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Nobel Prize in Physics 1982

Kenneth G. Wilson

The Nobel Prize in Physics 1982 was awarded to Kenneth G. Wilson *"for his theory for critical phenomena in connection with phase transitions"*.

Information about winners:

Kenneth G. Wilson,

Cornell University, Ithaca, USA

RESEARCH INFORMATION:

In daily life and from classical physics we know that matter can exist in different phases and that transitions from one phase to another may occur if we change, for example, the pressure or the temperature. A liquid goes over into a gas phase when sufficiently heated, a metal melts at a certain temperature, a permanent magnet loses its magnetization above a certain critical temperature, just to give a few examples.

Phase transitions have been studied in physics over a long time and for a large number of different systems. The phase transition is often characterized by an abrupt change in the value of some physical properties. In other cases the transition from one phase to another may be rather smooth. Examples of the latter case is the transition between liquid and gas at the critical point, and from ferromagnetism to paramagnetism in metals such as iron, nickel and cobalt. These smooth phase transitions show instead a number of typical anomalies near the critical point. Some quantities grow above all limits when one approaches the critical temperature. These anomalies, usually called *critical phenomena*, have to do with the very large fluctuations that occur in the system when we come close to the critical point.

A first qualitative description of the critical behaviour of some special al systems was given already around the turn of the century. Examples are the transition between liquid and gas and the transition between ferromagnetism and paramagnetism. The Soviet physicist L. Landau (Nobel Laureate in Physics 1962) published in 1937 a general theory for phase transitions, which contained the results of most earlier theories as special cases.

An essential step towards a further understanding was taken when L. Onsager (Nobel Laureate in Chemistry 1968) found the exact solution for the thermodynamic properties of a twodimensional model, that had been frequently discussed. It was a great surprise to find that the theory of Landau as well as all previous theories failed completely in predicting the behaviour close to the critical point. This puzzling result led to extensive and detailed studies of a large number of systems, and one found that the critical behaviour was quite different from the predictions by the Landau theory. Numerical calculations using different theoretical models also showed strong deviations from the Landau theory. M.E. Fisher, Cornell University played a leading role through his analysis of experimental data, supported by theoretical analysis and numerical calculations and, probably most important; by taking initiative and acting as a catalyst for further progress. One should mention important theoretical contributions by B. Widom, also at Cornell University, by the Soviet physcists *A.Z. Patashinskii* and *V.L. Pokrovski* and, most important by *L.P. Kadanoff*, University of Chicago. Kadanoff put forward a very important new and original idea which seemed to have strong influence on the later development. His theory, however, did not make it possible to calculate the critical behaviour.

The problem was solved in a definite and profound way by **Kenneth Wilson** in two fundamental papers from 1971 and followed by a series of papers in the following years.

Wilson realized that the critical phenomena are different from most other phenomena in physics in that one has to deal with fluctuations in the system. over widely different scales of length. We have normally to do with only one given scale of length for any given phenomenon. Examples of the normal situation is the physics of radio waves, hydrodynamic waves, visible light , atoms, nuclei, elementary particles where each system is characterized by a certain scale of length and we do not have to be concerned with widely different scales of length. For a condensed system or gas near the critical point, however, we cannot limit ourselves to one single scale of length. Besides the large-scale fluctuations of the same order of size as the entire system. We have fluctuations of shorter range all the way down to atomic dimension. In typical cases we may have fluctuations with a range of the order of centimetre and all the way down to less than one millionth of a centimetre. All these fluctuations are of importance near the critical point and a theoretical description must take into account the entire spectrum of fluctuations. A frontal attack with direct methods is out of the question even with the assistance of the fastest computers.

Wilson succeeded in an ingenious way to develop a method to solve the problem. instead of a frontal attack, he developed a method to divide the problem into a sequence of simpler problems, in which each part can be solved. Wilson built his theory on an essential modification of a method in theoretical physics called *renormalization group theory*, which was developed already during the fifties and was applied with varying success to different problems.

Wilson's theory for critical phenomena gave a complete theoretical description of the behaviour close to the critical point and gave also methods to calculate numerically the crucial quantities. His analysis showed that sufficiently close to the critical point most of the variables of the system become redundant. The critical phenomena are essentially determined by two numbers: the dimensionality of the system (1, 2 or 3) and the dimensionality of a key quantity called the *order parameter*, a quantity introduced already in Landau's theory. This is a physical result of great generality. It implies that many systems, different and completely unrelated, can show identical behaviour near the critical point. As examples we can mention that liquids, mixtures of liquids, ferromagnets, and binary alloys show the same critical behaviour. Experimental and theoretical work from the sixties suggested this form of universality, but Wilson's theory gave a convincing proof from fundamental principles. Calculations of the crucial parameters show consistently good agreement with experimental data.

Wilson is the first physicist to develop a general and tractable method where widely different scales of lengths appear simultaneously. The method is therefore, with proper modifications, applicable also to some other important and yet unsolved problems. Turbulence in fluids and gases is a classical example, where many different scales of length occur. In the atmosphere we find turbulent flow of all sized from the tiniest whirl of dust to hurricanes. Wilson's new ideas have also found application within particle physics. He has developed a modified form of the theory and successfully applied it to current problems in particle physics, particularly quark confinement. Wilson's theoretical methods represent a new form of theory which has given a complete solution to the classical problem of critical phenomena at phase transitions but which also seems to have a great potential to attack other important and up to now unsolved problems.

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