DIRECT DETECTION OF GRAVITATIONAL WAVES FROM NEUTRON STARS

Topic:
Gravitational waves and neutron stars

Concepts:
General relativity and interferometry

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LIGO-G1702384-v3

Image credit: Karan Jani/GaTech

The Discovery

On August 17, 2017, the Laser Interferometer Gravitational-wave Observatory (LIGO) and Virgo detected, for the first time, a **gravitational wave** signal from a binary **neutron star merger**.

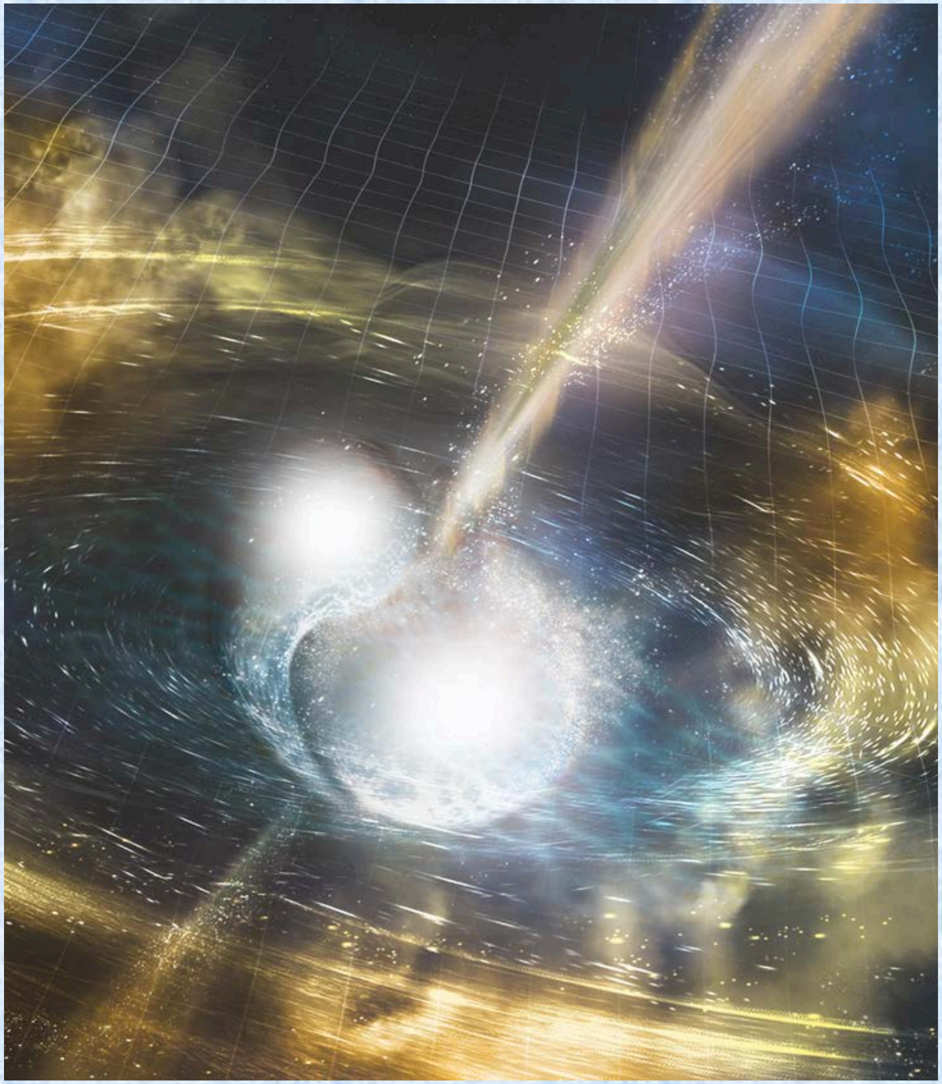
The event was also seen in gamma rays by the Fermi Gamma-ray Space Telescope.

