

An aerial photograph of a mountainous landscape, likely the Palomar Mountains. The terrain is covered in dense green vegetation. In the distance, a large white dome-shaped structure, the Palomar 60-inch telescope, is visible on a mountain peak. The sky is a pale, hazy blue.

# **The Robotic Palomar 60-Inch Telescope**

Derek B. Fox

Caltech Astronomy  
for the P60 Team

Swift New Orleans - Sept 7, 2004

# The P60 Team at Caltech and Palomar

Project Leads      Fiona Harrison & Shri Kulkarni

Project Scientist      DBF

Automation      John Henning

Camera      Dae-Sik Moon, S. Brad Cenko, Roger  
Smith, Marco Bonatti, Dani  
Guzman, Jill Burnham, John Klemic

DBF & SBC

Software      DBF, Avishay Gal-Yam, Bruce

Archive      Berriman, Schuyler Van Dyk (IPAC)

SBC, DBF, SRK, Alicia Soderberg

Operations



# The Palomar 60-Inch Telescope

- 60-inch (1.5-m) primary
- Feeder / photometer for the Hale 200-inch (5-m)
- Photometric calibrations for DPOSS
- CCD Imaging (13' FOV)
- IR Imaging (2.6' FOV)
- Echelle spectroscopy ( $R = 19,000$ )



P60

# The Palomar 60-Inch Telescope

- Undersubscribed after the end of DPOSS calibrations (2002)
- “Takeover” and upgrade financed by the GRB group at Caltech (80% of time)
- Premised on the impending launch of *Swift*



P60

# P60 Automation



# System Upgrade

- TCS systems, dome and windscreen fully automated
- Digital weather station and multiple temperature sensors
- Runs without guiding
- Remaining manual operations:
  - Liquid nitrogen refill, 2x daily
  - Filter-set changes (12-pos'n)
- P200 operator has override capability (clouds, system malfunctions, approaching storm)
- Private generator
- Alarm systems, klaxons, thermal shielding...
- Air conditioning (in process)



P60

# Camera Upgrade

- Leach-3 controller
- 2-amp, 35-s full-frame readout
- New dewar with increased hold time (12 hr)
- Remote operation option enabled via Arcview software (testing)
- “Focus mode” gives multiple exposures & one readout
- Arbitrary region-of-interest and binning selections
- 10-s readout for 1/4 chip (6.5' FOV)

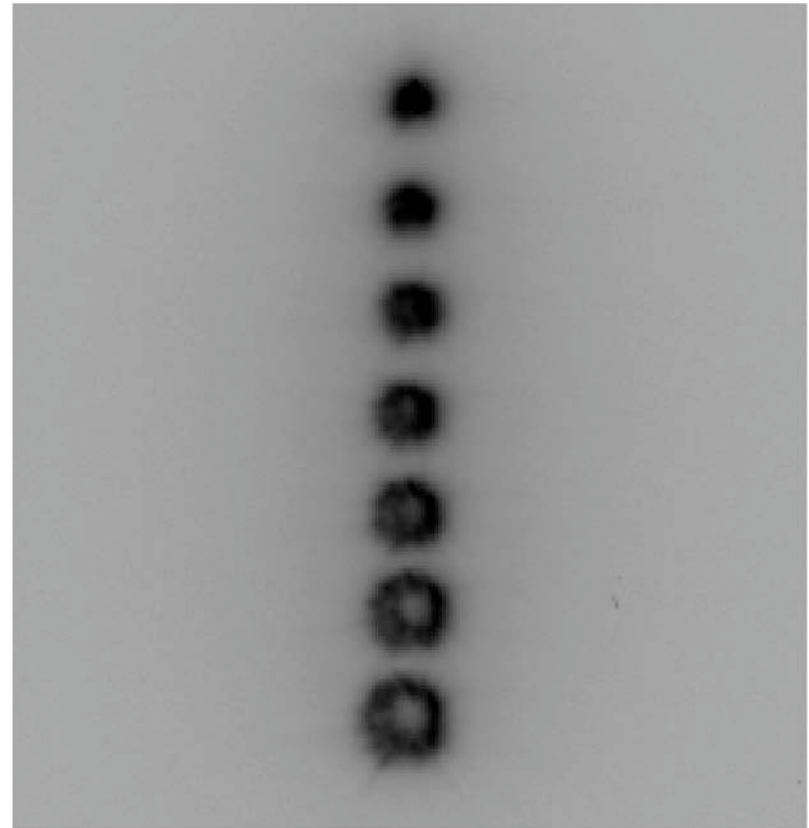


P60 New Camera



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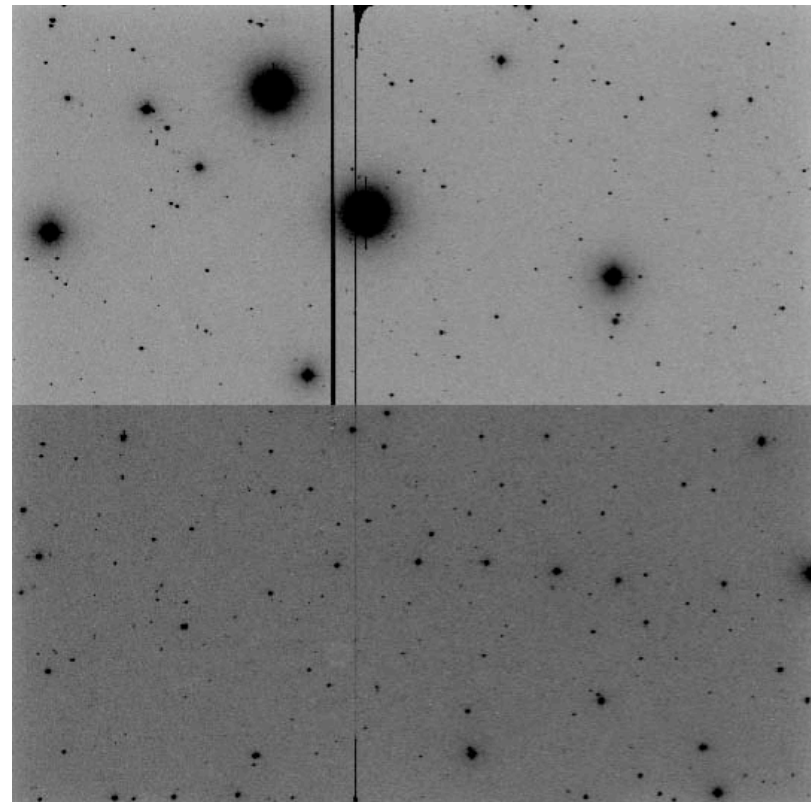


