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An Attempt to Resolve the Astrophysical Puzzles by Postulating Scale Degree of Freedom

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Abstract

If we assume that scale is a degree of freedom which a physical object, such as a galaxy possesses besides translational and rotational degrees of freedom, we are able to incorporate such diverse phenomena as the systematic cosmological red-shifts, anomalous red-shifts, controversals of quasars, and the expansion of Earth into a single theory. At the same time we can consider the proposed existence of active dilatation as a physical realization of conformal transformations. Active conformal transformations transform the rest masses of particles. The objection that this implies a continuous rest mass spectrum which is not observed is avoided by assuming that particles can form bound systems such as nuclei, atoms, crystals, galaxies, etc., only if 'discrete' scale relations are established among the constituent particles. Different galaxies can be dilated relative to each other. (Note the analogy with 'discrete' positions of atoms in a crystal. Different crystals can be translated arbitrarily each to the other.) An observer in a contracting galaxy experiences that the universe is expanding.

1. *Introduction*

In this paper we admit that dilatation (we use also the synonym scale transformation) may manifest itself in nature as an *active transformation*. Usually authors exclude active dilatation by arguing that it would imply a continuous rest mass spectrum (Niederle and Tolar, 1973), which, however, is not observed. We can show (see Section 2) that nonoccurence of continuous rest mass spectrum does not imply nonexistence of active dilatation. We adopt the concept of a conformally invariant mass (Barut and Haugen, 1972), but we permit the conformal transformations to be the active ones.

What do we mean by active dilatation or active conformal transformations? We assume that a physical object (a body, a particle, a galaxy, etc.) possesses not only translational and rotational degrees of freedom but also dilatational degrees of freedom. More illustratively, a physical object, a stone or a galaxy for example, can be translated, rotated or dilated. In all three cases, the shape and the internal structure of the physical object remains unaffected under transformation, provided the internal forces within the object are much stronger than the system forces due to the translational, rotational, or dilatational motion. An observer which is fixed in a given system of reference observes translation as a change of position of the physical object, rotation as a change of orientation, and dilatation as a change of scale.

By the change of scale we mean exactly the following: a physical object (stone, galaxy) changes its dimensions. First it is big, then during the scale motion it becomes smaller and smaller (or bigger and bigger). All the time, the internal structure of the physical object, as observed by an observer moving together with it in scale, remains the same or is slightly distorted because of system forces due to the scale motion.

I must stress that no 'pressure' is needed to maintain a scale motion. As there exists free translational and free rotational motion, there exists after our hypothesis also free scale motion. In order to initiate a free translational or a free rotational motion, a physical object must acquire a translational or rotational (angular) momentum, respectively. In an analogous way, to initiate a free scale motion a physical object must get *a scale momentum*. This may happen through a collision of two objects which are in relative scale motion, or through the action of so called *scale forces.* When an object changes its scale relative to a given system of reference, it also changes its rest mass.

All physical objects in our macroscopic surroundings (Earth, Solar system, possibly Galaxy) do not move in a scale relative to each other. Their relative scales are constant and can be set equal to unity. The constancy of scales in our galaxy is a matter of cosmological initial and boundary conditions. So we are unable to observe changes of scale in our galaxy.

On the other hand, it is possible that galaxies move in a scale relative to each other. There exists strong experimental indications in favor of this supposition.

The systematic cosmological red-shifts. Let us assume that our galaxy is contracting relative to the flat cosmological background, determined by the average behavior of galaxies. Then an observer in our galaxy would experience that the whole universe is expanding. The expanding universe, after usual practice, is described by the metric of conformally flat space-time. In a space-time with such a metric, there exists systematical red-shifts, which depend on the distance between a source of light and the coordinate origin, and which are in the case of the special form of the metric (see Synge, 1960) proportional to that distance (Hubble's law).

For an observer fixed in our galaxy, the metric is conformally flat, while for an observer fixed in the system attached to the average cosmological background, the metric is flat. (See also the further text.)

