

# Palomar Transient Factory Overview & first results

Eran Ofek

**CALTECH**

and the PTF collaboration



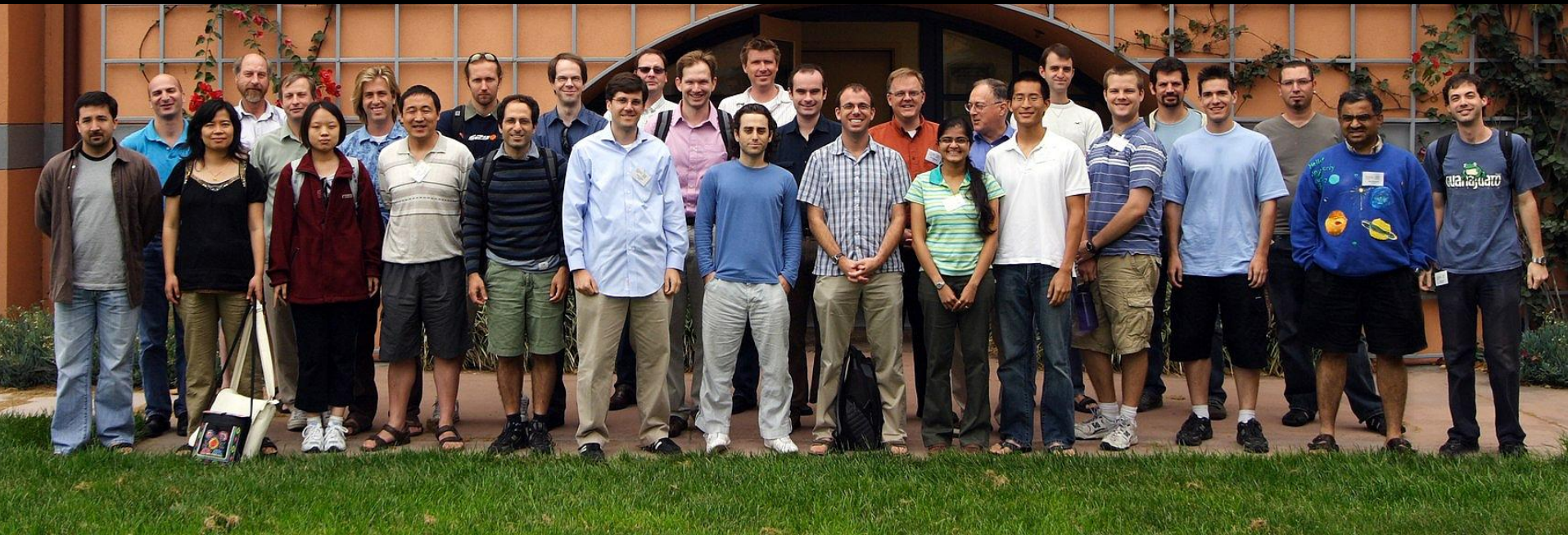
CALTECH ASTRONOMY

# Talk Layout

- ★ PTF science (see also: Rau et al. 09)
- ★ PTF overview (see also: Law et al. 09)
- ★ PTF pipelines
- ★ Projects
- ★ First discoveries

# PTF collaboration

PI: S. R. Kulkarni



Caltech, LCOGT, Berkeley, LBL, IPAC, Columbia, Oxford, Weizmann



# PTF science

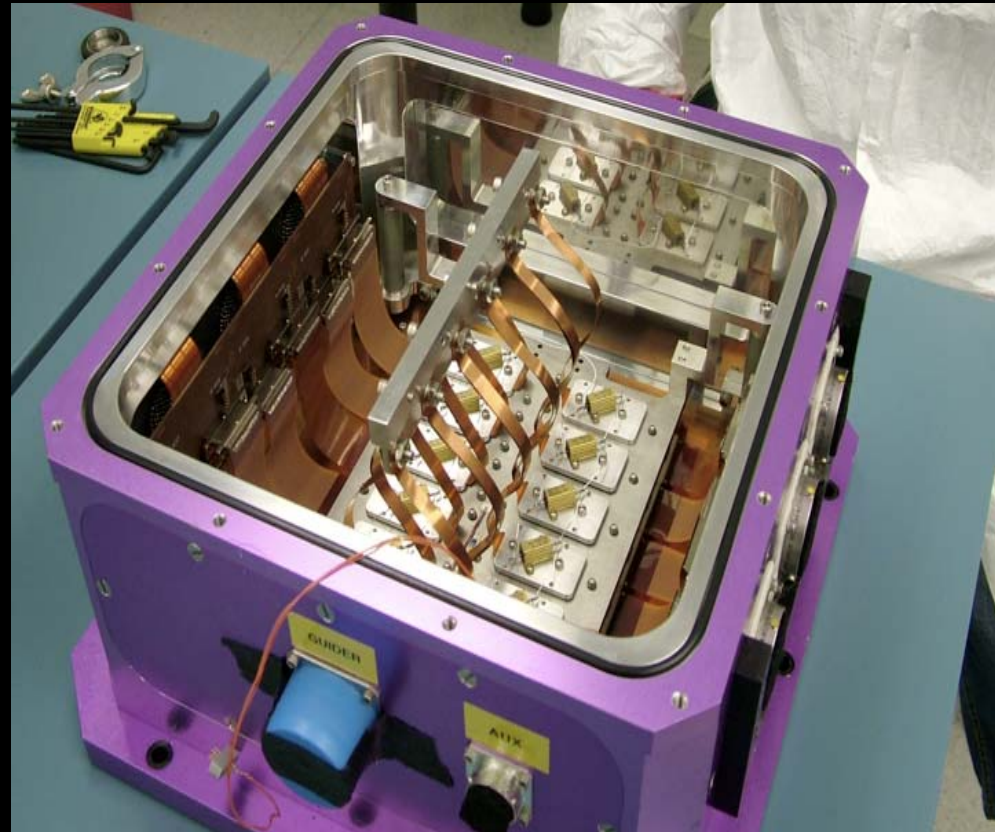
- ★ Explore the transient sky phase space
  - Unexplored regions of transients phase space
  - Rare events  
(maybe important for chemical evolution)
- ★ SN type-Ia calibration
- ★ SN type-Ia rapid HST/UV spec. (PI. Ellis)
- ★ CVs
- ★ Blazar variability and Tidal disruption events
- ★ Galactic structure, (SFR in) nearby galaxies,...

# PTF overview

- ★ 48" Oschin Schmidt Camera (Palomar observatory)
- ★ 7.2 deg<sup>2</sup> FOV CCD (92 Mpix), g&R filters
- ★ Scale: 1"/pix
- ★ Robotic telescope & scheduler
  - Full automatic operation
  - Auto. Selection of science targets
    - based on
      - cadence
      - (Moon) sky brightness
      - airmass
      - ...

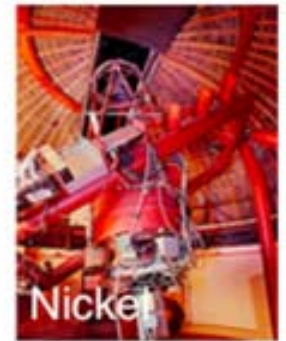
# PTF overview

- ★ 60s exposure + 30s readout  
~630,000 deg<sup>2</sup> yr<sup>-1</sup>  
(currently ~410,000 deg<sup>2</sup> yr<sup>-1</sup>)



# PTF followup

## PTF follow-up telescopes



# PTF overview

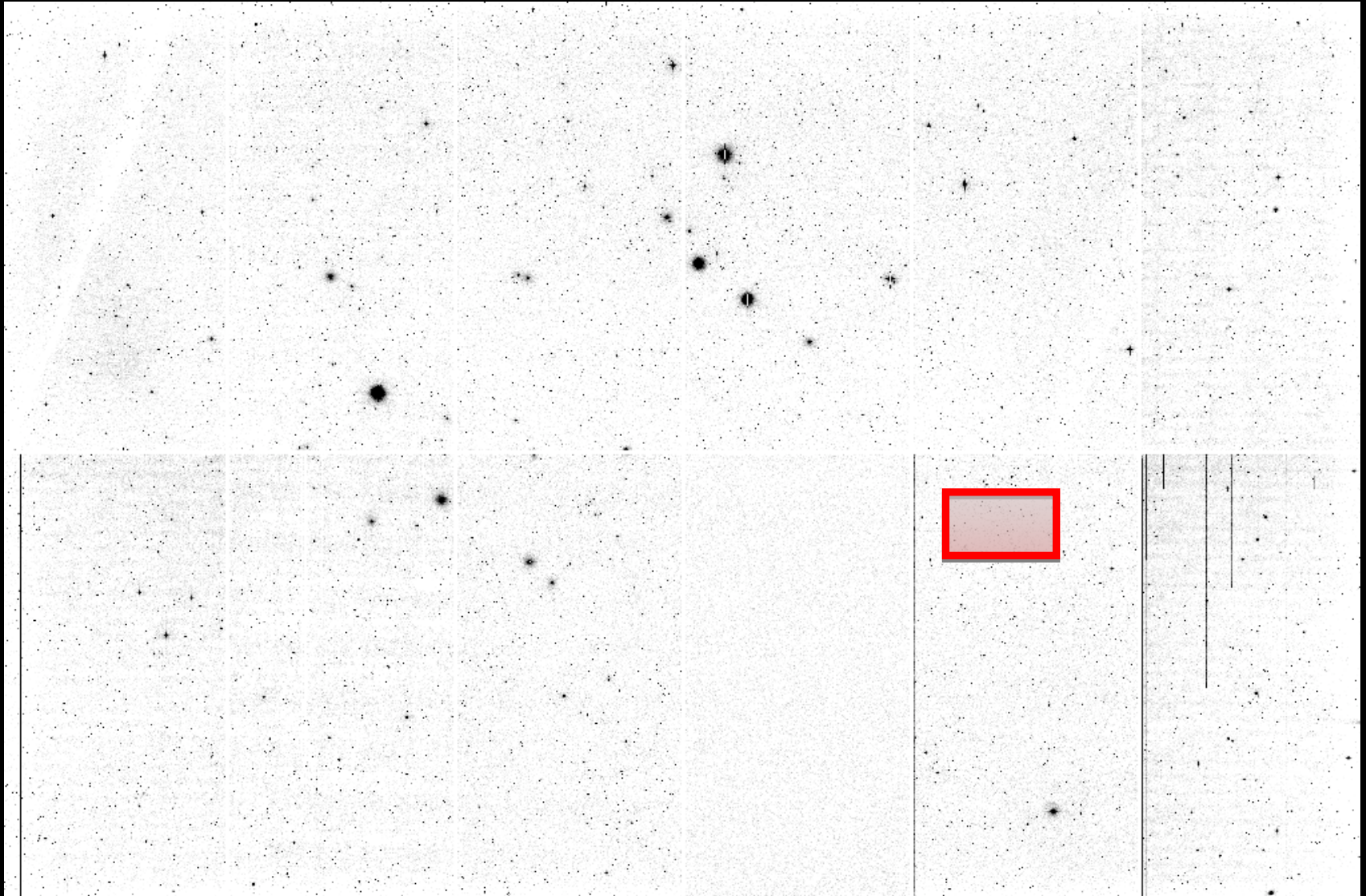
## Data quality

- ★ First light: December 2008
- ★ First science run: March 2009
- ★ Typical seeing  $\sim 1.8''$  (best  $1.4''$ )
- ★ Lim. Mag ( $5\sigma$ )  $\sim 21$  in g,R



