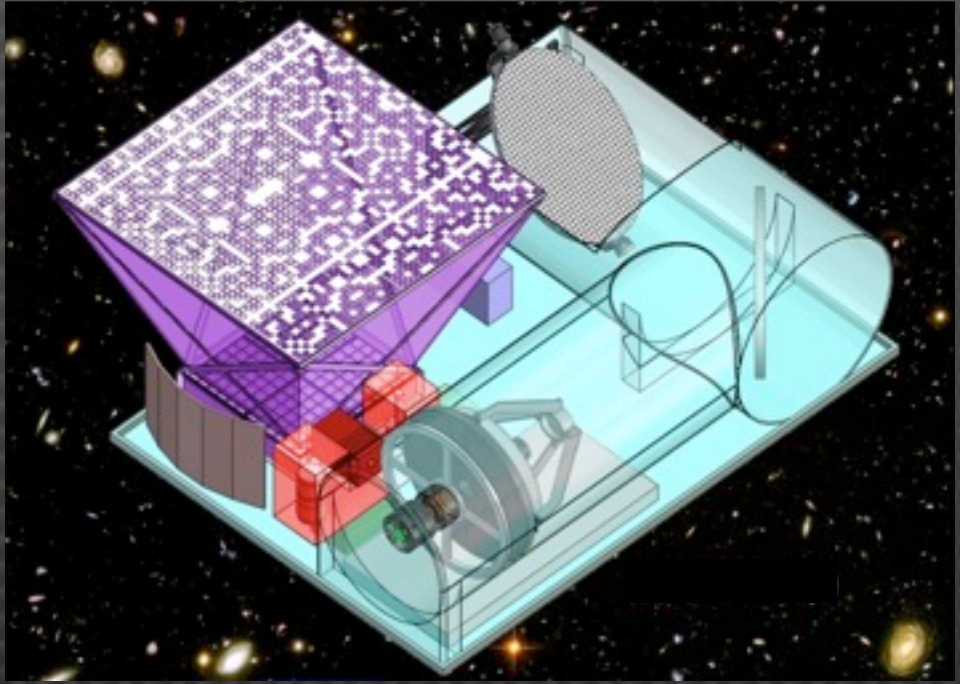

Science & Instruments for New GRB Missions

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UC Berkeley SSL
EXUL

EXUL/Skobeltsyn Institute MSU

Motivation

We are in an in-between era where Swift may stop in a few years, where there are few planned missions, and where resources are modest.

What can we do for GRB science now?

At my own peril, I concentrate on instruments which can result in good localizations (few arc min) for follow-up studies, and I ignore almost all other capabilities.

Outline

I. What do we know (and don't know)? - Science

II. What Do We Need? - Instruments

III. What's New - Solid State Detectors

WE KNOW

For example...

- Much about X, gamma light curves of LGRB (~ 10^2)
- GRB extend well into EOR (z> 6)
- LGRB <-> star-forming regions <-> massive star SNe
- NOT obviously standard candles
- AG likely related to prompt emission in a well-defined correlation (Bernardini, M. G.+12)
- etc...

We Don’t Know

- z-distribution beyond a few (& GRB as tools for high-Z universe: HI and Dust)
- Detailed prompt emission mechanism
- Relation of prompt optical and gamma
- Origin of SGRB
- (Of course much more...Origin of LC Pulsations (Interrupted Jet?), GW properties (of SGRB), etc. etc.)

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- (Of course much more...Origin of LC Pulsations (Interrupted Jet?), GW properties (of SGRB), etc. etc.)

... but new instruments will help us.

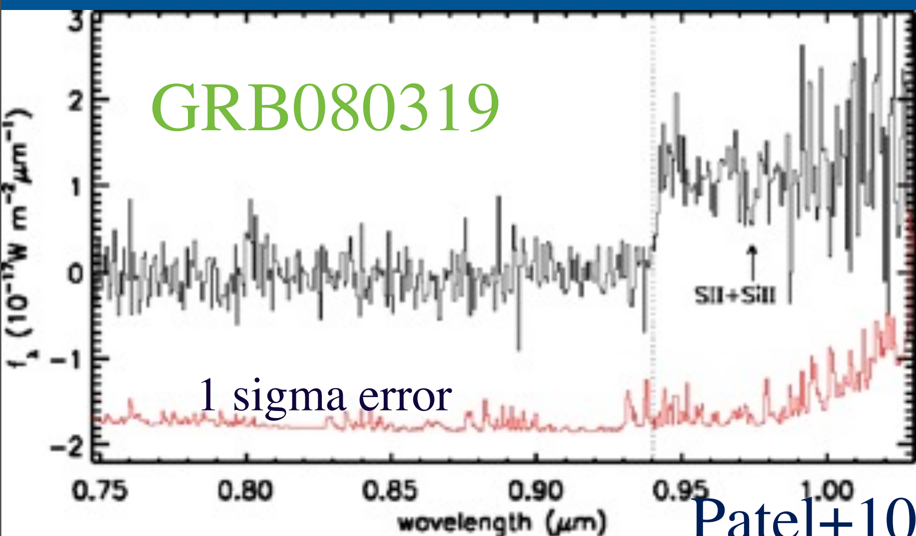
High-z GRB

- JANUS paper study (Burrows+12) showed:
  - Wide FOV beats alternative designs (HZGRBs expected rare, faint)
- General Expectation:
  - Need low-energy sensitivity for HZGRBs
    - Epk ~ 200 keV / (1+z)   or Epk (z> EOR) ~30 keV!
- Poor support of above...
  - Now: can only get z following Swift ID, 15-150 keV
  - Often too faint to constrain E_{peak}
  - No similar instruments with lower energy since HETE, but HETE not sensitive enough.

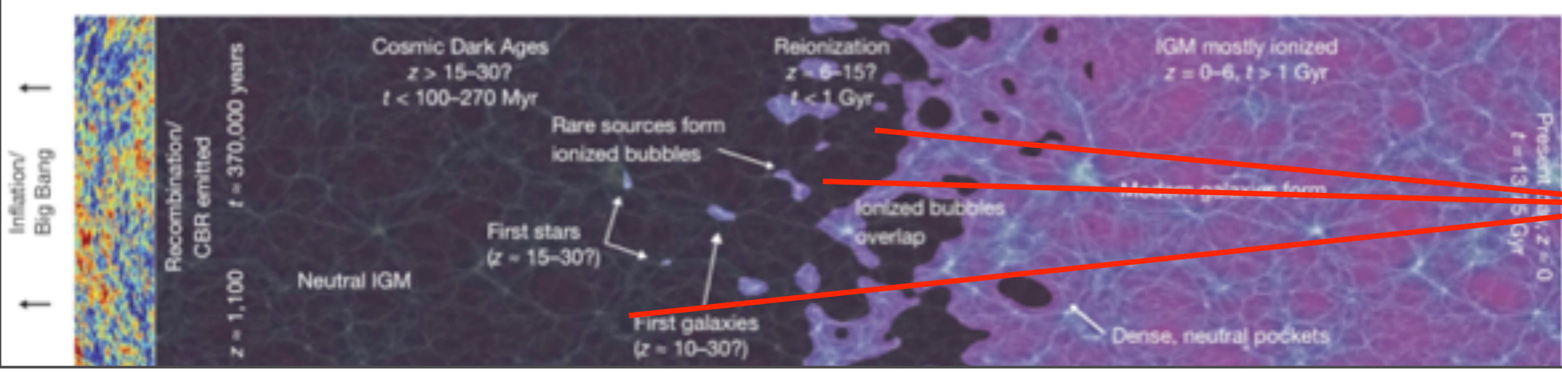
High-z for Early Universe Studies

- EOR ends at Z~6; Z > 6 GRB spectra already measured
- Can build up map of universe one line-of-sight at a time.

Note: HUDF galaxies too faint for spectroscopy; no way to do similar without GRBs.



1260Å SiII at 9743Å: " for tau<<1,we find that the region is ... r<2 proper Mpc, ... an upper limit to the neutral fraction of the IGM at z=6.7 of at a probability of 90%"



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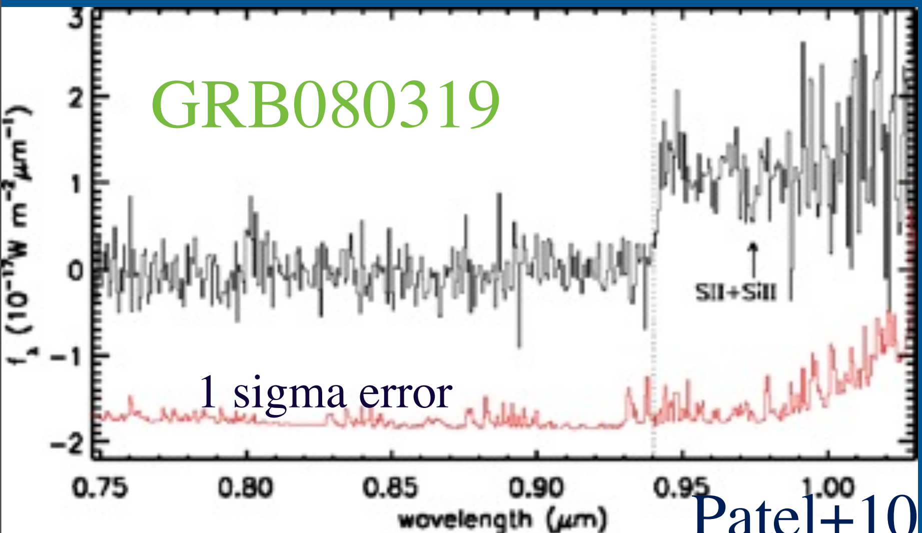

