Big Bang, inflation, standard Physics... and the potentialities of new Physics and alternative cosmologies

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Abstract – **We present an updated review of the situation of Cosmology and Particle Physics at the light of recent experimental results and observations. Recent results and analyses of Planck and South-Pole results are examined, as well as prospects and new projects. The role of Quantum Mechanics and Relativity in the early Universe is a crucial issue. Ultra-high energy cosmic rays are also an essential subject requiring further research.**

The potentialities of new Physics and alternative cosmologies in this context are discussed, including pre-Big Bang, new approaches to space-time, possible ultimate constituents of matter and alternatives to general relativity in the large-scale Universe.

The question of the possible origin of standard fundamental principles is equally dealt with.

(See also my ICNFP 2014 talk and poster)

LHC (CMS, ATLAS) :
SEARCHES FOR NEW PHYSICS

SUPERSYMMETRY ?

OTHER PHYSICS
BEYOND THE STANDARD MODEL ?

RUN2

13 TEV CENTER-OF-MASS ENERGY

WILL THE LHC FIND SIGNATURES
OF THE PHYSICS THAT MAY DOMINATE
AT MUCH HIGHER ENERGY SCALES ?

ATLAS – CMS : POSSIBLE SIGNATURES OF DIBOSON RESONANCES (WW, WZ) with masses in the TeV region

http://arxiv.org/abs/1506.00962v2

ATLAS - Diboson resonances with masses in the range from 1.3 to 3.0 TeV are sought

http://arxiv.org/abs/1507.00013 J. Brehmer et al.

Symmetry Restored in Dibosons at the LHC?

We perform a model-independent cross-section fit to the **results of all ATLAS and CMS searches** sensitive to these final states. **We then interpret these results in the context of the Left-Right Symmetric Model, based on the extended gauge group** $SU(2)_L \times SU(2)_R \times U(1)'$, and show that a heavy right-handed gauge boson W_R can naturally explain the current measurements (…)

http://arxiv.org/pdf/1507.05299v2.pdf L.A. Anchordoqui et al.

Stringy origin of diboson and dijet excesses at the LHC

AND IN MEMORY OF YOICHIRO NAMBU :

http://arxiv.org/abs/1508.06382

Just this week :

Pre-String Theory

Paul H. FRAMPTON

(Submitted on 26 Aug 2015)

In this note, I recollect a two-week period in September 1968 when I factorized the Veneziano model using string variables in Chicago. Professor Yoichiro Nambu went on to calculate the N-particle dual resonance model and then to factorize it on an exponential degeneracy of states. That was in 1968 and the following year 1969 he discovered the string action. I also include some other reminiscences of Nambu who passed away on July 5, 2105.

ULTRA-HIGH ENERGY COSMIC RAYS (UHECR)

CAN UHECR HELP
TO UNCOVER NEW PHYSICS ?

HOW FAR CAN THE STANDARD FUNDAMENTAL PRINCIPLES OF PHYSICS BE TESTED THROUGH UHECR ?

(See my previous contributions to ICNFP and my updated CRIS 2010 paper *Cosmic Rays and Tests of Fundamental Principles*, http://arxiv.org/abs/1011.4889)

1996-97 papers :

Physical and Cosmological Implications of a Possible Class of Particles Able to Travel Faster than Light, http://arxiv.org/abs/hep-ph/9610474

Vacuum Structure, Lorentz Symmetry and Superluminal Particles, http://arxiv.org/abs/physics/9704017

A POSSIBLE SIGNATURE OF NEW PHYSICS CONSIDERED :
ESCAPE THE GREISEN-ZATSEPIN-KUZMIN (GZK) CUTOFF

POSSIBLE UHE VIOLATIONS OF STANDARD PRINCIPLES :

LORENTZ SYMMETRY VIOLATION DEFORMING THE KINEMATICS AT UHE => WOULD ALTER THE KINEMATICAL BALANCES AND PREVENT GZK REACTIONS

ALSO, SPONTANEOUS DECAYS OF SUPER-HEAVY OR SUPER-ENERGETIC (SUPERLUMINAL) OBJECTS

OTHER POSSIBILITIES - ULTRA-HIGH ENERGY VIOLATIONS OF : STANDARD QUANTUM MECHANICS, UNCERTAINTY PRINCIPLE, ENERGY AND MOMENTUM CONSERVATION, EFFECTIVE SPACE-TIME DIMENSIONS, STANDARD VACUUM DYNAMICS AND PARTICLE PROPAGATION, …

