Meetings

Symmetry Principles at High Energy

Two important ideas, that nuclear forces arise from exchange of particles and that these forces are independent of charge, were combined in a Lagrangian theory by Kemmer in 1938. This charge independence is phrased in terms of isotopic spin symmetry, and the nature of the breaking of the symmetry via the electromagnetic interaction is understood. At the second Coral Gables conference on symmetry principles at high energy (Miami, Florida, 20–22 January 1965), J. Robert Oppenheimer (Institute for Advanced Study) suggested that perhaps the most pressing theoretical problem in high-energy physics is the understanding of the badly broken symmetries of strong interaction.

Indeed, during the past years the strong-interaction symmetry SU(3) has been useful in grouping particles of different isotopic spin and strangeness into multiplets and in relating the masses of particles in the same multiplet via the celebrated Gell-Mann–Okubo mass formula.

Another symmetry proposed during the past year by Sakita and, independently, by Gürsey and Radicati is that of SU(6), which combines SU(3) and the SU(2) group associated with spin. How to incorporate SU(6) into a relativistic theory is a problem which was recognized when the symmetry was first proposed. A. Salam (International Centre for Theoretical Physics, Trieste) presented a paper addressed to this problem. Salam reported work done in collaboration with R. Delbourgo and J. Strathdee. These workers consider a Dirac quark model, that is, a basic field ψ, which has a Dirac spinor index that runs from 1 to 4 and a SU(3) index that runs from 1 to 3. The interaction Lagrangian is assumed to be invariant under a group called $\widetilde{U}(12)$, which contains SU(6). The invariance of $\widetilde{U}(12)$ is broken by the kinetic energy term in the equations of motion. The physical particles are then assumed to transform like the products of ψ's and $\overline{\psi}$'s. A field that transforms like a product of a ψ and a $\overline{\psi}$ and satisfies a Duffin-Kemmer equation of motion describes both a nonet of pseudoscalar mesons and a nonet of vector mesons. The octet of $J^P = \frac{1}{2}^+$ baryon and the decuplet of $J^P = 3/2^+$ baryons are described by a field that transforms like the product of three ψ's and is fully symmetric in the three indices. This field obeys a Bargman-Wigner equation of motion. In the low-energy limit SU(6) symmetry obtains. B. Sakita (Argonne National Laboratory) reported on work he did with K. C. Wali, which was nearly identical with that of Salam. B. W. Lee (Institute for Advanced Study) presented a paper written in collaboration with K. Bardakci, J. M. Cornwall, and P. G. O. Freund, in which a Dirac quark field was again considered. The interaction Lagrangian is assumed to be invariant under a group called M(12) [identical to Salam's $\widetilde{U}(12)$], and again the kinetic energy part breaks the SU(6) symmetry. The breaking of SU(6) symmetry by the kinetic energy term of either the Lagrangian or the free equation of motion is a recurrent theme in the relativistic generalizations of the SU(6) symmetry.

Other quark models were discussed by S. Okubo (University of Rochester) and Y. Nambu (University of Chicago). Okubo, with R. E. Marshak, has considered the higher symmetries that are evidenced by the four Fermi interactions of the Dirac quarks. They have considered two cases: (i) "γ_5 diagonalization" which effects a mixing of the internal symmetry and parity and gives rise to parity doublets, and (ii) "γ_4 diagonalization," which effects a mixing of internal symmetry and the proper Poincaré group. For the latter, the symmetry group of the interaction contains SU(6), which again is broken by the kinetic energy term of the Lagrangian. Nambu expressed the belief that two basic triplets exist. The existence of two triplets negates the necessity of considering fractionally charged particles and gives rise to a new quantum number which has been called "charm." The physical particles observed so far have "charm" zero, and in the model Nambu described would be considered tightly bound states of the quarks. Nambu also discussed the possible field theoretic meanings of the SU(6) symmetry limit.

J. Schwinger (Harvard University) discussed how a symmetry exhibited by phenomenological fields may result from a symmetry of interaction of basic fields.

There has been considerable interest lately in the possibility of embedding an internal symmetry group [such as SU(3)] and the Poincaré group in a large group in a "non-trivial" fashion —that is, in such a way that representatives of the Poincaré group of different masses or spins or both are contained in an irreducible representation of the larger group. During the past year several theorems concerning the limitations of what can be achieved have been published. It has been in fact achieved in a very limited sense by the SU(6) symmetry. G. C. Sudarshan (Syracuse University) and L. Michel (Institute des Hautes Études Scientifiques) discussed this general problem in their talks. Sudarshan reviewed some of the results obtained so far and alluded to still more restrictive results recently obtained by L. O'Raiteartaigh (Syracuse University). He pointed out that there is no a priori reason to believe that the algebra generated by a broken symmetry group and the Poincaré group is indeed a finite dimensional Lie algebra. Michel in turn showed what can be accomplished within the framework of group extensions. In addition he showed the nature of the difficulties involved in the relativistic generalization of SU(6).

