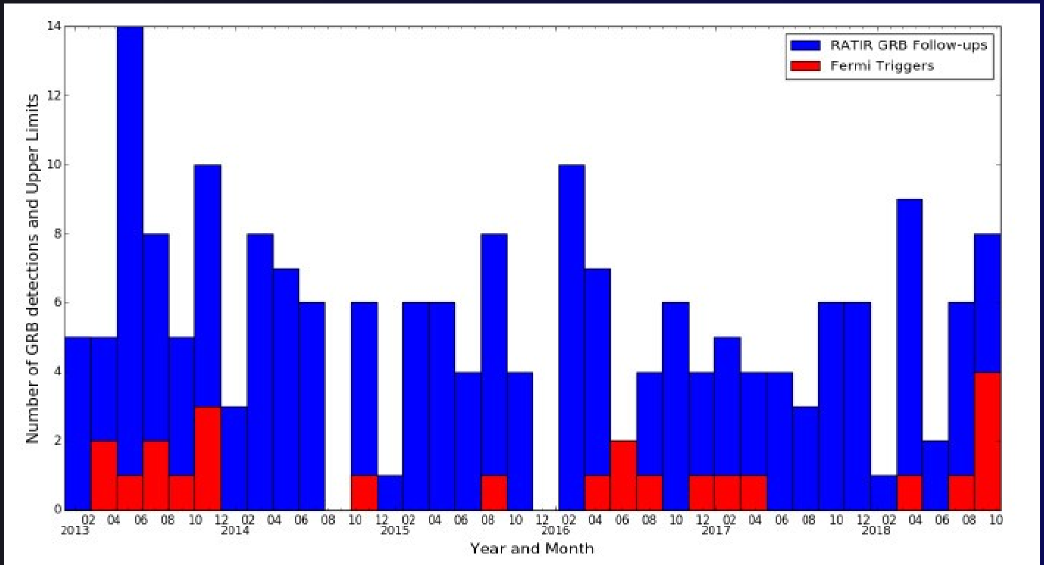
Chasing Astrophysical Transients

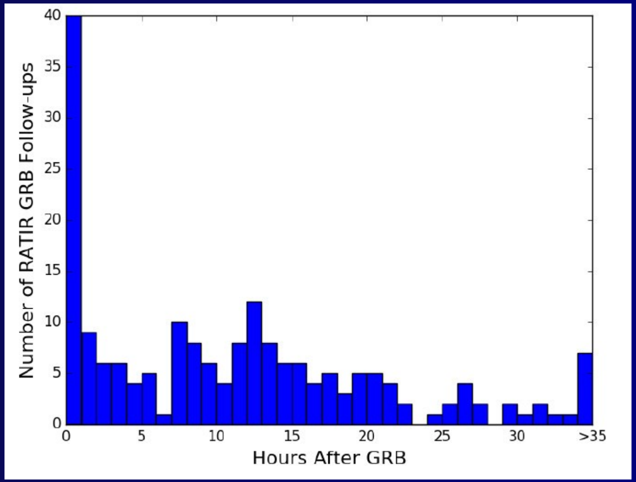
WIRED Magazine

Outline

Lesson from Swift & RATIR for SVOM & Colibri

* High-z GRBs * Jetting constraints * GW followup





Past ~6 years (2.7 GRBs/mo)

