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Broadband Suzaku observations of magnetars

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Abstract. Magnetars are a mysterious subclass of neutron stars and believed to have strong magnetic field, $B \sim 10^{14}$–10^{15} Gauss. Since its launch, *Suzaku* satellite has observed 11 magnetars both in quiescent and outburst states. Soft thermal X-rays from the stellar surface were recorded from all these sources and a newly discovered hard X-ray tail was detected from ~7 sources. Thanks to the broadband coverage from 0.2 keV to 600 keV, it is revealed that these two spectral components show a spectral evolution correlated with their characteristic age and magnetic field. In addition, accumulation of weak short bursts from an activated source, 1E 1547.0-5408, exhibits spectral resemblance to the persistent emission.

Key words. Stars: evolution – Stars: magnetars – Stars: magnetic field – Stars: neutron

1. Introduction

Soft Gamma Repeater (SGRs) and Anomalous X-ray Pulsars (AXPs) are a mysterious subclass of neutron stars (Mereghetti 2008), showing slow rotation (P~2–12 s) and high spin-down ($\dot{P}\sim10^{-12}$ s s^{-1}). Nearly 20 X-ray sources have been discovered in our Galaxy and in the Magellanic Clouds. Since the calculated release of their rotational energies falls ~2 orders of magnitude smaller than their relatively high soft X-ray luminosity (~10^{35} erg s^{-1}), and because the measured P and $\dot{P}$ imply unusually high dipolar magnetic field, $B \sim 10^{14} - 10^{15}$ G, exceeding the QED critical field, $B_{\rm QED} = 4.4 \times 10^{13}$ G, they are thought to be powered by dissipation of their huge magnetic energies, and called "magnetars" (Duncan & Thompson 1992; Thompson & Duncan 1995, 1996).

In addition to the well-studied thermal X-ray component with kT~0.5 keV, *INTEGRAL* discovered another hard power-law component above 10 keV (Kuiper et al. 2006), which extends at least up to ~100 keV with an extremely hard photon index $\Gamma_{\rm h}$ ~1. The Japan-US *Suzaku* X-ray observatory (Mitsuda et al. 2007) confirmed this hard X-rays at least from seven magnetars (Enoto et al. 2011, 2010c). Since the soft and hard X-rays can be simultaneously observed using a wide energy coverage (0.3–600 keV), we recently found that the broad-band (0.8–70 keV) X-ray spectra of known magnetars systematically change depending on their characteristic age $\tau_{\rm c}$ and magnetic field $B_{\rm s}$; the hard X-ray component becomes weaker relative to the soft component, and harder towards sources with older characteristic age (Enoto et al. 2010c). The present result provides additional support to the increasing evidence that SGRs and AXPs are intrinsically considered the same kinds of object.

Another important progress is the growing number of transient magnetars, most of which have been discovered by *Swift*/BAT detections of short burst activities (Rea & Esposito 2011).

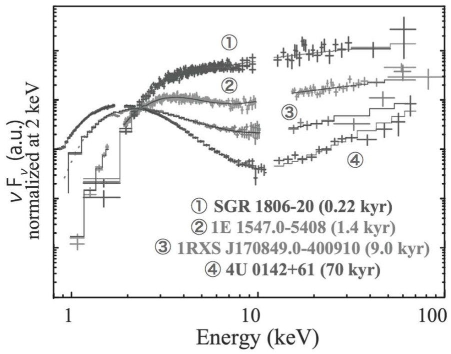

Fig. 1. Example of magnetar spectra in νF_ν forms, normalized at 2 keV. Object names are shown in figure with their characteristic age τ_c.

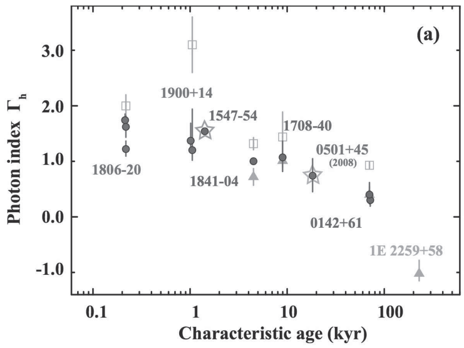

Fig. 2. Photon indices Γ_h of the hard-tail plotted as a function of τ_c. Circles represent SGRs and AXPs observed by *Suzkau*. Square points are *INTEGRAL* observations (Kaspi et al. 2010).

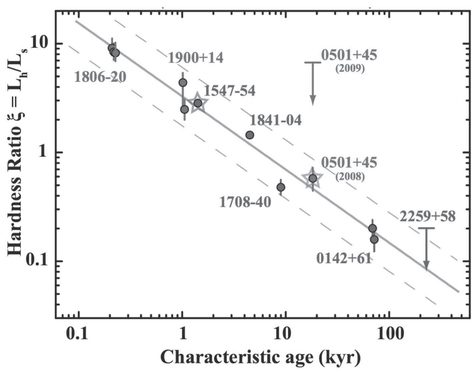

Fig. 3. Correlation between the hardness ratio (HR) ξ, defined as $\xi = L_{\mathrm{hard}}/L_{\mathrm{soft}}$ in 1–60 keV, and τ_c. Solid and dashed lines represent the best fit of $\xi = 0.09 \times (B/B_{\mathrm{QED}})^{1.2}$ and their boundaries shifted by a factor of two, respectively. Burst-active sources are shown with star symbols. See in detail Enoto et al. 2010c.

During such a burst-active period, the persistent soft X-ray intensity also increases by 1–2 orders of magnitude (Enoto et al. 2009), and then gradually decays within a couple of months. Interestingly, during the outburst, the above persistent hard X-ray components were also detected, presumably becoming bright as the soft X-ray components; SGR 0501+4516 (Enoto et al. 2010b), 1E 1547.0-5408 (Enoto et al. 2010a) and SGR 1833−0832. From our recent *Suzaku* analyses of SGR 0501+4516 (Nakagawa et al. 2011) and 1E 1547.0−5408 (Enoto et al. 2012), there are signs of spectral similarities between the persistent X-ray emission and the weaker short bursts, despite a difference of their fluxes by two orders of magnitude.

Acknowledgements. Figure 1, 2, and 3 are reproduced by permission of the AAS.

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