Gamma Ray Bursts: Observational Frontiers

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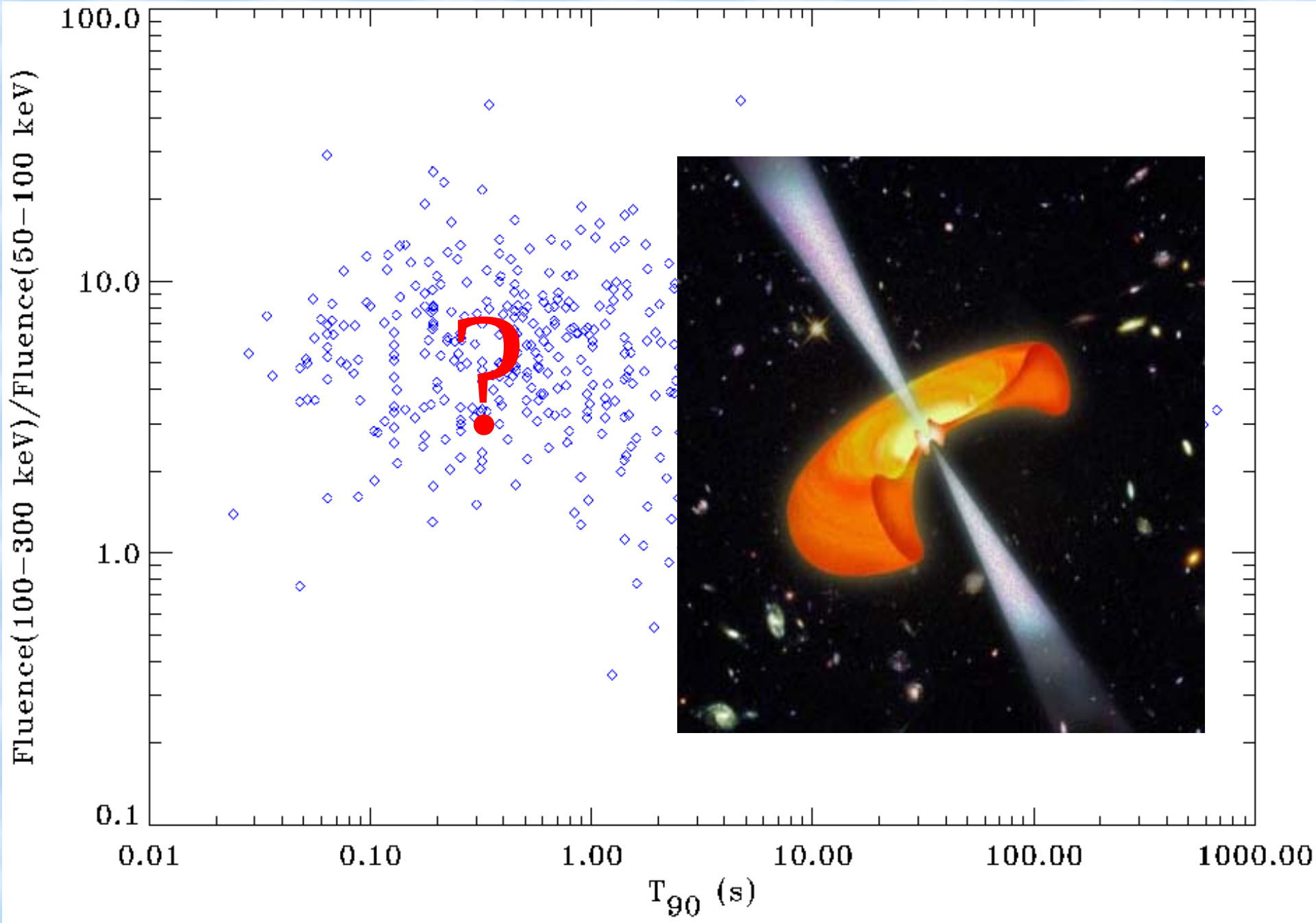
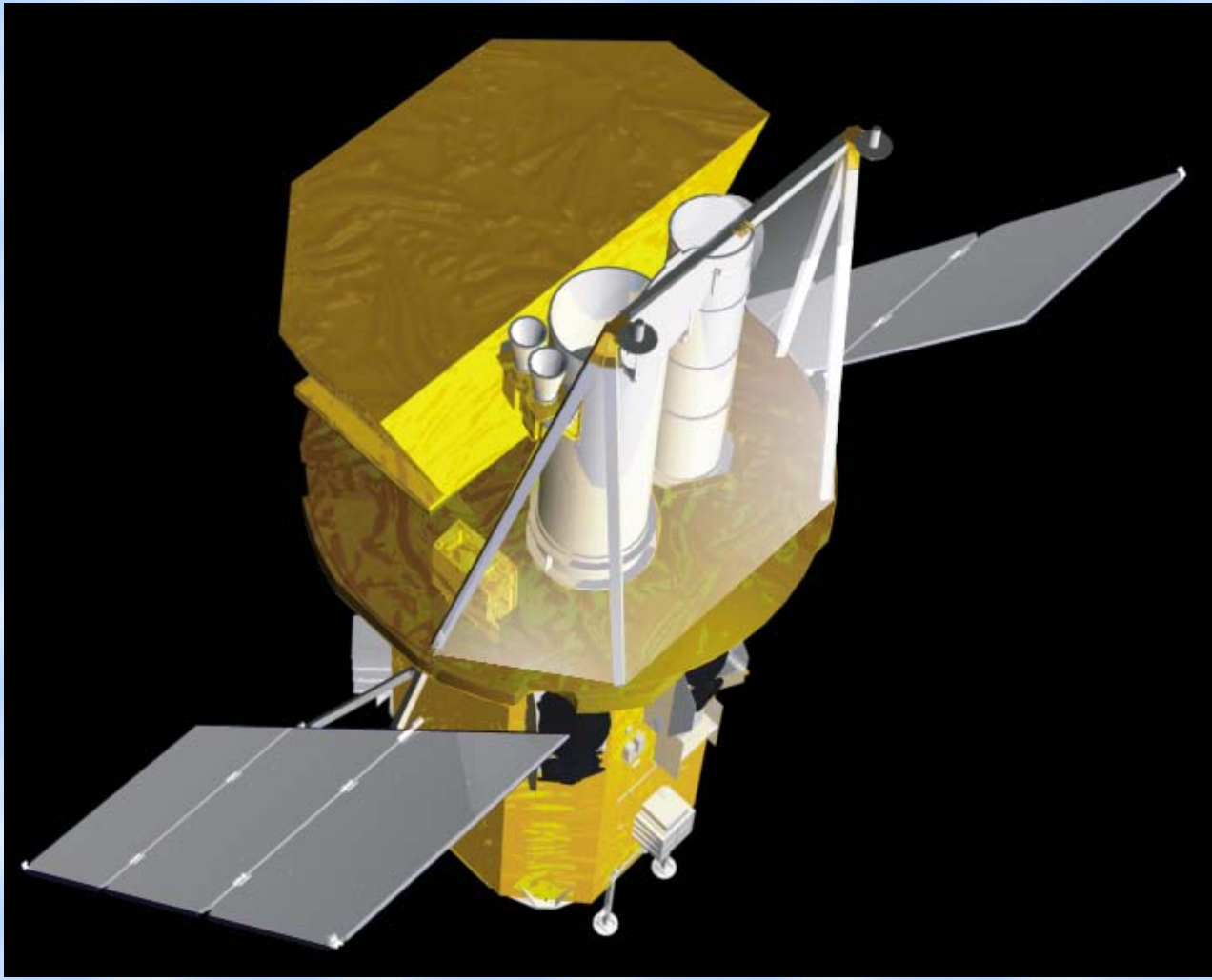
Short/Hard GRBs

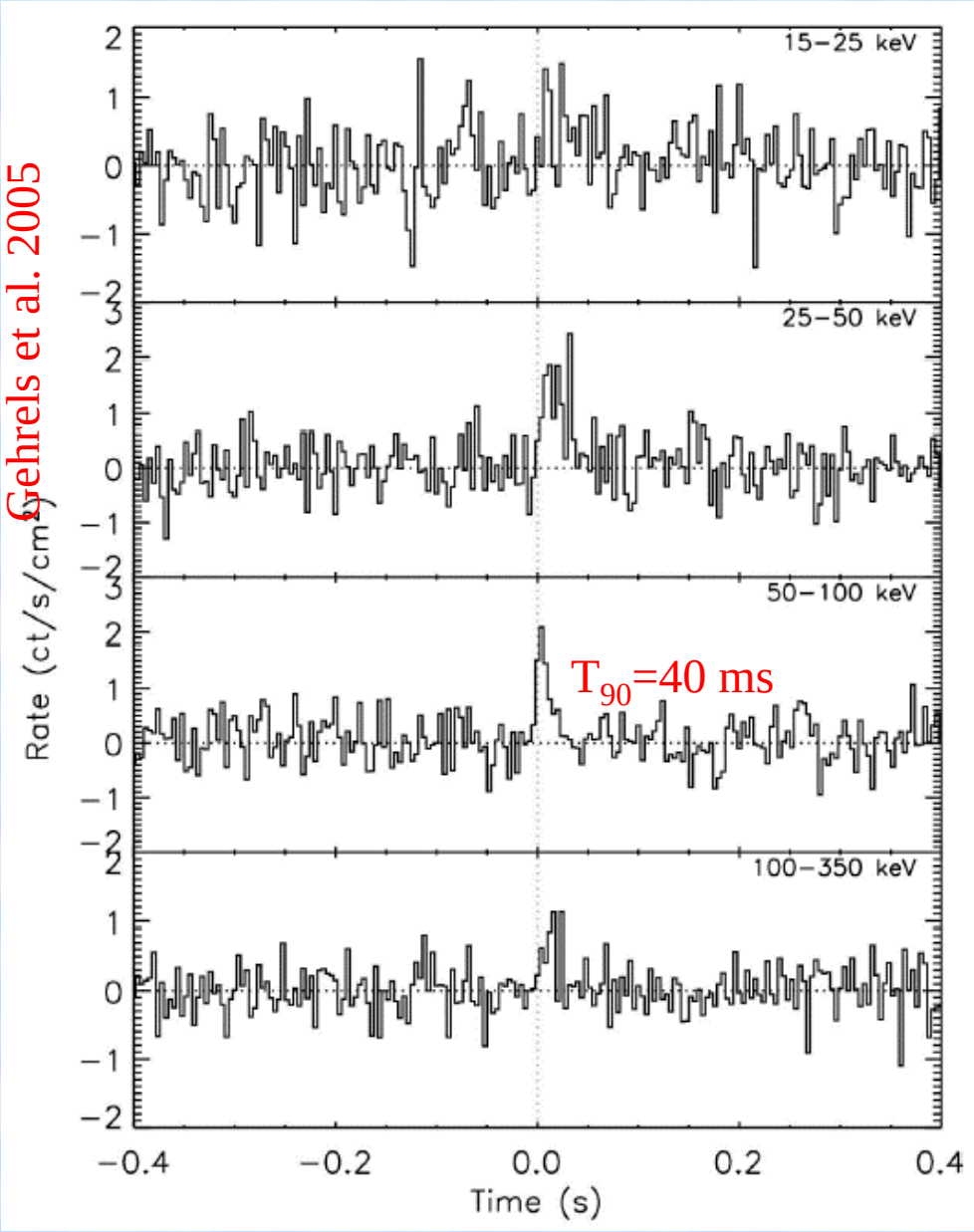


The Source is Swift

- BAT sees 1.4 ster
- Automated slew to GRB position
- X-ray telescope and UV/Optical telescope pinpoint the afterglow
- Positions available to ground observers within minutes

