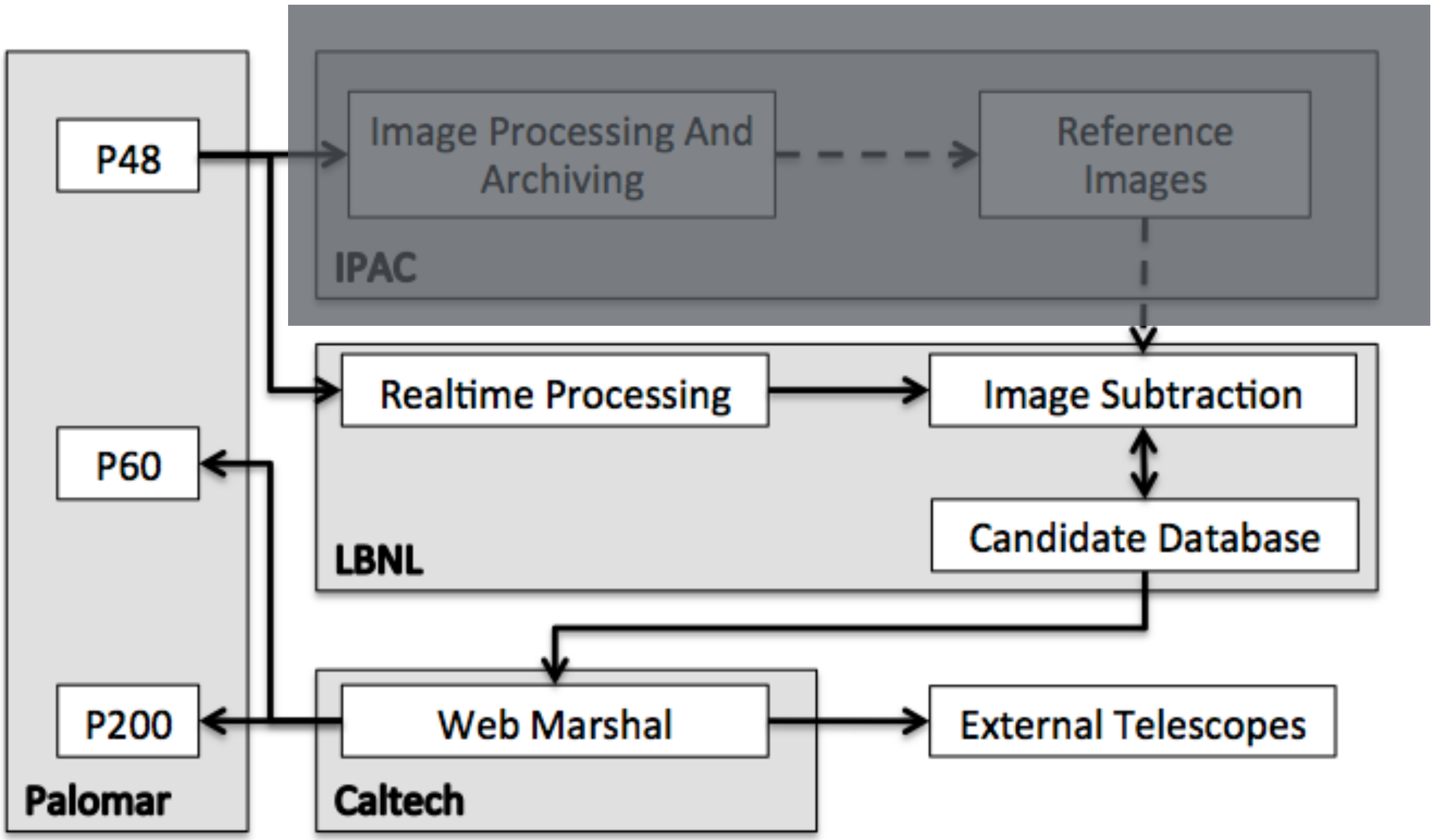
Summary of the iPTF fast-cadence experiments

Yi Cao (Caltech)
On behalf of the iPTF transient teams

Overview of iPTF



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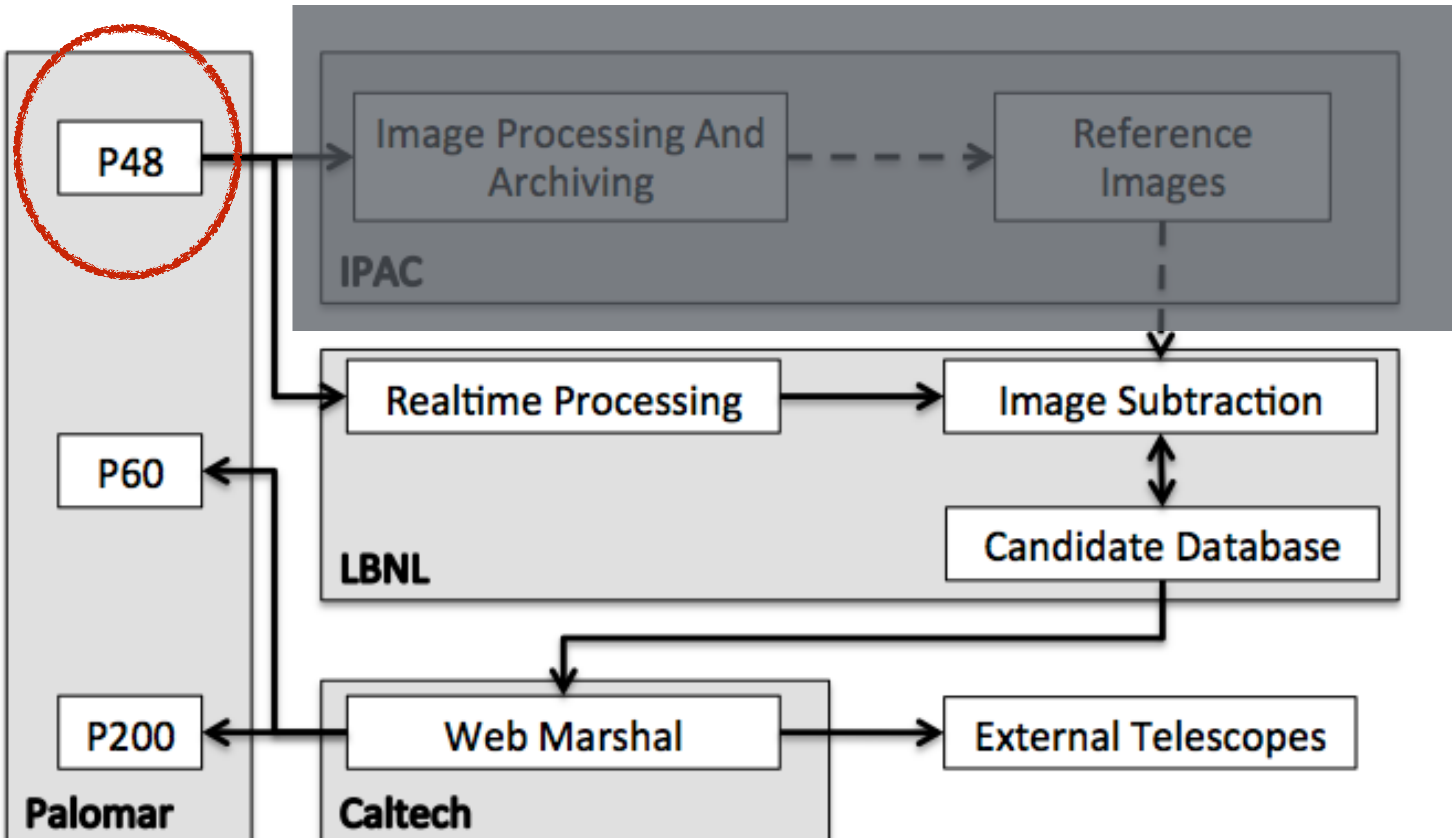
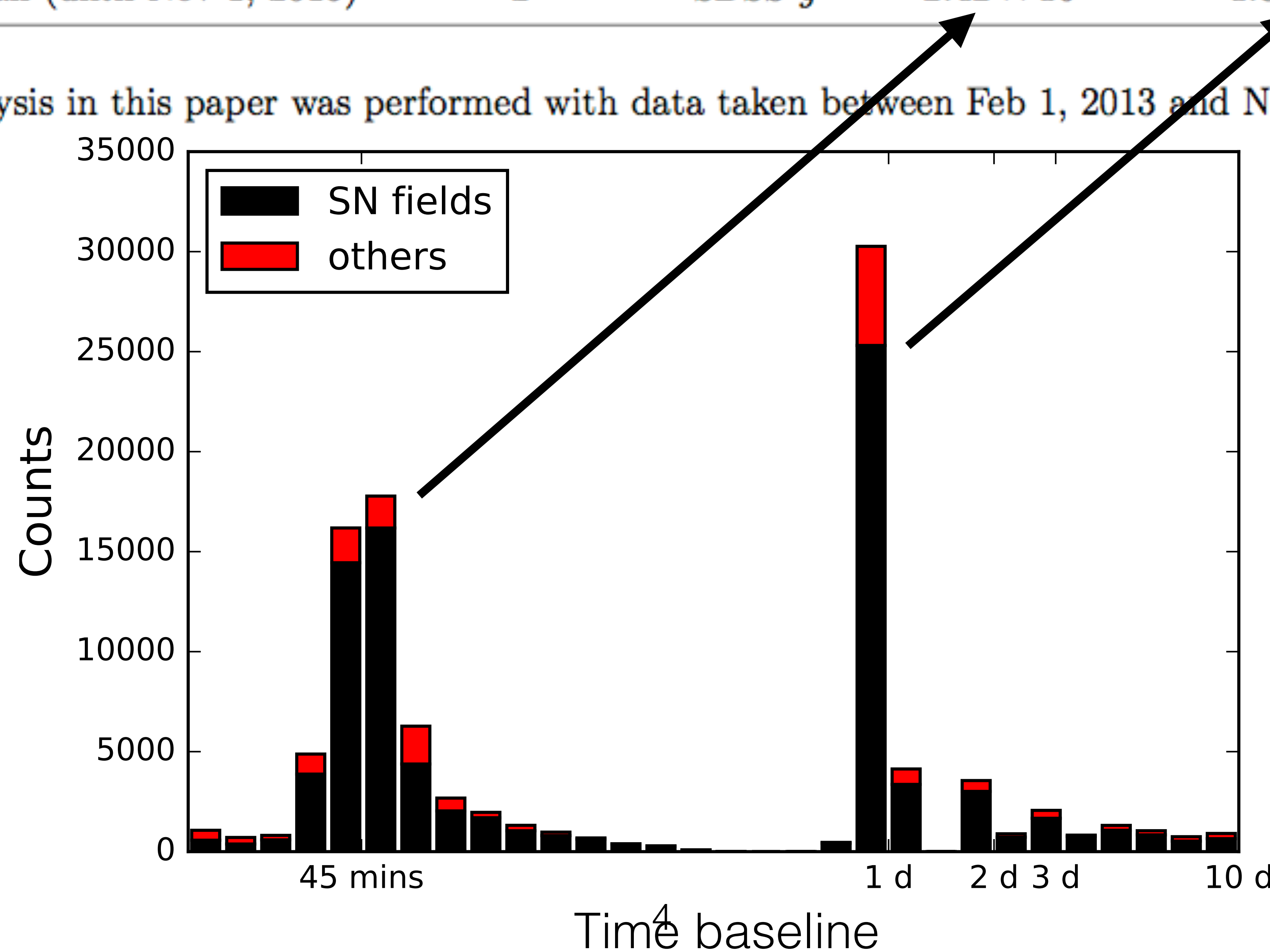


Experiments

Observing season	Nightly epochs	Filter	Ω(45 min) (deg^2)	Ω(1 day) (deg^2)
2013 Spring	3	Mould R	8.65×10^4	4.15×10^4
2013 Fall	2	Mould R	7.55×10^4	4.37×10^4
2014 Spring	2	Mould R	6.04×10^4	5.41×10^4
2014 Fall	2	SDSS g	4.19×10^4	2.96×10^4
2015 Spring	2	SDSS g	4.01×10^4	3.07×10^4
2015 Fall (until Nov 1, 2015)[a]	2	SDSS g	2.42×10^4	1.85×10^4

[a]Analysis in this paper was performed with data taken between Feb 1, 2013 and Nov 1, 2015.



