# On Hubble's Law of Redshift, Olbers' Paradox and the Cosmic Background Radiation

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*We utilize the principle of conservation of energy in a model which explains the cosmological redshift, Olbers' paradox and the cosmic background radiation. The model is based on a hypothesis of absorption and emission of light by galactic and intergalactic matter, and a mean temperature of matter in the Universe compatible with the background radiation. We also discuss the early works of Regener and Nernst related to these topics. Lastly we derive some known scaling laws for galaxies, i.e., luminosity to mass and luminosity to area, which had not been well understood up to now. All of this is accomplished supposing a boundless, stationary Universe that is homogeneous on the large scale.*

*Key Words: cosmology—cosmic background radiation—cosmological redshift—Hubble's law of redshift.*

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## Introduction

In this work we discuss a number of important cosmological questions, such as the origin of the cosmological redshift, Olbers' paradox, and the origin of the cosmic background radiation. In particular we show that these three topics are strongly correlated if we suppose a tired-light model based on the absorption of light by galactic and intergalactic matter. In the near future we hope to relate this model to a physical framework based on Mach's principle (Mach 1989). Recently (Assis 1989a) we presented a model to quantitatively implement Mach's principle based on Weber's law (Maxwell 1954; O'Rahilly 1965; Wesley 1990; Phipps 1990; Assis 1989b, 1990 and 1991; Assis and Caluzi 1991; Clemente and Assis 1991). In this earlier work (Assis 1989a), we showed how to derive the proportionality between inertial and gravitational masses using the gravitational interaction of any body with the rest of the Universe. It was also pointed out how the fictitious forces (centrifugal, Coriolis, etc.) only appear in a reference frame in which all "fixed stars" are rotating together.

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Though limited, the model yielded some interesting results. In this paper we discuss other topics of relevance to cosmology. Our working hypothesis is the emission, absorption and conservation of energy, and our aim is to construct an alternative coherent model of cosmology that is able to account for the data.

## Cosmological redshift

The first issue to be addressed is Hubble's law of redshifts. We assume a model in which Hubble's law is due to absorption of galactic light by the interstellar and intergalactic matter and not due to a Doppler effect. To investigate the underlying mechanisms, we can write Bouguer's law (Bouguer 1729; Mach 1926; Curtis 1978) as applied to the energy of a photon as:

$$E(r) = E_0 e^{-\alpha_L r} \tag{1}$$

where $E_0$ is the initial photon energy, and $\alpha_L$ is the mean absorption coefficient of light in the line of sight connecting the source and the earth. Using the Einstein relation (Einstein 1905) namely, $E = h\nu = hc/\lambda$, we can obtain a law of redshifts from Eq. (1):

$$z(r) \equiv \frac{\lambda(r) - \lambda_0}{\lambda_0} = e^{\alpha_L r} - 1 \cong \alpha_L r \tag{2}$$

In this equation $z$ is the fractional spectral shift, $\lambda_0$ is the wavelength emitted by the source, and $\lambda(r)$ is the wavelength detected at the Earth. Since we know that $z \cong H_0 r/c$ where $H_0$ is Hubble's constant, Eq. (2) yields $\alpha_L = H_0/c$. This is essentially the tired-light model. We will not present any new theory to explain this tired-light behaviour; we will merely review the main models which result in a derivation of Eq. (1).

The first to propose such an idea was Zwicky (1929), and later Hubble himself discussed this hypothesis with an open mind (Hubble and Tolman 1935; Hubble 1936a, b and c, 1937 and 1953). The main obstacle to acceptance of the tired-light model has always been the mechanism behind the loss of energy. On the other hand, as has been pointed out clearly by G. Reber (1986), the main reason for adopting the hypothesis of a Doppler effect as the cause of redshifts has been the assumption that intergalactic space is a void and that nothing happens to light in its journey from a galaxy to the Earth. Nowadays we know this is not the case: interstellar and intergalactic space is full of cosmic rays, clouds of dust, etc. This has led H. Alfvén to speak of the cosmos as a "Plasma Universe" (Alfvén 1981; 1986). Recently, Lerner has shown conclusively the existence of radio absorption by the intergalactic medium (Lerner 1990). The existence of intergalactic dust and gases had been deduced a long time ago based on observations (Zwicky 1953).

