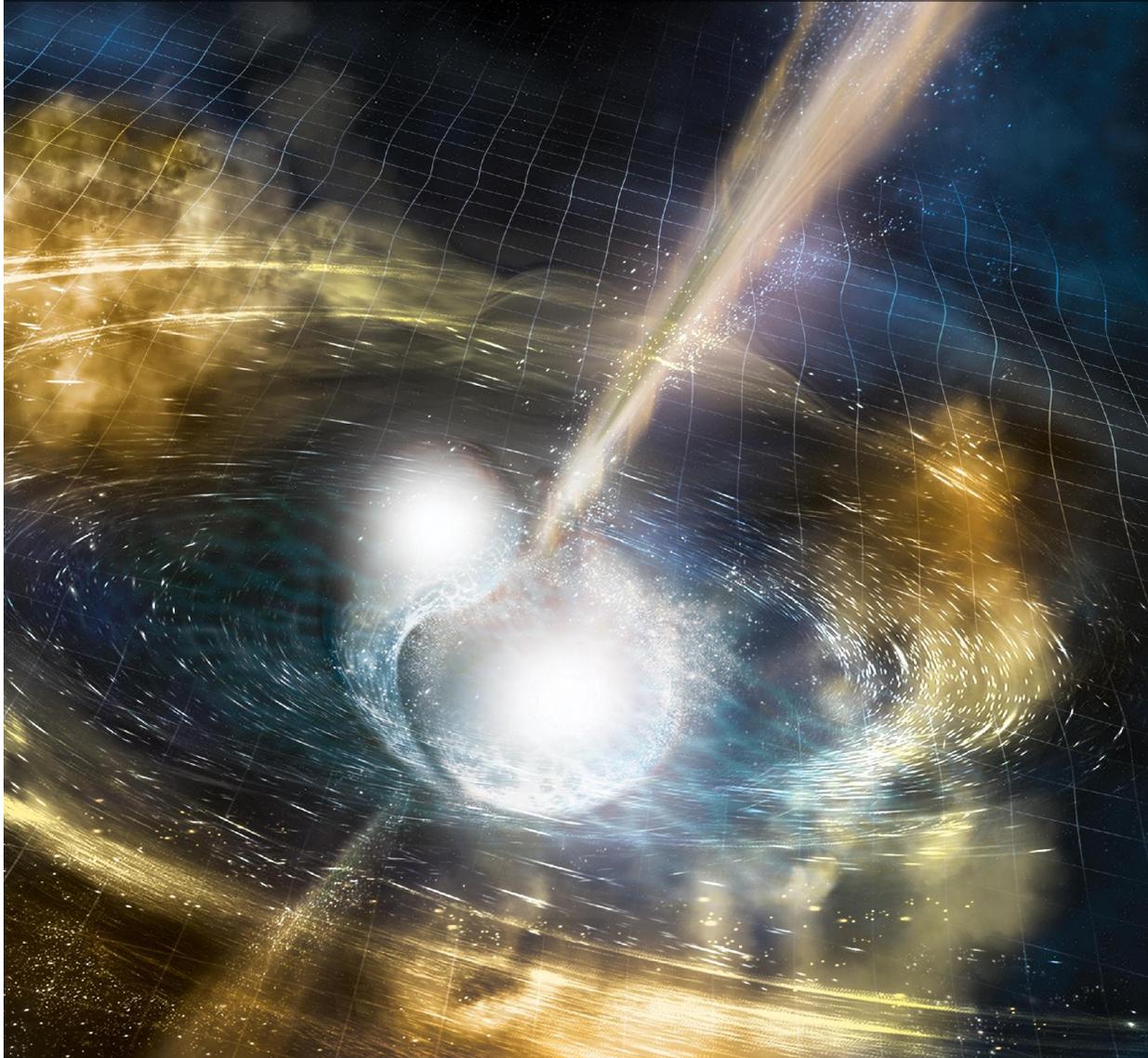


# Searching for prompt emission from binary neutron star mergers with LWA



Michael Kavic  
SUNY Old Westbury  
LWA User Meeting  
August 1<sup>st</sup>, 2019

