A QUANTUM APPROACH TO RELATIVISTIC COSMOLOGY

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Cosmology is the branch of astrophysics concerned with the large-scale structure of the cosmos and (in the current interpretation) the origin of the universe. Yet the scientific method employed in other branches of physics consists in equating the origins of the constituents of the physical world - the particles and fields that appear in it - to the ends of other elements: science seeks to explain the world from a principle of conservation.

It thus appears incongruous that an explanation of the large-scale structure of the universe should require the addition of another "origin", that of the universe as a whole. If the universe had a beginning, then matter and motion, space and time, had to be created. This point of view is obviously incompatible with a principle of conservation. A model that is consistent with the conservation principle, and therefore requires no cosmic beginning, can be investigated by examining the current conception of the large-scale structure of space and time in the light of physical theory. Analysis reveals that the conservation-violating universe model contradicts other theoretical principles which have received confirmation from empirical measurement. An alternative model is proposed to circumvent these difficulties, and an extension of general relativity theory is posited.

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Cosmology in the twentieth century has been dominated by two major advances: one observational, the other theoretical. The former - the discovery that the spectral lines of light emitted by external galaxies were shifted toward the red in proportion to distance - constitutes the primary empirical foundation for a cosmological model. How this correspondence between redshift and distance is interpreted in the light of theory determines the model.

Astronomers presently acknowledge that a universe model must be predicated upon the analytical framework established by the second scientific advance - the general theory of relativity. But unlike the present model for cosmology, relativity unambiguously retains a conservation theorem for momentum and energy. If the accepted universe model is found to exhibit further inconsistencies with relativity, then it is necessary to abandon this model in favour of one that concurs rigorously with theoretical principles.

Standard cosmology

The existence of galaxies lying outside the "Milky Way" was not confirmed until early in the twentieth century, with the advent of telescopes possessing adequate resolving power. First Slipher, and later, Hubble, noted that spectra obtained from light emitted by external galaxies exhibited a shift toward the longer wavelength end of the electromagnetic spectrum. By the late twenties Hubble and Humason had accumulated enough observational data to establish a correspondence between the distance of a "nebula" from our galaxy, determined by conventional means, and the degree of redshift of its light spectrum.

The fractional spectral shift, **z**, of light received from a galaxy is defined by

$$\mathbf{z} = D l / l_e = (l_o - l_e)/l_e$$

where l_o is the wavelength of radiation as measured by the observer and l_e is the wavelength at the point of emission, determined from a laboratory spectrum, assuming local laws of physics hold in the reference frame of the emitter.

Since the value of **z**, interpreted as a Doppler effect arising from radial motion between galaxies, was observed to be consistently greater than zero for galaxies beyond our local group, Hubble concluded that, for small values of **z**,

$$\mathbf{V_r = cz}$$

i.e., radial velocity $\mathbf{V_r}$ is equal to the product of spectral shift **z** and the speed of light **c**. He therefore proposed that a velocity of recession of a galaxy located at distance **r** from the observer could be calculated using

$$\mathbf{V_r = Hr}$$

Where the "Hubble constant" **H** is an empirically derived constant. This formula, which is interpreted as evidence of the expansion of the universe, is referred to as Hubble's law.

The Doppler interpretation of the observed redshift/distance relation has constituted the fundamental proposition of all orthodox cosmology since the twenties, though Hubble long regarded it as only tentative. Combined with non-static solutions to the field equations of general relativity obtained in the early twenties by Friedmann and LeMaitre, the expansion hypothesis has given rise to the Big Bang cosmological model. According to this model, the universe was created out of a "cosmic egg", a point-like spacetime singularity of infinite density, in a primordial explosion that marked the beginning of time and the origin of space. Most debate within contemporary astrophysics is concerned with the age of the universe since its alleged birth at a time $t = \mathbf{0}$, and with the possibility that the cosmic expansion will either continue indefinitely or reverse itself in a gravitational contraction culminating in a "big crunch".

Heterodox models

The only other cosmological model to receive serious consideration in the past several decades is the steady-state theory devised by Bondi, Gold and Hoyle in the fifties. This model is predicated upon a modification of the cosmological principle underlying the Friedmann models. Thus, in addition to being spatially isotropic and homogeneous (Hubble confirmed this characteristic with his observations), the universe is also homogeneous in time. To accommodate the hypothesis of galactic recession, this "perfect cosmological principle" requires that matter be continuously created in the interstices of galaxies; this new matter would fill the void left by the general expansion. This theory is not regarded as tenable today because of its inability to account for certain phenomena, most notably the **3 K**. microwave background radiation.

An alternative to the Big Bang theory was proposed in the last decade by Hoyle. Hoyle's "whimper cosmology" emerges from a curious equivalence. In the expansionary universe scenario, particle masses are regarded as constant, on the assumption that physical laws are invariant. However, Hoyle concluded that it was possible to dispense with expansion by assuming that particles (i.e atoms) in distant galaxies are lighter, and therefore larger than those in the local environment. The "old" electromagnetic radiation emitted by atoms from our past would therefore exhibit longer wavelengths than that radiated by contemporary atoms. By requiring particle masses to be inversely proportional to distance, the Hoyle theory can yield comparable redshift predictions to the Big Bang model.

The Hoyle cosmology incorporates a principle of delayed action at a distance, whereby inertial mass is understood as an effect of interactions with other particles in the universe. A variation of atomic masses with time is hypothesized to explain a time-correlated shrinkage of atomic radii and, by extension, the redshift-distance relation. Hence the larger atoms in distant galaxies are less massive because local atoms have "received" more mass through interactions with earlier matter in the universe. What appeared in the expanding universe model as a time-origin is now transformed into a zero-mass surface separating positive and negative mass aggregates ($t = \mathbf{0}$ is replaced by $\mathbf{m = 0}$), while the universe ceases to be limited to a finite spatial and temporal frame. Though it obviates the arbitrary interpolation of a spacetime singularity at an absolute temporal origin, the whimper cosmology abandons both the cosmological and perfect cosmological principles.

Paradigm and paradox

Little consideration has been given to Hoyle's whimper cosmology in the past decade, while the Big Bang paradigm is now regarded as virtually unassailable. Yet the former was devised in a conscious effort to avoid a temporal origin and violation of the conservation principle. Furthermore, it provides a quantum framework for understanding mass as a derivative of the structure of the universe. This was one of Einstein's objectives in developing the general theory. But because the final formulation of relativity divides reality into separate electromagnetic and gravitational components, it assumes mass to be autonomous and fixed for each particle.

Cosmology therefore faces the following paradox: the redshift phenomenon would seem to be explained with equal cogency by the Doppler-shift/expansion paradigm and the larger-atom/lower-mass hypothesis. The former interpretation, however, is plagued by a mathematical singularity at an absolute time $t = \mathbf{0}$, while the latter posits a time-dependent zero-mass surface in a universe divided into discrete positive and negative mass aggregates. Both models lead to perplexing apriorisms.

A novel and physically promising component in the Hoyle cosmology is the direct particle mass interaction, which necessitates a quantum reformulation of gravitation.[1] Yet, as we have seen this model circumvents the cosmological principle altogether by hypothesizing special zero-mass conditions ($\mathbf{m = 0}$) that are incompatible with spatial isotropy.

To overcome this theoretical antinomy we must seek an alternate cause for the redshift phenomenon which is non-velocity and does not lead to global metric singularities. In order to avoid a time asymmetry, this explanation must retain the Hoyle/Narlikar mass interaction, but freed of the Newtonian condition that mass density must fall to zero. What is required is a cosmology that adheres to relativistic principles and embodies a finite distance parameter derived from the quantum domain.

Redshift and cosmology

Einstein finalized the general theory of relativity and formulated the field equations defining the curvature of spacetime due to energy density in 1916. In the following year he proposed a cosmological solution for a quasi-static universe. Assuming spatial isotropy and galactic motions negligible in comparison to the speed of light, he modified the gravitational field equations by adding a constant of integration - the Λ -term or cosmological constant - to represent a negative pressure. The effect of the cosmological constant was to establish the mean density of matter that could remain in equilibrium, as well as the radius of the spherical, quasi-static space. But by the mid-twenties, after Friedmann had derived non-static solutions to the field equations, Einstein abandoned the search for a static model and acceded to the velocity interpretation of redshifts.

Meanwhile, reluctant to reject non-velocity explanations prematurely, Hubble continued to examine the implications of a static universe in relation to observational cosmology. In 1935, he and Tolman contrasted the Doppler mechanism with the hypothesis that galactic redshifts could be explained without recession. Specifically, they proposed that the observational results might be accounted for on

> *…the assumption that photons emitted by a nebula lose energy on their journey to the observer by some unknown effect, which is linear with distance and which leads to a decrease in frequency without appreciable transverse deflection and, in particular, without any decrease in rate of arrival at the observer.*[2]

Adopting an Einstein universe model with no systematic galactic motion as a limiting case of a quasi-static world, they used an infinitesimal line element to compute redshift as a function of the distance **r** to each galaxy and the "radius" **R** of the Universe:

$$\Delta\lambda/\lambda_e = k \int \mathbf{dr/(1 - r^2/R^2)^{1/2}}$$

In the following year, Hubble reviewed the non-velocity formulation of the redshift law, this time invoking a gravitational loss of energy proportional to distance as a possible explanation of the law in a static universe. But he concluded that the mechanism of the energy loss had yet to be found:

There must be a gravitational field through which the light-quanta travel for many millions of years before they reach the observer, and there may be some interaction between the quanta and the surrounding medium... Light ***may*** *lose energy during its journey through space, but if so, we do not yet know how the loss can be explained.*[3]

A similar hypothesis, based on quantum considerations, was advanced in 1954 by Finlay-Freundlich, who suggested the possibility 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 in coming from the most distant star systems.[4]

This notion, motivated by observations of anomalous reddening in radiation from large, hot stars, was supported by the supposition that light suffers loss of energy in a radiation field, perhaps due to photon-photon interactions which could occur in intergalactic space. Pecker, Roberts and Vigier have since returned to this problem.[5] They determined that an interpretation of the redshift based on photon-photon interactions could be reconciled with the problematic 3 ^{o} K. background radiation, when temperature **t** is calculated by

$$\mathbf{t^3 = H/cA},$$

with **A** obtained from

$$\mathbf{z} = \mathrm{Dn/n} = \mathbf{-At^4L}$$

where **L** is length of path through a radiation field.

A more recent attempt at a non-velocity explanation of the redshift phenomenon, the tired light theory - originated by Nottale, Pecker, Roberts, Vigier and Yourgau[6] - invokes an interaction between photons and a hypothetical scalar deBroglie f-particle with a mass of less than $\mathbf{10^{-48}}$ grams and no electric charge. In encounters with this particle a photon would lose the requisite amount of energy to yield the observed redshift. Abnormal redshifts associated with objects such as quasars, and irregularities produced by the passage of light from distant sources through or close to galactic clusters and large galaxies, are explained by a larger number of such collisions, and consequently a greater density of f -particles. Though the particles have not been identified, their density, r_f, is presumed to be proportional to the density of matter. Redshift produced over a small distance d**L** is thus expressed by

$$\mathbf{z} = \mathrm{dl/l} = a\ r_f \mathrm{d}\mathbf{L}$$

where a is a constant.

Relativity and the quantum

Hubble's investigation of redshifts generated by a static universe model, conducted at a time when relativistic quantum theory was still in its infancy, remained incomplete essentially because it could offer no explanation for photon energy loss. A quantum mechanism is suggested by the more recent hypotheses that redshift-related energy attrition may be produced by either photon-photon (g- g) or photon-scalar particle (g-f) interactions. We therefore consider the possibility that the field approach of general relativity may be combined with quantum particle interaction in a way that will provide a plausible elucidation of the cosmological problem.

Hoyle and Narlikar have proposed a quasiclassical quantum approximation to account for the mass interaction, and Born has indicated that generalized relativistic gravitation equations should set a finite length **q** satisfying the formula for Planck's constant **h/2**p **= qp** (where **p** = momentum) [7]. We would thus expect to achieve an understanding of the cosmological redshift by replacing the infinitesimal line element of the non-static models with a finite length scale. With a distance parameter defined in this way, **z** could be reformulated in terms of a Newtonian approximation to relativistic quantum dynamics.

The Schwarzschild solution to the field equations does provide the appropriate finite length,

$$\mathbf{r_s = 2GM/c^2}$$

which is the Schwarzschild radius for a black hole, i.e. extreme spacetime curvature.

One prediction of the general theory of relativity is that a photon climbing through a gravitational field will experience a loss of energy that manifests itself as a spectral reddening. This effect has been verified in terrestrial laboratory experiments [8], as has the gravitational bending of starlight by a massive object (observations of this phenomenon provided the first confirmation of Einstein's gravitation theory in 1919). Where n_e is the emission frequency of a photon leaving an object of radius **r** and mass **M**, and the frequency observed at a great distance is n_o, energy loss is given by:

$$\begin{aligned} \mathbf{dE} &= \mathbf{h}(n_e - n_o) \\ &= \mathbf{GM/r \text{ x } (\text{"mass of photon"})} \\ &= \mathbf{GMh}n_e\mathbf{/rc^2} \end{aligned}$$

If l = **c**/n, the gravitational or Einstein redshift is just:

$$\mathbf{z} = (n_e - n_o)/n_o = \mathbf{GM/rc^2}.$$

Cosmological Einstein redshift

A gravitational explanation for cosmological redshifts has been invoked only with reference to massive objects. These may be either the emission sources themselves, or interposed galaxies and clusters. Given the analogous effect - a redshift resulting from loss of energy - it is logical to posit an identity between the f-particle of the tired light theory (also the mechanism underlying the hypothetical photon-photon interactions) and the **quantum of gravity required by Einstein or gravitational redshift**. The formula for local gravitational energy loss could then be referred to a broader field of application, namely the observable universe, while cosmological redshift would be furnished with a quantum foundation.

Moreover, there is no reason to restrict the source of the Einstein or gravitational redshift to a **local** object (planetary or other body). Although spacetime on the cosmic scale is punctuated by gravitational "warping" associated with galaxies and clusters, in cosmology it is customary to ignore any local inhomogeneities and assume a uniform model universe composed of a kind of cosmic fluid or dust. Point sources within this fluid emit radiation which traverses a "gravitational field" that may also be regarded as uniform.

We must therefore generalize the gravitational energy loss formula from the local case of Einstein redshift

$$\mathbf{dE = GMh}n_e\mathbf{/rc^2}$$

to account for phenomena on a cosmic scale. In this new interpretation, observed frequency $n_{\mathbf{o}}$ is related to the energy density and radius of a determinate spherical section of the universe to yield the energy reduction at the observer due to gravitation. Assuming that the energy loss is carried off by some f-particle, and that this particle is associated with a gravitational field, we may posit a generalized field that incorporates electromagnetism. In the extreme case of maximum energy loss, the finite separation formula assumes the simplified form of the Schwarzschild cosmological radius, $\mathbf{R_s}$, expressed as:

$$\mathbf{R_s = 2GM_u/c^2}$$

In one of Einstein's first efforts to integrate special relativity with gravitation - prior to the complete formulation of general relativity - he deduced a gravitational time dilation associated with any form of field, even a homogeneous one. The unification of mass and spacetime achieved by general relativity encompasses matter as a special case, i.e. potentially as a singularity of the field. Gravitation is understood as an expression of the metric field, while every form of energy produces a gravitational effect. The local source of the field is not crucial to the theoretical result for the general case. As Einstein recalled in addressing the problem of space:

> *This train of ideas is based essentially on the field as an independent concept. For the conditions prevailing with respect to (any uniformly accelerated reference system) are interpreted as a gravitational field, without the question of the existence of masses which produce this field being raised.*[1]

A **local Einstein redshift** can in fact be obtained from a generalization of the gravitational energy loss formula given in the previous section. If we set **c = 1**, that formula takes the form

$$\mathbf{dE = GMh}n_e\mathbf{/r}$$

which suggests an infinitesimal derivation of gravitational time dilation from the special theory of relativity. A clock moving at a uniform velocity **v** relative to an observer will be seen to run at a frequency n_o, given by

$$n_o = g n_e$$

where g is the Lorentz factor

$$g = (1 - v^2)^{1/2}$$

Observed frequency is lower than n_e, the frequency of the clock when at rest[10].

