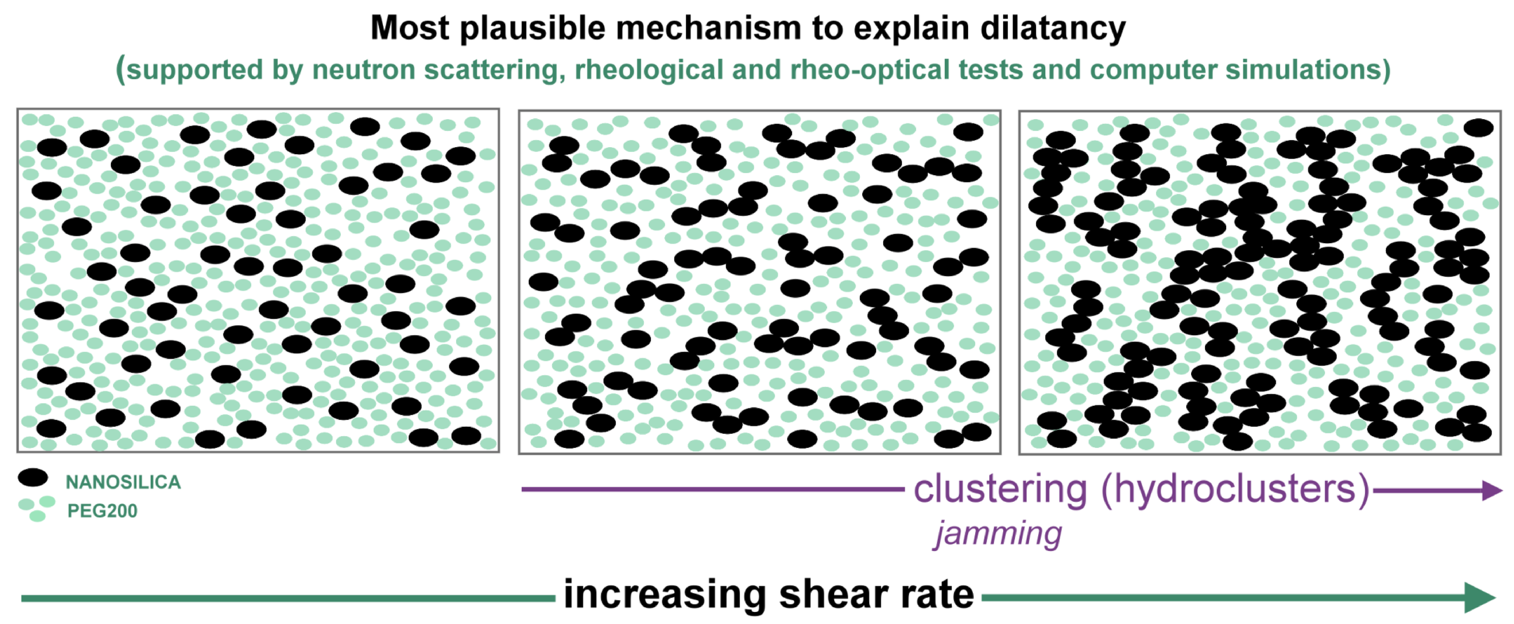
UCLA Dark Matter 2023 — Detection of dark matter-baryon matter non-gravitational interaction - Marco Fedi, *Ministero dell'Istruzione e del Merito, Italy* - contact: marco.fedi@istruzione.it