NO OBSERVED VIOLATION OF THE GZK CUTOFF, BUT THE EXPERIMENTAL SITUATION REMAINS UNCLEAR

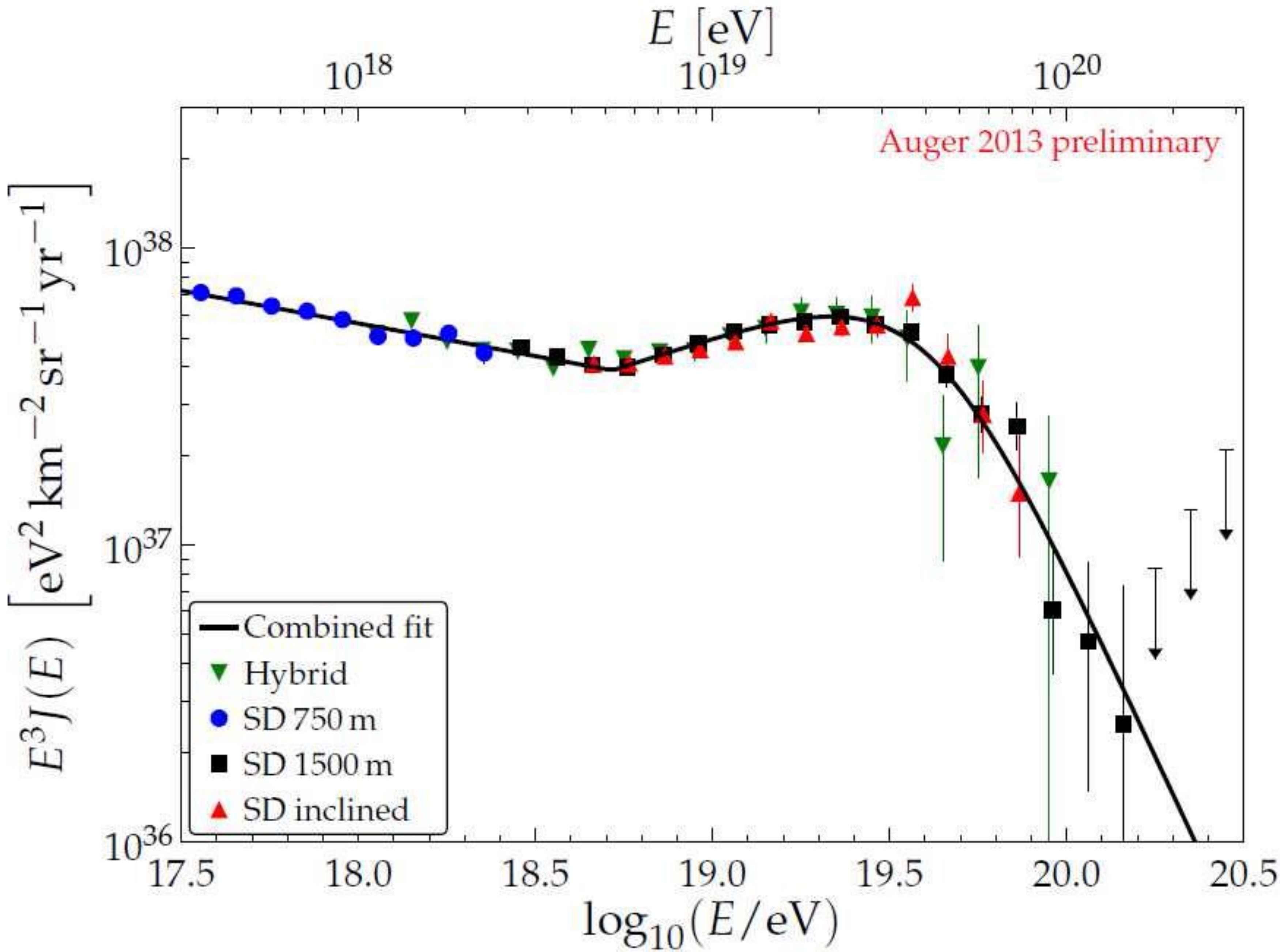
http://arxiv.org/abs/1503.09173

Recent results from the Pierre Auger Observatory

Abstract
The results obtained after the first decade of operation of the Pierre Auger Observatory are reviewed.

(…)

The **high-energy suppression** is also clearly seen in figure 1, being the significance of the departure from the extrapolation of the power-law observed at lower energies of more than 20σ. **The interpretation of this suppression is still not clear**, because it could be related to the predicted **GZK suppression** of a proton component attenuated by photo-pion processes off the CMB or to the **attenuation of heavy nuclei, such as Fe, by photo-disintegration effects.** It could also be affected by a **limiting maximum acceleration at the sources themselves**, which could not only modify the scenarios just mentioned but could also for instance allow for the so-called mixed scenarios, in which a maximum rigidity cutoff in the acceleration at the sources could lead to maximum energies for different nuclei scaling with the atomic number Z, with $E_{max} \simeq 5Z$ EeV.



