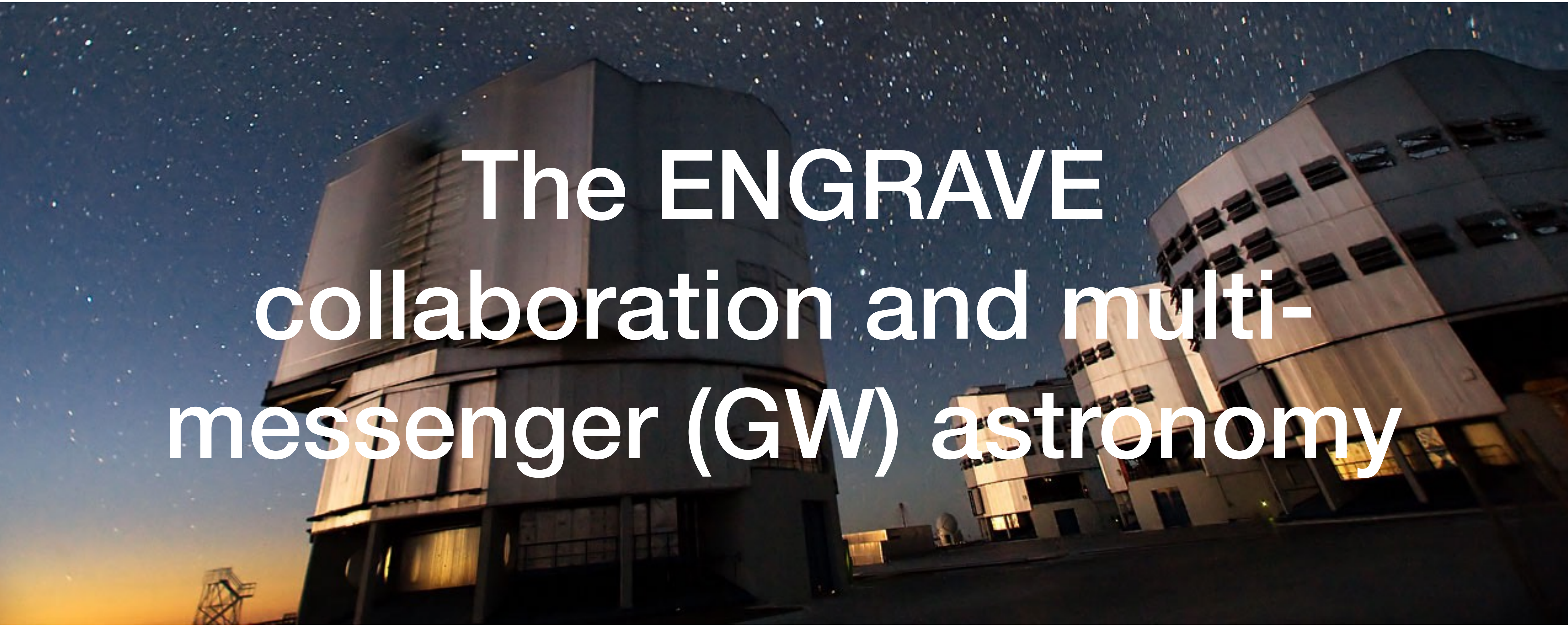
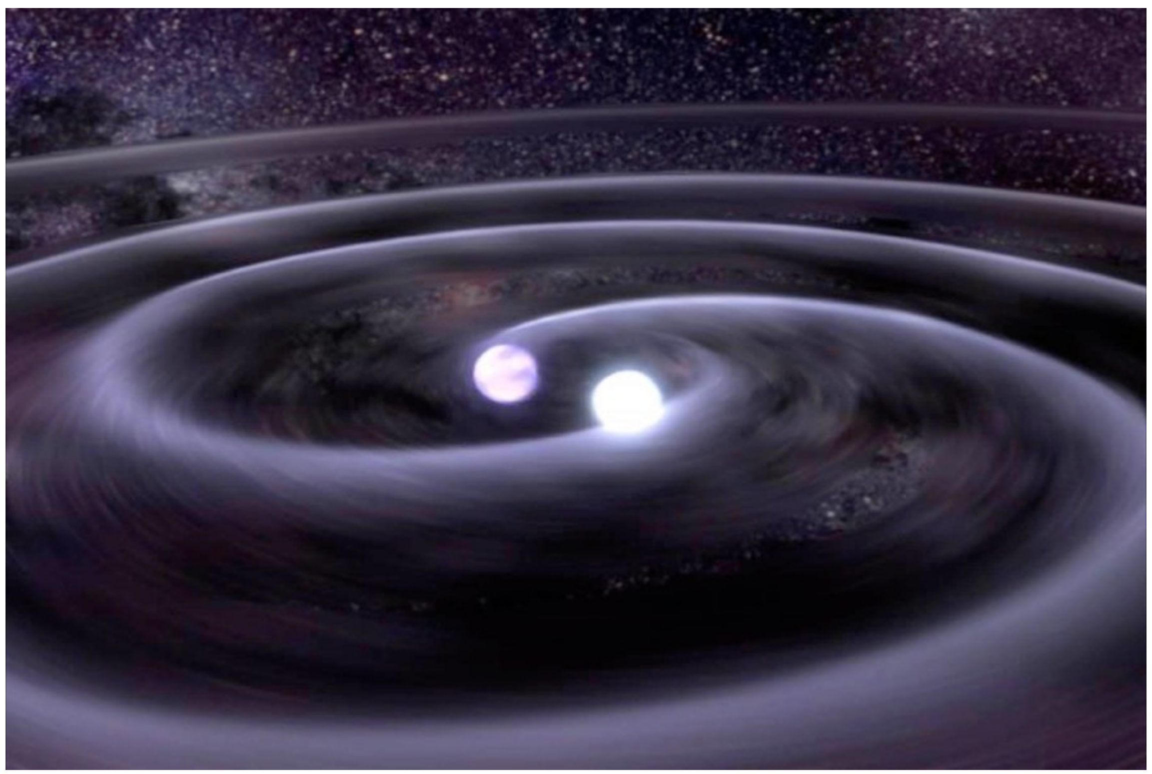
The ENGRAVE collaboration and multi-messenger (GW) astronomy

