Palomar-Quest and other modern surveys
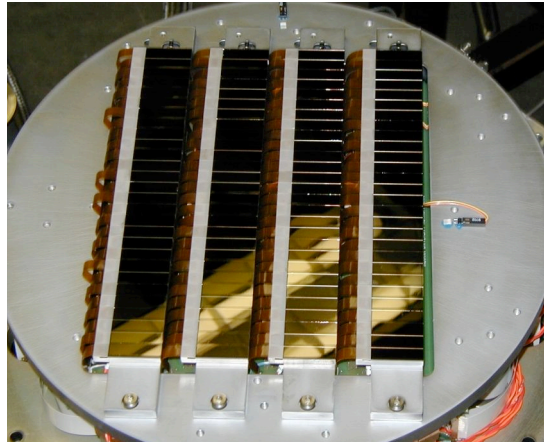
Some slides borrowed from G. Djorgovsky

Arne Henden

Director, AAVSO

arne@aavso.org

Palomar-Quest Digital Synoptic Sky Survey

- Uses Palomar 48-inch f/2.5 Samuel Oschin Schmidt Telescope and Quest2 112-CCD, 161 Mpix camera; fully automated operation
- A Caltech-Yale collaboration (Co-PIs: C. Baltay and S.G. Djorgovski); working with several other groups worldwide (LBL, NCSA, EPFL, INAOE)
- Many passes with up to 4 filters (*UBRI/griz*), time baselines from minutes to years
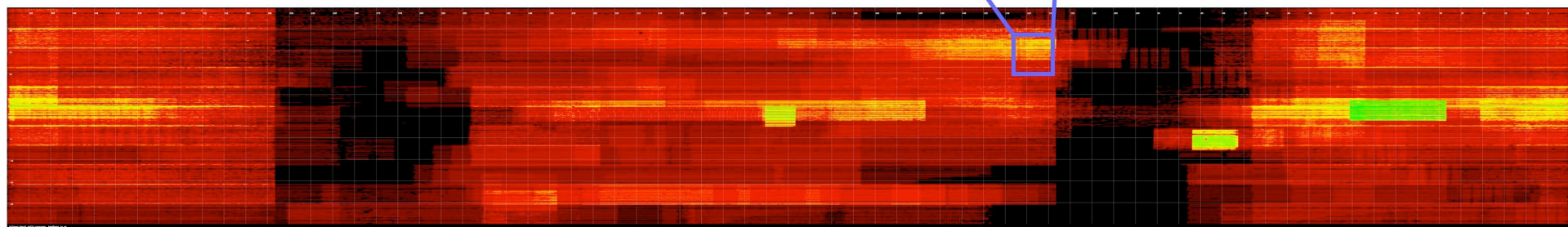- Data rate ~ 70 GB/night; > 25 TB of drift-scan data in hand, > 30 TB of point-and-stare data

PQ Sky Coverage, April 2007

RA: 360° to 0°
Dec: –25° to +25°

Johnson R
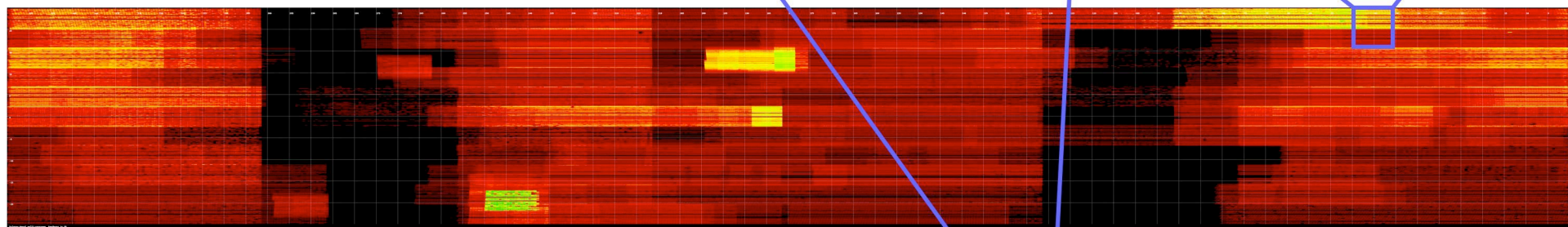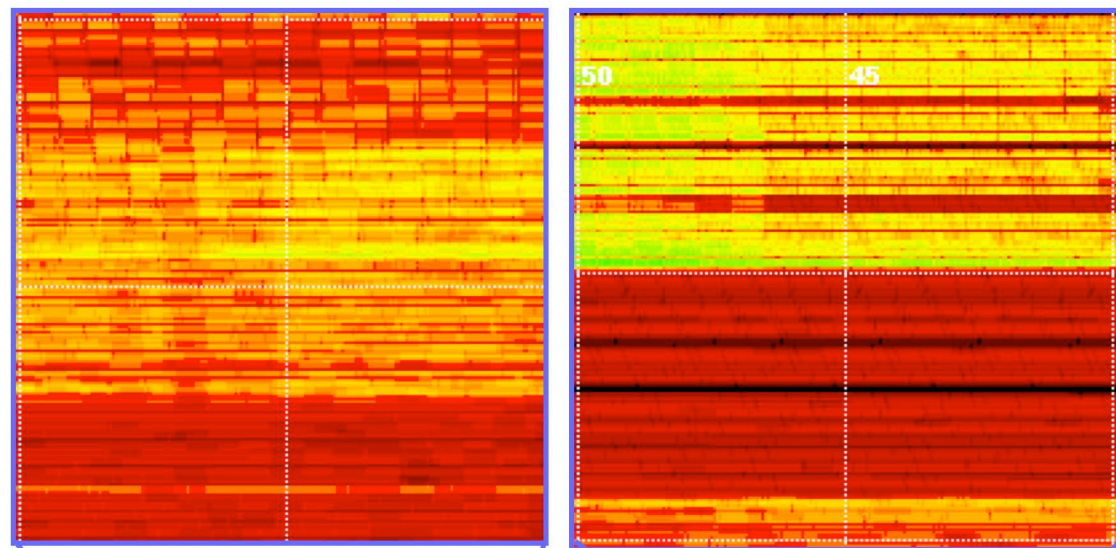
Gunn r

