Interchangeability of Kinematic and Gravitational Time Dilation

Nick Markov, PhD

Bulgarian Academy of Sciences

BSHC, 1 William Froude St, Varna 9003, Bulgaria

Abstract

This manuscript hypothesizes that space-time curvature is created by the finite speed of interactions and motions within a given mass. It also aims to show that the gravitational and kinematic time dilation can be interchangeable mathematically and observationally.

To support the claims, several mathematical and observational correlations are presented at the planetary, galactic, intergalactic and cosmologic scales, e.g. the similarity of the escape velocity and the speed of the seismic P-wave passing through the center of the Earth, galactic rotational curves following the total time dilation (gravitational & rotational), the equivalency of the Milky Way speed towards the Great Attractor and the total time dilation at our location within the galaxy, the mathematical equivalency of the Hubble formula and the gravitational time dilation at the cosmological scale. The implication is that the kinematic and gravitational time dilation resemble each other to the extent that kinematic time dilation may be confused with gravitational dilation (e.g. dark matter) while gravitational time dilation may be confused with kinematic dilation (e.g. Great Attractor, dark energy, Big Bang).

New formulas are derived to distinguish GR from the Newtonian gravity. The logic here is similar to the way the speed of sound travels faster in heavier materials not because they are heavier, but because of how the interactions propagate through the material. These formulas

can generate simple predictions to validate further the hypothesis based on observations from the Moon, Mars or in a laboratory.

Another proposed validation of the hypothesis may bring a really practical benefit. It may be possible to build an Alcubierre drive from an ammonia molecule. The frequent and spontaneous tunneling of the heavy nitrogen atom may be creating significant asymmetric space-time curvature that also allows electrical steering because the molecule is polar.

Introduction

Major discrepancies exist between theory and observations, which are being explained with dark matter and dark energy. Another invisible entity known as the Great Attractor is needed to explain the observations within our Laniakea Supercluster. There are also unexplained variations in the Hubble constant. Can these problems be linked to something more fundamental, such as the fact that we don't understand why mass deforms space-time? In other words, the listed discrepancies may be due to predictions based on an incomplete theory. The challenges seem to come from the changing perspective of being an external relative to the gravitational mass observer in the Solar system to an observer witnessing gravity from deep inside the mass at the galactic and cosmological scale. And, as we know, time dilation is relative and depends on the perspective, so let's try to perceive mass from a different "angle".

The shape and volume of any mass depends on the motions and interactions of its constituents. A planet would not keep its shape and volume without the numerous electromagnetic interactions and motions within the large gravitational mass. A galaxy would not be able to keep its shape and volume unless stars, gas and dust rotate around the galactic center.

To make it more intuitive, instead of shape and volume, we could think about the allocated space the mass takes. The next step would be to show that every mass lags relativistically to take its classically allocated space due to the finite speed of electromagnetic interactions. Then, the question would be, whether this relativistic lag equals the gravitational time dilation.

Also, it would be more intuitive to replace the abstract time dilation with the ease of movement. Instead of thinking of slower time at the planet surface, we could reason that it is easier to move in that region. Consider the following analogy: It's hard to move near a water cannon but it is easier to move far from the source, where the water jet slows down. Similarly, the relativistic lag of the mass to maintain its allocated space would produce the ease of motion (time dilation) similar to being farther from the water cannon.

How does the above logic manifest at different scales?

The planetary scale and the P-wave dilation

This section intends to show that a planet lags relativistiacally to keep its allocated space due to the finite speed of the electromagnetic interactions within the planet. To prove it, the average speed of the seismic pressure wave is compared to the planet escape velocity. A link between the kinematic time dilation of the P-wave and the gravitational time dilation is hypothesized.

