Pre-Big Bang, spinorial space-time, asymptotic Universe

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Abstract - Planck data can open the way to controversial analyses on the early Universe and its possible ultimate origin. Alternatives to standard Cosmology include pre-Big Bang approaches and new space-time geometries [1995 ->]. Basic issues related to a possible new cosmology along these lines deserve being discussed.

A generalization of the usual Friedmann approach using a spinorial space-time [1996 ->] deserves particular attention. The relation *H.t* = 1 where *H* is the ratio between relative speeds and distances at cosmic scale and *t* the cosmic time (age of the Universe) is automatically satisfied in the absence of matter and dark energy, and space curvature can play a stronger cosmological role than in the standard Friedmann equations. It can then be conjectured that the relation *H.t* = 1 provides the asymptotic limit of the Universe expansion as the cosmic time tends to infinity, and that the observed acceleration vanishes in this limit. Other scenarios can be considered.

also **Related papers :**

arXiv:astro-ph/9601090 , arXiv:astro-ph/9610089
arXiv:hep-ph/9610474 , physics/9702026 ,
physics/9704017
arXiv:09020994 , arXiv:0905.4146 ,
arXiv:0908.4070 , arXiv:0912.0725 ,
arXiv:1011.4889 , arXiv:1110.6171 ,
arXiv:1202.1277 ,
HEP 2011 EPS-HEP2011_479 (PoS)
ICFP 2012, mp_arc 13-18 and mp_arc 13-19
***Planck data, spinorial space-time and asymptotic universe*, mp_arc 13-33**

Beyond the notions of Big Bang and Planck scale ?

More than eighty years after the Big Bang (quantum) hypothesis formulated by Georges Lemaître :

G. Lemaître, *The Beginning of the World from the Point of View of Quantum Theory*, *Nature* 127, 706 (1931).

and, on the expansion of the Universe :

G. Lemaître, *Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques*, Ann. Soc. Sci. Brux. A 47, 49 http://adsabs.harvard.edu/abs/1927ASSB...47...49L

E. Hubble, *A relation between distance and radial velocity among extra-galactic nebulae*, PNAS 15, 168 (1929).

WMAP, Planck and subsequent programs may allow to explore the origin of the Universe, as well as the structure of matter and space-time, beyond the "primeval quanta" and, possibly, beyond quantum mechanics, relativity...

Together with UHECR experiments.

MANY OPEN QUESTIONS :

- Is there a « grand unification » of standard particles and interactions ?

- How « ultimate » are standard particles ? What can be beyond them ?

- How ultimate are standard principles of Physics? Is there a new physics beyond standard quantum mechanics, relativity… ?

- Does the Planck scale itself make sense ?

- What can be the ultimate space-time geometry ? What can be its cosmological role ?

(…)

Space-time as seen by « elementary » particles

Standard Particle Physics and Cosmology use a space-time with four real dimensions.

But in the real world, spin-1/2 particles seem to « see » a spinorial space-time described by two complex dimensions.

For space rotations, the spinorial SU(2) group contains twice the standard SO(3) : a 360 degrees rotation changes the sign of the spinor.

May look like a minor difference, but… Are there other (more subtle) differences ?

Why not to use a spinorial space-time instead of the conventional one ?

SPINORIAL SPACE-TIME

Half-integer spins exist in Nature, they cannot be generated through standard orbital angular momentum. => What is "inside" the standard particles assumed to be "elementary" ?

=> A possible way to start exploring fermion structure :

- **Replace the standard four-dimensional space-time by a SU(2) spinorial one, so that spin-1/2 particles become representations of the actual group of space transformations.**

- **Examine also possible cosmological implications of the spinorial space-time.**

⇒**Associate to each point of space-time a spinor ξ (two components, two complex numbers instead of the usual four real ones) with <u>a SU(2) group</u> that contains the space rotations SO(3).**

Then, extracting from a cosmic spinor ξ the scalar $|\xi|^2 = \xi^\dagger\xi$ where the dagger stands for hermitic conjugate, a positive cosmic time $t = |\xi|$ is defined => naturally expanding universe, arrow of time.

