

Gamma-Ray Bursts

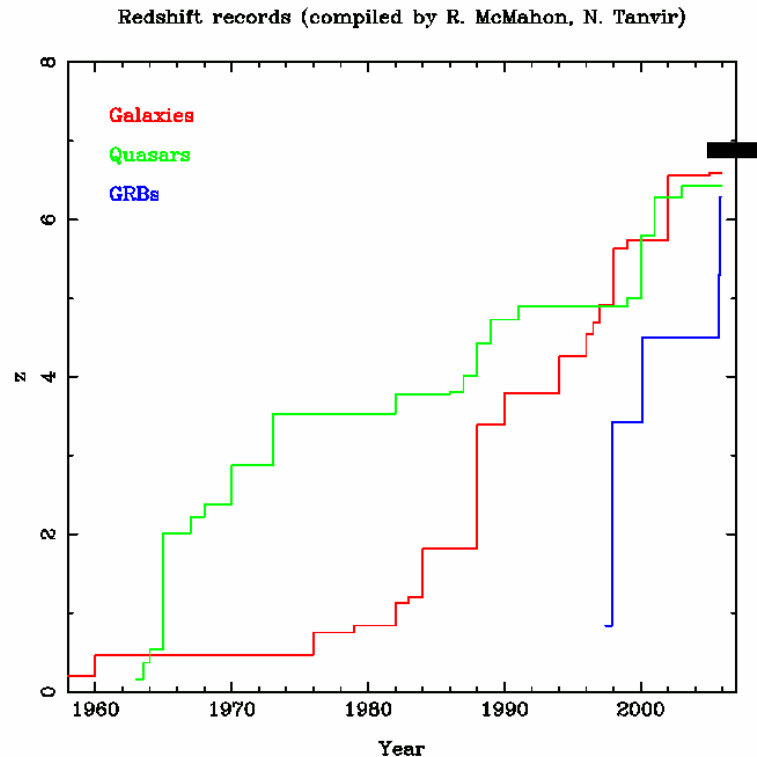
How to detect them at high- z ?

The experimental challenge

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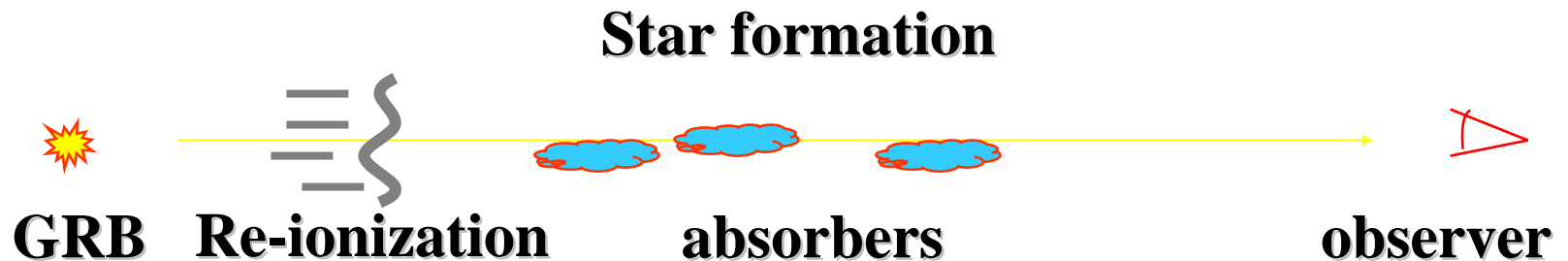
Outline

- ground-based attempts
- space-based possibilities
- GLAST: prospects

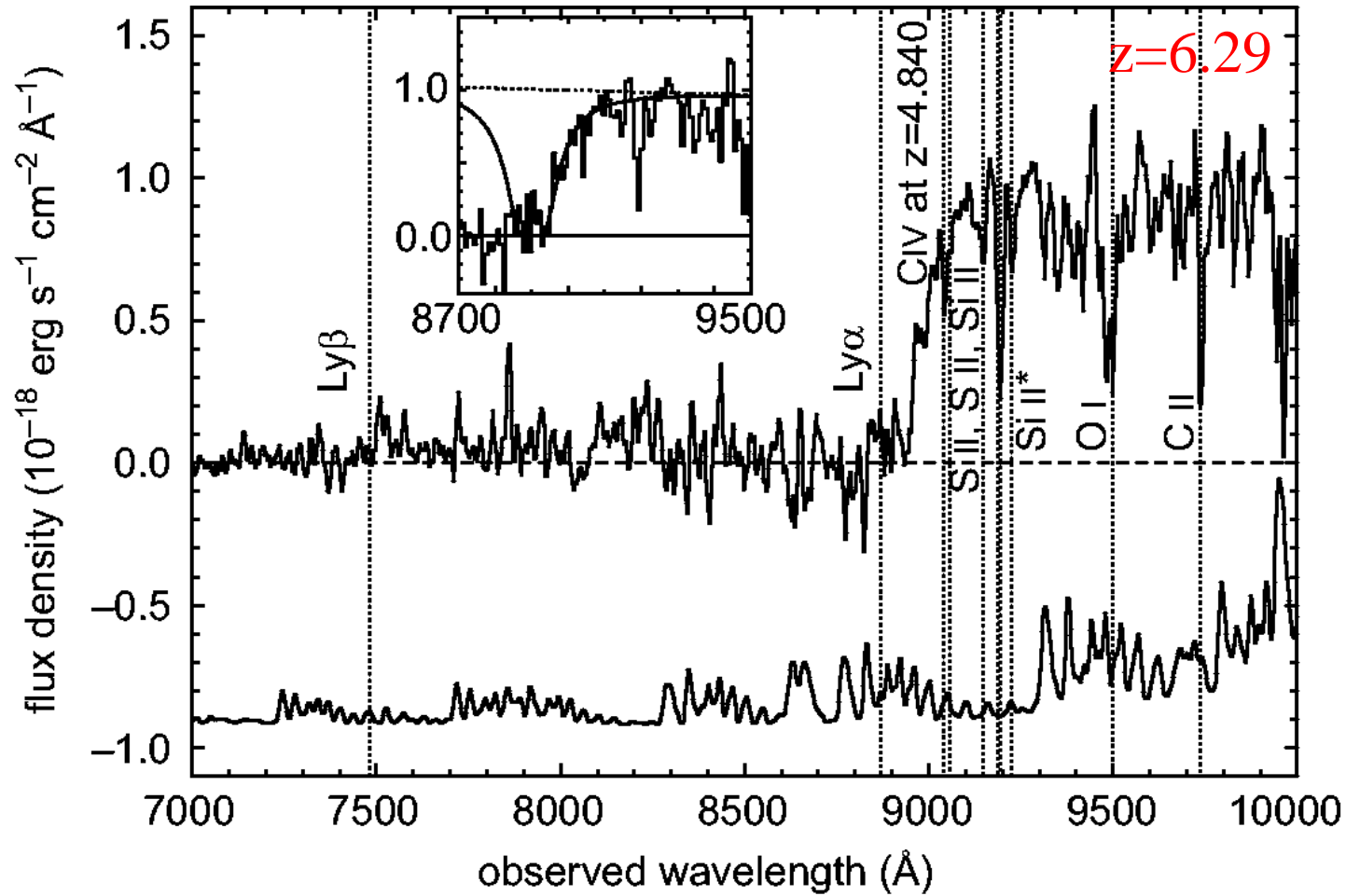


GRBs as light beacons

- Long-duration GRBs follow the star formation rate
- If rapidly identified: unique probes of early universe, including cosmic chemical evolution, re-ionization
- GRBs are ideal light beacons to study early universe
 - ☆ Bright
 - ☆ Not affected by dust extinction - unbiased sample
 - ☆ Simple spectrum (power law)
 - ☆ No pre-GRB ionization of surrounding



GRB 050904

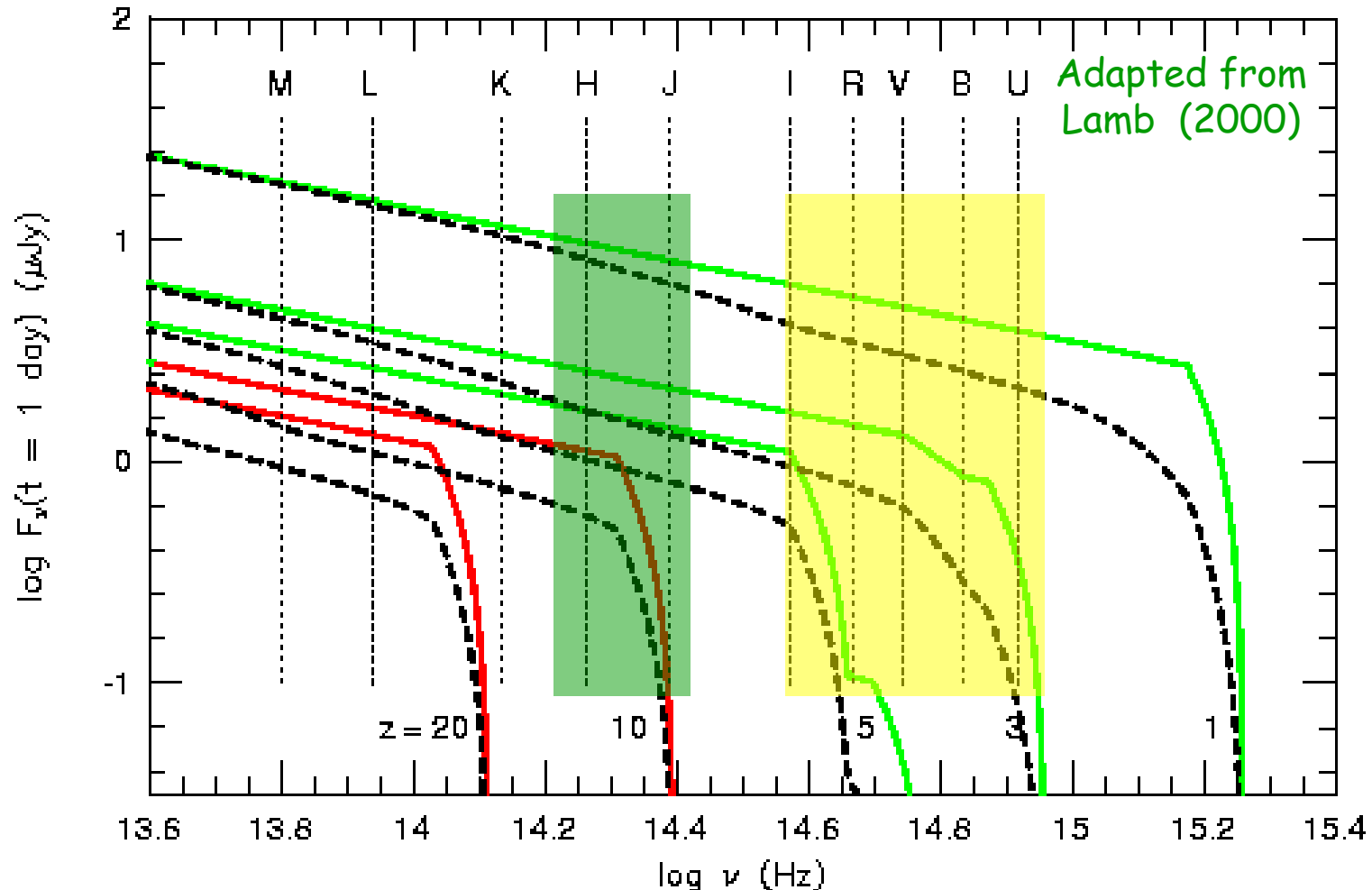


Kawai et al. 2005

How to find high-redshift GRBs?

