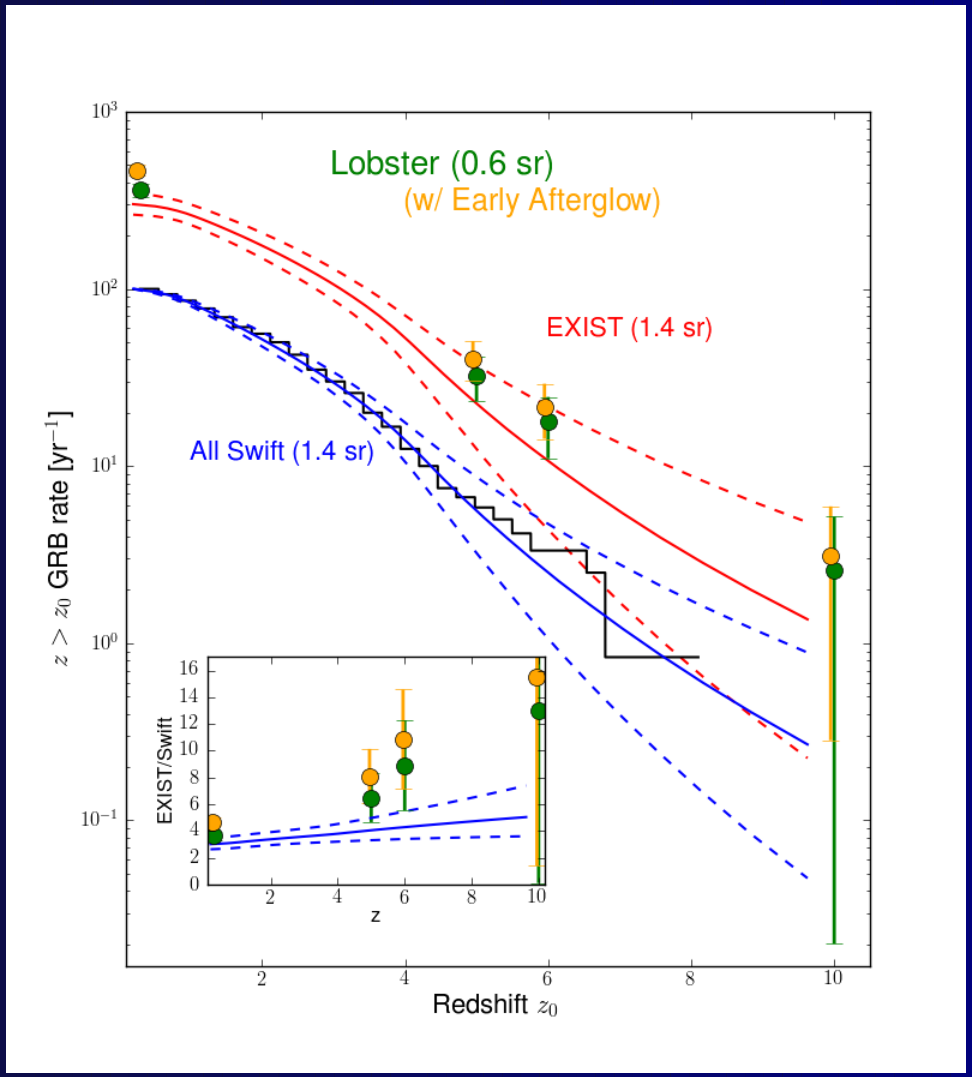
Exploiting XRF Rates

Going Soft
Ep ~ 10 keV vs Ep ~ 100 keV

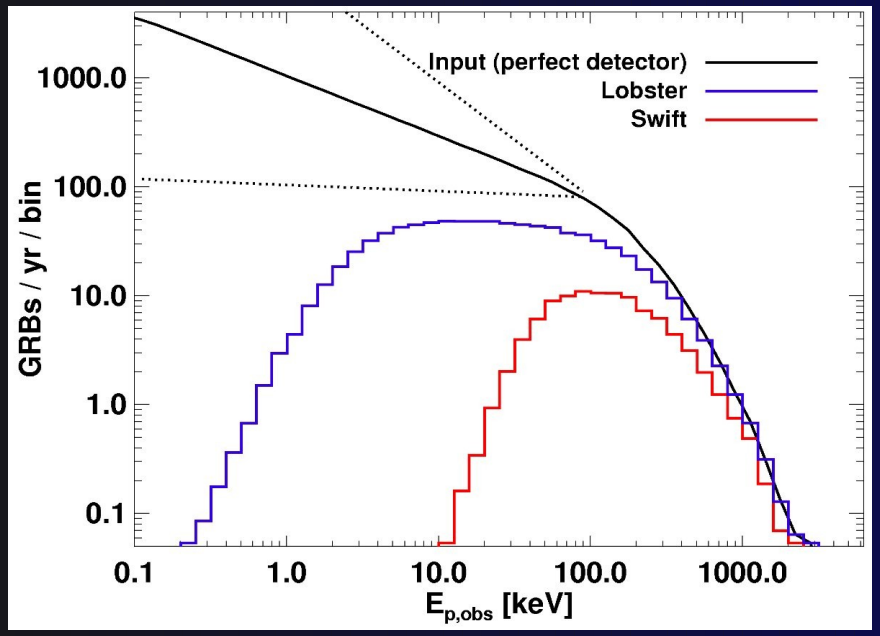
>2x increase in rates!

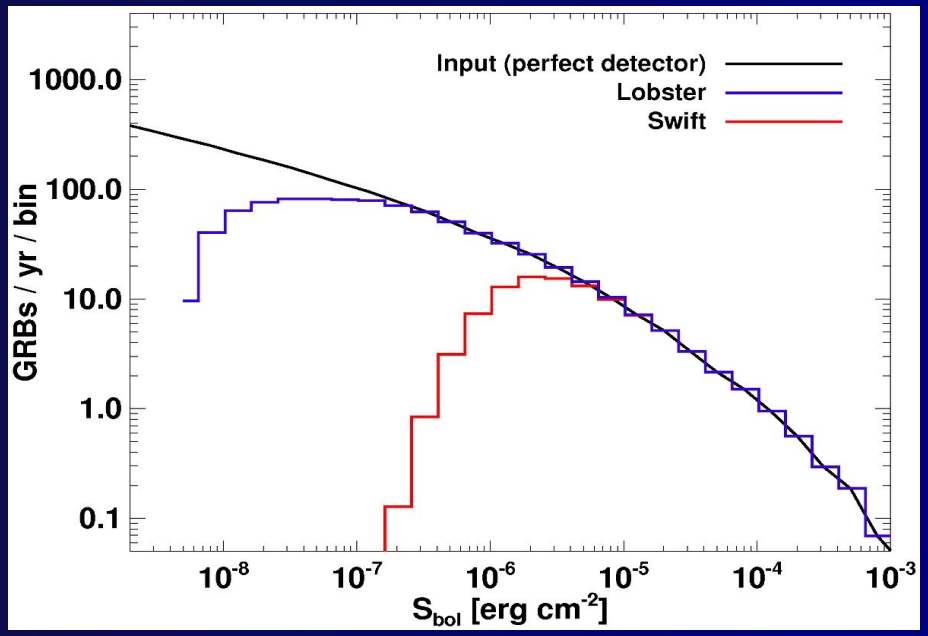
LOBSTER X-ray All-Sky Monitor

Gehrels+ (2010)



LOBSTER Challenges





Ep ~ 10 keV vs Ep ~ 100 keV → Very Faint ,

How will afterglow scale?

Conclusions

- GRBs Probe High-z: RATIR will Capitalize
  (see, poster by Ori Fox)

- To get GRBs in large number, go soft → these will be faint (but interesting)!