In the everyday life we comprehend our planet as being rigid. However, continents drift, the core rotates, atoms vibrate, the electrons have angular momentum, etc. Numerous interactions maintain the planet shape and volume while it is moving around the Sun. We normally think that the planet moves under its own inertia including all the particles it is composed of. But the particles are not free to move, and they certainly do not move along straight trajectories. The particles vibrate, rotate and interact. For the center of the planet to move, the outer layers need to move also because they are interconnected with chains of electromagnetic interactions. On a smaller scale, when a soccer player kicks a ball, it would take time for the opposite side of the ball to move because the pressure wave has to propagate through the ball. The electromagnetic interactions have finite speed. A relativistic lag may be expected to build up significantly over greater distances. The question is how can the lag be calculated for our planet? Following the football analogy, we could consider the speed of a pressure wave, since the speed of the seismic P-wave has been measured. It passes through the center of the Earth in 16-20 minutes. Knowing the diameter, the average speed is 11.8 km/s (= 12,742 km/18/60), which is fairly close to the escape velocity of 11.2 km/s. Another example can be the speed of the sound waves in the Sun. It is estimated to be hundreds kilometers per second along 90% of the Sun radius[1], while Sun's escape velocity is 615 km/s.

On the other hand, the gravitational time dilation is equivalent to a kinematic time dilation caused by planet's escape velocity v_e according to the Schwarzschild metric.

$$t_0 = t_f \sqrt{1 - \frac{v_e^2}{c^2}} \qquad (1)$$

Where the proper t_0 is time between two events for an observer close to a massive sphere and t_f is the coordinate time between the events for an observer at an arbitrarily large distance from the massive object.

We also have a formula for the P-wave speed, which is

$$v_p = \sqrt{\frac{B}{\rho}} \qquad (2)$$

where B is the elastic P-wave modulus and ρ is density[2]. B is defined as the ratio of axial stress to axial strain in a uniaxial strain state. This occurs when expansion in the transverse direction is prevented by the inertia of neighboring material, such as in an earthquake, or underwater seismic blast. If we compare v_p to the escape velocity

$$v_e = \sqrt{\frac{2GM}{R}} \tag{3}$$

then acceleration g at the planet surface would not be proportional to the plane is the gravitational constant t mass, but would partially depend on the average elasticity modulus B:

$$\text{g} = \left(\frac{BR}{2\rho}\right)\frac{1}{r^2} \tag{4}$$

Here G is the gravitational constant, M and R are the mass and the radius of the Earth, respectively. The logic here is similar to the way the speed of sound travels faster in heavier materials, not because they are heavier, but because of how the interactions propagate through the material.

Formula (4) obviously raises questions about the equivalency of the gravitational and inertial mass. The equivalency should still be in place in cases where the weight force is involved. But the weight force is experienced only during a direct contact between two bodies that produces a reaction force based on the acceleration from formula (4). Therefore, this hypothesis implies that space-time curvature generates a classical Newtonian force only during direct contact.

Formula (4) also implies that elementary particles do not generate gravity due to lack of internal interactions that would produce time dilation. Therefore to apply the GR mathematical apparatus at the particle level is as meaningful as applying Pascal’s pressure formula to a single molecule. Space-time curvature is continuous because the cumulative time dilation due to an enormous amount of quantum interactions smoothens out the quantization at the macro level.

Formula (4) can be used to validate the hypothesis by measuring the average P-wave speed passing through the center of the Moon or Mars or in a laboratory. Then v_p can be compared to v_e. And then analyze the implications for the mass and density of gas giants, neutron stars, etc.

The galactic scale and the rotational dilation

This section intends to show that a galaxy partially lags to keep its allocated space due to the relativistic time dilation of the galactic rotation. To prove it, the gravitational time dilation is compared to the kinematic time dilation along the galactic radius. A link between the total time dilation (kinematic + gravitational) and the rotational curves is hypothesized. Another example of how important the total time dilation is the fact that it corresponds to a 600 km/s velocity at our location within the Milky Way. The velocity vector coincides with the velocity towards the Great Attractor. Thus, both hypothetical entities (Dark Matter and Great Attractor) may be not needed when the rotational time dilation contributes to the galactic space-time curvature.

