The Robotic Optical Transient Search Experiment (ROTSE)

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May 18, 2009

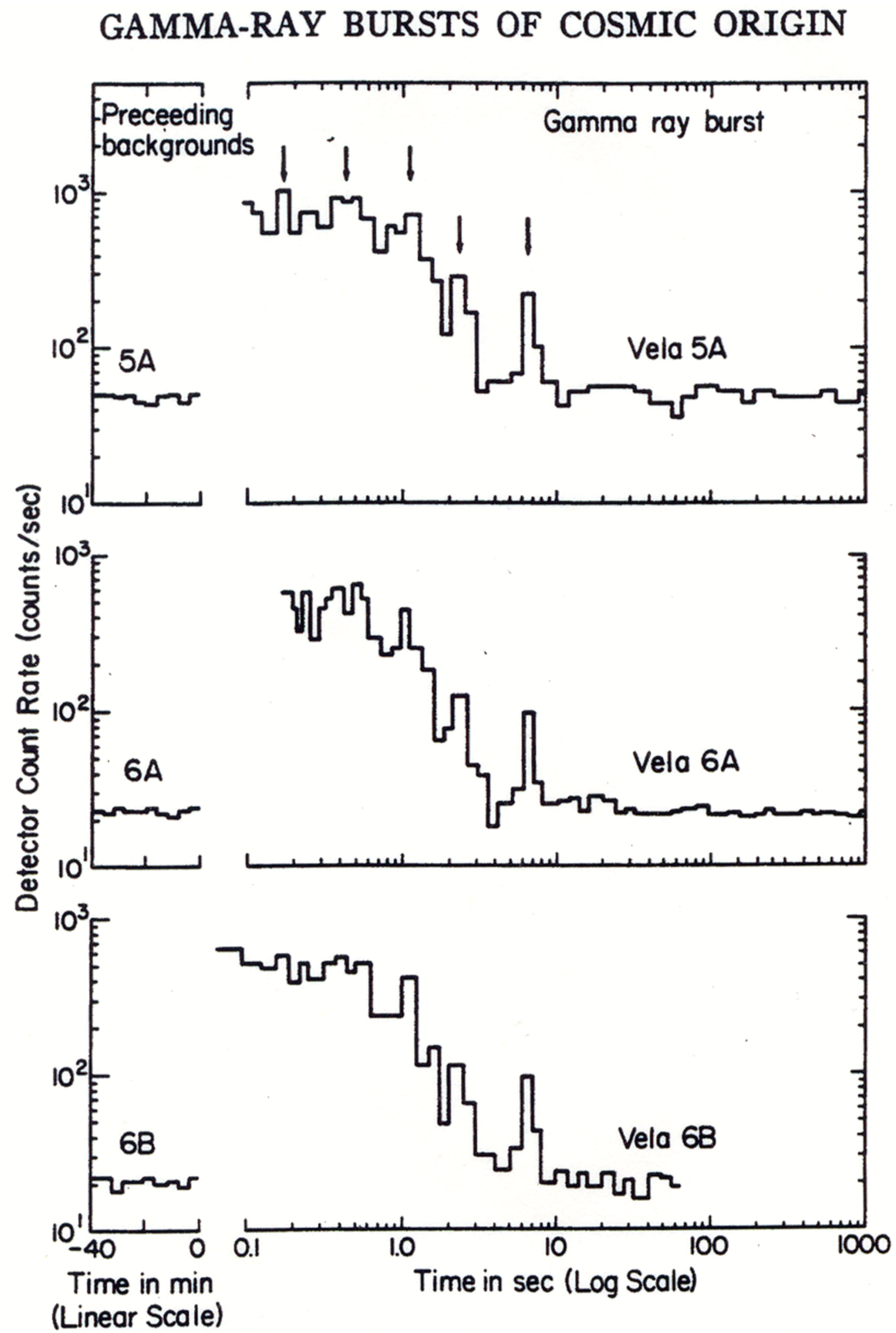
Although the Universe has evolved over a time scale of the order of 10^{10} years, much interest in astrophysics now centers on the behavior of objects over durations of 10^{-3} sec to years. In observing such phenomena, wide field of view, rapid robotic response and extensive data storage are more important than telescope aperture. The ROTSE project has been pursuing this avenue for the past 13 years, finding the optical counterparts of gamma-ray bursts and highly luminous supernovae.

www.rotse.net

GRB 700822

Klebesadel, Strong & Olson

ApJ 182, L85-88 (1973)



16 bursts detected between July 1969 and July 1972 with Vela satellites.

Time Line for GRBs

First pulsar discovered: July 1967

First GRB discovered: July 1969

Gamma-Ray Stars Conference in Taos: July 1986

Compton Gamma-Ray Observatory: April 5, 1991 – June 4, 2000

Huntsville Gamma-Ray Workshop: Oct. 16-18, 1991

Texas/PASCOS conference in Berkeley: December 13-18, 1992
Beginning of BACODINE/GCN and GROCSE collaboration (UM/LLNL)

"Great Debate" - Lamb and Paczynski: April 22, 1995

Beppo-SAX mission: April 30, 1996 - April 29, 2003

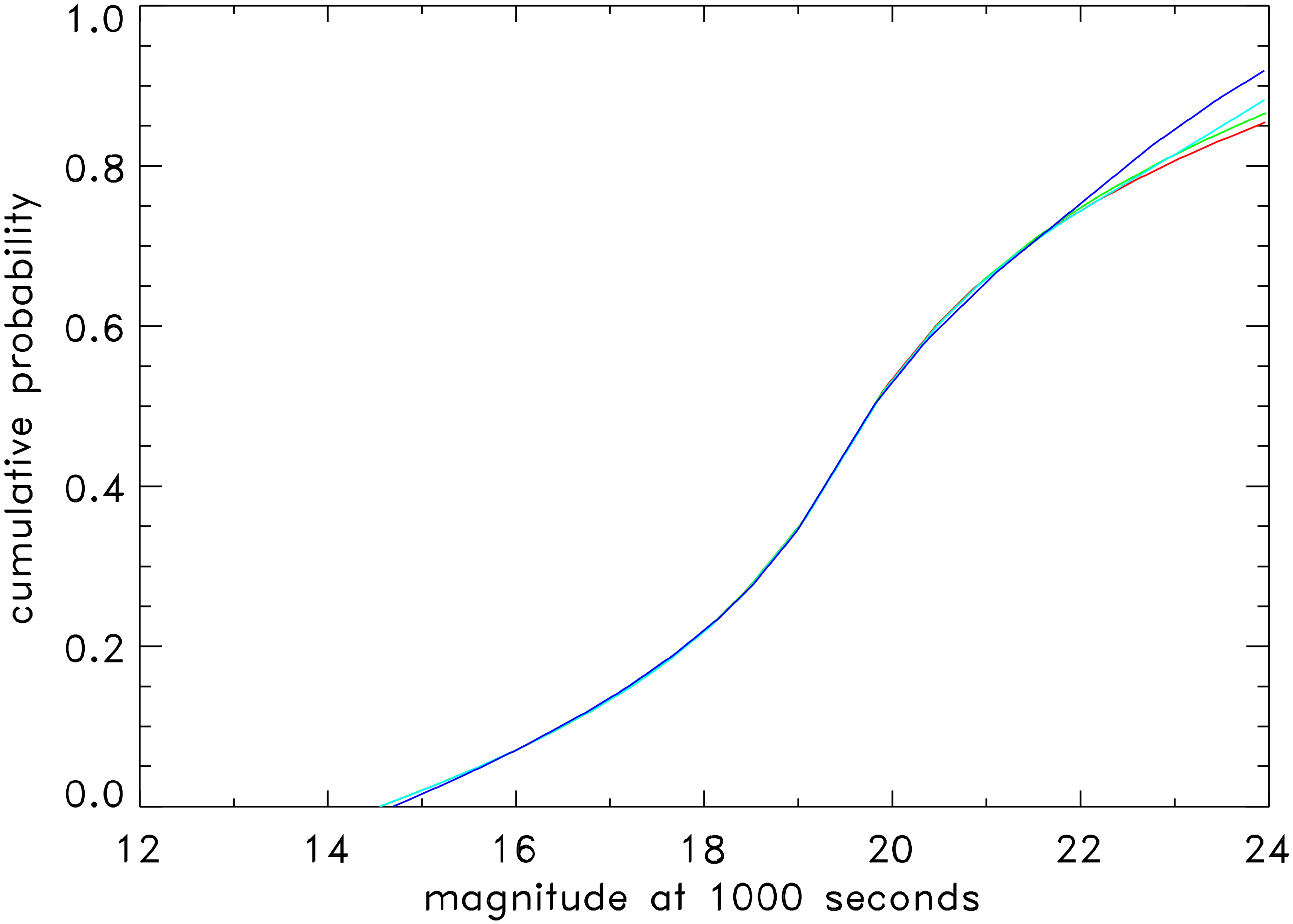
ROTSE Collaboration begins, Michigan & LANL: July 1996

