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Spinorial space-time and a new approach to Friedmann-like equations

Luis Gonzalez-Mestres[1,a]

[1] *Megatrend Cosmology Laboratory, Megatrend University, Belgrade and Paris Goce Delceva 8, 11070 Novi Beograd, Serbia*

Abstract. Planck and other recent data in Cosmology and Particle Physics can open the way to controversial analyses concerning the early Universe and its possible ultimate origin. Alternatives to standard cosmology include pre-Big Bang approaches, new space-time geometries and new ultimate constituents of matter. Basic issues related to a possible new cosmology along these lines clearly deserve further exploration. The Planck collaboration reports an age of the Universe t close to 13.8 Gyr and a present ratio H between relative speeds and distances at cosmic scale around 67.3 km/s/Mpc. The product of these two measured quantities is then slightly below 1 (about 0.95), while it can be exactly 1 in the absence of matter and cosmological constant in patterns based on the spinorial space-time we have considered in previous papers. In this description of space-time we first suggested in 1996-97, the cosmic time t is given by the modulus of a SU(2) spinor and the Lundmark-Lemaître-Hubble (LLH) expansion law turns out to be of purely geometric origin previous to any introduction of standard matter and relativity. Such a fundamental geometry, inspired by the role of half-integer spin in Particle Physics, may reflect an equilibrium between the dynamics of the ultimate constituents of matter and the deep structure of space and time. Taking into account the observed cosmic acceleration, the present situation suggests that the value of 1 can be a natural asymptotic limit for the product $H\,t$ in the long-term evolution of our Universe up to possible small corrections. In the presence of a spinorial space-time geometry, no *ad hoc* combination of dark matter and dark energy would in any case be needed to get an acceptable value of H and an evolution of the Universe compatible with observation. The use of a spinorial space-time naturally leads to unconventional properties for the space curvature term in Friedmann-like equations. It therefore suggests a major modification of the standard cosmology based on general relativity. In the new cosmology thus introduced, the contribution of the space curvature to the value of H^2 is positive definite independently of the apparent sign of this curvature, and has a much larger value than the standard curvature term. Then, a cosmological constant is no longer required. The spinorial space-time also generates automatically for each comoving observer a privileged space direction that, together with parity violation, may explain the anisotropies observed in WMAP and Planck data. Contrary to frequent statements, such a signature would not be a strange phenomenon. The effect emerges directly from the use of two complex space-time coordinates instead of the conventional four real ones, and the privileged direction would correspond to the phase of the cosmic spinor. We remind here our previous work on the subject and further discuss some cosmological implications of the spinorial space-time.

[a] e-mail: luis.gonzalez-mestres@cosmology.megatrend.edu.rs

1 A puzzling situation

The present situation in Cosmology and Particle Physics is intriguing. It can raise many exciting and unconventional debates leading to new ideas and approaches that should not be ignored.

WMAP [1] and Planck [2] analyses claim basically to have confirmed the validity of standard cosmological models. At the same time, the confirmation by CERN of the existence of the Higgs boson has not been followed by any clear indication suggesting the possible detection of supersymmetric particles. LUX results [3] do not seem to confirm dark-mater patterns based on low-mass WIMPs (Weakly Interacting Massive Particles), and the recent ACME collaboration result on the electron dipole model [4] does not favour supersymmetric dark matter. The possible interpretation of the AMS (Alpha Magnetic Spectrometer) results [5] is still being debated [6].

Clearly, Planck and WMAP data require further studies after the 2013 Planck results have been made available (see [7, 8] and other recent papers by the Planck Collaboration). Although WMAP and Planck have systematically used the ΛCDM model as the basic tool for data analysis, other possible cosmological approaches [9, 10] must be explored including pre-Big Bang patterns. Suitable new cosmologies can be related to new ultimate constituents of matter such as superbradyons (superluminal preons [11]) beyond the original preon idea [12] and to new physics at ultra-high energy [13, 14] possibly generated beyond Planck scale. Actually, it is even not obvious that the notion of Planck scale still makes sense or that quantum mechanics, relativity and grand unification of standard interactions are indeed relevant at these energy and distance scales [15, 16]. The actual preon-like dynamics and the effective space-time geometry may obey substantially different physical principles [9, 11].

