



The Gravitational-wave Optical Transient Observer (GOTO)

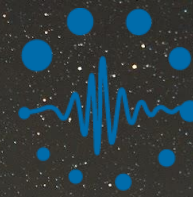
Joe Lyman
University of Warwick

on behalf of the GOTO collaboration
4th Astro-COLIBRI workshop

**UNIVERSITY
OF WARWICK**



**UK Research
and Innovation**



GOTO

GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER



PI: Danny Steeghs (Warwick)

B. Godson



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OF WARWICK**



**University of
Sheffield**



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OF TURKU**



**UNIVERSITY OF
PORTSMOUTH**



**UNIVERSITY OF
BIRMINGHAM**



**MONASH
University**



**ARMAGH
OBSERVATORY &
PLANETARIUM**
EXPLORING THE COSMOS SINCE 1790



**UNIVERSITY OF
LEICESTER**



**MANCHESTER
1824**
The University of Manchester



**Science and
Technology
Facilities Council**

Science motivation

The Dynamic and multi-messenger Universe



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Photons

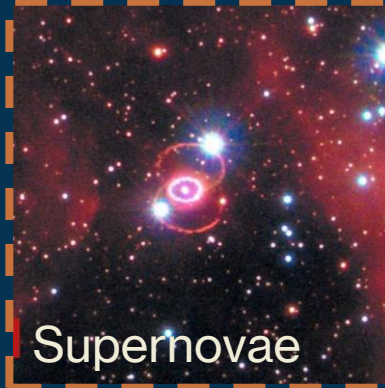
Cosmic rays

Neutrinos

Gravitational waves



GRBs



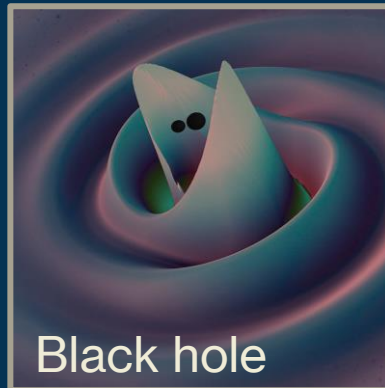
Supernovae



AGN



Neutron star



Black hole

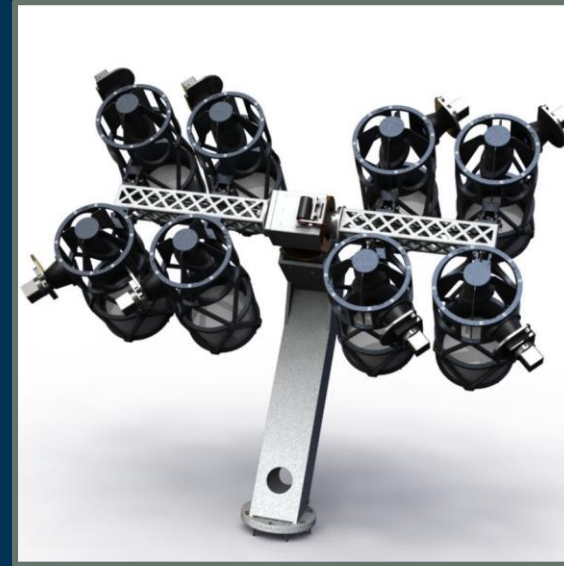


SMBH

Design specification

Multi-site optical wide-field sky survey

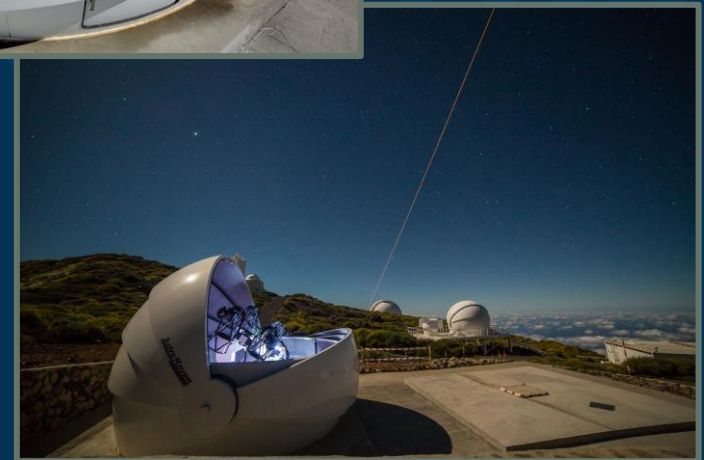
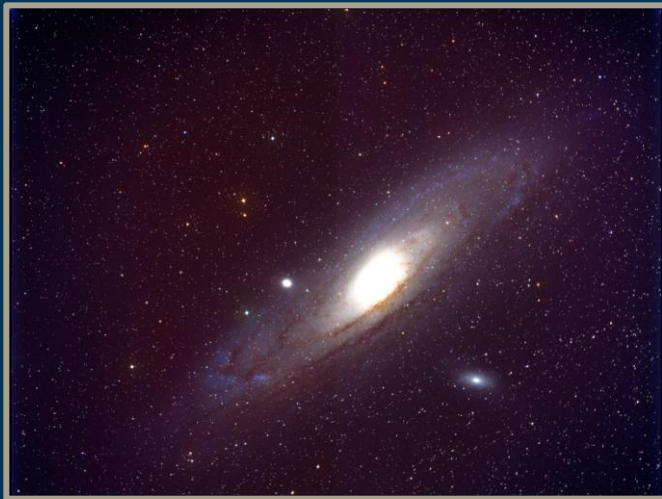
- First proposed in 2014: a **dedicated** facility for the **EM follow-up of GW alerts**.
- Focus on **rapid response**, **wide-field** and **autonomous** control systems and analysis pipelines.
- Multiple unit-telescopes (UTs) and mounts for a modular observatory: **staged deployment**, **scaling** and **adaptability**



Prototype system

2017-2020 (Steeeghs et al. 2022)

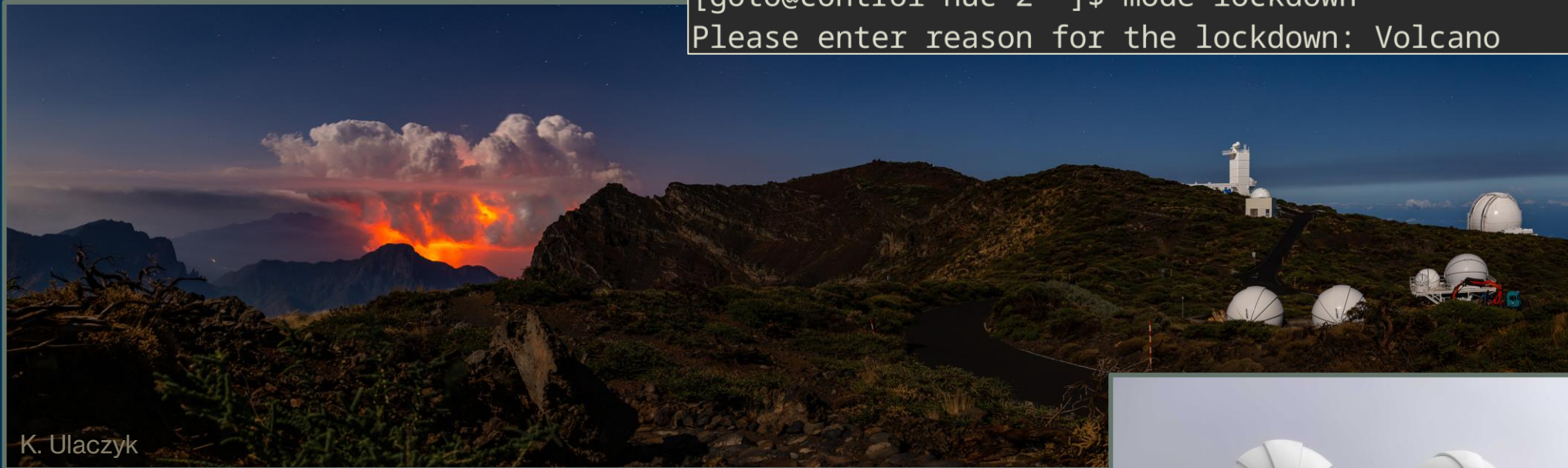
- **Four UTs**, one mount on **La Palma**
 - 40cm aperture, ~5.5 sq. deg. FoV per UT
- Expanded to include different OTA designs during commissioning to inform final design



Development

2020-2023

```
[goto@control-nuc-2 ~]$ mode lockdown  
Please enter reason for the lockdown: Volcano
```



- ☒ Pandemic
- ☒ Volcano
- ☒ Hail/Ice
- ☐ Locusts



Full Design

2023- (Steeghs et al. in prep.)

