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IS THE UNIVERSE REALLY EXPANDING?

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ABSTRACT

The no-evolution, tired-light model and the no-evolution, $q_0 = 0$, expanding universe cosmology are compared against observational data on four kinds of cosmological tests. On all four tests the tired-light model is found to make the better fit to the data without requiring the ad hoc introduction of assumptions about rapid galaxy evolution. The data may be interpreted in the simplest fashion if space is assumed to be Euclidean, galaxies cosmologically static, evolutionary effects relatively insignificant, and photon energy nonconserved, with photons losing about 5%–7% of their energy for every 10^9 light years of distance traveled through intergalactic space. The observation that redshifts are quantized may be accommodated by a version of the tired-light model in which photon energy decreases occur incrementally in a stepwise fashion.

Subject headings: cosmology — galaxies: general — galaxies: redshifts

Multiplicity ought not be posited without necessity.
William of Occam

I. INTRODUCTION

The notion that the cosmological redshift is a non-Doppler phenomenon in which photons continuously undergo an energy depletion or "aging" effect is not new. This idea was first suggested by Zwicky (1929). Later, Hubble and Tolman (1935) discussed this alternative, postulating that photon energy was depleted in a linear fashion with increasing photon travel distance. Hubble (1936) claimed that his galaxy number count results strongly supported the linear energy depletion hypothesis. However, he could offer no plausible explanation for such an effect. Since that time, several mechanisms for photon energy loss have been suggested, e.g., Marinov (1977), LaViolette (1985*c*); see also Schatzman (1957) for a review of earlier theories.

The photon energy-depletion interpretation of the cosmological redshift, or "tired-light cosmology" as it is now commonly referred to, implies the following energy loss relation:

$$E(r) = E_0 e^{-\beta r} , \quad (1)$$

where E_0 is the initial photon energy, $E(r)$ is the photon's energy after it travels a distance r, and β is the energy attenuation coefficient. Alternatively, relation (1) may be expressed as the following redshift-distance relation:

$$z(r) = \Delta\lambda/\lambda_0 = e^{\beta r} - 1 , \quad (2)$$

where z is the redshift of the photon's initial wavelength λ_0 after the photon has traveled a distance r. For cosmologically short propagation distances where $r \ll \beta^{-1}$, these exponential formulae become approximated by the following linear relations:

$$E_0 - E = -\beta E_0 r , \quad (3)$$

or

$$z(r) = \beta r . \quad (4)$$

Expressed in Doppler terminology, $\beta = H_0/c$, where H_0 is the Hubble constant and c is the velocity of light. Thus relation (4) is equivalent to Hubble's linear redshift-distance relation.

Past attempts to find a physical explanation for the tired-light effect have generally been of an inductive nature. As a point of departure, theorists have traditionally begun with the observational fact of the cosmological redshift, then postulated that this redshift might be due to a photon energy depletion effect, and finally, through a process of induction, attempted to conceive of a reasonable physical model that might explain the effect. More recently, however, the tired-light proposition has also been arrived at through a process of deductive prediction from theory (LaViolette 1985*a*, *b*, *c*). In this case, the point of departure is a field theory originally formulated for the purpose of modeling the formational and behavioral properties of quantum structures. Interestingly, this methodology, called subquantum kinetics, makes a rigid and testable prediction about photon energy behavior, namely that photons traveling through intergalactic space, where the gravitational field potential is least negative, should gradually decrease their energy at a given rate that is essentially wavelength-independent. A major objective of this paper is to determine the validity of the tired-light concept by checking this model's performance on several cosmological tests.

The alternative to the tired-light model, and the more widely held view, is the hypothesis that well-separated galaxies are receding from one another and that the cosmological redshift is due to a Doppler effect arising from this recession. Thus any test of the tired-light cosmology against available data must necessarily include a comparison with this standard "expanding universe" interpretation. Unless the tired-light model exhibits superior performance when compared against the observational data, there should be no incentive to abandon the classical Doppler interpretation. The underlying paradigmatic issue which is ultimately being decided in the contest between these two cosmologies is the following: Is the universe really expanding?

Some time ago, Geller and Peebles (1972) conducted a test of the tired-light model by comparing its performance on two cosmological tests, the angular size–redshift test and the Hubble diagram test, and concluded that the tired-light model did not make a good fit to the data. However, since their paper, a considerable amount of new cosmological data has become available. So a retest of the two cosmologies using more up-to-date observations is now warranted.

Several factors are considered important in designing an effective test of these hypotheses. First, it is desirable whenever possible to use data bases which contain observations of distant galaxies, since it is at large redshifts that the differences between the two rival cosmologies become most apparent. Second, an effective comparison would ideally require that the competing hypotheses be evaluated together on several different cosmological tests. This would allow a picture to be formed of the consistency of a given model's performance in various test arenas. Third, and most important, a "systems approach" should be utilized, whereby a model is simultaneously made accountable for its performance on all the various tests. Thus any assumptions introduced with the intention of adjusting a cosmology to fit the data on one test must be applied as constraints to the interpretation of the other tests. Moreover, a final judgement as to the appropriateness of a given cosmology should consider its overall performance on the test sequence as a whole, rather than on each test in isolation from the test.

The performance of the tired-light and expanding universe cosmologies are evaluated on four cosmological tests: the angular size–redshift test, the Hubble diagram test, the galaxy number-count–magnitude test, and the number-count–flux density test (log dN/dS–log S test). It is determined that on all four tests the tired-light model exhibits superior performance. That is, it makes the best fit to the data with the fewest number of assumptions. Finally, the redshift quantization phenomenon is briefly discussed. Although not a cosmological test per se, this phenomenon is something that any candidate cosmology must somehow address. It is shown that redshift quantization is quite compatible with the tired-light model. On the other hand, when the expanding universe hypothesis is adhered to, ad hoc assumptions must be introduced about the possible existence of macroscopic dynamical quantization in the universe's expanding motion.

II. THE ANGULAR SIZE–REDSHIFT TEST

The first cosmological test to be considered will be the angular size–redshift test. In one version of this test, the angular statistic θ is derived from the corrected harmonic mean of the projected angular separations between bright galaxies in a cluster and is compared to cluster redshift (Hickson 1977*a*, *b*; Bruzual and Spinrad 1978; Hickson and Adams 1979*a*, *b*). One z-θ data set which is quite suitable for testing alternate cosmologies is that published by Hickson and Adams (1979*b*) for a set of 94 galaxy clusters which includes moderately high redshift clusters, i.e., $0.02 < z < 0.46$.

