Inhomogeneous distribution of mass-density in a static, rotating universe generates a transverse Doppler redshift that mimics cosmological redshift and expansion.

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Abstract

Based on Newton's gravitational law as applied to a uniform continuous mass we posit a non-homogeneous distribution of mass at cosmological scales that would give rise to a constant acceleration that largely agrees with MOND's a_0. When mass-density distributes as 1/R in a spherically symmetric universe, rotational velocities arise that increase as the square root of radial distance. These would generate a transverse Doppler redshift that scales linearly with distance at short ranges and would mimic cosmological redshift and expansion. In the more distant regions, relativistic-high rotational velocities result in a highly redshifted background radiation that might distort the estimation of distances based on Hubble's Law. These phenomena might provide an alternative explanation for the observed redshifts and expansion.

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Modified Newtonian Dymanics (MOND) is a Newtonian-derived hypothetical model of gravity proposed 40 years ago by Mordehai Milgrom to explain the multiple gravitational anomalies observed in galaxies and galaxy clusters [1-3]. They are summarized and conventionally explained through the existence Dark Matter, an elusive new form of matter that interacts only gravitationally and is not included in the Standard Model of Particle Physics. While no such particles have yet been found, the search goes on and MOND usually plays a secondary role in the list of candidate explanations for dark matter. One of the reasons is that a_0, the distinctive feature of MOND, does not correspond to any physical entity, and –it is argued- was postulated solely as a means to obtain a gravitational law that fits the observations. It is sometimes called a phenomenological explanation.

While a_0 agrees to within one order of magnitude with the acceleration calculated at the border regions of the observable universe from the simple Newtonian gravitational formula and is also found to relate to Hubble's constant and to the square root of the cosmological constant Λ, in both cases scaled by the speed of light *c*, no physical representation of such an acceleration has been devised, and most physicists would agree that it represents another constant of nature, whose role would be to relate fundamental gravitational phenomena in the low-acceleration regime, implying probably some modification of the laws of gravity.

Part I. The Newtonian ball model of gravity

A generally accepted assumption of all current astrophysical models is the Cosmological Principle, the idea that the universe at large scales is both homogeneous and isotropic. While it may still be isotropic and strong constraints have been set on the range of variation in matter density, the homogeneity condition has little theoretical supporting evidence. Based on original ideas of Isaac Newton, we shall argue that the universe can be modelled as a continuous distribution of mass that obeys simple dynamics embodied in the Universal Law of Gravitation. As Newton found in the late 1600s [4], when a continuous distribution of mass with constant density is allowed to evolve according to such law, an acceleration appears that is null at the center and increases outwards in linear proportion to radial distance until it reaches, for a distance equal to the radius of the ball, the exact same value as predicted by conventional Newtonian gravity.

$F_B = G\ M\ m\ r\ /\ R^3$

as opposed to a point-mass gravitational field:

$F_N = G\ M\ m\ /\ R^2$

where F_B (the force in the Newtonian ball model) and F_N (Newton's conventional point-mass gravitational force) are the force on a test particle with mass m placed at a distance r from the center of the R-ball, or at a distance R from the central point-mass M, respectively. The acceleration for the ball with mass M is then

$$Acc_B = G\ M\ r / R^3 \qquad (1)$$

and solving for G

$$G = Acc_B\ R^3 / M\ r \qquad (2)$$

We now define G' as $4\pi G$ and substitute it for G above. The resulting expression is mathematically equivalent, though it may facilitate the visualization of upcoming considerations.

$$G' = (Acc_B\ 4\pi R^3) / (M\ r) \qquad [G' := 4\pi G] \qquad (3)$$

Multiplying both parts of the right-hand quotient by a factor of three,

$$G' = 3\ Acc_B\ 4/3\ \pi\ R^3 / M\ r \qquad (4)$$

and since $4/3\ \pi\ R^3 / M$ is the inverse of the mass density for the spherical volume ρ,

$$G' = 3\ (Acc_B / r) \cdot (1/\rho)$$

$$G' = 3\ Acc_B / (r \cdot \rho) \qquad (5)$$

where ρ is now the average, not necessarily constant matter density at radial distance r. It is well known that the Newtonian model for gravity in solid spheres is valid not only for spheres with uniform density, but for any sphere in which density depends only on radial distance, i.e, for any spherically symmetric distribution of matter.

Looking at equation (5) we see that in such a ball model of the universe, if ρ is constant, then the quotient (Acc_B / r) must be constant, which agrees with the Newtonian view but does not help us understand the existence of a constant acceleration pervading the whole universe that at the same time agrees with the Newtonian acceleration at its border regions, as MOND postulates and available evidence suggests.

We therefore let ρ vary with radial distance and assume that it is the product in the denominator of equation (5), $r \cdot \rho$ that is constant. In other words, we let density decay inversely with radial distance. We immediately see that since both G' and the product ($r \cdot \rho$) are constant, so must be Acc_B, and this acceleration agrees with MOND's universal acceleration a_0 and with the calculated Newtonian acceleration at the border regions of the visible universe to whithin one order of magnitude, as can be easily checked. Indeed, feeding in the accepted values for the mass of the observable universe (10^{53} Kg), radial distance (10^{26} m) and G, it turns out that the acceleration in the at the external regions of a hypothetical spherical universe is about $3.4 \cdot 10^{-10}$ $m \cdot s^{-2}$, quite close to the reported value for a_0 ($1.2 \cdot 10^{-10}$). According to the Newtonian ball model and assuming $r \cdot \rho$ constant, this same aceleration would be present as a background curvature in the whole universe, explainining its local influence in all galaxies, not just as a constant of nature, but as a real acceleration that would determine the observed accelerations through some kind of averaging with the local, Newtonian-derived acceleration. In MOND, a geometrical averaging seems to be required [1-3].

The range of variation in mass density that would be expected depends on how far we are from the central regions, and can be approximately estimated.

