Однако при возрасте Вселенной $t_0 \approx 1.4 \cdot 10^{10}$ лет толщина этого слоя составляет не более $10^{-5} - 10^{-4}$ от её радиуса, равного ct_0.

Итак, для самых надёжных наблюдательных данных найденное решение без эмпирических констант согласует значения времён жизни Вселенной и постоянной Хаббла лучше любых современных космологических теорий (*Λ*CDM) с тёмными энергией (*Λ*) и материей (CDM – Cold Dark Matter). Если тёмная материя может понадобиться для описания замедления расширения Вселенной, то в свете построенного решения, основные формулы которого, включая **u** = **r**/*t*, не содержат эмпирических постоянных, введение тёмной энергии излишне.

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THE MODEL OF THE BIG BANG AND THE UNIVERSE EXPANSION WITH THE DISPERSION TO THE VOID A GAS, COMPRESSED “ALMOST IN A POINT”. A COMPARISON WITH OBSERVATIONAL DATA AND MODERN COSMOLOGICAL THEORIES

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E. Hubble, measuring of the light Doppler shift, has formulated the law in 1929, according to which remote galaxies move away from us with speed **u,** proportional to distance **r** to them: **u** = *H*(*t*)**r**. Time-dependent *t* function *H*(*t*) called Hubble constant. If galaxies scatter, then, having a "suitable" solution, one can determine when they were together, i.e. when they (more precisely, particles of gas, from which the galaxies were then formed) "have scattered from a point" or "almost from a point". In the model of the expanding universe developed by the authors, it is principally important to involve the solution of the dispersion problem in the void of a finite mass of an inviscid and non-heat-conducting (ideal) gas, which is compressed in a point or "almost in a point", respectively, in the classical and relativistic approximations. Here, by analogy with the problem of a strong point explosion [1], "almost point" means a sphere which initial radius r_0 is small in comparison with the radius of the expanding Universe. It is not excluded, that r_0 should be less and even much less than the gravitational radius of the Universe $r_g = 2m_0G/c^2$, where $G = 6.67 \cdot 10^{-8}$ cm^3/(g·s^2) is the gravitational constant, and c is the speed of light. Therefore, the solution of the dispersion problem, found by the authors within STR, is valid for $ct >> r_0$ with the time, counted from the beginning of the dispersion. In contrast, the existing cosmological models are based on the non-stationary solution of GTR equations theor generalizations, obtained by A. Friedmann in 1922 (see below). According to Friedmann solution, the Universe is unbounded and homogeneous in all scalar parameters.

The fundamental difference between Friedmann solution and its modern generalizations from the solution of the dispersion problem is seen in the quotation (see [2] p. 38): "We turn to the law of expansion in the model of a homogeneous Universe filled with a relativistic gas. Can we say that high pressure is the cause of the expansion of the Universe and that the highly compressed matter expands for the same reason that the high-pressure gases formed upon the detonation of a charge of an explosive material disperse? No, such an opinion is totally incorrect. The qualitative difference is that a charge of an explosive material is surrounded by air at atmospheric pressure. Expansion is caused by the difference between the enormous pressure of the gases (the explosion products) and the comparatively weak pressure of the air surrounding them. However, when we consider the pressure in the homogeneous Universe, it is assumed that the pressure is distributed strictly uniformly! Consequently, there is no pressure difference between different particles at the same instant of time, and, therefore, there is no force which could influence the expansion and thereby be the cause of expansion. The fact that there is expansion in the existing theory is a result of the initial distribution of the velocities. The cause of this initial distribution is still unknown."

Friedmann solution was taken as the "appropriate" one after E. Hubble discovery. The moment of the singularity of always boundless Universe scalar parameters is taken for the beginning of the expansion in the solution. Time, which counted from this moment, is lifetime of the Universe. Possibility of the Universe expansion description, using Friedmann solution did not raise doubts till 1998, when two groups of American astronomers have found its discrepancy with observational data. To eliminate this discrepancy, Friedmann solution was generalized to non-zero values of the cosmological constant Λ, which is introduced by A. Einstein. The choice of Λ has allowed to coordinate observations with the new solution. The found Λ values, as well as considered by A. Einstein, lead to the effect of anti-gravitation. For the discovery of anti-gravitation and of the accompanying accelerated Universe expansion, three American astronomers won Nobel Prize in 2011. The hypothetical carrier of anti-gravitation is called dark energy.

