NEIL GEHRELS MEMORIAL SYMPOSIUM

ZWICKY TRANSIENT FACILITY

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How my scientific journey lead to Neil Gehrels

- V. Kalogera told us yesterday about Neil's direct engagement in the LIGO Scientific Collaboration (LSC). It was in this context that I first encountered Neil Gehrels.

- I started my Ph.D. in 2009, joining Caltech LIGO Laboratory to work for Alan Weinstein's group on real-time GW data analysis to support rapid EM follow-up.

- Neil joined the LSC in 2011. Starting shortly before this date I have strong memories of his talks at LSC meetings. At these meetings, his passionate advocacy for LIGO open data wildly successful *Swift* style resonated with me.

How my scientific journey lead to Neil Gehrels

- In 2012, I joined Palomar Transient Factory to work on multimessenger targets of opportunity, beginning with Fermi GRBs as a sort of dress rehearsal for LIGO counterpart searches (more on this shortly).

- It was only in the last two years of my Ph.D. that I started to realize who Neil was to the high-energy astronomy community, and from talking with Brad Cenko and with Neil's immediate former postdoc Jonah Kanner how supportive he was as a mentor.

- When Neil and Brad encouraged me to come to GSFC as a NASA Postdoctoral Program fellow in 2014, it was obvious to me that it was the right path.

How my scientific journey lead to Neil Gehrels

- I was one of Neil’s postdocs for two years, 2015–2016 (now a civil servant in the same lab).
- With Neil’s encouragement, the subject of the paper with Neil that John Cannizzo mentioned yesterday, on galaxy strategies for GW follow-up, became a theme of my research.
- During this time, I served LIGO/Virgo helping to coordinate its EM alert program. Sharing the excitement and challenges of the first GW detections with him, I looked to his ability to bring people together with a smile as a model.

Jonah Kanner:

“You know, we were lucky to see GW170817 when and where we did. We don’t really know yet, but its likely that such close by BNS mergers will prove to be rare. The sky position and time of day were such that many of the world’s best instruments were able to find and observe the counterpart within the first day. If this particular merger had come a half hour earlier or later, the prompt gamma-rays (and maybe the whole thing) may have been missed. The data are spectacular, and in some ways, feel just a little too good to be true - at least by chance. This is whimsical, but I can’t help but imagine that on his way out, Neil’s spirit gave a couple of neutron stars just a little nudge. One last gift for the astrophysics community, after a life of so many.”

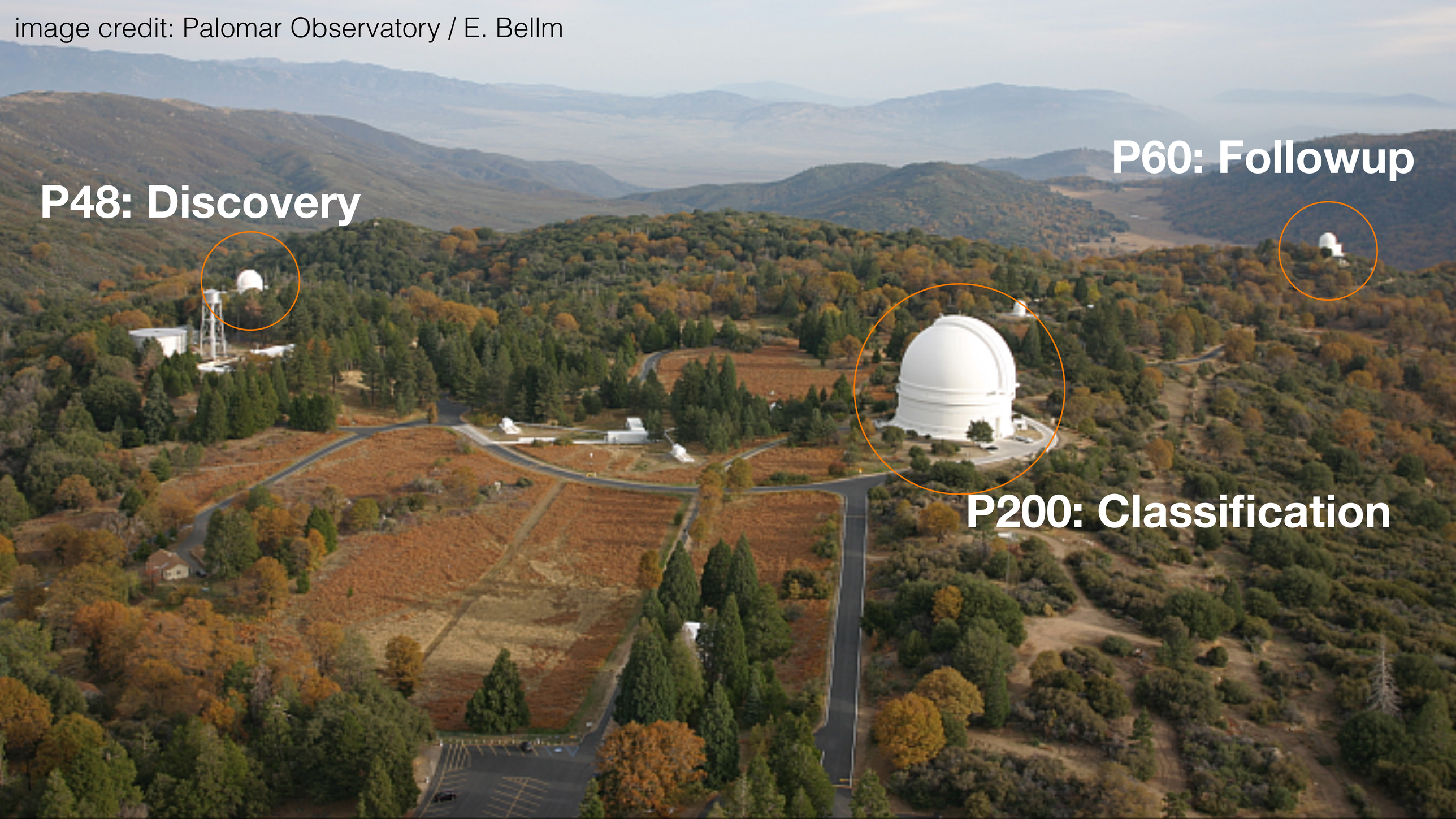
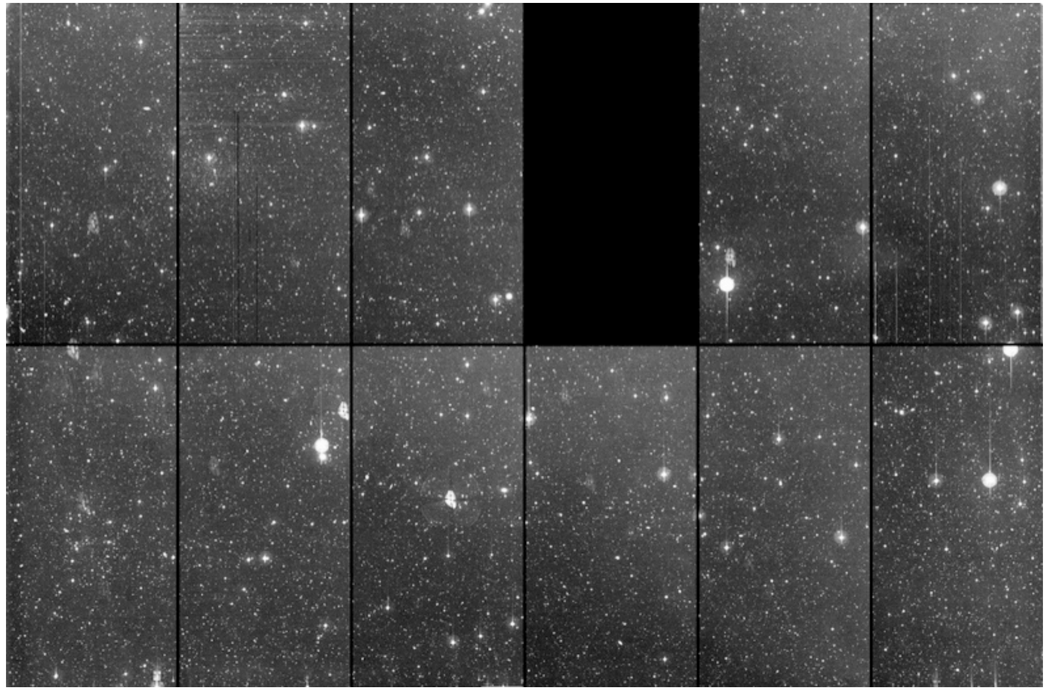


image credit: Palomar Observatory / E. Bellm
P48: Discovery
P60: Followup
P200: Classification

