Relativistic gas: Lorentz-invariant distribution for the velocities

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In 1911, Jüttner proposed the generalization, for a relativistic gas, of the Maxwell–Boltzmann distribution of velocities. Here, we want to discuss, among others, the Jüttner probability density function (PDF). Both the velocity space and, consequently, the momentum space are not flat in special relativity. The velocity space corresponds to the Lobachevsky one, which has a negative curvature. This curvature induces a specific power for the Lorentz factor in the PDF, affecting the Jüttner normalization constant in one, two, and three dimensions. Furthermore, Jüttner distribution, written in terms of a more convenient variable, the rapidity, presents a curvature change at the origin at sufficiently high energy, which does not agree with our computational dynamics simulations of a relativistic gas. However, in one dimension, the rapidity satisfies a simple additivity law. This allows us to obtain, through the central limit theorem, a new, Lorentz-invariant, PDF whose curvature at the origin does not change for any energy value and which agrees with our computational dynamics simulations data. Also, we perform extensive first-principle simulations of a one-dimensional relativistic gas constituted by light and heavy particles.