We stress again that we shall consider that our galaxy is contracting rather than the whole universe expanding. Historical analogy: instead of considering the whole universe as rotating, people accepted the view that the Earth is rotating. At the same time this view enables to explain 'anomalies' in the motion of planets.

The anomalous red-shifts of galaxies and extremely great red-shifts of quasars (as compared to their luminosity). There is a strong experimental evidence for deviations from the Hubble's law (News, 1972; Simkin, 1972; Wampler et al., 1973; Hazard et al., 1973; Wampler, 1973b), which we ascribe to different scales of observed galaxies. As is well known (Niederle and Tolar, 1973; Barut and Haugen, 1972; Barut, 1973), the rest mass is transformed under scale transformations when they are interpreted actively. Now imagine a constituent atom of a foreign galaxy. An observer fixed in that galaxy determines that the rest mass of a constituent electron e is m_0, and a characteristic transition frequency is ν_0. An observer in our galaxy, which has a different scale from the foreign galaxy, determines a different rest mass m'_0 for the same previously mentioned electron e, and therefore a different frequency ν'_0 of the emitted light.

The drift of continents and its explanation by the expanding Earth. In a rotating frame, an observer experiences system's forces, such as centrifugal or Coriolis force, which tend to deform a given object fixed in this system. By analogy, there must exist system forces due to scale motion. After our proposition such forces act for instance on Earth, which is fixed in our contracting galaxy, and tend to expand Earth relative to our galaxy.

There is also a question whether scale is really constant within our galaxy. Line-shifts of stars can be ascribed to gravitational effects, to the Doppler-effect, and to the scale effects. Broadening of lines can also be due to the Doppler-effect of thermal motion and/or to a statistical scale motion of atoms in stars. Interpretations of experimental data have not taken into account all those possibilities. A further important fact is (see Weber, 1961, p. 61) that line-shift measurements on the sun give different results at different points on the surface, as if different pieces of the surface had different scales.

Later in the text the terms scale, scale motion, and other concepts in this introduction, will be defined and described more precisely.

2. *Scale Kinematic*

In this section we describe scale kinematic which deals with the transformations between systems of reference with different scales (shortly different scale systems), and such concepts as scale velocity, scale acceleration, etc. We assume the existence of active scale transformations and scale motions.

First, we explain what we mean by saying that two systems of reference have a different relative scale, or in other words, two different scales. It means that an observer, when finding himself successively in different scale systems, measures different 4-distances between the same events. Let E_1 and E_2 be two infinitesimally separated events. The 4-distance between E_1 and E_2 as measured in the systems S and S' will be ds and ds', respectively. Then the following relation must be valid

$$ds' = \alpha ds \tag{2.1}$$

where α is the relative scale between the systems S and S', and where S and S' are different scale systems.

In every scale system of reference the 4-distances are measured with appropriate devices based on the atomic standards of units. The atomic units are different in different scale systems of reference. *I must stress that the systems S and S' for which (2.1) is true are not considered as systems with different chosen units without physical difference between both systems. On the contrary, between the S and S' there is the definite physical difference.* Standard atomic units of the system S are different from the standard atomic units of the system S'. An observer O in S sees an observer O' in S' together with the measuring devices of O' and constituent atoms, being smaller (or greater) than O himself by the factor α.

Illustration. The observer O is in a vehicle which travels in scale. His vehicle together with his measuring devices represents a system of reference (denoted S). An observer O' in the outside world sees how the scale vehicle together with the observer O changes its size (contracts for instance). The observer O in the scale shuttle sees how the outside world is changing its size in the opposite direction (expanding). When the shuttle stops, the outside world stops expanding. A characteristic dimension of the outside world is different from the corresponding characteristic dimension in the shuttle. For instance, outside atoms have different sizes and decay times than corresponding atoms inside the shuttle. We say that the outside system of reference S' and the system S connected with the shuttle have *a different scale.* If the sizes and decay times of corresponding atoms are the same, we say that both systems have *the same scale.*

We do not, however, dispose with such scale vehicles, but I suppose that our whole galaxy is such a scale vehicle.

Scale kinematic describes the scale motions of physical objects, transformations of physical quantities between different scale systems of reference, and systems in relative scale motion.