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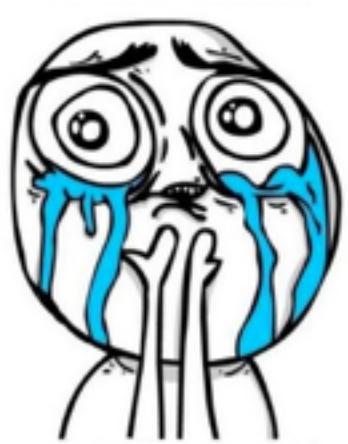
4 months (effectively)
25 night/mon
150 fields
7.26 sq. deg. (11 CCDs) or
6.60 sq. deg. (10 CCDs)

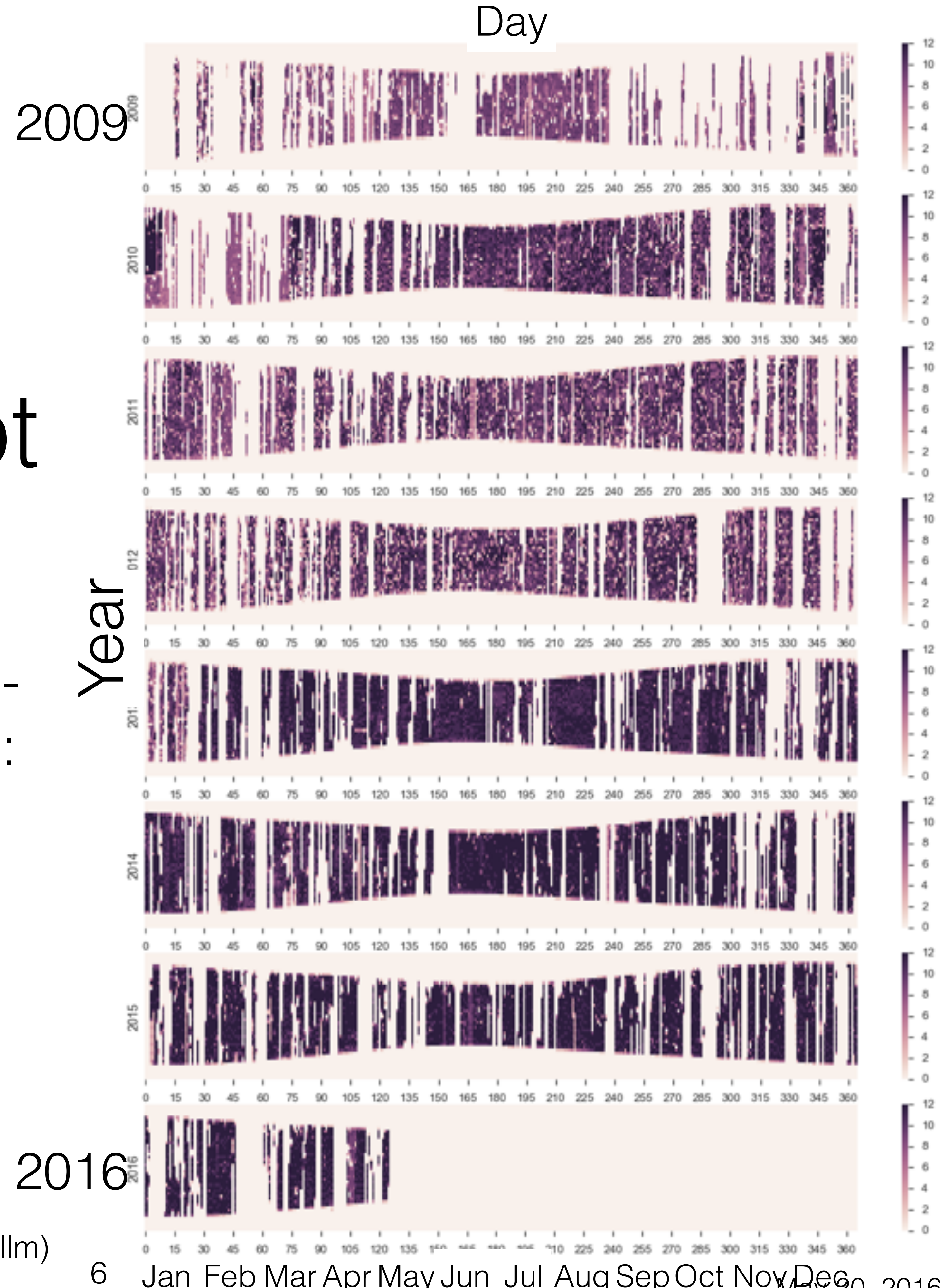
Ideal value:
Ω(1 day)=10^5 sq. deg.

Weather is not our friend.

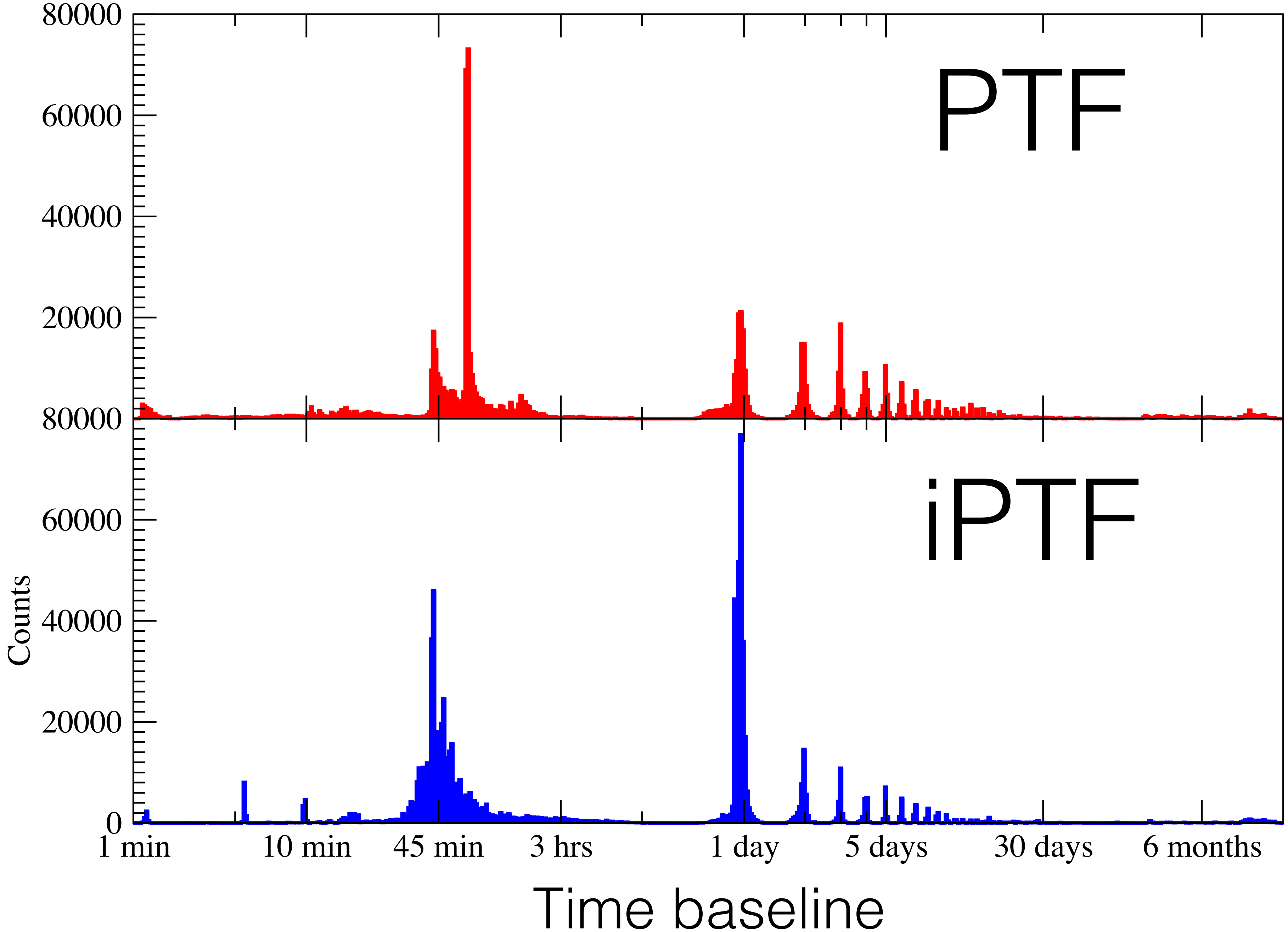
Best time of a year for one-night cadence experiment: late June -> early August



