X-ray and Gamma-ray Polarimetry Science NASA Astrophysics Roadmap Whitepaper

T. Kallman, M. McConnell, M. Baring, P. Bloser, S. Boggs, A. Harding, J. Hill, S. Hunter, K. Jahoda, P. Kaaret, R. M. Kippen, H. Krawczynski, D. Lazzati, H. Marshall, J. Ryan, J. Schnittman, J. Swank, J. Tomsick, M. Weisskopf, B. Zhang

Based on a small number of detections to date, X-ray and gamma-ray polarization measurements promise to provide unique insights into essentially all known classes of high energy sources. Polarization is sensitive to magnetic fields, scattering geometry and strong gravity effects and provides unique tests of fundamental physics. Here we describe a sample of the science problems which can be addressed using future missions.

Neutron stars are of interest as laboratories for the study of matter under extreme densities, and also for the study of plasmas in strong magnetic fields. Pulsed X-ray and gamma-ray polarization can refine and distinguish current models of the broad spectrum of emission from rotation-powered pulsars, search for signatures of photon splitting, constrain the location of the emission, and distinguish between synchrotron, inverse Compton and curvature radiation emission mechanisms. In many objects magnetic fields are strong enough to produce macroscopic manifestations of quantum electrodynamics, freezing the polarization to the field lines in strong field regions. This has a signature in the profile of pulsed X-ray polarization and also allows tests for models of energy release for magnetars in quiescence.

A major open question concerning gamma-ray burst sources (GRBs) is the composition of GRB jets. The standard model invokes a matter dominated "fireball" while an alternative scenario invokes a magnetically-dominated outflow. Related open questions include energy dissipation mechanisms and particle radiation mechanisms. Measurement of gamma-ray/hard X-ray polarization from a sample of GRBs can decide the jet composition and radiation mechanism. A positive detection of high polarization degree from a bright distant GRB would place stringent constraints on photon birefringence, and hence on Lorentz Invariance Violation and CPT violation theories.

General relativity predicts a signature swing in polarization direction with energy in a thermally emitting accretion disk around a black hole. This will allow measurements of the spin parameter to a precision of $\sim$1%. With high-sensitivity polarimeters capable of time-resolved spectro-polarimetry we will be able to observe the time-variable geometry of the accretion flow, addressing the long-standing mystery of black hole quasi-periodic oscillations. With large collecting area and high angular resolution, it will be possible to probe jet-corona properties of black holes on all scales from stellar mass to AGN, including dozens of gravitationally lensed quasars at high redshift. Observations of blazars will test models for the magnetic field structure and energy release mechanism in jets, probes similar to the case of gamma-ray bursts (GRBs).

X-ray polarimetry on arcsecond scales can probe the velocity structure of clusters of galaxies and Seyfert 2 galaxies, and can test models for magnetic field amplification and cosmic ray acceleration in supernova remnants.