Gamma-Ray Bursts
How to detect them at high-z?

The experimental challenge

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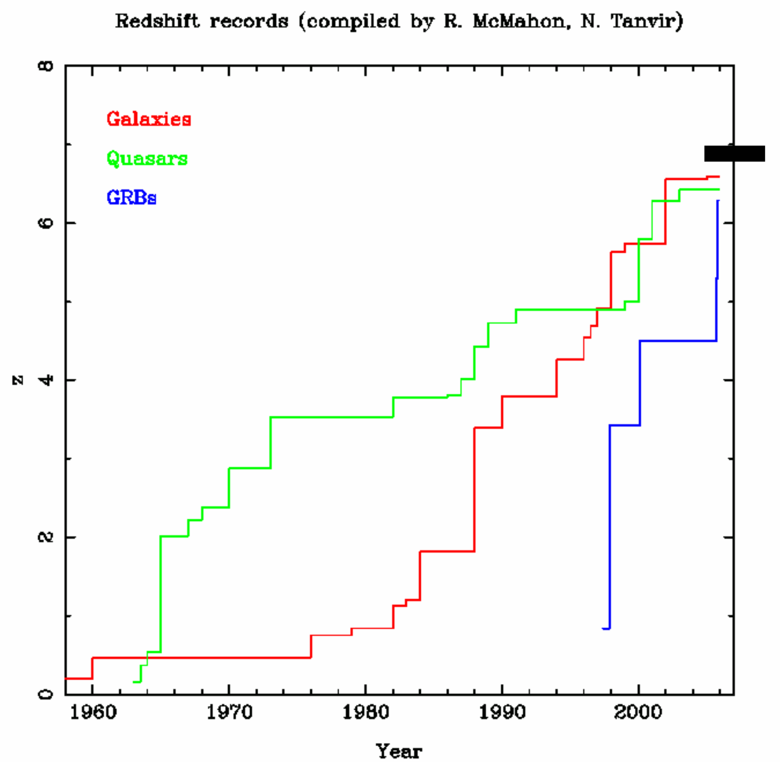
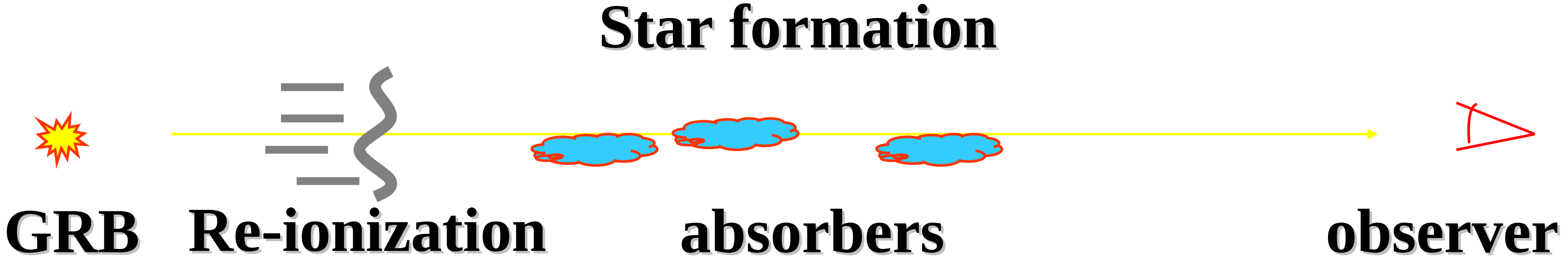
Outline

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

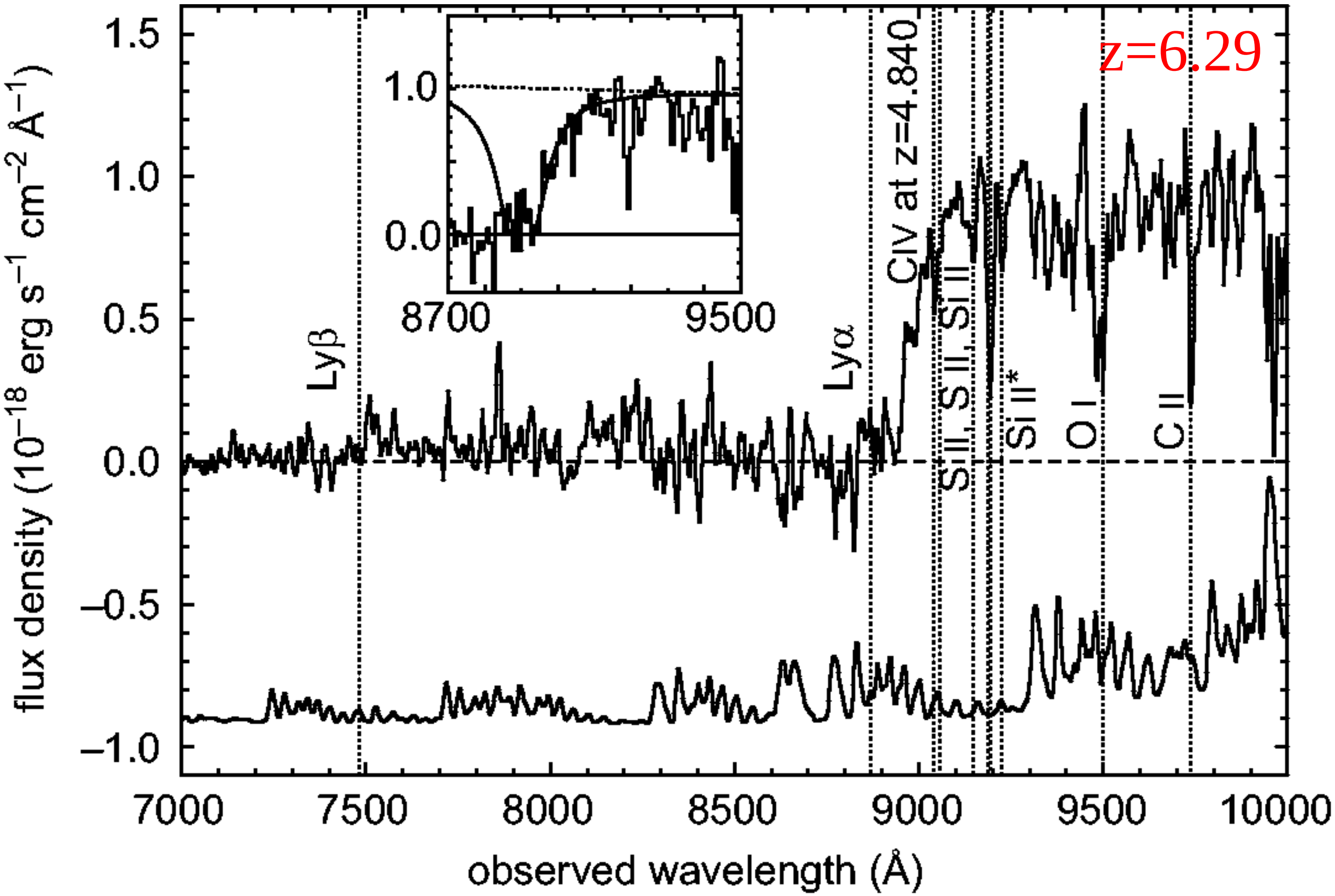


GRBs as light beacons

- 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

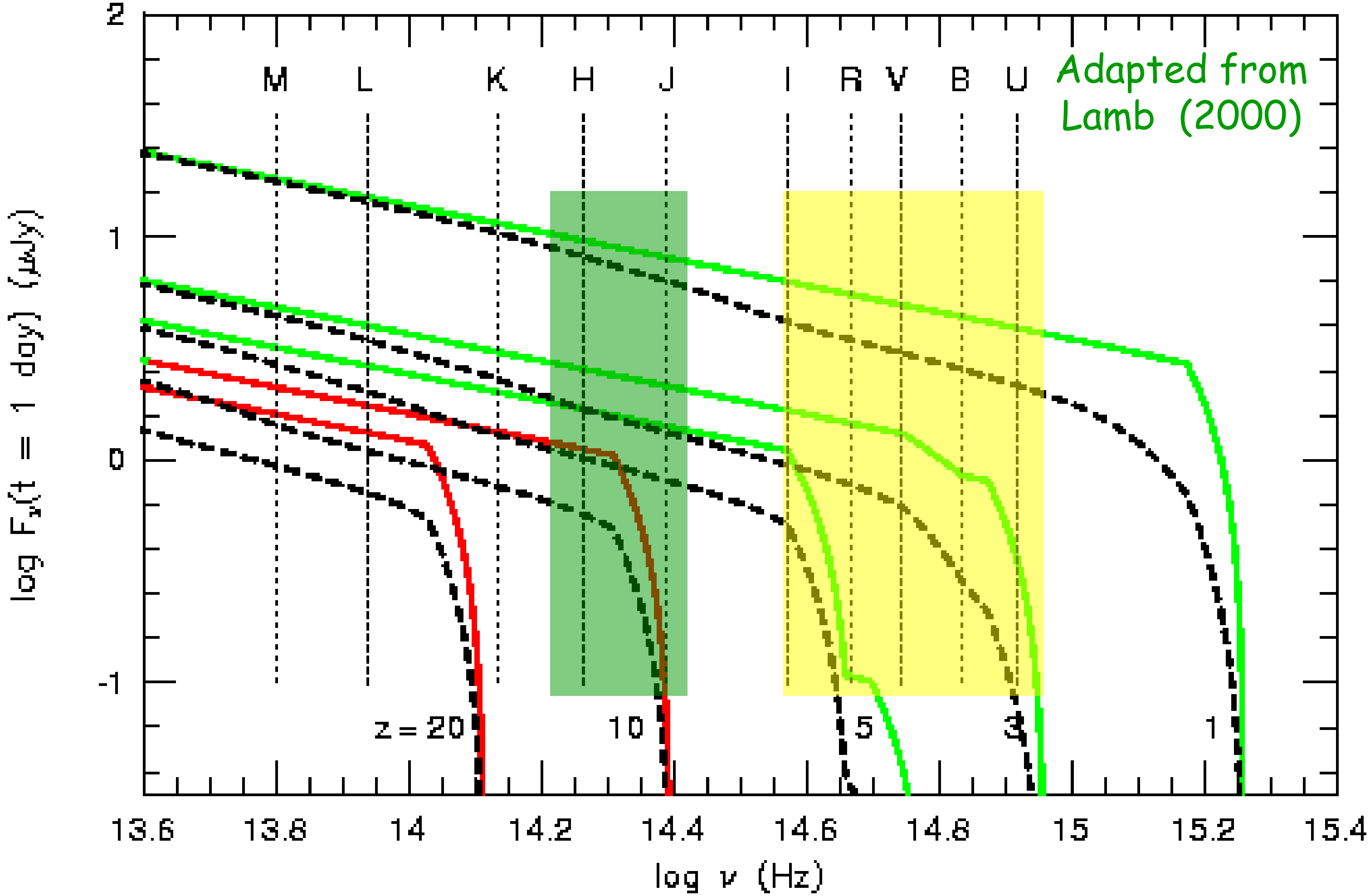


Kawai et al. 2005

How to find high-redshift GRBs?

