Arecibo data still yielding galactic insights

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For 57 years the Arecibo Observatory served as a world-class resource for radio astronomy research. Credit: UCF

Data collected by the Arecibo Radio Telescope before it collapsed late last year will help astronomers better understand how our local neighborhood of galaxies formed.

Arecibo was the world's largest single-dish radio telescope until it was surpassed in 2016 by China's Five-hundred-meter Aperture Spherical Telescope (FAST). At the end of 2020, Arecibo's 900-ton receiver platform suddenly and spectacularly fell onto the dish below, destroying the telescope.

A team of astronomers from the University of Western Australia and the International Centre for Radio Astronomy Research (ICRAR) in Perth have used Arecibo's observations of nearby galaxies to test the "Fall relation."

First presented by S. Michael Fall in 1983, the Fall relation suggests the mass of stars belonging to a galaxy and its rotation directly correlate to each other and dictate how a galaxy will grow and evolve.

Funded by the Australian Research Council and published in the journal *Monthly Notices of the Royal Astronomical Society* (*MNRAS*), the new study tests this relationship using data collected from 564 galaxies of varying shapes and ages, making it the largest representative sample of its kind.

Lead author and Ph.D. candidate Jennifer Hardwick said the study would help researchers better understand how a wide range of galaxies evolved and formed, including our galaxy, the Milky Way.

"Although the Fall relation was first suggested almost 40 years ago, previous research to refine its properties had small samples and was limited in the types of galaxies used," Hardwick said.

"This work challenges astronomers' current understanding of how galaxies change over their lifetime and provides a constraint for future researchers to develop these theories further."

Prior research into this relationship has been restricted by the type and number of known galaxies with resolved accurate data, which researchers use to measure galaxy rotation through the Doppler effect.

The study shows that the relationship between the mass of stars and a galaxy's rotation is not what we first thought, with different galaxy types displaying a different relationship between the two properties.

"Because galaxies evolve over billions of years, we have to work with snapshots of their evolution— taken from different stages of their life—and try to piece together their journey."

An example of the type of galaxy used in this study is the Andromeda galaxy, or M31, shown in this image captured by NASA's Galaxy Evolution Explorer (GALEX) space telescope. At approximately 2.5 million light-years away and 260,000 light-years across, Andromeda is so bright and close to us that it is one of only ten galaxies that can be spotted from Earth with the naked eye. Credit: NASA/JPL-Caltech.

