PASSPORT TO THE INFINITE

The Outskirts of Black Holes

To better understand black holes, astrophysicists study the sometimes-spectacular phenomena they generate in their surrounding environments.

One such phenomenon involves 'binary black holes' (BBHs), which are systems of two stars, one of which has evolved to the point where its core has collapsed into a black hole. In these pairs, the black hole can sometimes capture the outer layers of its twin star. Like water flowing down a sink, the captured matter spirals toward the black hole, forming a thin, glowing ring around its event horizon – the accretion disc. Given the typical size of the event horizon of black holes formed from stellar evolution (radius: 10–30 km), their accretion discs can cover an area comparable to the greater outskirts of a city like Paris.

Artist's impression of an accretion disc

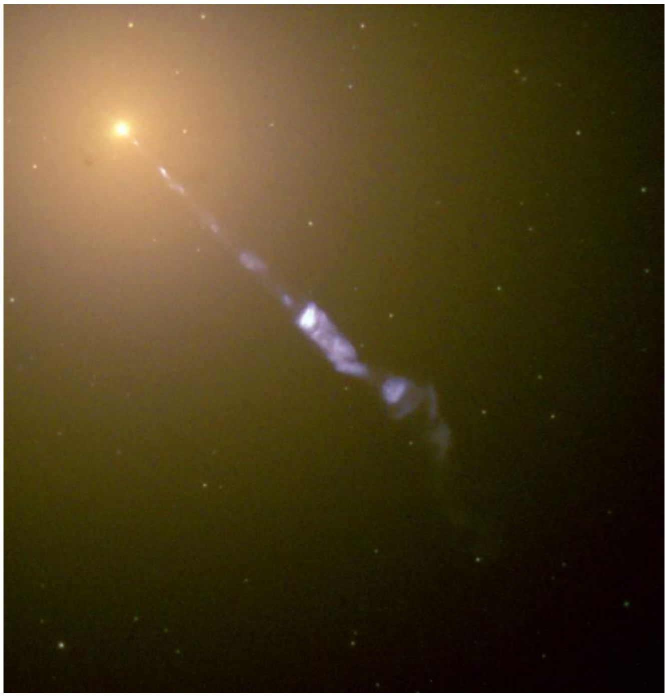
An accretion disc around a black hole captures the outer layers of its twin star, ejecting two jets of matter perpendicular to the plane of the disc.

Credit: NASA/ESA/M. Kornmesser (ESA/Hubble)

Much like Saturn's rings, an accretion disc does not rotate uniformly: the rotation speed of matter near the centre is higher than that in the outer regions. Rotating side by side at different speeds, these regions are the sites of intense friction phenomena. This is especially true in the innermost regions of the disc, which are heated to extremely high temperatures (up to 10^7 K). Like a star, the accretion disc behaves thermally like a blackbody, but its temperature is such that it shines with tremendous brilliance, primarily emitted in the X-ray spectrum. For example, a black hole with a mass of 3 $M_{\odot}$ can radiate up to

10^5 $L_\odot$, releasing an amount of energy comparable to that of the brightest stars in the visible and ultraviolet bands.

A similar but far more luminous occurs in active galactic nuclei. It involves the supermassive black holes at the very centres of most galaxies. Under certain, very specific conditions, these black holes can draw in large quantities of interstellar matter. Accretion discs are thus formed whose size and energy radiation are proportional to the mass of the black hole involved. Through accretion, a black hole with a mass of 10^9 $M_\odot$ can radiate up to 10^{11} $L_\odot$, producing as much energy as all the stars in its host galaxy combined!



Credit: NASA/The Hubble Heritage Team (STScI/AURA)

In most cases, the accretion process by a black hole is accompanied by the ejection of matter at relativistic speeds in the form of jets emitted from both sides of the disc, along an axis perpendicular to the disc. Jets produced by binary stellar black holes can extend over several light-years, while those from supermassive black holes can even span thousands of light-years. These relativistic jets, the most visible indicators of the presence of a black hole, remain enigmatic. Why are these jets so thin along their entire length? Is the ejection process fed by accretion?

A jet emitted by the nucleus of galaxy M87

This image captured by the Hubble Space Telescope reveals a jet of matter extending up to 5,000 ly from the core of the galaxy.

Translated from 'La banlieue des trous noirs',* Passeport pour les deux infinis, *IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG