'Missing link' galaxies discovered

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Astronomers at The University of Nottingham have identified a type of galaxy that could be the missing link in our understanding of galaxy evolution.

The STAGES study led by the University's Centre for Astronomy and Particle Theory examines galaxy evolution using images from the Hubble Space Telescope. A separate project — Galaxy Zoo — uses volunteers from the general public to classify galaxies. Both teams have identified a population of unusual red spiral galaxies that are setting out on the road to retirement after a lifetime of forming stars.

Astronomers place most normal galaxies into two camps according to their visual appearance: either disk-like systems like our own Milky Way, or round, rugby-ball shaped collections of stars known as ellipticals. In most cases, a galaxy's shape matches its colour; spiral galaxies appear blue because they are still vigorously forming hot young stars. Elliptical galaxies, on the other hand, are mostly old, dead and red, and tend to cluster together in crowded regions of space.

The Galaxy Zoo team examined the connection between the shapes and colours of over a million galaxies using images from the largest ever survey of the local universe — the Sloan Digital Sky Survey — and the help of hundreds of thousands of volunteers. A key ingredient to their success was reliably classifying the appearance of galaxies by actually looking at them, rather than relying on error-prone computer measurements. They found that many of the red galaxies in crowded regions are actually spiral galaxies, bucking the trend for red galaxies to

be elliptical in shape.

Dr Steven Bamford, a Science and Technology Facilities Council (STFC) postdoctoral researcher at The University of Nottingham, led the Galaxy Zoo study. He said: "In order to have spiral arms, they must have been normal, blue, spiral galaxies up until fairly recently. But for some reason their star formation has been stopped, and they have turned red. Whatever caused them to stop forming stars can't have been particularly violent, or it would have destroyed the delicate spiral pattern."

The Galaxy Zoo team concludes that a more subtle process must be at work, one that kills off star formation but does not disrupt the overall shape of the galaxy.

While Galaxy Zoo looked at the gross properties of millions of galaxies across a large chunk of sky, the STAGES project took a complementary approach by examining in detail just the sort of neighbourhoods where these transformations are expected to occur.

The team discovered that, despite their colour, the red spirals are actually hiding star formation behind a shroud of dust. Invisible to our (or Hubble's) eye, this star formation is only detectable in the infrared part of the spectrum — radiation emitted from the galaxies at wavelengths longer than visible light.

When observations from both projects are bought together, the picture that emerges is a gentle one. The star formation in blue spiral galaxies is gradually shut off and hidden behind dust, before petering out to form smooth "lenticular" (lens-shaped) red galaxies with no trace of spiral arms. To go further and transform the galaxy into an elliptical shape would require more violent mechanisms, such as the collision of galaxies.

Location is key to galaxy development. The red spirals are found primarily on the outskirts of crowded regions of space where galaxies cluster together. As a blue galaxy is drawn in by gravity from the rural regions to the suburbs, an interaction with its environment causes a slow-down in star formation. The closer in a galaxy is, the more it is affected.

But if environment decides where the process occurs, the mass of the galaxy decides how quickly it takes place. Because both STAGES and Galaxy Zoo looked at such large numbers of galaxies, they were able to further subdivide them according to how much they weighed. Both groups found that galaxy mass is also important.

Professor Bob Nichol of Portsmouth University, a Galaxy Zoo team member, explains: "Just as a heavyweight fighter can withstand a blow that would bring a normal person to his knees; a big galaxy is more resistant to being messed around by its local environment. Therefore, the red spirals that we see tend to be the larger galaxies — presumably because the smaller ones are transformed more quickly."

Meghan Gray, STFC Advanced Fellow at The University of Nottingham and leader of the STAGES survey, added: "Our two projects have approached the problem from very different directions, and it is gratifying to see that we each provide independent pieces of the puzzle pointing to the same conclusion."

Dr Christian Wolf, an STFC Advanced Research Fellow at the University of Oxford, trained the Hubble Space Telescope on a region of space crowded with galaxies known as the A901/902 supercluster for the STAGES project. Like the Galaxy Zoo team, Dr Wolf also uncovered a surprisingly large population of spiral galaxies in the supercluster that are red in colour.

Dr Wolf said: "For the STAGES galaxies, the Spitzer Space Telescope

provided us with additional images at infrared wavelengths. With them, we were able to go further and peer through the dust to find the missing piece of the puzzle". Within the supercluster, Dr Wolf discovered that the red spirals were hiding low levels of hidden star formation, despite their otherwise lifeless appearance in visible light.

The next step for both teams is to find out exactly what shuts off the star formation, by looking inside the galaxies themselves. They suspect that behind the slow demise of galaxies is a process known as strangulation, in which a galaxy's fuel supply is stripped away as it encounters the crowd. Starved of the raw material needed to form new stars, it will slowly change colour from blue to red as its existing stars age.

The STAGES team's findings on the properties of red spiral galaxies will appear online at arxiv.org/list/astro-ph/new .
The Galaxy Zoo results are available online at arxiv.org/abs/0805.2612

Source: University of Nottingham