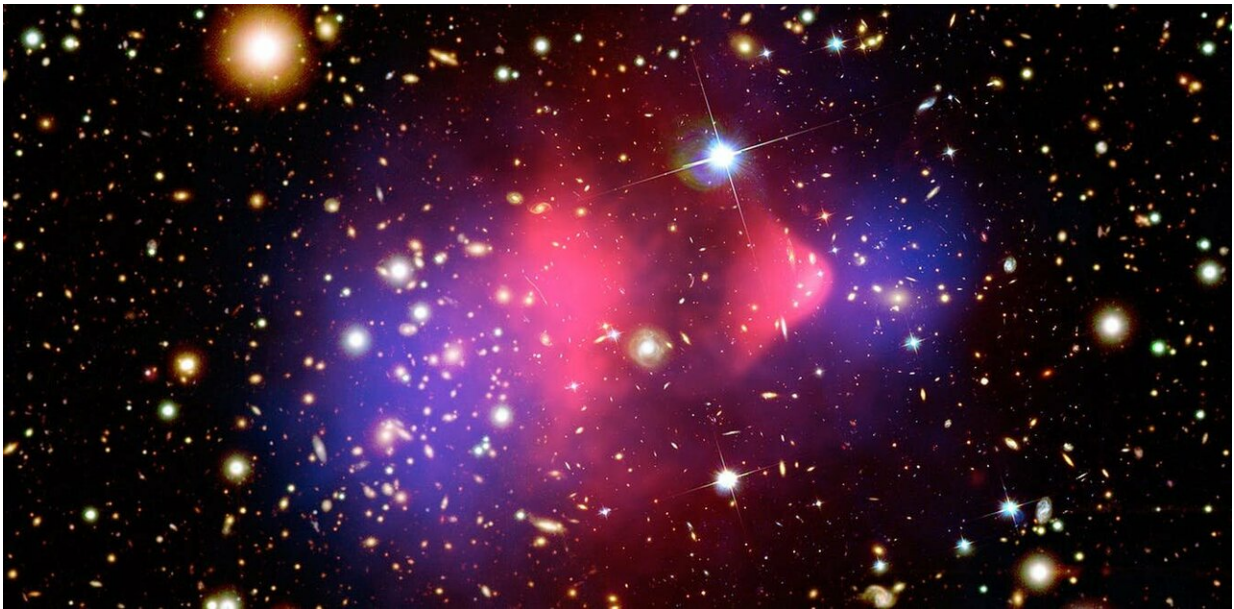


Dark matter may not actually exist – and our alternative theory can be put to the test

January 31 2019, by Juri Smirnov



The bullet cluster. Credit: NASA/CXC/M. Weiss

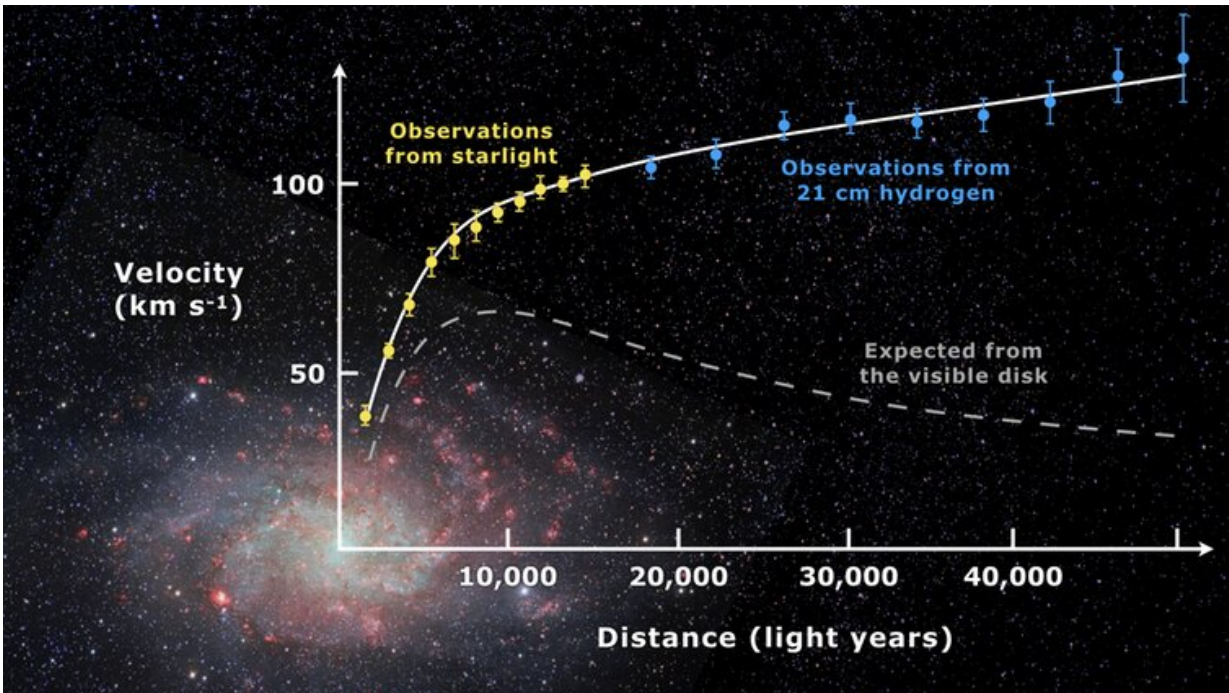
Scientists have been searching for "dark matter" – an unknown and invisible substance thought to make up the vast majority of matter in the universe – for nearly a century. The reason for this persistence is that dark matter is needed to account for the fact that galaxies don't seem to obey the fundamental laws of physics. However, dark matter searches have remained unsuccessful.

