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This report summarizes selected papers and reviews given at the Statphys-13 Conference held this summer in Haifa, Israel. Topics mentioned include fluctuation scaling, percolation processes, series expansions and renormalization techniques applied to various problems, fluids and turbulence, random systems, and many other areas of investigation in which the methods of Statistical Physics have been successfully employed.

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THE THIRTEENTH IUPAP CONFERENCE ON STATISTICAL PHYSICS

INTRODUCTION

The 13th IUPAP Conference on Statistical Physics—more commonly known as Statphys 13—was hosted by the Physics Department of the Technion-Israel Institute of Technology, Haifa, Israel. Taking place as it did between 24 and 30 August 1977, the Conference opened on the hottest day of the year, and these critical temperatures continued throughout, making the air-conditioned lecture theatres seem low-temperature havens. Situated on the slopes of Mount Carmel, the Technion forms a modern complex overlooking the port and city of Haifa. On the evening of the 23rd an informal "housewarming" party was held, at which percolation between the 350 participants and accompanying persons was aided by the freely provided contents for "spin" glasses.

Presentation of papers at the Conference took three forms, with the morning (and some afternoon) sessions consisting of plenary sessions of an hour's duration at which invited lecturers gave their talks. During the afternoons and evenings the other two modes were used, namely oral sessions comprising twenty-minute talks and discussions, and poster presentations. These posters were on view for about three hours, and their contributors were asked to be present for at least half-an-hour. It was generally felt that the discussion surrounding these posters was highly useful, though somewhat exacting for their authors. In the oral sessions the discussions tended to be rather more pertinent, but unfortunately suffered from the more rigid time limits necessarily imposed.

The first day began with greetings expressed by Professor Z. Berk, Vice-President of the Technion on its behalf, and Professor A. Kogan for the Israel Academy of Science and Humanities. Professor J. Felsteiner then expressed the warm welcome of the Israel Physical Society and the Israel National Committee for IUPAP, reminding those present that the Conference Proceedings would be published as Volume II of the *Annals of the Israel Physical Society*. Professor C. Domb (King's College, London) was called upon to give an obituary address for Lars Onsager who died last year. Sadly, on the last day of the Conference, the death was also announced of Professor T. Niemeijer in Holland.

In his obituary Domb spoke warmly of the character and ability of the late Professor Lars Onsager, recalling that he had attended the first IUPAP conference in 1949, and the great majority thereafter, contributing markedly to the discussion periods following many of the talks. Domb dwelt on the fact that Onsager's publications had been few for a man of such great ability, due to the extremely high standards which he imposed upon himself, exploring every aspect of work which he submitted for publication. Stressed throughout the obituary were the wide and varied nature of Onsager's interests, lying not merely within the area of his own field of research.

Particularly cited were his work performed on the two-dimensional Ising model, published in 1944, and his work on irreversible processes for which Onsager was awarded the Nobel Prize in 1968. Although physicists think of him as "their" Nobel prizewinner, it is, perhaps, revealing of the man to note that he always described himself as a chemist. An inspriation to his collaborators Onsager remains so even after his death as Domb indicated in his final remark, a quotation from the Talmud: "Great scholars have no rest either in this world or the next."

Next on the agenda was the presentation by Professor H. Callen, speaking as Chairman of the IUPAP Commission for Thermodynamics and Statistical Mechanics, of the second Boltzmann medal to Professor R. Kubo. Callen indicated the nonpolitical nature of IUPAP and its interest in securing the solidarity and freedom of interaction between physicists the world over. The Boltzmann medal, of which the first was awarded to K. Wilson at the previous Statphys conference, is an attempt to signify this. Kubo (Univ. of Tokyo) was awarded the medal for his work in the field of fluctuation theory.