Analysis of the LIGO & Virgo signal patterns pointed telescopes to a small sky region to look for a possible optical counterpart.

The event was then seen in light by dozens of ground- and space-based telescopes.

Known as **GW170817**, this was the first cosmic event viewed both in gravitational waves and light.

Neutron stars are the smallest, densest stars known; they form when massive stars explode in supernovas leaving behind a collapsed core of nuclear matter.

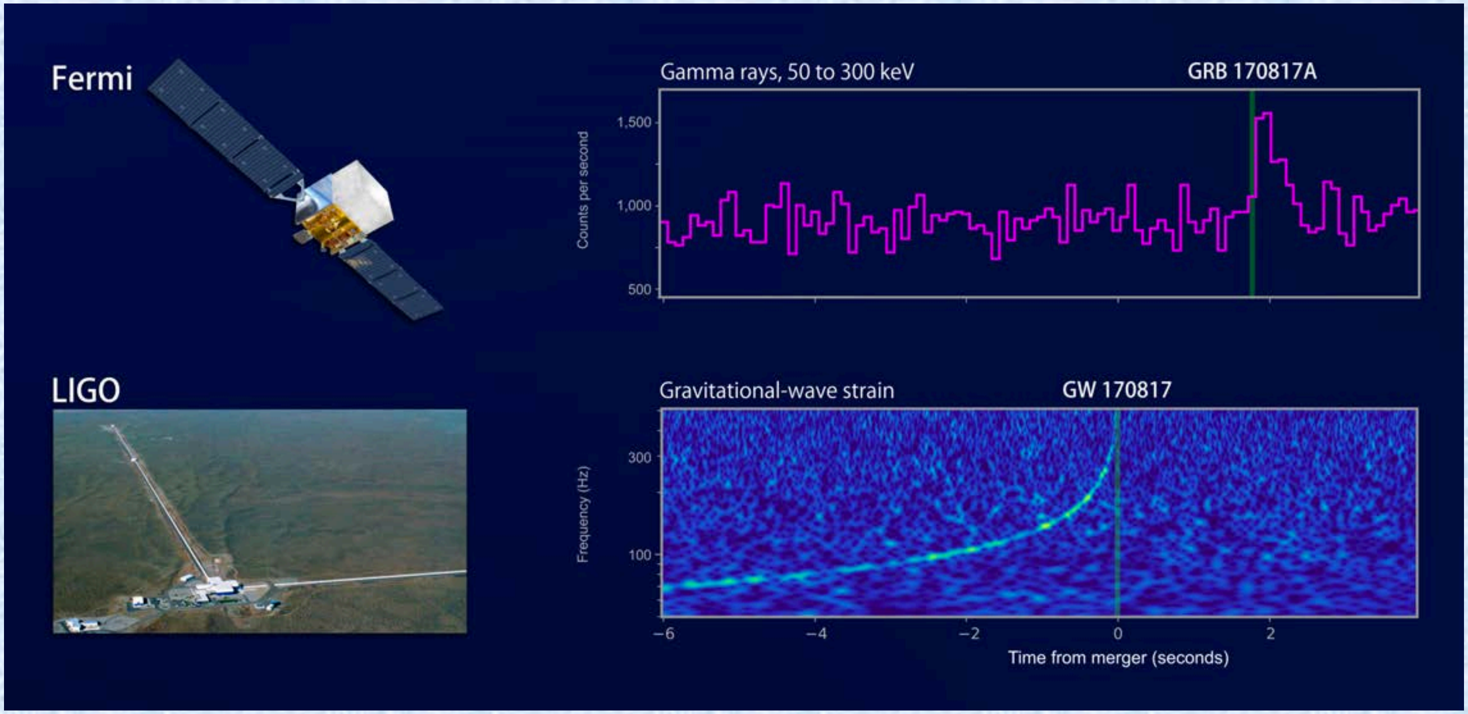


Artist's illustration of two merging neutron stars Spacetime ripples were detected by LIGO & Virgo.
Image Credit:NSF/LIGO/Sonoma State University/A.Simonnet

Discovery Method

The inspiraling **GW170817 neutron stars** emitted gravitational waves that were detectable for about 100 seconds; when they collided, a flash of **gamma rays** was emitted and seen by NASA's Fermi Space Telescope about two seconds after the gravitational waves. The **gamma ray burst** was soon confirmed by the European Space Agency's gamma-ray observatory INTEGRAL.

