Lorentzian Gravity and Cosmology*

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If a material vacuum exists, with the properties of a superfluid through which already recognized material moves, then it is capable of acting as a universal reference frame and as an intermediary for the production of particle pairs throughout the universe, which as they cool and recombine, become the source of both high- and low-temperature cosmic background radiation, as observed. Moreover, if there is a steady state overall in the universe and the depleted material vacuum is replenished within temporary galactic nuclei of hyperinflated mass, as predicted by certain classes of gravitational theory (Dicke 1961, Atkinson 1962), then the standard interpretation of cosmological redshifts and the reality of the big bang may be called in question.

Thus the existence of substantial dark matter in the universe, due to mass inflation in recurrent galactic nuclei, along with large scale streaming over the dimensions of superclusters and voids, not only revives the possibility of a considerable gravitational component (*cf.* Schmidt 1975) in the redshifts of quasars, which are then nearby, but raises again the

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possibility, foreseen with the static universe model of de Sitter (1917), that the cosmological redshift itself is purely gravitational in origin. Under these circumstances, the Lorentzian explanation of covariance is no longer implausible and we may recover the nineteenth-century assumption that the various observed fields in nature are manifestations of active physical states of the material vacuum associated with corresponding states of recognized matter. Theories that explain gravitational fields within this framework (*e.g.,* relativistic: Atkinson 1962; non-relativistic: Dicke 1961) predict the existence and recurring production of hyperinflated matter, and are relevant to our understanding of the strong nuclear force (Sinha *et al.* 1976a, b) and of the fundamental behavior of massive astronomical bodies in advanced states of evolution, *e.g.,* pulsars, quasars (Clube 1983). Such behavior (*i.e.* the formation of hyperinflated mass) is reflected, for example, in the widespread violent relaxation of galaxies, not least our own, and leads to an understanding of spiral structure different from that generally accepted at present (*e.g.,* Lin & Shu 1964), but first mooted many years ago by Jeans (1928) and Milne (1948).

Introduction

Lorentz invariance was originally understood to be due to the apparent isotropy of *c* arising from a specific interaction between visible matter in motion and the plenum (Lorentz 1904). Later it was understood to be due to the actual isotropy of *c*, implying the existence of (flat) space-time (Einstein 1905, Minkowski 1908). Both theories have been developed subsequently to incorporate weak field/low velocity effects that arise in gravitational physics. In the former case, this was done by introducing a further dependence of m and *c* on gravitational potential (Dicke 1961). In the latter case, it was done by preserving the isotropy and constancy of *c* and by introducing suitably curved space-time in the vicinity of gravitating bodies (Einstein 1916).

While the universe was assumed to be statistically at rest, the only space-time framework capable of predicting the familiar gravitational effects (*i.e.*, motion of the perihelion, deflection of light, slowing of atomic oscillators) and the cosmological redshift was due to de Sitter (1917). According to this model, the slowing of atomic vibrations implicit in the redshift was assumed to arise during accelerations in the presence of gravitational material along the line of sight (Eddington 1924). However, the static de Sitter universe also predicted a very large negative pressure in the universe which could only be understood physically in terms of the existence of an invisible plenum. The de Sitter universe, like the Lorentz universe, therefore presupposed the existence of a material vacuum with the character of a superfluid, introducing an intermediary for the production of particle pairs throughout the universe which, as they cool and recombine, become successive high- and low-temperature sources of cosmic background radiation.

As long as the distance scale was not known and it was uncertain whether dark matter existed, it was not at all clear whether there was sufficient matter in the universe to explain the cosmological redshift as a gravitational effect. With improvements in the distance scale, however (*cf.* Rowan-Robinson 1988), the detection of "dark matter" in multigalactic systems (*e.g.,* Bahcall 1988), the discovery of very high redshifts in exceptional galactic nuclei (*e.g.,* Schmidt 1975) and with the realization that mass inflation may occur in nature (Guth 1981), it is possible in principle to validate or dismiss the assumption that cosmological redshifts are gravitational. In effect, the very high redshifts of quasars are understood on this hypothesis to include a large gravitational component indicating the principal locations of dark matter; while on a very large scale, where the exceptionally strong dynamical effects of one or more quasars may be felt, the universe is expected to exhibit very considerable streaming.

In the event, however, the confirmation of the existence of cosmological redshifts (Hubble 1929) before the existence of mass inflation and extreme gravitational redshifts was appreciated brought about something of a crisis in astrophysics (Eddington 1931; *cf.* Ellis 1988 for a pertinent review). This could only be resolved at the time by introducing the non-static cosmological framework due to Friedmann-Lemaître-Robertson-Walker, which has subsequently become the basis of hot Big Bang cosmology.