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- **Four mounts**, each holding **8 UTs**
- **Two nodes**, one in La Palma, one in Siding Spring
- **Improved OTA** and mount design
- Wide optical filter **L** (400-700nm)
- Fully **autonomous** scheduling and **real-time** pipeline



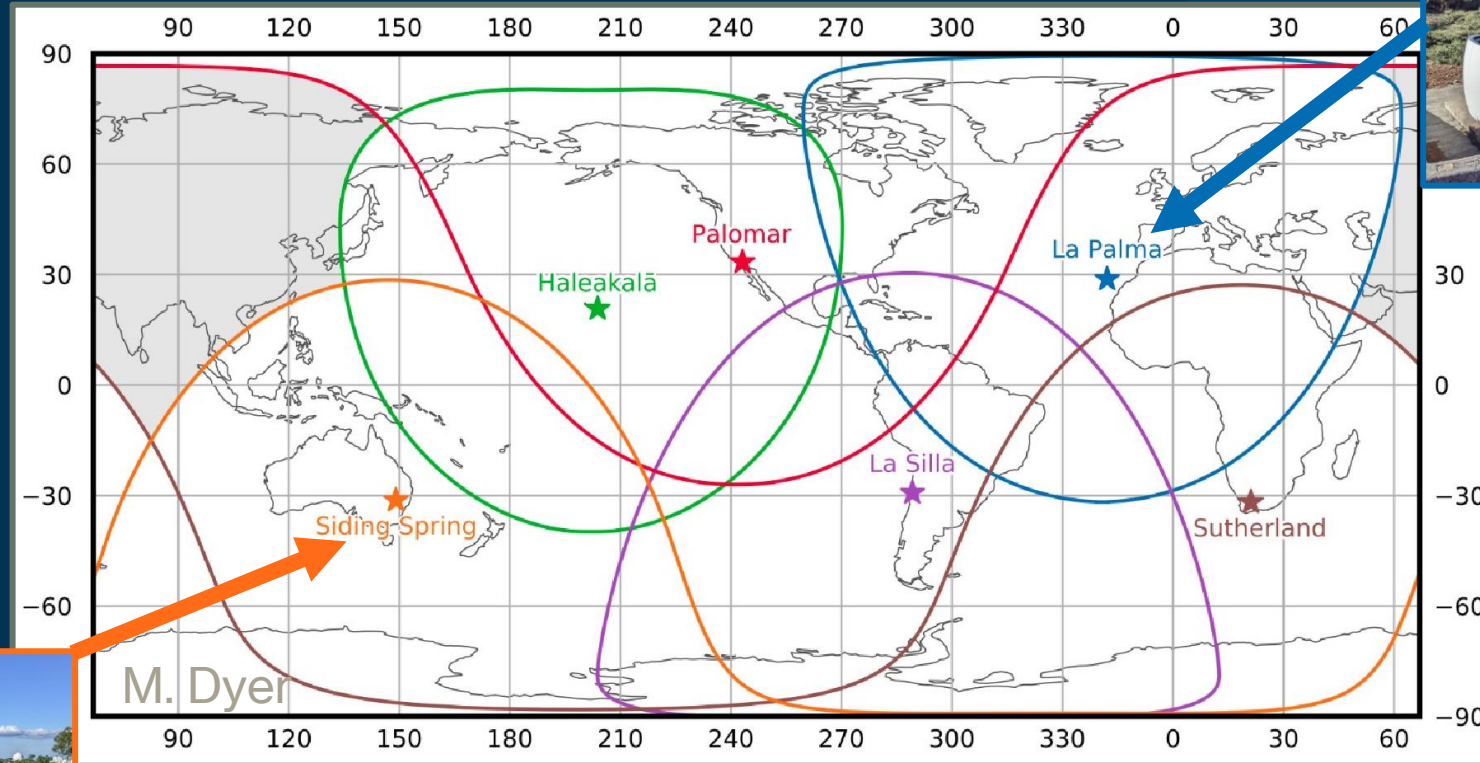
Full Design

2023- (Steeghs et al. in prep.)



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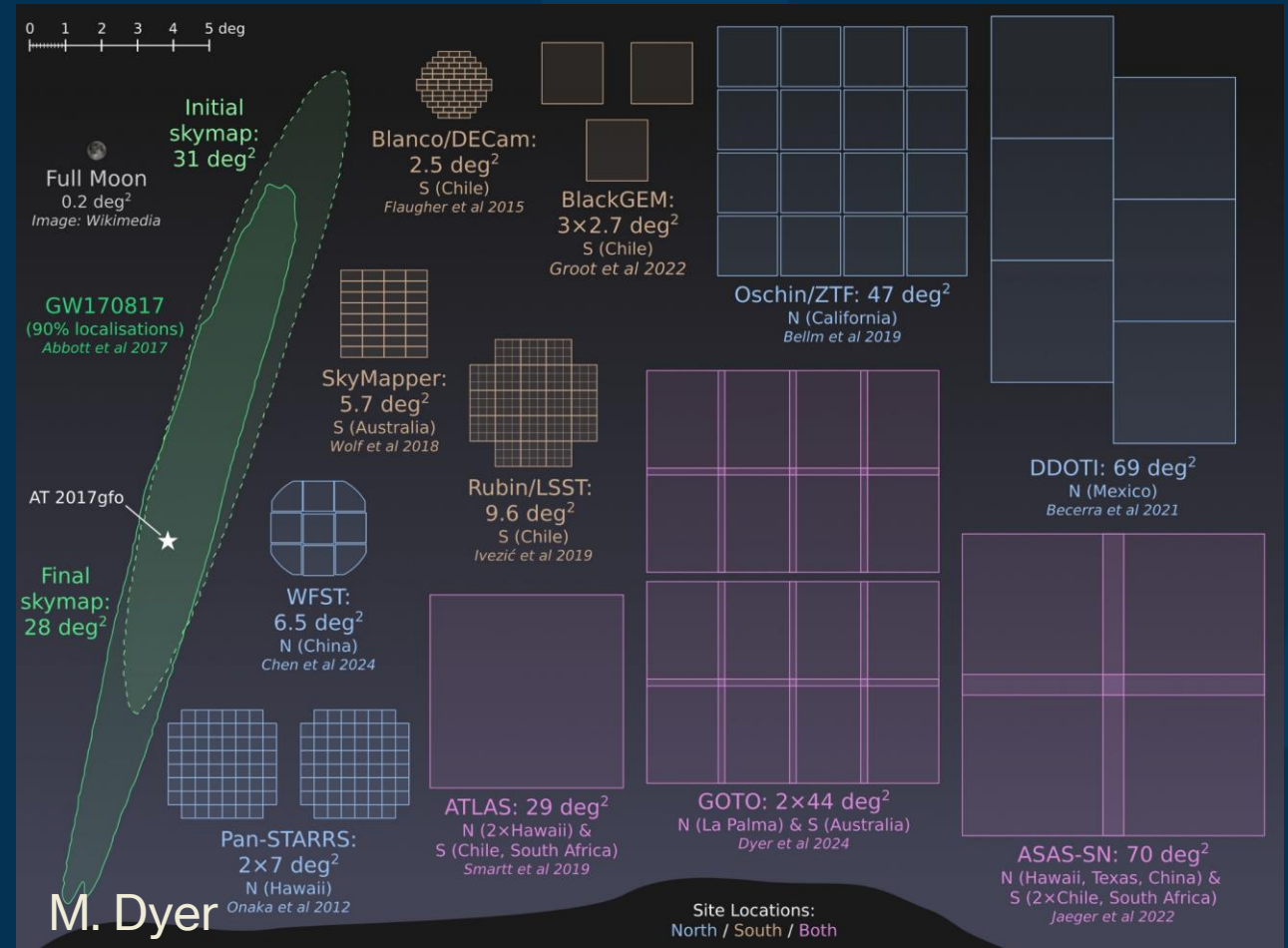
GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER



Full Design

2023- (Steeghs et al. in prep.)