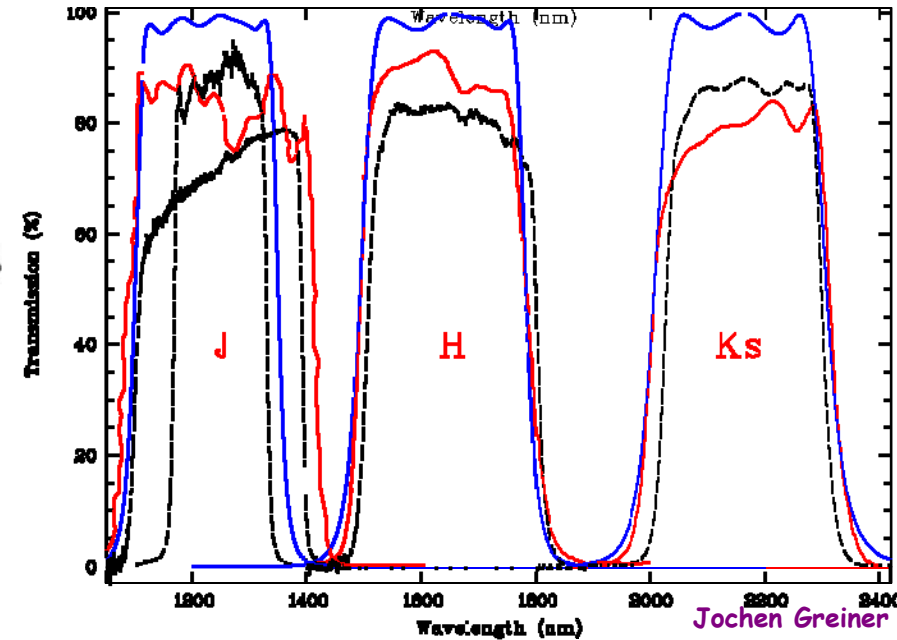
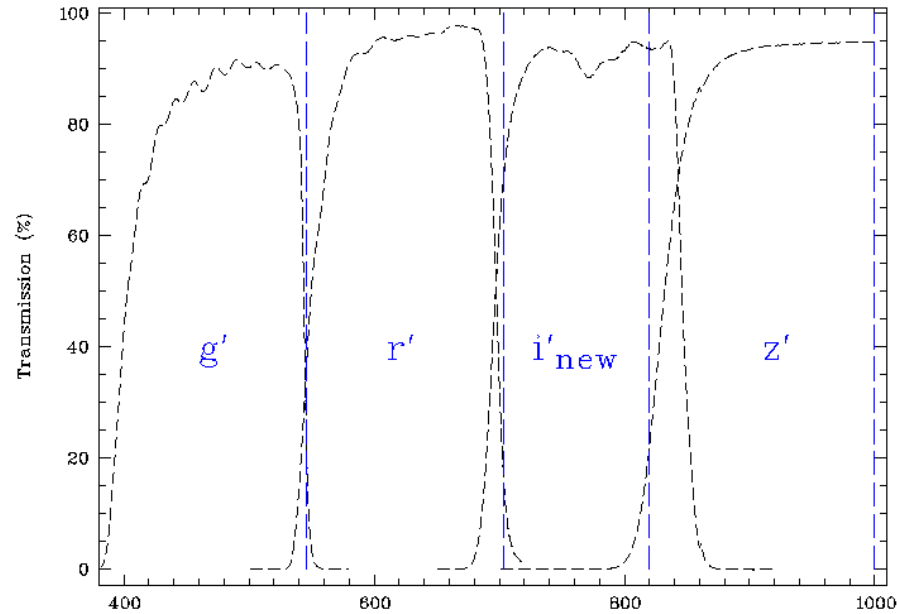
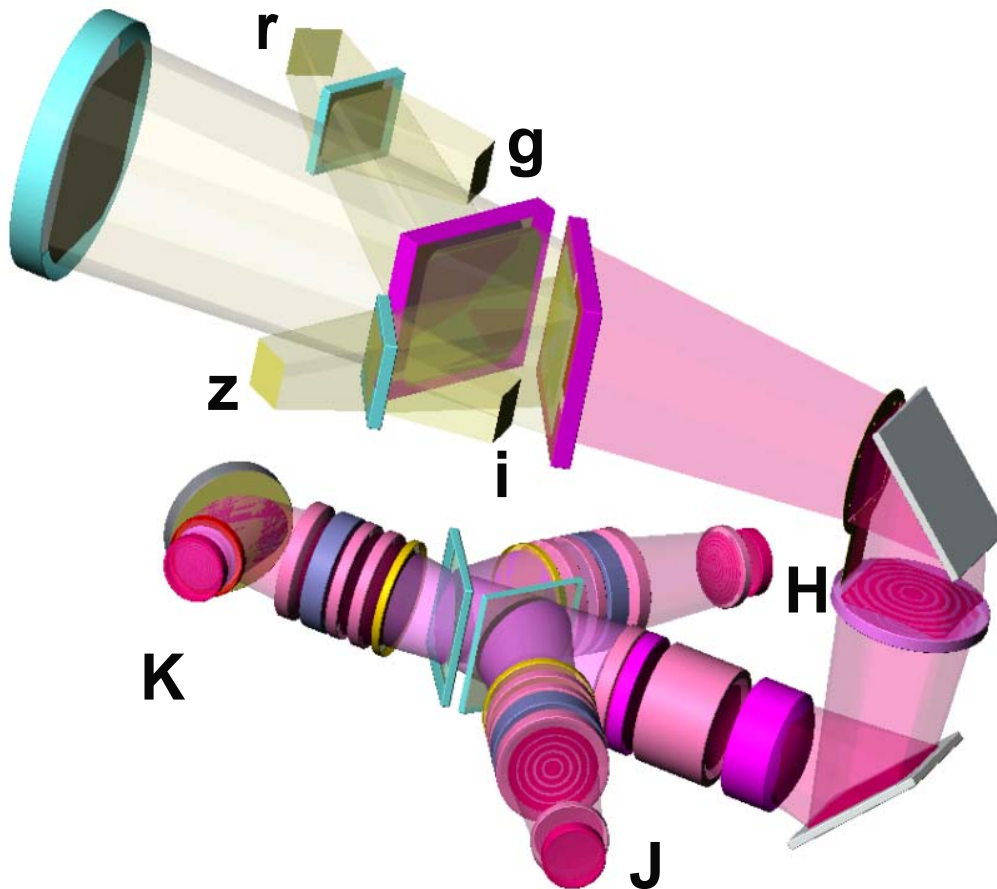
Due to characteristic spectrum of GRB Afterglow:

- ☆ Photometry in optical: up to $z \sim 6$
- ☆ Photometry in NIR: up to $z \sim 12-14$ (GROND)



GROND=GRB Optical/NIR Detector

Imaging in 7 channels simultaneously



GROND: General Design

- **7 filters: Sloan g', r', i', z' and J, H, K**
One detector for one filter band (no movable filters!)
3 HAWAII 1K*1K Arrays + 4 E2V 2K*2K CCDs
- **Field-of-view: Visual: 5.4'x5.4' (0.16"/pixel)**
NIR: 10'x10' (0.59"/pixel)
- **Dichroics tuned to minimize intrinsic polarization effects**
- **2 shutters, i.e. g'r' and i'z' pairs of CCDs have same exposure**
- **Combined telescope and intrinsic mirror (K-band) dithering**
- **Sensitivity:**

	4 min	1 hr
gr	21.5 mag	24.5 mag
iz	20.5 mag	23.5 mag
J/H/K	18.5/17.5/16.5 mag	21.5/20.5/19.5 mag

GROND - capabilities and selected results

Status:

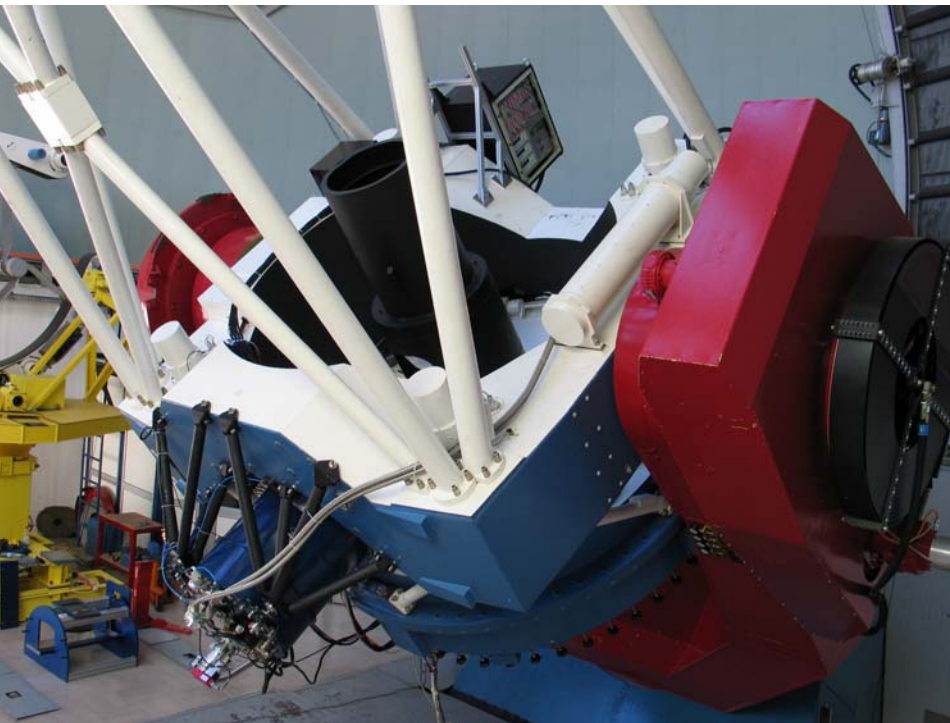
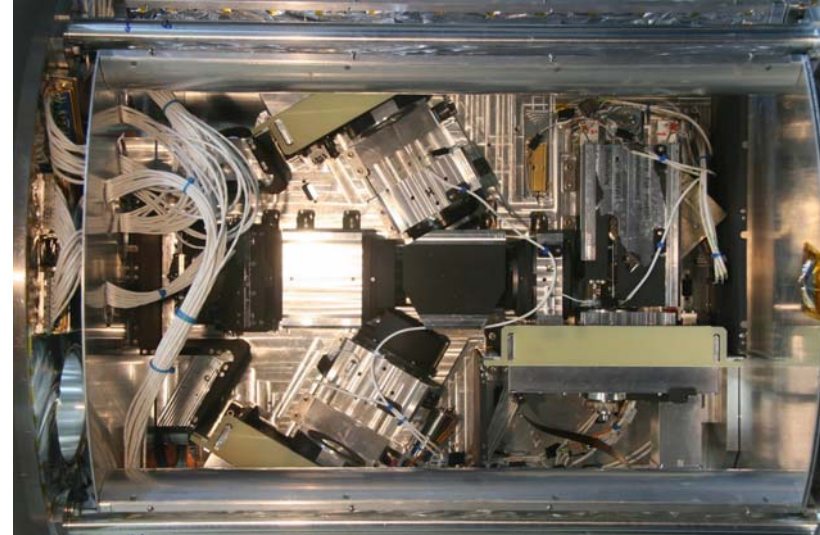
First light: Apr 30, 2007