PQ Survey Science
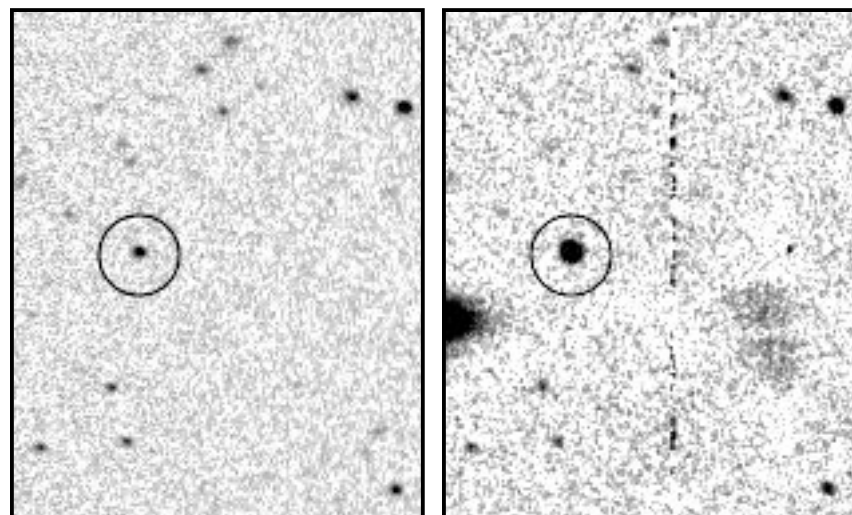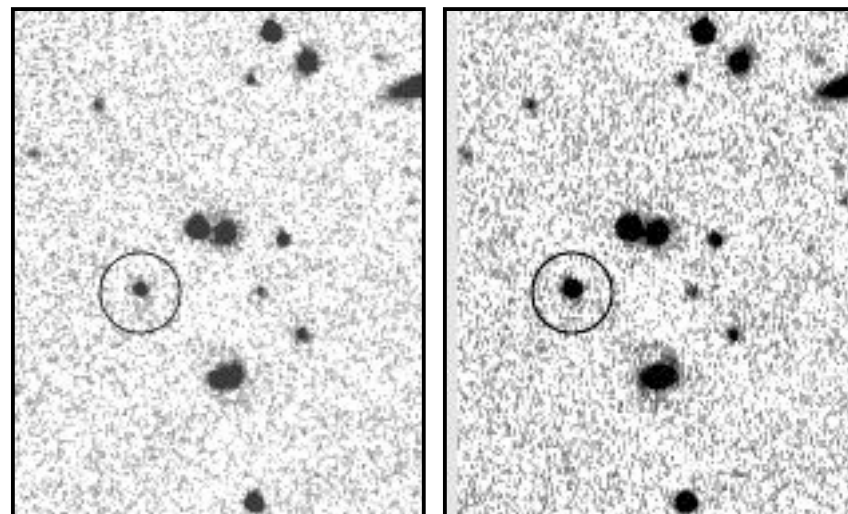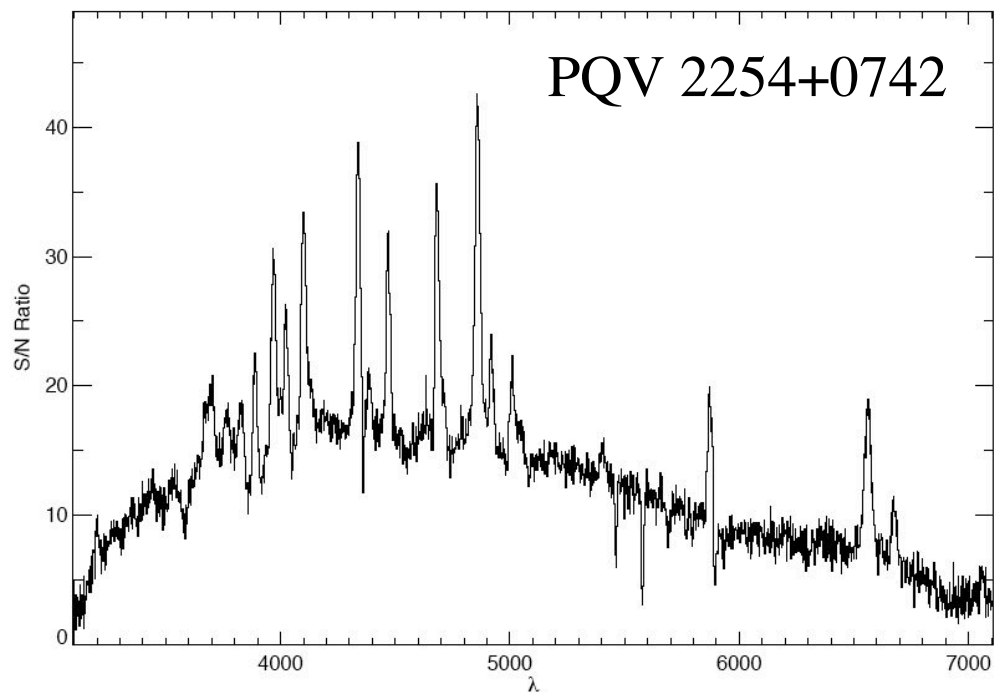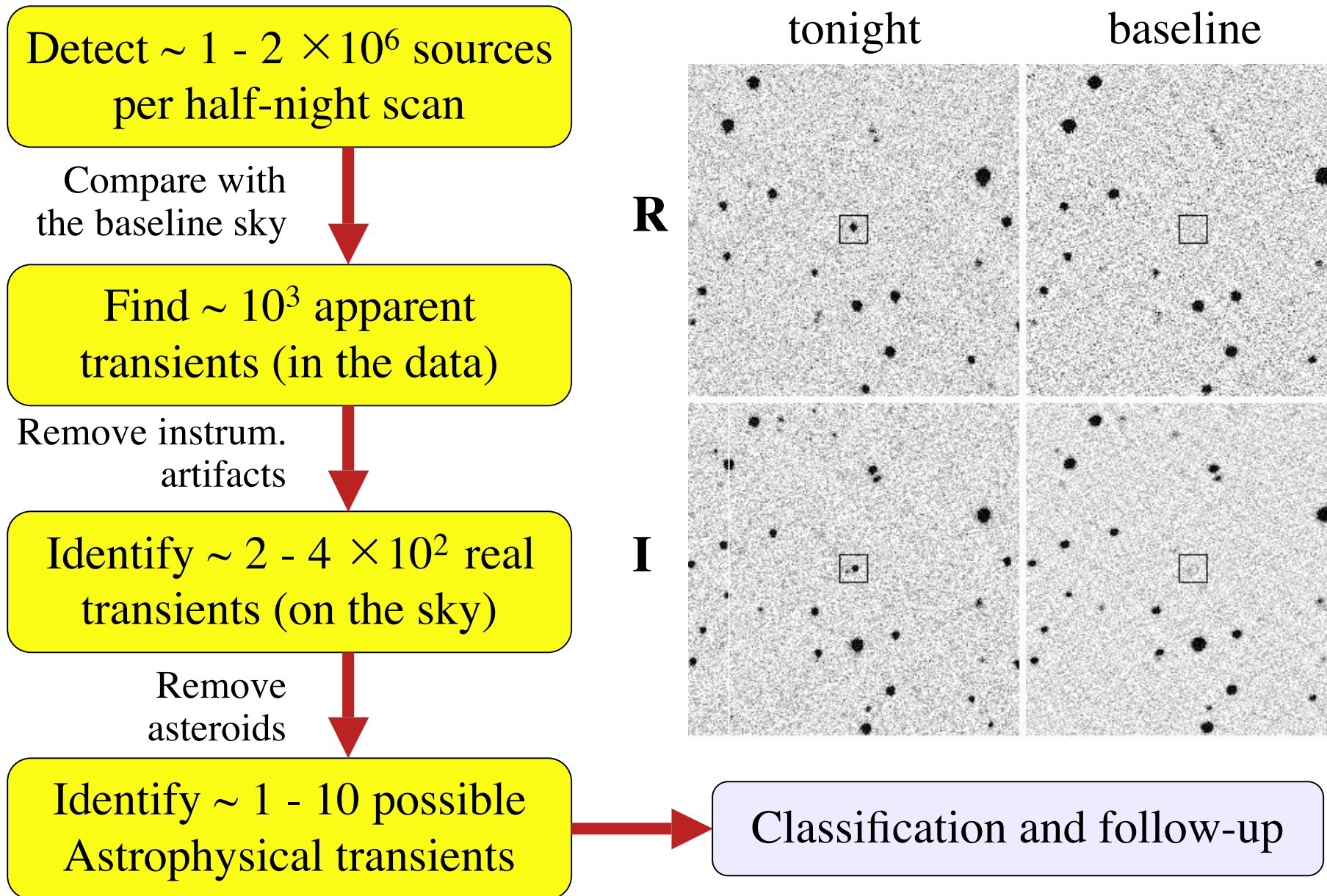
Exploration of the time domain is the key science driver

- A systematic approach to mapping and discovery in a relatively poorly explored portion of the observable parameter space

- Our strength is the synoptic nature of the survey, coupled with a wide area coverage and a moderate depth ($\sim 21^m$)

- Specific projects include:

  ★ Supernovae for cosmology (mainly with LBNL NSNF)

  ☆ Also peculiar SNe, probes of massive star explosions, etc.