P60 SAOFOCUS run



# Pipeline Software

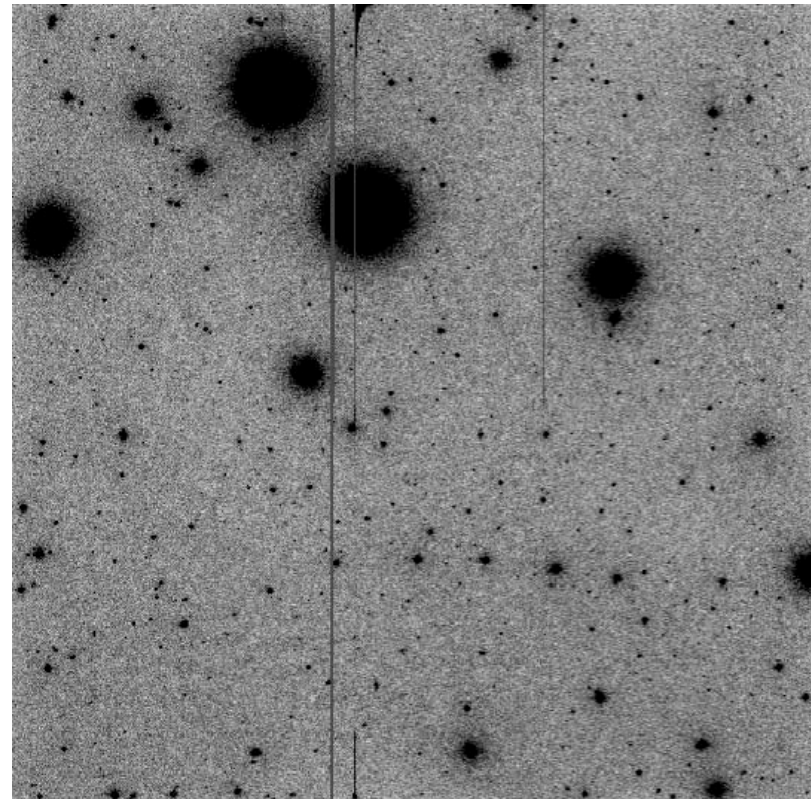
- Data reduced in real-time (approx. 1 minute per image)
- Mixed Python/Pyraf with system calls for Sextractor and WCS-fitting (C program)
- Observers get these processed files as well as raw images



P60 Raw Image

# Pipeline Software

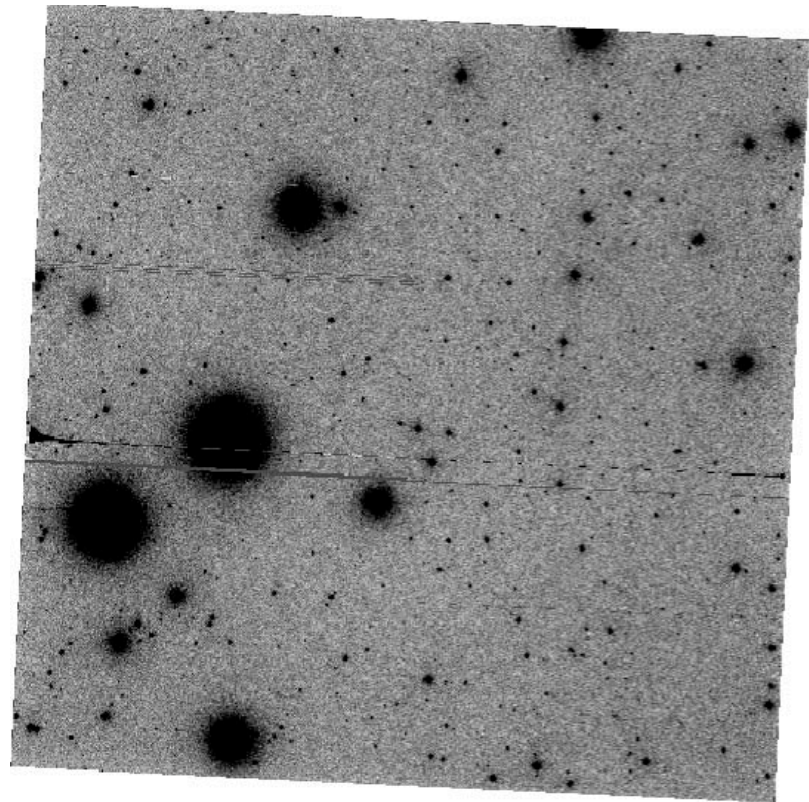
- Basic CCD reduction pipeline:
  - Overscan subtraction (per-amp)
  - Demosaic amp sections
  - Bias subtraction (full-chip)
  - Flatfield against dome flats
  - Mask bad pixels/columns
  - Add dead-reckoning WCS
  - Object detection (SExtractor)
  - Refine WCS against USNO B-1.0
  - Measure current seeing, pointing offset, transparency (soon)



