X-RAY OBSERVATIONS OF THE MOST MASSIVE DLS SHEAR-SELECTED GALAXY CLUSTERS

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Abstract  We report on preliminary results of our X-ray survey of the most massive clusters currently identified from the Deep Lens Survey (DLS). The DLS cluster sample is selected based on weak lensing shear, which makes it possible for the first time to study clusters in a baryon-independent way. In this article we present X-ray properties of a subset of the shear-selected cluster sample.

Keywords: dark matter, gravitational lensing, large-scale structure of universe, X-rays: galaxies: clusters

1. Introduction

Nonbaryonic dark matter is apparently the dominant component of galaxy clusters, yet all large samples of clusters to date are selected on the basis of emission from the trace baryons they contain: visible light from galaxies or X-rays from hot intracluster gas. Now, for the first time, we have a direct survey of mass in the Universe that is unbiased with respect to baryons, the Deep Lens Survey (DLS). The DLS is a deep, wide area, multicolor (BVRz') imaging survey being carried out at the NOAO 4-m telescopes. The survey was designed to detect large scale structures in the Universe through weak lensing shear, i.e., distortions to the shapes of distant background galaxies caused by gravitational lensing of massive foreground objects. The DLS team has already shown that shear-selection is effective at finding new galaxy clusters: Wittman et al. (2001) report the discovery of CL J2346+0045, the first galaxy cluster identified by its gravitational effect rather than its radiation.

For this project, 12 square degrees of the DLS data (the maximum sky area available at the time) were processed through the weak lens shear pipeline (Wittman et al. 2003), revealing mass concentrations over a wide range of redshifts. These mass clusters were rank-ordered by their shear signal and the top
candidates were proposed for observation by the Chandra X-Ray Observatory in cycle 4. Seven targets were awarded; an additional candidate was available through the Chandra archive. One of the principle goals of the follow-up X-ray observations is to confirm that the DLS shear-selected clusters are associated with true virialized, collapsed structures. The basic X-ray information (luminosity, size, morphology, extent of central concentration, and gas temperature) obtained on the clusters will allow us to assess the effect of shear-selection on the $L_X - T_X$ relation, the cluster temperature function, and the relation of these to cluster mass. The full DLS X-ray cluster sample will also allow us to quantify the false-positive rate of “aligned filaments,” i.e., line-of-sight projections that appear as spurious mass concentrations in weak lensing shear maps (e.g., White, van Waerbeke, & Mackey 2002).

2. X-ray Observations

We have confidently detected extended X-ray emission from at least five of the eight DLS clusters in the Chandra cycle 4 sample. Although the other three targets have been observed, our analysis is not yet complete and we do not comment on them further here.

Figure 1 shows maps of the projected mass (left panels) and X-ray surface brightness (right panels) over the 0.5–2 keV band for several of the DLS mass clusters. In the X-ray images serendipitous point sources have been removed and circles denote the locations of extended X-ray sources detected at signal-to-noise ratios greater than 3. The two highest-ranked shear-selected clusters are strong X-ray sources, with multiple subclusters associated with each system. This can be seen clearly in the X-ray image of DLS cluster 2 (top panel of Figure 1). In the optical images there are a large number of bright galaxies that are presumably cluster members, however no published redshifts are available. The fourth ranked cluster (middle panels) is unusual in having only a single X-ray component. It is centered on a galaxy at a redshift of $z = 0.19$. The last ranked cluster in the Chandra cycle 4 sample (bottom panels) shows two significant extended X-ray sources. The southwestern component was confirmed by the DLS team as a massive cluster at $z = 0.68$ (Wittman et al. 2003) and even shows a giant arc from strong lensing. There is no redshift available for the northern X-ray concentration.

In Table 1 we present selected numerical results for the five X-ray clusters associated with shear peaks. In each case only values for the X-ray cluster component with the highest flux are given. Redshift information for clusters 2 and 7 is not yet available; we give very preliminary luminosity and mass estimates based on approximate redshifts from the magnitudes of the member galaxies. Photometric redshifts for all X-ray clusters are in the process of being determined from our imaging data. We used the X-ray luminosity-temperature
relation (Arnaud & Evrard 1999) to estimate cluster temperatures and then the mass-temperature relation (Evrard, Metzler, & Navarro 1996) to determine the mass within a density contrast of $\delta_c = 200$. These relations are derived from or calibrated against low-redshift clusters; at this point we have not made any adjustments for the redshift range of our sample. Still the mass estimates are consistent with simulations by our group that show an expected mass range for DLS shear-selected clusters extending from roughly $5 \times 10^{13} M_\odot$ to $10^{15} M_\odot$ with a peak near $3 \times 10^{14} M_\odot$. An additional direct measurement of the mass can be made from the shear maps; this work is in progress.

3. Conclusions

The DLS is clearly discovering true three-dimensional clusters of mass, hot X-ray gas, and galaxies. We find a wide range of X-ray luminosity for clusters with similar weak lensing shear. Nearly every shear peak contains multiple X-ray clusters, while the high mass clusters we detect are particularly complex with up to 4 or 5 individually resolved subcomponents. Work in progress on this unique galaxy cluster sample includes measuring X-ray temperatures from Chandra and XMM-Newton spectra, deriving redshifts and velocity dispersions from ground-based spectroscopy, more detailed mass determinations, and additional numerical simulations.

Acknowledgments

This work was partially supported by Chandra grant GO3-4173A and NASA LTSA grant NAG5-3432 to JPH.

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Figure 1. Projected mass (left) and X-ray surface brightness (right) of DLS mass clusters no. 2 (top), 4 (middle), and 8 (bottom).