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Downsized black hole is much brighter than it should be

Reduced size puts into question theories of how supermassive black holes form.

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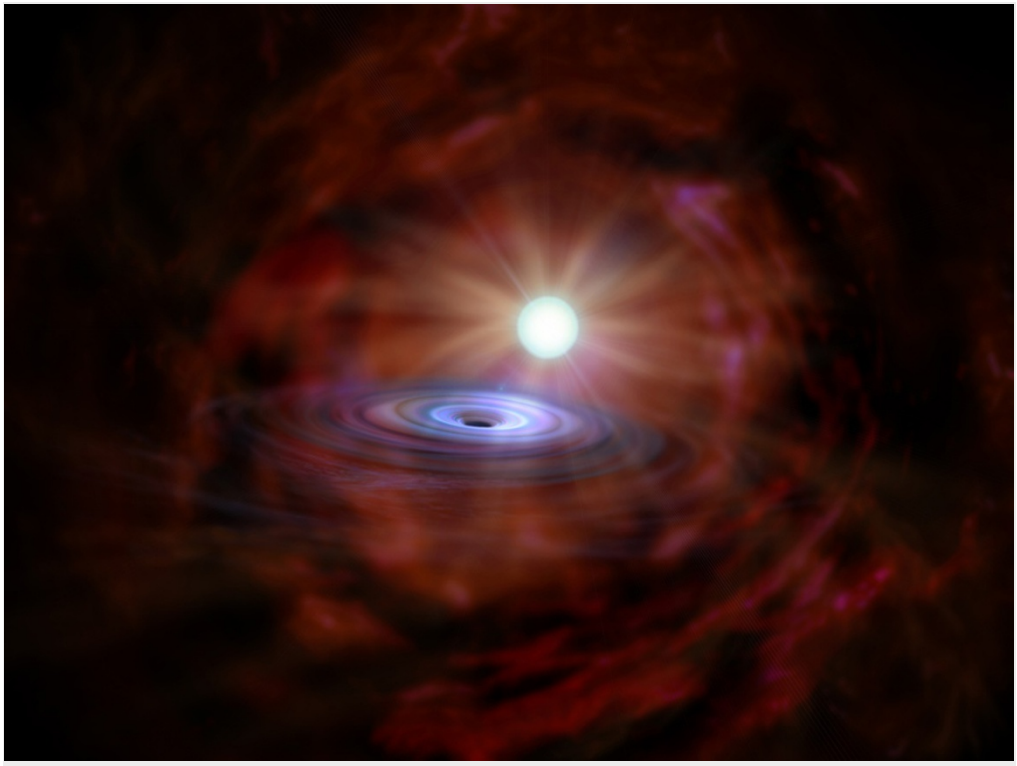

Jingchuan Yu

Researchers determined that M 101 ULX-1 is a stellar-sized black hole after measuring the orbital velocity of a companion star, shown here in an artist's impression.

As a black hole pulls matter into a disk around it, friction can cause the spiralling gas to get very hot and emit X-rays that we can detect from Earth. Astronomers have suggested that some 'ultraluminous' X-ray sources are too bright to be ordinary black holes formed from the collapse of a star, and could instead be bigger than any star, themselves the seeds for the 'supermassive' black holes that are thought to reside at the centre of most galaxies.

But one of the first candidate intermediate-mass black holes to have its mass measured through rigorous methods does not fit the bill. Publishing in *Nature*[1] today, astronomers have shown that M 101 ULX-1, which lies in an arm of the Pinwheel galaxy, 6 million parsecs (21 million light years) away, is no more than a stellar-mass black hole, behaving in a way that challenges current theories about how black holes form.

M 101 ULX-1 intermittently flares with X-rays that are around one order of magnitude brighter than one would expect from an ordinary black hole. Because such outbursts are intermittent, astrophysicist Ji-Feng Liu of the Chinese Academy of Sciences in Beijing and colleagues exploited the quiet periods to look at the light coming from a companion star to determine the black hole's mass.

Measuring the star's 'radial velocity' — how much it moves towards and away from Earth owing to the black hole's gravitational pull — by the shifts in the frequency of its light, the team estimated the black hole's mass at 20 to 30 times the mass of the Sun. This puts it within the boundaries of a black hole caused by the collapse of a single massive star.

A mysterious light

However, one thing remains that is puzzling astronomers. Theoretical models of black-hole accretion suggest that a small black hole radiating ultraluminous X-rays would give out a 'hard' spectrum, filled with very energetic photons generated by a corona around the disk. But the light coming from M 101 ULX-1 shows only the 'softer' part of the X-ray spectrum, typical instead of emissions from the

accretion disk of a large black hole collecting matter more quietly.

Given its small mass, how the black hole got to be so bright and yet give off such a soft spectrum remains a question. “People have observed X-rays from black holes for half a century. If we compare this source with what we know… it fits nowhere,” says Liu.

Despite the conundrum, Andrew King, an astrophysicist at the University of Leicester, UK, says that the measurement of the black hole's mass is convincing. “When a system is persistently bright, you can never be sure the red and blue shifts you are seeing represent the radial velocity of the companion star, rather than gas flying about. But here are results you can believe,” he says.

The authors speculate that the reason for the bright X-rays could be that the black hole is feeding off a hot stellar wind coming from its companion star — a 'Wolf-Rayet' star that has shed its hydrogen and is little more than a burning helium core. King says that this mechanism is normally thought to be too inefficient to produce such luminous X-rays. But here, helium that blows off the star seems to be building up in a disk around the black hole until it begins to ionize, causing rapid accretion and the sudden, very bright X-rays, he says.

The findings are a blow to astronomers looking for evidence for intermediate-mass black holes, which have been theorized as the seeds of supermassive black holes but whose existence has yet to be definitively confirmed.

Ruling out one of the most promising candidates — in one of the few instances where such a definitive mass measurement can be made — will “make people think”, says Liu. “The search for intermediate black holes will go on until people find one, or until they find it’s not necessary to ask for intermediate black holes at all,” he says.

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References

1. Liu, J.-F., Bregman, J. N., Bai, Y., Justham, S. & Crowther, P. *Nature* **503**, 500–503 (2013).