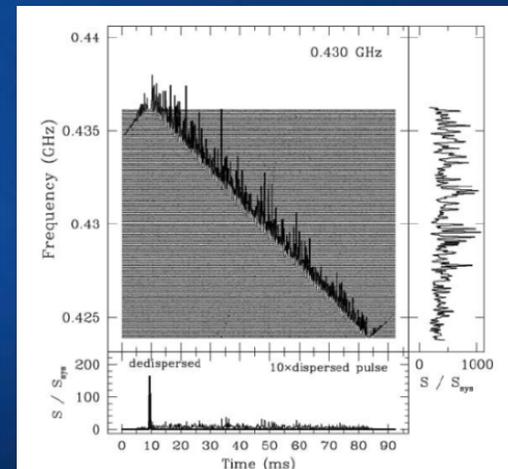
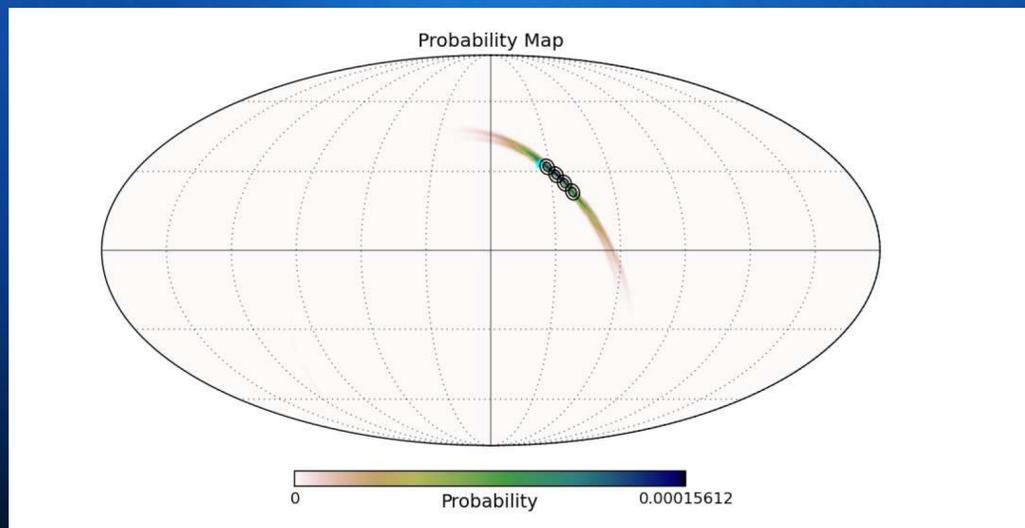
Collaborators: John Simonetti (VT),  
Chris League (LIU), Peter Shawhan (UMD)  
Jonah Kanner (Caltech), Jamie Tsai (VT)

# Outline

- Low frequency radio follow-ups to gravitational wave triggers
- GW170817
- LWA follow-up
- Outlook

# Follow-up observations at low frequency

- Simultaneous emission signals can be found by establishing a spatio-temporal search window for partner instruments.
- The LWA-1 station as a solitary instrument has 2 degree resolution at 80 MHz and 8 degree resolution at 20 MHz, at the zenith. LIGO produces probability sky-maps for candidate events which can be effectively tiled with beams.
- The dispersive delay for low frequency emission provides a window of time within which to respond to the GW trigger, for a  $DM=300 \text{ pc/cm}^3$  and  $\nu=40 \text{ MHz}$  the dispersive delay is  $\sim 13$  minutes.

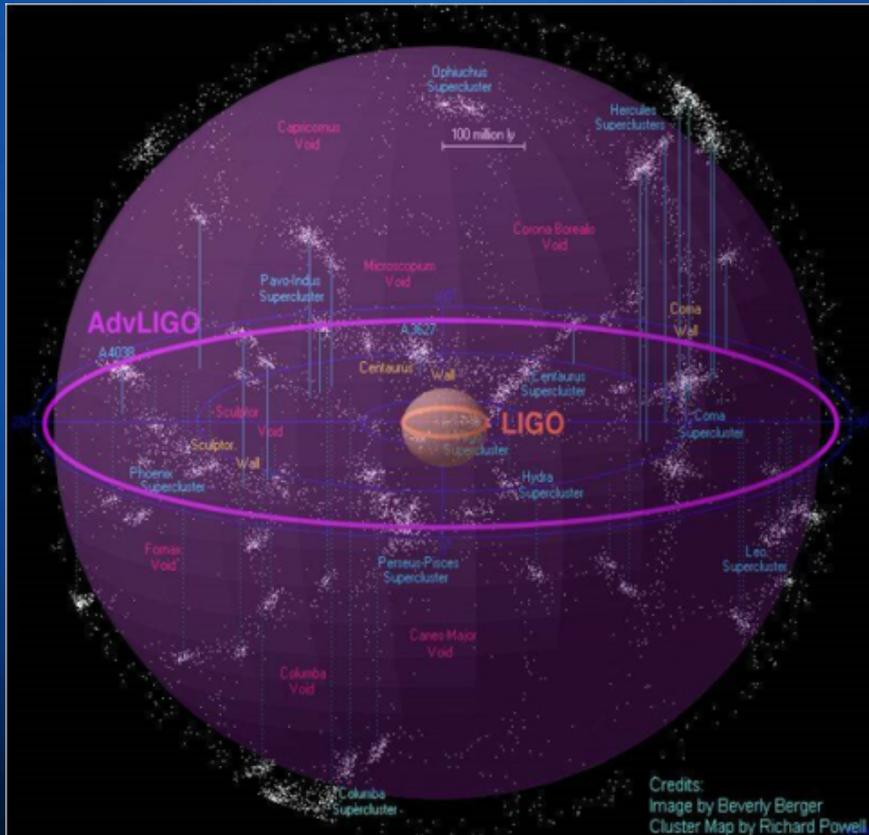
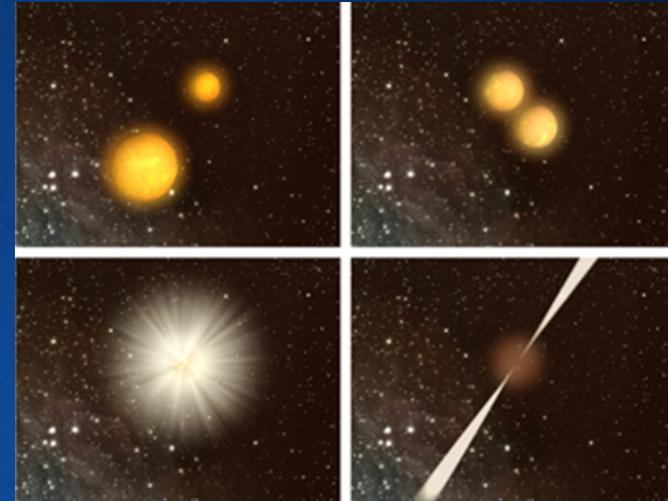


