GOTO

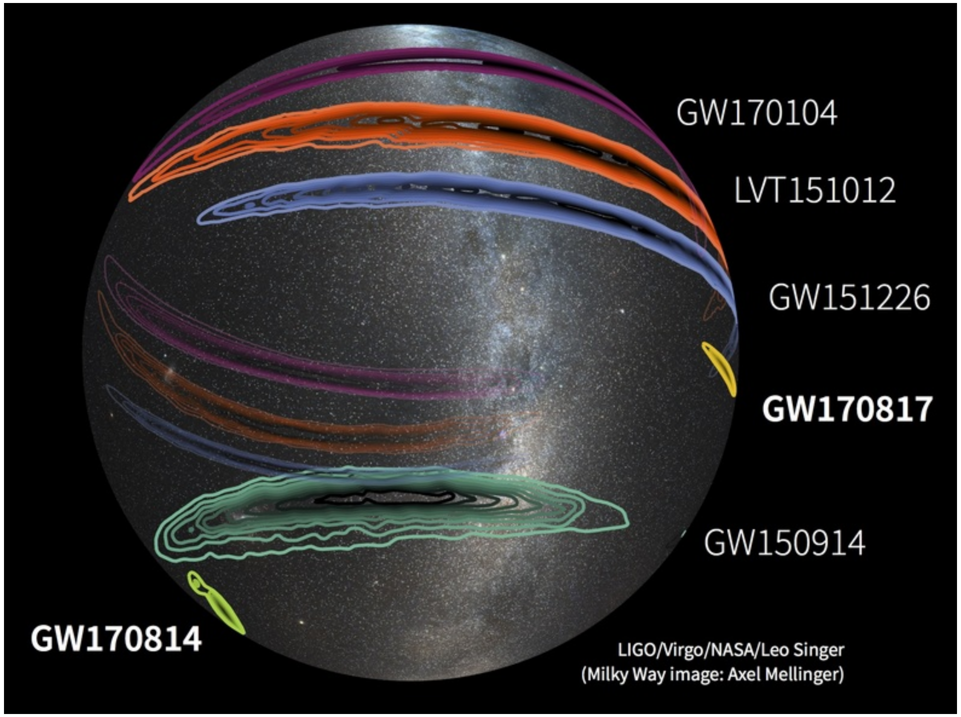
GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER

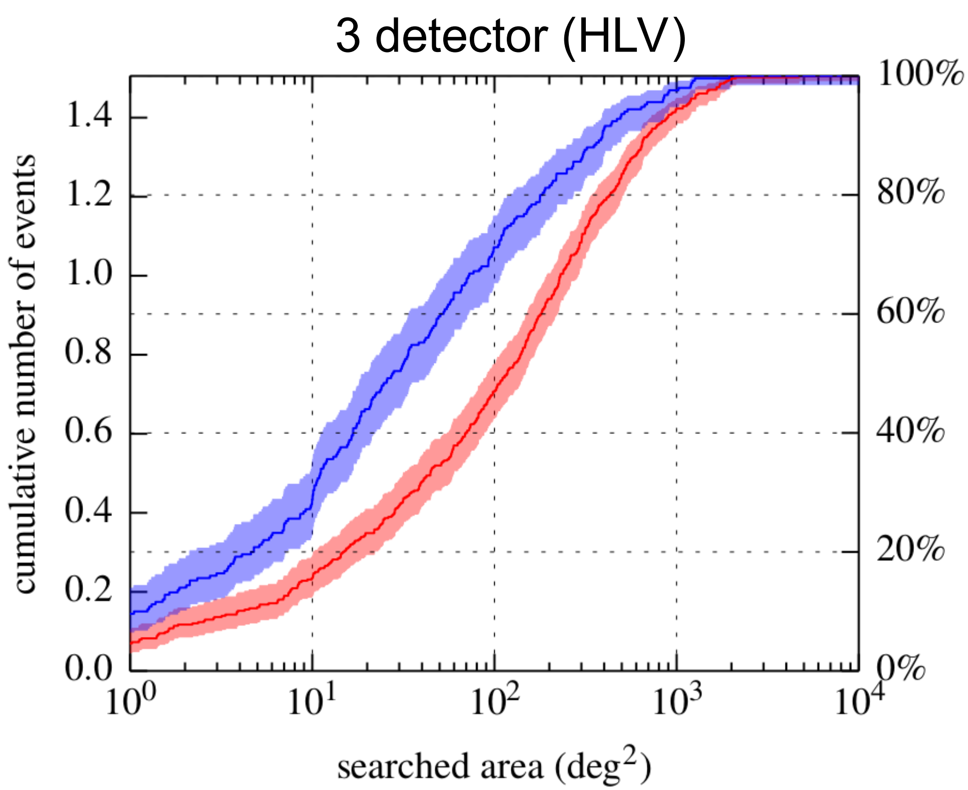
WARWICK

University of Warwick – Monash University – Armagh Observatory
University of Sheffield – University of Leicester – NARIT – IAC
[Turku – Manchester]