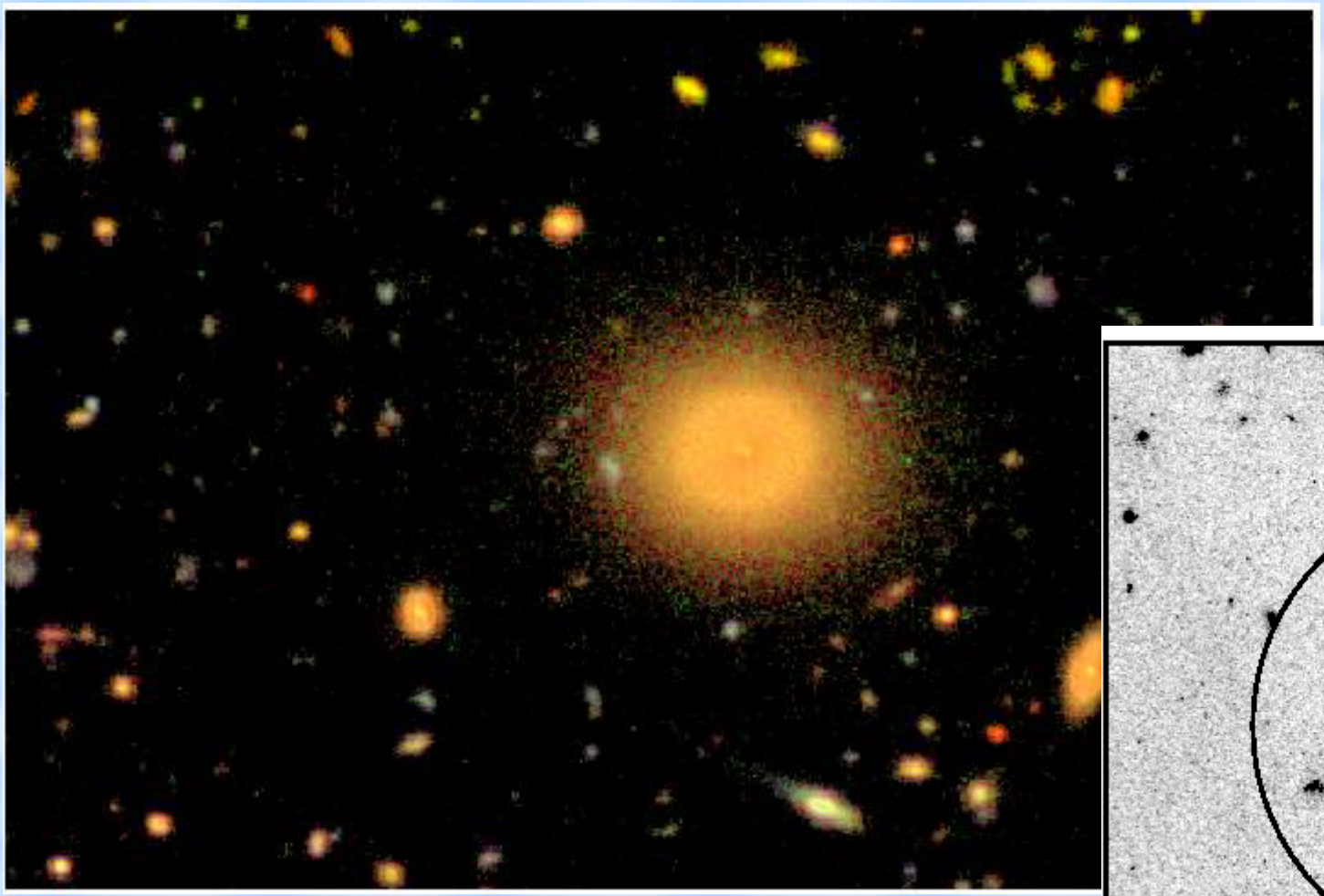


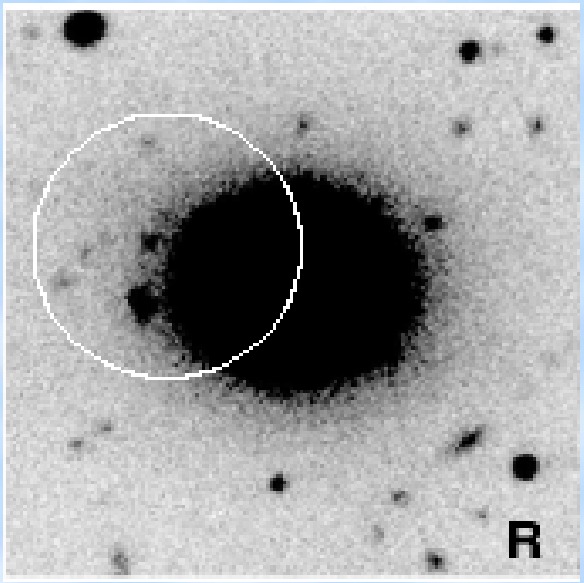
GRB 050509B: Swift Detection

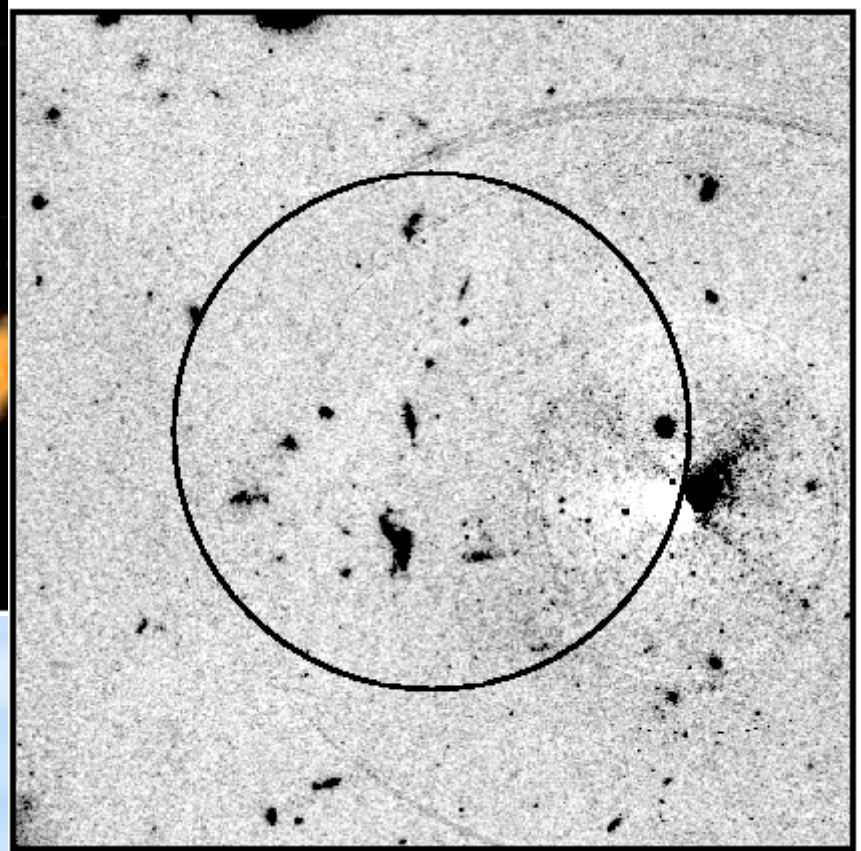


- BAT: very faint GRB
- XRT: T+62 s detects 11 photons(!)
- No optical, no radio. very faint limits
  - Low energy event and/or low density medium?
- Giant elliptical galaxy in cluster @ z=0.22 Host?