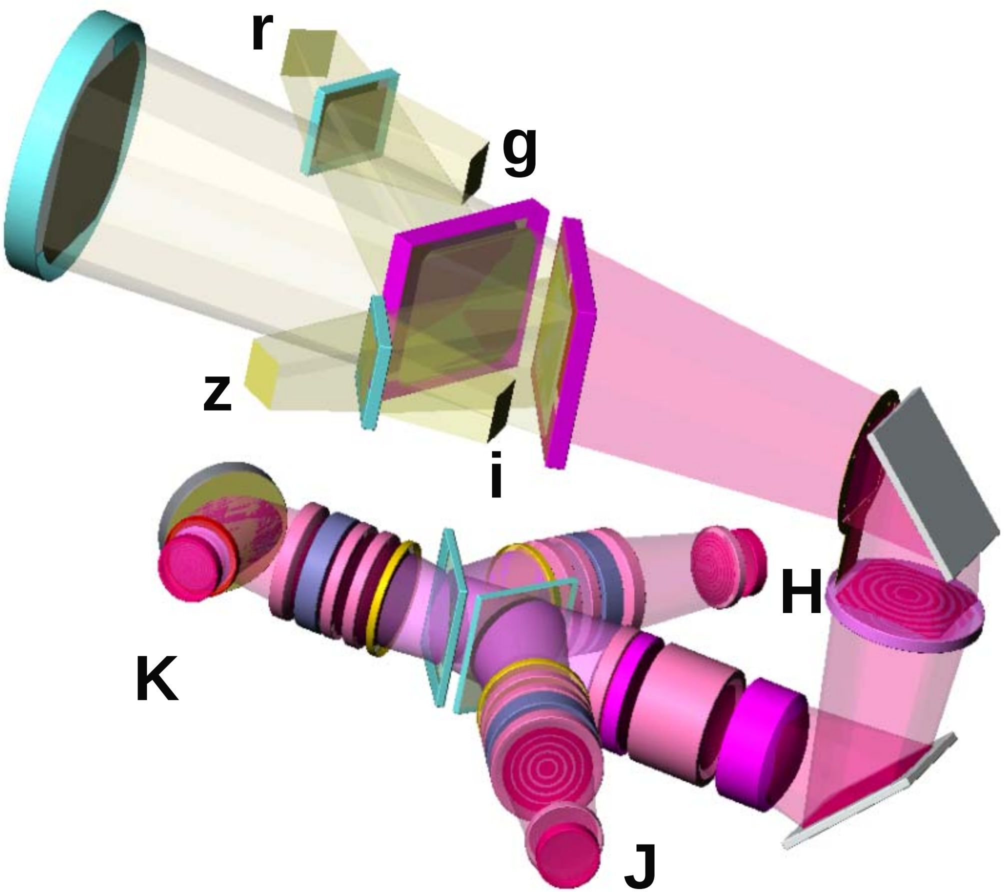
Due to characteristic spectrum of GRB Afterglow:

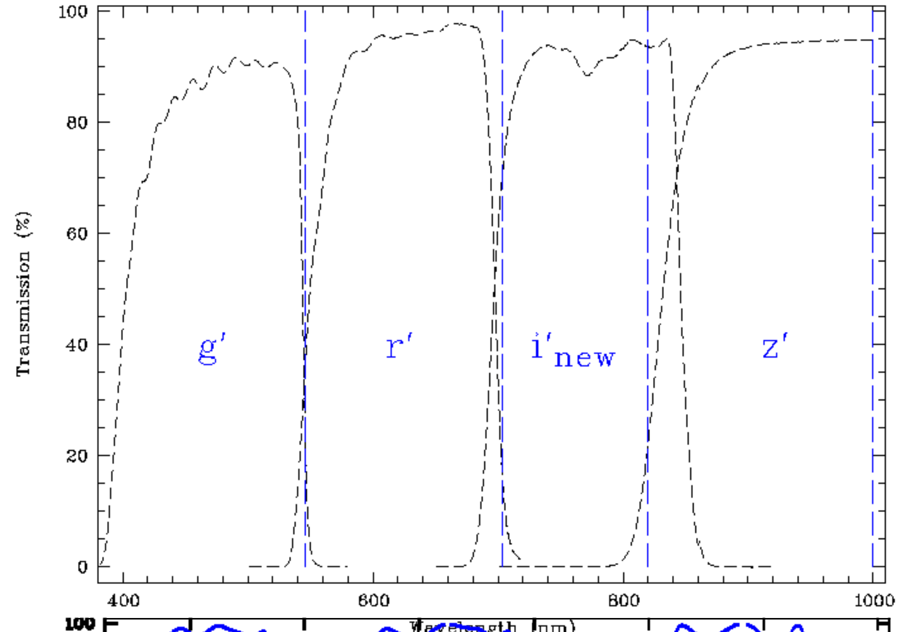
- ☆ Photometry in optical: up to z~6
- ☆ Photometry in NIR: up to z~12-14 (GROND)

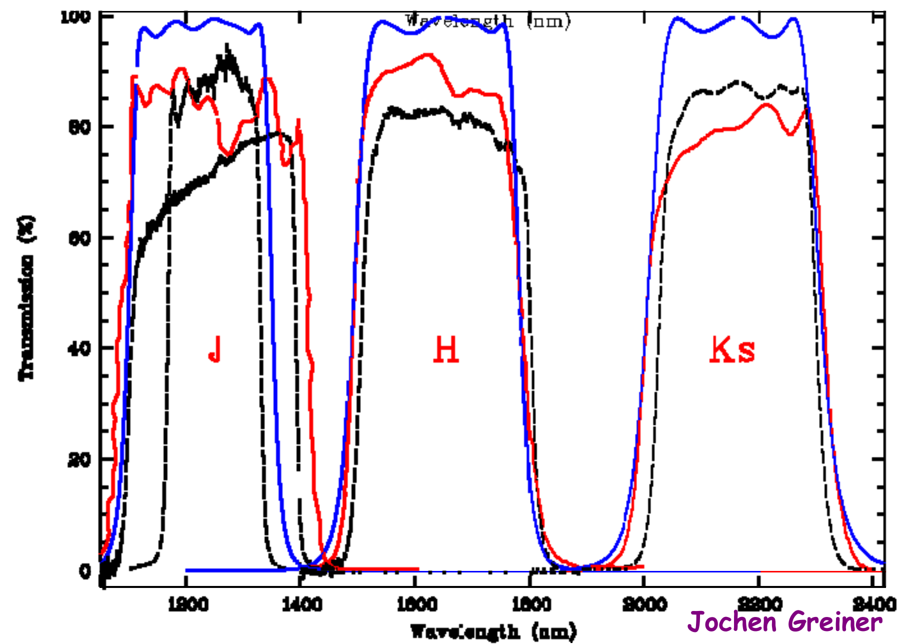


GROND=GRB Optical/NIR Detector

Imaging in 7 channels simultaneously







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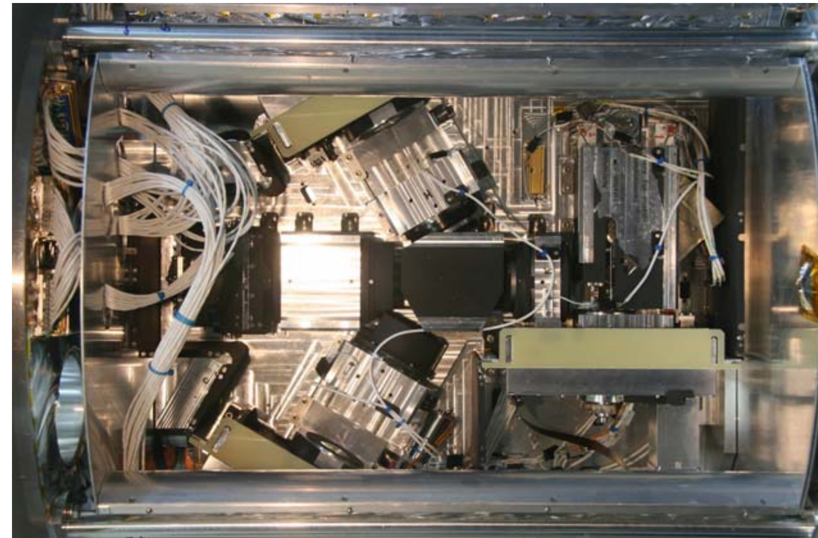
GROND: General Design

- 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:

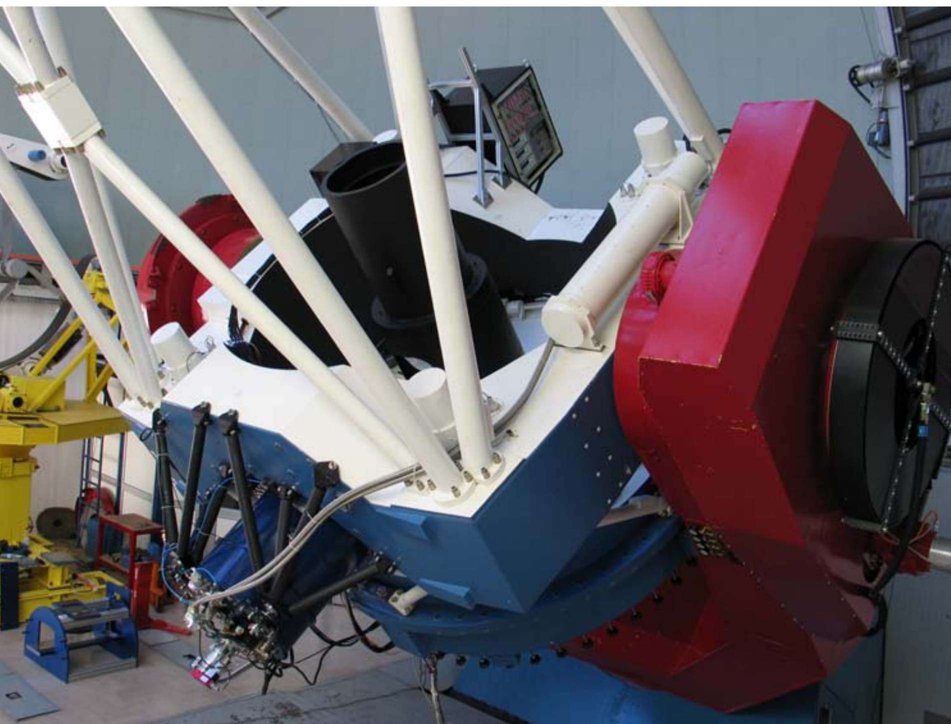
Sensitivity:	4 min	1 hr
gr	21.5 mag	24.5 mag
iz	20.5 mag	23.5 mag
J/H/K	18.5/17.5/16.5 mag	21.5/20.5/19.5 mag