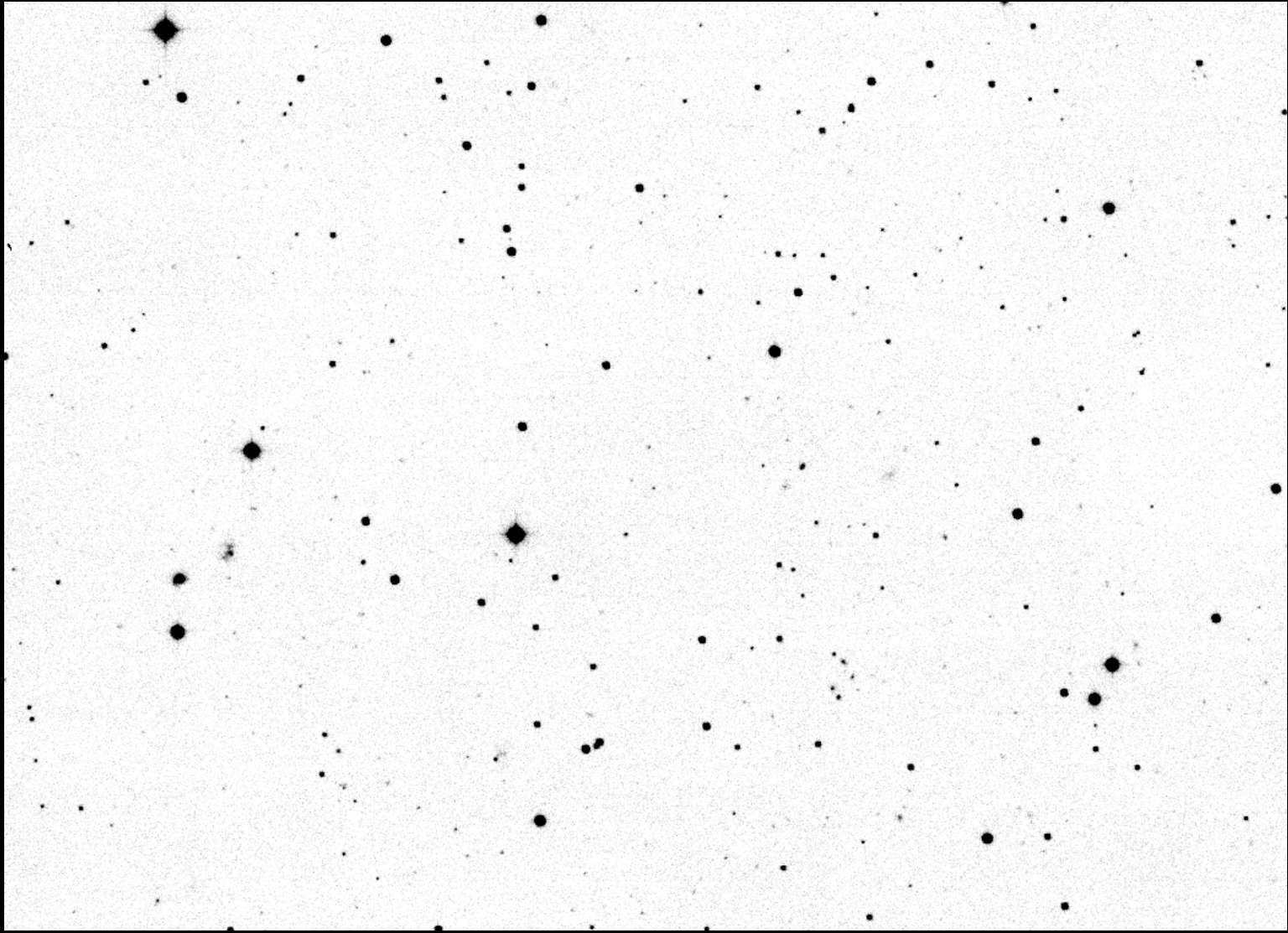
# PTF overview

## Data quality



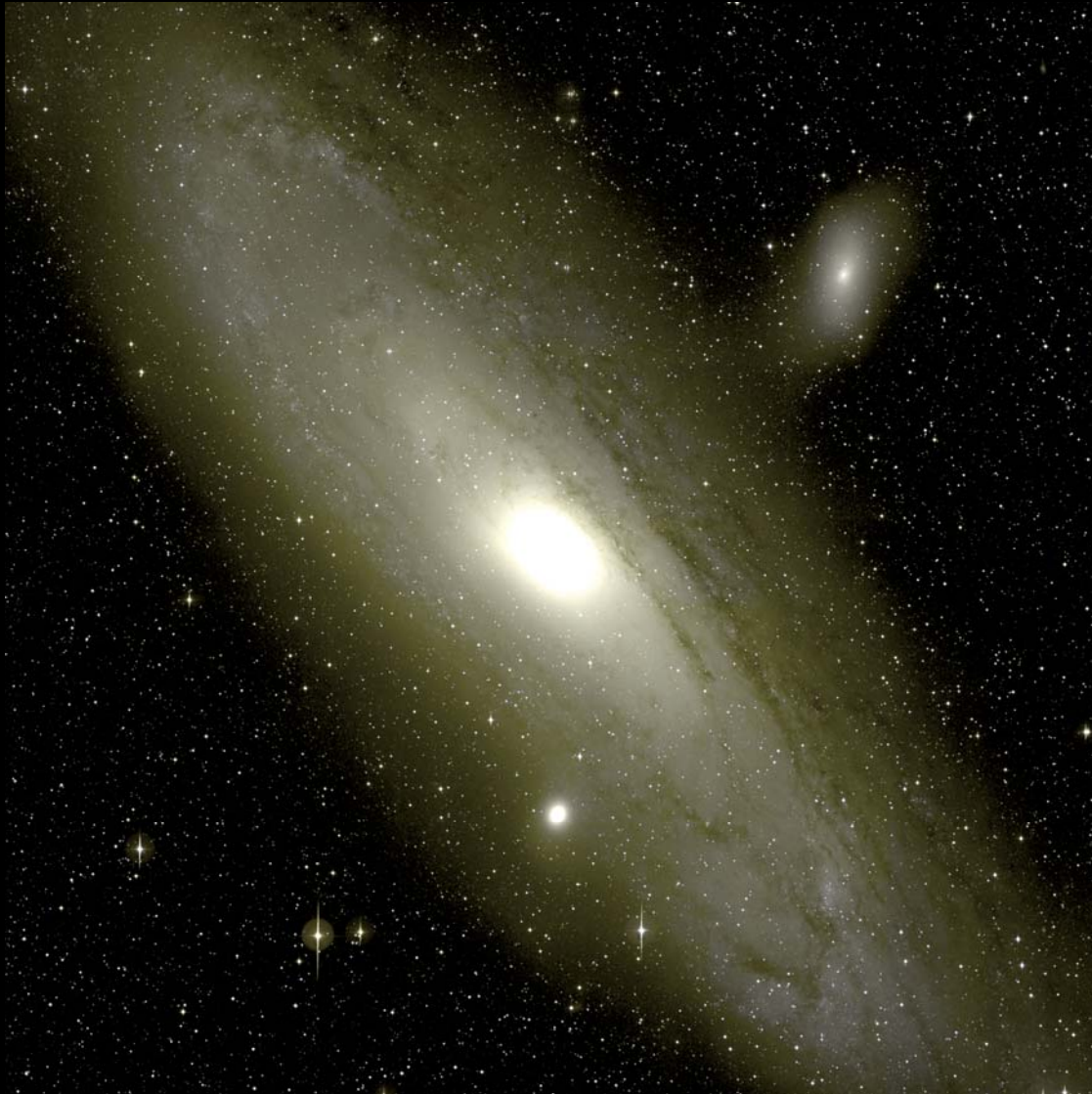
# PTF overview

Data quality



# PTF overview

## Data quality

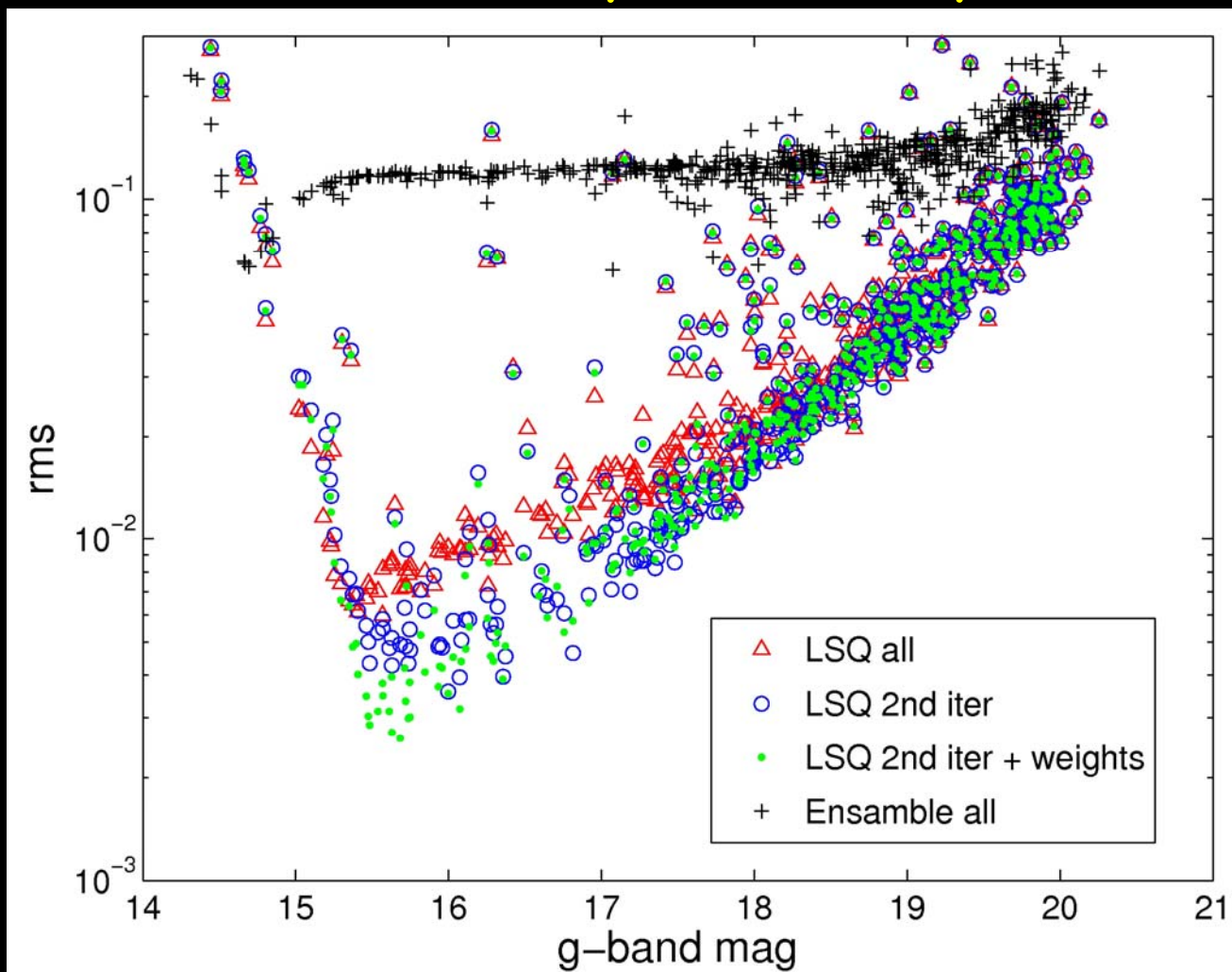


P. Nugent, D. Poznanski

# PTF overview

Data quality

Relative photometry



# PTF overview

★ Two separate pipelines

LBL image subtraction pipeline

IPAC images and catalogue pipeline

# Image subtraction pipeline

Lead by P. Nugent

★ Main goal: efficient discovery of transients in near real time

Currently ~12 hr  
near future ~1 hr

20090716 ptf\_4063 C05 PTF200907161822\_2\_o\_43531\_05.w\_cd.ptf\_4063\_05\_R\_v2

<< 20090629 | 1 | 2 | >> << 4062 | 4238 >> << 4 | 6 >>

rundate	visit	field	chip
20090710	1	4057	0
20090711	2	4058	1
20090712	3	4059	2
20090713	4	4060	4
20090714	5	4061	5
20090715	6	4062	6
20090716	7	4063	7

Hide chipthumbs

minsig 5.0  
maxa 4.0  
minb 0.5  
max2sig11 10.0  
max3sig11 10.0  
minfwhm 0.5  
maxfwhm 2.0  
maxflag 10.0  
matchtime 1.5  
matchrad 5.0  
nminmatch 1  
maxsym 10000.0  
minrb 0.0

Redraw

limmag: 21.55, seeing: 1.60, filter: R  
Flag Subtraction

Passed 2 of 477 candidates

411.6, 1453.2 sigma 20.7 ra 213.1700963 dec 31.0675920 mag 19.16 +/- 0.05 a 0.98 b 0.97 max2sig 3 max3sig 0 fwhm 1.52 flags 0	NEW	REF	SUB	20090716v2 SUB
1650.8, 3952.2 sigma 6.6 ra 213.5629377 dec 30.3606714 mag 20.76 +/- 0.17 a 0.76 b 0.62 max2sig 9 max3sig 2 fwhm 1.80 flags 0	NEW	REF	SUB	

20090716 ptf\_4063 C05 PTF200907161822\_2\_o\_43531\_05.w\_cd.ptf\_4063\_05\_R\_v2

<< 20090629 | 1 | 2 | >> << 4062 | 4238 >> << 4 | 6 >>

