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Is the Universe Expanding ?

"Les faits ne pénètrent pas dans le monde où vivent nos croyances, ils n'ont pas fait naître celles-ci, ils ne les détruisent pas; ils peuvent leur infliger les plus constants démentis sans les affaiblir"

Marcel Proust, *Du côté de chez Swann*

Introduction

Everybody knows that the universe is expanding and was born in a Big Bang some time ago! Not so: a small and eclectic minority of scientists think otherwise. For instance, Irving Ezra Segal, professor of Mathematics at MIT till he died on August 30 1998, thought that the universe is static and eternal as Albert Einstein had first suggested in 1917.

Segal was a very knowledgeable mathematician, member of the National Academy of Science of the USA, and author of many mathematical and physics papers and books. In particular, he has authored a treatise on mathematical extragalactic astronomy [1]. His numerous efforts at demonstrating the truth of his cosmological thesis, though well documented and truly scientific, have been met with scorn and indifference.

The theme of the present paper is well illustrated by the following quotation from Hannes Alfvén, a Nobel Prize winner who had repeatedly his papers rejected by astrophysical journals because they contradict conventional wisdom. He says:

> "When scientists are specialized, it's easy for orthodoxy to develop. The same individuals who formulate orthodox theory enforce it by reviewing papers submitted to journals, and grant proposals as well. From this standpoint, I think the Catholic Church was too much blamed in the case of Galileo -- he was just a victim of peer review." [2, p. 53]

This article is mostly devoted to the story of the denial of Segal's right of reply to articles purporting to demonstrate that his theory is wrong and about the shortcomings of such studies. We chiefly analyze one such study on the basis of a sharp and extensive rebuttal found in an unpublished manuscript [3] submitted by Segal and his collaborator Jeff Nicoll, from the Institute of Defense Analysis, but which was rejected by the Astrophysical Journal in 1998. **

The present paper attempts to be self-contained but for background material the reader is referred to the appended list of references and, in particular, to our recent paper with Arturo Sangalli: "Einstein's static universe: an idea whose time has come back? " [4]. From many universities, it is accessible at the following address :

http://www.ams.org/notices/200101/fea-daigneault.pdf

Testing the Expanding Universe Hypothesis

The belief in the Expanding Universe Hypothesis is first and foremost rooted in the phenomenon of the redshift which is the observed displacement towards the red end of the spectrum of the absorption lines of light or, more generally, of all electromagnetic radiation, reaching us from extragalactic objects.

The Hubble law, $cz = Hr$, which asserts that the redshift z of an extragalactic object is directly proportional to its distance r, H being the so-called Hubble constant and c the velocity of light, is indeed by far the most important falsifiable prediction of the Expanding Universe Hypothesis. Edwin Hubble only described the relation as "roughly linear" on the basis of a very small number of observations, which by today's standards are very limited, and using uncertain distance indicators. What could be seen already from Hubble's observations was that the larger the redshift was, the fainter the object appeared to be as a general rule. Since it is well known that the more distant an object is the fainter it appears to us, z was from the start taken to be a distance indicator i.e. a *monotone increasing* function of r.

Nevertheless, statistical evidence for the *linear* redshift-distance law is difficult to track down and therefore, as Segal says:

> "it is very important that it be tested rigorously by modern statistical methods and accurate measurements on objectively defined samples."

The Expanding Universe Hypothesis rests on a Doppler interpretation of the redshift about which Hubble himself expressed reservations. According to this interpretation, an object with redshift z is moving away from us at a speed $v = cz$ where c is the velocity of light. Indeed, as a conclusion to Hubble's 1935 article [5] written with Tolman, he declared:

> "It seemed desirable to express an open-minded position as to the true cause of the nebular redshift, and to point out the indications that spatial curvature may have to play a part in the explanation of existing nebular data."

It is of paramount importance to understand that refuting Hubble's linear law entails refuting the Expanding Universe Hypothesis when this hypothesis is coupled with the more generally accepted Copernican Principle (CP). The latter holds that space is homogeneous and isotropic and hence that our position (or anyone else's) in space is in no way privileged. This means that, at any time, any two points of space are equivalent and similarly for any two spatial directions originating from any one point. This principle implies in particular that space retains its shape as it expands and is embodied in the definition of the Friedman-Robertson-Walker (FRW) spacetimes which model expanding universes. [32 p.134; 33 p.135 –136]

That the shape of space is assumed to remain unchanged as the expansion takes place means that the riemannian metrics of space at two different instants are homothetically related i.e. that the metric at one instant is the product of a strictly positive constant (dependent on these instants) with the metric at the other instant. This entails that the distance between two points of space at the first instant is similarly related to the distance between those same points at the other instant.

