Science highlights from ZTF: Exotic Asteroids

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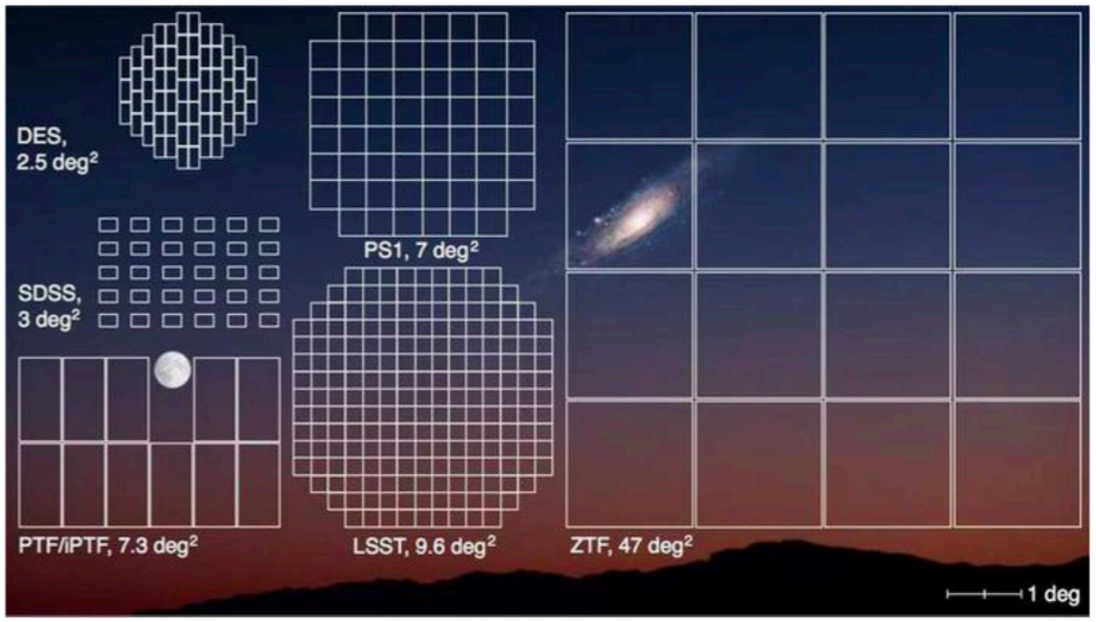
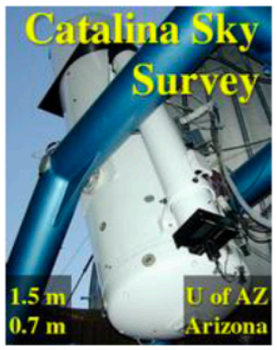
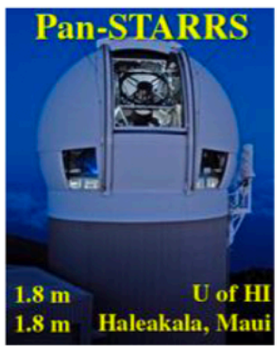
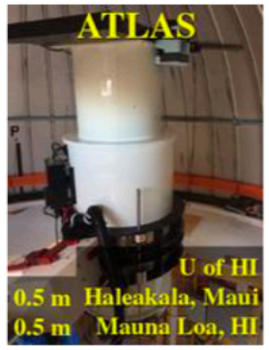
Celebrating ZTF-I & Soft Launch of ZTF-II 23 October, 2020

ZTF has an enormous field of view
+ moderate depth!









CSS 0.7-m

ATLAS 0.5-m
(single system)

Surveys 3800 sq. deg/ h to r~20.5

NEO Discovery (Bolin, Helou, Kramer, Masci, Prince)

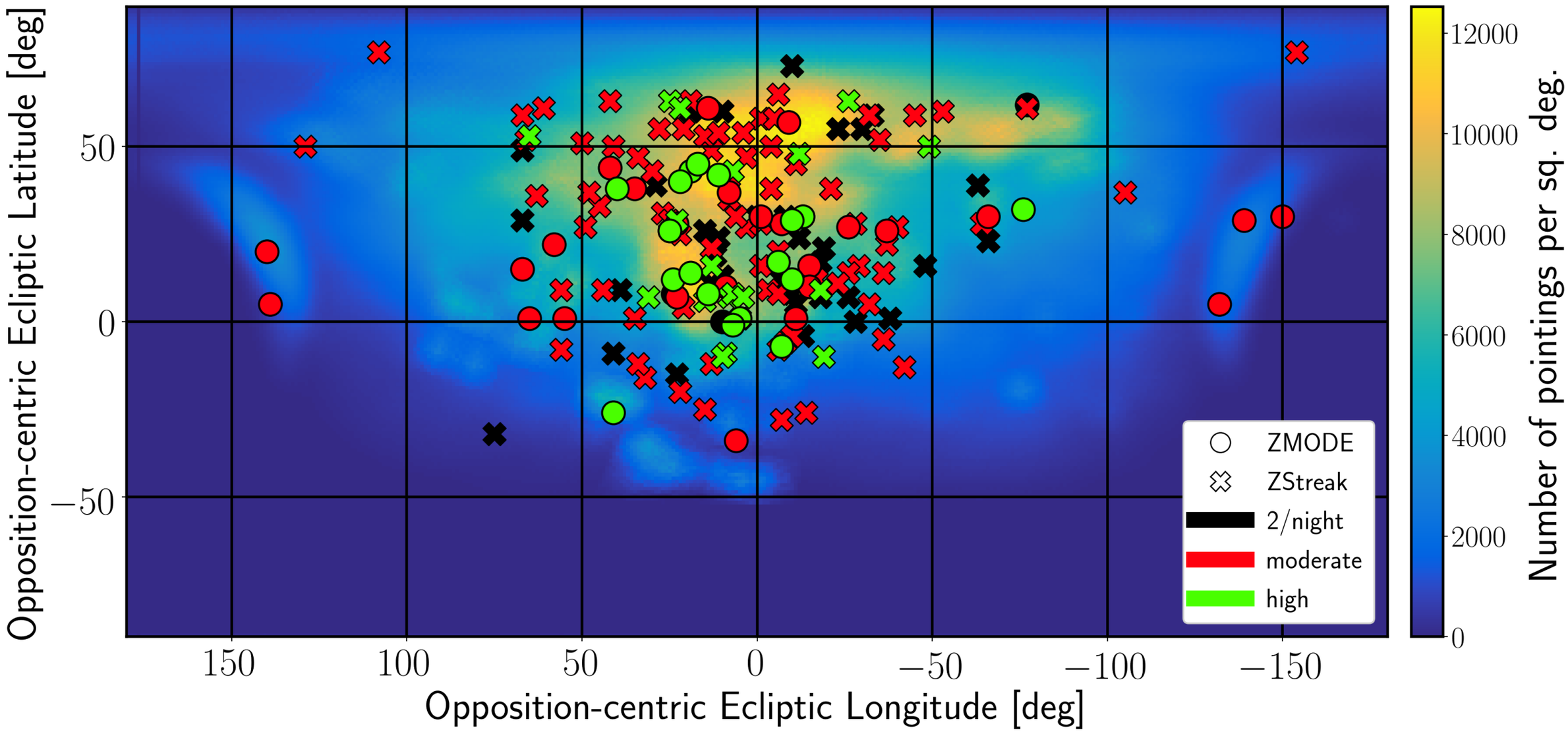
>180 NEOs discovered to date

- ZMODE: detection of point-like moving object
  - Main-belt asteroids; distant NEAs; comets

  Masci et al. 2019

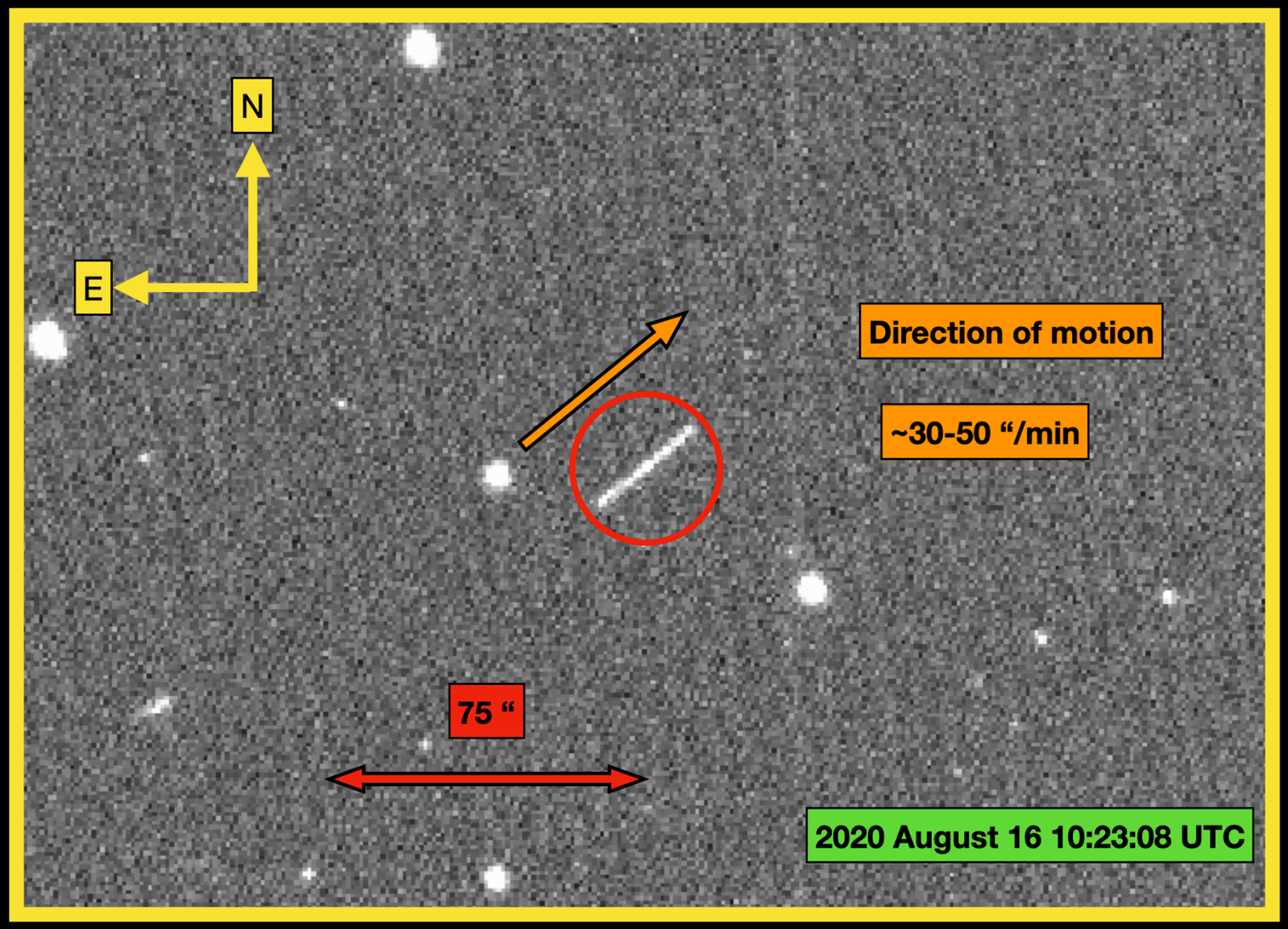
- ZSTREAK: detection of fast-moving objects (streaks)
  - Asteroids less than 0.01 au (~5 lunar distances) from the Earth
  - Also detect a lot of artificial satellites (a few dozens a night)
  - The new DeepStreaks algorithm reduced the false positive rate by 100x (thank you **Dima Duev** and **Ashish Mahabal**!)

Skyplane Distribution



Bolin et al. in prep

2020 QG



Kunal Deshmukh (IITB)

Kritti Sharma (IITB)

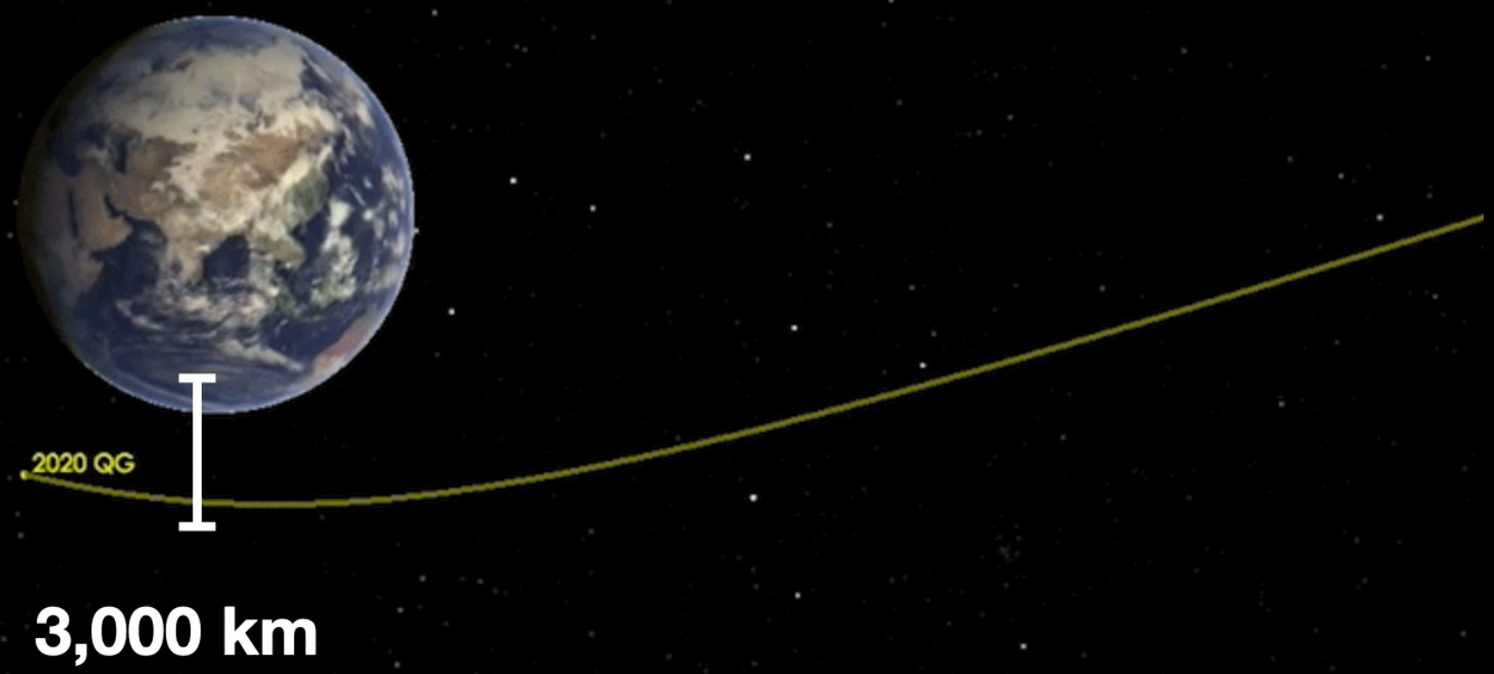
Chen-Yen Hsu (NCU)

Closest asteroid to fly-by the earth passing only 3,000 km above its surface

Discovered by student volunteers Kunal Deshmukh (IITB), Kritti Sharma (IITB), Chen-Yen Hsu (NCU)

Bolin et al. 2020b, MPEC 2020-Q51

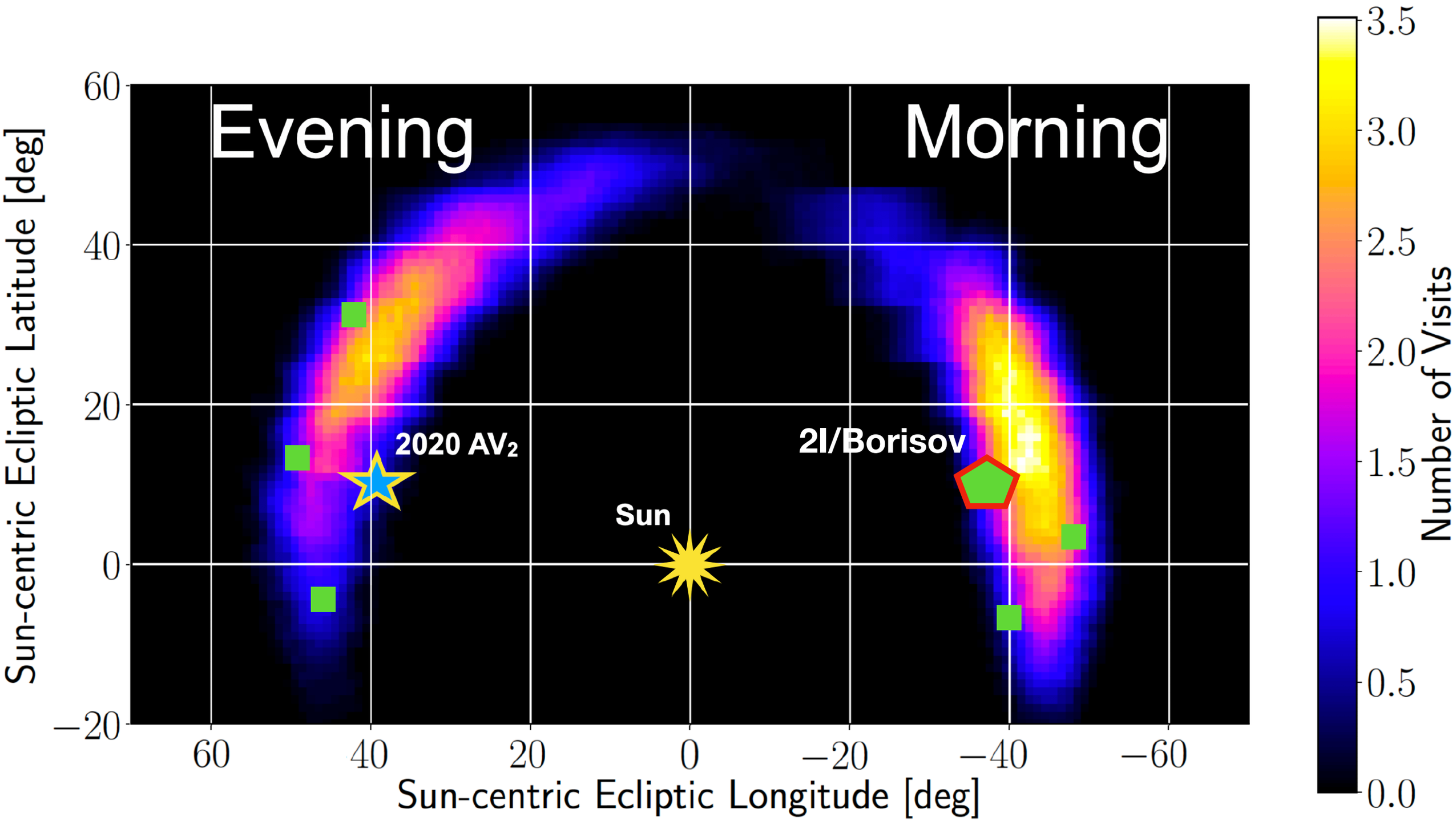
2020 QG



JPL/Farnocchia

Closest asteroid to fly-by the earth passing only 3,000 km above its surface

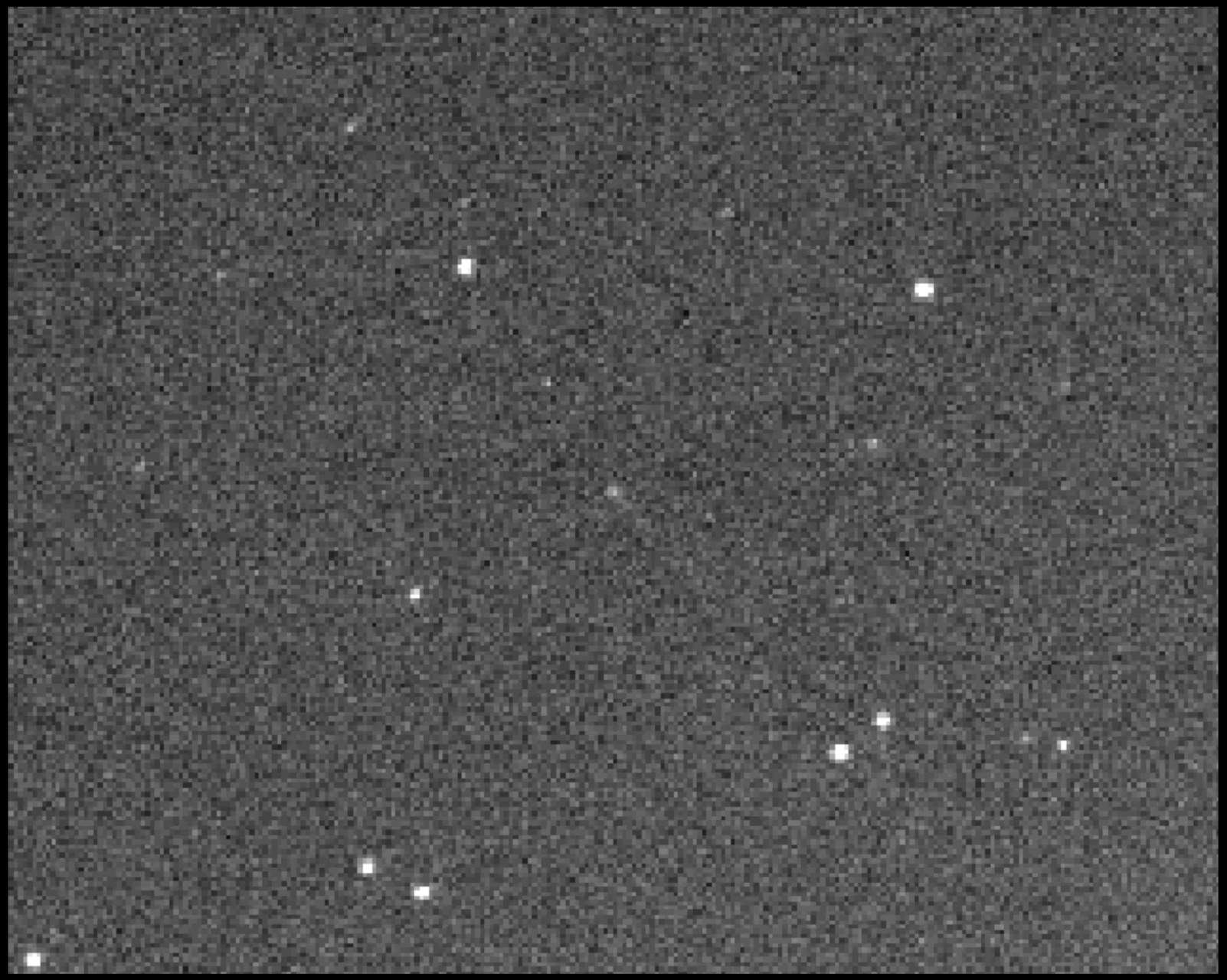
Inner Earth/Inner Venus objects



Twilight Survey

surveys sky ~18 deg. Twilight

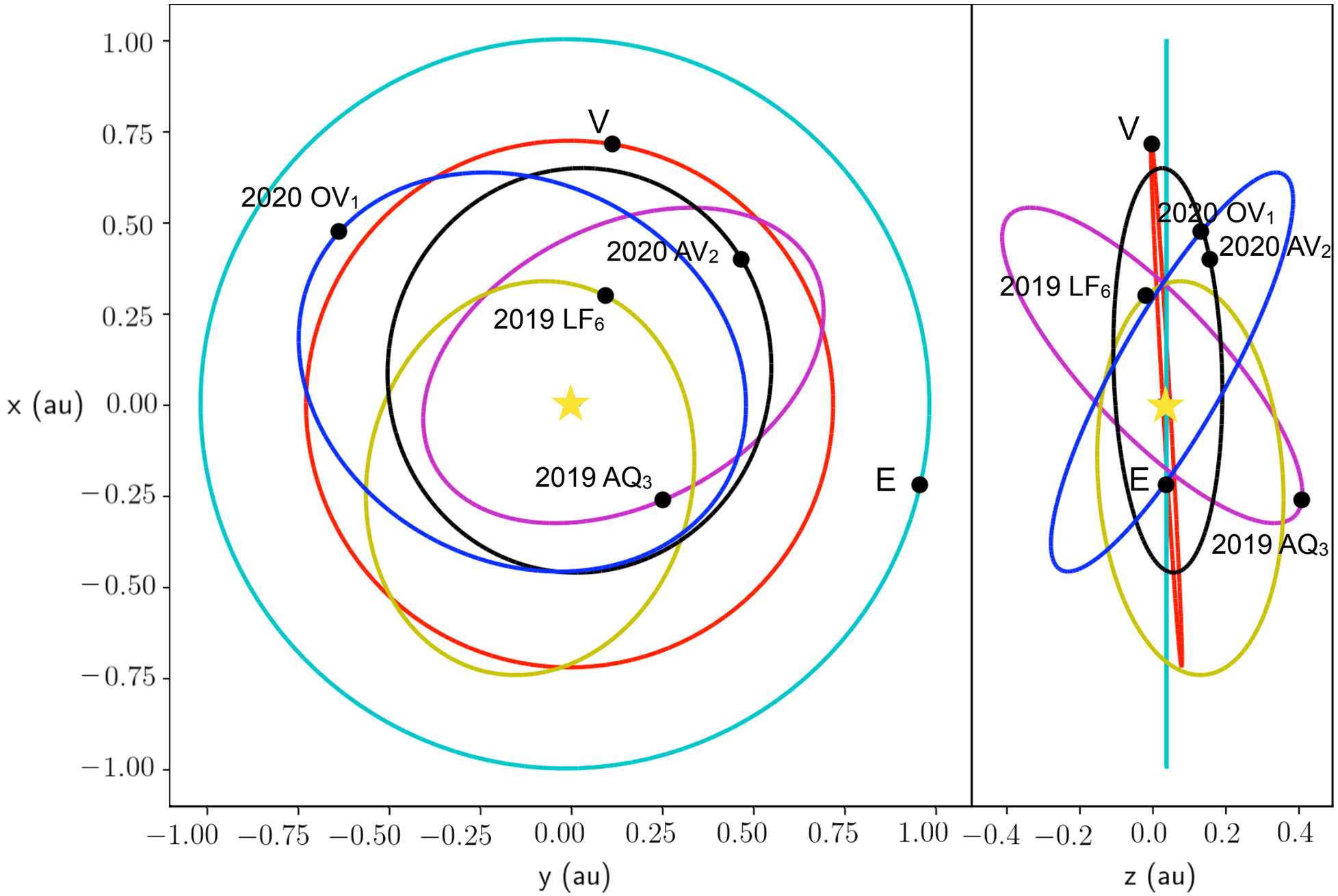
Discovery images



Discovered 2020 January 4, by ZTF, astrometric follow up by SEDM/KPED

Bolin et al. 2020c, MPEC 2020-O66; Ip, Bolin et al., under review

Inner-Earth/Inner-Venus objects



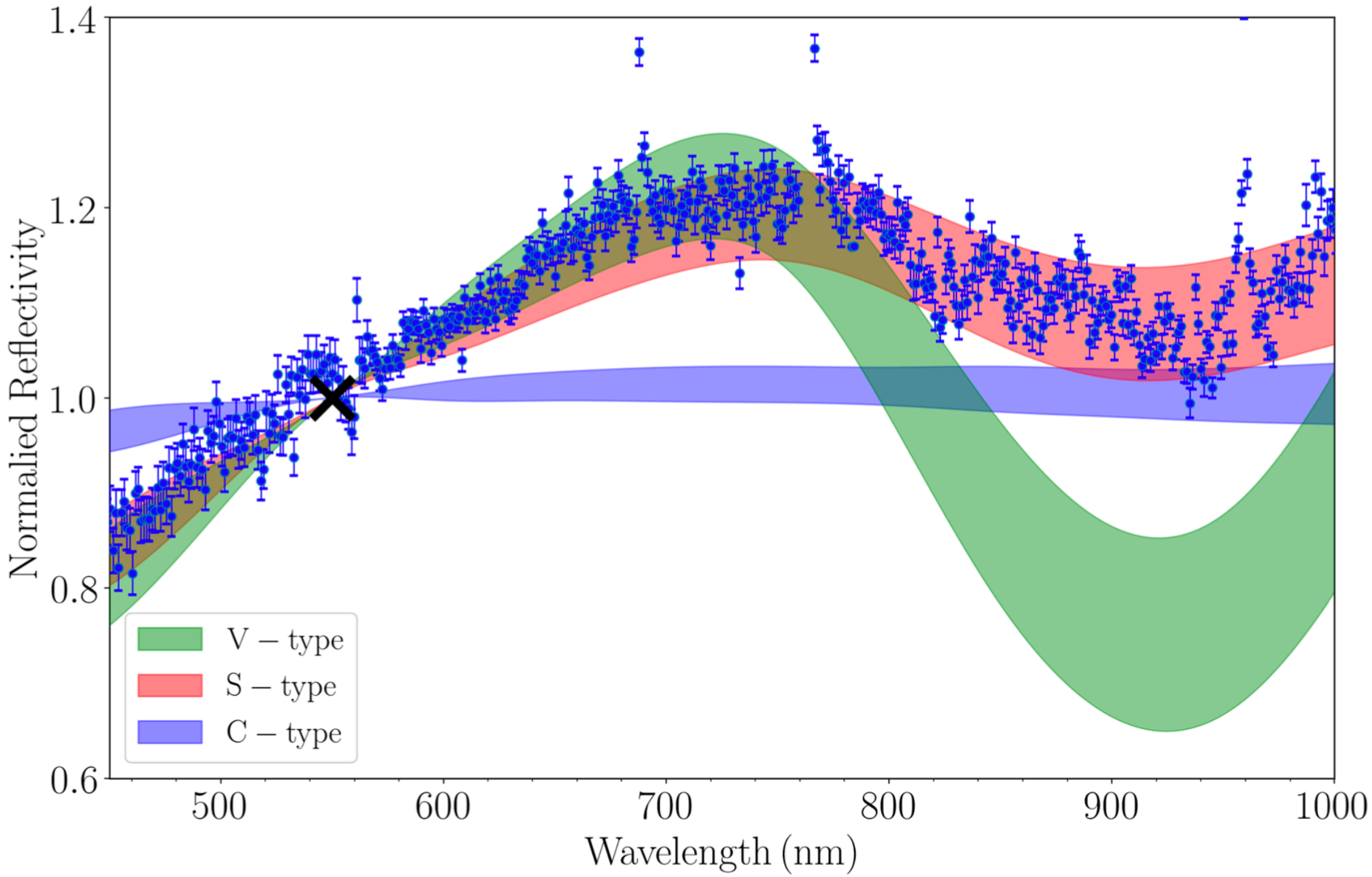
3 Atira/inner-Earth objets, 1 inner-Venus object

In 2020: inner-Venus object 2020 AV2 (Bolin et al. 2020c, MPEC 2020-A99) , Atira 2020 OV1 (Bolin et al. 2020d, MPEC 2020-O66)

2020 AV2 presently the shortest orbital asteroid: 151.192 days

Albedo and Spectrum

Keck/LRIS spectrum taken by M. Graham 2020-01-23

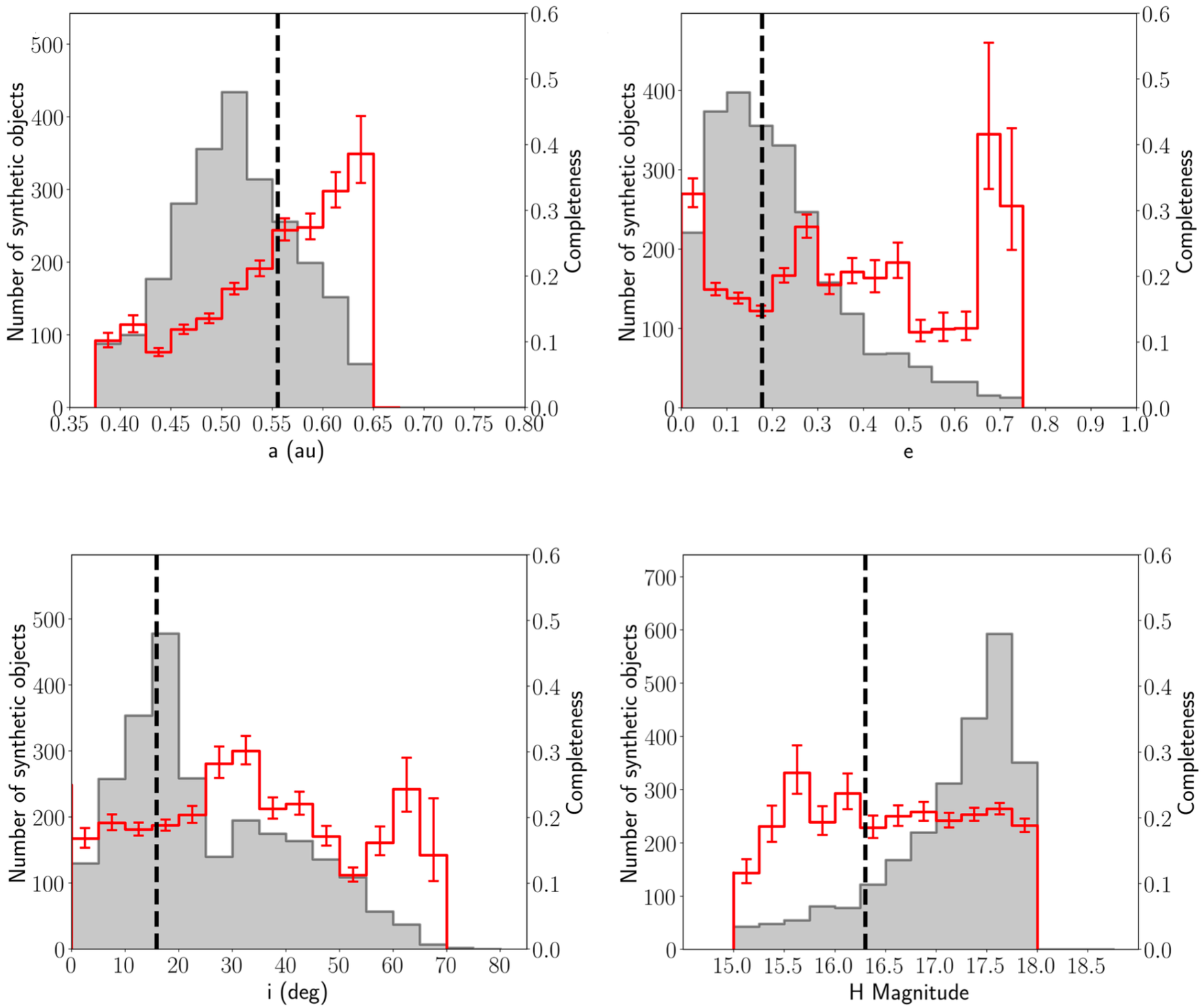


ν_6 resonance most likely source, albedo ~0.2 and size ~1.5 km (Morbidelli et al. 2020)

Spectrum most like S-type

Ip, Bolin et al. under review

Survey completeness



Combined Granvik et al. 2018 IEO model with ZTF Survey Simulation

~5% chance of detecting 2020 AV2

Interstellar Objects

Only two known ISOs: 1I/‘Oumuamua and 2I/Borisov

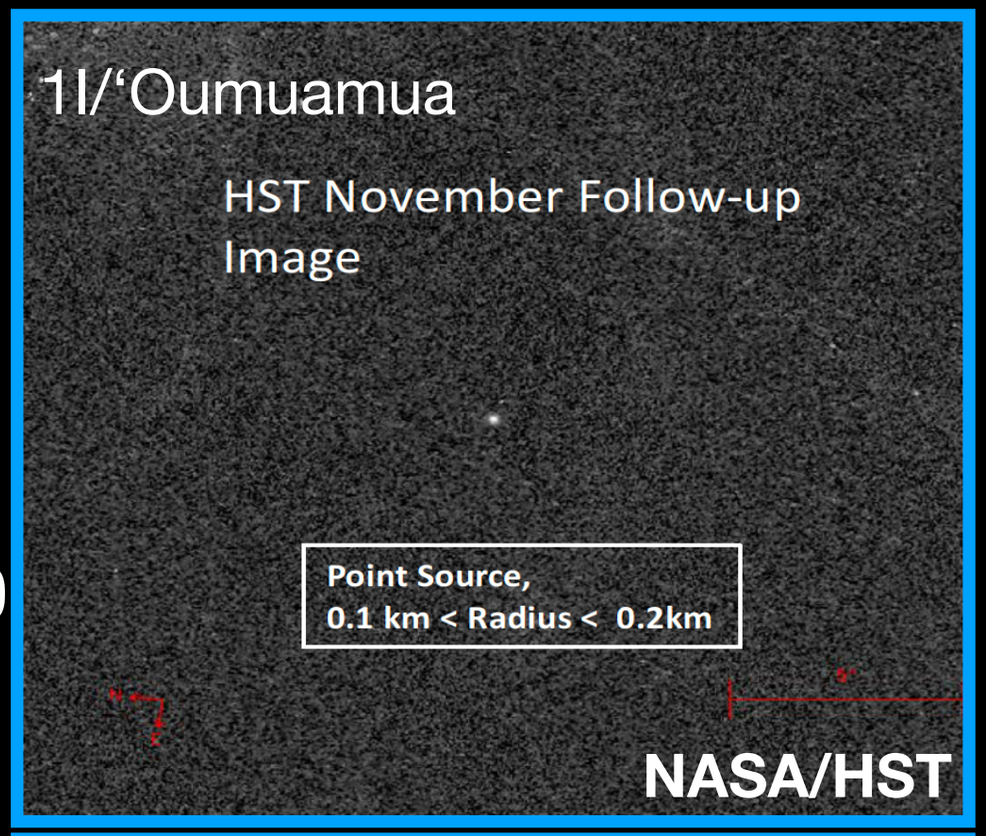
Eccentricity >1 !!!

