Kilonova Seekers

Crowdsourcing real-time astronomical discovery through global citizen science

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Motivation and background

The **Gravitational-wave Optical Transient Observer (GOTO)** telescopes in Spain and Australia scan the entire night sky every 2-3 days, in search of cosmic explosions. This creates a massive data challenge: identifying real astronomical events among countless artifacts. The most exciting targets are **kilonovae** - the afterglows of colliding neutron stars that forge gold, platinum, and other heavy elements. These explosions are detected by gravitational-wave observatories like LIGO, but finding their faint optical counterparts requires rapid analysis of vast amounts of telescope data **(TB/night)**.

GOTO uses machine learning classifiers working on the image-level data to meet this challenge, but:

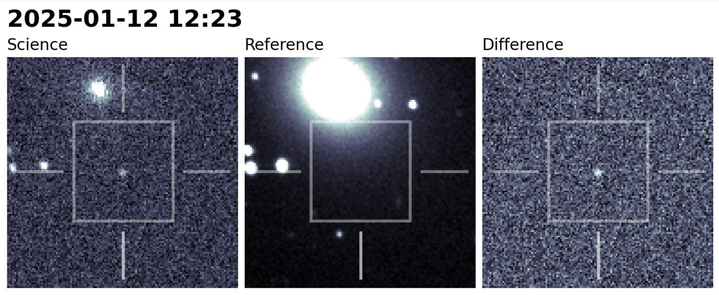
1) **How can we be sure we don't miss interesting objects that are just below the ML score threshold?**
2) **How can we validate that the classifier is performing as intended in deployment, and gather high-quality labels on novel examples to further improve performance?**

This challenge motivated the development of **Kilonova Seekers**, a unique citizen science project to directly embed members of the public in the **search for cosmic explosions in real-time**.

GOTO-North located at the Roque de los Muchachos Observatory, La Palma.
Image credit: K. Ulaczyk (2024)

How it works

We invite members of the public to play 'spot the difference' with images taken by GOTO in real time, via a workflow hosted on the **Zooniverse** platform. Volunteers are asked a simple question - **is there a real transient centred in the Science and Difference images?**



Each object is seen by up to **14 volunteers**, to not only ensure the accuracy of labels, but to derive calibrated uncertainties on each example for training ML classifiers. If **80%** of volunteers agree after at least **8** have voted, an alert is sent to us to investigate the object further.

Real-time impact

All Kilonova Seekers discoveries are reported to the International Astronomical Union, with the **volunteers included as co-authors for official recognition.** By making these public immediately, other teams follow up on our discoveries, and the volunteers get instantly credited for their work, often only a few hours after the data was taken.

SN2024bch (multicolour)
Image credit: LCO/B. Godson (2024)

Kilonova Seekers is the only project to be doing science and public engagement on a **real time, largely unfiltered dataset,** with volunteer effort actively increasing the number of discoveries GOTO is making, and drawing interesting/faint objects to the attention of the team. Colleagues are also doing further studies of Kilonova Seekers discoveries, feeding back into the public aspects of the project.

3,890
participants*

3,844,000
total classifications*

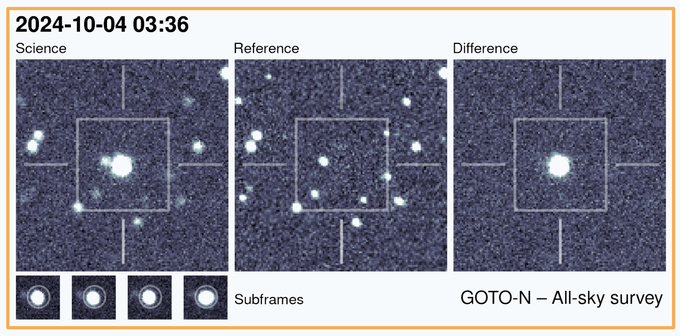
292,769
examples with 10 or more labels*

77
first discoveries by the volunteers*

* Figures correct as of 16:30 on 22nd September 2025

Discovery of GOTO0650

In October 2025, Kilonova Seekers volunteers discovered an exploding star that **dramatically brightened by 2,500 times - now known as GOTO0650**. Volunteers spotted this outburst just 4 hours after the telescopes captured it, enabling us to study the object from its very first moments, and allowed follow-up observations with space telescopes and ground-based facilities worldwide. **Half the co-authors on the resulting scientific paper published in Astronomy and Astrophysics were citizen scientists** - volunteers who helped make the discovery and study possible.



The GOTO0650 discovery gained **international media attention (BBC, Wall Street Journal, Popular Science),** with volunteers not only making the discovery but fielding questions from press, and writing their own articles in popular science magazines in their communities.

What's next?

Kilonova Seekers has been running for 2 years non-stop, and so the project will undergo a number of upgrades over the coming months as part of a scheduled break, alongside a re-launch in **February 2026**

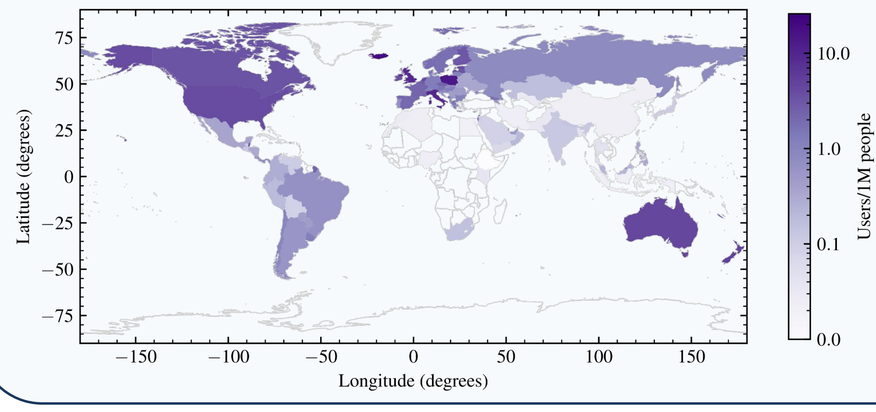
These include:

- **A new labelling workflow** - to capture not only if an object is real/an artefact, but what type it is. This will let volunteers annotate supernovae and variable stars, which can be used to train more comprehensive classifiers.
- **Adaptive machine learning** - to ensure we can benefit from volunteers' effort in real time, and always have the most up-to-date classifier based on their inputs.
- **A dedicated educational version** of the project for use in schools and education settings, with higher-quality examples, and more in-depth tutorials and guides with tailored information.

A thriving global community of volunteers

Kilonova Seekers has attracted a truly global audience, with volunteers in over 105 countries, and all continents except Antarctica - for now. Given telescopes in both the Northern and Southern Hemisphere, it means someone is always looking at the data.

The project is being used actively in schools around the world, but also as part of extracurricular activities in the Global South.



> We are now authors of a scientific article in one of the most important journals in the field. This shows the importance of citizen science, both scientifically and personally, as it was for me. Even from your bed, or on the street with your cell phone, there is the possibility of making a very important discovery
> **Cledison Marcos da Silva**

Volunteers enjoy being involved with genuine scientific discovery, and and value being part of a community of people with similar interests. Many participants find the classification tasks fun and rewarding. Many have shared how important citizen science has been in their lives, and to be a part of this is very humbling as researchers and educators.

Join the search!

Kilonova Seekers paper

GOTO0650 paper

GOTO GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER

UNIVERSITY OF WARWICK