THE REIONIZATION AND TRANSIENTS INFRARED/OPTICAL PROJECT

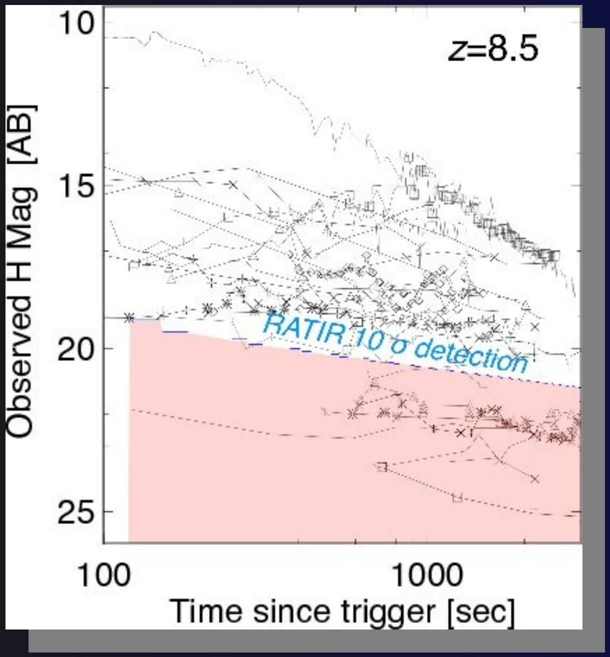
RATIR

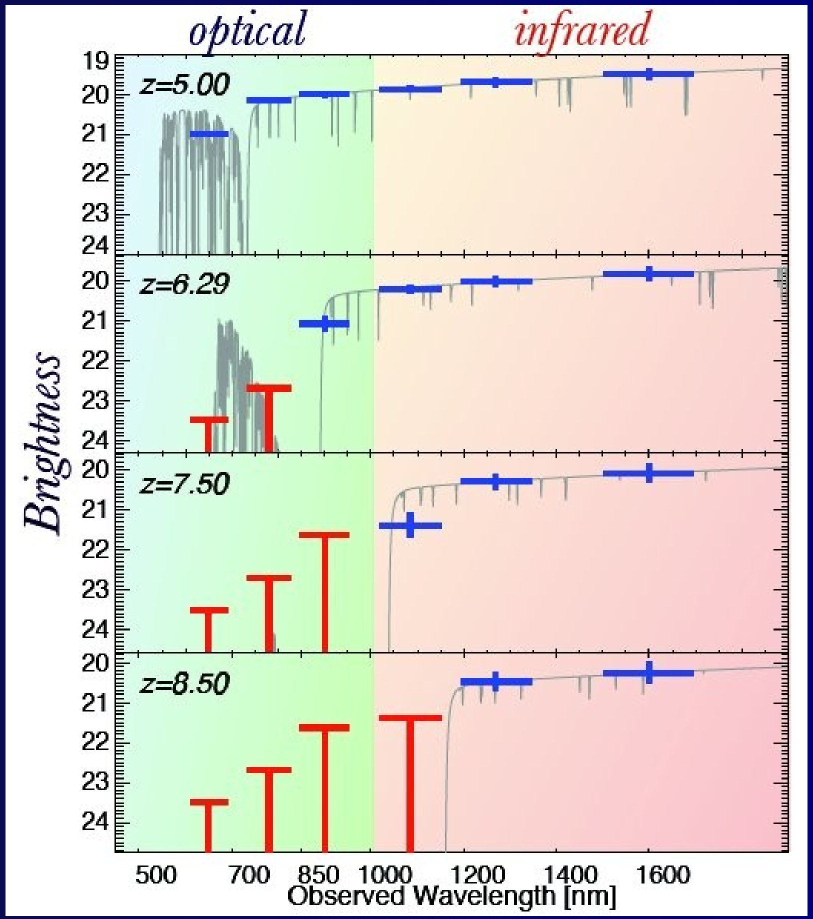
http://www.ratir.org

Nathaniel Butler	(PI & Project Manager; ASU)
Chris Klein (w/ Josh Bloom)	(Software Lead; UC Berkeley)
Alejandro Farah	(Mechanical Design; UNAM)
Jesus Gonzalez	(Optical Design; UNAM)
Alexander Kutyrev (w/ Harvey Moseley, Neil Gehrels)	(IR Dewar Lead; Goddard)
Ori Fox	(NIR Detectors, Goddard)
Dave Rapchun	(NIR Dewar, Goddard)
Alan Watson (w/ Michael Richer)	(Telescope Automation; UNAM)

William Lee, David Clark, Carlos Roman, Leonid Georgiev (UNAM), J. Xavier Prochaska, Enrico Ramirez-Ruiz (UCSC/Lick), Gennadiy Lotkin, Frederick Robinson, Matthew Samuel, Leroy Sparr (Goddard), ...