  ★ Blazars and highly variable AGN

  ★ As yet unknown transients and strong variables

- Other scientific goals and projects include:

  ★ A search for high-redshift quasars

  ★ A search for gravitational lenses

  ★ Many other projects are viable…
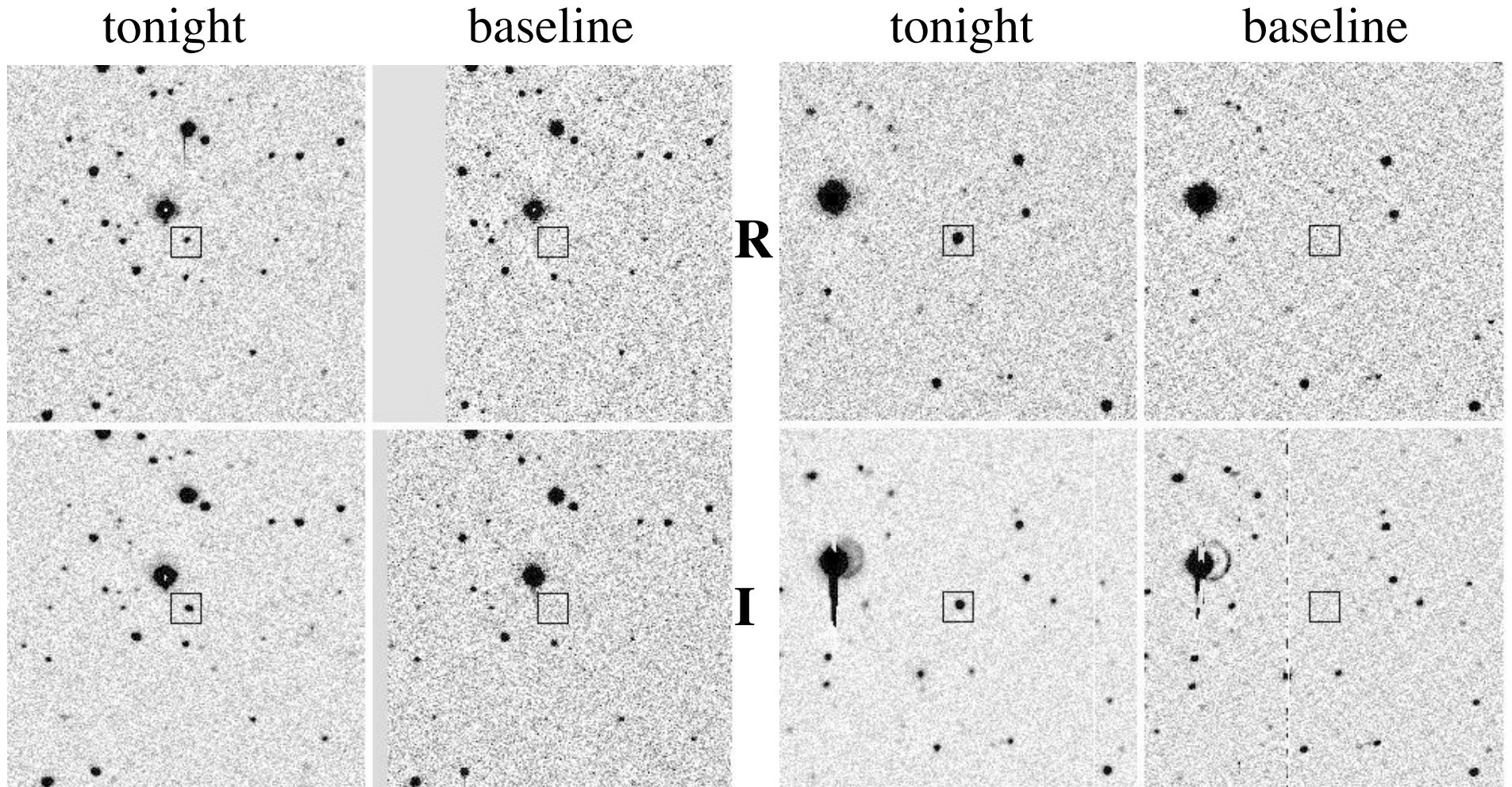
PQ Variability-Selected CVs:

PQV 2254+0742

PQV 2325-0140
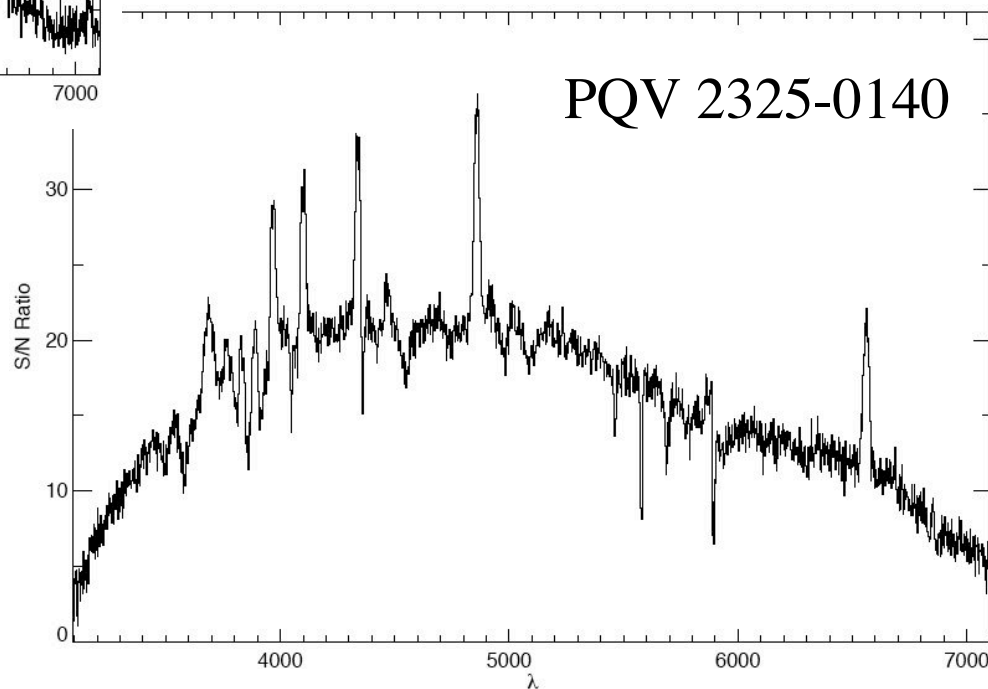
The Palomar-Quest Event Factory

tonight   baseline

Detect $\sim$ 1 - 2 $\times 10^6$ sources per half-night scan

Compare with the baseline sky

Find $\sim 10^3$ apparent transients (in the data)

Remove instrum. artifacts

Identify $\sim$ 2 - 4 $\times 10^2$ real transients (on the sky)

Remove asteroids

Identify $\sim$ 1 - 10 possible Astrophysical transients

R

I

Classification and follow-up

Real-Time Discovery of Transients

Examples of optical transients discovered in the real time in Sept.'06, using a prototype real-time pipeline

