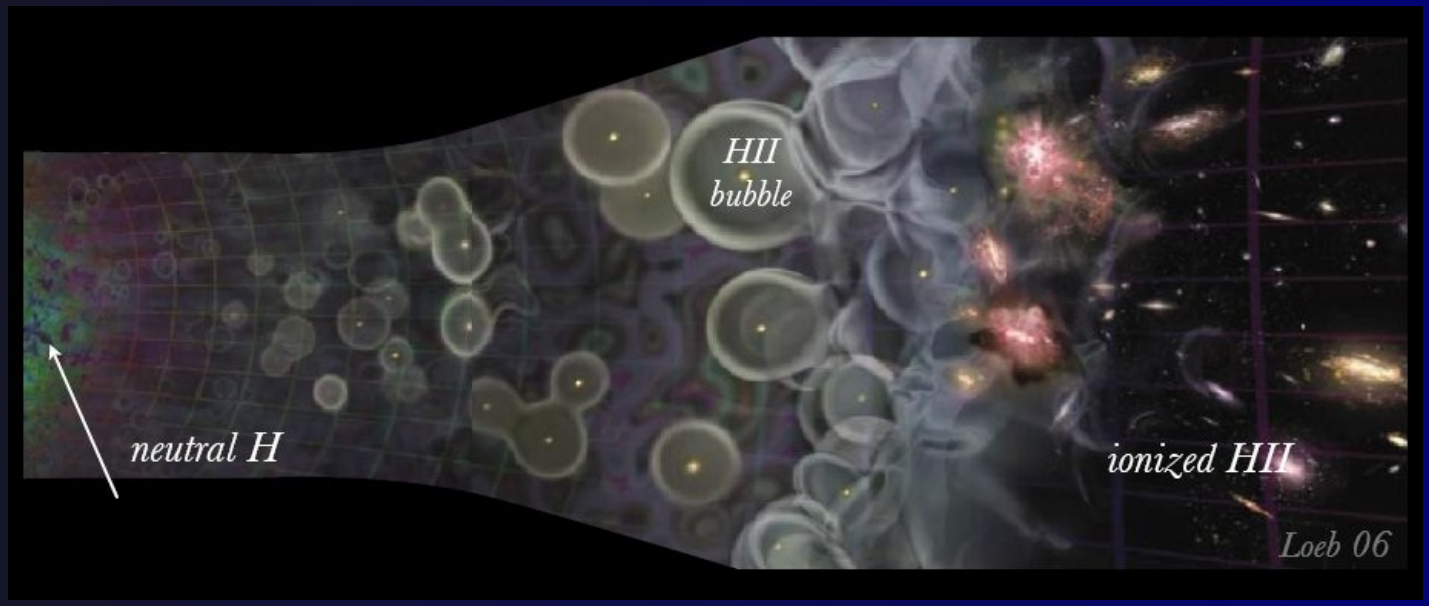
Probes to the Early Universe



Nat Butler (UC Berkeley)

Outline

Prompt GRB Observations:

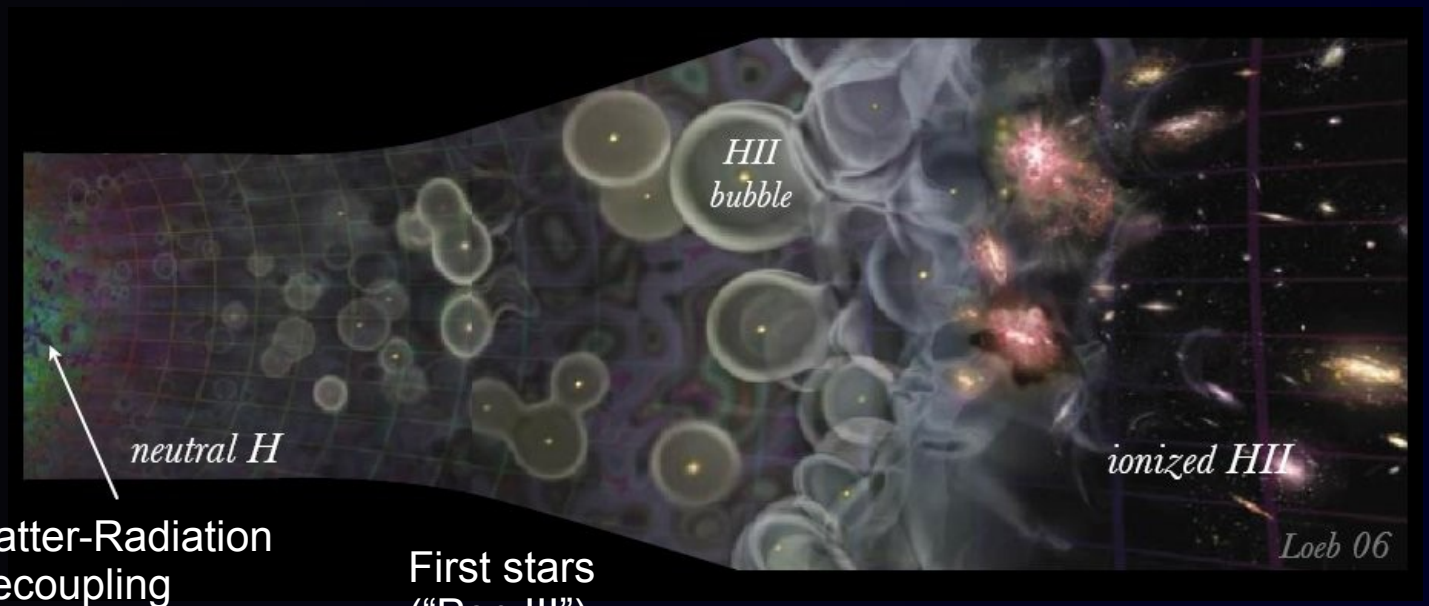
The luminosity function &
intrinsic rate of GRBs.

