

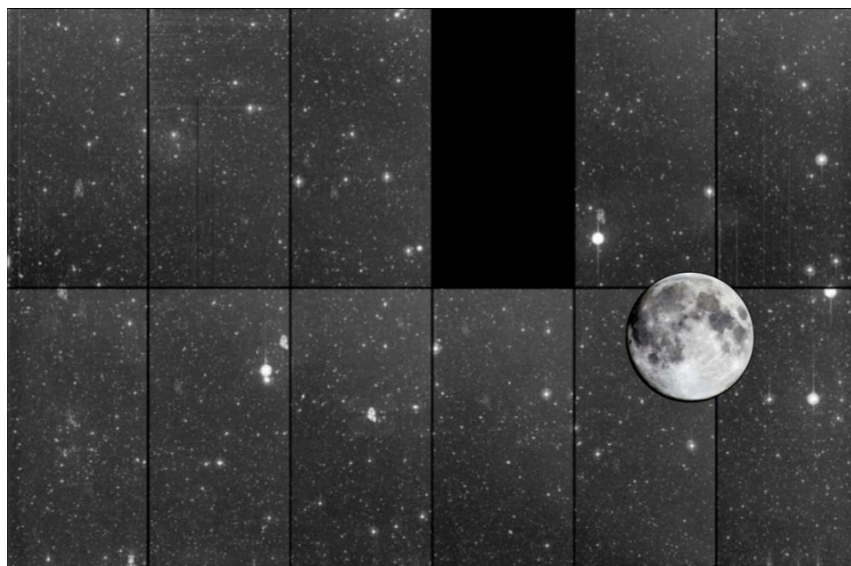
A new method to search for Supernova Progenitors in the PTF Archive

Frank Masci & the PTF Collaboration



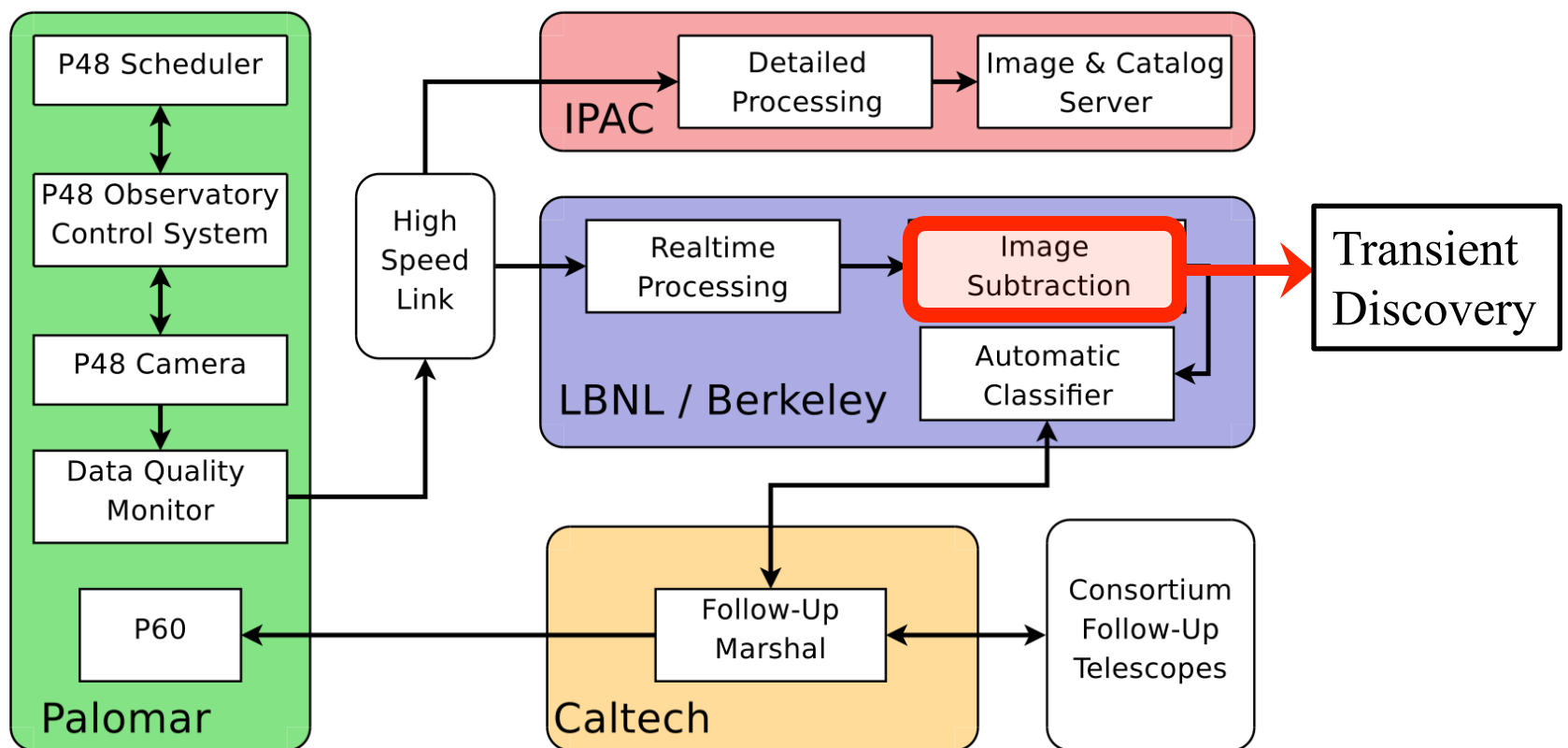
The Palomar Transient Factory (PTF)

- Fully automated wide-field time-domain survey in optical
- Carried out on 48" Schmidt telescope on Mt Palomar
- 7.2 deg^2 FOV, 11 CCDs with ~ 92 megapixels, $\sim 1''/\text{pixel}$
- Image up to 2000 deg^2 per night (g and R filters) to 5σ depth of $R \sim 20.5$ with typical seeing $\sim 2''$
- Science operations began in March 2009
- $>100 \text{ TB}$ of image data and 10^{12} extracted sources per year
- Cadence: 1 min to 5 days: SNe, variable stars, asteroids...