PLENARY SESSIONS

In his acceptance lecture, Kubo thanked the committee for his award, apologizing for the fact that his intended talk was not strictly in line with the work for which the medal had been presented, saying that the lecture had been prepared before his notification of the presentation. The title was in fact "Nonlinear relaxation and fluctuation." He explained that for a physical system near equilibrium there are three kinds of observations which can be made and which are internally related. The fluctuation-dissipation theory demonstrates this relationship, and Kubo went on to consider to what extent this theorem could be generalized for systems in whatever state of equilibrium, reintroducing the extensivity ansatz which he had used some time ago and which concerns the probability distribution of the macrovariable associated with a system. As a simple case for his argument he considered the case of ideal Brownian motion.

Professor M. Nelkin (Cornell Univ.) then spoke on the topic "Universality and scaling in fully-developed turbulence." Translating existing ideas from turbulence into the language of statistical physics, he was concerned particularly with fluids characterized by a high Reynolds number. For such fluids, whose behavior is well described by the Navier-Stokes equation, there exists a family of universal-scaling exponents. A key physical assumption in the formalization of these problems is that the energy-dissipation rate is, in fact, independent of the viscosity, in the limit of the viscosity tending to zero. Since the Reynolds number is inversely proportional to the viscosity, this was the region Nelkin dealt with. Using assumptions generally made in this field, he then went on to obtain an energy-spectrum equation, in which the power of one of the variables used in the solution differed from other results, though

the actual form remained the same. Since the difference between the two results should be experimentally detectable, Nelkin threw down the challenge to experimentalists to determine the true result.

The final plenary session of the first day was taken by R.D. Levine (Hebrew Univ. of Jerusalem) and entitled "Nonlinear statistical mechanics applied to nuclear and molecular collisions." Four questions were considered during this talk: a) optimal means of characterization of the final-state distribution in the collision; b) compaction of the voluminous body of experimental (or computer-simulated) data; c) development of measures of specificity and selectivity; and d) development of computational schemes that will complement the currently available quantum-mechanical (or classical) procedure. Information theory was used in an attempt to realize these aims by forging a link between collision phenomena and nonequilibrium statistical mechanics.

Continuing the plenary sessions, Domb addressed the Conference on the "Shape and size of Ising clusters and the Whitney polynomial." Considering the droplet model of condensation, he outlined the role which "ramified" clusters have to play. It was explained that this is the name given to those types of clusters that have a sponge or tree-like shape, whereas before only "compact," i.e., spherical or ellipsoidal clusters, have been considered. Monte Carlo data obtained by E. Stoll and T. Schneider (both of IBM Research Laboratory, Zurich) were used to demonstrate just how vital ramified clusters are to the theory. Finally the Whitney polynomial was introduced, and Domb showed how Temperley had related it to the q-state Potts model and hence percolation theory (which results when $q = 1$), and the Ising model (when $q = 2$).

Professor Amnon Aharony (Tel-Aviv Univ.) delivered a "Review of multicritical phase diagrams" in which he broke down the Hamiltonian of the system into three effective Hamiltonians, one expressed in terms of the order parameter, another in terms of the elastic behavior, and the third, interaction Hamiltonian. Using this technique, he demonstrated the occurrence of first-order phase transitions, going on to consider the application of anisotropic stresses to the system. Renormalization techniques were then covered by two lectures, one given by Dr. van Leeuwen (Technological Univ. of Delft) and the other by Professor E. Brezin (Centre d'Etudes Nucléaires de Saclay, France).

Van Leeuwen's talk was entitled "Position space renormalization approach," and he presented a remarkably clear review, giving as examples both Ising-like systems and the Potts model. Three possible strategies were outlined: a) simple approximation schemes consisting of a simple renormalization transformation (RT) followed by some standard scheme such as finite lattice, cumulants, clusters, Monte Carlo or low-temperature expansions; b) variational methods; and c) systematic expansion in a small parameter that implied independence of RT since the final results depend

only on the small parameter and are independent of the choice of RT (a highly desirable result as the choice of RT is in itself artificial). Van Leeuwen considered particularly variational methods, showing how well they compare with experiment, but outlining some of their disadvantages.