To replicate the infinitesimal conditions of the energy loss formula, we take the derivatives of both sides

$$dn_o \sim g\,dn_e$$

and since we restrict ourselves to low velocities, we substitute an approximation to the full Lorentz factor, which gives

$$dn_o \sim \exp(-v^2).dn_e$$

If the clock is non-inertial (rotating around the observer on a disk, for example), rather than in uniform motion, then it is subject to a constant acceleration **a**, and its velocity is determined by

$$v^2 = ar$$

where **r** is the distance of the clock from the observer at the centre.

Integrating both sides to restore relativistic conditions and substituting for $\mathbf{v^2}$, we have the following approximation to the Einsteinian formula:

$$n_o \sim \exp(-ar)\, n_e$$

To convert to gravitational conditions, we invoke Kepler's Third Law, which relates period of rotation **P** to the radius of an orbit by

$$r^3 = AP^2$$

Substituting for **P** we have

$$r^3 = A\,(2pr/v)^2$$

and finally, we obtain:

$$v^2 r = A(2p)^2$$

But by Newton's gravitational laws we know that

$$A(2p)^2 = GM$$

and hence, with **M** the mass of the local object,

$$v^2 = GM/r = ar$$

The local redshift formula therefore becomes:

$$z \sim 1 - n_o/n_e \sim 1 - \exp(-GM/r)$$

Furth has arrived at a **generalized** result[11] by hypothesizing that a photon guided along a curved trajectory in a gravitational field (i.e. in accelerated motion) would lose energy in the form of gravitational waves, or gravitons. He proposed that the energy of photons travelling from remote galaxies would be dependent upon distance, since the trajectories of these photons would in fact be curved paths. Assuming energy proportional to frequency, and taking $\mathbf{M_u}$ as the Schwarzschild universe mass, Furth's formula can be written:

$$z = 1 - \exp(-kr/GM_u)$$

where k is a constant or order of magnitude unity.

To investigate the uniform gravitational field present in the observable universe, we adopt the simplest condition for matter: that of a homogeneous incompressible fluid or energy-continuum. This quasi-static space will possess a Schwarzschild radius representing the limit of electromagnetic transmission by the cosmic fluid, which can be considered to be in equilibrium. Within this "radius of the universe", the effect of the cosmic gravitational field will be to reduce the energy (and therefore frequency) of each photon in proportion to distance, i.e. in the case of small distances, by

$$z = Hr.$$

Light emitted from the Schwarzschild universe radius, or electromagnetic boundary, is redshifted to a maximum value.

Particle mass and the principle of equivalence

The immediate implication of this result is that the photon has a nonzero rest mass, since this component appears in the quantized energy loss formula. If $\mathbf{m_g}$ is photon mass, then the theoretical frequency at which the wavelength reaches a maximum, the photon's DeBroglie wavelength, occurs at

$$n_{min} = m_g c^2/h,$$

by Proca's equations[12]. At this value, electromagnetic flux falls to a minimum.

Experimental measurements have yielded an upper limit on the photon's "rest mass" at $\mathbf{10^{-49}}$ gram. We can calculate a cosmological radius to a good approximation by setting **wavelength equal to the Schwarzschild world radius**. Accordingly we write:

$$R_s = l_{max}$$

Hence:

$$R_s = h/m_g c.$$

For the experimentally measured upper limit on the photon rest mass, the electromagnetic radius of the universe would be on the order of $\mathbf{10^{20}}$ cm. Conversely, assuming the electromagnetically observable universe to have a radius of $\mathbf{10^{26}}$ cm, we arrive at a theoretical photon mass of $\mathbf{10^{-71}}$ gm.

The version of the equivalence principle applied throughout this analysis is the strong one. Since we encountered a photon mass in our approximation to quantum relativistic gravitation, it was necessary to transcend the restricted formulation of the weak principle, according to which the mass of the point particle plays no role in physical effects produced by a gravitational field. With the strong equivalence principle, we are permitted to introduce quantum mass values and equate accelerated systems with gravitational fields. The validity of the equivalence principle for the quantum realm has been confirmed by experiments involving neutron interferometers.[13]

When we introduce a photon mass into Maxwell's equations, and subsequently into the redshift formula, we therefore adhere strictly to a quantum relativistic approximation. The approximation obtained is more comprehensive than the short gravitational field equation, since it incorporates a length constant of integration representing electromagnetic repulsion. Einstein's objection to the loss of economy implied by the introduction of the cosmological constant is overridden by the fact that the mathematically more complete formula encompasses the very electromagnetic phenomena which serve as tests for the theory of relativity, but which the original field equations did not embrace.

The time symmetry established by the application of the strong form of the equivalence principle to the cosmological problem constitutes a higher-order distinction between accelerated motion (as in the Friedmann expanding model) and gravitational field (Schwarzschild metric). But in terms of observable effects, the two models will yield nearly identical predictions.

Luminosity and the velocity of light

Hubble felt that an expanding model corresponded better to observed effects because of an important oversight[14]: the apparent magnitude-redshift relation used in his heuristic non-velocity model retains Euclidean geometry, i.e., flat spacetime. The postulate of a cosmological gravitational redshift necessitates an alteration of the redshift-luminosity equation adopted by Hubble and Tolman for a static universe. Relativity requires a departure from linearity to reflect spatial curvature.