Similar questions can be raised about the meaning of standard concepts such as dark matter and dark energy that, according to Planck analysis, would account for 95% of the energy in our Universe. Even assuming that the recent AMS results correspond to a dark matter signature, alternatives to fashionable theories already exist [17] and dark energy is an ambiguous concept used *ad hoc* to help standard cosmology to explain data. As already emphasized in [9, 13], fundamental physics at ultra-high energy and very small distances can be different enough from standard relativity and quantum field theory (QFT) to radically change the situation concerning the cosmological constant and the cosmic forces contributing to the expansion of the Universe. Vacuum structure may be substantially different from that considered in standard QFT.

In particular, the dark energy term in the standard Friedmann equations may be hiding a leading contribution of purely geometric origin unrelated to any cosmological constant or conventional quantum field [9, 15]. The question of the role of cosmic space curvature is in this respect a major one, but measuring the actual curvature at large cosmological scales can be a very difficult task if the Universe is much larger than the observable one. The global space curvature can even be masked by more local phenomena. Even so, such a small cosmic space curvature generated beyond standard matter and without the conventional space-time geometry may turn out to provide the leading contribution to the expansion of the Universe [9, 18] contrary to standard expectations.

Inflation is often presented as having been confirmed by Planck and WMAP data, but the actual situation seems extremely unclear in spite of the remarkable effort in model building for more than thirty years. Pre-Big Bang cosmologies with a new fundamental space-time geometry and new ultimate constituents of matter can naturally provide suitable alternatives to inflation [9, 11] avoiding all the standard problems that led to such a hypothesis within the conventional cosmological framework.

More globally, the conventional ΛCDM cosmology used in WMAP and Planck analyses leads to a conceptually unclear situation for the ratio between relative velocities and distances at cosmic scales given by the Lundmark-Lemaître-Hubble (LLH) constant (see [9, 19] and references [20] to [24]). In the ΛCDM approach, the value of the LLH constant from Friedmann equations depends crucially on a set of poorly identified phenomenological parameters. On the contrary, if H is the LLH constant and t the age of the Universe, the product $H\,t$ can be identically equal to 1 in other cosmological geometries already before introducing matter, energy and gravitation [9, 10]. No cosmological constant is then needed, while the cosmological constant is a source of trouble in standard cosmology.

1.1 Towards a new cosmology?

Even assuming the existence of a realistic physical concept similar to the cosmological constant, in alternative approaches to quantum field theory [9, 27] one can expect this phenomenon to be generated only in the presence of standard matter. The ultimate vacuum may be made of more fundamental objects not obeying QFT, with a ground-state structure that does not incorporate standard bosons (including their zero modes) as permanent condensates. In this case, the contribution of the new cosmological constant to Friedmann-like equations will decrease like the matter density as the Universe expands, and the relation $H = t^{-1}$ will be preserved in suitable space-time patterns as a limit at large t [9, 10] except if new (small) corrections to the effective geometry must be taken into account.

It is not difficult to conceive patterns escaping the usual cosmological constraints. Starting from the standard Friedmann equations [25, 26], we can consider the relation :

$$H^2 = 8\pi\, G\, \rho/3 - k\, R^{-2}\, c^2 + \Lambda\, c^2/3 \quad (1)$$

where $H = a_s^{-1}\, da_s/dt$ is the LLH constant, a_s the scale factor, G the gravitational constant, ρ the energy density associated to standard matter, c the speed of light, $k\, R^{-2}$ the curvature parameter, R the present curvature distance scale of the Universe (the curvature radius, and possibly the radius of the Universe, for $k = 1$) and Λ the cosmological constant.

Then, taking $\rho = 0$, $\Lambda = 0$ and $a_s^{-1}\, da_s/dt = R^{-1}\, dR/dt$ leads for $k = -1$ (negative curvature, hyperbolic space) to the identity $H\, t = 1$ with the simple relation $dR/dt = c$. But such a result does not appear to be compatible with cosmological observations, as the value $R = c\, t$ would be too small for a realistic fit to data. The problem can potentially be solved [10] replacing c by a much larger constant c', but this implies abandoning the standard Friedmann formulation based on a direct extrapolation from general relativity and on the role of c as a universal critical speed.

