The Era of Synoptic Surveys

Peter Nugent (LBNL)

“Current” Optical Surveys

Photometric:

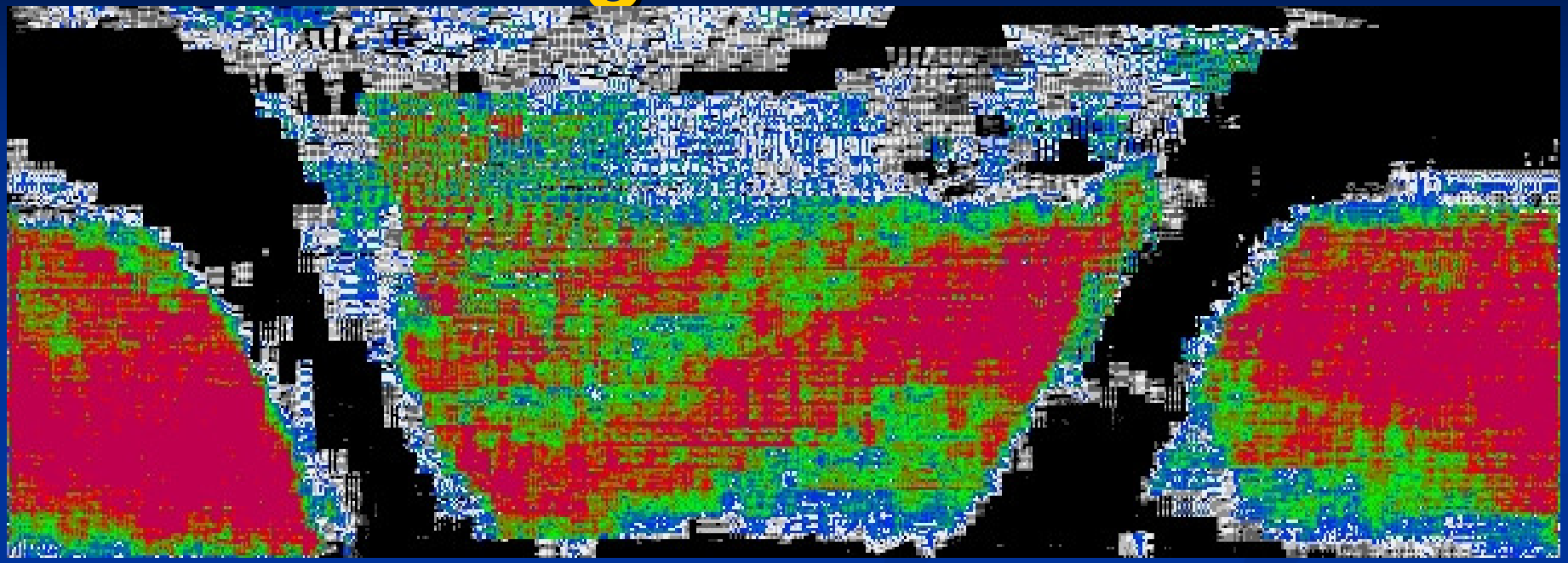
- Palomar Transient Factory
- La Silla Supernova Search
- SkyMapper
- PanSTARRS

Spectroscopic:

- SDSS III

All of these surveys span astrophysics from planets to cosmology, from the static to the transient universe.

Origins of PTF



The NEAT & Palomar-QUEST surveys on the Oschin schmidt telescope began the thought process on creating PTF. The data from these surveys span 9 years and almost 20,000 square degrees in open and RG610 filters. During this time the focus was on KBO's & NEOs, and to a lesser extent qso's. An active supernova search piggy-backed off of these efforts.

Origins of PTF

QuickTime™ and a
decompressor
are needed to see this picture.

Discovered over 1000 SNe of all types (show in red above) all over the northern sky, and of course the Pluto killers Sedna & Eris among others.

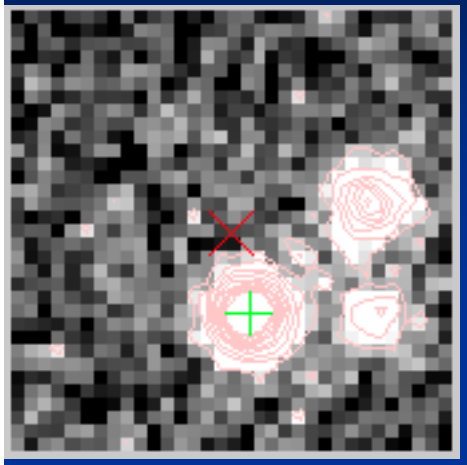
One of the biggest problems for the SN search was answering the question, “Is this transient really new?”

SN Factory Pipeline

QuickTime™ and a
decompressor
are needed to see this picture.

SN Factory Discoveries

References



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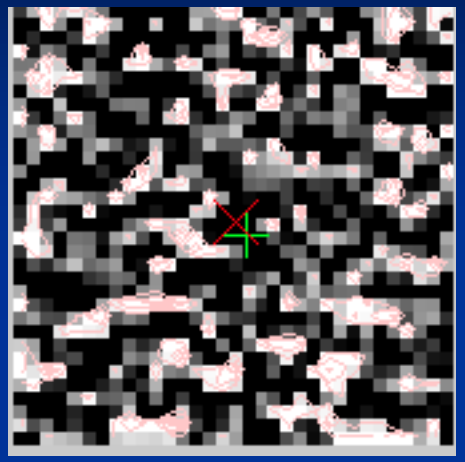

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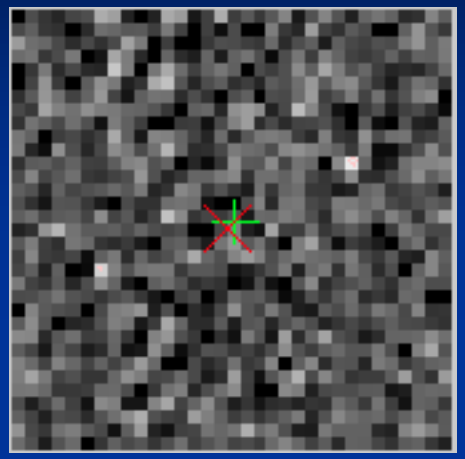

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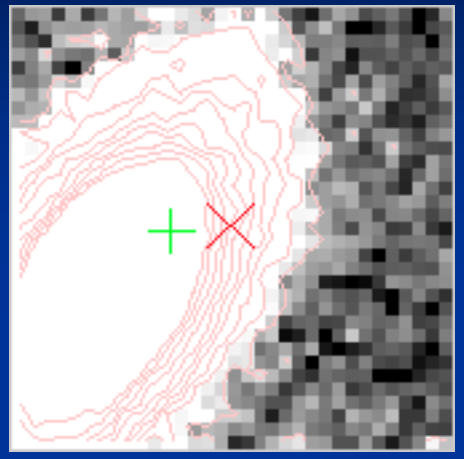

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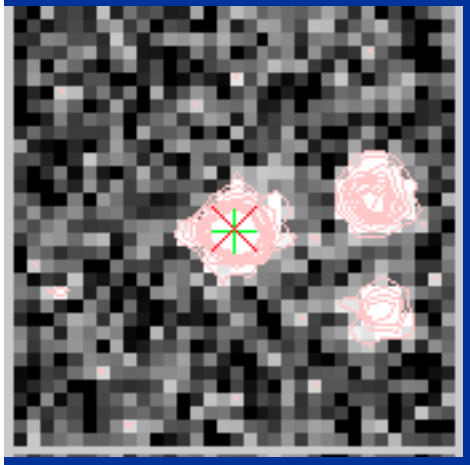
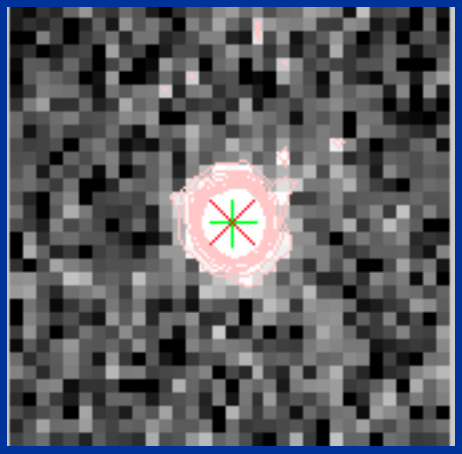
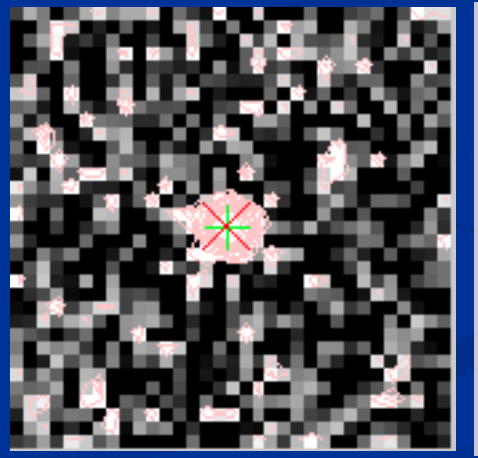
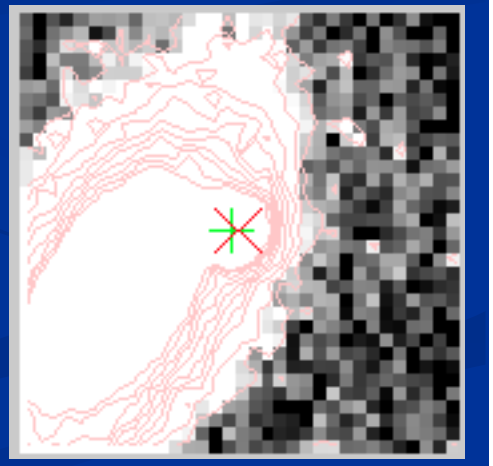