Lorentzian Gravity

On the other hand, it has now been shown that the gravitational redshift of the de Sitter universe can be understood as an effect superposed on flat space-time due to a specific dependence of m and *c* on gravitational potential (Atkinson 1962, 1965, Clube 1980). The dependences introduced by Dicke and Atkinson are in fact very similar and have identical dynamical consequences in the post-Newtonian regime (Clube 1977, *cf.* Sinha *et al.* 1976a, b). Furthermore, since hidden variable formulations of physics appear to require superluminary action to explain certain classes of quantum measurement statistics, and the velocity of light may be neither universally constant nor maximal (Bell 1981), there is *prima facie* evidence at the quantum level that the non-relativistic theory due to Dicke may be correct. On the face of it, therefore, the de Sitter-Atkinson gravitational theory, requiring an invisible plenum and treating the Hubble relationship as an effect of the presumed static universe, may merely be serving as a close approximation to the more fundamental Lorentz-Dicke gravitational theory.

According to Lorentz-Dicke theory (Dicke 1961), mechanical Lagrangians may be represented by

$$L = -mc^2 g^{-1}$$
$$= -mc\left(c^2 - u^2\right)^{1/2}$$

while (m,c) are functions of the Newtonian potential f, expressed as a positive number, such that

$$m = m_0 \exp\left(3f / c_0^2\right)$$
$$c = c_0 \exp\left(-2f / c_0^2\right)$$

It follows that the high gravitational redshifts of quasar continuum sources may be indicative of the greatly inflated mass and potential of supermassive stars in galactic nuclei which have evolved to a terminal state. Such inflation is no different in principle from that conceived for the universe as a whole during its proposed high-density phase (Guth 1981), but evidently appears most conspicuously, according to the Lorentz-Dicke theory, as a short-lived localized phenomenon occurring repeatedly in galactic nuclei. It follows then that recurring activity in galactic nuclei (*cf.* Clube 1980, Bailey & Clube 1978) may be understood as a general precursor of spiral structure due to the violent collapse and subsequent release of material from the central regions of galaxies (*i.e.* ≤ 1 kpc) when the masses of successive supermassive stars ($M \sim 10^6\ M_{\odot}$) become temporarily inflated at the ends of their lives (Clube 1983). For a static universe in overall equilibrium, there is an expectation on this theory that the nett production of particle pairs in the vacuum at large will be balanced by their nett annihilation, converting recognized matter into material vacuum, in the cores of supermassive stars, especially during the final phases of their evolution and energy production prior to the formation of inert cores.

This understanding of spiral structure as a recurring, short-lived outflow is incompatible with its current explanation in terms of density waves (*e.g.,* Lin & Shu 1964), but is not a particularly new idea. Thus, Jeans (1928) also envisaged a central condensation in galaxies and an outward flow; he evidently supposed that these effects were due to a change in the space-time curvature of the nucleus, implying therefore a change in its gravitational mass. Milne (1948) likewise presupposed a stationary universe in which spiral galaxies regularly undergo condensation and dissolution, each nucleus having a secularly varying gravitational constant and the associated spiral structure then being explained in equivalent kinematic rather than gravitational terms.

Spiral Structure

Whereas it appears nowadays that non-static cosmology was introduced out of the need for a model of the universe which did not also include a plenum (*i.e.*, the cosmological redshift of the static de Sitter universe was arbitrarily set aside), it is clear that static cosmology was still often enough studied during the 1930s for one of the decisive factors at the time influencing the future course of cosmology to have been the presumed nature of spiral arms. Thus, neither Jeans nor Milne disallowed the possibility that arms were recurrently injected into the disc from the galactic nucleus, and to the extent that spiral structure was still recognized as a short-lived recurring process, the detection of spiral streaming in galaxies remained an important and fundamental issue.

It is a common misconception that this issue was settled when van Maanen's measurements of spiral arm proper motions in extragalactic nebulae were shown to be false (Hetherington 1972). However, a far more relevant issue was the question of streaming among nearby stars (Eddington 1924), for while it had been necessary to discount this effect to substantiate the Oort-Lindblad theory of galactic rotation (Oort 1926), the observations were not considered decisive one way or the other (Smart 1938).

The indecision is hardly surprising since Lindblad's theory was originally developed to explain streaming that was actually observed and which at first, by general consent, reflected the rotation velocities of different Galactic subsystems about an assumed center in the general direction of the constellation of Cygnus. By modifying the Lindblad theory in accordance with what was then a new but unexpected direction of the center (*i.e.*, towards the constellation of Sagittarius), Oort had been forced to assume that the streaming was an illusion, thereby contradicting the usual interpretation given at this time to the observations of nearby stars. In fact, this was a very serious issue for the Lindblad theory, and Oort's modification was seen at the time as a remarkable *tour-de-force* saving appearances, albeit by contradicting something that had previously been regarded as obvious. Thus, the capacity of the Oort-Lindblad theory of purely rotating galaxies to avoid what was otherwise something of an embarrassment, namely a theory that gave the wrong direction for the galactic center, proved to be highly persuasive to astronomers and was certainly a contributory factor leading to the decline of any notion such as Jeans' and Milne's that spiral arms were commonly streaming away from galactic nuclei. The result was a general reinforcement of the non-static theory of the universe and an (inevitable) growing tendency to favour the density wave theory of spiral structure (Lin & Shu 1964).

