

Eastern Theoretical Physics Conference

Astrophysics, quantum field theory, elementary-particle physics (mostly symmetries and current algebras), solid-state physics and the many-body problem—these were the concern of 300 physicists who met last 25, 26 Nov. for the Fifth Annual Eastern Theoretical Physics Conference at Brown University.

Astrophysics. In the opening session E. L. Schücking (University of Texas) presented a review of the current status of cosmological theories based on currently adopted laws of physics and the Einstein field equations. Current cosmological theories are based on the concepts of isotropy and homogeneity. The homogeneity are based on the concepts of isotropy assumption has been validated for distances up to that of the Coma cluster, whose recession velocity is of the order of 7000 km/sec, corresponding to a distance of 100 megaparsecs. From the red-shift-vs-magnitude relation the assumption of isotropy is also shown to be valid to within 1%, up to 100 megaparsecs.

The most important question concerning the structure of the universe is curvature. Curvature is related to the deceleration parameter q_0 ($q_0 = -R\ddot{R}/\dot{R}^2$, R is the proper length and t is the proper time; $d \log R / dT$ is the Hubble constant). For a matter universe, with $q_0 < 0.5$, the universe is negatively curved and open and for $q_0 > 0.5$ the universe is positively curved and closed. q_0 can be determined from observation of the relation between magnitude and red-shift for distant galaxies. Unfortunately the present observation does not give a conclusive answer. Although quasars are believed to be intrinsically 100 times brighter than galaxies—because of the wide scatter in their intrinsic brightness—they do not serve as a good standard candle for distance measurements. Apart from observational difficulties, there are theoretical difficulties in accepting a value of q_0 even as small as 1. The required matter-energy content of our universe, corresponding to this value of q_0 is 100 times greater than what is

observed. From observation of quasars it has been concluded that there is very little intergalactic neutral hydrogen. Can there be a large amount of intergalactic ionized hydrogen? In answer to this question and other important cosmological questions, Schücking concludes that a large number of 5-meter telescopes or even bigger telescopes are needed. The price of a 5-meter telescope, asserted Schücking, is only comparable to intermediate-energy particle accelerators already available to some universities in this country, and so far only one such telescope has been built.

Edwin E. Salpeter (Cornell) discussed the problem of hydrogen molecules in interstellar space. Because the reaction $H + H \rightarrow H_2 + \gamma$ with both hydrogen atoms in their ground state is a forbidden transition, the formation of hydrogen molecules requires some catalysts. The most favorable process is through recombination of pairs of hydrogen atoms that have stuck to the surface of interstellar dust grains. The quantitative details of such surface recombination are still in doubt but the process is probably fairly efficient. Hydrogen molecules are destroyed only when they move through an ionized region, and their average abundance is estimated to be between 0.001 and 10 times that of atomic hydrogen.

Malvin A. Ruderman (NYU) reviewed the kinds of matter that could exist in stars at the end of stellar evolution: (1) white-dwarf matter of density $\rho < 10^9$ gm/cm³, which may constitute stars of mass less than 1.2 solar masses, (2) neutron-star matter of density greater than 10^{12} gm/cm³ composing stars of mass up to perhaps 2 solar masses and (3) stars collapsing indefinitely toward their Schwarzschild limits. White-dwarf matter is reasonably amenable to theoretical treatment. At zero temperature the ions form a body-centered cubic crystal in a degenerate electron sea. The lattice melts around 10^7 °K, typical of known internal temperatures. The heat capacity of a cooling white dwarf varies from that of a perfect gas through Dulong-Petit and Debye forms, but the heat of fusion is still a

significant uncertainty.

Neutron-star matter is characterized by a considerable proton impurity that can cluster into "quasi-nuclei." The main neutron fluid may be a superfluid with a gap that becomes nonisotropic as p -wave neutron-neutron attraction becomes the dominant force between paired neutrons at the top of the Fermi sea. An understanding of such details is crucial for discussions of the lifetimes of neutron stars as x-ray sources.