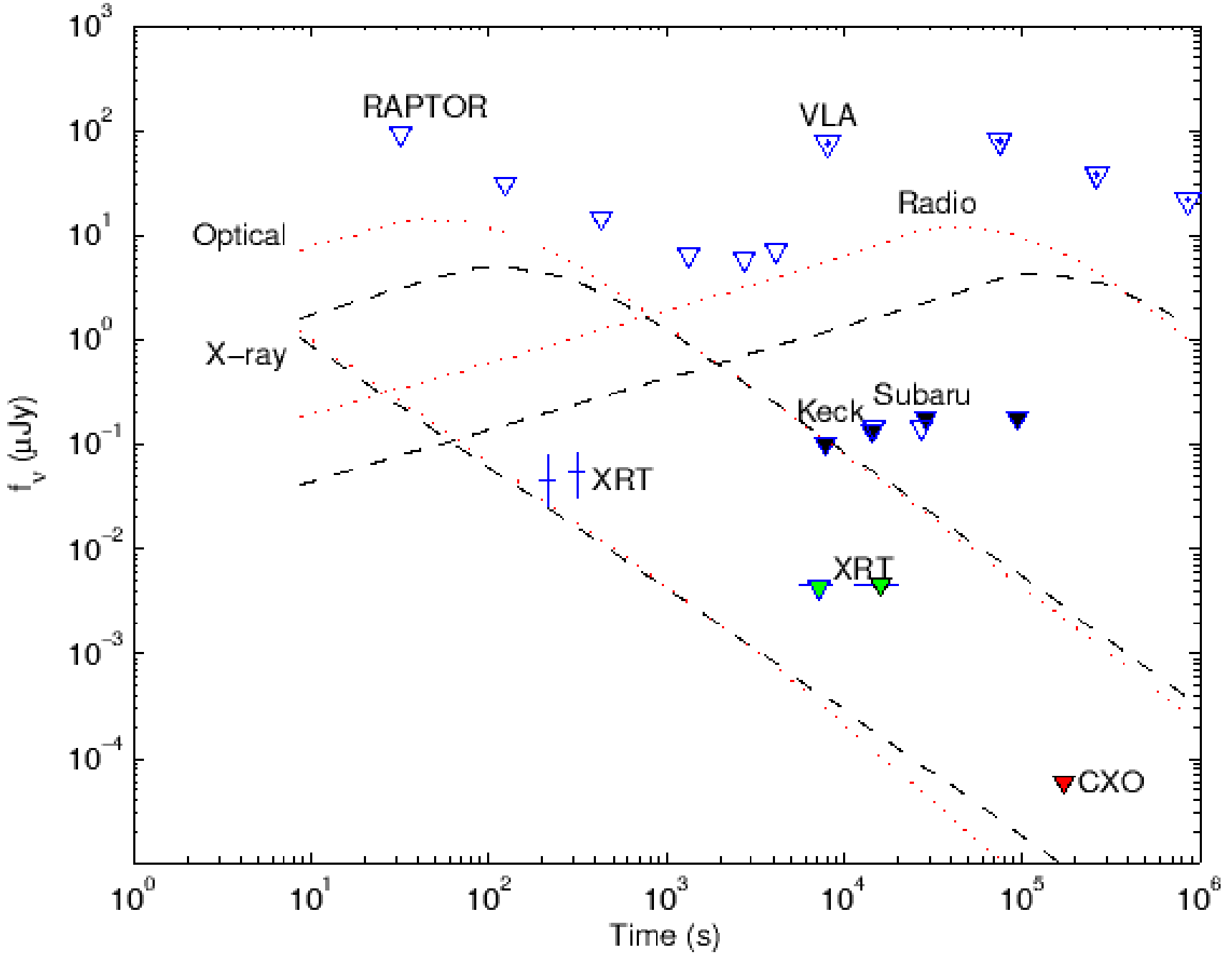
GRB 050509B



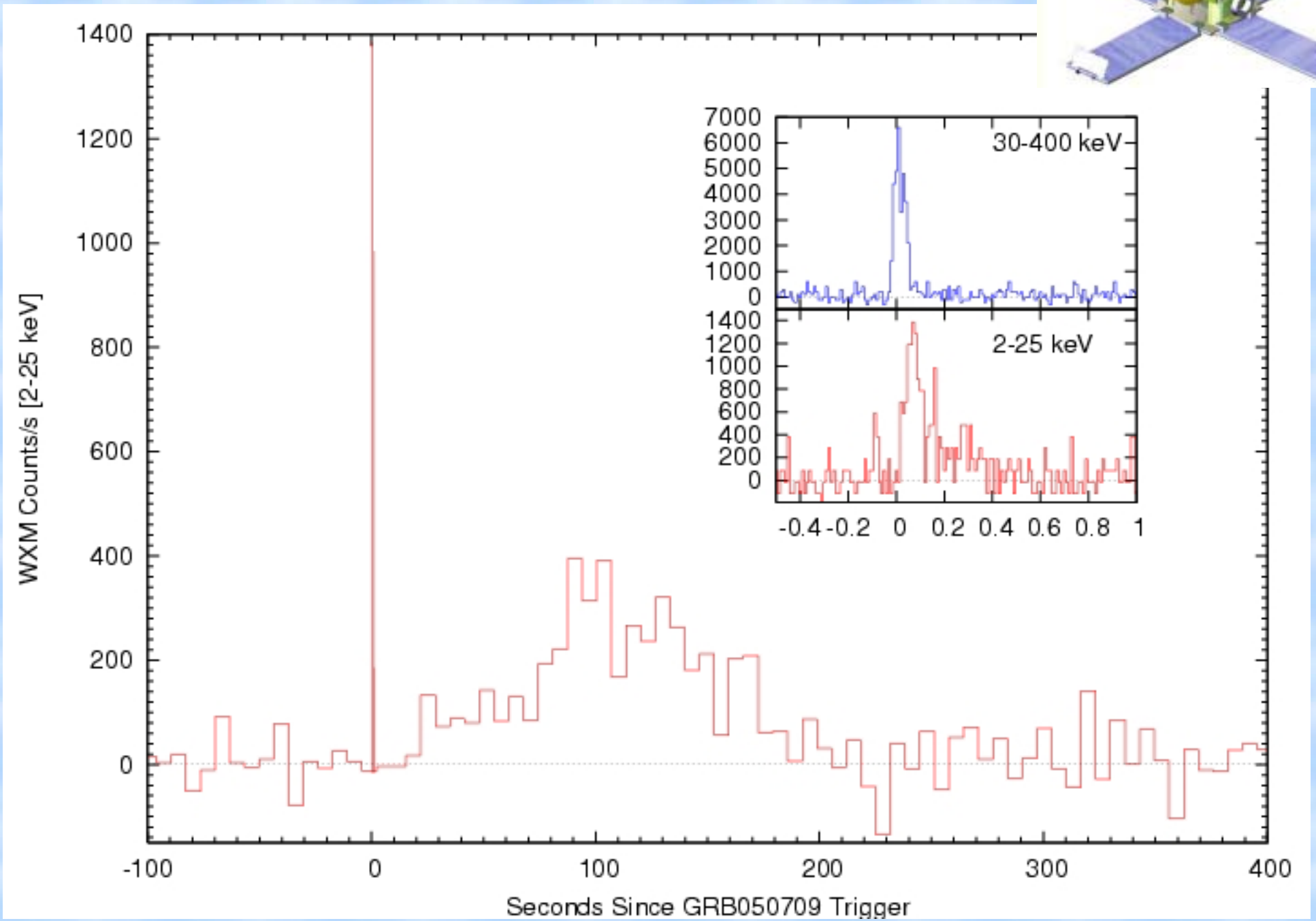




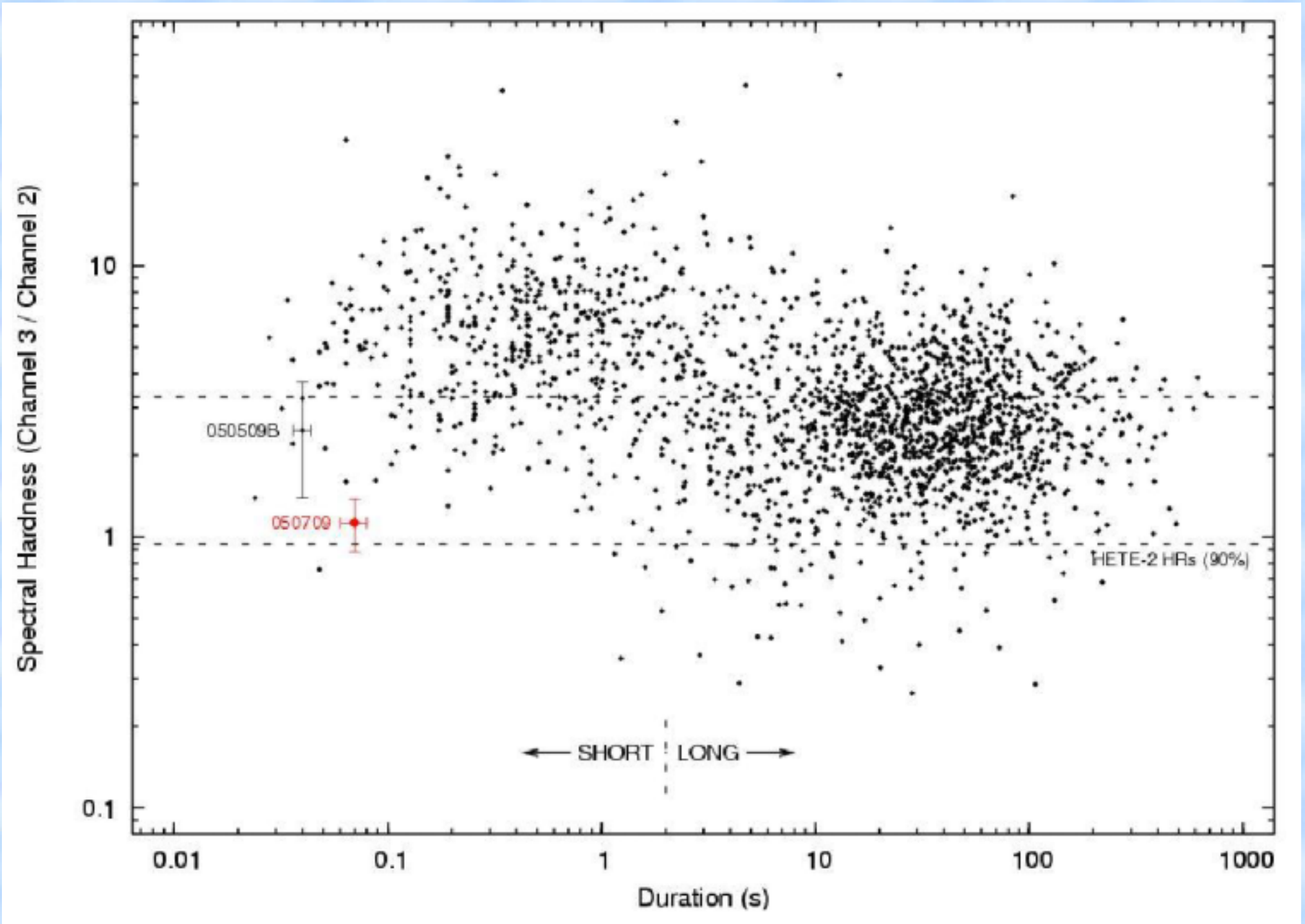
GRB 050509B


RAPTOR
VLA
Optical
Radio
X–ray
Subaru
Keck
XRT
XRT
CXO
f_ν (μJy)
Time (s)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^0
10^1
10^2
10^3
10^4
10^5
10^6

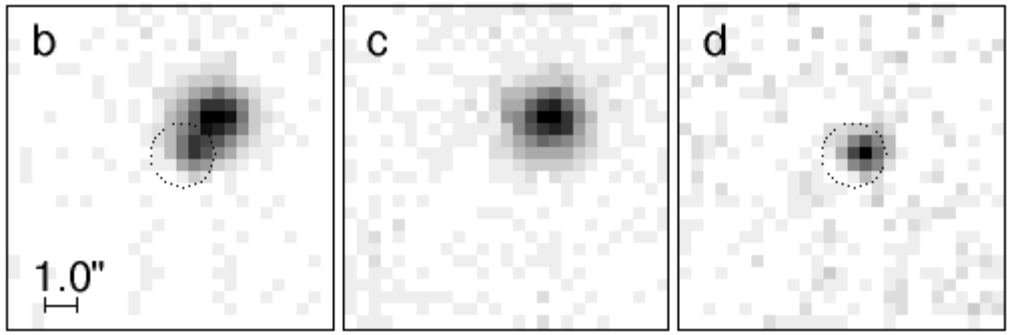
GRB 050709

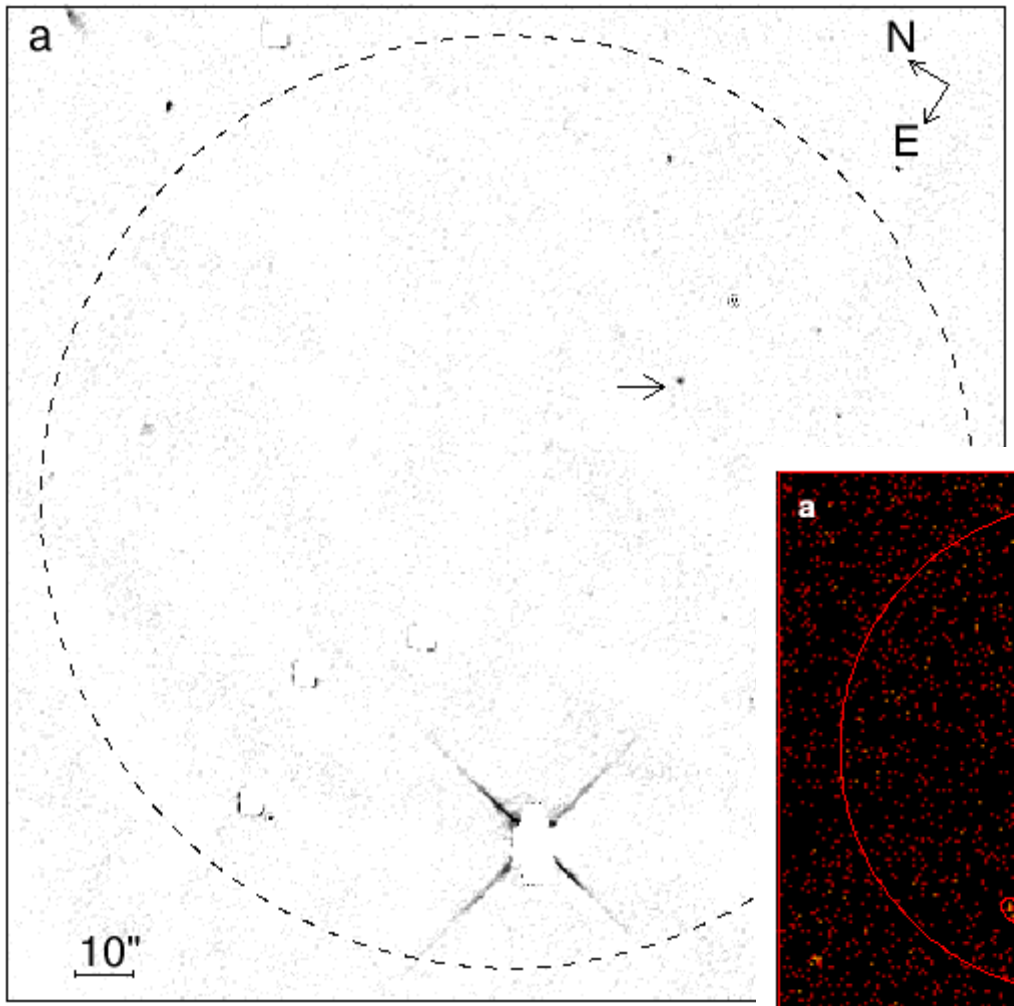

WXM Counts/s [2-25 keV]
Seconds Since GRB050709 Trigger
30-400 keV
2-25 keV

GRB 050709


Spectral Hardness (Channel 3 / Channel 2)
10
1
0.1
050509B
050709
HETE-2 HRs (90%)
SHORT
LONG
0.01
0.1
1
10
100
1000
Duration (s)

