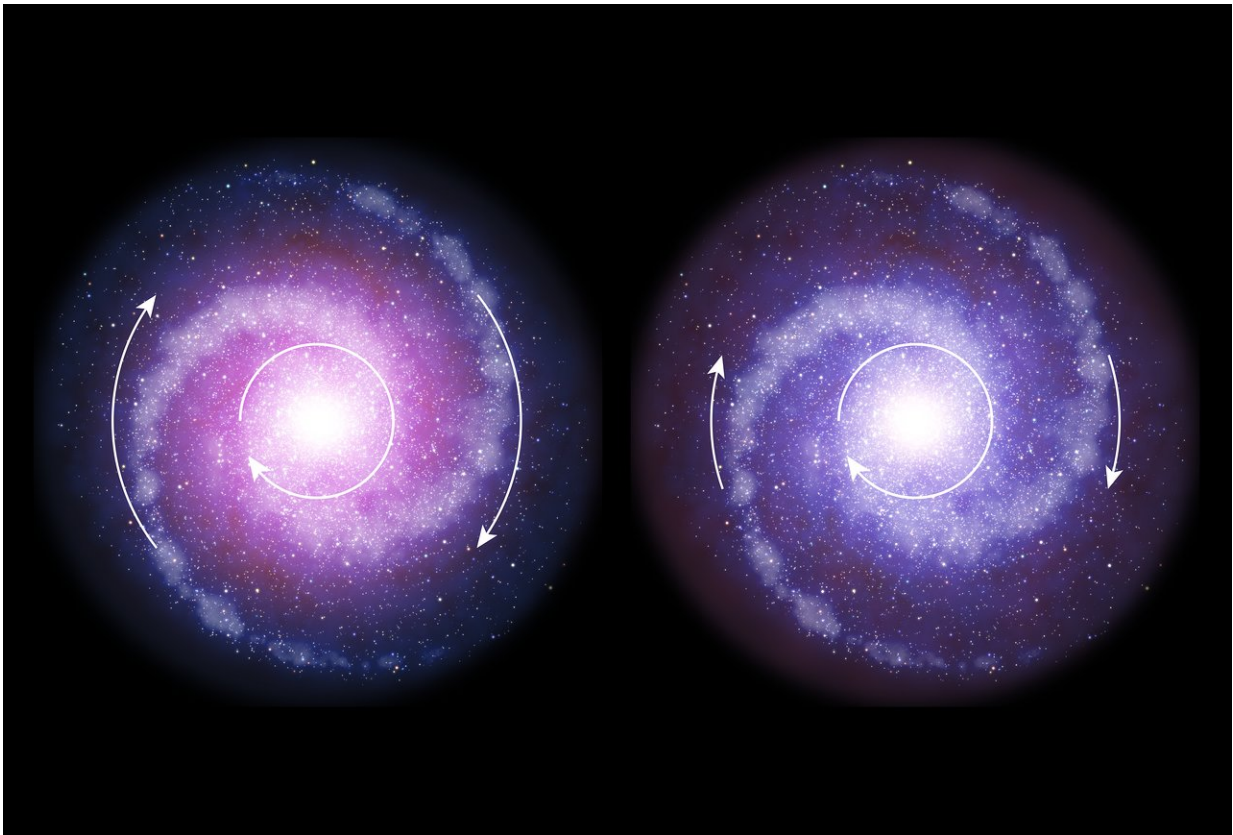


Dark matter less influential in galaxies in early universe

March 15 2017



Schematic representation of rotating disc galaxies in the early Universe (right) and the present day (left). Observations with ESO's Very Large Telescope suggest that such massive star-forming disc galaxies in the early Universe were less influenced by dark matter (shown in red), as it was less concentrated. As a result the outer parts of distant galaxies rotate more slowly than comparable regions of galaxies in the local Universe. Credit: ESO/L. Calçada

New observations indicate that massive, star-forming galaxies during the peak epoch of galaxy formation, 10 billion years ago, were dominated by baryonic or 'normal' matter. This is in stark contrast to present-day galaxies, where the effects of mysterious dark matter seem to be much greater. This surprising result was obtained using ESO's Very Large Telescope and suggests that dark matter was less influential in the early universe than it is today.

We see normal matter as brightly shining stars, glowing gas and clouds of dust. But the more elusive dark matter does not emit, absorb or reflect light and can only be observed via its gravitational effects. The presence of dark matter can explain why the outer parts of nearby spiral galaxies rotate more quickly than would be expected if only the normal matter that we can see directly were present.

Now, an international team of astronomers led by Reinhard Genzel at the Max Planck Institute for Extraterrestrial Physics in Garching, Germany have used the KMOS and SINFONI instruments at ESO's Very Large Telescope in Chile to measure the rotation of six massive, star-forming galaxies in the distant Universe, at the peak of galaxy formation 10 billion years ago.

What they found was intriguing: unlike spiral galaxies in the modern Universe, the outer regions of these distant galaxies seem to be rotating more slowly than regions closer to the core—suggesting there is less dark matter present than expected.

"Surprisingly, the rotation velocities are not constant, but decrease further out in the galaxies," comments Reinhard Genzel, lead author of the *Nature* paper. "There are probably two causes for this. Firstly, most of these early massive galaxies are strongly dominated by normal matter, with dark matter playing a much smaller role than in the Local Universe. Secondly, these early discs were much more turbulent than the spiral

galaxies we see in our cosmic neighbourhood."

Both effects seem to become more marked as astronomers look further and further back in time, into the early Universe. This suggests that 3 to 4 billion years after the Big Bang, the gas in galaxies had already efficiently condensed into flat, rotating discs, while the [dark matter halos](#) surrounding them were much larger and more spread out. Apparently it took billions of years longer for [dark matter](#) to condense as well, so its dominating effect is only seen on the rotation velocities of galaxy discs today

This explanation is consistent with observations showing that early galaxies were much more gas-rich and compact than today's galaxies.

The six galaxies mapped in this study were among a larger sample of a hundred distant, star-forming discs imaged with the KMOS and SINFONI instruments at ESO's Very Large Telescope at the Paranal Observatory in Chile. In addition to the individual galaxy measurements described above, an average rotation curve was created by combining the weaker signals from the other galaxies. This composite curve also showed the same decreasing velocity trend away from the centres of the galaxies. In addition, two further studies of 240 star forming discs also support these findings.

Detailed modelling shows that while normal matter typically accounts for about half of the total mass of all galaxies on average, it completely dominates the dynamics of galaxies at the highest redshifts.

This research was presented in a paper entitled "Strongly baryon dominated disk [galaxies](#) at the peak of [galaxy formation](#) ten billion years ago", by R. Genzel et al., to appear in the journal *Nature*.

More information: *Nature*,

[nature.com/articles/doi:10.1038/nature21685](https://doi.org/10.1038/nature21685)

Provided by ESO

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