Danny Steeghs

Localisation challenge





Singer et al. / Berry et al. (2014)

GRAVITATIONAL-WAVE OPTICAL TRANSIENT OBSERVER

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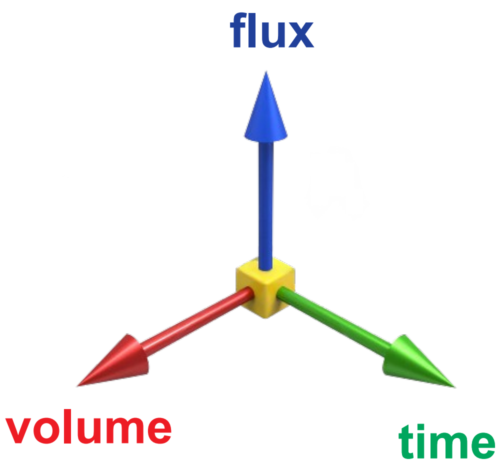
Key points:

Specifically designed and optimized for rapid response GW-EM searches

Wide area capability to sufficient depth

Aim to catch counterparts early to allow follow-up with other facilities



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Key points:

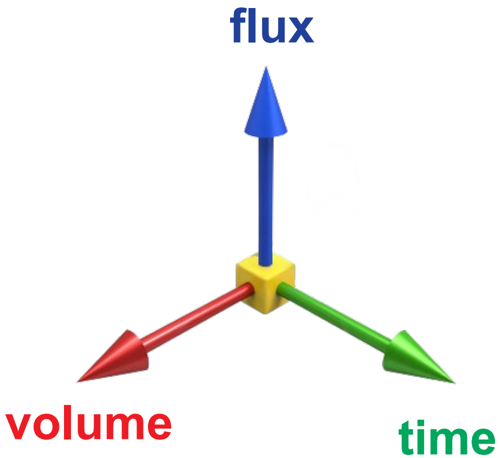
Cost-effective and scalable

Survey speed, depth and filter coverage can be adapted to changing needs

Good site (ORM La Palma)

Operates in *sky survey mode* most of the time to have recent reference images of the visible sky

(also means lots of secondary science)



GOTO Phase I ; first light

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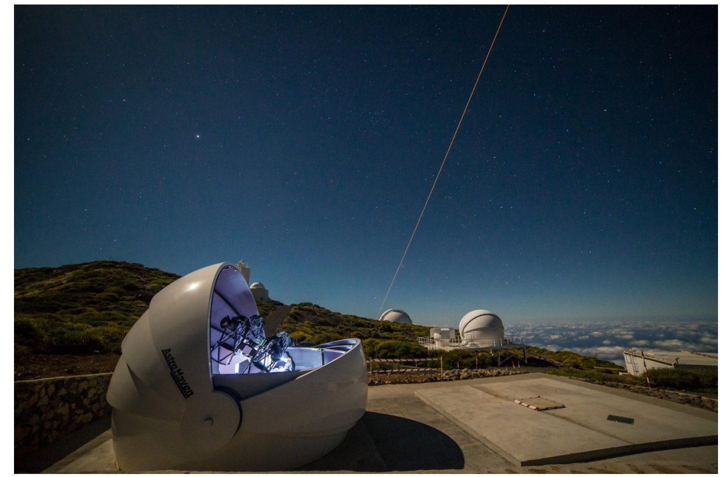
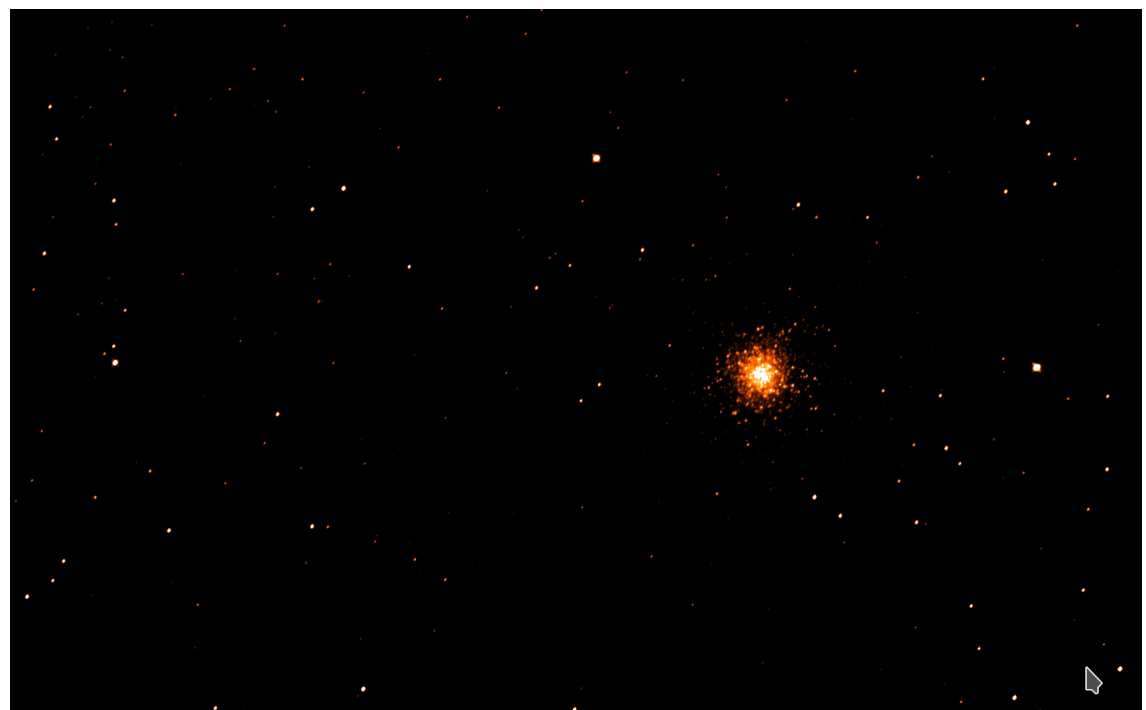
Installation