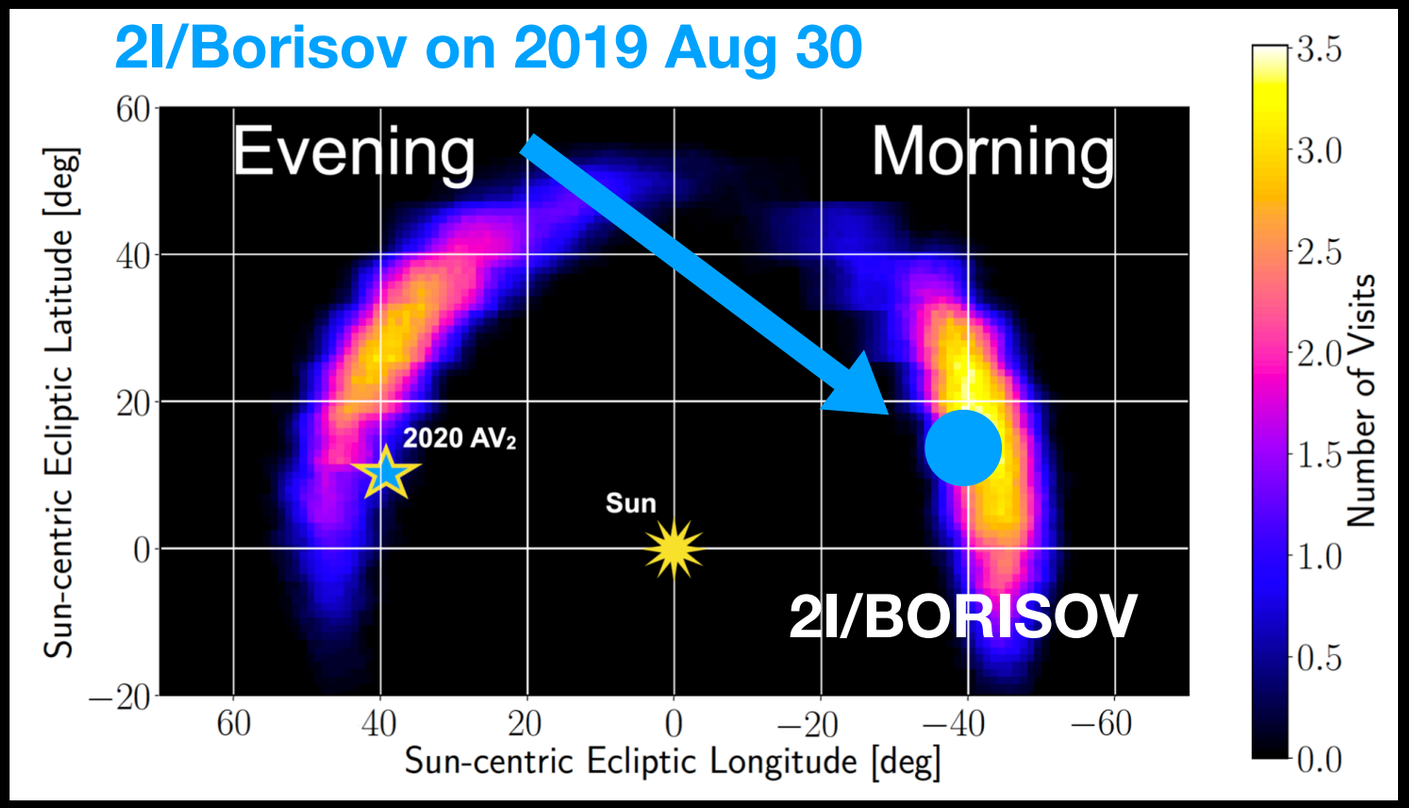
$e_{1I} = 1.20$, $q = 0.25$ au, $v_\infty = 26.3$ km/s

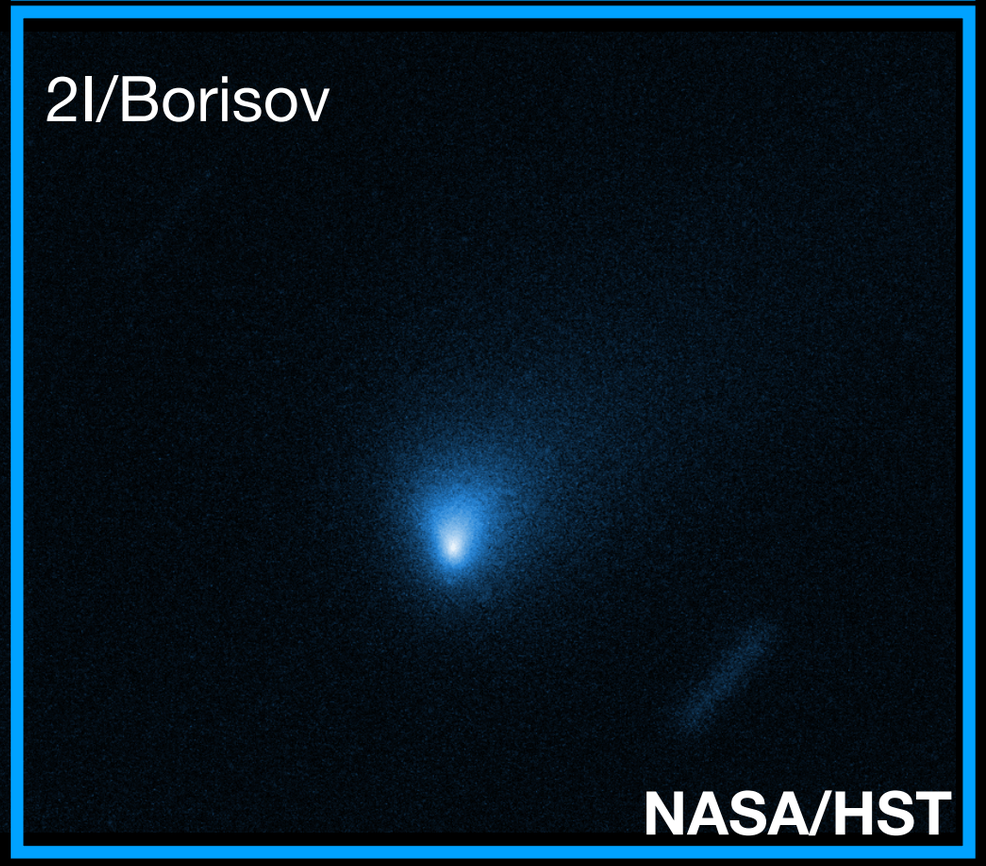
$e_{2I} = 3.35$, $q = 2.0$ au, $v_\infty = 32.5$ km/s

2I Discovered by G. Borisov on 2019 Aug 30

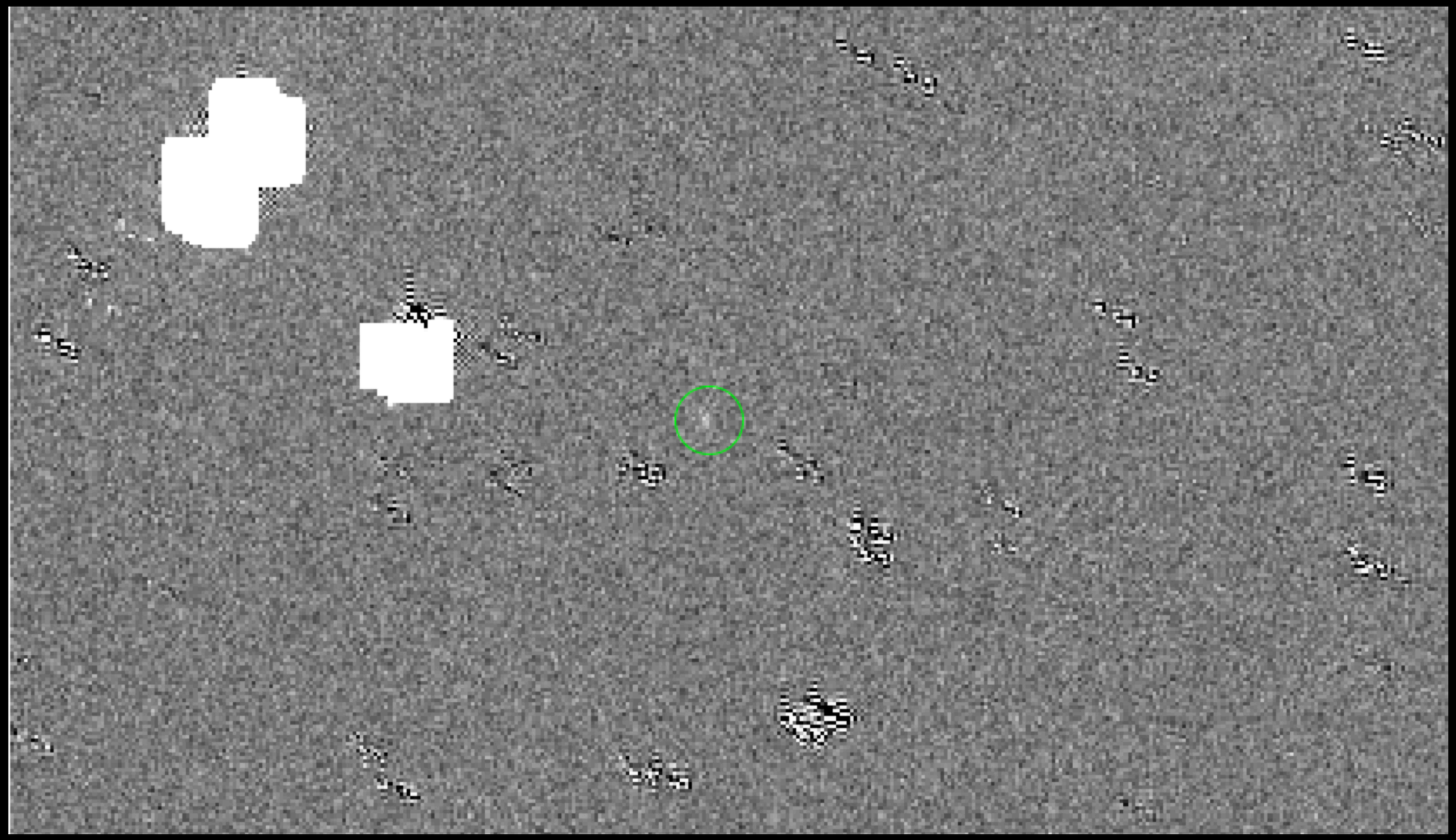
Found at V~18 in morning twilight







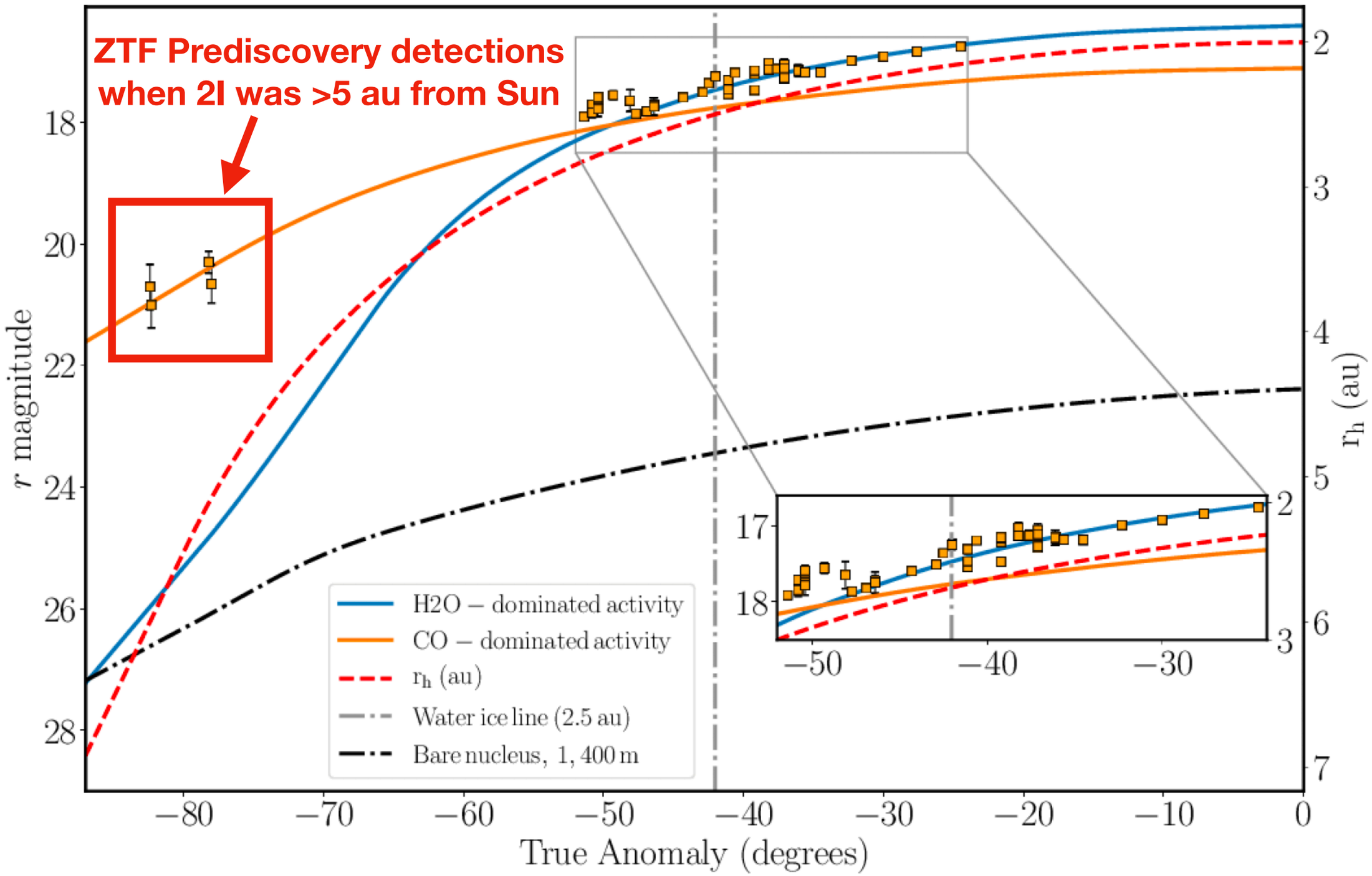
ZTF Pre-disovery data



2019-05-02 180 s r band stack,
more detections as far back as Dec 2018

Bolin et al. 2020e

Long-term Lightcurve



Brightness in pre-discovery images implies activity at >6 au, supervolatile (CO) activity

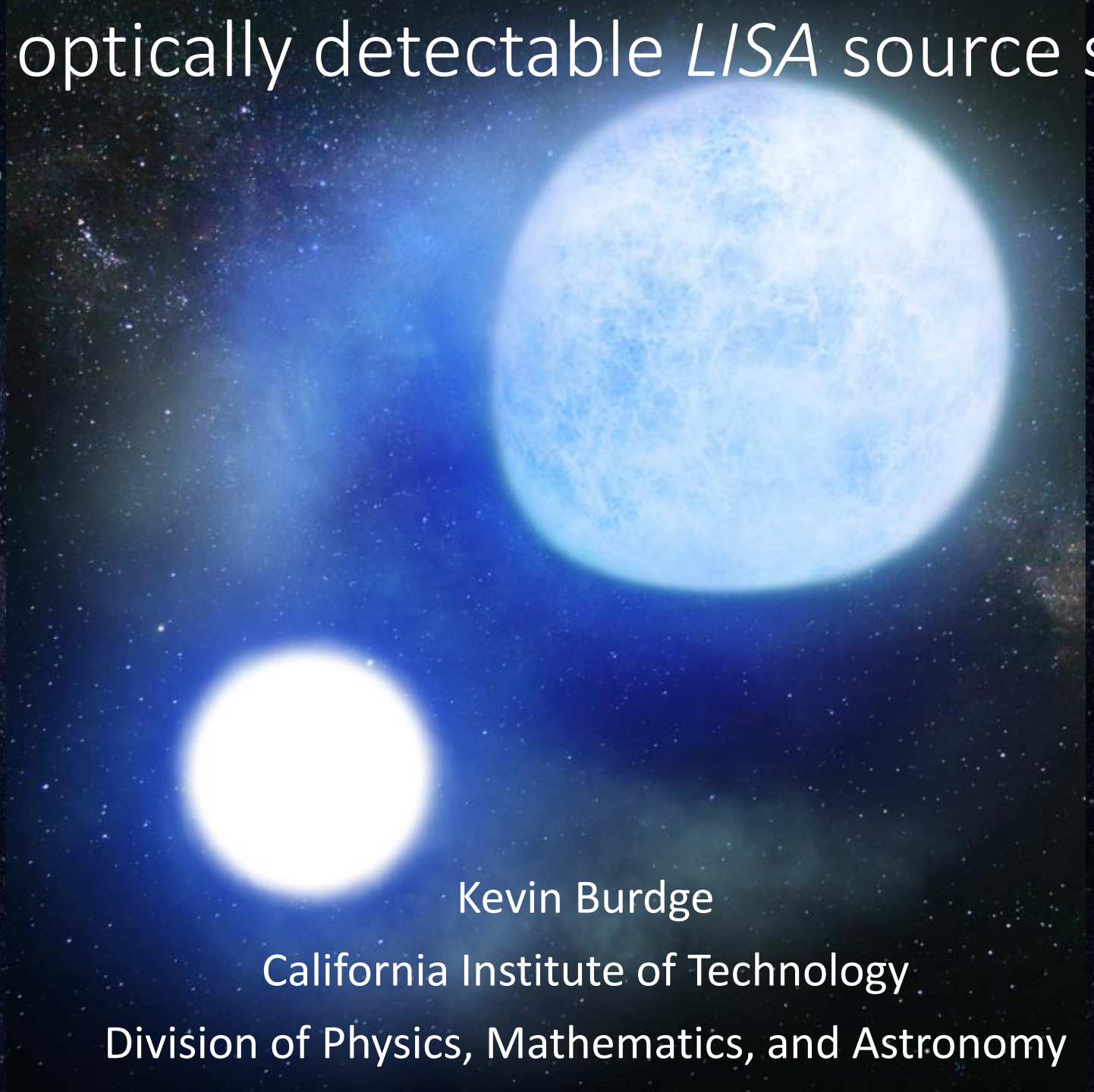
Recent turn on of H_2O

Bolin et al. 2020e

Summary

- **ZTF: Large étendue optical survey**
- **Two distinct modes of NEO detection: ZMODE and ZSTREAK**
- **Unique capability to identify fast-moving and close in objects (2020 OQ6, 2020 QG!)**
- **Capability of finding inner-Venus and inner-Earth objects (2020 AV2, 2020 OV1)**
- **Supports Solar System Science (Comets, Interstellar Objects)**

The optically detectable *LISA* source survey



Kevin Burdge

California Institute of Technology

Division of Physics, Mathematics, and Astronomy

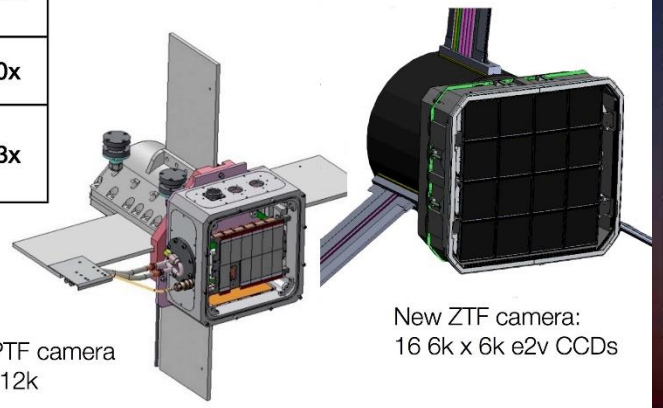
Discovery: using the Zwicky Transient Facility

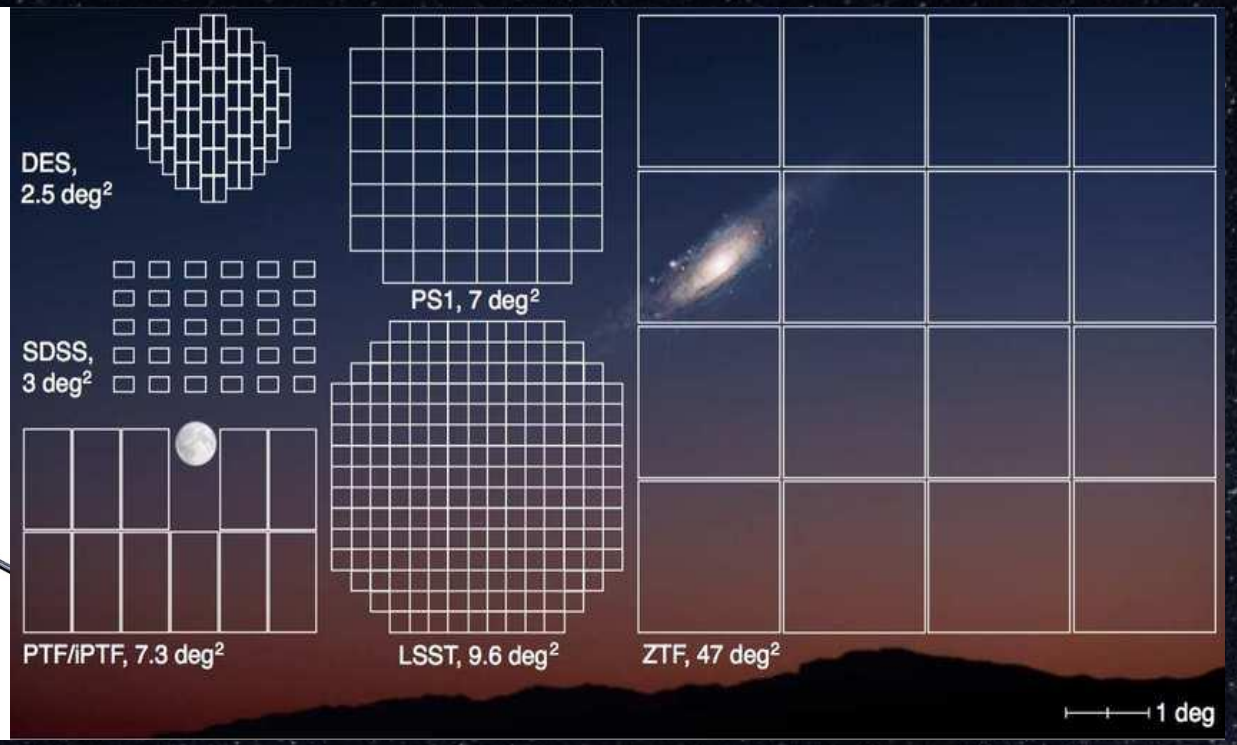
ZTF will survey an order of magnitude faster than PTF.

	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**

3750 deg^2/hour
⇒ 3π survey in 8 hours

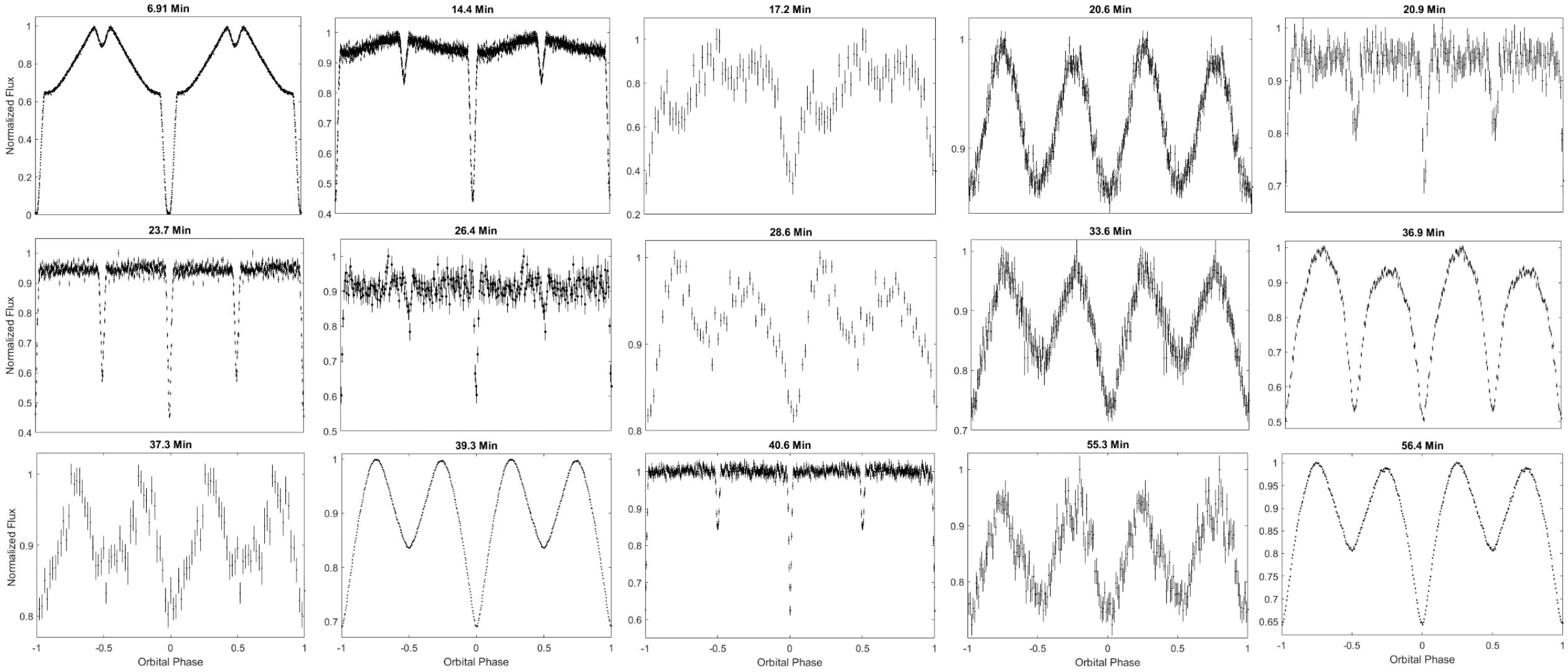
>250 observations/field/year
for uniform survey

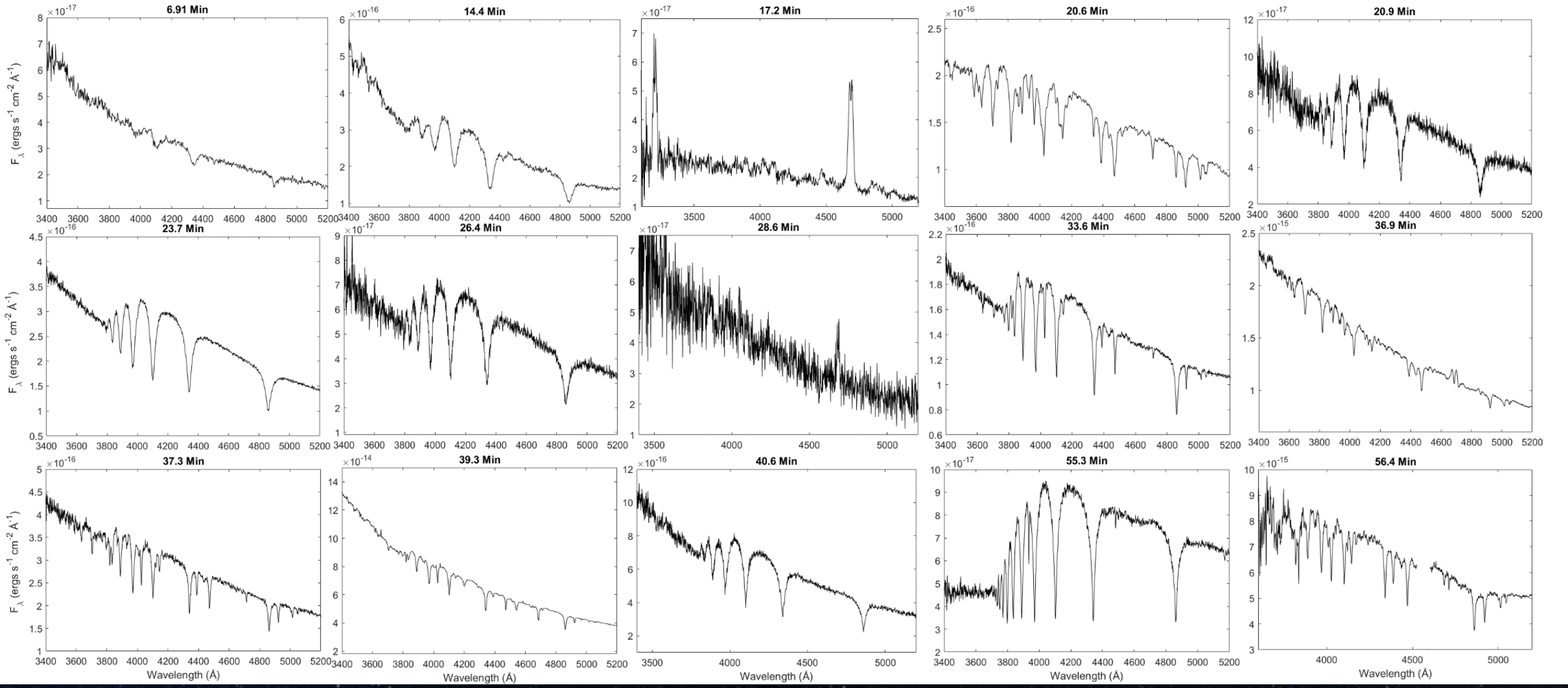


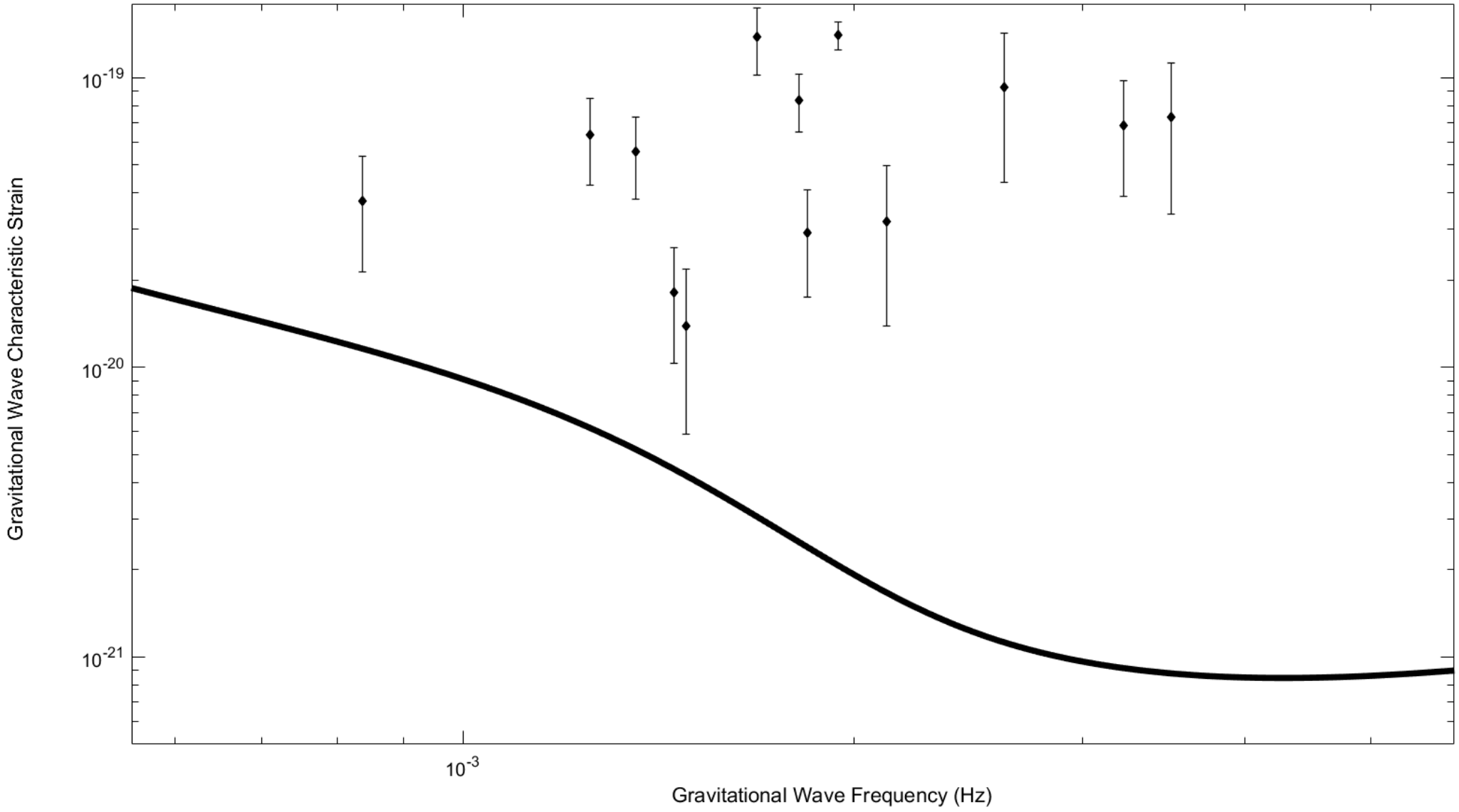


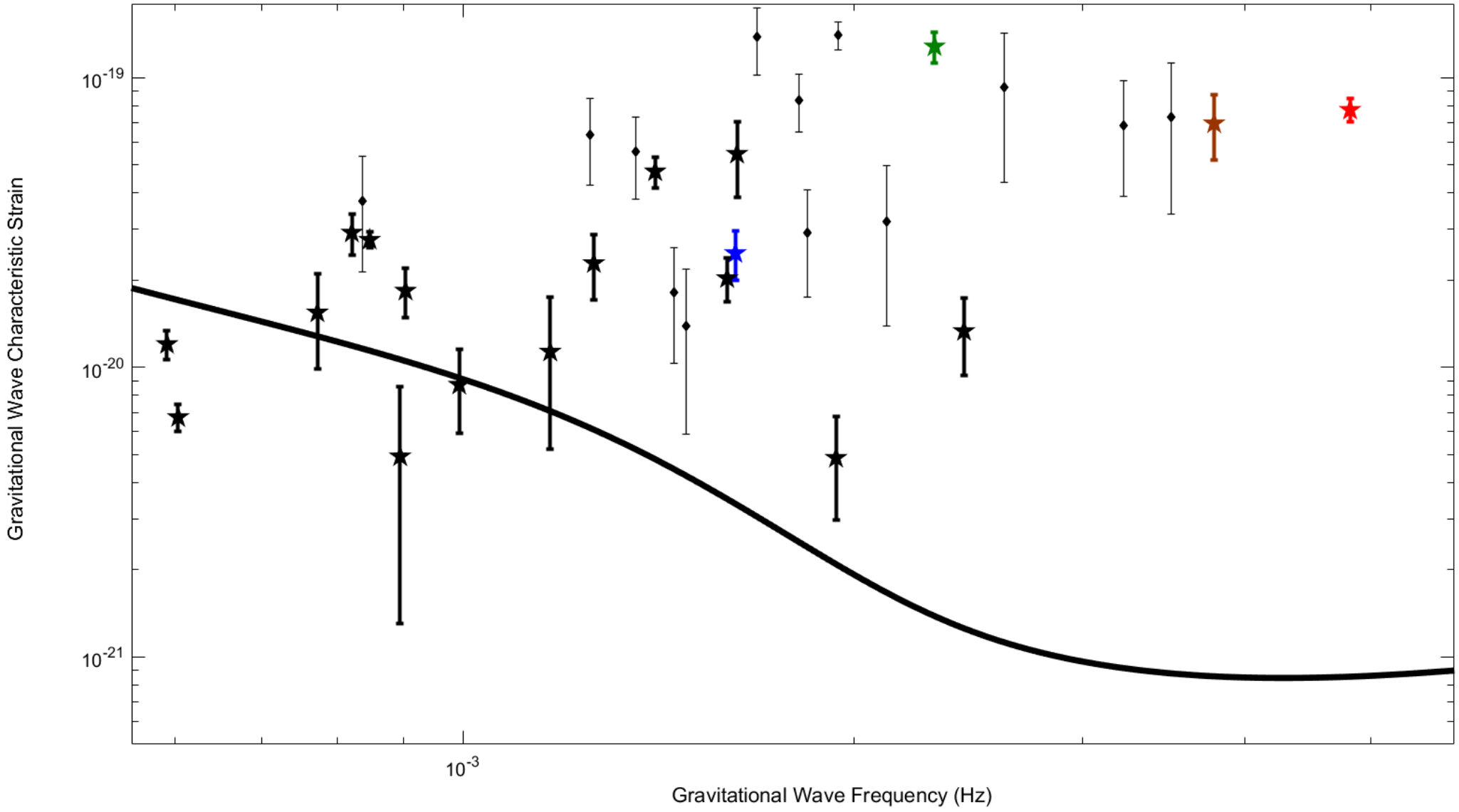
The crucial element: ZTF has a large field of view, and accumulates many epochs quickly

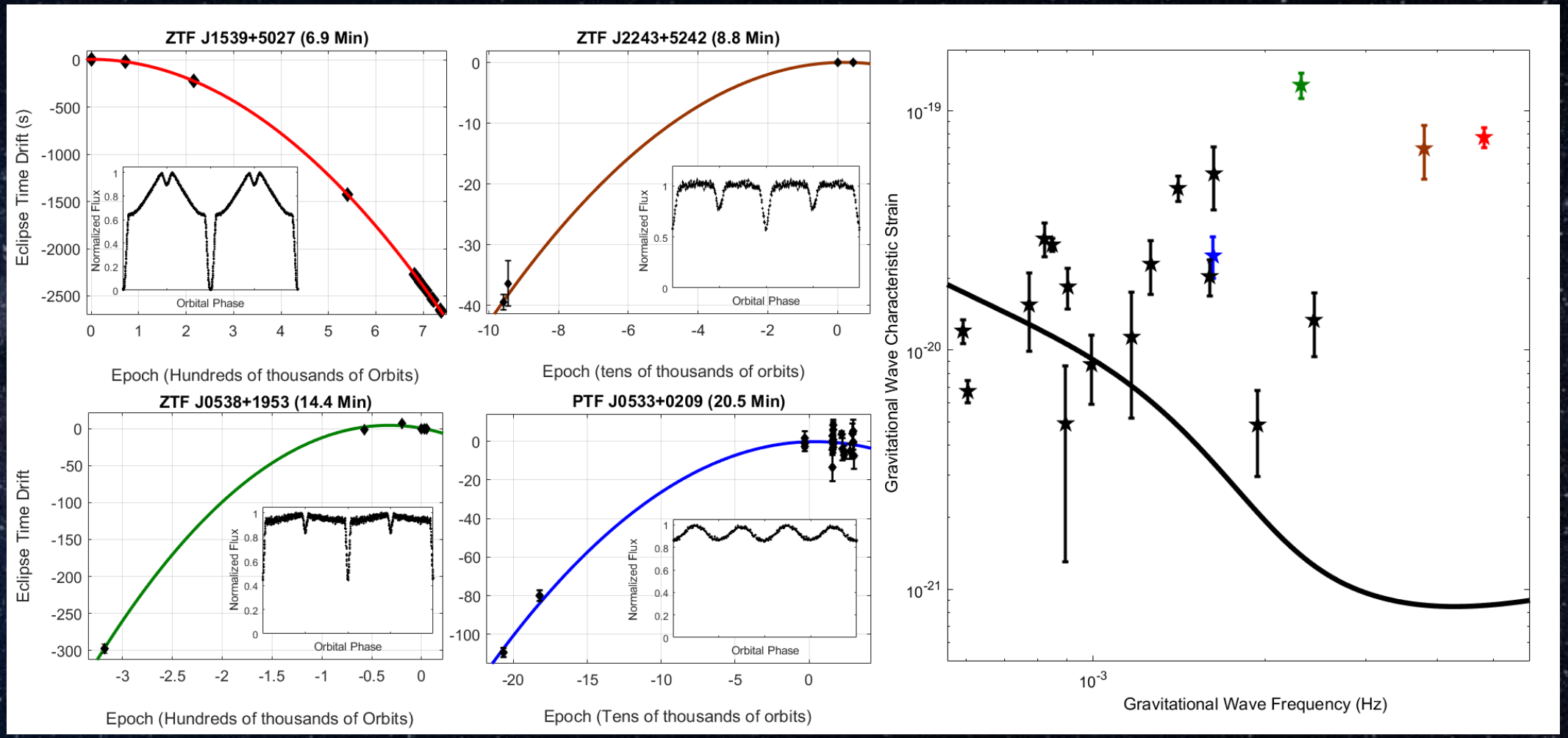
Okay, now let’s get to the good stuff


6.91 Min
14.4 Min
17.2 Min
20.6 Min
20.9 Min
23.7 Min
26.4 Min
28.6 Min
33.6 Min
36.9 Min
37.3 Min
39.3 Min
40.6 Min
55.3 Min
56.4 Min
Normalized Flux
Orbital Phase


6.91 Min
14.4 Min
17.2 Min
20.6 Min
20.9 Min
23.7 Min
26.4 Min
28.6 Min
33.6 Min
36.9 Min
37.3 Min
39.3 Min
40.6 Min
55.3 Min
56.4 Min
F_λ (ergs s^-1 cm^-2 Å^-1)
Wavelength (Å)


Gravitational Wave Characteristic Strain
10^{-19}
10^{-20}
10^{-21}
10^{-3}
Gravitational Wave Frequency (Hz)


Gravitational Wave Characteristic Strain
10^{-19}
10^{-20}
10^{-21}
10^{-3}
Gravitational Wave Frequency (Hz)

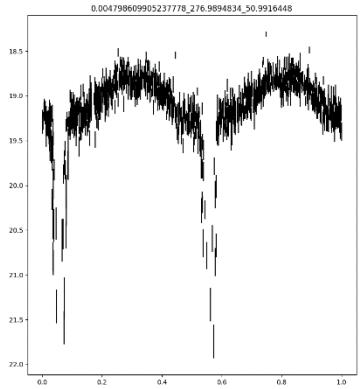

ZTF J1539+5027 (6.9 Min)
Eclipse Time Drift (s)
Normalized Flux
Orbital Phase
Epoch (Hundreds of thousands of Orbits)
ZTF J2243+5242 (8.8 Min)
Normalized Flux
Orbital Phase
Epoch (tens of thousands of orbits)
ZTF J0538+1953 (14.4 Min)
Eclipse Time Drift
Normalized Flux
Orbital Phase
Epoch (Hundreds of thousands of Orbits)
PTF J0533+0209 (20.5 Min)
Normalized Flux
Orbital Phase
Epoch (Tens of thousands of orbits)
Gravitational Wave Characteristic Strain
Gravitational Wave Frequency (Hz)

Looking to the future

1. In phase II, ZTF will accumulate enough epochs to start discovering variables with very narrow temporal features, such as eclipsing double CO WD pairs

2. ZTF's baseline is sufficiently long to begin measuring pdots directly from ZTF data. This also means we need to begin conducting acceleration searches in order to identify the shortest period variables

