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Gravity and nonequilibrium thermodynamics: the origin of evolution equations

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An extension of standard nonequilibrium thermodynamics is presented, where the gravitational potential is a thermodynamic state variable, (P. Ván & S. Abe, Physica A 588 (2022) 126505). Then standard and rigorous methods of Rational Mechanics and nonequilibrium thermodynamic framework allow a set of evolution equations to be derived for the gravitational field and the derivation of thermodynamic forces and fluxes. The method effectively substitutes variational principles for ideal systems without dissipation, and provides the evolution equations for dissipative continua at the same time. An important aspect of this framework is the application of β-, or thermometer flow-frame (F. Becattini, Acta Physica Polonica B, (2016) **47**:1819–1832), *i.e.* tying the flow of the continuum, the flow-frame, to the temperature four-vector, compared to the usual Landau-Lifshitz (or energy) or Eckart (conserved particle) flow-frames, which have been proved unstable.

With certain straightforward assumptions for the gravitating system, a nondissipative gravitational field equation can be derived in the form of a modified Poisson equation:

$\Delta\varphi = 4\pi G\rho + K(\nabla\varphi)^2$,

resulting in modified gravity. Analytical solutions show a double crossover, allowing for different gravitational behaviour on different size scales (S. Abe & P. Ván, Symmetry 2022, 14, 1048(7)). This property presents a possible approach to explain Dark Matter-related phenomena on galactic scales, and different dynamics on extragalactic scales. Moreover, a direct connection to quantum mechanics is presented, as well, (P. Ván, Physics of Fluids, (2023) 35(5).).

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