An intuitive understanding of this is notably enriched by thinking of space as (the boundary of) an inflating balloon, a 2-sphere. One sees readily that the greater the distance between two given dots on this balloon, the faster these dots move apart as the balloon expands. The relationship is linear and it is easy to demonstrate in this case that the so-called Hubble constant H, which is a function of time, is then the quotient $S'(t)/S(t)$ where $S(t)$ is the radius of the balloon at time t and $S'(t)$ its derivative with respect to time. No assumption is needed regarding the functions $S(t)$ and its derivative and the same proof works with a 3-sphere in place of the 2-sphere. Indeed, the formula $H = S'(t)/S(t)$, where $S(t)$ is suitably interpreted and known as the radius of the universe, is valid in general no matter what the shape of space is, the Copernican Principle being assumed.

[32, p. 135-137]

Segal has developed a cosmological theory incorporating the Cosmological Principle, known as Chronometric Cosmology (CC) which is based on Einstein's original 1917 model for the universe and in which the redshift appears as a consequence of the curvature of space, a fact unnoticed by Einstein who abandoned his model after the expansion of the universe had been largely, and, it would appear today, quite prematurely, recognized as an established fact. However, in CC, the redshift-distance relationship is quadratic, taking the form $z = Kr^2$, for moderate values of z, instead of being linear. This Einstein Universe (EU) in which space is a 3-sphere of fixed radius and Minkowski spacetime (M) in which space is ordinary Euclidean space, are the only two non expanding FRW spacestimes. In EU the redshift mechanism proposed in CC is entirely different from the Doppler one and there is no redshift in M of the CC type.

Beginning in the 1970s, Segal together with a few collaborators published several articles that presented rigorous statistical analyses of all available and reliable astronomical data they could get hold of. These invariably concluded in favor of the quadratic law and found the linear law to be untenable. In spite of this, these studies remained largely ignored by the astronomical community establishment for whom the expanding universe idea and its offspring the Big Bang Cosmology (BBC) had become a dogma.

The ultimate test of a physical theory is its capacity for the prediction of directly observed quantities. The impossibility of distance measurements to extragalactic objects prevents the direct validation of any distance-redshift relationship. Tests must be based on consequences of putative such relationships involving only measurable quantities.

Chief among such variables are the apparent magnitude m, which is a measure of the luminosity of the object as it appears to us, the redshift z of this object, and its apparent angular diameter. From an observation (m, z) on an object and on the hypothesis of the validity of a given cosmology C, i.e. a distance-redshift relationship, one can deduce the absolute or intrinsic magnitude M of this object. The absolute magnitude is the apparent magnitude the object would have if it were placed at a fixed (but arbitrary) distance, the same for all objects.

For instance, the relationship defining the cosmology C may be $z = Kr^p$ where p is 1 in the case of the Hubble law and p is 2 in the case of the quadratic law. Then the following formula can be established:

$$m = (5/p)\mathrm{Log}\, z + M$$

For fixed z (and p), the larger m and M are, the fainter the object is. The larger z is, the more distant the object is.

Other than the existence of the two contenders p = 1 and p = 2 for which there are theoretical indications, there is no particular reason for assuming a relationship of the kind $z = Kr^p$. Yet, this places the two rival cosmologies in a family out of which we may aim at selecting the member best in accord with the available observations. Segal and associates contend that p = 2 comes out the winner on all counts. Of course, if this is correct, it does not prove that Chronometric Cosmology is true beyond reasonable doubt as a physical theory can only be disproved.

On the basis of a statistically valid sample S of measurements (m, z) one can derive the luminosity function LF(C) predicted by a given cosmology C . This function LF(C) is the probability distribution of absolute magnitudes of extragalactic objects if C is true. The determination of LF assumes the hypothesis LU of luminosity uniformity. It is widely agreed on, at least for relatively small redshifts. Luminosity uniformity is to the effect that the probability distribution of the intrinsic luminosities of the sources is independent of the location of the sources.

Without LU, the question of whether any putative distance-redshift relationship is correct becomes moot. For large values of z, proponents of the Big Bang Cosmology hold that LU is no longer valid as they claim that largely unknown evolution has taken place since this far away radiation was emitted whereas in Chronometric Cosmology, which holds that the universe is static and eternal, LU is assumed for all values of z.

