X-ray Echoes From Accreting Black Holes

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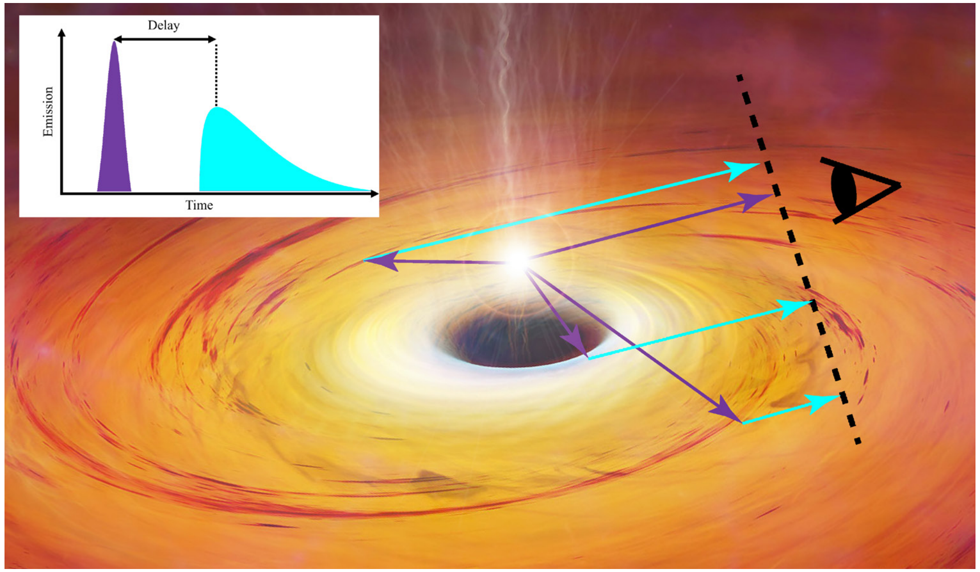
Luminous accreting black holes are among the most powerful electromagnetic sources in the Universe. Their radiative power is dominated by thermal emission from the accretion disc, a thin structure formed by matter spiralling down towards the central black hole. For stellar-mass black holes, such as those powering X-ray binaries via accretion of matter from a companion star, disc emission peaks in the X-rays, the energy band in which the *Athena* X-ray observatory is sensitive. For super-massive accreting black holes at the center of galaxies (a.k.a. Active Galactic Nuclei or AGN), the disc emission peaks instead at lower energy, outside of the *Athena* sensitivity band. X-ray emission is nevertheless ubiquitous in such systems, due to the interaction of disc photons with a population of very energetic electrons above the disc (the disc's "corona") that exchange energy with the disc photons producing X-ray emission. This X-ray emission illuminates its surroundings, including the accretion disc itself. The disc heats up which can be seen as a temperature and luminosity increase. The disc can also "reflect" the irradiating X-rays, imprinting on the final observed X-ray spectrum several distinct physical "signatures."

The geometry of the disc-corona system in the immediate vicinity of accreting black holes remains mysterious. However, in recent years, new tools and data analysis techniques have emerged leading us to fresh territory in our understanding of accretion flows. These tools are based on the idea that disc heating and/or reflection must occur with some time delay with respect to the irradiating X-rays. If, as largely expected theoretically, the corona and disc are spatially separated the paths light travels (and hence the lights' travel times) from the corona to the observer and from the corona to the disc and then back to the observer are bound to be different as schematically shown in the Figure. The good news is that these time delays are measurable as the primary irradiating X-rays and the reprocessed photons from the disc dominate different energy bands.

Current X-ray missions have already provided a series of important results using this idea, both for X-ray and AGN, but results are limited to only the brightest objects. With its great increase in X-ray mirror area, *Athena* provides a fantastic tool to bring these studies to the next level. By reducing significantly the time delay uncertainties, *Athena* will enable us to probe not only the geometry of the disc and corona but also its dynamics, time evolution, and its dependence on fundamental accretion properties such as accretion rate and luminosity. *Athena* will make it possible to carry out these studies not only in a few bright and exceptional cases but in large samples of sources providing a much more accurate and statistically significant view of the accretion phenomenon at large.



Schematic picture of expected time delays. The corona (purple) emits X-rays that directly reach the observer and irradiate the accretion disc. The reprocessed emission from the disc (blue) reaches the observer with a given time delay depending on the geometry of the disc-corona system. Measuring and modeling these time delays is a powerful tool to infer the structure of the innermost accretion flow in the immediate vicinity of accreting black holes.
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