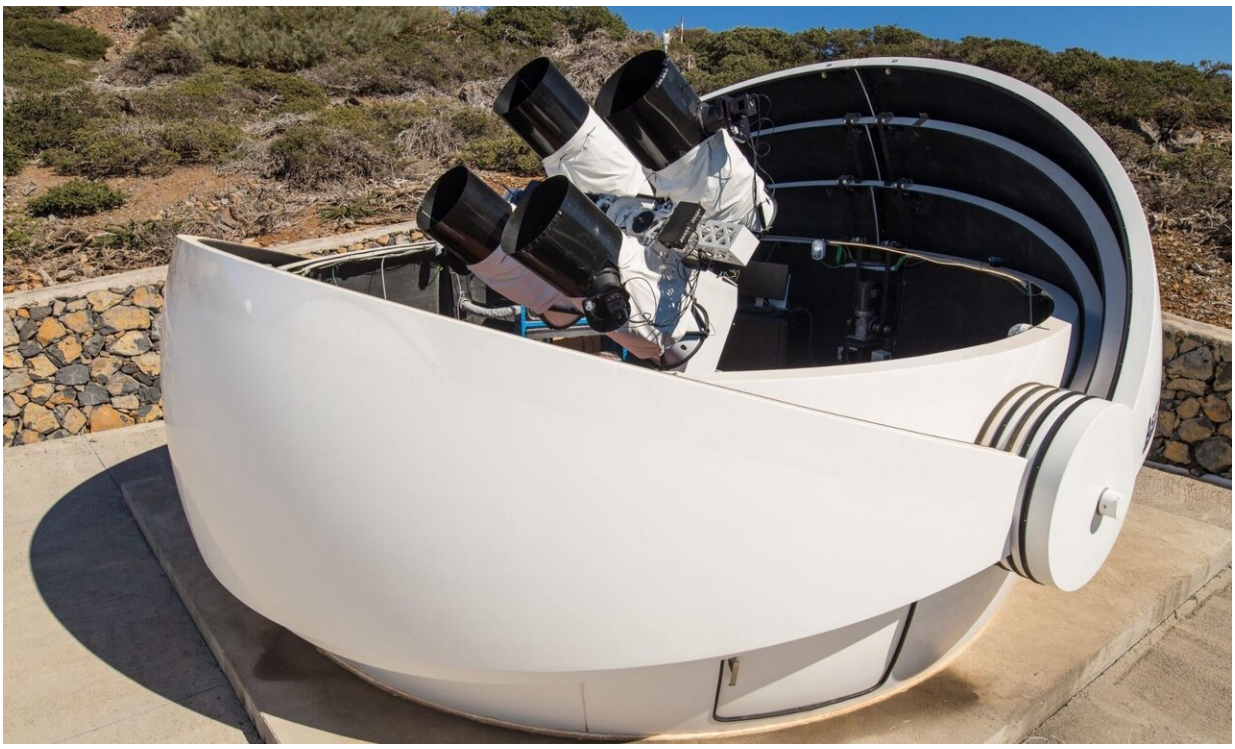
The Kilonova-Chasing Gravitational-Wave Optical Transient Observer is about to be watching the whole sky

December 21 2020, by Andy Tomaswick



Credit: GOTO Project

Lately, there has been a flood of interest in gravitational waves. After the first official detection at LIGO / Virgo in 2015, data has been coming in showing how common these once theoretical phenomena actually are.

Usually they are caused by unimaginably violent events, such as a merging pair of black holes. Such events also have a tendency to emit another type of phenomena—light. So far, it has been difficult to observe any optical associated with these gravitational-wave emitting events. But a team of researchers hope to change that with the full implementation of the Gravitation-wave Optical Transient Observer (GOTO) telescope.

The GOTO project is designed specifically to find and monitor the parts of the sky that other instruments, such as LIGO, detect gravitational waves from. Its original incarnation, known as the GOTO-4 Prototype, was brought online in 2017. Located in La Palma, in the Canary Islands, this prototype consisted of four "unit telescopes" (UTs) housed in an 18ft clamshell dome. In 2020, this prototype was upgraded to 8 UTs, allowing for a much wider view of the sky.