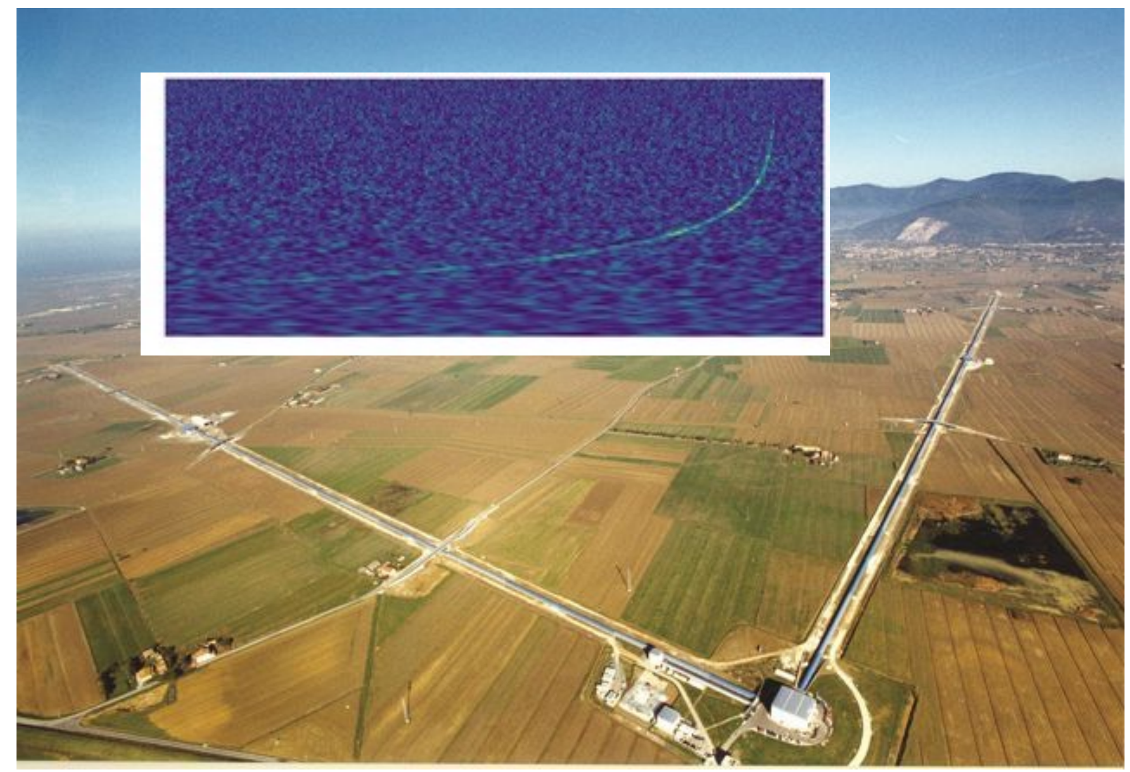


Morgan Fraser
University College Dublin
Royal Society – SFI University Research Fellow

Gravitational waves



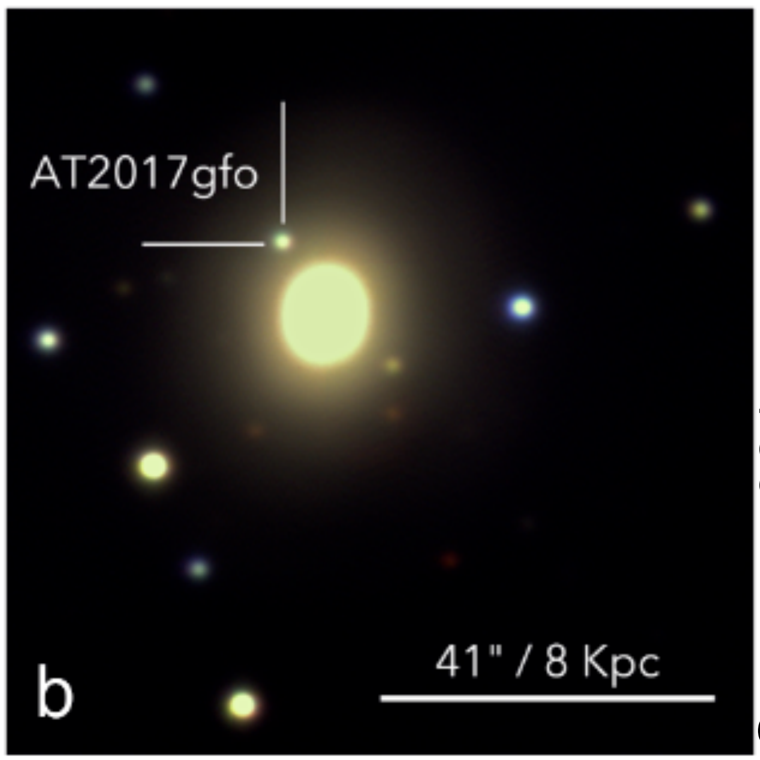
Neutron star / black hole binaries produce Gravitational Waves when they merge



