【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Elucidation of ultra-strong magnetic field of neutron stars with highly-sensitive X-ray and Gamma-ray polarimetry

TAMAGAWA, Toru
(RIKEN, Cluster for Pioneering Research, Chief Scientist)

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【Purpose and Background of the Research】

"Are the neutron stars called Magnetar really extreme objects with a magnetic field above 10^{10} Tesla where the perturbative calculation of quantum electrodynamics (QED) breaks? In such a celestial object, is our knowledge on QED valid?" In this research, we aim to directly verify the hypothesis that Magnetar is strongly magnetized neutron star by the world's first highly sensitive X-ray and gamma-ray polarization observations.

A neutron star is an object with a radius of about 10 km, which remains after a massive star explosion, and is the densest substance (2-3 times of the nucleus density) in our universe. Most of the periodically blinking neutron stars called pulsars are known to have a strong magnetic field of about 10^8 Tesla and knowing the interior and the origin of the magnetic field is one of the important themes not only in astrophysics and astronomy but also elementary particle physics and nuclear physics.

"Magnetar", a species of neutron stars, is believed to have a strong magnetic field of as high as $10^{10\text{-}11}$ Tesla and to shine by releasing its magnetic energy. However, this is only a hypothesis, and direct observational verification of ultra-high magnetic field is competed worldwide.

【Research Methods】

We set the following two goals to verify the strong magnetism of Magnetar.

(Goal-1) The existence of a QED effect "vacuum resonance" is verified in a neutron star binary whose magnetic field is known by the presence of cyclotron absorption lines (about 10^8 Tesla).

(Goal-2) By observing another QED effect "vacuum birefringence" which can be notable only at 10^{10} Tesla or more, we will proof the ultra-strong magnetic field of Magnetar observationally (Fig. 1).

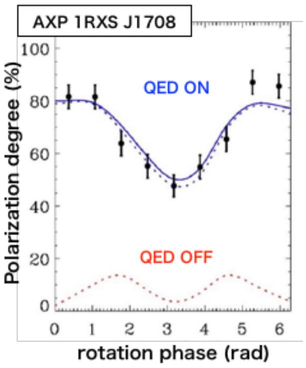

Figure 1 Expected polarization of magnetar.

To realize these goals, we will conduct NASA's X-ray polarimetry small satellite IXPE (launch in 2021), which we provide hardware and participate as core members, and the US-Japan joint balloon experiment XL-Calibur (flights in 2021, 2023). We will achieve the world's first sensitive polarimetry of neutron star binaries and Magnetars in X-ray and gamma-ray band (Fig. 2).

【Expected Research Achievements and Scientific Significance】

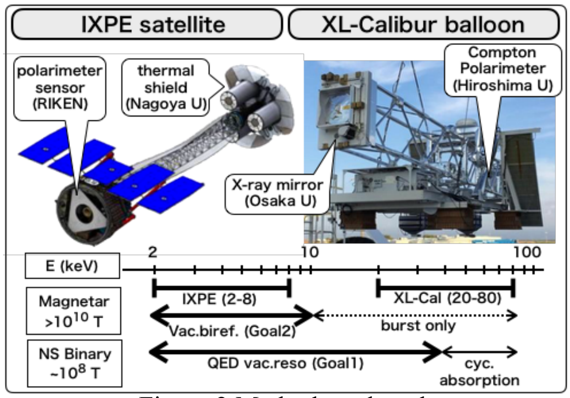

Figure 2 Methods and goals.

By demonstrating that Magnetar has an ultra-high magnetic field, we will pioneer the field "highly-magnetized nuclear matter" as an experimental field of basic science. This is complementary to the observation of the QED limit in the electric field using the high-intensity laser, and leads to the research progress of "physics in strong field" connecting space observation and ground experiment. In addition, as our study opens up new methods of X-ray and gamma-ray polarimetry, it must have a large ripple effect on high energy astrophysics in general.

【Publications Relevant to the Project】

・S. O'dell, et al., "The Imaging X-ray Polarimetry Explorer (IXPE): technical overview", Proc. of SPIE 10699, 10699X1 (2018).

・A. Yatabe and S. Yamada, " Systematic Analysis of the Effects of Mode Conversion on Thermal Radiation from Neutron Stars", Astrophys. J. 850, 185 (2017).

【Term of Project】 FY2019-2023

【Budget Allocation】 142,300 Thousand Yen

【Homepage Address and Other Contact Information】

https://astro.riken.jp/ks-xpol.html