

This dissertation elaborates on X-ray polarization features of astrophysical environments near accreting black holes. Although the work was originally assigned to supermassive black holes in active galactic nuclei, the results are also largely applicable to stellar-mass black holes in X-ray binary systems. Several numerical models predicting the X-ray polarization from these sources are presented, including their immediate applications in the interpretation of the latest discoveries achieved thanks to the *Imaging X-ray Polarimetry Explorer (IXPE)* mission that began operating in December 2021. The modeling ranges from radiative transfer effects in atmospheres of accretion discs to general-relativistic signatures of X-rays travelling in vacuum near the central black holes to reprocessing events in distant, circumnuclear components. Various scales in physical and computational complexity are examined. A unifying element of this dissertation is the focus on reflection of X-rays from partially ionized matter.