Could kinematical effects in the CMB prove Finsler character of the space-time?

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1. There is a series of astrophysical observations which show that the Universe is anisotropic not only up to 100-200 Mpc but much further, maybe up to the visible border of it. These facts demand to search for the generalization of Minkowski metric to Finsler one. In order to be efficient, such generalization must be non-contradictive to the modern pseudo-Riemannian ideas of the space-time and must provide the consequences that agree to the observations of the anisotropy.
2. Among the observations that verify the global anisotropy of our Universe, there are the following:
- the anisotropy of the CMB investigated in frames of the WMAP program;
- the anisotropy of the proper motion of the quasars observed by MacMillan
Titov O., The apparent proper motions of reference radio sources (GEOSCIENCE, Australia) "Finsler Extensions of Relativity Theory", 24 - 30 September 2007, Moscow - Fryazino, Russia

and Titov;
M. L. McClure, C. C. Dyer, Anisotropy in the Hubble constant as observed in the HST Extragalactic Distance Scale Key Project results.

- the anisotropy of the Hubble parameter distribution observed by McClure and Dyer up to the distances of 300Mpc.
Minkowski space-time

Orthogonal basis

\[ S^2 = c^2 t^2 - x^2 - y^2 - z^2 \]

Berwald-Moor space-time

Orthogonal basis

\[ S^4 = c^4 t^4 + x^4 + y^4 + z^4 - 2c^2 t^2 (x^2 + y^2 + z^2) - 2(x^2 y^2 + x^2 z^2 + y^2 z^2) + 8c t x y z \]

Isotropic basis

\[ S^2 = h_1' h_2' + h_1' h_3' + h_1' h_4' + h_2' h_3' + h_2' h_4' + h_3' h_4' \]

\[ S^4 = h_1' h_2' h_3' h_4' \]

Arbitrary basis

\[ dS^2 = g_{ij}(x) dx^i dx^j \]

\[ dS^4 = g_{ijkl}(x) dx^i dx^j dx^k dx^l \]

3. One of the most perspective candidates to substitute Minkowski space is the 4-dimensional Finsler space with Berwald-Moor metric. In arbitrary basis, the corresponding metric has the forms shown on the slide. The close relations between the two spaces can be seen already here, and most clearly it can be seen in the so-called isotropic basis whose all the four vectors lie on the light cone.
4. Among the properties making these spaces alike, we would mention:

- space homogeneity and the energy-momentum conservation laws following from it;
- equal rights of the time-like directions and the location of the inertia center conservation and relativistic invariance that follow from it;
- the presence of the SO(3) symmetry group, though its invariants are not the 4-dimensional intervals but more complicated metrical objects;
- invariance of the light-speed which similarly to Minkowski space doesn’t depend on the observer’s velocity and on direction;
- the presence of the light cone which divides all the space into the cone of the future, the cone of the past and the region of the absolutely distant events;
- the ordering of events along the time coordinate which makes it possible to speak about the correspondence to the causality principle.
5. But there are also essential differences:
- the group of motions (isometric transformations) of this Finsler space has 7 parameters instead of the 10 parameters of Poincare group;
- the group of conformal transformations is infinite dimensional instead of 15-parametric conformal group of Minkowski space;
- in the affine representation, the light cone of the regarded space has a form of two pyramids and not a form of a circular cone as in Minkowski space;