A. Nonrelativistic Scale Kinematic

We consider the transformation of coordinates of a given event E from the system S to the system S' which moves in scale relative to S. First we consider homogeneous scale transformations, when both systems have a common coordinate origin, and next the inhomogeneous scale transformations.

Homogeneous scale transformations. Let us assume that the scale factor is time dependent

$$\alpha = \alpha(t) \tag{2.2}$$

In a nonrelativistic case the time t is independent of the velocity transformation. Then the nonrelativistic scale transformation D is

$$
\begin{aligned}
D: S \to S' \qquad & r \to r' = \alpha(t) r \qquad r \equiv (x, y, z) \\
& t \to t' = \int_0^t \alpha(t)\, dt \\
D^{-1}: S' \to S \qquad & r' \to r = \alpha^{-1}(t) r' \\
& t' \to t = \int_0^{t'} \alpha^{-1}(t)\, dt'
\end{aligned}
\tag{2.3}
$$

The transformation of velocity is

$$
D: S \to S' \qquad \frac{dr'}{dt'} = \frac{d(\alpha r)}{dt} = \frac{\alpha dr/dt + r\, d\alpha/dt}{\alpha} \tag{2.4}
$$

where dr'/dt' is the velocity as measured in S', dr/dt the velocity as measured in S, $d\alpha/dt$ the scale velocity as measured in S.

Nonrelativistic explanation of cosmological red-shifts. Let S be the system of reference connected with our galaxy which moves in scale relative to the background cosmological system S' in which all galaxies are at rest on the average (at rest with respect to translational, rotational and dilatational motion). Let x' be a coordinate (in the system S') of a point on a distant galaxy which emits the light. This distant galaxy is assumed to be at rest in S', hence

$$
dx'/dt' = 0. \tag{2.5}
$$

What is the velocity of the same point measured in S (our galaxy)? The transformation of coordinates is

$$
x = \alpha^{-1} x' \equiv \rho x' \tag{2.6}
$$

$$
t = \int_0^{t'} \rho\, dt' \quad \text{or} \quad dt = \rho\, dt'
$$

$$
\frac{dx}{dt} = \frac{d(\rho x')}{dt} = \rho \frac{dx'}{dt} + x' \frac{d\rho}{dt} = \frac{x}{\rho} \frac{d\rho}{dt} \tag{2.7}
$$

where (2.5) and (2.6) are taken into account. Here x is a coordinate of the distant galaxy measured in our galaxy. We see that the apparent velocity of a distant galaxy depends on the distance x.

Let us assume now the validity of the Classical Doppler effect

$$
\frac{\Delta\nu}{\nu} = \frac{v}{c} = \frac{1}{c\rho} \frac{d\rho}{dt} x = H.x \tag{2.8}
$$

where $H = (1/c\rho)\, d\rho/dt$ (the Hubble's constant).

This is the well known Hubble's law. The expansion of the universe is after our hypothesis only apparent. There exists a system of reference, connected with the average behavior of the universe, in which the universe does not expand, but our galaxy contracts. Note that the apparent expansion of the universe is total so that not only distances between galaxies, but also the sizes of galaxies and their constituent atoms, are enhanced.

If we extrapolate the presently observed expansion of the universe back into time, we come to a moment when all the universe was seemingly concentrated into a single point. This in fact never indeed happened, after our hypothesis. All data 'supporting' the big-bang theory are also consistent with our hypothesis.

Inhomogeneous scale transformations. Thus far, the systems S and S' had a common coordinate origin. Now suppose that the origins of the systems do not coincide. The transformations are then

$$\begin{aligned} D_I : S \to S' \qquad & r' = \alpha r + r'_0 \\ & t' = \int \alpha \, dt + t'_0 \\ D_I^{-1} : S' \to S \qquad & r = \alpha^{-1} r' - \alpha^{-1} r'_0 \\ & t = \int \alpha^{-1} \, dt' - \alpha^{-1} t'_0 \end{aligned} \tag{2.9}$$

