OF HIGHER SYMMETRIES

Theorists from East and West recently spent two months at the IAEA Trieste Center discussing particles and high energies. The author, a reader in theoretical physics at the University of Cambridge and a fellow of Trinity College, recalls here what was said of SU(6), relativity, "nearly conserved" parity, and broken symmetries.

By J. C. Polkinghorne

During the past year the in-trays of elementary-particle physicists have been brightened by a new type of preprint cover, the cool blue and white of the International Center for Theoretical Physics at Trieste. The preprints inside have been remarkable for their number, their interest, and the diversity both of their subjects and the home countries of their authors. A truly international institute, drawing postdoctoral workers from every continent, has come into being and has enjoyed a remarkable first year of fruitful activity. This activity reached an appropriate climax in the Seminar on High-Energy Physics and Elementary Particles, held during the months of May and June, 1965, just three years after the first such seminar, held in Trieste in 1962, under the auspices of the International Atomic Energy Agency. The 160 participants came from 29 different countries and the two-month seminar provided a unique and valuable opportunity for survey in depth and continued discussion of all the most important aspects of the subject. Such a period of sustained communal activity provides an altogether different experience from the fleeting contacts possible at conventional short conferences. It constitutes an opportunity for the physicist from a developing country to make lasting contacts with workers from all over the world. However, it is equally welcome to all physicists since the complexities of modern problems demand a time scale of weeks rather than days for their discussion.

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It was fitting that the subject of higher symmetries, and in particular the marriage of SU (6) and relativity, should have been the dominant theme of the seminar. Not only has this field been the one in which recent progress has been most rapid and most exciting, but also much of the work has been created in Trieste by Professor Salam and his co-workers.

In the summer of 1964, Gürsey and Radicati, and independently Sakita, suggested that for elementary particles a useful symmetry group would be SU (6) , formed by combining the SU (3) unitary spin with ordinary spin in the same way that Wigner had combined isotopic spin and ordinary spin in his discussion of nuclei. Such a group combining internal quantum numbers with space-time properties links together in the same multiplet particles with different intrinsic angular momenta. It was found that the known mesons and baryons would just correspond to two of the simplest representations of the group. This striking fact clearly called for relativistic generalization.

Several solutions to the problem have been propounded. One is essentially to replace the Pauli

The Center's temporary quarters in Trieste

σ matrices by Dirac γ matrices and generate the celebrated noncompact group $\tilde{U}(12)$. The particle interpretation is then introduced via the Bargmann-Wigner equations. An account of this theory was given by Salam. Similar equations were also obtained by Schwinger in a fascinating series of lectures which gave a somewhat different rationale. If we believe, as indeed we must believe,

that the observed particles are associated in a field theory with very complicated but localized functionals of the fundamental fields, then at an intermediate level on the way to experimental comparison it is useful to construct what Schwinger calls a "phenomenological field theory". This remains an as yet not completely defined but provocative concept. Its equations turn out to be those of the $\tilde{U}(12)$ theory.

While these theories both lead to interactions which are $\tilde{U}(12)$ invariant, the invariance is necessarily broken by the free-field kinetic-energy terms and by the operation of unitarity. In an interesting piece of research completed during the seminar Rühl was able to show what symmetries can survive for single particles and for colinear and coplanar processes.

A different approach to the problem was given by Gell-Mann. He uses the current algebra technique which he developed some years ago and which works in terms of quantities which are readily related to experiment. The basic dynamical assumptions are that the integrated parity-conserving components of the currents belong to an algebra $U(6) \times U(6)$ and are "nearly conserved"—that is, they only have large matrix elements connecting states with similar energies. In an elegant and economical way this theory produces the same correct experimental consequences as the other approaches. As a complement to this method, Fubini gave an extremely interesting account of how to use dispersion theory to calculate the corrections to the "nearly conserved" assumption.

Finally Gürsey, in a long awaited talk, gave an account of how he and Radicati make SU (6) relativistic in terms of the nonlocal spin operators of the Lorentz group.

One might suppose that the group-theoretically minded would feel content with these advances. However, they have even more ambitious plans

Abdus Salam, director of the IAEA International Center for Theoretical Physics, talks with Deputy Director Paolo Budini, who is also director of the Institute for Nuclear Physics at the University of Trieste

afoot. It has long been known that all the bound states of the hydrogen atom can be thought of as constituting one infinite-dimensional unitary representation of a certain noncompact group. It is conjectured that the same might be true of baryons and mesons, both known and yet to come. This work is still at a tentative stage, but exploratory accounts were given by Gell-Mann, Barut, and Fronsdal.

Such speculations involve new and heady mathematics, and two pure mathematicians, Professors Stein and Hermann, were on hand to give survey talks and utter Awful Warnings about too glib generalization. As usual, one felt the contrast between the mathematician's insatiable urge to generalize and the physicist's inescapable concern with the particular.

Not all the lectures were concerned with this year's group theory. There were basic accounts of older work: SU (3) , S-matrix theory and analyticity, bootstraps, and axiomatic field theory; and also, of course, there were lectures on recent developments in other branches of the subject. The topics which particularly remain in one's memory will vary from participant to participant. This writer recalls Bros' account of his work with Glaser and Epstein on deriving sufficient analyticity for crossing from axiomatic field theory; the various talks on high-energy-behavior predictions from analyticity; the extremely interesting, if at times somewhat gnomic, account of broken symmetries in bootstrap dynamics given by Cutkosky.

A two-month seminar cannot be all work. The generous hospitality of the city and the region found expression in several enjoyable receptions and the seminar ended with a magnificent seaside banquet at which Tavkelidze was voted the most jovial participant. Trieste enjoys a coastline with many bathing establishments, the wild highlands of the Carso, the remarkable limestone caverns of Yugoslavia, and a two-hour train service to Venice. If May proved that the wind can blow and rain come down in torrents, June showed us that the sun can also shine. There are many good restaurants, and the Mensa (a railway workers' canteen close by, which provided a special long table for the exclusive use of seminar participants) is the nearest thing socially, if not gastronomically, to a Cambridge High Table which this writer has encountered outside England.