3. ZTF has a lot of room to improve in its archival photometry. Forced difference image photometry could hugely increase its discovery potential. Currently, non-detections are being omitted from archival data.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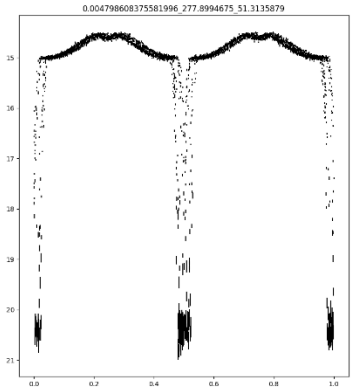
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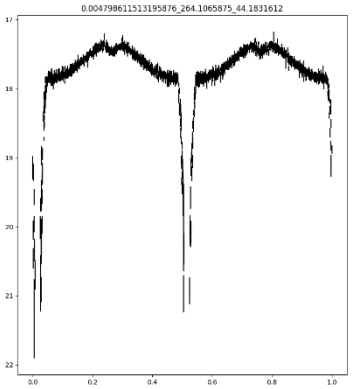
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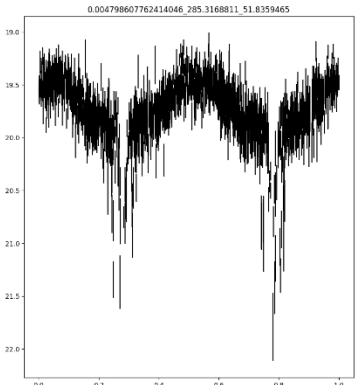
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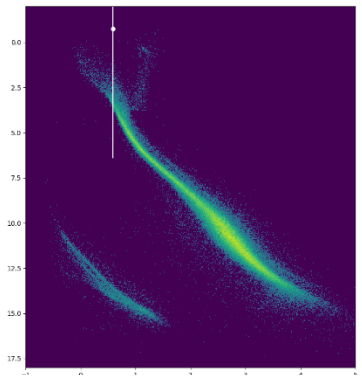

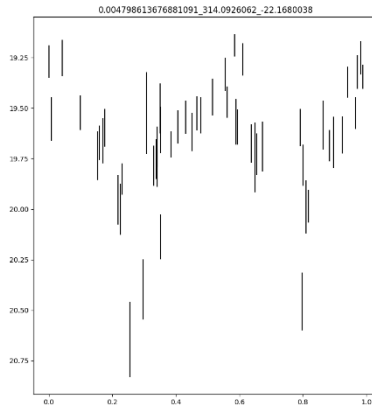
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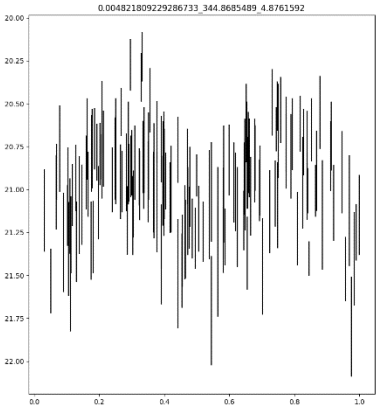
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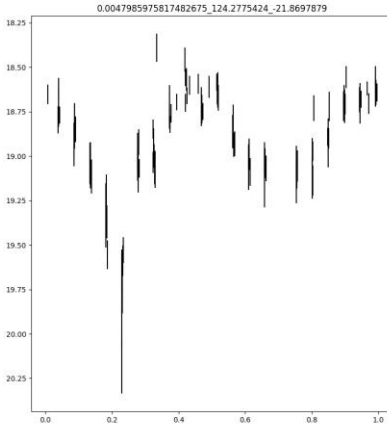
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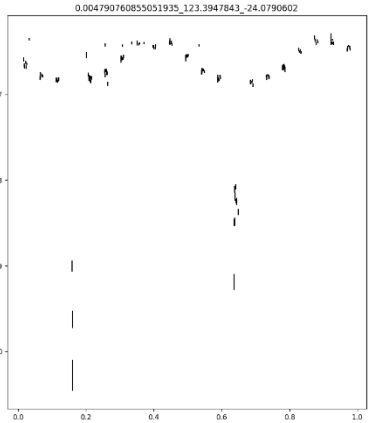
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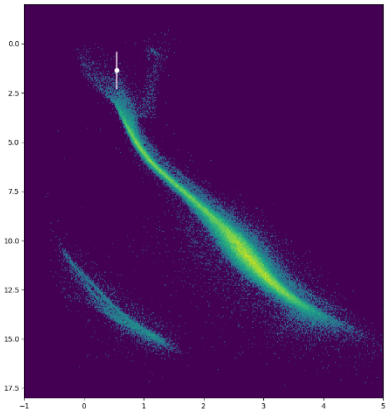

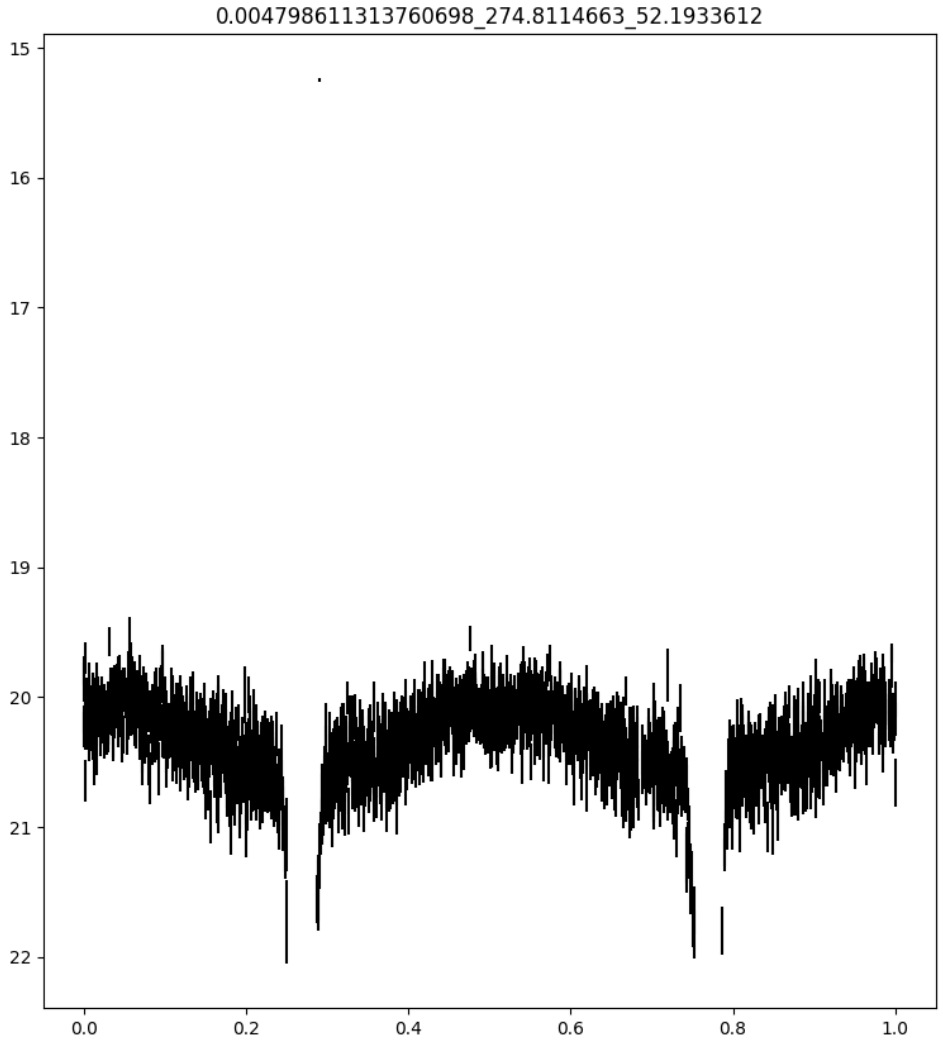
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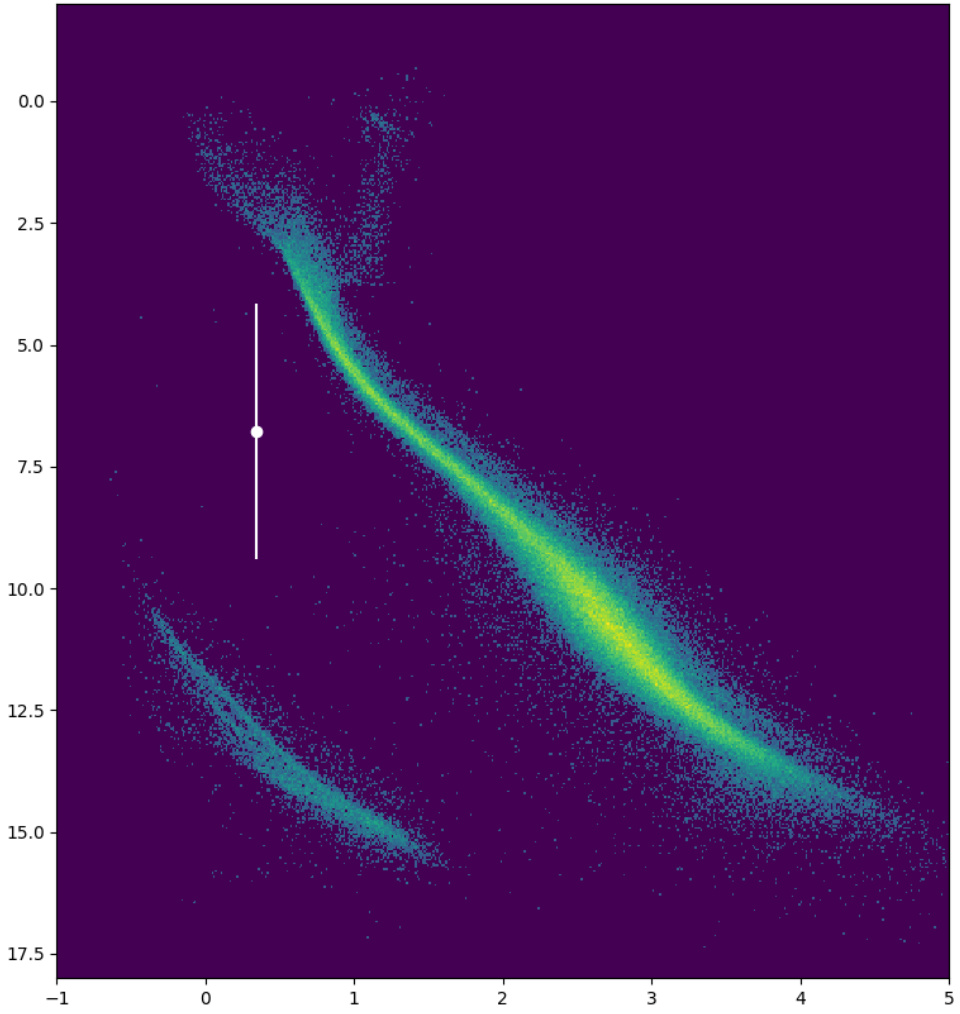
0.6
0.8
1.0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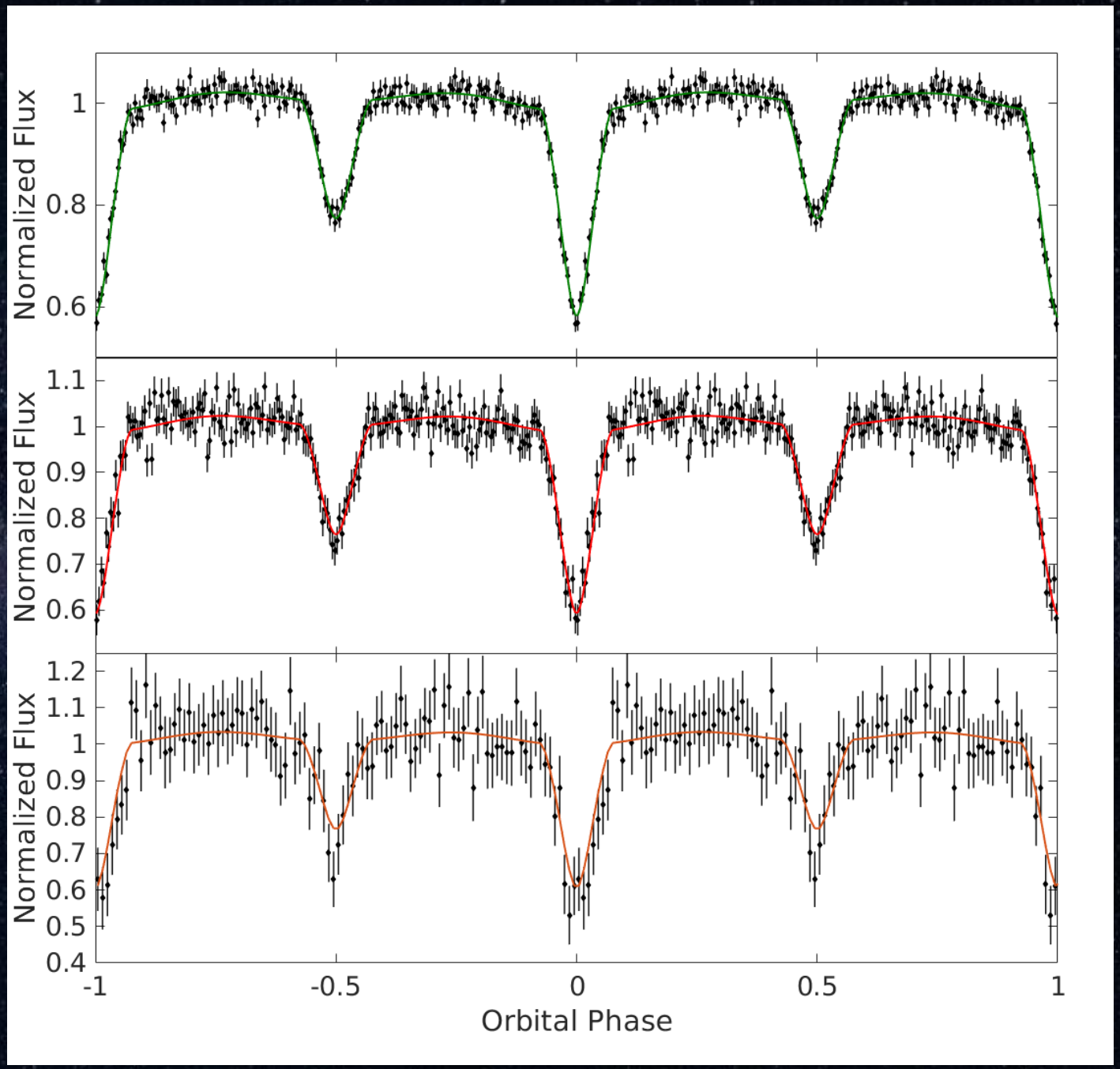
2
3
4
5


Normalized Flux
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0.8
0.6
Normalized Flux
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1
0.9
0.8
0.7
0.6
Normalized Flux
1.2
1.1
1
0.9
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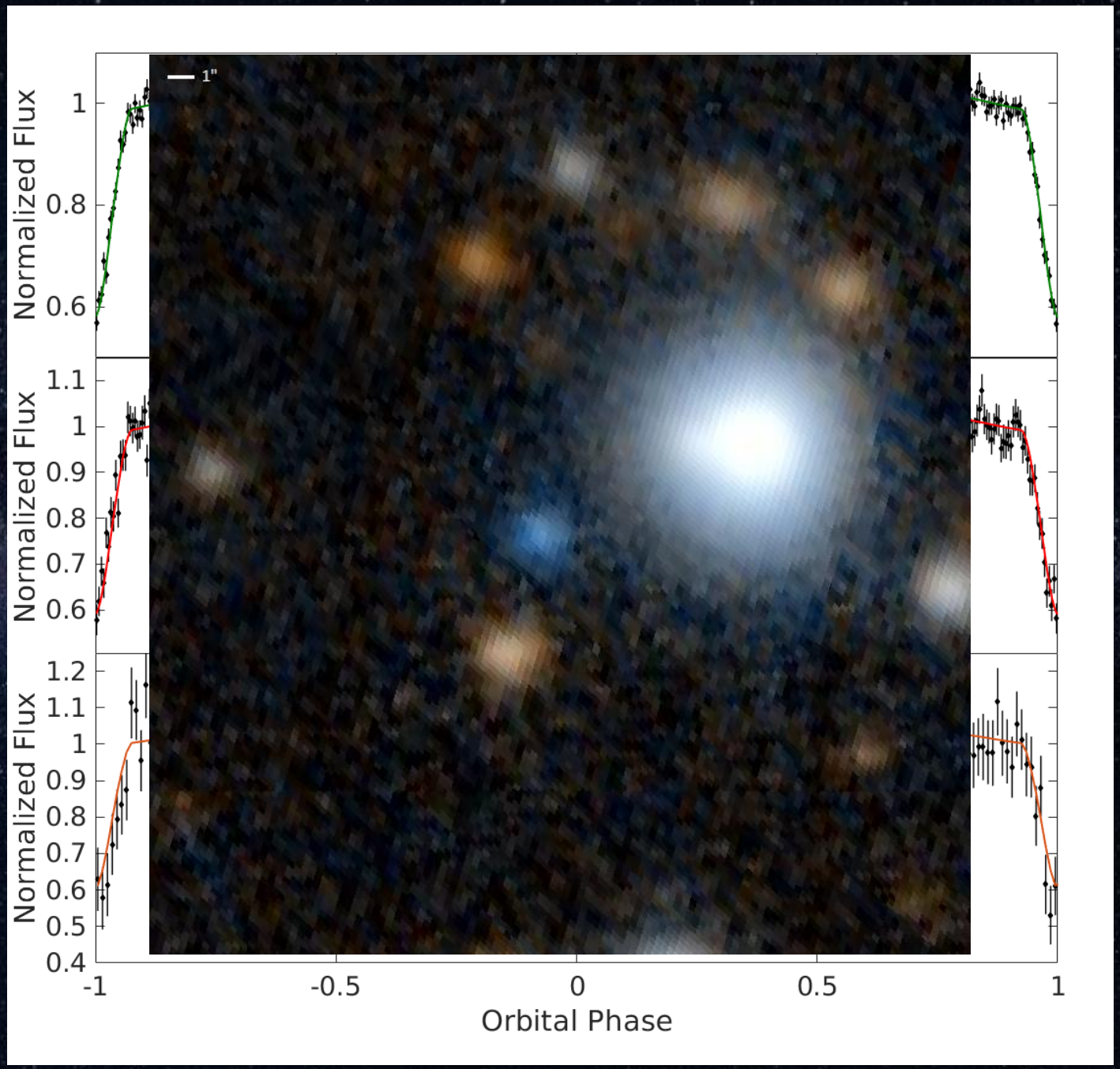
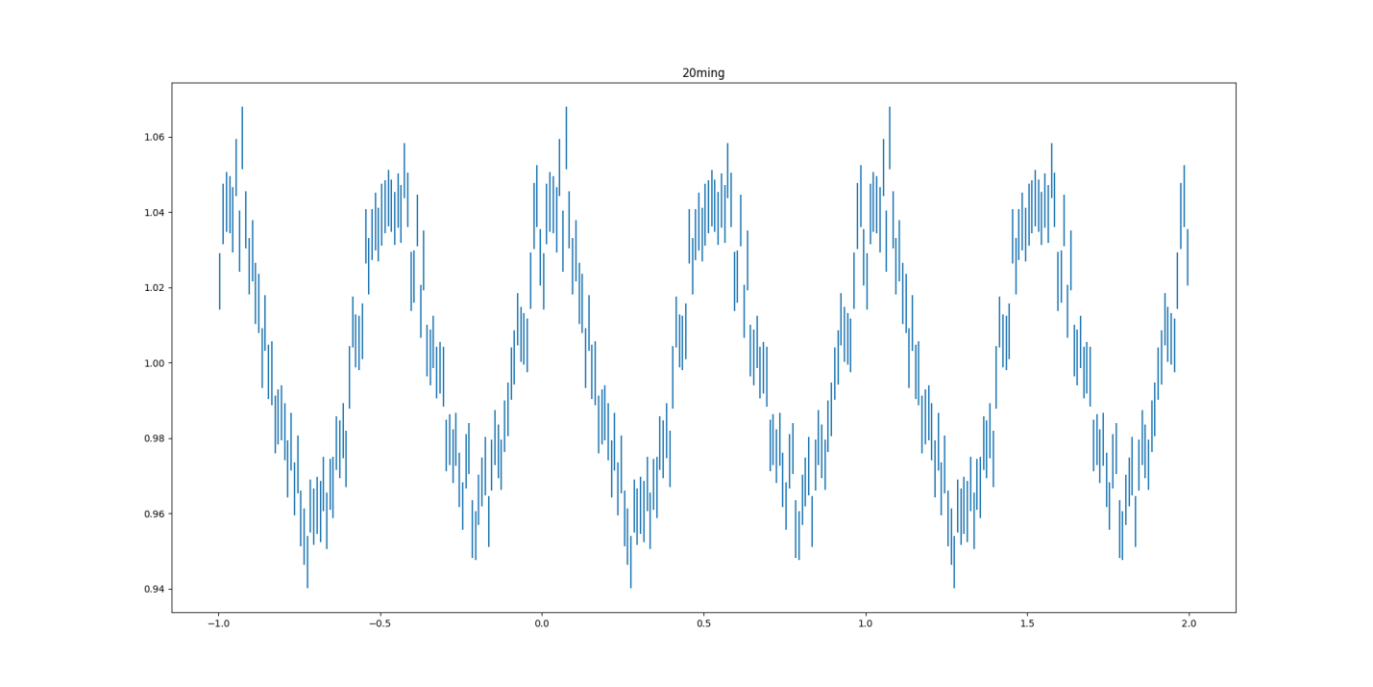
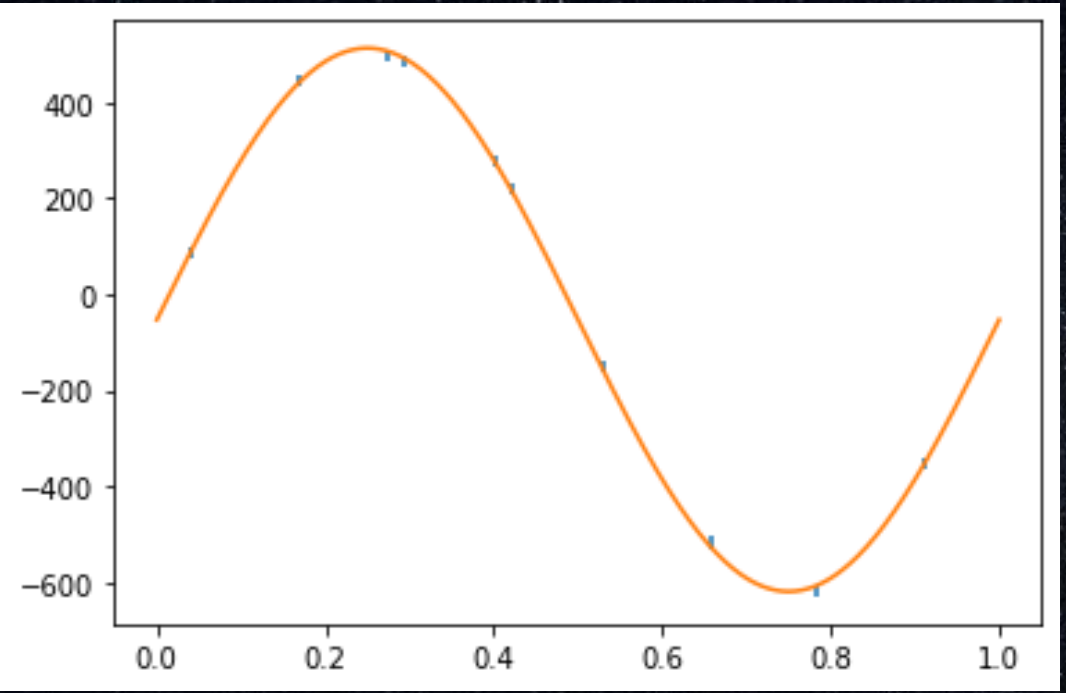
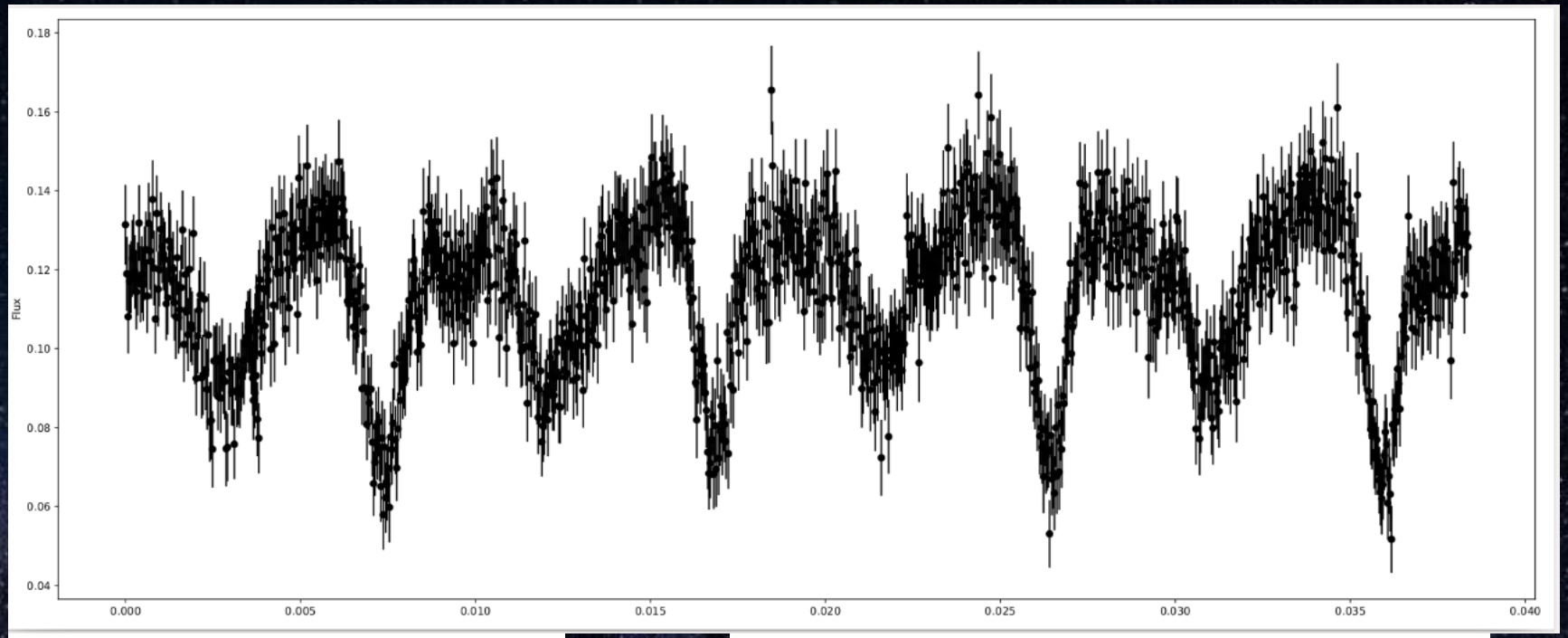
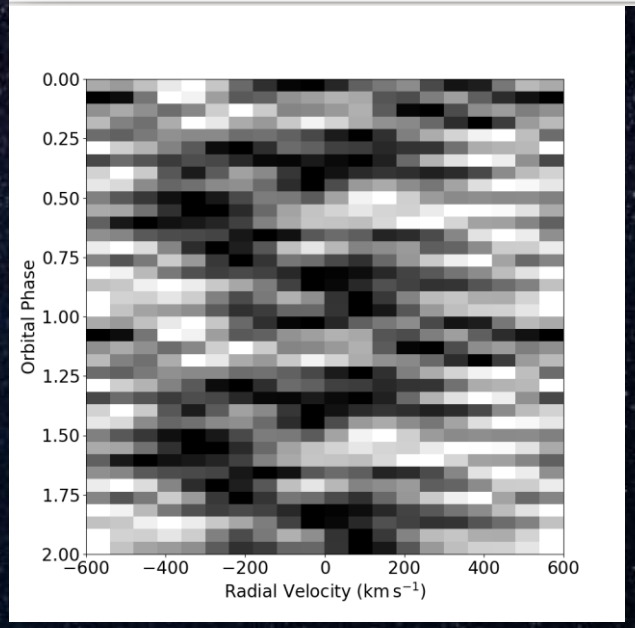
0.6
0.5
0.4
-1
-0.5
0
0.5
1
Orbital Phase

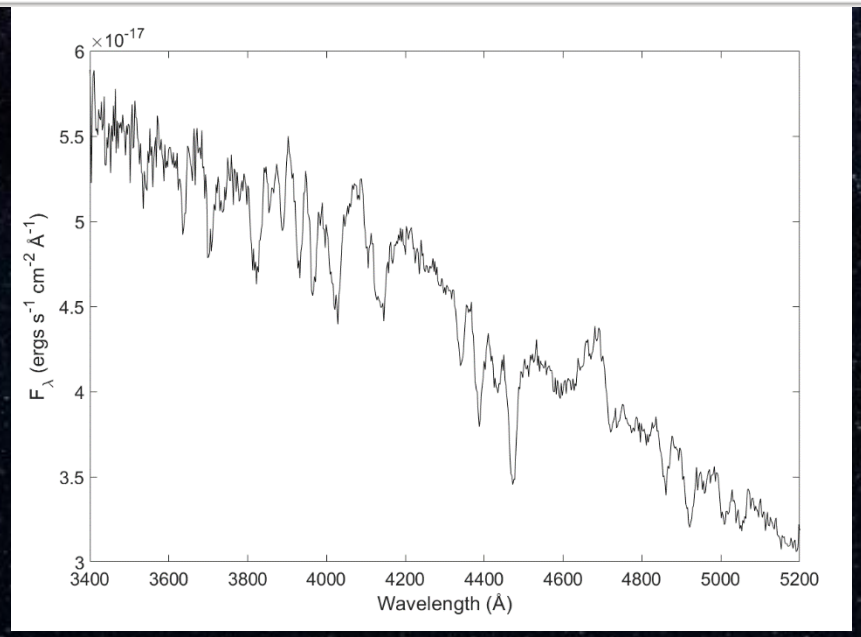

1"
Normalized Flux
1
0.8
0.6
Normalized Flux
1.1
1
0.9
0.8
0.7
0.6
Normalized Flux
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
-1
-0.5
0
0.5
1
Orbital Phase


20ming
1.06
1.04
1.02
1.00
0.98
0.96
0.94
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0


400
200
0
−200
−400
−600
0.0
0.2
0.4
0.6
0.8
1.0


Flux
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040


Orbital Phase
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
−600
−400
−200
0
200
400
600
Radial Velocity (km s^{-1})


$\times 10^{-17}$
F_λ (ergs s^{-1} cm^{-2} Å^{-1})
6
5.5
5
4.5
4
3.5
3
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
Wavelength (Å)

The Zwicky Transient Facility Bright Transient Survey:

An Unbiased View of the Transient Sky

Christoffer Fremling (Caltech)

Shri Kulkarni (Caltech), Adam Miller (Northwestern), Daniel Perley (LJMU)
Aishwarya Dahiwale, Yashvi Sharma, Don Neill (Caltech),
Jesper Sollerman, Suhail Dhawan, Ariel Goobar, Rahul Biswas (Stockholm),
Kirsty Taggart (LJMU), Melissa Graham (Washington), Jakob Nordin (Humboldt), Alison Dugas (Hawaii), Rachel Bruch, Steve Schulze, Ido Irani, Erez Zimmerman (Weizmann),
Kishore Patra, Shaunak Modak, Andrew Hoffman, Alex Filippenko (UCB),
Jannis Necker, Ludwig Rauch, Samantha Goldwasser (DESY)

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Kishore Patra, Shaunak Modak, Andrew Hoffman, Alex Filippenko (UCB),
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The ZTF Bright Transient Survey

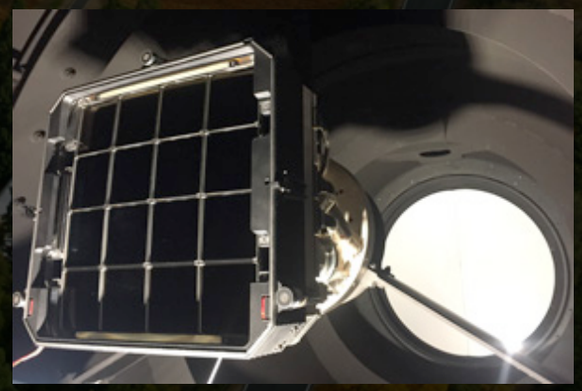
BTS

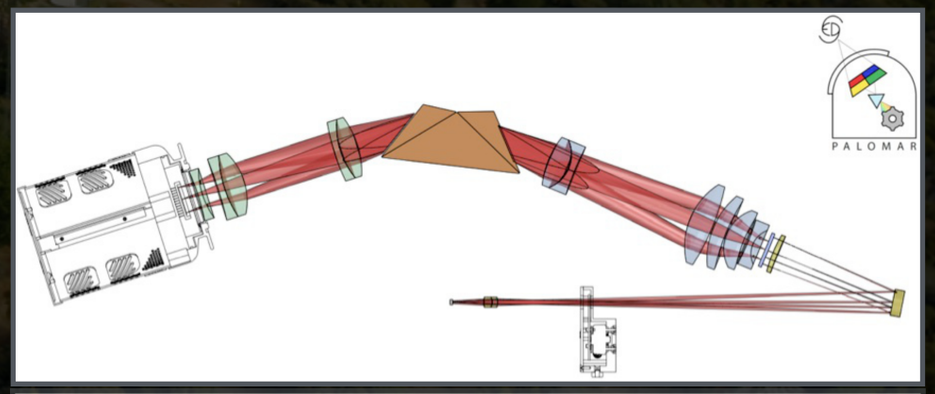
Magnitude limited survey, spectroscopically complete to 18.5 mag.

1. Catalog all SN candidates < 19 mag and send to the Transient Name Server
2. Classify all <18.5 mag SNe using mainly Palomar 60 inch with SEDM

Data from the public ZTF Northern Sky Survey

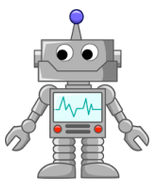
("Celestial Cinematography"; Bellm & Kulkarni, 2017, Nature Astronomy 1, 71)





ZTF-I: 3d cadence, in g & r filters. **ZTF-II: 2d cadence!**

BTS in Practice



ZTF public alert stream
(10^5 alerts/night)

Real, not moving, no long-term history, not by a bright star, <19 mag, |b|>7

Candidates list
(~50 alerts/night)

Not obviously stellar/AGN

Saved event list
(~10/night sent to TNS)

m < 18.5, or rising/ notable

SEDM queue
(~5 requests/night)

Ambiguous classification, m_{peak} < 18.5, and fading?

Ambiguous classification and m<18.5?

Other spectrographs
(LT, P200, etc.)

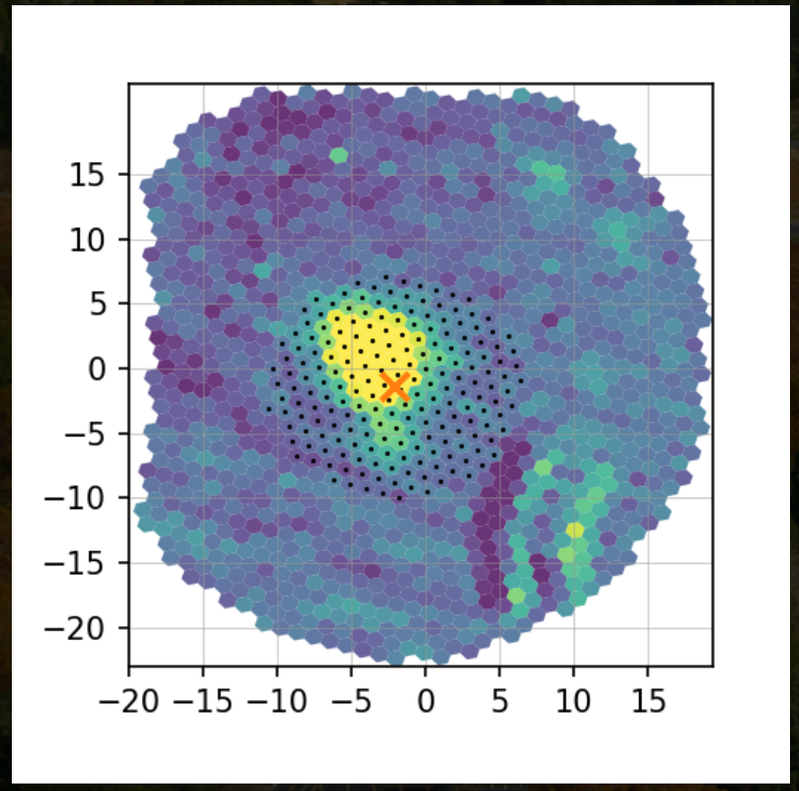
Successful classification

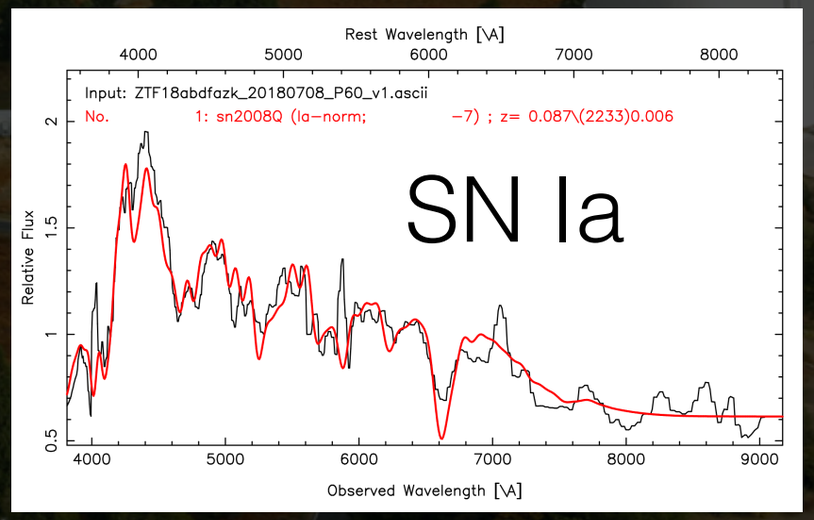
Classified SN
(~3/day sent to TNS)

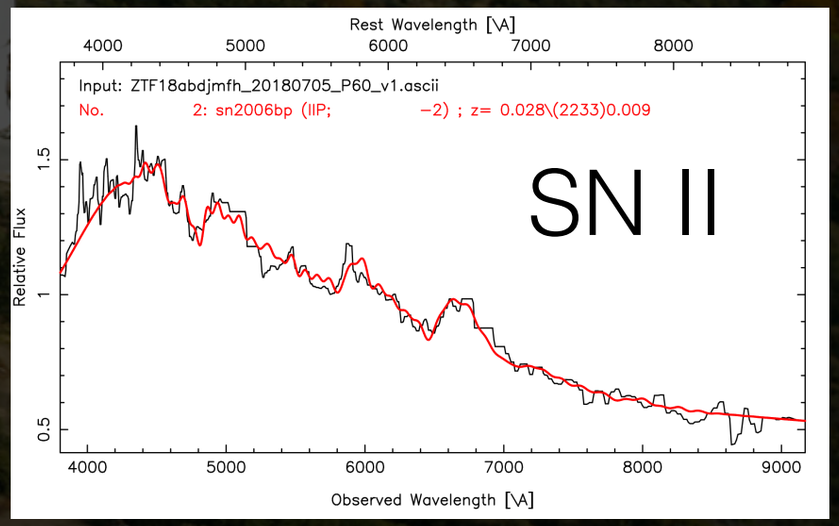
The ZTF Bright Transient Survey (BTS)

BTS classifications

Goal is to spectroscopically classify all transients brighter than 18.5 mag, using mainly SEDM. Currently we trigger all SN candidates at ~19 mag, with rising priority towards <18.5 mag.