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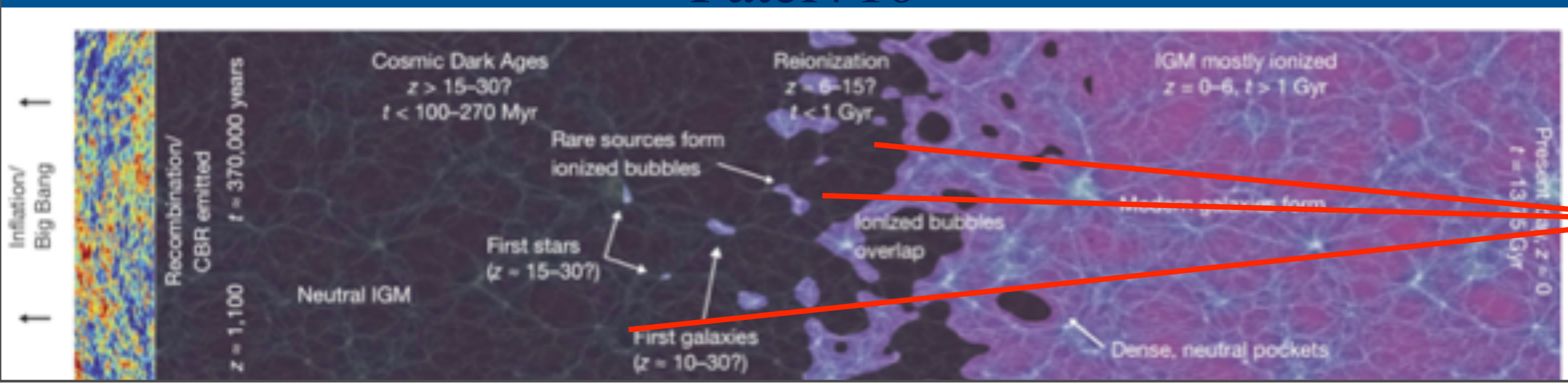
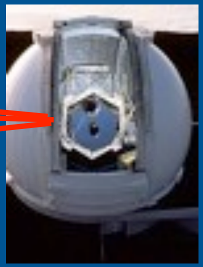
See Wanderman & Piran10 for LF to hi-z. Do you think there is room for any surprises?





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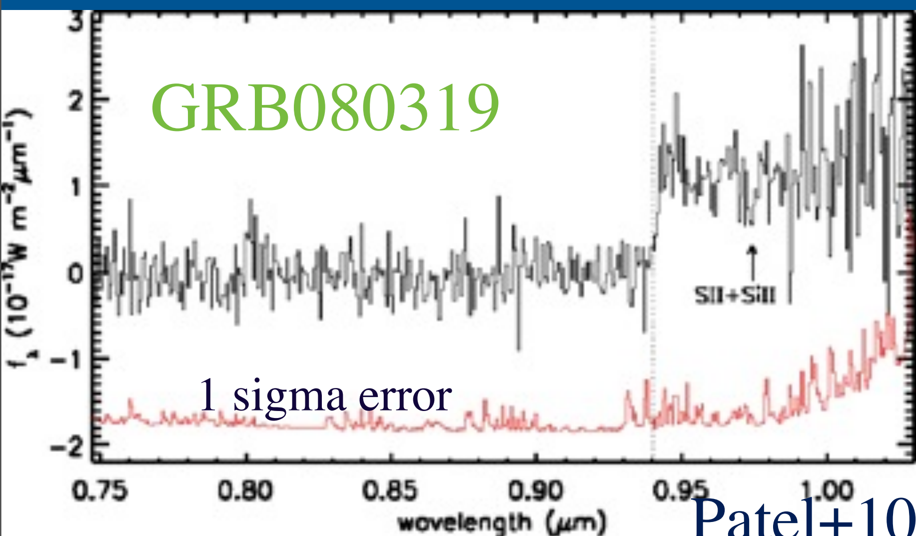

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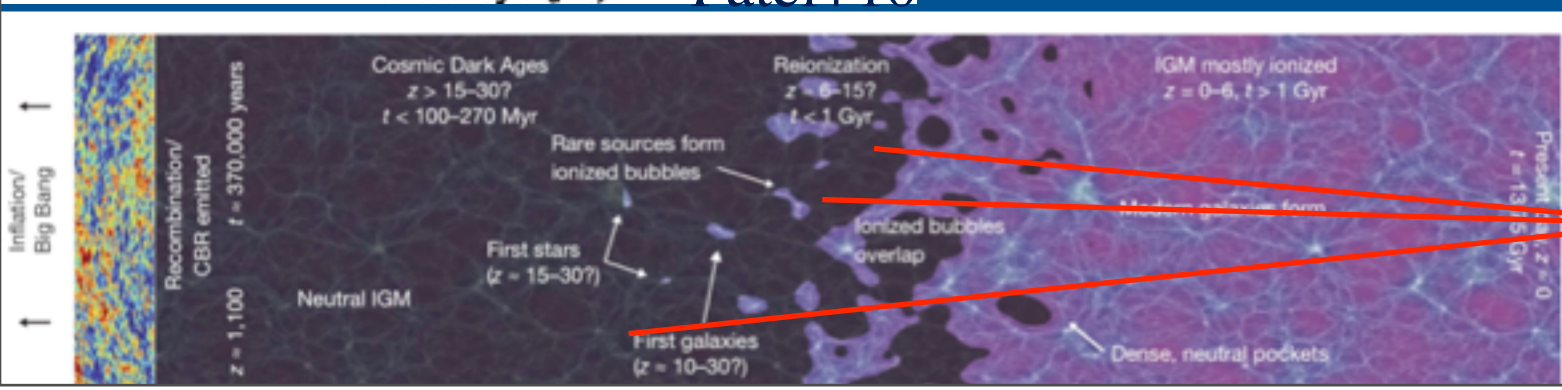
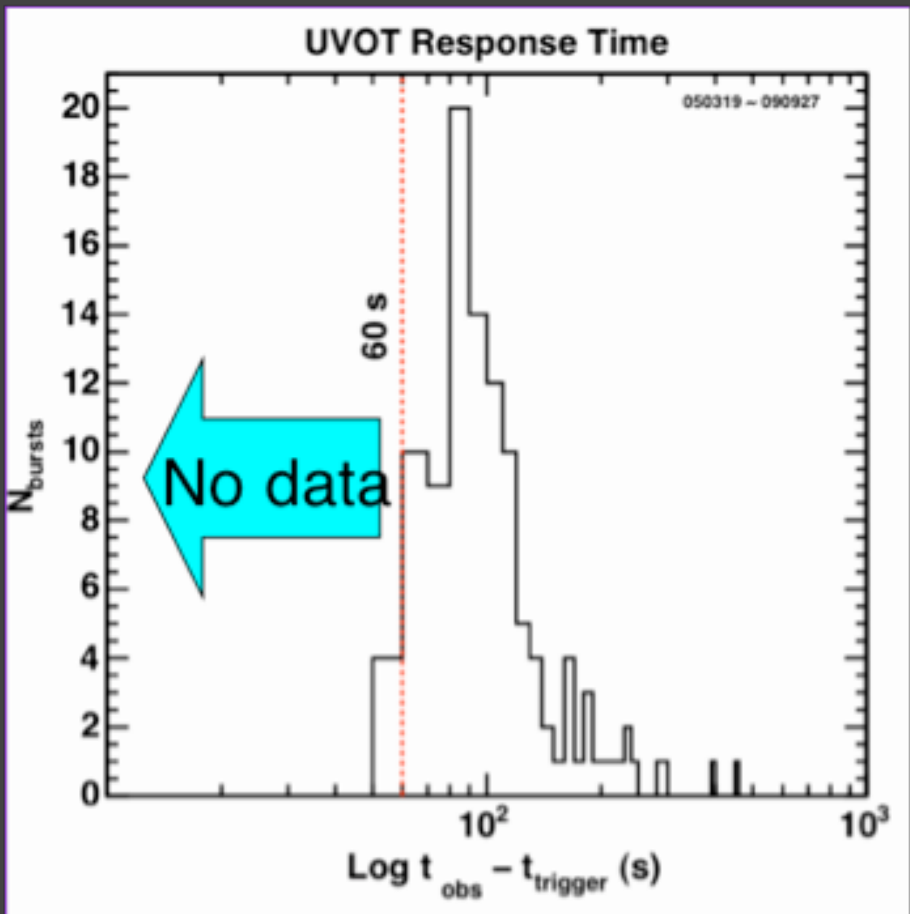


Emission Mechanism

- Basic Question: Are GRBs polarized?
  - Very Limited X/gamma-ray Data from Yonetoku (IKAROS GAP); others not so clear
  - Optical (mostly afterglow, usually) varies. (What does that tell us?)
  - Basic emission mechanism supposed to be synchrotron
    - Can we verify this? In a variety of GRB?
- Answer: YES, one.
  - Usually Compton Telescope, but polarization info in e.g. NuStar detectors.
  - Not complete information (c.f. “laying this to rest” discussion Wed.), but
    - at least we have a good diagnostic/indicator
    - One measurement is usually not so much progress.