- **All-sky survey** with ~2d cadence on average
- Large areas of much higher cadence (**~hours**) when responding to triggers



Control and Scheduling

G-TeCS (Dyer et al. 2018, 2020, 2024)

- All four mounts **fully autonomous and independent**
- **Automated processing** and classification of external alerts (GRB, GW, neutrino)
- **One central scheduler** responsible for enacting follow-up strategies and all-sky survey

 **GOTO-2** APP 6:41 PM
GOTO-2: Pilot reports startup complete


Conditions are good
age ✓ - dew_point ✓ - diskspace ✓ - humidity ✓ - ice ✓ - internal ✓ - link ✓
- override ✓ - rain ✓ - sky_temp ✓ - temperature ✓ - ups ✓ - windgust ✓ -
windspeed ✓
Today at 6:41 PM

System is in robotic mode

Local environment page - Mountain forecast - ING - NOT - TNG

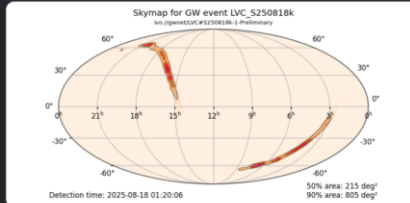
External webcam view
Image attached:

IR satellite view
Image attached:

 **GOTO Status Bot** APP 2:20 AM
LVC notice: [ivo://gwnet/LVC#S250818k-1-Preliminary](https://gwnet/LVC#S250818k-1-Preliminary)
Notice type: PRELIMINARY
Notice time: 2025-08-18 01:20:35.000 (0.0h ago)

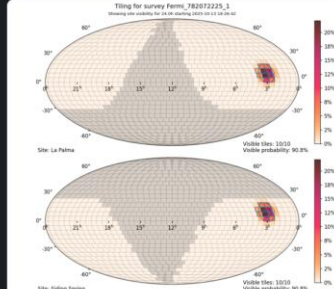
Event: LVC_S250818k
Detection time: 2025-08-18 01:20:06.030 (0.0h ago)
Pipeline: pycbc
Instruments: H1,L1,V1
GraceDB page: <https://gracedb.ligo.org/superevents/S250818k/view/>
FAR: ~2 per year (significant=False)
Group: CBC
Classification: Terrestrial:70.5%, BNS:29.5%
HasNS: 100%
HasRemnant: 100%
GWSkyNet score: 0.9690
Distance: 263+/-75 Mpc
90% probability area: 805 sq deg

Observing strategy: [GW_RANK_3_WIDE](#)
Cadence: 99 observations, delays of 1h/0h/1h/..., valid for 72h
Constraints: alt>30°, sun<-12°, moon≤B, moonsep>10°
Exposure sets: 4x90L
Valid until: 2025-08-21 01:20:46.122
LVC_S250818k_skymap ▼



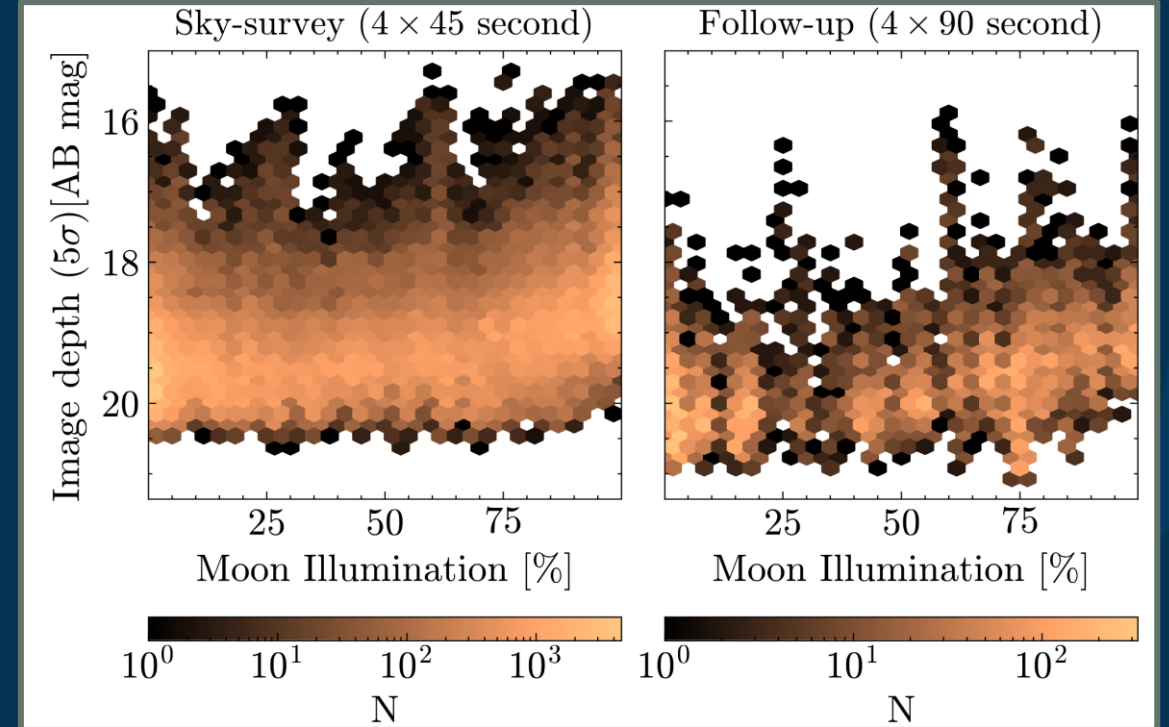
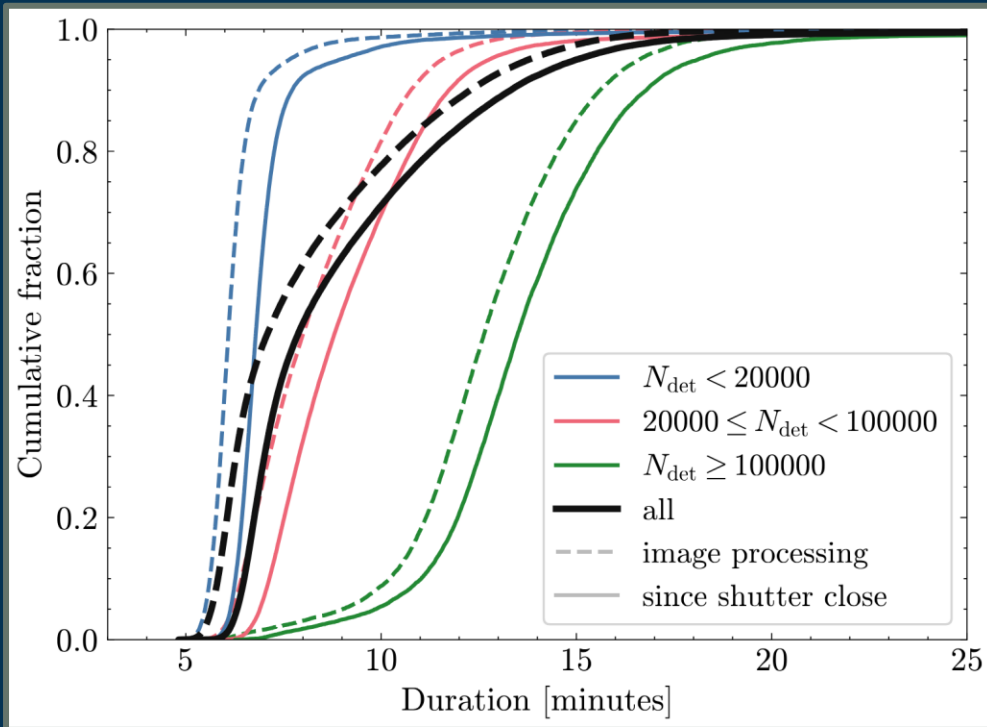
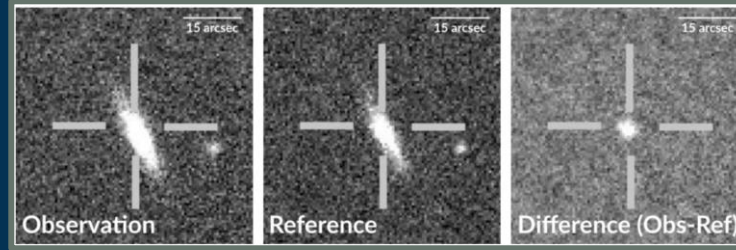
Fermi notice: [ivo://nasa.gsfc.nasa.gov/Fermi#GBM_Fin_Pos2025-10-13T18:17:00.39_782072225_0-501](https://nasa.gsfc.nasa.gov/Fermi#GBM_Fin_Pos2025-10-13T18:17:00.39_782072225_0-501)
Notice added to database (ID=13069)
Notice linked to Event [Fermi_782072225](#) (ID=6325)
- Event is linked to 1 notices and 1 surveys
- Event has 10 scheduled targets
Notice linked to new Survey [Fermi_782072225_1](#) (ID=1834)
- Survey contains 10 targets
Total probability in survey tiles: 90.8%
Predicted visibility from La Palma:
- Tiles visible during valid period: 10/10
- Probability in visible tiles: 90.8%
Predicted visibility from Siding Spring:
- Tiles visible during valid period: 10/10
- Probability in visible tiles: 90.8%