First GRB: May 2007

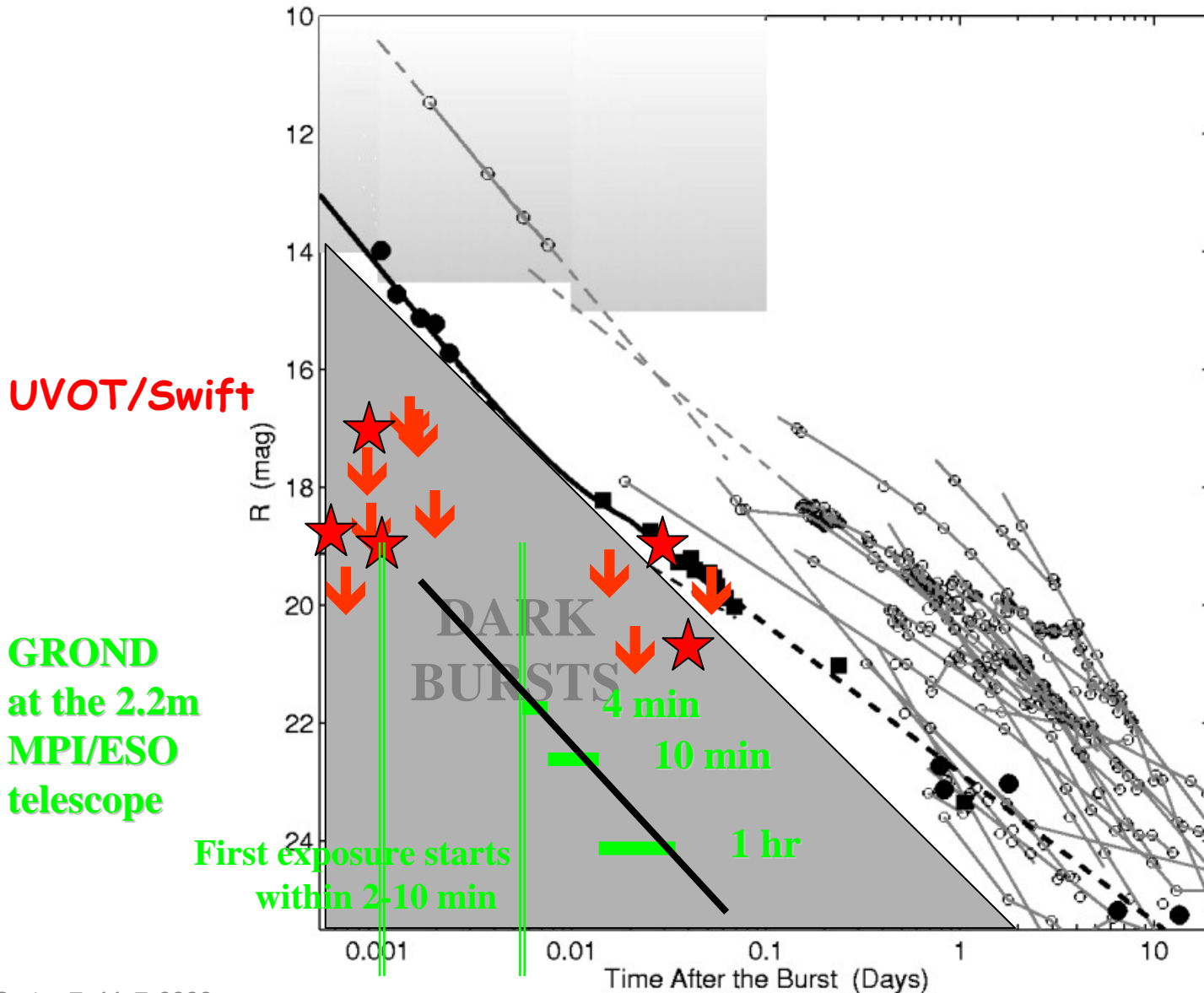
Photometric calibration: Jul 2007

since then routine observations

fastest response time: 2 min



Limits wrt to pre-SWIFT dark GRBs



GROND first results: I

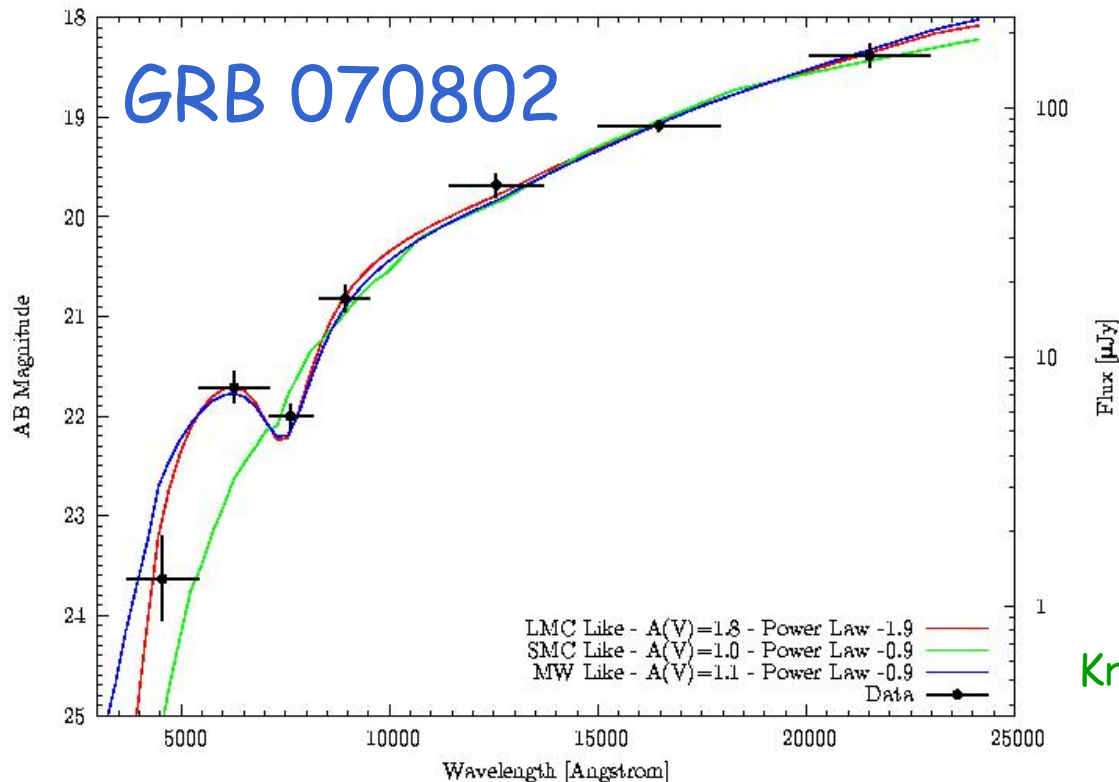
Operational since May 2007 (but only 8 months effective observing)

47 GRBs observed (as of 09 Jul 2008)

11 non-detections (\rightarrow still $\sim 25\%$ dark GRBs)

4 GRBs with Ly-alpha affecting g' -band ($z \sim 2.5-3.5$)

1 with 2175 Å bump (GRB 070802 at $z=2.45$)



Krühler et al. (2008)

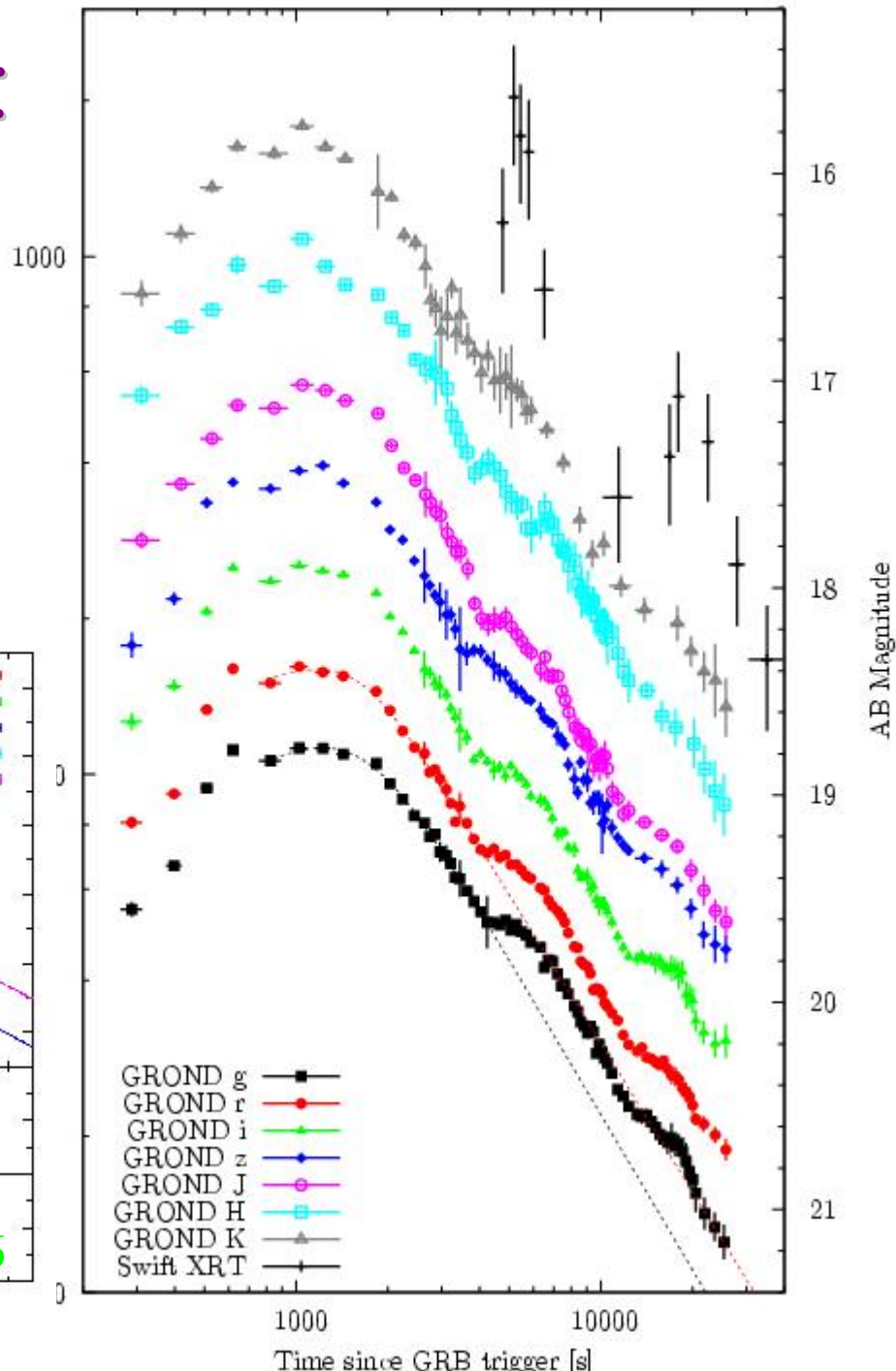
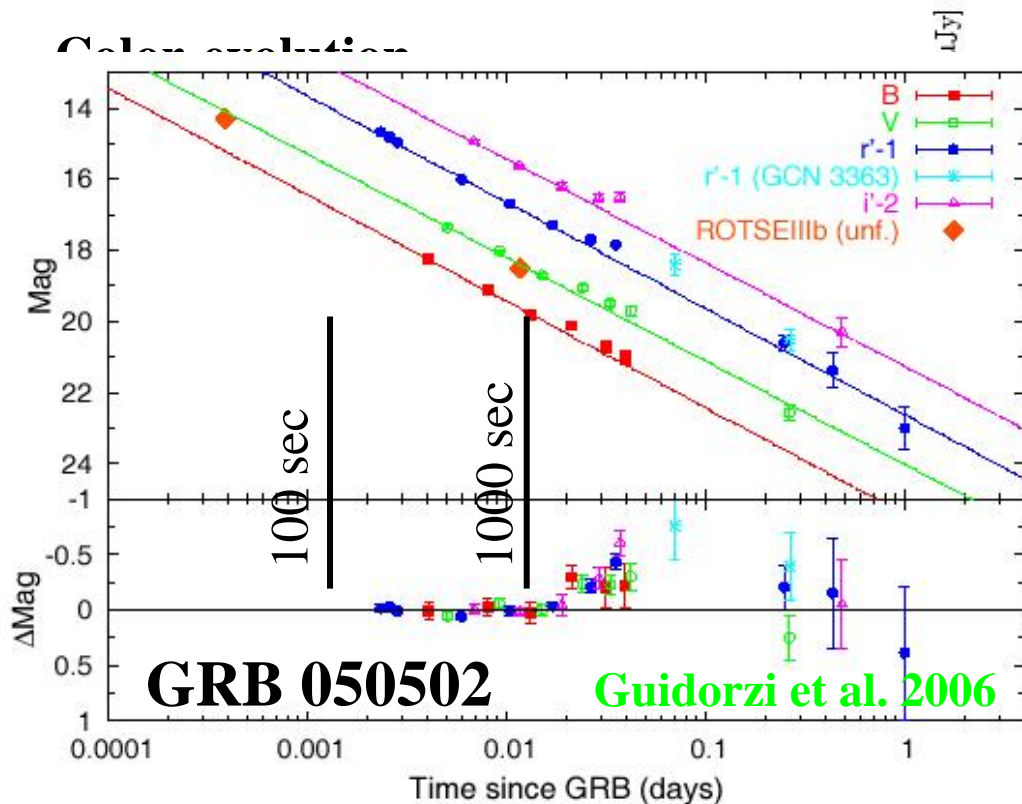
GROND first results: II