First GRB optical counterpart: GRB 970228

First GRB redshift measurement (~ 1.09): GRB 970508

First GRB contemporaneous optical counterpart: GRB 990123

***Swift* launch: November 20, 2004**

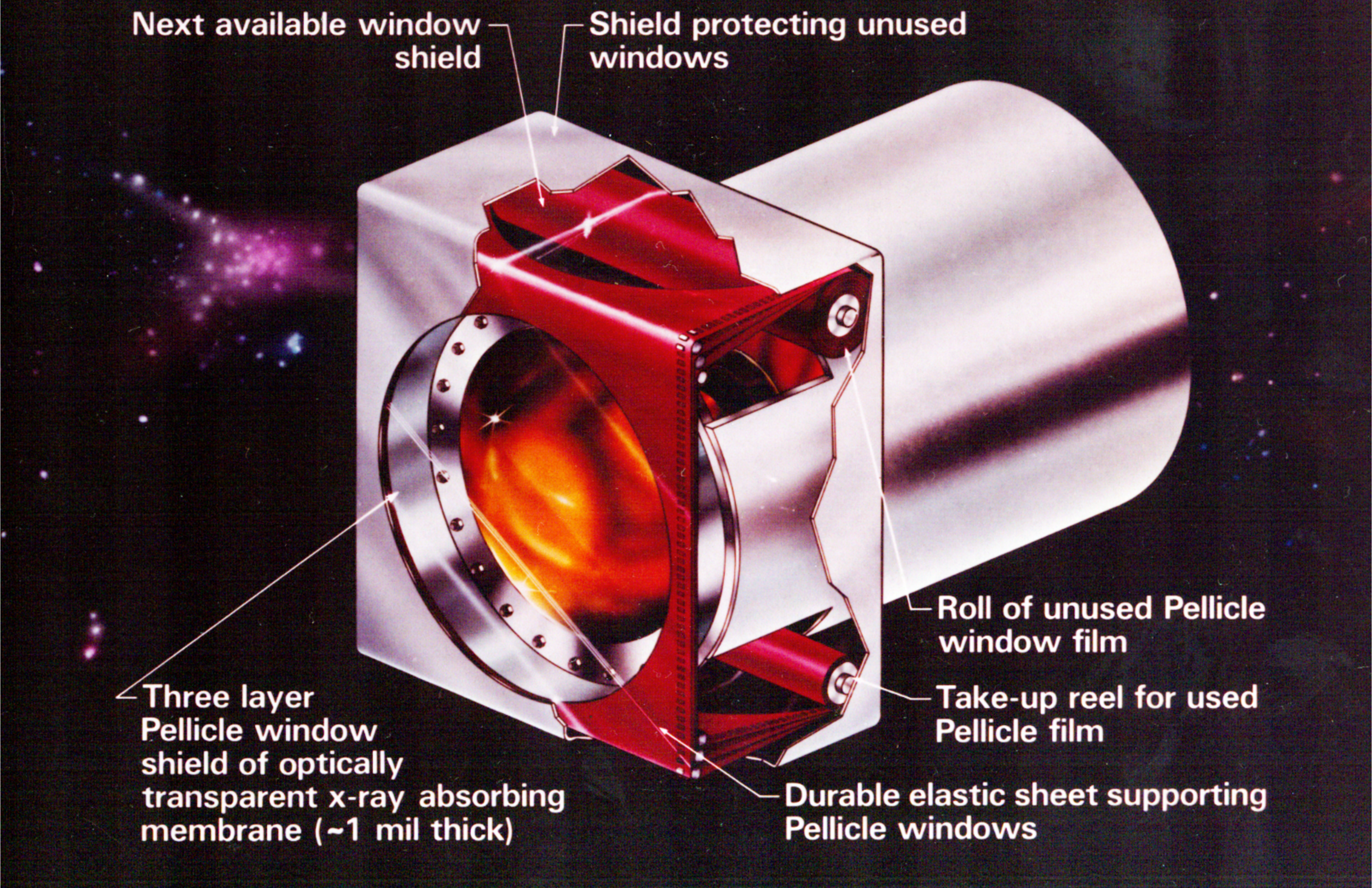


GRB optical afterglow brightness at 1000 s

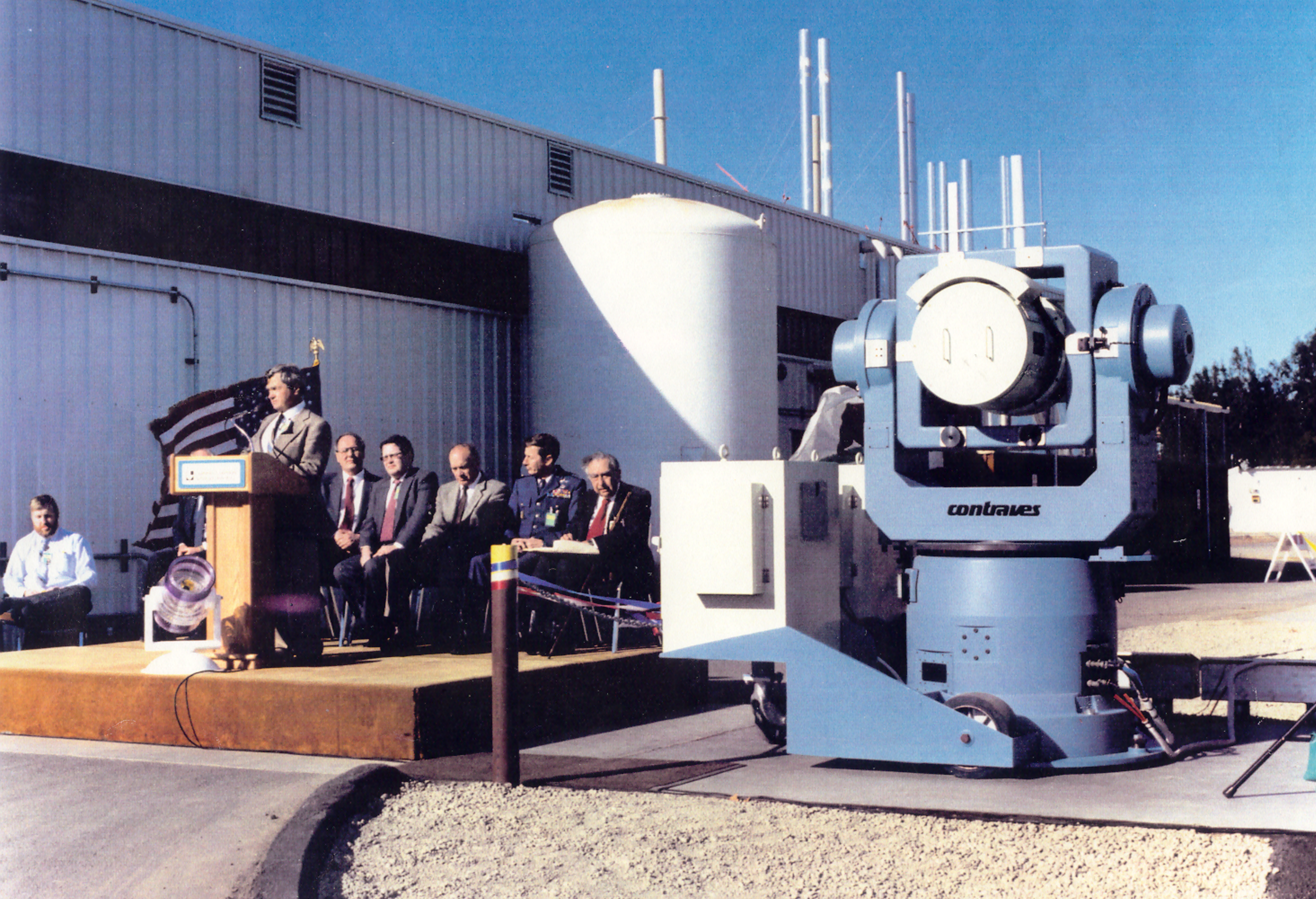
Rate: ~ 1 10^{-6} events str^{-1} s^{-1}

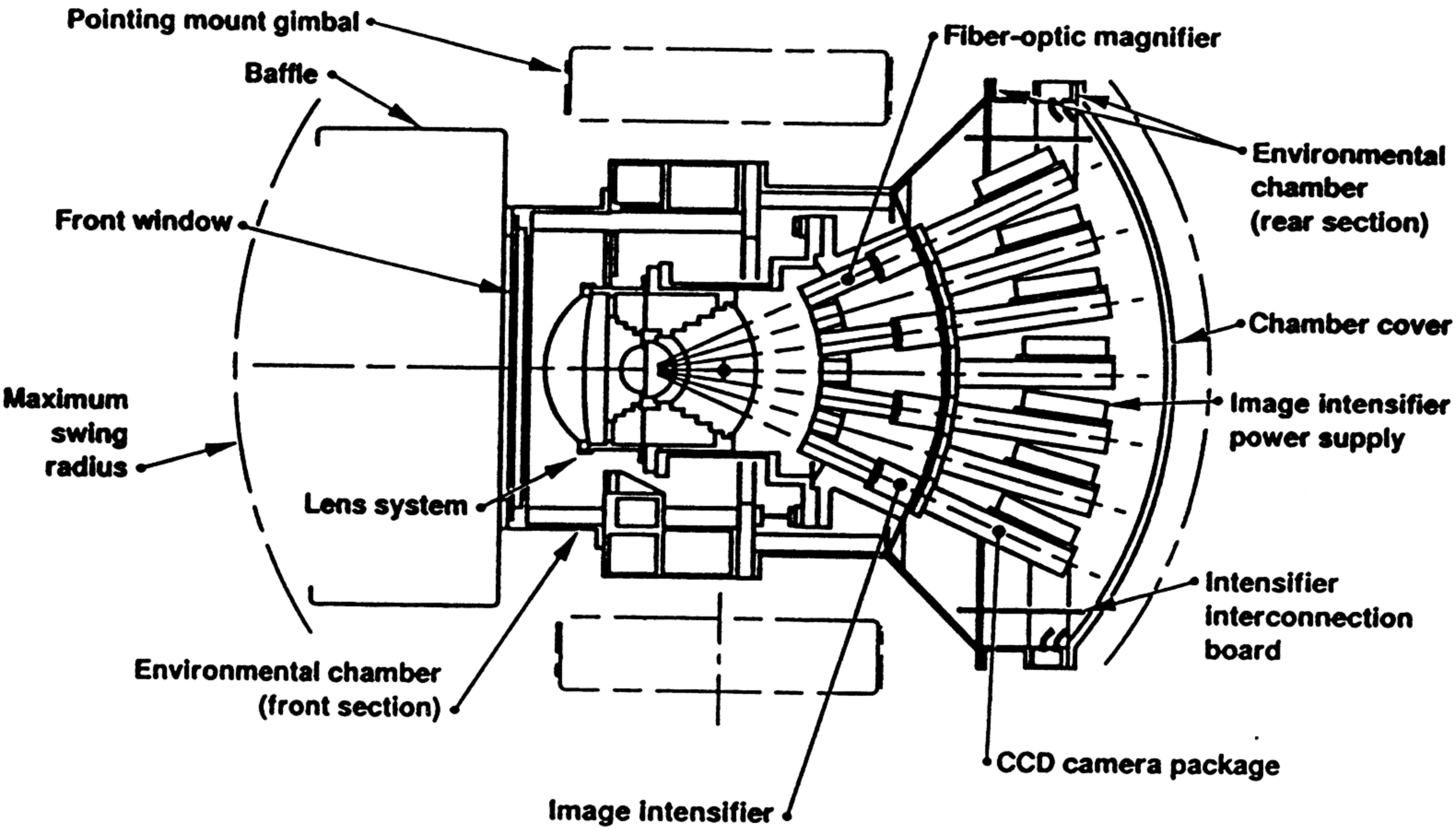
Experimental Design

High-Resolution, Wide Field of View Camera with Optics Shield ("Star Wars" Program)



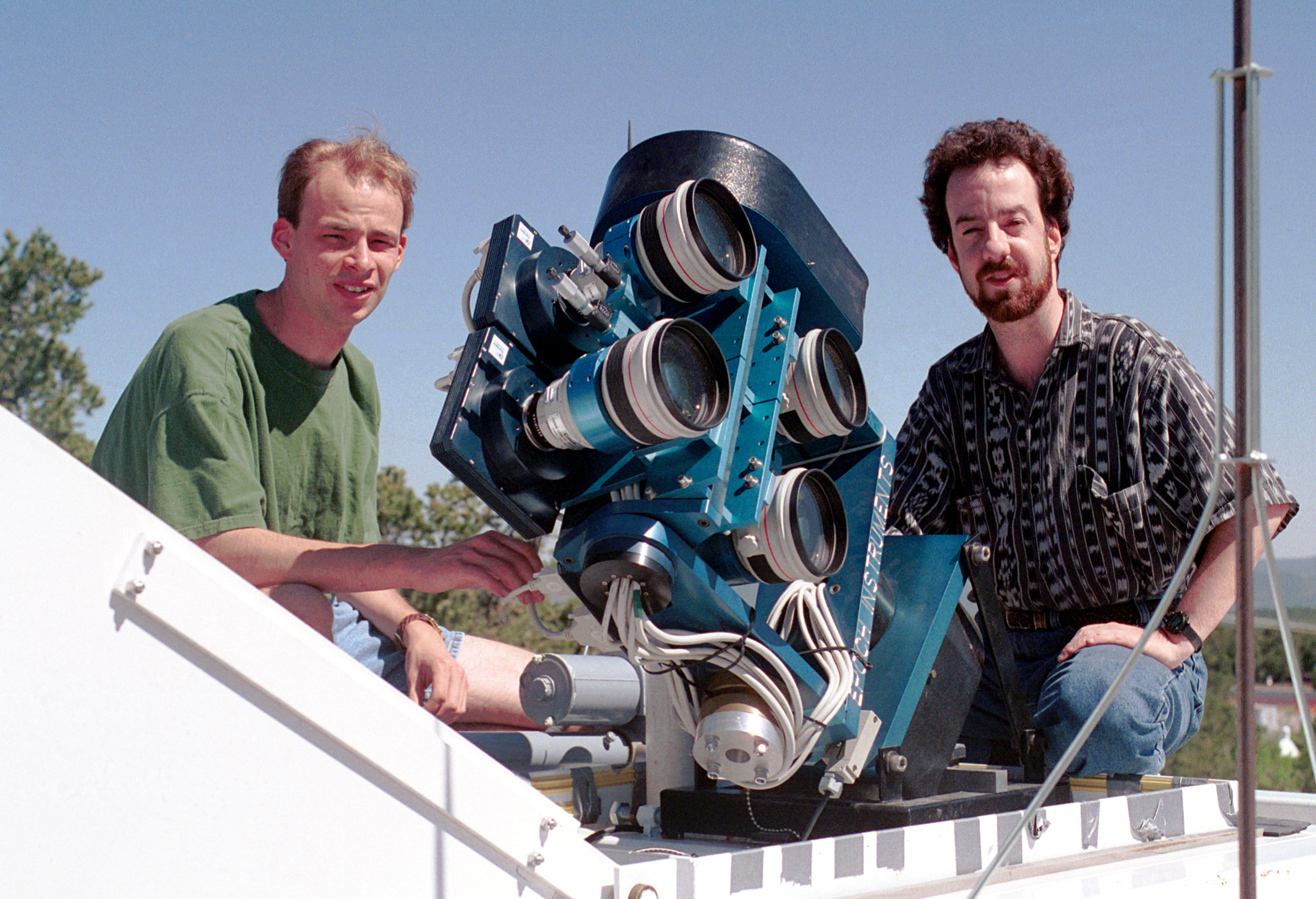
Dedication of LLNL WFOV Camera (1985?)





LLNL Wide-Field-of-View Camera, f/2.8, 250 mm f. l.