RATIR GRB Sensitivity



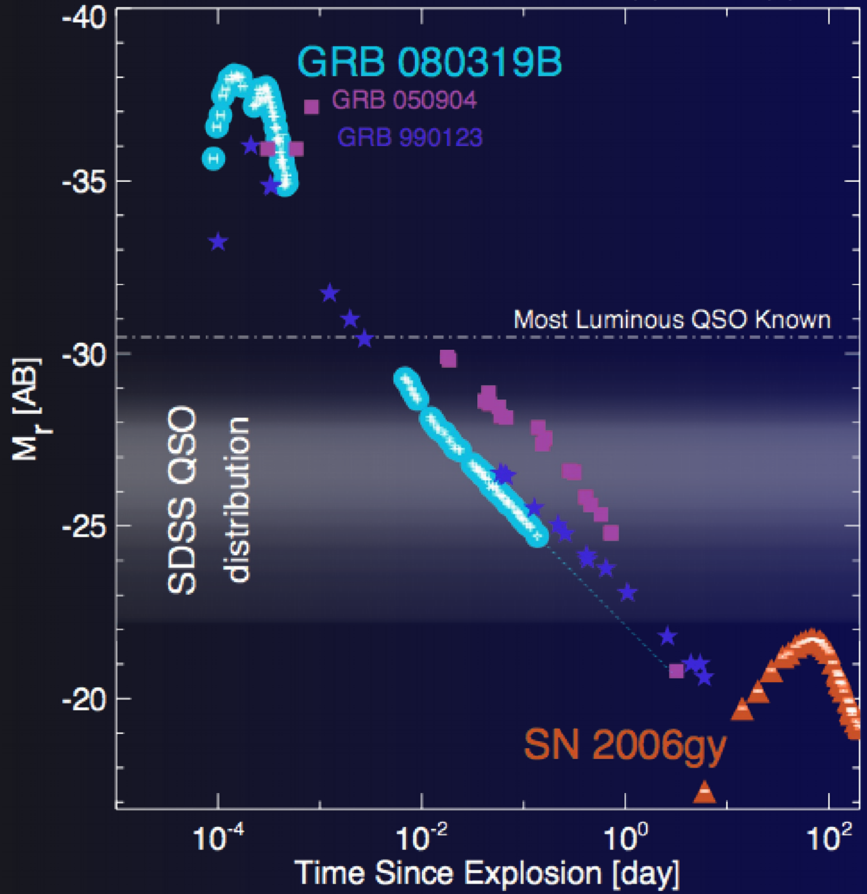


Detects 83% of Swift events, even at z=8.5

Will observe 12 Swift events per year within 10 minutes (actual 9/yr within 1 hr).

The Promise of GRBs: Extremely Distant & Piercing

Bloom++ 08



1000x brighter than brightest QSO

Median (Swift) z=2

10% z>4 (Detectable z>10)

GRBs as Cosmological Lighthouses

I. DIRECT

Standard Candles?

High-Energy Observables
+ Redshift
→ Cosmology

II. INDIRECT

Backlights at Edge of Universe

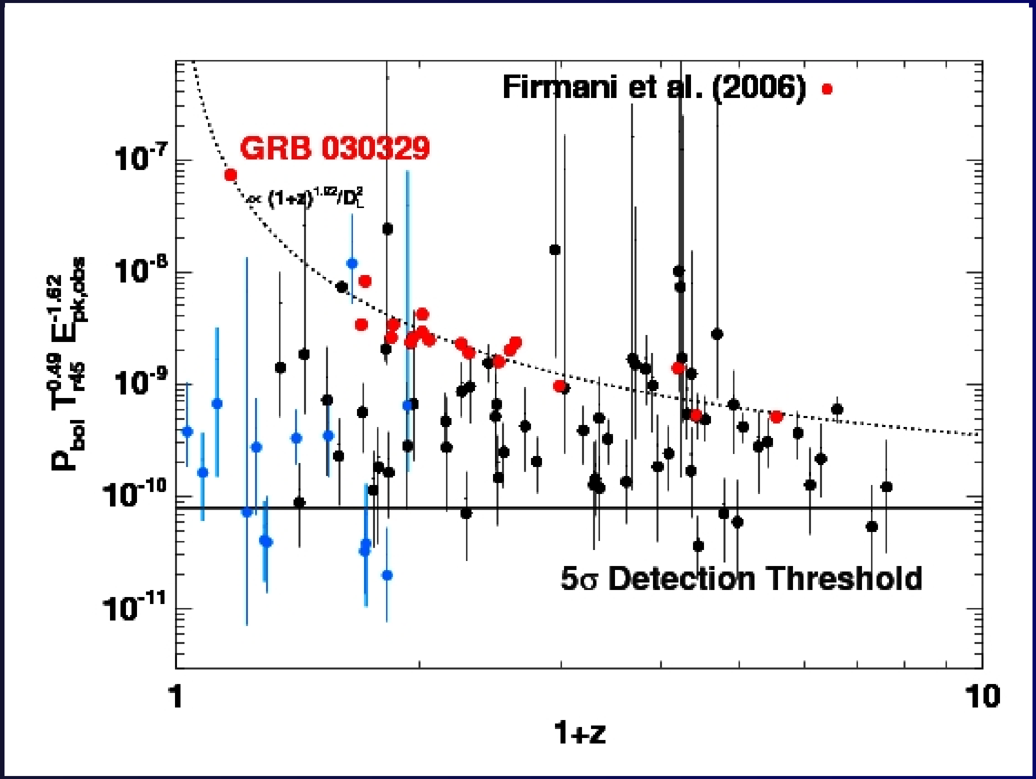
Optical/IR/X-ray Absorption
→ Gas/Dust in Distant Galaxies, Inter-Galactic Medium

APOD 11/26/07

Standard Candles?

Essentially 3 Observables: Duration, Flux, Hardness

Assume Cosmology, Observables → Distance (or z)



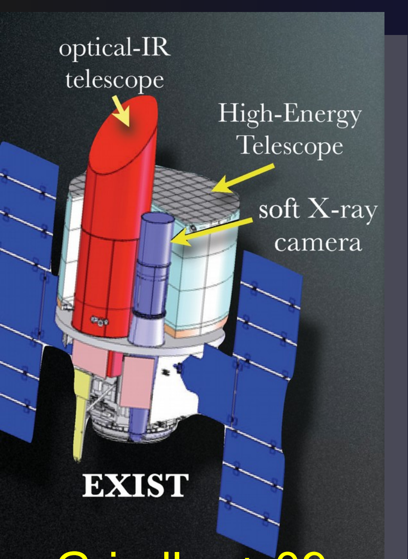
Pernicious Statistics! (*Butler+ 07,09,10*)