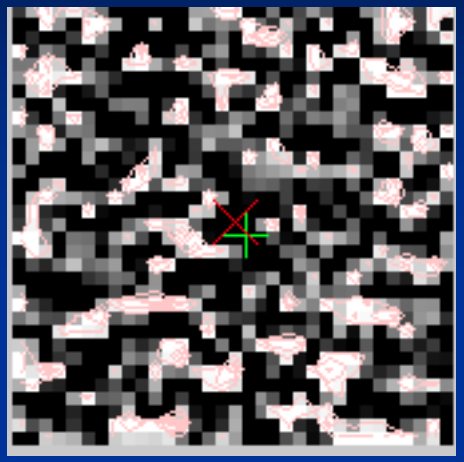


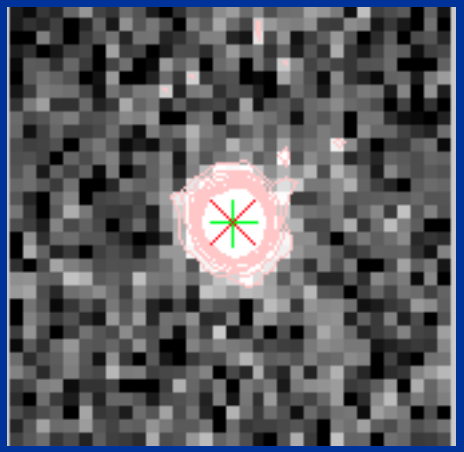


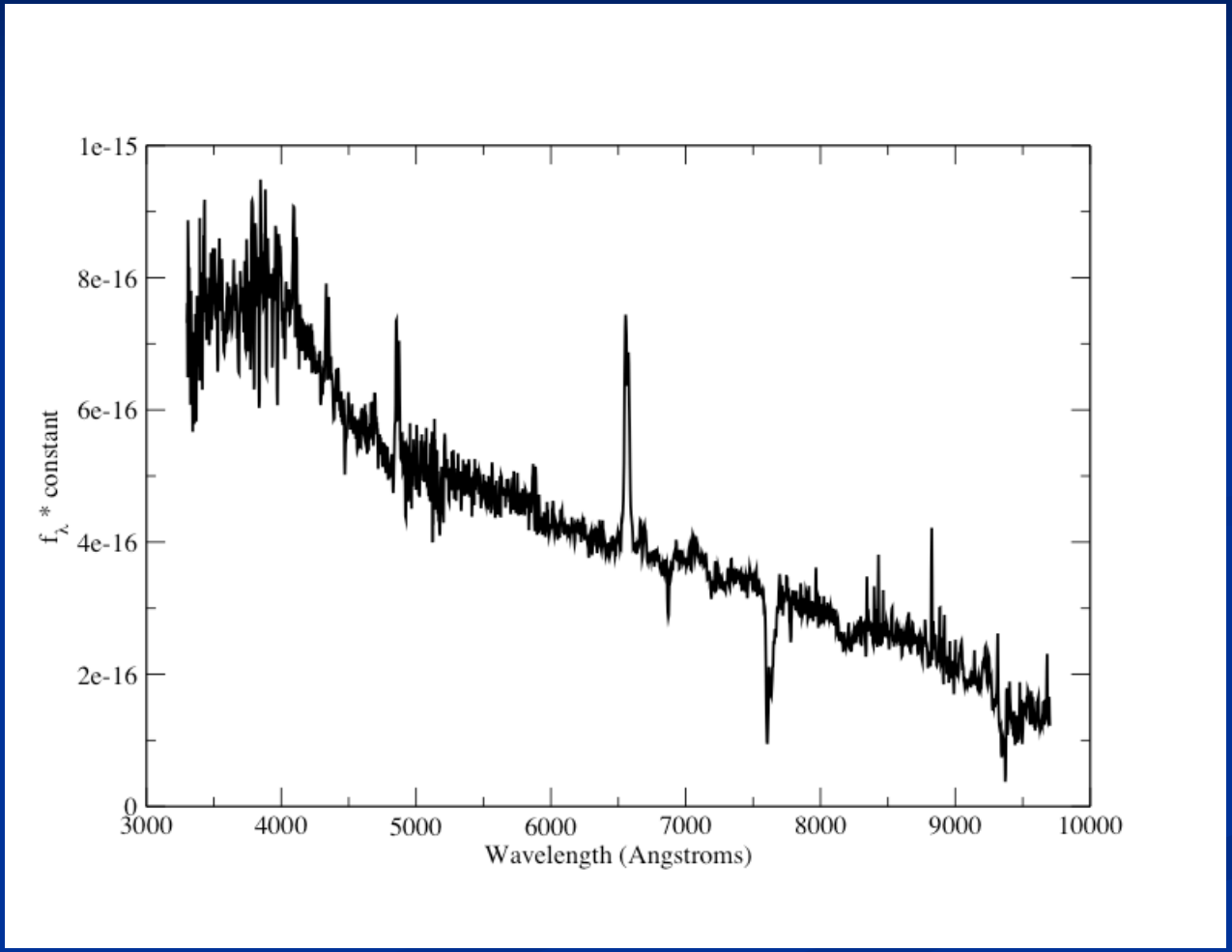


News

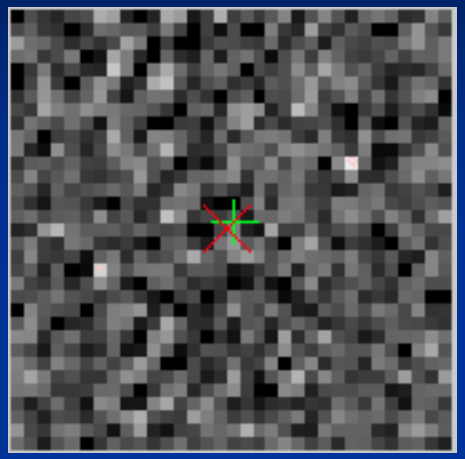
Case #2

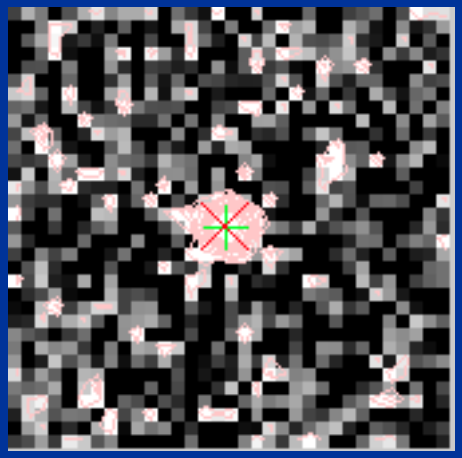


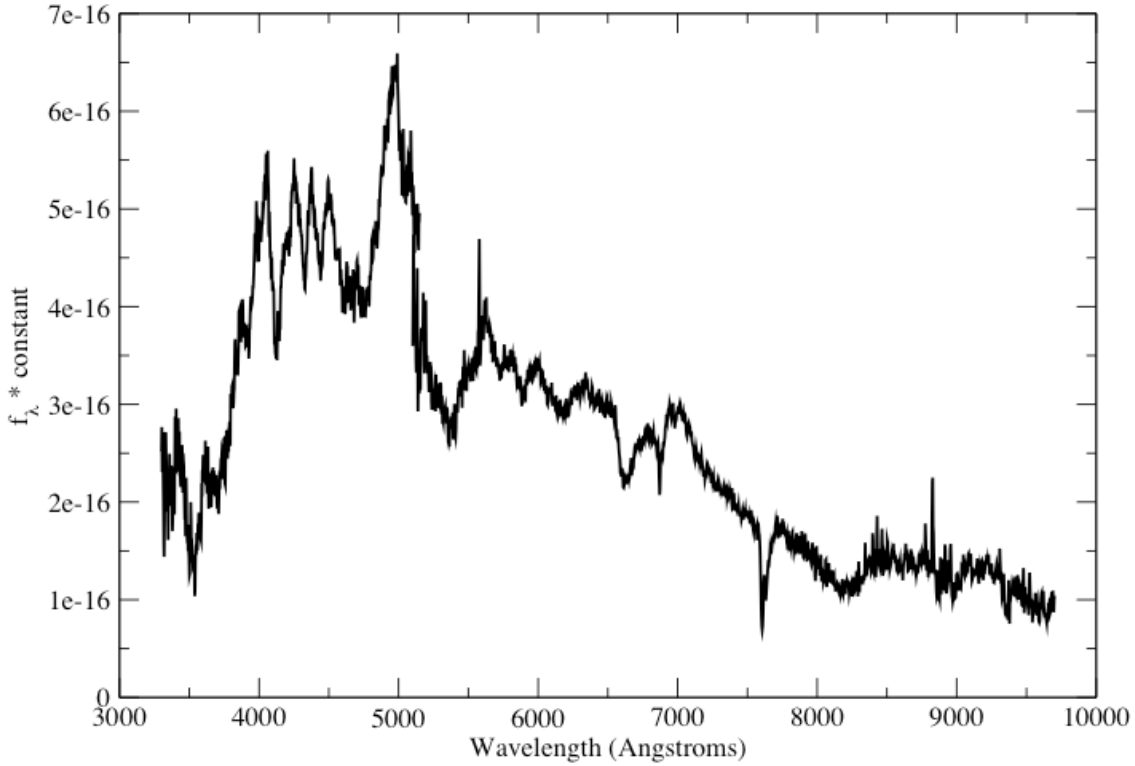



1e-15
8e-16
6e-16
4e-16
2e-16
0
f_λ * constant
3000
4000
5000
6000
7000
8000
9000
10000
Wavelength (Angstroms)

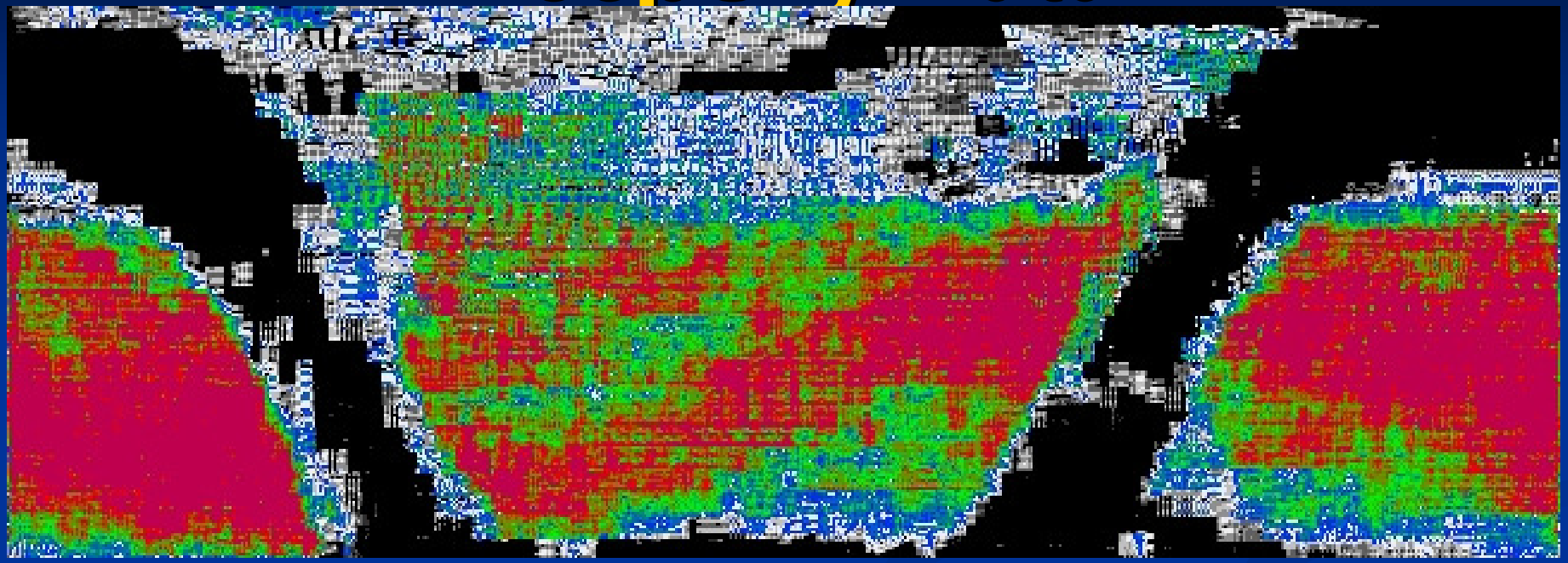
Case #3






7e-16
6e-16
5e-16
4e-16
3e-16
2e-16
1e-16
0
f_λ * constant
3000
4000
5000
6000
7000
8000
9000
10000
Wavelength (Angstroms)

DeepSky Data



Above, white represents about 20-40 pointings, blue around 100, green 200 and red 300. The exposure times were mostly 60s long and 2-4 were taken each night. Seeing was 2.1 - 3.0 “. The entire dataset is 75 TB and creates both a temporal and static catalog of astrophysical objects. NERSC has re-processed and hosts this data on spinning disk - 11.5M images.

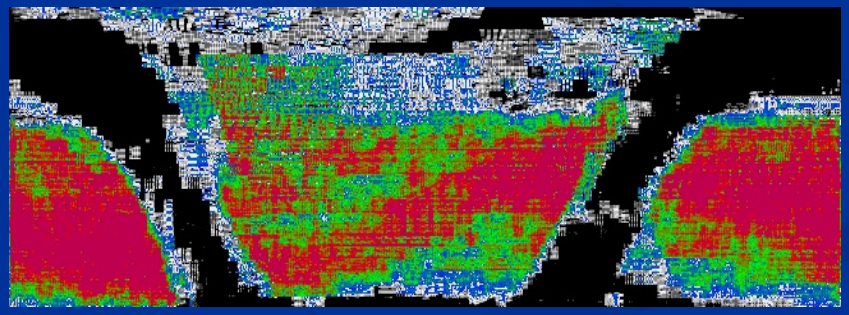
See: http://supernova.lbl.gov/~nugent/deepsky.html
And http://www.deepskyproject.org

DeepSky Archive

Science Gateway
Nodes
DeepSky Database

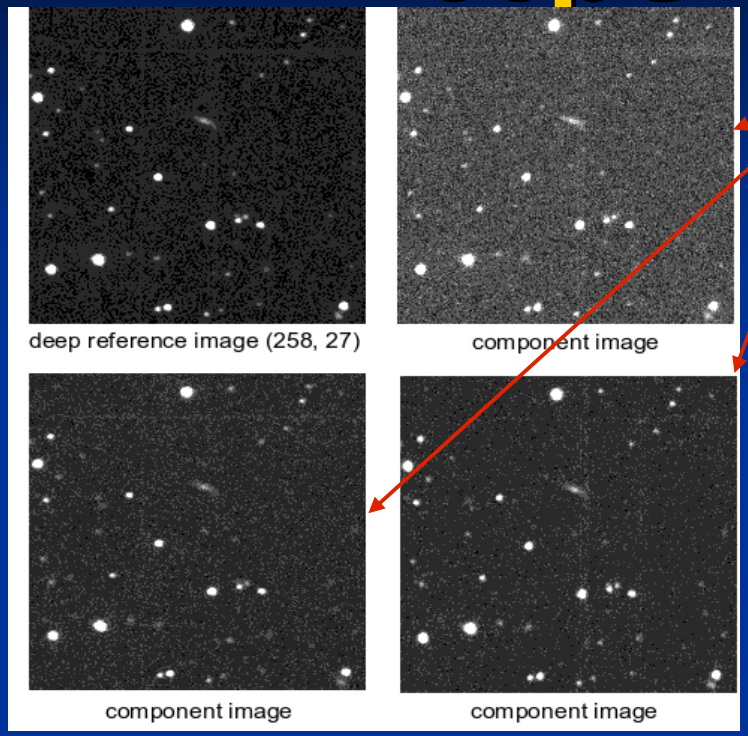
Jacquard
712 cpus 2 GB ram/cpu

Davinci
32 cpus 192 GB ram shared



NGF - 90TB IBM's GPFS

DeepSky Database



Database holds information about

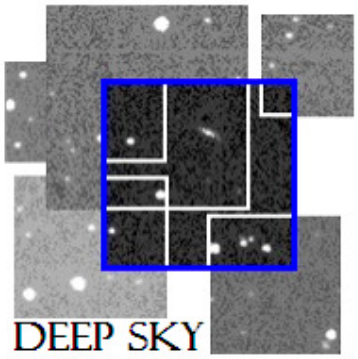
- **processed images,**
- **calibration data**
- **deep reference images** (result from co-adding processed images);
- **objects** found in references (soon).

Postgres 8.2.7 (open source) used for the DBMS. Postgres performance better than MySQL performance with transaction management and foreign key constraints implemented (InnoDB storage engine).

The Deep Sky database will be used to:

- check the quality of the images produced by the processing pipeline;
- get the list of processed images to be co-added to produce a deep reference image;
- retrieve the deep reference image and processed images that correspond to user-specified RA and DEC values (database backend to the UI).

DeepSky UI



The Deep Sky Project

Deep Sky is an astronomical image database of unprecedented depth, temporal breadth, and sky coverage. Image data are gathered from the Near Earth Asteroid Tracking (NEAT) project from the 3-CCD and Quest 112-CCD cameras on the Samuel Oschin telescope at the Palomar Observatory in San Diego County, California. Containing a total of eleven million images, or 70 terabytes of image data, Deep Sky covers nearly the entire northern sky.

Deep Sky images cover:

- 20,000 square degrees,
- one decade of temporal coverage, consisting of eleven pointings on average at any given set of sky coordinates,
- image depth an order of magnitude greater than most other large sky surveys.

Query Deep Reference Images

RA/DEC Suggestions help

Query By: RA/DEC Object Name

RA (degree):

DEC (degree):

Size (arcsec): 300

Start date:

End date:

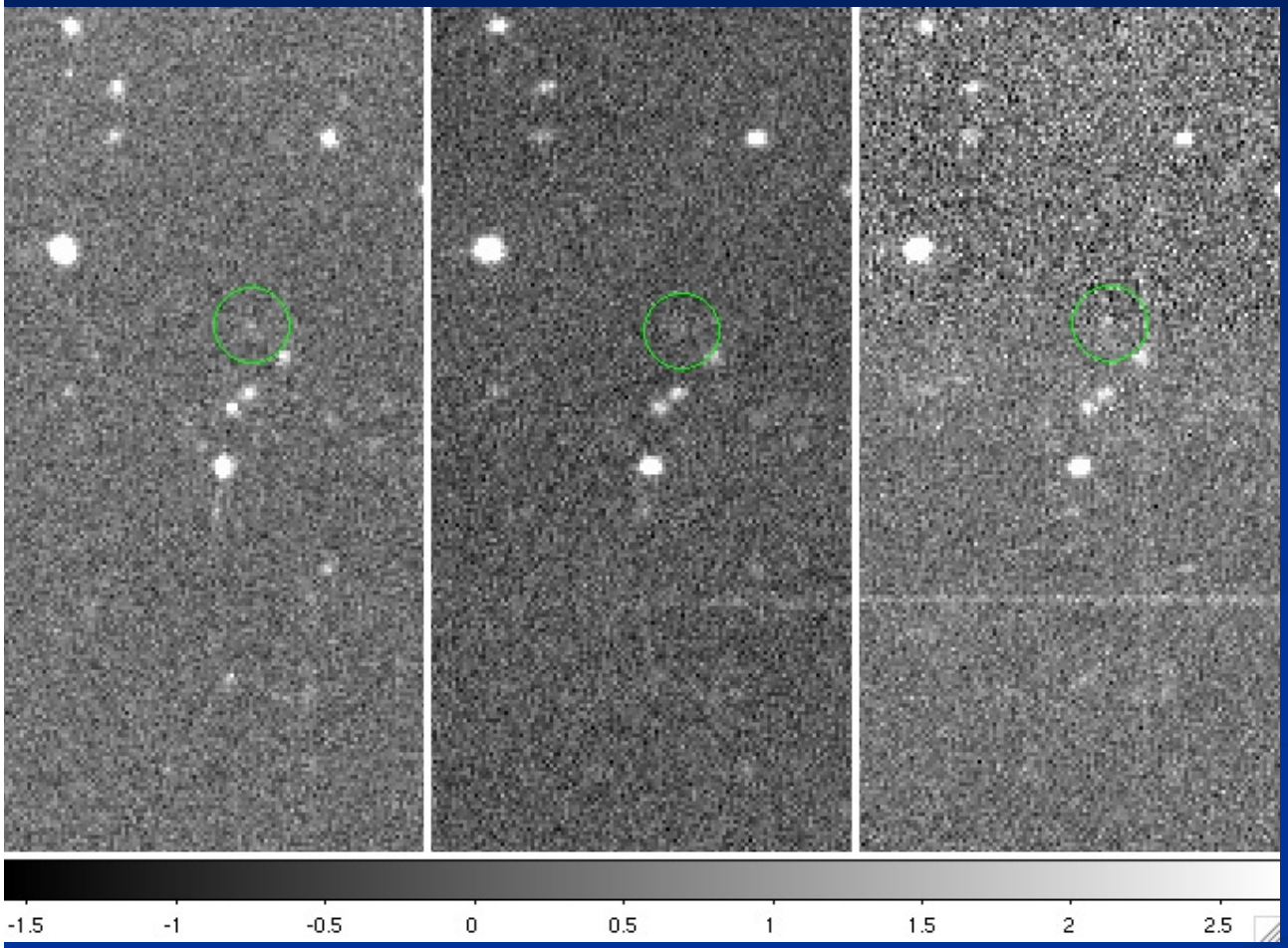
Advanced Image Options

Device Type

- (All Devices)
- Observation
- Telescope
- Instrument

Query Images

Image quality



This is what a mag ~21.0 qso (variable) looks like in a random pointing on stripe 82, with only 8 images per year going into these 3 co-adds (2006, 2007 and 2008).

This represents what can be done over almost the entire northern sky in the worst case for every year from 2000-2008.

Science

QuickTime™ and a
decompressor
are needed to see this picture.

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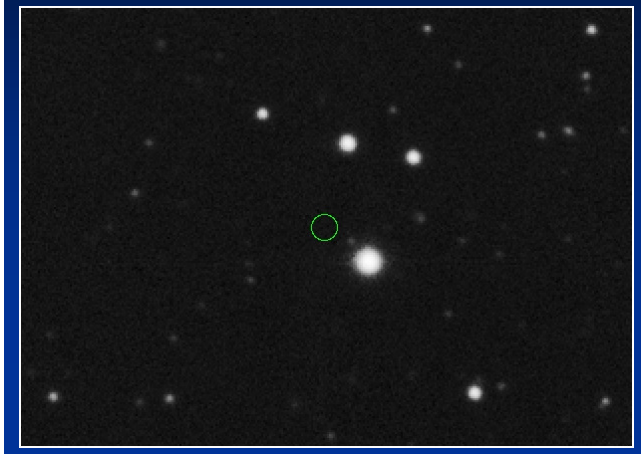
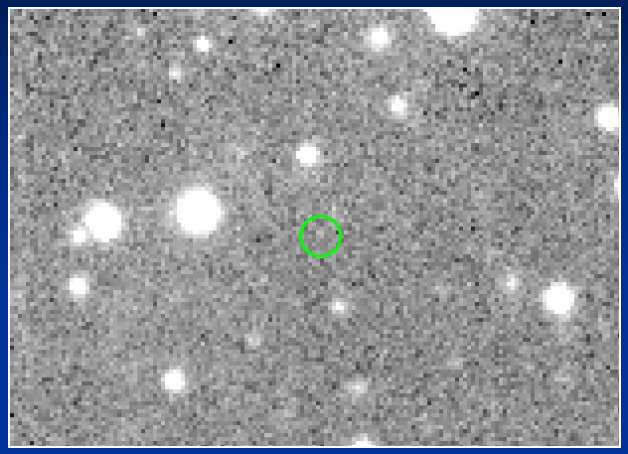
decompressor
are needed to see this picture.

