Pan-STARRS in the Era of Wide-Field Surveys

Armin Rest, Harvard University

Outline

- PS1 overview
- Status
- First Science
- Future

Pan-STARRS 1 Commissioning Observations 2007.12.02

Eugene A. Magnier, Kenneth C. Chambers, Jeffery Morgan, Nick Kaiser, John Tonry, William Burgett and the Pan-STARRS Team

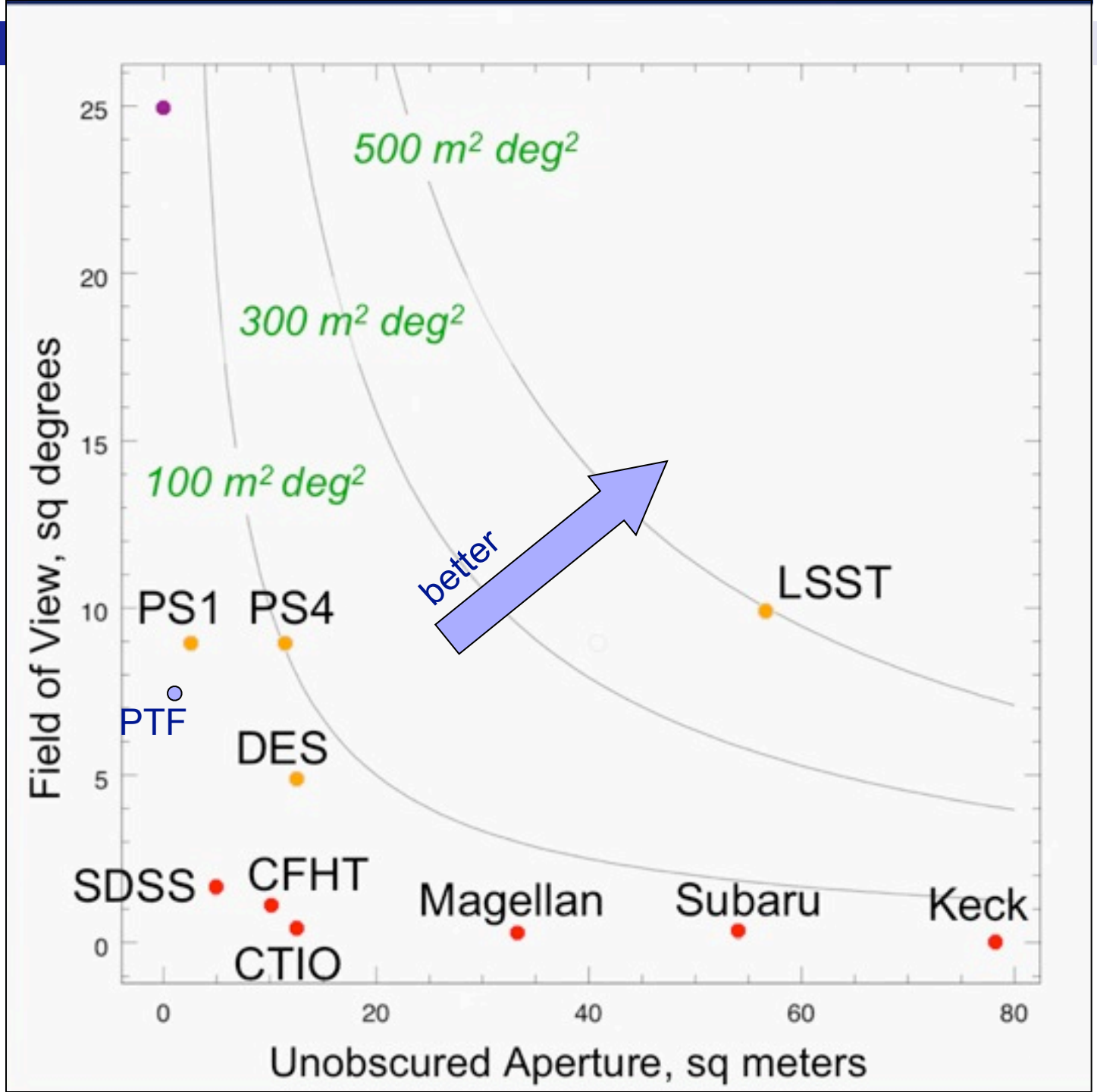
Survey Figure of Merit (FOM)

$$FOM = S/t \propto \frac{A\Omega\varepsilon}{f_{sky} FWHM^2}$$

System:
- Collecting Area
- FOV
- Efficiency

Site:
- Sky brightness
- Seeing

- Each generation of astronomical survey hardware is providing a substantial increase in AΩ product.
- Still on steep part of FOM vs. cost curve.


500 m² deg²
300 m² deg²
100 m² deg²
better
PS1
PS4
PTF
DES
SDSS
CFHT
CTIO
Magellan
Subaru
Keck
LSST
Field of View, sq degrees
Unobscured Aperture, sq meters
0
5
10
15
20
25
0
20
40
60
80

The Pan-STARRS project

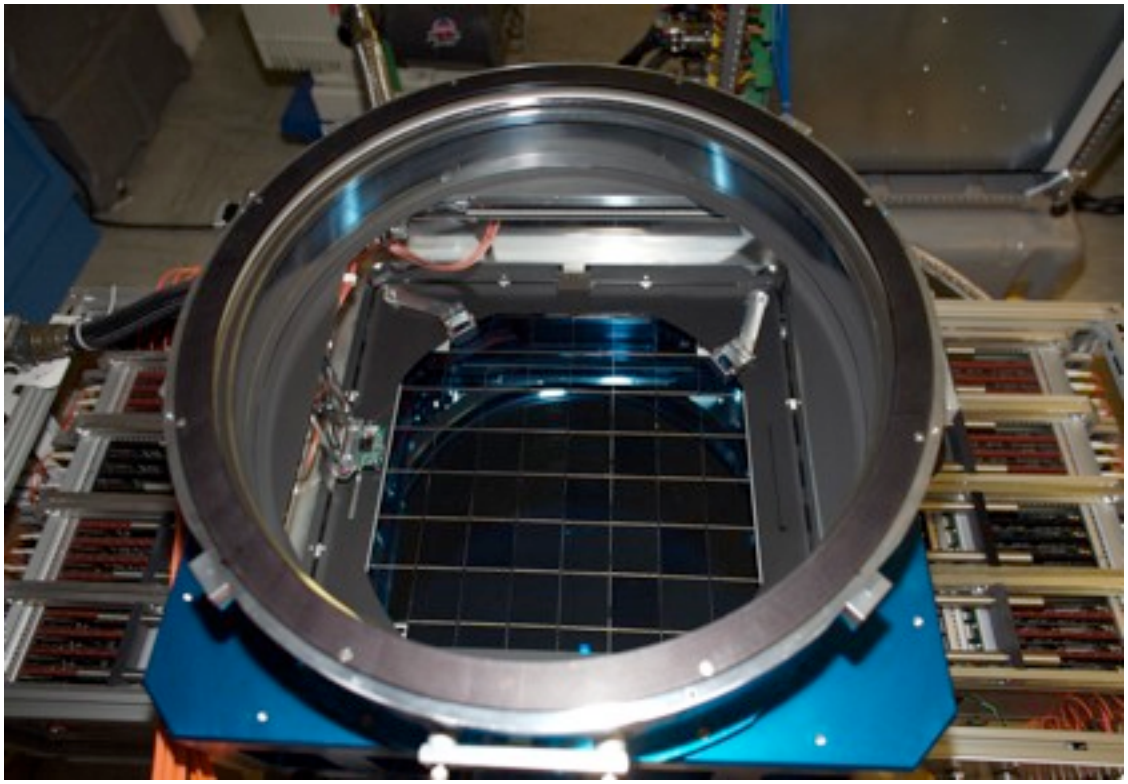
Panoramic Survey Telescope and Rapid Response System

PI: N. Kaiser
Project Manager: W. Burgett
Camera Lead : J. Tonry
Telescope Lead: J. Morgan
IPP Lead: G. Magnier
PSPS: J. Heasley

- Univ. of Hawaii project : USAF funded, technology demonstrator – sky surveys
- Construction of prototype PS1 and 1.4Gigapix camera (GPC1)
- Now moving to PS2 and PS4 construction

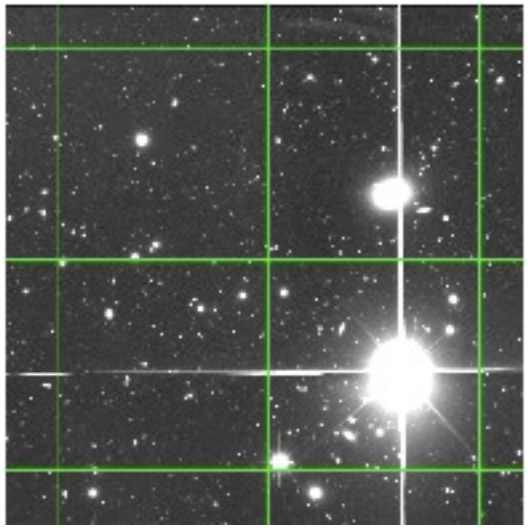
- PS1SC is funding a 3.5 yr science mission with PS1 2009-2012
- PS1 data products release to the consortium – full public release 1yr after survey finishes
- PS1SC have “long term lease”

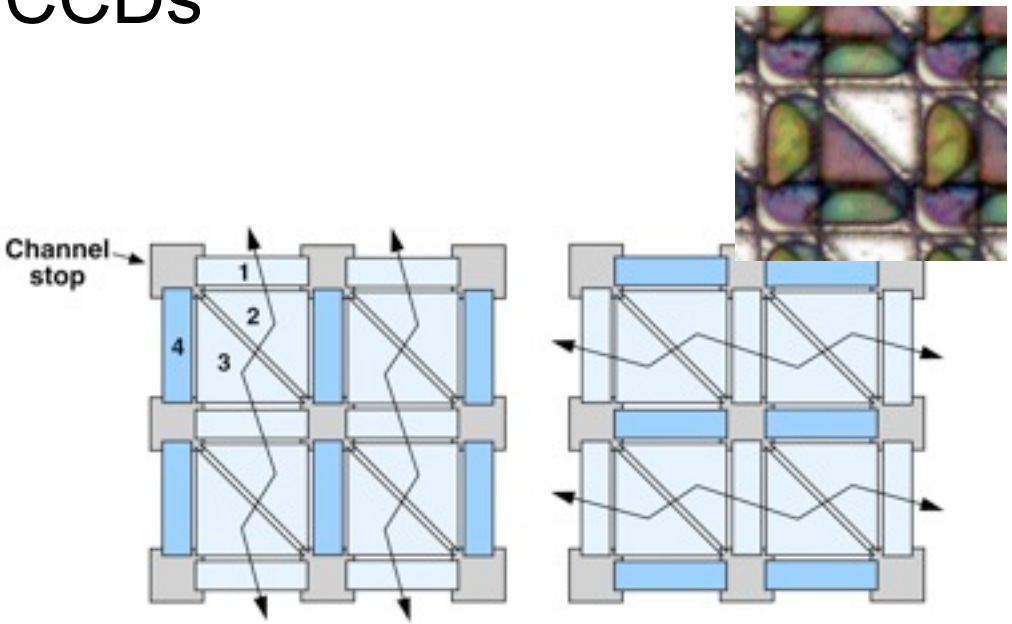
PS-1 Telescope and GPC1 Camera



- 1.8m telescope on Haleakala (Maui)
- 1.4 gigapixel camera (GPC1)
- 40x40 cm focal plane
- 7 sq. deg. FOV, 0.26” pixels
- 8x8 chips, 8x8 cells per chip, 584x591 pixels