GRB 050709





TITLE: GCN GRB OBSERVATION REPORT
NUMBER: 3612
SUBJECT: GRB 050709: optical afterglow candidate
DATE: 05/07/14 22:04:37 GMT
FROM: Paul Price at IfA,UH <price@ifa.hawaii.edu>

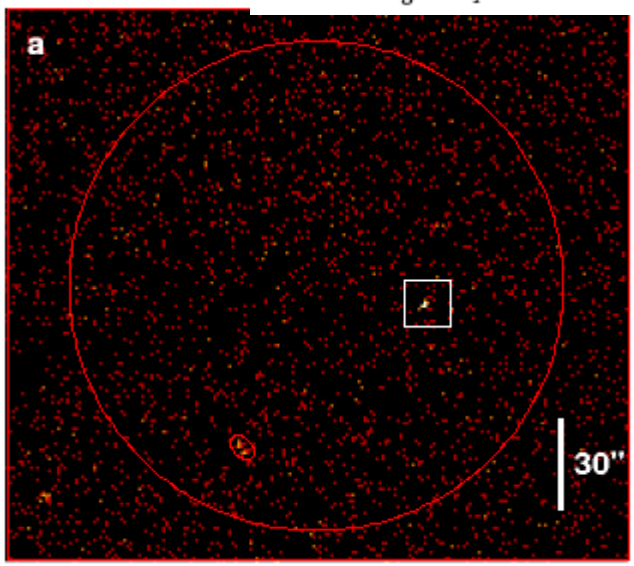
P. A. Price (IfA, Hawaii), B. L. Jensen, U. G. Jargensen, J. Hjorth, J. P. U. Fynbo, D. Watson, J. M. Castro Ceron, K. Pedersen, H. Pedersen, and J. Sollerman (DARK Cosmology Centre, Niels Bohr Institute) report:

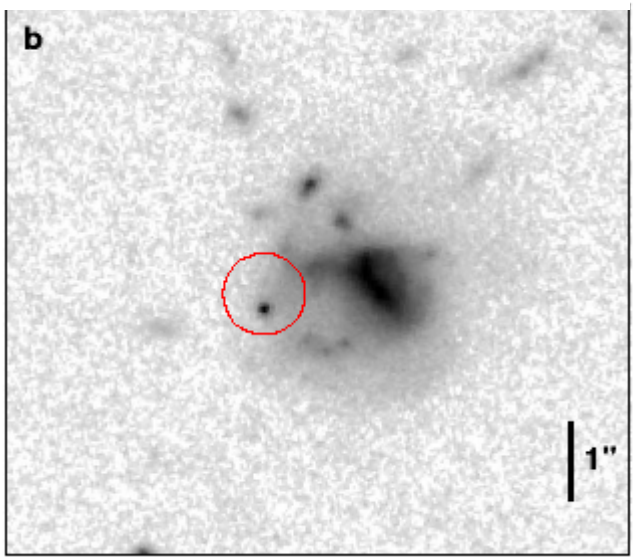
We have performed PSF-matched image subtraction on the images acquired by Jensen et al. (GCN #3589). The images were obtained from the Danish 1.54m+DFOSC at La Silla on 2005 July 11.3 and 12.3 UT.

PSF-matched image subtraction using the Pan-STARRS Optimal Image Subtraction (POI Sub) code reveals a residual, in the sense that the source fades between the first and the second epochs. The position of the variable source corresponds to the source identified by Jensen et al. (GCN #3589) on the edge of a nearby galaxy (z=0.16; Price, Roth & Fox, GCN #3605) as consistent with the Chandra source (Fox et al., GCN #3585). This detection of optical variability increases the likelihood that this source is the afterglow of the short/hard GRB 050709.

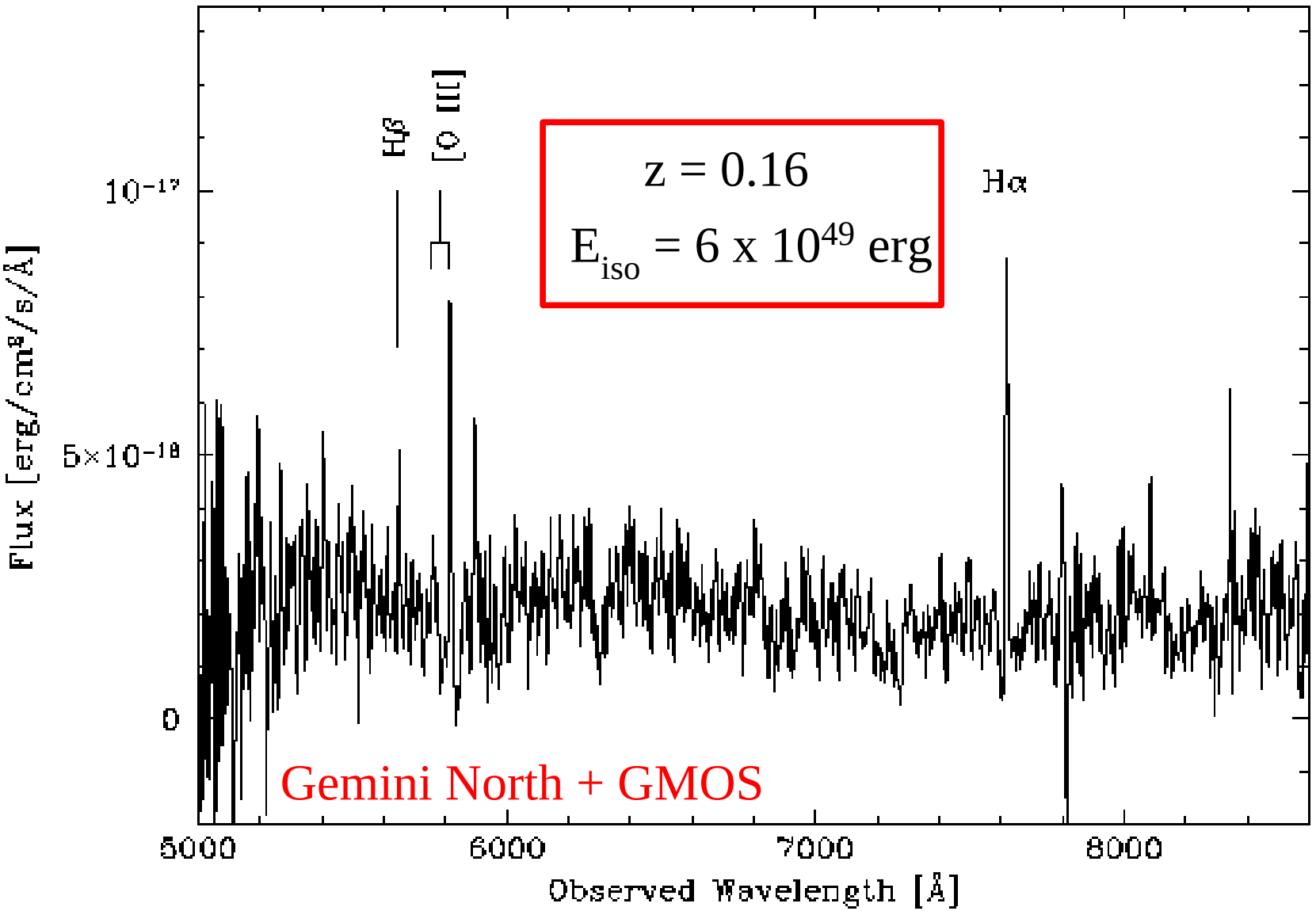
A figure showing the subtraction is available at
http://www.ifa.hawaii.edu/~price/grb050709candidate.jpg

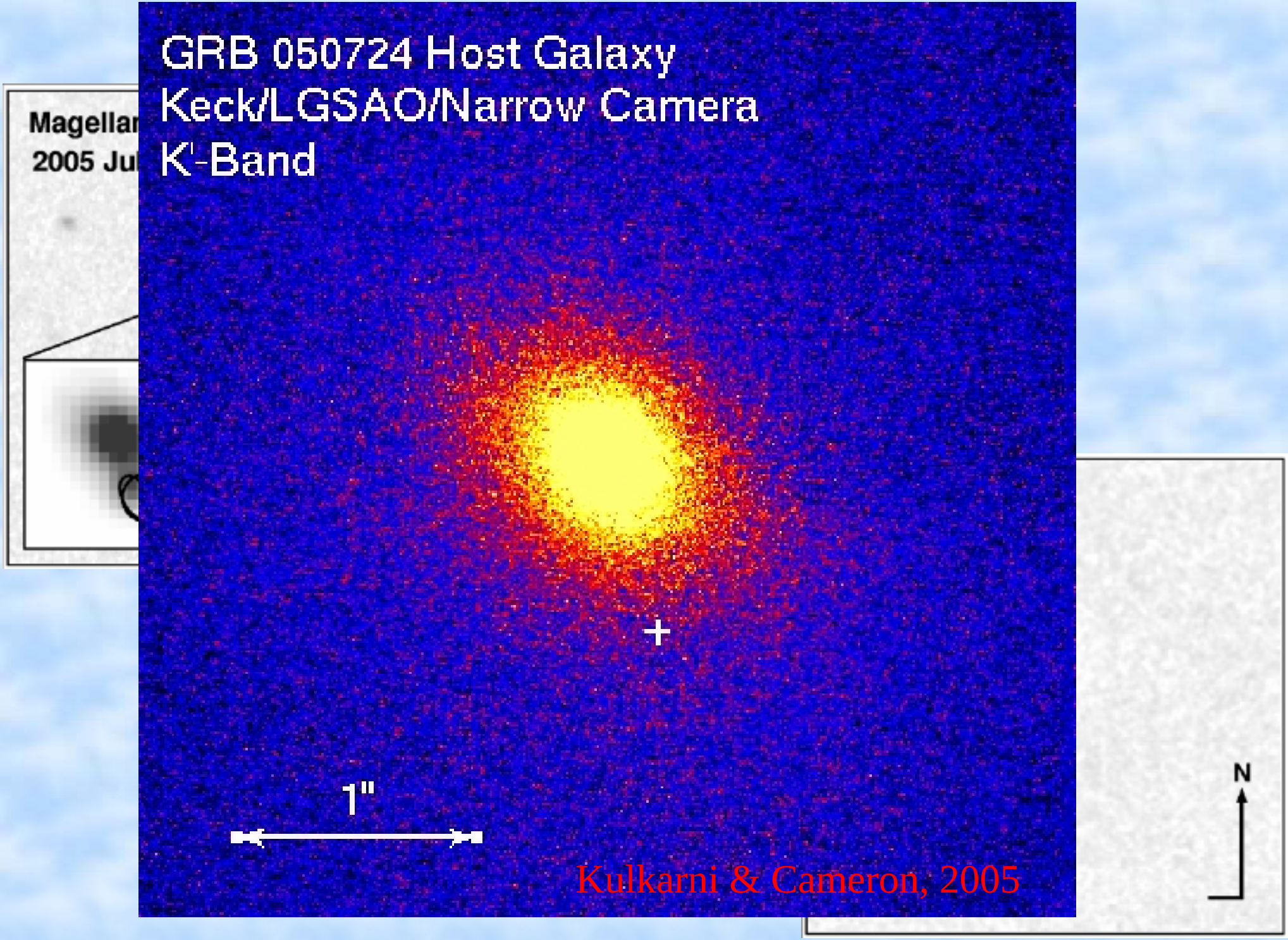
This message may be cited.