Starting from a positive space curvature, the spinorial space-time (SST) geometry we introduced in 1996-97 [28, 29] yields a more clear result concerning the possible geometric origin of the relation $H = t^{-1}$ where the cosmic time t is now given by the modulus of a cosmic SU(2) spinor (or a function of this modulus). The cosmic space at time t is described by the associated hypersphere with a natural positive space curvature and no critical speed at that stage. The law $H = t^{-1}$ holds then automatically in the absence of matter and cosmological constant [9, 15], just as in the previous negative curvature example. The associated Friedmann-like equation equivalent of (1) is then:

$$H^2 = -\, dH/dt \quad (2)$$

where $-\, dH/dt = t^{-2}$ is a positive curvature term from the SST geometry, with a sign contrary to that expected from the standard Friedmann equations and much larger in modulus due to the explicit identity between the cosmic time and the radius of the Universe.

Thus, in the SU(2) spinorial space-time the inverse square of the age of the Universe plays the role of the Friedmann-like curvature term replacing from the beginning the expression $-\, k\, R^{-2}\, c^2$ in the equation equivalent to (1). In this way, the ratio $c\, R^{-1}$ is directly replaced by an independent inverse time scale and the − sign multiplying the space curvature term is removed. The curvature term is now positive for $k = 1$. As already stressed, no space units, critical speed(s), matter, relativity and gravitation have been introduced yet. Standard matter and a cosmological constant are not required in order to get a sensible value of H. Indeed, SST appears to give rise to a new cosmology.

Another specific property of the spinorial space-time is the existence of a privileged space direction for each point of the cosmic space-time [9, 15]. This is a direct consequence of the use of two complex coordinates, instead of the usual four real ones, to describe the cosmic space-time position. Cosmic SU(2) transformations correspond to space translations, and the privileged space direction is associated to the SU(2) generator that leaves unchanged the space-time position spinor [15, 29]. Space translations following this generator leave the cosmic space-time position spinor invariant up to a complex phase. Thus, the possible existence of a privileged space direction in WMAP and Planck data on Cosmic Microwave Background (CMB) should not be considered as a strange phenomenon even if further data and analyses are required to confirm and interpret such a result.

Together with parity violation [18, 30], this basic property of the cosmic spinorial space-time, again previous to the introduction of standard matter and relativity, can indeed be at the origin of the asymmetry in the average temperatures on opposite hemispheres of the sky (therefore defining a privileged space direction) possibly confirmed by Planck [31] after previous WMAP observations. The fact that such a natural effect may look surprising from a conventional point of view suggests that the fundamental principles of Cosmology possibly remain to be explored and explicitly formulated.

2 The spinorial space-time (SST)

Although the use of spinors in Particle Physics to describe fermions is very old [32, 33], and the most fundamental presently known standard matter fields have spin 1/2, the basic description of space-time has remained based on the conventional four real numbers describing integer angular momenta: a time dimension and three space dimensions. However, particles with half-integer spin are not, strictly speaking, representations of the real SO(3) rotation group. In [28, 29], we suggested to replace this standard real four-dimensional space-time by the complex two-dimensional one actually felt by spin-1/2 particles. The standard rotation group SO(3) for space dimensions is then replaced by the spinorial SU(2) allowing spin-1/2 particles to be representations of the actual rotation group. Such a natural choice turns out to have important cosmological implications [10, 30].

2.1 A privileged space direction

In our original formulation of the spinorial space-time (SST), it was necessary [29] to elucidate how the usual four real space-time coordinates would be related to the two complex coordinates of the SU(2) spinor ξ. We then were led to first consider: i) the SU(2) invariant $\mid \xi \mid^2 = \xi^\dagger \xi$ where the dagger stands for hermitic conjugate; ii) the vector $\vec{\mathbf{z}} \;=\; \xi^\dagger \vec{\sigma} \xi$ where $\vec{\sigma}$ is the vector formed by the Pauli matrices. The role of both expressions had to be carefully determined.

In [28], we had already proposed to interpret $t = \mid \xi \mid$ as the cosmic time. Then, one has: $z = t^2$ where z is the modulus of $\vec{\mathbf{z}}$. Actually, other definitions of t in terms of z (i.e. $t = z$) are also possible and lead to the same physical results provided the definition of space coordinates is adapted to that of the cosmic time. The point $\xi = 0$ corresponds to the cosmic time origin in a naturally expanding Universe were the speed of light is not an intrinsic fundamental constant and inflation is no longer needed. Because of the pre-existing spinorial geometry, the S^3 hypersphere at constant t incorporates an additional structure with a privileged space direction associated to each comoving observer.