Normalizations: Hybrid: 0.94, 750 m array: 1.02, Inclined: 1.05

AUGER WILL CONTINUE OPERATING

https://www.auger.org/ , **https://www.auger.org/index.php/observatory**

http://arxiv.org/abs/1503.09173

Regarding the future, **the Auger Observatory is expected to continue operating for another decade and moreover an upgrade is foreseen** in which the electronics of the WCDs will be improved and each WCD will be supplemented with a 4 m^2 scintillator detector on top of it. This should allow the separate reconstruction of the electromagnetic and muonic components of each shower and hence provide an improved determination of the CR composition using the SD. This should also allow to reach a better understanding about the modelling of the hadronic interactions at the highest energies. In addition, in the Infill region scintillators buried underground are being deployed (AMIGA detectors) in order to measure directly the muonic component of the showers. **All this should allow to gather a larger quantity of data with an improved quality, so that one could expect that further advances in the field will be achieved in the near future.**

(end of quote)

SD = surface detector consisting of an array of ~ 1600 water-Cherenkov detectors (WCD) separated by 1.5 km and covering an area of 3000 km^2. AMIGA = AUGER Muons and Infill for the Ground Array, **https://www.auger.org/index.php/cosmic-rays/pierre-auger**

COSMOLOGY, BIG BANG, INFLATION, UNCERTAINTIES…

STANDARD COSMOLOGY :

Planck Time $t_{Planck} \sim 5 \cdot 10^{-44}$ s

Inflation epoch : from 10^{-36} s to ~ 10^{-32} s ?

Decoupling epoch (leading to CMB radiation) => Universe ~ 380.000 years old

=> Time of decoupling ~ 10^{49} . Time of beginning of inflation ~ $10^{57}\ t_{Planck}$

HOW PRECISELY, AND HOW FAR, CAN CMB DATA AND STANDARD COSMOLOGY (BIG BANG + INFLATION) PROVIDE US RELIABLE INFORMATION ON THE BEGINNING OF THE UNIVERSE ?

SIMILARLY,

Planck Energy $E_{Planck} \sim 1.22 \cdot 10^{28}$ eV
Planck Temperature $T_{Planck} \sim 1.4 \cdot 10^{32}$ K

UHECR energy $E_{UHECR} \sim 10^{20}$ eV
Equivalent temperature $T_{UHECR} \sim 10^{24}$ K

LHC *pp* center-of-mass energy $= 1.3 \cdot 10^{13}$ eV
Equivalent temperature $T_{LHC} \sim 10^{17}$ K

Grand Unification Energy $E_{GUT} \sim 10^{25}$ eV **??**
Equivalent temperature $T_{GUT} \sim 10^{29}$ K **??**

=> E_{UHECR} **has a "strategic" value =>**

THE RESULTS OF UHECR EXPERIMENTS
WILL BE CRUCIAL
FOR COSMOLOGY AND PARTICLE PHYSICS

JEM-EUSO

http://arxiv.org/abs/1504.02593

Physics Goals and Status of JEM-EUSO and its Test Experiments

The JEM-EUSO mission aims to **explore the origin of the extreme energy cosmic rays (EECRs) through the observation of air-shower fluorescence light from space**.

(…)

JEM-EUSO is planned as a three to ve year mission, where initially the launch **was foreseen in 2017. Due to financial reasons this will not be possible.** However, the JEM-EUSO collaboration continues the efforts to improve the baseline design and the capabilities and sensitivity of such an instrument with the aim to launch it to space at a later opportunity.

WHAT ABOUT INFLATION ?

(See ICNFP 2014 Proceedings, paper *BICEP2, Planck, spinorial space-time, pre-Big Bang*, article 03014, and references therein)

The detection of CMB B-modes by BICEP2 was finally not confirmed. But if such a detection were confirmed in the future, would it be an evidence for cosmic inflation ?

Not if alternative cosmologies are allowed.

ALTERNATIVE INGREDIENTS : Pre-Big Bang, new approaches to space-time => can generate primordial gravitational waves in a "non standard" way, or a new form of anisotropy with vector perturbations and B-modes.

See also : *CMB B-modes, spinorial space-time and Pre-Big Bang (II)* , http://arxiv.org/abs/1408.6441

http://arxiv.org/abs/1502.00612

A Joint Analysis of BICEP2/Keck Array and Planck Data

We report the results of a joint analysis of data from BICEP2/Keck Array and Planck. BICEP2 and Keck Array have observed the same approximately 400 deg^2 patch of sky centered on RA 0h, Dec. −57.5 deg. The combined maps reach a depth of 57 nK deg in Stokes *Q* and *U* in a band centered at 150 GHz. Planck has observed the full sky in polarization at seven frequencies from 30 to 353 GHz, but much less deeply in any given region (1.2 μK deg in *Q* and *U* at 143 GHz). We detect 150×353 cross-correlation in *B*-modes at high significance. We fit the single- and cross-frequency power spectra at frequencies ≥150 GHz to a lensed-ΛCDM model that includes dust and a possible contribution from inflationary gravitational waves (as parameterized by the tensor-to-scalar ratio *r*), using a prior on the frequency spectral behavior of polarized dust emission from previous \planck\ analysis of other regions of the sky. **We find strong evidence for dust and no statistically significant evidence for tensor modes.** We probe various model variations and extensions, including adding a synchrotron component in combination with lower frequency data, and find that these make little difference to the *r* constraint. Finally we present an alternative analysis which is similar to a map-based cleaning of the dust contribution, and show that this gives similar constraints. The final result is expressed as a likelihood curve for *r*, and yields an upper limit $r_{0.05} < 0.12$ at 95% confidence. Marginalizing over dust and *r*, lensing *B*-modes are detected at 7.0 σ significance.