Butler, Bloom, & Poznanski (2009; arXiv:0910.3341)

Afterglow Observations:

RATIR, the Reionizations &
Transients InfraRed Camera

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

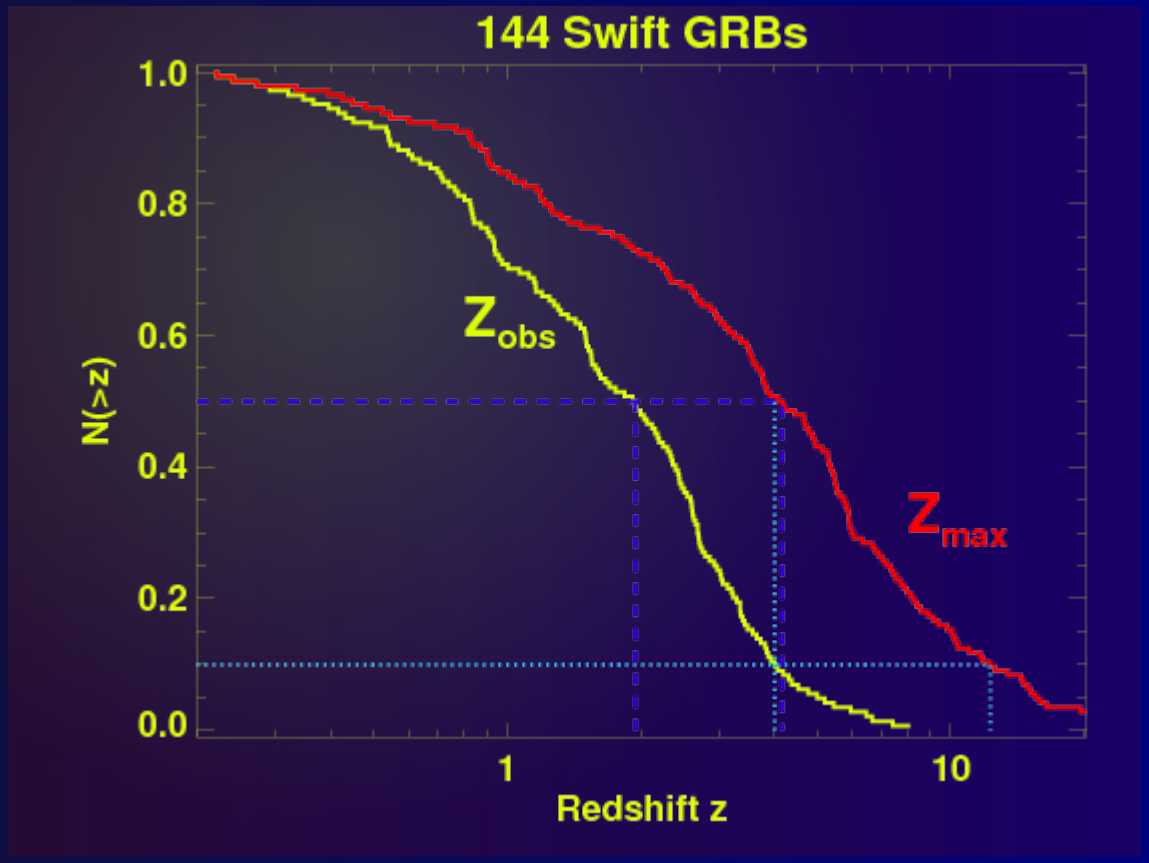
Extremely Piercing

Median Observed
z ~ 2.

(Detectable to z=4)

10% Observed z>4

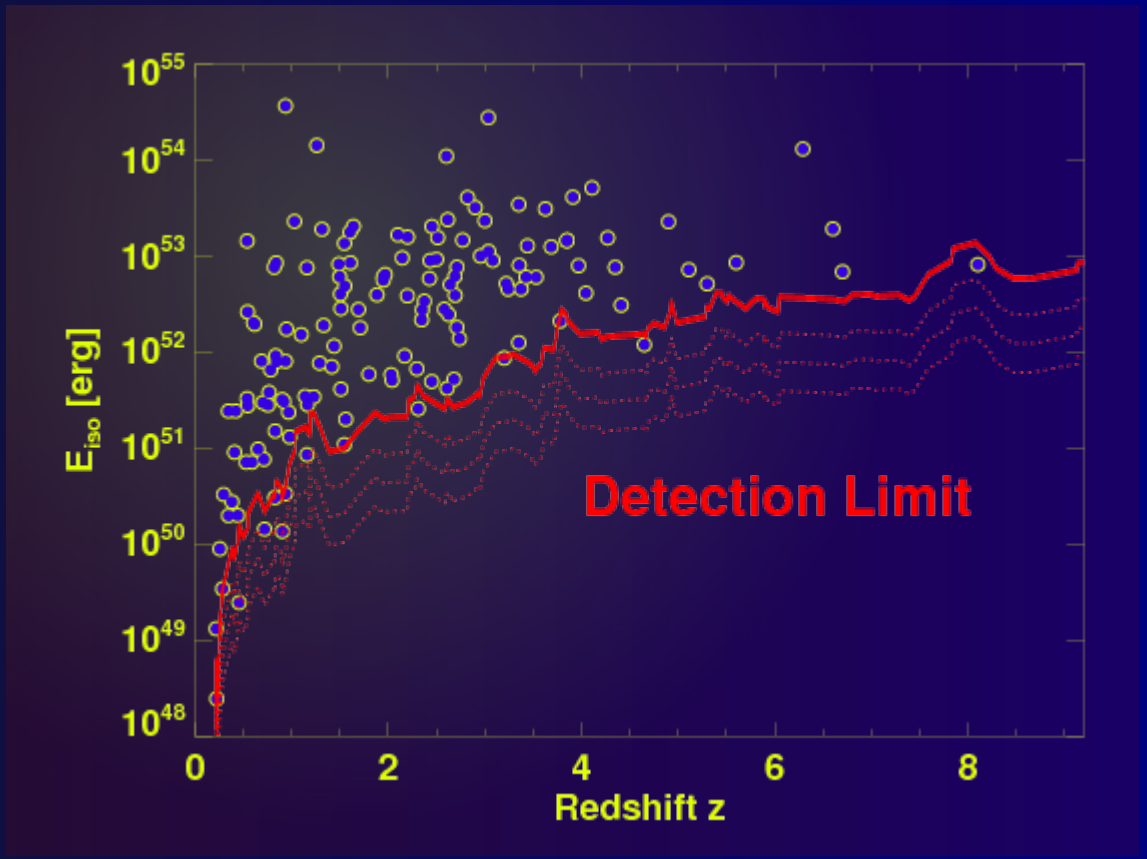
(Detectable to z>10)