It immediately turned out [29] that it was not possible to interpret $\vec{\mathbf{z}}$ as providing the space coordinates: one coordinate, corresponding to an overall phase of the cosmic spinor, was missed by both

t and $\vec{\mathbf{z}}$. Therefore, a different description of space was necessary on the S^3 hypersphere of constant t . The vector $\vec{\mathbf{z}} = \xi^\dagger \vec{\sigma} \xi$ turned out to be the tangent direction of a whole cosmic trajectory naturally associated to the cosmic spinor ξ . Such a direction corresponds locally to the σ matrix that leaves ξ invariant. Thus, the privileged space direction immediately emerged when trying to define space coordinates in [29], as a natural consequence of the additional geometric structure carried by the S^3 hypersphere of constant t obtained from the SST. The additional geometric structure was just the expression of the original complex coordinates. This point was further developed in the 2011 Post Scriptum to [15], and reminded in [9] before the Planck announcement [31]. The SST prediction of a privileged space direction for each commoving observer may have been confirmed by Planck data. As reminded in [18, 30], parity violation is also expected to play a crucial role.

2.2 Space in the constant-time hypersphere

The standard real space coordinates are then generated locally in the SST [29]. The SU(2) transformations of a cosmic spinor ξ correspond to curved space translations leaving unchanged the space-time origin $\xi = 0$. Relative space coordinates are defined in this way through the parameters of the relevant cosmic SU(2) rotation. Conventional space rotations of these coordinates around a fixed space-time point ξ_0 are then SU(2) transformations acting on the SU(2) group itself. The distance between two points on the space hypersphere at $t = t_0$ is given by t_0 times the angle θ separating the two points in a circle of radius t_0 . As a 2π SU(2) rotation changes the sign of the spinor ξ_0 , the value $\theta = 2\pi$ corresponds to the antipodal space-time position $-\xi_0$.

On the S^3 $\xi = t_0$ hypersphere and taking $\xi = \xi_0$ as the space origin (the observer position), a point ξ can be described [29] as :

$$\xi = U \xi_0 \tag{3}$$

where U is a SU(2) transformation. Writing:

$$U = exp\,(i/2 \ \ t_0^{-1} \ \vec{\sigma}.\vec{\mathbf{x}}) \equiv U(\vec{\mathbf{x}}) \tag{4}$$

the vector $\vec{\mathbf{x}}$, with $0 \leq x$ (modulus of $\vec{\mathbf{x}}$) $\leq 2\pi\, t_0$, can be naturally interpreted as the position vector at constant time t_0 . The privileged space direction just defined corresponds to the set of values of $\vec{\mathbf{x}}$ such that $U(\vec{\mathbf{x}})\ \xi_0 = exp\ (i\ \phi)\ \xi_0$ where $exp\ (i\ \phi)$ is a complex phase factor. Such a definition is invariant under SU(2) transformations and remains stable under comoving time evolution. Using the equivalent definition (local tangent direction) provided by the vector $\mid \xi_0 \mid^{-2}\ \xi_0^\dagger\ \vec{\sigma}\ \xi_0$, the value of $\mid \xi \mid^{-2}\ \xi^\dagger\ \vec{\sigma}\ \xi$ is common to all points ξ lying on the privileged space trajectory and on its comoving equivalents.

Under a SU(2) transformation V turning $\vec{\sigma}.\vec{\mathbf{x}}$ into $V\ \vec{\sigma}.\vec{\mathbf{x}}\ V^{-1}$ (the vector representation), the operator U defined in (4) transforms into VUV^{-1} (space rotation around ξ_0). The vector $\vec{\mathbf{v}}$ obtained from the equation $V = exp\ (i/2\ \ \vec{\sigma}.\vec{\mathbf{v}})$ defines the rotation axis and angle. Acting on position vectors, the SU(2) transformations are actually SO(3) rotations. $\vec{\mathbf{x}}$ provides the space coordinates of ξ with respect to ξ_0 and transforms like a SO(3) real vector [29].

2.3 Cosmology

Cosmologically comoving frames naturally appear in the SST and correspond to straight lines through the cosmic origin $\xi = 0$. They provide local privileged rest frames. At the stage considered here, the spinorial space-time does not require the introduction of any critical speed. The cosmic time is actually the only physical dimension and the distance between two comoving observers on the S^3 hypersphere is proportional to t times the angular separation as seen from the space-time origin

$\xi = 0$. This automatically leads to: i) a constant relative speed between two comoving observers given by their angular separation; ii) a universal ratio between relative velocities and distances among comoving observers for a given value of t (the LLH law defining the LLH constant H).

