GLOBAL GRAVITATIONAL-OPTICAL GRADIENT LENS IN EXPANDING UNIVERSE

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Gravitational-optical gradient lens, comoving with radiation, is formed in observer's frame of reference of time and spatial coordinates (FR) due to evolutional decrease of average density of matter in the Universe as well as due to evolutional decrease of refraction index of interstellar medium. This diverging lens and Hubble gravitational lens together form virtual image of all infinitely far points of Euclidean background space of FR, comoving with expanding Universe, on its focal surface, which is the imaginary observer horizon. Events that take place in different points but simultaneous in observer's FR are nonsimultaneous in cosmological time of FR, commoving with Universe, due to Universe expansion. Therefore world point of imaginary Big Bang is present in observer's intrinsic space at every moment of his proper time. This point and observer's dislocation point are the opposite poles of four-dimensional hypersurface of observer's space. When gradient lens is not taken into account one may come to a conclusion that Hubble lens forms the horizon of cosmological past (imaginary observer horizon) in vacuum external solutions of equations of gravitational field when cosmological constant is nonzero. This also leads to spatial homogeneity of the negative power of global gravitational lens and, consequently, this leads to a linear dependence of red shift of radiation spectrum of astronomical objects on the distance to those objects. However, when gradient lens is taken into account this dependence becomes nonlinear and corresponds to accelerated expansion of the Universe, while imaginary observer horizon of cosmological past degenerates into point of imaginary Big Bang of the Universe. This is similar to degeneration of the imaginary horizon of cosmological future (Schwarzschild sphere) in internal solution of equations of gravitational field.

PACS: 03.30.+p, 04.20.-q, 98.62.Py, 95.35.+d

Value of Schwarzschild radial coordinate of the luminous astronomical object is connected with the difference between absolute M and non-relativistic-corrected visible $\tilde{\mathrm{m}}$ its stellar magnitudes via the following relativistic photometric dependence [1]:

$$r = 10^{1-(\mathrm{M}-\tilde{\mathrm{m}}_R)/5} = (10^{\xi/5} + H/c)^{-1} = (1/R_N + H/c)^{-1}\,, \tag{1}$$

where: $\xi = \mathrm{M} - \tilde{\mathrm{m}} + 5\lg[(z+1)/(\tilde{z}+1)] - 5 = -5\lg R_N = 5\lg(1/r - H/c) = 5\lg(H/c) - 5\lg\tilde{z}$; $\tilde{\mathrm{m}}_R = \tilde{\mathrm{m}} - 5\lg(z+1)$ – relativistic-corrected visible stellar magnitude of this object; z and $\tilde{z} = Hr/(c - Hr) = HR_N/c$ – not corrected and corrected (caused only by evolutionary process, which is the cause of Universe expansion) values of red shift correspondingly; R_N – radial coordinate of astronomical object in background Euclidean space [2] of comoving with Universe frame of reference of spatial coordinates and time (FR); $H = c\sqrt{\Lambda/3}$ – Hubble constant; Λ – cosmological constant; c – constant of the velocity of light.

Evolutionary process, which is the cause of Universe expansion [3], forms in vacuum space-time continuum (STC) of observer not only the gravitational field that force distant astronomical objects to "run away" from the observer, but also global gravitational lens that corresponds to this removable field. This comoving with radiation diverging lens possesses negative Hubble lens power:

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$$\Phi_H = -H/c = -1/r_c = 1/R_N - 1/r = 1/R_N - (z+1)10^{(\mathrm{M}-\tilde{\mathrm{m}})/5-1} \quad (2)$$

and creates virtual image of infinitely far points ($R_N = \infty$) of background flat space of comoving with Universe FR on the fictive spherical surface ($r = r_c$) of imaginary observer horizon in observer vacuum STC.

