Feature Article

Nadine Neumayer

32 years old, born in Germany
Place of work: European Southern Observatory (ESO), Munich, Germany
Website: http://cosmicdiary.org/blogs/eso/nadine_neumayer/

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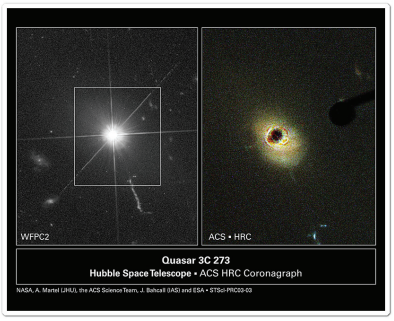
Enjoying clear views of the night sky as a child, Nadine became fascinated with the idea that there are millions of other galaxies. With the goal of becoming a professional astronomer, she studied Physics and Astronomy in Heidelberg and Cambridge. Currently, Nadine works at the European Southern Observatory in Germany. Nadine likes the idea of giving people insight into the work and life of astronomers, helping to demystify the work they do.

Few scientific topics capture people's imaginations as well as black holes. The mere mention is often enough to interest and captivate an audience. But how much do scientists actually know about these astronomical anomalies? How are they related to quasars, x-rays, and galaxies? And of course, if they swallow light, how can we see them? This article will help put many pieces of the puzzle together, resulting in a clear image explaining all about the nature of black holes.

Black Holes

Black holes are among the brightest objects in the Universe. This sounds strange, doesn't it? Well, let's rephrase it a little: black holes give rise to the brightest objects in the Universe. Better?

Indeed, the brightest objects in the Universe, the so-called "quasars", led astronomers to the concept of black holes. Quasars are very distant objects and are as bright as a million to a billion stars. But unlike stars, quasars emit radiation over a huge range of wavelengths, from radio to X-rays. Their extreme luminosities come from within a very small region, and if one looks close enough, one always finds that the quasar is sitting in the middle of a galaxy: the host galaxy. The vast energy output of quasars cannot be explained by the same mechanisms that make stars shine. It can best be explained by material spiralling onto a supermassive black hole.

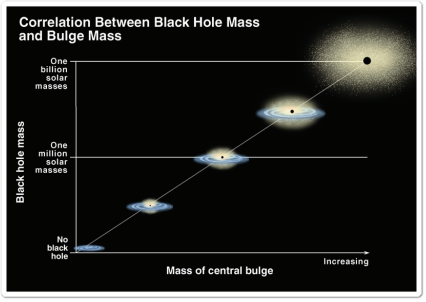


The Hubble Space Telescope has provided the clearest view yet in visible light of the nearby quasar, 3C 273 [image at right]. Using a mask (called a coronagraph) to block the light from the brilliant central quasar, astronomers discovered that the quasar's host galaxy is significantly more complex than had been suggested in previous observations.
Image credit: NASA, A. Martel (JHU), the ACS Science Team, J. Bahcall (IAS) and ESA.

Hungry holes

Quasars are very far away. They are the farthest objects observed in the Universe, with their distances in the region of a few to a hundred billion light years. These enormous distances make it difficult to study them – and especially their faint host galaxies – in detail. Fortunately we find scaled down versions of quasars in our cosmic neighbourhood (at ten to a hundred million light years). They share the common feature of an extremely luminous point source sitting at the centre of a galaxy and are thus combined under the name "active galactic nuclei". They are fainter than their more distant counterparts. This is due to the fact that their central black holes are not as big, and that there is less material to feed them.

Finding galaxies with lower and lower central activity led astronomers to speculate that there must be black holes that completely ran out of fuel and are now sitting quietly and unseen at the centres of galaxies. These black holes are not directly observable, but they are actually still detected. The gravitational influence of black holes on stars and gas moving around them betrays the disguise of quiescent black holes.



Astronomers believe that every galaxy with a bulge of stars at its centre also harbours a supermassive black hole. Observations suggest a direct relationship between the mass of the black hole and the total mass of the bulge. That means the formation of the black hole and the bulge may be related.
Image credit: University of Texas.

A monster at the heart of our Galaxy

The best example is the black hole at the centre of our own galaxy, the Milky Way. Although not visible, there must be an object present with a mass of about three to four million times the mass of our Sun, to explain the fast movement of stars at the Galactic Centre. The region within this enormous mass is so small that no other explanation holds other than the presence of a black hole.

Current observations suggest that Nature cannot make a big galaxy without a black hole at the centre. Indeed, the central black hole seems to be linked to the rest of the galaxy, in the sense that bigger galaxies tend to have bigger black holes. This suggests that galaxies and their central black holes evolve and maybe even form together.

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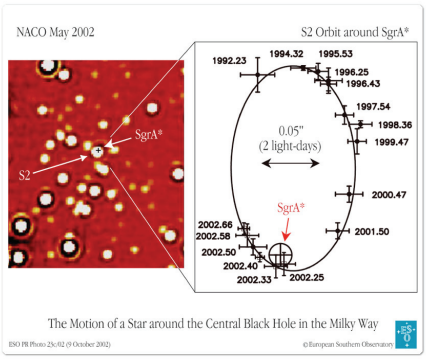
Part of the story is fairly well understood. It seems likely that galaxies grow and evolve by merging. If two galaxies merge, the resulting galaxy is roughly the sum of the individual galaxies. During the merger process the two black holes sink to the centre of the newly formed system and will eventually merge to a single black hole, with a mass being the sum of the individual black holes. Computer simulations show that these processes work and are able to explain the observations.



The right panel displays the orbit of the star S2 as observed between 1992 and 2002, relative to SgrA* the black hole that sits at the centre of the Milky Way. The star is whizzing around at incredible speed.
Image credit: ESO.

Enduring mysteries

However, it remains unclear how black holes get to the centres of galaxies in the first place. This is one of the questions that I am particularly interested in. There are galaxies that seem not to have grown black holes at their centres yet, or at least they are so small that current telescopes are unable to detect them. But for a large number of these small galaxies astronomers have observed a very dense cluster of stars at the centre. These star clusters could be the birthplaces of black holes and might provide the key to understanding the formation of these unusual gravitational phenomena.

A new discovery has resolved some of the mystery surrounding Omega Centauri, the largest and brightest globular cluster in the sky: it appears to harbour an elusive intermediate-mass black hole in its centre.
Image credit: ESO

Very recently, a black hole was discovered in the biggest star cluster in the Milky Way, Omega Centauri. Astronomers have long been speculating that this cluster is the remnant of a small galaxy that merged with the Milky Way a long time ago. The mass of Omega Centauri's black hole is about 40 000 times the mass of our Sun.

Using the current best telescopes available and the next generation of improved telescopes, black holes of intermediate masses will probably be detected at the centres of small nearby galaxies. These could be the seeds for the larger super-massive black holes found in bigger galaxies. So, pieces of the puzzle for black hole formation are beginning to fit together. Still, there is a lot to discover!

This feature article was written as part of the Cosmic Diary Cornerstone project for the International Year of Astronomy 2009. To find out more, check out www.cosmicdiary.org and www.astronomy2009.org.