Asteroids: The Main Contaminant

- The vast majority of "transient" detections are *mostly asteroids*
- We find ~ **1 - 3 asteroids / *deg²*** down to ~ 20 - 21 mag, at moderate ecliptic latitudes
  - ✗ Only ~ 50% are previously known
  - ✗ **They outnumber the astrophysical transients by   a factor of ~ 10² - 10³ !**
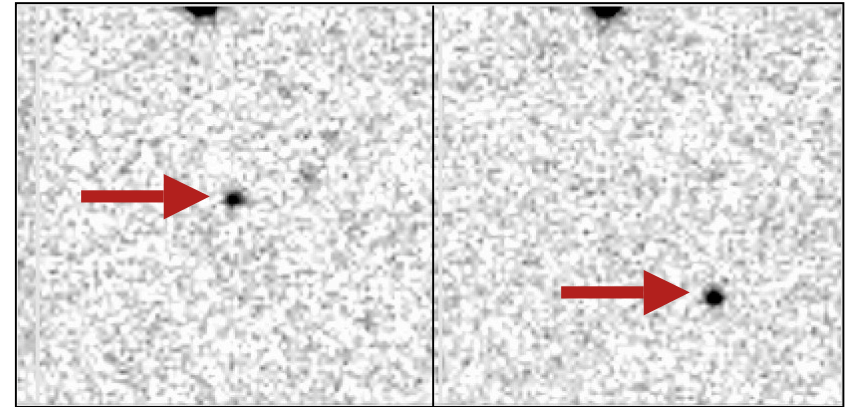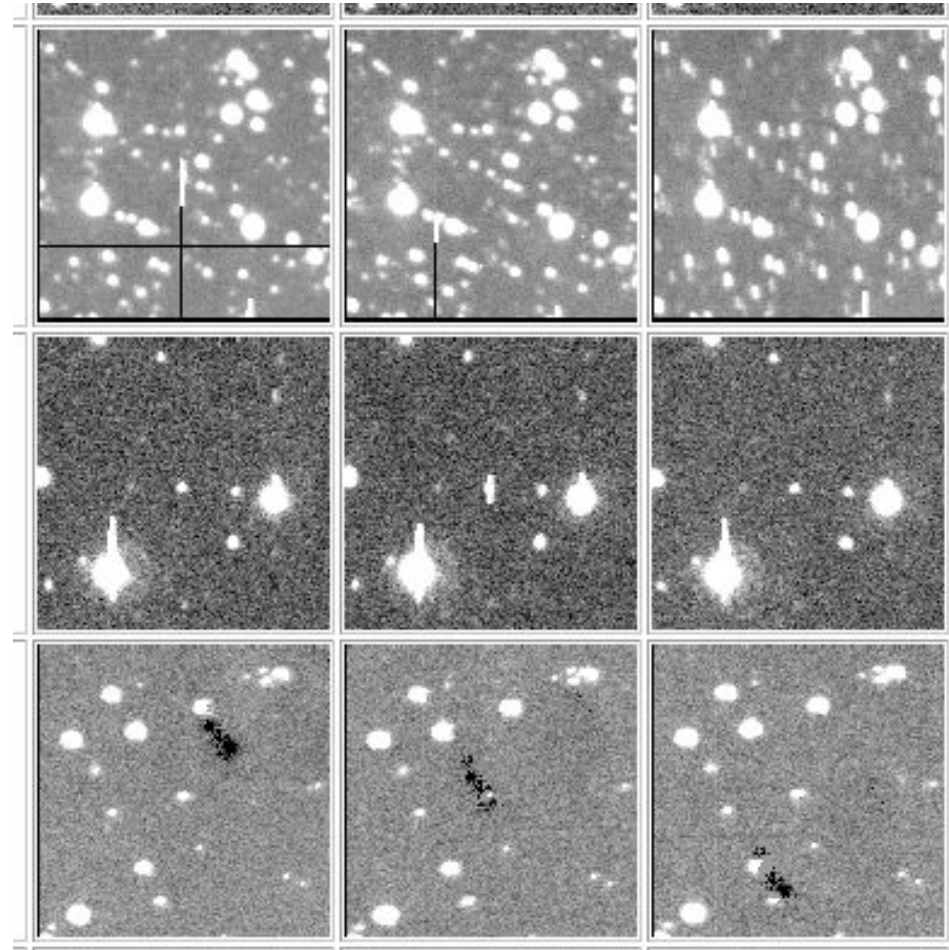

Sometimes they overlap stars:
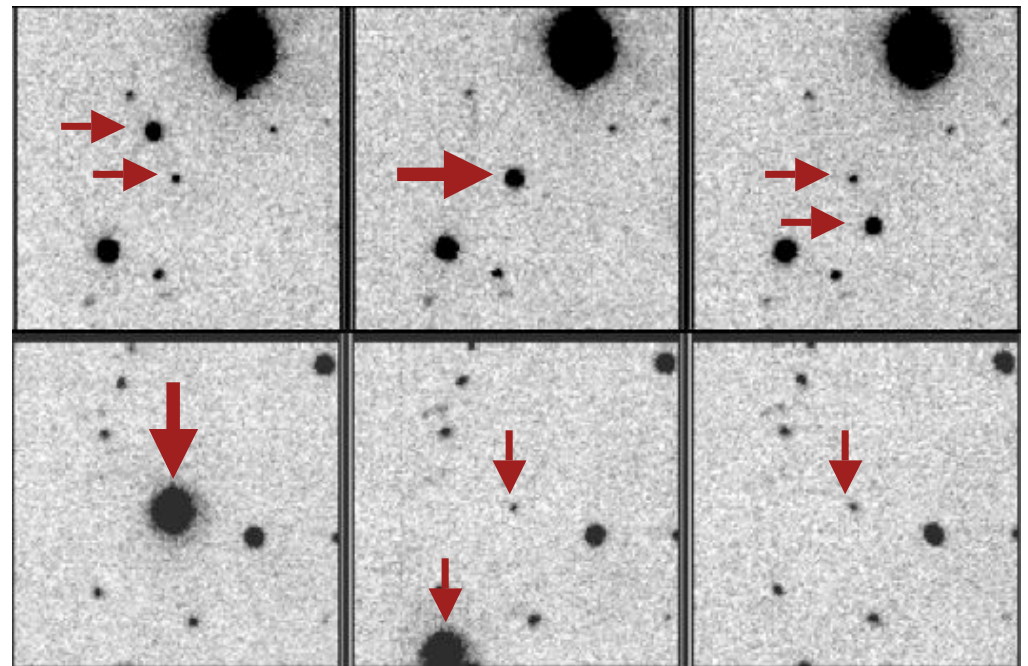
Mitigation:
- Optimized cadence: scan and rescan ~ 1 - 4 hours apart
- Crossmatch to asteroid DB's (HORIZONS, IMCCE)
- Improved proper motions and colors

