presented work (with C. Itzykson) on the algebraic formulation of the relativistic two-body problem.

Gravitation. The remainder of the conference consisted of talks on gravitation by John Wheeler (Princeton), Joseph Weber (Maryland), David Finkelstein (Yeshiva), and Peter Freund (Chicago). These reports were interesting and are, perhaps, deserving of extensive summary, but their relevance is to cosmology and not to the small times and short distances involved in high-energy physics. At least this is the case at present, and it is not expected to change until we have accelerators of about 10^{38}eV. Assuming the present logarithmic rate of growth of accelerator energies, one predicts that this will occur in about two centuries. Such predictions, of course, are usually wrong so it is better to say we simply do not know when gravitation will begin to play a role in high-energy physics. It could even be next year! After all, weak interactions, which in comparison to strong interactions hardly even exist, have been important tools in the elucidation of strong interactions—and the masses of hadrons and leptons *are* the masses of gravitating objects. Let us simply say: We do not know.

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The conference was organized by Behram Kursunoglu, at the Center for Theoretical Studies, University of Miami, Coral Gables, Florida. The proceedings will be published by Gordon and Breach.

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Exact Statistical Mechanics at Irvine

A very informal symposium on exact results in statistical mechanics was held at the University of California, Irvine on 8–9 November. The idea for such a symposium, with the purpose of an unhampered discussion of progress and problems in this rapidly evolving field, was generated in correspondence between Alexei Maradudin (chairman of the physics department at Irvine), Meinhard ("Hardy") Mayer (who holds a joint appointment in physics and mathematics at Irvine) and David Ruelle (of the Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, a visiting professor of mathematics and physics at Irvine during the fall quarter).

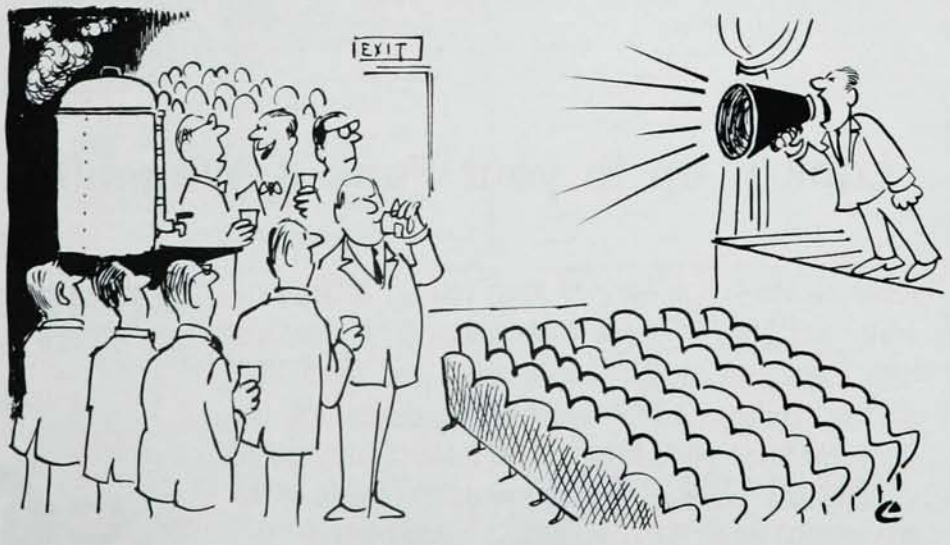
The symposium brought together a small number of active workers in the field of "exact statistical mechanics," who, characteristically for this field, can be found on the faculties of departments of chemistry, mathematics or physics (sometimes with joint positions in any combination of these). Also characteristic for the field is that, unlike most other areas of theoretical physics, mathematical sophistication and rigorous analysis are not luxuries, to be superimposed on top of results that one can also derive by means of the usual handwaving approach to mathematical physics. On the contrary, sophistication and rigor are real necessities for attaining any kind of progress in the field, as became clear only during the last decades. One might even claim that this area of physics demonstrates clearly that the mathematical training of our future theoretical physicists is at least 30 years out of date, and that unless something is done about it, the new generation of theorists will have to spend a good deal of their postdoctoral time learning 20th-century mathematics, in order to tackle the physics of the 21st century.

