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Quest for Mathematical Tools to Investigate Space-Time-Energy Properties

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Abstract
The scientific community is actively working to reconcile General Relativity and Quantum field theory. However, recent experimental results, suggesting that space-time can be anisotropic and asymmetric, do not align with the proposed theories. These deformations depend on energy thresholds that vary for different interactions, with the metric parameters being energy-dependent. The recent results from the James Webb Space Telescope are cited in support of an asymmetric and anisotropic space-time. These facts suggest that the violation of Lorentz invariance is of geometrical, rather than dynamical, nature. A recovery of invariance is sought after introducing energy as a fifth dimension. A complete description of the 5-dimensional space-time-energy universe is the challenge proposed.

Keywords: Space-Time, Lorentz Invariance, James Webb Space Telescope, Symmetry, Isotropy, Metric Parameters, Space-Time-Energy

Introduction
The Standard Model of Physics indeed relies on two foundational theories: General Relativity and Quantum Field Theory, which unfortunately do not seamlessly integrate. The scientific community is actively working to reconcile these theories, focusing on several approaches. One significant avenue involves exploring the concept of spacetime at the Planck scale, where the effects of quantum gravity are expected to emerge. Additionally, researchers are investigating alternative definitions of spacetime that might bridge the gap between these theories. Singularities present a major challenge in General Relativity, raising both physical and mathematical concerns, highlighting the need for a deeper understanding of the fundamental structure.

This paper aims to inspire mathematicians to develop new mathematical tools for describing and managing the physical properties highlighted by recent experiments regarding space-time behavior. In particular, energy emerges as a critical factor from various perspectives: the parameters of the space-time metric are associated with energy-dependent thresholds that vary across different interactions. Moreover, an anisotropic and asymmetric space-time can be understood as a four-dimensional projection of an isotropic and symmetric five-dimensional space, with energy acting as a fifth parameter. Thus, energy functions both as a variable and a metric parameter. Consequently, analyzing a process solely as a function of energy can be misleading when employing probes that utilize different interactions.

Deformed Spacetime
While avoiding a general review of the attempts to overcome the limits of the Standard Model, which could deserve a paper apart, we take into consideration two recent cases: one deals with the nature of space-time, the other is a part of a collective effort to obtain mathematical tools able to overcome the problems of non-smooth space-time [1,2].

The former aims to use the gauge formalism of quantum field theory in a gauge field theory for gravity. To this aim, the authors use the eight-spinor formalism and the associated unitary symmetries to introduce a space-time dimension field, a geometric object which enables extracting four-dimensional space-time quantities from the eight-dimensional spinor space [1,3].

Concerning the latter, fundamental rules on singularities, like Roger Penrose's theorem and Stephen Hawking's theorem, or any differentiation assume a smooth space-time [2,4,5]. On the other hand, many authors hypothesize a discrete space-time at the Planck scale, thus preventing the application of known mathematical tools.

The authors were able to evaluate curvature and re-prove Penrose's singularity theorem in non-smooth space-times. This is hopefully a first step for a mathematical foundation of quantum gravity.

The two examples above are cited as representative of the manifold efforts made by the scientific community, approaching the problem from various and different points of view. However, they all are not aware of some experimental results and the related theory that were reported in the last decades. In the following, we report a sketch of the main results, which are a challenge to find adequate mathematics.

One of the astonishing results is that the metric parameters of space-time are functions of the energy [6]. These functions are characterized by thresholds, above which or below which space-time is deformed, i.e., it can be non-isotropic and non-symmetric. Such behavior is different for the different interactions.

In order to understand the meaning of the above sentence, one must consider that the effects of all the interactions are detected through the electromagnetic interaction: in fact, our instrumentation and our human senses are based on the electromagnetic interaction. Thus, also if a strong interaction is studied - just to make an example - we observe the process from our "electromagnetic universe", not the strong one. The "other universe", the strong universe, may be different from ours. It is "deformed" with respect to our point of view.