Brezin followed with a lecture entitled "Recent advances concerning the (d-2) and (4-d) expansions." Early on in his talk he mentioned the (1/n) expansion, but dismissed it as inadequate. The (d-2) expansion, though useful, was held to be too highly restrictive, and most of the lecture was therefore used to describe the (4-d) expansion. This was shown to be divergent, and although successive coefficients of the power series become increasingly hard to calculate (e.g., for the cubic term—of the order of months of work), Brezin disagreed with those who claim that the squared term gives the limit of accuracy, maintaining that the more terms that are available the better.

Professor L. Schulman (Univ. of Indiana and the Technion) then spoke on "Measurability in the two-dimensional Ising model." He looked at short-range forces, emphasizing that the type of problem they present has to be dealt with by a separate approach to that of long-range order. His talk was based on analytic continuation of the largest eigenvalue of the transfer matrix. Since an $N \times \infty$ transfer matrix contains $2^N \times 2^N$ terms, this means that for N increasing the matrices rapidly become unwieldy, e.g., N = 5, 7, 9, 11, 2^N = 32, 128, 512, 2048. However, because of translational symmetries, it is possible to diagonalize the matrix and a certain amount of progress can be made. The results obtained agreed fairly well with Monte Carlo and exact results at lower order, but the procedure broke down at higher order. In the heated discussion provoked by this lecture Professors M. Kac (Rockefeller Univ.) and L. Kadanoff (Brown Univ.) argued in favor of a restricted-ensemble approach.

Friday was opened by Professor M. Lecar (Smithsonian Observatory) who gave the first of a session of two lectures that provided an interesting digression from the more usual critical phenomena bias, though the techniques used were familiar to most of those present. Lecar pointed out that gravity, although a weak force, is one of the most fundamental in the universe, and he discussed three systems: globular clusters, galaxies, and the universe itself. He showed that globular clusters, unlike galaxies, can be regarded as a relaxed form of a system. Lecar then continued to consider the correlation between galaxies in the expanding universe. The second of these lectures was delivered by Dr. H. Haken (Univ. of Stuttgart) on "Nonequilibrium quantum statistics of lasers and nonlinear optics" which he introduced with a brief review of the physical principles involved in the construction of a laser. He showed that it is necessary to develop a nonequilibrium quantum-statistical theory and explained that we want to know the physical properties of visible light. Reminiscent of Aharony's lecture, Haken divided the Hamiltonian into three parts: field, atom, and the interaction between them.

Over the weekend the majority of participants took advantage of the arranged tours. The first of these, on Saturday, was a trip to Galilee. The trip was most interesting, and the effects of the recent wars were made visible to all the "tourists." Sunday was spent on an expedition to the old city of Jerusalem and a visit to the Church of the Holy Sepulchre, built, according to tradition, on the site of the tomb of Christ.

On Monday the task of recommencing the more serious side of the Conference was left in the capable hands of Professor M. Kac. He spoke wittily and concisely on the subject of "Some mathematical models exhibiting phase transitions" and on what might be learned from them. He considered three models: a) mean-field, b) two-dimensional Ising model with nearest-neighbor interactions, and c) the spherical model which he described as less realistic but computable. Kac then put forward the "soft-horn" model as one that combines the best of both worlds provided by the 2-D Ising model and spherical model. His replies to the questions posed at the end of the lecture were as lively and interesting as the lecture itself. After the comparative freedom allowed in this lecture, a brutally rigorous talk was given by Professor B. Simon (Princeton Univ.). Entitled "New rigorous existence theorems for phase transitions in model systems," it lived up to every word in that title.

Simon developed two related, but distinct, methods for the determination of phase transitions. The first of these relies on improved contour estimates that reduce to simple estimates of thermodynamical quantities and the second on the use of infrared bounds. The new results he obtained using these methods can be summarized as follows: there exist proofs of phase transitions in model systems including classical Heisenberg and quantum-spin $\frac{1}{2}$ XY model in three or more dimensions. Further, the results illuminated older proofs for a) the results of phase transitions in one and two dimensions for the quantum case, b) the existence of phase transitions in the classical anisotropic Heisenberg model for arbitrarily small anisotropy, and c) the existence of a phase transition for Heisenberg antiferromagnetic model in external field. However, Simon also stated that a gap exists in some previous work done on the quantum ferromagnet, although the proof for the quantum antiferromagnet is sound.

