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Forget dark matter – embrace my MOND theory instead

By **Marcus Chown**

"Dark matter was the hypothesis of least daring, just add gravitating stuff"
(Image: Jonathan Bloom)

It supposedly makes up 80 per cent of the matter in the universe, but we still have no direct evidence that dark matter exists. Physicist ***Mordehai Milgrom*** *tells* ***Marcus Chown*** *that it's time to abandon the idea – because he has a better one*

Why is now a good time to take an alternative to dark matter seriously?
A host of experiments searching for dark matter, including the Large Hadron Collider, many underground experiments and several space missions, have failed to see anything convincing. This comes on top of increasing realisation that the leading dark matter model has its failings. Among other things, it predicts that we should see many more

dwarf galaxies orbiting our Milky Way than we actually do.

Set against this is the fact that in the past two years, numerous observations have added support to my proposed alternative, modified Newtonian dynamics (MOND).

What does dark matter explain?

To give one example, according to Newton's laws of motion and gravitation, stars at ever greater distances from the centre of a spiral galaxy should orbit the centre ever more slowly because of the rapid drop-off in gravity. But this doesn't happen.

The mainstream explanation is that every spiral galaxy, including our Milky Way, is embedded in a "halo" of dark matter that enhances gravity at the galaxy's outer regions, preventing stars from simply flying off into intergalactic space. But for that to work, you have to give each galaxy its own arbitrary amount and distribution of dark matter.

So what is MOND, your alternative?

I believe that galaxies are governed by laws that differ from Newton's. According to MOND, the faster-than-expected motion of stars in the outer regions of spiral galaxies could be due to either a new law of gravity that yields a stronger-than-expected force or a new law that reduces the inertia of stars. This departure from Newtonian dynamics occurs when the acceleration of stars drops below a hundred billionth of a g, which happens at different distances from the centre in different galaxies. So, with a single parameter, MOND can predict the rotation curves of all galaxies with no need for dark matter.

What new evidence is there for MOND?

I will mention just two recent findings. In what's known as galaxy-galaxy lensing, light from distant galaxies is distorted as it passes by nearer galaxies on its way to Earth. This enables us to probe the gravitational field of millions of galaxies of all types – not just spiral galaxies, where it is easy to see MOND at work. Predictions made using MOND agree well with recent observations (*Physical Review Letters*, vol 111, p 041105).

Other evidence comes from our neighbouring galaxy Andromeda. Because MOND assumes that there is no dark matter, it must predict the velocity of stars orbiting in a galaxy from the distribution of visible matter alone. Last year, with Stacy McGaugh at Case Western Reserve University in Cleveland, Ohio, we predicted the velocities of stars in about 30 dwarf satellite galaxies of Andromeda. When these velocities were actually measured, our predictions proved correct (*The Astrophysical Journal*, vol 775, p 139). The main dark matter paradigm has no such predictive power; it can only explain after the event.

When did you first come up with this alternative to dark matter?

More than 30 years ago, I began to wonder whether the gravitational dynamics changed at a particular distance from the centre of a galaxy. That didn't appear to be the case. I tried a few other things and, finally, in April 1981, I hit on acceleration. The meagre data we had then could be explained if at a critical acceleration – a mere hundred billionth of a g – gravity switched from a type that weakens in line with the familiar Newtonian law to a type that falls off more slowly, following a different law. That alternative law is MOND. At first, I didn't tell anyone. Only after working on the idea for six more months did I announce it in three papers. By and large, they were met by

silence.

Why didn't most people take it seriously?
Dark matter was the hypothesis of least daring – just add some gravitating stuff that gives out no light. Modifying dynamics, on the other hand, meant tampering with fundamental things such as Newton's and Einstein's theories of gravity. That appalled people. Also, initially, the theory applied only to nonrelativistic systems – with constituents that move slowly compared with light. To be taken seriously, MOND had to be made compatible with Einstein's principles of relativity.

So how did you solve that problem?
It took a while, but in 2004 Jacob Bekenstein at the Hebrew University of Jerusalem put forth a theory known as TeVeS (tensor-vector-scalar). It built on his earlier work with Bob Sanders at the University of Groningen in the Netherlands. TeVeS describes gravity with three fields and made MOND compatible with Einstein's relativity. After it was introduced, people started to take MOND more seriously.

Is MOND more elegant than dark matter?
It is certainly far more economical. For every galaxy, dark matter theorists must fit a made-to-measure amount and distribution of dark matter. So, if we understand 10 galaxies, we still don't understand an 11th. Dark matter explains only after the fact. MOND predicts things ahead of time. This is key.

What do the dark matter theorists say to this?
They believe the problems with dark matter will one day be solved. A single MOND formula perfectly describes every spiral galaxy, even though the birth of each one is chaotic, complex and unique. It is hard to see how the dark matter model can explain this. Still, they cling to the hope that it will one day be possible. To my mind there is no hope of that happening.

Does it bother you that most physicists remain dismissive of your idea?
Fifteen years ago, I found it somewhat dismaying. Now my spirits are up. There has been an explosion in interest. In recent years, around 700 papers dealing with MOND have been published. It's very encouraging.

What killer observation could support MOND?
Well, if dark matter is discovered, that would kill MOND. But I don't think there is one killer observation that will clinch the idea in the minds of dark matter advocates. Hundreds of MOND predictions have been vindicated already; what more can one ask for?

How long should we keep looking before giving up on dark matter?
The ongoing, failed attempts to find it actually benefit MOND, so I would like to see the search continue. To my mind it is already high time to give up on dark matter. So much time, money and effort can be saved.

Human nature being what it is, that might take 10 years or longer. I envision a gradual disillusionment as dark matter continues not to turn up in experiments. Even Einstein's theory of gravity was accepted only slowly. So I'm not despairing. Far from it.

Profile

Mordehai Milgrom is professor of physics at the Weizmann Institute of Science in Rehovot, Israel. He proposed the theory of modified Newtonian dynamics (MOND) as an alternative to dark matter