P60 Processed Image

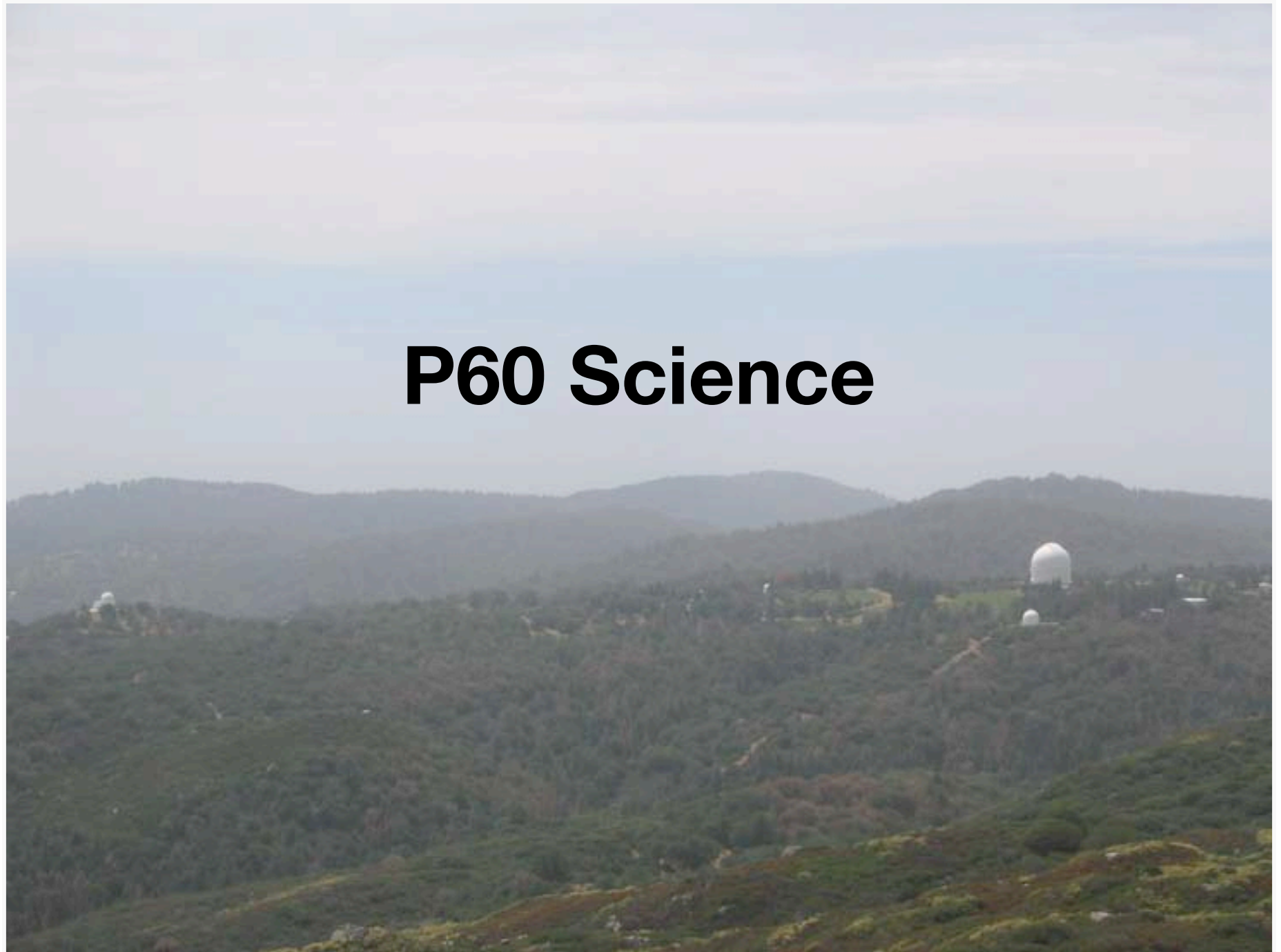
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P60 Processed Image  
(WCS-aligned)

# P60 Science



# Science with P60

A multi-filter (12-position) robotic facility with various capabilities:

- Intensive photometric campaigns
- Many-object surveys
- Photometric monitoring or long-term lightcurves

All of this science is currently being pursued by various observers (P60 team + Caltech, IPAC, JPL)

Focus on SN science for this talk.

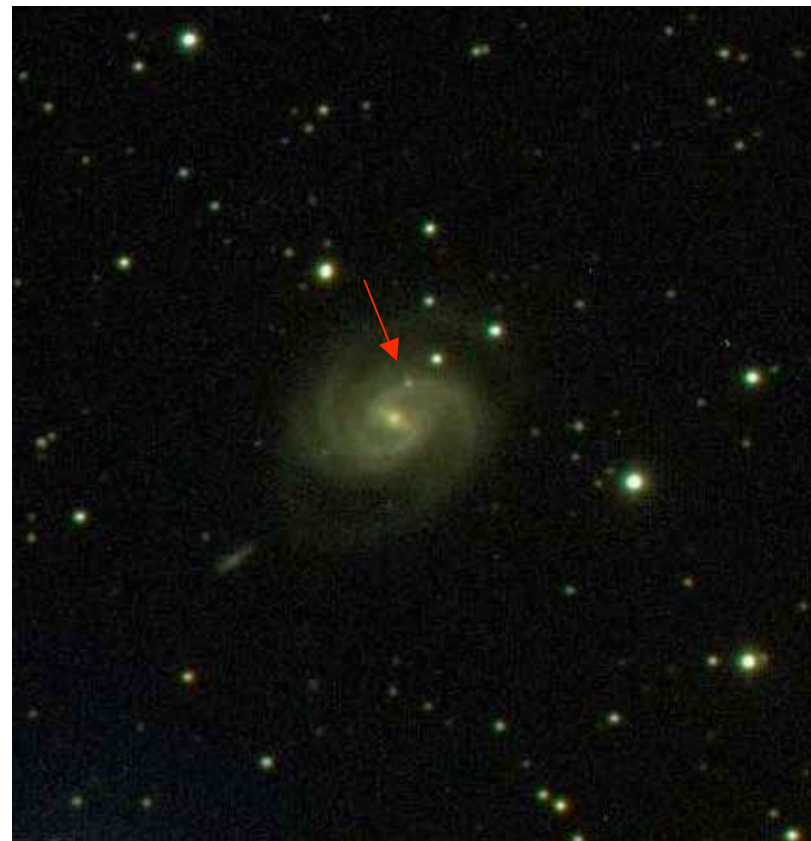


SN2003ja

# P60 for Supernovae

## Advantages:

- Relatively few, bright targets
- Varying over days to weeks
- Queue management with low overhead
- Individual events require ~15 min per epoch
- Begin with daily observations through peak, then twice-weekly observation

