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PROBING THE COSMIC FILAMENTS BY MEANS OF X-RAY OBSERVATIONS

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Abstract. Recent observations and numerical simulations show that galaxies are not distributed in the Universe randomly. They are placed like the pearls of a necklace. The matter is spread into the space in the form of cosmic filaments and voids. The intersection regions of these cosmic filaments are what we observe as "clusters of galaxies". In this work we selected 9 clusters of galaxies (A1644, A1736, A3528, A3530, A3532, A3556, A3558, A3560, A3562) from SHAPLEY super cluster region, the largest concentration of galaxies in our nearby Universe. The XMM-Newton and Chandra archival data are used for the analysis. We interpret the morphology of the clusters in the region and gravitational perturbations as a result of close encountering in the Shapley. The cosmic filaments and webs are portrayed from the Shapley super cluster region analysis results.

1. INTRODUCTION

The matter in the universe is not evenly distributed on large scale as assumed, instead is assembled in long filaments, web-like structures. The filaments are composed of galaxies. Clusters of galaxies are expected to develop at the intersections of these webs. Thus, these filaments intersect as clusters of galaxies with large empty spaces between the filaments. Recent observations and simulations show that the universe has the appearance of a Swiss cheese. The matter distribution is modelled for a better understanding of the formation of structure in the Universe by MPA Millennium Team[1] (Springel et al. 2008).

Clusters of galaxies also gravitationally attract each other and get together to form *Superclusters*. The Shapley Supercluster is the largest concentration of galaxies in the nearby Universe. It is a gravitationally interacting unit, the galaxies pull themselves together instead of expanding with the Universe. Shapley lies very close to the direction of the Local Group of galaxies (including our Galaxy). Thus, it is thought to be reason of our peculiar motion.

In this study, we have selected a cluster sample of 9 Shapley Supercluster members. The mosaic soft X-ray images of 7 Shapley member is shown Fig. 1. The extended

[1]http://www.mpa-garching.mpg.de/galform/millennium/

X-ray emission perturbations are used for tracing and modelling the locations of filaments in the region. The elongations of the intra-cluster medium (ICM) are observed to be towards the closest neighbor cluster. Throughout the work we assume H_0=75 km s^{-1} Mpc^{-1} and cosmological deceleration parameter of q_0=0.5.

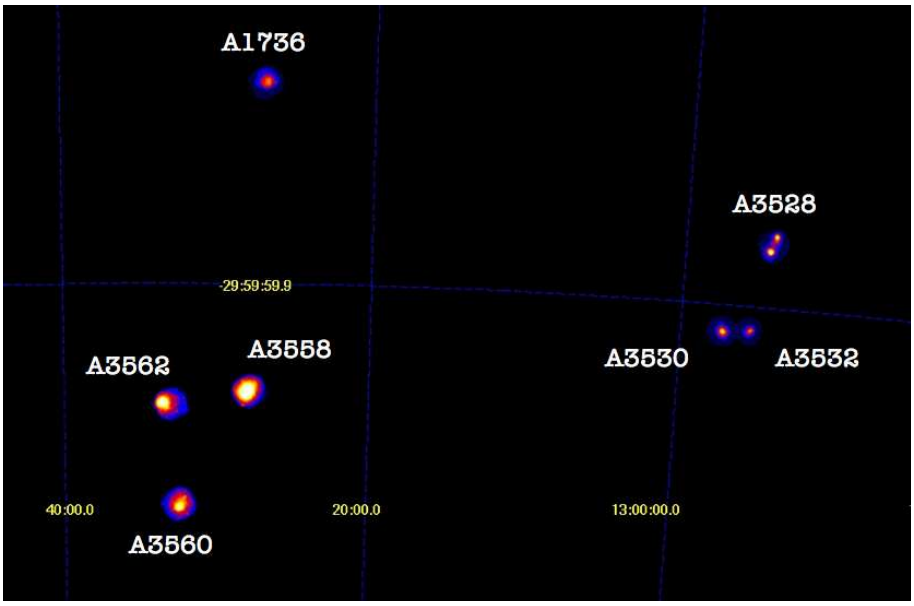

Figure 1: X-ray image of Shapley Supercluster constructed by mosaic images.

