A Steady-State Cosmology

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We analyze a steady-state cosmology based on a boundless universe which has always existed and which is homogeneous on the very large scale. As this is a stationary model without expansion, it does not require a continuous creation of matter, in contrast to the steady-state model of Bondi, Hoyle and Gold. We study the problems and properties of this model relating to inertia and gravitation (Mach's principle and the origin of inertia, the Seeliger-Neumann term), the cosmological redshift (alternatives to the Doppler interpretation of Hubble's law, the Finlay-Freundlich model), and the cosmic background radiation (predictions of a background temperature around 3° K previous to the experimental discovery by Penzias and Wilson in 1965). Some observational tests of this general model are outlined.
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I. Introduction

In this paper we present a steady-state model of the universe that has grown out of two previous works (Assis 1992 a, b). Essentially, the model which we adopt complies with the perfect cosmological principle, which can be stated as follows: apart from local irregularities, the universe presents the same aspect from any place at any time (Bondi 1960, Ch. 2, p. 12). The history of this principle and its empirical foundations have been discussed by Rudnicki (1989) and Jaakkola (1989). The main properties of the universe at large assumed here are as follows: the universe ex-

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tends in all directions indefinitely; it has an infinite age; it is homogeneous on a large scale; the density of matter and energy are finite and constant, except for local irregularities; it is in a steady-state without expansion and without creation of matter; it complies with the principles of conservation of mass and energy.

In this work we will discuss this model and its relation with inertia and gravitation, the cosmological redshift, and the cosmic background radiation. Since we have analyzed Olbers' paradox (Olbers 1826) in detail in previous work (Assis 1992 a), we will not discuss it here.

II. Gravitation and Inertia

For low velocities and low energy densities, Newton's law of gravitation is known to be valid with high accuracy. However, when we try to apply it to an infinite and homogeneous universe, certain difficulties arise which can be easily visualized in Figure 1. Suppose we want to calculate the gravitational force on a particle of mass m_o located at point P due to the whole universe. If the origin of the coordinates is at O and the distance between O and P is r, the net force on m_o is given by

$$\frac{G\left(4\pi r^3\rho/3\right)m_o}{r^2}=\frac{Gm_o\rho 4\pi r}{3}$$

pointing from P towards O. In this expression G is Newton's gravitational constant ($G=6.67\times10^{-11}\,\mathrm{Nm^2\,kg^{-2}}$) and ρ is the uniform mass density of this hypothetical homogeneous universe. This result is due to the fact that a spherical shell of mass M and radius R exerts no force on any internal point, and attracts any external point as if its whole mass were concentrated on its center, according to Newton's law of universal gravitation, as Newton proved in the *Principia* in 1687. On the other hand,

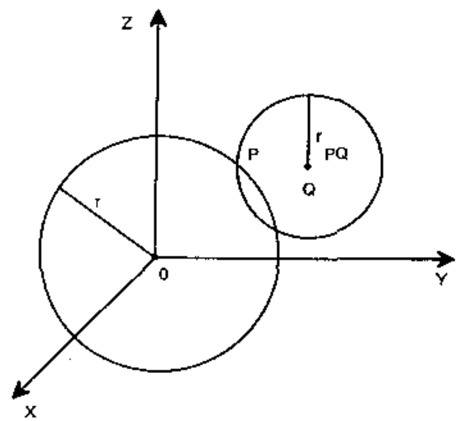

Figure 1. An infinite and homogeneous universe with constant mass density ρ. A mass m_0 is located at P. If we utilize spherical coordinates to calculate the net force on m_0 we will obtain different results if the origin of the coordinate system is at O or at Q.

if we calculate the net gravitational force on m_o from the point Q as the center of the coordinate system (see Figure 1), we find its value to be $Gm_o\rho 4\pi r_{PQ}/3$ pointing from P towards Q, where r_{PQ} is the distance between P and Q. This is different from the previous value, which shows that we can get any value for the net force on m_o depending on our arbitrary choice of the point Q.

This is certainly undesirable. In order to overcome the problem we can either assume that the universe is not infinite and homogeneous in space and time, or that Newton's law of gravitation should be modified when there is a many-body interaction. Here we will follow H. Seeliger and C. Neumann who in 1895 and 1896 proposed that the Newtonian gravitational potential should be modified by the introduction of the factor $e^{-\alpha r}$, where α is a small quantity which would only be significant for large values of r. Laplace had introduced an exponential in Newton's force law of gravitation as early as 1846 (North 1965, Ch. 2; Assis 1992 b).