Palomar Transient Factory

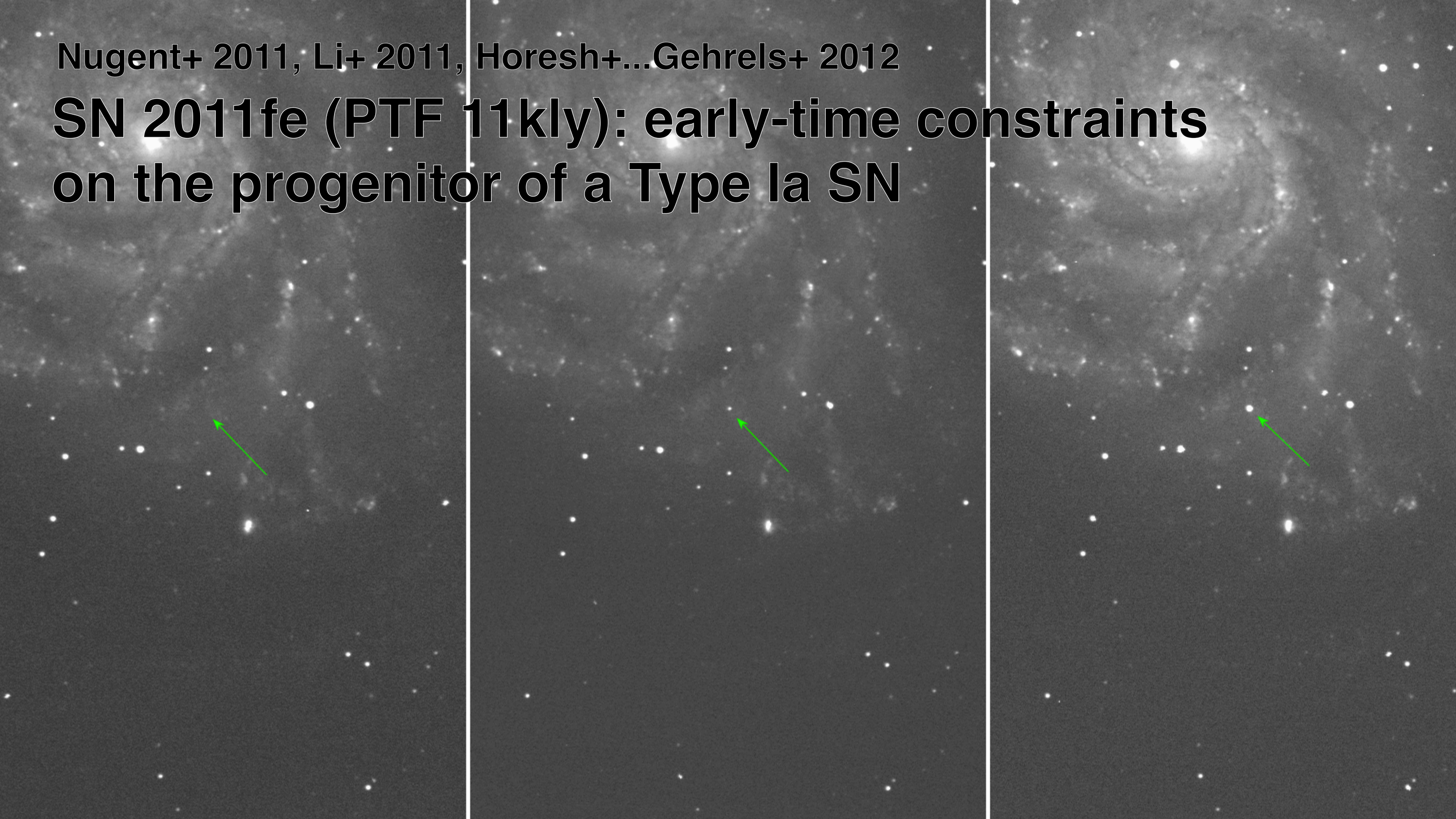


P48 Discovery, ≈7 deg^2, R≈20.6 in 60 s
P60 Robotic, photometric follow-up (*BVgriz*)
P200 Spectroscopy, classification
Keck, **Gemini**, **LCOGT** follow-up programs

- Maintain high survey cadence w/ limited filter set: *R*, *g*'
- Deep co-added reference images over most of accessible sky
- Real-time image subtraction, source extraction, and machine-learning pipeline provides discovery stream
- Marshals: database/web apps organize resources and data around broad science areas (galactic, extragalactic, TOO)
- Team of duty astronomers selects most interesting targets and orchestrates follow-up
- On-call team to follow up targets of opportunity (e.g. GRBs, GW events)
- Transformative capability to do early spectroscopy of supernovae (e.g. Gal-Yam+ 2014)

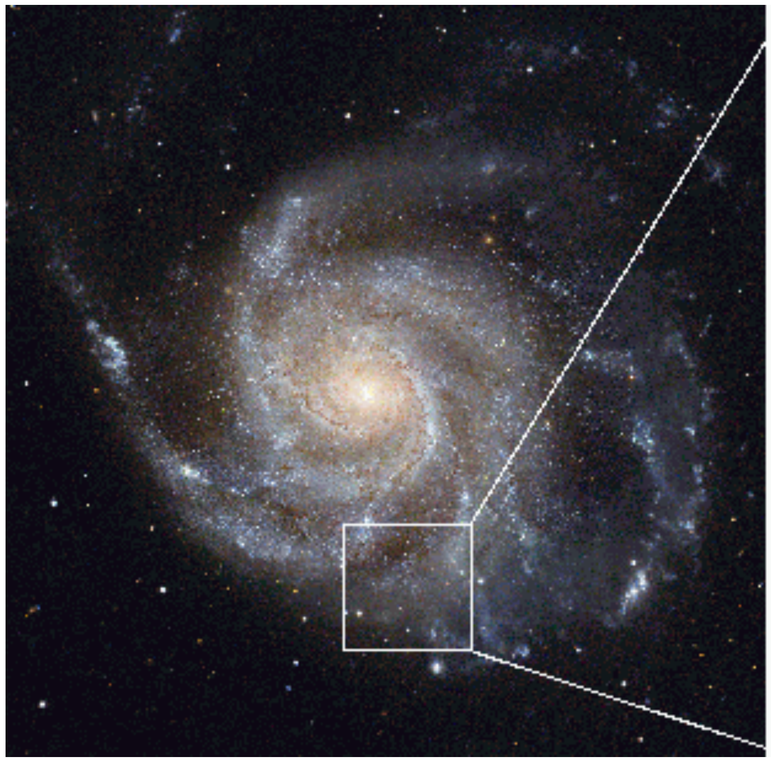
Nugent+ 2011, Li+ 2011, Horesh+...Gehrels+ 2012

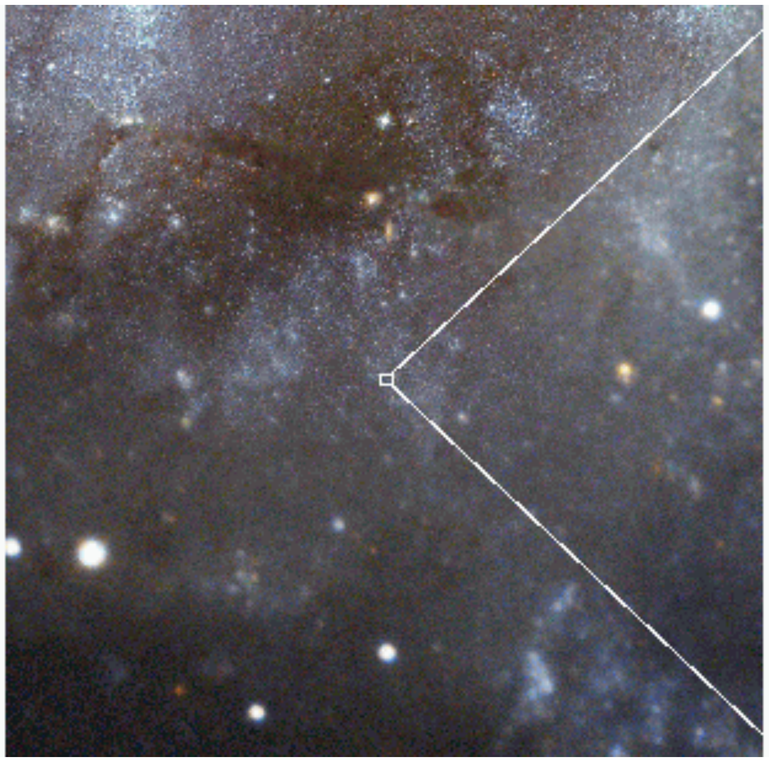
SN 2011fe (PTF 11kly): early-time constraints on the progenitor of a Type Ia SN