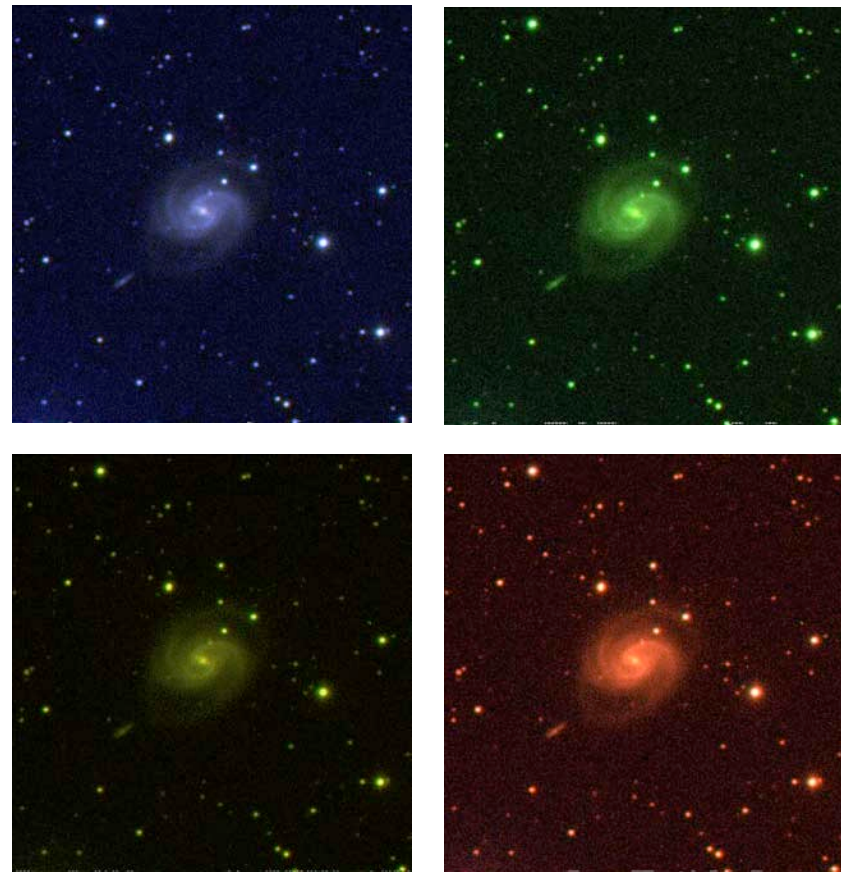


SN2003ja



# Supernova Phototyping

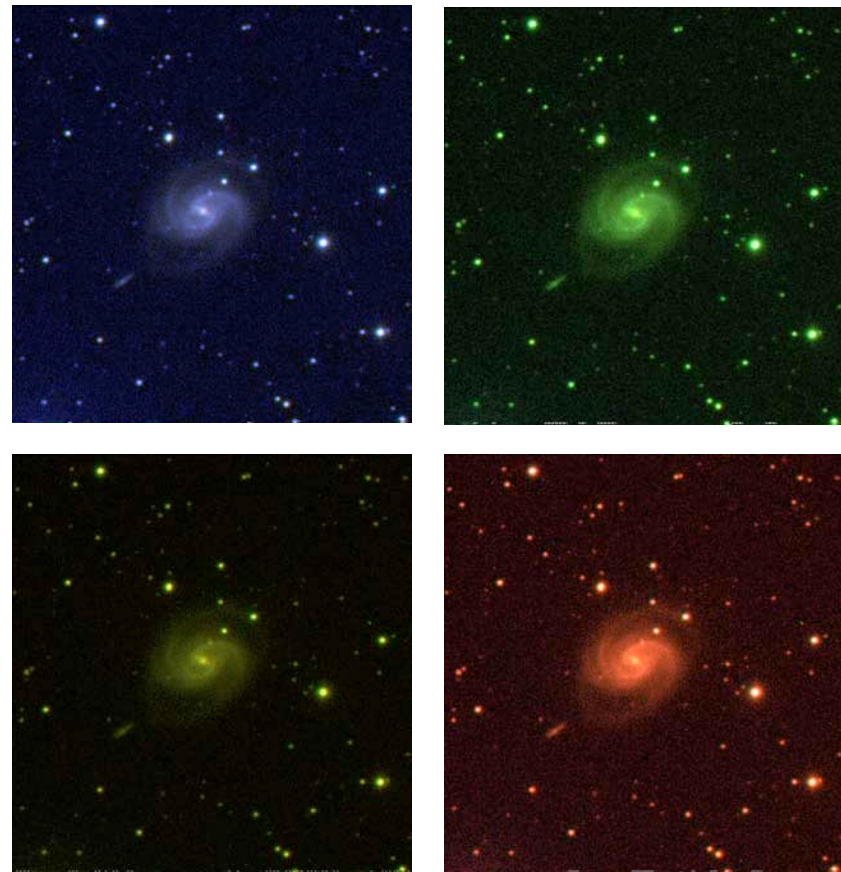
- Increased discovery rate for young supernovae (deliberate choice of Wei-Dong Li & Alex Filippenko)
- Some groups interested in SN Ia only (?)
- Some interested in core-collapse events only (Ibc + II)
- Delays of days to weeks before first spectroscopy
- 4-color photometry allows probabilistic estimate of type
- Potentially does the job within two days (Poznanski et al. 2002; Gal-Yam et al. 2004)