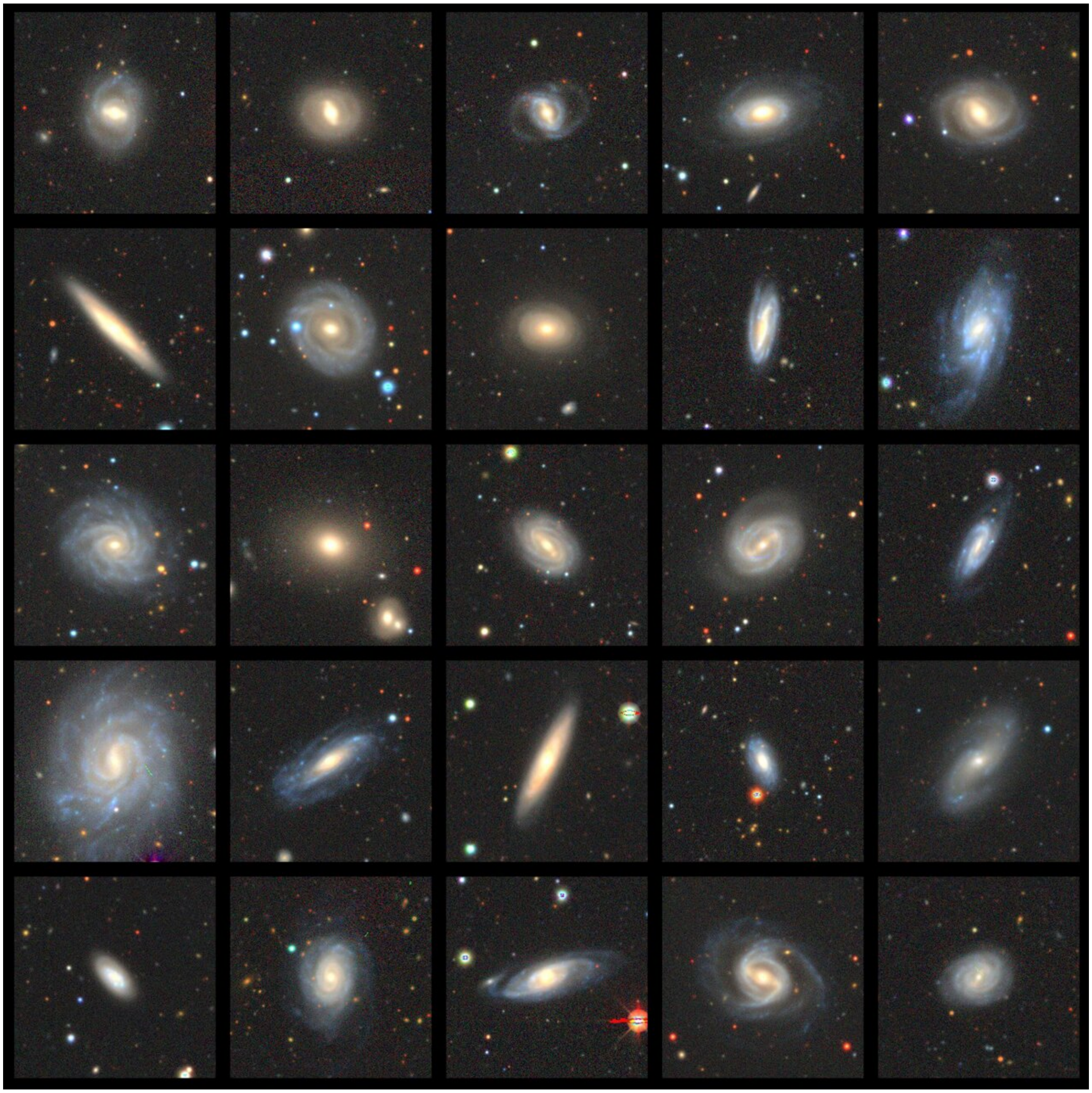
This process has left astronomers with lots of unanswered questions about a galaxy's lifecycle.

"By developing a better understanding of galaxies properties now, we can incorporate these into our simulations to work backwards," she said.

Associate Professor Luca Cortese, Ms Hardwick's supervisor and co-author, said the study shows the importance of revisiting research as our technology advances.

"This creates a cycle of technological development, resulting in new discoveries which push for further advances," he said. "However, before getting to the new discoveries, it is critical to revisit previous knowledge to make sure that our foundations are correct.

"Since the dawn of extragalactic astronomy, it was clear that angular momentum is a key property for understanding how galaxies form and evolve. However, due to the difficulty of measuring angular momentum, direct observational constraints to our theory have been lacking.