It seems natural to describe opened by Hubble expansion of the Universe, to take the solution the problem on dispersion a large, but finite, mass m_0 of gas, but attempts to obtain such a solution have been unsuccessful until recently. One of the first to try to involve the dispersion problem in describing the expansion of the Universe is E. Milne, on the pediment of his book [3] a spherical Universe of radius $r = ct$ is drawn. Assuming that from the beginning of the dispersion the particles of gas, and then the galaxies formed from them, move away with zero acceleration, he, not solving the problem of the dispersion, came to the law of velocity distribution

$$\mathbf{u} = \mathbf{r}/t \tag{0.1}$$

and showed its invariance to the Lorentz transformations. In addition, in [3], from the requirement of the same invariance for the bulk density of particles, its distribution is found in the expanding according to the law (0.1) Universe. For such a law, the bulk density of particles, was unlimitedly growing when approaching the Universe boundary, which moves with the speed of light. Although the law (0.1) is derived not from the solution of the dispersion problem, but from the assumption of zero acceleration of the scattered particles, it is used throughout almost the entire monograph of Milne. He finishes the formulae

$$\mathbf{u} = (2/3)\mathbf{r}/t, \tag{0.2}$$

which is a consequence of Friedmann solution for expansion of the Universe, consisting of a cold monatomic gas. After Milne, the law (0.1) was not involved in the description of the expansion of the Universe.

An attempt is made to solve the problem on spherical dispersion of a finite mass of an ideal perfect gravitating gas in the approximation of classical gas dynamics in [4]. A solution satisfying the Hubble law was sought, by virtue of which in the expanding gas sphere the single radial velocity component u is a linear function of the distance from the center of the ball r. It turned out that for the realization of such a solution the entropy of each particle of the expanding gas have to change in a completely definite way. But in the shockless expansion of an inviscid and non-heat-conducting gas, its entropy does not change. Consequently, the solutions considered are useless for description of the Universe expansion.

Having formulated and partially solved the self-similar problem on dispersion into the void of a finite mass of gas compressed in a point, the authors of [5] already faced a different problem in the classical approximation. The solutions obtained with a linear dependence of u on r, i.e. satisfying the Hubble law, did not satisfy the other condition, the vanishing of the pressure p at the boundary of the gas ball expanding into the void. Moreover, it was established that in the plane of self-similar variables there is no segment of the integral curve, which realizes the required solution in the problem under consideration. The solution of the problem obtained in [6-8], which was called in [5] "the paradox of the expansion into a void", in the classical approximation led to a solution with instantaneous gas expansion to the whole space with zero pressure, density ρ, temperature T and the speed of sound a for any time $t > 0$, while the velocity of the scattering particles $\mathbf{u} = \mathbf{r}/t$, i.e. the solution led to the formula (0.1). It is also obtained for $r \le ct$ within the special theory of relativity (STR) without gravity. This solution describes observations better than any modern cosmological theory. Below a condensed presentation of the main results [6-8], a section is presupposed, one of the purposes of which is to find out the reasons that prevented the construction of the required solutions of the dispersion problem in [4, 5].

1. Within classical gas dynamics one-dimensional non-stationary flows (and rest) of an ideal gravitating two-parameter gas with planar, axial or spherical symmetry and with unique component speed u are described by the equations

$$\frac{\partial(r^{\nu-1}\rho)}{\partial t} + \frac{\partial(r^{\nu-1}\rho u)}{\partial r} = 0,\quad \frac{du}{dt} + \frac{1}{\rho}\frac{\partial p}{\partial r} + \frac{Gm}{r^{\nu-1}} = 0,\quad \frac{\partial m}{\partial r} = f_\nu r^{\nu-1}\rho,\ m(0,t) = 0,$$
$$\frac{ds}{dt} = 0 \propto \frac{d\rho}{dt} = \frac{1}{a^2}\frac{dp}{dt} = \frac{\rho}{a^2}\frac{dh}{dt},\quad \frac{d}{dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial r},\quad f_1 = 1,\ f_2 = 2\pi,\ f_3 = 4\pi. \tag{1.1}$$

