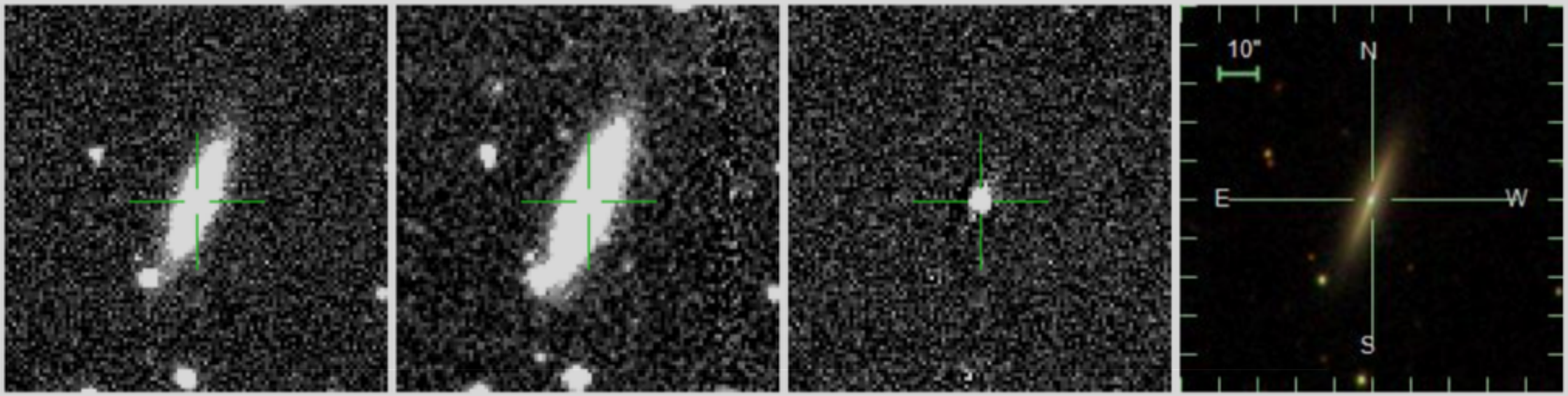
Caltech

GROWTH
Global Relay of Observatories Watching Transients Happen

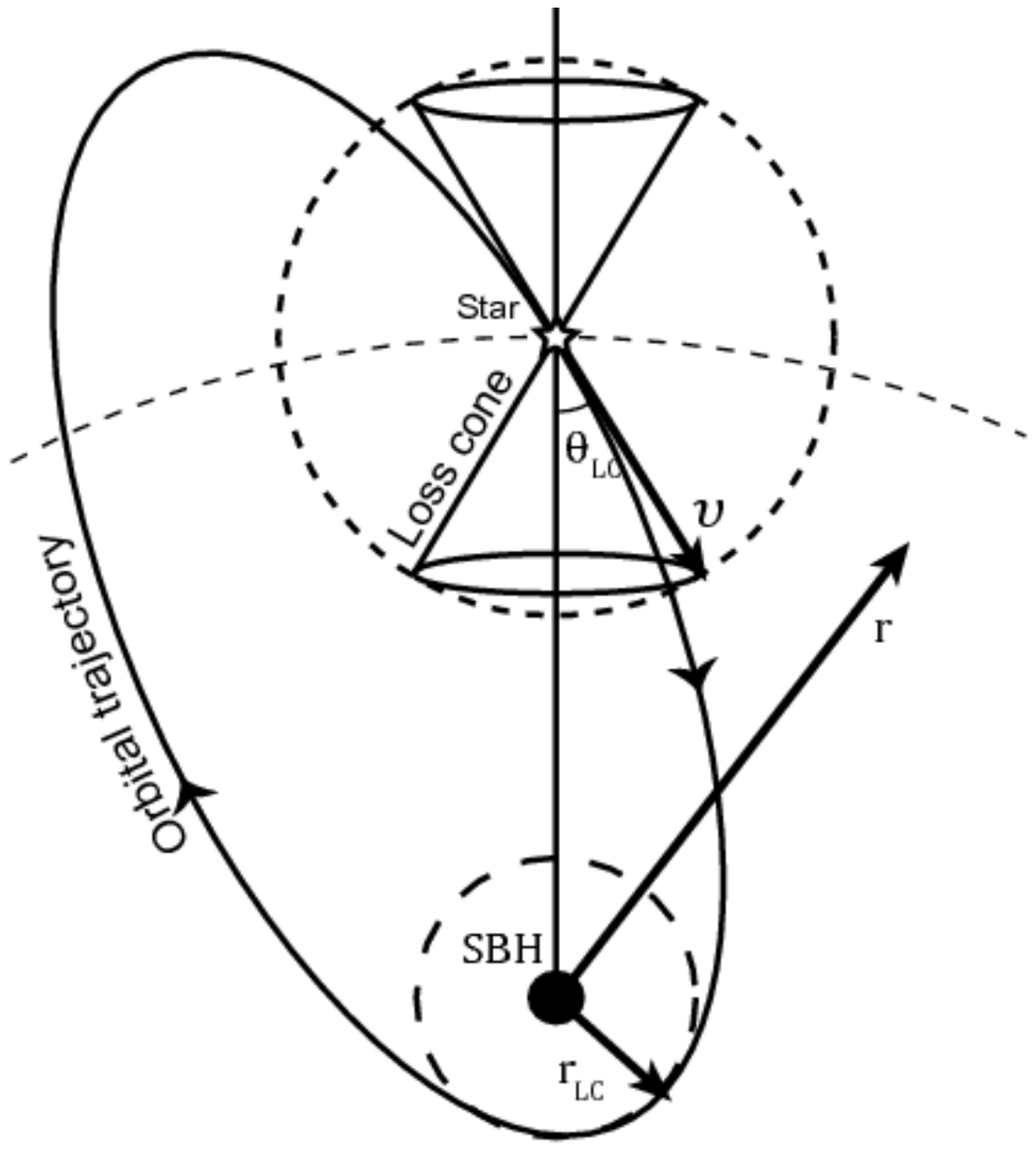


iPTF16fnl - a faint and fast TDE in an E+A galaxy

Nadia (Nadejda) Blagorodnova
with Suvi Gezari, Tiara Hung, Shri Kulkarni, Brad Cenko, Lin Yan

Unveiling the Physics Behind Extreme AGN Variability
12th July, 2017, St. Thomas

A star gets disrupted when…



MBH

Stellar density

$\int$

Binary SMBH

}

SMBH mass and spin

BH occupation fraction

Stellar population

Merritt,2013

Predicted rates of tidal disruption events

- **Magorrian & Tremaine (1999)** – 10^{-4} to 10^{-5} gal^{-1} yr^{-1}. Rates dominated by low luminosity galaxies.

- **Wang & Merritt (2004)** – ~10^{-4} gal^{-1} yr^{-1}

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- **Stone & Metzger (2016)** – ~10^{-4} gal^{-1} yr^{-1} (see **N. Stone talk**)

Observed rates of tidal disruption events

- **Donley (2002)** – ROSAT (X-ray) – 1.8 x10^{-5} galaxy^{-1} yr^{-1} (active), 9.1x10^{-6} gal^{-1} yr^{-1} (inactive)

- **Esquej et al. (2008)** – XMM-Newton (X-Ray) – 5 additional archival candidates: 2.3x10^{-4} gal^{-1} yr^{-1}

- **van Velzen et al (2014)** – SDSS (optical) – 2 archival candidates: $N = (1.5–2.0)^{+2.7}{}_{-1.3} \times 10^{-5}$ gal^{-1} yr^{-1}

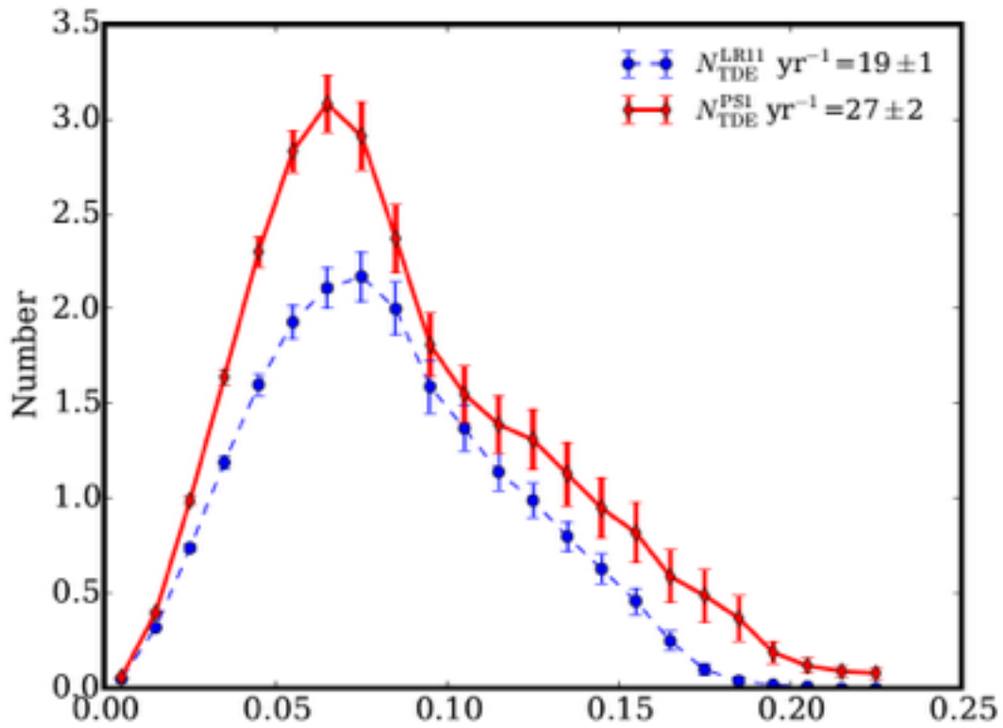
- **Holoien et. al. (2016)** – ASASSN (optical) – three candidates: 4.1 $\times$ 10^{-5} gal^{-1} yr^{-1}

TDE detection in ongoing surveys

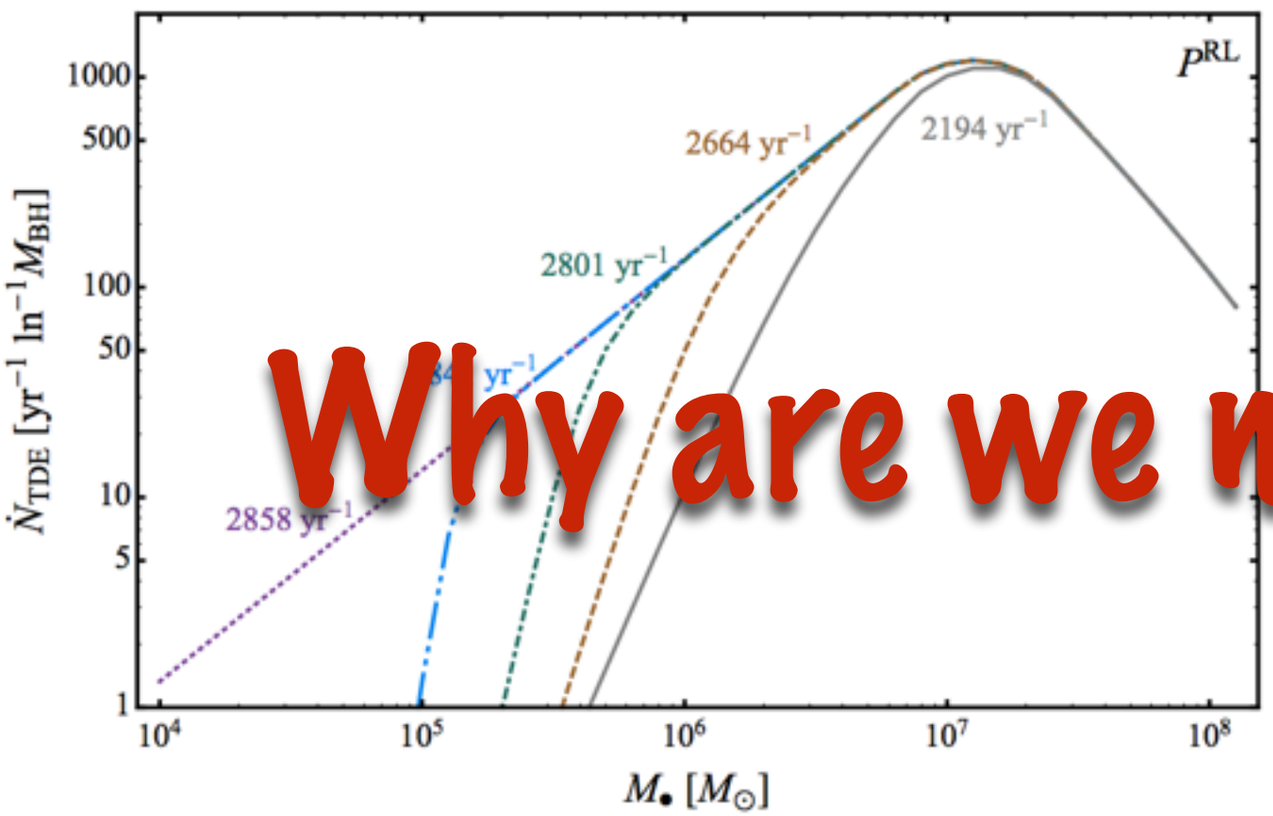
SDSS-like events prediction - Gaia: 20 vs 0

(See poster - Nuclear transients in OGLE and Gaia Surveys)

Blagorodnova+2016



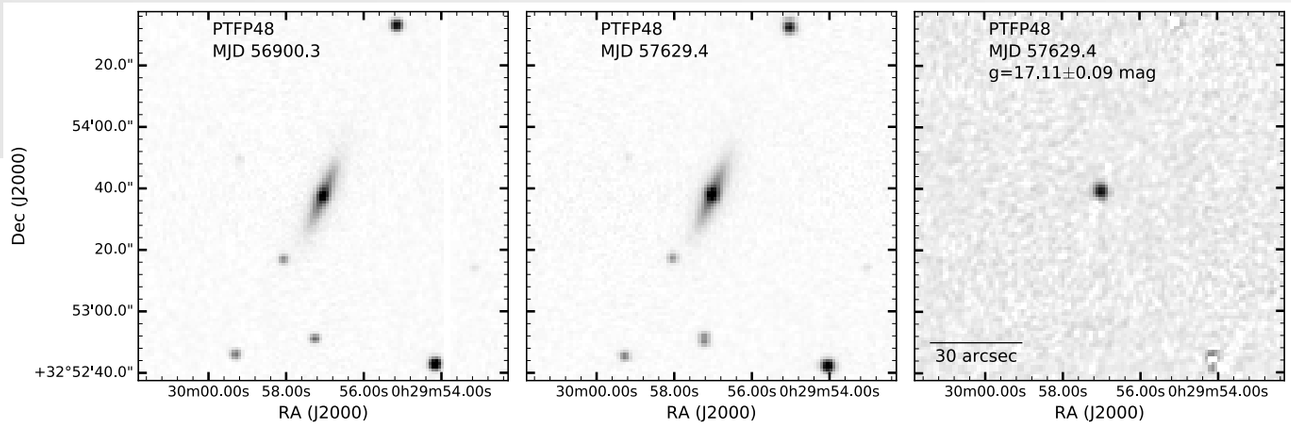
Stone, Metzger 2016



Why are we missing TDEs?

