

Is it possible to find an inertial reference frame to determine the true age of the most distant galaxies?

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Abstract

For decades, the scientific community has recognized that our universe is expanding at an accelerating rate (Riess A. G. et al., 1998); however, in some respects, cosmology has not taken this into account. The FLRW metric assumes that time has always passed in the same way at every moment and place, that is, that the Lapse function is equal to one. In recent years, this problem has been studied in greater depth (Melia, F., 2019, 2023), demonstrating that a Lapse function equal to one is only valid for non-accelerating universes and not for accelerating ones. Therefore, errors are made when referencing times to reference frames with a Lapse function equal to one, so these times are not the true times. It is necessary to find an inertial reference frame in our accelerating universe that allows us to determine times correctly, and to find it, we must modify the Lapse function. In this work, we have studied what the Lapse function should be in order to lead to a free-fall reference frame and in it determine the true times of the ages of galaxies.

Keyword: large-scale structure of Universe, cosmology: theory, distant galaxies, Lapse function

1. Introduction

Current experimental research in cosmology has led to a difficult for the Λ CDM model. Problems such as the uniformity of the cosmic microwave background, the Hubble Tension, impossible galaxies, BAO determinations, and the parameter values of the equation of state are proving impossible to solve using the Λ CDM model. Consequently, many scientists are considering a new paradigm to address these issues. Until such a paradigm is developed, it is important to keep in mind the resources that the FLRW metric currently offers but has not yet been fully utilized. One such resource is the consideration of our universe as one of accelerated expansion

and the implications this has for determining the timescales and velocities involved.

In the FLRW metric universe, time is governed by the Lapse function, contained in the position g_{00} of the metric tensor. This value has always been considered equal to one; that is, time has been considered a symmetry that simplifies the Friedmann equations and flows uniformly at all points and in all epochs. Uniformity in space was mandated by the Cosmological Principle, but nothing was said about temporal uniformity. In 2019, Professor Fulvio Melia (Melia F, 2019) published a paper in which, following documentation by Professor S. Weinberg (Weinberg S,

1972), he analyzes the validity of a Lapse function as simple as the one used in the FLRW metric, $g_{00} = 1$, and the implications this may have. He discovers that the commoving frame to which this Lapse function leads is not an inertial frame in accelerating universes (Melia F, 2023). Therefore, in our accelerating universe, errors are being made in determining time because it is not referenced to a suitable inertial frame of reference; in an accelerated system, time dilates. It is therefore worthwhile to study this problem carefully and see how it affects the ages of the most distant galaxies, which show anomalies with respect to their compatibility with the age of the universe.

To solve this problem and determine the appropriate inertial free fall frame, we first study the Local Flatness Theorem.

At all times, we consider a Planck neighborhood, that is, a spatially flat universe (Planck, 2018).

2. Local Flatness Theorem

According to the Local Flatness Theorem (Weinberg S, 1978), (Melia F, 2019, 2023) there exists a locally inertial coordinate system $\xi_\mu(X)$ in the vicinity of any spatiotemporal point X_μ . The system ξ_μ is in free fall X_μ . Therefore, any non-inertial effect on the coordinate system x_μ — as a dilation of time— can be measured absolutely in ξ_μ . In this way, the FLRW metric results:

$$ds^2 = L^2 c^2 dt^2 - a^2(dx_1^2 + dx_2^2 + dx_3^2)$$

being $L^2 = g_{00}$, the Lapse function.

The conditions that the coordinates of the inertial free-fall frame must meet ($\xi_0, \xi_1, \xi_2, \xi_3$) with respect to of the point's coordinates, (x_0, x_1, x_2, x_3) , they are as follows:

$$d^2\xi^\alpha/dx^\mu dx^\nu = \Gamma^\lambda_{\mu\nu} d\xi^\alpha/dx^\lambda \quad (1)$$

according to the Cosmological Principle, ξ_0 is a function of time only.

Christoffel symbols being non-null:

$$\Gamma^0_{00} = (1/2L^2) (dL^2/d(ct))$$

$$\Gamma^0_{ii} = -(1/L^2c) (aa')$$

$$\Gamma^i_{i0} = \Gamma^i_{0i} = (1/c) (a'/a) = (1/c) H$$

Thus, we will demonstrate what conditions the inertial frame of free fall ($\xi_0, \xi_1, \xi_2, \xi_3$), must meet to satisfy the tensor equation (1):

$$d^2\xi^\alpha/dx^\mu dx^\nu = \Gamma^\lambda_{\mu\nu} d\xi^\alpha/dx^\lambda$$

$$\xi^0 = \int_0^{ct} L d(ct')$$

For $\alpha = \mu = \nu = 0$

$$x_0 = ct$$

$$d^2\xi^0/dx^0 dx^0 = \Gamma^0_{00} d\xi^0/dx^0$$

$$(d^2\xi^0/dx^0 dx^0) = dL/dx^0$$

$$\Gamma^0_{00} d\xi^0/dx^0 = (1/2L^2) (dL^2/dx^0)$$

$$d\xi^0/dx^0 = (1/2L^2) (2L dL/dx^0) (L) = dL/dx^0$$

The equation is fulfilled

For $\alpha = \mu = 0; \nu = i$

$$d^2\xi^0/dx^0 dx^i = \Gamma^i_{0i} d\xi^0/dx^i$$

as per the Cosmology Principle ξ^0 is a function only of time and not of position.

$$d^2\xi^0/dx^0 dx^i = 0$$

$$\Gamma^i_{0i} d\xi^0/dx^i = 0$$

The equation is valid for $i = 1, 2, 3$.

For $\alpha = 0; \mu = \nu = i$

$$d^2\xi^0/dx^i dx^i = \Gamma^0_{ii} d\xi^0/dx^0$$

the Cosmological Principle, due to the conditions of uniformity and isotropic it implies, requires that ξ^0 only depends on

time and not on position, and according to this,

$$d^2\xi^0/dx^i dx^i = 0$$

$$\Gamma^0_{ii} d\xi^0/dx^0 = (1/L^2c) (aa') d\xi^0/dx^0 = (1/L^2c) (a') L$$

in order for the equation to be fulfilled, it is necessary that $a' = 0$. Under this condition, the equation is satisfied. This restricts the FLRW metric equation to universes of $H = 0$.

3. Conclusions

In the FLRW metric, the comoving reference frame is not an inertial frame for accelerating universes like our own. Recent work has shown that a Lapse function equal to unity, as in the FLRW metric, only leads to an inertial comoving reference frame in non-accelerating or empty universes. Therefore, if we want to accurately determine measurements of time and distance, we need to reference them to a free-falling reference frame—that is, an inertial frame. This implies

developing a new, suitable Lapse function. In this work, we have studied the conditions under which a Lapse function in the FLRW metric can lead to a free-fall inertial reference frame that allows us to determine the true ages of the most distant galaxies. These galaxies, due to their proximity to the age of the universe, are impossible to explain in the LCDM model. Furthermore, since the FLRW frame, with a Lapse function equal to unity, is not an inertial reference frame, their ages determined within it are greater than their true ages (time dilates in an accelerated system). The conclusion we have reached is that the coexistence of the Local Flatness Theorem and the Cosmological Principle makes it impossible to find a Lapse function that meets both requirements. The work details how we obtained this conclusion which makes it impossible to find an inertial frame of reference for our determinations of cosmic times. What is valid at the local level (Local Flatness Theorem) is not valid at the global level (Cosmological Principle).

Data availability:

No new data were generated or analyzed in support of this research.

Conflict of interest:

The author states that there is no conflict of interest

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