RR Lyrae searches are now being conducted on this dataset to 20th magnitude as well as building structure functions for QSO's.

Science



GRB 070809



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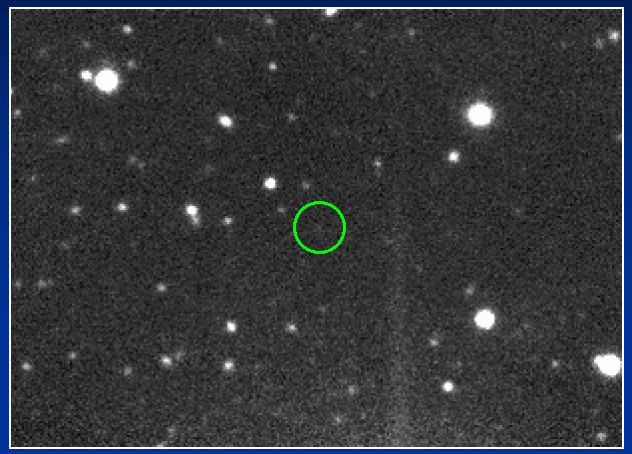


SNF 20070825-001

Limiting mag ~ 23.3

We have published several results in the Gamma Ray Bursts Coordinates Network Circulars and the Astronomer's Telegrams on the discovery (or limiting brightness) for many host galaxies of GRB's and/or supernovae. In addition we have used the time history of data to commence searches for historical supernovae. We have also started looking for dropouts in comparison to the UKIDSS survey.

Sept. 1, 2009

A Previous Transient Consistent with the Location of SN 2009ip Suggests that SN 2009ip is Not a Supernova

ATel #2183; *A. A. Miller (UC Berkeley), W. Li (UC Berkeley), P. E. Nugent (LBNL), J. S. Bloom (UC Berkeley), A. V. Filippenko (UC Berkeley), and A. T. Merritt (UC Berkeley)*
on 1 Sep 2009; 23:13 UT
Distributed as an Instant Email Notice (Transients)
Password Certification: Weidong Li (weidong@astron.berkeley.edu)

Subjects: Infra-Red, Optical, Novae, Supernovae, Transients, Variables, Stars
Referred to by ATel #: 2184

We have examined historical DeepSky (ATEL #1213) images of NGC 7259 and find that a transient consistent with the location of SN 2009ip (Maza et al. 2009; CBET 1928) was present in 2005. Relative to USNO-B1, preliminary photometry yields that the transient was at R ~ 20.6 mag on 2005 Jun 20 (UT dates are used throughout) and R ~ 21.0 mag on 2005 Jul 03. On a stacked image from 2008 Aug 23 we do not detect the transient down to R ~ 22.0 mag. Typical uncertainties when calibrating relative to USNO-B are 0.2 mag.

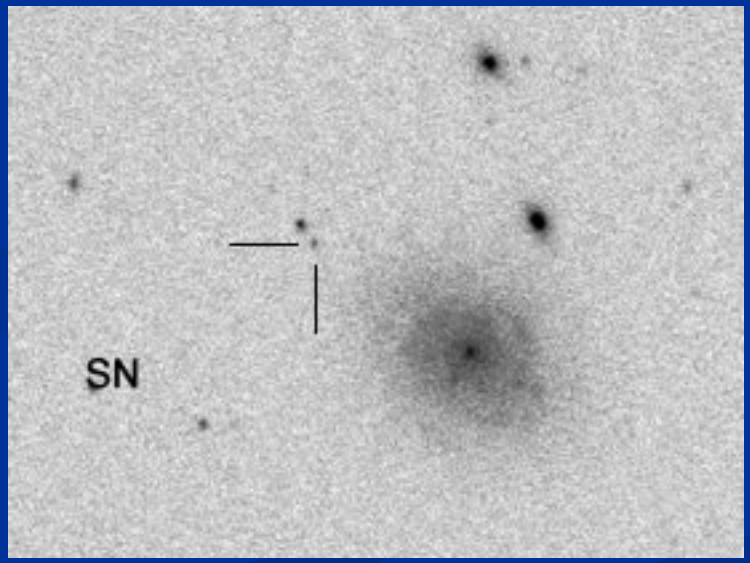
In a ground-based KAIT image taken on 2009 Aug 30, we measure SN 2009ip to have an unfiltered magnitude of 18.2, which corresponds to an absolute magnitude of M ~ -13.7 mag at the distance of NGC 7259.

We have downloaded an archival HST/WFPC2 image of the field which was taken on 1999 Jun 29 (HST proposal ID 6359). From an astrometric solution between the WFPC2 and KAIT images, we identified a potential progenitor for the transient at

R.A. = 22:23:08.20, Decl. = -28:56:52.6 (J2000.0),

with F606W = 21.8 mag, which corresponds to an absolute magnitude of M ~ -10.1 mag at the distance of NGC 7259

SN 2009ip classification as an LBV through DeepSky.



Sept. 2, 2009

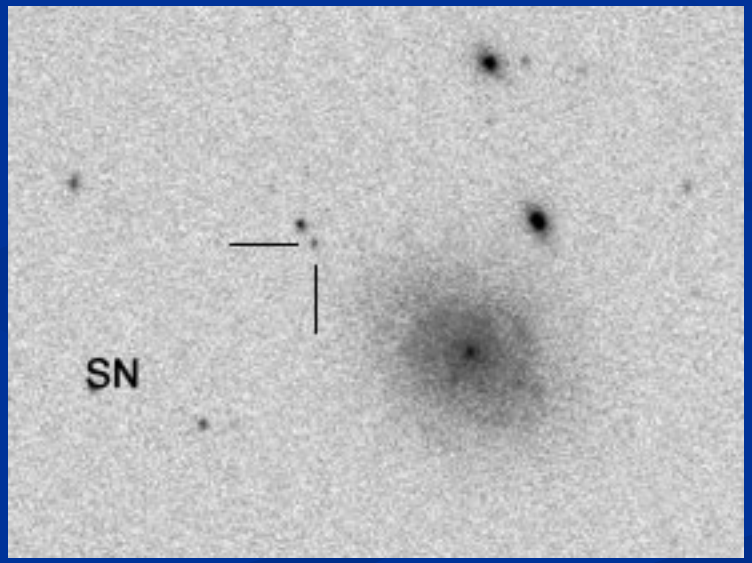
SN 2009ip is an LBV Outburst

ATel #2184; *E. Berger, R. Foley (Harvard), and I. Ivans (OCIW/Princeton)*
on 2 Sep 2009; 1:28 UT
Distributed as an Instant Email Notice (Supernovae)
Password Certification: Edo Berger (eberger@astro.princeton.edu)

Subjects: Optical, Novae, Supernovae, Transients

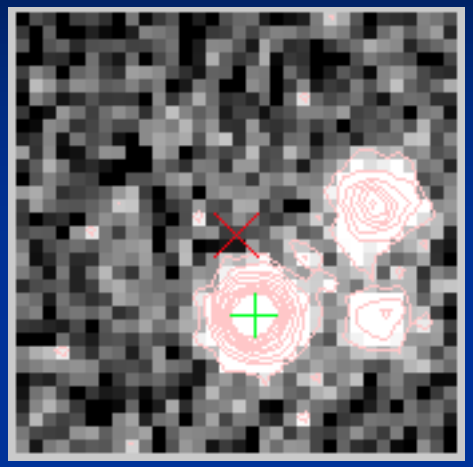
We obtained medium-resolution optical spectra of SN2009ip in NGC 7259 (CBET # 1928) with the Magellan Echellete Spectrograph mounted on the Magellan/Clay 6.5-m telescope on 2009 September 1.24 UT. The spectra exhibit narrow (FWHM ~ 550 km/s) hydrogen Balmer emission lines centered at the systemic velocity of NGC 7259. These properties, along with a peak optical absolute magnitude of about -13.7 mag, previous variability at the same position, and a potential progenitor with M~-10 mag (ATEL #2183) indicate that SN2009ip is a luminous blue variable (LBV) outburst, similar to previous SN impostors such as SN1997bs (Van Dyk et al. 2000, PASP, 112, 1532).

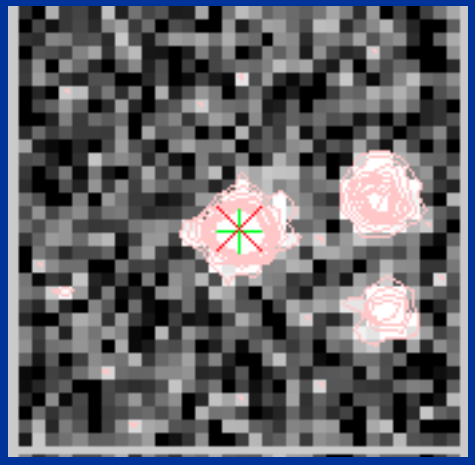
SN 2009ip classification through DeepSky.

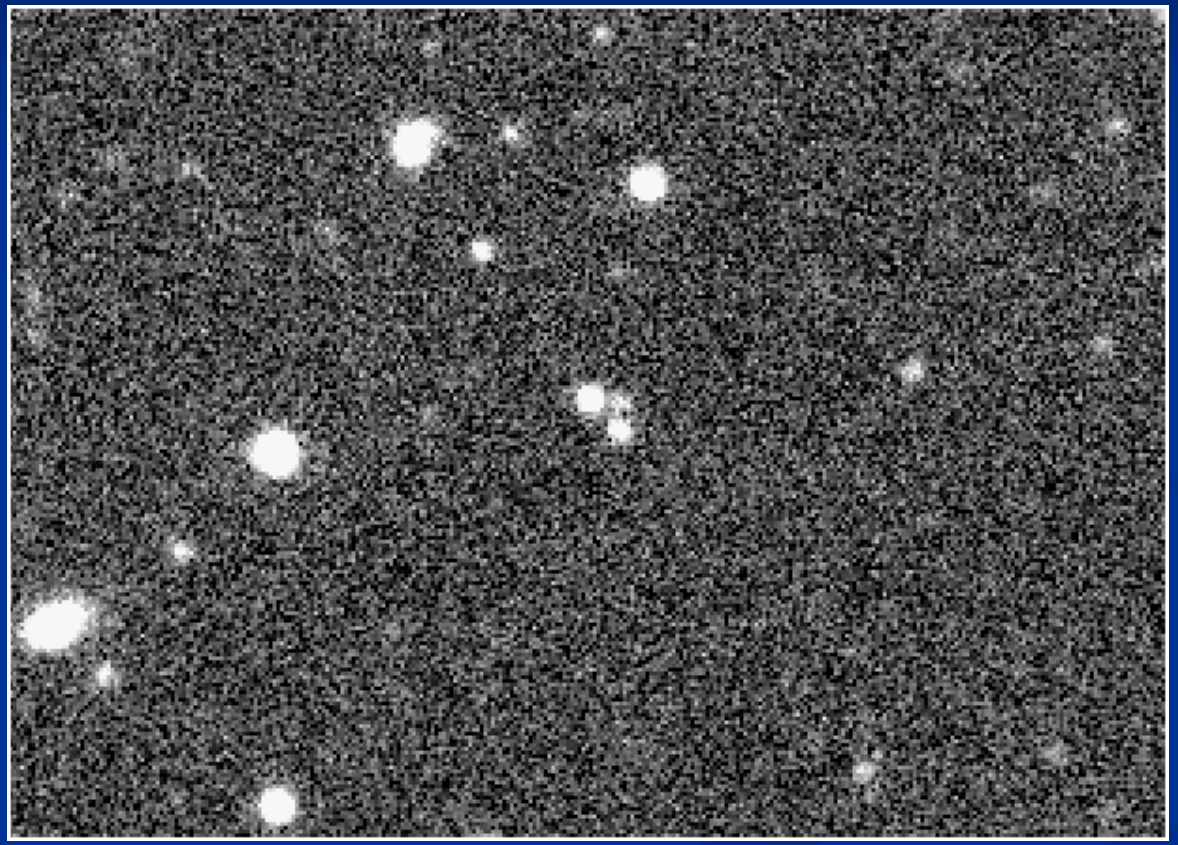


See Smith *et al.* (2009)
arXiv:0909.4792

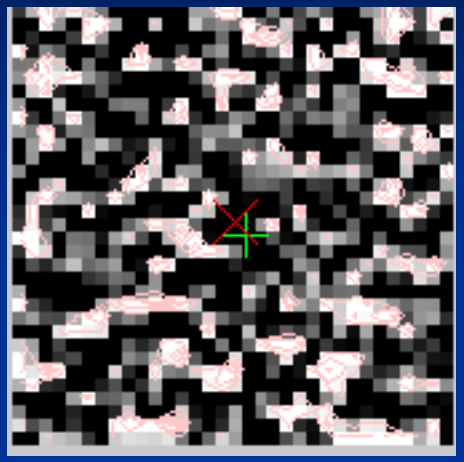
Case #1

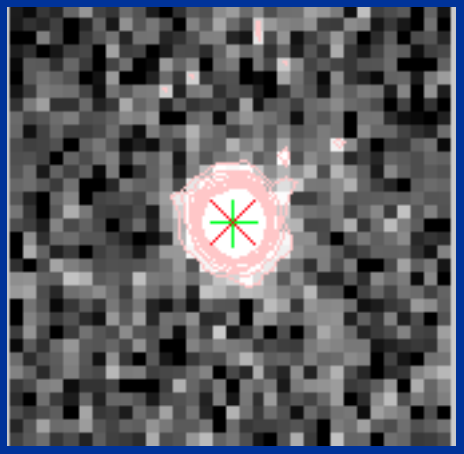






Case #2





QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

PTF Test Run

In 2007 LBNL & Caltech started to explore how to get more science out of the PQ survey. LBNL would continue the work on SNe Ia's while Caltech would make a concerted effort to target anything else that went bump in the night.

This immediately paid dividends for both groups and became a cornerstone for how PTF would operate.