The threshold for electromagnetic interaction was found after an experiment on evanescent waves, having velocity v> c (c is a constant equal to light speed in a vacuum) [6,7]. This speed corresponds to a violation of the Lorentz invariance given by the parameter b=v/c.

The threshold for weak interaction was found after analyzing the mean life of the K0s meson in the energy range from 30 to 350 GeV [6,8,9]. The threshold was found to correspond to the mass of the W boson. Above this threshold, the electromagnetic and weak metric parameters are coincident, in agreement with the unification of the two interactions.

Concerning the strong interaction, the anisotropic correlation function of the Bose-Einstein correlation for mesons produced by proton-antiproton annihilation was considered [6,10].

In the gravitational case, the relative rates of clocks at different heights were fitted [6,11,12].

It is interesting to note that a low energy threshold was also found for the electromagnetic interaction below which space-time is deformed with respect to the "usual" one.

Rather than energy thresholds, it is better to consider the energy density thresholds [13]. In fact, an interaction volume was found within which the energy density of the process is to be evaluated. Energy and volume are evaluated in the electromagnetic universe.

The features of the above deformed space-time are more general than the curved space-time of General Relativity or the warped space-time of Yang-Mills type, both being particular cases, which can be derived from the former [chapter 9 of [6]].

In General Relativity, the problem of curvature is tackled by considering a tangent space-time locally approximated to a flat Minkowsky one, which is isotropic and symmetric. No anisotropies and asymmetry are considered.

A consequence of deformed space-time is the violation of the Lorentz invariance, which is of geometrical rather than dynamical nature, i.e., the problem is not if the limit speed is equal to the constant "c" but if space-time is deformed [14].

In the past, the invariance of three-dimensional (3D) distance in the space defined by the Galileo metric was found to be violated. An invariant distance was obtained by introducing a further dimension: time. Thus, the invariance of four-dimensional (4D) distance in the space-time was obtained starting from the Lorentz equations. As the deformed space-time violates the Lorentz invariance, an invariant five-dimensional (5D) distance and the corresponding equations are to be sought.

The fifth dimension was envisaged in energy, after transforming anisotropic results into isotropic ones by adding the energy as a further parameter.

That is the case of proton-antiproton annihilation, a strong interaction reaction [15]. The dense, highly energetic, and short-lived set of particles formed during this reaction is called a fireball.

The fireball was measured in the energy range from 35 GeV to 350 GeV It was an ellipsoid with spatial sizes (semi-axes): z= 0.20 10^-13 cm along the collision direction of the two parent particles (direction of Z axis); x=0.06 10^-13 cm and y=0.08 10^-13 cm in the two perpendicular directions, X and Y axes respectively. The time size was t= 0.67 10^-24 s (or c t= 0.20 10^-13 cm).

The original paper did not report the experimental errors; thus, one of the authors, F.C., was questioned: the error ranges from 4.5% to 6.5%. For the sake of simplicity, we assume a value of 7% here and in the following.

Thus, the fireball is anisotropic in 3D space, while isotropic in the (Z, ct) plane of 4D space.

The 5D-shape was obtained in units of energy by

$$a_1\ (eV) = \hbar\, c / x$$
$$a_2\ (eV) = \hbar\, c / y$$
$$a_3\ (eV) = \hbar\, c / z$$
$$a_4\ (eV) = \hbar / t$$
$$a_5\ (eV) = E$$

being $\hbar = h/(2\pi)$, where h is the Planck constant.

The proton mass was assumed to be as value of energy E.

This way, a spherical shape was obtained in the (Z, time, energy) space; being:

$$a_3\ (eV) = \hbar\, c / z = 0.99 \pm 0.07\ GeV$$
$$a_4\ (eV) = \hbar / t = 0.98 \pm 0.07\ GeV$$
$$a_5\ (eV) = E = 0.94 \pm 0.07\ GeV$$

A test was conceived to counteract the effects of space-time deformation. A torsional antenna made of two vertical loops mutually perpendicular was used [16]. Each loop was made of two semi-circular branches having a radius of 16 cm. The axis of the antenna is the diameter common to the two perpendicular loops.

