Unique prediction of 'modified gravity' challenges dark matter theory

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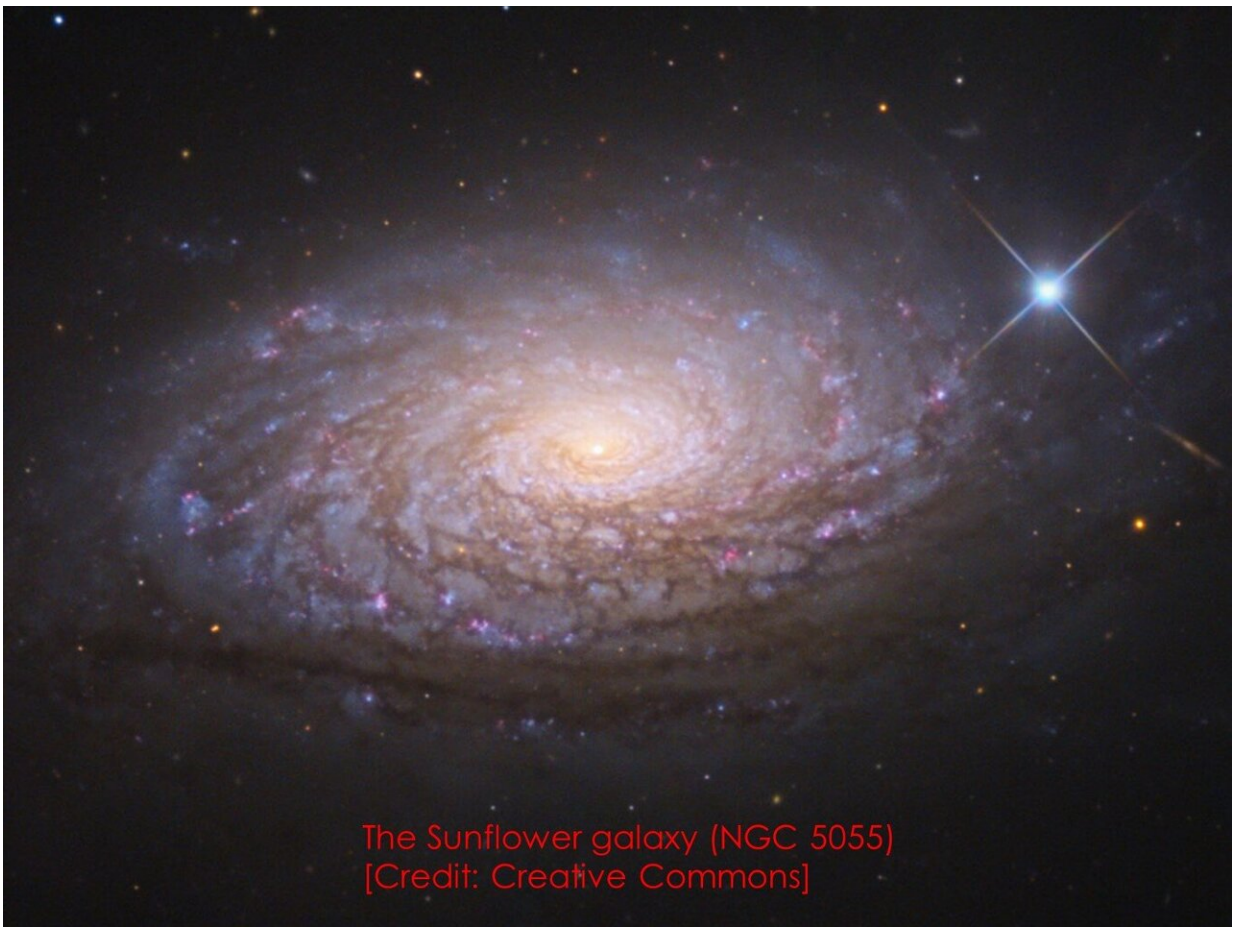

The best example is represented by the Sunflower galaxy (NGC 5055) with the strongest external fieldamong SPARC galaxies, whose well-measured rotation curve shows a mildly declining behavior at largeradial distance and can be accurately modeled only with an external field effect. Credit: Creative Commons

An international group of scientists, including Case Western Reserve University Astronomy Chair Stacy McGaugh, has published research contending that a rival idea to the popular dark matter hypothesis more accurately predicts a galactic phenomenon that appears to defy the classic rules of gravity.