This determination of the LF has to overcome the so-called observational magnitude cutoff bias (OCB). To put it in a nutshell, the OCB is to the effect that far away objects are not as easily detected as nearer ones. Following suggestions from statisticians Michael Woodroofe and Herman Chernoff, Segal established a statistical routine which he called ROBUST and which "J. F. Nicoll brilliantly programmed for use on a small computer". This routine enables the efficient nonparametric estimation of the luminosity function and the testing of the consistency of the predictions of cosmological theories with observations obtained from a sample.

The ROBUST computation of the luminosity functions makes no further assumptions than luminosity uniformity and, as far as the observations to be used are concerned, the absence of discrimination in the selection of objects on the basis of apparent magnitude down to a limiting apparent magnitude. In particular, contrary to some other algorithmic methods or to some misconceptions of CC, it does not presuppose any uniformity on the spatial distribution of the sources though it may lead to results compatible with this idea on a sufficiently large scale in the case of a particular cosmology. In the case of samples where apparent diameters are used instead of apparent magnitudes, LU is replaced by a similar assumption stating that the distribution of absolute diameters is independent of the distances of the sample objects or equivalently that there is no evolution in angular diameter up to the maximal value of z involved in the sample. Also then, the absence of discrimination in selection on the basis of apparent diameter, down to a limiting diameter, is assumed.

The ROBUST algorithm had a hard time drawing attention: as Segal writes [6, p.72]:

> "Following a year or two of rejections from journals in the U.S., a letter summarizing it was accepted by Astronomy & Astrophysics, subject to the referee's stipulation that no comparative cosmological results be included!"

Without entering into the details of the mathematical description of ROBUST, it is essential to note that the estimation of the LF is achieved by approximating it by a histogram as is often done in any experimental science. This implies a choice of binning i.e. a choice of the number of bins (the rectangles constituting the histogram) and of bin sizes (the widths of the bins). Once this choice is made, the estimation consists in determining the parameters which are the heights of the bins. This is done by maximum likelihood estimation on the basis of a statistically valid sample of data (m, z) or of a sample using the apparent diameters in place of the apparent magnitudes.

Several possibilities exist for the binning: for instance, one can use the same number N of equal-sized bins for all cosmologies to be compared, in which case a cosmology with a more extended LF would have a larger bin size than a cosmology with a less extended LF. The extent or range of the LF(C) goes from the brightest to the faintest absolute magnitude according to cosmology C. For the cosmology C(p) described by the formula $z = Kr^p$, this range R(p) is typically monotone decreasing with increasing p. Or else, one may use the same bin size for all cosmologies to be tested in which case the number of bins will vary with the cosmology thus yielding a larger number of bins, hence of parameters, to a cosmology with a more extended LF.

In view of this, smaller values of p are favored over larger ones in this latter kind of binning as they benefit from more degrees of freedom. Hence using a fixed bin size, the same for all values of p assuming a relationship $z = Kr^p$, would not be statistically appropriate for the estimation of p, i.e. determining which value of p best describes the observations.

Given a sample, the relative merits of contending cosmologies are measured on the basis of the ability of their respective LF to predict the values taken by directly observable statistics (or known functions of such) in that sample.

Given a putative LF, a directly observable statistic t and a sample S (statistically valid or not) one may generate artificial observations out of the LF by constructing what is known as bootstrap samples using a Monte Carlo method. Taking the average (called the prediction) of the values the statistic t takes in a large number of such samples and subtracting it from the value (called the observation) t takes in the sample S, yields the error in the prediction of the value of t on the basis of LF or on the basis of a cosmology C in case LF is LF(C). Analyzing the distribution of the values of t over the bootstrap samples gives an estimation of the probability of deviations as large as those observed between predictions and observations.

> " In observational practice, LF bins are most commonly 1 magnitude, but on occasion 0.5 mag. or as much as 2 mag. There appears to be no reported evidence of any structure in observational LFs on a scale finer than 0.5 mag., and the plethora of known perturbative but not directly observational effects on measurements, - absorption, peculiar velocities, possible bulk motions, clustering and conceivable gravitational effects, etc. – suggest that the use of substantially finer binning would probably be physically unrealistic. " [3, p. 12, 13]

Despite the fact that taking the same bin size for comparing the various cosmologies C(p) impairs statistical equitability by favoring lower values of p over larger ones, thus favoring p = 1 over p = 2, it is found that the comparative predictive efficiency of the various C(p) depends rather little on which type of binning is used. [3, p. 12]

The Koranyi and Strauss challenge to Chronometric Cosmology

> " Despite the importance of Segal's claims over the years there has been very little response in the literature to this work ".