Then, the $H\,t = 1$ law automatically follows in the absence of standard matter and of a cosmological constant [9, 15]. Such a strong result is close to Planck data that suggest $H \simeq 67.3$ km/s/Mpc and $t \simeq 13.82$ Gyr leading to $H\,t \simeq 0.95$.

The $H\,t = 1$ relation can thus be a suitable limit for the evolution of the Universe, as the standard matter density is expected to decrease with the Universe expansion faster than the SST curvature term [10, 18]. Since no critical speed has yet been introduced, the Universe corresponding to the cosmic SST can be naturally assumed to be much larger than our visible Universe.

As discussed above, another important cosmological implication of the SST geometry is the existence of a privileged space direction for each commoving observer. Standard cosmology using only real space-time coordinates cannot exhibit such a geometric property, as the possible memory of an underlying spinorial space-time structure is lost from the beginning by such an approach. It is therefore crucial to elucidate if the asymmetry between opposite hemispheres of the sky observed by Planck [31] has a primordial origin or corresponds to a more accidental phenomenon.

3 Standard relativity and SST Cosmology

An essential characteristics of the SST is the fact that it naturally incorporates a cosmic space curvature previous to the introduction of matter and relativity. Furthermore, no global Lorentz symmetry appears to be required as local preferred reference frames exist in standard Cosmology.

Then, conventional relativity is not necessarily a global cosmic law and may instead just correspond to the space-time structure felt locally by standard matter at low energy [11, 16]. The SST structure would also be dominant at very small distances and manifest itself in particular in the internal structure of spin-1/2 particles generating a spinorial wave function [15].

If the SST geometry is the expression of some form of preonic vacuum, standard matter can nucleate during a specific period of the history of the Universe corresponding to a new form of the conventional Big Bang. Thus, the spinorial space-time appears as a natural framework for pre-Big Bang patterns. It may then happen that standard matter does not nucleate everywhere in the Universe, but only in some regions, and that vacuum is not really homogeneous at very large cosmic scale. If so, the whole Universe would not be really homogeneous and isotropic as usually assumed. Finding possible signatures of such a situation would be a major cosmological challenge.

The introduction of a spinorial space-time implies by itself an unavoidable modification of the cosmological equations derived from general relativity, as the curvature tensor does no longer vanish in the absence of standard matter and of a cosmological constant. Therefore, the Einstein field equation [34, 35]:

$$R_{\mu\nu} \;-1/2\; g_{\mu\nu} \;+\; g_{\mu\nu}\,\Lambda \;=\; 8\pi\,G\,c^{-4}\,T_{\mu\nu} \tag{5}$$

($R_{\mu\nu}$ = Ricci curvature tensor, R = scalar curvature, $g_{\mu\nu}$ = metric tensor, $T_{\mu\nu}$ = stress-energy tensor), usually considered as the starting point of modern cosmology, can no longer remain unchanged. A new term should be added to this equation accounting for the pre-existing global cosmic curvature of the SST. One can then modify (5) writing:

$$R_{\mu\nu} \;-1/2\; g_{\mu\nu} \;+\; g'_{\mu\nu}\,S \;+\; g_{\mu\nu}\,\Lambda \;=\; 8\pi\,G\,c^{-4}\,T_{\mu\nu} \tag{6}$$

where the term $g'_{\mu\nu}\,S$ describes the SST curvature term. Taking a local frame where $g'_{\mu\nu}\,S$ is diagonal with a time-like direction and three space-like directions, the structure of $g'_{\mu\nu}\,S$ is fundamentally different from standard relativity. In particular, the speed of light c does not govern the ratio between space and time components. Then, a very small SST space curvature is compatible with a dominant time-like contribution from the same $g'_{\mu\nu}\, S$ tensor to the relevant Friedmann-like equation.

3.1 A modified Friedmann equation

Such an approach does not contradict experiment. The SDSS-III Collaboration [36, 37] has recently published [38, 39] more stringent bounds on the effective cosmic space curvature. But the space-like part of the tensor $g'_{\mu\nu}\, S$ can be consistent with these bounds without questioning the leading role of its time-like component in a modified Friedmann equation as suggested by (2).