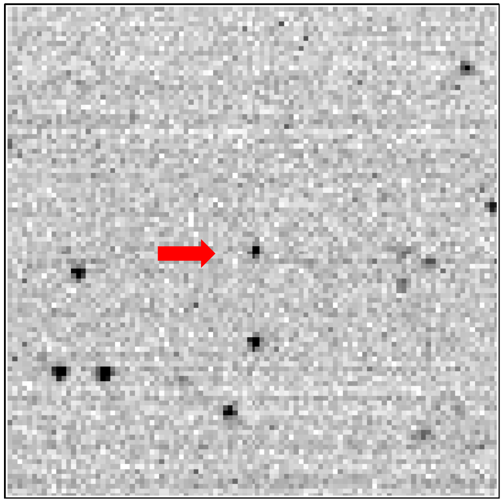
ROTSE-I camera array at Los Alamos National Laboratory



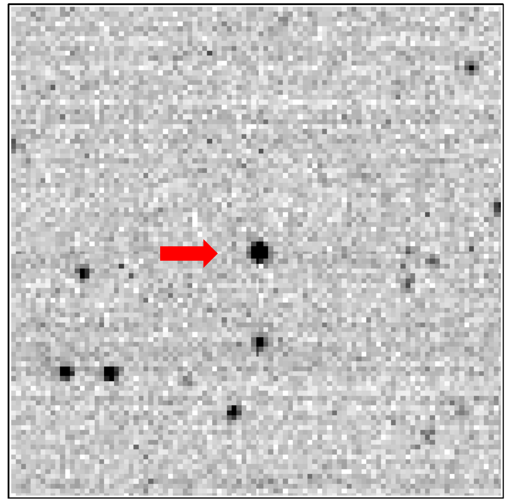
Leonid meter breakup – November 17, 1998