Thus spoke Daniel Mark Koranyi (Ph.D. Harvard 2000) and Michael A. Strauss (Ph.D. Berkeley 1989) in their 1997 paper [7] critical of the quadratic law on the basis of a sample of Karl B. Fisher (Ph.D. Berkeley 1992) et al. The sample, hereafter called S7, consists of most data picked up by the *Infrared Astronomical Satellite* in a survey called an IRAS survey for that reason. This particular survey is labeled FIRAS by Segal et al (F as in Fisher). It is a quite substantial enlargement of an earlier one labeled SIRAS (S as in Strauss) that they had used in [8, 9].

A good point for Koranyi and Strauss (henceforth KS) is that, unlike so many others, they recognize the importance of tests of the redshift-distance law.

In addition to the two kinds of binning that we have described, yet a third kind is used by Segal et al in [8, 9, 10] for instance and by KS in [7]. We will not describe it except to note that it allows all cosmologies the same number of adjustable parameters. KS argue that the number N =10 of such parameters with which Segal et al had been working is too small and unduly favors C2. They say that the number should be increased to at least N = 25. Using this number and the FIRAS sample S7, they claim that " the Hubble law is indeed more strongly supported by the analysis than is the quadratic redshift-distance relation." But they concede that " the difference between models is not as stark as one might expect. " However setting N= 25 leads to bin sizes of the order of 0.1 magnitude which, as we have noted, is unusual and judged physically unrealistic by Segal et al.

This of course is taken note of in the unpublished and rejected rebuttal [3] of Segal & Nicoll (henceforth SN). But SN accept to play the game with small bin sizes to respond to the claims of KS. Working with the two kinds of binning that we have first mentioned, they allow values of N (the number of equal-sized bins) ranging from 5 to 100 and equal sized bins of 1 magnitude down to very fine bins of .1 mag. or less.

To determine the optimal value of p, they study all 20 values of p for which 1/p (a statistically more natural parameter than p by virtue of the noted relationship between M, m and z) ranges from 0.05 to 1 in steps of 0.05. This, they do using seven samples labeled S1 up to S7 the first six of which they hold to be amongst the best available for the purpose at hand and S7 being, as already noted, most of the enlarged IRAS survey FIRAS used by KS.

With one exception, all tested samples behave similarly no matter the binning used, up to the extremely fine one advocated by KS, not only favoring p = 2 over p = 1 but declaring the value of .5 for 1/p near the optimal one. The only exception is the KS sample S7 and only under physically unrealistic and unusual very fine binnings. Illustrations depicting the almost optimality of the value .5 of the parameter 1/p can be found in [6, 10].

> "The overall cosmological thrust of S7 is essentially identical to that of the other six samples, in being quite favorable to C2 and quite unfavorable to C1, when normal observational binning is used. Such bins of 1.0 or 0.5 mag. already provide C1 with many more adjustable parameters than C2 but KS argue for still more" [3, p.4].

SN opine that :

> "These statistically quite exceptional features of the KS sample appear to represent an artifact deriving from nuanced discretionary adjustments and selections. " [3, p.4].

They say that the KS sample is " neither truly directly observed nor cosmology-independent, and remarkably sensitive to binning" the data having been corrected in a selective manner thus rendering the FIRAS sample inhomogeneous. [3, pp. 30, 31, 32]

Such corrections, qualified as ‘inherently uncertain’, are indeed acknowledged by Fisher et al in [11, p. 71].

To support their opinion, SN make several arguments of which we briefly list two. In the first place, an analysis of a subsample of the KS sample S7, labeled S8, representing about 40% of the latter, and obtained by deleting the clearly identified data that may have been contaminated by these corrections, leads to the same conclusions as the other six samples even when using the quite fine binning of 0.1 mag. as argued by KS. [3, p. 34]

Secondly:

> "A further anomaly is the fact that the S6 sample shows none of the sensitivity to binning shown by the KS sample S7, although it is a subsample, apart from the corrections to the flux and redshift assignments made in S7. " [3, p. 35]

SN find many faults with the statistical methodology of KS. They rightfully charge that:

> " KS ignore basic degrees of freedom issues….In particular, the chi-square statistics

> presented by KS are devoid of theoretical statistical validity " [3, p.39, 40].

