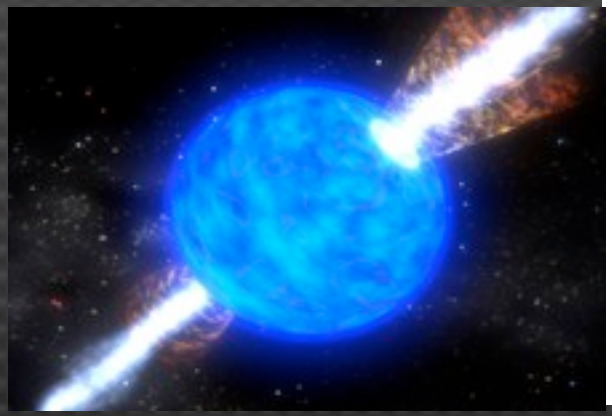
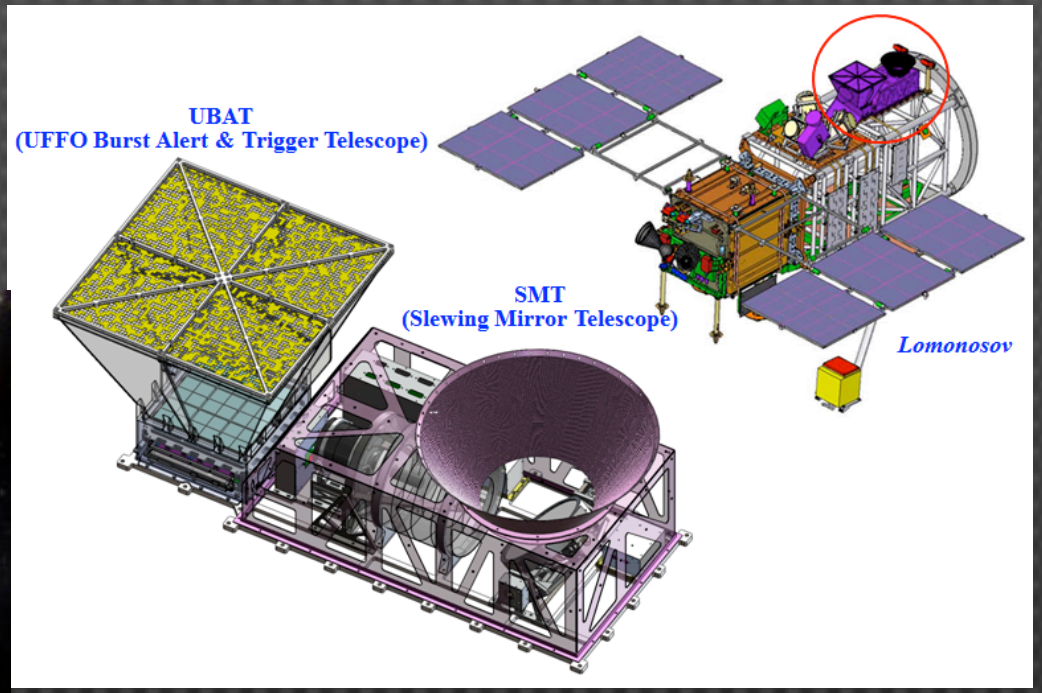




UFFO Slewing Mirror Telescope

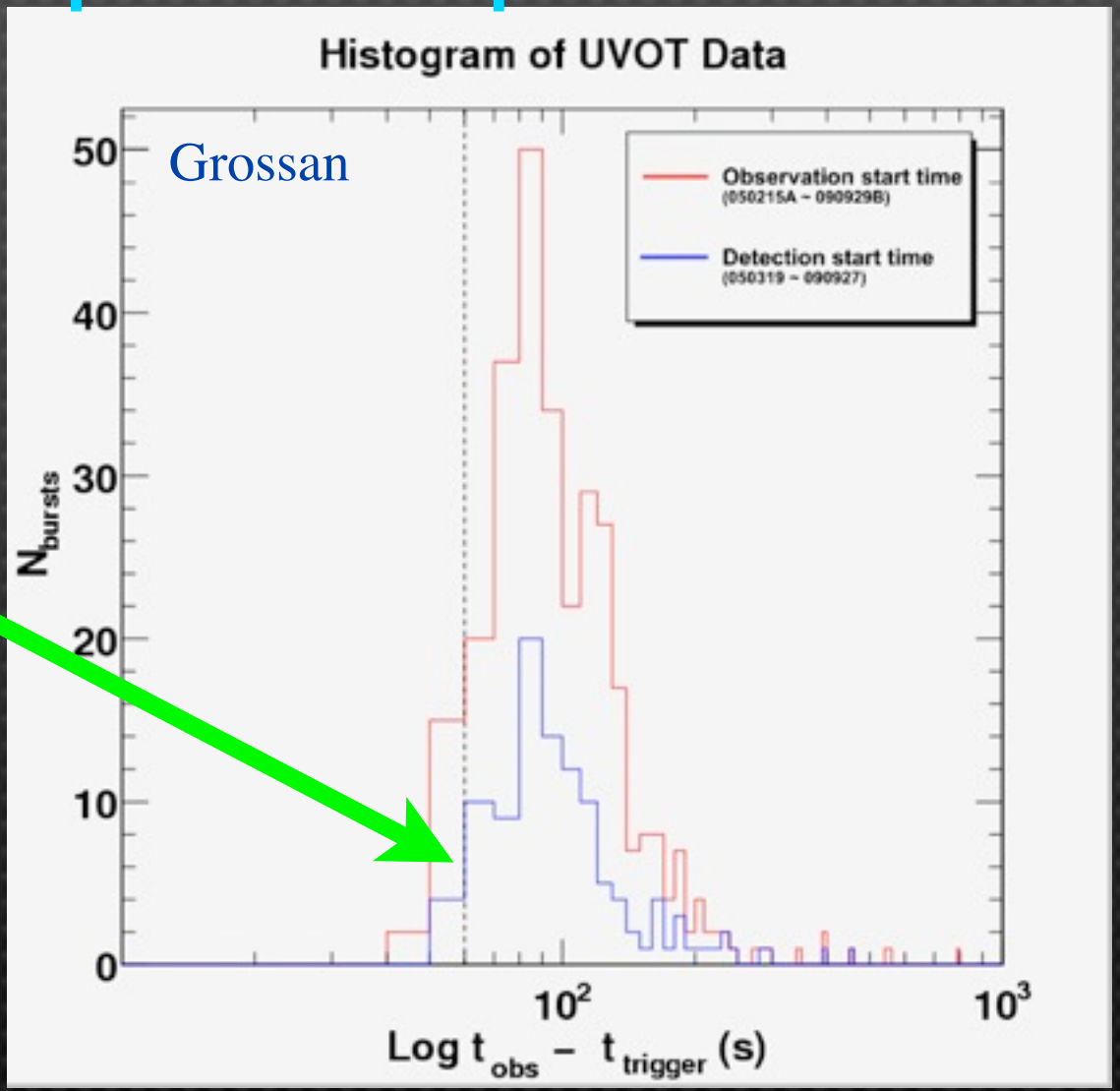
B. Grossan
SSL, EUL

EUL/Skobeltsyn Institute
MSU

Swift is **too slow** to measure the rise of most GRB optical emission.

SWIFT response speed limited

- SWIFT has few data $t < 60$ s !



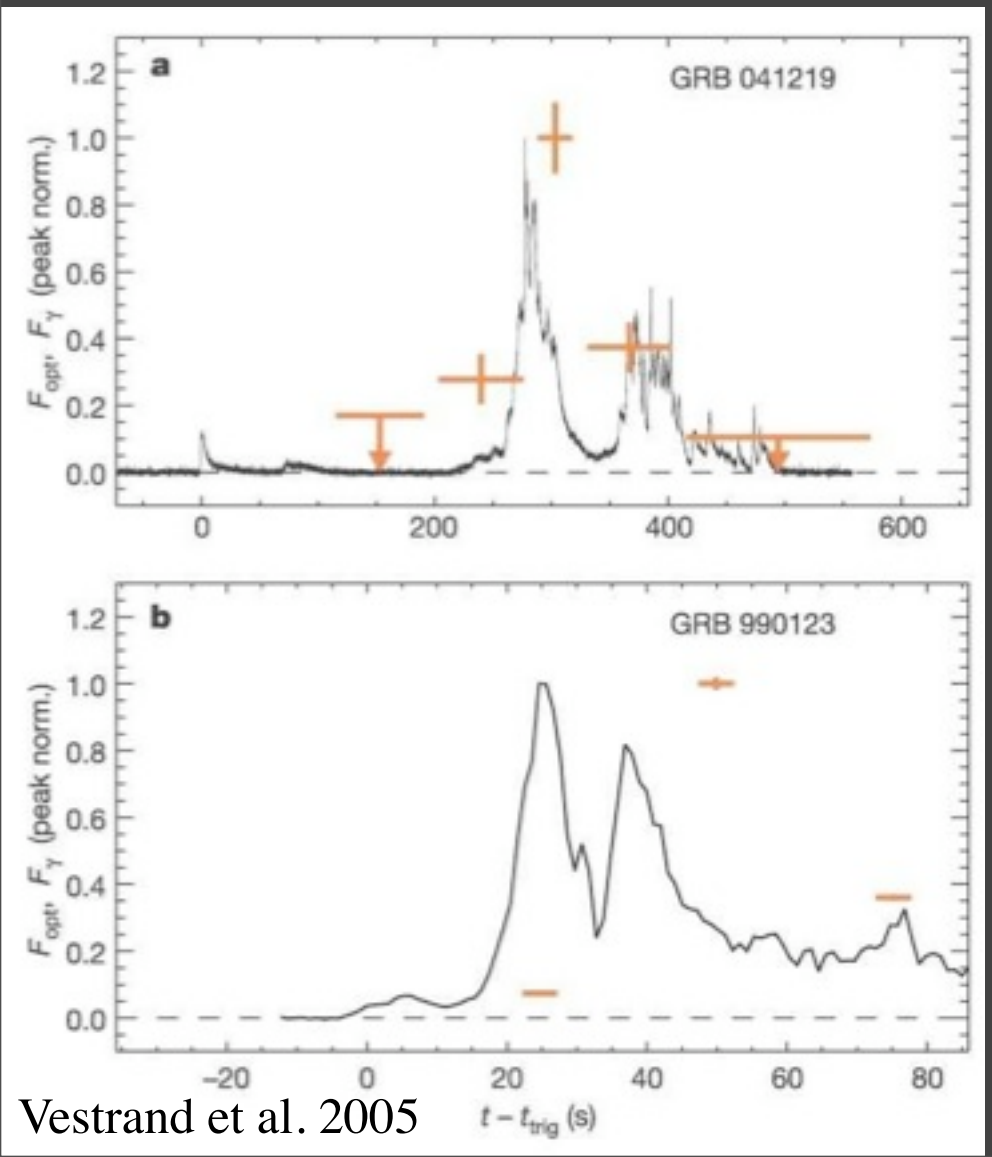
How will we ever get a large sample of rise times, shapes?

So...?

- What you could to **with faster response...**

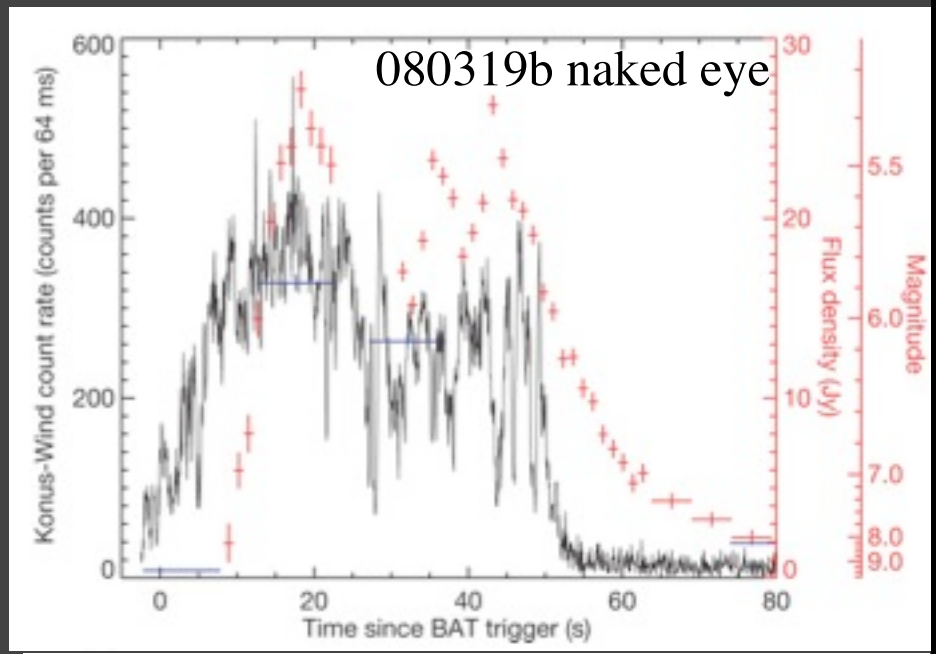
Correlation of early Opt, γ

- Both examples, and counter-examples
  - Data marginal except for 080319b
  - need faster response, resolution, to improve.



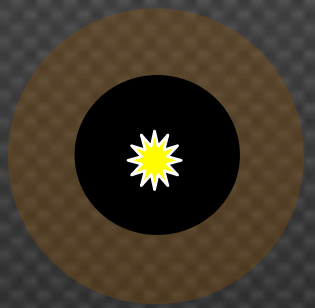
Vestrand et al. 2005

- 041219 - Probably.
- 990123- No.
- 080319b- Mostly
  - (best data)



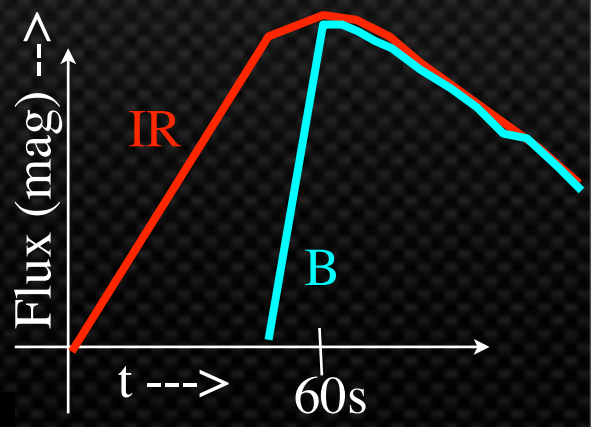
080319b naked eye Racusin et al. 2008

Probing Progenitor Environment via Dust Evaporation



- GRB have enough energetic photons to vaporize dust throughout typical dust cloud(1)
  - Typical time <~ 60 s
- *Time-dependent* extinction measurement would
  - confirm dust distribution (e.g. in cloud vs. behind dust lane), composition, evaporation models
- Need time-dependent spectral slope **with faster response** than current.

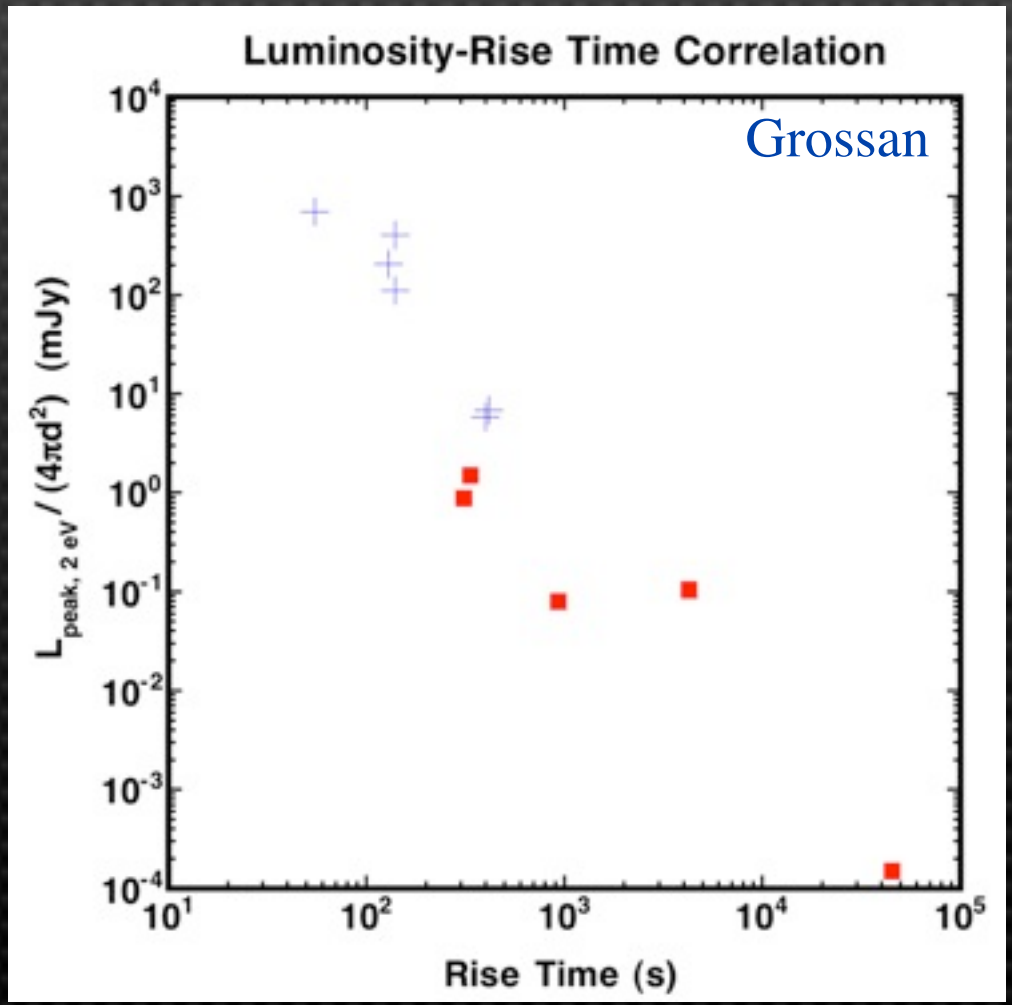
(note Fynbo talk "circumburst or other?")



