



Rapid Transient Follow-up with the Unistellar Network of Citizen Scientists

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Unistellar Space Science Principal

Lauren Sgro^{1,2}, Amaury Perrocheau¹, Franck Marchis^{1,2}

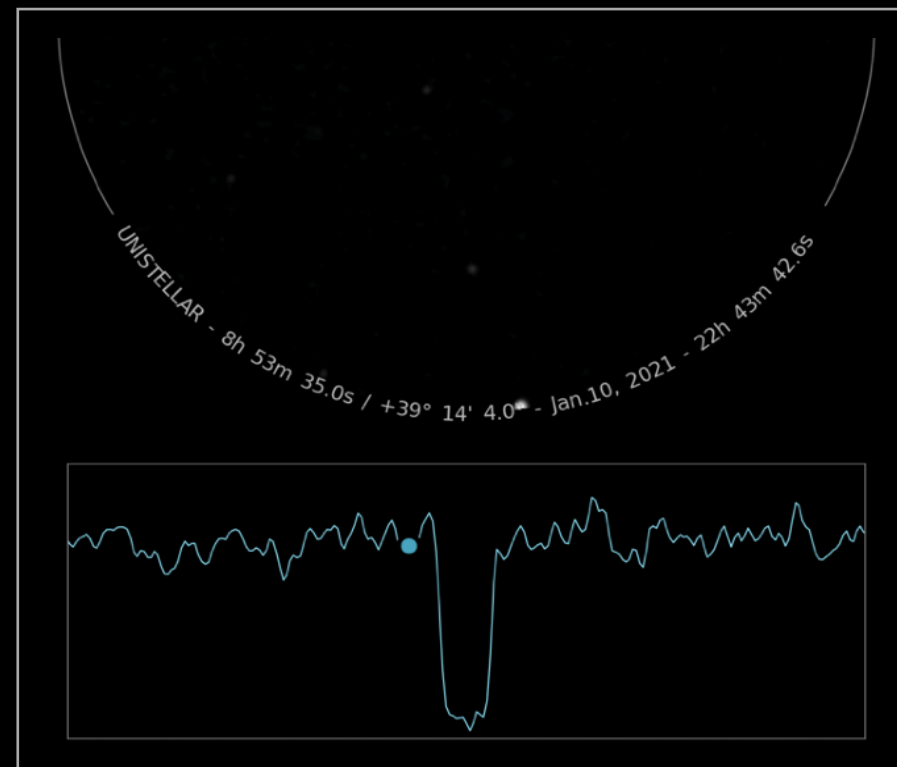
Special thanks to our 500+ Citizen Astronomers & the Unistellar team

1 SETI Institute; 2 Unistellar

Five main scientific campaigns for Unistellar citizen scientists

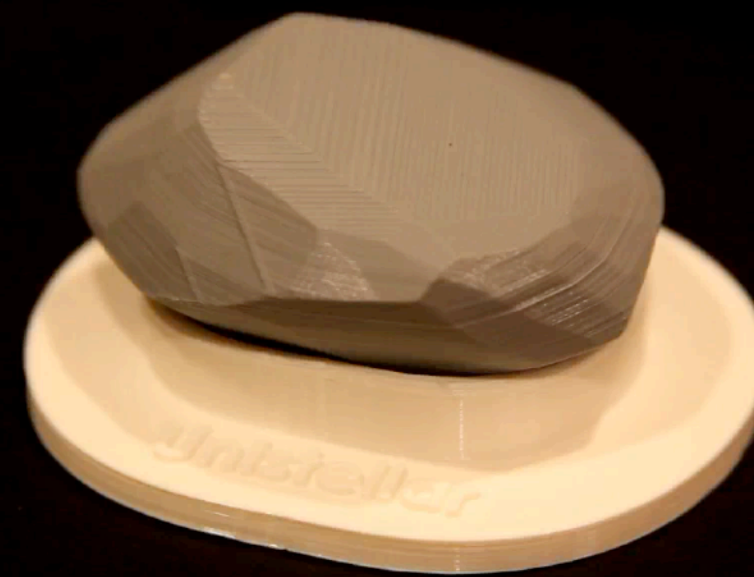
Asteroid Occultations

Shapes of Asteroids



Planetary Defense

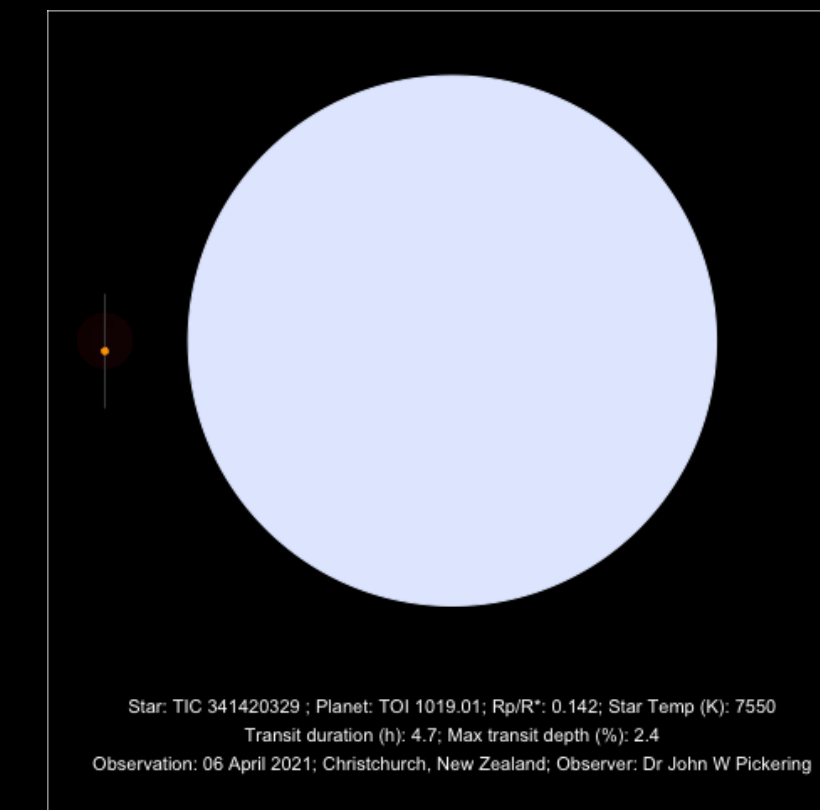
Orbits & Shapes of Near-Earth Asteroids



Asteroid "1999AP10"

Exoplanet Transits

Planet Timing & Confirmation



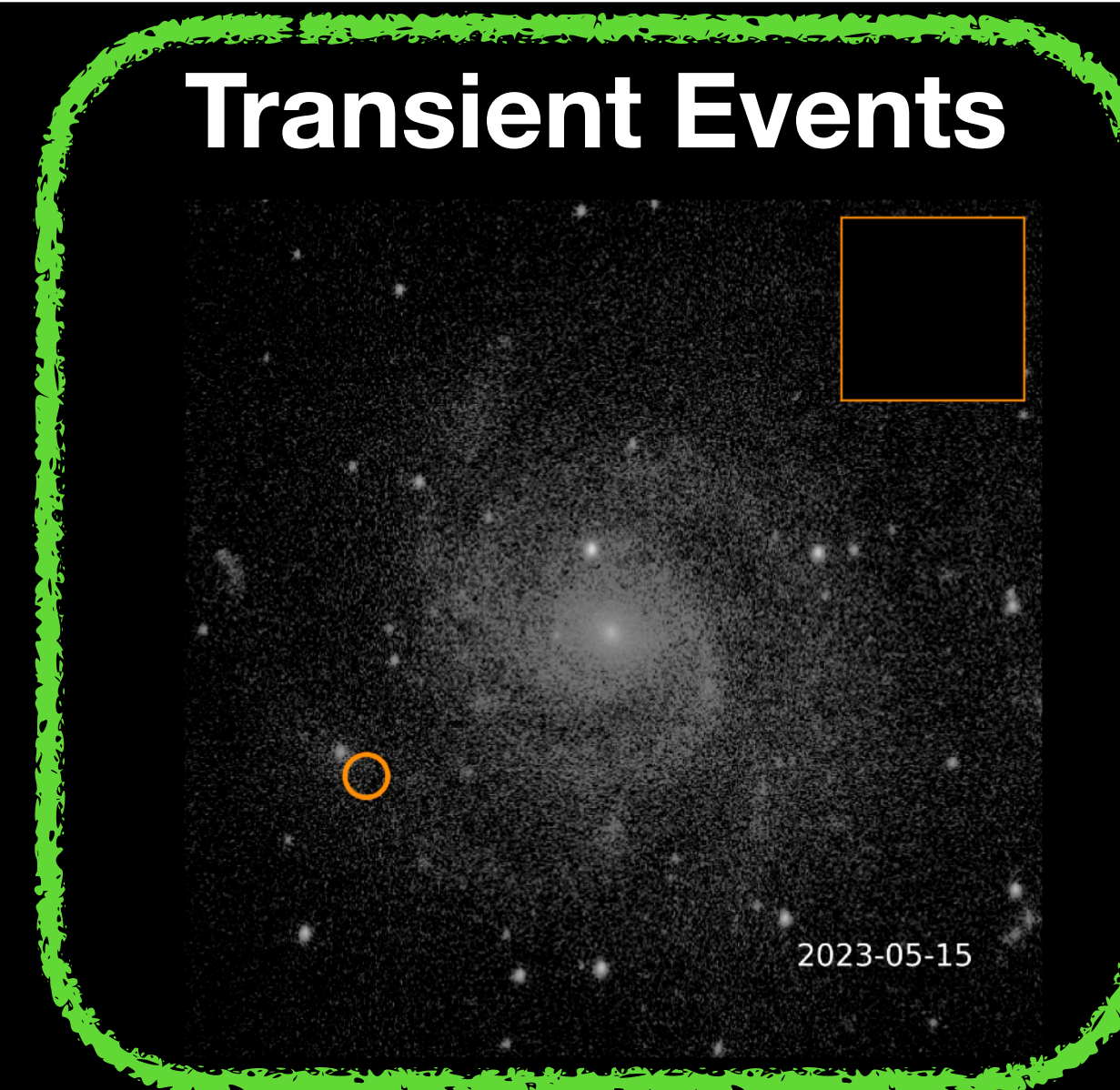
Created by
citizen astronomer
John W. Pickering