ROTSE-I images of GRB990123 optical counterpart

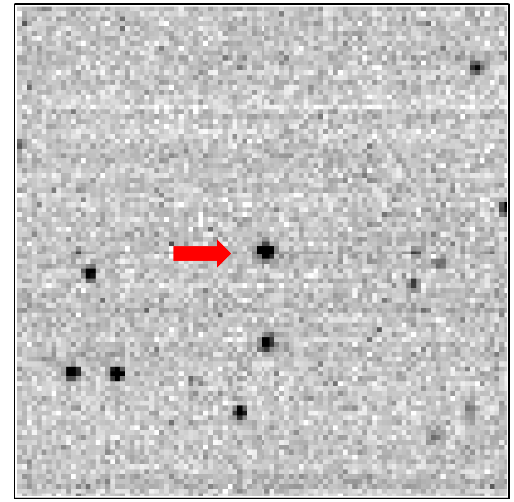
22.18 seconds, V=11.70



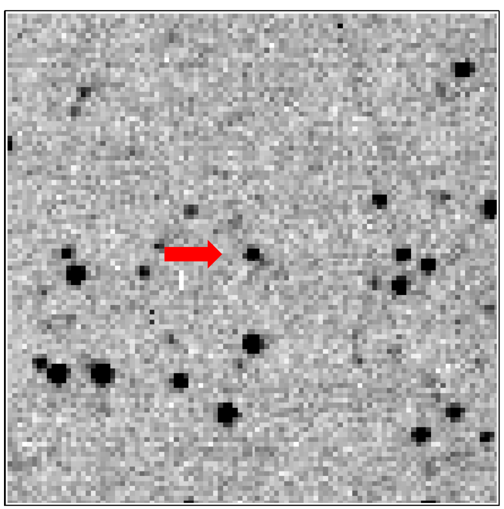
47.38 seconds, V= 8.86



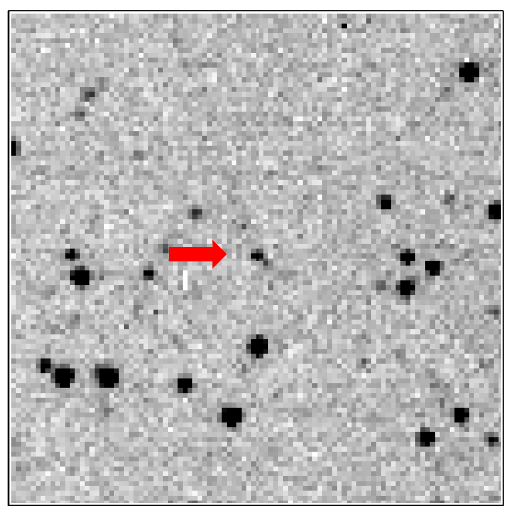
72.67 seconds, V= 9.97



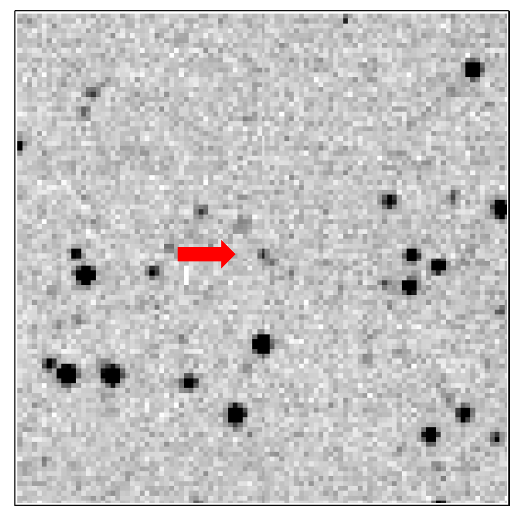
281.40 seconds, V= 13.07

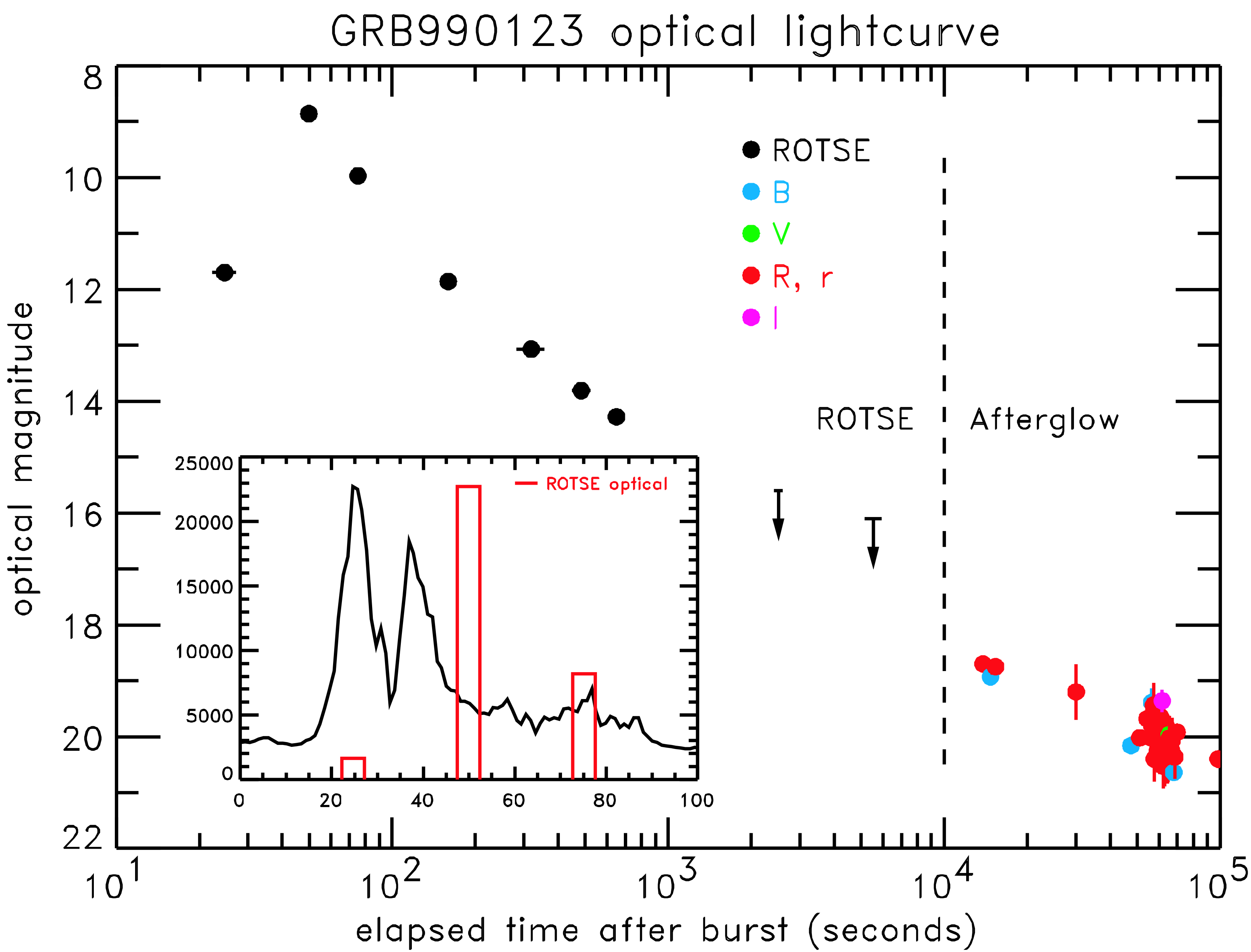


446.67 seconds, V= 13.81

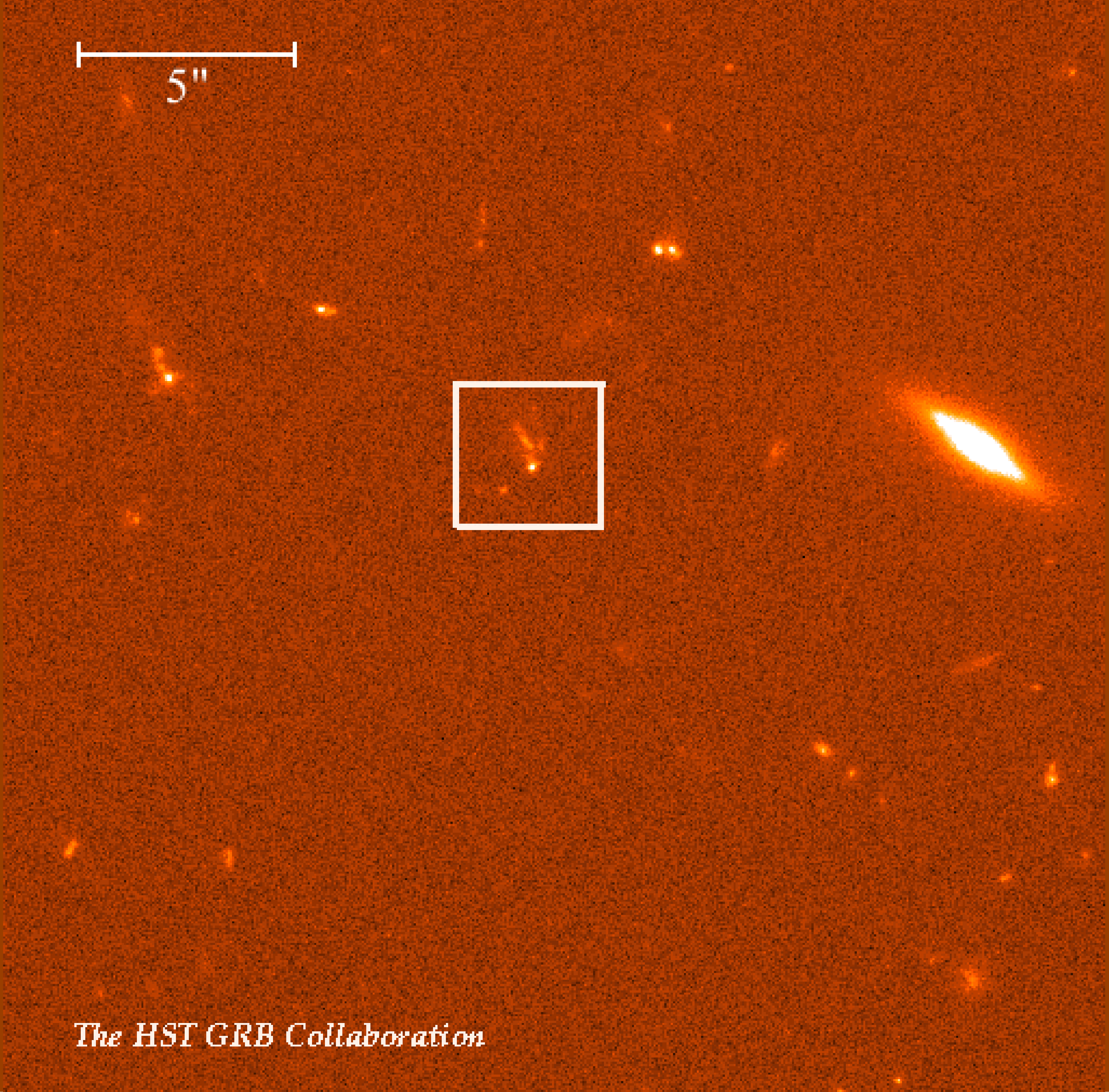


611.94 seconds, V= 14.28





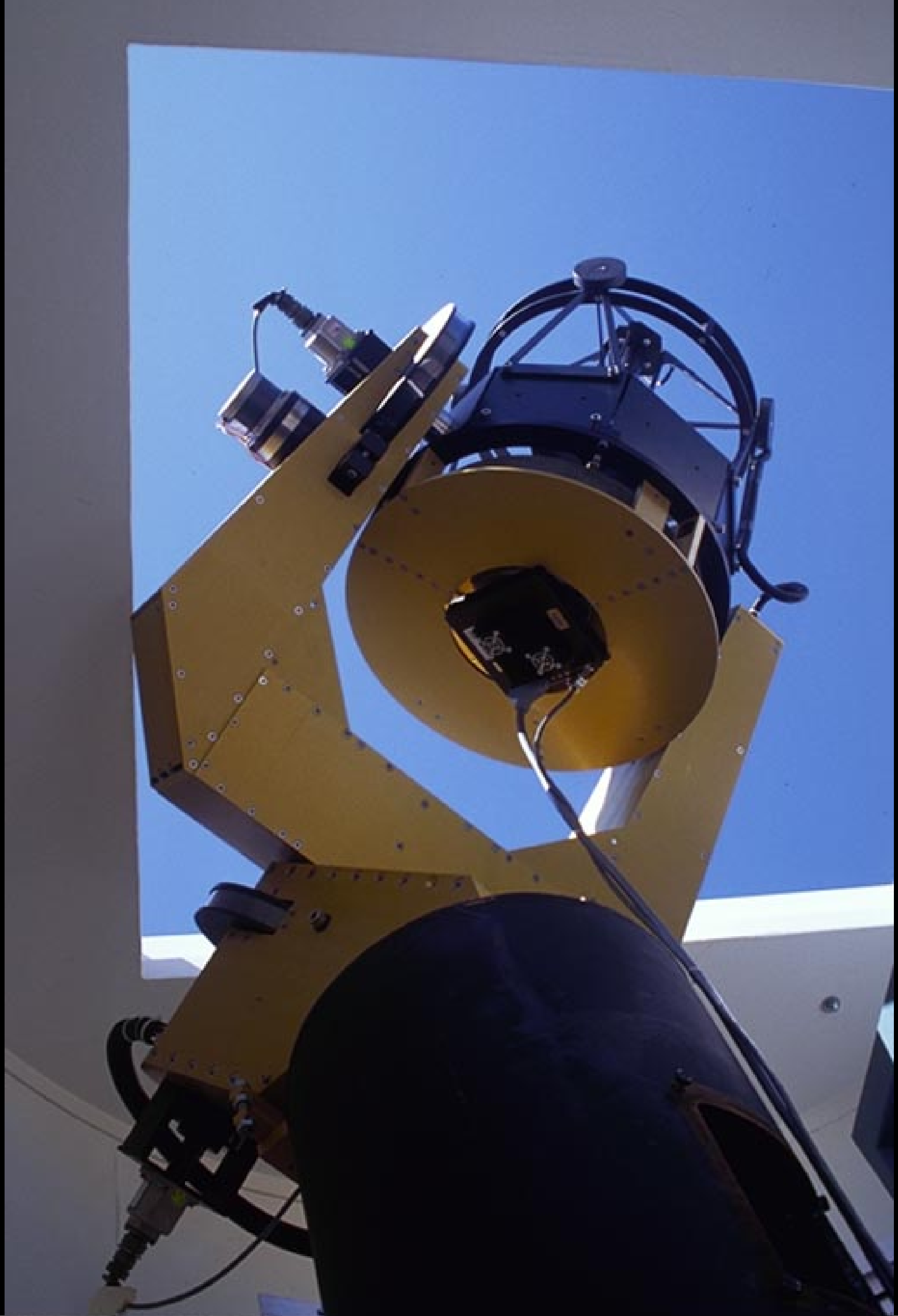
GRB990123 optical lightcurve
optical magnitude
elapsed time after burst (seconds)
8
10
12
14
16
18
20
22
10^1
10^2
10^3
10^4
10^5
ROTSE
B
V
R, r
I
ROTSE
Afterglow
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
ROTSE optical


5"
The HST GRB Collaboration


GEODSS tracking telescope
1 m aperture, 2° FoV
contraves

ROTSE-II

(a complete disaster)



ROTSE-III

0.45 m aperture, *f*/1.9
1.83° ▪ 1.83° FoV

ROTSE

“The sun never rises on the ROTSE empire”


ROTSE folk

characteristics of GROCSE, ROTSE-I, and ROTSE-III

project	aperture (m)	#	∑ pixels	∑ FoV (°)	lim mag @ secs	cost ($)
GROCSE	0.089	1	5 a 10^6	2000	8.5 @ ½	~5 ▪10^6
ROTSE-I	0.11	1	1.7 ▪10^7	256	14 @ 60	1 ▪10^5
ROTSE-III	0.45	4	1.7 ▪10^7	13.8	18 @ 60	1 ▪10^6

ROTSE-III sites

location	latitude	longitude	altitude	First Light
Fort Davis, Texas	+30.680°	-104.014°	2074 m	January 2003
Coonabarabran, Australia	-31.273°	+149.064°	1097 m	February 2003
Mt. Gamsberg, Namibia	-23.272°	+16.500°	1800 m	June 2003
Bakirlitepe, Turkey	+36.825°	+30.333°	2500 m	May 2004

Current ROTSE-III Activities

1. Observe GRB afterglows detected by Swift
   140 GCN messages, 43 afterglow detections

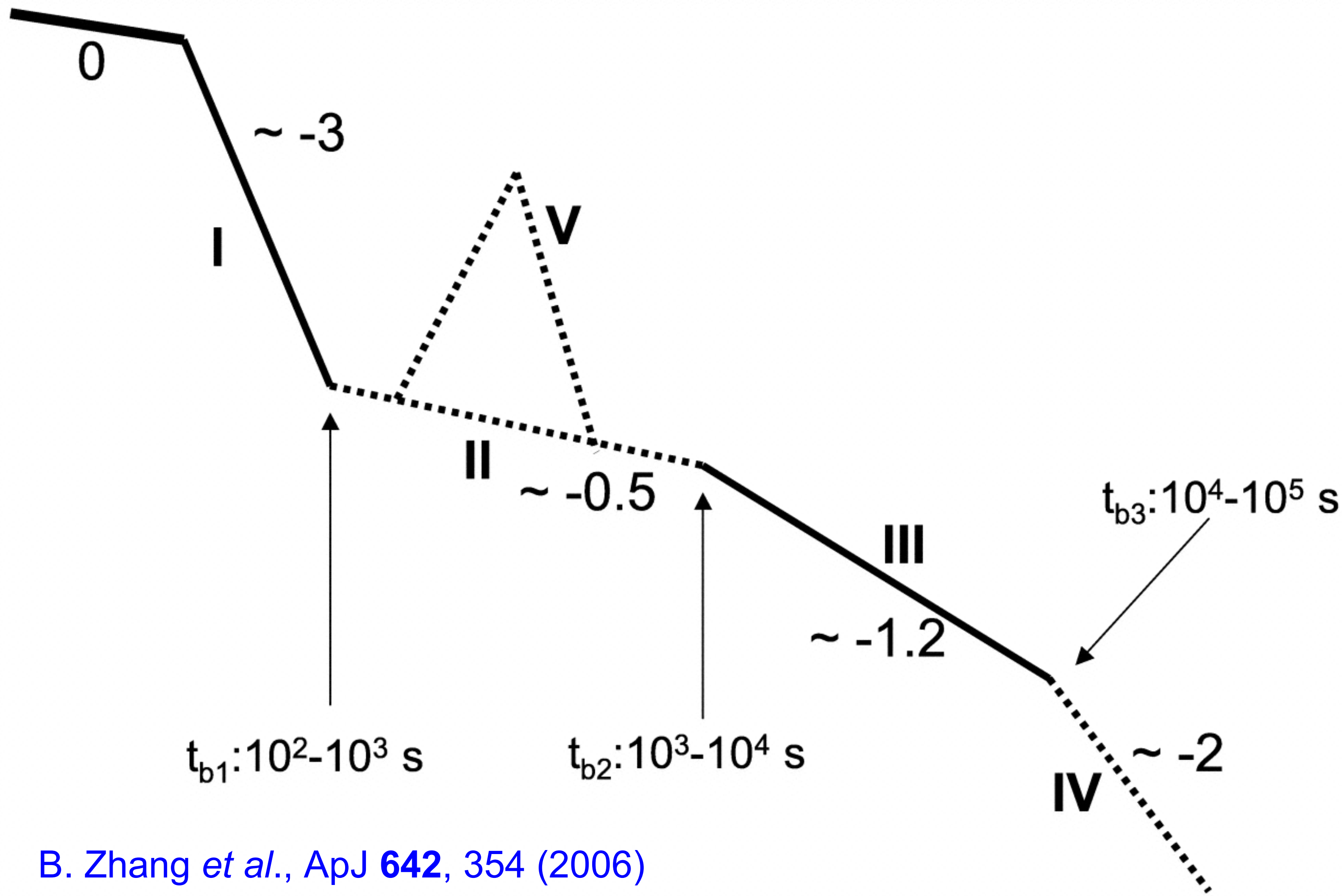
1. Find GRB afterglows detected by FGST/LAT

1. Discover SNe in sky patrol mode
   36 SNe since August 2007

1. Search for optical counterparts of IceCube ν triggers

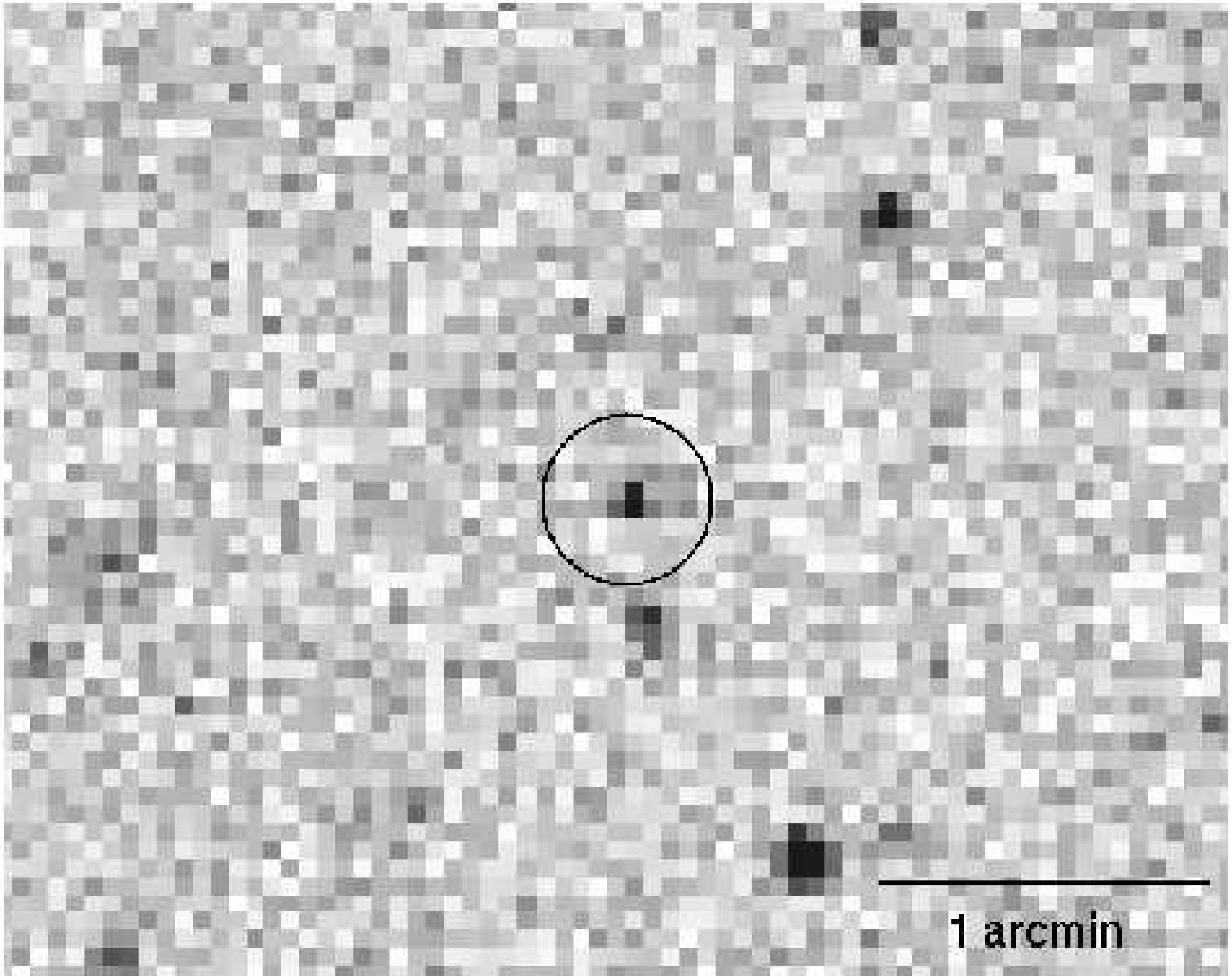
2. Undergraduate research with exoplanets and variable stars

