BICEP2, spinorial space-time, pre-Big Bang

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Abstract – The recent experimental result by BICEP2 suggesting the possible existence of *B*-modes in the polarization of the cosmic microwave background (CMB) radiation arXiv:1403.3985, arXiv:1403.4302 - see also the published version PRL 112, 241101 (2014) - has often been interpreted, if confirmed, as an evidence for cosmic inflation and primordial gravitational waves. However, such an interpretation ignores alternative cosmologies and space-time structures, including pre-Big Bang patterns and possible new ultimate constituents of matter.

In particular, the spinorial space-time (SST) we suggested in 1996-97 (arxiv:hep-ph/9610474, arxiv:physics/9702026)

automatically generates a privileged space direction (PSD) for each comoving observer - arxiv:1011.4889 and ICNFP Proceedings 2012, 2013.

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The existence of such a PSD may have been confirmed by Planck data arXiv:1303.5083.

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This space-time geometry can naturally produce vector perturbations leading to CMB *B*-modes and providing an alternative to the tensor perturbations from gravitational waves of cosmic inflation.

We discuss the origin and implications of the PSD and the possible properties of pre-Big Bang cosmologies based on the spinorial space-time, focusing on CMB and alternatives to inflationary mechanisms.

As the SST just corresponds to a possible description of the space-time as seen by fermions,

we also consider potential links between the properties of the Universe at very large scale and the internal structure of standard "elementary" particles.

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Ultimate particle structure ⇔ Early Universe ⇔ present very large scale structure of the Universe

⇩

Go beyond the notions of Big Bang and Planck scale

⇩

Possibly : a new cosmology, a deeper structure of matter

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VACUUM STRUCTURE ? ⇔ SPACE-TIME ?

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 and 390 (PoS)
ICFP 2012 Proceedings (two articles) and references therein
ICNFP 2013 Proceedings (two articles) and references therein
and more recently :
***CMB B-modes, spinorial space-time and Pre-Big Bang* (I) and (II), mp_arc 14-16 and 14-60, and references therein**

BICEP2 : experiment and results

http://www.cfa.harvard.edu/CMB/bicep2/

BICEP2 builds on the small aperture telescope design of BICEP1, but greatly increases the number of detectors to increase mapping speed. **The BICEP2 detectors are polarization sensitive bolometers made from a pair of transition edge sensors coupled to orthogonal phased antenna arrays.** The transition edge sensors provide background-limited sensitivity at the observing frequency of 150 GHz while antenna arrays improve the scalability of the design.

http://www.cfa.harvard.edu/CMB/bicep2/instrument.html

BICEP2 observes on degree angular scales deep into the same patch of sky as BICEP1, employing cutting-edge technology to pack many more detectors onto the same size focal plane as BICEP1, thus dramatically increasing sensitivity. BICEP2 aims to measure the polarization of the cosmic microwave background (CMB) with better sensitivity than ever before.

Also : http://physics.princeton.edu/strings2014/slides/Kovac.pdf http://arxiv.org/pdf/1009.3685v1.pdf

Antenna-coupled TES Bolometer Arrays for BICEP2/Keck and SPIDER

Figure 1. (a) Array of antenna-coupled polarimeters fabricated on a 4-inch silicon wafer. Each small square (highlighted) is a complete polarimeter, for a total of 64 at 150 GHz ; (b) A polarimeter unit consists of a pair of co-locating orthogonal phased-array antennas, microstrip summing networks, microstrip lters and two TES bolometers, one for each linear polarization. The size of the polarimeter is 7.5 mm at 150 GHz.; (c) Details of the beam-forming antennas: orthogonal slot sub-antennas and summing network. The sub-antennas array format is a 12 x 12 cell for the polarimeter in (b); (d) SEM image of the thermally isolated silicon nitride island with the TES bolometer; (e) Microstrip bandpass lter.

http://www.cryogenicsociety.org/csa_highlights/bicep2_and_the_outer_edge_of_the_universe/

Cryogenic Society of America, Inc.