Three model cosmologies are compared against this data base, each of which makes a different prediction about the relation between distance r and redshift z; see Figure 1. The first assumes that space is static and Euclidean, that galaxy clusters do not change their size appreciably over long look-back times, and that redshift varies linearly with distance as $r = z/\beta$ (relation [4]). For flat space, the following relation between cluster angular size θ and distance r is expected:

$$\theta = d_0/r \, , \tag{5}$$

where d_0 is the measured intrinsic size of a typical cluster. For linear r-z dependence, this may be rewritten as

$$\theta = k/z \, , \tag{6}$$

where $k = \beta d_0 = H_0 d_0/c = 1.375 \times 10^{-4}$ for $H_0 = 55$ km s^{-1} Mpc^{-1} and $d_0 = 0.75 \pm 0.15$ Mpc, the value reported by Hickson (1977*a*) for nearby galaxy clusters. This relation is plotted in Figure 1.

The second hypothesis, the no-evolution, tired-light model, is identical to that described above with the exception that a logarithmic term is introduced in the denominator in accordance with the nonlinear r-z dependence specified by relation (2). The z-β relation for the tired-light cosmology is therefore given as

$$\theta = k/\ln\,(1 + z) \, , \tag{7}$$

where k is the same as in equation (6). This relation, which is also plotted in Figure 1, is seen to diverge upward from the $1/z$ relation.

The third cosmology tested is the no-evolution, Friedmann expanding universe model having a $q_0 = 0$ deceleration parameter and a $\Lambda = 0$ cosmological constant. The z-θ dependence for this model is given as (Hickson 1977*b*)

$$\theta = \frac{k(1 + z)^2}{z(1 + z/2)} \, , \tag{8}$$

where k is again constrained to be the same as in equation (6). This appears in Figure 1 as the uppermost diverging solid line.

The $q_0 = 0$ assumption is reasonable. In a Friedmann model, the value of the deceleration parameter is equal to the value of the cosmological density parameter σ_0, which is determined from estimates of the mean mass density of the universe ρ_0 according to $q_0 = \sigma_0 = 4\pi G\rho_0/3H^2$. However, based on a variety of observations, it may be concluded that unless "hidden mass" is present, q_0 should have a value of about 0.03 ± 0.01 (Peimbert and Torres-Peimbert 1974; Tammann 1973; Gott *et al.* 1974; Davidsen, Hartig, and Fastie 1977). Consequently, it is permissible to consider q_0 to be essentially zero and to adopt relation (8) as being a reasonable representation of a no-evolution, expanding universe model.

To test these three models, a variance-like statistic ΔV was determined for each model curve as follows. Residuals $\Delta\theta$ between the predicted and observed θ values were determined and normalized relative to the θ value predicted by relation (6). Each normalized residual was then squared, and all such values summed together for the 94 data points, giving

$$\Delta V = (\Delta\theta/\theta)^2 \, . \tag{9}$$

The "variances" determined in this way for the linear $\theta \propto 1/z$ model, the tired-light model, and the expanding universe model were found to be in the ratio 1:1.2:5.0. Repeating the calculation for the 31 most distant clusters ($z > 0.1$) gives relative variance ratios of 1:1.4:10. Thus the static, Euclidean cosmologies are significantly favored over the expanding universe model. The linear $1/z$ relation exhibits a slightly lower variance than the tired-light model. However, at the high-z end of the sample the difference between these two model predictions is so slight compared to the intrinsic scatter of the sample that it is better to say that they fit the data about equally well.

Increasing the value of q_0 will not help the expanding universe model, since this would cause the z-θ curve to move upward at high z, not downward. Working with 88 z-θ data points, a subset of the Hickson-Adams data base, Hickson (1977*b*) finds that a $\Lambda = 0$ Friedmann model makes its best fit to the data for a *negative* q_0 value of $q_0 = \sigma_0 = -0.9 \pm 0.2$. However, such a Friedmann model is unrealistic, since it would require a negative mass density, i.e., a repulsive gravitational force field. Relaxing the restriction that Λ be zero does not