The transformation of velocity is

$$v' = \frac{dr'}{dt'} = \frac{d(\alpha r)}{dt'} + \frac{dr'_0}{dt'} = \frac{\alpha v + r\dot{\alpha}}{\alpha} + v'_0 \tag{2.10}$$

where $\dot{\alpha} \equiv d\alpha/dt$. In the special case $\dot{\alpha} = 0$ (no relative scale motion), the equation (2.10) reduces to

$$v' = v + v'_0 \tag{2.11}$$

In a similar way we could write the transformation formula for acceleration. It is not our present purpose to develop nonrelativistic scale kinematic in detail. We have shown some examples as to what such kinematic would be like, mainly in order to illustrate and fix the concepts of scale transformations and scale motions.

B. Relativistic Scale Kinematic

In this section we interpret conformal transformations as those between different scale systems of reference. A consequence of conformal transformations (we use also the synonym scale transformations) when interpreted actively is the transformation of the rest mass. Conventionally this is regarded as being in contradiction with the experiment, since in that case a continuous rest mass spectrum would be observed (see Niederle and Tolar, 1973). We shall show that there is no contradiction. All rest masses are observed in our own scale system of reference. In such a fixed scale system there is a discrete mass spectrum of particles which form stable structures like nuclei, atoms, and crystals. In some other scale systems the rest masses are changed by an arbitrary continuous scale factor, while all proportions between the masses are still the same. Such other scale systems of reference could be a distant galaxy. The rest masses of our galaxy observed in the foreign galaxy are changed by the scale factor α, and inversely, the rest masses of the foreign galaxy as observed from our galaxy are also changed by the inverse scale factor α^{-1}.

In the theory of relativity the square of the line element ds^2 is unchanged under the transformation from one system of reference (say S) to the other system S′

$$ds'^2 = ds^2 \tag{2.12}$$

If we admit the existence of scale degrees of freedom, the relation (2.12) is true only in a special case when both systems of reference have *the same scale*, or in other words, their relative scale α is equal to unity. Generally, the relative scale between different systems is an arbitrary constant or space time function. Therefore the line elements are generally not the same when measured in different scale systems, but related as

$$ds'^2 = \alpha^2(x)\,ds^2 \tag{2.13}$$

where $\alpha(x)$ is a space-time dependent scale, and $x \equiv (x^0, x^1, x^2, x^3)$. The line element ds is measured by the atomic units of the system S, and the ds' by the equivalent atomic units of the system S'.

Coordinates transform generally as

$$x'^\mu = f^\mu(x) \tag{2.14}$$

If the upper transformations satisfy (2.13) they are called *conformal transformations.* We use also the synonyms *scale transformations* or *dilatation.*

Now let us consider the special scale transformations which leave the Maxwell equations invariant. These transformations can be mathematically identified with the so-called *special conformal transformations.* Our interpretation of them is, however, completely different from other known interpretations. The coordinates x^μ transform under the special conformal transformation as

$$x'^\mu = \sigma^{-1}(x)(x^\mu - c^\mu x^2) \tag{2.14}$$

where

$$\sigma(x) = 1 - 2c^\nu x_\nu + c^2 x^2, \quad \text{and} \quad x^2 = x^\nu x_\nu \tag{2.15}$$

They satisfy

$$ds'^2 = \sigma^{-2} ds^2 \tag{2.16}$$

In the special case $\alpha(x) = \alpha =$ constant the transformation of coordinates is

$$x'^\mu = \alpha x \tag{2.17}$$

This is a dilatation with a constant scale factor (usually called simply dilatation, but we reserve the term because of its illustrative meaning and also for the cases when the scale factor is not constant). It also leaves the Maxwell equations invariant.

The Klein-Gordon equation

$$(\Box^2 - m^2)\varphi = 0, \qquad (c = 1, \hbar = 1) \tag{2.18}$$

is invariant under conformal transformations, provided mass m is transformed as $\Box^2$, i.e.

$m^2 \to \alpha^{-2} m^2$ under dilatation with constant α

$m^2 \to \sigma^2(x) m^2$ under special conformal transformations.