BICEP2 and the Outer Edge of the Universe

by Dr. Peter V. Mason, California Institute of Technology, ret. Jet Propulsion Laboratory, CSA Fellow

(…)

BICEP1 and BICEP2 had conventional LN_2/liquid helium outer baths. The Keck Array and BICEP3 have mechanical cryocoolers and thus will be much easier to maintain and service. (…)

The detector array was enclosed in the 1.2 m cryostat. Inside the cryostat was a closed-cycle three-stage refrigerator, He4, He3 and He4/He3 dilution, which achieved about 270 milliKelvin at the focal plane (…)

http://microdevices.jpl.nasa.gov/capabilities/superconducting-devices/tes-bolometers.php

TES and Cosmic Microwave Background Detection

Transition edge sensor (TES) bolometers sense small temperature changes that occur when photons are absorbed and converted to heat. The use of TESs enables arrays with a much larger number of pixels than is practical with spider-web bolometers. Sustaining its leading role in superconducting TES array technology, MDL developed and continues to improve a process to create arrays of thousands of TESs with high yield (>90 percent). These arrays are being employed on three major astro physics projects, all with the same goal: generating detailed maps of the polarization of the cosmic microwave background (CMB).

In 2009, MDL delivered TES focal plane arrays for BICEP2 (Background Imaging of Cosmological Extragalactic Polarization 2) (…) Also : http://hfi.planck.fr/article227.html http://arxiv.org/pdf/1009.3685v1.pdf

Antenna-coupled TES Bolometer Arrays for BICEP2/Keck and SPIDER

Each TES bolometer consists of Ti (Tc ~ 520 mK) and Al (Tc ~ 1.34 K) connected in series.

http://www.cfa.harvard.edu/CMB/bicep2/instrument.html

The BICEP2 telescope is a small aperture, refracting telescope, allowing for precise control of systematic effects. The telescope optics are cooled to 4K. BICEP2 relies on the same principles as BICEP1, but with new detectors which allow for closer packing onto the focal plane. BICEP2 has 512 antenna-coupled TES bolometers in the focal plane. **The focal plane is kept at 250 mK for CMB observations.**

150 GHz ⇔ 2mm wavelength

http://arxiv.org/abs/1403.3985v1 (March 17, 2014)

BICEP2 I: Detection Of B-mode Polarization at Degree Angular Scales

We report results from the BICEP2 experiment, a Cosmic Microwave Background (CMB) polarimeter specifically designed to search for the signal of inflationary gravitational waves in the B-mode power spectrum around *l* = 80. (…) The observed B-mode power spectrum is well-fit by a lensed-LCDM + tensor theoretical model with tensor/scalar ratio $r = 0.20{+0.07}{-0.05}$, with r= 0 disfavored at 7.0 σ. Subtracting the best available estimate for foreground dust modifies the likelihood slightly so that r = 0 is disfavored at 5.9 σ.

l = angular multipole

http://journals.aps.org/prl/pdf/10.1103/PhysRevLett.112.241101

PRL 112, 241101 (2014) version of 13 June 2014

Detection of B-Mode Polarization at Degree Angular Scales by BICEP2

(…) Cross correlating BICEP2 against 100 GHz maps from the BICEP1 experiment, the excess signal is confirmed with 3σ significance and its spectral index is found **to be consistent with that of the CMB, disfavoring dust at 1.7 σ. The observed B-mode power spectrum is well fit by a lensed-ΛCDM + tensor theoretical model with tensor-to-scalar ratio r = 0.20 + 0.07 − 0.05 , with r = 0 disfavored at 7.0 σ.** Accounting for the contribution of foreground, dust will shift this value downward by an amount which will be better constrained with, upcoming data sets. **(Also, a Post Scriptum added)**

Interpreting BICEP2 results

Recombination, photon decoupling : primordial CMB B-modes can be generated by vector or tensor perturbations. However, **vector perturbations are not taken into account** in inflationary scenarios :

http://cosmology.berkeley.e/du/~yuki/CMBpo

Cosmic Microwave Background Polarization:
The Next Key Toward the Origin of the Universe

(…)

Vector perturbation: Vorticity in the plasma cause Doppler shifts resulting in the quadrupole lobes in the figure. **However, vorticity would be damped by inflation and is expected to be negligible.**

(…)

But what if :

i) Cosmic inflation is replaced by an alternative scenario (pre-Big Bang…)

ii) The early Universe is not locally isotropic for some fundamental reason

???????