$$DM = \int n_e dl.$$

$$t_{\text{Dispersion}} = 4.2 DM \nu_{\text{GHz}}^{-2} \text{ ms.}$$

# Prompt Emission from NS-NS Mergers

**Neutron Star Binaries:**  
Advanced LIGO: ~ 200 Mpc



LWA-1 can detect these events out to ~1 Gpc.

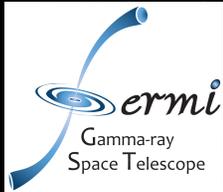
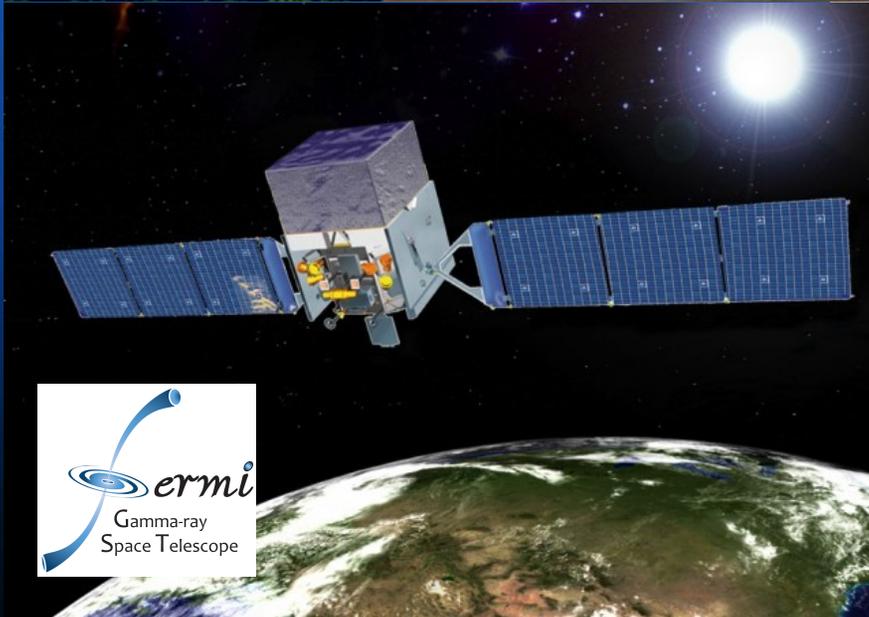
M.S. Pshirkov, K.A. Postnov *Astrophys. Space Sci.* 330 (2010)