PTF Test Run - Blazars

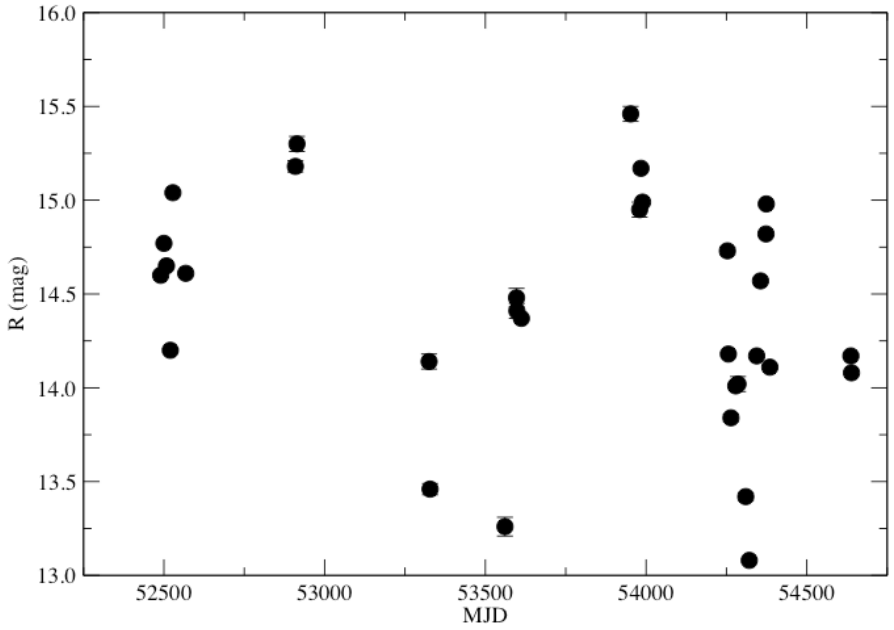
Archival light curves for the gamma-ray bright blazar 3C 454.3

ATel #1684; S.G. Djorgovski, T. Morton, A.J. Drake, A. Mahabal, E. Glikman (Caltech), P. Nugent (LBNL), C. Baltay, D. Rabinowitz (Yale), E.C. Beshore, S.M. Larson (UA/LPL), R. Williams, D. Gopal, C. Donalek, M. Graham (Caltech), A. Bauer, N. Ellman, R. Scalzo, J. Jerke (Yale), E. Christensen (Gemini Obs.)
on 28 Aug 2008; 3:44 UT
Password Certification: S. George Djorgovski (george@astro.caltech.edu)

Subjects: Optical, AGN, Quasars

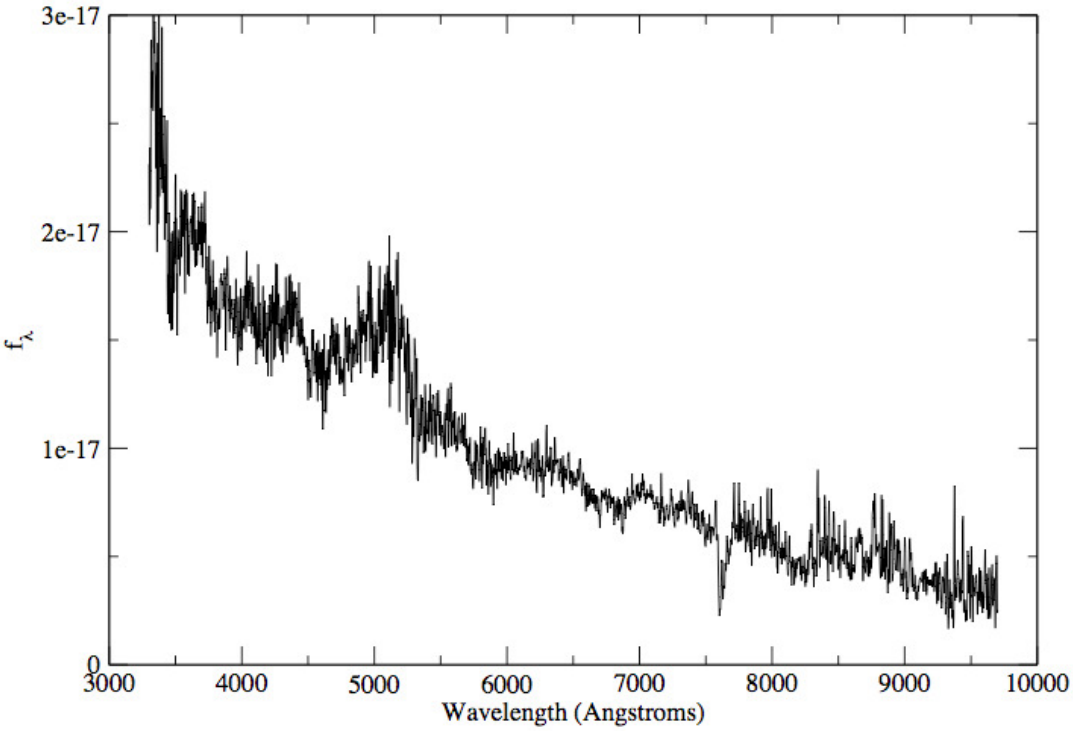
We compiled archival light curves for the blazar 3C454.3, which is currently dominatin extragalactic gamma-ray sky as seen by the early GLAST/Fermi observations.

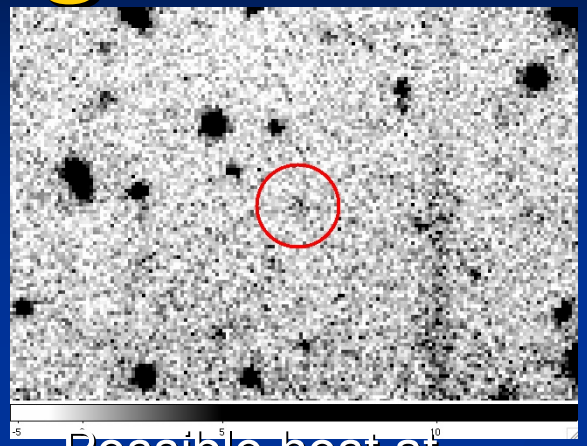
One data set is from the Palomar-Quest (PQ) survey, a combination of exposures taken scan and point-and-stare modes, supplemented by a few early observations from the JPl team. These data were obtained at Palomar 48-inch Schmidt Samuel Oschin Telescope, range of about 6 years, from 04 Aug 2002 UT, through 22 June 2008 UT, and consist of exposures taken on 32 separate dates. All data are in red bands, brought to an empirical determined common zero-point using nearby stars, and roughly zero-pointed using USN catalog. The other data set is from the Catalina Sky Survey (CSS), obtained at the Mt. E 27-inch Schmidt telescope, with an unfiltered CCD, and consist of 86 exposures taken c separate dates, from 03 July 2005 UT, through 13 June 2008 UT. No attempt is made at account for the color terms, and a more detailed photometric calibrations are in progres



Fermi/GLAST observations of blazars.

PTF Test Run - Strangeness



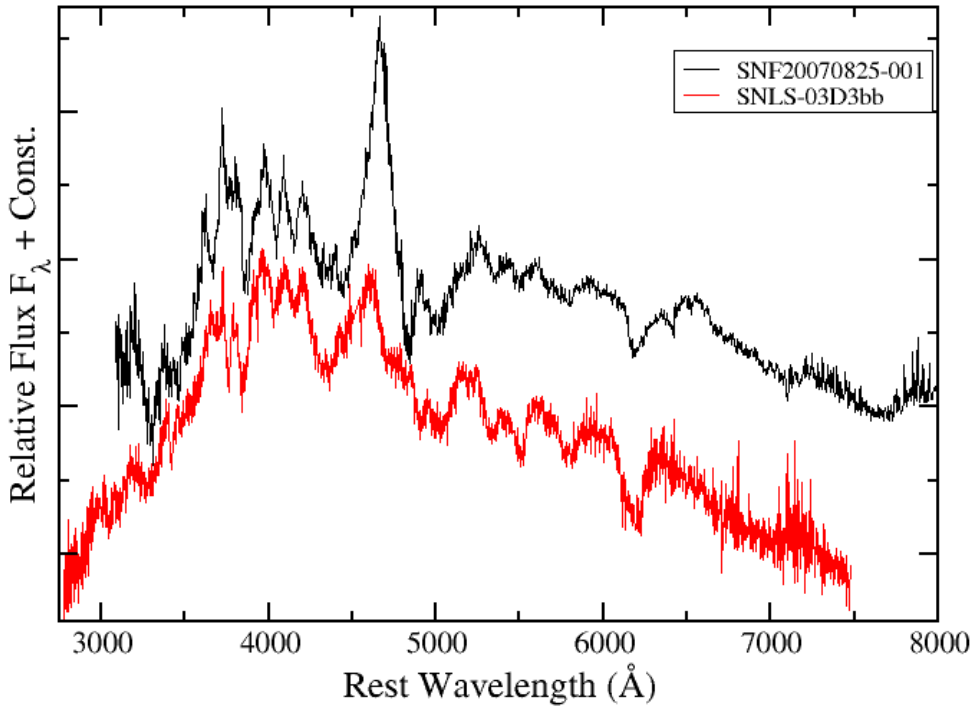


Possible host at mag ~24 (DeepSky)

In three weeks it went from this to mag 17.7.

Spectrum taken within 24 hrs of discovery.

Strange -> Super Chandra SN Ia



Caltech took the spectrum a week later that showed it was a SNLS-03d3bb look-alike.

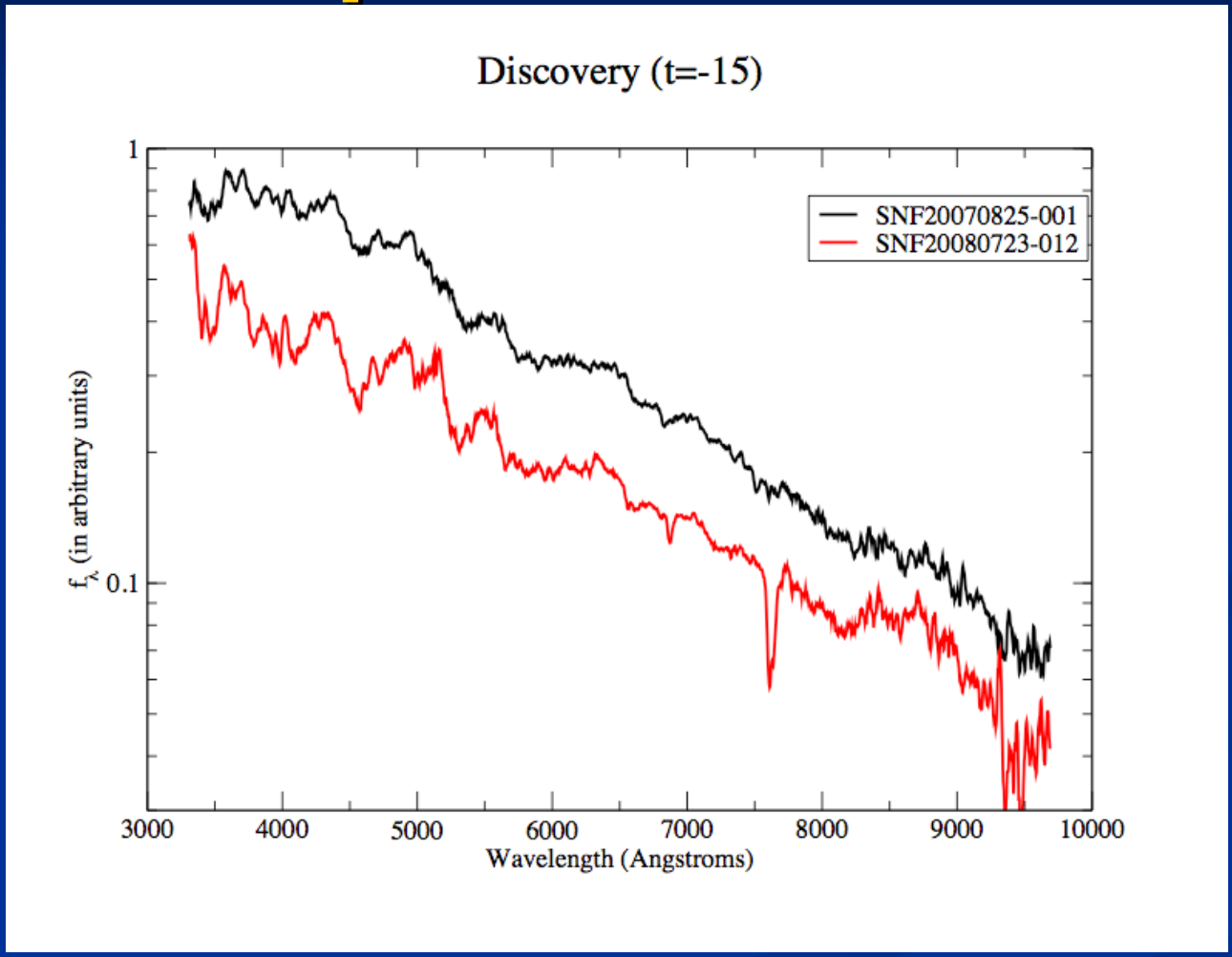
A SN Ia with:

$M_{SN} = -20$
$M_{host} = -14$

Scalzo *et al*, (ApJ, 2010)

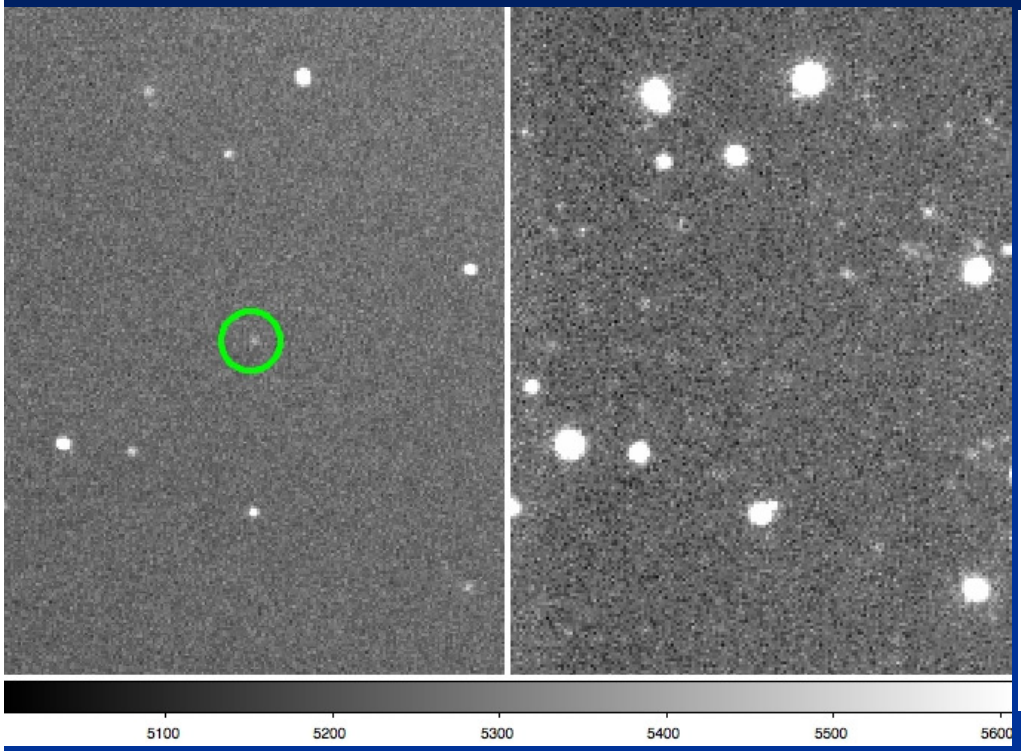
Lesson learned: ***continue to hit it until you figure out what it is***.

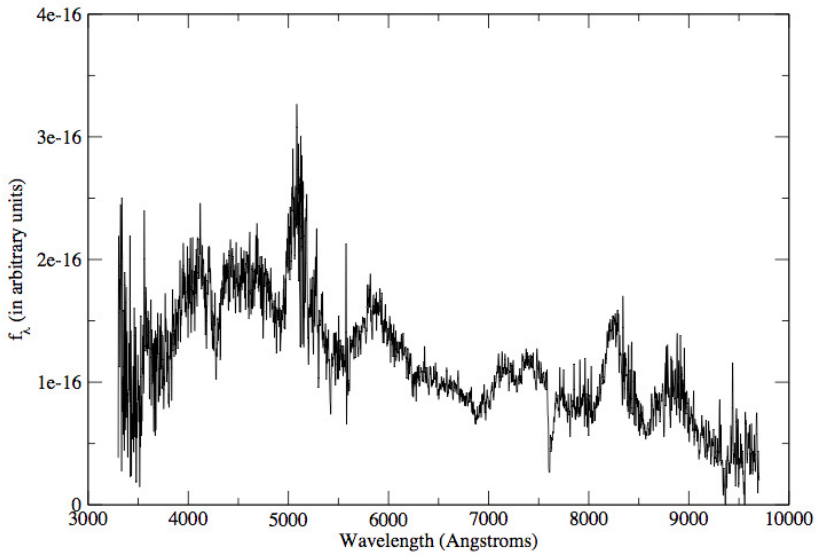
More Super Chandra SNe Ia



One year later we found another!