Here r is the distance from the plane (ν = 1), the axis (ν = 2) or the center (ν = 3) of symmetry (hereinafter, the “center of symmetry” – CS), while h and s are the specific enthalpy and entropy (known functions, for example, of p and ρ). In this section, using equations (1.1), we consider interesting for the future gravitationally balanced rest and some features of the one-dimensional non-self-similar gas expansion into the void. We confine ourselves to the perfect gas, for which

$$h = \frac{\gamma p}{(\gamma-1)\rho} = \frac{a^2}{\gamma - 1},\quad s = \frac{\gamma p}{\rho^\gamma} = \frac{a^2}{\rho^{\gamma-1}}, \tag{1.2}$$

where γ is the ratio of specific heats (adiabatic exponent), and s is not the entropy, but its function (the “entropy function”).

For a gas at rest in a planar, cylindrical and spherical volume, which is bounded by an impenetrable shell (hereinafter, in a “ball of radius r_0”), the first equation (1.1), the continuity equation, is satisfied identically, and the second (equation of motion) becomes an equilibrium equation. For a fixed radius of the sphere r_0, entropy function $s = s_0$, and gas mass m_0, the distributions of the gas parameters in the sphere are determined by the solution of the boundary value problem:

$$\frac{dR}{d\xi} = -\alpha\frac{MR^{2-\gamma}}{\xi^{2(\nu-1)/\nu}},\quad \frac{dM}{d\xi} = R,\ 0 \le \xi \le 1,\ M(0) = 0,\ \ M(1) = 1 \tag{1.3}$$

with normalized variables and constant α, which are equal to

$$0 \le \xi = \frac{r^\nu}{r_0^\nu} \le 1,\ R(\xi) = \frac{\rho f_\nu r_0^\nu}{\nu m_0},\ 0 \le M(\xi) = \frac{m}{m_0} \le 1,\ \alpha = G\frac{(f_\nu)^{\gamma-1} m_0^{2-\gamma}}{\nu^\gamma s_0} r_0^{l(\nu,\gamma)},\ l(\nu,\gamma) = 2 - 2\nu + \nu\gamma .$$

It is convenient to solve the boundary value problem (1.3) as a Cauchy problem with initial data for $\xi = 0$, choosing the value of R (0) so as to satisfy the condition M (1) = 1.

We consider the unconstrained compression, which is of interest for this investigation (with $r_0 \to 0$), of the gravitating gas. The behavior of the constant α is essential for such a compression. Since $l(1, \gamma) = \gamma$, $l(2, \gamma) = 2(\gamma - 1)$ and $l(3, \gamma) = 3\gamma - 4$, then in the planar and cylindrical cases $\alpha \to 0$ for unlimited compression of the gas for any real values γ. In the spherical case $\alpha \to 0$ for $r_0 \to 0$, not for any perfect gas, but when the inequality $\gamma > 4/3$ is fulfilled. According to the equation (1.3) and performed calculations, if $\alpha \to 0$ for $r_0 \to 0$, then in the indicated limit $R(\xi) \to 1$ and unboundedly increasing density, and with it the pressure, temperature and speed of sound are aligned. In the limit,

$$\rho(\xi) \approx \rho_0 = \frac{K}{r_0^\nu},\ a(\xi) \approx a_0 = \frac{s_0^{1/2} K^{(\gamma-1)/2}}{r_0^{\nu(\gamma-1)/2}},\ p(\xi) \approx p_0 = \frac{s_0 K^\gamma}{\gamma r_0^{\nu\gamma}},\ K = \frac{\nu m_0}{f_\nu} . \tag{1.4}$$