Fraction at High-z

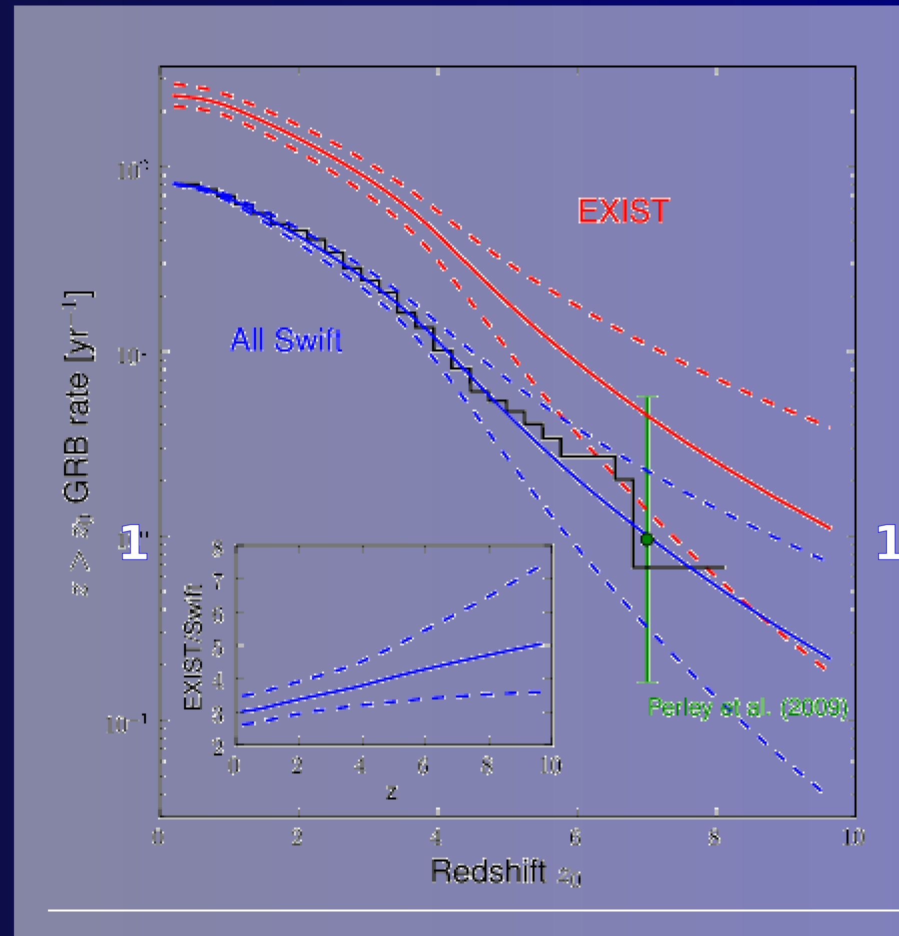
5±3 Swift GRBs/yr @ z>5

1±1 Swift GRB/yr @ z>7

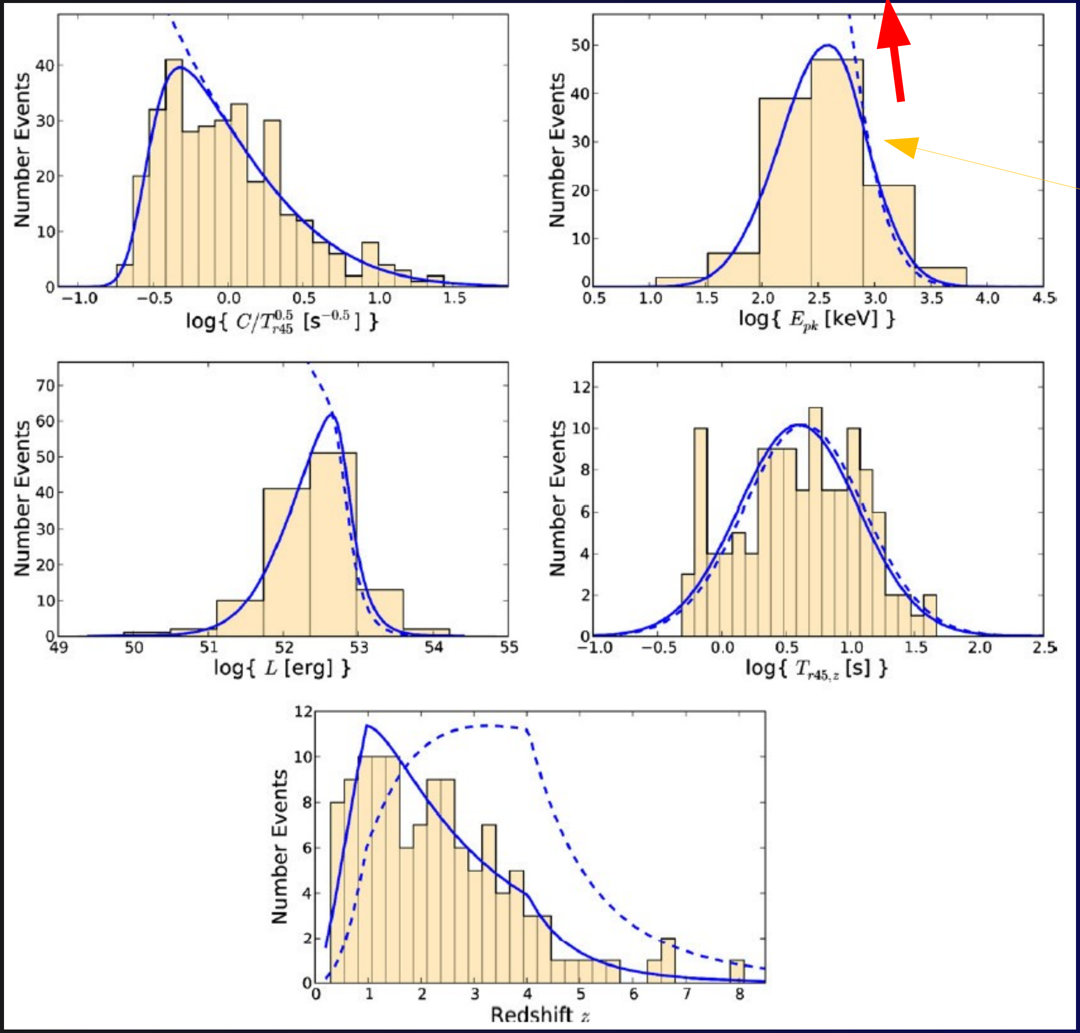
(see, also, Perley...Butler+ 09, Fynbo+ 09)



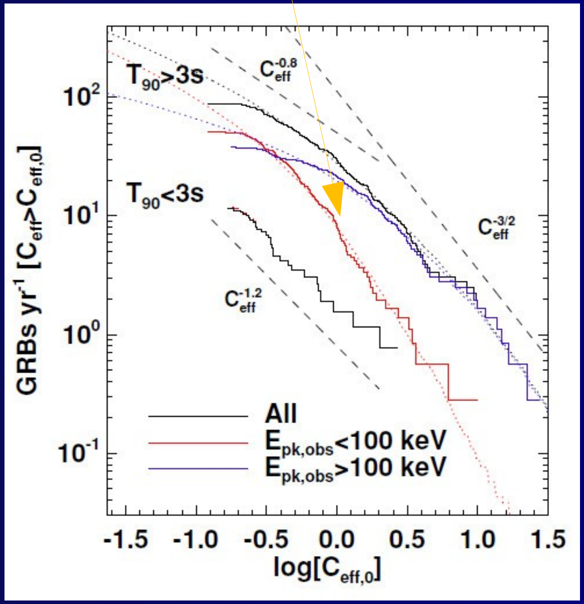
Grindlay+ 09



Eclairs Soft Response → More GRBs

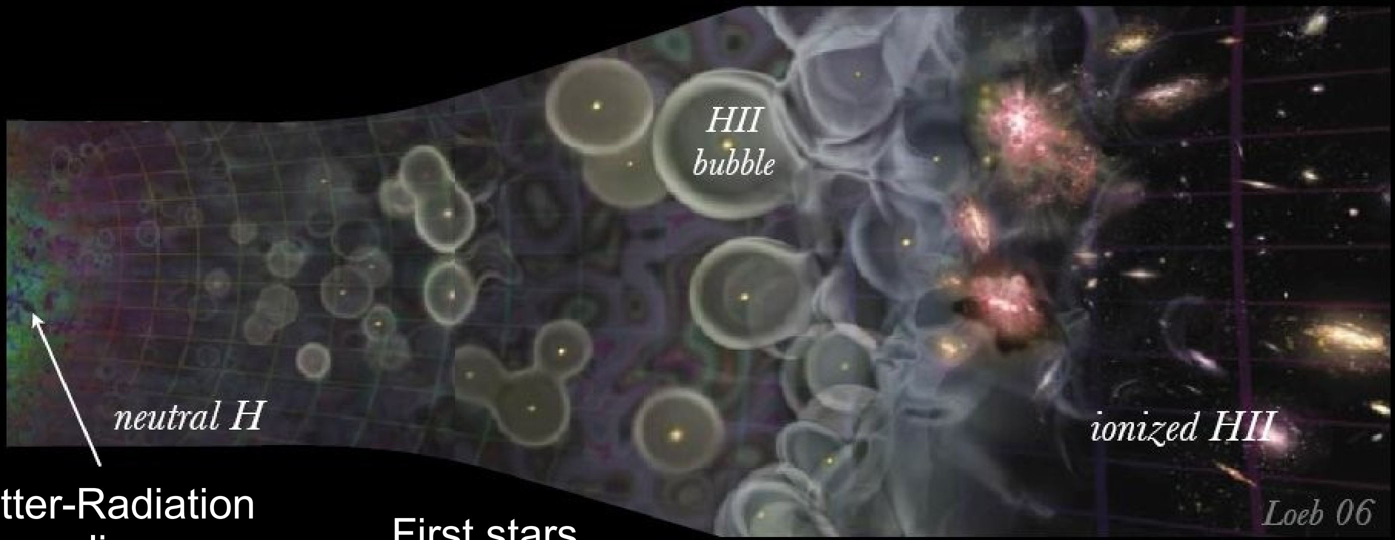


Soft GRB Population!



