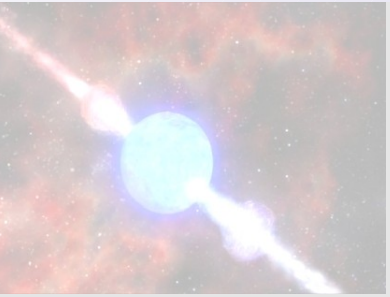
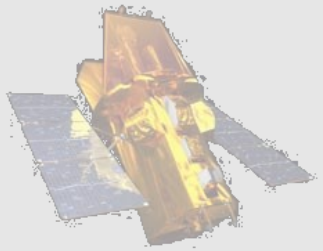




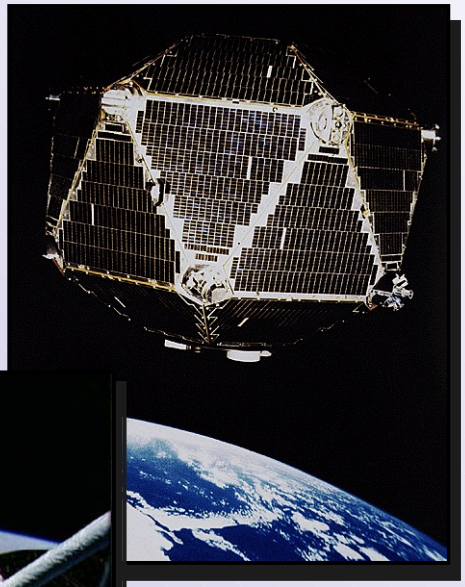
Gamma-Ray Burst Follow-Up: Lessons & Prospects

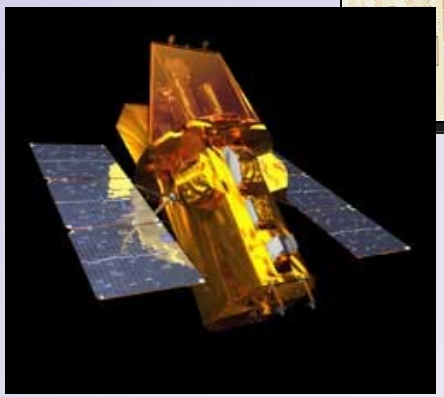
Derek B. Fox
Penn State University

GWHEN – APC – Paris
19 May 2009

GRB Follow-Up

- 40 years of GRB studies
- *May* be GWHEN sources
- Even if not…
  - Unpredictable
  - Hard to localize
  - Faint, transient counterparts
  - Cosmological distance
- Seems likely that…
  - Photonic observers can contribute
  - May even be required (for some science)
  - Most useful at the start!