Interferometers can detect and localise these GWs on the sky

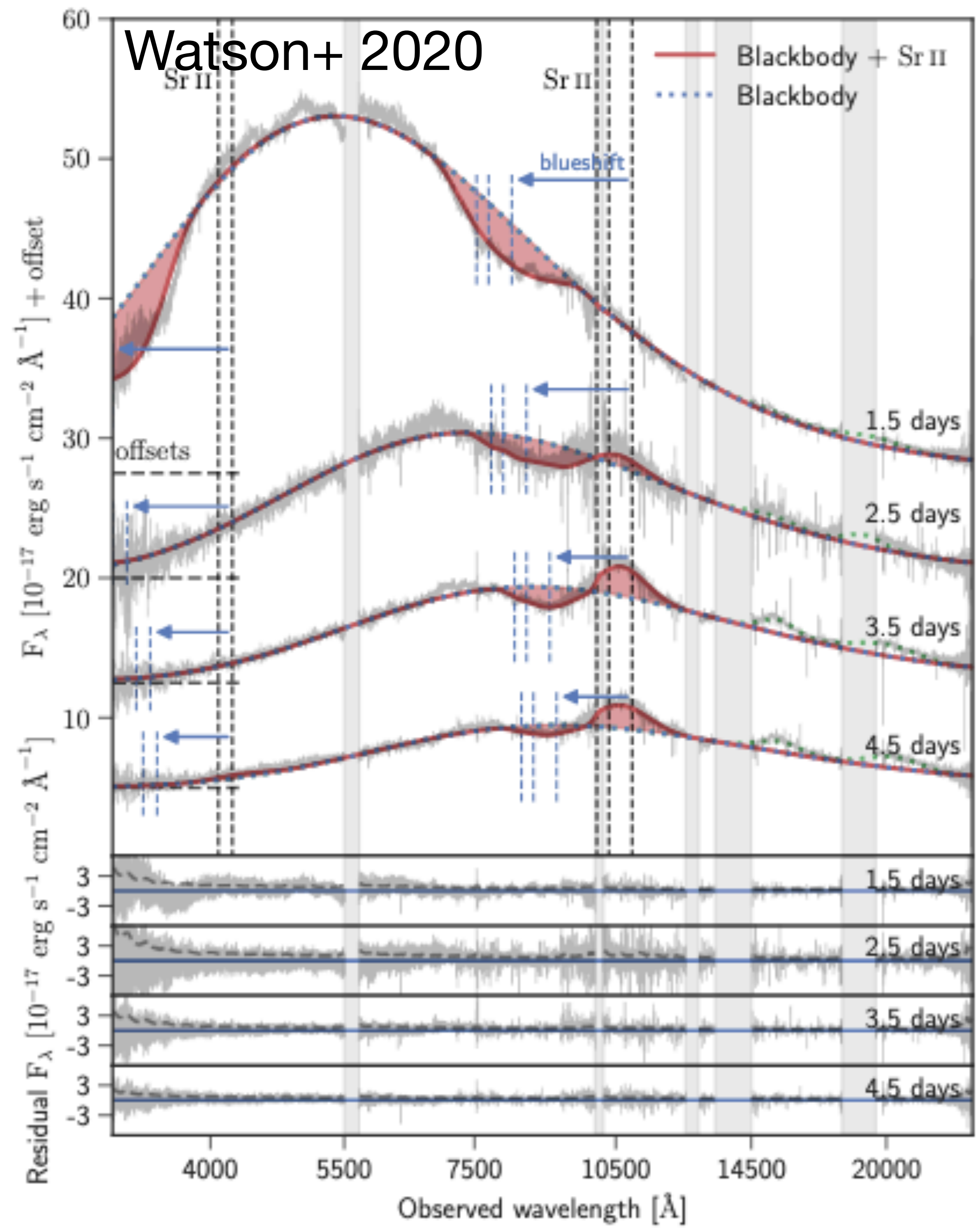
GW170817

We got lucky! 40 Mpc, and well localised (~30 sq deg)!

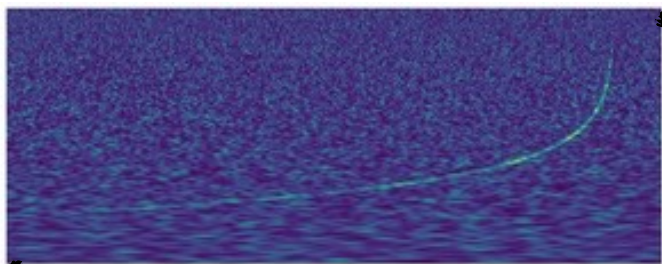


Smartt+ 2017

(also see many papers eg. Arcavi et al. 2017, Coulter et al. 2017, Lipunov et al. 2017,Soares-Santos et al. 2017, Tanvir et al. 2017, Valenti et al. 2017, Kahn et al. 2017, Haggard et al. 2017, Hallinan et al. 2017, Kasliwal et al. 2017, Margutti et al. 2017, Troja et al. 2017…

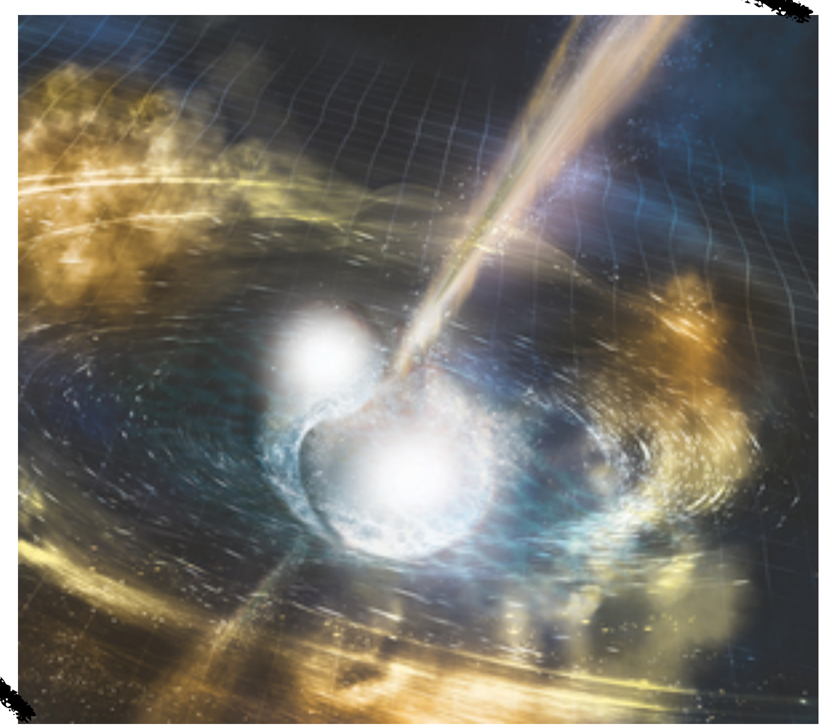


Goals of ENGRAVE



Heavy element budget of the universe!

Identify individual elements!



Measure H0

Contribution of different KN components (disk wind, ejecta)

Determine geometry of explosion. Jet structure?

Study matter at nuclear densities - NS EoS

Astrophysical pathways to mergers (environment, age etc)

GW190814

TITLE: GCN CIRCULAR
NUMBER: 25324
SUBJECT: LIGO/Virgo S190814bv: Identification of a GW compact binary merger candidate
DATE: 19/08/14 23:39:31 GMT
FROM: Geoffrey Mo at LIGO <geoffrey.mo@ligo.org>

The LIGO Scientific Collaboration and the Virgo Collaboration report:

We identified the compact binary merger candidate S190814bv during real-time processing of data from LIGO Hanford Observatory (H1), LIGO Livingston Observatory (L1), and Virgo Observatory (V1) at 2019-08-14 21:10:39.013 UTC (GPS time: 1249852257.013).
The candidate was found by the GstLAL [1], pycbc [2], MBTAOnline [3], and CWB [4] analysis pipelines.

S190814bv is an event of interest because its false alarm rate, as estimated by the online analysis, is 2e-33 Hz, or about one in 1e25 years. The event's properties can be found at this URL:

https://gracedb.ligo.org/superevents/S190814bv

The classification of the GW signal, in order of descending probability, is MassGap (>99%), Terrestrial (<1%), BNS (<1%), BBH (<1%), or NSBH (<1%). These values are based on point mass estimates which assigns an estimate of 100% to a single astrophysical class when the Terrestrial probability is very small. We will provide updates based on parameter estimation as soon as they become available.

Assuming the candidate is astrophysical in origin, there is strong evidence against the lighter compact object having a mass < 3 solar masses (HasNS: <1%). Using the masses and spins inferred from the signal, there is strong evidence against matter outside the final compact object (HasRemnant: <1%).

wo sky maps are available at this time and can be retrieved from the raceDB event page:
 a sky map generated by BAYESTAR [5] using data from the

Assuming the candidate is astrophysical in origin, there is strong evidence against the lighter compact object having a mass < 3 solar masses (HasNS: <1%). Using the masses and spins inferred from the signal, there is strong evidence against matter outside the final compact object (HasRemnant: <1%).