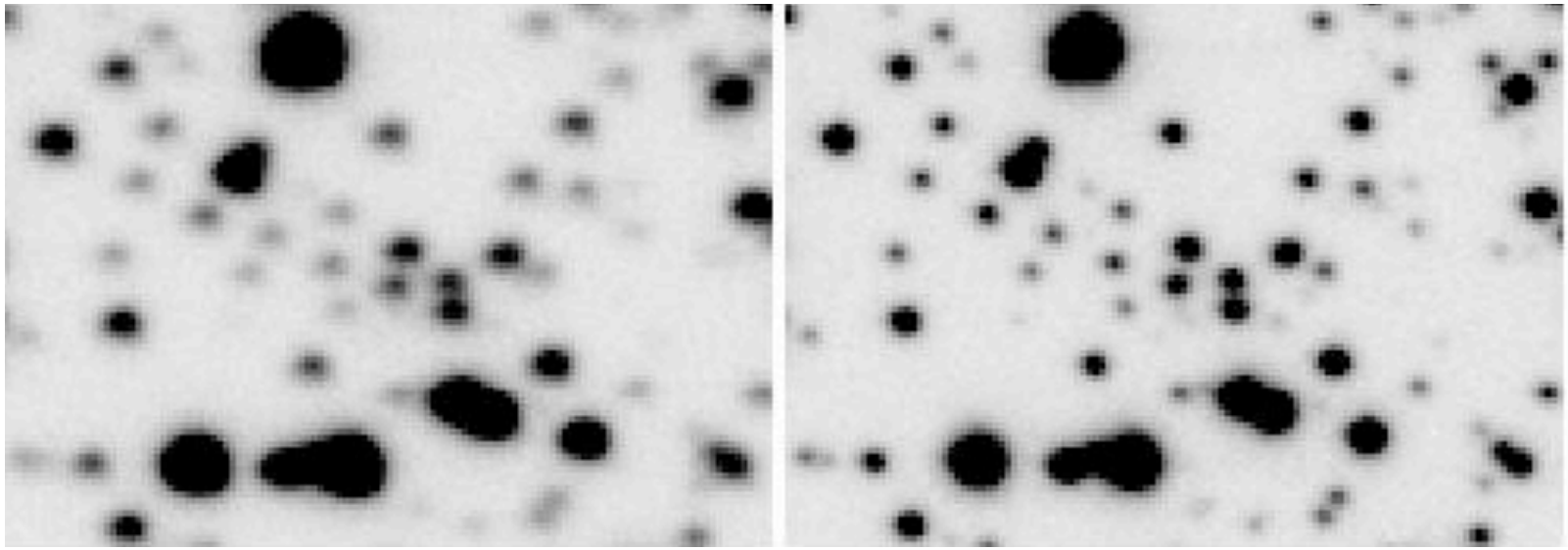
Orthogonal Transfer CCDs





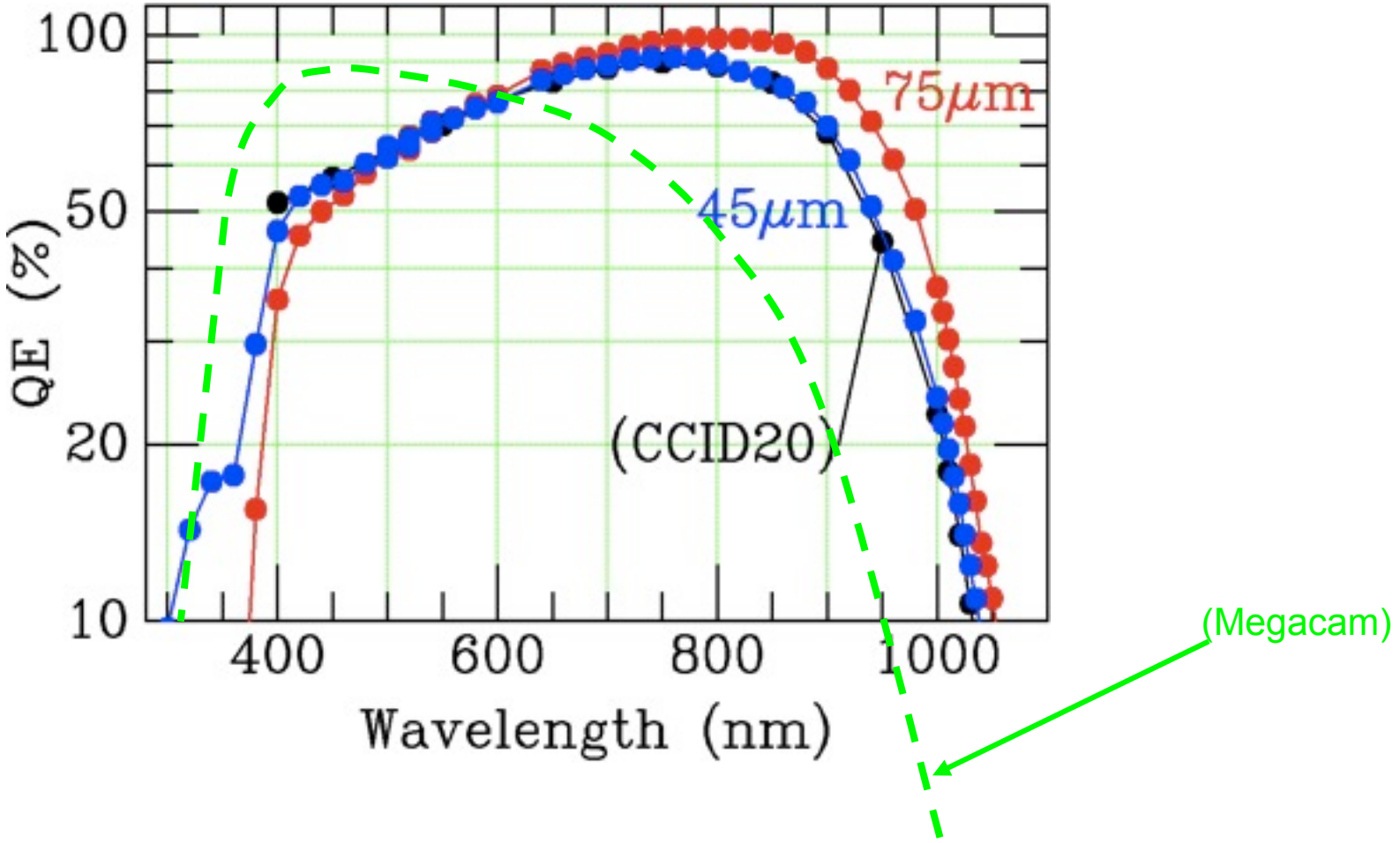
Normal guiding (0.73")

OT tracking (0.50")

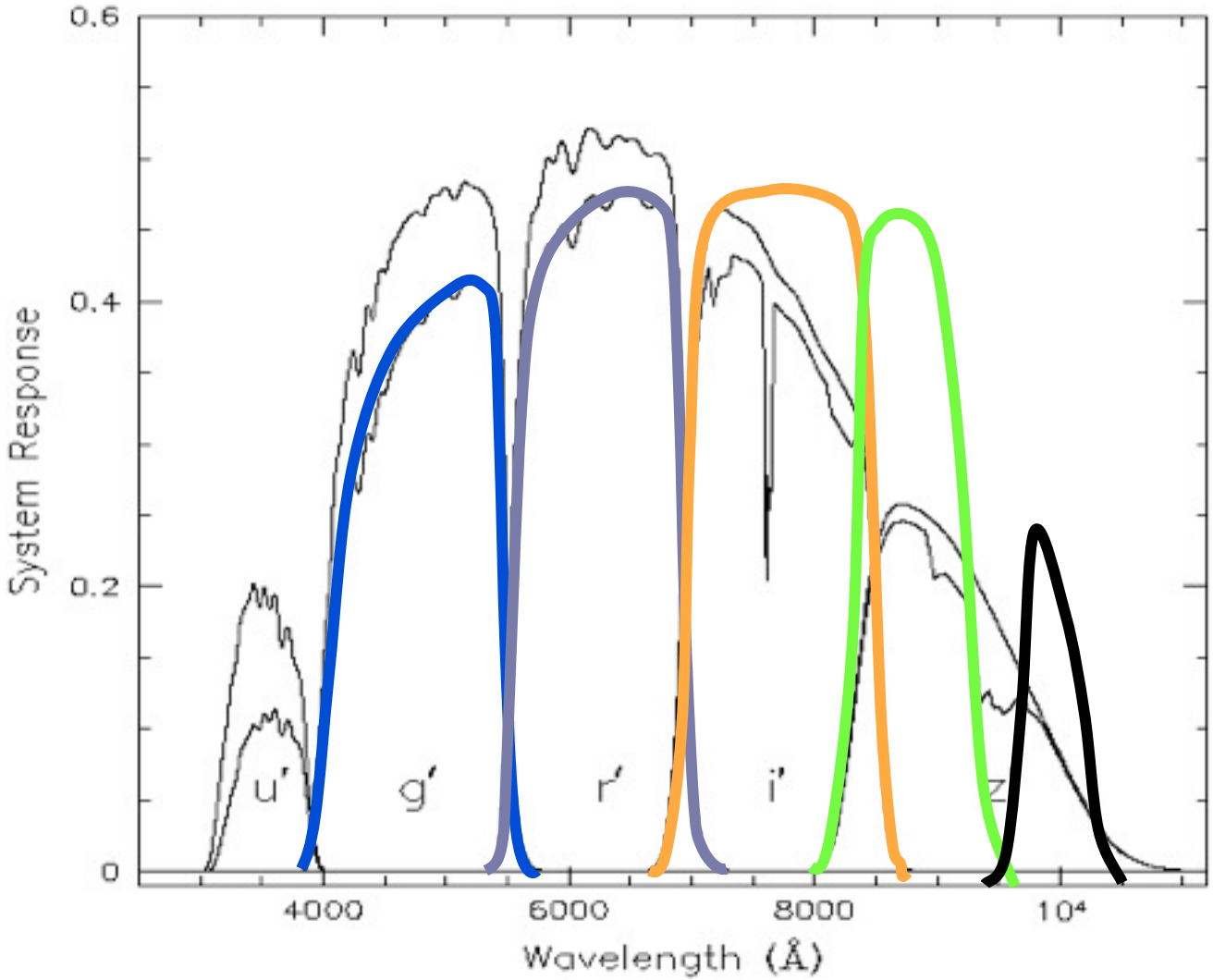


OTA Quantum Efficiency

- Red sensitivity!