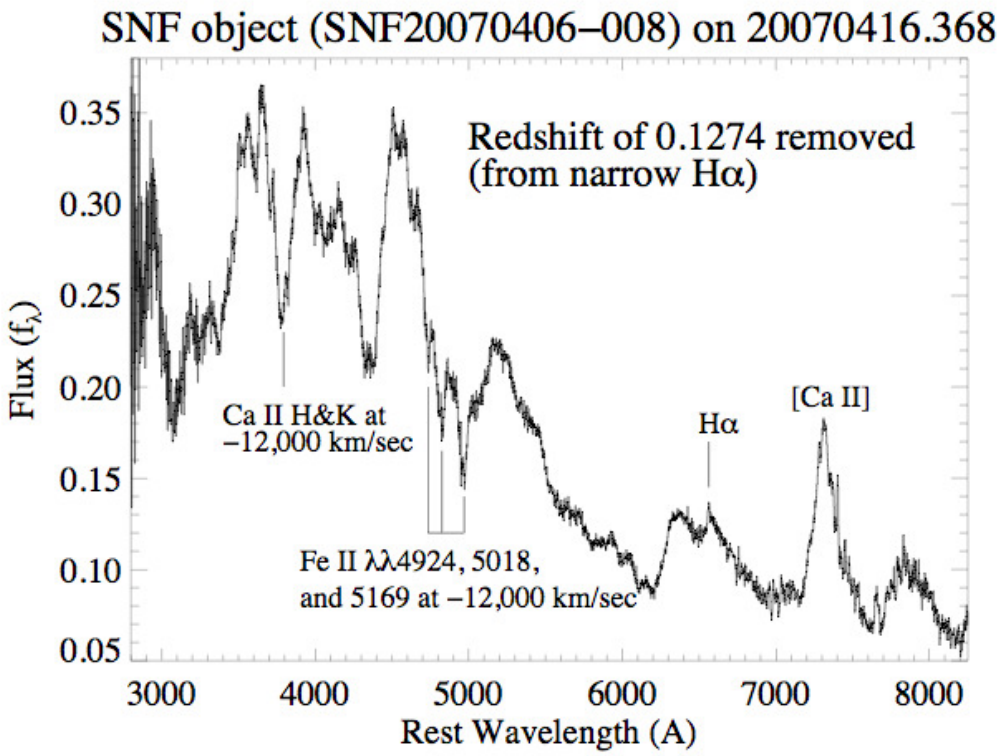
Strange SN Ic





Found Apr 6th, 2007 SN Ic w/ z ~ 0.1
Host has M_g= -16.4
M_V = -20.5

Strange SN Ic



Confirmed at Keck by Filippenko, Bloom, Foley & Chornock.

Similarity to SN 1999as was noted.

Pair Instability SN

Nature paper accepted (Gal-Yam *et al*., 2009):

SN 2007bi: an explosion of an extremely massive star due to pair instability

QuickTime™ and a
decompressor
are needed to see this picture.

Pair Instability SN

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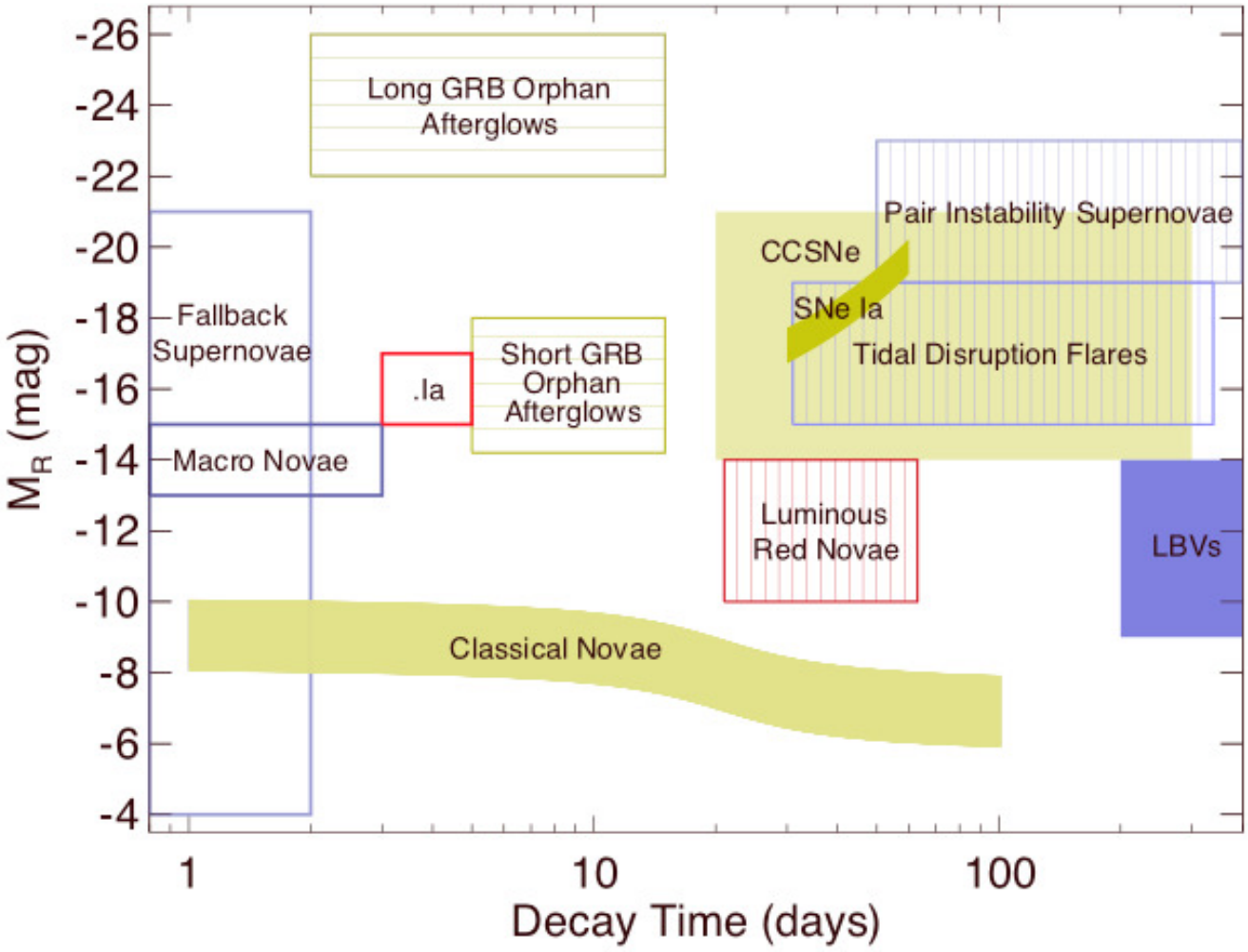
Competition

The competition were two wide-field multi-color surveys with cadences that we either unpredictable (SkyMapper) or from days to weeks (PanSTARRS) in a given filter.

How could we do something better/different?

- Start quickly - P48” coupled with the CFHT12k camera
- Don’t do multiple colors
- Explore the temporal domains in unique ways
- Take full advantage of the big-iron at NERSC
- Get all the science we possibly can out of this program

Phase-Space


Long GRB Orphan Afterglows
Pair Instability Supernovae
CCSNe
SNe Ia
Tidal Disruption Flares
Fallback Supernovae
.Ia
Short GRB Orphan Afterglows
Macro Novae
Luminous Red Novae
LBVs
Classical Novae
-26
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
M_R (mag)
1
10
100
Decay Time (days)

PTF (2009-2013)

- CFH12k camera on the Palomar Oschin Schmidt telescope
  - 7.8 sq deg field of view, 1” pixels
  - 60s exposures with 15-20s readout in r, g and H-alpha
  - Improvements to telescope (seeing, tracking, scheduling)
  - First light Nov. 24, 2008.
  - First useful science images on Jan 13th.

- 2 Cadences (Mar. - Nov.)
  - Nightly (35% of time) on nearby galaxies and clusters (g/r)
  - Every 5 nights (65% of time) on SDSS fields with minimum coverage of 2500 sq deg. (r) to 20th mag 10-sigma
  - H-alpha during bright time (full +/-2 days)

  Nov-Feb, minute cadences on select fields.

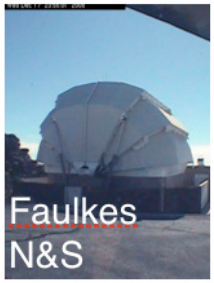
PTF Science

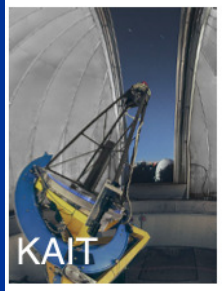
PTF Key Projects	
Various SNe	Dwarf novae
Transients in nearby galaxies	Core collapse SNe
RR Lyrae	Solar system objects
CVs	AGN
AM CVn	Blazars
Galactic dynamics	LIGO & Neutrino transients
Flare stars	Hostless transients
Nearby star kinematics	Orphan GRB afterglows
Rotation in clusters	Eclipsing stars and planets
Tidal events	H-alpha ½ sky survey

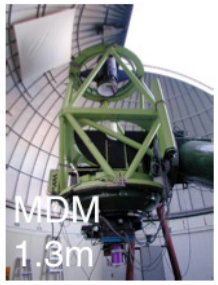
The power of PTF resides in its diverse science goals and follow-up.

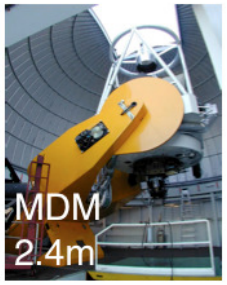
PTF Science

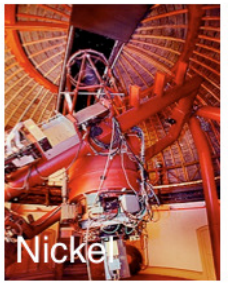
▼ ▶ Detected transients will be followed up using a wide variety of optical and IR, photometric and spectroscopic followup facilities.

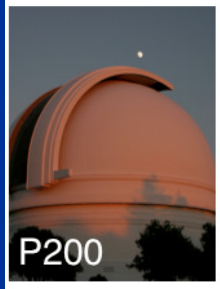


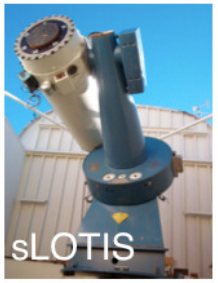






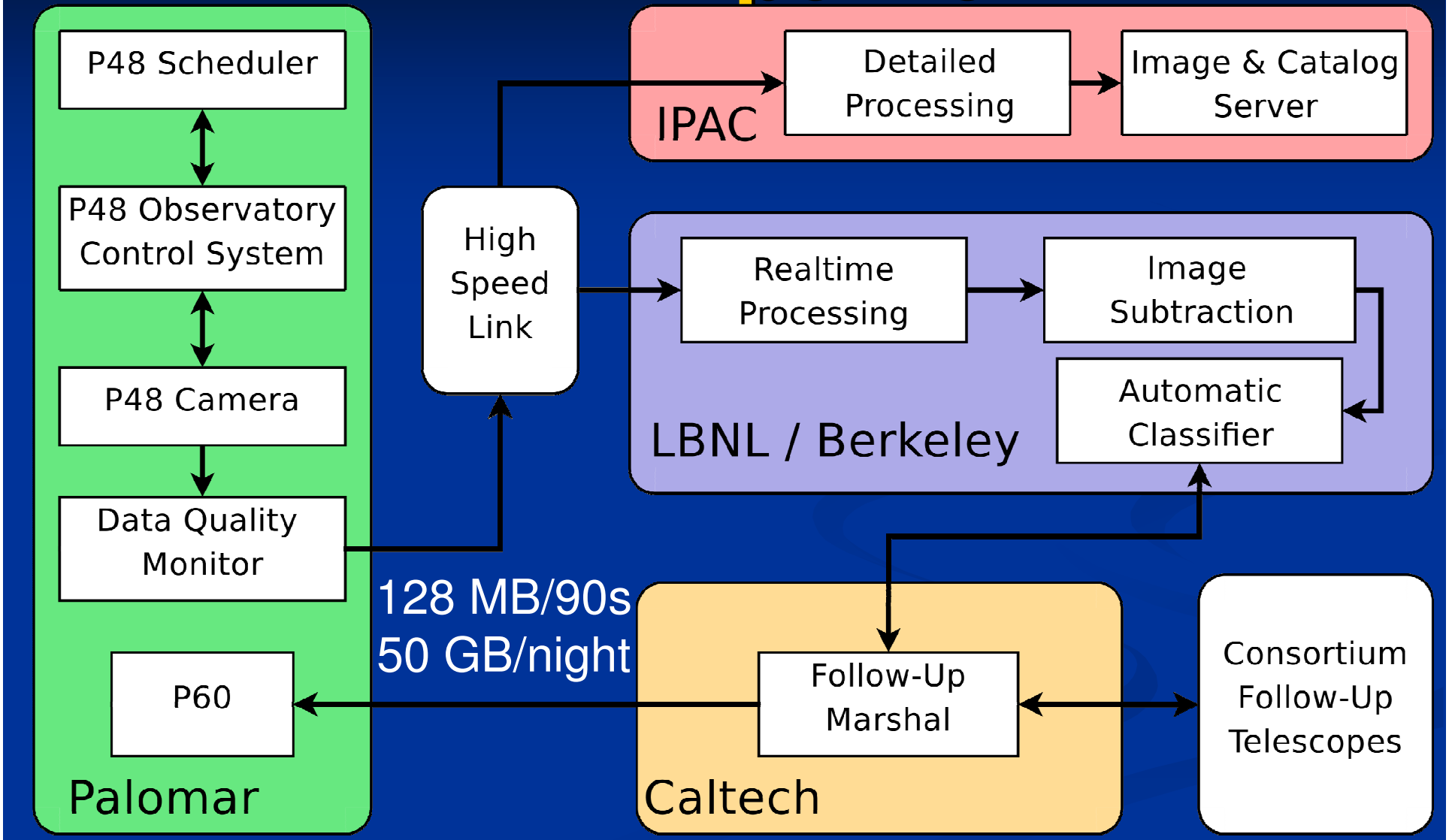






The power of PTF resides in its diverse science goals and follow-up.