# Image subtraction

## LBL image subtraction pipeline

- ★ Challenge: 0.5-1 M sources detected in Subtracted images each night!
- ★ after cleaning - large number of candidates (~10%)
- ★ However, only a few % are real variable/transients

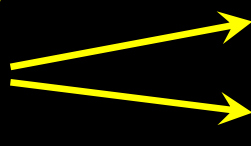
### ★ Solutions:

Machine vetting

Humans vetting

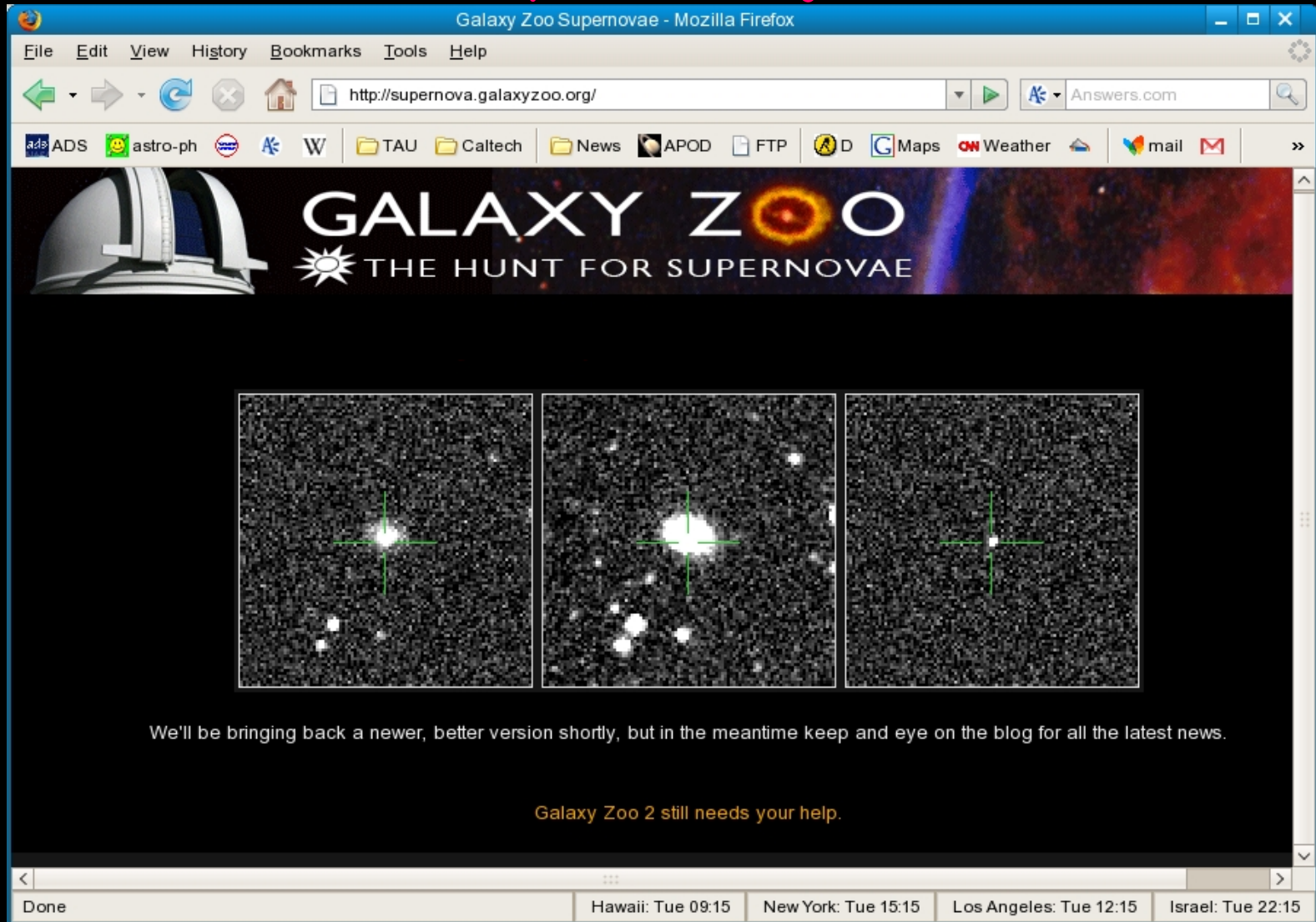
Scientists

Public



# Image Subtraction

## Galaxy Zoo Project



The screenshot shows a Mozilla Firefox browser window titled "Galaxy Zoo Supernovae - Mozilla Firefox". The address bar contains the URL "http://supernova.galaxyzoo.org/". The browser's toolbar includes various icons for navigation and search. The website's header features a logo with a telescope and the text "GALAXY ZOO THE HUNT FOR SUPERNOVAE". Below the header, three side-by-side astronomical images illustrate the process of image subtraction. Each image shows a star field with a central star marked by a green crosshair. The first image is the original observation, the second is the original with a model of the star subtracted, and the third is the resulting image where the star has been removed, revealing fainter objects. Below the images, a text message reads: "We'll be bringing back a newer, better version shortly, but in the meantime keep an eye on the blog for all the latest news." At the bottom, a call to action states: "Galaxy Zoo 2 still needs your help." The browser's status bar at the bottom shows the time in different time zones: Done, Hawaii: Tue 09:15, New York: Tue 15:15, Los Angeles: Tue 12:15, and Israel: Tue 22:15.



