The Ephemeris

Focus and book reviews

Space is 3-Dimensional

"Dimensionality" is understood here in the sense of degrees of freedom or, equivalently, the number of independent basis vectors into which an arbitrary vector can be decomposed. This is a *topological* dimension, quite different from the non-integral *Hausdorff* dimensions made popular by *Julia* sets and by *Mandelbrot*'s "fractals".

Einstein's "special" and general relativity theories do not content themselves with *three* spatial dimensions and a "flat" *Euclidian* geometry. However, this "mathematization" of space is not only unnecessary, but it twists physical ideas into meaningless kinematical games that are not in agreement with empirical fact.

Dynamics and 3-Dimensionality

Newton's three "laws" are, actually, three *definitions*:

(*i*) of the inertial frame
(*ii*) of the force of inertia and
(*iii*) of the closed system.

These definitions are, both in principle and in practice, fundamental to all physics—not only to dynamics. The explicit form of a force, which has to balance the force of inertia, is a *force-law*. All physical laws, *e.g.* the "$1/r^2$ law," Maxwell's equations, the law of diffusion, the law of radioactive decay, were discovered in an (approximate) inertial frame of reference (IFR). The very definition of the IFR already refers to two kinds of motion: *Rotational* motion ("an IFR is not allowed to rotate") and *translational* (or *linear*) motion ("a material body not acted upon by forces moves uniformly along a straight line"). The marvellous palace of Newtonian dynamics is built upon the idea that *every* motion is a combination of translational and rotational motions, a so-called *instantaneous roto-translational motion* (with a center of rotation at every moment). According to a general theorem concerning the effect of a system of (sliding) forces upon a rigid body, the action of a system of forces is equivalent, at every moment, to a resultant force (R) and a resultant torque (M_o). The four possible situations, namely $R=0$ and $M_o=0$, $R\neq 0$ and $M_o=0$, $R=0$ and $M_o\neq 0$, $R\neq 0$ and $M_o\neq 0$, correspond to equilibrium, translational motion, rotational motion, and roto-translational motion, respectively.

The two vectors, R and $M_o = R\otimes r_o$ are qualitatively different, *polar* and *axial* vectors, respectively, and correspond to the two fundamentally different kinds of motion, *translation* and *rotation*. A *polar vector* has no peculiarities related to the dimensionality of the physical space—it behaves equally well in 1D, 2D, or 3D. An *axial* vector, however, defined by a *vector product*, (equivalent to a second order antisymmetric tensor), requires a *third* dimension. (Even for the hypothetical, abused, 2-D creatures, the third dimension is hinted by the fact that a bi-dimensional sheet has two faces!). The very idea of the "sense of rotation" is conceivable only when a third dimension—as for an advancing screw—exists. This is implemented in the definition of the *vector product*, allowing coherent definitions of: tangential velocity $\omega\otimes r$, moment of force $r_o\otimes F$, angular momentum $r\otimes mv$, Lorentz force $v\otimes B$, cyclotron (Larmor) motion, *etc*. Remarkably, Maxwellian electrodynamics, a tautological correspondence between *sources* (particles) and *fields* which requires for ist completion a *force law between moving charges*. For example, the (limited) Lorentz force is built upon a *polar* vector **E** and an axial vector **B**, which are responsible for translational and rotational motion of a charge. Remarkably, Planck [1] gave an axiomatic foundation to Maxwell's electrodynamics, based on the following postulates:

1. There are two kinds of vectors necessary to build-up electrodynamics: the *polar (electric) vector* **E** and the *axial* (magnetic) vector **B**.
2. The energy density of the electromagnetic field is: $\frac{1}{2}(\varepsilon_0\mathbf{E}^2 + \mu_0\mathbf{B}^2)$
3. The energy flux is represented by the Poynting vector $\mathbf{E}\times\mathbf{B}$.

This approach was further developed by Imai[2].

Long-Range Order and Dimensionality

Phase transitions in general and the possible occurrence of spontaneous magnetic order below some critical temperature T_c, in particular, have attracted attention on the role of dimensionality in condensed matter physics, too. The two important models, the highly anisotropic unidirectional *Ising* model and the isotropic *Heisenberg* model predicted no spontaneous magnetization in one dimension. In two dimensions, however, the rigorous *Onsager* solution of the *Ising* problem predicted (for the first time) a finite value of T_c. The experimental testing of various models was always plagued by the so-called "island structure" of ultrathin (below 10 nm) films which impeded the realization of "pseudo two-dimensional" films. When the epitaxial growth technique was finally mastered, the interest of research (driven, of course, by the interests of sponsors) was already shifting from magnetism to semiconductor physics applied to microelectronics.

As far as the *Heisenberg* model is concerned:

$$H = -\sum_{i,j} J(r_{ij}) S_i S_j \qquad (1)$$

(H, J, S_i = Hamiltonian, exchange integral, spin operator, respectively), the *Mermin-Wagner* thorem [3]—derived from the more general Bogoliubov inequality [4]—predicted that for covergence

$$\int_0^\infty J(r) r^2 \mathrm{d}r < \infty \qquad (2)$$

no spontaneous long-range order in one and two dimensions is possible. Besides the difficulty of finding materials in terms of an isotropic Heisenberg model and the equally difficult growth of (substrate-induced) stress-free continuous monolayer films, the situation was further plagued by the seemingly impossible task of calculating Heisenberg's exchange integrals $J(r)$ from first principles, *i.e.* from overlapping wave functions. It may come as a surprise that even textbooks on the *quantum theory of magnetism* actually work with "exchange parameters," *i.e.* phenomenological parameters to be fitted to experimental data. The indirect exchange (or *s-d*) model between localized ions *via* itinerant (*s*) electrons of *Ruderman*, *Kittel*, *Kasuya*, *Yoshida* (RKKY model of transition metals) provided -after several simplifications- an analytical form:

$$J(r) = -CF(2k_F r) \text{ where } F(x) = (x.\cos x - \sin x)/x^4 \qquad (3)$$

with C a constant, k_F the Fermi wave vector representing the momentum of conduction electrons in the metal .

For a quadratic dispersion law of the itinerant electron and for x larger than the nearest-neighbor (NN) distance, the above formula (3) fulfills in 3D the criteria for the *Mermin-Wagner* theorem. For x comparable with the NN distance, (3) yields a critical temperature of several hundred degrees K. For intermediate distances x, $F(x)$ oscillates, so that ferro- and antiferromgnetic ordering as well as paramagnetism (*i.e.* no ordering) are functions of x.

