Four reasons why the quantum vacuum may explain dark matter

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(PhysOrg.com) -- Earlier this year, PhysOrg reported on a new idea that suggested that gravitational charges in the quantum vacuum could provide an alternative to dark matter. The idea rests on the hypothesis that particles and antiparticles have gravitational charges of opposite sign. As a consequence, virtual particle-antiparticle pairs in the quantum vacuum form gravitational dipoles (having both a positive and negative gravitational charge) that can interact with baryonic matter to produce phenomena usually attributed to dark matter. Although CERN physicist Dragan Slavkov Hajdukovic, who proposed the idea, mathematically demonstrated that these gravitational dipoles could explain the observed rotational curves of galaxies without dark matter in his initial study, he noted that much more work needed to be done.

Now with a new analysis, Hajdukovic has taken another step toward demonstrating the credibility of this idea by showing that the gravitational polarization of the quantum vacuum can explain four cosmological observations, only some of which can be explained by dark matter models or theories of modified gravity. In his paper, which was recently published in *Astrophysics and Space Science*, he starts off with some background information.

Background

“Contemporary physics has two cornerstones: General Relativity and the Standard Model of Particle Physics,” he writes. “General Relativity is

our best theory of gravitation. The Standard Model is a collection of Quantum Field Theories; according to the Standard Model, everything in the Universe is made from six quarks and six leptons (and their antiparticles) which interact through exchange of gauge bosons (photon for electromagnetic interactions, W and Z for weak interactions and eight gluons for strong interactions)."

He goes on to explain that these two theories do not fit with certain observations, one of which is that the gravitational field in the universe appears much stronger than it should be according to General Relativity and the existing amount of baryonic matter, which is composed of Standard Model particles. While thousands of scientists around the world are trying to figure out whether one of the two cornerstone theories needs modification, Hajdukovic's idea does not require modifying gravity or invoking new matter. He summarizes it this way:

"In simple words, according to the Quantum Field Theory, all baryonic matter in the Universe is immersed in the quantum vacuum; popularly speaking, a 'sea' of short-living virtual particle-antiparticle pairs (like electron-positron pairs with the lifetime of about 10^{-22} seconds, or neutrino-antineutrino pairs with a lifetime of about 10^{-15} seconds, which is a record lifetime in the quantum vacuum). It is difficult to believe that the quantum vacuum does not interact gravitationally with the baryonic matter immersed in it. In spite of it, the quantum vacuum is ignored in astrophysics and cosmology; not because we are not aware of its importance but because no one has any idea what the gravitational properties of the quantum vacuum are. In absence of any knowledge, as a starting point, we have conjectured that particles and antiparticles have the gravitational charge of opposite sign. An immediate consequence is the existence of the gravitational dipoles; a virtual pair is a gravitational dipole (in the same way as a virtual electron-positron pair is an electric dipole), that allows the gravitational polarization of the quantum vacuum. The initial study has revealed the surprising possibility that the

gravitational polarization of the quantum vacuum can produce phenomena usually attributed to dark matter."

He said that the idea is not a full theory yet, and acknowledges that it conflicts with many of our basic human assumptions.

"I would say a theory in the early stage," he told *PhysOrg.com*. "Thousands of scientists work on the development of the cold dark matter theory and the theories of modified gravity; I am working alone in this third direction. The involvement of the other scientists in the research is crucial but still uncertain. On one side I have obtained a few results in striking agreement with the measurements, but on the other side a huge majority of physicists is 'allergic' to the idea of the gravitational repulsion between matter and antimatter; the most common experience of all humans is that everything falls down, and it is not easy to swallow the idea that antimatter may 'fall up.'"

Four phenomena

In this study, Hajdukovic focuses on four other phenomena, all of which have been established by observations of galaxies. Neither the cold dark matter model (CDM) nor Modified Newtonian Dynamics (MOND) - a theory of modified gravity - can explain all these phenomena, with CDM running into problems at small scales and MOND facing problems at large scales.