http://arxiv.org/abs/1502.02114

Planck 2015 results. XX. Constraints on inflation

We present the implications for cosmic inflation of the Planck measurements of the cosmic microwave background (CMB) anisotropies in both temperature and polarization based on the full Planck survey. The Planck full mission temperature data and a first release of polarization data on large angular scales measure the spectral index of curvature perturbations to be $n_s = 0.968 \pm 0.006$ and tightly constrain its scale dependence to $dn_s/d\ln k = -0.003 \pm 0.007$ when combined with the Planck lensing likelihood. When the high-ℓ polarization data is included, the results are consistent and uncertainties are reduced. **The upper bound on the tensor-to-scalar ratio is $r_{0.002} < 0.11$ (95% CL), consistent with the B-mode polarization constraint $r < 0.12$ (95% CL) obtained from a joint BICEP2/Keck Array and Planck analysis.** These results imply that $V(\phi) \propto \phi^2$ and natural inflation are now disfavoured compared to models predicting a smaller tensor-to-scalar ratio, such as R^2 inflation. Three independent methods reconstructing the primordial power spectrum are investigated. The Planck data are consistent with adiabatic primordial perturbations. We investigate inflationary models producing an anisotropic modulation of the primordial curvature power spectrum as well as generalized models of inflation not governed by a scalar field with a canonical kinetic term. **The 2015 results are consistent with the 2013 analysis based on the nominal mission data.**

PLANCK : a general check

arXiv:1507.08853 **Planck** 2015 results. III. LFI systematic uncertainties

arXiv:1507.02704 **Planck** 2015 results. XI. CMB power spectra, likelihoods, and robustness of parameters

(…)

arXiv:1506.07135 **Planck** **2015 results. XVI. Isotropy and statistics of the CMB**

We test the statistical isotropy and Gaussianity of the cosmic microwave background (CMB) anisotropies using observations made by the Planck satellite. Our results are based mainly on the full Planck mission for temperature, but **also include some polarization measurements.**

In particular, we consider the CMB anisotropy maps derived from the multi-frequency Planck data by several component-separation methods. For the temperature anisotropies, we find excellent agreement between results based on these sky maps over both a very large fraction of the sky and a broad range of angular scales, establishing that potential foreground residuals do not affect our studies.

Tests of skewness, kurtosis, multi-normality, N-point functions, and Minkowski functionals indicate **consistency with Gaussianity, while a power deficit at large angular scales is manifested in several ways, for example low map variance.**

The results of a peak statistics analysis are consistent with the expectations of a Gaussian random field. The "Cold Spot" is detected with several methods, including map kurtosis, peak statistics, and mean temperature profile. **We thoroughly probe the large-scale dipolar power asymmetry, detecting it with several independent tests, and address the subject of a posteriori correction. Tests of directionality suggest the presence of angular clustering from large to small scales, but at a significance that is dependent on the details of the approach.**

We perform the first examination of polarization data, finding the morphology of stacked peaks to be consistent with the expectations of statistically isotropic simulations. **Where they overlap, these results are consistent with the Planck 2013 analysis** based on the nominal mission data and provide our most thorough view of the statistics of the CMB fluctuations to date.

=> Polarization data will be crucial to confirm Planck 2013 results including possible new Physics

http://arxiv.org/abs/1508.03375

Planck 2013 results. XXXI. Consistency of the Planck data

The Planck design and scanning strategy provide many levels of redundancy that can be exploited to provide tests of internal consistency. One of the most important is the comparison of the 70GHz and 100GHz channels. Based on different instrument technologies, with feeds located differently in the focal plane, analysed independently by different teams using different software, and near the minimum of diffuse foreground emission, these channels are in effect two different experiments. The 143GHz channel has the lowest noise level on Planck, and is near the minimum of unresolved foreground emission. In this paper, we analyse the level of consistency achieved in the 2013 Planck data. We concentrate on comparisons between the 70/100/143GHz channel maps and power spectra, particularly over the angular scales of the first and second acoustic peaks, on maps masked for diffuse Galactic emission and for strong unresolved sources. Difference maps covering angular scales from 8deg-15arcmin are consistent with noise, and show no evidence of cosmic microwave background structure. Including small but important corrections for unresolved-source residuals, we demonstrate agreement between 70 and