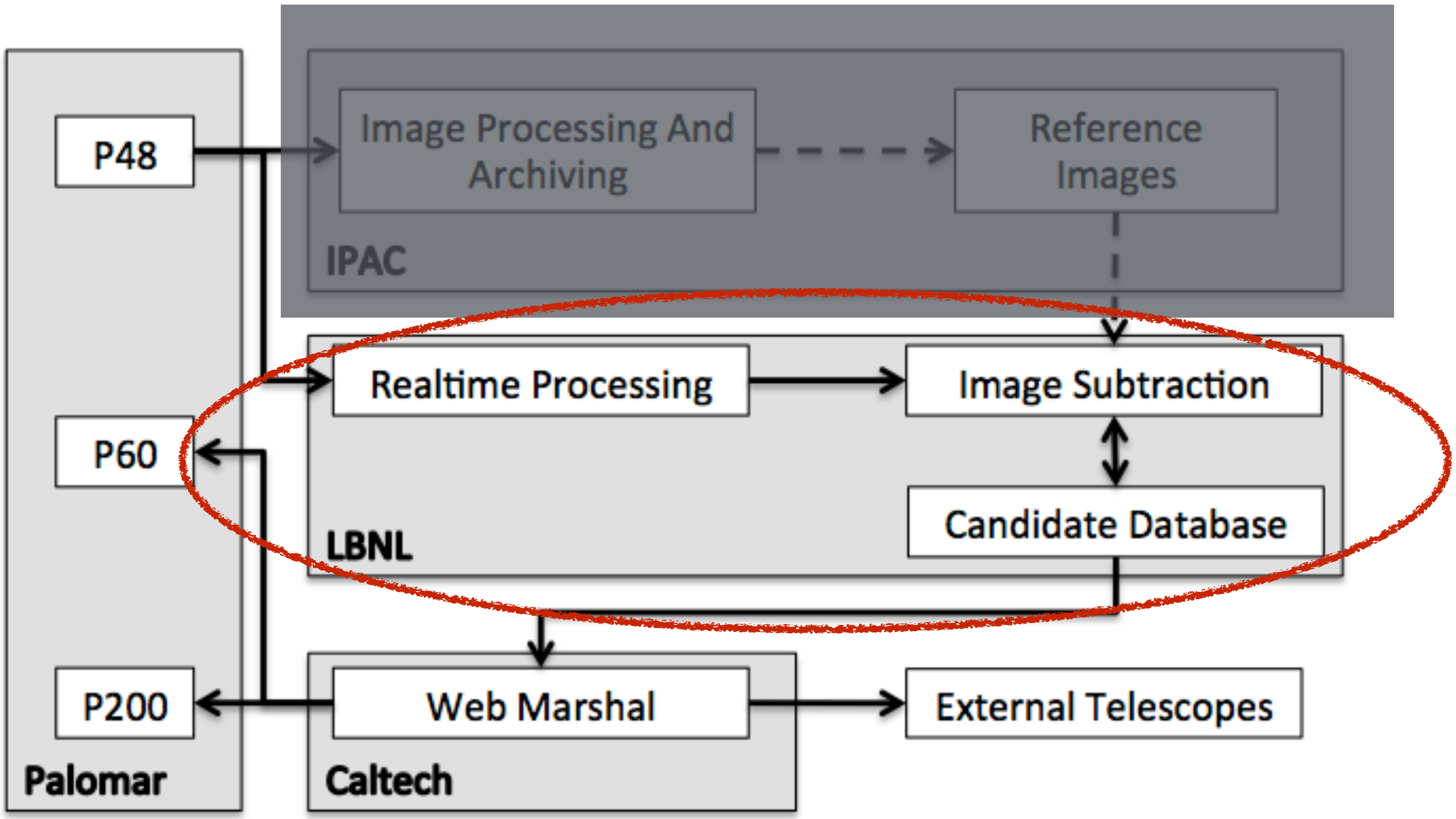
(Courtesy of E. Bellm)



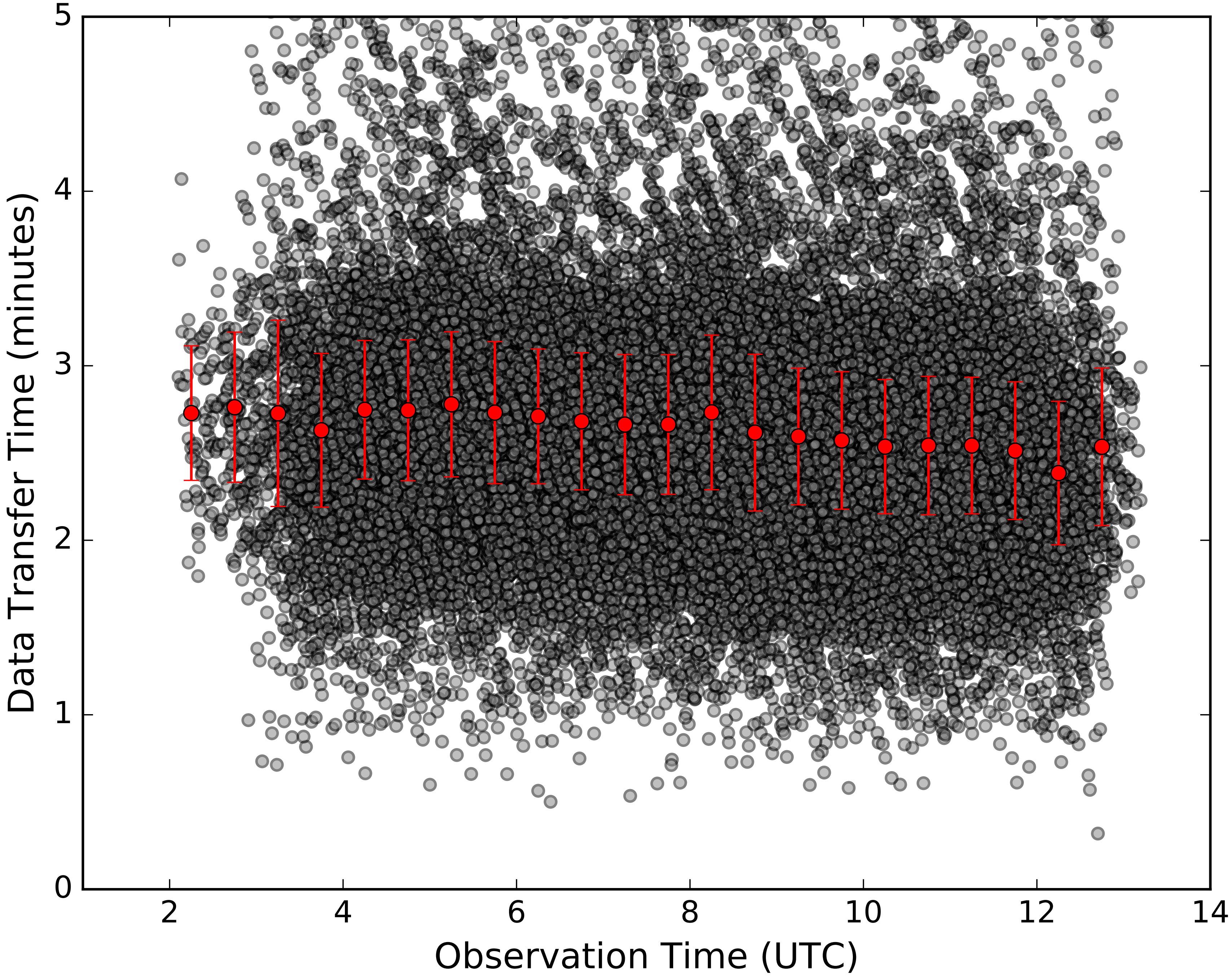
PTF vs. iPTF


80000
60000
40000
20000
80000
60000
40000
20000
0
PTF
iPTF
Counts
1 min
10 min
45 min
3 hrs
1 day
5 days
30 days
6 months
Time baseline