Cometary Activity

Brightness & Evolution of Comets



Transient Events



"Cosmic Cataclysms"

Astro-COLIBRI Workshop
21 Nov 2023

Our Unistellar-SETI Institute Team in San Francisco

Dr. Franck Marchis

*Co-founder
Science Team Lead
Chief Scientific Officer*



Dr. Tom Esposito

*Transients Lead,
Exoplanets co-I
February 2020*



Dr. Lauren Sgro

*Exoplanets Lead
May 2022*



(Atlanta, GA)

Dr. Ryan Lambert

*Planetary Defense,
Satellites Lead
March 2022*



Dr. Ariel Graykowski

*Comets Lead
June 2022*



(Washington, D.C.)

Dr. Ian Weaver

*SETI Education Associate,
August 2023*



Amaury Perrocheau

*Transients Researcher
October 2023*

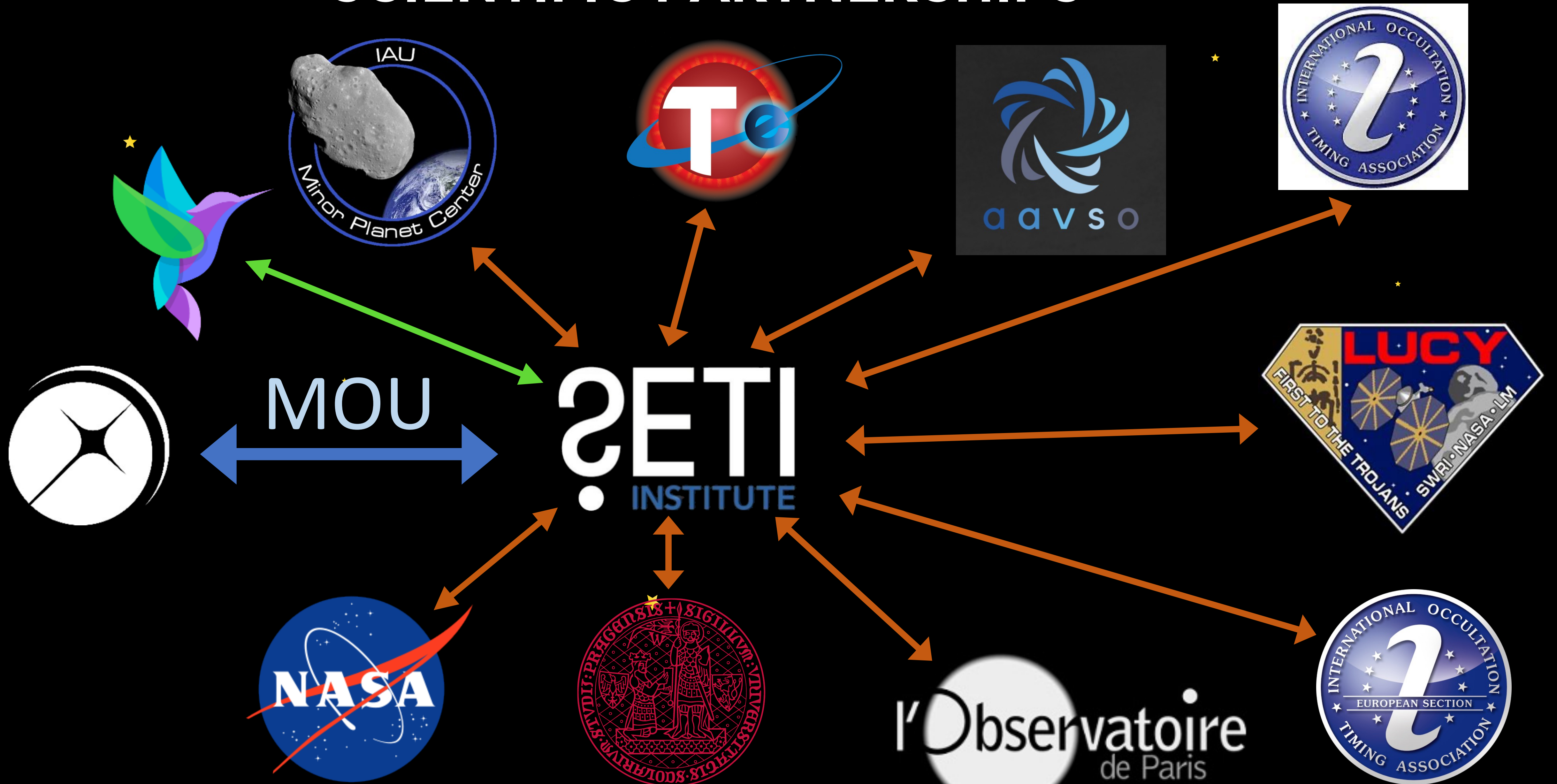


San Francisco office



Astro-COLIBRI Workshop
21 Nov 2023

SCIENTIFIC PARTNERSHIPS



MOU

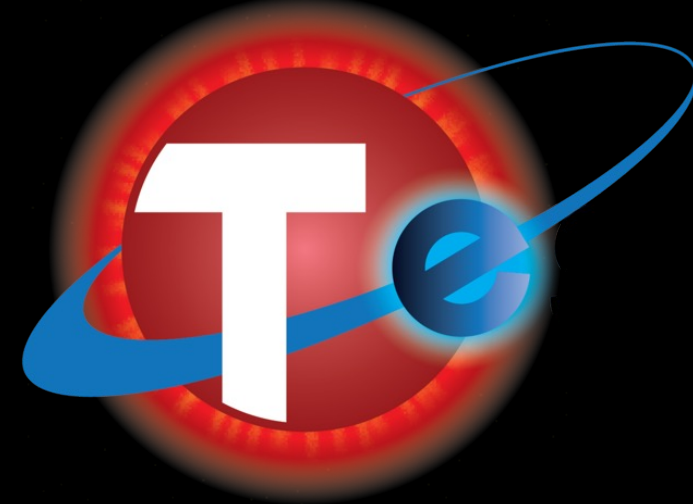
?ETI
INSTITUTE

NASA



l'Observatoire
de Paris

INTERNATIONAL OCCULTATION
TIMING ASSOCIATION
EUROPEAN SECTION



Unistellar Network aims to provide the fastest ground-based photometric follow-up of bright optical transients

Goals of the *Cosmic Cataclysms* campaign:

- Routinely obtain photometry on new transients <1 hour after their identification (within 5 minutes in best cases)
- Provide *coordinated* long-term and high cadence monitoring of the most interesting science cases (e.g., multiple measurements per day over months)
- Guide new science and discoveries in the era of Vera Rubin/LSST (2024+)

Timeline

- Started beta testing in June 2022 (Unistellar Network was formed in 2020)
- Full operations with automatic alerts and data processing since February 2023
- Added Astro-COLIBRI app notifications in August 2023



UNISTELLAR's Enhanced Vision Telescope

"eVscope" Specs

- **11.2 cm aperture**
- **CMOS RGB sensor, 400–900 nm**
- **Alt-Az mount**
- **Controlled from mobile app (iOS, Android)**
- **Autonomous field detection**
- **Portable (10 hr battery, 15.4 lbs incl. tripod)**
- **On-board computer**
- **Cameras by model:**

eVscope 1 / eQuinox 1
37' x 28' FOV; 1.72 "/pix
Sony IMX224

eVscope 2 / eQuinox 2
45' x 34' FOV; 1.33 "/pix
Sony IMX347



Images uploaded to Unistellar cloud storage via WiFi



"Come for the Enhanced Vision, Stay for the Science"



The Unistellar Network of telescopes is >10,000 strong and growing!

>500 people observed for science campaigns

>1,200 following transients

>1,700 in Slack workspace

2019-2023

Making it easy to become a citizen astronomer

Target information is on Unistellar's website, Slack, and Astro-COLIBRI app

Cosmic Alert Targets

Visibility note: If your observing location's *latitude* is within +/- 70 degrees of the target's "Dec" value (its first number), then the target is likely visible to you. The closer your latitude is to the Dec, the higher in the sky the target will rise for you. We will be adding maps soon to make determining visibility easier.