*BgVR* Phototyping

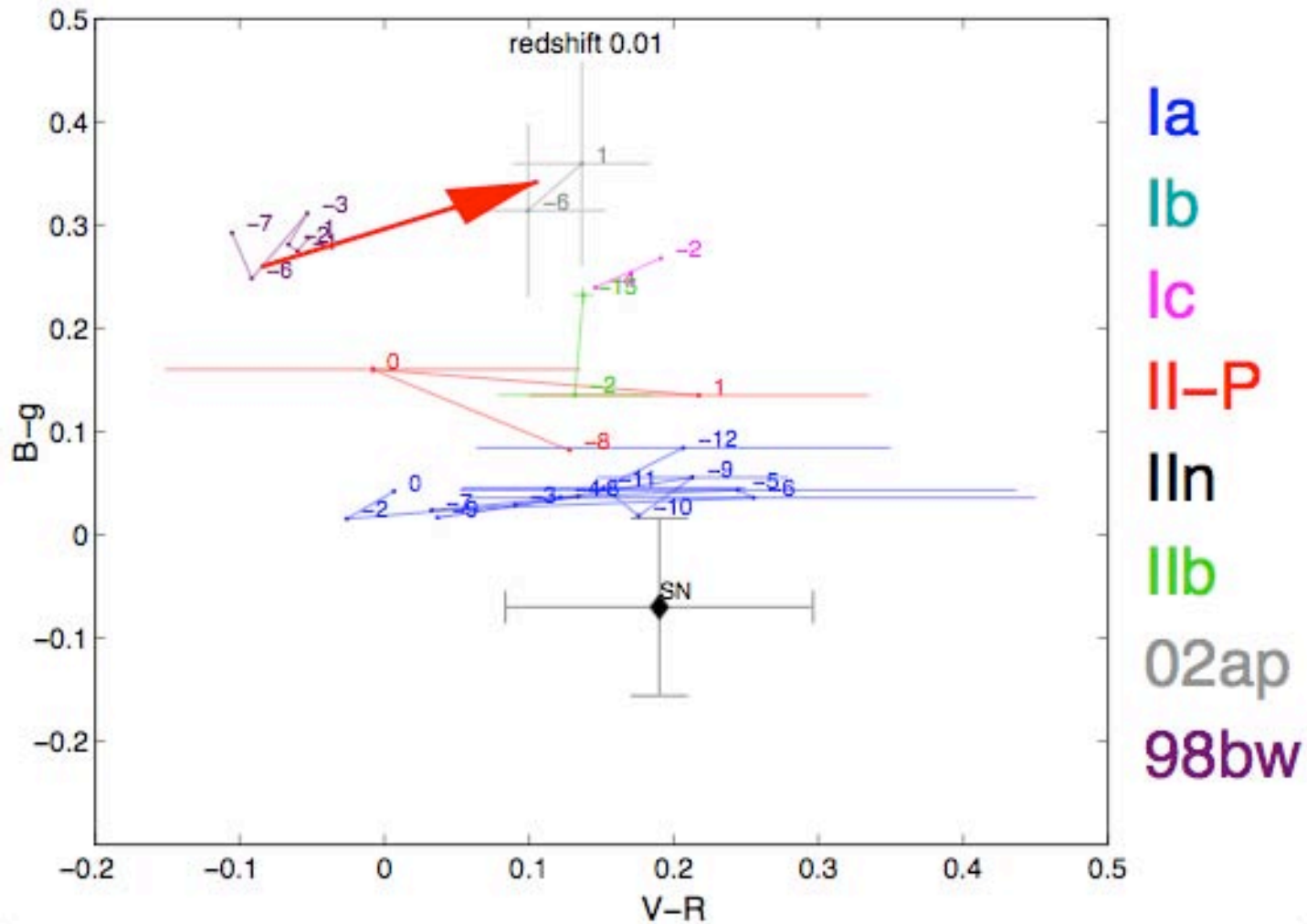
# Supernova Phototyping

- Summer project with AG-Y and Anne Rajala (Caltech undergrad)
- PSF photometry for the SN
- Calibrated by reference to nearby PSF stars (aperture correction) and Stetson standard fields
- Comparison to SN spectral libraries of Poznanski et al. (2002) using the Poznanski-Gal-Yam “typing machine”
- Several tricks to get a quick answer under questionable conditions
- Derived phototypes of three young supernovae...

