Connecting supermassive black-holes with the cosmic web

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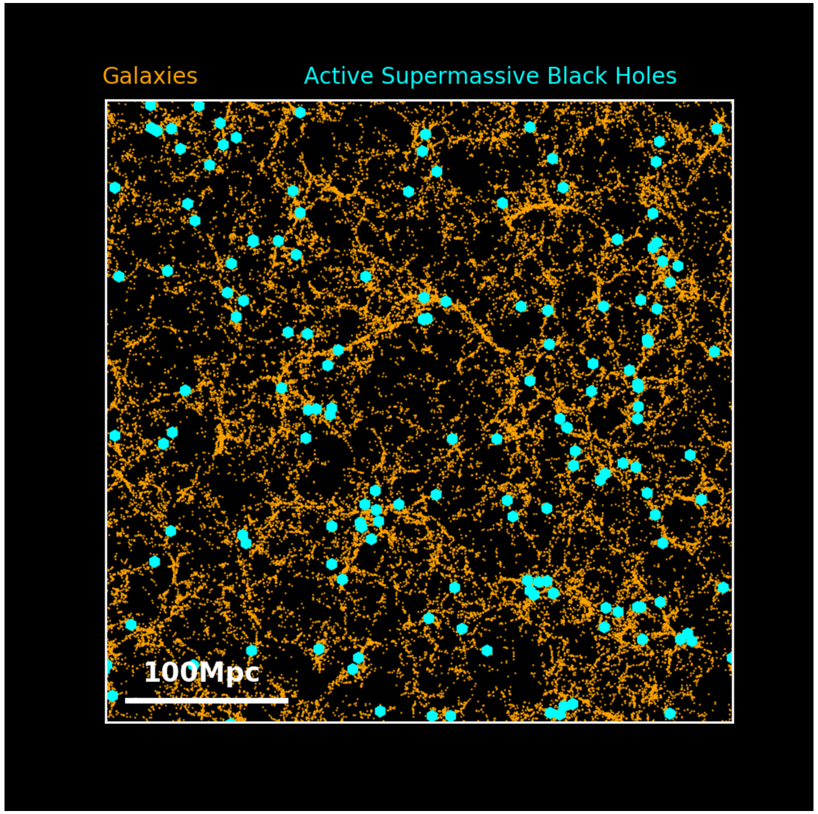
The most recent observational campaigns have placed the total number of galaxies in the Universe in the trillions. The majority, if not all of them, are thought to host at their centers large black holes, millions or even a billion times heavier than our Sun. These beasts build up their mass over time by devouring material from their surroundings. During this process they emit huge amounts of energy that impacts the physical conditions of the surrounding interstellar and intergalactic medium, with far-reaching implications for the formation and evolution of stars, galaxies and large-scale structures in the Universe. Despite the ubiquity of black holes among galaxies, observations show that at any given time only a tiny fraction, fewer than 1 in 10000, are active, i.e. accreting material and growing their masses at a significant rate. The vast majority appear dormant. This observational fact had led astronomers to debate the physical conditions and environments that may be responsible for the activation of supermassive black holes. Are there specific triggering mechanisms required to initiate an accretion event at the centers of galaxies (e.g. interations between galaxies)? Or is black-hole growth a stochastic phenomenon that occurs naturally as part of the normal life-cycle of the stars and gas in galaxies and does not require specific triggers or favourable conditions?

To answer these questions astronomers are trying to isolate those factors that can potentially modulate the level of activity in the centers of galaxies. One of them is the environment around the host galaxy, measured by the local density of galaxies in their neighborhood. It is well established that matter in the Universe is organized in filaments, groups and clusters separated by large voids (see Figure). The conditions in these diverse environments of the cosmic web vary widely in terms of density of matter, frequency of galaxy encounters, and temperature of the intergalactic medium. We know that these different conditions imprint observable signatures on galaxies and affect the way they evolve with time. It is therefore natural to wonder if the position of a galaxy on the cosmic web also determines the activity of its central "supermassive" black hole. To date such a connection remains unclear largely because of lack of appropriate observational data that leads to poor sampling of the diverse densities of the cosmic web.

The *Athena* X-ray observatory will provide both the quality and quantity of observations required for detailed studies of the role of environment on the activation of supermassive black holes. The sensitivity and survey speed of *Athena* will enable a unique census of this activity covering a broad range of environments, from voids to large clusters. These observations will allow astronomers to explore with unprecedented accuracy how the incidence and strength of accretion activity onto supermassive black holes varies with position on the cosmic web and as a function of the age of the Universe.



N-body simulation of the cosmic web as traced by galaxies and active galactic nuclei. The orange dots (MultiDark programme) show the positions of simulated galaxies. These are organised in groups, and clusters, which in turn are connected by filaments and separated by low-density voids. The cyan dots mark active supermassive black holes within the galaxy population. The Athena X-ray Observatory will map the distribution of accretion events (i.e. the red stars) on the cosmic web and explore the connection between activation of the supermassive black-hole and the density of the local environment.

Credit: Antonis Georgakakis