SWIFT/BAT Rates, Butler et al. 2010

Detect High-z GRBs → Epoch of Reionization



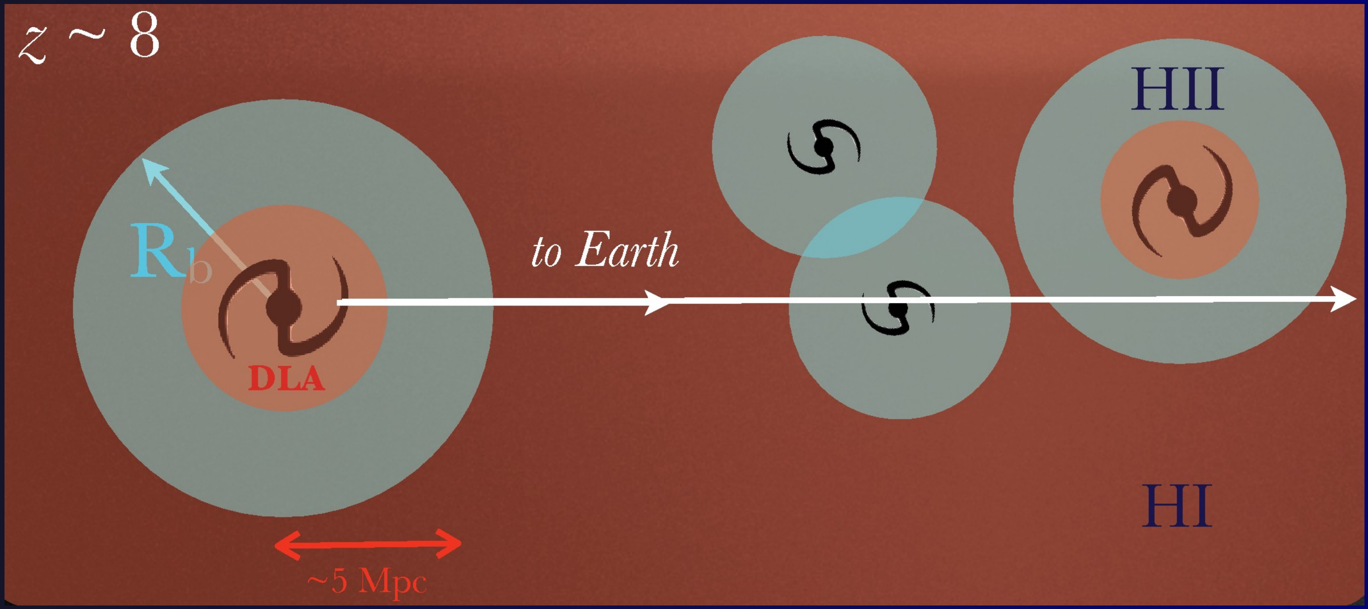
Matter-Radiation Decoupling
z=1100 (CMB)

First stars
("Pop III")
z=20-30

"reionization"
z~8-15

Most-distant known galaxies
z=7-10

Epoch of Reionization



Directly Infer neutral fraction of Hydrogen $x_{H\ I}$ versus redshift
(*Miralda-Escudé 98, McQuinn+ 08,
Mesinger & Furlanetto 08)*

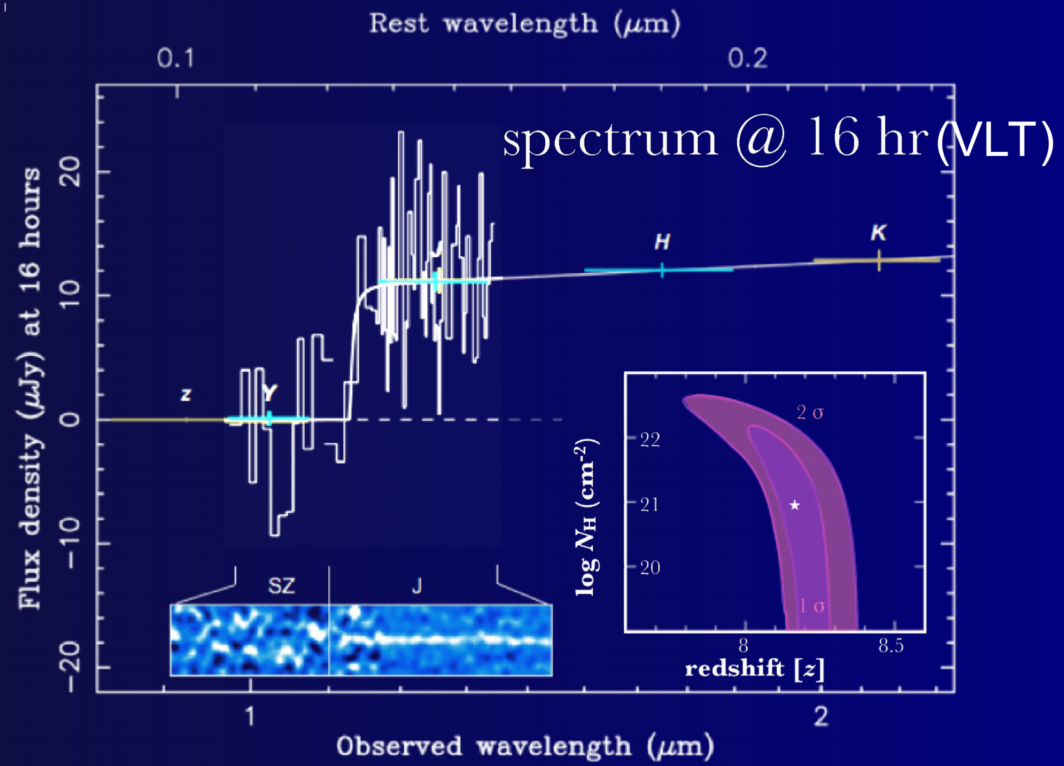
GRB 090423 ($z \approx 8.3$)

