Do you mean Understanding the X-ray spectrum of anomalous X-ray pulsars and soft gamma-ray repeaters?*

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Abstract Hard X-rays above 10 keV are detected from several anomalous X-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs), and different models have been proposed to explain the physical origin within the frame of either a magnetar model or a fallback disk system. Using data from Suzaku and INTEGRAL, we study the soft and hard X-ray spectra of four AXPs/SGRs, 1RXS J170849–400910, 1E 1547.0–5408, SGR 1806–20 and SGR 0501+4516. It is found that the spectra could be well reproduced by the bulk-motion Comptonization (BMC) process as was first suggested by Trümper et al., showing that the accretion scenario could be compatible with X-ray emission from AXPs/SGRs. Do you mean Simulated results from the Hard X-ray Modulation Telescope using the BMC model show that the spectra would have discrepancies from the power-law, especially the cutoff at ~200 keV. Thus future observations are promising will allow researchers to distinguish different models for the hard tail of magnetars and may will help us understand the nature of AXPs/SGRs.? Note: you do not mention “hard tail” later in the article after Section 1. Our editorial staff thinks it is better to not include this term if you do not describe what you mean later in the article.

Key words: stars: neutron — pulsars: individual (1E 1547.0–5408, 1RXS J170849–400910, SGR 0501+4516, SGR 1806–20) — X-rays: stars

1 INTRODUCTION

Do you mean Since the discovery of radio pulsars in 1967, various kinds of pulsar-like objects have been observed, which exhibit diverse manifestations. Among them, anomalous X-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs) are peculiar kinds of sources (Mereghetti 2008). Their persistent X-ray luminosities are much higher than spin down energy, s

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could be highly super-Eddington. Besides, AXPs/SGRs have long spin periods clustered in the range of 2–12 s, and their period derivatives are also large.

Conventional models for AXPs/SGRs are magnetars (Duncan & Thompson 1992), isolated neutron stars with extremely strong dipole and multipole magnetic fields (higher than the quantum critical magnetic field $B_{QCD} = m_e^2 c^3 / e h = 4.4 \times 10^{13}$ G). The persistent emission is powered by magnetic field decay; magnetic dipole radiation would contribute to their spin-down, and the effects of a twisted magnetosphere (Thompson et al. 2002) and wind braking (Tong et al. 2013) have also been considered. A sudden release of magnetic energy, such as magnetic reconnection, could result in bursts or giant flares. Although the magnetar model could explain some of the properties of AXPs/SGRs, it is still facing some problems arising from accumulating observations: few predictions have been confirmed yet. After all, there is no direct evidence for the existence of a super-strong magnetic field. Alternative models of AXPs/SGRs are not only possible but also welcome.

Do you mean AXPs/SGRs are suggested to be normal-field pulsar-like objects accreting from supernova fallback disks (Chatterjee et al. 2000; Alpar 2001)? Accretion energy could power the persistent emission, and the propeller effect may account for the braking mechanism, as well as the period clustering of AXPs/SGRs. However, fallback disk models could not explain the super-Eddington bursts or giant flares. The problem could be solved if the compact star is a solid quark star (Xu 2003), since the self-confined surface (Alcock et al. 1986) could explain the super-Eddington phenomena, and the energy released during star quakes (Xu et al. 2006) may be an alternative power source for bursts and giant flares. Therefore, AXPs/SGRs could be quark star/fallback disk systems (Xu 2007; Tong & Xu 2011).

Determining whether AXPs/SGRs are magnetars or fallback disk systems is of fundamental importance. Do you mean It could help us understand the observational phenomena of AXPs/SGRs, and even give hints on the nature of pulsar-like stars, which is related to the state of cold matter at supra-nuclear density and where strong interactions play an important role. In this paper, we would like to study the problem from the perspective of the X-ray spectrum of AXPs/SGRs. AXPs/SGRs have soft spectra below 10 keV that are generally fitted by a combination of a steep power-law with photon index $\Gamma \sim 2–4$ and a blackbody with temperature $kT \sim 0.5$ keV (Mereghetti 2008). Non-thermal hard X-ray components above 15 keV in AXPs/SGRs were discovered in recent years, with different spectral properties from the soft X-ray band (Kuiper et al. 2006). The hard X-ray spectra are well fitted by flat power-laws with photon index $\Gamma \sim 0.5 – 1.5$, and the luminosity is similar to that of the soft X-ray band. Therefore, the hard X-rays provide us with important information to understand the magnetic fields and surface properties, and could put strong constraints on the theoretical modeling of AXPs/SGRs. The physical mechanism of hard X-ray emission is still unknown, but some possibilities have been proposed that trying to explain it.