Livingston, Louisiana

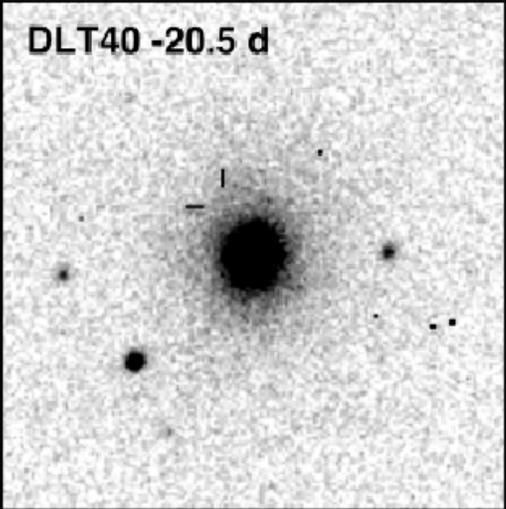
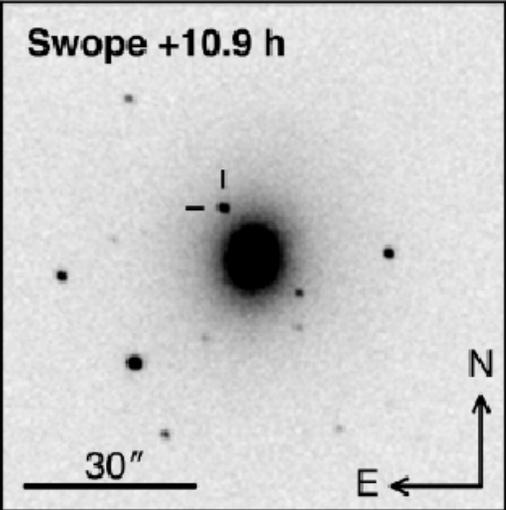
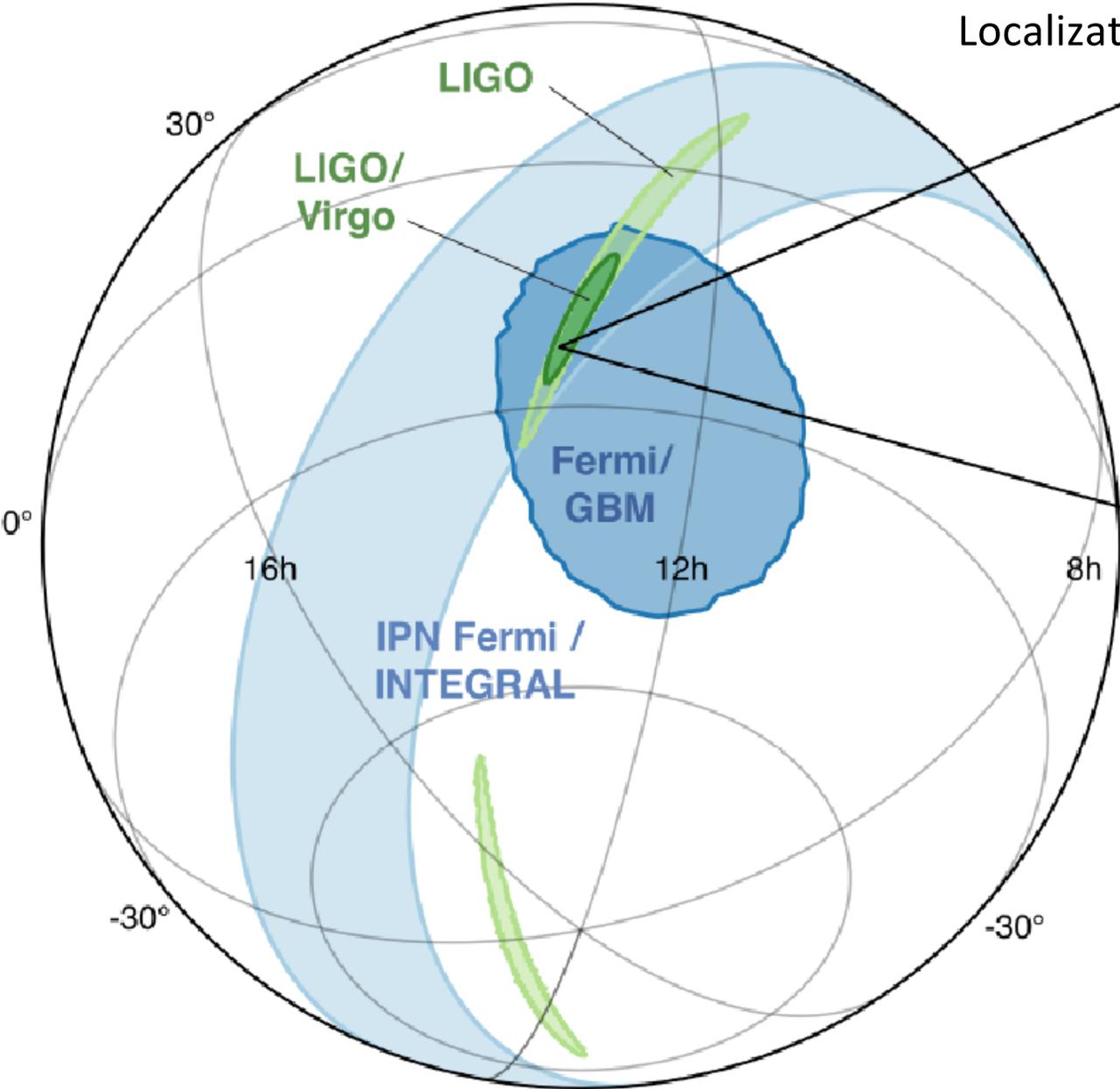


