



Research Highlight

An unexpected X-ray transient favors very stiff neutron-star matter

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Short-duration gamma-ray bursts (SGRBs) are mysterious gamma-ray flashes with durations less than two seconds, which occur at the cosmological distances. Some of them usually not only have very tenuous medium gases and old host galaxies but also are in the outskirts of the galaxies, suggesting an origin of binary neutron star (NS) mergers [1]. This origin was confirmed undoubtedly thanks to the discoveries of a gravitational wave event named GW170817 and its electromagnetic counterparts (an SGRB, a multiwavelength kilo-nova, and a broadband afterglow) [2]. Moreover, the X-ray afterglows from almost half of SGRBs exhibit temporal plateaus in a few hundreds to thousands of seconds followed by a decaying flux with an index close to two or much greater than two, indicating a post-merger central engine of long-lived massive millisecond magnetars (ultra-strongly magnetized neutron stars with a rotation period of order \sim a millisecond) or of short-lived supra-massive millisecond magnetars [1]. A question becomes very interesting: does a similar X-ray transient event occur in the case without an observed SGRB?

Recently an X-ray transient source dubbed XT-2 was reported in the April 11th issue of *Nature*, led by Yongquan Xue (University of Science and Technology of China) [3]. The properties of XT-2, discovered unexpectedly during the survey of NASA's Chandra X-ray Observatory, are similar to those of the X-ray afterglows of SGRBs

mentioned above, that is, a plateau with a duration of nearly two thousands of seconds for XT-2 is followed by a decaying flux with an index slightly larger than two. These properties favor a stable millisecond magnetar powering such a transient source. Furthermore, XT-2 is not only associated with a star-forming galaxy at redshift of 0.738 [4] but also lies in the outskirts of the galaxy [3]. In addition, the estimated XT-2-like rate density is similar to the rate density of binary neutron star merger events that is calculated in the case of GW170817 [3]. Therefore, these facts strongly suggest that XT-2 should have arisen from a stable millisecond magnetar left behind a binary neutron star merger, as shown in Fig. 1.

A further analysis of XT-2 was reported in the July 1st issue of *The Astrophysical Journal Letters*, led by Di Xiao (Nanjing University, China), based on the physical model in which a millisecond magnetar ejects an ultra-relativistic wind with internal gradual magnetic dissipation [5]. In particular, this model can explain why the post-plateau decay index is slightly larger than two. This analysis strengthens the important conclusion drawn by Xue and his collaborators.

The accidental discovery of Xue et al. [3] is groundbreaking because it has provided direct evidence for the formation of a stable magnetar after the merger of two neutron stars. The exis-

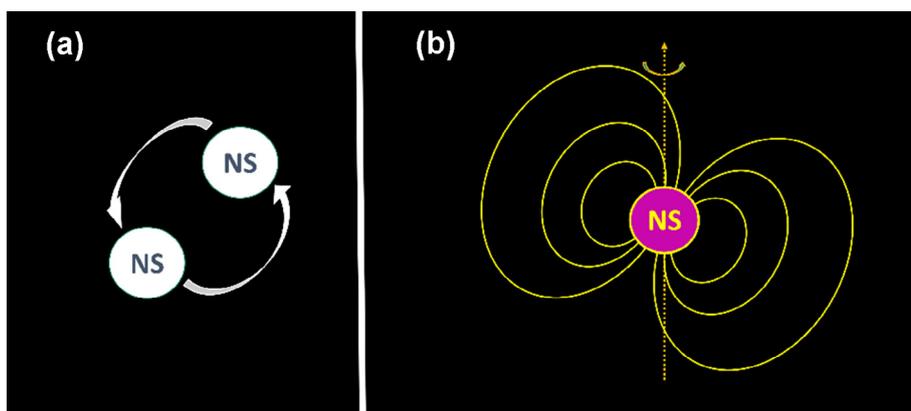


Fig. 1. (Color online) (a) The inspiral of two neutron stars, leading to a gravitational wave event. (b) The formation of an ultra-strongly magnetized millisecond pulsar post-merger.

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tence of this massive magnetar implies a very stiff equation of state in the interior of a neutron star, strongly supporting the early suggestion based on some observations [6–8]. Such an equation of state, if a post-merger long-lived magnetar occurs in other more cases, will shed light on strong interactions unknown so far in dense neutron-star matter. In addition, the discovery of Xue et al. [3] will provide a unique understanding of binary neutron star mergers and of their multi-messenger signals such as gravitational wave events, neutrino bursts, SGRBs, kilonovae, and afterglows.

Conflict of interest

The author declares that he has no conflict of interest.

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Zigao Dai got his Ph.D. degree of Astrophysics from Nanjing University in 1993. He became a full professor at Nanjing University in 1999. His research interest is high-energy astrophysics including neutron stars, gamma-ray bursts, fast radio bursts, and super-luminous supernovae.