With an unlimited increase in density and a decrease in the size of the ball, the unevenness of the parameters caused by gravity would seem to grow. It turns out otherwise. For fixed m_0 and s_0 when $l(\nu, \gamma) > 0$ and $\nu \ne 1$ there are always finite $\alpha = \alpha_{\mathrm{m}}(\nu,\gamma) > 0$ and

$$r_{\mathrm{m}} = \left[\frac{\alpha_{\mathrm{m}}(\nu,\gamma)\nu^\gamma s_0}{G(f_\nu)^{\gamma-1} m_0^{2-\gamma}}\right]^{1/l(\nu,\gamma)},$$

that R (1), and together with it the pressure p (1) on the boundary of the ball vanishes. Setting $r_0 > r_{\mathrm{m}}$ does not make sense, because it corresponds to the volume with gas in the center and a void in the periphery. In the planar case, it follows from the solution of the problem (1.3) in quadratures that $\alpha_{\mathrm{m}}(1,\gamma) = \infty$.

If at $t = 0$ the shell, which bounds the gas considered above, instantly disappears, then its isentropic outflow into the void begins. On the $C^\pm$-characteristics of equations (1.1) describing the flow that has arisen, below equations are valid

$$C^\pm:\ \frac{dt}{dr} = \frac{1}{u \pm a},\ \frac{du}{dr} \pm \frac{2}{\gamma-1}\frac{da}{dr} \pm \frac{(\nu-1)au}{r(u \pm a)} + \frac{Gm}{r^{\nu-1}(u \pm a)} = 0, \tag{1.5}$$

and its rt-diagram, as in Fig. 1, includes a centered rarefaction wave (CRW) with a focus at the point $r = r_0,\ t = 0$. The right boundary of the CRW is one of the generating it C^--characteristics, coinciding with the pathline (C^0-characteristic), i.e. with the boundary of the expanding gas and a void. On the boundary $a \equiv 0,\ m = m_0$, and the corresponding equation (1.5) takes the form

$$\frac{du}{dr} + \frac{Gm_0}{r^{\nu-1}u} = 0 . \tag{1.6}$$

Due to the equation (1.5), for a C^+-characteristic crossing the CRW at the focus, the velocity of the gas at the initial point of the boundary with a void is equal to $u_+ = 2a(1)/(\gamma-1)$, and taking (1.4) taken into account (1.4) for sufficiently small r_0, we obtain the formula

$$u_+^2 = \frac{4 s_0 K^{\gamma-1}}{(\gamma-1)^2 r_0^{\nu(\gamma-1)}} .$$

Integrating from $r = r_0$, where $u^2 = u_+^2$ and $t = 0$, (1.6) and the equation for t from (1.5), we find that on the gas-void boundary

$$u^2 = \frac{4 s_0 K^{\gamma-1}}{(\gamma-1)^2 r_0^{\nu(\gamma-1)}} + 2Gm_0 \begin{cases} (r_0 - r),\ \nu = 1 \\ (\ln r_0 - \ln r),\ \nu = 2 \\ (1/r - 1/r_0),\ \nu = 3 \end{cases} \approx \frac{4 s_0 K^{\gamma-1}}{(\gamma-1)^2 r_0^{\nu(\gamma-1)}},\ t \approx \frac{(\gamma-1) r_0^{\nu(\gamma-1)/2}}{2\sqrt{s_0 K^{\gamma-1}}}(r - r_0)$$

with approximate equalities, which are valid for the same γ, for which $\alpha \to 0$ when $r_0 \to 0$. Consequently, in all these cases the rate of expansion of the boundary of a strongly compressed gas increases with decreasing r_0, turning to infinity when $r_0 = 0$. For sufficiently small r_0, the influence of gravity on the expansion of the boundary with the void is insignificant.