Limited by Detector Sensitivity

Observed bright GRBs at high-z :

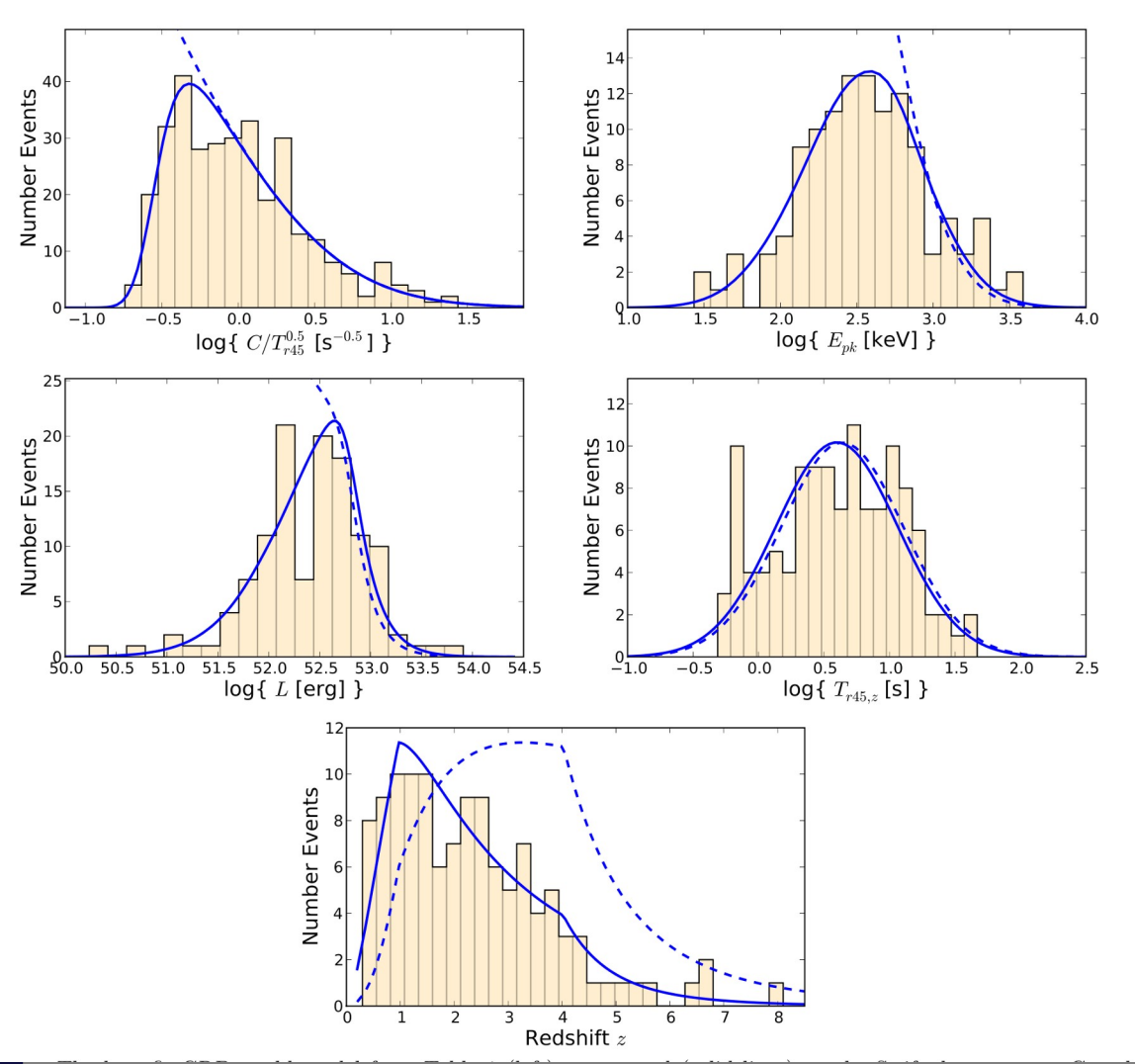
Due to Malmquist bias
+
Luminosity Evolution?
+
Number Evolution?