One way of interpreting this exponential decay in the gravitational potential or force law is to regard this term as an absorption of gravity: instead of having a potential given by Gm_1m_2/r, it would be given by $Gm_1m_2e^{-\alpha r}/r$, where α depends on the distribution and amount of matter in the straight line connecting m_1 and m_2. We can then look for experimental support of this proposal. Some anomalies in pendulum behavior during solar eclipses which could be due to a screening effect for gravitation have been described by Dragone (1990). To our knowledge, the best experiments specifically designed to test the idea of a gravitational absorption are due to Q. Majorana (Martins 1986, Assis 1992 b). He found a positive value with an absorption coefficient for liquid mercury of the order of $\alpha \approx 10^{-10}$ m^{-1}. Because his experiments were never repeated, we cannot have complete confidence in these results. On the other hand, the fact that they were never contested shows that there is a real possibility the effect exists, which, as we have seen, is of great cosmological significance.

A similar situation arises with inertia if we follow Mach's principle, according to which the inertia of any body is due to its interaction with the remainder of the universe (Mach 1960, Barbour 1989). For instance, recently we implemented Mach's principle quantitatively utilizing a Weber-type force law (Assis 1989 a). In order to derive Newton's first and second laws from a gravitational interaction of any body with the remainder of the universe, we postulated that the resultant force (including all kinds of interaction—gravitational, electromagnetic, nuclear, elastic, inertial, *etc.*) on any body is always zero in all frames of reference, even when the test body is in motion and accelerated. Beyond this, we also assumed that Newton's force of gravitation should be modified following the structure of Weber's force. Weber's law was introduced in electromagnetism in 1846 in order to unify electrostatics, magnetism (force between current elements) and electromagnetic induction (Weber 1872, 1892-4 and 1966; Maxwell 1954, Volume 2, Ch. 23; O'Rahilly 1965, Volume 2, Ch. 11; Wesley 1990 and 1991, Ch. 6; Phipps 1990 a, b; Assis 1989 b, 1990, 1991 and 1992 c; Assis and Caluzi 1991; Assis and Clemente 1992; Clemente and Assis 1991). The first to propose a similar modification for gravitation seems to have been G. Holzmuller in 1870, and in 1872, F. Tisserand utilized the same force law (North 1965, Ch. 3, pp. 46-47; Assis 1989 a). Recently other authors have followed the same procedure, applying a Weber-type force law to gravitation: (Eby 1977, Sokol'skii and Sadovnikov 1987). A similar idea has been followed by Ghosh, arriving at equivalent results (Ghosh 1984, 1986, 1988 and 1991). Although his force law is not exactly like Weber's, he has also succeeded in implementing Mach's principle.

Moreover his expression involves a velocity drag term, not present in Weber's force, which leads to many interesting and reasonable results.

In our previous work (Assis 1989 a) implementing Mach's ideas mathematically, we derived Newton's first and second laws from a gravitational interaction of any body with the remainder of the universe. This was done by integrating a Weber-type force law for gravitation in a finite universe of radius $R = c/H_o$, where $c = 2.998\times10^8\,\mathrm{m\,s^{-1}}$ is the light velocity in vacuum and $H_o \approx 3\times10^{-18}\,\mathrm{s^{-1}} \approx 10^{-10}$ years is Hubble's constant, so that $R \approx 10^{26}\,\mathrm{m}$. If we had integrated over an infinite universe with a constant mass density compatible with the value estimated from observations ($\rho \approx 3\times10^{-27}\,\mathrm{kg\,m^{-3}}$), this model would not have worked. Accordingly, we suppose here the Mach-Weber model modified by the Seeliger-Neumann term, such that the potential energy U of the gravitational masses m_1 and m_2 is given by

$$U = -H_g \frac{m_1 m_2}{r}\left(1 - \frac{\xi}{2}\frac{\dot{r}^2}{c^2}\right)e^{-\alpha r}. \tag{1}$$

In this equation H_g is a constant, r is the distance between m_1 and m_2, namely,

$$r = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2},$$

and $\xi = 6$ in order to obtain the correct value of the precession of the perihelion of the planets (Assis 1989 a). Moreover, $\dot{r} \equiv \mathrm{d}r/\mathrm{d}t = \hat{r}\cdot(\vec{v}_1 - \vec{v}_2)$, where $\hat{r} \equiv (\vec{r}_1 - \vec{r}_2)/r$ is the unit vector pointing from m_2 to m_1 and $\vec{v}_1 - \vec{v}_2 \equiv \mathrm{d}(\vec{r}_1 - \vec{r}_2)/\mathrm{d}t$, and α is a constant characteristic of the medium in the straight line between m_1 and m_2 ($\alpha = 0$ in a complete vacuum).