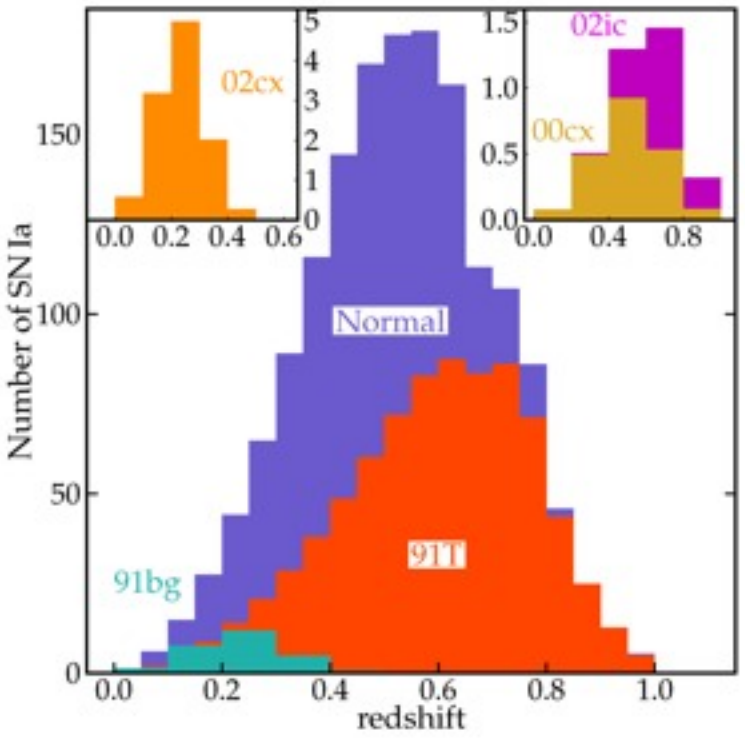
SDSS and Pan-STARRS bandpasses



PS1: surveys

- 3pi survey
  - 3 years: 12 epochs in grizy
  - 30 sec, 2 x grizy in 15 days, then another epoch one month later
  - 24000 SNe per year
- Medium-Deep Fields (MDFs)
  - gr=8x120 sec
  - iz=8x240 sec
  - Repeats every 4 days
  - ~1000-2000 SNe in 1 year
  - Limiting magnitudes:
    g, r, i, z = 23.6, 23.3, 23.3, 22.3

Courtesy of Steve Rodney



PS1: surveys

- Solar System Sweet Spot Survey
  - 2 rectangles ~500 deg. at opposition region +/- 30 deg.
  - w(gri) TTI, 3 nights in 15 days.
  - MOPS software ready!
- Deep M31 survey
  - r=2x360s, i=360s nightly
  - g=360s dark time,
  - z=300s, y=60s bright time
  - Limiting mag after 3 years: gri=27th mag
  - Microlensing, Novae, LBV's, Cepheids, Eclipsing binaries
- Stellar Transit Survey (STS)
  - Search for Exoplanets
  - One 7deg^2 field: 400,000 dwarfs
  - ~1h per night

Key Projects

1) ISS - Populations of objects in the Inner Solar System [Jedicke]
2) OSS - Populations of objects in the Outer Solar System (beyond Jupiter) [Holman]
3) LMS - Low-Mass Stars, Brown Dwarfs, and Young Stellar Objects [Magnier, Brandner]
4) STS - Search for Exo-Planets by dedicated Stellar Transit Surveys [Afonso, Henning]
5) MW - Structure of the Milky Way and Local Group [Bell, Rix]
6) M31 - Dedicated Deep Survey of M31 [Seitz, Bender]
7) MSSP - Massive stars and supernova progenitors [Smartt, Bresolin]
8) CIVET - Cosmology Investigations with Variables & Explosive Transients [Tonry, Riess, Stubbs]
9) GAL - Galaxy Properties [Heckman, Meurer, Ferguson]
10) AGNHZQ - Active Galactic Nuclei and High Redshift Quasars [Chambers, Walker]
11) CL - Cosmological Lensing [Heavens, Kaiser, Taylor]
12) LSS - Large Scale Structure [Cole, Phleps, Bender]

PS1: status

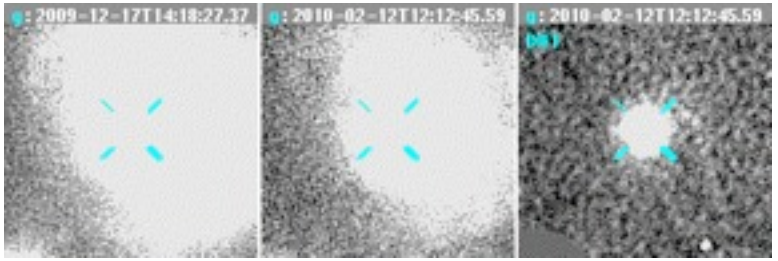
- First real stream of images of MDFs in summer 2009
- Growing pains
  - CCD artifacts
  - Software not quite ready to deal with all the data
  - System PSF still significant
  - Magic
- First set of SN and transients in June+ 2009
  - 50 SN-like lightcurves
  - 13 spectr. confirmed SN, $z<0.4$
  - Boticella et al., arXiv:1001.5427
- Setback in fall 2009: 6 week shutdown to fix secondary

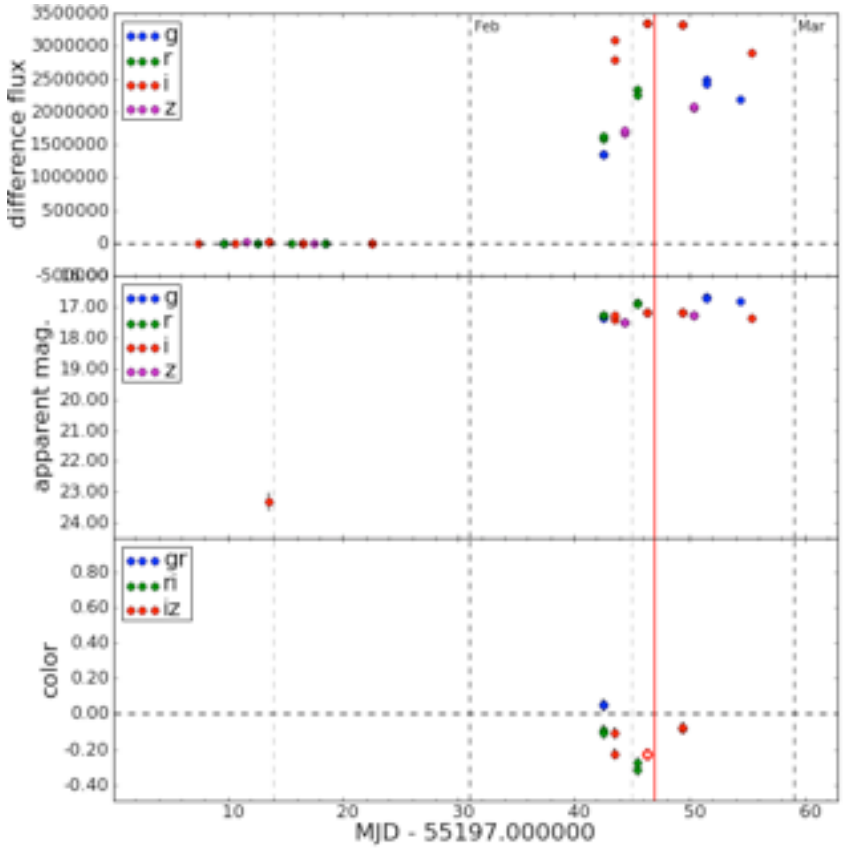
PS1: status

BUT: turned the corner in the last 2 month!

- Transient search very succesful!
  - Harvard/JHU
    - IPP stacks
    - ESSENCE diffim pipeline & alert system
    - 200-300 SNe in 2 month in MD fields
    - End2end system
  - QUB
    - IPP End2end
    - Classification!
    - 60 Sne in 1 month

SN Ia @ z=0.03





PS1: status

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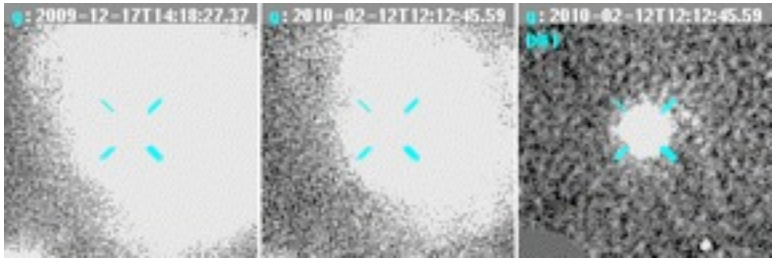
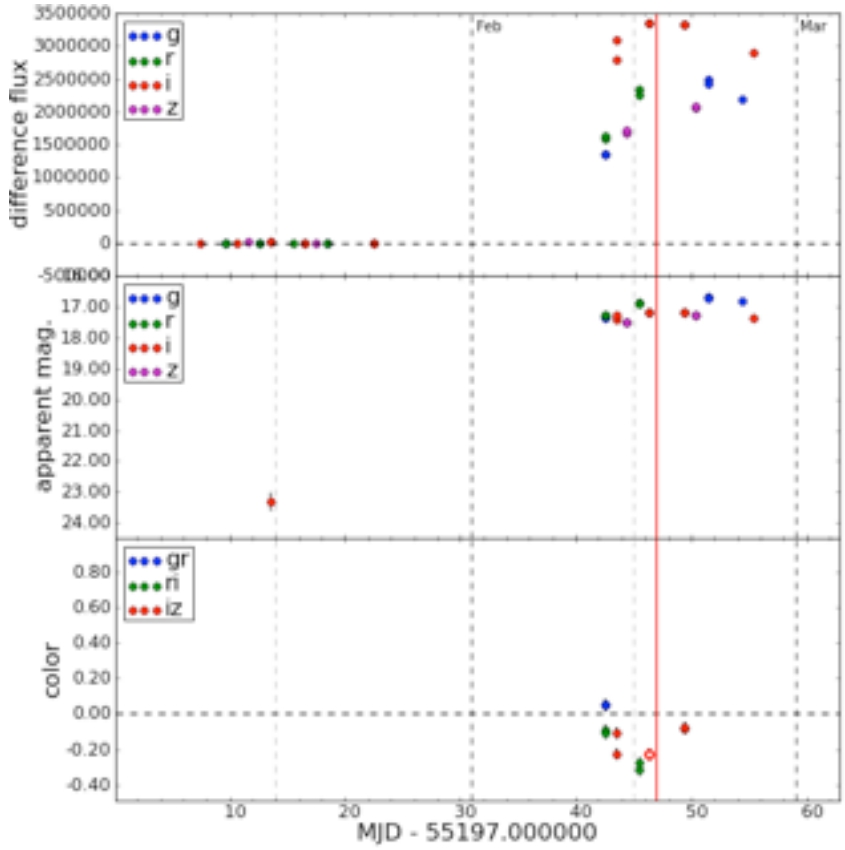
SN Ia @ z=0.03