Theoretical Prediction - PTF: 100 vs 2

Discovery

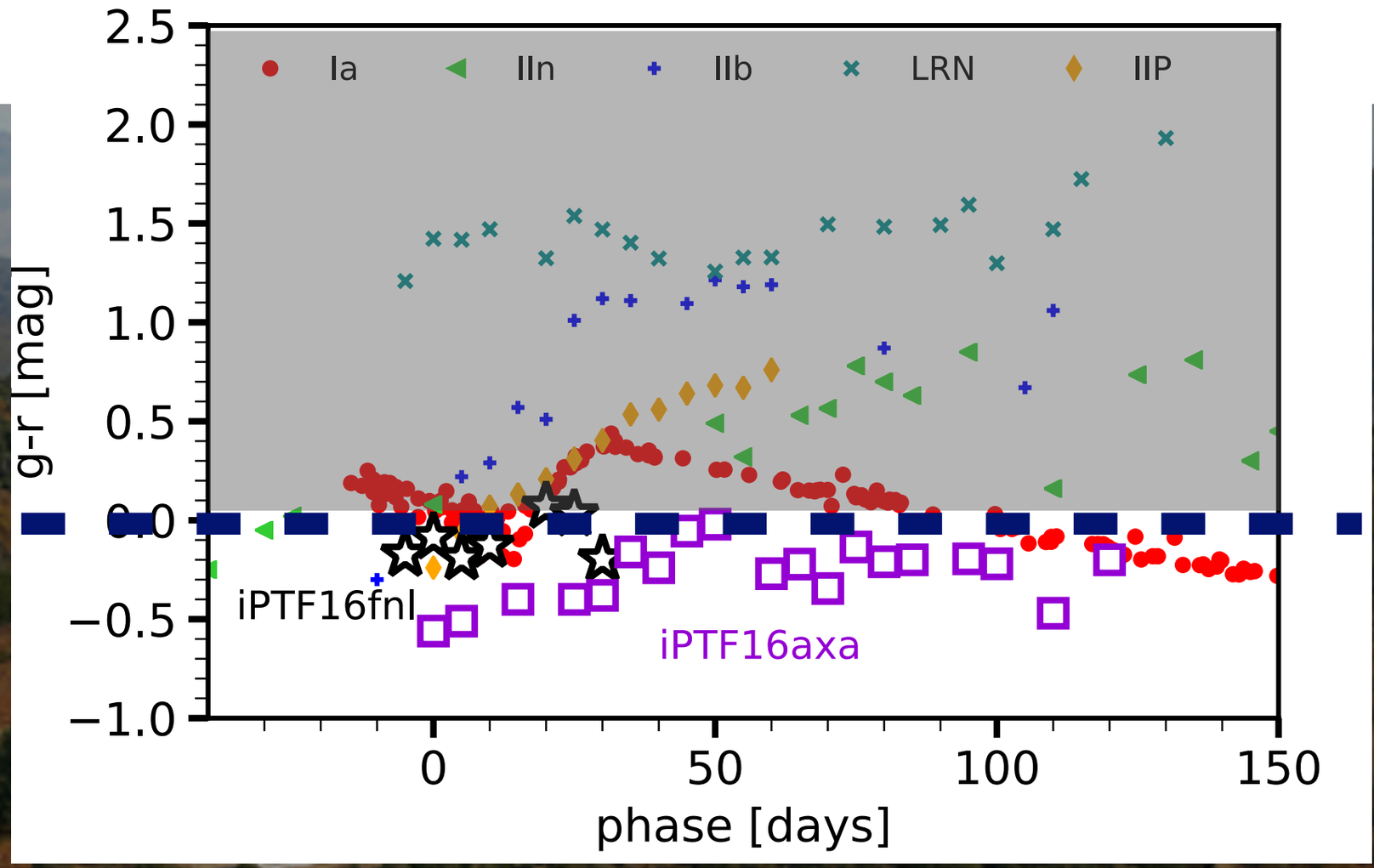


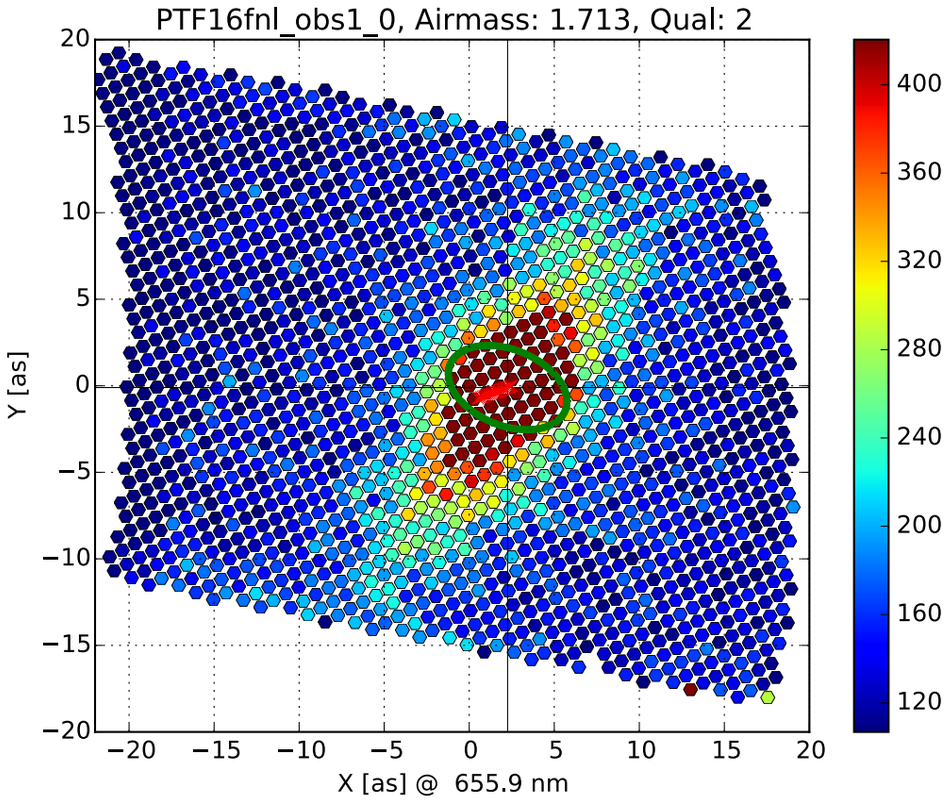
26th August 2016

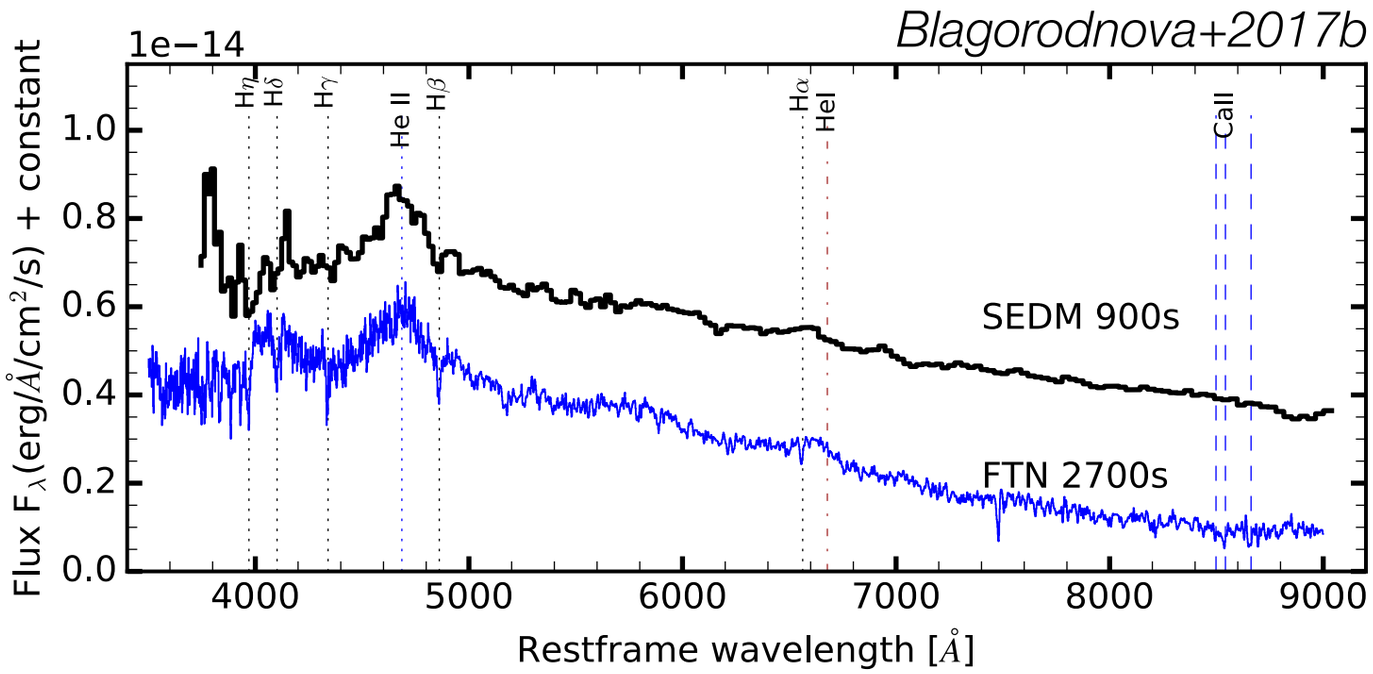
g+R survey

(Miller+2017)

29th August 2016 —> g-R<0



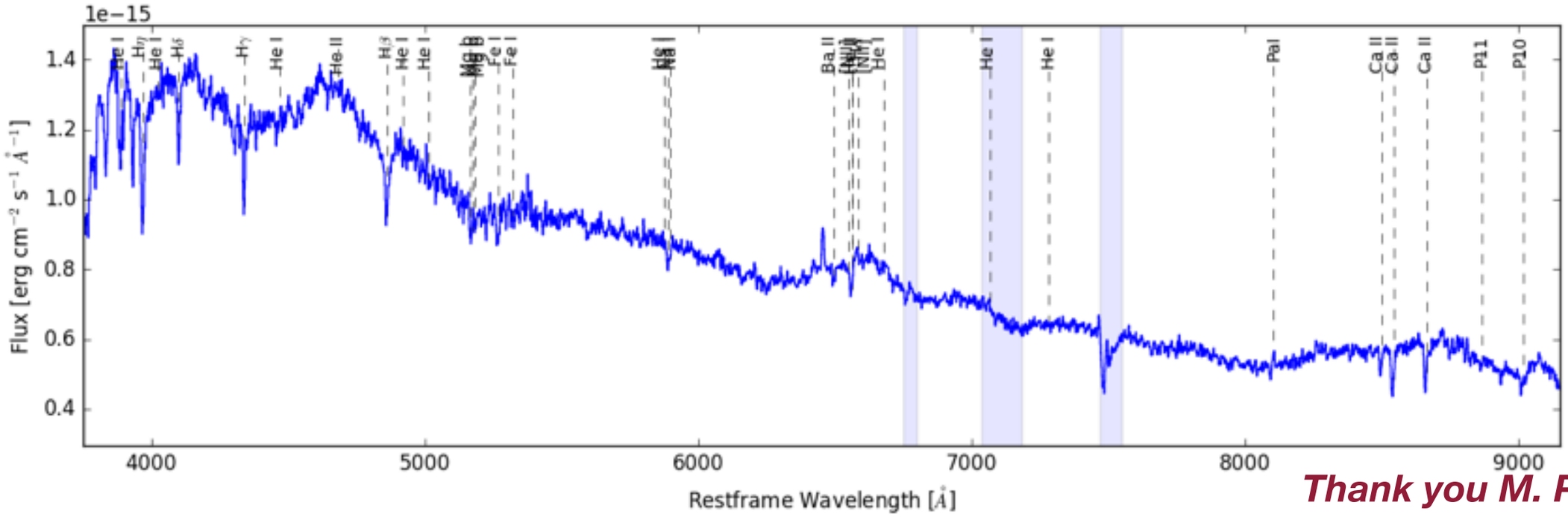




Discovery!
PTF
(1.2m)

SEDM
Classification!
(1.5m)
+0.8 days

Discovery



Thank you M. Powell! :)