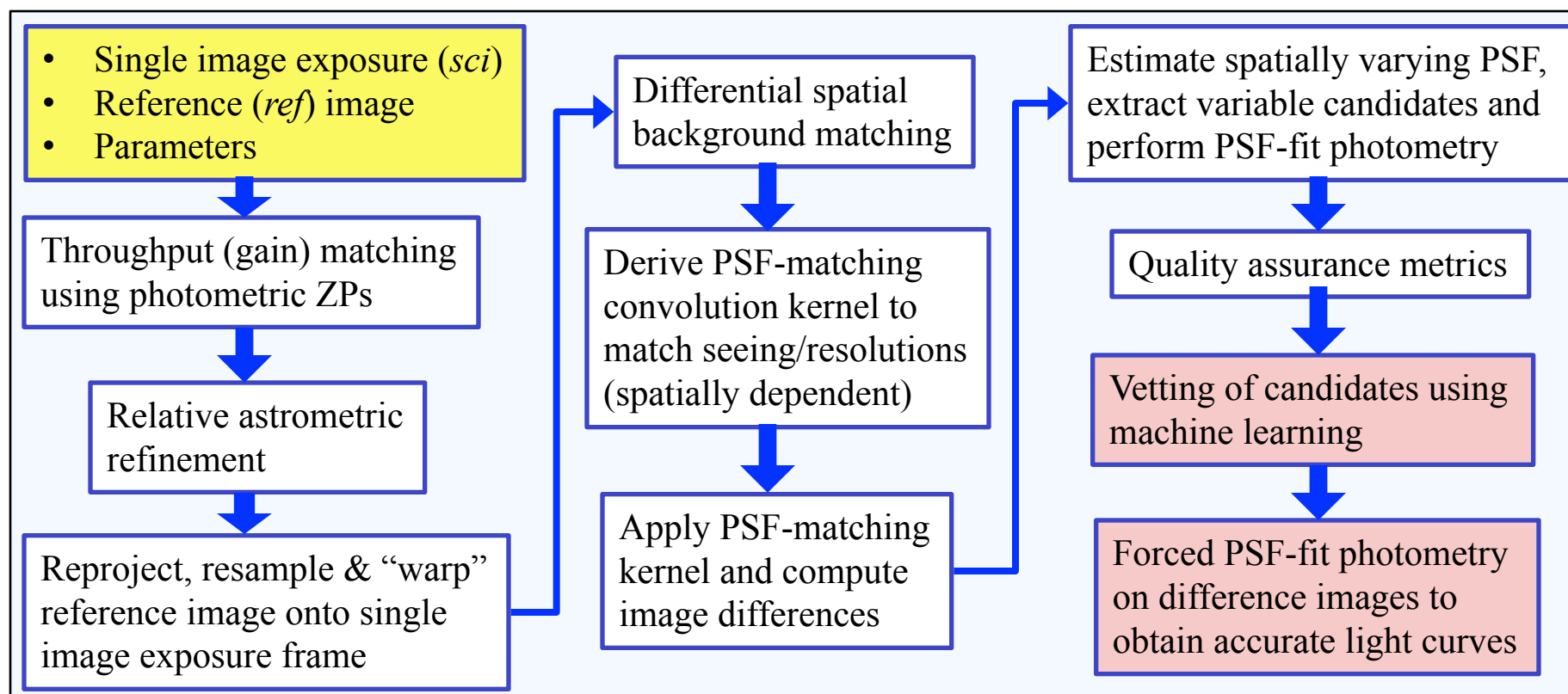
Edwin Hubble, 1949

PTF Data Flow and Processing



PTF Image-Differencing & Extraction pipeline (PTFIDE)

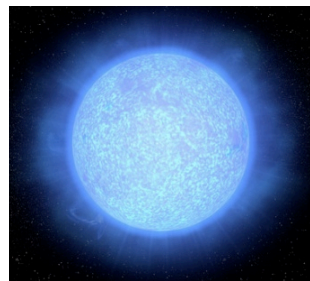
An engine for discovering candidate transients in near real-time for later vetting and follow-up



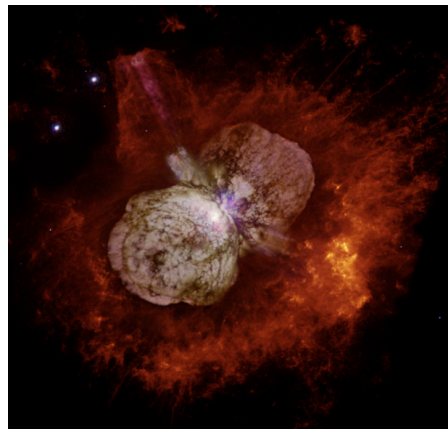
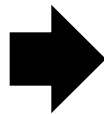
<http://web.ipac.caltech.edu/staff/fmasci/home/miscscience/ptfide-v4.0.pdf>

Validating PTFIDE on archival image data

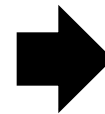
- While validating pipeline, can we use new functionality to perform any new archival science?
- **PLAN:** look for activity at the locations of previously discovered supernovae before they exploded
 - ⇒ missed pre-supernova eruptive mass-loss events
 - ⇒ tighter constraints on progenitors and massive-star evolution
- Started a campaign to reconstruct the light-curves of previously discovered supernovae by processing archived image data through new image-differencing pipeline
 - ⇒ with forced PSF-fit photometry, photometric accuracy is vastly improved
- Out of >10,000 PTF transient candidates, ~ 1900 are spectroscopically confirmed supernovae



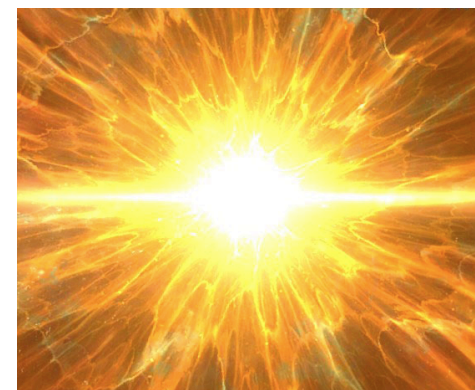
Supergiant Star



Eta Carina (Hubble)