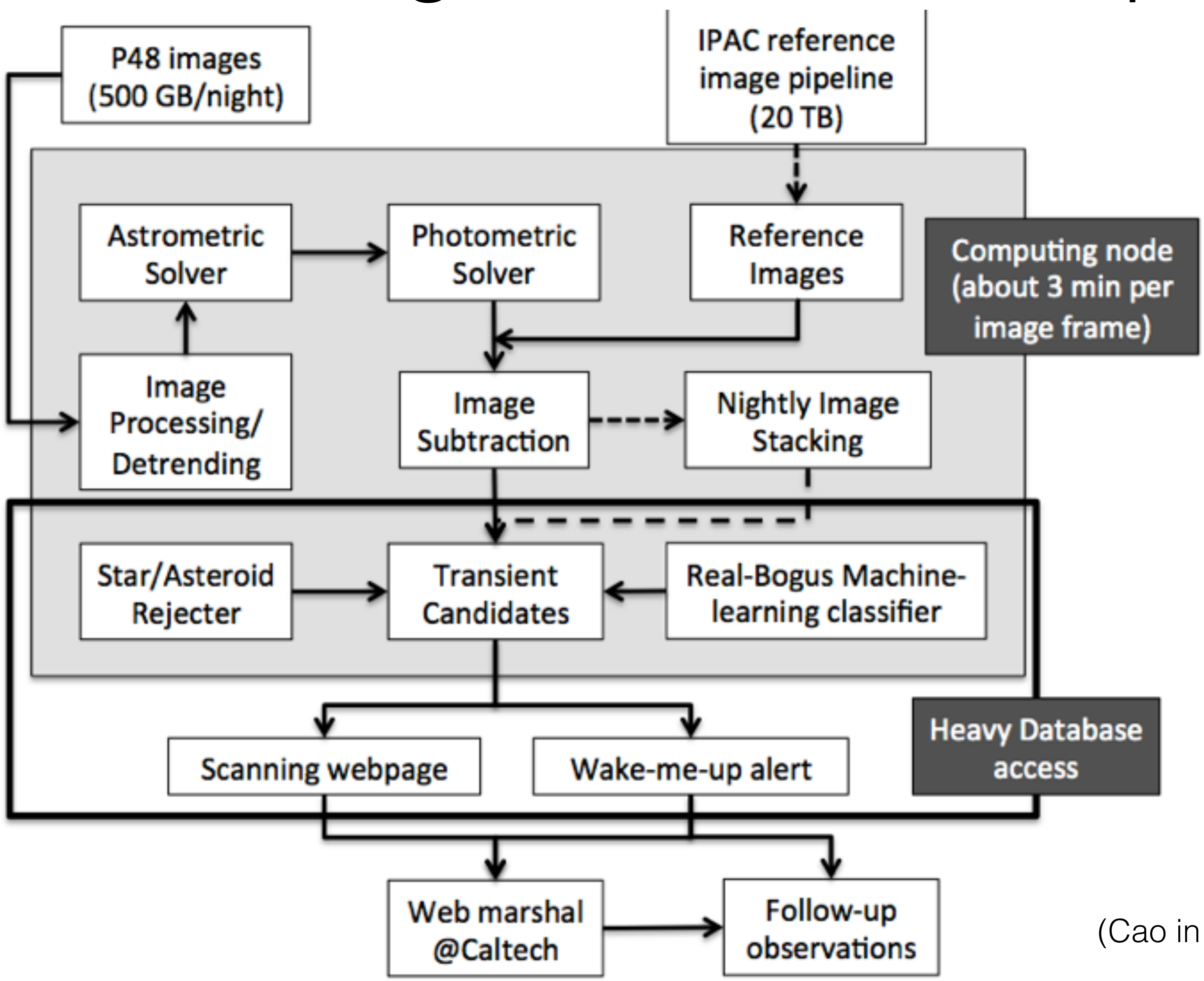
Overview of iPTF



Data Transfer

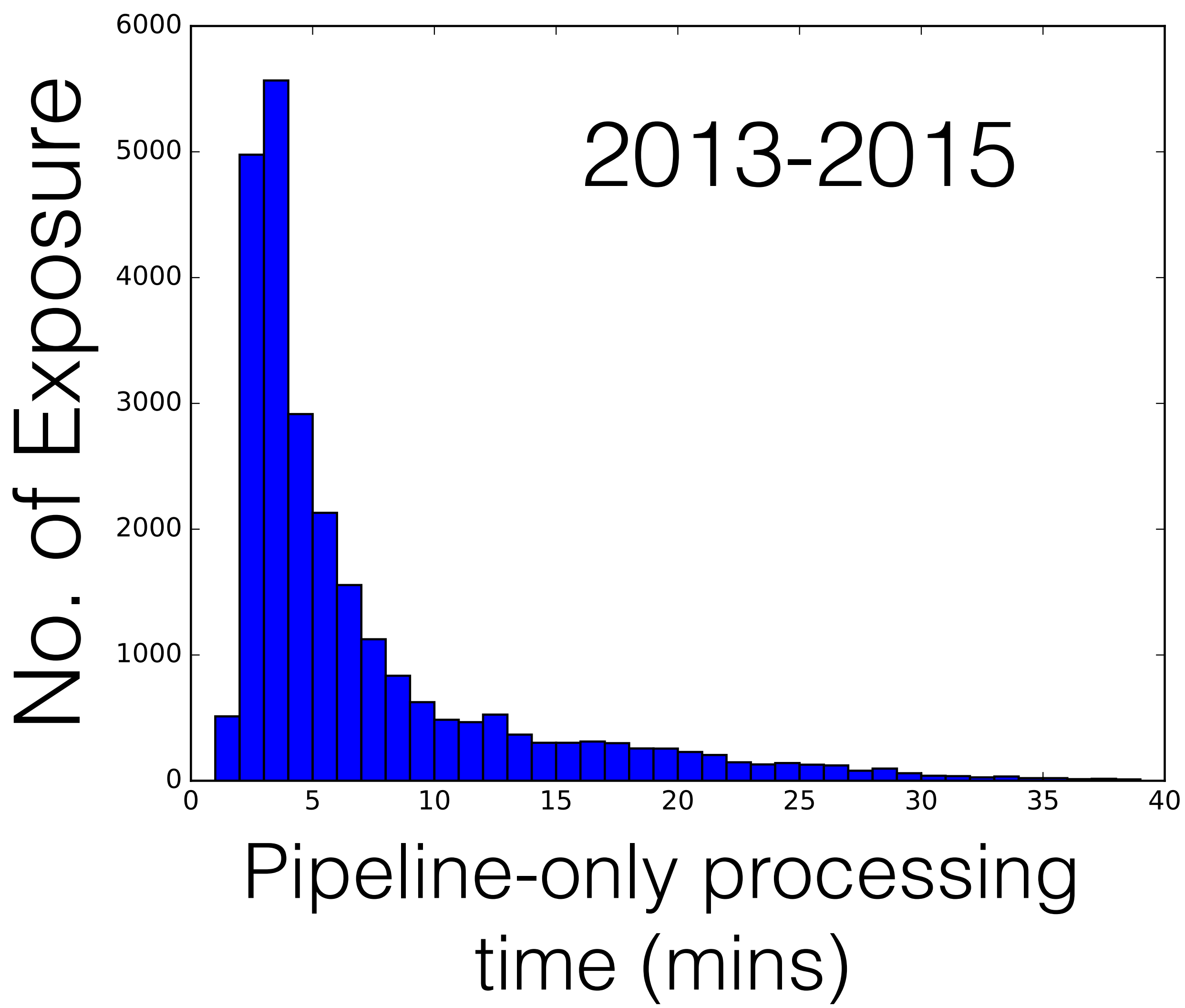


iPTF Transient Surveys: Realtime Image Subtraction Pipeline



(Cao in prep.)

iPTF Transient Surveys: Realtime Image Subtraction Pipeline



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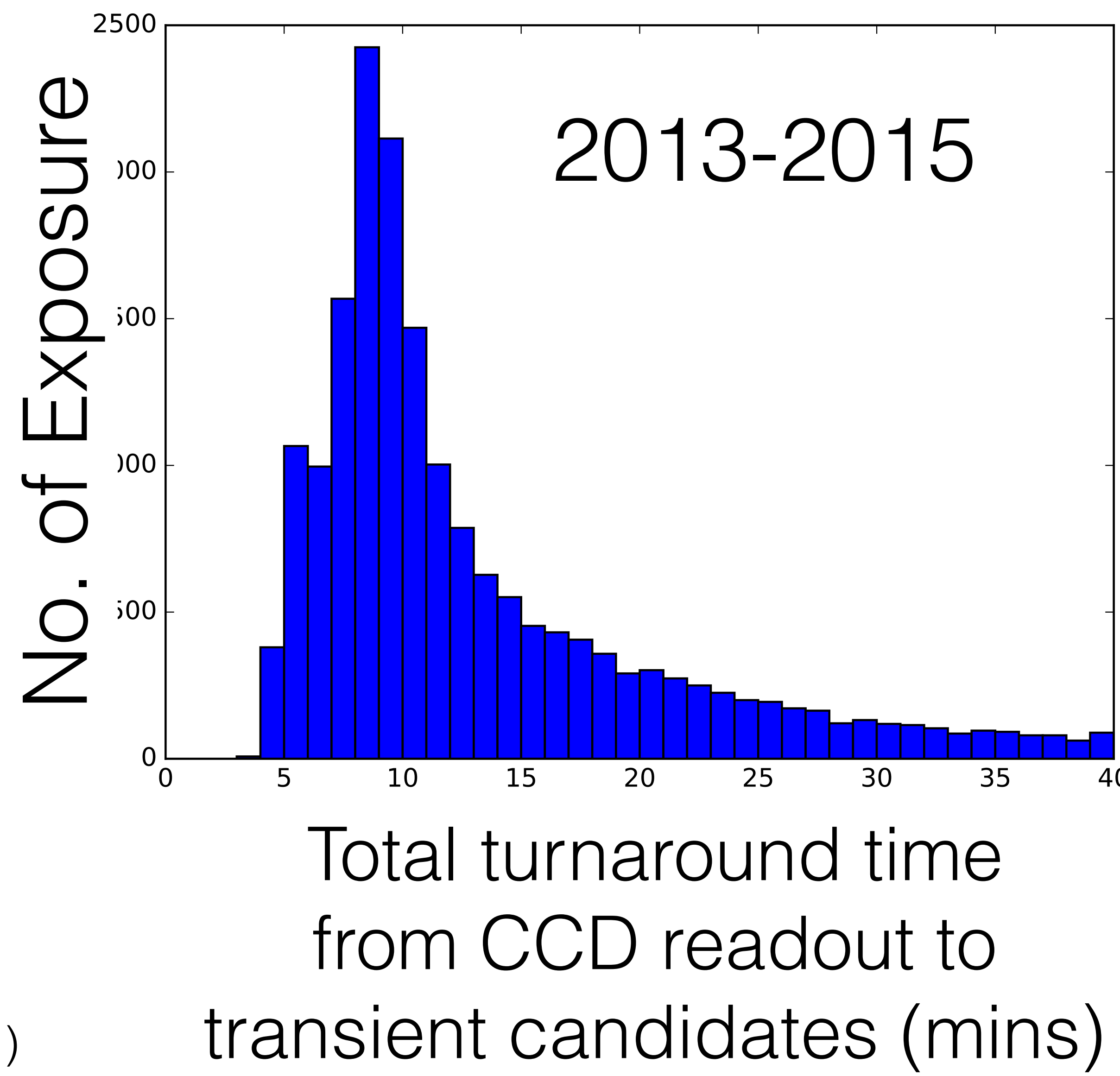