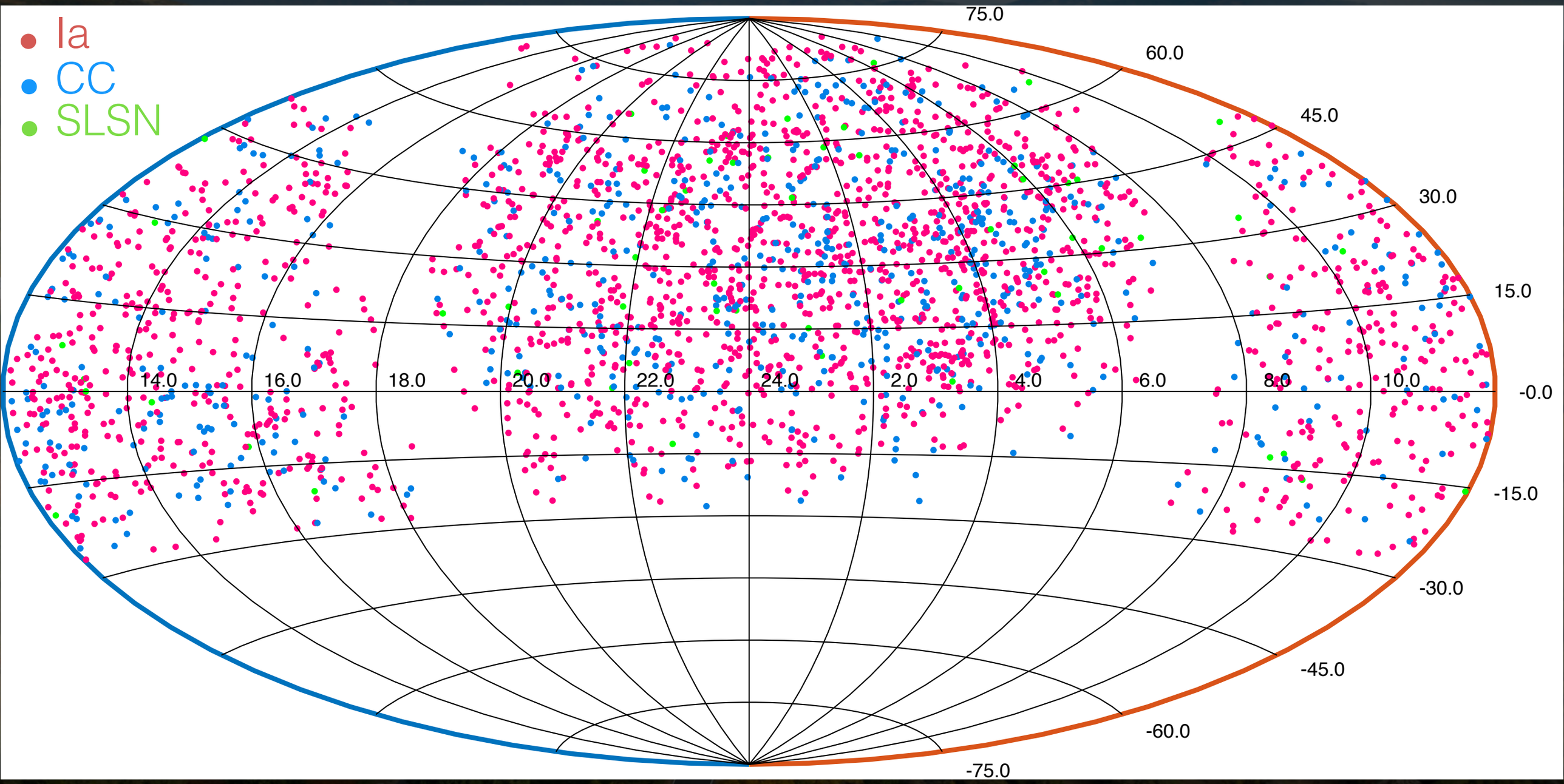




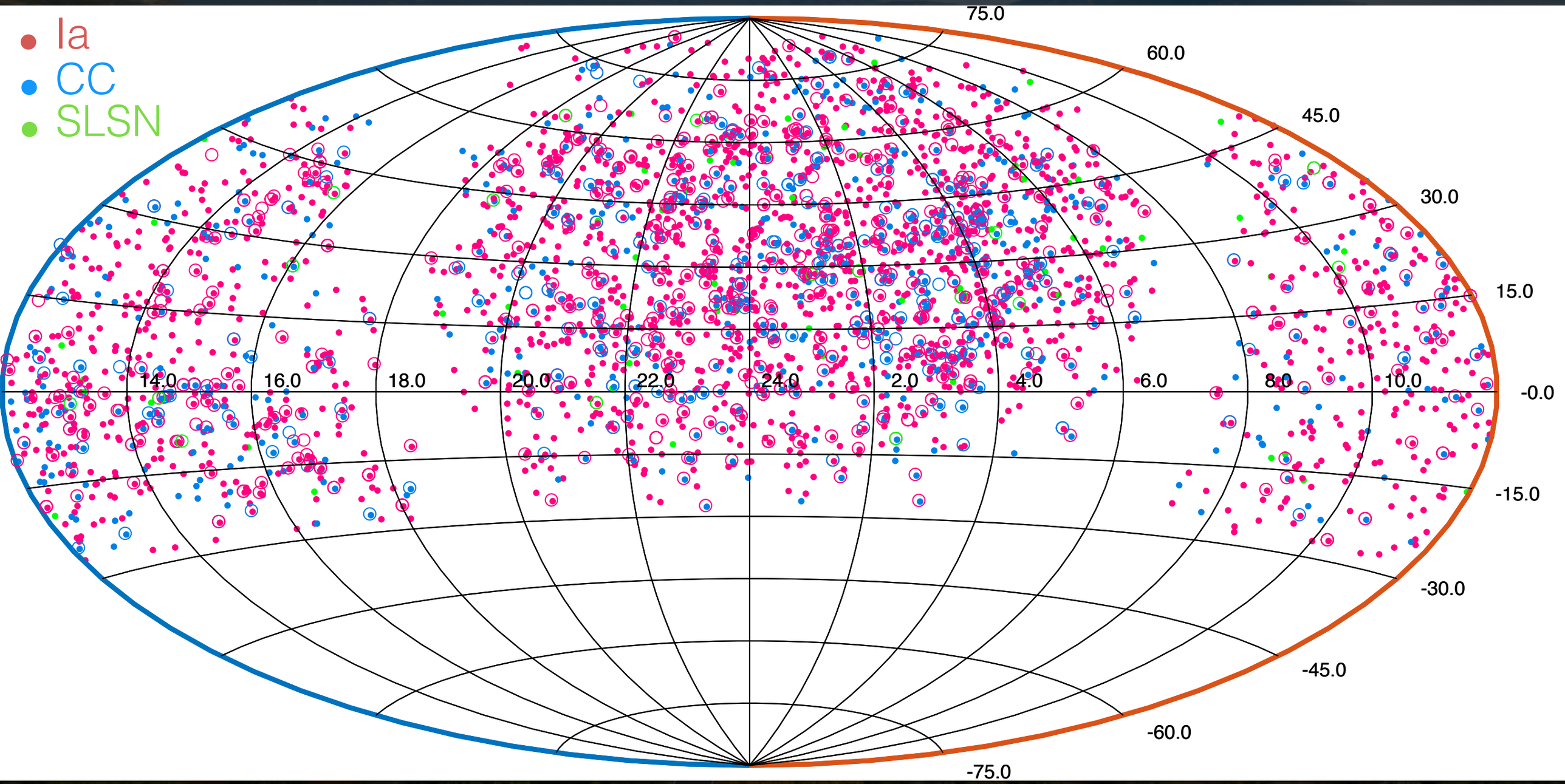
Based on template matching (e.g., SNID)

Daily, we publish successful classifications to TNS

BTS SN sky positions



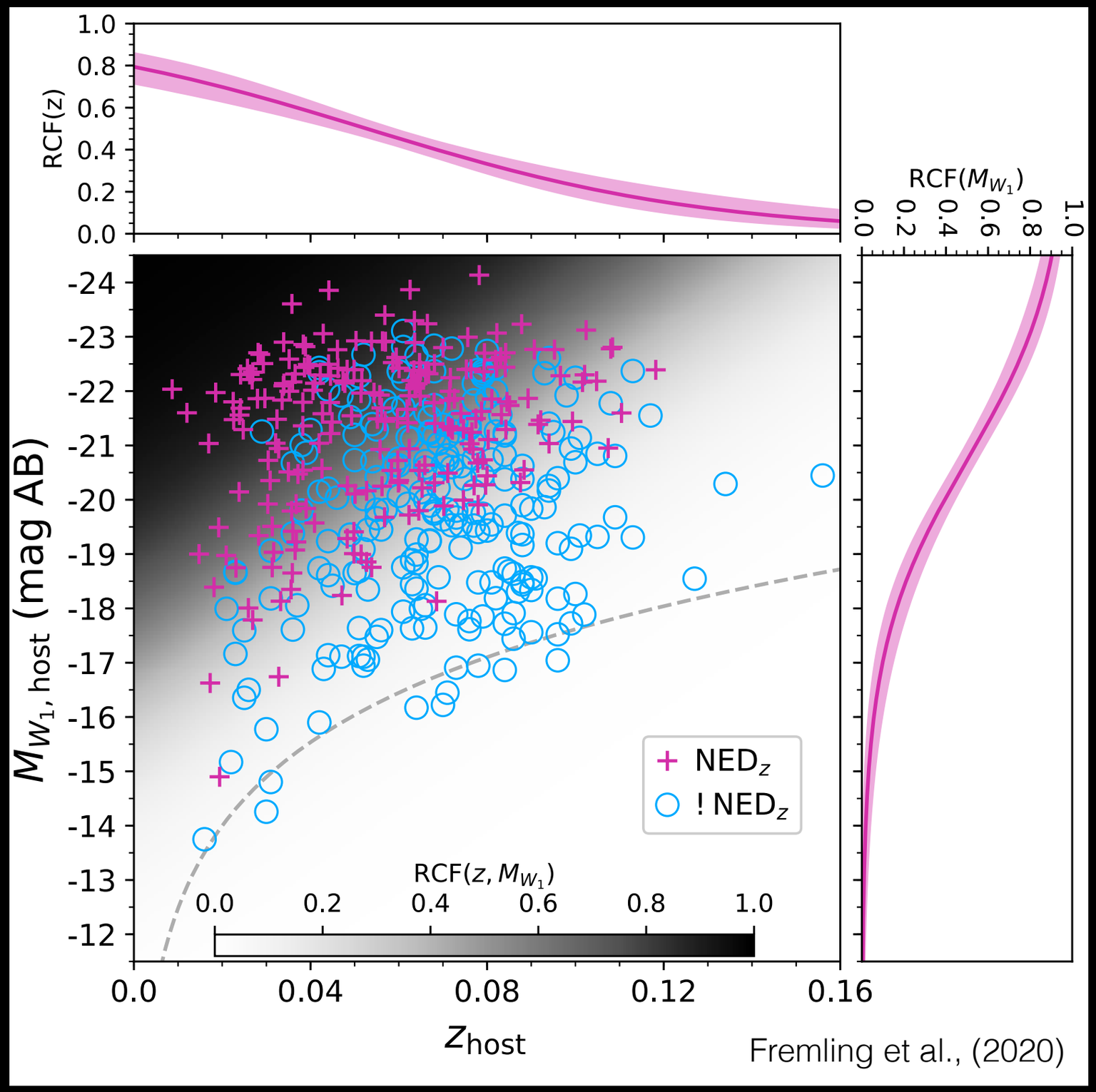
BTS SN sky positions



SNe in galaxies with known redshifts circled.
This is why an untargeted survey is needed!

Redshift completeness of current local galaxy catalogs

RCF ~ 0.6 at 200 Mpc



Fremling et al., (2020)

Status of the BTS Sample

Classified Extragalactic Transient Count (2020 October)

3687 ex.gal. transients

2610 SN Ia

incl. 10 Iax

209 SN Ib/c

incl. 13 Ibn, 30 Ic-BL, 37 SLSN-I

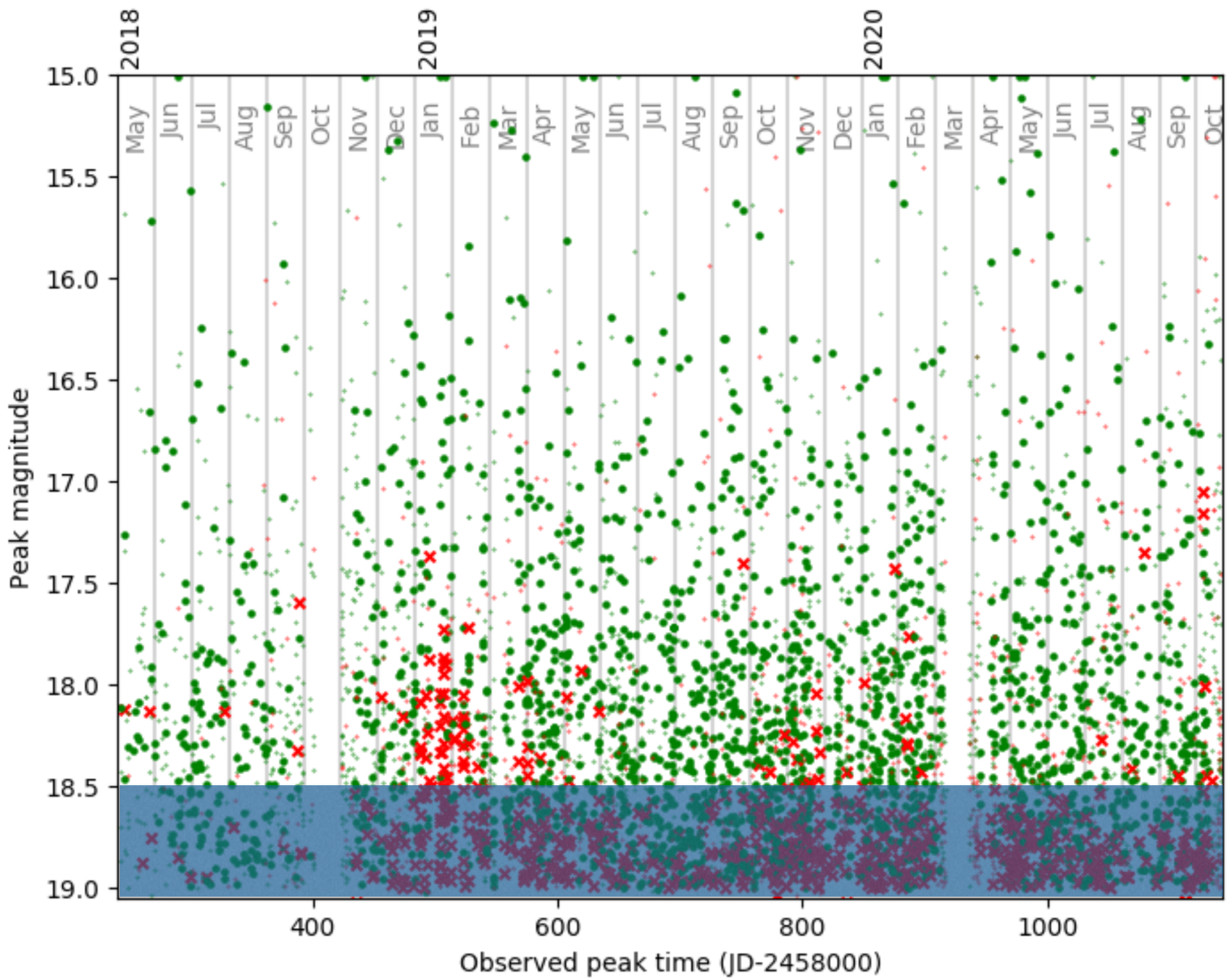
943 SN II

incl. 53 IIb, 104 IIn, 25 SLSN-II

+ 19 TDEs

+ 39 "other" (Gap, Ca-rich, Novae, ILRTs, FBOTs, LBVs)

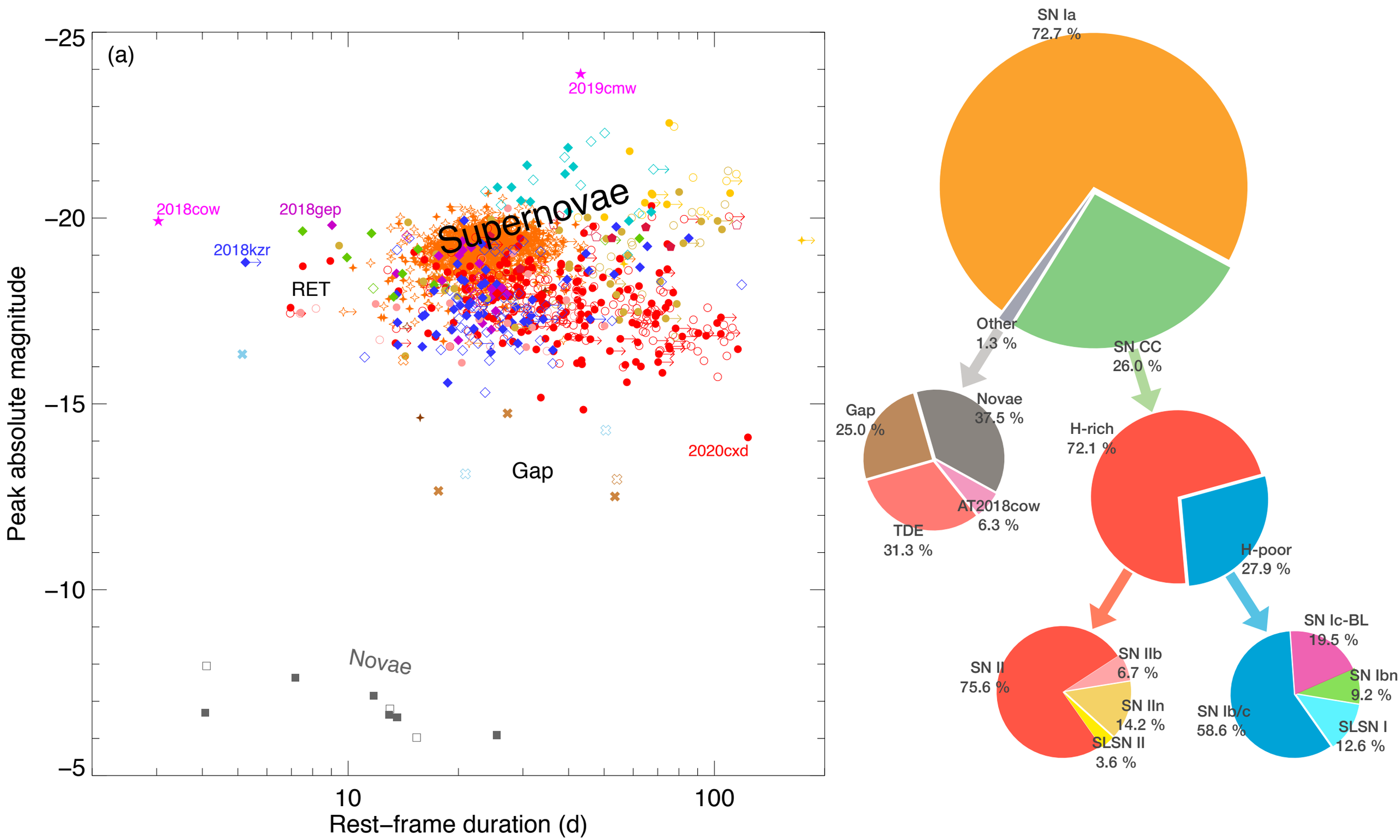
Completeness over time



Average 94%, some months virtually 100%

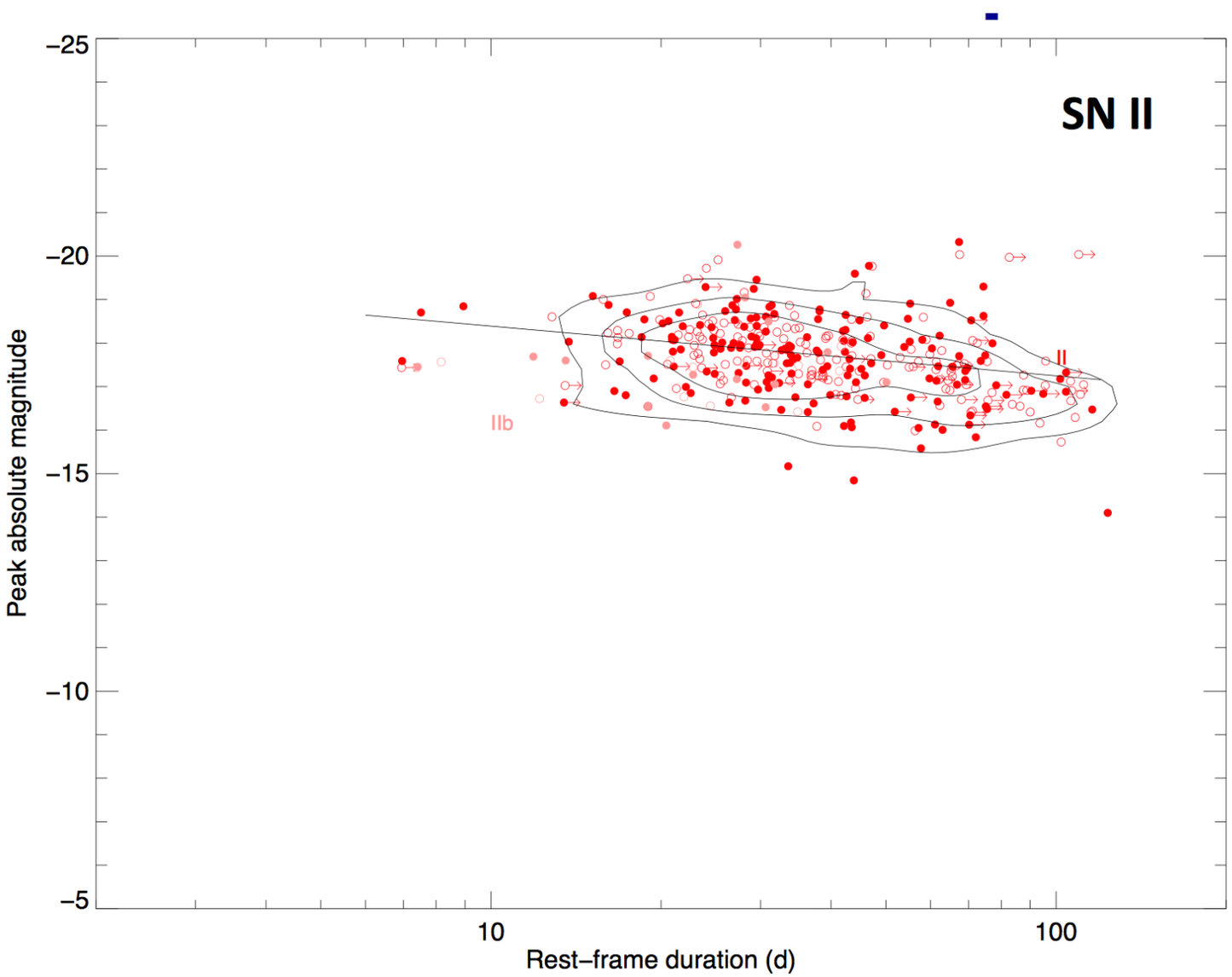
https://sites.astro.caltech.edu/ztf/rcf/rcf/status.php

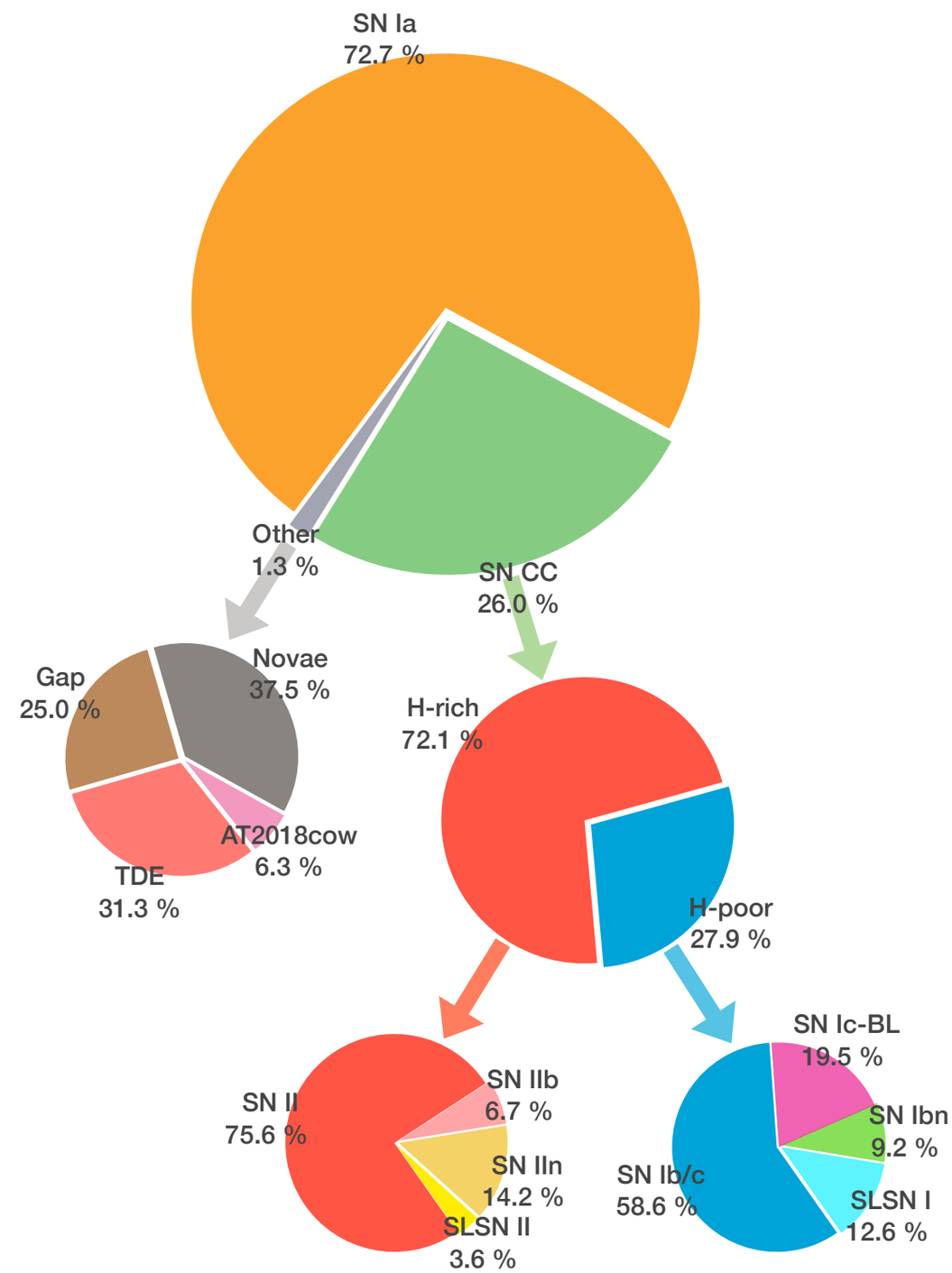
BTS Transient Lightcurve Parameter Space



Perley+ 2020

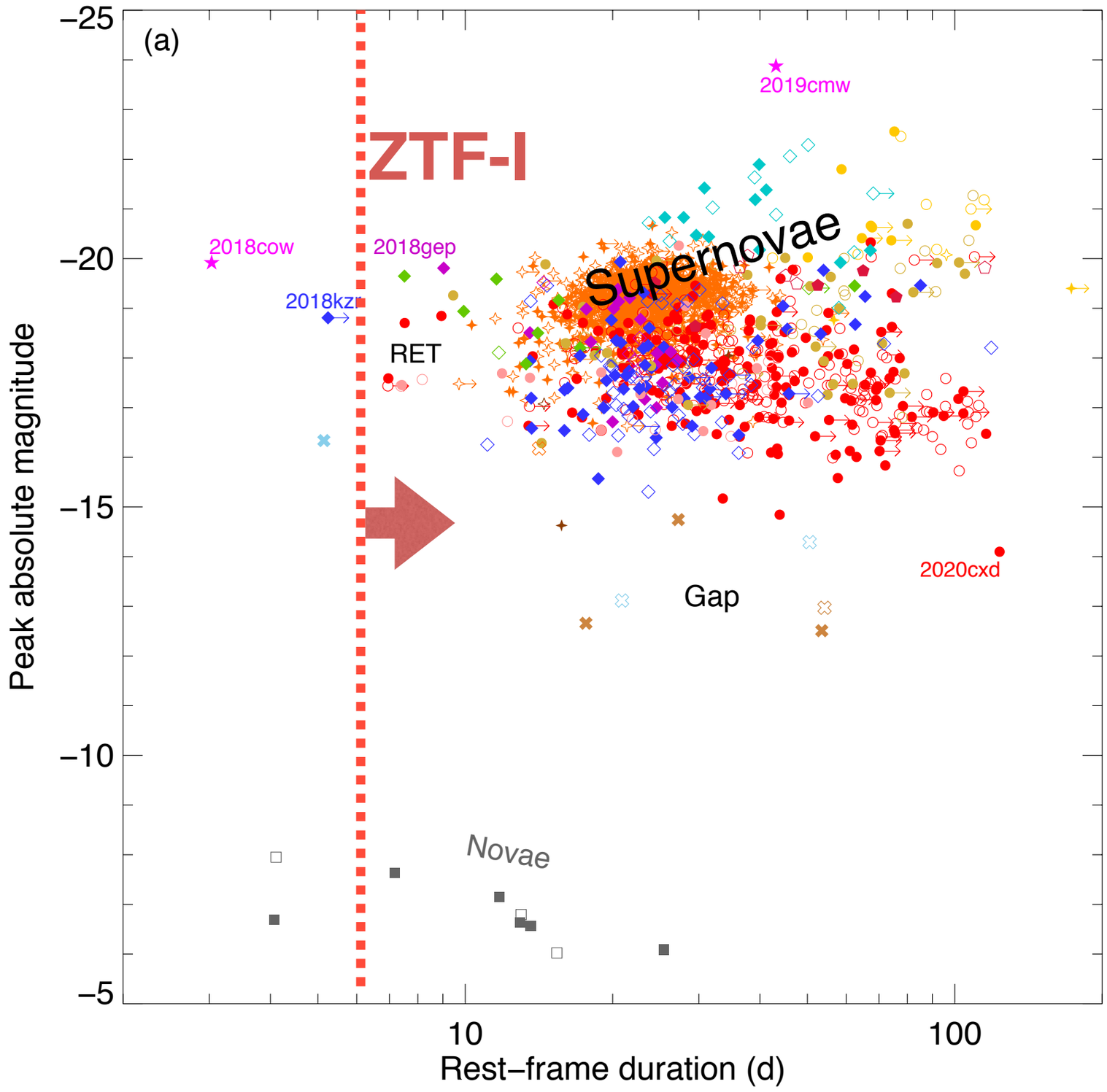
BTS Transient Lightcurve Parameter Space

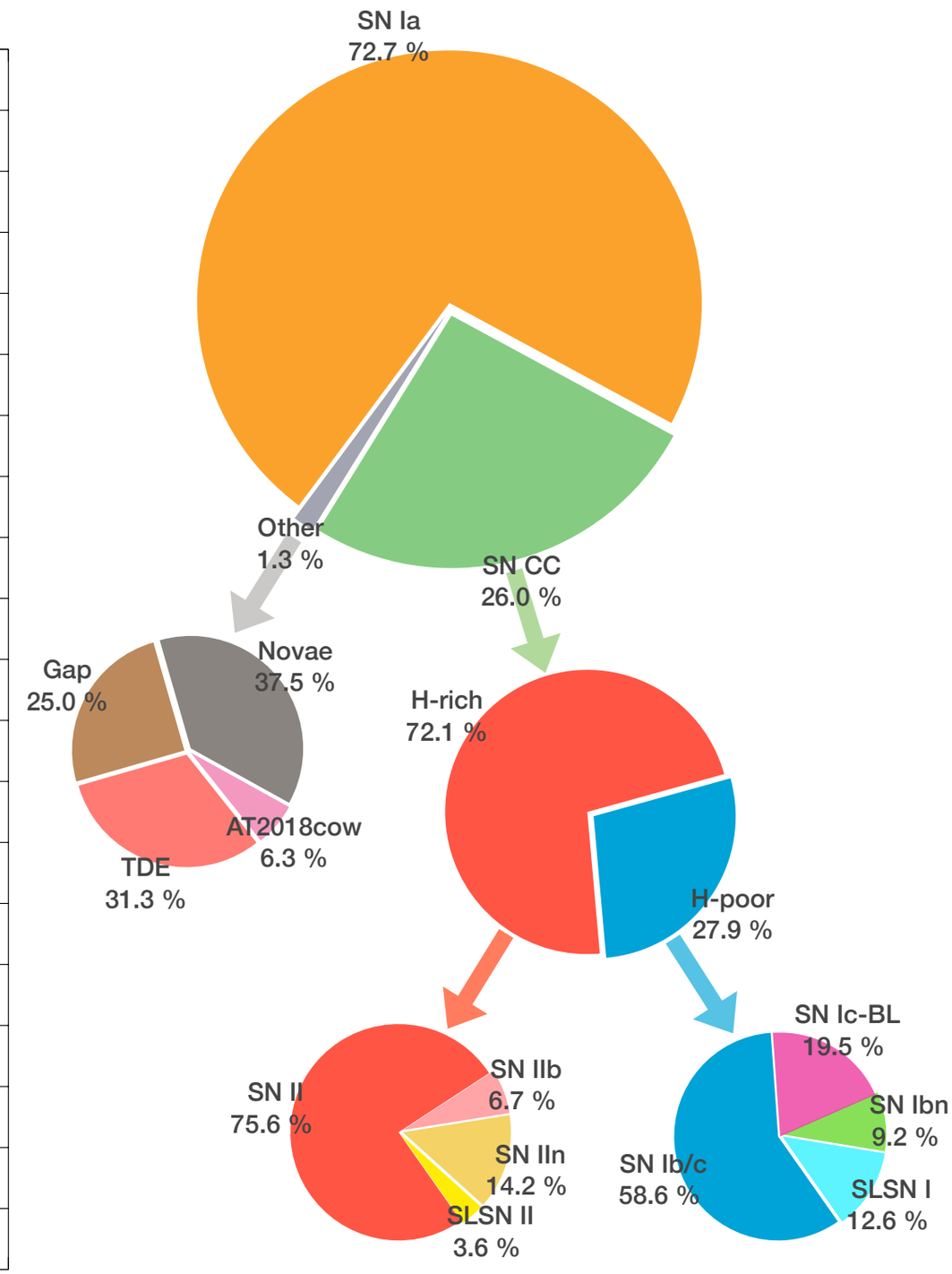




Perley+ 2020

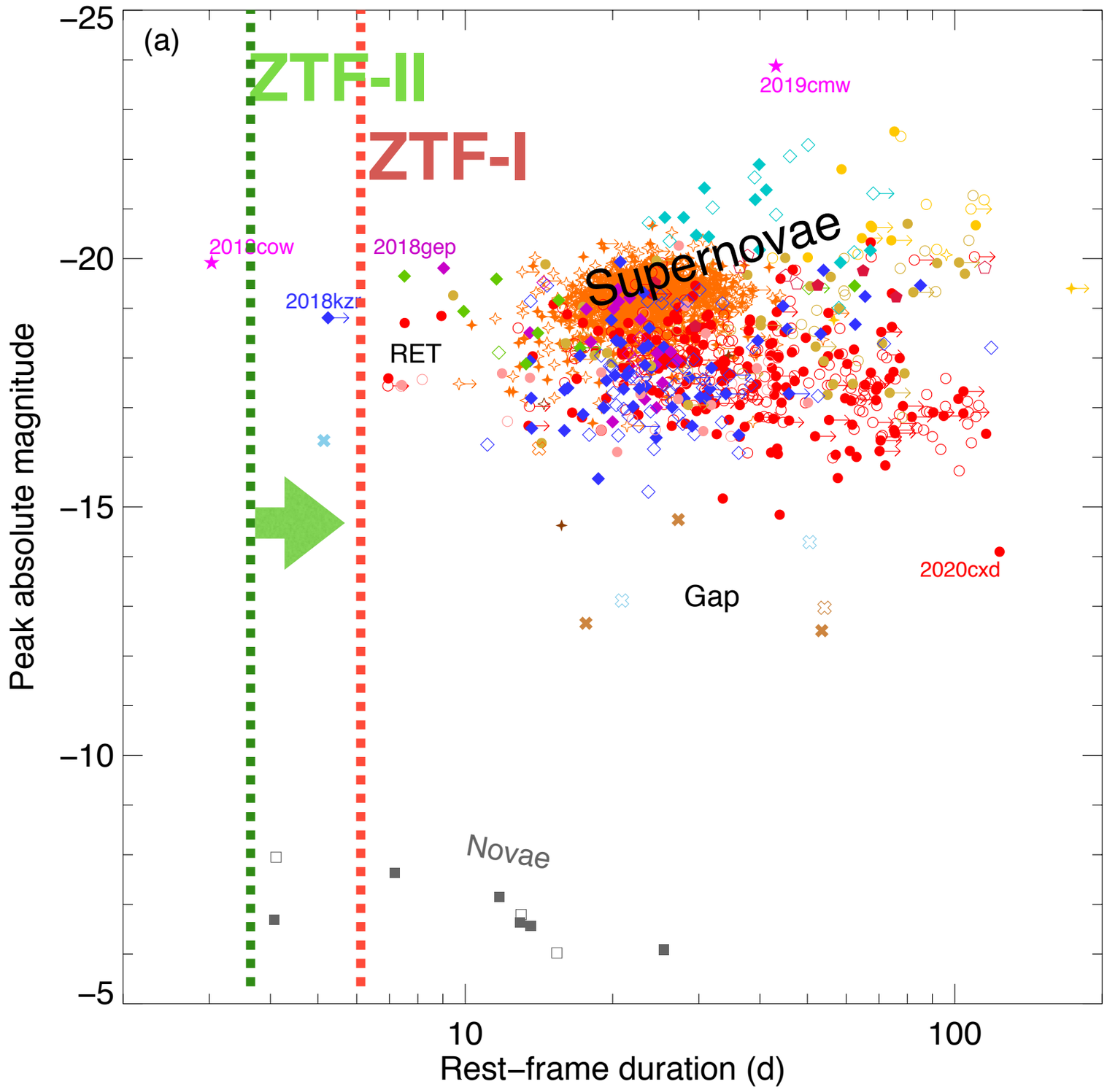
BTS Transient Lightcurve Parameter Space

