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Clues to the formation and evolution of magnetars from X-ray observations of the associated supernova remnants

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Magnetars, i.e., neutron stars (NSs) with extremely strong magnetic fields, are thought to be produced by Type II supernovae (SNe), like other NSs. Indeed, several of them are located inside supernova remnants (SNRs). However, we do not know how the magnetar-producing SNe differ from those creating the other NSs.

Observations of the SNRs associated with magnetars are expected to provide key information on the above issue. Using Suzaku, the 5th Japanese X-ray satellite, we observed the SNR CTB109 hosting the magnetar (AXP) 1E 2259+586. From measured temperatures of the X-ray emitting plasmas, we estimated the SNR age as 13 kyr, and the explosion energy as 0.7e+51 erg, both in agreement with previous estimates (e.g. Sasaki et al. 2012). These and other X-ray properties of CTB109, including its abundance patterns, were not significantly different from those of other Type II SNRs. However, we reconfirmed the huge discrepancy between the age (1.3 kyr) of CTB109 estimated in this way and the measured characteristic age of 1E 2259+586, 230 ky.

We presume that this age problem arises because characteristic ages of pulsars (including magnetars) are generally calculated assuming constant fields, whereas magnetars must be spending its magnetic energy and hence their magnetic fields must be decaying with time.
Employing a simple power-law decay of the magnetic field (e.g., Colpi et al. 2000, Dall'Osso et al. 2012), we successfully obtained a family of field-decay solutions that can explain away the age discrepancy between CTB109 and its magnetar.

This result has several important implications. First, the apparent age overestimations of magnetars are now considered, conversely, to provide evidence for the magnetically-powered nature of magnetars. Second, it directly follows that magnetars are likely to be systematically younger than previously thought. This view is further supported by a systematic difference between magnetars and pulsars in their Galactic spatial distributions. Finally, the magnetar birth rate must be accordingly much higher than considered before, and hence a considerably fraction of Type II SNe may produce magnetars rather than ordinary pulsars with ˜1e12 G magnetic fields.

Author: NAKANO, Toshio (University of tokyo)

Co-authors: Prof. MAKISHIMA, Kazuo (The university of tokyo, Riken, Resceu); Dr ENOTO, Teruaki (Riken, Goddard Space Flight Center)

Presenter: NAKANO, Toshio (University of tokyo)

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