Dr. B. Mandelbrot (IBM Watson Research Center) was then called upon to address the Conference on "Geometrical facets of statistical physics: scaling and fractals." Some interesting films and slides were shown as he explained what he meant by scaling and fractals, laying emphasis on the geometrical facets of statistical physics. During his talk he pointed out that the fractal dimension (not necessarily an integer) is less than or equal to the Euclidean dimension but greater than or equal to the topological dimension. Mandelbrot linked together many aspects of statistical physics including percolation, his work applying only to finite systems.

Next on the agenda was Professor R.J. Baxter (Australian National Univ.) whose talk on "Soluble models on the triangular and other lattices" must surely rank as one of the highlights of the Conference. With deceptive simplicity he stated the conditions governing the type of model he had been searching for, and then proceeded to produce it with calm assurance. It turned out to be an eight-vertex model on the Kagomé lattice which, with the correct interpretation of parameters can be reduced to the Ising and Dimer models on any planar lattice, the square ice-type models, the square-lattice eight-vertex model, and the three-spin triangular model. The evening offered a panel discussion on "Systems of low dimensionality." This proved so popular that extra seats had to be brought into the lecture room, and the concurrent oral sessions were almost completely deserted. The panel consisted originally of six speakers, Professor E. Brezin, Dr. H. Gutfreund (Hebrew Univ.), Professor L. Kadanoff, Dr. J. Solyom (Hungarian Academy of Science), Dr. F.Y. Wu (Northeastern Univ.), and Professor J. Zittartz (Universität Köln), under the moderation of Professor M. Kac. This was unfortunately reduced to five when Brezin withdrew. Each panelist was expected to speak for eight minutes, but since this allocation was invariably overrun, the session closed with no time for discussion.

The final day of the Conference was opened by Kadanoff who spoke on the topic of "Gauge theories for two-dimensional statistical mechanics problems." His main emphasis was on the contribution of statistical mechanics to quark and string theories in particle physics via simplified two-dimensional models. A Gaussian model was used for the quarks, a planar model for the strings, and the interactions were via vortices in the planar model (called instantons). Using such a model, he successfully obtained results in which the quark-quark interactions varied proportionally to the distance between them, i.e., the closer together the weaker the interaction and vice-versa. Dr. H. Satz (Bielefeld Univ.) followed with a talk entitled "Statistical concepts in hadron physics." He reviewed the statistical treatment of multihadron production and discussed two particular cases that characterize the limits of conventional statistical physics. These two cases are termed the FERMI and HAGEDORN models.

In the second plenary session of the day the Conference warmly welcomed Professor M. Ya. Azbel, who has taken a post at the Tel-Aviv University after recently being allowed to leave the USSR and continue his work in the West. His lecture subject was "Thermodynamics and the thermodynamic decoding of long molecules (DNA, RNA, etc.)." In actual fact, because of the time limit, he confined himself to DNA. Using a thermodynamic approach, he calculated the internal and boundary energies of a decoded sequence of DNA consisting of 203 links (provided by Professor W. Gilbert). The results he obtained were in good agreement with experimental data. Finally, Azbel said he would like to make an immense number of acknowledgements to the people who had helped him reach the West, but the time was too restrictive. He did, however, particularly mention Professor A. Aharony who had acted as his mentor since his arrival in Israel.

In the first of an afternoon filled with plenary lectures, Dr. R. Zallen (Xerox Corporation) gave a talk entitled "Percolation theory: overview, applications, and polychromatic percolation." He gave a general review of percolation, with various illustrations of what is meant by a percolating cluster, with one particularly good example of a coffee pot in which the water percolates among hexagonal coffee beans. He dealt with critical exponents, dimension, and renormalization-group theories, giving a review of the best results obtained by such methods. He discussed topological disorder, continuum percolation, and critical volume (cv) fraction. For the cv fraction he described an undergraduate experiment in which a random mixture of plastic and aluminum spheres could be introduced into the space bwtween two conducting plates in an attempt to complete the circuit. Finally, Zallen introduced the concept of polychromatic percolation in which there exist in a mixture three or more types of sites of which two or more types must percolate before one can be said to have a percolating cluster. In order to achieve this, the percolation threshold must be lowered, either by going to next-nearest-neighbor interactions or increasing dimensionality.

