SUZAKU observations of Anomalous X-ray pulsar 1E 1048.1-5937

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Abstract

We report results of SUZAKU observation of anomalous X-ray pulsar 1E 1048.1-5937 performed in November 2008. We perform a spectral and a timing analysis on XIS (0.2-12 keV) data. It is found that only power law plus blackbody model (kT∼0.604 keV, photon index∼3.2) is acceptable with a flux level of 7.4×10^{-12} ergs/cm^{2}s at 2-10 keV energy bands, which is consistent with the previous study. No line features have been detected in the spectrum. The pulse period (p = 6.4595 sec) and the pulsed profile have been derived by epoch folding method, and the pulsed fraction is estimated to be 0.5. The period, pulse profile and pulsed fraction are also consistent with previous observations. We also perform a spectral analysis on PIN data, and a marginal flux has been detected in the range 14-22 keV with only 3.3 confidence level.

Key words: observation -X-rays: AXPs: individual (1E 1048.1-5937)

1. Introduction

1E 1048.1-5937 is the one of the class of the pulsars known as AXPs (Anomalous X-ray pulsars). The spectra properties of X-ray emissions in 1-10 keV bands from AXPs are described by the thermal plus very soft non-thermal components with a flux in excess available spin-down power of the pulsars. Some of them are also discovered above 10 keV with a very hard spectrum (photon index∼1, Kuiper et al. 2006). The emission mechanism of the non-thermal component above 10 keV is one of the unresolved important issue of the AXPs.

For 1E 1048.1-5937, no hard X-ray emissions above 10 keV in persistent stage have been reported by the previous observations. On the other hand, a hard X-ray emissions above 10 keV was reported by RXTE during X-ray flare occurred in 2007 (Dib et al. 2009). At the activities in 2007, the pulsed optical emissions are also detected for the first time(Dhillon et al. 2009). On these ground, to understand the emission properties in wide energy bands for 1E 1048.1-5937, it will be important to perform a more deep X-ray observations above 10 keV.

The Suzaku observation of 1E 1048.1-5937 was performed in November 2008, about one and half year after the X-ray flare that started in March 2007. The 1E 1048.1-5937 was observed by the XISs instrument with 100 ks (standard mode) exposure time and by HXD with 63 ks exposure time.

2. Spectral analysis

Figure 1 shows the spectral properties measured by XISs (below 10 keV) and HXD/PIN (hard 10 keV). The circles and triangles represent the spectra of the background and the emissions after subtraction of the background, respectively.

As Figure 1 shows the emissions from the source significantly exceeds the background, the spectral behavior below 10 keV can be determined very well. For XISs, the data after subtraction the background are fitted well by an absorbed power low plus blackbody components; the column density $N_H = 1.8 \times 10^{22}$ /cm^2, the surface temperature $kT \sim 0.603$ keV and the photon index $\Gamma \sim 3.2$. These results are consistent with the previous observations in persistent stage before 2007 (Tiengo et al. 2005). We note that a single power law model and the spectral model with the line features were not acceptable.

For HXD/PIN, the background level greatly exceeds the emissions from the source as Figure 1 shows. Although a marginal flux excess is detected with 3.3σ confidential level, it is hard to confirm with the present data.

3. Pulse profile

Although frame of time of the XISs (8s) is longer than the spin period ($P \sim 6.46$ s) of 1E 1048.1-5937, we can obtain the timing information with equivalently time resolution of ~ 1.5s. Figure 2 shows the folded light curve of XISs with two rotational period. It is found that the light curves is characterized by a broad, nearly sinusoidal

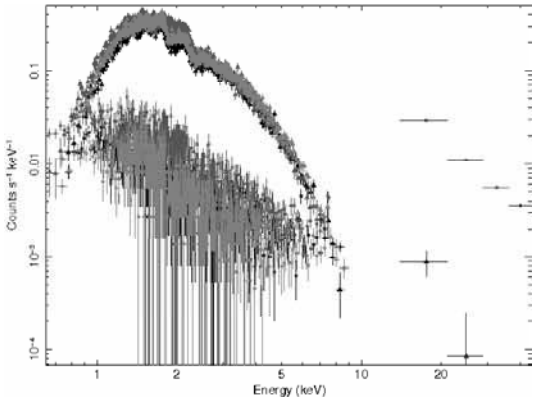

Fig. 1. The spectra of the X-ray emissions from 1E 1048.1-5937 emasured by SUZAKU XISs (below 10 keV) and HXD/PIN (above 10 keV). The opened circles and triangles represent the spectra for the background emission and for the emission after subtraction of the background.