Even if gravitational waves can still be present :

- they are not necessarily related to inflation

- they will not necessarily dominate over vector perturbations to produce CMB B-modes

What can generate local anisotropies in the early Universe ?

- Planck result on CMB anisotropies

- Spinorial space-time

http://arxiv.org/abs/1303.5083

Planck 2013 results. XXIII. Isotropy and statistics of the CMB

(20 March 2013)

(…) Indeed, when the power spectra of two hemispheres defined by a preferred direction are considered separately, one shows evidence for a deficit in power, while its opposite contains oscillations between odd and even modes that may be related to the parity violation and phase correlations also detected in the data. Although these analyses represent a step forward in building an understanding of the anomalies, a satisfactory explanation based on physically motivated models is still lacking.

Nature News, Planck telescope peers into primordial Universe, March 21, 2013

http://www.nature.com/news/planck-telescope-peers-into-primordial-universe-1.12658

(...) **The asymmetry "defines a preferred direction in space, which is an extremely strange result", says** (...) **one of Planck's lead researchers** (...)

http://arxiv.org/pdf/1011.4889v4.pdf (September 22, 2011, in the Post Scriptum) **L. Gonzalez-Mestres, *Cosmic rays and tests of fundamental principles*, CRIS 2010 Proc.**

(...) **Thus, "looking at" the initial point of our Universe ξ = 0 from a point ξ of the present time spatial hypersphere naturally leads, in the spinorial coordinates considered here, to the definition of a privileged space direction on the space hypersphere itself.** (...)

ICFP 2012 paper, online preprint versions (28 February 2013)

http://www.ma.utexas.edu/mp_arc-bin/mpa?yn=13-18
http://hal.archives-ouvertes.fr/hal-00795588

Pre-Big Bang, fundamental Physics and noncyclic cosmologies

L. Gonzalez-Mestres

(...)

A specific cosmological property of such a spinorial space-time is [17] that to each point ξ , a privileged space direction can be associated at cosmic scale through the subspace where for any point ξ' one has:

$$\xi^{\dagger} \xi' = |\xi'| \, |\xi| \exp (i\varphi)$$

and exp ($i\varphi$), with real φ, stands for a complex phase. This subspace is generated using a matrix of which ξ is an eigenstate. Then, the privileged space direction is obtained by multiplying by an arbitrary complex phase. ([17] = L. Gonzalez-Mestres, arXiv:1011.4889) http://arxiv.org/pdf/1011.4889v4.pdf (September 22, 2011, in the Post Scriptum) **L. Gonzalez-Mestres, *Cosmic rays and tests of fundamental principles*, CRIS 2010 Proc.**

(…) Thus, ”looking at” the initial point of our Universe ξ = 0 from a point ξ of the present time spatial hypersphere naturally leads, in the spinorial coordinates considered here, to the definition of a privileged space direction on the space hypersphere itself.

The direct memory of the geometry leading to such a privileged space direction is basically lost if standard space coordinates on the constant-time hypersphere are used and standard matter is dealt with without incorporating its deepest structure as well as the most primordial origin of the Universe. However, several possible tracks from this spinorial effect in Cosmology and Particle Physics can still be considered. (…)

http://arxiv.org/pdf/1011.4889v4.pdf (September 22, 2011, in the Post Scriptum) **L. Gonzalez-Mestres,** ***Cosmic rays and tests of fundamental principles*****, CRIS 2010 Proc.**

In particular :

-**The internal structure of standard spin-1/2 particles**, as well as **their interaction properties at very small distance scales**, may contain the expression of a similar phenomenon.

