



# Annual Meeting QGSKY – Quantum Universe

**Genova, 5th - 6th October 2023**

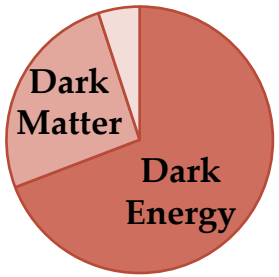
## Non-local gravity effects in galaxy cluster lensing

**Filippo Bouchè**

# Non-local gravity

**ΛCDM model**

**General Relativity**




**UV shortcomings**

**IR shortcomings**

**Infinite Derivative Gravity**

**Integral Kernel Gravity**

**Kinematical non-locality** can be implemented by discretizing spacetime and introducing a minimal length scale

**Dynamical non-locality** can be achieved through the addition of non-local geometrical operators to the gravitational Lagrangian

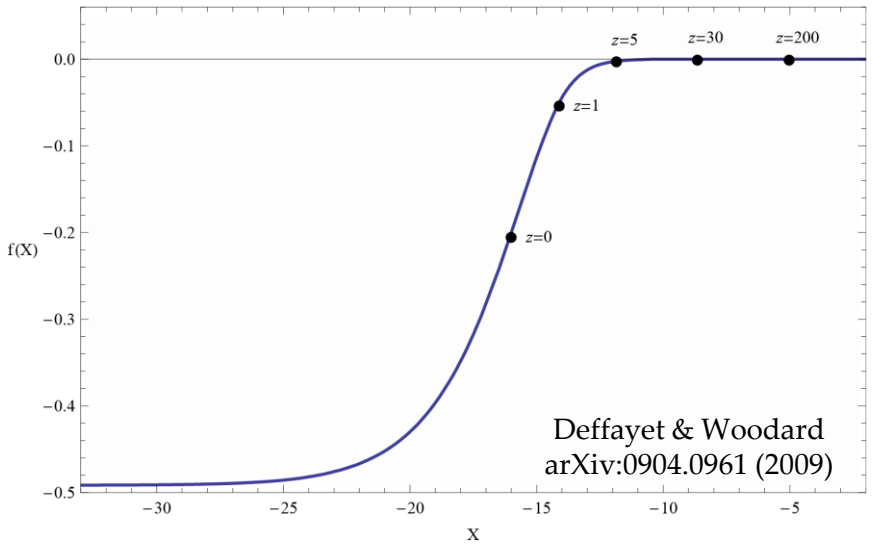
Non-locality can be read as either a fundamental feature of gravity or an effective approach:

- It is possible to retain unitarity and renormalizability as long as the principle of locality is given up
- Non-local geometric operators naturally emerge in one-loop effective actions on curved backgrounds

# Non-local cosmology

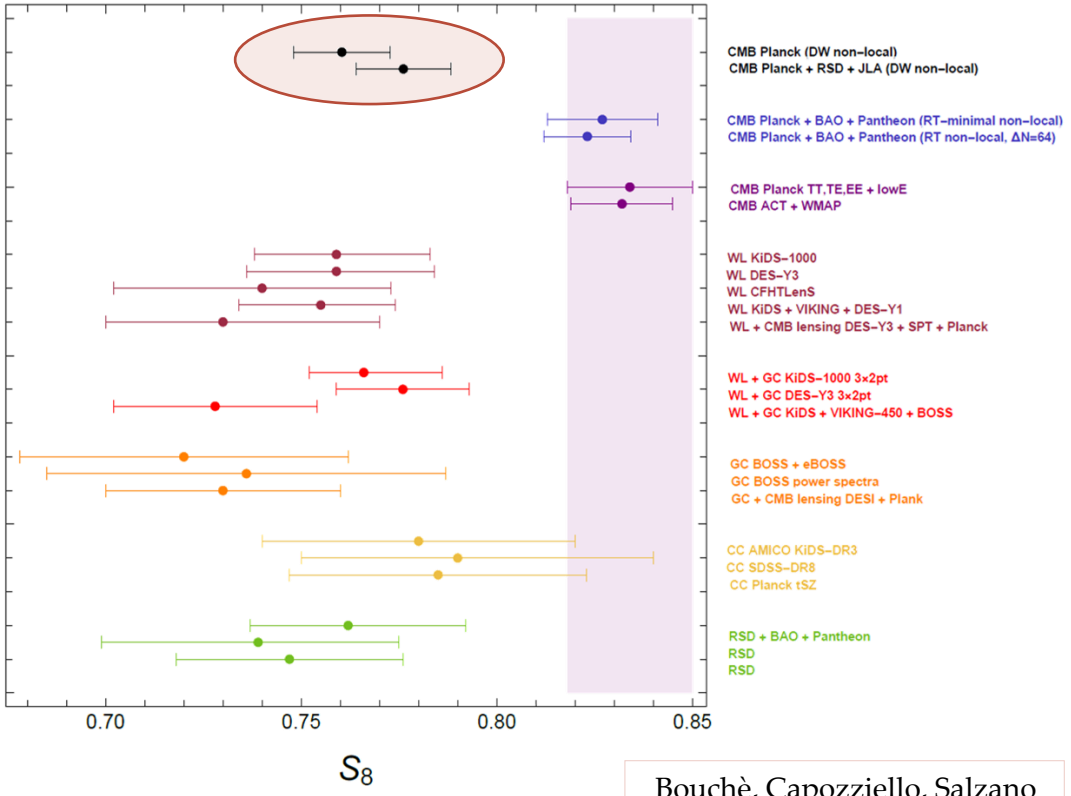
$$S = \frac{1}{2\kappa}\int d^4x\,\sqrt{-g}\,R[1+f(\Box^{-1}R)]$$

