RELATIVISTIC DOPPLER EFFECT AND RELICT RADIATION

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Relativistic Doppler effect for uniform particle movement driven by relict radiation is estimated numerically. Obtained results demonstrate that baryon mass is comparable with the energy of relict radiation, divided by c^2, absorbed by the matter for the whole period of Universe existence.

Relict radiation (RR), discovered in 1965, is a subject of careful study till now. Maps with relict radiation are regularly updated and values of different parameters are specified [1]. Relativistic Doppler Effect for particle movement in space filled by relict radiation is studied in this work.

Let us consider isolated body (at considerable distance from all the others – motionless objects), which moves at constant velocity. For observer, related with moving body reference frame, homogeneity of relict radiation is abused, that is caused by Doppler Effect.

As it was determined with high accuracy experimentally [2], radiation frequency ν', measured by motionless observer, is related with natural frequency ν^0 of radiation source by the following relation:

$$\nu^0 = \nu' \frac{1 - {(\mathbf{v},\mathbf{n})}/{c}}{\sqrt{1 - {\mathbf{v}^2}/{c^2}}}, \tag{1}$$

where $\mathbf{v}$ – source velocity in respect of observer, vector $\mathbf{n}$ – value, which determines radiation direction in observer reference frame. In the considered case, radiation source is motionless and observer (body) is moving at $\mathbf{v}$ velocity. It follows that frequency of radiation quanta ν_+, falling at the body in the opposite direction of it motion, equals to:

$$\nu_+ = \nu \frac{\sqrt{1-\mathbf{v}^2/c^2}}{1-\frac{|\mathbf{v}|}{c}}, \quad (2)$$

and frequency of radiation quanta, falling along the body, motion equals to:

$$\nu_- = \nu \frac{\sqrt{1-\mathbf{v}^2/c^2}}{1+\frac{|\mathbf{v}|}{c}}. \quad (3)$$

Difference between quanta impulse values, falling at the body in the opposite direction of its motion and along its motion, equals to:

$$\Delta p = \frac{h}{c}\nu_+ - \frac{h}{c}\nu_- = 2\frac{h\nu}{c}\frac{|\mathbf{v}|}{c\sqrt{1-\mathbf{v}^2/c^2}} = \frac{2p}{\sqrt{1-\mathbf{v}^2/c^2}}\frac{|\mathbf{v}|}{c}. \quad (4)$$

Here and further p - average relict radiation quanta impulse. Average quanta number, falling at the body in the opposite direction of its motion and along its motion, according to the STR clauses, are the same and equals to:

$$\dot{n}_\pm = \frac{\dot{n}}{6}\sigma, \quad (5)$$

Whe $\dot{n}$ – specific (per unit surface) relict radiation quanta flux intensity, σ – cross section of relict radiation, absorbed by the body. Thereby, the force, preventing free and even body motion at $\mathbf{v}$ velocity equals to:

$$\mathbf{F}_f = -\sigma\frac{\dot{n}p}{3c}\frac{\mathbf{v}}{\sqrt{1-\mathbf{v}^2/c^2}}. \quad (6)$$

But results of observations does not confirm body's slowing at macroscale. To eliminate this contradiction it is necessary to assume existence of a force equal by value and and opposite by direction with $\boldsymbol{F}_f$, force, which counterbalance it. Body impulse arises as a result of this force action on the body during certain time interval ΔT. That time, necessary for establishing constant body velocity, is a time necessary to establish balance with Doppler resistance force. In case when this force remains constant by value during the whole time interval ΔT, impulse value **p**, reached by the body, equals to:

$$\mathbf{p} = -\mathbf{F}_f \cdot \Delta T = \sigma \frac{\dot{n}p}{3c} \Delta T \frac{\mathbf{v}}{\sqrt{1 - \mathbf{v}^2/c^2}}, \tag{7}$$

On the other hand, according to the main relativistic ratio

$$E^2 - \mathbf{p}^2 c^2 = m^2 c^4, \tag{8}$$

where m - invariant body mass, E - its complete energy. Body impulse is determined by:

$$\mathbf{p} = \frac{m\mathbf{v}}{\sqrt{1 - \mathbf{v}^2/c^2}}. \tag{9}$$

Equating (7) and (9), we will obtain

$$m = \frac{\sigma}{3} \frac{\dot{n}p}{c} \Delta T. \tag{10}$$

Thereby, body mass, according to (10), equivalent to impulses amount of absorbed relict radiation quanta over the time ΔT, normalized to light velocity.

To estimate validity of this conclusion, let us make use well-known values of real Universe parameters.

Specific (per unit surface) relict radiation intensity with T temperature, in accordance with Stefan-Boltzmann's law for ideal black body, will constitute:

$$\Phi = \sigma_S T^4, \tag{11}$$

where σ_S – Stefan-Boltzmann's constant, T = 2.728 K [3]. Actual intensity will double, because relict radiation falls per unit surface from both sides of the plane. Relating average flux values with integral one, we will obtaine:

$$\dot{n}pc = 2\sigma_S T^4. \tag{12}$$

Ratio of Cross-section σ of relict radiation, absorbed by atoms and molecules, to their mass may be estimated using data on electric waves scattering (Thomson) by free electrons, which cross-section is not wavelength dependent. It is possible to use simplification, assuming that in atoms and molecules one electron fall on two nucleons. Ratio of electron's Thomson cross-section to 2 atomic mass units equals to:

$$\frac{\sigma}{m}=\frac{8\pi}{3}\frac{r_e^2}{2m_{\mathrm{amu}}}=197\ \mathrm{sm^2кg^{-1}}=0.327\,\mathrm{barn/a.m.u.}, \tag{13}$$

where r_e – classical electron radius, m_{amu} – atomic mass unit value. Substituting value of this ratio together with (12) into (10), we will obtain:

$$\Delta T=\frac{3c^2}{2\sigma_S T^4}\cdot\frac{m}{\sigma}=2.18\cdot10^{24}\,\mathrm{c}. \tag{14}$$

Numerical value of the time necessary to reach equilibrium exceeds age of the Universe (~$5\cdot10^{17}$s [1]) over than by six orders. However, this value considerably depends on relict radiation temperature. If the Universe was earlier hotter, this will lead to reduction of estimated value ΔT in formula (14). For example, for the averaged by time temperature of relict radiation ~ 100 K, ΔT value will be by order of the Universe age.

Thereby, if ΔT corresponds to the Universe age, then its mass corresponds to the value of relict radiation energy (with accuracy up to multiplier c^2), transformed into matter by means of relict radiation absorption over all this time.

BIBLIOGRAPHY

1. C. L. Bennett et al. *Astrophys. J. Suppl.* **208** 20 (2013)
2. H. E. Ives, G. R. Stilwell *J. Opt. Soc. America* **28** 215 (1938)
3. G. F. Smoot "The Cosmic Microwave Background Spectrum"; astro-ph/9705101