Possibility of observing local anisotropy of space-time with the aid of the Doppler effect

G. Yu. Bogoslovskiĭ

Nuclear Physics Institute of Moscow State University
(Submitted December 26, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 4, 192–194 (20 February 1976)

A relativistic expression is obtained for the Doppler effect in a locally anisotropic space. The effect is sensitive to the orientation of the experimental setup in space. It is proposed to set up a corresponding experiment for the purpose of observing local anisotropy of space.

PACS numbers: 03.30.+p

The idea of local anisotropy of space was advanced in[1,2] and a closed special relativistic theory of anisotropic space-time was constructed. According to this theory, there exists in space a preferred direction, defined by a unit vector $\vec{\nu}$, and the interval between the two units is given by the formula

$$\Delta s = \left[\frac{(c\,\Delta t - \vec{\nu}\Delta\vec{x})^2}{c^2\Delta t^2 - \Delta\vec{x}^2}\right]^{r/2}\sqrt{c^2\Delta t^2 - \Delta\vec{x}^2}\ , \qquad (1)$$

where the parameter r characterizes the value of the anisotropy (at $r=0$ the space of events is pseudo-Euclidean and the usual special relative theory holds). Obviously, if local anisotropy exists in our time, it should be sufficiently small ($|r| \ll 1$), otherwise it would have been observed long ago. Since the existence of even a small anisotropy of space in time would be of great fundamental significance, special experiments are needed for direct observation and measurement of the anisotropy. As it seems to us now, the anisotropy should be manifest in purest form in the Doppler effect, since the gravitational effect of frequency change can be excluded by placing the source and the receiver sufficiently close to each other.

To obtain a formula for the Doppler effect in anisotropic space it is necessary to know how the total four-vector $k^i = (\omega/c, \mathbf{k})$ is transformed. Since the wave four-vector transforms in accordance with the same law as the four-momentum, we have in accordance with[1,2]

$$\omega = \omega' \frac{\sqrt{1 - \dfrac{\vec{v}^2}{c^2}}}{1 - \dfrac{v}{c}\cos\alpha}\left[\frac{1 - (\vec{v}\vec{\nu}/c)}{\sqrt{1 - (\vec{v}^2/c^2)}}\right]^r . \qquad (2)$$

This is indeed the relativistic formula for the Doppler effect in anisotropic space. At $r=0$ it goes over into the classical formula of special relativity theory. In formula (2), ω' is the natural frequency of the source, α is the angle between the direction of emission of the wave and the direction of $\mathbf{v}/|\mathbf{v}|$ of the source motion in the rest system of the receiver, $\vec{\nu}$ is the singled-out direction in the rest system of the receiver, and r is the anisotropy parameter. Formula (2) indicates that at given and fixed $|\mathbf{v}|$ and α the effect depends on the orientation of $\mathbf{v}$ relative to the preferred direction $\vec{\nu}$. In practice, in order to reveal this dependence, it suffices to fix $\mathbf{v}$ and α, and repeat the experiment at a different time of day. Then, during the time between experiments the earth's rotation will change the orientation of the laboratory, meaning also $\mathbf{v}$ relative to $\vec{\nu}$. It is probable that $\vec{\nu}$ changes little within the limits of the solar system and is on the average directed perpendicular to the plane of the earth's orbit.

To obtain an upper bound of the anisotropy parameter r, we use the fact that in an accelerator, at a Lorentz factor $\gamma = 10^4$, the relative error in the determination of the energy is $\Delta E/E = 10^{-4}$.[3]

Stipulating that at this velocity the relative discrepancy between the energies calculated from the relativistic formulas with and without allowance for the anisotropy be $\lesssim 10^{-4}$, we get the estimate $|r| \lesssim 10^{-5}$. It is interesting to note that the weak-interaction constant is also at this level. It is possible that this circumstance is not an accident, all the more since the metric (1) of the anisotropic space of the event is not invariant relative to the reflection of space or time.

In one way or another, if we tentatively assume the parameter value $5\times 10^{-10} \lesssim |r| \lesssim 10^{-5}$, it becomes possible in principle to observe experimentally local anisotropy by measuring the Doppler effect with the aid of the Mössbauer effect.

[1]G. Yu. Bogoslovskiĭ, Dokl. Akad. Nauk SSSR **213**, 1055 (1973) [Sov. Phys. Dokl. **18**, 810 (1974)].
[2]G. Yu. Bogoslovskiĭ, JINR R1,2-8529, Dubna, 1975.
[3]D. I. Blokhintsev, Usp. Fiz. Nauk **89**, 185 (1966) [Sov. Phys. Usp. **9**, 405 (1966)].