The New High-Energy Nuclear Particles and Gravitational Energy

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1954

Until very recently, it was thought by leading physicists, and indeed by the main body of scientists, that the building-blocks of the universe were all known, as well as the qualitative laws governing them. It was then felt that the domain governed by the Einstein General Relativity Theory was either completely separate from, or only very weakly interacting with, the more energetic electromagnetic and nuclear forces. Under those circumstances, it was felt by the experts that conventional gravitation could not profitably be employed to activate (i.e. transfer energy to) matter.

These beliefs may well have been gravely shaken by a whole flood of new evidence which has been filling the technical journals of all nations.

While it is hardly possible to enter into a detailed analysis of these results in this short essay, we should like to outline here the nature and possible implications of these new events. The original observations consisted of hitherto unknown particles seen to interact strongly with nuclear matter both in photographic emulsions and Wilson cloud-chambers. These particles (now classified as hyperons and K-particles), of which an astonishing variety is by now known to exist, have furthermore been produced in controlled experiments by the latest high-energy machines such as the Brookhaven "cosmotron"[1]. This last fact is to be especially noted, for science can best study entities which can be manipulated at the will of the experimenter. The properties which these particles exhibit are extremely strange, and have not been fitted into any existing theoretical framework. This is not surprising, since conventional theories form a closed system, which is not flexible enough to allow for this rich variety of interactions. Most common among the hyperons is the so-called Λ^0 particle[2] which decays into a π-meson (boson field) and a proton (fermion field). This is the first of a family, the others having higher masses and an interlocking decay scheme between them. Of special significance is the amazingly long lifetime of 10^{-10} sec. (compared with nuclear times of 10^{-23} sec.). The second class of new particles, the K's, consists of lighter particles, which do not involve nucleons, but only mesons. This is exemplified by the θ_0 and $\tau^{\pm}$ particles[3] which decay by the scheme:

$$\theta_0 \rightarrow \pi^+ + \pi^-$$

$$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^+ + \pi^-$$

They are also long-lived. As a final extremely recent example, we mention the very high energy photon (electromagnetic) shower reported in the August 1, 1954 Physical Review[4]. There a burst of gama-rays was observed to emanate from a single point, with energy much greater than ever seen before in a purely electromagnetic interaction. No known particle can explain the origin of such a phenomenon[5].

The discussion thus far has been concerned with the nuclear and sub-nuclear domain governed by the Quantum Theory of Fields. We must at this point make an excursion into what is at first sight the very opposite realm of physics, Relativistic Cosmology. This field is concerned with the application of the General Theory of Relativity and Gravitation to the problems of the structure of the universe. The particular theory upon which we shall focus is one recently enunciated by Bondi, Hoyle, and others[6]. The chief experimental fact to be explained is the expansion of the universe (while still maintaining the elegant and satisfying aspects of a steady state theory). This has been a central point in several other previous attempts, notably by Einstein and others. Guided by a general Cosmological Principle which states that the universe presents the same aspect from any place at any time (aside from local irregularities) it was possible to set up a complete cosmological theory in agreement with observation. The fundamental principle apparently implies the existence of a steady state universe. This would appear superficially to be in contradiction with the expanding universe. However, it is a consequence of the theory that solutions involving expansion are actually allowed. This would lead to an inconsistency with the fundamental principle since the density of matter would decrease in time. (the available matter distributing itself in an increasingly larger volume) unless simultaneously matter was created. This last is the most crucial aspect of the Bondi-Hoyle theory, and of the highest significance to our development.

It is a completely accepted view that the Quantum Theory is valid only for microscopic regions (10^{-8} cm) while the General

Theory of Relativity holds only at macroscopic sizes. The biggest unsolved problem of modern physics, in fact, centers about the unifications of these disciplines. It has been felt that, were this achieved, gravitation would indeed come to include domains of strong interaction and thus permit extraction of gravitational energy without outside sources. This unification is still in the distant future. However, what we wish to submit here is that at this one point, the continuous creation postulate, cosmology does overlap with the quantum domain.