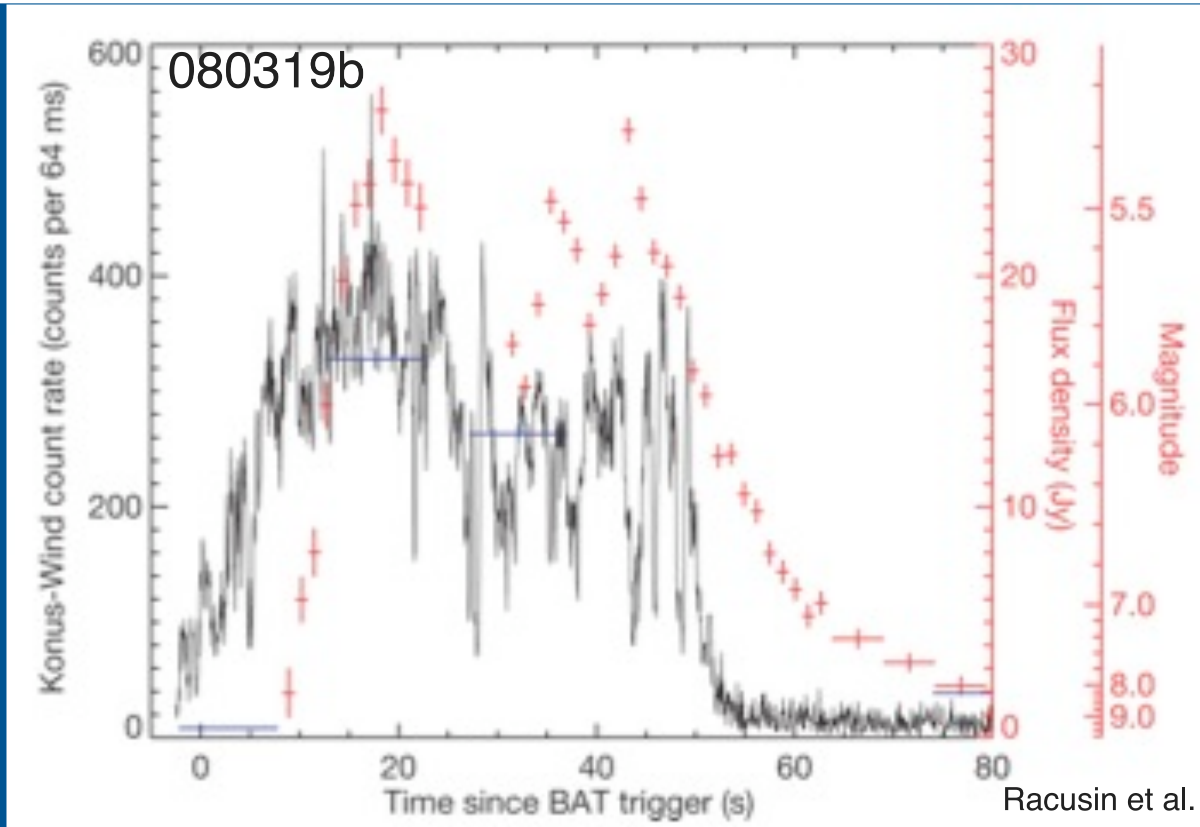
What is relation of prompt gamma and optical?



- **We are data starved on prompt optical.**
- **Swift Optical Response Speed Limited:**
  Few data t< 60 s
- ROTSE, etc. important, but small number of t_{rise} < 60 s.

Fast-Response GRB Science

Γ, Cross-Correlations & Delays

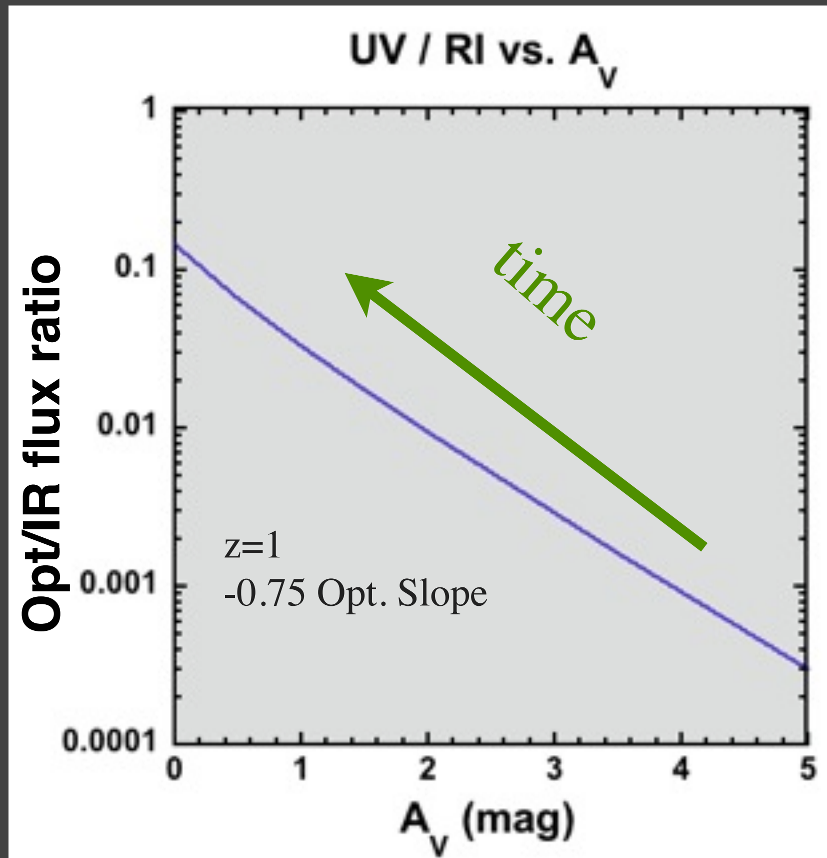


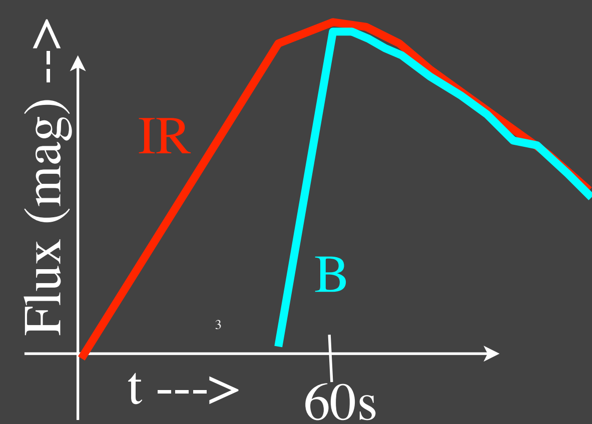
- Naked Eye burst showed us many things are possible: Measurement of Γ (Lorentz) ,
- cross-correlations & delay (multi-messenger astrophysics), etc.
- But RARE - need faster response for more!

Rapid Color Information

Dynamic Dust *via* Dynamic Color Measurement

- **Sub-60 s: allows dynamic dust vaporization measurement**





Models: Salvaterra+09, Perna+03; >60 s too late: Oates+09, Perley+10

SGRB

- We only have ~ 15 SGRB optical detections; compare to hundreds of LGRB!
- No detailed optical like Naked Eye Burst; no prompt optical, or any kind of early optical at all.
- Lower-z than LGRB, often large offset different lag, lower fluence

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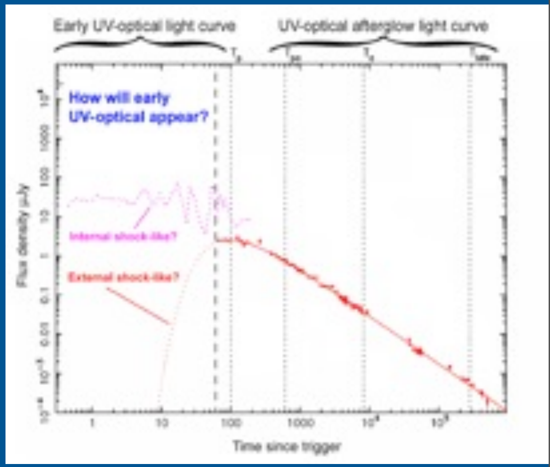

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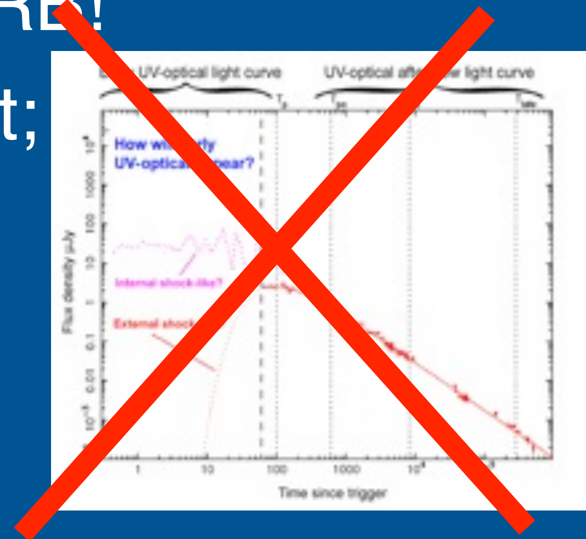

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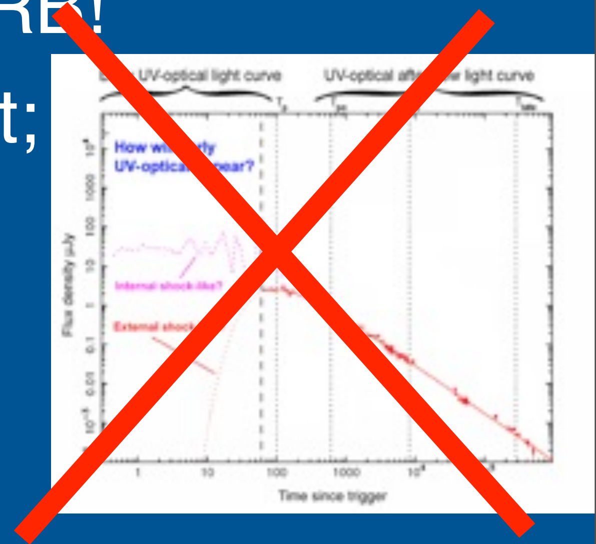


We could certainly learn from more data!

Why not build an instrument for ~ 100 SGRB optical light curves, spectra!

What do we need?

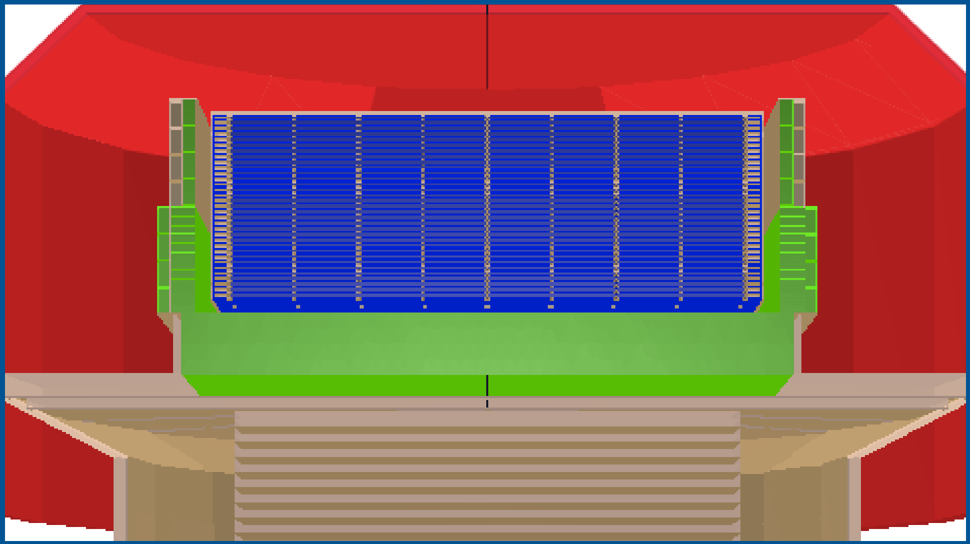
- We need more capabilities... with Swift-like precise location, to learn new things.

