

Astrowatch

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Relativity passes test on a galactic scale

Einstein's theory of gravity, general relativity, is known to work well on scales smaller than an individual galaxy. For example, the orbits of the planets in our solar system and the motion of stars around the centre of the Milky Way have been measured precisely and shown to follow the theory. But general relativity remains largely untested on larger length scales. This makes it hard to rule out alternative theories of gravity, which modify how gravity works over large distances to explain away mysterious cosmic substances such as dark matter. Now a precise test of general relativity on a galactic scale excludes some of these alternative theories.

Using data from the Hubble Space Telescope, a team led by Thomas Collett from the University of Portsmouth in the UK has found that a nearby galaxy dubbed ESO 325-G004 is surrounded by a ring-like structure known as an Einstein ring – a striking manifestation of gravitational lensing. As the light from a background object passes a foreground object, the gravity of the foreground object bends and magnifies the light of the background one into a ring. The ring system found by Collett's group is therefore a perfect laboratory with which to test general relativity on galactic scales.

But it isn't easy to make such a test, because the size and structure of the ring depend on several factors, including the distance of the background galaxy from Earth, and the distance, mass and shape of the foreground (lensing) galaxy. In previous tests the uncertainty on some of these factors resulted in large

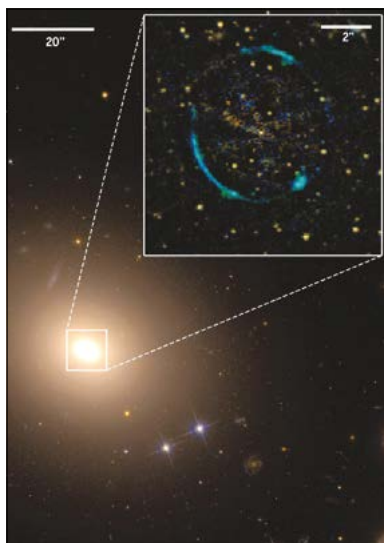


Image of the nearby galaxy ESO 325-G004, produced using data from the Hubble Space Telescope. The inset shows the vicinity of the galaxy in more detail and uncovers an Einstein ring (blue) resulting from the gravitational lensing by ESO 325-G004 of light coming from a distant galaxy. Scale bars are in arc seconds.

systematic errors in the modelling of the gravitational-lensing effect, allowing only weak constraints to be placed on alternative theories of gravity. Now Collett and colleagues' discovery of an Einstein ring around a relatively close galaxy, ESO 325-G004, along with

high-resolution observations of that same galaxy taken with the Multi Unit Spectroscopic Explorer (MUSE) on the European Southern Observatory (ESO) Very Large Telescope, has allowed the most precise test of general relativity outside the Milky Way.

The researchers derived the distances of the background galaxy and the lensing galaxy from measurements of their redshifts. Measuring the mass and the shape of the lensing galaxy is more complex, but was made possible here thanks to the MUSE observations that allowed the team to perform measurements of the motions of the stars that make up the galaxy relative to the galaxy's centre. Since these motions are governed by the gravitational fields inside the galaxy, they can be used to indirectly measure the mass and shape of ESO 325-G004.

The team put all of these measurements together and determined the gravitational effect that ESO 325-G004 should have on the background galaxy's light if general relativity holds true. The result, which, technically, tests the scale invariance of a parameter in general relativity called gamma, is almost in perfect agreement with general relativity, with an uncertainty of only 9%. Not only does it show that gravity behaves on a galactic scale in the same way as it does in our solar system, it also disfavors alternative gravity models, in particular those that attempt to remove the need for dark energy.

● Further reading

E Collett *et al.* 2018 *Science* **360** 1342.

Picture of the month

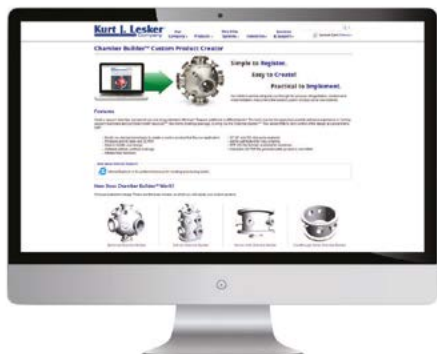
This apparently quiet part of our galaxy shows an active state in which stars are formed. It can be found towards the constellation of Taurus between the Pleiades cluster of stars and the California emission nebula. Several bright blue stars are visible against brown dust clouds. Other stars are partly or fully obscured by dense dust columns. As the dust interacts mainly with the bluer part of the stars' light, the partly obscured stars appear red. If massive enough, the dense clouds of gas and dust that lie between the stars collapse gravitationally to form new stars. These new stars produce new dust in their atmospheres and destroy old clouds with their radiation and wind.



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