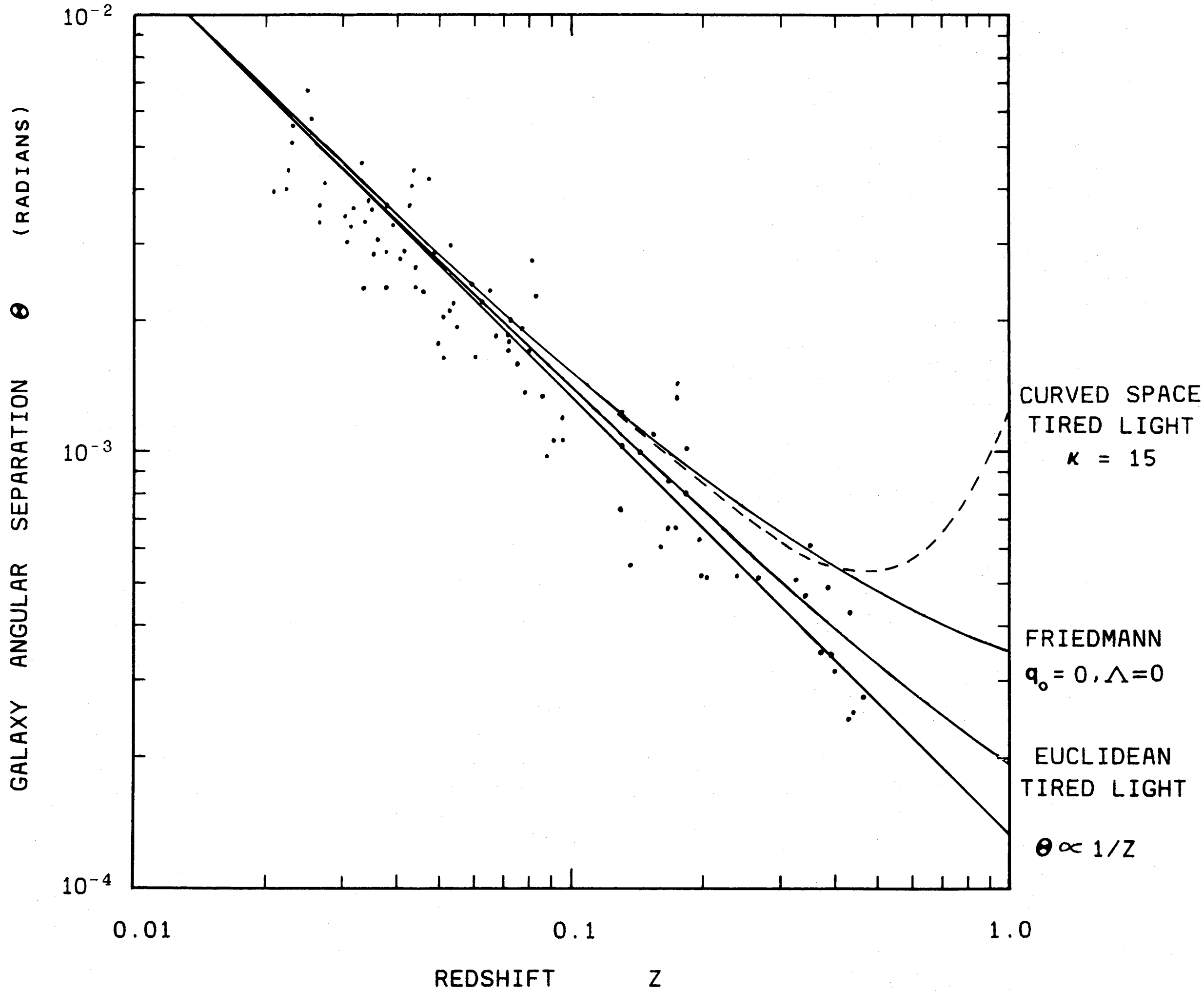

FIG. 1.—Harmonic mean angular separation for the brightest galaxies in a cluster plotted vs. redshift for 94 galaxy clusters. The predictions of several cosmological models are shown for comparison. Data from Hickson and Adams (1979*b*).

help, either. For example, Hickson and Adams (1979*b*) show that their data make the best match to a $\Lambda \neq 0$ model having an even greater negative mass density of $\sigma_0 = -4.3$.

One way to save the expanding universe cosmology is to introduce the assumption that galaxy clusters were larger at earlier epochs and that they have been gradually collapsing. However, Hickson (1977*b*) finds that expected rates of cluster collapse would succeed in making q_0 more positive by only ~ 0.1, far short of the required amount. It has been speculated that the Friedmann model's apparent discrepancy with the data could be resolved if dynamical friction effects are sufficiently intense in very high density clusters, so as to lead to shorter cluster relaxation times (Hickson and Adams 1979*b*). But this view should be weighed against the observational evidence presented by Tifft (1977), which seems to indicate that galaxies are relatively noninteractive gravitationally with their more distant cluster neighbors.

Thus, unless special ad hoc evolutionary assumptions are introduced, whose basis is questionable, it must be concluded that the expanding universe postulate is not consistent with the data. A static, Euclidean universe exhibiting tired-light behavior and minimal cluster evolution then comes out as being the better choice on this particular test.

Geller and Peebles (1972), however, report quite different findings for their test of the tired-light model. They used an angular size–redshift test in which galaxy angular diameter was taken as the angular statistic and came to the conclusion that the tired-light model was compatible with their data only if space was assumed to be tightly curved with a curvature parameter of $\kappa = (c/H_0 R)^2 = 15$, $R = 1550$ Mpc being the radius of curvature that would be required for such a universe; see Figure 1 (*dashed line*). They then showed that such a model was unrealistic. However, the z-θ data which they used were from Baum's (1972) study, in which the sizes of individual galaxies in four galaxy clusters were measured using an image smearing technique. Thus Geller and Peebles based their test of the tired-light model on a fit to a data sample consisting of just four data points, of which only two have redshifts greater than 0.1. By comparison, the Hickson-Adams data set, which is used here and which has become available since the time of the Geller and Peebles study, consists of 94 data points, 31 of which have redshifts greater than 0.1. Thus the Hickson-Adams data base must be considered superior in the sense that it is less vulnerable to statistical errors. It is apparent in Figure 1 that the curved-space, tired-light model does not make a good fit to the Hickson-Adams data.

Bruzual and Spinrad (1978) have also published an angular size–redshift data set which utilizes for the angular statistic the corrected harmonic mean of galaxy separations in a cluster. However, for the purposes of testing alternative cosmologies, the Hickson-Adams data were preferred for a number of reasons. First, the Bruzual-Spinrad data set represents a sample of 54 clusters, of which only 13 have redshifts greater than 0.1. Thus the Hickson-Adams data base is 3 times larger at the high-z end. Second, the dispersion in the Bruzual-Spinrad data is 2–3 times larger than that found for the Hickson-Adams data; see Figure 1 in Hickson and Adams (1979*b*) for a comparison. Bruzual and Spinrad found that, for a $\Lambda = 0$ Friedmann cosmology, their data made a best fit for a deceleration parameter of $q_0 = +0.27 \pm 0.58$. By comparison, the value $q_0 = -0.9 \pm 0.2$ found by Hickson (1977*b*) for the 88 cluster subsample has a standard deviation 3 times smaller. Hickson's q_0 value of -0.9 lies within 2 standard deviations of Bruzual and Spinrad's $+0.27$ value, while Bruzual and Spinrad's $+0.27 q_0$ value lies outside 6 standard deviations of Hickson's -0.9 value. Thus, the Bruzual-Spinrad data base does not definitely rule out a $q_0 = -0.9$ fit, whereas the Hickson data do rule out a $+0.27$ value at the 6 σ level.

The different results projected by these two data bases may be partly due to the way in which the authors have selected clusters to compose their respective samples. For example, Bruzual and Spinrad's data contain more rich clusters and fewer irregulars. Also, some differences may be due to the way the angular size of a cluster was estimated. For example, Bruzual and Spinrad used a smaller aperture size for bounding their clusters. As Hickson and Adams (1979*b*) point out, this may have introduced an aperture-dependent effect into the Bruzual-Spinrad data, causing systematic errors to arise.

Brief mention should be made of another type of angular size–redshift test which utilizes, as the angular statistic, measurements of radio lobe separation in double radio galaxies and quasars. Such tests (Miley 1971; Kellermann 1972) have covered the redshift range up to $z = 2$. Although there is a large amount of scatter in the data, it is apparent that the upper boundary of the z-θ sample obeys the relation $\theta \propto 1/z$, which is very close to the kind of dependence that would be expected for the tired-light model, given a static, Euclidean, nonevolving (or slowly evolving) universe. At the same time, nonevolving expanding universe models are not favored, since at high z they predict values of θ that are much larger than are actually observed.

The expanding universe cosmology may be saved on this radio galaxy test by introducing the ad hoc assumption that galaxy radio lobes have been gradually increasing in size over time. However, not only does this further increase the complexity of the expanding universe cosmology vis-à-vis the tired-light cosmology, but it requires that one accept that galaxy cluster size and galactic radio lobe size, two normally unrelated physical quantities, both change over time in just the right manner so as to allow the expanding universe model to make a good fit to the data! One might indeed be justified in asking the question, "Are we drawing too many epicycles?" (Kellermann 1972). The law of parsimony would instead point to the tired-light model as the candidate model that is capable of explaining the greatest amount of data with the fewest assumptions.