3. Educational outreach programs, specifically with Thailand

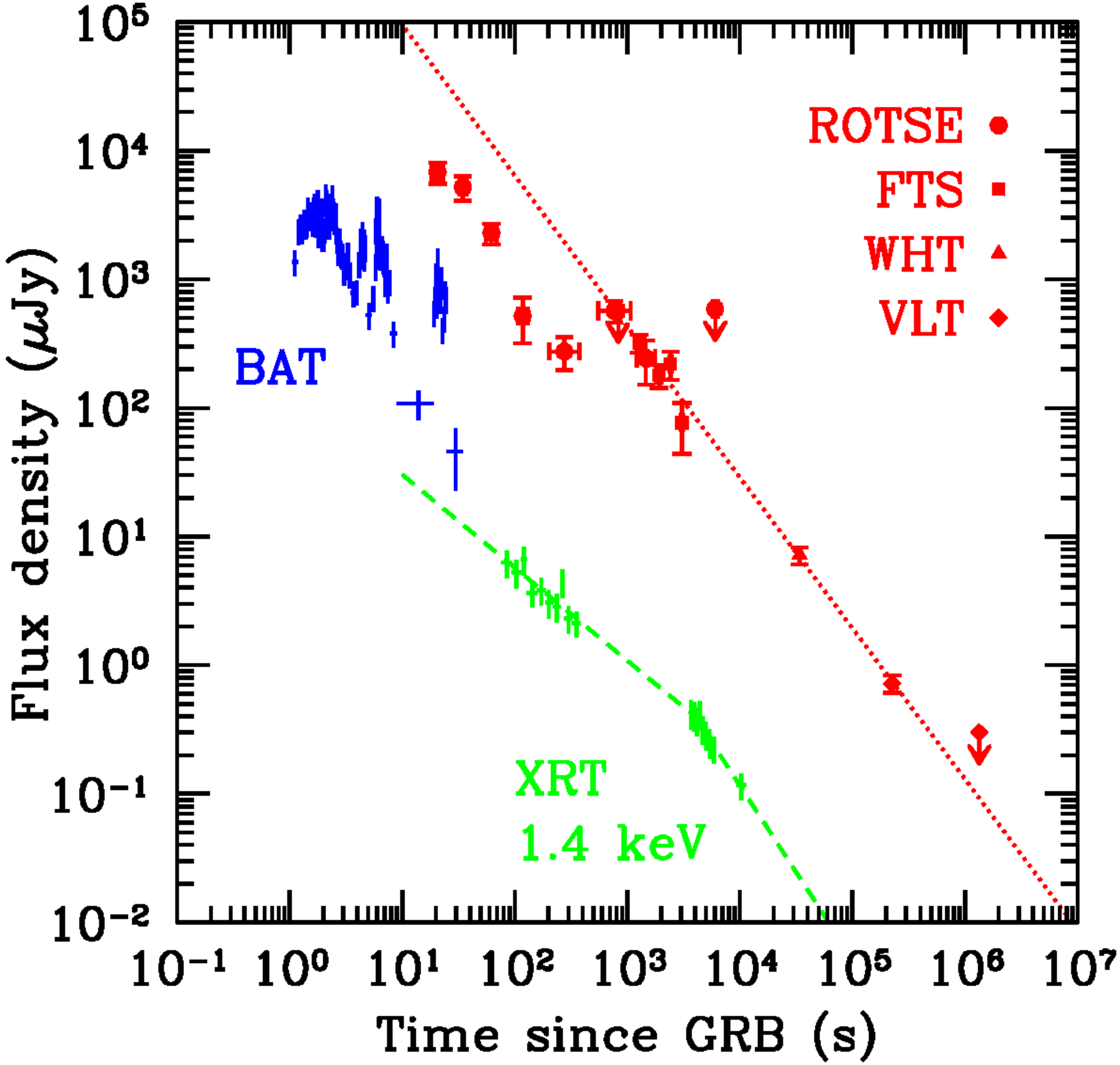


B. Zhang *et al*., ApJ **642**, 354 (2006)

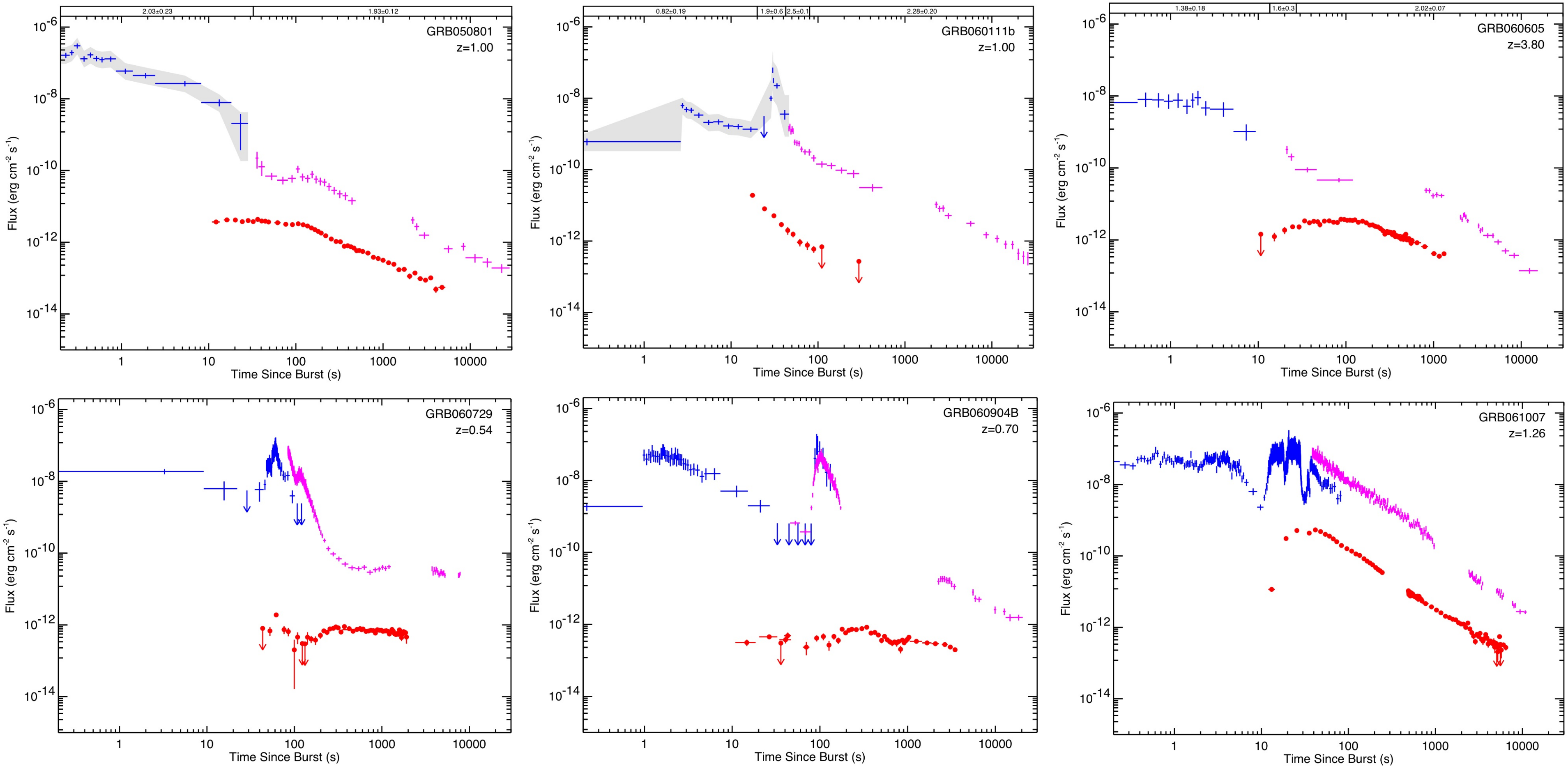
morphology of *Swift* XRT lightcurves



ROTSE-IIIa detection of GRB 060927 @ z = 5.47



Lightcurves for GRB 060927, z = 5.47



BAT (15 – 150 KeV) **XRT (0.2 – 10 KeV)** **ROTSE (1.4 – 3.2 eV)**

Early lightcurves obtained with Swift and ROTSE

Interesting SNe discovered with ROTSE-III

Program initiated by Robert Quimby at UT-Austin, extended by Fang Yuan, et al.