In a conference dealing with the symmetries of high-energy physics the weak interactions cannot be ignored. In fact one of the most interesting phenomena of the symmetries of the strong interaction is the relation of these symmetries to the currents of the weak interaction. R. Dashen (California Institute of Technology) discussed the "bootstrap" dynamics of strong interactions as providing a possible explanation for this connection. B. d'Espagnat (Université de Paris) indicated how CP violation in the weak interactions, which seems to be implied by recent experiments, can be incor-

porated in Cabibbo's weak interaction theory. (CP invariance means invariance under the product of charge conjugation and space reflection.) G. Zweig (California Institute of Technology), reporting on work performed with F. Zachariasen, showed how the generator densities of U(12), which contains SU(6), can be used as weak interaction "currents." Their use results in a CP violation in the parity-violating part of the weak interaction. This theory also predicts no CP violation in the leptonic decays.

Four more theoretical papers were presented at the conference. L. Brown (Northwestern University) presented theoretical arguments, involving meson decays, for the existence of the σ particle, a scalar meson with $J^P = 0^+$ and isotopic spin zero with a mass of about 2.9 times that of a π-meson. So far, there has been no direct experimental obsertion of this particle. Tests of SU(3) and higher symmetrics were the subject of a talk by H. Lipkin (Weizmann Institute of Science). Y. Ne'eman (California Institute of Technology) discussed the role of non-compact groups and their representations in strong interaction physics. A group which combines SU(3) symmetry and the Poincaré group was described by B. Kursunoglu in his talk.

The two experimental talks given at the conference were excellent. G. Goldhaber (University of California) gave a survey of the experimental status of many of the recently discovered resonances, while he emphasized the difficulties of analysis that arise when one deals with higher resonances whose decay products include another resonance. The present status of very-high-energy scattering experiments was described by S. Lindenbaum (Brookhaven National Laboratory).

The wide-ranging considerations of symmetry principles in high-energy physics were shown clearly in the résumé of Y. Ne'emann, who gave an admirable summary of the past successes and possible future directions of symmetry principles in particle physics.

The conference was sponsored by the University of Miami, the National Science Foundation, Air Force Office of Scientific Research, the National Aeronautics and Space Administration, and the Atomic Energy Commission. The principal organizer was Behram Kursunoglu.

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Forthcoming Events

May

9–13. **Electrochemical** Soc., San Francisco, Calif. (ES, 30 E. 42 St., New York)

9–13. American Assoc. of **Orthodontists**, annual, Dallas, Tex. (J. E. Brophy, 7477 Delmar Blvd., St. Louis, Mo. 63130)

9–13. American **Urological** Assoc., New Orleans, La. (W. P. Didusch, 1120 N. Charles St., Baltimore 1, Md.)

9–14. **Condensation Nuclei**, 6th intern. symp., Albany, N.Y., and University Park, Pa. (Organizing Committee, Office of the Director, ASRC-SUNY, P.O. Box 7112, Albany 12224)

10–11. **Passive Gravity-Gradient Stabilization**, symp., Moffett Field, Calif. (B. Tinling, Theoretical Guidance and Control Branch, NASA Ames Research Center, Moffett Field 94035)

10–12. **Aerospace Electronics**, natl. conf., Dayton, Ohio. (Inst. of Electrical and Electronics Engineers, 1414 E. 3 St., Dayton 2)

10–12. Canadian **Nuclear** Assoc., intern. conf., Quebec. (General Manager, CNA, 19 Richmond St. W., Toronto, Ont.)

10–12. **Organic Crystals**, intern. symp., Chicago, Ill. (Secretary of the Symposium, Univ. of Chicago, 5640 S. Ellis Ave., Chicago 60637)

10–12. **Quality Control**, 1st Pan American congr., Mexico, D.F. (E. R. Ott, c/o Statistics Center, Rutgers Univ., New Brunswick, N.J. 08903)

10–13. National **Geriatrics** Soc., New York, N.Y. (W. Spigler, 1355 Cheltenham Ave., Philadelphia, Pa.)