III. THE HUBBLE DIAGRAM TEST

The Hubble diagram test uses galaxy apparent magnitude m as a distance indicator for comparison to galaxy redshift. Figure 2 displays the R magnitude m-z data of Djorgovski and Spinrad (1985) together with those of Lilly (1983); Schneider, Gunn, and Hoessel (1983); Hoessel (1980); Kristian, Sandage, and Westphal (1978), and Sandage, Kristian, and Westphal (1976). Superposed for comparison are the no-evolution, tired-light model with $\beta = H_0/c = 5.1\%$ (10^9 lt-yr)$^{-1}$ and the $q_0 = 0$, no-evolution, expanding universe model with $H_0 = 50$ km s^{-1} Mpc^{-1} (after Djorgovski and Spinrad 1985).

Since the data points are not corrected for K-dimming and cosmology, K-corrections have been incorporated into the models. The K-corrections used are based on those used by Bruzual (1981, Tables 20A and 25A) in calculating magnitudes for the $q_0 = 0$, $H_0 = 50$ km s^{-1} Mpc^{-1}, no-evolution expanding universe model. These were determined by assuming that the galaxy spectra remain invariant with z and resemble a typical present-day elliptical galaxy. The expanding universe model m-z relation also includes magnitude corrections for the effects of expansion, e.g., relativistic time dilation and cosmological curvature.

Equation (2) for the tired-light model projects the following m-z dependence:

$$m_R = 5 \log [\ln (1 + z)/\beta] + C , \qquad (10)$$

where $C = 14.1$. Magnitudes derived from equation (10) for various values of z, the respective K-corrections Δm, and K-corrected magnitudes m'_R are listed in Table 1. Note that use of an R (rather than V) magnitude data base for the Hubble diagram test reduces the size of potential errors in the K-corrections resulting from incorrect galaxy spectrum assumptions.

As seen in Figure 2, the no-evolution, tired-light model apparently makes a reasonably good fit to the data. At the high-z end of the sample, $z > 1.3$, there is a tendency for the data points to lie to the left of the line. But this is probably due to a selection effect, since the data bases are magnitude-limited. That is, they include only galaxies brighter than $R \approx 23$. The high-redshift galaxy 3C 256 ($z \approx 1.82$) is about 3 mag brighter than the tired-light relation would predict. But this galaxy may be anomalously bright. Indeed, Djorgovski and Spinrad note that 3C 256 is one of the brightest ionization galaxies in their sample. Thus the inclusion of this galaxy in the data base could be questioned.

By comparison, the no-evolution, $q_0 = 0$, expanding universe model does not make nearly as good a fit as the tired-light model. The former departs significantly from the data trend for $z > 1$, predicting magnitudes up to 3 mag dimmer than the tired-light model. By assuming a high positive value for q_0, the no-evolution expanding universe model would be moved closer to the data trend. However, such an assumption would raise several difficulties. First, there would be the problem of accounting for the source of the missing mass

TABLE 1

R MAGNITUDES AND CORRESPONDING K-CORRECTIONS DERIVED FOR THE TIRED-LIGHT MODEL

z	m_R	Δm	m'_R
0.1.........	15.41	0.0	15.41
0.3.........	17.61	0.04	17.65
0.5.........	18.55	0.23	18.78
1.0.........	19.72	1.37	21.09
1.5.........	20.32	2.78	23.10
2.0.........	20.72	4.89	25.61