But there are other approaches to make sense of why [galaxies](#) behave so strangely. Our new study, published in the [Journal of Cosmology and Astroparticle Physics](#), shows that, by tweaking the laws of gravity on the enormous scales of galaxies, we may not actually need dark [matter](#) after all.

The Swiss astronomer [Fritz Zwicky](#) discovered in the 1930s that velocities in galaxy clusters were too high to account for how much matter we could see. A similar phenomenon was described by several groups of astronomers, such as [Vera Rubin](#) and [Kent Ford](#), when they studied the motion of stars at the far edges of the Andromeda Galaxy.

The velocities of the stars far from its centre were expected to decrease, as they experience less [gravitational force](#). That's because, according to [Newton's second law](#) of motion, the [gravitational pull](#) on orbiting matter can be equated to a product of its mass and acceleration (which is related to velocity).

However, the measurements showed that there was no such decrease in velocities with distance. That led scientists to believe there must be some invisible matter there to create a stronger gravitational pull and faster stellar motion. In the past decades, countless other probes of gravitating systems at very large length scales indicated the same problem.



Rotation curve of spiral galaxy Messier Triangulum. Credit: Mario De Leo/wikipedia, [CC BY-SA](#)

Beyond dark matter

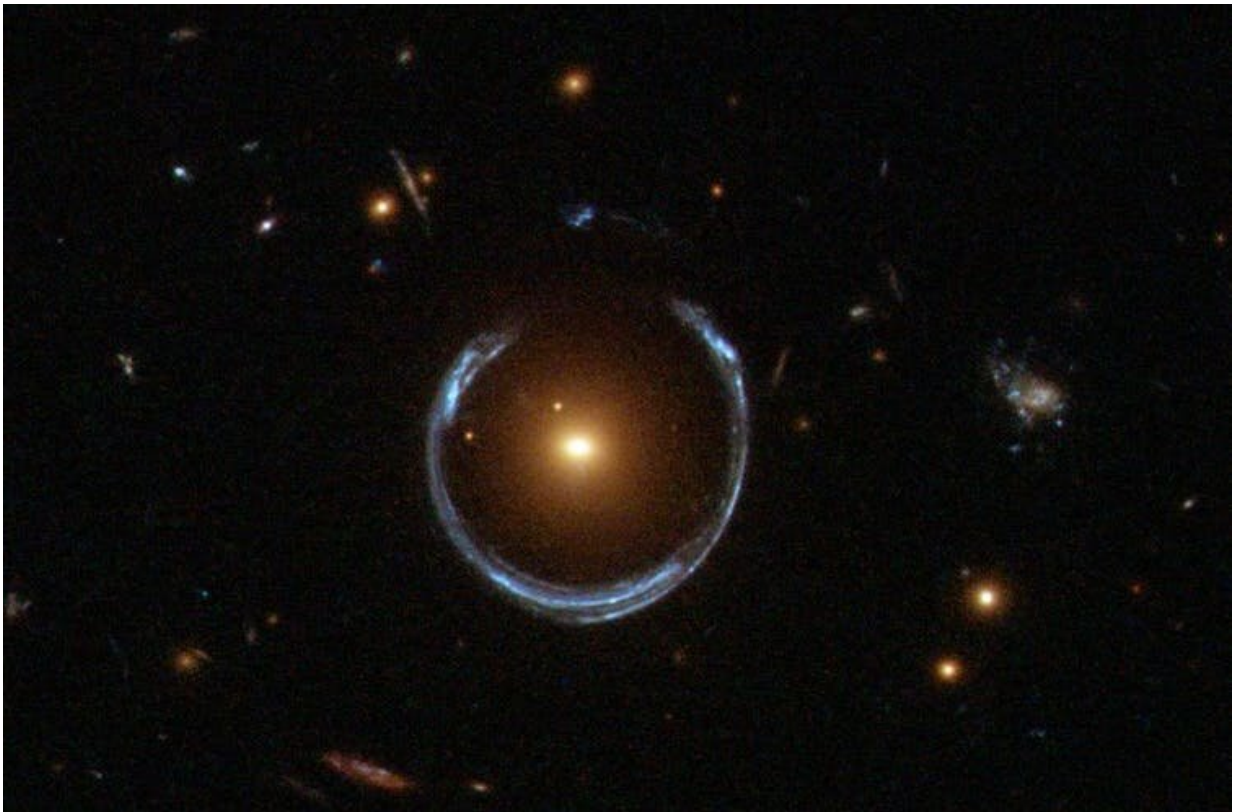
The mystery of what dark matter actually is remains the ultimate challenge of modern fundamental physics. The core question is whether it is indeed a missing mass source, such as a new type of matter, or whether the gravitational law is simply different at gigantic length scales.

