Study of Fe-K line Resonance Scattering in the Intracluster Medium with Monte-Carlo Simulation and Suzaku Data

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ABSTRACT

In the formation of galaxy clusters, clusters collide with each other and merge. The kinetic energy in the collision changes into the thermal energy and generates turbulence in the intracluster medium (ICM). By studying turbulence in galaxy clusters, we could get the history of its formation. We can measure the turbulent velocity by measuring the Doppler shift of emission lines of the ICM. However, the past X-ray observations could not measure the Doppler shift well. ASTRO-H, which has an excellent spectral resolution is expected to detect the line Doppler broadening and we can measure the turbulence velocity. Measuring the resonance scattering of Fe-K lines is another way to study the turbulence. We can constrain the turbulent velocity by using intensity ratio among Fe-K lines with various oscillator strength. To estimate the resonance scattering, we are constructing the Monte-Carlo simulator. The merit of Monte-Carlo simulation is that we can treat asymmetric ICM structures unlike the analytical method. In addition, we apply this simulator for the Perseus cluster and compare the results with the Suzaku 824ks observations. In this poster, we introduce the Monte-Carlo simulator and report the comparison between the simulation and Suzaku data.

Key words: workshop: X-ray — line profiles — resonance scattering — turbulence — galaxy cluster — ASTRO-H — Suzaku

1. Introduction

Galaxy cluster consists of stars, intracluster medium (ICM) and dark matter. Non-thermal pressure provided by ICM turbulence affects the hydrostatic and thermodynamic structure, and introduces bias on the mass estimation or the physical interpretation of X-ray and Sunyaev-Zeldovich effect observation (Nagai et al. 2013). Study of the ICM turbulence is important science of ASTRO-H. Here, we constructed the Monte-Carlo simulator of the resonance scattering on the ICM turbulence for future observations, as well as Zhuravleva et al. 2013. We also analyzed the Suzaku 842ks observation of Perseus cluster.

2. Method

2.1. Resonance scattering and ICM turbulence

When we search for the motion of the ICM, we use the Doppler broadening and obtain the velocity toward the line of sight. However, we cannot distinguish some of ICM motions, for example, bulk motion, rotation, turbulence. Apart from the Doppler, we can utilize resonance scattering. The larger the velocity of turbulence is, the less the amount of resonance scattering is, leading to change of the line ratios. This is independent information against the Doppler, and could distinguish the type of ICM motions.

2.2. Construct the Monte-Carlo simulator of resonance scattering

ASTRO-H which is 6\(^{th}\) X-ray observation satellite has an extremely high energy resolution(\(~7eV\)). Then, it is expected to detect the line Doppler broadening and also resolve Fe-K emission lines with difference resonance scattering cross section. So, we construct the Monte-Carlo simulator of resonance scattering on the ICM turbulence. By using the Geant4 tool kit, which is widely utilized for detector design in the accelerator, astrophysics, and medical regions. Geant4 provide the simulation environment of physical interactions of particles and photons in the material. We originally put the cross section of resonance scattering, where the ICM turbulence effect can be included and we put the Fe(Fe\(^{+24}\), Fe\(^{+25}\)) and Ni(Ni\(^{+26}\), Ni\(^{+27}\)) lines(total 13 lines). We performed the simulation with various turbulent velocities.

The output data of Geant4 are fed into the ASTRO-E2 XRS simulator, since the ASTRO-H SXS simulator is now not available. The Perseus cluster is constructed in the simulation.
3. Results and discussion
3.1. Result of ASTRO-H simulation
We simulated Fe and Ni lines of the Perseus Cluster center region with the ASTRO-H SXS (Fig.1). This figure shows that ASTRO-H observation can resolve Fe-K multiple lines, as reported by Zhuravleva et al. 2013.

![Fig. 1. The result of Fe-Kα line ASTRO-H simulation](image)

We analyzed the line ratios of the case of no resonance scattering(noRS) to that of resonance scattering(RS) (Fig.2). Resonance scattering effect can be seen only in the cluster center part. The larger the velocity of turbulence is, the less the amount of resonance scattering is. ASTRO-H observation is expected to constrain turbulence.

![Fig. 2. Line ratios of noRS to RS](image)

3.2. Result of Suzaku-XIS 824ks observation
We analyzed the XIS 824 ks data of the Perseus cluster(Fig.3). We fitted the Fe-K and Ni-K lines and obtained the line ratios against Fe²⁺Kα 6.7 keV line. Then, we constrained the allowed kT region with the 7.0/6.7 keV line ratio, and derived the apec model prediction of 7.80, 7.88, 8.27 keV to 6.7 keV line ratios(Fig.4). As shown in table 1, the line ratio of (7.80+7.88)/6.7 is larger than the model at r<1 arcmin with the allowed kT region, suggesting that the 6.7 keV line is weakened.

![Fig. 3. Perseus Cluster XIS-0,2,3 sum(r<1arcmin)](image)

![Fig. 4. Line intensity ratio against Fe²⁺Kα6.7keV](image)

<table>
<thead>
<tr>
<th>Region</th>
<th>Energy[keV]</th>
<th>Observed</th>
<th>apec model</th>
</tr>
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<tbody>
<tr>
<td>r &lt; 1′</td>
<td>7.80+7.88</td>
<td>0.13 ± 0.01</td>
<td>0.105±0.004 −0.003</td>
</tr>
<tr>
<td></td>
<td>8.27</td>
<td>0.03 ± 0.01</td>
<td>0.034±0.001 −0.002</td>
</tr>
<tr>
<td>r = 2 − 4′</td>
<td>7.80+7.88</td>
<td>0.12 ± 0.01</td>
<td>0.114±0.003 −0.001</td>
</tr>
<tr>
<td></td>
<td>8.27</td>
<td>0.035 ± 0.003</td>
<td>0.046±0.002 −0.002</td>
</tr>
</tbody>
</table>

We compared the Suzaku-XIS observation data and Suzaku simulation data, which are generated by feeding the Geant4 output to the Suzaku-XIS simulator, for various turbulence velocities. The comparison suggested that Much number M would be larger than 0.35.

References
Churazov E. et al. 2004 MNRAS., 347, 29
Zhuravleva I. et al. 2013 MNRAS., 435, 3111