Though SN do not elaborate on this point, it may be said that the KS claims are based on a wrong use of the chi-square test. It is wrong on three counts. First, the estimation of the parameters must be based on the observed frequencies (in the 20 bins used for the test) and not on the original observations [12]. Secondly, it is the expected (or hypothetical) frequencies in each of the 20 bins which must be larger than 5 and not the observed frequencies [13, p. 440]. Third, should there be theoretical (or expected) frequencies smaller than 5, some bins should then be amalgamated and such bins cannot simply be ignored in the computation of the chi-square statistic.

SN also challenge the KS claim that spatial homogeneity considerations favor C1. On the basis of their own sample S7 and also of a different one at higher redshift, they find that the evidence clearly favors C2 over C1, but spatial homogeneity (or uniformity) SU appears quite inexact in both cosmologies in the lower redshift regime though it may be applicable at high redshifts. [3, pp.4, 38 and Figure 20]

SN conclude with the comment that:

> "The main problem with the KS analysis is however probably not so much the heuristic statistical methodology, as its unjustified extension to binning that is much finer than normal observational usage, given that the data incorporates uncertain nuanced corrections and assignments [of redshifts] that effectively, if no doubt unwittingly, favor the linear law ". [3, p. 41]

The following comments of Segal extracted from his correspondence with the editor of the Astrophysical Journal in connection with the submission of the (later rejected) SN manuscript [3] are illuminating.

Referring to a first referee's comments, Segal writes in his letter of 12 December 1997 :

> "The review states that there are better samples than those used, but makes no specific references to such. Inquiries among astronomers, including all who are members of the National Academy of Sciences, have failed to elicit any references to samples that were clearly objectively selected (e.g. complete) and provide nontrivial positive indications for the linear law."
>
> "It is widely accepted as a matter of basic scientific methodology that while a scientific theory can never be proved, it can be disproved. Failure of some basic predictions of the theory to agree with direct model-independent observation shows it to be incorrect....Deviations of its predictions from direct observations averaging more than 40 standard deviations, for the maximum error in the six samples considered, with normal binning of 1/2 magnitudes, disestablish the linear law by normal scientific standards, in the absence of extremely large ancillary perturbations. With the finer binning of .1 magnitude the results are similar."

After a second referee had filed a longer report, Segal writes in his "*Reply to astronomical referee*" enclosed with his letter of 23 January 1998 :

> "The referee presents clearly subjective criticisms of all of the samples except one, which he commends. By objective standards, this is the sample that has the least to recommend it, but coincidentally is the sample on which Koranyi & Strauss base their criticisms of our article on infrared data. All of the samples treated are taken from the published literature. We had no hand in the selection, observation, correction, or

> reporting of any of them. This contrasts in a methodologically important way with the sample used by Koranyi & Strauss, in which Strauss has a major hand in all aspects, in addition to the comparison of the observations with theory. It is difficult to make discretionary adjustments and corrections to data that are truly objective when one favors a particular theory that will be tested by the data."

Among the (first) six samples tested, three are subsamples of a very extensive one comprising more than 10,000 galaxies of well known French astronomer Gérard de Vaucouleurs, "a notably scrupulous man who suggested that we use the sample as a test base " says Segal in the same " *Reply* ". A distinguished and skeptical astrophysicist, Jean-Claude Pecker, once described Gérard de Vaucouleurs, as a man reputed for "sticking primarily to observational data". The full sample had earlier been used by SN in [6, 14] with the same results.

The other samples in the set S1-S7 have also been used in other publications of Segal and collaborators. For instance S7 is used in [6, 10] but only with ordinary bin sizes. It is only in the rejected paper [3] that the defects of S7, and only under very fine binning, are visible and pointed out. The insensitivity of analyses conducted with statistically valid samples even under very fine binning is further illustrated in [15].

The cosmological constant: a case of disinformation

The cosmological constant Λ (lambda) was introduced by Einstein in his 1917 paper that was the starting point of modern cosmology. It is pertinent for Chronometric Cosmology which uses Einstein's initial model of the universe put forward in this 1917 paper. Ever since the Expanding Universe Hypothesis became established dogma, Λ has been largely decried and derided. Nevertheless conventional cosmologists now appear to be in dire need of it to reconcile new data with their beliefs.