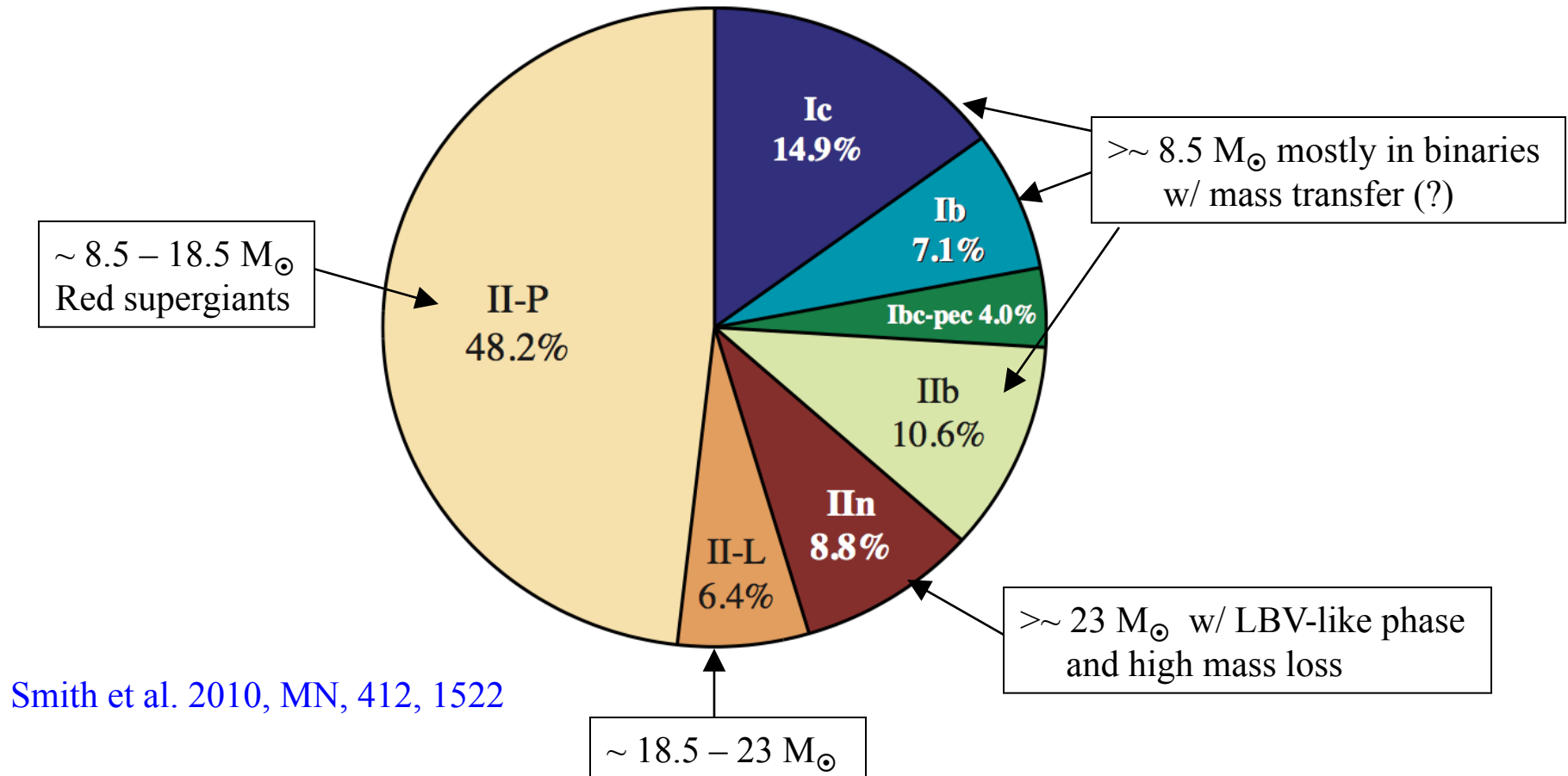


?



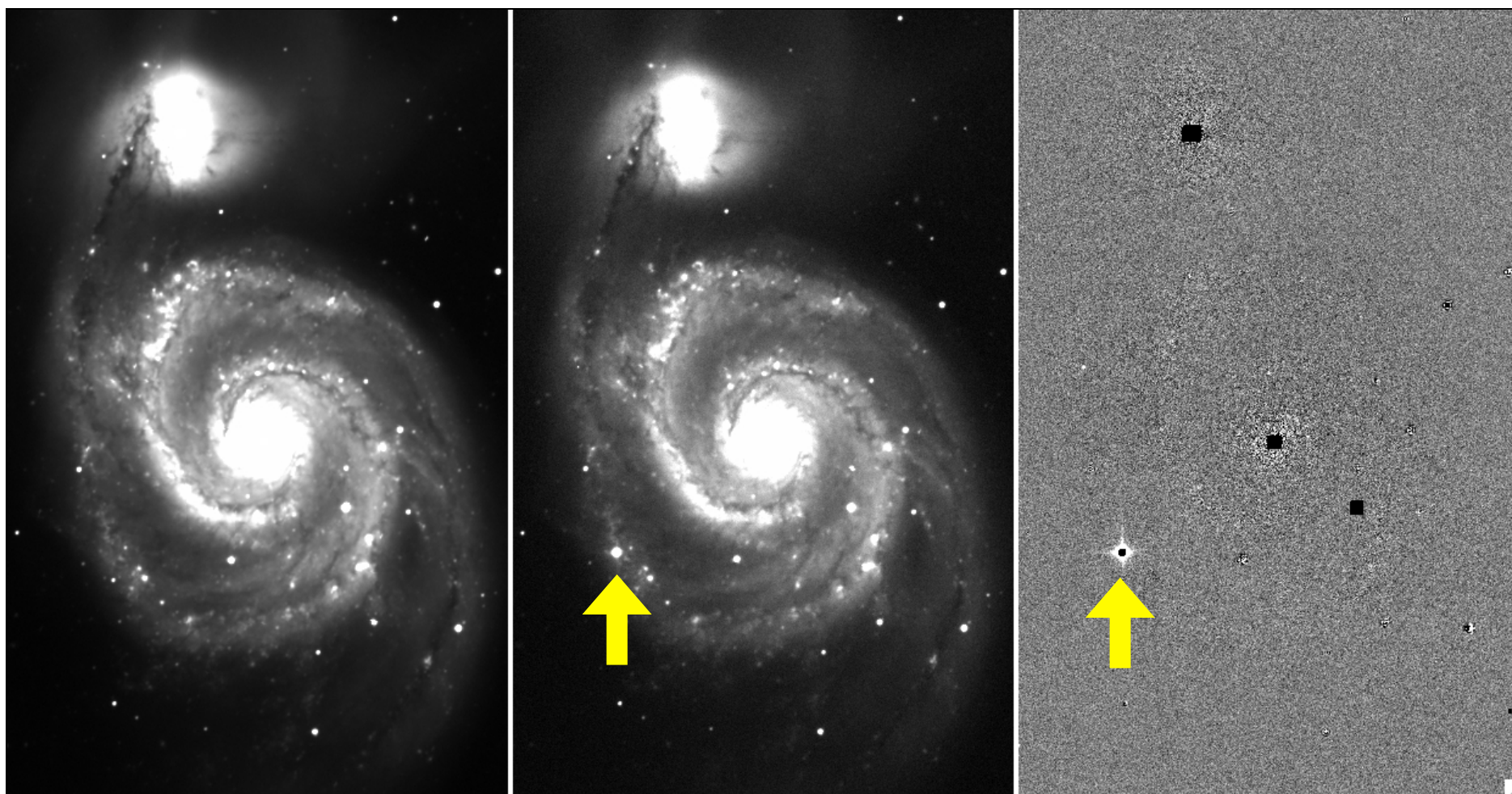
Type X Supernova?