According to the theory of relativity, there are relativistic delays due to gravitational mass and relativistic motion[3]. Let's follow the perspective of an observer loacted outside the gravity well, while looking towards the rotating galaxy (the observer may be located at the center of the galaxy, as well, providing it is not occupied by a stellar object). The presented in Figure 1 gravitational time dilation ratio *GTD(r)* is computed based on the Schwarzschild metric:

$$\boldsymbol{GTD\ (r) = \sqrt{1 - \frac{2\,GM(r)}{rc^2}}}, \tag{5}$$

where *r* is the distance to the galactic center, *G* is the gravitational constant, *c* is the speed of light, and *M(r)* is the mass (in solar mass units) residing in a sphere with radius *r*.

$$\boldsymbol{M\,(r) = \; 2\pi \int_0^r R\, S_b(R) dR} \tag{6}$$

Note that *M* doesn't necessarily represent inertial mass based on the logic in the previous section.

where $S_b(R)$ is the surface brightness in units of the solar luminosity normalized by surface area, and r-band corrected for inclination and dust extinction[4,5].

The velocity time dilation ratio *VTD(r)* is computed based on the special relativity formula:

$$\boldsymbol{VTD\,(r) = \sqrt{1 - \frac{v^2(r)}{c^2}}} \tag{7}$$

where *v(r)* is the rotational velocity measured at a distance r from the galactic center[4,5]. The data used to compute time dilation was summarized in an atlas[6] and available for download at the University of Tokyo website.

The total (combined) time dilation *TTD(r)* is computed similar to the way used for the Global Positioning System (GPS) corrections[7]:

$$\boldsymbol{TTD\,(r) \; = \sqrt{1 - \frac{2\,GM(r)}{rc^2} - \frac{v^2(r)}{c^2}}} \tag{8}$$

Figure 1 compares the computed time dilation based on measured velocities and optical photometry in r-band[4,5.] The results show good agreement for mass derived from optical photometry in r-band, denoted as "C-sample"[8].

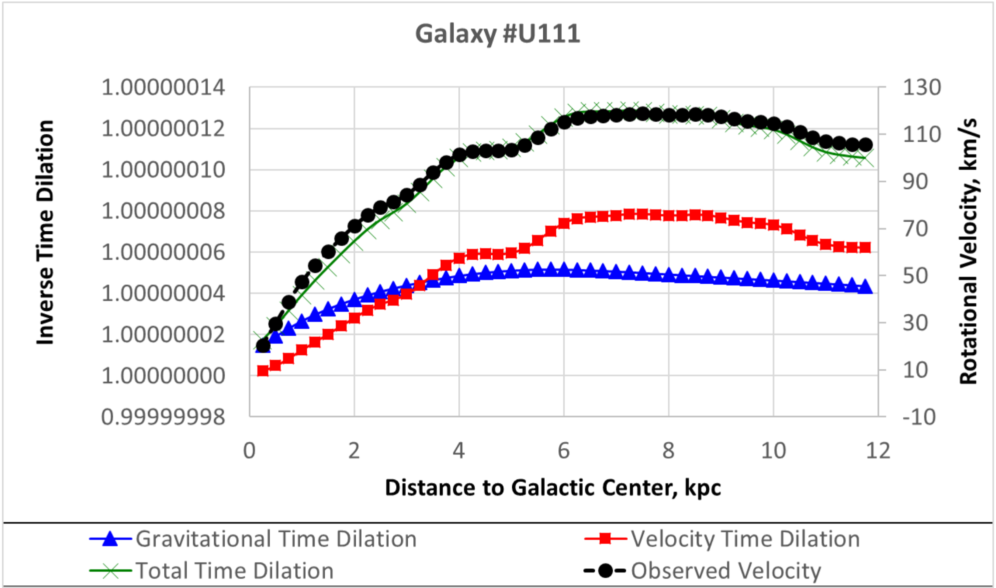

Figure 1: Correlation between combined time dilation and measured rotational velocities for # U111

Similar correlations for other galaxies are also available[9].

