GRAVITY RESEARCH FOUNDATION
New Boston, New Hampshire

SELECTED ESSAYS FOR 1967

Bostick, Winston H. — GRAVITATIONALLY STABILIZED HYDROMAGNETIC MODEL OF THE ELEMENTARY PARTICLE (II)

The author describes the concept he has proposed of hydromagnetic stabilization of electric charge which requires that an elementary particle like the electron be composed of a charged filament circulating with a velocity v = c. He has developed his model to obtain spin 1/2 for fermions and a value of the gyromagnetic ratio

$$g = \frac{e}{2mc}\ 2\left[1 + \frac{1}{2\pi\ 137} \pm \sim \frac{1}{137^2}\right]$$

for the electron. The theory predicts that all mass and momentum (including spin) are electromagnetic in origin and that the internal stresses which keep the electromagnetic energy bound into the particle are self-gravitational.

Bramanti, Donato — PRINCIPLE OF EQUIVALENCE AND DETECTION OF GRAVITATIONAL WAVES

The first part of this essay discusses the hypothesis that the principle of equivalence may not hold for free electromagnetic energy and other cases not yet supported by experiments. It examines those proprieties of gravitational phenomena which could follow from this assumption and the possibilities of building monopolar or dipolar detectors of gravitational waves.

In the second part two detectors are proposed which could be used to detect high frequency g-waves generated in the laboratory or to search for interstellar ones.

Clemence, G. M. & Szebehely, V. — ANNUAL VARIATION OF AN ATOMIC CLOCK

The error of an atomic clock arising from the annual variation in the distance of the earth from the sun is discussed.

It is shown that if an accuracy of four decimals is required, the atomic time contains errors varying between +17 and -17 units.

DeWitt, Bryce — IS THE UNIVERSE UNIQUE

A discussion is given of some remarkable conclusions which may be drawn from the canonical quantum theory of finite worlds. In the absence of asymptotically Minkowskian coordinates the dynamics of such worlds must be described in intrinsic terms. This description is provided by the so-called Hamiltonian constraint. The operator which appears in this constraint has a spectrum which extends from $-\infty$ to ∞. Only the zero eigenvalue has physical significance. Evidence is presented that the spectrum, although discrete, is everywhere dense on the real line. This means that the universe may have only a single unique wave function. An interpretation of such a wave function is given within the framework of a set of ideas originally formulated by Everett.

Harrison, E. R. — MATTER-ANTIMATTER AND THE ORIGIN OF GALAXIES

Baryon inhomogeneities in the early high density stage of the universe account for the origin of galaxies. The inhomogeneity is amplified by baryon pair annihilation as the universe expands and eventually galaxies and antigalaxies are formed. This process is more efficient than the usual process which assumes that the initial conditions of a structured universe are density fluctuations.

Hawking, Stephen W. — THE RELATION BETWEEN THE ASYMPTOTIC AND LOCAL MEASURES OF MASS

An intrinsically defined integral over a spacelike two-surface is given which can in certain cases be regarded as the total mass inside the surface. Asymptotically, this integral tends to the expression given by Bondi and others and would provide a means of relating this to the local distribution of mass-energy.

Hood, C. Gregory — A CRITIQUE OF MACH'S PRINCIPLE AND THE PRINCIPLE OF EQUIVALENCE

Our theoretical understanding of gravitational phenomena is best expressed by the general theory of relativity. In order to further our understanding, however, a more comprehensive framework is needed. It is argued herein that there is no need to appeal to Mach's principle when discussing accelerated reference frames. A purely local interaction is sufficient. Moreover, it is pointed out that the equivalence principle does not, in fact, describe gravitational effects and, furthermore, it fails to conform to the general principle of relativity. A reformulation of theory in terms of the completeness of interactions is advanced.