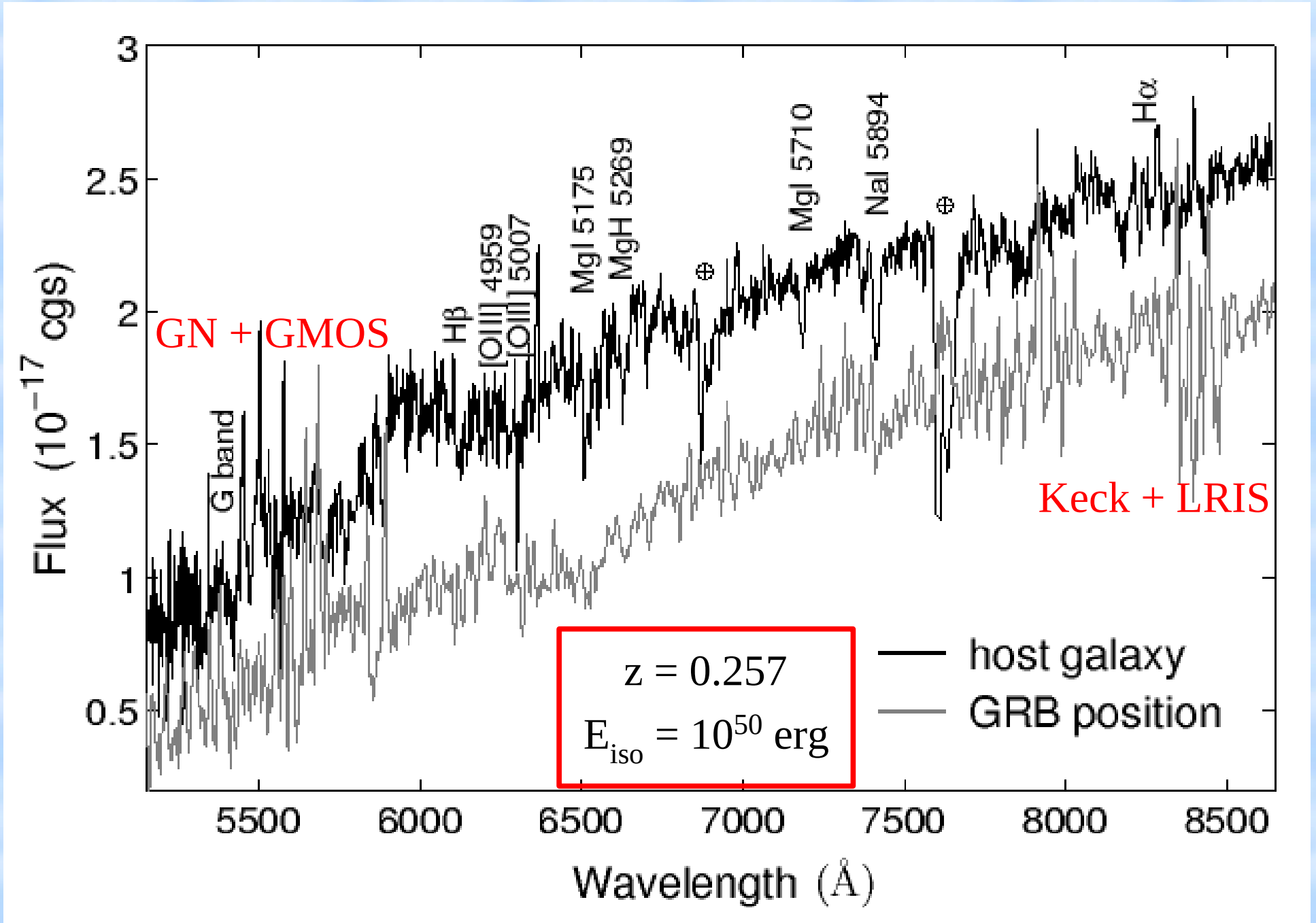


GRB 050709


z = 0.16
E_{iso} = 6 x 10^{49} erg
Hβ
[O III]
Hα
Gemini North + GMOS
Flux [erg/cm²/s/Å]
10⁻¹⁷
5×10⁻¹⁸
0
5000
6000
7000
8000
Observed Wavelength [Å]


GRB 050724 Host Galaxy
Keck/LGSAO/Narrow Camera
K'-Band
1"
N
Kulkarni & Cameron, 2005

GRB 050724

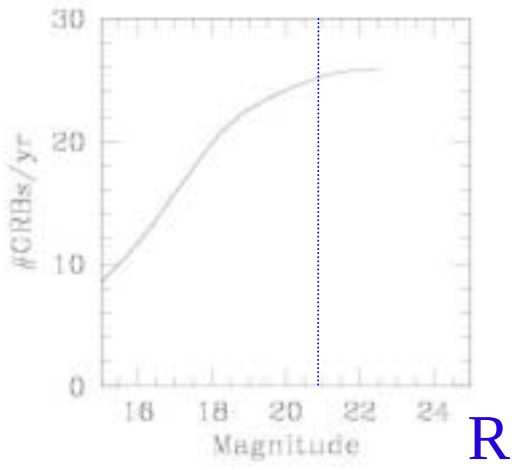

GN + GMOS
Keck + LRIS
G band
Hβ
[OIII] 4959
[OIII] 5007
MgI 5175
MgH 5269
MgI 5710
NaI 5894
Hα
⊕
⊕
z = 0.257
E_iso = 10^50 erg
host galaxy
GRB position
Flux (10^-17 cgs)
Wavelength (Å)
0.5
1
1.5
2
2.5
3
5500
6000
6500
7000
7500
8000
8500

Some short conclusions

- Short/hard GRBs are of cosmological origin
  - Relatively low redshift compared to long/soft GRBs
- Typical energy release of several 10^{49} erg
  - Jets?
- Afterglows typically fainter than for long/soft
  - Brightness correlated with position on host galaxy?
- Observed in both star forming galaxies and ellipticals
  - Points to compact merger