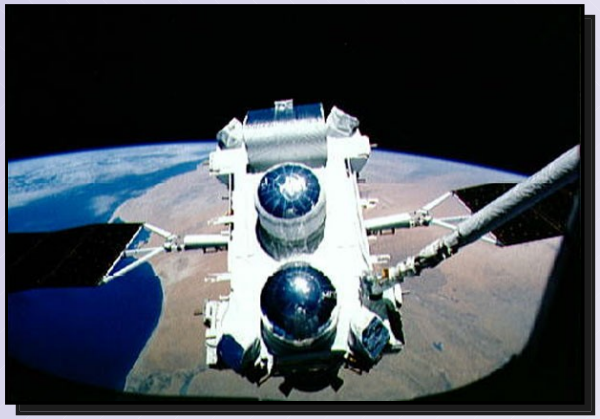


Lesson 1: Localization, Localization, Localization

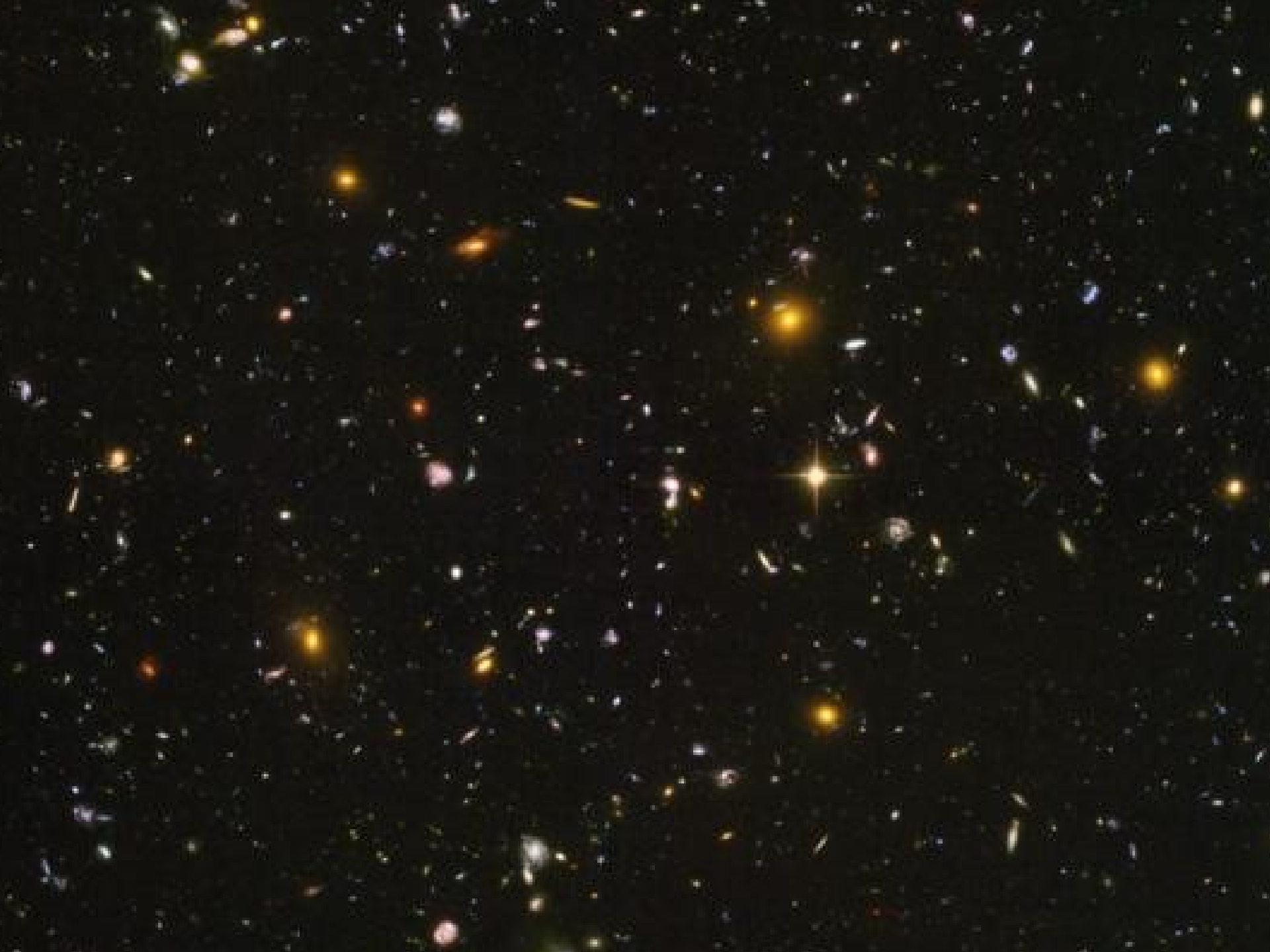
GWAED

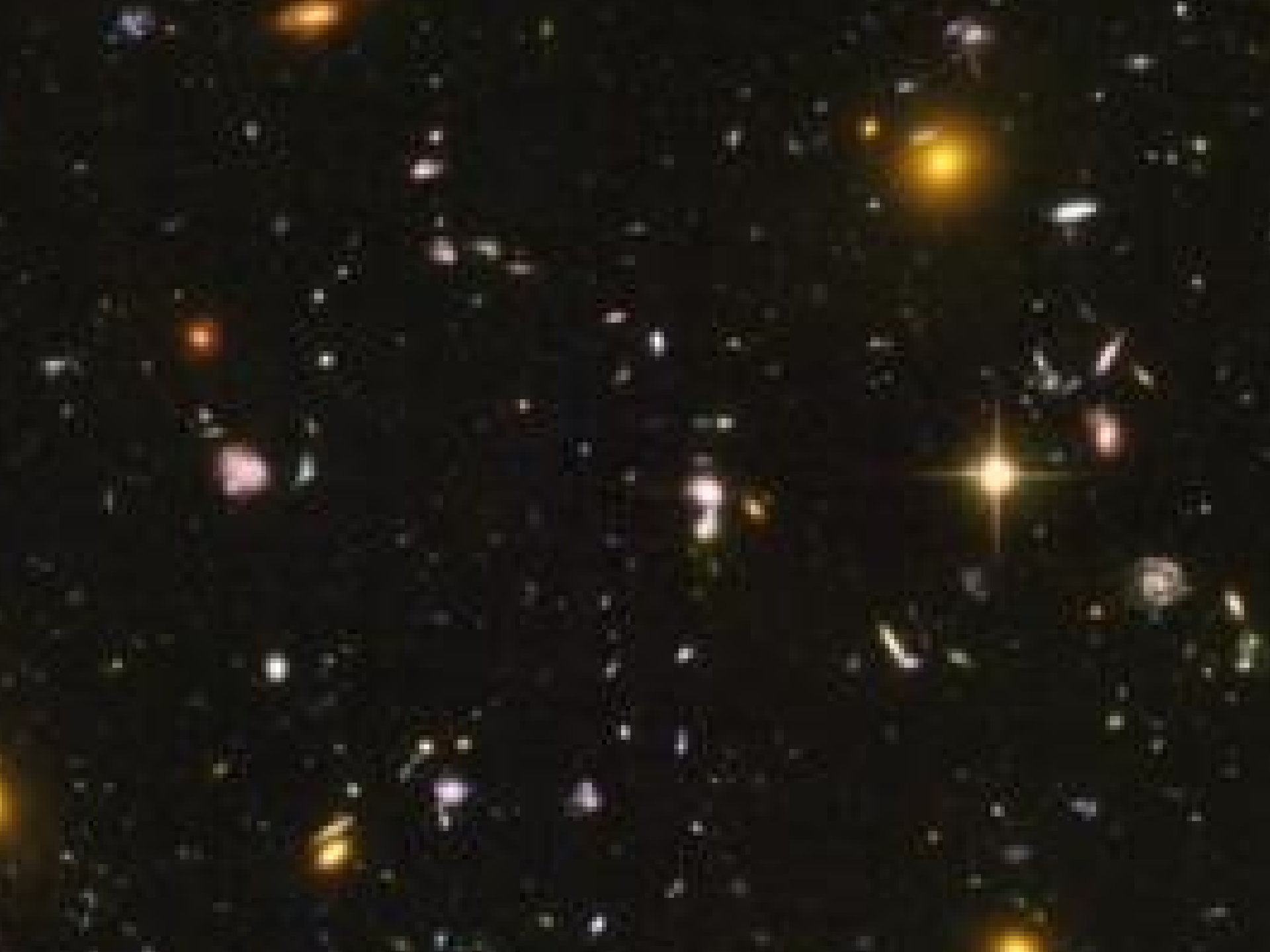
Localization…

- *Vela* localization by time delay
  - Design feature (exclude Solar flares)
  - Established GRBs as cosmic phenomena (extra-Solar system)
- *Compton GRO*
  - Coded-aperture X-ray experiment excluded
  - Cue: *Beppo-SAX*



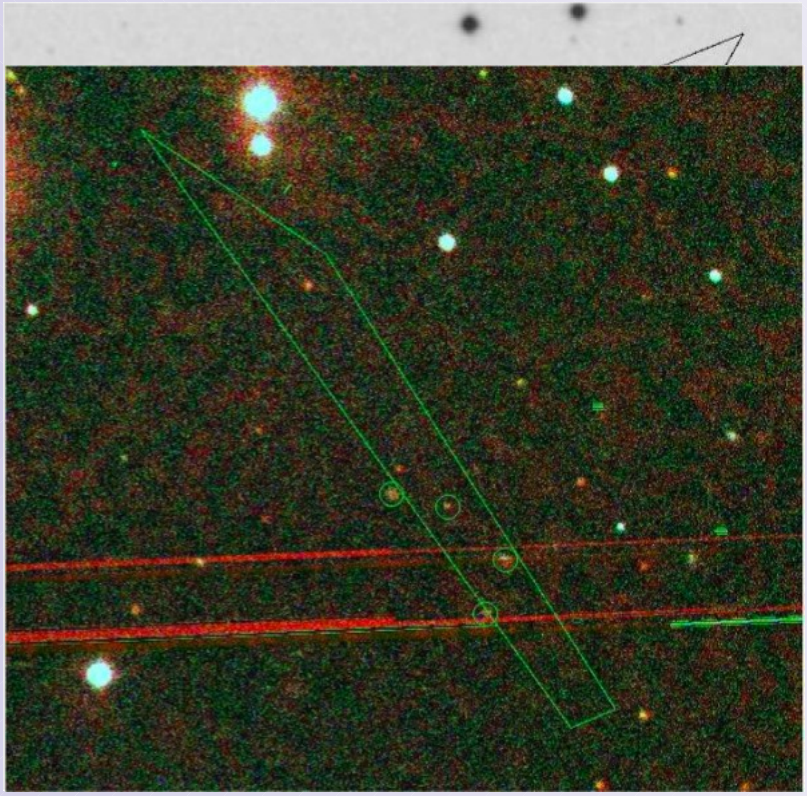

3'