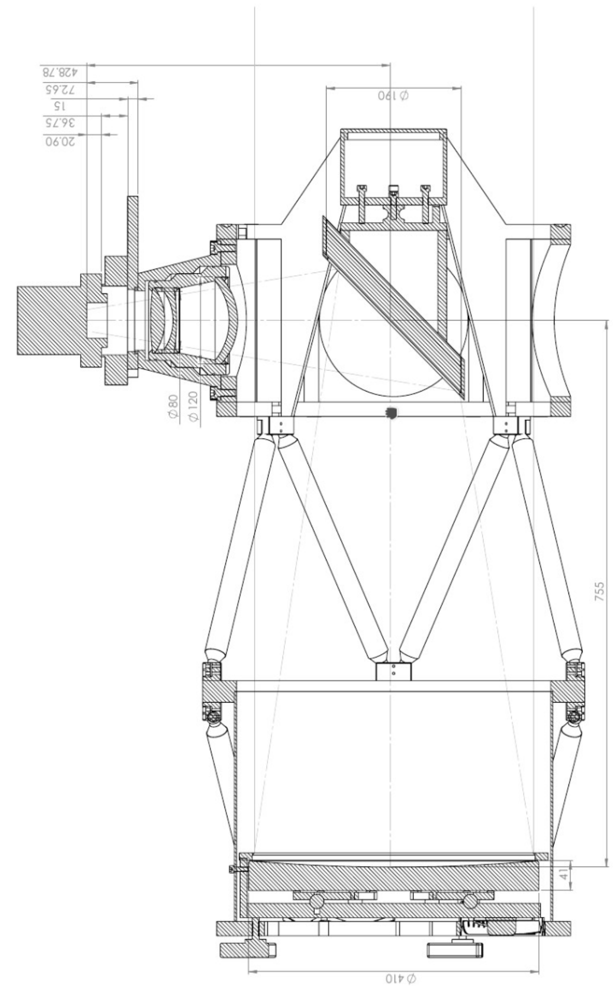
Site work : Sep – Nov 2016
Dome erected : Nov 2016
Telescope system : June 2017