Core-Collapse Supernova types and their progenitors



Degree of mass loss from progenitor star also determines which SN is seen

SN 2011dh (PTF11eon) in Messier 51

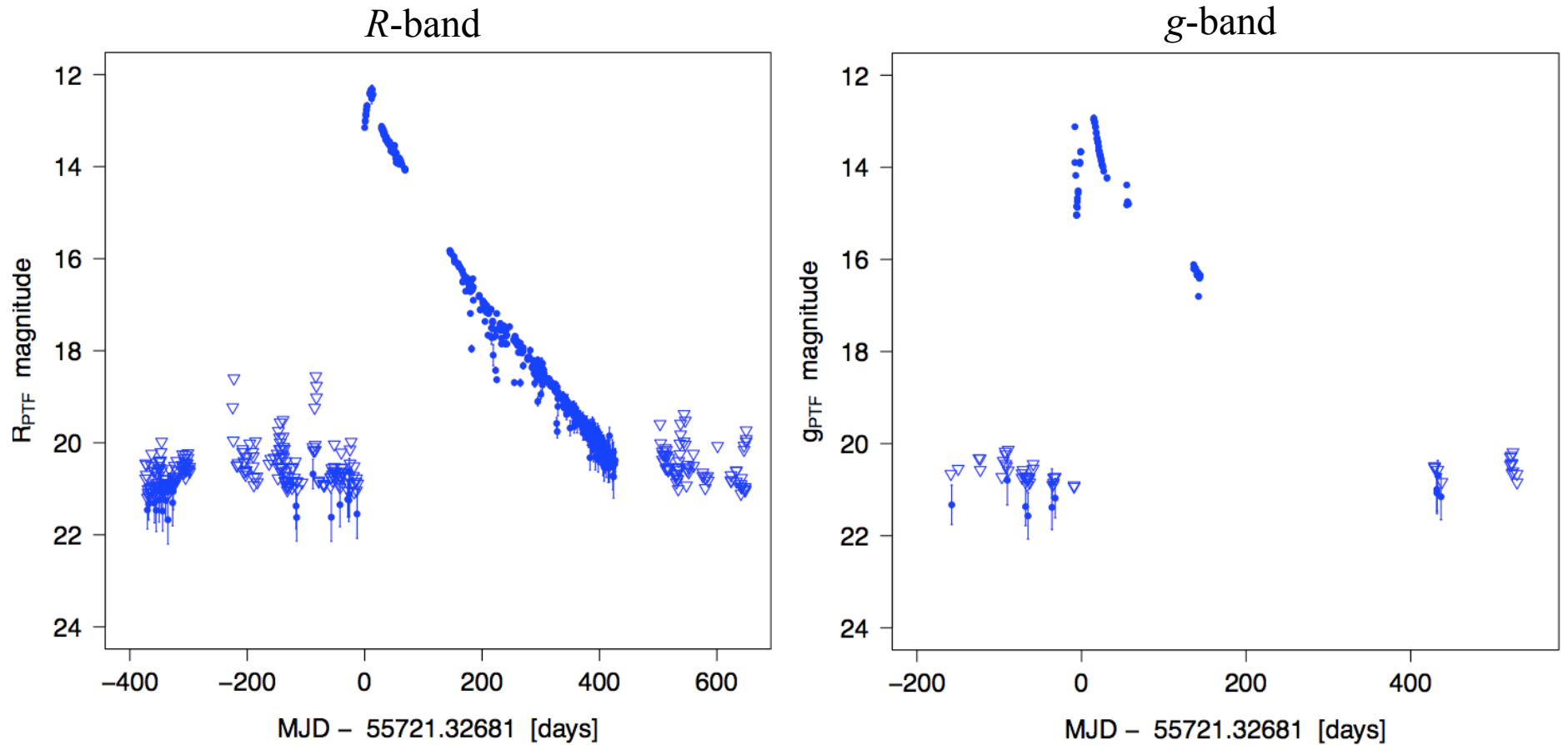


Reference image = co-add of 20
R exposures (pre-outburst)

