Pre-Big Bang, fundamental Physics and noncyclic cosmologies

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Abstract - WMAP and Planck open the way to unprecedented Big Bang phenomenology, not only for the standard Big Bang scenario but also for less conventional approaches including pre-Big Bang cosmologies. 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)

A detailed study of WMAP and Planck data can have significant implications for noncyclic pre-Big Bang approaches incorporating : i) a new fundamental scale (or a "zero scale") beyond the Planck scale ; ii) potentially, new ultimate constituents of matter with unconventional basic properties as compared to standard particles.

=> superbradyons, critical speed $c_s >> c$ (speed of light) ?

Superbradyons = nonstandard preons.

Alternatives to standard physics can be considered from a cosmological point of view. In particular : the structure of the physical vacuum, the nature of space-time, the origin and evolution of our Universe, the validity of quantum field theory and conventional symmetries, unconventional solutions to the cosmological constant problem, the validity of inflationary scenarios, the need for dark matter and dark energy, the interpretation of string-like theories...

=> How "global" and "universal" is our present cosmology

Lorentz-like symmetries for the properties of matter may correspond to naturally stable space-time configurations resulting from more general primordial scenarios that incorporate physics beyond the Planck scale and describe the formation and evolution of the physical vacuum.

Also, a possible answer to the question of the origin of half-integer spins can be provided by a spinorial space-time with two complex coordinates instead of the conventional four real ones => half-integer orbital angular momentum. Taking the cosmic time to be the modulus of a SU(2) spinor automatically leads to an expanding universe, with a ratio between cosmic relative velocities and distances equal to the inverse of the age of the Universe. New version of the Lemaître – Hubble law => But in this case => No reference to standard matter, hidden fields, gravitation or relativity is required to get this purely geometric result that looks quite reasonable from an observational point of view.

Naturally => A universe with "small" or "very small" positive curvature (at global scale).

We discuss basic ideas and phenomenological issues for noncyclic pre-Big Bang cosmologies in the present context, focusing in particular on their potentialities as alternatives to standard dark matter and dark energy patterns.

The cosmological implications of more general patterns involving violations of standard fundamental principles (relativity, quantum mechanics...) at energies close to Planck scale are also considered. (end of the abstract)

Previous papers : Invisible Universe 2009 arXiv:0912.0725 http://pos.sissa.it/archive/conferences/134/479/EPS-HEP2011_479.pdf (HEP 2011) ; Planck 2011 arXiv:1110.6171 CRIS 2010 arXiv:1011.4889 (including my arXiv addenda)

Beyond Big Bang and Planck scale ?

More than eighty years after the Big Bang 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 and Planck data may allow to explore the origin of the Universe, as well as the structure of matter and space-time, beyond the "primeval quanta" => a long-term program beyond WMAP and Planck ?

=> Explore noncylcic pre-Big Bang patterns with a possible new era before the Big Bang, new properties of matter and a new space-time structure beyond Planck scale. => Alternatives to standard cosmology, relativity, inflation, dark matter and dark energy.

Other fundamental principles and conventional basic hypotheses can then be questioned : quantum mechanics, quark confinement, energy and momentum conservation, vacuum homogeneity and "static" properties, effective space dimensions...
=> Possible effects that can be tested in high-energy cosmic-ray experiments (=> thursday talk).

NEW PREON PATTERNS : Contrary to early models using preons as mere building blocks with similar properties to those of standard particles, assume new preonic Physics : the superbradyon hypothesis proposed in 1995.

In his December 1979 Nobel lecture, Abdus Salam said:

"Einstein knew that nature was not economical of structures: only of principles of fundamental applicability. The question we must ask ourselves is this: have we yet discovered such principles in our quest for elementarity, to justify having fields with such large numbers of components as elementary.

Recall that quarks carry at least three charges (colour, flavour and a family number). Should one not, by now, entertain the notions of quarks (and possibly of leptons) as being composites of some more basic entities (PRE-QUARKS or PREONS), which each carry but one basic charge ? " **(Here, Salam quotes Paty and Salam and other authors)**

But why sould preons be only « building blocks » of standard particles with similar properties ?

=> Superbradyonic physics can be substantially different from standard particle theory, and superbradyons are just an illustrative example of possible new physics beyond Planck scale obeying to new laws and leading to a new Cosmology. => Therefore, all conventional fundamental principles require further experimental verification at ultra-high energies but also through possible relevant signatures from the primordial Universe.

=> Together with the cosmic-ray studies presented elsewhere, the approach we suggest here is not a purely phenomenological one. It incorporates a coherent set of possible basic hypotheses and contains the embryo of a new fundamental theory, to be made more precise as experimental information will help to clarify the situation.

=> Address also basic unsolved questions of standard particle Physics (spin 1/2…).

SPINORIAL SPACE-TIME

Half-integer spins exist in Nature, but it is well known that they cannot be generated through standard orbital angular momentum. Why this situation?