The popular but oversimplified Landau theory of second order phase transitions predicts—neglecting fluctuations—the following critical behavior for the order parameter m:

$$m^2 \propto (T_c - T) \qquad (4)$$

The behavior of the critical fluctuations, on the other hand, is governed by the Fourier transform of the generalized susceptibility which leads to the *Ginsburg criterion*:

$$\langle \delta m^2 \rangle / m^2 \propto [(T_c - T)/T_c]^{(d-4)/2} \qquad (5)$$

If the dimensionality d is higher than 4, the fluctuations of m can be neglected as compared to m itself, so that Landau's theory is supposed to work. If $d = 3$, the ratio $\langle \delta m^2 \rangle / m^2$ diverges for $T \to T_c$.

Wilson [5] has expressed the critical exponents as a function of $\varepsilon \equiv 4 - d$. For $d > 4$, these turn out to be independent of d. For $d < 4$, *in accordance with the universality hypotheses*, *the critical exponents depend only on the dimensionality of the order parameter and the dimensionality of space*. (They are independent of the symmetry of the crystal lattice, degree of anisotropy, kind and range of interactions, *etc.*) For many practical magnetic systems, the universality hypothesis was confirmed. The theory of phase transitions, however, provides no arguments in favor of or against the observed 3-dimensionality of space.

Highly Anisotropic Structures and Pseudo Dimensionality

Intensive research has been devoted to the unusual consequences of reduced dimensionality of some *materials*. *Nota bene*: Space always remains 3D, only the structure of the material becomes highly *anisotropic*, a fact which *mimics* reduced dimensionality. "One-dimensional metals," *i.e.* metals in which electrons are constrained to move preferentially in one direction by the molecular arrangement, are intrinsically unstable against the formation of a variety of distorted states at low temperatures. They may become magnetic or non-magnetic insulators, or possibly even high-T_c superconductors. The instabilities arise from the response of the system to weak perturbations; the response "blows up" when the temperature is lowered. On the other hand, *truly* 1D systems cannot undergo phase transitions at any T above absolute zero. *This apparent contradiction—that the system is unstable against distortions, but cannot distort—is removed by the actual 3D nature of the crystals.*

The 1/*r* argument

If one imagines the field produced by a point-like source as isotropically distributed "force lines," their density per unit area will decrease with the distance (r) from the source like the reciprocal surface area,

$1/4\pi r^2$, of the sphere with radius r. There seems to be a connection between this "$1/r^2$ law" and the 3-dimensionality of physical space. This corroborates well with the fact that the $1/r$ potential -which has to be a solution of the *Laplace* equation- is possible only in 3 dimensions.

Indeed, for

$$x \quad (1D)$$
$$r = \sqrt{(x^2+y^2)} \quad (2D) \qquad (6)$$
$$\sqrt{(x^2+y^2+z^2)} \quad (3D)$$

the Laplace equation

$$\partial^2\varphi/\partial x^2 \quad (1D)$$
$$0 = \Delta\varphi = \quad \partial^2\varphi/\partial x^2 + \partial^2\varphi/\partial y^2 \quad (2D) \qquad (7)$$
$$\partial^2\varphi/\partial x^2 + \partial^2\varphi/\partial y^2 + \partial^2\varphi/\partial z^2$$

has the respective solutions

$$A_1 r + B_1$$
$$\varphi(r) = A_2 \ln r + B_2 \qquad (8)$$
$$A_3/r + B_3$$

The third principle of general relativity, Einstein's "general theory of relativity," actually a so-called theory of gravity, is said to rely upon two principles:

(a) the principle of *covariance* and
(b) the principle of *equivalence*.

The gravitational field equations were postulated as:

$$G_{\mu\nu} = \kappa T; \quad G_{\mu\nu} \equiv R_{\mu\nu} - ½Rg_{\mu\nu} \qquad (9)$$

contains the contracted *Riemann* tensor, $R_{\mu\nu}$ and the scalar curvature, R. As a consequence of the Bianchi identities, $G_{\mu\nu}$ has the covariant derivative $G^{\mu\nu}{}_{;\nu} \equiv 0$. The latter identity means that the energy-momentum tensor of matter has a vanishing covariant derivative $T_{\mu;} \equiv 0$, too.

This, in turn, *implies a violation of the energy-momentum conservation principle for matter, expressed by means of ordinary derivatives*: $\partial_\nu T_\mu{}^\nu \neq 0$.

Now our concern is the inability of the theory to determine the value and the nature of the constant κ in (9). This is most clear recalling the spherically symmetric line element:

$$\mathrm{d}s^2 = c^2\left(1-\frac{2A}{c^2 r}\right)\mathrm{d}t^2 - \frac{\mathrm{d}r^2}{1-2A/c^2 r} - \\ -r^2\left(\mathrm{d}\theta^2 + \sin^2\theta \mathrm{d}\Phi^2\right) \qquad (10)$$

of the Schwarzschild solution, *i.e.* the "vacuum solution" of (4) with $T_{\mu\nu} \equiv 0$ which leaves the constant A undetermined. The usual way to fix A is to identify $2A/c^2r$ with the Newtonian solution A_3/r for which $A_3 = GM$ with M the gravitational mass of the source and G Newton's gravitational constant. In other words, *Einstein's theory needs a third additional principle, a correspondence principle with Newton's theory* in order to have any relevance to our material world, at all. This principle of correspondence has to be openly added to the principles of covariance and equivalence, respectively. As correctly pointed out by Narlikar and Padmanabhan[5], the Schwarzschild problem requires $T_1{}^1 = T_0{}^0$ on one hand and $T_0{}^0$ as the only non-zero component of $T_\mu{}^\nu$ for a source particle at rest on the other hand, which is a sheer impossibility.

In any case, Einstein's initial Machian program to derive the geometry of physical space from the distribution of matter failed. The theory was supposed to determine the metric tensor $g_{\mu\nu}$ starting with $T_{\mu\nu}$. It takes, however, the existence of three spatial dimensions for granted, even if $T_{\mu\nu} = 0$. Why on earth does Einstein's vacuum to have precisely *three* spatial dimensions?