As usual, we can define the force exerted by m_2 on m_1 by $\vec{F} \equiv -\hat{r}\,\mathrm{d}U/\mathrm{d}r$ so that

$$\vec{F} = -H_g \frac{m_1 m_2 \hat{r}}{r^2}\left[1 - \frac{\xi}{2}\frac{\dot{r}^2}{c^2} + \xi\frac{r\ddot{r}}{c^2} + \alpha r\left(1 - \frac{\xi}{2}\frac{\dot{r}^2}{c^2}\right)\right]e^{-\alpha r} \tag{2}$$

where

$$\ddot{r} \equiv \frac{\mathrm{d}^2 r}{\mathrm{d}t^2} = \frac{(\vec{v}_1 - \vec{v}_2)\cdot(\vec{v}_1 - \vec{v}_2) + (\vec{r}_1 - \vec{r}_2)\cdot(\vec{a}_1 - \vec{a}_2) - \dot{r}^2}{r}$$

and $\vec{a}_1 - \vec{a}_2 \equiv \mathrm{d}^2(\vec{r}_1 - \vec{r}_2)/\mathrm{d}t^2$.

Weber's original expressions for the potential energy between the electric charges q_1 and q_2, and the force exerted by q_2 on q_1 are the same as equations (1) and (2) with the replacements $-H_g m_1 m_2 \to q_1 q_2/4\pi\varepsilon_o$, $\xi \to 1$ and $\alpha \to 0$.

We now follow the same procedure as in our previous work (Assis 1989 a) to calculate the force on a test mass m_o due to an isotropic distribution of mass extending to infinity. We suppose an observer at the origin of a coordinate system, such that for this observer the universe (which is supposed to have a constant mass density ρ) as a whole is spinning with an angular frequency $\vec{\omega}$. Integrating equation (2) utilizing spherical coordinates yields

$$\vec{F} = -Am_o\left[\vec{a}_o + \vec{\omega}\times(\vec{\omega}\times\vec{r}_o) + 2\vec{v}_o\times\vec{\omega} + \vec{r}_o\times\frac{d\vec{\omega}}{dt}\right] \tag{3}$$

In this equation A is a dimensionless constant given by

$$A = \frac{4\pi}{3}H_g\frac{\xi}{c^2}\rho\int_0^\infty re^{-\alpha r}dr = \frac{4\pi}{3}H_g\frac{\xi}{c^2}\frac{\rho}{\alpha^2},$$

where α would be the mean absorption coefficient of the universe. By analogy with the cosmological redshift, which will be described in the next section (and which can be interpreted as an absorption of light by intergalactic matter), we propose that $\alpha = H_o/c$.

As in our previous work (Assis 1989 a) we can then derive Newton's first and second laws, with a very important development: these two laws are now derived in an infinite and homogeneous universe. The main idea is that the Seeliger-Neumann term both solves the gravitational paradoxes arising from Newton's law of gravitation, and leads to a derivation of inertia in full compliance with Mach's principle in an infinite and homogeneous universe. A complete derivation of these results and an analysis of its consequences is given by Assis (1992 b).

III. Cosmological Redshift

Our next subject is the cosmological redshift. When the spectra of the extragalactic nebulae or external galaxies are observed, what we measure are the apparent luminosities of nebulae and shifts in their spectra (Hubble 1958, p. 3). It has been observed that the fainter the nebula, the larger the redshift (with the exception of the nearby galaxies, most galaxies present a shift toward the red instead of the blue). By assuming the faintness of the nebulae to be related to their distance by a certain function, Hubble was able to conclude that there exists a linear relation between redshifts and distances (Hubble 1929). This relation can be written as

$$z(r) \equiv \frac{\lambda(r)-\lambda_o}{\lambda_o} = \frac{H_o}{c}r \tag{4}$$

In this relation $z(r)$ is the fractional spectral shift, λ_o is the wavelength of a certain line as observed in the laboratory (when the source and detector are at rest relative to the earth), $\lambda(r)$ is the wavelength as observed in the earth's detector of the same line which had been emitted (presumably at a wavelength λ_o) by a galaxy which is at a distance r from the earth, and H_o is Hubble's constant.