[4] Klimenko et al. PRD 93, 042004 (2016)
[5] Singer & Price PRD 93, 024013 (2016)

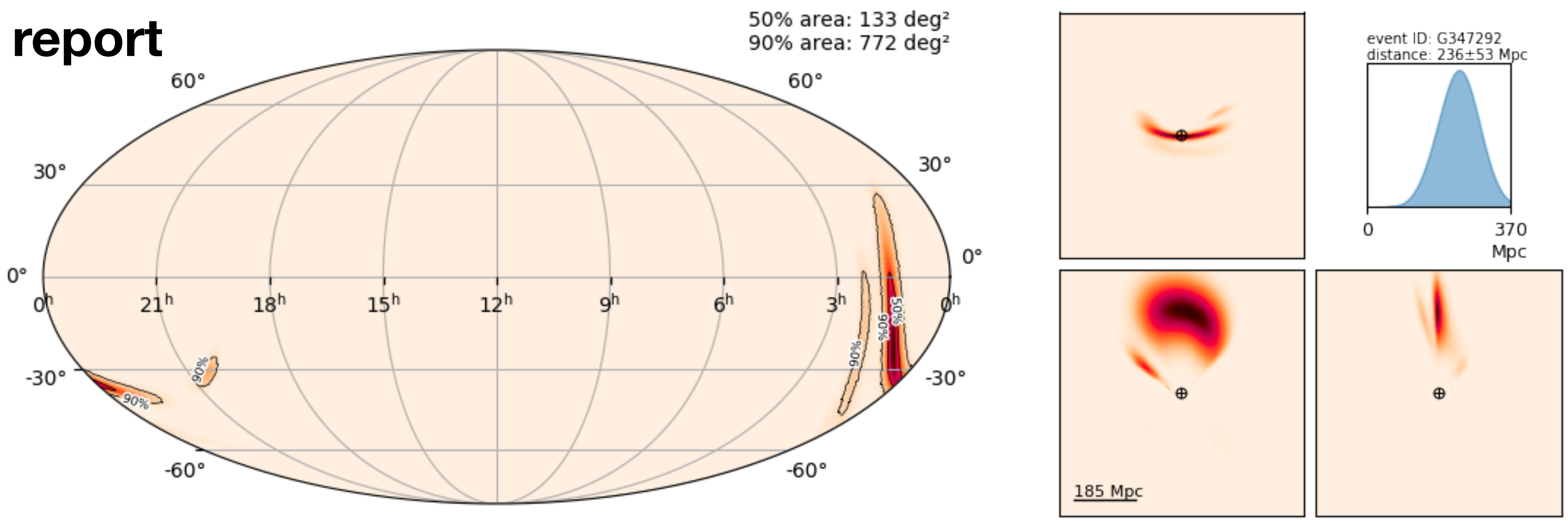
GW190814 was found by all three detectors. Very low FAR, and correspondingly small localisation. Also relatively nearby (~260 Mpc)

Initially 100% probability of **"Mass Gap"** (Either M_1 or M_2 in the range 3-5 M_{sun})

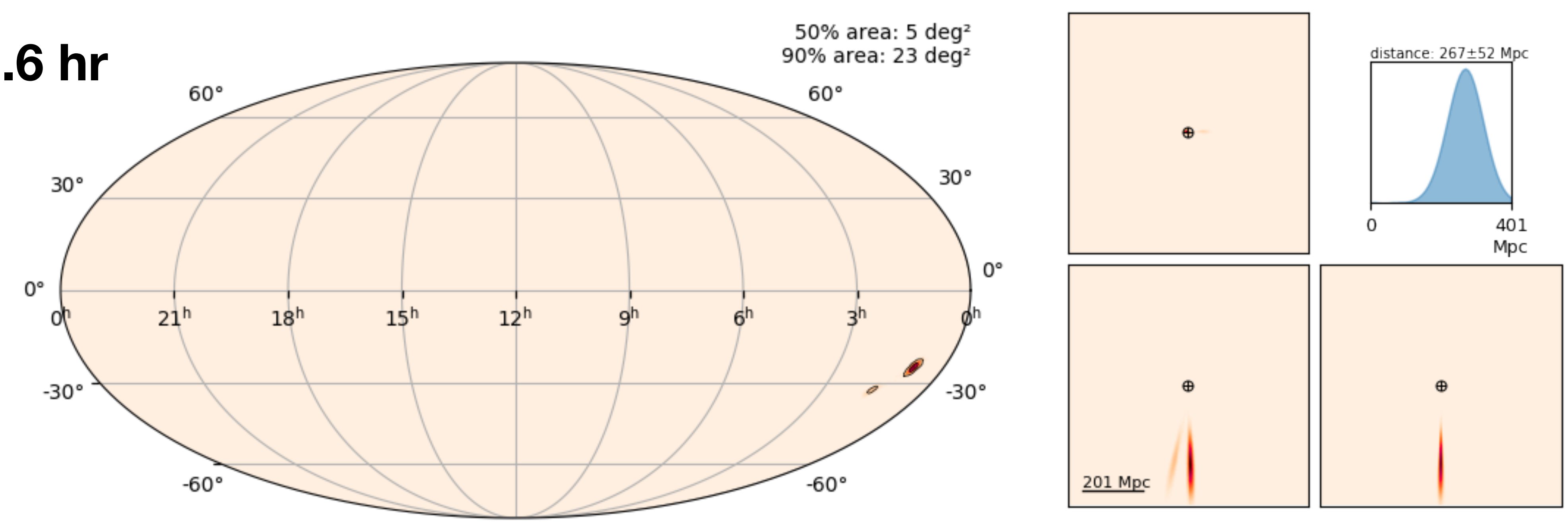
Revised to >99% probability **NSBH** ($M_1 > 5\ M_{sun}$, $M_2 < 3\ M_{sun}$)

Refined localisation

First report



+11.6 hr



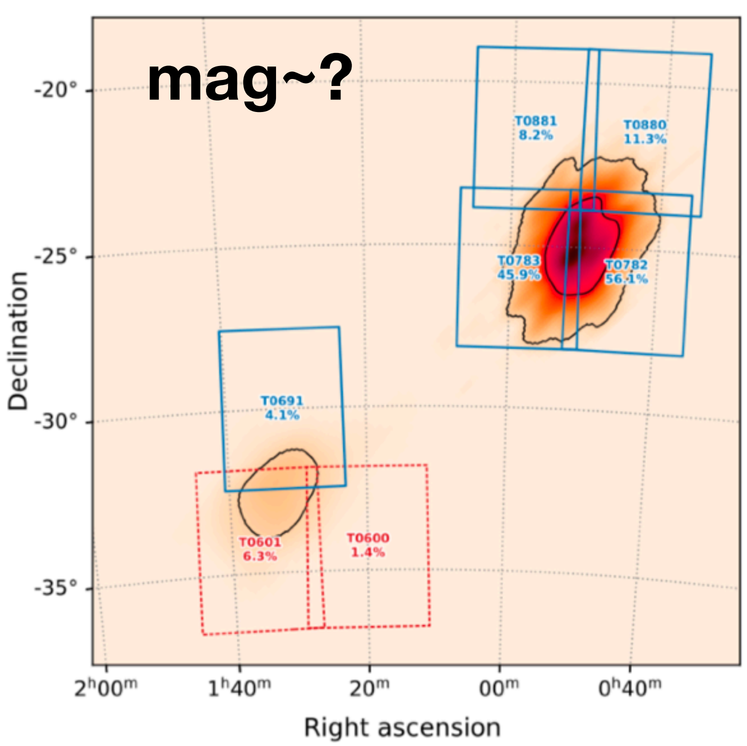
No major systematic shift between first and last maps!