General Relativity and Dimensionality

(a) In the *2D case*, an anti-symmetric tensor $A_{\mu\nu} = -A_{\nu\mu}$ has only one non-vanishing component A_{12}, since $A_{\mu\nu} = a\varepsilon_{\mu\nu}$ with a a scalar and the 2D Levi-Civitá symbol

$$\varepsilon_{\mu\nu} = \begin{cases} 1 & \mu = 1;\ \nu = 2 \\ 0 & \mu = \nu \\ -1 & \mu = 2;\ \nu = 1 \end{cases} \qquad (11)$$

Knowing that Riemann's curvature tensor has the symmetry properties

$$R_{\mu\nu\lambda\rho} = -R_{\nu\mu\lambda\rho} = -R_{\nu\mu\rho\lambda} \qquad (12)$$

it necessarily has the form $R_{\mu\nu\lambda\rho} = K\varepsilon_{\mu\nu}\,\varepsilon_{\lambda\rho}$. One can further show that

$$R_{\mu\nu} - ½Rg_{\mu\nu} \qquad (13)$$

which means—see (9)—that $G_{\mu\nu} \equiv R_{\mu\nu} - ½Rg_{\mu\nu}$ vanishes identically. Therefore, the energy-momentum tensor $T_{\mu\nu}$ vanishes identically, too. With no energy and no momentum the fields of an imaginary two-dimensional world cannot be physical at all!

(b) In the *3D case*, the symmetry properties (12), together with the identities of Bianchi and of Ricci:

$$R_{\alpha\mu\nu\lambda}\,\varepsilon_{\mu\nu\lambda} = 0 \qquad (14)$$

with $\varepsilon_{\mu\nu\lambda}$ a 3D Levi-Civitá symbol, reduce the number of components of both Riemann (7) and Ricci (8) tensors to *6*.

The following expression for *Riemann*'s curvature tensor

$$R_{\sigma\tau\lambda\rho} = R_{\sigma\rho}g_{\tau\lambda} + R_{\tau\lambda}g_{\sigma\rho} - R_{\rho\lambda}g_{\tau\rho} - R_{\tau\rho}g_{\sigma\lambda} + \\ +\tfrac{1}{2}R\left(g_{\sigma\lambda}g_{\tau\rho} - g_{\sigma\lambda}g_{\tau\rho}\right) \qquad (15)$$

holds in 3D only! In account of the field equations (4), one has:

$$R = 2\kappa T \qquad (16)$$

and

$$R_{\mu\nu} = -\kappa(T_{\mu\nu} - Tg_{\mu\nu}) \quad (17)$$

Therefore:

$$R_{\sigma\tau\lambda\rho} = -\kappa\begin{bmatrix} T_{\sigma\rho}g_{\tau\lambda} + T_{\tau\lambda}g_{\sigma\rho} + T_{\sigma\lambda}g_{\tau\rho} + T_{\tau\rho}g_{\sigma\lambda} + \\ +T\left(g_{\sigma\lambda}g_{\tau\rho} + g_{\rho\sigma}g_{\tau\lambda}\right) \end{bmatrix} \quad (18)$$

The latter relationship shows that Riemann's curvature tensor vanishes everywhere where the energy-momentum tensor $T_{\mu\nu}$ vanishes. In other words, in the absence of matter and fields (excepting the gravitational field!) space-time has to be plane (*i.e.*, zero curvature). In particular, the Schwarzschild problem is Euclidian!

Only in the 4D case can space-time have non-zero curvature in the absence of matter and the gravitational field have an independent existence in the sense of Einstein's theory. That this theory doesn't comply with energy-momentum conservation for matter is a different (and lethal) difficulty.

Physical and algebraic geometry

N-dimensional spaces and non-Euclidean geometries are well established branches of mathematics. Here we are interested in the geometry of the real world, the only object of physical research. We have always to keep in mind that geometry deals with things that have more than logical existence and must, therefore be founded on objective conditions, rather than on logical relations alone. Also, the relations of the elements of a geometrical object are expressible in the form of algebraic equations, but the opposite is not true: not all possible algebraic equations can be construed as geometric forms and figures. One can algebraically generalize Pythagoras'theorem to a sum of squares, but the geometrical meaning is lost for $N > 3$. Four dimensionality is geometrically inconceivable and unrepresentable[5]. Physicists collect all experimental data from the only available 3D and Euclidean world and we can'not transfer them to an *N*-dimensional , non-Euclidean, algebraic geometry.

One can well use a geometrical jargon and define an "orthogonal basis" $\{f(1), f(2),....,f(n)\}$ so that the integral over $f(i).f(j)$ vanishes for i different from j, but this has nothing in common with two lines being perpendicular.

The way Riemann introduced his "multiply-extended-manifolds" was seemingly trivial: "A point in motion generates a line, or a magnitude of one dimension; a line in motion at right angles to itself generates a plane, or a magnitude of two dimensions; similarly, a plane in motion at right angles to itself generates a volume, or a magnitude of three dimensions...And it is easy to see how this construction may be continued"!! It is definitely not!

The analysis of J.J.Callahan[3], "A Proof of the Parallel Theory and a Critique of Metageometry," has traced back the genesis of the non-Euclidean geometries, contradicting Euclide's fifth postulate, to Euclide's *definition through negation* of parallel lines: "Parallel straight lines are lines which, being in the same plane and being produced indefinitely in both directions, do not meet one another in either direction." Callahan's 1931 redefinition reads: "Parallel lines are lines that lying in the same plane are equidistant at equidistant points." With this definition, Euclid's fifth postulate can be proven as a theorem, so that non-Euclidean geometries are excluded.

One could, like Gauss, consider the intrinsic geometry of a sphere as non-Euclidean in a positively curved, two-dimensional space, but this does not change the fact that the sphere exists in a three-dimensional Euclidean space. The crux of the problem is that one has always to start with the three-dimensional , unique, physical space, which is just there, and than to abstract the (2D) plane and the (1D) straight line.

Euclidean space and uniform time are indispensable for the definition of velocity, thus for physics in general. In turn, uniform time, uniform motion and inertial frame of reference (IFR) imply each other, in spite of the "general relativistic" claim that IFR's were dethroned from their privileged status. As a matter of fact, all physical laws have been discovered in an (approximately) IFR

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Book Reviews

Weber's Electrodynamics, A. K. T. Assis (Kluwer, Dordrecht, 1994, ISBN: 0-7923-3137-0, US$ 125.00, 288 pages, Volume 66 of the series Fundamental Theories of Physics).

