GRAVITY RESEARCH FOUNDATION

New Boston, New Hampshire 03070

Abstracts of Award Winning and Honorable Mention Essays for 1970

Award Winning Essays

First Award - Using Gravity to Determine the Nature of Superluminous Astronomical Objects by P. A. Feldman and J. R. Gribbin, Institute of Theoretical Astronomy, University of Cambridge, Cambridge, England.

Abstract - Power spectrum analysis of the optical variations of Sco X-1 reveals periodicities which may be intepreted as atmospheric vibrations of an underlying star. This hypothesis leads to an estimate for the effective gravity in the atmosphere which implies that the star associated with this X-ray source is either a white dwarf or a neutron star. The authors suggest that similar analysis of the optical variations of other astronomical objects can provide similar information about their basic structure; in particular, the problem of the nature of quasars might be resolved by this means.

Second Award - A New Approach to Singularities by B. G. Schmidt, Institute for Theoretical Physics, University of Hamburg, Hamburg, Germany.

Abstract - One central issue of the theory of Gravitation within the framework of General Relativity is the issue of singularities whose definition creates serious difficulties. The essay presents a surprisingly simple and powerful solution of the problem. To any space time a boundary is attached on which incomplete geodesics terminate as well as inextendable time-like curves of finite length and bounded acceleration. The construction is free of ad hoc assumptions concerning the topology of the boundary and the identification of curves defining the same boundary point. Moreover it is the direct generalization of the Cauchy completion of positive definite Riemannian spaces.

Third Award - Gravitational Waves and a Search for Associated Microwave Electromagnetic Radiation by R. B. Partridge, Joseph Henry Laboratories, Princeton University, Princeton, New Jersey, and Remo Ruffini, Institute for Advanced Study, Princeton, New Jersey.

Abstract - The authors discuss astronomical sources which might produce the pulses of gravitational waves reported by Weber. A fraction of the energy emitted by such sources may emerge as electromagnetic radiation. The authors are now searching for electromagnetic pulses associated with the reported gravitational events. They observe the galactic center at a favorable microwave frequency, 19 GHz. The directional sensitivity of Weber's detector (given below) is a maximum during the observing period, allowing a direct comparison between the data of Weber and of the authors. If positive correlations are found, the propagation velocity of gravitational waves can be determined to one part in 10^{11} relative to c.

Fourth Award - The Application and Principle of Gravity-Assist Trajectories for Space Flight by Victor C. Clarke, Jr., Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.

Abstract - In January, 1970 NASA authorized the Mariner Venus/Mercury 1973 Project. This action was historic because, for the first time, a highly beneficial use of a planet's (Venus) gravity field will be made in spaceflight. This will be accomplished by employing a "gravity assist" trajectory to fly from Earth to Mercury. This essay describes the application and principle of gravity assist trajectories, i.e., the use of a planet's gravity field to sharply alter a spacecraft's course. Discovery of this principle has opened a new frontier of solar system exploration at considerable savings in launch vehicle size and cost.

Fifth Award - Laboratory Experiments on Quantum Detection of Non-Newtonian Gravitational Effects by J. A. Tyson, Bell Telephone Laboratories, Murray Hill, New Jersey.

Abstract - The Lense-Thirring effect remains the only classical prediction of Einstein's General Theory of Relativity which has not to date been observed. Predicted shortly after the General Theory appeared, the Lense-Thirring rotation survives as the single example of Mach's Principle in the various predictions of Einstein's theory. Early attempts at astronomical verification were beset with both experimental (observational) and theoretical problems: the predicted L.T. precession of Jupiter's 5th moon is nearly canceled by the direct Einstein precession! No other astronomical test of the L.T. effect has been suggested, except for the ambitious artificial satellite experiment proposed by Schiff and Fairbank. Laboratory observation of the L.T. effect has not been regarded seriously because of a variety of noise problems. In this essay an experiment is described which is in progress in which laboratory observations of the L.T. rotation and other effects are attempted by making use of the novel inertial response of quantum fluids.

Honorable Mention Essays (Alphabetical Order)

1. Gravitational Waves and Cosmology by Bruno Bertotti, European Space Research Institute, Frascati, Italy and Alfonso Cavaliere, Center for Space Research, M.I.T. Cambridge, Massachusetts.

