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Abstract

We carry out a careful analysis of the notion of observation of distant objects in a curved static universe. To this end, we introduce an observer-based representation referential endowed with a Euclidean structure, and postulate that all measurement are performed with respect to this reference frame. For a universe of constant positive spatial curvature, this causes a distortion of metric quantities which grows with the distance to the observer. In this context, the redshift of cosmological objects is not caused by their recessions, but instead by the spatial curvature along the trajectory of photons from the emitting source to the observer. Applying these considerations to the Einstein's static universe, we obtain a redshift/distance relationship that is consistent with cosmological measurements. We show that this effect also explains the existence of a Cosmic Microwave Background whose characteristics agree with the observations of the Planck mission. Furthermore, this model predicts the abundance of well-formed galactic structures in the high redshift universe, which were recently detected by the JWST.

1 Introduction

In 1917, Albert Einstein proposed a finite static solution to its equations of general relativity as a representation of the universe. Assuming a uniform and homogeneous distribution of matter, and after introducing an additional term to his field equations, he derived a universe of constant spherical curvature. However, this view of the universe soon faced two major challenges. Firstly, in 1930, Eddington raised concerns about the stability of the Einstein world and demonstrated that it is in fact unstable against a small variation of the total matter density, causing it to exponentially expand or contract [2]. However, this kind of non-local perturbation is non-physical in nature and it is still not clear today if the Einstein world is indeed unstable against perturbations having physical relevance. We defer to the very interesting chapter [3] for a detailed discussion of the matter. The discovery, by Hubble, of a linear relation between the redshift of galaxies and their distances [4] achieved to convince Einstein, at the beginning reluctant, to change his mind and accept the growing consensus on models based on expansion of space [5, 7, 8]. Such models suited quite well the small amount of observational data yet available, although the existence of an initial spacetime singularity it requires raised important physical and philosophical questions, that still remain unanswered today. The discovery of a cosmic microwave background (CMB) made by Penzias and Wilson in 1964 [9] became a strong support for this theory, since its characteristics are compatible with the radiation of a dense primordial plasma. In 1998, an *acceleration of the expansion of the universe* was detected and surprised cosmologists [10]. This led to the introduction in the models of a dark energy that acts as a repulsive gravitational force, whose origin remains very speculative. Efforts have been made to combine all these considerations and the most accomplished result is the standard model of cosmology,

so called ΛCDM.
Alternative theories have been developed to explain the redshift of cosmological objects, such as tired light theory [11], but errors have been pointed out and the theory has never been commonly accepted [12]. In the current understanding of general relativity, if we neglect hypothetical physical processes that steal energy from photons, the only possible explanation for this redshift is a mechanism that acts on the metric of spacetime. As for now, there is growing evidence that this standard cosmological model has fundamental flaws. Thanks to a new generation of telescopes, and to an enhanced precision of measurements, some tensions in the standard model have become increasingly apparent [13, 14] and the James Webb Space Telecope has recently discovered well formed galactic structures and supermassive black holes that cannot be explained within the current concordance model.
We here propose an alternative explanation for the redshift of cosmological objects, by postulating that the wavelength of photons (as well as their frequency) is affected by the radial curvature of space along the geodesic connecting the source to the observer. In the Einstein's static universe, the curvature produces a redshift for incoming photons that grows with the distance of the light source, in a way that is consistent with cosmological observations. In the proposed theory, this effect originates from the observer's natural perception of its spatial environment as being flat, even though they live in a curved universe, inducing a distortion of the images of cosmological objects and affecting the wavelength of incoming photons. We first motivate the idea by discussing the notion of observation of distant objects in curved spacetimes. This will lead us to introduce an observer-based referential in which the rules of Euclidean geometry apply. We then postulate that all observations of our physical environment are performed with respect to this referential. This allows us to derive a formula for the redshift in function of the distance in the context of a static universe of closed spatial geometry, that we test successfully against observational data. In the final section, we show that our model accounts for the existence of the CMB and of its characteristics.