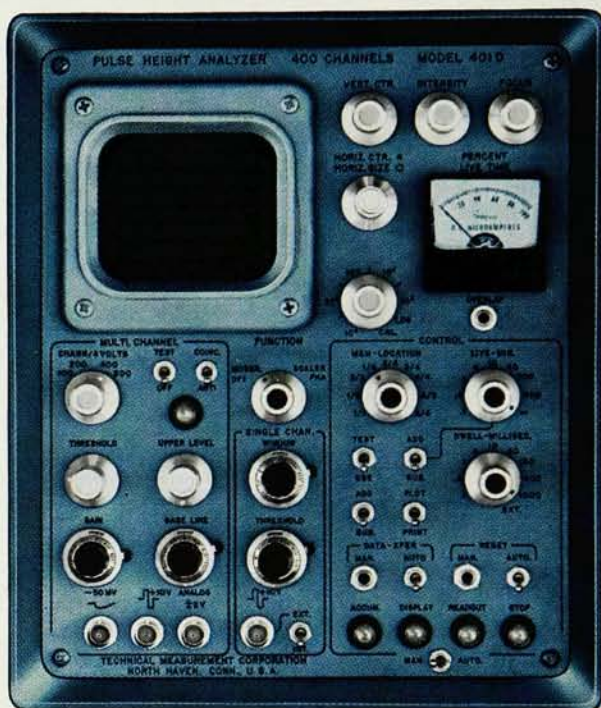
Philip Morrison (MIT) reviewed x-ray and gamma-ray astronomy. He discussed the opacity of our universe to photons and found that at energies between 10^3 and 10^{13} eV the universe should be reasonably transparent. He also pointed out that from about 150 hours of x-ray astronomy in rockets and balloons 24 discrete sources have been discovered, and so far two optical identifications have been made. Those identified are the Crab nebula and the x-ray star Sco X-1.

There are two mechanisms for x-ray emission: magnetic bremsstrahlung (synchrotron radiation) and Coulomb bremsstrahlung. The difficulty with magnetic bremsstrahlung is the relatively short lifetime of the relativistic electrons. Morrison thinks Coulomb bremsstrahlung is a more favorable mechanism for x-ray emission.

Elementary particles. Benjamin W. Lee (Stony Brook), in his talk on the application of current algebras, first reviewed successes in application of the equal-time commutator of hadron currents (in conjunction with the additional assumption of partially conserved axial-vector current) to the calculation by Adler and Weisberger of the axial-vector coupling constant G_A , to nonleptonic hyperon and K-meson decays and to s-wave pion-nucleon scattering lengths. On the question of pion-pion scattering, recent calculations of Steven Weinberg suggest that the imposition of partially conserved axial-vector current requires low-energy scattering to be very small.

The second part of Lee's talk dealt with classification of hadron states according to irreducible representations of the chiral $SU(3) \times SU(3)$ group whose Lie algebra is that gener-

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ated by the eightfold-vector and axial-vector currents. In the first approximation the SU(6) results are reproduced. Various technical advances in current algebra were then discussed in terms of a model of pion-isovector-photon scattering. Lee showed that the high-energy behavior of weak and electromagnetic amplitudes is quite different from that of hadronic amplitudes and is controlled by a fixed pole at $J = 1$ in the complex angular momentum plane: this point was further discussed by Francis E. Low (MIT). It was suggested that the above considerations give justification to a nonrelativistic quark model.

Low then discussed the very relevant question of consistency of current algebras based on the canonical field-theory formalism. In particular he elaborated on some recent work done with K. Johnson (MIT) in which they took a simple theory of quarks interacting with a scalar neutral boson and computed in power series the commutators of currents to see whether the results they got were the same as those that could be formally derived in the quark model. Whereas in general they found extra (Schwinger) terms, for the time components of the vector and axial-vector currents they showed a consistency with the usual current-algebra assumption. The algebra generated by V_0 and A_0 is precisely the domain where generally successful comparison with experiment is made. The situation becomes much more complex with vector-meson interactions, and it is questionable whether even the above conclusion holds.

J. J. Sakurai (Chicago) proposed that many calculations in current algebra lead to results that can in fact be obtained from models based on vector-meson dominance. He illustrated this equivalence with examples from pion-nucleon scattering-length formulas, ρ dominance for electromagnetic form factors, comparison of rates for ω and η mesonic and radiative decays, and K^* dominance in nonleptonic decays. He concluded, however, that even though many of the successes of current algebra can be derived in a completely trivial way from the vector-meson-dominance model, nevertheless the former theory is pertinent in that

it may provide the underlying theoretical basis for the success of a particular model: vector-meson dominance.