First light, M13
June 11 2017



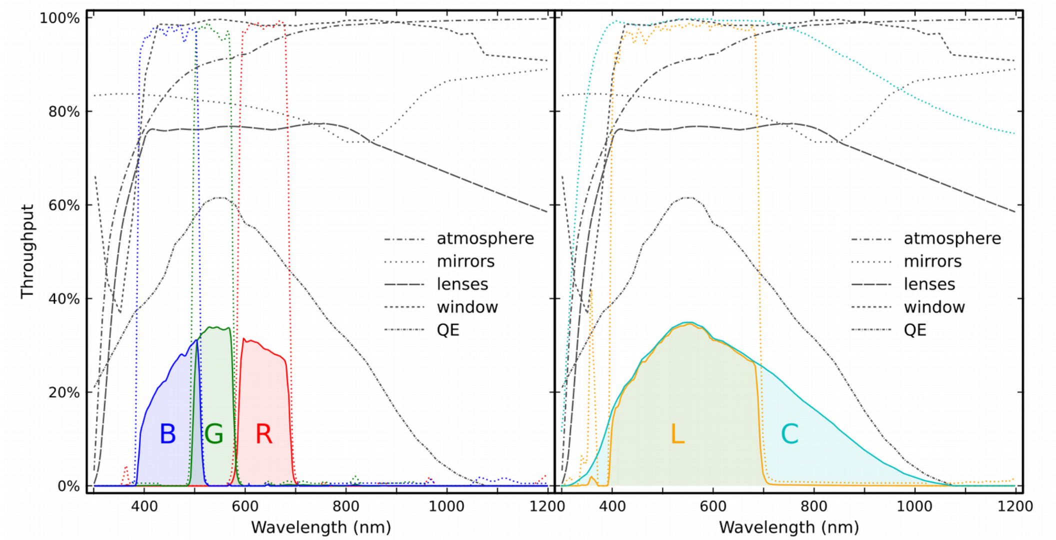
GOTO Phase I

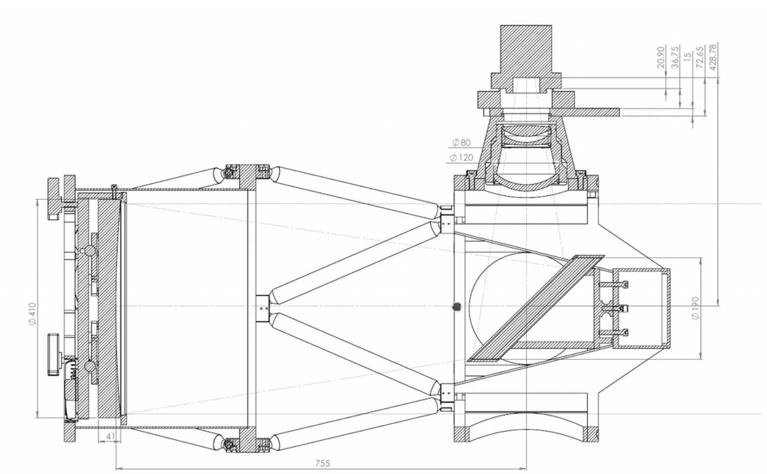


D=40cm f/2.5 Newtonian Wynne-Riccardo OTAs

1 telescope = 2.85 x 2.114 degrees , 1.25”/pixel (50 Mpixel CCD) ~ 5 sqr.deg
5-slot filterwheel (currently LRGBC)
Data is sent for processing to Warwick data centre via 1Gb level-2 VLAN

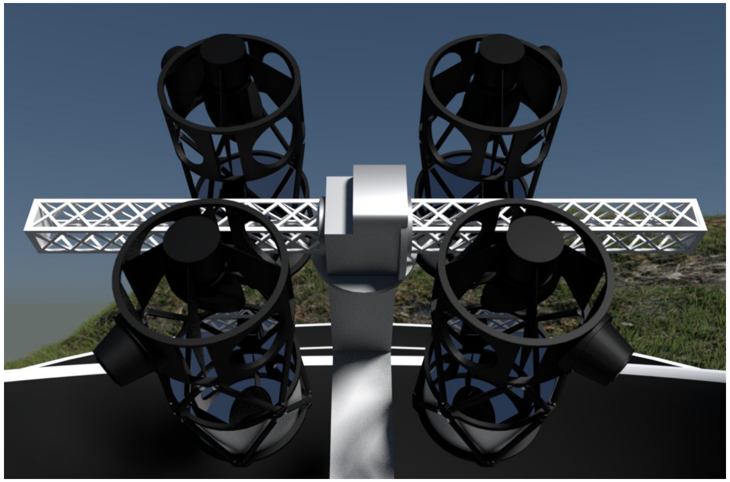
GOTO Phase I



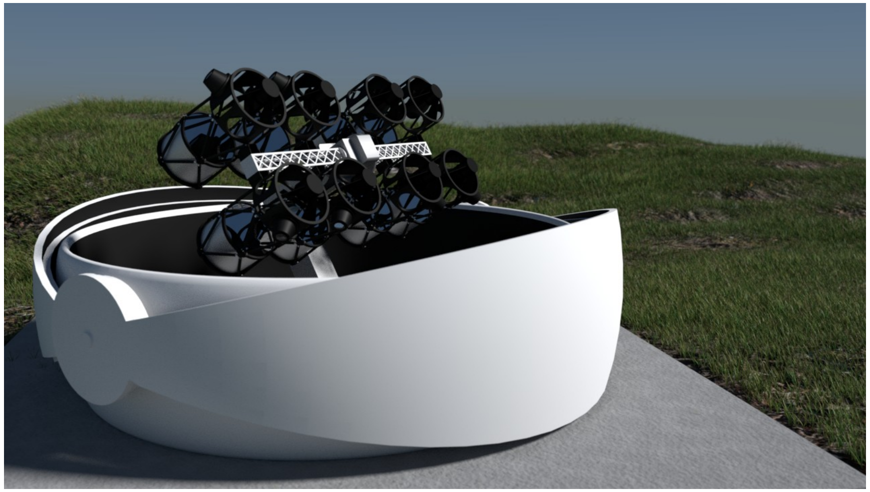


Nominal exposures are 120s delivering 5-sigma limit of 19.5-20.5 in L filter (chiefly moon-phase dependent)