Assuming that the local comoving frames from standard cosmology are close enough to those generated by the SST cosmic geometry, a new version of the first Friedmann equation can be:

$$H^2 \; = \; 8\pi\, G\, \rho/3 \; - \; k\, R^{-2}\, c^2 \; + \; t^{-2} \; + \; K \; + \; \Lambda\, c^2/3 \tag{7}$$

where K is a correction term accounting in particular for :

- a possible small difference between the comoving frames of standard cosmology and those (pre-existing) obtained from the underlying SST cosmic geometry;

- a reaction of the nucleated standard matter to the pre-existing expansion of the Universe led by the SST geometry [9, 10];

- vacuum inhomogeneities at cosmic scale and other non-standard effects.

As the present value of $H\ t$ is close to 1, one can reasonably assume K to be small. But the situation may have been different at earlier stages of the Universe. Similar corrections will also be present in a modified second Freedmann equation where the possible difference (tending to disappear at large t) between SST and standard comoving frames can produce a significant effect.

As previously emphasized, in such a description of the Universe evolution Λ does not stand for the conventional cosmological constant from standard QFT but for a possible new concept [9, 13] associated to pre-BigBang cosmologies [40, 41] and to new fundamental Physics [17, 27].

4 SST and space curvature

Equation (7) has been formulated without considering a possible variation of the sign of the term t^{-2} on the right-hand side. As previously seen, he sign and the value of this term have been obtained [9, 15] from the S^3 spatial hypersphere naturally associated to the spinorial space-time at constant cosmic time t . But the question can be raised whether the SST may lead to a different value and sign for the contribution of the curvature term to the first modified Friedmann equation.

At the stage of the calculation leading to this curvature term, only a cosmic time scale exists and plays simultaneously the role of an effective distance scale with the spherical space structure naturally suggested by the SST geometry. No distinct distance scale or critical speed has yet been introduced. Thus, it is in principle possible to redefine the spatial distance at cosmic scale as seen by a comoving observer at a point ξ_0 on the $\xi \; = \; t$ hypersphere.

4.1 Hyperbolic coordinates in the SST

In particular, an effective hyperbolic curvature can replace the initial spherical one with a suitable redefinition of the observed distances. Contrary to the hyperspherical configuration common to all comoving observers, such a hyperbolic structure would have a privileged comoving observer. But in all cases, the spinorial structure of space-time is more fundamental and will remain unchanged by this new definition of distances on the S^3 hypersphere.

If D is the cosmic distance on the space hypersphere corresponding to the angular distance θ times t [9, 15] and leading to the LLH law [10, 15], a possible alternative to this natural definition would be to send to infinity, from the point of view of the spatial distance on the S^3 hypersphere, the antipodal point $-\xi_0$ ($\theta = 2\pi$) as seen by the comoving observer based at ξ_0 . This transformation turns $D = \theta t$ into a new definition of distance, D', such as for instance:

$$D^2 = 4\pi^2 \mid \xi_0 \mid^2 D'^2 (4\pi^2 \mid \xi_0 \mid^2 + D'^2)^{-1} \tag{8}$$

$$D'^2 = 4\pi^2 \mid \xi_0 \mid^2 D^2 (4\pi^2 \mid \xi_0 \mid^2 - D^2)^{-1} \tag{9}$$

leading to :

$$D'^2 = 4\pi^2 \mid \xi_0 \mid^2 \theta^2 (4\pi^2 - \theta^2)^{-1} \tag{10}$$

$D = 2\pi \mid \xi_0 \mid$ ($\theta = 2\pi$) corresponds to $D' = \infty$ and the spherical curvature can thus become a hyperbolic one. The LLH law and the $H\,t = 1$ equation remain unchanged by this redefinition of distance where D' is proportional to t.

The standard orthogonal coordinates $x = t \sin(\theta/2)$ and $y = t \cos(\theta/2)$, where θ is the angular distance to ξ_0 , can then be replaced by suitable new coordinates x' and y' such that:

$$(dD')^2 = (dx')^2 + (dz')^2 \tag{11}$$

A hyperbolic geometry can be built writing:

$$x' = \alpha \mid \xi_0 \mid [exp(w) - exp(-w)] \tag{12}$$

$$y' = \alpha \mid \xi_0 \mid [exp(w) + exp(-w)] \tag{13}$$

$$y'^2 - x'^2 = 4\alpha^2 \mid \xi_0 \mid^2 \tag{14}$$

where α is a constant and w a new variable. One has then:

$$(dD'/dw)^2 = 2\alpha^2 \mid \xi_0 \mid^2 [exp(2w) + exp(-2w)] \tag{15}$$

allowing also to relate w and θ. With $w = 0$ for $\theta = 0$ and taking small values of both variables, one gets:

$$(d\theta/dw)^2 \simeq 4\alpha^2 \tag{16}$$

so that $d\theta/dw \simeq 1$ for $\alpha = 1/2$.