Each loop was powered by a dedicated output of an HP 8510 Vector Network Analyzer, at a frequency of 240 MHz, with no reciprocal phase shift.

Two configurations were used: one with the antenna axis in a horizontal plane (with respect to the local surface of the earth), and the other with the axis vertical.

In both cases, the whole antenna rotated around a vertical axis by 180 steps of 2° (thus sweeping 360° in the horizontal plane).

A fixed log-periodic antenna detected the signal emitted by the torsional antenna at a distance of 2.20 m in the horizontal plane. A more detailed description of the whole apparatus can be found in reference [16].

A polar representation of intensity received by the fixed log-periodic antenna during the 360° rotation of the torsional antenna was not isotropic, both in the horizontal and in the vertical configuration. It was approximately cardioid-shaped.

A torsion of the two loops was then induced by rotating one zone of their intersection with respect to the other. Eight torque angles (alpha) were studied: alpha=0, π/4, π/2, 3π/4, π, 6π/5, 5π/4 and 3π/2 radians.

In the horizontal configuration, a quasi-isotropic distribution of intensity was registered when the torque angle was 6π/5, 5π/4, and 3π/2 rad (and not at the other alpha values), while a cardioid shape was obtained in the vertical configuration in all cases.

The expected distribution of intensity was evaluated by creating a numeric model of the antenna and applying standard software based on Maxwell's equations [16]. No quasi-isotropic distribution and no dramatic difference between horizontal and vertical cases was obtained.

Thus, the quasi-isotropic cases correspond to a violation of the known laws; in particular, a violation of the Lorentz invariance.

Violation of the Lorentz invariance in those directions was also reported in a different experiment concerning a static conductor in a static magnetic field: a voltage different than zero was detected [17].

Both results indicate that the violation is of a geometrical nature.

When the Lorentz symmetry is violated in the torsional antenna, a symmetry is obtained if one considers the energy distribution. Energy is a higher dimension (the fifth dimension) where a symmetry is obtained.

This way, energy is both a dynamic variable, which we measure in our electromagnetic universe, and a metric parameter, able to recover a violated symmetry. What is the relationship between the two aspects of energy?

We measure energy or energy density in our electromagnetic universe. The obtained value determines the values of the metric parameters of the different interactions. Interestingly, one of these parameters is energy, which can be different for different interactions.

The seeming non-conservation of energy is solved by considering the energy taken or given in the relative deformation of the space-times.

The angles at which Lorentz symmetry is broken were found to be the same also for other interactions. In fact, the neutron emission induced by ultrasound, the alpha emission induced by compression, and the neutron emission induced by compression, besides corresponding to a Lorentz violation for their nature, also are strongly asymmetric in space and characterized by maxima of intensity at those angles [18-20].

The asymmetry recorded in the above experiments was also put in correlation with asymmetries of the cosmic microwave background emission [14].

Discussion

Recent data, obtained by the James Webb telescope, are indicative of asymmetries that are not in agreement with the current standard model. They concern the cosmic microwave background, the distribution of galaxy rotation axes , the distribution of galaxies and galaxy clusters, the variation of the Hubble constant in time - the so-called "Hubble tension" [21-24]. From a deep examination of these data one can also deduce that the same Hubble tension is not isotropic.

It is interesting to note that an explanation of the Hubble tension was suggested by introducing an anisotropic universe [25].

The isotropy of the Universe was already questioned in the past, basing on the results of various cosmological probes [26].

All considered, the breakdown of Lorentz symmetry is not a question of speed greater than c (let's consider that, due to the necessity of a speed limit, Einstein chose that limit equal to c after a phenomenological observation, not after a theoretical derivation), but rather a question of asymmetry, which has been observed at some peculiar directions. The recovery of symmetry by considering energy as a fifth metric element, at the moment, has been obtained experimentally, but appropriate tools to describe the corresponding 5D geometry and physics have not yet been found.

