Direct Measurement of Dark Halo Ellipticity with Weak Lensing

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Clusters of galaxies are the system that galaxies are gravitationally bound thanks to the large amount of dark matter inside the clusters. Their density structure is determined mainly by the property of unknown dark matter particles as well as global history of the evolution of density fluctuations. Therefore, clusters of galaxies serve as an ideal laboratory to test the current standard structure formation scenario. The density structure has been well predicted by the so-called *N*-body simulation, which indicates that the dark matter distribution in clusters (dark halo) is highly flattened and deviates significantly from the simple spherical symmetric mass distribution[1]. Its observational test is very important, as the predicted shape reflects the cold and collisionless assumptions on dark matter particles, but the difficulty lies in the unseen nature of dark matter.

We conducted detailed analysis of *Subaru* Suprime-cam images[2] of 25 X-ray selected massive clusters to measure the ellipticity of projected dark matter distribution using weak lensing technique[3]. In particular we developed a method to analyze the two-dimensional shear map directly, without a priori assumption on the center of the dark matter distribution, which leads to reliable and robust measurements of the ellipticity (Fig. 1). A challenge lies in the weakness of the lensing signals which limits the detailed study. Here we adopt highquality wide-field *Subaru* images, and combine results for 25 clusters, to detect the deviation from spherical symmetry at 7σ level (Fig. 2). The measured mean ellipticity of $\langle e \rangle = 0.46 \pm 0.04$ is in excellent agreement with 0.42 predicted by *N*-body simulations, which represents the first direct confirmation of the flattened dark matter distribution, an important theoretical prediction of the current standard model. Our result also demonstrates the feasibility of exploring the nature of dark matter via flattening in the dark matter distribution.

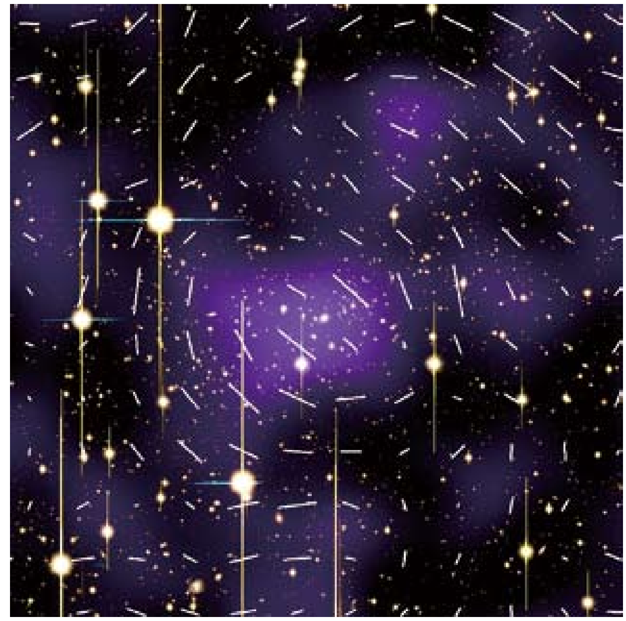

Figure 1: *Subaru* Suprime-cam image of Abell 2390, along with dark matter distribution inferred from weak lensing. Weak lensing distortions, which are obtained by averaging shapes of background galaxies, are shown by white bars. Dark matter densities measured by the weak lensing signal are indicated by purple hue.

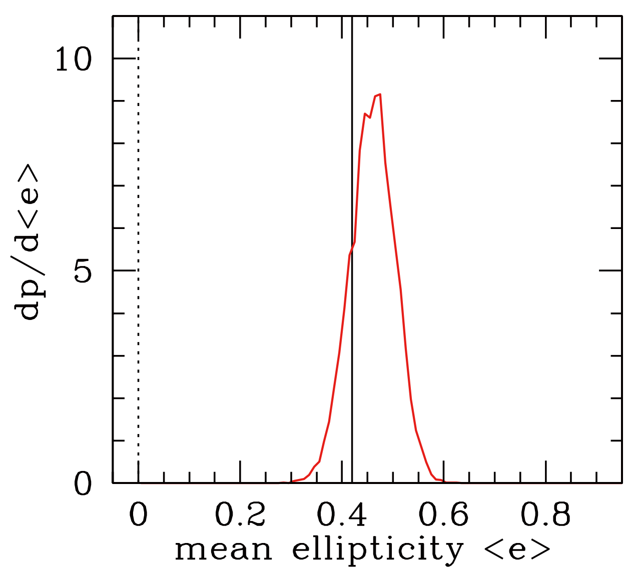

Figure 2: The likelihood distribution of average dark halo ellipticities among the cluster sample analyzed. The vertical solid line indicates the expected mean ellipticity from *N*-body simulation predictions.

References

[1] Jing, Y. P., Suto, Y.: 2002, *ApJ*, **574**, 538.
[2] Okabe, N., Takada, M., Umetsu, K., Futamase, T., Smith, G. P.: 2009, *PASJ*, **62**, 811.
[3] Oguri, M., Takada, M., Okabe, N., Smith, G. P.: 2010, *MNRAS*, **405**, 2215.