Exact statistical mechanics is rather difficult to delineate and explain to the nonspecialist. As Joseph Mayer of the University of California, San Diego justly remarked in his opening talk at the symposium, it suffices to switch off all interactions to obtain the only "realistic" exact system: the ideal gas. Roughly speaking, however, one may divide the field (at least as it was represented at this meeting) into the following four areas:

- Proofs of the existence of "thermodynamic limits." By this we mean proofs of the existence of extensive thermodynamic functions in the limit as the particle number and volume go to infinity, with the density remaining constant; it became clear some time ago that this limit is necessary for the existence of phase transitions. For finite systems the functions are "too analytic," that is, in many cases, they are polynomials.
- Analyticity properties of partition functions in temperature and activity. These properties are also important for phase transitions.
- Exactly soluble models. The best known of these are the various modifications of the Ising model (first solved by Lars Onsager, last year's Nobel Laureate in chemistry), lattice gases with model potentials and hardsphere gases.
- The algebraic approach. This approach replaces the limiting process $V, N \to \infty$ by a direct formulation of statistical mechanics for infinite systems, where the observables form C* algebras.

The reader who wishes to get a more exact idea of the first three topics (or their status before our symposium) is referred to the excellent review by Joel Lebowitz,[1] and for the fourth topic and a detailed discussion of most of the others to the forthcoming book by David Ruelle.[2]

Because our informal symposium came shortly after the "big" confer-



". . . and often the speakers were asked to talk louder so that they could be heard near the coffee urn at the back of the room . . ."

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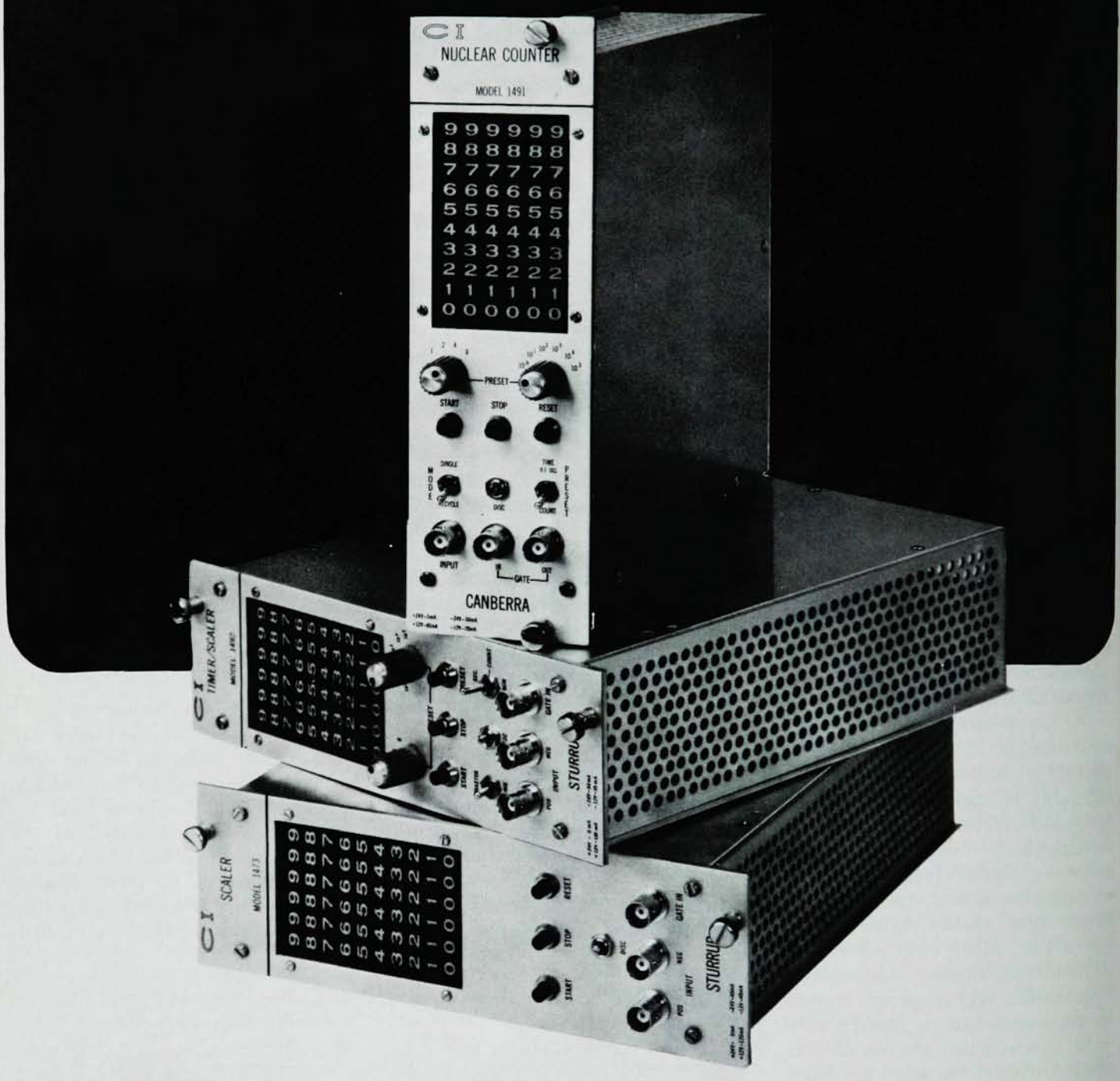