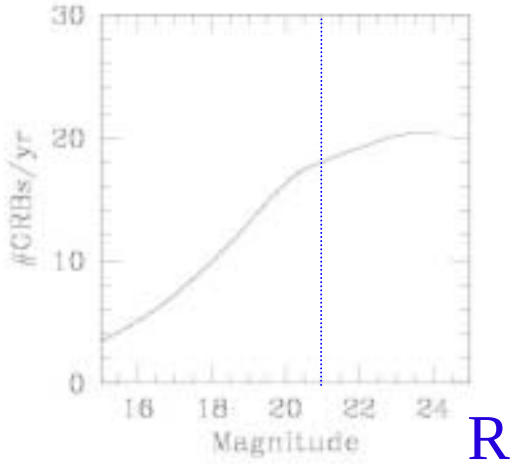
Long/soft GRBs at t_{GRB} + ½ hour

0.5 < z < 1.5



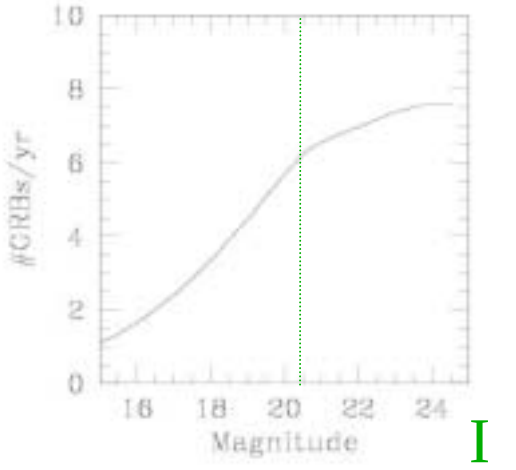
R

2.5 < z < 3.5



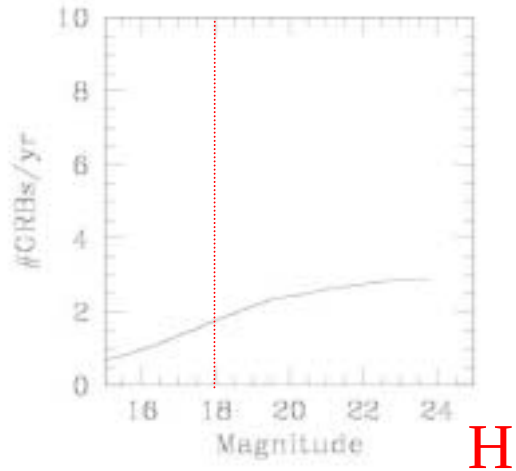
R

4.5 < z < 5.5



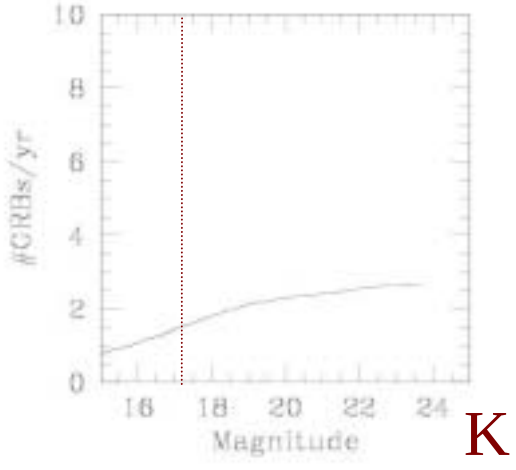
I

7 < z < 8



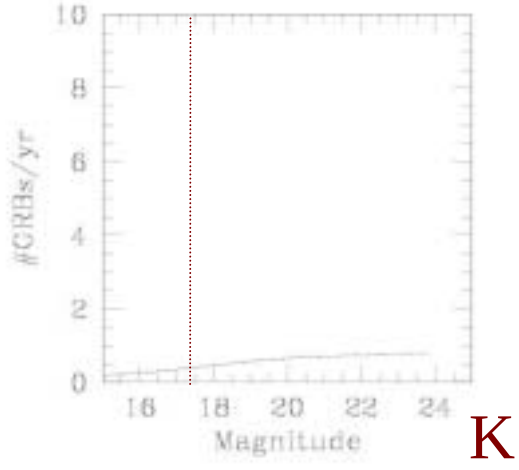
H

9 < z < 11



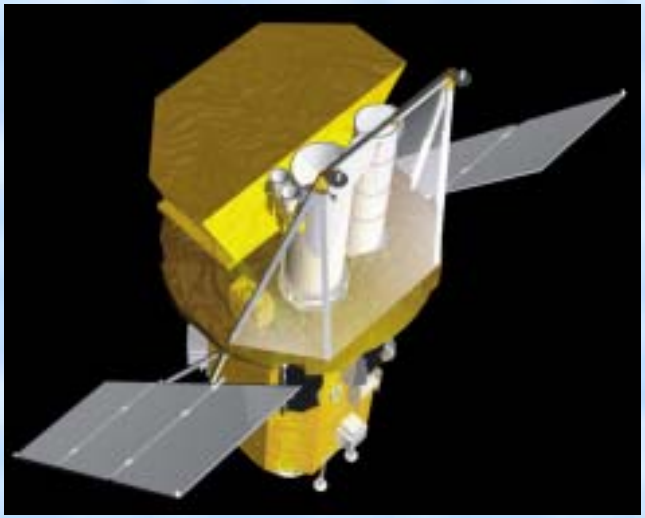
K

14 < z < 16

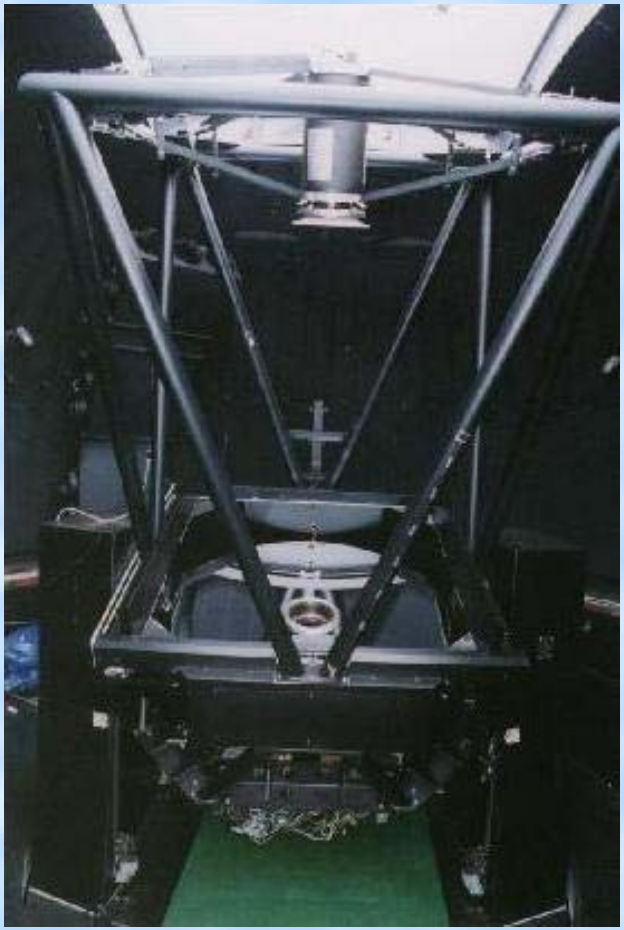


K

To the Edge of the Universe...



Swift:
x-ray position to a few arcsec

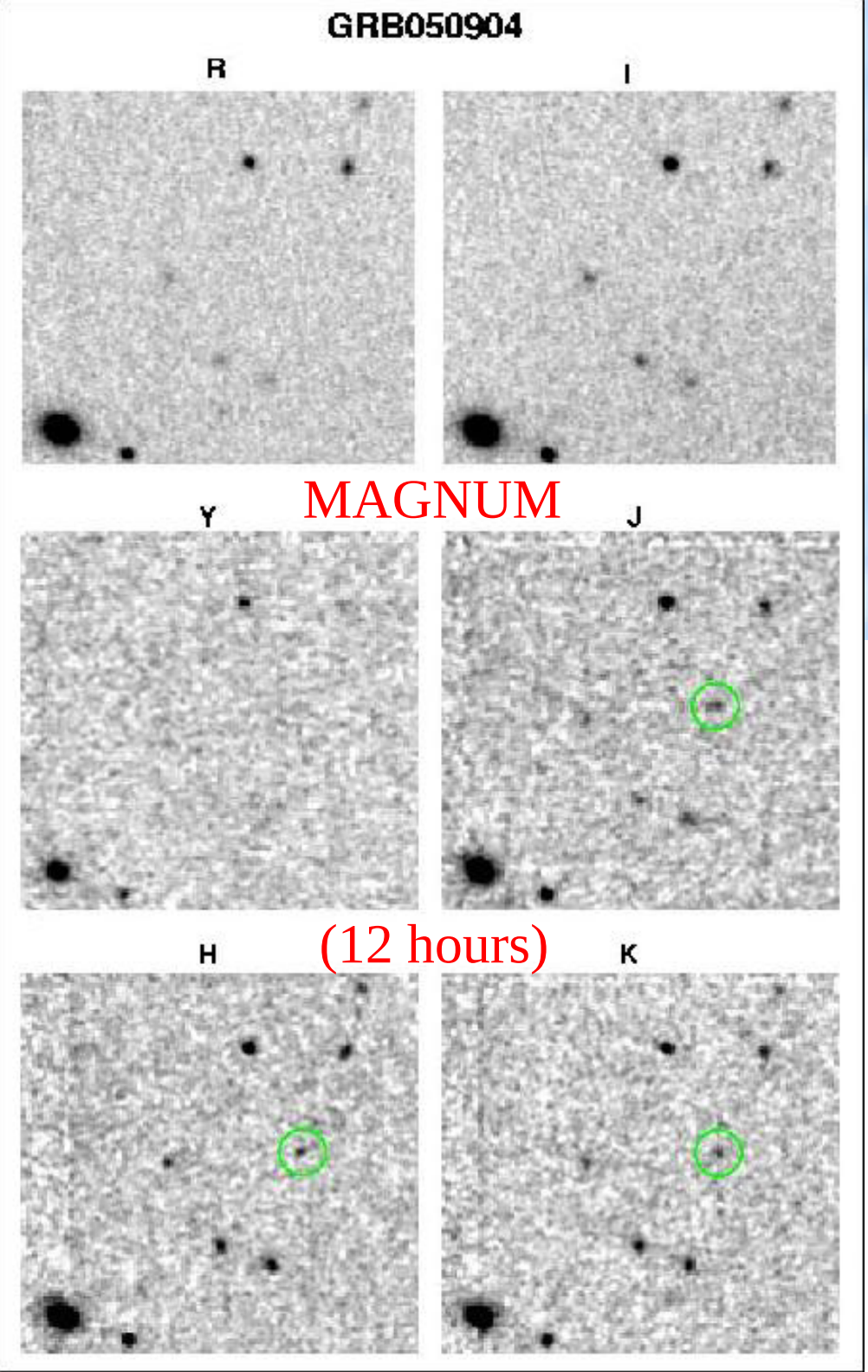


MAGNUM:
Precise position, colour

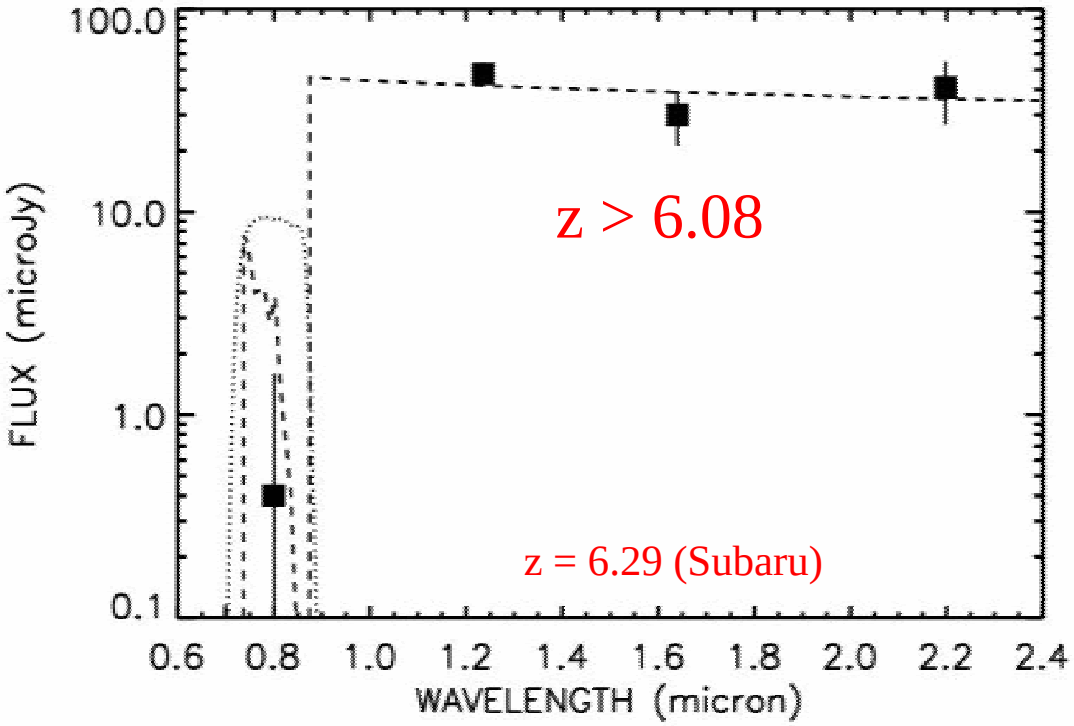
Gemini North:
Spectroscopy

Gemini ToOs

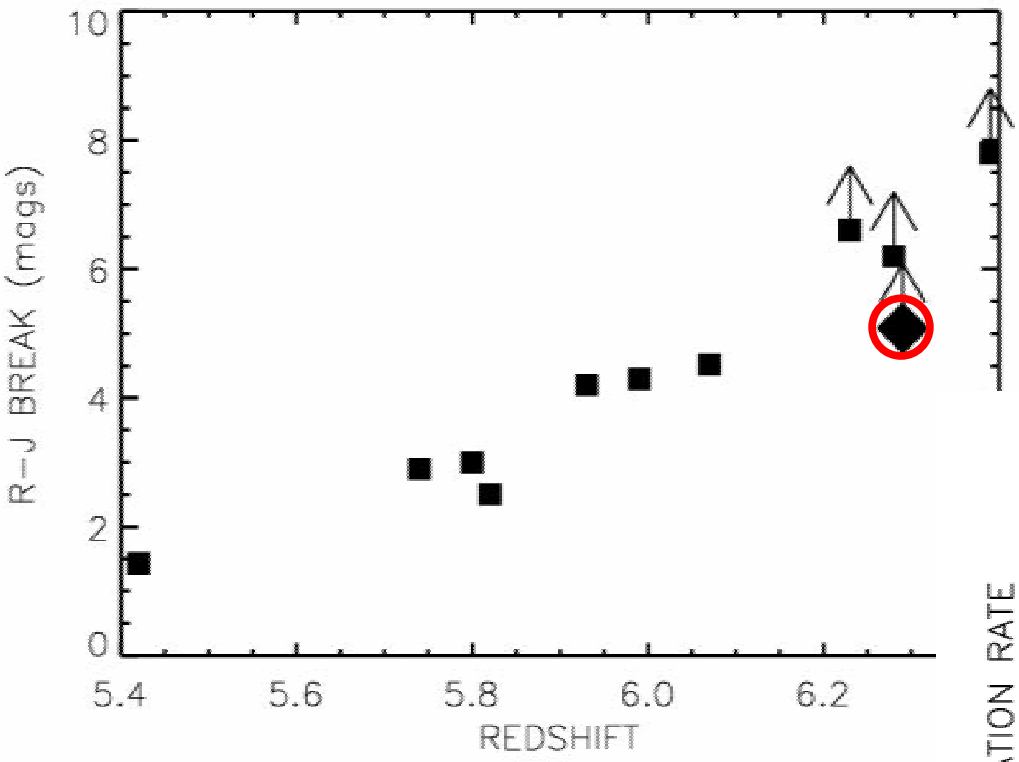
- Gemini observes (mostly) in queue mode, so minimal interruption to observers
- Telescope and instrument status available on www
- Pre-defined observation templates: easy
- Jukebox instruments: can observe in both optical and NIR
- Trigger via Observing Tool or www: no phone calls!
- ./gemini.pl GN-2007A-Q-19 BLAH 140 Swift263361 9:52:23.52 10:28:57.72 NIRI -note “Please observe this GRB as soon as possible.”
- https://128.171.88.221:8443/too?prog=GN-2007A-Q-19&password=BLAH&obsnum=140&target=Swift263361&ra=9:52:23.52&dec=10:28:57.72&note=Please%20observe%20this%20GRB%20as%20soon%20as%20possible%2E%0A&posangle=0&ready=true&group=Swift263361&gstarget=1005-0178236&gsra=9:51:57.44&gsdec=10:30:33.86&gsmag=13.88&gsprobe=PWFS2