Minkowski space-time

Berwald-Moor space-time
6. The similarity of the two spaces reveals especially when the speeds are low in comparison with the light speed – both of them have the Galilean space as their limits. For large speeds the problem is not solved, but there could be found a parameter for the limit transition. Independently of this, a question may be posed: are there any experimental or observational evidence that show that the real World can be better described by Finsler geometry and not by pseudo Riemannian? There is an idea that if such phenomena do exist, they must be searched for on the cosmological intervals.
7. Among various tests, the CMB anisotropy is of the special interest. This phenomenon is related to the events that took place billions of years ago and are as far as billions of light years from us. That is they are just there where the specific anisotropic Finslerian effects must be seen most boldly.
8. Besides, there are two clear anomalies related to the CMB. The importance of the first of them was underlined by Sir Roger Penrose: the amplitude of the quadrupole is too low – it is 7 times less than that predicted by the standard model.
9. The second anomaly deals with the suspicious parallelism of the axis of the 3 highest spherical harmonics – dipole, quadrupole and octopole. This phenomenon is sometimes called “the Axis of Evil”. If Finsler geometry could give the verifiable explanations for these two anomalies and could give a prediction of some additional phenomena that could be later tested in experiment, then the new geometry could obtain profound support.
10. In order to do this, let us regard two observers, one of whom is in Minkowski space-time and the other is in 4-dimensional Berwald-Moor space-time. The main characteristic feature of the second observer is the splitting of the observable 3-dimensional space and of the 2-dimensional sky into 4 equal zones.
11. The origin of these zones is defined by the geometry of the Finsler space light cone which consists of the 4 isotropic hyper planes.
11. Their cross sections divide the visible space and the sky of the observer into 4 separate zones. In Minkowski space the base of the cone is a sphere. Therefore, there are no distinguished zones or directions.
12. Let both observers be surrounded by the clouds of similar particles that have the same value of the velocity modulus, \( v \). The states of these particles for various directions relative to observers will be described with the help of the notion of temperature.
13. Obviously, if the observer’s velocity relative to the center of inertia of the particles is equal to zero, the temperature distribution for both skies must be homogeneous.
14. If the observer starts to move relatively to the mass center with velocity $V$, the initial homogeneous temperature distribution would change to an anisotropic one which is due only to kinematics. In order to calculate the numerical values of such anisotropy, we need to know the transformation rule for energy and momentum.
Minkowski space-time \((c = 1)\)

\[
E' = \frac{E - P_1 V_1 - P_2 V_2 - P_3 V_3}{\sqrt{1 - (V_1^2 + V_2^2 + V_3^2)}};
\]

where \(E^2 (P_1^2 + P_2^2 + P_3^2) = m^2\)

Bervald-Moor space-time \((c = 1)\)


\[
E' = \frac{E - P_1 V_1 - P_2 V_2 - P_3 V_3}{\sqrt{1 - \sqrt{(1+V_1+V_2+V_3)(1+V_1-V_2-V_3)(1-V_1+V_2-V_3)(1-V_1-V_2+V_3)}}};
\]

where \((E + P_1 + P_2 + P_3)(E + P_1 - P_2 - P_3)(E - P_1 + P_2 - P_3)(E - P_1 - P_2 + P_3) = m^4\)