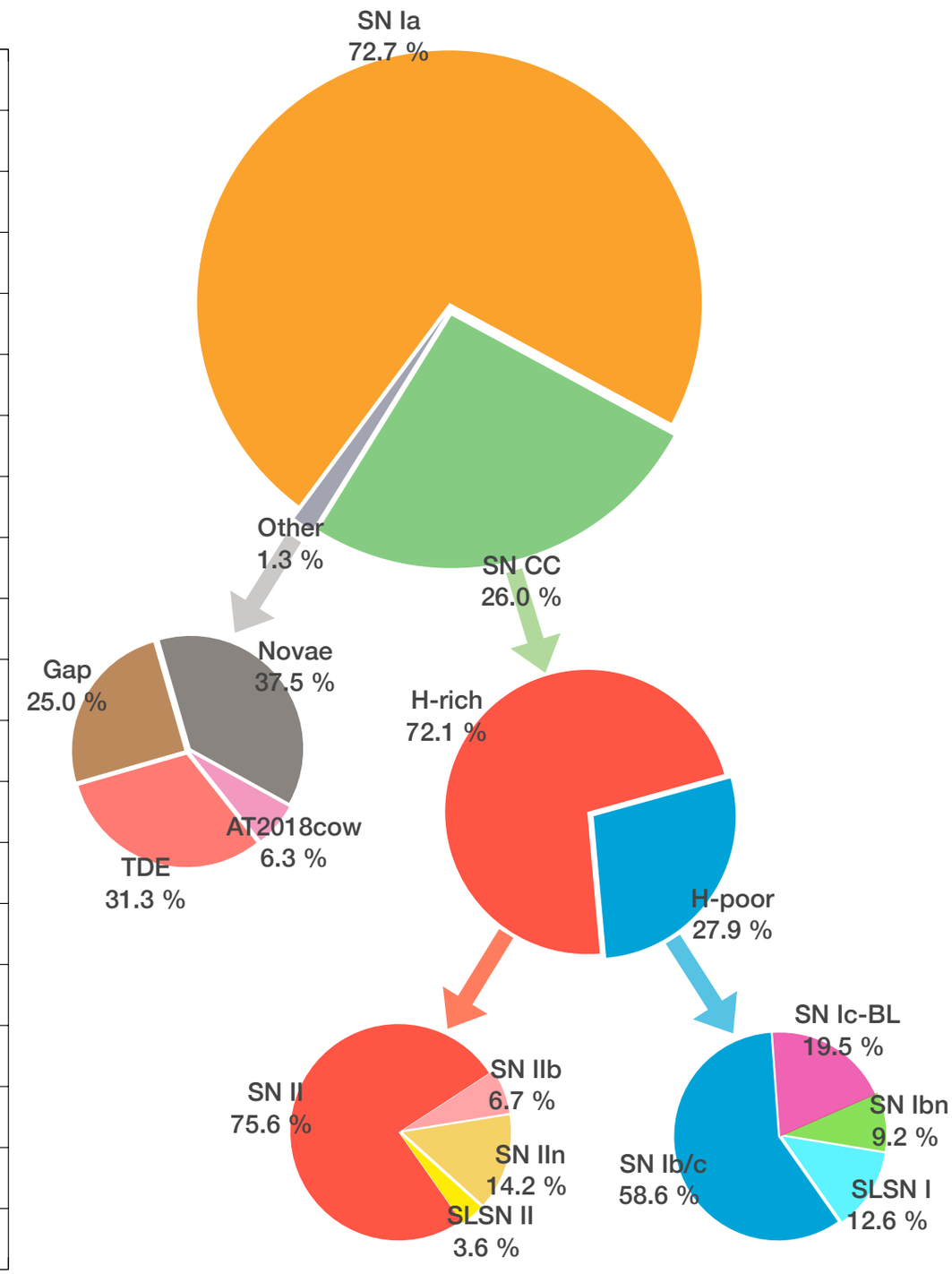




Perley+ 2020

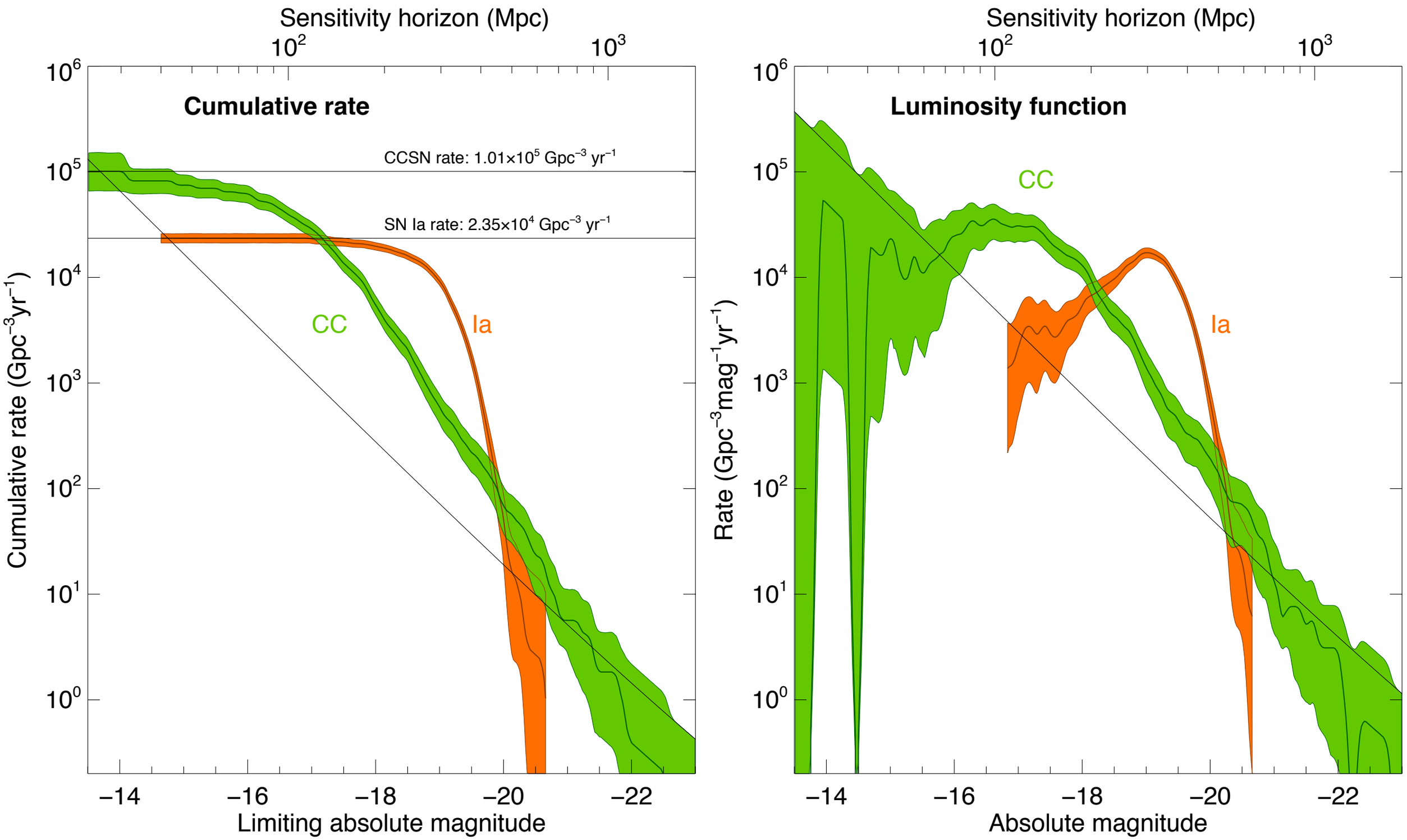
BTS Transient Lightcurve Parameter Space





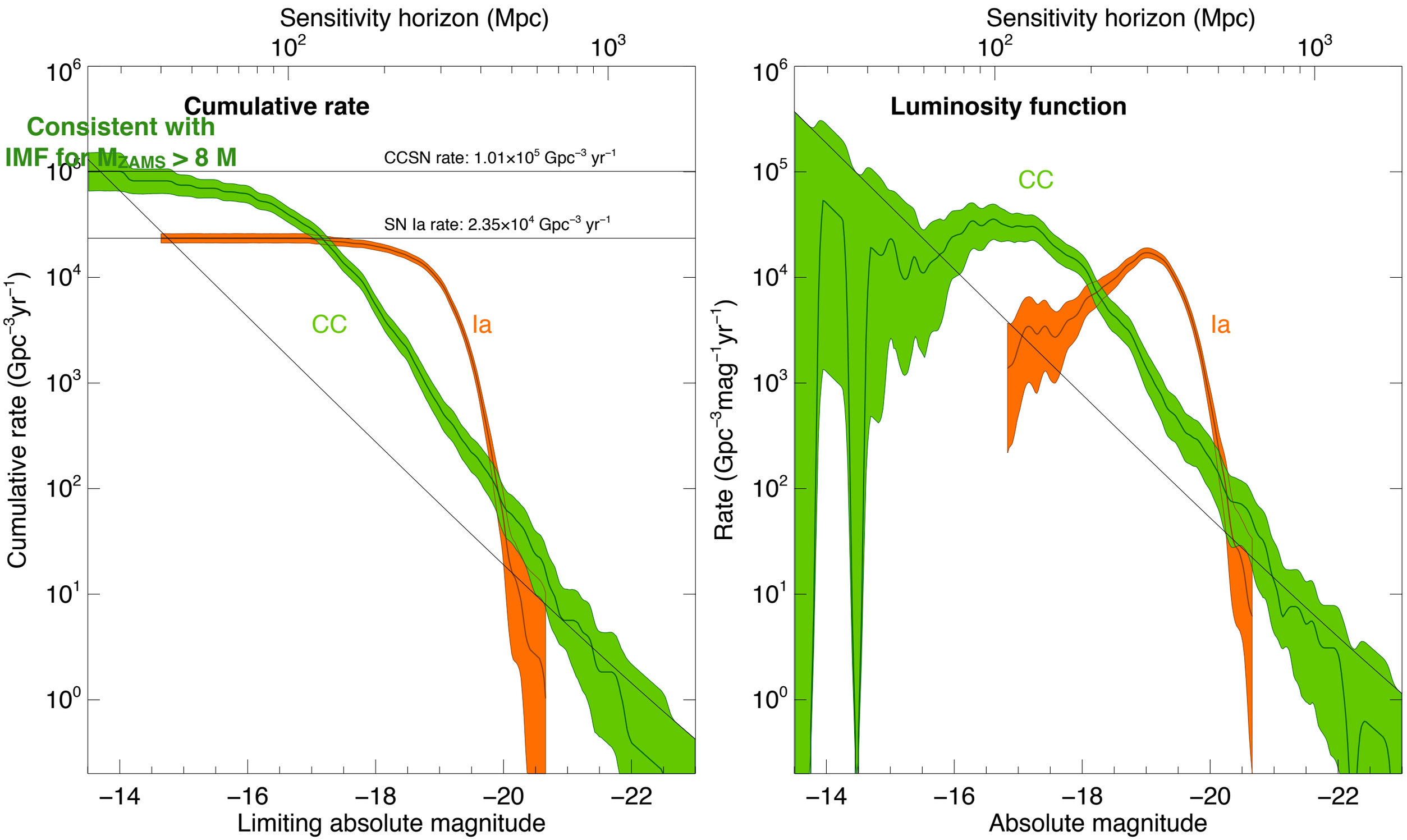
Perley+ 2020

Supernova Lightcurve Parameter Space



Perley+ 2020

Supernova Lightcurve Parameter Space



Perley+ 2020

Transients in the local universe with ZTF

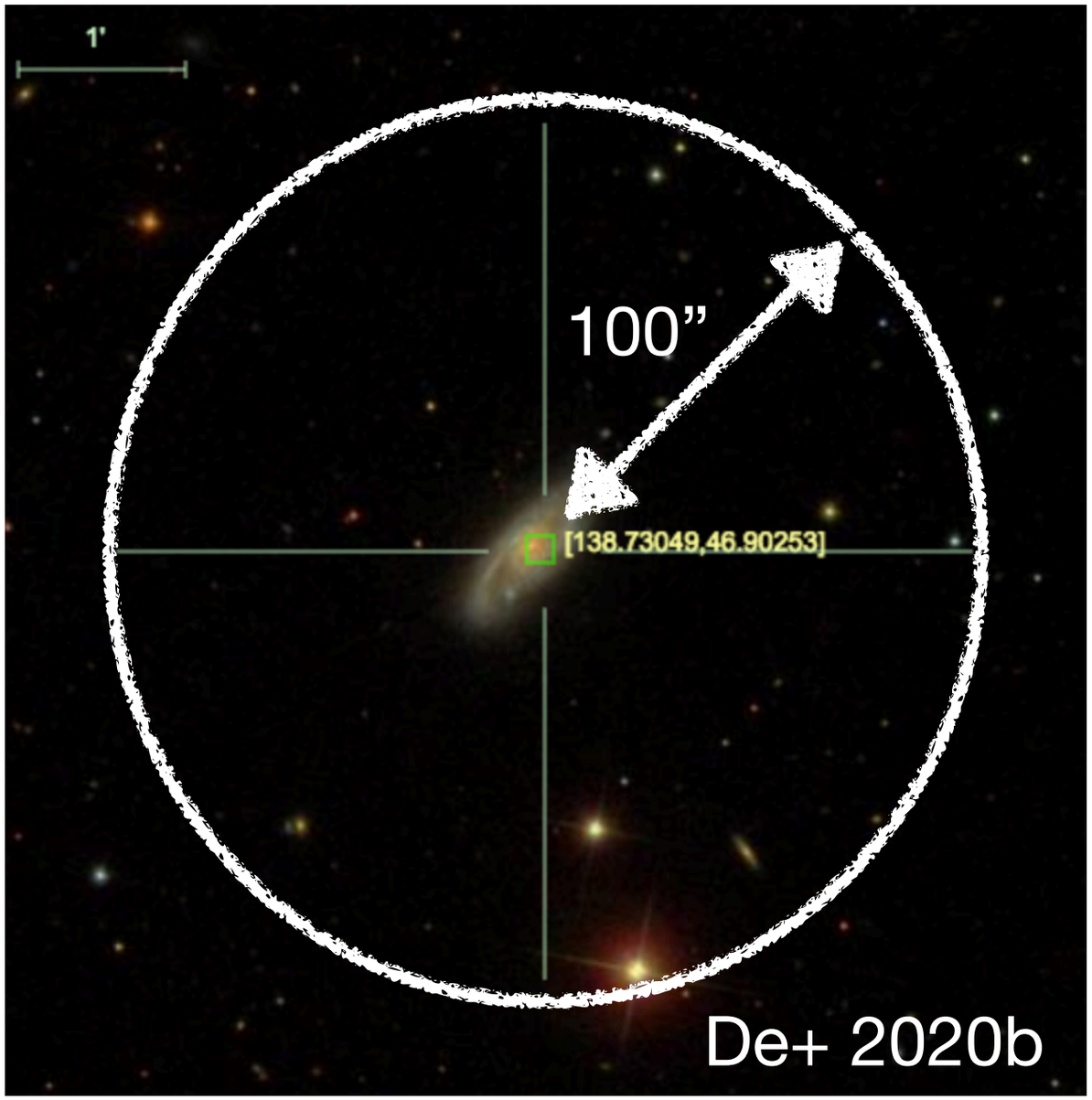
Kishalay De

Caltech

With Andy Tzanidakis, Yuhan Yao, Mansi Kasliwal and the ZTF collaboration

Volume-limited Census of the Local Universe (CLU) experiment

A powerful complement to the Bright Transient Survey to probe the faintest end of the luminosity function



- Transients announced publicly on the Transient Name Server
- Spectroscopic follow-up of all events brighter than 20 mag, within 100” of host galaxy within 200 Mpc (Cook+ 2019)

Aim complete sample of transients brighter than M = -16.5 (within 200 Mpc) and M = -15 (within 100 Mpc)

P60 SEDM:
Brighter than 19 mag

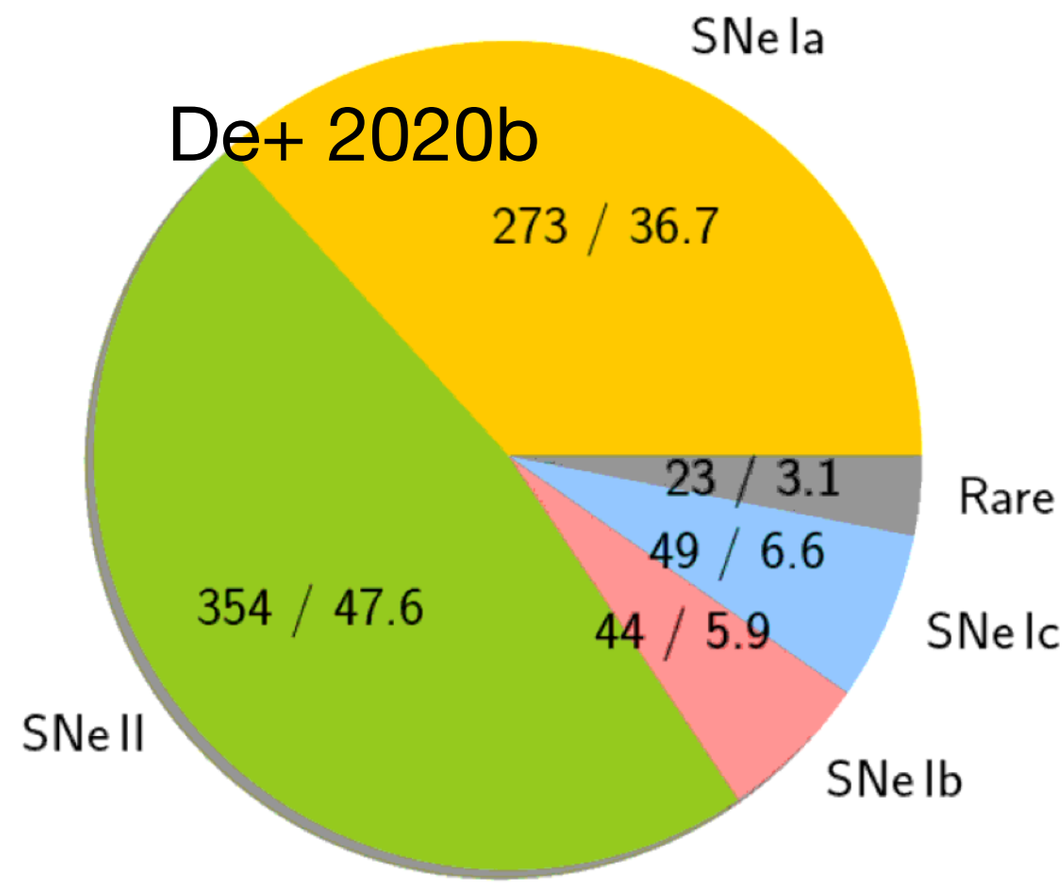
P200 + DBSP:
Between 19-20 mag

Keck I + LRIS:
Follow-up

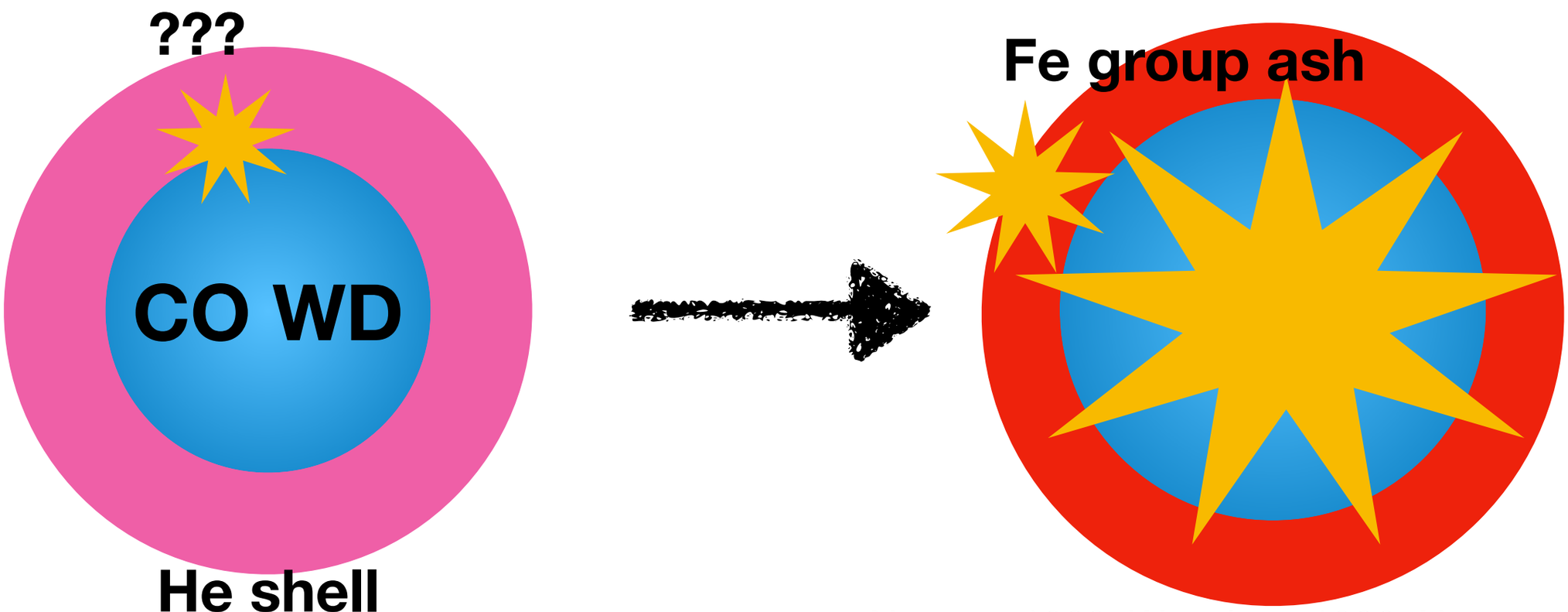
+ community effort + ZTF collaboration follow-up

754 spectroscopically classified transients in 16 months (90% complete; ~ 1500 as of October 2020)

The largest volume-limited supernova sample till date



A systematic sample of faint thermonuclear supernovae: The fates of helium accreting white dwarfs

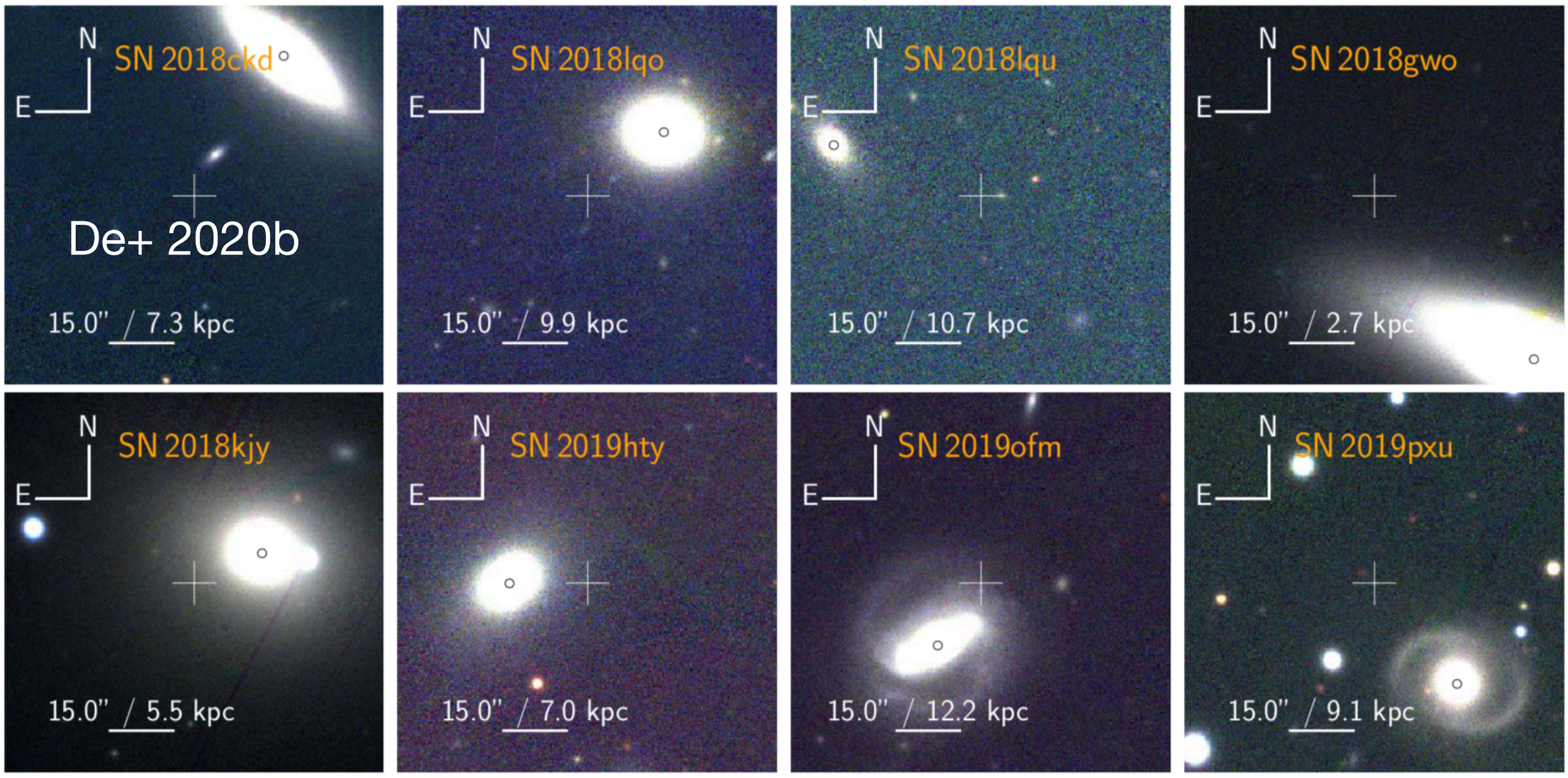


Helium nova? Type Ia supernova? .Ia supernova? Ca-rich transients?

Nomoto 1982; Woosley+ 1986; Nugent+ 1997; Bildsten+ 2007; Shen+ 2010; Waldman+ 2011; Fink+ 2010; Sim+ 2012; Shen & Moore 2014; Polin+ 2019a,b and many others..

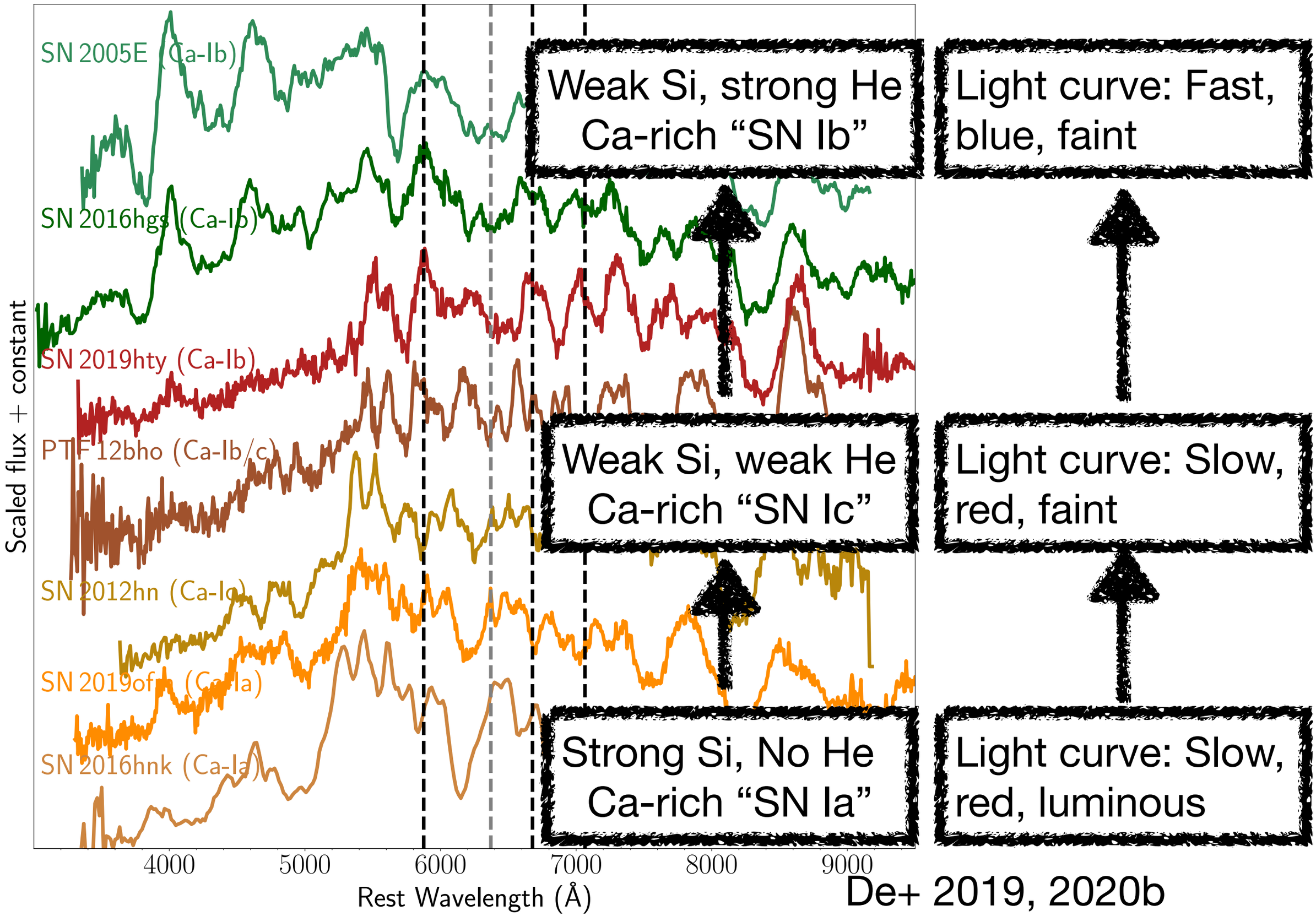
Motivation: Fate of old low mass stars, accretion + explosion physics, gravitational wave sources, chemical nucleosynthesis

The largest systematic sample of ‘Ca-rich’ transients



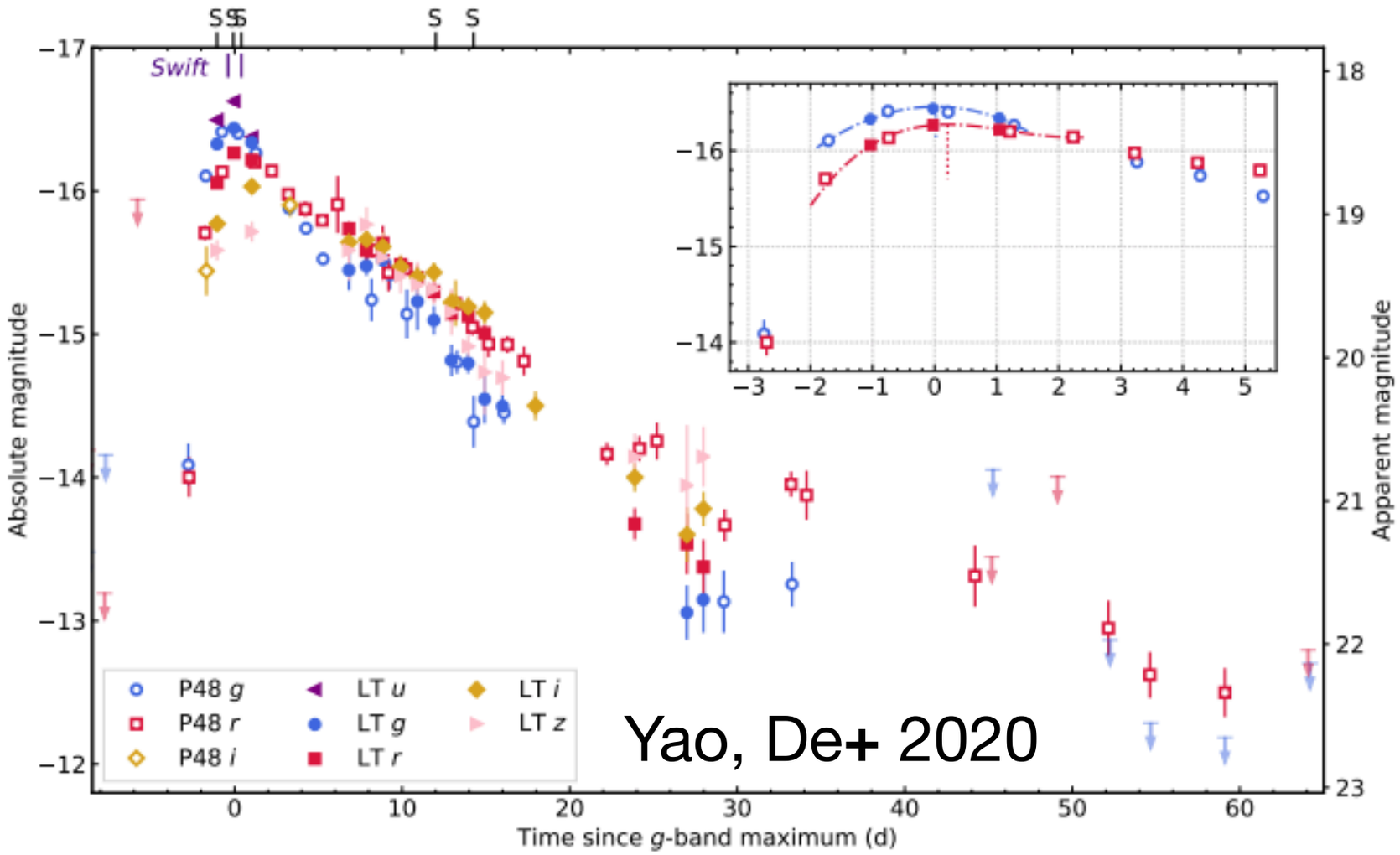
Consistently found in the outskirts of early type galaxies. Doubles the previously known population.

Evidence for a continuum of helium shell explosions from low mass white dwarfs



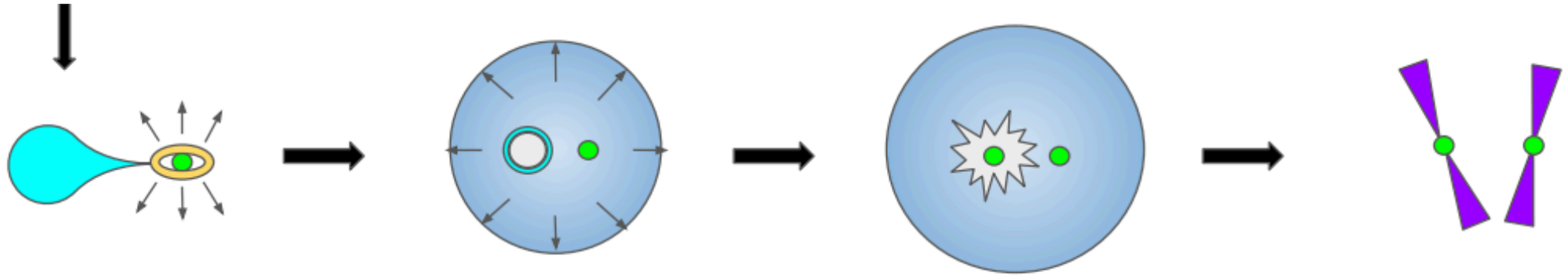
De+ 2019, 2020b

A systematic exploration of faint and fast “ultra-stripped” core-collapse supernovae



Yao, De+ 2020

ZTF constraints on volumetric rate: 2-12% of core-collapse supernovae



He star (stable/unstable) RLO. Most He is ejected from the system

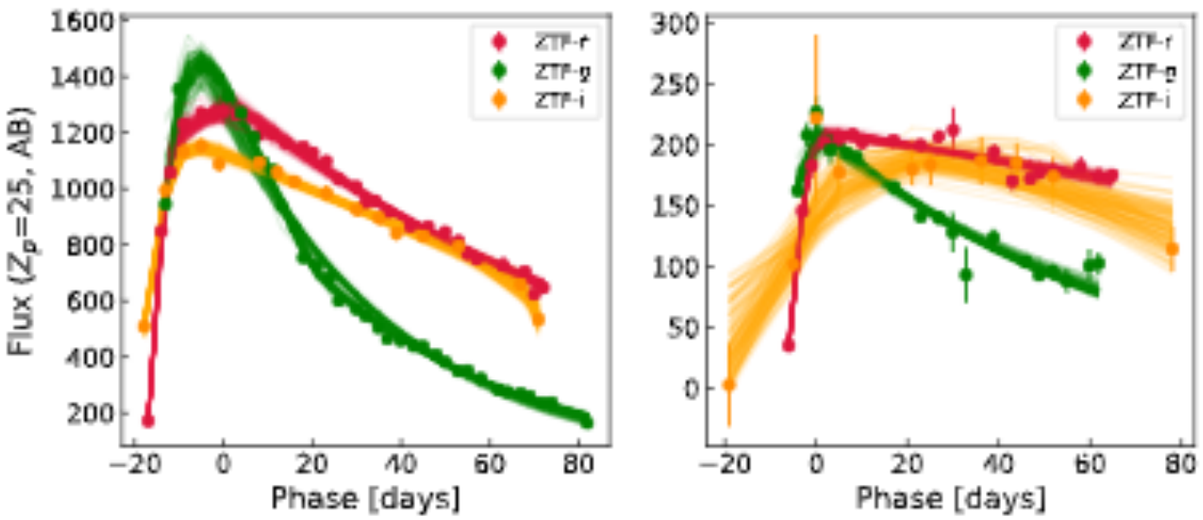
Stripped He star + NS **Intense mass loss leads to expanding envelope.**

iPTF 14gqr: Ultra-stripped SN inside He-rich envelope

Double NS system

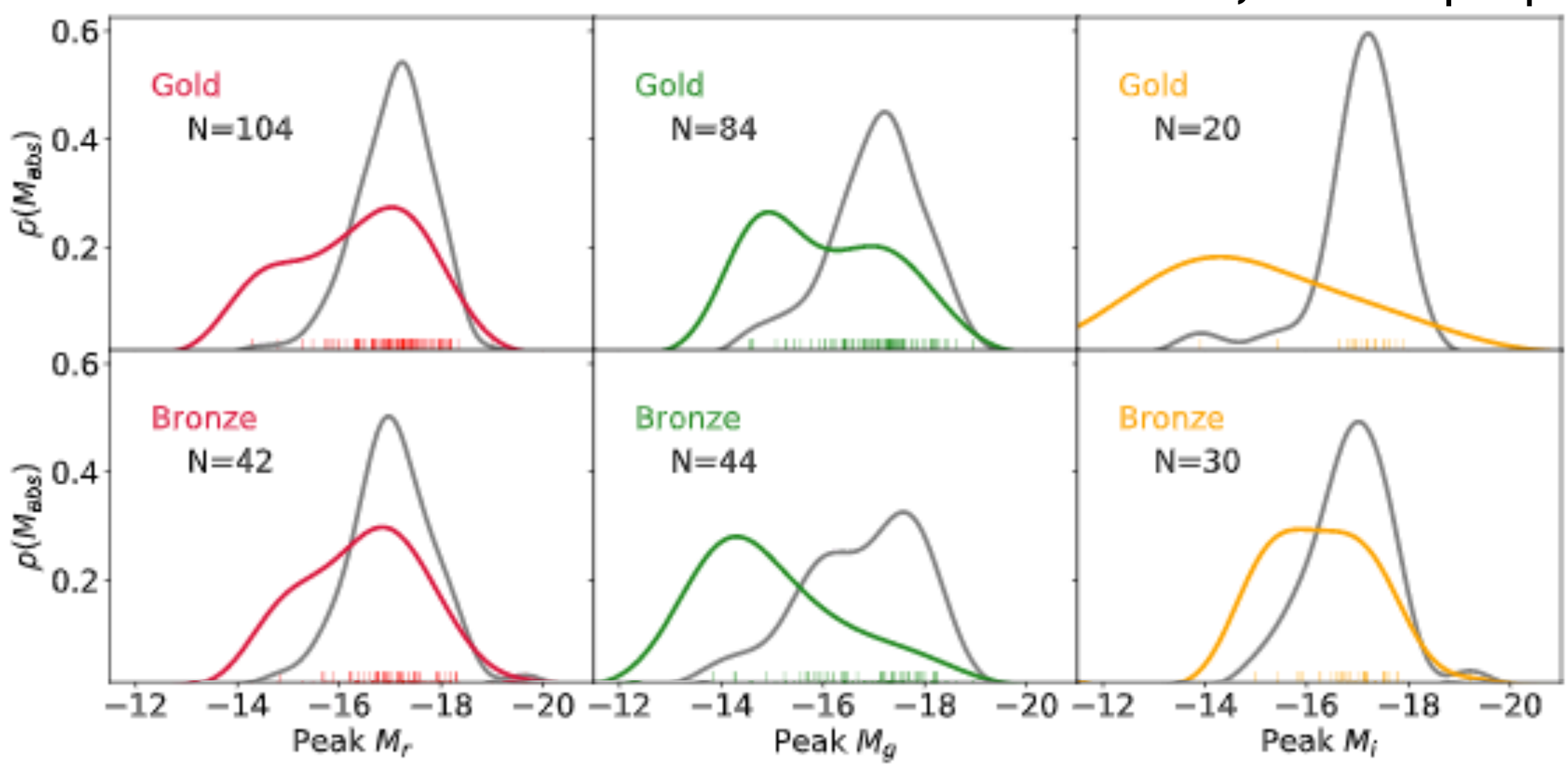
De+ 2018a, De+ 2020d

Constraints on the faintest core-collapse supernovae



Volume-limited luminosity function of ~300 Type II supernovae: Evidence for a population of faint events