Finder images have been temporarily removed. If you use the deeplink or RA & Dec coordinates from the table below, there is no need to check your field of view.

Highest priority targets are those with the most recent "Discovered" date. But we still want to collect observations for all targets in this table.

Link	Name	Class	Discovered ^{UTC}	V mag	Ra	Dec	Exp.	Cad.	Gain	Duration
	SN2023rve	SN	Sep 8	13	02h 46m 18s	-30° 14' 22"	3970	3970	30	600
	ZTF23abaaghg	SN	Aug 27	16.8	19h 42m 32s	-18° 38' 40"	3970	3970	30	1800
	ZTF23aawcybl	SN	Aug 6	16.5	13h 02m 26s	+52° 12' 30"	3970	3970	30	1800
					17h 52m 49s	-20° 24' 15"	3970	3970	29	600
							3970	3970	4	600
							3970	3970	30	1200
							3970	3970	18	1200

AstroBot APP 22:49
NEW COSMIC ALERT FOUND

[CLICK TO OBSERVE](#)

Target: ZTF23abaaghg (SN)
Visibility: Both Hemispheres (Declination -19°)
Constellation: Sagittarius
Visual Magnitude: 16.8
Deeplink to observe (tap & hold to copy)

For observing details go to the [Cosmic Alerts webpage](#).

Get target details and FOV [here](#) from ALeRCE ZTF.
@Tom Esposito [Lead Transients Astronomer]

1
7 replies Last reply 1 month ago

Source info

Selected: ZTF23abaaghg

Time: 2023-08-27 05:49:05
RA/Dec: 295.63° / -18.64°
RA/Dec: 19h42m31.98s / -18d38m39.51s
E(B-V): 0.11 mag

[Search for ATels!](#)

observatory: ZTF

Photometry:
first: 16.80 mag (gZTF; 2023-08-27 05:02:37)

[show visibility](#)

Links to other websites and services:

[ALADIN](#) [ESASky](#)

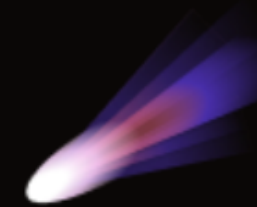
Astro-COLIBRI app

Unistellar Slack

Scientific observa...

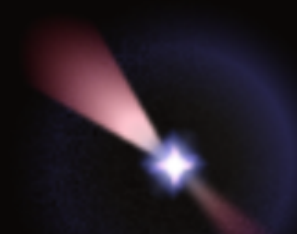
Cometary activity

Monitor the evolution of comets as they approach and recede from the sun (10-30min).



Cosmic cataclysms

Detect and study luminous phenomena like supernovae just a few minutes after they appear (5 to 20 minutes).



Unistellar app



Catalog



Science



Gallery

Observations are conducted with a dedicated app component & a "one-tap" deeplink

Images are uploaded via app+WiFi to Unistellar cloud storage & the SETI cloud pipeline posts a result within ~24 hours

UNISTELLAR

Cosmic Cataclysms Detected



Supernova SN2023ixf

On the night of September 26th to 27th, 2023

Event

Target type
Supernova
Discovery date
2023/05/22

Measured magnitude (V)
14.3 +/- 0.1

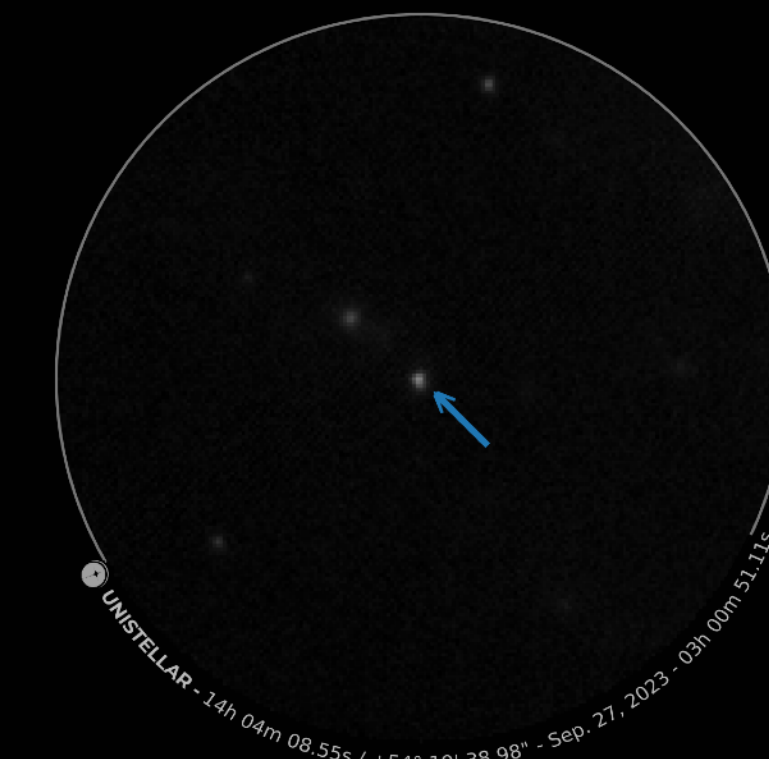
Citizen Scientist

Name
Sophie Saibi
Location
US, California

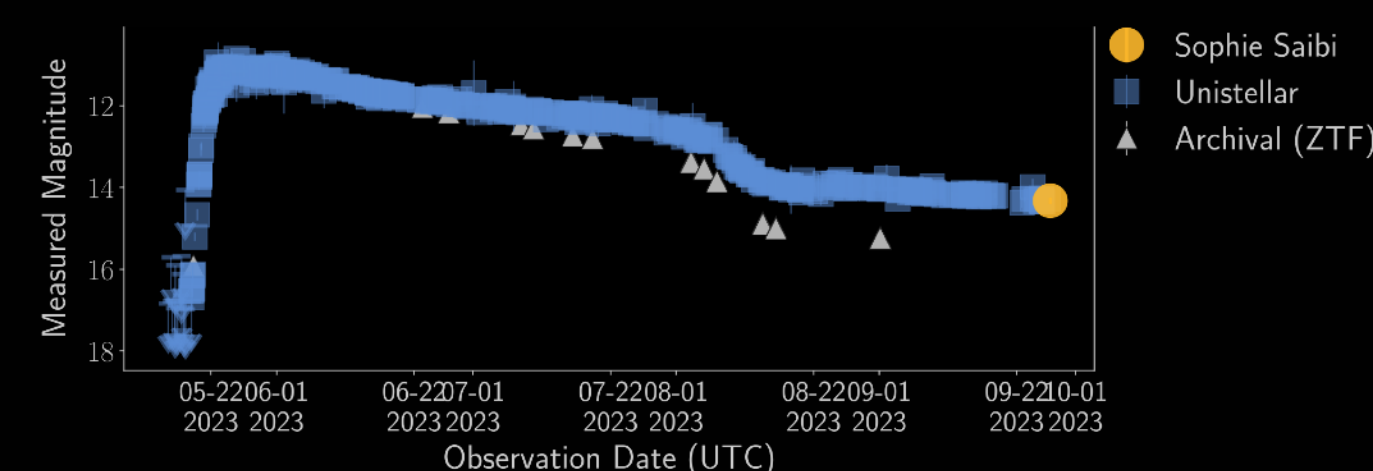
Observations

Start time (UT)
02:50:55.6
Duration
20 min

Exposure time
3.97 s
Gain
11 dB

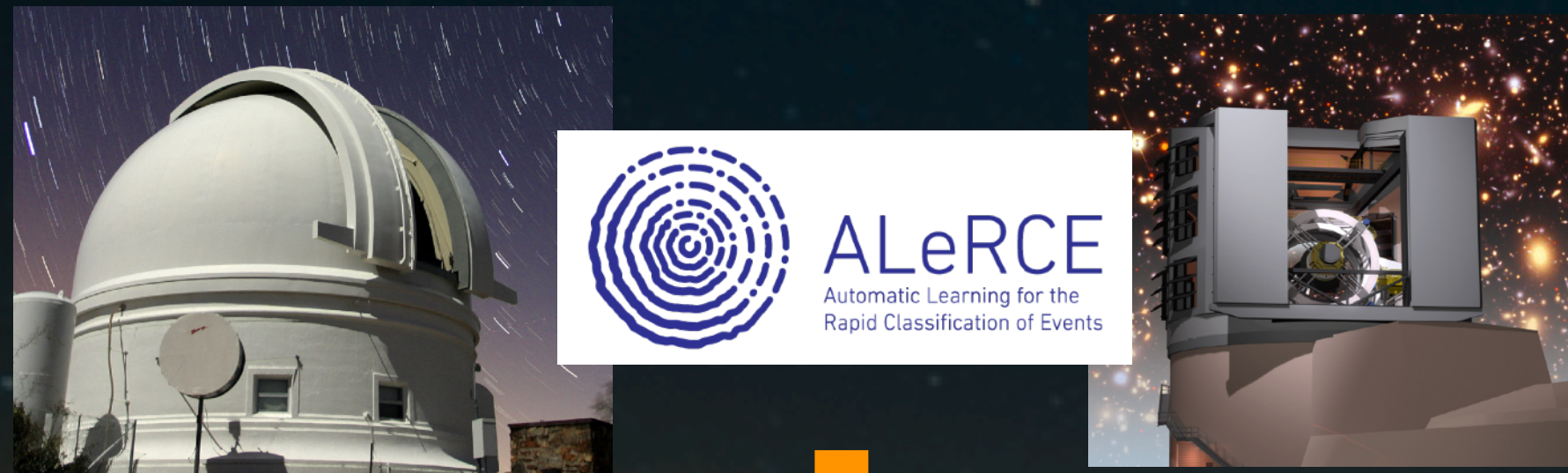


Light Curve



Unistellar Alerts System select targets automatically every "night"