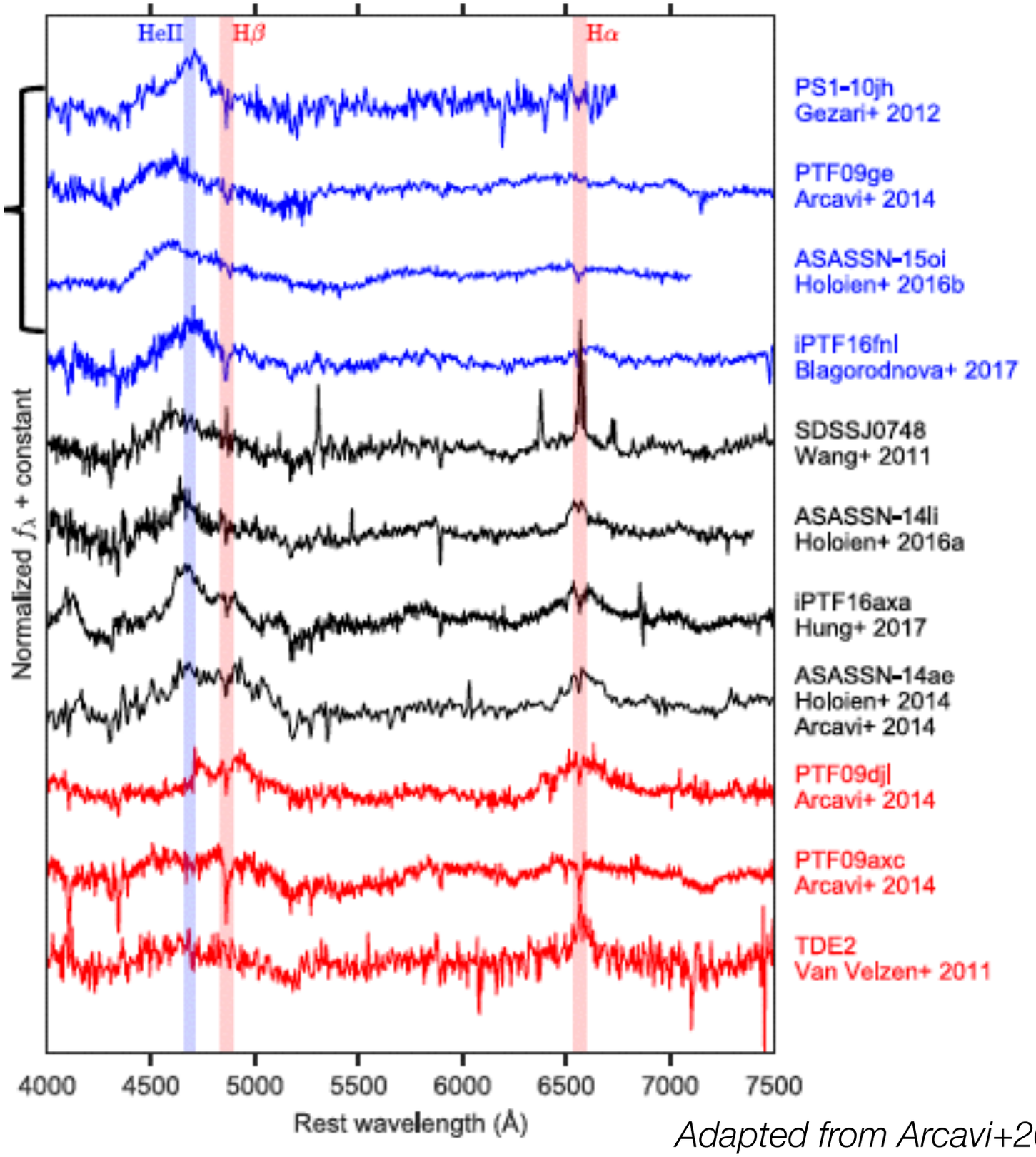
Discovery!
PTF
(1.2m)

Follow-up!
(5m)
+1.9 days

SEDM
Classification!
(1.5m)
+0.8 days

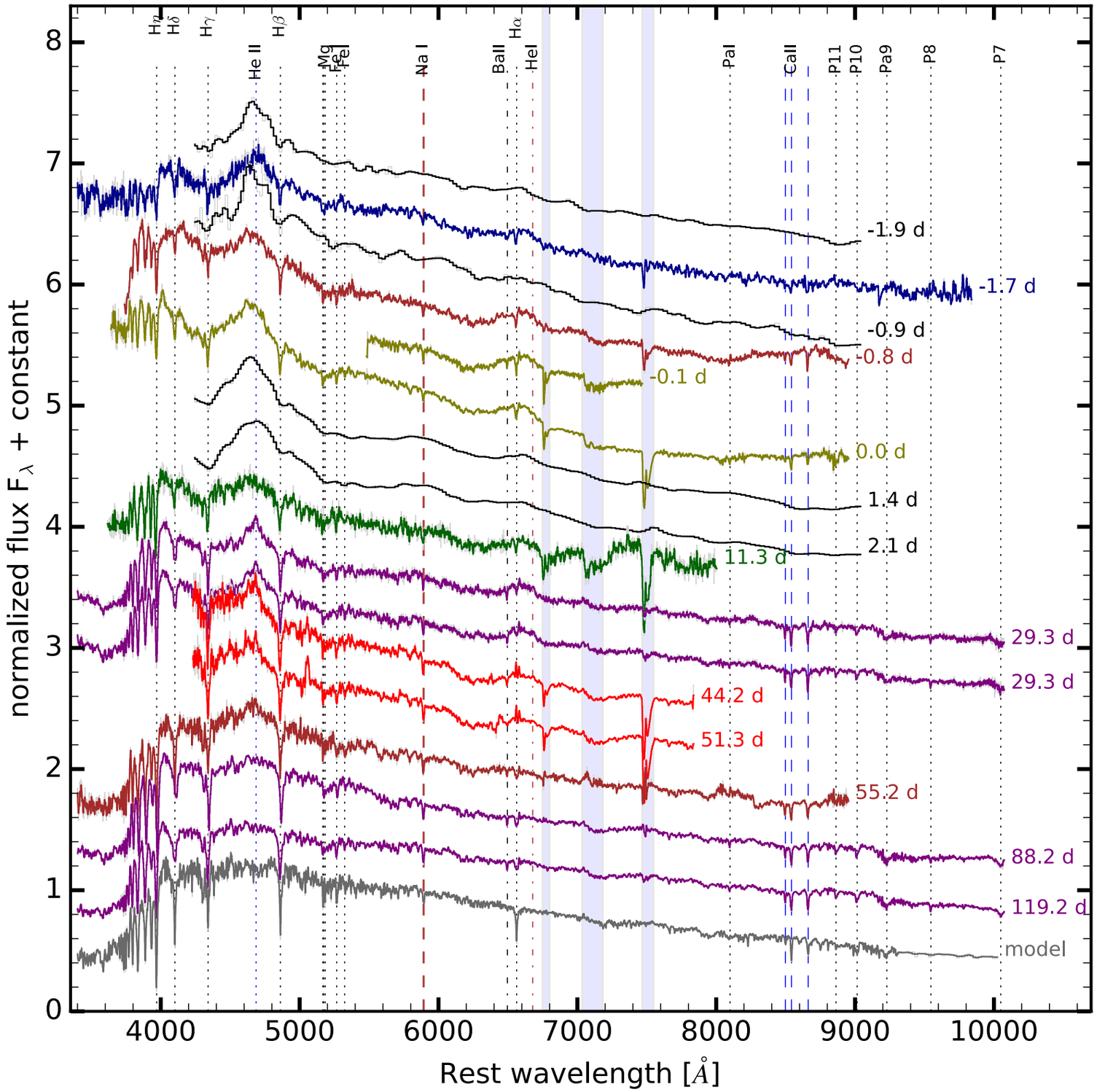
Spectroscopic signature: He II & H lines

1/3 show no H:
not likely all from
stripped stars.

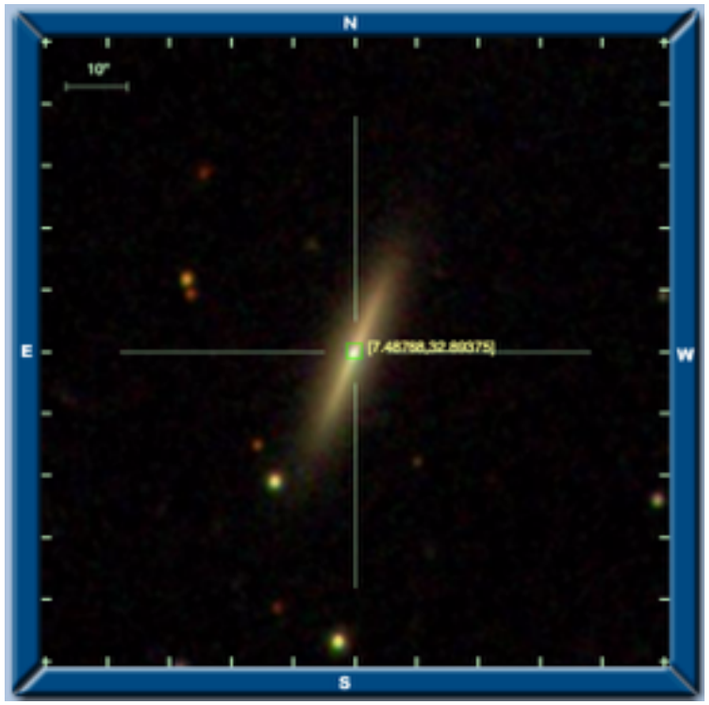


Adapted from Arcavi+2014. Courtesy of I Arcavi

Spectra and host galaxy

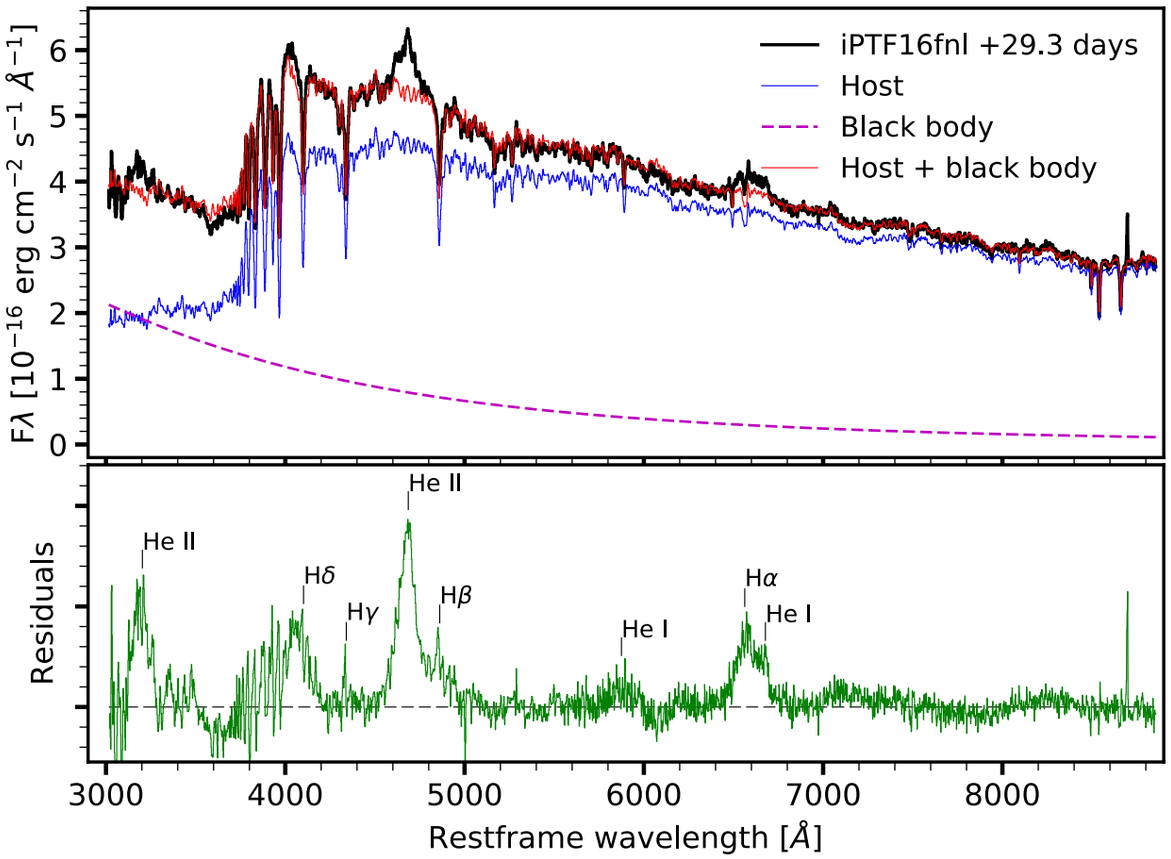


$$M_* \simeq 9.7 \times 10^9 M_\odot$$
$$\mathrm{Age} \simeq 650 \pm 300\,\mathrm{Myr}$$
$$\mathrm{Z} = 0.18\ (\mathrm{Z}_\odot = 0.2)$$