Hi-Z: Low-E Response

- LGRB E_{peak} ~ 160 keV; z=7-14 E_{peak} -> 22 - 11 keV
- Swift BAT Detectors: 15-150 keV
  - Why no LE response?
    - VERY low noise electronics required for < 10 keV response - still difficult today
    - Some technologies require cooled detector plane
- Future ...we need to invent it!
  - JANUS was planned for Si detectors, sensitive down to 0.5 keV, ...but no start
  - SVOM planned for CdTe, for ~5-10 keV minimum, but ... ?? will be downsized.
- Last In Talk: Detector Choice for LE response

Hi-Z: Another Way

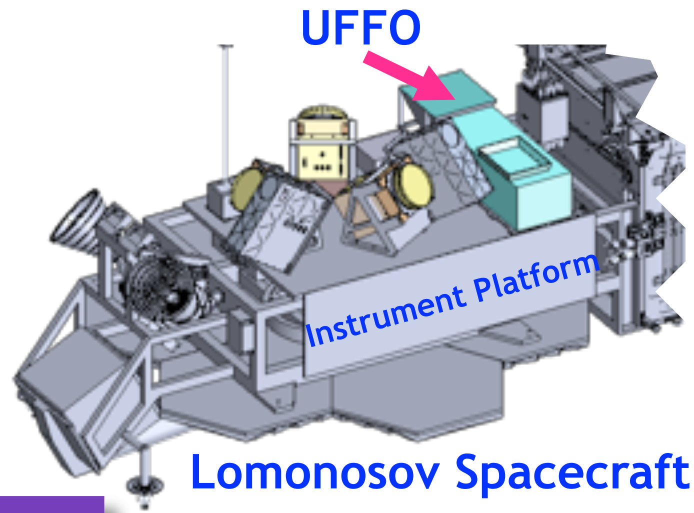
- Don't forget... GROME can also get *z* via Nuclear Resonant Scattering
  - See A. Iyudin talk Wed.
  - (Iyudin+'05, '08, Greiner.+09 ...etc.)
  - If POP III stars have very high columns, could be important probe of early universe.

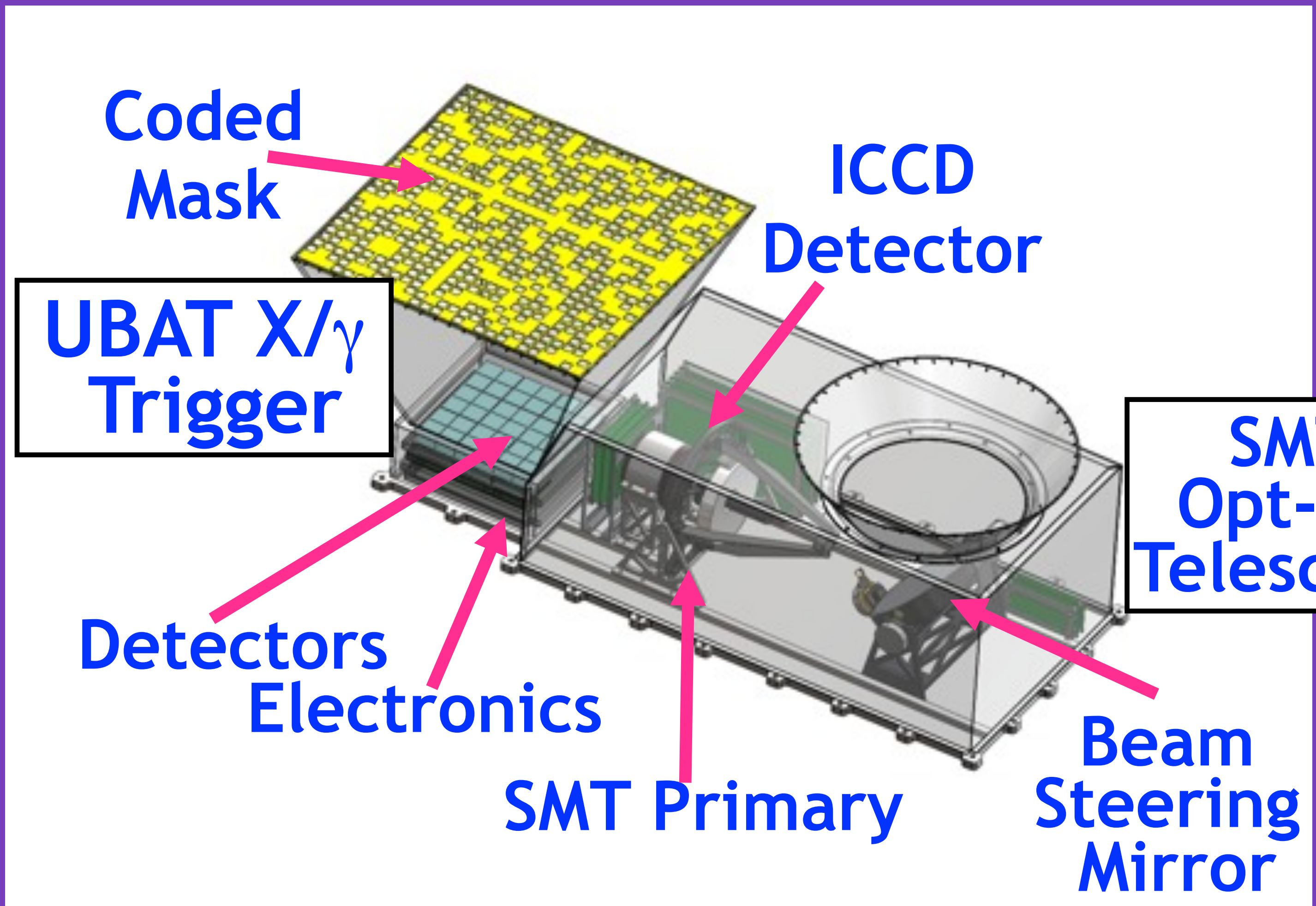


Configuration of GROME-S . Red colour= elements of the anticoincidence shielding. Imager, composed of Si-strip detectors is shown in blue. Green colour shows side-walls and bottom calorimeters made of LaBr3:Ce scintillating craystals viewed by suitable Si-diodes, or Si-PMs

UFFO Pathfinder 2013

- $t_{response} < 1$ s
- 10 cm optical telescope





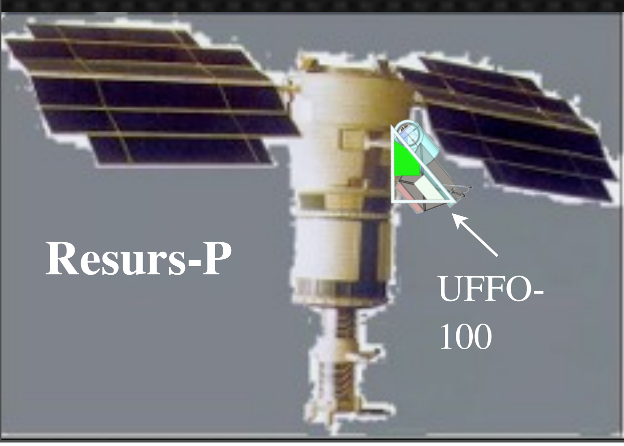
- 20 kg, 10 W
- X-ray Camera $A=190$ cm^2

