The Cosmological Redshift as a Virtual Effect of Gravitation

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The concept of a minimal decrease of the velocity of light ($a_c = -Hc$) is used to connect cosmological redshift with the eigen gravitation of the universe. The universe's Hubble and Einstein radii turn out to be identical. The cosmological model this leads to yields predictions as to the total mass and density of the universe.

Keywords: cosmological redshift—gravitation—Hubble parameter—velocity of light

Introduction

"Will the universe expand forever?" (Gott *et al.* 1974, 1976) This has been one of the main questions of cosmology since the interpretation of the redshifted light of remote stars and galaxies as a Doppler phenomenon was accepted by the majority of cosmologists. Prodigious efforts have been made to estimate the amount of matter in the universe and to determine quantities such as the Hubble parameter H_o and the deceleration paramater q_o (Scheuer 1993). At present, it appears as if the quotient Ω_o of average density of the universe r_o and critical density r_c is between 0.1 and 1. The existence of large quantities of cold dark matter (CDM) is uncertain but likely, although the spook of the 17-keV neutrino seems finally to have been banished. What remains is an uneasiness concerning some features of conventional Big Bang cosmology (Arp *et al.* 1990). Any alternative model, however, has to account for the cosmological redshift (Hoyle 1972). This paper deals with the possibility of a non-kinematic redshift.

The Radii of Hubble and Schwarzschild

It is historically and logically obvious—E. Harrison (1993) recently pointed this out again—that Hubble's redshift-distance law and the Doppler-inspired velocity-distance law are two totally different things. Yet the two are generally confused in today's cosmology. The most common cosmological models, for example, use Robertson-Walker-metrics, which describe a certain kind of expanding space. Two objects on the sphere separate from each other; yet they do not move, which means their coordinates don't change. Therefore, it is erroneous to ascribe kinetic energy to them, as is done in most calculations on the expanding universe, where kinetic and gravitational energy offset one another, as the transformed Friedmann equation suggests. With R as the radius of the universe and scale factor, M, as the total universal mass and G as the gravitational constant, we may write

$$\frac{1}{2}\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \frac{GM}{R} = -\frac{kc^2}{2} \tag{1}$$

The left term of the left side represents the kinetic, the right side the gravitational term. Their difference determines the space parameter k. This is the common interpretation. However, if $\dot{R}$ is understood as an increasing scale factor, there is no systematic motion of cosmic objects relative to the coordinates. Because of the Newtonian analogy, it is tempting to neglect the physical definition of motion.

Both terms are connected with a specific radius. The kinetic term with the Hubble radius R_H, the gravitational term with the Schwarzschild radius R_S. R_H indicates the distance at which the cosmological redshift z goes to infinity (or at which the object escapes with the speed of light in the common interpretation). We can insert the velocity of light for v in Hubble's law

$$v = HR \tag{2}$$

and, with $H = 1.7 \cdot 10^{-18}\ \mathrm{s}^{-1}$ (~ 52.5 km s^{-1} Mpc^{-1}), we obtain:

$$R_H = \frac{c}{H} \approx 1.76 \cdot 10^{26}\ \mathrm{m} \tag{3}$$

From the gravitational equations of General Relativity we can derive R_S, the radius attributed to a mass within which the frequency of a beam of light will be reduced to zero by gravitation. We can determine R_S for the entire universe using its estimated density of 10^{-29} g cm^{-3}. Its half Schwarzschild radius, referred to as the Einstein radius, is

$$R_E \approx \sqrt{\frac{3c^2}{4pGr}} \approx 1.79 \cdot 10^{26}\ \mathrm{m} \tag{4}$$