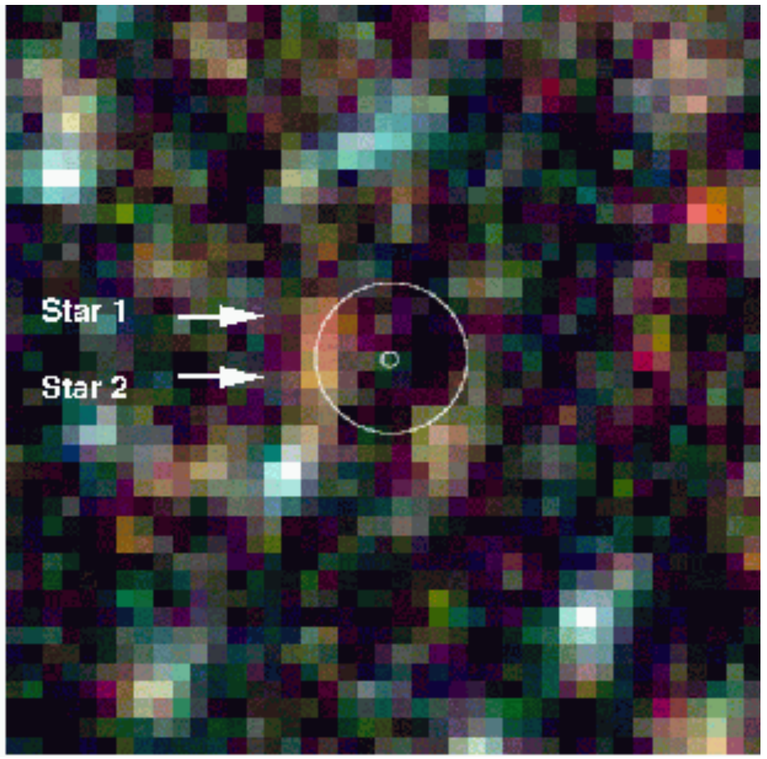


Nugent+ 2011, Li+ 2011, Horesh+...Gehrels+ 2012

SN 2011fe (PTF 11kly): early-time constraints on the progenitor of a Type Ia SN







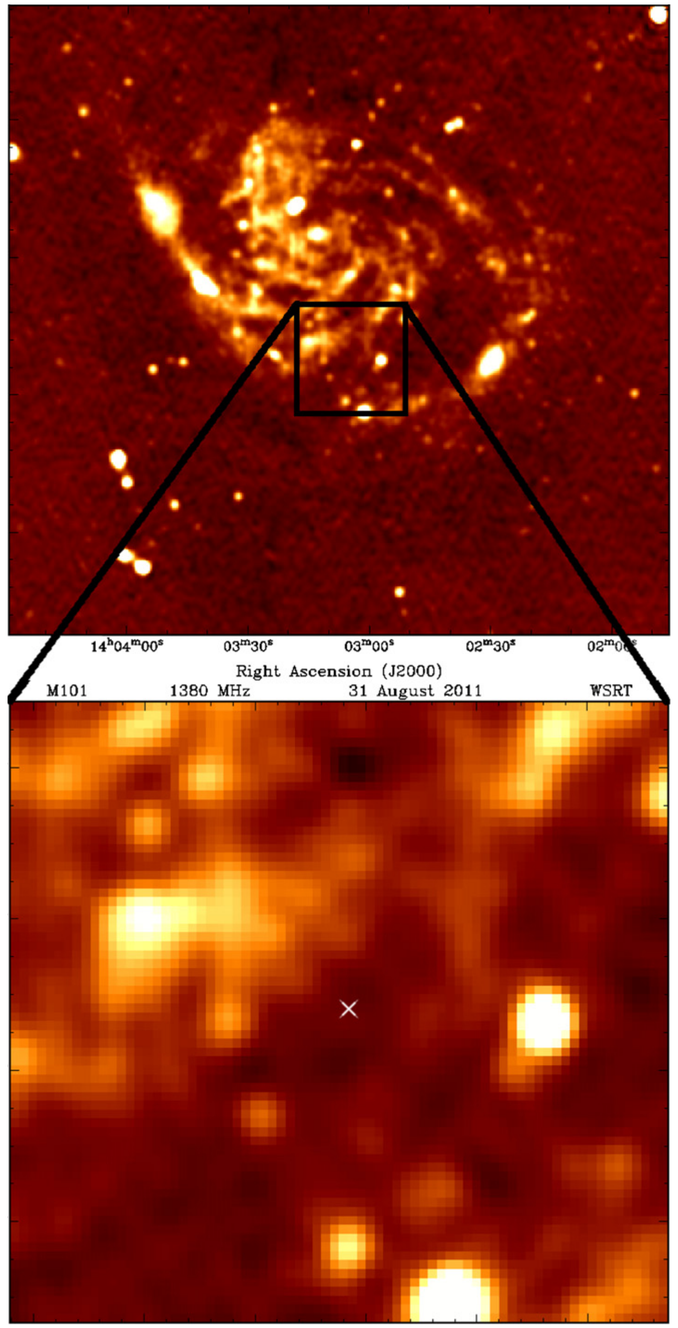
Nugent+ 2011, Li+ 2011, Horesh+...Gehrels+ 2012

SN 2011fe (PTF 11kly): early-time constraints on the progenitor of a Type Ia SN

- Type Ia supernova in M101 at 6.4 Mpc
- Detected by PTF just over 11 hours after explosion
- X-ray follow-up with *Swift* started just a day after explosion, also *Chandra* and radio follow-up with CARMA, EVLA, WSRT

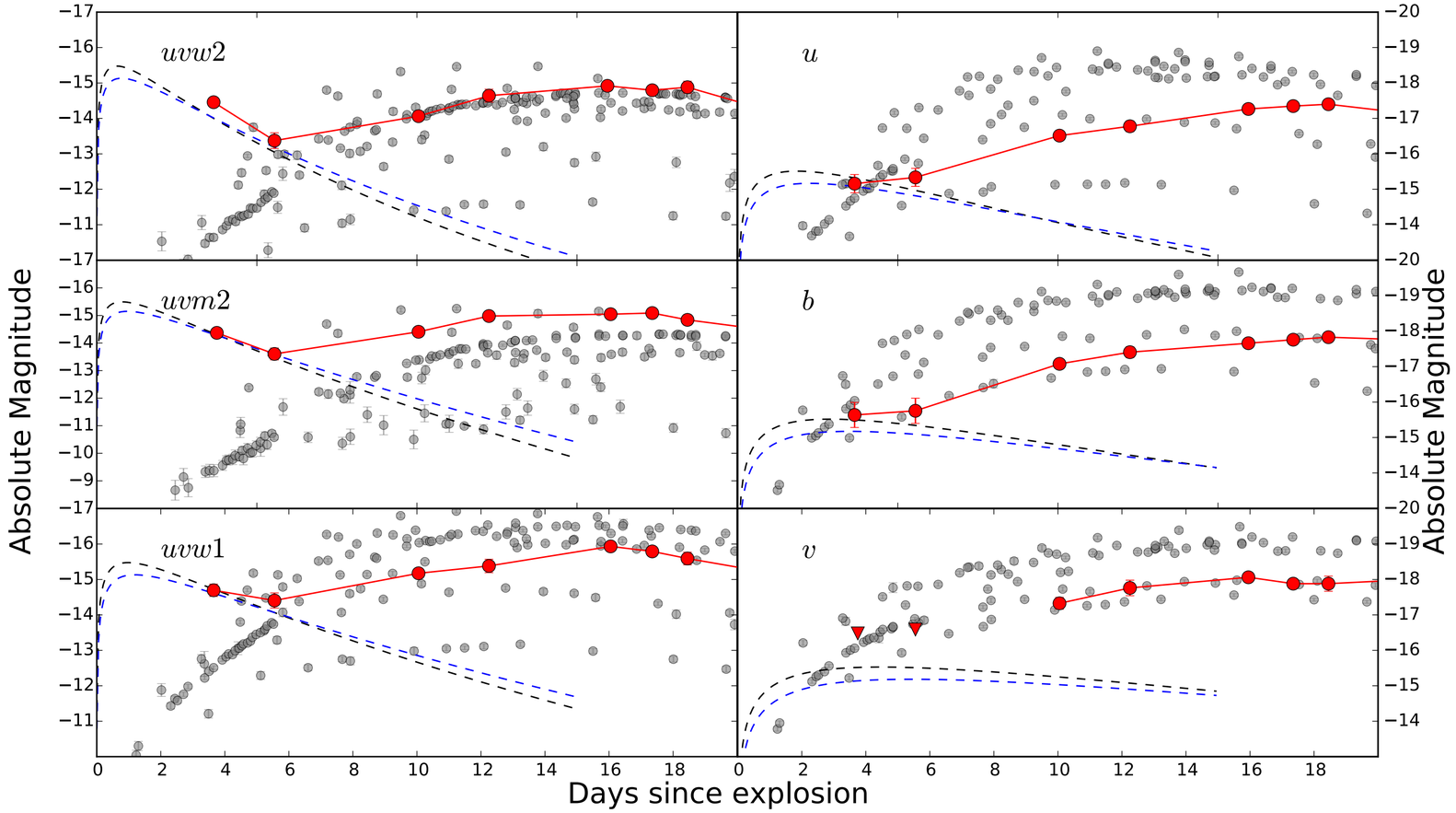
- Ruled out red giant donor and favored main sequence or WD companion due to:

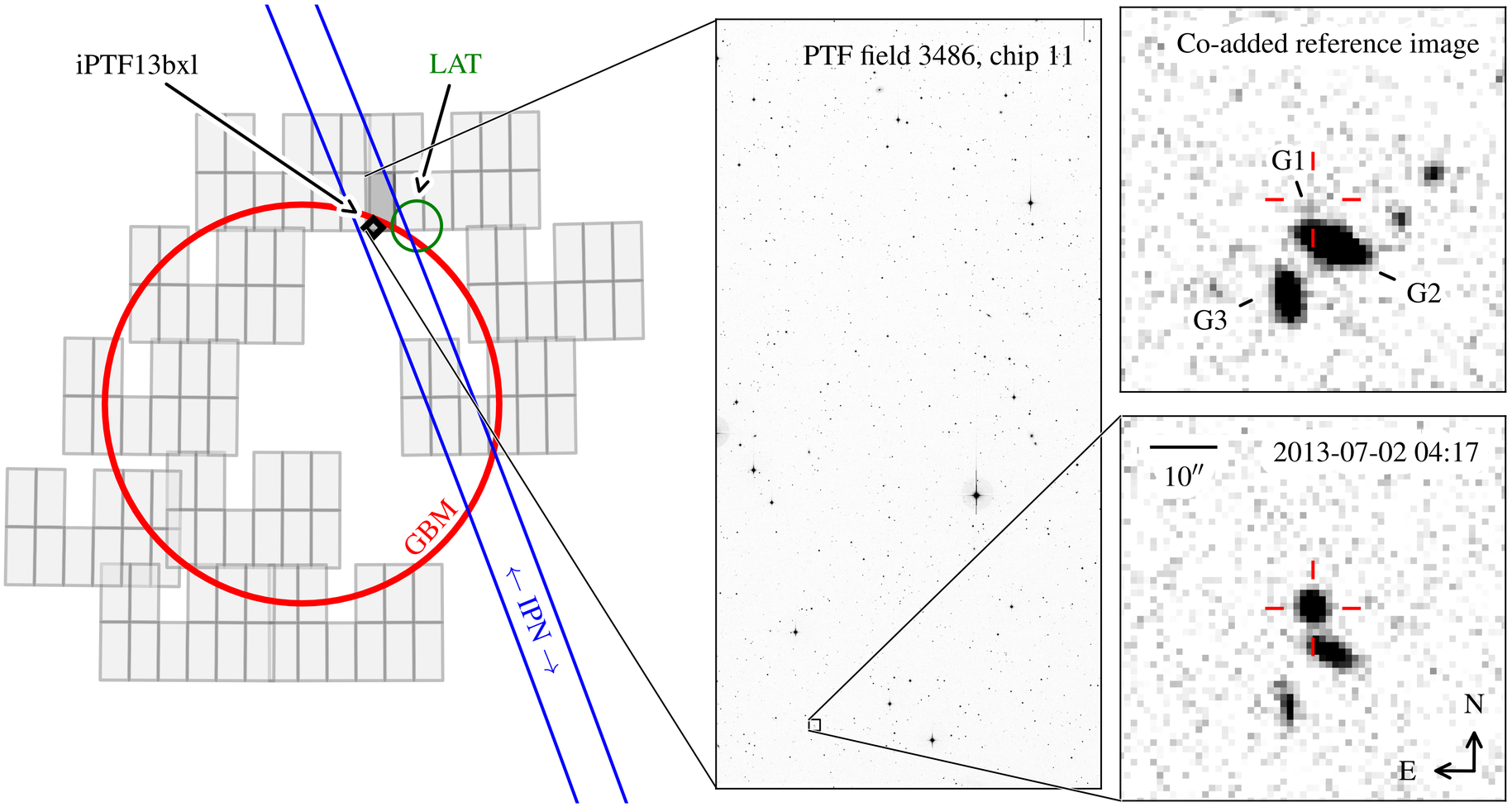
1. Early time photometry and spectroscopy
2. Pre-explosion limits from HST
3. X-ray and radio constraints on mass loss rate



Cao+ 2014

iPTF14atg: ruling out the doubly degenerate channel



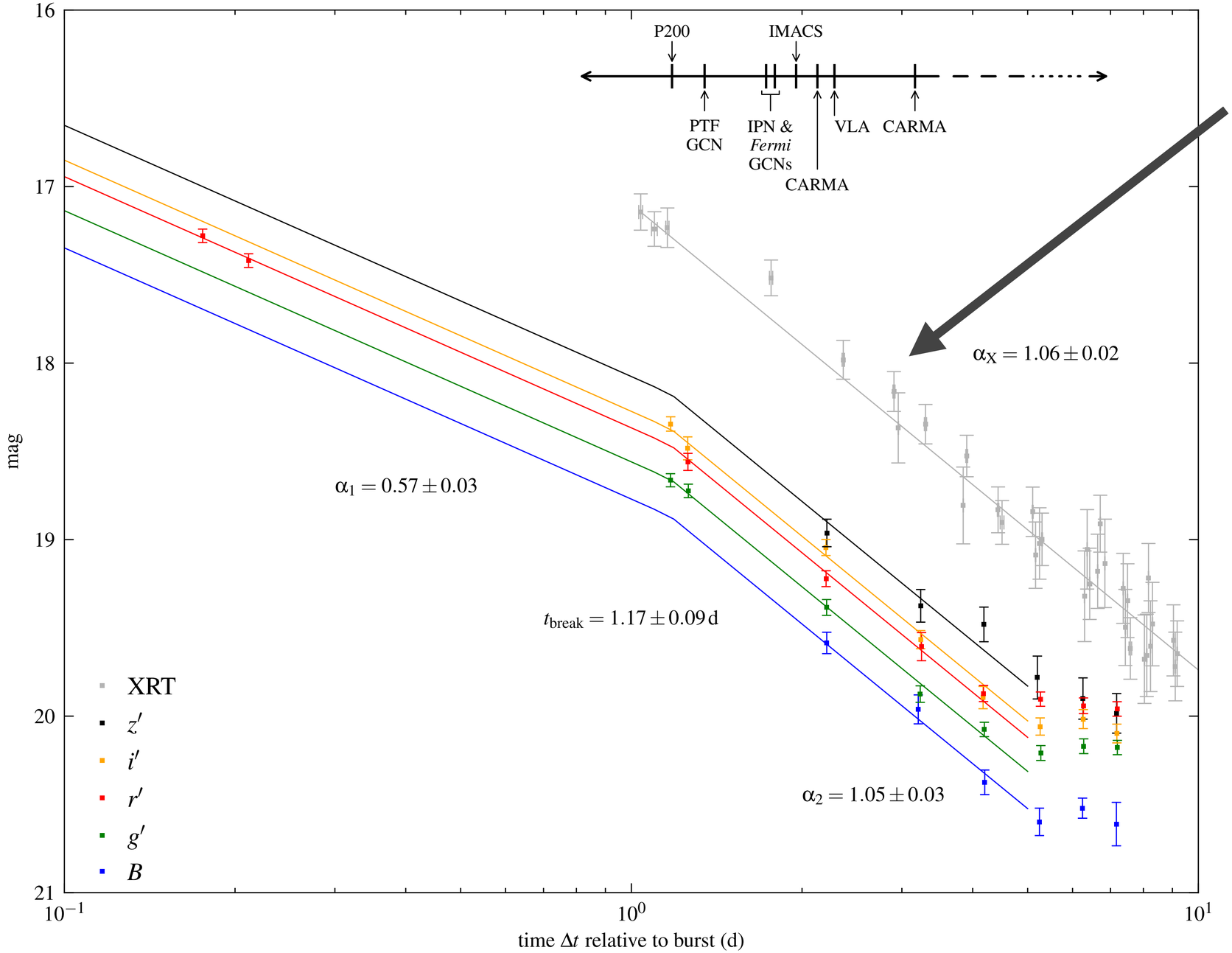


Discovery & redshift of a an optical afterglow in 71 deg^2

Singer et al. 2013, ApJL
arXiv:1307.5851

Confirmation by rapidly fading X-ray emission from *Swift* XRT + blue featureless optical spectrum, and eventual IPN triangulation