1. Fetch target candidates from survey telescopes + brokers every ~1 minute



alerts.unistellaroptycs.com

3. Alert Unistellar observers: Web, Slack, Astro-COLIBRI app

Cosmic Alert Targets										
Link	Name	Class	Discovered ^{UTC}	V mag	Ra	Dec	Exp.	Cad.	Gain	Duration
	SN2023rve	SN	Sep 8	13	02h 46m 18s	-30° 14' 22"	3970	3970	30	600
	ZTF23abaaghg	SN	Aug 27	16.8	19h 42m 32s	-18° 38' 40"	3970	3970	30	1800
	ZTF23aawcybl	SN	Aug 6	16.5	13h 02m 26s	+52° 12' 30"	3970	3970	30	1800
	V6598 Sgr	CV	Jul 15	12.5	17h 52m 49s	-20° 24' 15"	3970	3970	29	600
	T CrB	CV	Jul 14	9.5	15h 59m 30s	+25° 55' 13"	3970	3970	4	600

2. Filter targets to find those appropriate for eVscopes

- $V < 16.8$ mag
- SN prob $> 30\%$
- No bright sources within $8''$

```

2023-08-27 05:48:53:INFO: 11 alerts found since UTC 2023-08-26 23:34:29.142
2023-08-27 05:48:53:INFO:
Last poll: UTC 2023-08-27 05:48:53.235
2023-08-27 05:48:53:INFO:
oid ndethist ndet class classifier probability
0 ZTF18aawzdzt 3 1 SN stamp_classifier 0.745087
1 ZTF23abaaifss 6 1 SN stamp_classifier 0.663782
2 ZTF23abaadsl 1 1 SN stamp_classifier 0.587291
3 ZTF23abaahf 31 1 SN stamp_classifier 0.504856
4 ZTF23abaachl 1 1 SN stamp_classifier 0.489494
5 ZTF23abaaghg 1 1 SN stamp_classifier 0.476087
6 ZTF23abaaggs 5 1 SN stamp_classifier 0.469303
7 ZTF23aazzyw 1 1 SN stamp_classifier 0.439752
8 ZTF23abaaifpp 4 1 SN stamp_classifier 0.381700
9 ZTF23aazzyjm 1 1 SN stamp_classifier 0.380367
10 ZTF23aazzymp 7 1 SN stamp_classifier 0.379641
2023-08-27 05:48:53:INFO: 11 alerts remaining with class probability >= 0.35
2023-08-27 05:48:56:INFO: Rejected ZTF23abaadsl for bright source too close (0.8 arcsec)
2023-08-27 05:49:00:INFO: Rejected ZTF23abaaggs for bright source too close (0.2 arcsec)
2023-08-27 05:49:04:INFO:
0 of 11 alerts removed because already existing campaign targets: []
2023-08-27 05:49:04:INFO: 10 of 11 remaining alerts removed for magnitude > 16.8
2023-08-27 05:49:04:INFO: 2 of 1 remaining alerts removed for nearby source (likely false alarm)
2023-08-27 05:49:04:INFO: 1 alerts remain after filtering
2023-08-27 05:49:04:INFO:
oid ndet magMax magMax_method magMax_filter
nearestSep_arcsec
5 ZTF23abaaghg 1 16.788996 magpsf_corr g NaN
2023-08-27 05:49:04:INFO: **** NEW ALERT(S) SELECTED ****
2023-08-27 05:49:04:INFO: |
2023-08-27 05:49:05:INFO: Posted alert to Slack
2023-08-27 05:49:06:INFO: Pushed App notifications to: ['colibri']
    
```

NEW COSMIC ALERT FOUND

Target: ZTF23abaaghg (SN)
 Visibility: Both Hemispheres (Declination -19°)
 Constellation: Sagittarius
 Visual Magnitude: 16.8

CLICK TO OBSERVE

Source info:
 Selected: ZTF23abaaghg
 Time: 2023-08-27 05:49:05
 RA/Dec: 295.63° / -18.64°
 RA/Dec: 19h42m31.98s / -18d38m39.51s
 E(B-V): 0.11 mag

From ID to observer in ~2 minutes

4. Collect data!



Alerts System now testing GW, GRB, Neutrino sources

1. Fetch target candidates from Kilonova Catcher every ~1 minute

Work by Amaury Perrocheau



3. Alert Unistellar observers: Web, Slack, Astro-COLIBRI app

Cosmic Alert Targets												
Link	Name	Class	Discovered ^{UTC}	V mag	Ra	Dec	Exp.	Cad.	Gain	Duration		
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	ZTF23aawcybl	SN	Aug 6	16.5	13h 02m 26s	+52° 12' 30"	3970	3970	30	1800		
	V6598 Sgr	CV	Jul 15	12.5	17h 52m 49s	-20° 24' 15"	3970	3970	29	600		
							59m 30s	+25° 55' 13"	3970	3970	4	600
							41m 09s	+30° 01' 30"	3970	3970	30	1200
							03m 39s	+54° 18' 42"	3970	3970	18	1200

alerts.unistellaroptycs.com

AstroBot APP 14 hours ago
 ✨ **NEW COSMIC ALERT FOUND** ✨

[CLICK TO OBSERVE](#)

Target: S231113bw GW
 Visibility: Northern Hemisphere (Declination 46°)
 Constellation: Boötes
 Observation needed: 20+
[Deeplink to observe](#) (tap & hold to copy)

For observing details go to the [Cosmic Alerts webpage](#).

20 replies

AstroBot APP 14 hours ago
 Observation priority n° 1 : [unistellar://science/transient?ra=235.1273885350318&dec=45.88257172940262&c=3970&et=3970&g=30&d=120&t=1699833600000&scitag=t231113S231113bw](#)

AstroBot APP 14 hours ago
 Observation priority n° 2 : [unistellar://science/transient?ra=234.3440552016985&dec=44.74923839606928&c=3970&et=3970&g=30&d=120&t=1699833600000&scitag=t231113S231113bw](#)

AstroBot APP 14 hours ago
 Observation priority n° 3 : [unistellar://science/transient?ra=235.9107218683651&dec=47.01590506273596&c=3970&et=3970&g=30&d=120&t=1699833600000&scitag=t231113S231113bw](#)

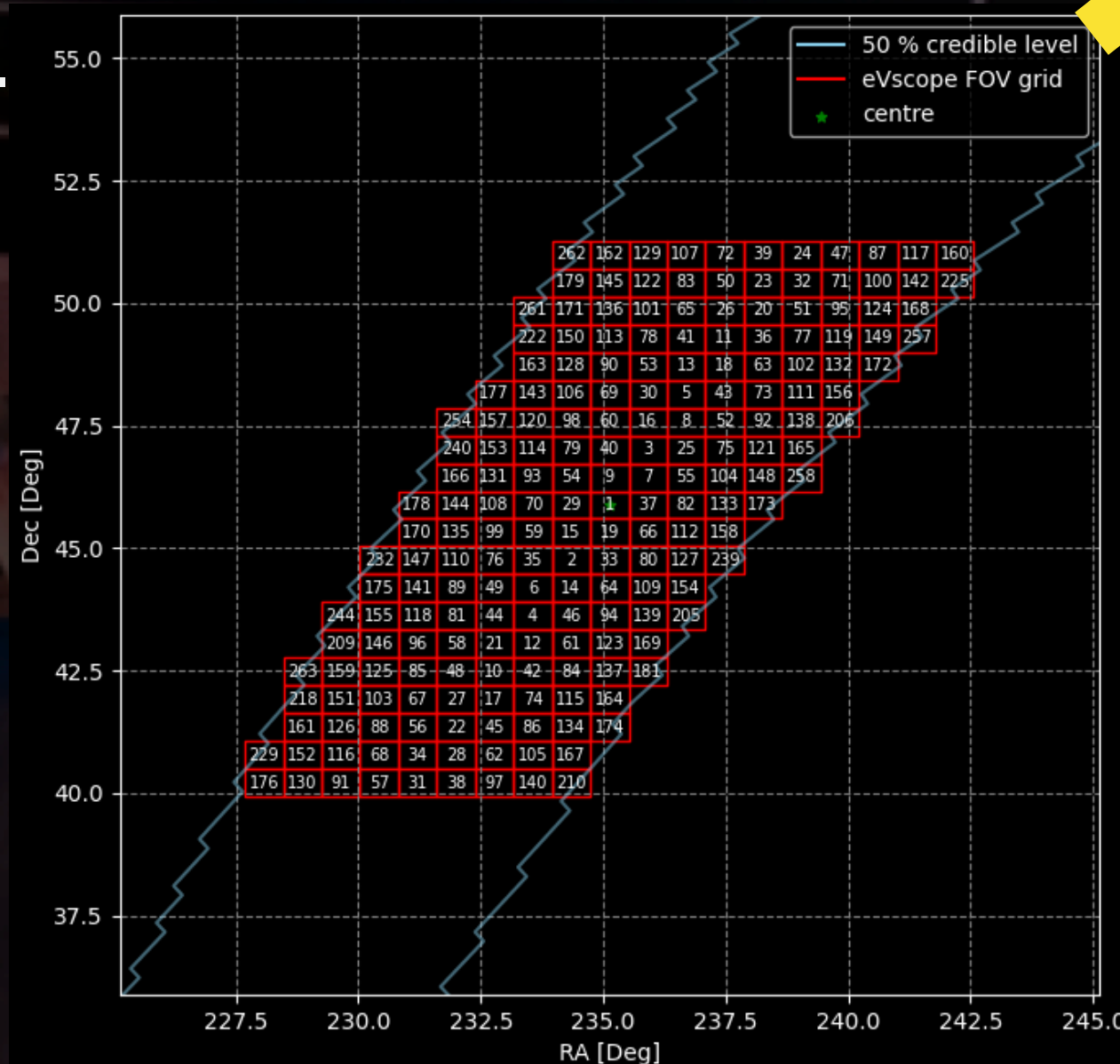
+ new interactive interface for users to report fields they've observed?