Observational astronomy yields an empirical redshift-luminosity relation

$$\mathbf{m = 5 \log (1+z) + a\ constant},$$

where **m** is apparent magnitude and **(1+z)** is flux. This relation is the one predicted by the velocity-shift interpretation. The corresponding relation in flat spacetime is less than that obtained from observation by a factor of **(1+z)**:

$$\mathbf{m = 2.5 \log (1+z) + a\ constant}.$$

In the velocity-shift formula, which accords with the empirical **z - m** relation, "curvature" is only an illusion introduced by Hubble acceleration. Spacetime actually remains flat, while the acceleration of reference frames creates the redshift and flux dilution effects that add up to $\mathbf{(1+z)^2}$. Naturally, we also find a departure from the linear picture of flat spacetime with the Schwarzschild metric, since the gravitational field reduces energy (redshift) and diminishes photon arrival rate. The apparent magnitude formula for the gravitational redshift interpretation therefore replicates the empirical relation, and it has the advantage of not introducing an arbitrary mechanical motion. Luminosity declines exponentially with distance and appears to "switch off" at $\mathbf{R_s}$, exactly as in the case of the nonzero mass photon at the electromagnetic propagation limit.

Einstein had already accounted for the non-linear redshift effect in his 1911 article - alluded to above - in which he deduced a gravitational redshift. In this article, the dependency of the speed of light c' on gravitational potential, given by

$$\mathbf{c = c'(1 + GM/c^2r)}$$

is equivalent to a relativistic dilution of flux. It is interesting to note that this effect - variable speed of light - is commonly thought to have been overlooked by relativity. After Einstein's original treatment, it was not investigated again until 1964, and when a slowing down of light was observed by means of radar echo experiments[15] conducted within the solar system in 1968, it was regarded as a new confirmation of relativity.

In 1945, Einstein reaffirmed his rejection of the static universe model, arguing that the speed of light reflected between two distant points should not be affected by distance travelled. But light propagating through space also travels through a gravitational field, and hence must undergo a change of velocity that can be detected. We have just seen that differences in travel time have in fact been noted for radar signals reflected within the solar system: the influence of the sun's gravitational field was found to increase travel time for a light signal. With the confirmation of this effect, no further objection to the quasistatic universe model can be sustained. The principle of equivalence decides unambiguously in favour of an Einstein cosmological redshift.

Gravitation and electromagnetism

To demonstrate gravitational redshift, we equate the "inertial mass" of the photon to its gravitational mass. This step enables us to express the redshift phenomenon as a quantum effect, and is consistent with the strong principle of equivalence. Rather than resort to a mechanical Doppler explanation of the galactic redshifts, we first extend the local gravitational field of our freely falling inertial frame to the distant galaxies. Then, using the conclusions of general relativity, we interpret the observed spectral shifts as a gravitational time-dilation. The distant galaxies are thus no longer receding as a result of the expansion of a finite universe; they are instead the foci of events in a cosmic fluid, which may be regarded as a spacetime-energy continuum, infinite but bounded. The portion of the universe visible from any galaxy appears as if it were the interior of a black hole with an electromagnetic horizon. Space is only apparently finite.

Unlike the classical general theory, this dual-field description does not assume mass to be intrinsic to each particle; instead, it regards the gravitational attraction of any two particles as an effect of the aggregate mass of the observable "universe".

The defect of the cosmology developed by Hoyle on the hypothesis of a variation of particle masses with time lies in its treatment of cosmic spacetime as equivalent to the local Euclidean environment[16]. Its mass variation and zero-mass state of matter mean essentially that distant clocks - the radiating atoms in external galaxies - are **actually** running slower, whereas Einstein demonstrated that this apparent slowing-down of time was due not to the intrinsic construction of the clocks, but to the curvature of spacetime induced by the density of energy, and consequently the strength of the gravitational field. Radiation emitted by distant atoms has merely lost energy to, and therefore been reddened by the cosmic gravitational field.

In this view, the cosmological redshift acquires a new significance. It can no longer be ascribed to an expansion of the universe, since the theoretical foundations and mathematical treatment of the expanding Friedmann models are unnecessarily truncated. The inclusion of cosmological constant, the L-term in Einstein's field equations yields a mathematically and physically more complete treatment of spacetime, while the resulting quasistatic model obviates the time asymmetry of the expanding Friedmann solutions to the field equations.

Combining a generalized mass-response (attraction) with the complementary electromagnetic-response (repulsion), we achieve a cosmology that resolves the artificial time-origin of the Big Bang model and the zero-mass surface of the whimper cosmology into a Schwarzschild universe horizon.

The Friedmann solutions on which the Big Bang models are based admit no electromagnetic response condition[17], and consequently place an absolute edge on the universe at an arbitrary time $t = \mathbf{0}$. It is because of their treatment of time as an independent variable that expanding models lead to a metric singularity and infinite density at an absolute temporal origin. This peculiarity is analogous to the **a priori** interpolation of mass in general relativity. An extension of relativity to remove this autonomy makes both mass and proper time dependent upon the large-scale structure of space. Einstein was aware of this limitation in his theory:

> *The present theory of relativity is based on a division of physical reality into a metric field (gravitation) on the one hand, and into an electromagnetic field and matter on the other hand. In reality space will probably be of a uniform character and the present theory be valid only as a limiting case.*[18]

Since it eliminates the asymmetries inherent in the Friedmann solutions, the introduction of the cosmological constant into the field equations thus constitutes a framework for approaching a more general theory, of which the standard field equations are a locally valid or limiting case, and achieves a more consistent explanation of the observed effects, i.e., one not requiring violation of conservation laws or recourse to mechanical motion.