Fermi_782072225_tiles ▼

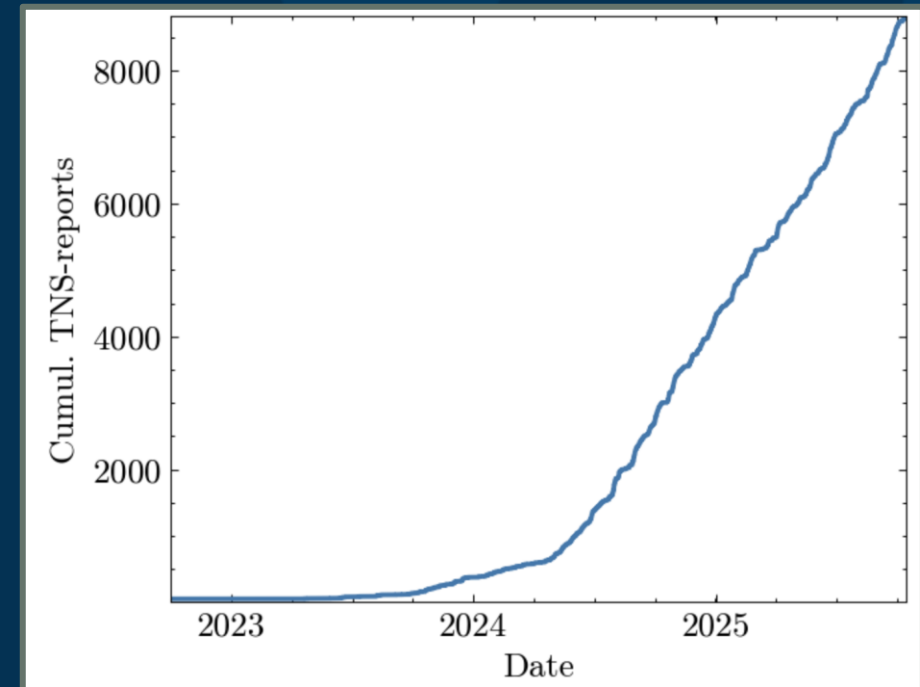
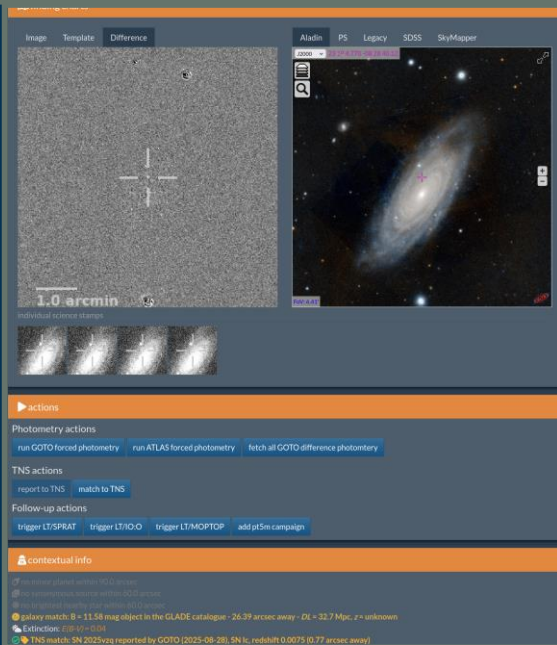
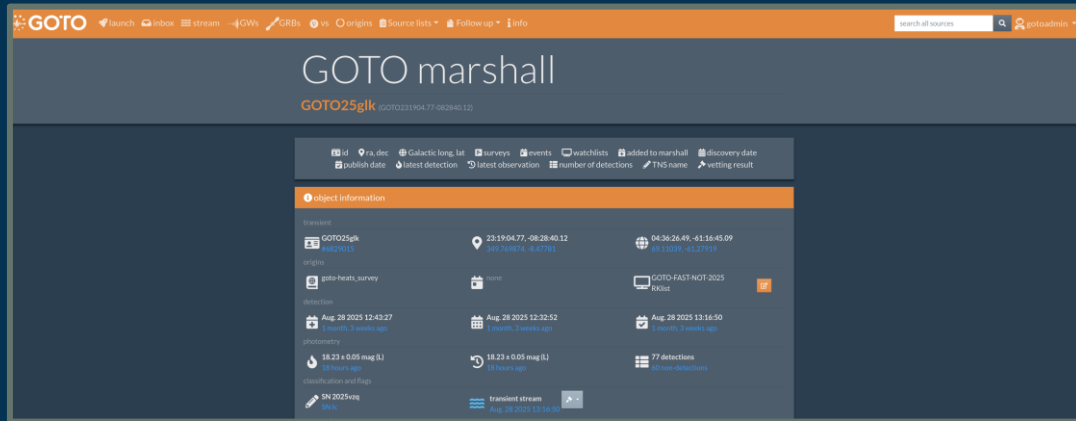


Pipeline and Marshall

Lyman et al. (to be submitted)



Lyman et al. (to be submitted)



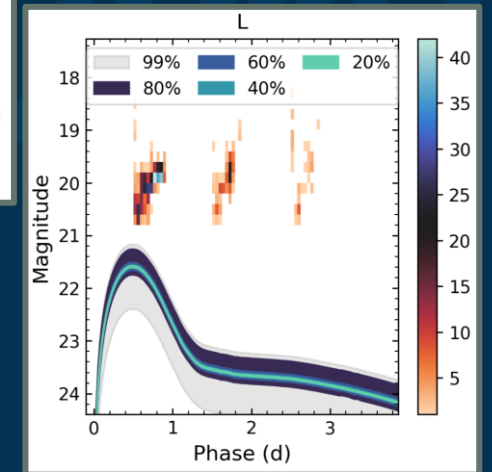
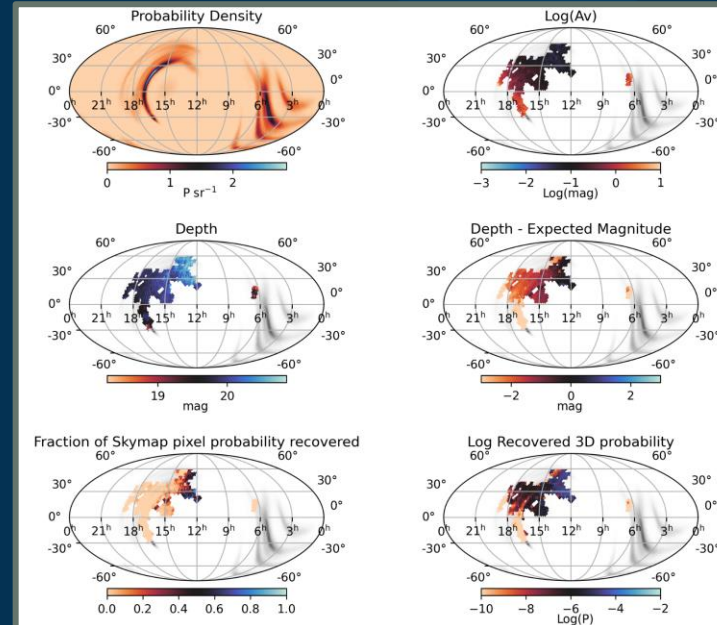
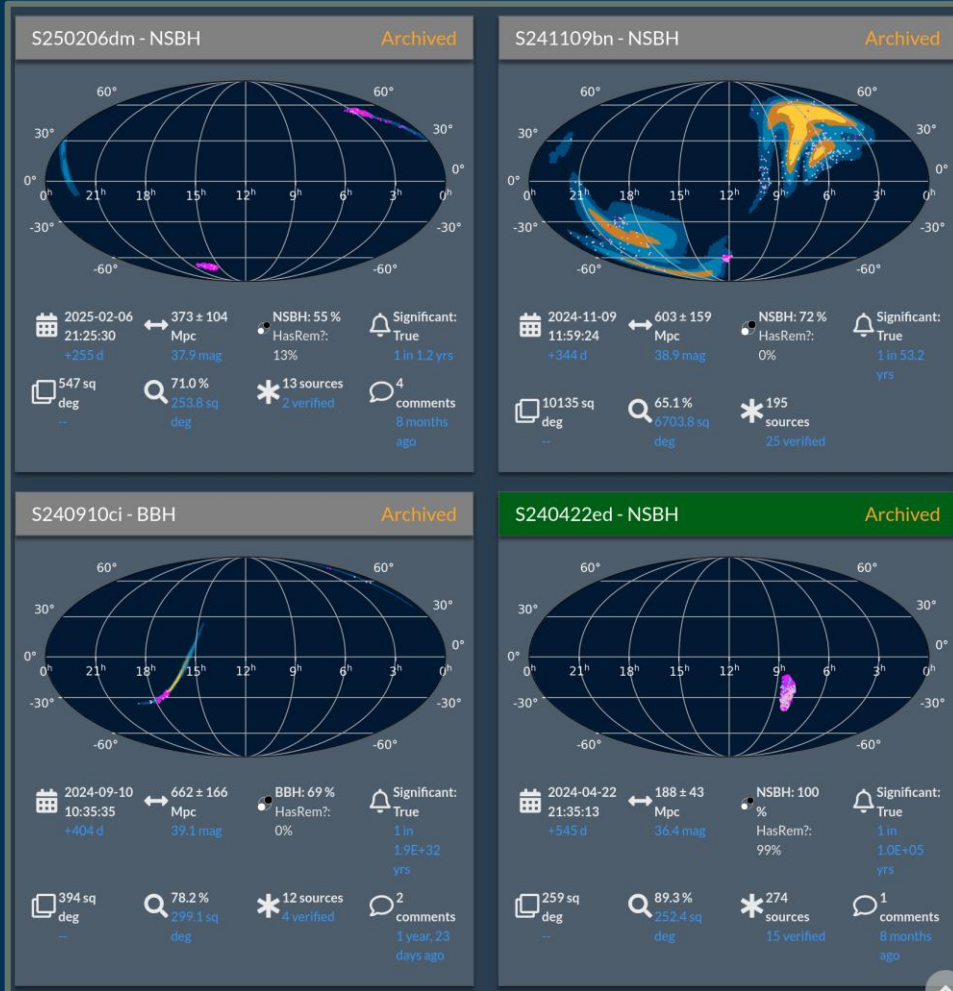
Pipeline and Marshall