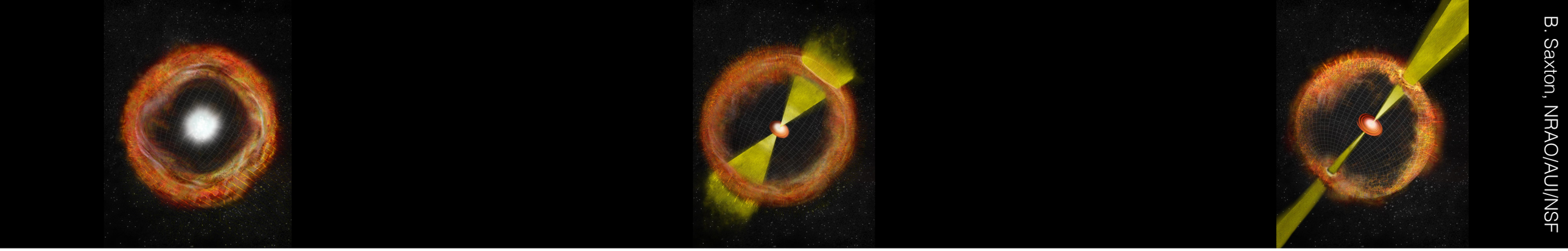
Tzanidakis, De+ in prep



Summary of results from the ZTF CLU sample

- The largest volume-limited sample of extragalactic transients till date (De+ 20b)
- New insights into the explosive fates of helium accreting white dwarfs and progenitors of Type Ia supernovae (De+ 19, De+20b)
- Fast evolving “ultra-stripped” supernovae and the formation of neutron stars in compact binaries (Yao, De+ 20; De+ 20d)
- Evidence for a faint population of Type II supernovae in the local universe (Tzanidakis, De+ 20)

kde@astro.caltech.edu
www.astro.caltech.edu/~kde

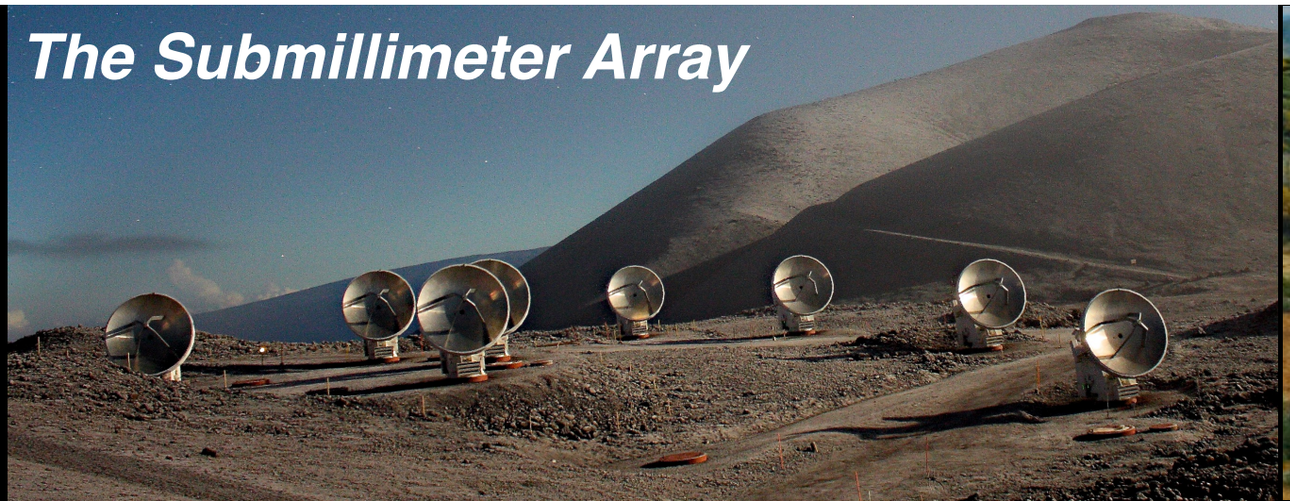


B. Saxton, NRAO/AUI/NSF

The Landscape of Fast & Luminous Transients

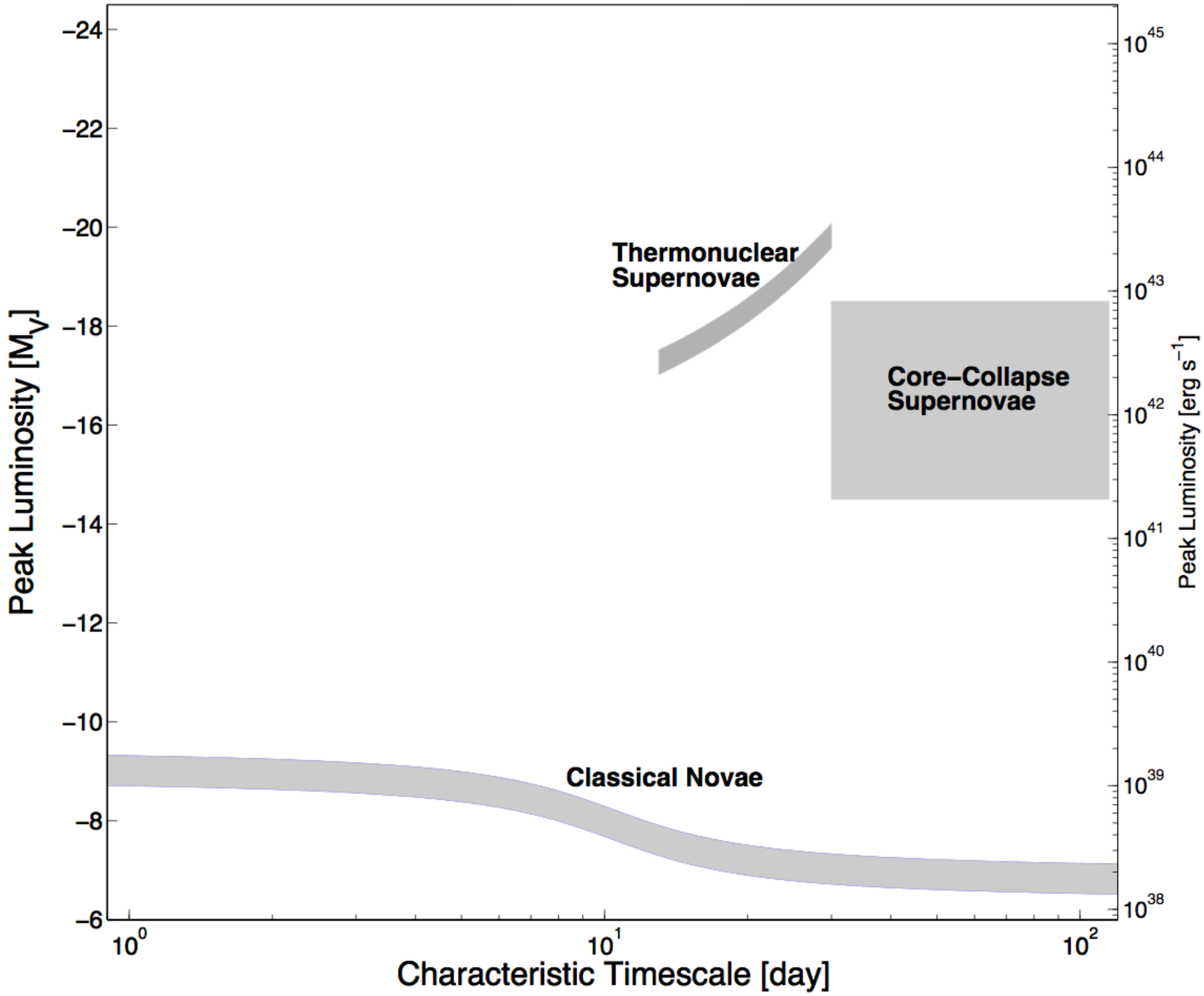
Anna Y. Q. Ho (Miller Fellow, UC Berkeley)

with D. Perley, Y. Yao, A. Corsi, S. Kulkarni, and many others



“Extreme” Observationally: The Landscape of Optical Transients

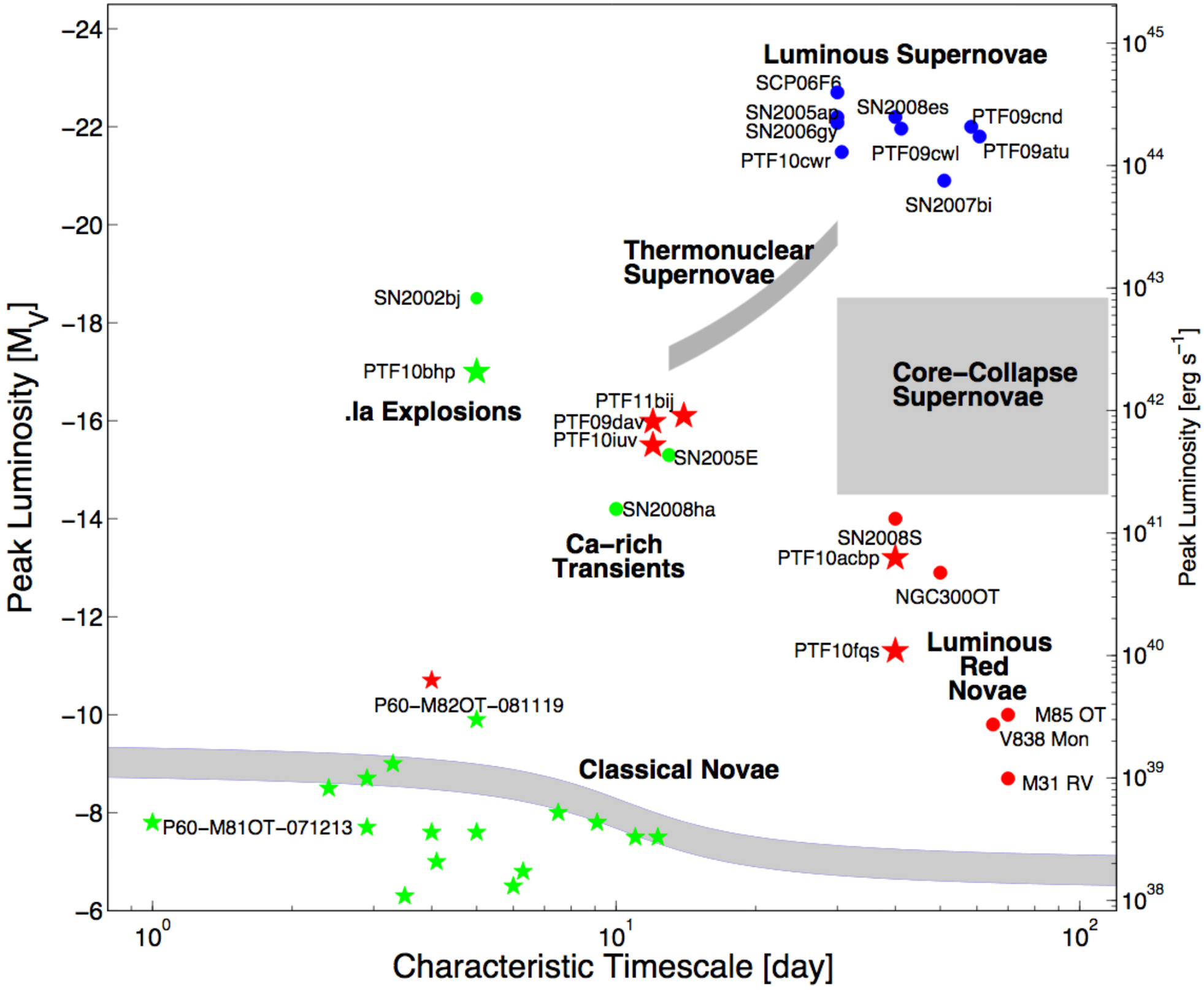
2005



Kasliwal (2011) PhD Thesis

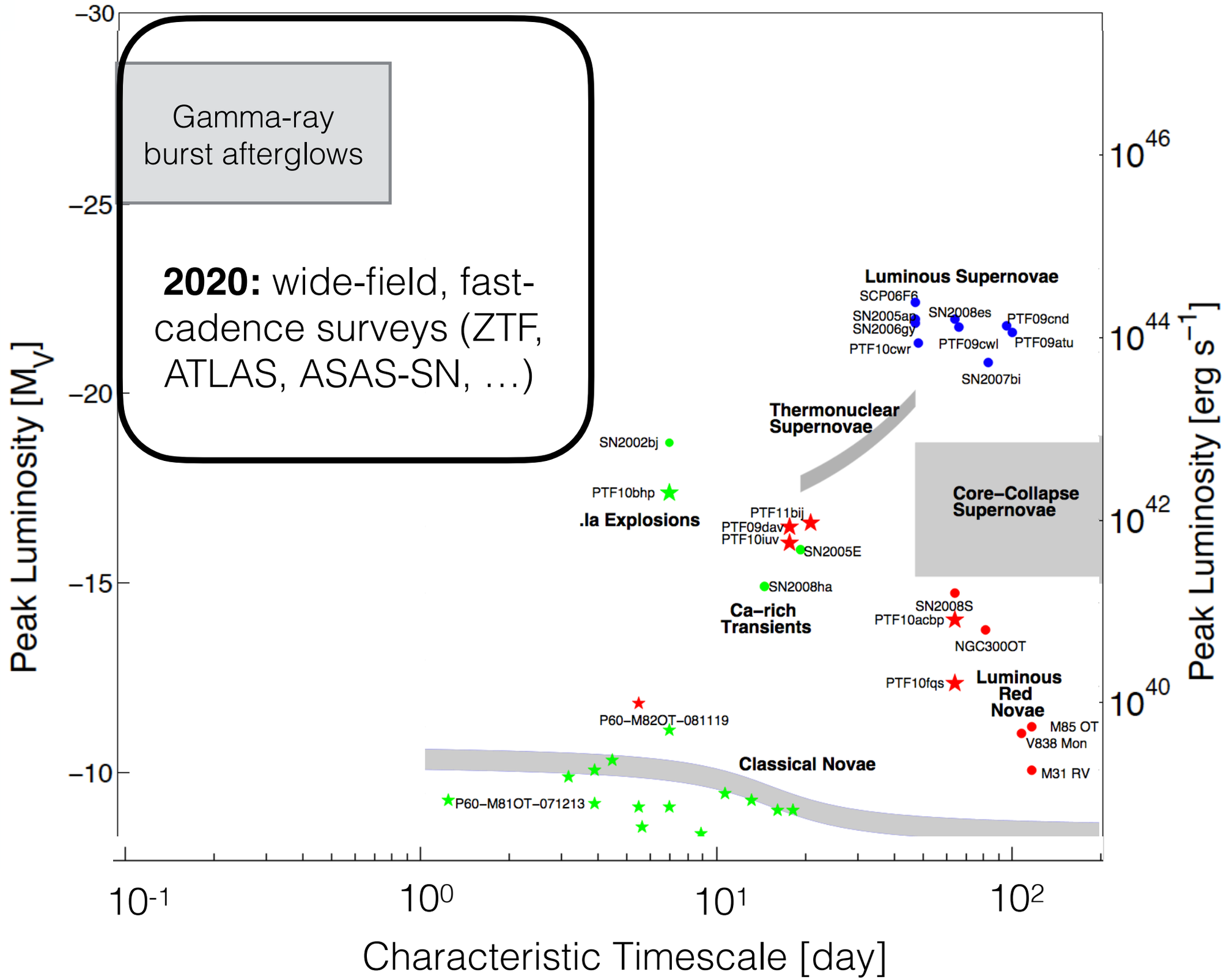
Wide Field-of-View, Untargeted, High-Cadence Surveys

2011

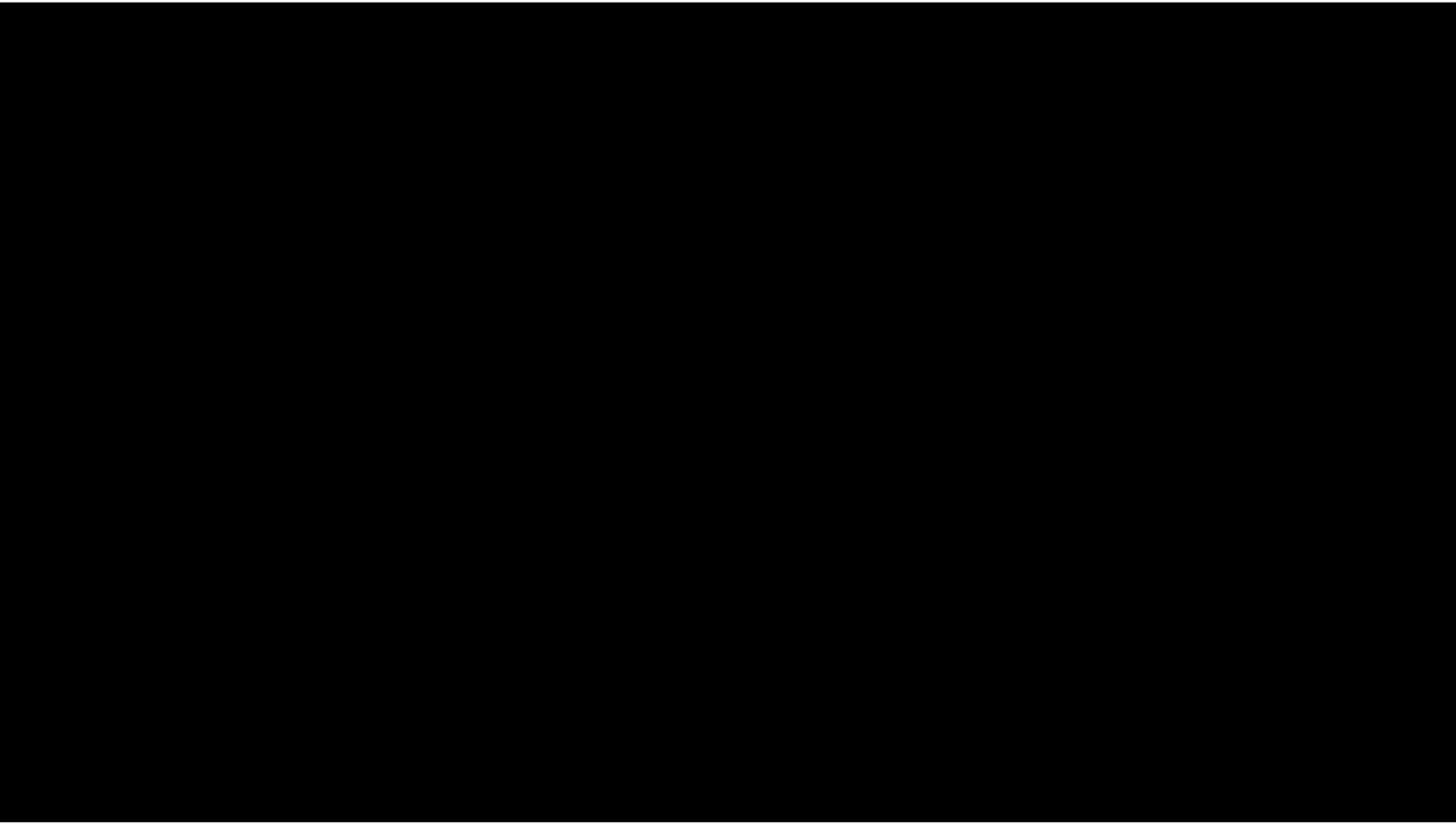


Kasliwal (2011) PhD Thesis

The Next Frontier: Fast & Luminous Transients



Relativistic jet in collapsing star: Long-duration gamma-ray burst + supernova
Spectroscopic Type Ic-BL (no H/He), “broad-lined” (high velocities)



Video credit: NASA’s Goddard Space Flight Center

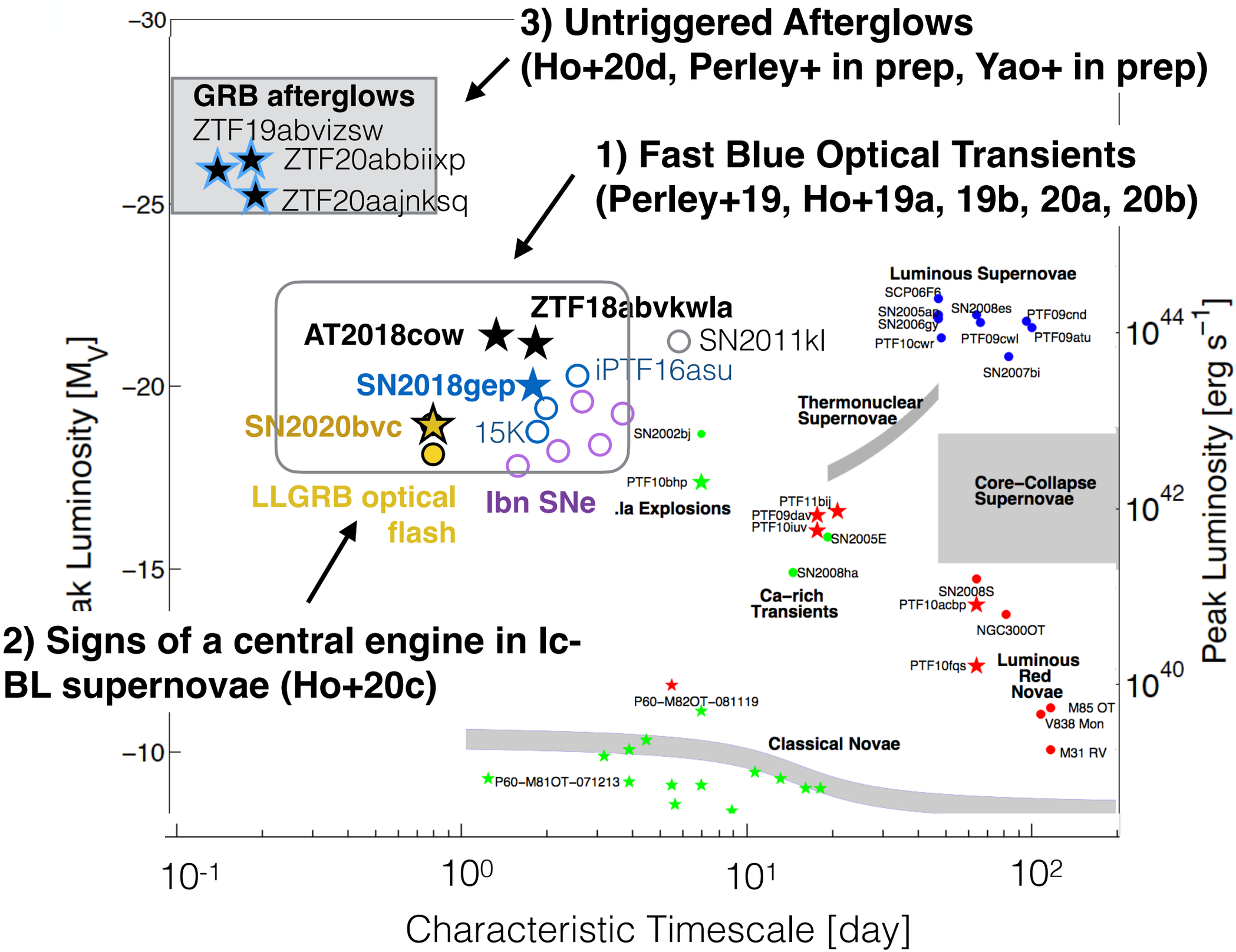
Relativistic jet in collapsing star: Long-duration gamma-ray burst + supernova
Spectroscopic Type Ic-BL (no H/He), “broad-lined” (high velocities)

Conditions (break-out, hyper-relativistic velocities) are contrived:
perhaps GRBs are the extreme of a continuum?

“Dirty fireball” (Dermer 1999): low Lorentz factor jet, afterglow lacking GRB

Can’t rely on GRB satellite ⟶ Search for fast & luminous optical transients

Summary of Fast & Luminous Transients in ZTF Phase I



modified from Kasliwal (2011)

1) A Detour: Fast Blue Optical Transients (FBOTs)

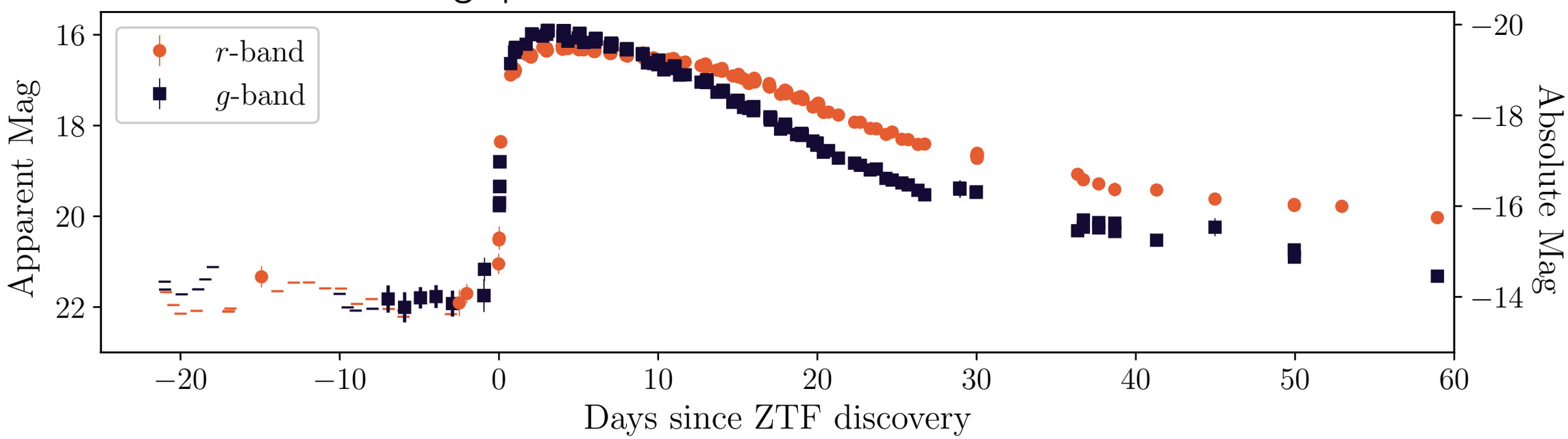
Motivation *Status* *Future*

- Originally identified in Pan-STARRS (Drout+2014)
- Fleeting ($t_{1/2}$ < 12d) common (4-7% CC SN rate) explosions with -16 < M < -21
- Starforming host galaxies suggest massive-star origin
- 100 additional events from Dark Energy Survey (Pursiainen+2018)
- No spectroscopic classifications (no information on composition)
- Handful of individual events: CSM interaction is key, progenitors are diverse
- Why do so many massive stars explode surrounded by dense CSM?

1) A Detour: Fast Blue Optical Transients (FBOTs)

- Notable individual events in ZTF:
  - Engine-driven FBOT in dwarf galaxy, GRB-like afterglow (Ho+20b)
  - Ultra-stripped He-rich SN2019dge (Yao+20)
  - Ic-BL SN with dense CSM shell (Ho+18b)

Ic-BL SN: SN2018gep modified from Ho+2019b



- Large sample paper in prep
  - 20 FBOTs with spectra: diverse compositions (H-rich, He-rich, H/He-poor, engine-powered…)

2) Signatures of a central engine in Ic-BL SNe

Motivation

- Almost all GRBs accompanied by Ic-BL SN, but most Ic-BL SNe lack GRB
    - Jets off-axis? Choked?
- To find out, search for luminous **radio** emission in Ic-BL SNe (VLA; PI Corsi)

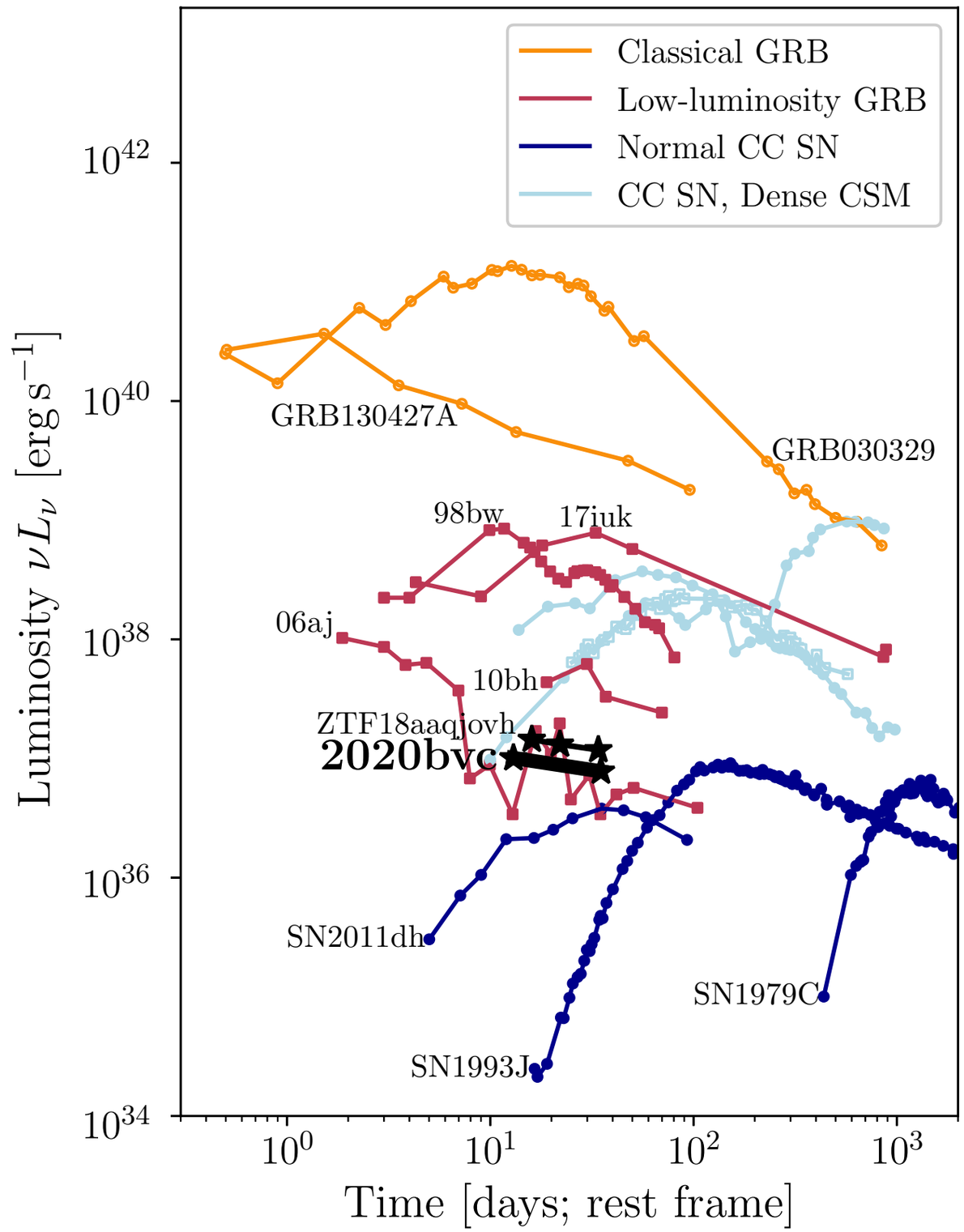
Status

- Published two detections (Ho+20a, 20c)
- Now have several more (stay tuned…)

Future

- Discovery of engine-driven SNe via double peaked **optical** light curves (Ho+20c)

Radio (<10 GHz) light curves



3) Untriggered Afterglows

Motivation

Search for dirty fireballs

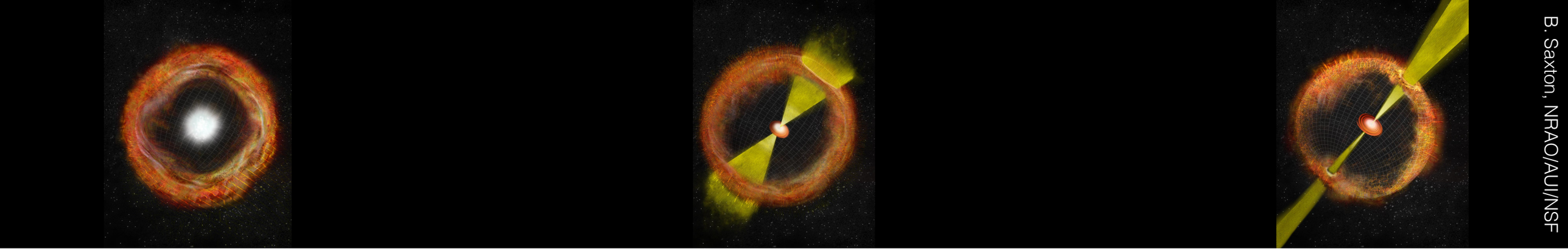
Status

Prior to ZTF, only three untriggered optical afterglows had been found, and the only one with a redshift measurement turned out to be a normal GRB

In ZTF, we have found four afterglows in the last year, two with a redshift measurement *and* no detected GRB (Ho+2020d, Perley+ in prep.)

Future

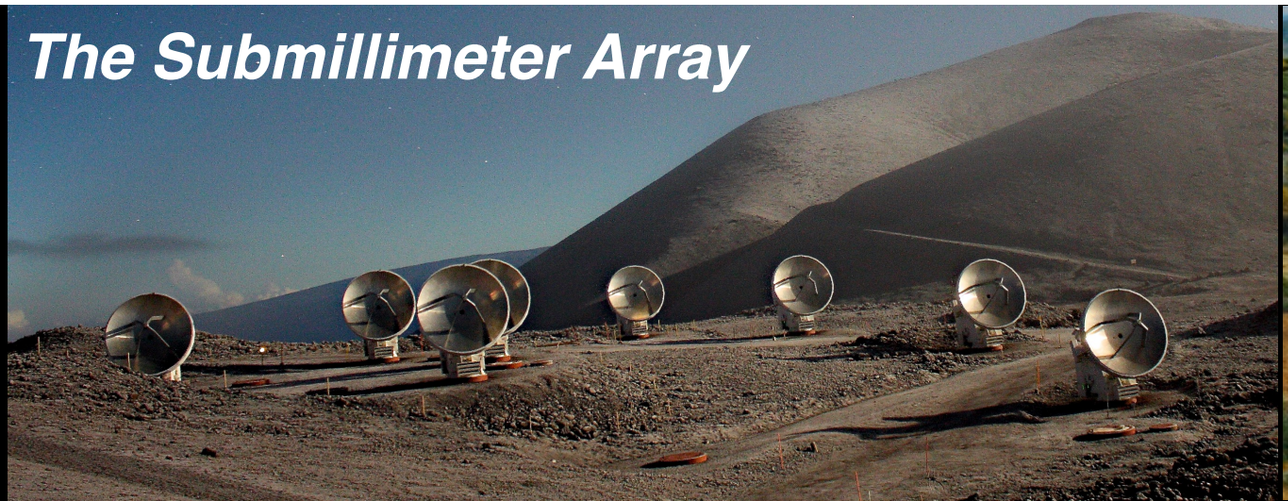
Rate of dirty fireballs <~ classical GRB rate
To find out whether dirty fireballs truly exist, will need sensitive all-sky X-ray surveys (MAXI, eROSITA) + afterglow observations

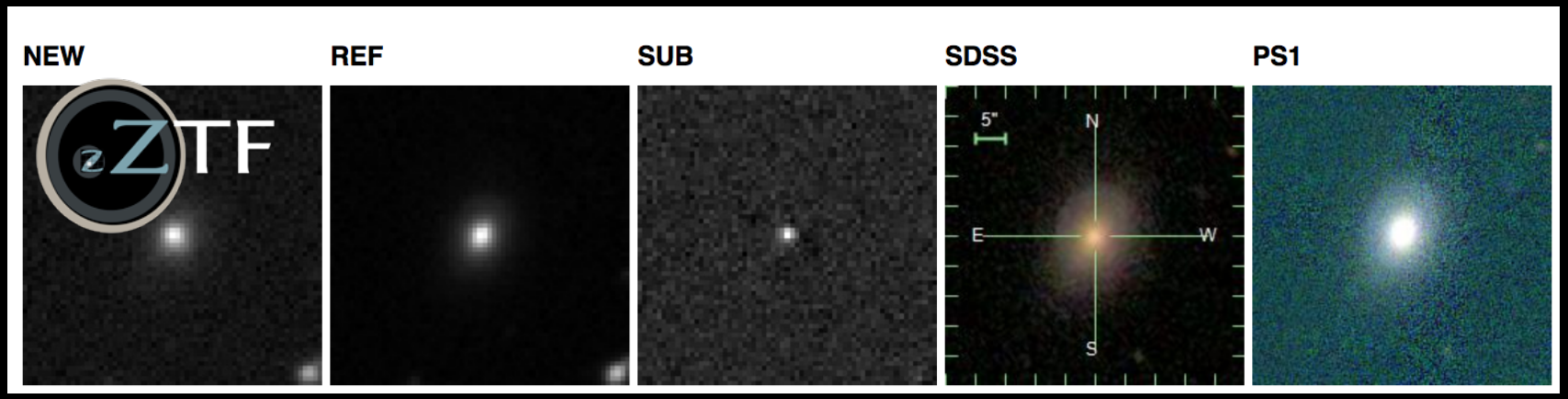


B. Saxton, NRAO/AUI/NSF

Questions?

