論文の内容の要旨

論文題目 Weak lensing analysis of structure formation of the Universe

(弱重力レンズ効果による宇宙の構造形成の解明)

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The standard cosmological model predicts the existence of structures called voids and filaments, which are seen in both N-body simulations and observations. However, the voids and filaments have been relatively unexplored, partly because of the uncertainty associated with the relation between galaxy distribution and underlying dark matter distribution. Weak lensing provides a means of studying the mass distributions of the voids and filaments directly. We investigate weak lensing properties induced by voids and filaments through the full ray-tracing simulations including the effect of the large-scale structure along the line-of-sight.

First, by using the stacked lensing method which reduces errors in weak lensing measurements statistically, we explore the prospect to measure the dark matter distribution of voids without the assumption of the galaxy bias. The gravitational lensing effect produces coherent distortions of background galaxy shapes, such as an isotropic stretching of images called convergence and anisotropic distortion of images called shear. We identify voids from a large set of N-body simulations and explore their lensing signals. We show that the stacked weak lensing enables to detect matter distributions of voids at a significant level ($S/N \geq 5$) for a 5000 degree^2 survey area, for a wide range of void radii up to ~ 50 Mpc. Since the gravitational lensing effect traces all matters on the line-of-sight, we also explore the effect of ridges surrounding voids on the lensing signals. In order to infer the three-dimensional mass distribution of voids realized in N-body simulations, we construct a simple void model which consists of constant matter density profiles in both the void region and ridge region. By comparing the lensing signals in simulations and those predicted in the model, it is found that dense ridges around voids have a great impact on the weak lensing signals, suggesting that proper modeling of the void density profile including surrounding ridges is essential for evaluating the average total underdense mass of voids.

Next, we study the detectabilities and statistical properties of filaments connecting clusters of galaxies. We select 4639 halo pairs with masses higher than $10^{14}h^{-1}M_{\odot}$ from the simulations. We estimate convergence profiles between the halos, which correspond to matter profiles, and perform profile fitting with two free fitting parameters which characterize mass and size of each matter distribution. We find that their matter distributions between halos can be classified into four regions in a plane of the fitting parameters, which allows us to select straight filaments from the ray-tracing simulations. We also investigate statistical properties of these filaments, finding them to be consistent with the results in Colberg et al. (2005). We find that 37% of halo pairs possess straight filaments, 4% of which can directly be detected at $S/N \geq 2$ with weak lensing. Furthermore, we study statistical properties of halos at the edges of filaments. We find that halos are preferentially elongated along filamentary structures and are less massive with increasing filament masses. These statistical properties could be explained by the hierarchal structure formation theory.

This work indicates that direct measurements of mass distributions of voids and filaments are indeed feasible in the future wide-field surveys such as the Subaru Hyper Suprime-Cam survey. Comparisons of theoretical predictions of their lensing signals presented in this thesis with observations will serve as a new test of structure formation scenarios in the Universe.