DERIVATION OF HIGHER ORDER GRADIENT THERMODYNAMIC GRAVITY

Máté Pszota[1,2,*], Péter Ván[2,3,4]

[1]Eötvös Loránd University, Institute of Physics, Budapest, Hungary,
[2]HUN-REN Wigner Research Centre for Physics, Department of Theoretical Physics, Budapest, Hungary,
[3]BME, Department of Energy Engineering, Budapest, Hungary,
[4]Montavid Thermodynamic Research Group, Budapest, Hungary,
[*]pszota.mate@wigner.hun-ren.hu

ABSTRACT

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] and Ván [3], for a general field-dependent energy contribution to the internal energy in the form of

$$u = e - \varphi - \frac{\varepsilon(\varphi, \nabla\varphi, \nabla^2\varphi, \nabla^3\varphi)}{\rho}. \tag{1}$$

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

$$\begin{aligned}\tau\partial_t\varphi = l^2 4\pi G\Bigg(&\nabla\cdot(\partial_{\nabla\varphi}\varepsilon) - \rho - \partial_\varphi\varepsilon - \nabla^2 : \partial_{\nabla^2\varphi}\varepsilon + \nabla^3 \dddot{:} \partial_{\nabla^3\varphi}\varepsilon \\ &+ 2K\left[-3\varepsilon + (\partial_{\nabla\varphi}\varepsilon - \nabla\cdot\partial_{\nabla^2\varphi}\varepsilon + \nabla^2 : \partial_{\nabla^3\varphi}\varepsilon)\cdot(\nabla\varphi) + (\partial_{\nabla^2\varphi}\varepsilon - \nabla\cdot\partial_{\nabla^3\varphi}\varepsilon) : (\nabla^2\varphi) + (\partial_{\nabla^3\varphi}\varepsilon) \dddot{:} (\nabla^3\varphi)\right]\Bigg).\end{aligned} \tag{2}$$

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).

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] Ván, P. & Abe, S. Emergence of extended Newtonian gravity from thermodynamics. *Physica A: Statistical Mechanics And Its Applications*. **588** pp. 126505 (2022), https://www.sciencedirect.com/science/article/pii/S0378437121007780