annayqho@berkeley.edu
annayqho.github.io





Science Highlights from the ZTFbh: AGN and TDE Science Working Group

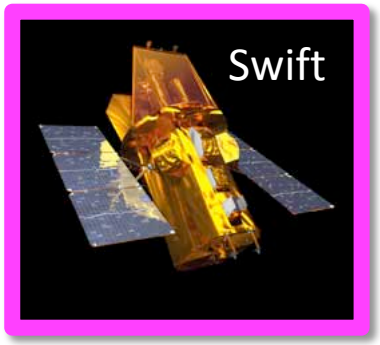
Suvi Gezari

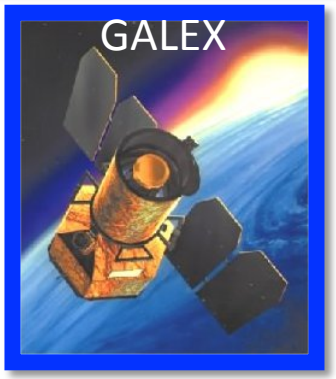
UNIVERSITY OF MARYLAND → STScI | SPACE TELESCOPE SCIENCE INSTITUTE

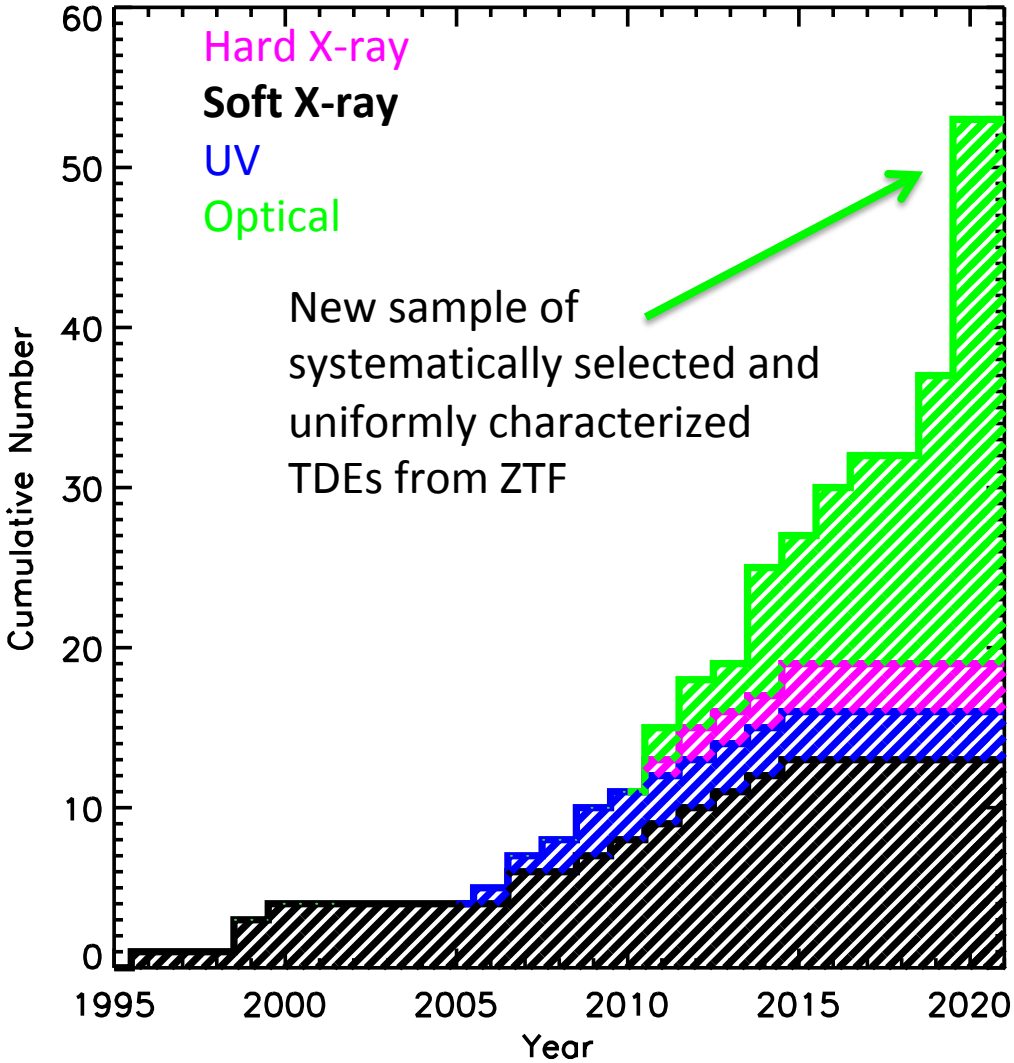
ZTF-I Celebration

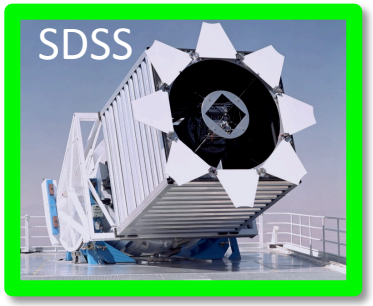
October 23, 2020

Multi-λ Searches







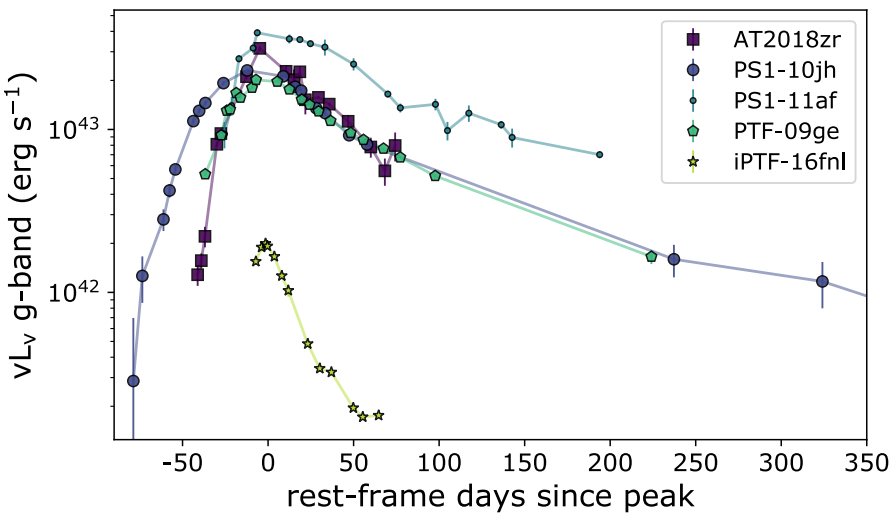


Seventeen Tidal Disruption Events from the First Half of ZTF Survey Operations: Entering A New Era of Population Studies

van Velzen et al. 2020

ZTF Pre-Peak Light Curves

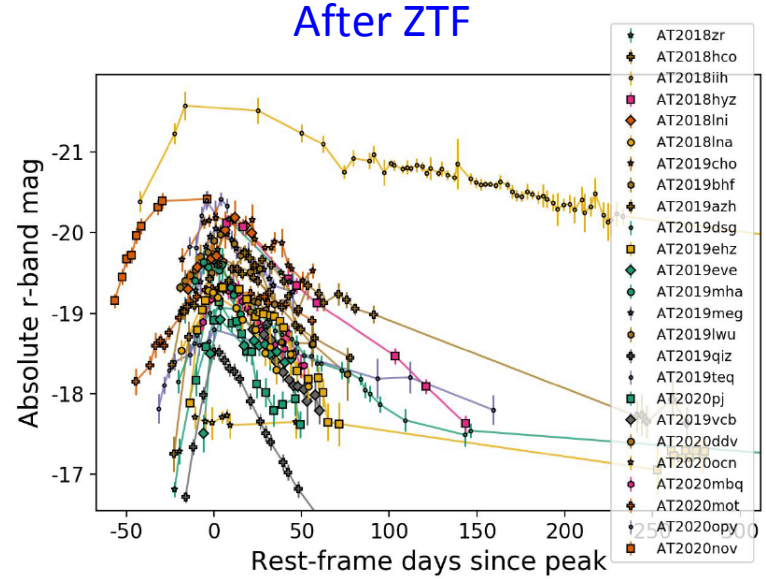
Before ZTF



van Velzen, Gezari, et al. 2018

*AT2018zr, the first TDE detected by ZTF, was one of only 5 TDEs discovered **before** peak!*

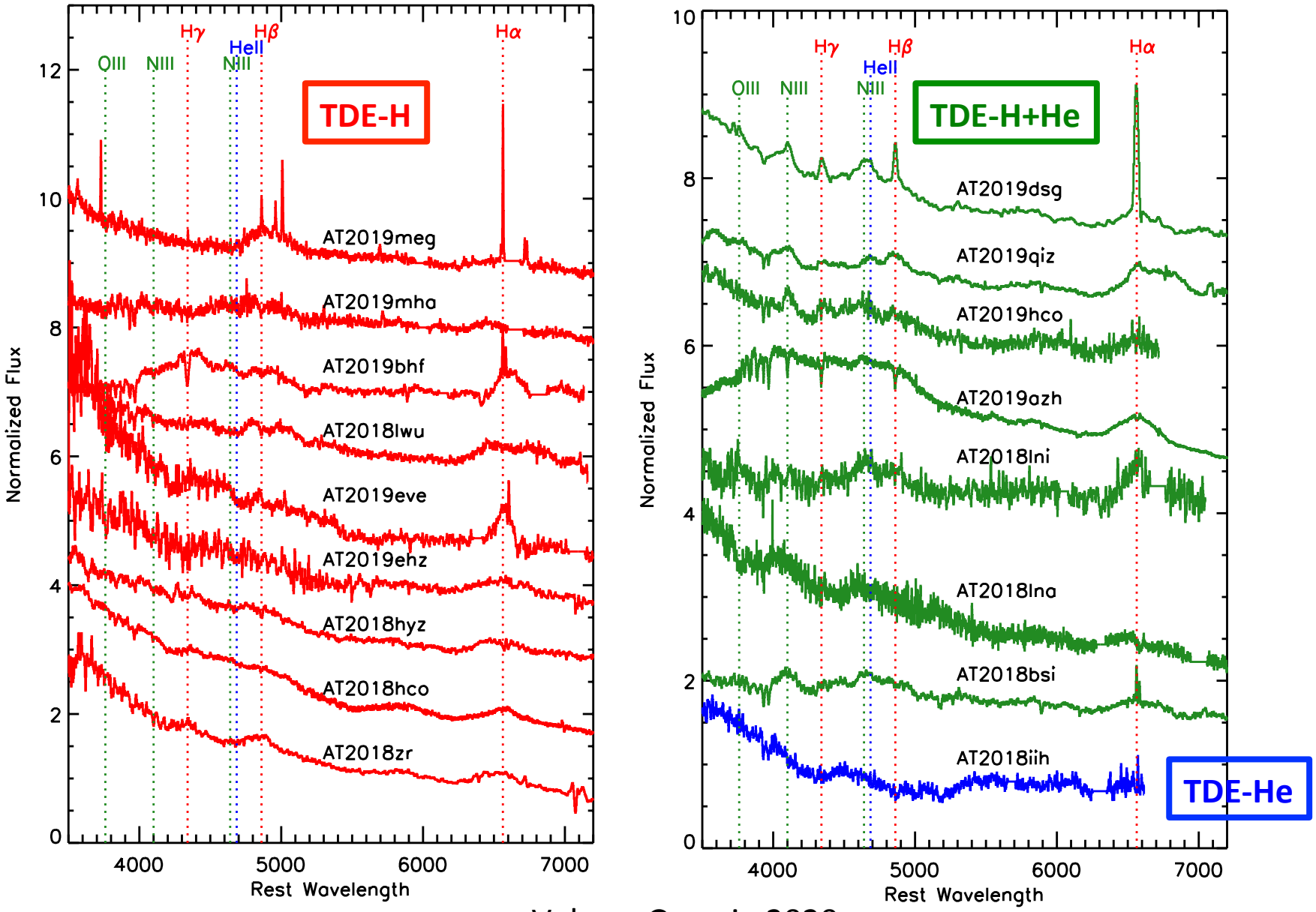
After ZTF



van Velzen, Gezari+ 2020

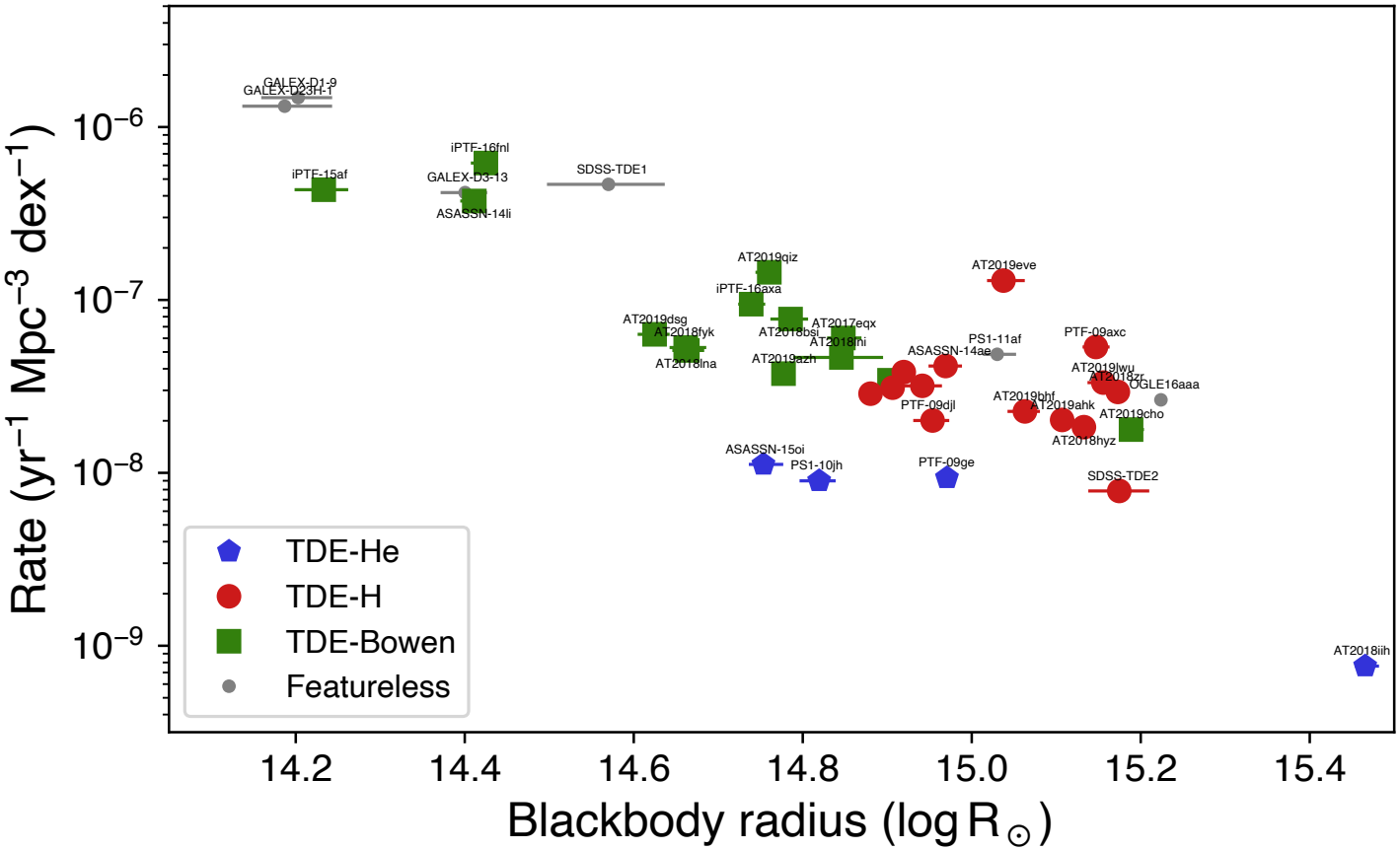
In ZTF-I, we have detected 25 more!

ZTF TDE Spectral Types



van Velzen, Gezari+ 2020

Separation of Spectral Types



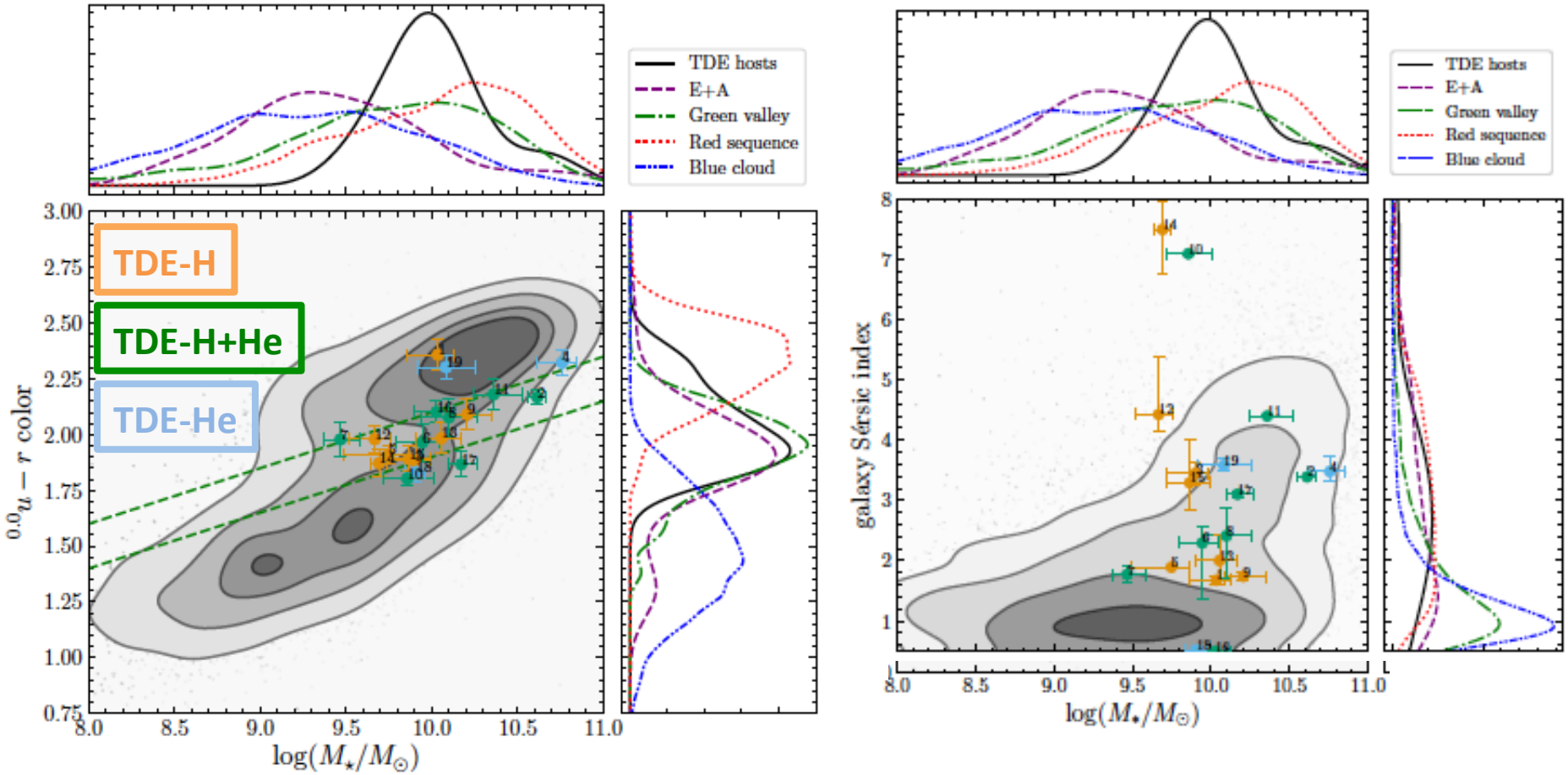
TDE-Bowen class are the most common, perhaps indicating disruption of low-mass stars?
TDE-He class are the least common, perhaps indicating the disruption of rare He stars?

van Velzen, Gezari+ 2020

TDE Hosts are Green and Centrally Concentrated: Signatures of a Post-Merger Galaxy

Hammerstein et al. 2020

TDE Hosts are Green and Centrally **Concentrated**

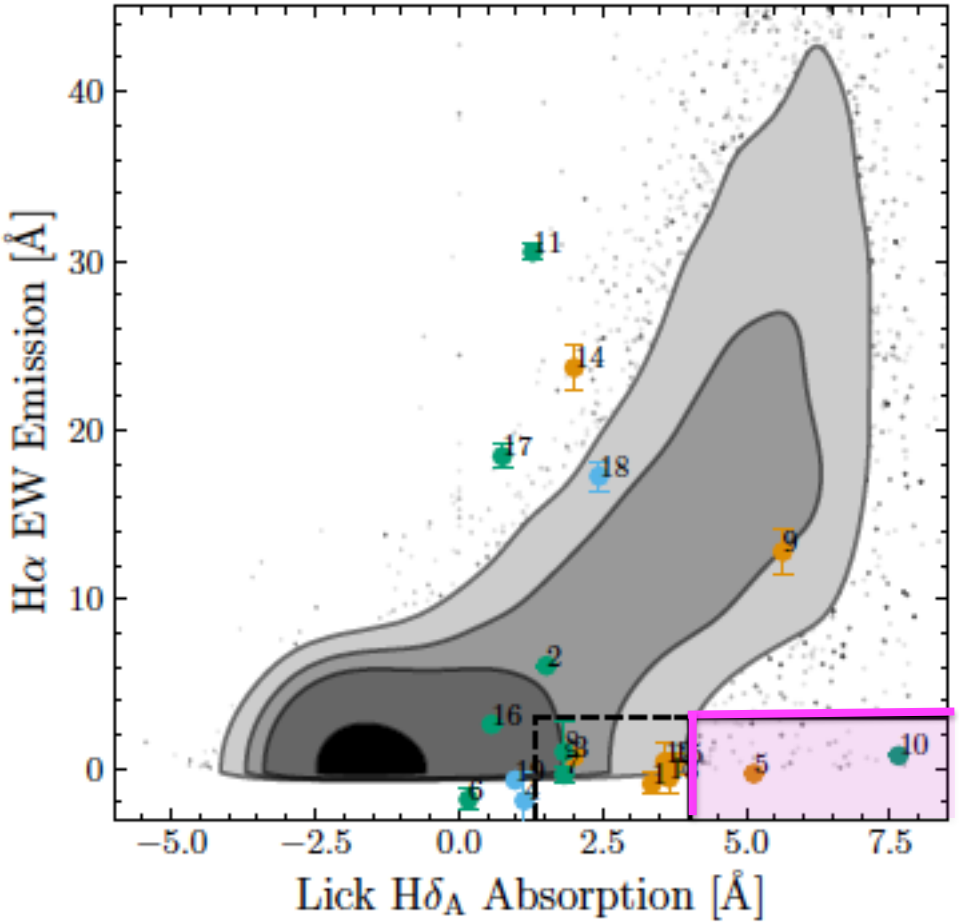


Hammerstein, Gezari+ 2020

TDE-H

TDE-H+He

TDE-He



E+A galaxy overrepresentation disappears when you select for only green galaxies with n > 2

E+A galaxies

Hammerstein, Gezari+ 2020

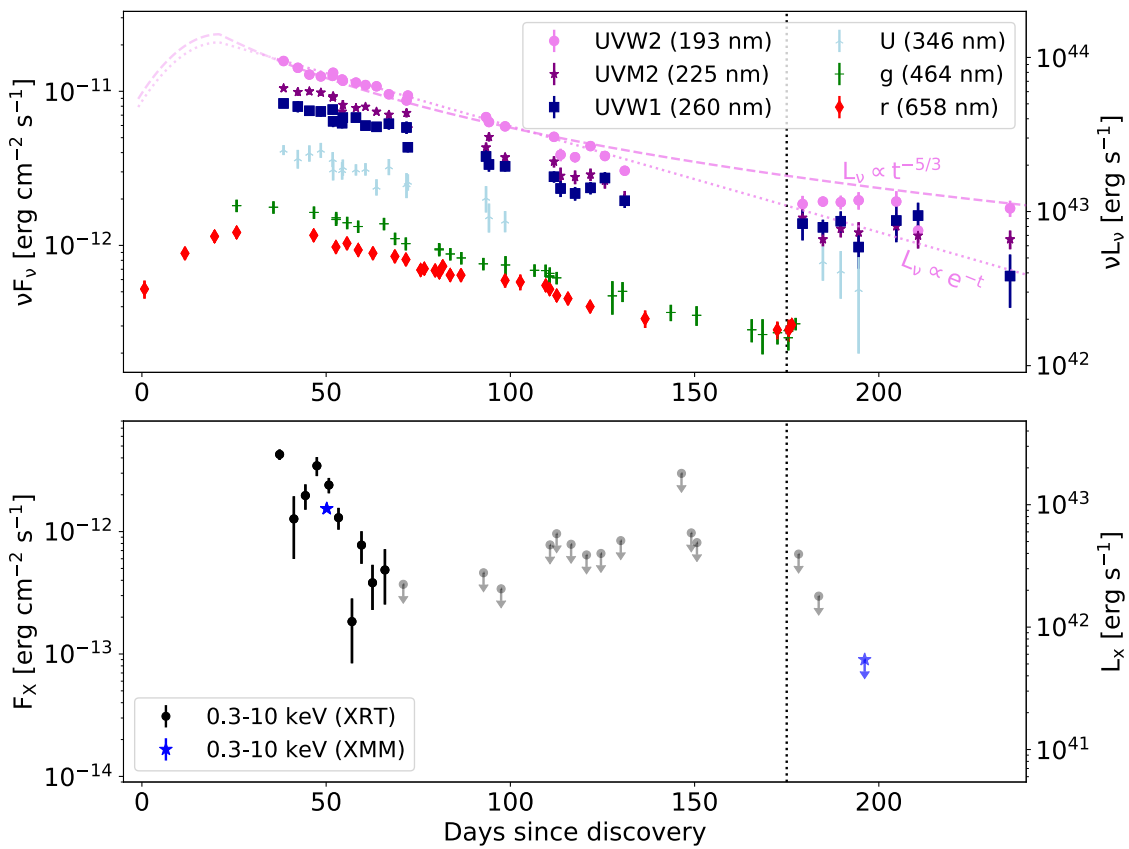
Table 2. E+A Overrepresentation

	Overall	Green Valley	$n_g > 2.0$	Green Valley $+ n_g > 2.0$
Full Sample (sF16)	22×	7×	15×	3×
$9.47 \leq \log(M_\star/M_\odot) \leq 10.76$ (sF16)	29×	8×	29×	1×

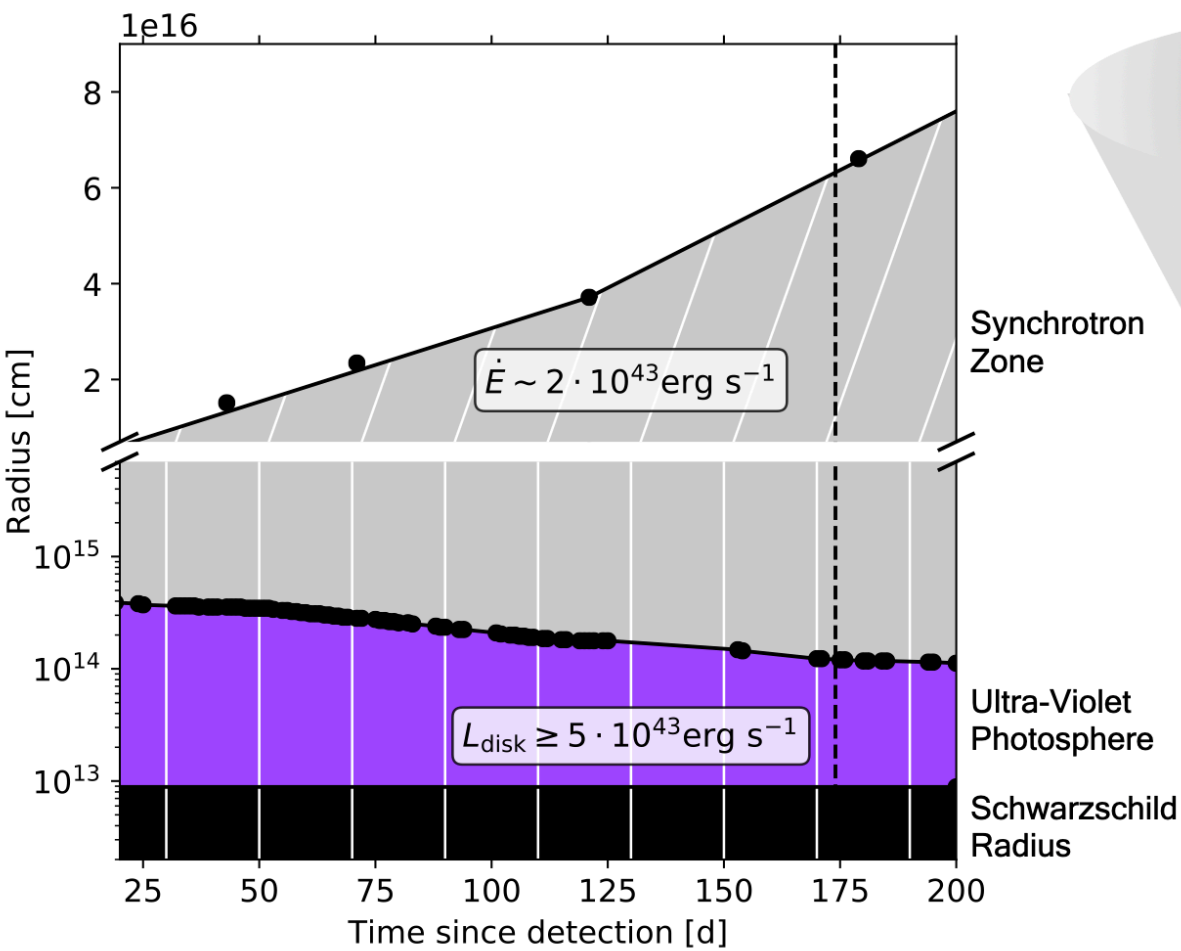
A Tidal Disruption Event Coincident with a High Energy Neutrino

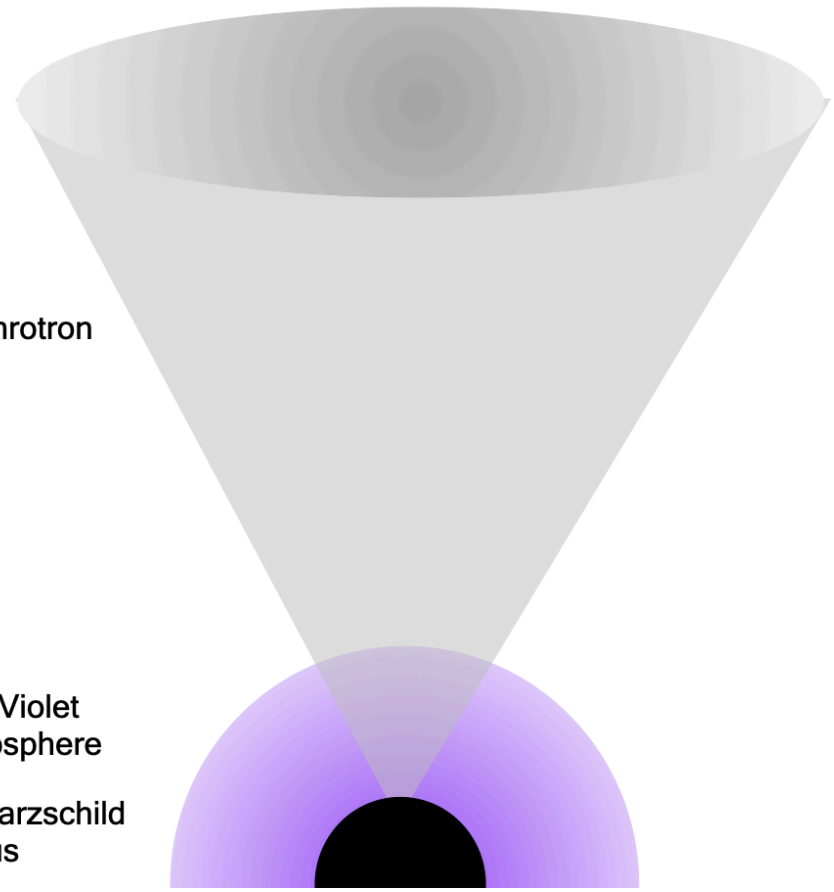
Robert Stein

Stein et al. 2020



A Tidal Disruption Event Coincident with a High Energy Neutrino



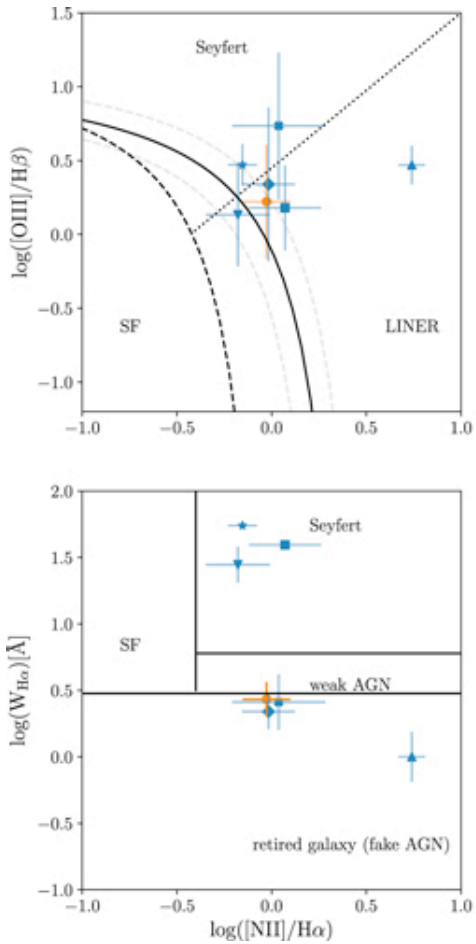


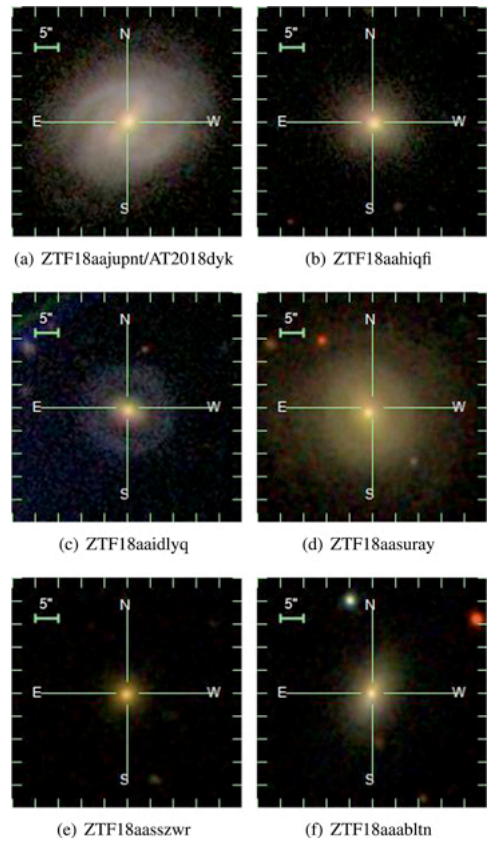
Stein+ 2020

A New Class of Changing-Look Quasars

Frederick et al. 2019

5 new LINERS caught changing look into type 1 AGN by ZTF



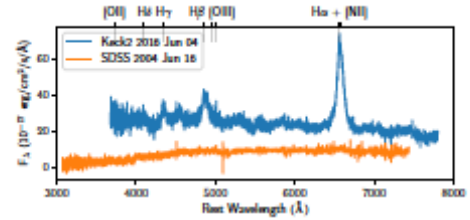


(a) ZTF18aajupnt/AT2018dyk (b) ZTF18aahiqfi

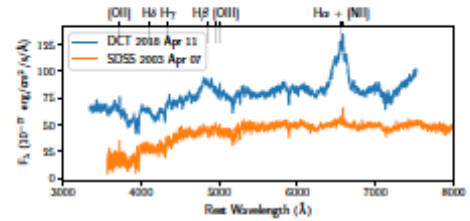
(c) ZTF18aaidlyq (d) ZTF18aasuray

(e) ZTF18aasszwr (f) ZTF18aaabltn

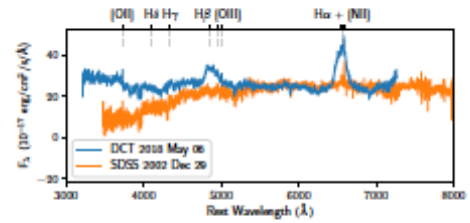
Frederick, Gezari et al. 2019



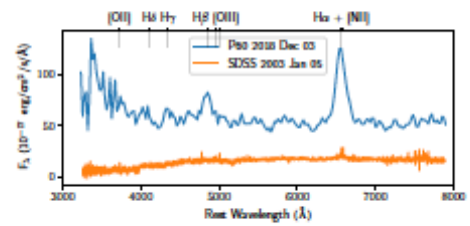
(a) iPTF 16bco



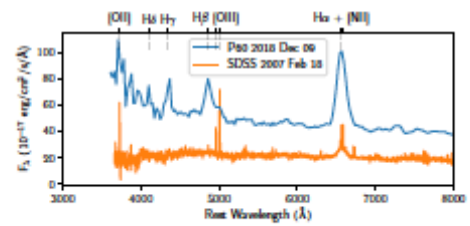
(b) ZTF18aahiqfi



(c) ZTF18aaidlyq



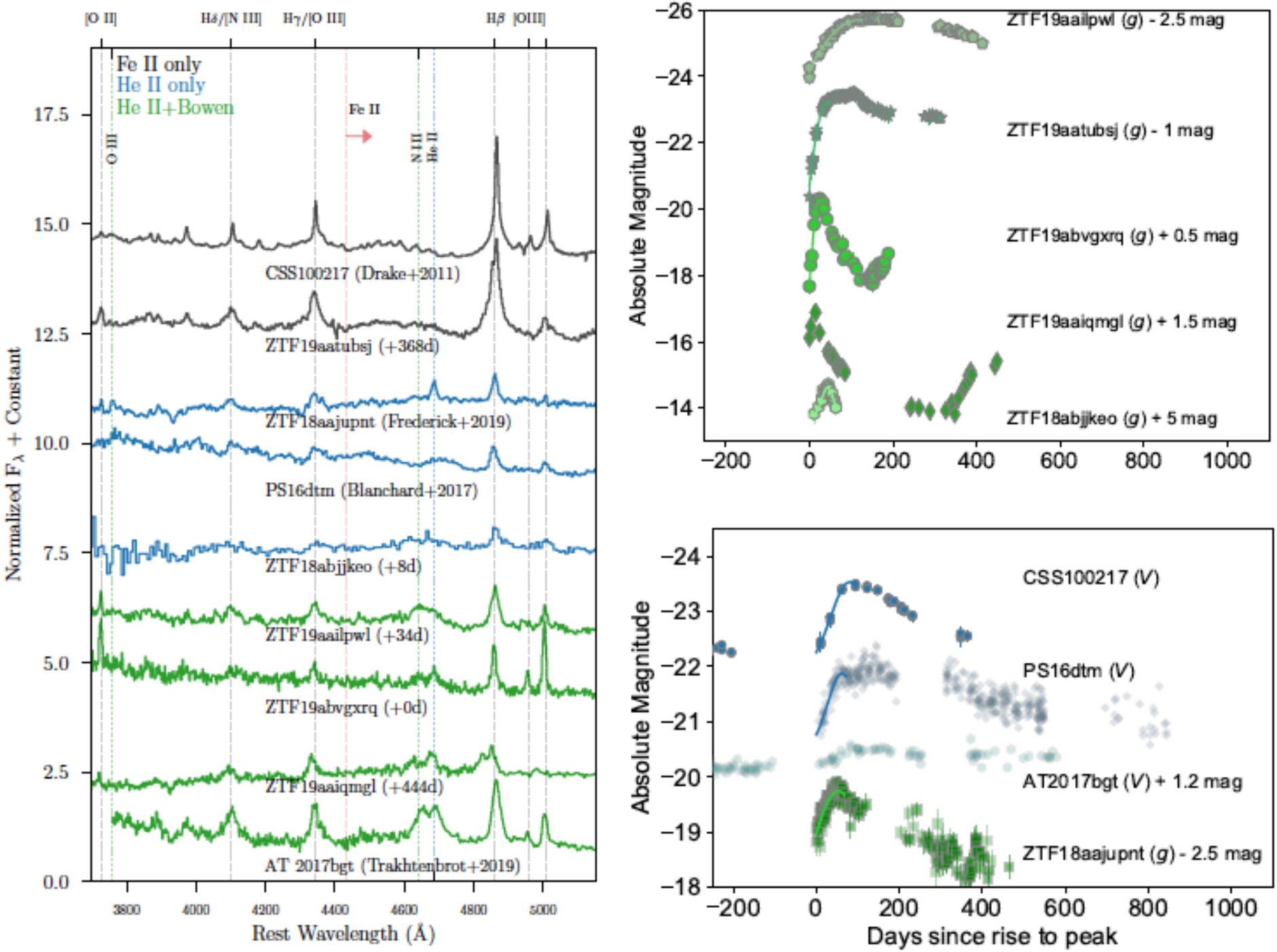
(d) ZTF18aasszwr



(e) ZTF18aaabltn

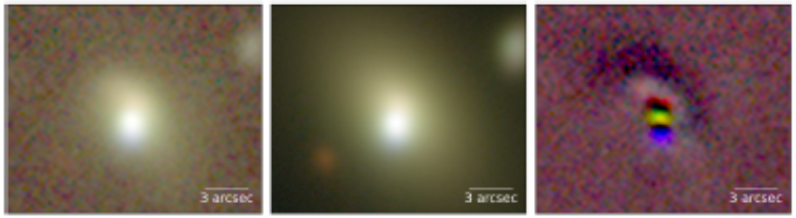
A Family Tree of Optical Transients from Narrow-Line Seyfert Galaxies

Frederick et al. 2020


[O II]
Hδ/[N III]
Hγ/[O III]
Hβ
[OIII]
Fe II only
He II only
He II+Bowen
Fe II
O III
N III
He II
CSS100217 (Drake+2011)
ZTF19aatubsj (+368d)
ZTF18aajupnt (Frederick+2019)
PS16dtm (Blanchard+2017)
ZTF18abjjkeo (+8d)
ZTF19aailpwl (+34d)
ZTF19abvgxrq (+0d)
ZTF19aaiqmgl (+444d)
AT 2017bgt (Trakhtenbrot+2019)
Normalized F_λ + Constant
Rest Wavelength (Å)
ZTF19aailpwl (g) - 2.5 mag
ZTF19aatubsj (g) - 1 mag
ZTF19abvgxrq (g) + 0.5 mag
ZTF19aaiqmgl (g) + 1.5 mag
ZTF18abjjkeo (g) + 5 mag
Absolute Magnitude
CSS100217 (V)
PS16dtm (V)
AT2017bgt (V) + 1.2 mag
ZTF18aajupnt (g) - 2.5 mag
Days since rise to peak

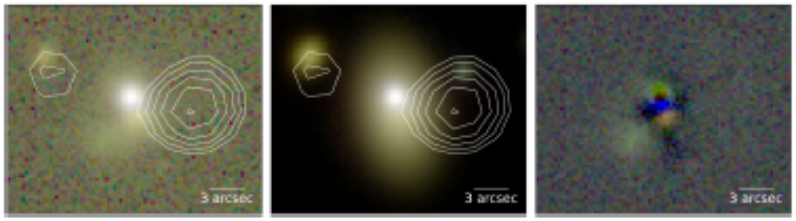
AGN on the Move: A Search for Off-Nuclear AGN from Recoiling SMBHs from ZTF