The conventional space at cosmic time t_0 corresponds to the $|\xi| = t_0$ S^3 hypersphere from the four real numbers contained in the two spinor components => local (global) SU(2) transformations provide the spinorial space rotations (translations)

TRANSLATIONS = SU(2) rotations around $\xi = 0$ at cosmic time t_0

$\xi = U\,\xi_0$ with $U = \exp\left(i/2\, t_0^{-1}\, \underline{\sigma} \cdot \underline{x}\right) \equiv U(\underline{x})$

$\underline{x}$ = position vector of ξ with respect to ξ_0

$\underline{\sigma}$ = vector of σ matrices

ROTATIONS = SU(2) transformations acting on the translations and leaving invariant a point $\xi_0 \neq 0$

$U(\underline{x'}) = U(\underline{y})^\dagger\, U(\underline{x})\, U(\underline{y})$

$\underline{x'}$ = new position vector of ξ with respect to ξ_0

$\underline{y}$ defines rotation axis and angle

No matter, no critical speed, yet.

Arbitrariness in the definition of cosmic time : *t* can also be a different fonction of the spinor modulus $|\xi|$ => f.i. $t = |\xi|^2$ closer to identifying cosmic space-time variables with : $\xi^\dagger$ (sigma quadrivector) ξ

=> Does not change the analysis that follows.

Spatial distances at a given cosmic time must be measured on the constant time S^3 hypersphere.

At this stage, no space units other than the implicit time units associated to the cosmic time $t = |\xi|$.

=> For a given age of the Universe, this geometry can describe a Universe of any size as compared to our usual distance scales.

Comoving frames in this space-time are straight lines through $\xi = 0$

The distance between two such straight lines at a given time is : angular distance x cosmic time

=> the relative velocity is given by the angular distance => Lemaître – Lundmark –Hubble law.

=> *H.t = 1* is natural law in this context, as *t* is the only available scale.

<u>A natural hypothesis :</u>

The *H.t = 1* law can remain asymptotically true at very large *t* if the matter density in the Universe decreases with time, as usually assumed.

LEMAITRE – HUBBLE LAW FROM PURE GEOMETRY

In a simple approach using the spinorial space-time with only a time scale, the Lundmark - Lemaître – Hubble constant turns out to be naturally equal to the inverse of the age of the Universe. *H.t* = 1 on purely geometrical grounds.

There is also a privileged space direction at each point of space-time (the sigma matrix of which ξ is an eigenstate) => Planck data ? =>POSTER

WHAT ABOUT STANDARD MATTER ?

A possible answer: just vacuum excitations similar to phonons, solitons… in condensed matter.

Standard relativity would be a low-energy limit of these excitations (similar to phonon Physics)

SPINORIAL SPACE-TIME LINKED TO NEW VACUUM PROPERTIES ?

A deeper vacuum structure, involving more fundamental matter or pre-matter with new physical properties (critical speed, mechanics…) and pre-Big Bang instead of inflation ?

An example : superbradyons, superluminal preons with critical speed in vacuum $c_s \gg c$ (c = speed of light), or "something" beyond them.

Standard matter would "nucleate" at some stage during the evolution of the Universe. When ? Everywhere or only in some regions?

=> A privileged local rest frame (straight line)

A NEW COSMOLOGY WITH A (NOT REALLY) NEW SPACE-TIME AND NEW PHYSICS

The speed of light *c* is no longer a fundamental quantity in space-time geometry, and no explicit reference to standard matter, relativity or gravitation is required to get the *H.t = 1* law.

The usual standard laws of Physics (relativity, quantum mechanics…) can be just a low-energy limit applying in the sectors of the Universe where standard matter has nucleated => Interaction between standard matter and the pre-existing geometry

=> could the apparent acceleration of the expansion of our Universe be just a fluctuation due to such an interaction? *H.t = 1* preserved asymptotically ?