Introduction

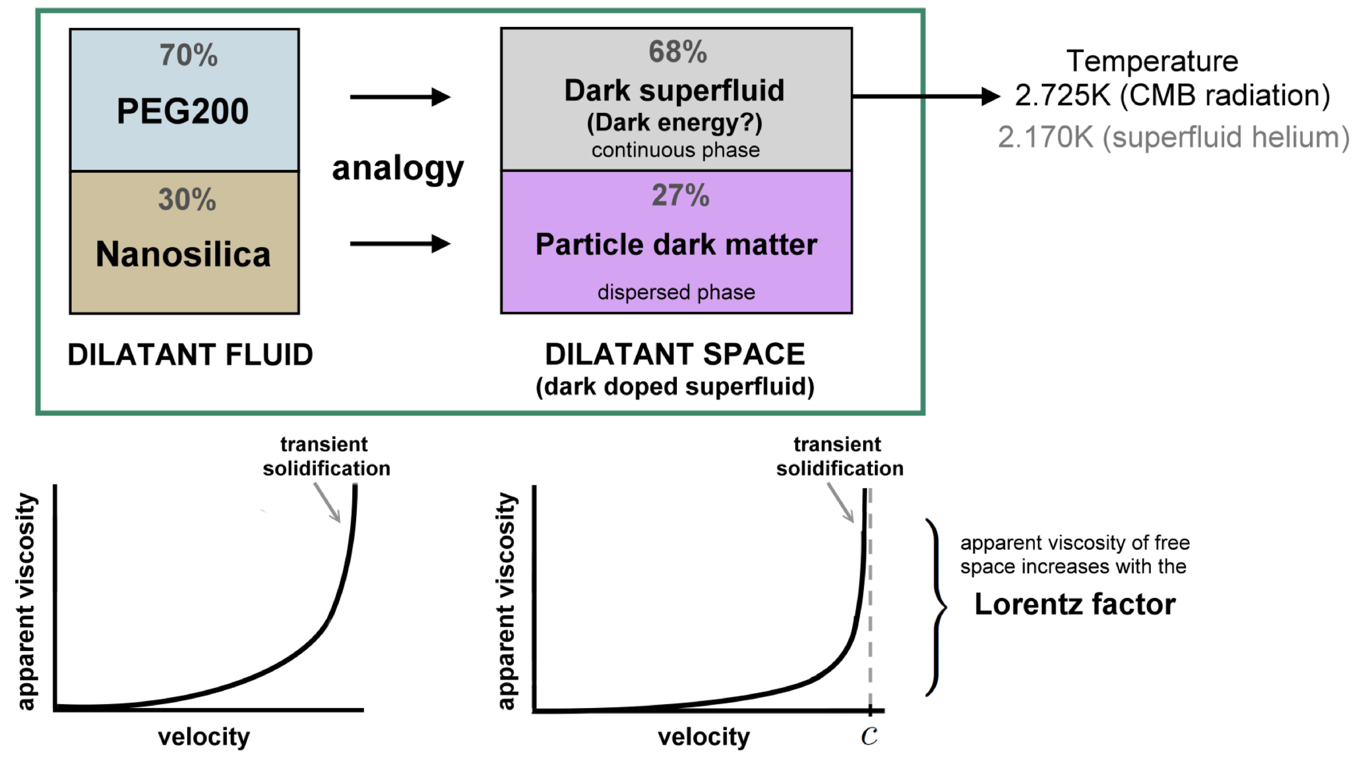
Does 95% of the still unknown energy-matter in the universe (the dark universe) possess hydrodynamic characteristics like gases or fluids? And can this dark fluid directly interact with large baryon-matter bodies that travel through it? By considering space as a dark non-Newtonian, shear-thickening fluid (a dark dilatant fluid that we can call *dilatant space*) we can use a modified Stokes' formula for viscous drag, in which the Lorentz factor is used as a dilatancy factor, and we see that it is possible to obtain evidence of a viscous behavior of space, similar to that of shear-thickening fluids, probably due to dark matter jamming (hydroclusters), which occurs under shear stress. In this poster, several situations concerning the possible viscous interaction between dark matter and macroscopic bodies that travel at high speed through free space are analyzed: anomalous acceleration of space probes, perihelion precession, stability of planetary orbits despite a dilatant space and the Breakthrough Starshot Project, along with other issues addressed in this theory, such as the flat-profile of the rotation curves of spiral galaxies and the formation of the large-scale structure of the universe from a rotating cosmic superfluid doped with particle dark matter.

Shear-thickening fluids (dilatant fluids)



Hypothesis

Space is a dark superfluid doped with particle dark matter that gives it dilatant behavior, expressed by the Lorentz factor (reinterpreted as the dilatancy factor of space).