# IPAC images and catalogue pipeline

Lead by J. Surace

## ★ Data products:

Reduced images

~100TB per year

Catalogue

~ $10^{12}$  sources per year (10 TB)

# PTF overview

## IPAC image and catalog pipeline

NASA/IPAC Infrared Science Archive  
for NASA's Infrared and Submillimeter Data

Home About Holdings Missions Sitemap Helpdesk

**Catalog Search**  
Basic  
General

**Image Services**  
Finder Charts  
2MASS Images  
2MASS Ext. Srcs.  
Mosaics  
Cutouts

**Inventories**  
IRSA Holdings  
NVO Sky  
Coverage

**Tools**  
OASIS Visualizer  
Montage  
Image Validation  
Object Lookup  
QA Tools  
Dust Extinction  
Data Tags

**Data Sets**  
2MASS  
COSMOS  
IRAS  
IRTS

**PTF Archive Service**

Location or Object Name

Region Size (degrees)

Location Example: 79.895895 20.167458 l m31

Start Date (yyyy-mm-dd)  Start Time (hh:mm:ss.ddd)

End Date (yyyy-mm-dd)  End Time (hh:mm:ss.ddd)



**Note:** If all of the date/time fields are left empty, there will be no datetime search constraint. Wrongly formatted date and time fields will result in error messages. The start and end date fields take "yyyy-mm-dd" format. The start and end time input fields take "hh:mm:ss.ddd" format, e.g. "12:20:35.678". The default value is "00:00:00.000" for the time fields.

[View PTF Nightly Summary](#)  
[Search PTF Nightly Summary by Date](#)  
[View IRSA PTF Data Processing Status](#)

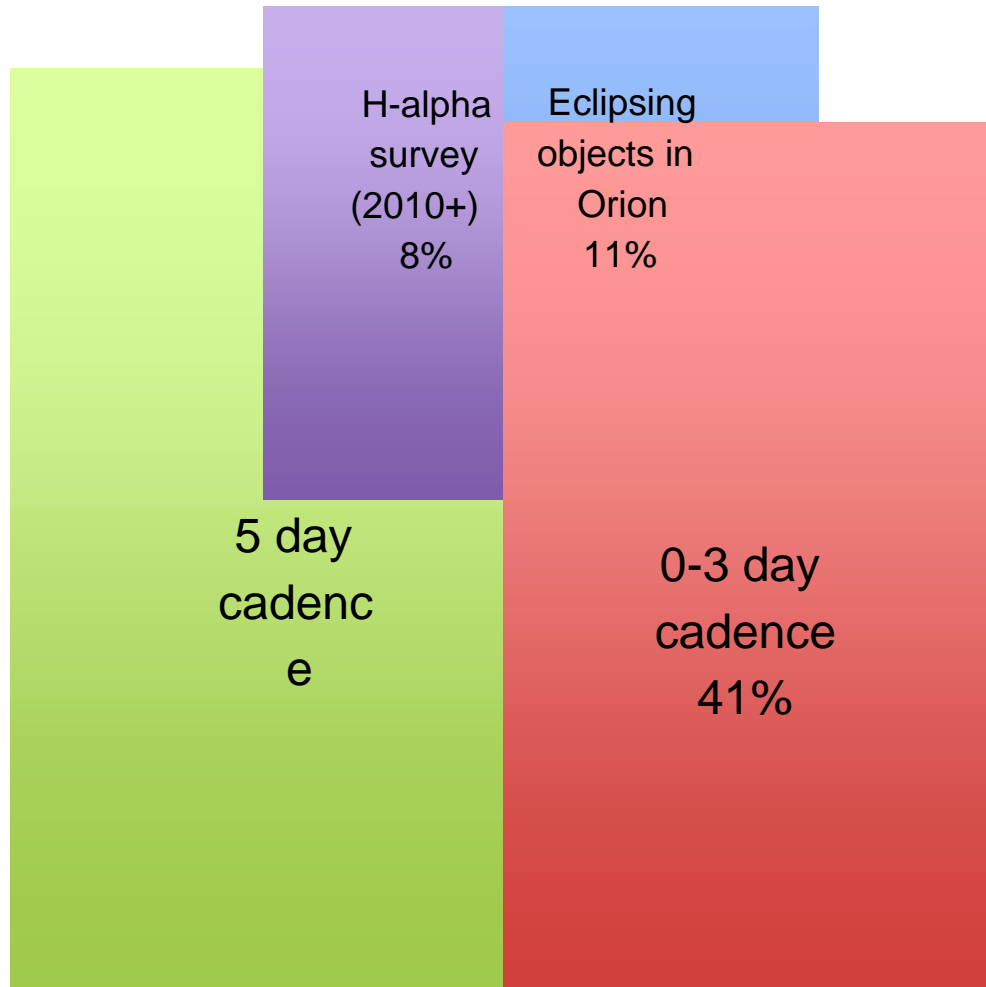
Google

WWW  IRSA

Contact the IRSA Help Desk



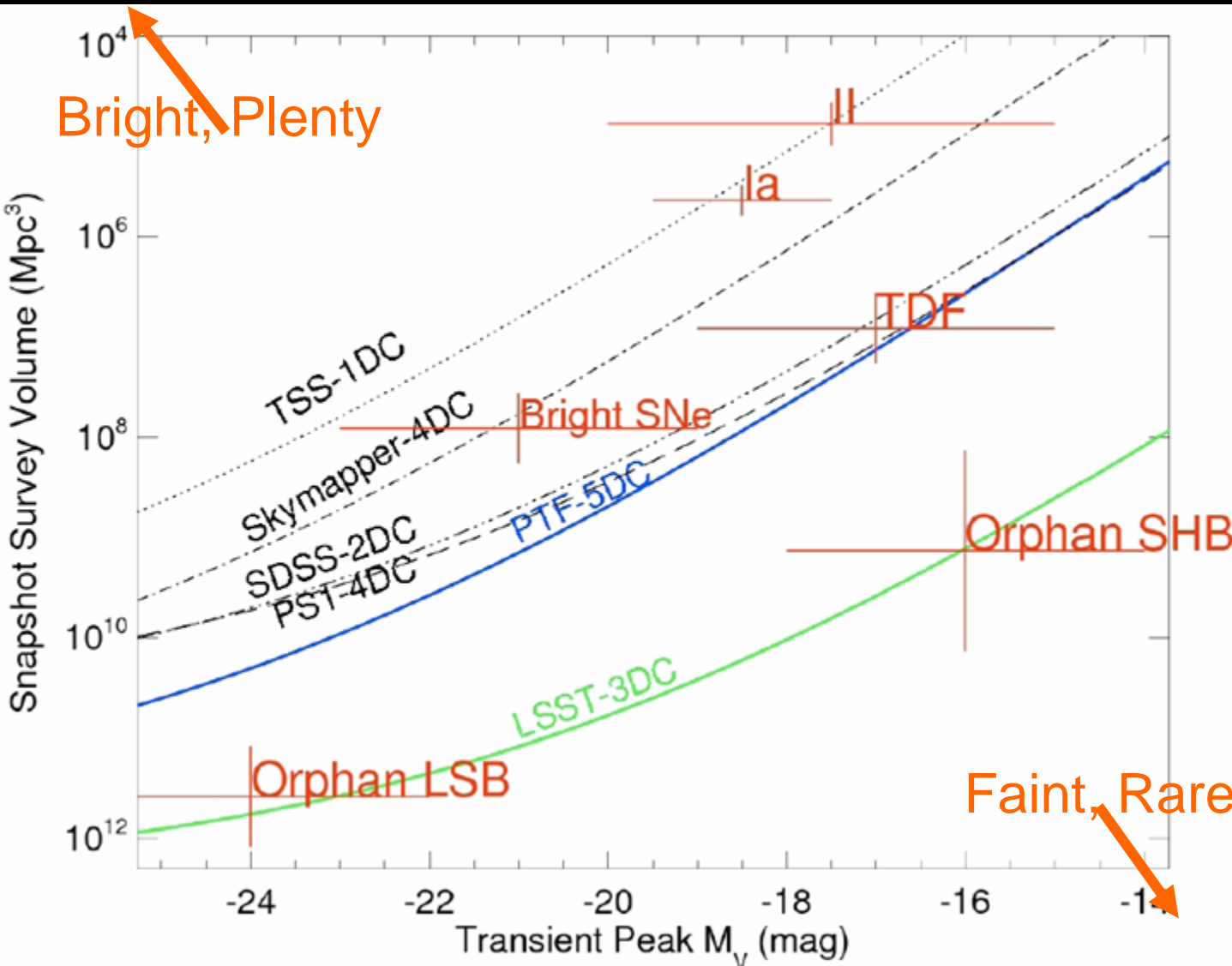
# PTF projects



PTF Key Projects	
Transients in nearby galaxies	Search for eLIGO/neutrino EM counterpart
Thermonuclear SNe	Core Collapse SNe
Blazars/AGN	Tidal Disruption Flares
H-alpha Sky Survey	Orphan GRB afterglow
AM CVn	CVs
Galactic dynamics	RR Lyrae
Flare stars	Rotation in clusters
Nearby Star Kinematics	Eclipsing stars and planets
Asteroids	KBOs

