Non-bias survey of cluster of galaxies with MAXI

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http://maxi.riken.jp/cluster

Abstract We analyzed the spectra of 192 clusters of galaxies observed by MAXI, and obtained metal-abundances, temperatures, and luminosities. Among these clusters, the abundance ratios relative to solar composition were determined for 33 clusters, yielding a weighted average of 0.29 ± 0.06, which is consistent with the previous studies. For 186 clusters with determined temperatures, we investigated the relation between temperature T and luminosity L, resulting as approximately $L \propto T^{3.9^{+0.5}_{-0.4}}$. This result may not be consistent with previous studies, which was reported $L \propto T^{2.53 \pm 0.15}$.

1. Objective

MAXI performs unbiased scanning of the whole sky, allowing for high-quality spectra of X-ray-bright cluster of galaxies.
The average exposure was 23000 cm^2 ks for each cluster.
By investigating all-sky cluster of galaxies (Fig. 1), we determine their temperatures from the spectra and examine the statistical properties of these clusters.
We also compare our findings with previous studies to assess any differences.

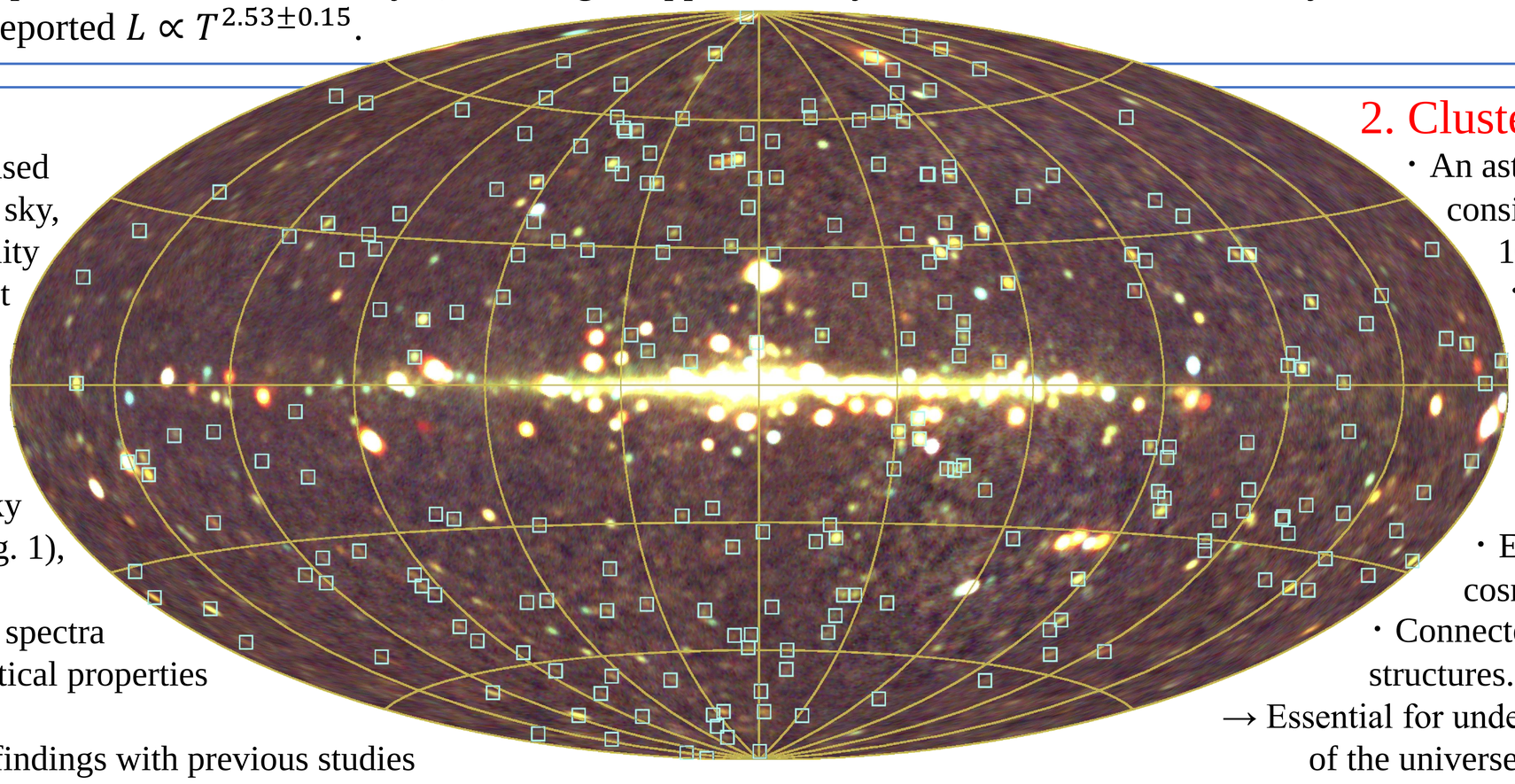

Fig. 1 : All-sky image by MAXI. Squares : Clusters of galaxies analyzed in this study.

2. Cluster of galaxies

- An astronomical object consisting of approximately 100 to 1,000 galaxies.
- The largest self-gravitating system in the universe.
- Nodes of the large-scale structure of the universe.
- Evolved through the cosmological time scale.
- Connected by filamentary structures.

→ Essential for understanding the structure of the universe as a whole.

3. Analysis

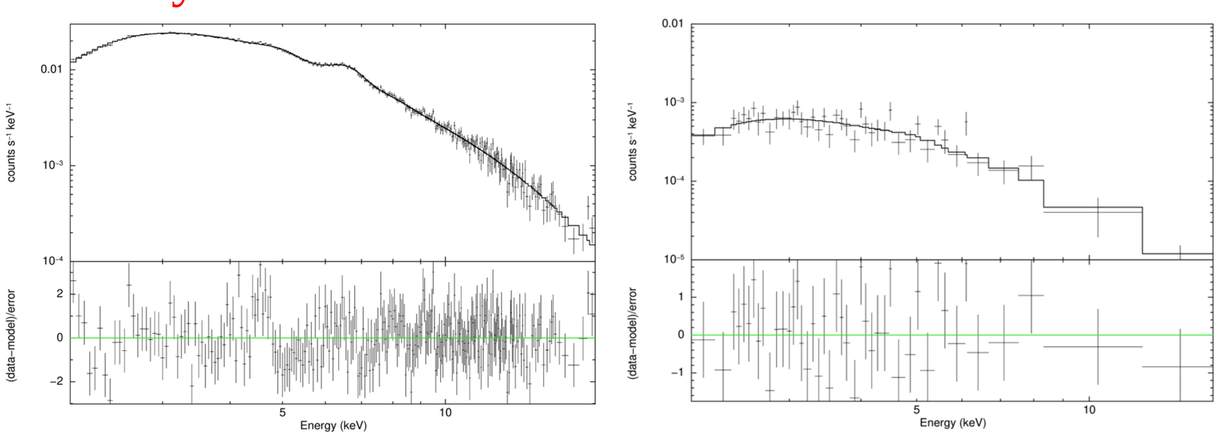

Fig. 2 : Spectral fits of the Strongest cluster (left) and Typical cluster(right).

Table. 1 : Fitting parameters for clusters of galaxies.

