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X-ray searches for new galactic particle-acceleration sites with Suzaku

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Abstract. Origins of cosmic-rays are still mystery for 100 years from the discovery. Neutron stars (NSs) and supernova remnants (SNRs) are considered as textbook cases of particle acceleration sites, but many unresolved problems remain numerically. Searches for new sites are crucial for astrophysics. We focus on two candidates which can contribute a few to ten % of Galactic cosmic-ray electrons: magnetic white dwarfs (MWDs) and runaway O-stars. The former have rotating magnetospheres like NSs, and the latter have termination shocks by fast stellar winds like SNRs. We performed six observations of MWDs in binaries and three single MWDs with Suzaku, and found some evidences of particle acceleration from three. We performed Suzaku observation of a runaway-star BD+43 3654, from where Synchrotron radio emission is reported. The upper limit in X-ray flux indicates low Lorentz factor of electrons, meaning low-turbulent magnetic field in shock.

Key words. acceleration of particles – stars: white dwarfs – stars: early-type

1. Introduction

Origins of cosmic-rays (CRs) are long-standing mystery for 100 years from the discovery. In our Galaxy, pulsars and supernova remnants (SNRs) are the textbook-type candidates of CRs, accelerating high energy particles via, roughly saying, electric-field and shock acceleration mechanisms, respectively. In this paper, we report searches for other particle-acceleration sites in similarity with pulsars and SNRs.

Table 1. Summary of Suzaku observations

Object Name	year	Exp	ref
AE Aqr	2005	70 ks	Terada+ 08
AE Aqr	2006	50 ks	Terada+ 08
AE Aqr	2007	160 ks	(prep)
AM Her	2008	100 ks	Terada+ 10
IGRJ00234+6141	2010	80 ks	(prep)
V2487 Oph	2010	50 ks	(prep)
EUVE J0317-85.5	2010	60 ks	(Harayama+)
EUVE J1439+75.0	2012	40 ks	
PG 1658+440	2012	50 ks	
BD43°3654	2011	100 ks	Terada+ 12

2. Magnetic white dwarfs

Magnetic white dwarfs (WDs) are objects similar to neutron star (NS) pulsars in the sense that they are rotating magnetic-compact objects. After the first proposal that the WDs can contribute CRs by Ostriker (1970), de Jager (1994) pointed out that one of magnetic WDs, AR Aqr, is a millisecond-equivalent of pulsar. In fact, several authors report non-thermal emissions from magnetic WDs in the radio (Nelson and Spencer 1988; Abada-Simon et al. 1993) and TeV bands (Bhat et al. 1991; Meintjes et al. 1992, 1994). Therefore, we performed a sensitive X-ray observation of AE Aqr with Suzaku (Mitsuda et al. 2007), and found that the object shows hard X-ray pulses like NS pulsars (Terada et al. 2008). In addition, we found that the pulsed component has very low abundance, implying that it is of non-thermal origin. We further performed Suzaku observations of WDs as listed in Table 1. In order to avoid strong thermal emissions, which are normally seen in magnetic WD binaries (Patterson 1994; Terada et al. 2001, 2004), we searched for 1) WD binaries but in the very low-accretion state and 2) isolated magnetic WDs showing hard spectra in X-ray band. As a results, the X-ray emission from AM Her in the very low-accretion state may consists of low-temperature plasma and possible non-thermal power-law emission (Terada et al. 2010). On the other hand, it is hard to detect X-rays from isolated WDs.

3. Runaway star

Runaway stars are early-type massive stars running away from OB associations with the velocity of about 30 km/s. These objects have very fast stellar-winds, reaching a few thousand km/s. This value is comparable with the shock speeds of young SNRs (Bamba et al. 2005), and thus we can expect shock acceleration mechanism also in this system. In fact, Synchrotron emission is reported with VLA from a bow shock region of a runaway star, BD+43°3654 (Benaglia et al. 2010). Therefore, we performed X-ray observation of the object with Suzaku as in the Table 1. Although it is not the first detection of non-thermal X-ray from this class (López-Santiago et al. 2012), we obtained the upper limit of the X-ray flux from this object at 1.1×10^{32} erg s^{-1} per 41.2 $arcmin^2$ in the 0.5 – 10 keV band (Terada et al. 2012). As a result, the maximum energy of electrons does not exceed 10 TeV, corresponding Lorentz factor of $< 10^7$. This fact implies that the magnetic field might not be so turbulent as in pulsar wind nebulae or SNRs (for detail, see Terada et al. 2012).

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