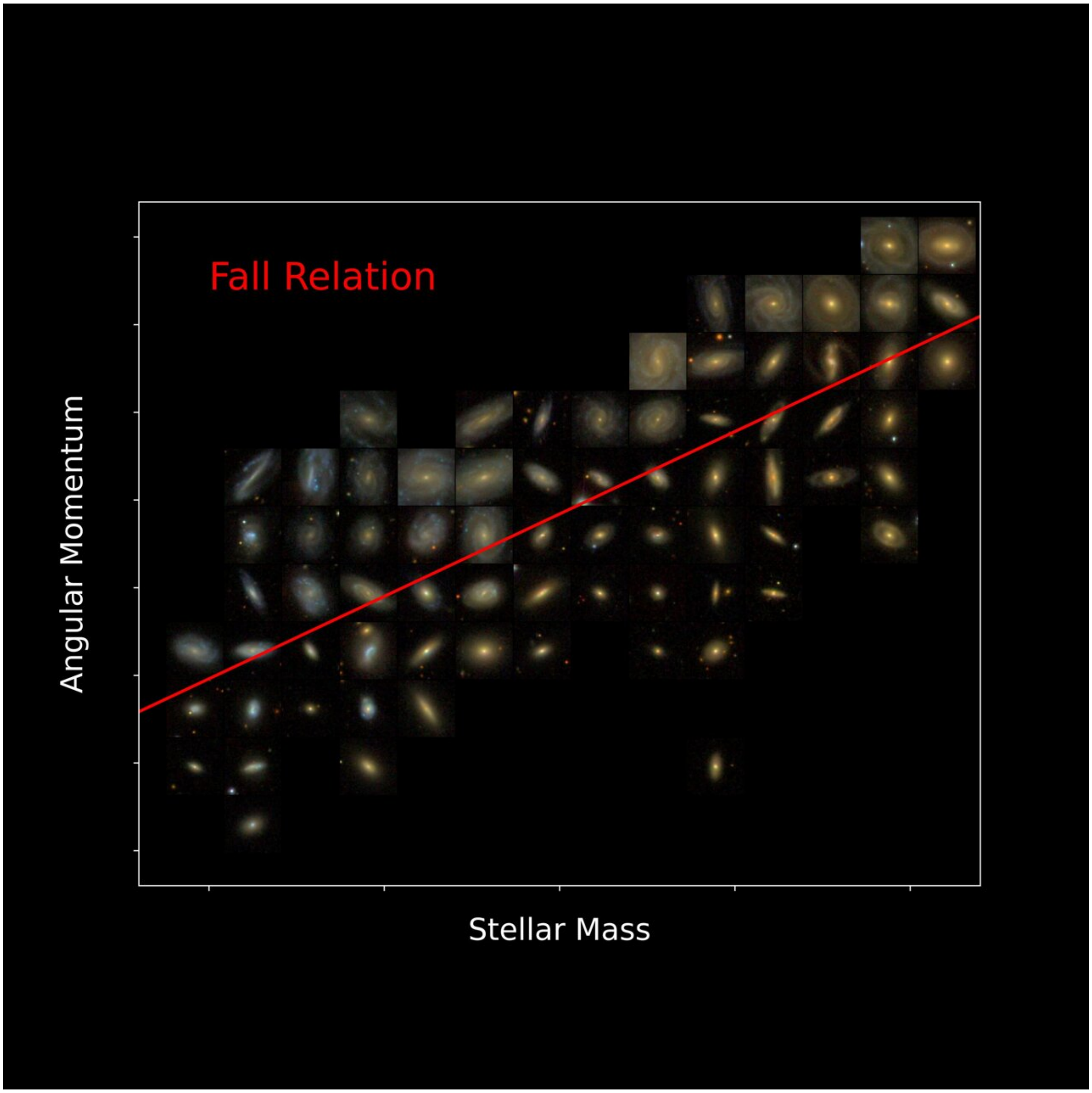


Some of the 564 galaxies observed by the Arecibo telescope used to refine the Fall relation—the relationship between the mass of stars in a galaxy and the rotation of the galaxy. Credit: Jennifer Hardwick, ICRAR-UWA / GALEX Arecibo SDSS Survey (GASS) / DESI Legacy Imaging Survey.

"This work provides an important reference for future studies, offering one of the best measurements of the connection between angular momentum and other galaxy properties in the local Universe."

The research also reinforces the importance of the Arecibo Radio Telescope to astronomy over the past 58 years, even after its forced retirement in 2020.

"Despite the fact that the Arecibo Radio Telescope suddenly collapsed last year, observations of atomic hydrogen content in galaxies carried out with this facility still provide the deepest census of gas content in galaxies," Associate Professor Cortese said.



A graph showing Specific Angular Momentum of neighbouring galaxies versus their Stellar Mass—key physical parameters that govern galaxy formation and evolution. Credit: Jennifer Hardwick, ICRAR-UWA

"We will have to wait for the second half of this decade before these kinds of observations are superseded by data obtained with the precursors of the Square Kilometre Array, such as Australia's SKA Pathfinder Telescope (ASKAP), South Africa's Karoo Array Telescope (MeerKAT) and China's Five-hundred-meter Aperture Spherical radio Telescope (FAST)."

More information: Jennifer A Hardwick et al, xGASS: Characterising the slope and scatter of the stellar mass – angular momentum relation for nearby galaxies, *Monthly Notices of the Royal Astronomical Society* (2021). DOI: 10.1093/mnras/stab3261

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