GROND – capabilities and selected results



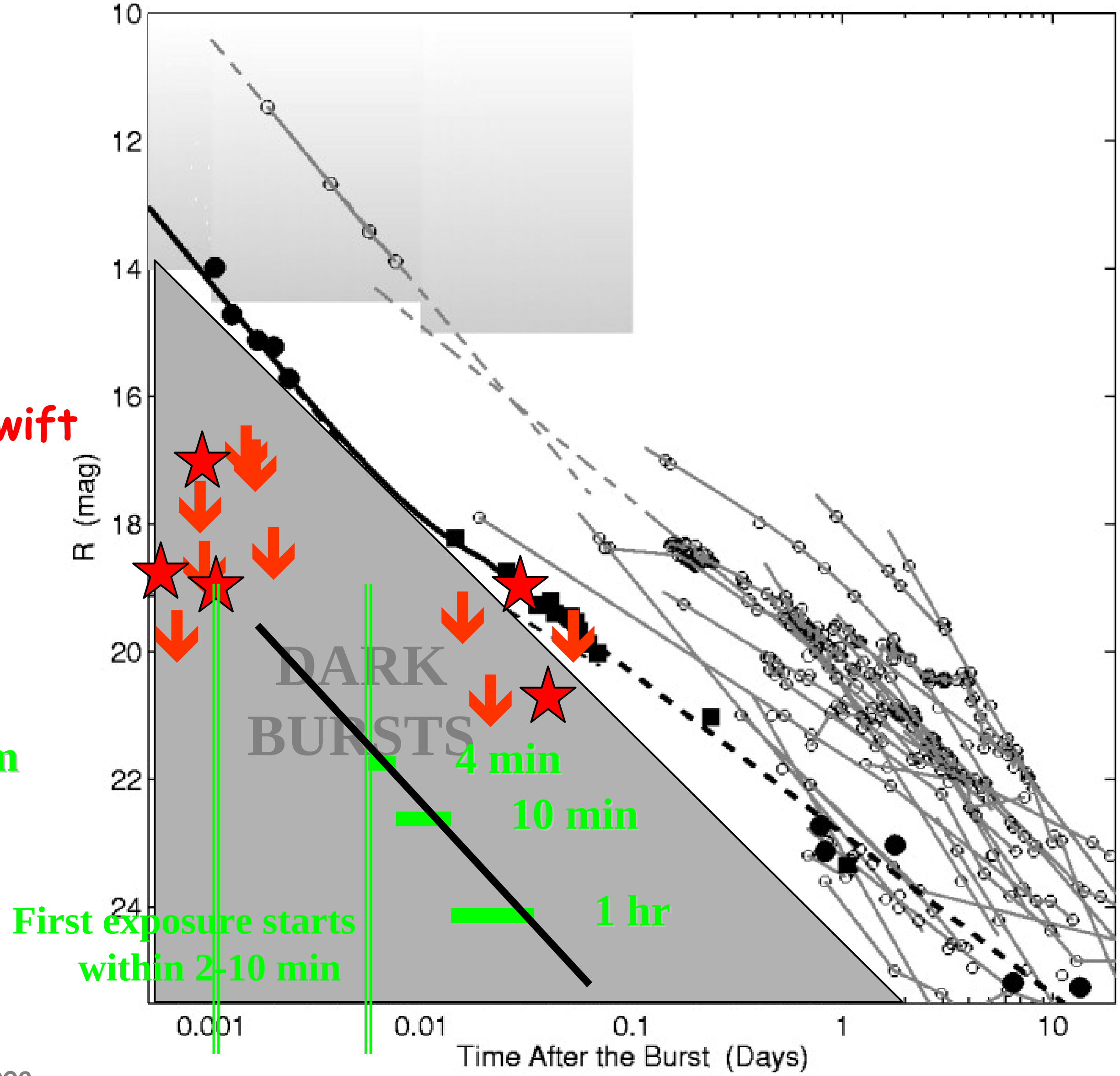
Status:

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

UVOT/Swift



GROND at the 2.2m MPI/ESO telescope

GROND first results: I

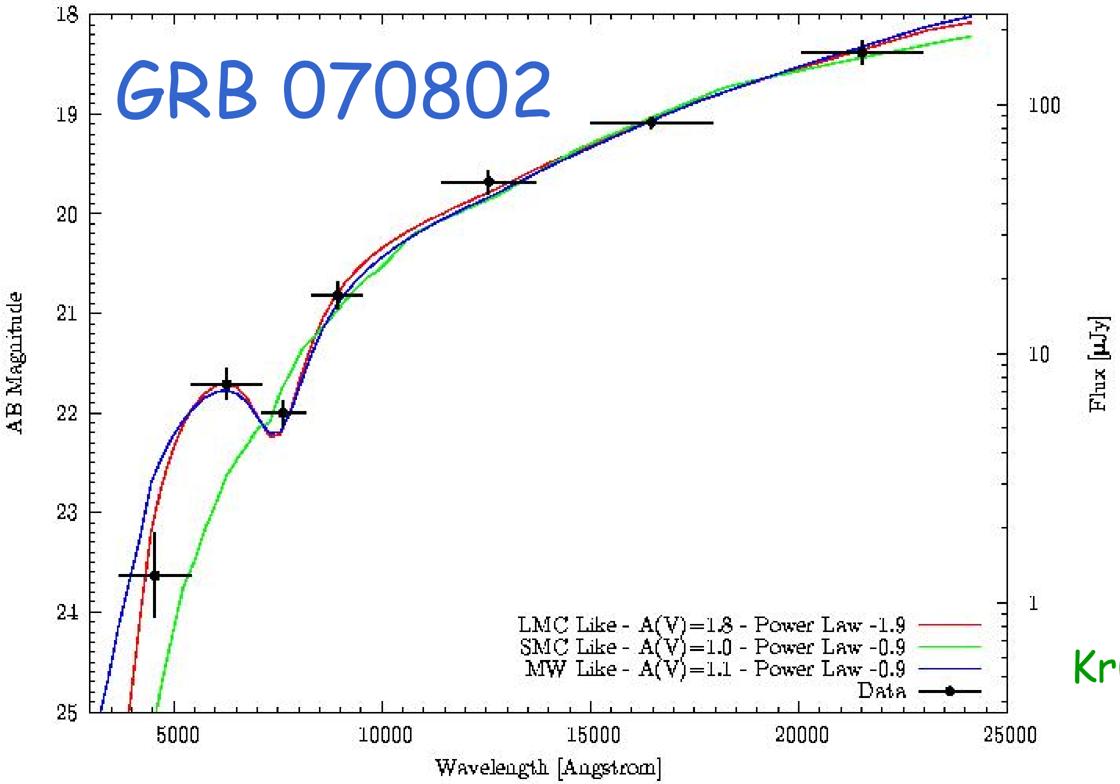
Operational since May 2007 (but only 8 months effective observing)

47 GRBs observed (as of 09 Jul 2008)

11 non-detections (→ still ~25% dark GRBs)

4 GRBs with Ly-alpha affecting g'-band (z~2.5-3.5)

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



Krühler et al. (2008)

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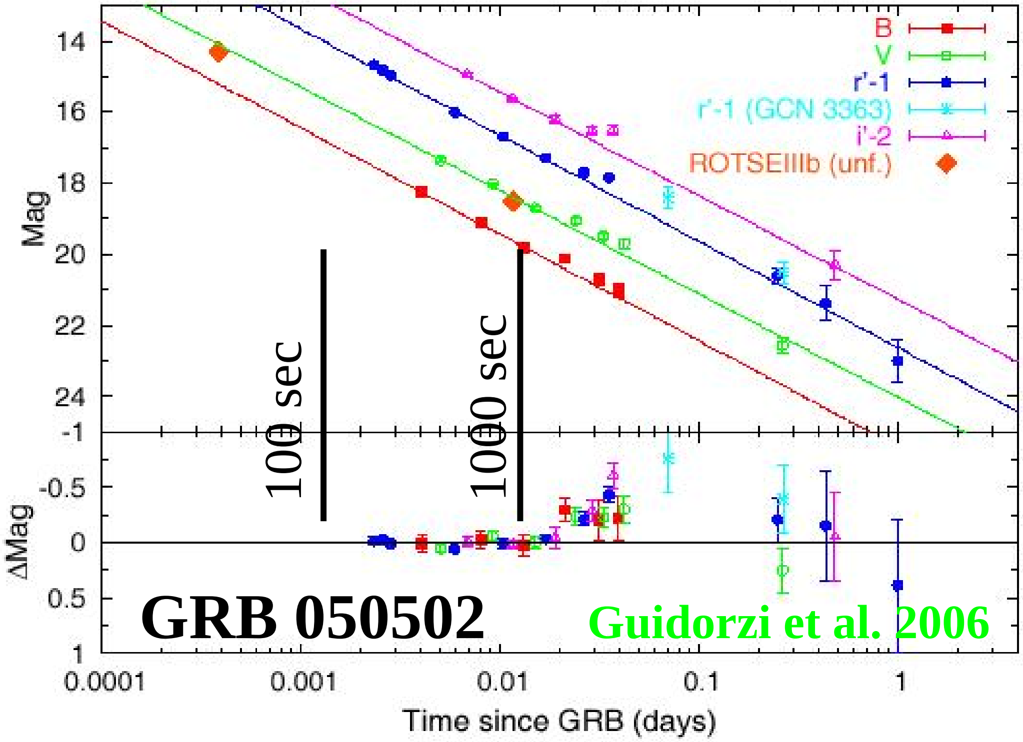
GROND first results: II

