UNLOCKING THE MYSTERY OF BLACK HOLE GROWTH OVER COSMIC TIME

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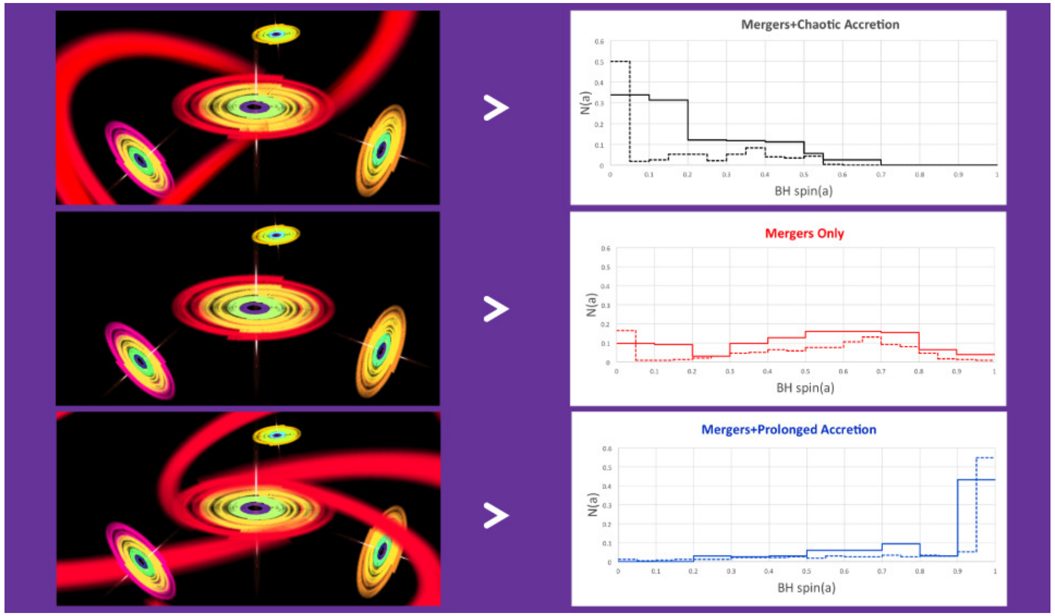
Supermassive black holes (SMBHs) are thought to reside in the cores of nearly every galaxy in the Universe, including our own. These monsters exist in a symbiotic relationship with their hosts, growing via some combination of gas accretion and mergers with smaller black holes while driving powerful outflows that seed the surrounding interstellar medium with matter and energy. This "feedback" may ultimately regulate star formation within the host galaxy, reaching far beyond the SMBH's gravitational sphere of influence and profoundly altering the evolution of the system as a whole.

In spite of their ubiquity and importance, we have little direct information about how SMBHs form and grow. The physical processes described above take place over millions of years, meaning that any data we receive from observations is effectively only a snapshot. An SMBH's inherent simplicity works to our advantage, however: these objects can be fully described by only their mass and angular momentum, or spin. The accretion of matter over time can substantially change the angular momentum of the black hole depending on the accretion mode. Studying a statistical sample of masses and spins thus provides information on whether merger- or accretion-driven growth has been dominant. Further, by examining data from actively-accreting SMBH systems over a range of redshifts, we can effectively look backwards in time, studying potential changes in the growth of SMBHs over cosmic time.



Spin as a probe of SMBH growth history. The distribution of black hole spins in the local Universe depends on whether they have accumulated their mass predominantly via mergers, steady accretion or chaotic accretion. The theoretical expectations for each SMBH growth scenario (dotted histograms) is shown (Berti & Volonteri 2008) and compared to simulated Athena measurements (solid histograms), accounting realistically for all observational errors and spectral complexities. The plot is made in the assumption that 50% of the brightest Seyfert 1 galaxies in the sky have a reflection component relativistically distorted (De la Calle et al. 2010). Mean exposure time per source is 100 ks.
Credit: Composition by ACO Team.

While determining a black hole's mass may be accomplished using a variety of different observational techniques, measuring its spin demands an examination of the material nearest to the event horizon, which radiates primarily in X-rays. Here both general and special relativity come into play. The strong gravitational field experienced by photons travelling close to the black hole shifts their wavelength to the red while the Doppler effect induced by fast rotation of the material produces blue and red wings. We can therefore compare theoretical models to the observed spectral data in order to measure spin, but this science requires an enormous number of photons over the 2-10 keV bandpass in order to obtain accurate and precise results.

Current missions such as Chandra and XMM- Newton have been able to measure spins accurately for a handful of bright, nearby active galactic nuclei (AGN), but long exposure times must be used and they are unable to probe out to $z > 0.5$ owing to a lack of collecting area. Athena will greatly improve upon this situation, enabling such observations to be made in a fraction of the time, and allowing us to measure spin accurately out to $z > 1$ and beyond routinely. Further, the X- IFU calorimeter will provide unprecedented spectral resolution, allowing us to differentiate between models and to unambiguously isolate the signatures of inner disk emission from those processes occurring further away from the black hole.