From Eq (1), taking $Acc_B = a_0 = 1.2 \cdot 10^{-10}$ ms^{-2}; $R_U = 4.4 \cdot 10^{26}$ m; $G' = 8.38 \cdot 10^{-10}$ $m^3 \cdot Kg^{-1} \cdot s^{-2}$, we have

$r \cdot \rho = 0.4295$ $Kg \cdot m^{-2}$

$\rho = 0.4295 / r$

Assuming we are in a mid-radius region, $R_0 = 2.2 \cdot 10^{26}$ m and making $dr = 1$ Mpc $= 3.1 \cdot 10^{22}$ m, it turns out that the expected decrease in density per Mpc at a radius half the universe's radius would be:

$d\rho = -0.4295 \cdot R_0^{-2} \cdot dr$

$d\rho = 6.29 \cdot 10^{-30}$ $Kg/m^3/Mpc$

This is aproximately 1% of the accepted baryonic mass density of the universe (4.6% of the critical density 10^{-26} Kg/m^3, or $4.6 \cdot 10^{-28}$ Kg/m^3). For regions closer to the center, the predicted relative variations are larger. In more external regions they would become much smaller and practically unmeasurable.

Observational evidence for the distribution of mass density in the universe is scant. The large-scale average density, known as the cosmic density parameter (Ω) depends on its composition and, according to the ΛCDM model, is very close to the critical mass density Ω_c, the one required to make the universe flat. The density of matter, including dark matter, would amount to about 28% of the global density ($\Omega_m = 0.28$), while the density of baryonic matter is thought to comprise a bare 4.6% of the total density. Distribution of average density as a function of distance is generally assumed to follow the general trend of decreasing as the radius increases, reflecting the overall dilution of matter on larger scales, but observations are dominated by a complex hierarchical structure, the so-called cosmic web, that makes a precise estimation difficult. As a result, no reliable data are currently available.

Several authors [5-9], notably Peebles, Karachentsev, Nuza and others have probed into the mass distribution in the vicinity of our Milky Way and found that, on average, its density is significantly lower than the average for the whole universe. We would thus be in a local region of low density, the Local Void, which makes the observations not representative of the whole universe. The interpretation of the results is also compounded by the influence of dark matter and structure formation, two processes of which we know little.

In two important studies [5, 6] the authors examined the distribution of the mean density of matter in spheres of various radii in our Local Universe and found that mass density up to about 50 Mpc decays with distance. The authors conclude that density is on average lower than the global density for the universe ($\Omega_{m,local}$ = 0.08 vs Ω_m = 0.28) and tends to an asymptotic minimum value. However, looking at the data in the figures, we speculate that they might also be consistent with a 1/r decay in that range. However, as the authors point out, larger scale distances are needed to avoid local variations, probably 100 Mpc at least. In the papers, uncertainties in the range up to 90 Mpc seem too large to draw a conclusion.
Also, as shown previously, a reliable measurement of the variations in mass density around the Milky Way could be used to gauge our proximity to the center of the universe.

Another interesting observation is the striking ressemblance of equation (5) with the Friedmann equation. The Friedman equation can be expressed as [10]

$$a''/a = - 4/3\cdot\pi\cdot G\ (\rho + 3p/c^2) + \Lambda c^2/3 \qquad (6)$$

And making a customary simplification that consists of replacing

$\rho \longrightarrow \rho - \Lambda c^2/8\pi G$

$p \longrightarrow p + \Lambda c^4/8\pi G$

we have

$$H^2 = (a'/a)^2 = 8/3\cdot\pi G\rho - \kappa c^2/a^2 \qquad (7)$$

Assuming flat space (κ=0) and substituting G' for G (G' = 4πG) results in

$$G' = 4\pi G = (3/2) \cdot H^2 / \rho \qquad (8)$$

which reminds us of Eq 5:

$G' = 3 \cdot Acc_B / (r \cdot \rho)$

In the last expression, since dimensions of Accel / r are $[1/T]^2$, we have

$$G' = 3\cdot (1 / t)^2 \cdot (1 / \rho) \qquad (9)$$

If we now interpret 1/t as the constant rate of expansion H, it turns out that Eq (1) can be viewed as equivalent to

$$G' = 3 \cdot H^2 / \rho \qquad (10)$$

which differs from the Friedmann equation by a factor of 2. The reason for the discrepancy we ignore, but it has happened before in astrophysics that a classical, non-relativistic approach has been later superseded by the appropriate relativistic version that differs from it by a factor of two, e.g., in the old pre-Einstein estimation of the lensing of light from Newtonian gravity by Johann Soldner in 1804.

Thus, the hypothesis of a decreasing density of matter that scales inversely with distance seems a reasonable one and, from Newtonian mechanics, this would lead to a constant background cosmic acceleration that agrees with MOND's a_0 and would account for the rotation curves in galaxies. The observed accelerations around galaxies below MOND's a_0 have been shown from observations to be the geometric average of the Newtonian acceleration and a_0. This might be understood as a real physical phenomenon related to the interaction of two competing accelerations, not only a mathematical artifact.

We cannot discuss here the other predictions of MOND related to dark matter. We would rather refer the reader to the works of the original author [1-3].

As for the CMB, it is our understanding that it has some problems that limit its ability to be used as the gold standard to adjudicate prospective fundamental theories. We'd like to draw attention to one of those problems, namely the strong anisotropy observed in the CMB, the so-called CMB multipole (dipole, quadrupole, octopole), that is generally considered as originating from the movement of our galaxy with respect to the Hubble flow. But the velocities needed for the dipole are higher than 350 Km/s [11] and the quadrupole shows a coincidence in orientation with the solar system that is hard to explain.

In summary,

1. In a modified Newtonian ball model of the universe, a continuously decreasing mass density that scales as 1/r, as opposed to the uniform distribution from the Cosmological Principle, would give rise to a constant universal physical acceleration that agrees with MOND's a_0.

2. This would provide a physical basis for MOND and support it as a viable interpretation of the dark matter problem, even if it cannot fully explain the need for a modification of the gravitational laws.

3. The resulting mass-density distribution may be hard to verify experimentally since the densities involved, as well as the variations incurred are very low. A variation in mass density around 1% per Mpc is expected.

Part II. Acceleration and redshift in a static, rotating universe.

We now turn our attention to the mysterious empirical relation observed between a_0 and the parameters that reflect the universe's expansion, H_0 and Λ.