$$S = \frac{1}{2\kappa}\int d^4x\,\sqrt{-g}\,\{R[1+f(\eta)-\xi]-\nabla^\mu\xi\nabla_\mu\eta\}$$




Deffayet & Woodard
arXiv:0904.0961 (2009)

## Non-local growth of perturbations




Bouchè, Capozziello, Salzano
arXiv:2301.01503 (2023)

# Astophysical tests of non-local gravity

**Noether Symmetry Approach**

$$f(\eta) = 1 + e^{\eta}$$

⇩

**Weak-field limit**

$$\Phi(r) = -\frac{GM}{r} + \frac{G^2M^2}{2c^2r^2}\left[\frac{14}{9} + \left(\frac{3}{r_\eta} - \frac{11}{6r_\xi}\right)r\right]$$

$$\Psi(r) = -\frac{GM}{3r} + \frac{G^2M^2}{2c^2r^2}\left[\frac{2}{9} + \left(\frac{3}{2r_\xi} - \frac{1}{r_\eta}\right)r\right]$$

⇩

Tests of the non-local model in gravitationally bound systems

S2 star (arXiv:1812.09289) $\sim 5 \times 10^6\, M_\odot$

Ultra-Diffuse Galaxies (ongoing) $\sim 10^8 - 10^{11}\, M_\odot$

Elliptical galaxies w/o DM (arXiv:2209.01696) $\sim 10^{10} - 10^{12}\, M_\odot$

Galaxy clusters (arXiv:2205.03216) $\sim 10^{15}\, M_\odot$

⇩

**Lensing convergence**

$$\kappa(R) = \frac{1}{c^2}\frac{D_{ls}D_l}{D_s}\int_{-\infty}^{+\infty} \nabla_r^2\left[\frac{\Phi(R,z) + \Psi(R,z)}{2}\right]dz$$

# Galaxy cluster lensing

**CLASH**

Cluster Lensing and Supernova survey with *Hubble*

19 galaxy clusters from X-ray catalogues

Mass range

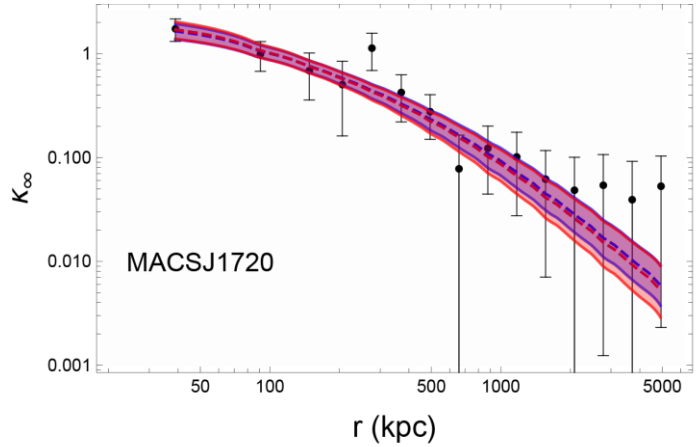
$5 \lesssim M_{200}/10^{14} M_{\odot} \lesssim 30$