Large $N_{H\,I}$ obscures ionization state!

(*Tanvir+ 09, also Salvaterra+ 09*)

But 10-20% of GRBs still have sufficiently low $N_{H\,I}$.

(*Chen+ 08*)



RATIR Constraints on Jetting

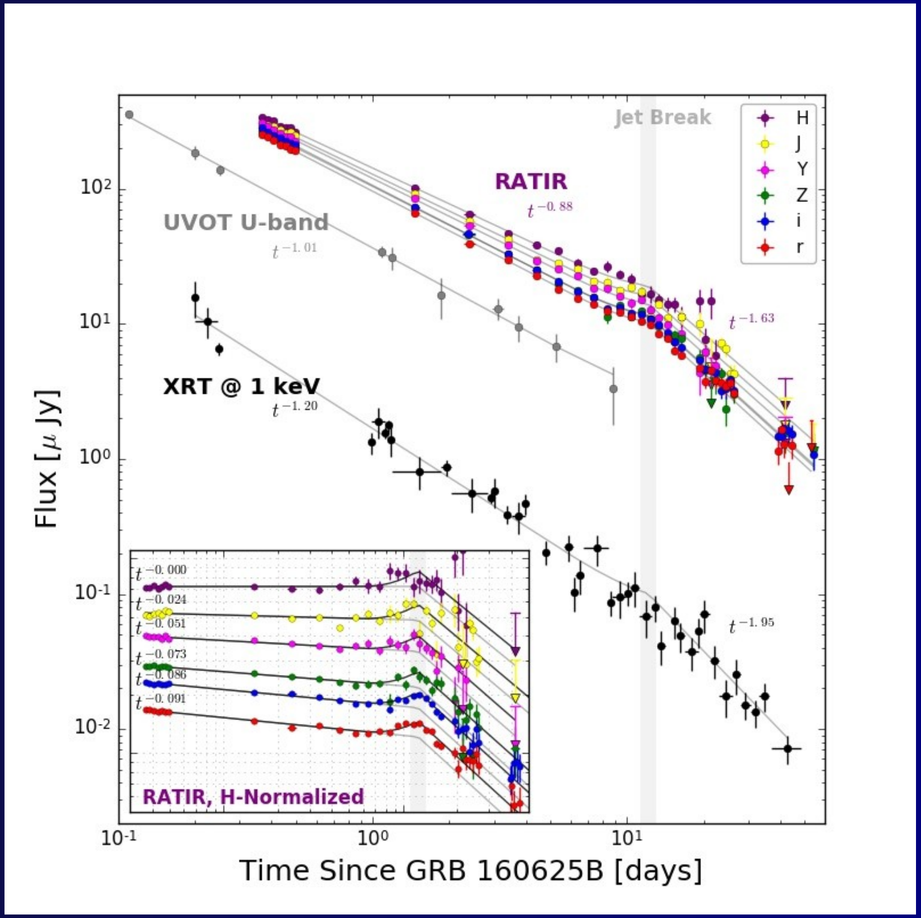
GRB 160625B (Troja et al. 2018; Nature):