While the first option seems very tempting, we haven't actually found any dark matter yet. Also, while gravity laws are well tested within the solar system, [one has to be careful extrapolating this](#) to scales which are at least one billion times larger.

One well known attempt to get rid of the need for dark matter is

Modified Newtonian Dynamics (MOND), which suggests that Newton's law of gravity becomes irregular when the gravitational pull is very weak – as is the case in the outer regions of the galaxy. But this theory, although successful in many respects, hasn't passed the same stringent tests as our standard model of cosmology, which includes dark matter.

The main problem is that MOND cannot explain the missing mass problem in galaxies and galaxy clusters at the same time. Another very strong argument against MOND is based on the observation of colliding [galaxy clusters](#), where the stars of each galaxy pass through each other, but the gas clouds stick together and stay behind. A famous example is the [Bullet Cluster](#), which consists of two such colliding clusters. Observations suggest that dark matter follows the stars in these events, which have a lower total mass than the gas cloud. MOND cannot explain why that is.



Gravitational lens around a galaxy. Credit: NASA

Space bubbles

We set out to tweak the laws of gravity in a different way. Our approach assumed that a phenomenon known as [Vainshtein screening](#) is at work. This suggests that each sufficiently dense, compact object in space generates an invisible sphere around it which determines how the laws of physics behave with growing distance. This sphere is a theoretical concept to help us understand the difference between small and big scales, rather than an actual physical membrane.

According to our theory, within this bubble the laws of ordinary Newtonian gravity that we see in our solar system hold for objects interacting with the massive body at the centre. Outside the bubble, the theory suggests that the gravitational pull by the central object can be significantly enhanced – even though there is not more mass present.

The bubble size would be proportional to the mass of the central object. If, for example, in a galaxy this sphere has a radius of a few thousand [light years](#) – a typical distance at which signs of dark matter is observed – the corresponding sphere of our sun would have a radius of 50.000 astronomical units (one such unit is the distance between the sun and the Earth). However, the edge of the solar system is only 50 astronomical units away. In other words, there are no objects we could observe that far from the sun to test whether the sun has a different gravitational pull on them than it has on Earth. Only the observation of entire systems very far away allows us to do that.

The surprising effect is that the size of the Newtonian bubble grows with the enclosed mass in a particular way. This means that the law of gravity changes at different length scales in galaxies and clusters of galaxies respectively and therefore it can explain the apparent dark matter in both systems simultaneously. That's not possible with MOND. Furthermore, it is consistent with the observation of the Bullet Cluster. That's because the gas clouds left behind in the collision are not compact enough to generate a sphere around them – meaning that the apparent dark matter is only notable around the more compact stars. MOND doesn't distinguish between stars and gas clouds.

To our big surprise, our theory allowed us to explain the stellar velocities in galaxies a lot better than with [Einstein's general relativity](#), which allows for dark matter to exist. So there may actually be less mysterious [dark matter](#) out there than we think – and maybe even none at all.

We plan to further investigate this interesting phenomenon. It could also be responsible for the high [variability of galactic motion](#), for which we gather more and more evidence.

Any massive body warps the space and time around it, according to general relativity. As a result, light rays take an apparent turn around the object rather than travelling in a straight line – an effect dubbed gravitational lensing. An extremely interesting test of our finding would be the observation of precise gravitational light deflection by individual galaxies, which is albeit a difficult measurement. Our theory predicts a stronger light deflection for very compact galaxies so, excitingly, it could one day be falsified or confirmed by such a measurement.

More information: Moritz Platscher et al. Long range effects in gravity theories with Vainshtein screening, *Journal of Cosmology and Astroparticle Physics* (2018). [DOI: 10.1088/1475-7516/2018/12/009](https://doi.org/10.1088/1475-7516/2018/12/009)

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