Indeed, the numerical value of MOND's a_0 has been found to be approximately

$$a_0 \sim (c / 2\pi) \cdot H_0 \sim (c^2 / 2\pi) \cdot \mathrm{SQRT}(\Lambda/3)$$

Why is that? What is the intimate relation of a_0 to the accelerated expansion of the universe?

Motivated by the previous ideas and some inconsistencies in the current cosmological models, namely the discrepancies in the measurements of the rate of expansion -the Hubble tension-, the existence of galaxies much older than allowed by our current ideas on galaxy formation [12], and the failure to determine the magnitude and origin of the accelerated expansion, an alternative explanation is sought for the original observations that led to the idea of an expanding universe. According to the extensively confirmed Hubble Law ($v = H_0D$), redshift from stars and galaxies is linearly related to distance, suggesting increasing recessional velocities in the context of a global expansion. Despite its evident internal logic and agreement with multiple observations, we shall make here no assumptions on homogeneity, isotropy, nor expansion. Our arguments will be checked against the basic observational facts. Namely, the Hubble Law relating redshift to distance, and the existence of a pervasive background low-energy radiation in the form of the CMB. Ideally, the model should also provide an explanation for the accelerated expansion in recent epochs, as described by Riess, Perlmutter and Schmidt in 1998, as well as for the anisotropy observed in the CMB, its dipole.

Modelling Transverse Doppler Redshift (TDR) and gravitational blueshift (GB)

In the ball model of the universe, a 1/R mass-density distribution leads to a constant background acceleration a_0, sometimes called cosmological acceleration a_Λ, that has been measured at $1.2 \cdot 10^{-10}\ \mathrm{ms}^{-2}$ [1-3].

From Eq 5 we can calculate acceleration in a spherically symmetric gravitational field, which gives us an expression equivalent to the Poission equation in one dimension:

$$\mathrm{Accel}(r) = 1/3 \cdot 4\,\pi\,G\,\rho(r) \cdot r \qquad (11)$$

For fixed point masses in empty space, the density distribution that describes it is a $1/r^3$ mass density function. We see then that the acceleration scales as $1/r^3 \cdot r = 1/r^2$ as in Newton's Law.

If we take the 1-D integral of this expression along the radial distance r for a $1/r^3$ distribution of density, it returns a gravitational potential that scales as 1/r, as expected.

$$\Phi(r) = \text{Int}(\text{Accel}, dr) = \text{Int}(\ 4\ \text{Pi}\ G\cdot\ \rho(r) \cdot r\ , dr) \sim\ \text{Int}(r^{-2}, dr) = -1/r \qquad (12)$$

But eq (11) is more general and includes other possible distributions of density. In particular, for a 1/r distribution, the acceleration according to (11) is constant and agrees with MOND's a_0 to within one order of magnitude ($1/3\cdot 4\pi G\ \sim\ a_0 = 1.2 \cdot 10^{-10}\ m\cdot s^{-2}$). In what follows, we will use either expresson (11) for acceleration or its MOND value a_0, when it is expedient to simplify the calculations.

Centripetal acceleration as a function or radial distance is then

$$v^2/r = a_0 = \text{constant} \qquad (13)$$

$$v = \text{SQRT}(a_0 \cdot r) \qquad (14)$$

and rotational velocities appear that increase as the square root of radial distance from the center. For the estimated radius of the observable universe ($R_U = 4.4 \cdot 10^{26}$ m) we have that in a non-relativistic approximation, rotational velocities in the external shells would be

$$v = \text{SQRT}(1.2\cdot 10^{-10} \cdot 4.4\cdot 10^{26})\ m/s\ =\ 2.29 \cdot 10^8\ m/s\ \sim\ c \qquad (15)$$

a striking coincidence.

Transverse Doppler Redshift

We consider the transverse Doppler redshift that would be observed from light emitted from distant galaxies on the same radial direction as the observer [13]:

$$1 + z = 1 / \text{SQRT}(1 - (v_T^2/c^2)) \qquad (16)$$

where v_T is the velocity of the emitting galaxy in the direction perpendicular to light trajectory, relative to the observer. Redshift goes to infinity as v_T approaches c.

For shorter distances and lower velocities (v << c), the approximate formula is

$$z \sim 1/2\ (v_T/c)^2 \qquad (17)$$

and we see that, since rotational velocities increases as the square root of distance (14) and redshift scales as the square of relative velocity (17), there must be some reference frame in which redshift increases linearly with distance. We claim that an observer located near the center of the universe is one such frame.

Transverse Doppler redshift (TDR) is thus a function of relative (transverse) velocity between the emitter and the observer. To calculate relative velocity we must comply with the relativity requirement that the universe looks the same for all observers. This means that even if there is a preferred place in the universe, its coordinates should not be necessary for an observer to describe the physical phenomena at his location. Hence we define relative velocity as the velocity calculated from centripetal acceleration, taking as distance the relative radial distance between emitter and observer.

$$V_{rel}^2 / |r - ro| = \text{Accel} \qquad (18)$$

$$V_{rel}(r) = \text{SQRT}(\ \text{Accel} \cdot |r - ro|\ ) \qquad (19)$$

Where r is the position of the emitter, *ro* the position of the observer, and Accel is the (constant) acceleration between them. This is the value for relative transverse velocity that goes into equation (16). Since acceleration remains constant, Eq 19 does not need to be integrated over distance.

Gravitational Blueshift (GB).

Light coming from distant galaxies, whether at the edge of the universe or closer to us, must then overcome the gravitational potential between its source point and us and, by so doing, it is subject to gravitational blueshift, which is given by:

$$z_G = \Delta U / c^2 \qquad (20)$$

For a constant acceleration a_0, the general definition of gravitational potential at radial distance r from the center of the universe is:

$$\Delta U = a_0 \cdot r \qquad (21)$$

Redshift is then given by

$$z_G = a_0 \cdot r / c^2 \qquad (22)$$

This formula does not require correction from general relativity, since it is derived from the equivalence principle [14]. If we consider an observer located at a distance *ro* from the center, then the recorded gravitational redshift becomes:

$$z_G = a_0 \cdot |r - ro| / c^2 \qquad (23)$$

By comparing Eqs 16 (or 17) and 23, one can see that gravitational blueshift is in general smaller than TDR, from which it must be subtracted to obtain the total lightshift.

Furthermore, there is a gravitational well from the emitting galaxy that light has to overcome (with redshift) before reaching the observer. In general, this redshift is compensated by a similar blueshift from the gravitational sink that the photons fall into when arriving the observer's galaxy. If both galaxies are about the same size, both effects are comparable and the net shift from gravity is just a blueshift caused by the acceleration along the path (in our case, constant a_0) and the relative radial distance. Hence Eq 23 is adequate in most cases. However, when one or both galaxies are rotating at relativistic speeds, a higher gravitational well around the galaxy arises from its relativistic mass, which is larger for fast-rotating galaxies in the outer regions. For an observer near de center looking at light coming from a galaxy far in the outer regions, there is a larger redshift from the relativistic mass of the emitter which must then be subtracted from the blueshift. Therefore, gravitational blueshift will be in general overestimated by Eq 23, which must be rather viewed as an upper bound for gravitational blueshift.

In practice, since it is smaller than TDR, gravitational blueshift can be ignored when estimating the observed total redshift, but in some cases it can have significant impact and shoud be included (for instance, when studying the behavior of redshift in old epochs as compared to recent ones).

Results

The resulting transverse Doppler redshift (TDR) calculated from Eqs 16 and 19 increases linearly with distance and picks up exponentially for large distances ($Z > 0{,}3$-$0{,}5$), mimicking an expanding universe. When gravitational blueshift (GB) calculated from Eq 23 is subtracted from TDR, a slightly decreased total redshift is observed, since GB is small compared to TDR, between 1/10 and 1/15 at the mid- and border regions (from Eqs 11-16, 23, and Figs 2-3).

In the figures, TDR, GB and the observed redshifts known from public sources [15] are represented for an observer at a distance from the center that is 1/32 and 1/1000 of the radius of the observable universe. Rotational velocities are also plotter, assuming a distribution of mass-density that decays as the inverse of radial distance.

$$\rho = 1/R \qquad (24)$$

With this density distribution, transverse Doppler redshift increases linearly at short distances but falls short of the observed redshifts (red dashed line vs red crosses, Fig 1).

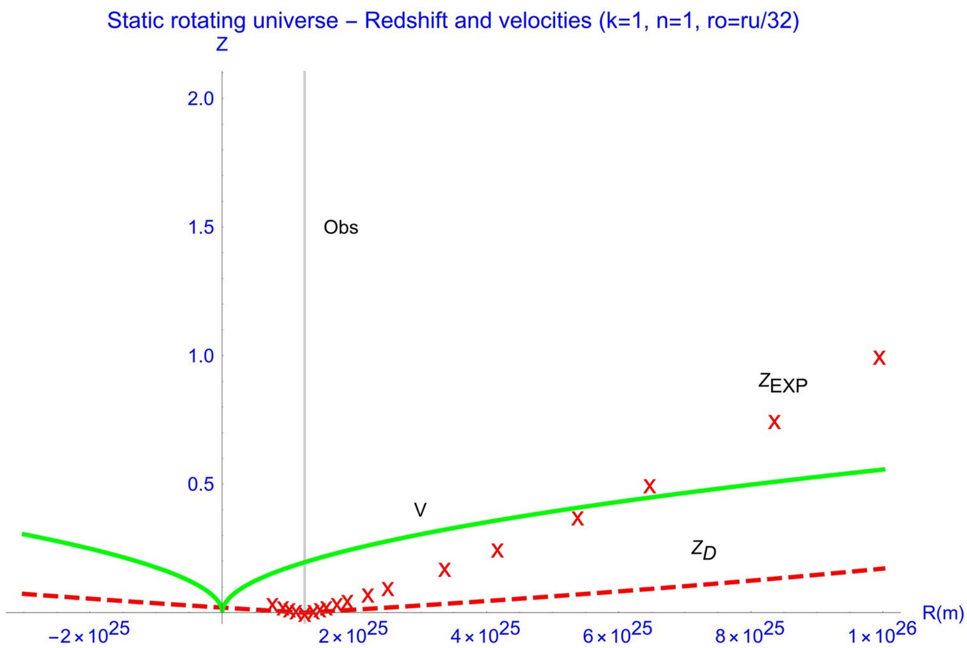
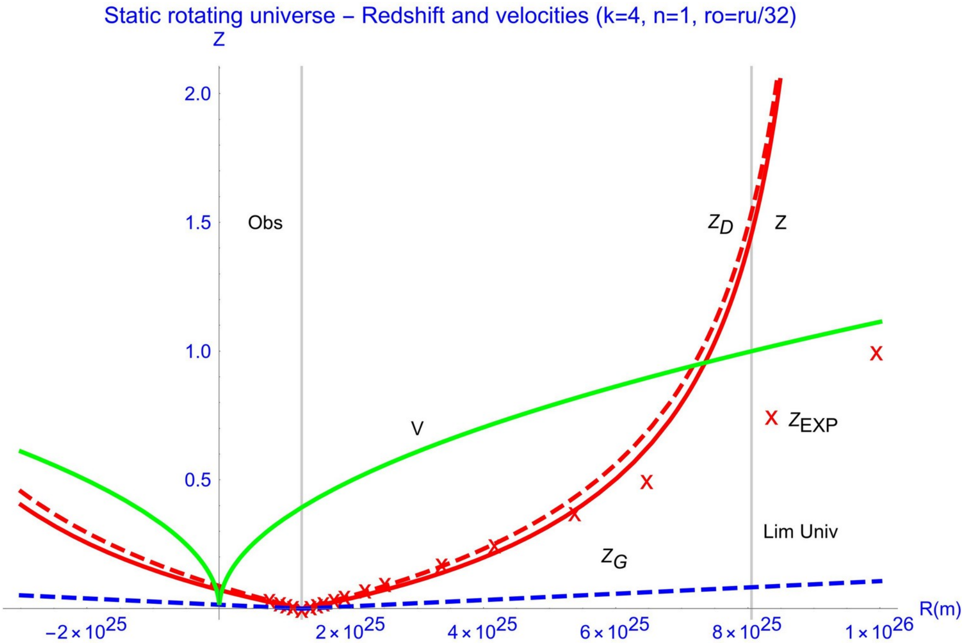