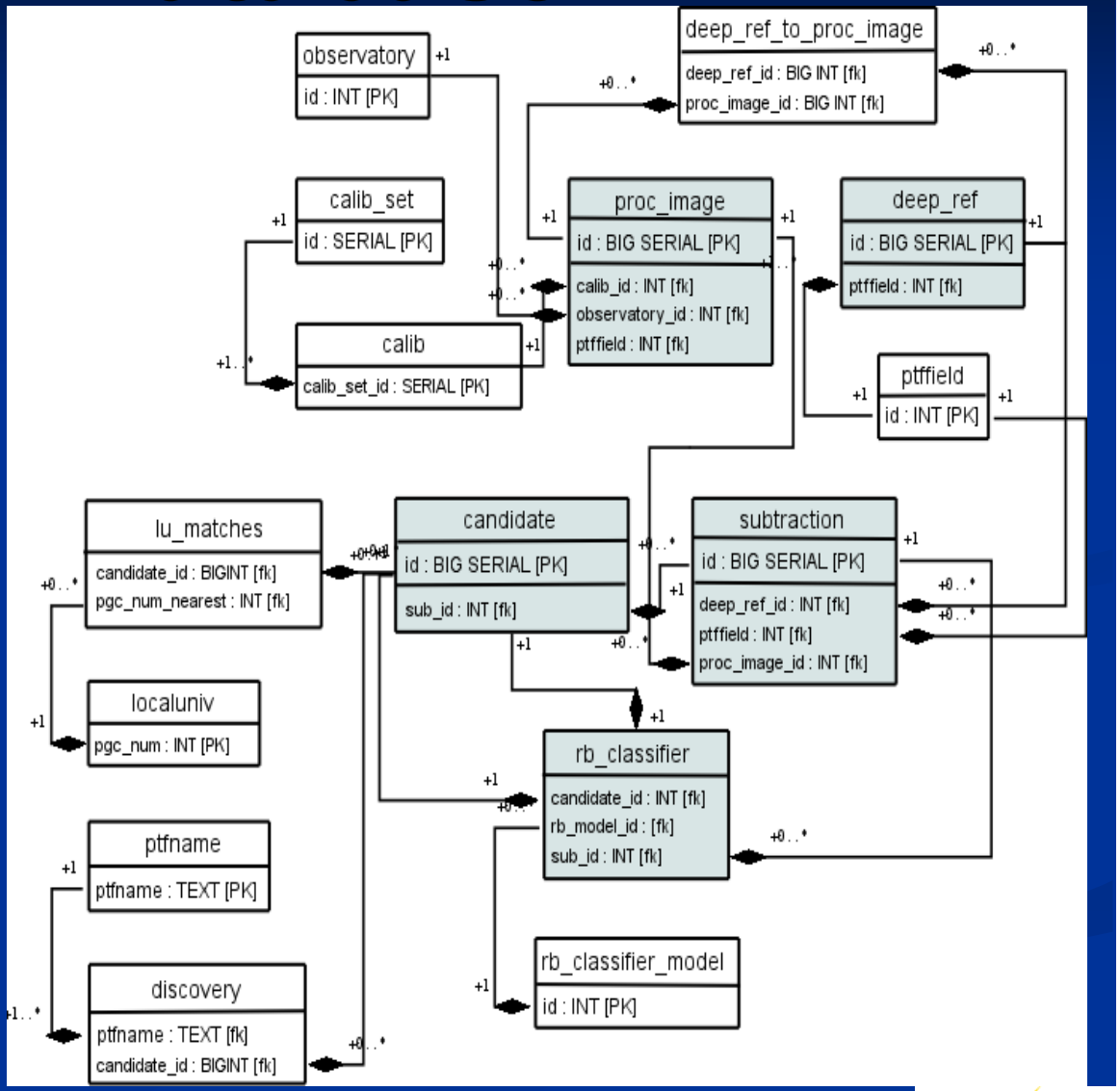
PTF Pipeline



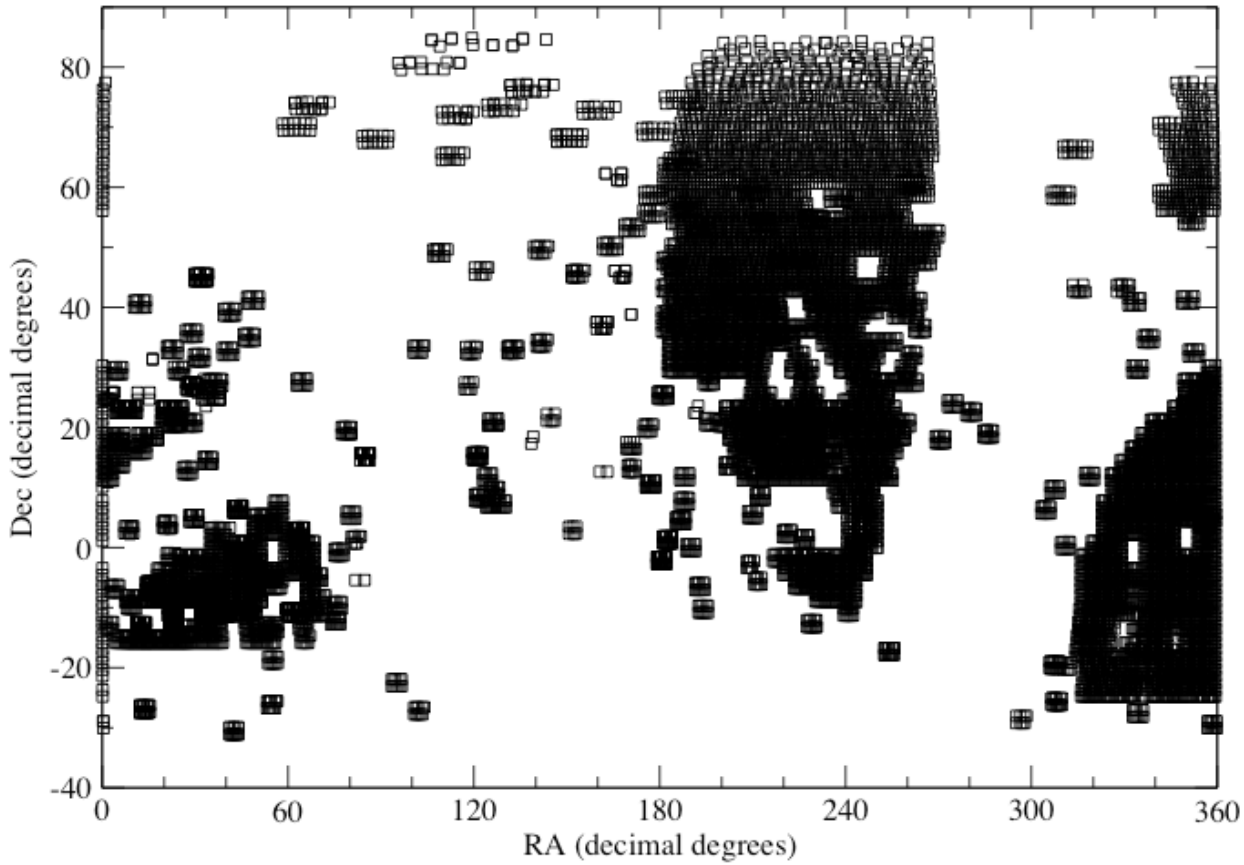
PTF Database

- 400k images
- 15k references
- 175k subtractions
- 108M candidates
- 9k saved transients

All in just 140 nights.

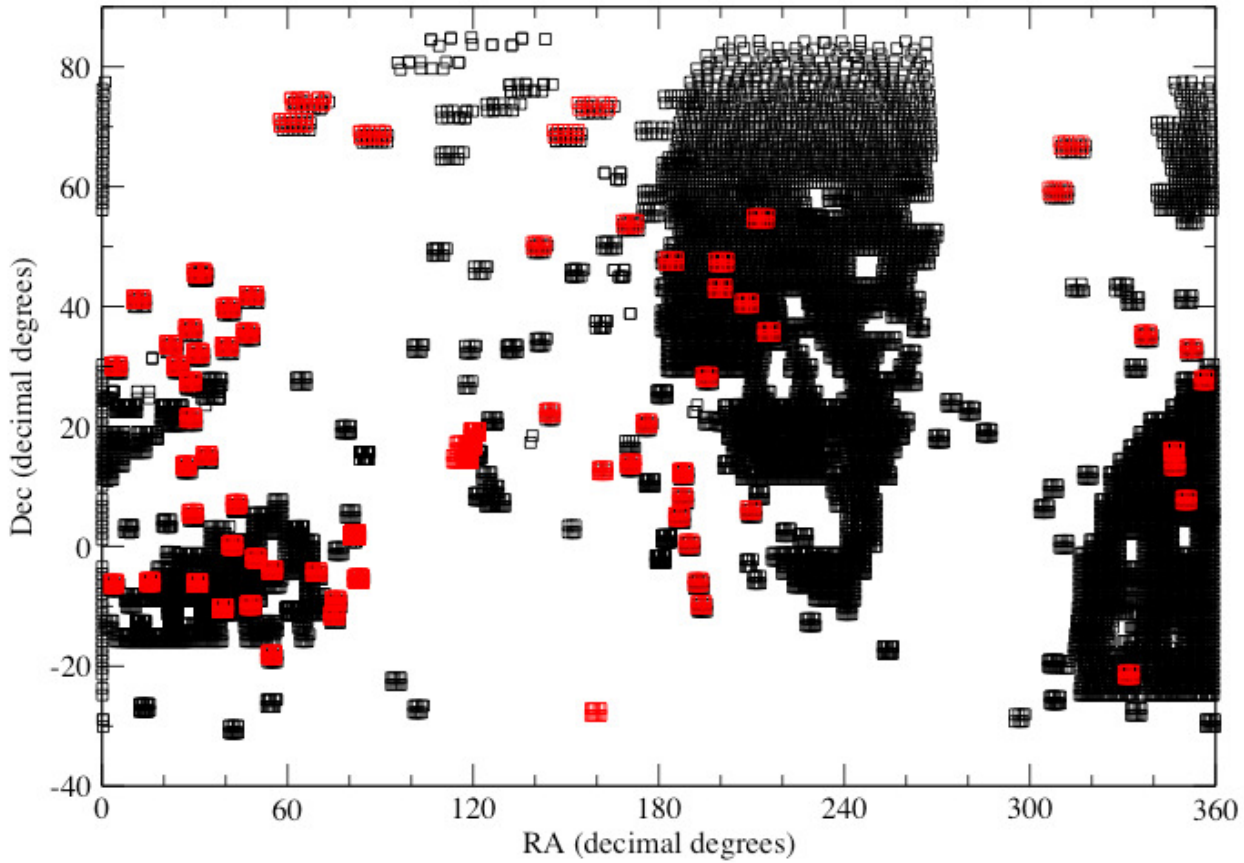


PTF Sky Coverage



To date, references have been made for ~10000 sq.deg.

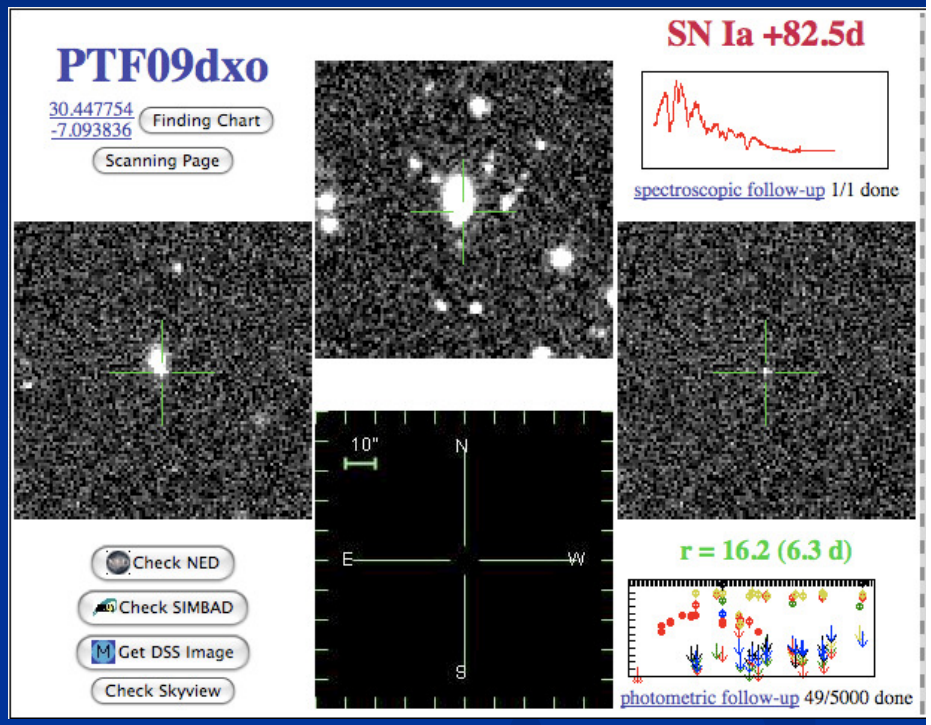
PTF Sky Coverage



Recently we cover ~1000 sq. deg. two times per night. This should improve…

Users…

QuickTime™ and a
decompressor
are needed to see this picture.



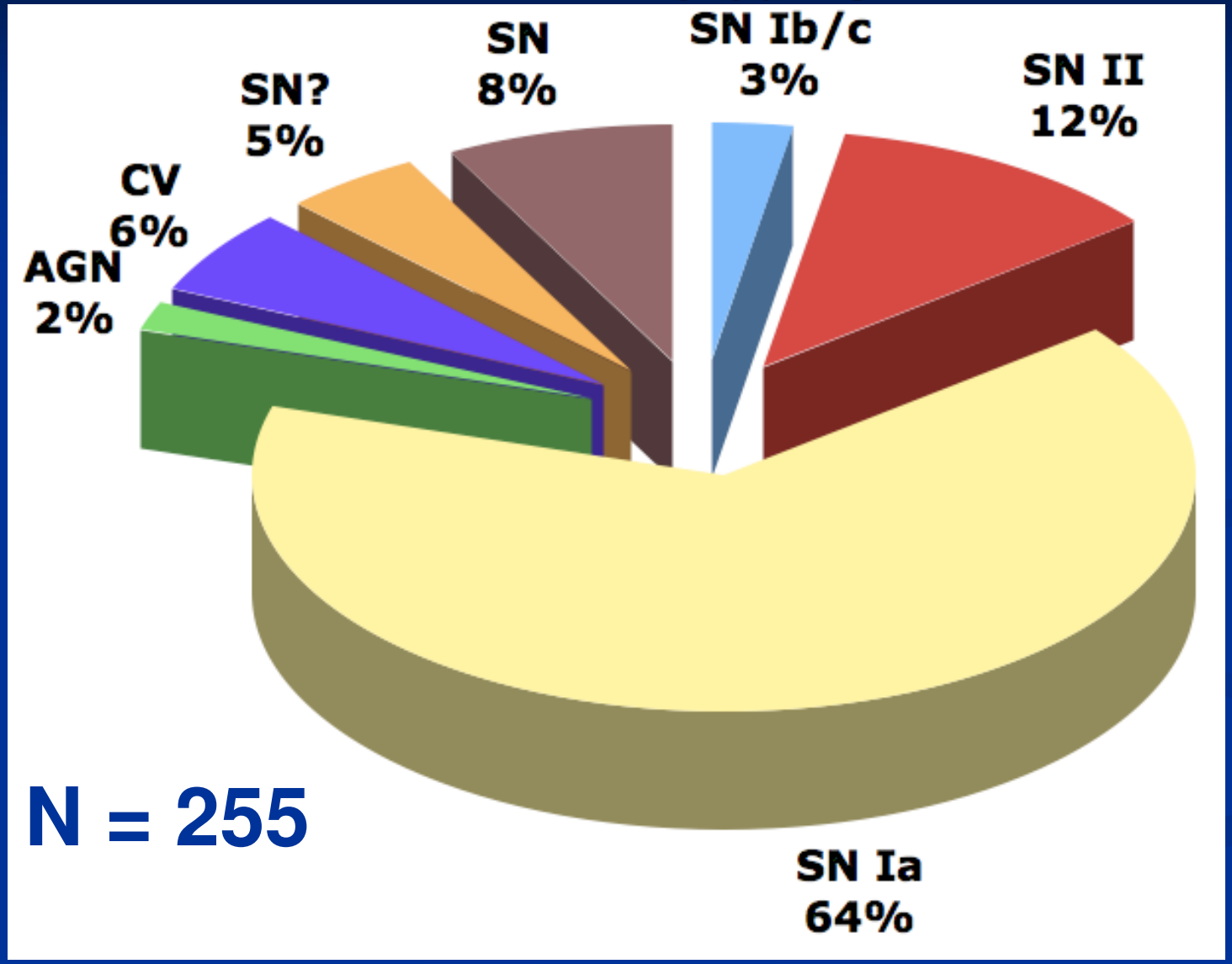
Citizen Scientists…

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

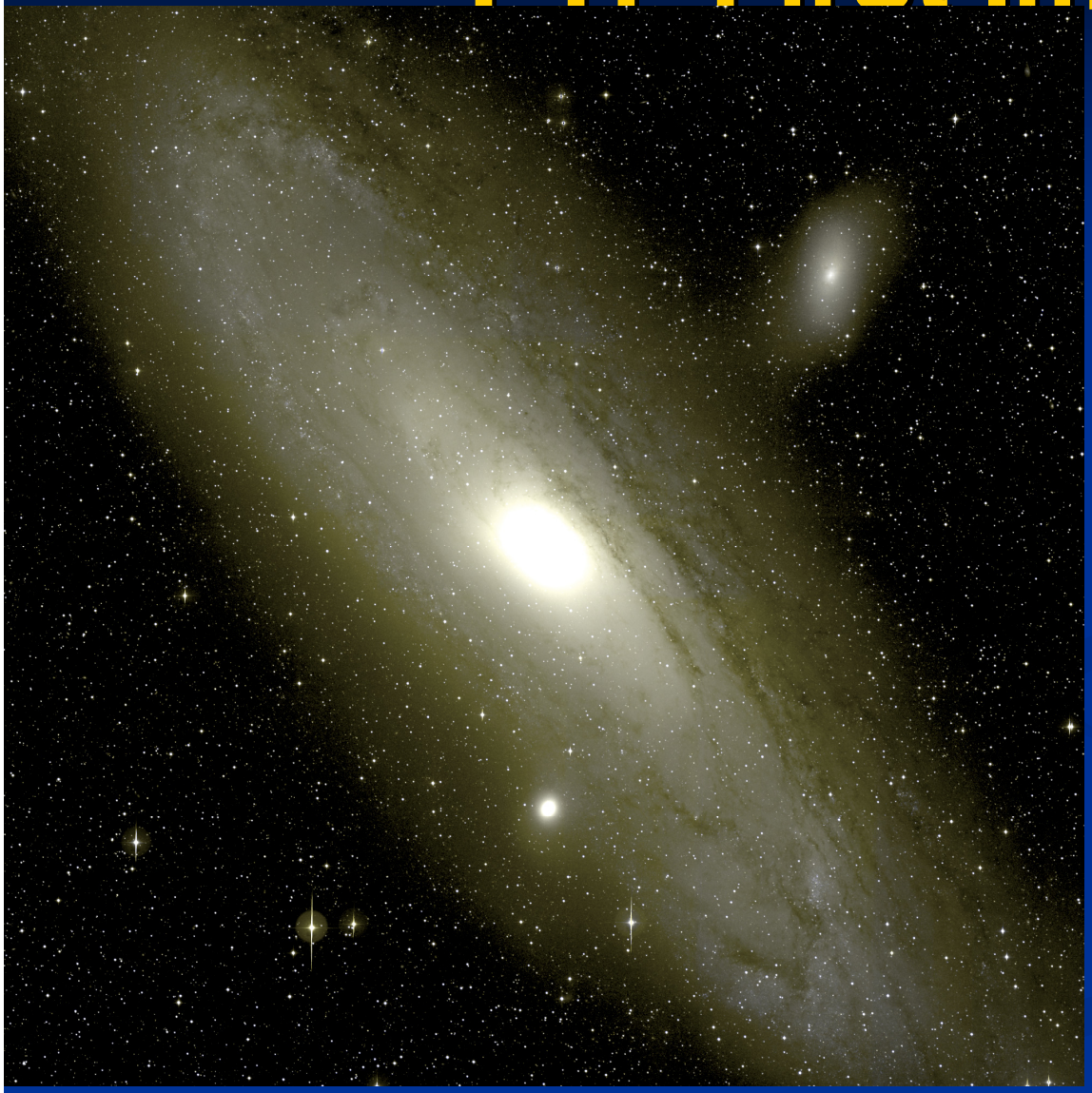
http:// supernova.galaxyzoo.org is now up and running!
A beta version appeared 3 months ago to support the SN Ia program in PTF and a WHT spectroscopy run. I spent a week with the folks at Oxford setting up the db and giving them training sets of good and bad candidates. They did the rest… 1200 members of galaxy zoo screened all the candidates between Aug 1 and Aug 12 in 3 hrs. The top 50 hits were all SNe/variable stars and they found 3 before we did. They scanned ~25,000 objects - 3 objects/min.

