xenon isotopes. A thermal neutron flux of $\approx 2.8 \times 10^{13}$ neutrons cm^{-2} s^{-1} on ^{235}U would produce $^{131}Xe : ^{132}Xe : ^{134}Xe : ^{136}Xe = 0.36 : 0.54 : 1.00 : 1.41$, in agreement with the yields calculated above for X. As we have shown that this enrichment of heavy xenon isotopes is not produced by *in situ* nuclear processes, the absence of neutron-capture anomalies in the rare earths is no longer an obstacle to this model. Also because of the large thermal neutron capture cross-section of ^{135}Xe, a high thermal neutron flux would yield a large $^{136}Xe : ^{134}Xe$ ratio for the induced fission of any transbismuth nuclide. An early deuterium burning stage in the outer region of the Sun or the irradiation of planetary material prior to accretion into planetary bodies, as proposed by Fowler *et al.*[31], is a possible source of the neutrons.

In summary, the enrichment of heavy xenon isotopes released from carbonaceous chondrites near 600°–1,000 C is accompanied by an enrichment of the light xenon isotopes. The high degree of correlation between these two isotopic anomalies suggests that both result from a common source. Because no known nuclear or physical process is capable of producing both anomalies *in situ*, we suggest that they result from the release of isotopically anomalous xenon (component X) that was trapped in the meteorites.

This investigation was supported by NASA.

Received August 14; revised October 27, 1972.

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LETTERS TO NATURE

Gravitation, Strong Interactions, and the Creation of the Universe

I CONSIDER the hypothesis that the strong interactions are gravitational in origin, and that unitary symmetry is a consequence of the equivalence principle of general relativity[1]. This hypothesis is a natural extension of the Misner–Wheeler "geometrodynamics"[2] which gives a world view that describes all of physics in terms of space-time curvature and multiply connected space-like hypersurfaces or "wormholes". Quantum geometrodynamics for strong interactions[1] assumes that the fundamental building block for hadronic matter is the parton[3,4] which is identified with a very massive "quantum blackhole" of bare mass 10^{-5} g, radius 10^{-33} cm, spin $\frac{1}{2}\hbar$, and electric charge quantized in units of $e/6$. The large bare mass comes from equating the Schwarzschild radius $2Gm/c^2$ with the quantum wormhole radius[2] $(G\hbar/c^3)^{\frac{1}{2}} = 10^{-33}$ cm. The Schwarzschild solution in general relativity for a spherically symmetric mass, as well as the Reissner–Nordstrom solution[5] for a charged mass, have time-symmetric space-like hypersurfaces with wormhole topology. In the Reissner–Nordstrom case, test particles above a critical mass will not fall into the blackhole singularity at $r=0$. Further, the throat of the wormhole will not pinch off in finite proper time because of the pressure of the trapped electric flux in the wormhole[5]. All of the partons whose bound states are mesons and baryons are of the Reissner–Nordstrom type with additional terms due to zero point quantum fluctuations in a W.K.B. model.

The value of $e/6$ for electric flux quanta trapped in the quantum blackholes or partons comes from fitting quantum geometrodynamics to the Bacry–Nuyts–van Hove[6] integer charged quark model. In this synthesis of models, the quark is a bound state of three partons plus a "sea"[3,4] of virtual parton-antiparton pairs due to quantum fluctuations. The large bare parton mass of 10^{-5} g gives a strong gravitational force between bare partons with strength $Gm^2 \approx \hbar c/4 = 1233(e/6)^2$ which is large compared with the strength of electrical forces between the bare partons. Mesons and baryons are built out of bare partons in a two-stage process. First, the bare partons form stable quark states consisting of three partons plus the virtual sea of parton-antiparton pairs. The primordial fusion process results in the release of almost all of the bare rest mass of 3×10^{-5} g in the form of gravitons, photons and neutrinos. This energy release is of the order of 10^{22} MeV per fusion event which should be compared to the binding energy of ^4He which is only 28 MeV. Thus, the fusion of bare partons is a truly cataclysmic event which occurred at the creation of the universe in the primordial "big bang". One might conjecture that this process is providing the energy source for quasars. The effective mass of dressed parton "quasiparticles" in the quark state is of the order of 10 BeV or greater. In the second stage, the quarks form mesons and baryons according to the SU(3) scheme with the release of a relatively small amount of binding energy. The effective mass of dressed parton quasiparticles in hadronic matter is only of the order of 2 BeV so that the impulse approximation can be used to describe deep inelastic electron-proton scattering[3,4]. The quantum geometrodynamic model gives the correct average mean square charge per dressed parton, that is $\bar{Q}^2=0.17$ for the proton as measured experimentally[7]. Other phenomenological quark models predict 0.33 or 0.22 for $\bar{Q}^2$ (refs. 3, 4). In quantum geometrodynamics, the internal quantum numbers, isotopic spin, hypercharge and so on describe the distribution of electric flux quanta among the three partons making each quark. This feature when combined with the equivalence principle leads to a natural explanation[1] of the observed universality of the slopes of Regge trajectories. In the limit of zero internal quantum numbers, there are no electrical forces, and the equivalence principle ensures that all quarks have the same mass. Therefore, SU(3) strong interaction symmetry is a consequence of the universality of gravitation as first recognized by Galileo. I have shown how gravitation can act superstrongly on the primordial level of bare partons or quantum blackholes. Gravitation presents a dual aspect on the collective level of hadronic matter. In the latter case, gravitation acts directly in the normal weak way, but it also acts indirectly in a strong way. Thus, the fusion of bare partons into quarks lowers the rest mass so that quarks have a weak direct gravitational interaction among themselves. A hadron is a loose collection of integer charged quarks[6]. The nuclear forces due to Yukawa exchange of virtual mesons exist because of this loose binding so that it is relatively easy for quark–antiquark pairs to split off from the sea of parton–antiparton virtual pairs which have themselves formed a loose association of quark–antiquark pairs. That is, the probability amplitudes for virtual meson emissions and absorptions are large, and so are the corresponding nuclear force coupling constants. Thus, the nuclear forces represent an indirect collective gravitational effect.