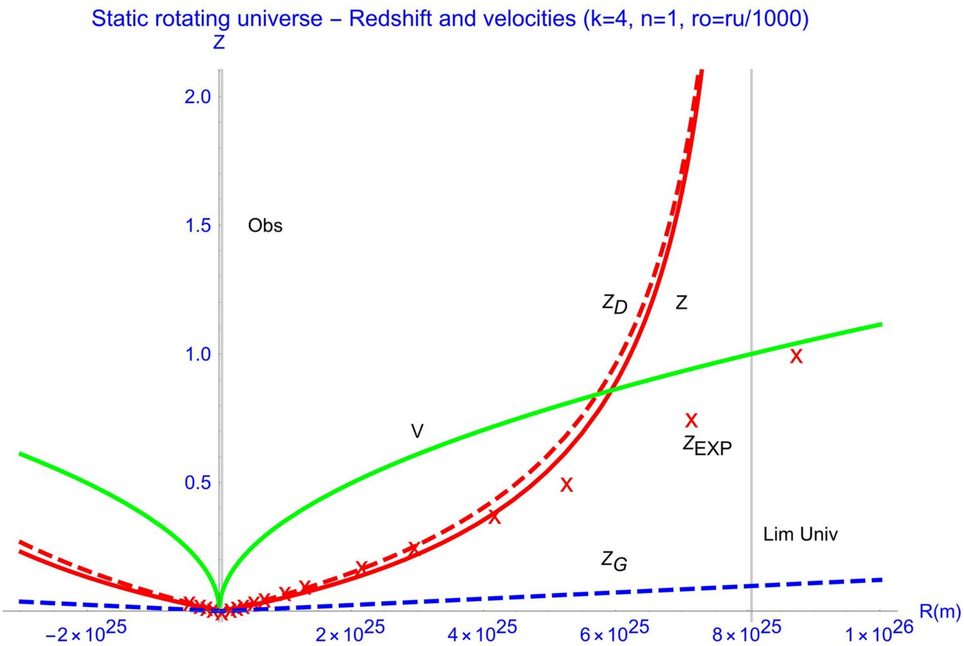
Fig 1. TDR (Z_D, dashed red line) as viewed by an observer (Obs) placed at 1/32 of the radius of universe (R_U) for a mass density that distributes as 1/r compared to observed redshifts (red crosses, Z_{EXP}). Green lines are rotational velocities expresed as multiples of *c*. Rotational velocities approach *c* at a radial distance equal to the that of the observable universe (not shown).

However, we can consider a more general function for the distribution of mass-densitiy:

$$\rho = k / R^n \qquad (25)$$

with k a free variable to be fitted, and n very close or exactly equal to one. We then find out the k that best fits TDR to the observed redshifts in its ‘linear region’ at short distances. An optimal value is k = 4 (Figs 3, 4).





Figs 3 and 4. Calculated transverse Doppler redshift (Z_D, dashed red line) gravitational blueshift (Z_G, dashed blue line) and total redshift (Z, red line), together with rotational velocities (V, green line) for a mass density distribution 1/r and k = 4 (Eq 25). Observer (*ro*) is placed at 1/32 and 1/000 of R_U from the center, respectively. Red crosses are observed redshifts (Z_{EXP}). Vertical grey lines indicate the center of universe, the position of the observer, and the distance at which rotational velocities become larger than *c*.

In Figs 2 and 3, redshift increases linearly at first, then relativistically starting from distances about the limit of our local universe, z ~ 0.3. Velocities increase as the square root of distance and reach values of *c* at a distance from the center slightly smaller than 10^{26} m, i.e., about one fourth to one fifth the currently accepted value of the visible universe's radius. At that point, the idea that there is some physical limit is hard to dismiss, and that limit looks shorter than the visible universe of ΛCDM. Alternatively, velocities might stop increasing and flat out with a corresponding change in the distribution of mass-density, allowing for larger radii and involving new mechanisms that cannot as yet be forseen.

Caveats and limitations

1. Equations 16 and 19 assume that both the observer and the emitting galaxies are located along a common radial direction. For different locations, the same reasoning would hold, provided that their relative distance is large compared to the distance from the observer to the center. Isotropy is then ensured and measured distances are then independent from the particular location of the observer along its orbital path.

2. Slight adjustments are possible for both n and k in the distribution of mass-density (Eq 25). We haven't seen a clear benefit in the predictive power as compared to setting n = 1 and adjusting k. In the graphics, we have adjusted k for the best fit of Z_D to observed redshifts. In the appendix there is an example of what happens when n is slightly modified.

3. We have not atempted to model the velocities and redshifts that take place when the emitter is on the other side of the universe from the center (to the left in the graphics). Though essentially the same findings are expected, the calculation of gravitational accelerations and redshifts include some new phenomena that are hard to model with simple tools and might give rise some significant asymmetries. For simplicity, we assumed that all processes are symmetric on both sides, which is a reasonable hypothesis when the observer is located very close to the center.

4. As we can see in the graphics, redshifts outside our local universe (approximately z > 0.3) increase relativistically as predicted (eq 16) and become much larger than the currently accepted ones. Also, velocities reach approach c for distances shorter than R_U, the currently accepted radius of the observable universe. Since rotational velocities larger than *c* make no sense, we plot a vertical line in the graphics at the point where such velocities are achieved, with the implied suggestion that the universe might actually end there.

But how can distances outside the local universe be overestimated by our current ΛCDM models?

Discrepancies with the SN-Ia distance ladder for measuring distances.

We come thus to the disturbing conclusion that redshifts in a static, rotating universe are practically identical to those of an expanding universe for distances smaller than z ~ 0.3, but progressively disagree for larger distances. Since distances in standard ΛCDM are measured by means of a well-tested, sequential method that is ultimately anchored on optical parallax, the natural question to ask is whether there could be a problem in the last ladders or our current distance method. Could Type Ia Supernovae (SNe Ia) erroneuously measure distances outside of our local universe?