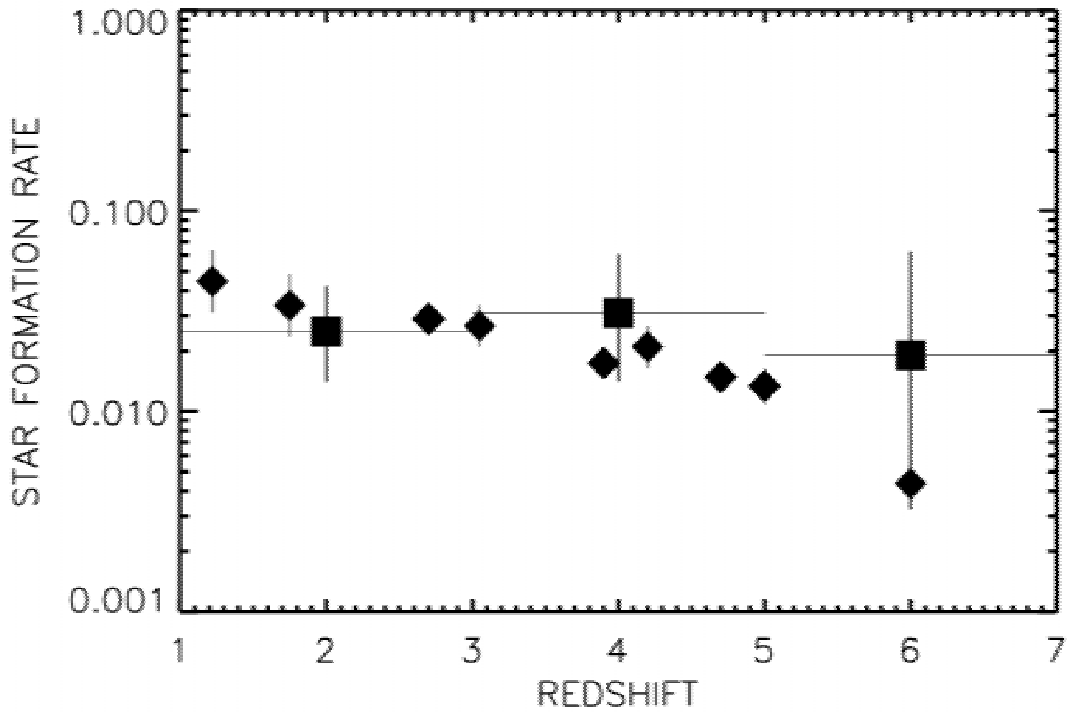


- 4' position from Swift
- Optical observations at 3h didn't see anything
- Bright NIR afterglow

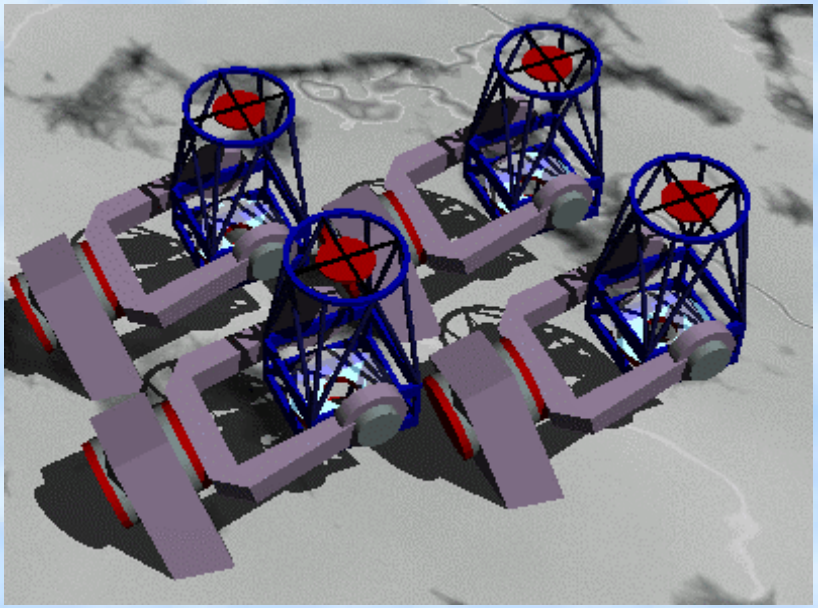


GRB 050904 for Cosmology





Processing Petabytes for Pan-STARRS



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Eugene Magnier, Joshua Hoblitt, Nick Kaiser

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ASTRONOMY

MAUI HIGH PERFORMANCE COMPUTING CENTER

SAIC Science Applications International Corporation An Employee-Owned Company

LINCOLN LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Pan-STARRS

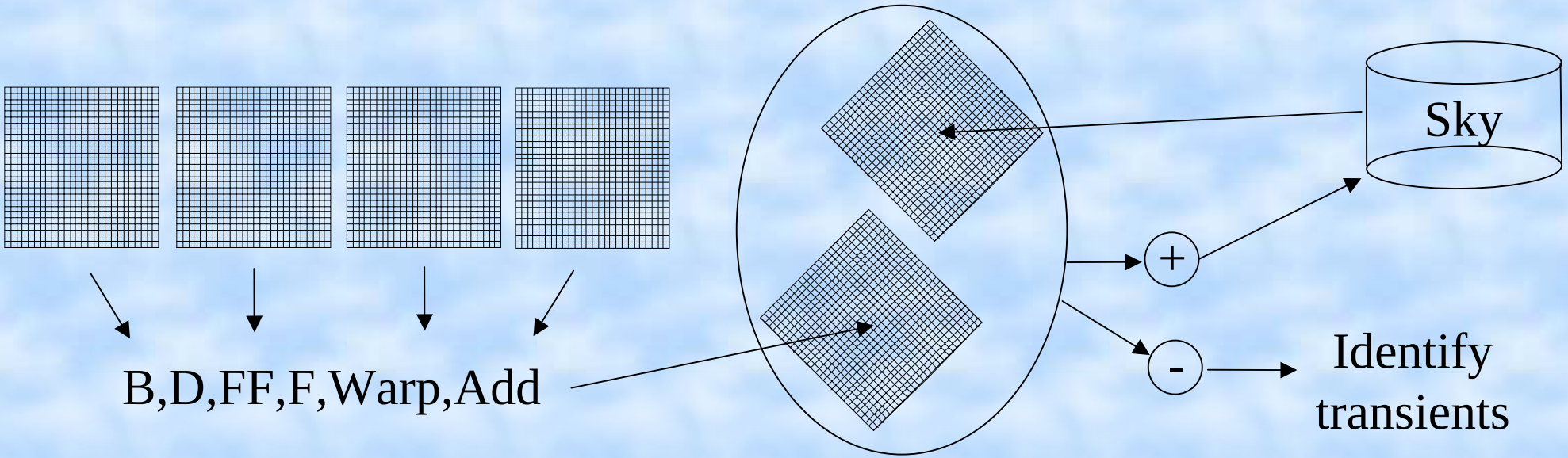
- Panoramic Survey Telescope And Rapid Response System
- A fore-runner to the LSST, funded by AFRL
- A dedicated optical survey instrument, 54 $m^2 deg^2$
  - 4 individual 1.8m telesecopes, each with a gigapixel camera
  - Orthogonal transfer CCDs
- Mission:
  - Secure future employment for Bruce Willis
  - To boldly see what no-one has seen before
  - Things that go bump in the night

The Data Reduction Challenge

- PS1: 1.4 Gpix / 35 sec --> 2.8 TB raw data per night
- PS4: 5.6 Gpix / 35 sec --> 11.5 TB raw data per night
- Must process data in near-real time to avoid drowning in data, and in order to identify TGBN
- Finite $$$, personnel, time
- Can't afford ($ or time) to reprocess the data many times
- Identification of TGBN must be of high quality: can't afford an army of grad students
- For testing purposes, want a flexible system that can be used to reduce other mosaic data (e.g., MegaCam, SuprimeCam, YourCameraHere)
- Keep all the collaborators happy (all things to all researchers?)

Required Operations

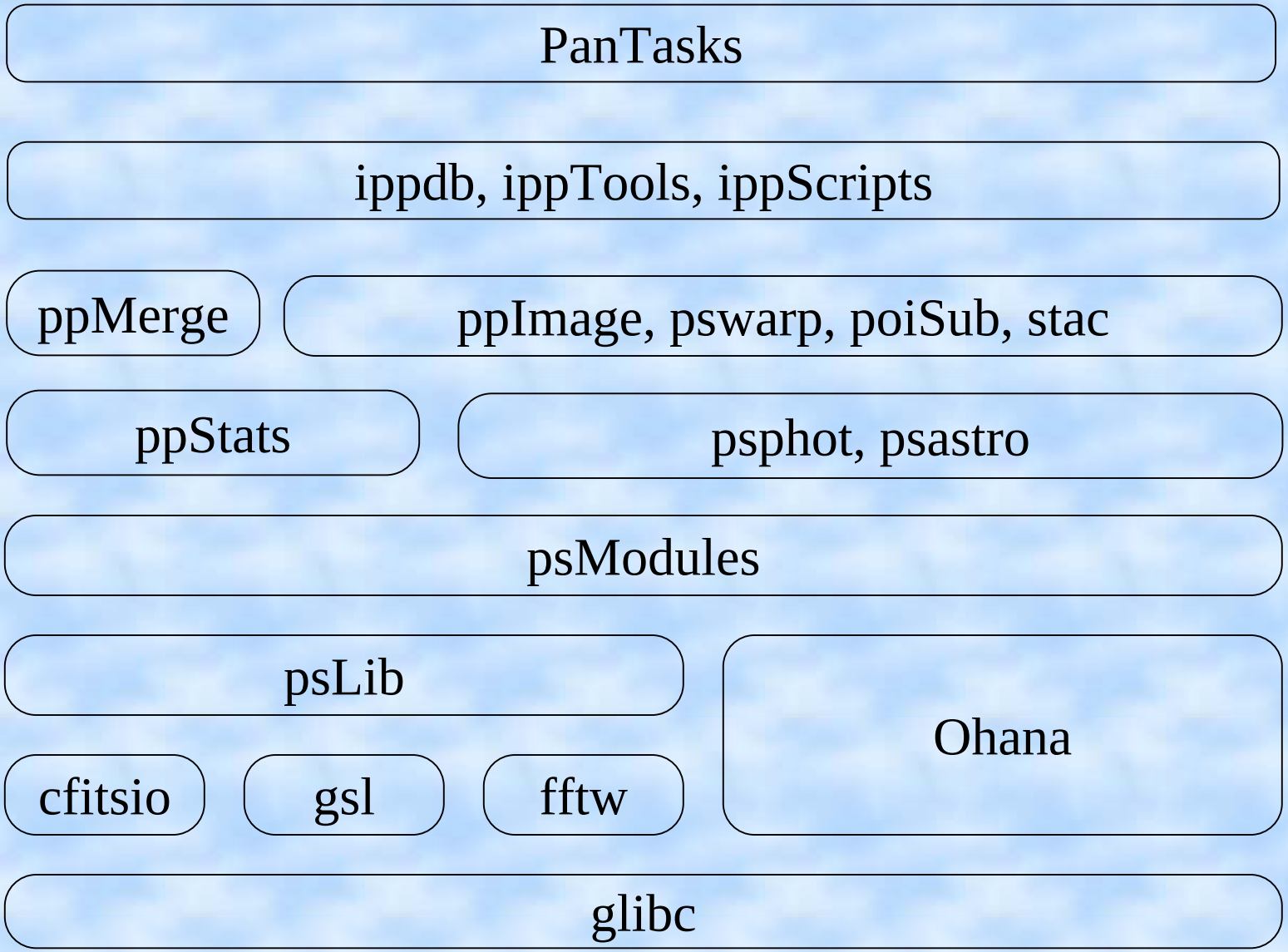
- Detrend: Bias, dark, flat-field, fringe
- Photometry and astrometry of objects
- Warp images to sky
- Subtract template sky; identify and characterise transients
- Combine multiple exposures; more photometry
- Generate master detrend images / validate new detrend images