2 The perception of distant objects in a curved universe

In his book *Wholeness and the implicate order* [15], David Bohm points out a fundamental duality of the physical reality: a world, hardly accessible to our senses, home to unfamiliar processes that he calls the *implicate order*, reveals itself in an unfolded, *explicate order*, in which measurements can be performed, and which corresponds to our everyday experience of the physical environment. Originally thought to account for the puzzling properties of quantum mechanics, these views also find an echo in general relativity. In the latter, the fundamental object is a curved 4-dimensional pseudo-Riemannian manifold in which space and time are entangled in a profound interlace. Yet in our way of representing this environment, space and time are fundamentally distinct objects, for otherwise no measurement would be possible. We will refer to this fact as the *separation principle*.
In this explicate world of observation, the environment is also perceived as being flat, as we are living in a locally flat portion of the universe and our brains are equipped to make linear representations of our surroundings. To this extent, Albert Einstein writes in one of his famous 1905 paper [16]:

"*If a material point is at rest relatively to a system of co-ordinates, its position can be defined relatively thereto by the employment of rigid standards of measurement and the methods of Euclidean geometry, and can be expressed in Cartesian co-ordinates.*"

A few years later, the development of general relativity challenged this view and introduced more sophisticated geometrical tools to describe the physical world.
Let us now take the point of view of an observer living in a universe whose geometry is described by Einstein's field equations. In order to measure quantities such as lengths and durations associated to events around him, the observer can directly compare them with dif-

ferent measuring devices, such as a ruler or a chronometer. In Minkowskian spacetime and for objects in uniform linear motion with respect to the observer, direct comparison is not possible and a procedure was proposed by Einstein to determine the length of such an object, based on the constancy of the speed of light c. This procedure turns out to give a value in the direction of motion that is different from the length one would measure directly by comparing the object with a ruler. This is the core of special relativity. A similar procedure allows to determine the distance between the observer and an object at rest: one can send a light ray in the direction of the object at time t_0, and wait for the light ray to be reflected back at time t_1. The distance d from the event s is then defined in the following way:

$$d(s) = c\frac{t_1 - t_0}{2}. \tag{1}$$

This definition of distance extends to more general spacetime geometries and is called *proper* distance in the context of a static universe. It can be thought of as the length of the shortest spatial geodesic connecting the observer to the object.

Now that he is able to determine the distance of an object, the observer may ask the following question: Is there a procedure to assign lengths and durations to events situated at large distances, and how to do so? In a flat spacetime, and if the object is at rest, the answer is trivial: it can be done by using of the tools of Euclidean geometry. To answer this question in the more general set up of curved spacetime geometry, we have to introduce a *representation referential* R_{obs}, according to which the observer creates a consistent representation of its physical environment.

Consider an observer living in a spatial universe U, that we suppose static. The position of the observer is denoted by $\mathcal{O} \in U$. We denote R_{obs} the tangent space of U at $\mathcal{O}$. Let $x \in U$ be a point at proper distance d_U from $\mathcal{O}$. Denote $T(x) : U \to R_{obs}$ the *representation map*, which transforms a point $x \in U$ to the point $T(x)$ in R_{obs} situated at distance $d_R = d_U$ from $\mathcal{O}$ and such that the vector $\overrightarrow{\mathcal{O}T}(x)$ has the same initial direction as that of the minimal geodesic connecting $\mathcal{O}$ to x in U. If we suppose that T is invertible, any object $X \subset U$ has a unique representation $T(X)$ in R_{obs}. In that case, T^{-1} is called the exponential map in the mathematical literature. In R_{obs}, the trajectory of a photon traveling from x to $\mathcal{O}$ in U is represented as a straight line. We now impose a linear geometric structure in R_{obs}, by endowing it with the Euclidean metric. Note that T does not constitute a mere change of the coordinates describing the spatial geometry, since the metrics in U and R_{obs} describe, in general, different geometries.

In the reference frame R_{obs}, physical objects are represented stretched, deformed, eventually split and present at different locations, which corresponds exactly to the way we perceive them. There would be no way for the observer to recover the spatial geometry in U from its observations in R_{obs} without further knowledge of the constitution of its physical environment. For this reason, we will postulate that all the measures performed by the observer are performed with respect to R_{obs}, and are therefore consistent with the rules of Euclidean geometry. In particular, we postulate that radiation behave as in a flat space and the photons, once emitted, keep a constant wavelength in the representation space.

Now, in curved spatial geometries, although the proper distance of an object is preserved by T, its size in R_{obs} differ from the ones in the object's natural referential, even if it is at rest with respect to $\mathcal{O}$. To quantify this distortion, we introduce for each point x in U a scalar $a(x)$, the *scaling factor*, which can be determined in the following way: a bundle of light rays with infinitesimal solid angle $\delta\Omega$ is sent in the direction of x, and we compute

$$a(x) = \sqrt{\frac{\delta S}{\delta S_{obs}}},$$

where δS is the area intersected by the bundle in the neighborhood of x in the natural local referential at x and δS_{obs} is the area that intersects the bundle in R_{obs}, that is $\delta S_{obs} = d^2\delta\Omega^2$ for a point at proper distance d from $\mathcal{O}$. The obtained scaling field is a priori not continuous, can contain singularities and domains where it is not defined (in a black hole region for example). In order to compute it in a general set up, one needs to study the metric induced

on geodesic balls. To the author's knowledge, no general formula for a exists in the mathematical literature. It is obvious that if U is the Euclidean space, then $a(x) = 1$ for all x. Note that if we assume a continuous metric, the value of $a(x)$ is entirely determined by the spatial curvature along the geodesic connecting x to $\mathcal{O}$ and therefore the theory satisfies the principle of locality. We make the additional assumption that the speed of light is constant equal to c everywhere when measured in R_{obs}. For that, we suppose that the scaling factor $a(x)$ also applies to durations associated to events happening at x. Such time dilations have been observed for distant Supernovae [17]. In the following section, we will compute $a(x)$ explicitly in the case when U has spherical geometry.

3 Cosmological considerations

3.1 Einstein's world

Let us from now on place ourselves in the Einstein's static universe of radius of curvature R. It has closed spatial geometry and is the only static solution to the field equations, assuming a fined-tuned homogeneous distribution of matter/energy and a positive cosmological constant [1]. The spatial component of the metric is the one induced by the ambient Euclidean metric in $\mathbb{R}^4$ on the manifold

$$U = S^3 = \{(x_1, x_2, x_3, x_4) \in \mathbb{R}^4 : \sum_{i=1}^{4} x_i^2 = R^2\}.$$

The time component of the metric is set equal to -1 and allows the possibility of a cyclic time. In this eternal return scenario, contemplated by many cosmogonies, the age of astronomical objects would be bounded, as observed for nearby stars.

3.2 Scaling factor and redshift

The procedure described in the preceding section gives for a point at distance d from the observer the following scaling factor:

$$a = \sqrt{\frac{\delta S}{\delta S_{obs}}} = \frac{R \sin(\frac{d}{R})}{d}. \tag{2}$$

In Fig. 1, we give a visual representation of this distortion effect in dimension 2.

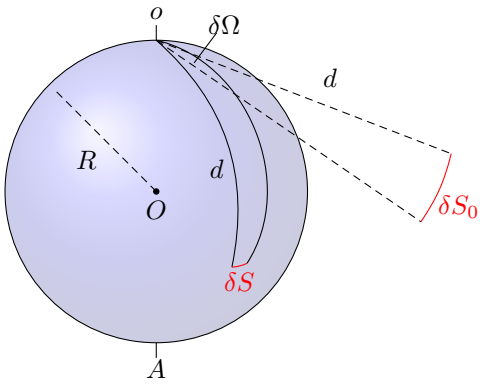
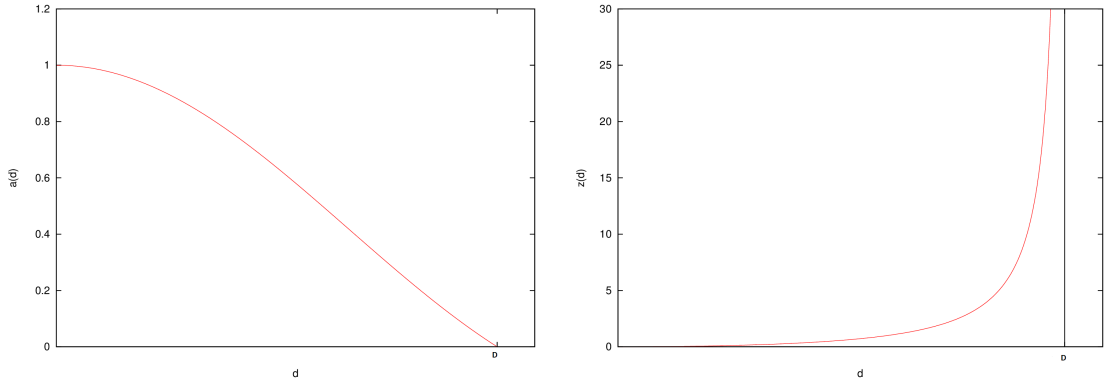


Figure 1: 2-dimensional representation of the distortion effect in the Einstein universe.



(a) (b)

Figure 2: Evolution with proper distance of the scaling factor (left) and the redshift (right) in the Einstein universe

As seen in Fig. 2a, the scaling factor decreases with the distance d until degeneration when the antipode A is reached, which corresponds to the distance $D = \pi R$. From the observer's perspective, space seems to vanish at this point. An infinitesimally small object located at A appears stretched over the whole celestial vault. As postulated in the previous section, incoming photons, which act as a messenger between the emitting source and the observer, keep track of the orthogonal dilation of the metric quantities. The resulting redshift z can be computed by comparing the measured wavelength λ_{ob} of an incoming photon with its wavelength at emission λ_{em}. We have by definition:

$$z = \frac{\lambda_{ob} - \lambda_{em}}{\lambda_{em}}. \tag{3}$$

Since

$$a = \frac{\lambda_{em}}{\lambda_{ob}}, \tag{4}$$

we get that:

$$z = \frac{d}{Rsin(\frac{d}{R})} - 1. \tag{5}$$

A graphical representation of Eq. 5 is shown in Fig. 2b. The derivative of the scaling factor, that in big bang theories is interpreted as the rate of expansion of the universe, is given by

$$a'(d) = \frac{cos(\frac{d}{R})}{d} - \frac{R}{d^2} sin(\frac{d}{R}). \tag{6}$$

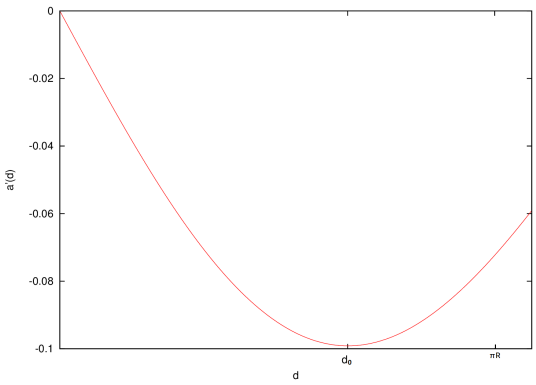


Figure 3: Evolution of the derivative of the scaling factor with proper distance

As seen in Fig. 3, a' changes monotony at a certain distance d_0. Observations of type Ia Supernovae have confirmed this behavior [6], and actual cosmological models attribute it to an acceleration of the expansion of the universe that started a few billions years ago. In the present model, we do not have to refer to dark energy to explain this behavior. It is a simple consequence of the distortion effect.

3.3 The relation between different distances

The proper distance of celestial bodies is difficult to estimate from observations. Instead, two redshift-independent methods are commonly used to assess their distance. Both require some knowledge about the observed object. The luminosity distance d_L is computed by comparing the flux of incoming light with the known luminosity of the source. The estimation of the angular diameter distance d_A requires for its part some knowledge about the size of the observed object.
d_L is defined implicitly in the relation:

$$F_{obs} = \frac{L}{4\pi d_L^2}. \tag{7}$$

Here, F_{obs} is the flux measured by the observer and L is the known luminosity of the object in its local referential. Let us consider an object situated at proper distance d from the observer, that emits n photons of energy $h\nu$ per unit of surface per unit of time, where all these quantities are expressed in the natural referential of the object. In R_o, the situation is equivalent to the following: in a flat universe, an object at proper distance d is emitting n photons of energy $h\nu/(z+1)$ per $(z+1)^2$ units of surface per $(z+1)$ units of time. Therefore, the luminosity of the object for the observer is

$$L_{obs} = L/(z+1)^4.$$

In the flat space R_o, the measured flux follows the inverse square law, so that

$$F_{obs} = \frac{L_{obs}}{4\pi d^2} = \frac{L}{4\pi d^2 (z+1)^4}. \tag{8}$$

Combining 7 and 8, we get that

$$d_L = d(z+1)^2. \tag{9}$$

In a space of spherical geometry, the angular diameter distance d_A is for its part given by