Example artifacts

o   CCD defects

o   Reflections

o   Grazing CRs

o   Partially uncorrected bad
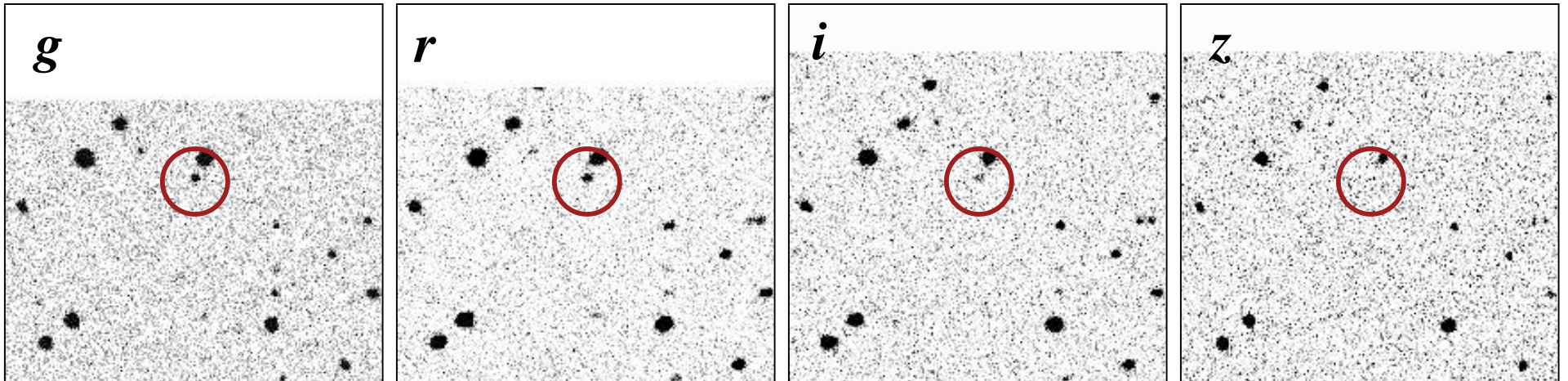   columns

o   unknowns

An Unidentified PQ Real-Time Event
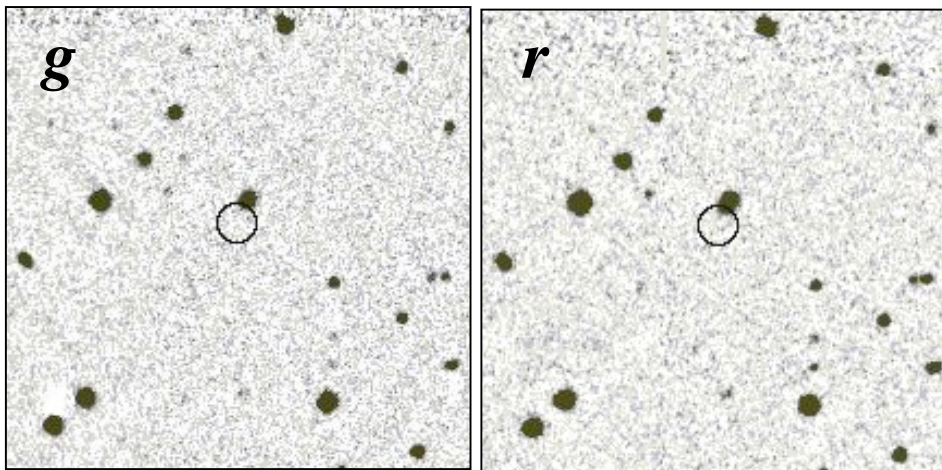
PQOT 070519:143933+054636

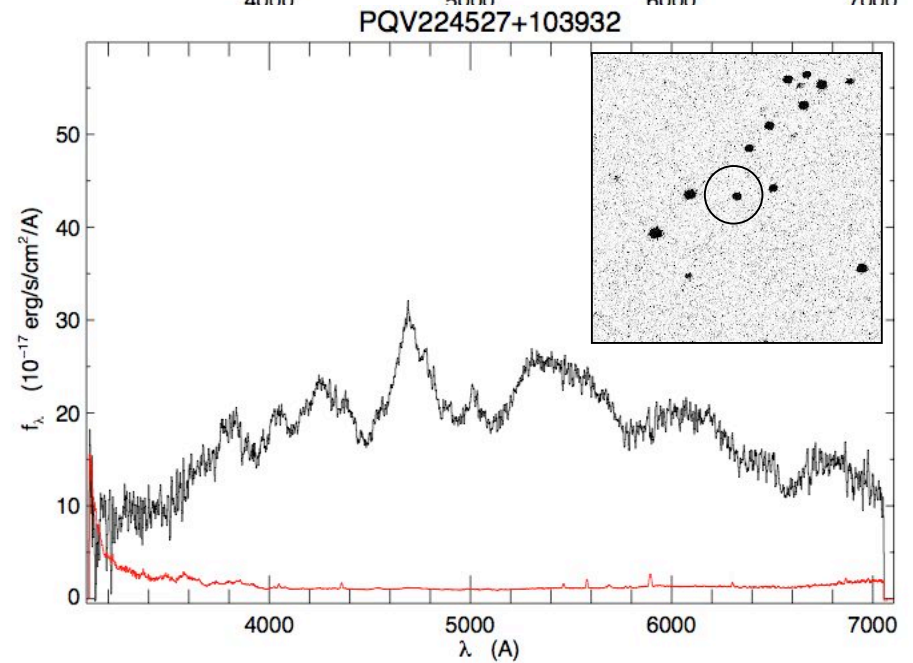*A. Drake et al., ATel 1083*

Discovery images:

Baseline comparison:

- Initially very blue, but getting redder rapidly
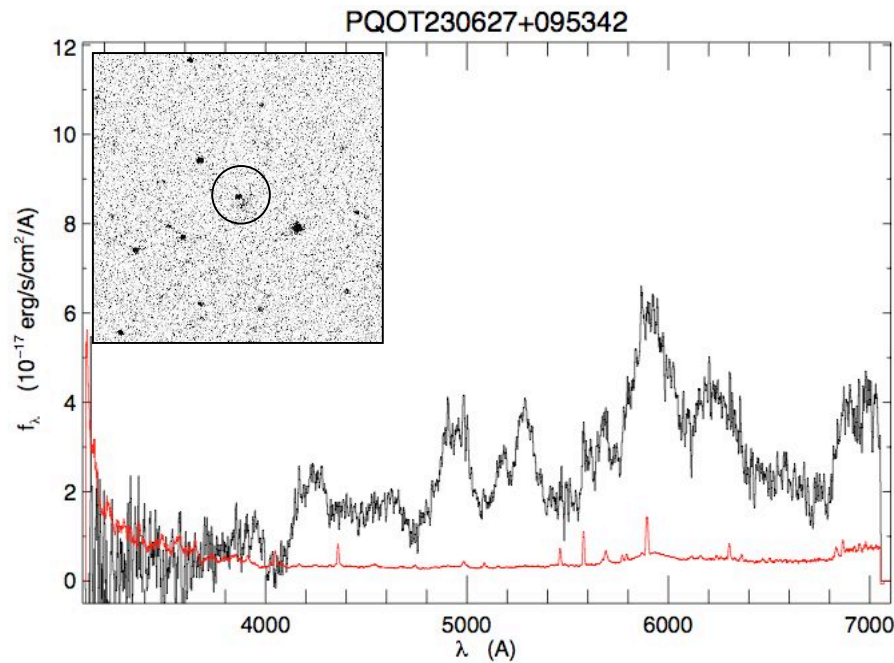- Slow fading, 0.3 - 0.4 mag/day, reached plateau
- Possible SN ?
- Followed up by *SWIFT* (*ATel 1088*) - no X-ray detection

PQ Real-Time SN Discoveries

P200 spectroscopy within an hour of initial detection: Young SNe Ia
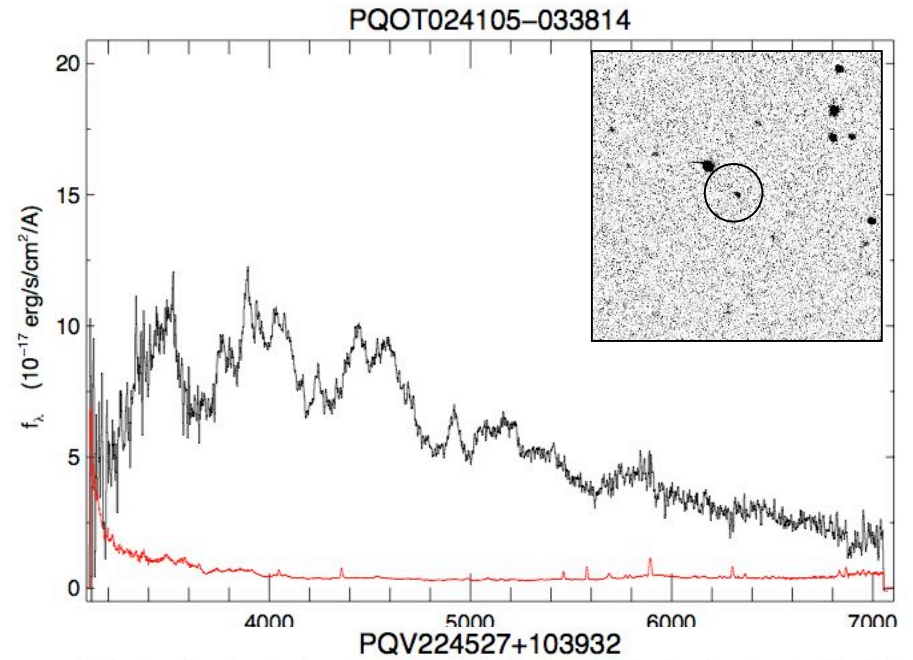
PQT 080119:091534+081356 - A Dwarf Nova