Redshift and the arrow of time

Hoyle and Narlikar developed their mass interaction theory out of a hypothesis of electromagnetic action at a distance in a static universe put forward by Feynman and Wheeler in the forties[19]. Reasoning from the time-symmetry of Maxwell's equations for electromagnetism and classical gravitation theory, Feynman and Wheeler deduced that it would be possible to couple electromagnetism to matter by assuming a response from all electric charges in the universe to local field disturbances. Their calculation led them to the conclusion that, for classical physics, the response of the universe would cancel local advanced radiation - waves that go backward in time - leaving a local asymmetry in favour of retarded response - i.e. waves that radiate into the future. This is the foundation of the local "arrow of time". Hoyle and Narlikar subsequently confirmed these results for quantum theory, using the quasiclassical approximation alluded to above. In their approach, retarded wave response was shown to correspond to a non-zero probability of electron transitions to lower energy states accompanied by radiative energy loss. They therefore provide a global context for understanding the time-asymmetry encountered in local phenomena of electromagnetism, normally regarded as a manifestation of "vacuum" fluctuations. According to Hoyle and Narlikar,

> *...quantum phenomena which are usually taken to arise from zero-point fluctuations of the quantized electromagnetic field can also be explained in a fully time-symmetric theory in terms of the response of the universe... ... time-symmetric solutions to the electromagnetic equations can yield all the observed effects, provided local problems are properly related to the universe and provided the universe has an appropriate large-scale structure.*[20]

The correct universe structure for global electromagnetic symmetry is one that absorbs retarded waves fully and advanced waves partially, so that advanced waves will cancel. Expanding Friedmann universes do not have the requisite perfect future absorber and imperfect past absorber, and consequently must introduce a universal time asymmetry - the cosmic clock.

Hoyle and Narlikar have argued that only a steady state expanding model possesses the correct combination of absorbers, since the density of matter remains constant with expansion when the perfect cosmological principle is invoked, whereas the Big Bang universe with decreasing density either cannot absorb retarded radiation fully, or swallows up all advanced waves in its infinitely dense singular origin.

However, a relativistic quasistatic universe such as the one proposed here also incorporates a perfect cosmological principle. It thus possesses constant matter density and absorbs advanced responses fully: its perfect future absorber is a corollary of gravitational energy loss - the cosmological redshift - which results in maximum energy depletion at the Schwarzschild universe boundary.

Quasistatic field equations

A model that derives local asymmetries of electromagnetism and time from symmetrical laws describing the large scale structure of the universe points to the need for a new mathematical formalism, and introduces a radically different orientation in physical research. The symmetry underlying this new paradigm may be stated as follows: the strength of local gravitational attraction between particles (or the value of Newton's constant **G**) depends on the rest of the mass in the electromagnetically observable universe, just as electromagnetic repulsion is determined by the aggregate of electrical charges in the gravitationally bounded universe.

Under this paradigm, the first requirement of physical research is a unified equation in which electromagnetism and gravitation appear naturally. Classical general relativity and Maxwellian electromagnetism would be deduced from this extended theory as special cases. This investigation of a static particle-coupled model represents no more than a crude approximation, corresponding to a pseudo-quantization of the cosmological constant in the relativistic field equations. In other words, we replace of the original field equation of gravitation expressing the relationship between energy density and the curvature of spacetime with the static equation containing the cosmological constant (or electromagnetic repulsion term), where the latter defines the (Schwarzschild) radius $\mathbf{R_s}$ of a spherically homogeneous space by an inverse square law:

$$L = \mathbf{1/R_s^2}$$

But if this Schwarzschild gravitational world radius is also defined by Proca's equation, then we have

$$L = (\mathbf{m_C c/h})^2$$

where $\mathbf{m_c}$ is photon rest mass; or

$$L = \mathbf{m_C^2 \text{ x a constant}}$$

Hence we define the cosmological term as proportional to the square of the mass of the photon.

Objections to the introduction of the cosmological term may be countered by the observation that there is a very strong precedent for the extension of the field equations. In the last century, Maxwell, also motivated by considerations of symmetry, added an extra term to his field equations for electricity and magnetism, and found that the additional term accounted for a new, unsuspected phenomenon: magnetic induction. We should not be surprised if the "repulsive" force of the cosmological term, like gravitation itself, is revealed to be a an inductive effect of aggregate charges, and hence masses, as Weyl has suggested[21]. Einstein's "greatest mistake" may ultimately prove to be his most seminal intuition.

Symmetry and mass

For each world-point (our terrestrial observatory, for example) we may envision a surrounding spacetime-mass aggregate bounded by a horizon that defines the extent of electromagnetic visibility and "shields" the central point (in effect a singularity) from electromagnetic interactions originating outside the horizon. The wavelength of radiation emitted from the limit is "dilated" to a maximum value - time stands still - since radiation emitted from that point must travel through an equivalent Schwarzschild gravitational potential to reach the electromagnetic horizon corresponding to its emission point; at the horizon, all its electromagnetic energy has been converted into gravitational energy through mass interactions. The modification of relativity obtained by inserting the mass interaction makes it possible to explain the phenomenon of mass within the observable universe by deriving the universe horizon from the symmetry of the electromagnetic and gravitational interactions.