The intergalactic scale and the rotational dilation

The intent of this section is to show that the rotational time dilation may be responsible for an important portion of the space-time curvature in our cluster and in other galactic clusters.

The Great Attractor

The space-time curvature at the Solar System location within the Milky Way can be decomposed into gravitational time dilation component (equivalent to ~550 km/s escape velocity) and kinematic rotational velocity term of ~230 km/s; see Figure 2. The vector sum produces ~600 km/s, which is also the estimated velocity of the Milky Way towards the hypothetical Great Attractor. According to the proposed model, this is not a true velocity but a skewed perspective due to distorted curvature at our off-center location within the galaxy. This would also explain why the great attractor appears to be approximately in the galactic bulge direction. Our 600 km/s time dilation would also produce a bias in the red-shifts of the galaxies in the local group creating a false motion appearance.

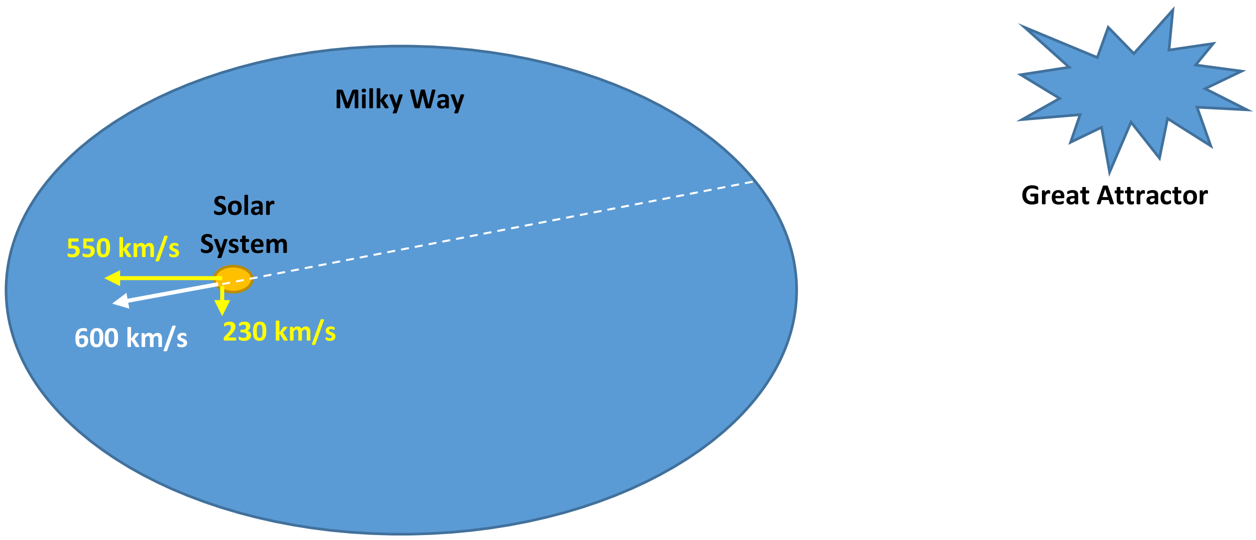

Figure 2: Great Attractor or total time dilation?

'Ensemble'-type cluster

Figure 3 shows how the total time dilation correlates with the rotational velocities in an 'ensemble'-type cluster, which was built from the combined data from 59 clusters[10]. As expected, the kinematic time dilation component dominates the gravitational dilation for the entire radial range.