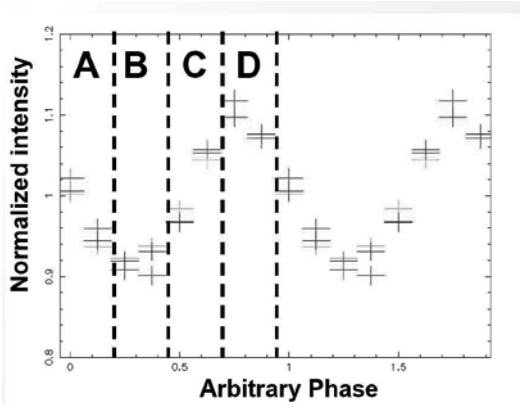

Fig. 2. The folded pulsed profile of 1E 1048.1-5937 measured by XISs. The A, B, C and D represents the phase interval chosen for the phase-resolved analysis (see Figure 3).

profile. This pulse profile is consistent with the previous observations in persistent stage before the X-ray flares in 2007. The true pulsed fraction (Φ_{true}) is estimated from $\Phi_{true} = (1-\alpha)\Phi_{measured} \sim 50$ % with $\alpha = 6.46/8$, where $\Phi_{measure}$ is the measured pulsed fraction.

An anti-correlation between pulsed fraction and the total X-ray flux of 1E 1048.1-5937 has been discovered in previous research (Tiego et al. 2005) before X-ray flares in 2007. It is found that our result of the X-ray flux and pulsed fraction is consistent with the correlation between the X-ray flux and the pulsed fraction determined by the previous observations.

4. Phase-resolved analysis

Phase resolved spectral analysis was performed by dividing the XISs data into 4 phase intervals, which provide an enough photon number for each bin to perform the spectral analysis. Because of the large frame time compared

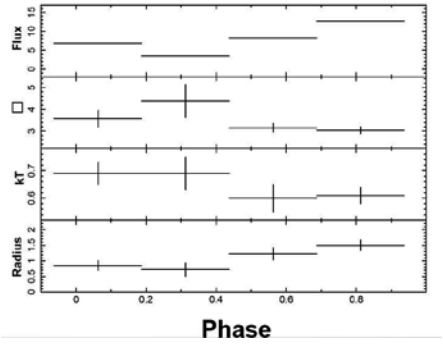

Fig. 3. The emission properties for the phase-resolved spectra measured by XISs. The top, second, third and the bottom panels represent the X-ray flux (in units of 10^{-12} erg/cm^2), the photon index, the surface temperature (keV) and the effective radius (km).

with the rotation period, we remove the contamination from other phase intervals. The true phase-resolved spectrum S_{true} at each phase is estimated as $S_{true} = (S_{measured} - \alpha S_{average})/(1-\alpha)$, where $\alpha = 6.45/8$, $S_{average}$ and $S_{measured}$ are the measured phase-resolved spectrum and the measured phase-averaged spectrum.

Figure 3 summarized the emission properties of the phase-resolved spectra. The top, the second, the third, and the bottom panels represent the X-ray flux (in units 10^{-12} erg/cm^2) and the photon index, the surface temperature (keV) and the effective emission radius (km). Although we see a variability on the spectral properties (e.g. fitting photon index and temperature) with the present spectral analysis, a more deep observation is required to confirm it.

In summary, we have performed the spectral and timing analysis of the X-ray emissions from anomalous X-ray pulsar, 1E 1048.1-5937, measured by SUZAKU. We find the spectral properties below 10 keV are consistent with the previous observations in persistent stage. It is found that the properties of the X-ray emissions in persistent stage is very stable, while he significant flux and timing variability has been observed during the X-ray flare and burst stage. This indicate the X-ray emission process and properties in persistent sate are not affected by the existence of the X-ray flares and bursts. The existing of hard X-ray emissions in persistent stage is sill mystery for this AXP, requiring a more deep observations.

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