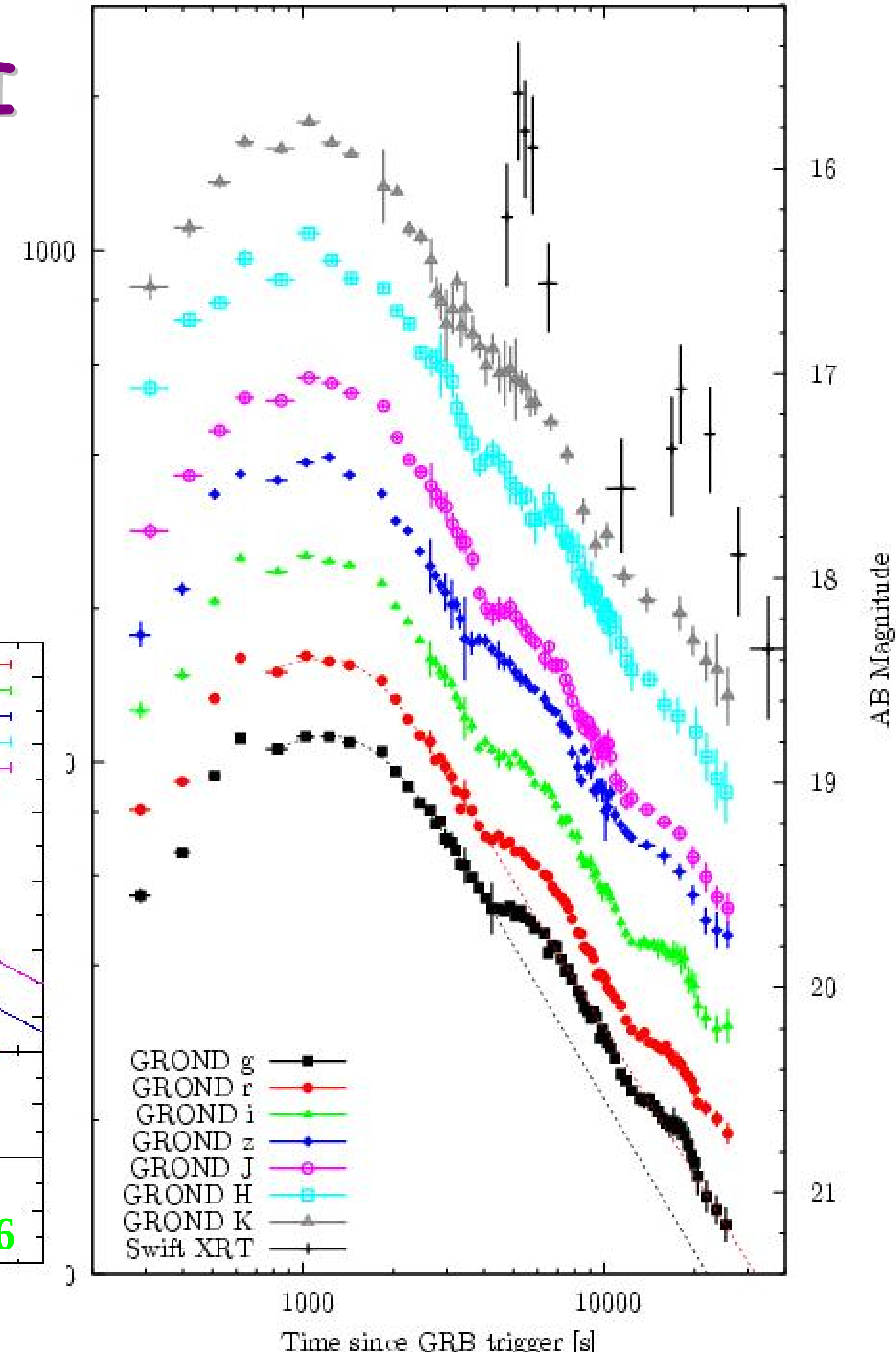
• **First image: 4 min after GRB onset, ~80 sec after trigger**

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

ß-evolution (instead of one for all AG)

Color evolution





GROND first results: III

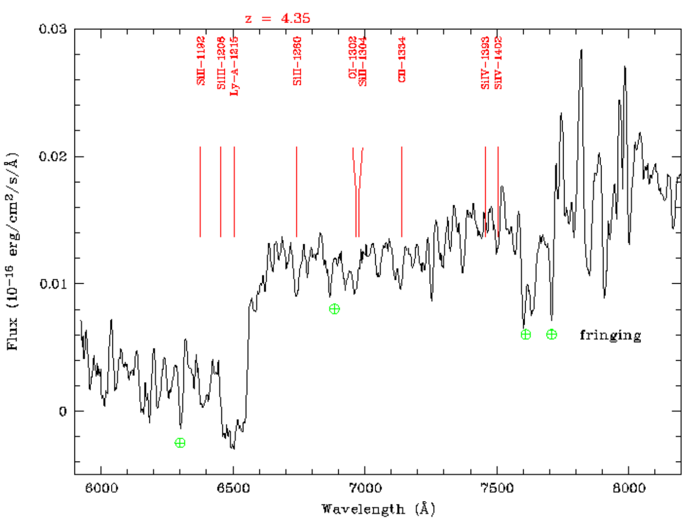
The disappointment so far: # of GRBs with z>3.5

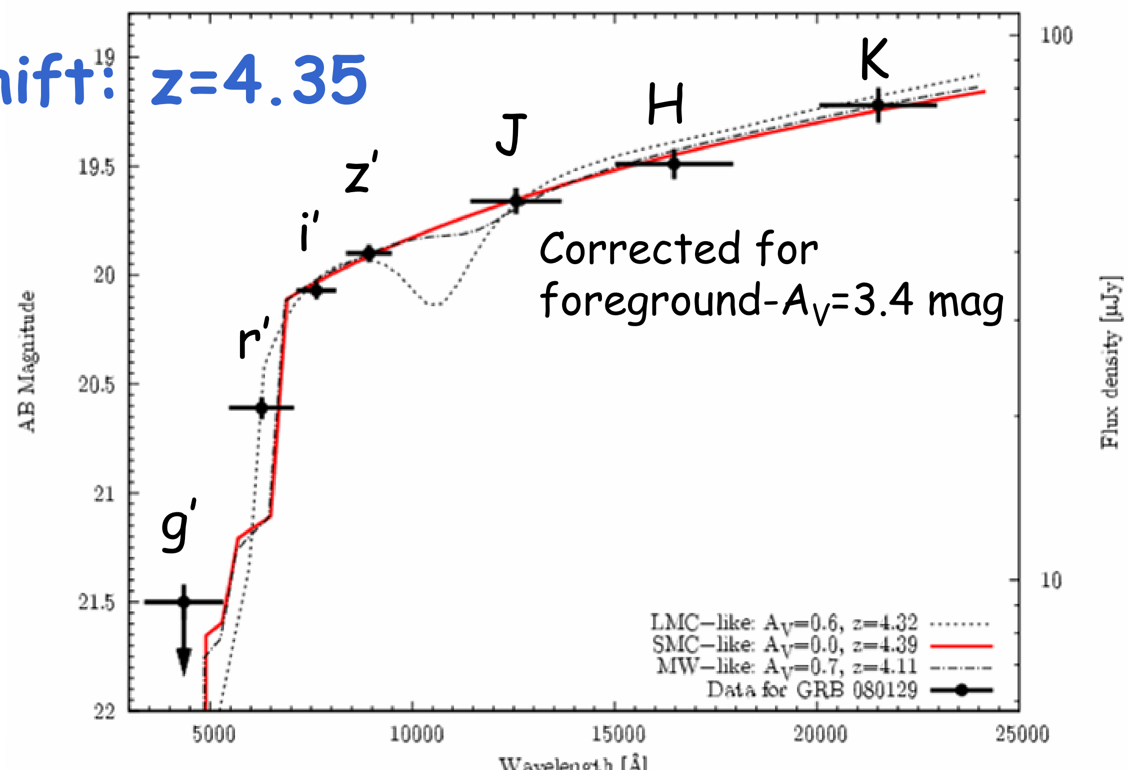
Dec. 2004 – Apr 2007: 14 (~ 6/yr)

since May 2007: 1 (~ 1/yr)

Greiner et al. (2008)

Spectroscopic redshift: z=4.35

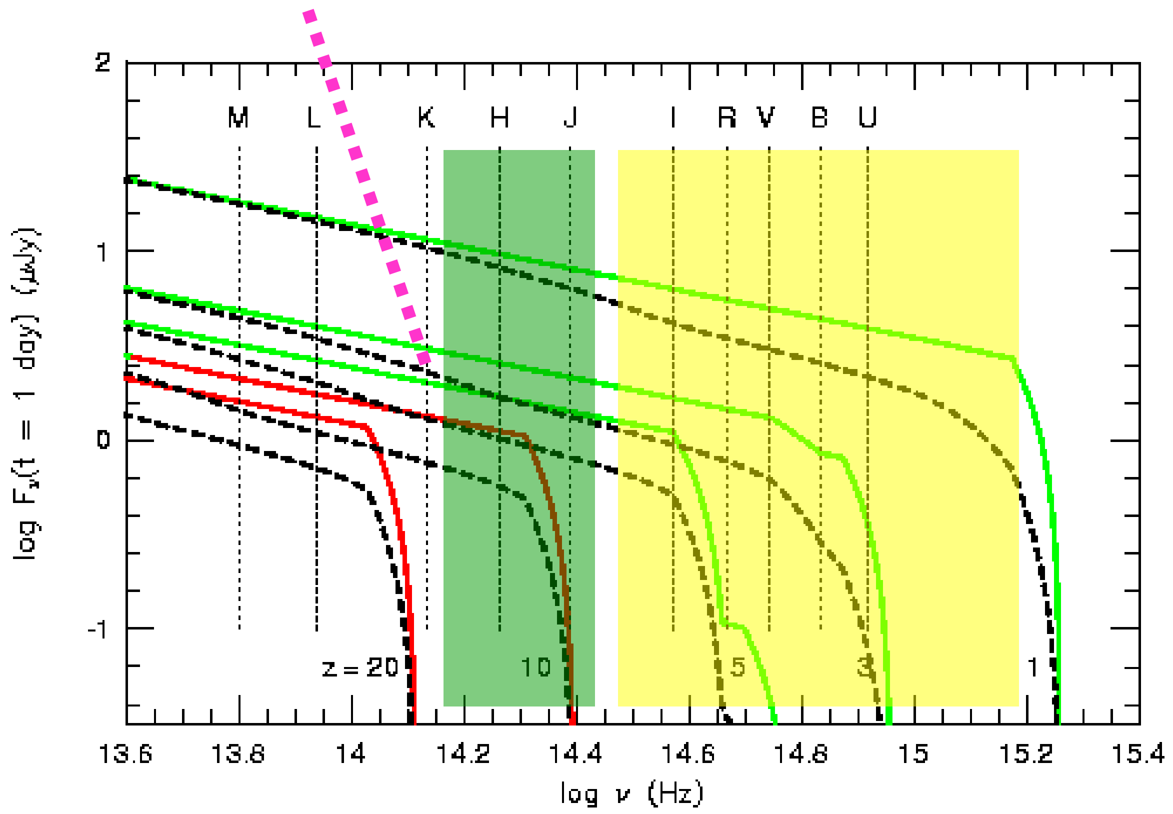




How to find high-redshift GRBs?

Due to characteristic spectrum of GRB Afterglow:

- ☆ Photometry in optical: up to z~6
- ☆ Photometry in NIR: up to z~12-14 (GROND)
- ☆ Beyond z~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!