Polarization detection by Master

Late-time, extraordinary high-cadence jet break

→ best observations to date of a jet break

→ the jet is very narrow (few degrees) and may have edge structure



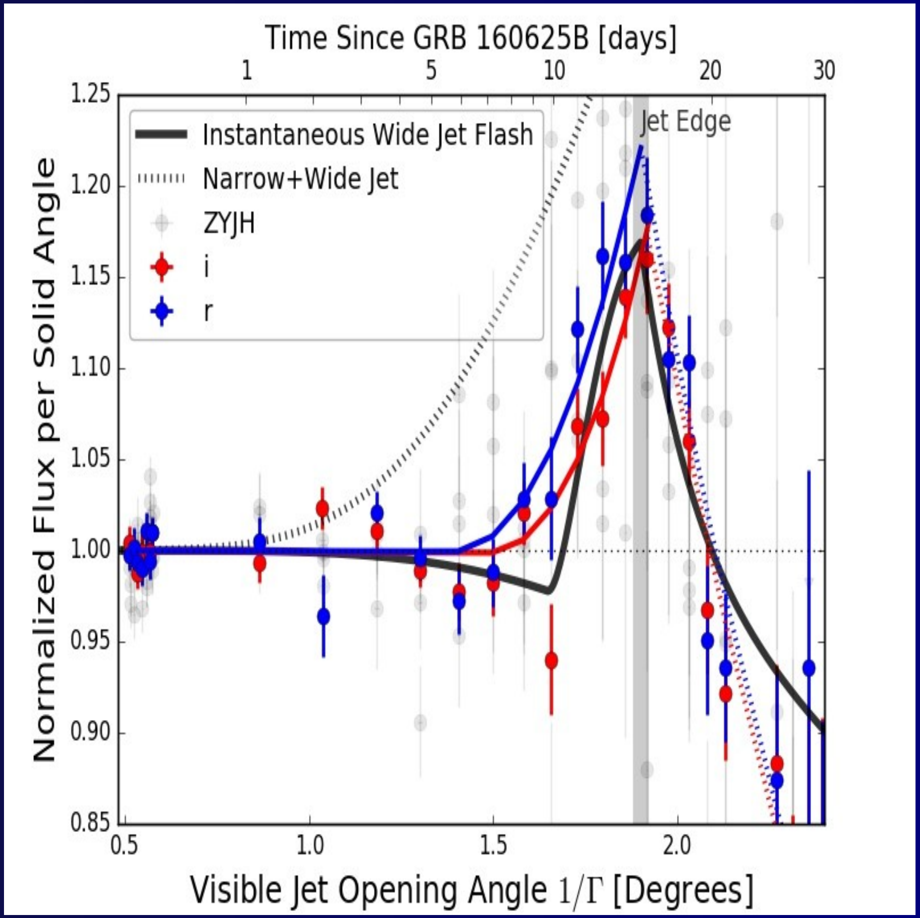
Strausbaugh et al. 2018

RATIR Constraints on Jetting

GRB 160625B (Troja et al. 2018; Nature):

Zoom-in lightcurve bump:

→ possible edge structure inferred from bump at time of “jet break”



Strausbaugh et al. 2018

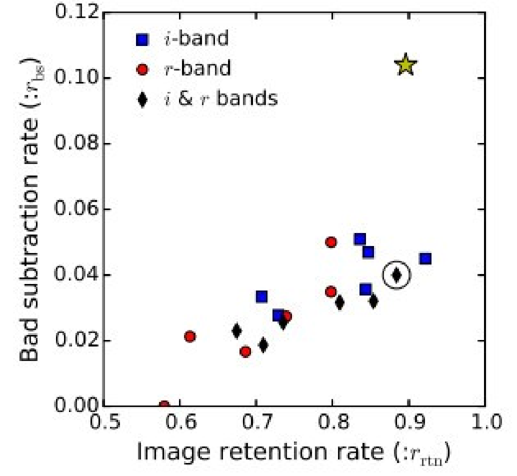
$$\theta_{\rm jet} = 3.27\left(\frac{t_{\rm jet}}{\rm days}\right)^{3/8}\left(\frac{1+z}{2}\right)^{-3/8}\left(\frac{E_{\rm iso}}{10^{53}\ {\rm erg}}\right)^{-1/8}\left(\frac{\eta}{0.2}\right)^{1/8}\left(\frac{n}{0.1\ {\rm cm^{-3}}}\right)^{1/8} = 2.28\left(\frac{t_{\rm jet}}{12.6\ {\rm days}}\right)^{3/8}\ {\rm degrees}$$

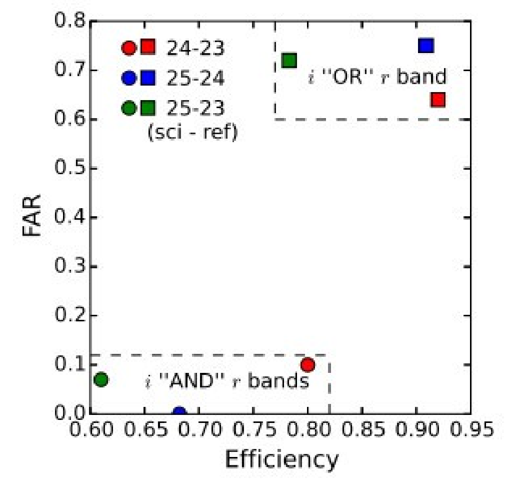
GW Followup with RATIR

“Reionization And Transients InfraRed camera”

GW Followup from 2015+ described in Golkhou et al. 2018.

We target the known galaxies and do image subtraction.





Consider seeing, depth of image pairs, avoid bad subtractions.

Use multiple bands to drive down FAR.