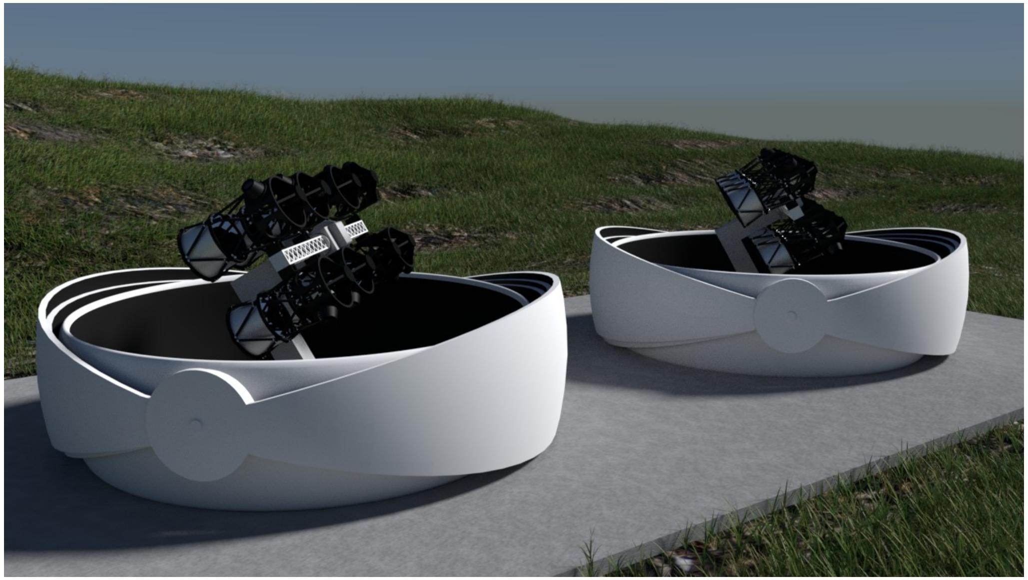
GOTO vision



Phase I (now) : 4x40cm ~20 sqr.deg



Phase II : 8x40cm ~40 sqr.deg
(Late Spring 2018)



Phase III : 16x40cm ~80 sqr.deg

Fast cadence across visible sky

Phase IV : Southern/Australian copy

GW170817

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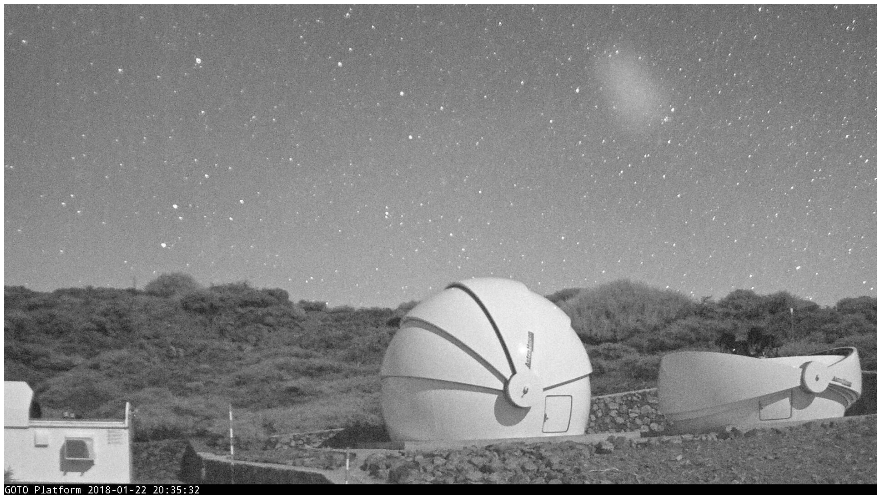
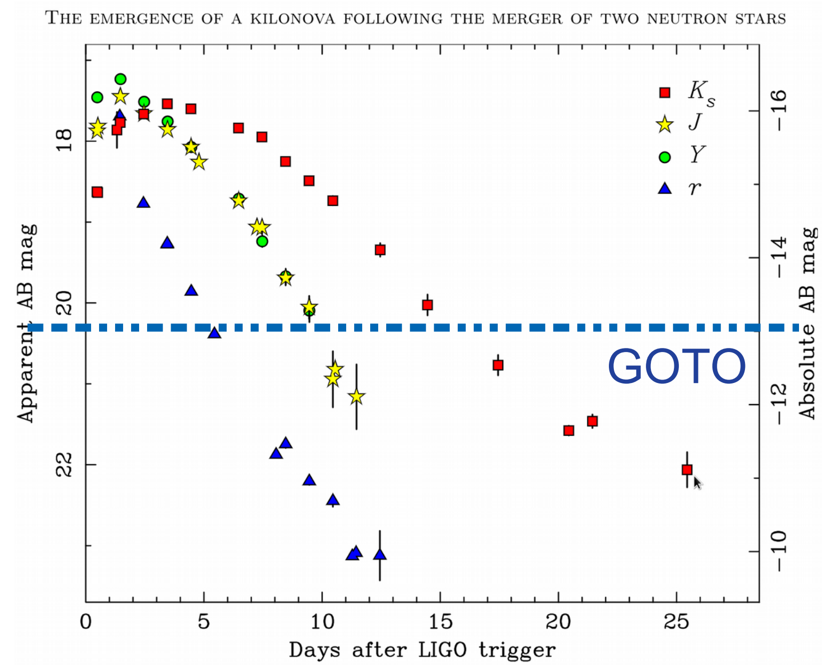
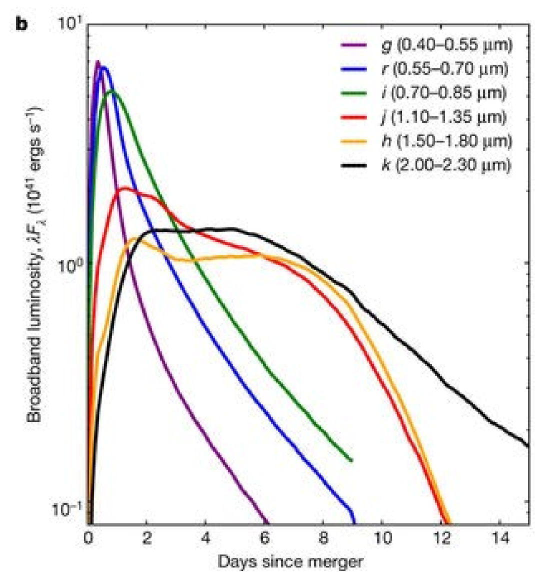