GRB World Model

Observed Rates =

Luminosity Function
+
Rate Density
+
Detector



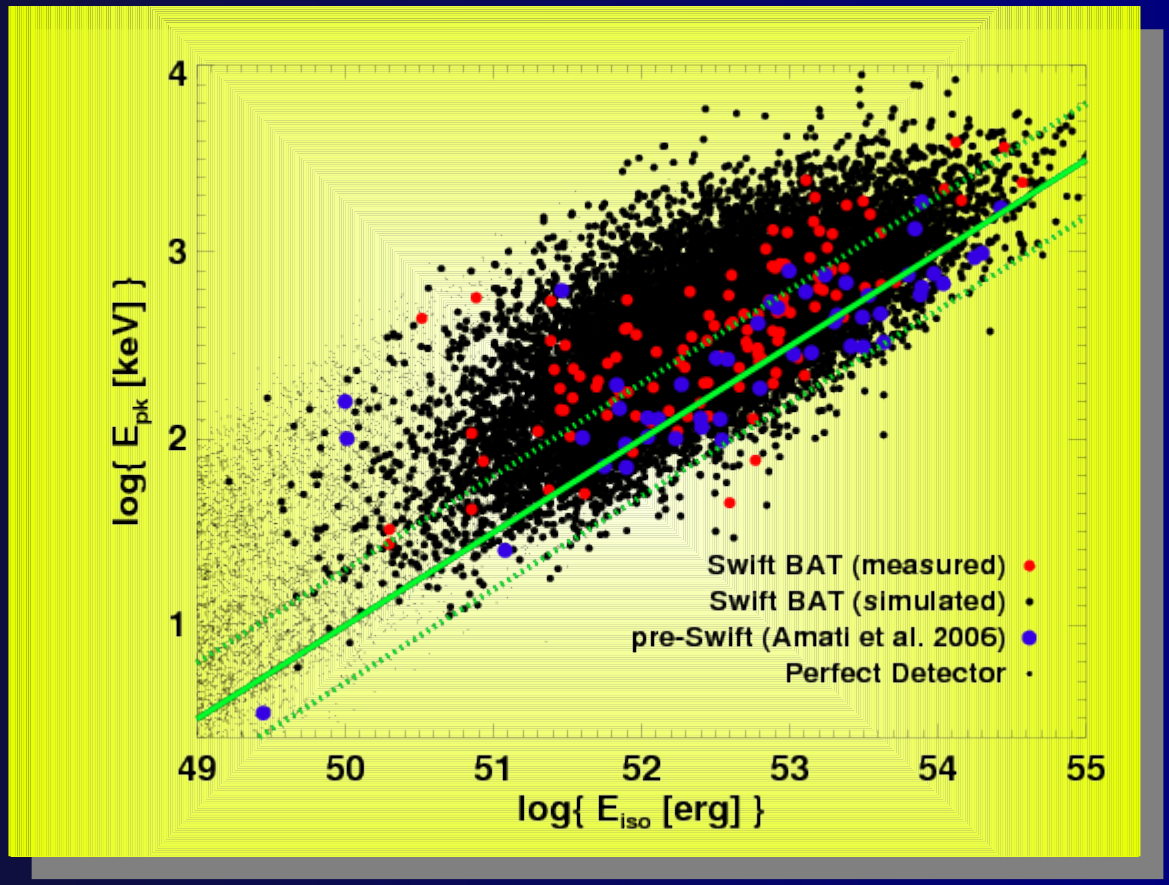
Butler, Bloom, & Poznanski (2009; arXiv:0910.3341)

GRB Correlations

Shortcuts to Cosmology?

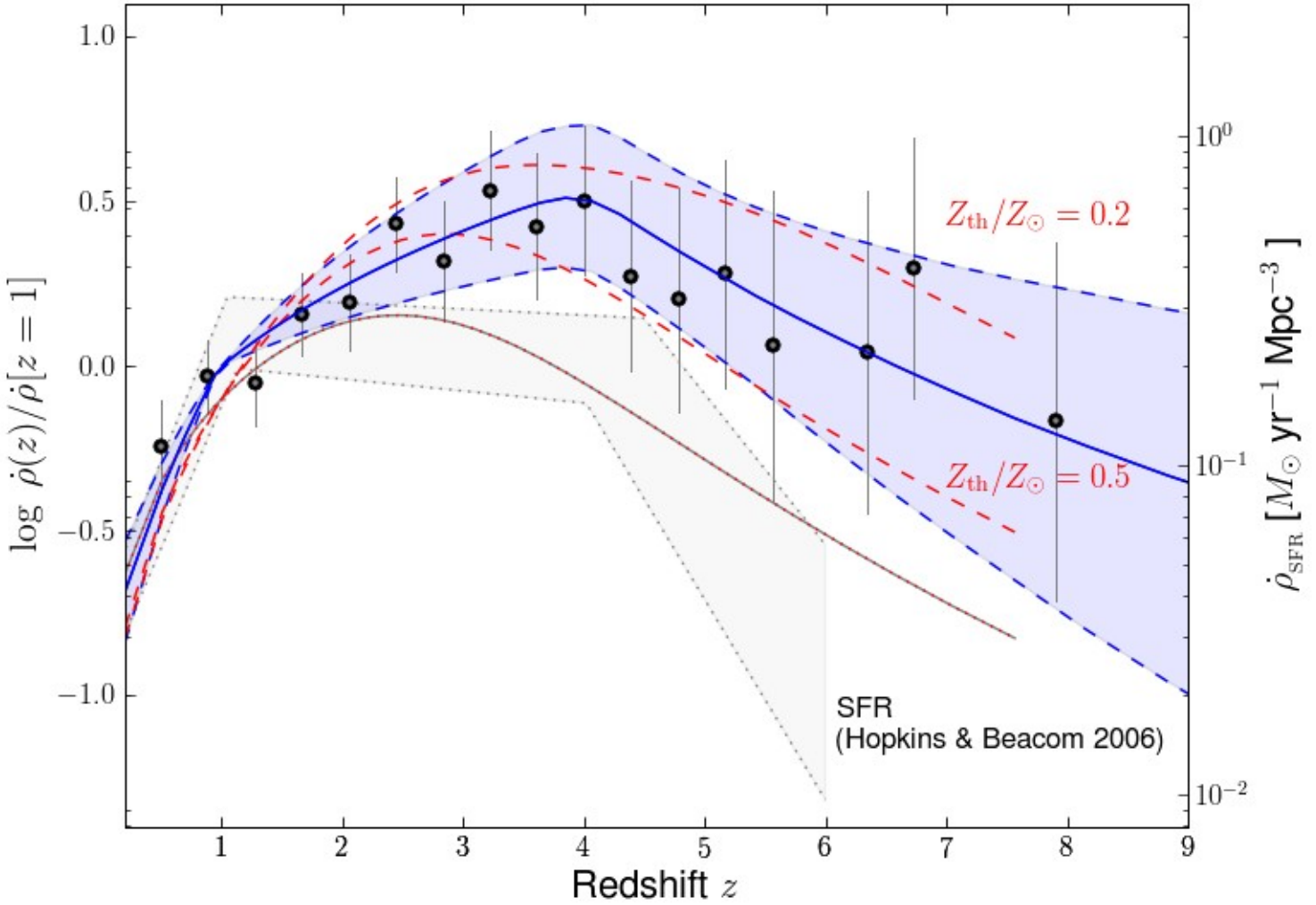
Clues to Intrinsic processes?

Selection Effects?