R exposure on June 19, 2011
Type IIb supernova $\sim 10^9 L_{\odot}$

Difference image:
exposure - reference

SN 2011dh light curves from PTF difference image photometry

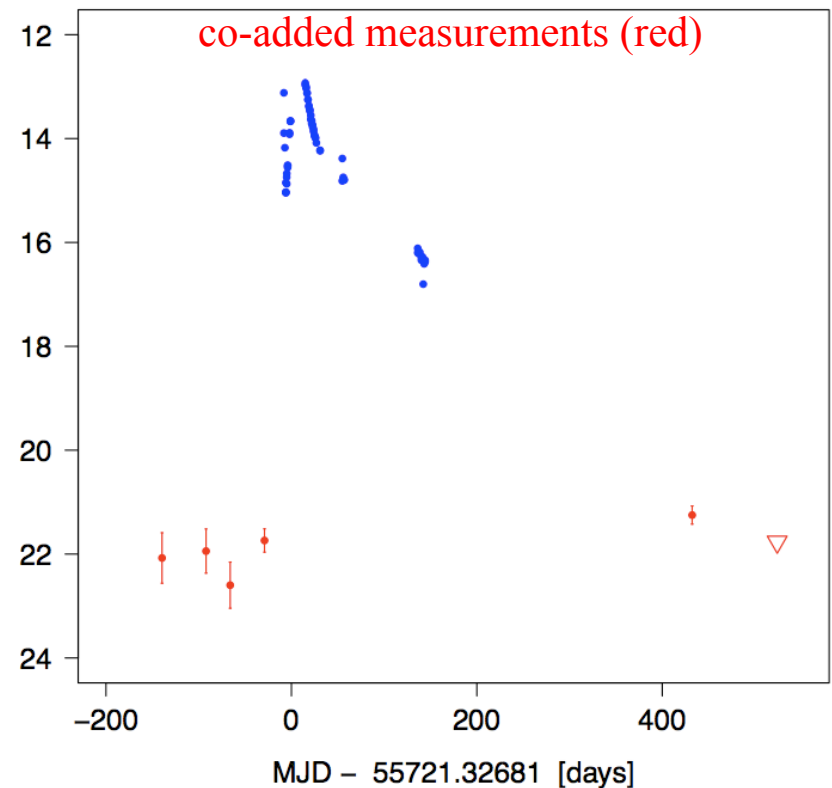
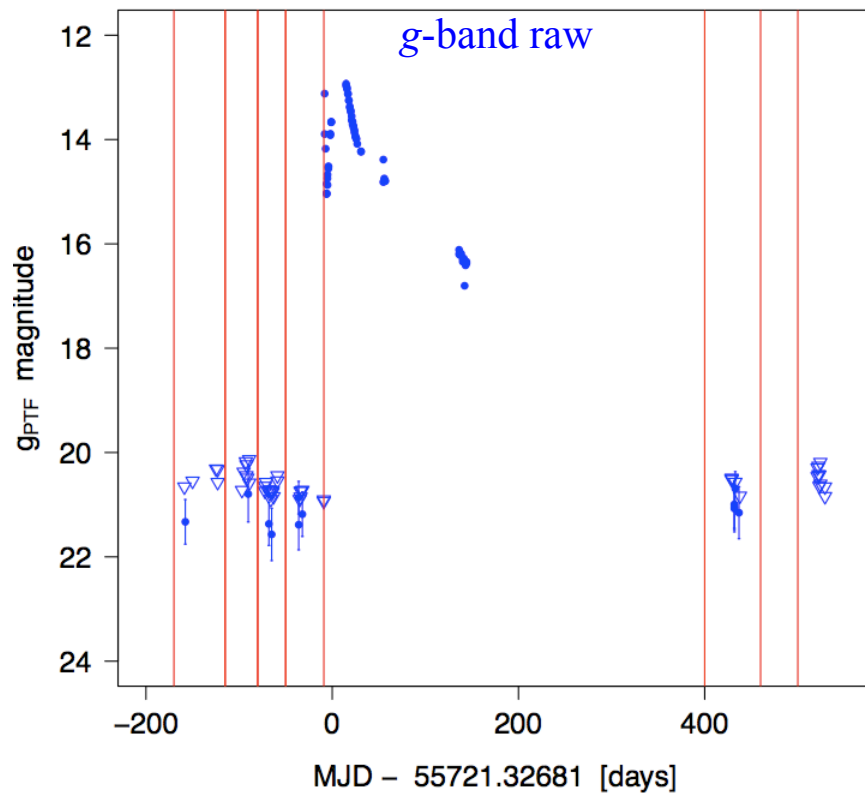


triangles: non-detections shown as 3.5σ upper limits

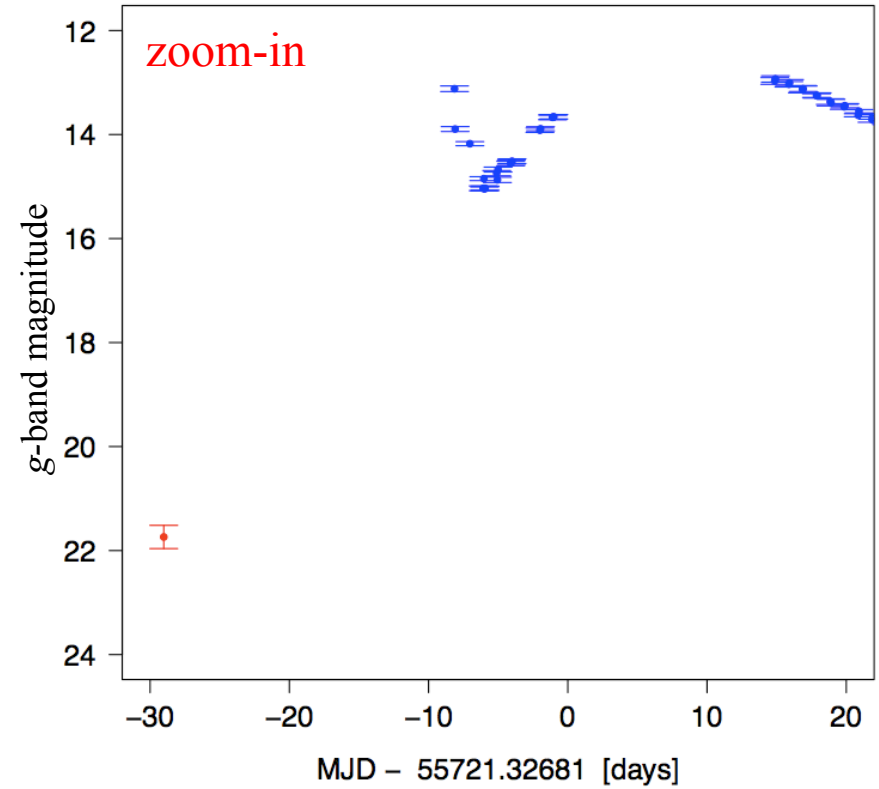
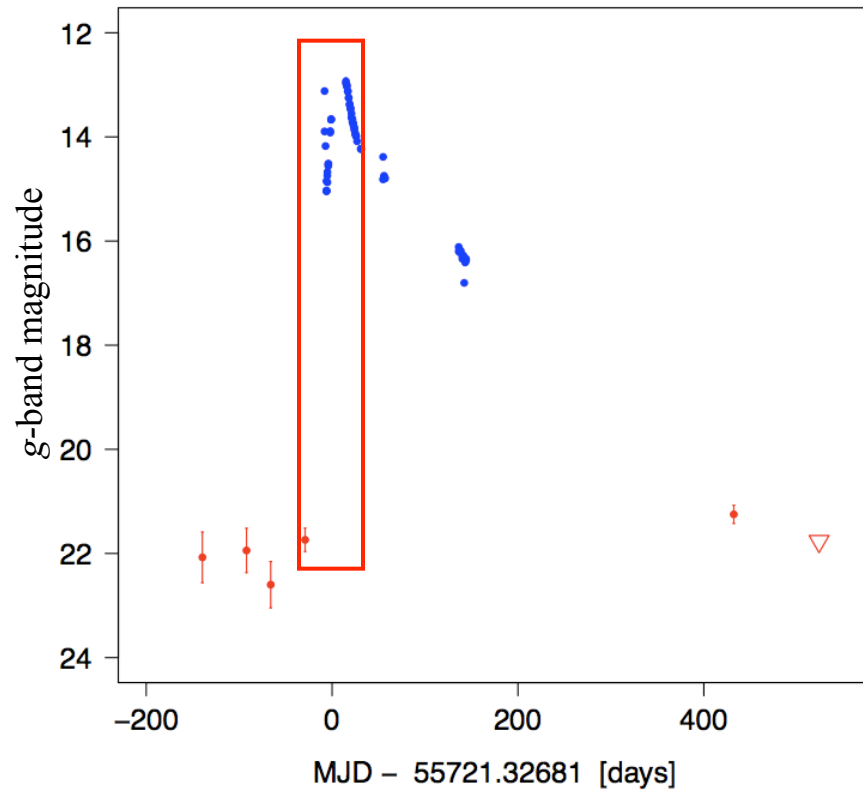
SN 2011dh light curves from windowed-averaging