2 sets of four 60 s exposures, Δt = 30 m

40 fields per night, 140 degrees^2

SN 2005ap – Brightest SN ever discovered

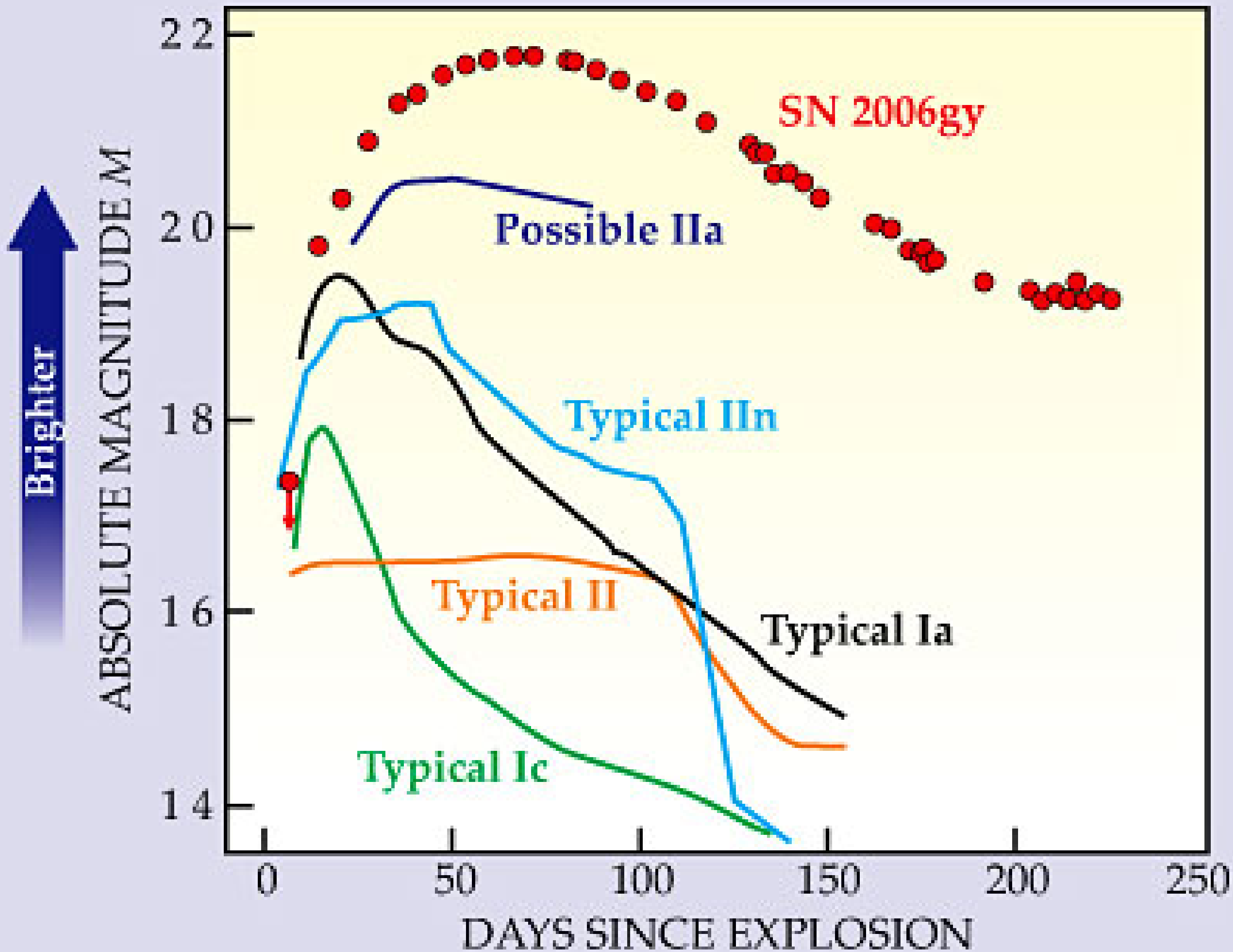
SN 2005cg – Ia in a dwarf galaxy

SN 2005hj – Ia 20% brighter than normal

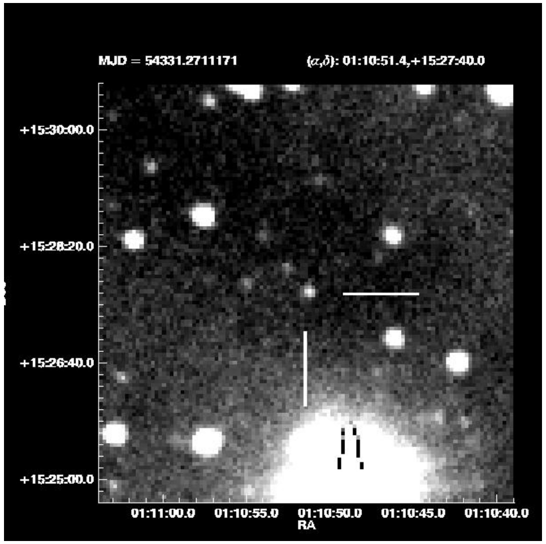
SN 2006gy – Second brightest SN

SN 2007if – Second super-Chandresekhar Ia

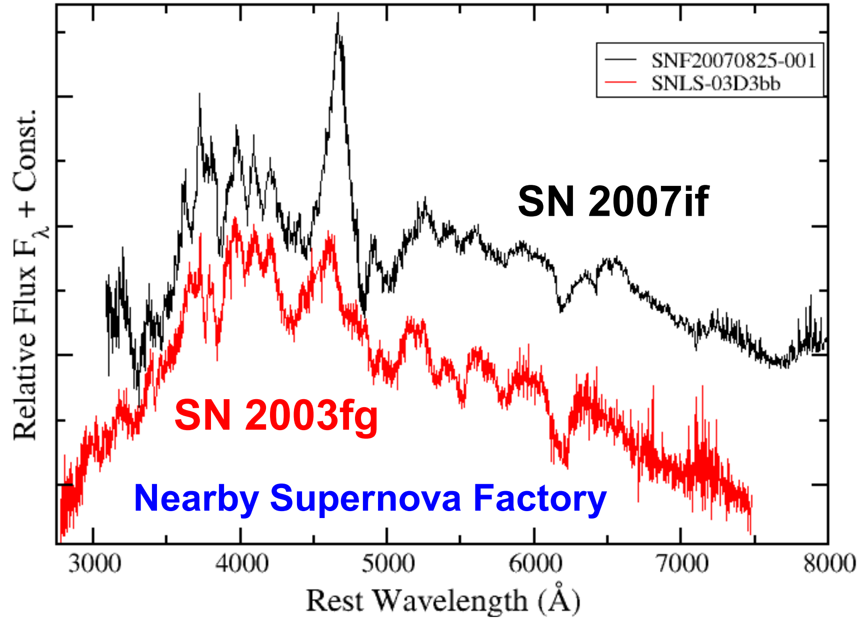
N. Smith *et al.*, ApJ **666**, 116 (2007)



Lightcurve for SN 2006gy, z = 0.019



ROTSE-III finding chart
z = 0.07



SN 2007if:

the second example of an SN Ia with a super-Chandresekhar mass

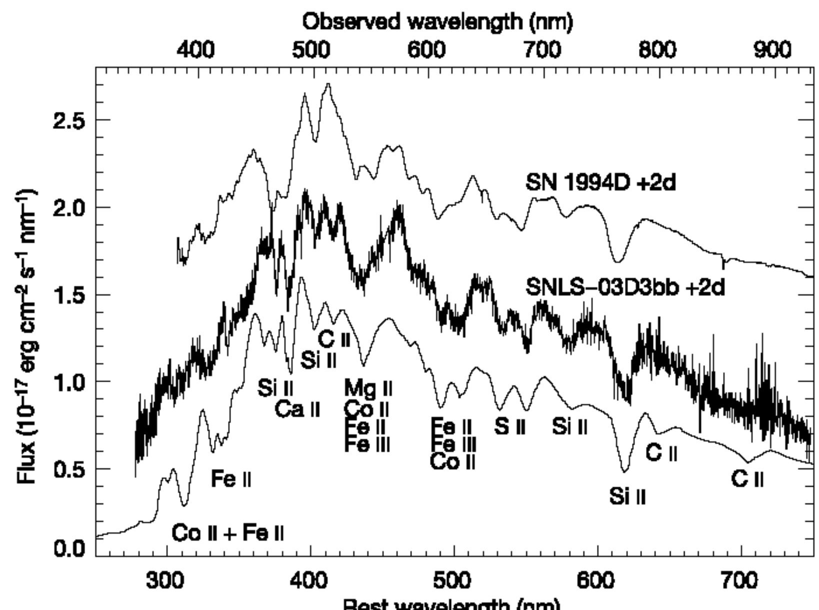
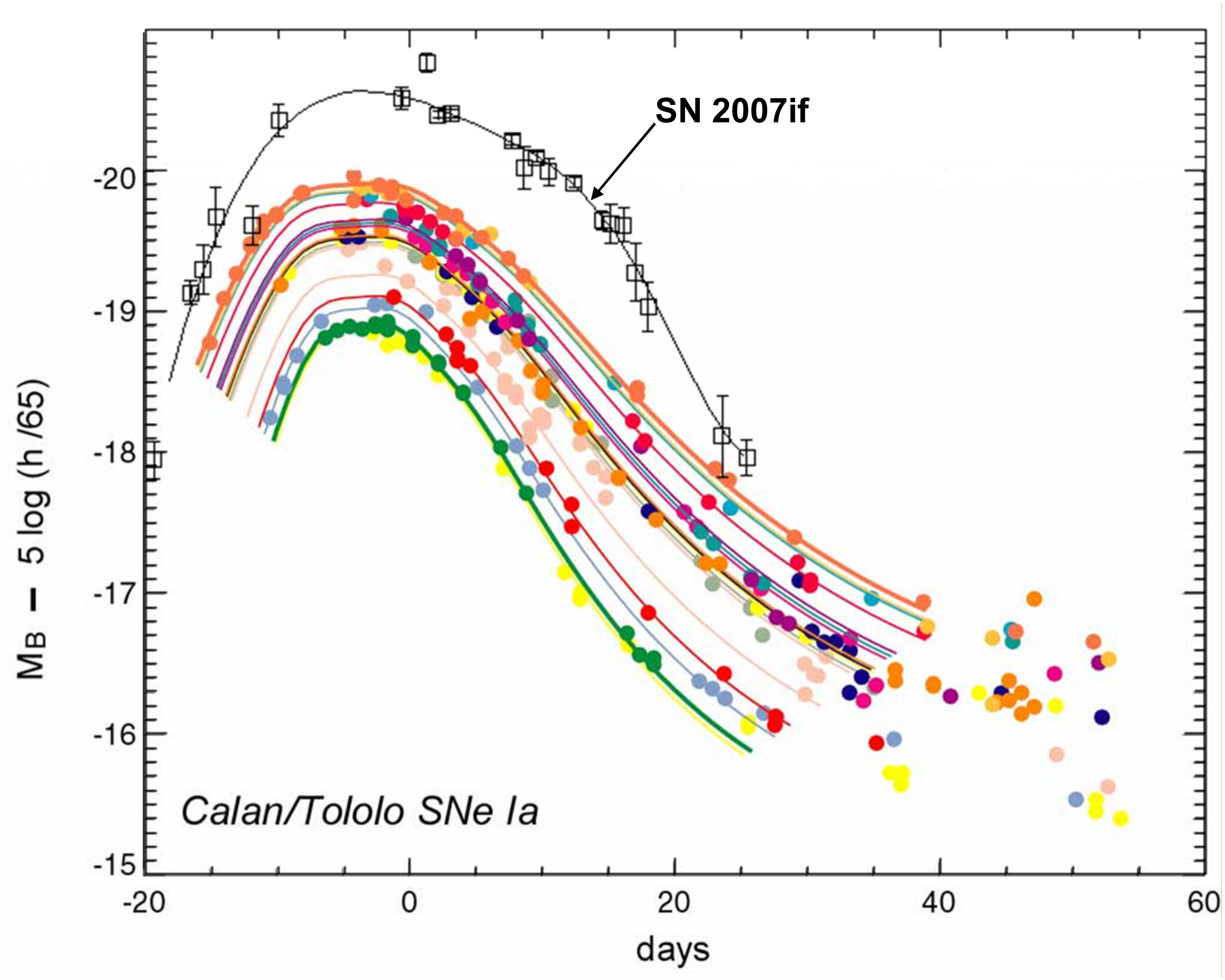
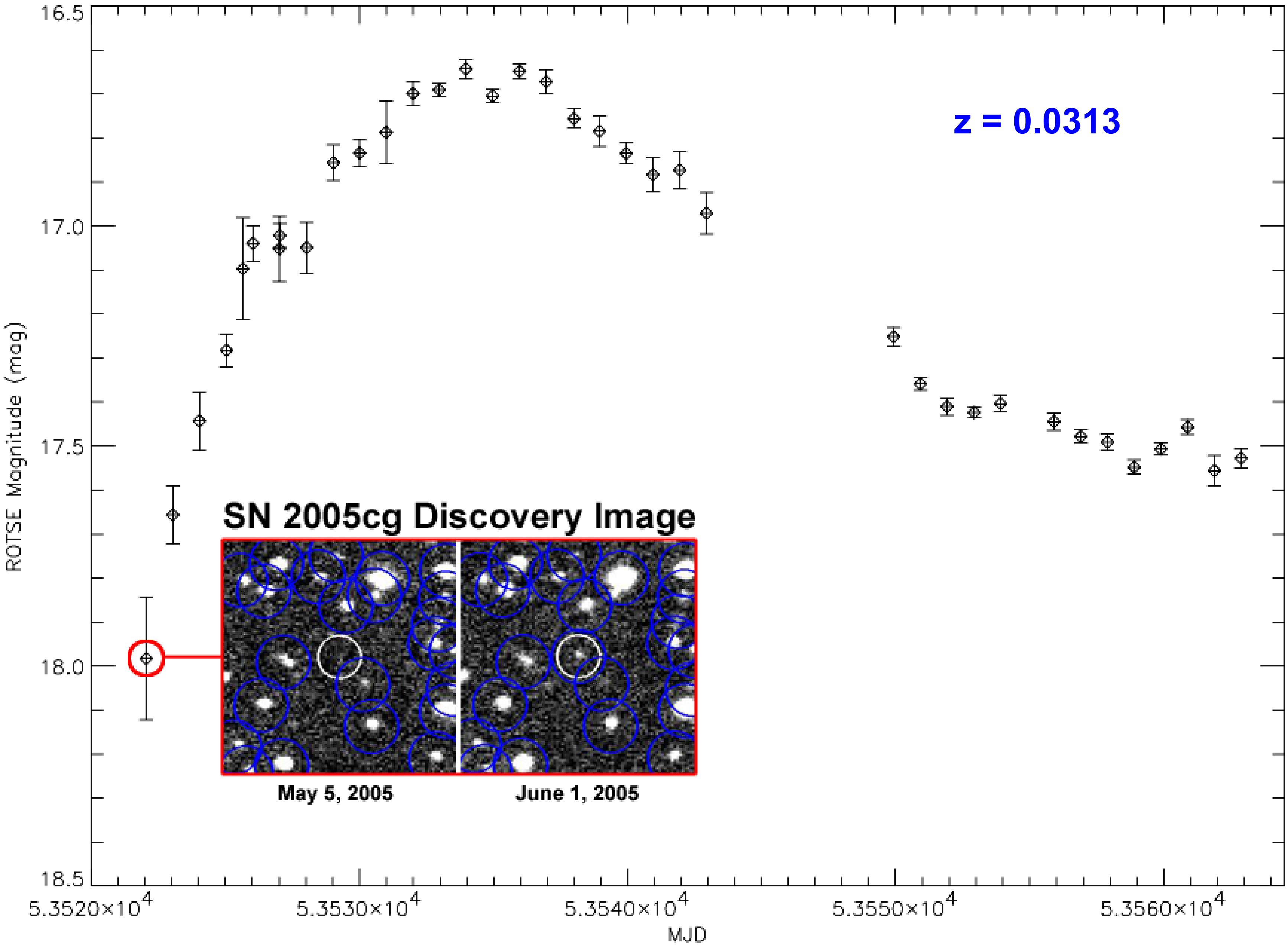