This is significant, the astrophysicists say, because it further establishes the hypothesis—called modified Newtonian dynamics (MOND), or "modified gravity"—as a viable explanation for a cosmological dilemma: that galaxies appear to buck the long-accepted rules of gravity traced to Sir Isaac Newton in the late 1600's.

The mystery: For decades, we've measured more gravitational pull in space than we think we should have—that there's not enough visible or known matter to account for it all.

So, dark matter proponents theorize that most of the known universe is actually made of material that doesn't interact with light, making it invisible and undetectable— but that this material accounts for much of the gravitational pull among galaxies. It has been the prevailing theory for nearly 50 years.

MOND theory, a counter explanation introduced by physicist Mordehai Milgrom from Weizmann Institute (Israel) in the early 1980s, says this gravitational pull exists because the rules of gravity are slightly altered.

Instead of attributing the excess gravitational pull to an unseen, undetectable dark matter, MOND suggests that gravity at low accelerations is stronger than would be predicted by a pure Newtonian understanding.

In addition, MOND made a bold prediction: the internal motions of an object in the cosmos should not only depend on the mass of the object

itself, but also the gravitational pull from all other masses in the universe—called "the external field effect" (EFE).

Milgrom said the findings, if robustly confirmed, would be "the smoking gun proving that galaxies are governed by modified dynamics rather than obeying the laws of Newton and of general relativity."

150 galaxies tested for EFE

McGaugh and his collaborators, led by Kyu-Hyun Chae, from Sejong University in South Korea, say they detected this EFE in more than 150 galaxies studied.

Their findings were published recently in *The Astrophysical Journal*.

"The external field effect is a unique signature of MOND that does not occur in Newton-Einstein gravity," McGaugh said. "This has no analogy in conventional theory with dark matter. Detection of this effect is a real head-scratcher."

The team of six astrophysicists and astronomers includes lead author Chae and other contributors from the United Kingdom, Italy and the United States.

"I have been working under the hypothesis that dark matter exists, so this result really surprised me," Chae said. "Initially, I was reluctant to interpret our own results in favor of MOND. But now I cannot deny the fact that the results as they stand clearly support MOND rather than the dark matter hypothesis."

Analyzing rotating galaxies

The group analyzed 153 rotation curves of disk galaxies as part of their study. The galaxies were selected from the Spitzer Photometry and Accurate Rotation Curves (SPARC) database, created by another collaborator, Federico Lelli, during his postdoctoral studies at Case Western Reserve, McGaugh and co-author James Schombert, of the University of Oregon.

In addition to Chae, McGaugh, Lelli and Schombert, the authors of the research were Pengfei Li from Case Western Reserve and Harry Desmond from the University of Oxford.

The scientists said they deduced the EFE by observing that galaxies in strong external fields slowed (or exhibited declining rotation curves) more frequently than galaxies in weaker external fields—as predicted by MOND alone.

Lelli said he was skeptical by the results at first "because the external field effect on rotation curves is expected to be very tiny. We spent months checking various systematics. In the end, it became clear we had a real, solid detection."

McGaugh said that skepticism is part of the scientific process and understands the reluctance of many scientists to consider MOND as a possibility.

"I came from the same place as those in dark matter community," he said. "It hurts to think that we could be so wrong. But Milgrom predicted this over 30 years ago with MOND. No other theory anticipated the observed behavior."

More information: Kyu-Hyun Chae et al, Testing the Strong Equivalence Principle: Detection of the External Field Effect in Rotationally Supported Galaxies, *The Astrophysical Journal* (2020). DOI:

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