- Low redshift: z = 0.145. Energetics bridge gap between “standard” GRBS and llGRBs.
- iPTF13bxl / GRB 130702A = SN 2013dx! Detailed spectroscopy of SN: D’Elia, Toy + Cenko
- Low-metallicity dwarf satellite of a higher-metallicity host Kelly+ 2013
- First clear identification of a galaxy cluster or group containing a GRB host D’Elia+ 2015
- Search for other SNe associated with *Fermi* GBM bursts Kovacevic+ 2014
- LAT-detected burst at low redshift → search for TeV emission with HAWC (Woodle 2015)



Swift XRT light curve

Confirmation by rapidly fading X-ray emission from *Swift* XRT + blue featureless optical spectrum, and eventual IPN triangulation

The needle in the haystack

127,676 optical transient candidates in difference images

78,951 not coincident with point source in reference image (rejects stellar sources)

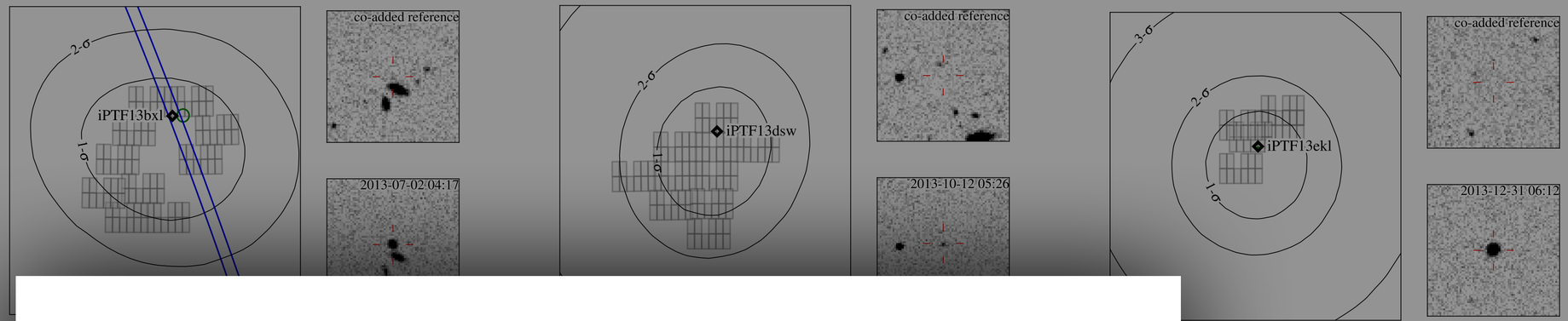
15,624 detected in two images separated by >30 minutes (rejects main belt asteroids)

5,803 passed strict machine-learning real-bogus cut

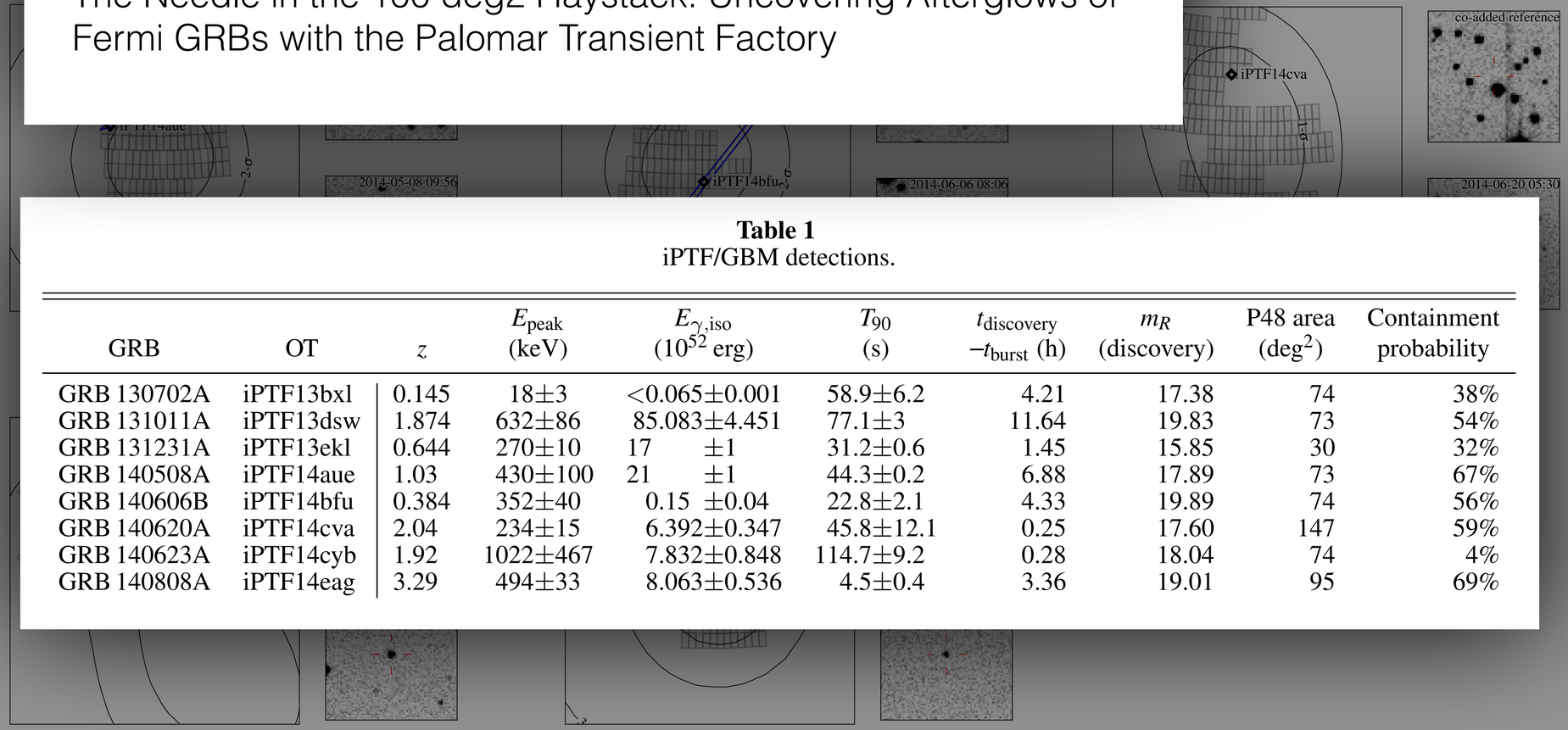
1,007 coincident with nearby galaxy (<200 Mpc)

13 candidates selected by human vetting of light curve properties and archival analysis