In science, heresy or heretical theory is considered to contain some kind of error, mistake, failure, delusion, fallacy, or unscientific argument. Those errors have several patterns: an error that arises owing to the generalization of phenomena through direct observational experiences—the Ptolemaic system as an example; an incorrect representation of an object by introducing a nonexistent entity, such as ether; a mistake caused by extending an application beyond the limitation of a fundamental theory. There are, also, many common mistakes due to unscientific procedures, subjective observations, or incorrect analyses.

A theory that does not come under the category of paradigm is considered heretical. No one denies the fact that Maxwell's theory of electromagnetism constitutes the present paradigm for the study of electromagnetic phenomena. In the middle of the 19th century, however, the theories on electrical forces and currents were not well settled. There were two main notions to deal with the theories: one based on the theory of action at a distance, and the other, theories based on the concept of fields and ether. Weber's electrodynamics theory, developed around 1846, is based on the principle of action at a distance. Maxwell's theory is based on the electric and magnetic field and the medium called ether.

Wilhelm Weber's theory on electrodynamics became heretical even though his conceptual framework permits the explanation and investigation of the known electromagnetic phenomena. The Weber force between two moving charges naturally conforms to Newton's third law, the action and reaction principle, but the standard Lorentz force does not. The formulation of electrodynamics by Weber was quite successful in correctly describing the known phenomena of electromagnetism. Maxwell, whose argument against Weber's force was based primarily on conceptual grounds, acknowledged this.

In Weber's electrodynamics only the charges, their separations, their velocities (their first time-derivatives) and accelerations (second time-derivatives) are important to describe the forces between two moving charges. Studies based on the action at a distance were in the main current in the Continent in those days. The fields were not necessary to describe their interactions. Maxwell had different conceptions. Based on the ether and fields, he showed that his model could also explain the main electromagnetic phenomena as well. All electromagnetic phenomena could be explained as sorts of elastic strains and rotational motions of ether. The permittivity and permeability were introduced for ether. The field concept, the main ingredient in Maxwell's theory, had given a leaping result to lead to the discovery of the existence of electromagnetic wave that was considered as a traveling electromagnetic disturbance in ether. When Hertz experimentally showed the existence of electromagnetic waves, people thought that the existence of ether was also proved. However, the Michelson-Morley experiments raised a serious doubt against the existence of ether. In addition, the theories based on electric and magnetic fields had some deficiencies in describing effects between moving charges.

Einstein tried to fix the shortcomings by his special theory of relativity. The special theory of relativity is now generally accepted. Maxwell's electromagnetic theory without the ether has been widely accepted and become the paradigm for the study of electromagnetism. We now only talk about fields, associated potentials, and delayed action due to finite velocity of propagation of the interactions.

It is interesting to note that Weber's theory is shown to be compatible with Maxwell's theory as to the basic laws of Ampere's and Faraday's. Weber's theory cannot be called as "wrong" in the scientific term. The conceptual framework of the theory does not have any logical error. The main shortcoming of Weber's theory is that the theory cannot apparently describe electromagnetic radiation. This incapacity is a limitation of Weber's electrodynamics, but not an error. Maxwell's theory fails to consistently account for the forces between moving charges. Einstein's special theory of relativity was needed to fix the shortcomings. The analyses based on Weber's theory can give results correct to second order in the velocity without relativistic treatments. Maxwell's theory is medium-based, while Weber's theory is particle-based and is therefore congenial to the analysis of charged-particle behavior.

Weber's theory is only heretical in the sense that the theory does not conform to the orthodox Maxwell theory of electromagnetism that uses the concept of fields. Weber's force and Ampere's force should always be in the study of electrodynamics. However, not many publications are easily available to students of electromagnetism. Given the scarcity of easily available publications about Weber's theory, Assis's book is very valuable for the scientific community to reacquaint with the concepts of Weber's unjustly undervalued theory and it will provide a stimulus for a better understanding of difficult electromagnetic phenomena.

The author of *Weber's Electrodynamics*, A. K. T. Assis, is a professor at the Institute of Physics, State University of Campinas, Brazil. He is recognized as one of the top leaders in the study of Weber's theory. He has made numerous contributions to the understanding of the concepts underlying attempts to formulate electrodynamics as well as gravity through Weber's theory.

The book is developed from his lecture notes given to undergraduates and graduate students. It starts with vector analysis and a review of classical electromagnetism. The book is intended for students and scientists in the area of physics, engineering, mathematics, history and philosophy of science, requiring no previous knowledge of Weber's theory. After two review chapters, Assis begins with a short historical background related to Wilhelm Weber and the electromagnetism of his days. The detailed account of Weber's force and associated potential are presented, followed by applications of Weber's force to various current elements and the law of induction, emphasizing important differences from other formalisms. In the following chapters, forces of Weber, of Lorentz and other formulas are compared to elucidate differences in their resulting predictions. Chapter 7 deals with the dynamics of charged bodies and extends to applications of Weber's force to gravitation including Mach's principle. These problems are dealt with in a lively and interesting way, and although some of the author's philosophical sympathies can be guessed, the exposition is as objective as one can be on the subject, emphasizing open questions for further study. In this book Assis is successful in presenting the difficult subject in a rigorous but clear and comprehensive manner.

I would strongly recommend that anyone interested in electromagnetism, especially anyone teaching E & *M* at College level read this book and familiarize himself with the law and the concept developed by Weber. This book should be recommended to students and utilized as a complementary book to the ones usually adopted by the teachers. It includes a large volume of bibliography that is very useful.

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Black Holes, the Big Bang Theory and Other Scientific Nonsense, by Henry P. Dart III, 1998, Starlight Press, 2048 East 7th Street, Tucson, Arizona 85719-5603.

As the title implies, the author's aim is no less than to overturn some of the major scientific theories of our day. While always a tall order, Dart does succeed at least in throwing a new light on some old problems. The six chapters of *Black Holes* are supported by an appendix consisting of reprinted earlier papers. In some cases, these papers must be read in order to understand the main text.

The essence of Dart's ideas are contained in his 'Scalar Field Theory', which is proposed as an alternative to General Relativity. Assuming that the universe is infinite in time and space, Dart assigns to each point in space a value N (dimensionless), which is given by $(G/c^2)(M/R)$. Here (M/R) represents the sum of the mass-distance ratios from that point to every particle in the universe. For a point situated in outer space away from a large body, $N \approx 1$. A particle at this point has a mass equal to its ordinary rest mass, m_0 .