Tryon[8] has presented a semiclassical model of hadronic matter as a "spinning loop" of parton–antiparton pairs. This model has the virtue of giving good agreement with experiments on Regge trajectories. There also exist "hadronic string"[9,10] models of a more sophisticated kind. All of these models must make phenomenological dynamical assumptions. It appears likely that general relativity with W.K.B. quantum corrections[1] can give a fundamental dynamical foundation for these models[7–10]. A spinning loop appears if we picture a hadron as having a blackhole pointlike centre which is the result of the parton fusion. For example, the centre of a baryon might consist of a composite blackhole formed from three quarks. The metric external to the blackhole is given by the squared line element

$$ds^2=f(r)c^2dt^2-f(r)^{-1}dr^2-r^2\ (d\theta^2+\sin^2\theta\, d\varphi^2)$$

where in an oversimplified case I take

$$f(r)=1-r_s/r+r_s r^2_c(L+\tfrac{1}{2})^2/4r^3$$

such that $r_s=2GM/c^2$, $r_c=\hbar/Mc$, and L is the angular momentum of the rotating blackhole. The mass M is much smaller than the bare parton mass of 10^{-5} g and the Compton wavelength r_c is much larger than 10^{-33} cm. This metric ignores the presence of electric charge but includes the effect of rotation. Even if there were no net rotation ($L=0$), there is still a repulsive centrifugal barrier term from the quantum zeropoint fluctuation $\frac{1}{2}\hbar$. The gravitational potential is essentially $f(r)-1$ (ref. 11) which has a minimum at $r'=(3/4)^{\frac{1}{2}}\ (L+\frac{1}{2})\ (\hbar/Mc)$. One can imagine a spinning loop of quark–antiquark pairs located at r'. The quarks in the loop have the same internal quantum numbers as the quarks in the central blackhole. The average of the internal quantum numbers in the loops is zero because each quark has a corresponding antiquark. Ross[11] has proposed a similar model to explain the mass spectrum of leptons. One can go further and derive a Heisenberg antiferromagnetic exchange interaction giving zero net spin for the quark pairs in orbit at r' around the central blackhole[1]. This kind of interaction must be postulated *ad hoc* in the hadronic string model[9,10] but appears as a natural consequence of gravitation in quantum geometrodynamics.

It has already been suggested that the primordial parton fusion must primarily occur in the earliest stages of the initial singularity associated with a "big bang" cosmology. Penrose[12] and Hawking[13] show that singularities in the solutions of the equations of general relativity are to be expected. I conjecture that such classical singularities are unstable and split into a "tangle" of quantum singularities of bare mass10^{-5} g. Verification of this conjecture will have to await the quantization of general relativity. But the above considerations suggest that the conjecture is a fruitful working hypothesis. The scenario for the creation thus starts with the most primitive state of matter in the form of quantum blackholes or partons. The partons start to fuse into quarks with the release of enormous zero rest mass energy. The initial ratio of radiation to matter energy after the parton fusion occurs is of the order of 10^{20}. The primordial fireball is cooled by the expansion of the universe and part of its remnant is in the form of 3 K blackbody radiation. One would also expect remnants in the form of neutrinos and gravitons.

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Received July 4, 1972.

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A New Way to Observe Gravitational Waves

I GIVE a new interpretation of the nature of gravitational waves of high frequencies and intensities and a new method of finding evidence for them.

It is possible to reverse the polarity of a fermionic system in a very short time by electromagnetic methods (bosonic systems require more energy). Such a spin reversal changes the internal mass-energy structure of particles and gives rise to gravitational waves. There are, however, difficulties of interpretation because we do not know how to incorporate quantum effects into a gravitational theory and because it is only in the linear form of Einstein's theory of gravity that we know how to include time changes in inertial moments as sources for the equations of gravitational waves[1]. Here I give a source description applicable both to quantum theory and to the complete form of general relativity.

If the energy momentum conservation laws are written in the form of an ordinary divergence[2]

$$[\sqrt{-g}(T^K{}_I+t^K{}_I)]_{,K}=0 \qquad (1)$$