Lyman et al. (to be submitted)



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GeRRY (O'Neill et al. 2024)

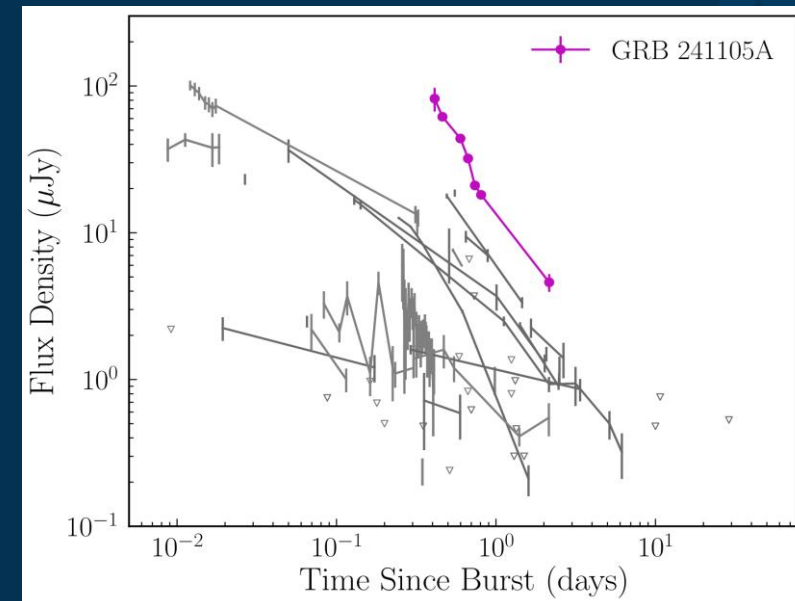
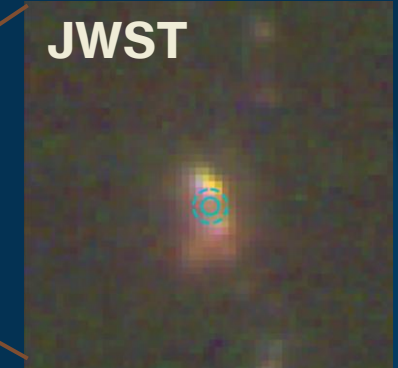
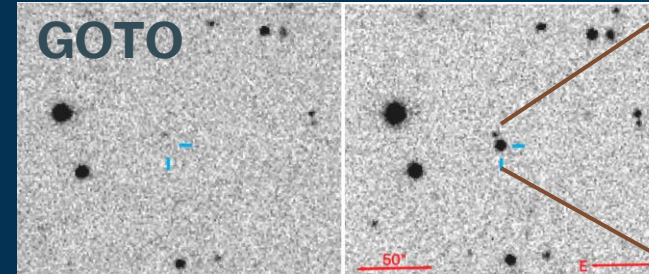
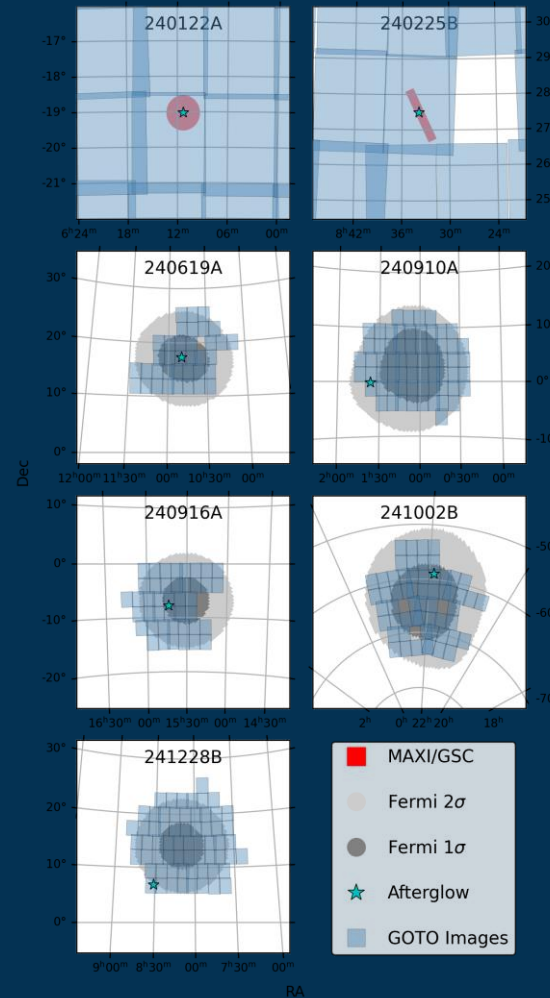
GRB Afterglow localisation

Kumar et al. (2025); Dimple et al. (2025)