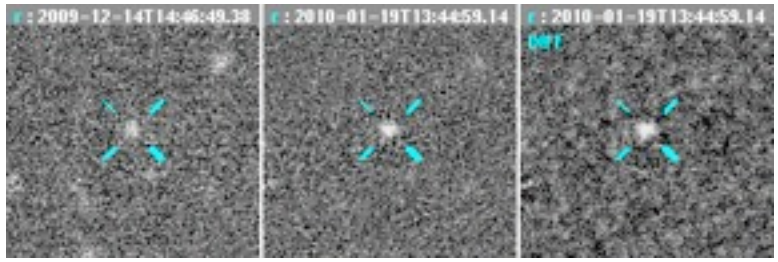


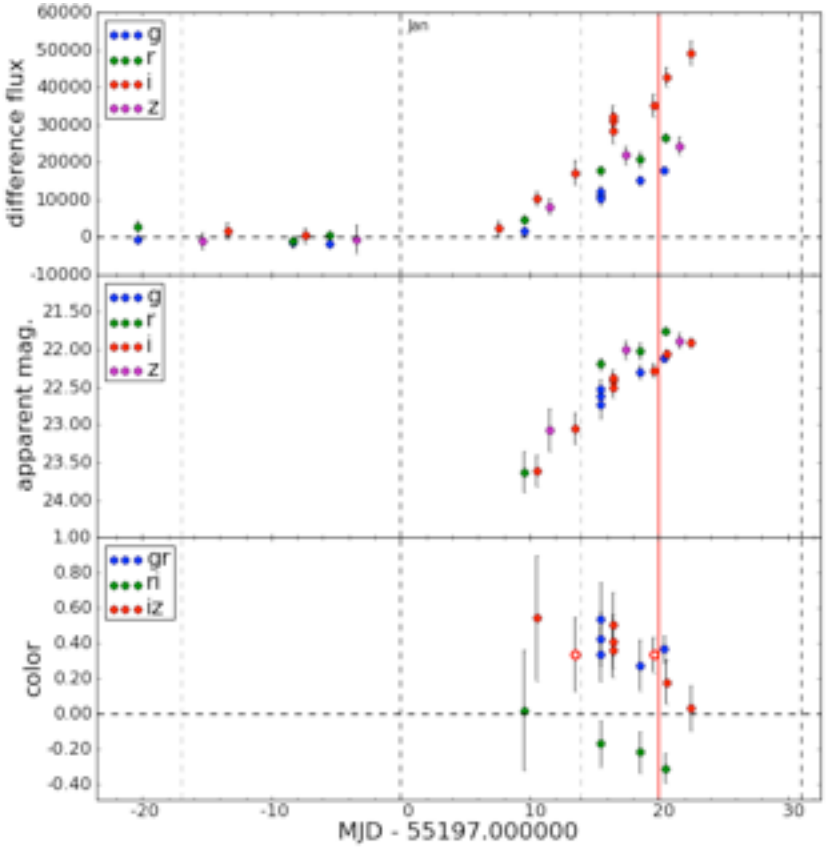


PS1: MDF transients

- Good lightcurves
- Early discovery!
  - In January: 2 SN Ia 6 days before max

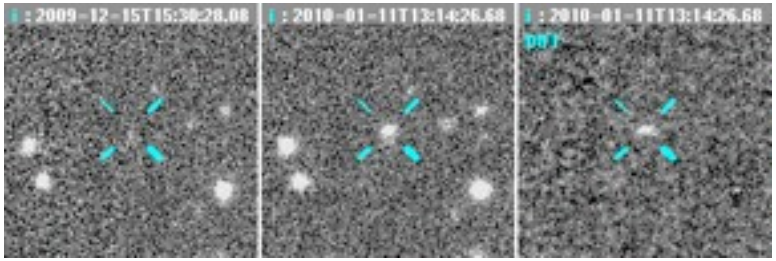
SN Ia @ z=0.31



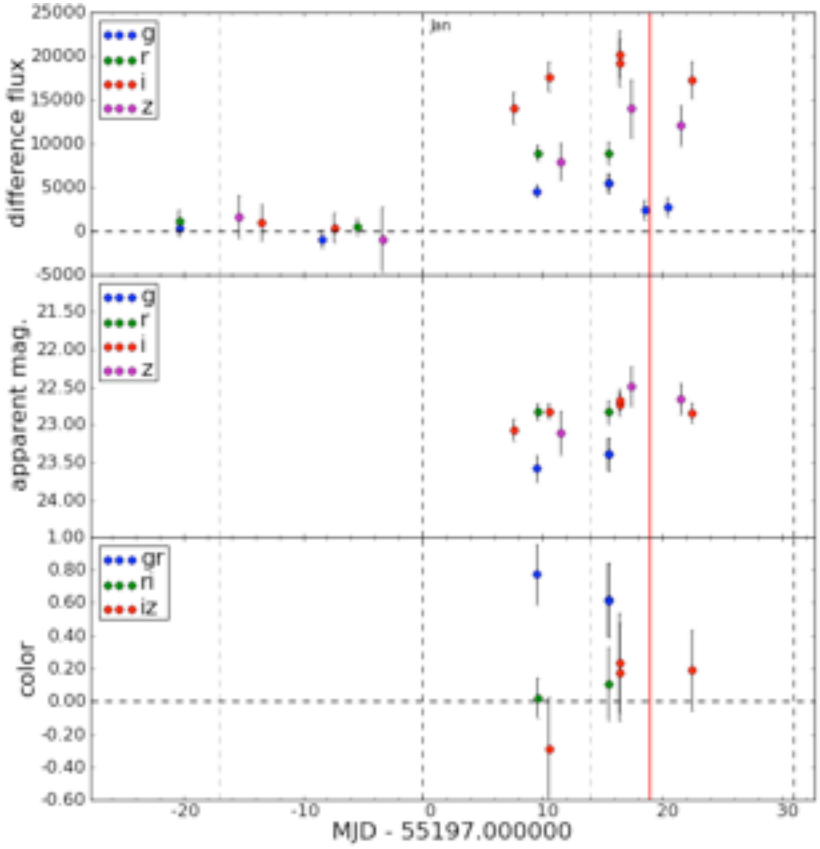


PS1: MDF transients

SN Ia @ z=0.6



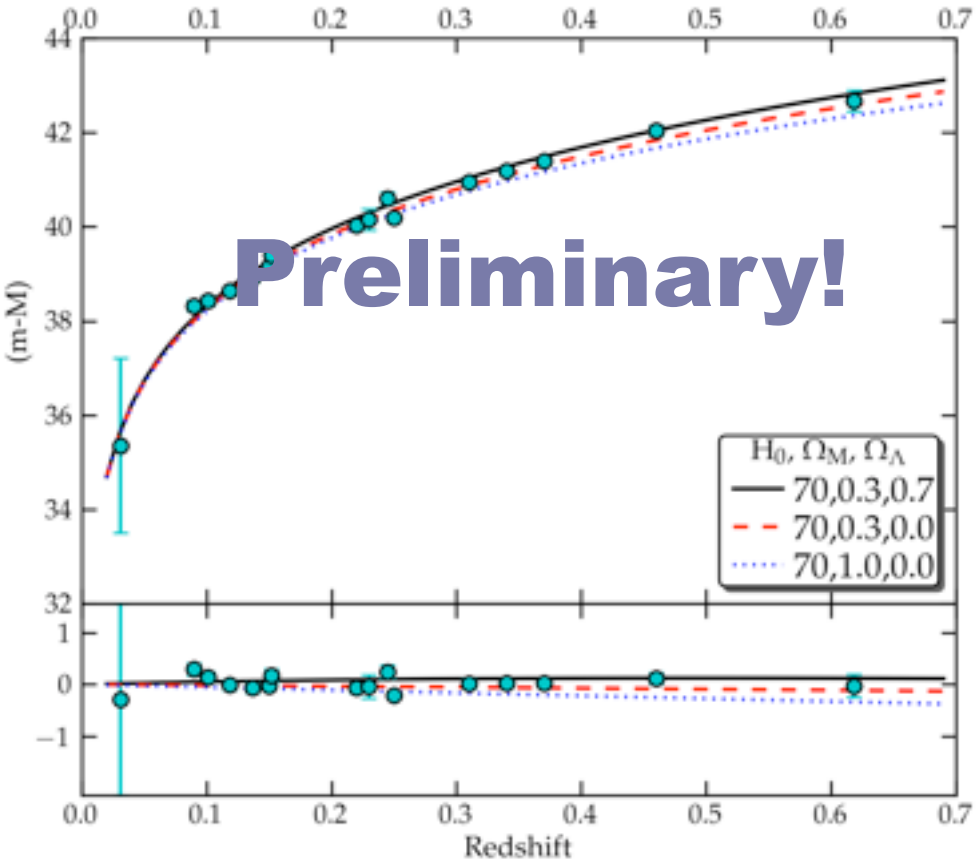
- Faint!
  - Good lightcurves at z=0.6!
  - Great lightcurves in the red!
- 25 spectr. Confirmed Sne in Jan/Feb



SNe Ia in MD

- >1000 SN Ia per year
- Select SN to minimize sytematics!
  - Host galaxy
  - Distance to host
  - Lighcurve coverage
  - …
- Unprecedented range in redshift!
- Spectroscopy for all not possible!
  - Lightcurve-only
  - SNACC filter (Riess, Scolnic,

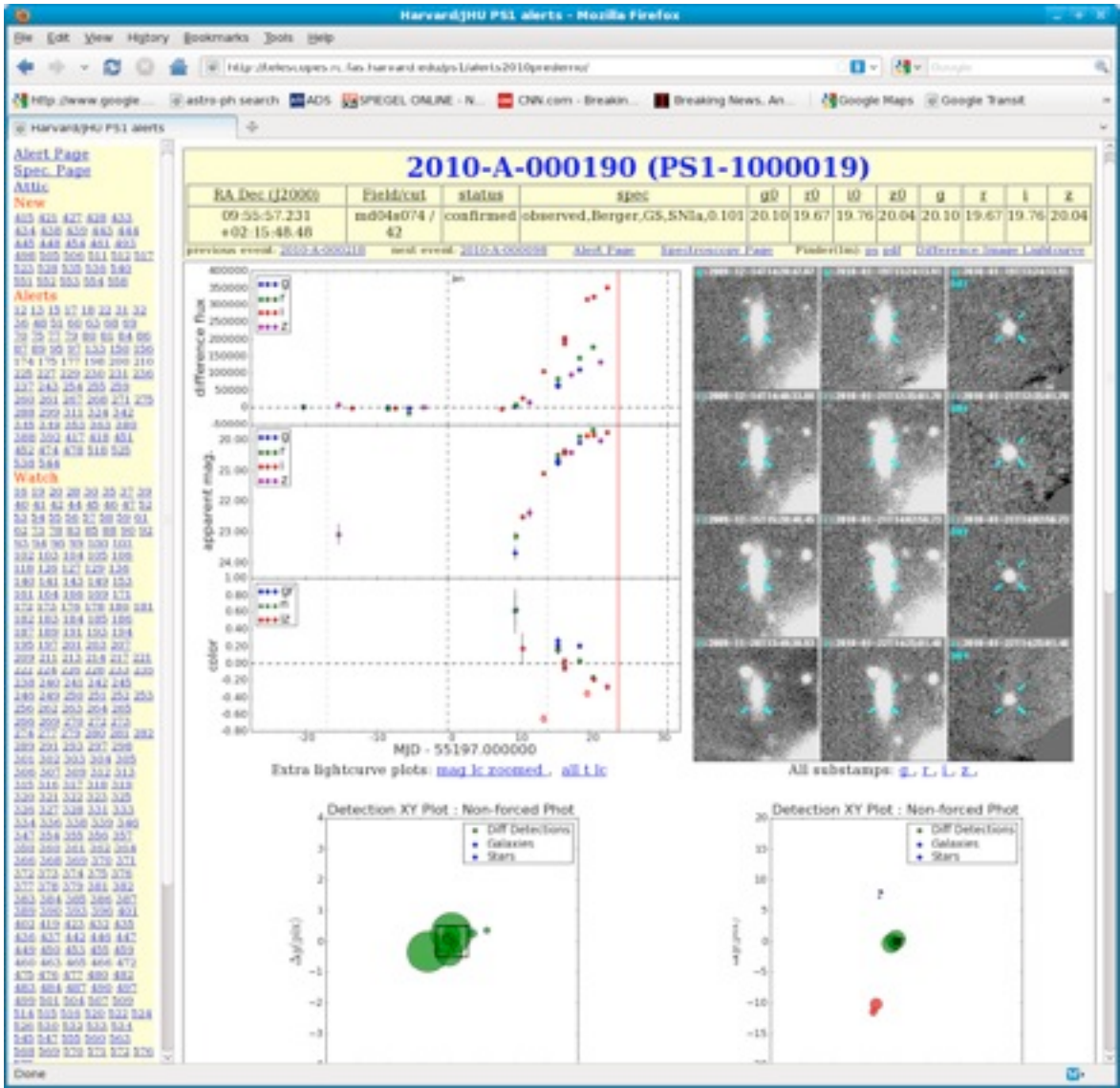
17 PS1 SN Ia, spec. confirmed in Jan 2010, SALT lightcurve fitting