Near a large body, however, the 'scalar field strength' must be augmented by an additional factor $(G/c^2)(M/R)$, where (M/R) is the mass-distance ratio for the large body. The total 'field strength' is then $N = 1 + (G/c^2)(M/R)$ and a particle has its mass increased by this new factor. Since both mass and time scale with N in Dart's theory, however, the rest energy of a particle near the large body actually *decreases* as $1/N$. This decrease in rest mass energy is matched by a corresponding increase in the kinetic energy of the particle as it falls in on the large body. The key result is that the total energy of a particle does not rise indefinitely with its velocity, as it does in Special Relativity, but is instead pegged at a constant value. At a particular velocity, this may be expressed as $E_{tot} = E_{rest(v)} + E_{kin(v)}$. The rest energy only equals m_0c^2 when $v = 0$. In the process, Dart develops a new expression for kinetic energy, $E_{kin} = mv^2/(1 + A)$, where A is $(1 - v^2/c^2)^{½}$. A nice feature of this formula is that it reproduces in an obvious way the classical expression for kinetic energy at low velocities.

With this formula, Dart shows that the maximum free fall speed for an object falling in on a large body, and conversely the escape speed from that same body, are both c. Black holes are thus banished and large gravitational redshifts from large objects, such as quasars, become admissible. Dart argues moreover that at the centres of large objects a repulsive force is generated which counteracts gravity. While I had difficulty following this particular argument, it should be noted that some sort of repulsive force inside dense objects is needed in a static cosmology to ultimately return the matter in these objects to interstellar space.

In another interesting section, Dart emphasizes that when large, multiple redshifts are involved in observations it is incorrect to simply add them up, as is the usual practice. Instead they must be multiplied together. The composite redshift law developed by Dart is not original; in fact, it is the conventionally accepted law! Yet Dart may perhaps be forgiven for supposing he is the first to have given the formula. I only found it by chance in Stuart Clark's book *Redshift,* where it is noted that conventional astronomers, possibly seeking to avoid Arp's interpretation of the large redshift of Markarian 205, have used the formula (in conjunction with an enormous supposed Doppler shift caused by its ejection from NGC 3419)! But Dart may be the first to show the importance of this law in a static cosmology. In Dart's rendition, the composite redshift is given by

$$(1 + z_c) = (1 + z_H)(1 + z_G)(1 + z_D),$$

where the subscripts C, H, G and D stand for composite, Hubble, gravitational and Doppler. Other redshift factors could be added as necessary. Thus, if we have $z_H = 1$ and $z_G = 1$, then $z_c = 3$, whereas merely adding them gives $z_c = 2$. Arguing that many large objects could have large gravitational redshifts (since black holes cannot exist in his model), Dart describes a number of situations where the composite law may be significant, such as in the case of the galaxy Malin 1.

The composite redshift law could also explain the dearth of quasars beyond $z = 2$, often hailed by Big Bang proponents as proof of 'cosmic evolution'. The high intrinsic redshifts of quasars quickly inflate z_c for these objects far beyond the value which would be obtained through simply adding the redshifts. Given that the number of quasars in a thin spherical shell centred around the earth varies as R^2, there would thus be an *apparent* reduction in the quasar number in a particular shell since the quasars which appear to be in this shell are actually from a shell with a smaller R possessing fewer quasars.

Dart also updates his earlier hypothesis for the Hubble redshift, which previously appeared in *Apeiron* (no. 17, October 1993). He models the photon as a simple harmonic oscillator, which sheds a small particle of mass (an 'ejecton') during each half-cycle. With the loss in energy, the photon is redshifted, while the ejectons fall into galaxies to comprise the dark matter or 'missing mass'. Dart tries to refute some of the past criticisms of his model, such as the apparent violation of conservation of momentum.

Finally, Dart derives a general formula for the Doppler effect which takes into account the motion of emitter and receiver in a universal rest frame defined by the cosmic microwave background. This formula is to replace the one obtained using the theorem of composition of velocities in SR. Dart shows that each formula makes the same prediction as to the expected frequency received by an observer. The difference is that Dart's formula allows for emitter and receiver to obtain independently speeds up to c with respect to the background and thus a maximum possible mutual recession speed of $2c$. In SR, by contrast, the maximum recessional speed is only c.

While I enjoyed the book, some readers will find problems with it. There are a number of instances where the ideas could perhaps be expressed more clearly. But for those attempting to draw up a rational, static cosmology, it may be unwise to dismiss Dart. He may just have added a few important tools to our toolbox.

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Seeing Red: Redshifts, Cosmology and Academic Science by Halton Arp, 306 pages, Apeiron, Montreal, 1998 (also available from Meta Research).

Don't Read This Book. For if you should decide after reading this review to disregard this advice, you will need to prepare to have your universe turned upside-down. Should you then make your way through this small print, 306-page *tour de force*, you will very likely come away doubting what you thought you knew of the large-scale structure of the universe. The cosmological interpretation of redshift for quasars and active galaxy nuclei has been challenged often before, although never so successfully. But one seldom sees serious suggestions that even the redshift-distance relation for ordinary galaxies may be wrong, as you will see here. And as if the implied revolution in cosmology were not enough, your view of the professionalism of scientists and academics in general, and of astronomers in particular, will be another casualty of your reading.

One can consume this book to different degrees. For example, a short summary of the evidence and implications appears on pp. 239-241. If the writing proves too technical in places even with the aid of the extensive glossary, one can get the essence of the evidence by just scanning the plates (8 pages in color), figures, and captions that appear on almost every page. For example, it's not difficult to look at the picture of the X-ray filaments in Markarian 205, featured also on the book cover, and to grasp the deep implications of that image. For if a low-redshift Seyfert galaxy is physically connected to and interacting with two high-redshift quasars, one on either side, then redshift can be neither a distance nor a velocity indicator. And that single picture then disproves the Big Bang and most of mainstream cosmology in its present form.

Arp knows the extragalactic sky perhaps better than any other living astronomer. He builds his case against the customary interpretation of redshift methodically. The earliest hints of problems with redshift came in 1911 with the discovery that the bright, blue stars in our own Milky Way galaxy have systematically higher redshifts than the rest of the stars by about 10 km/s. Later observations showed that the O-stars in clusters within our galaxy are redshifted with respect to the B-stars by another 10 km/s or so—something called the "K-effect" and still disputed because it has no accepted theoretical explanation. However, doubts about the validity of the data were undercut and the K-effect confirmed by more recent measures of the redshifts of supergiant stars in the two Magellanic Clouds, nearby companion galaxies of the Milky Way. These too are redshifted by about 30 km/s with respect to other stars in those small galaxies. Yet no one suspects that all supergiant stars in our galaxy or in our immediate neighbors are fleeing away symmetrically from our own location well out toward one edge of the Milky Way.