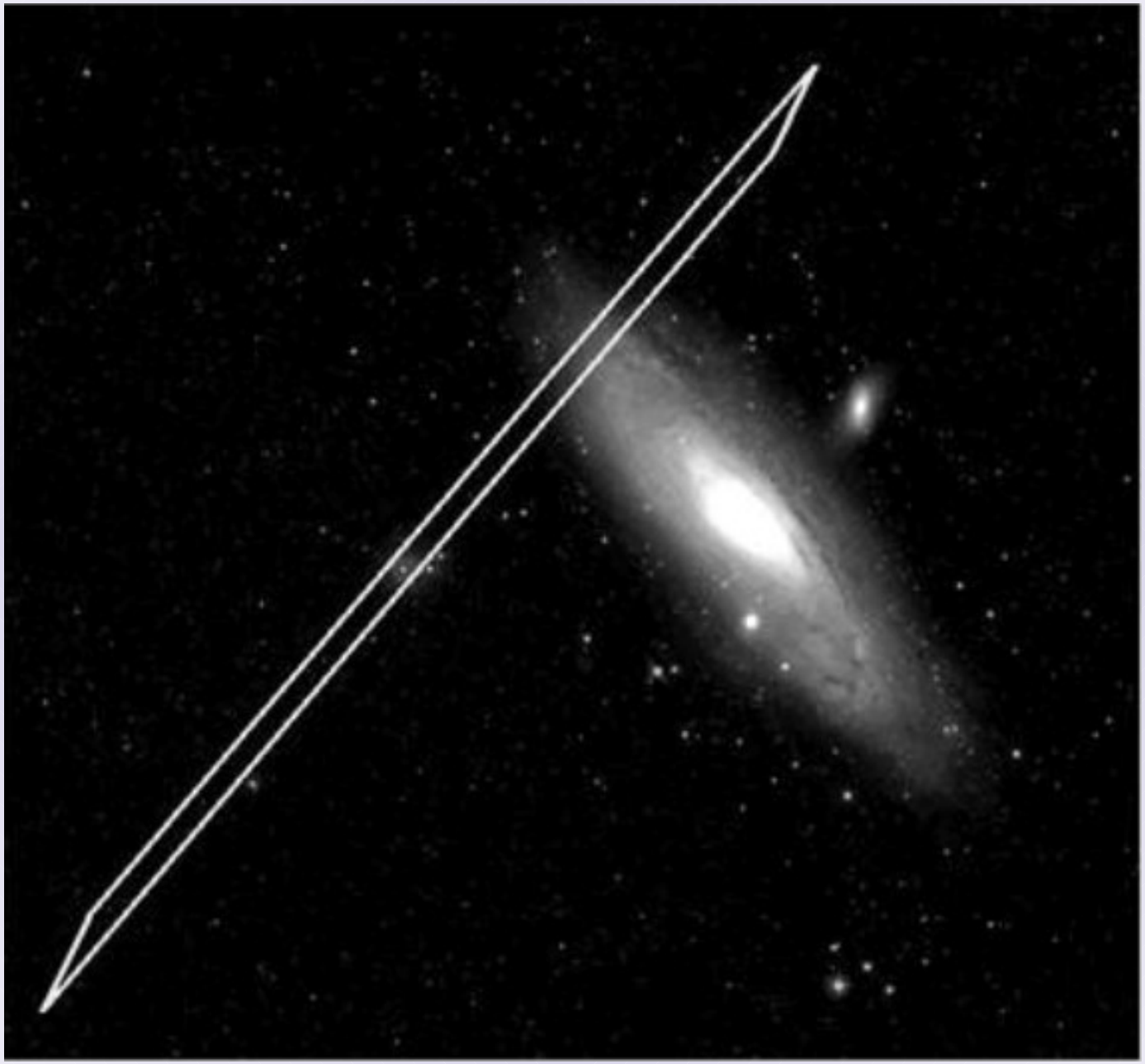


Localization…

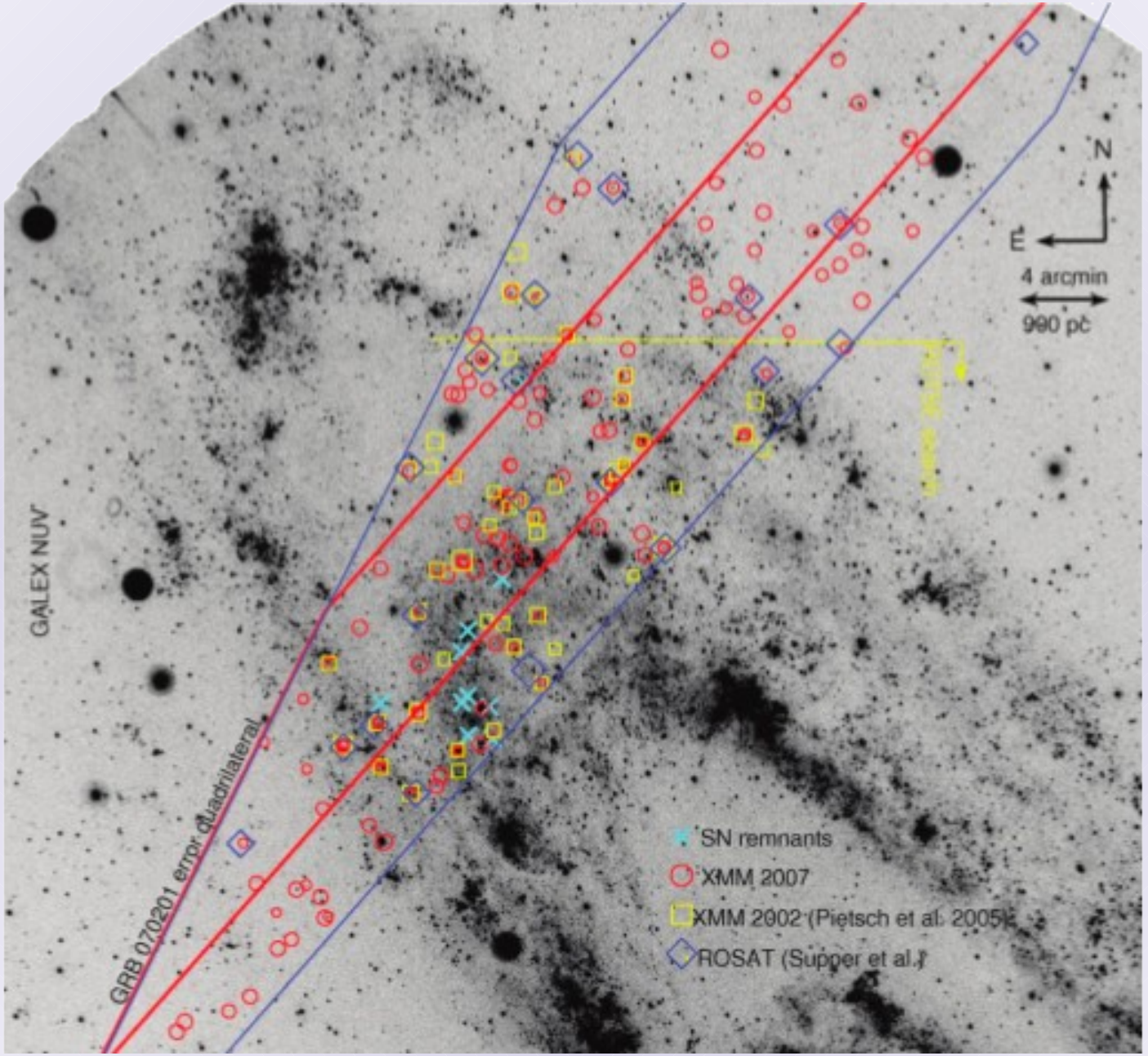
- IPN provided best BATSE-era positions
  - Numerous searches of ~10 arcmin^2 boxes
  - “No-host problem”
  - Missed cluster for SHB 790613
- Mainly concern for HEN
  - Sources likely at cosmological distance
  - Compare luminosity function to L^{-2}…
- What about GW?



Gal-Yam et al. 2008



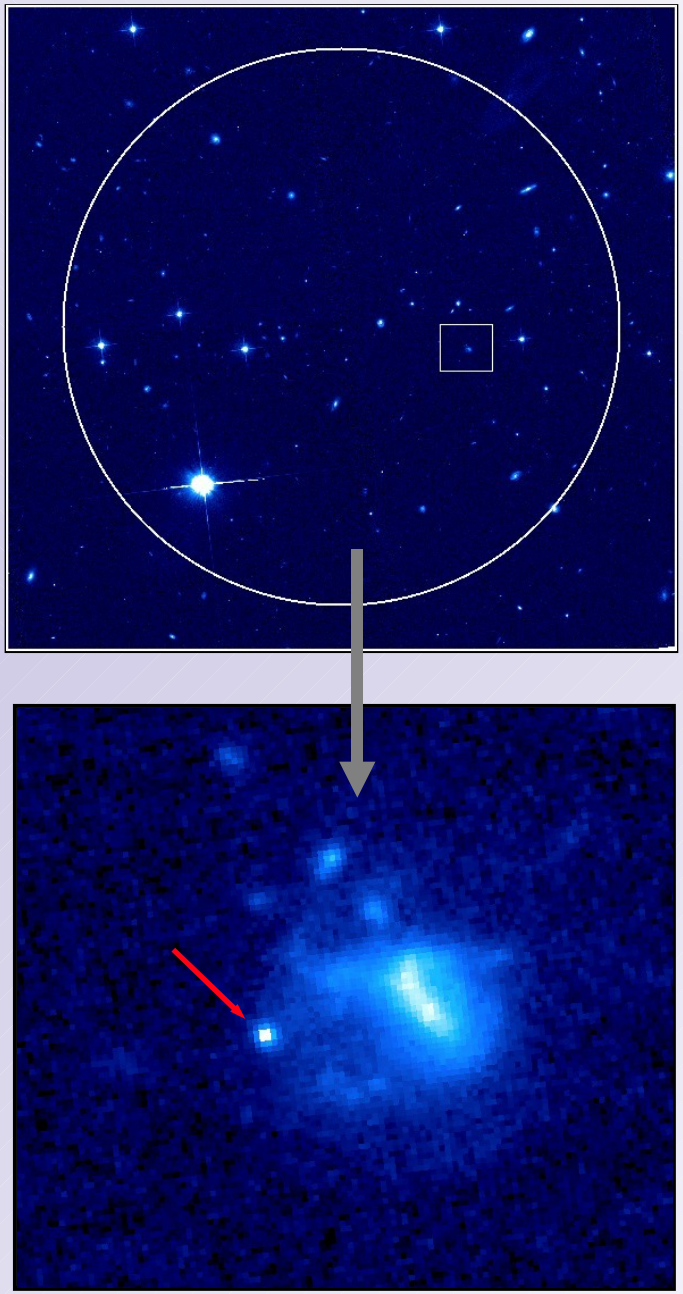
Abbott et al. 2008



Ofek et al. 2008

Localization…

- But localization is hard!
  - GRB observers know
  - GRB observers sympathize
- Photons can help
  - (see Part 2 of talk)
- To that end…