The present model of the redshift mechanism is premised on absorption of light energy by the distribution of matter in space (and not, for instance, an absorption by the ether or by space). Other mechanisms have been proposed, such as an instability of the photon with a steady reduction of mass as it ages (Waldron 1981 and 1985), or energy depletion due to an electrical conductivity of the background space (Monti 1988; Vigier 1990). Nernst supposed the luminiferous ether to absorb the photon energy (Nernst 1937 and 1938). Reviews due to Schatzman (1957) and Keys (1987) discuss a number of other tired-light models. An excellent study of the many theories of a stationary Universe in which the photons lose energy in inelastic collisions with matter distributed throughout interstellar and intergalactic space was done by Pecker (1976). Rather than enter into details of all these proposals, we wish to mention a few other specific models that deserve consideration, namely: Pecker, Roberts, and Vigier (1972); Ellis (1984); Pecker and Vigier (1987); Crawford (1987). We call attention also of the cogently argued proposals of Reber and Marmet (Reber 1986; Marmet 1988a; Marmet and Reber 1989; Marmet 1989). In these works they present specific calculations and show that their model is compatible with many observational results. They explain the redshift on the solar limb (Marmet 1989), the different average redshifts of binary stars and radio astronomy observations at 144-m wavelength (Reber 1986), etc. A criticism of big bang cosmological models based on interpretations of the redshift and why these models should be replaced by static ones was presented by Kierein (1988).

We would like to point out here that our model is based on an interaction of light (photons) with matter in interstellar and intergalactic space. We suppose that a photon is absorbed and then re-emitted with a smaller energy. *This is not simple scattering*. Moreover, matter (clouds of dust, ionized particles, etc.) also radiates energy, so that if this matter is in equilibrium with the galactic and intergalactic light, it will absorb on average the same amount of energy as it radiates. The model presented here is based on a stationary and homogeneous Universe (on the large scale) that is boundless in space and in time. As such, this model requires no evolutionary effects on a large scale. In agreement with this prediction, astronomical tests have found that no such effects exist in the known Universe as a whole (Jaakkola 1982, 1983 and 1991; Laurikainen and Jaakkola 1985).

To conclude this discussion, we would like to point out that, independent of the specific model for the energy loss of the photon, the tired-light model presented in Eq.(2) seems to be more consistent than big bang cosmologies, as has been shown by LaViolette (1986);

and Jaakkola, Moles and Vigier (1979). They have shown, in particular, that the tired-light model makes a better fit to the data in four far-reaching tests: the angular size—redshift test, the Hubble diagram test, the galaxy number count—magnitude test and the differential log $N$—log $S$ test.

## Olbers' Paradox and the Cosmic Background Radiation

The second important cosmological question to be dealt with in this work is Olbers' paradox (Bondi, 1960). This subject was first discussed in print by Edmund Halley in 1720 (Halley 1720; Hoskin 1985). Olbers noted an error in Halley's analysis and solved the problem supposing an absorption of light by matter in interstellar space (Olbers 1826 and 1894; Jaki 1969). Essentially the same idea had been put forth by Chéseaux (1744), but his work had a lesser impact than that of Olbers (Jaki 1969). Olbers' solution to the problem was later criticized on the assumption that if matter absorbed radiant energy then it would heat up until its emitting power was equal to its absorbing power. It is usually argued that if this were the case the night sky would be so bright as to have a temperature comparable to the surface of the Sun (Hoyle and Narlikar 1980). We show here that this need not be the case.