Zallen was succeeded by Professor T.C. Lubensky (Univ. of Pennsylvania) who spoke on "A review of phase transitions in strongly random systems." In a very compact talk he actually covered weak randomness, spin glasses, phase transitions in randomly diluted system, the conductivity of a random resistor network, the Potts model, and field theory. He repeated Brout's argument that two types of random systems exist. Physically these correspond to annealed and quenched systems, mathematically to averaging the partition function or its logarithm. In describing the means used to obtain solutions for a quenched system, he outlined the replica method originally due to S. Edwards and P. Anderson.

A film was then shown on percolation clusters. Produced by Dr. E. Stoll, Professor C. Domb and Dr. T. Schneider, this used Monte Carlo techniques to show the growth of percolating clusters in a finite 85 × 85 net. Dr. I. Riess (Technion) is suspected of sabotaging this film, since there first appeared a short cartoon sequence of Popeye, but the guilt has not been firmly established. The film itself used three colors and plotted against a scale of increasing percolation probability. The last lecture was given by Professor P.G. de Gennes (College de France). Entitled "Problems of polymer statistics," it consisted of a review of the main theoretical methods used to discuss the behavior of strongly interacting flexible chains, and some typical applications were presented. After this lecture the conference departed, en masse, for a much-needed beach party or "Kumsitz."

PARALLEL SESSIONS

In addition to the plenary sessions a total of sixty oral sessions were given, and ninety-two posters presented. These covered a wide range of topics from phase transitions in magnetic systems to astrophysics and

relativity. It was regrettable, though necessary because of sheer numbers, that many of these had to clash in their time of delivery. For this reason and, of course, in the interests of brevity, selected papers only are mentioned.

On the first day the poster sessions covered the broad topics "Phase transitions in magnetic systems," "Fluids and turbulence," and the oral sessions dealt with "Critical phenomena" and "Fluctuations," generally. Among the oral sessions were two which are worthy of particular note on random systems. Dr. H.G. Schuster (Univ. of Saarbrucken) considered the effect of Gaussianly distributed random fields on the X-Y model using a method which can be generalized to any n-vector model where $n > 2$. Both he and Drs. S. Fishman (Weizmann Institute) and A. Aharony, who presented the subsequent paper on random systems, used the $n \to 0$ trick where the log of the partition function is replaced by the limit of the partition function as $n \to 0$, i.e.,

$$\log Z^n = \lim_{n \to 0} \frac{1}{n} (Z^n - 1).$$

Schuster dealt particularly with the use of his methods in the explanation of the lack of transverse long-range order in the 1-D conductor. Fishman followed by showing that the straightforward renormalization-group calculations on a system composed of two types of magnetic ions A* (with probability of occurrence P) and B* [with probability of occurrence (1-P)] lead to a breakdown of scaling in the region of the tetracritical point.

After an informal beach trip in the early afternoon of the following day, the parallel sessions were again in full swing. Papers were presented on "Relativity and astrophysics," "General statistical mechanics and superfluids," "Biophysics," "Critical phenomena," "Systems of low-dimensionality," "Random systems," and "Fluids and turbulence." Dr. J.W. Essam (Westfield College, London) spoke on the "Low-density pair-connectedness for percolation models." He explained what is meant by correlated percolation and defined the pair-connectedness $P(\underline{r}_1\underline{r}_2)$ as the probability density for finding particles at position vectors $\underline{r}_1$ and $\underline{r}_2$ of the model, having a (directed) walk from the first to the second. There were several points worthy of note in his approach: (i) no Hamiltonian is required; (ii) the limit of $s \to 1$ in the Potts model is avoided; (iii) problems are formulated directly in the continuum thereby avoiding the lattice-to-continuum transitions of previous treatments; and (iv) the origin of the result for the critical dimension $d_c = 6$ becomes clear because third-order vertices arise as soon as there is a choice of path through the system. Now Dr. A.J. Guttmann (Univ. of New South Wales) continued dealing with the topic of series expansions, speaking of "Phase transitions in 2-D isotropic spin systems." He looked at the classical Heisenberg, planar-classical Heisenberg, infinite-spin X-Y and Step models. He was able to show from his analysis that while there is strong evidence of a phase transition at real positive temperature, further analysis of the meromorphic