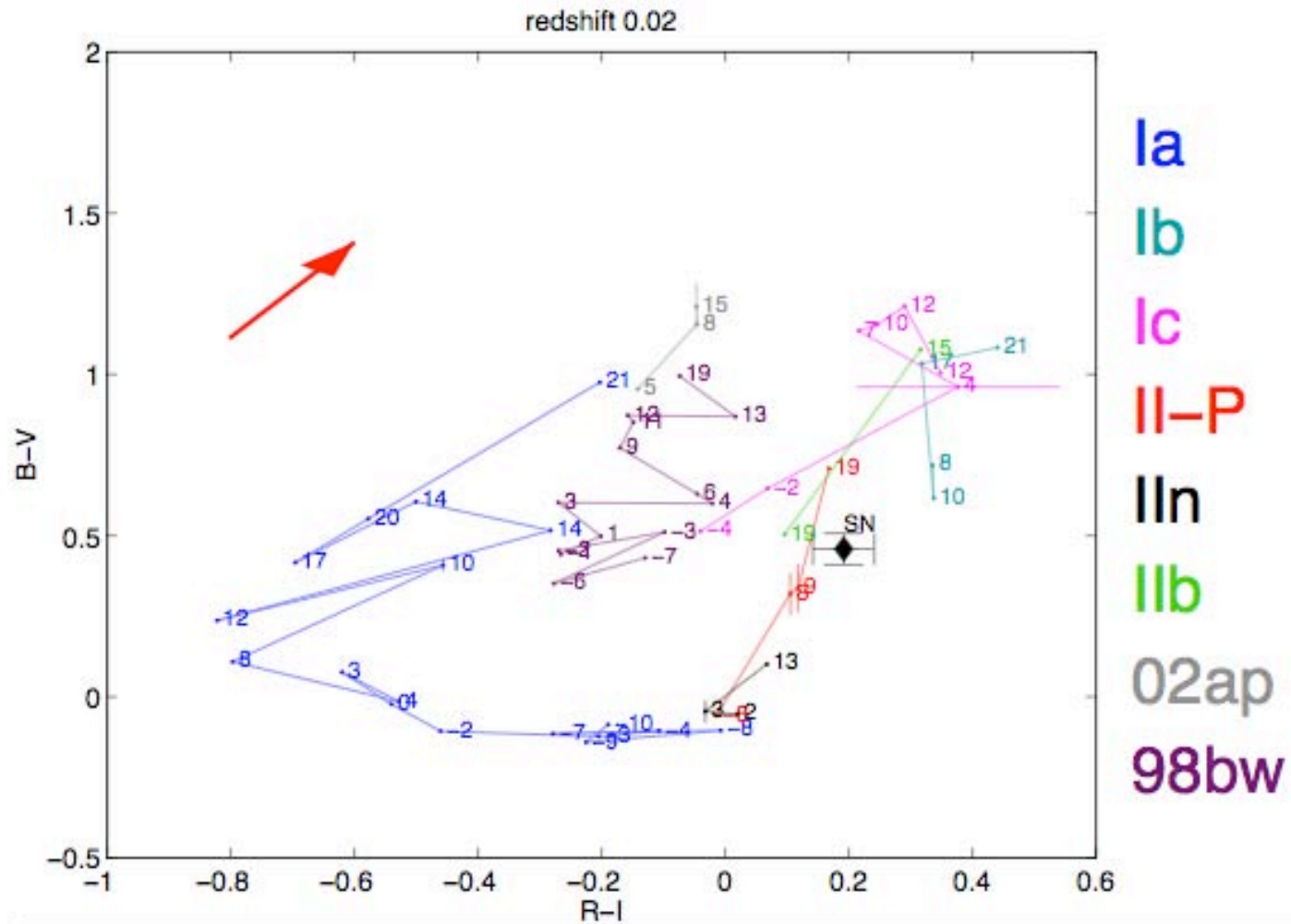


*BgVR* Phototyping

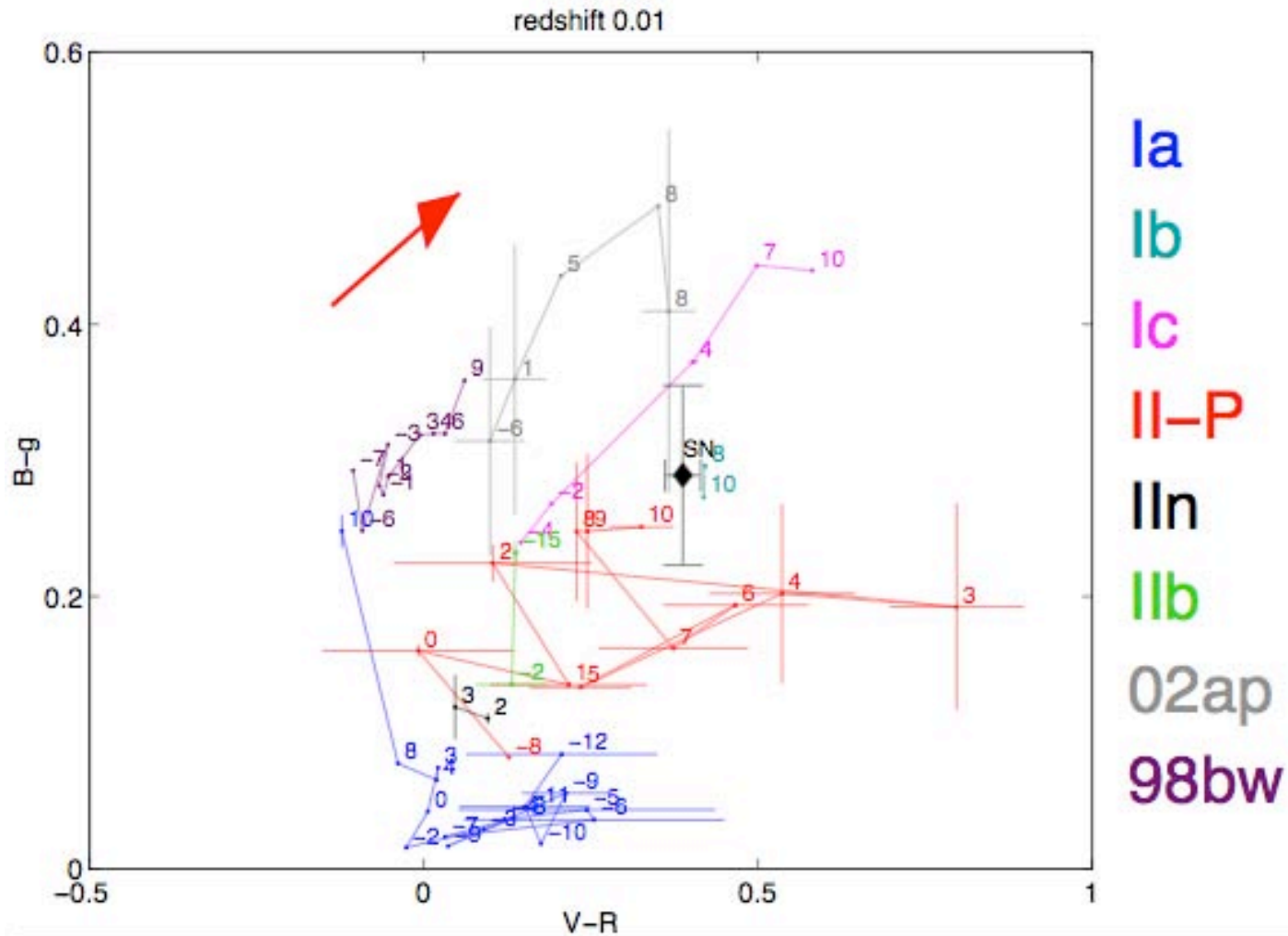
# SN2004cs (Phototype Ia)



# SN2004dh (Type IIp)



# SN2004dk (Type Ic)



# The Caltech Core Collapse Project (CCCP)

- “A year in the life of core-collapse supernovae”
- All events discovered at a provably young age in 2004B + 2005A
- Additional targets: All local type Ibc; HST targets; SN2003dj
- P60 provides *BVRI* photometry
- Monthly P200 runs for spectroscopy
- Additional near-IR photometry at P200 when time allows



SN2003ja

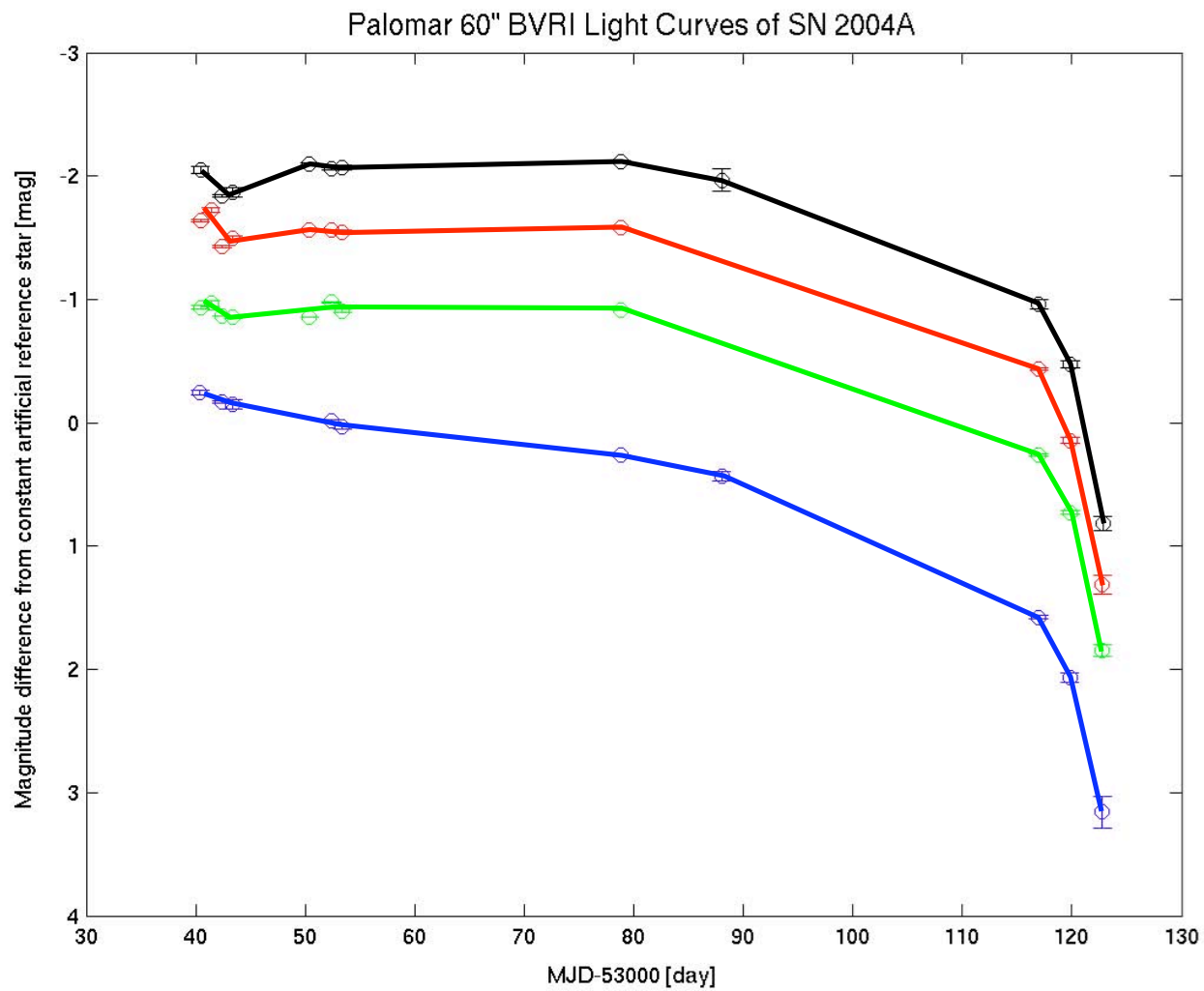
# The Caltech Core Collapse Project (CCCP)