Methods

Assuming that space behaves as a non-Newtonian dilatant fluid due to the presence of scattered particle dark matter that exerts a drag force against baryon bodies which travel through free space, the classical Stokes' law is used to measure the force acting on the interface between the dark fluid and a traveling object. However, the Lorentz factor, multiplied by a unitary constant expressed in $\mathrm{kg \cdot s^{-2}}$ is used instead of the viscosity coefficient of Newtonian fluids, to express the non-linear growth of the interfacial tension due to the progressive hardening of the dark fluid as shear rate and apparent viscosity increase.

$$F_d = -6\pi r \eta v$$ **Stokes' law** (Stokes' drag)

$$F_{\varnothing} = -6\pi r \eta_{\varnothing}$$ **Modified Stokes' equation** for bodies traveling in free space, treated as a dark dilatant fluid, due to **dark matter jamming**.

where $\eta_{\varnothing} = (\gamma - 1)\,\kappa$, with $\kappa = 1\mathrm{kg \cdot s^{-2}}$,

is the **drag factor of free space**, in which we see the Lorentz factor, in the form $\gamma - 1$, multiplied by a unit constant expressing interfacial tension. The value of the factor increases with the speed of the moving body.

$$F_{\varnothing} = -6\pi r \left(\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - 1 \right) \kappa$$

Formula for viscous drag in free space
(Modified Stokes' equation)

Results: detection of viscous interaction with particle dark matter. Evidence and predictions.

Direct solution to the Pioneer anomaly

Unlike the solution currently accepted by NASA - which has a large margin of error and is based on thermal simulations, run with partially uncertain data - an exact and direct solution to the Pioneer anomaly is calculated, by inserting into the modified Stokes equation only three simple parameters of the Pioneer 10 spacecraft, i.e. the antenna radius, the mass of the probe net of the burnt hydrazine and the maximum speed at the flyby of Jupiter.
A direct and precise solution is obtained, suggesting the interaction of the probe with a dark medium having shear-thickening characteristics.

Let's use the modified Stokes' equation in Newton's second law:

$$\vec{a}_P = \frac{\vec{F}_{\varnothing}}{m_P} = -\frac{6\pi r_P \eta_{\varnothing}}{m_P} = -\frac{6\pi r_P \left(\frac{1}{\sqrt{1-\left(\frac{v_{max}}{c}\right)^2}} - 1 \right)\kappa}{m_P} =$$

$$= -\frac{6\pi \cdot 1.371\,\mathrm{m} \cdot \left(\left(\sqrt{1-\left(\frac{36737\,\mathrm{m \cdot s^{-1}}}{299792458\,\mathrm{m \cdot s^{-1}}}\right)^2} \right)^{-1} - 1 \right) \cdot 1\mathrm{kg \cdot s^{-2}}}{222\,\mathrm{kg}} =$$

radius of the antenna; maximum speed at flyby of Jupiter; mass of the probe (258kg) minus burnt hydrazine (36kg)

$$= -8.74 \times 10^{-10}\mathrm{m \cdot s^{-2}}$$ ✓

Pioneer acceleration

Perihelion precession

Most evident for the planet Mercury, a fraction of the precession of perihelia is due to general relativity and is calculated by resorting to a specific Einstein's formula. However, by using the modified Stokes' equation, which has already been successful for the Pioneer anomaly, it can be shown that this part of perihelium precession is due to the viscous drag of free space, probably justified by the presence of particle dark matter scattered throughout space. Indeed, the following relation can be successfully tested:

$$\Delta\phi = \left\| \frac{2F_{\varnothing}}{r\kappa} \right\| = 12\pi\,(\gamma - 1)$$

as the orbit is elliptic let us use in γ the mean orbital velocity calculated by resorting to the harmonic mean orbital radius, which corresponds to the semi-latus rectum $\ell = a\,(1-e^2)$

that is $\bar{v} = \sqrt{\frac{\mu}{a\,(1-e^2)}}$ (where $\mu = GM$) and we have $\Delta\phi = 12\pi \left(\frac{1}{\sqrt{1-\frac{\mu}{a(1-e^2)c^2}}} - 1 \right)$

By applying the formula to Mercury, it yields the correct relativistic precession as in general relativity, without involving curved spacetime:

$$\Delta\phi = 12\pi \left(\frac{1}{\sqrt{1-\frac{1.3272\times10^{20}\mathrm{m^3 \cdot s^{-2}}}{5.7909\times10^{10}\mathrm{m}\cdot(1-0.2056^2)(299792458\mathrm{m \cdot s^{-1}})^2}}} - 1 \right) = 5.0186\times10^{-7}\mathrm{rad/rev.} = 42.98''/\mathrm{century}$$ ✓