In the frame of magnetars, a quantum electrodynamics model (Heyl & Hernquist 2005), bremsstrahlung model (Beloborodov & Thompson 2007) and resonant inverse Compton scattering model (Baring & Harding 2007) have been explored, predicting power-law spectra with different cutoff properties. The spectral cutoff properties of AXPs/SGRs are not well understood yet. Do you mean Upper limits in MeV bands are obtained with the archival CGRO COMPTEL data of four AXPs, which indicate cutoff energy is below 1 MeV (Kuiper et al. 2006). 4U 0142+61 is the brightest AXP. Accumulating INTEGRAL IBIS data, representing the time-averaged spectra of 4U 0142+61, that have accumulated over 9 years, the time-averaged spectrum of 4U 0142+61, the brightest AXP, can be fitted with using a power-law with an exponential cutoff at $\sim 130$ keV. This aspect might rule out models involving ultra-relativistic electrons (Wang et al. 2013). In the context of a fallback disk-frame, Trümper et al. (2010) considered producing the hard X-ray emission by the bulk-motion Comptonization (BMC) process of surface photons in the accretion flow. Their work shows that for 4U 0142+61, the BMC model could reproduce both the soft and hard X-ray spectra. The BMC model is successful in explaining the spectra of 4U 0142+61, but its applicability to other sources remains in doubt.
In this work, we study the broadband X-ray spectrum of AXPs/SGRs, try to put further constraints on the BMC model, and perform a simulation to discuss how to distinguish different models by future observations. Do you mean? Using data from Suzaku and the INTEGRAL Gamma-Ray Astrophysics Laboratory (INTEGRAL), we derive the soft and hard X-ray spectra of four sources, namely AXP 1RXS J170849–400910, AXP 1E 1547.0–5408, SGR 1806–20 and SGR 0501+4516 (hereafter abbreviated as 1RXS J1708–40, 1E 1547–54, SGR 1806–20 and SGR 0501+45). Do you mean? We find that the spectra of all the chosen sources can be well fitted with the XSPEC model compTB, showing that the accretion scenario could be compatible with X-ray emission from AXPs/SGRs. Do you mean? To investigate the feasibility of discriminating various models of hard X-ray emission by future observations, we also perform results from the hard X-ray eModulation eTelescope (HXMT). 1. Simulated spectra from the BMC model exhibit a cutoff around 200 keV, which could distinguish BMC from other cases in the magnetar model. Do you mean? In Section 2 we will introduce the utilized Suzaku and INTEGRAL observations that we utilized, along with data analysis including spectral properties and time variabilities. Then we present the averaged spectra and the fitting of the compTB model in Section 3. HXMT simulations are shown in Section 4, and possible discrepancies between various models of the hard tail magnetars are also discussed. Note: please see the previous note about “hard tail” not mentioned later in the text. Finally we draw our conclusions in Section 5.

2 OBSERVATIONS AND DATA ANALYSIS

2.1 Source Selection

Suzaku provides for the first time simultaneously observed soft and hard X-ray spectra from seven AXPs/SGRs (Enoto et al. 2010a) for the first time. Do you mean? Among these seven sources, SGR 1900+14 is only detected up to ∼50 keV due to its relatively low flux, and the soft X-ray spectrum of 1E 1841–045 is contaminated by emission lines from the surrounding supernova remnant (see Enoto et al. 2010a, fig. 1). Do you mean? Therefore, in our analysis we will only focus on four sources, namely 1RXS J1708–40, 1E 1547–54, SGR 1806–20 and SGR 0501+45, while the data from 4U 0142+61, SGR 1900+14 and 1E 1841–045 are not analyzed. For the hard X-ray spectra, INTEGRAL observations are also used, which could reach higher energy and place better constraints on parameters. Do you mean? Because the hard X-ray detector on INTEGRAL has a of the lower sensitivity of INTEGRAL, hard X-rays than the detector than that of Suzaku, the spectrum from a single observation has to be summed up to get an acceptable signal-to-noise ratio (S/N), Do you mean? The spectral fitting software used is XSPEC version 12.8.0, and all cited errors are at the 1σ level.