Usually authors claim (Barut, 1973) that this is not a symmetry transformation for the particle of the definite mass m, because after their interpretation of conformal transformations it connects the states of the particle with the mass m with those of an *other particle* with a mass m'. Therefore it is usually concluded that mass is a manifestation of scale symmetry breaking (Wilson, 1969; De Alwis and O'Donnell, 1970; O'Donnell, 1971; Ellis, 1969; Crewthers, 1971; Carruthers, 1971). Some others (Niederle and Tolar, 1973; Jackiw, 1972) took into account the possibility of active scale transformations, and realized that this would imply the continuous rest mass spectrum which, however, is not observed. Therefore, they conclude that active dilatation is not realized in Nature, and scale symmetry is not valid for the massive world. I claim that this conclusion is invalid because it is based on certain tacit assumptions.

Firstly, I should mention a very important paper (Barut and Haugen, 1972) in which the authors introduce the concept of the conformally invariant mass. On its basis they develop a theory which is conformally invariant even for the massive world. The introduction of the conformally invariant mass m_{00} is analogous to the introduction of the Einsteinian rest mass m_0. But a really 'final' step to complete this analogy is not done in Barut's paper. Namely, the Einsteinian inertial systems really move relative to each other, i.e., the velocity transformation is an active one. Barut's and Haugen's interpretation of the conformal transformations is that physical laws should be invariant under a change of units of measurements; only the units are changed but physical objects retain their absolute sizes. In order to complete the above analogy, we postulate that physical objects can change their relative scales (see the previous text). To every physical object is attached its proper scale system of reference, where the units of measurement are defined by the aid of atomic standards *in the same way* in every scale system. When such units of different scale systems are compared between them, they are found to be different. Also the rest mass m_0, when measured in different scale systems, has different values. If we measure the rest mass of a given body in the special scale system in which the scale of the body is $\alpha = 1$ ($\alpha = 1$ means that atomic sizes of the body and the reference systems are the same), we obtain the special value for the rest mass, namely m_{00}. In all other scale systems with $\alpha \neq 1$ the rest mass of the body is $m_0 = \alpha^{-1} m_{00}$. Though the rest masses of particles can have arbitrary continuous values, the relations between the masses of particles forming the stable bound systems cannot be arbitrary. We shall illustrate this by the following analogy: Imagine a fictitious microscopic observer who is fixed in a crystal in such a way that he is unable to move translatory relative to the crystal. Suppose that he is able to observe only the interior of his crystals. He sees that the atoms in the crystal have *fixed positions.* Only these 'discrete' positions are possible. He measures all distances from a chosen coordinate origin and is certain that active translation is not a possible transformation. Eventually a passive translation (change of the coordinate origin) would be applicable.

Such a conclusion would be ridiculous for us because we are aware that different crystals can have arbitrary relative positions, though the positions of atoms within the crystals are discrete.

In the case of dilatation, the situation is analogous. Our surroundings (Earth, solar system, galaxy) is a structure with well defined scale relations (which manifest themselves in definite masses of constituent particles). This scale relation cannot be changed arbitrarily, but this does not mean that there is no scale invariance. The scale invariance holds if we suppose that the surroundings (for instance our galaxy) can be dilated. Then the masses of constituent particles, as the mass of the whole galaxy, are transformed by a scale factor α, but all relations between the masses of constituent particles remain the same.

For instance, in the system S the proper masses of particles $a_1, a_2, a_3, \ldots$ are $m_1, m_2, m_3, \ldots$. Then in the system S' which is related to the system S by the scale transformation $ds' = \alpha\, ds$ the proper masses of the same particles $a_1, a_2, a_3, \ldots$ are $m_1' = \alpha^{-1} m_1, m_2' = \alpha^{-1} m_2, m_3' = \alpha^{-1} m_3$, etc. If we may interpret the scale transformations actively also, then there must exist in the system S a body which consists of particles with the proper masses m_1, m_2, m_3, etc., and which can be dilated by the scale factor α so that the rest masses of its constituent particles as its total mass m become $\alpha^{-1} m_1, \alpha^{-1} m_2, \alpha^{-1} m_3$, etc., and $\alpha^{-1} m$, respectively.

