Special issue

Nonextensive statistical mechanics and thermodynamics

Ten years ago, Constantino Tsallis, from the Centro Brasileiro de Pesquisas Físicas, in Rio de Janeiro, proposed a more general form of entropy, given by the expression

$$S_q = k\frac{1}{q-1}\left[1-\sum_{i=1}^{W} p_i^q\right] \ ,$$

where k is a positive constant, q is a certain parameter, and p_i is the probability of finding a system in the microscopic state i (out of a total number W of microstates). This special issue of the Brazilian Journal of Physics is entirely dedicated to the consequences of this proposal.

The entropy of Tsallis reduces to the usual Boltzmann-Gibbs formula,

$$S = -k\sum_{i=1}^{W} p_i \ln p_i \ ,$$

in the limit $q \rightarrow 1$. For $q \neq 1$, S_q is not extensive and gives rise to a host of new and interesting effects (which would be relevant for the description of thermodynamically anomalous systems).

The developments of the last ten years are reviewed by Tsallis himself in the opening article of this issue. There are theoretical connections to anomalous diffusion, and applications that range from gravitational problems to models of granular systems and of decision making in the financial market. There are also applications to problems of optimization and the analysis of several experimental situations (as the turbulence in electron plasmas, and the flux of solar neutrinos). This opening article refers to the subsequent papers and works as an introduction to this special issue.

The papers by Curado and Landsberg refer to theoretical questions raised by generalizations of Boltzmann-Gibbs entropy (different functional properties of entropy give rise to distinct thermodynamics, as pointed out by Landsberg). A. Plastino and A. R. Plastino use the Tsallis nonextensive measure to rewrite the forrmalism of Jaynes for statistical physics. Theoretical applications and consequences of nonextensive thermostatistics within several contexts are presented by Rajagopal (quantum formalism of operators of the Tsallis ensemble and their parameter differentiation), Mendes (field theoretical methods), A. R. Plastino and A. Plastino (Vlasov-Poisson equations to describe gravitational systems), and Bhogosian (Navier-Stokes equations for a two-dimensional electron plasma).

There are then some papers referring to several applications of non-extensive thermostatistics to physical problems. The mechanisms of anomalous diffusion are described by Zanette. The fractal analysis of non-Markovian processes with long-range correlations is the subject of Caceres. Wio and Bouzat write about the role of asymmetric potentials and non-Gaussian noise in the two-state theory of the phenomenon of stochastic resonance. C. R. da Silva, H. R. da Cruz, and M. L. Lyra consider low-dimensional nonlinear dynamical systems at the edge of chaos to show the connections between the scaling analysis of the multifractal attractor and the q-dependent measure of nonextensive thermostatistics (the form of S_q was indeed suggested by the definition of the generalized fractal dimensions). The thermal distributions in stellar plasmas, nuclear reactions and solar neutrinos are reviewed by Coraddu, Kaniadakis, Lavagno, Lissia, Mezzorani, and Quarati. Borland and Menchero apply non-extensive thermostatistics to study tight-bind models with long-range hopping terms. In the final papers, Straub and Andricioaei, Hansmann and Okamoto, and Mundim and Ellis, review computational methods (Monte Carlo and molecular dynamics algorithms for simulating classical and quantum systems, with special emphasis on the protein folding problem) according to Tsallis statistics.

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