Our starting point is an equivalent to Eq. (1), namely, that the flux emitted by a typical astronomical body, for instance, a galaxy, falls off as

$$F(r)=\left(\frac{L}{4\pi r^2}\right)\exp(-\alpha_L r)$$

where $L$ is the luminosity of the object (its emitted bolometric power). If we have $n$ bodies per unit volume the total flux received from the whole Universe will be (taking $L$ as an average value for all bodies)

$$F=\int_0^\infty \frac{Lr^{-\alpha_L r}}{4\pi r^2} n 4\pi r^2 dr=\frac{Ln}{\alpha_L} \qquad (3)$$

This at once explains why the night sky is dark, for even with an infinite Universe we can equate Eq. (3) with the measured value of the mean flux received from the Universe. This gives a correct measured value of the mean received flux, as we will see when discussing the work of Regener.

We obtained previously that $\alpha_L = H_0/c$. Equating $n$ with $\rho_0/M$, where $\rho_0$ is the mean density of matter in the Universe and $M$ is the average mass of the bodies in the Universe, we obtain

$$F=\frac{L\rho_0 c}{H_0 M}$$

Since we are supposing a Universe in a stationary state, a body in equilibrium must emit the same quantity of energy as it absorbs. Denoting by $R$ the radius of the object, its emitted flux will be $L/4\pi R^2$. Equating this with the absorbed flux yields

$$\frac{M}{R^2}=4\pi\frac{\rho_0}{H_0}c \cong 1-10\frac{kg}{m^2} \qquad (4)$$

This would seem to be a naive result, but it is a necessary consequence of our model, and, significantly, it happens to be valid for most galaxies. For instance, for the Milky Way we have

$$M/R^2 \cong 4x10^{41}\,kg/\left(3x10^{20}\,m\right)^2 \cong 4kgm^{-2}$$

Of course we cannot put exact numbers in these relations due to uncertainties in the determination of $\rho_0$, $H_0$, $M$ and $R$ (Börner 1988), and also because the galaxies exhibit certain irregularities in form (for flat galaxies the emitted flux is better represented by $L/(\pi R^2)$, instead of $L/4\pi R^2$, for instance). It is nevertheless remarkable that this relation seems to be valid not only qualitatively but also in orders of magnitude. It can be remarked that Eq. (4) must be valid for a body in equilibrium with the remaining Universe in any kind of interaction. For instance, if the body is in gravitational equilibrium it should emit and absorb the same amount of gravitational energy. This condition is also expressed by Eq. (4) due to the fact that the luminosity or any other kind of interaction power cancels out in this expression.

We now answer the criticism that an explanation of Olbers' paradox based on absorption of light would require the night sky to be as bright as the surface of the Sun. Our main assumption is that the mean temperature of matter in the Universe is 2.7° $K$. With this hypothesis the cosmic background radiation (CBR) is explained at once. This explains also the darkness of the night sky: the night sky is bright enough that its temperature is approximately 2.7° $K$. One argument in favour of this assumption is the fact that Regener, in 1933, equating the measured value of flux of energy of the night sky, due to light and heat or due to cosmic radiation with Stefan-Boltzmann's law, obtained a mean temperature of 2.8° $K$ for interstellar space (Regener 1933; Monti 1987).

This is especially remarkable as it preceded by 32 years the discovery by Penzias and Wilson of the blackbody spectrum of 2.7 $K$ (Penzias and Wilson 1965). Although Regener's momentous work is not well known, it should be emphasized that it anticipates by 15 years to the works of Gamow (Alpher, Bethe, and Gamow 1948; Gamow 1953) that are always cited in favour of an interpretation of the CBR as a relic of a hot big-bang (Dicke, Peebles, Roll, and Wilkinson 1965). We, on the other hand, think of the CBR as a blackbody radiation due to the average temperature of matter in the cosmos. If this interpretation is correct, then a body in equilibrium with this radiation must absorb the same energy as it emits. We then have a new relation, namely

$$\frac{Ln}{\alpha_L} = \frac{L}{4\pi R^2} = \sigma T^4 \qquad (5)$$

where $\sigma$ is Stefan-Boltzmann's constant. The first equality gave Eq. (4). Equating the first and second terms of Eq. (5) with the third term yields, with $T = 2.7^\circ\ K$:

$$\left.\begin{aligned} \frac{L}{M} &\cong 10^{-5}\, Wkg^{-1}, \\ \frac{L}{R^2} &\cong 4\cdot 10^{-5}\, Wm^{-2} \end{aligned}\right\} \qquad (6)$$