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ence at Kyoto, where "completely baked ideas" had been presented, it was the ideal place for the exchange and presentation of "half-baked ideas" (at least one of which, the existence of the thermodynamic limit for systems with Coulomb potentials, emerged fully baked from the symposium). All participants agreed that the style adopted should be used more often: They were no chairmen with alarm clocks or other means of intimidation (like microphones, pointers or the threat of published proceedings); everybody talked at the approximately preassigned time, for as long as he could last; interruptions were the rule rather than the exception, and in some talks the audience spoke more than the speaker. There were also no formal coffee breaks, because coffee and donuts were available in the lecture hall, and often the speakers were asked to talk louder so that they could be heard near the coffee urn at the back of the room. Finally, it may be characteristic that only three (rather old) slides were shown during the whole meeting, and despite the fact that most sessions ran as much as 60–90 minutes late, no one got impatient for lunch or dinner.

Long-range order. Michael Fisher, of the chemistry and mathematics departments of Cornell University, spoke about "long long-range order" and "short long-range order" in Ising ferromagnets and on the nonconvexity of the surface energy of the boundary of a two-dimensional Ising spin system. He was followed by Andrew Lenard, of the mathematics and physics departments of Indiana University, Bloomington, who reviewed his work with Freeman Dyson on the proof of "stability of matter" under Coulomb forces (with the assumption that at least one of the species of particles obeys Fermi statistics). He raised the problem of proving Ruelle–Fisher-type theorems for Coulomb forces, a problem that was solved partially in the course of this symposium by Joel Lebowitz of Yeshiva University and Elliott Lieb of MIT.

Exactly soluble models. Lieb talked about recent progress in the "ice problem" and the related F model of antiferroelectrics and KDP model of ferroelectrics. The first problem is of explaining the residual entropy of ice near absolute zero, where the empirical value is approximately $S = Nk \log_e 1.5$. Lieb has solved a two-dimensional model where the oxygen atoms occupy the vertices of a square net, with the hydrogens situated on the bonds, six configurations being possible. See the Lebowitz review[1] for details. The ferroelectric KDP ($=KH_2PO_4$) can be assumed to have similar structure. Lieb was followed by Tai Tsun Wu of Harvard University, who gave what he called a subjective view of all that was known on the two-dimensional Ising model. He was mainly concerned with two- and four-spin correlation functions, surface effects and a comparison with the solution of the ice problem. The next two speakers were Barry McCoy and Bill Sutherland, both from the Institute of Theoretical Physics of SUNY, Stony Brook, who spoke respectively of their work on an Ising model with impurities and the ice problem.

The algebraic approach. David Ruelle talked about recent work with Oscar Lanford on states with short-range correlations and the nonexistence of metastable states within this setting; a mestastable state is defined as an invariant equilibrium state with entropy below the equilibrium entropy. There was some discussion on whether it is at all proper to talk about metastability in the framework of equilibrium statistical mechanics.

The next speaker, Oscar Lanford III of the mathematics department of the University of California, Berkeley who, like Ruelle and I, is a convert to statistical mechanics from axiomatic quantum field theory) talked about evolution equations for one-dimensional systems within the framework of classical mechanics.

He was followed by Giovanni Gallavotti, of the Rockefeller University, who used the algebraic approach for a lattice gas to prove that the partition functions are holomorphic functions of two complex variables (the inverse temperature and fugacity) in a certain domain, and how these properties lead to Kirkwood–Salsburg equations for correlation functions.