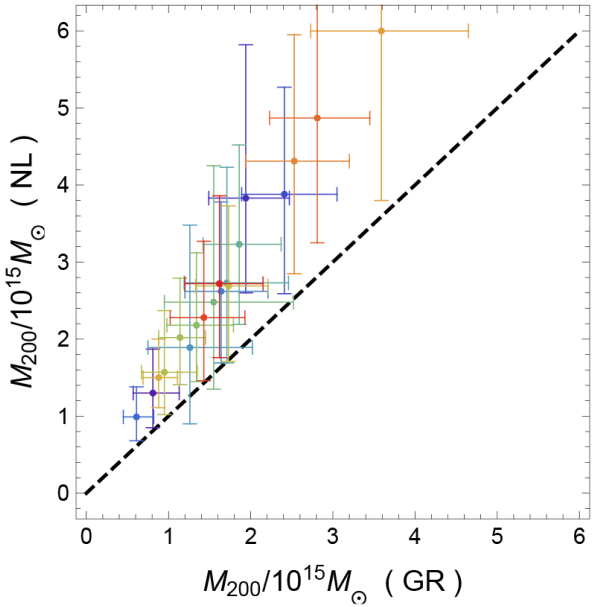
Redshift range

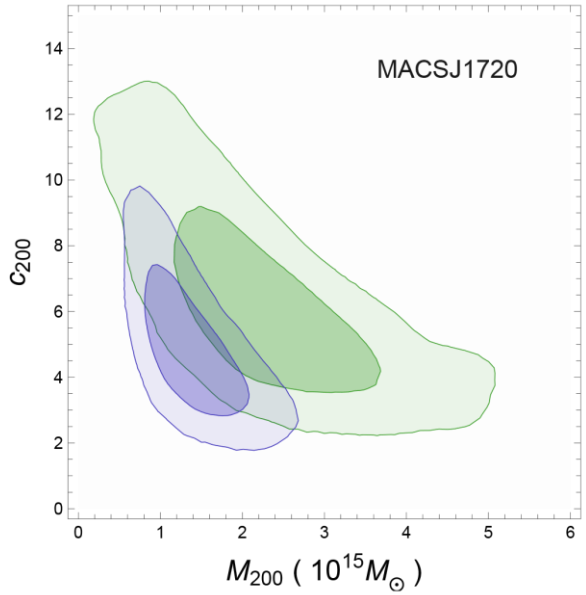
$0.187 < z < 0.686$

15 measured values of the lensing convergence $\kappa(R_i)$

4 measures $\kappa(R_i)$ from strong lensing and 11 measures $\kappa(R_i)$ from weak lensing observations

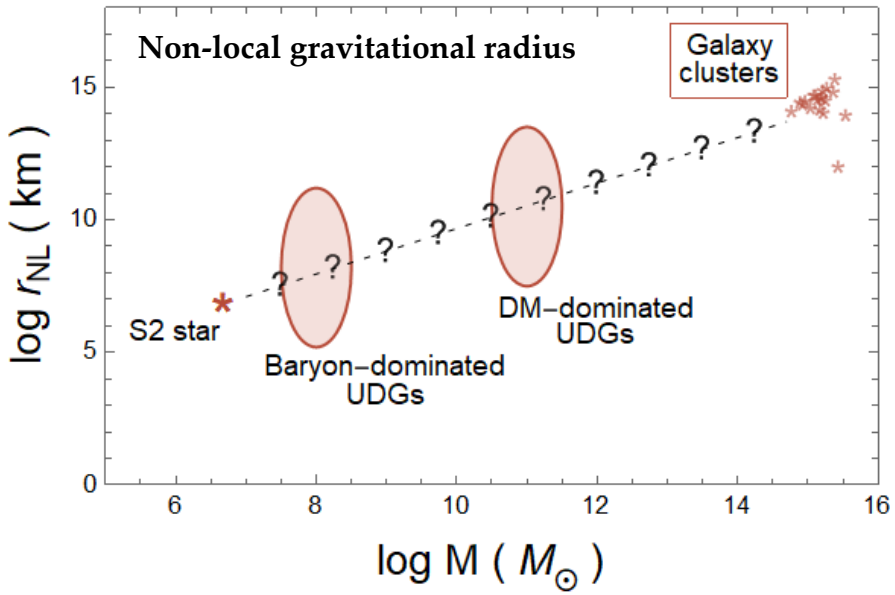


# Summary and Conclusions

- Non-local gravity may represent a viable extension of GR to address both the IR and UV shortcomings of the ΛCDM model
- The non-local Deser-Woodard model provides an appealing mechanism for the late-time cosmic acceleration as well as the mitigation of the growth tension
- The impact of the non-local corrections within gravitationally bound systems can be analyzed to test non-local gravity in the non-linear regime
- Non-local effects have been tested at galactic bulge, galactic halo and galaxy cluster scales, showing no evidence for spoiling effects
- Non-local gravity may provide an additional gravitational radius related to the mass of the gravitating object, whose effects should be investigated in the context of the hierarchical structure formation

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