These are simple relations as well, but again they are important consequences of our model. As with Eq. (4), the striking argument in favour of our interpretation of the CBR is that Eq. (6) holds for most galaxies (Faber and Jackson 1976; Tully and Fisher 1977; Faber and Gallagher 1979; Kormendy 1982). For instance, for the Milky Way we have

$$\left.\begin{aligned} \frac{L}{M} &\cong 2.5\cdot 10^{-5}\, Wkg^{-1} \\ \frac{L}{R^2} &\cong 15\cdot 10^{-5}\, Wm^{-2} \end{aligned}\right\}$$

It should be remarked that the origin of these scaling laws had not been well understood up to now (Börner 1988). A derivation of relations similar to these based also on the conservation of energy in a static Universe has been given recently in an important paper by Shlenov (1991). As in our model, he assumes an infinite Universe without expansion.

In conclusion, we may say that with this interpretation of Olbers' paradox the material bodies which are responsible for the absorption of electromagnetic radiation will heat up only up to the point that they are in thermal equilibrium with this radiation, namely, $2.7^\circ\ K$.

## Discussion and Conclusions

In this paper we have utilized a single principle, namely, emission, absorption and conservation of energy, to understand and correlate many phenomena. In particular we applied this principle to a study of the cosmological redshift, Olbers' paradox, and the $2.7^\circ\ K$ cosmic background radiation. We showed how the cosmological redshift can be coherently interpreted with this hypothesis and discussed how this can give a better quantitative fit for data in this field than other interpretations. Our model is based on a stationary and boundless Universe, homogeneous on a large scale, infinite in extent and in duration. With regard to the many assumptions needed for expanding Universe cosmologies to fit the known redshift data, we might ask, with Kellermann (1972): "Are we drawing too many epicycles?". The model developed here can accommodate a number of the anomalies in Hubble's law, such as those observed by Arp *et al.* (Arp 1967, 1971, 1974, and 1987; Field, Arp and Bahcall 1973; Arp, Burbidge, Hoyle, Narlikar and Wickramasinghe 1990), in which two physically linked astronomical objects have quite dissimilar redshifts. To understand these findings we only need to remember that $a_L$ is roughly proportional to the absorption coefficient between the object and the Earth. Since each object is surrounded by a different environment (atmospheres, charged particles forming a diffuse plasma, etc.), we would expect the redshifts associated with different types of objects to show these peculiarities. This framework for explaining the redshift of the quasars and galaxies is thus in general agreement with the mechanism proposed by Marmet (1991). According to this mechanism, the photon, through inelastic collisions with molecules, loses its energy to the intervening matter between the source of light and the Earth. A clear discussion of Marmet's previous works has been given by Phipps (1989). One consequence of such mechanisms is that, in the future, analysis of spectral redshift may be utilized as a probe for the detection and study of the structure of different bodies and their surrounding matter. However, a detailed discussion of these topics is beyond the scope of the present work.

We then studied Olbers' paradox in the context of absorption of electromagnetic energy. We concluded that this is a very reasonable assumption, provided the mean temperature of matter in the Universe is that given by the cosmic background radiation. We developed some important consequences from this hypothesis (luminosity-to-mass and luminosity-to-area constant for galaxies) and pointed out that exactly these scaling laws are found in nature. Even the numerical values of the constants agree with observations. Since there are still some uncertainties in the determination of $\rho_0$ and $H_0$, we might hope for an improvement in these relations in the near future. A limited statement that matter in the Universe is at $2.7^\circ\ K$ and that this matter is responsible for the CBR was given by Marmet (1988b). The difference is that he supposed only dark matter to be at this temperature, while we assume all matter in the Universe to be at this mean temperature.