Hanford, Washington



Pisa, Italy

Localization of source on sky map

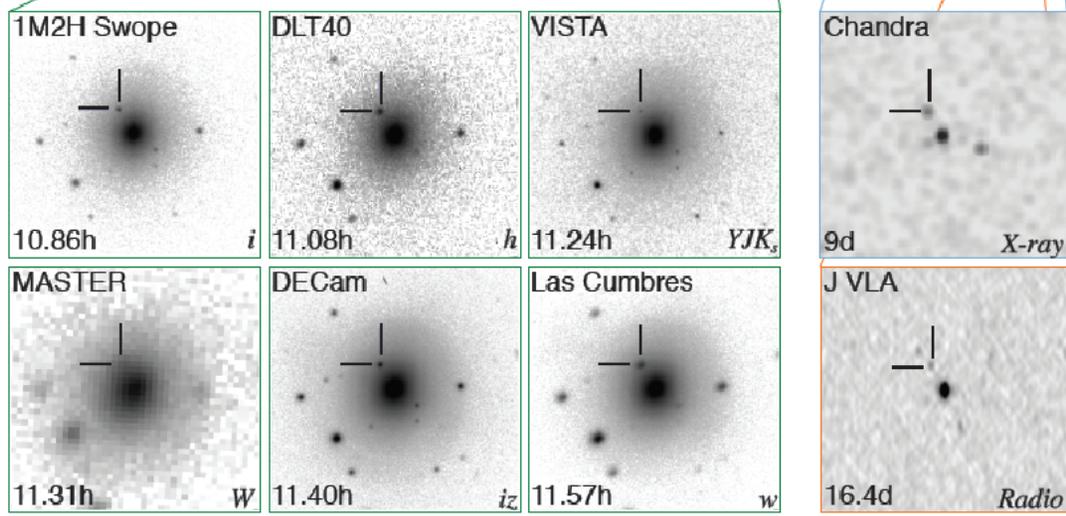
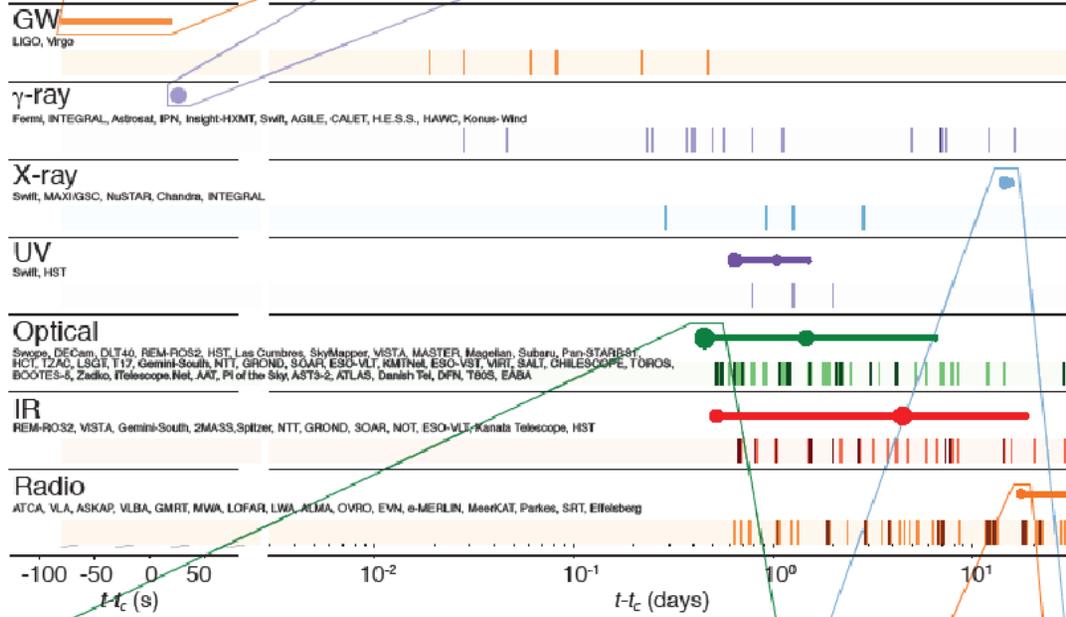
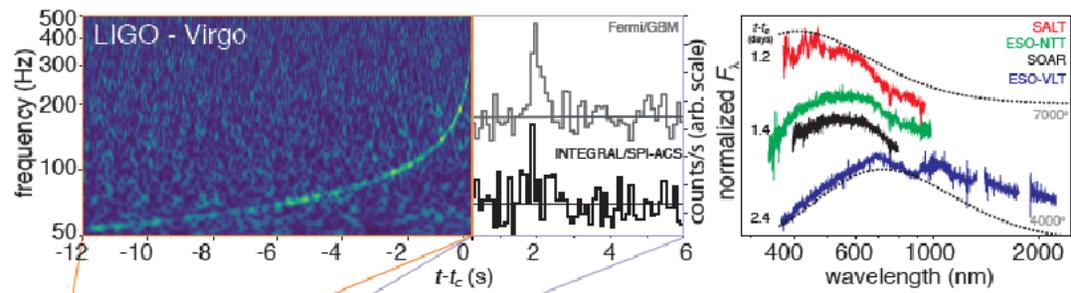