Usually this redshift is interpreted as a Doppler shift. This interpretation is what leads to the idea of the expansion of the universe, the big bang, *etc*. If this were the case we would have (Sciama 1971, p. 71)

$$1 + z(r) = \frac{\lambda(r)}{\lambda_o} = \sqrt{\frac{c+v}{c-v}} = 1 + \frac{v}{c} + O\left(\frac{v^2}{c^2}\right) \tag{5}$$

This would mean

$$\frac{v}{c}=\frac{(1+z)^2-1}{(1+z)^2+1} \tag{6}$$

In 1929 the largest value of v/c given by Hubble was $v/c=6\times10^{-3}$ (Hubble 1929, Table 2), and by 1936 when he wrote *The Realm of the Nebulae* this value had increased to $v/c = 0.13$ (Hubble 1958, plate VII). In 1971 the record redshift was 2.88, which implies $v/c = 0.87$ (Sciama 1971, p. 70). This applies to quasi-stellar objects (quasars) as well as some galaxies. For instance, Arp described some galaxies which according to the Doppler interpretation of redshifts would be moving away from us at $v/c = 0.1$ (Arp 1987, Ch. 6). These extremely large recession velocities are a source of doubt for the interpretation of the redshift as a Doppler effect. The reason is that all other velocities of astronomical objects known to us are much smaller. For instance, the orbital velocity of the earth around the sun is approximately 30 km s^{-1} ($v/c=10^{-4}$); the orbital velocity of the solar system relative to the center of our galaxy is approximately 250 km s^{-1} ($v/c=10^{-3}$); and the random or peculiar motion of galaxies is of this same order of magnitude.

There are other problems with the big-bang model: the age of some structures in the universe (some galaxies and agglomerates of galaxies) is supposedly greater than the "age of the universe" derived from the big-bang model; there are intrinsic redshifts of quasars and some galaxies which are clearly not due to a Doppler effect, *etc.* (Arp 1987, Arp and van Flandern 1992). A general criticism of big bang cosmological models has been given by Kierein (1988).

If the redshift is not due to a Doppler effect, what is its origin? We prefer to assume that a photon loses energy in its journey from the surface of a star to the earth. The energy which is lost by the photon would be acquired by the matter with which it interacts in its journey. If this is the case, there would be two components in the redshift of any astronomical object: one intrinsic, due to the interaction of the photon with the atmosphere of the astronomical body (a star and its atmosphere, for instance) and with the matter surrounding it (interstellar matter), and one external component due to intergalactic matter. Both redshifts may be due to the same mechanism, but only the latter (the cosmological or Hubble component) would obey the redshift-distance relation (equation (4)). The first component should be independent of our distance to the source if the source is an external galaxy or a star belonging to this external galaxy. If the source is a star in our own galaxy, then its redshift should have an intrinsic component (due to interaction of its light with its own atmosphere and immediately surrounding matter) and a component which should depend on our distance to the star due to the interaction of its light with the interstellar matter.

This interpretation of the redshifts is usually called the tired light model. We discussed this model in our previous work (Assis 1992 a). In simple terms, the cosmological or Hubble component utilizes Einstein's expression for the energy E of a photon related to its frequency ν and wavelength λ: $E=h\nu=hc/\lambda$, $h= 6.6 \times 10^{-34}$ Js being Planck's constant. This expression is coupled to the energy lost by the photon to the matter with which it interacts in its journey from the surface of a star to the earth: $E(r)=E_o e^{-\alpha r}$, E_o being the initial photon energy at the surface of the star, or the equivalent energy of a photon of the same frequency in the laboratory.

$E(r)$ is the energy of the photon upon its arrival at the Earth, and α is the mean absorption coefficient of light in the line of sight connecting the source and the earth. From these two relations we obtain

$$z(r) \equiv \frac{\lambda(r) - \lambda_o}{\lambda_o} = e^{\alpha r} - 1 \simeq \alpha r + \frac{\alpha^2}{2} r^2 \tag{7}$$

Comparison with (4) yields $\alpha = H_o/c$. A good discussion of the tired light model can be found in Reber (1983) and LaViolette (1986). LaViolette, in particular, has shown that the tired light model fits the data better than the big bang model in four important tests: the angular size-redshift test, the Hubble diagram test, the galaxy number count-magnitude test, and the differential log N—log S test.