GOTO

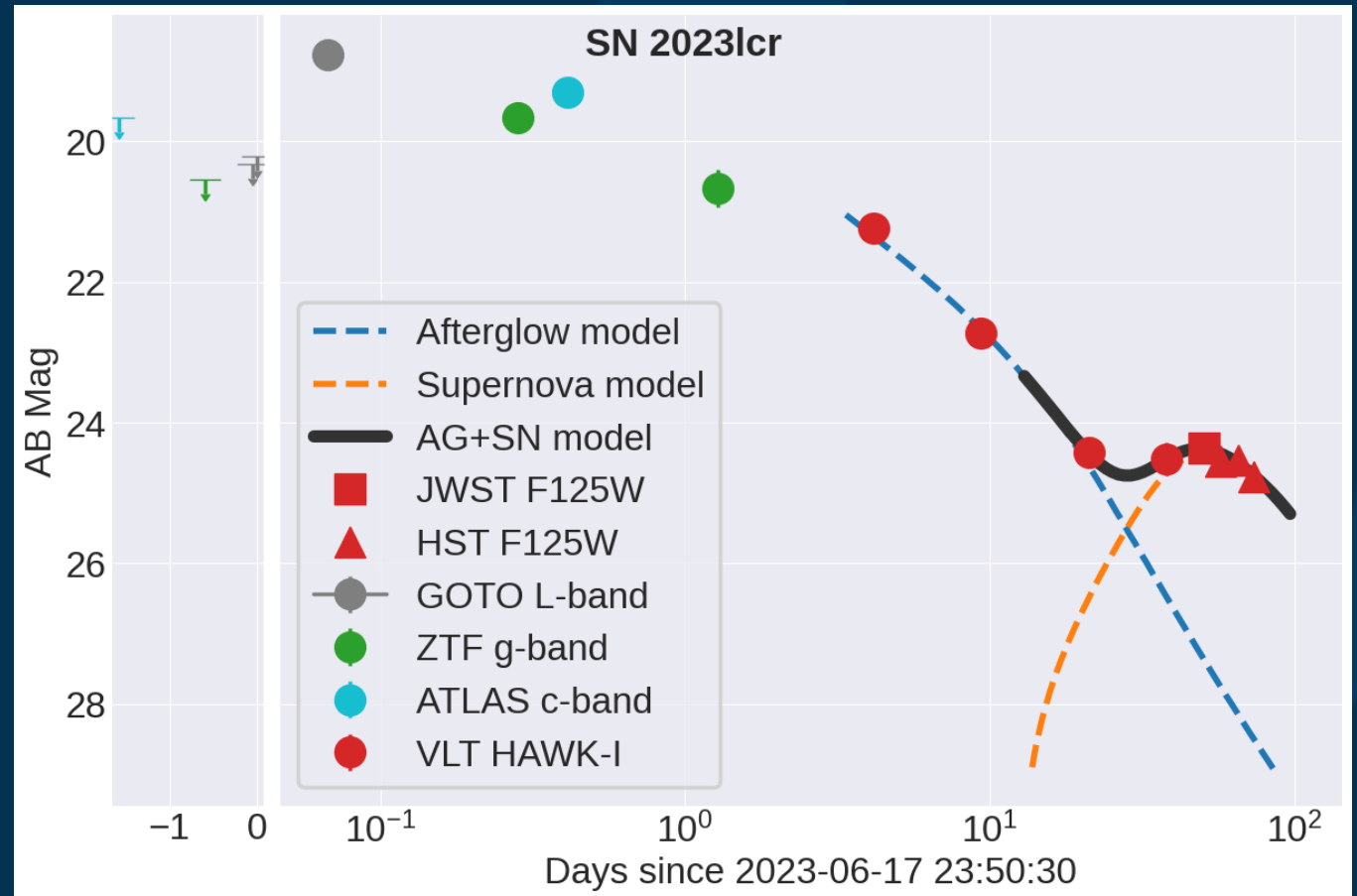
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GRB orphan afterglow

Martin-Carrillo et al. (in prep)

- **Fading transient** reported by **ZTF**
- **1.5 hour non-detection** window in **GOTO**
- **No high-energy** trigger coincident
- **HST/JWST follow-up confirm afterglow**
 - **JWST spectrum of SN at $z \sim 1$!**



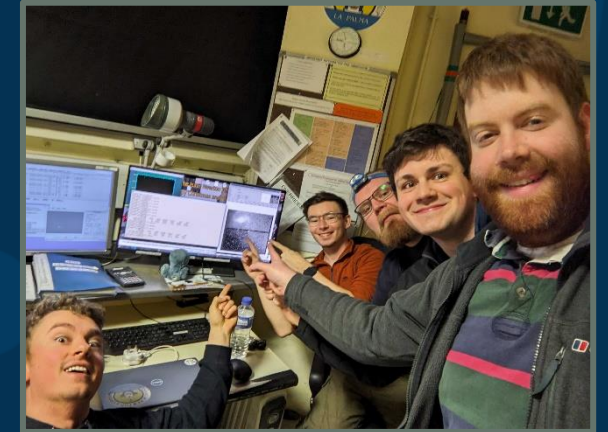
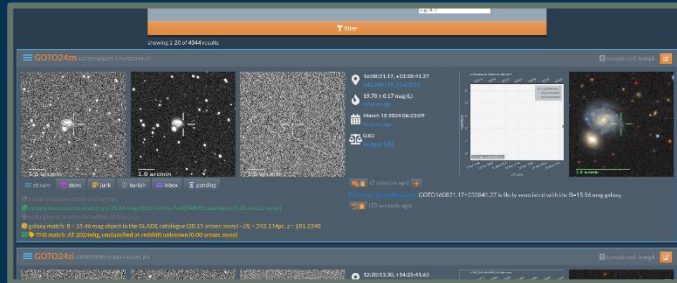
GOTO-FAST

Immediate spectroscopic follow-up of discoveries



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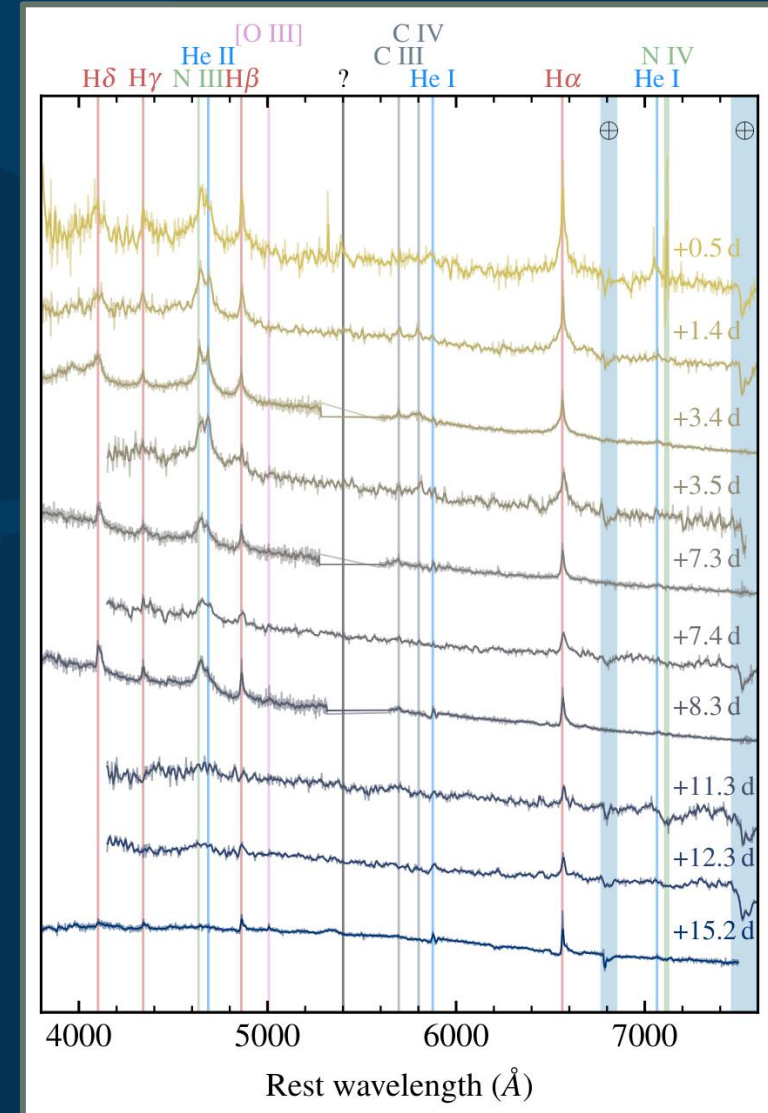
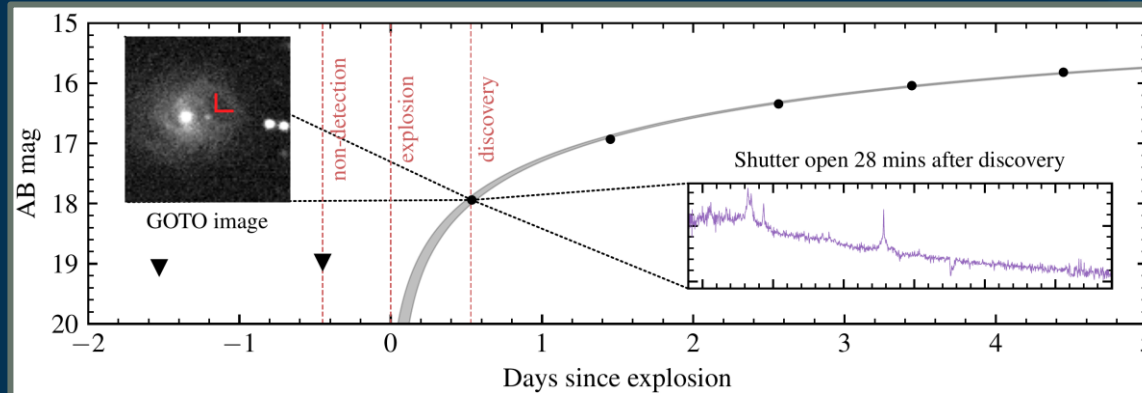
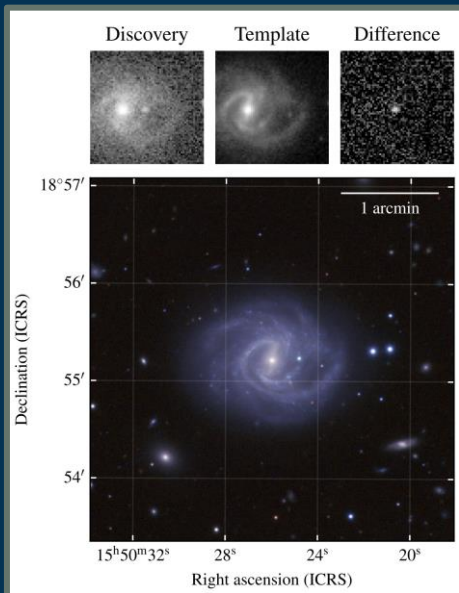