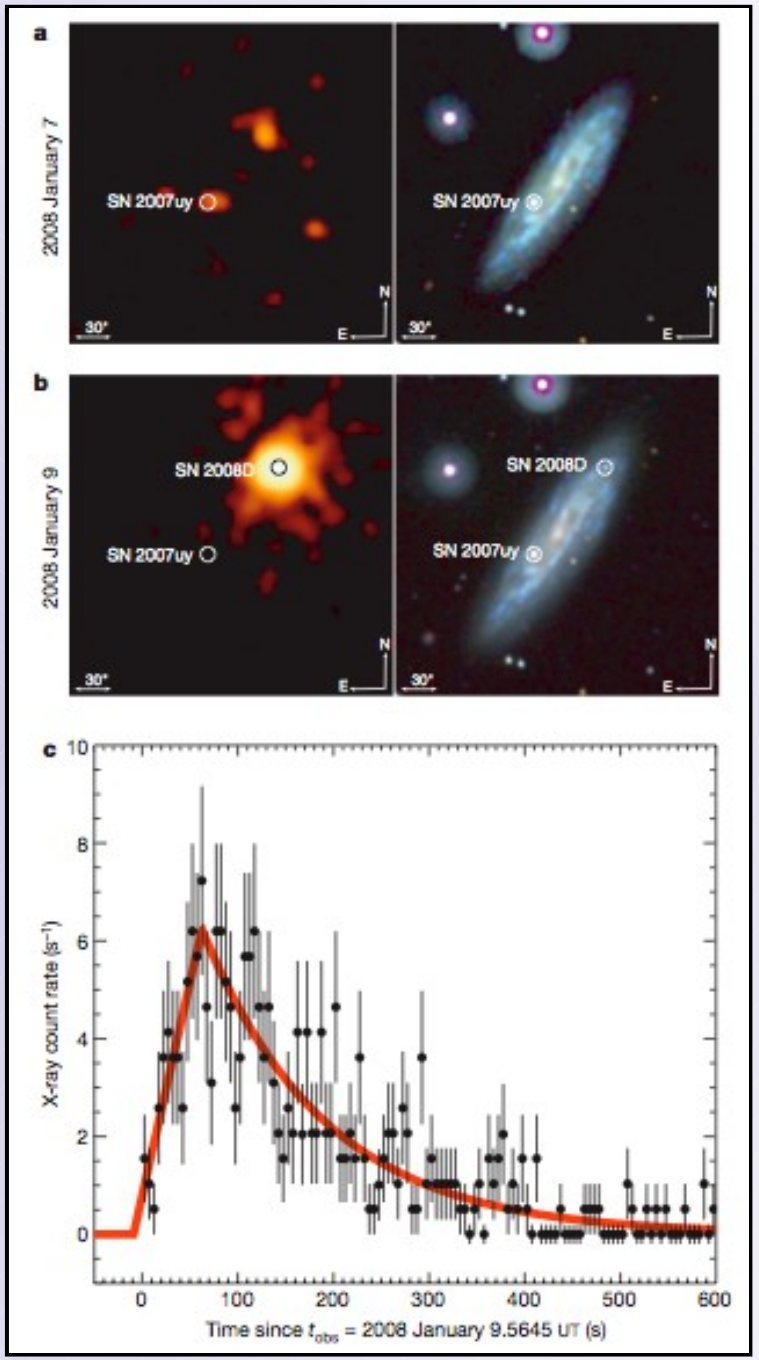


Fox et al. 200

Lesson 2:
Minimal Delay,
Maximal Distribution

Time Delays

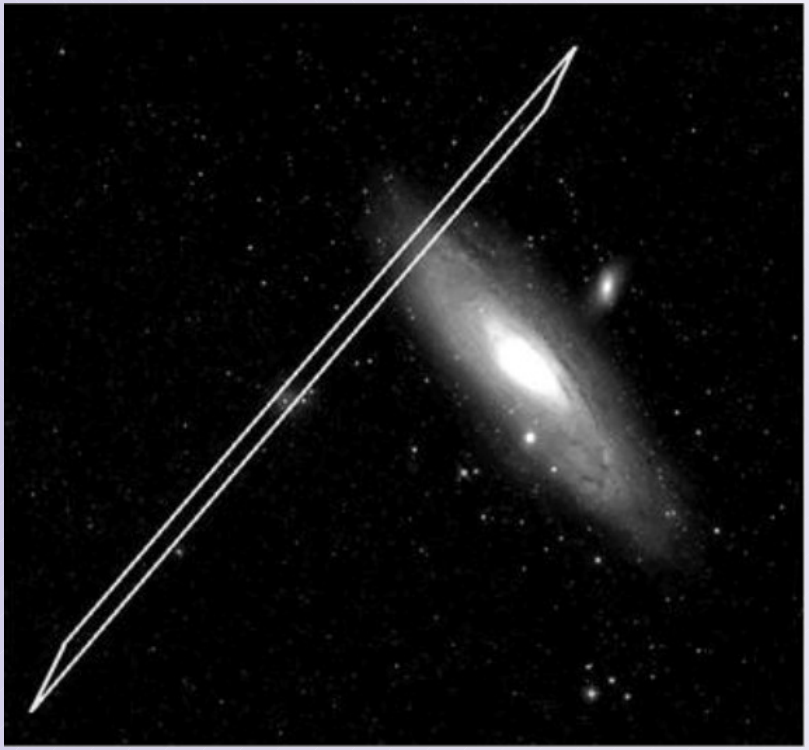
- The GRB example
  - "Seconds matter"
  - At least sometimes
  - GRB 990123 (BATSE alert + *Beppo-SAX* localization)
  - SN 2008D
- Most other scenarios less demanding
  - Delays of minutes? Hours?
- Impending IceCube upgrade from hours → minutes (A. Franckowiak)



Soderberg et al. 200

Distribution

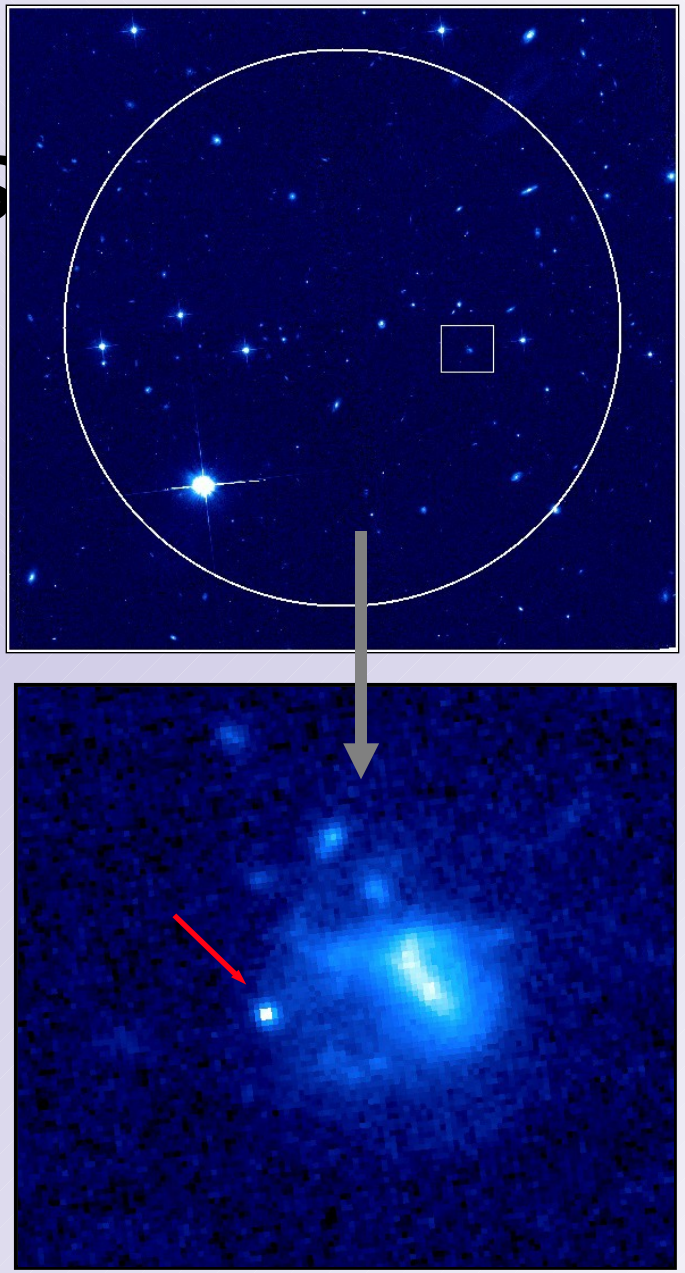
- LIGO-VIRGO opening up coincidence triggers (F. Marion)
- IceCube partnered with ROTSE and open to new collaborations (A.Franckowiak)
- Great to hear
- GRB positions restricted for a long time
- GRB 970228 observed in optical “by accident”
- Positions immediately public soon thereafter
- Public positions get more follow-up → more, better science



Abbott et al. 200

Summary Lessons

- 40 years of GRB studies
  - 30/35 years to distance scale
  - Let's not do that again
- Localization
  - Made the difference for GRBs, over and over
  - Mainly an issue for HEN (cosmological)
  - Consider in design/upgrades
- Distribution
  - Minimal delays
  - Maximal distribution