2. SAMPLE SELECTION AND ANALYSIS

Shapley is located in the Southern Hemisphere at a redshift going from z ∼0.03 to z ∼0.05 and extending over several square degrees (Fig. 1). We have selected 9 Shapley member clusters and obtained X-ray observations from archival data. Table 1 shows the selected sample with the redshift values and the observation log.

We processed the observation data files and created calibrated event files using the SAS version 7.0.0 for $XMM-Newton$ and CIAO version 4.0 for *Chandra* data. The event lists were generated from the observation data files (ODF) by the tasks EMCHAIN and EPCHAIN. In the standard analysis, the events were selected with PATTERN 0-12 for MOS and single and double pixel events (PATTERN 0-4) for PN. In order to exclude the contribution from the background flare events, we extracted light curves for the full field of view. It is known that a high-energy band is more sensitive to flare events than a soft-energy band. We thus choose hard band for $XMM-Newton$ (10-12 keV for MOS and 12-14 keV for PN). The extracted light curves were clipped to clean the contamination by soft proton flares as described by Hudaverdi (2005). These Good Time Intervals (GTI) were applied to the event lists and filtered events files are produced.

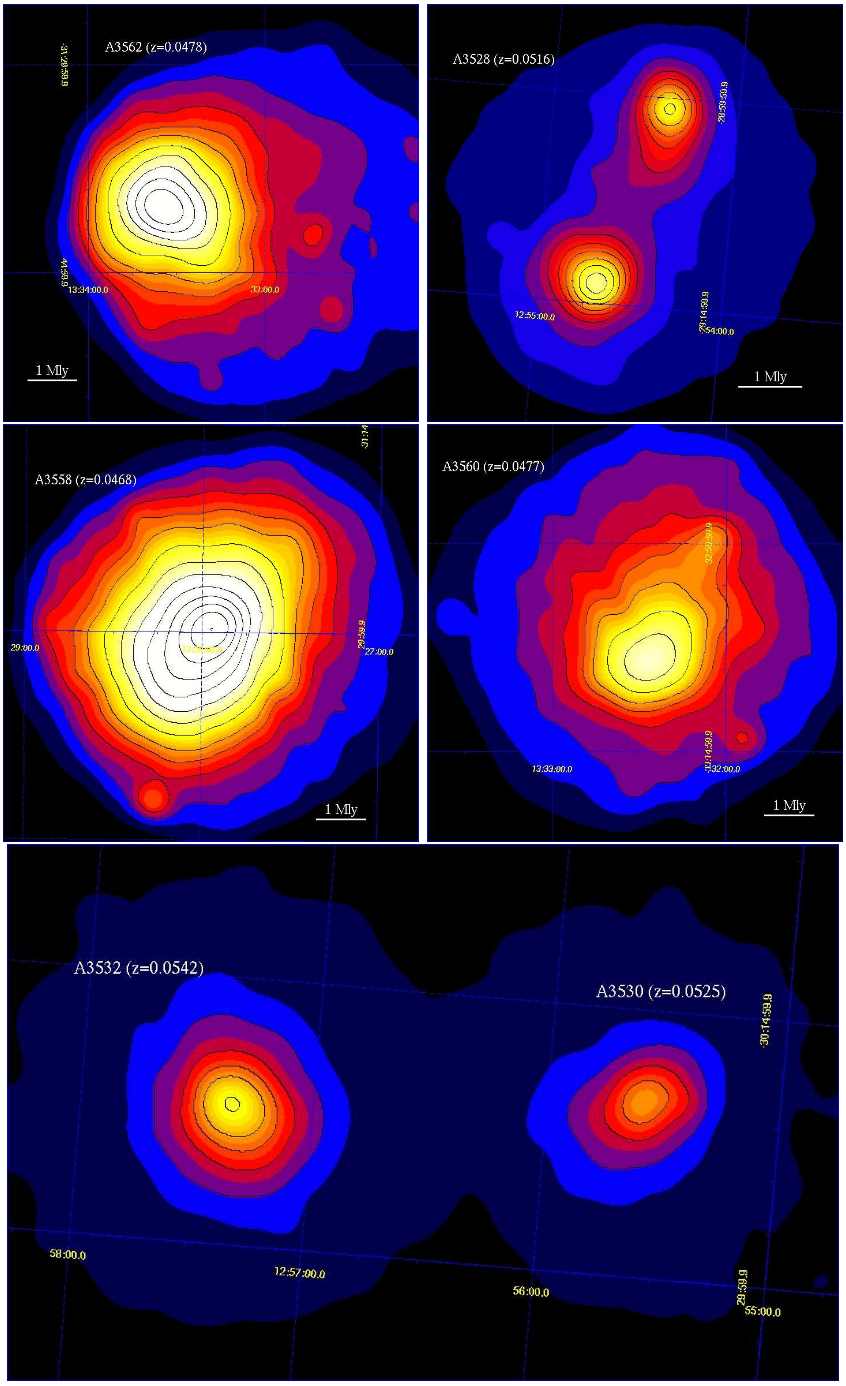

Figure 2: Soft X-ray [0.3-2 keV] images of A3562, A3528, A3558, A3530 and A3532 binary and A3560. The images are no-background subtracted and adoptively smoothed.

Table 1: Log of X-Ray (XMM-*Newton* and *Chandra*) observations.

Source	z	Mission	Date	α (2000)	δ (2000)	Exp. (sec)
Abell 1644	0.0473	*Chandra*	2001.01.08	12:57:09.60	-17:24:36.00	18960
		XMM-*Newton*	2001.01.08	12:57:32.80	-17:20:38.80	22806
		XMM-*Newton*	2001.01.08	12:57:32.83	-17:20:39.00	10908
Abell 1736	0.0458	*Chandra*	2003.04.19	13:26:53.70	-27:10:35.50	15120
		XMM-*Newton*	2006.08.08	13:26:48.73	-27:10:36.90	23852