Even the PanSTARRS Universe is still accelerating….

Alerts pages

- Lightcurves automatically updated
- Organize follow up
- Finders etc



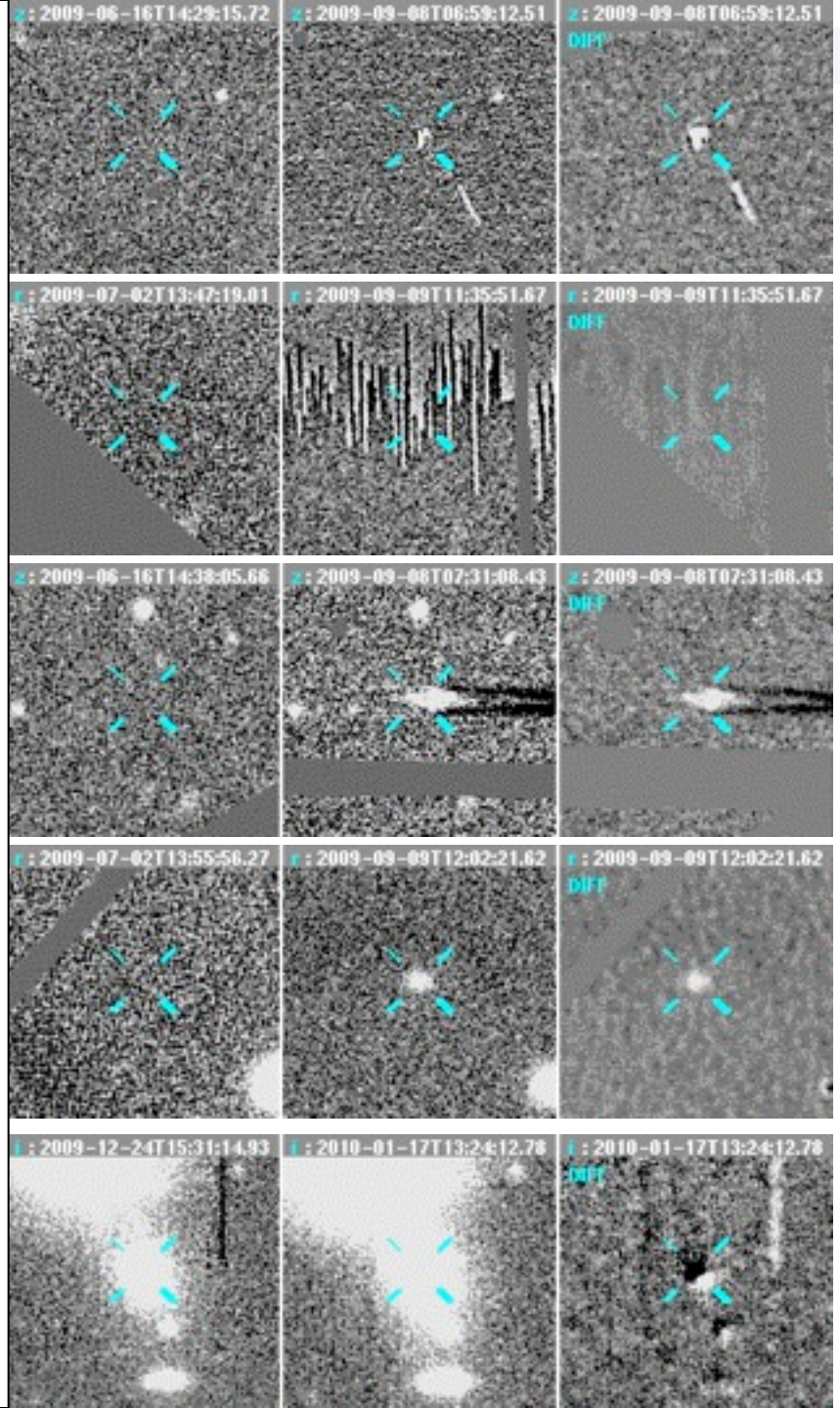
Cosmic Rays

Icicles

Burns

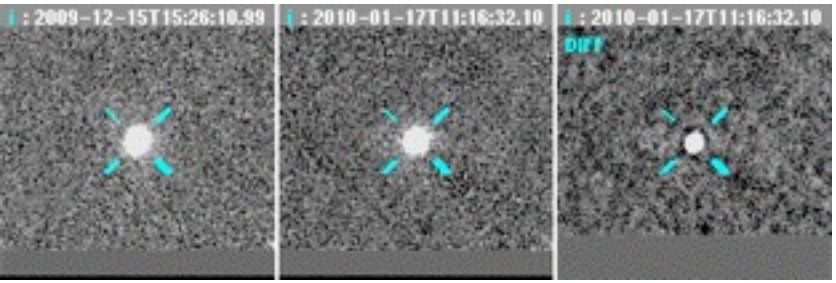
Xtalk

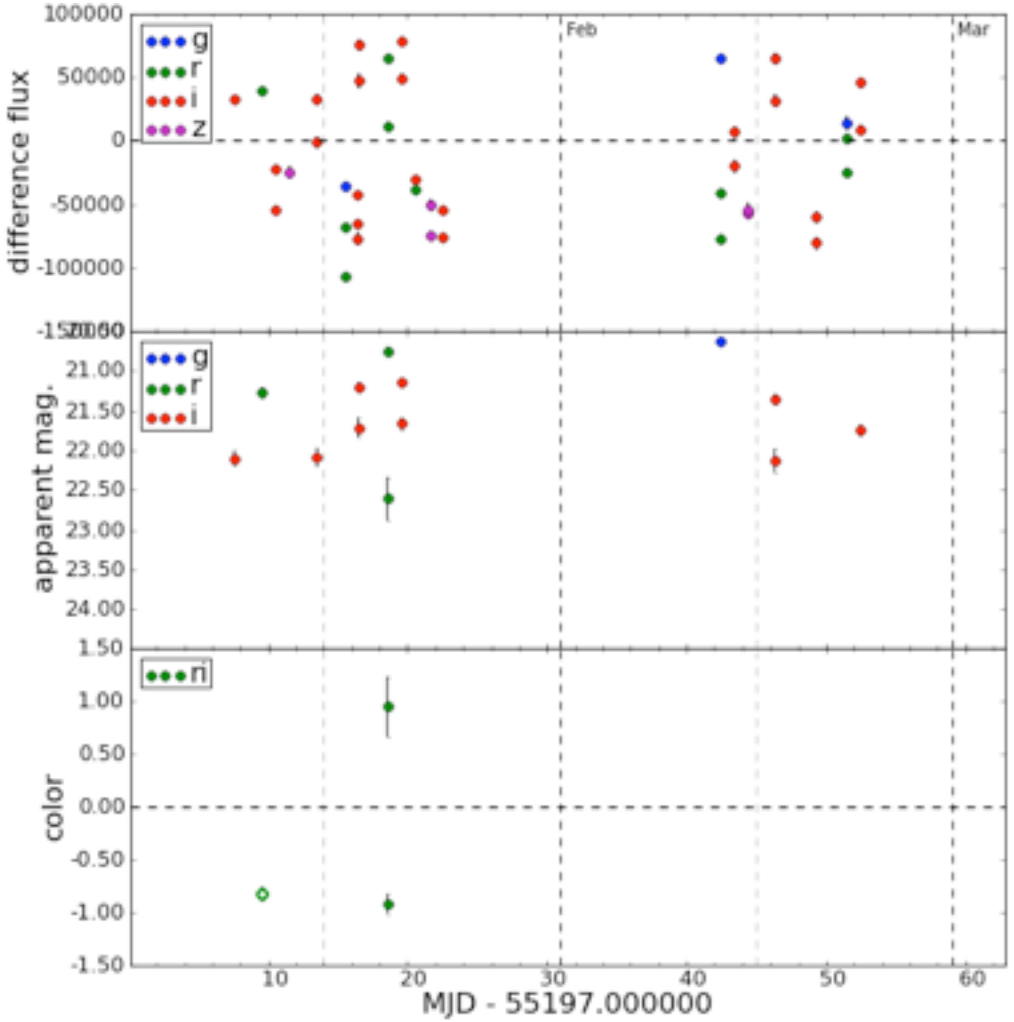
Diffim Artifact



Variable Objects

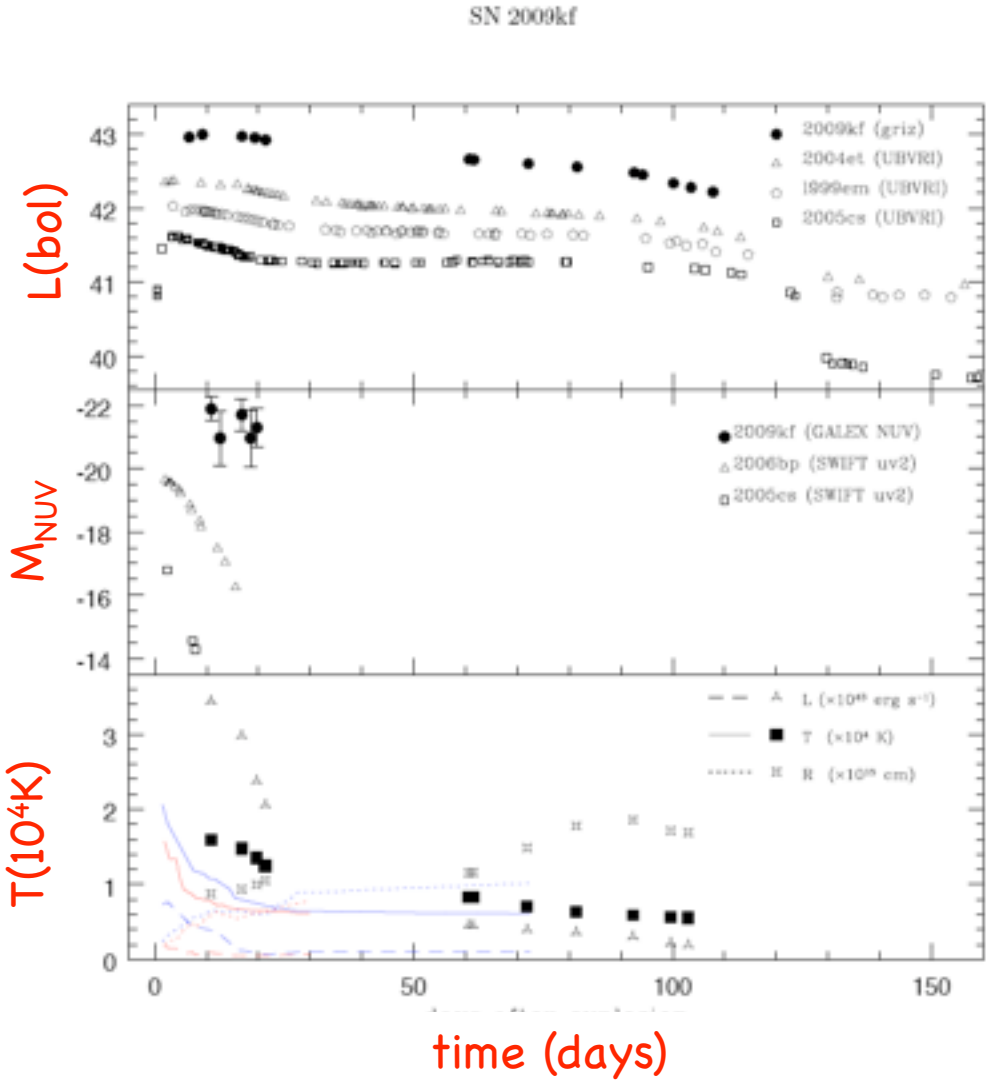
- RR Lyrae
- LBVs
- AGN
- QSO





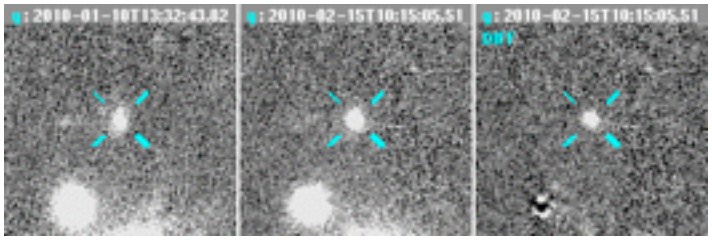
PS1 + GALEX Time Domain Survey

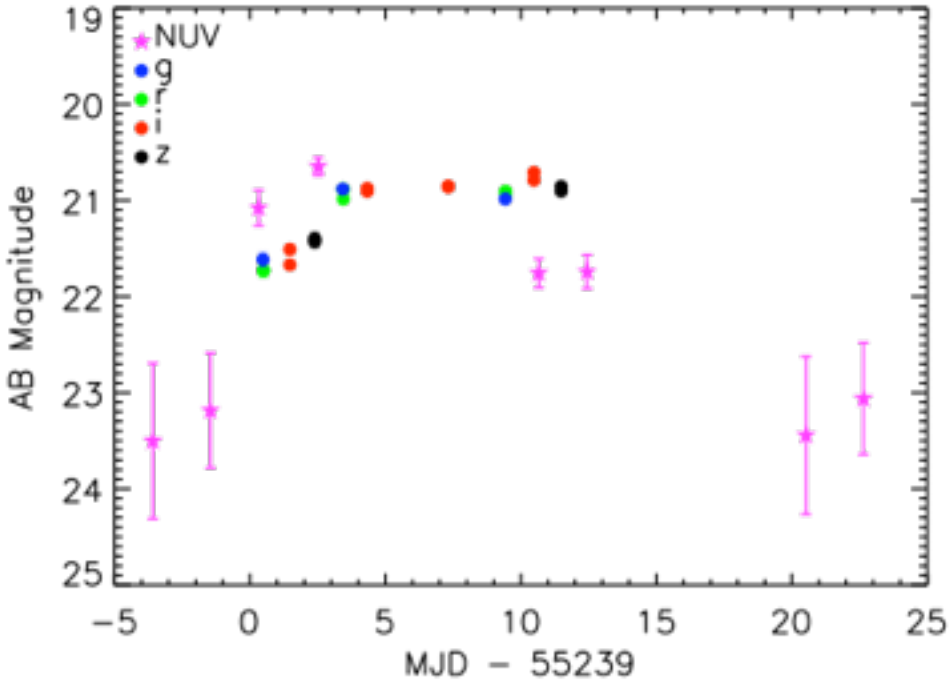
- Lead by Suvi Gezari
- Initial results: UV-luminous Type II-P SN at z=0.18 (Boticella et al., arXiv:1001.5427)
- Potentially detectable (with no extinction) by PS1 at z=2.5!

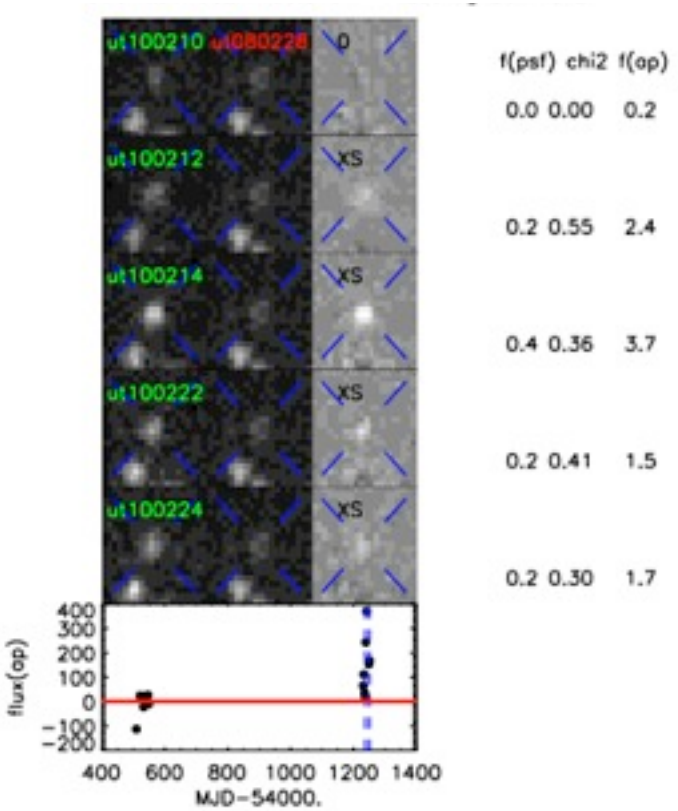


PS1 + GALEX Time Domain Survey

- Initial results: Early UV light curve of Type IIP SN at z=0.086 (Gezari et al., in prep)