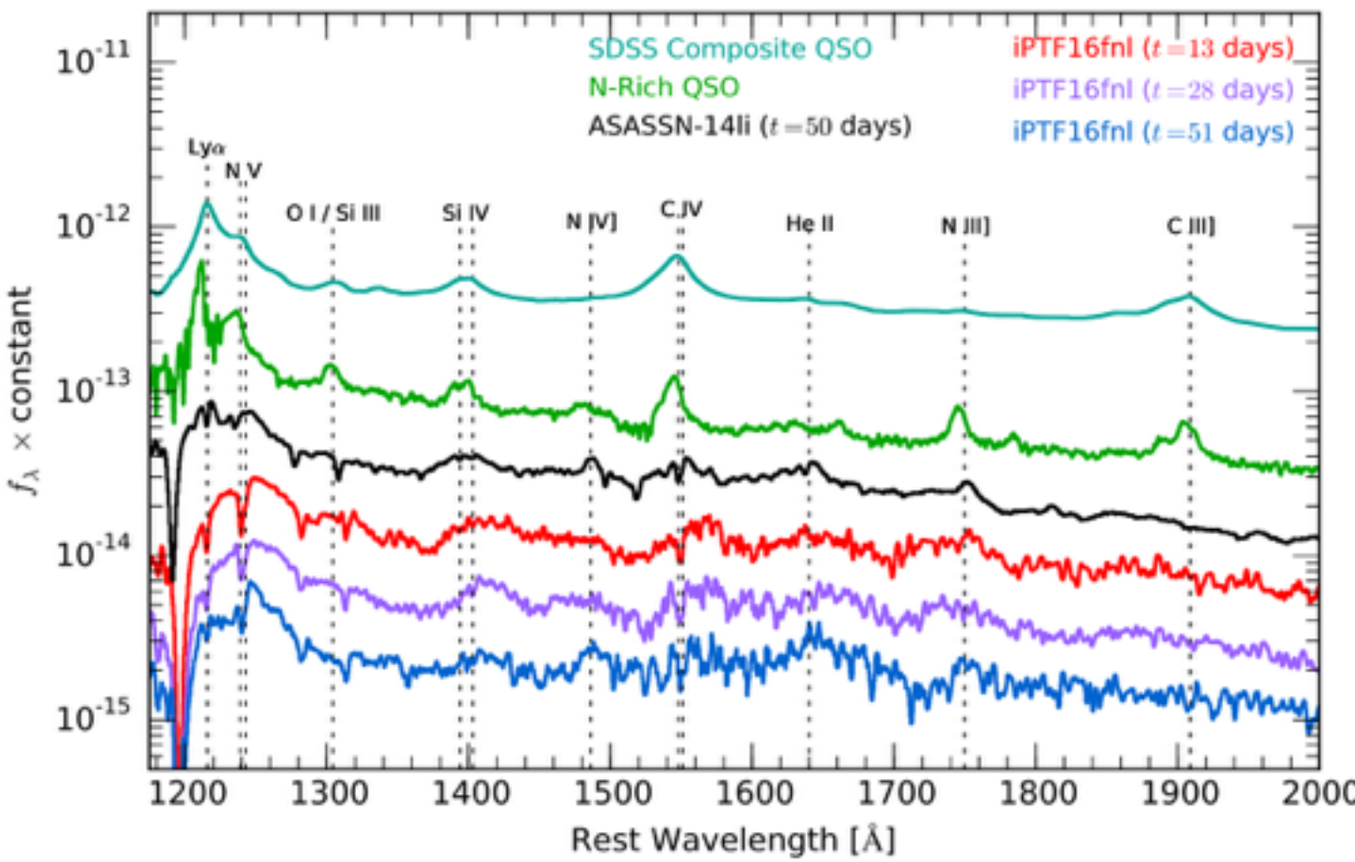
Blagorodnova et. al. 2017b

Optical + UV spectra



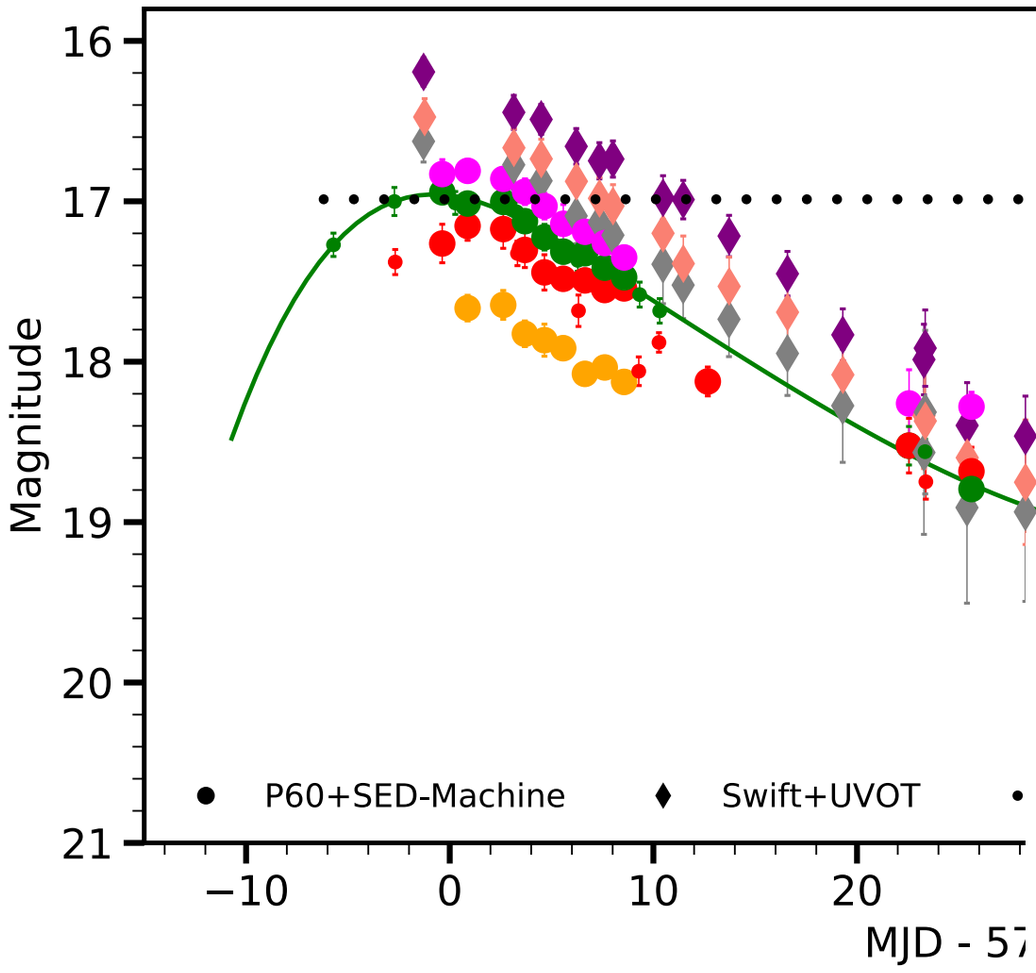
Blagorodnova et. al. 2017b

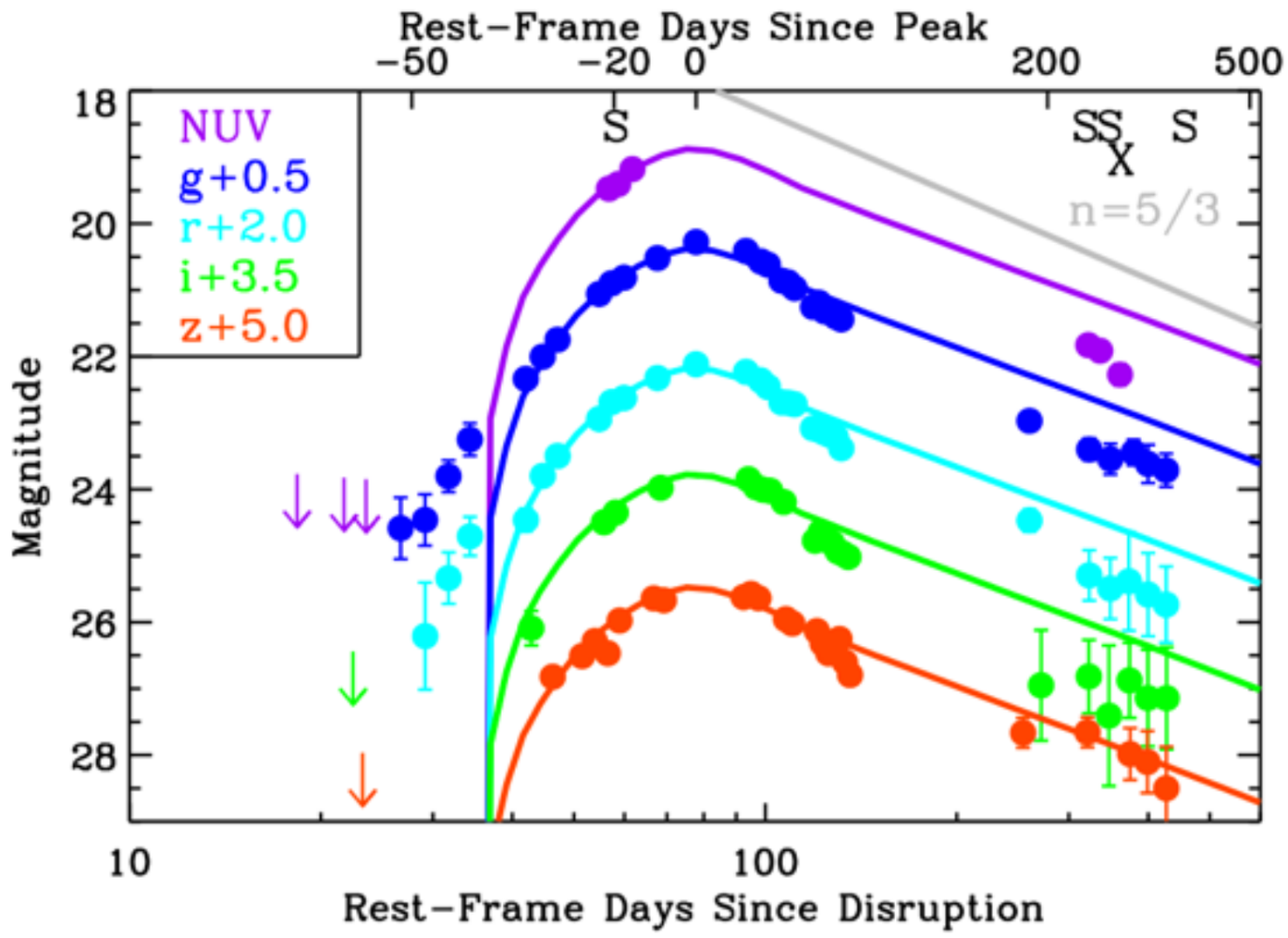
HeII and H lines.
He I lines detected.
N-rich
C III] deficient ->
dense emitting region



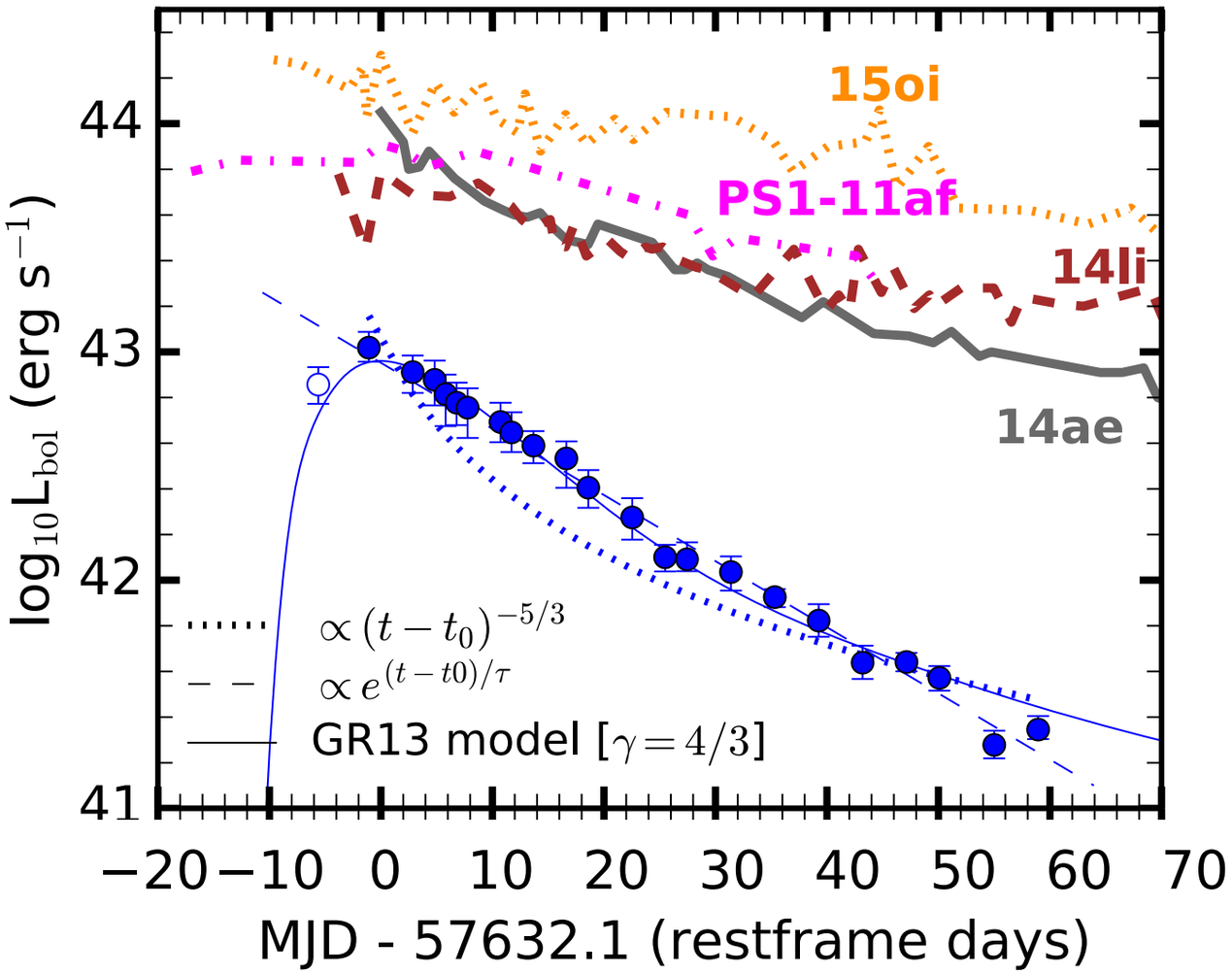
Brown et. al. 2017

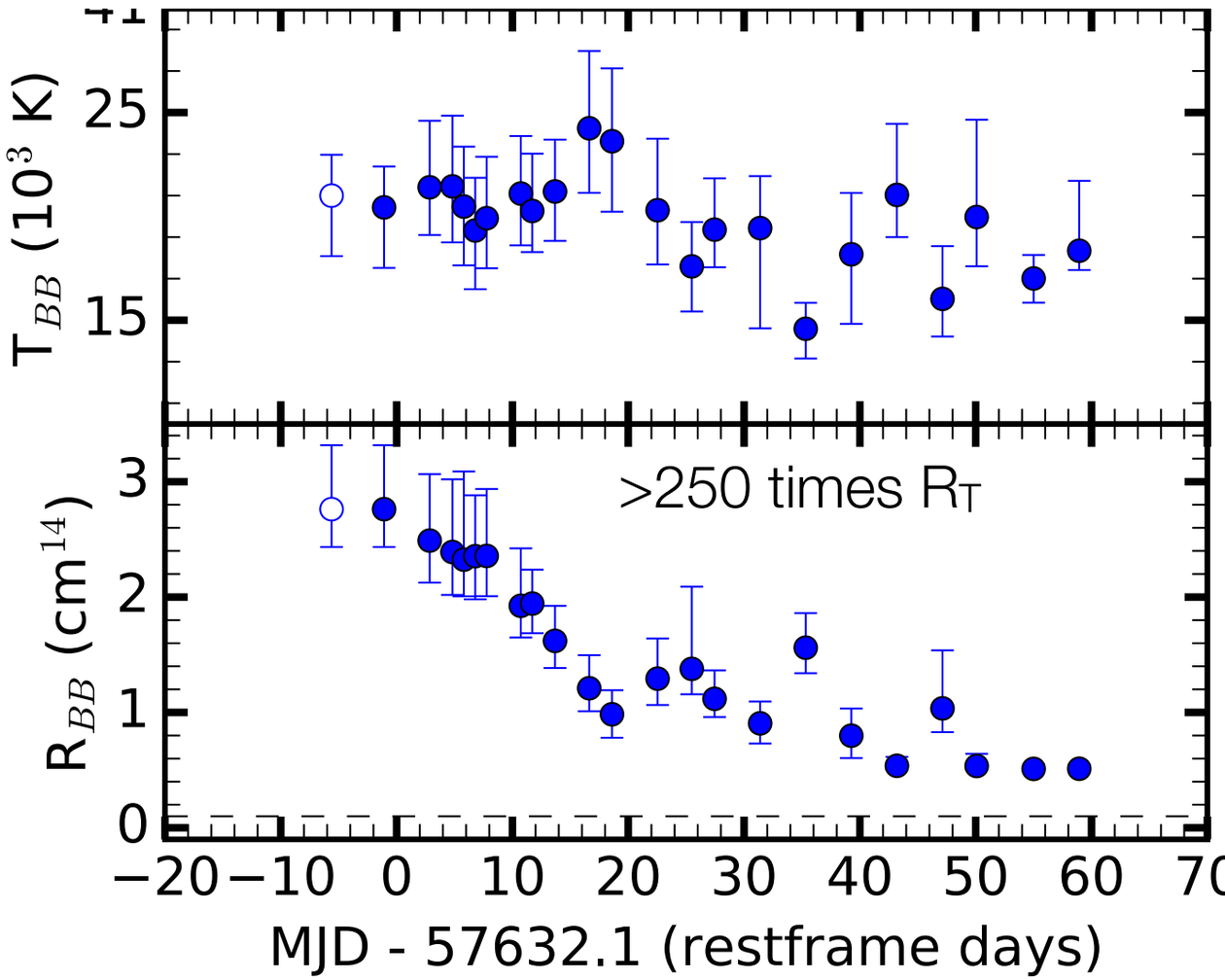
Photometry


UVW2
UVM2
UVW1
u
g
r
i+0.5
Magnitude
16
17
18
19
20
21
−18
−17
−16
lute magnitude
P60+SED-Machine
Swift+UVOT
−10
0
10
20
MJD - 57