As Hoyle has pointed out, one consequence of time-dependent cosmologies (i.e. the Friedmann models) has been to raise a metaphysical barrier at an initial time $t = \mathbf{0}$. What lurks behind the temporal singularity is regarded as unknowable, and is ultimately equated with a Creator: the Big Bang is commonly referred to as the "creation". Relativity unified mass and spacetime, yet by failing to incorporate direct particle action, it required an autonomous mass as the explanation for the properties of a spacetime. Modern standard cosmology makes the anti-relativistic mistake of interpolating this autonomy of mass to back to spacetime. The Big Bang model reverts to an absolute cosmic time and space, tenuously united with mass in the artifice of an "origin", in reality a witches' brew of mathematical delusion. In the relativistic direct particle model, mass disappears as an independent magnitude, to be replaced by a gravitational-electromagnetic response symmetry which accounts for rest mass and the structure of spacetime in a unified action continuum without absolutes of time, mass or space.

The central component of a relativistic cosmology is the Schwarzschild solution to Einstein's field equations. The anomalous phenomena associated with the Schwarzschild solution, such as the singularity and event horizon, have been interpreted primarily in local contexts. Indeed, only local confirmations of the theory were feasible at the time relativity was developed, but this physical constraint should not be perceived as an insurmountable theoretical barrier.

Our approach has entailed generalizing the inferences of extreme spacetime "curvature" or redshift from the special cases proposed for the evolutionary sequence of supermassive stars and galactic centres to a form that explains the cosmological redshift and the "edge" of the observable cosmos. In the course of our work we were obliged to recognize the limitations of relativity theory, and we have attempted to overcome them by hypothesizing a quantum description of gravitation predicated on a unification of gravity and electromagnetism. This step enabled us to derive a photon mass from the structure of the universe through direct particle interactions.

Infinite spacetime

The religious implications of the cosmic egg and Big Bang did not fail to cause some trepidation among physicists when the new theory first took shape. The very hypothesis of an expanding universe prompted Einstein to write: "This circumstance irritates me." Many astronomers finally decided that it would be more economical to create matter than activate inert matter into expansion. For example, British physicist Edmund Whittaker wrote that "it is simpler to postulate creation **ex nihilo -** Divine will constituting Nature from nothingness." And Edward Milne has stated bluntly: "our picture is incomplete without Him". Having accepted an origin, many astronomers have thus been constrained to embrace a Creator. But the voices of scepticism were legion, at least in the first half of the century. Many instinctively rejected the hypothesis of an origin. Eddington exclaimed: "The notion of a beginning is repugnant to me... I simply do not believe that the present order of things started off with a bang... the expanding Universe is preposterous... incredible... it leaves me cold."

For Hubble, the expansion theory always remained largely a hypothesis, and we saw that he envisioned (prophetically) the possibility that an explanation of the redshift might emerge from a quantization of the gravitational field. This expectation would now appear to be confirmed. Similarly, Hubble's collaborator, Tolman, was loathe to accept the "creation" theory. In a posthumously published note[22], Tolman expressed his doubts about the implications of the expansionary interpretation:

> *... I think we have to begin by putting the phrase "age of the universe" in quotation marks, since I see at present no evidence against the assumption that the material universe has always existed. For me all that such a phrase could mean is the estimated time back to some important large-scale event, for which we have evidence...*

Now the voices of dissent are almost extinguished. Hoyle and Narlikar have done interesting work on particle interaction, and we have incorporated their premises, but not their cosmological conclusion that clocks (in other words, atoms) in distant galaxies actually "tick" at a slower rate than those on earth. To do so would have been tantamount to repudiating general relativity. J-C. Pecker has suggested that our observable universe may be akin to a black hole, but the quantum problem has never been resolved satisfactorily, and consequently the possibility of a quasi-static universe has never been investigated seriously. Indeed, the Big Bang theory is now almost unanimously heralded as the obligatory paradigm for all future cosmology. As we have indicated, the root of the matter lies in a half-digestion of relativity.

That Einstein's theory introduced a complete revolution in the conception of space and time is contested by no one. It would be more accurate to state that relativity provides the materials for such a revolution, but that the impact of the new view has been nullified by the persistence of a mechanical mode of reasoning. In cosmology, the effect is utterly negated by the prejudices of a spatially finite universe, a Newtonian universal, absolute time, and a metaphysical separation between matter (singularity) and field (energy).

For relativity theory the totality of matter, motion, space and time constitutes a unified reality: they are united in the concept of the field. Space and time do not exist independently of the field, as in the pre-relativistic view, but are determined by the field. Consequently "there is no such thing as an empty space, i.e. a space without field". The field is fundamental and primary, and determines all dynamic effects. The cosmos can be thought of as a continuum of spacetime and the energy-field. Time or space as such, as an absolute, with a beginning and a finite extent, cannot be said to exist. This continuum is the site of dynamical phenomena which are compounded to form motion and evolution within a physically real space and time.

Summary

A cosmology erected on apriorisms (time origin at $t = 0$, global time asymmetry, non-conservation of momentum, systematic expansion) is at variance with relativity theory and represents a retrograde paradigm, since the essential conditions of any spacetime description are the conservation principle, symmetry laws and the principle of equivalence. Indeed, the evolution of physics suggests that the very notion of a cosmology, understood as a model for a closed system, arises from an erroneous projection of local asymmetrical, decoupled and mechanical relations to the cosmic scale.