4th Astro-COLIBRI workshop – 20 October 2025

GOTO-FAST

SN2024cld – a complex RSG CSM environment and dust factory
(Killestein et al. submitted + in prep)

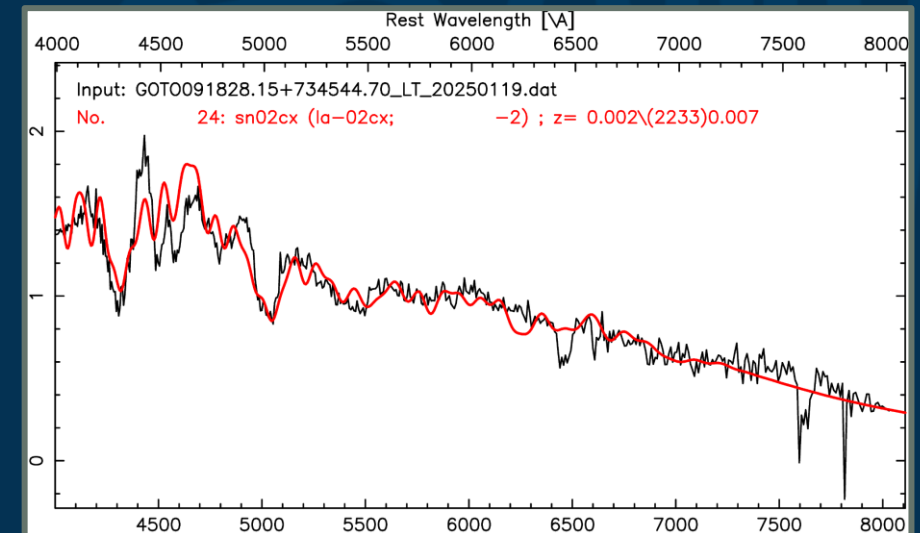
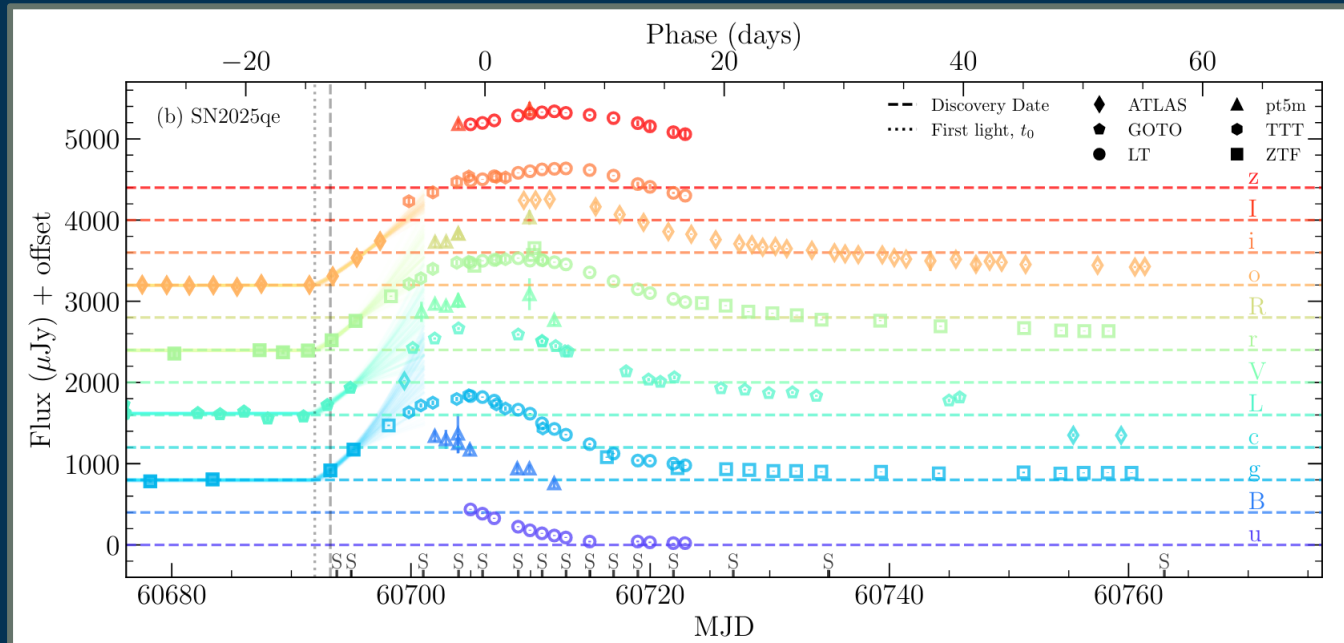
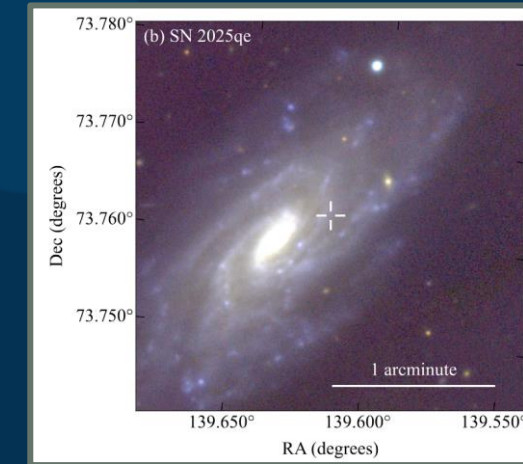
- Three follow-up facilities triggered **within an hour** of discovery
- First spectrum **~12hr post-explosion**
- Still being observed **20 months later**



GOTO-FAST

SN2025qe – automated spectroscopic follow-up of an infant SN Iax
(Magee et al. 2025)

- **Automatic trigger** sent by GOTO Marshall to Liverpool Telescope upon discovery
- **Earliest** SN Iax classification spectrum



Citizen Science

Kilonova Seekers (Killestein, Kelsey et al. 2025)



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PROJECTS ABOUT GET INVOLVED TALK BUILD

SIGN IN REGISTER



Kilonova Seekers



ENGLISH

Co-leads: Lisa Kelsey, Tom Killestein
Laura Nuttall, JL, Coleman Krawczyk

ABOUT CLASSIFY TALK COLLECT

★ Important Kilonova Seekers update: [read more](#)



KILONOVA SEEKERS

Find cosmic explosions in real-time with the Gravitational-wave Optical Transient Observer (GOTO) - new data uploaded every 15 minutes!

By the numbers

3,969

Volunteers

4,178,387

Classifications

320,445

Subjects

320,304

Completed subjects

You can do real research by clicking to get started here!