2.2 Suzaku Observations used to extract spectra of

Do you mean? Suzaku observations utilized for acquired from the four sources are listed in Table 1. Do you mean? We extracted spectra using data from the X-ray Imaging Spectrometer (XIS; Koyama et al. 2007) and the Hard X-ray Detector (HXD; Takahashi et al. 2007), which are sensitive in the energy range of 0.2–12 keV and 10–70 keV. The data reduction was carried out using HEASOFT version 6.13. The XIS and HXD data were reprocessed with the pipeline processing version 2.4, employing the recommended data screening criteria. We accumulated screened data of XIS from a region within a 2′ radius of the source centroid, and derived a background spectrum from source-free regions in the immediate vicinity of the target. For HXD-PIN data, non-X-ray background (NXB) and cosmic X-ray background (NXB) were subtracted to obtain spectra.

We fit the soft X-ray spectra with a two component blackbody plus power-law model affected by photoelectric absorption, and the hard X-ray spectra with a single power-law model. The fitting

1 http://heat.tsinghua.edu.cn/hxmtsci/hxmt.html
Sources are within 10 degrees of the pointing direction from 2003 to 2011. The IBIS-ISGRI data imager IBIS (Imager on Board the INTEGRAL Satellite; Ubertini et al. 2003) has a low-energy

<table>
<thead>
<tr>
<th>Name</th>
<th>Time span (yy/mm/dd)</th>
<th>Exposure (ks)</th>
<th>INTEGRAL Revs.</th>
<th>Time span (yy/mm/dd)</th>
<th>Exposure (Ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RXS J1708–40</td>
<td>09/08/23 – 09/08/24</td>
<td>47.9</td>
<td>0037 – 1088</td>
<td>03/02/01 – 11/09/13</td>
<td>5.84</td>
</tr>
<tr>
<td>1E 1547–54</td>
<td>09/01/28 – 09/01/29</td>
<td>31.0</td>
<td>0767 – 0769</td>
<td>09/01/28 – 09/02/01</td>
<td>0.16</td>
</tr>
<tr>
<td>SGR 1806–20</td>
<td>07/10/14 – 07/10/15</td>
<td>46.6</td>
<td>0286 – 1080</td>
<td>05/02/16 – 11/08/20</td>
<td>4.24</td>
</tr>
<tr>
<td>SGR 0501+45</td>
<td>08/08/26 – 08/08/27</td>
<td>50.7</td>
<td>0047 – 1141</td>
<td>03/03/03 – 12/02/17</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Notes: The observation time and exposure of INTEGRAL are for the data selected to derive time-averaged spectra, which could be different from those of all the available observations.

2.3 INTEGRAL Observations

Table 1 

<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>$N_H$</th>
<th>$kT$</th>
<th>$\Gamma$</th>
<th>$\chi^2$/d.o.f.</th>
<th>Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RXS J1708–40</td>
<td>BB+PL</td>
<td>1.40 ±</td>
<td>0.45 ±</td>
<td>2.72 ±</td>
<td>3.17 ± 0.01 / --</td>
<td></td>
</tr>
<tr>
<td>1E 1547–54</td>
<td>BB+PL</td>
<td>3.46 ±</td>
<td>0.61 ±</td>
<td>2.38 ±</td>
<td>6.63 ± 0.07 / --</td>
<td></td>
</tr>
<tr>
<td>SGR 1806–20</td>
<td>BB+PL</td>
<td>8.43 ±</td>
<td>0.40 ±</td>
<td>1.97 ±</td>
<td>0.95 ± 0.02 / --</td>
<td></td>
</tr>
<tr>
<td>SGR 0501+45</td>
<td>BB+PL</td>
<td>1.06 ±</td>
<td>0.69 ±</td>
<td>2.96 ±</td>
<td>2.94 ± 0.01 / --</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The first four rows are BB+PL fitting to the soft X-ray spectra; the middle four rows are fitting results of broad-band X-ray spectra. **BB and PL represent black-body and power-law respectively.**