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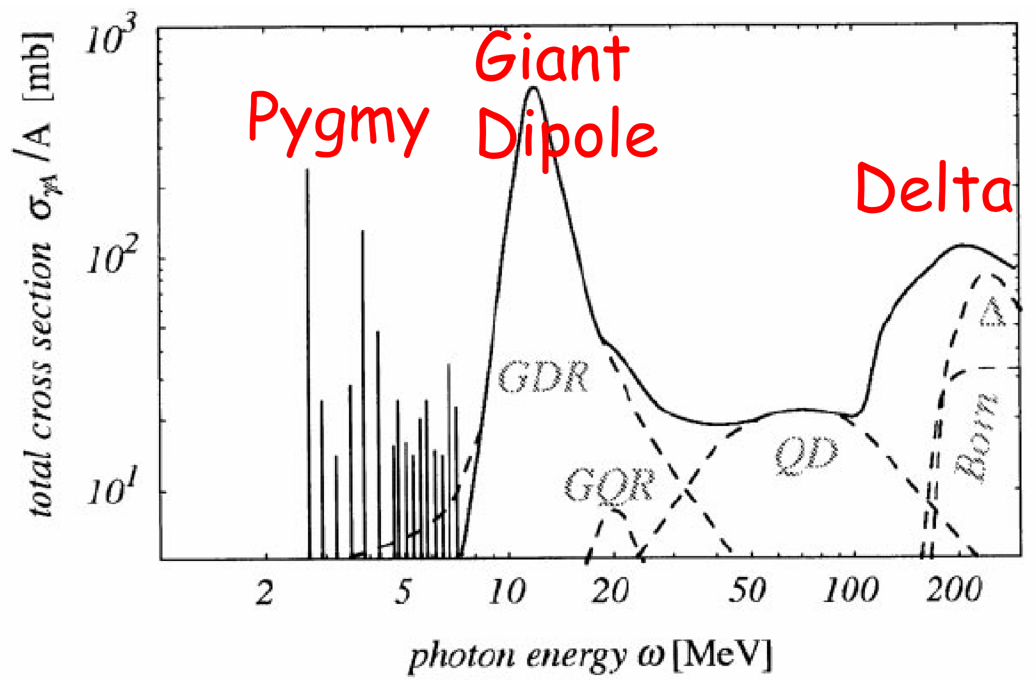
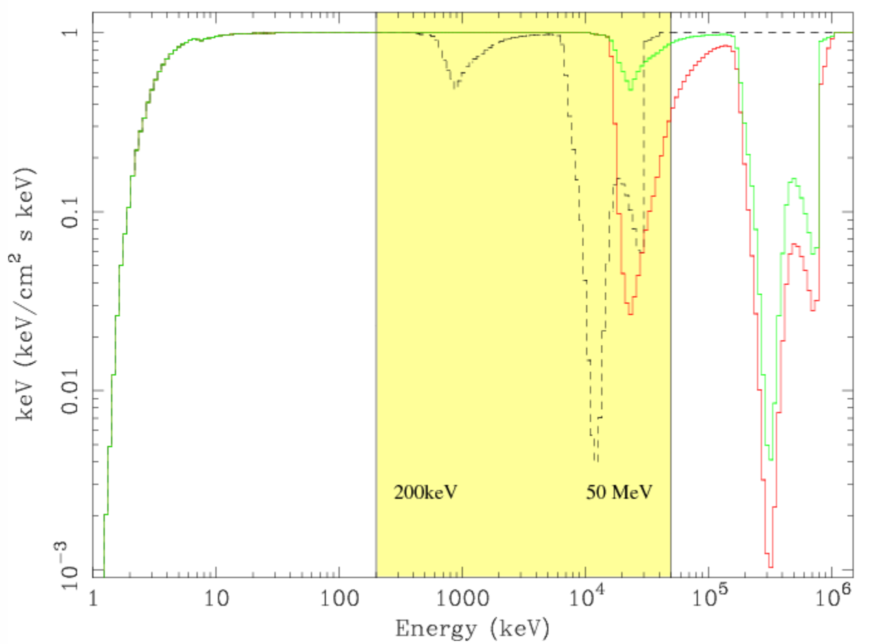
Interactions of Photons and Atomic Nuclei





We See Effects of (with increasing energy):

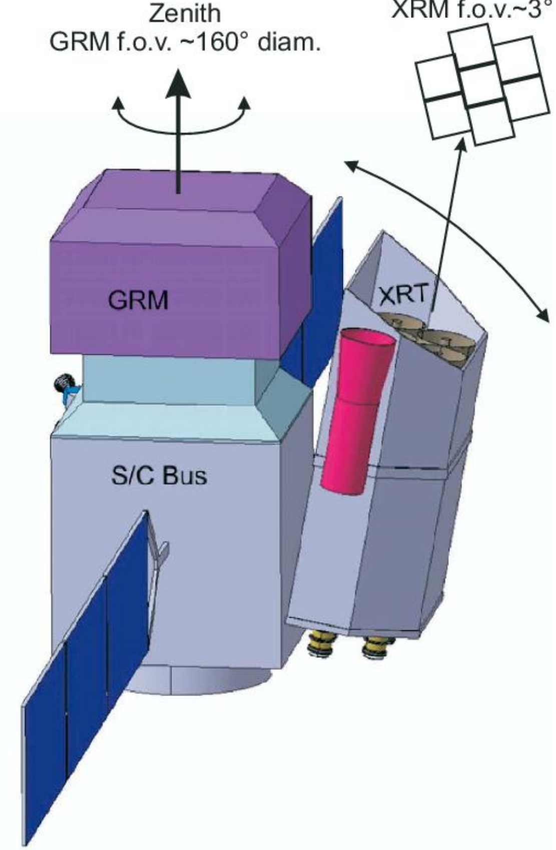
- Excitation of Single Nucleons in Nucleus Potential ("Nuclear Lines")
  - $h\nu = E_{nucl}$
- Collective Excitations of Nucleon Groups ("Pygmi/Giant Resonances")
  - giant resonances: protons versus neutrons
  - quasi-deuteron resonances: a pair of proton and neutron
  - each of these occur in all multipole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

Absorption independent of

- ionization state
- isotope ratio
- GDR/DR ratio: metallicity

GRIPS MISSION

Mission Concept



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

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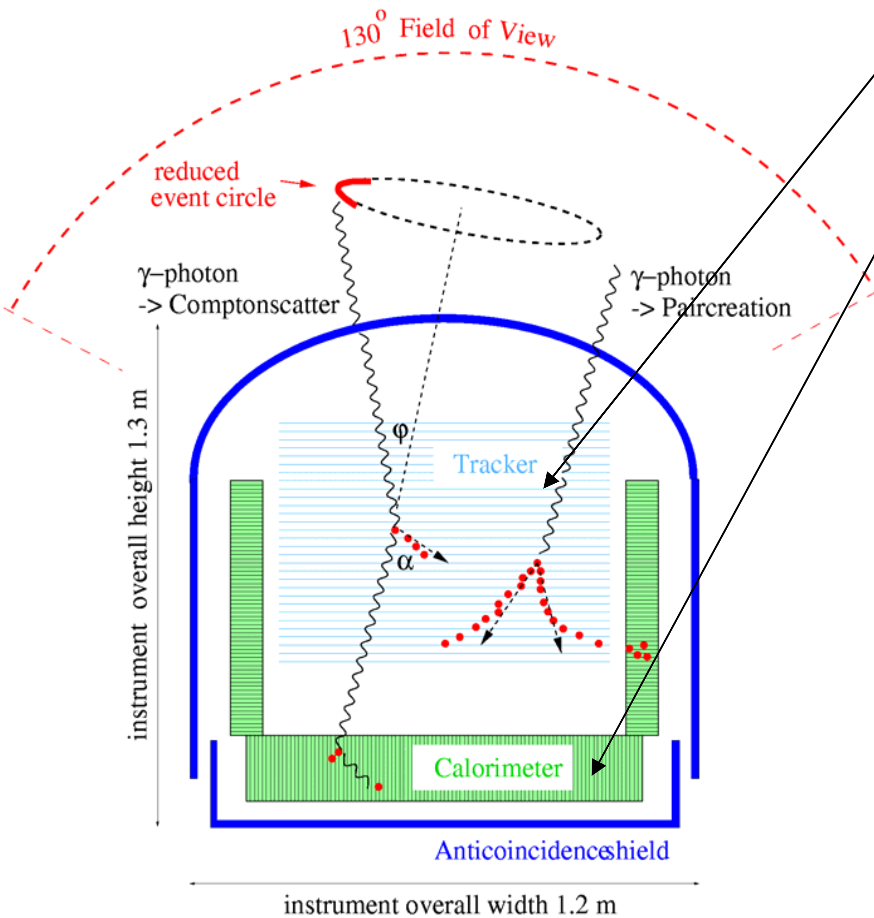
The Telescope Concept

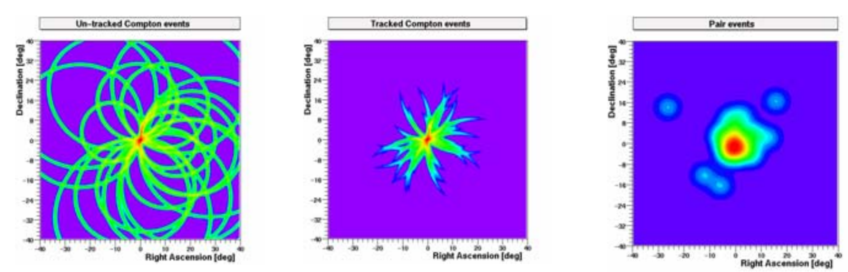


Tracker: double sided Si strip detectors

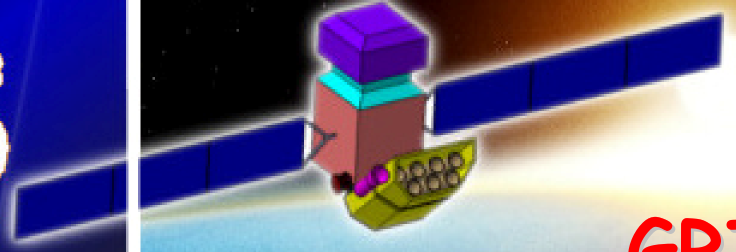
Calorimeter: 3D resolving $LaBr_3$ / Si drift diode