Companion galaxies in general seem to have net redshifts that exceed that of their parents. All eleven companion galaxies in the Local Group have redshifts with respect to their parent, the Andromeda galaxy in the center of the group. Likewise, all eleven companion galaxies of the neighboring M81 group have redshifts relative to M81. Yet, if these companions were orbiting their parent galaxy, roughly 50% of them ought to have been blue-shifted. Although the evidence for companion redshifts is less definitive for more distant galaxy groups, it is still statistically significant. Excess redshifts over blueshifts for companion galaxies relative to their parents are apparently a verifiable feature of the local universe. And that means the redshift must have some cause other than velocity.

We begin to get some clues about what may be happening when Arp reminds us of basic facts about radio galaxies. These were discovered long ago to have giant, usually double, radio lobes to either side, presumably the result of explosions and ejections of material from the parent galaxy. Higher resolution radio telescopes have found filaments connecting these lobes to the central galaxy. And the ejected radio pairs are now known to correspond closely with X-ray pairs across the same galaxy.

That brings us to the keys to unlocking the whole puzzle—the quasars—because quasars also often correspond with X-ray sources. High and low redshift quasars are associated far more often than reasonable chance allows. These sometimes display interactions and connections and often form pairs across low-redshift objects, which unrelated objects would not do.

Working entirely from the observational data, Arp shows us that ejections from active galactic nuclei at speeds up to 10% of the speed of light lead to escape. But ejections at slower speeds may not, especially since all ejections apparently decelerate on the way out. Slower objects end up captured at about 400 kpc from their parent galaxy. But both captured and escaped quasars end up with quite small peculiar velocities. Moreover, the closest and therefore most recent ejections have the highest relative redshifts, and the lowest intrinsic luminosities. This leads Arp to suggest that the redshift of matter is an inverse function of the age of that matter. As much as one wishes to resist this conclusion, Arp shows case after case that conforms to it, many found well after this hypothesis was in print, each with odds of thousands to one against chance. Moreover, these apparently ejected quasars with redshifts ordered inversely with distance from their parent also tend to line up along the minor axis of the parent galaxy.

The generality of these startling conclusions is shown by repeated examples, such as the Arp/Hazard pair of similar triplet quasars, having discordant redshifts and a Seyfert galaxy between them. Many other good examples were discovered by mainstream astronomers. However, even when looking in depth at single examples, Arp makes a compelling case against coincidence. A survey of all bright quasars showed that these have a concentration around the Virgo cluster at the center of the Local Supercluster, despite having redshifts that should place them far out into the universe in that direction and make them unrelated to one another. The most conspicuous quasar in the sky is 3C273, one member of a pair of quasars almost exactly aligned across the brightest galaxy in the Virgo cluster center. A peculiar hydrogen cloud known to be in the Virgo cluster near the coordinates of 3C273 has a long, narrow shape pointing back toward the quasar, which itself has a jet pointing toward the hydrogen cloud. An X-ray radiation map (see Figure 5-16) also shows connections between the cluster to the quasar. Yet the quasar is supposed to be 54 times farther away than the cluster, according to its redshift. As Arp says, over 30 years ago, the field of astronomy took a gamble against odds of a million to one that this situation was an accident. The newer X-ray and hydrogen cloud evidence have confirmed that this was a bad gamble, although the field is not yet ready to accept its losses and move on.

Because redshift is not a good distance indicator, Arp points out that apparent brightness often is. Quasars near M49 appear relatively random on a sky map until just the brighter ones in a half-magnitude range are plotted. Then magically, there appears a line of quasars emerging from M49 with redshifts decreasing with distance, just as the observation-driven model predicts.

Whenever secondary distance indicators are available, they support this picture. In some cases, Faraday rotation caused by traversing a magnetized plasma can be measured for quasars. So the amount of such rotation ought to be a distance indicator. But it was then discovered that quasars with redshifts of about 2 had only 1/3 as much Faraday rotation as quasars with redshifts of about 1, when they ought to have had twice as much rotation. By contrast, this is in accord with Arp's model because the redshift $z = 2$ quasars are intrinsically fainter, and therefore generally seen only at closer distances, than those with $z = 1$.

Arp concludes that quasars are initially faint, point-like objects of high redshift that transform into lower-redshift, compact objects surrounded by a fuzz as they evolve. These develop into small, high-surface-brightness galaxies with more material around them. Ultimately these mature into normal, quiescent galaxies.

In this new view of relationships among astrophysical objects, Seyfert galaxies and their close cousins, BL Lac objects are a short-lived evolutionary stage associated with quasar ejection from active galaxy nuclei. In effect, Seyferts are quasar factories. Strong quasar number-counts are associated with a nearly complete sample of bright Seyferts, as compared with non-Seyfert control fields. Some of these associations have laughable explanations in mainstream journal articles. Quasar GC0248+430 is described as a "possibly microlensed quasar behind a tidal arm of a merging galaxy," which just happens to be a Seyfert.

Indeed, quasars look to astronomers like small portions of active (Seyfert-like) galactic nuclei. Their pairing across such nuclei, their alignment with radio emission pairings, the correspondences of X-ray maps, and the data from optical emission lines all strongly support the ejection interpretation. If nature has not already provided enough hints, an apparent magnitude *vs*. redshift (Hubble) diagram shows that Seyfert galaxies have too much redshift at fainter magnitudes and do not follow the same relationship as normal galaxies. Indeed, the Hubble diagram for Seyferts trends toward that for quasars, which likewise do not show a normal Hubble relationship between brightness and redshift. One wonders how many different ways nature must repeat this message about redshift not corresponding to distance before it sinks in.

Other astrophysical objects are in accord with this message. Water maser emissions are also seen in pairs roughly aligned with quasars. X-ray filaments or jets emerge from Seyfert galaxies and end at quasars, often in pairs of similar redshift on opposite sides of the minor axis of the galaxy between. And high-luminosity spiral galaxies have excess redshifts compared to normal spirals, as judged by the Tully-Fisher method of judging distances from rotation rates (which is independent of redshift).