PTF Totals



N = 255

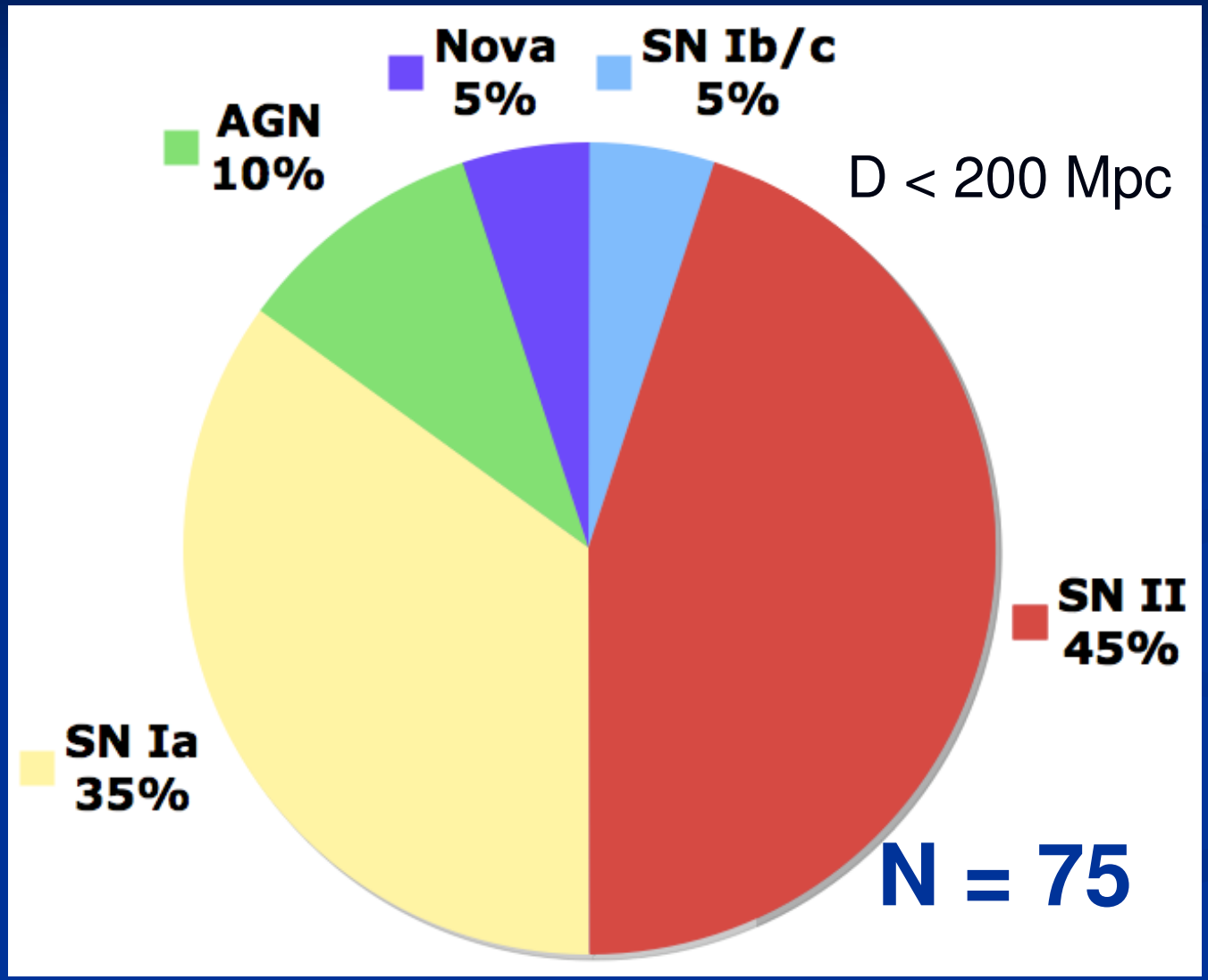
PTF First Images



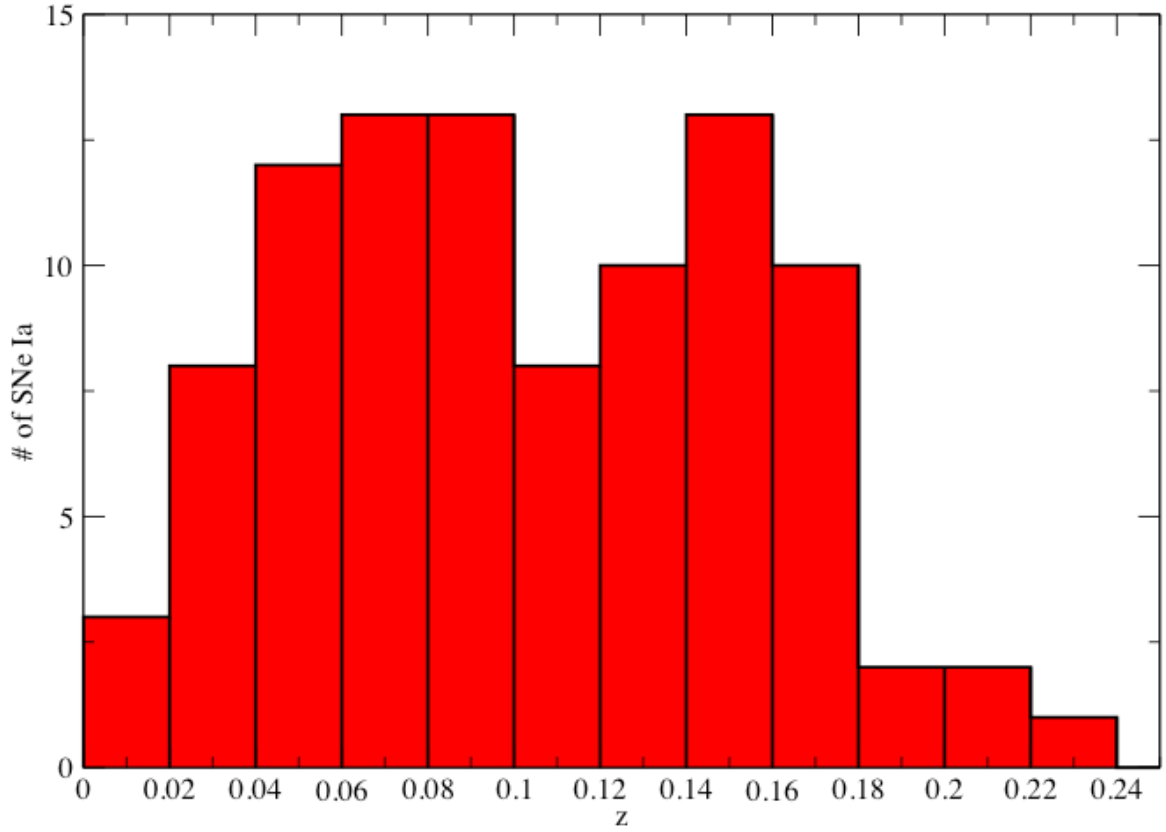
M31 as seen from PTF in February 2009. 412 images went into making this co-add.

Not just a pretty picture…Have now discovered over 200 variable stars and one new nova since Sept 1 (only 17 nights due to Great Station Fire - ash).

PTF Totals- Local Universe

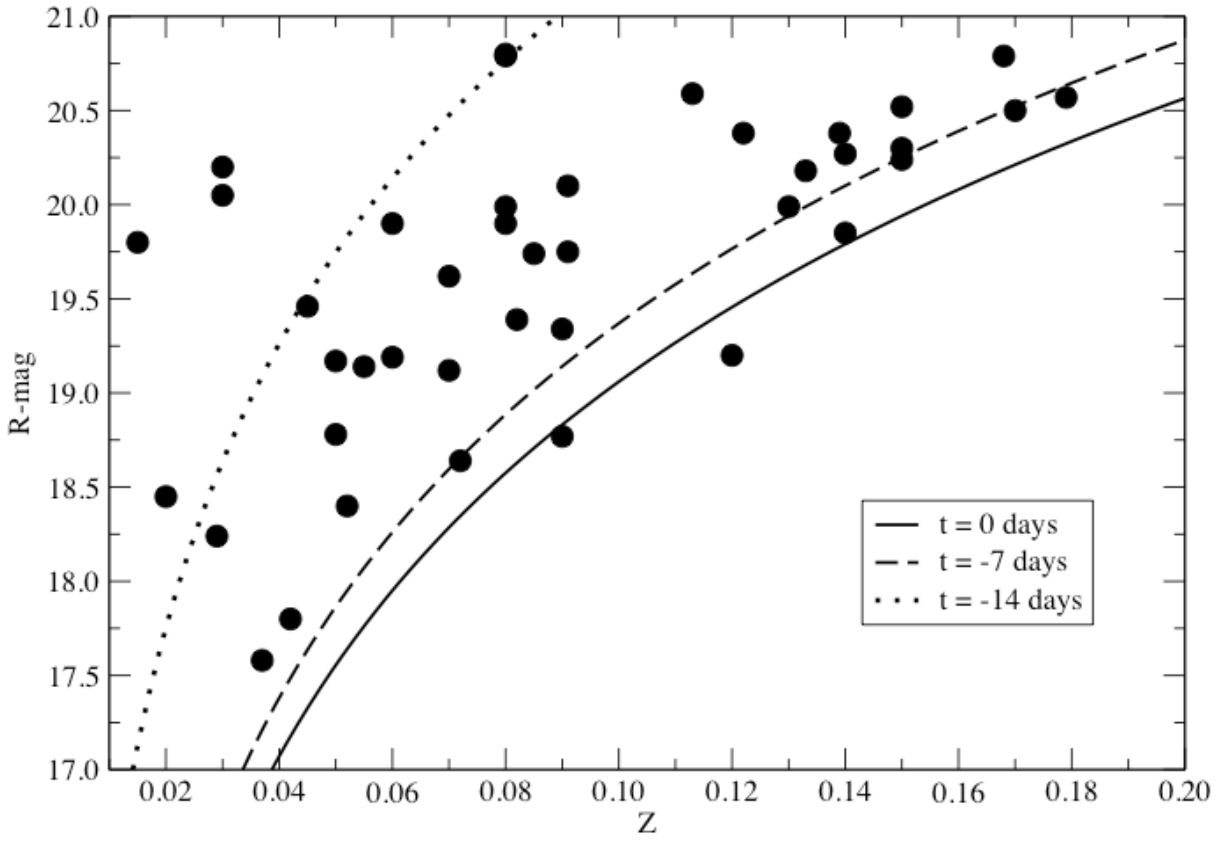


PTF SNe Ia



Redshift histogram is about what you would expect given that we want to find them early with $z < 0.1$

PTF SNe Ia

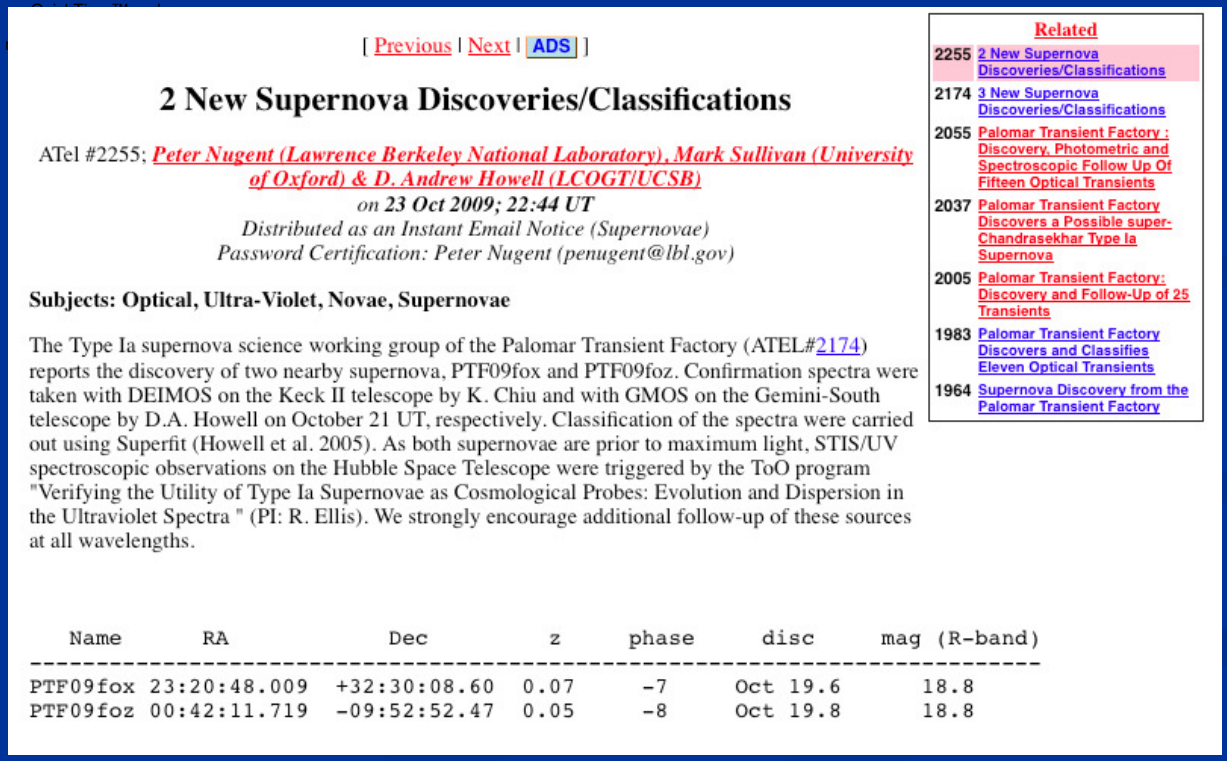

21.0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
17.0
R-mag
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Z
t = 0 days
t = -7 days
t = -14 days

SN Ia Program

We have spectroscopically identified 150 SNe Ia in 4 months of searching. When we have rolled, we catch the SNe 2 weeks before peak brightness with $z < 0.1$

HST UV Program

7 Incredibly early Type Ia supernovae sent to the Hubble Space telescope.



[Previous | Next | ADS]

2 New Supernova Discoveries/Classifications

ATel #2255; *Peter Nugent (Lawrence Berkeley National Laboratory), Mark Sullivan (University of Oxford) & D. Andrew Howell (LCOGT/UCSB)*
on 23 Oct 2009; 22:44 UT
Distributed as an Instant Email Notice (Supernovae)
Password Certification: Peter Nugent (penugent@lbl.gov)