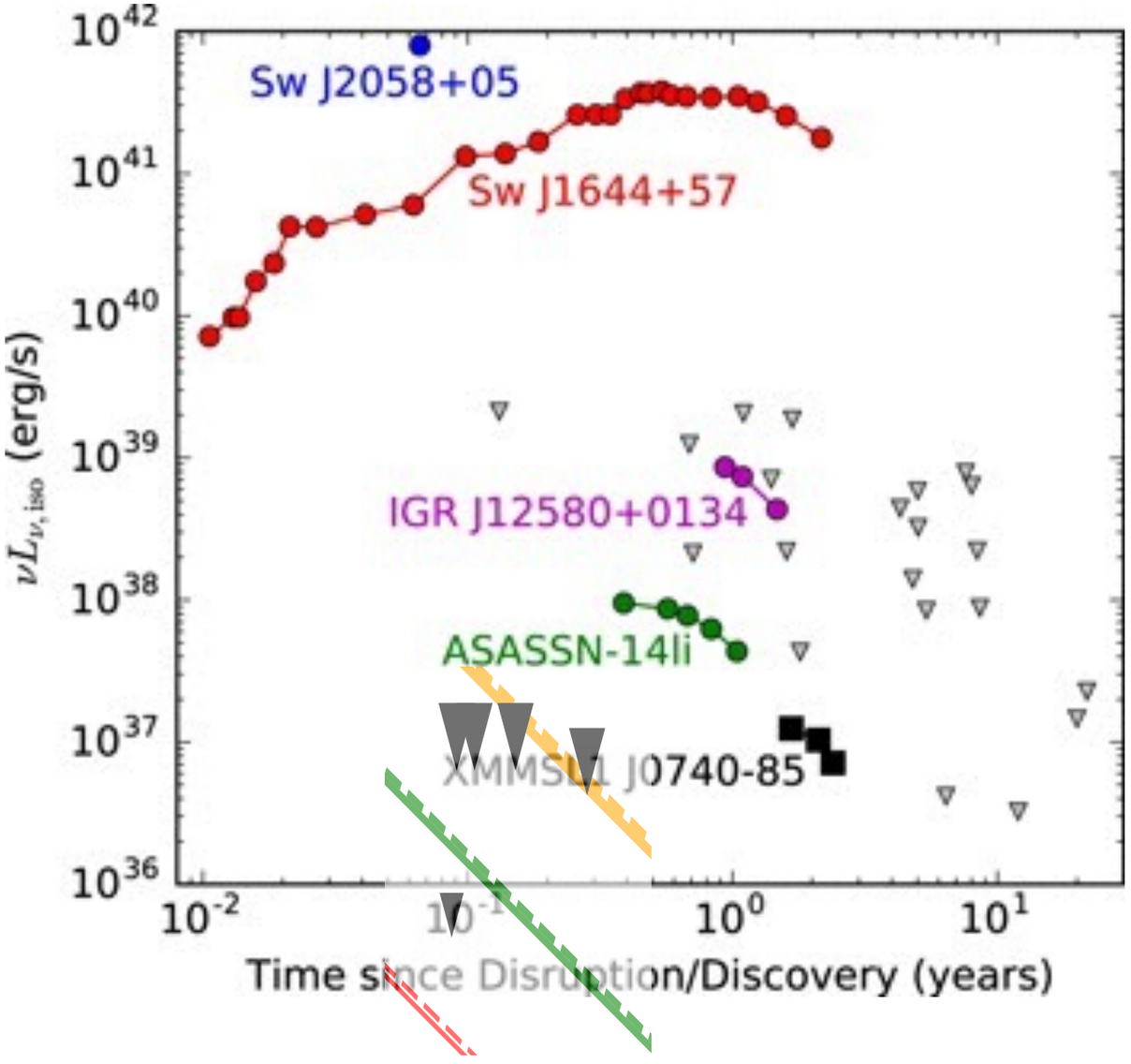

Gezari et. al. 2012
Rest−Frame Days Since Peak
−50
−20
0
200
500
NUV
g+0.5
r+2.0
i+3.5
z+5.0
S
SS
X
S
n=5/3
Magnitude
18
20
22
24
26
28
10
100
Rest−Frame Days Since Disruption

Luminosity


15oi
PS1-11af
14li
14ae
$\propto (t-t_0)^{-5/3}$
$\propto e^{(t-t0)/\tau}$
GR13 model [$\gamma = 4/3$]
$\log_{10} L_{bol}$ (erg s^{-1})
MJD - 57632.1 (restframe days)


T_{BB} (10^3 K)
R_{BB} (cm^{14})
>250 times R_T
MJD - 57632.1 (restframe days)

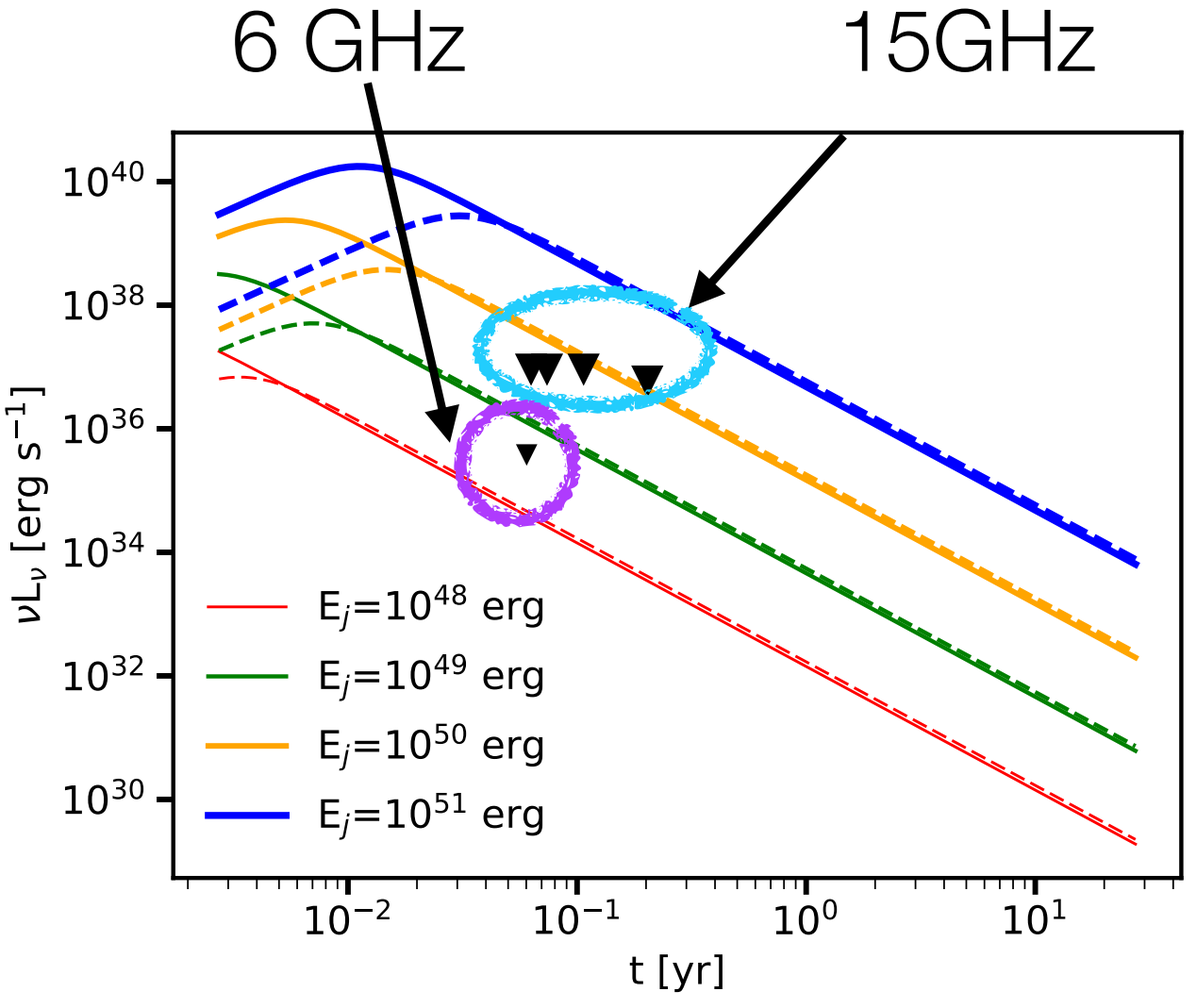
Radio & X-ray



Alexander+2017

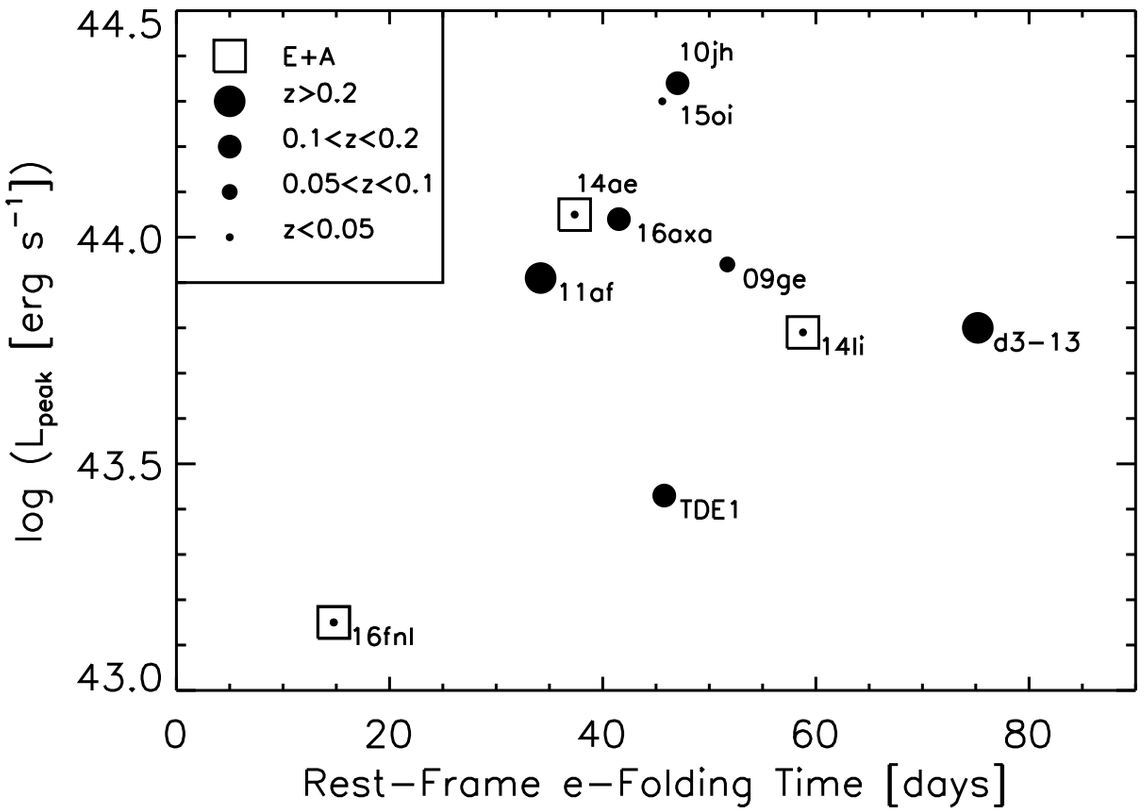
Marginal X-ray detection

(100 times fainter than ASASSN-15oi)