- First image: 4 min after GRB onset
~80 sec after trigger

1st night: 6 hrs continuous exposure;
350 data points

β -evolution (instead of one for all AG)

Color evolution



GROND first results: III

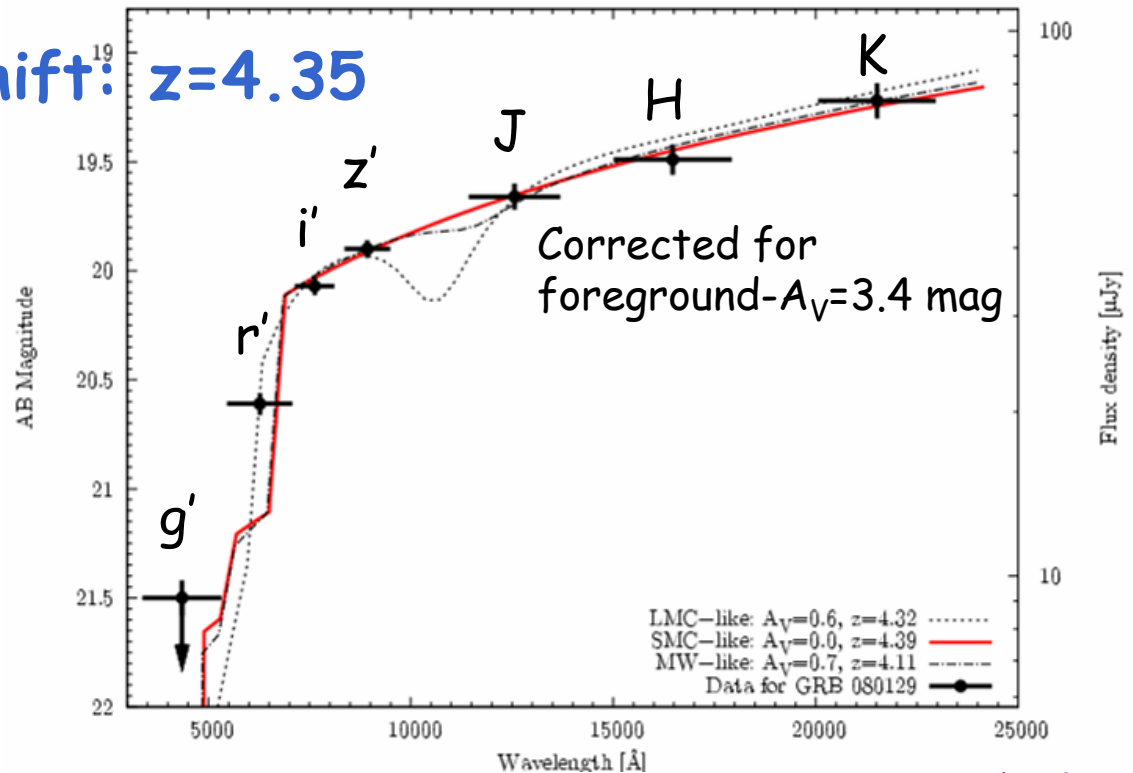
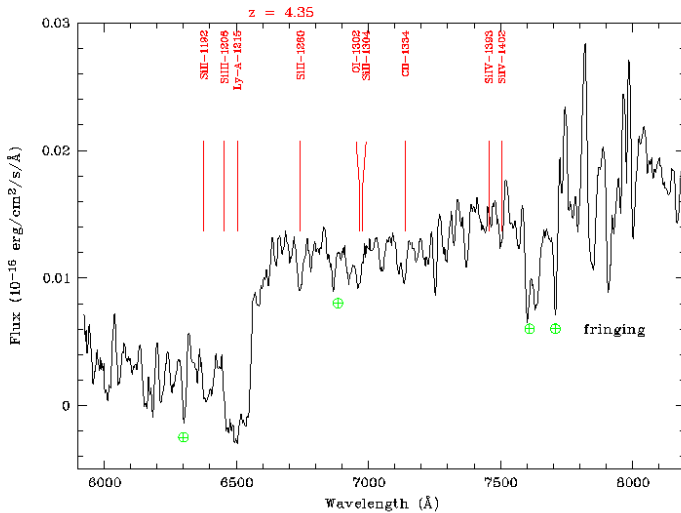
The disappointment so far: # of GRBs with $z > 3.5$

Dec. 2004 - Apr 2007: 14 ($\sim 6/\text{yr}$)

since May 2007: 1 ($\sim 1/\text{yr}$)

Greiner et al. (2008)