- Combine measurements within windows to improve S/N or obtain tighter upper limits on non-detections
- assumption:** fluxes in a window \sim constant with time. Can also collapse using more complex model based on prior (slope fit)

$$f_{coadded} = \frac{\sum_i f_i / \sigma_i^2}{\sum_i 1 / \sigma_i^2}$$

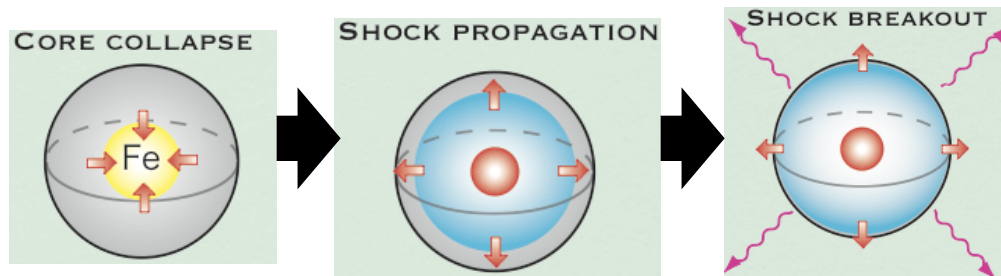
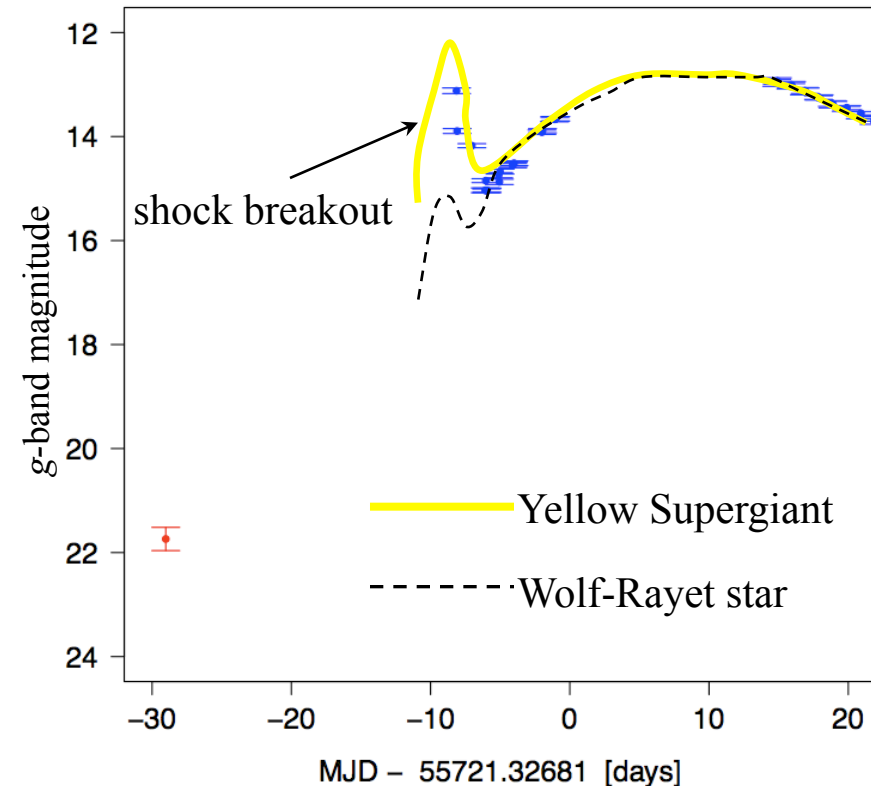


