Abstract

The concurrent growth of supermassive black holes (SMBHs) and their host galaxies remains to be fully explored, especially at high redshift. While often understood as a consequence of self-regulation via active galactic nuclei (AGN) feedback, it can also be explained by alternative SMBH accretion models. In this thesis, we expand on previous work by studying the growth of SMBHs with the help of a large suite of cosmological zoom-in simulations (MassiveFIRE, MassiveFIRE2, FIREbox) that are part of the Feedback in Realistic Environments (FIRE) project. The growth of SMBHs is modeled in post-processing with different black hole accretion models, placements, and merger treatments, and validated by comparing to on-the-fly calculations. Scaling relations predicted by the gravitational torque-driven accretion (GTDA) model agree with observations at low redshift *without* the need for AGN feedback, in contrast to models in which the accretion rate depends strongly on SMBH mass. At high redshift, we find deviations from the local scaling relations in line with previous theoretical results. In particular, SMBHs are under-massive, presumably due to stellar feedback, but start to grow efficiently once their host galaxies reach $M_* \sim 10^{10} M_\odot$. We analyze and explain these findings in the context of a simple analytic model. In Chapter 3, we show that the predicted scaling relations depend sensitively on the SMBH location and the efficiency of SMBH merging, particularly in low-mass systems. In Chapter 4, we use a series of simulations from the MassiveFIRE-2 suite to show that the GTDA approach can be used to model SMBH growth in the first billion years of the Universe. In particular, for our fiducial settings, the GTDA model generates SMBH masses comparable to those estimated by the Bondi model. While none of the simulated galaxies in our samples are predicted to host $10^9 M_\odot$ SMBHs at $z \gtrsim 6$ likely due to the limited volume probed, we find that some galaxies can harbor SMBHs that are sufficiently luminous to be detected by the ongoing observational projects, e.g. with Subaru HSC. In Chapter 5, we analyze the concurrent growth of galaxies and their SMBHs with the FIREbox cosmological volume simulation. This simulation allows us to extend our analysis to the low redshift Universe. These findings highlight the importance and challenges of modeling the various physical processes involved in galaxy and SMBH growth to better understand the evolution of SMBH-galaxy scaling relations and to provide more accurate theoretical predictions of current and future observational efforts.