8 had no history of prior variability in PTF archive



B 131231A / iPTF13ekl



GRB 140623A / iPTF14cyb

GRB 140808A / iPTF14eag

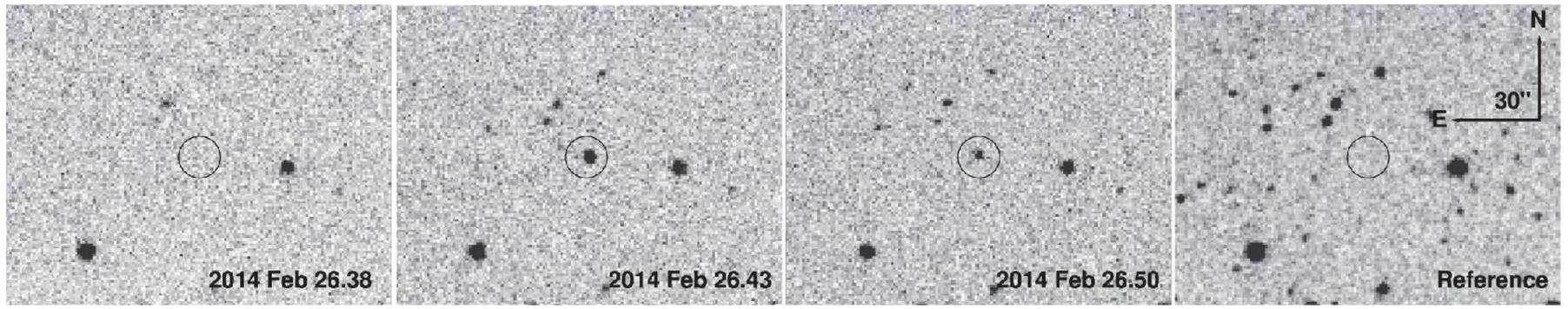
Singer+ 2015, ApJ, 806, 52

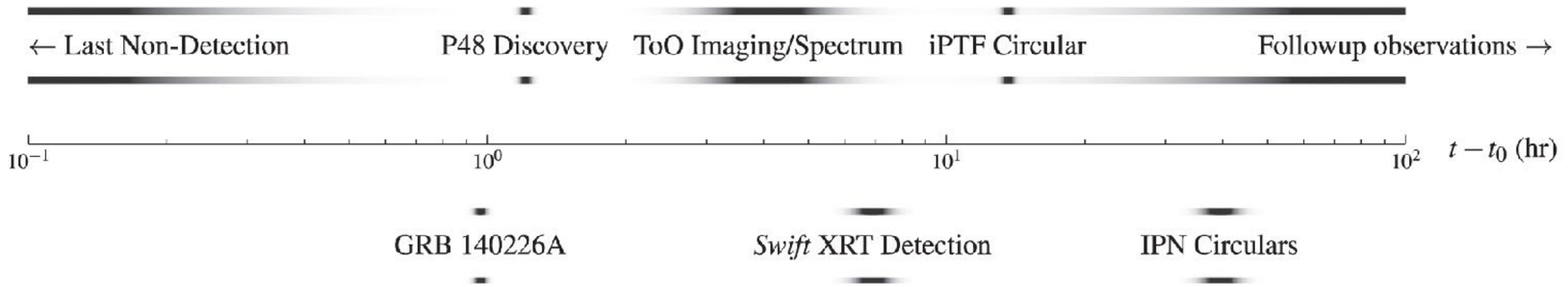
The Needle in the 100 deg2 Haystack: Uncovering Afterglows of Fermi GRBs with the Palomar Transient Factory

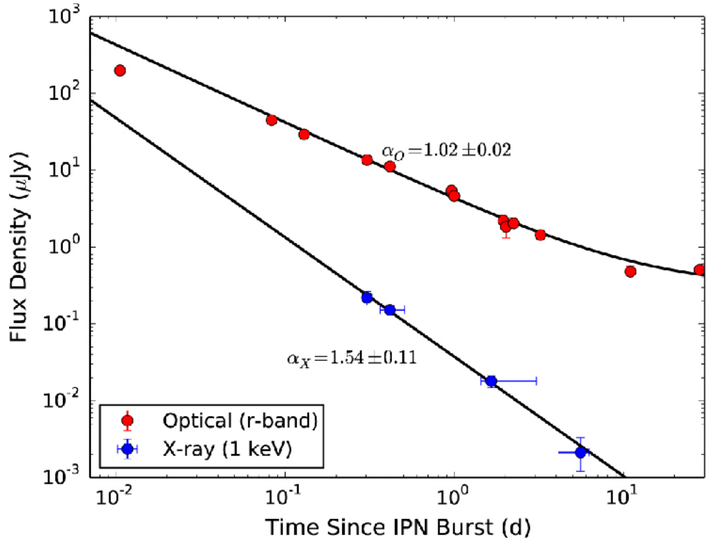
Table 1
iPTF/GBM detections.

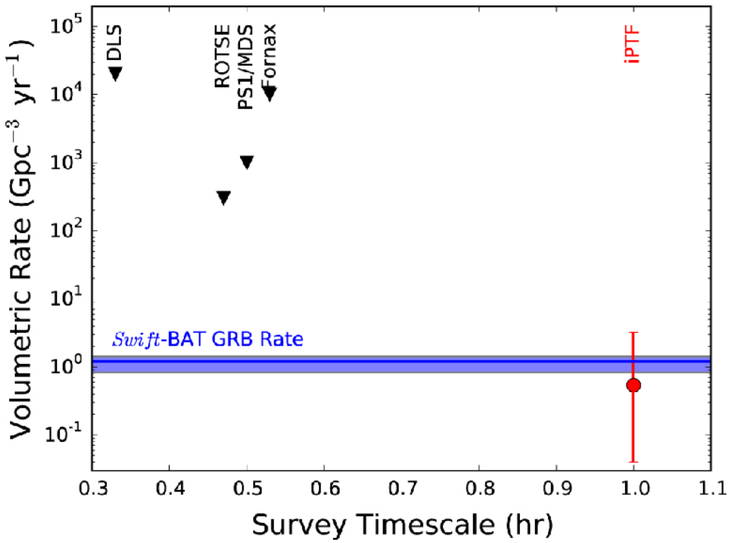
GRB	OT	z	$E_{\rm peak}$ (keV)	$E_{\gamma,\rm iso}$ (10^{52} erg)	T_{90} (s)	$t_{\rm discovery} - t_{\rm burst}$ (h)	m_R (discovery)	P48 area (deg^2)	Containment probability
GRB 130702A	iPTF13bxl	0.145	18±3	<0.065±0.001	58.9±6.2	4.21	17.38	74	38%
GRB 131011A	iPTF13dsw	1.874	632±86	85.083±4.451	77.1±3	11.64	19.83	73	54%
GRB 131231A	iPTF13ekl	0.644	270±10	17 ±1	31.2±0.6	1.45	15.85	30	32%
GRB 140508A	iPTF14aue	1.03	430±100	21 ±1	44.3±0.2	6.88	17.89	73	67%
GRB 140606B	iPTF14bfu	0.384	352±40	0.15 ±0.04	22.8±2.1	4.33	19.89	74	56%
GRB 140620A	iPTF14cva	2.04	234±15	6.392±0.347	45.8±12.1	0.25	17.60	147	59%
GRB 140623A	iPTF14cyb	1.92	1022±467	7.832±0.848	114.7±9.2	0.28	18.04	74	4%
GRB 140808A	iPTF14eag	3.29	494±33	8.063±0.536	4.5±0.4	3.36	19.01	95	69%

iPTF14yb: first *optically discovered* GRB afterglow







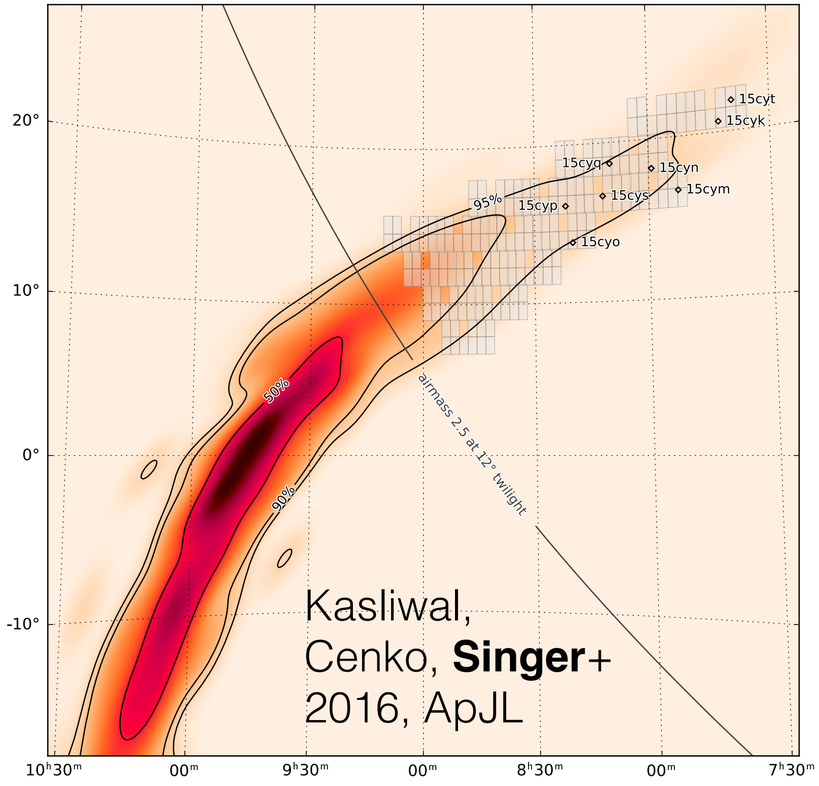


Cenko, Urban+ 2015, A. Urban Ph.D. thesis

Confirmation by rapidly fading X-ray emission from *Swift* XRT + blue featureless optical spectrum, and eventual IPN triangulation

PALOMAR TRANSIENT FACTORY

FOLLOW-UP OF GW150914



TITLE: GCN CIRCULAR
NUMBER: 18337
SUBJECT: LIGO/Virgo G184098: iPTF Optical Transient Candidates
DATE: 15/09/20 01:39:01 GMT
FROM: **Leo Singer at NASA/GSFC** <leo.p.singer@nasa.gov>

[GCN OPS NOTE(19sep15): This Circular was originally published on 03:09 18-Sep-2015 UT.]