99% COMPLETE

Real bogus classification



kilonova-seekers.org

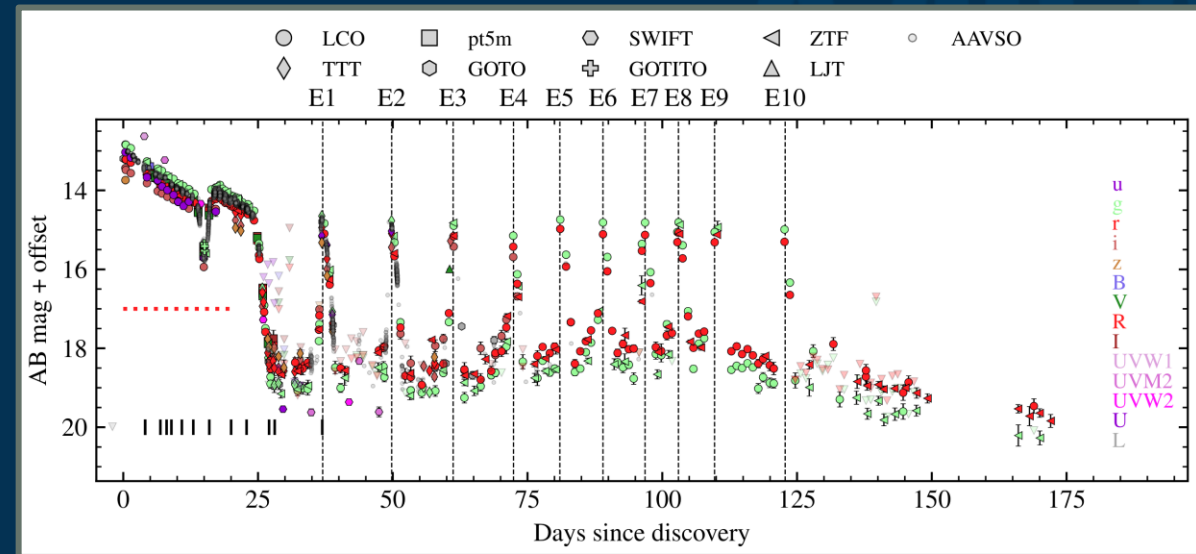
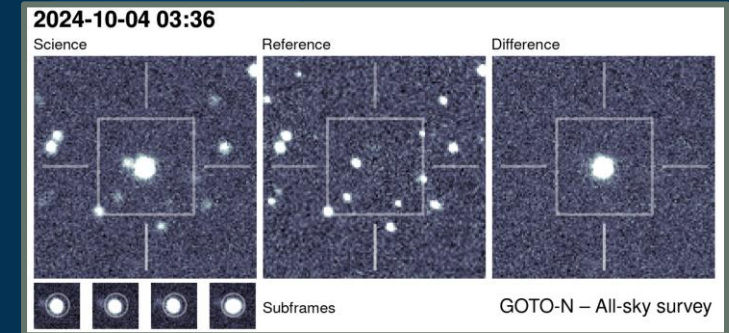
Citizen Science

A remarkable Dwarf Nova in Killestein et al. (incl. volunteers), 2025
Castro-Segura et al. (2025)

Discovered by, followed up, and written up with
citizen scientist volunteers

GOTO065054+593624: An 8.5 mag amplitude dwarf nova identified in real time via Kilonova Seekers

T. L. Killestein^{1,2,*}, G. Ramsay³, M. Kennedy⁴, L. Kelsey⁵, D. Steeghs², S. Littlefair⁶, B. Godson²,
J. Lyman², M. Pursiainen², B. Warwick², C. Krawczyk⁷, L. K. Nuttall⁷, E. Wickens⁷, S. D. Alexandrov^{8,9},
C. M. da Silva^{8,10,11}, R. Leadbeater¹², K. Ackley², M. J. Dyer⁶, F. Jiménez-Ibarra¹³, K. Ulaczyk²,
D. K. Galloway¹³, V. S. Dhillon^{6,14}, P. O'Brien¹⁵, K. Noysena¹⁶, R. Kotak¹, R. P. Breton¹⁷, E. Pallé¹⁴,
D. Pollacco², A. Kumar^{2,18}, D. O'Neill², T. Butterley¹⁹, R. Wilson¹⁹, S. Mattila^{1,20}, A. Sahu², R. Starling¹⁵,
C. Y. Wang²¹, Q. Liu²², A. Li^{23,24}, Z. Dai^{25,26}, H. Feng²⁷, W. Yuan^{28,29}, R. Billington⁸, A. G. Bull^{8,30,31},
S. Gaudenzi^{8,10}, V. Gonano⁸, H. Krawczyk⁸, M. T. Mazzucato^{8,31,32}, A. Pasqua⁸, J. A. da Silva Campos^{8,33},
M. Torres-Guerrero⁸, N. N. Antonov³⁴, S. J. Bean¹², E. T. Boeneker¹⁰, S. M. Brincat¹⁰, G. S. Darlington^{12,10},
F. Dubois^{35,36}, F.-J. Hambsch^{36,10,37,38}, D. Messier^{10,39}, A. Oksanen^{10,40}, G. Poyner¹², F. D. Romanov^{10,41},
I. D. Sharp¹², T. Tordai⁴², T. Vanmunster^{10,39}, and K. Wenzel³⁸



Post 04

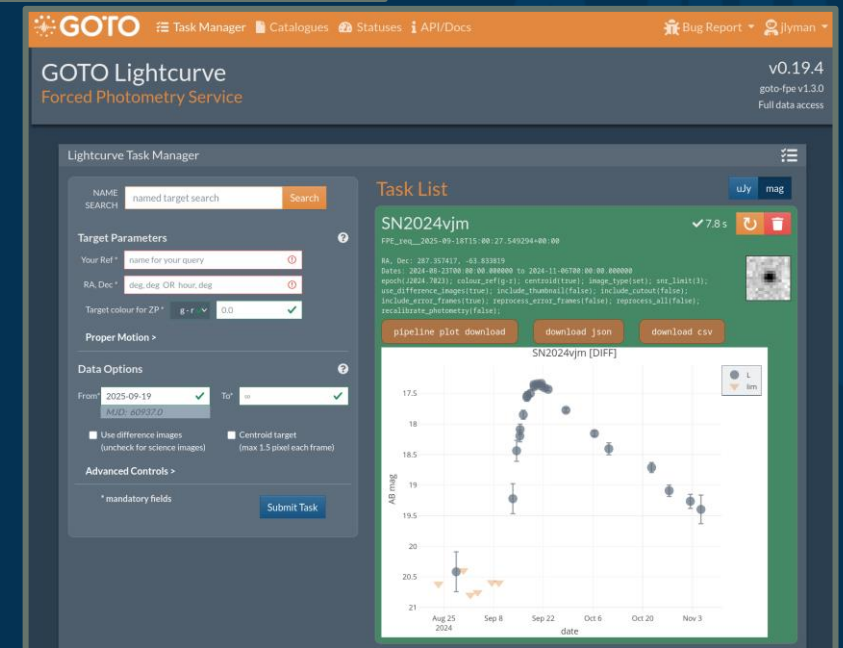
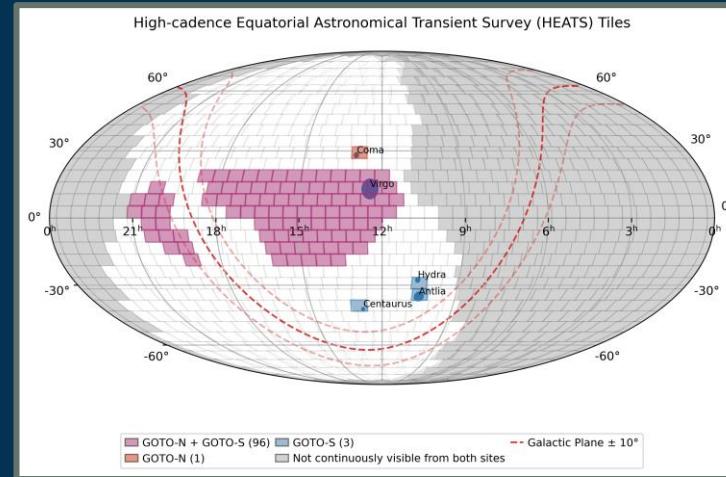
(~1 month)

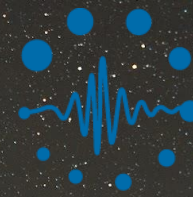
Custom sub-sky surveys for specific science cases

- **~0.3 night extragalactic equatorial survey** for infant transients
- **Galactic plane stares** for rapid variability

Easier access to data products

- **Forced photometry API** (Jarvis et al. in prep)
- **Kafka producer** of GOTO DIA alerts





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Thank you

B. Godson



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Technology
Facilities Council**