Testing fundamental principles with high-energy cosmic rays - Description of HEP 2011 poster 678

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It is not yet clear whether the observed flux suppression for ultra-high energy cosmic rays (UHECR) at energies above $4.10^{19} eV$ (AUGER, HiRes) is a signature of the Greisen-Zatsepin-Kuzmin (GZK) cutoff or corresponds to the maximum energies available at the relevant sources. Both phenomena can be sensitive to violations of standard special relativity modifying cosmic-ray propagation or acceleration at very high energy, and would allow to set bounds of Lorentz symmetry violation (LSV) parameters in models incorporating a privileged local reference frame (the "vacuum rest frame", VRF). These effective parameters are expected to be directly linked to Planck-scale physics, or even to physics beyond Planck scale, as well as to the dynamics relating LSV patterns for nucleons, quarks, leptons and the photon. Other possible violations of fundamental principles and conventional basic hypotheses (quantum mechanics, energy and momentum conservation, vacuum homogeneity and "static" properties, effective space dimensions...) can also be considered and tested in high-energy cosmic-ray phenomena. We present an updated discussion of the theoretical and phenomenological situation, including new ideas and prospects for earth-based and space experiments.

1. Measuring the Planck scale

With the mention *First paper suggesting GZK suppression in LSV + VRF*, the poster includes the page 1 of the original April 1997 paper by the author [1] *Vacuum structure, Lorentz symmetry and superluminal particles* suggesting for the first time that simple patterns of Lorentz symmetry violation at the Planck scale, together with the existence of a privileged rest frame (the VRF), can be at the origin of a suppression of the Greisen-Zatsepin-Kuzmin cutoff for UHECR and produce other observable signatures (stability of unstable particles at very high energy...). Also joined is, with the mention *UHECR from superbradyon decays ?*, the page 1 of the author's June 1996 paper *Superluminal matter and high-energy cosmic rays* [2] considering the possibility that UHECR would result from superbradyon decays.

The poster quotes this extract from Lee Smolin in The Trouble with Physics [3] :

Remarkably, it took until the mid 1990 for us to realize that we could indeed probe the Planck scale. A sometimes happens, a few people recognized it but were in effect shouted down when they tried to publish their ideas. One was the Spanish physicist Luis Gonzalez-Mestres, of the Centre National de la Recherche Scientifique, in Paris...

(end of quote)

on which the poster comments : *But actually, all my results and ideas were published, presented and internationally referenced in due time.*

As references associated to this text, the poster includes :

- Page 1 of the May 1997 paper [4] *Absence of Greisen-Zatsepin-Kuzmin Cutoff and Stability of Unstable Particles at Very High Energy, as a Consequence of Lorentz Symmetry Violation*, presented at the ICRC 1997 conference (Vol. 6 of the Proceedings distributed at the beginning of the conference).
- Page 1 of the June 1997 paper [4] *Possible Effects of Lorentz Symmetry Violation on the Interaction Properties of Very High-Energy Cosmic*

Rays [5], presented at the Auger pre-conference Workshop of the ICRC 1997 conference. Poster mention : *Discusses allowed LSV ranges, patterns and parameters.*

- Page 1 of the August 1997 paper *High-Energy Nuclear Physics with Lorentz Symmetry Violation* [6], contributed to HEP 1997. Mention : *Considers LSV for nuclei analysed as sets of nucleons* => $\alpha \propto N^{-2}$ *rule*, where N is the number of nucleons and the kinematics considered in the comment is QDRK (Quadratically deformed relativistic kinematics).

QDRK is introduced by the poster as follows :

$$E \simeq pc + m^2c^3(2p){-}1 - \alpha\ pc(ka)^2/2 \quad (1)$$

E = energy, p = momentum, m = mass, k = wave vector, a = fundamental length, in the region : $ka \ll 1$, $p \gg mc$.

With the text :

Leads to testable predictions in the UHECR region (possible suppression of the Greisen-Zatsepin-Kuzmin cutoff, stability of unstable particles...). The interpretation of data depends crucially on UHECR composition.

At energies where the deformation term becomes larger than the mass term, all basic principles can be "deformed".

(end of quote, the last sentence refers to the balance between the mass term $m^2c^3(2p)^{-1}$ and the deformation $-\alpha\ pc(ka)^2/2$)

Three other included references are associated to this text :

- Page 1 of *Internal Structure of Ultra-High Energy Particles with Lorentz Symmetry Violation at the Planck Scale* [7], ICRC 2003, with the mention *UHECR internal structure modified by LSV with a VRF.* See also the September 1997 paper by the author : *Lorentz Symmetry Violation, Vacuum and Superluminal Particles* [8].

- Page 1 of *Lorentz Symmetry Violation and Acceleration in Relativistic Shocks* [9], with the mention *Suppression of synchrotron radiation for UHECR (QDRK).* This paper makes explicit the 1997 suggestion by the author that LSV can suppress synchrotron radiation and similar effects at astrophysical sources.

