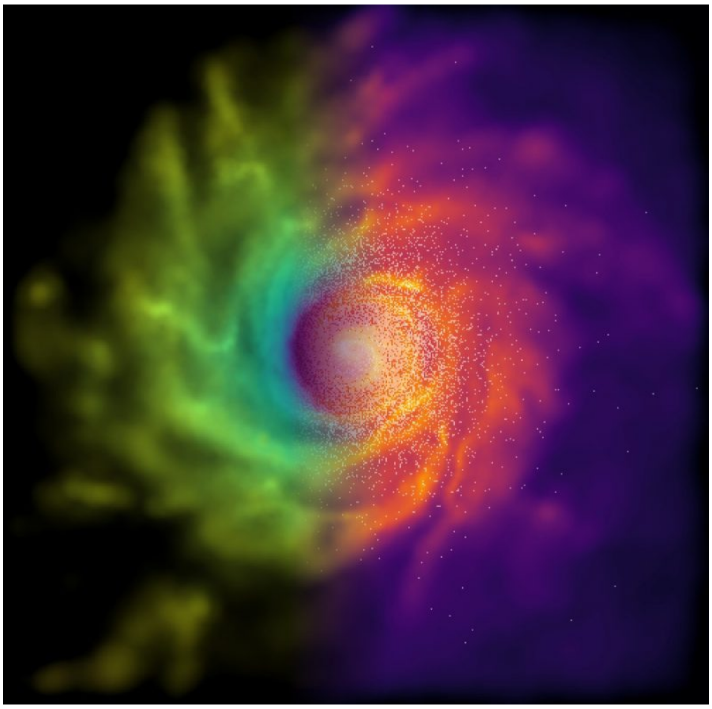
Success with a new theory of gravity?

Supercomputer simulations of galaxies show that Einstein's general theory of relativity might not be the only way to explain how gravity works or how galaxies form. The new Chameleon Theory is a possible alternative.



From the new study, a computer-simulated image of a galaxy, as seen from the side. On right, in red-blue color, you are seeing the gas density within the disk of the galaxy, with the stars shown as bright dots. On left, you see the force changes in the gas within the disk, where the dark central regions correspond to standard General Relativity-like forces and the bright yellow regions correspond to enhanced (modified forces).

Since the early 1900s, Einstein's theory of gravity – called the General Theory of Relativity – has dominated the theories and calculations of cosmologists, those who explain the workings of our universe as a whole. General relativity has been proven again and again, most recently with the first direct black hole image. Now, physicists at Durham University in the U.K. say that Einstein's general theory of relativity might not be the only way to explain how gravity works or how galaxies form. They've had dramatic research success with an alternative model for gravity called a Chameleon Theory, because, in their words, "it changes behavior according to the environment." They say this Chameleon Theory is an alternative to general relativity in explaining the formation of structures in the universe. It might also help further understanding of dark energy, a mysterious substance thought to be accelerating the expansion rate of the universe.

The images on this page are the results of recent computer simulations run on the DiRAC Data Centric System at Durham University. The simulations show that galaxies like our Milky Way could still form in the universe even with different laws of gravity. Earlier work had shown that theoretical calculations using Chameleon Theory reproduce the success of general relativity on the relatively small scale of our solar system. The Durham team has now shown that this theory allows for realistic simulations of large-scale structures like our Milky Way. Research co-lead author **Christian Arnold**, said:

Chameleon Theory allows for the laws of gravity to be modified so we can test the effect of changes in gravity on galaxy formation. Through our simulations we have shown for the first time that even if you change gravity, it would not prevent disk galaxies with spiral arms from forming.

Our research definitely does not mean that general relativity is wrong, but it does show that it does not have to be the only way to explain gravity's role in the evolution of the universe.

The researchers looked at the interaction between gravity in Chameleon Theory and supermassive black holes that sit at the center of galaxies. Black holes play a key role in galaxy formation because the heat and material they eject when swallowing surrounding matter can burn away the gas needed to form stars, effectively stopping star formation.

The amount of heat spewed out by black holes is altered by changing gravity, affecting how galaxies form. However, the new simulations showed that even accounting for the change in gravity caused by applying Chameleon Theory, galaxies were still able to form.

The work might also shed light on our understanding of the observed accelerating expansion of the universe. Scientists believe this expansion is being driven by dark energy, and the Durham researchers say their findings could be a small step toward explaining the properties of this substance. Research co-lead **Baojiu Li** commented:

In general relativity, scientists account for the accelerated expansion of the universe by introducing a mysterious form of matter called dark energy – the simplest form of which may be a cosmological *constant, whose density is a constant in space and time. However, alternatives to a cosmological constant which explain the accelerated expansion by modifying the law of gravity are also widely considered given how little is known about dark energy.*

The Durham researchers are theoretical physicists, as Einstein was. When Einstein's general theory of relativity was first proven – during a total solar eclipse of 1919 – Einstein was catapulted into rock star fame. Now general relativity is fundamental to modern cosmology. The next step for Chameleon Theory would likewise be to test and hopefully confirm it via observations. There's no doubt but that observational astronomers will soon be on the job, creating their own tests for the new Chameleon Theory, and perhaps proving it. If and when that happens, it will be super exciting!

Albert Einstein in 1912. He published his general theory of relativity in 1915. The theory was confirmed in 1919.

Supercomputer simulations of galaxies have shown that Einstein's theory of General Relativity might not be the only way to explain how gravity works or how galaxies form.

The resulting images produced by the simulation show that galaxies like our Milky Way could still form in the universe even with different laws of gravity.

The findings show the viability of Chameleon Theory -- so called because it changes behaviour according to the environment -- as an alternative to General Relativity in explaining the formation of structures in the universe.

General Relativity was developed by Albert Einstein in the early 1900s to explain the gravitational effect of large objects in space, for example to explain the orbit of Mercury in the solar system.

It is the foundation of modern cosmology and even plays a role in everyday life, for example in calculating GPS positions in smartphones.

The Durham team has now shown that this theory allows realistic galaxies like our Milky Way to form and can be distinguished from General Relativity on very large cosmological scales.

As Dr Christian Arnold, in Durham University's Institute for Computational Cosmology, said:

Chameleon Theory allows for the laws of gravity to be modified so we can test the effect of changes in gravity on galaxy formation.

The researchers looked at the interaction between gravity in Chameleon Theory and supermassive black holes that sit at the centre of galaxies. Black holes play a key role in galaxy formation because the heat and material they eject when swallowing surrounding matter can burn away the gas needed to form stars, effectively stopping star formation. The amount of heat spewed out by black holes is altered by changing gravity, affecting how galaxies form.

However, the new simulations showed that even accounting for the change in gravity caused by applying Chameleon Theory, galaxies were still able to form.

General Relativity also has consequences for understanding the accelerating expansion of the universe.

Scientists believe this expansion is being driven by dark energy and the Durham researchers say their findings could be a small step towards explaining the properties of this substance. They expect their findings to be tested through observations using the Square Kilometre Array (SKA) telescope, based in Australia and South Africa, which is due to begin observations in 2020. SKA will be the world's largest radio telescope and aims to challenge Einstein's theory of General Relativity, look at how the first stars and galaxies formed after the Big Bang, and help scientists to understand the nature of dark energy.

Typical Galaxy, Andromeda M31 (stock image)

AK, with EarthSky and Wikipedia Notes