3. *Consequences of Relativistic Scale Kinematic*

Now we shall show which are the experimentally verifiable consequences of scale kinematic.

(a) In a system which moves in scale, the metric is no more a flat one but a conformally flat one. In such a conformally flat metric there exist systematic red-shifts, proportional to the distance between sources and the coordinate origin, provided the metric has a special form (see Synge, 1960). Such red-shifts of the light emitted from distant galaxies are really observed.

Let S' be the system connected with the flat cosmological background with the metric $\eta_{\mu\nu} = \mathrm{diag}(1, -1, -1, -1)$. In this cosmological background there is our galaxy which moves in a scale (more specifically, it is contracting) relative to S'. The system connected with our galaxy is denoted by S. The relative scale between S and S' differs from unity and is changing with time. The atomic units of the system S' are different from the atomic units of the system S.

The line element $ds^2 = \eta_{\mu\nu}\, dx^\mu\, dx^\nu$ transforms as

$$ds'^2 = \alpha^2(x)\eta_{\mu\nu}\, dx^\mu\, dx^\nu \tag{3.1}$$

We can choose a passive or active interpretation of (3.1).

After the passive interpretation the line element between given events E_1 and E_2 is $ds^2 = \eta_{\mu\nu}dx^\mu dx^\nu$ as observed from the system S, and $ds'^2 = \alpha^2(x)\,ds^2 = \alpha^2(x)\eta_{\mu\nu}\,dx^\mu\,dx^\nu$ as observed in the system S'.

Actively, the relation (3.1) can be interpreted as a four-distance between two extragalactic events (for instance, successive emissions of light by extragalactic atoms) as measured by intragalactic atomic units. The relation (3.1) measures the expansion of an extragalactic world relative to our galaxy. The atomic units of extragalactic world (system S') are different at different space-time points when compared with the atomic units of our galaxy (system S).

For example, the four-distance between two characteristic events (such as successive 'ticks' of the atomic clock) is denoted by $d\tau$, as measured in the system in which the atomic clock has the scale $\alpha = 1$, and $d\tau(\Sigma)$ as measured in an arbitrary scale system Σ. The characteristic four-distance of extragalactic world $d\tau_E$ is a space-time constant $d\tau_E(S') =$ constant in the system S', and a space-time function $d\tau_E(S) = (\alpha^2(x)\eta_{\mu\nu}\,dx^\mu\,dx^\nu)^{1/2}$ in the system S. Similarly, the characteristic atomic four-distance $d\tau_I$ in our galaxy is the space-time constant $d\tau_I(S) =$ constant in the system S, and a space-time function $d\tau_I(S') = (\alpha'^2(x')\eta_{\mu\nu}\,dx'^\mu\,dx'^\nu)^{1/2}$ in the system S'.

In this sense we understand the concept of conformally flat space. The space we experience in our galaxy is conformally flat. The space as experienced by an observer in the cosmological average system S' is the flat one.

Now we wish to calculate the red-shifts of light emitted from distant galaxies. We must use the equation (3.1) which compares the four-distance between two extragalactic events (in our case two successive vibrations of light emitted by the atom in the distant galaxy) with atomic units of our galaxy. In other worlds, equation (3.1) describes the expansion of the extragalactic world. If we assume that $\alpha(x) = \omega(t)$ then the metric form is

$$d\delta^2 = \omega^2(t)\eta_{\mu\nu}\,dx^\mu\,dx^\nu, \qquad t \equiv x^0 \tag{3.2}$$

and the problem is now identical with the problem of the expanding universe (see for instance Synge, 1960). In such conformally flat metric there exists a systematical distance dependent red-shift

$$\frac{\nu' - \nu}{\nu} = 1 - \frac{\omega(t_1)}{\omega(t_2)} \tag{3.3}$$

where t_1 is the moment of emission of light from a distant galaxy, and t_2 the moment of detection in our galaxy.

