FOSSIL GALAXY DISCOVERED THREE BILLION LIGHT-YEARS AWAY

Thanks to very high-resolution observations from the Large Binocular Telescope in Arizona, a team led by the Italian National Institute for Astrophysics (INAF) has confirmed the existence of a galaxy that has remained virtually unchanged for about seven billion years: an authentic cosmic fossil that allows us to study the formation of the first galaxies in the history of the universe.

Rome, 30 June 2025. Throughout the history of the cosmos, galaxies tend to grow and evolve through mergers with other galaxies. There are, however, rare examples that are a sort of time capsule: these galaxies, called fossils or relics, formed quite rapidly in the very early stages of the universe, producing almost all of their stars in less than three billion years after the Big Bang, and have remained virtually intact ever since. In astronomical observations, they appear as dense and compact, populated by stars that are rich in heavy elements, and without any sign of ongoing star formation.

A new study has now observed **the most distant relic galaxy ever discovered: a cosmic fossil that has remained unchanged for about 7 billion years**. It is called KiDS J0842+0059 and is **the first massive fossil galaxy confirmed outside the local universe**, through spectroscopic observations and high-resolution images.

The discovery, by an international team of researchers led by the Italian National Institute for Astrophysics (INAF), was made possible thanks to the Large Binocular Telescope (LBT), which is managed by Italy, Germany and the United States on the summit of Mount Graham, in Arizona. The results are published in the July issue of the journal *Monthly Notices of the Royal Astronomical Society*.

“We have discovered a galaxy that has been ‘perfectly preserved’ for billions of years, a true archaeological record that tells us how the first galaxies were born and helps us understand how the universe has evolved up to today”, explains **Crescenzo Tortora**, INAF researcher and first author of the work. “Fossil galaxies are like the dinosaurs of the universe: studying them allows us to understand the environmental conditions in which they formed and how the most massive galaxies we see today evolved.”

The galaxy, which we observe as it was about three billion years ago, was initially identified in 2018 within the KiDS (Kilo Degree Survey) project, a public survey of the European Southern Observatory (ESO) carried out by the Italian VST (VLT Survey Telescope) telescope at the Paranal Observatory in Chile. The KiDS images provided an estimate of the mass and size of the galaxy, whose properties were further characterised by observations with the X-Shooter instrument on ESO's Very Large Telescope, also in Chile. All its characteristics seemed to point towards a fossil galaxy: from its stellar mass, around a hundred billion solar masses, to its lack of star formation for most of the galaxy's life, to its size, which is more compact than other galaxies with a similar stellar mass.

Some uncertainties remained, however, about the size and structure of the galaxy. New observations with the Large Binocular Telescope (LBT) were crucial to confirm the compactness of the galaxy. LBT is capable of obtaining much sharper images thanks to the SOUL adaptive optics system, which compensates in real time for the effects of atmospheric turbulence. The LBT observations of KiDS

J0842+0059 are ten times more detailed than data from the KiDS survey: they are the most detailed images ever of a relic galaxy at this distance and allow us to study its shape and size like never before.

“The data from the Large Binocular Telescope allowed us to confirm that KiDS J0842+0059 is indeed compact and therefore a true relic galaxy, with a shape similar to NGC 1277 and the compact galaxies that we observe in the early stages of the Universe,” explains co-author **Chiara Spiniello**, a researcher at the University of Oxford, INAF associate and principal investigator of the INSPIRE project that contributed to characterising the properties of this galaxy. Until now, NGC 1277 was one of the few confirmed prototypes of this rare class of galaxies. “This is the first time we could do this with such high-resolution data for such a distant relic galaxy.”

The existence of massive relic galaxies like KiDS J0842+0059 or NGC 1277 shows that some galaxies can indeed form rapidly, remain compact, and then stay inert for billions of years, avoiding the growth process that affected most of their counterparts through mergers with other galaxies.

“Studying these cosmic fossils helps us reconstruct the history of formation of the cores of today’s massive galaxies, which — unlike relic galaxies — have undergone merger processes, accreting matter precisely around those first (compact) galaxies from which they originated”, concludes Tortora. “With cutting-edge technologies like adaptive optics and the support of telescopes such as LBT, we can improve our understanding of this type of galaxies. Besides, in the near future we will take a step forward, aiming to search for, confirm and study new relic galaxies through the data of unique quality and resolution of the Euclid space telescope.”

For further information:
The paper “INSPIRE: INvestigating Stellar Populations In RElics – IX. KiDS J0842 + 0059: the first fully confirmed relic beyond the local Universe”, by C. Tortora, G. Tozzi, G. Agapito, F. La Barbera, C. Spiniello, R. Li, G. Carlà, G. D’Ago, E. Ghose, F. Mannucci, N. R. Napolitano, E. Pinna, M. Arnaboldi, D. Bevacqua, A. Ferrè-Mateu, A. Gallazzi, J. Hartke, L. K. Hunt, M. Maksymowicz-Maciata, C. Pulsoni, P. Saracco, D. Scognamiglio e M. Spavone, is published in *Monthly Notices of the Royal Astronomical Society*.

Image caption: The relic galaxy KiDS J0842+0059, observed with the VST as part of the KiDS survey (left) and with the Large Binocular Telescope (right). Crediti: C. Tortora/INSPIRE/VST/ESO/LBT

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