2011dh g-band light curve



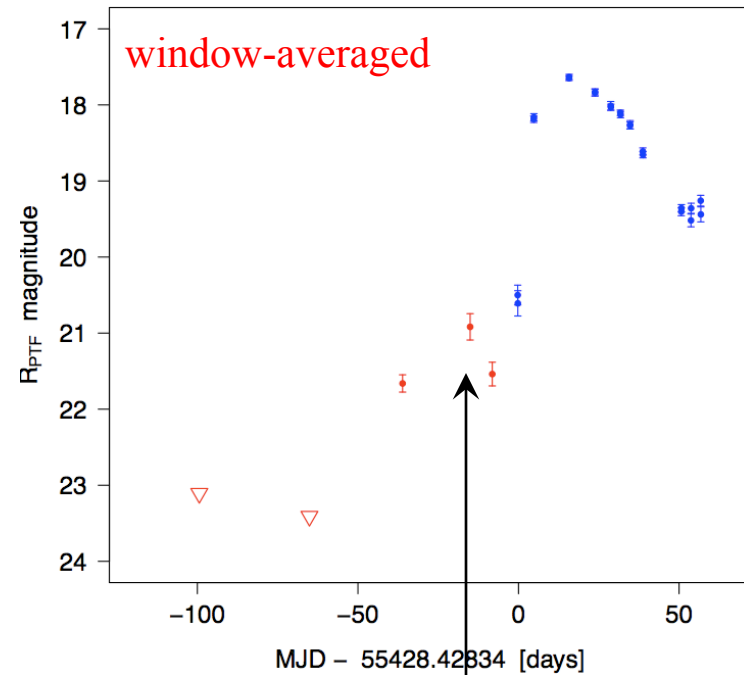
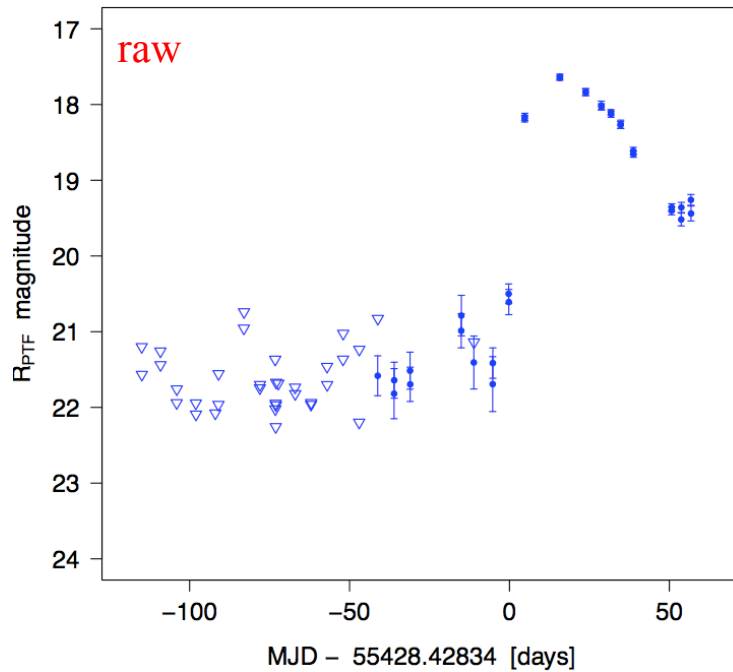
2011dh g-band light curve

- Bersten et al. (2012): light curve modeling: shape consistent with shock-breakout from photosphere of a yellow supergiant star.
- YSG progenitor consistent with pre-explosion HST photometry by Maund et al. (2011) & Van Dyke et al. (2011) with outer *H* envelope stripped, perhaps by a companion.



SN 2010mc (PTF10tel)

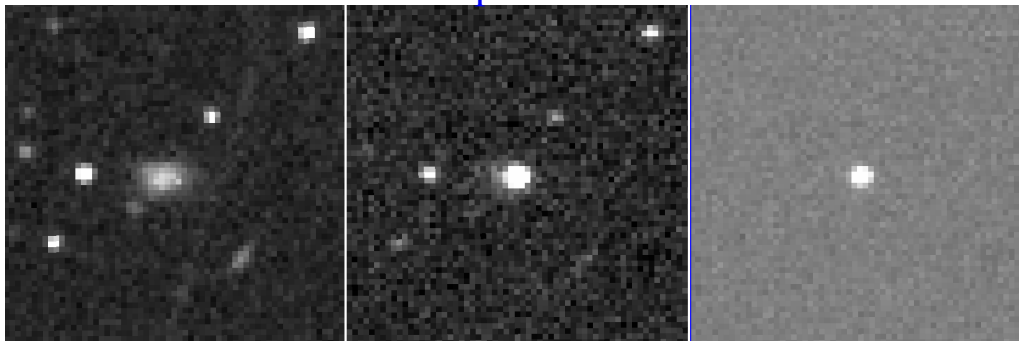
Type IIIn supernova in unknown galaxy at ~ 153 Mpc



reference

exposure

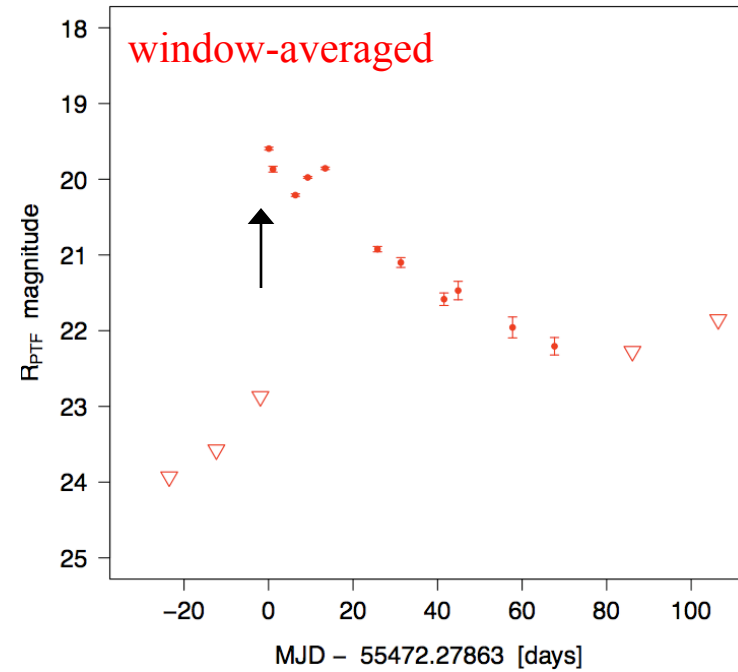
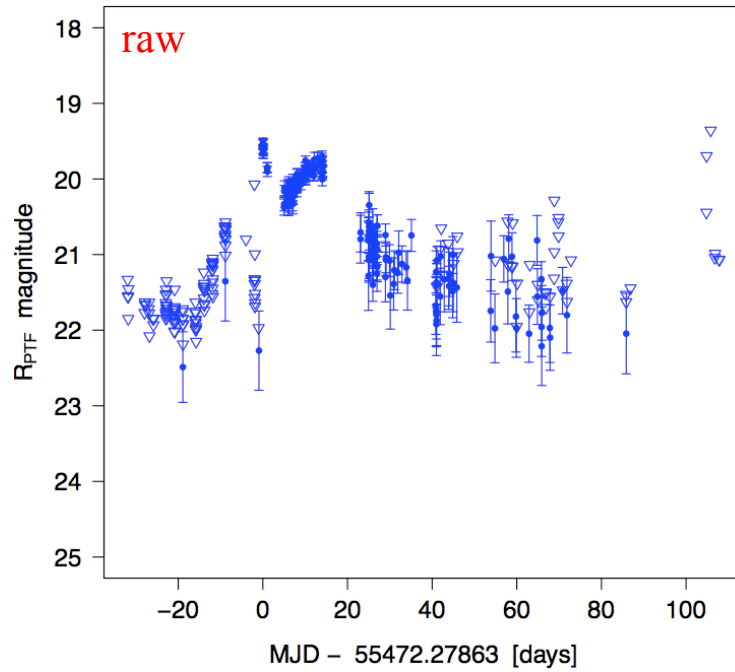
difference