100 GHz power spectra averaged over 70 < l < 390 at the 0.8% level, and agreement between 143 and 100 GHz power spectra of 0.4% over the same l range. These values are within and consistent with the overall uncertainties in calibration given in the Planck 2013 results. We also present results based on the 2013 likelihood analysis showing consistency at the 0.35% between the 100/143/217GHz power spectra. We analyse calibration procedures and beams to determine what fraction of these differences can be accounted for by known approximations or systematic errors that could be controlled even better in the future, reducing uncertainties still further. Several possible small improvements are described. Subsequent analysis of the beams quantifies the importance of asymmetry in the near sidelobes, which was not fully accounted for initially, affecting the 70/100 ratio. Correcting for this, the 70, 100, and 143 GHz power spectra agree to 0.4% over the first two acoustic peaks. The likelihood analysis that produced the 2013 cosmological parameters incorporated uncertainties larger than this. We show explicitly that correction of the missing near sidelobe power in the HFI channels would result in shifts in the posterior distributions of parameters of less than 0:3 except for A_s, the amplitude of the primordial curvature perturbations at 0.05 Mpc^{-1}, which changes by about 1. We extend these comparisons to include the sky maps from the complete nine-year mission of the Wilkinson Microwave Anisotropy Probe (WMAP), and find a roughly 2% difference between the Planck and WMAP power spectra in the region of the first acoustic peak.

PLANCK 2013 PAPER

http://arxiv.org/abs/1303.5083

Planck 2013 results. XXIII. Isotropy and statistics of the CMB (20 March 2013, last revised 27 Jan 2014)

(…) 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. (…) (end of quote)

***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 Proceedings

(…) **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.** (…) (end of quote)

The spinorial space-time naturally introduces a privileged space direction for each comoving observer (cosmic space-time position spinor x complex phase). See also my previous contributions to ICNFP and the original papers :
Physical and Cosmological Implications of a Possible Class of Particles Able to Travel Faster than Light **http://arxiv.org/abs/hep-ph/9610474 ,**
Space, Time and Superluminal Particles
http://arxiv.org/abs/physics/9702026

RECENT WORK BY BICEP2, KECK ARRAY…

The origin of the wrong BICEP2 announcement on the CMB B-modes and the claimed evidence for inflation was not a problem of instrumentation, but of data analysis and interpretation. The experiment itself worked correctly.

=>THE SOUTH-POLE PROGRAM FOR CMB IS HIGHLY PERFORMANT FROM A TECHNOLOGICAL POINT OF VIEW, AND FURTHER WORK IS IN PROGRESS TO IMPROVE THE DETECTORS AND INTRODUCE NEW EXPERIMENTS

http://bicepkeck.org/

http://arxiv.org/abs/1502.00619
Antenna-coupled TES bolometers used in BICEP2, Keck array, and SPIDER

http://arxiv.org/abs/1502.00643 BICEP2 / Keck Array V: Measurements of B-mode Polarization at Degree Angular Scales and 150 GHz by the Keck Array

IN SPITE OF THE FAILED BICEP2 ANNOUNCEMENT ABOUT PRIMORDIAL CMB B-MODES, THE SOUTH POLE INITIATIVE IS SUCCESSFUL

GETTING IMPORTANT RESULTS IS NOW JUST A MATTER OF TIME AND OF PROGRESSIVE TECHNICAL IMPROVEMENTS

AN EXAMPLE : SPTpol http://arxiv.org/abs/1210.4970

SPTpol: an instrument for CMB polarization measurements with the South Pole Telescope

SPTpol is a dual-frequency polarization-sensitive camera that was deployed on the 10-meter South Pole Telescope in January 2012. SPTpol will measure the polarization anisotropy of the cosmic microwave background (CMB) on angular scales spanning an arcminute to several degrees. The polarization sensitivity of SPTpol will enable a detection of the CMB "B-mode" polarization from the detection of the gravitational lensing of the CMB by large scale structure, and a detection or improved upper limit on a primordial signal due to inflationary gravity waves.

http://arxiv.org/abs/1503.02315 (A RECENT MEASUREMENT RESULT)

Measurements of Sub-degree B-mode Polarization in the Cosmic Microwave Background from 100 Square Degrees of SPTpol Data

We present a measurement of the *B*-mode polarization power spectrum (the *BB* spectrum) from 100 deg^2 of sky observed with SPTpol, a polarization-sensitive receiver currently installed on the South Pole Telescope. The observations used in this work were taken during 2012 and early 2013 and include data in spectral bands centered at 95 and 150 GHz. We report the BB spectrum in five bins in multipole space, spanning the range $300 \leq \ell \leq 2300$, and for three spectral combinations: 95 GHz × 95 GHz, 95 GHz × 150 GHz, and 150 GHz × 150 GHz. We subtract small (< 0.5 σ in units of statistical uncertainty) biases from these spectra and account for the uncertainty in those biases. The resulting power spectra are inconsistent with zero power but consistent with predictions for the BB spectrum arising from the gravitational lensing of E-mode polarization. If we assume no other source of BB power besides lensed B modes, we determine a preference for lensed B modes of 4.9σ. After marginalizing over tensor power and foregrounds, namely polarized emission from galactic dust and extragalactic sources, this significance is 4.3σ. Fitting for a single parameter, A_{lens}, that multiplies the predicted lensed B-mode spectrum, and marginalizing over tensor power and foregrounds, we find $A_{lens} = 1.08 \pm 0.26$, indicating that our measured spectra are consistent with the signal expected from gravitational lensing. The data presented here provide the best measurement to date of the B-mode power spectrum on these angular scales.