- Page 1 of *Weak doubly special relativity and ultra-high energy cosmic ray experiments* [10], contributed to the I Symposium on European Strategy for Particle Physics, January 30 - February 1st, 2006, supporting a statement in favour of UHECR space experiments. Poster mention : *Weak doubly special relativity = incorporating the VRF* (to clearly differentiate the author's work from versions of doubly special relativity where the laws of Physics are indentical in all reference frames).

2. Internal structure of particles and basic principles

The poster raises the question : *How does LSV with a VRF influence the internal structure of UHE particles ?* (UHE = ultra-high energy) and states :

Above the transition region $E \sim E(trans)$ where $\alpha(ka)^4 \simeq (2a)^2h^{-2}m^2c^4$, all kinematical balances are modified => the GZK cutoff can disappear because of the new cost in energy to split the term $-pc(ka)^2/2$ in the dispersion relation. Other QDRK effects appear.

BUT IMPORTANT PHYSICAL QUESTIONS :

What is the right value of α for each particle? What is the "fundamental" value of α for standard matter, if a is the Planck length ?

Is the fundamental scale the Planck scale ?

What other fundamental principles are also "deformed" at such energy and distance scales ?

Assuming relativity is the only basic principle to be tested at UHECR energies, potential consequences of HiRes and AUGER results have been discussed in our CRIS 2008 [12] and CRIS 2010 [13] papers. See also the note added to arXiv:0912.0725 [14] on the exclusion of negative values of α. Cosmic-ray composition is a crucial issue, "maximal" LSV at Planck scale cannot yet be excluded and space experiments are necessary.

LSV with a VRF can also be associated to other violations of basic principles and unconventional effects at ultra-high energy, such as for instance

: energy-dependent deformation of quantum mechanics ; changes in the structure of "elementary" particles ; nontrivial vacuum structure and possible vacuum inhomogeneities ; violations of energy and momentum conservation ; new physical phenomena including emission of new objects such as superbradyons in UHECR collisions ; changes of the effective space-time dimension...

LSV and other "exotic" phenomena at astrophysical sources must also be considered.

FURTHER WORK IS IN PROGRESS

(end of quote)

Four references associated to this text are included in the poster :

- Page 1 of *AUGER-HiRes results and models of Lorentz symmetry violation*, CRIS 2008 [12].
- Page 1 of *Cosmic rays and tests of fundamental principles*, CRIS 2010 [13].
- Page 1 of *Lorentz violation, vacuum, cosmic rays, superbradyons and Pamir data* [15], with the mention *Possible superbradyonic effect* (possible superbradyon emission in the interaction of cosmic rays with the atmosphere at very high energy, at the expense of the available transverse energy).
- Page 1 of *Preon models, relativity, quantum mechanics and cosmology (I)* [16], with the mention *Deformation of Quantum Mechanics.*

REFERENCES

1. L. Gonzalez-Mestres, http://arxiv.org/abs/astro-ph/9606054
2. L. Gonzalez-Mestres, http://arxiv.org/abs/physics/9704017
3. Lee Smolin, **The Trouble with Physics**, Penguin Books, 2008 edition, page 225.
4. L. Gonzalez-Mestres, http://arxiv.org/abs/physics/9705031 or http://ccdb4fs.kek.jp/cgi-bin/img/allpdf?199706012
5. L. Gonzalez-Mestres, http://arxiv.org/abs/physics/9706032 or http://ccdb4fs.kek.jp/cgi-bin/img/allpdf?199707045
6. L. Gonzalez-Mestres, http://arxiv.org/abs/nucl-th/9708028
7. L. Gonzalez-Mestres, http://www-rccn.icrr.u-tokyo.ac.jp/icrc2003/PROCEEDINGS/PDF/424.pdf
8. L. Gonzalez-Mestres, http://arxiv.org/abs/physics/9709006 , published in *Open Questions in Relativistic Physics*, Ed. By Franco Selleri, Apeiron 1998.
9. L. Gonzalez-Mestres, http://arxiv.org/abs/astro-ph/0011182
10. L. Gonzalez-Mestres, http://arxiv.org/abs/hep-ph/0601219
11. L. Gonzalez-Mestres, http://arxiv.org/abs/0908.4070
12. L. Gonzalez-Mestres, CRIS 2008, http://arxiv.org/abs/0902.0994 and references therein.
13. L. Gonzalez-Mestres, CRIS 2010, http://arxiv.org/abs/1011.4889 and references therein.
14. L.Gonzalez-Mestres, http://arxiv.org/abs/0912.0725
15. L. Gonzalez-Mestres, http://arxiv.org/abs/1009.1853
16. L. Gonzalez-Mestres, http://arxiv.org/abs/0908.4070