In the hours, days and weeks following the collision, other forms of light, or electromagnetic radiation — including X -ray, ultraviolet, optical, infrared, and radio waves — were detected by about 70 light-based observatories.

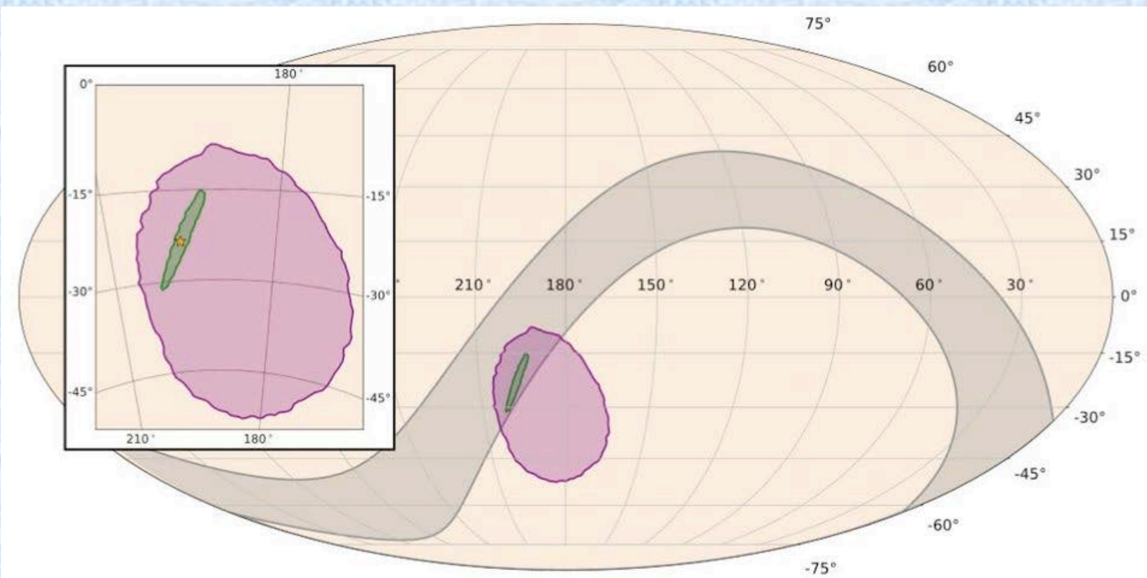


Credit: NASA.GSFC

Localization

The LIGO & Virgo data provided a sky-map narrowing down the possible location of the source of the gravitational waves. This location sits inside the regions of the sky estimated to contain the source of the gamma ray burst as determined by Fermi and INTEGRAL.

Detection of **GW170817** in many forms of electromagnetic radiation further narrowed its location. The source was discovered in visible light from galaxy NGC 2993, some 130 million light years distant



LIGO-Virgo skymap (green), and Fermi (purple) and INTEGRAL (grey) gamma-ray sources. Inset shows position of the galaxy NGC2993 (orange star) containing the source observed in light. Credit: NASA/ESO

