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Book Review: *Dynamics and Thermodynamics of Systems with Long-Range Interactions*

Dynamics and Thermodynamics of Systems with Long-Range Interactions. T. Dauxois, S. Ruffo, E. Arimondo, and M. Wilkens (eds.). Springer-Verlag, Berlin, 2002.

Do two spaceships approaching each other at a speed of 0.7c really not have a relative velocity of 1.4c? Some concepts that seem, at first sight, obvious turn out, with deeper thought, to be richer. Scientific revolutions have come from finding new physics beyond Galilean invariance, parity conservation, Euclidean geometry, and Maxwell's equations applied to electron orbitals. Can the same be said about physical systems when one goes beyond short-ranged interactions to consider systems with long-ranged interaction? Is there a rich new physics in systems with long-range interactions? That is the main question addressed, with affirmation, in this series of articles presented as lectures at a Les Houches, France Winter School in 2002. The articles are arranged into four sections: statistical mechanics; astrophysics; Bose–Einstein condensation; and nonlinear dynamics. The focus of the articles is on nonlinear dynamics and thermodynamics for systems with long-range interactions. These lectures are generally, long on theory, but short on experiment.

Is thermodynamics richer than the examples found in traditional textbooks? Can a theory , developed to explain heating in cannons and the working of a steam engine, be generally applicable to more complex systems? Electromagnetic forces and the gravitation force are long-ranged and astrophysics is a good starting point in this arena. As an example, stars get hotter as they radiate energy because a gravitational collapse is also in progress. Taking both the radiation and gravitational effects into account the star appears to have a negative specific heat getting hotter as it loses heat. This makes for interesting thermodynamics! This example does not imply that something is wrong with thermodynamics, but just that care must be taken when applying it to a complex system. Some lectures discuss new insights and applications of nonextensive thermodynamics. These

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papers explore generalizations of Boltzmann–Gibbs statistics with so-called q-statistics, but the question of bringing two systems with different q values together and achieving their thermal equilibrium still needs to be addressed. Mean field theories of a phase transition are, by fiat, long-range as every particle interacts with every other particle through the mean field. The Blume–Emery–Griffiths mean field spin model is examined. Its Hamiltonian is of the type where the energy is not additive and unusual thermodynamics prevails. A swallowtail catastrophe is found when entropy in the microcanonical is plotted in 3D as a function of energy and an order parameter.

The lectures discuss systems that have bifurcations, nonergodic phase spaces, mixing chaos and quasiperiodicity, canonical and microcanonical ensembles with different physical predictions, phase transitions in finite systems in which surface and interface energies dominate, and catastrophes and other instabilities. These discussions lead one to rethink assumptions and to deepen one's intuition about dynamics and thermodynamics gained from simpler problems. Other thought-provoking topics addressed in this book include nonlinear dynamics of vortices in 2D; dipolar interactions, fracture stress fields, Bose–Einstein condensates, fractal clusters, and plasmas. Overall, these lectures provide a host of interesting still open areas of research for the reader.

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