Table 2 Soft and Hard X-ray Spectral Properties of Suzaku Data

<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>$N_H$</th>
<th>$kT$</th>
<th>$\Gamma$</th>
<th>$\chi^2$/d.o.f.</th>
<th>Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RXS J1708–40</td>
<td>BB+PL</td>
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<td></td>
</tr>
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<td>0.61 ±</td>
<td>2.38 ±</td>
<td>6.63 ± 0.07 / --</td>
<td></td>
</tr>
<tr>
<td>SGR 1806–20</td>
<td>BB+PL</td>
<td>8.43 ±</td>
<td>0.40 ±</td>
<td>1.97 ±</td>
<td>0.95 ± 0.02 / --</td>
<td></td>
</tr>
<tr>
<td>SGR 0501+45</td>
<td>BB+PL</td>
<td>1.06 ±</td>
<td>0.69 ±</td>
<td>2.96 ±</td>
<td>2.94 ± 0.01 / --</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The first four rows are BB+PL fitting to the soft X-ray spectra; the middle four rows are fitting results of broad-band X-ray spectra. **BB and PL represent black-body and power-law respectively.**

Results, as shown in Table 2, of 1RXS J1708–40 and SGR 1806–20 are in agreement with values from other observations of the sources within error (Rea et al. 2007; Esposito et al. 2007; Enoto et al. 2010a). Since 1E 1547–54 and SGR 0501+45 are in outburst during the Suzaku observations we used, it is not feasible to compare the fitting parameters with observations in quiescent states. So, we fit the broad-band spectra of 1E 1547–54 with a two component blackbody plus a power-law model, while a three component model including two blackbodies and a power-law is applied to SGR 0501+45, as tried in a previous analysis of the same observations (Enoto et al. 2010b,c), and the parameters are also consistent with former results. The spectral properties during the outburst are similar to those of the source in quiescence.

2.3 INTEGRAL Observations

Do you mean The gamma-ray mission INTEGRAL—International Gamma-Ray Astrophysics Laboratory (Winkler et al. 2003) has been operational since October 2002. **Note:** you previously write “INTEGRAL” so our editorial staff moved the longer version of the name to the first place you refer to this satellite (not counting “INTEGRAL IBIS” which is an instrument on the satellite). Its imager IBIS (Imager on Board the INTEGRAL Satellite; Ubertini et al. 2003) has a low-energy detector sensitive between 20–300 keV, the INTEGRAL Soft Gamma-Ray Imager (ISGRI; Lebrun et al. 2003). We used all public data from the INTEGRAL Science Data Center (ISDC) where the sources are within 10 degrees of the pointing direction from 2003 to 2011. The IBIS-ISGRI data
were reduced with the Off-line Scientific Analysis (OSA) software version 10. Following the standard procedures described in the IBIS analysis user manual, we created images in four energy bands (20–40, 40–60, 80–100, 100–300 keV) for source detection- and extracted spectra of the sources for each individual pointing.

To get a better S/N, spectra of individual pointings are summed up to derive the time-averaged spectra. Even so, the detection significance level of detection for SGR 0501+45 is very low (2.72 σ), making it impossible to extract a spectrum of high S/N, so we only analyze INTEGRAL spectra of the other three sources. Considering possible variability of the sources in over such a long time, we divide the INTEGRAL observations from 2003 to 2011 into one-year time intervals and extract spectra respectively. The spectra are fitted with a single power-law model, and the fitting results as well as 20–150 keV fluxes are listed in Table 3. We also plot the photon indices Γ and fluxes in Figure 1.

For 1RXS J1708–40, the deviation of photon indices and fluxes from the time averaged value is within the 2σ level, thus there is no significant variation. In the case of SGR 1806–20, the fluxes in 2003 and 2004 are apparently higher than those of the other years, presumably due to its giant flare in 2004 (Hurley et al. 2005). In the following seven years, the fluxes and photon indices do not change significantly, so we only sum up spectra of observations from 2005 to 2011.