(*e.g., Butler et al. 2007, 2008*)

Rates Relative to Star Formation



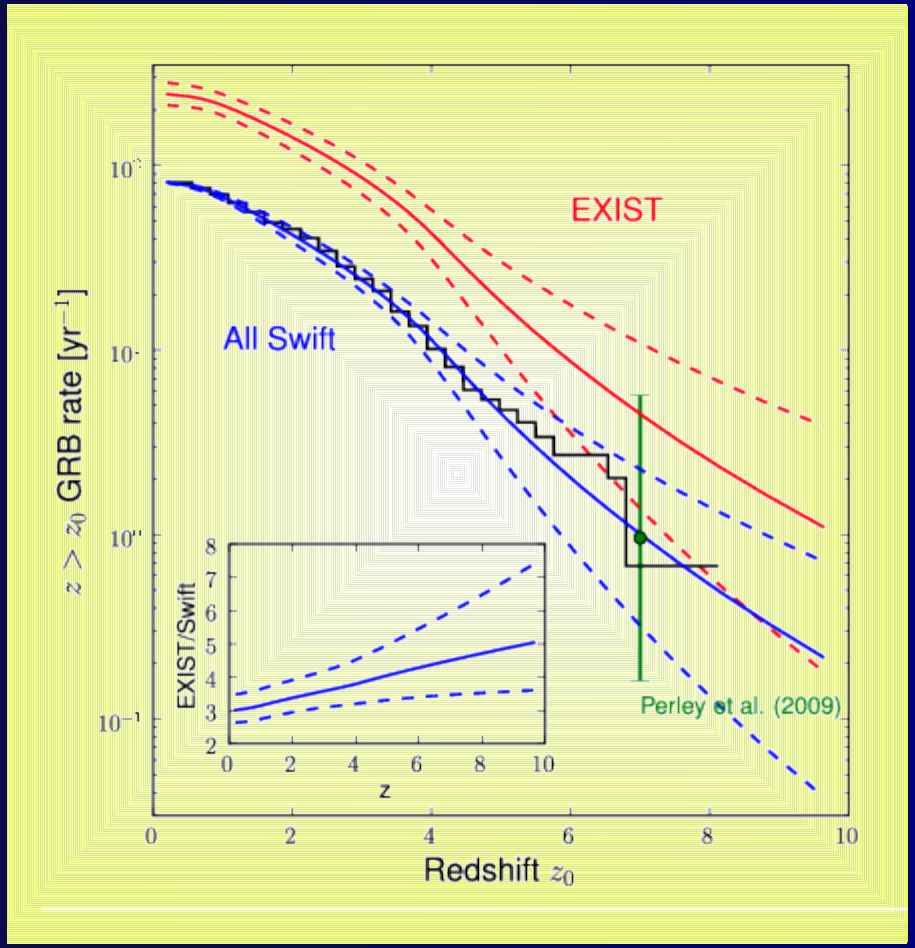
also, Kistler et al. (2007, 2008); Salvaterra et al. (2007, 2008, 2009).

Fraction at High-z

6±3 % of Swift GRBs
@ z>5

1±1 % of Swift GRBs
@ z>8

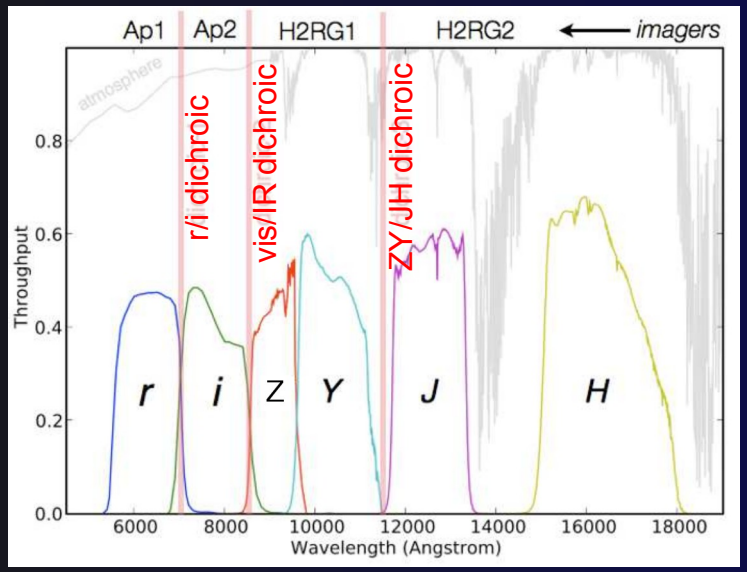
see, also, Perley et al. (2009), Fynbo et al. (2009)



http://www.ratir.org

Nathaniel Butler	(PI & Project Manager; UC Berkeley)
Joshua S. Bloom	(Co-I & Software Lead; UC Berkeley)
Alejandro Farah	(Co-I & Mechanical Design; IA-UNAM)
Julien Girard	(Co-I & User Interface; ESFM-IPN)
Jesus Gonzalez	(Co-I & Optical Design; IA-UNAM)
Alexander Kutyrev	(Co-I & IR Dewar Lead; Goddard)
William Lee	(Co-I; IA-UNAM)
J. Xavier Prochaska	(Co-I; UCO/Lick)
Enrico Ramirez-Ruiz	(Co-I; UC Santa Cruz)
Michael Richer	(Co-I & Telescope Co-Lead; IA-UNAM)
Alan Watson	(Co-I & Telescope Co-Lead; CRyAUNAM, IA-UNAM)