In conclusion, a stationary model of the Universe, extending without limit in all directions, and in time, is consistent with all known cosmological data. But it should be remarked that our model more resembles Nernst's proposal (Nernst 1937 and 1938) than the steady state theory of Bondi, Gold and Hoyle (Bondi and Gold 1948; Hoyle 1948). The main difference is that since we do not have expansion of the Universe, we do not need to postulate continuous creation of matter. Consequently, we also avoid the problems that arise from a finite time for the Universe. Harrison has shown that in all big bang models with suitable evolution, the Universe has existed for only a finite time (Harrison 1964, 1974 and 1981). Because we have given a plausible resolution of Olbers' paradox with a homogeneous, limitless Universe, without any singularity in time, we cannot agree with Tipler's statement that "there were (and are) only two ways of resolving the Paradox: the Universe of stars must be either inhomogeneous in space, or inhomogeneous in time" (1988).

The theory discussed here is incomplete in that it makes no attempt as yet to consider the growth of entropy in a Universe in a steady state. This is the most important and difficult question to answer in any model which assumes an Universe in a stationary and homogeneous state. The only clue as to where a solution might lie (although we will not follow it up here) is that we have a limitless and open system (the whole Universe) with infinite degrees of freedom. This implies that the inclusion of entropy in the model may require a more general thermodynamics, adequate for open systems. Once again, it must be emphasized that Nernst, the founder of the third law of thermodynamics related specifically to entropy, was among those who advocated a model of a limitless Universe in a steady state without expansion or creation of matter (Nernst 1937 and 1938).

In our model we assumed that galaxies are in thermal equilibrium with the 2.7° $K$ cosmic background radiation. Althouth most photons emitted by ordinary galaxies originate at stellar surfaces which are not at 2.7° $K$, this is a reasonable assumption for two reasons. The first is that the typical age of a galaxy is comparable with the Hubble time, $\cong 10^{10}$ years (Binney and Tremaine 1987; Börner 1988). To exist for so long, a stable system like a galaxy must be in some sort of dynamic equilibrium with its environment. The second reason is that the energy density of the CBR ($\cong 1\,eV\,cm^{-3} = 1.6 \times 10^{-13}\,Jm^{-3}$) is just the energy density inside our own galaxy due to the various modes of internal interstellar excitation—starlight, cosmic rays, magnetic fields and turbulent gas clouds (Sciama 1973). This is a clear quantitative indication of a thermal average equilibrium between the matter that makes up a galaxy and its external environment, the CBR. The model presented in this paper is limited, and we make no attempt to address the issue of the origin of the elements and their observed abundances. The correct prediction of these abundances is one of the main evidences in favour of the standard cosmology based on the big bang. We will not consider this subject from the point of view of a static cosmology because our own ideas on this topic are not yet well developed. A possible quantization of the redshifts (Broberg 1982 and 1991; Arp 1989), though an extremely interesting development, is also beyond the scope of this work.

Obviously the model developed here is still crude and yields only rough predictions. Nevertheless, we feel this type of theory deserves consideration, for the reasons stated above. In the future, we hope to present an improved model with greater sophistication. In subsequent work the relationship between these ideas and Mach's principle (Mach 1989; Assis 1989a; Barbour 1989; Graneau 1990) will be worked out in more detail. In a series of recent studies, a number of authors have developed connections between inertia, gravity, electromagnetism, and cosmology (Ghosh 1984 and 1991; Roscoe 1991a and b; Jaakkola 1987 and 1991; Kropotkin 1991 and Shlenov 1991). We hope to relate our own approach to the approaches taken by these authors in the future.

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