However, the fluxes of 1E 1547–54 vary dramatically and an outburst is observed in 2009, during which its hard X-ray emission was first discovered by Suzaku. Do you mean For compatibility with Suzaku soft X-ray data of 1E 1547–54, the INTEGRAL observations utilized are only Revs. 768–769, from Jan. 28, 2009 to Feb. 1, 2009, which overlap in time with Suzaku observations from Jan. 28, 2009 to Jan. 29, 2009. As both the soft and hard spectra vary slightly from Jan. 28, 2009 to Feb. 7, 2009, the longer time span of INTEGRAL observations than that of Suzaku observations would make little difference.

The selection of INTEGRAL data for the three sources to get averaged spectra is analyzed above, and we summarize the resulting total exposure time in Table 1. We also fit the averaged spectra with a power-law model, and the fitting results are given in Table 3.

3 APPLICATION OF BMC MODEL TO THE AVERAGED SPECTRA

If AXPs/SGRs are fallback disk systems, soft photons emitted from the polar cap would be in the accretion flow. Some of the seed photons get upscattered by the Comptonization process with high-energy electrons, producing the hard X-ray emission, while others escape directly and constitute the soft X-ray spectra (Trümper et al. 2010). In spectral fitting, the BMC process is described by the
Fig. 1 Photon indices (left panels) and fluxes (right panels) for every one-year time interval of 1RXS J1708–40, 1E 1547–54 and SGR 1806–20. Do you mean: Horizontal dashed lines represent time-averaged values, with their 1σ errors indicated by grey bands, and vertical dotted lines indicate the observation time of Suzaku. Fluxes in the energy range of 20–60 keV and 60–150 keV are in red (with diamond markers) and blue (with triangle markers) respectively. For SGR 1806–20, time-averaged values from 2005 to 2011 are also plotted.
To Understand the X-ray Spectrum of AXPs and SGRs

Table 4: The Fitting Results of Suzaku Data with the compTB Model

<table>
<thead>
<tr>
<th></th>
<th>1RXS J1708–40</th>
<th>1E 1547–54</th>
<th>SGR 1806–20</th>
<th>SGR 0501+45</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_\text{e}(\text{10}^{22} \text{cm}^{-2})$</td>
<td>1.50 ± 0.01</td>
<td>3.42 ± 0.03</td>
<td>7.80 ± 0.15</td>
<td>0.79 ± 0.01</td>
</tr>
<tr>
<td>$kT_e$ (keV)</td>
<td>1.07 ± 0.01</td>
<td>1.17 ± 0.02</td>
<td>1.06 ± 0.02</td>
<td>1.09 ± 0.01</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.26±0.01 0.17</td>
<td>0.79 ± 0.04</td>
<td>0.20 ± 0.01</td>
<td>1.27 ± 0.01</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.62 ± 0.01</td>
<td>0.60 ± 0.01</td>
<td>0.32 ± 0.01</td>
<td>0.28±0.04 0.04</td>
</tr>
<tr>
<td>$\delta$</td>
<td>44.0±15.4</td>
<td>1.34±3.04</td>
<td>200(&gt;9.23)</td>
<td>18.6±2.9</td>
</tr>
<tr>
<td>$kT_e$ (keV)</td>
<td>1.57 ± 0.06</td>
<td>31.1±2.0</td>
<td>34.2±7.2</td>
<td>3.29±0.48</td>
</tr>
<tr>
<td>log(A)</td>
<td>−0.58 ± 0.01</td>
<td>−0.47 ± 0.01</td>
<td>−1.44 ± 0.02</td>
<td>−1.25 ± 0.02</td>
</tr>
<tr>
<td>$\chi^2$ (d.o.f.)</td>
<td>1.108 (177)</td>
<td>1.003 (102)</td>
<td>1.008 (95)</td>
<td>1.13 (237)</td>
</tr>
</tbody>
</table>

XSPEC model compTB (Farinelli et al. 2008), in which thermal and bulk-motion Comptonization of seed photons are considered. Do you mean This model consists of two components, the direct seed photon spectrum, and the Comptonized seed spectrum obtained as a self-consistent convolution of the seed spectrum with the system’s Green function. The seed photon spectrum is a modified blackbody $S(E) \propto E^\gamma/(e^{E/kT_e} − 1)$, where $kT_e$ is the blackbody temperature and $\gamma$ represents a modification of the blackbody. The Comptonization process is described by three parameters, bulk parameter $\delta = (E_{\text{bulk}}/E_{\text{th}})$ describing the relative efficiency of bulk over thermal Comptonization, electron temperature $kT_e$ and energy index of the Comptonization spectrum $\alpha$. There are also two coefficients, illumination factor $A$ and normalization of the seed photon spectrum $C_N$.