Baseline

Discovery

$g = 17.6$ mag, $r = 17.7$ mag

SDSS

SDSS counterpart: $g = 22.8$ mag, $r = 23.0$ mag

P200 spectrum (G. Herczeg)
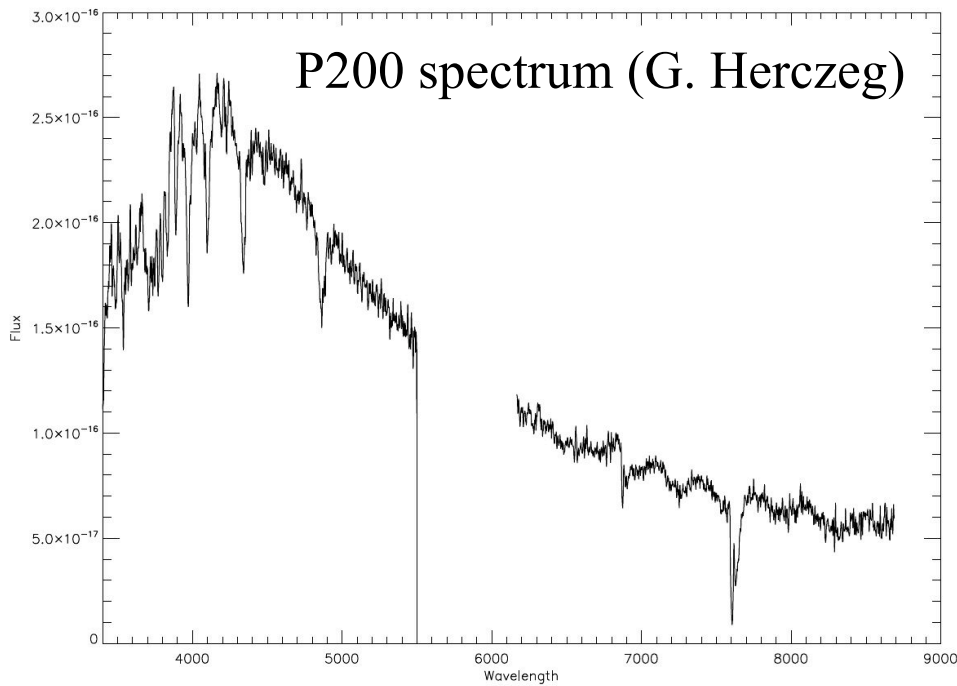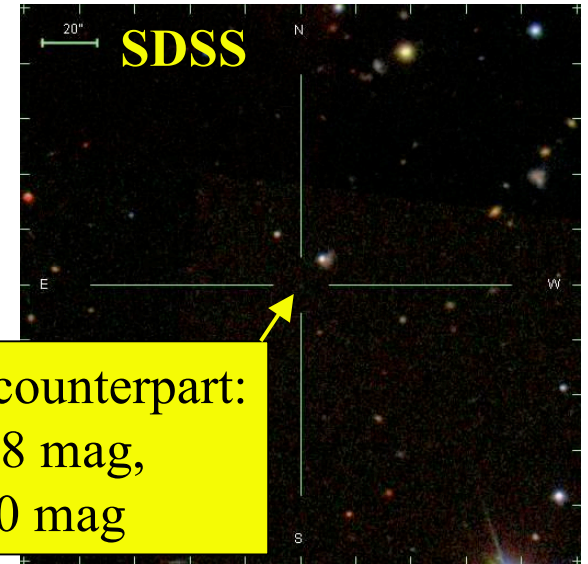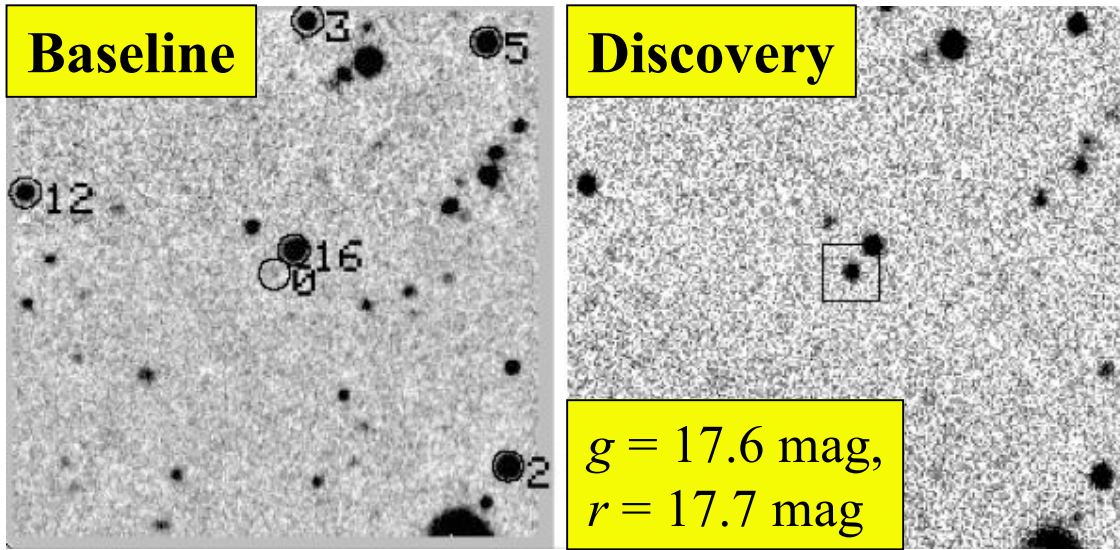
Donalek et al. ATel 1362, Glikman et al. ATel 1367

P60 follow-up (Mahabal et al.)

Jan. 20   Jan. 31
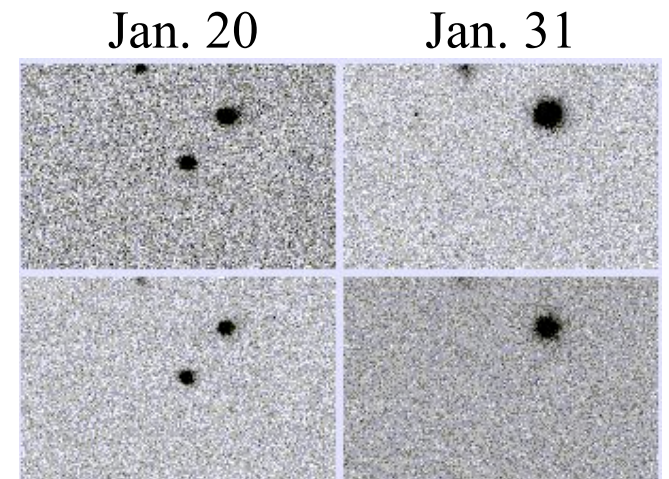
Introducing the Catalina Sky Survey

CSS is a search for near-Earth, potentially hazardous asteroids, led by S. Larson, E. Beshore, et al. (UAz LPL). The survey uses the 24-inch Schmidt on Mt. Bigellow, and a single, unfiltered 4k×4k CCD (and also telescopes at Mt. Lemmon and Siding Spring). Coverage up to ~ 800 deg²/night
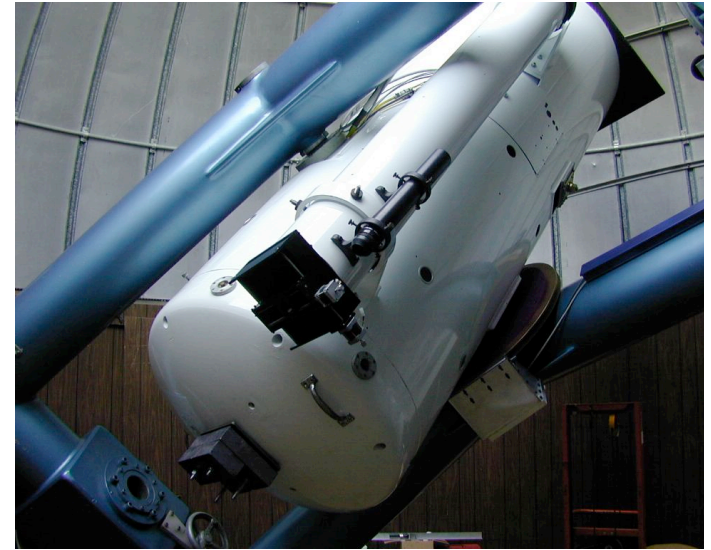
We are processing their data stream to look for astrophysical transients