The same follows from the Schwarzschild solution in comoving with Universe [3]:

$$R_N(r,\tilde{\tau}) = r_i \exp\left(H(\tilde{\tau}_i - \tilde{\tau}) + \int_{r_i}^{r} \frac{\sqrt{ab}}{fr} dr \right),$$

$$R_N(r,t) = r_i \exp\left(H(t_i - t) + \int_{r_i}^{r} \sqrt{\frac{a}{b}} \frac{f}{r} dr \right), \quad (3)$$

where: $a \equiv g_{11}$ и $b \equiv -g_{44} = f^2 - \Lambda r^2/3 = f^2 - (Hr/c)^2$ – functions of components of STC linear element of spherically symmetric Schwarzschild solution [3], which determine the mutual desynchronization of cosmological time:

$$\tilde{\tau} = \tilde{\tau}_i + \left[(t - t_i) - \frac{H}{c^2} \int_{r_i}^{r} \sqrt{\frac{a}{b}} \frac{r}{f} dr \right], \quad (4)$$

that is counted by metrically homogeneous (for the matter) scale and coordinate-like intrinsic time t of matter in space points, which are distant for the point i of synchronization of these times counts; $f(r)$ – function that determines velocity of propagation of radiation in comoving with Universe FR. For comoving with radiation time moments:

$$t_i - t = \frac{1}{c} \int_{r_i}^{r} \sqrt{\frac{a}{b}} dr \quad (5)$$

the following relation takes place:

$$\tilde{R}_{Nc} = r_i \exp \int_{r_i}^{r} \frac{\sqrt{ab}}{r(f - Hr/c)} dr \quad (6)$$

Hence for conventionally free space ($ab = 1$) and for: $r >> r_i > r_g$ ($f \approx 1$) the following relation is received:

$$-H/c = 1/\tilde{R}_{Nc} - 1/r$$

Values of radial motion velocity v of distant astronomical objects of expanding Universe tend to the values of coordinate-like velocity of light $v_c = c\sqrt{b}$ at approaching imaginary observer horizon and so at deepening into cosmological past. This leads to a very big relativistic shrinkage of dimensions of these objects and of distances between them. Also this is the formal cause of the formation of imaginary observer horizon in comoving with matter FRs. According to Schwarzschild solution, presence of imaginary observer horizon, which is also the horizon of cosmological past, in vacuum STC of matter is inevitable at nonzero value of cosmological constant. Galaxies of expanding Universe fall free on imaginary observer horizon, but they cannot reach it in principle, because of zero value of coordinate-like velocity of light on its fictive surface. And, therefore, galaxies cannot hide behind the imaginary observer horizon [3].

However, rotation of observer in background Euclidean space, which causes ellipticity of fictive surface of imaginary observer horizon, as well as the presence of astronomical objects in its space, as well as solid filling of the Universe with initial matter nearby this imaginary horizon, are not taken into account by Schwarzschild solution. Therewith, expression (2) for the power of Hubble lens corresponds only to homogeneous optical medium – hypothetical absolute vacuum, used in Schwarzschild solution. Indeed, conventionally free space that surrounds any compact matter is filled in by very rarefied gas-dust matter, pressure in which only gradually decreases at distancing from compact matter and cannot be smaller than the value of pressure of relict radiation. Therefore, it is worthwhile to examine the solution of gravitational field equations also for non-free space that surrounds compact matter. In commoving with Universe FR all equations, except the one that determines the rate of matter gauge-self-contracting:

$$\frac{1}{r}\left(\frac{\partial r}{\partial \tilde{\tau}}\right)_{R_N} = cf\sqrt{(\Lambda+\kappa\, c^2 <\mu>)/3} = fH\sqrt{1+\frac{c^2<\mu>}{p_\Lambda}} \qquad (7)$$

come to thermodynamic identities, where: $(\partial r/\partial R_N)_{\tilde{\tau}} = r/R_N$; $f=(ab)^{1/2}$; κ – Einstein constant, $<\mu(\tilde{\tau})>$ – average density of the mass of matter in the Universe, $p_\Lambda = \Lambda/\kappa = 3H^2/\kappa\, c^2 = p_{\min}/2$, a $p_{\min}$ – minimal value of gravitational pressure in arbitrary rarefied matter [4]. Then, for comoving with radiation moments of cosmological time (in «comoving with radiation» FR) the following relations take place: $d\tilde{\tau}_c = -(r/cfR_N)dR_N$, and:

$$\frac{dr}{dR_N} = \left(\frac{\partial r}{\partial R_N}\right)_\tau + \left(\frac{\partial r}{\partial \tilde{\tau}}\right)_{R_N}\frac{d\tilde{\tau}}{dR_N} = \frac{r}{R_N}\left[1-r\sqrt{(\Lambda+\kappa\, c^2<\mu>)/3}\right] = \frac{r}{R_N}\left[1-\frac{v}{c\sqrt{b}}\right] \qquad (8)$$