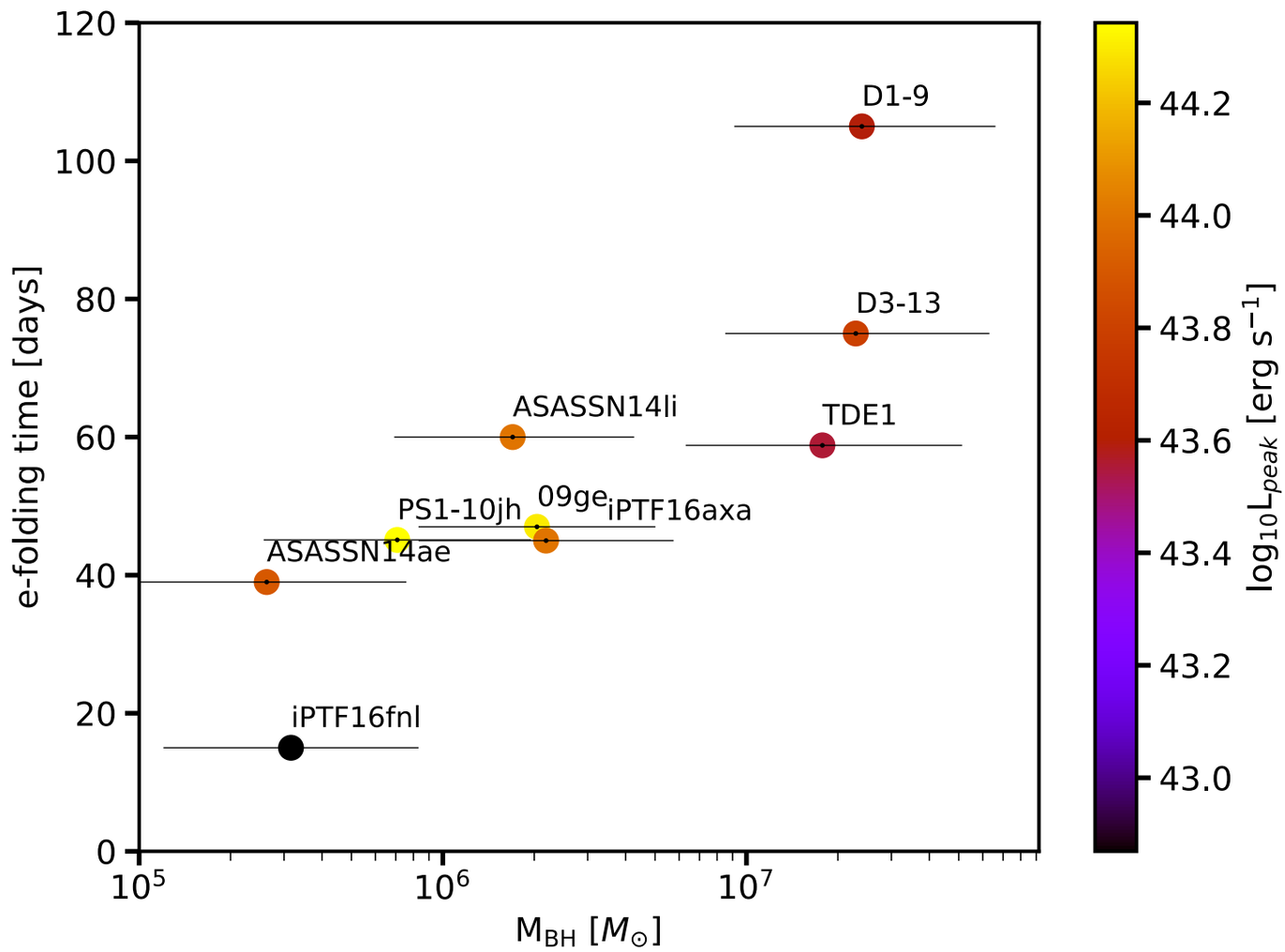
Blagorodnova et. al. 2017b

Timescale correlated with SMBH?



Enhanced E+A TDE population at lower redshifts.

No clear correlation of peak luminosity and timescale.