GW170817 showed prompt 'blue kilonova' signature

Validates GOTO strategy to hunt in the optical on short timescales

No follow-up without localisation



Tanvir et al. (2017)
Kasen et al. (2017)

Summary

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GOTO is optimized for and primarily dedicated to GW-EM searches
(even poorly localized/lower FAR events)

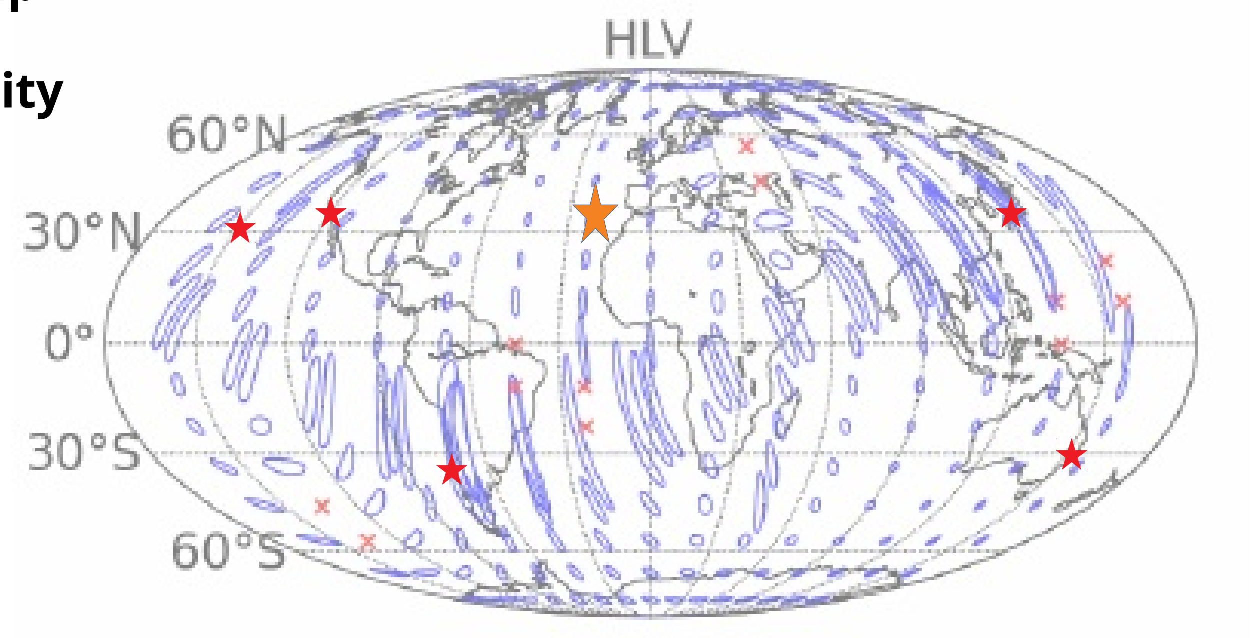
Early identification of candidates (GW & other notable/fast transient)