4. Collect data!

From ID to observer in ~2 minutes

- Favor nearby, BNS sources
- Known galaxies



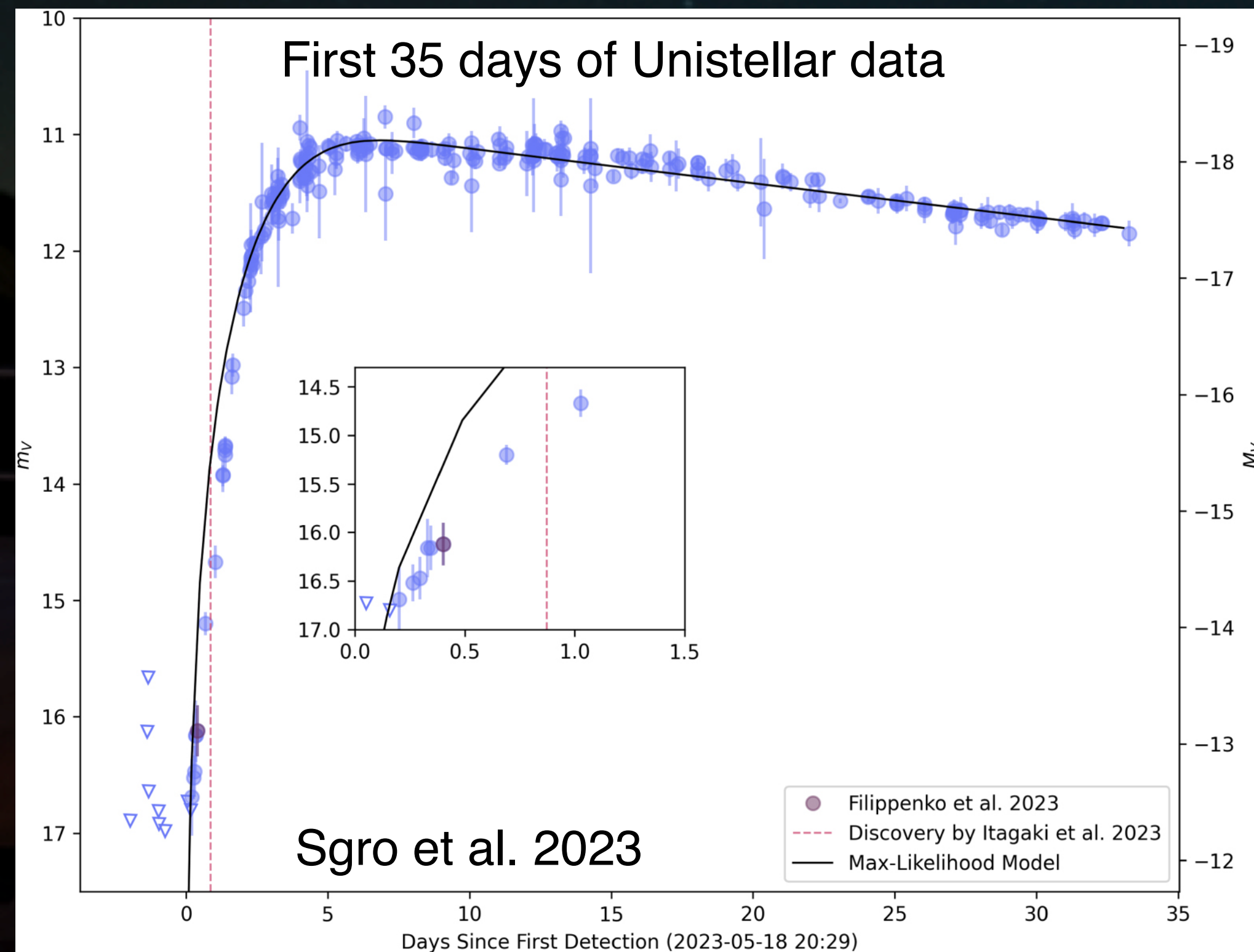
2. Filter targets to find those appropriate for eVscopes. Prioritize search fields.



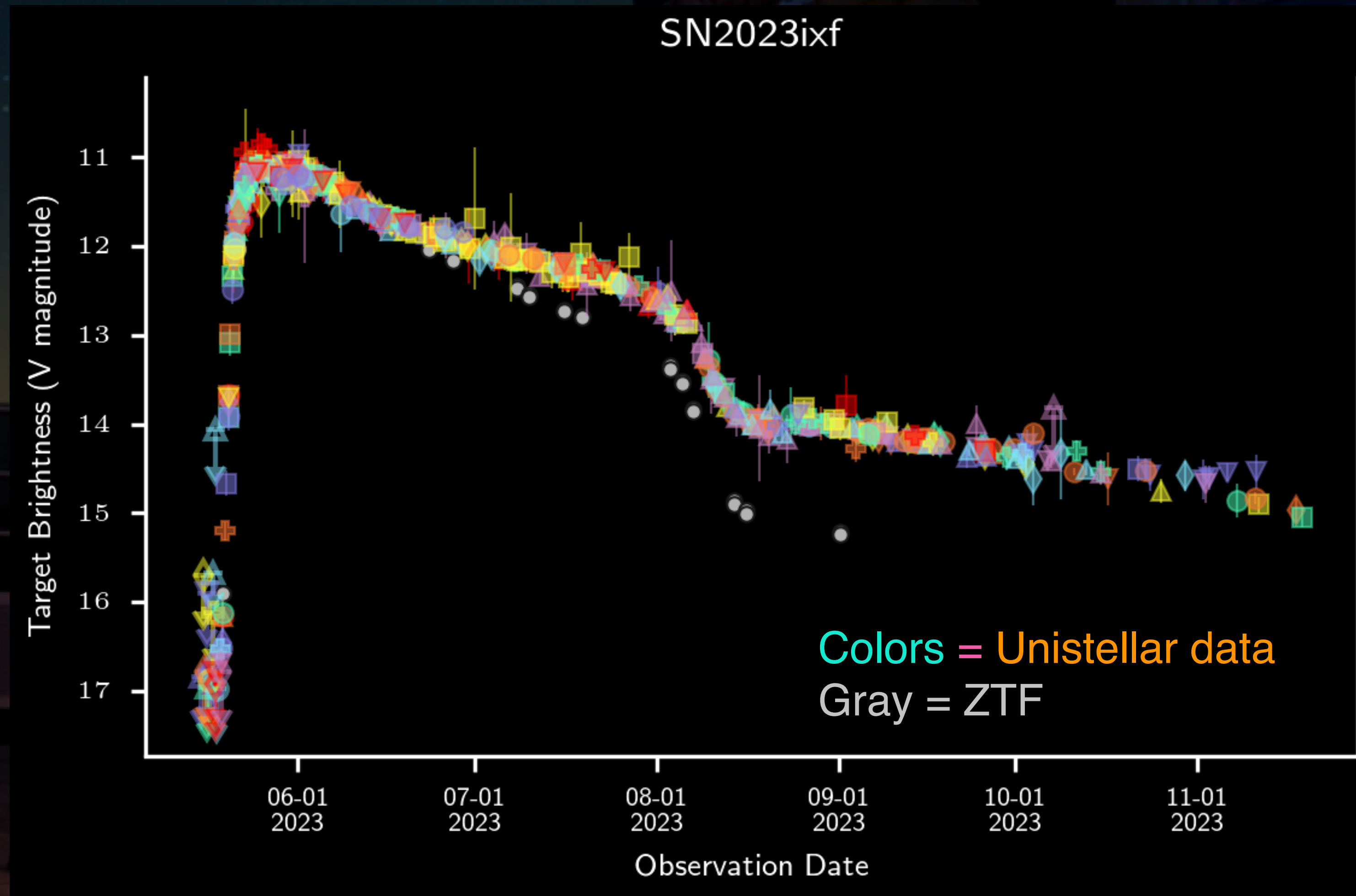
Unistellar Network Results: Type II supernova SN 2023ixf from start to finish