(1) models: Salvaterra+09, Perna+03; >60 s too late: Oates+09, Perley+10

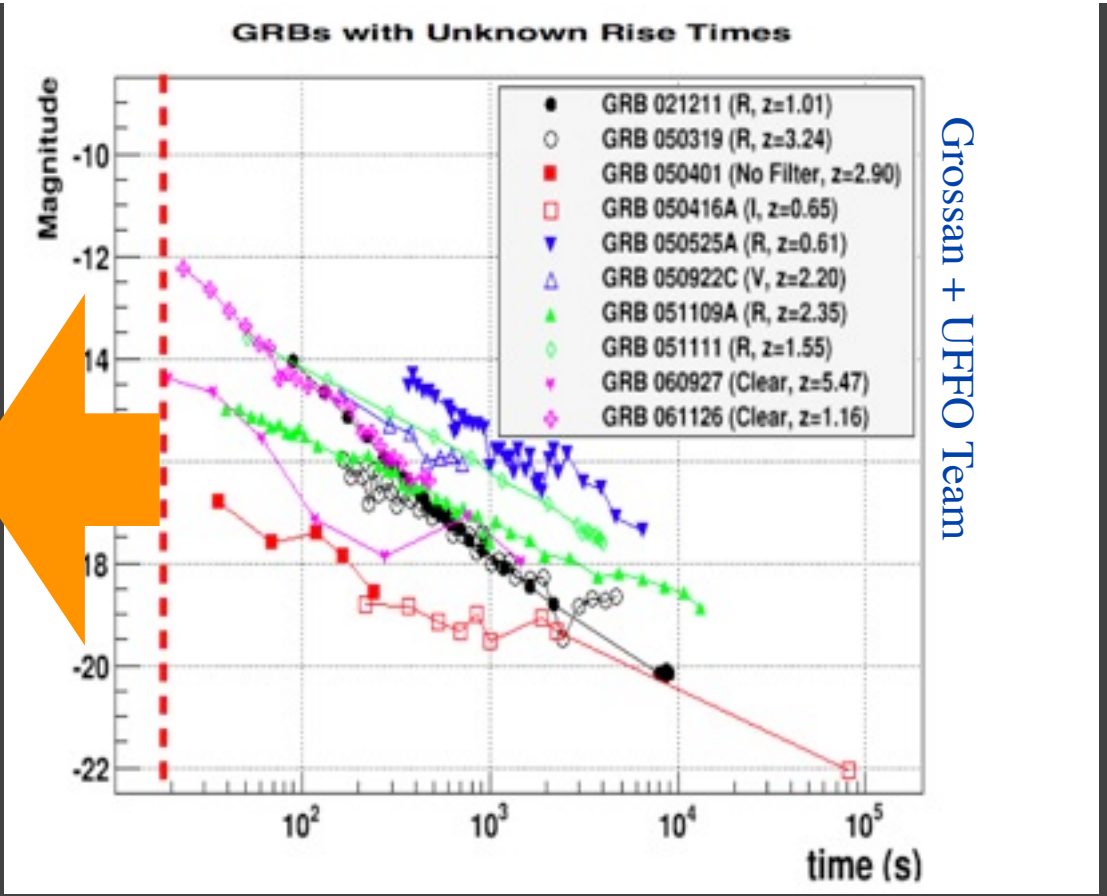
GRB Luminosity Calibration? Cosmological tool?

- PV08: calibrate L_{peak} with rise time:



Well, *those* points correlate, but ...

Same paper, but not plotted....

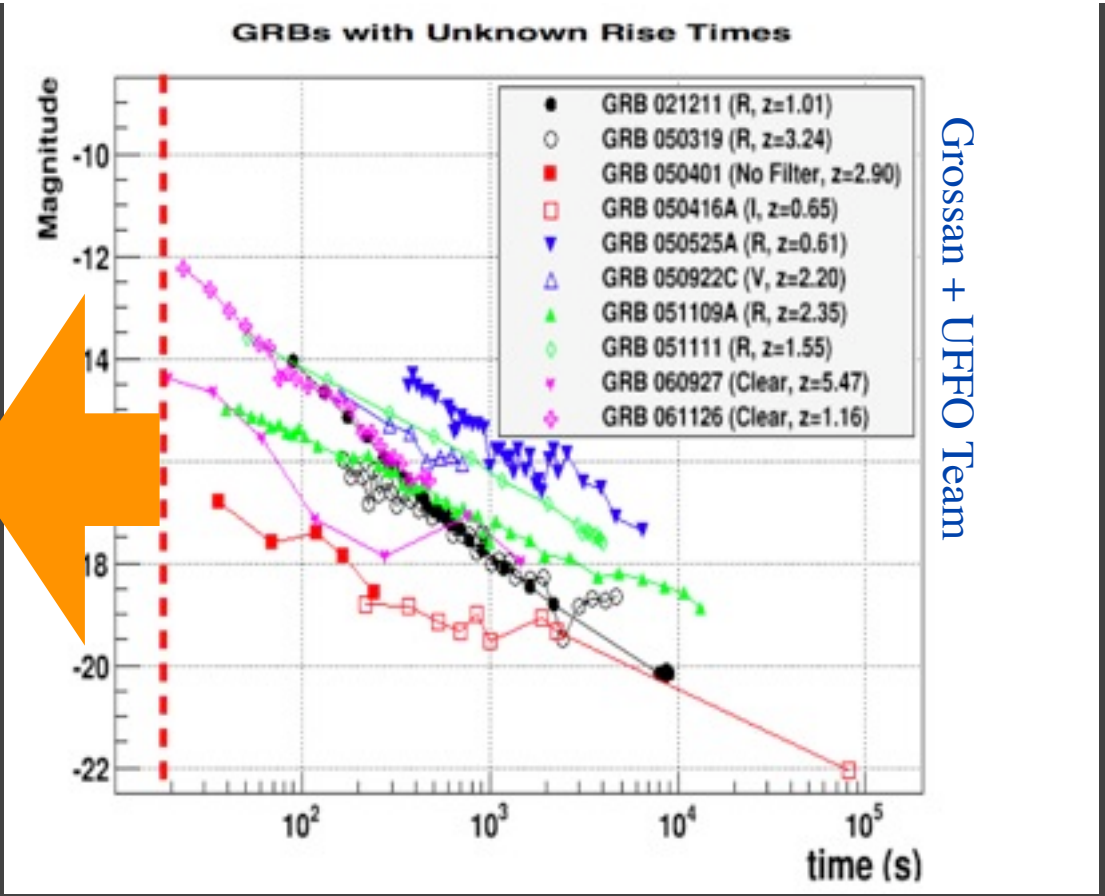


- 2/30 TOTAL in PV08 have < 60 s peak, but majority (18/30) have no clear peak.

Well, *those* points correlate, but ...

- Majority of sample data not used... **because lacking early data**...

Same paper, but not plotted....



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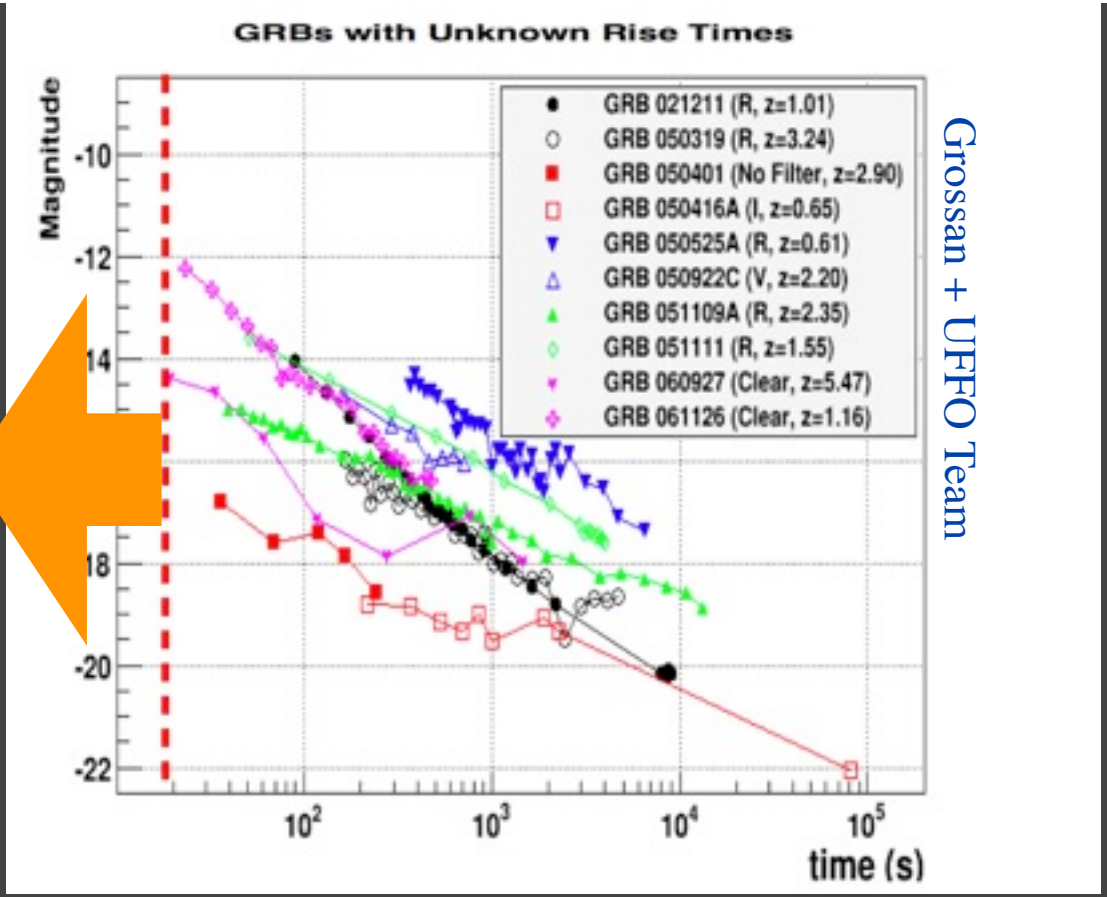

- **MOST t_{rise} unknown.**
- **Need more data at earlier time!**

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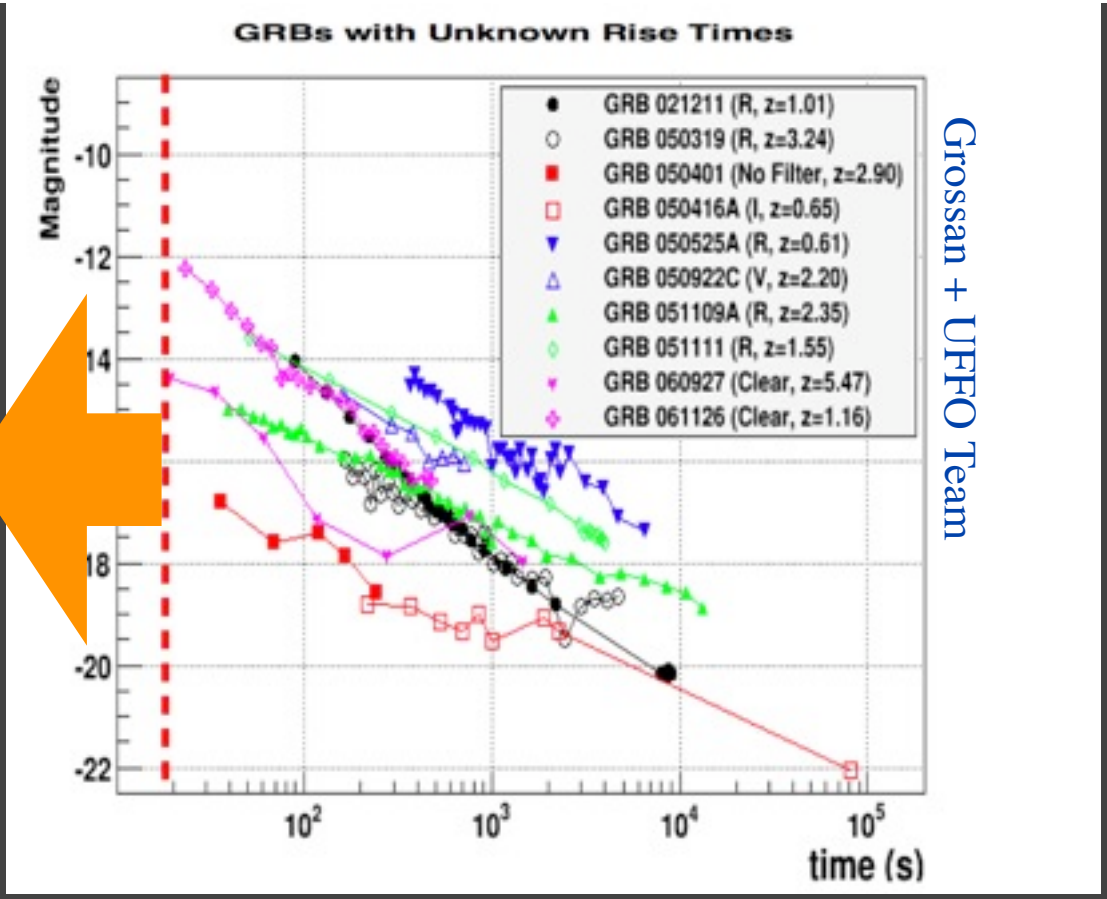
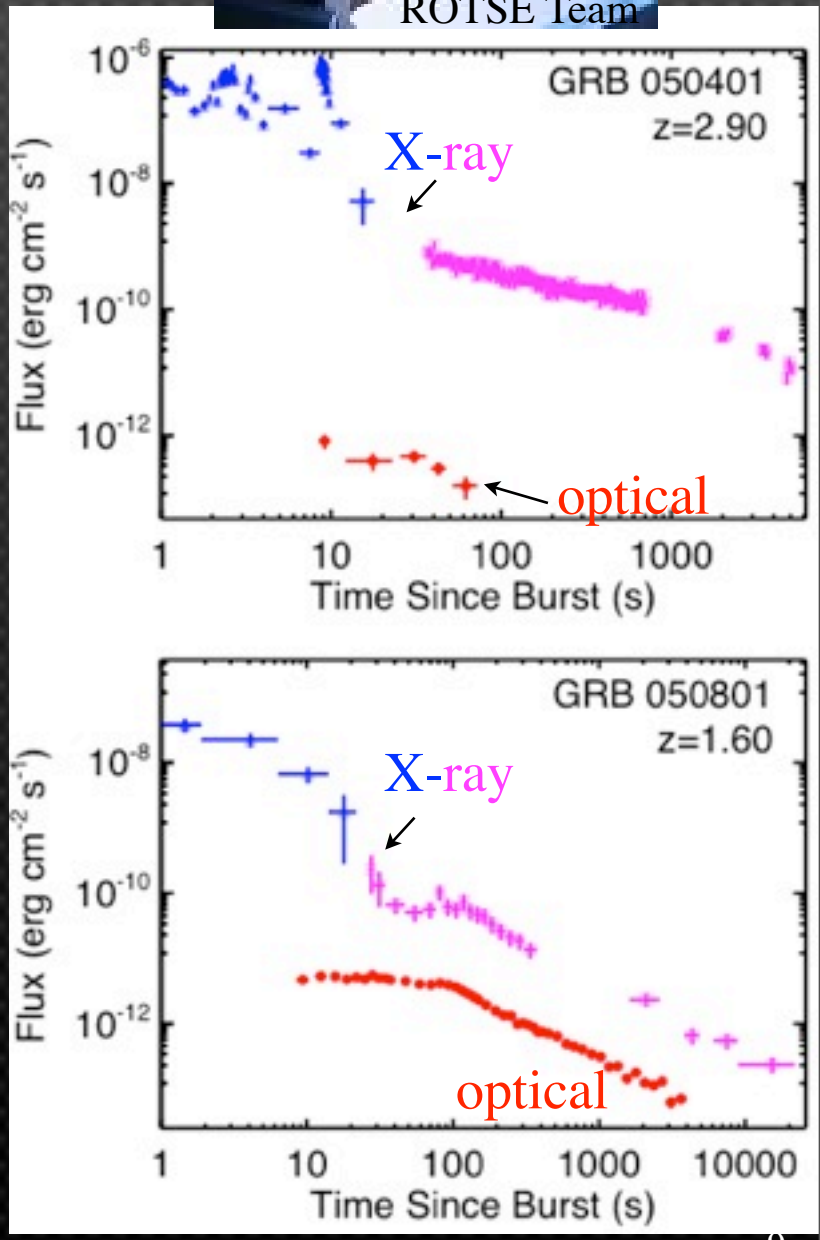


- **MOST t_{rise} unknown.**
- **Need more data at earlier time!**
- **NEED FASTER RESPONSE TO EVALUATE!**
  - 2/30 TOTAL in PV08 have < 60 s peak, but majority (18/30) have no clear peak.

Ground-Based Telescopes? Small # of Rapid Results Very Interesting

- Many robot scopes, but Rotse-III dominates
- *Fast=small, limited sensitivity*
- Fastest Responses (in Rykoff +09): Still Too Slow for Rise
  - In all of Rykoff, < 60 s responses... =ONE rise time measure.
  - What if, e.g. rise times are really bi-modal? Wouldn't you like to know?

...but still too slow and rare.



Rykoff+09, red points are ROTSE-IIII

Rapid-Reponse Optical Observations: Current Status

- Robotic observatories respond to GCN Alerts
  - ROTSEs, BOOTES, PAIRITEL, RATIR, RAPTOR, Super-Lotis, Watcher, etc.
- Rapid-response detections < 60 s: Not Frequent
  - My list has 10 examples(1), *probably missing several*, but total is small.
    - SOME upper limits useful, but most not.
    - More is better: How many bursts did we have before we understood short vs. long?
  - Ground-based response will *always* be tough due to clouds, sun, moon.
- SWIFT UVOT, which is *supposed* to do the well-defined, statistical samples, has little data t< 60 s...

(1) 990123, 080319b (Naked Eye), 060526, +Rykoff+09;

Future Prospects

- SIX YEARS of SWIFT+ Ground Systems-few rapid detections
  - Weather, limited sky, small aperture limit impact of ground-based *rapid* follow-up.