WHAT AFTER PLANCK ?

=> CMB POLARIZATION (B-MODES…)

=> HIGHER ANGULAR RESOLUTION

INCLUDING A NEW SATELLITE MISSION

EUCLID (« DARK UNIVERSE MISSION »)

http://www.euclid-ec.org/

http://sci.esa.int/euclid/

ESA : « Euclid is an ESA mission to map the geometry of the dark Universe (…) Euclid will cover the entire period over which dark energy played a significant role in accelerating the expansion **»**

=> Nature and origin of this acceleration ?

IN PARALLEL : GAIA (SATELLITE)
http://sci.esa.int/gaia/

… mission to chart a three-dimensional map of our Galaxy, the Milky Way, in the process revealing the composition, formation and evolution of the Galaxy. Gaia will provide unprecedented positional and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and throughout the Local Group. This amounts to about 1 per cent of the Galactic stellar population.

GAIA HAS JUST COMPLETED
1 YEAR OF OBSERVATIONS

=> ORIGIN OF GALAXY FORMATION ?

AND IN THE USA :

http://arxiv.org/abs/1309.5381

(Last version : 30 May 2014)

Inflation Physics from the Cosmic Microwave Background and Large Scale Structure

Report from the "Dark Energy and CMB" working group for the American Physical Society's Division of Particles and Fields long-term planning exercise ("Snowmass"). Current version matches what will appear in the Snowmass 2013 issue of Astroparticle Physics.

http://desi.lbl.gov/

Dark Energy Spectroscopic Instrument (DESI):

The Dark Energy Spectroscopic Instrument (DESI) will measure the effect of dark energy on the expansion of the universe. It will obtain optical spectra for tens of millions of galaxies and quasars, constructing a 3-dimensional map spanning the nearby universe to 10 billion light years.

(…)

PARTICLE PHYSICS AND COSMOLOGY HAVE NOWADAYS “STANDARD MODELS”

BUT THE EXCEPTIONAL INSTRUMENTAL EFFORT MADE WITH HIGH-ENERGY ACCELERATORS OPENS THE WAY TO MANY SEARCHES FOR NEW PHYSICS

SIMULTANEOSLY, THE STANDARD BIG-BANG + INFLATION (ASSUMED TO LEAD TO THE PHENOMENOLOGICAL ΛCDM)

HAS NOT BEEN DISPROVED BUT :

- THERE IS NO DIRECT PROOF OF INFLATION

- POSSIBLE SIGNATURES OF NEW PHYSICS EXIST IN PLANCK RESULTS

LAST YEAR TRANSPARENCY

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 ?**

(…)

SUGGESTIONS TO RELATE STANDARD BASIC PHYSICS TO COSMOLOGY CAN ALSO BE VERY DIVERSE

A recent example (by Juan Maldacena) :

http://arxiv.org/abs/1508.01082

A model with cosmological Bell inequalities

We discuss the possibility of devising cosmological observables which violate Bell's inequalities. Such observables could be used to argue that cosmic scale features were produced by quantum mechanical effects in the very early universe. As a proof of principle, we propose a somewhat elaborate inflationary model where a Bell inequality violating observable can be constructed.

=> BUT IS STANDARD QUANTUM MECHANICS AN ULTIMATE FUNDAMENTAL PRINCIPLE, OR DOES IT HAVE A DEEPER ORIGIN, AND CAN IT BE « DEFORMED » ?

POSSIBLE NEW PHYSICS AND ALTERNATIVE COSMOLOGIES

THREE BASIC, RELATED QUESTIONS :

- Are the standard « elementary » particles really « elementary » ? What is the vacuum made of ?

- Has there been a pre-Big Bang era ?

- What are the ultimate space-time geometry, the ultimate laws of Physics… ?

On the possible origin of Quantum Mechanics and the potential cosmological implications of the pattern suggested, see posters 21 and 22 :

Spinorial Regge trajectories and Hagedorn-like temperatures

Spinorial Space-Time and the origin of Quantum Mechanics

WHAT CAN BE PREONS AND A PREONIC VACUUM ?

Do they obey standard relativity and quantum mechanics ?

My suggestion since 1995 (see the posters) :

Standard particles are like phonons or solitons in a « condensed matter » made of ultimate constituents => Their critical speed is much lower than that of the ultimate constituents => Preons are superluminal objects (superbradyons, $c_s >> c$, c = speed of light, c_s = superbradyon critical speed in vacuum if they can exist as free particles).

SUPERBRADYONS WOULD NOT BE TACHYONS : THEY WOULD HAVE POSITIVE MASS AND ENERGY, AND CAN OBEY A SYMMETRY AND KINEMATICS OF THE LORENTZ TYPE WITH c_s INSTEAD OF c

=> CAN ONE TRY TO SEARCH FOR FREE SUPERBRADYONS ?