	Perseus cluster	ACO 2657
kT(keV)	$5.57^{+0.09}_{-0.09}$	$4.8^{+1.6}_{-1.0}$
Abundance	$0.30^{+0.01}_{-0.01}$	0.3 (fixed)
redshift z	0.018 (fixed)	0.04 (fixed)
$N_H(/\mathrm{cm}^2)$	$0.30^{+0.04}_{-0.04} \times 10^{22}$	0.0 (fixed)
Flux $2-10$keV $(\mathrm{erg/cm^2/s})$	$1.04^{+0.01}_{-0.01} \times 10^{-9}$	$2.3^{+0.4}_{-0.3} \times 10^{-11}$
χ^2	332 (dof 249)	39 (dof 42)

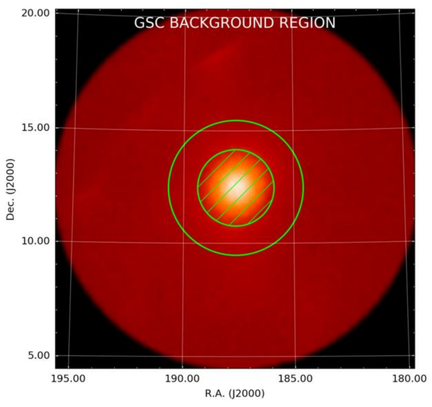

Fig. 3 : X-ray image of the Virgo cluster.

Data were obtained using MAXI-ondemand (http://maxi.riken.jp/mxondem). X-rays from cluster of galaxies consist of thermal bremsstrahlung from intracluster ionized gas and emission lines from heavy-element ions. The examples of spectra and X-ray images are shown in Fig. 2 and 3. The best-fit parameters of the APEC and tbabs model are in Table 1.

We analyzed 192 clusters of galaxies. The redshift distribution is shown in Fig. 4, indicating that the number is approximately one-tenth of that in the ACO and MCXC catalogs. The redshift-flux distribution is shown in Fig. 5. The detection limit of MAXI is read to around 1×10^{-11} $\mathrm{erg/cm^2/s}$.