Earth

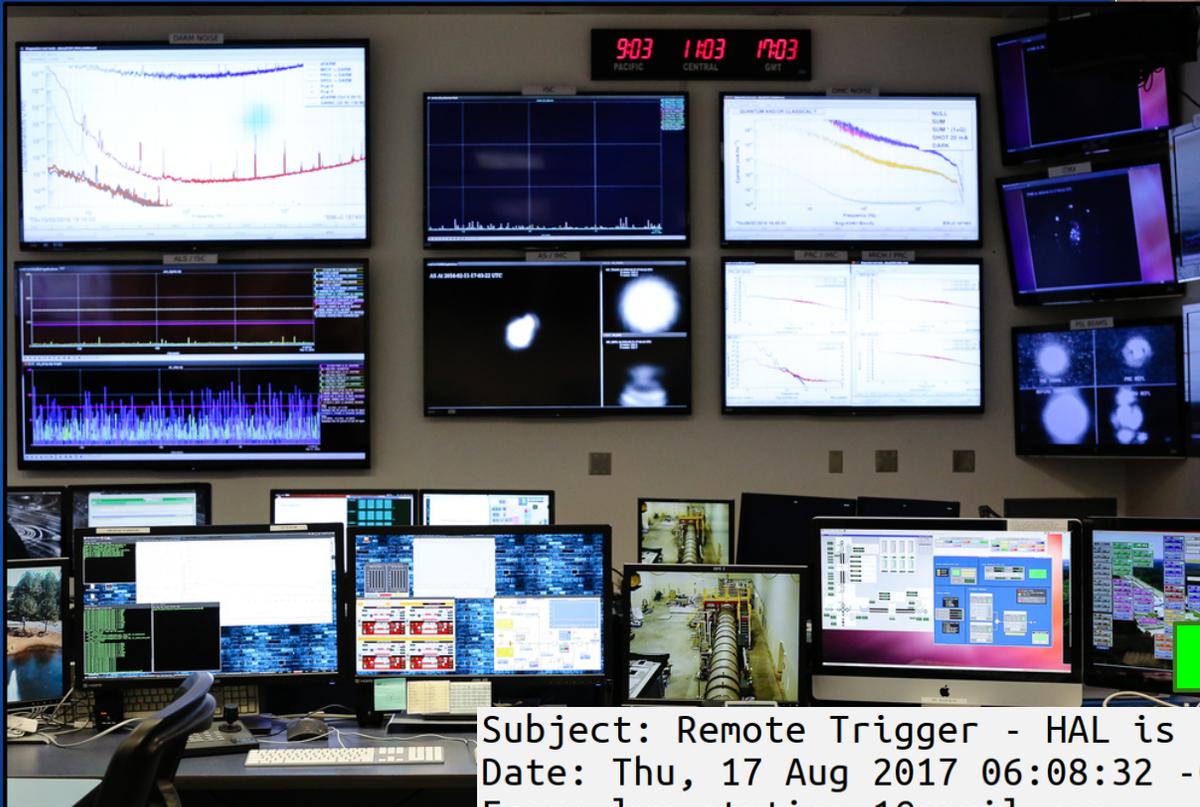
Space



GW & EM Observatories Map. Credit: LIGO-Virgo



# LIGO → LWA remote trigger

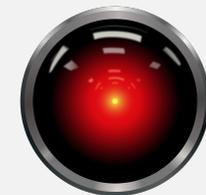


Control room at LIGO Livingston  
Photo by Paige Jarreau

- Trigger sent at 13:08:16 UTC.
- LWA began observations 1.58 mins later.



Subject: Remote Trigger - HAL is taking control of the station  
Date: Thu, 17 Aug 2017 06:08:32 -0700  
From: lwa.station.1@gmail.com  
Reply-To: lwa1ops@phys.unm.edu  
To: lwa1ops@phys.unm.edu



HAL is taking control of LWA1 in order to observe the LIGO trigger 'LVC\_Initial #298048' which occurred at 2017-08-17 12:41:03.999993. Observations will start at 2017-08-17 13:09:51 (0:28:47.000007 after the event) and continue until 2017-08-17 17:09:51 on beams #2, #3, #4, #1

The following 'at' commands have been canceled:

\* 32134

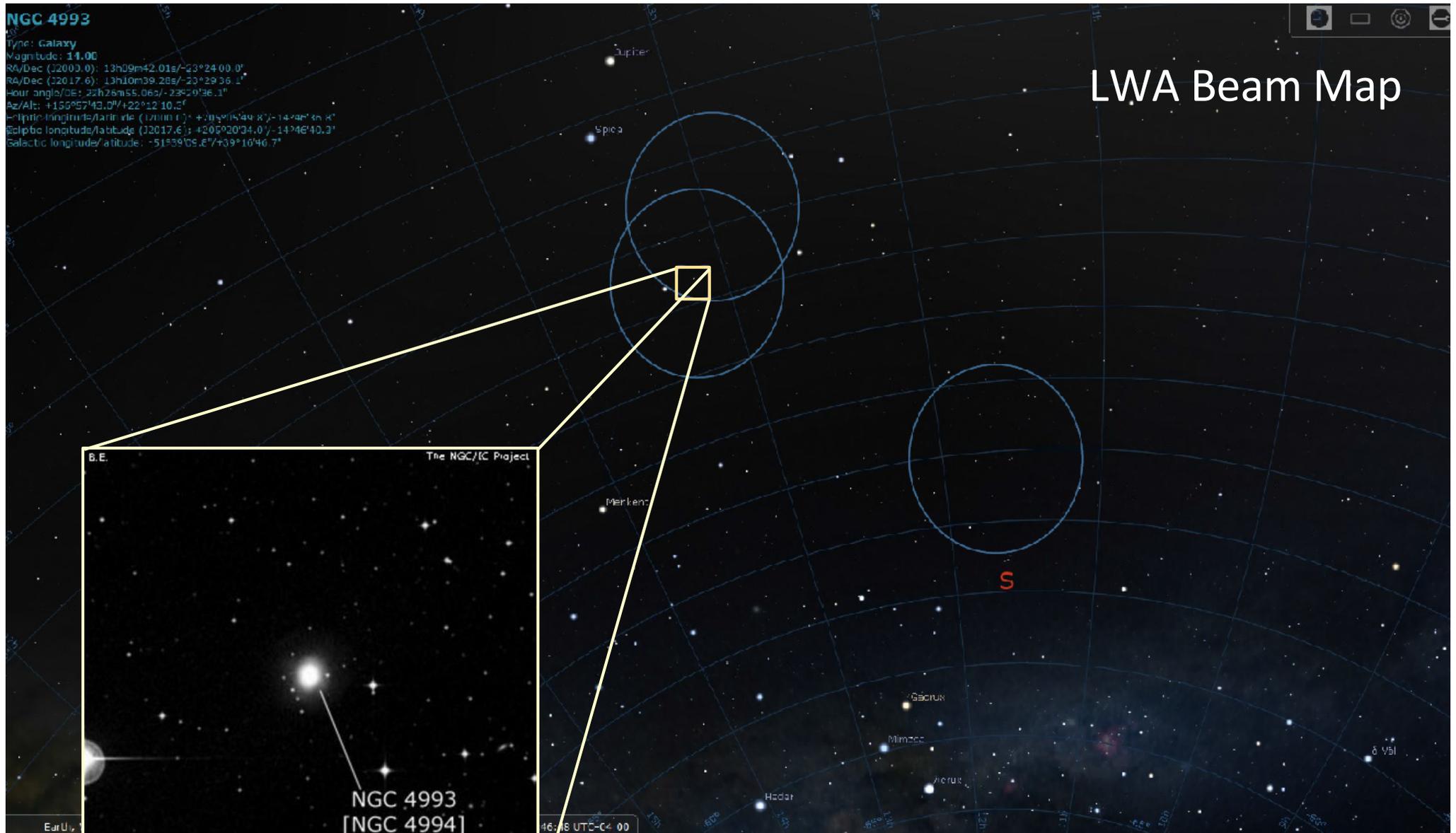
# NGC 4993

Type: Galaxy  
Magnitude: 11.00  
RA/Dec (J2000.0): 13h09m42.01s/-23°24'00.0"  
RA/Dec (J2017.6): 13h10m39.28s/-23°29'36.1"  
Hour angle/DE: 22h28m55.06s/-23°29'36.1"  
Az/Alt: +155°57'43.0"/+22°12'10.0"  
Elliptic longitude/latitude (J2000.0): +205°05'49.8"/-14°46'40.8"  
Ecliptic longitude/latitude (J2017.6): +205°20'34.0"/-14°46'40.3"  
Galactic longitude/latitude: +51°59'05.8"/+39°16'46.7"