The present trend toward theorizing the limitations of relativity theory (e.g., its arbitrary treatment of mass) as the absolute bounds of human knowledge and the exhaustion of physical nature is utterly irreconcilable with the dynamic character of scientific theory, as defined by Einstein:

> *However we select from nature a complex (of phenomena) using the criteria of simplicity, in no case will its theoretical treatment turn out to be forever appropriate (sufficient). Newton's theory, for example, represents the gravitational field in a seemingly complete way by means of the potential... This description proves to be wanting; (general relativity) takes its place. But I do not doubt that the day will come when that description, too, will have to yield to another one, for reasons which at present we do not surmise.* **I believe that the process of deepening the theory has no limits.**[23]

Tolman too was keenly aware of the approximate nature of all physical theories, and equally sensitive to the shortcomings of the expansionary model. Recognizing that the problems of empirical fit might lie with relativity theory, he enumerated a number of speculations that could be considered as alternate solutions:

> *(a) that the nebulae actually stay put in space and the red shifts result not from recession but from some unknown and doubtless extremely important physical principle in accordance with which the frequency of a photon would change with time (Zwicky), (b) that the actually correct laws of gravity could themselves be derived from the homogeneity of the universe (Milne), (c) that there are two mysterious kinds of time, a "kinematical time" and a "dynamical time" which are logarithmically interconnected (Milne), and (d) that the constants of nature are not really constant but have values which change with time (Dirac). Some of these possibilities must be regarded as interesting. Furthermore, it is reasonable to regard general relativity as a development which like others before it will sometime find its place in some broader theoretical structure.*[24]

It can readily be seen that speculations (a) and (b) are those explicitly adopted in this study, while (c) and (d) - without time-dependence of the constant - imply that the preceding hypotheses may be accommodated within a model that represents macro-micro relations by means of an invariant cosmic time tied to a comoving reference frame, or ether, and a local time and coupling constant which are dependent on the number of mass quanta that make up each individual particle system.

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APPENDIX TO "QUASISTATIC COSMOLOGY"

Seeliger's non-Newtonian term can in fact be derived from materials already at hand, *i.e.* without introducing new concepts, unconnected with present physical knowledge. All that is required is the Lorentz transformation and the principle of equivalence, to yield what might be called a "Lorentzian gravitation theory," by contrast to the Einstein theory.

Einstein (gravitational) redshift

General relativity predicts a redshift of light due to the gravitational field of an emitting object of mass *M*, according to

$$dE = h\left(n_e - n_0\right) = \frac{GM}{r}\frac{hn_0}{c^2}$$

where hn_0/c^2 is the mass of the photon. This effect has been interpreted in two ways: the textbook view (Berry, 1976) is that the photon may be emitted at a standard frequency, but lose energy as it "escapes" through the gravitational field; Einstein's view (Einstein, 1916), in keeping with the conclusions of the special theory of relativity—was that the atom "absorbs or emits energy at a frequency that depends on the potential of the gravitational field in which it is situated."

It is not immaterial which interpretation is adopted, though the result in either case is derived from the Lorentz transformation by applying the principle of equivalence to the behaviour of clocks and rods on a rotating (and hence accelerated) reference body. In Einstein's classical demonstration, the ratio of the "frequencies" of a stationary clock placed at the origin of a rotating disk and another on the circumference moving with the disk can be approximated as $\left(1 - v/2c\right)$, where v is the relative velocity between the rest clock and the moving one. If the rotating clock is regarded as subject to a gravitational field with a potential equal to the centrifugal force due to rotation, the ratio of frequencies resulting from the action of the gravitational field is

$$\frac{n}{n_0} = \frac{1 + GM}{c^2 r}$$

where *M* is the gravitating mass responsible for the "acceleration." The quantity GM/c^2 is of course the Schwarzschild radius of that body. Naturally, if the above approximation is not introduced, a different redshift factor will be obtained.

Non-Einstein redshift

A more precise characterization of the gravitational redshift effect can be obtained through a strict derivation from the Lorentz transformation. In a recent article, Desloge and Philpott (1987) reviewed the case of uniformly accelerated Lorentzian reference frames. They showed that the world line of an observer moving with constant acceleration of unit magnitude with respect to an instantaneously comoving frame is the equation of a hyberbola:

$$x = \left(1 + t^2\right)^{1/2}$$

such that as t approaches infinity, the velocity of the accelerated observer with respect to the rest frame approaches the speed of light. When such an observer measures the time interval between two events at another point in the same accelerated reference frame, proper time measurements, *i.e.*, measurements taken at the point where the event occurs, will apparently differ from improper time measurements, *i.e.*, those taken by the remote observer, by a factor e^r.

When the term r is much less than 1, the ratio of times will be approximately one. For an acceleration of $g = 9\text{m s}^{-2}$ between two clocks located one meter apart, the clocks will appear to diverge by 1 second approximately every 10^{16} seconds, or 1 second every 3×10^8 light years.

Lilley (1981) has applied the principle of equivalence to this exponential form of the law for constant acceleration observers, and discovered that it yields a non-Newtonian form of gravitational acceleration:

$$a = -\frac{GM}{r^2}\exp\left(\frac{2GM}{r}\right)$$

and a metric:

$$ds^2 \sim \exp\left(\frac{-2GM}{r}\right)dt^2 - \exp\left(\frac{2GM}{r}\right)dr^2 - r^2 dq^2$$

If the expression found by Lilley is the actual form of the gravitational acceleration, the energy depletion due to gravity is just the exponential term:

$$\frac{e}{e_0} = \exp\left(\frac{2GM}{r}\right)$$

In the general case, assuming the visible universe can be modeled as a large black hole of radius c/H, the redshift factor is:

$$\frac{n}{n_0} = \exp\left(\frac{-Hr}{c}\right)$$

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