I. Park Ewha)) PI of UFFO, w/ MSU, Uvalencia, SSL, NTU, IAA, and many more.

Next Generation Rapid Response

- OIR Tele- 30 cm
  - Optical CCD camera
  - NIR Camera
- X-ray - 1024 cm^2

- Different possible launches under discussion



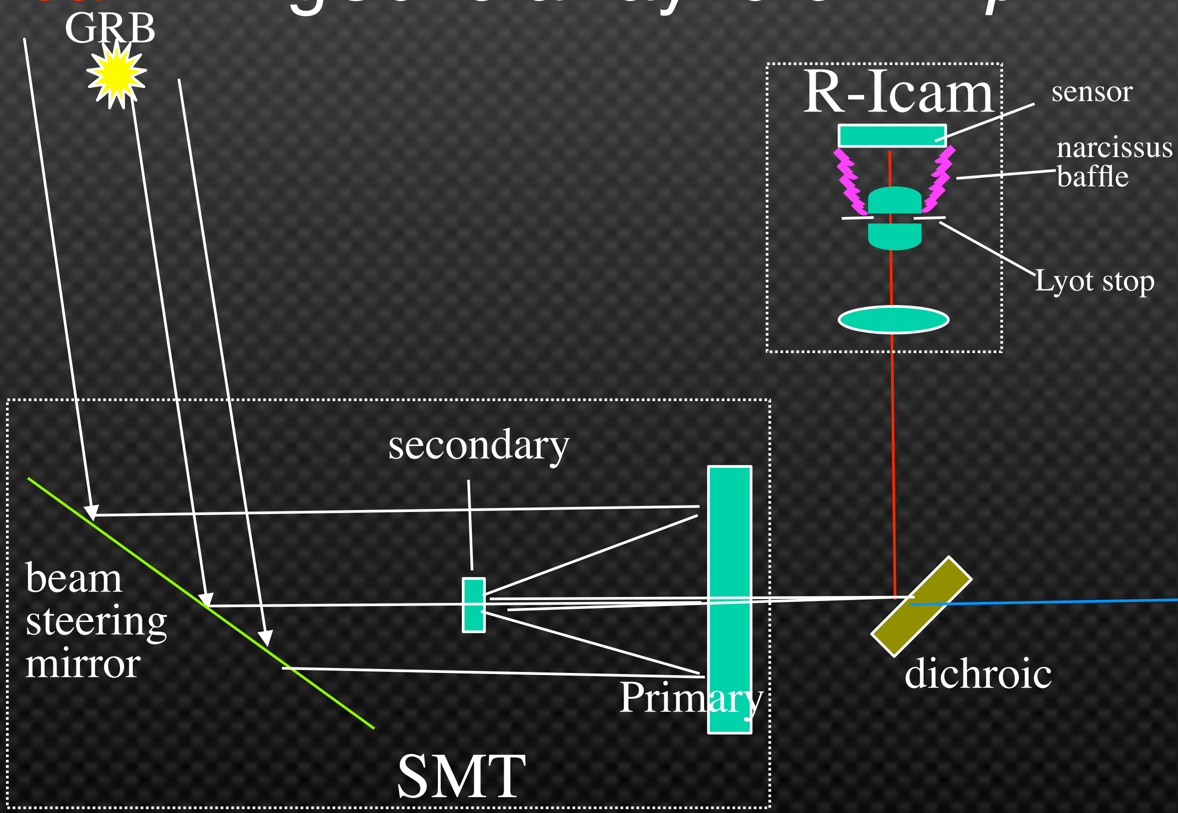
UFFO-100 Consortium

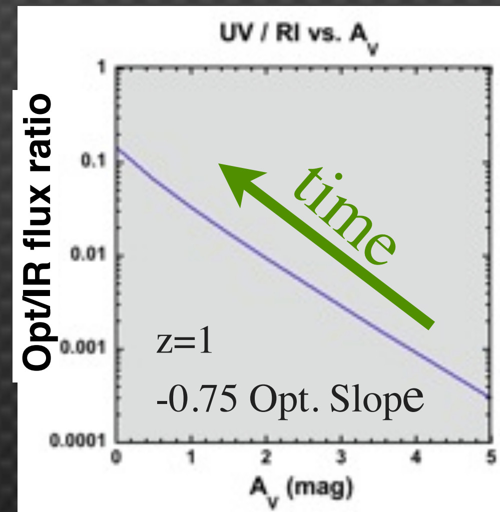
Ewha RCMST, IEU
MSU: SINP & EXUL
University of Valencia
LaCOSPA (NTU)
UCBerkeley SSL

... and many more

Dichroic for Simultaneous Opt & IR

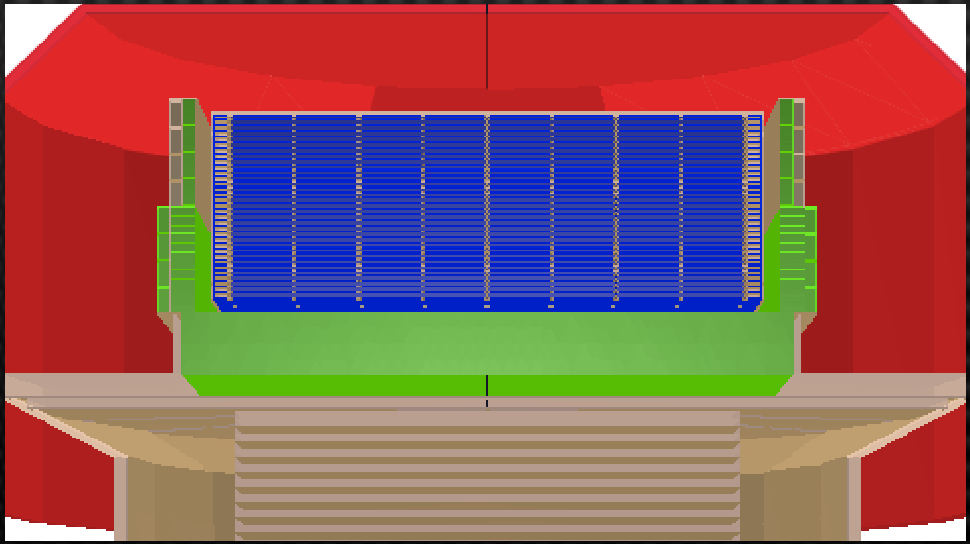
- Dichroic splits beam to...
- Optcam - 0.38-0.75 μm
- R-Icam - HgCdTe array 0.6-1.7 μm





Polarization

- Many Polarization Sensitive Instruments Discussed Already
  - compton telescopes have possibility to get polarization information
  - Information can also be extracted from consideration of nearest neighbor hit patterns in many pixelated imaging detectors.
  - Don't forget GROME.



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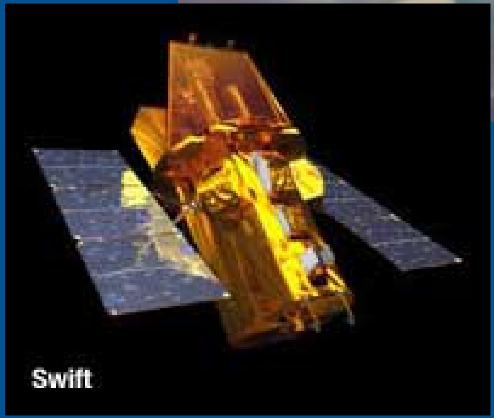
Higher Energy -> More SGRB

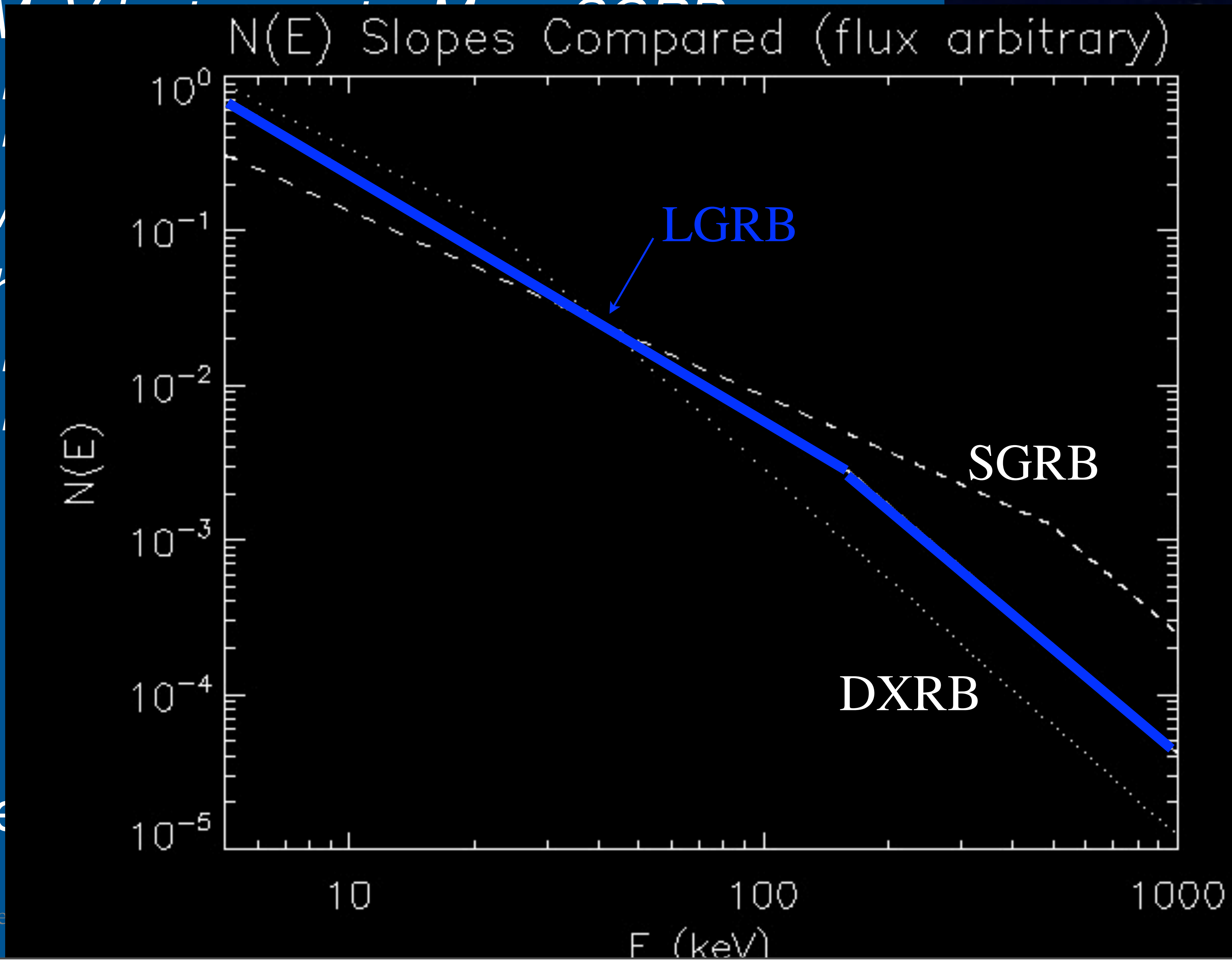


- *~ MeV instruments: More SGRB*
  - *BATSE, Fermi get lots of SGRB (~50%) BUT r > ~deg, NO FOLLOW UP*
- *Swift -up to ~150 keV- only ~10% SGRB*
- *Why?*
  - *E_{peak} LGRB ~ 160 keV;*
  - *E_{peak} SGRB ~ 490 keV!*

- Need higher energy AND imaging!