- Earliest detection was 4.8 hr after absolute earliest known and 16.2 hr before discovery
- Averaged 3.3 hr sampling rate

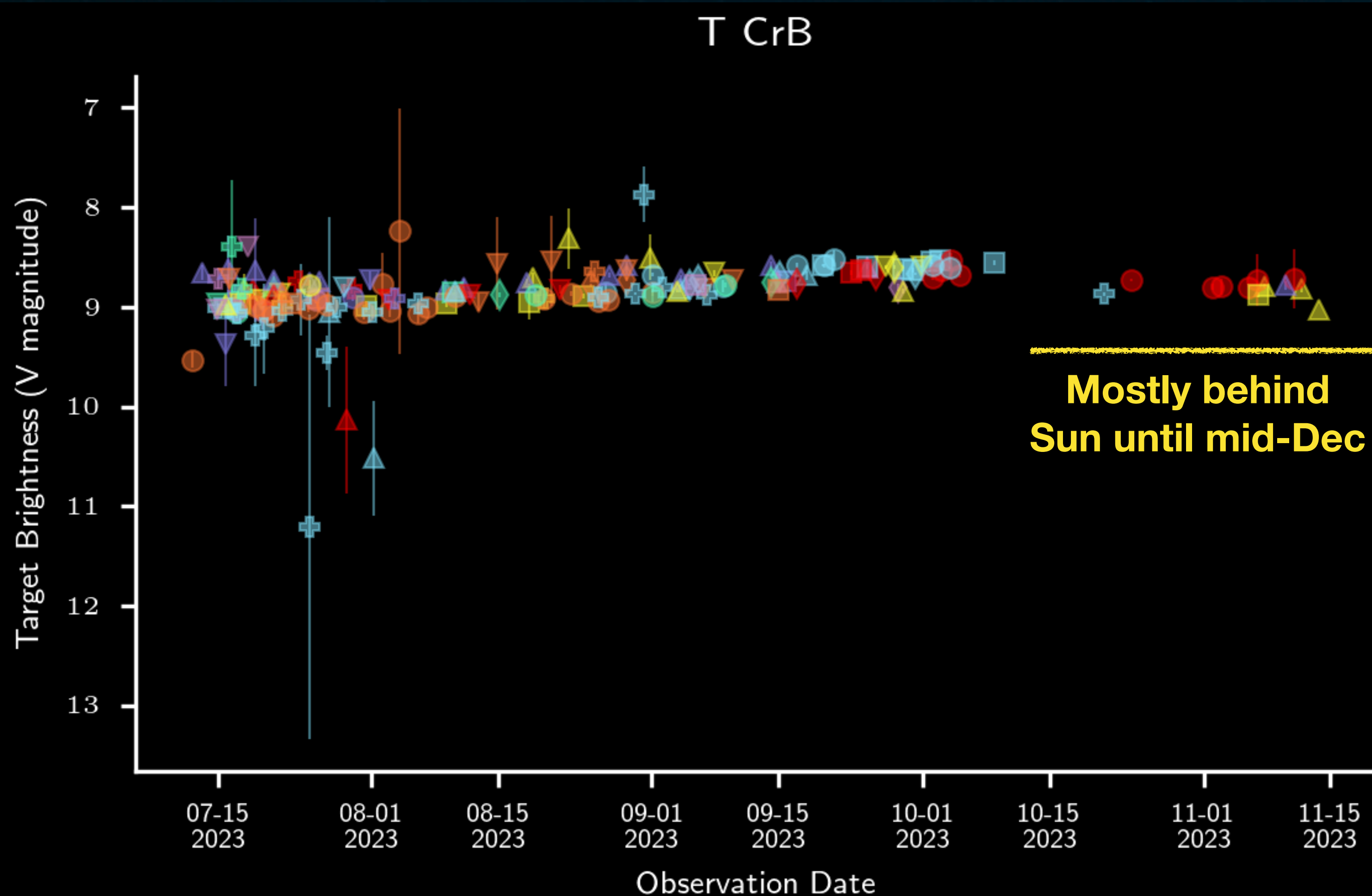
502 V-band magnitudes since 16 May



Fit for peak time (± 1 hr) and magnitude



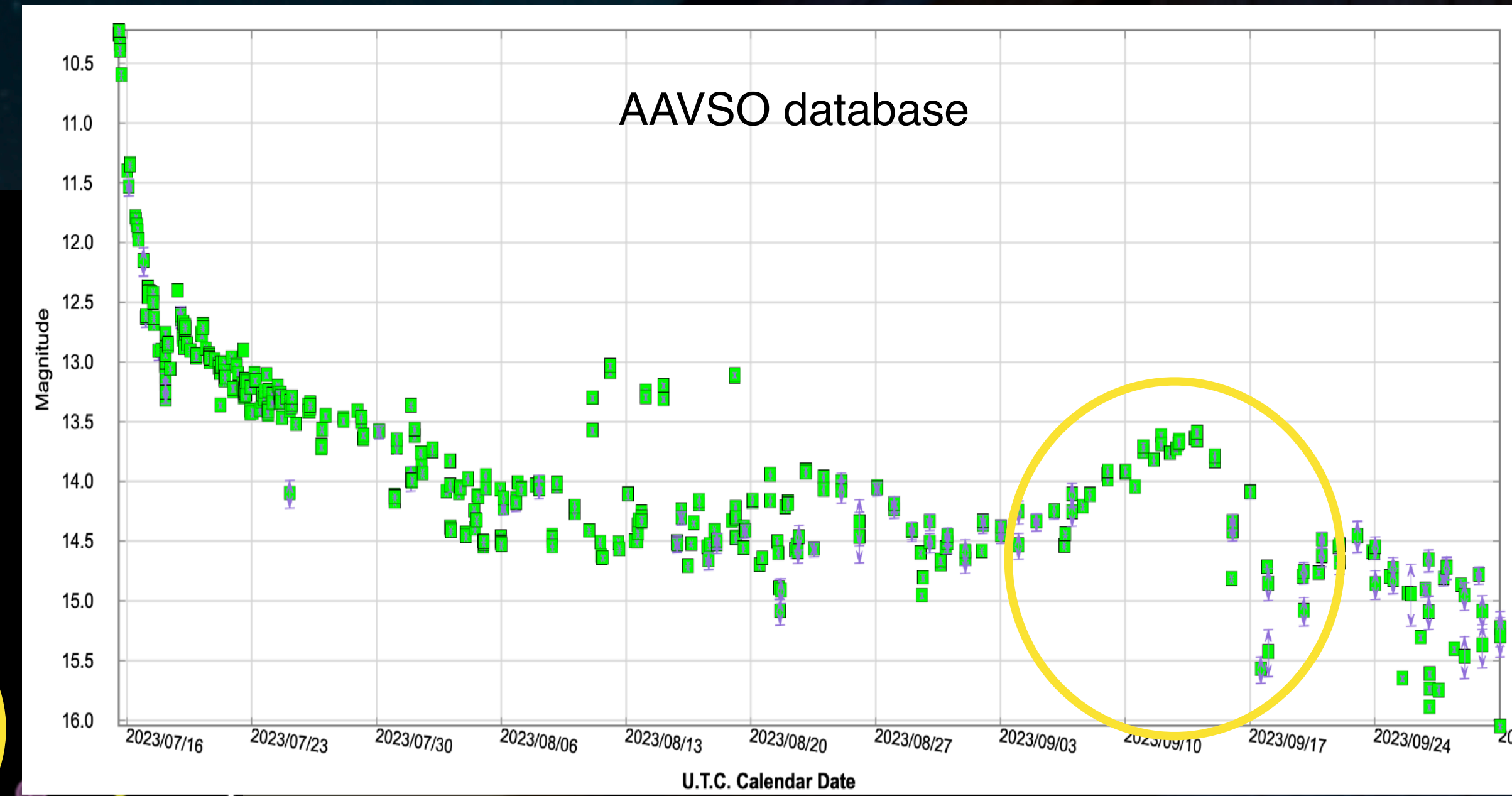
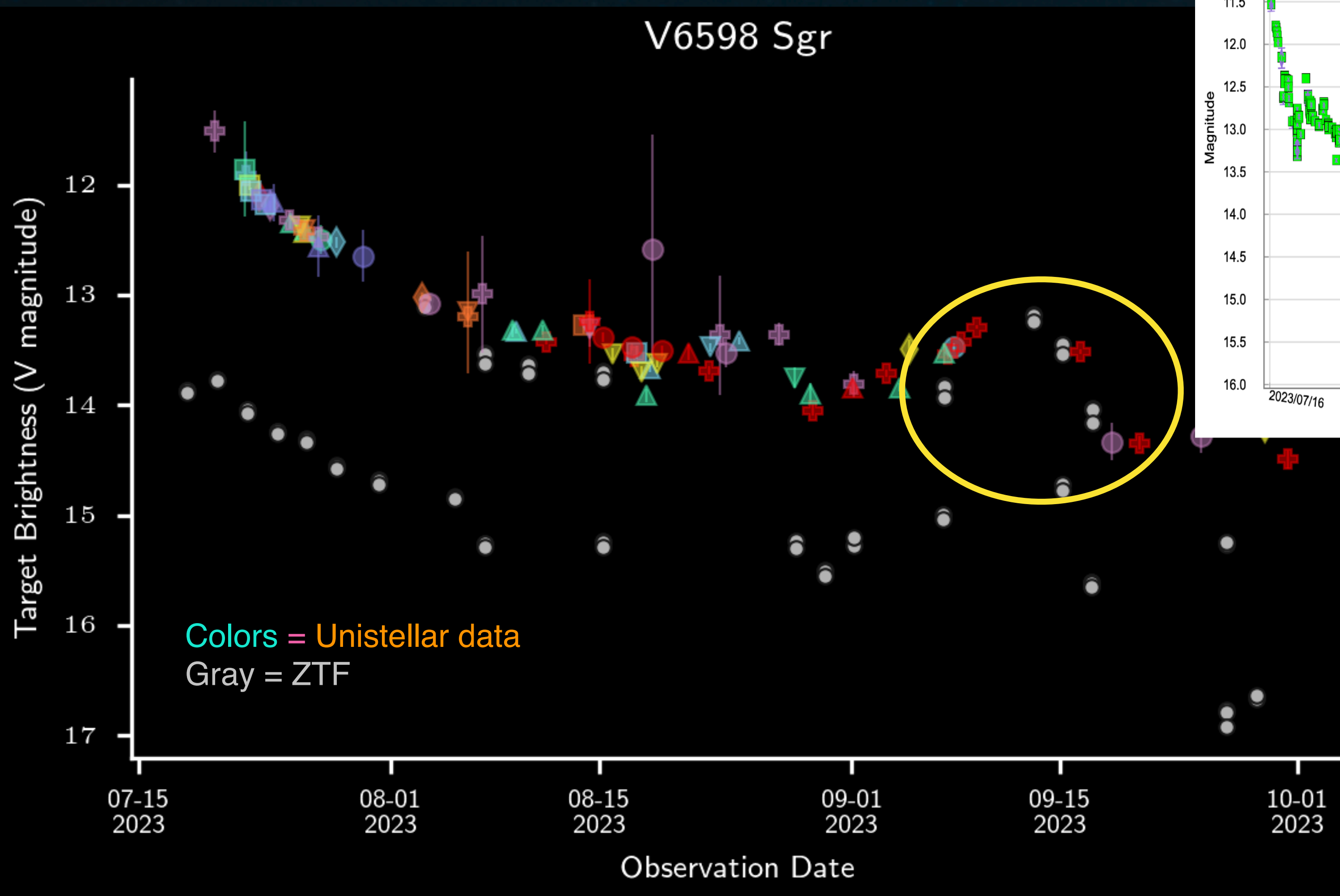
Unistellar Network Results: Watching for nova T CrB's next eruption