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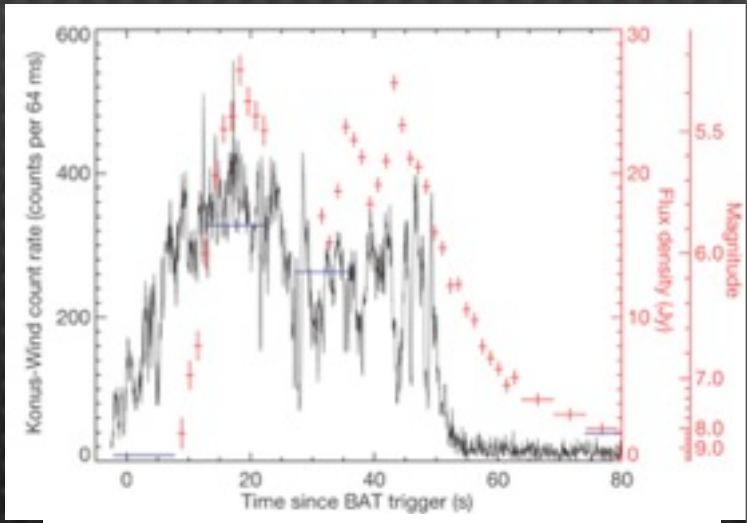
080319B is really the "Lucky" burst: 10° and 30 min. after another!



080319b naked eye Racusin et al. 2008

ONE in six years!!

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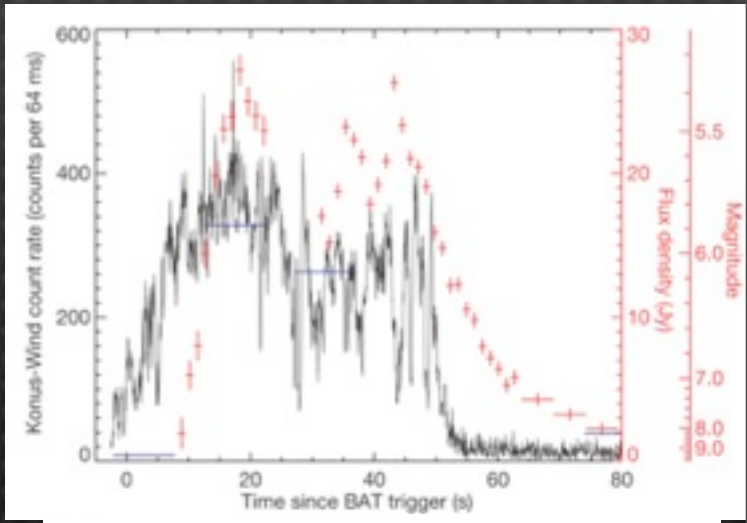


080319b naked eye Racusin et al. 2008

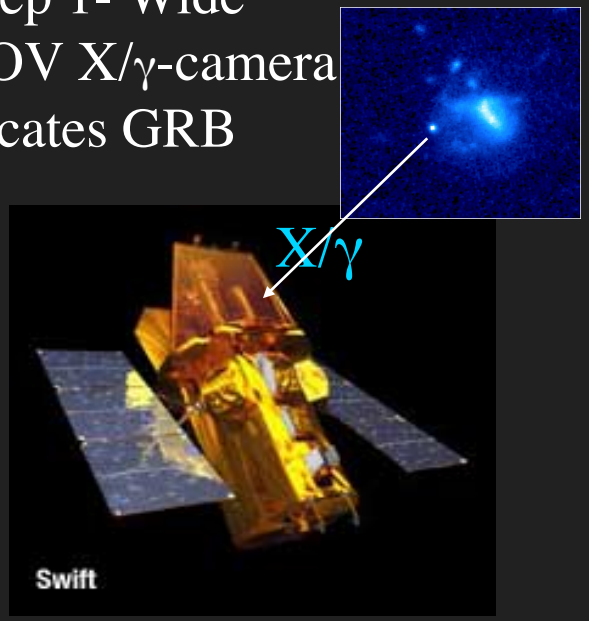
- SWIFT life is finite; after, alerts stop!
- **NEED FASTER SYSTEM FOR GAME-CHANGING PROGRESS!**

ONE in six years!!

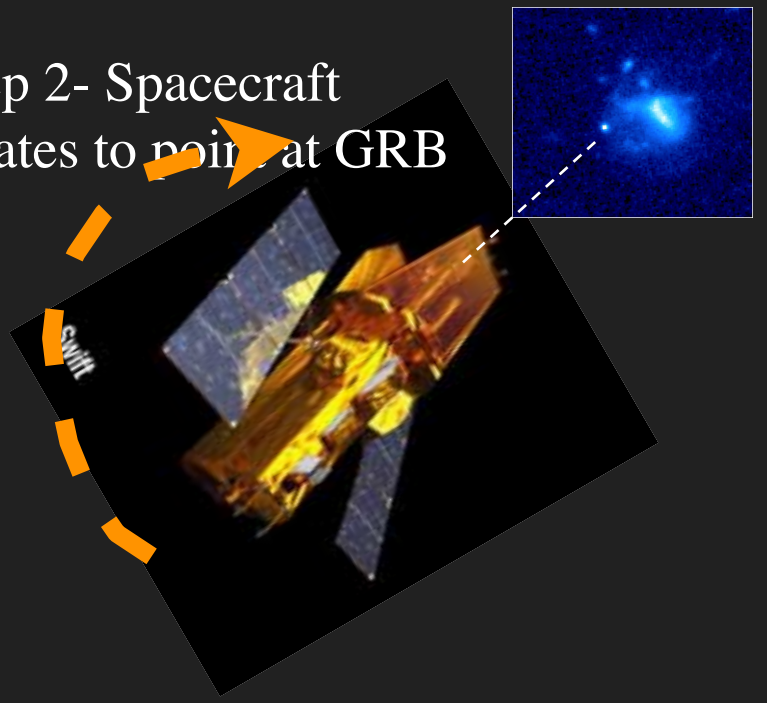
Respond Faster?

- SWIFT rotates entire spacecraft to point opt instrument

Step 1- Wide FOV X/γ-camera locates GRB



Step 2- Spacecraft rotates to point at GRB



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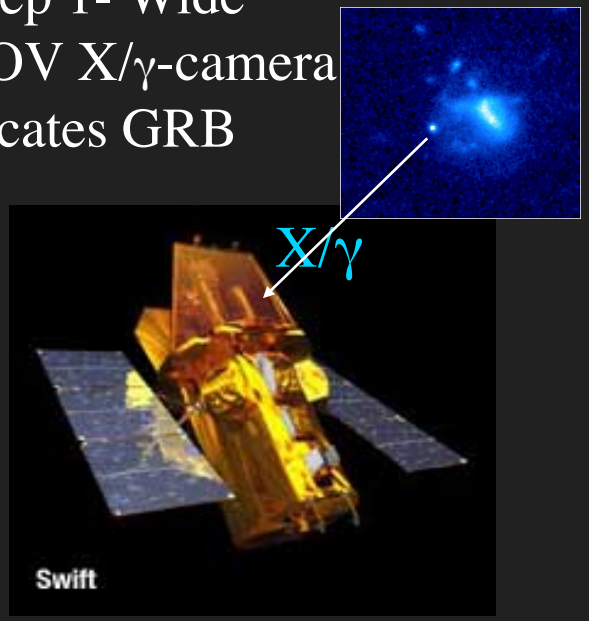

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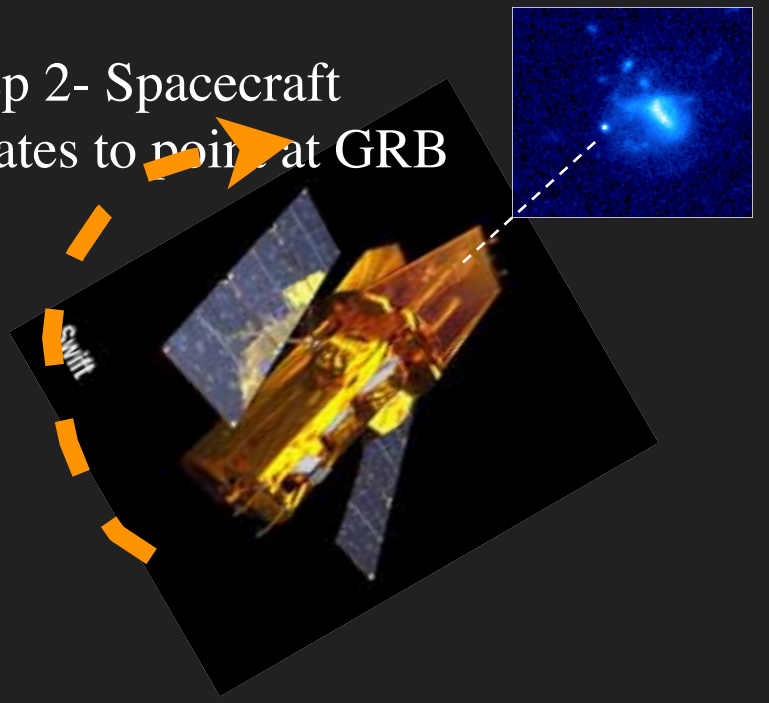

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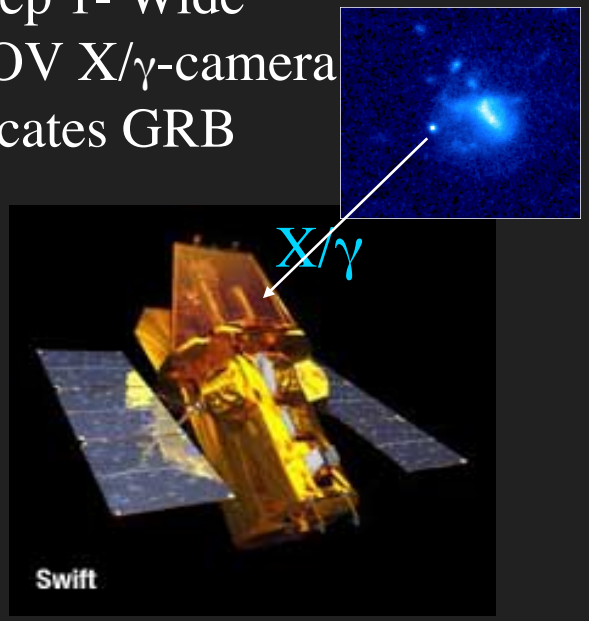

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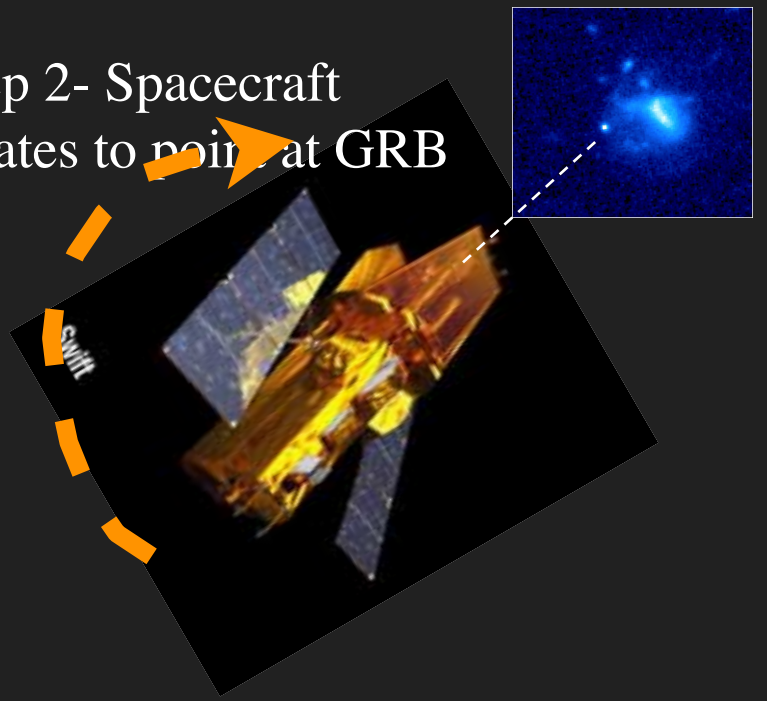
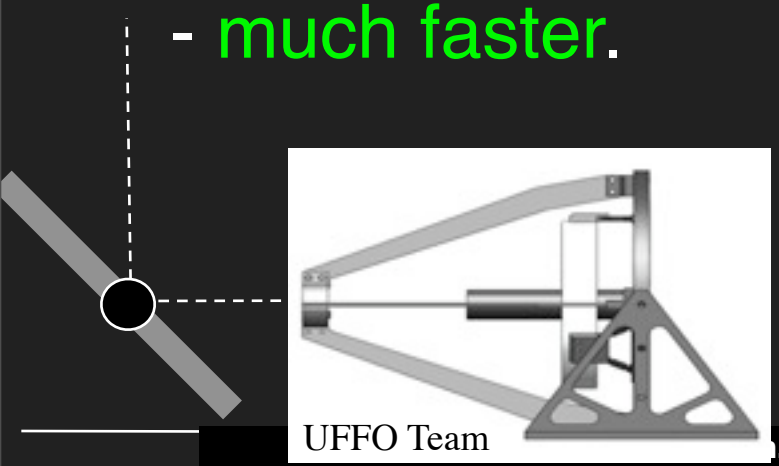
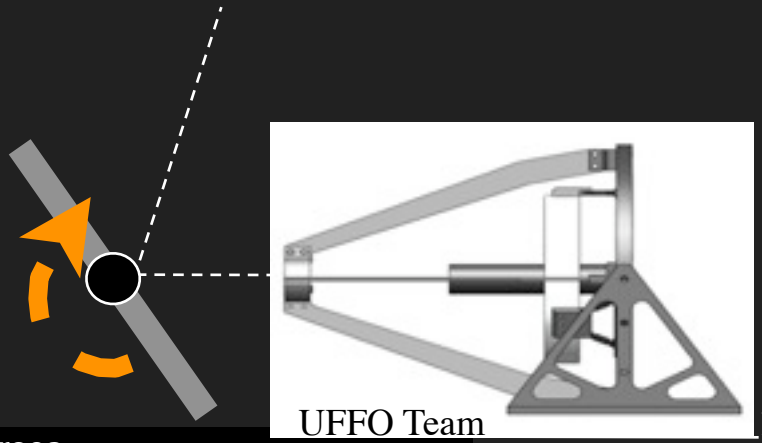
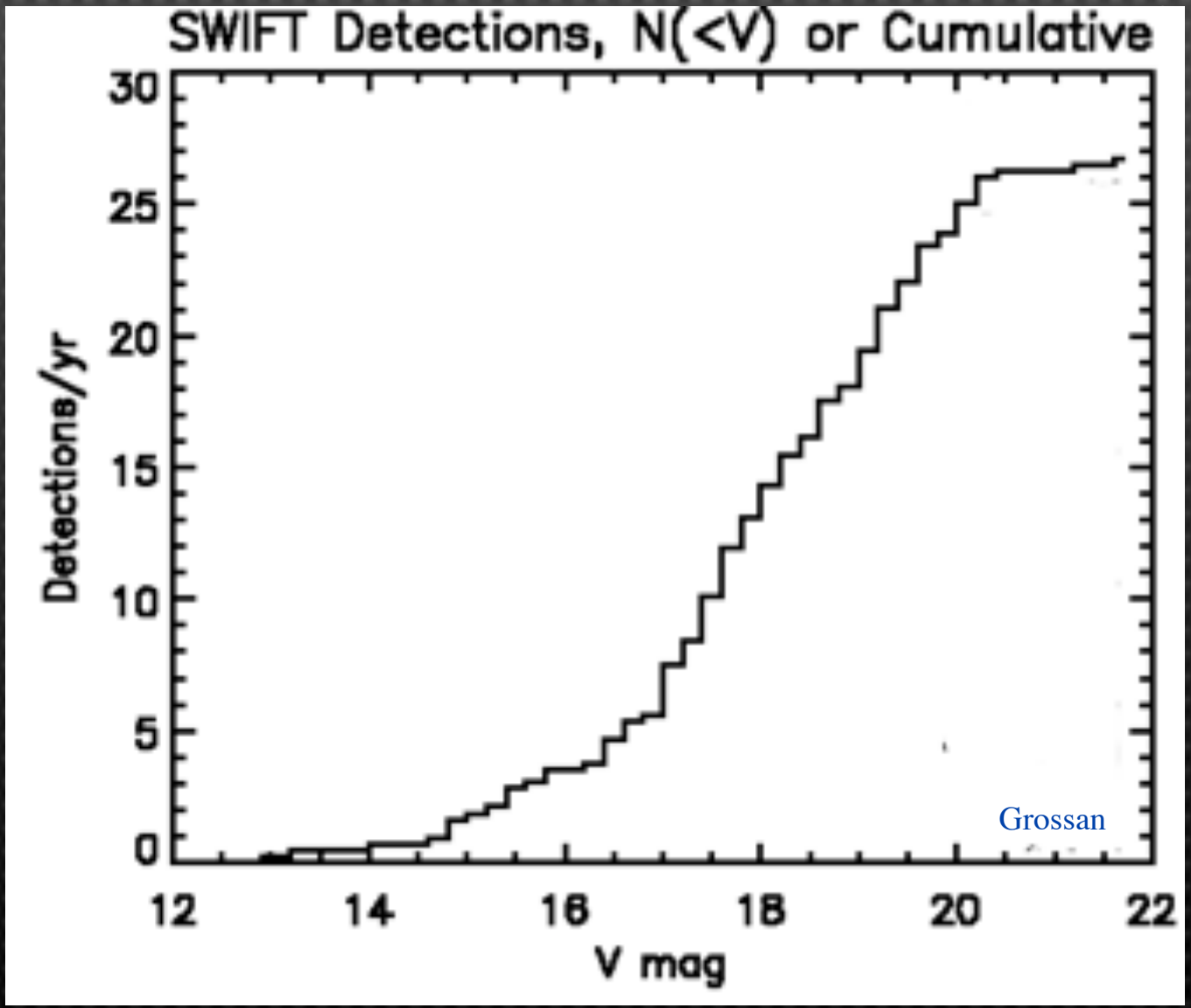


- We use mirrors to steer the *beam*, not the spacecraft - much faster.