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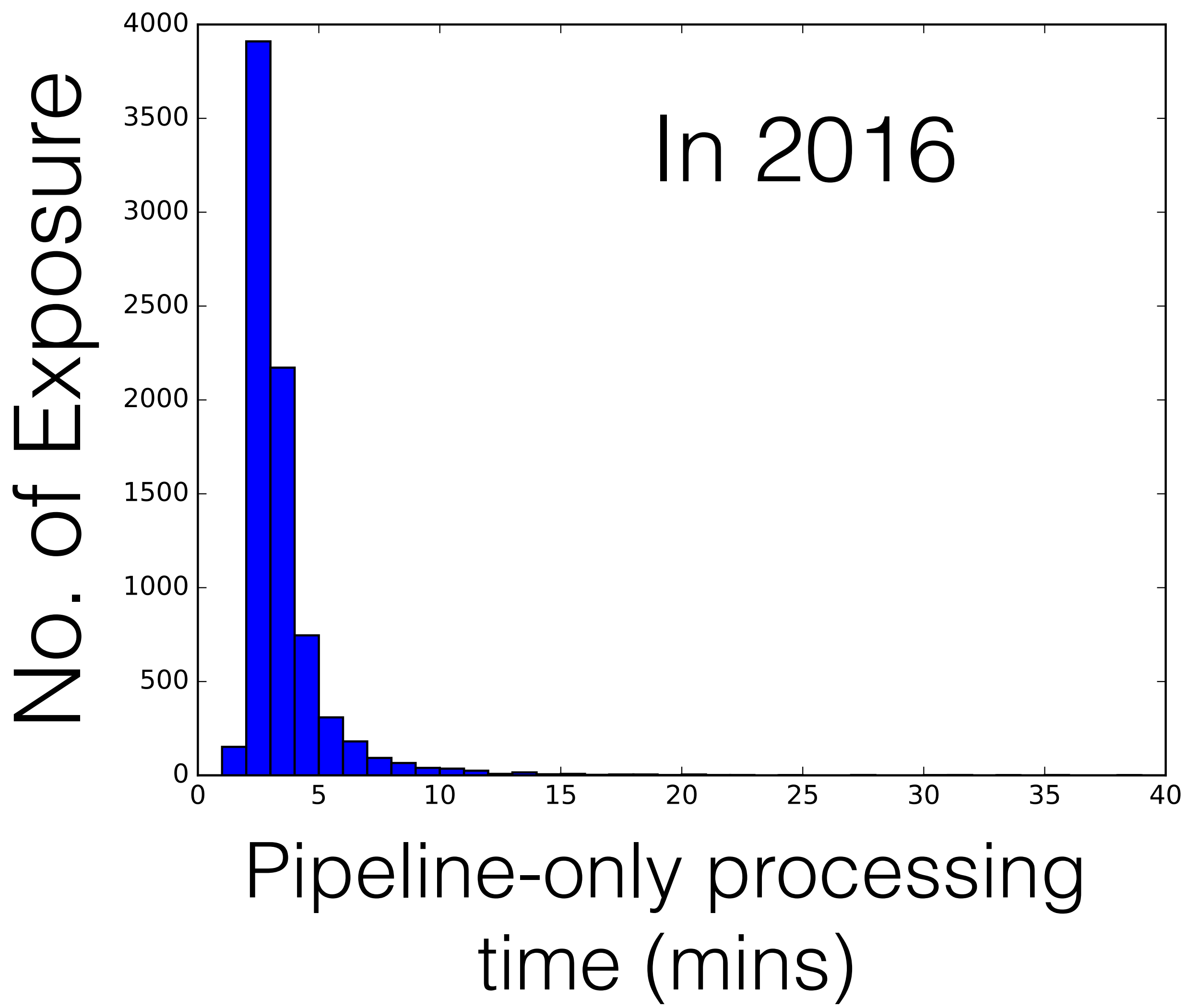
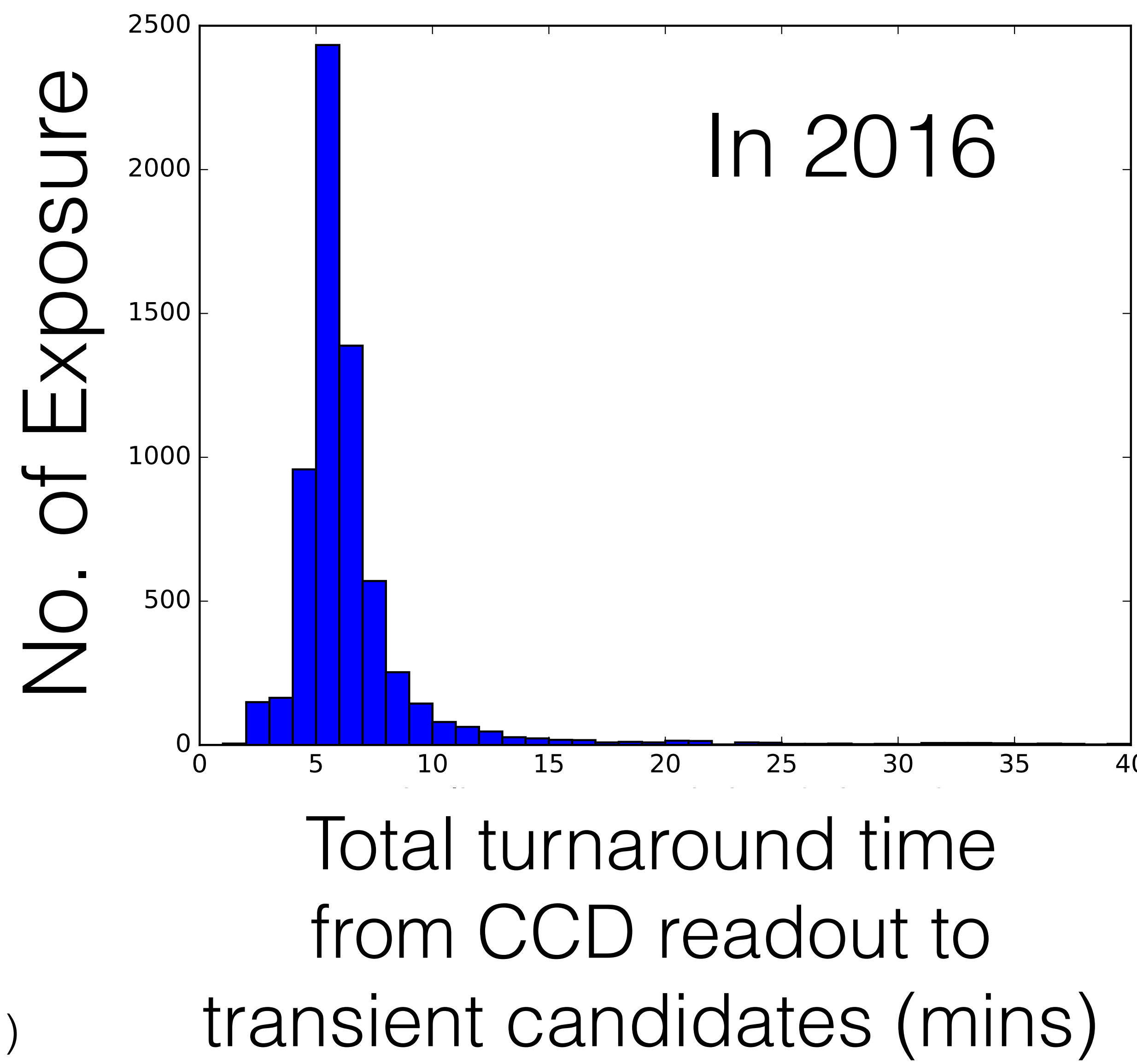
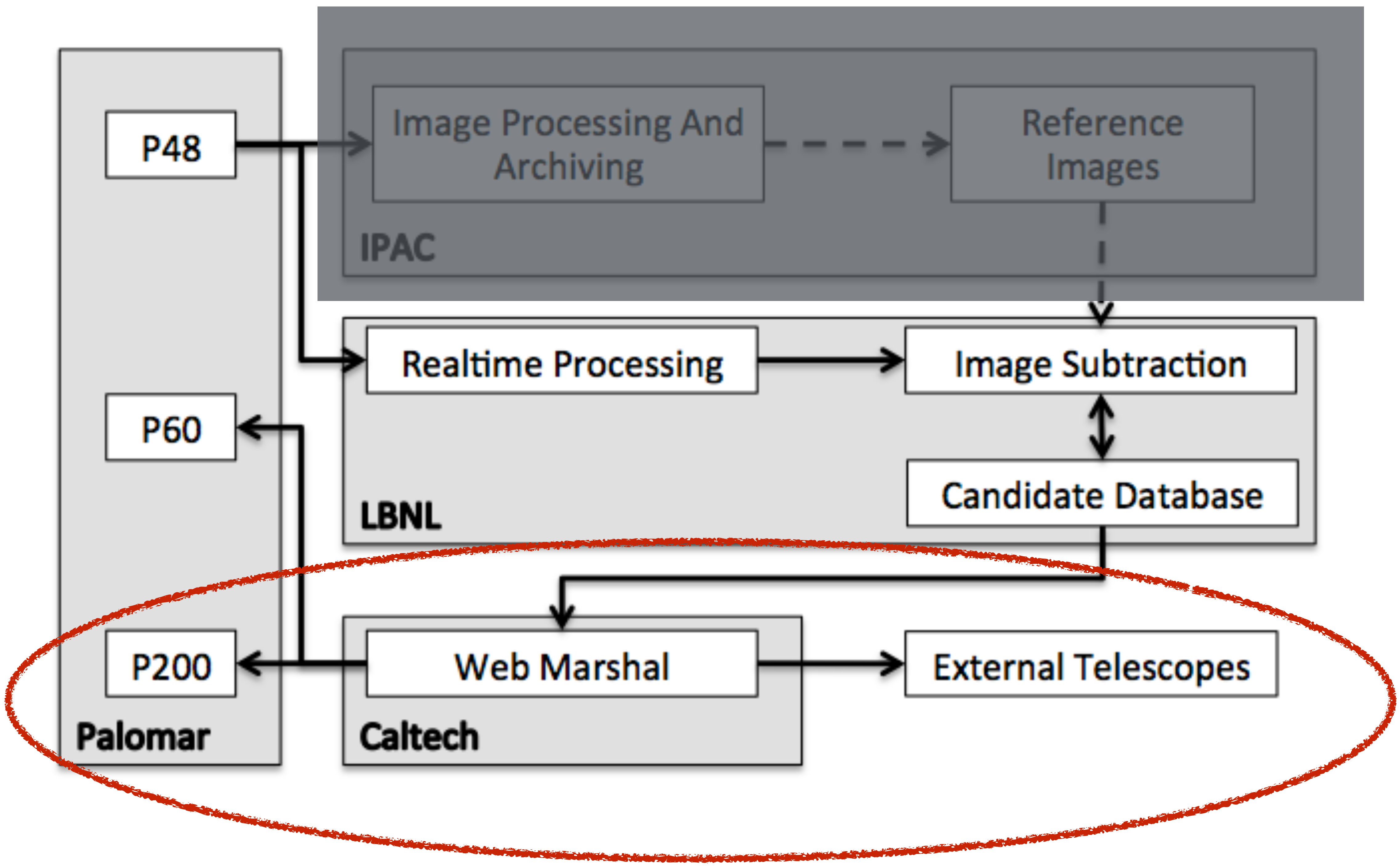




(Cao in prep.)

Overview of iPTF



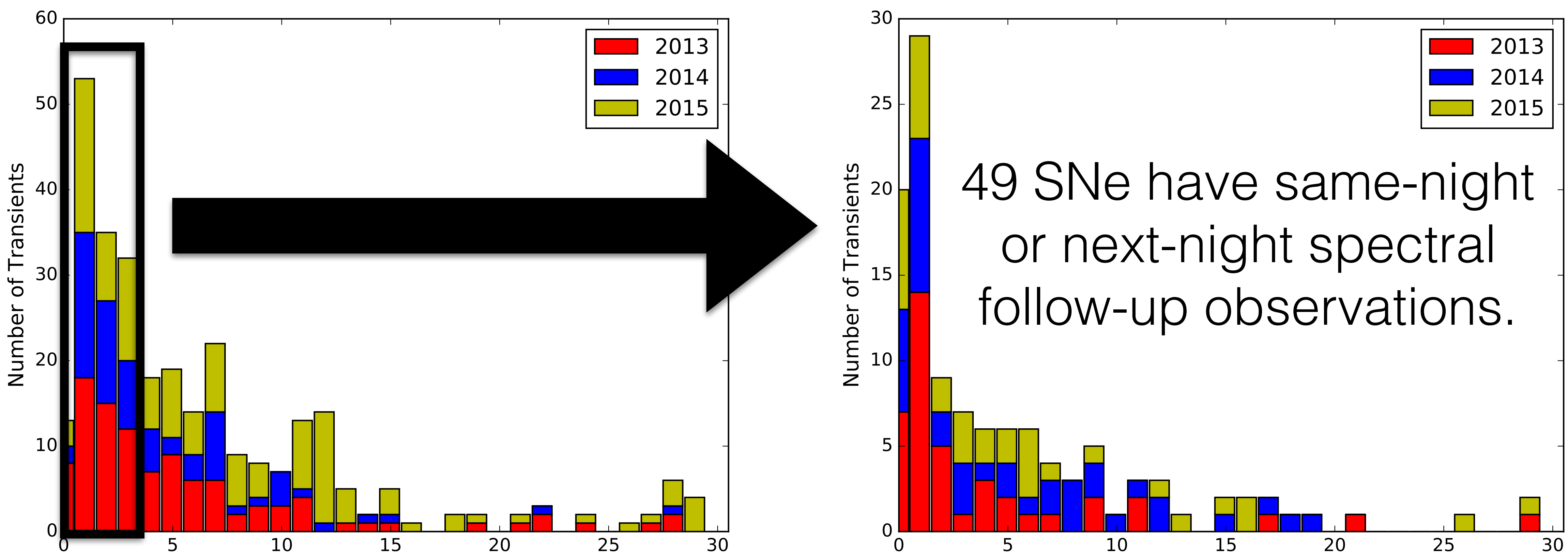
iPTF Transient Surveys: Follow-up Observations