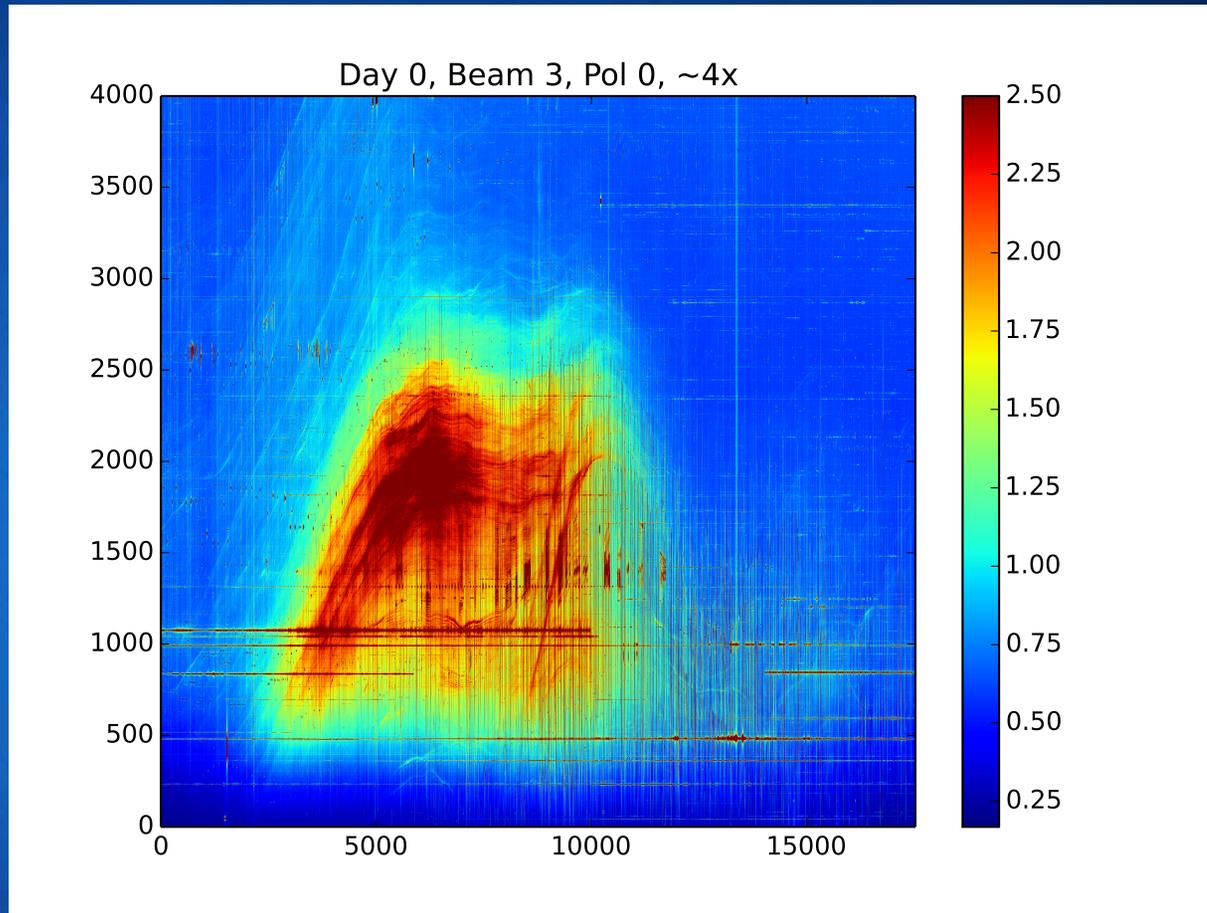
# LWA Beam Map



S



# LWA Observations



Telescope	UT Date	Time since GW Trigger (days)	Central Frequency (GHz)	Bandwidth (GHz)	Flux ( $\mu$ Jy), $3\sigma$	GCN/Reference
LWA1	Aug 17 13:09:51 UTC	0.02	0.02585	0.020	...	Callister et al. (2017a)
LWA1	Aug 17 13:09:51 UTC	0.02	0.04545	0.020	...	Callister et al. (2017a)
LWA1	Aug 17 19:15:00 UTC	0.27	0.02585	0.020	$<2 \times 10^8$	Callister et al. (2017a)
LWA1	Aug 17 19:15:00 UTC	0.27	0.04545	0.020	$<1 \times 10^8$	Callister et al. (2017a)

# GW170817: Summary

- NGC 4993 distance: 40 Mpc (130 M light year)
- Masses:
  - $(0.86 - 1.36) M_{\text{sun}}$  and  $(1.36 - 2.26) M_{\text{sun}}$
  - Total  $2.8 M_{\text{sun}}$
- 84 EM Telescopes involved
  - gamma ray: 11
  - x-ray: 5
  - UV: 2
  - Optical: 38
  - IR: 12
  - Radio: 16



# Current status and prospects

- LWA effectively followed-up on GW170817.
- The latencies and localization currently achievable are adequate to observe prompt emission.
- The aLIGO O3 science runs is underway.
- 20 detections but no additional NS-NS merges have been observed.
- NS-BH detection!?!? (S190426c)
- Searching for prompt emission from NS-NS mergers with LWA has a bright future!