We can add integer and half-integer angular momenta, but half-integer spin comes from "elementary" spin 1/2 carried by "elementary" particles.

What is "inside" the standard particles assumed to be "elementary" ?

=> A possible way out :

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

=> Associate to each point of space-time in our Universe a spinor ξ (two components, two complex numbers instead of the usual four real ones) with a SU(2) group that contains the space rotations SO(3) and can, if necessary, be extended to SL(2,C) incorporating Lorentz-like symmetry.

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 $t = |\xi|$ can be defined which leads in particular to a naturally expanding universe, with an arrow of time.

At this stage, only a natural kind of cosmic units : the time units, even to measure distances.

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 SU(2) spinor components => SU(2) transformations provide the spinorial space rotations on this constant-time space.

No matter, no critical speed, involved 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 the idea of identifying cosmic space-time variables with : $\xi^\dagger$ (sigma quadrivector) ξ

=> Does not change the analysis that follows

LEMAITRE – HUBBLE LAW FROM PURE GEOMETRY

In such a spinorial space-time, comoving frames correspond to straight lines through the origin $\xi = 0$

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

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

With the same units, the relative velocity is given by the angular distance.

Leads to the Lemaître – Hubble law : $v / d = t_0^{-1}$ where : v = relative speed, d = spatial distance at constant t .

The Lemaître – Hubble constant turns out to be equal to the inverse of the age of the Universe.

A GOOD VALUE OF THE LEMAITRE – HUBBLE CONSTANT FROM PURE GEOMETRY

The "automatic" value obtained for the Lemaître – Hubble constant, i.e. equal to the inverse of the age of the Universe, with this simple, purely geometric, spinorial pattern is a quite reasonable one from a phenomenological point of view.

No matter, relativity, gravitation, standard interactions… has yet been introduced => could the apparent acceleration of the expansion of our Universe be just a fluctuation due to the history of these "local" parameters ?

Possible role of preonic (superbradyonic) matter, new Physics beyond Planck scale, pre-Big Bang phenomena and structures… ?

SPINORIAL SPACE-TIME AND GEOMETRY

Such as just formulated, the spinorial space-time incorporates no critical speed, nor a "relativistic" SL(2,C) pattern. => Make it "relativistic", perhaps with some finite (superbradyonic ?) critical speed, or keep the SU(2) scheme with a preferred reference frame right from the beginning ? => In both cases, standard Lorentz symmetry may be only a "local" property of standard matter and a local preferred reference frame can anyway be generated.

We can assume that the critical speed c_s of the possible new preonic constituents (superbradyons) is much larger than the speed of light *c*, just as *c* is about a million times the speed of sound. The physical vacuum would then be a material medium ultimately made of the new fundamental matter (the superbradyons), where conventional particles can exist as excitations similar to phonons, solitons...

The choice of a Lorentz metric for superbradyons with c_s as the critical speed appears natural, as other space-time metrics may produce vacuum instabilities.

For instance, if euclidean $E^2 + p^2 = m^2$ (skipping speed units) => i) the particle phase space is strongly restricted ; ii) the vacuum is made unstable by the spontaneous emission of particles with $p = m$.

=> Lorentz-like metrics can be naturally stable metric configurations for matter, spontaneoulsy generated from other initial metrics => relativity can be a (composite) expression of this phenomenon.

The spinorial space-time just described has a $t = 0$ ($\xi = 0$) point where the Universe is supposed to begin. Between this point and the Planck time, our standard principles of Physics do not in principle apply.

If $\xi = \xi_0$ is the observer position on the $|\xi| = t_0$ S^3 hypersphere, space translations on this hypersphere correspond to cosmic SU(2) transformations (rotations around $\xi = 0$) acting on the cosmic spinor space, i.e. $\xi = U\,\xi_0$ with $U = \exp(i/2\, t_0^{-1}\, \underline{\sigma} \,.\, \underline{x}) \equiv U(\underline{x})$, $\underline{x}$ = position vector, $\underline{\sigma}$ = vector of σ matrices.

The vector $\underline{x}$ is the position vector of ξ with respect to ξ_0 , and is different from the spinorial position $\xi - \xi_0$.

Simultaneously, space rotations are obtained as similar SU(2) transformations acting on $U(\underline{x})$.

=> Both space rotations and space translations are described by SU(2) transformations acting on different kinds of representations => very specific and fundamental property, different from the convetional structure of Poincaré-like groups.

INTERNAL STRUCTURE OF SPIN-1/2 PARTICLES

With the above description, a fonction of x would carry integer angular momentum, but a fonction of the spinorial position $\xi - \xi_0$ can produce a wave fonction with half-integer angular momentum.

Apparent problem : the « straigth line » path between ξ_0 and ξ crosses previous values of time (like a straight line between two points of a circle) and violates causality.