Typically, deviations from Lorentz symmetry are sought at the Planck scale. This scale is at a very small length (the Planck length is about $1.62 * 10^{-35}$ m). It is also at very high energy (the Planck energy Ep is about $1.22 * 10^{19}$ GeV..).

The Deformed Space Time theory introduces a different point of view. First, if one investigates a phenomenon as a function of energy, one must consider which interaction is involved. A different space-time may correspond to a different interaction at the same energy. In particular, as long as the electromagnetic interaction is involved, deviations from a Minkowsky space-time occur at very low energy (less than about 4 microeV [6]). These deviations do not occur at high energy. On the other hand, interactions that violate Lorentz symmetry (and correspond to a non-Minkowsky space-time) at high energy are characterized by a huge deviation at the Planck energy.

For instance, two of the metric parameters of the strong interaction (the time parameter b_0^2 and one of the space parameters, b_3^2) vary with energy (E) by following the relationship [6].

$$b_0^2 = b_3^2 = \begin{cases} 1 & \text{if } E \leq E_s \\ (E/E_s)^2 & \text{if } E > E_s \end{cases}$$

where Es = (367.5±0.4) GeV is the threshold energy of the strong interaction (hadronic interaction).

At the Planck energy (E=Ep), these parameters have a value of 1.1 10^33, very far from 1, which is the value corresponding to flat Minkowsky space-time.

We could hypothesize that any cinematic deviation, however detected, is a secondary consequence of these huge deviations of geometrical nature.

The same non-constancy of the Fine Structure Constant could be linked to the non-Minkowsky nature of space-time [27].

In conclusion, one can say that 4D space-time is fundamentally anisotropic and asymmetric. Symmetry is a particular case. Therefore, it is not necessary to introduce a symmetry breaking at the beginning of the universe. Asymmetry is already a fundamental characteristic of 4D space-time.

Taking into consideration the anisotropies and asymmetry of the universe is a challenge for new mathematics. Some preliminary steps have already been done, while others are required: the dependence of space and time parameters on energy for the known interactions together with the corresponding thresholds has been derived, while the dependence of parameter energy on the variable energy is a question to be answered [6].

One can think that the fifth dimension, in analogy with the Kaluza-Klein theories, must be assumed space-like because the number of time-like parameters must not be larger than one, to avoid causal loops [28]. However, we are not handling a Kaluza-Klein theory because a cylindricity condition for compactification is not necessary. As a consequence, the metric coefficient of energy can either be positive or negative, or, in some cases, it can change.

While scalar fields are characteristic of an isotropic space-time, vector fields could be conceived in the anisotropic and asymmetric case. A heavyside function could be introduced to consider the energy thresholds.

Finally, the 4D Maxwell equations have to be substituted by 5D equations, and an invariant 5D-distance is to be found.

Conclusions

Some recent experiments suggest that the 4D space-time is not isotropic and symmetric, thus violating the Lorentz invariance. A deformed space-time occurs with thresholds at a different energy for a different interaction.

These results are reinforced by recent observations of the James Webb Space Telescope: anisotropies in the microwave background, in the distribution of galaxy rotation axes, in the distribution of galaxies and galaxy clusters, besides the occurrence of the Hubble tension, which could be explained by introducing an anisotropic universe.

The isotropy of the Universe has already been questioned, based on the results of various cosmological probes.

In the past, a violation of invariance was recovered by considering an invariance at a higher dimension. It was the case with the violation of the invariance of Galileo's 3D spatial distance, which was resolved by introducing the concept of 4D space-time distance.

In our case, energy is a candidate to be the additional dimension, leading to a 5D space-time-energy universe. Initially, this approach was taken to resolve a cinematic violation of the Lorentz invariance, mirroring the move from 3D-space to 4D-space-time, which solved a cinematic problem. However, the obtained consequences have paved the way for a geometrical vision of the interactions.

Some laws ruling this 5D universe have been suggested, but a complete description is still missing and constitutes a challenge for a complete theory.

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