$$d_A = R\sin(\frac{d}{R}) = \frac{d}{z+1}, \tag{10}$$

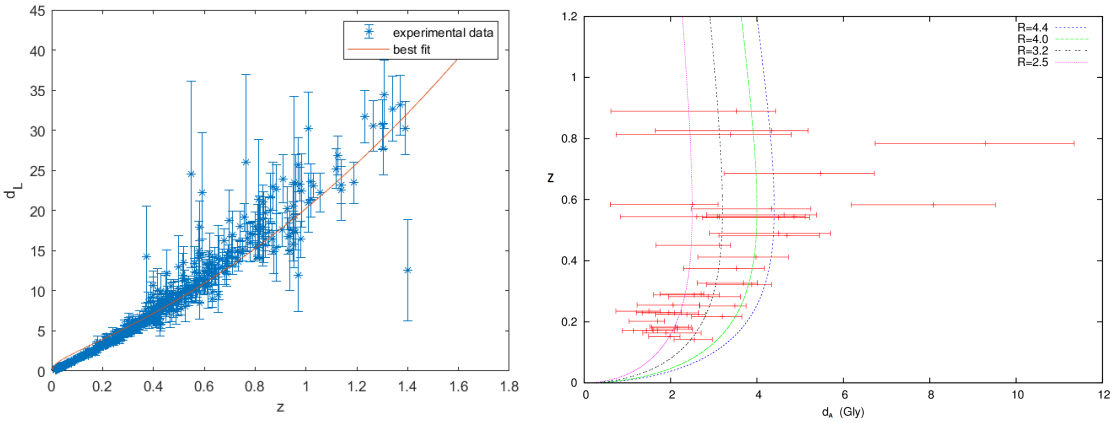
so that

$$d_L = d_A(z+1)^3. \tag{11}$$

Note that the Etherington-Ellis reciprocity theorem does not hold in this theory.

3.4 Tests

In Fig. 4a, we test our theory by showing its best χ_2 fit for the Supernovae 1A data of the Union 2 catalog [18], performed on its 257 most distant galaxies. The same general trend is observed between the theoretical curve and the observational data, although the fit for small values of z is not satisfying. We stress however that these data are model dependent and therefore systematic bias may be at stake [19]. The local dynamics of galaxies and the local spatial geometry of our universe should also affect the observed redshift of photons emanating from nearby sources in our model. The best fit is obtained for $R \approx 2.67$ Gly, for which the antipodal region is at proper distance $D = R\pi = 8.4$ Gly. That is of the same order of magnitude as estimates of the distance of the cosmological horizon in the current standard model of cosmology [6].
In the right hand side of Fig. 4, we plotted 4 curves for the angular diameter distance/redshift relationship given by Eq. 3.3 for different values of R, together with the observational data taken from the hydrostatic equilibrium scenario in [20]. The large error bars for these data render a proper fit irrelevant. The estimates of R seem consistent for both approaches, although a more precise analysis of this relation, using model independent data needs to be performed. We stress that in both cases, our fits involve only one parameter: the radius of curvature R of the universe.



(a) (b)

Figure 4: Left: Best fit of the model using the 257 most distant supernovae of the catalog. The best χ^2 fit is obtained for $R = 2.67$ Gly. Right: Comparison between theoretical curves and angular diameter distance data, for different values of R.

4 On the CMB

The Cosmic Microwave Background is a radiation detectable at all point of the universe which has the property of being extremely regular in all directions in space, although having small anisotropies distributed with privileged angle scales [9]. The observed spectrum of this radiation is one of a black body that has a maximum of emission at $\Lambda \approx 2$ mm. The existence and the characteristics of the CMB are thought to be a strong evidence for a big bang scenario since it fits very well the predictions of ΛCDM [21], although several anomalies have been pointed out [22]. The aim of this section is to show that the presented theory may also be compatible with these observations.

4.1 Over the horizon

Until here, our study has been limited to distances smaller that the maximal geodesic distance $D = \pi R$. Although it corresponds to an apparent horizon, one can perceive in this model (ghost) images from objects at distances larger than D. We now extend the definition of proper distance d to objects over this horizon, so that it corresponds to the length of the trajectory of a photon from the object to the observer. Applying the arguments developed in the previous sections, we get that the scaling factor is given by:

$$a(d) = \left| \frac{R \sin(\frac{d}{R})}{d} \right|.$$

The observed redshift is then:

$$z(d) = \left| \frac{d}{R \sin(\frac{d}{R})} \right| - 1.$$

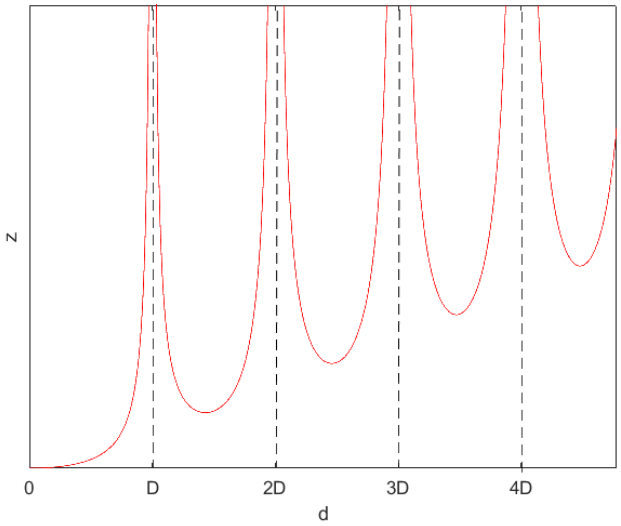


Figure 5: Evolution of the redshift with distance

4.2 Thermal radiation

In the context of a static universe, we cannot explain the CMB by an extremely hot black body that emitted light in a primordial state of the universe. These photons must emanate from standard cosmological objects. By looking at Fig. 5, we can characterize two classes of sources that produce highly redshifted light, which could contribute to the CMB:

1. Very old objects whose radiation has traveled around the universe many times before arriving to us, at huge distance from us. This type of sources will be referred as class 1.

2. Objects that emitted the perceived light in the region of one pole of the 3-sphere (our current position or its antipode), whose distance is near a multiple of D. This type of objects will be referred as class 2.

We assume that the contribution of class 2 objects does not make up the essential of the microwave background, their proportion being negligible compared to type 1 objects. If we assume a homogeneous and isotropic universe, the cumulative effect of the abundant class 1 objects would generate a highly regular background radiation, with no privileged direction. The ancient light emitted by these objects, having undergone substantial redshift, has experienced scattering and absorption. In the context of the static and fully symmetric Einstein universe, these photons should exhibit a uniform spatial distribution, and have the characteristics of a photon gas in thermal equilibrium. Consequently, the resulting spectrum is that of a black body, with a low characteristic temperature T_{CMB}, due to the highly redshifted wavelengths associated with type 1 sources. The specific value of T_{CMB} could be determined independently of directly measuring the CMB, by examining the emission and absorption properties of the universe's matter content, along with the distribution and properties of radiation sources.

4.3 Anisotropies

We must now explain the different levels of primary anisotropies of the radiation. We stated in the previous section that the contribution of class 1 objects should make up a very regular background, leaving no place for irregularities. These small perturbations could be explained by the presence of type 2 objects (mostly galaxies) in the pole regions. It is a well established fact that the distribution of the anisotropies in the CMB is consistent with the distribution of galactic structures in the universe. The radiation of these objects is highly redshifted and leaves some prints on the CMB. Each pole, at different times, contributes to one level of anisotropy and explains the peaks in the angular power spectrum of the CMB temperature anisotropy.
To formalize this idea, we will first assume that the emission spectrum of a galaxy is reduced to its strongest wavelength λ_0 which we assume to be the same for every galaxy. We will also assume that the power spectrum of the CMB is centered around its strongest wavelength Λ. These strong restrictions should still provide a decent estimate of the location of the peaks in the power spectrum.
To add to the regular background of wavelength Λ, the received light must also have observed wavelength Λ, so the source must be at a distance d that satisfies the equation

$$\frac{\lambda_0}{a(d)} = \Lambda,$$

that is:

$$\frac{\lambda_0}{\Lambda} d = \mid R \sin(\frac{d}{R}) \mid . \tag{12}$$

The solutions of the above equation are typically close to the pole at distance $k\pi R$ from us, that we will call the pole k. For each k, there are two associated solutions d_k and d'_k, which correspond to distances from the pole k of $l_k = k\pi R - d_k$ and $l'_k = d'_k - k\pi R$. Replacing in equation 12, we obtain:

$$\begin{cases} \frac{\lambda_0}{\Lambda}(k\pi R - l_k) = \mid R \sin(\frac{l_k}{R}) \mid, \\ \\ \frac{\lambda_0}{\Lambda}(k\pi R + l'_k) = \mid R \sin(\frac{l'_k}{R}) \mid . \end{cases} \tag{13}$$