- **Signatures from a pre-Big Bang era** can yield relevant information on this privileged space direction and on effects of the same origin through **WMAP, Planck and other experiments**.

- Similarly, **ultra-high energy cosmic rays** may be sensitive to both cosmological and ”beyond Planck” phenomena containing effects related to the privileged space direction.

Further work on this subject is clearly required.

BICEP2 + Planck : A double evidence for the spinorial space-time (SST) with a local privileged space direction (PSD) ?

In both cases, primordial CMB signatures?

PSD => More stable vector perturbations in the early Universe => able to generate primordial CMB *B*-modes => No need for inflation and gravitational waves

L. Gonzalez-Mestres, *CMB B-modes, spinorial space-time and Pre-Big Bang (II)* (conference site) http://hal.archives-ouvertes.fr/hal-01037854/ 22/07/14

The spinorial space-time (SST)

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 « 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…

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

SPINORIAL SPACE-TIME

Half-integer spins 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.

=> Associate to each point of space-time 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).

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 $t = |\xi|$ (or a function of $|\xi|$) is defined => naturally expanding universe, arrow of time.

The conventional space at cosmic time t_0 corresponds to the $|\xi| = t_0$ hypersurface => SU(2) transformations provide the space translations

If $\xi = \xi_0$ is the observer position on the $|\xi| = t_0$ S^3 hypersphere with the additional complex structure, 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 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 the *U* (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 conventional structure of Poincaré-like groups

Alternatives to the scenarios considered in Coleman-Mandula and Haag-Lopuszanski-Sohnius theorems to combine space-time and internal symmetries ?

=> WHAT ABOUT STANDARD RELATIVITY ? The SST approach implies a local privileged rest frame

No matter, no real space units, no critical speed, yet. *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 the four real components of : $\xi^\dagger$ (sigma quadrivector) ξ

=> But this definition actually leads to the PSD (L. Gonzalez-Mestres, arxiv:physics/9702026)

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

Comoving frames 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.

Cosmology with the SST

LUNDMARK - LEMAITRE – HUBBLE LAW FROM PURE GEOMETRY

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

WHAT ABOUT STANDARD MATTER ?

Possibly, just vacuum excitations similar to phonons, solitons… in condensed matter. Standard relativity would be a low-energy limit of the kinematics of these excitations (similar to phonon or solition Physics), even if it can hold very exactly in our sector of the Universe.

A GOOD VALUE OF THE LLH CONSTANT FROM PURE GEOMETRY

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

No matter, relativity, gravitation, standard and other 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 ? => *H.t* = 1, possibly a good asymptotic limit => Standard matter can even react to a pre-existing expansion of the Universe : such a reaction would decrease with matter density => L. Gonzalez-Mestres, *Planck data, spinorial space-time and asymptotic Universe*,
http://hal.archives-ouvertes.fr/hal-00812060 April 11, 2013

If ***H.t*** **-> 1 at large *t* up to (apparently) small corrections => What will be the role of these corrections ? => In principle, the expansion can be accelerated or slowed down.**

A basic question : cosmic time ⇔ standard matter time ? ⇔ Time dependence of the standard laws of Physics in a geometrically expanding Universe ? ⇔ Time dependence of vacuum structure around us and far away?

=> What about the cosmological constant problem ?

SST ⇔ UNDERLYING PREONS ?

F.i. superluminal preons, superbradyons with critical speed $c_s >> c$ (speed of light). Just as $c >> c_{sound}$ (speed of sound)

=> Vacuum made of superbradyonic matter

=> Standard particles, vacuum excitations

In a superbradyonic pattern, it may happen that the actual vacuum does not contain by itself 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.