Robert Griffiths, of the Carnegie-Mellon University, first reported that he was able to show that "those things that one can prove for spin-1/2 Ising ferromagnets can also be proved for arbitrary-spin Ising mod-

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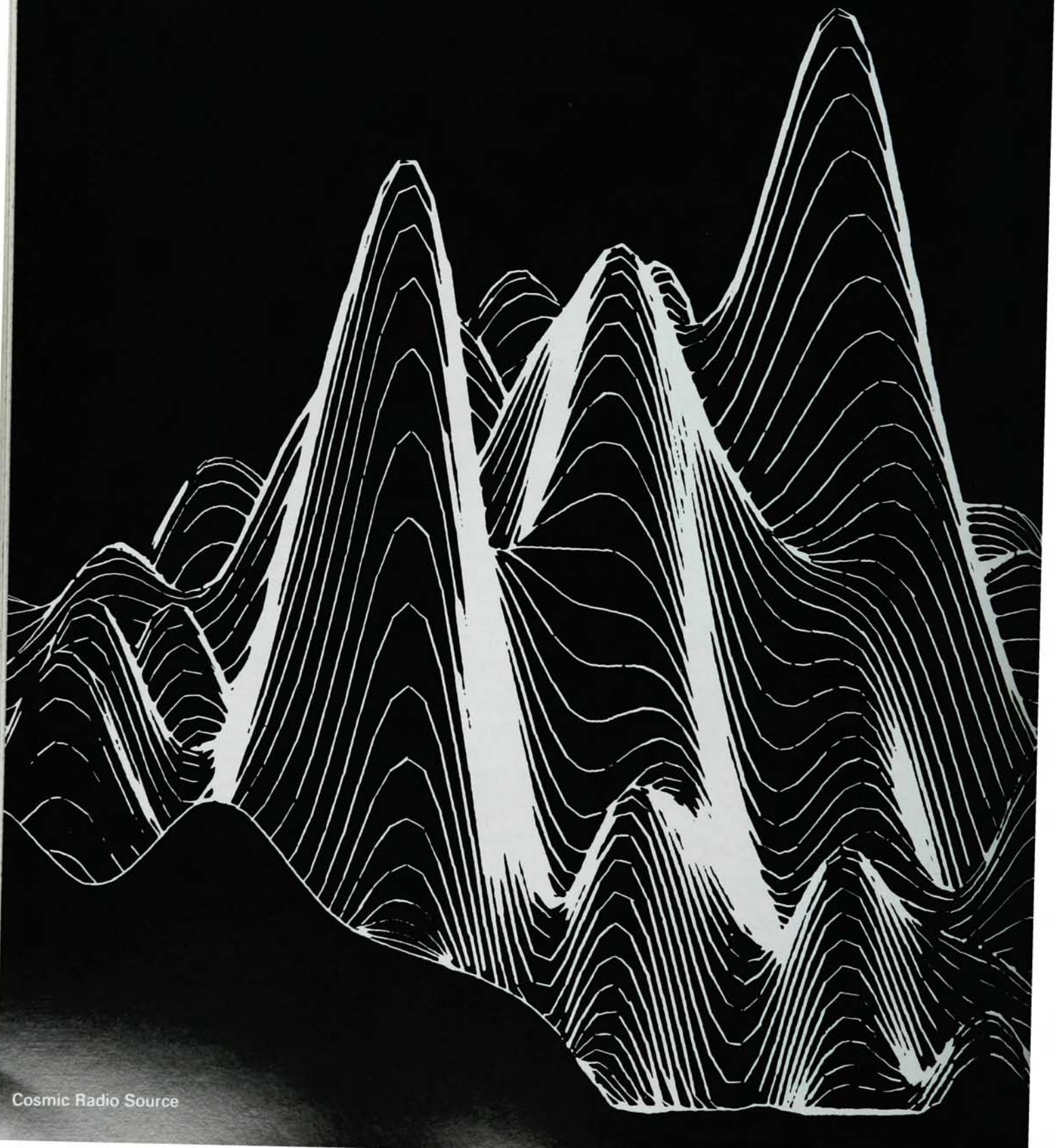

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els." He then proceeded to review ingredients used in proving the existence of the thermodynamic limit (stability, subadditivity and stereometry, to make the alliteration complete) that led him to a discussion of systems with dipole–dipole interactions.

This talk led naturally into the following one by Lebowitz, who brought up what was perhaps the most exciting subject of the symposium: the existence of a thermodynamic limit for neutral systems with Coulomb potentials. The problem was actually solved during this meeting by Lebowitz and Lieb, with active participation of many others, and the proofs are due to appear shortly. The details of the problem are too technical to be presented here, but it will make any physics teacher feel better to know that this most obvious of all interactions behaves normally!

The last speaker was Johannes Groeneveld, of SUNY Stony Brook and the Belfer Graduate School, Yeshiva University, who talked about cluster expansions for the case of long-range forces.

On the whole, the symposium was extremely useful for all who participated (in addition to those listed as speakers, there were present several faculty members and graduate students of the departments of mathematics and physics at Irvine, Don Babbitt and Richard Herman of UCLA, and Kurt Shuler and several of his graduate students at the chemistry department of University of California, San Diego and there is hope that it will be repeated.

* * *

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