DISCOVER — ENGAGE — IMPACT

HEART OF DARKNESS

From big things, little things grow – in outer space, anyway! UQ is part of a multi-institutional team that is pioneering new discoveries in astrophysics research, finding double the number of supermassive black holes than previously thought, and paving the way for future discoveries in the discipline.

A UQ astrophysicist is helping to unravel the big origins of some of the universe's smallest galaxies.

M60-UCD1 is an innocuous name for what might be a very important galaxy.

Approximately 54 million light years away from Earth in the Virgo constellation, this little galaxy might hold the answer to a long-running debate among astronomers about how certain very small galaxies are formed.

Ultra-compact dwarf (UCD) galaxies are, as the name suggests, very small and very dense. M60-UCD1 is just 160 light years across but contains 100 million times the mass of our sun, making it 1000 times smaller than the Milky Way, but at the same time also 1000 times denser.

If you look up into the night sky on Earth, you can see up to 4000 stars with your naked eye. If you were standing on a planet in M60-UCD1, you would be able to see a million stars.

Now, UQ's Associate Professor Holger Baumgardt is part of an international team investigating the galaxy for clues to its origin.

"The research was inspired by the discovery of ultra-compact dwarf galaxies 15 years ago," says Associate Professor Baumgardt.

"Following their discovery, astronomers started to wonder how these galaxies could have formed, with some astronomers arguing that they are stripped-down versions of larger galaxies, while other astronomers argued that they were formed from the merger of small star clusters."

The team knew that most, if not all, large galaxies have a supermassive black hole at their centre. If they could find evidence of such a black hole at the centre of M60-UCD1, they would be able to settle the question of how it was formed.

"We first acquired images of galaxy clusters, large concentrations of hundreds to thousands of galaxies, and looked for galaxies which could be ultra-compact dwarf galaxy candidates. We then measured the velocities of these candidates to distinguish the ultra-compact galaxies from background galaxies that are much further away," says Associate Professor Baumgardt.

The best candidate for this research was M60-UCD1, near the large elliptical galaxy M60, in the constellation Virgo. This galaxy was discovered by a team led by Assistant Professor Jay Strader from Michigan State University.

"In the initial discovery paper for M60-UCD1, we presented a few pieces of evidence that the object might contain a supermassive black hole," says Assistant Professor Strader.

"The first was its origin: the system looked like the central region of a galaxy like our Milky Way, with everything else stripped away."

The galaxy also showed evidence of an x-ray source at its centre, which can be a sign of a black hole, as many supermassive black holes emit x-rays as they swallow nearby gas. Furthermore, the galaxy's mass was higher than predicted based on the amount of light coming from its stars, which suggested the presence of an invisible source of mass like a black hole.

A new research team, including Associate Professor Baumgardt, was formed to search for firm evidence of a supermassive black hole at the heart of M60-UCD1. They created detailed images of the galaxy by combining images from the Hubble Space Telescope and the Gemini North Telescope, on the summit of Hawaii's Mauna Kea.

The team found that stars at the galaxy's centre moved much faster than expected, which could only be explained by the presence of a supermassive black hole.

Associate Professor Baumgardt was brought on to the team because of his expertise in creating simulations of the formation of UCDs.

"I investigated whether M60-UCD1 could have formed by tidal stripping of a larger galaxy," he says.

The simulation Associate Professor Baumgardt created shows how, over hundreds of millions of years, the much larger M60 galaxy could have torn stars away from the M60-UCD1 progenitor galaxy, leaving the compact remnants astronomers see today.

"We don't know of any other way you could make a black hole so big in an object this small," says Assistant Professor Anil Seth from the University of Utah, who led the research.

If, as scientists suspect, other UCDs also have supermassive black holes at their centre, it could double the number of supermassive black holes known to science.

"There are a lot of similar ultracompact dwarf galaxies, and together they may contain as many supermassive black holes as there

are at the centres of normal galaxies," says Assistant Professor Seth.

"Finding a supermassive black hole in such a small galaxy is important because black holes can dramatically influence the growth of a galaxy," says Dr Lee Spitler from Macquarie University, one of the other researchers involved in the project.

"Small galaxies are very abundant, so the findings imply there are a whole lot more supermassive black holes in the universe than we previously knew about. The implications of this will take years to understand."

As the team continue to learn more about UCDs and search for more supermassive black holes, Associate Professor Baumgardt is excited about where this research might lead.

"Black holes are very fundamental objects. They are the most concentrated form of matter that we know of. So black hole astrophysics is important for fundamental physics, and this might lead to new knowledge and technology in the future that at the moment we can't even imagine."

What are black holes?

Black holes are objects in space that have so much mass packed into a small area that nothing can escape their gravity – not even light.

Black holes come in many different sizes. The best known are called stellar-mass black holes. Formed from supernovae, they can hold as much as 30 times the mass of the sun. Scientists also speculate that there may be black holes as small as the size of an atom that were formed when the universe began.

Supermassive black holes are the biggest known black holes, and can contain from a million to a billion times the mass of our sun. They are thought to exist at the centre of most large galaxies, including the Milky Way.

Scientists are uncertain how supermassive black holes are formed. Recently, evidence from space telescopes orbiting Earth, including Hubble, suggested the existence of intermediate black holes, in between the size of stellar and supermassive black holes.

It's thought that stars in compact clusters might collide together, forming extremely massive stars, which then collapse to become intermediate-mass black holes. These black holes could then merge to form a supermassive black hole.

Now that the evidence from M60-UCD1 has shown that supermassive black holes may be much more common than previously thought, scientists may be able to discover much more about their origins.

uq.edu.au/research/impact

(Photo credit: NASA/CXC/MSU/J Strader et al)

The adventure so far:

2012: Scientists search for UCDs in the Virgo constellation by combining images from the Chandra and Hubble space telescopes

September 2013: Assistant Professor Jay Strader et al publish the discovery of the M60-UCD1 galaxy and hypothesise the presence of a black hole at its centre

September 2013: UQ's Associate Professor Holger Baumgardt joins the team of scientists searching for evidence of a black hole at the centre of M60-UCD1

September 2014: The team publishes a letter in *Nature* proving the existence of a supermassive black hole at the heart of M60-UCD1

February 2017: The team publishes a paper in Nature announcing the existence of a middleweight black hole, the first black hole of its mass known to science

Contact details:

Associate Professor Holger Baumgardt, UQ School of Mathematics and Physics
Email: h.baumgardt@uq.edu.au
Phone: +61 7 33653430
Web: smp.uq.edu.au/people/HolgerBaumgardt/