One might well wonder what galaxy clusters have so say about this, since these are clearly physically associated groupings of galaxies. The supporting evidence they provide is truly extensive. Classically, whole galaxy clusters obey a Hubble diagram relation between redshift and brightness with a dispersion of just a few tenths of a magnitude. But 14 clusters north of Cen A have a much larger dispersion with a maximum range of 4 magnitudes. Such clusters have no relationship of the type claimed for ordinary galaxies, and raise doubts that the classical Hubble relationship can have the meaning usually attributed to it—that redshift indicates distance—for anything. We may simply have been fooled by both luminosity and redshift being functions of mass, which would lead to an apparent Hubble relationship despite no true distance dependence.

Some of the cluster examples are certainly head-turners. Abell clusters of galaxies with higher redshifts are distributed right down the spines of both the Virgo cluster and its southern-hemisphere twin, the Fornax cluster. A complete sample over a large region of the southern sky showed that the strongest X-ray cluster concentration had the two brightest galaxies (M83 and Cen A) at its center, despite much larger redshift for the X-ray clusters. In general, X-ray clusters appear more commonly with redshifts of about 0.06 than chance allows, which in Arp's interpretation marks them as young and intrinsically redshifted.

Supporting data includes cooling flow measures, which indicate that at least 100 solar masses per year are being lost from these clusters. This implies 100 billion solar masses in a billion years. Where is it going? The obvious possibilities can all be ruled out. BL Lac objects, at redshifts intermediate between quasars and cluster galaxies, are apparently progenitors of clusters of galaxies. Normal galaxies within certain redshift ranges tend to align on the sky in strings, with the lowest redshift galaxy near the center. For example, 13 of the 14 brightest northern hemisphere spiral galaxies in uncrowded fields fall on well-marked lines of galaxies that have concentrations of fainter, higher-redshift galaxies. And there are anomalous faint, blue, often active galaxies that fill out clusters in the redshift range between 0.2 and 0.4. These apparently evolve into the higher luminosity, lower redshift objects seen at $0.02 < z < 0.2$. Finally, below redshifts of about 0.02 we find strings of galaxies aligned through the brightest nearby spiral galaxies, presumably representing the last evolutionary stage of protogalaxies before becoming the slightly higher redshift companions of the original ejecting galaxies. We are so accustomed to thinking of this sequence as a time evolution that it takes some effort to re-think the whole picture as a mass-luminosity-redshift evolution at a nearly fixed time.

So the young-appearing objects with the highest redshifts are aligned on either side of eruptive objects, which implies the ejection of protogalaxies and the association of redshift with youth. Increasing distance from parent leads to brighter, lower redshift objects, so this is the direction of evolution with age. At redshifts of about 0.3 and distances of about 400 kpc from the parent, quasars become very bright at optical wavelengths and in X-rays, and evolve into BL Lac-type objects—a short-lived stage because there are few of them. Finally, these evolve into clusters of galaxies, which are seen to appear at comparable distances to the BL Lac objects, implying that clusters may originate from the breakup of BL Lac objects.

There is more. Tight multiple-quasars-image groupings were originally dismissed as observational errors until the gravitational lens theory was invoked. Then many more examples were quickly found. G2237+0305 was essentially a high-redshift quasar in the nucleus of a low-redshift galaxy. Lensing was the only way out for cosmologists. The four quasar images were all within one arc second of the galaxy nucleus. But Hoyle computed the probability of such a lensing event as two in a million. Moreover, instead of being arcs as lensing theory predicted, the quasar images are extended back toward the central galaxy. Real arc images don't look much like the predicted arcs either, but rather like part of an expanded shell. This alternative is in better agreement with the existence of radial arcs, jet arcs, dog-leg arcs, and ejected jets that end in transverse arcs.

The last main observational area deals with the quantization of redshifts. In essence, redshifts do not take on all values with equal ease, as they must if they are caused mainly by the velocities of the observed objects. For example, redshifts near 0.061, 0.3, 0.6, 0.91, 1.41, 1.96, *etc*. occur more frequently than chance permits. Smaller redshifts too occur at preferred periodic intervals, as Tifft has shown in a study confirmed in an independent sample by Guthrie and Napier. The existence of preferred values for redshifts proves that either we are at the center of a series of expanding shells, or redshift does not indicate velocity. Arp cautions that faint quasars with high redshifts do not continue to show this effect, perhaps because the form of the relationship changes at great distances from us (as faintness would suggest). Also, much of the spread that exists around these preferred redshift values is apparently due to the speed of ejection, which can be up to 0.1 c. The average redshift of a quasar pair generally falls closer to a preferred redshift value than does either individual redshift. BL Lac objects show the same quantization, but to a less pronounced degree, as befits their relationship to quasars. Figure 8-16 shows a striking set of bands and gaps for galaxy redshifts in the X-ray cluster Abell 85 that illustrates the redshift quantization effect at a glance.

Arp's strength is observational extragalactic astronomy. With theory he is less proficient, but has enlisted the aid of Narlikar, Hoyle and others. The concept of mass increasing with age has no adjustable parameters (the characteristic age being given by the measured age of our own galaxy), yet allows prediction of intrinsic redshifts for objects from K-effect stars to quasars, with results better than an order of magnitude. The Big Bang with many adjustable parameters cannot do as well. Redshift, then, indicates youth. And the slope of the Hubble diagram comes directly from our own galaxy's age. Since luminosity evolves with mass squared, the apparent brightness-redshift relationship is coincidental, and not an indicator of distance. I am no doubt biased here by seeing simpler theoretical explanations for Arp's observational constraints than his variable-mass theory can provide. But Arp concedes in places that theories need to evolve with discoveries, something that the Big Bang stopped doing at a fundamental level a generation ago.

Some of the most entertaining reading in this book is provided by Arp's interactions with his colleagues and with referees and journal editors. Arp spices up these exchanges with a bit of his own philosophy. Despite its pessimism, I wonder how any of us could have evolved a philosophy much more optimistic if we had been in Arp's shoes. Anonymous referees frequently use abusive language such as "ludicrous," or unwarranted generalizations such as "bizarre conclusions based on an extreme bias of the authors wishing to find non-cosmological redshifts." It was not infrequent to find referees suggesting that the implications should have been used to prove the observations wrong! A Nobel laureate and former teacher is quoted as saying "Arp did not get anything right in my course. I should have flunked him but I could not bear to have him repeat the course with me."

We see in the anecdotes frequent occurrences of "sniping," unbacked claims that something is true or false for some reason that is not presented to the author for rebuttal. One example: "Oh those claims have been completely disproved." Arp introduces a few names for some of these battle tactics himself. The "Pleiades maneuver" is one such: Measure so much background that the statistical significance of the obvious foreground (such as the Pleiades cluster) is reduced to insignificance. Reaction to the X-ray map showing the connection of the Virgo cluster and quasar 3C273 produced five arrogant and patronizing referee rejections at two journals, and was viewed even by some colleagues as "a grisly auto accident along the highway."