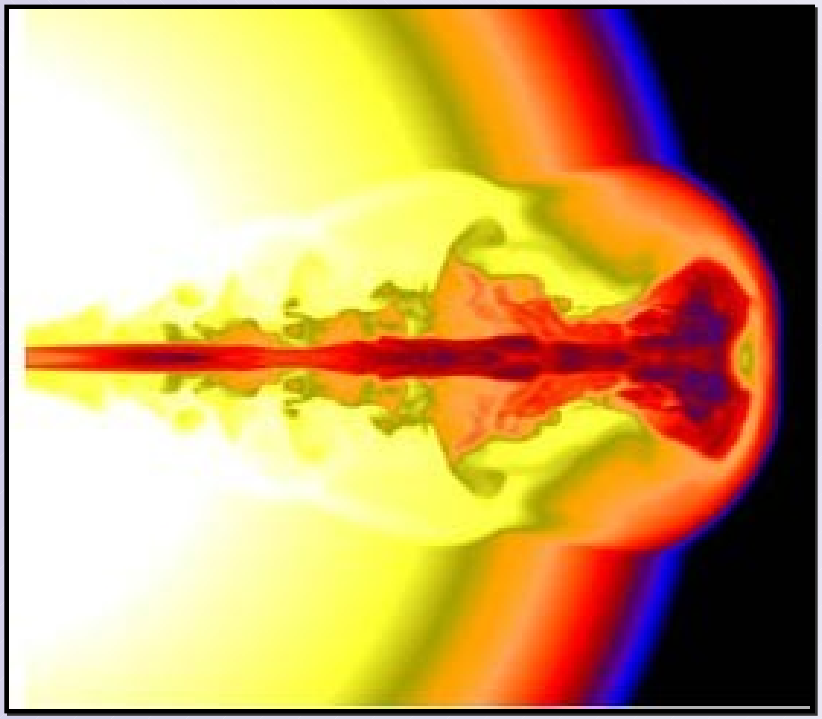
Fox et al. 20

Prospect 1: Triggered Photonic Searches

GWEC

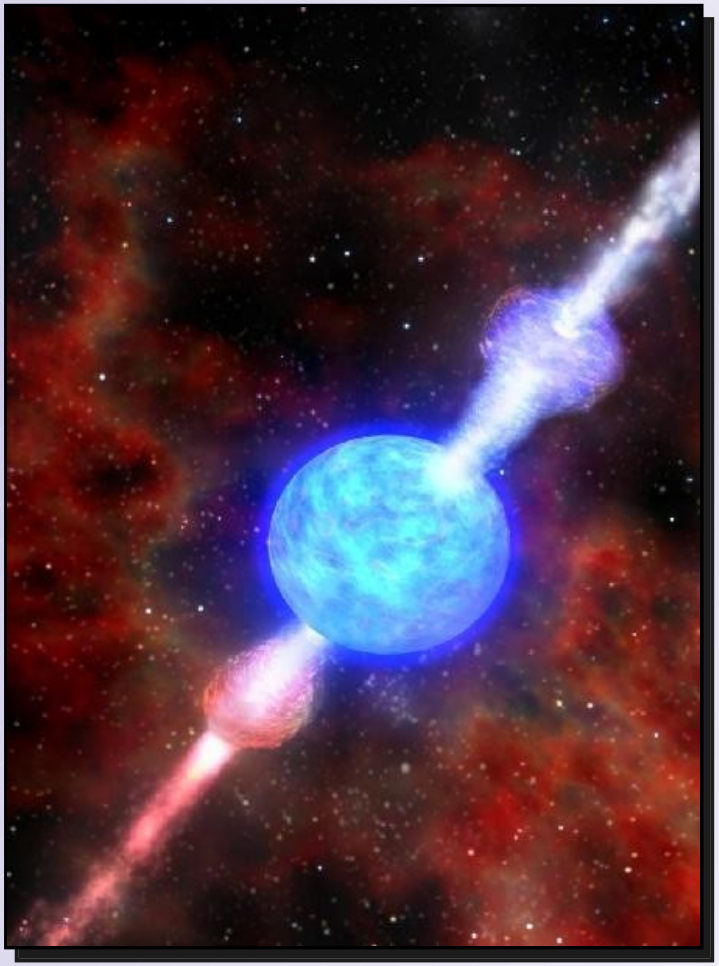
Quenched-Jet Supernovae

- Proto-GRB inside a 10 $M_\odot$ hydrogen envelope
- Jet is quenched $\rightarrow$ No GRB
- Relatively ordinary, nearby supernova with HEN emission
- Opportunity for triggered optical searches
- Monday talks by P. Mészáros, E. Waxman, S. Ando

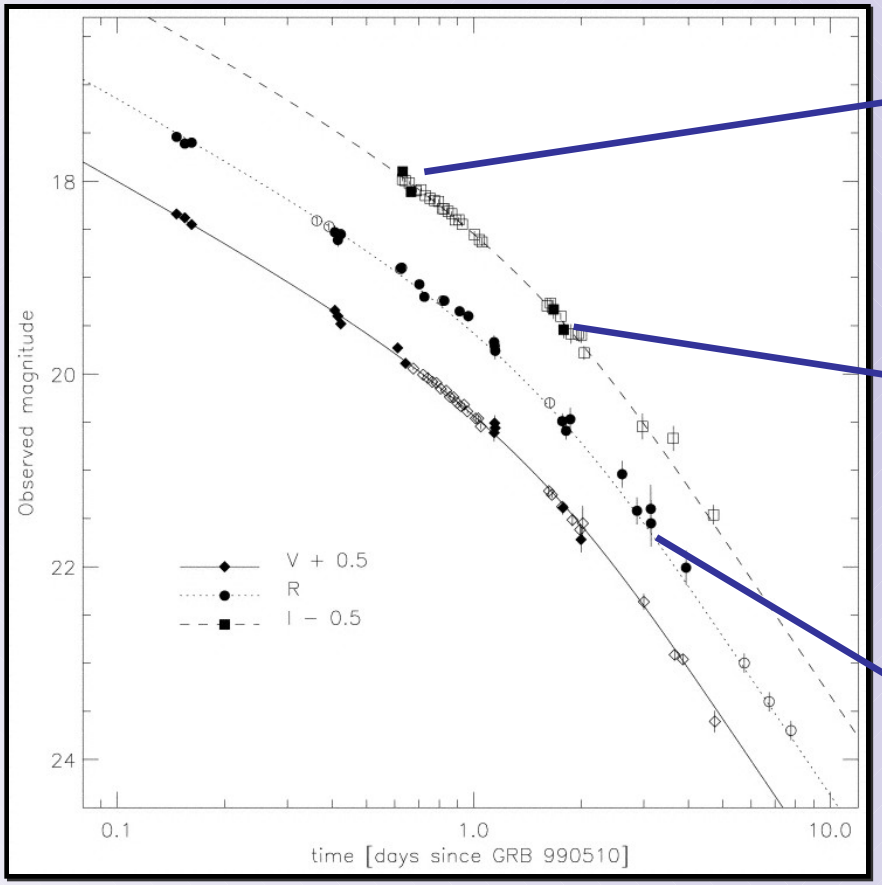


Orphan Afterglows

- Believe GRBs result from collimated outflows:
  - Energetics
  - Theoretical and numerical models
  - “Jet breaks” in afterglow light curves
- Both short and long bursts
- Implies orphan afterglows
  - Not yet observed
  - Brightest orphans will be from nearest bursts