The wide field of view is necessary for its work detecting gravitational-wave based optical phenomena, as directionality of gravitational waves are notoriously difficult to pin down. The wider the field of view of a telescope, the more likely it will be able to detect an event that happens.

As such, the operators of GOTO started an upgrade plan in 2020. These upgrades included an additional 8 UT in a separate dome at the same observatory, which is due to be added in early 2021. More ambitiously, the team plans to recreate the two-unit array in La Palma at the Siding Spring Observatory in New South Wales, Australia. With these telescopes on opposite sides of the world, GOTO will "enable close to 24-hour observations, ensuring that GOTO is able to react to alerts whenever they occur," according to a recent paper.

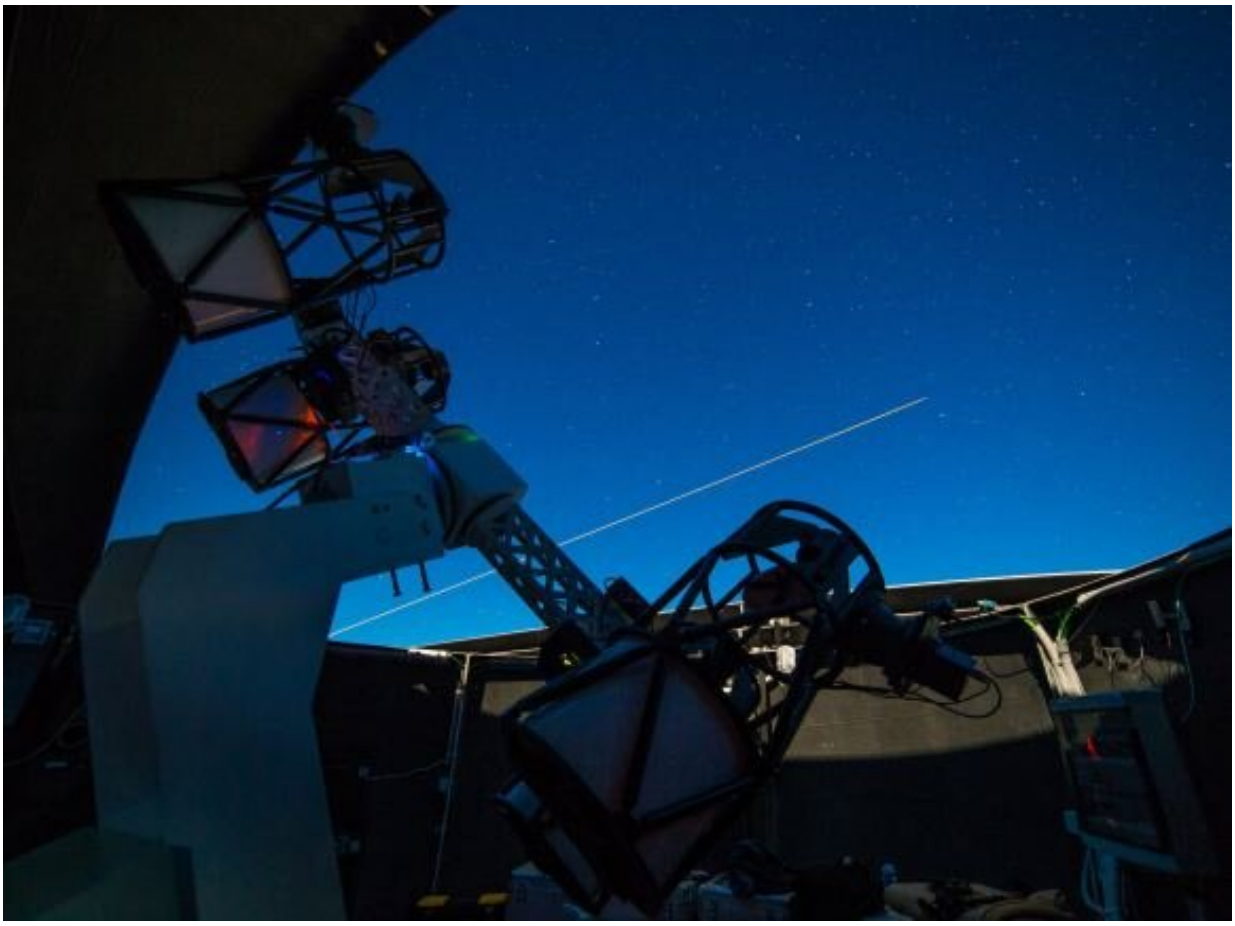


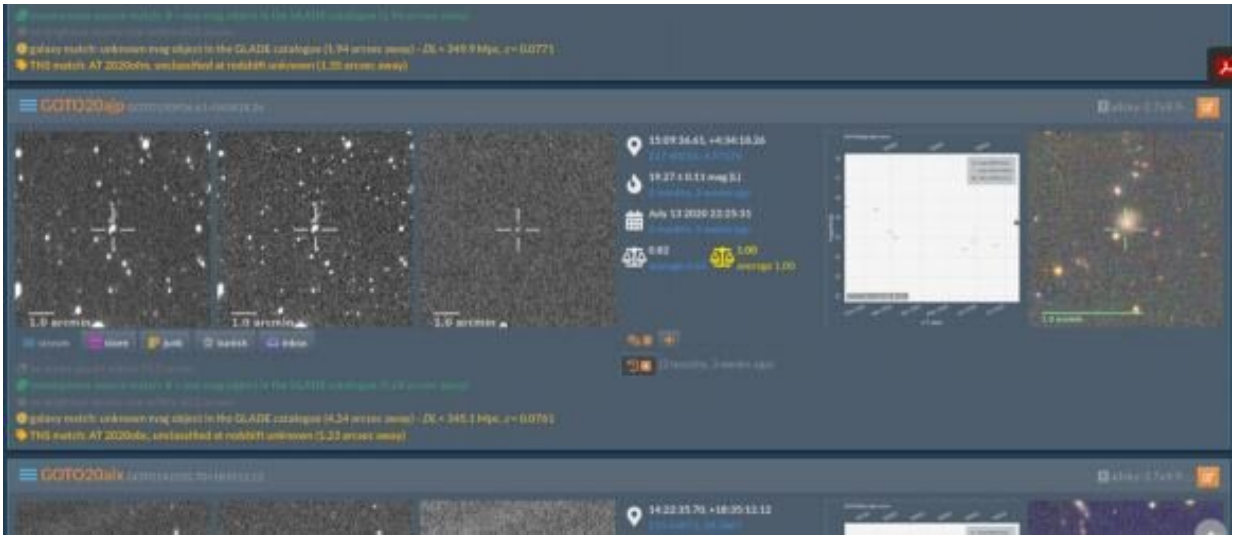
Image of the GOTO prototype as work. Credit: GOTO Project

University of Warwick’s observatory on the Canary Islands, with the GOTO domes on the right. Credit: GOTO Project

Those alerts are an extremely important part of GOTO's observational planning. They come from NASA's Gamma-ray Coordination Network (GCN), an alert system that monitors not only gravitational waves, but also other phenomena that could produce interesting optical data, such as kilonovas or gamma ray bursts.

GOTO monitors this network through it's software package, which is also a key component to overall system operation. The GOTO Telescope Control System (G-TeCS) is a custom-written Python script that monitors for signals of interest, calculates which signal is the highest

priority, and then physically moves the telescopes to an observing position. It is also able to do all of that in less than 30 seconds, allowing for an extremely quick turnaround in order to observe these transient phenomena of interest.



Screenshot from GOTO's software showing a potential candidate. Credit: GOTO Project

Once the telescopes are positioned, G-TeCS is also able to collect and analyze images. It compares any images it captures with a calibration image, and uses a type of artificial intelligence known as a convolutional neural network to assign a score to the likelihood that it detected a signal of interest. As with so much AI assisted research, humans are the last part in the analysis chain. Researchers use a tool called GOTO Marshall to individually validate high interest targets, and can also schedule follow-up observations with other telescopes in the area.

All of this software system is controlled remotely at the University of

Warwick, who leads the GOTO project, which includes nine other institutions from the U.K., Australia, Thailand, Spain, and Finland. As they continue to implement their planned improvements, and data continues to come in, we'll start to be able to visualize the catastrophic events associated with some of the most violent phenomena in the universe.

More information: Martin J. Dyer et al. The Gravitational-wave Optical Transient Observer (GOTO), *Ground-based and Airborne Telescopes VIII* (2020). DOI: 10.1117/12.2561008

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