Search for WHIM in the Shapley Supercluster with Suzaku

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Abstract

The Shapley supercluster was observed with Suzaku to search for emission from a warm-hot intergalactic medium. An excess was suggested in the energy spectrum, compared to the spectrum of an offset pointing that is 4 degrees away from the supercluster. A similar excess was also observed in a nearby (1 degree away) field. This excess can be represented by a thermal plasma of $kT \sim$1 keV, at a redshift of either 0 or that of the supercluster. The excess does not contain redshifted O emission lines, and an upper limit for the O VIII line intensity is 5.6 $\times 10^{-8}$ photons s^{-1} cm^{-2} arcmin^{-2}, which corresponds to an overdensity of 204 for WHIM emission.

Key words: X-rays:galaxies:clusters, Xrays:individual:Shapley Supercluster , Cosmolofy:large-scale structure of universe

1. Introduction

The Universe consists of dark energy (73 %), dark matter (23 %) and baryons (4 %). However, more than half of the local baryons are not yet observationally detected (Fukugita et al. 1998). These hidden baryons are called "missing baryons". Cosmic numerical simulations predict that most of them hide as a hot filamentary interglactic medium whose temperature range is 10^5-10^7 K, termed the warm-hot intergalactic medium (WHIM; e.g., Cen & Ostriker 1999). The WHIM is also thought to be a good tracer of cosmic large-scale structure defined by the dark matter distribution (Yoshikawa et al. 2001).

2. Shapley Supercluster

The Shapley supercluster (z = 0.048) is one of the biggest and densest superclusters in the local Universe. Previously, ROSAT detected excess emission between 0.5 and 2 keV in the Shapley supercluster compared to background regions (Kull et al. 1999). One interpretation is that the emission is from the WHIM.

We observed a region between A3556 and A3558, near the center of the Shapley supercluster. In addition, we observed two offset regions at $\sim$1 (OFFSET1) and $\sim$ 4 (OFFSET2) degrees from A3558. Table 1 gives the pointing positions and their net exposure time. OFFSET2 was observed to obtain a template spectrum of the foreground emission, including the local structure of the soft X-ray diffuse emission.

3. Analysis and Results

We extracted and analysed spectra from XIS1 data using HEAsoft version 6.5.1 and XSPEC 12.4.0ad. We estimated the non X-ray background (NXB) using a dark Earth database and the "xisnxbgen" ftools task (Tawa et al. 2008). The NXB level was normalized in the 10 to 15 keV band for each of the three observed specta. We removed point sources detected in the 0.5 to 2 keV band whose 2 to 10 keV fluxes are above 2×10^{-14} ergs cm^{-2} s^{-1}. Then we evaluated the cosmic X-ray background (CXB) level by fitting a power-law model between 2 to 5 keV.

After subtracting the NXB component, we fitted each spectrum using a typical Galactic emission model, that is apec$_1$ + phabs$\times$(apec$_2$ + power-law), where "apec" is a thin thermal plasma emission in collisionally ionization equilibrium with metals of Solar abundances (see details in Yoshino et al. 2009). While the spectrum in OFFSET2 region can be well represented by that model, Shapley and OFFSET1 regions cannot be fitted well, especially in 0.4–0.5 keV band where the data are in excess of the model, as shown in Figure 1. The excess can be fit if we allow a high Ne/O ratio (∼2 solar) or if we add one more "apec" component whose temperature is 0.8 or 0.9 keV, respectively for the two regions. We did not detect statistically significant redshifted Oxygen emission lines. We show the fitted spectrum of the supercluster with three thermal emission components and the best-fit parameters in Figure 2 and Table 2, respectively. The present data do not constrain the redshift of the excess.

4. Discussion

Since the temperature of the third apec component is higher than that of typical Galactic emission, there remains a possibility that it has a supercluster origin. Although we can not distinguish between a local ($z = 0$) or supercluster ($z = 0.048$) origin within the statistical and systematic uncertainties, we placed an upper limit on the emission measure of any plasma in the supercluster assuming that all of the third component comes from the supercluster. The 2 σ upper limit corresponds to an overdensity of $\delta < 255 \left(\frac{L}{4\ \mathrm{Mpc}}\right)^{-1/2}$ with respect to the mean density of the Universe, according to the method of Takei et al. (2007). Similarly, we constrained the overdensity of the WHIM from the intensities of redshifted O VII and O VIII emission lines. The upper limit of O VIII line intensity at $z = 0.048$ is 5.6×10^{-8} photon $\mathrm{s^{-1}\ cm^{-2}\ arcmin^{-2}}$. This is the tightest limit in comparison with past observations as shown in Figure 3. If we assume $T = 3\times10^{6}$ K, the temperature for the maximum emissivity of O VIII, the overdensity is $\delta < 204 \left(\frac{Z}{0.1\ Z_\odot}\right)^{-1/2} \left(\frac{L}{4\ \mathrm{Mpc}}\right)^{-1/2}$.