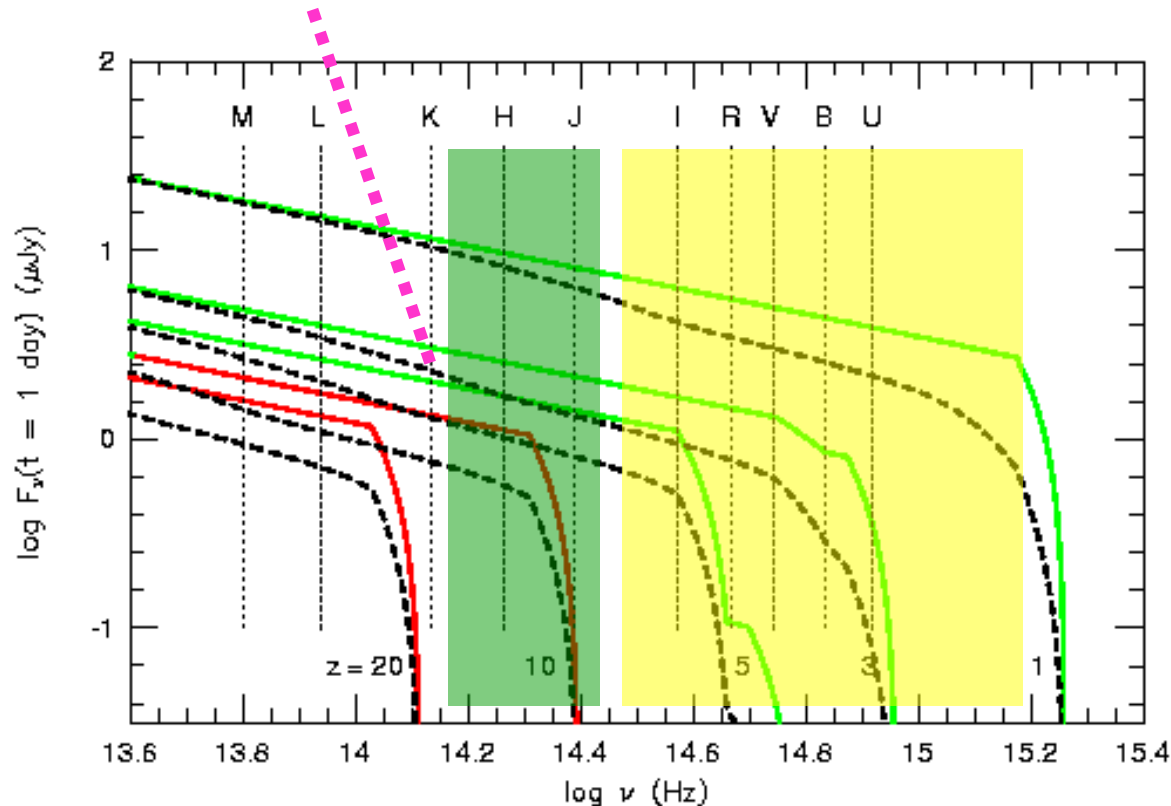
Spectroscopic redshift: $z = 4.35$



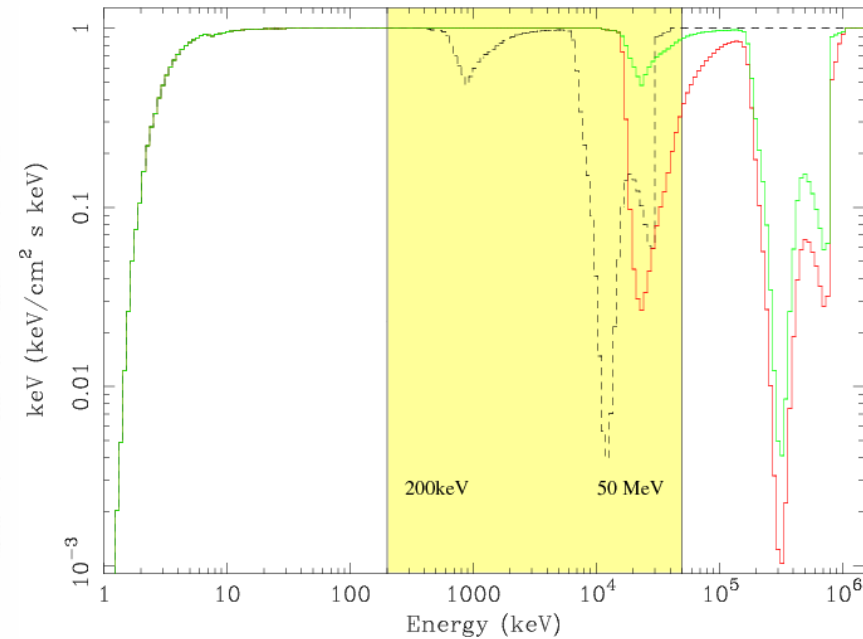
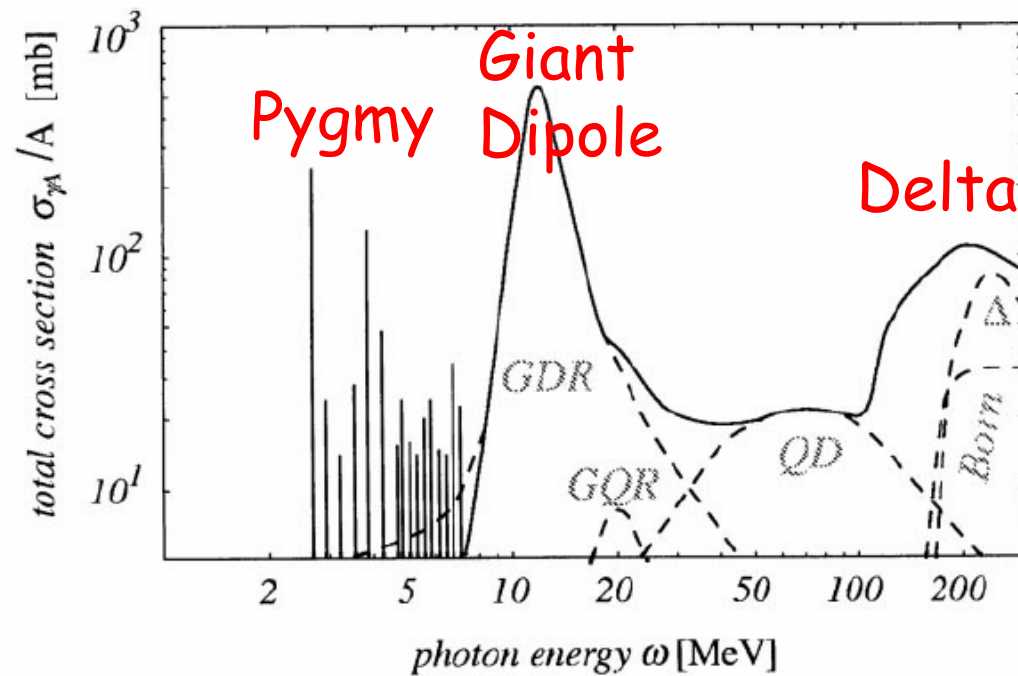
How to find high-redshift GRBs?

Due to characteristic spectrum of GRB Afterglow:

- ☆ Photometry in optical: up to $z \sim 6$
- ☆ Photometry in NIR: up to $z \sim 12-14$ (GROND)
- ☆ Beyond $z \sim 14$: not feasible from ground:
L-band sensitivity about 7 mag fainter than K-band
→ in gamma-rays?!
Needs a spectral feature above 10 keV!



Interactions of Photons and Atomic Nuclei



We See Effects of (with increasing energy):

- ☞ Excitation of Single Nucleons in Nucleus Potential ("Nuclear Lines")
 - $h\nu = E_{\text{nuc}}$
- ☞ Collective Excitations of Nucleon Groups ("Pygmi/Giant Resonances")
 - giant resonances: protons versus neutrons
 - quasi-deuteron resonances: a pair of proton and neutron
 - each of these occur in all multipole orders
- ☞ Excitations of Single Nucleons ("Delta Resonance")

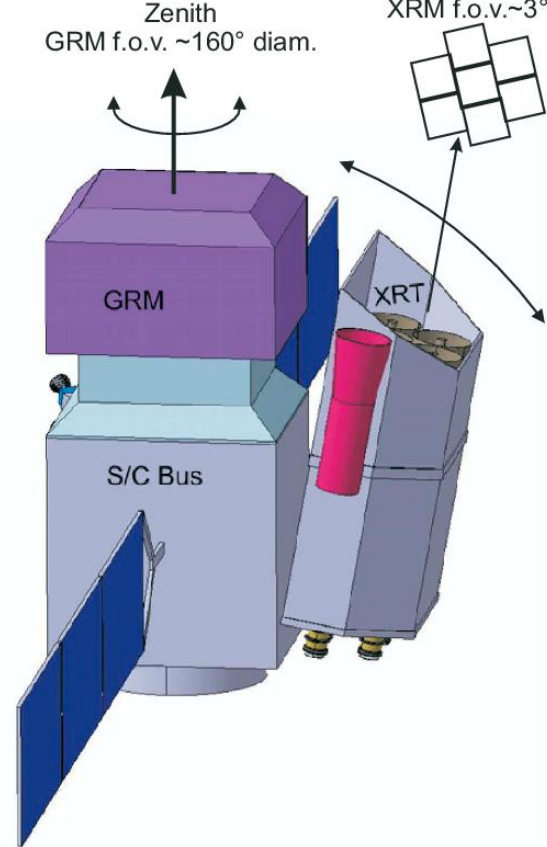
- Absorption independent of
 - ionization state
 - isotope ratio
 - GDR/DR ratio: metallicity

GRIPS MISSION



Proposed for ESA's Cosmic Vision 2007
Ranked 4th; only 1-3 selected for study

LEO, 0 degree, 500 km, zenith pointing
Gamma-ray Monitor: 160° FOV
X-ray telescope: 3° FOV
GRB alerts for follow-up



Instruments/capabilities

Gamma-ray Monitor

Energy range 200 keV-50 MeV
Localisation 1° (radius)
Polarisation 1% (@top 10% GRB)

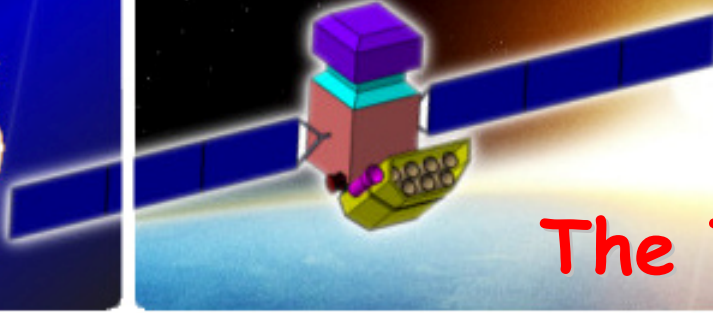
X-ray Monitor

Energy range 0.1-10 keV
Localisation 30" (radius)

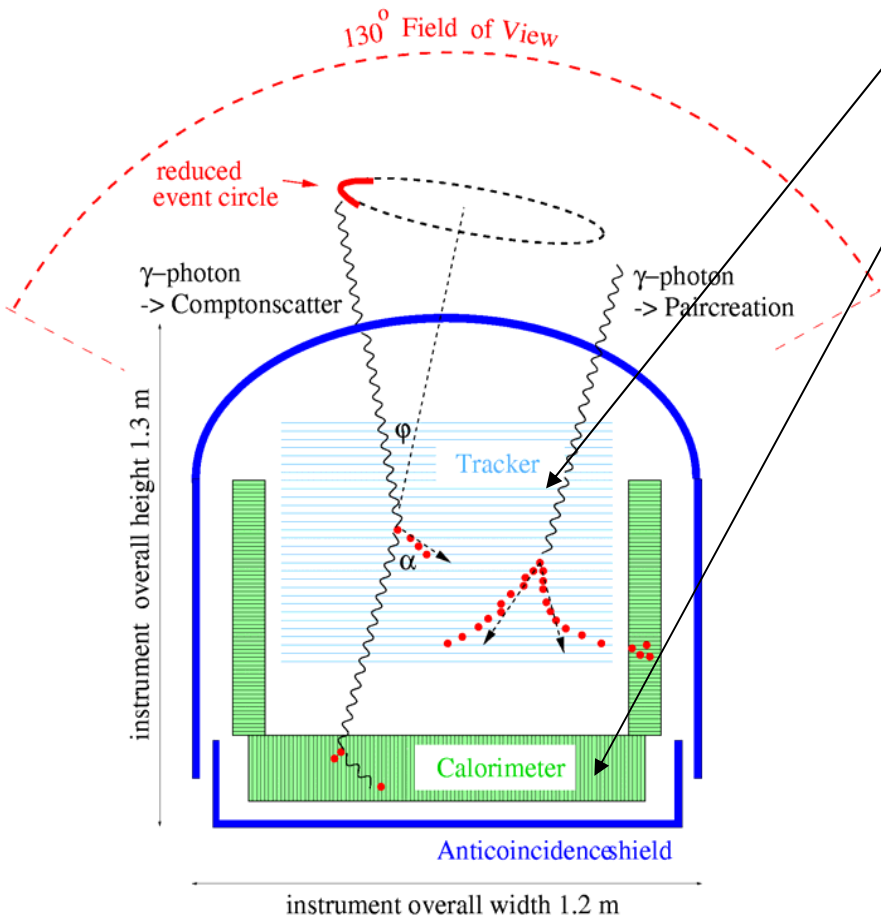
Source detections in 1 yr

Type	#
GRBs	660
Blazars	820
Other AGN	250
Pulsars/AXP	60
Unidentified	170

GRIPS MISSION



The Telescope Concept



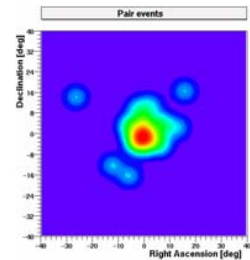
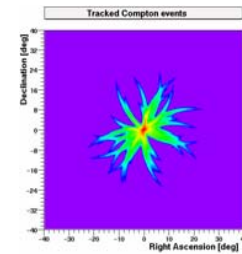
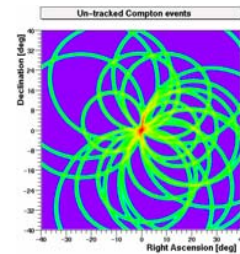
Tracker: double sided Si strip detectors