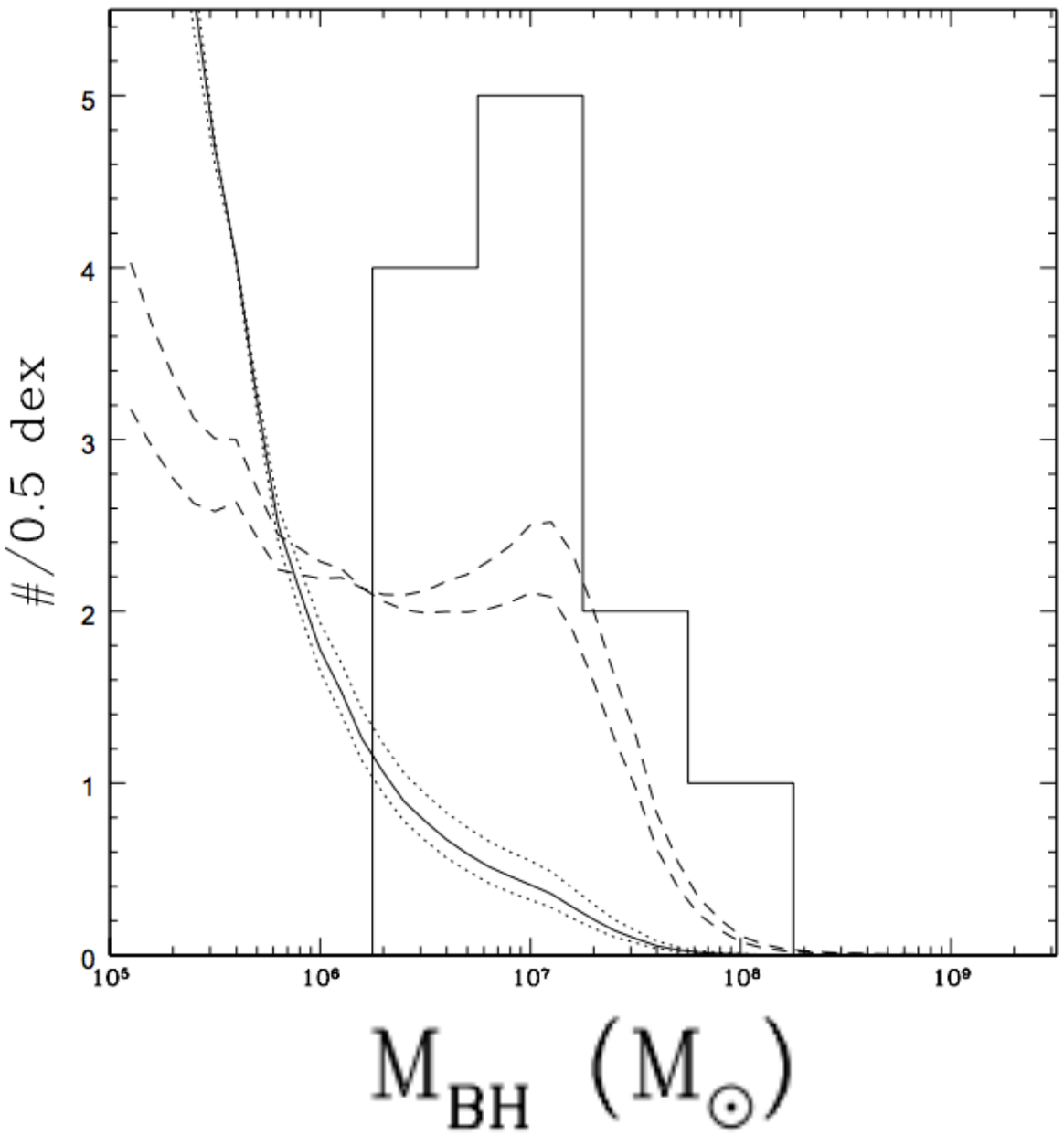


Decay timescales possibly related to MBH

Adapted from Blagorodnova+2017 with MBH from Wevers+2017

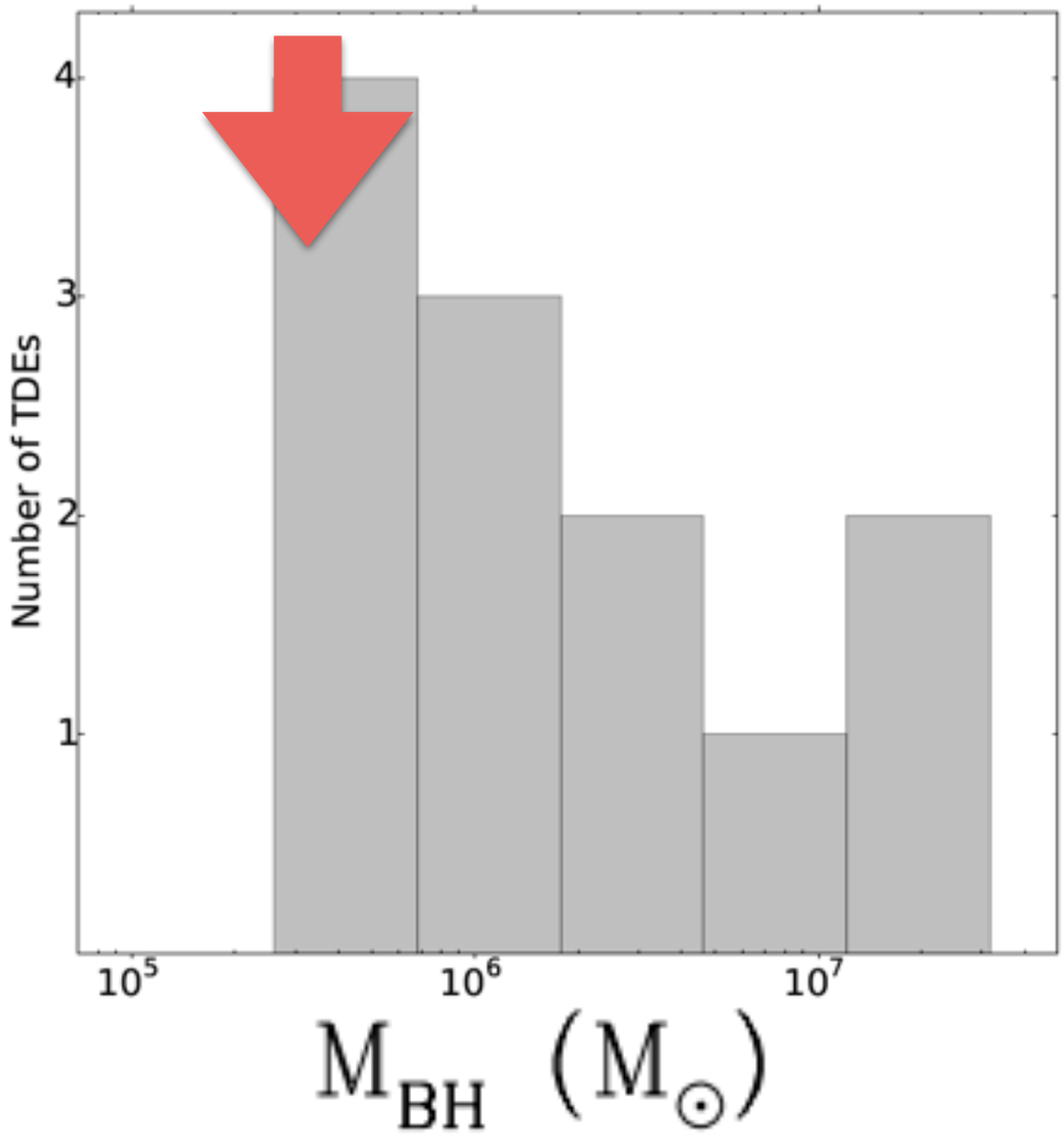
TDE hosts and rate implications

Yesterday



Kochanek, 2016

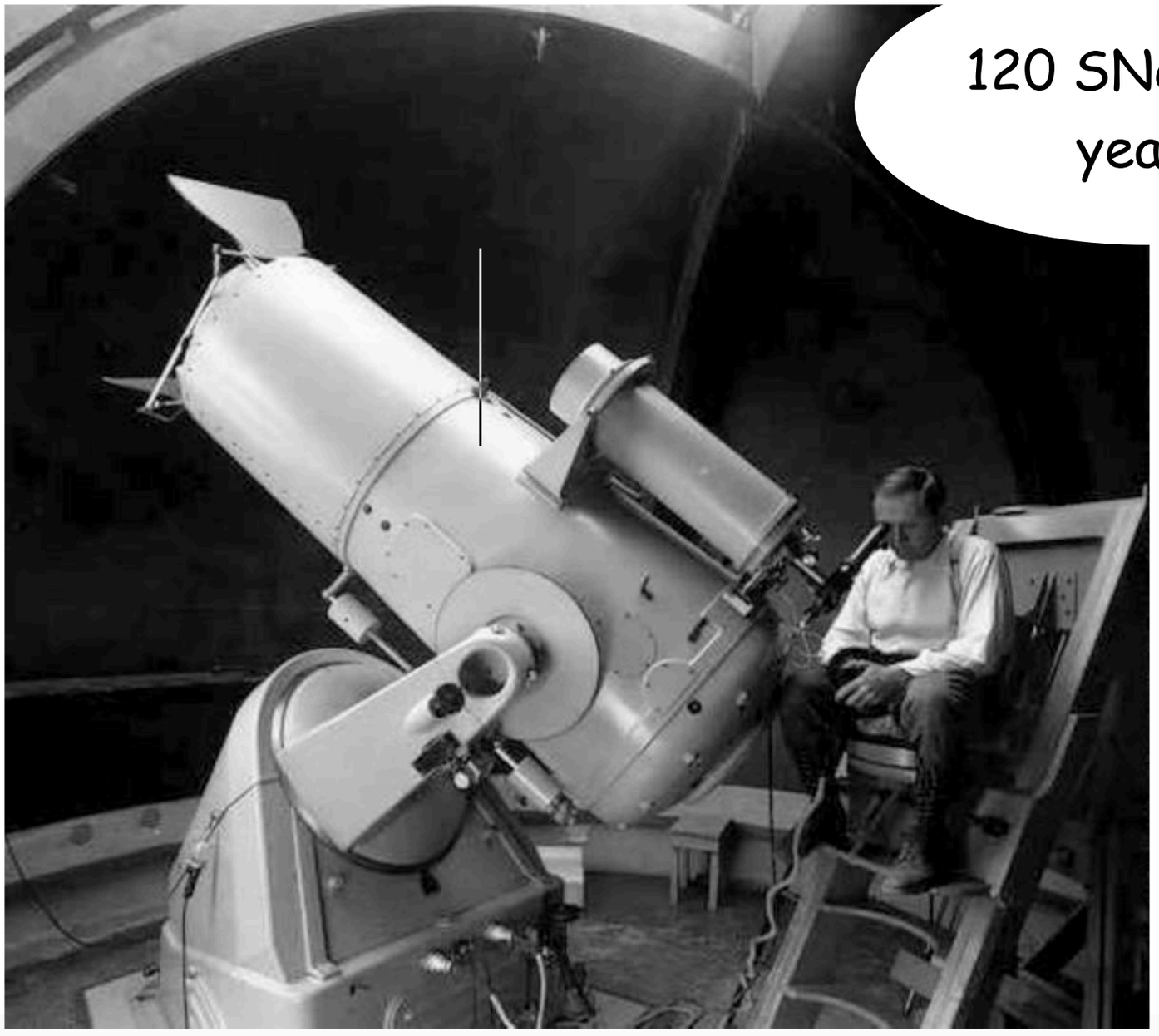
iPTF16fnl **Today**

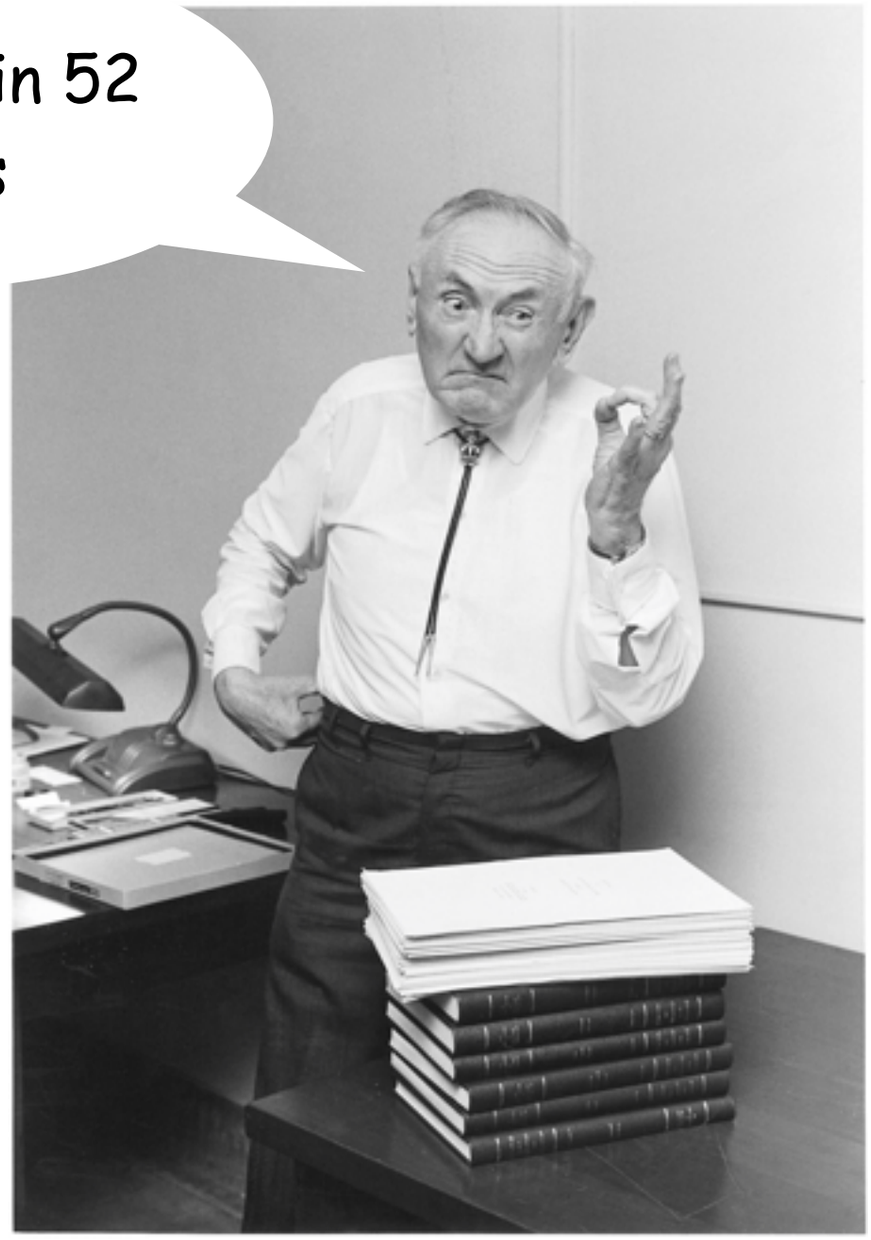


Wevers+2017

(Sjoert's talk)

Future prospects with optical surveys

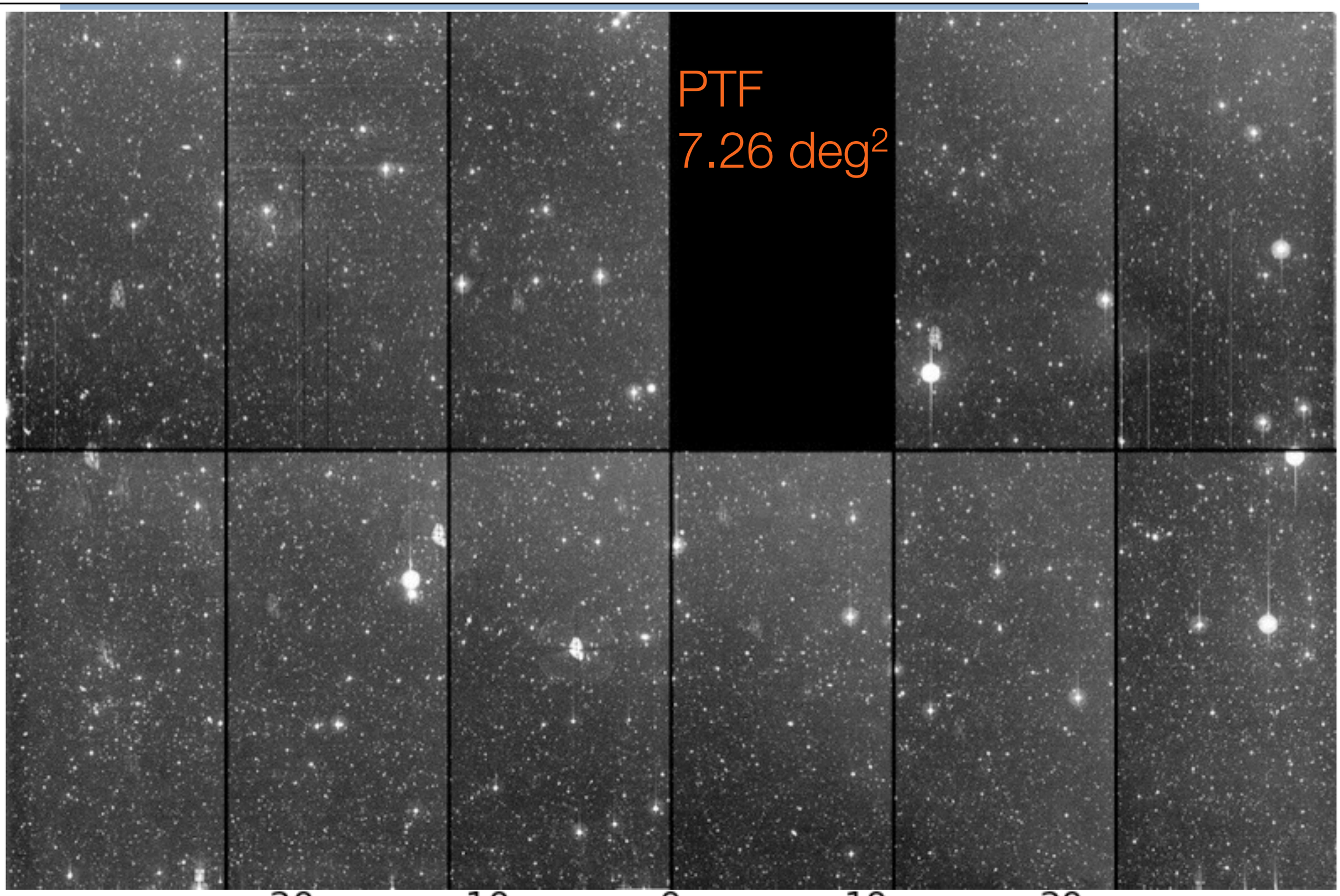




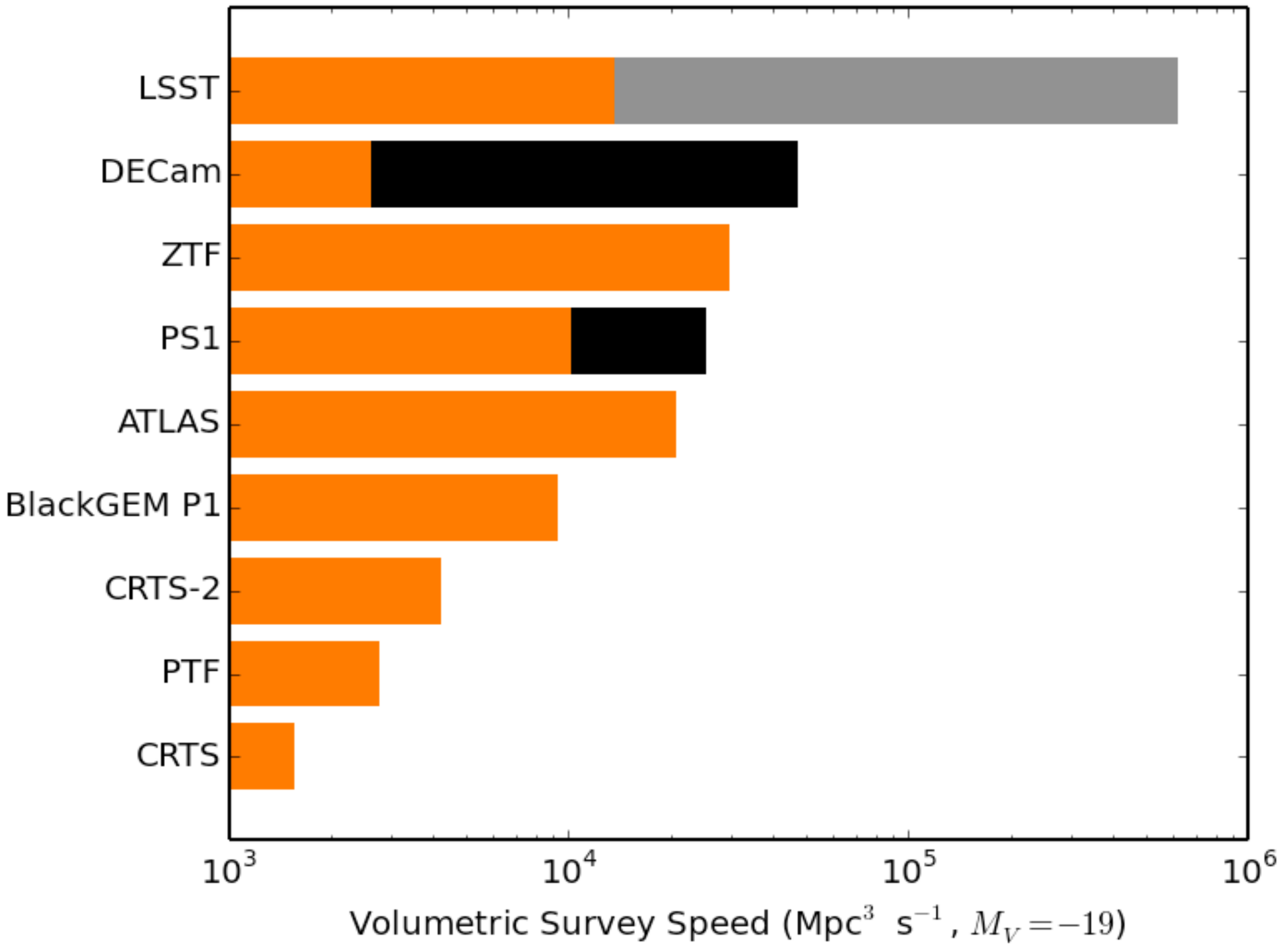
Fritz Zwicky looking through the 18-inch Schmidt's guide scope, circa 1936.

Source: Caltech archives

A new camera will fill the P48 focal plane.



ZTF will have world-leading speed in finding spectroscopically-accessible transients