double-log susceptibility series, i.e.,

$$\frac{d}{dT} \ln \frac{d}{dT} \ln \chi \sim \frac{1+\gamma}{(T_c-T)}$$

showed that there is no evidence of a conventional algebraic singularity for any of the four models. However, fairly strong evidence exists for an essential singularity in the PCH approximating the Kosterlitz type, though possibly it can prove to be more complex than this. Values for the convergence of the series were given for PCH and CH. Convergence for the Step model was poor and the series for the X-Y model too short to be able to say much about the latter. During the discussion that followed, Professor D.D. Betts (Univ. of Alberta) told the assembly that he and his collaborators now have 12 terms for the $S = \frac{1}{2}$ X-Y model having essentially looked at the 4th derivative of the free energy with respect to the field and that he tentatively suggests that the singularity is more likely to be given by a power-law form than an exponential. Now Dr. A. Coniglio (Univ. of Naples) completed the talks for this oral session by considering the problem of "Cluster size and percolation on the Ising model." He showed how recent results relate the percolation probability, mean-cluster size and pair-connectedness to the magnetization, susceptibility and pair correlation function, respectively. He established three theorems, the first showing that spontaneous magnetization can exist only if there is an infinite cluster, the second showing that a large correlation function implies large pair-connectedness, and a third which states that an infinite (+) cluster can never coexist with an infinite (-) cluster. [A (-) cluster/(+) cluster was defined as a maximal set of down/up spins linked together by their nearest-neighbor bonds.] Coniglio explained how information on the shape of clusters is deduced from a relation connecting the susceptibility, the mean-cluster size and perimeter. He also showed that in 3-D, Theorem 3 does <u>not</u> generally hold because the critical probability of a percolating ∞(-) cluster is reached before T_c is attained. This agrees with the case for the Bethe lattices and fluid systems, also.

On the third day of the Conference, talks given during oral sessions were based broadly on the topics of "Astrophysics and relativity," "Critical phenomena (dynamical)," and "Nonequilibrium statistical mechanics." Of particular interest was that given by Stoll and Schneider. Stoll spoke on "Critical dynamics of a kinetic Ising model with quenched relaxing impurities." A film was shown based on Monte Carlo computer-simulated results for a finite-lattice system in which two types of atom are distributed. Later Professor H.J. Kreuzer (Univ. of Alberta) talked about exactly soluble models in nonequilibrium statistical mechanics. He justified his nuclear-physics approach (he trained as a nuclear physicist) by citing examples such as the shell-model optical potential, etc. Betts presented a paper in the poster sessions dealing with new work on the ground state of the X-Y magnet and Heisenberg antiferromagnet in 2-D. He was at hand to explain the method of procedure which consisted of taking a finite "tile" representative of the lattice and containing N = 4, 8, 10, 16 or 18 spins and generalizing this to the whole lattice. Extrapolation

of the results for the ground state v. 1/N yielded estimates for the ground-state energy of the infinite lattice.

After another organized trip to the beach on the 29th, the parallel sessions were in full force again. The broad headings were "Phase transitions and molecular processes," "General statistical physics," "Critical phenomena," "Low dimensionality: Fermion systems," and also many last-minute papers covering the general range of the Conference, some of which were still awaiting referees. The parallel sessions continued after dinner although their attendance suffered considerably from the strong competition of the Panel Session (mentioned previously). There were no parallel sessions on the last day.

Warmest thanks and congratulations are due to the staff, both academic and administrative, of the Technion for their very considerable efforts on behalf of the participants. Special mention must be due to Professor C. Kuper and Dr. I. Riess for their organization of such a stimulating and pleasant conference.

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