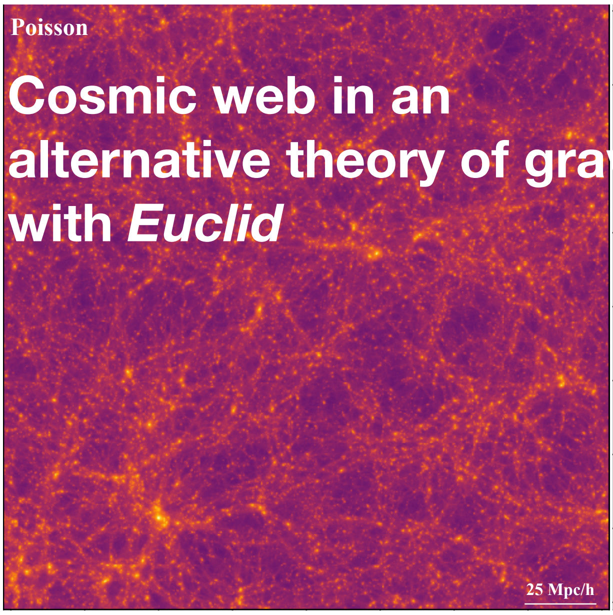
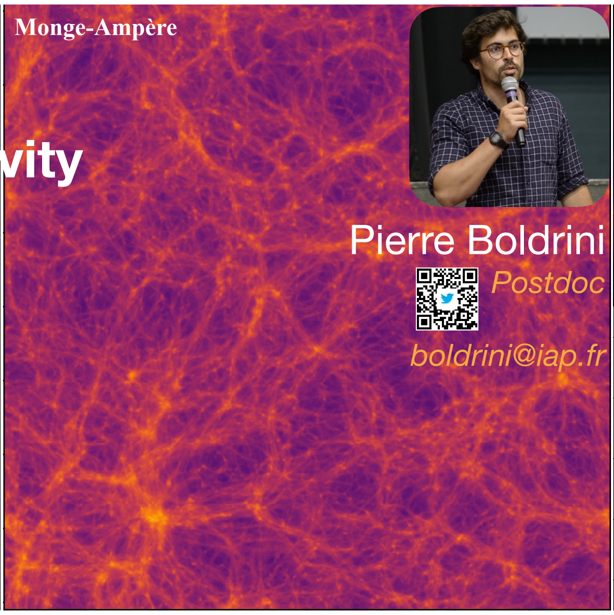


Cosmic web in an alternative theory of gravity with *Euclid*



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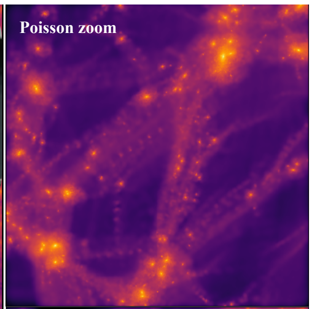
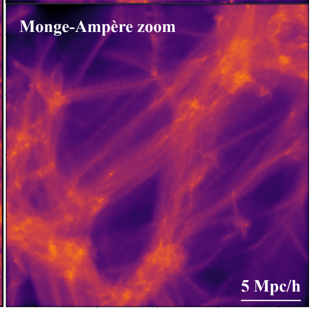




Motivation

Now, we have several observational programs, such as Gaia, JWST, and Euclid, which will either verify the ΛCDM model or necessitate a significant revision of our current paradigm. Indeed, there are still challenges in this model such as the $\sigma 8$ tension or the cusp-core problem. In response to this, alternative theories of dark matter such as fuzzy or self-interacting dark matter were initially proposed, but it is also necessary to consider testing alternative theories of gravity that can be tested on cosmological scales especially with the Euclid mission.

Which alternative theory of gravity?

Recently, it has been suggested that the Monge-Ampère equation may provide an alternative model for self-gravitating systems [1,2]. Yann Brenier has shown that Monge-Ampère gravity can arise from a microscopic system in which a finite number of indistinguishable particles move on independent Brownian trajectories without any interaction. Then, gravity emerges through application of a principle of statistical physics, namely the large deviation principle [1].