First we fit the broad-band Suzaku spectra of the four sources with compTB, which provides good fits from the statistical point of view. However, when initial values of parameters are changed, the spectral fitting could give different results with similar $\chi^2$. We list some fitting results in Table 4. The parameters are poorly constrained, with the problem mainly lying in the degeneracy of $\delta$ and $kT_e$. $\delta$ ranges from $\sim 1$ to $\sim 100$, and $kT_e$ ranges from $\sim 1$ keV to $\sim 10$ keV. Do you mean This should be attributed to the low S/N of Suzaku data in the hard X-ray band, while the equivalence of the BMC and TC processes in upscattering seed photons might cause such a situation to some extent.

The parameter $\gamma$ is left free in spectral fitting, and its best-fit values are in the range of 0.18–1.2, indicating a significant modification of the seed spectrum. Such large deviation of the seed spectrum from a pure blackbody is questionable, so we freeze $\gamma$ at 3 and try to fit the spectra with compTB again. The spectra of 1E 1547–54 and SGR 1806–20 can be fitted with a larger $\chi^2$, and $kT_e$ is similar to the temperature of a blackbody plus a power-law fit to soft X-ray data. However, 1RXS J1708–40 and SGR 0501+45 cannot get acceptable fits. On the other hand, the broad band spectra of 1E 1547–54 and SGR 1806–20 could be fitted with an absorbed blackbody plus power-law model, while an additional blackbody component is required for the spectral fitting of 1RXS J1708–40 and SGR 0501+45.

Do you mean To better constrain the parameters, we replace the hard X-ray spectra with ISGRI data, which are detected up to $\sim 150$ keV, higher than the $\sim 70$ keV limit of HXD. The compTB model could also be used to produce a good fit to the joint Suzaku XIS and IBIS-ISGRI spectra, though giving a slightly worse reduced $\chi^2$ than the former results of Suzaku data. The degeneracy of $\delta$ and $kT_e$ is partly removed, and a set of parameters with apparently better reduced $\chi^2$ can be found. The best fit parameters are shown in Table 5, and the corresponding unfolded spectra are presented in Figure 3. The fitting results of $\delta$ and $kT_e$ for the three sources do not differ much from each other. The electron temperature $kT_e$ is in the range of $2.11$–$3.48$ keV, a little higher than the blackbody temperature $kT_b$. Do you mean While the values of $\delta$ vary from $31.8$ to $51.8$, showing that the BMC process would be dominant over the TC process.

Note: According to the understanding of our editorial staff, you mean that the BMC process is more important than the TC process in
We also draw error contours for different values of $\delta$ and $kT_e$ to explore the reliability of fitting results, as shown in Figure 4. For 1RXS J1708–40, there is a satisfying constraint for the two parameters; while the parameters of 1E 1547–54 are not well constrained, as a result of the relatively short exposure time of the INTEGRAL data utilized; the situation of SGR 1806–20 is similar to that of 1RXS J1708–40.