Calorimeter: 3D resolving LaBr_3 / Si drift diode

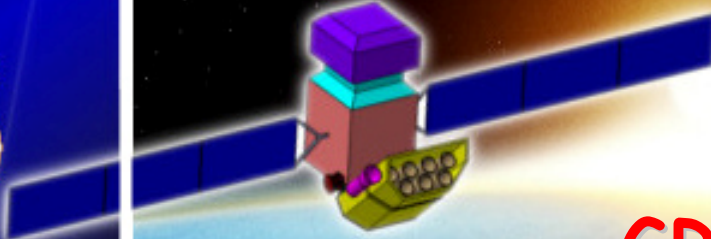
Classical
Compton

Images
Tracked
Compton

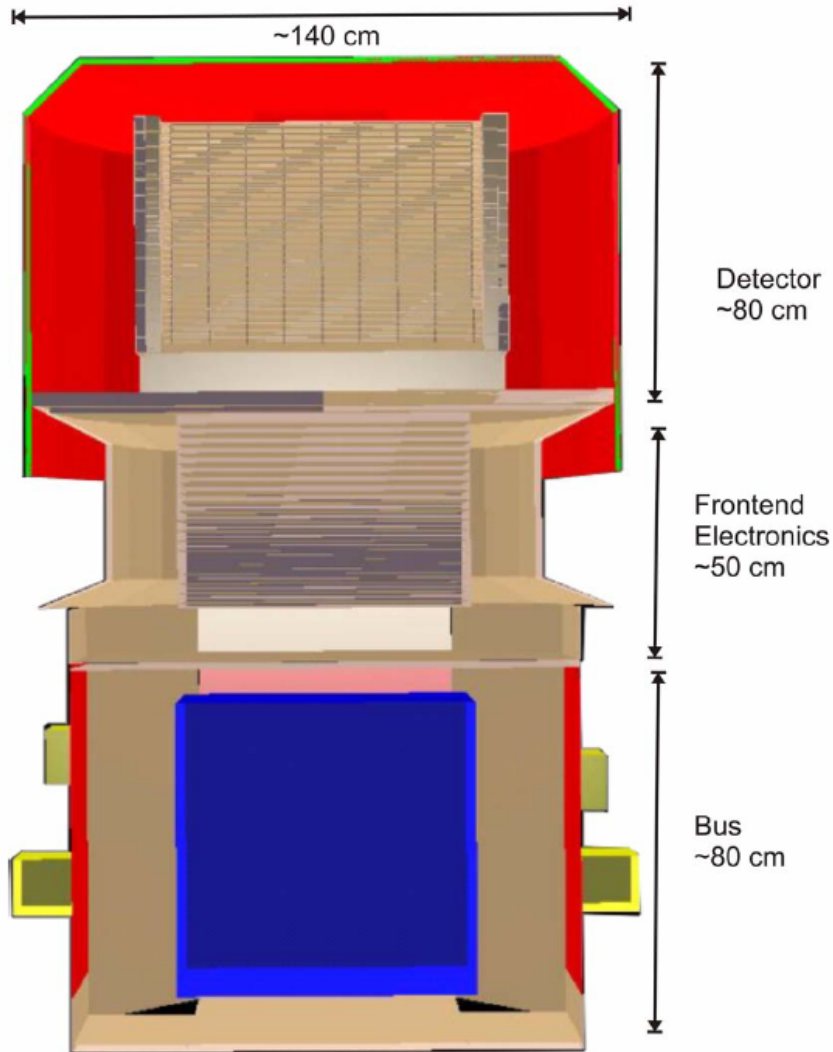
Pairs



GRIPS MISSION



GRIPS components



1 layer = 4x4 wafers of
10x10 cm² each

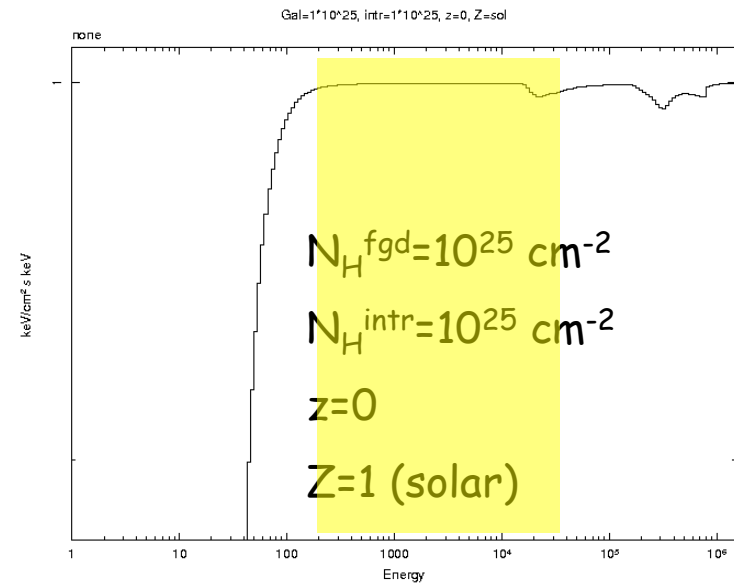
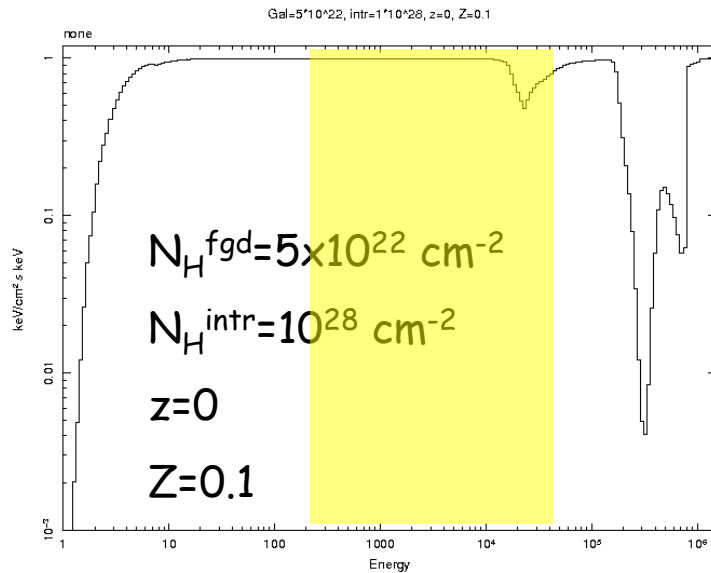
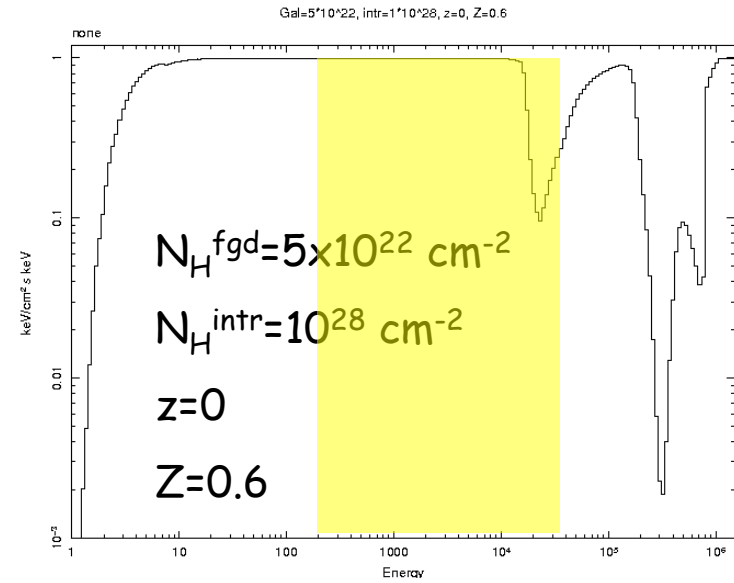
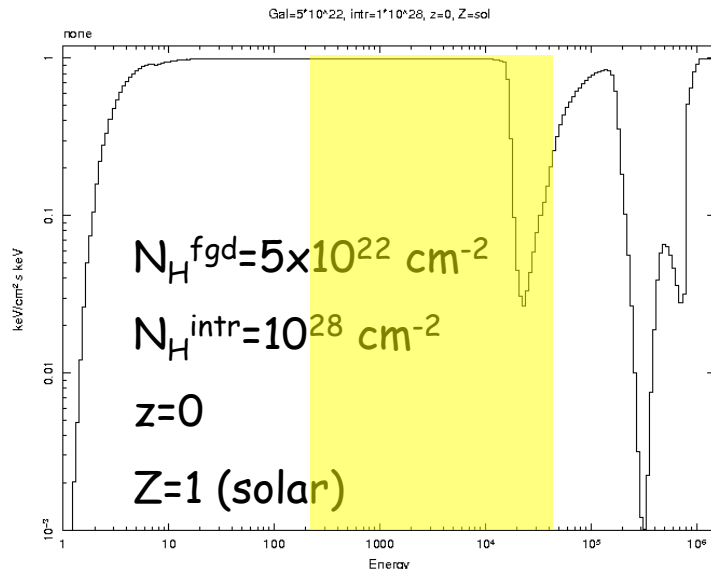
1 tower = 64 layers
spaced 5 mm (v.1)
3 mm (v.2)

4 towers

~500.000 read-out channels

LaBr ₃	750 kg
Si (tracker)	50 kg
Ne110	150 kg
Structure+Electr	200 kg
GRM margin	430 kg
eROSITA	660 kg
Gaia bus	510 kg
Contingency	550 kg
Propellant	200 kg
Sum	3500 kg