Abstract - The strong bursts of gravitational waves detected by J. Weber, if confirmed, suggest the presence in the galactic centre of a relativistic cluster of collapsed bodies which "burns" its own gravitational potential energy and slowly decays into a dead, collapsed object. The authors discuss the possibility of this being a common feature throughout the universe and consider a simple cosmological model in which the "missing mass" is attributed mainly to gravitational waves and dead, dark galaxies. The production of the former is described by a simple rate equation containing a characteristic frequency α. Using the known values of the Hubble constant H and the present visible mass density they find $\alpha \simeq 8$ H; the corresponding gravitational brightness of an average galaxy turns out to agree with Weber's figure (assuming a wide band spectrum) to within a factor 2. This model features an isotropic cosmological background of gravitational waves, with energy density about 30 times smaller than the energy arriving from the galactic nucleus.

2. Annihilation of Gravitational Forces by Jeffrey M. Cohen, Institute for Advanced Study, Princeton, New Jersey.

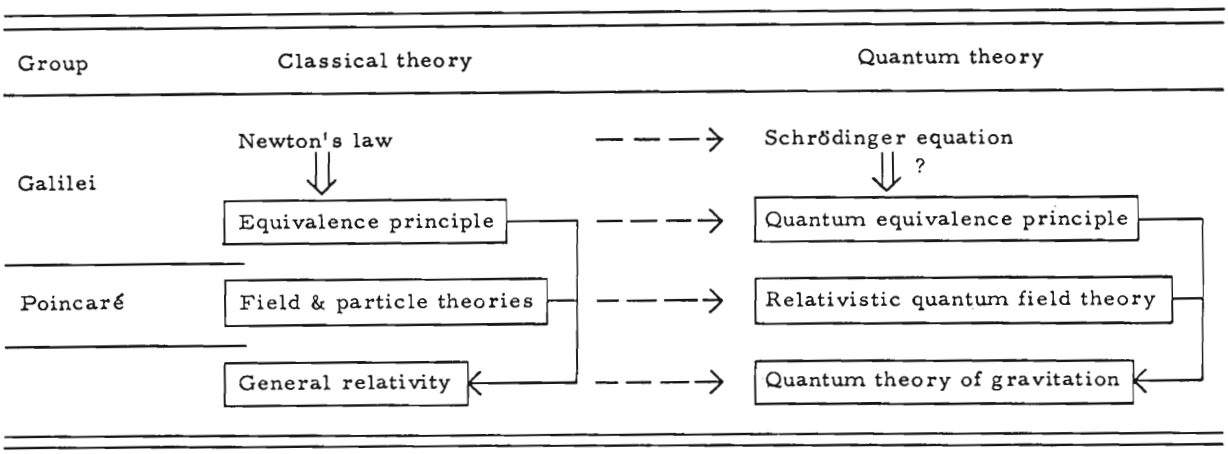
Abstract - In Newtonian mechanics, a distinction is made between gravitational and inertial forces since inertial forces can be eliminated via coordinate transformation. Gravitational forces can also be eliminated in the same way, Einstein noted. The difficulty with these methods is that they can destroy the observer. If he jumps out of a window and then releases a ball, it will not fall relative to him as they both fall toward destruction. In this paper is described a machine which can annihilate certain gravitational forces without destroying the observer.

3. A New Class of Gravitation Wave Detectors by D. H. Douglass, Jr., Department of Physics and Astronomy, University of Rochester, Rochester, New York

Abstract - Generalized mechanical resonators with one degree of freedom are considered as gravitational radiation detectors. Two classes are defined: Class I corresponds to $\omega_o \sim \ell^{-1}$ and Class II corresponds to $\omega_o \sim \ell^{-2}$, where ω_o is the resonant frequency and ℓ is the size. Class I detectors (Weber type) are found to be impractical to construct below about 1000 Hz, whereas Class II detectors do not become impractical until a frequency of about 30 Hz. It is shown that Class II detectors have a power sensitivity comparable to a Class I detector at a frequency 100 times higher. Detection of gravitational radiation from the crab pulsar may be feasible with Class II detectors. Finally, it is pointed out that a Class II detector also can detect scalar gravitational radiation and discriminate between it and tensor gravitational waves.