Quite independently of many astrophysicists' present love affair with Λ, more cautious Jean-Claude Pecker, from the Collège de France, writes:

> "..there is no reason...why we should not use a cosmological constant Λ different from zero........Had we used in the past Occam's razor as some use it now (first to assume Λ = 0, then to assume that the photon mass = 0), we could as well have missed gravitation (G = 0 ?) or quantum physics (h = 0 ?)" [16, pp. 9, 13, 14]

Helped by the media, diehard myths about the history of Λ resist eradication. One may judge from the following excerpt from a letter Segal wrote to the New York Times on March 3, 1998 which the newspaper chose not to publish :

> "Today's Times (p. C2) repeats for the nth time the apocryphal story that "Soon after Edwin P. Hubble discovered the expanding universe in 1929, Einstein renounced the cosmological constant as the greatest blunder of his career". Having been associated with the Einstein group when assistant for some years in the 1940s to his general relativistic colleague Oswald Veblen, I was skeptical of the authenticity of this old chestnut, which is a favorite among cosmologists who would like to support their views with Einstein's authority, and inquired of John Stachel, one of the editors of the Einstein's papers, regarding its documentation. He said they had searched far and wide for someone who had actually heard him make this statement, and came up empty-handed.
>
> What is on record is that Einstein was strongly opposed to the Expanding Universe

models of the Russian meteorologist Alexander Friedman and of the Belgian Abbé George Lemaître in the 1920s. His later acceptance of the Expanding Universe states only (in a footnote) that if he had known about Hubble's law, he would not have proposed his 1917 model incorporating the cosmological constant. This is a far weaker admission of error, and to the extent that the Hubble law may be questionable, it is hardly a reversal of his earlier views at all.

> The early Einstein model, cosmological constant and all, had a lot going for it, including a satisfying description of the large-scale gravitational structure of the universe, and consistency with the law of conservation of energy, which is lost in the Expanding Universe model. But it was rejected because of the fixed naive idea, which the Hubble law supported (altho Hubble himself did not), that the redshift was a Doppler, 'motion' effect, and so couldn't happen in the Einstein Universe.

> Today, however, the Einstein model is alive and well, providing the basis for a redshift theory that is presently heterodox but quantitatively very well documented by the observations in large disinterested samples of galaxies and quasars, as shown by two dozen or so papers in the major astronomical journals, and which finds the Hubble law and the whole concept of the Expanding Universe to be seriously flawed."

In his May 23, 1923 letter to Hermann Weyl, Einstein writes "If there is no quasi-static world, then away with the cosmological term". In 1931, referring to the experimental discoveries of Hubble, Einstein formally abandons the cosmological term, 'which is theoretically unsatisfactory anyway'. [17, p. 288]

Two other challenges to Chronometric Cosmology

To illustrate further the strange and unscientific attitude of the astronomical community towards Segal's dissent from conventional ideas, let us look briefly at two more attempts by members of the establishment at defusing the threat posed by Chronometric Cosmology to the accepted dogma.

First the 1979 article by R. M. Soneira [18]. Its author pedantically declares from the outset, referring to Nicoll & Segal papers then in existence on the quadratic law:

> "There is a possibility that if these incorrect analyses remain unchallenged they may somehow entrench themselves into the literature as a real uncertainty…..Our method does not require statistical analysis." !

We will not enter into the details of Soneira's critique. What is important is that Segal & Nicoll published devastating but subsequently ignored rebuttals [19, 20, 21, 22] of Soneira's work.

If one is looking for a demonstration of the linear law, one should normally expect to find a good one in a voluminous treatise such as P. J. E. Peebles' "Principles of Physical Cosmology" [23] written by a firm believer in the Expanding Universe Hypothesis. What one finds there (p. 82-93), in addition to a reference to a 1991 "private communication" of T. Shanks, is based entirely on the above mentioned work of Peebles' student Soneira purporting to defeat Segal's theory with no mention at all of the Segal & Nicoll's replies. Soneira's work is also referred to on the first page of the KS paper discussed above without any reference to these replies.

The second incident which we also very briefly report concerns the 1992 paper by statistician

Bradley Efron and astrophysicist Vahé Petrosian from Stanford University [24]. This interesting paper tackles the problem of testing a proposed redshift distance relation from a different angle by asking whether it is compatible with luminosity uniformity (LU).

The theoretical statistical development appears sound and leads to the conclusion that the linear law is compatible with LU for small redshifts whereas the relationship of chronometric cosmology is not. However, Petrosian informed us that the data which were used are not easily available and, in any case, are unreliable as they have been largely criticized. It would be interesting to use the statistical technique developed in this paper for further testing.

From the present viewpoint what is important, is that again a prepared response (which we do not have) that Segal submitted to the Astrophysical Journal was rejected, thus again offending the democratic process in scientific communication.