It is amazing that both radii are quantitatively identical, although they are obtained from two different fields, R_E from theoretical physics and R_H from empirical astronomy. Thus, it was a triumph for the relativistic theory of gravitation that Hubble's redshift law could be associated with the universal expansion, which follows from the simple but fundamental assumption of the isotropy and homogeneity of the universe. It is remarkable that Friedmann's equation

$$\left(\frac{\dot{R}}{R}\right) = -\frac{kc^2}{R^2} + \frac{8p}{3}Gr \tag{5}$$

with $H = \dot{R}/R$, $r = 3M/4pR^3$ and $R = R_H = c/H$ yields the relation

$$R_H = \frac{R_S}{k+1} \tag{6}$$

While R_H is usually regarded as a horizon *in* space, the Schwarzschild radius of the universe marks the border *of* space. According to (6), however, they are too closely related to be separated, as is usually done. The possibility of $k = -1$ is remarkable: in this case, the Hubble radius would be zero or infinite, or not exist at all. Because we can indeed assume a finite R_H, shall we conclude from this, that the hyperbolic space structure $k = -1$ is not realized in our universe? In any case, it is somehow mysterious that there are two differently defined radii, which have about the same size, both deal with gravitational *resp.* recessional redshifts, are mathematically related and yet—should not refer to one and the same natural phenomenon? In the following we shall demonstrate that with the assumption of a general, yet minimal, decrease of the velocity of light those two quantities can be regarded as identical.

The Assumption of "Retarded Light"

Various "tired-light" mechanisms have been introduced in the past few years; they will not be discussed here. Instead, we will tentatively suggest a new mechanism, which would certainly have been discussed already if it did not seem to contradict a fundamental physical law: the constancy of light. Yet, this postulate is *not* inconsistent with Special and General Relativity (GR). The requirement that c be the maximal speed for transmission of information and the limiting speed for the motion of masses is thoroughly sufficient to obtain the structural elements of Relativity. A permanent, small decrease of c is basically compatible with it; the quantitative deviation from constant-light Relativity, however, must be small enough not to affect its empirically proved main results.

Retarded Light Relativity postulates expanding space as indistinguishable from light retardation, as long as light itself is the standard and there is no terrestrial standard, such as a material rod. This is certainly the case for cosmic distances. Because c is the speed of all physical interactions, the transmission speed is a more fundamental category than terrestrial "distance" definitions. Even the replacement of the solid meter stick by an electromagnetic definition is terrestrial (*i.e.*, its validity is only guaranteed in a spatially and temporally limited range), as long as the temporal constancy of c is assumed. The concept of light retardation, however, implies that the travel time of light between the ends of a material rod becomes longer and longer. Once the velocity of light is set constant, a scale expansion follows immediately. This reflects the situation in today's expanding-Universe cosmology. It may be worthwhile to investigate the alternative view, which explains the increasing travel time of light as light retardation combined with constant length scales. To prove or disprove the postulated decrease of c will be a task for experimental physics. The temporal variation can be estimated by asking how great light retardation must be to fit into Hubble's law. The quantitative analysis was done in an earlier paper (Huber 1992). The result is a deceleration rate of Hc, suitably expressed as negative light acceleration

$$a_c = \dot{c} = -Hc \tag{7}$$

This is equivalent to a decrease of c by 1.6 m s^{-1} in 100 years ($H = 1.7 \cdot 10^{-18}$ s^{-1}). As we can see, this value is indeed very small and, considering the current value of $c = 299792458.8 \pm 0.2$ m s^{-1}, beyond the limit of detection in the next decade.

Equation (7) suggests that the temporal variation of the deceleration rate is an exponential function, and, indeed, authors who seek to explain the Hubble redshift by any kind of energy loss of a photon usually favour an inverse exponential progress along the lines of Hugo von Seeliger's law of gravitation of 1909 (Ghosh 1991, Jaakkola 1991, Kropotkin 1991). Although this view is worth serious consideration, we have approximatively set $a_c = \dot{c} = const.$ to obtain the numerical result of (7). Setting $\dot{a}_c = \ddot{c} = 0$ would require a Hubble parameter that varies in time, given by