SPINORIAL SPACE-TIME
AND SPATIAL CURVATURE

Such as just presented, the spinorial space-time accounts for a space hypersphere (positive curvature). However, no specific global space units have been introduced and a transformation is possible

= > send to infinity to antipodal point (ξ rotated by 360 degrees) => turns the hypersphere in to a hyperbolic structure

For a distance d on the hypersphere bewteen 0 and $\pi\ |\xi|$, replace d by d' with a relation of the type

$$d^{\,2} = \pi^2\ |\xi|^2\ d'^{\,2}\ (\pi\ |\xi|^2 + d'^{\,2})^{-1}$$

USUAL FRIEDMANN-LIKE EQUATIONS

First Friedmann equation :

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

$H = a_s^{-1}\, da_s/dt$ = LLH constant

a_s = scale factor

G = gravitational constant,

ρ = energy density,

$k\, R^{-2}$ = curvature parameter,

R = present curvature distance scale of the Universe (curvature radius, and possibly the radius of the Universe, for $k = 1$)

Λ = cosmological constant.

What if c is no longer a fundamental constant ?

In the cosmology based on the spinorial space-time, with $\rho = 0$ and $\Lambda = 0$, one has $H = t^{-1}$

=> t^{-2} replaces $- k R^{-2} c^2$ in the Friedmann-like equation => amounts to :

=> replacing *c* by a much larger effective speed

=> changing the sign of the curvature term

=> CAN DRASTICALLY CHANGE THE COSMOLOGICAL ROLE OF THE CURVATURE TERM IN FRIEDMANN-LIKE EQUATIONS.

IN PARTICULAR :

=> NO NEED FOR DARK MATTER AND DARK ENERGY AT THAT STAGE, AS THE CURVATURE TERM ALONE CAN GENERATE THE RIGHT VALUE OF *H* => NO NEED FOR A COSMOLOGICAL CONSTANT

THE COSMOLOGICAL CONSTANT IS NO LONGER NEEDED, EVEN FROM THE POINT OF VIEW OF PARTICLE PHYSICS (different vacuum dynamics)

ALSO, A NEW APPROACH TO THE SIGN AND WEIGHT OF THE CURVATURE TERM :

-The spinorial space-time can describe both spherical and hyperbolic space configurations, having in both cases the relation *H.t = 1* in the absence of matter and dark energy.

-The contribution to the curvature term in a Friedmann-like equation is the same in both cases, has the same (positive) sign and is able to play a leading role.

ON COSMIC ACCELERATION

In the ΛCDM model, cosmic acceleration is linked to the second Friedmann equation:

$$A = - 4/3\ \pi G\ (\rho\ + 3\ p_U c^{-2}) + \Lambda\ c^2/3$$

$A = dH/dt + H^2 = a_s^{-1}\ d^2 a_s / dt^2$

p_U **= pressure parameter**

Dark energy contributions decreasing like the matter density as the Universe expands would not alter the relation $H = t^{-1}$ as a limit at large t .

New forms of Λ consistent with this requirement would still be acceptable (new vacuum Physics)

BUT WHY THE PRESENT ACCELERATION ?

New mechanisms can be imagined to explain the observed cosmic acceleration in our region of the Universe. In particular, a new term describing the reaction of standard matter to the pre-existing geometric expansion of the Universe can provide a natural way out, together with a term describing the counter-reaction of the geometry itself.

As an example, two possible phases :

- **1. In our region of the Universe, standard matter opposes to the Universe expansion and slowers it down around us.**

- **2. As the matter density decreases, its reaction to the pre-existing space-time geometry becomes weaker. At some point, the counter-reaction of the geometry becomes stronger and the Universe expansion starts accelerating until it reaches the asymptotic *H.t = 1* law.**

Observed approximate value : *H.t = 0.96*

CONCLUSION AND COMMENTS

Considering a possible pre-Big Bang, as well as possible new ultimate constituents of matter and a new fundamental space-time can lead to important effects and to a new approach to cosmological observations => Where does the *H.t = 1* law really come from ? What will it become ?

It is of fundamental importance to elucidate the ultimate real origin of the expansion of our Universe => is it standard cosmology, or a more primordial geometry such as the spinorial space-time considered here ?

Considering the intrinsic properties of the spinorial space-time and the purely geometric origin of this property, we conjecture that the *H.t = 1* law will remain valid as *t* tends to infinity, up to possible small corrections.