The discordant redshifts of Halton Arp and the remedy of Emil Wolf

The lack of openness on the part of the astronomical establishment towards observations or ideas challenging the conventional wisdom is further illustrated by the career of Halton Arp. A distinguished observational astronomer, he was for 29 years a staff member of the Observatories known originally as the Mt. Wilson and Palomar Observatories. He is currently at the Max-Planck-Institute in Munich. His most recent 1998 book "Seeing Red" [25] and also his 1987 book "Quasars, Redshifts and Controversies" [26] expound the details of his findings and tell the vicissitudes of his scientific life and publications. He is also the author of an "Atlas of Peculiar Galaxies" (1963) as well as numerous articles in scholarly journals.

Essentially, what Arp teaches, is that the redshift cannot be a distance indicator as he lists numerous '*discordant redshifts*' consisting of pairs of celestial objects having very different redshifts which must nevertheless be at the same distance from us since he views them being in interaction.

Arp's observations have generally been disregarded or denied by mainstream cosmologists. A 1986 important discovery (see for instance [27, 28]) that its finder calls "Correlation-induced spectral changes" might explain Arp's discordant redshifts. It was made by Emil Wolf, Professor of Optical Physics at the University of Rochester, and it appears to have been generally ignored or incorrectly explained. Wolf is coauthor with Max Born of the monumental work on optics [29].

According to Wolf's theory, in some well defined circumstances one may "generate shifts of spectral lines which are indistinguishable from those that would be produced by the Doppler effect" [28, p.48]. These theoretical predictions were subsequently verified by experiments conducted by two of Wolf's colleagues, G. M. Morris and D. Faklis [30, 31].

It is appropriate here to recount Nature's rejection of the Morris-Faklis note [30] on the basis of the flabbergasting referee's comment: "This is a cute experiment, but since Wolf's theory is wrong anyway, their note should not be published"!

Arp remains skeptical about this theory of Wolf, apparently because it predicts not only redshifts but also, in some cases, blueshifts as well. However, in all cases for which Wolf and his colleagues did some modeling only redshifts occurred.

For his part, Segal seems to minimize the importance of Arp's findings in declaring, after offering some possible explanation of his own, that "the effect on overall quasar statistics would be marginal and hardly detectable until substantially larger complete samples had been observed". In any case, it is possible to interpret Wolf's discovery as bridging the gap between chronometric cosmology and Arp's observations. Let us have an open mind !

References

[1] I. E. Segal, "*Mathematical Cosmology and Extragalactic Astronomy",* Academic Press, New York, 1976.

[2] Eric Lerner "*The Big Bang never happened* ", Random House, 1991

[3] I. E. Segal & J. F. Nicoll, "Parallel tests of redshift-distance laws in diverse wave bands" unpublished 62 page manuscript including 15 tables with, in addition, 21 figures, dated 10 September 1997, rejected by the *Astrophysical Journal*.

[4] Aubert Daigneault and Arturo Sangalli, "Einstein's static universe: an idea whose time has come back?" *Notices Amer. Math. Soc.* 48 (2001), no. 1, 9--16.

[5] E. P. Hubble & R.C. Tolman, (1935), *Astrophys. J.* 82, 302-337.

[6] I. E. Segal, " Modern statistical methods for cosmological testing" p.67-81 in "*Statistical challenges in modern astronomy II* " / G. Jogesh Babu and Eric D. Feigelson, editors. ; New York, Springer, c1997 ; LC Call No.: QB149.S74, 1997

[7] Daniel M. Koranyi and Michael A. Strauss, "Testing the Hubble Law with the IRAS 1.2 Jy Redshift Survey", *Astrophysical Journal* , vol. 477: p. 36-46, March 1 1997.

[8] I. E. Segal & J. F. Nicoll "Apparent nonlinearity of the redshift-distance relation in infrared astronomical satellite galaxy samples" ; *Proceedings of the National Academy of Sciences*, Vol. 89, p. 11669 (1992).

[9] I. E. Segal, J. F. Nicoll, P. Wu, P., & Z. Zhou, "Statistically efficient testing of the Hubble and Lundmark laws on IRAS galaxy samples", 1993, *Astrophysical J*, 411, pp. 465-484.

[10] I. E. Segal & J. F. Nicoll, "Astronomy Phenomenological Analysis of Redshift-Distance Power Laws ", *Astrophysics and Space Science*, 274 : 503-512, 2000, Kluwer Academic Publishers.