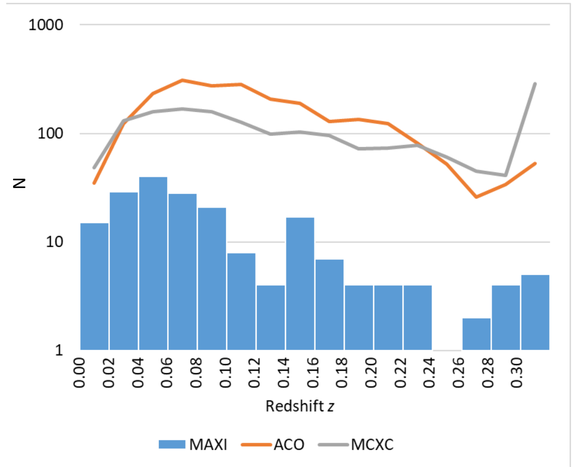

Fig. 4 : Redshift distribution of this study

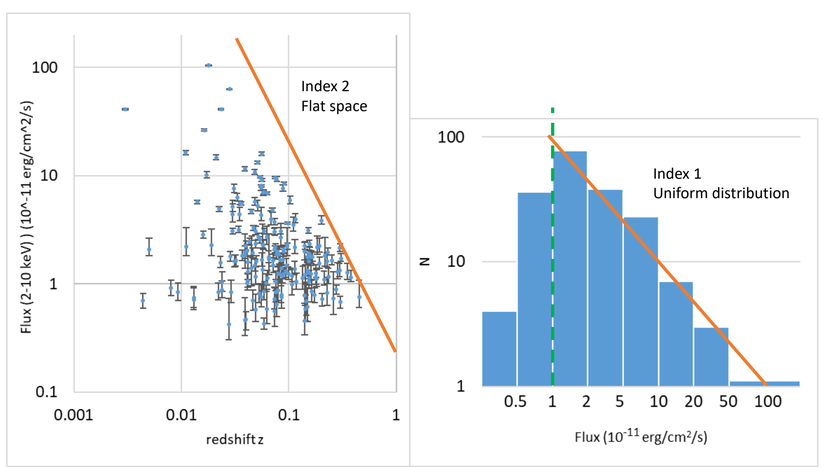

Fig. 5 : Redshift-Flux distribution and Flux histogram

4. Results

The values of the abundance are shown in Fig. 6. The weighted average abundance is 0.28 ± 0.09 (previous studies : 0.2–0.3 [2]).
The relation between the temperature and luminosity of the cluster of galaxies is shown in Fig. 6. Fitting the data with a power-law function $y = a \cdot x^b$ resulted in b=4.2 (previous studies : b=2.53 ± 0.15 [2]). The reduced chi-squared is 7.64, which is not an acceptable.
After adding artificial errors to adjust the reduced chi-squared to be 1, the index resulted in $b = 3.9^{+0.5}_{-0.4}$ (Fig. 7)
The temperature-luminosity relation almost follow a power-law relation, but does not precisely reproduce the data. One possible reason, according to previous studies [3], is that when a cluster of galaxies has a cool core, the temperature-luminosity relation scatters more. In a cool-core, radiation cooling makes the temperature at the center of the cluster lower, which results in the cooler temperature than the surrounding region.

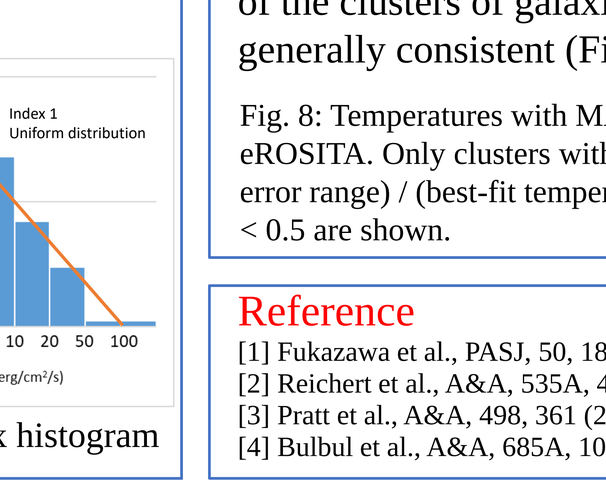

Fig. 6 : Abundances of the 33 bright clusters of galaxies (90% confidence).

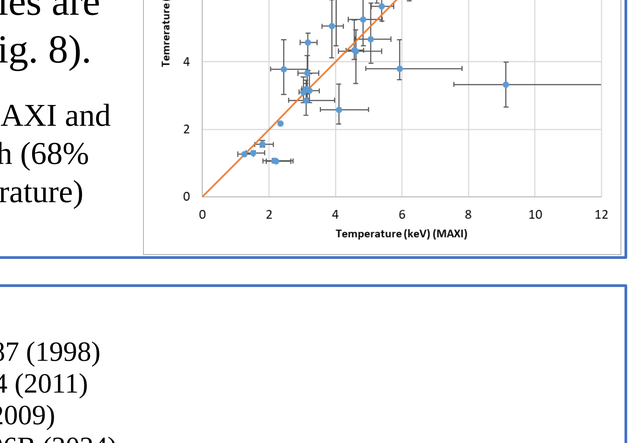

Fig. 7 : Temperature-luminosity relationship of 186 clusters of galaxies (68% confidence). yellow : b=3.9, green : b=4.3, red : b=3.5, purple : b=2.53 [previous study].

5. Comparison

Comparison between MAXI and eROSITA observations [4] indicates that the temperatures of the clusters of galaxies are generally consistent (Fig. 8).

Fig. 8: Temperatures with MAXI and eROSITA. Only clusters with (68% error range) / (best-fit temperature) < 0.5 are shown.

Reference

[1] Fukazawa et al., PASJ, 50, 187 (1998)
[2] Reichert et al., A&A, 535A, 4 (2011)
[3] Pratt et al., A&A, 498, 361 (2009)
[4] Bulbul et al., A&A, 685A, 106B (2024)