Table 2.3. TOO follow-up programs

Telescope	P.I.	Observation type
Palomar 60-inch	S. R. Kulkarni	Optical photometry
Palomar 200-inch	S. R. Kulkarni	Optical spectroscopy
Keck I & Keck II	S. R. Kulkarni	Optical spectroscopy / Adaptive Optics
Gemini-North and South	M. M. Kasliwal	Optical spectroscopy
LCOGT network	D. A. Howell	Optical photometry and spectroscopy
Nordic Optical Telescope	J. Sollerman	Optical photometry and spectroscopy
APO ARC-3.5m	M. M. Kasliwal	Optical spectroscopy
TNG	F. Taddia	Optical spectroscopy
VLT	R. Amanullah	Optical/IR spectroscopy
Magellan	M. M. Kasliwal	Optical/IR photometry and spectroscopy
Spizter	M. M. Kasliwal	IR photometry
JVLA	A. Horesh	Radio
CARMA	A. Horesh	Radio
Swift	M. M. Kasliwal & Y. Cao	X-ray / UV photometry and spectroscopy
HST	A. Gal-Yam & S. R. Kulkarni	UV spectroscopy

(Cao in prep.)

iPTF Transient Surveys Science Performance

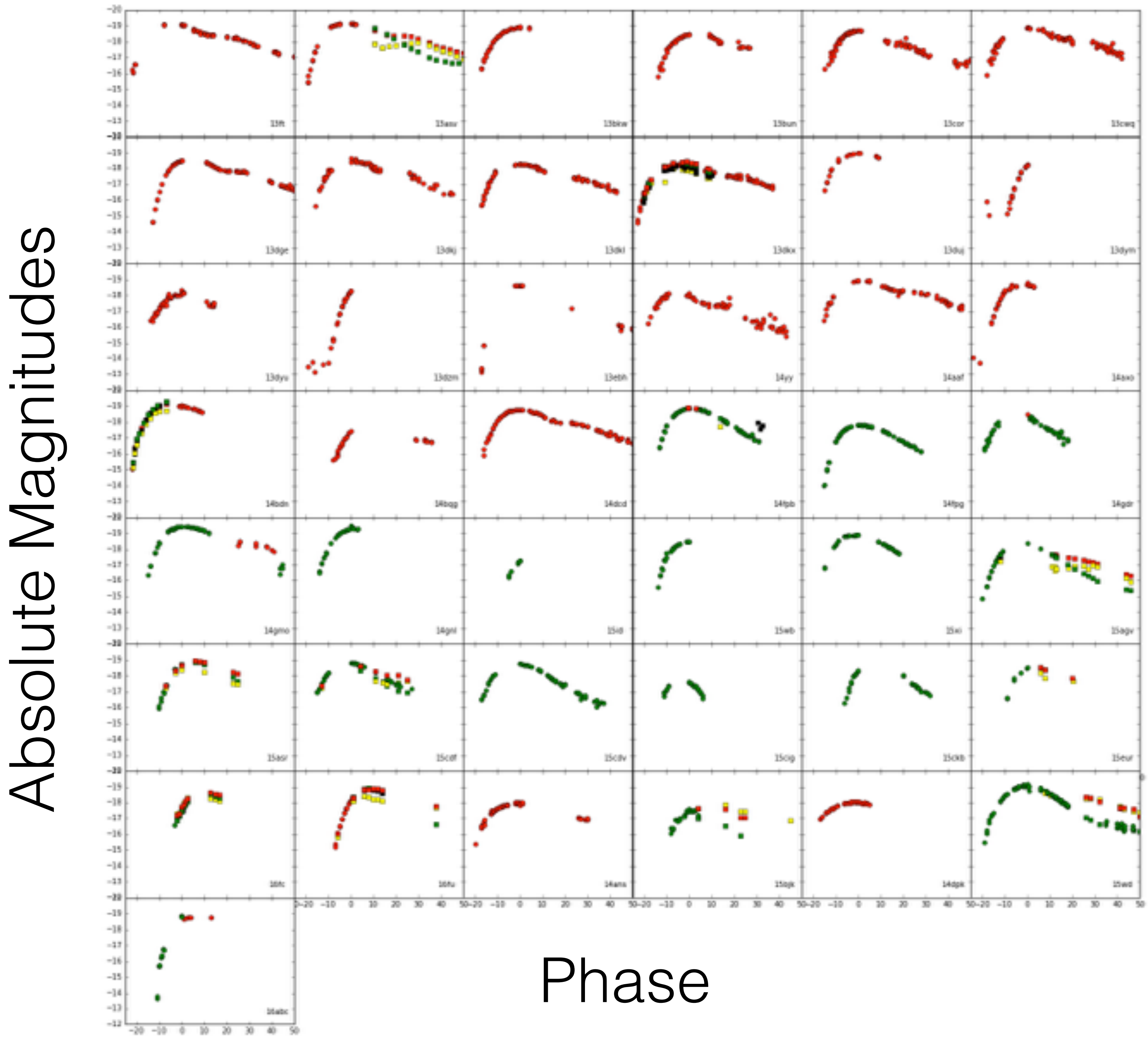


Discovery - Last Upper Limit (days)

1st Spec.Obs. - Discovery (days)

(Cao in prep.)

Gallery of young SNe Ia light curves



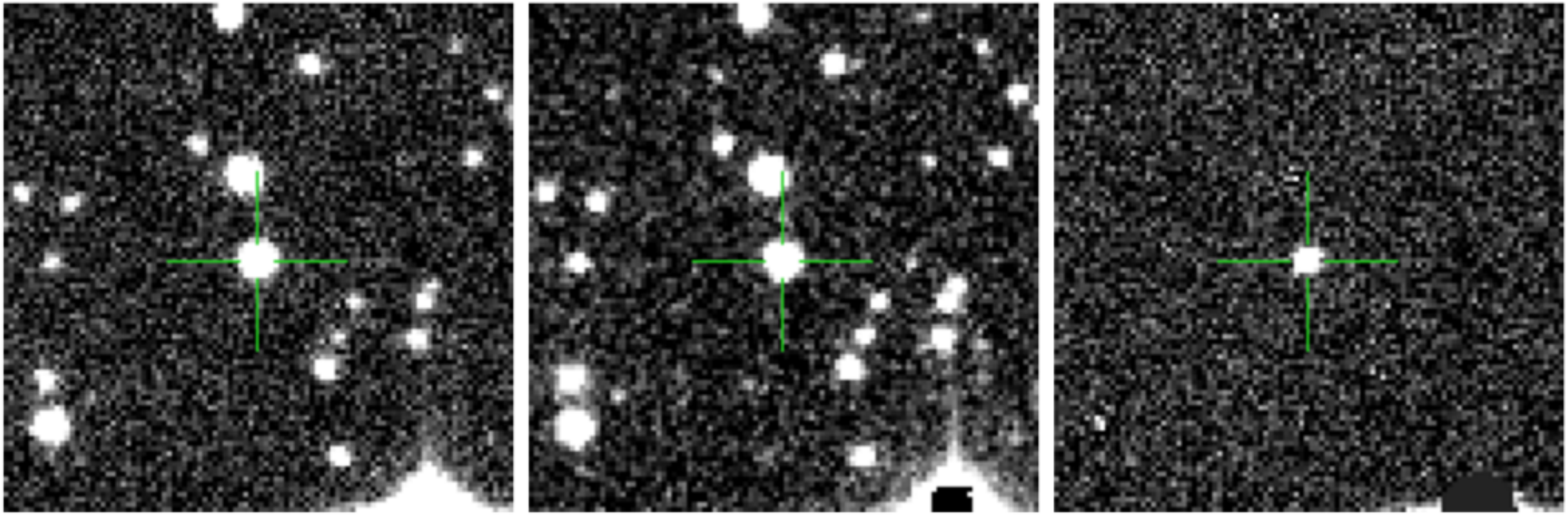
Publications of young SNe and fast-evolving transients

Table 2.4. iPTF publications on infant SNe and fast transients

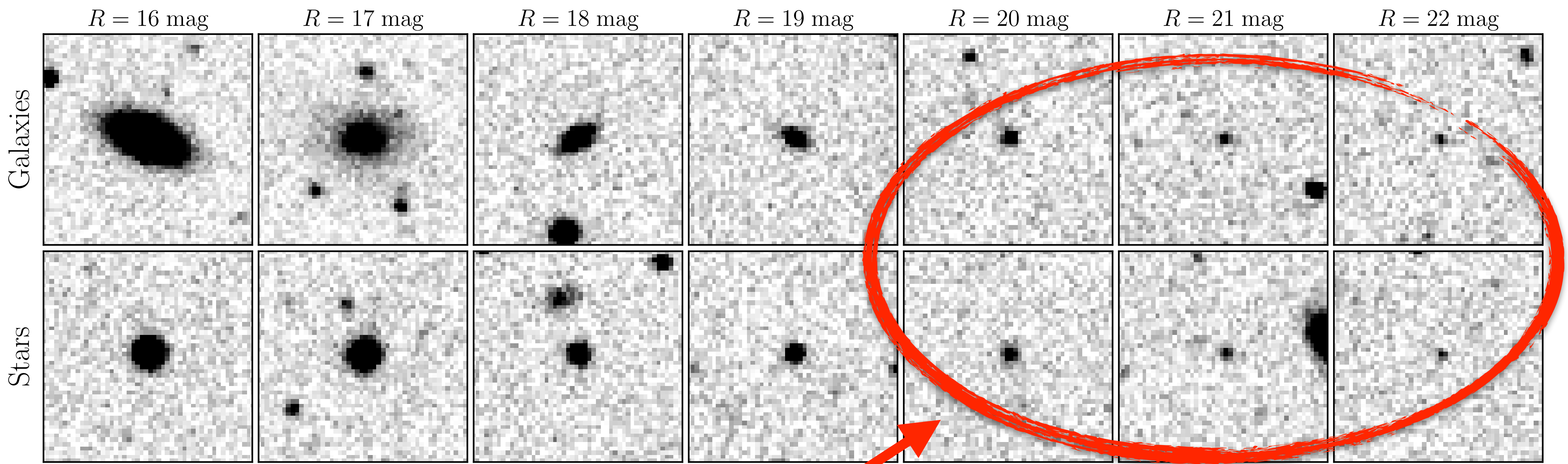
Objects	Publications	Titles
57 Type II Supernovae	Rubin *et al.* (2016)	Type II Supernova Energetics and Comparison of Light Curves to Shock-cooling Models
84 Type II Supernovae	Khazov *et al.* (2016)	Flash Spectroscopy: Emission Lines from the Ionized Circumstellar Material around $<$ 10-day-old Type II Supernovae
iPTF14atg	Cao *et al.* (2015)	A strong ultraviolet pulse from a newborn type Ia supernova
iPTF13ebh	Hsiao *et al.* (2015)	Strong near-infrared carbon in the Type Ia supernova iPTF13ebh
iPTF14yb	Cenko *et al.* (2015)	iPTF14yb: The First Discovery of a Gamma-Ray Burst Afterglow Independent of a High-energy Trigger
iPTF13beo	Gorbikov *et al.* (2014)	iPTF13beo: the double-peaked light curve of a Type Ibn supernova discovered shortly after explosion
iPTF13ast	Gal-Yam *et al.* (2014)	A Wolf-Rayet-like progenitor of SN 2013cu from spectral observations of a stellar wind
iPTF13bvn	Fremling *et al.* (2014)	The rise and fall of the Type Ib supernova iPTF13bvn. Not a massive Wolf-Rayet star
iPTF14jj	Goobar *et al.* (2014)	The Rise of SN 2014J in the Nearby Galaxy M82
iPTF13bvn	Cao *et al.* (2013a)	Discovery, Progenitor and Early Evolution of a Stripped Envelope Supernova iPTF13bvn