T. D. Lee (Columbia) discussed extremely interesting work done with Norman M. Kroll (La Jolla) and Bruno Zumino (NYU) that appears at last to put the much discussed question of vector-meson dominance of the electromagnetic interactions on a well defined and firm basis. The question whether the entire hadronic electromagnetic current operator can be identical with a linear combination of the renormalized field operators for the known vector mesons ρ^0 , ϕ^0 and ω^0 is thoroughly investigated in the context of a Lagrangian field theory. It is found that such an identity is completely consistent with gauge invariance, provided that these mesons are coupled only to conserved currents. They also discuss the general renormalization problem of the strong interaction of these vector mesons. They show that the proposed identity between hadronic electromagnetic current and the renormalized meson fields can be related to the possible identity between the unrenormalized currents generating the vector mesons and those generating the photon; furthermore, this proposed identity leads to an exact relation between the entire $O(e^2)$ hadronic contribution to the photon propagator and the renormalized propagators of the neutral vector mesons, and such a relation implies, among other consequences, that to $O(e^2)$ the ratio of the unrenormalized charge and the renormalized charge is finite if one neglects leptonic contributions. Lee gave various experimental applications. In particular, he made the analysis of ϕ - ω mixing and ϕ and ω leptonic decay rates independent of the validity of SU(3) symmetry.

Field theory. Arthur S. Wightman (Princeton) reviewed ideas, methods and results connected with proving the existence of solutions in quantum field theory. He stressed the physical importance of essential self-adjointness of the Hamiltonian in an n -body Schrödinger theory. Fundamental results of Toshio Kato in this area have essentially established existence of solutions for a large class of Hamiltonians in atomic and nuclear physics. Wightman proceeded to explore various problems associated with statistical

mechanics for finite systems, relativistic theory of charged particles in external fields, and cutoff relativistic field theories. The difficulty associated with the general field-theoretic case is that one is interested in the limit in which both the ultraviolet cutoff and the volume go to infinity.

Y. S. Jin (Brown) spoke about analyticity and asymptotic behavior of scattering amplitudes. The motivation here has been that ever since Stanley Mandelstam conjectured that the double spectral representation in energy and momentum-transfer variables should have well delineated analyticity properties, interest has been mushrooming in how much analyticity there is in fact in a local field theory. A. Martin, in particular, has proposed technical advances in extending the analyticity domain by using unitarity. Jin then enumerated several applications of the analyticity procedure including the question of bounds on the scattering amplitude in the asymptotic limit. Further progress in the field appears to depend on existence of an integral representation for the triple commutator and a more judicious use of unitarity.

Marvin L. Goldberger (Princeton) gave a delightful exposition of recent developments in Regge-pole theory. He first pointed out that this theory was almost forced to an early grave by experimentalists when the much trumpeted prediction of diffraction-peak shrinkage in high-energy hadron scattering was not confirmed. Theorists struck back recently, however, armed with a full repertoire of nonet vector and tensor mesons not known several years back. In particular there has been the notable success in explaining the dip in $\pi^- + p$ charge-exchange scattering where only the ρ Regge trajectory contributes. The situation with respect to polarization is unclear however, since with just the ρ trajectory, no polarization is predicted (experimentally some polarization is known to exist). In conclusion, Goldberger reported that although there remain problems associated with possible fixed singularities, conspiracies among trajectories, and moving branch points in Regge-pole theory, the theory's reported death is emphatically premature.

Julian Schwinger (Harvard) elaborated

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MEETINGS

rated on a new foundation for particle theory that was born out of frustration with a field theory of strong interactions having little contact with experiment and out of dissatisfaction with S-matrix particle theory because the weight of mathematical machinery developed here is entirely out of proportion to the physical ideas involved. The idea is to seek a middle ground between the two in which field theory is used to suggest a structure as the basis for calculation. Schwinger explored the general notion of source in its complementary aspects both as a numerical function $S(x)$ with space-time localizability (akin to a field theory) and as a function of momentum $S(p)$ (akin to S-matrix theory). The dynamics of particle interaction is abstracted into this source, which then serves as the practical tool for computation. Detailed application of this procedure is promised at a later date.