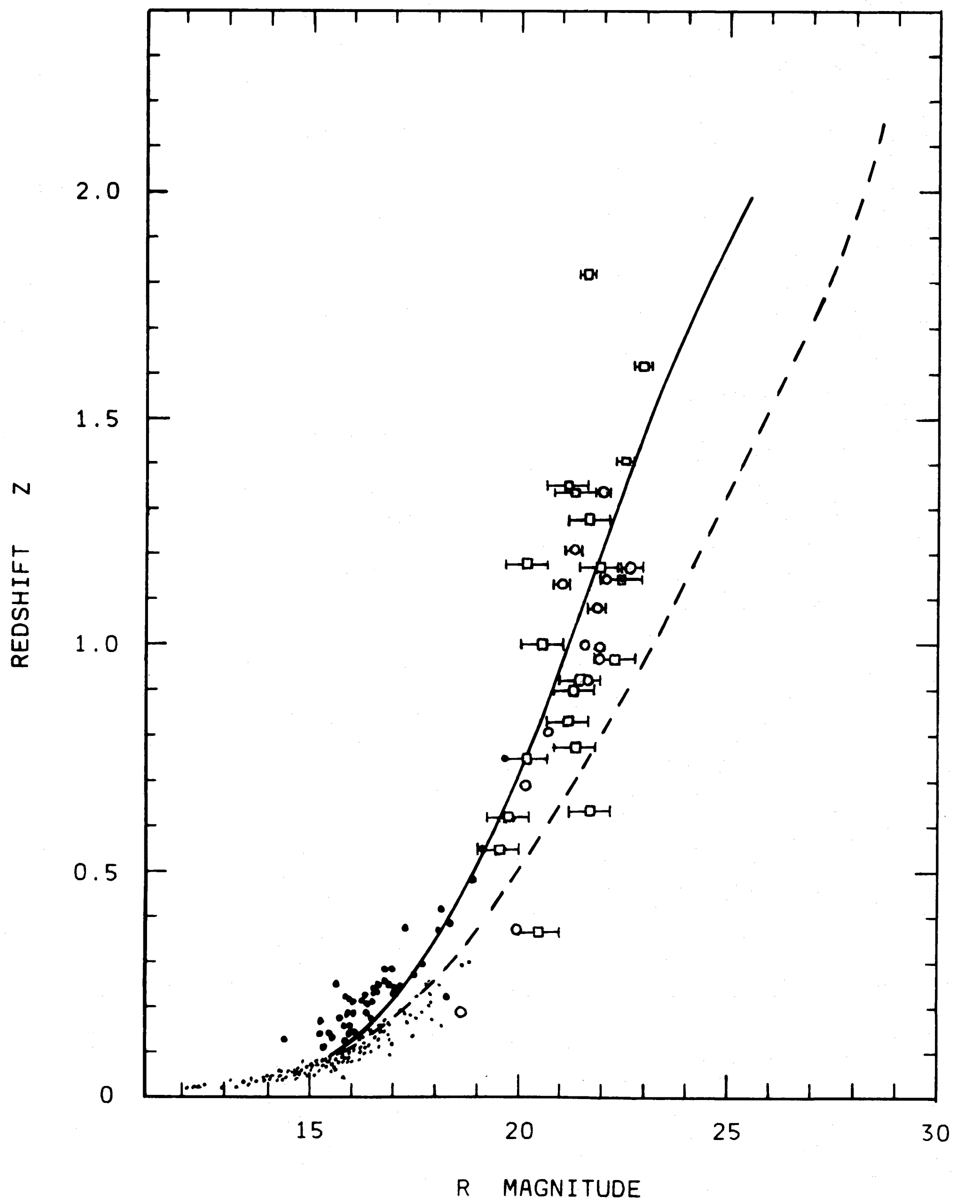

FIG. 2.—The Hubble diagram for the brightest cluster galaxies and for strong radio galaxies. The tired-light model $\beta = 5.1\%$ (10^9 lt-yr)$^{-1}$ (*solid line*) and the $q_0 = 0$, $H_0 = 50$ km s^{-1} Mpc^{-1} no-evolution expanding universe model (*dashed line*) are superposed for comparison. Reverse K-corrections and cosmological corrections have been included. Data from Djorgovski and Spinrad (1985, *open squares*); Lilly (1983, *open circles*); Schneider, Gunn, and Hoessel (1983, *small dots*); Hoessel (1980, *small dots*); Kristian, Sandage, and Westphal (1978, *large dots*); and Sandage, Kristian, and Westphal (1976, *large dots*). Adapted from Fig. 4 of Djorgovski and Spinrad (1985).

needed to close the universe. Second, if a higher value is assumed for q_0, then the expanding universe model would make an even worse fit on the angular size–redshift test, as was mentioned in the previous section. Finally, the assumption of high q_0 values would require that the angular size–redshift curve should turn upward at high z-values, with angular size progressively increasing with distance, rather than decreasing. Accordingly, one would expect to observe a *minimum* angular size near $z \approx 1$. But no such inflection is apparent in the quasar and radio galaxy data (Kellermann 1972).

Djorgovski and Spinrad (1985) alternatively suggest that the intrinsic luminosity of galaxies has evolved, claiming that galaxies were several magnitudes brighter in earlier epochs. However, it should be noted that the proposal that galaxy luminosity has evolved is based *a priori* on the acceptance of the expanding universe model. Thus it must be regarded as an ad hoc assumption. It has been shown that the intrinsic *color* of galaxies has evolved, galaxies being bluer at earlier epochs (Kron 1980; Bruzual and Kron 1980; Bruzual 1981). However, whether such color evolution is accompanied by an appreciable change in galaxy luminosity and whether such luminosity would be such as to lead to intrinsic brightening by the required amount in earlier times is heavily dependent on the kind of galaxy evolution model that one chooses to assume.

To account for such high early luminosities, Djorgovski and Spinrad (1985) propose models with accelerated rates of star formation, which predict that supernovae should have occurred at the rate of one every 0.7–3 yr at $z \approx 2$. This is over an order of magnitude higher than rates observed in our own Galaxy, which are on the order of one every 30–40 yr (Milne 1979). The no-evolution, tired-light model instead predicts supernova occurrence rates in line with those observed locally. Observations should be carried out with the Space Telescope to determine whether the supernova rate in fact increases at high z, as Djorgovski and Spinrad predict.

The introduction of assumptions about high q_0-values or strong luminosity evolution or both in early times necessarily makes the expanding universe cosmology theoretically more complex. This would then place it at a disadvantage relative to the no-evolution, tired-light model, which already makes a reasonably good fit to the data without requiring additional modifications. But then the following question presents itself: Are we not dishonoring Occam's principle by adhering to the expanding universe cosmology and assuming that "hidden mass" is present in just the right amounts, or that quite substantial luminosity evolution has taken place in just the right way to allow this model to fit the data, when in fact there is a cosmology at hand (the tired-light cosmology) which already adequately fits the data without requiring the introduction of such extreme assumptions?

IV. THE GALAXY NUMBER COUNT–MAGNITUDE TEST

Another kind of cosmological test which has been used to check the predictions of cosmological models compares the differential number count dN, the number of galaxies per square degree falling in a given apparent magnitude interval dm, to m, the average magnitude of that interval. For a static, nonevolving, energy-conserving (non–tired-light), Euclidean universe uniformly filled with galaxies, one would expect the integral galaxy number count to increase with the cube of distance, $N \propto r^3$, and galaxy brightness to decrease according to the inverse square of distance, or $r \propto 10^{0.2m}$. This would then give $N \propto 10^{0.6m}$, or similarly for differential counts: $dN/dm \propto 10^{0.6m}$. If $dN_0(m)$ is defined as the set of differential galaxy number counts that would be expected in such an ideal case, then deviations from this ideal case may be more clearly represented by dividing the observed differential galaxy number counts $dN(m)$ by their corresponding $dN_0(m)$ values, a normalization statistic which may be abbreviated as n/n_0. Graphical plots of log (n/n_0) versus m offer an ideal format for comparing cosmological models.

One such logarithmic differential number count plot, shown in Figure 3, compares a no-evolution, tired-light model (*solid line*) and a no-evolution, expanding universe model (*dashed line*) to the data of Tyson and Jarvis (1979) for four high-latitude sky fields. The theoretical curves for these two competing cosmologies are taken from Figures 6 and 8 in Tinsley's (1980) paper. The predictions of the two cosmologies essentially differ by a factor of $1 + z$, the expanding universe cosmology predicting an additional dimming of galaxy apparent magnitude due to the relativistic time dilation effect (the Hubble "number effect"). Visual inspection indicates that, of the two cosmologies, the tired-light model makes a much better fit to the number count data, especially at high redshifts. The horizontal dashed line at log $n/n_0 = 0$ represents the idealized Euclidean universe discussed above.

It is unlikely that luminosity evolution could account for the discrepancy of the expanding universe model, since the number count sample is estimated to extend out to only $z \approx 0.6$ (Jarvis and Tyson 1981), and in this low-z range luminosity evolution would be minimal. Moreover, the luminosity evolution that would be required would be in the opposite sense to that indicated by the Hubble diagram data. As an alternative, the expanding universe cosmology could be made to fit the