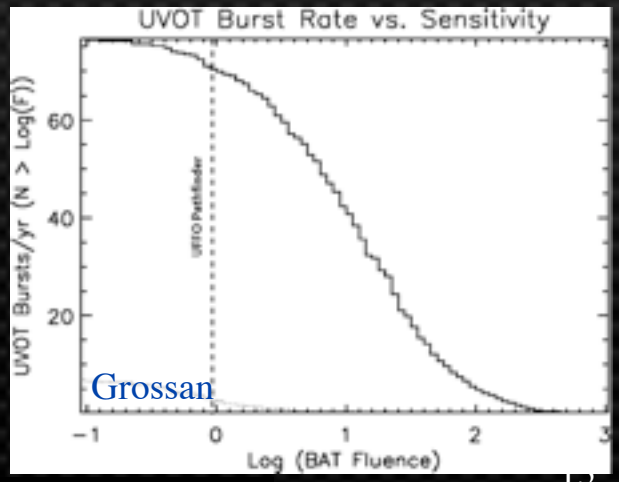


Optical Sensitivity Critical



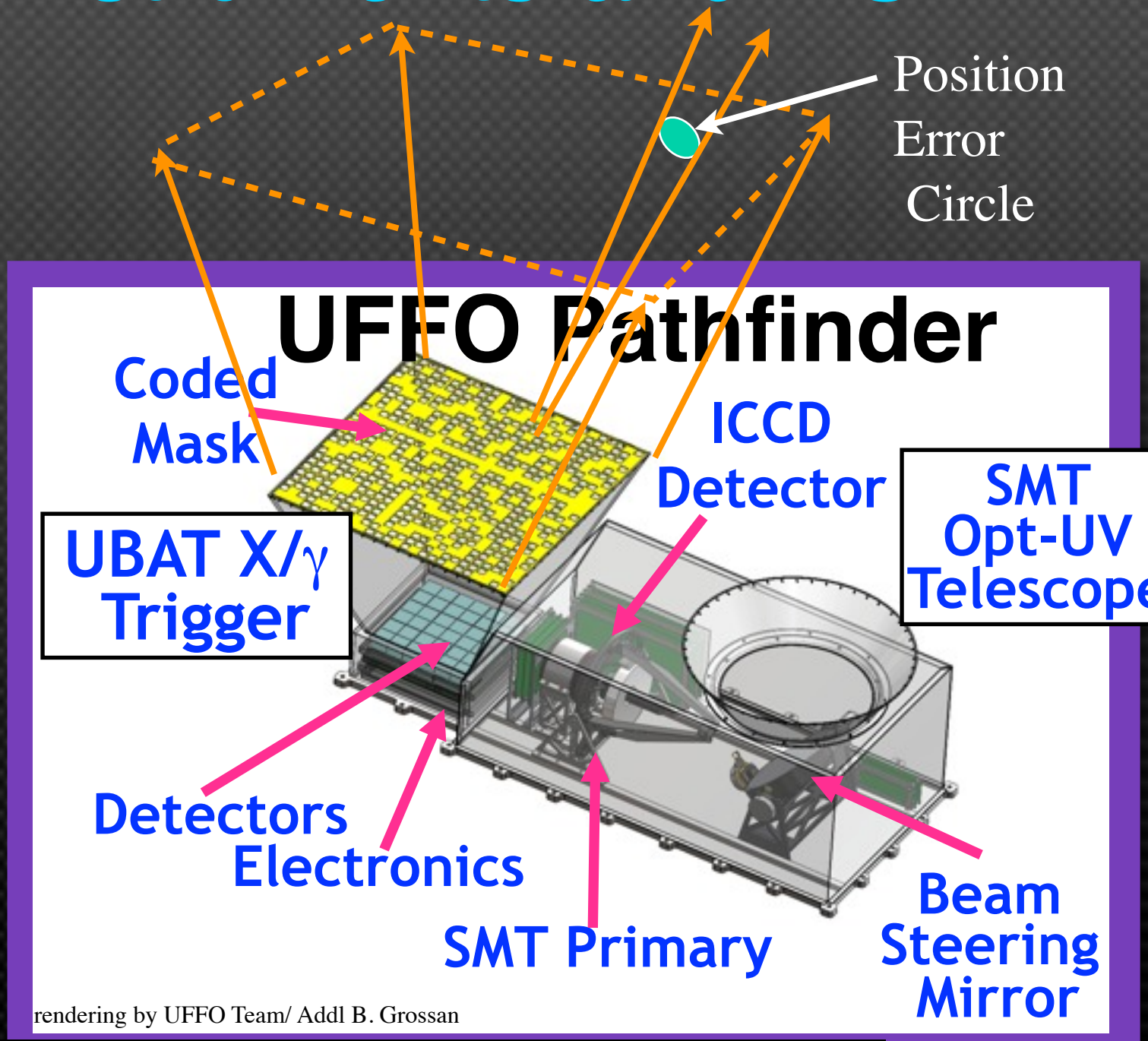
NOT Like the X-ray Fluence

- X: factor of 10 Smin, los of 5%
- Opt: Factor 10, loose about 1/2!!!!



UFFO Instruments and FOV

- UBAT has huge ~68 deg HCFOV
- Challenge for SMT to cover this!
- Position error typically ~ 8’ 90% at S/N=8
- => Big area to cover!



Some SMT Numbers

Title: SMT Characteristics
Instrument Type: RCT with Scanning Mirror
SMT Mass: 11.5 kg
SMT Power: 10 Watt
RCT Aperture: D=10 cm
RCT F-Number: 11.4
RCT FOV: 17 arcmin x 17 arcmin
Slewing Mirror Size: D=6"
Minimum Step Size: 4 arcsec (Mechanical)
Slewing Speed: 15 deg / sec (Mechanical)
ICCD Gain: 10^3-10^6
ICCD number of pixels: 256 x 256
ICCD Quantum Efficiency: 5~20% at 200-650 nm
CCD dynamic range: 62 dB (TBC)
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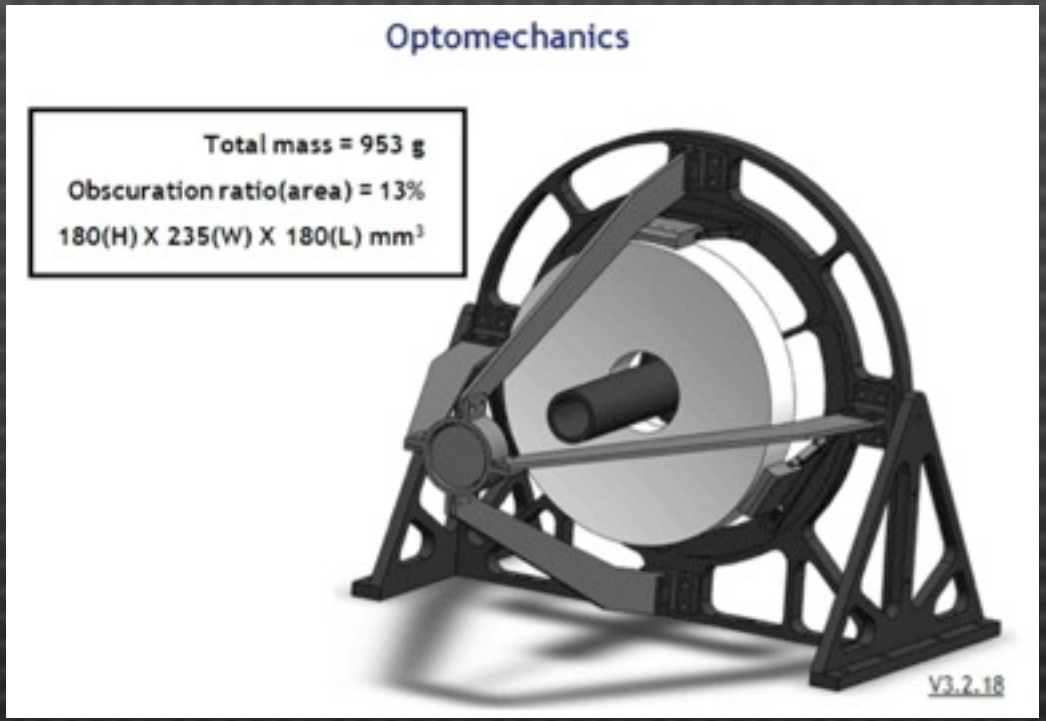
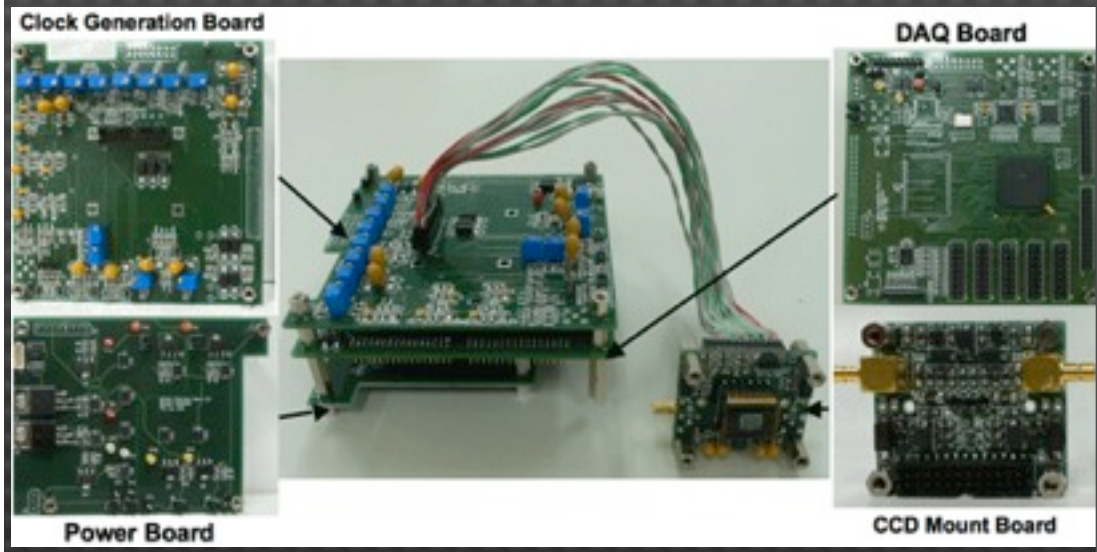
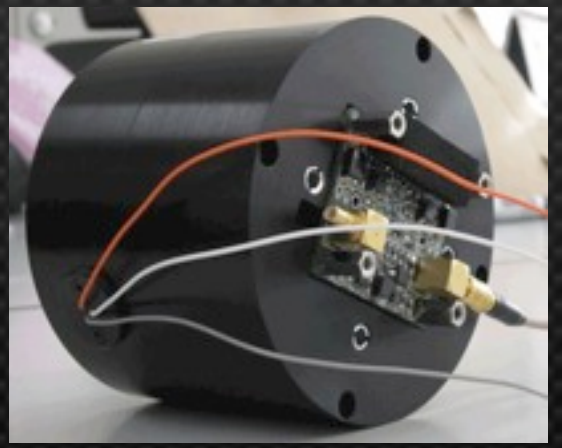
Random Pathfinder Components

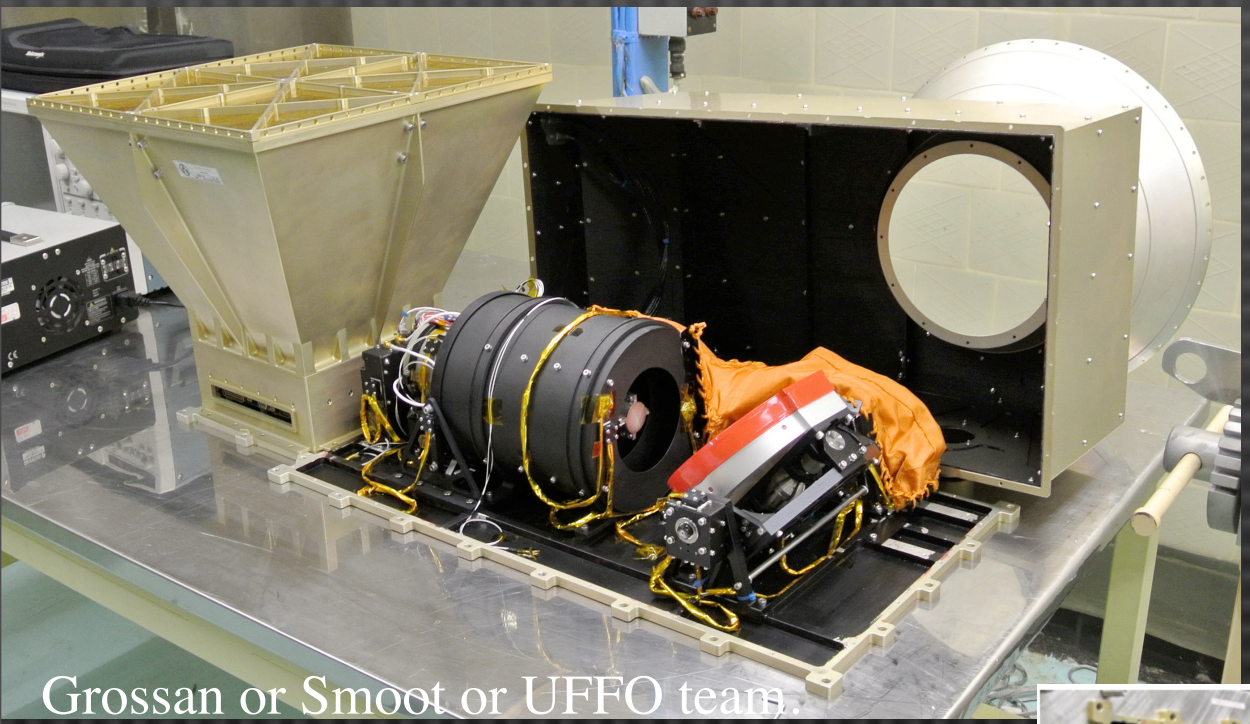






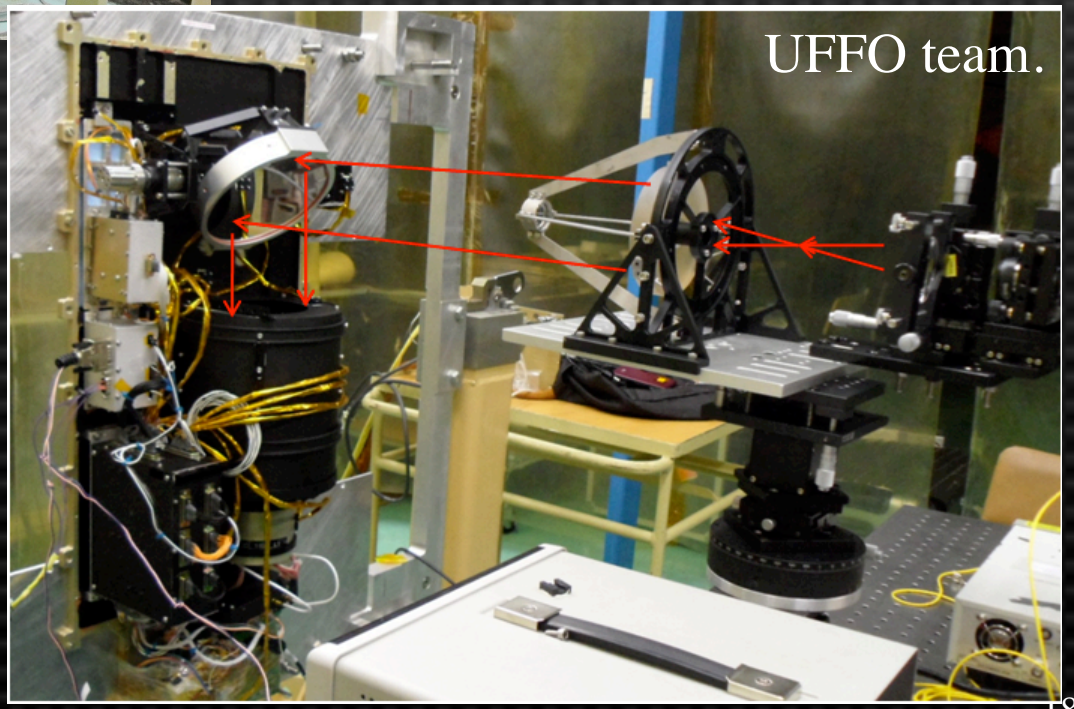
All images by UFFO team.

SMT Recent



Grossan or Smoot or UFFO team.

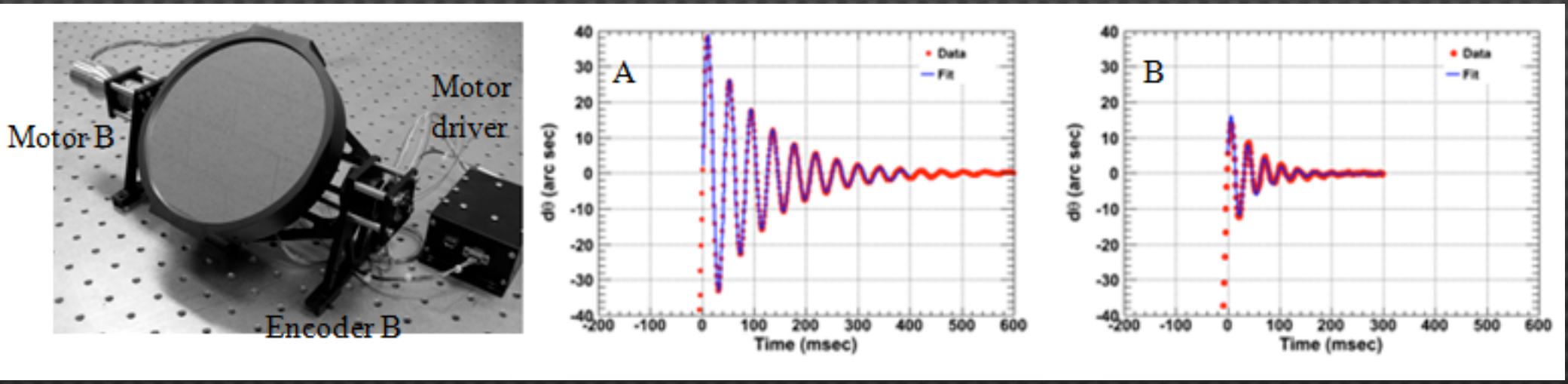
Flight model of Slewing Mirror Telescope (Flight model of UBAT is mounted together on the UFFO base-plate and final cross calibration has been done)



UFFO team.

System verification during the final integration in ISTRA, Russia (Flight model of SMT is mounted vertically and parallel beam was made from pre-flight Ritchey-Chrétien telescope)

UFFO-Pathfinder Mirror Technology



UFFO team.