Outburst 40 days before explosion:
Ofek et al. (2013), Nature, 494, 65

SN PTF10xfh

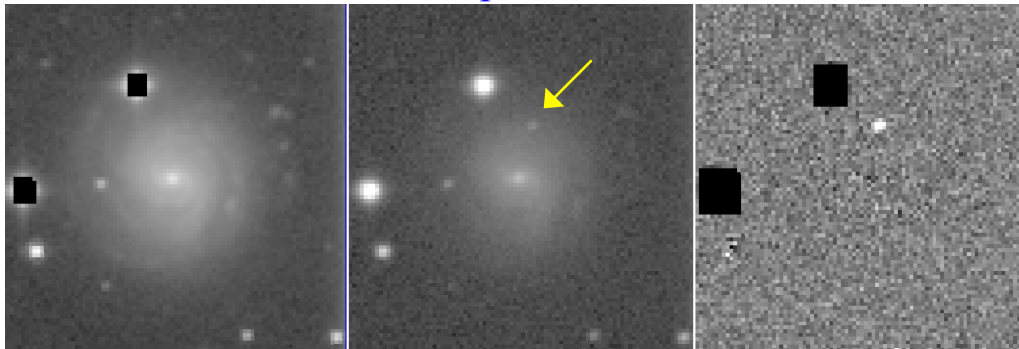
Type Ic supernova in NGC 717 at ~ 65 Mpc (Yi Cao, private communication)



reference

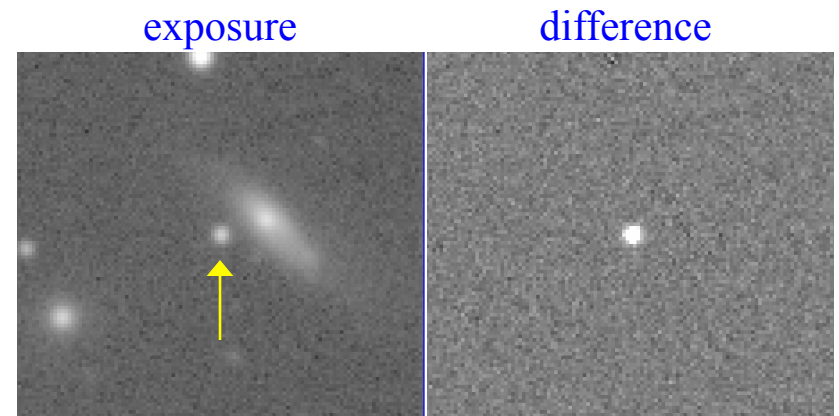
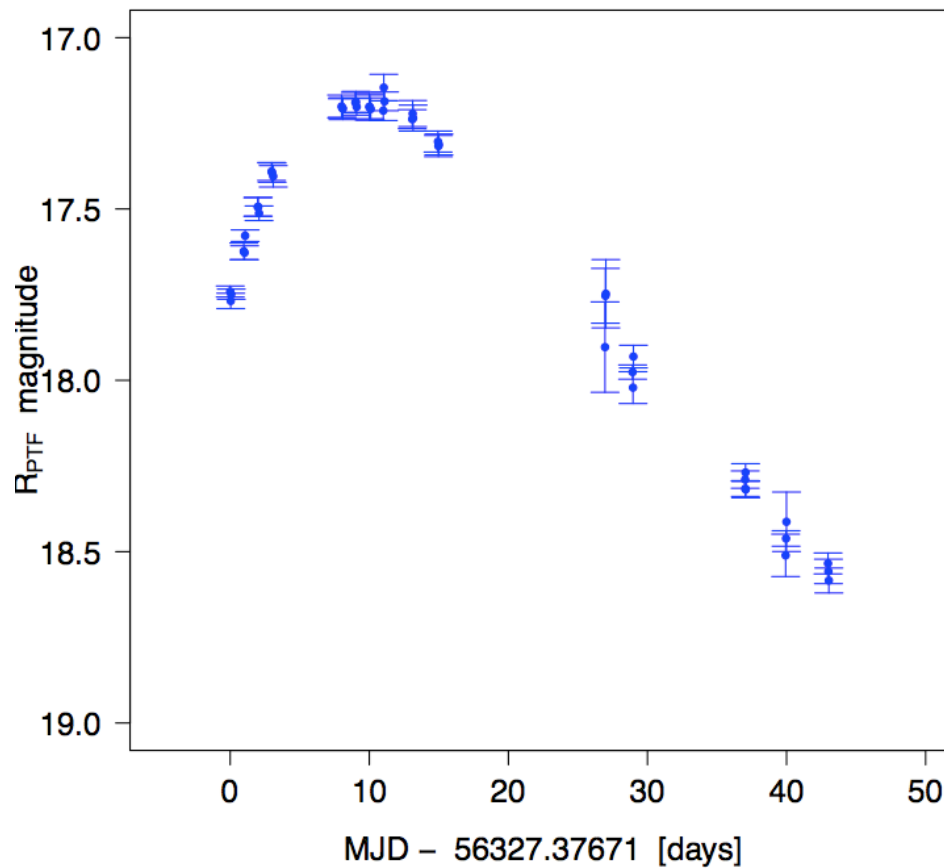
exposure

difference



SN PTF13ai (or PSN J12541585+0926259)

- Type Ia Supernova in galaxy PGC 43884 (~ 197 Mpc); discovered Feb 5, 2013
- One of the first to be discovered in new phase of PTF project: **iPTF**



Summary

- developed a suite of tools to enable accurate light curve generation from difference imaging
- good image subtraction with PSF-fit photometry and judicious time-window-averaging is the key at maximizing signal-to-noise!
- Started a campaign to reconstruct the light curves of confirmed supernovae using PTF archive
 - explore any missed pre-outburst (mass loss) episodes across different supernova types
 - better constraints on SN progenitors
 - better light-curve templates for classification or to support archival searches for missed SN