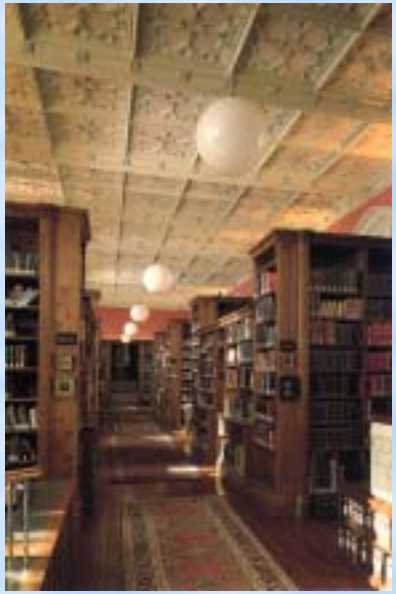
Hardware

5U Dual-dual Opteron

Software Hierarchy

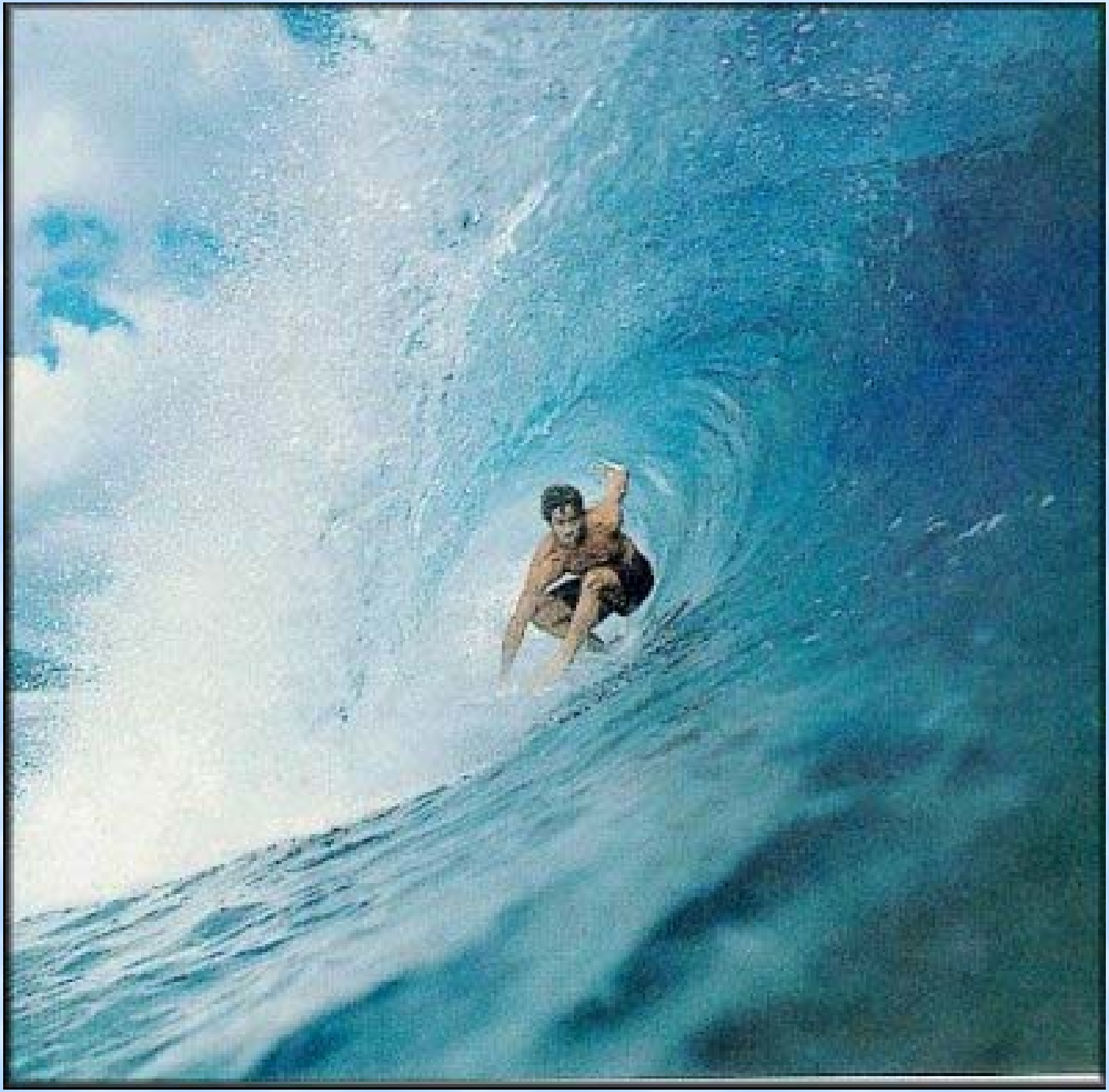


psLib

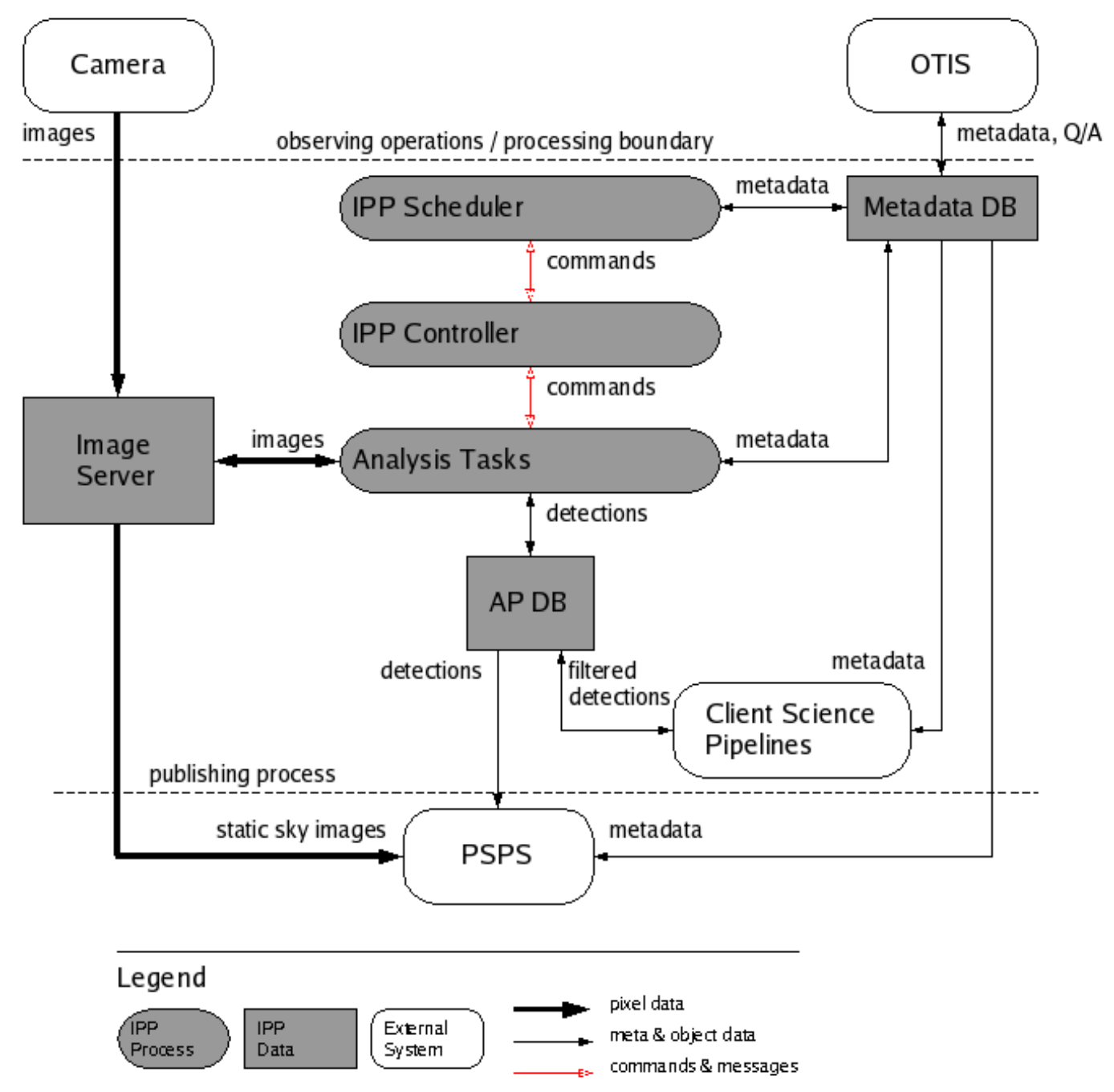


- System utilities: Memory allocation, tracing, logging, errors
- Data collections: linked lists, hashes, arrays, metadata
- Arithmetic: Vectors/matrix operations, statistics, polynomial fitting, spherical geometry
- Simple image handling: rotations, extractions, FITS
- Time handling: UTC, LST, JD, leap seconds...
- Database interaction: mysql

Pipeline



Pipeline


Camera
OTIS
images
observing operations / processing boundary
metadata, Q/A
IPP Scheduler
metadata
Metadata DB
commands
IPP Controller
commands
Image Server
images
Analysis Tasks
metadata
detections
AP DB
detections
filtered detections
metadata
Client Science Pipelines
publishing process
static sky images
PSPS
metadata
Legend
IPP Process
IPP Data
External System
pixel data
meta & object data
commands & messages

Pipeline Phases

- Register – Ingest images + metadata into database
- Guide – Determine rough astrometry and QA from guide stars
- Chip – Apply detrend images, performs basic object detection, determines improved astrometry and photometry
- Camera – Tweak astrometry, photometry
- Warp – Warp images to the sky
- Diff – Difference sky image against a template, photometry and astrometry of variable objects
- Stack – Combine multiple sky images, photometry and astrometry on combined image
- Detrend – Process, combine, normalise, and reject detrend images

Final Data Products

- Subtracted images
- List of variables identified in subtracted images
- Static sky images
- Source catalogues from calibrated and sky images
- Client Science Programs will plug in to have access to the streams (e.g. planet transits)
- Other access via Pan-STARRS Published Science database

Status

- IPP passed CDR January 2006
- psLib mostly complete
- psModules quite mature
- psphot being validated against SDSS
- Pipeline running register, chip, camera, detrend phases on prototype cluster
- Demonstrated image subtraction and stacking using pipeline
- MegaCam, ISP, CTIO-MOSAIC2