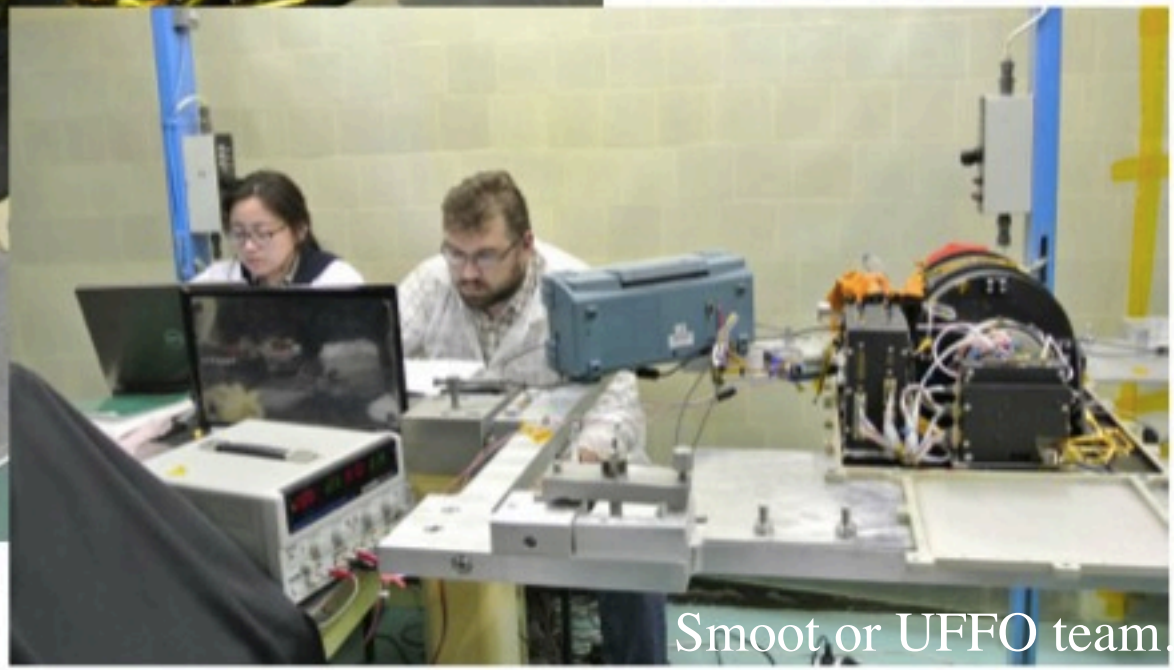
- Limiting Slew time - settle time - < 400 ms

UFFO Now In Testing @ Istra

Preparation for "Input control" of UFFO-P

SMT Now In Testing @ Istra

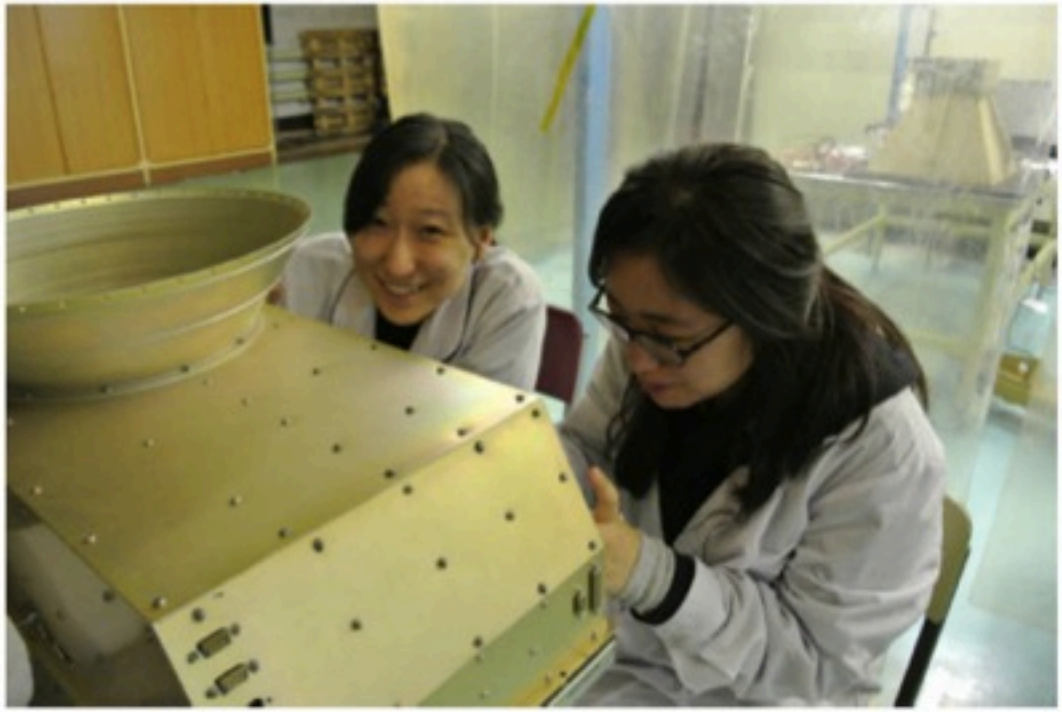
Smoot or UFFO team.

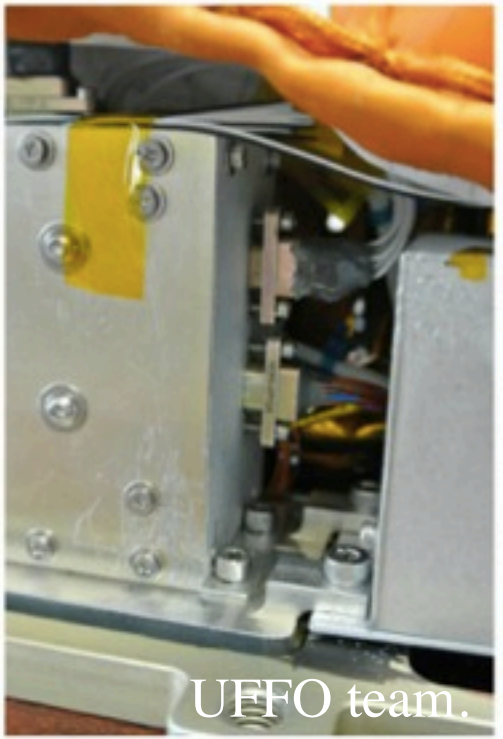


Smoot or UFFO team.

Spaceflight...

3. Epoxy was put on SMT case fasteners / ICCD structures / FM RC structures / SMT readout and UDAQ/ UFFO power electronics boxes (But if we need, it can be removed)

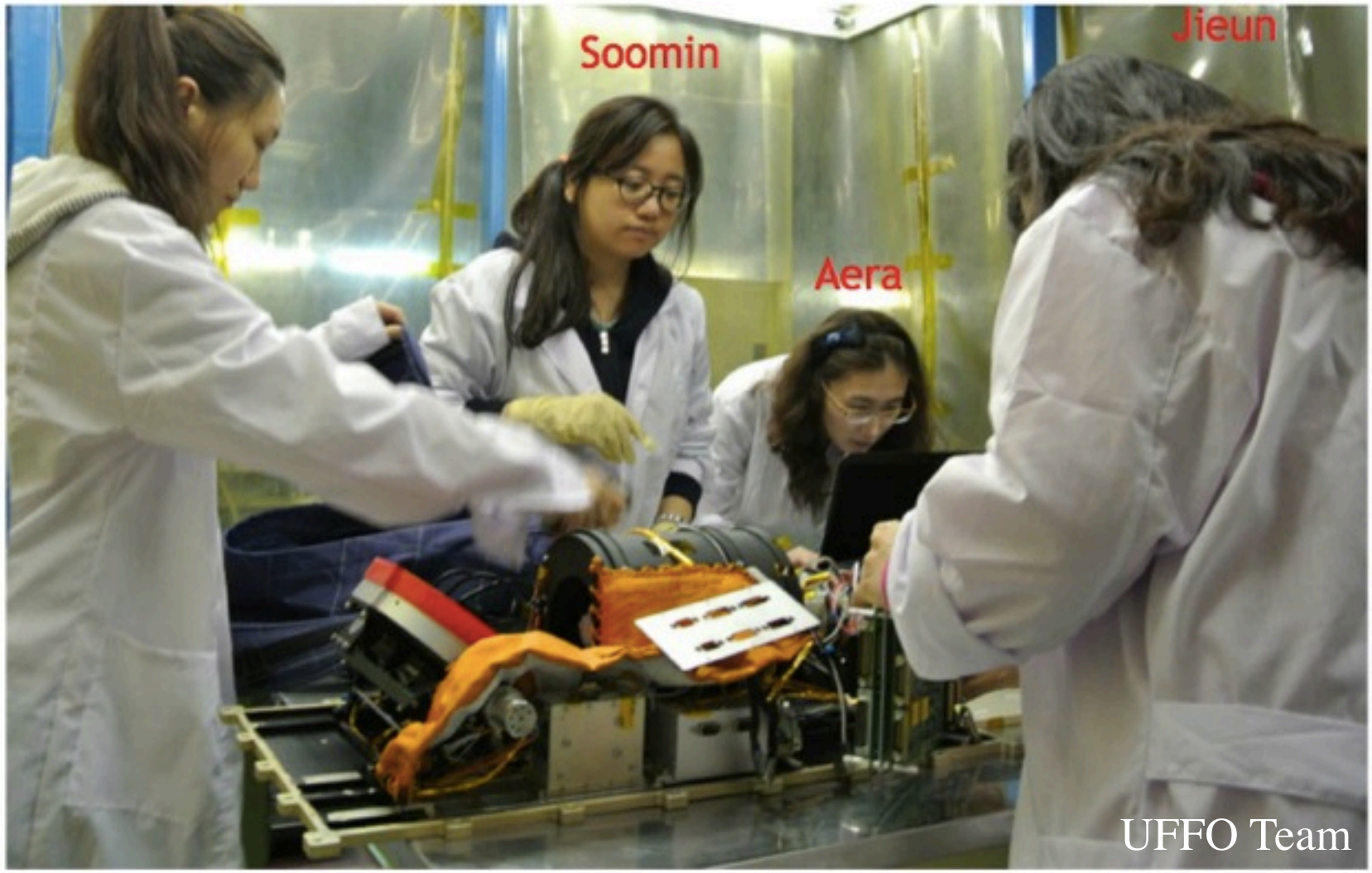




UFFO team.

Expert Team

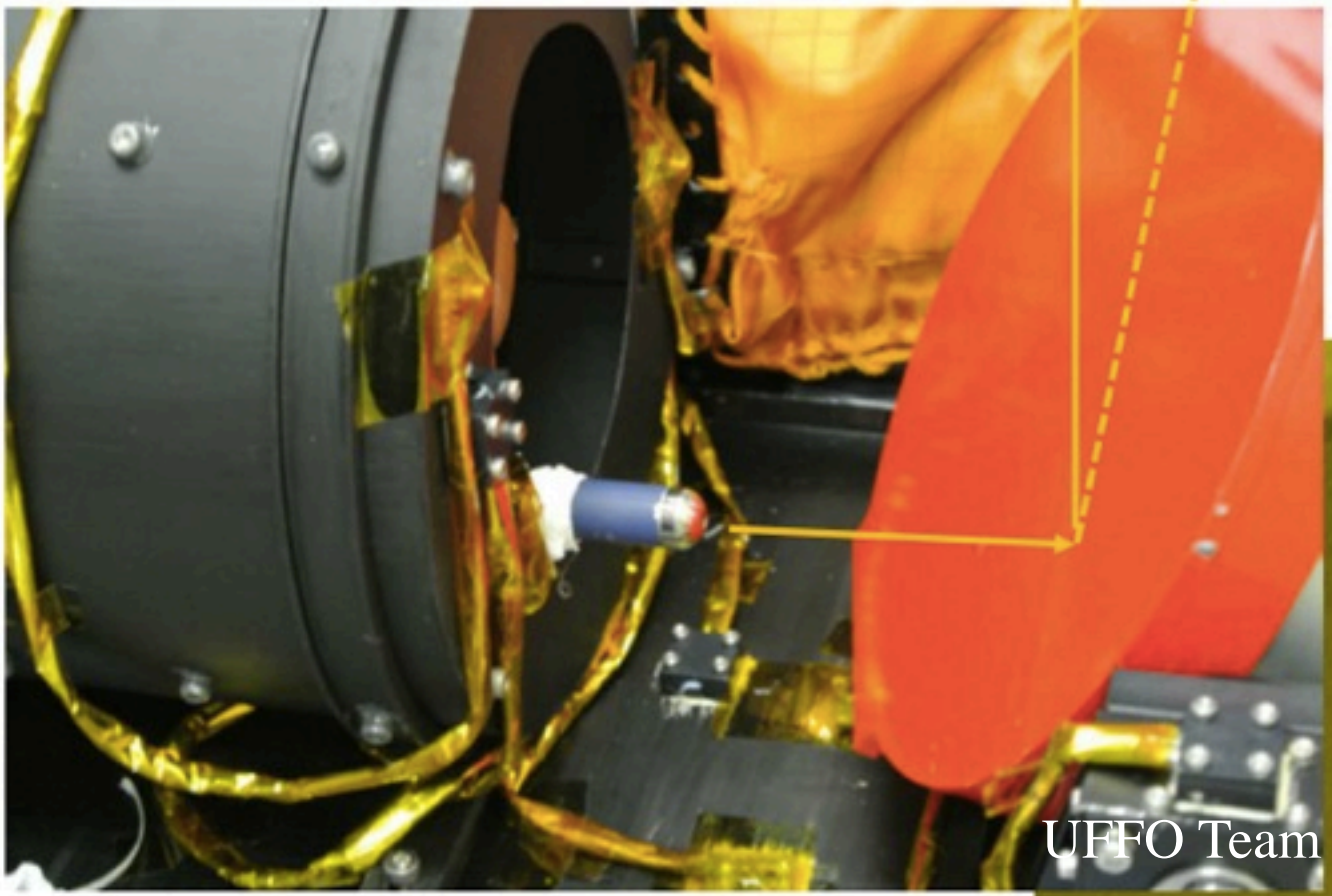
4. New UFFO-power board check with integration

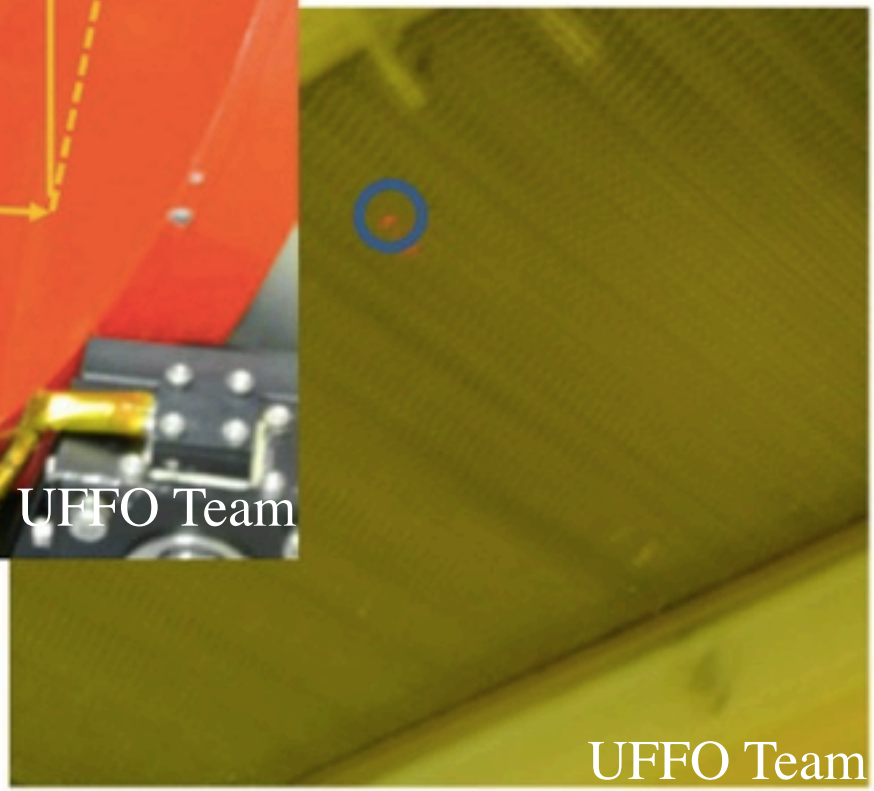


Mirror Control Testing

5. 2nd version SMT logic was updated

- By Tingyun ,Jiwoo and Jieun successfully integrated 2nd version SMT logic -> Confirmed in Taiwan and ISTRA

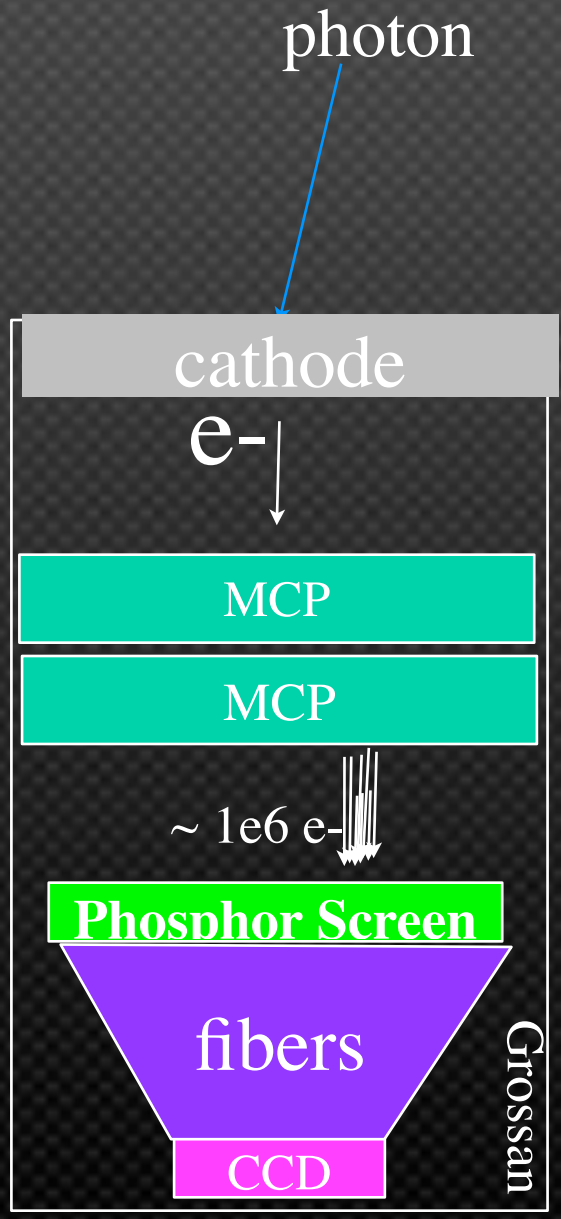




-As following the current test setup -> Repeatability and accuracy : less than ~10 arcmin

