Abstract

Cosmic voids may play key roles in cosmology, both as an environment for galaxy formation that disfavours the virialisation of dark matter haloes, and as having a gravitational lensing effect of dispersing a light bundle rather than focussing it.

This thesis has two main aims. First, we investigate if the location of a galaxy in the cosmic web has a measurable effect on its properties. We denote the potential hill of a void as the "elaphrocentre", which should counteract the formation of a matter halo and weaken matter infall. Second, we explore to what degree geometric-optics maps can reveal the underdensities in the intrinsic, non-luminous matter distribution of cosmic voids.

We carry out cosmological N-body simulations, building merger-history trees for the simulated haloes and populate them with galaxies using semi-analytical recipes. The same tools are employed on the Bolshoi simulation for a significantly increased mass resolution. Voids are identified using watershed algorithms. Based on an N-body realisation we estimate a surface overdensity map and maps of weak gravitational lensing and geometric-optics scalar variables. We propose a heuristic algorithm with which we identify voids in the projected radial profiles of these detector variables.

While we do not find evidence that an elaphrocentric position weakens matter infall, we do find a significantly later formation epoch of galaxies in voids. We find void galaxies being of lower mass, smaller and having a higher spin parameter. Galaxies modelled in the Bolshoi simulation also yield later formation epochs of haloes in voids and, for halo masses $M_{\rm vir} \gtrsim 10^{10} M_\odot/h$, higher spin parameters for galaxies in underdense environments. The differences in the Bolshoi simulation are found for sub–cluster-mass haloes, i.e. masses below $\sim M_{\rm vir} = 10^{10} M_\odot/h$–$10^{11} M_\odot/h$. For a fixed mass, the Bolshoi simulation analysis yields a significantly higher stellar mass in galaxies in the dense regions. Overall, we find that the isolated environment of a void yields quantifiable effects on galaxy formation.

In our geometric-optics work, our heuristic algorithm shows that maps of the weak-lensing tangential shear, the Sachs expansion and the Sachs shear modulus significantly reveal the centres of the underlying three-dimensional watershed-detected voids.

In this thesis, we have shown that the cosmic void environment yields measurable differences in galaxy properties compared to galaxies found in denser regions. Moreover, we have extended the prospects for the observational detection of voids to the use of geometric-optics maps, as we find preliminary evidence that our algorithm provides a viable technique that should provide predictions for spectroscopic survey followups.