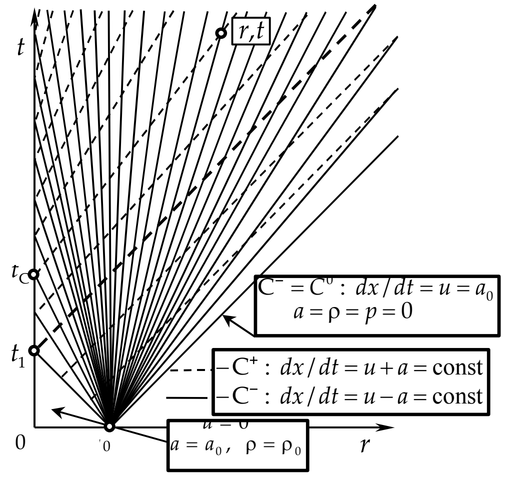

Figure 1. *rt*-flow diagram for ν = 1 and γ = 3

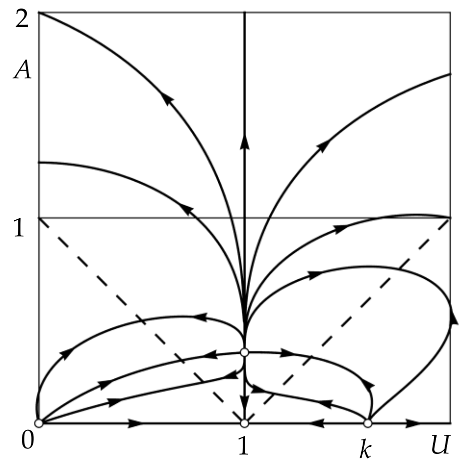

Figure 2. The integral curves of equation (2.3)

The solution to the above problem of expanding a flat layer of a perfect gas with γ = 3 without gravity gives very valuable information not only on the motion of a boundary with a void, but on the entire flow. Although there are really no such adiabatic exponents, it was the solution of this problem in [6-8] that prompted the authors the correct solution in the general case. This problem deserves more detailed consideration than in [6-8], for a number of other reasons too

The solution of the formulated non-self-similar problem is easily obtained in the case γ = 3, because the invariant $u + 2a/(\gamma - 1) = u + a$ is constant for such γ in a planar isentropic flow on C^+-characteristics. Similarly, the invariant $u - a$ is constant on C^--characteristics. As a result, as it is shown in Fig. 1 for $r \ge 0$, these invariants are constant on the rectilinear characteristics of both families. Due to this and the fact that the velocity of the gas u is equal to zero on the plane of symmetry (on the t axis) when $t_C \ge t_1 = r_0/a_0$, taking into account the formulas for the slopes of the rectilinear $C^{\pm}$-characteristics, we find

$$\frac{r_0}{t_C} = \frac{r}{t - t_C} = u + a, \quad \frac{r - r_0}{t} = u - a \to t_C = \frac{r_0 t}{r_0 + r}, \ u = \frac{r}{t}, \ a = \frac{r_0}{t}. \tag{1.7}$$

This solution is valid in the sector $0 \le r \le a_0(t - t_1)$, although the speed of sound a decreases to zero, and the gas velocity u increases till a_0 in the strip $a_0(t - t_1) \le r \le r_0 + a_0 t$. This strip turns into a line that lies on the r-axis when $r_0 \to 0$ (as a consequence of this $a_0 \to \infty$ and $t_1 \to 0$). We find in the limit in the whole quadrant ($r \ge 0$, $t \ge 0$):

$$u = r/t, \ a = 0. \tag{1.8}$$

Failures [4, 5] were in the searching for solutions with finite velocities of the gas sphere boundary expansion.

The solution (1.7) is interesting not only as a step on the way to the self-similar limit (1.8). In addition, it demonstrates how, for an arbitrarily small but non-zero value r_0, the superdense gas continuously expands to a void. Such a demonstration removes questions about the applicability of the equations of a continuous medium (1.1) to the self-similar solution (1.8) obtained in their framework with zero speed of sound, and, together with it, the density of the gas.