# PTF discoveries

Comparison with other surveys



Courtesy: L. Bildsten

# PTF discoveries

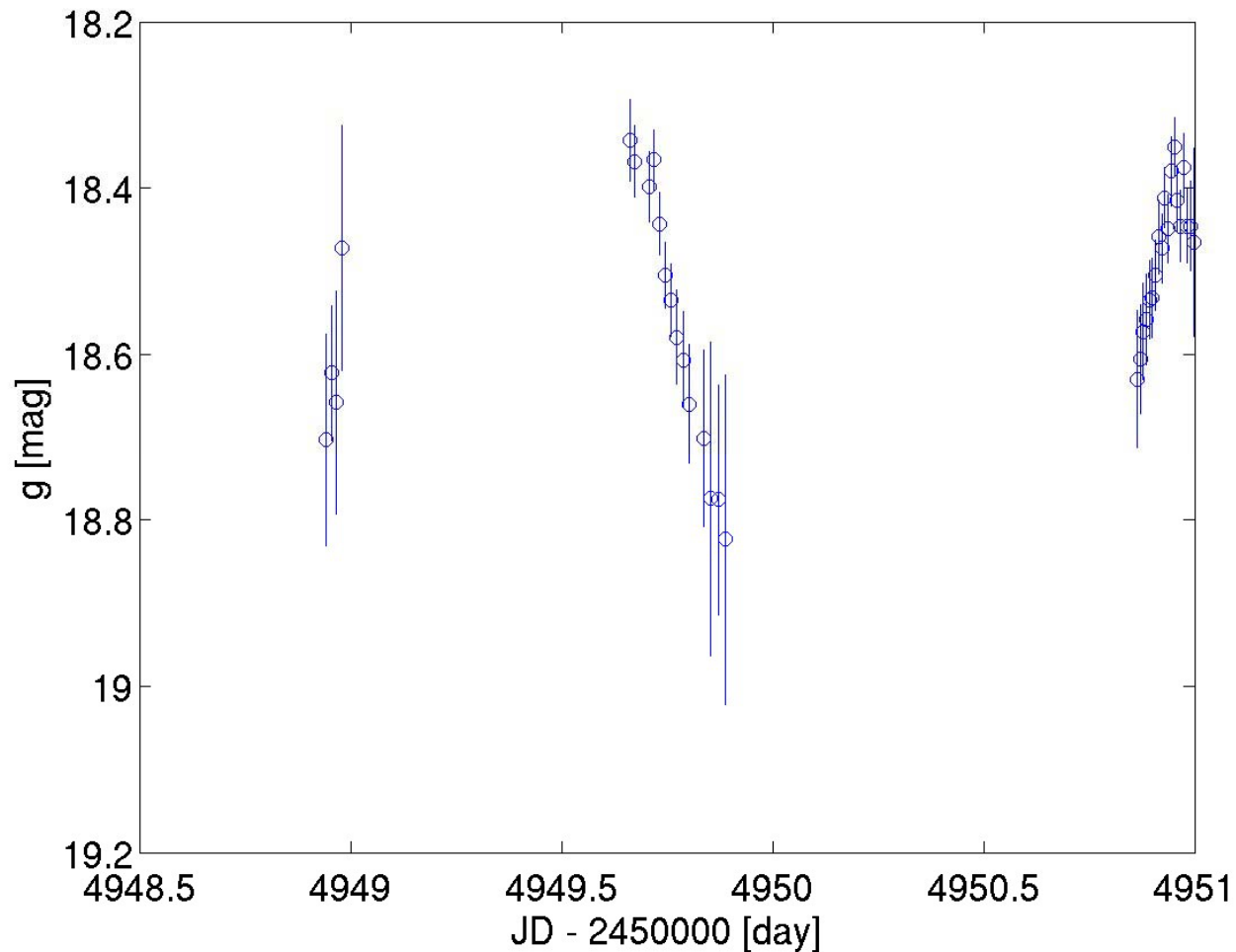
## Commissioning



First SN - March 11, 2009

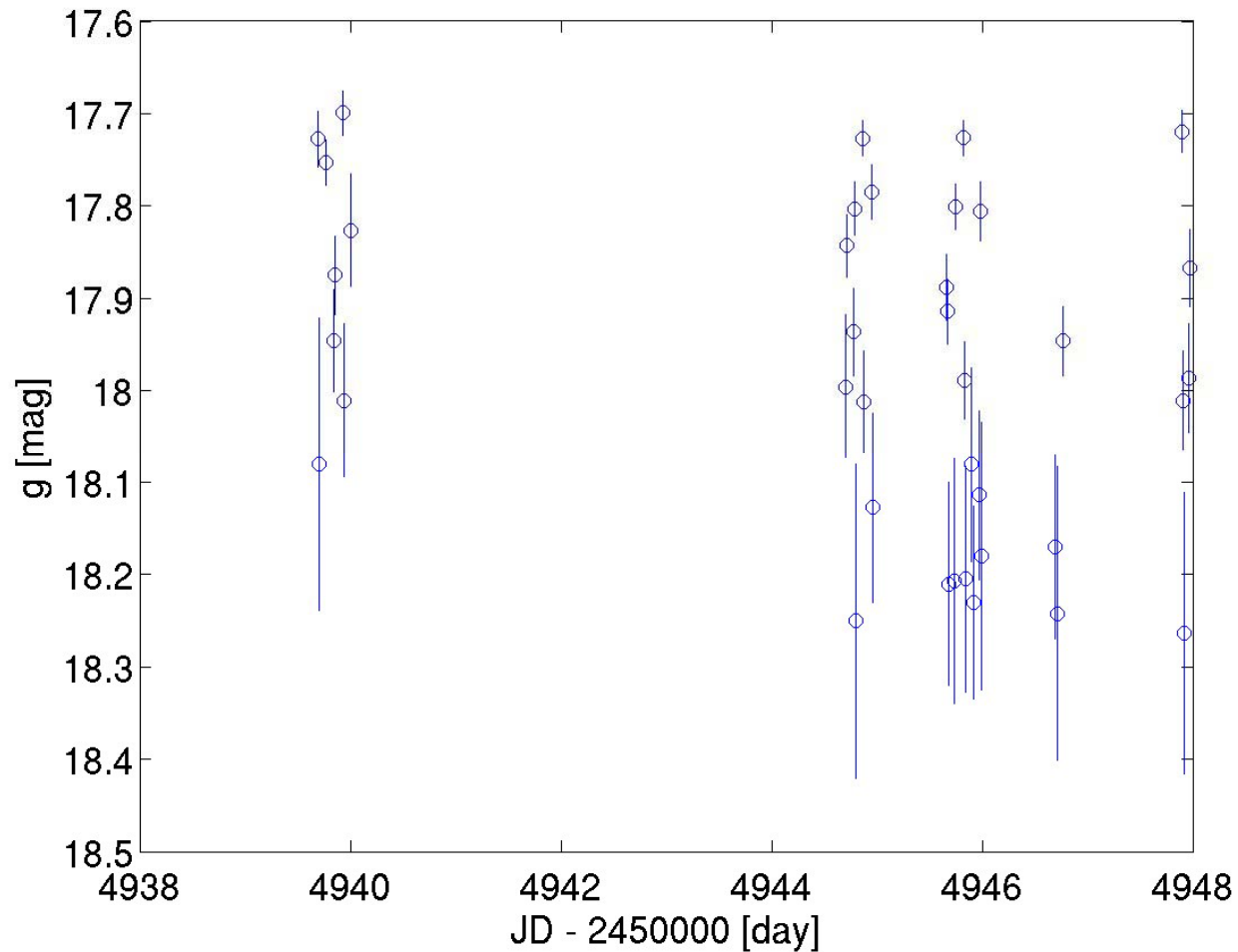
# PTF discoveries

## Variable stars



# PTF discoveries

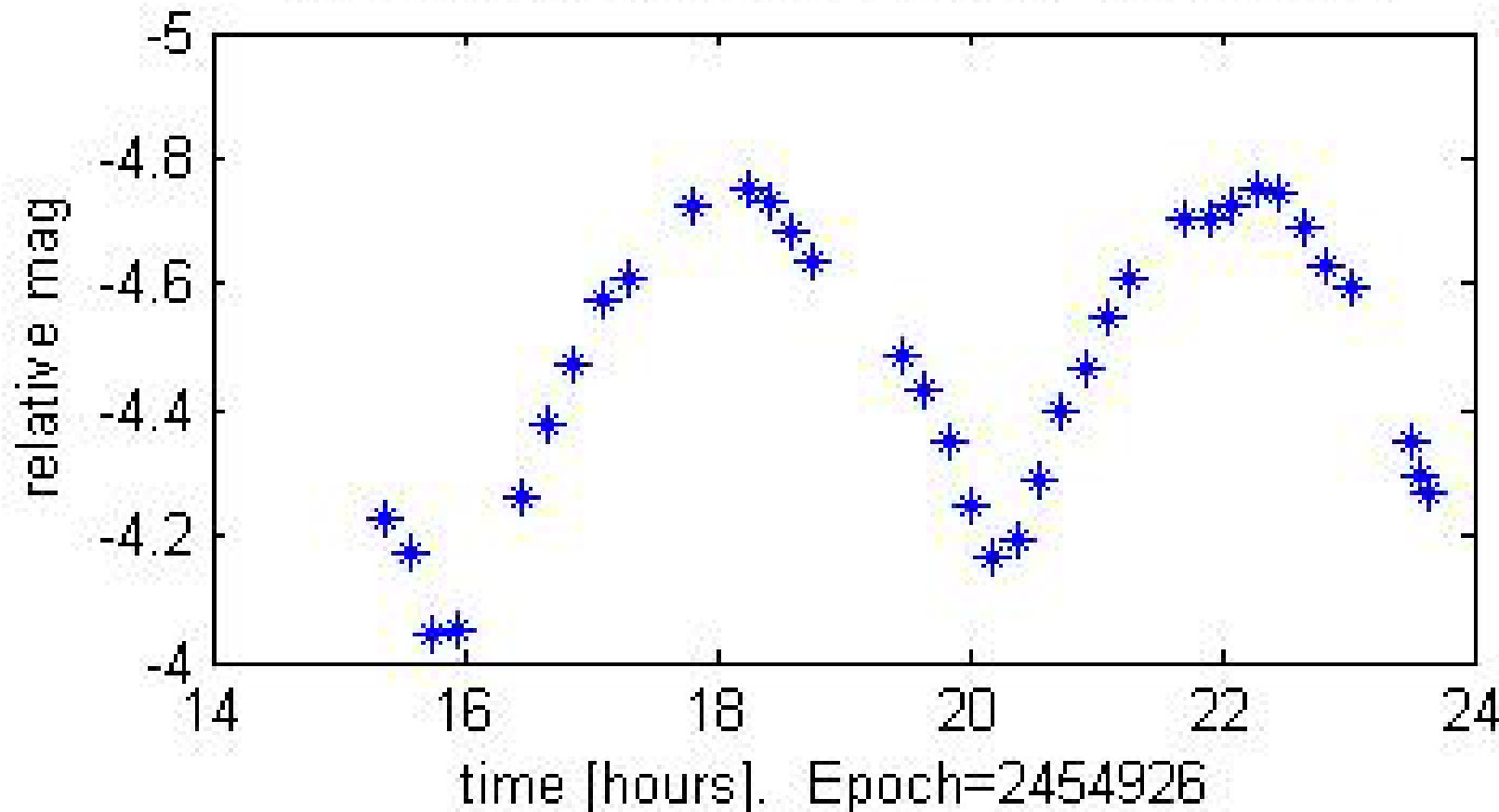
## Variable stars



# PTF discoveries

Variable asteroids  
Prudentia (474)