In the first place, we should consider that in this static rotating model of universe (SRMU), high rotational velocities are achieved that are real. For velocities > 0.3-0.5·*c*, relativistic masses must be used for all dynamical analyses. In ΛCDM in contrast, recessional velocities are 'apparent' and caused by an expanding spacetime. In the reference frame of any particular galaxy, its velocities are sub-relativistic. This is why in ΛCDM galaxies do not violate Special Relativity despìte recessional velocities much higher than *c.* Despite recent reports that indicate that time dilation occurs for distant galaxies and quasars [16, 17] (which in itself is somewhat problematic) the whole ΛCDM is rooted on a mass that is relatively insensitive to recessional velocities. In SRMU instead, masses do increase relativistically in proportion to Z. This means that for all galaxies and stars beyond the local universe, their effective mas is relativistic mass (m_R), which is higher than their rest mass (m_0). If the explosion of SNe-Ia takes places at a fixed mass, this -we argue- must be its relativistic mass. This would mean that they explode at a smaller value of their rest mass, which is what is contemplated for nearer galaxies, those for which a distance confirmation is available from cepheids and parallax. The only thing that is needed then to explain the discrepancy between true distance and distance from type Ia Supernovae is that luminosity depend not on relativistic mass, but rather on rest mass. This might indeed be the case, since luminosity, the number of photons emitted per unit time, is subject to relativistic time dilation, which must be accounted for and would cause a downward correction. Even though radiant energy itself should depend on relativistic mass, when luminosity is down-corrected for relativistic time dilation, this would counter the increased luminosity by the same proportion (γ) by which it increased when going from rest to relativistic mass and might result in a luminosity that is roughly proportional to rest mass (calculations not done). The end result might be an overestimation of intrinsic luminosities. In the graphics, for any galaxy at radial distance R from the observer, intrinsic luminosity at the time of its explosion might be smaller than calculated fom the usual M/L function and, to acount for that, one can either make the aforementioned relativistic corrections or assume a larger distance from the observer. In an expanding universe, only the second option is available. The increase in distance that corrects redshifts by the right amount to offset their relativistic increase in mass seems to be just the horizontal projection of the 'true' redshift, represented by the red lines, onto the 'experimental redshift', represented by the red crosses. If to every redshift we attribute the distance represented by this projection, then both redshift and distance can be made consistent with the inverse-square law of propagaton of light and with the mas-to-light ration inferred from closer-by galaxies. The discrepancy would increase exponentially at higher redshifts, in parallel with the increase in rotational velocities and relativistic masses, and might likewise affect our estimation of the size of the universe.

Second, there’s another possible source of error in the calculation of distances: the headlight effect [18]. In an expanding universe, no significant headlight effect should take place for distant galaxies, since velocities in their reference frame are sub-relativistic. But in a rotating static universe, there is a (most likely small) decrease in the light received by an observer that is facing the emitting galaxy sidewise. This effect might also contribute to an overestimation of distance, since -again- lower-than-predicted luminosities can only be explained by assuming larger distances from the observer.

Both potential sources of error -if they exist- would go unnoticed in the lower rungs of the distance ladder (cepheids and parallax), since no relativistic corrections are needed nor used in their ranges.

Conclusions

Subject to the previous limitations and the provisional, semi-quantitative character of the present model, we conclude that:

1. A mass density that scales as 1/r in a static rotating universe gives rise to a constant cosmological acceleration consistent with MOND's a_0. This would generate rotational velocities that increase as the square root of radial distance from the center, reaching relativistic speeds at the outer regions.
2. Such velocities would generate a transverse Doppler redshift that scales with radial distance, mimicking recessional velocities and expansion.
3. Assuming the observer is placed relatively close to the center, a total (transverse minus gravitational) redshift that mimics the isotropic cosmological redshift of an expanding universe would be observerd from all directions.
4. In this model, there is no cosmological redshift. All light shifts are of gravitational or Doppler origin. Strongly redshifted light coming from the farthest external shells of the universe is expected to predominate, possibly giving rise to images similar to those observed in the CMB.
5. Current methods based on the distance ladder and SNe-Ia might overestimate cosmological distances, and might overestimate the actual size of the universe as well. In contrast, the lifespan and stability of the universe might be grossly underestimated.

Discussion

Several authors, most notably Lombriser, Buchert, Roukema *et a*l [19-21] have proposed that the expansion of the universe might be an apparent phenomenon caused by distortions in the gravitational fields at cosmic scales, but the models are incomplete, difficult to test and, in some cases they include radical unobserved features like a variation in the mass of particles.

Late American astronomer Halton Arp performed detailed observations on redshifts from quasars and galaxies around the turn of the last century, calling the attention on several inconsistencies and unexplained findings at large distances [22]. Redshift often distributes with regular patterns and periodicities that are hard to explain if expansion and the relation of redshift with distance are both correct. Morever, sometimes wide differences in redshift from close-by galaxies was recorded. For these reasons, Arp opposed to the idea of recessional velocities as the major or unique origin of cosmological redshift. Unfortunately, the alternative he postulated, i.e., that redshift is quantized and caused by intrinsic properties of galaxies and quasars, like their plasma content, has little suppport and we lack any leads to either confirm or disprove it.

On the other hand, the hypothesis that light's energy and frequency might decay across large distances, the 'tired light' hypothesis, has not gained traction mainly due to the fact that it would imply a modifications of *c*, contradicting Special Relativity. There have recently been some remarkable attempts [23] to make the tired light hypothesis consistent with the observation of large galaxies at early times and with ΛCDM by way of a hybrid model. However, it also needs modifications in the basic physical constants G, *c,* and Λ.

The present semi-quantitative model is based on the assumption of a mass density that decreases inversely with distance, a reasonable hypothesis that is consistent with Newtonian gravity and supported by MOND and by a handful of preliminary observations on actual mass densities in the local universe. The assumption might soon be tested by the James Webb Space Telescope and other observatories. It offers a picture of a static, rotating universe that would generate the phenomena of redshift and background low-energy radiation that we observe today and constitute the backbone of modern cosmology.

High rotational velocities are not excluded from the lack of detection of changes in the position of distant galaxies. For the same reason that the rotation of earth is not detected by us, as noted by Galileo, and rotation of the Milky Way has never been directly detected even if it amounts to hundreds of meters per second.

Unfortunately, in this model the universe could essentially no longer be expanding, nor the Big Bang could take place 14 billion years ago. On the plus side, the mass-energy composition of the universe might be better understood, and the law of conservation of energy would no longer be violated at cosmic scales. The universe would be much older and stable than previously though and, though static, it would offer an ample range of exciting features to work with and speculate.

