Light From merging neutron stars

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Image Credit: NASA/GSFC/CI Lab
NASA Missions Observing GW170817/GRB 170817A

Credit: Observatory images from NASA, ESA (Herschel and Planck), Lavochkin Association (Specktr-R), HESS Collaboration (HESS), Salt Foundation (SALT), Rick Peterson/WMKO (Keck), Germini Observatory/AURA (Gemini), CARMA team (CARMA), and NRAO/AUI (Greenbank and VLA); background image from NASA.
The morning of August 17, 2017

Fermi
Reported 16 seconds after detection

LIGO-Virgo
Reported 27 minutes after detection

INTEGRAL
Reported 66 minutes after detection

Image Credit: NASA GSFC, Caltech/MIT/LIGO Lab and ESA
Electromagnetic signatures from the merger of two neutron stars

Stellar lives, brilliant death, and black hole birth
The August gravitational wave event from merging neutron stars, and associated panchromatic transient, were billions of years in the making. This figure follows a plausible formation channel, starting with two massive stars orbiting each other and ending with a black hole and the creation of many Earth-mass amounts of precious metals. The light comes from both the fast-expanding kilonova and the cocoon/jet breakout observed ~30° off axis.

Making a neutron star binary
In one formation scenario, the massive stars in a binary system (1) both undergo a core-collapse supernova, leaving behind two neutron stars (2). Occasionally these neutron stars remain in a slowly decaying gravitationally bound orbit (3).

The merger
Gradually, over billions of years, the binary orbit decays as it emits gravitational wave energy (4). In the few minutes before merger, the gravitational wave signal becomes “loud” enough to detect (5). The stars merge to form a black hole (6) as a few percent of a solar mass is ejected.

Discovery of a Kilonova 12 hours later

Credit: NASA/GSFC CI Lab


Coulter et al. 2017, 10.1126/scienceaap9811

Surprise! – a bright UV source with Swift

Credit: NASA/Swift
Fading Kilonova in Optical/IR

Image Credit: NASA and ESA, Acknowledgment: A. Levan (U. Warwick), N. Tanvir (U. Leicester), A. Fruchter and O. Fox (STScI)
Late time IR Observations – Sep 29, 2017

Spitzer

Composite image
Filtered Image
Host galaxy subtracted

Image Credit: NASA/JPL-Caltech
X-ray and Radio Observations

Radio VLA (B) Sep 9 (C) Aug 22-Sep1

Credit: NASA/GSFC CI Lab

X-ray Aug 26, 2017

Credit: NASA/CXC/E. Troja

Hallinan et al., Science 10.1126/science.aap9855 (2017)
Summary and Conclusions

• This event is the first unambiguous joint detection of gravitational waves and electromagnetic radiation
• The unprecedented range of electromagnetic fireworks included the entire spectrum, from gamma-rays to radio waves.
• Combining these observations we can learn fundamental physics
  – the speed of gravity
  – the composition of the densest matter in the universe
  – the local expansion rate of the universe