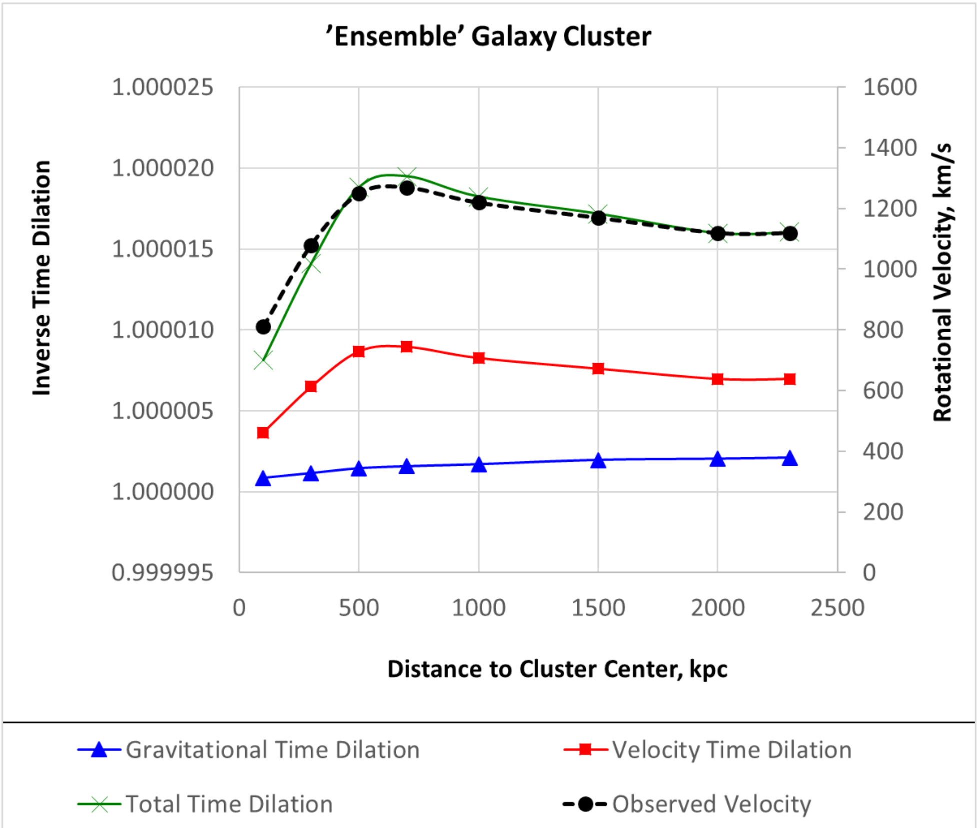

Figure 3: Correlation between combined time dilation (8) and measured rotational velocities in a galaxy cluster

The cosmologic scale and the gravitational redshift

This section intends to show that the cosmologic redshift is due to relativistic lag of the universal mass to keep its shape or its allocated space. In other words, the cosmologic redshift may represent gravitational redshift relative to our position in the universe. It means that the redshift is how the universal gravity is perceived when looking from the inside out, which is an unusual perspective, since we have used to witness the gravity as external observers to the mass concentrated in the Sun, Earth, etc. It would also mean that the relative distances between the galaxies are not increasing due to expansion, which may help with the latest early galactic formation challenges related to the JWST data.