- Diversity of core-collapse supernovae
- Spectroscopic library
- Optical and NIR photometry beginning before peak
- Necessary to compare to high-redshift events
- Including GRB-Supernovae



SN2003ja

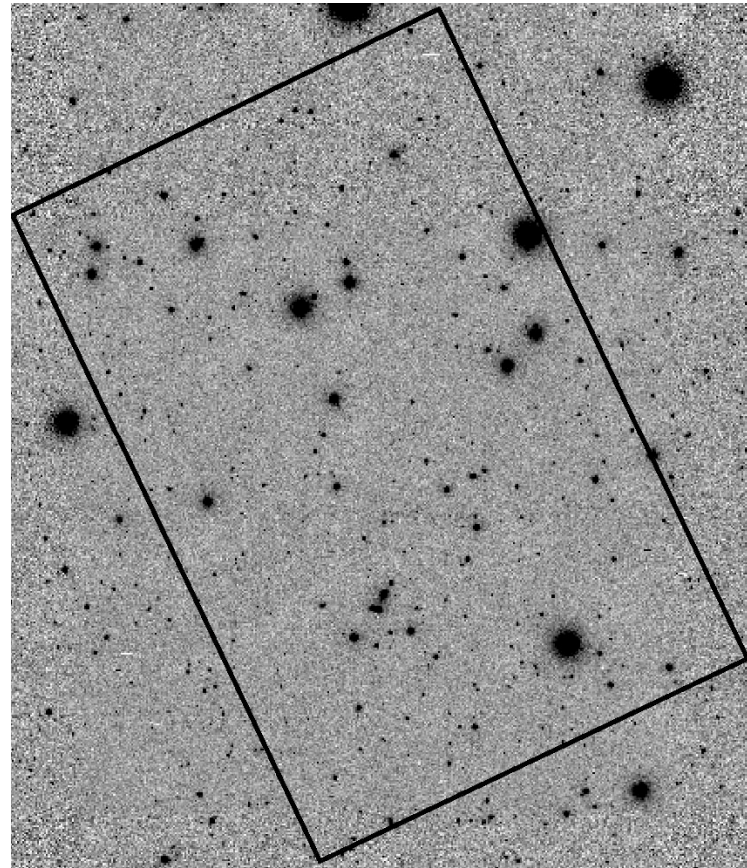
# P60 *BVRI* Lightcurve for SN2004A





# P60 for GRBs

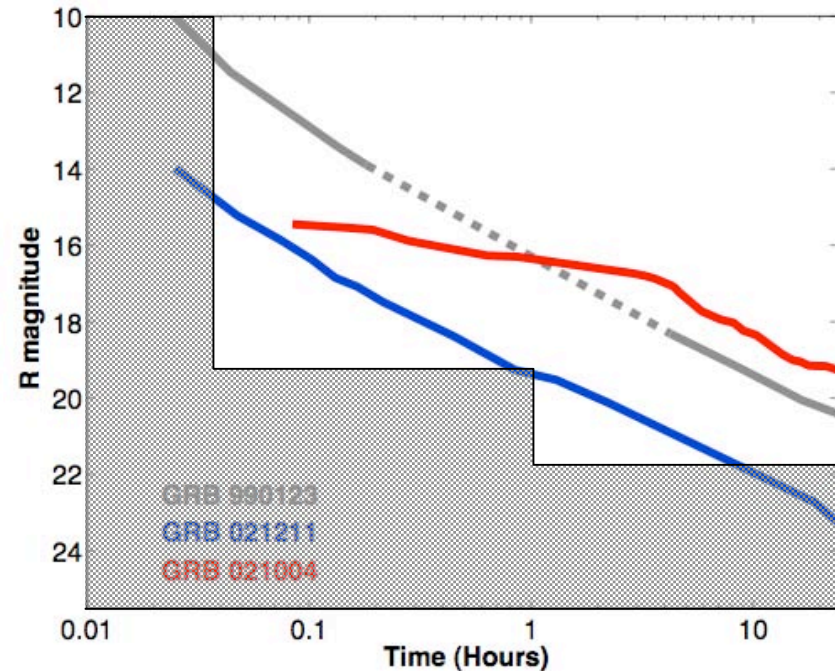
- Responding to *Integral* and *HETE* alerts
- XRF040825B: 10.2' x 15.5' error box
- Tiled as 3x3 pointings with 1/2 fov steps
- Several epochs over first three nights post-burst
- Post-pipeline: Fringe subtraction, mask bleed trails, combine with *Suarp*
- Deeper coverage of the central 13' x 13'
- No variability to  $I > 21.5$



XRF040825B

# P60 for GRBs

- $< 3$ -min response to new alerts with  $< 6.5'$  radius
- $R > 19$  in seconds
- Follow burst decay for hours
- Pipeline processing for transient discovery
- Multi-filter photometry ( $BVR/z$ )
- The search for interesting behavior at early times:  
Decreasing  $t \Rightarrow$  Increasing  $\Gamma$
- Trigger for spectroscopy, NIR observations, radio, X-ray ...