**Table 5**  
Fitting Results of Suzaku and INTEGRAL Data with the compTB Model

<table>
<thead>
<tr>
<th></th>
<th>1RXS J1708–40</th>
<th>1E 1547–54</th>
<th>SGR 1806–20</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_H$ ($10^{22}\text{cm}^{-2}$)</td>
<td>1.52 ± 0.01</td>
<td>3.40 ± 0.03</td>
<td>7.89 ± 0.15</td>
</tr>
<tr>
<td>$kT_e$ (keV)</td>
<td>1.16 ± 0.01</td>
<td>1.14 ± 0.03</td>
<td>0.89 ± 0.02</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.12 ± 0.01</td>
<td>0.82 ± 0.02</td>
<td>0.17 ± 0.01</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.43 ± 0.01</td>
<td>0.72 ± 0.02</td>
<td>0.67 ± 0.04</td>
</tr>
<tr>
<td>$\delta$</td>
<td>50.8 ± 1.7</td>
<td>36.5$^{+29.6}_{-7.6}$</td>
<td>31.8$^{+2.4}_{-2.0}$</td>
</tr>
<tr>
<td>$kT_e$ (keV)</td>
<td>2.11 ± 0.06</td>
<td>3.78$^{+0.81}_{-0.48}$</td>
<td>3.48$^{+0.22}_{-0.18}$</td>
</tr>
<tr>
<td>$\log(A)$</td>
<td>−1.54 ± 0.01</td>
<td>−0.18 ± 0.02</td>
<td>−0.43 ± 0.03</td>
</tr>
<tr>
<td>$\chi^2$ (d.o.f.)</td>
<td>1.14 (173)</td>
<td>1.01 (94)</td>
<td>0.92 (86)</td>
</tr>
</tbody>
</table>

This context. Currently, the sentence is worded to support this viewpoint. If our understanding is not correct (i.e. the TC process is more important), please indicate this to our editorial staff.
To Understand the X-ray Spectrum of AXPs and SGRs

Fig. 3 $E^2 f(E)$ spectra of the three studied AXPs/SGRs, along with the best-fit compTB models and residuals in units of $\sigma$. Do you mean Suzaku XIS and INTEGRAL IBIS-ISGRI data are in black and red respectively?

Fig. 4 Error contours of $\delta$ (delta) and $kT_e$ for compTB fitting to Suzaku and INTEGRAL data of 1RXS J1708–40, 1E 1547–54 and SGR 1806–20. The sign '+' indicates parameter values with the minimum $\chi^2$. 1$\sigma$, 2$\sigma$ and 3$\sigma$ contours are in black, red and green respectively.
could provide more information and put better constraints on theoretical models. As we still lack observational data in the 10–20 keV range, the complete 1–250 keV HXMT spectra spectral resolution and S/N high enough to distinguish between those models.

100 HXMT simulations of the HXMT spectra of magnetar energy higher than 1 MeV. The resonant inverse Compton scattering model (Baring & Harding 2007) also predicts a power-law with cutoff break energy for all sources. Hernquist (2005) predicts a cutoff energy far above 1 MeV and high flux in agreement with different cutoff properties. The can thus be represented by a power-law without a cutoff below 250 keV? The errors associated with \( \delta \) and \( kT_e \) are much smaller than the results of Suzaku and INTEGRAL data, but the constraints on other parameters are similar. Error contours of \( \delta \) and \( kT_e \) are also drawn in Figure 6, which exhibit better constraints than those in Figure 4.

In the frame of magnetars, the hard X-ray spectrum is generally expected to be power-law with different cutoff properties. The model based on quantum electrodynamics model by Heyl & Hernquist (2005) predicts a cutoff energy far above 1 MeV and high flux in the \( \gamma \)-ray band. However, the \( \gamma \)-ray flux of 4U 0142+61 is not detected by Fermi-LAT (Şasım Muş & Göğüş 2010). Do you mean the bremsstrahlung model by Beloborodov & Thompson (2007) might have a cutoff at a few hundred keV, but the emerging spectrum will have a photon index of \( \Gamma \sim 1 \), which is below the break energy for all sources, which is inconsistent with current observations? The resonant inverse Compton scattering model (Baring & Harding 2007) also predicts a power-law with cutoff energy higher than 1 MeV. Do you mean These hard X-ray models that are used in the study of magnetar frame can thus be represented by a power-law without a cutoff below 250 keV?

According to the parameters of power-law fitting to the ISGRI data in Table 3, we also simulate the HXMT spectra of the power-law model, shown by the blue lines in Figure 5. Comparing the HXMT simulations of the power-law and BMC model, there are obvious discrepancies above ~ 100 keV, since the spectra of the BMC model could have a cutoff around 200 keV; Do you mean below ~ 100 keV, spectra of the two models are roughly similar, but there are also differences in the details? The relatively low cutoff energy of the BMC model results from the low electron temperature, different from ultra-relativistic electrons in other models. The quality of INTEGRAL spectra is not able to discriminate these differences, but future HXMT observations should have spectral resolution and S/N high enough to distinguish between those models. Besides In addition, as we still lack observational data in the 10–20 keV range, the complete 1–250 keV HXMT spectra could provide more information and put better constraints on theoretical models.