4. The Physical Interpretation of Quantum Theories of Gravitation by H. Ekstein, Argonne National Laboratory, Argonne, Illinois.

Abstract - An essential part of gravitational theory is the manner in which observations are influenced by the state of motion (acceleration) of the observer (line or inanimate). Einstein's point of departure was the equivalence principle of Newtonian mechanics. The general theory of relativity can be considered as a synthesis of the Newtonian equivalence principle with special relativity. On the other hand, the efforts to construct a quantum theory of general relativity start from classical general relativity. It may be fruitful to explore an alternative approach to a quantum theory of gravitation in which a quantum version of the Newtonian equivalence principle is married to special relativistic quantum field theory. The following chart shows the proposed scheme of exploration.



5. Superspace and Cosmology; or the Big and the Small by Arthur Elliot Fischer, Department of Mathematics, University of California, Berkeley, California.

Abstract - Cosmology can be broadly interpreted as an attempt to understand both the topological and geometric structure of the universe in the large. As the experimental evidence available to cosmologists is not of such a global nature, the cosmologist is forced to construct a global geometrical model of the universe out of its local properties. This is usually accomplished by means of some "Copernican" type of principle, variously phrased as "we do not occupy a privileged place in the universe," or as a strong principle of equivalence, whereby one assumes that the results of local experiments hold universally. The author emphasizes that such a principle is not enough to piece together a cosmological model from its local properties, even if these properties are assumed to be everywhere the same. What is needed is an additional "communication" type of principle, which assumes that each point of the space can be translated into any other point of the space by means

of some group action. Moreover, if the local metric structure is assumed to be symmetric "enough", then these two principles are sufficient to construct a cosmological model out of the local metric properties of the space. The author shows how this group action can be introduced in Superspace. A short description of Superspace and its usefulness is given.

6. Gravitational Radiation--The Key to the Cosmic Mystery? by Donald W. Goldsmith, Institute for Plasma Research, Stanford University, Stanford, California.

Abstract - Weber's apparent detection of gravitational radiation from the center of our galaxy suggests that gravitational energy waves hold the key to the universe's expansion. The waves of gravitational radiation that Weber has observed imply an energy production rate at the galactic center of seventy solar mass energy units per year. If mass has been converted into energy at this rate in other galaxies, then the resultant gravitational radiation has more mass than the total of all galaxies and could assure that the present universal expansion will not continue indefinitely.

7. Non-Markoffian Kinetic Theory and Hierarchical Cosmologies by M. J. Haggerty, The University of Texas, Austin, Texas.

Abstract - Prigogine and Severne have developed a non-markoffian kinetic theory to describe binary gravitational interactions in a many-body system. It was found that gravitational energy is irreversibly transferred into thermal energy, and that there is no approach to a thermodynamic equilibrium. The author suggests that the theory provides a possible dynamical mechanism for the growth of a hierarchical structure of clusters in the expanding universe. Explicit modifications to the newtonian Friedmann model are developed.

8. Collapsed Objects of Very Low Mass by Stephen Hawking, Institute of Theoretical Astronomy, Cambridge, England.

Abstract - It is suggested that there may be a large number of gravitationally collapsed objects of mass 10^{-5} gm upwards which were formed as a result of fluctuations in the early universe. They could carry an electric charge of up to 30 units. Such objects would produce distinctive tracks in bubble chambers and could form atoms with orbiting electrons or protons. A mass of 10^{17} gm of such objects could have accumulated at the centre of a star like the sun. If such a star later became a neutron star there would be a steady accretion of matter by a central collapsed object which could eventually swallow up the whole star in about ten million years.

9. Redshift Fluctuations Due to Gravitational Waves by William J. Kaufmann, Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California.

Abstract - The interaction between gravitational waves and photons is examined in the geometrical optics limit. It is found that gravitational waves will cause a beam of photons to experience small fluctuations in frequency. The amplitude and period of the fluctuations in the energy of the photons are related to the amplitude and period of the gravitational waves in a simple fashion. More importantly, gravitational waves from certain types of catastrophic astronomical events should be detectable using the Mössbauer Effect.