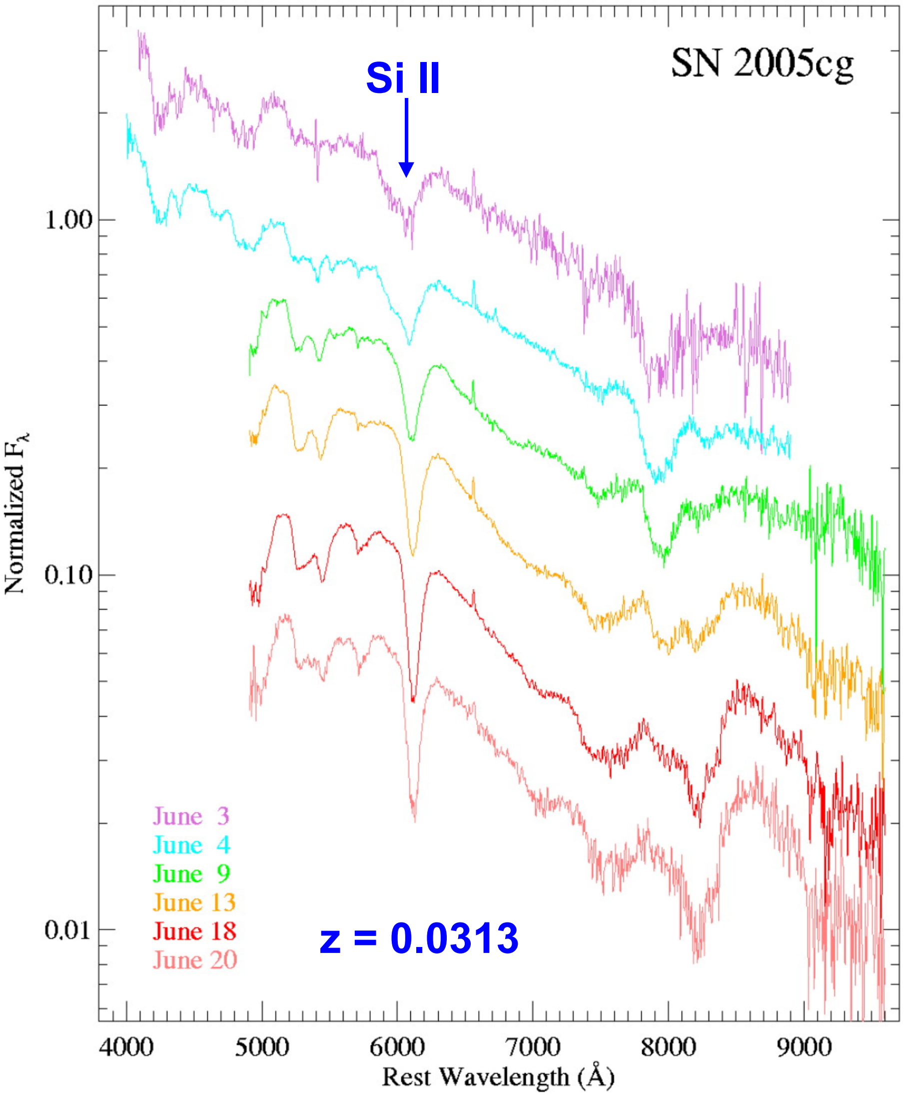
Figure 3 | Keck LRIS spectrum of SNLS-03D3bb at two days after maximum light compared to a spectrum of the normal type Ia supernova SN 1994D. Howell, et al, Nature **443**, 308 (2006)