Subjects: Optical, Ultra-Violet, Novae, Supernovae

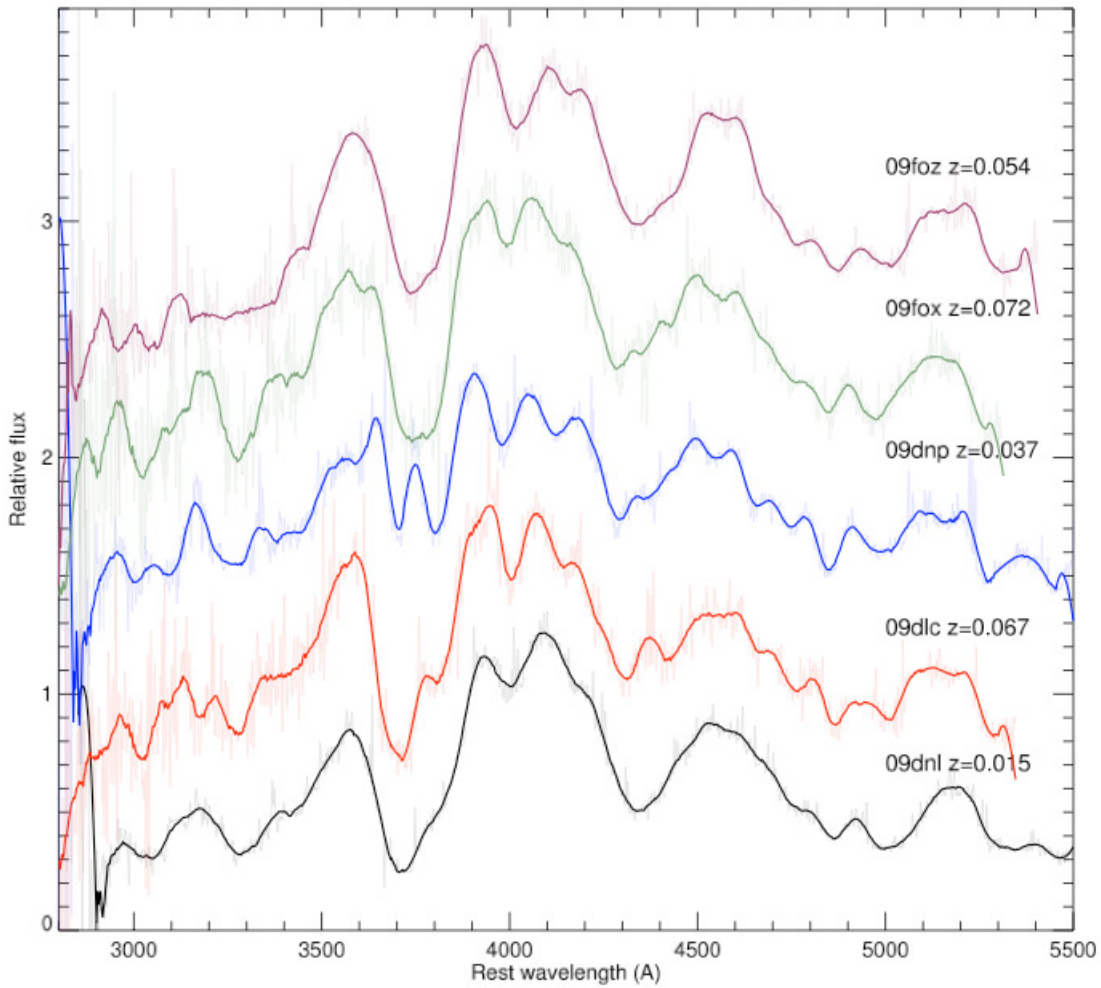
The Type Ia supernova science working group of the Palomar Transient Factory (ATEL#2174) reports the discovery of two nearby supernova, PTF09fox and PTF09foz. Confirmation spectra were taken with DEIMOS on the Keck II telescope by K. Chiu and with GMOS on the Gemini-South telescope by D.A. Howell on October 21 UT, respectively. Classification of the spectra were carried out using Superfit (Howell et al. 2005). As both supernovae are prior to maximum light, STIS/UV spectroscopic observations on the Hubble Space Telescope were triggered by the ToO program "Verifying the Utility of Type Ia Supernovae as Cosmological Probes: Evolution and Dispersion in the Ultraviolet Spectra " (PI: R. Ellis). We strongly encourage additional follow-up of these sources at all wavelengths.

Name	RA	Dec	z	phase	disc	mag (R-band)
PTF09fox	23:20:48.009	+32:30:08.60	0.07	-7	Oct 19.6	18.8
PTF09foz	00:42:11.719	-09:52:52.47	0.05	-8	Oct 19.8	18.8

Related

2255	2 New Supernova Discoveries/Classifications
2174	3 New Supernova Discoveries/Classifications
2055	Palomar Transient Factory : Discovery, Photometric and Spectroscopic Follow Up Of Fifteen Optical Transients
2037	Palomar Transient Factory Discovers a Possible super-Chandrasekhar Type Ia Supernova
2005	Palomar Transient Factory: Discovery and Follow-Up of 25 Transients
1983	Palomar Transient Factory Discovers and Classifies Eleven Optical Transients
1964	Supernova Discovery from the Palomar Transient Factory

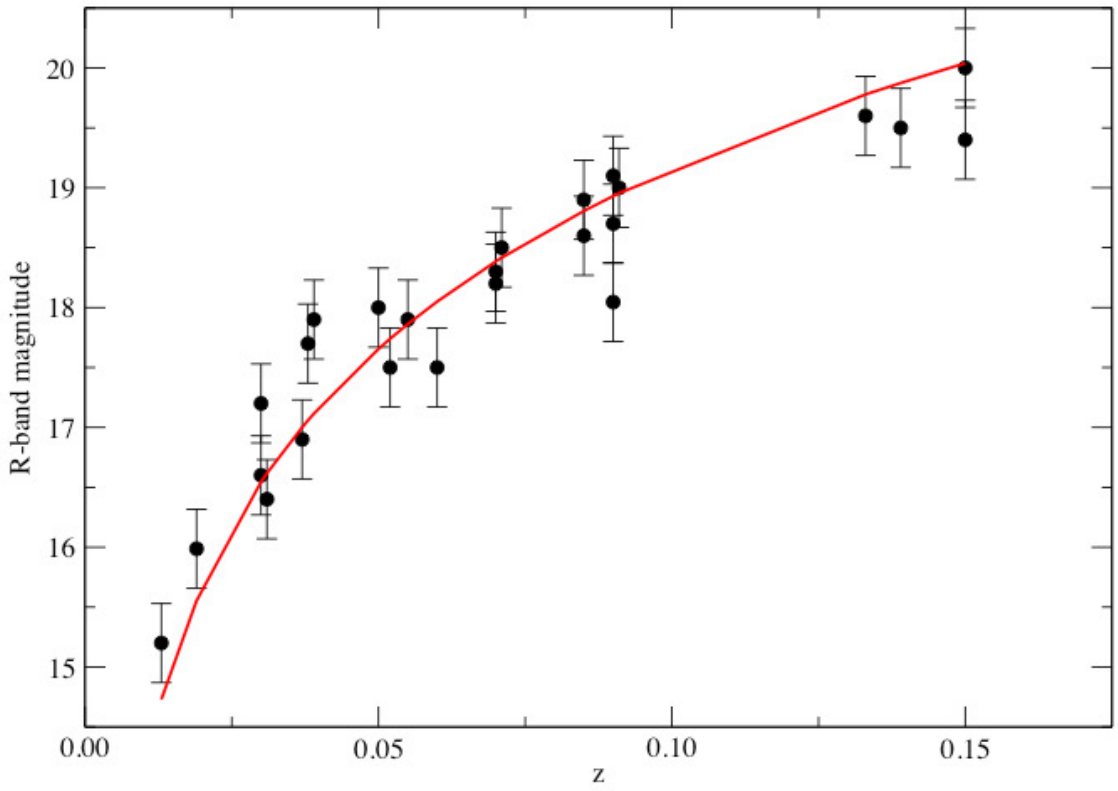
HST UV Program



5 Incredibly early Type Ia supernovae sent to the Hubble Space telescope.

All within 2 days of peak when HST observed them with STIS.

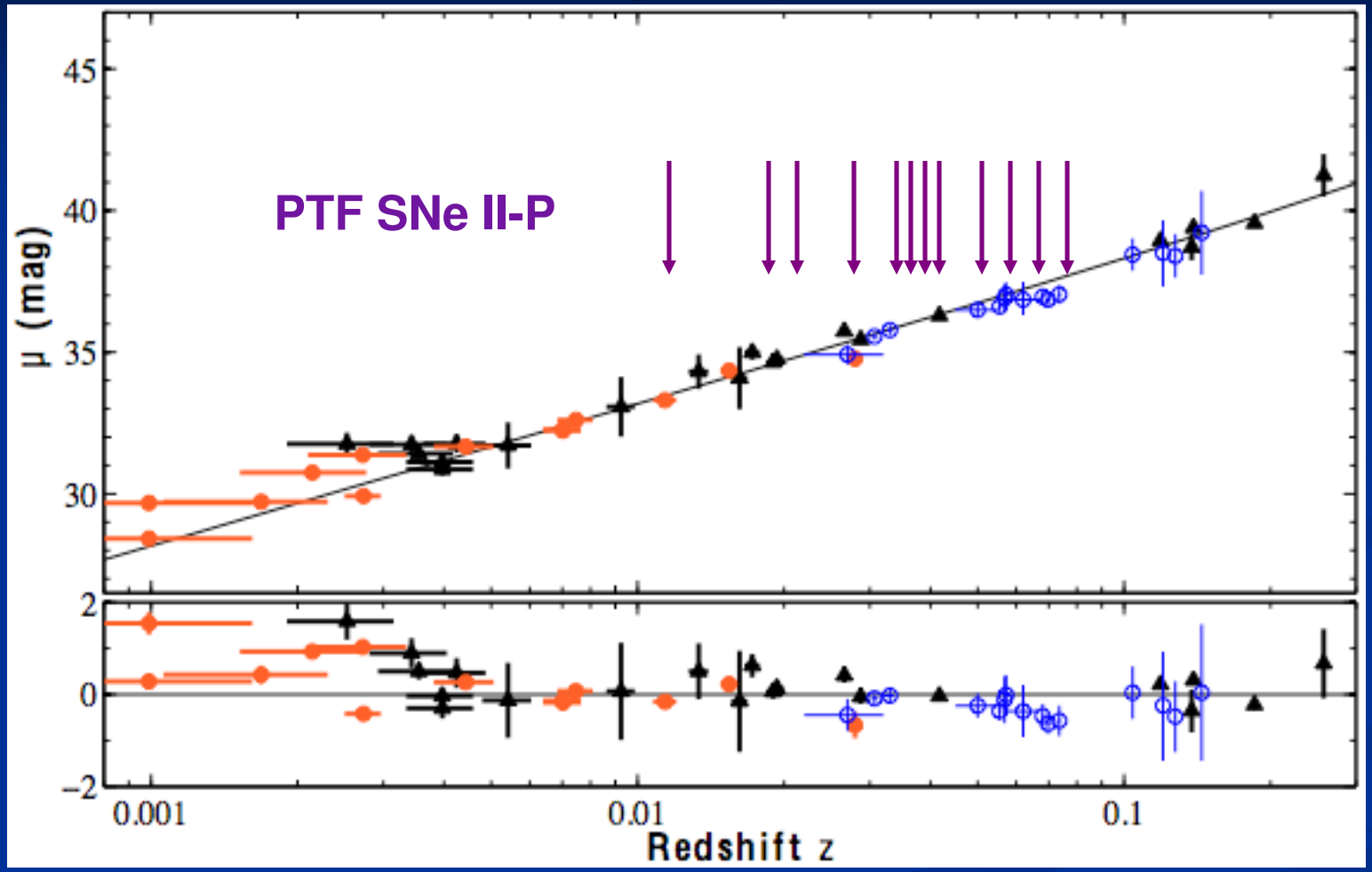
Hubble diagram



R-band Hubble diagram straight from PTF subtraction pipeline.

Scatter is 0.25 magnitudes which is about what one would expect for no extinction and lightcurve shape corrections.

PTF SNe II-P



Avishay Gal-Yam, PI of the PTF Core-Collapse program

BigBOSS

BAO: 50M galaxies 0.2 < z < 2.0

BAO: 1M QSO 2.0 < z < 3.0

QuickTime™ and a decompressor are needed to see this picture.

BigBOSS

LAMOST-like fiber positioner

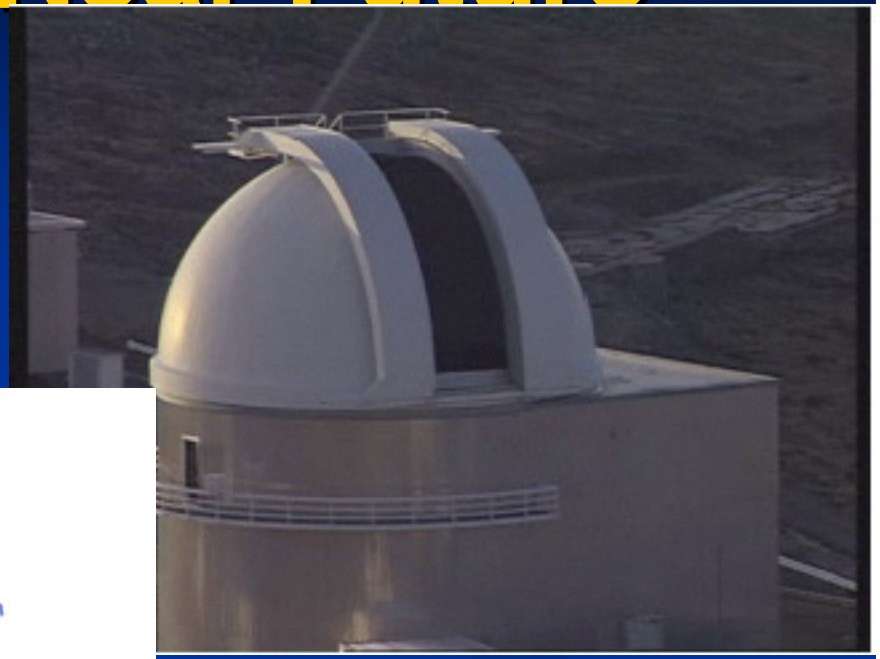
QuickTime™ and a
decompressor
are needed to see this picture.

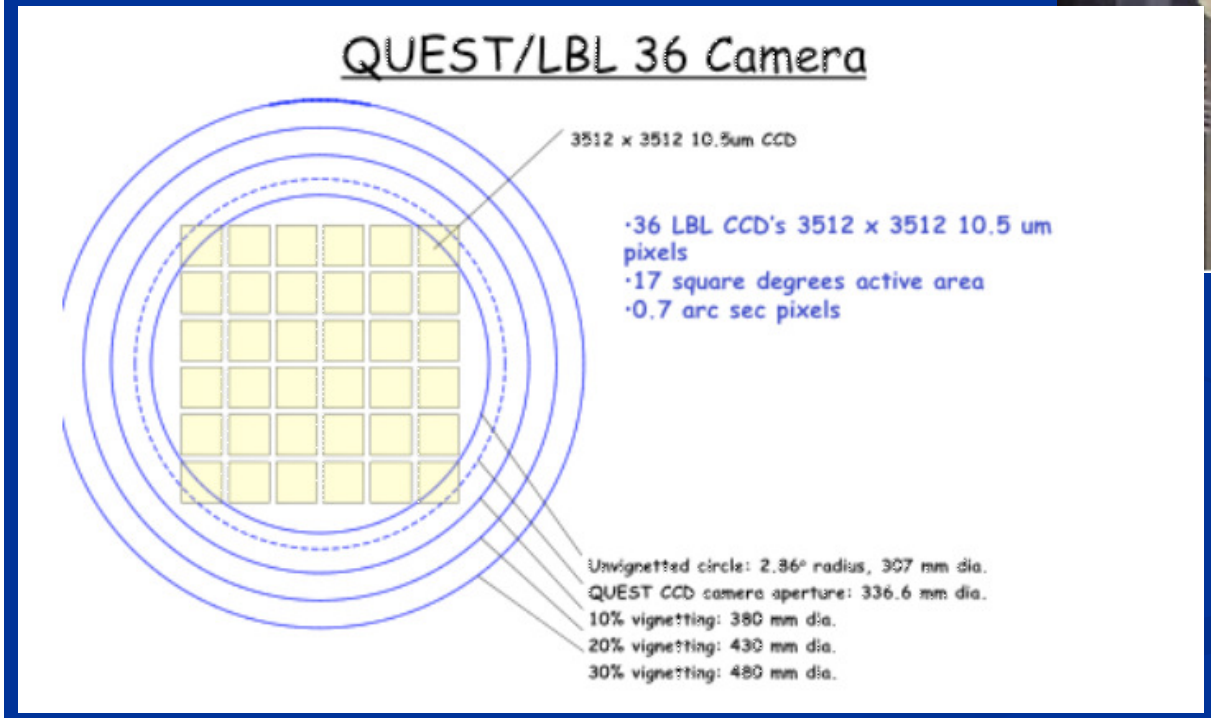
BigBOSS & PTF

QuickTime™ and a
decompressor
are needed to see this picture.

Conclusions - Near Future

La Silla Schmidt Search
-Upgrade?





Students & Postdocs to work on this, PTF, BOSS/BigBOSS, DES and perhaps JDEM, LSST & SASIR.