Catalina Survey Fast Transient (a flare star), 02 Nov 2007 UT:
4 individual exposures, separated by 10 min   Baseline coadd:

The VOEventNet Project

PI: R. Williams

- A telescope sensor network with a feedback
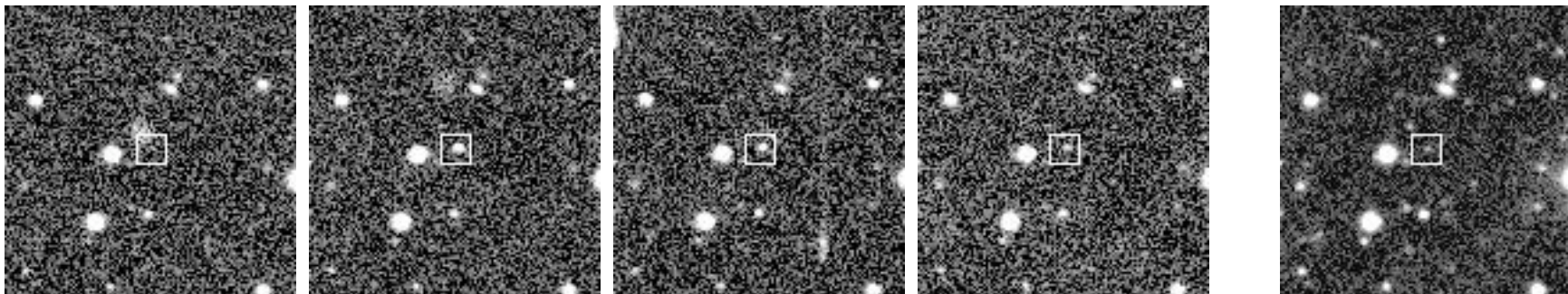- Scientific measurements spawning other measurements and data analysis in the real time
- Please see **http://voeventnet.org**
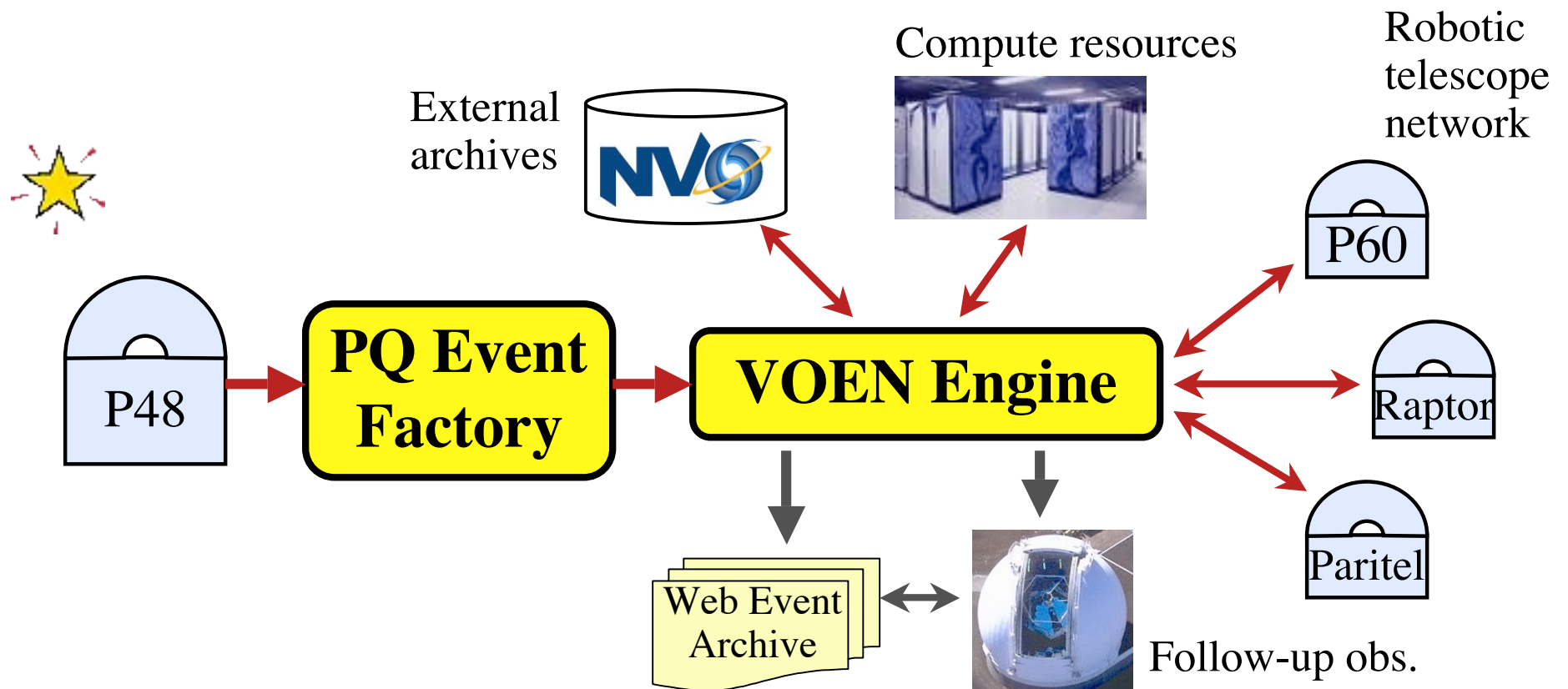
Automatically Generated Image Cutouts and Coadds, Webpages for Each Event

asteroid junk index

| New | Gunn coadd | Johnson coadd |

ID = 7101001343110540076
newast = 0.000000
av_motn = 0.017245
av_deltime = 8.081280
av_uncertx = 0.050421
av_uncerty = 0.049168
av_inclin = -134.201264
Time = 2454383.917890
…

Human-readable relevant event data ➜

Real-Time Event Publishing & Distribution With VOEventNet

R. Williams, A. Drake, M. Graham, et al. **http://voeventnet.caltech.edu**

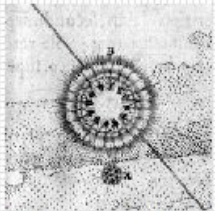voeventnet.caltech.edu

- Home
- Project Description
- Personnel
- GCN VOEvents
- SDSS Supernovae
- ESSENCE Supernovae
- OGLE Microlensing
- PQ Transients
- Transients in the Griffith Park "Big Picture"
- IVOA VOEvent pages
- Search the Nexus
- Subscribe
- Wiki

VOEventNet: Real-Time Astronomy with a Rapid-Response Telescope Grid

VOEvents from the Palomar Quest Transient Search

- This page is generated automatically as incoming PQ events are received and was last updated at
- Additional information about PQ Transients that are available **here** .
- Information on subscribing to receive PQ Transients and other VOEvents in **real time** is here:
- A near real time feed is available here: **XML** **RSS**
- This table contains information about Transients obtained from PQ (Table Help).