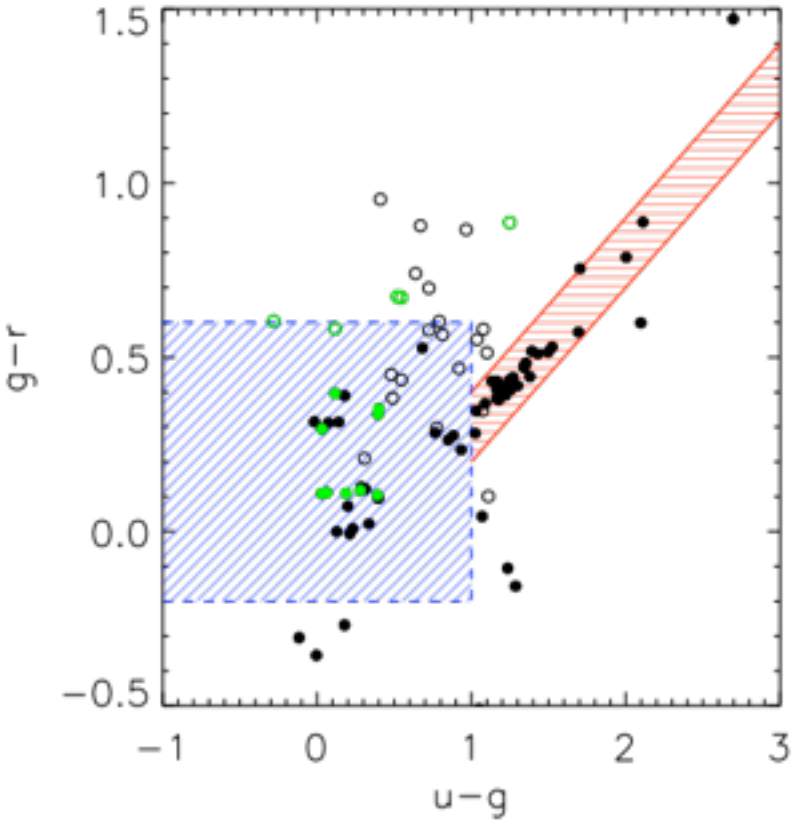






PS1 + GALEX Time Domain Survey

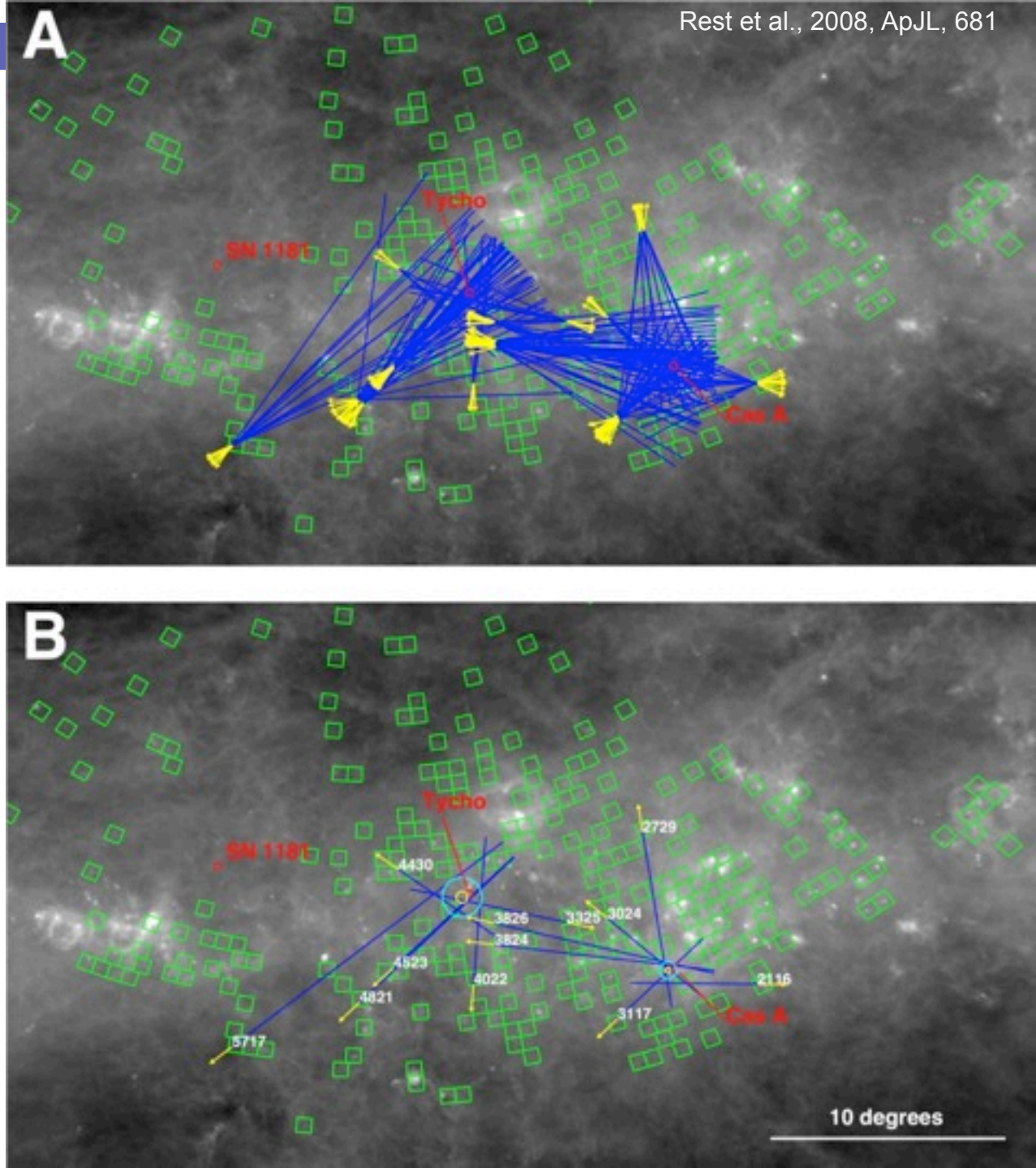
- During PS1 “Demo Month” in February, GALEX TDS monitored the MD04 field every 2 days.
- Detected:
  - 32 variable stars
  - 29 QSOs
  - 23 AGNs
  - 1 SN
- → Goal: tidal disruption events



3pi survey

- 30 sec, 2 visits per night (TTI pair)
- grizy in 15 days, then another epoch one month later
