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Relativistic Gravitational Instability and the Weight of Heat

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The gravitational instability, responsible for the formation of structure in the Universe, is a Newtonian phenomenon, occurring in the weak-field limit of General Relativity. It occurs at low energies and big radii of a self-gravitating gas when thermal energy can no longer counterbalance self-gravity. I will show that if such an ideal, self-gravitating gas with constant rest mass is sufficiently heated up, it becomes subject to a novel relativistic gravothermal instability, which occurs at high energy and small radii, even if the rest mass satisfies the Newtonian weak-field approximation. In the one hand, thermal energy tends to stabilize a gas with respect to self-gravity, but on the other, being a form of mass-energy, it gravitates as well. According to Tolman-Ehrenfest effect, the temperature profile is inhomogeneous at thermal equilibrium in General Relativity. Heat rearranges itself in order to counterbalance its own self-gravity, just like rest mass does. I find that there is always a threshold beyond which thermal energy cannot support its own gravitational attraction. Applications of the phenomenon include neutron stars and core-collapse supernovae. I apply the formalism to hot protoneutron stars and generalize the Oppenheimer-Volkov calculation of the mass limit to the whole non-zero temperature regime. An ultimate upper mass-limit of 2.4 solar masses at a radius of 15km is reported at a temperature relevant to core-collapse supernovae.

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