Jets and Jet Breaks



$\Gamma > \theta^{-1}$

θ

Γ^{-1}

$\Gamma = \theta^{-1}$

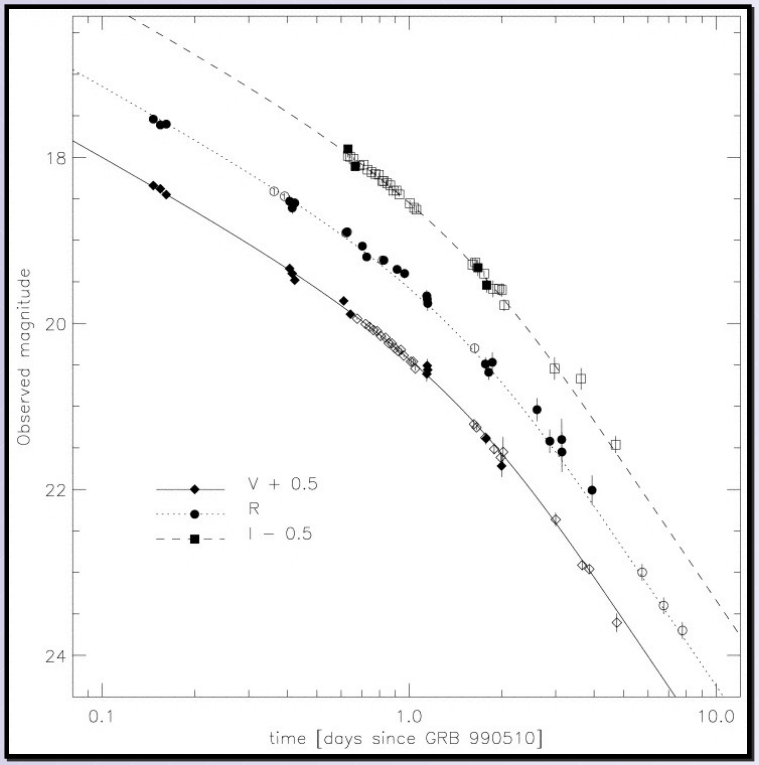
θ

$\theta \rightarrow \pi$

$\Gamma \rightarrow 1$

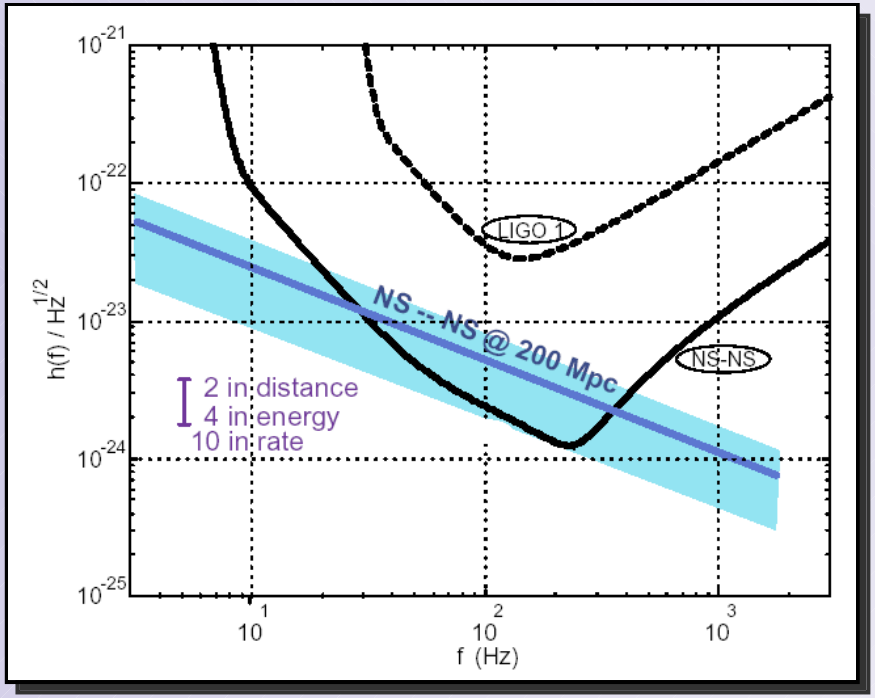
Orphan Expectations

- Orphan peak magnitude is ~ afterglow magnitude at break
- Rise time: ~ 0.1 t_{jet}
- Fading as power-law
  - Power-law index α ~ 2.3
  - Referenced to burst time
- Observational signatures: Brightness, power-law spectrum, lightcurve
- Rate determined by burst rate + beaming fraction
- Focus on short bursts
  - Higher local rate
  - Stronger connection to GW
- Long bursts orphans also interesting



SHB Orphans and GW

- 30:1 to 500:1 odds against any given GRB illuminating Earth
- GW distances strictly limited
- Nearest merger events will not be GRBs!
- “Orphan afterglow” searches increase LIGO sensitivity by 1.5x



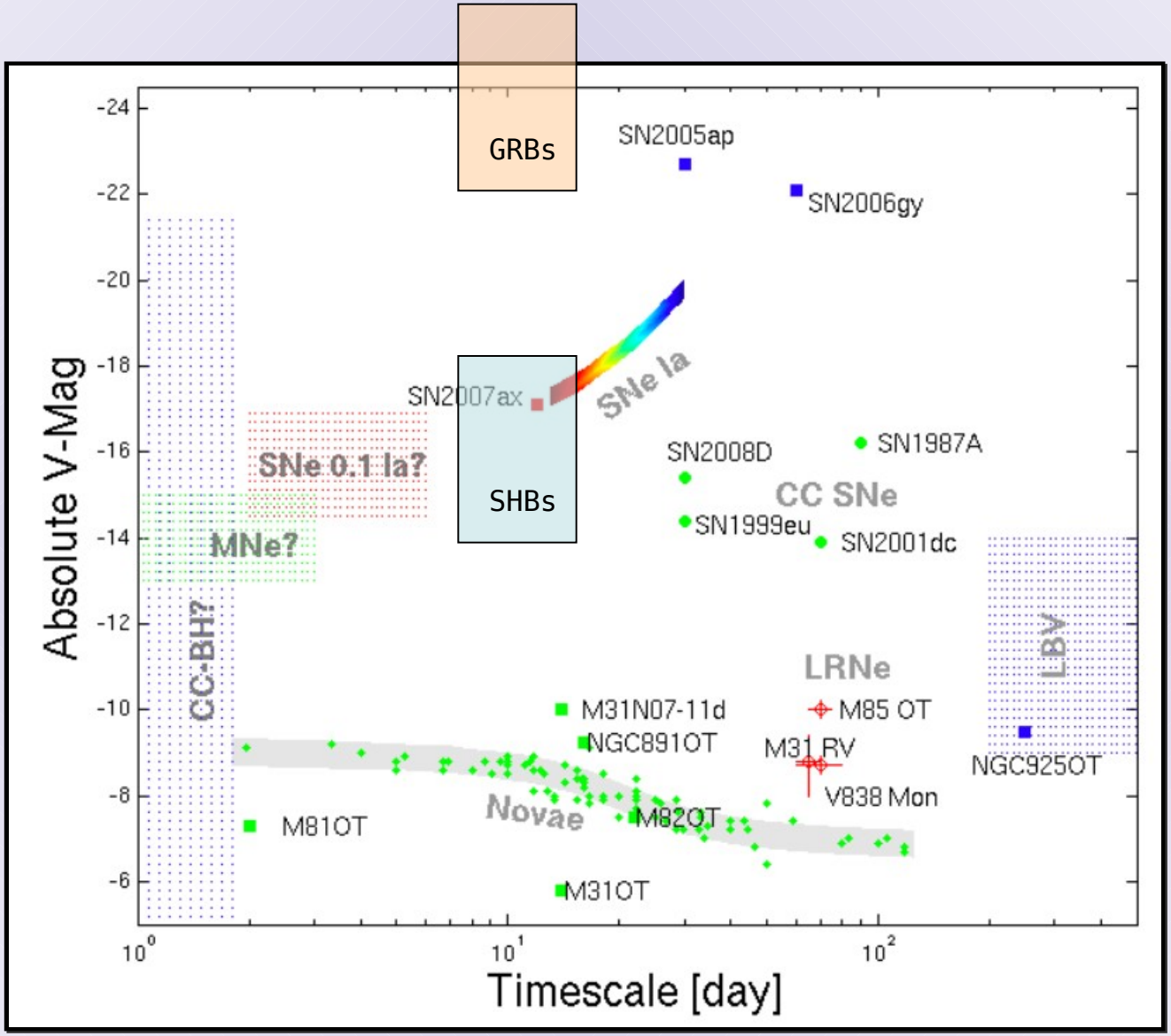
K.Thorne / NSF Review

Short Burst Beaming

GRB	z	t_{jet}	Beaming	Break
050709	0.16	10d	30:1	i = 25.8
051221	0.55	4d	130:1	r = 24.8

050709 at 10 Mpc: $I > 16.4$ mag ($M_I > -13.6$ mag)

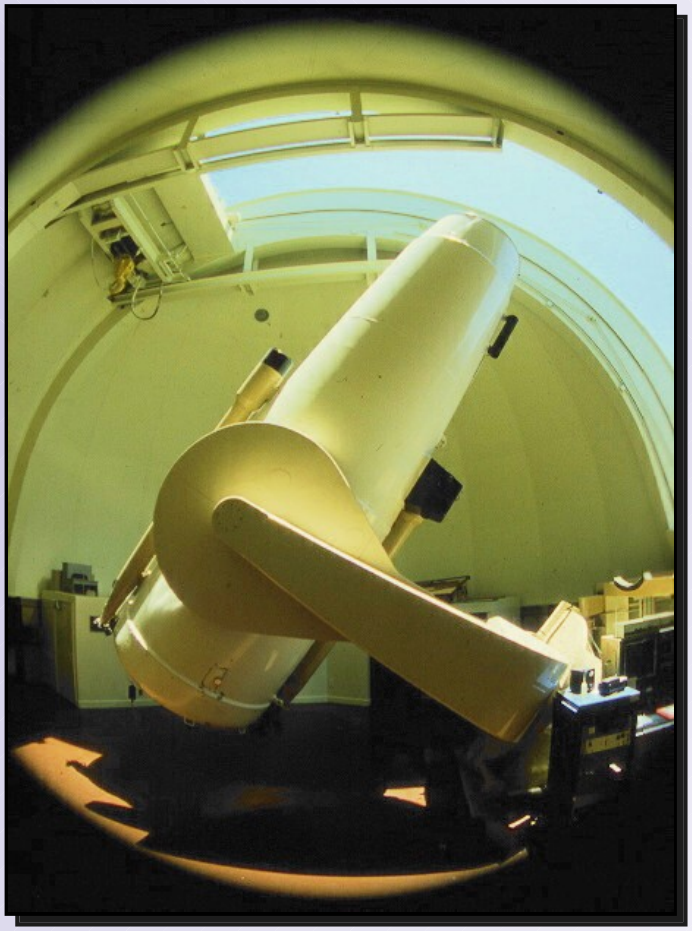
051221 at 10 Mpc: $r > 12.3$ mag ($M_r > -17.7$ mag)



Rau et al. 2009

Palomar Transient Factory

- New 7-deg^2 100 Mpix camera (former CFHT 12k)
- Dedicated use of Oschin Schmidt telescope at Palomar
- Three year dedicated project, 2009-2012
- Focus on fast transients and supernovae
- *R* and *g'* band
- Depths of *R*, *g'*≈ 21 mag, cadence of (<1d, 5d)
- Aim for 150 fields per night
  - 1000 deg^2 per night
  - 6000 deg^2 monitoring
- TOO mode for LIGO-VIRGO and IceCube