First, researchers (Donato, et al.) have observed that the dark matter haloes (or a strong gravitational field) that surround galaxies have a surface density that is nearly constant and independent of galaxy luminosity, mass, size, form, etc. Although the discovery of this universal property of galaxies is a surprise, Hajdukovic's theory predicts a surface density that is in very good agreement with the measured density value of 140 solar masses per square parsec. The universality of

the dark matter surface density of dark matter haloes can be explained by MOND, but not by CDM.

Second, the first direct measurements of dark matter distribution in two nearby dwarf galaxies, Fornax and Sculptor, were recently taken by Matt Walker and Jorge Peñarrubia. Surprisingly, the measurements revealed that (what appears to be) dark matter is evenly distributed within the central few hundred parsecs of each galaxy. Although even distribution is compatible with MOND, it contradicts predictions by CDM in which dark matter is located in a cusped halo.

“In the case of a dwarf spheroidal galaxy, the measurements show that there is a cored dark matter halo in the central part of the galaxy, while the cold dark matter model predicts a mass-density profile that diverges toward the center, forming a so-called ‘cusp,” Hajdukovic explained. “So CDM is in conflict with observations: there is a cored, not a cusped halo. In the framework of the gravitational polarization of the quantum vacuum, the cusped halo is impossible, and it is a good sign for my theory.”

Third, both CDM and MOND predict the existence of a hypothetical dark matter disk to surround our Milky Way Galaxy, positioned on the same place as the visible galactic disk but thicker. When researchers (Moni Biden, et al.) looked for a dark matter disk, they did not find evidence for the dark disk. In contrast, Hajdukovic found that when the gravitational polarization of the quantum vacuum is taken into consideration, there should be no gravitational disk.

Fourth, when scientists observed two galaxy clusters (e.g., the bullet cluster) collide, the galaxies within the clusters passed by each other without interacting due to the large distances between galaxies. However, the plasma clouds - which are made of baryonic matter - between the galaxies did interact, so much so that they slowed each other down.

Currently, the plasma clouds are located between the two galaxy clusters, while the clusters are moving past and away from each other. During this collision, dark matter and baryonic matter must have separated, since dark matter is collisionless. While this separation is compatible with CDM, it contradicts the predictions of MOND, in which (the illusion of) dark matter should be centered on baryonic matter. Hajdukovic explains that this separation should be compatible with the gravitational polarization of the quantum vacuum, although simulations are needed for confirmation.

Future

Although the theory is in the very early stages, some other scientists are hopeful that it can explain the universe better than current theories. Theoretical physicist Massimo Villata of the Observatory of Turin in Italy is investigating whether the gravitational repulsion between matter and antimatter can explain the universe's expansion without dark energy.

"I am confident that we are faced with an engaging explanation of the 'dark matter' phenomenon, especially now that gravitational repulsion between matter and antimatter has a theoretical basis and is no longer a mere, questionable assumption," he said.

Astrophysicist Michael Dopita of the Australian University in Canberra, who is also editor-in-chief of *Astrophysics and Space Science*, thinks that Hajdukovic's idea and others that have recently been proposed look promising.

"Unlike Milgrom's Modified Newtonian Dynamics (MOND), the distribution of vacuum polarization will depend on the distribution of matter, so the apparent extra acceleration towards the center of mass will vary from one object to another, and as a function of position within the object," he said. "This is an idea which can be tested. All in all, we might

conclude that what is sorely needed is a true quantum gravitational theory with a quantum granulation of spacetime."

In the future, Hajdukovic plans to further investigate another intriguing consequence that arises from his equations. When he extended one equation from describing the radius of a galactic dark matter halo to the radius of the entire observable universe (about 14 billion parsecs), the equation predicted the current dark matter content of the entire universe to be about 1.7 x 1023 solar masses, which is consistent with accepted estimates. However, Hajdukovic's equation has one important difference from the accepted ratio of baryonic to dark matter, which is currently estimated at about 1:5.

"The contemporary cosmology is based on the assumption that the ratio of baryonic to dark matter is a constant, not changing with time," he said. "If my theory is correct, this ratio decreases with the expansion of the universe. The solution of the cosmological equations must be different with a fixed and a variable ratio. It will be the subject of one of my future publications."

More information: Dragan Slavkov Hajdukovic. "Quantum vacuum and dark matter." *Astrophysics and Space Science*. DOI: 10.1007/s10509-011-0938-9