10. The Runaway Point Charge in General Relativity by W. Kinnersley and M. Walker, Center for Relativity Theory, Department of Physics, The University of Texas at Austin, Austin, Texas.

Abstract - A solution of the Einstein Maxwell equations is studied and shown to be the field of a uniformly accelerating point charge. It contains three arbitrary parameters corresponding to mass, charge, and acceleration. In the weak-field limit when the mass and charge are small, it is shown that the source follows a uniformly accelerating path in flat space. If instead the acceleration is set to zero, the Reissner-Nordstrom field of a charge at rest results. Unusual properties of the solutions are discussed, including a crease which extends to infinity and an angular distribution of gravitational waves which is singular along one direction.

11. The Interplay of Gravitation and Magnetism in Stars and Galaxies by David Layzer, Harvard College Observatory, Cambridge, Massachusetts.

Abstract - A wide spectrum of bizarre and hitherto unexplained astronomical observations relating to explosive events in galaxies, multiple galaxies, radiogalaxies, and quasars may result from an interplay between gravitational and magnetic forces in systems whose internal energy resides mainly in a magnetoturbulent field. On theoretical grounds, such a field may be expected to come into being in any sufficiently massive self-gravitating gas cloud, and ultimately to absorb a large faction of the energy released by the cloud in the course of its gravitational contractions.

12. A Class of Singularity-Free Einstein Fields and its Cosmological Implications by J. Pachner, Department of Physics, University of Saskatchewan, Regina Campus, Regina, Saskatchewan.

Abstract - Some qualitative arguments are given for a possible existence of a narrow domain of singularity-free solutions of Einstein equations in the case of rotating incoherent matter. Singularity is here defined as a state with infinite mass density. A method of numerical integration of Einstein equations is briefly described. The domain of singularity-free solutions, confirmed by that method elsewhere, is roughly delimited. Impact of these singularity-free Einstein fields upon cosmology is discussed. A new hypothesis of the formation of galaxies and their spiral structure is formulated and compared with observational data.

13. The Astronomical Significance of Mass Loss by Gravitational
by D. W. Sciama, Scuola Normale Superiore, Pisa, Italy.

Abstract - If the events detected by Weber represent gravitational radiation emitted by our Galaxy, the astronomical implications are serious. The author examines the consequences of assuming that the present radiation rate R($\sim$300 $M_\odot yr^{-1}$) has been maintained for (a) 10^8 years, (b) 10^9 years, (c) 10^{10} years.

In case (a) the absence of a K term in the radial motions of nearby stars implies that R must be less than 200 $M_\odot yr^{-1}$. If the Kerr expansion is correct, R$\sim$70 $M_\odot yr^{-1}$. Other considerations show that (b) and (c) are marginally possible also, although they require high radiation efficiencies and imply that most of the energy-density in the Universe is now in gravitational radiation.

14. Quasistellar Objects and Gravitational Collapse: A Re-evaluation
by T. J. Sejnowski, Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08540

Abstract - As experimental data on extragalactic objects are accumulated, the inadequacy of any single theoretical model has become apparent. This essay re-examines some features of proposed models with the help of recent observations and theoretical work. A new point of view emerges in which a massive gravitationally collapsed central object in a compact cluster of stars plays a crucial role in the evolution and generation of energy in compact galactic nuclei, which approach appears particularly promising.

15. Does the Elementary Particle Vacuum Have a Phase Transition at High Temperature? by R. M. Williams, 8 Midfield Lane, Willingboro, New Jersey.

Abstract - A known analogy between Fermions described by Dirac's equation and zero temperature superconductor quasiparticles is extended to non-zero temperatures. This extended analogy does not appear to contradict known experimental results although it predicts that, as the temperature increases, the Fermion rest mass decreases to zero at and above a critical temperature. This critical temperature is analogous to the temperature at which a superconductor becomes a normal metal but is in the range (above 1,000,000,000° K.) where many nuclear, astrophysical, cosmological and general relativistic phenomena occur. Experimental consequences of these predictions are discussed.