And yet, caution is advised when contemplating these hypotheses. Our current models of the universe are self-consistent and offer a complete picture of the events up to the first nanoseconds from the origin. Even if countered by a few important discrepancies, our current cosmological models work. The present ideas are an alternative view motivated by reasonable arguments, many of them inspired by the work of other authors. They might be worth being looked into, scrunitinized and, if they end up being ruled out from disagreement with observations, the task ahead remains unchanged, which consists of seeking truth and bettering our understanding. *For us, there is only the trying. The rest is not our business* [24].

Appendix I

Mathematica ® v.12 code for the graphics

Global constants

ro=1/250*10^26 (* Observer position at ~1/1000 of R_U *) ;

c=3*10^8 (* Speed of light *) ;

g=6.67*10^-11 (* Gravitational constant *);

k=4 (* Density constant *);

n=1 (* Parameter *);

a0=1.1*10^-10;

(* Constant cosmologiical acceleration, agrees with MOND and approximately equal to

1/3· 4π · G *);

Functions

density[r_]:= k*Abs[r]^-n (* Density *);

acceleration[r_]:=1/3*4*Pi*g*density[r]*Abs[r] (* Acceleration from Eq 11 *);

(* When density decays as 1/r, acceleration is constant in r and agrees to within one order of magnitude with MOND's a0 – we use it interchangeably with a0 *)

```
v[r_]:=Sqrt[acceleration[r]*Abs[r]]  (* Velocity of galaxies *);
```

```
vrel[r_]:= Sqrt[acceleration[r]*Abs[r-ro]]
```

```
(* Relative velocity between galaxy at r and observer at ro *);
```

```
u[r_]:= acceleration[r]*Abs[r]  (* Grav potential general formula (not used) *);
```

```
zg[r_]:= a0*Abs[r-ro] /c^2 (*  Gravitational redshift  *);
```

```
(* An alternative roughly equivalent definition in terms of potential function would be: zg[r_]:=
u[r-ro] /c²  *);
```

```
zd[r_]:=1/Sqrt[1-(vrel[r]/c)^2]-1  (* Transverse doppler redshift *) ;
```

```
vplot[r_]:= Abs[v[r]]/c (* Velocity of emitting galaxy in units of c *);
```

```
limu=r/.NSolve[vplot[r]==1&&r>0,{r}][[1]]  (* Distance at which v=c *);
```

```
table={{0,0},{42.8,0.01},{74.6,0.0175},{106.2,0.025},{158.2,0.0375},{209.4,0.05},{309.9,0.075},
{407.7,0.1},{686.4,0.175},{945.2,0.25},{1338.6,0.375},{1691.9,0.5},{2303.8,0.75},{2818.3,1},
{3644.3,1.5},{4285.9,2},{4804.1,2.5},{5234.6,3}};
```

```
(* Table of experimental data {Mpc, Redshift} from reference 15 *) ;
```

```
dists=Take[Transpose[table][[1]]*3.0857*10^22+ro,18] (* Conversion Mpc to meters *);
```

```
dists1=Rest[Take[2*ro-dists,5]] (* Distances to the left of the center *);
```

```
ereds=Take[Transpose[table][[2]],18] (* Redshifts to the right of the center *);
```

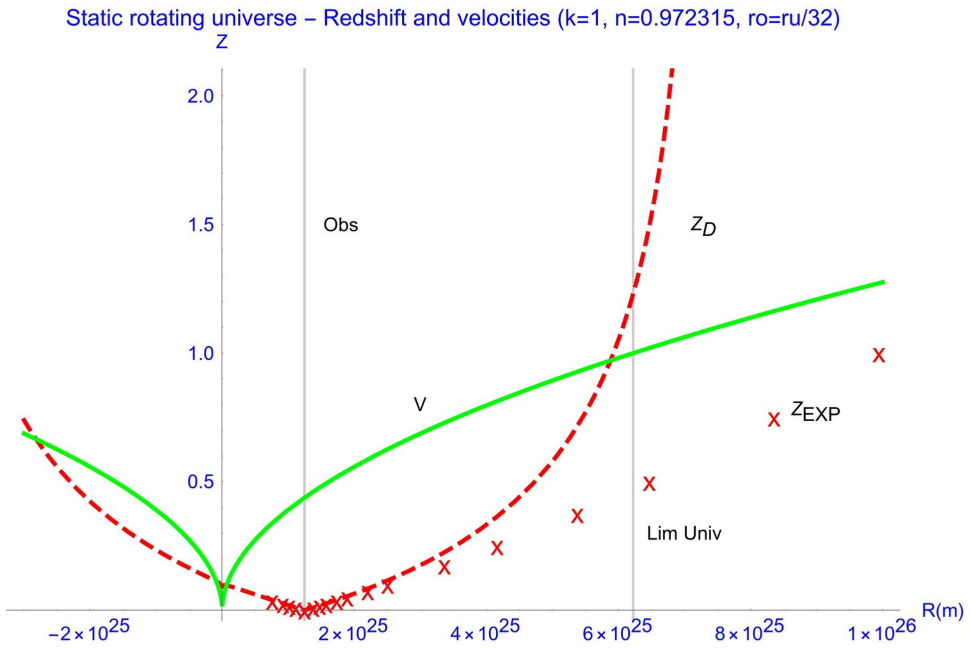
```
ereds1=Rest[Take[ereds,5]] (* Redshifts to the left *) ;
```