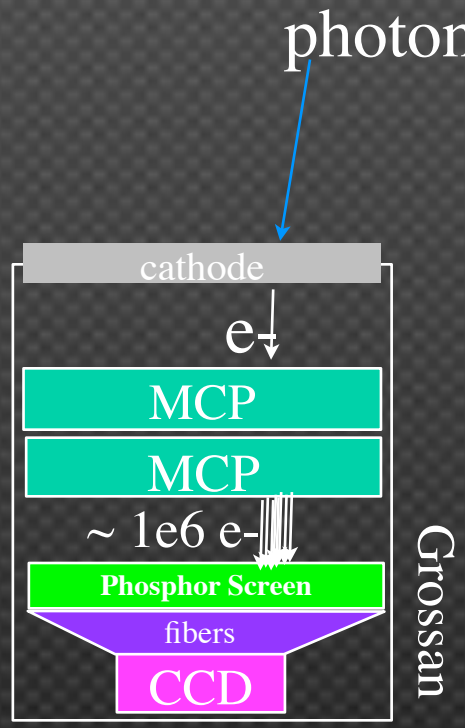
SMT ICCD

- Intensified CCD is a metal cathode detector first surface
  - coupled to charge amplifiers
  - converted to light via phosphorus,
  - coupled to fast-read CCD
  - CCD counts light proportional to original incoming photons
- Very fast, good for high time resolution
- Little Red Sensitivity
- bright light causes permanent damage
- Thermal electrons makes dark current

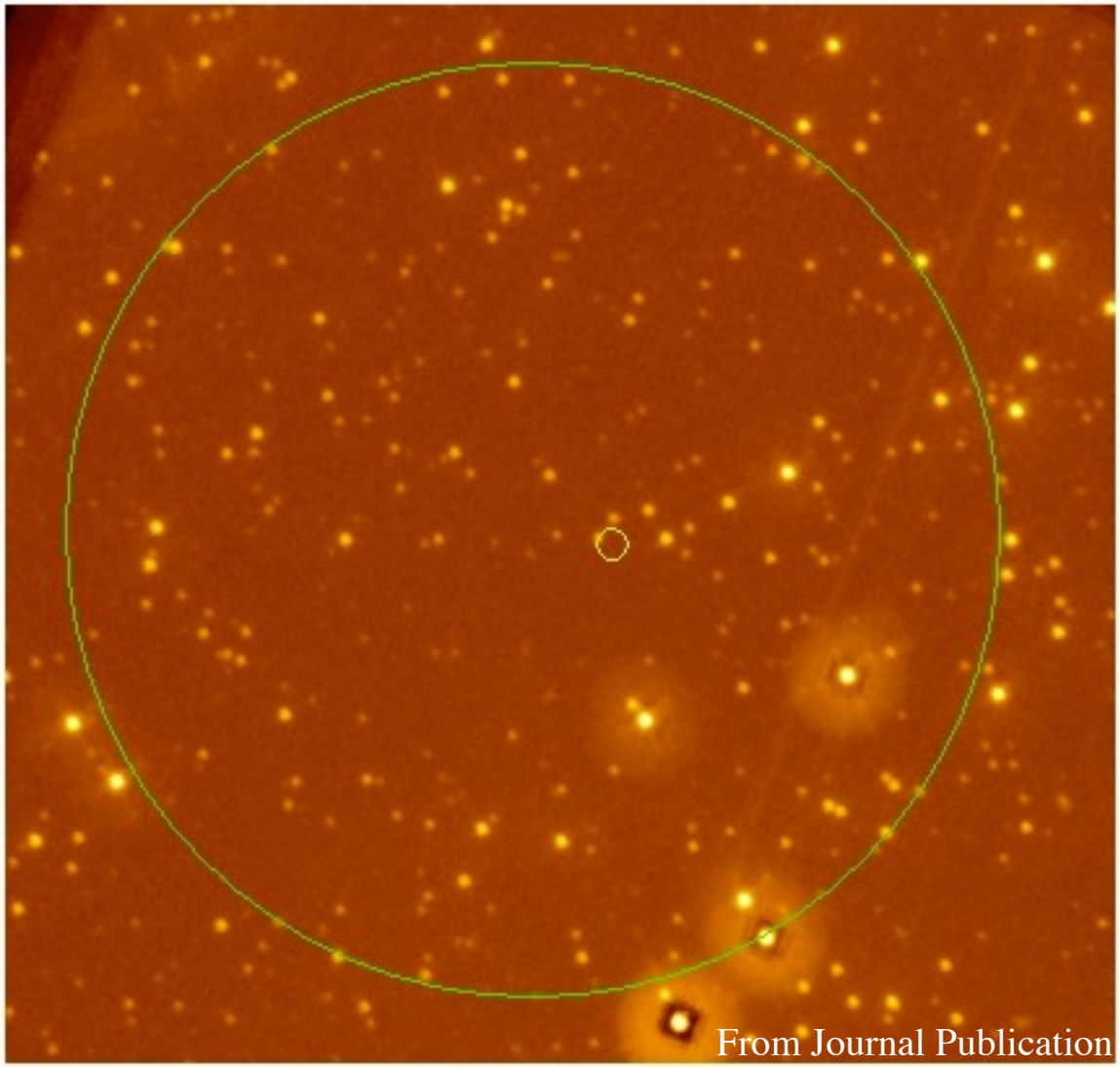


UVcam- ICCD

- Pretty Much Clone of SWIFT UVOT ICCD
  - ICCD = Microchannel Plate detector/intensifier with phosphorus screen+CCD - Off-The-Shelf (pretty much).
  - can nearly time-tag photons---> maximum data and flexibility for high time resolution
  - disadvantage: low efficiency compared to CCD
  - Cathodes have improved since SWIFT
- Bright Light Issue - emergency shutoff photodiode can react very quickly (large acceptance angle).

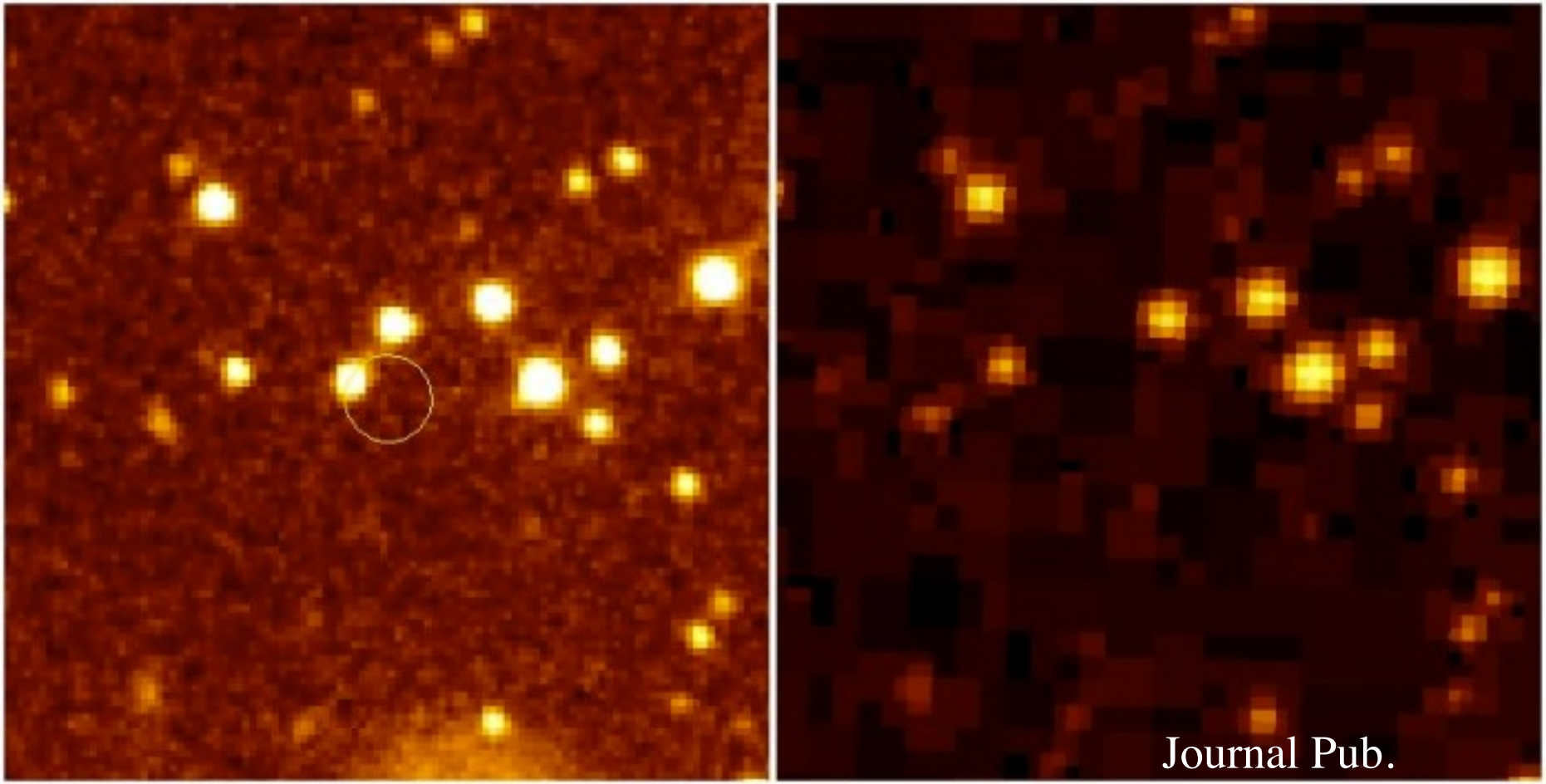


ICCD Data (Swift)



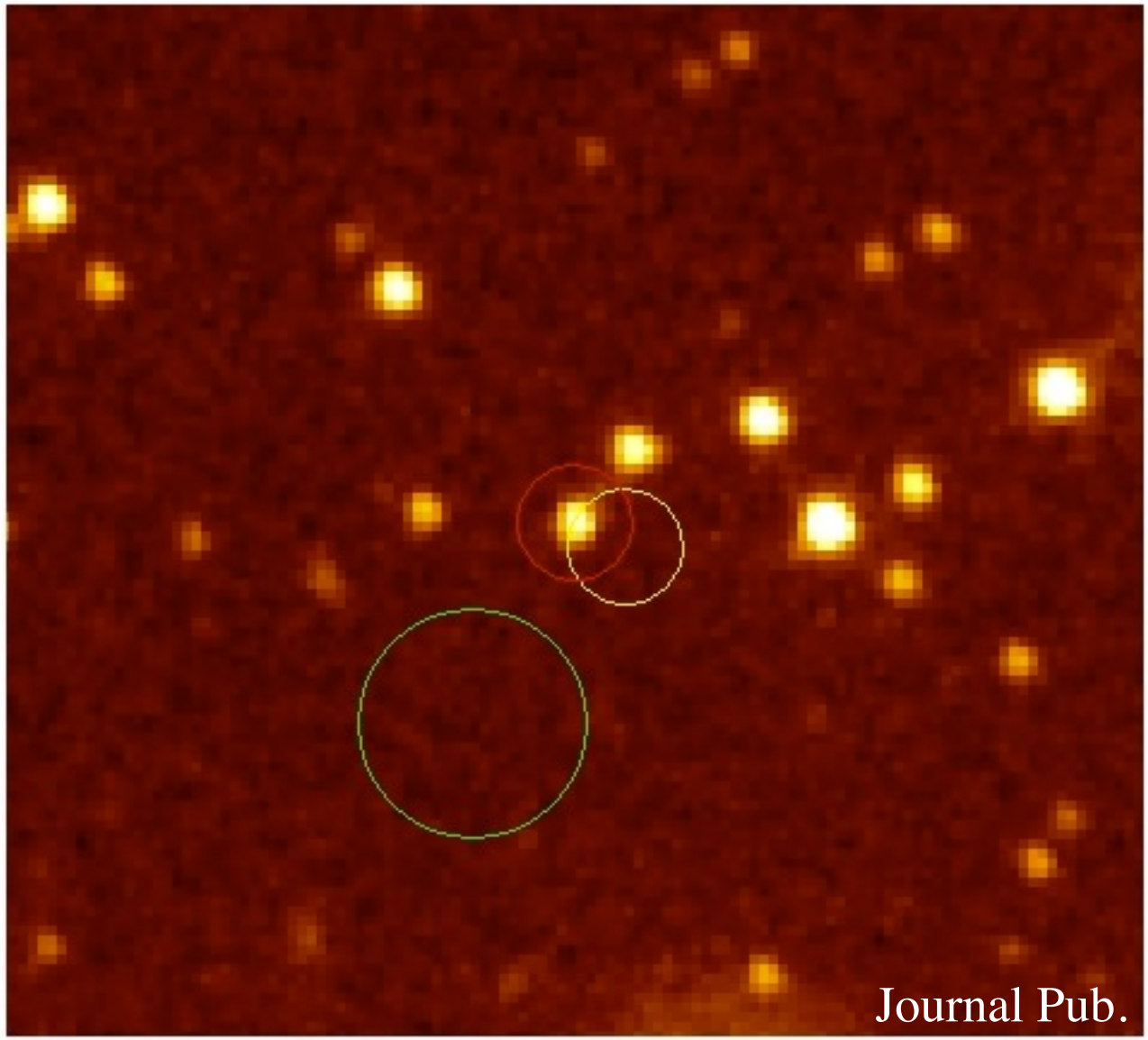
The green circle (with a radius of 3-arcmin) in the image above gives the BAT error position, the yellow circle (with radius 6-arcsec) gives the XRT error position for GRB 050525A.

New Sources



Click on "Frame", "Blink Frames" to search for an apparent new source in the UVOT *V*-band image within the error positions. In our example you can see a point-like optical/UV source in each of the filters at the eastern edge of the XRT source position. This source is not visible in the (pre-burst) DSS image.

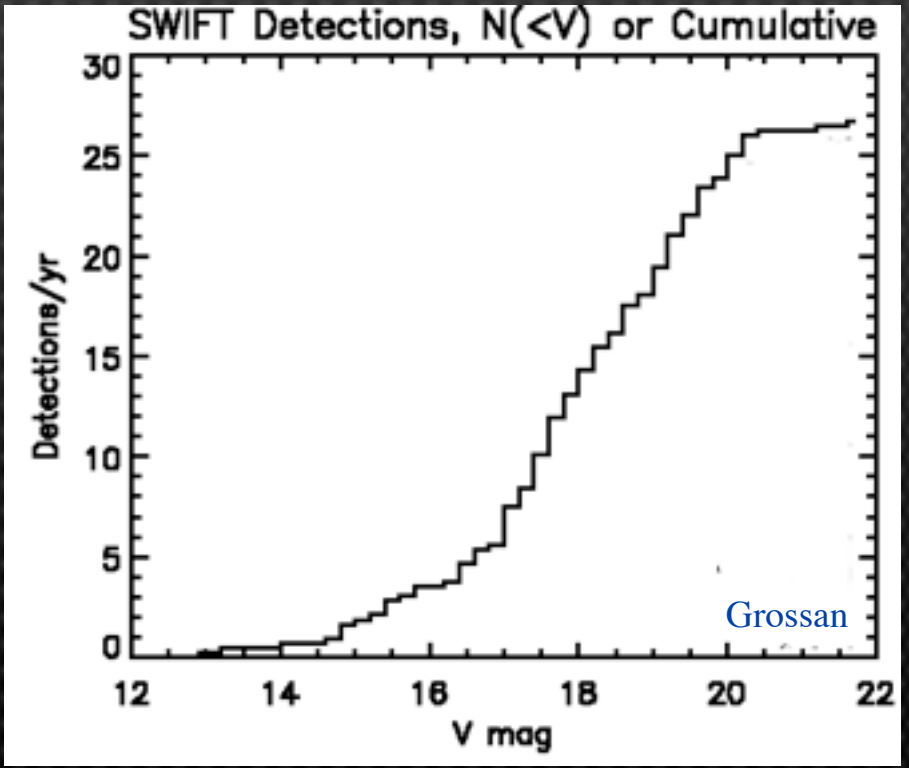
Note Background Calculation



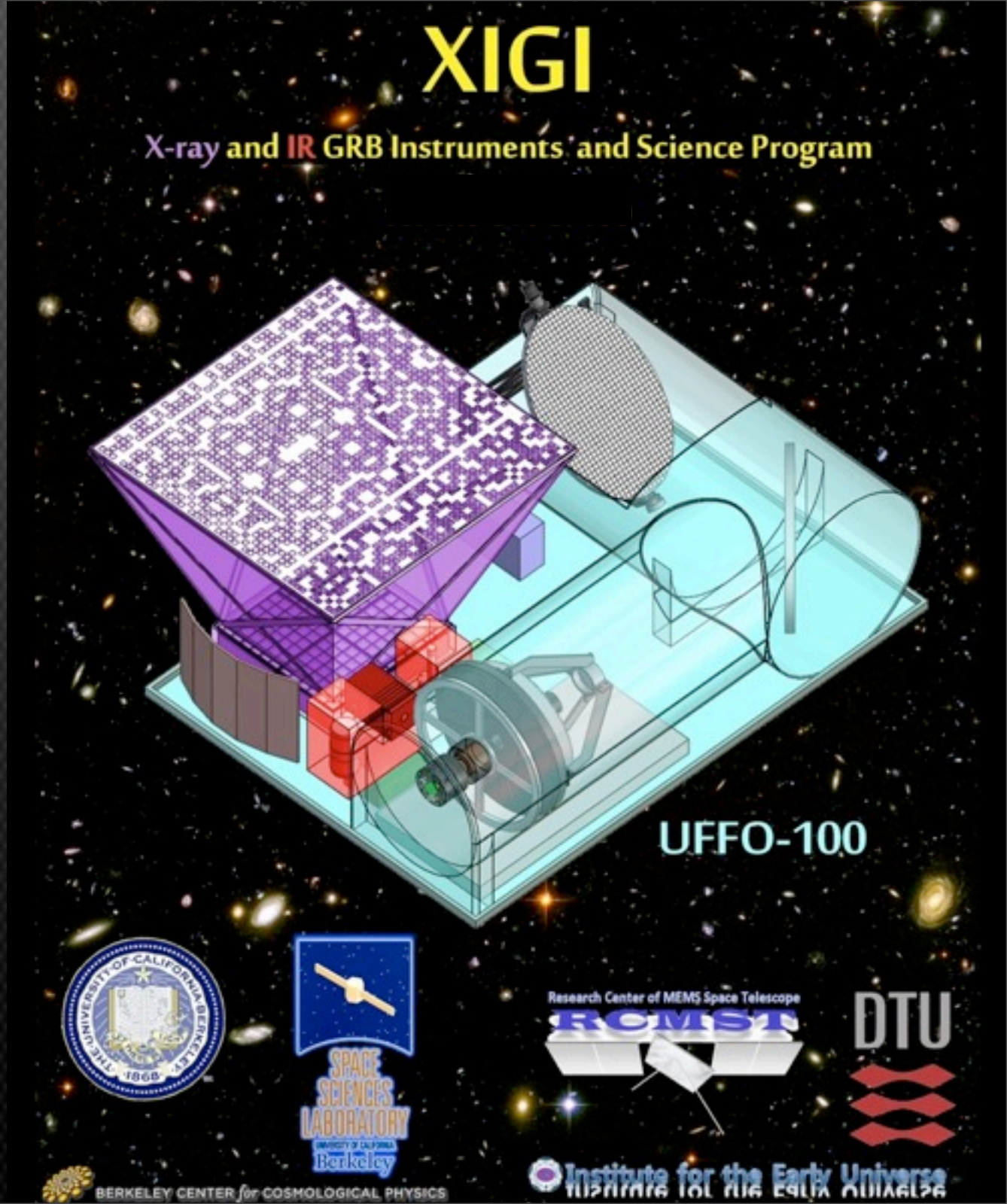
The above summed UVOT V-band image gives the XRT error position (yellow), the source counts extraction region (red), as well as th region used to extract the background level (green) for GRB 050525A.