Sadly, the mainstream is well adapted for survival. So when Arp succeeds in running the minefield and getting his results published despite the referees, an unwritten understanding is that no discussion or citations will follow, so the embarrassing result will soon be forgotten. Arp suggests that a sampling of referee reports, showing "manipulative, sly, insulting, arrogant, and above all angry" referees, ought to be published because it would allow people to evaluate the objectivity of the information they are being allowed to read.

Here are some brief quotes outlining what Arp has learned from these exchanges:

(a) "When presented with two possibilities, scientists tend to choose the wrong one."
(b) The stronger the evidence, the more attitudes harden.
(c) "The game here is to lump all the previous observations into one 'hypothesis' and then claim there is no second, confirming observation."
(d) "No matter how many times something has been observed, it cannot be believed until it has been observed again."
(e) "If you take a highly intelligent person and give them the best possible, elite education, then you will most likely wind up with an academic who is completely impervious to reality.
(f) "When looking at this picture no amount of advanced academic education can substitute for good judgment; in fact it would undoubtedly be an impediment."
(g) "Local organizing committees give in to imperialistic pressures to keep rival research off programs."
(h) "It is the primary responsibility of a scientist to face, and resolve, discrepant observations."
(i) "Science is failing to self-correct. We must understand why in order to fix it." The book has many more like these.

As with any work of such length and depth, a few errors turned up along with a few points that are of dubious merit. None of us can be experts in everything, and we are always pushing the limits of our knowledge and training. Worth a comment are these points:

(a) Arp's arguments against tired light models (p. 97) make a common invalid assumption that quantum particles must be responsible for the energy loss. But there is good reason to suspect that quantum particles are by no means fundamental.
(b) Arp's proposal (p. 219) that even planetary and satellite masses may be quantized uses an invalid statistical argument when bridging large ranges of mass. But he may well be right for small mass differences. Origin in twin pairs by fission usually creates masses in the approximate ratio of 5:4, which may partly explain Arp's planet statistics. It might also explain his magical 1.23 redshift quantization ratio if a similar fission process is responsible for the twin ejections in galaxies.
(c) On p. 234, Arp cites the surface brightness test, which must vary as $(1+z)^4$ in the Big Bang. He applies that to his own model on the assumption that observations support it. However, the observed dependence goes as $(1+z)^2$. Evolution of galaxies is said to be responsible for the difference in the Big Bang, but that argument would not apply to Arp's model.
(d) On p. 237, Arp incorrectly states that the cosmic microwave radiation must come from a thin shell, saying this has not been explained. But that radiation is supposed to have flooded the universe shortly after the Big Bang, and been cooling ever since. So every point in the universe is today receiving cooled radiation, and there is no shell anywhere. Arp correctly goes

on to provide more probable explanations for the radiation than a fireball residue.

(e) Arp's use of statistics cries out for him to explain the difference between *a priori* and *a posteriori* probabilities, if only to assure us that he understands the difference and its importance.

(f) It was disappointing to see no mention of the role of giant elliptical galaxies in the evolutionary scheme of things.

Arp correctly points out that one side in this meaning-of-redshift debate must be completely and catastrophically wrong. This leads him to wonder how many other uncertain assumptions might exist in other areas affecting our daily lives about which we are innocently overconfident. That is perhaps the most sobering thought of all.

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Open Questions in Relativistic Physics, edited by Franco Selleri, 375 p. Apeiron, Montreal, 1998.

To begin this discussion of Selleri's recent book challenging the foundations of relativity theory, I would like to recall two recent incidents.

In one, a commentator criticized an author for not citing his own published work, on the grounds that he was obviously not doing research in the field. (In the particular case, the criticism was not particularly relevant, because the author was simply summarizing published literature.) But I have often criticized work that cited *only* or *mainly* the author's own work, on the grounds that he made little attempt to relate his work to reality; this failure to read literature is a frequent flaw of critics of relativity theory. On the assumption that Einsteinian relativity theory is just plain wrong, there would be no need, of course, to have one's theory agree with Einstein's. However, there is no excuse not to seek out experiments. Writers who cite only their own work therefore doom their own work by overlooking the necessity to agree with experiment.

In another incident, a speaker gave us a nice colloquium about the background blackbody radiation, but did not acknowledge any attempts prior to the 1960s to determine the temperature of the universe. After I explained how knowledge [1] of the Stefan-Boltzmann radiation law was used for over 50 years to that purpose, the speaker asked me, "Well, if it was so well known, why didn't I know about it? Why hadn't I ever encountered it?" I replied, "Well, in Marshall Walker's words, 'Physicists don't read.'" Lest the criticism sound too unfair, be reminded that physicists like to obtain theoretical results from the smallest possible set of assumptions, using the backs of envelopes when possible. The delight of "figuring things out" from pure logic (mathematics) and a handful of physical laws is the kind of enjoyment that drove this class of people to study physics in the first place.

All of the foregoing is to say that a bibliography tells much about the work. I make no apologies for looking there first.

Franco Selleri has assembled 38 papers, evidently from a conference], that discuss relativity theory from one of several points of view: the velocity of light; history and philosophy; structures in space and time; cosmology and astrophysics; and quantum theory and relativity. Contrary to what relativists might expect, most of the authors of these largely dissident papers are from physics departments at respectable universities.

As an exercise, I chose three numbers (<39) at random, looked up the papers corresponding to those numbers, and went to their bibliographies. Totally, there were 61 references cited, most of which were not the author's work. Of the 61, a few were popularized books and many were from refereed journals that are not mainstream. However, there were 48 references to articles in indisputably orthodox journals: *Phys. Rev., Phys. Rev. Letts., Nature, Ann. der Physik, Review of Scientific Instruments*, and the like. I am satisfied that Selleri's book is a serious endeavor.

There are papers on the difficult topics of time and space measurements on rotating platforms (including GPS), Bells' theorem, relativistic magnetic tops, and cosmological interpretations, to name a few. Though I have not had time to read them all (let alone to understand them), I can say that I have found very interesting reading in Selleri's book. May it sell well!

References

[1] A.K.T. Assis, "History of the 2.7 K Background Radiation Prior to Penzias and Wilson, *Apeiron*