Resonance absorption: the effect



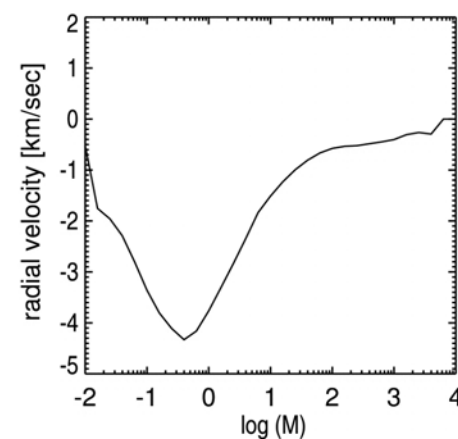
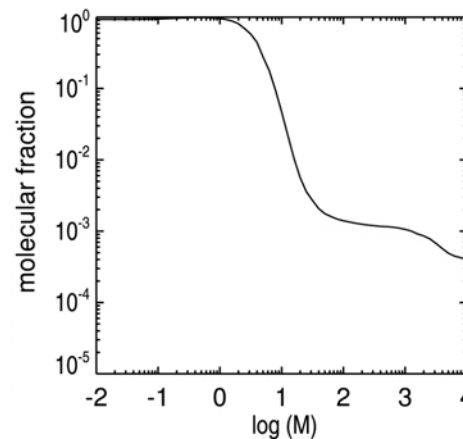
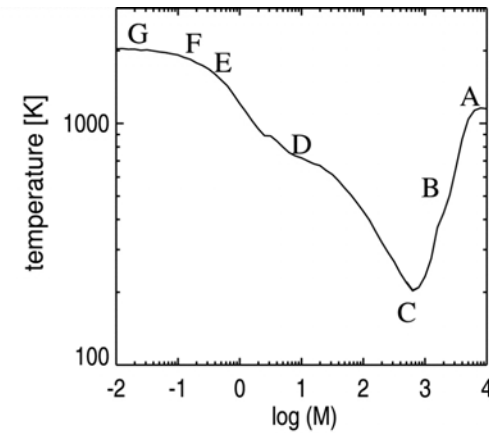
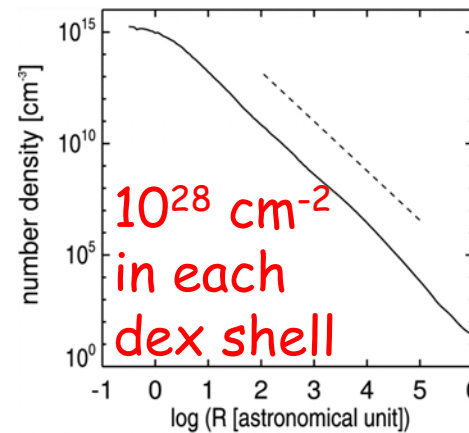
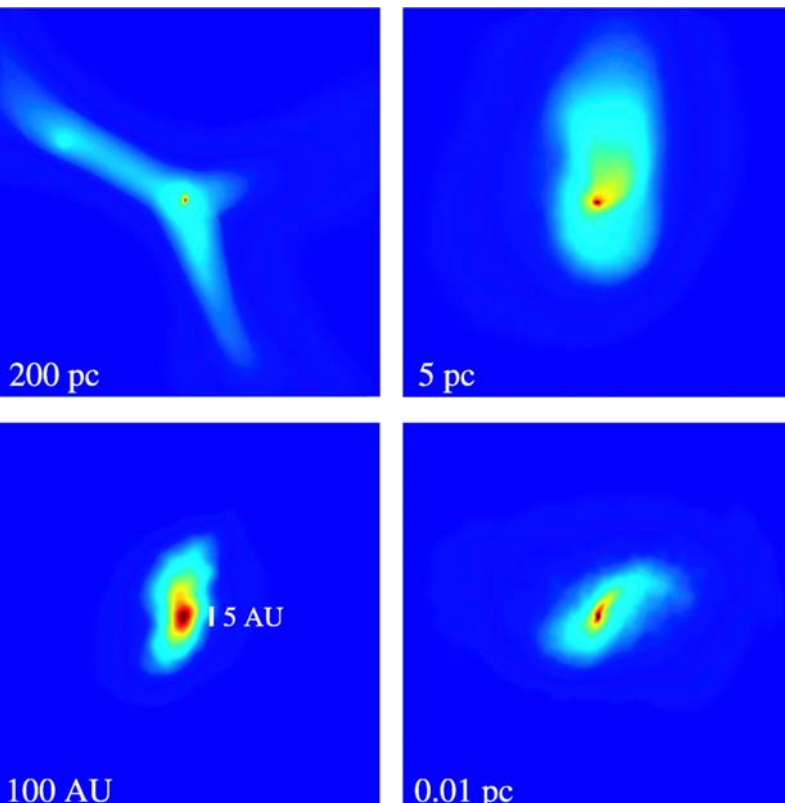
Matter near first star/GRB

- Gas clouds stable against fragmentation (no star clusters)
- Substantial fraction is ionized
- Mass or mass ranges for first stars still difficult to predict
- Radiation pressure is generally not important (no dust)

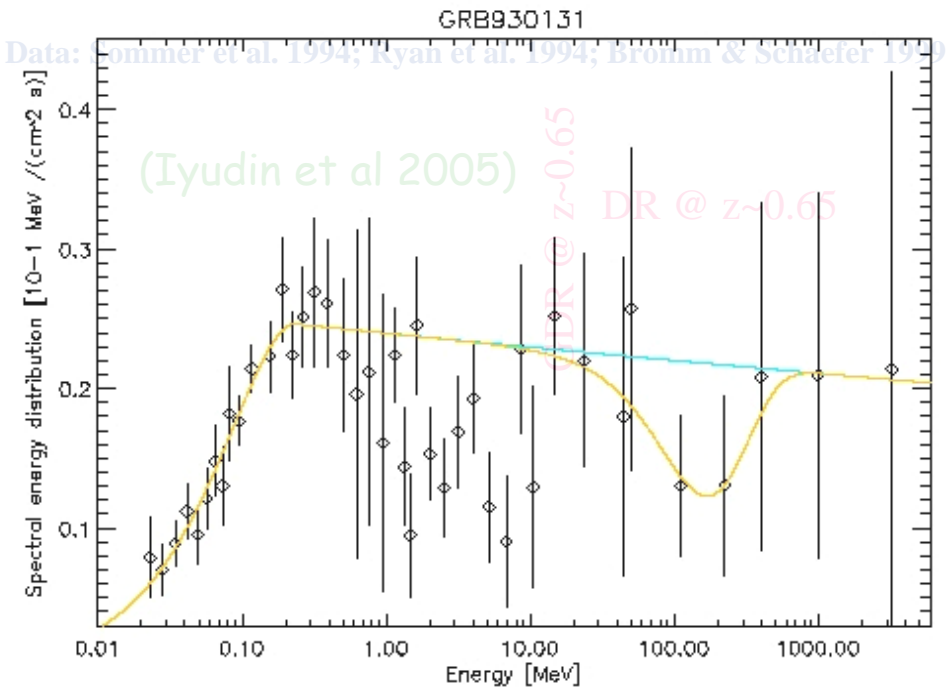
Yoshida et al 2006, ApJ 652, 6

Radial profiles at $z=19$.

Projected density distribution at $z=19$

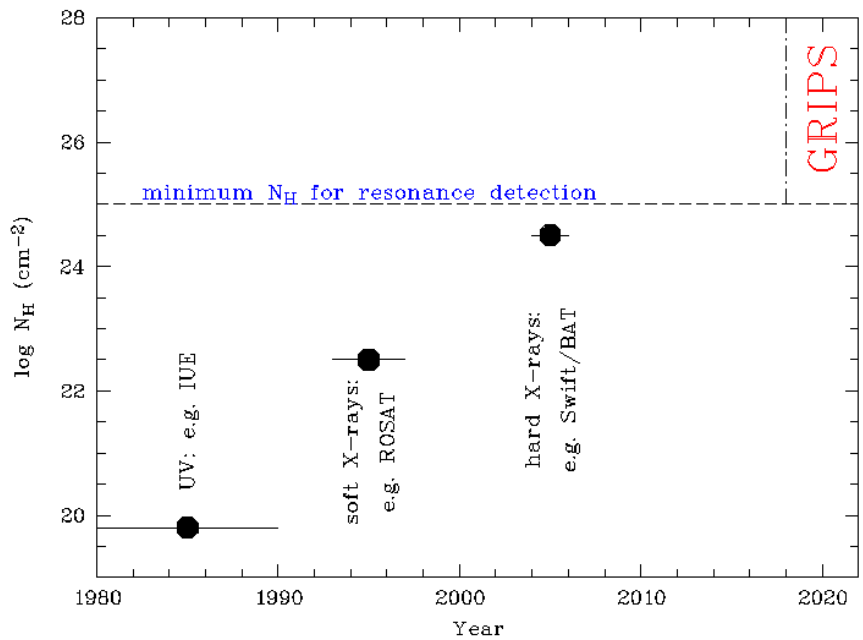


Brightest COMPTEL/EGRET burst 930131: 1σ hint



Minimum column to be detectable with GRIPS: 10^{25} cm^{-2}

Absorption seen in AGN



GLAST: NASA's New Gamma-Ray Telescope

Successfully launched: June 11

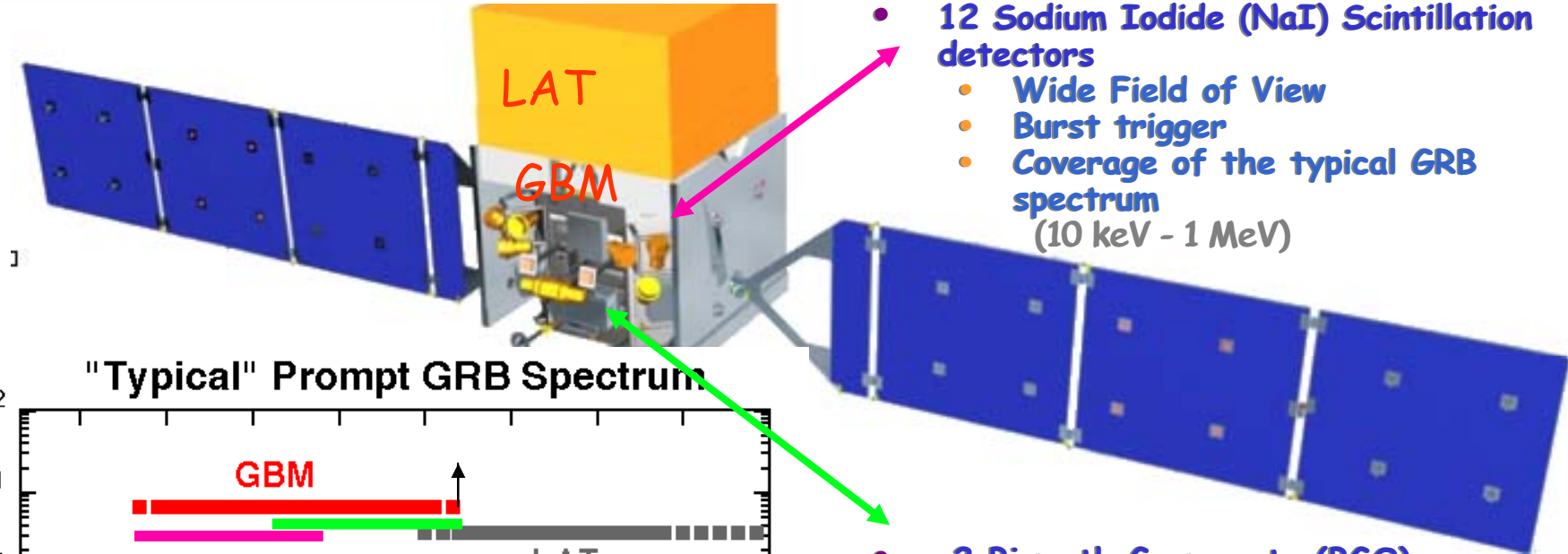
Presently in commissioning phase

Swift-GRBs 070630, 070701,
070703 have been seen

Expect start of operation in
mid-August



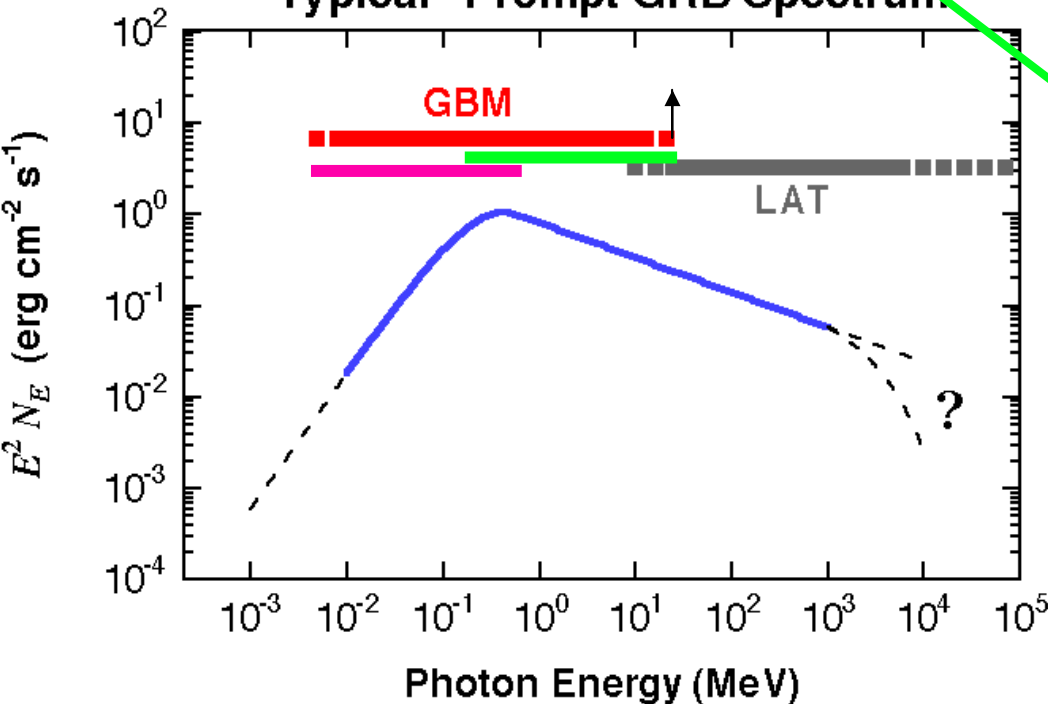
GLAST: Gamma-ray Large Area Space Telescope