8x40cm ~40 sqr deg for O3 searches

Complements longitude/latitude and strategy of other facilities

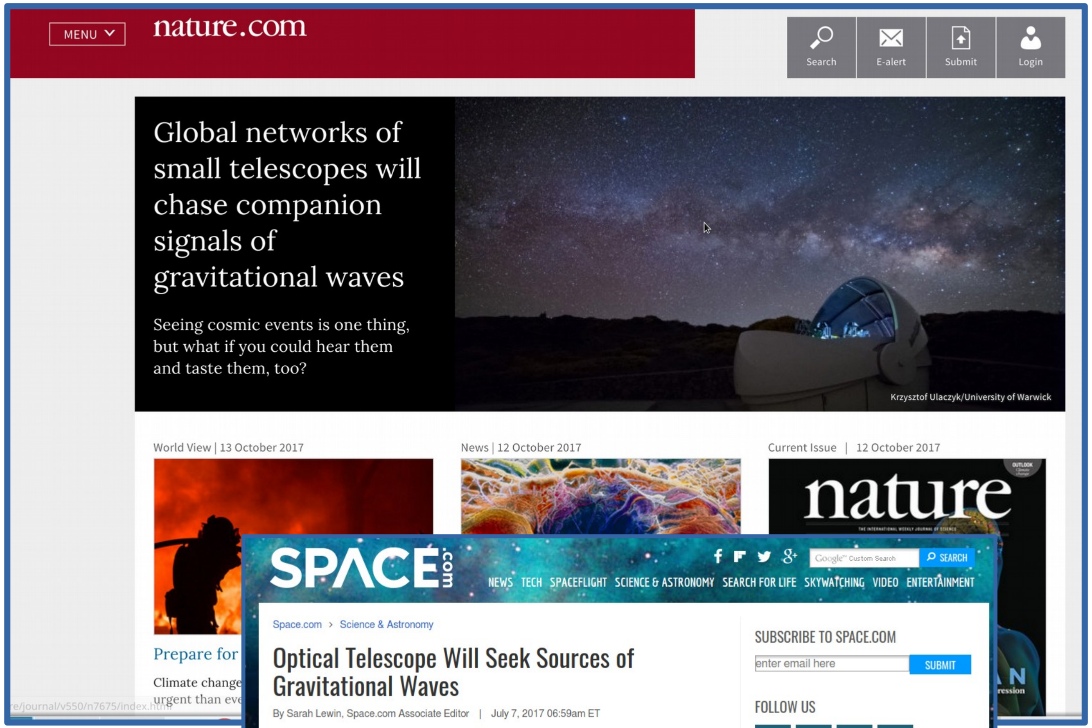
Feeder facility for follow-up

General time-domain facility




Astro Haven
ENTERPRISES

GOTO Interest



nature.com

Global networks of small telescopes will chase companion signals of gravitational waves

Seeing cosmic events is one thing, but what if you could hear them and taste them, too?

Krzysztof Ulaczyk/University of Warwick

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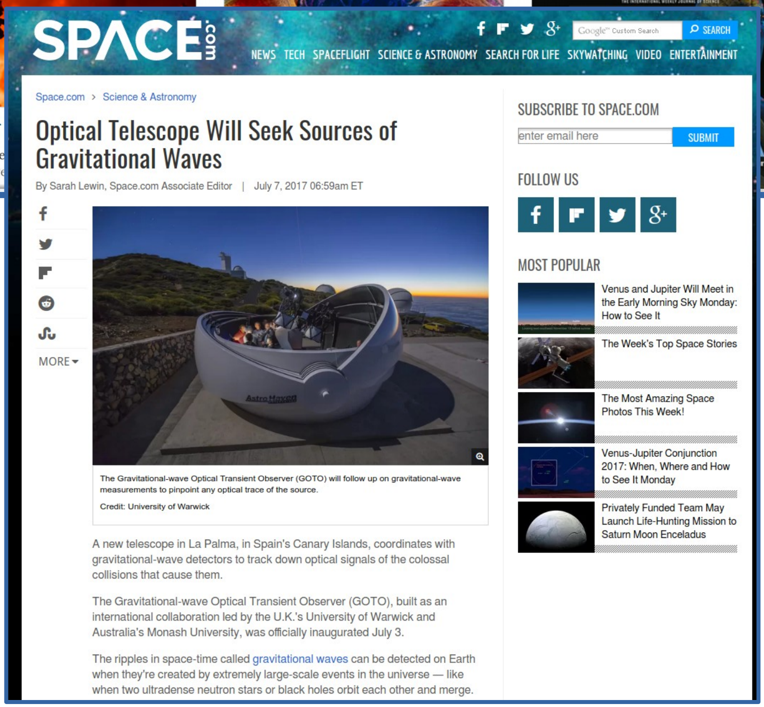
Prepare for

Climate change
urgent than eve



Space.com › Science & Astronomy

Optical Telescope Will Seek Sources of Gravitational Waves

By Sarah Lewin, Space.com Associate Editor | July 7, 2017 06:59am ET

The Gravitational-wave Optical Transient Observer (GOTO) will follow up on gravitational-wave measurements to pinpoint any optical trace of the source.

Credit: University of Warwick

A new telescope in La Palma, in Spain's Canary Islands, coordinates with gravitational-wave detectors to track down optical signals of the colossal collisions that cause them.