LHC, electron-positron, large-surface detectors…

- At accelerators : mainly annihilations producing objects with very high energy and low momentum

- In earth or underground detectors : look mainly for objects with a speed lower than c

ACCELERATORS CAN PRODUCE ONLY SMALL-MASS SUPERBRADYONS (ASSUMING LORENTZ KINEMATICS WITH c_s INSTEAD OF c)

=> FOR TeV ENERGY WITH $c_s = 10^6 c$, THE ALLOWED MASS WOULD BE IN THE eV RANGE

FREE SUPERBRADYONS WOULD DECAY SPONTANEOUSLY EMITTING IN VACUUM A « CHERENKOV » RADIATION OF STANDARD PARTICLES => SUPERBRADYONS CROSSING EARTH OR UNDERGROUND DETECTORS WOULD HAVE VELOCITIES CLOSE TO c OR LOWER,

THEY CAN BE PART OF THE COSMIC OR GALACTIC DARK MATTER, AND ARE EXPECTED TO INTERACT WEAKLY WITH THE DETECTOR

IN SPACE

http://arxiv.org/abs/physics/9702026

Space, Time and Superluminal Particles (February 1997**)**

(see **Poster 21**)

(…) A superluminal particle moving with speed $\vec{v}$ with respect to the vacuum rest frame, and emitted by an astrophysical object, can reach an observer, moving with laboratory speed $\vec{V}$ with respect to the same frame, at a time (as measured by the observer) previous to the emission time. Such a phenomenon will happen if $\vec{v} . \vec{V} > c^2$, and the emitted particle will be seen to evolve backward in time (but it evolves forward in time in the vacuum rest frame). If they interact several times with the detector, superluminal particles can be a directional probe preceding the detailed observation of astrophysical phenomena, such as explosions releasing simultaneously neutrinos, photons and superluminal particles. (…)

Velocity composition
and observed time arrow

$$\vec{v'} = (\vec{v} - \vec{V})\,(1 - \vec{v}.\vec{V}\; c^{-2})^{-1}$$

$\vec{V}$ = Laboratory velocity with respect to the vacuum rest frame (VRF), f.i. ~ 600 Km s $^{-1}$

$\vec{v}$ = velocity of a superluminal particle with respect to the VRF

$\vec{v}$ parallel to $\vec{V}$, $\vec{v}.\vec{V}\; c^{-2} = 1$ for v ~ 500 c

$\vec{v'}$ = particle velocity felt by the laboratory

(time) singularity if the denominator vanishes => relative velocity arrow changes

AN EXAMPLE OF SPACE-TIME :
THE SPINORIAL SPACE-TIME (SST)

=>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 in our Universe a cosmic spinor ξ (two components, two complex numbers) with a SU(2) group that contains the space rotations SO(3).

=> 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.

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

No matter, no critical speed, involved yet.

The definition of cosmic time is not unique :

***t* can also be a different fonction of the spinor modulus $|\xi|$ => f.i. $t = |\xi|^2$**

Does not change the analysis that follows, and has no practical consequences

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.

LUNDMARK- LEMAITRE – HUBBLE LAW FROM PURE GEOMETRY

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

The Lundmark - Lemaître – Hubble constant turns out to be equal to the inverse of the age of the Universe. This "automatic" value obtained with such a simple, purely geometric, spinorial pattern is a quite reasonable one from a phenomenological point of view.

No 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 that initially opposed to the expansion? (See my previous papers)

SST AND RELATIVITY

EVEN IF RELATIVITY WILL REMAIN AN ESSENTIAL PROPERTY OF STANDARD MATTER, IT IS NOT EXPECTED TO BE AN EXACT SYMMETRY IN THE SST

=> NOT REALLY PART OF THE BASIC GEOMETRY

RELATIVITY WILL IN PRINCIPLE BE VIOLATED AT VERY LOW DISTANCES AND ULTRA-HIGH ENERGIES (f.i. by preon dynamics)

SIMILARLY, GENERAL RELATIVITY IS NOT EXPECTED TO BE A DOMINANT FEATURE OF THE UNIVERSE AT THE LARGEST DISTANCE SCALES (IMPLICATIONS OF A POSSIBLE PRE-BIG BANG COSMOLOGY)

THE POSSIBLE ORIGIN OF QUANTUM MECHANICS (Poster 22)

HAVING DEFINED THE COSMIC TIME IN THE SST AS $t = |\xi|$, HOW TO DEFINE, IN THE LIMIT OF VERY SMALL TIME AND DISTANCE SCALES, THE LOCAL TIME AND SPACE AROUND A POINT ξ_0 DIFFERENT FROM THE COSMIC ORIGIN ?

ASSUME THAT, HAVING A PREONIC VACUUM, WE INTRODUCE LOCAL SPINORIAL COORDINATES SIMILAR TO THE COSMIC ONES THROUGH THE LOCAL SPINOR $\xi - \xi_0$ LEADING TO A LOCAL TIME $| \xi - \xi_0 |$ => A CONTRADICTION ARISES AT VERY SMALL DISTANCES BETWEEN LOCAL AND COSMIC TIME => CONSEQUENCES FOR MATTER ?