PTF: Date 20090405, Field 100014, CCD 06



Courtesy: D. Poolishok

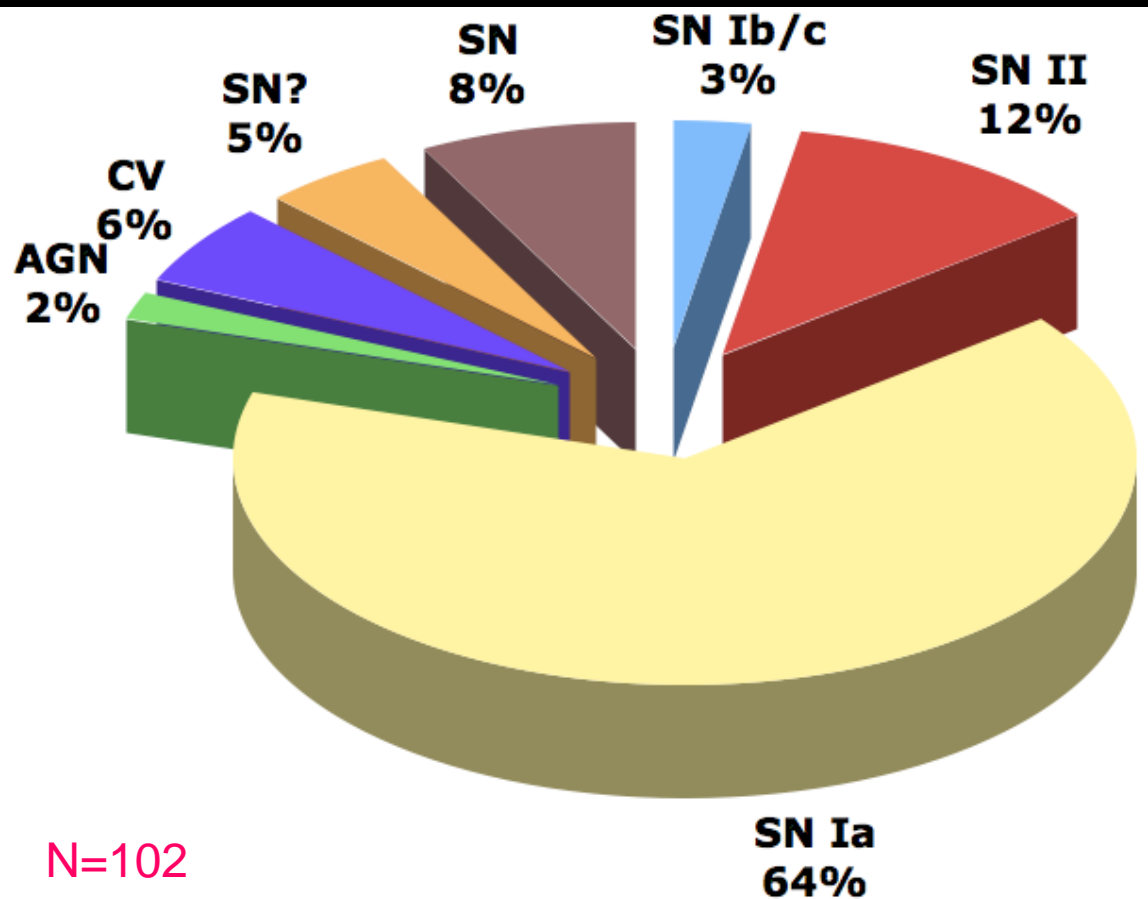


# PTF discoveries

Till ~August 10<sup>th</sup>, 2009

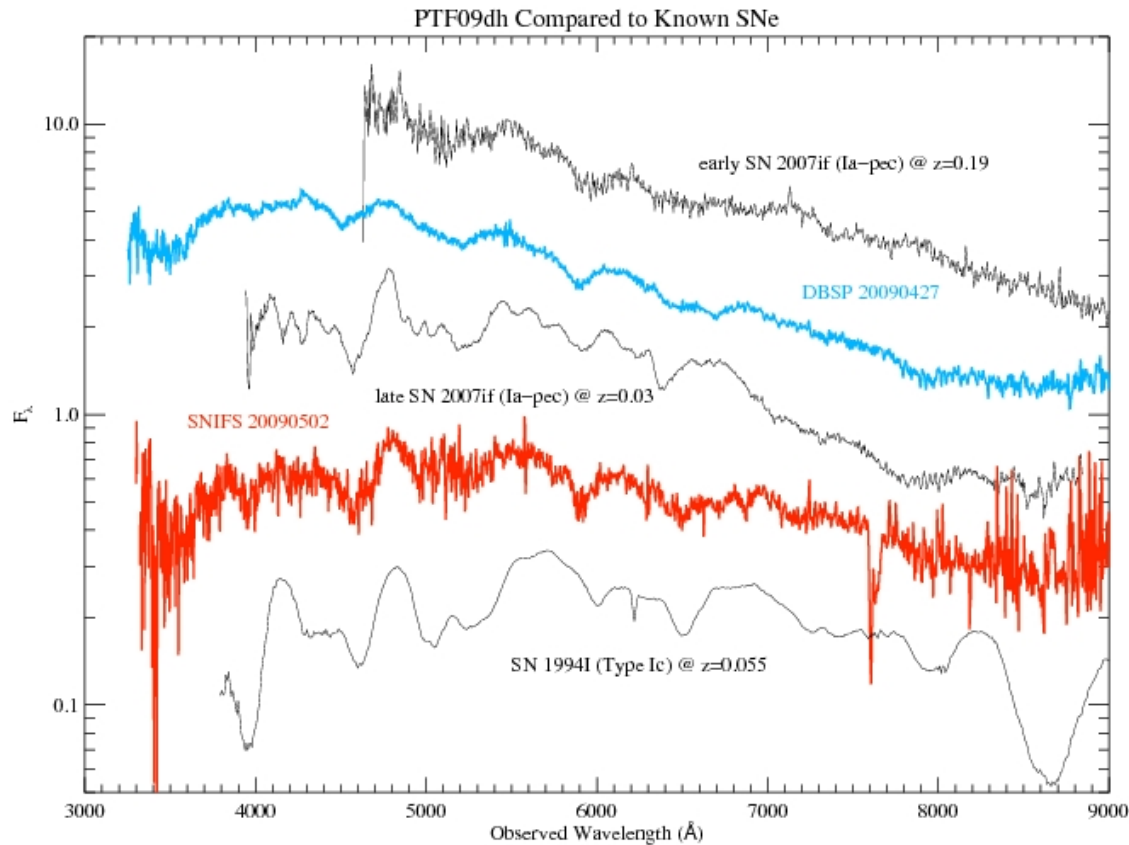
★ ~900 transient candidates

★ ~3000 variable stars



# PTF discoveries

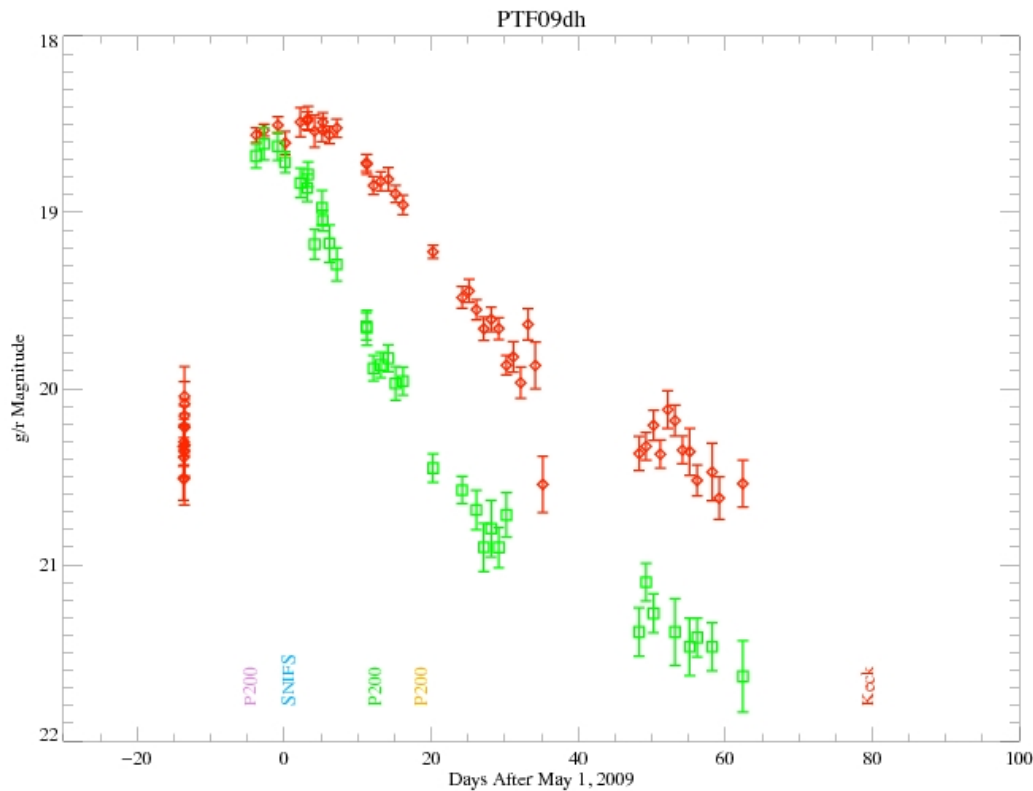
## Examples for interesting SNe



# PTF discoveries

Examples for interesting SNe

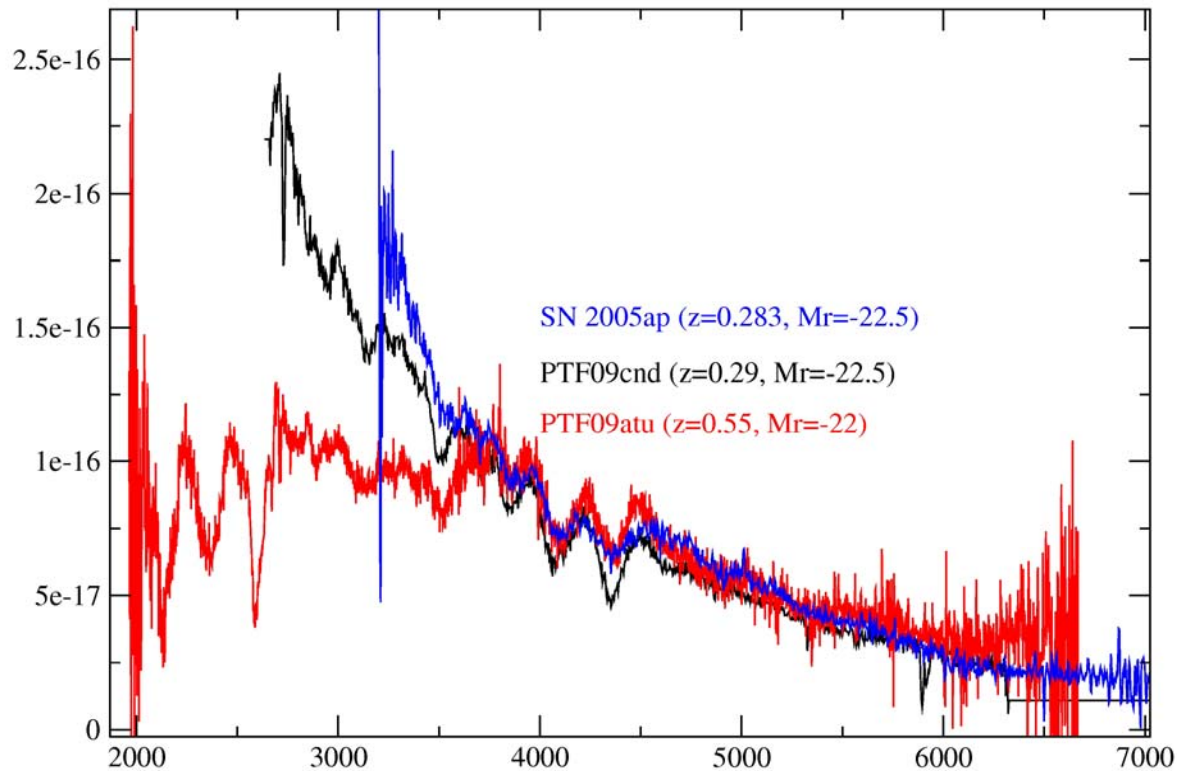
P60 light curve - generated automatically



# PTF discoveries

Examples for interesting SNe

## 2005ap-like (quimbies) SNe



# Summary

★ 48" Schmidt camera + 7.2 deg<sup>2</sup> FOV CCD

Description: Law et al. 09, Rau et al. 09



Lesson: followup - limiting factor for future surveys

Lesson: lim. Mag ~21 enables long term followup  
with 4-10m class telescopes

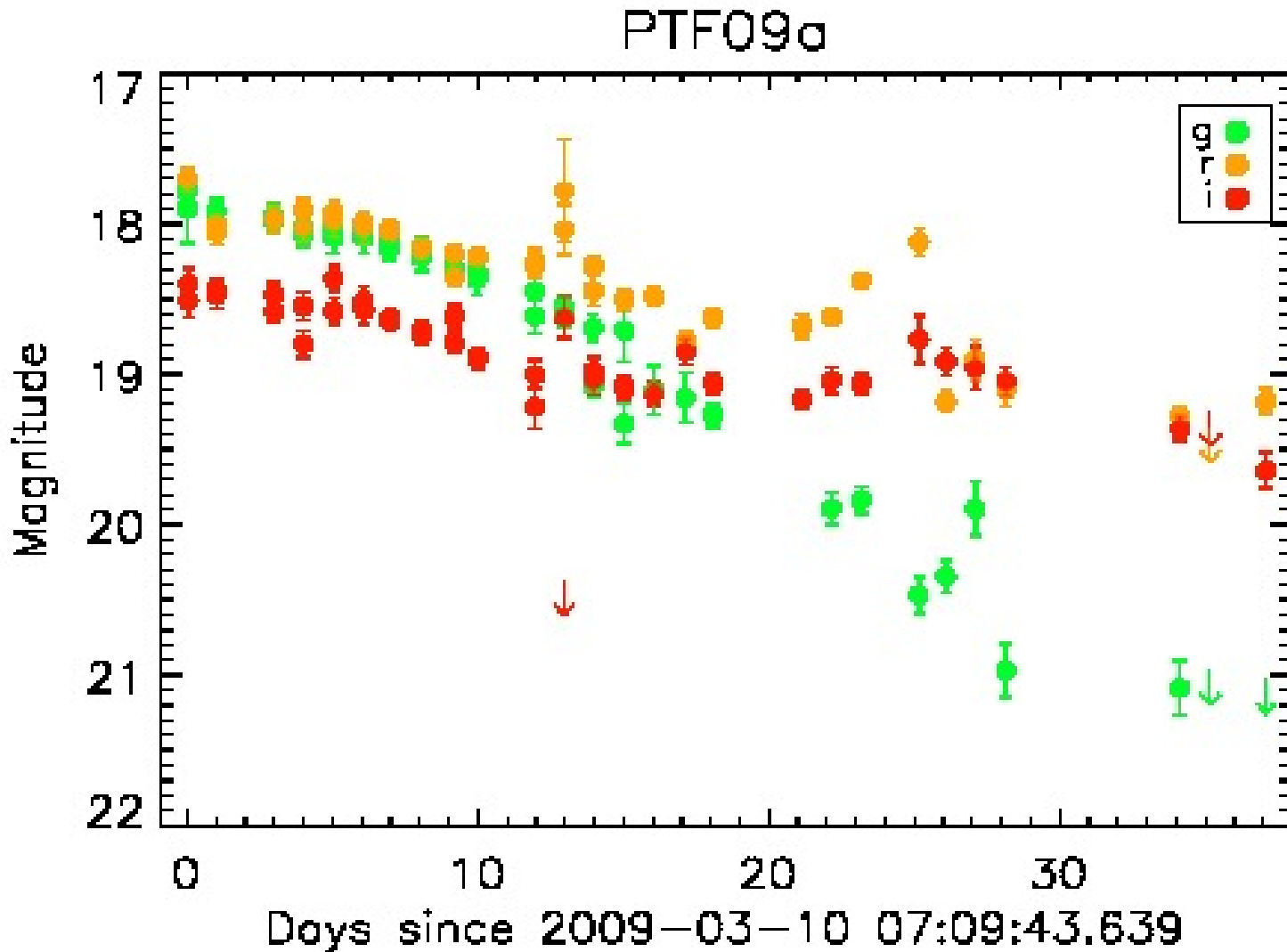
★ Data releases expected in 2010

End

Thank you!

# PTF discoveries

Commissioning



First SN - March 11, 2009