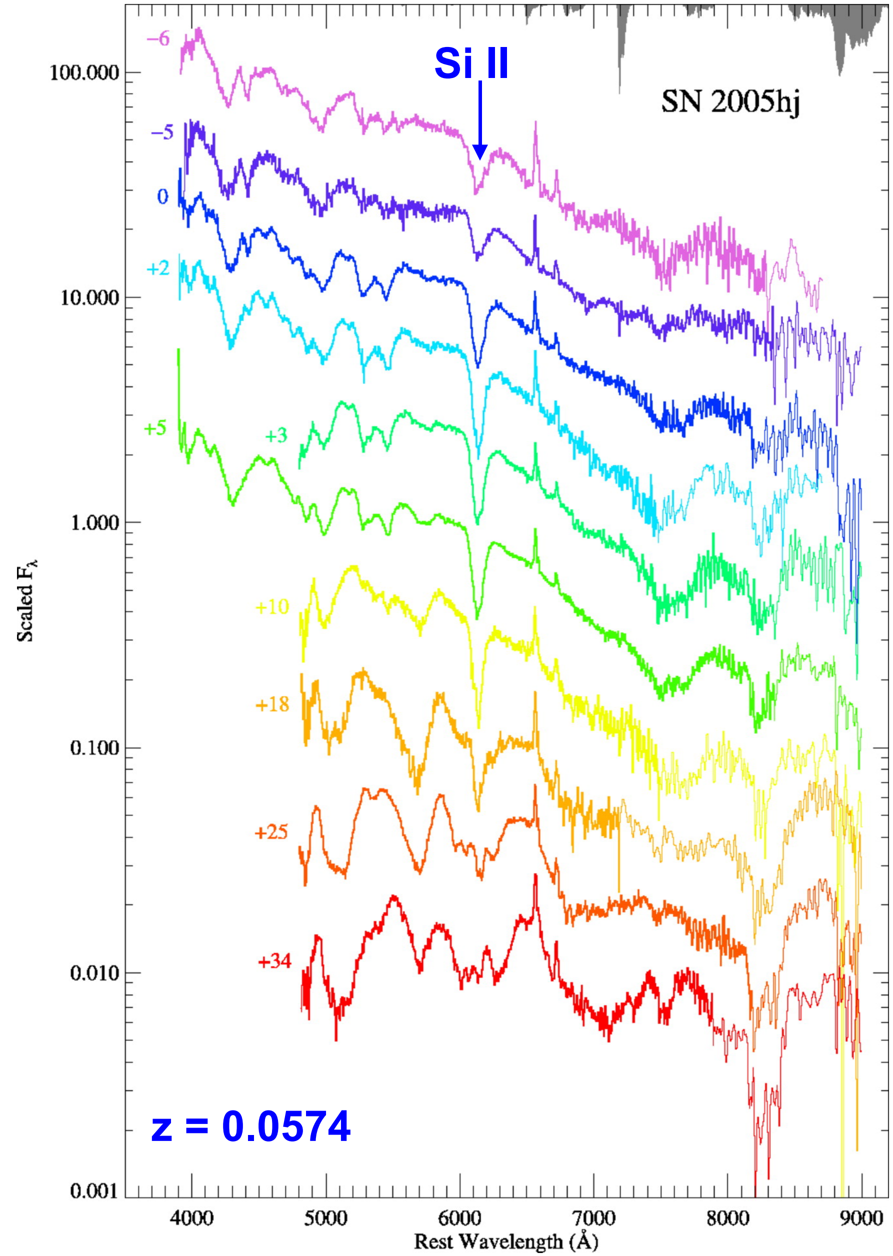
Lightcurve for SN 2007if

ROTSE's Discovery and Observation of Type Ia Supernova



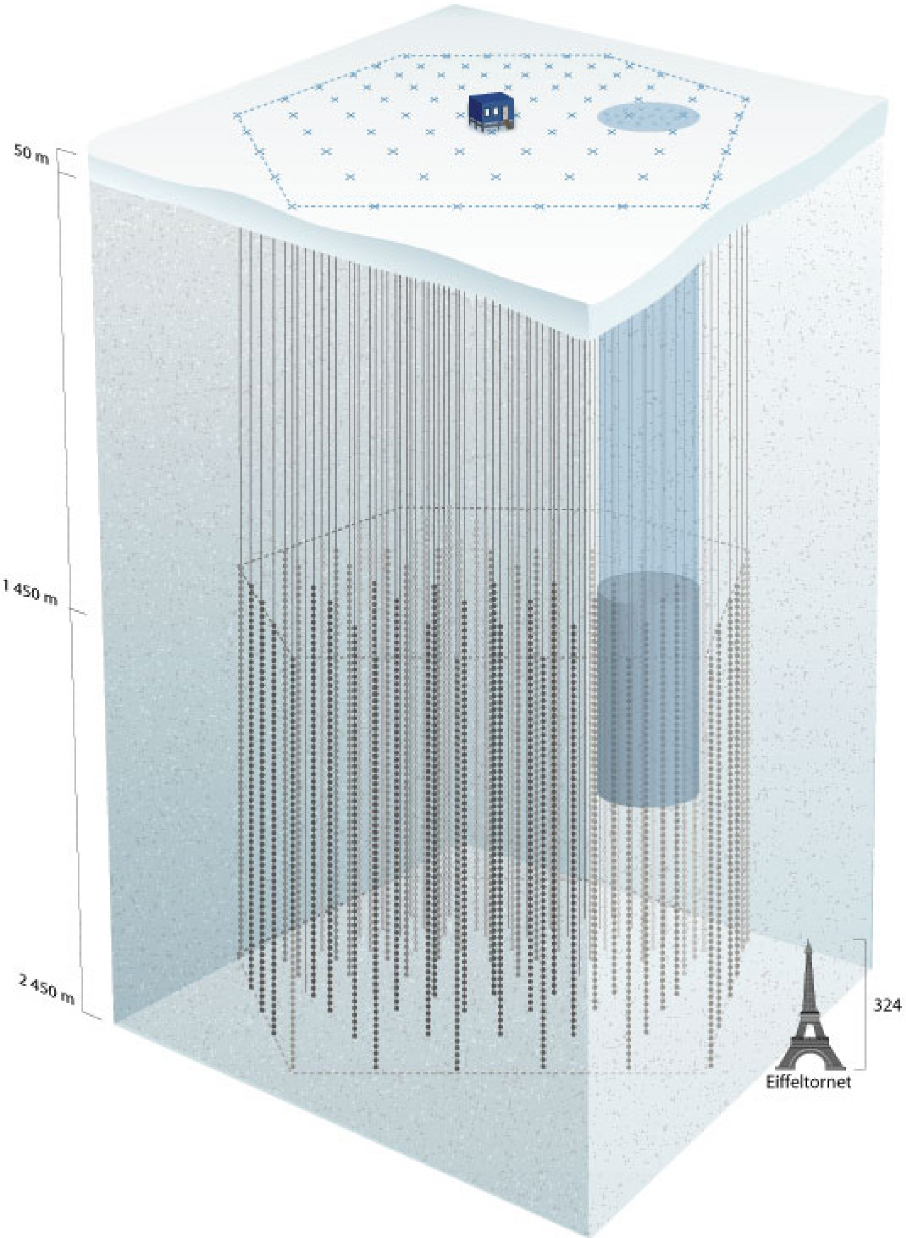


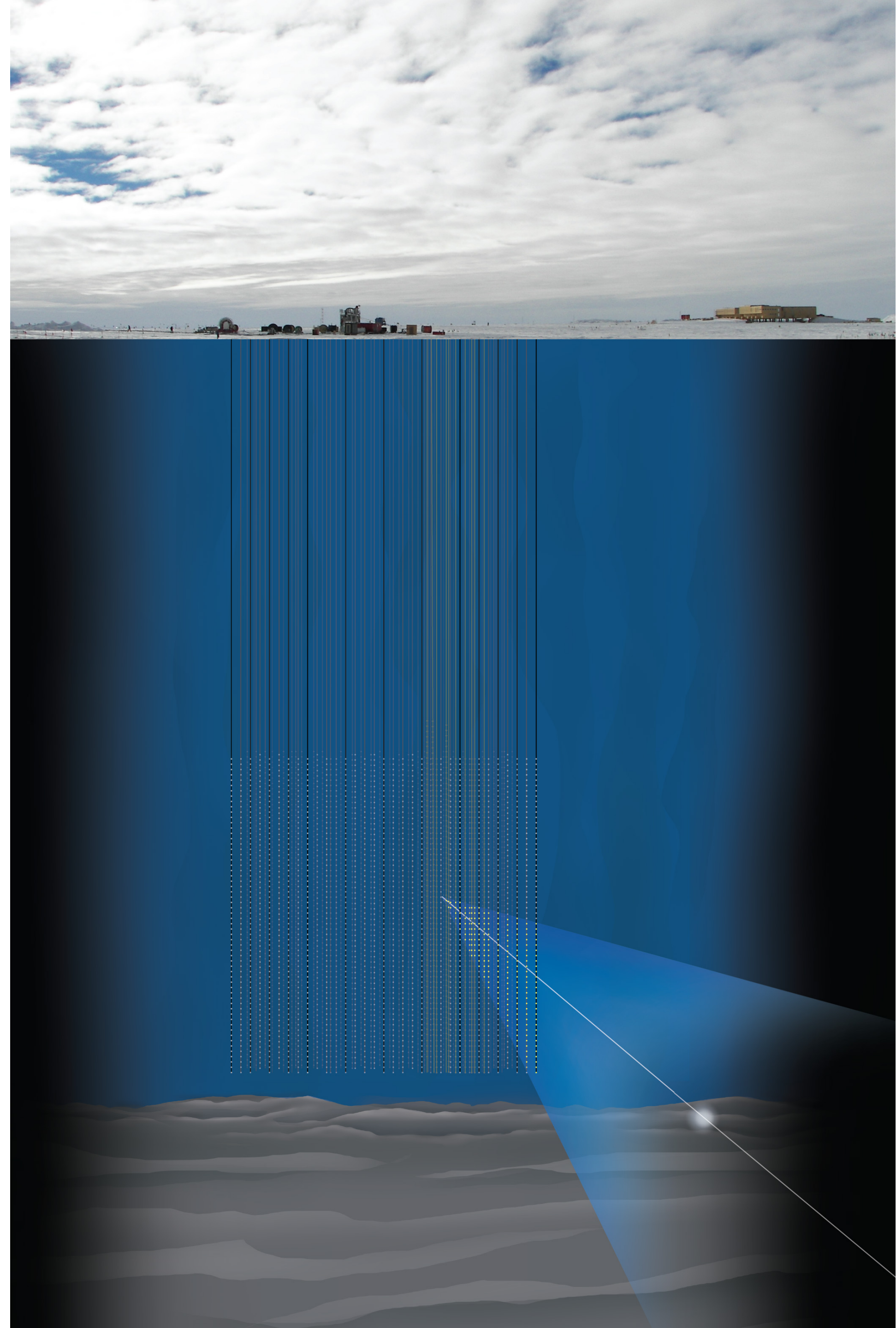
Quimby *et al.*, ApJ **636**, 400 (2006)



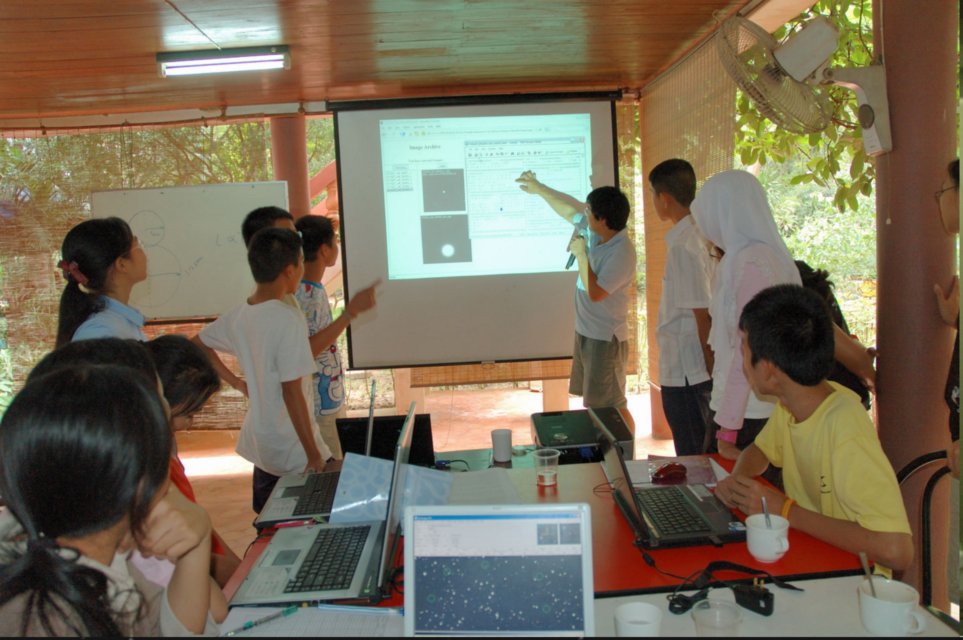
Quimby, *et al.*, ApJ **666**, 1083 (2007)

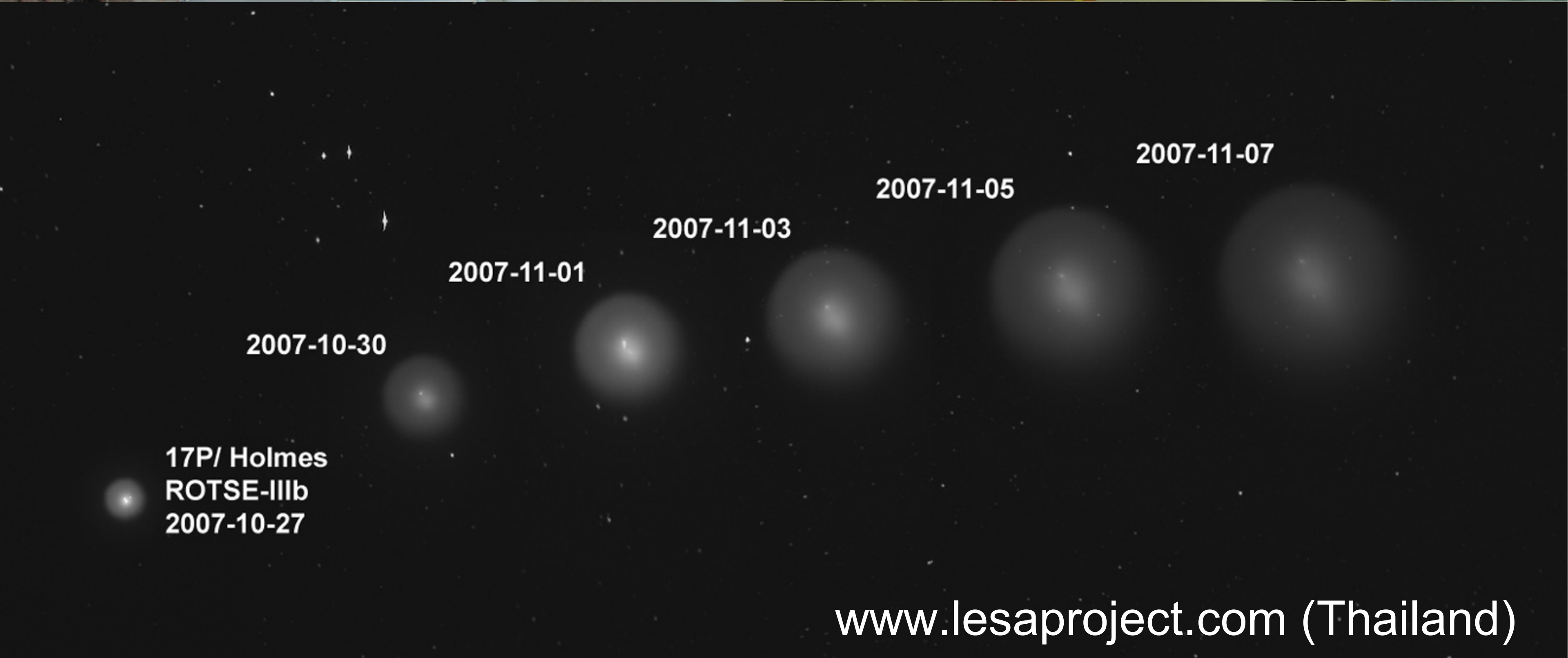
two over-luminous SN Ia





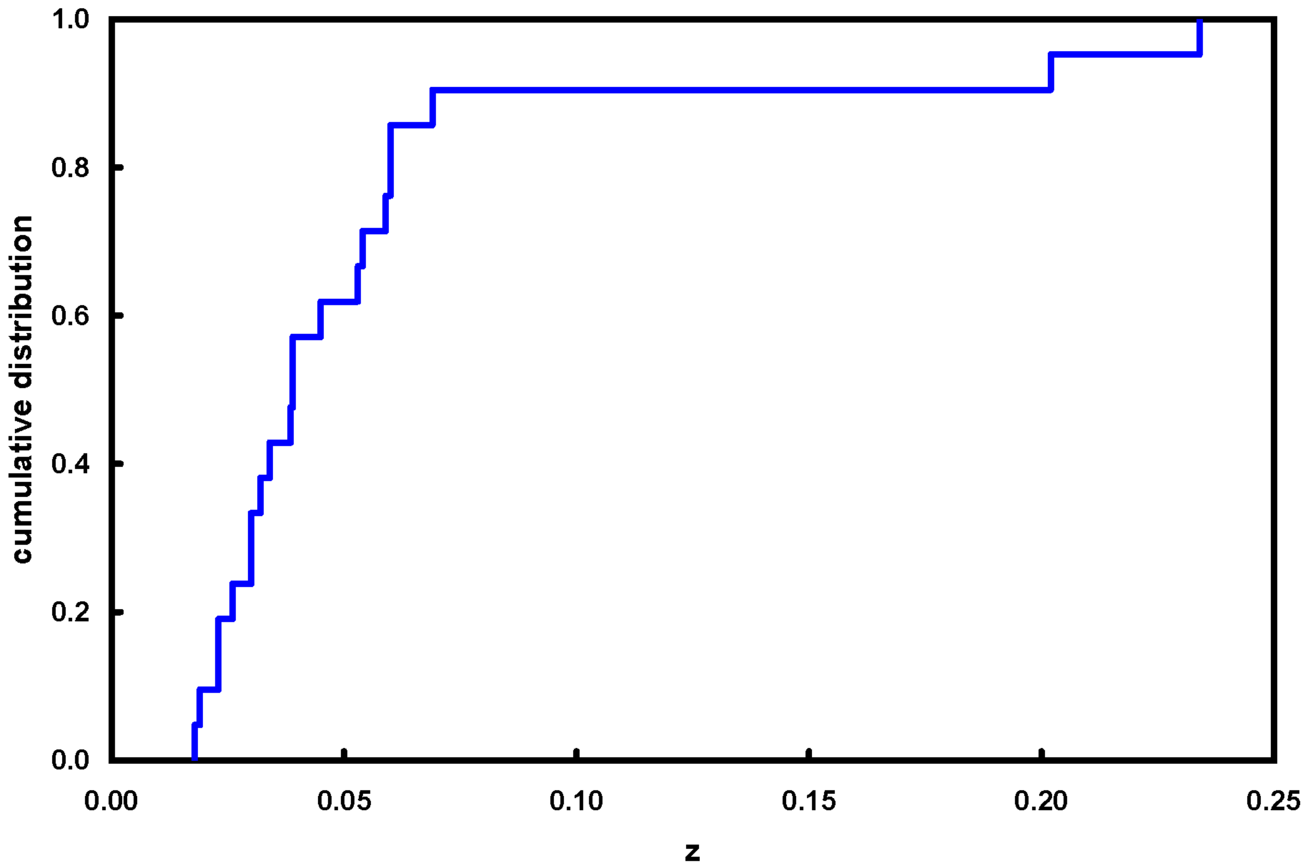
IceCube Neutrino Detector




17P/ Holmes
ROTSE-IIIb
2007-10-27
2007-10-30
2007-11-01
2007-11-03
2007-11-05
2007-11-07
www.lesaproject.com (Thailand)

Summary

- **Robotic telescopes are essential for studying transients**
- **Reliable operation requires considerable design care**
- **ROTSE-III has been operating since January 2003**
- **GRB lightcurves are much more complex than expected**
- **ROTSE finds unusually bright SN with untargeted sky scan**
- **Even SN Ia show diverse behavior**
- **Future ROTSE program:**
  - Find GRBs with lower *Swift* trigger thresholds
  - Find counterparts for ~5 GLAST bursts/year
  - Identify ~30 SNe/year to find outliers
  - Search for optical counterparts of Ice^3 ν events
  - Search for optical counterparts of LIGO triggers



cumulative redshift distribution for ROTSE-III SNe

ROTSE-III response time to GRB alert