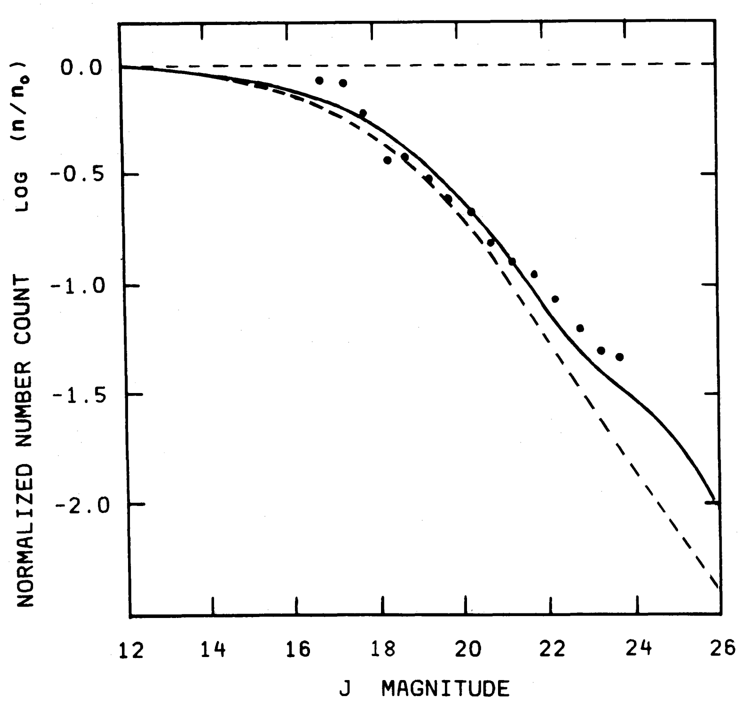

FIG. 3.—Differential galaxy number counts with the Euclidean dependence log $N_0 \propto 0.6m$ normalized out and plotted against uncorrected J magnitude. Superposed for comparison are the no-evolution, tired-light model (*solid line*) and the no-evolution, $q_0 = 0$, expanding universe model (*dashed line*). After Tinsley (1980, Figs. 6 and 8). Data from Tyson and Jarvis (1979).

number count data by introducing the ad hoc assumption that galaxies had a higher number density in the past. But then this raises the following question: Is it justified to assume that galaxy space density has varied in just the right manner so as to allow the expanding universe model to make a good fit to the data, given that the tired-light cosmology already makes a reasonably good fit?

V. THE DIFFERENTIAL log N–log S TEST

The differential number count test may also be performed at radio wavelengths, with interesting results. One such test compares dN, the number of radio galaxies in a given radio flux density class dS, to the radio flux density S. For a static, homogeneous, nonevolving, energy-conserving universe, one would expect to have $N \propto r^3$, where N is the integral number count, and $S \propto L/r^2$, where L is the intrinsic luminosity of the radio source. These relations in combination would give $N \propto S^{-1.5}$, and $dN/dS \propto S^{-2.5}$ for differential number counts. As with the optical number count data, by dividing the observed differential number count data by the differential number counts expected for the idealized Euclidean universe, a normalized differential statistic may be produced, $dN(S)/dN_0(S)$, which may be abbreviated as n/n_0. This in turn may be plotted against radio flux density.

An example of such a log (n/n_0)–log S plot is shown in Figure 4. The hatched region represents the data published by Kellermann (1972, Fig. 2) and comes from radio surveys made at radio frequencies of 6, 11, 20, and 75 cm. The bulk of the observed sources, $\sim 10^4$, are found to lie in the range $10 < N < 10^3$ sr^{-1}, where N represents cumulative number of counts; see scale at top of Figure 4. Only a few hundred radio sources fall in the ranges $N < 10$ sr^{-1} and $N > 10^3$ sr^{-1}. As is seen here, the majority of the data, about 98% of the radio source sample, conforms relatively closely to the $n/n_0 = 1$ normalization line.

Also plotted on the graph are the relations that would be expected for the no-evolution tired-light model and the no-evolution expanding universe model. For the tired-light model, $S \propto (1 + z)^{-1}$, and hence integral radio source number counts would vary as

$$N \propto S^{-1.5}(1 + z)^{-1.5} . \tag{11}$$

For the expanding universe model, $S \propto (1 + z)^{-4}$, one factor of $1 + z$ being due to relativistic time dilation, one factor being due to the Doppler redshift effect, and two factors being due to relativistic geometrical aberration (Hubble 1936). Hence the integral number count for the expanding universe model would be expressed as

$$N \propto S^{-1.5}(1 + z)^{-6} . \tag{12}$$

The radio flux density values predicted by these two models differ by a factor of $(1 + z)^3$, whereas in the number count test described in the previous section, predicted magnitudes differed by only one factor of $1 + z$. Thus the number count–flux-density test allows a more decisive test to be made of the expansion hypothesis.

As a very rough approximation, theoretical log (n/n_0)–log S relations for the two cosmologies have been devised as follows. For the nonevolving tired-light model, the normalized differential number count values have been adjusted downward from their $n/n_0 = 1$ position by a factor of $(1 + z)^{1.5}$; and for the $q_0 = 0$ nonevolving expanding universe model, by a factor of $(1 + z)^6$. These relations are shown in Figure 4 for comparison to the observed data. In plotting these relations, a value of $z = 2$ was arbitrarily assigned as the characteristic redshift of sources at the faint end of the sample having a flux density in the range of 0.03 W m^{-2} Hz^{-1} at 75 cm. This is probably a reasonably good estimate, since a large portion of Kellermann's (1972) radio source sample is made up of quasars,