[11] K. B. Fisher , J. P. Huchra, M. A. Strauss, M. Davis, A. Yahill, D. Schlegel, " The IRAS 1.2 Jy Survey : Redshift Data ", 1995, *Astrophysical J. Supplement Series*, 100, pp. 69-103.

[12] Herman Chernoff and E. L. Lehmann, "The use of maximum likelihood estimates in chi-square tests for goodness of fit", *Annals of Mathematical Statistics*, vol 25, pp. 579-586 (1954).

[13] Maurice G. Kendall and Alan Stuart." *The advanced theory of statistics* ", VOL 2, 1961, Oxford University Press, 1987.

[14] I. E. Segal & J. F. Nicoll, "Phenomenology of the Local Angular Diameter to Redshift Relation ", *Astrophysical Journal*, 488:L87–L90, October 20, 1997

[15] I. E. Segal, "Is redshift-dependent evolution of galaxies a theoretical artifact ?" ; *PNAS*, November 23, 1999, vol. 96, no. 24, 13615-13619

[16] Jean-Claude Pecker, "Some critiques of the Big Bang cosmology" in "The Big Bang and

alternative cosmologies. A critical appraisal", a conference held in Bangalore, India, 6-8 January 1997.

[17] Abraham Pais, "'*Subtle is the Lord...' The Science and the Life of Albert Einstein*", Oxford University Press, 1982.

[18] R. M. Soneira, "A cosmological redshift-distance square law?", *Astrophysical Journal. Letters to the Editor*, vol.230, no.2, pt.2, p.L63-5,1 June 1979.

[19] Segal, I.E, "Some recent tests of the chronometric cosmology", *Proceedings of the National Academy of Sciences of the United States of America*, vol.77, no.1, p.10-13, Jan. 1980

[20] I. E. Segal, "The redshift-magnitude relation for bright galaxies at low redshifts", *Monthly Notices of the Royal Astronomical Society*, vol.192, no.3, p.755-67, Sept. 1980

[21] J.F. Nicoll & I.E. Segal, "Spatial homogeneity and redshift-distance laws", Proceedings of the National Academy of Sciences of the United States of America, vol.79, no.12, p.3913-17, June 1982

[22] J.F. Nicoll & I.E. Segal, "Correction of a criticism of the phenomenological quadratic redshift-distance law", *Astrophysical Journal* , vol. 258, no.2, pt.1, p.457-66, 15 July 1982.

[23] P.J. E. Peebles, "*Principles of Physical Cosmology*", Princeton University Press, 1993, 718 pages.

[24] Bradley Efron and Vahé Petrosian " A simple test of independence for truncated data with applications to redshift surveys " *Astrophysical Journal,* vol.399, no.2, pt.1, p.345-52; 10 Nov. 1992.

[25] Halton Arp, "*Seeing Red: Redshifts, Cosmology and Academic Science*", 306 pages plus 8 pages of colour plates, Apeiron, Montreal, ISBN 0-9683689-0-5. Advertised on Apeiron's website at http://redshift.vif.com/

[26] Halton Arp, "*Quasars, Redshifts and Controversies*" (1987); 198 pages, Interstellar Media; ISBN 0-941325-00-8

[27] Emil Wolf "Non cosmological redshifts of spectral lines", Nature, Vol. 326, pp. 363-365, 1987.

[28] Emil Wolf, "The Redshift Controversy and Correlation induced Spectral Changes", in *Waves, Information and Foundations of Physics*, R. Pratesi and L. Ronchi eds. Conference Proceedings vol. 60 (1998), 41-49 (Italian Physical Society, Bologna, Italy).

[29] Max Born & Emil Wolf, "*Principles of optics : electromagnetic theory of propagation, interference and diffraction of light* ", Cambridge University Press, 1997, xxviii, 808 p., ISBN 0521639212 (pbk.) 1997.

[30] G. M. Morris and D. Faklis, " Effects of source correlation on the spectrum of light", Optics Communications, vol. 62, no. 1 p. 5-11, 1987.

[31] G. M. Morris and D. Faklis, " Spectral shifts produced by source correlations", Optics Letters, vol. 13, no. 1 p. 4-6, 1988.

[32] S. W. Hawking and G. F. R. Ellis, "*The Large-Scale Structure of Space-Time*", Cambridge Univ. Press, 1973.

[33] H. Andrillat, "*Introduction à l'étude des cosmologies*", Librairie Armand Colin, Paris, 1970.

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