We must mention that Dirac in his paper (Dirac, 1973) distinguishes between ds_A (atomic line element) and ds_E (Einstein line element, which enters Einstein equations). This distinction is necessary to reestablish consistency between Weyl's theory with variable scale and atomic theory with fixed scale. Here we can associate ds_A with $d\tau_I(S)$ and ds_E with $d\tau_E(S)$. Thus we have found a strong intuitive basis for ds_A and ds_E in the assumed existence of a scale degree of freedom.

A consequence of the Weyl geometry that the proper time depends on the history of the particle is quite realistic. Such a difference in proper times cannot be found in ordinary conditions on Earth, because ordinarily the scale is constant. Under conditions, not yet realized experimentally, and in foreign galaxies (strong experimental evidence) a scale can be different from our own scale. By assuming the existence of scale motion, when a body changes its dimensions (see Introduction and Section 2), we obtain the history dependent proper time. Indeed, the proper time

$$\tau = \int_{E_1}^{E_2} \alpha(x)\, ds \qquad (3.4)$$

is different for different $\alpha(x)$, i.e., different scale motions (= histories), even in the case when the initial and the final space-time points, E_1 and E_2, remain unaltered.

(b) Besides the systematic distance dependent red-shift due to the scale motion of our galaxy relative to the average cosmological background, the anomalous red-shifts due to the proper scales of the observed galaxies are also predicted. There is indeed a very strong experimental evidence that such anomalous red shifts exist (News, 1972; Simkin, 1972; Wampler *et al.*, 1973; Hazard *et al.*, 1973).

The mass of the electron e' fixed in the foreign galaxy (the system S') is m'_0. The frequency of light emitted by the atom in S' is ν'_0

$$\nu'_0 = R'Z^2\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) \qquad (3.5)$$

where $R' = {e_0}^4 m'_0/(2\hbar^3)$. In our galaxy (the system S) the mass of the foreign electron e' is $m_0 = \alpha m'_0$, and therefore the frequency

$$\nu_0 = \alpha\nu'_0 \qquad (3.6)$$

provided the relative velocity and the scale velocity between our galaxy and the foreign galaxy (systems S and S') are zero. Otherwise additional terms such as Doppler-shift and systematical distance-dependent ('cosmological') red-shift must be added to (3.6). Note also that the transformation of coordinates is $x' = \alpha x$, where α is constant.

The explanation that the anomalous red-shifts are due to different electron masses in different galaxies was done in the 'News' of Physics Today (News, 1972), where these differences, however, were not assigned to different scales of different galaxies as in the present paper.

(c) Disaccordance between (i) extremely great red-shifts of quasars (Morrison, 1973; Tritton, 1974) which could be conventionally assigned to their great distances, and (ii) relatively intense luminosities of quasars (which indicates that the distances are not so great) can be resolved by assuming the existence of a scale degree of freedom. Namely, we have only to assume that quasars are objects with extremely great scales which results in extraordinarily great red-shifts, even if such objects are near our galaxy.

(d) Modern geophysical theories explain the drift of continents by the expansion of Earth. After the conventional view this expansion is due to gravitational coupling of Earth with the expanding universe. The alternate point of view (though in a sense equivalent to the previous one) is that the universe is stationary on the average, while our galaxy is contracting. We can imagine that in such a contracting reference frame there exists systematical dilatational forces which tend to expand Earth relative to our galaxy.

4. *Conclusion*

By assuming that the scale is a degree of freedom which a physical object possesses besides translational and rotational degrees of freedom we are able to find a natural and intuitively clear physical interpretation of conformal transformations. At the same time we could incorporate such diverse phenomena as the systematic cosmological red-shifts, the anomalous red-shifts, controversals of quasars, and the expansion of the Earth into a single physical theory.

In the future it will be necessary to formulate laws of scale motion. One way could be the use of symbolism and laws developed by Barut (1972), but with the modified interpretation of conformal transformations, as pointed out in this paper.

The proposed scheme which deals with the scale degree of freedom, and which permits the active interpretation of conformal transformations, is so promising in attempts to incorporate the new astrophysical and geological data into a single theoretical framework, that it deserves further detailed studies. Another argument is that it seems more natural to postulate that our galaxy is contracting rather than the whole universe is expanding. The analogy with the Copernican revolution is obvious.

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