The necessity for our detour into the macroscopic theory is now apparent. For this continuous creation of matter (and hence energy) is to be linked with precisely those subnuclear events that were discussed above. In fact, we should like to suggest that these new particles represent the conversion of gravitationally produced energy into the potentially useful nuclear energy. While it is not within the scope of this essay to discuss the practical use of the released energy, but only to point out its existence, it is worthy of note that nuclear energy is an optimal form of such released power, especially when the particles involved are sufficiently long-lived to be dealt with as desired. It is now also clear why the examples of new particles given above encompassed not only electromagnetic but nuclear and subnuclear (mesonic) energy releases.

Of course, we have yet to discuss the theoretical framework within which the above facts can be described. Interesting preliminary work in this direction has been done by Prof. B. DeWitt of Berkeley[7]. Unfortunately, as Prof. DeWitt later discovered, his suggestion did not correctly take into account Pais' original theory. In general, the conversion process mentioned above may be envisaged as follows: the expansion of the universe, viewed thermodynamically, is analagous to the adiabatic expansion of a piston. In this case the energy lost in the expansion instead of being transferred to the walls disappears. In order to preserve the basic steady state of the Bondi theory (i.e. conservation of total energy) this energy must manifest itself in the new hyperon and K-particles. Thus there is necessarily a coupling between the large scale equations governing the behavior of the universe as a whole and the small scale equations of the new particles. More quantitatively we propose the following field equations describing the above phenomena:

$$-kT_{\mu\nu} = R_{\mu\nu} + \tfrac{1}{2} R g_{\mu\nu} + C_{\mu\nu}[\Phi, \Psi]$$

$$[\tfrac{1}{i}\gamma^{\mu}\partial_{j\mu} + m + \lambda\sigma^{\mu\nu}K_{\mu\nu}(x)]\Psi = 0$$

with a similar equation for Φ. In the above, Ψ represents the hyperon wave functions, and Φ the K-particle quantized field operators. The first three terms in the first equation are the usual structures in the Einstein General Relativity. The last term, $C_{\mu\nu}$, is the "creation" tensor[8] which is to give us our conversion from gravitational to nuclear energy. It is like $T_{\mu\nu}$ in being an energy-momentum term. In the second equation ∂j_μ represents the covariant derivative while γ^μ is a generalized Dirac matrix arranged so that the second equation is indeed covariant under the general group of coordinate transformations. The $\sigma^{\mu\nu}K_{\mu\nu}$ term will automatically include the higher hyperon levels. $C_{\mu\nu}$ is a functional of the hyperon and K-field variables Ψ and Φ. As can be seen these equations are coupled in two ways: first the creation term $C_{\mu\nu}$ depends upon the field variables Ψ and Φ while the gravitational metric tensor $g_{\mu\nu}$ enters through the covariant, derivative, *etc.* λ is a new universal constant giving the scale of the level spacings of the hyperons. Rigorously speaking the field equations should be, of course, second quantized. For purposes of obtaining a workable first approximation it is probably adequate to take expectation values and solve the semi-classical equations. The creation tensor $C_{\mu\nu}$, must be a bilinear integral of the Φ and Ψ fields and may have cross terms as well of the form $\int \Phi\bar{\Psi}\Psi(dx)$. These equations will indeed be difficult to solve, but upon solution will give the distribution of created energy and hence lead eventually to the more practical issues desired.

We have attempted in this work to show how it may be possible to bring gravitation at last to bear on matter in its most useful state, i.e. the nuclear state. This particular result is but a special application of a general attempt to describe the nature of the physical universe in the light of the latest experimental findings. Of course both the experimental and theoretical results quoted here are preliminary and need deeper investigation. These investigations should serve as guides to the more elaborate theories which will eventually be evolved. This is consonant with the development of other physical ideas as the history of science shows. One of the most hopeful aspects of the problem is that until now gravitation could be observed but not experimented on in any controlled fashion while now with the advent in the past two years of the new high energy accelerators (the Cosmotron and the even more recent Berkeley Bevatron) the new particles which have been linked with the gravitational field can be examined and worked with at will. Furthermore, the previously insuperable stumbling block to any useful application of gravitation has been removed by the suggested transformability of gravitational energy into the strongly coupled nuclear particles.

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