# PTF projects

## Orion field

- ★ Eclipsing binaries and planets in the Orion star forming region
- ★ During ~1 month (November)



# PTF projects

H $\alpha$  all-sky survey

★ Lim. Mag.  $2 \times 10^{-17}$  erg cm $^{-2}$  s $^{-1}$   $\sim$  0.6R

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- ★ Galactic ionized hydrogen contributes to CMB background
- ★ Detection of faint nearby galaxies
- ★ Estimate the SFR in galaxies within 70Mpc
- ★ All sky search for PN
- ★ Galactic structure
- ★ Shells around old novae

# Candidates

## Marshal

PTF Target 09tm - Mozilla Firefox

File Edit View History Bookmarks Tools Help

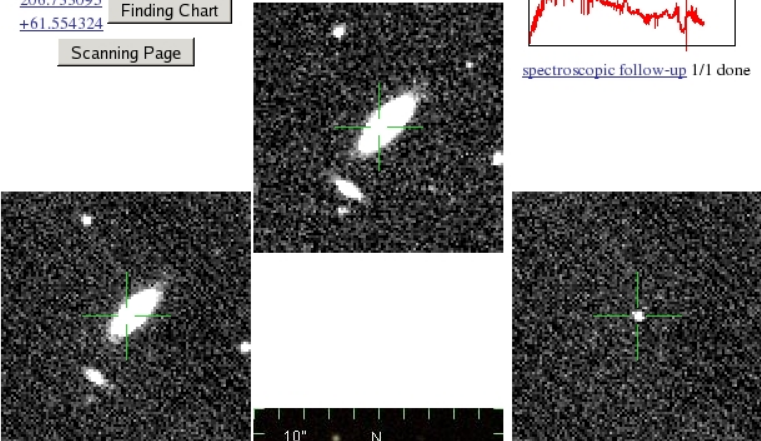
http://navtara.caltech.edu/cgi-bin/ptf/view\_source.cgi?name=09tm

Most Visited Eran Google ADS Tel-Aviv Cat Images SDSS Lensing GRB Reference

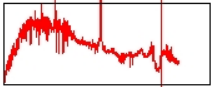
Enter the PTF name of a source  (e.g. "09ab")

### PTF09tm

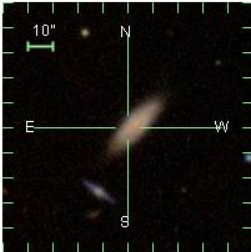
206.733095 Finding Chart  
+61.554324 Scanning Page