10–13. Southwestern **Surgical** Congr., 17th annual, Hot Springs, Ark. (Central Office, 301 Pasteur Medical Bldg., Oklahoma City, Okla. 73103)

10–14. **Pulsed Neutron Research**, Karlsruhe, Germany. (J. H. Kane, Intern. Conferences Branch, U.S. Atomic Energy Commission, Washington, D.C. 20545)

10–14. Specific **Tumor Antigens**, Sukhumi, Georgia, U.S.S.R. (Acad. of Medical Sciences of the U.S.S.R., 14, Solyanka, Moscow)

10–21. Committee on **Space Research**, 8th plenary meeting, Buenos Aires, Argentina. (Secretariat, 55 Boulevard Malesherbes, Paris 8e, France)

11–13. **Vectorcardiography**, intern. conf. New York, N.Y. (E. C. Meilman, Long Island Jewish Hospital, New Hyde Park, N.Y. 11040)

11–14. **Gas Chromatography**, 5th symp., Berlin, Germany. (Unterkommission für Gaschromatographie, Sektion Chemie, Deutsche Akademie der Wissenschaften zu Berlin, Permoserstr. 15, Leipzig 05, Germany)

12. Institution of **Metallurgists**, annual, London, England. (Institution, 4 Grosvenor Gardens, London, S.W.1)

12–13. Control of **Water Quality**, natl. forum, American Soc. for Testing and Materials, Philadelphia, Pa. (ASTM, Committee D-19 on Industrial Water, 1916 Race St., Philadelphia 19103)

12–24. **Power Instrumentation**, 8th natl. symp., New York, N.Y. (H. H. Johnson, 4 Irving Pl., New York 10013)

13. Society for **Personnel Administration**, 4th annual conf., Catholic Univ., Washington, D.C. (H. G. Vavra, SPA, 1221 Connecticut Ave., NW, Washington, D.C.)

13–14. American Inst. of **Mining, Metallurgical, and Petroleum Engineers**, New England regional conf., Hartford, Conn. (AIMMPE, 345 E. 47 St., New York 10007)

13–14. Canadian Council of **Professional Engineers**, annual, Charlottetown, Prince Edward Island. (CCPE, 116 Albert St., Ottawa 4, Ontario)

13–14. **Signal Transmission and Processing**, symp., New York, N.Y. (L. E. Franks, Bell Telephone Laboratories, 1600 Osgood St., North Andover, Mass. 01845)

13–15. American Inst. of **Industrial Engineers**, 16th annual, Chicago, Ill. (W. J. Jaffe, Dept. of Industrial Engineering, Newark College of Engineering, Newark, N.J. 07102)

13–15. **Powder Metallurgy**, 3rd intern., Eisenach, East Germany. (Gesellschaft Deutscher Berg- und Hüttenleute, Wallstr. 68, Berlin C.2, East Germany)

13–19. **Space Science**, 6th intern. symp., Buenos Aires, Argentina. (COSPAR Secretariat, 55, Boulevard Malesherbes, Paris 8e, France)

14–15. Association of **University Radiologists**, annual, Seattle, Wash. (A. R. Margulis, AUR, Dept. of Radiology, Univ. of California Medical Center, San Francisco)

16–19. American Inst. of **Chemical Engineers**, 56th natl., San Francisco, Calif. (A. E. Aronson, A. B. Dick Co., 5700 W. Touhy Ave., Chicago 48)

16–20. Institute of **Food Technologists**, annual, Kansas City, Mo. (C. L. Wiley, Suite 1350, 170 W. Adams St., Chicago, Ill. 60603)

16–21. **Mass Spectrometry**, 13th annual conf., St. Louis, Mo. (H. M. Rosenstock, Natl. Bureau of Standards, Washington, D.C. 20234)

17–18. Canadian **Aeronautics and Space** Inst., annual, Vancouver, B.C. (H. C. Luttman, 77 Metcalfe St., Ottawa 4, Ont.)

17–19. **Application of Computing Methods to Reactor Problems**, conf., Argonne, Ill. (B. J. Toppel, Reactor Physics Div., Argonne Natl. Laboratory, 9700 S. Cass Ave., Argonne)

17–19. American College of **Physicians**, Far East session, Tokyo, Japan. (Session Coordinator ACP, USAF Hospital Tachikawa, APO 323, San Francisco, Calif.)

17–21. American Soc. of **Civil Engineers**, Minneapolis, Minn. (W. H. Wisely, ASCE, 345 E. 47 St., New York 10017)

17–21. **Nondestructive Testing in Nuclear Technology**, symp., Bucharest, Rumania. (P. Ghelardoni, Div. of Scientific and Technical Information, Intern. Atomic Energy Agency, Kärntner Ring 11, Vienna 1, Austria)

17–21. Society of **Photographic Scientists and Engineers**, annual conf., Cleveland, Ohio. (W. E. Granshaw, Eastman Kodak Co., 4605 Mackall Rd., South Euclid 21, Ohio)

17–21. Technical Literature Abstracting and Indexing, American Univ., Washington, D.C. (P. W. Howerton, 2000 G St., NW, Washington 20006)

18–20. **Aerospace Fluid Power Systems and Equipment**, conf., Los Angeles, Calif. (Soc. of Automotive Engineers, 485 Lexington Ave., New York 10017)