Higher Energy -> More SGRB

- ~ M
- Sw
- Wh
- Ne



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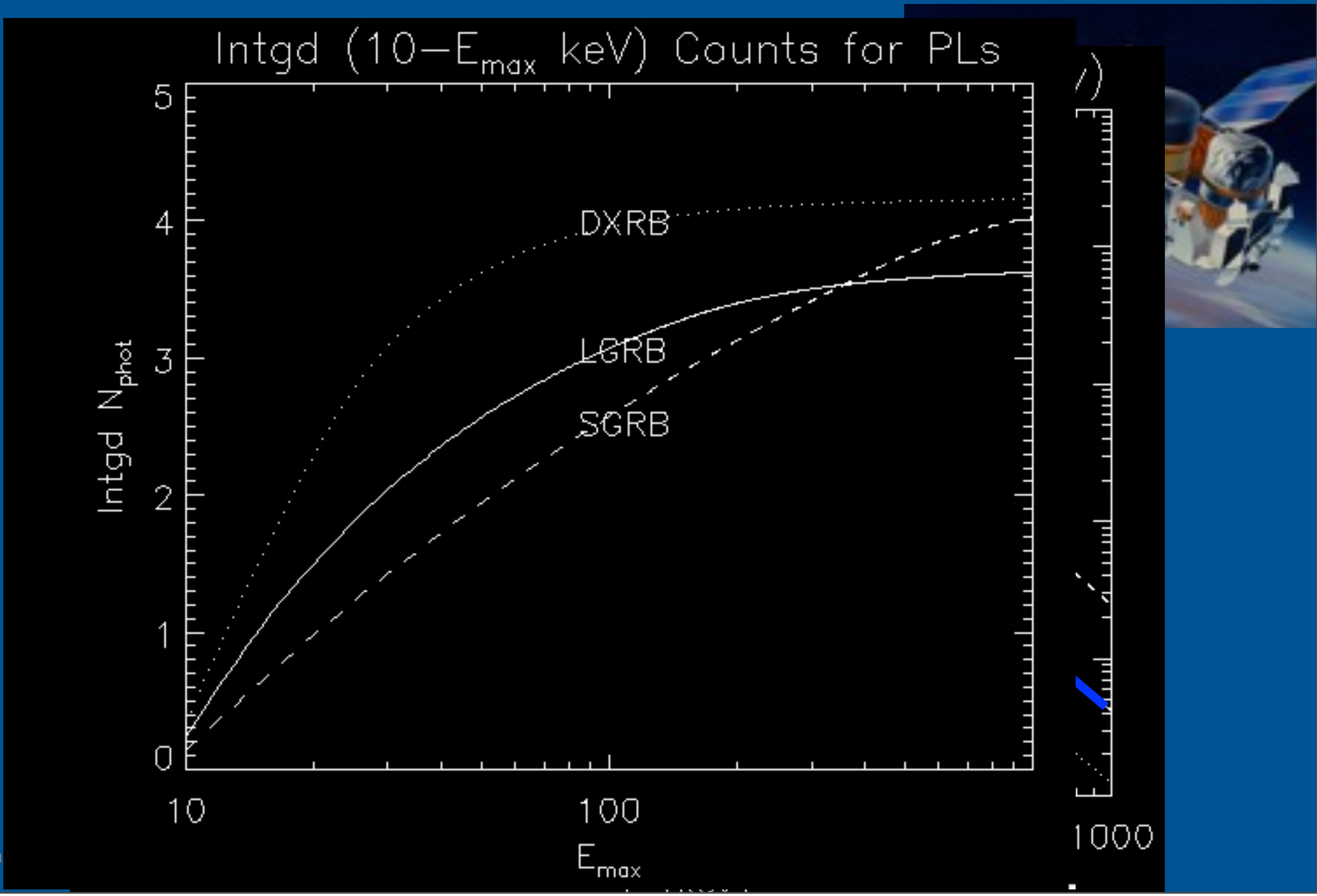
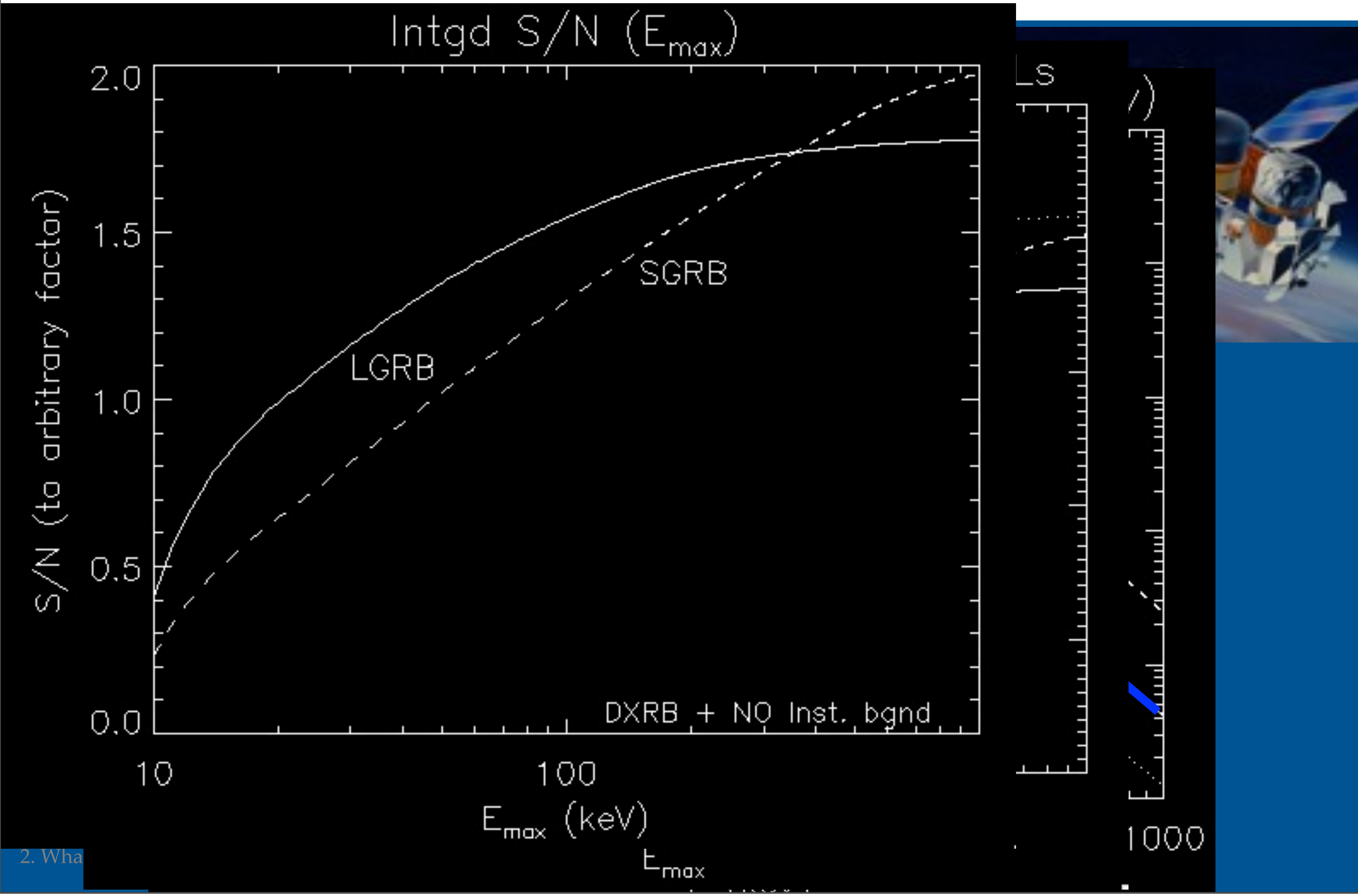


2. Wha

Higher Energy -> More SGRB



Higher E: What's the Big Deal?

- Why doesn't swift respond to hard sources?
  - Little instrumental response > 200 keV

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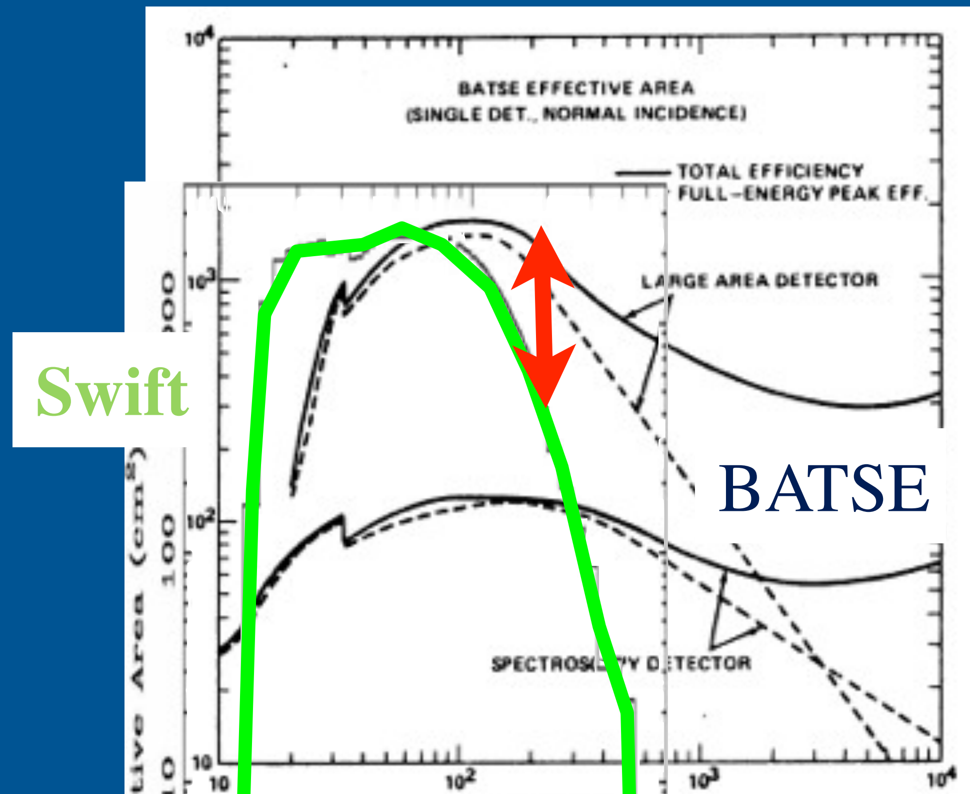