How to distinguish gravity models at cosmological scales?

One way we have decided to explore is computing cosmic connectivity, namely the number of filaments connected to a given galaxy group or cluster. Fig. 1 displays the mean connectivity from observations and from ΛCDM simulations assuming Poisson gravity. As it is an important ingredient in shaping mass assembly of galaxy group and clusters, it should be sensitive to the dynamics of DM governed by the assumed gravity model. Filament properties have already been explored as alternative probes of cosmologies [3,4].

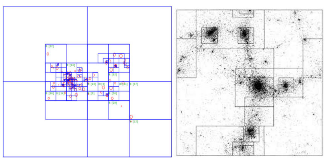
Aim

I plan to test the validity of the Monge-Ampère gravity model at cosmological scales with the Euclid mission

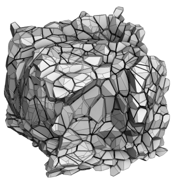
1. Developing a DM only cosmological simulation for this alternative theory of gravity by using new efficient algorithm from optimal transport theory
2. Exploring the cosmic web properties to distinguish gravity models

N-body simulations

Poisson	Monge-Ampère
Tree-Code	Optimal transport algorithm



$\mathcal{O}(N \log N)$



$\mathcal{O}(N \log N)$

We also emphasise that Monge-Ampère equation is invariant under a larger group of symmetries, i.e. SL(3) or unimodular affine symmetry, than the Poisson equation which is invariant only under SO(3) and does not support deformation or shearing transformations.

Monge-Ampère gravity

The extra symmetry facilitates the formation of anisotropic structures such as filaments, but it also makes them more resistant to collapse, which reduces the formation of halos.

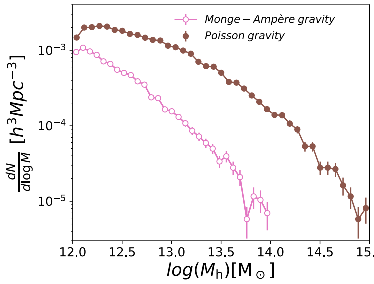
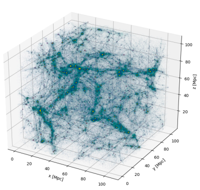
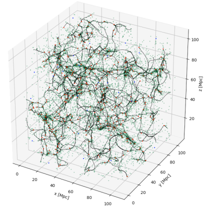


Fig. 1 Halo mass functions derived from the halo finder adaptaHOP [8].

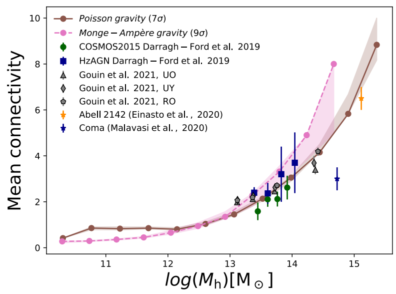
Methodology



Filament detection technique **DisPerSE** [9]



Results



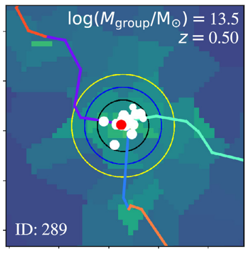


Fig. 2 Mean connectivity as function of the halo mass for both Poisson and Monge-Ampère simulations. Connectivities deviate at high halo mass. From ΛCDM simulated samples, it has been measured a connectivity between 2 and 4 in this mass range. Right figure is taken from [6].

The Euclid mission will allow to explore cosmic filaments at higher redshifts with more statistics very useful especially at high mass where the difference between the models is the most important, hence providing an extraordinary dataset to robustly test gravity models.

This poster shows that
The filament connectivity could be used as a probe of our gravity model at cosmological scales with the Euclid mission

Based on *Brenier, Lévy, Boldrini et al. 2023, submitted to PRL*
Boldrini & Laigle 2023, in prep.

Institut d'Astrophysique de Paris

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