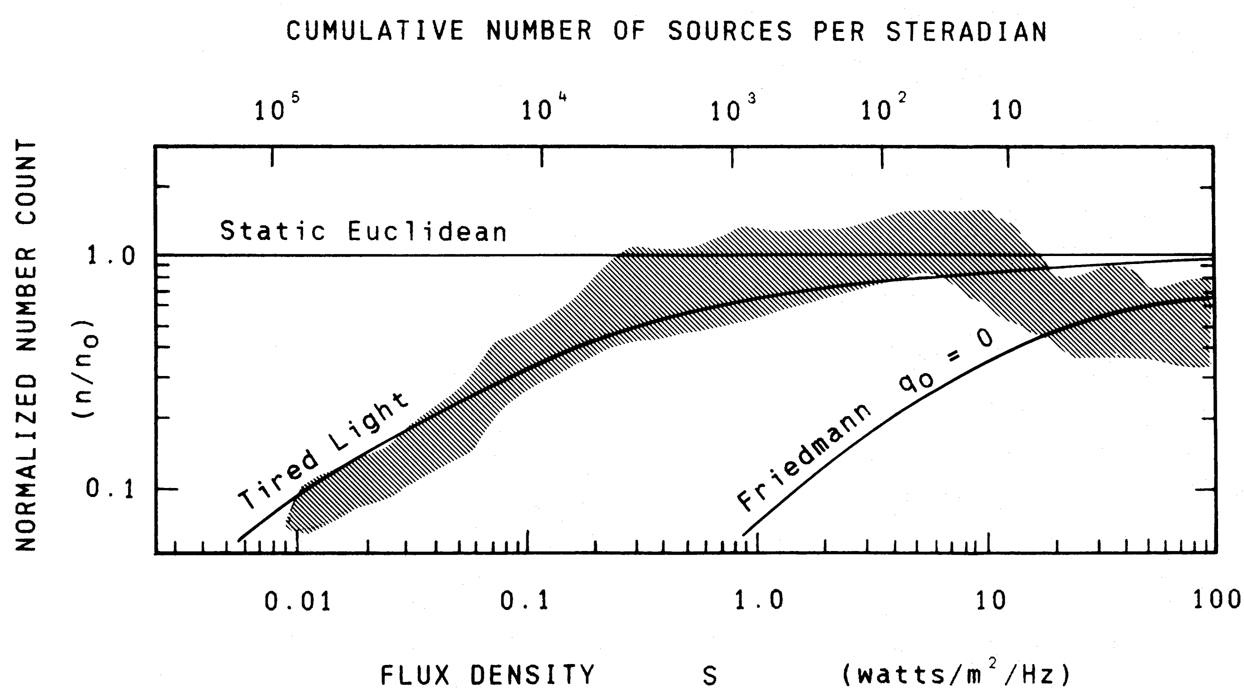

FIG. 4.—Combined differential source counts n for observations at radio wavelengths of 6, 11, 20, and 75 cm, normalized to number counts n_0 expected for a static, homogeneous, energy-conserving, Euclidean universe (*shaded region*). A radio flux density scale for a wavelength of 75 cm is given at the bottom, and the common cumulative source counts at the top. The no-evolution, tired-light model is seen to fit the data much better than the no-evolution, $q_0 = 0$, expanding universe model. Data base from Kellermann (1972).

many of which are known to have redshifts as high as 2–3. Redshifts corresponding to other values of S were calculated by assuming that the distance of a typical radio source falling in a given dS increment varies according to the inverse square of corrected S. Of course, this is a rough estimate, since the intrinsic luminosity of an individual radio source can vary over a considerable range. Nevertheless it should be approximately correct for collections of sources.

Although there may be some error in the placement of these theoretical curves relative to the data set, it is nevertheless clear that the number count distribution predicted for the nonevolving tired-light model makes the better fit to the data. As may be seen in Figure 4, the tired-light curve conforms surprisingly well to the data trend. If the decreased n/n_0 number counts for $N > 10^4$ sr^{-1} are real and not due to a statistical artifact, then this could be evidence of photon energy damping, which at high redshift would reduce the apparent value of S and cause n/n_0 to trend downward.

At $z = 2$, the nonevolving expanding universe relation predicts values of n/n_0 that are over two orders of magnitude lower than those predicted by the tired-light model. The expanding universe cosmology could be adjusted to fit the data by relaxing the assumption that the space density of radio sources has been the same for all epochs and assuming instead that such sources were more abundant in earlier times. However, this ad hoc version then runs the risk of being overly contrived, since the required number density evolution would have to be of just the right amount such that the effects of recession would be compensated for; see Kellermann (1972, Table I, Paradox 1).

But the claim for radio source density evolution becomes even less plausible in view of the work by Stewart and Hawkins (1978), who point out that previous determinations of quasar radio source number density evolution did not consider the Scott effect. When such selection effects are taken into account, it is found that a nonevolving number density is the most probable choice. As an upper limit, they found that the number density for epochs corresponding to a redshift of 2–3 would have been no more than 5 or 6 times local number densities. This amount, though, falls short by one to two orders of magnitude from the amount needed to properly adjust the expanding universe cosmology at high redshifts.

As pointed out by Kellermann (1972), earlier studies which reported a strong evolution of radio source number density were in error. The data discussed in those surveys were presented in integral rather than differential format and hence were found to have a steep log N–log S slope of close to -1.8 out to $N \approx 10^3$ sr^{-1}, eventually dropping off to about -0.8 for cumulative source counts near 10^5 sr^{-1}. As a result, it was concluded that the radio sources were more abundant at earlier epochs. However, as Kellermann has shown, this initial steep slope is an artifact of the data generated by an apparent relative deficiency of strong local sources ($N < 10$ sr^{-1}), a portion of the sample for which the sampling statistics are relatively poor.

VI. THE REDSHIFT QUANTIZATION EFFECT

The tired-light interpretation of the cosmological redshift is also compatible with the finding that extragalactic redshifts have a discrete rather than continuous distribution. Spectral studies indicate that cosmological redshifts are quantized and that they manifest in $\frac{1}{6}$ submultiples of $c\Delta z = 72.45$ km s^{-1} (or $\Delta z = 2.415 \times 10^{-4}$), the 24 and 36 km s^{-1} harmonics being most prevalent (Tifft 1976, 1978, 1980, 1982*a*, *b*; Cocke and Tifft 1983; Tifft and Cocke 1984). This effect has been demonstrated most convincingly by studying differential redshifts within galaxy pairs and compact groups obtained by both radio and optical means. The existence of a 72 km s^{-1} submultiple periodicity in the data is now well established, with a 10^{-6} probability that it is due to chance.

Cocke and Tifft (1983) suggest two explanations for this phenomenon. One interpretation is that the redshifts are due to Doppler motion, the observed quantization indicating that the expansion of the universe is quantized (Cocke 1983). The second interpretation they suggest is that the universe is stationary and the photon emission properties of atoms are quasi-stationary, with some parameter, such as the Rydberg constant, monotonically changing its value over time in discrete steps (Tifft 1978).

However, a third interpretation of the redshift quantization effect may also be conceived, namely, that the redshift increments represent discrete steps in the decay of photon energy as photons propagate through space. Such a description fits very well with the tired-light cosmology. Thus, rather than losing energy continuously, as implied by relation (1), photon quanta might be supposed to change their energy/wavelength states in an incremental fashion. If Δr is the distance an average photon travels before undergoing a redshift transition of amount Δz, then the redshift over n increments would be given as

$$z = n\Delta z = n\beta\Delta r \, , \tag{13}$$

where $(n-1)\Delta r < r < n\Delta r$ and where $\Delta r = 7.9 \times 10^5$ lt-yr, given that $\Delta z = 4 \times 10^{-5}$ ($c\Delta z = \frac{1}{6} \times 72.5$ km s^{-1}) and $c\beta = H_0 = 50$ km s^{-1} Mpc^{-1}. For extended distances, equation (13) would be given as

$$z = e^{n\beta\Delta r} - 1 = e^{n\Delta z} - 1 \, . \tag{14}$$

The above equations would be substituted for relations (4) and (2) respectively.

Discrete steplike energy transitions are a common feature of quantum-level phenomena. So it does not seem too implausible to assume that photon energy loss through a tired-light effect might also occur in a discrete fashion. It might be imagined that for a considerable part of its journey a photon's energy remains relatively constant, but that after the appointed distance (or time interval) has elapsed, a photon enters a period of instability in which its former energy state becomes unstable to small perturbations and undergoes rapid change to a new stable state. Such step-function behavior is entirely compatible with the wave model discussed by LaViolette (1985*c*).

It is worth noting that the cosmological test results presented here, in which the tired-light model is favored over the expanding universe model, encourage the choice of non-Doppler interpretations of the redshift quantization effect. Adherence to the expanding universe hypothesis would necessitate adopting a Doppler shift interpretation of this phenomenon. This would then require the assumption of new physics at the macroscopic level, which would further increase the assumptive burden of a cosmology that is already overburdened with assumptions.