$$\dot{H} = H^2 \tag{8}$$

After integration we find

$$H(t) = \frac{1}{\frac{1}{H_o} - t} \tag{9}$$

In contradiction to conventional cosmology, the Hubble parameter increases with time. That provides the Hubble time T_H with a new meaning: T_H can now also be considered as the period of time light needs to decelerate from the present value c_o to $c = 0$. This time can be calculated as

$$T_H = \frac{v - v_o}{a} = \frac{0 - c_o}{-H_o c_o} = \frac{1}{H_o} \tag{10}$$

This interpretation of T_H therefore has a "count-down" character, giving the remaining time from the present t_o to the moment $c = 0$. The distance R_B which retarded light travels during T_H is

$$R_B = \int_{t=0}^{\frac{1}{H_o}} \left(c_o - H_o c_o t\right) \mathrm{d}t = \frac{c_o}{2H_o} \tag{11}$$

Whereas R_H stands for the maximum distance at which a signal emitted in the past can reach us, R_B shows the distance a signal emitted at T_o can travel into the future. Each event is the center of a "bubble", which can maximally expand to R_B. Thus, the "bubble radius" R_B of the "Big Bang" (if it ever occurred) is actually related to the maximum expansion radius of the universe, namely R_S. Furthermore, the bubble radius is the half of the defined Hubble radius. Obviously, the interaction horizon—the physical meaning of R_B—diminishes with time. The contraction speed is

$$\dot{R}_B = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{c}{2H}\right) = -c \tag{12}$$

The negative sign symbolizes contraction; the value itself is in accordance with cosmological considerations (Zeng Xinchuan 1990).

Gravitation and Retarded Light

What is the cause of light retardation? One of the main results of GR is that light is subject to gravitation. While Einstein's gravitation law describes local interactions between matter and space, it does not, however, say anything about global interactions. We understand the interaction of two masses m_1 and m_2—independent of their distance—as local, the interaction of m_1 and M as global, where M represents the resulting total mass of the universe, which can be associated with Mach's "distant mass". A distinction between local and global effects was made by Stein (1990), leading to the conclusion that cosmological redshift results from the gravitation of distant mass. Because the sum of mass-energy is constant in the universe, the gravitational drag should be constant as well. (This is another argument for constant a_c.) It may be equivalent, though, postulating that light retardation is prior and the resulting expansion creates gravitation out of inertia. The mathematical preconditions have been developed by Roscoe (1991).

The interpretation of the cosmological redshift as isotropic gravitation-determined light retardation enables us to regard cosmological and global gravitational redshift as one and the same thing. The suggested light retardation, especially with $\ddot{c} = const.$ implies a closed space structure. From (6) we then find

$$R_\mathrm{E} = \frac{1}{2} R_S = \frac{GM}{c^2} = R_H = \frac{c}{H} \tag{13}$$

where R_E is referred to as Einstein radius. This leads to the universal mass

$$M = \frac{c^3}{GH} \qquad (14)$$

and to the total universal energy

$$E = \frac{c^5}{GH} \qquad (15)$$

The total mass of the universe should therefore be $2.38 \cdot 10^{53}$ kg. By replacing the universal mass with $M = r\,\frac{4}{3}pR^3$ and inserting $R_H = c/H$ we find