Solid state. At the final session Philip W. Anderson (Bell Labs) discoursed on theories of magnetism in metals. He pointed out that the existence of magnetism per se implies that the coupling is very strong—that metallic conduction implies a Fermi surface exists; so the problem is intrinsically as hard as the strong-coupling field theories of high-energy physics. In the case of pure metals, encouraging progress has been made in understanding, and parameterizing in a pseudo-potential scheme, the simple one-electron band theory of Ehrenreich, Phillips and Heine, who used elegant techniques of scattering theory. Anderson then discussed the busy field of localized magnetic states in metals where the questions are: (1) whether such things exist and (2) how to solve even the simplest many-body theories in the presence of strange anomalies at low temperatures. He concluded by calling attention to the wealth of unexplained experimental data that show very large anomalous effects.

C. N. Yang (Stony Brook) gave an account of the most exciting recent work, by him and his brother C. P. Yang, on the one-dimensional anisotropic chain with nearest-neighbor spin-spin interaction. They first rigorously proved Bethe's form of the

ground-state wave function for any fixed magnetization. In the limit of an infinite chain, for any given value of magnetization per site, the ground-state energy per site is then expressed, without approximation, in terms of the solution of an integral equation. It is interesting that the behavior of this ground-state energy per site, as a function of the magnetization per site, depends on the precise value of the anisotropy. The method of solution is then modified to yield precise information about eigenstates near the ground state. The result clarifies greatly the meaning of energy-momentum relations of so-called "elementary excitations" for a many-body system. Finally, by a most ingenious use of thermodynamics—in particular the entropy—the problem is solved exactly for finite temperatures, again in the limit of the infinite chain. All the results can be reinterpreted in terms of the mathematically identical problem of the one-dimensional quantum lattice gas.

Elliott W. Montroll (Rochester) reviewed work over the past few years in the theory of thermal transport coefficients. He covered the elegant formalism behind the theory of equilibrium and nonequilibrium processes and their relation to calculation of thermal conductivity, diffusion constant and viscosity.

Freeman J. Dyson (Institute for Advanced Study) spoke on the question whether the laws of quantum mechanics are by themselves sufficient to make matter stable. He took a simple model of a nonrelativistic system of N positive and N negative charges, all having equal mass and charge, interacting according to the Coulomb law. Imposition of the usual rules of quantum mechanics *without* the exclusion principle leads to the following inequality for the ground-state energy $E_N < -A_1 N^{7/5} R$ where $A_1 = (1944 \pi^4)^{-1}$ is an absolute constant and R is the Rydberg constant. Typically the binding energy of a macroscopic number of charges would be of the order of or greater than that of a medium-sized hydrogen bomb! Thus quite generally matter without the exclusion principle is unstable. Dyson also commented on application of this result to the nonexistence of a weakly interacting charged boson.

Drawing on his experience as director of the International Centre for Theoretical Physics in Trieste, Abdus Salam, who gave the banquet address, emphasized the potentially key role to be played by the United Nations in fostering international collaboration in science. Interestingly enough, the center at Trieste marks the first important step taken by the United Nations in the direction of the support of pure as opposed to applied science. It also serves as a perhaps unique meeting ground between physicists from the East and the West, which can also help in large measure to solve the problem of the isolation of physicists from developing countries who must otherwise exile themselves abroad if they are to remain active in science. Salam expressed the fervent hope that the natural extension of this activity by the United Nations would consist ultimately in the founding of one or several United Nations Universities.

The proceedings of this conference will be published shortly, and the next such conference will be held at Vanderbilt University in the fall.

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The authors thank T. T. Wu (Harvard) for discussions and suggestions. They feel that David Feldman (Brown) is to be congratulated for his efforts as chairman in organizing this conference.

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Kyoto: the Physics of Semiconductors

In reporting on the highlights of the 7th International Conference on the Physics of Semiconductors (Kyoto, Japan, 8-13 Sept. 1966) we are amazed at the breadth and depth of the subject matter—basic phenomena of lattice dynamics, electromagnetic theory, quantum theory in connection with band structure, many-body effects dealing with plasmons, phonons and interactions between them, quantitative effects in transport, magneto-optical and magnetoacoustic effects and scattering.

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