SIMILARLY, SUCH A LOCAL DEFINITION OF SPACE AT VERY SMALL DISTANCES IS NOT THE SAME AS "SEEN" AT COSMIC LEVEL

=> CAN NATURALLY LEAD TO AN INTERNAL STRUCTURE FUNCTION « EXTENDED IN TIME » FOR A STANDARD SPIN-1/2 PARTICLE DESCRIBED AS A LOCAL EXCITATION OF THE PREONIC VACUUM => THEN, CONTINUOUS MOTION CAN BECOME IMPOSSIBLE BECAUSE OF THE OVERLAP IN TIME IT GENERATES

=> DISCRETE MOTION WOULD NATURALLY BE GENERATED LEADING TO A SITUATION CLOSE TO THE FEYNMAN PATH INTEGRAL => THE ORIGIN OF QUANTUM MECHANICS ?

THE SPINORIAL SPACE-TIME AND THE MODEL PRESENTED IN POSTER 22 PROVIDE JUST AN EXAMPLE OF A SUITABLE FRAMEWORK FOR SUCH A MECHANISM LEADING TO THE GENERATION OF QUANTUM MECHANICS

THE SITUATION DESCRIBED IN POSTER 22 CAN POTENTIALLY BE GENERATED WITH ANY DYNAMICAL PATTERN IMPLYING A DEFINITION OF TIME AT VERY SMALL DISTANCES IN CONTRADICTION WITH THE MACROSCOPIC ONE OR NATURALLY INTRODUCING AN INTRINSIC TIME UNCERTAINTY => DESERVES FURTHER INVESTIGATION

WHAT IS TIME AT VERY SMALL SCALES ?

COSMOLOGICAL IMPLICATIONS

WHAT CAN BE THE CONSEQUENCES FOR COSMOLOGY OF A FUNDAMENTAL PREONIC STRUCTURE OF MATTER?

IF PREONS ARE SUPERLUMINAL, A PRE-BIG BANG ERA CAN REPLACE THE WHOLE BIG BANG + INFLATION PATTERN (already pointed out in my 1995-96 papers)

THE TRANSITION FROM A SUPERBRADYONIC ERA TO THE UNIVERSE DOMINATED BY STANDARD MATTER WOULD BE GOVERNED BY THE SPONTANEUS DECAY OF SUPERBRADYONS INTO STANDARD PARTICLES => DARK MATTER?

AS POINTED OUT IN POSTER 21, THIS KIND OF SCENARIO CAN ALSO IMPLY ASSOCIATED HAGEDORN-LIKE TEMPERATURES LEADING TO OBSERVABLE PHENOMENA

A SUPERBRADYONIC VACUUM CAN ALSO MODIFY OF THE SITUATION OF BOSONIC CONDENSATES, INCLUDING ZERO MODES OF HARMONIC OSCILLATORS => DO NO LONGER NEED TO BE PERMANENTLY CONDENSED IN VACUUM FOR ALL ENERGIES => NO COSMOLOGICAL CONSTANT PROBLEM

SIMULTANEOUSLY, THE SST PREDICTS THE EXISTENCE OF A PRIVILEGED SPACE DIRECTION (COSMIC SPINOR x COMPLEX PHASE) FOR EACH COMOVING OBSERVER => PLANCK DATA ?

REMNANT PREONS CAN BE SUPERHEAVY DARK MATTER, AND SPONTANEOUSLY DECAY PRODUCING ULTRA-HIGH ENERGY COSMIC RAYS

(see my 1996 papers, f.i.
http://arxiv.org/abs/astro-ph/9606054
http://arxiv.org/abs/astro-ph/9610089
http://arxiv.org/abs/hep-ph/9610474)

NOW, THIS CAN ANSWER THE QUESTIONS RAISED IN ARTICLES LIKE :
http://arxiv.org/abs/1504.01319

Super Heavy Dark Matter in light of BICEP2, Planck and Ultra High Energy Cosmic Rays Observations

R. Aloisio, S. Matarrese, A.V. Olinto

IN PARTICULAR, SUPERBRADYONS CAN BE THIS SUPERHEAVY DARK MATTER

CONCLUSION

THESE ARE JUST SOME EXAMPLES OF THE POTENTIALITIES OF NEW PHYSICS AND OF ALTERNATIVE COSMOLOGIES

IT REALLY SEEMS THAT ALTERNATIVE COSMOLOGIES CAN SOLVE BASIC PROBLEMS AND PRODUCE NEW SIGNATURES THAT ARE NOT EXCLUDED BY OBSERVATIONS

NEW PHYSICS IS EXPECTED TO BE DIRECTLY INVOLVED IN SUCH COSMOLOGIES AND, POSSIBLY, NEW SPACE-TIME GEOMETRIES AT BOTH COSMIC AND VERY SMALL SCALES

FURTHER WORK REQUIRED (THEORY, EXPERIMENTS, OBSERVATIONS…)