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Enrico Fermi and the birth of modern non-linear physics

In the early fifties in Los Alamos E. Fermi in collaboration with J. Pasta and S. Ulam started investigating what they assumed would be a very simple nonlinear mechanical system, i.e. a one dimensional chain of equal masses connected by a weakly nonlinear spring. The key question was related to the understanding of the phenomenon of conduction in solids; in particular they wanted to estimate the time needed to reach a statistical equilibrium state characterized by the equipartition of energy among the normal modes. They approached the problem numerically using the MANIAC I computer; however, the system did not thermalize and they observed a recurrence to the initial condition (this is known as the FPU-recurrence). This unexpected (and unexplained) result has led to the development of the modern nonlinear physics (discovery of solitons and integrability). In this colloquium, I will give an historical overview of the subject and present the different approaches that have been proposed in the last 60 years for explaining this paradox. Very recent results on the estimation of the time scale and on the mechanism of equipartition will also be reported and discussed.