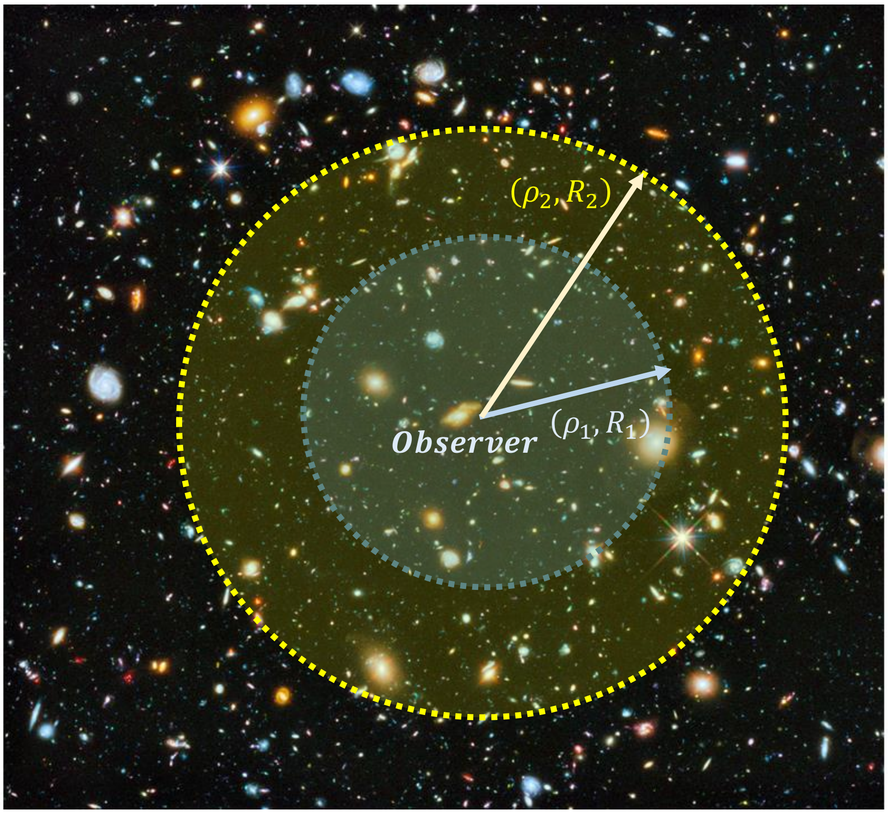

Figure 4: Dark energy or gravitational time dilation ?

The universal mass that surrounds us lags to take its allocated space due to the cumulative (from our perspective) time dilation of its constituents. Then, what is the total lag in this case? It is easy to show that the gravitational time dilation is equivalent to the Hubble velocities for flat space-time.

The gravitational time dilation can be estimated from the escape velocity based on formula (1). Formula (3) can be rewritten in terms of density:

$$v_e \sim \sqrt{\rho} R \tag{9}$$

Let's imagine an observer located at the center of a spherical volume (Figure 4) with constant density ρ. Based on formulas (1) and (9), the time dilation would be increasing with the distance from the center R.

We know that photons redshift when moving from a region with higher to a region with lower time dilation. The time dilation is relatively lower at our location than then at the periphery of any universal mega sphere surrounding us. Formula (9) also resembles Hubble's law, with the exception that the Hubble constant would be proportional to $\sqrt{\rho}$:

$$H_0 = \sqrt{8/3\pi G\rho}, \tag{10}$$

Formula (10) is also equivalent to a flat universal space time with an average universal density, but may explain the observed variations when applied using the local density of a smaller region. For example, 9% higher constant, would correspond to 18% higher density in the near universe relative to the average universal density. Again, ρ might not be the density associated with inertial mass according to the P-Wave Dilation hypothesis.

Formula (5) also corresponds to the following relation

$$a = \frac{H_0^2}{2} r \tag{11}$$

for the acceleration of the universal expansion. Correlations (10-11) may help to validate further the hypothesis.

Quantum propulsion method

This section intends to validate the hypothesis by proposing a practical quantum propulsion method (Q-Drive) based on the presented interchangeability between kinematic and gravitational time dilation. The ammonia molecule NH_3 is known to invert its shape (Figure 5) billion times a second due to the spontaneous quantum tunneling of the nitrogen. This phenomenon was used in the first atomic clocks and masers.