The mathematical connection with Einstein formula emerges by applying Taylor $2\,(\gamma-1) \approx (v/c)^2$, so we have $12\pi\,(\gamma-1) \approx 6\pi\,(v/c)^2$

and replacing, as above, with the mean orbital velocity containing the harmonic mean radius, one directly obtains the known formula

$$\Delta\phi = 6\pi \frac{GM}{a\,(1-e^2)\,c^2} = \frac{24\pi^3 a^2}{T^2\,(1-e^2)\,c^2}$$ which for Mercury yields the precession value $42.98''/\mathrm{century}$

Stability of planetary orbits

By putting the modified Stokes' equation for space's viscous drag into the second law of dynamics, to measure the negative acceleration of bodies that travel through free space, we can immediately see that space probes (such as the Pioneers) due to their small mass can be slowed down, albeit minimally, while a planet, which has a much greater mass, undergoes negligible deceleration over billions of years. Planetary orbits are therefore stable even in a shear-thickening space. A more noticeable effect of the direct interaction between scattered particle dark matter and celestial bodies is rather a contribution to the precession of perihelia, as analyzed in this poster.

For the Earth (⊕) the orbital deceleration due to direct interaction with particle dark matter is only

$$a_{\oplus} = \frac{F_{\varnothing}}{m_{\oplus}} = -\frac{6\pi(6371000\,\mathrm{m}) \left(\left(\sqrt{1-\left(\frac{29780\,\mathrm{m/s}}{299792458\,\mathrm{m/s}}\right)^2} \right)^{-1} - 1 \right) \cdot 1\,\mathrm{kg \cdot s^{-2}}}{5.97\times10^{24}\,\mathrm{kg}} =$$

$$= -9.92 \times 10^{-26}\mathrm{m \cdot s^{-2}}$$

that is, less than $-3.13\times10^{-9}\,\mathrm{m/s}$ **every billion years.**

Even the rotation of pulsars, due their huge mass, would be insignificantly slowed down by viscous drag. For the Crab pulsar, the estimated deceleration is only $-1.35\times10^{-30}\mathrm{m \cdot s^{-2}}$

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FEDI, M.: Physical vacuum as a dilatant fluid yields exact solutions to Pioneer anomaly and Mercury's perihelion precession, Can. J. Phys. (2019), 97(4): 417-420, doi:10.1139/cjp-2018-0744

FEDI, M.: Relativistic mass due to a dilatant vacuum leads to quantum re-formulation of the relativistic kinetic energy, Can. J. Phys. (2019)

J.Kliever on CSP Blog: https://blog.cdnsciencepub.com/describing-space-as-oobleck-solves-decades-old-physics-mystery/

Prediction for the Breakthrough Starshot project

Considering **a = F / m** we also see that, for tiny masses, the deceleration caused by the interaction with dark matter becomes enormous and a mission based on the lightness of space probes, such as the Breakthrough Starshot, is doomed to fail due to the deceleration suffered even at 15% of the speed of light (see calculation below). According to the modified Stokes' equation, a large lightsail of about 16m² would make the situation even worse by increasing the deceleration. By interpreting the relativistic kinetic energy as the greater energy necessary to counteract space dilatancy caused by particle dark matter jamming, it is possible to note that an accelerated electron in the LEP at CERN loses 10^{13} times more energy (as synchrotron radiation) than a much heavier proton, when they travel at almost the same relativistic speed.

Breakthrough Starshot: Mission failure due to ultralight mass.

Example with speed = 0.15c:

$$a_{(StarChip)} = \frac{F_{\varnothing}}{m} = -\frac{6\pi r \left(\frac{1}{\sqrt{1-\left(\frac{v_{max}}{c}\right)^2}} - 1 \right)\kappa}{m} =$$

$$= -\frac{6\pi \cdot 2.256\,\mathrm{m} \cdot \left(\left(\sqrt{1-\left(\frac{44968868\,\mathrm{m \cdot s^{-1}}}{299792458\,\mathrm{m \cdot s^{-1}}}\right)^2} \right)^{-1} - 1 \right) \cdot 1\,\mathrm{kg \cdot s^{-2}}}{0.002\,\mathrm{kg}} =$$

