Higher-order nonlocal thermodynamic theories of gravity

Máté Pszota[1,2]

[1]HUN-REN Wigner RCP, Budapest, Hungary, [2]Eötvös Loránd University, Budapest, Hungary

In this presentation, the generalised derivation of a gradient modification of Newtonian gravity is presented within a thermodynamic framework. The resulting field equation is compared to the models considered by Franklin [1], Lazar [2], Bekenstein & Milgrom [3] and Ván & Abe [4], for a general field-dependent energy contribution to the internal energy with extended state space including up to third order spatial gradient dependence.

When assuming a cross-effect (characterised by the parameter K derived from coupling the Onsagerian relations) between the mechanical and gravitational thermodynamic forces and fluxes, the theory results in a dissipative field equation relaxing to a generalised and extended Poisson's equation for gravity.

The resulting nonrelativistic modifications of gravity may potentially explain astronomical observations of phenomena usually contributed to dark matter, or help exploring the potential corrections to the results of Solar system-level tests (for example, with Yukawa-like terms).

The theory of Ván and Abe [4] is investigated in detail. The resulting nondissipative gravitational field differs from the Newtonian Poisson's equation, delivering modified gravity with an extra square-gradient term due to coupling between the mechanical and gravitational thermodynamical forces. Analytical solutions show a crossover, allowing for different gravitational behaviour on different size scales [5]. This effect is considered a possible explanation for the source of dark matter-related effects on the galactic scale while allowing different dynamics on the extragalactic scales. The analysis for three galaxies from the Spitzer Photometry and Accurate Rotation Curves (SPARC) sample is presented with observational data as the source for the density distribution [6].

References:

[1] Franklin, J. Self-consistent, self-coupled scalar gravity. American Journal Of Physics. 83, 332-337 (2015,4), https://doi.org/10.1119/1.4898585

[2] Lazar, M. Gradient modification of Newtonian gravity. Phys. Rev. D. 102, 096002 (2020,11), https://link.aps.org/doi/10.1103/PhysRevD.102.096002

[3] J. Bekenstein and M. Milgrom. Does the missing mass problem signal the breakdown of Newtonian gravity? Astrophysical Journal, 286:7–14, November 1984.

[4] P. Ván, S. Abe. Emergence of modified Newtonian gravity from thermodynamics, Physica A, 588:126505, 2022.

[5] S. Abe, P. Ván, Crossover in extended Newtonian gravity emerging from thermodynamics, Symmetry, 14:1048(7), 2022.

[6] M. Pszota, P. Ván, Field equation of thermodynamic gravity and galactic rotational curves, Physics of the Dark Universe, 46:101660, 2024