Recent progress

Uncatalogued stars



PTF Star-Galaxy Separation

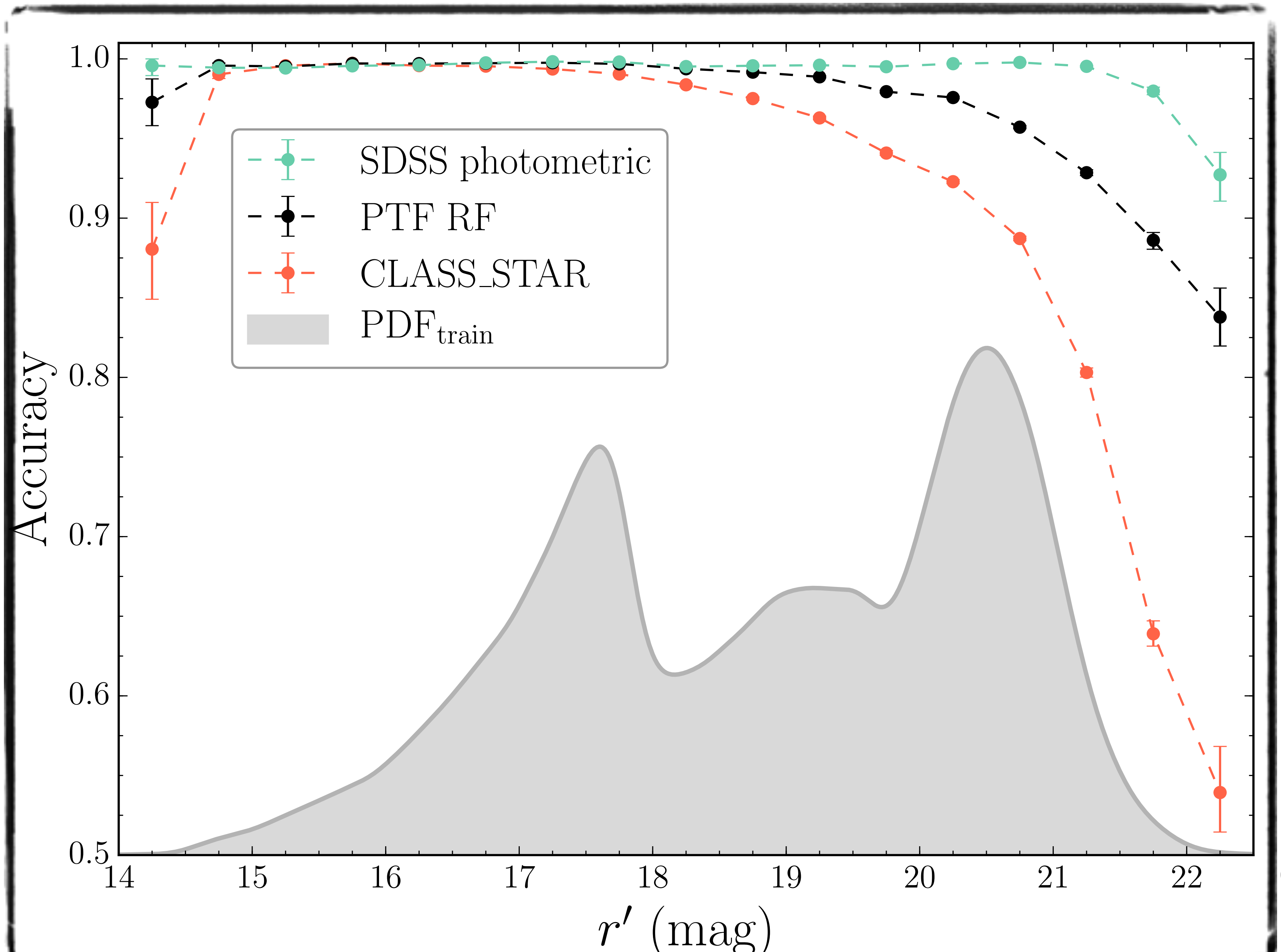


While scanning,
impossible to tell faint stars from faint galaxies

(Miller et al. in prep.)

PTF Star-Galaxy Separation

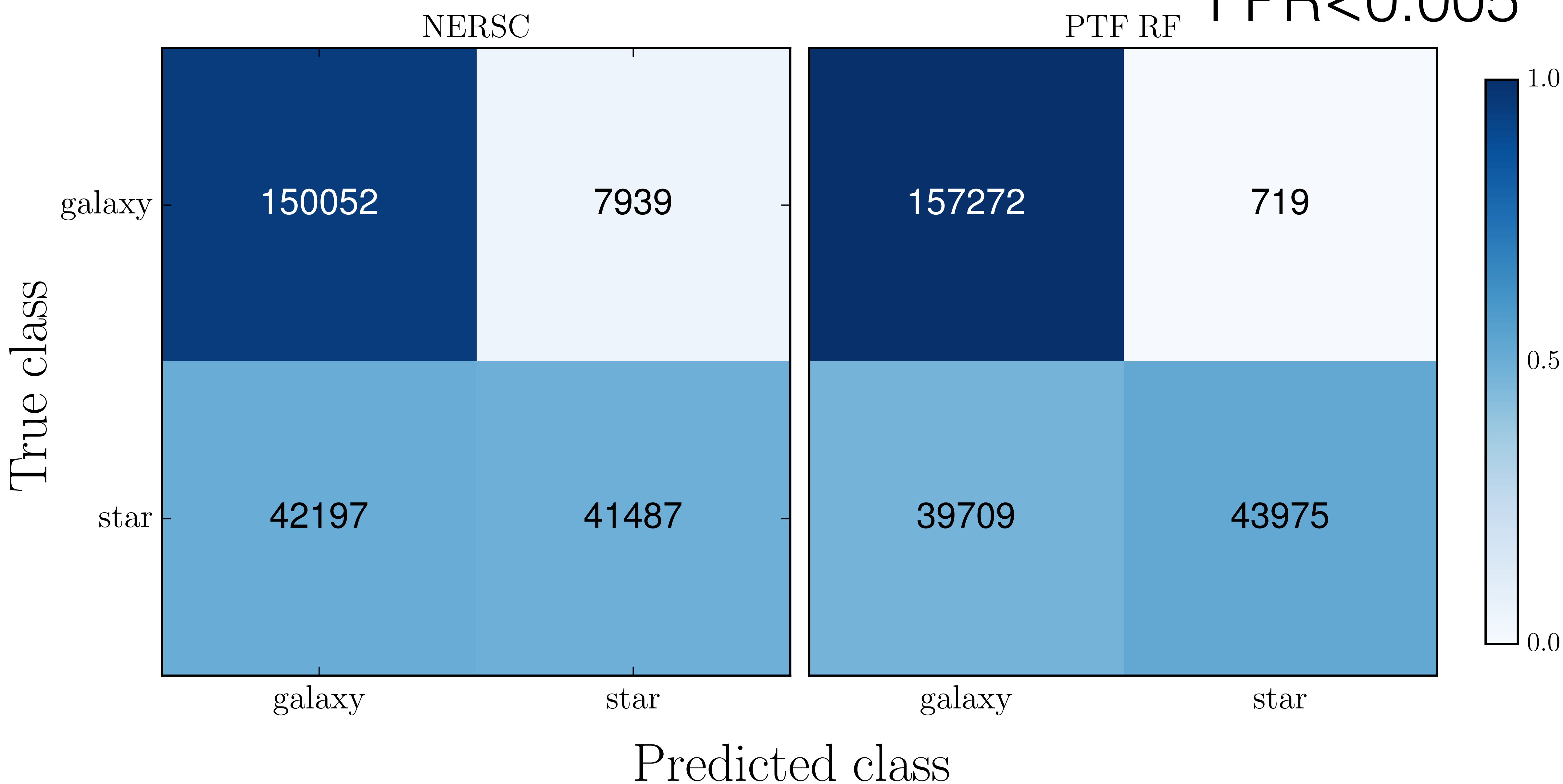
- Random Forest machine-learning model
- training set: ~3M SDSS spec
- training features: SExtractor params (r_{petro}, elongation, FWHM, etc)
- $SDSS_{photo}$ >> PTF RF >> SExtractor



(Miller et al. in prep.)