Images

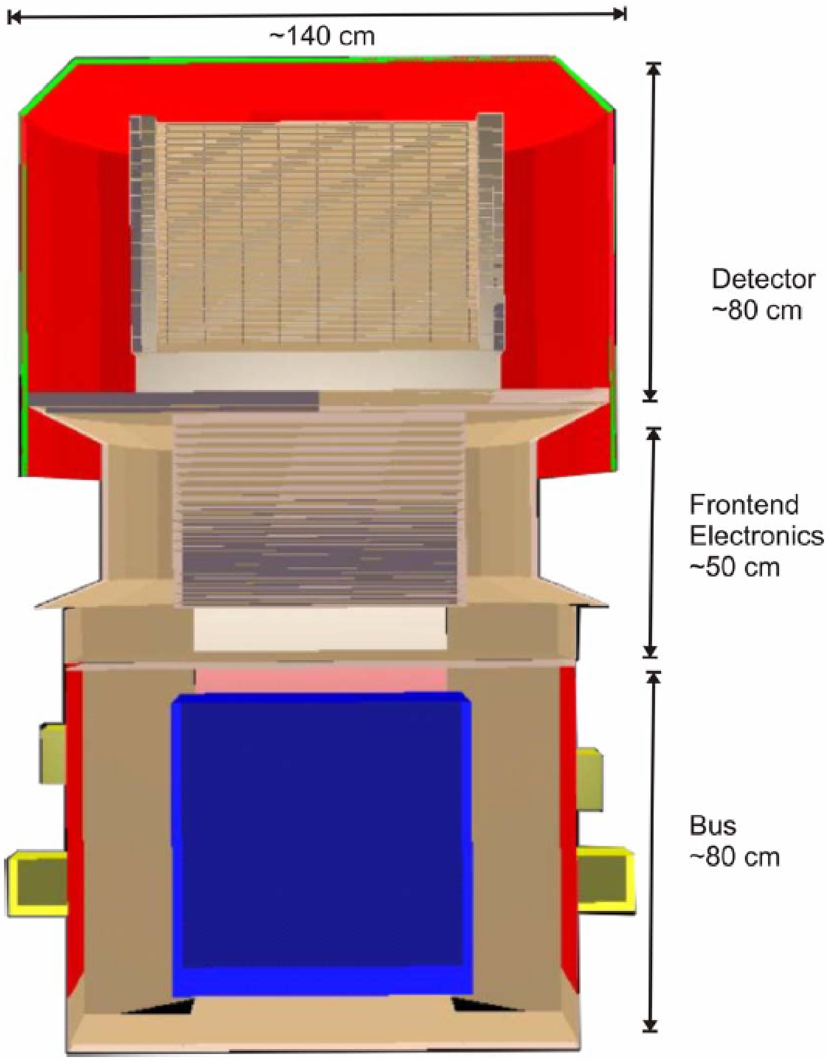
Classical Compton	Tracked Compton	Pairs



GRIPS MISSION



GRIPS components



1 layer = 4x4 wafers of
10x10 cm^2 each

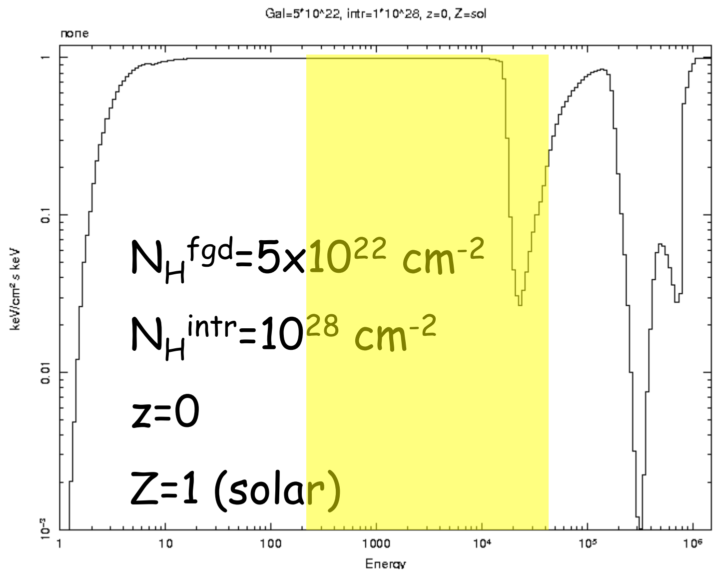
1 tower = 64 layers
spaced 5 mm (v.1)
3 mm (v.2)

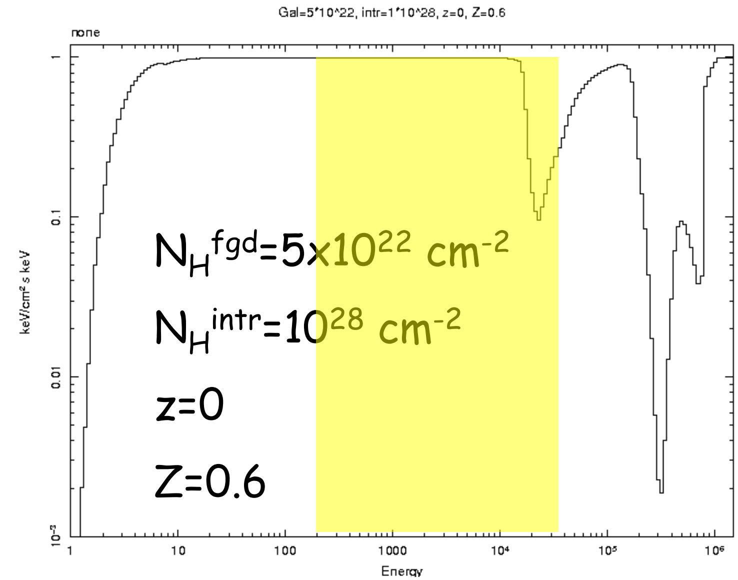
4 towers

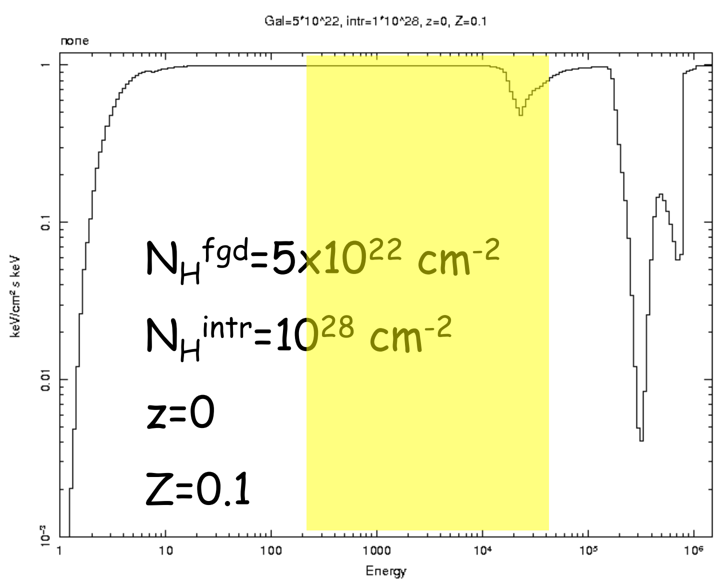
~500.000 read-out channels

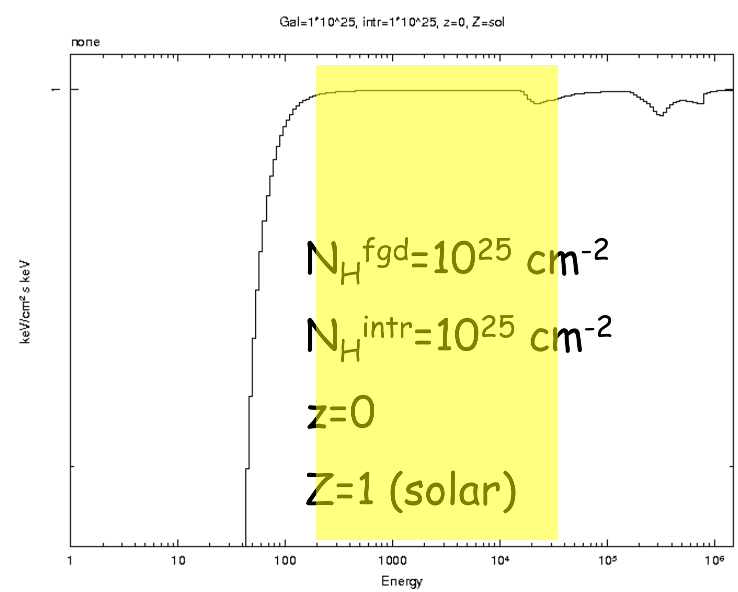
$LaBr_3$	750 kg
Si (tracker)	50 kg
Ne110	150 kg
Structure+Electr	200 kg
GRM margin	430 kg
eROSITA	660 kg
Gaia bus	510 kg
Contingency	550 kg
Propellant	200 kg
Sum	3500 kg