- Challenges:
  - Need follow-up!
  - Cadence: How can we find the interesting objects?
  - Next year: better templates
- Incredible amount of transients!

Light Echoes



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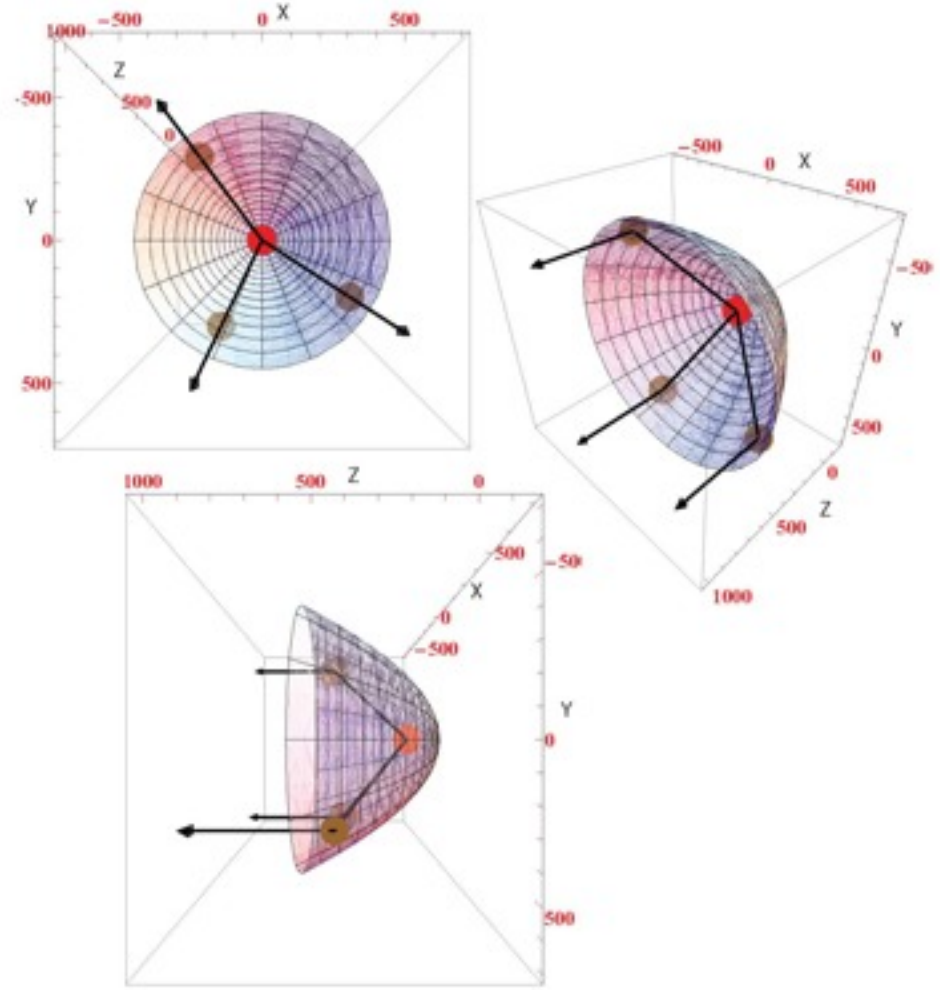
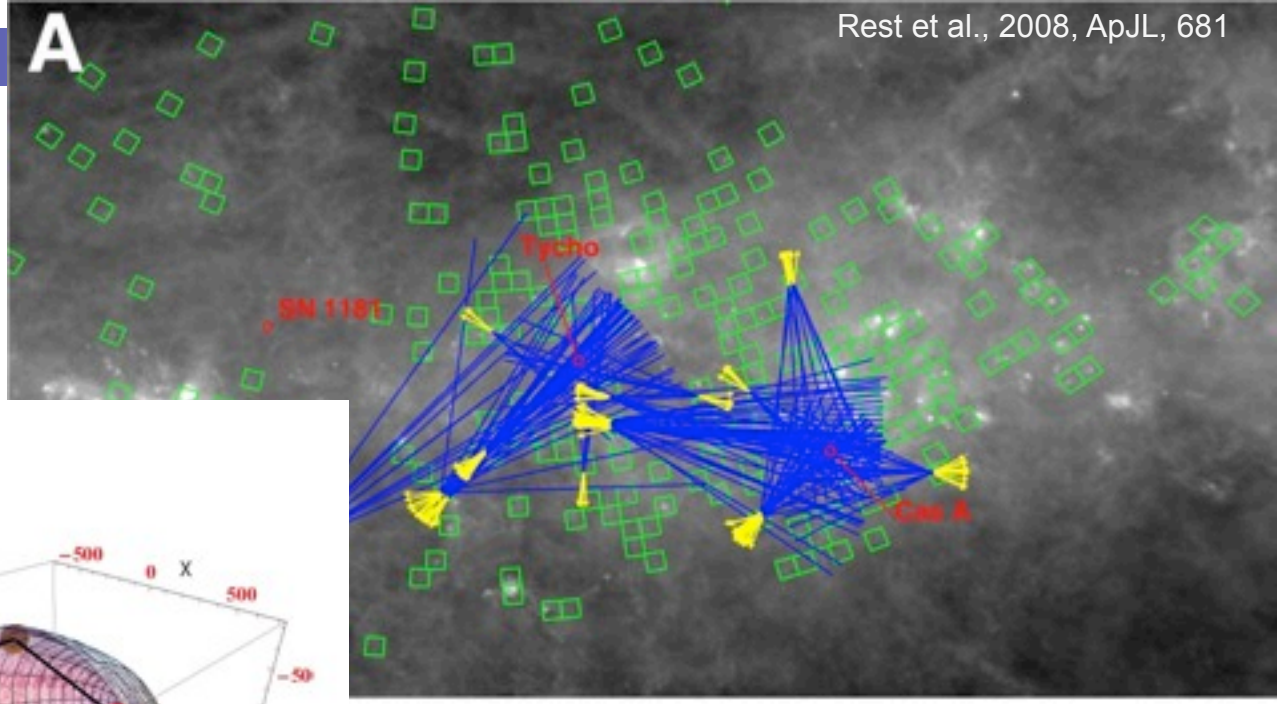
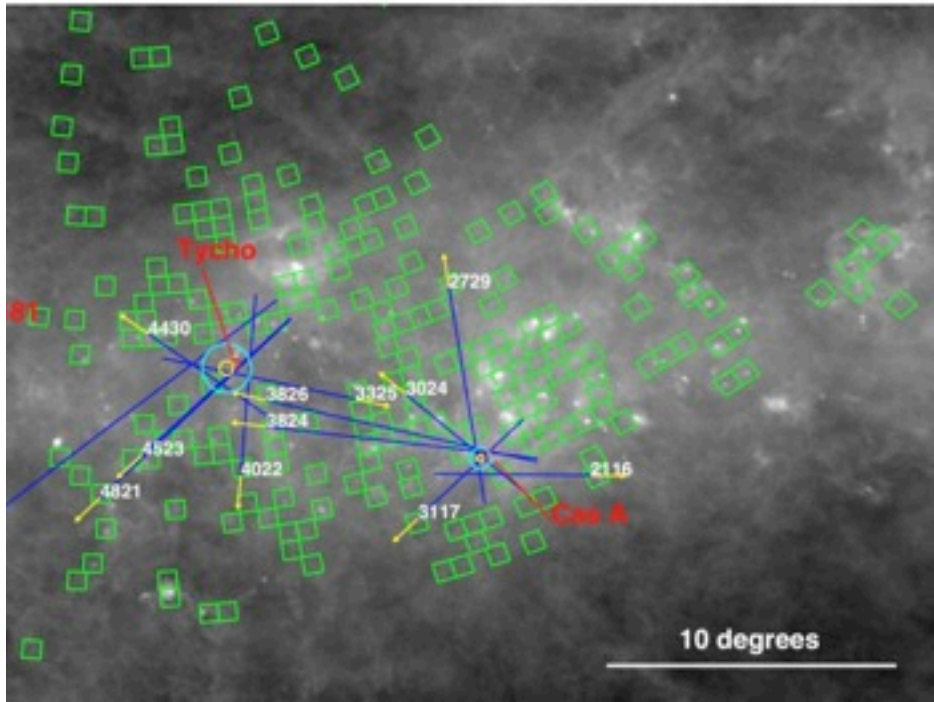
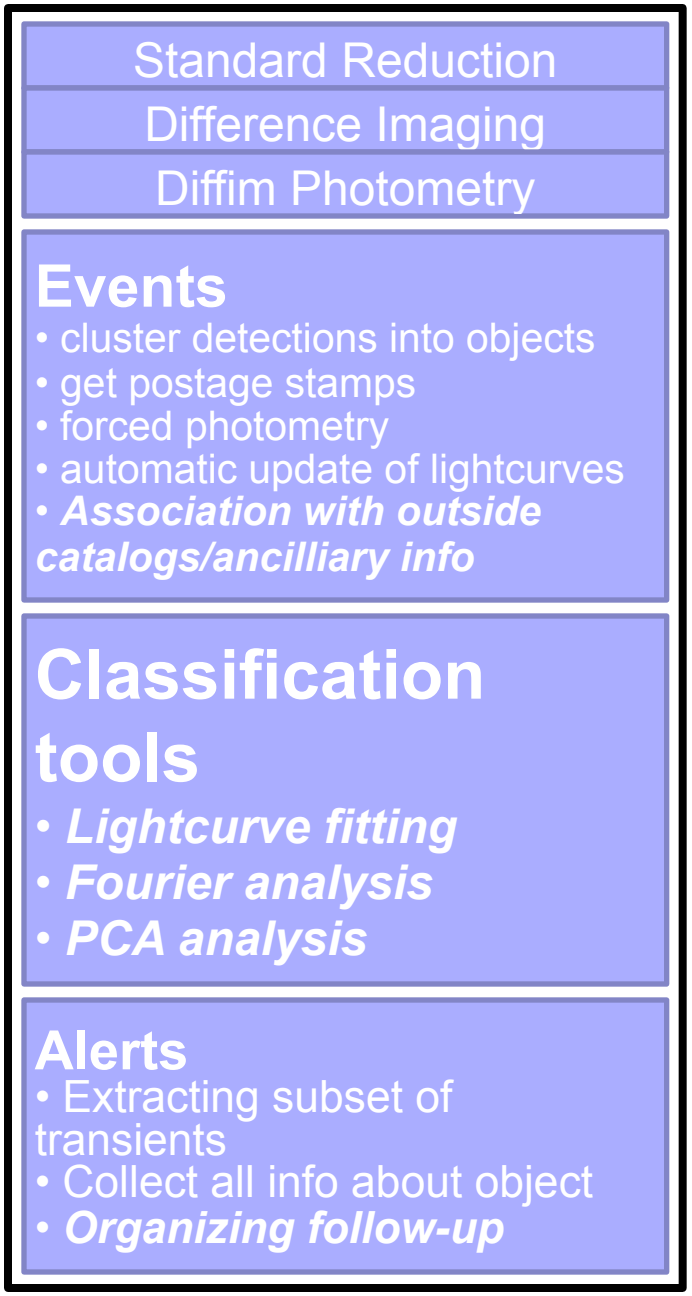






