Why Today's Galaxies Don't Make As Many Stars As They Once Did

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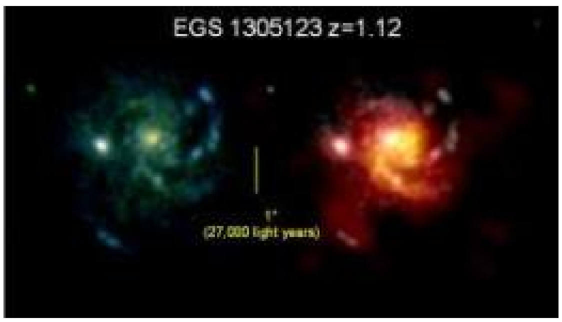

Viewed through the Hubble Space Telescope at visible light (left), a galaxy does not reveal its full secret underlying star formation. Only when observed using a combination of radio emission and infrared wavelengths, the galaxy reveals a massive, rotating disc measuring about 60,000 light years across (right). This disc consists of cold molecular gas and dust, the raw materials from which stars are born.

(PhysOrg.com) -- University of Arizona astronomers have helped solve a mystery surrounding the birth of stars in galaxies that has long puzzled scientists. Their results are published in the Feb. 11 issue of *Nature*.

"We have known for more than a decade that in the early universe - three to five billion years after the Big Bang or nine to eleven billion years before today - galaxies churned out new stars at a much faster rate than they do now," said Michael Cooper, a postdoctoral Spitzer fellow at the UA's Steward Observatory.

"What we haven't known is whether this was because they somehow formed stars more efficiently or because more raw material - molecular gas and dust - was available," said his colleague Benjamin Weiner, an assistant astronomer at Steward Observatory and one of the co-authors on the paper.

Compared to the average galaxy today, which produces stars at rates equaling about 10 times the mass of our sun per year, the rate of star formation in those same galaxies appears to have been up to 10 times higher when they were younger.

In its efforts to find an answer, the scientific community has tended to turn telescopes toward few, rare, very bright objects, mostly because the instruments available did not allow for the study of less extreme, more typical galaxies. By focusing on the rare, bright objects, the results obtained cast doubts as to whether they are true for the majority of galaxies populating the universe.

"It is a little bit like studying only individuals who are seven feet tall instead of looking at those who fall in a more common range of body height," said Cooper.

He and his coworkers took advantage of more sensitive instruments and refined surveying methods to hone in on more than a dozen ‘normal' galaxies. "Our study is the first to look at the ‘five-foot eight' kinds of galaxies, if you will," Copper said. "Our results therefore are more representative of the typical galaxy out there. For the first time, we are getting a much more complete picture of how galaxies make stars."

New stars form from vast swaths of cold gas and dust that make up large parts of a galaxy. Because the star-forming raw material is not easily detected and data on its distribution are sparse and difficult to obtain, researchers until now had trouble knowing which of the following two scenarios is true: Do typical galaxies still hold sufficient quantities of the ingredients required for star formation, but for some reason their efficiency of making stars has slowed down over cosmic time? Or, do present-day galaxies form fewer stars than they did in the past simply because they have used up most of their gas and dust supplies in the process?

To answer such questions, astronomers have to look not only far out into space, but also far back in time. To do that, they take advantage of a phenomenon known as the Doppler effect.

The Doppler effect is apparent to a motorist waiting at a traffic light when the sound of an oncoming ambulance changes to a slightly lower pitch as it passes through the intersection. This happens because the ambulance truck's speed adds to the speed of the sound waves produced by its siren. As the vehicle passes and moves away, the sound waves take slightly longer to reach the observer's ears.

Because the universe is expanding, galaxies behave a bit like cosmic ambulance trucks: As they move farther away from an observer based here on earth, the light they emit shifts to a slightly lower frequency toward the red in the light spectrum.

Astronomers use this red shift to determine the speed with which a galaxy is receding from earth, allowing them to calculate its distance. In the vastness of the universe, distance equals time: The light we see from a galaxy that is, say, five billion light years away, has been traveling through space for five billion years before it hit the lens of our telescope. Therefore, the galaxy we observe today actually represents that galaxy five billion years in the past.

Cooper and his colleagues used data from an earlier study, in which they had surveyed about 50,000 galaxies, to pick a sample representing an 'average' population of galaxies. They then pointed various telescopes, among them the Hubble and the Spitzer space telescopes and radio telescope arrays in France and California, toward their study objects.

"By observing those galaxies in the infrared spectrum and measuring their radio frequency emissions, we were able to make their cold gas clouds visible," explained Cooper.

"What we found now is that galaxies like the ancestors of the Milky Way had a much greater supply of gas than the Milky Way does today," said Weiner. "Thus, they have been making stars according to the same laws of physics, but more of them in a given time because they had a greater supply of material."

The research team also obtained images revealing the extent of the star-forming material that permeates galaxies. In one image of a typical galaxy named EGS 1305123, seen as it was a mere 5.5 billion years after the Big Bang, the scientist's observations for the first time show a massive, rotating disc measuring about 60,000 light years across.

The disc, made up of cold gas and dust, is similar in size and structure to that in a typical galaxy, such as our own, the Milky Way, and gives an impression of what it would have looked like at the time, eight and a half billion years ago.

"From our study, we now know that typical galaxies in the early universe contained three to ten times more molecular gas than today," said Cooper, "a strong indication that the rate of star formation has slowed because those galaxies have less raw material available compared to when they were younger, and not because there was some change in efficiency with which they make new stars."

Cooper and Weiner have led the U.S. portion of this large undertaking, which is headed by scientists from the Max-Planck-Institute for Extraterrestrial Physics in Garching, Germany. The paper, "High molecular gas fractions in normal massive star-forming galaxies in the young universe," is published in the Feb. 11 issue of *Nature*.

Provided by University of Arizona