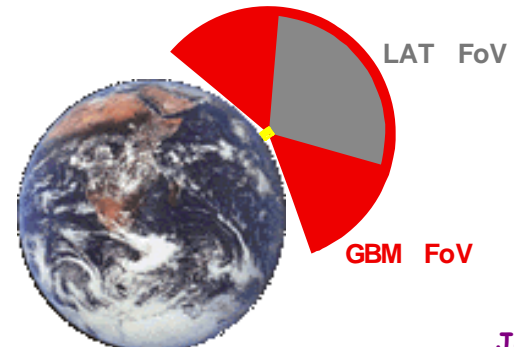
Glast Burst Monitor

- 12 Sodium Iodide (NaI) Scintillation detectors
- Wide Field of View
- Burst trigger
- Coverage of the typical GRB spectrum (10 keV - 1 MeV)

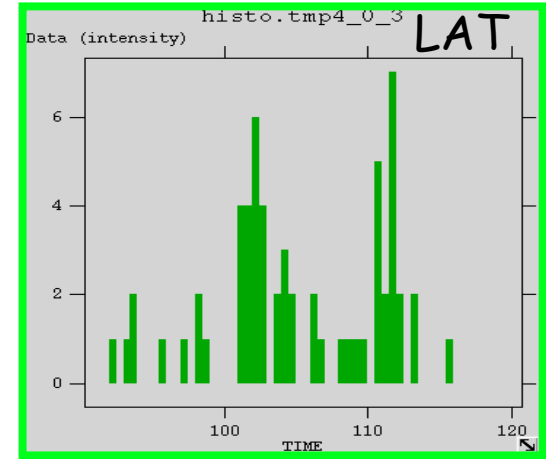
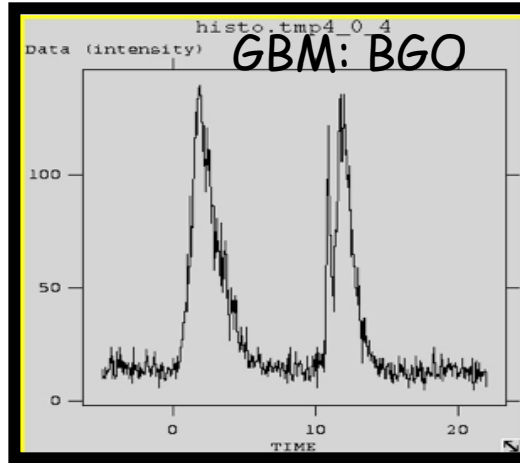
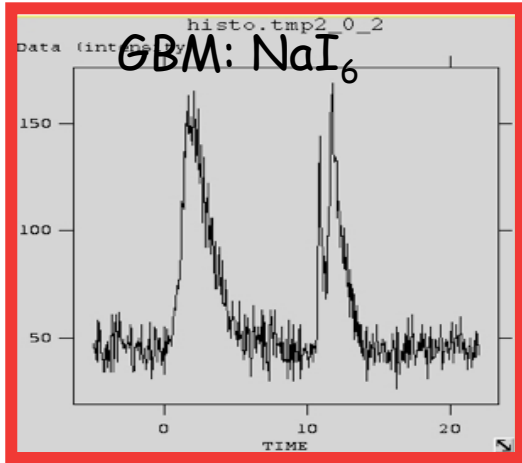
"Typical" Prompt GRB Spectrum



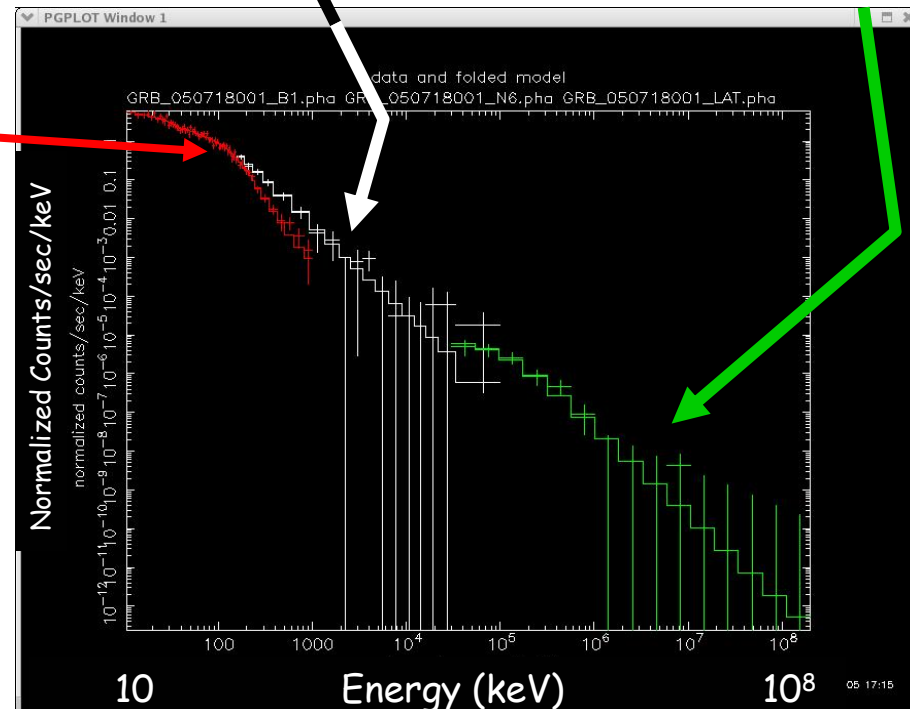
- 2 Bismuth Germanate (BGO) Scintillation detectors
- Spectral overlap with the LAT (150 keV - 30 MeV)



GLAST/GBM Simulations: (Detectors)



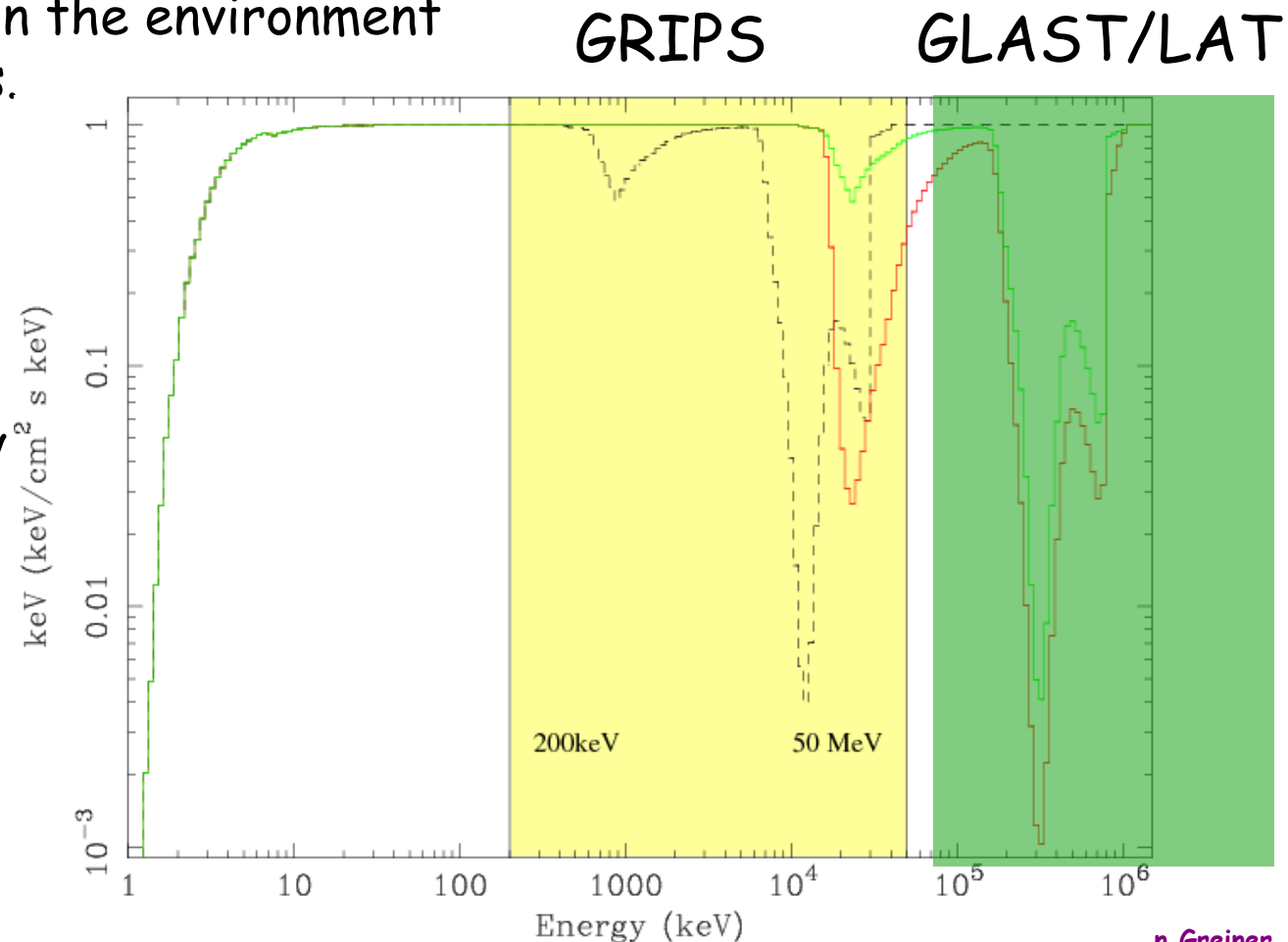
- Simulated response of both GBM and LAT.
- Energy Spectrum
 - Combined detectors cover ~7 decades in energy.



GLAST: expectation for nuclear resonance

GLAST-LAT is the obvious experiment to establish the existence of large column densities in the environment of cosmic sources.

BUT:
LAT only covers $z < 3$,
using just DR
GBM sensitivity not
sufficient > 5 MeV



Summary

- Community is eagerly waiting for Swift-GRB at $z > 6.x$
- GLAST-era is soon to start; likely will show nuclear resonance absorption lines in QSO/Blazars
- IF very high- z GRBs are behind $> 10^{25} \text{ cm}^{-2}$ then:
New generation of γ -ray missions are able to measure GRB redshifts up to $z = 20-60$ from γ -ray spectrum