For the same moment of intrinsic time of compact matter those relations are the following: $d\tilde{\tau}_t = -(r^2\sqrt{(\Lambda+\kappa\, c^2<\mu>)/3}/cfR_N)dR_N$, and:

$$\frac{dr}{dR_N} = \frac{r}{R_N}\left[1-r^2(\Lambda+\kappa\, c^2<\mu>)/3\right] = \frac{r}{R_N}\left[1-\frac{v^2}{c^2 b}\right] = \frac{r}{aR_N} \qquad (9)$$

According to (8) and (9) value *r* at first increases at distancing from the observer until it reaches its maximal value $r_{\max}$ on the singular spherical surface of relativistic observer horizon ($v = v_c = c\sqrt{b}$). Then this value begins to decrease and it tends to zero in the point of imaginary Universe Big Bang. Therefore *r* should be considered not as radial coordinate, but only as Schwarzschild coordinate-like parameter (Schwarzschild radial pseudo-coordinate). Maximal values of this parameter are not the same in comoving with radiation FR and comoving with compact matter FR. They corresponds to not the same moment of cosmological time and, consequently, to not the same value of average density of Universe matter: $<\mu(\tilde{\tau})> = (3r^{-2}-\Lambda)/\kappa\, c^2 = 3(r^{-2}-H^2c^{-2})/\kappa\, c^2$. Radial distances to observed astronomical objects in background Euclidean space of comoving with Universe FR in comoving with radiation moments of cosmological time are determined by the following relation:

$$\tilde{R}_{Nc} = r_i \exp\int_{r_i}^{r}\frac{dr}{r\left[1-r\sqrt{(\Lambda+\kappa\, c^2<\mu>)/3}\right]}. \qquad (10)$$

Radial distances to observed astronomical objects in background Euclidean space of comoving with Universe FR in moments of cosmological time that correspond to the same moment of intrinsic time of compact matter are determined by the following relation:

$$R_N(r,t) = r_i \exp\int_{r_i}^{r}\frac{dr}{r\left[1-r^2(\Lambda+\kappa\, c^2<\mu>)/3\right]} = r_i \exp\left[\frac{\rho_i-\rho(r)}{\rho_c-\rho(r)}\right], \qquad (11)$$

where: ρ – radius-vector of observed object in nonlinearly transformed world space of comoving with Universe FR when appropriate nonlinear transformations of cosmological time and radial distance ($\acute{R}_N \equiv r$) is used. Since velocity of moving away from observer distant astronomical objects of expanding Universe is the following:

$$v = Hr\sqrt{b(1+\kappa\, c^4<\mu>/3H^2)} = Hrf\sqrt{\left[1-r^2(\kappa\, c^2<\mu>/3+H^2/c^2)\right](1+\kappa\, c^4<\mu>/3H^2)},$$

corrected value of the red shift of their radiation spectrum should be determined by the following relation:

$$\tilde{z}=\sqrt{\frac{1+v/c\sqrt{b}}{b(1-v/c\sqrt{b})}}-1=\frac{1}{f(1-v/c\sqrt{b})}-1=\frac{c}{f(c-Hr\sqrt{1+\kappa\ c^4<\mu>/3H^2})}-1. \qquad (12)$$

