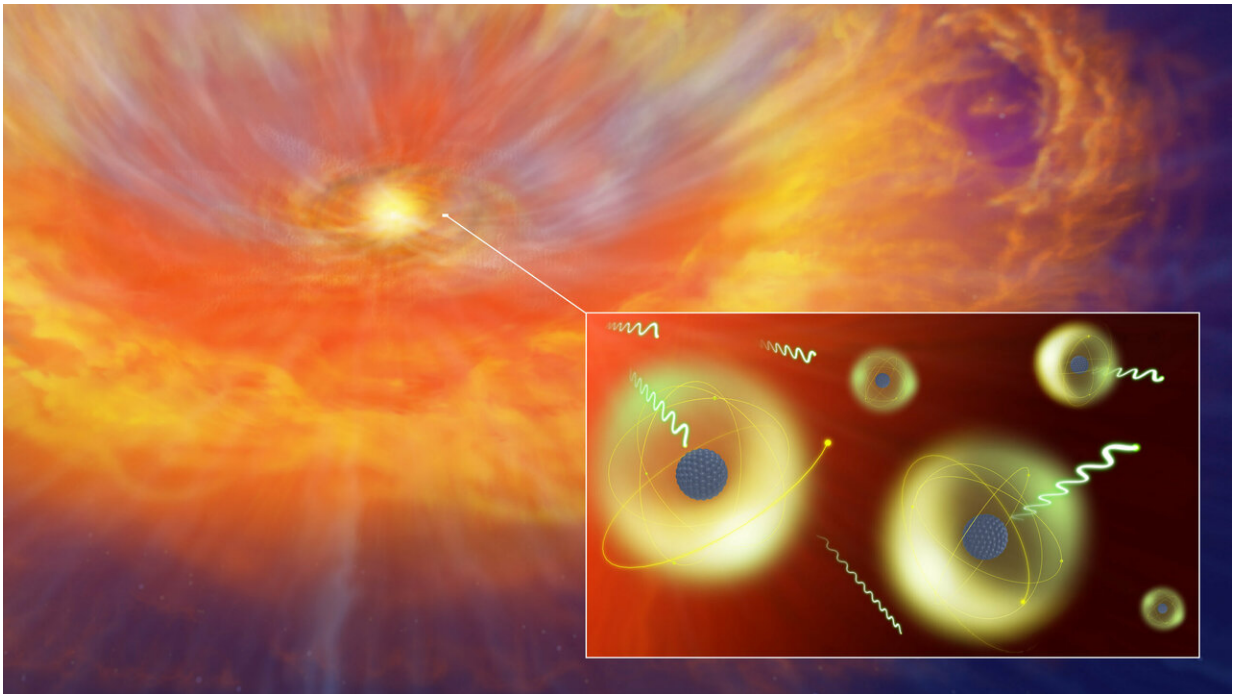# Collaboration enables investigation of the origin of heavy elements

March 12 2019

Artist's impression of a kilonova caused by a neutron star merger. In the material released by the merger, various heavy elements are formed, which then absorb and emit light. New atomic data calculations help to clarify kilonovae. Credit: National Astronomical Observatory of Japan

A team of experts in atomic physics, nuclear fusion, and astronomy has computed high-accuracy atomic data for analyzing light from a kilonova, a birth place of heavy elements. They found that their new data set could

predict kilonovae brightness with much better accuracy than before. This aids our understanding of the cosmic origins of heavy elements.

Atoms and ions can absorb and emit certain colors of light. By analyzing the detailed colors of inaccessible objects, like high temperature plasmas in a [fusion](#) chamber or [distant stars](#), scientists can identify their elemental abundances. This analysis needs atomic data about the wavelengths of light absorbed and emitted by each element. But there is no comprehensive, accurate atomic data for the heavy elements which are thought to be formed in kilonovae.

A team led by Daiji Kato, Associate Professor at the National Institute for Fusion Science (NIFS) in Japan, and Gediminas Gaigalas, Professor at Vilnius University in Lithuania, applied methods from [nuclear fusion](#) research to compute millions of highly accurate atomic data for neodymium ions. Neodymium is one of the important elements for kilonovae radiation, and is well studied by experiments and simulations. "The Aatomic structure of neodymium is more complicated than those of lighter elements, such as iron, calculated for nuclear fusion science. We needed to extend and optimize our calculation methods for such an [element](#) with suchso complicated structures," Kato said.

When two [neutron stars](#) collide they break apart, spewing waves of unstable nuclear material into space. This material rapidly decays causing radioactive afterglow known as a kilonova. Scientists believe that the [nuclear reactions](#) in neutron star mergers could be one of the primary sources for the heavy elements, including precious metals such as gold and platinum, and rare earth metals such as neodymium.

The neodymium atomic data computed by the Japan-Lithuania team agree with the experimental data, far better than any other calculations have done. An astronomer in the research group, Masaomi Tanaka, Associate Professor at Tohoku University simulated the light of a

kilonova with a supercomputer at theof National Astronomical Observatory of Japan (NAOJ) using new atomic data, and for the first time in the world, he could evaluate the influence of the database precision on the predicted brightness of a kilonova. He found that the answer varied by about 20% at most, which is sufficiently accurate to give astronomers confidence in their interpretation of kilonova observations. By calculating atomic data for other metals with this method developed in fusion science, the detail abundances of cosmic heavy elements formed by kilonovae will come to light.

Provided by National Astronomical Observatory of Japan