This is just an example of a possible hyperbolic structure generated from the spinorial space-time and using $\mid \xi_0 \mid$ as the natural distance scale. Another possibility in order to generate a hyperbolic curvature would be to send to infinity, from the point of view of distance as seen by the observer, a whole circle of the spatial hypersphere writing:

$$D'^2 = 4\pi^2 \mid \xi_0 \mid^2 D^2 (4\lambda\pi^2 \mid \xi_0 \mid^2 - D^2)^{-1} \tag{17}$$

where $0 < \lambda < 1$.

Then, one gets:

- $D' = \infty$ for $D = 2\pi\,\lambda^{1/2} \mid \xi_0 \mid$
- an imaginary D' for larger values of D.

In particular, no signal traveling in space from comoving points at $D > 2\pi\,\lambda^{1/2} \mid \xi_0 \mid$ can ever reach the comoving observer at ξ_0 . However, this hidden region of the Universe remains connected to the observer through the spinorial coordinates in potential causality-violating paths.

4.2 Some consequences

As the new definitions of the spatial distance just considered remain equal to $\mid \xi_0 \mid$ times a function of θ, the relation $H = t^{-1}$ is preserved together with the spinorial space-time structure.

Thus, contrary to conventional patterns, the spinorial space-time can account for both spherical and hyperbolic space curvatures with the same (dominant) positive-definite curvature term in the Friedmann-like equation and the $H = t^{-1}$ law in the absence of matter and of a cosmological constant. In particular, the curvature term t^{-2} in (7) turns out to be related to the primordial space-time geometry and not to the space curvature directly observed.

Similarly, as the underlying SST structure is not modified by the coordinate transformation, nothing in the transition from spherical to hyperbolic curvature appears to remove the existence of a privileged space direction for each comoving observer. Comoving observers will remain defined by the original SST geometry and the change in the definition of distances will not modify the LLH law.

A potentially significant difference between the spherical and hyperbolic views of space with the underlying spinorial space-time geometry is that the spherical description with positive curvature is generated as a direct consequence of the mathematical spinorial structure and is the same for all comoving observers. This is not the case of the hyperbolic structure that is specific to each observer even in the choice of the (antipodal) point sent to infinity.

Such unconventional properties of the Cosmology based on the spinorial space-time clearly indicate the presence of a more fundamental geometry than that usually considered in theories obtained from standard relativity. This ultimate geometry would play a crucial role in both particle structure and the origin of our Universe. Further work in this direction is obviously required.

5 Conclusion

The indications from Planck and WMAP suggesting the existence of a privileged space direction as predicted by the spinorial space-time, together with the automatic implementation of the LLH law and of the $H\,t = 1$ relation in the SST approach irrespectively of the apparent sign of the space curvature, are encouraging properties from a phenomenological point of view.

Further confirmation of the observational evidence [31] for a privileged space direction seems necessary, as well as a careful study of the structure of this phenomenon. It also remains to be checked in practice if the new (SST) curvature term in the modified first Friedmann equation (7) can successfully replace the conventional cosmological constant in a global phenomenological description of the Universe. Alternative cosmological models should be built and compared with observation.

In any case, the fact that the SST approach can account for both spherical and hyperbolic descriptions of the observed space with the same (leading) cosmological weight of the space curvature in (7) and the same law relating H and t is a new and promising feature. These basic properties turn out to be directly related to the structure of the new ultimate space-time geometry provided by the SST.

Another encouraging feature of the SST approach is that it provides the potential space-time expression of a new fundamental vacuum structure beyond standard QFT, possibly associated to new ultimate constituents of matter and allowing to avoid the cosmological constant problem [9, 40]. Explicit vacuum and particle structure, and pre-Big Bang, patterns along these lines remain to be explicitly built and compared to available data.

The study of ultra-high energy cosmic rays can provide complementary relevant information [13, 14]. Possible superbradyon searches are also an important topic. In particular, cosmic superbradyons can be part of the dark matter [17] or decay emitting high-energy cosmic rays [28].

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