Oschin Schmidt Telescope

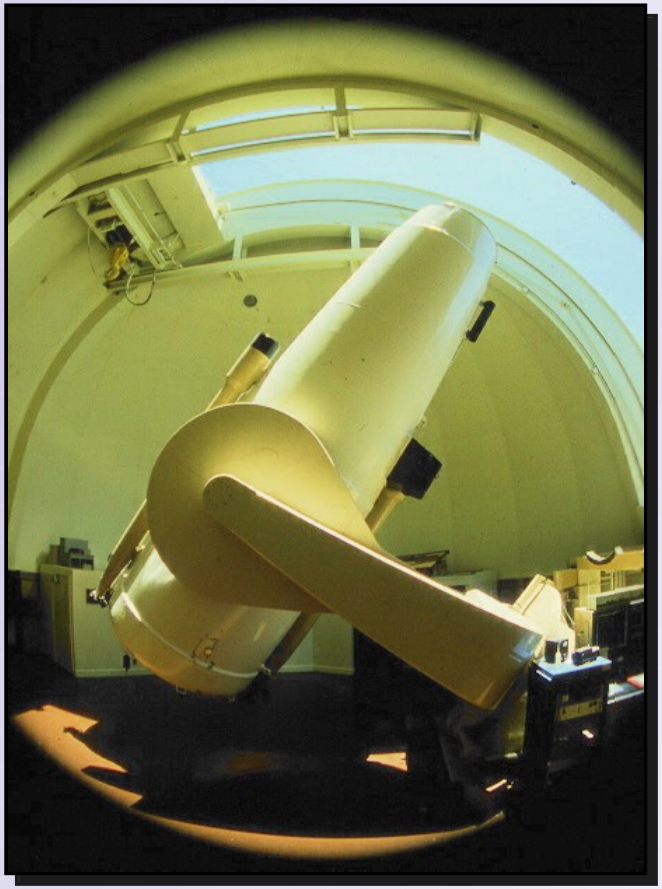
SkyMapper

- New 1.3-m, 8-deg^2 telescope at Siding Springs Obs.
- 5.7-deg^2 camera
- Five-year “Southern Sky Survey”, 2009-2014, 20k deg^2
- Primary goal: 5-band imaging
- Transient survey “piggy backed”
- Single-epoch depth to *griz*~21.5 mag
- TOO-capable for LIGO-VIRGO and IceCube

SkyMapper

Searches Summary

- Triggered searches
  - Excellent progress
  - ROTSE + IceCube active
  - PTF & SkyMapper coming online
- Consider also:
  - ATA and other radio
  - Nearby galaxy screen for narrow-fov facilities
- Orphan afterglow searches
  - Potential discovery of the new generation of optical surveys
  - Useful as GW input
  - Expect detection in PS4 / LSST era



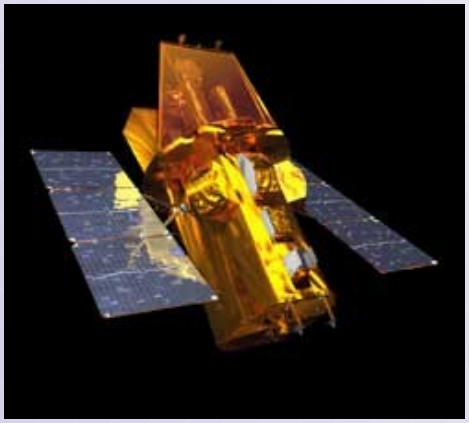
Oschin Schmidt Telescope

Prospect 2:
A GWHEN Mission

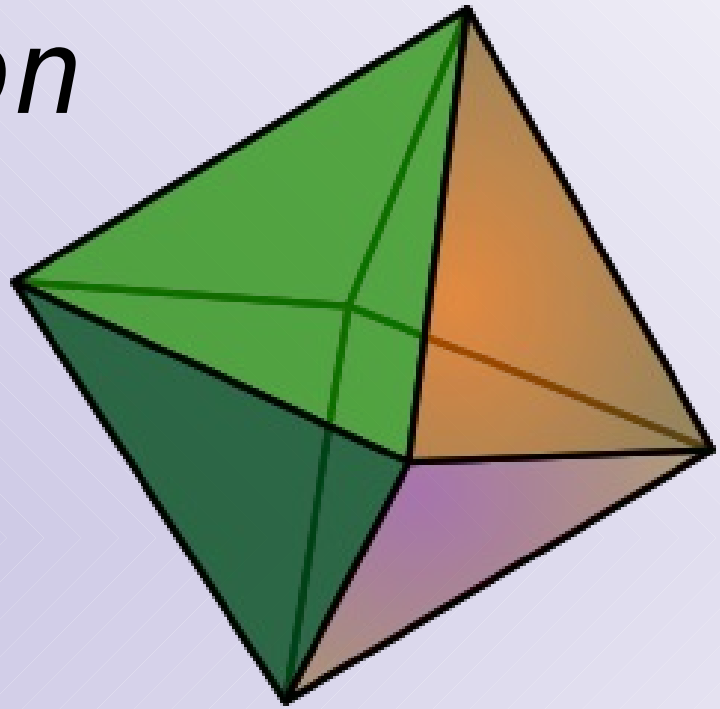
GWHEN

High-Energy Photonics

- *Swift*
  - Best sensitivity (but few short bursts)
  - Arcsec localizations (incl. external triggers)
  - Sees 1/8 of sky
- *Fermi*
  - GBM positions >degrees
  - Sees 1/2 of sky
  - LAT data for few (albeit very interesting) bursts
- IPN
  - All-sky, all the time
  - Brightest bursts
  - Poor localizations
  - Delayed by ~day from burst



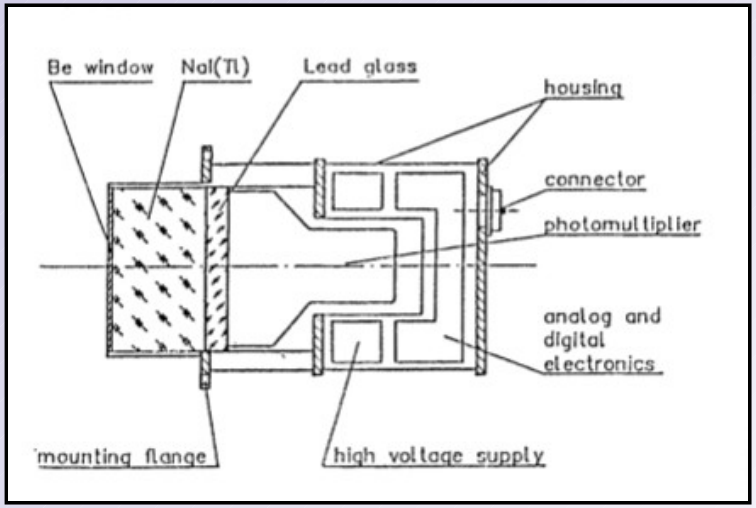
A GWHEN Mission



- All-sky, all the time
- Real-time alerts
- Sub-arcmin positions
- Brighter bursts

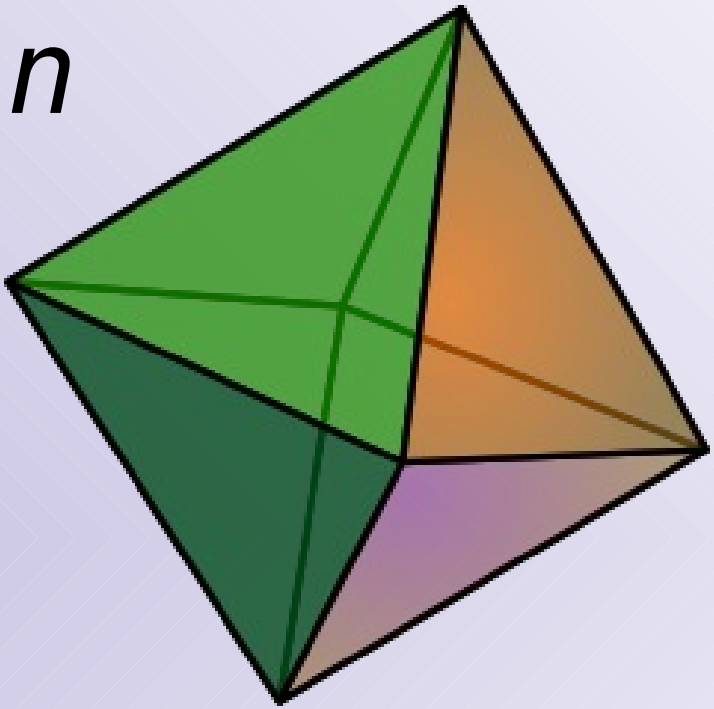
KONUS-Wind

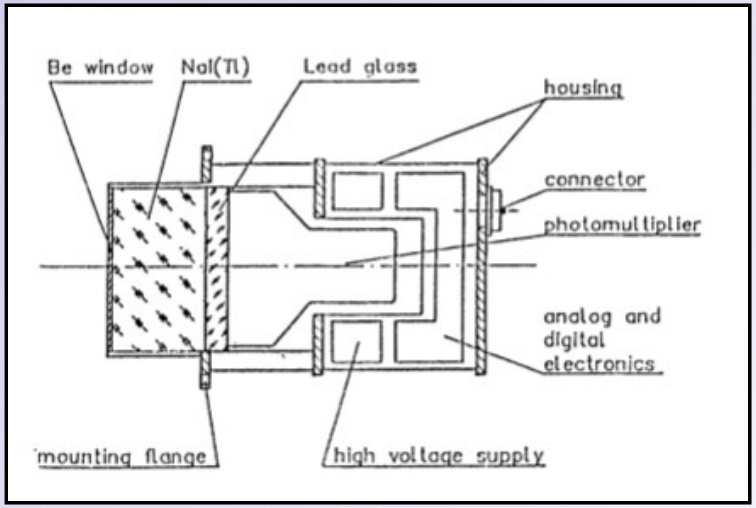
- Node of the IPN @ L1
- PMT: D=13 cm, h=7.5 cm
- Two modules
- All-sky, 123 GRBs