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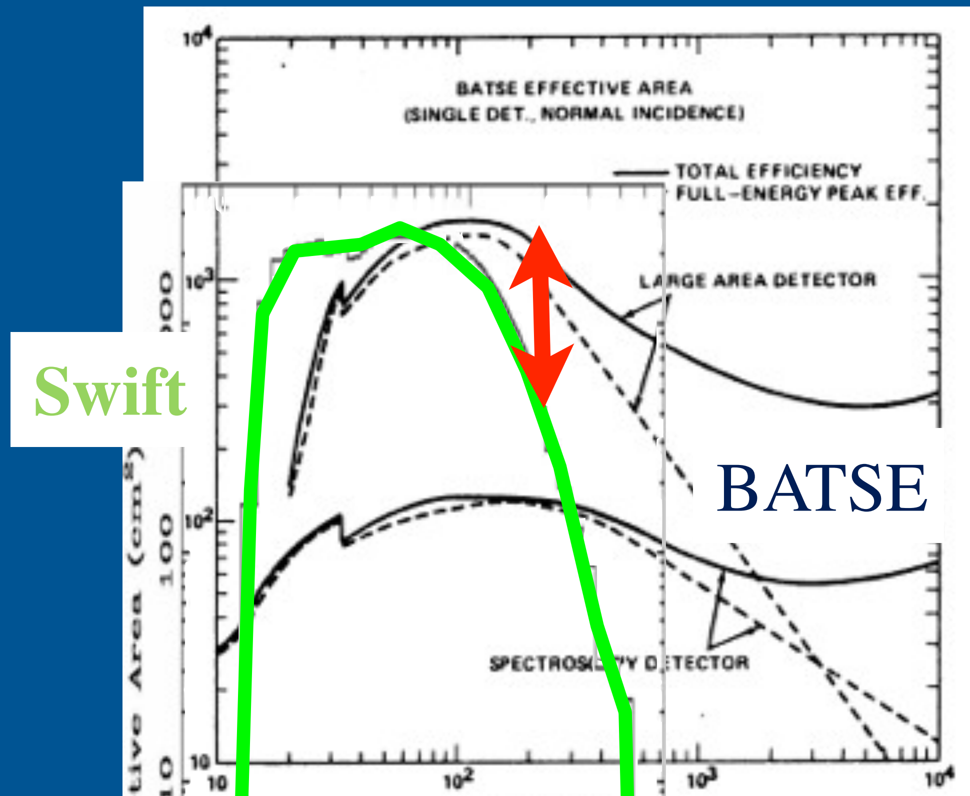
- Is this hard to do?
  - Look at the BACKGROUND



Friday, June 15, 12

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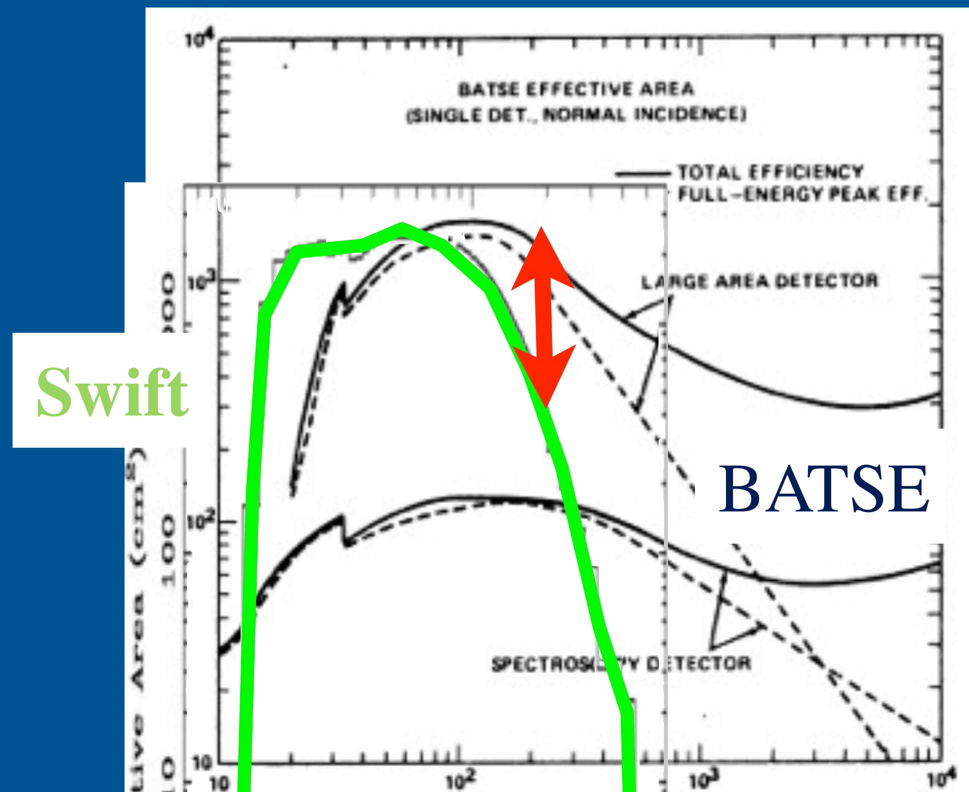
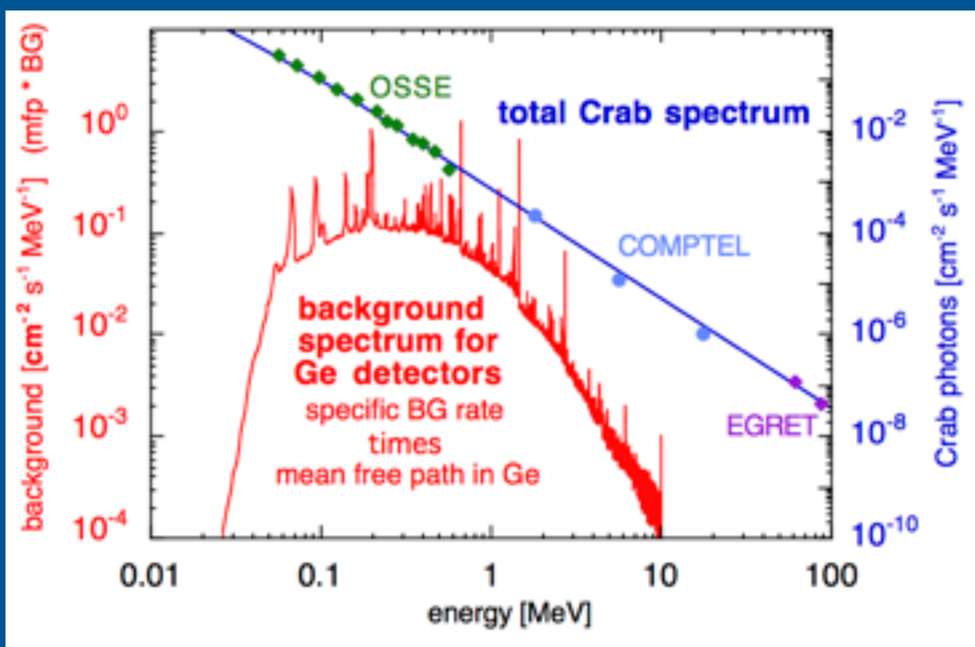
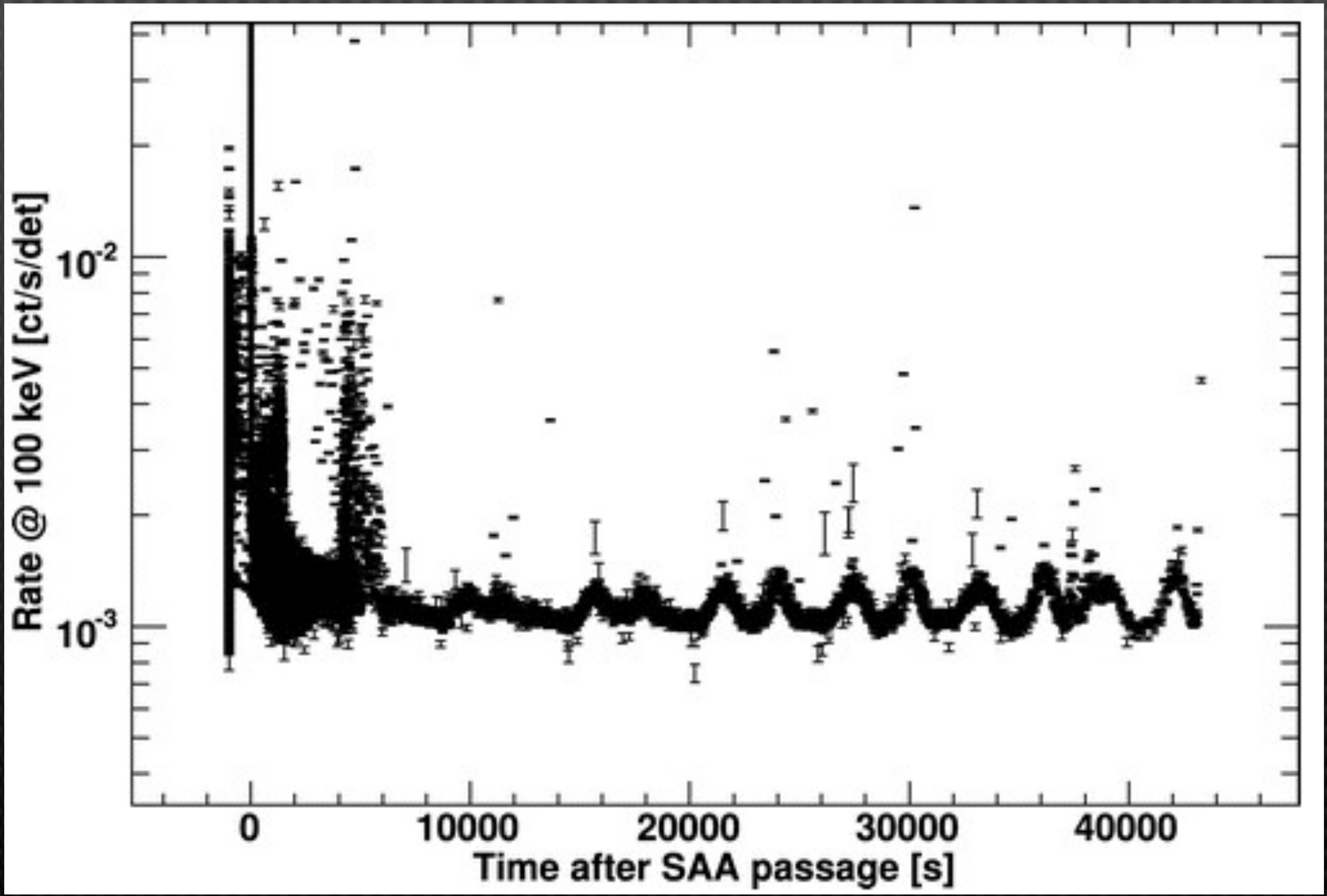


