Abstract

Galaxies changed our view of the Universe and of the nature of the fundamental forces repeatedly. They are tracers of the Universe's large-scale structure and its evolution for the last 13 billion years or more. They are also "factories" where cold hydrogen gas fuels the formation of stars, which leads to the production of heavier elements, and eventually to life. Moreover, it appears that the luminous matter in galaxies only accounts for 1 to 5% of their entire mass, and the rest is seemingly invisible. The exact nature of their "dark" components is perhaps the gravest enigma of modern science. Exploring and understanding galaxies, their formation, and evolution is therefore of paramount interest to cosmology, particle physics, astronomy, and astrophysics.

In this thesis, we explore how models of galaxies can be incorporated with observations of the strong gravitational lensing phenomenon in order to test galaxy formation theories. Despite the unique circumstances leading to lensing systems which provide the opportunity to unravel otherwise hidden properties of their lensing galaxies, lens-modelling attempts have yet to consistently yield quantifiable constraints on galaxy formation scenarios. Conventional lens-modelling techniques use a set of parameters to describe the form of lensing galaxies. Here, we first examine free-form lens models and apply measured time delays of lensed quasars in order to constrain the cosmological parameter for the rate of cosmic expansion, the Hubble constant, but also to optimize the lens models themselves. Furthermore, a particularly interesting study of an extraordinary lensing system is presented for which lens models indicate a distinct type of galaxy, a fossil group galaxy, which is considered the final phase of a group galaxy's evolution. We then investigate drawbacks and issues of such free-form lens models in a blind-study with simulated lenses. While conventional techniques conveniently and efficiently generate models, they remain rather simplified. Galaxy-formation simulations on the other hand, are highly tuned to produce realistic galaxy models from first principles. For this reason, we tested the plausibility of utilizing such simulations for a direct comparison to lensing data. At last, we propose a novel strategy which efficiently matches projected galaxy models from simulations to lensing observations and evaluates relative posterior probabilities of the underlying galaxy formation scenarios. In future, such methods are essential for upcoming wide-field surveys, as they will increase the number of galaxy lenses, and thus the workload, possibly a hundredfold.