As l_k and l'_k are typically small compared to R, we get

$$\begin{cases} \frac{\lambda_0}{\Lambda}(k\pi R - l_k) \approx l_k \\ \\ \frac{\lambda_0}{\Lambda}(k\pi R + l'_k) \approx l'_k, \end{cases} \tag{14}$$

so that

$$\begin{cases} l_k = \frac{k\pi R}{\frac{\Lambda}{\lambda_0}+1} \\ \\ l'_k = \frac{k\pi R}{\frac{\Lambda}{\lambda_0}-1}. \end{cases} \tag{15}$$

Since $\frac{\Lambda}{\lambda_0}$ has a big order of magnitude ($\approx 10^4$), l_k and l'_k correspond roughly to the same distance to the pole k, that we will call again l_k:

$$l_k = \frac{\lambda_0 k\pi R}{\Lambda} \tag{16}$$

Now that we have found the typical distance of these galaxies to the pole k, we can estimate the contribution of the pole k to the anisotropy power spectrum, by computing the number of galaxies near the pole k that will imprint their mark on the CMB. To constitute an anisotropy, their image must have an observed wavelength between $\Lambda - \varepsilon$ and $\Lambda + \varepsilon$, being ε of the order of the width of the CMB spectrum.
From equation (16), these galaxies are at a distance from the pole k between

$$l_1^k = \frac{\lambda_0 k\pi R}{\Lambda + \varepsilon}$$

and

$$l_2^k = \frac{\lambda_0 k\pi R}{\Lambda - \varepsilon}.$$

Let ρ be the mean density of galaxies in the universe (we assume a homogeneous distribution of galaxies). In S^3, the volume of space between l_1^k and l_2^k is given by

$$\begin{aligned} V &= \pi R^2(2l_2^k - 2l_1^k + R\sin(\frac{2l_2^k}{R}) - R\sin(\frac{2l_1^k}{R})) \\ &\approx 4\pi R^2(l_2^k - l_1^k), \end{aligned} \tag{17}$$

so that the number of galaxies at distances between l_1^k and l_2^k to the pole k is

$$\begin{aligned} N &= k\pi\rho 4\pi R^3\lambda_0(\frac{1}{\Lambda - \varepsilon} - \frac{1}{\Lambda + \varepsilon}) \\ &\approx \frac{8\pi^2 R^3\rho k\lambda_0\epsilon}{\Lambda^2}. \end{aligned} \tag{18}$$

The number of galaxies associated to the pole k whose images are imprinted in the CMB is then $2N$, since the galaxies at distance d'_k also leave the same characteristic prints. If we assume equidistribution of the galaxies and independence between the images of the galaxies at distances d_k and d'_k, these galaxies are equally spaced on the celestial vault and their number corresponds to the multipole moment P_k for which there is a peak in the power spectrum:

$$P_k = \frac{16\pi^2 R^3\rho\lambda_0\varepsilon k}{\Lambda^2} = C_\varepsilon k. \tag{19}$$

Equation (19) shows a linear relation between P_k and k. We also predict that the strength of these peaks decreases with k, mostly because distant source undergo more extinction effects.
Overall, these results seem compatible with the measurements of the Planck collaboration [21], although we are presently not able to provide a more detailed analysis of the matter. We have made some approximations in our computations and quite strong restrictions to arrive at this result: in reality, the spectra of both galaxies and CMB are composed of a large band of wavelengths. Moreover, the density of galaxies ρ and there precise distribution may differ for the different pole regions, in particular due to the lacunary structure of the large-scale distribution of matter in the universe.