$$r = \frac{3H^2}{4pG} \qquad (16)$$

This value is twice as high as the classical critical density $r_c = 3H^2/8pG$, which seems quite surprising because theoretical considerations favour a value $\Omega = 1$. On the other hand, the estimated value of Ω has increased in the last few years. Early approximations were about $0.02\Omega \pm 0.01$ (Weinberg 1972). Gott (1974) estimated Ω at about ten times higher. Recent counts of galaxies suggest a value $0.4 < \Omega < 1.6$ (Loh and Spillar 1986). A value of $\Omega = 2$ does not seem very unrealistic. As pointed out earlier, the escape velocity is virtual, resulting from gravitation-determined deceleration of light, which is equivalent to expanding space. The essential difference between classical and Retarded Light cosmology can be studied with a *gedanken* experiment. What happens to the universal expansion rate when additional matter is put into the universe? The classical answer is that the expansion slows down, because it is delayed by more gravitation. *In the suggested model, however, the expansion speeds up virtually, because increasing gravitation delays light propagation, which accelerates the expansion of cosmic distances.* This view is supported by Friedmann's solution (5). Increasing r or M makes the left side $\dot{R}/R$ increase, which is Hubble's expansion factor H. The expansion thus appears as both virtual and real; virtual, because it is not based on *eigen* movements of objects, and real, because a reduced signal transmitting velocity is physically equivalent to space dilatation. Due to the close connection between R_E and R_H, it is obvious that the masses M of whole universes can always be expressed with Equation (11), though with altered values for c, G and H.

Conclusion

The interpretation of Hubble's law as light retardation caused by the gravitation of distant mass enables us to treat cosmological redshift and gravitational redshift, represented by Hubble radius R_H and Einstein radius R_E, as identical. Regarding the travel time of light as the only physical distance scale, a retardation of the velocity of light cannot be distinguished from an expansion of space. On the other hand, light retardation is an effect of the *eigen* gravitation of the universe, and results in a *temporal* deflection of a light beam, whereas GR describes the photon's interaction with single masses as *spatial* deflection (curvature). A startling consequence is that matter is the cause of expansion and not the universal brake. The unified redshift yields a value for the universal mass with the expression $M = c^3/GH$. This expression should claim validity as a definition of "universe": Any accumulation of matter will constitute a universe, whenever this condition is fulfilled. Otherwise it is only a fraction of the universe. The resulting density is $2r_c$. However, the critical density and the deceleration parameter q_o are meaningless in the Retarded Light model, because the classical calculation is based on the antagonism between expansion and gravitation. Indeed, the introduction of q was required by the opinion that the universal expansion should be slowed down by gravitation. This study has shown that, from the standpoint of retarded light, expansion is a consequence of gravitation (or *vice versa*).

References

Arp, H.C., Burbridge, G., Hoyle, F., Narlikar, J.V., Wickramasinghe, N.C., 1990, The extragalactic Universe: an alternative view, *Nature* 346:807.

Ghosh, A., 1991, Velocity-dependent inertial induction: a possible tired-light mechanism, *Apeiron* 9-10:35.

Gott, J.R.,III., Gunn, J.E., Schramm, D.N., Tinsley, B.M., 1974, An unbound Universe?, *Astrophys. J.* 194:543.

Gott, J.R.,III., Gunn, J.E., Schramm, D.N., Tinsley, B.M., 1976, Will the universe expand forever?, *Scientific American* 234,3:62.

Harrison, E., 1993, The redshift-distance and velocity-distance-laws, *Astrophys. J.* 403:28.

Hoyle, F., 1972, in: *The Redshift Controversy* ed. G. Field, H. Arp, J.N Bahcall, (Reading, Mass.: W.A. Benjamin, Inc.):295.

Huber, P., 1992, Does velocity of light decrease?, *Apeiron* 14:15.

Jaakkola, T., 1991, Electro-gravitational coupling: empirical and theoretical arguments, *Apeiron* 9-10:76.

Kropotkin, P.N., 1991, The Perfect Cosmological Principle and the Hubble effect, *Apeiron* 9-10:91.

Loh, E.D., Spillar, E.J., 1986, A measurement of the mass density of the Universe, *Astrophys. J.*, 307, Letters:L1.

Roscoe, D.F., 1991, Gravity out of inertia, *Apeiron* 9-10:55.

Scheuer, P., 1993, Weighing the Universe, *Nature* 361:112.

Stein, E., 1990, Relativity, gravitation, and the redshift of galaxies, *Physics Essays* 3:169.

Weinberg, S., 1972, Gravitation and cosmology, (New York: John Wiley and Sons).

Xinchuan, Z., 1990, The relation between the speed of light and the expansion of the Universe, *Physics Essays* 3:165.