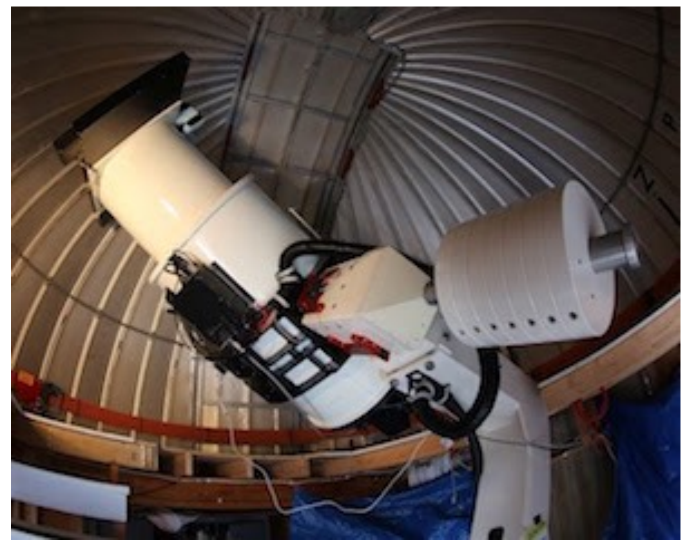
Response

- 21:10 UT, LIGO/VIRGO detects GW190814
- 21:32 UT, Alert received via SMS
- Channel created on Slack within a minute or two of alert, 6 active contributors to Slack discussion within first 10 mins.
- Galaxy lists from HOGWARTS within 8 mins of alert.
- Observations start as soon as possible…

