Gravitational waves may have made human life possible

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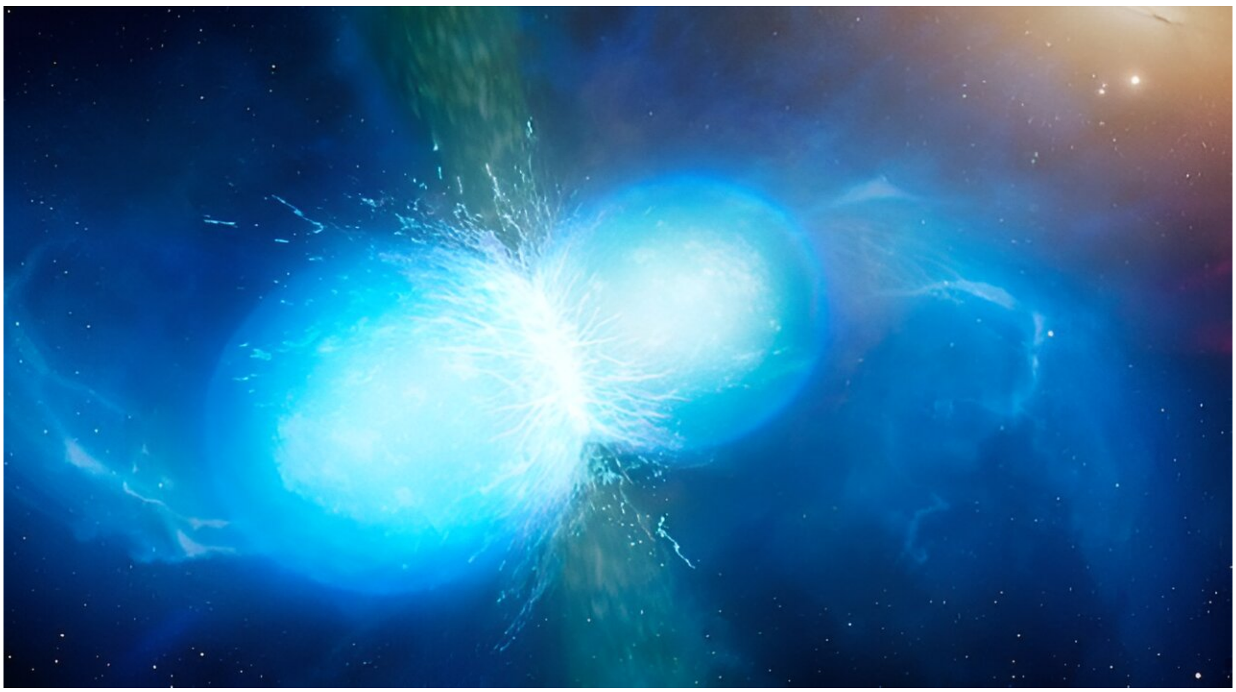

Artist's impression of neutron stars merging, producing gravitational waves and resulting in a kilonova. Credit: Mark Garlick, University of Warwick, from Wikipedia licensed under CC BY 4.0.

Could it be that human existence depends on gravitational waves? Some key elements in our biological makeup may come from astrophysical events that occur because gravitational waves exist, a research team headed by John R. Ellis of Kings College London suggests.

In particular, iodine and bromine are found on Earth thanks to a particular nuclear process that happens when neutron stars collide. In turn, orbiting neutron star pairs inspiral and collide due to their emissions of energy in the form of gravitational waves. There may thus be a direct path from the existence of gravitational waves to the existence of mammals.

Humans are mostly made up of hydrogen, carbon and oxygen, with many additional trace elements. (There are 20 elements essential to human life.) Those with an atomic number less than 35 are produced in supernovae, implosions of stars that have exhausted their nuclear fuel and collapsed inward. The collapse results in an explosion that spews their atoms all over the universe.

But two elements are provided by other means—iodine, needed in key hormones produced by the thyroid, and bromine, used to create collagen scaffolds in tissue development and architecture.

Thorium and uranium have been indirectly important for human life, as their radioactive decays in Earth's interior heat the lithosphere and allow tectonic activity. The movement of tectonic plates removes and submerges carbon from the crust of the planet, which is itself removed from the atmosphere via water reacting with carbon dioxide and silicates, avoiding the possibility of a runaway greenhouse effect like has happened on Venus.

About half the heavy elemental atoms on Earth (heavier than iron) are produced by what's known as the "r-process"—the rapid neutron-capture process. The r-process occurs when a heavy atomic nucleus captures a succession of free neutrons before the nucleus has had a chance to decay (usually by beta decay).

With a high enough density of free neutrons, calculated to be about 10^{24}

per cubic centimeter, and at high temperatures, around a billion Kelvin, neutrons are absorbed and heavier isotopes of an element are synthesized.

Ellis and his colleagues calculate that the r-process has provided 96% of the abundance of ^{127}I on Earth, an isotope essential for human life, and most of the abundance of bromine and gadolinium in the Earth's crust, plus all of the Earth's thorium and uranium and a fraction of the molybdenum and cadmium.

Where does the r-process occur? One possibility is the material ejected during the rebound from a core-collapse supernova, the explosions of stars near the end of their thermonuclear lifetimes. But there is long-standing uncertainty in the detailed physics of this process.

One phenomenon where the r-process does occur is the merger of two neutron stars, called a kilonova. Such mergers are directly caused by gravitational waves.

As the binary pair spiral towards one another over hundreds of millions of years, they radiate an enormous amount of energy in the form of gravitational waves near the end. In fact, it was just such an event that produced the gravitational wave event GW170817 detected in 2017 at the LIGO and Virga gravitational wave observatories in the United States. The amount of energy can be huge—trillions of trillions of watts in the last few milliseconds.

Kilonovae outbursts are important sites of the r-process, as neutron stars are made almost entirely of neutrons. Besides the gravitational wave observatories, other detectors detected GW170817 in the electromagnetic spectrum, and found spectroscopic evidence of the material created and tossed out from the merger.

The paper concludes that the iodine essential for human life was "probably produced by the r-process in the collisions of neutron stars that were induced by the emissions of gravitational waves, as well as other essential heavy elements." The group suggests searching for ^{129}I in lunar regolith, which is uncontaminated by manmade sources.

"Neutron star collisions occur because binary systems lose energy by emitting gravitational waves," said Ellis, "so these fundamental physics phenomena may have made human life possible."

Their paper, "Do we owe our existence to gravitational waves?," is available on the *arXiv* preprint server.

More information: John Ellis et al, Do we owe our existence to gravitational waves?, *arXiv* (2024). DOI: 10.48550/arxiv.2402.03593