### 4 HXMT SIMULATION

Although IBIS-ISGRI covers the 20–500 keV energy band, data points above ~ 150 keV have low S/N, and the spectra are insufficient to differentiate models. Do you mean The first space telescope developed by China, HXMT, is will be launched in late 2014 or early 2015. HXMT is a collimated hard X-ray telescope based on the direct demodulation method and NaI(Tl)/CsI(Na) phoswich detecting techniques. The payload consists of three telescopes; they work in the low, middle and high energy range respectively, covering the 1–250 keV energy band. Among them, the high energy telescope, sensitive between 20 and 250 keV, has a large collecting area of 5000 cm² and hence high sensitivity. Based on the fitting results of the compTB model in Table 5, we simulate spectra with the HXMT response matrix and background file, shown by green lines in Figure 5. With an exposure time of 1 Ms, obvious cutoff around 200 keV can be seen for the three sources.

The simulated spectra are also fitted with the compTB model to examine the improvement of parameter constraints, and the fitting results are listed in Table 6. Do you mean The errors on \( \delta \) and \( kT_e \) are much smaller than the results of Suzaku and INTEGRAL data, while the constraints on other parameters are similar. Error contours of \( \delta \) and \( kT_e \) are also drawn in Figure 6, which exhibit better constraints than those in Figure 4.

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In the frame of magnetars, the hard X-ray spectrum is generally expected to be power-law with different cutoff properties. The model based on quantum electrodynamics model by Heyl & Hernquist (2005) predicts a cutoff energy far above 1 MeV and high flux in the \( \gamma \)-ray band. However, the \( \gamma \)-ray flux of 4U 0142+61 is not detected by Fermi-LAT (Şasım Muş & Göğüş 2010). Do you mean The bremsstrahlung model by Beloborodov & Thompson (2007) might have a cutoff at a few hundred keV, but the emerging spectrum will have a photon index of \( \Gamma \sim 1 \), which is below the break energy for all sources, which is inconsistent with current observations? The resonant inverse Compton scattering model (Baring & Harding 2007) also predicts a power-law with cutoff energy higher than 1 MeV. Do you mean These hard X-ray models that are used in the study of magnetar frame can thus be represented by a power-law without a cutoff below 250 keV? The errors associated with \( \delta \) and \( kT_e \) are much smaller than the results of Suzaku and INTEGRAL data, while the constraints on other parameters are similar. Error contours of \( \delta \) and \( kT_e \) are also drawn in Figure 6, which exhibit better constraints than those in Figure 4.

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Fig. 5 HXMT simulated spectra of 1RXS J1708–40, 1E 1547–54 and SGR 1806–20. The low (in black) and middle (in red) energy bands are based on the parameters of the compTB model, while the high energy spectra are simulated for both the compTB and power-law model, shown in green and blue respectively.

5 CONCLUSIONS

Whether AXPs/SGRs are magnetars or quark star/fallback disk systems remains a problem that needs to be settled. We study the soft and hard X-ray spectra of four AXPs/SGRs with Suzaku and INTEGRAL observations. The broad-band Suzaku spectra could be well reproduced by the BMC process, and the BMC model could also fit the combined Suzaku and INTEGRAL spectra, with parameters better constrained. Thus the fallback disk system could be compatible with the X-ray emission of AXPs/SGRs, implying that the existence of accretion flow is possible. In addition, HXMT simulated spectra of the BMC model exhibit cutoff around 200 keV, showing a significant discrepancy from the power-law spectra. Do you mean We can expect to be able to distinguish the BMC model from other hard X-ray models in research related to the magnetar frame by future Chinese using future observations from the Chinese satellite HXMT—observations, and which will allow astronomers to further understand the nature of AXPs/SGRs.

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Fig. 6 Error contours of $\delta$(delta) and $kT_e$ for compTB fitting to HXMT simulated spectra of 1RXS J1708–40, 1E 1547–54 and SGR 1806–20. The sign ‘+’ indicates parameter values with the minimum $\chi^2$. 1$\sigma$, 2$\sigma$ and 3$\sigma$ contours are in black, red and green respectively.

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