All-sky Simulations of Gravitational Lensing

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Gravitational lensing is one of the most promising tools to probe matter density distribution in the Universe. The foreground gravitational field causes small image distortion of distant galaxies. The small distortion contains, collectively, rich cosmological information about the matter distribution. We can reconstruct the foreground mass distribution from observed image of distant galaxies with statistical analysis. Ongoing and upcoming imaging surveys such as Hyper Suprime-Cam (HSC) survey in the near future, will provide the largest dark matter map we have never seen before. Therefore, it is important and timely to investigate the cosmological information content of the reconstructed mass map.

In order to realize the realistic situation in galaxy imaging surveys, we perform gravitational lensing simulations on curved full sky as shown in Figure 1. We then utilize these simulations to create two hundreds of mock weak lensing catalogs with the proposed sky coverage in ongoing HSC survey. These mock catalogs enable us to study the statistical property of reconstructed mass map from gravitational lensing observables.

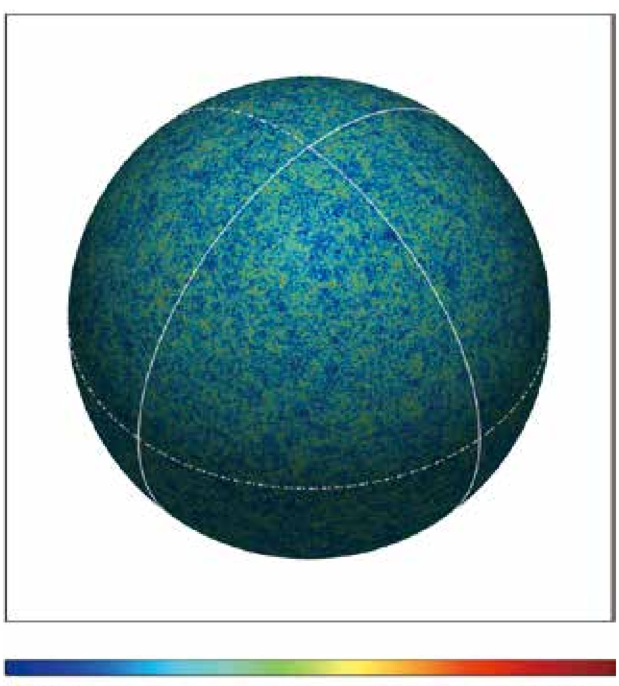

Figure 1: One of our simulated gravitational lensing maps. The red regions represent high surface mass density regions, while the blue regions correspond to under-dens regions in the Universe.

In Ref [1], we explore a variety of statistics of clusters selected with cosmic shear measurement by utilizing both analytic models and large numerical simulations. Weak lensing selection of clusters does not rely on conventional assumptions such as the relation between luminosity and mass and/or hydrostatic equilibrium, allowing us to construct *clean* cluster sample. We first develop a halo model to predict the abundance and the clustering of weak lensing selected clusters. Observational effects such as galaxy shape noise are included in our model.

We show that our theoretical model agrees well with the ensemble average of statistics and their covariances calculated directly from the mock catalogues. With a typical selection threshold, ignoring shape noise correction causes overestimation of the clustering of weak lensing selected clusters with a level of about 10 %, and shape noise correction boosts the cluster abundance by a factor of a few.

Furthermore, we extend our theoretical framework to model the statistical properties of clusters in variants of cosmological models as well as in the standard ΛCDM model in Ref [2]. We use a large set of realistic mock weak lensing catalogs as well as analytic models to make a forecast for constraining two competing cosmological models, the *w*CDM model and modified gravity model, with our lensing statistics. We show that weak lensing selected clusters are excellent probes of cosmology when combined with cosmic shear power spectrum even in the presence of galaxy shape noise and masked regions. With the information from weak lensing selected clusters, the precision of cosmological parameter estimates can be improved by a factor of ~1.6 and ~8 for the *w*CDM model and modified gravity model, respectively. The HSC survey with sky coverage of 1250 degrees squared can constrain the equation of state of dark energy w_0 with a level of $\Delta w_0 \sim 0.1$. It can also constrain the additional scalar degree of freedom in the $f(R)$ gravity model with a level of $|f_{R0}| \sim 5 \times 10^{-6}$, when constraints from cosmic microwave background measurements are incorporated.

References

[1] Shirasaki, M., Hamana, T., Yoshida, N.: 2015, *MNRAS*, **453**, 3043-3067.
[2] Shirasaki, M., Hamana, T., Yoshida, N.: 2016, *PASJ*, **68**, 414.