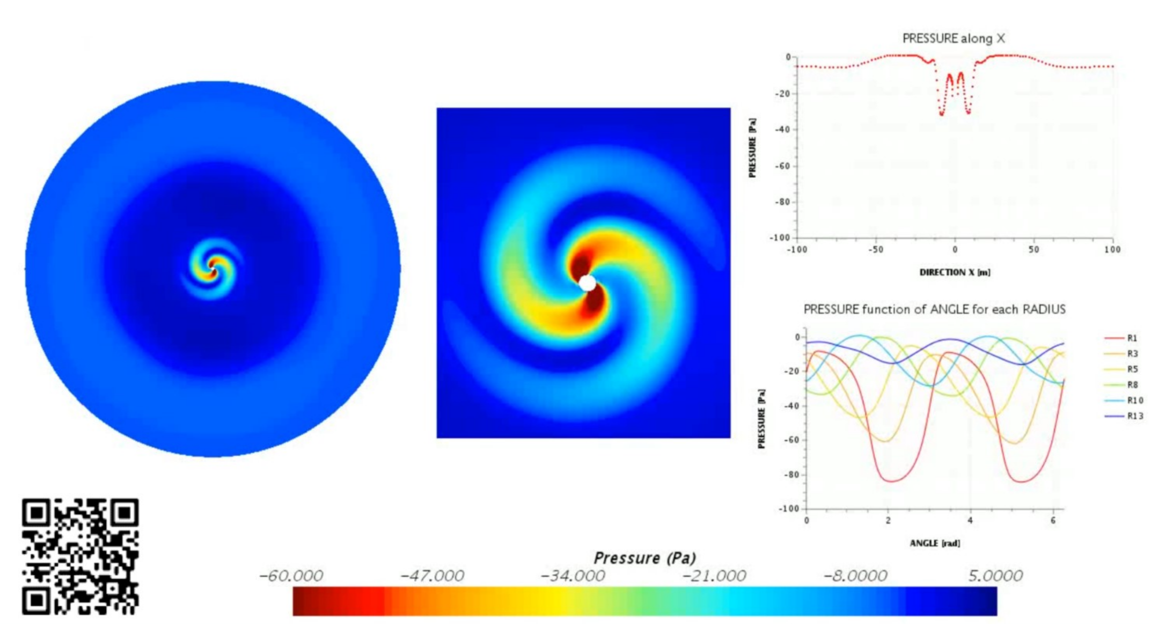
$$= -243.31\ \mathrm{m \cdot s^{-2}}.$$

The kinetic energy of the microprobe should be therefore increased by 59 J/s (59 W) for as long as it is necessary to keep it at 0.15c

Flat rotation curves

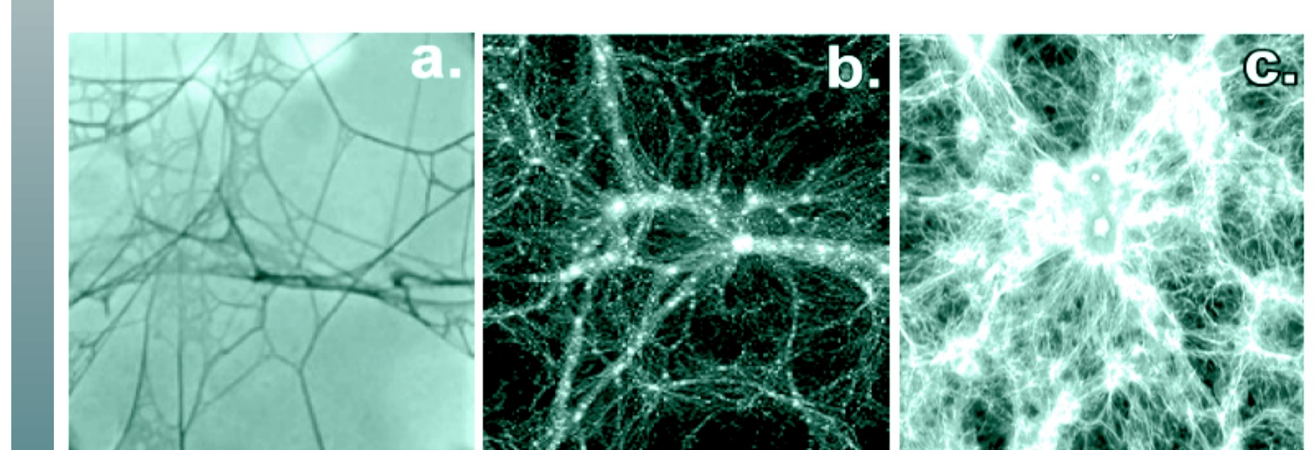
As a further clue, CFD simulations show that if spiral galaxies rotated in a dilatant space, due to the presence of scattered particle dark matter, a flat profile of the rotation velocity curve would emerge. The spiral galaxy was generated considering the gravitational attraction of two black holes in the core (white circle in the figure) which creates distorted pressure corridors in the dark fluid and correctly shapes the galaxy.