Basically, as signals in such a vacuum can travel faster than light, one can imagine that standard fields exist in vacuum only in the presence of surrounding standard matter => no permanent condensates if no standard matter around => no permanent zero modes condensed for all wavelengths => a less static interaction between vacuum and standard particles

=> CAN POTENTIALLY SOLVE THE COSMOLOGICAL CONSTANT PROBLEM

=> AN EFFECTIVE COSMOLOGICAL CONSTANT DEPENDING ON MATTER DENSITY AND DECREASING AS THIS DENSITY DECREASES

=> Already suggested in my 2011 papers (f.i. the July 2011 Post scriptum to the Invisible Universe 2009 paper arXiv:0912.0725 or at HEP 2011 Grenoble)

FRIEDMANN-LIKE EQUATIONS

L. Gonzalez-Mestres, ICFP 2012, ICNFP 2013 and references therein

Already without standard matter, the SST leads to :

$dH/dt + H^2 = 0$ $\qquad$ $H = LLH$ constant

$H = t^{-1}$ $\qquad$ t = cosmic time => very large space scale

In the presence of standard matter :

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

t^{-2} leading term at cosmic scale

Λ new version of the cosmological constant decreasing like the matter density as the Universe expands

K correction term (interaction matter - expanding space, vacuum inhomogeneities, comoving frames…)

SST and high-spin fields

Assume standard particles to be bound states in an internal spinorial space-time => "angular momenta" multiples of 1/2 : 0, 1/2, 1, 3/2, 2, 5/2...

=> A NEW FIELD THEORY ?

Not only a different interaction with vacuum leading to a different cosmological constant, but also a different « new standard » (SST bound states made of preons) particle spectrum including new particle spins (not SUSY).

=> Search for such particles (accelerators, cosmic rays…), understand their dynamics

=> Develop a consistent field theory

An example of theory with high-spin fields

http://www.jetpletters.ac.ru/ps/1398/article_21196.shtml

JETP Letters 44, 622 (1986)

Gravitational interaction of massless high-spin (s > 2) fields

Vasil'ev M. A., Fradkin E. S.

In contradiction of the general opinion, a noncontradictory gravitational interaction of massless fields of high spins s > 2 exists at least in the first nontrivial order. A fundamentally new aspect of the gravitational interaction of high spins is that it is nonanalytic in the cosmological constant.

(January 2014, 160 pages)

Elements of Vasiliev theory

V.E.Didenko, E.D.Skvortsov

http://arxiv.org/abs/1401.2975

We propose a self-contained description of Vasiliev higher-spin theories with the emphasis on nonlinear equations. The main sections are supplemented with some additional material, including introduction to gravity as a gauge theory; the review of the Fronsdal formulation of free higher-spin fields; Young diagrams and tensors as well as sections with advanced topics. The shortest route to Vasiliev equations covers 40 pages.
The general discussion is dimension independent, while the essence of the Vasiliev formulation is discussed on the base of the four-dimensional higher-spin theory. Three-dimensional and *d*-dimensional higher-spin theories follow the same logic.

Some preliminary conclusions

The SST leads to the LLH *H.t* = 1 law from pure geometry : no need for standard matter or general relativity => A strong hint ?

Analyses relating BICEP2 data to cosmic inflation through primordial gravitational waves tacitly or explicitly exclude *a priori* possible primordial vector perturbations on the grounds of inflation itself.

Furthermore, pre-Big Bang scenarios can naturally generate gravitational waves but they are not taken into account in recent claims on the interpretation of BICEP2 data.

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.

Flatness problem solved by the new Friedmann-like equation.

=> In principle, no obvious need for inflation.

- A possible unification of the SST SU(2) with ultimate internal symetries?

- Specific no-go theorems?

- Do standard internal symmetries hold close to Planck scale? Or are they replaced by new Physics? (more general than the SST scenario)

The primordial CMB B-modes possibily detected by BICEP2 are not necessarily a signature of gravitational waves and, in all cases, not a compelling evidence for cosmic inflation.

Alternative cosmologies must be taken into account :

- Pre-Big Bang

- More fundamental space-time structures

- Possible ultimate constituents of matter

In particular, the spinorial space-time can account for : CMB B-modes ; a privileged space direction ; together with superluminal preons, solve the cosmological constant problem and have no need for cosmic inflation.