- Recurrent nova with ~ 80 yr period
- May be brightest nova in living memory (peak $V \sim 2.0$)
- Predictions for the next eruption date include 2024.4 ± 0.3 (Schaefer 2023) and as early as 2024.1 (Maslennikova et al. 2023)
- We plan to regularly monitor variability and then catch the start of the eruption
- 164 observations since 14 July

Target recommended to us by Unistellar citizen scientist and professional astronomer Stephen Lawrence (Hofstra U.)

Unistellar Network Results: Cataclysmic Variable V6598 Sgr monitoring



Unistellar Network Results: SN 2023wrk rise

ETI INSTITUTE
Cosmic Cataclysms **Detected**

UNISTELLAR



Supernova SN2023wrk

On the night of November 18th to 19th, 2023

Event

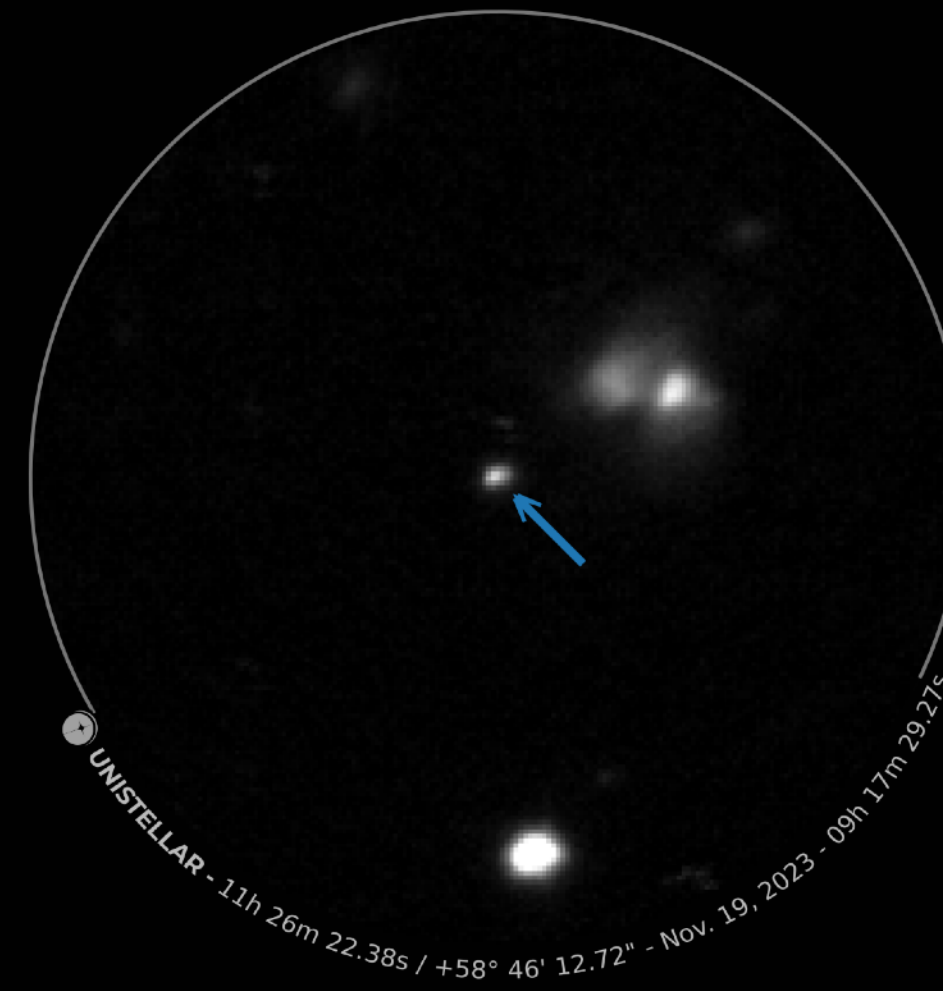
Target type
Supernova
Discovery date
2023/11/05
Measured magnitude (V)
14.1 +/- 0.1

Citizen Scientist

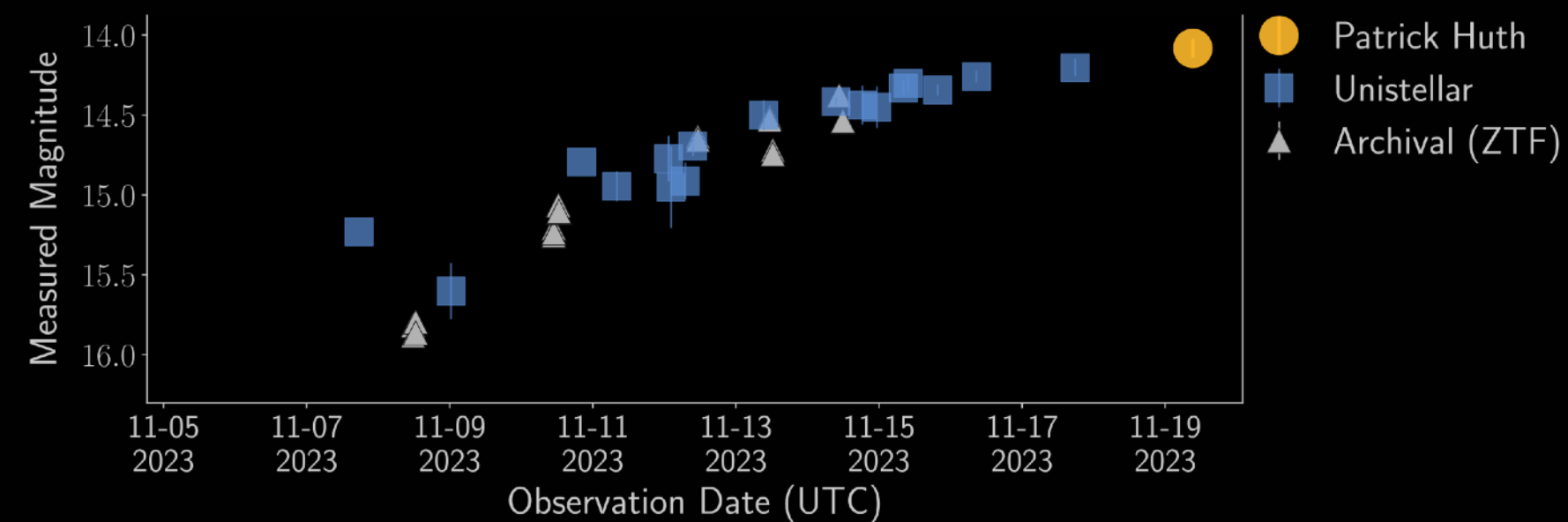
Name
Patrick Huth
Location
US, Pennsylvania