=> But such an apparent violation of causality can be allowed at very small distances and time scales (« inside » quarks, electrons…) => generate the observed spin 1/2

=> A spinorial space-time naturally allows for a description of standard "elementary" particles in terms of something like superbradyonic constituents, including "orbital" spin

=> spinorial SU(2) rotation angles between 0 and 4 π

Then, space translations - our initial SU(2) - and space rotations – the same SU(2), but acting on a local vector representation – can form a SO(4) group acting on a space where the four real directions correspond to the four real components of the space-time SU(2) spinor. The cosmic time is given by the modulus of the real SO(4) four-vector.

=> A compact (not yet relativistic) space rotation + space translation group acting on cosmic space-time => cosmic unification with internal symmetries going from SO(4) to SO(N) or to some other group ? => relativistic version, from SU(2) to SL(2,C), global or "local" ? =>…

=> New ways to possibly unify space-time and internal symmetries potentially escaping the "no-go" Coleman-Mandula theorem that applies to standard space-time with the standard Poincaré group ???

SPACE DIRECTIONS AND COSMIC SU(2)

Assume a cosmic non-relativistic SU(2), with a privileged cosmic reference frame.

Then, for each space-time position spinor ξ , it is possible to find a representation of (cosmic) sigma matrices such that ξ is an eigenstate of one of them (f.i. σ_z) => multiplying ξ by a complex phase - possible with SU(2) - does not change this situation.

=> As each SU(2) transformation acting on cosmic spinors corresponds to a space translation, σ_z can define a privileged space direction from the position of the space-time spinor ξ => Each point of cosmic space-time may keep a track from the $\xi = 0$ origin of the Universe, through a privileged space direction.

INFLATION, DARK MATTER, DARK ENERGY

A superbradyonic phase in the history of the Universe with $c_s >> c$ can naturally solve the horizon problem.

Similarly, deviations from standard field theory at ultra-high energy can solve the monopole problem.

=> In principle, no obvious need for inflation.

The spatial size of the Universe is not known *a priori*, as time units are the only ones in the spinorial description of space-time => the actual size can be very large.

The Lemaître – Hubble law is there from fundamental spinorial geometry, previous to any local cosmology, with a reasonable value of the cosmic *v* / *d* constant

=> cannot be ignored by Friedmann-like equations, even if General Relativity remains valid as a low-energy property of standard matter in the Universe around us (superbradyons will be weakly coupled to gravitation, graviton = composite…)

Similarly, the string model can be a composite pattern with an underlying superbradyonic physics or some other preonic constituent scenario.

The complexity and structure of strings may indeed suggest the existence of an underlying composite dynamics. The string picture originated initially from the dual resonance models of hadronic physics , and was then interpreted in terms of ”fishnet” Feynman diagrams involving quark and gluon lines.

arXiv:0908.4070 => H. B. Nielsen and P. Olesen, Phys. Lett. 32B, 203 (1970), B. Sakita and M. A. Virasoro, Phys. Rev. Lett. 24, 1146–1149 (1970) ...

Current string patterns could be associated to possible superbradyonic ”fishnet” diagrams. Superluminal constituents can directly replace strings at the Planck scale, or lead to an alternative theory.

General relativity will in any case be a low-energy, cosmologically "local" limit of a more involved scenario.

"Local" Friedmann-like cosmology must necessarily incorporate modifications due to the role of the fundamental spinorial space-time and of a possible pre-Big Bang era => Including the global "spinorial" expansion of the Universe just described, or possible ultimate constituents of matter implying new Physics and a new cosmological era.

=> Concerns in particular : cosmological constant, dark matter, dark energy, but also quantum fields

If the vacuum is made of superbradyonic matter, standard gauge theories and conventional symmetries (including Lorentz symmetry) will provide only a sectorial low-energy limit. The Higgs boson and the zero modes of bosonic harmonic oscillators do not need to be permanently materialized in vacuum in the absence of standard matter.

In a superbradyonic pattern, it may happen that the actual vacuum contains by itself only a little amount of standard matter fields, and that the conventional condensates of Quantum Field Theory appear only as a reaction of the vacuum to the presence of standard matter.

This would not invalidate the Casimir effect, but it would considerably change the value and the role of the standard cosmological constant.

Similarly, one can consider the possibility that the standard vector boson fields carrying the usual gauge forces would be generated from the superbradyonic vacuum state only in specific situations. Basicallly, when the nearest-neighbour couplings turn out to depend on position, time and direction due to the material presence of standard particles associated to the same family of local excitation modes. In the absence of surrounding standard particles, the vacuum structure would not follow QFT.

CONCLUSION

Considering a possible pre-Big Bang, as well as possible new ultimate constituents of matter and a new fundamental space-time, is not a purely academic exercise => it can lead to important effects in Cosmology, Particle Physics, Quantum Field Theory…

Obviously, the fundamental question is not whether this new Physics and Cosmology beyond the Big Bang and the standard model are "necessary", but whether they are true.

For instance, 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 one considered here ?

Is the electron spin 1/2 an internal, causality violating, "orbital" angular momentum ?

Etc…