SN II +50.7d

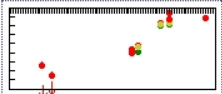


spectroscopic follow-up 1/1 done



10" N  
E W S

r = 16.8 (21.8 d)



photometric follow-up 16/3000 done

#### Comments:

- Aug 14 MANSI [dismod]: 35.91
- Aug 14 MANSI [nearpgc]: 3385354
- Aug 04 PETER [type]: Transient
- Jul 29 BRAD [redshift]: 0.034
- Jul 29 BRAD [classification]: SN II
- Jul 29 BRAD [phase]: +30 days
- Jul 29 BRAD [comment]: Type IIa
- Jul 28 MANSI [type]: Transient
- Jul 13 PETER [type]: Transient
- Jul 12 MANSI [type]: Transient
- Jul 03 ROBERT [redshift]: 0.15
- Jul 03 ROBERT [classification]: SN II
- Jul 03 ROBERT [phase]: 6 days
- Jul 03 ROBERT [comment]: Similar to SN 1999aa at +5d
- Jul 03 ROBERT [redshift]: 0.03
- Jul 03 ROBERT [classification]: SN II
- Jul 03 ROBERT [comment]: SN IIa. Spectra riddled with narrow absorption features and a few emission lines as well
- Jun 25 ROBERT [type]: Transient
- Jun 25 MANSI [type]: Transient

Add a Comment:

info Save Comment

Quick P48 LC

Done

# PTF science

## H alpha - all sky survey

- ★ Galactic ionized hydrogen contributes to CMB background
- ★ Detection of faint nearby galaxies
- ★ Estimate the SFR in galaxies within 70Mpc
- ★ All sky search for PN
- ★ Galactic structure
- ★ Shells around old novae

# PTF projects

5 day cadence SNe search

- ★ Scan  $\sim 2700 \text{ deg}^2$  every 5 days in R-band  
Total footprint  $\sim 9000 \text{ deg}^2$

Motivation:

- ★ SN type-Ia
  - e.g., Cosmology
  - HST UV spectroscopy project
- ★ Exploring the core collapse zoo
  - e.g., IIP cosmology project
  - Bright SNe (Quimbies)

# PTF projects

<1 day cadence transients search

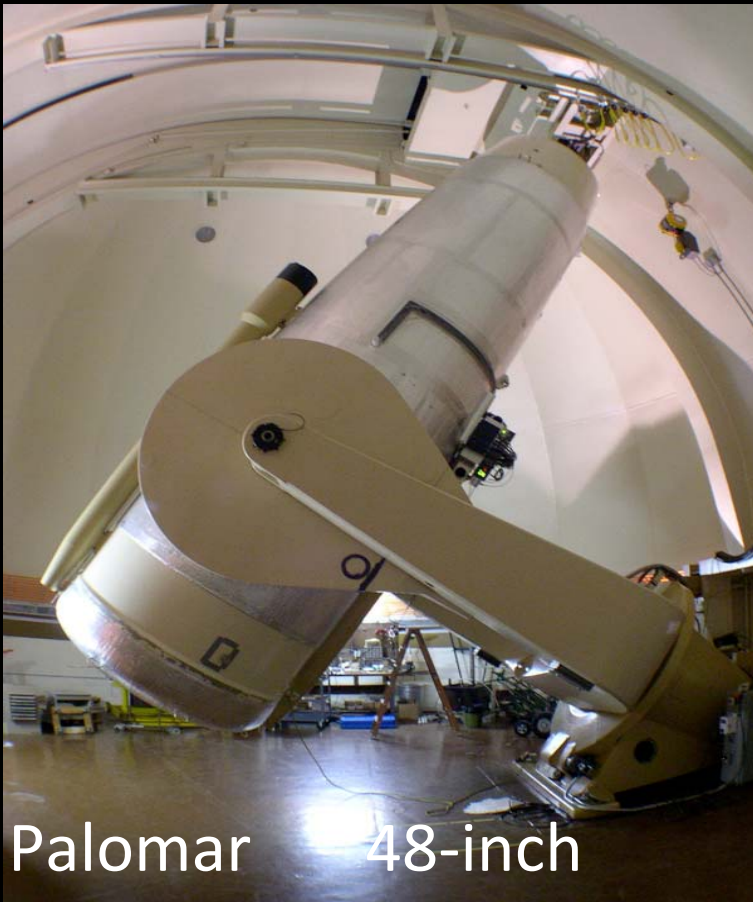
- ★ New kind of (fast) transients
- ★ Transients in the local Universe (<200Mpc)

# PTF discoveries

## Commissioning

- ★ PTF first light: December 2008  
(less than 2 years after project started)
- ★ Started test observing: January 2009  
Complete telescope robotization: March 2009

# PTF followup



Palomar 48-inch



Palomar 60-inch

# PTF projects

5 day cadence SNe search

- ★ Scan  $\sim 2700 \text{ deg}^2$  every 5 days in R-band  
Total footprint  $\sim 9000 \text{ deg}^2$

$< 1$  day cadence transients search

- ★ New kind of (fast) transients
- ★ Transients in the local Universe ( $< 200 \text{ Mpc}$ )



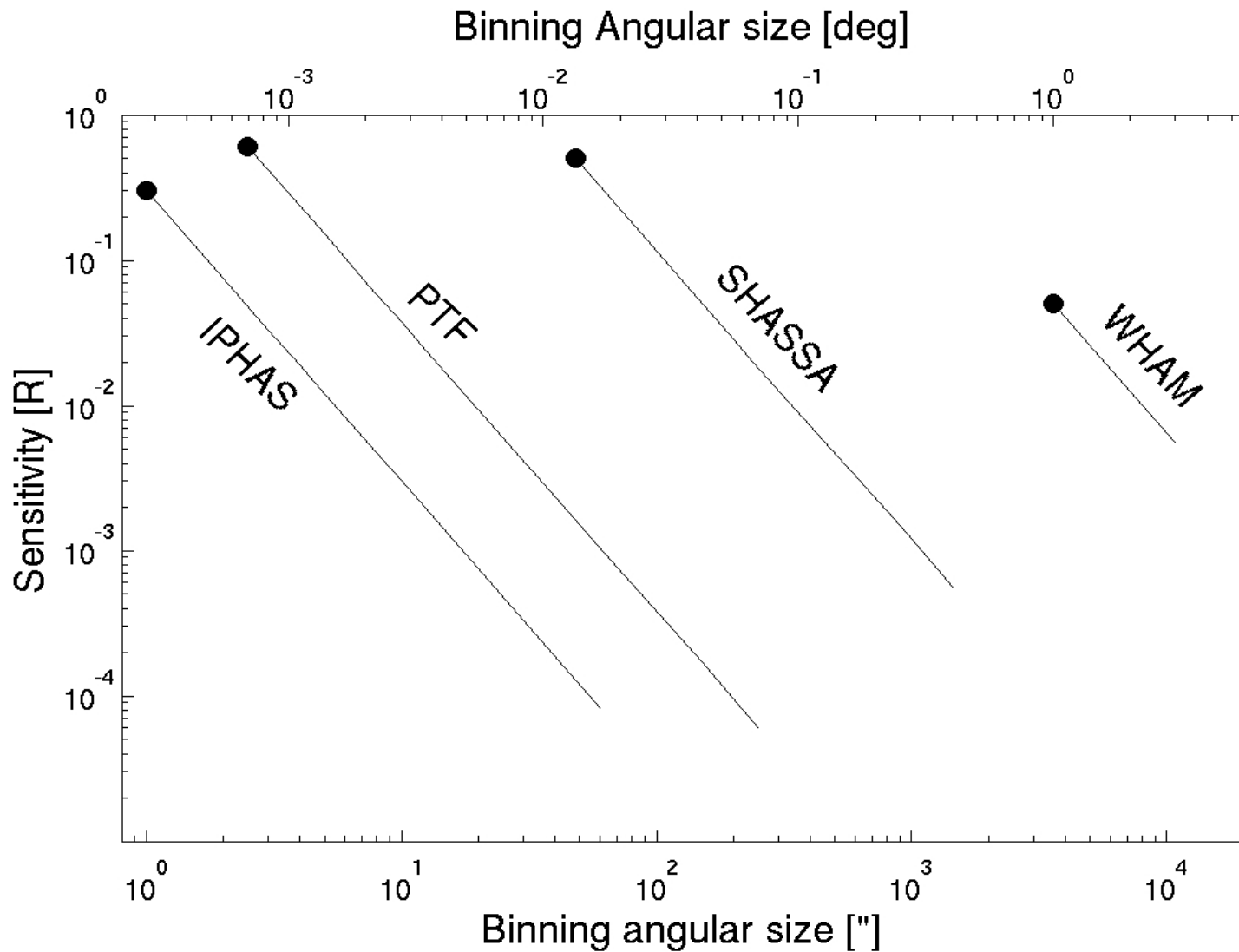
# The PTF H alpha survey

- ★ H alpha survey of  $3\pi$  sr ( $\text{dec} > -20^\circ$ )
- ★ Lim. Mag.  $2 \times 10^{-17}$  erg  $\text{cm}^{-2}$   $\text{s}^{-1} \sim 0.6R$
- ★ With 3 nights per month:
  - $\sim 1$  year for 2 images per pointing  
(dithering to fill the gaps)
  - $\sim 2$  years to complete the H alpha survey

# Other surveys

- ★ **IPHAS** Drew et al. (2005)  
Galactic lat < 5 deg    ~1800 deg<sup>2</sup>  
sensitivity ~0.3 R
- ★ **WHAM** Tufte et al. (1998)  
dec > -30°  
Resolution: 1 deg    Sensitivity: ~0.05R
- ★ **SHASSA** Gaustad et al. (2001)  
dec < +15°  
Resolution: 0.8'    Sensitivity: 0.5R

# Other surveys



# Calibration

- ★ Constructing a list of H alpha calibration stars
- ★ Synthetic photometry of SDSS stellar spectra
- ★ Estimated 1s accuracy  $\sim 0.06$  mag  
 $\sim 0.03$  mag using 10 stars
- ★  $\sim 25,000$  stars with reliable H alpha flux

# Decisions

- ★ How many filters: 2, 3?, 4?
- ★ Calibration outside the SDSS footprint?
- ★ Get filters from CFHT? Or buy it?

End