Jordan, Pascual

EMPIRICAL TESTS OF DIRAC'S HYPOTHESIS ABOUT GRAVITATION

This essay discusses the present status of the empirical test of the gravity hypothesis put forward in 1937 by the famous physicist Dirac. In a book (published several months ago), the author showed that in geophysics and geology no really proven fact seems to exist in disagreement with the hypothesis. Then two possibilities of testing the hypothesis by modern astronomical precision measurements are discussed.

Kraus, Alfred A. Jr.

NON-ZERO REST MASS OF THE GRAVITON

If the graviton is assumed to be a particle of mass $0 < m < 0.7 \times 10^{-60}$ grams, one can understand the size of galaxies and resolve a difficulty about the potential energy of a particle in an infinite universe. In addition, such an assumption may lead to a better understanding of the way galaxies condensed from primordial matter and provide corrections to the General Theory of Relativity which may give alternate theories of the structure of the universe.

Kraus, K.

DEFINITION OF RENORMALIZED MASS IN CLASSICAL GRAVIDYNAMICS

In Einstein's theory of gravitation, energy and momentum of sufficiently regular systems can be defined either as space integrals of suitable densities, or alternatively as surface integrals of certain superpotentials.

For singular fields, these definitions are in general not equivalent. This is shown explicitely for an electrically charged point particle (Reissner-Nordstrom metric). The first method produces, similar to classical electrodynamics, a divergent self-energy, whereas the second method gives a finite result, thus leading automatically to a renormalized mass. Perhaps quantized gravity might cause similar improvements of a quantum field theory.

Layzer, David

GRAVITATIONAL SHIELDING AND THE RANGE OF GRAVITATIONAL FORCE

Current ideas on the nature of gravitation are based mainly on the results of applying Newtonian theory to distributions of matter embedded in empty space. Application of Einstein's theory to a statistically uniform distribution of matter filling all space shows that these ideas need to be revised. In particular, gravitational shielding occurs and has important observable consequences; and gravitational forces have a finite range, essentially the radius of the theoretically visible universe. The last fact may explain the observation that the size of self-gravitating systems has a well-defined upper limit.

Levy-LeBlond, Jean Marc — GRAVITATIONAL UNSTABILITY IN QUANTUM MANY-BODY SYSTEMS

Rigorous inequalities are derived for the ground-state energy of a non-relativistic quantum-mechanical system of N particles in gravitational interaction. It is shown that gravitational forces do not saturate, the binding energy per particle increasing with N like $N^{4/3}$ at least. This explains quantitatively why gravitational forces finally predominate over Coulomb forces for large enough systems. An extension to the case where relativistic effects enter only at the kinematical level, permits to derive rigorously from first principles the Chandrasekhar mass limit, above which no collection of cold matter is stable against gravitational collapse (as in white dwarf stars).

Misner, Charles W. — THE THEORY OF THE UNIVERSE

The cosmic blackbody ($3^{\circ}K$) radiation which is assumed to originate in the early epochs of a "hot big bang" cosmology has been observed to have remarkably little anisotropy ($< 1\%$). We seek to "explain" this observation, which is the most accurate cosmological datum known, within relativistic cosmology theory. A new Lagrangian technique for studying homogeneous cosmological models allows us to discuss, analytically, solutions of greater complexity than were previously manageable. We find that the neutrinos which should also be thermally produced early in the big bang have important gravitational effects once they become collisionless, due to the large anisotropic stresses they can develop in an anisotropically expanding universe. In conjunction with the overall expansion these neutrino restoring forces can reduce the anisotropy (expansion ratio in different directions) from 10^5:1 just before neutrino collisions cease to less than 1.01:1 before photon scattering stops, and there are additional mechanisms which should make the reduction in anisotropy even more dramatic.

Nordtvedt, Kenneth, Jr. — THE EQUIVALENCE PRINCIPLE, GRAVITATIONAL THEORIES, AND THE STABLE LIBRATION POINT OF LAGRANGE

It is pointed out that the Equivalence Principle has not been confirmed for massive bodies to the accuracy it is confirmed for very small bodies. The location of the stable libration point of LaGrange is shown to be a sensitive test of the Equivalence Principle for massive bodies. A radar reflection experiment is proposed as a test.