Resonance absorption: the effect









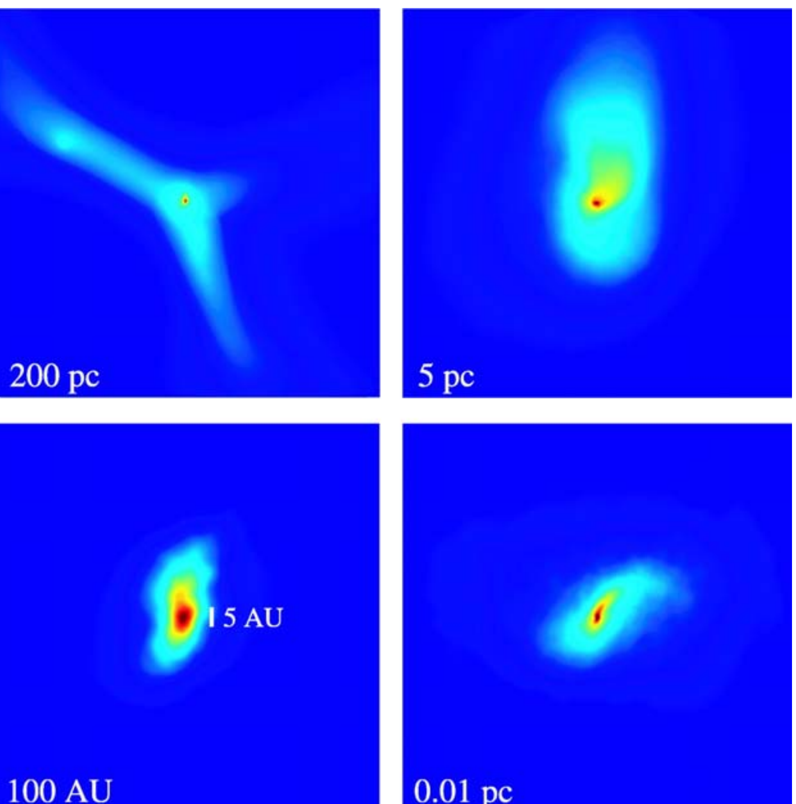
Matter near first star/GRB

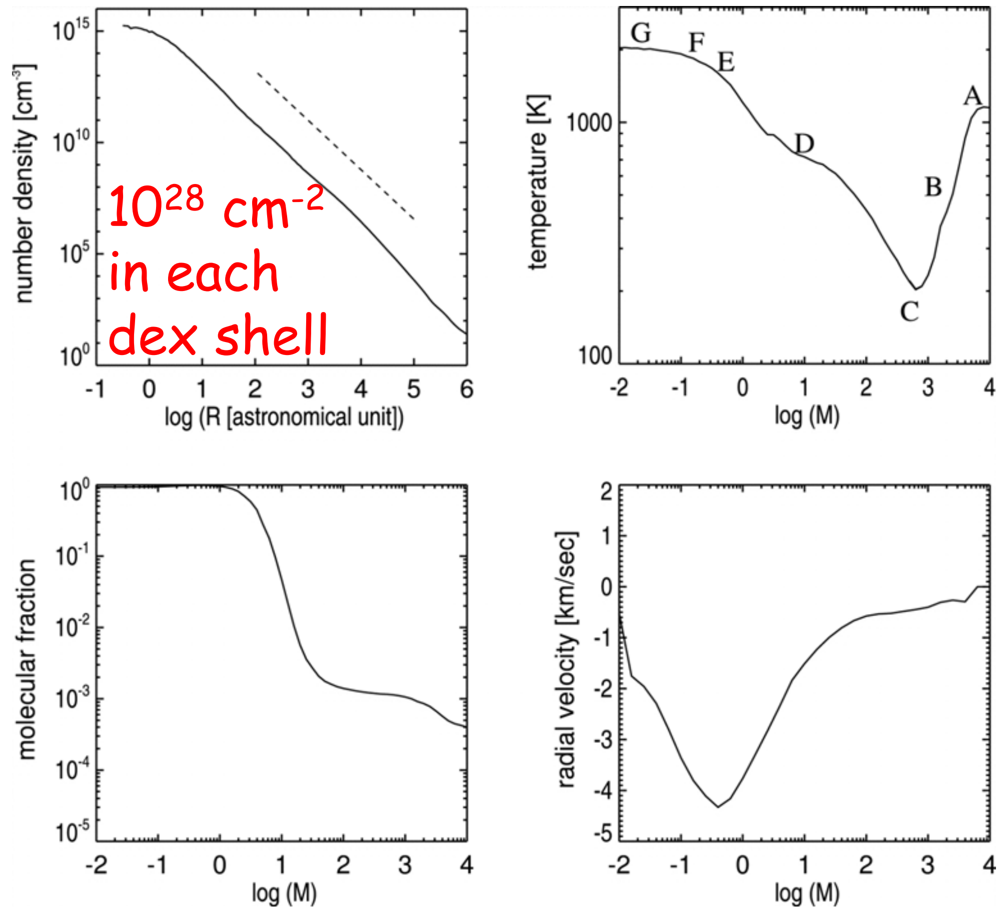
- Gas clouds stable against fragmentation (no star clusters)
- Substantial fraction is ionized
- Mass or mass ranges for first stars still difficult to predict
- Radiation pressure is generally not important (no dust)

Yoshida etal 2006, ApJ 652, 6

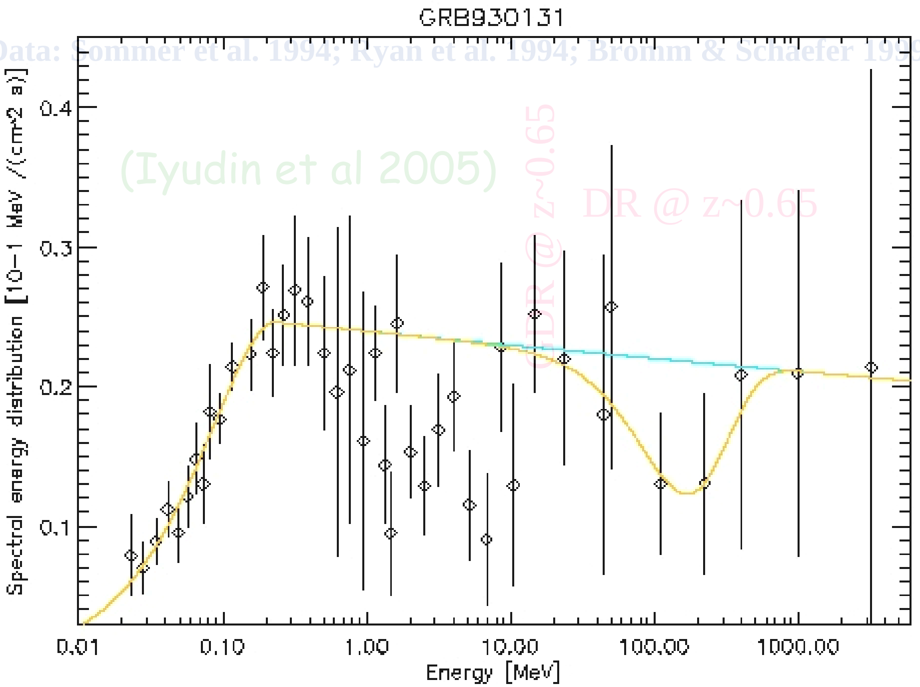
Radial profiles at z=19.