What is our Rate?

- Swift Sensitivity: V=19.94 mag 5 sigma / 100s
- Scale by diameter:
  - **What do you have to assume?**
- Scale by time:
  - 10 s SMT sensitivity = ...?
- N detect=....?
-

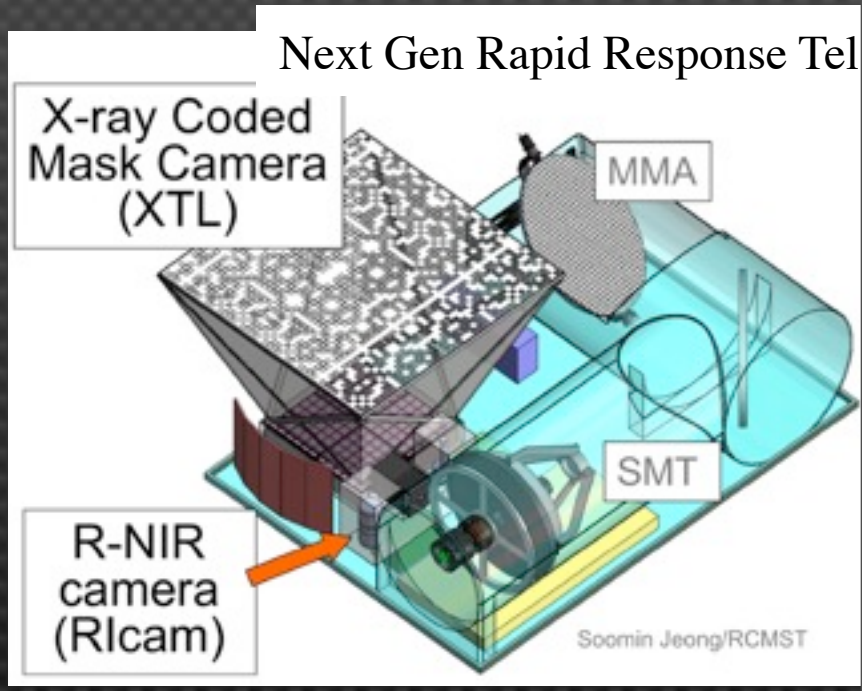


NASA "Partner Mission of Opportunity" Proposal



Next Generation
30 cm Slewing Mirror Telescope (SMT)

- 120 kg, ~ 1 m^3
- 30 cm aperture R-C telecsope
- Smaller, less massive, faster than SWIFT
  - smaller X-ray detector, 1024 cm^2 CZT
  - Design taken from ASIM MXGS instrument, thanks to collaborators
  - Faster because beam-steered, not spacecraft steered.

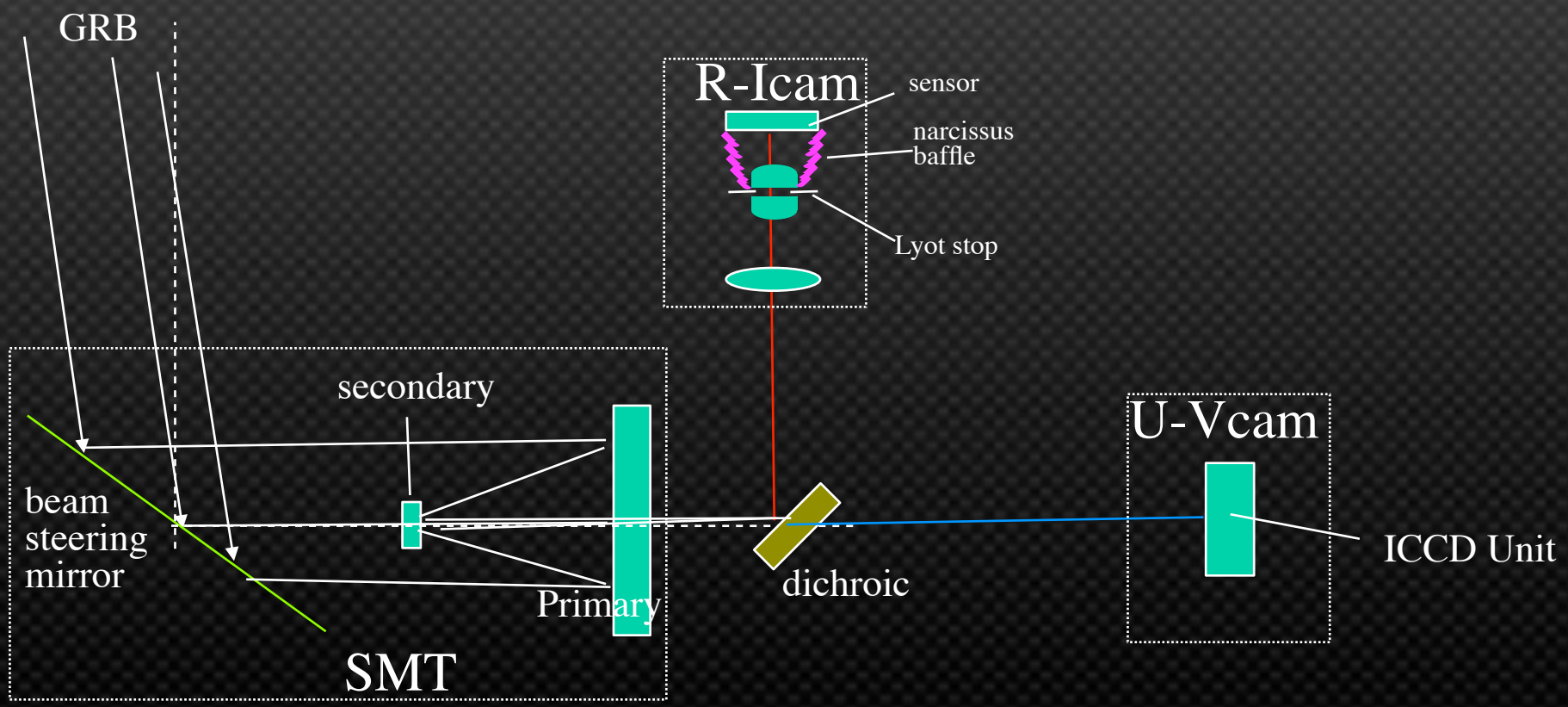


Preliminary artist rendering of one concept (compact package) only.

Lots of work on this by RCMST, MSU, U Valencia, Berkeley SSL

Separate UV, IR cameras for telescope

- Dichroic splits beam to...
- U-Vcam - just like ICCD in UFFO-Pathfinder 0.2-0.57 μm
- R-Icam - HgCdTe array 0.57-1.7 μm <- SSL/Berkeley



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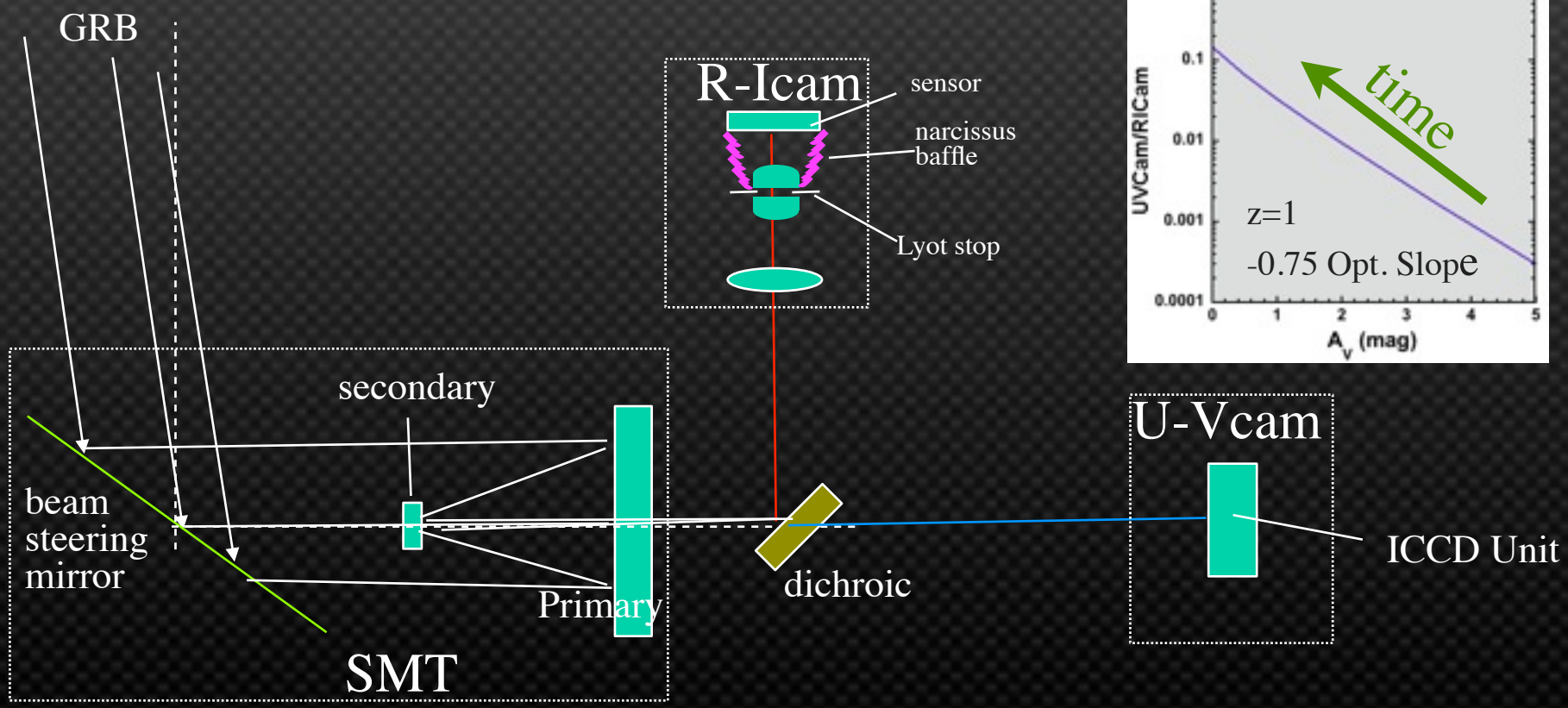
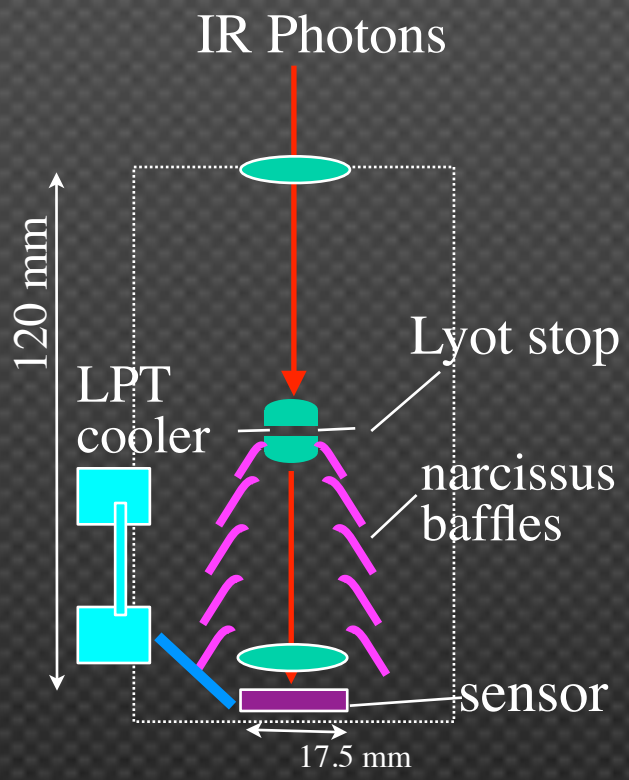


R-Icam Design

- HgCdTe Sensor H2RG 1.7 μm cutoff
  - short cutoff -> little thermal background
- Optics Design
  - Lyot stop, narcissus baffles reduce thermal background
    - by Brian Sutin
- Big, Wide Band 0.6 -1.7 μm
  - get more photons in NIR

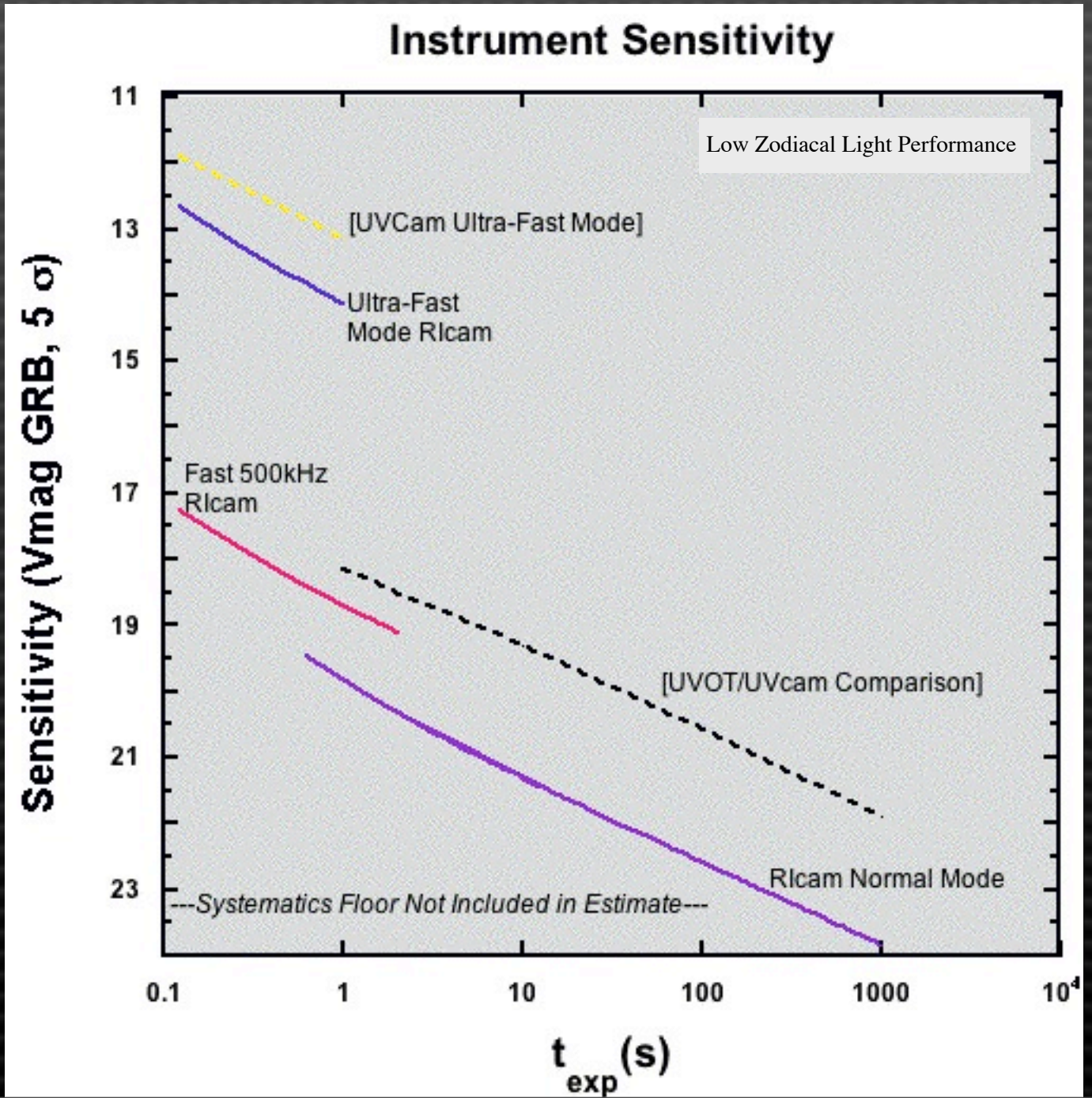


Wide Band • Low Space Background • Steep Object in IR

This is a winning combination!

