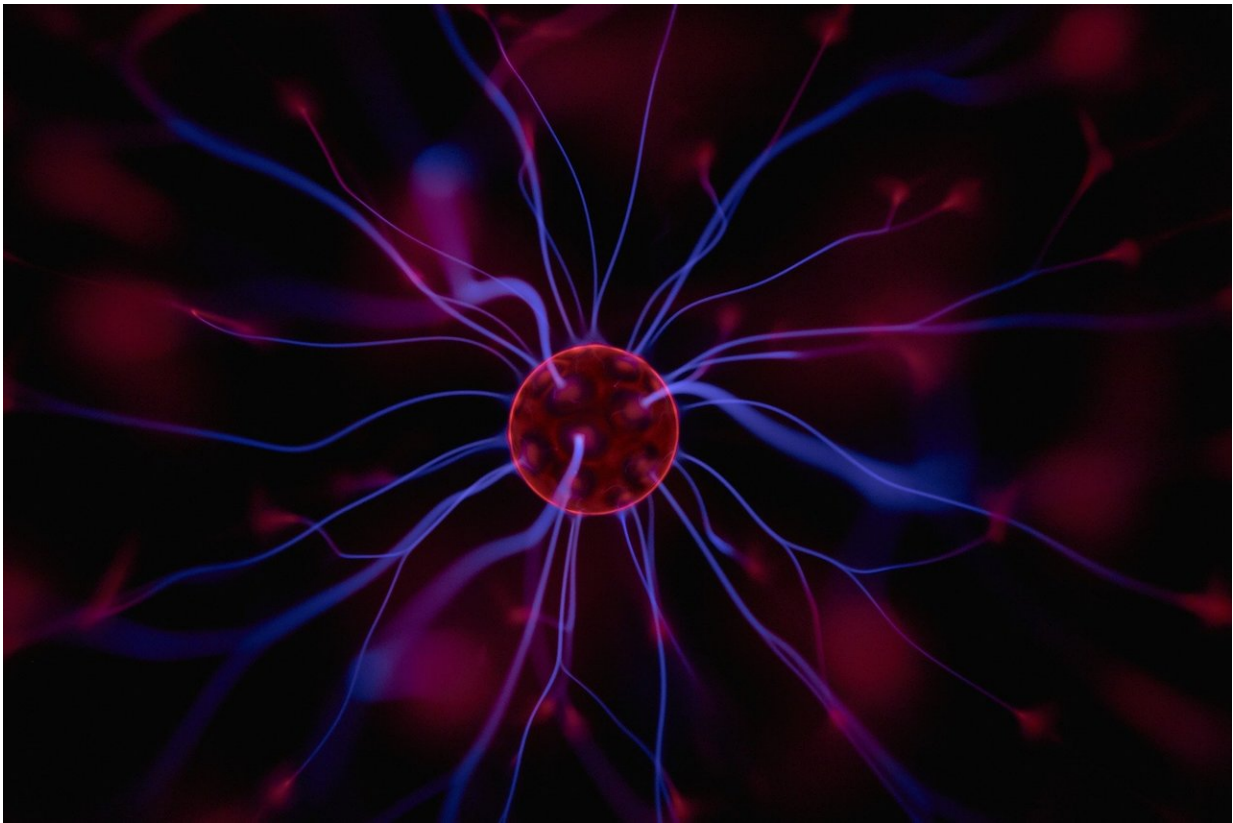


New insights into pion condensation and the formation of neutron stars

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In 1973, Russian physicist A.B. Migdal predicted the phenomenon of pion condensation above a critical, extremely high—several times higher than that for normal matter— nuclear density. Although this

condensation has never been observed, it is expected to play a key role in the rapid cooling process of the core of neutron stars. These city-size heavy stellar objects are so dense that on Earth, one teaspoonful would weigh a billion tons.

Recently, researchers from the RIKEN Nishina Center for Accelerator-Based Science and Kyushu University, performing an experiment at the RIKEN RI Beam Factory on a very [neutron](#)-rich tin isotope, investigated whether this process could really occur in neutron stars having the mass of about 1.4 times that of our sun. Similar investigations were conducted previously on [stable isotopes](#), such as ^{90}Zr or ^{208}Pb , but this time the researchers decided to study the case of ^{132}Sn , an isotope of tin. This doubly magic unstable nucleus has a fairly simple structure that makes the theoretical calculations easily compared to other [isotopes](#) with similar mass. Furthermore, ^{132}Sn with its large neutron excess (it consists of 50 protons and 82 neutrons) provides better conditions than the stable isotopes for extending this study toward the pure neutron matter in the [neutron stars](#).

A secondary cocktail beam containing ^{132}Sn was produced by projectile fragmentation of a uranium primary beam colliding with thick a beryllium target. Then, a liquid hydrogen target was irradiated with ^{132}Sn . Resulting in the collective excitation of the neutrons and protons of the tin nuclei, with the neutron spin and proton spin oscillating out of phase. This excitation mode, called "giant resonance," is suitable for studying the short-range interactions that, while being crucial in the onset of pion [condensation](#), are complex and extremely difficult to measure.

According to Masaki Sasano from RIKEN Nishina Center, who is one of the first authors of this study, their result, which was published in the *Physical Review Letters* journal, shows that the pion condensation should occur at around two times normal nuclear density, which can be realized

in a neutron star with a mass of 1.4 times that of the sun. Sasano said that in order to understand the possibility of the pion condensation fully, they plan to extend these unique studies of giant resonances to other neutron-rich nuclei that are far beyond the stability line, having large neutron-proton asymmetry.

More information: J. Yasuda et al. Extraction of the Landau-Migdal Parameter from the Gamow-Teller Giant Resonance in Sn132, *Physical Review Letters* (2018). [DOI: 10.1103/PhysRevLett.121.132501](https://doi.org/10.1103/PhysRevLett.121.132501)

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