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Longitudinal Oscillations in Relativistic Plasmas: A Nonextensive Statistics Approach

V. MUÑOZ[1,2]

[1] *Department of Earth System Science and Technology, Kyushu University, Fukuoka 816-8580, Japan*
[2] *Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile*

The dispersion relation of longitudinal electrostatic oscillations in a relativistic plasma is studied in the context of the nonextensive statistics formalism proposed by Tsallis, where entropy is a nonextensive quantity given by[1] $S_q = k_B(1 - \sum_i p_i^q)/(q-1)$, where k_B is the Boltzmann constant, and q is a real number. $q = 1$ corresponds to the usual Boltzmann-Gibbs, extensive statistics formalism.

Equilibrium distribution functions which maximize S_q are non-Maxwellian, and strongly resemble particle distribution functions observed in space and laboratory,[2,3] and turbulent pure electron plasmas.[4]

In the nonrelativistic regime,[5] normalizability of the equilibrium distribution function implies that $-1 \leq q \leq \infty$. We show that in the relativistic regime much tighter constraints must be satisfied, namely $0 \leq q \leq 1 + k_B T/mc^2$, where T is the temperature of the plasma, and m is the particle mass.

As an application, we study longitudinal oscillations in a proton-electron plasma, assuming immobile protons, and electrons whose distribution function maximizes Tsallis's entropy. The dispersion relation of these oscillations is written in integral form for the long wavelength limit. Explicit expressions in terms of generalized hypergeometric functions can be found for all possible values of q in the ultra-relativistic regime, allowing to numerically solve the dispersion relation.

References

[1] C. Tsallis, J. Stat. Phys. **52**, 479 (1988).
[2] E. Marsch, K.-H. Mühlhäuser, R. Schwenn, H. Rosenbauer, W. Pilipp, and F. M. Neubauer, J. Geophys. Res. **87**, 52 (1982).
[3] J. M. Liu, J. S. D. Groot, J. P. Matte, T. W. Johnston, and R. P. Drake, Phys. Rev. Lett. **72**, 2717 (1994).
[4] X.-P. Huang and C. F. Driscoll, Phys. Rev. Lett. **72**, 2187 (1994).
[5] J. A. S. Lima, R. Silva, Jr., and J. Santos, Phys. Rev. E **61**, 3260 (2000).