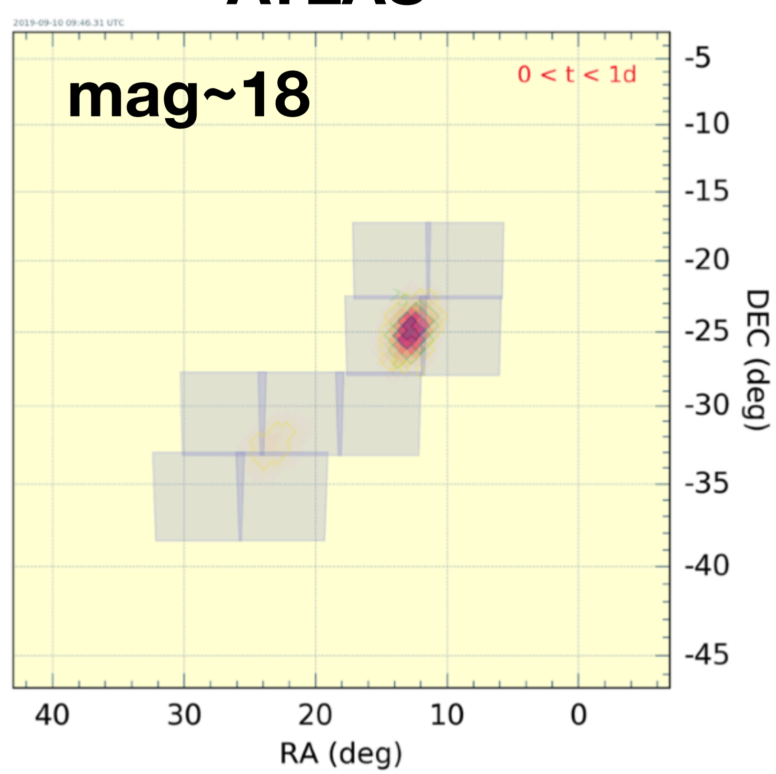
Wide-field followup

GOTO

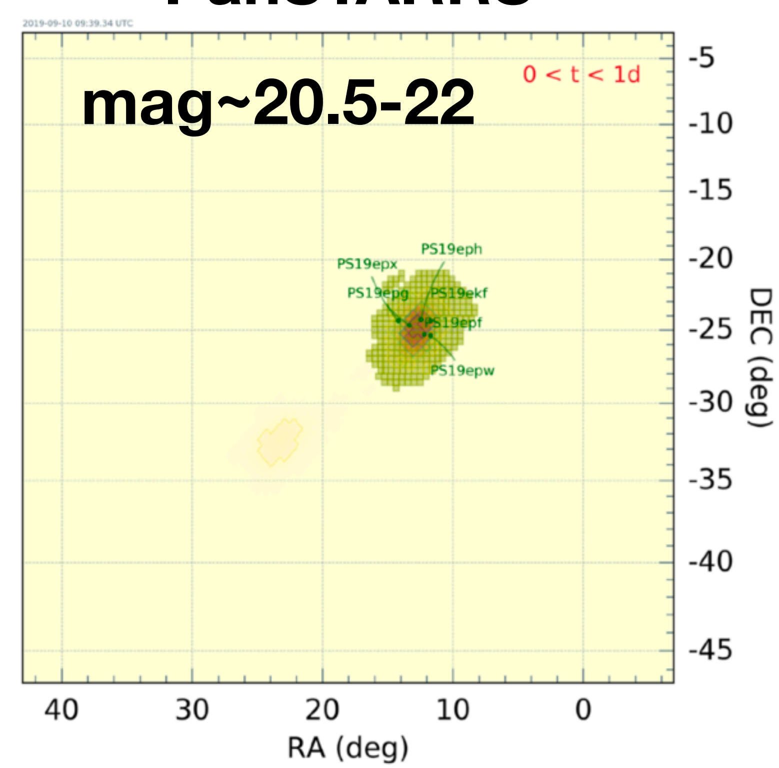




ATLAS



PanSTARRS



(Deeper) wide-field followup

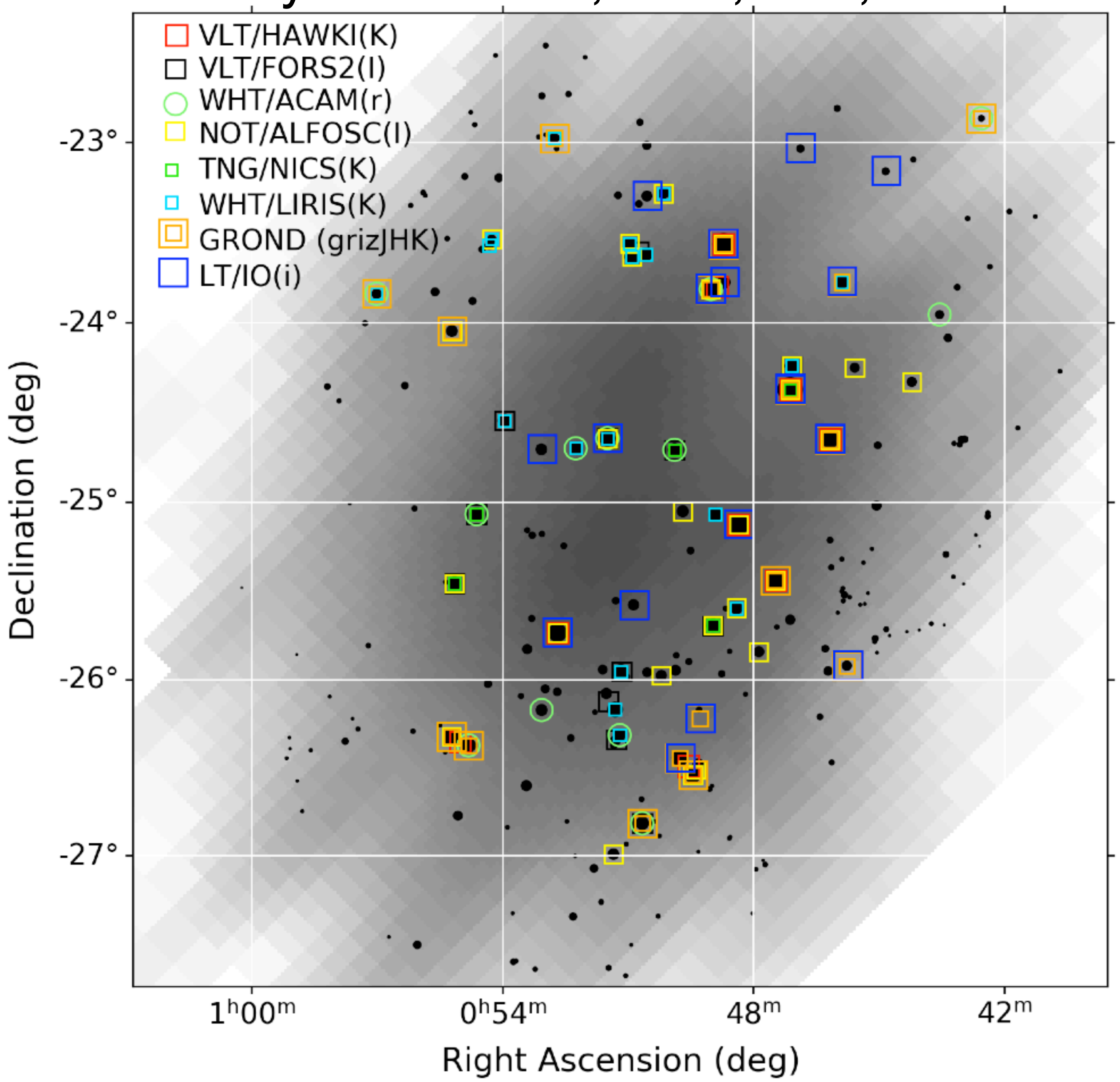
At 267 Mpc, a limiting mag of ~21 is an absolute mag limit -16.

In this case, shallower (ATLAS/GOTO) data not constraining.
VST and PanSTARRS ideal

Telescope	Start MJD	Time after GW	Probability Coverage	Limiting mag	filter
ATLAS	58709.52	-8.7 hrs	100%	18.0	c
GOTO	58710.03	+3.6 hrs	??89.6??%	??	L
VST	58710.37	+11.5 hrs	60.7%	20.9	r
Pan-STARRS1	58710.528	+15.50 hrs	89.4%	20.6, 20.3	i_{P1}, z_{P1}
ATLAS	58710.60	+17.23 hrs	100%	18.0	o
GOTO	58711.??	?? d	??94.1??%	??	L
VST	58711.2	+1.5 d	71.5%	21.9	r
ATLAS	58711.5	+1.6 d	100%	17.6	o
Pan-STARRS1	58713.5	+3.6 d	70.4%	21.6	z_{P1}
VST	58714.2	+4.3 d	87.7%	21.7	r
Pan-STARRS1	58716.5	+6.6 d	70.7%	22.3	z_{P1}
VST	58717.1	+7.2 d	87.7%	21.8	r
VST	58724.4	+14.5 d	87.7%	22.0	r

Combined targeted limits

Ackley et al. 2020, A&A, 643, 113

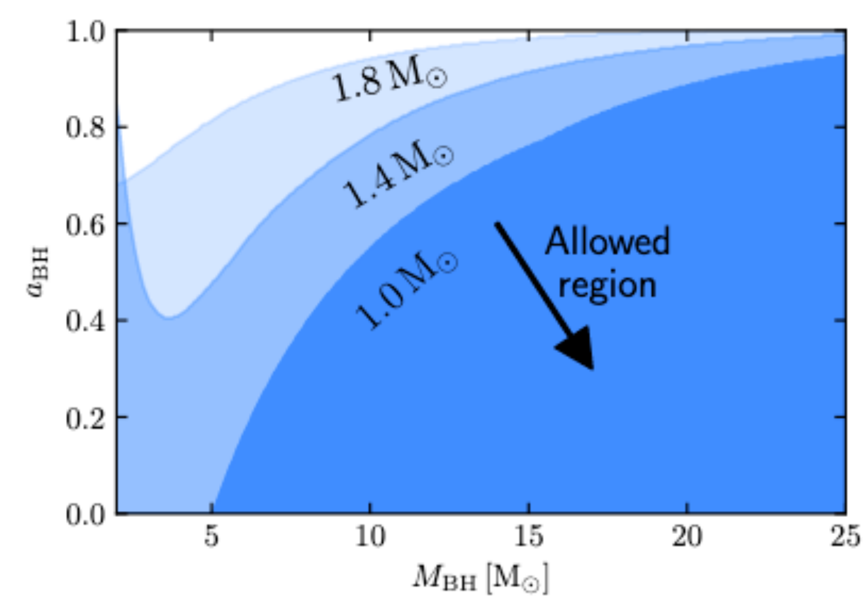


73 transients found!