A GWHEN Mission

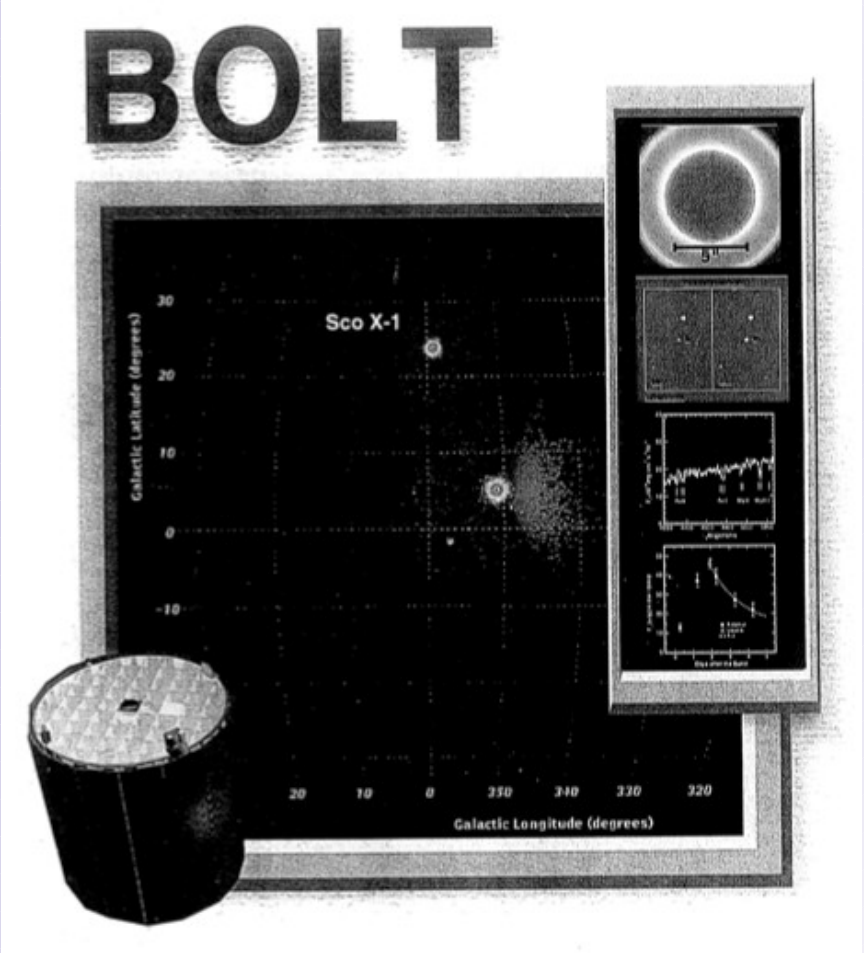
- All-sky, all the time
  - Booster launch into high-apogee orbit
  - Low, stable background
- Real-time alerts
  - Onboard position calculation
- Brighter bursts
  - Konus-grade sensitivity fine
  - 100 GRB year^{-1} goal
- Cheap
  - NaI + PMT
  - No position-sensitive detectors
- Sub-arcmin positions
  - ?





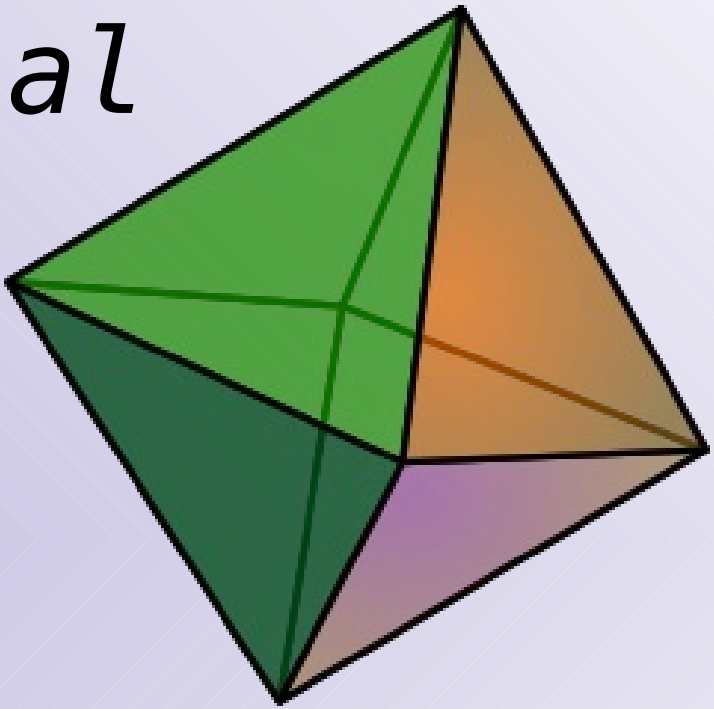
Sub-arcmin positions?

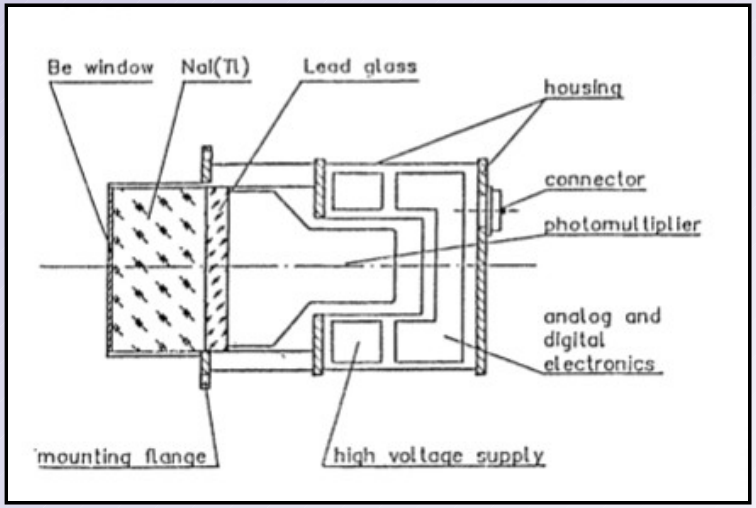
- Rotation Modulation Collimator
  - Rotation-dependent shadowing
  - Position via timing analysis
- *BOLT* SMEX mission proposal (PI Chuck Hailey, Columbia)
  - All-PMT, spin-stabilized, 1 Hz
  - 6000 cm^2 NaI (~36 K-W modules)
  - <10” positions for bright bursts
  - >10x BATSE sensitivity over 3.1 sr



Mission Proposal

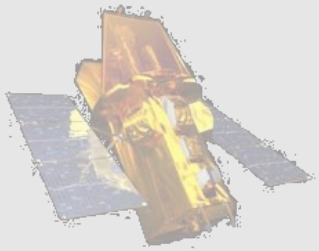
- Pair of RMCs oriented normal to each face of octahedron – 8 on top, 8 on bottom – 16 total
- Effective area per-face comparable to KONUS-Wind
- Fits within SMEX envelope – 1m diameter, 2m height (but.. booster?)
- Individual rotating collimators (only complex element)
- Position resolution improves with burst brightness
- Sub-arcmin readily achievable





HERMES

- **H**igh-
  Energy
  Reconnaissance
  for
  Multimessenger
  Event
  Science



Conclusions

GRB Follow-Up and GWHEN

Lessons

1. Localization
   - All the difference
2. Distribution
   - Minimal delays, maximal distribution

Prospects

1. Triggered searches
   - Already begun
   - Next-generation facilities well suited
2. A GWHEN mission
   - All-sky, all the time for bright bursts
   - Providing localizations for maximum science

Special thanks to Chuck Hailey fo providing his BOLT proposal materia

Finis