L. P. Singer (NASA/GSFC), M. M. Kasliwal (Caltech), S. B. Cenko (NASA/GSFC), V. Bhalerao (IUCAA), A. Miller (Caltech), T. Barlow (Caltech), E. Bellm (Caltech), I. Manulis (WIS), A. Singhal (IUCAA), and J. Rana (IUCAA) report on behalf of the intermediate Palomar Transient Factory (iPTF) collaboration:

We have performed tiled observations of LIGO/Virgo G184098 using the Palomar 48-inch Oschin telescope (P48). We imaged 18 fields spanning 135 deg2. Based on the LIB localization, we estimate a 2.3% prior probability that these fields contain the true location of the source. The small containment probability is because the southern mode of the updated ("LIB") localization was too far south to be observable from Palomar, whereas most of the northern mode rose after 12° twilight.

Sifting through candidate variable sources using image subtraction by both our NERSC and IPAC pipelines, and applying standard iPTF vetting procedures, we flagged the following optical transient candidates for further follow-up:

iPTF15cyo, at the coordinates:
RA(J2000) = 8h 19m 56.18s (124.984069 deg)
Dec(J2000) = +13d 52' 42.0" (+13.878337 deg)

Our P48 photometry includes:
-483 days: R > 20.88
+3 days: R = 17.75 +/- 0.01

The position is consistent with the galaxy SDSS J081956.62+135241.7, whose spectroscopic redshift of z = 0.02963 implies an absolute magnitude for the transient of M_R = -17.8, suggestive of a supernova.

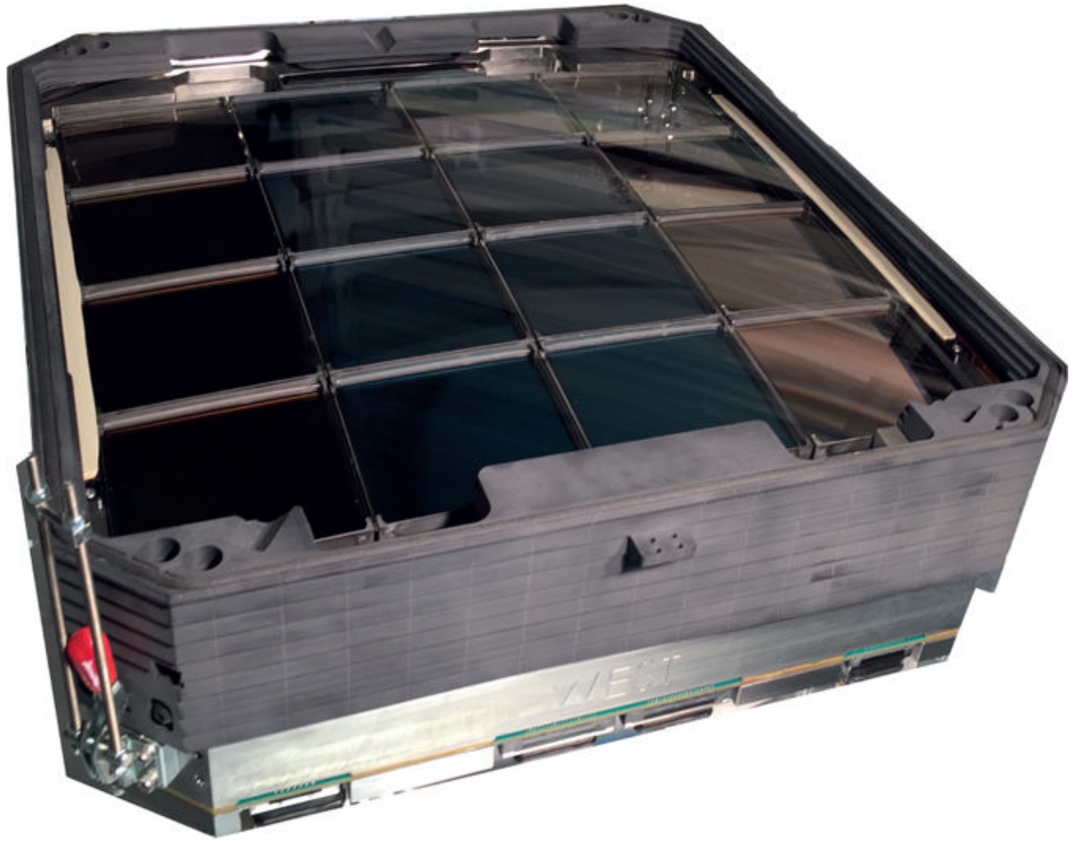
iPTF15cyq, at the coordinates:
RA(J2000) = 8h 10m 00.86s (122.503586 deg)
Dec(J2000) = +18d 42' 18.1" (+18.705039 deg)

. . .

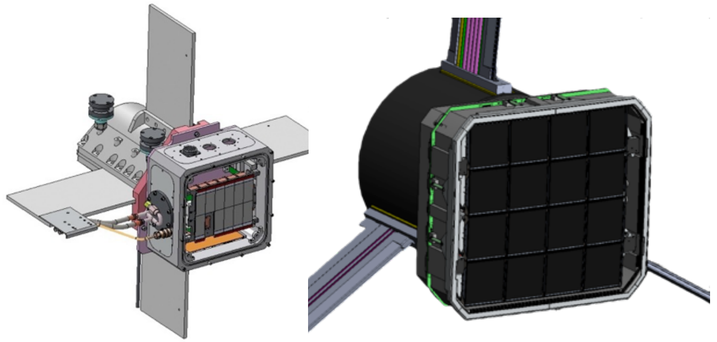
We have obtained Keck II + DEIMOS spectra of all of the above targets. We will report our analyses of these spectra shortly.

Times are relative to the LIGO/Virgo trigger. Magnitudes are in the Mould R filter and in the AB system, calibrated with respect to point sources in SDSS as described in Ofek et al. (2012, http://dx.doi.org/10.1086/664065).