VII. CONCLUSION

The nonevolving, Euclidean tired-light model has been compared to the $q_0 = 0$, $\Lambda = 0$ expanding universe model on four kinds of cosmological tests (z-θ, m-z, log $[dN/dm]$ vs. m, and log $[dN/dS]$ vs. log S). It is concluded that the tired-light model makes a better fit *on all four data sets.* The expanding universe hypothesis may be considered plausible only if it is modified to include specific assumptions regarding the evolution of galaxy cluster size, galaxy radio lobe size, galaxy luminosity, and galaxy number density. In addition, if the redshift quantization effect is also to be accounted for, special assumptions must be introduced regarding the operation of dynamical quantization on a cosmological scale. But the required assumptions are numerous. Consequently, the tired-light model is preferred on the basis of its simplicity. Presently available observational data, therefore, appear to favor a cosmology in which the universe is conceived of as being stationary, Euclidean, and slowly evolving, and in which photons lose a small fraction of their total energy for every distance increment they cover on their journey through space.

Future observations to be made with the Space Telescope and with ground-based CCD observational techniques should succeed in extending the data bases for a variety of cosmological tests into the $z > 1$ domain. In this high-z range it should be possible to check more precisely the nature of the departure from linearity evident in the observational data, an effect which is only marginally perceptible in the $z < 1$ domain. If such curvature is found to have a well-defined exponential form, then this would constitute additional supporting evidence strongly favoring the tired-light model and would serve as a check on the conclusions reached here.

Since the big bang hypothesis depends critically on the Doppler interpretation of the cosmological redshift, the abandonment of the Doppler interpretation in favor of the tired-light interpretation would necessitate that the big bang hypothesis itself be abandoned. However, this raises the responsibility of finding other explanations for the observational data traditionally cited in support of the big bang hypothesis.

The 3 K microwave background radiation is one example. However, it is worth noting that the proposal that the microwave background is of big bang origin is premised on the acceptance of a critical assumption. Namely, it is required that the fireball expansion velocity was of just the right amount to cause the blackbody radiation field to become redshifted by a factor of ~ 1500 down to its presently observed temperature of 2.8 K. The ad hoc nature of this expansion velocity assumption may be excused if one has at hand solid evidence independently verifying the occurrence of the big bang. However, in view of the cosmological test results discussed above, a somewhat more tentative stance is called for. Since the big bang hypothesis makes no rigid prediction as to the precise magnitude of the fireball expansion velocity, a big bang origin of the microwave background should no longer be regarded as a foregone conclusion. It is therefore desirable to consider alternative interpretations of the 3 K background radiation. See Clube (1980) or LaViolette (1983, Appendix B) for two possible non–big bang interpretations.

If the big bang hypothesis is to be abandoned, this also raises the necessity of finding some new explanation for the origin of the matter and energy making up the universe. A prospective alternative cosmology would be one that did not require creation to take place all at once in a singular primordial explosion event. Rather, the candidate cosmology would preferably be one in which matter is continuously created in a universe that remains cosmologically static. The cosmology of subquantum kinetics fulfills this requirement, since it predicts not only intergalactic tired-light behavior, but continuous matter creation as well. The physics of subquantum kinetics projects that subatomic particles on occasion are able to arise spontaneously in space and that, once materialized, such particles serve as nucleation sites for further particle creation (LaViolette 1985*c*). This physics also predicts that matter creation should occur most rapidly in regions of negative gravitational field potential, e.g., within stars and condensed masses, and particularly within the massive objects located in galactic cores. Such a continuous creation scenario is broadly compatible with the ideas of Jeans (1928) and McCrea (1964).

The subquantum kinetics cosmology would necessarily predict a much greater age for the physical universe as compared with the big bang model. For example, it might take many times 10^{12} years for a single self-nucleated particle to evolve into a galaxy of stars. However, since the rate of matter creation would grow exponentially over time, this would not pose a problem. Most of the matter in a given galaxy would be expected to be of relatively recent origin ($\Delta t \approx 10^{10}$ yr), being produced at a comparatively high rate by the condensed mass evolved at a galaxy's center. Thus, in the considerably extended lifetime of the universe, it is only in "recent" times that we have the privilege of observing a universe full of star-laden galaxies.

The steady state theory is another example of a continuous creation cosmology. The classic version of the theory (Bondi and Gold 1948; Hoyle 1948) proposes that single particles arise spontaneously throughout space in a continuous fashion, whereas the revised version, also known as the C-field theory (Hoyle and Narlikar 1966), proposes that matter creation preferentially occurs in regions of high material density where the gravitational potential field is particularly negative. However, both forms of the theory adopt the expanding universe hypothesis and thus are incompatible with the tired-light interpretation. Like the Friedmann model, the steady state expanding universe cosmology encounters difficulty in conforming to observational data. On the Hubble diagram, for example, the steady state theory prediction lies even further from the data trend than the $q_0 = 0$ Friedmann model; see, e.g., Sandage (1970). A similar circumstance is encountered in the log N–log S test; see Kellermann (1972).

It is also worth considering what significance the result of these cosmological tests have for the energy conservation law. If photons do exhibit tired-light behavior, then, one might ask, what happens to the energy that the photons lose? Is total energy conserved, with the lost energy emerging either as longer wavelength electromagnetic radiation, or perhaps as gravitational radiation wavelets? Or, is total energy nonconserved, the lost energy permanently disappearing from the universe? Subquantum kinetics predicts the latter, the nonconservation of photon energy being a corollary of the physics underlying this methodology. Such a "violation" of the First Law of Thermodynamics is not at variance with laboratory observation, since this cosmological energy loss is predicted to occur only in intergalactic regions of space. Even there, the effect would be very small. For $\beta = 5.1\%$ (10^9 lt-yr)$^{-1}$, the change in photon energy would amount to only one part in 2×10^{25} over a laboratory distance of 10 m. Regarding the theory's prediction of photon energy behavior in the vicinity of massive bodies, see LaViolette (1985*c*, *d*).

The cosmological test results presented here are seen to support a critical prediction of the subquantum kinetics cosmology. But the results also broadly support tired-light models in general. At the same time, the relatively poor performance of the Friedmann expanding universe model on these tests calls into question the Doppler shift interpretation of the cosmological redshift and thus weakens one of the prime supports of the big bang hypothesis. However, it must be acknowledged that there are other sets of observational data (e.g., the 3 K background) which have traditionally been cited in support of the big bang theory and which are not addressed in this paper in particular detail. For an alternate cosmology to be successful, these other sets of data must be explained in new ways. It is hoped that, with future work, adequate alternate interpretations of such data will be found.

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