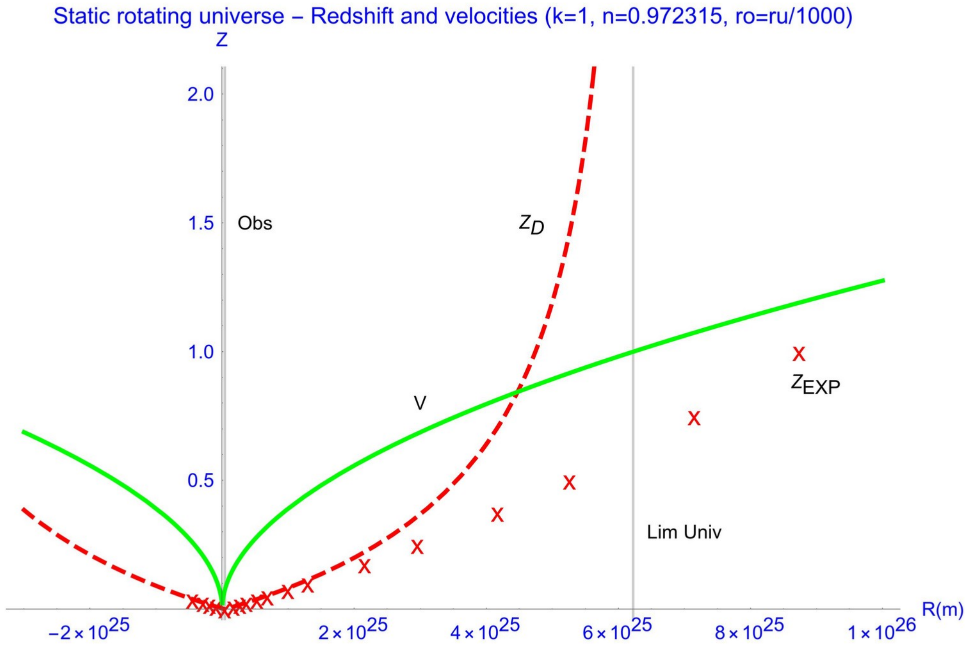
Plots

```
zo=ListPlot[Join[Transpose[{dists1,ereds1}],Transpose[{dists,ereds}]],PlotMarkers->
Style["x",Red]];

(* Experimental data Plot *);


rshift=Plot[{Style[zd[rad],Red,Dashed],Style[zd[rad]-
zg[rad],Red],Style[zg[rad],Blue,Dashed],Style[vplot[rad],Green]},{rad,-3*10^25,1*10^26}];

(* Traverse Doppler and Velocity plot *);


graph=Show[zo,rshift,PlotRange-> {{-3*10^25,1*10^26 },{0,2}},AxesOrigin-> {0,0},GridLines->
{{ro,limu},{}},PlotLabel-> "Static rotating universe - Redshift and velocities (k=4, n=1, ro=ru/
32)",LabelStyle->Directive[Blue,7],Epilog-> {Text[Style["V",FontColor-> Black,FontSize-> 7],
{3*10^25,0.7}],Text[Style["Subscript[Z, D]",FontColor-> Black,FontSize-> 7],{6*10^25,1.2}],

Text[Style["Z",FontColor-> Black,FontSize-> 7],{7*10^25,1.2}],

Text[Style["Subscript[Z, EXP]",FontColor-> Black,FontSize-> 7],{7.4*10^25,0.65}],

Text[Style["Obs",FontColor-> Black,FontSize-> 7],{0.7*10^25,1.5}],

Text[Style["Lim Univ",FontColor-> Black,FontSize-> 7],{8.8*10^25,0.3}]},AxesLabel->
{"R(m)","Z"}] ;
```

Appendix II

Additional graphics assuming n < 1 in Eq 22.





Transverse Doppler redshift as a function of radial distance in formula for It is shown that a mass density decay that scales as k / R^n and n < 1 can also generate redshifts consistent with the observed ones. Observer at 1/32 and 1/1000 of the radius of universe. Nothing prevents in principle that mass-density deviates from an exact 1/R distribution, but we would rather eschew those models since their main feature is lost, i.e., a constant acceleration that pervades the whole universe. Rotational velocities also pick up quite steadily. Mixed models (with both k and n different from 1) are also possible.

Appendix III

Cosmology that would result from a Static Rotating Universe

In the SRMU, size would be determined by rotational velocities that are limited by the speed of light. No physical object can move at speeds higher than *c*, and since there is no expansion of spacetime, no exceptions are acceptable. This entails that the size of the universe is determined internally by the fundamental laws of physics: relativity, QM and gravity. The universe shoud be much more stable than our current models predict. Not necessarily eternal though, since matter would be continually generated and simultaneously consumed into spacetime. In the mature and old phases of its lifetime, the universe might convert more matter into space than the reverse and it might eventually run out of mass. At that time, which might occur 10^{50} to 10^{100} years from its origin or more, the universe would lack the necessary mass to maintain its present properties, its rotational velocities and its size, and might collpase and 'disolve' into spacetime, gas and dust, adding to the general pool in the outer 'inter-universe' medium. Other 'young' universes might exist that have not yet reached its full rotational velocities and size limit and are therefore capable of growing by accreting mass. These young universes would grow from the recycling of mass (and spacetime?) from the inter-universe medium until they reached their full mature size, most likely the same size as our own.

The question of what lies outside of our current universe has thus no proper answer that can be validated experimentally. However, the logic of the model -the fact that the limiting size is detemined internally- and common sense suggest that outside of our universe there might be just spacetime and mass governed by the same physical laws, and similar events might unfold, including other universes similar to our own. If other universes actually exist, we can infer at least two of their most likely properties: 1) They shoud have about the same size and life span as our own universe, and 2) The spatial and time scales involved would very large and proportional to the scales that we observe. Judging from the scales we see in our universe, where stars are separated an average of 1 pc, and galaxies are separated an average of 1 Mpc, we should expect that other universes -if they exist- might be separated one million times that distance. They might be about 1 trillion parsecs (10^{28} m) away from each other on average, or more. Their life span would likely be immense and be measured by powers of 50s to 100s. But all this is highly speculative and not the point of the present work.

Acknowledgements

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Abbreviations:

MOND: Modified Newtoniant Dynamics.

TDR: Transverse Doppler redshift

GB: Gravitational blueshift

SR(M)U: Static rotating (model of the) universe.

SNe-Ia: Type Ia Supernovae.

a_0: MOND's postulated acceleration that works as its scaling factor. It agrees with cosmological accelerations a_Λ and with the constant acceleration in this model ($1/3 \cdot 4\pi G$).

G': Defined as $4\pi G$

Changes from version 1 of the paper:

- An error in the calculation of gravitational redshift has been corrected.

- Gravitational redshift has been included in the graphics (vblus dashed line)

- Legibility of the Mathematica ® source code for the graphics has been improved, and corrections were made for typos and expression.