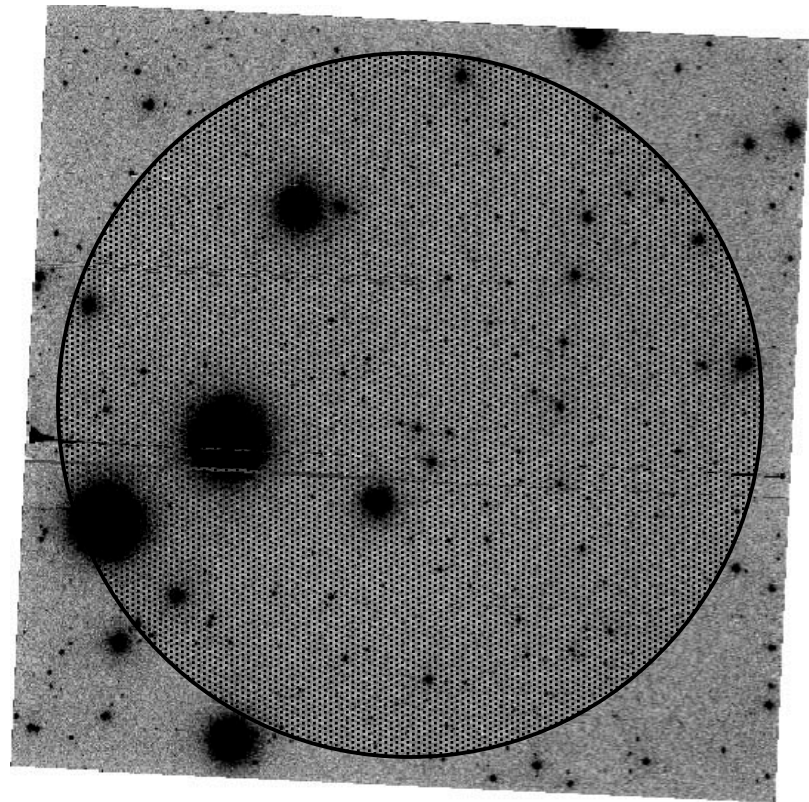


# P60 Future



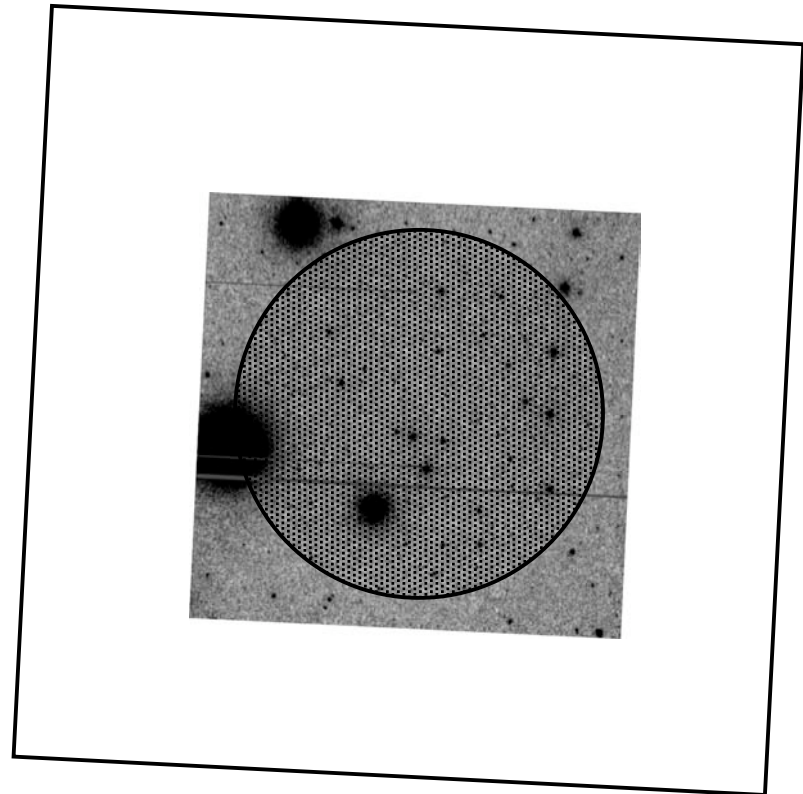
# Swift and P60

- Factors of 2 matter
  - 6' radius vs. 6' diameter is 35-s readout vs. 10-s readout
  - 30-s vs. 60-s
- Look in the UV where we can't
- Grism!
- Send us your poor, your wretched, your 2.5-sigma
- The need for live-ammunition testing
- GCN specification update
- Dummy web-pages, datafiles, finding charts ...



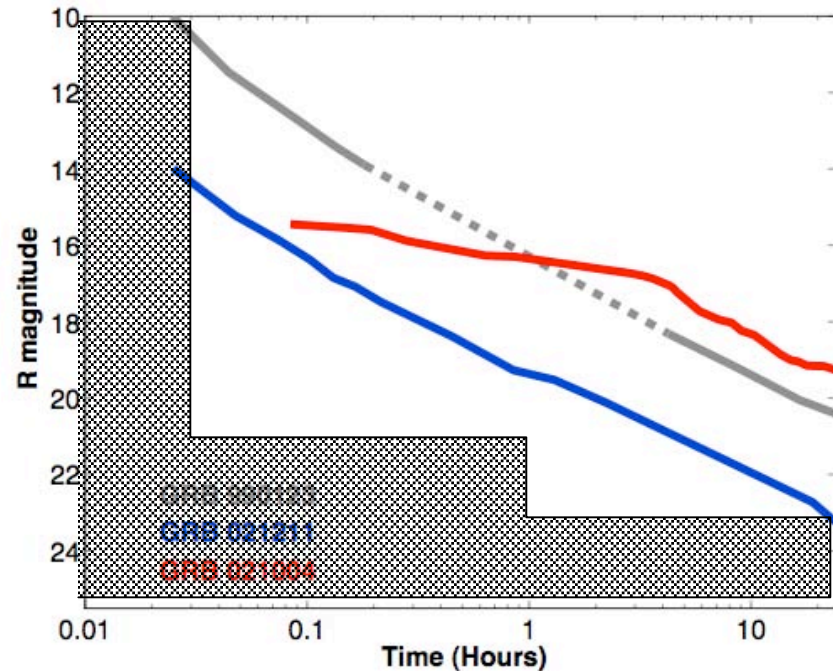
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- Grism!
- Send us your poor, your wretched, your 2.5-sigma
- The need for live-ammunition testing
- GCN specification update
  - More downstream info
  - Possible positions going upstream
- Dummy web-pages, datafiles, finding charts ...



# P60 and *Swift*

- Auto-triggered from *Swift* alerts
- More than 70% of time for GRB or other transient science
- Many more GRB light-curves from early times
- Redder filters (*R/z*) than the UVOT
- Continuous coverage for the first few hours (no orbit gaps)
- Lightcurves extending for days after each burst (until  $R > 23$ )
- All data archived at IPAC
- 3-month proprietary time



“An extension of *Swift*”

# Facility Upgrades

- Air conditioning for the dome
- IR camera + CCD joint mount
  - Use former IR camera (NICMOS)
  - Mechanical mount at Cassegrain
  - Motor switches out IR/CCD
- Improved efficiency of observations
- Database tracking of observations
- Increased sophistication of the pipeline



P60

# Turnabout is Fair Play

- The promise of *Swift* (+\$\$) has brought new life to an aging facility
- The robotic P60 is already producing valuable scientific results
- P60 would now like to return the favor