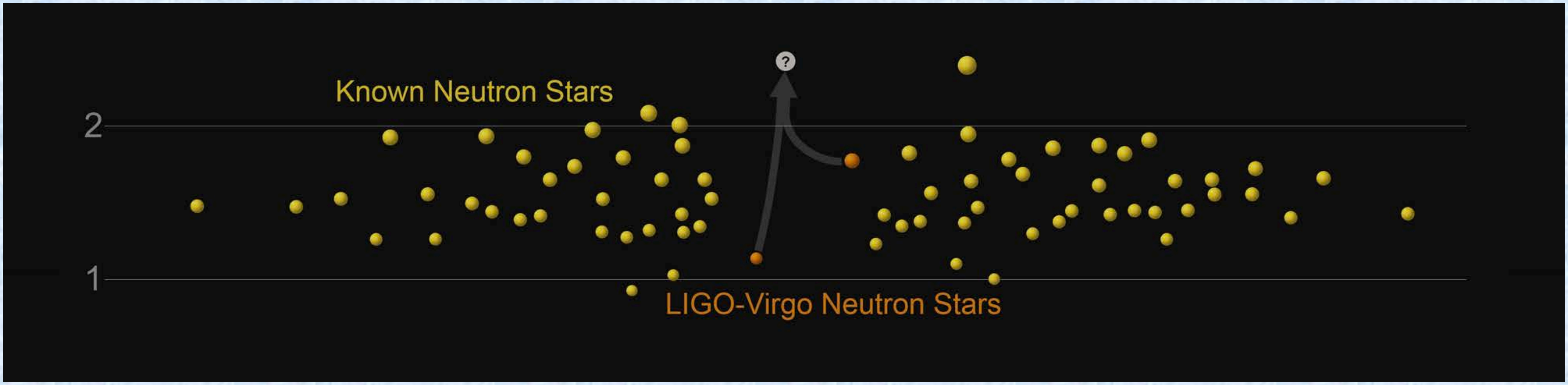
Short-lived visible fireball that resulted from the merger of two neutron stars in that galaxy NGC 2993.
Credit: 1M2H/UC Santa Cruz and Carnegie Observatories/Ryan Foley

Advances from this discovery

Confirming origin of short gamma-ray bursts

Gamma-ray bursts were first detected by US satellites in the 1960s. Studies revealed they were very likely coming from distant sources, well beyond the Milky Way. They are the brightest electromagnetic events known in the universe. Roughly a third of the **gamma ray bursts** have a short duration of less than two seconds and are hypothesized to come from the merger of two **neutron stars**.

The combined gravitational wave and electromagnetic data on **GW170817** support the **neutron star merger hypothesis**. The gravitational wave data indicates the merging objects had **neutron star** scale masses, and the **gamma ray** flash indicates the objects are not like black hole mergers, which are not expected to give off electromagnetic radiation.



Credit: LIGO

Resources

LIGO Scientific Collaboration (LSC) homepage: http://www.ligo.org

Includes page with information on **GW170817**

http://www.ligo.org/detections/GW170817.php

Provides additional information about detections made by LIGO to date: http://ligo.org/detections/

The LSC is a collaboration of more than 1200 scientists from over 100 universities and research institutions in 18 countries.

GEO600 homepage: http://www.geo600.org

Advanced Virgo homepage: http://public.virgo-gw.eu/language/en/

The Virgo Collaboration has more than 300 members from many institutions in six European countries.

LIGO Open Science Center (with access to LIGO data):

https://losc.ligo.org/about/

Educator's Guide

https://dcc.ligo.org/LIGO-P1600015/public

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BONUS CONTENT

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Image credit: Karan Jani/GaTech

Multi-messenger Observation of a Binary Neutron Star Merger

GW170817 gave astronomers an unprecedented probe of a collision of two **neutron stars**. For example, observations by the U.S. Gemini Observatory, the European Very Large Telescope, and the Hubble Space Telescope reveal evidence of recently synthesized material, including gold and platinum, solving a decades-long mystery of where about half of all elements heavier than iron are produced.

The light-based followup observations provide new insight on the "**kilonova**" that is thought to appear following the initial "fireball" created by the **neutron stars** merger.