An opportunity to reconsider stellar streaming in the solar neighborhood arose in the 1950s and 1960s when distant HI arms between the Sun and the Galactic Center were discovered streaming away from the nucleus at high velocity. Instead of treating the phenomenon as a fundamental "grand design" effect however, due to a possible physical process involving the symmetrical injection of spiral arms from the nucleus into the galactic disc (as conceived during the 1920s and 1930s), it was immediately interpreted (Rougoor & Oort 1960) as no more than a minor perturbation on a galactic system that was otherwise in purely circular motion, thus ensuring that the Oort-Lindblad theory was still regarded as strictly true. Enchantment with the Oort-Lindblad theory was thereby sustained, and, along with it, the non-static theory of the universe.

Nature of Comets

The significance of the fundamental distinction drawn here between static (Lorentz-Dicke) and non-static (Friedmann-LemaŒtre-Robertson-Walker) theories of the universe lies in the fact that our present understanding of the universe is bound up in a remarkable way with very basic notions about the nature of spiral arms and comets.

Thus, by general consent, the non-static model is aligned with the density wave theory of spiral structure and specifically eliminates stellar streaming. This has led to the expectation that stars are formed by the gravitational collapse of tenuous interstellar gas and dust, following an initial compression by a density wave, and that the most primitive condensations (proto stars and comets) are unlikely to suffer much heating. There are severe theoretical and observational difficulties with this picture, namely removal of the differential rotation resisting collapse (McCrea 1978) and the lack of good evidence in the crystal cores of well-preserved grains from comets (Brownlee 1985) and primitive meteorites (Ming & Anders 1987) for the expected eroded structure (Greenberg 1987) and the lengthy exposure times (Seab 1987) associated with their residence in the disc between formation and absorption into primitive condensations.

On the other hand, the static model is, as we have seen, most closely aligned with theories in which the central material of galaxies is drawn into compact gravitational condensations and regularly released as dense plasma (jets) in the form of spiral arms. The size of the condensations that arise in spiral arms when dense plasma cools is not readily predicted (*cf.* Palla 1988, Fabian *et al.* 1985) but a sequence of Jeans condensations whose lower limit corresponds to "parent bodies" (Anders 1964) or "giant comets" (Clube 1988) is certainly plausible. It follows then that star formation proceeds by the aggregation within spiral arms of dark matter with the characteristics of rapidly differentiating floccules $\geq 10^{-9}\,M_{\odot}$ (*cf.* McCrea 1978). Star formation thus takes place in a refractory-depleted molecular gas (*cf.* Tarafdar *et al.* 1983) in the presence of volatile-depleted "parent bodies" (Yamomoto 1987), consistent with the reduced dust-to-gas ratio observed in the vicinity of rapidly evolving stars (Seab 1988).

The important distinction between these two spiral-arm scenarios is the nature of comets in interstellar space. According to density-wave theory, comets are relatively peripheral to the formation of stars and are not found in any abundance in spiral arms, while their cold origin implies that they are formed by accretion in a fairly dense state ($r \sim 1$). According to the spiral-arm injection theory, however, comets are fundamental and are found in great abundance in spiral arms, while their essentially hot origin implies also the formation within large comets of highly devolatilised mantles during differentiation, with the very weak structure of Brownlee particles ($r \sim 0.1$). Such comets captured from spiral arms as the Sun orbits through the Galactic disc have the capacity to induce strong catastrophic effects on the earth, imposing also an episodic 15 Myr cycle on the geomagnetic reversal frequency (Clube & Napier 1989). This phenomenon is now well observed (Mazaud *et al.* 1983) and is not otherwise explained, so the evidence broadly favours an injection rather than a density-wave picture.

Spiral Streaming

The terrestrial and cometary evidence tends therefore to distinguish between static and non-static theories of the universe, while spiral streaming is expected to be present and not present, respectively. A critical observation is thus the motion of the local standard of rest in the galaxy relative to the latter's center. As noted above, the arbitrary elimination of nearby stellar streams (Oort 1926) and, hence, spiral streaming in our galaxy has never been universally endorsed (Smart 1938, Eggen 1963, Clube 1983), but it has not been possible to provide a convincing independent check on the hypothesis without a detailed study of motions in the galactic nuclear region.

This has recently become possible since a slightly inclined but otherwise reasonably symmetric circumnuclear disc has been detected at the center of our galaxy with a systemic radial motion of 40 kms^{-1} relative to the nearest spiral arm (Gatley *et al.* 1987). To preserve the Oort-Lindblad theory, it has become necessary to postulate a high degree of asymmetric streaming within the circumnuclear disc (Genzel & Townes 1987), but the spectra of individual bright infrared sources near the center are not consistent with the asymmetric streaming, and the simple Oort-Lindblad theory again appears not to be correct (Clube & Waddington 1989).

Conclusion

A wide variety of new evidence now suggests that injection rather than density waves provides a more adequate framework in which to understand the origin of spiral arms, thus favouring a static rather than a non-static theory of the Universe. Increasingly, therefore, one is led to suppose that gravity may be understood in terms of Lorentzian rather than relativistic theory. New insights into comets and the terrestrial record, along with infrared observations at the galactic nucleus, may therefore have profound implications for physics.

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