The hunt for super-Eddington accretion flows in ultraluminous X-ray sources

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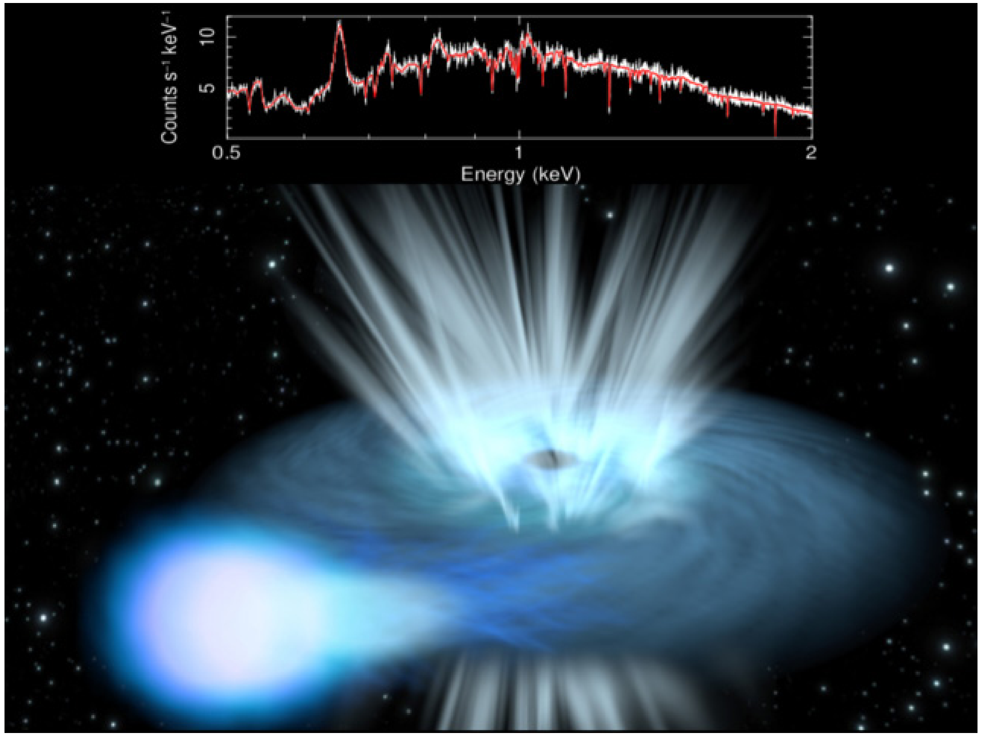
There is nothing hungrier than black holes in the Universe. How many of them managed to grow up to 10 billion Solar masses in less than a billion years after the Big Bang is one of the greatest mysteries in astrophysics and cosmology. Supernova stellar explosions normally form stellar-mass black holes of ~10 Solar masses. To grow a million-fold times, they must have accreted matter from nearby stars or interstellar gas at exceedingly high rates, well beyond the theoretical Eddington limit. This is the accretion rate above which the pressure of radiation dominates over the gravity of the black hole and blows away the matter that it had been trying to accrete. This effect is not small, as the matter is ejected in the form of hot gas flows with velocities of about 10-20% of the speed of light. How much material is then channelled onto the black hole or blown out by the winds?

Ultraluminous X-ray sources (ULXs), the most extreme among binary stars, can help us to address the question. In the X-ray energy band alone, they can shine as a 10 Solar-mass black hole accreting at 100 times the Eddington limit. After the recent discovery of pulsations and powerful winds in several ULXs we know that most ULXs are ignited by super-Eddington accretion of matter onto neutron stars and stellar-mass black holes. The winds are a major prediction of super-Eddington accretion theory and were discovered only thanks to deep observations of the ESA's XMM-*Newton* X-ray telescope. Its high-resolution X-ray spectrometer (RGS) enabled the first detection of emission and absorption lines, the latter blueshifted by up to 20% of the speed of light. These winds may take away 50% of the accreted matter, prolonging the lifetime of the compact object (in the case of a neutron star) and producing the interstellar cavities found around many ULXs with their huge kinetic power.

Current instruments do not have the sensitivity to probe how these winds vary on time scales shorter than a day, which is necessary to determine their mass outflow rate, kinetic power and launching mechanism.

The *Athena* X-ray Integral Field Unit (X-IFU) will revolutionise the study of accretion flows in the coming decades. Our simulations show that the X-IFU will boost the detectability of the spectral lines imprinted by the outflowing plasma in ULX spectra with exposure times shorter than an hour (see Figure). The response of the wind to changes in the ULX spectral state will determine its nature and outflow rate, which will tell us how quickly can black holes accrete matter and grow.



Artist's impression of a black hole feeding on gas at a high rate from a companion star in a ULX binary system. The conversion of matter into energy produces X-ray radiation whose enormous pressure launches a wind at 20% of the speed of light. Athena / X-IFU will detect a forest of emission and absorption lines from the wind at an unprecedented precision (see inset). This will enable us to compute the mass loss in the wind and the growth rate of the compact object. Credit: image (ESA-C. Carreau). Inset: Pinto et al 2020, Fig. 13.