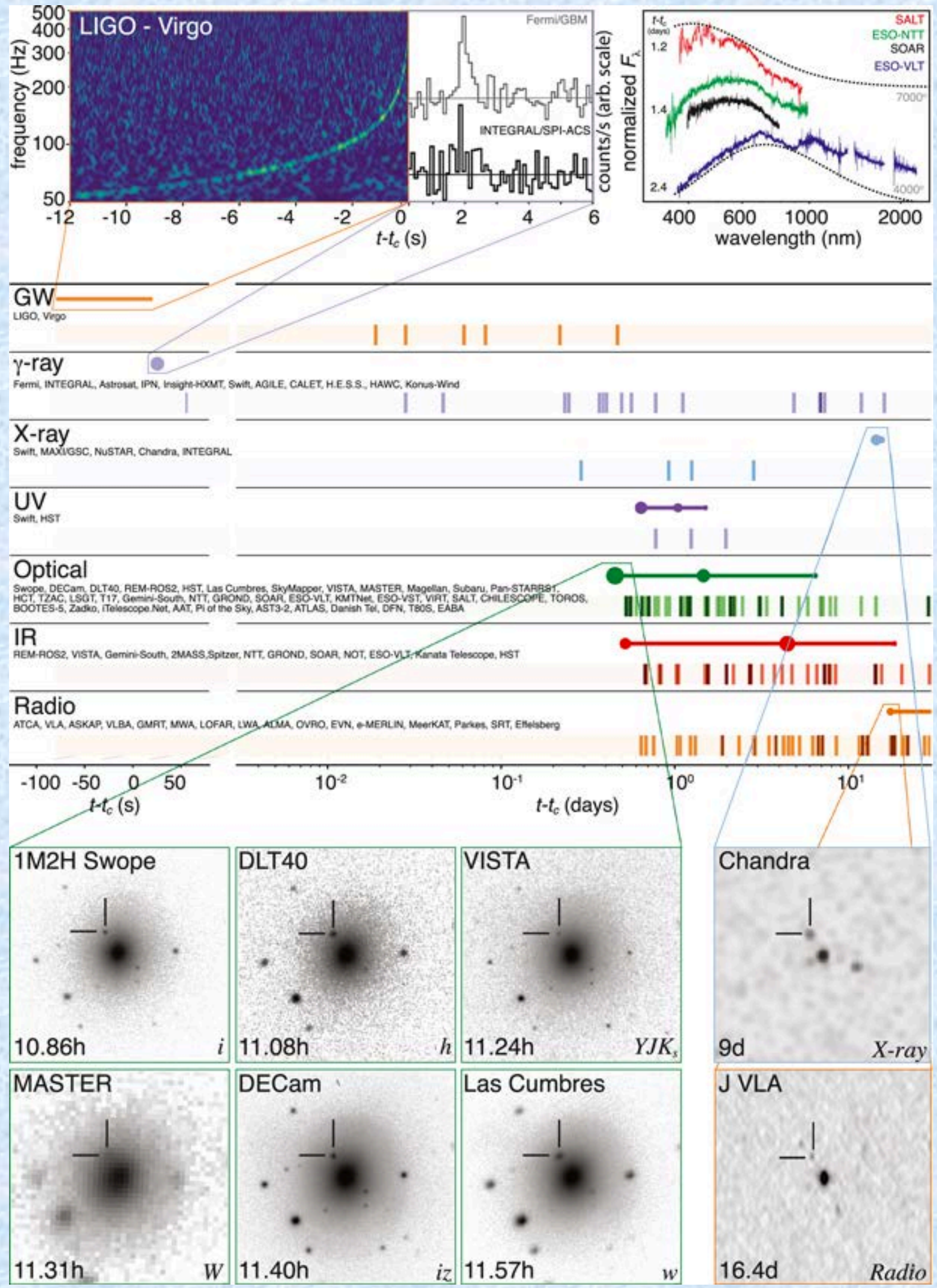

Figure from *Multi-messenger Observations of a Binary Neutron Star Merger*
B. P. Abbott et al. 2017 ApJL 848 L12 doi:10.3847/2041-8213/aa91c9