2. If gravity is neglected (*G* = 0) in solved in [6-8] self-similar problem of the gas expansion into a void from a point with infinite initial values a_0, p_0 and ρ_0, $u = 0$ and finite m_0 both s_0, the solution of equations (1.1) is sought in the form ($\tau = Ct/r^k$ is self-similar variable with found from the analysis of dimensions self-similar exponent k and the constant $C = (m_0^{\gamma-1} s_0)^{1/2}$)

$$u = \frac{r}{kt}U, \quad a = \frac{r}{kt}A, \quad \rho = \frac{m_0}{r^{\nu}}R, \quad p = \frac{m_0}{k^2 r^{\nu-2} t^2}P, \quad k = 1 + \frac{\gamma - 1}{2}\nu, \quad P = \frac{1}{\gamma}A^2 R. \tag{2.1}$$

Here *U*, *A* and *R* are functions of τ, defined by two differential equations and an “entropy integral”

$$\tau\frac{dU}{d\tau}=\frac{(U-1)f_1}{kf},\quad \tau\frac{dA}{d\tau}=\frac{Af_2}{4kf},\quad R=\left[A/(k\tau)\right]^{2/(\gamma-1)},$$

$$f=(1-U)^2-A^2,\quad f_1=U(U-k)-\nu A^2,\quad f_2=2[(2k+1-\gamma)U-2k](U-1)+(\gamma-1)^2\nu U-4A^2.$$

The consequence of the first two equations is the differential equation

$$\frac{dU}{dA}=4\frac{U-1}{Af_2}f_1, \tag{2.2}$$

which reduces the solution of the problem to the analysis of its integral curves (IC) in the *UA* plane. In addition, the substitution of the formulas (2.1) in the first equation (1.1) gives the “mass integral”:

$$R(1-U)=K$$

with constant *K*, which is different on different IC. Thus, $K = 0$ on the lines $U = 1$ and $A = 0$, which are the IC of the equation (2.2).

Fig. 2 presents IC (solid lines) and singular points of equation (2.2) in the plane *UA* for $\nu = 3$ and $\gamma = 1.4$. All singular points of the equation (2.2) lie on its IC, the lines $U = 1$ and $A = 0$, and only the node $U = k$, $A = 0$ is needed for what follows. “Mach” lines $f = 0$ are given by dashes: the “left-hand” line corresponds to $1 - U = A$ and “right-hand” line corresponds to $1 - U = - A$. The arrows on the IC show the direction of self-similar variable τ increase.

Comparing the solution (1.8) and the expressions for *u* and *a* from (2.1) with $k = 2$, we find $U(\tau) = k$, $A(\tau) = 0$ for $0 \le \tau \le \infty$. Corresponding the node $U = k$, $A = 0$ of the equation (2.2), this solution holds for any ν and γ. The gas speed $u = r/t$ is a linear function of *r* for all $t > 0$ in the solution, and the pathlines are diverging from the origin rays. The latter is a natural consequence of the zero density and pressure of the “gas”, which, in turn, is the result of instantaneous expansion of its finite mass into the entire space. In contrast to all self-similar problems of gas dynamics, the solution obtained is not given by a segment of the IC, but a singular point.

Although the intermediate results, in particular, the value *k* and the formula for the self-similar variable τ are functions ν and γ, the final solution (in vector form for speed of gas)

$$\mathbf{u}=\mathbf{r}/t,\ a=p=\rho=h=0,\ 0<t\le\infty,\quad 0\le r\le\infty\to 0\le u\le\infty \tag{2.3}$$

does not depend on the symmetry of the problem and on the properties of the gas, not only on γ, but also on its mass m_0 and entropy s_0. Moreover, the substitution of (2.3) into Eq. (1.1) shows that this solution also holds when gravity is taken into account and for any gas, for which the thermodynamic parameters appearing in (2.3) simultaneously vanish for fixed entropy.

The remarkable astonishing universality of the solution obtained above initiated its use to the description of the Big Bang and the expansion of the Universe. According to (2.3), we have for the Hubble constant H_0, which is the coefficient of proportionality of the velocity *v* to the distance between the scattered particles, which then formed the galaxies,

$$H_0=977.813/t_0. \tag{2.4}$$

with the lifetime of the Universe in Gyrs and H_0 in km / (s·Mpk). Almost all NASA [9] (more than two hundred) versions with the results of treatment of four sets of the most reliable observational data by dozens of cosmological theories form the region covered by grey crosses in Fig. 3. The horizontal and vertical segments of each a cross are equal to the errors in determining t_0 and H_0 (there are no ten versions with errors exceeding 10%). The curve *1* defined by (2.4), crosses this region, matches the values t_0 and H_0 better than the all the theories used in [9].