This explanation is a very simple one and avoids the problem of the high velocities mentioned above. It was advocated, for instance, by de Broglie (1966). After discussing the Doppler interpretation of the redshift, he said explicitly:

> *Cependant je ne suis pas personnellement persuadé que l'interprétation des déplacements spectraux observés par un effet Doppler lié à une expansion de l'univers s'impose réellement. A mon sens, l'effet observé pourrait être dû à un "vieillissement du photon", c'est-à-dire à une perte progressive d'energie par le photon au cours de son long parcours intersidéral. Cet effet, jusqu'ici inconnu de toutes les théories de la lumière même ce tenus de l'existence des photons, pourrait résulter d'une cession continue d'énergie par le photon à l'onde qui l'entoure.**

In a previous paper he had explained in more detail how this loss of photon energy might occur (de Broglie 1962):

> *Un photon venant à nous d'une nébuleuse très lointaine pourrait voir son onde u s'affaiblir par suite d'un étalement lent ou d'une absorption par les milieux absorbants extrèmement ténus qui existent, on le sait aujourd'hui, dans les espaces intersidéraux.... Il y aurait ainsi une diminution progressive du quantum $h\nu$, donc un déplacement vers le rouge, par un mécanisme tout à fait différent de l'absorption forte par le photon et de l'effet Comptom, mécanisme relié à l'affaiblissement 'faible' et continu de l'onde u.***

What are the main arguments which have been raised against this explanation? Recently Arp pointed out five observational tests tired light theories must confront in order to become useful theories (Arp 1990): (1) absence of blurring in the optical images of extragalactic objects; (2) existence or not of a correlation between

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* Translation (Keys 1991): Personally, however, I am not convinced that the interpretation of the observed spectral shifts as due to a Doppler effect connected with expansion of the universe is really necessary. In my opinion, the observed effect could be due to a 'photon aging', *i.e.* a gradual loss of energy by photons during their long intergalactic voyage. This effect, hitherto unknown in any theory of light, even theories that admit photons, could be due to a continuous loss of energy by the photon to its surrounding wave.

** Translation (Keys 1991): A photon arriving from a very distant nebula could have its wave *u* weakened through a slow attenuation or absorption by the extremely tenuous absorbing matter that we now know exists in interstellar space.... This would result in a gradual decrease of the quantum $h\nu$, and hence a redshift, through a mechanism quite different from strong photon absorption or the Compton effect. The actual mechanism would be the continuous 'weak' absorption of the wave *u*.

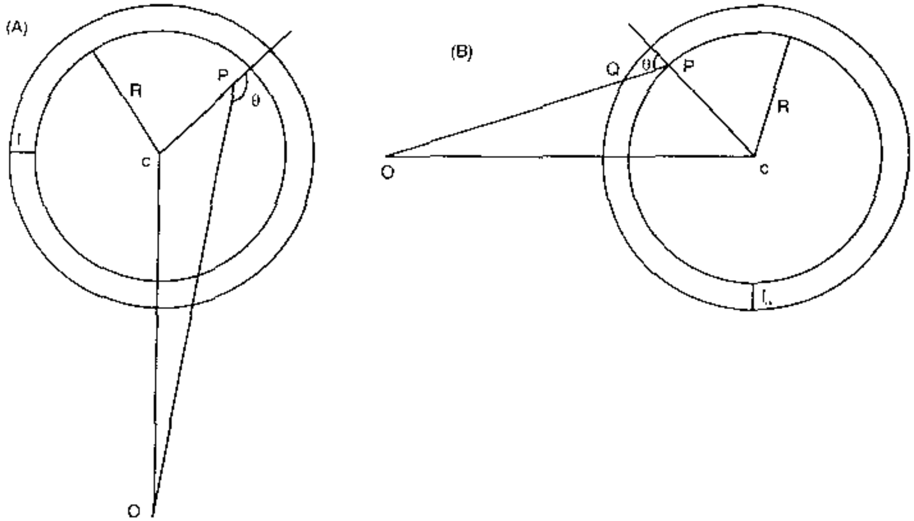

Figure 2. (A) An observer O looking at a point P in the surface of the sun (centre C, radius $R_\odot$, atmosphere with a thickness $l_0 \ll R_\odot$).

(B) The same situation in a plane cutting the sun and containing the points O, C and P. The path traversed by a photon in the sun's atmosphere is given by $l = PQ = l_0/\cos\theta = l_0 \sec\theta$.

redshifts of stars and the column density of gas (hydrogen or molecular clouds, ionized gas clouds) in front of each star; (3) the fact that two galaxies may be interacting so that they are at the same distance but may have much different redshifts; (4) spiral galaxies embedded in a redshifting medium should show a gradient of redshift from center to edge; (5) there should be severe redshift dislocations along the edge of objects due to the redshifting medium. All five tests have been specifically analyzed by Jaakkola, who showed that observational evidence complies with the tired light model (Jaakkola 1990).

