"Understanding Black Holes with X-ray Polarimetry"

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Photons carry a few basic pieces of information: energy, direction, and polarization. Since the founding of X-ray astronomy 50 years ago, we have seen many orders of magnitude improvement in the spectral range and spatial-, timing-, and energy-resolution of X-ray observations, but essentially no progress in the sensitivity of polarization measurements. Polarization is extremely important, because it fundamentally probes the geometry of the emission region and can break many degeneracies of purely spectral models, providing complementary information to more traditional methods. For point sources like accreting black holes, with angular extent less than a *nanoarcsec*, spatial resolution is not feasible, so spectra-polarimetry observations are likely the best way to understand the magnetic field geometry, accretion flows, and space-time structure around a black hole.

Thirty years from now, a next-generation polarimeter as a primary instrument on a large collecting area (>10m^2), high angular resolution (<1") X-ray observatory would provide remarkable science capabilities. With Bragg reflection, photoelectric, and Compton detectors, an extremely broad energy band of ~0.1-1000 keV should be attainable, with polarization sensitivity as low as ~0.1%. With this level of precision, we will be able to measure the spins of stellar mass black holes to better than a few percent accuracy, determine the geometry of the hot corona, and even test general relativity by measuring the detailed properties of the warped space-time immediately surrounding the horizon. With time-resolved polarimetry observations, we will finally be able to probe the structure of dynamic accretion flows and identify the underlying source of the quasi-periodic oscillations seen in many stellar-mass black holes.

With 10m^2 collecting area, we will be able to measure polarization at the <1% level for thousands of active galactic nuclei, including dozens of gravitationally lensed quasars at high redshift. These sources would provide a unique opportunity for probing galactic structure, the distribution of dark matter, and extreme magnification of the innermost regions of the accretion disk, jet, and corona.

Simulated X-ray image of an accretion disk around a spinning black hole with mass 10 M_{sun}, viewed from an inclination of 75º. The disk is oriented such that the gas on the left is moving towards the observer, and thus is relativistically boosted. Because of the strong gravitational deflection of photons near the black hole, X-rays that are emitted from one side of the disk can scatter off the opposite side of the disk before reaching the observer. This effect is encoded in the polarization signal, and serves as a powerful probe of strong gravity. (reproduced from Schnittman & Krolik 2009)