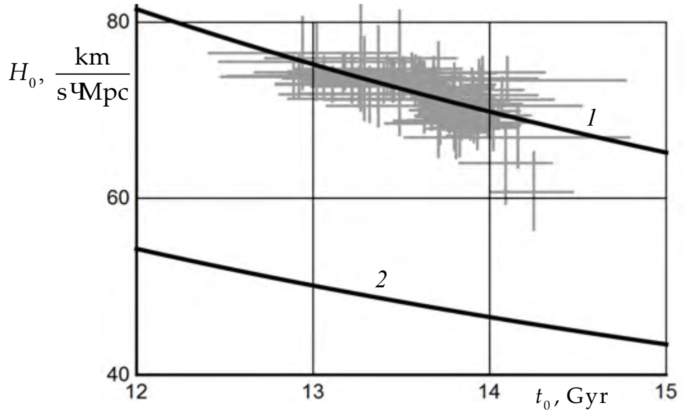

Figure 3. The dependence between H_0 and t_0 according to NASA is shown by grey crosses, and the dependence on the formulas (2.4) and (0.2) is shown by the curves *1* and *2*, respectively

3. In the classical approximation, a finite mass of gas compressed in a point instantaneously spreads out to the whole space. The consequences of this are unlimited speed, zero density everywhere and the absence of influence of gravity. According to both STR and the general theory of relativity (GTR), the gas speed can not exceed the speed of light *c*, and the same problem is to be solved within STR or GTR. However, the classical solution is not useless even here. In spite of the self-gravitation of a gas compressed in a point, which is infinite for $t = 0$, unlike Friedmann solution, gas dispersion is also determined by an infinite initial pressure drop in the solution. This justifies the solution within STR, but not GTR, and without gravity, as in the classical approximation. Problems with gravity in the Section 1 tell also in the benefit of the offered approach. Relativistic effects introduce fundamental changes already in the formulation of the problem, as energy and mass of the gas are related by the equality $E = mc^2$. The initial mass of a gas compressed in a point would be infinite together with its energy, and gravity, which resist dispersion of a gas, would be infinite also at any finite extension. Consequently, already only owing to the equality $E = mc^2$, in relativistic approach dispersion begins not from a point, but from finite, small on a comparison with the subsequent expansion of the volume, at finite, though big initial mass m_0 and energy $E_0 = m_0c^2$. Along with them, we will consider that specified total number N_0 of the dispersing atoms is invariable.

Within STR without gravitation, one-dimensional unsteady flows of an ideal gas are described by the equation of continuity and two energy-momentum equations

$$\frac{\partial(r^{\nu-1}nu^0)}{c\partial t} + \frac{\partial(r^{\nu-1}nu^1)}{\partial r} = 0, \quad u^0 = \sqrt{\beta}, \quad u^1 = \frac{u}{c}\sqrt{\beta}, \tag{3.1}$$

$$\frac{\partial(r^{\nu-1}T^{00})}{c\partial t} + \frac{\partial(r^{\nu-1}T^{01})}{\partial r} = 0, \quad \frac{\partial T^{01}}{c\partial t} + \frac{\partial T^{11}}{\partial r} + \frac{\nu-1}{r}\frac{\beta w u^2}{c^2} = 0, \quad \beta = \frac{1}{1-u^2/c^2},$$
$$T^{00} = \beta w - p, \quad T^{01} = \frac{\beta w u}{c}, \quad T^{11} = \frac{\beta w u^2}{c^2} + p, \tag{3.2}$$

Here n is the number of particles per unit volume (particle number density), and $w = \varepsilon + p$ and ε are the enthalpy and internal energy per unit volume. The self-similar solution of these equations is sought in the form

$$\xi = \frac{r}{ct}, \quad u = cU, \quad \varepsilon = \frac{m_0c^2}{r^\nu}E, \quad w = \frac{m_0c^2}{r^\nu}W, \quad p = \frac{m_0c^2}{r^\nu}P, \quad n = \frac{N_0}{r^\nu}N, \tag{3.3}$$

where U, E, ... are functions of ξ or $\tau = 1/\xi$, and ξ and U vary from zero to unity.