Abell 3528	0.0528	*Chandra*	2007.03.20	12:54:41.50	-29:13:33.00	8180
Abell 3530	0.0537	XMM-*Newton*	2004.01.15	12:55:35.87	-30:19:51.40	21914
		XMM-*Newton*	2001.12.27	12:55:35.65	-30:19:42.80	18821
Abell 3532	0.0554	XMM-*Newton*	2002.07.03	12:57:16.85	-30:22:11.10	16895
Abell 3556	0.0479	*Chandra*	2003.03.08	13:23:49.40	-31:43:59.00	20050
Abell 3558	0.0480	*Chandra*	2001.04.14	13:27:56.91	-31:29:43.90	14619
		XMM-*Newton*	2002.01.22	13:27:57.20	-31:30:18.70	23317
		XMM-*Newton*	2002.01.21	13:27:57.24	-31:30:19.50	44615
Abell 3560	0.0489	XMM-*Newton*	2004.08.07	13:32:16.62	-33:05:24.70	45522
Abell 3562	0.0490	*Chandra*	2003.05.22	13:33:36.00	-31:40:27.00	19540
		XMM-*Newton*	2003.01.12	13:33:05.51	-31:41:25.20	47167

3. DISCUSSION

Fig. 2 shows 0.3-2.0 keV soft energy band merged images 7 clusters. The images are raw, non-background subtracted and adaptively smoothed to enhance cluster emission above the background emission. The elongations indicate low surface brightness filaments between clusters. A3528 is a binary cluster and the diffuse filament is evident. A3530 and A3532 are separated about ~2 Mpc. We can recognize a faint filament in between. A3558 and A3560 are ~10 Mpc separated. There is no extend lobe emission between the clusters, but the X-ray plasma deforms towards each other. The X-ray point sources are also aligned in the same direction. This shows that galaxies do not fall into gravitational potential of clusters randomly, but they funnel trough the cosmic filaments. The plasma residuals from brightness profile models would better give the direction of the formations and the deformations. The work will be completed after the study of the β profiles and reciprocal deviations from symmetry for each system, and the study of the gravitational effects in Shapley region.

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