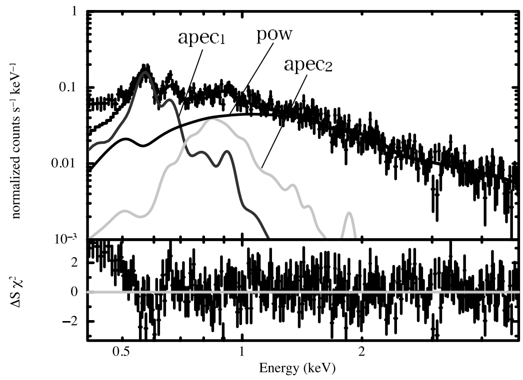

Fig. 1. Obtained spectrum of Shapley supercluster region. Models: $\mathrm{apec_1}$ + phabs×($\mathrm{apec_2}$ + power-law)

Table 1. Observation logs.

parameters\region	Shapley	OFFSET1	OFFSET2
Obs time	2008-07-10	2008-07-18	2008-07-19
(RA, DEC) J2000	(201.4, -31.6)	(201.1, -30.6)	(204.9, -29.9)
exposure [ks]	82	143	41

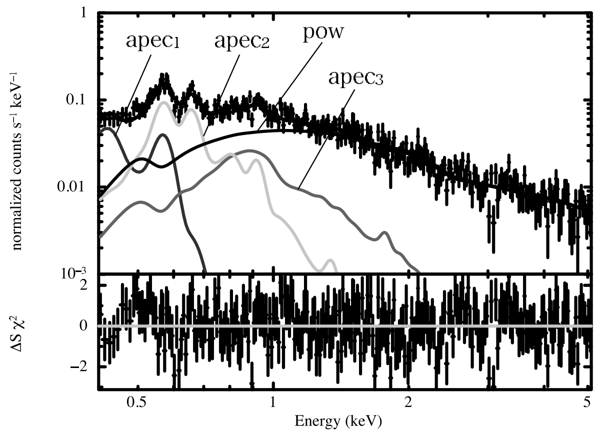

Fig. 2. Obtained spectrum of Shapley supercluster region. Models: $\mathrm{apec_1}$ + phabs×($\mathrm{apec_2}$ + $\mathrm{apec_3}$ (z=0.048) + power-law)

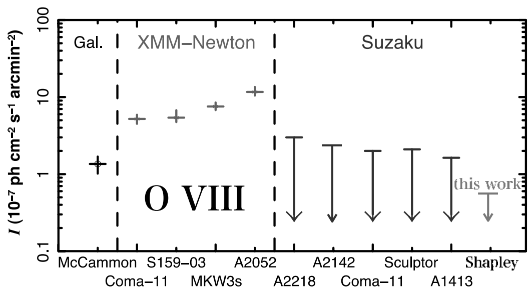

Fig. 3. Obtained intensity of O VIII emission line from this work with previous work.

Table 2. Obtained fitting parameters.

model	Galactic *	+apec (z=0.048)
kT_1 [keV]	$0.16^{+0.01}_{-0.01}$	$0.052^{+0.024}_{-0.028}$
kT_2 [keV]	$0.64^{+0.06}_{-0.05}$	$0.19^{+0.06}_{-0.02}$
kT_3 [keV]		$0.78^{+1.7}_{-0.10}$
$\chi^2/d.o.f$	340 / 254	255 / 255
Line intensity (O VIII)†		$< 5.6 \times 10^{-8}$
δ (O VIII)		< 204

* Galactic model means $\mathrm{apec_1}$ (*z=0, Z=1*) + phabs×($\mathrm{apec_2}$ (*z=0, Z=1*) + power-law)
† The unit is [photon/s/cm^2/arcmin^2]

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