RATIR Overview



Reionization and Transients InfraRed CAMERA

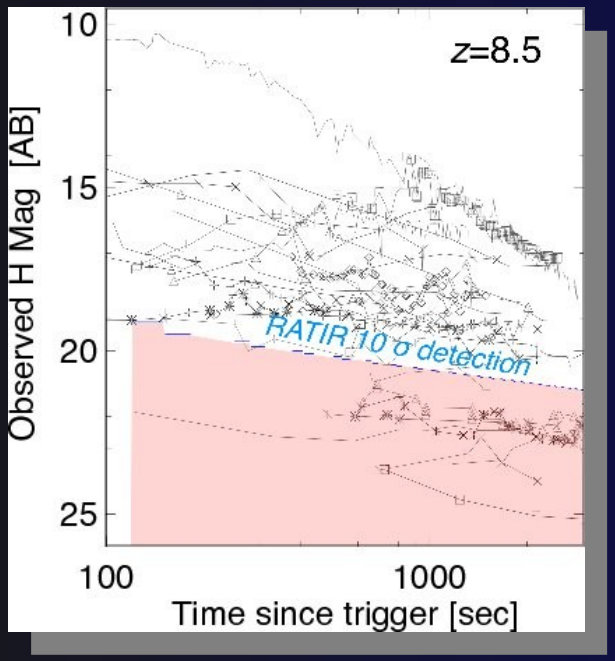
6 channel optical/NIR imager

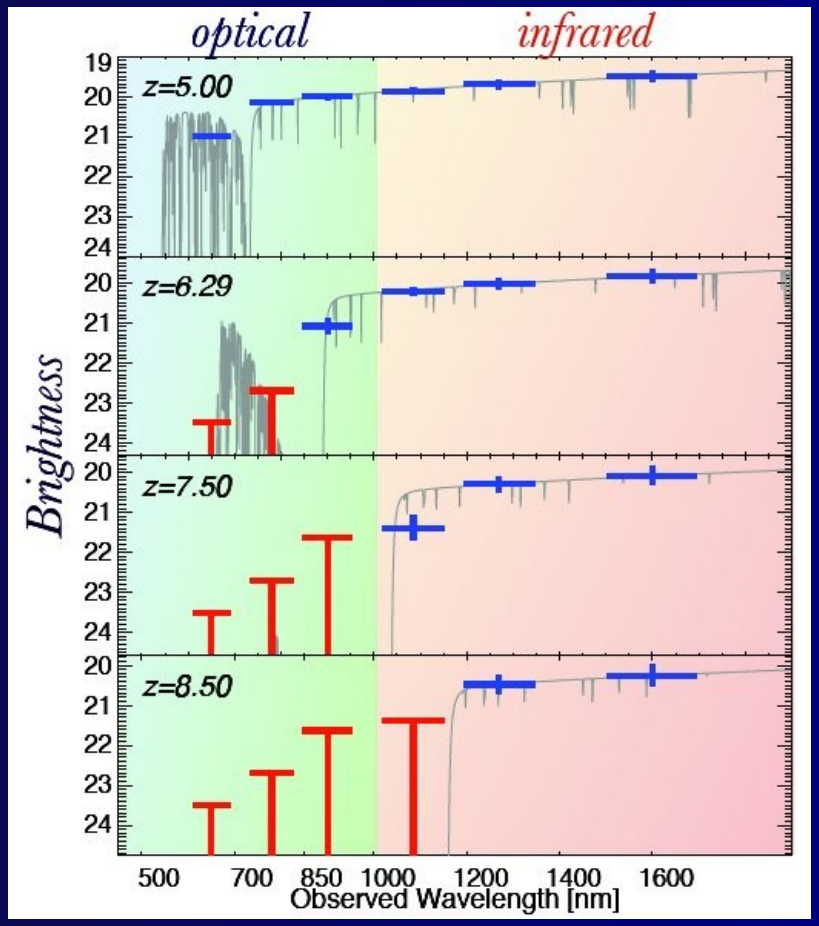
(associated project RATTEL)

Funded by Swift to:
- Infer high-z (z>6) GRBs
- Measure Early Afterglows

But most time Mexican Non-ToO Science

US / Mexico Collaboration





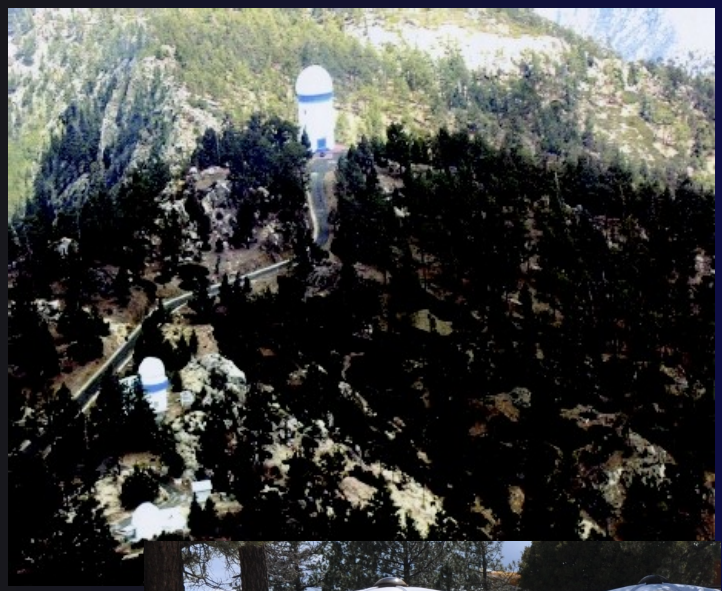
Establish:

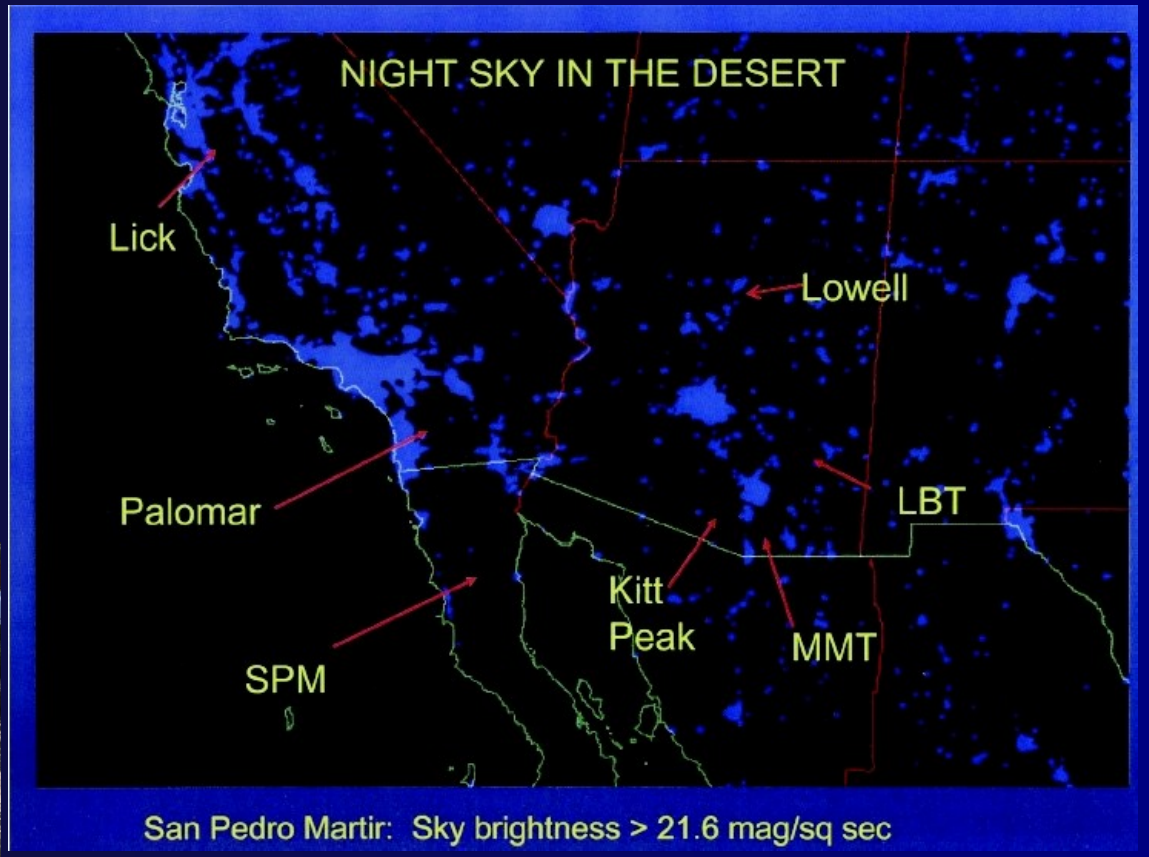
IR Sky brightness for SASIR (J. Bloom PI; *www.sasir.org*)

Infrastructure / Roboticization

Experience with IR detectors

Utilizing 1.5m Harold Johnson (2yrs)

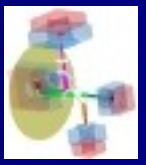


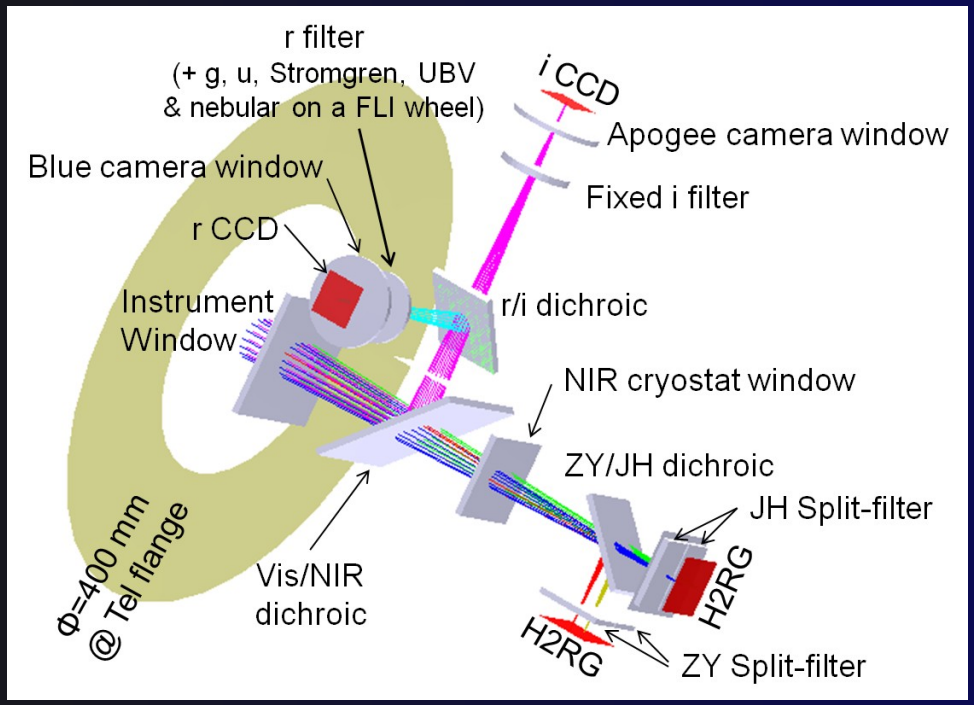


Excellent site! ; 2800m above sea

>61% nights photometric ; >81% spectroscopic (20yr study: Tapia '03)