Projected density distribution at z=19



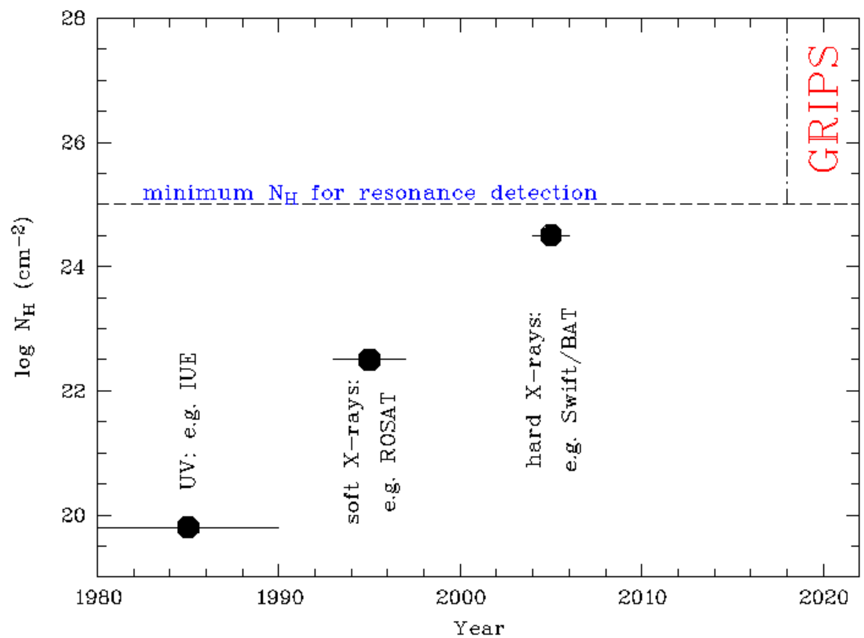


Brightest COMPTEL/EGRET burst 930131: 1σ hint



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

Absorption seen in AGN



GLAST: NASA's New Gamma-Ray Telescope

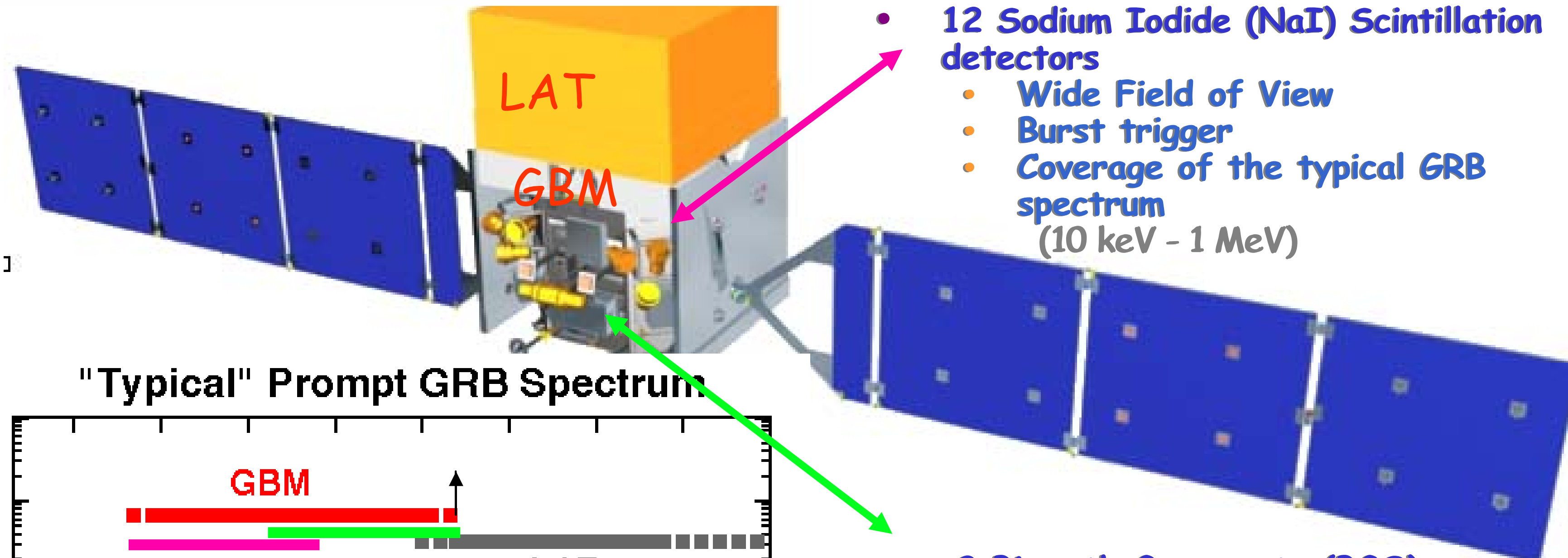
Successfully launched: June 11

Presently in commissioning phase

Swift-GRBs 070630, 070701, 070703 have been seen

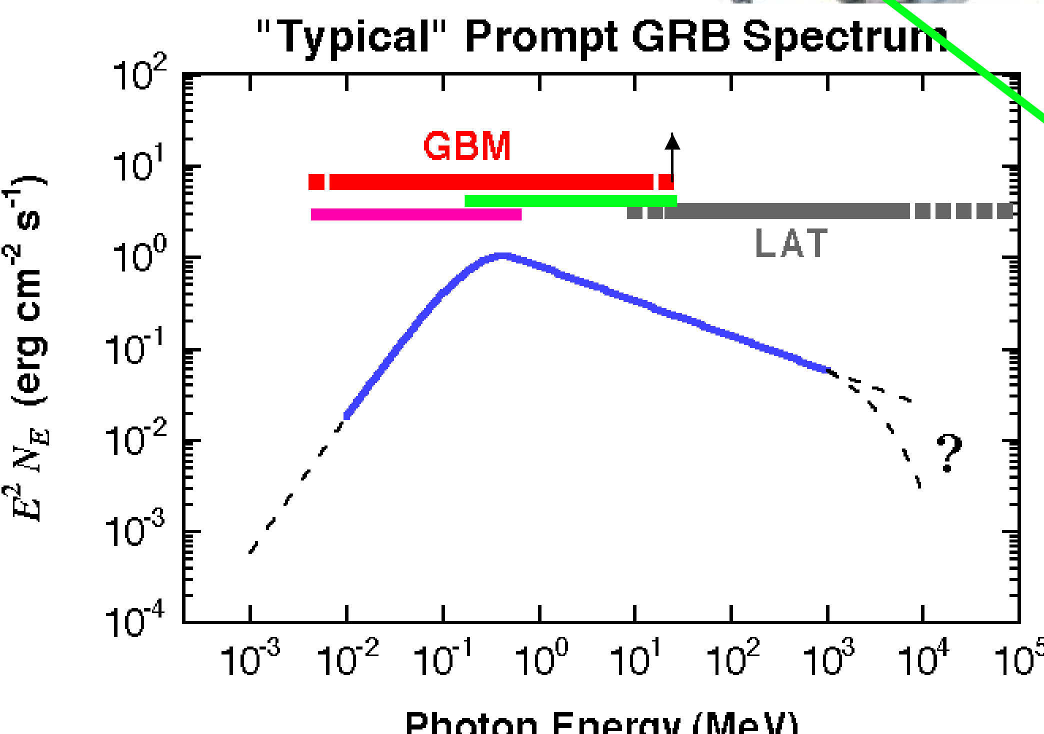
Expect start of operation in mid-August

GLAST: Gamma-ray Large Area Space Telescope

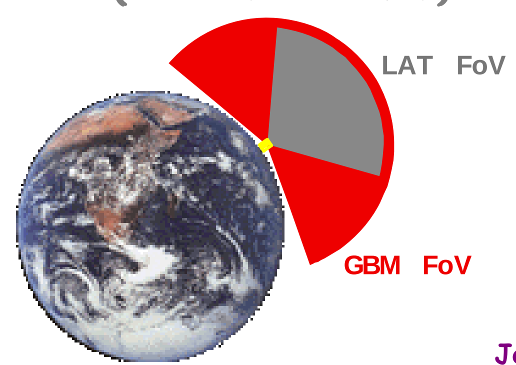


Glast Burst Monitor

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



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



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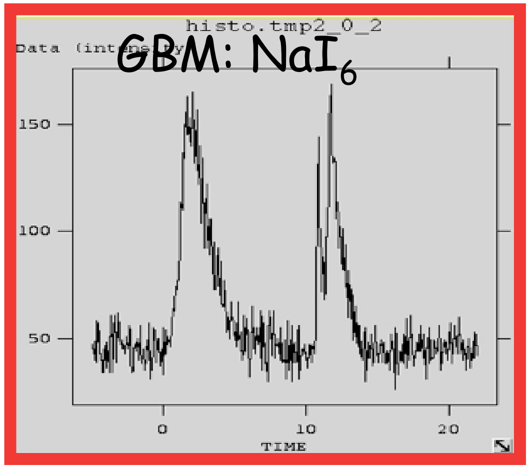
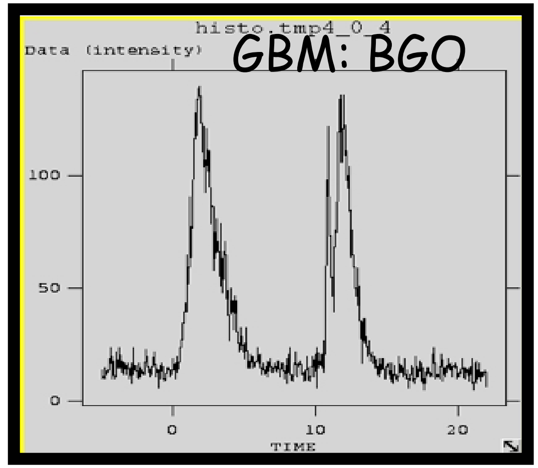
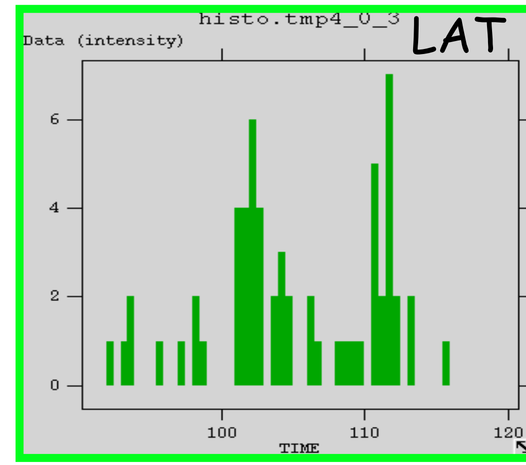
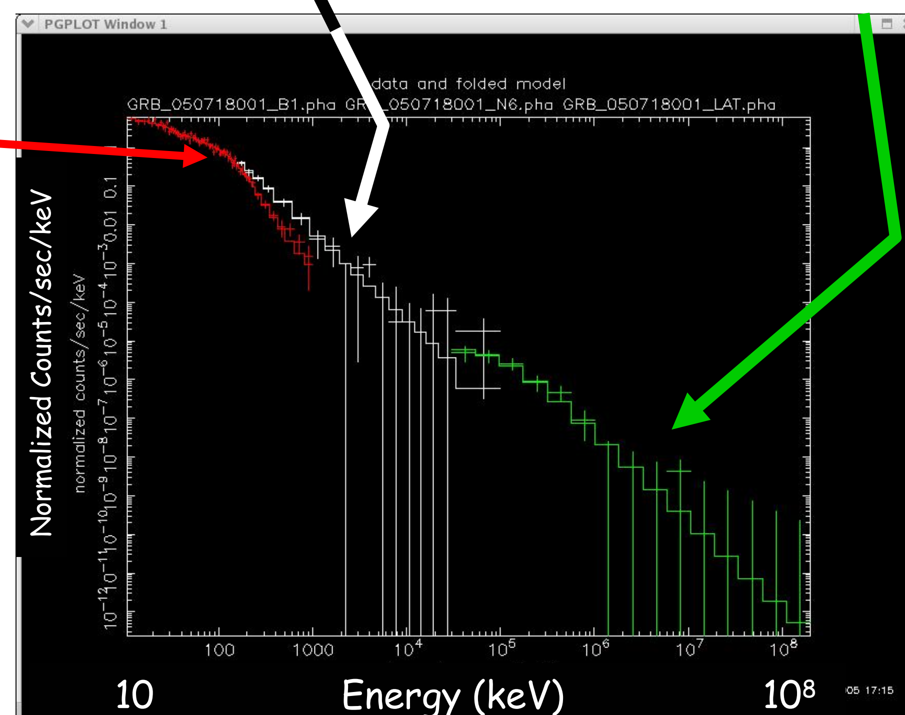
GLAST/GBM Simulations: (Detectors)







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



Paris, 7-11.7.2008

Omodei et al. 2007

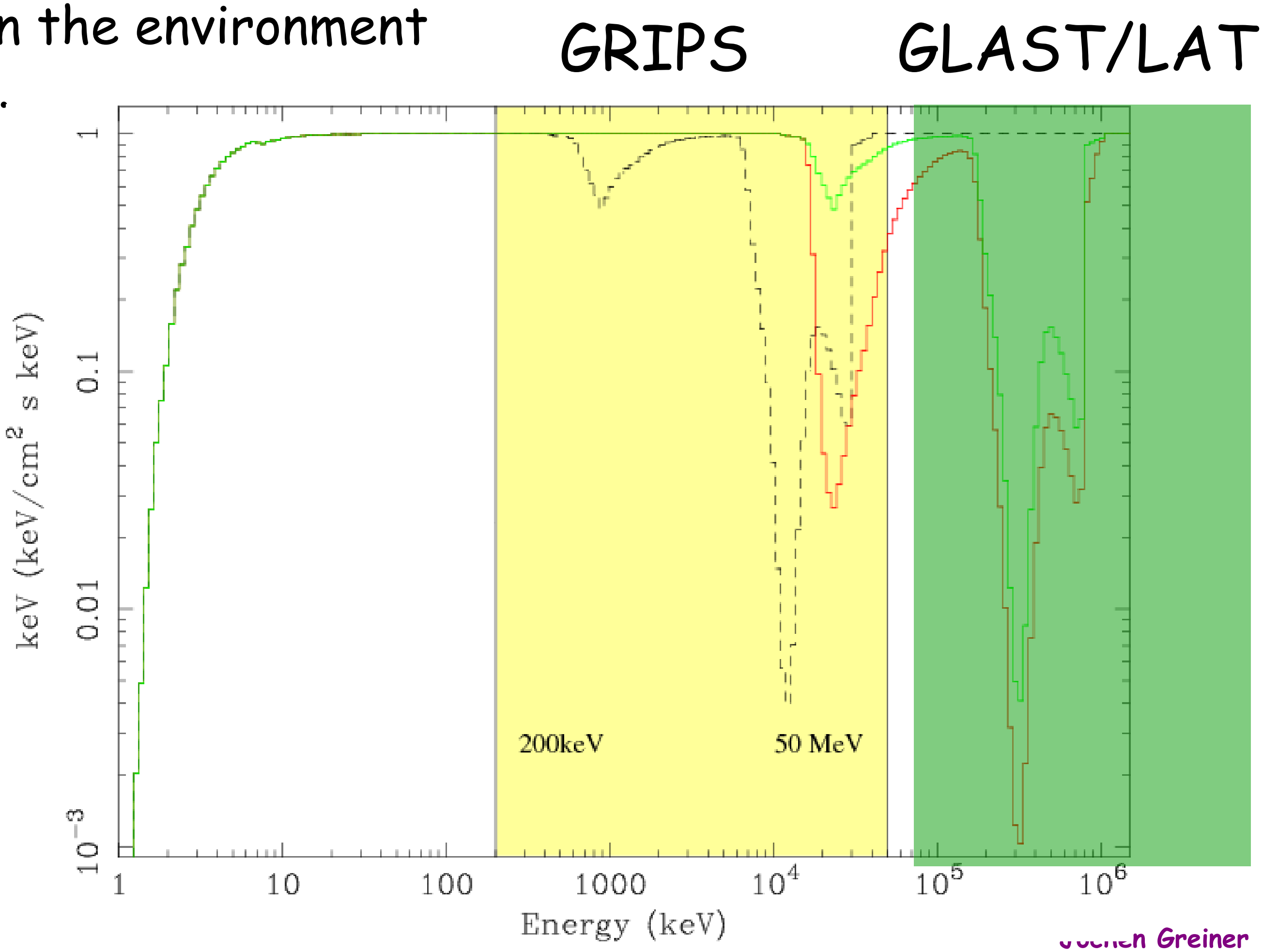
GLAST: expectation for nuclear resonance

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



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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 $>10^{25}$ cm^{-2} then:
  New generation of γ-ray missions are able to measure GRB redshifts up to z=20-60 from γ-ray spectrum