5 Conclusion and comments

We have performed an analysis of the notions of perception in general relativity, which led us to introduce a representation referential in which measurements are performed. Our theoretical framework aligns with extensive observations on a macroscopic scale, including redshift-distance diagrams and the properties of the Cosmic Microwave Background (CMB), while clearing away questions raised by the existence of an initial space-time singularity, and a dark energy that derives the galaxies away. Furthermore, the absence of a chronological history for the Universe within this model provides an explanation for the coherent structure of galaxies in the high-redshift universe, recently detected by the James Webb Space Telescope. This theory accommodates the concept of galactic dark matter entirely composed of neutrinos, a notion previously dismissed within conventional Big Bang scenarios. Our model also predicts the existence of a gravitational wave background, whose origin is analog to that of the CMB.
More complete and model-independent data-based studies are required to bring support to this theory. In particular, a careful analysis of the CMB characteristics in the present context still needs to be performed. Several complementary predictions could be verified experimentally on the short and longer run. The theory predicts for instance double images for galaxies in the antipodal region. More difficult to check at our temporal scale, the temperature of the CMB should not vary in time, and its anisotropies should move according to the characteristic dynamics of galaxies.
The fact that lengths and durations are not absolute properties of observed events but depend on the referential in which they are measured is well established since the development of relativity. The present theory constitutes an extension of the relativity principle to distant objects in curved spacetime geometries.

6 Declarations

Ethical Approval
Not applicable

Competing interests
Not applicable

Authors' contributions
TC is the only author of this manuscript

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References

[1] A. Einstein; *Kosmologische Betrachtungen zur allgemeinen Relativitatstheorie*, Naturwissenschaften 7, 232 (1919).

[2] A.S. Eddington; *On the instability of Einstein's spherical world*, Monthly Notices of the Royal Astronomical Society 90 (7), 668–678 (1930).

[3] C. D. McCoy, *Stability in Cosmology, from Einstein to Inflation*, Thinking About Space and Time 15 (2020).

[4] E.P. Hubble; *A relation between distance and radial velocity among extra-galactic nebulae*, Proc. N. A. S. 15 (3), 168-173 (1929).

[5] H. Nussbaumer; *Einstein's conversion from a static to an expanding universe*, The European Phys. Journ. H 39 37–62 (2014).

[6] J.A. Friedman, M.S. Turner, Dragan Huterer; *Dark Energy and the Accelerating Universe*, Annual Review of Astronomy and Astrophysics 46, 385-432 (2008).

[7] G.Lemaître, *Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques*, Annales de la Société Scientifique de Bruxelles A47, 49-59 (1927).

[8] A. Einstein, W. de Sitter; *On the Relation between the Expansion and the Mean Density of the Universe*, Proceedings of the National Academy of Science 18 (3), 213-214 (1932).

[9] A.A. Penzias, R.W. Wilson; *A Measurement of Excess Antenna Temperature at 4080 Mc/s*, Astrophysical Journal 142, 419-421 (1965).

[10] E.J. Copeland, M. Sami and S. Tsujikawa; *Dynamics of dark energy*, International Journal of Modern Physics D 15 (11), 1753-1935 (2006).

[11] F. Zwicky; *On the Red Shift of Spectral Lines through Interstellar Space*, Proceedings of the National Academy of Sciences 15(10), 773-779 (1929).

[12] E.L Wright; *Errors in Tired Light Cosmology*

[13] A.G. Riess, S. Casertano, W. Yuan, L.M. Macri, D. Scolnic; *Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics Beyond LambdaCDM*, ApJ 876, 85 (2019).

[14] E. Di Valentino, A. Melchiorri, J. Silk; *Planck evidence for a closed Universe and a possible crisis for cosmology*, Nature Astronomy 4, 196–203 (2020).

[15] D. Bohm, *Wholeness and the Implicate Order*, Routledge (1980).

[16] A. Einstein; *Zur Electrodynamik bewegter Koerper*, Annalen der Physik 322 (10), 891-921 (1905).

[17] G. Goldhaber et al.; *Observation of cosmological time dilatation using type 1A Supernovae as clocks*, Thermonuclear Supernovae 486 (1997).

[18] Union 2 Catalog, *http://supernova.lbl.gov/Union/Union2.html*

[19] M. E. Moreno-Raya et al, *On the dependence of type Ia SNe luminosities on the metallicity of their host galaxy*, ApJL 818 (1) 19 (2016).

[20] M. Bonamente, M.K. Joy, S.J. LaRoque, J.E. Carlstrom, E.D. Reese and K.S. Dawson; *Determination of the cosmic distance scale from Sunyaev-Zel'dovich effect and Chandra X-ray measurements of high red-shift galaxy clusters*, ApJ 647 25 (2006).

[21] Planck collaboration, *Planck 2015 results. XI. CMB power spectra, likelihoods, and robustness of parameters*, A&A 594 (2016).

[22] D. J. Schwarz et al, *CMB anomalies after Planck*, Class. Quantum Grav. 33 184001 (2016).