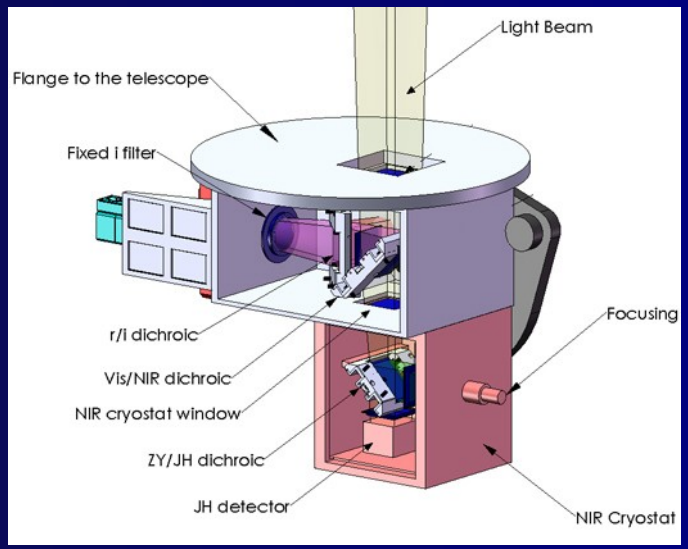
Optical / Mechanical Designs



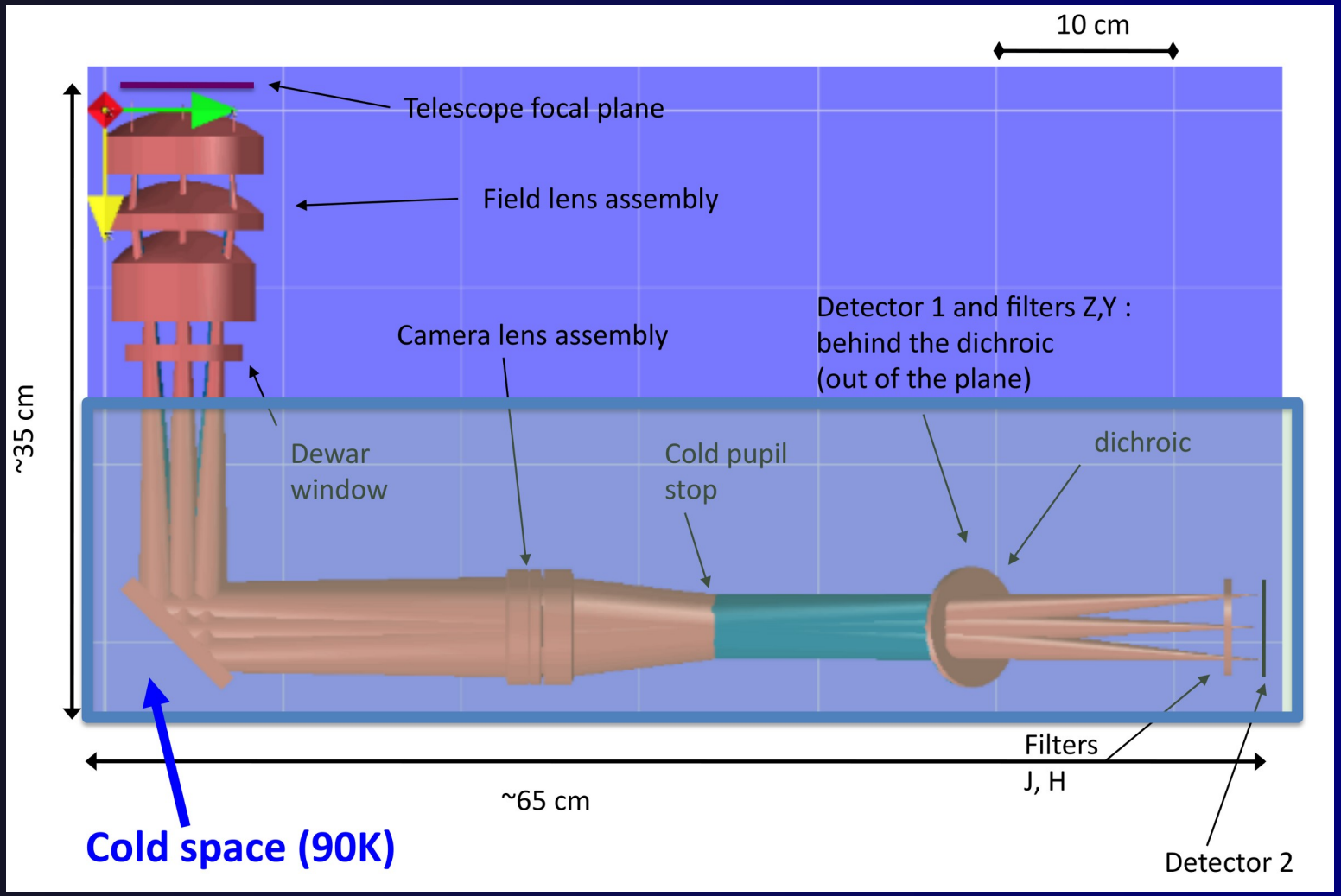


Optical Design, (Jesus Gonzalez)

Mechanical Design (Alex Farah)



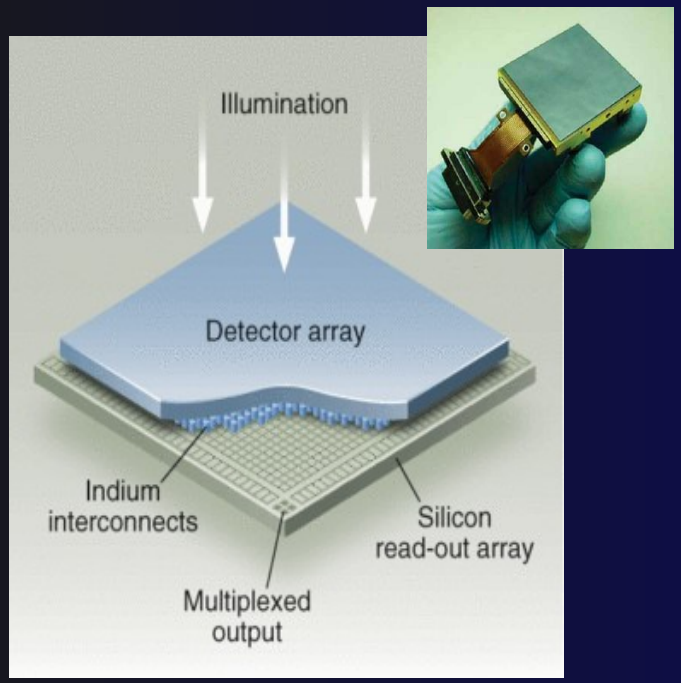
IR Dewar Design



Design being finalized now (Alexander Kutyrev, Harvey Moseley)

Detectors

* Off-the-shelf Apogee Optical Camera's
* Teledyne H2RG arrays for NIR - (buy/borrow, 2.5μm)



Utilize Teledyne “SIDECAR” ASICs to write fits.

Timeline

* Swift Cycle 5 Proposal: “GRB Correlative IR Capabilities”
  (Nov '08)

* High-level design/specifications & Conceptual Optical layout
  (Nov '08 - March '09)

* Additional Funding + Goddard Manpower
  (Jan/Feb '09)

* Design Review
  (April '09)

* **Design Revisions and initial Lab tests**
  (Summer '09)

* **Most Hardware in Lab**
  (Fall '09)

→ First Light in Summer 2010!