The main criticisms against the tired light model are its *ad hoc* assumption and lack of a suitable mechanism which could account for the observed phenomena. In this work we will not analyze any possible mechanism in depth, but will discuss an important example which gives considerable support to the tired light idea, namely the center-to-limb variation of solar lines (the sun being the star that is best known to us). The fact that the redshift in the solar lines changes from the center of the sun to the limb has been known since the turn of the century. In Figure 2 (A) (not drawn to scale) we present the main parameters which describe this phenomenon. An observer O on the earth observes a point P on the surface of the sun. The sun has a radius $R_\odot = 7\times10^8$ m and an atmosphere of thickness $l_o \ll R_\odot (l_o \approx R_\odot/2000)$. We represent by θ the angle between the line of sight and the solar radius to the point where the line of sight cuts the solar surface. In Figure 2 (B) we have the same situation in a plane which cuts the sun but contains the sun's center C, the observer O and the point P. Observations in the visible spectrum ($\lambda = 6100$ Å) show a redshift which changes from center to limb according to (Finlay-Freundlich 1954)

$$\lambda_{obs} - \lambda_{lab} = (2.72 + 1.85\sec\theta)\times 10^{-3} \text{ Å} \tag{8}$$

which leads to a fractional change of

$$z = \frac{\lambda_{obs} - \lambda_{lab}}{\lambda_{lab}} = (4.5 + 3.0\sec\theta)\times 10^{-7} \tag{9}$$

The observed points and relation (8) are represented in Figure 3, taken from Finlay-Freundlich (1954).

Let us now try to understand the origin of this observed redshift. Is it a Doppler redshift? The answer seems to be no, because equation (9) was obtained after taking into account the known Doppler shifts resulting from the relative motion of the sun and the earth (Marmet 1989). The rotation of the sun has no influence, since equation (8) is observed everywhere on the surface of the sun (Marmet 1989). The spots on the sun's surface have a period T of rotation of approximately 21 days. This would lead to a Doppler shift of $z = v/c = 2\pi R_{\odot}/Tc = 8.1\times 10^{-6}$, suggesting a redshift at the points on the surface of the sun which are moving away from us and a blue shift at the points which are coming towards us. This is not what is described by equation (9).

Is it a gravitational redshift? According to Einstein's theory of relativity, light emitted with frequency ν_1 from a place of gravitational potential Φ will arrive at a place of relative gravitational potential zero with frequency ν_2 such that (North 1965, p. 53):

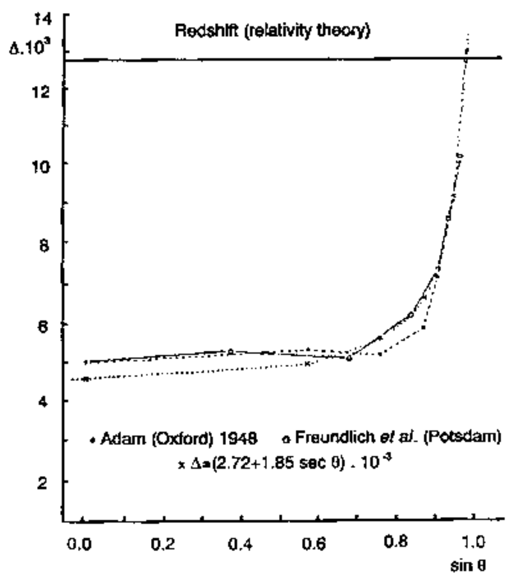

Figure 3. The redshift from the centre of the sun to the limb (from Finlay-Freundlich 1954). Full and open circles represent two sets of observations. The dotted line with ×'s is the least square solution given by (8) which best fits the data. The horizontal line is the gravitational redshift according to Einstein's theory of relativity.

$$\frac{\nu_1 - \nu_2}{\nu_2} = \frac{\Phi}{c^2} \tag{10}$$

Applying this to the sun would yield $z = \Delta\lambda/\lambda = -\Delta\nu/\nu = GM_\odot/R_\odot c^2 = 2.12\times 10^{-6}$, where $M_\odot$ is the sun's mass. As we can see from Figure 2, this is near the observed value at the limb of the sun but is much larger than the value in the center. As the gravitational potential is a constant over the surface of the sun, the redshift should not vary from center to limb. So the conclusion is that the redshift of the sun is not wholly due to a gravitational redshift.