The substitution of expressions (3.3) in the equation of continuity (3.1) leads to equation

$$\frac{d}{d\tau}\left(N\frac{1-\tau U}{\sqrt{1-U^2}}\right) = 0,$$

and then, when integration constant is zero, to the integral

$$N(1-\tau U)=0\,. \qquad (3.4)$$

Integration constant is zero even for $N\sim\,(1-\xi)^{-2}$ found in [3].

Because $N_0 > 0$ and the dispersion rate is finite, now the only consequence of integral (3.4) is a formula $U = \xi$. The result of this is the solution (in the vector form)

$$\mathbf{u}=\mathbf{r}/t,\ \ 0<t\le\infty,\quad 0\le r\le ct,\ \ 0\le u\le c\,, \qquad (3.5)$$

which differs from the first equality in (2.3) only by relativistic restrictions $r \le ct$ and $u \le c$. Within STR this law is valid if we combine the beginning $\mathbf{r}'$ with an arbitrary gas particle, as shown in [3] for $\mathbf{u} \sim \mathbf{r}/t$. In this case, the time t is naturally replaced by the time t', counted from the start of the dispersion in the coordinate system, which is moving with the chosen particle.

The substitution of expressions (3.3) into the first equation (3.2) leads to the equation

$$\frac{d}{d\tau}\left(W\frac{1-\tau U}{1-U^2}-P\right)=0$$

and to its integral

$$W\frac{1-\tau U}{1-U^2}-P=K\,.$$

Hence, taking into account the equality $1 - \tau U = (\xi - U)\tau = 0$, which holds for all ξ, and the fact that $p = 0$ for $\xi = \tau = U = 1$, i.e. on the boundary with the void, we will find that $p = 0$ for all ξ. Finally, the substitution $u = c\xi$, $p = 0$ and the expression for w from (3.3) to the second equation (3.2) gives the final equation $\nu\beta\xi W(\xi) = 0$. The only consequence is the equality is that W and w are zero for all ξ. It is essential that the solution of equations (3.1) and (3.2) above does not require the use of state equations.

According to the results obtained, the solution of the problem consists in instant (at $t = +0$) vanish of pressure p, a specific enthalpy w, and hence, an internal energy $\varepsilon = w - p$ for all $0 \le \xi \le 1$, i.e. within STR without gravity, all the internal energy of the gas is instantly transformed to its kinetic energy, when gas disperses from a point into a void. So,

$$\varepsilon=w=p=0,\ \ 0<t\le\infty,\quad 0\le r\le ct \qquad (3.6)$$

at the absence, that is essential, of the same equations for ρ and n.

As in the classical model, the solution (3.5) and (3.6) satisfies the relativistic equations (3.1) and (3.2) with the total number of particles invariable. However, in the first three minutes [10], and then during the 10^5-10^6 years, the composition and thermodynamics of the hot, dense and inhomogeneous Universe underwent enormous changes. The equilibrium and non-equilibrium processes determining them depend on many dimensional constants, which make this stage of the dispersion non-self-similar. Because it is assumed that the composition is constant, the solution constructed is certainly incorrect in the initial period indicated and, as a consequence, in the corresponding layer near the boundary of the Universe. However, at the age of the Universe $t_0\approx1.4\cdot10^{10}$, the thickness of this layer will amount to no more than $10^{-5}-10^{-4}$ of its radius, which is equal to ct_0.

So, for the most reliable observational data, the solution obtained without empirical constants matches the lifetime values of the Universe and the Hubble constant better than any modern cosmological theories (the *Λ*CDM model) with dark energy (*Λ*) and matter (CDM is Cold Dark Matter). If dark matter may be needed to describe the deceleration of the expansion of the Universe, then in the light of the solution, the basic formulas of which, including $\mathbf{u} = \mathbf{r}/t$, do not contain empirical constants, the introduction of dark energy is unnecessary.

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