The ZTF Instrument: a 47 deg2 camera on a 1.2m telescope



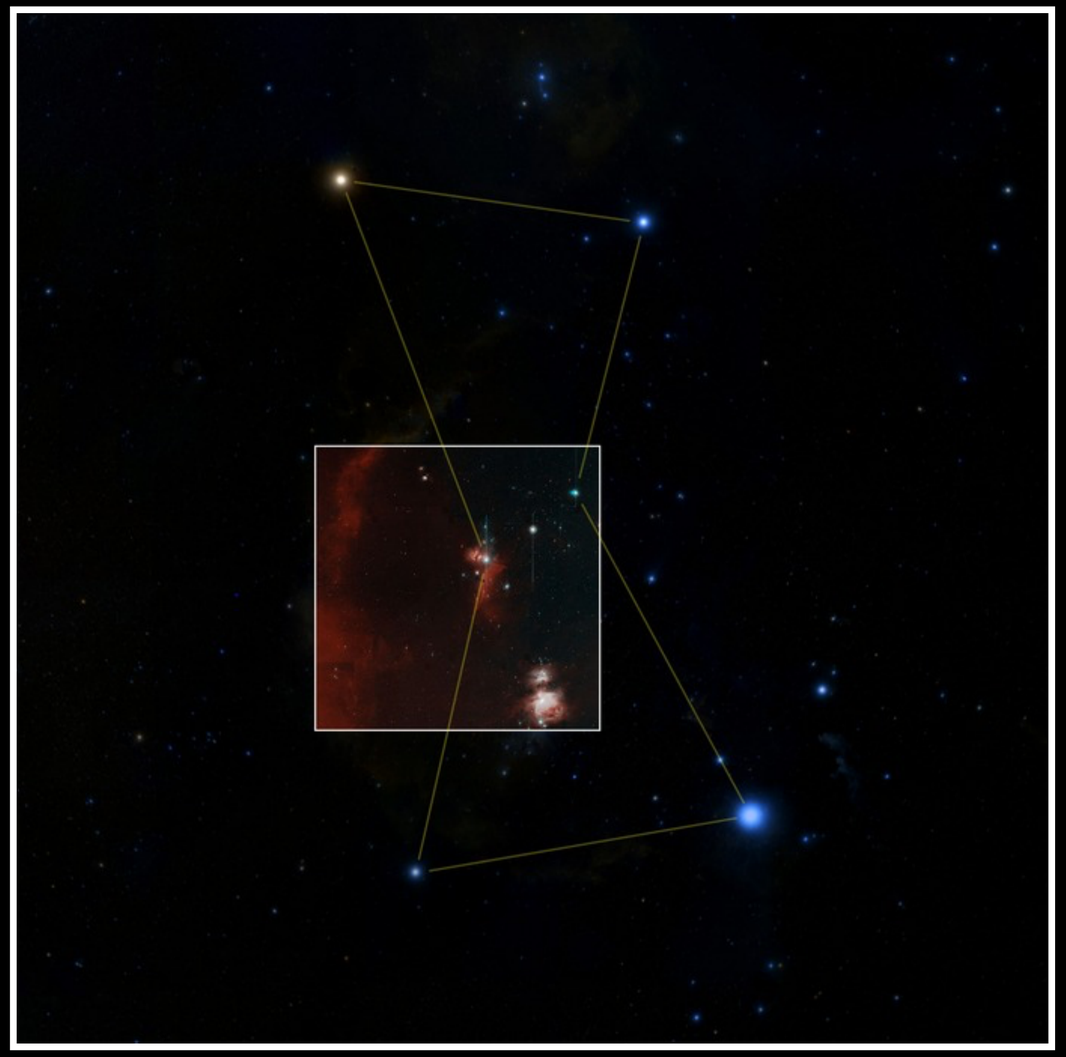
Roger Smith / Michael Feeney, Caltech Optical Observatories



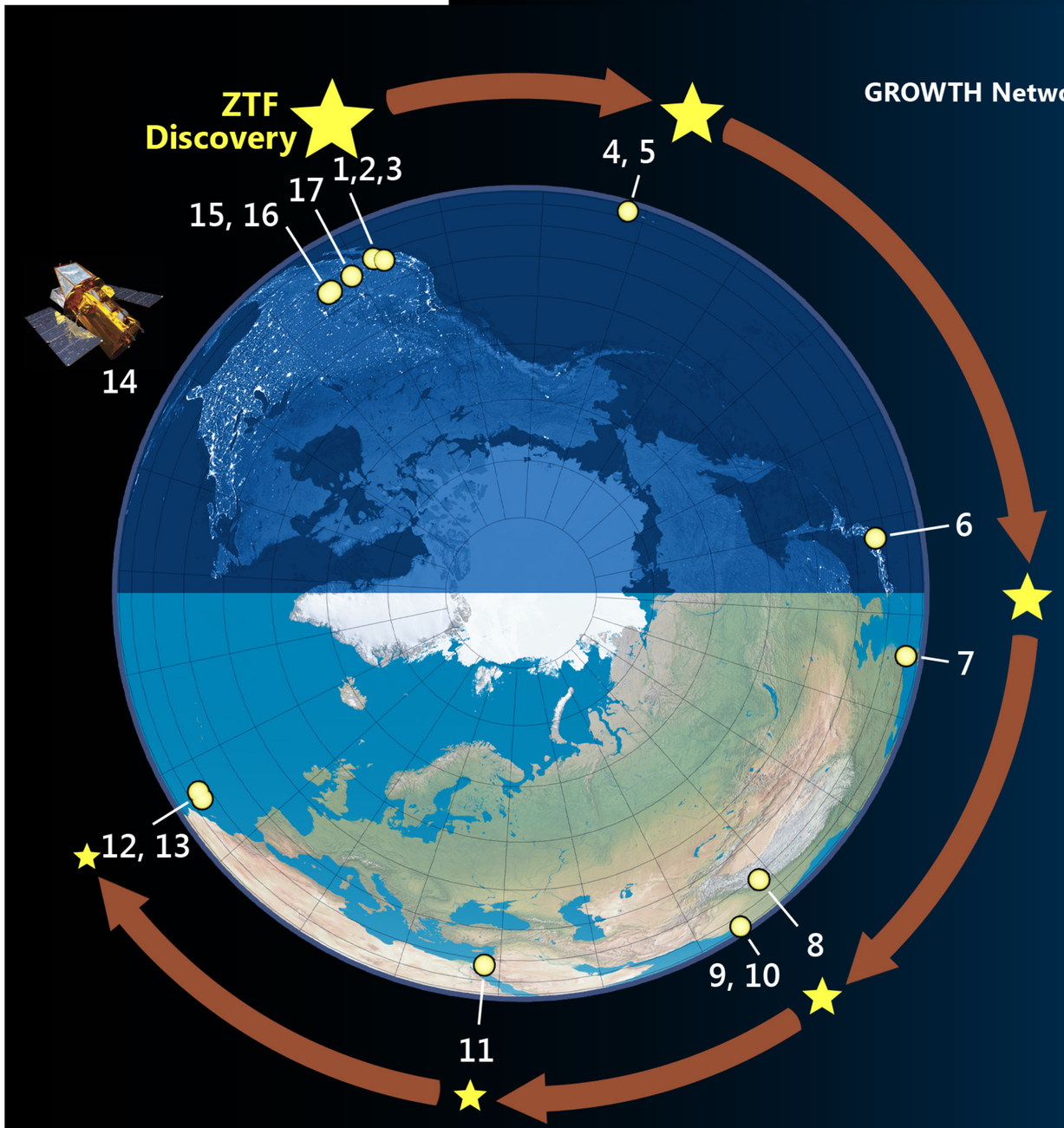
	PTF	ZTF
Active Area	7.26 deg^2	47 deg^2
Readout Time	36 sec	10 sec
Exposure Time	60 sec	30 sec
Relative Areal Survey Rate	1x	**14.7x**
Relative Volumetric Survey Rate	1x	**12.3x**

E. Bellm
Bellm+ 2014
Smith+ 2014

The ZTF Instrument:
FIRST LIGHT



Caltech Optical Observatories, November 14, 2017



GROWTH Network:

1. **Palomar Observatory**
   Caltech (USA)
2. **Table Mountain Observatory**
   Pomona College (USA)
3. **Mount Laguna Observatory**
   San Diego State University (USA)
4. **Gemini North Observatory**
   NOAO (USA) - Mauna Kea
5. **W. M. Keck Observatory**
   Caltech (USA)
6. **Murikabushi Observatory**
   Tokyo Tech University (Japan)
7. **Lulin One-meter Telescope**
   National Central University (Taiwan)
8. **Himalayan Chandra Telescope**
   Indian Institute of Astrophysics (India)
9. **Giant Metrewave Radio Telescope**
   NCRA (India)
10. **IUCAA Girawali Observatory**
    IUCAA (India)
11. **WISE Observatory**
    Weizmann Institute (Israel)
12. **Stella Observatory**
    Humboldt University (Germany)
13. **Nordic Optical Telescope**
    Oskar Klein Centre (Sweden)
14. **Swift Satellite (Ultraviolet and X-ray)**
    NASA (USA)
15. **Expanded Very Large Array (Radio)**
    NRAO (USA)
16. **Fenton Hill Observatory**
    Los Alamos National Laboratory (USA)
17. **Discovery Channel Telescope**
    University of Maryland/JSI (USA)

\+ **University of Wisconsin-Milwaukee**

Samaya Nissanke:

“Aside from being a brilliant and fantastic scientist brimming with enthusiasm, energy and ideas that we have all been celebrating, I would like to remember and to thank Neil for his selfless and tireless advocacy and hard work on supporting and championing through direct action equity and inclusion for physicists and astronomers, especially women and those from under represented groups. Neil did this with such modesty, humility, and kindness and his work in this area has impacted all areas of high-energy astrophysics, gravitational waves and cosmology. I saw this first hand with Neil in his capacity as the LIGO Scientific and Virgo collaborations diversity co-chair, where Neil was always responsive by email and skype. We miss you Neil, you were in my thoughts everyday in the months following GW170817 and thank you for championing astronomy for all and shining brightly both as a scientist, mentor and incredible individual. I will remember Neil being the first participant to dive (with a huge smile and glint in his eye) from a boat into the Red Sea in Eilat at a transients conference dinner in November 2014. Fearless and a trailblazer always!”