An alternative interpretation of the cosmological or Hubble redshift has been presented by Arp (1991). According to this model, the cosmological redshift, rather than a Doppler effect, would depend on the epoch of creation of the astronomical object. This model explains many anomalous and intrinsic redshifts of some galaxies made of younger matter but cannot explain the variation of the redshift from center to limb in the sun, as the age of the matter at the sun's surface should be the same everywhere.

What explanation is left? Figure 2 (B) shows that the length that light travels across the sun's atmosphere is given by $l \equiv PQ$. From the triangle OCP it can be easily seen that (as $l_o \ll R_\odot$) $l \equiv PQ \approx -l_o/\cos(\pi-\theta) = l_o \sec\theta$. Consequently, an explanation which almost forces itself upon us is that the redshift is due to the interaction of light in its passage through the atmosphere of the sun. The redshift would then be proportional to the length of travel, which as we have seen, is proportional to $\sec\theta$. Finlay-Freundlich has successfully explained the redshift of the solar lines, as well as those anomalous redshifts of *O*, *B* and *A* stars, supergiant *M* stars, Wolf-Rayet stars and the cosmological redshift, with a simple formula (Finlay-Freundlich 1954)

$$\frac{\Delta\lambda}{\lambda} = -\frac{\Delta\nu}{\nu} = AT^4 l \tag{11}$$

where $A = 2\times 10^{-27}$ K^{-4} m^{-1} is a constant, T is the temperature of the radiation field where light is moving (it is not necessarily the temperature of the source) and l is the length of path traversed through the radiation field. This formula explains reasonably well the second term on the right hand side of equation (8).

This redshift of the sun's line is a clear proof that the tired light proposal meets Arp's condition (2) due to the proportionality between the redshift and the length of path across the sun's atmosphere, namely, z is proportional to $\sec\theta$, which is proportional to l.

The dependence of the solar redshift on the length of path through its atmosphere is remarkable and lends support to a tired light model. If this is the case, what is the physical mechanism responsible for this effect? When presenting equation (11), Finlay-Freundlich suggested that it might be due to a photon-photon interaction. A variation of this proposal was given by Pecker *et al.* (1972). Another mechanism based on an inelastic collision of the photon with atoms or molecules has been given by Marmet, and he has also successfully explained the redshift of the solar limb (Marmet 1988, 1989). Another possibility is an interaction of photons with free electrons (Kierein 1990). There are many other proposals; however, we will not discuss them here. The main difficulty which I see with regard to Marmet's proposal (or any other of this kind) is that atoms and molecules have extremely well defined levels of energy, and therefore they can only absorb and emit in these frequencies. On the other hand, an interaction between photons and free electrons would appear more plausible, since free electrons can absorb and emit photons of any frequency. Another problem is that to explain Hubble law of redshifts by the same mechanism, Marmet (1988) needed to assume an average density of hydrogen atoms throughout the universe of 2.5×10^4 atoms m^{-3}. But as we have seen, the estimated mass density in the universe (based on observations of visible galaxies, *etc.*) is only $\rho \simeq 3\times10^{-27}$ kg m^{-3}, which is equivalent to only one hydrogen atom per cubic meter, four orders of magnitude smaller than what is required in Marmet's proposal.

Whatever the nature of the mechanism (there may even be several mechanisms at work simultaneously), a tired light model does seem to satisfactorily account for the data on redshifts. The center-to-limb variation of the solar lines shows clearly that there exist redshifts which are not due to a Doppler effect or a gravitational redshift, and are also not age dependent. This constitutes a proof that another mechanism is at work to create this redshift. This is the case at the sun's surface. Why should the same mechanism not work in other stars and in interstellar and intergalactic space?

IV. Cosmic Background Radiation

In 1965, working with a horn-reflector antenna at 4080 Mc s^{-1} ($\nu = 4.08\times10^9$ Hz, $\lambda = c/\nu = 7$ cm), Penzias and Wilson discovered an excess temperature of $3.5 \pm 1.0°$ K (Penzias and Wilson 1965). They found this temperature to be isotropic, unpolarized, and free from seasonal variations. It was soon interpreted by Dicke *et al.* as cosmic black-body radiation, a relic of a hot big-bang (Dicke *et al.* 1965). The idea of a hot big bang had been developed by Gamow, Alpher, Herman and others in the period 1948-54 (see for instance Alpher *et al.* 1948). Later, a dipole anisotropy was found in the cosmic background radiation which is usually interpreted as being due to the earth's motion through the radiation field. The value of the dipole anisotropy is well known nowadays, and allows a precise determination of our motion relative to this radiation background (see, for instance, Lubin *et al.* 1985).

