

## Re: Dark Matter / Energy

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- *From:* [brian@xxxxxxx](mailto:brian@xxxxxxx) (Brian Tung)
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Paulus wrote:

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I have recently become interested in this subject, however there is something that troubles me that no-one seems to bother discussing or explaining. If there is someone out there that can I would appreciate it.

As I understand it dark matter and energy have been theorized due to the observed behaviour of galaxies. Both internally and between each other galaxies appear to behave in a way that contravenes Newton's inverse square law without the addition of extra mass.

What I don't get is that if this extra 'dark' mass is there why isn't it here? Why is it that the planets within our solar system appear to be obeying Newton's inverse square law? Why aren't we seeing the effect of additional mass within the solar system? Why is it only on the large scale of the behaviour of galaxies?

If anyone can explain I would appreciate it.

It is here. You just don't feel it.

Gravitational forces in general—in other words, even when involving ordinary matter—become dominant only at large scales. At scales such as solar-system-sized arrangements of matter, the effect of dark matter is simply too small to be felt.

Here is perhaps some intuition for why gravity becomes increasingly dominant at larger scales. A typical bowling ball has a mass of about 7 kg. If you put two bowling balls a meter apart, and you were somehow able to isolate them from all other forces—such as air resistance, friction, the Earth's gravity, and so forth—they would attract each other pretty much according to Newton's law (the "pretty much" of it

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being an allowance for the minuscule modification made by Einstein).

The problem is that bowling balls are so puny from an astronomical perspective that the gravitational force is overwhelmed by things like air resistance, friction, and the Earth's gravity, which in practice we really can't separate out sufficiently. (Even so, exquisitely sensitive torsion balances can and have been designed to measure even this tiny gravitational force.)

But suppose you were to scale everything up by a factor of 1,000. The bowling balls would now be a kilometer apart, and the attenuation due to the inverse square law would therefore be greater by a factor of 1,000 squared, or 1,000,000.

However, it is not only the distance that gets larger. The bowling balls do, too, and at a much faster rate. These bowling balls are now 1,000 times wider (probably about 200 meters across), and would as a consequence have 1,000,000,000 times the mass. What's more, the force of gravity is proportional to the *product* of the masses of the two super bowling balls, divided by the square of the distance. The upshot is that the force of attraction between the bowling balls is a trillion times what it was in the ordinary case.

To be sure, the bowling balls have a billion times their original inertia, too, so they are a billion times harder to move for a given force. That still means, though, that the acceleration we measure for the bowling balls is 1,000 times larger than it was. Still pretty small by everyday standards, but a heck of a lot easier to measure than for two bowling balls. (Of course, there's that problem of trying to find and arrange two stadium-sized bowling balls that each weigh 8 million tons.)

All in all, things add up, and by the time you get to Earth-sized objects, you're talking some serious gravity—9.8 meters per second per second at the Earth's surface.

Granted, the Earth is a single, more or less solid spherical body, and we measure the effects of gravity outside it, whereas dark matter is a very tenuous something arranged in some way in and amongst the galaxies. But even though the effects of dark matter are too small to be felt by ordinary objects like you or me or the planet Earth, it is nevertheless significant enough at large scales (for reasons similar to the ones laid out above) to be noticeably nudging galaxies this way and that.

Recently, a paper by two Canadian astrophysicists named Cooperstock and Tieu suggested that dark matter might not be necessary after all—at least not to explain anomalous galactic rotation. One of the reasons that astronomers felt that dark matter had to exist was that the outer portions of many spiral galaxies rotated faster than they "ought" to, if we were to judge solely on the amount of visible mass in the galaxies. If there were somehow more mass in the galaxies, invisible

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and distributed in a spherical halo around the galactic center, that would explain the faster rotation.

It must be emphasized that there are various caveats that have to be addressed in making such a deduction. For instance, one can't simply go out to a galaxy and measure how much visible mass there is there. We can't even do that precisely for our own galaxy. Instead, we must rely on our knowledge of stellar evolution and galactic morphology, and deduce that a certain amount of starlight means a certain amount of visible mass. We must also assume that what we know of gravity in our own little corner of the world also applies to other galaxies.

In short, there are many things we can't know for sure, which we have to assume are true if we are to deduce the existence of dark matter. Relaxing any of those significantly would be sufficient to obviate dark matter, and yet, astronomers are reluctant to do so. Our notions of gravity and stellar evolution are so experimentally successful that it is thought that dark matter would disturb our ideas of cosmology less than the absence of dark matter would disturb our ideas of gravity and stellar evolution.

In the midst of this surefire reasoning, however, came the paper by Cooperstock and Tieu. You see, a gravity is a fairly complex thing. It is not a simple matter to calculate how fast the outer portions rotate based on a mass distribution in the galaxy, if you are to use every last detail of our model of gravity. It is beyond the ability of people to do with pencil on paper; it is a challenge even for computer simulations.

So certain approximations are made. We assume an idealized distribution for the visible galactic mass and the proposed dark matter. We neglect the interaction with other galaxies. And we use the simpler Newtonian approximation to gravity, rather than the more exacting Einsteinian general relativity formulation.

It was this last approximation that Cooperstock and Tieu showed might be fatal. It was assumed that since stars are mostly low-mass (from a general relativity perspective) point objects separated by huge distances, the Newtonian formulation would yield an accurate simulation. The calculations of Cooperstock and Tieu showed that this is, at least in some basic cases, not so. The fact that there are so many stars means that they constitute a sort of galactic "dust," and deviations between Newtonian gravity and general relativity build up significantly as one makes one's way from galactic center to galactic boondocks. Enough, it seems, to make dark matter unnecessary for this particular problem.

So far, the results are preliminary. Some physicists believe that the model Cooperstock and Tieu used for their galactic distribution of matter is too simplistic and unrealistic. Others have pointed out that dark matter is useful to explain other phenomena (such as the

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cohesiveness of galactic clusters) that cannot be explained away by their approach. But the notion that the difference between Newtonian gravity and general relativity might be responsible for even one spectre of dark matter is a provocative one. Time will tell if the explanation actually represents nature as it is.

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Brian Tung <brian@xxxxxxx>

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