15. These rules are well known for Minkowski space, and for the space-time with Bervald-Moor metric they were obtained recently by Garas’ko, Bogoslovsky and by the author. The corresponding formulas for both geometries are given above.
16. In Minkowski space the final picture of the kinematical anisotropy of the background temperature contains two extrema: the maximum in the direction of the relative velocity and the minimum in the opposite direction.
The expansion of this picture into spherical harmonics contains the monopole and the dipole with the amplitude of order \((v/V)\), but besides, there is a quadrupole (with the amplitude of the order of \((v/V)^2\)) and other kinematic multipoles. All these harmonics have an axial symmetry coinciding with the direction of the relative velocity.
18. At first sight, the similar calculations in Berwald-Moor space lead to the similar picture of the temperature distribution anisotropy as in Minkowski space. There are also two extrema along the relative velocity direction.
19. But if we subtract the values of temperature on the sky of the observer in Minkowski space from the temperature distribution in Berwald-Moor space, there will be a certain difference. First of all, there are 4 additional extrema with the amplitude of the order of $(v/V)^2$, that are located not symmetrically to the axis but as separate spots. The causes for the appearance of these local extrema are the specific features of Berwald-Moor geometry related to the 4-sides structure of its light cone.
20. Increasing the accuracy of calculations, one could find not only these 4 extrema, but also 8 separate extrema. These two groups of extrema could be called Finsler kinematics quadrupole and octopole. Their main difference from the analogous kinematics multipoles in Minkowski space is that they have no axis of symmetry.
21. With the change of the value and of the direction of the relative velocity of the observer, for example, due to the summation of the orbit motion and the motion along some straight line, the anisotropic temperature distribution will also change. In both cases it looks like the following:
22. The difference between the corresponding distributions in Minkowski space and in Berwald-Moor space for various positions of the observer on the orbit has the following character:
23. Since at any moment of time the origin of the temperature distribution on the sky is caused only by kinematics, the expansion of the result into spherical harmonics preserves all the axis of the multipoles (both pseudo Euclidean and Finslerian) related to each other and to the direction of the vector of the relative velocity of the observer.
24. In the picture regarded above, the particles of the cloud could be changed for photons with the temperature of the relic radiation. Instead of the observer’s velocity variations, one could take the value of the Earth orbital velocity around the Sun and summate it with the linear velocity of the Solar system measured relative to the distant galaxies. Then the results of our calculations can be compared to the real measurements of the anisotropy of CMB.
25. In the context in question, we are not interested in the anisotropy related to the events of the far cosmological Past. Only the phenomena caused by Doppler effect are of importance here. As to the kinematic multipole appearing in Minkowski geometry, it is not hard to separate them from the rest of the picture. The situation with rather probable Finslerian kinematic multipole is more difficult. Since their existence was not taken into consideration when the maps of the anisotropy were drawn, they could very probably remain present in the whole picture.
26. This can really be so, and the indirect evidence of it is the anomaly known as cosmological “Axis of Evil” mentioned above. As it was mentioned above, in Finsler space with Berwald-Moor metric the correlation of the axis of the kinematic multipole is as natural as the axis symmetry of the kinematic multipole in Minkowski space.
27. It seems that the anomalously small amplitude of the quadrupole also finds explanation. In the interior of the light cone of Berwald-Moor space-time, there should be a discrete symmetry not only between the halves, but also between the quarters and even between eighths of the sky. In other words, from the cosmological point of view, not only non-kinematic dipole must be principally absent, but also non-kinematic quadrupole and octopole must be absent too. If this is really so, then the quadrupole and octopole present on the real maps of the CMB anisotropy are related not to the historical events of the far Past, but are the consequences of the observer’s kinematics. In this case the amplitude of the quadrupole must be of the order of \((v/c)^2\) which is in agreement with the observations.
28. What is really important is the fact that this hypothesis can be checked in experiment. In order to do this, the complete maps of the relic radiation obtained for relatively short periods of time and separated by periods from several months to a year must be compared. If one of such distributions is subtracted out of the other, then only the kinematic effects related to the orbital motion of the Earth will remain. This will be due to the fact that the cosmological anisotropy and the kinematics related to the Solar system motion relative to the CMB will cancel out.
29. If after this cancellation of the constant components of the CMB, the kinematic dipole corresponding to Minkowski space is also subtracted, then the resulting picture will give the answer to the question: in which geometry do we live? If the axially symmetric distribution remains, then the pseudo Riemannian character of the space-time will be confirmed. If there is 4 and more local extrema that have no ring symmetry and their amplitudes and phases vary with season according to our predictions, then the presence of Finsler effects will be proved.
30. Right now the active phase of the “Planck” program is in progress. The anisotropy of the temperature of the CMB will be measured with more accuracy than before. As far as I know, the scans of the sky performed by “Planck” can be obtained every 3 months. This is worse than a “momentary shot”, but is sufficient for the proposed check.
31. Our Institute “Hyper Complex Systems in Geometry and Physics” which specializes on the research of Finsler spaces has reached the authorities of “Planck” program and got an answer that any changes in the research plan could be made only by agreement with two Principal Investigators. If in this audience there is a specialist who has contacts with the Principal Investigators of the Planck program, I ask to help us to receive the positive answer. However small could seem the probability to prove that the real space-time has Finsler nature, it is not zero. If our hypothesis is confirmed, this result will seriously affect not only Astronomy and Physics but Mathematics as well.
Thank you!