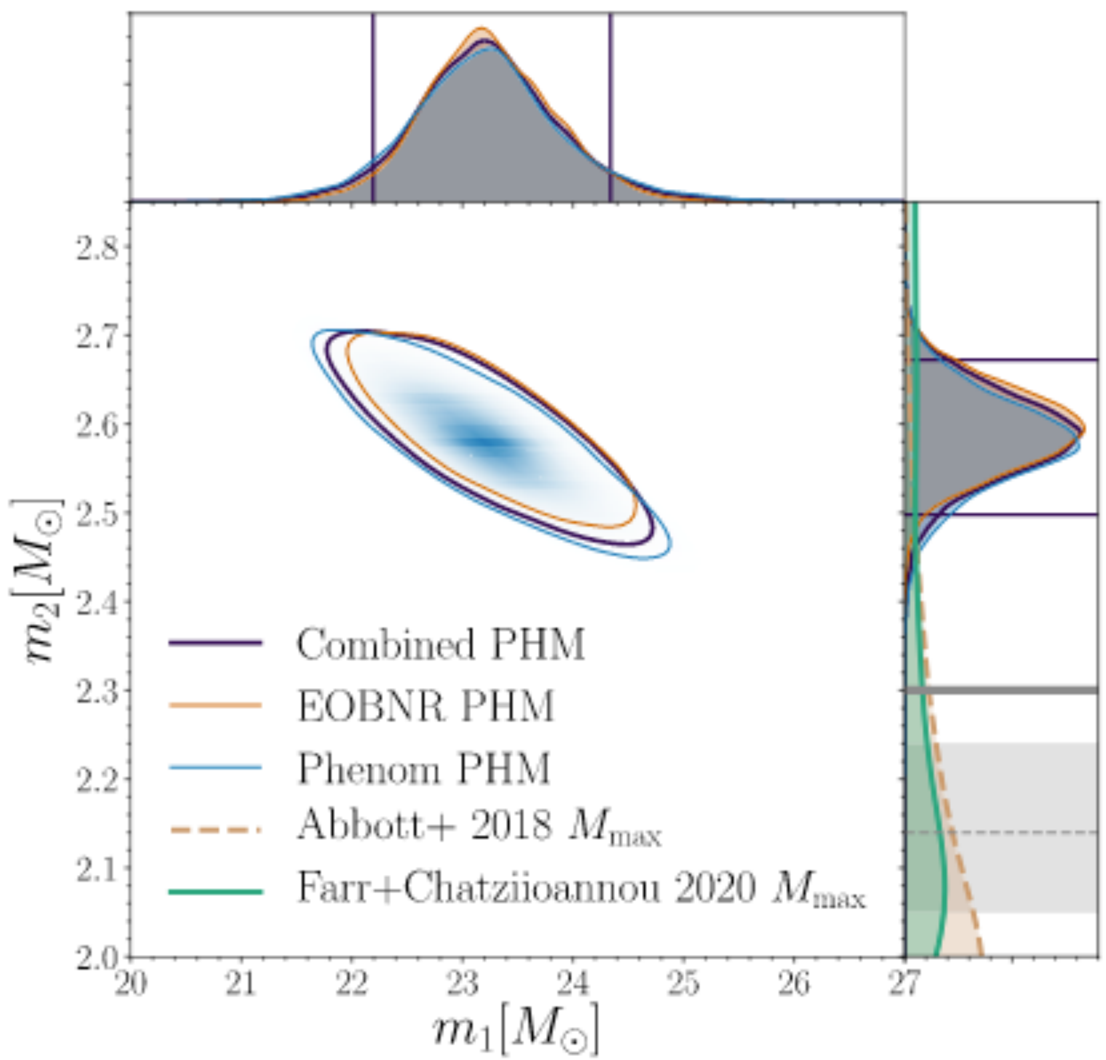
Majority conclusively ruled out (some where we have insufficient data to do so)

AGN variability, stellar flares, supernovae…

Non-detections can still give useful information…



GW190814

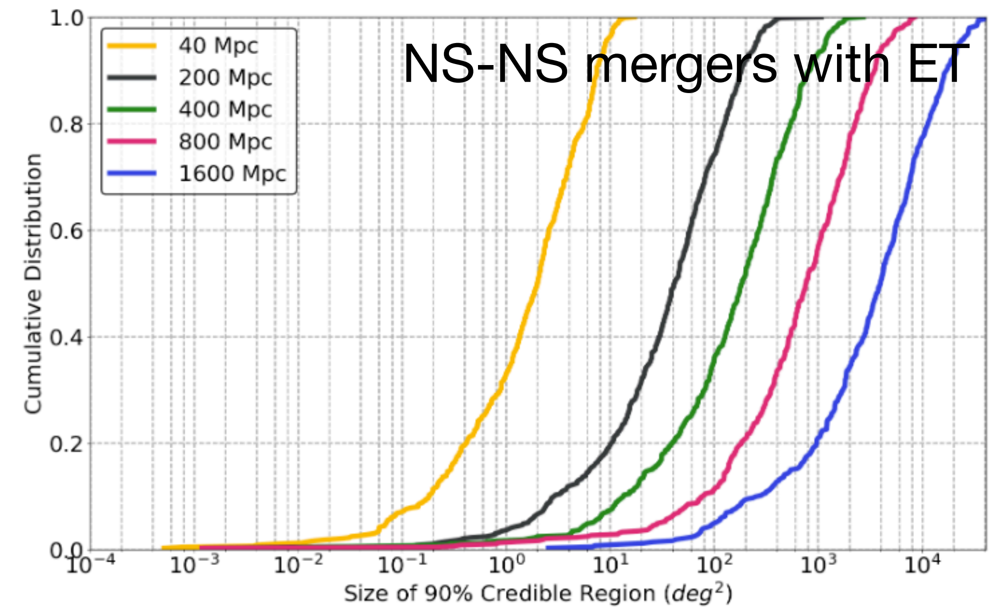


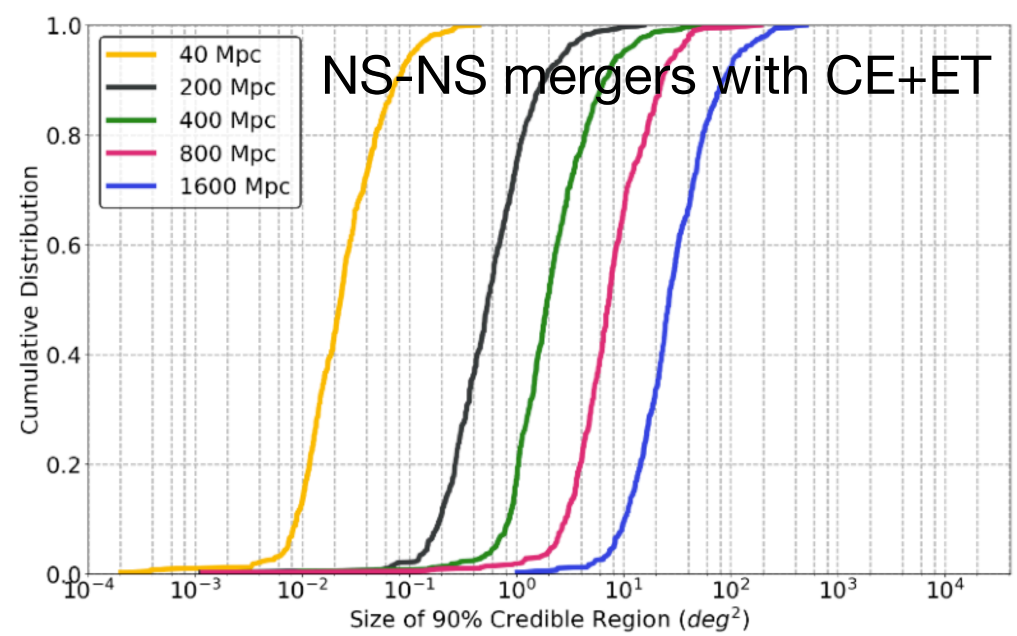
Abbott et al. (2020)
ApJ, 896, 44

Paper by LIGO/Virgo collaboration on GW190814 last year - likely a BH-BH merger (although possibly could be BH-NS depending on EoS)…