Palomar Quest Events					
ID	Alert Time (UT)	Event Time (UT)	RA (deg)	Dec (deg)	Error
7052101243010670393	2007-05-21T08:43:11	2007-05-21T07:06:38	234.5119299	15.9229255	2.16
7052101243030690374	2007-05-21T08:43:09	2007-05-21T07:11:12	235.7001958	15.5061457	2.16
7052101233260390193	2007-05-21T08:43:07	2007-05-21T05:56:58	217.9791300	11.6790801	2.16
7052101243170240345	2007-05-21T08:43:06	2007-05-21T05:21:33	208.2908345	13.1145446	2.16
7052101243030690374	2007-05-21T07:26:34	2007-05-21T07:11:12	235.7001958	15.5061457	2.16
7052101243010670393	2007-05-21T07:16:57	2007-05-21T07:06:38	234.5119299	15.9229255	2.16
7052101243090550350	2007-05-21T06:47:02	2007-05-21T06:36:37	226.9676221	14.4591642	2.16
7052101233260390193	2007-05-21T06:36:53	2007-05-21T05:56:58	217.9791300	11.6790801	2.16

Automated Link to VO Resources

Useful for event classification and analysis

Towards Automated Event Classification

A **necessity** for large synoptic surveys

Event parameters:
$m_1(t), m_2(t),\ldots$
$\alpha, \delta, \mu, \ldots$
image shape…

Event Classification Engine

contextual information

Expert and ML generated priors

colors   lightcurves   etc.

$P(SN\ Ia) = \ldots$
$P(SN\ II) = \ldots$
$P(AGN) = \ldots$
$P(CV) = \ldots$
$P(dM) = \ldots$
….

Classification probabilities (evolving, iterated)
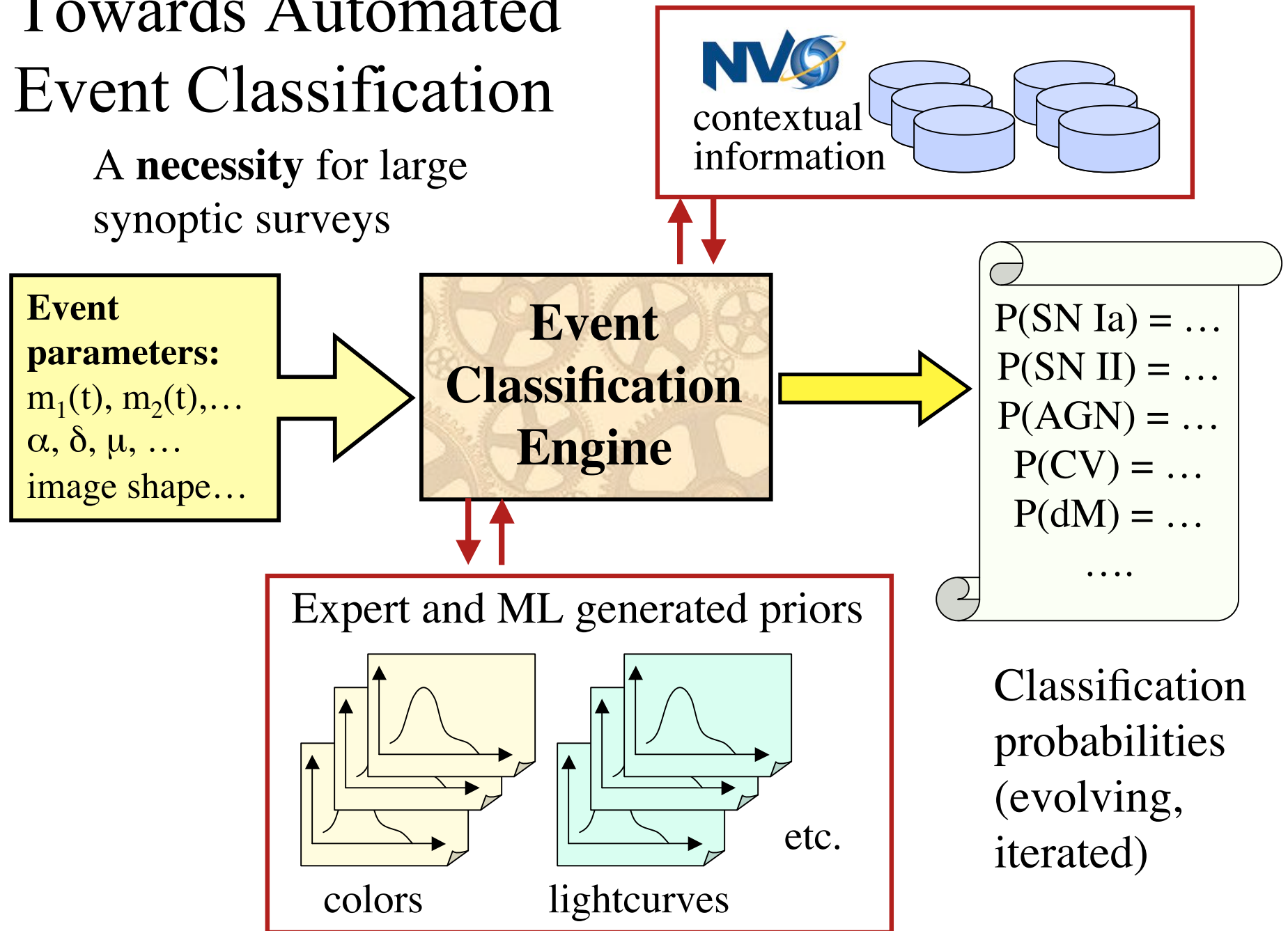
PQ Limitations

- 5-10 visits per field on average, insufficient for classification by light curve
- UBRI (no V!) or some mix griz, rizz, so not many visits in same filter
- Lots of cosmetic defects, chip gaps, poor scanning pattern
- Data taken in all weather conditions, so photometry poor (perhaps salvagible with differential photometry)
- Drift scan to +/- 25deg dec, so poor image quality at extremes
- Avoids galactic plane

AAVSO's role

- Beta test their database design (CAS)
- Light curves of known objects
- Cream skimming - high amplitude objects
- Help especially on CSS for developing image training set for incorrect transients

Image Datasets

- NEO telescopes, wide field but typically coarse pixels. Usually unfiltered or at most single wide-R filter. Often proprietary, but willing to work with VS. Avoid gal. plane

- 2-4m telescopes with prime focus camera. Good pixels, often multifilter, good seeing. Typically one square degree, so less sky coverage. Public.

- My secret weapon!

Near Earth Asteroid Tracking (NEAT)

- Uses the Oschin Schmidt for 1/2 time
- Used unfiltered, 4x4k CCD, stare mode thru 2003
- http://skyview.gsfc.nasa.gov/skymorph/
- 600,000 images available from 1998-2003
- Triplets per night, 20min/90min cadence, then revisit weeks/months later
- http://www.astro.caltech.edu/~dposs/NEAT
- for current transient candidates

Other NEO

- LONEOS. Lots of data over 10-year timespan. Raw, unprocessed. Archive on HD - have to ask PI for frames. elgb@lowell.edu

- Spacewatch. Used 1.8m telescope on KPNO.
  - http://fmo.lpl.arizona.edu/cgibin/mosaic_archive/point_history.cgi

INT WFC

- Wide-field camera survey
- 4 2kx4k CCDs over 1 degree field
- INT (2.5m)
- http://casu.ast.cam.ac.uk/casuadc/archives/ingarch/@@query.html
- Note: other telescope archives available there
- Includes INT Photometric Halpha Survey (IPHAS), though photometric data available at:
- http://casu.ast.cam.ac.uk/surveys-projects/iphas

More images

- http://www1.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/cadc/
- Searchable archive for HST, CFHT, Gemini, etc.
- CFHT best choice, has 12K plus megaprime wide-field imagers

Microlensing surveys

- MACHO, OGLE, PLANET, etc. all surveyed large areas of dense star fields. Some data public. Good for VS work as excellent time series.

- http://wwwmacho.anu.edu.au/Data/MachoData.html is main MACHO photometry portal; Images at

- http://www3.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/macho/index.html

Image use

- Excellent seeing/depth
- Multifilter
- Good to look for precursors, close companions, differential color
- All fits, calibrated, so can perform photometry; mosaics require IRAF
- Some sites require registration, but simple
- AAVSO will have Henden, SRO images available soon as another searchable archive (but smaller total field)

Upcoming Surveys

- PanSTARRS, LSST, SkyMapper
- All will process data in real-time, unlikely to retain image data
- Lots of data mining available to everyone!