Observations

Start time (UT)
09:07:33.8
Duration
20 min
Exposure time
3.97 s
Gain
30 dB



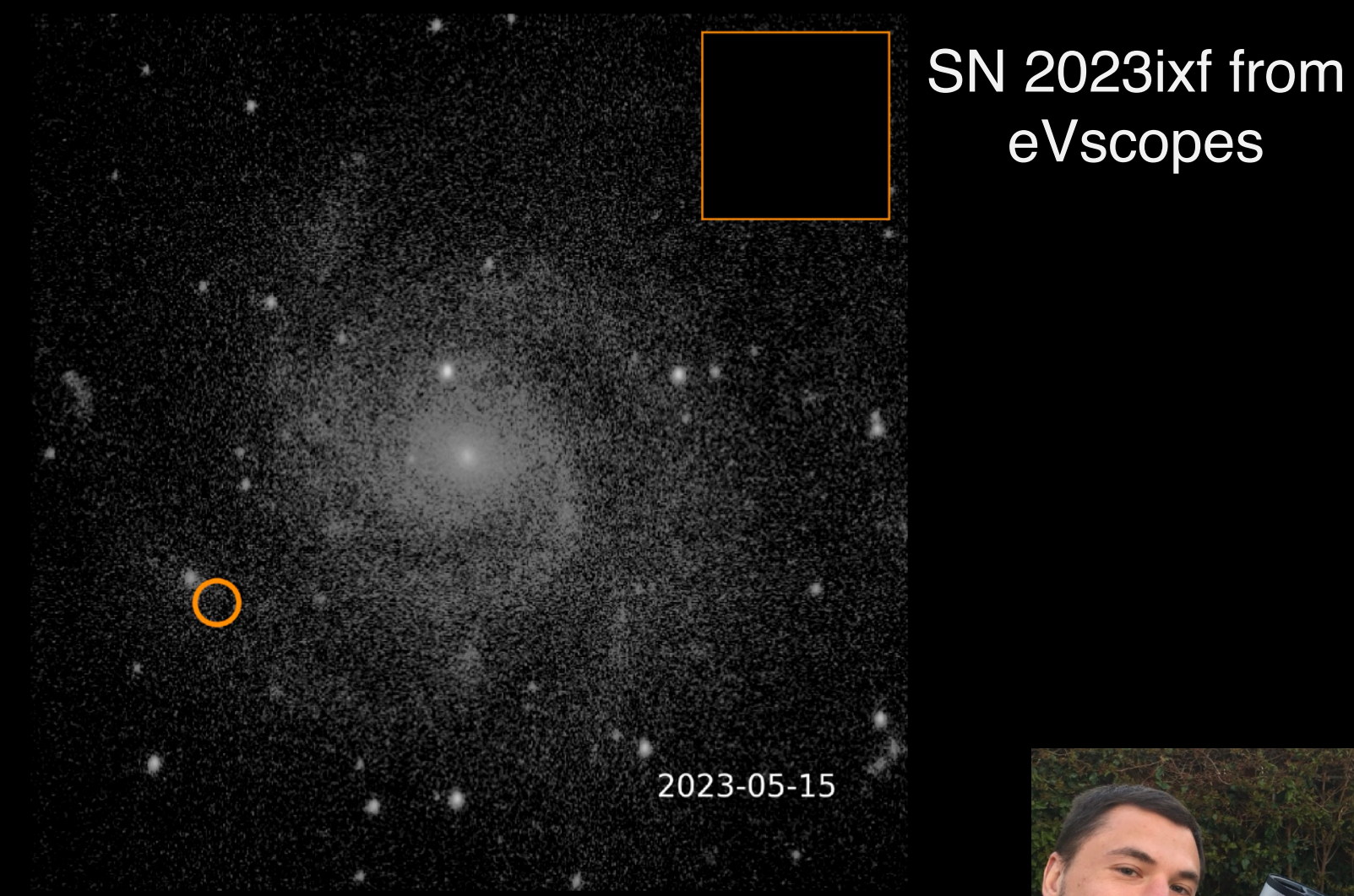
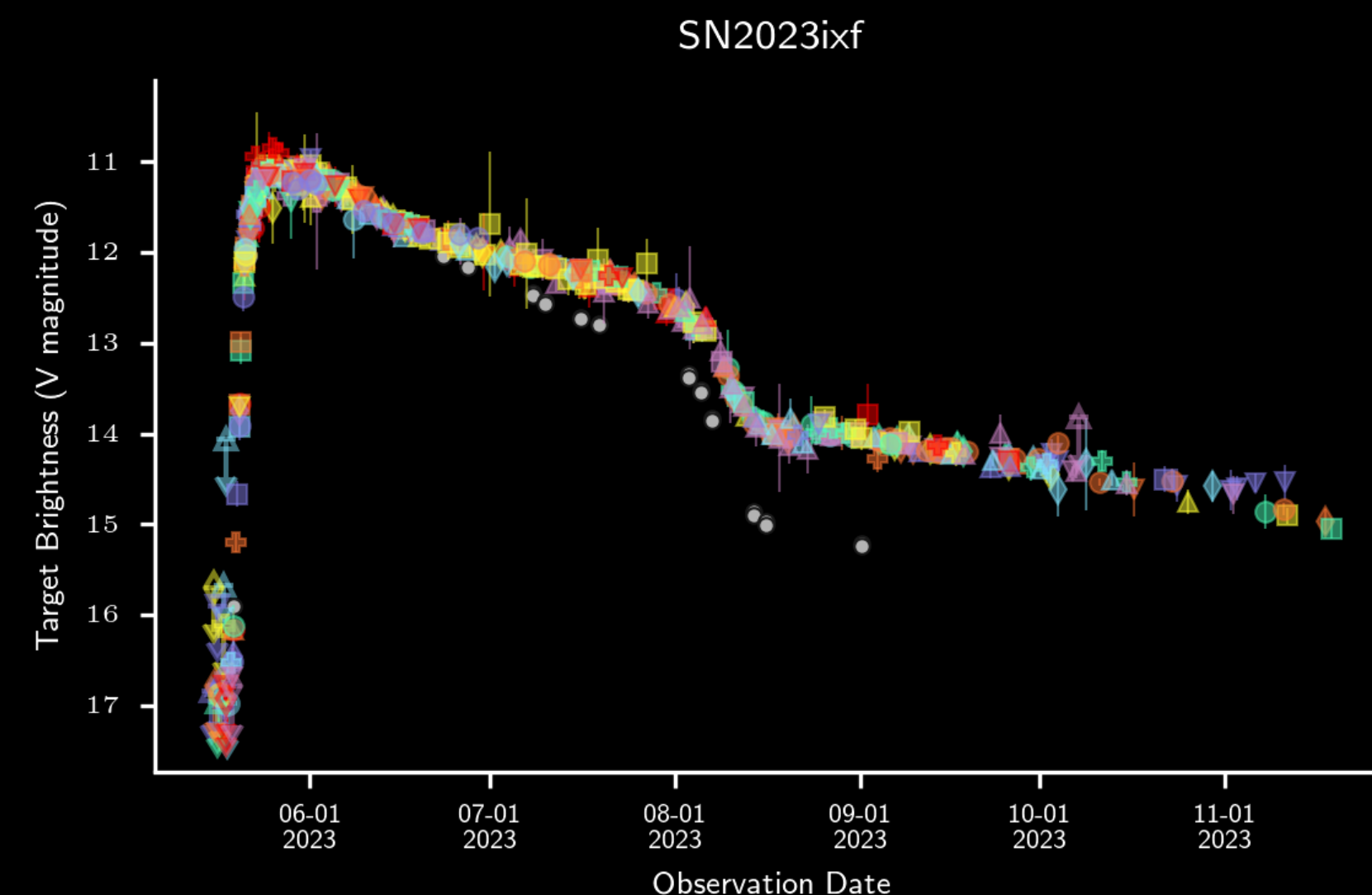
Light Curve



ALeRCE reported it at 16.9 mag -- 0.1 mag below our cutoff -- so we added this target manually

Unistellar Network for Rapid Photometric Follow-up of Transients

- Real-time alerts (~2 minutes) for ZTF (& next LSST)
 - Website, Slack, Astro-COLIBRI
 - alerts.unistellaroptycs.com
- 1,630 transient observations in 2023 from 180 citizen scientist observers worldwide
- Automatic results processed within 24 hours of data upload (~10–20 minutes per data set)
- Light curves for SN 2023ixf, 2023wrk, novae T CrB and V6598 Sgr, and 46 other transient candidates
- Coming soon:
 - More alert sources: GW, gamma-rays, neutrinos
 - Photometry (incl. multi-color) into public databases
 - **YOUR IDEA HERE!**



Astro-COLIBRI Multi-Messenger
Astrophysics Workshop
21 November 2023



Tom Esposito
tesposito@seti.org