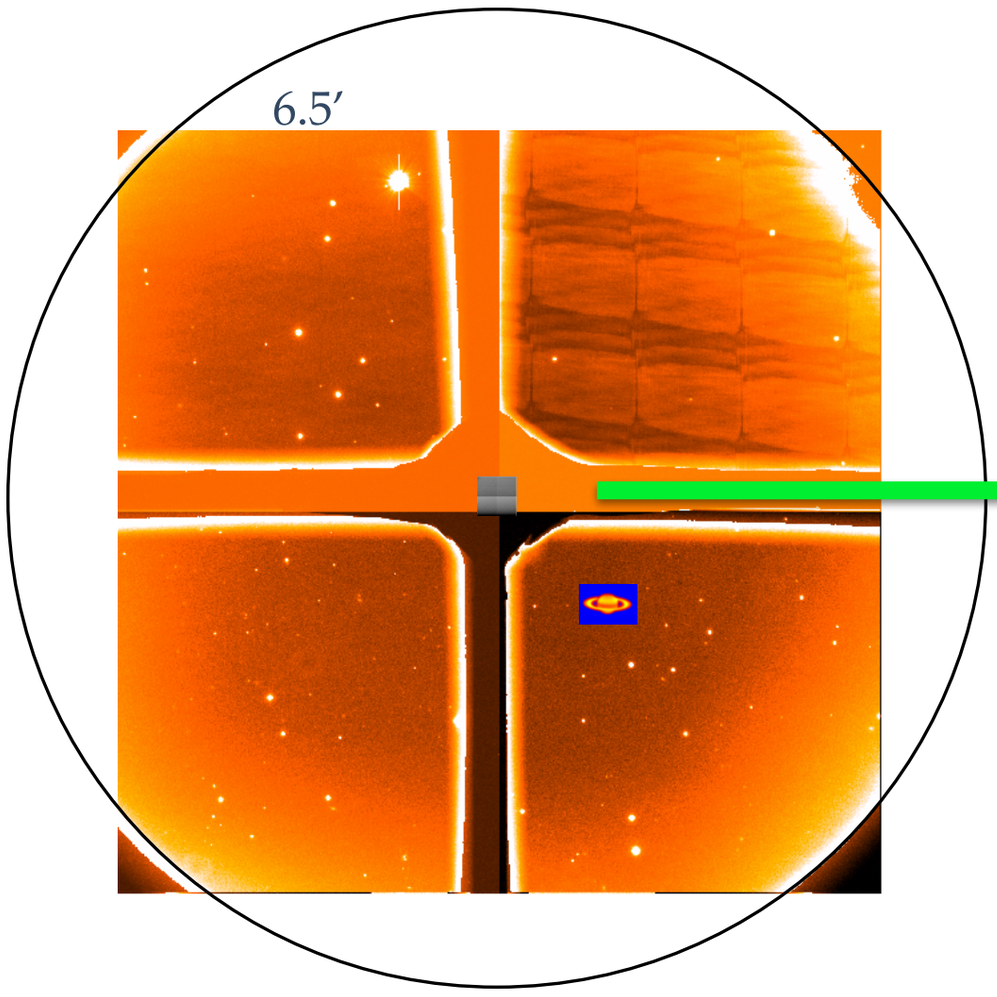
TDE search with ZTF

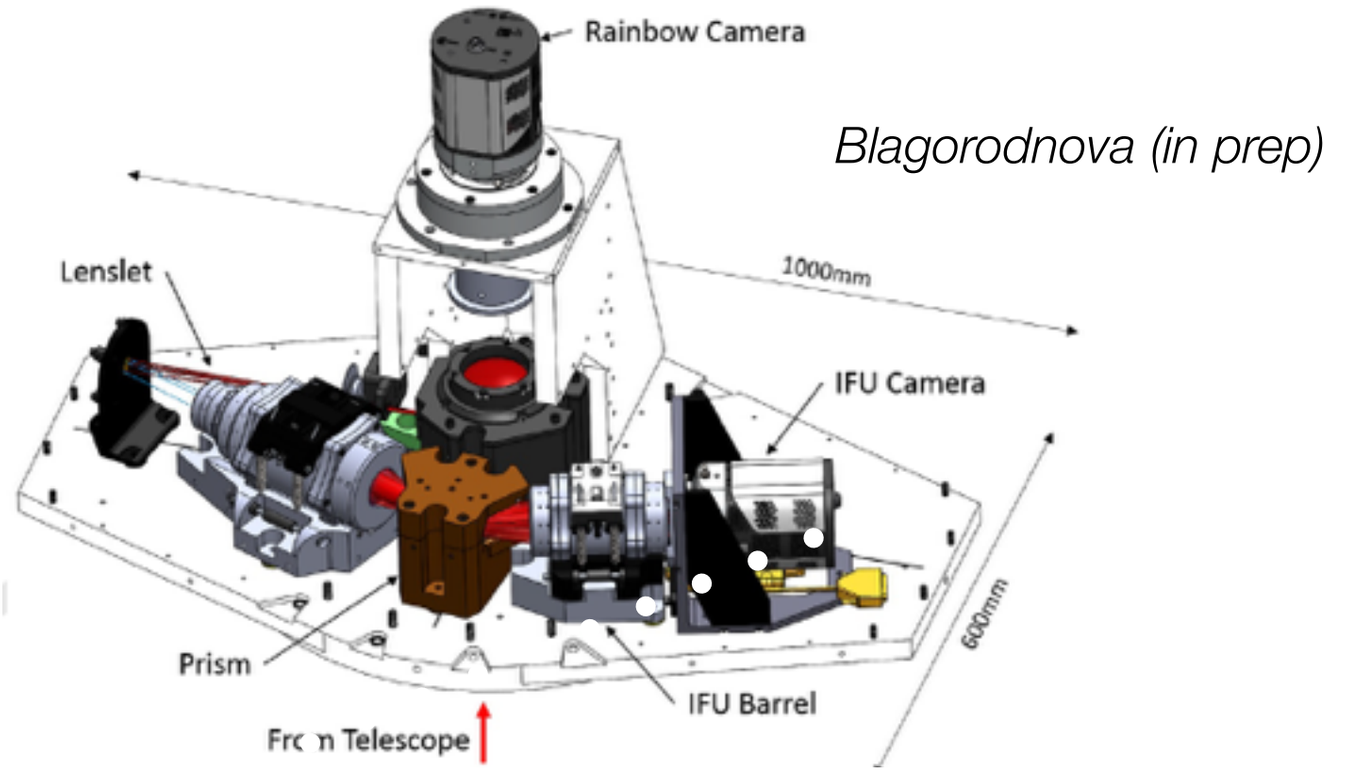
	PTF	ZTF
Active Area	7.26 deg^2	47 deg^2
Overhead Time	46 sec	<15 sec
Optimal Exposure Time	60 sec	30 sec
Relative Areal Survey Rate	1x	**15.0x**
Relative Volumetric Survey Rate	1x	**12.3x**
TDEs /yr	1-2	>15

- Good temporal sampling ->
  - rise time constraints
  - early time spectroscopy
  - selection using g+r colour + position
- Follow-up needs:
  - Readily available spectroscopic resources (SEDM)
  - UV + X-ray follow-up

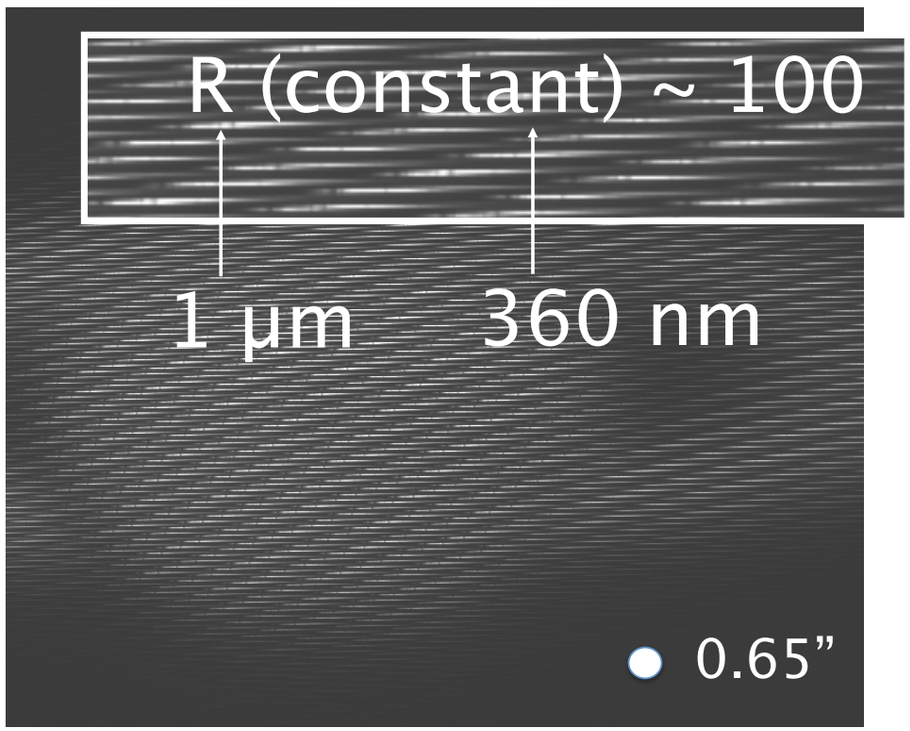
Classification (with 1.5 m telescopes)

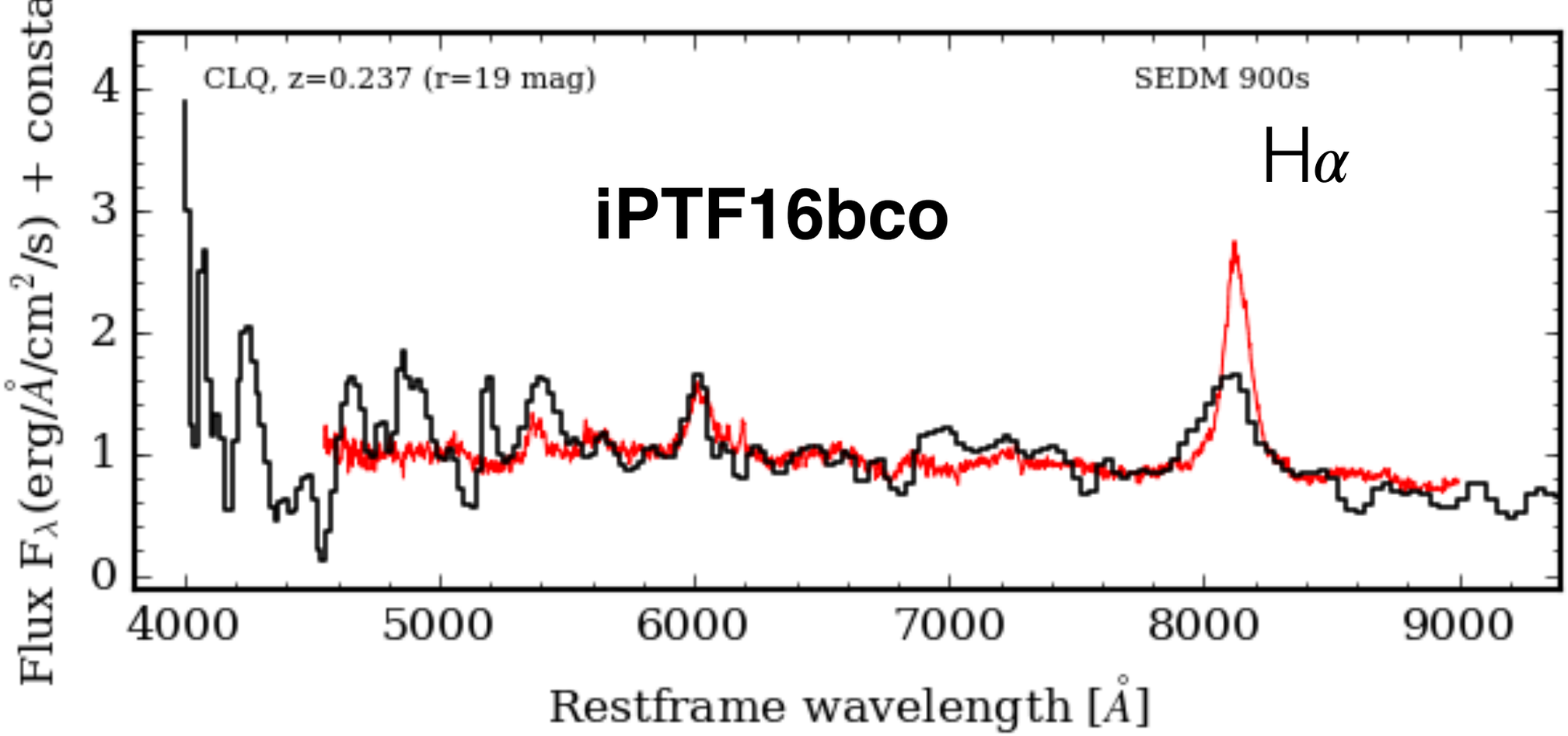
PTF: 4 x 10^4 events/night
ZTF: 3 x 10^5 events/night
LSST: 2 x 10^6 events/night



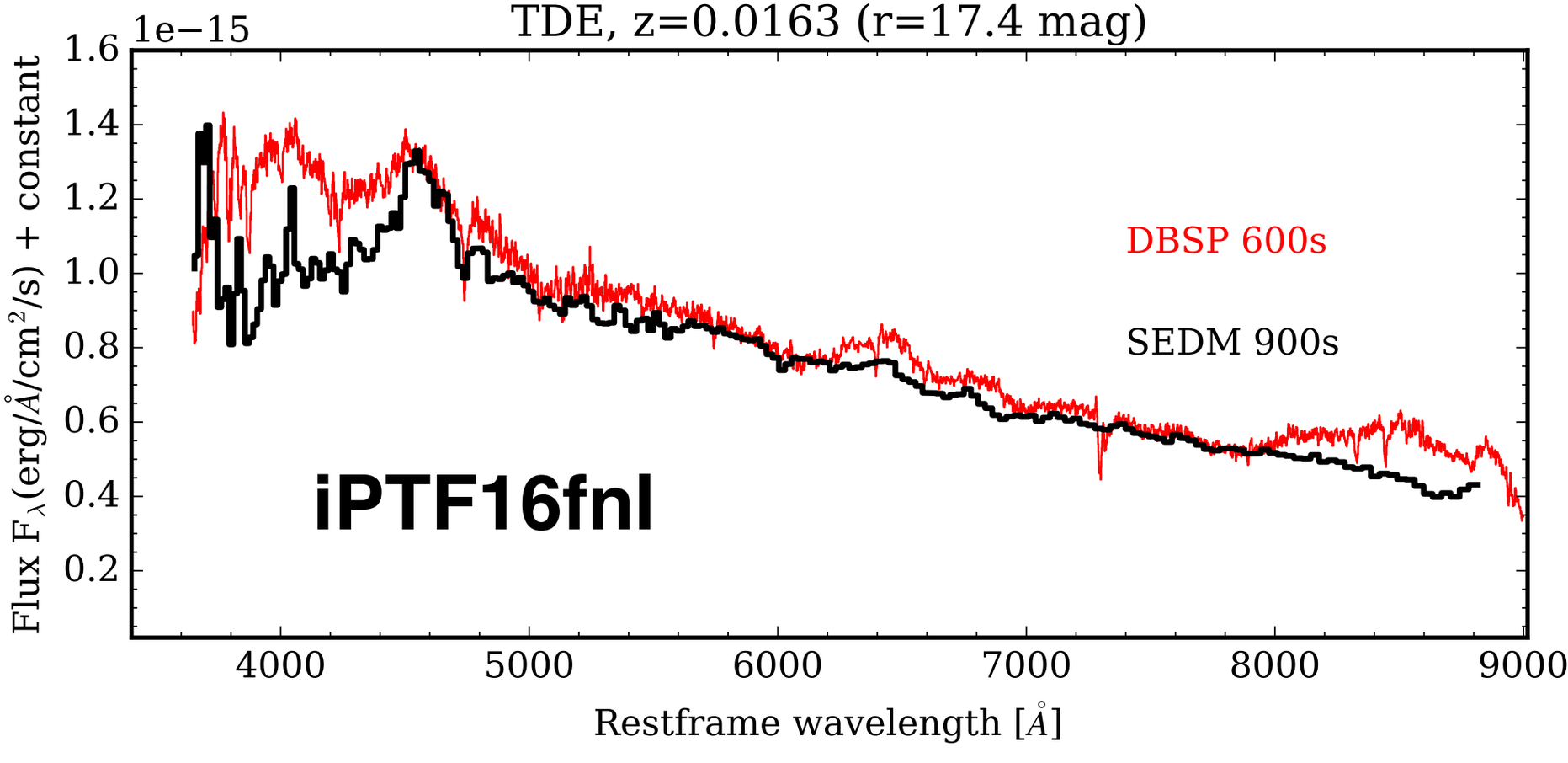


Blagorodnova (in prep)





SEDM
vs.
Long slit



Conclusions

- Field is evolving fast: new theory and observations
- Wide range of observable properties
- Tension on predicted vs. discovery rates may be alleviated by low-luminosity TDE similar to iPTF16fnl.
- Current only a small heterogeneous sample is know. ZTF will provide ~15 TDE/yr using a homogeneous selection process
- Big discoveries to be made! Follow-up is crucial!