Ward et al. 2020

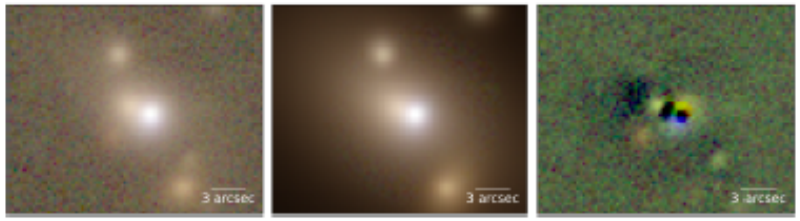


(a) ZTF19aautrth

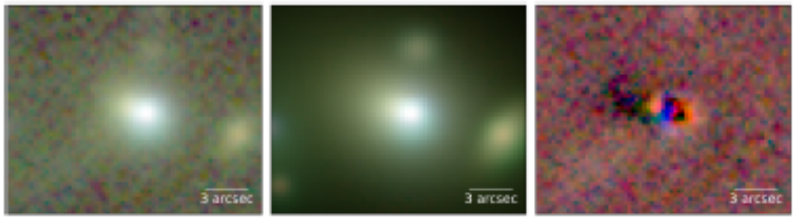
(b) ZTF19aadgijf



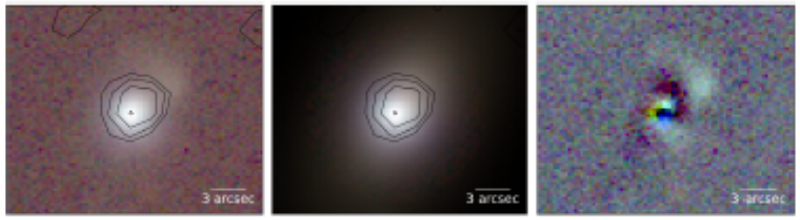
(c) ZTF18aaxmrom



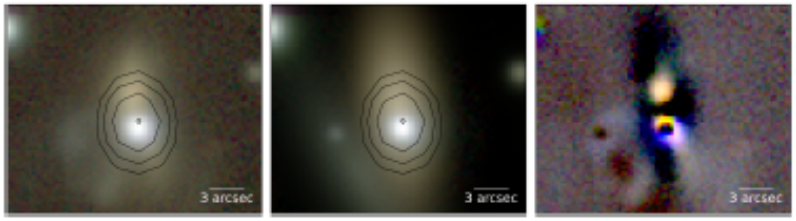
(d) ZTF19aayrjsx



(e) ZTF18aalsidi

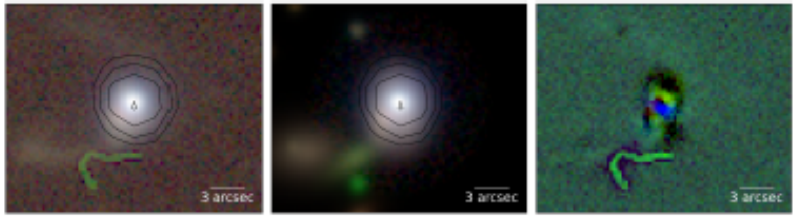


(f) ZTF18accptjn

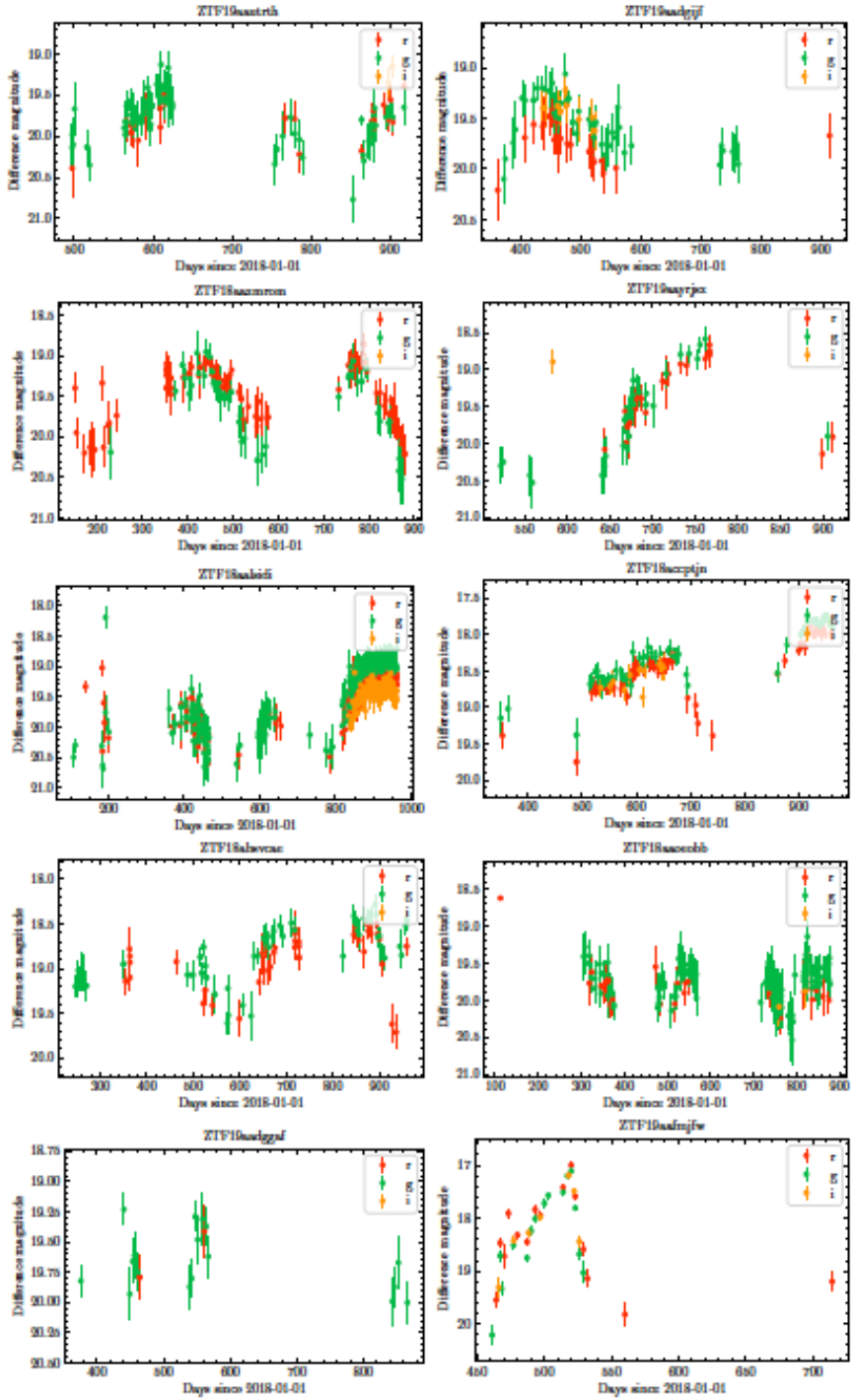


(g) ZTF18absvcae

(h) ZTF18aaoeobb



(i) ZTF19aadggaf


ZTF19aastrth
ZTF19aadgjf
ZTF18aazmrom
ZTF19aayrjx
ZTF18aabiii5
ZTF18aacptjn
ZTF18abwcac
ZTF18aacobb
ZTF19aadggaf
ZTF19aadmjfw
Difference magnitude
Days since 2018-01-01
r
g
i

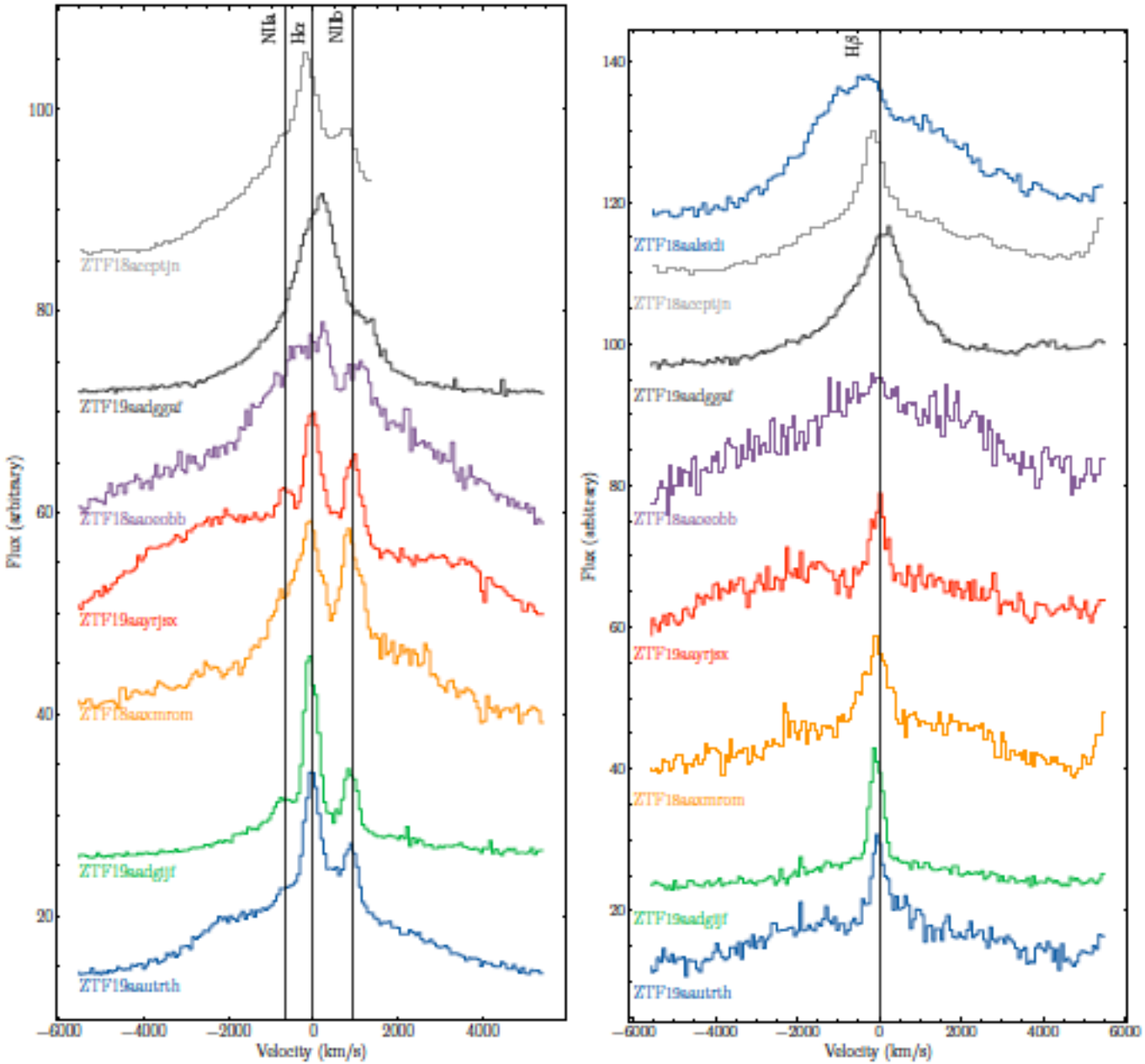

NIIa
Hα
NIIb
Hβ
ZTF18aaisidi
ZTF18acceptjn
ZTF19aadggaf
ZTF18aaoeobb
ZTF19aayrjsx
ZTF18aaxmrom
ZTF19aadgjjf
ZTF19aautrth
Flux (arbitrary)
Velocity (km/s)

Image credit: NASA/JPL-Caltech/T. Pyle (SSC)

PLANETARY DEBRIS AROUND WHITE DWARFS IN ZTF

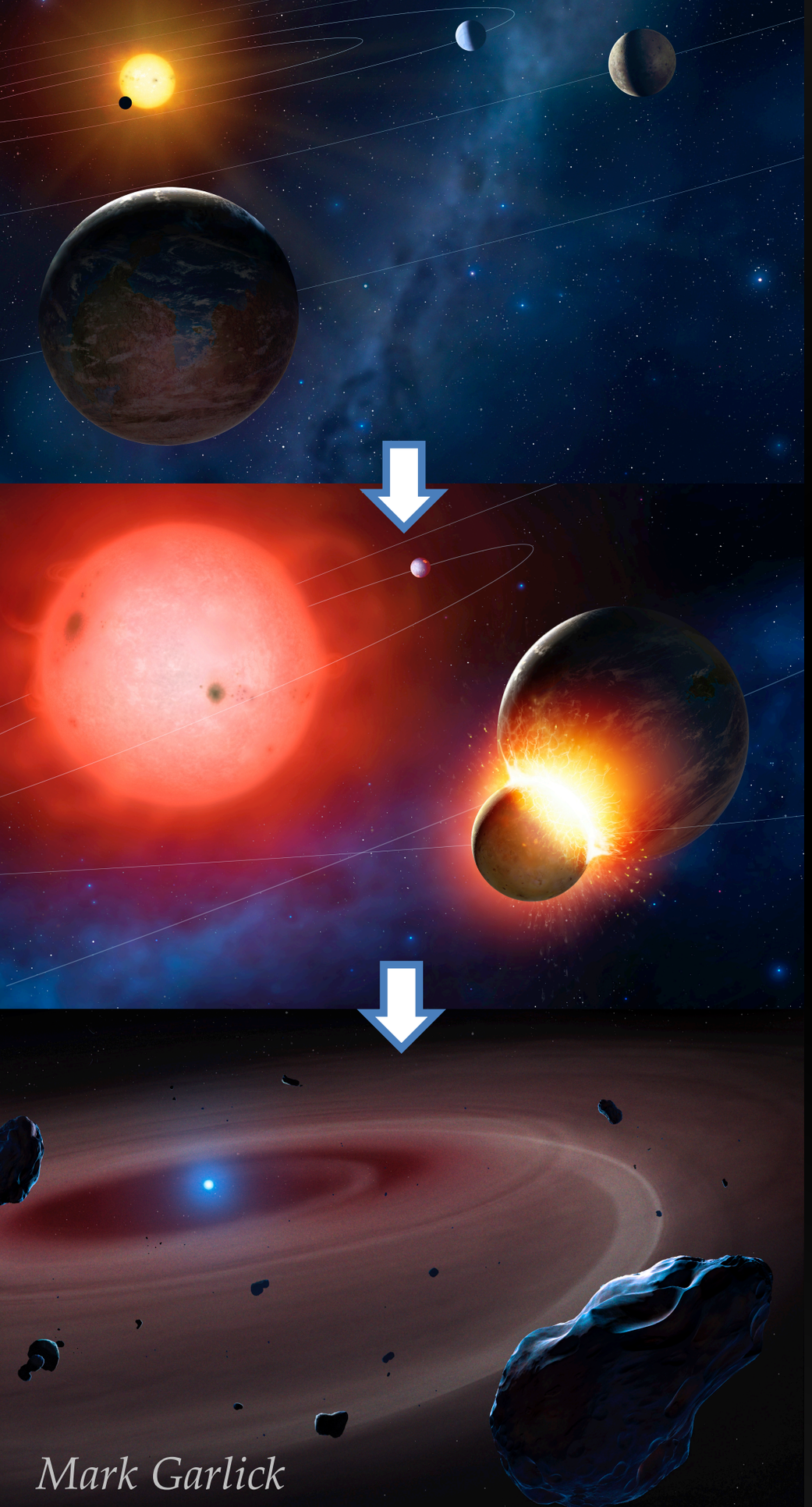
Zach Vanderbosch, *UT Austin*

J.J. Hermes, *Boston University*

McDonald Observatory
The University of Texas at Austin

The University of Texas at Austin
Department of Astronomy
College of Natural Sciences

WOOTTON CAPP



1. We are observing the future of planetary systems around 2-3 solar-mass ZAMS stars.

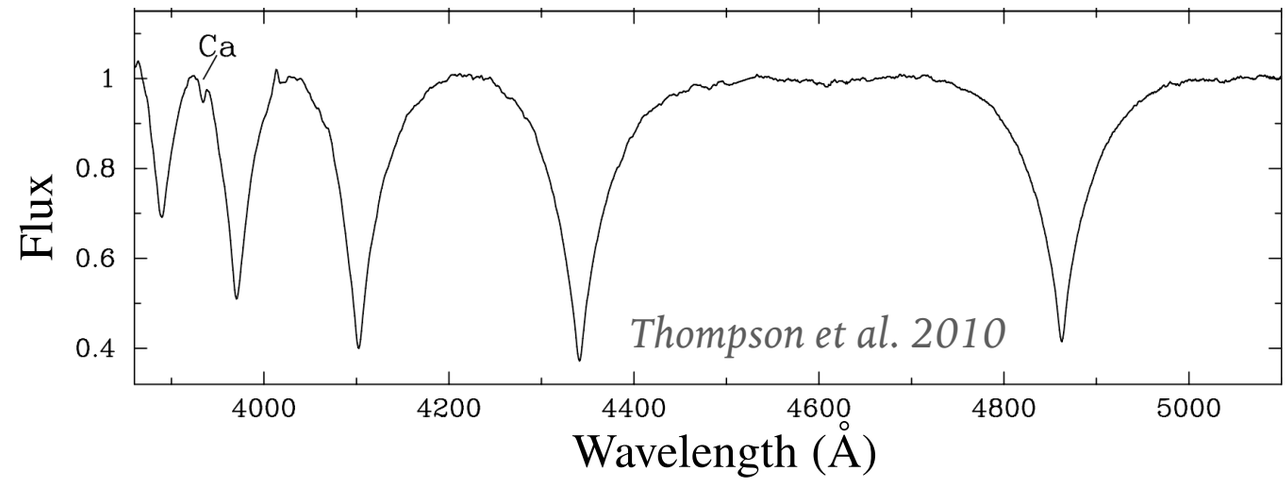
2. As the host evolves, the **orbits** of surviving planets **expand**. Objects destabilize, some **scatter** in.

3. Ancient solar systems have leftover debris. We can see it if it pollutes a pristine **white dwarf**.

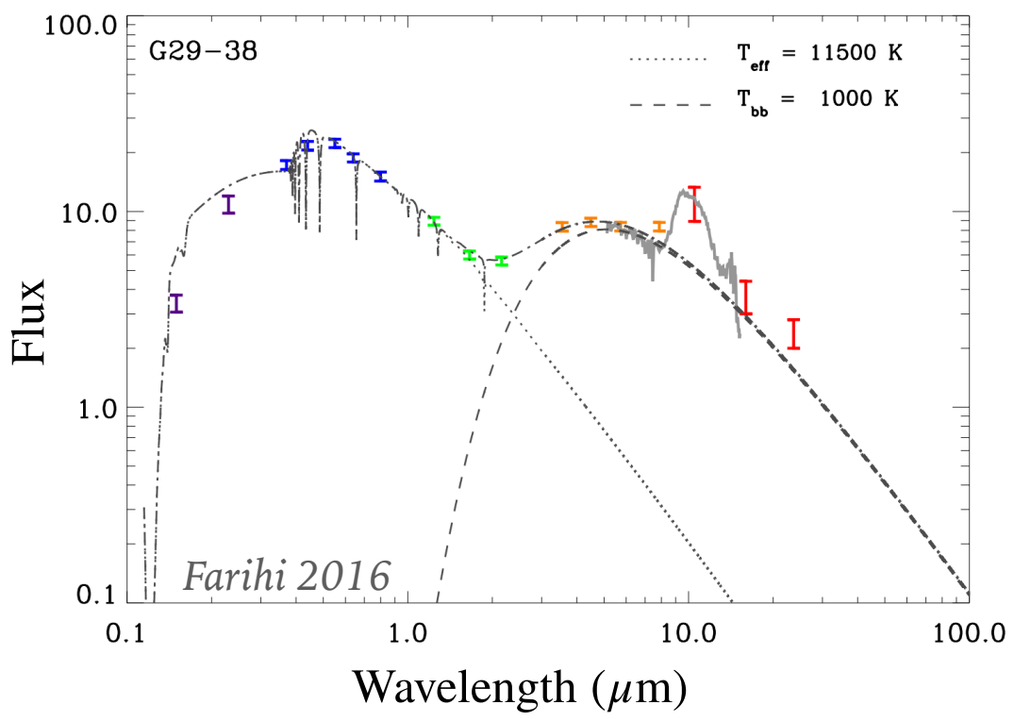
DETECTING PLANETARY DEBRIS AROUND WHITE DWARFS

DAZ = Metal Polluted H-atmosphere White Dwarf

≈30% of white dwarfs below 20,000 K exhibit metal pollution

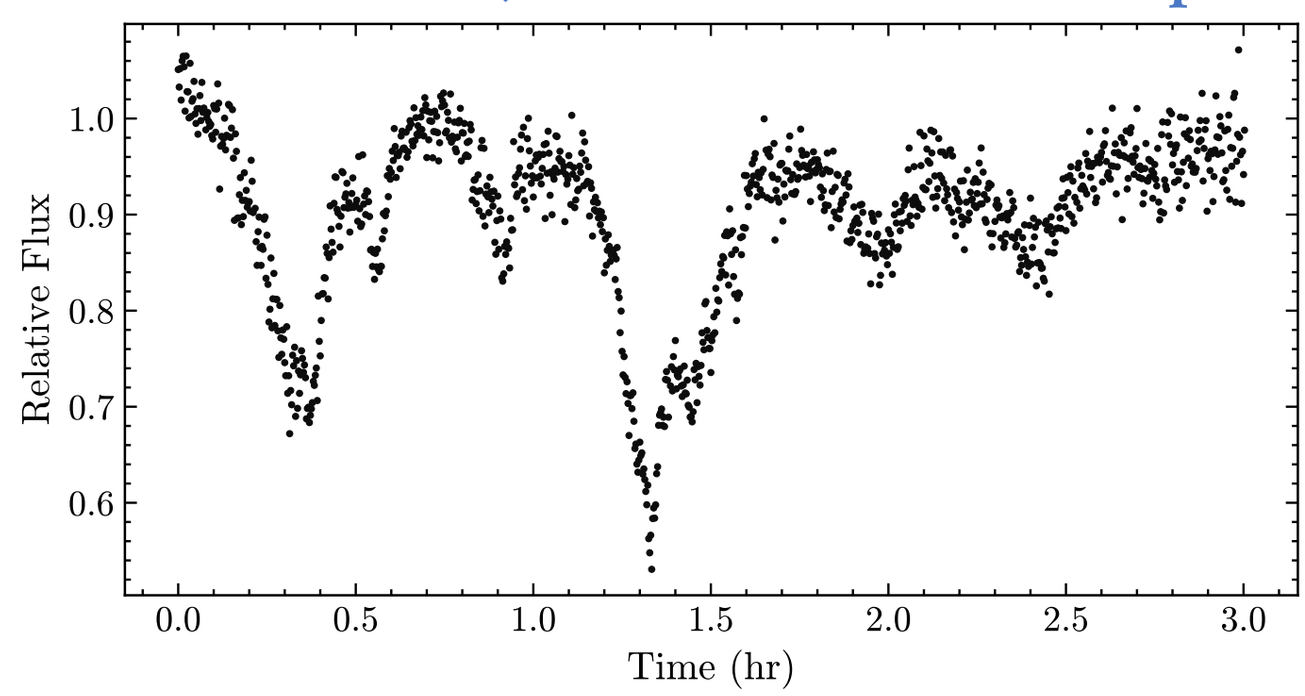


IR-excess due to warm circumstellar dust seen in 1-2% of white dwarfs



Transiting Planetary Debris offers the most direct evidence, only two objects known

WD 1145+017, 4.5–4.9 hour orbital periods

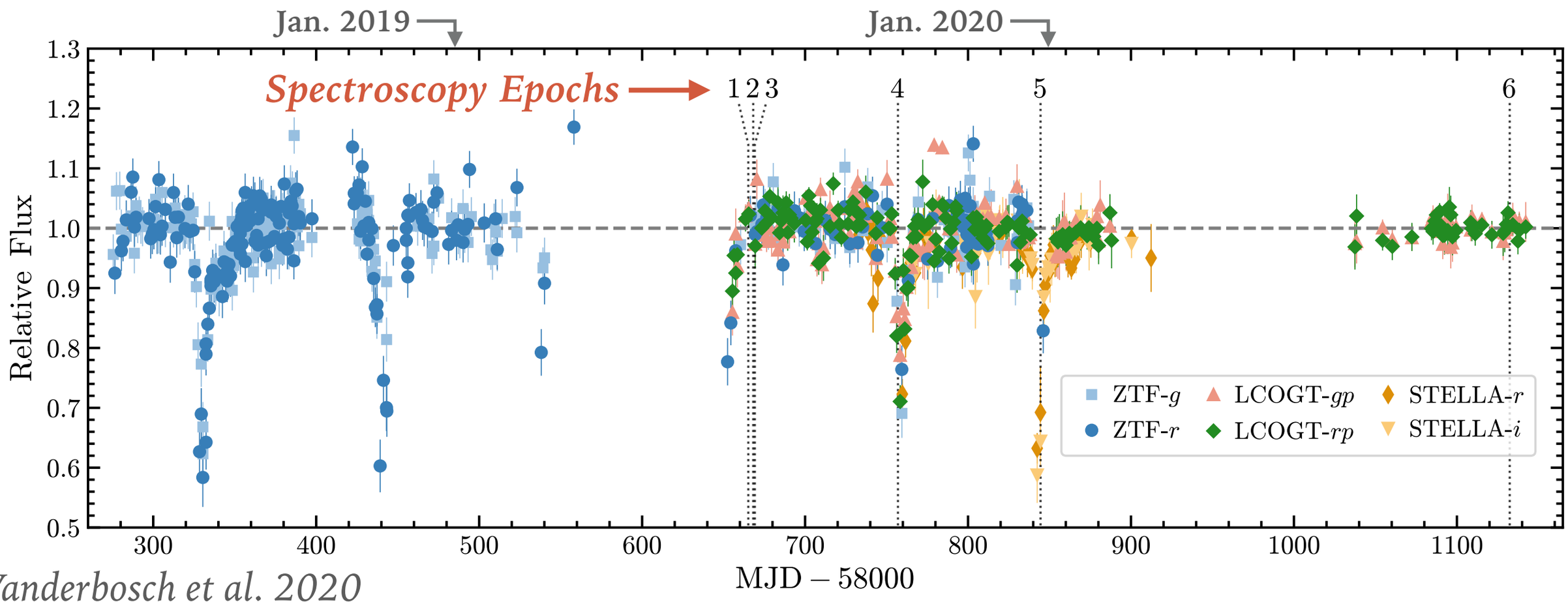


ZTF J0139+5245: TRANSITING DEBRIS IN A 107-DAY ORBIT

Orbital period **Two Orders of Magnitude** longer than WD 1145+017!

Key Properties

$T_{\rm eff} = 10{,}530\,K$	$P_{\rm orb} \approx 107$ days
$M_* = 0.52\,M_\odot$	Transit Durations $\approx 15 - 25$ days
$1 - 10$ year Ca Diffusion Timescale	Minimum Debris Mass comparable to solar system objects ($> 10^{16}$ g)

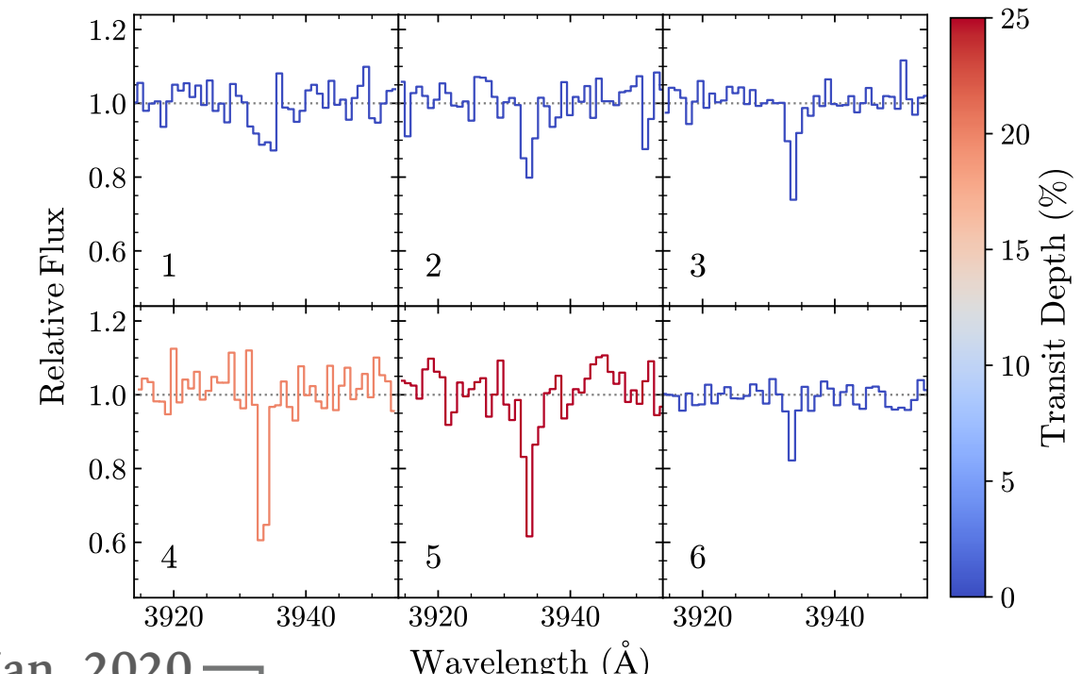


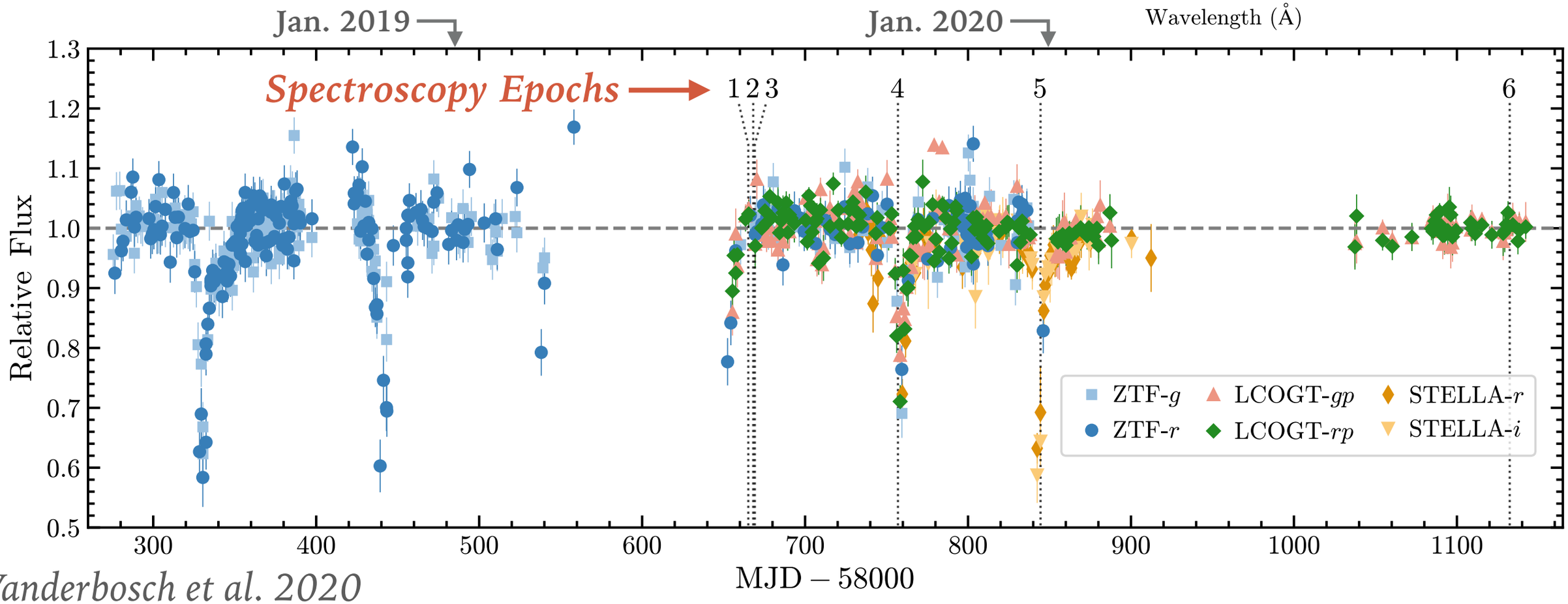
Vanderbosch et al. 2020

ZTF J0139+5245: DEPTH-DEPENDENT CALCIUM ABSORPTION

- 1-10 year diffusion timescale suggests recent accretion events are an unlikely source.

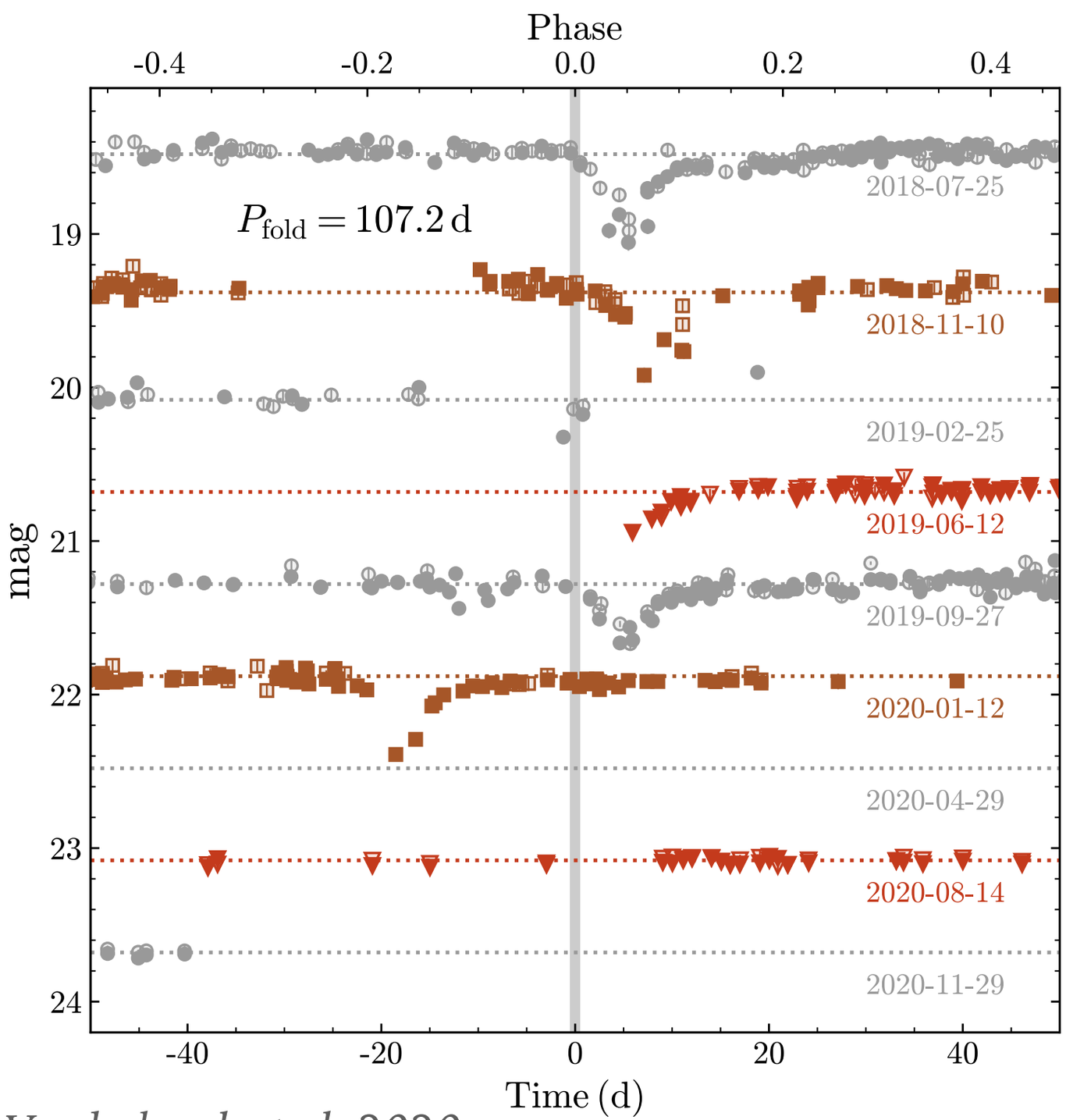
- **Absorption from circumstellar debris** is likely responsible.
- **Active disruption or collision events are** required to maintain supply of metallic gas.





Vanderbosch et al. 2020

ZTF J0139+5245: A DYNAMIC SYSTEM

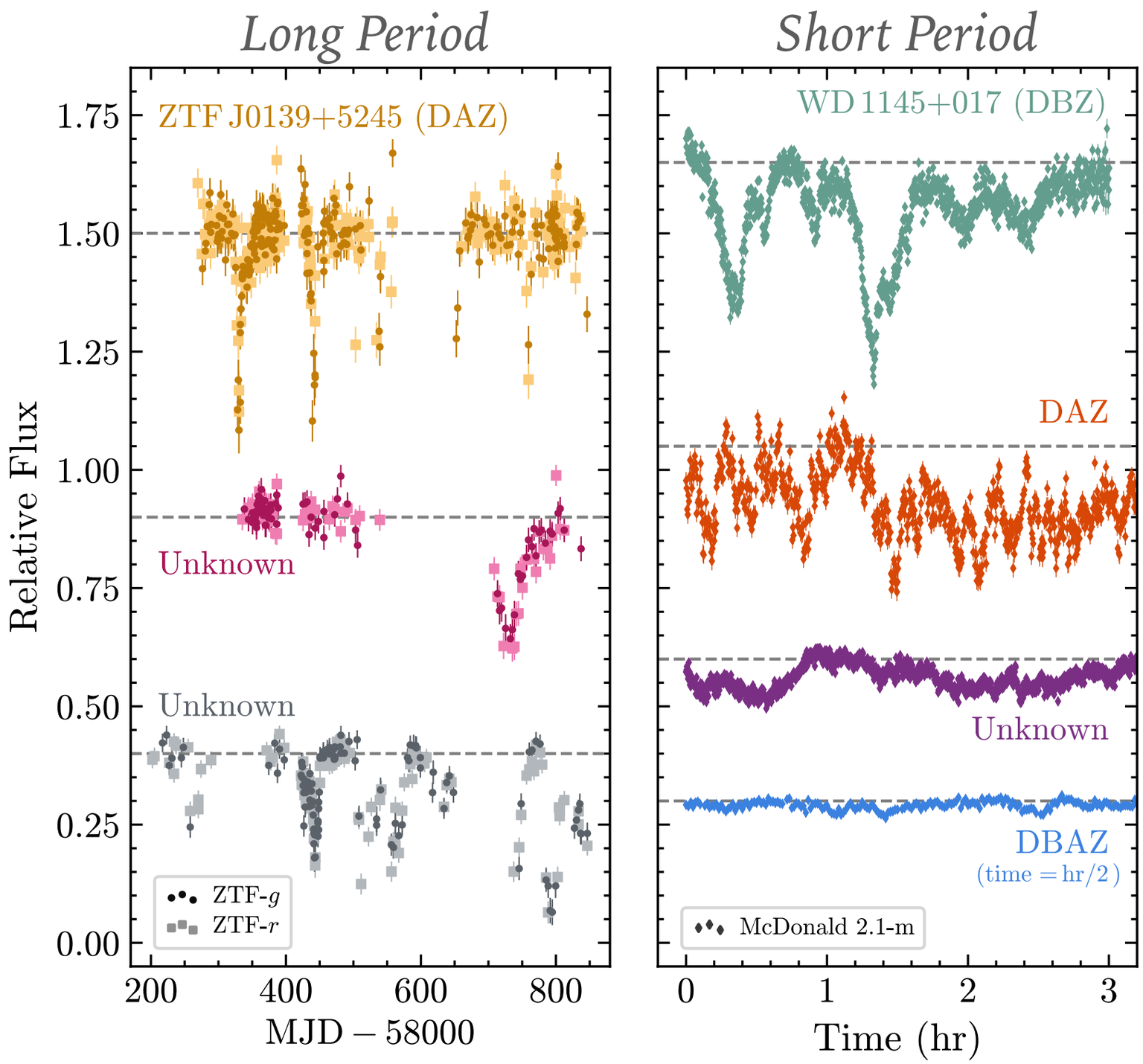


Vanderbosch et al. 2020

Transit Recurrence Times Observed to Vary up to 20-days

- Is the planetary debris evolving onto a closer orbit?
- Is the system actively generating new debris?
- **Ongoing photometric monitoring is required** to determine whether the transit recurrence time has shrunk permanently, or if variations of this magnitude are commonplace.
- Finding more transiting debris systems is necessary

KNOWN AND CANDIDATE PLANETARY DEBRIS SYSTEMS



Guidry et al. in prep

Transiting Debris Candidates Identified using **ZTF + *Gaia* Variability Metrics**

- **Excess ZTF Light Curve Scatter, excess *Gaia* flux uncertainty, and ZTF Alerts**
- **No J-band IR-excess**
- **Spectroscopic Metal pollution**
- **Flux dips on short or long timescales**
- **Gemini FT proposal accepted to get spectral IDs for two objects**

DAZ = Metal polluted H-atmosphere White Dwarf