The Gravitational-wave Optical Transient Observer (GOTO), built as an international collaboration led by the U.K.'s University of Warwick and Australia's Monash University, was officially inaugurated July 3.

The ripples in space-time called gravitational waves can be detected on Earth when they're created by extremely large-scale events in the universe — like when two ultradense neutron stars or black holes orbit each other and merge.

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mission control

Chasing light from the crest of a wave

The Gravitational-wave Optical Transient Observer telescope will provide a rapid response to gravitational wave event triggers in order to locate optical counterparts for subsequent multi-wavelength follow-up, explains **Danny Steeghs**.

The past few years have seen the long-awaited era of gravitational wave (GW) astrophysics not just kick off, but proceed at a remarkable pace, with the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo consortium announcing several firm detections arising from black hole–black hole mergers. Corresponding signals at electromagnetic (EM) wavelengths were also expected for merger events involving neutron stars, promising a unique combination of constraints using both GW and EM measurements. We have just seen this hope vindicated by event GW 170817 (B. P. Abbott et al. *Phys. Rev. Lett.* **119**, 161101; 2017). This event was not only the first binary neutron star merger detected in GWs, but also offered a rich variety of EM signals in the days following the GW signal (B. P. Abbott et al. *Astrophys. J. Lett.* **848**, L12; 2017).

The ability of advanced gravitational wave detectors such as LIGO and Virgo to constrain the direction of the sources responsible for gravitational waves is limited. Thus, significant areas of the sky need to be scanned and searched over promptly in order to identify counterparts consistent with the GW signal. It is this specific challenge that was the motivation behind the Gravitational-wave Optical Transient Observer (GOTO) and drove the design decisions behind it. The sooner a viable EM counterpart can be identified following a GW detection, the more opportunities we have to study the inevitably short-lived source and its environment with our armada of follow-up telescopes and satellites. It was indeed thanks to a relatively good localization for GW 170817, that this challenge was made a little easier. For many events the expected search areas will be much larger.

GOTO employs an array of relatively modest wide-field optical telescopes with apertures of 40 cm and fast focal ratios whose individual fields of view (5 deg^2) can be combined to build up sky coverage. Its goal is to sweep large areas on the sky multiple times per night to a depth that should enable it to detect optical components from mergers within 100 Mpc or so — the horizon distances that are expected to be achieved by the GW arrays. A custom equatorial robotic mount has been developed that can hold up to eight such telescopes within a single dome enclosure, saving costs and avoiding the complexity of needing to operate many individual mounts within their own enclosures. This concept means the project is scalable: more unit telescopes can be deployed to build up capability, and different trade-offs can be made between field of view, survey speed, depth or filter coverage across the combined array. This is not only cost effective, but also ensures that the operational mode can evolve as we learn more about the properties of the EM signals.

The first components of the GOTO project (Fig. 1) were installed in June 2017 and are currently being commissioned at the Roque de los Muchachos Observatory on the island of La Palma, Spain. Survey work is expected to commence in late 2017. The facility is linked to a data centre at the University of Warwick in the UK by a fast network link. In the present initial phases, four telescopes are mounted on a shared mount, offering a field of view of up to 20 deg^2. An additional four telescopes that can be accommodated on the same mount are expected in early 2018. More are planned: a fully deployed site incorporates 16 telescopes split over two mounts and domes; an additional site in the Southern Hemisphere would be desirable to ensure full coverage of the sky.

The push towards even more telescopes addresses a second challenge in this effort: dealing with false positives. In order to identify viable counterparts, one needs to search a sizeable proportion of the sky. But the sky is full of variable and transient phenomena, and thus we need to be wary of unrelated sources that are active in the target area close in time to the GW detection. GOTO will spend most of its time in patrol mode in order to provide us with crucial information about ongoing activity in the sky in anticipation of GW signals. This in itself will be an excellent data set offering insights into a variety of short-lived phenomena, but will also increase the reliability and speed with which we can expect to identify viable GW counterparts. Faster is indeed better in this case. Over the next few months, the GOTO team will work hard to optimize its observing and data analysis strategy towards its principal goal, but at the same time is looking forward to a broad range of interesting time-domain science that can be pursued with GOTO.

GOTO is operated at the La Palma observing facilities of the University of Warwick on behalf of a consortium including the University of Warwick, Monash University, Armagh Observatory, the University of Leicester, the University of Sheffield, the National Astronomical Research Institute of Thailand (NARIT) and the Instituto de Astrofisica de Canarias (IAC).

Fig. 1 | The GOTO project is an array of telescopes on custom mounts inside clamshell domes at the Roque de los Muchachos Observatory in La Palma, Spain. It aims to find visible counterparts to gravitational wave-generating merger events.
Credit: K. Ulaczyk/University of Warwick

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Published online: 2 November 2017
https://doi.org/10.1038/s41550-017-0317-8