Here we want to emphasize certain other parallel developments which are not so well known. First of all, in 1954 (prior to the discovery by Penzias and Wilson) Finlay-Freundlich developed his alternative interpretation of the cosmological redshift on the basis of a tired light model (see equation (11)). As a corollary he predicted a mean temperature of intergalactic space between 1.9 and 6.0° K (Finlay-Freundlich 1954), stating that: "One may have, therefore, to envisage that the cosmological redshift is not due to an expanding universe, but to a loss of energy which light suffers in the immense lengths of space it has to traverse coming from the most distant star systems. That intergalactic space is not completely empty is indicated by Stebbins and Whitford's discovery (1948) that the cosmological redshift is accompanied by a parallel unaccountable excess reddening. Thus the light must be exposed to some kind of interaction with matter and radiation in intergalactic space." Max Born discussed Finlay-Freundlich's ideas, and indicated his support for them (Born 1954).

Less well-known is an important text by Regener which was published in 1933—well before Gamow's paper (1948). Regener utilized the Stefan-Boltzmann law, equating it to the measured value of the flux energy of the night sky (due to light, heat and cosmic radiation), and obtained a mean temperature for interstellar space of 2.8° K (Regener 1933, Monti 1988). Regener's work was taken up by Nernst in his model of a boundless universe, homogeneous on the large scale and without expansion (Nernst 1937, Monti 1988). Nernst is another advocate of the tired light model.

Even before Regener, a temperature of interstellar space of 3° K had been given by Eddington in his famous book first published in 1926 (Eddington 1988, p. 371).

The conclusion we draw is that the existence of a background radiation of 2.7° K cannot be used as a proof of the big bang theory. This is true not only because other models are compatible with it, but also because other models had even predicted its existence prior to its discovery.

V. Predictions of the Model and Conclusion

Here we would like to present some consequences of the model described in this paper. These are not predictions to be tested in the laboratory, but something to be expected in future observations.

We assume that the universe is isotropic, homogeneous and boundless (extending indefinitely in all directions with a constant, finite mass density). This means that, in principle, there should be galaxies at all distances from us. Consequently, one prediction is that with the development of observational instruments we should find galaxies at an ever increasing distance from us, without limit (the only limitations are the resolving power of the instruments and the range of propagation of electromagnetic radiation).

The universe is also assumed to be homogeneous in time (on a macroscopic scale, the same in the past, now and in the future). A second prediction is thus that in any large region of space, no matter how far from us, we should find approximately the same number of galaxies dying out and being created. In the big-bang model, on the other hand, all the galaxies were formed at approximately the same time. Therefore any young galaxy found at large distance from the earth lends support to a model of the universe which is in a steady state on a large scale.

Another prediction of the model can be obtained by comparing equations (4) and (7). According to equation (4), H_o should be a constant independent of the distance. But if we write equation (7) in the same form as equation (4) we obtain a Hubble "constant" which should depend on the distance, namely

$$z(r) = e^{\alpha r} - 1 \equiv \frac{H(r)}{c} r = \alpha r + \frac{\alpha^2}{2} r^2 + \frac{\alpha^3}{3!} r^3 + O\left(\alpha^4 r^4\right) \tag{12}$$

As we have already identified α with H_o/c, we obtain:

$$H(r) = H_o + \frac{H_o^2 r}{2c} + \frac{H_o^3 r^2}{6c^2} + \ldots$$

This shows that Hubble's "constant" should in fact increase with the distance according to the tired light model. Is there any indication that this is the case? If we measure the distance of galaxies by a method which does not depend on their redshift we find that the redshift does not in fact seem to be a linear function of distance (Arp 1988; Arp and Van Flandern 1992). Furthermore, the slope of the curve $H(r)\times r$ seems to agree with equation (12). With an improvement in the observations and an increase in the number of observed galaxies, it will be possible to test this prediction in more detail in the near future.

We may thus conclude that an absorption of light offers an explanation of the cosmological redshift in an infinite and homogeneous universe which is essentially static and without expansion. A similar phenomenon in the realm of gravitation yields inertia as due to a gravitational interaction with the remainder of the universe, in compliance with Mach's principle. Moreover, this is obtained in the framework of the simplest of all models of the universe: a universe which has always existed, in which there is no expansion or creation of matter, and which is essentially uniform and homogeneous in all directions and at all distances.

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