Possible missing link between young and old galaxies

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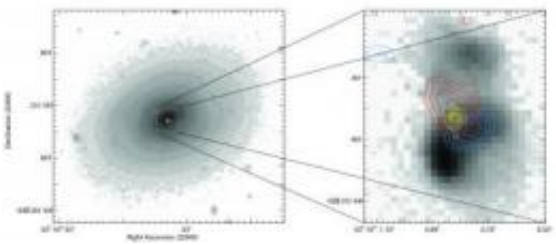

The S0 lenticular galaxy NGC 1266 is unremarkable when observed in optical light (left, grayscale and black contours) very much an example of a "red and dead" galaxy but becomes alive and violent the instant telescopes sensitive to other parts of the electromagnetic spectrum are pointed at it. At the very center, within 100 light years of the few million solar mass black hole, molecular gas, the essential building block of all stars, is squashed to concentrations 100 times greater than the densest molecular clouds in the Milky Way (yellow). The gas is also being expelled at a pace faster than the gravity of the galaxy can contain. This rapidly expelled gas appears as two outflowing lobes, traveling away from the galaxy at up to 400 kilometers per second in opposite directions (red and blue contours). Along the way, the gas excites other wavelengths of light, including a red spectral line of hydrogen (H-alpha), seen only where there is ionized hydrogen (right, grayscale). Credit: Katherine Alatalo/UC Berkeley

University of California, Berkeley, astronomers may have found the missing link between gas-filled, star-forming galaxies and older, gas-depleted galaxies typically characterized as "red and dead."

In a poster to be presented this week at the American Astronomical Society meeting in Seattle, UC Berkeley astronomers report that a long-known "early-type" galaxy, NGC 1266, is expelling molecular gas, mostly hydrogen, from its core.

Astronomers have long recognized the distinction between early-type red and dead galaxies, thought to be largely devoid of gas and dust and thus not forming stars, and galaxies that are currently forming stars from the raw material molecular hydrogen. One of the outstanding problems in astronomy is how galaxies evolve from being star-forming spirals to red and dead.

With such a rapid outflow – about 13 solar masses per year traveling at up to 400 kilometers per second – the galaxy NGC 1266 could easily shed all of its molecular gas in less than 100 million years, equivalent to about one percent the age of the Milky Way, according to the researchers.

"This is the first example of an early-type galaxy where all the molecular gas – the star-forming gas – is concentrated in the nucleus and where we have such a high-resolution picture of what's going on with the molecular gas in the core," said Leo Blitz, UC Berkeley professor of astronomy. "We see molecular gas being expelled at speeds that will allow it to escape from the galaxy and return to the intergalactic medium, and we see the reservoir of gas from which it's drawing. That tells us that if things go on at the current rate, the gas will only last another 85 million more years."

Gas expulsion from the center of the galaxy could be one of many mechanisms that help gas-rich star-forming galaxies evolve into the gas-poor red and dead galaxies littering the cosmos, he said.

While most known galactic jets are associated with intense starburst

regions in galaxies, this old galaxy doesn't have enough star formation to drive an outflow, according to UC Berkeley graduate student Katherine Alatalo. A hungry central super-massive black hole could well be the energy source fueling the jets, she said.

Based on optical and radio observations, the molecular gas is concentrated in a small, dense rotating disk about 300 light years across in the core of the galaxy, instead of being evenly distributed throughout the galactic plane. The rapidly rotating disk in the nucleus confines the outflow into two jets of material that can be seen clearly in radio observations.

"The best way to force all the gas to the center is to smash two galaxies into each other, which provides a way for the gas to lose its angular momentum and fall directly into the center," Alatalo said. "But there is no evidence that NGC 1266 is undergoing any sort of interaction like that, meaning we don't know how this gas lost that momentum."

The region of rapidly swirling gas, located not far from the central black hole, is much like the rotating gas and dust disk from which individual stars form, the researchers said, but is 10 to 100 million times more massive.

"The concentration of gas in the center probably had to have happened rather quickly, yet there is no obvious mechanism for how this happened," Blitz added. "That allows for the possibility that this is just a pathological galaxy, but it may very well be the first of its kind representing a general case of early-type galaxies that have shed their gas by way of a strong central outflow."

The galaxy, catalogued as an S0 lenticular galaxy without spiral arms, is one of 263 galaxies in the ATLAS3D survey, which aims to study all early-type galaxies in a small volume of space within about 140 million

light years of Earth. NGC 1266 is about 100 million light years away in the direction of the constellation Eridanus.

The ATLAS3D survey consists of optical spectroscopy using the SAURON integral-field unit on the William Herschel Telescope in La Palma, Spain; radio and millimeter observations with the Westerbork Radio Synthesis Telescope in the Netherlands and the Institut de Radioastronomie Millimétrique (IRAM) 30 meter telescope in Granada, Spain; and millimeter observations by the Combined Array for Research in Millimeter-wave Astronomy (CARMA), an Owens Valley, Calif., facility operated by the California Institute of Technology, UC Berkeley, the University of Maryland and the University of Illinois at Urbana Champaign. One of the survey's goals is to determine how much molecular hydrogen older galaxies harbor.

Evolving to become red and dead

As galaxies age, much of the molecular gas, consisting of cold, molecular hydrogen and traces of other molecules, including carbon monoxide, gets processed into new stars. Once the molecular gas is used up, star formation ceases unless the molecular gas can be replenished. After about 10 billion years, as the big, bright stars flare out or explode, and as star-forming gas is used up, galaxies are left with primarily small, red, long-lived stars – hence the nickname "red and dead."

Based on observations over many years, astronomers have concluded that these red and dead galaxies have amazingly little molecular gas. One major question has been, "Where did it go?"

The new, more detailed survey, however, is gathering evidence that these old, early-type galaxies may have more molecular hydrogen than once thought.

"If you look at other galaxies of this type, it was thought that only exceptional cases contain star-forming molecular gas, and that only a small fraction contain any gas at all. Before our survey, it was believed that once these types of galaxies lose their gas, they become permanently red and dead," Blitz said. "Our study is showing that, while they're still red, they are not so dead, and they may be forming stars at a rate that is controlled by the molecular gas."

"NGC 1266 is an old, fairly normal looking early-type galaxy that turns out have this deep underbelly of violence going on in the very center," Alatalo said. "We are still at a loss to explain some of it."

More information: Alatalo, Blitz and their ATLAS3D team members detail their results in a paper to be published in *The Astrophysical Journal.*

Provided by University of California - Berkeley