(Scan the QR code below for a video simulation, for which I thank Engr. M.L. Artigiani. Pressure scale is arbitrary).



Large-scale structure of the universe

As superfluid helium-4 doped with metallic atoms rotates, a filament structure emerges which is analogous to the dark matter filaments of the large-scale structure of the universe.
This seems to be further proof that space is a dark superfluid doped with particle dark matter.
If this is true, the cosmic filaments rotate, as they are nothing but filamentous eddies on a cosmic scale. This analogy shows us the universe as a spinning superfluid bubble.



a) metal atoms trapped in filamentous vortices when doped superfluid helium-4 rotates.
MOROSHKIN, P., LEBEDEV, V., GROBETY, B., et al., Europhysics letters, Vol. 90, N.3 (2010)
b) large-scale structure of the universe (cosmic voids and filaments)
c) baryon matter (gas) structured on the dark matter filaments.
ECKERT, D., JAUZAC, M., SHAN, H. et al.: Nature 528, 105–107 (2015)

Conclusions

The **new and precise solutions** shown for the **Pioneer anomaly** and the **relativistic perihelion precession**, along with the positive results obtained via CFD simulations as regards the **flat profile of the rotation velocity curve** of spiral galaxies and, finally, the formation in doped superfluids of a structure that closely resembles the **large-scale structure of the universe**, are initial but significant evidence to start considering **space as a non-Newtonian dilatant dark fluid** (a dark superfluid doped with particle dark matter that makes it dilatant) which **directly interacts with baryon matter via viscous drag**, a phenomenon that is probably caused by **hydroclusters formation (jamming) in a sea of scattered particle dark matter**. The equations also show that in agreement with the second principle of dynamics, such a viscous drag has a **greater effect on lighter bodies**, predicting the **failure of the Starshot Breakthrough mission** and indicating, on the contrary, a **totally negligible orbital decay** of celestial bodies, due to their very large mass. The most plausible explanation to this fluidlike behavior of free space seems to be the widespread presence in space of particle dark matter but this preliminary study did not deal with understanding **which type of dark matter candidate is the most suitable to justify this unexpected classical dynamic interaction (drag force) between dark and ordinary matter**. Further studies and considerations are needed. What we can however deduce from premises and results is that in this theory there is place for **two different dark particles**, one for the **superfluid** continuous phase and another one for the **scattered particles that cause dilatancy**, which are probably **fermionic** dark matter. To make this theoretical framework stronger, the solution obtained for the first classical test of general relativity and the fact that the viscous force exerted by the dark, dilatant cosmic fluid obeys the Lorentz factor (reinterpretable then as a factor of space dilatancy) build some first **connections with Einstein's relativity** and its possible quantum reformulation, which would therefore directly depend on the presence and on the specific hydrodynamic characteristics of particle dark matter. We can look at relativity in another light: due to this viscous drag, moving clocks slow down, length gets shorter in the direction of motion, and accelerating a body requires more and more energy. This time the null result of the ether drift tests is not an obstacle, because if the solution to those tests is **special relativity**, this theory **can incorporate it by demonstrating a different physical meaning of the Lorentz factor**, which denotes the behavior of dilatant space, whose reference can be for example the CMB, i.e. its temperature, taking into account the Unruh effect observed in other reference frames. Among further tests that could be carried out, **a specific monitored space probe** would be absolutely useful to measure accurately and directly the viscous drag predicted by the new equation.