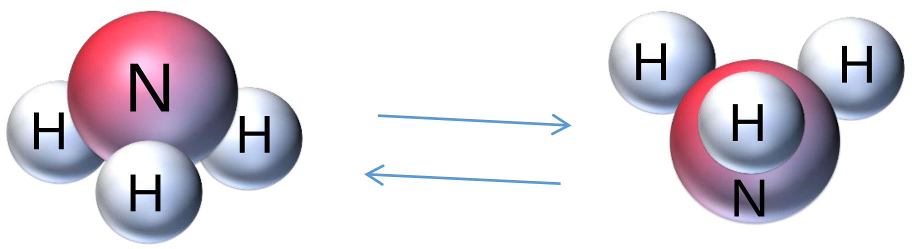

Figure 5: Nitrogen inversion

The heavy nitrogen changes its position with speeds near the speed of light. The resulting kinematic time dilation is asymmetric from hydrogen's perspective. The lagging shape change should create significant local space-time curvature according to the logic described in the sections above. The three hydrogen atoms must respond to the relativistic changes. The curvature asymmetry resembles the asymmetry required in the Alcubierre drive concept.

The ammonia molecules are polar and can be oriented with an external electric filed. The electric steering would be especially easy when the vibrational and rotational kinetic energy of the molecule is insignificant at the low temperatures of the outer space. The proposed experiment would be to monitor whether the ammonia molecules accelerate translationally when exposed to a high-voltage field. Then attempt to detect pressure bias and resultant propulsion forces. Experiments suggest that slow motion of a 1 kg container may be produced even at room temperature using the Q-Drive approach[11].

Note that a successfully developed Q-drive does not use chemical or nuclear reactions. Ammonia is not used as fuel but as a working fluid similar to the ammonia refrigerators, which makes the Q-drive environmentally safe. It would also work anywhere since the nitrogen inversion is always present in space and at room temperatures. But, the greatest benefit may be that the Q-Drive seems to be propellantless, which would be extremely useful for interstellar travel.

Conclusion

Is space-time curvature created by the finite speed of interactions and motions within a given mass? Can gravitational and kinematic time dilation be interchangeable mathematically and observationally? And can the presented multiple relations and numerical matches be incidental?

The new mathematical relations can easily produce predictions to generate additional observational matches to validate or discard the hypothesis.

A successful development of a quantum drive would represent the ultimate validation and significant practical benefits, which would be impossible based on the existing theory.

References

1. Christensen-Dalsgaard, J., 1996, The current state of solar modeling. Science 272, 1286–1292.
2. Mavko, G., Mukerji, T., Dvorkin, J., 2003, The Rock Physics Handbook. Cambridge University Press (paperback). ISBN 0-521-54344-4
3. Misner, C. W., Thorne, K. S., Wheeler, J. A., 2017, Gravitation, *Princeton University Press, ISBN-13: 978-0691177793*
4. Courteau, S., 1996, Deep r-Band Photometry for Northern Spiral Galaxies*ApJS*, *103, 363*
5. Courteau, S., 1997, Optical Rotation Curves and Linewidths for Tully-Fisher Applications *AJ*, *114*, *2402*
6. Sofue, Y., 2017, Rotation and mass in the Milky Way and spiral galaxies, Publ. Astron. Soc. Japan, vol. 69, issue 1
7. Ashby, N., 2003, Relativity in the Global Positioning System. Living Rev. Relativ. 6, 1. https://doi.org/10.12942/lrr-2003-1
8. Sofue, Y., 2014, Rotation and Mass in the Milky Way and Spiral Galaxies, Publ. Astron. Soc. Japan (2014) 00(0), 1–34, doi: 10.1093/pasj/xxx000
9. Markov N., 2019, Time Dilation and Space-Time Curvature, 10.5281/zenodo.3975444

10. Biviano, A., Salucci, P., 2006, The radial profiles of the different mass components in galaxy clusters, A&A. 452(1)

11. Markov, N. 2019, A Quantum Propulsion Method, IMAM2019, Propulsion, International Maritime Association of the Mediterranean, DOI: 10.5281/zenodo.3384416