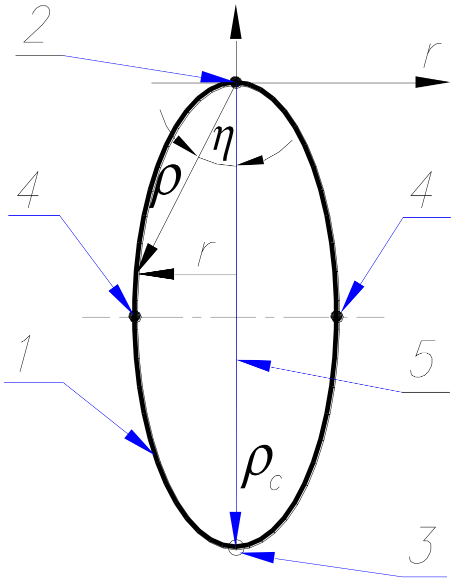
Since, according to (12), value of red shift of the frequency of radiation that comes from observer horizon of "comoving with radiation" FR can be only infinitely big this horizon is an imaginary observer horizon. And, consequently, its fictive surface separates nothing from observer in infinite space of the Universe. Comoving with radiation gravitational-optical gradient lens is formed in observer FR due to evolutionary decrease of average density of matter in the Universe and of refractive index of interstellar medium. Together with Hubble gravitational lens this diverging lens, which has spatially inhomogeneous negative lens power:

$$\Phi(r)=\frac{1}{r_i}\exp\int_{r_i}^{r}\frac{dr}{r\left[r\sqrt{(\Lambda+\kappa\ c^2<\mu>)/3}-1\right]}-\frac{1}{r}, \qquad (13)$$

forms virtual image of all infinitely far points of background Euclidean space of comoving with Universe FR on its focal surface, which is the imaginary observer horizon.

Relativistic observer horizon of comoving with compact matter FR is not an imaginary. World points of its singular surface are not connected by light signals to observer. Coordinate-like velocity of light on its surface is equal to zero in the moment of registration of radiation that has come from it, but not in the moment of its generation. Therefore, this horizon determines only the configuration of intrinsic space of compact matter and this horizon is the true event horizon of the past. Since Universe is expanding, events, which are simultaneous in observer FR but take place in different points, are not simultaneous in cosmological time of comoving with Universe FR. Therefore, world point of imaginary Big Bang of the Universe is present in intrinsic space of the observer in every moment of observer intrinsic time. This point and the point, where observer is, are opposite poles of four-dimensional hypersurface of observer space. Schwarzschild radial pseudo-coordinates are only the radiuses of latitudinal cross-sections of this hypersurface. If gradient lens was not taken into account, then lens power of global gravitational lens would be spatially homogeneous and, therefore, red shift of radiation spectrum of astronomical objects would linearly depend on the distances to these objects. If gradient lens is taken into account, then this dependence becomes nonlinear. And if correct spatial distribution of the function $f(r)$ in observer intrinsic space (this distribution is compatible with the law of evolutionary change of global gravithermodynamic state of matter in the Universe) is used, then it corresponds to accelerated Universe expansion. In this case imaginary observer horizon (pseudo-horizon of cosmological past), which corresponds to infinitely far points of background flat space of the Universe, degenerates at the transition from ideal to real intrinsic FR of astronomical body and transforms into the point of imaginary Big Bang of the Universe. This fact is an analogy to degeneration of the horizon of cosmological future (Schwarzschild sphere) in internal solution of gravitational field equations.

So, imaginary observer horizon in the Universe is an attribute of only ideal intrinsic FRs of the bodies and of corresponding to them STCs. Singular surface, which maybe corresponds to time moment of origination of free radiation in the Universe, takes the maximum value of photometric radius in real intrinsic observer FR, as it is shown on the picture below. Behind this surface photometric radius (Schwarzschild radial pseudo-coordinate) of world space of astronomical body begins to decrease at deepening into cosmological past [1]. And, consequently, additional decreasing of the value of photometric radius of astronomical objects, takes place. This additional decreasing is caused by the presence of irremovable gravitational field in real observer FR and additional lens power of global gravitational-optical gradient lens that corresponds to this field.



Pic. Intrinsic space of astronomical body in its real FR in the concrete moment of its intrinsic time.

1 – intrinsic space of the body (one from the set of radial directions in this space);
2 – world point of body center;
3 – world point of imaginary Big Bang of the Universe that does not belong to body space;
4 – points of world surface of the Universe with maximal value of photometric radius r (Schwarzschild radial pseudo-coordinate);
5 – exponential scale, by which cosmological time is counted;
ρ – radius-vector of observed object in nonlinearly transformed fundamental world space of comoving with Universe.

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