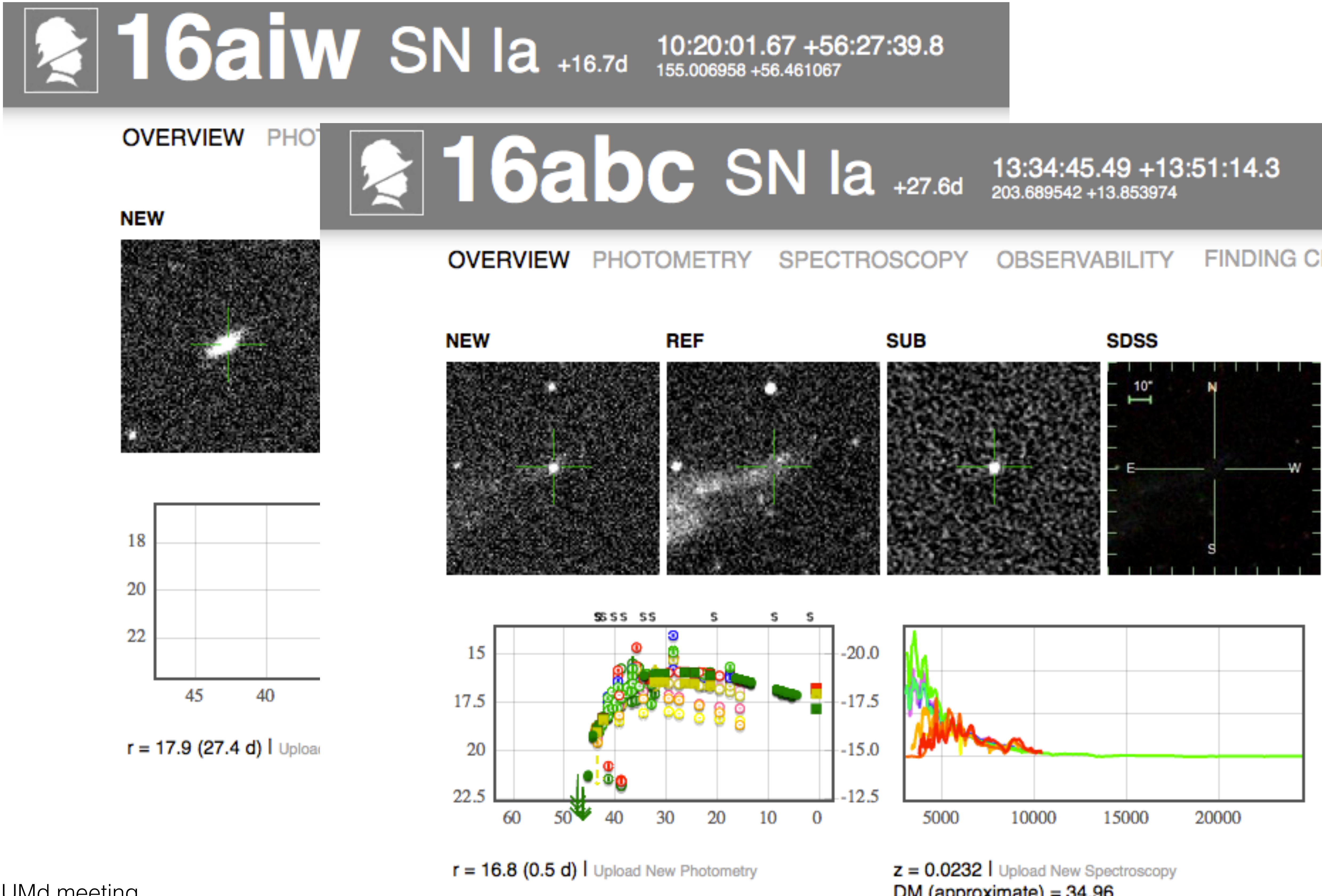
NERSC vs. PTF RF

FPR<0.005

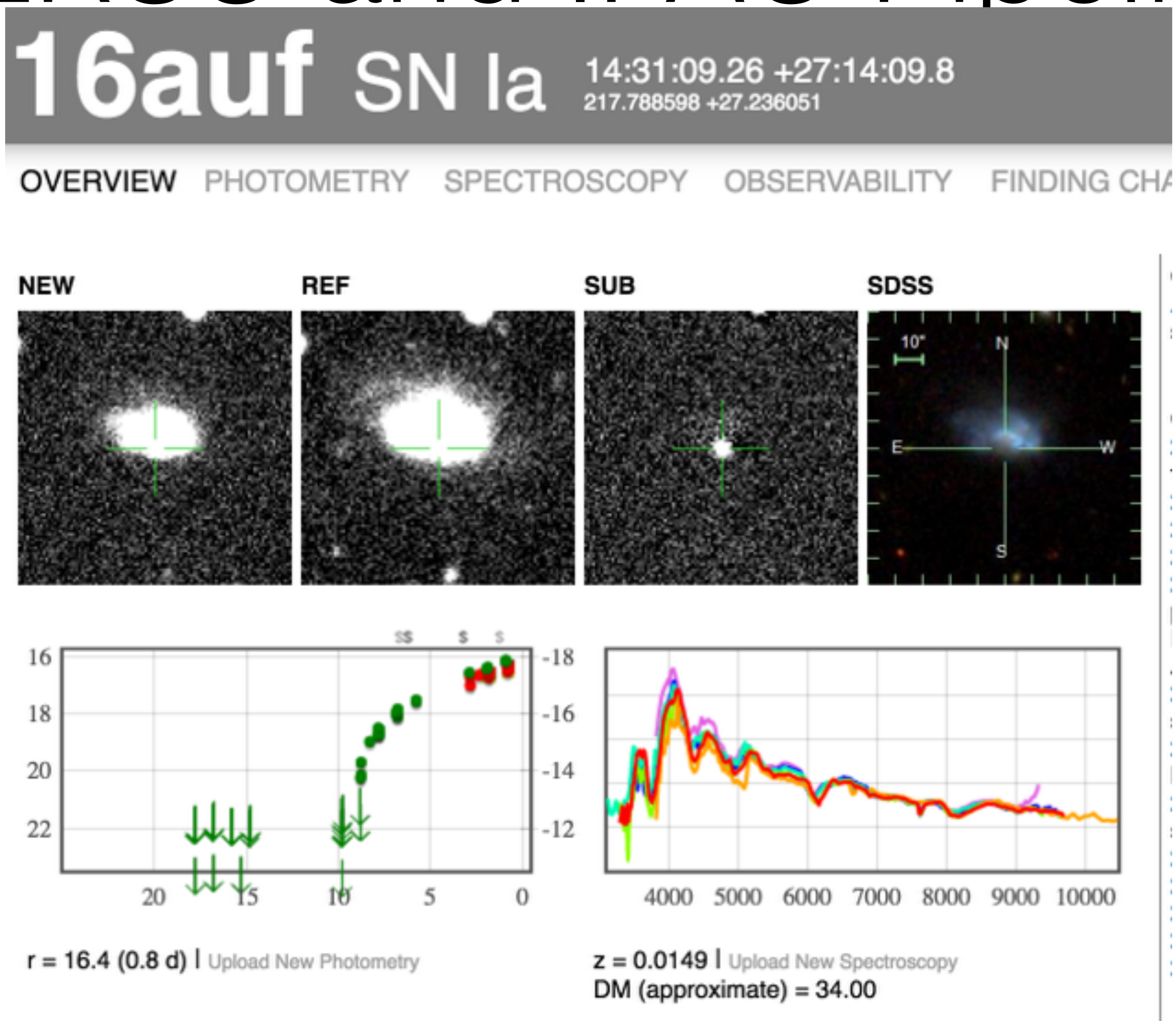


IPAC Scanning Pages

Notable Discoveries



a Young SN Missed by Both NERSC and IPAC Pipeline



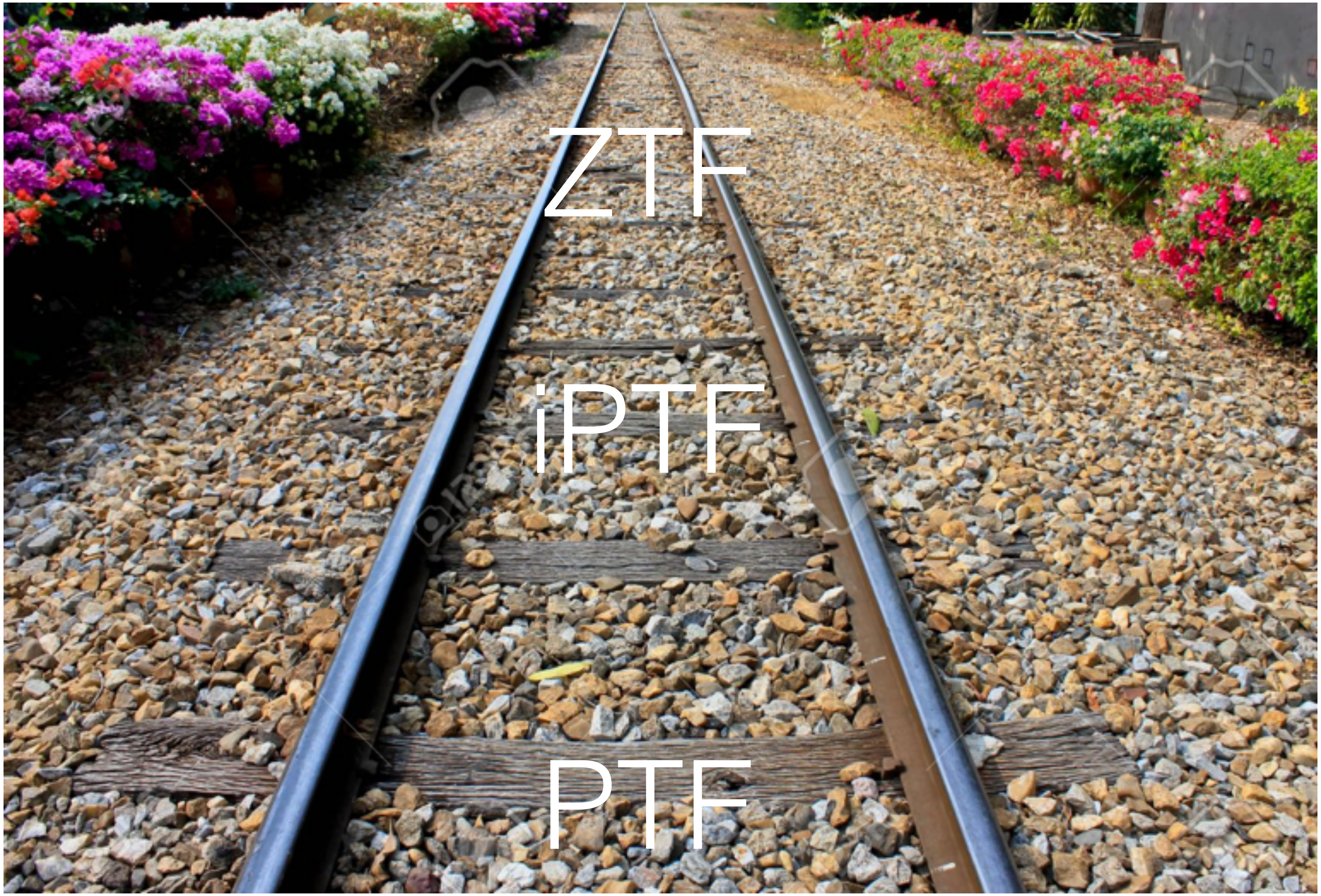
Conclusion

- Despite unfriendly weather, we managed to strictly control our fast cadences in the transient surveys.

- The NERSC pipeline was able to deliver transient candidates within ten minutes of images being taken.

- We found over 100 young supernovae, 49 of which acquired same-night or next-night spectroscopic observations following discovery.

- The PTFIDE realtime image differencing pipeline and the new star-galaxy classifier will hopefully increase our efficiency further.


ZTF
iPTF
PTF


THANK YOU!