It is shown that the validity of the Equivalence Principle for massive bodies is not a trivial consequence of gravitational theories, rather it puts demands on the non-linear structure of the theories.

The proposed radar experiment is shown to test the space-time metric components in a new way, including a measurement of g_{oo} to non-linear order, and also a measurement of the off diagonal components g_{ok}, which have not previously been tested by any gravitational experiment.

Sadeh, Dror — GALAXIES AS GRAVITATIONAL LENSES

The possibility for a galaxy to gather light from another remote galaxy, deflect and focus it towards an observer on earth - is known to depend on the mass, radius and the distance of the nearer galaxy. If the nearer galaxy is found to be at a distance larger than a certain value (which depends on its mass and radius) it can act as a gravitational lens provided there is a galaxy behind it. The question we pose is whether the objects called quasars are single intrinsically luminous entities or are the result of an accidental alignment along the line of sight of two normal galaxies, the more distant of the two having its light amplified by the gravitational lens effect of the nearer galaxy. If galaxies are distributed at random in the universe, the probability that we shall see two galaxies one exactly behind the other is calculated and found to be so small that the answer to our question is negative. But, if we assume that most galaxies come in pairs, we can find, depending on the cosmological model ~ 30 galaxies one exactly behind the other in such a way that an amplification of the order of fifty can occur. This model explains also the intensity variations in the quasars, but fails to explain other observational properties of the quasars.

Sciama, D. W. — A NEW TEST OF MACH'S PRINCIPLE USING THE COSMIC MICROWAVE BACKGROUND

Mach's Principle, on which Einstein's theory of gravitation is based, requires that distant matter be non-rotating when viewed from an inertial frame. This requirement is known to be true to within 5 seconds of arc per century. This accuracy can be improved ~ 5,000 times if the excess microwave background arises from distant matter. For the sun probably rotates around the Virgo cluster of galaxies with an angular velocity ~ 10^{-3} seconds of arc per century. The corresponding velocity of 500 km/sec would, on Mach's Principle, lead to an anisotropy ~ 0.1% in the microwave background. This should be detectable within a year.

Silk, Joseph — THE ORIGIN OF GALAXIES

One of the most fundamental problems in cosmology is to explain the origin of fluctuations in an expanding universe. Von Weizsaecker's hypotheses of primordial turbulence is rediscussed in the light of recent observations. A somewhat speculative means of resolving the principle difficulty, namely the origin of the cosmic turbulence is proposed. Our

suggestion is motivated by a recent observation of quasar anisotropy and is that there may have been two "big bangs". We show that this leads to the formation of galaxies in a mass range consistent with the observations, and may also account for metagalactic cosmic rays.

Sturrock, P. A. — CONVERSION OF GRAVITATIONAL ENERGY IN QUASARS AND RADIO GALAXIES

The enormous radio output of quasars and radio galaxies, following explosions in these objects, is commonly attributed to the conversion of gravitational energy into high-energy particles. In this essay a mechanism is suggested by which this energy-conversion might take place.

If intergalactic space contains a primeval magnetic field, a mass of gas condensing under gravity will convert gravitational energy into magnetic energy. The resulting magnetic field configuration will have singular surfaces known as "sheet pinches". A certain instability at this surface provides a mechanism for converting magnetic energy into high-energy plasma which later forms twin radio clouds.

Weinstein, D. H. — THE MEANING OF MACH'S PRINCIPLE

Mach's Principle is discussed in the light of the Equivalence Principle. It is found that with the exception of Planck's Constant, physical quantities such as mass, charge, etc. are functions of the difference in gravitational potential between the local system of an observer and a non-local system. The intimate connection between physical measurements and the velocity of light is developed. It is then shown that one can remove the difficulties present in the current interpretation of Mach's Principle.