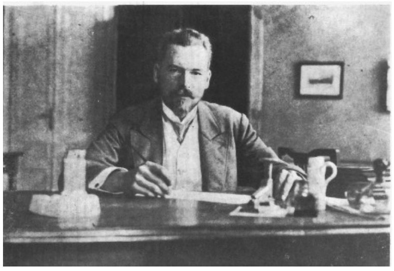

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Foundations of statistical mechanics for unstable interactions

Sunday, 18 September 2022 15:55 (25 minutes)

Traditional Boltzmann-Gibbs statistical mechanics does not apply to systems with unstable interactions, because for such systems the conventional thermodynamic limit does not exist. In unstable systems the ground state energy does not have an additive lower bound, i.e. no lower bound linearly proportional to the number N of particles or degrees of freedom. In this presentation (see [1] for details) unstable systems are studied whose groundstate energy is bounded below by a regularly varying function of N with index $\sigma \geq 1$. The index $\sigma \geq 1$ of regular variation introduces a classification with respect to stability. Stable interactions correspond to $\sigma = 1$. A simple example for an unstable system with $\sigma = 2$ is an ideal gas with a nonvanishing constant two-body potential. The foundations of statistical physics are revisited, and generalized ensembles are introduced for unstable interactions in such a way, that the thermodynamic limit exists. The extended ensembles are derived by identifying and postulating three basic properties as extended foundations for statistical mechanics: firstly, extensivity of thermodynamic systems, secondly, divisibility of equilibrium states, and thirdly statistical independence of isolated systems. The traditional Boltzmann-Gibbs postulate resp. the hypothesis of equal *a priori* probabilities are identified as special cases of the extended ensembles. Systems with unstable interactions are found to be thermodynamically normal and extensive. The formalism is applied to ideal gases with constant many-body potentials. The results show that, contrary to claims in the literature, stability of the interaction is not a necessary condition for the existence of a thermodynamic limit. As a second example, the formalism is applied to the Curie-Weiss-Ising model with strong coupling. This model has index of stability $\sigma = 2$. Its thermodynamic potentials, originally obtained in [2] are confirmed up to a trivial energy shift. The strong coupling model shows a thermodynamic phase transition of order 1 representing a novel mean-field universality class. The disordered high-temperature phase collapses into the ground state of the system. The metastable extension of the high-temperature free energy to low temperatures ends at absolute zero in a phase transition of order 1/2. Between absolute zero and the critical temperature of the first order transition all fluctuations are absent.

References

[1] Physical Review E, **105**, 024142 (2022).
[2] Physica A, **320**, 429 (2003).

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