- Is this hard to do?
  - Look at the BACKGROUND
  - YES, Much more difficult



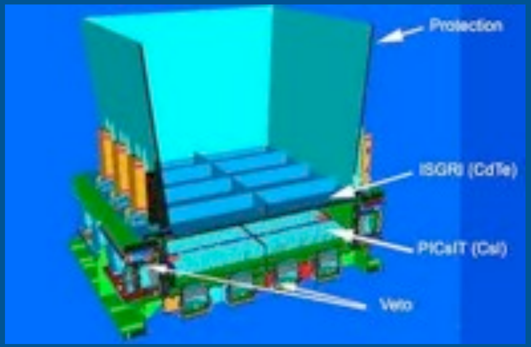
Friday, June 15, 12

BAT Background

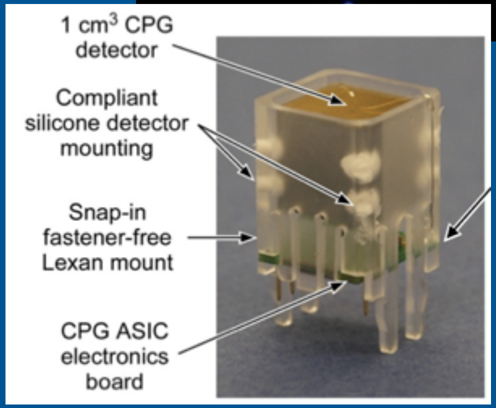


Higher Energy -> Best Way?

- *Quotes from Von Ballmoos on MeV Instruments:*
  - “Terrible”, “Unlucky”, “Very DIfficult”, “Crazy”.
  - ***Worse here: requiring r < 15’ (typical optical FOV), ≥ 1.5 Sr FOV***



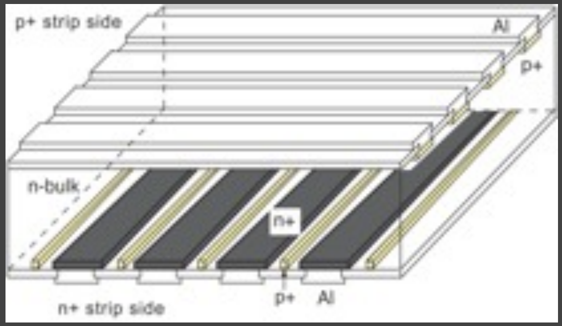
- Straightforward:
  - ISGRI-like coded-mask camera; bigger FOV, finer location
    - heavy, more complex instrument - active shielding/veto
- A bit more complex:
  - Tracking Instrument + Coded Mask
    - 10 ‘ possible???? (Not Common)
    - Probably Ge (=cryogenic cooling!)
    - too much on-board processing?
  - Active Mask Design (CZT)
    HEMI (LBNL); Amman, Vetter



Schedule Updates

Many New Semiconductor Detectors

- LE: Silicon - no cooling!
- JANUS: Hybrid CMOS Si 0.5-20 keV (pixels)
  - much higher energy than CCDs
  - Commercial Product by Teledyne; Visa and Mastercard Accepted!
- Astro-H, etc.: DSSSD (Double Sided Si Strip Detectors)
  - Commercial Products down to 25 μm spacing
  - N_{chan} ~ 2 N not N^2 ----> save money on electronics!
  - MULTI-LAYERS permit higher energy response!

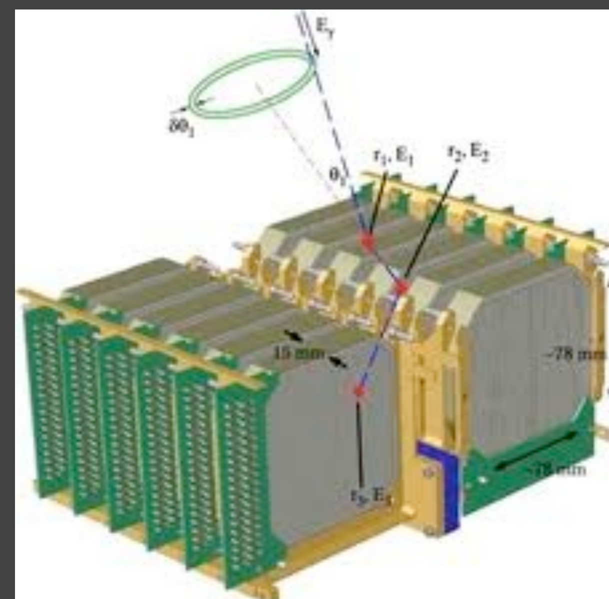


Figures - Takeda+08

Many New Semiconductor Detectors

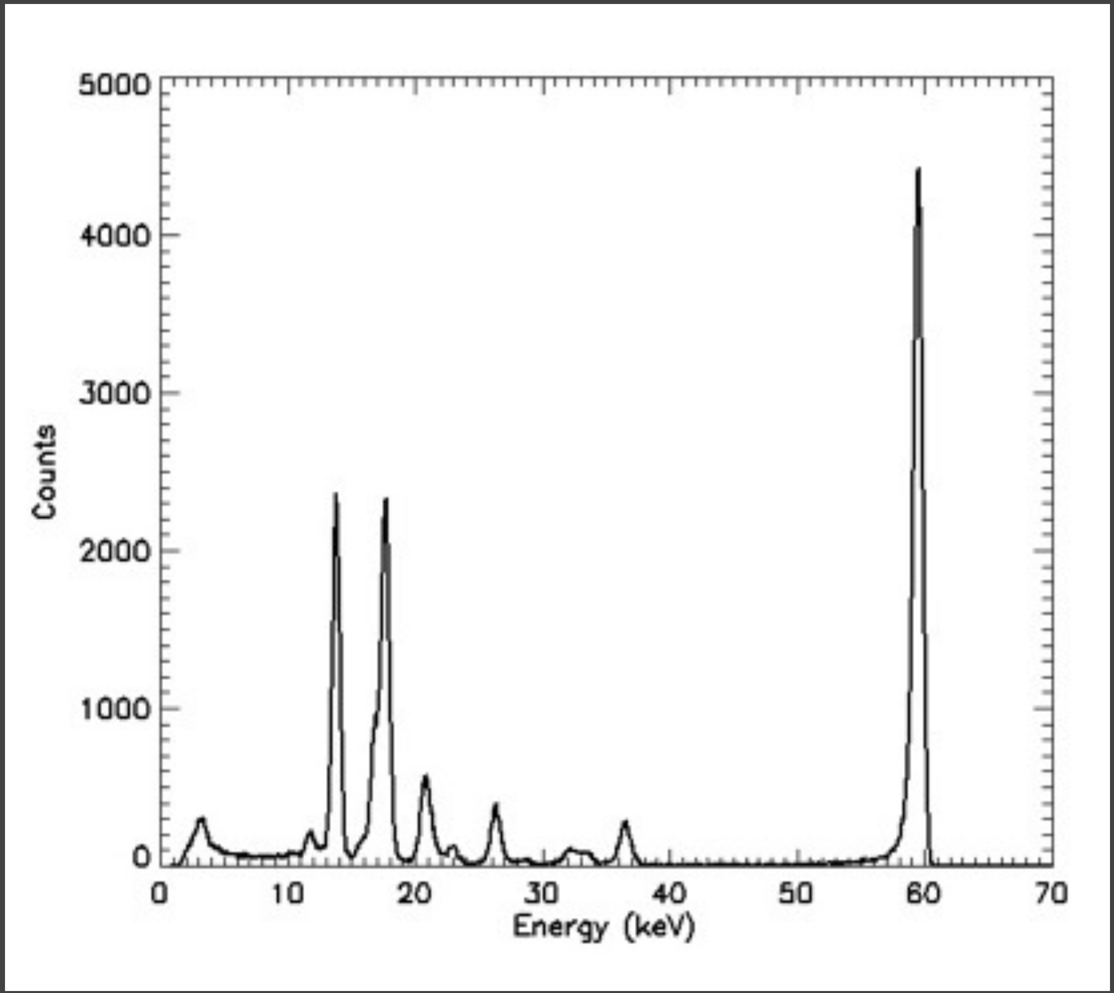
- LE: Cooled CZT, CdTe
  - ECLAIRs: CdTe Response < ~ 4 keV - 150 keV ((Philippe Laurent), factor of 3-4 lower than Swift --- **LARGE FACTOR FOR STEEP LGRB!**)
  - Must be cooled to -20 C (but not liquid He Temp!)
  - Electronics difficult (need expertise or development program)

- NCT: Ge DSSD
  - FANTASTIC spectral resolution
  - Gives depth information
  - HE response; good for tracking detectors
  - drawbacks:
    - Must be cryogenically cooled,
    - specialized fab



CdTe

- LE: Cooled CdTe
  - CdTe Response < ~ 4 keV - 150 keV (Philippe Laurent, CEA)
  - -20C



Summary

I. Science - Many topics in GRB Science can be addressed directly by new instruments

II. Instruments - Some of these are straightforward, out-of-the-box (almost) possible. Others require substantial optimization and specialized design

III. Recent advances in solid state detectors give us many tools; limited only by our imagination.