Next Steps

- Image reduction and transient identification works
- Huge amount of data!
- Full classification not yet ready
- Archive/Public Release
- 3pi biggest challenge
- Moving objects on track
- M31, STS just starting…



Summary

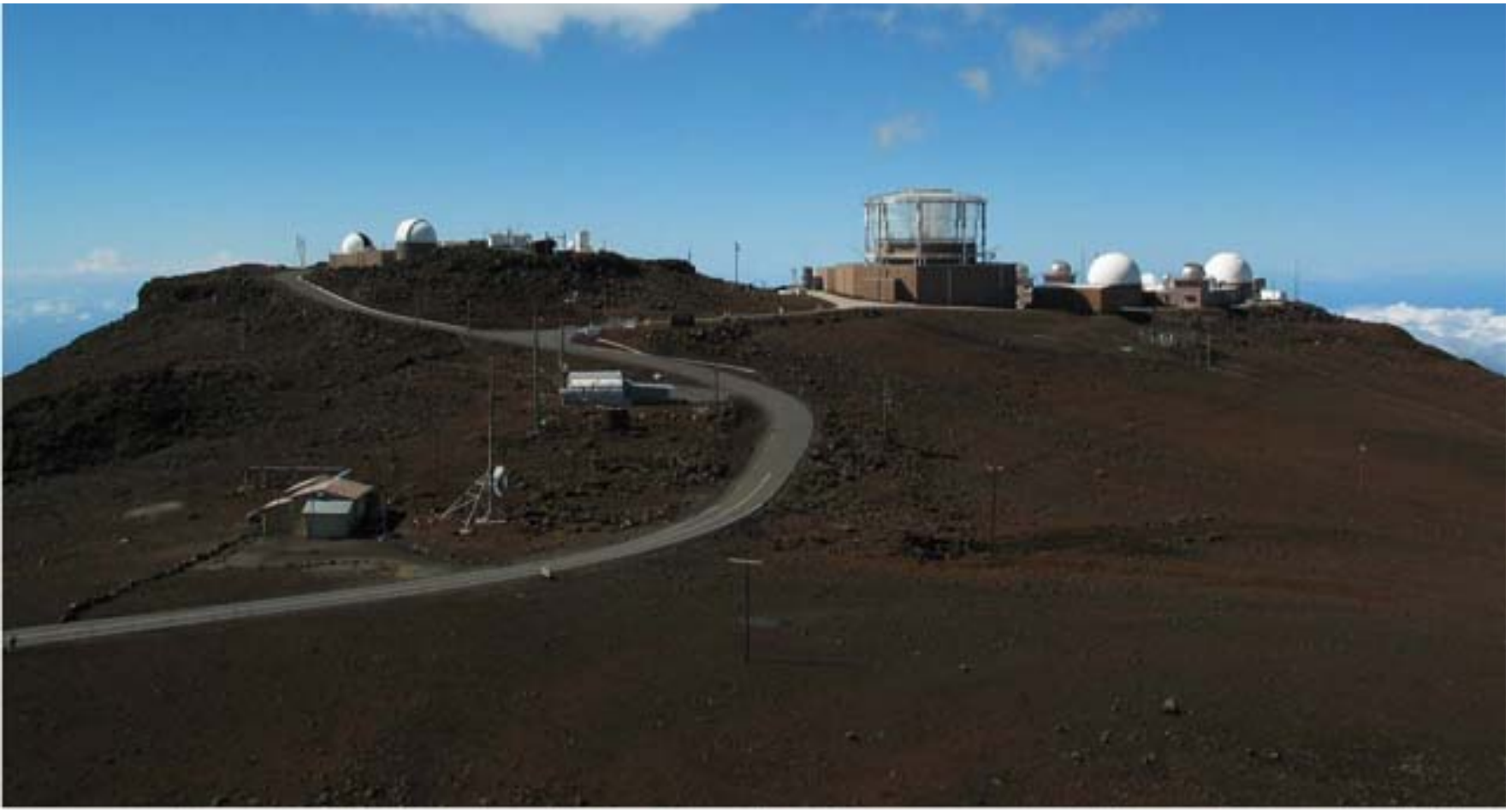
- Lots of data in last months!
  - PS1 inching towards survey mode
- Lots of hard work by telescope/camera/pipeline teams
- Camera, data analysis push current technology
- MDF Transients: turned the corner in depth, stability, latency, false-positives
  - SNe: driver
  - End2end system
  - 100s of transients in just a couple of month
  - Good lightcurves
  - First papers
- Tip of the iceberg! Incredible data set.

- Event Identification Break-out session:
  - Saturday, 9am!
  - Please come and bring ideas!

Moving objects

- MOPS software ready to go!
- Currently finishing up processing

Haleakala Observatory, Maui

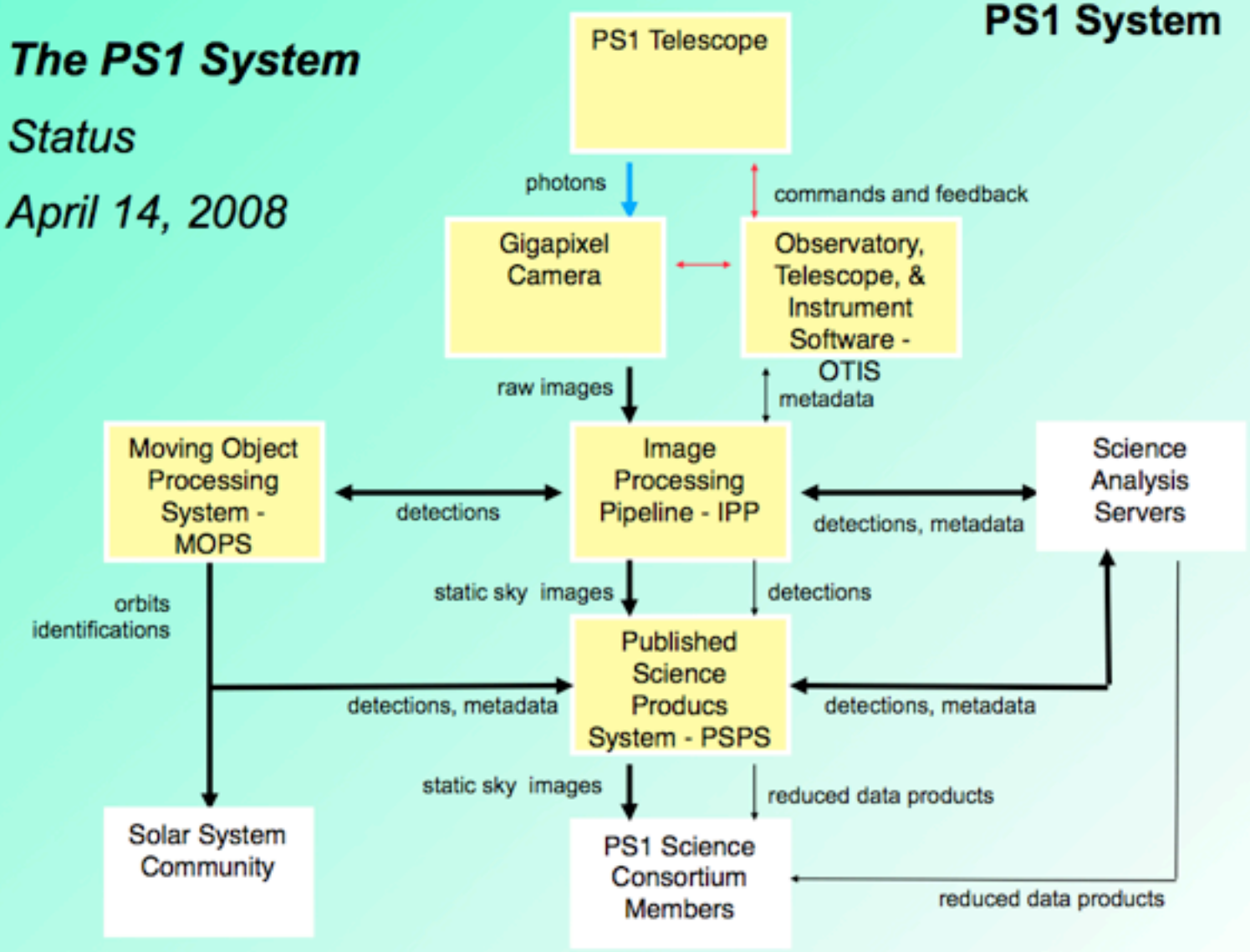


Haleakala Observatory, Maui

General Survey Cadences

Survey		Visit/night	Intra-night	Inter-night	Visit/mth	Visit/yr	Visit/3 yr
3PI		2	TTI	4,5 d	2x3-4 band	4x5 band	12x5 band
MDS		1	8	1	30	8x30	24x30
Sweet Spot		2	TTI	4,5 d	3x1 band	3x1 band	18x1 band
STS		30	4 min	4,5 d	5x30	150	
M31		2	0-5 hr	1	30-60	45x5	675
Calib		2	1-2xTTI	var	var	180/band	540/band

The PS1 System

Status

April 14, 2008