Take-away points

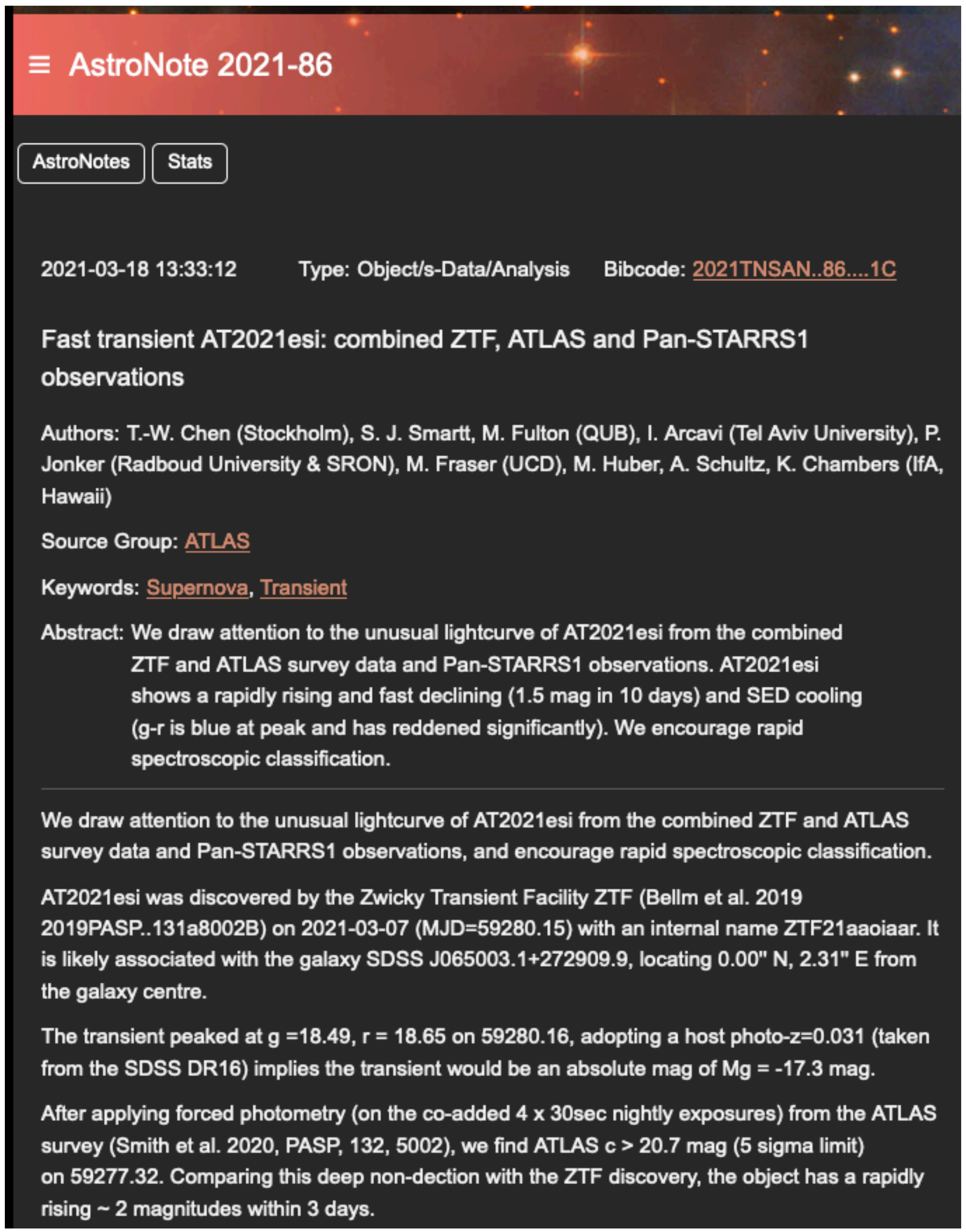
- We were lucky with GW170817!
- Need a large collaboration, lots of telescope time (across many sites), and a broad spread of expertise.
- At 250 Mpc we are swamped by contaminants!
- Shallow observations don't help for distant events - need to reach mag~21 at least.
- Localisation is key… (high energy helps)
- We were ***very*** lucky with GW170817!





Man Leong et al. (2018) PhRvD, 97, 123014

GW counterparts without a GW



≡ AstroNote 2021-86

AstroNotes Stats

2021-03-18 13:33:12 Type: Object/s-Data/Analysis Bibcode: 2021TNSAN..86....1C

Fast transient AT2021esi: combined ZTF, ATLAS and Pan-STARRS1 observations

Authors: T.-W. Chen (Stockholm), S. J. Smartt, M. Fulton (QUB), I. Arcavi (Tel Aviv University), P. Jonker (Radboud University & SRON), M. Fraser (UCD), M. Huber, A. Schultz, K. Chambers (IfA, Hawaii)

Source Group: ATLAS

Keywords: Supernova, Transient

Abstract: We draw attention to the unusual lightcurve of AT2021esi from the combined ZTF and ATLAS survey data and Pan-STARRS1 observations. AT2021esi shows a rapidly rising and fast declining (1.5 mag in 10 days) and SED cooling (g-r is blue at peak and has reddened significantly). We encourage rapid spectroscopic classification.

We draw attention to the unusual lightcurve of AT2021esi from the combined ZTF and ATLAS survey data and Pan-STARRS1 observations, and encourage rapid spectroscopic classification.

AT2021esi was discovered by the Zwicky Transient Facility ZTF (Bellm et al. 2019 2019PASP..131a8002B) on 2021-03-07 (MJD=59280.15) with an internal name ZTF21aaoiaar. It is likely associated with the galaxy SDSS J065003.1+272909.9, locating 0.00" N, 2.31" E from the galaxy centre.

The transient peaked at g =18.49, r = 18.65 on 59280.16, adopting a host photo-z=0.031 (taken from the SDSS DR16) implies the transient would be an absolute mag of Mg = -17.3 mag.

After applying forced photometry (on the co-added 4 x 30sec nightly exposures) from the ATLAS survey (Smith et al. 2020, PASP, 132, 5002), we find ATLAS c > 20.7 mag (5 sigma limit) on 59277.32. Comparing this deep non-dection with the ZTF discovery, the object has a rapidly rising ~ 2 magnitudes within 3 days.

- While we wait for O4, we can try and find a KN from optical survey data alone.
- Should be <200 Mpc, faint, fast rise and fast decline…
- So far, all have turned out to be cooling tail from shock breakout in SN, other contaminants!