RIcam Sensitivity

- **Equivalent V-mag shown**
  - GRB opt slope= -0.75 assumed (compare to UVOT)
  - Optimistic Zodi,etc.
  - About two mag more sensitive than SWIFT UVOT
  - Good because: (1)wide band, (2) low-bgnd, (3)steep spec. target



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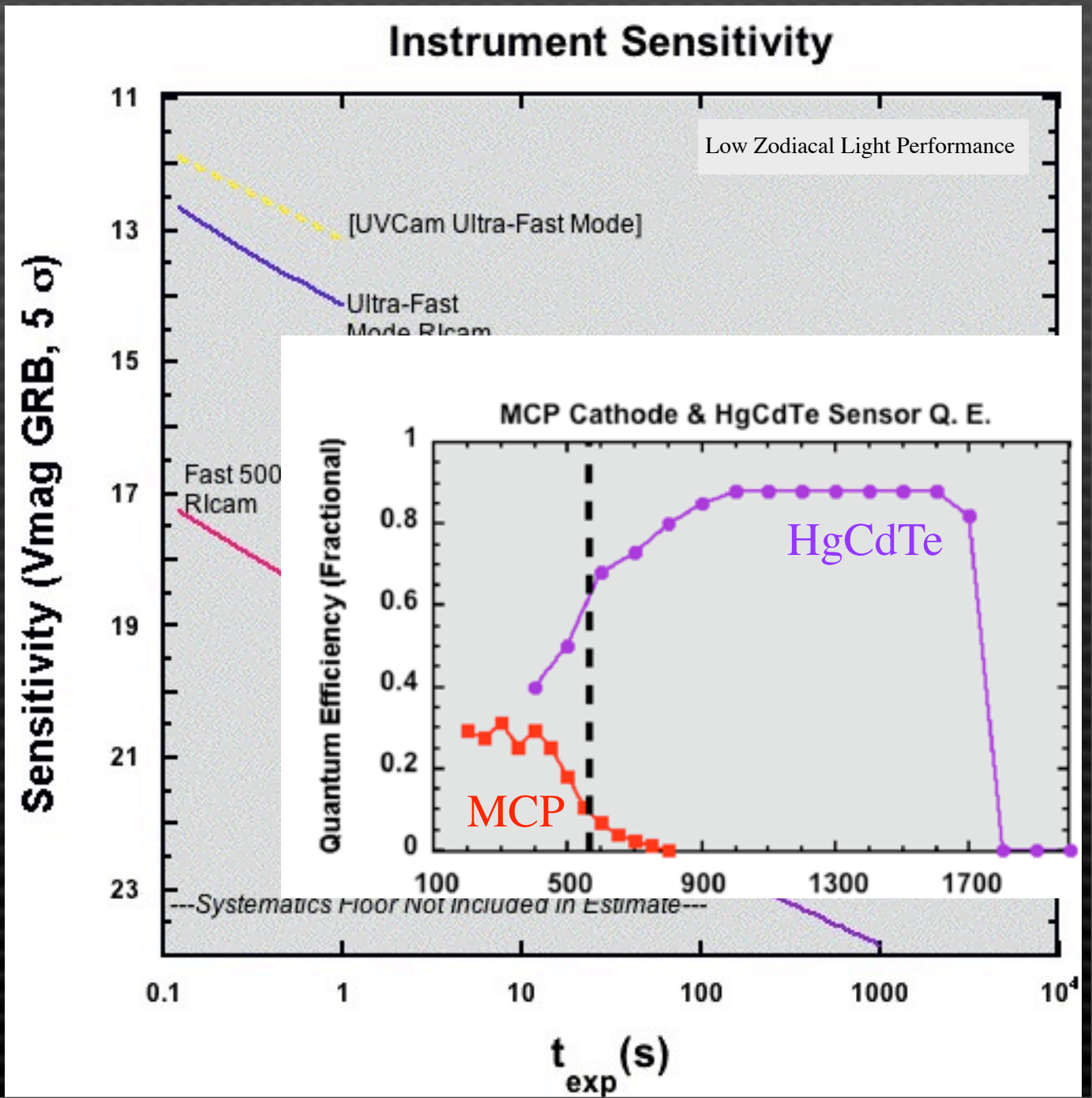


Followup

- Will broadcast on GCN via Globalstar SMS
- BOOTES[1] + ...? Ground-based follow-up
- GCN broadcast enables more sensitive X-follow-up
  - Fermi - lots of sky coverage for additional "prompt" coverage to higher-E
  - pointed X-ray observations by other operational narrow-field instruments
    - SWIFT & Suzaku, for now, hopefully they will "sign up"
- YOUR FOLLOW-UP INSTRUMENT HERE
  - Spectroscopy especially welcome.

(1) Thanks to Collborator - Alberto Castro-Tirado

UFFO-100 Estimates

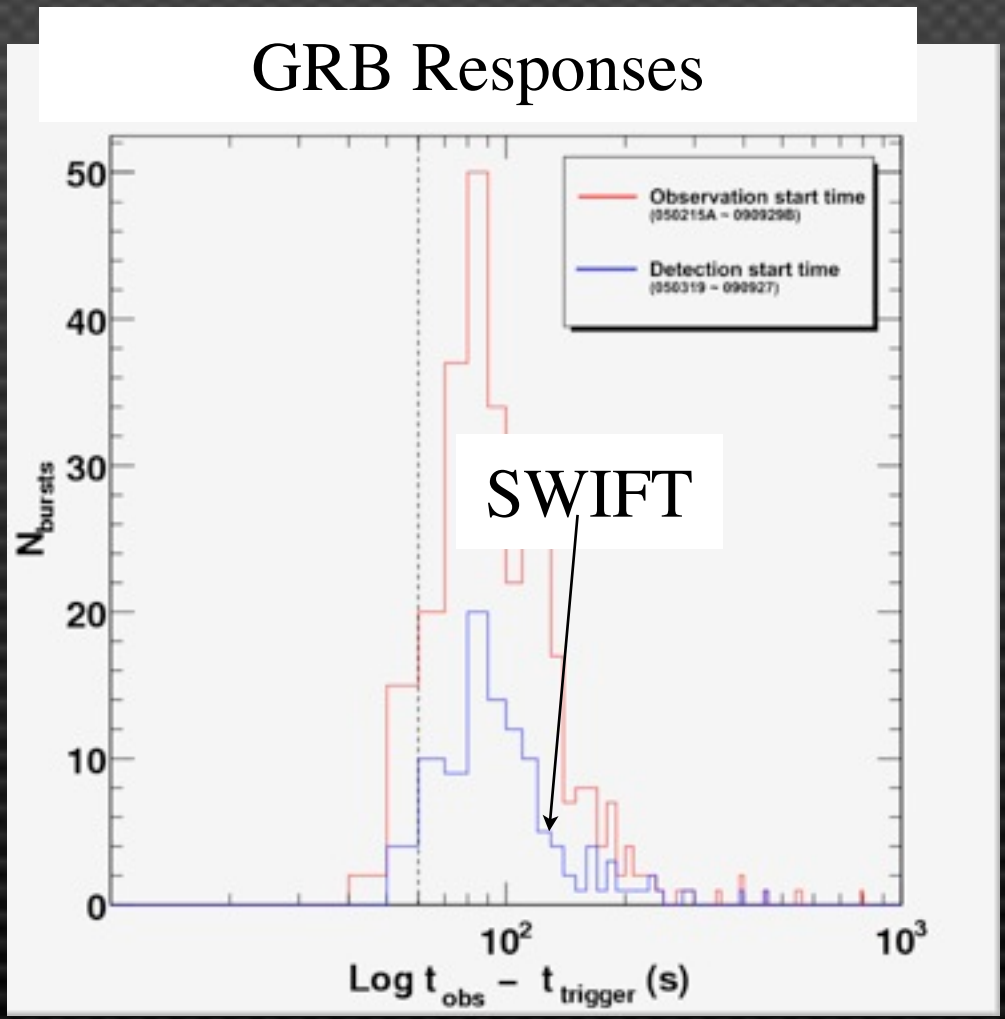
	SWIFT BAT	UFFO XTL
Area (cm^2)	5200	1024
Triggers/yr	77	64
SHGRB/yr	6.9	~ 5 (uncertain)

- Approximate: Scales SWIFT, Uses fluence histo, assumes duty cycle

	UVOT[1]	**UVcam**	**RIcam[1]**
sensitvity (Vmag,5σ) 1/10/100 s	18.1/19.3/20.5	<--- ~ same	14.3 ultra/ 19.3 fast t=1s Normal:.../ 21.9/ 23.2
N_{detect} / yr	27	> 15 10s (> for early peaks, because we are faster!)	≥ 29 (including extinguished) more via sensitivity? Most SHGRB?

- Approximate: assume fixed fraction detectable, 1.3X for RIcam due to extinguished bursts
- (1)UVOT Sens. from GCNs; RICam & UVOT both at low zodiacal light

Wouldn't you like to see this?*



- Response time function of mode/sensitivity + true t_{peak}

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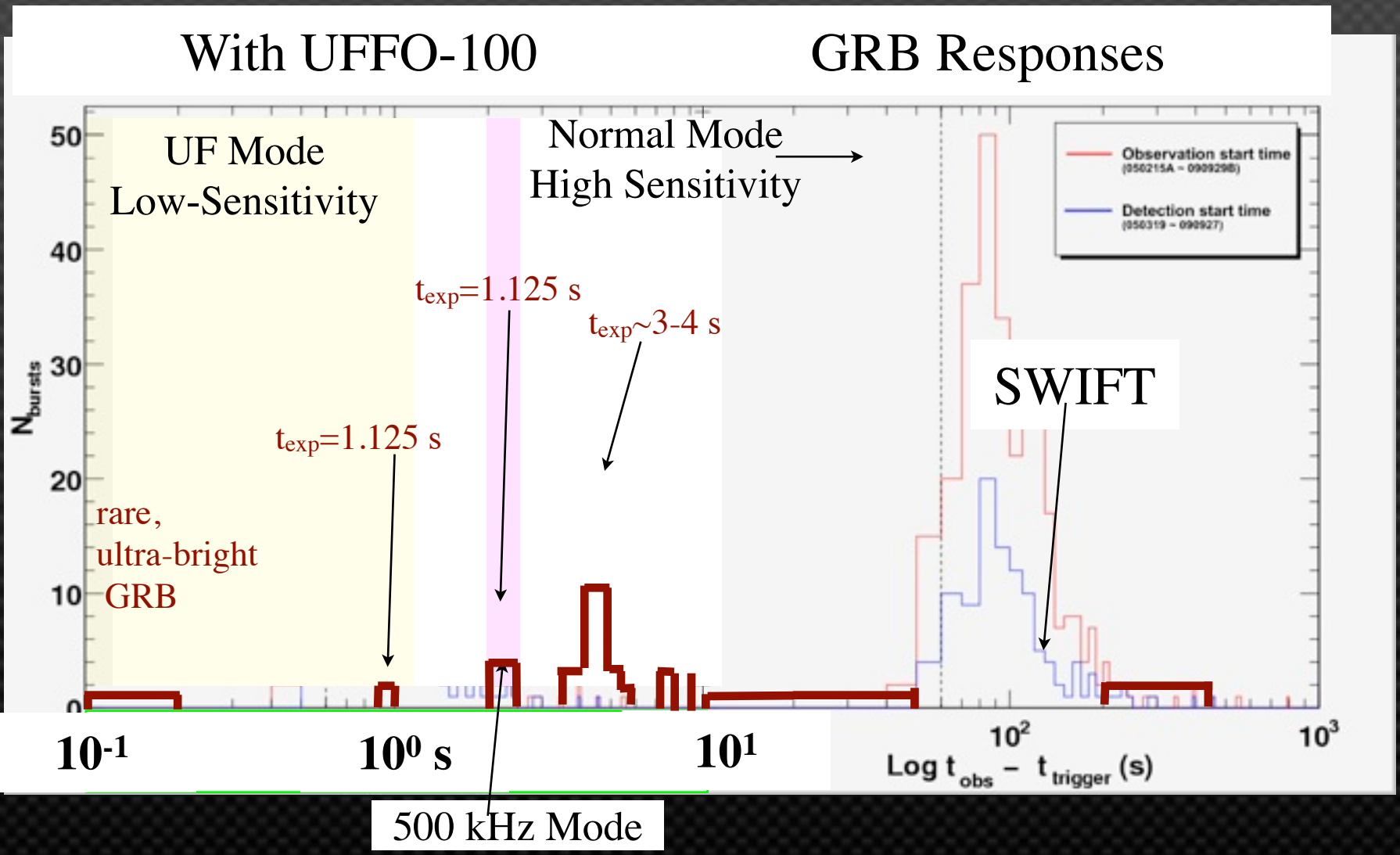


(* Please note this plot is grossly unprofessional conjecture.)

- Response time function of mode/sensitivity + true t_{peak}

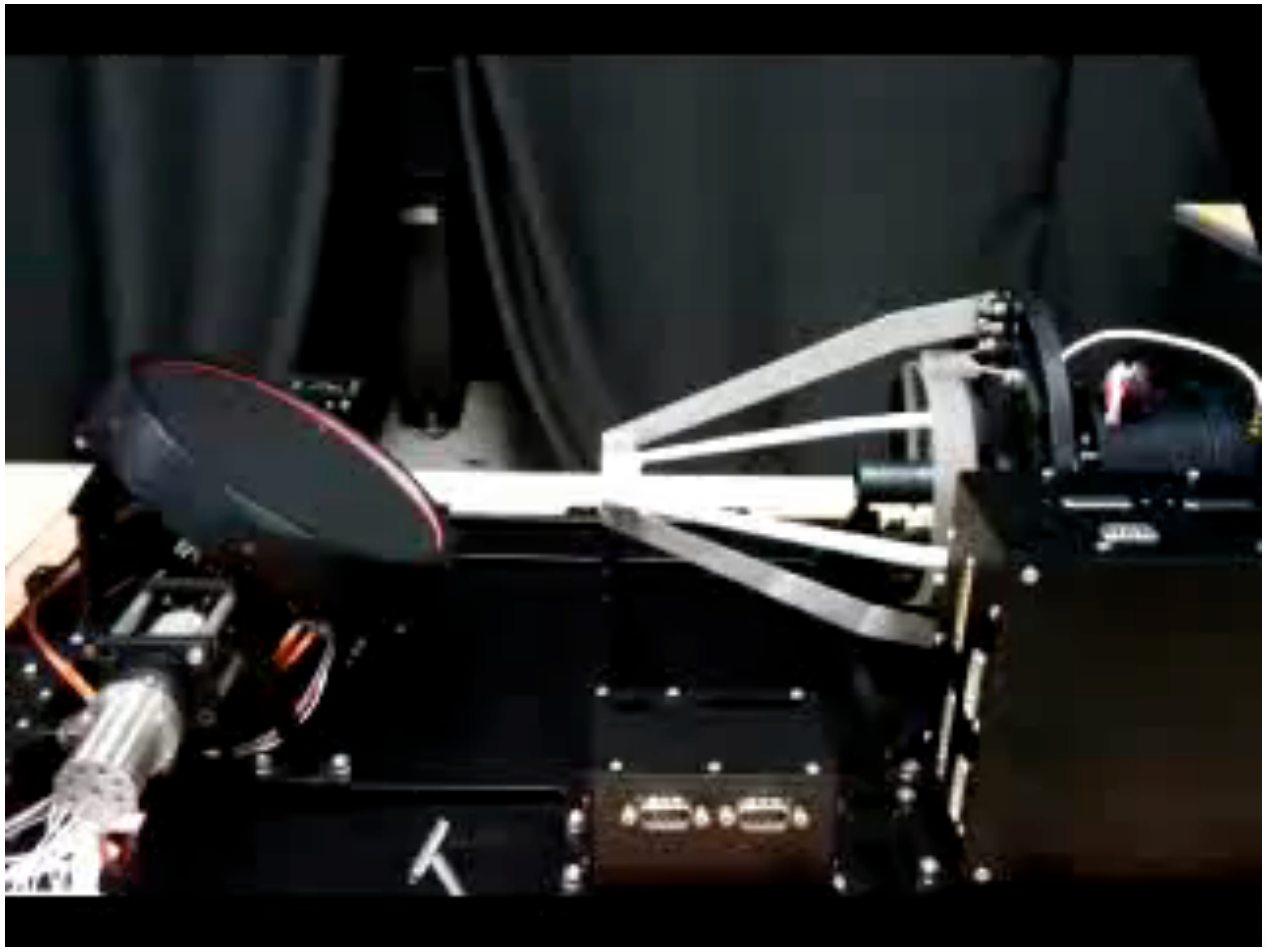
Summary

- Project Objectives:
  - Significant sample of GRB rise phase light curves
  - some 0.1-1 s measurements
  - Bulk Lorentz factors, rise times, X-opt correlations, possible multi-messenger measurements
- UFFO-Pathfinder D=10 cm Nov. 2011 on Lomonosov
- Next Generation D=30 cm proposed
- All projects open to follow-up & other contributions

Collaborators (Thanks!)

- RCMST Seoul: Il Park, Jiwoo Nam, Heuijin Lim, Soomin Jeong ... and Many others
- M. Panasyuk, A. Iyudin, S. Svertilov, etc. etc. MSU/ SINP/EUL
- Kevin Hurley, Henry Heetderks, (SSL)
- Søren Brandt, Carl Budtz-Jorgens (DTU)
- Alberto Castro-Tirado, Chris Eyles, Paul Connell (IAA)
- Nikolai Østgaard, Kjetl Ullulland (UBergen)
- Enrico Ruiz-Ramirez, UCSC
- George Smoot, IEU, UCB, PCCP, EUL...+many more

GCN hopefully next year! -Thank You-



UFFOConsortium

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Moscow State University: SINP & Extreme Universe Laboratory - N. Vedenkin, S. Svertilov, M. Panasyuk, I. Yashin

University of Valencia- P. Connell, C. Eyles, V. Reglero,

Inst. Astrofisica de Andalucia- A. J. Castro-Tirado

LaCOSPA (NTU)- , J. W. Nam, Alfred Ming-huey, T. Liu, P. Chen

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Université de Paris-Sud 11, s. Dagoret-Campagne, C. De La Taille

... and many more

http://uffo.ewha.ac.kr/

RCMST

Skobeltsyn Institute of Nuclear Physics

EUL/Skobeltsyn Institute MSU

Thank You