Abstract

The aim of this thesis is to provide a complete and gauge-invariant theoretical description along with numerical evaluations of general relativistic effects in cosmological weak lensing observables, therefore making vital steps towards a precise interpretation of the large-scale data measured by upcoming surveys. Since the first observations of cosmic shear in the year 2000, cosmological weak lensing has developed into one of the most important tools to enhance our knowledge of cosmology and fundamental physics. Cosmic shear as well as the lensing magnification can be used to study the growth and distribution of structure in our universe. Being determined purely by gravitational effects, they are sensitive directly to the whole matter distribution and do not rely on any assumption for the relation between dark and ordinary matter.

Next-generation weak lensing surveys will map out large parts of our universe with unprecedented precision. Thereby, we are entering a regime where not all observables are well described by linear Newtonian physics. Hence, precise theoretical modeling of cosmological observables is vital in order to draw the correct conclusions from the data. The standard formalism used for weak lensing however fails to yield gauge-invariant results for the observables, indicating that not all physical effects are correctly accounted for. In this thesis, two gauge-invariant formalisms for cosmological weak lensing are presented, accounting for all general relativistic effects at linear order. These formalisms follow two independent approaches, confirming each other by providing coinciding results. To correctly describe magnification effects, the standard convergence needs to be replaced by the distortion in the luminosity distance. The cosmic shear components obtain an additional contribution from tensor modes that is absent in the standard prediction. Furthermore, the gauge-invariant formalisms also show that the lensing rotation is fully vanishing at linear order even for vector and tensor modes. Apart from providing precise formalisms on a purely theoretical level, this thesis also studies the impact of general relativistic effects on weak lensing angular power spectra numerically.

The magnification of images induced by cosmological weak lensing does not only affect the luminosities and sizes of galaxies, but also their number densities. Therefore, lensing terms need to be taken into account in a complete, gauge-invariant treatment of the galaxy number density fluctuation. While general relativistic effects were previously believed to cause an infrared divergence in the galaxy power spectrum, this thesis shows that this divergence is merely an artifact of not correctly accounting for all terms. The fully relativistic theory power spectrum devoid of such unphysical divergencies is presented.