A theory of type-II minimally modified gravity

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106 Congresso nazionale SIF, 2020

[with S. Mukohyama, A. Doll. ArXiv:2004.12549]

CGP
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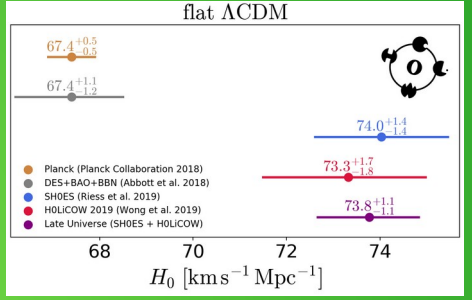
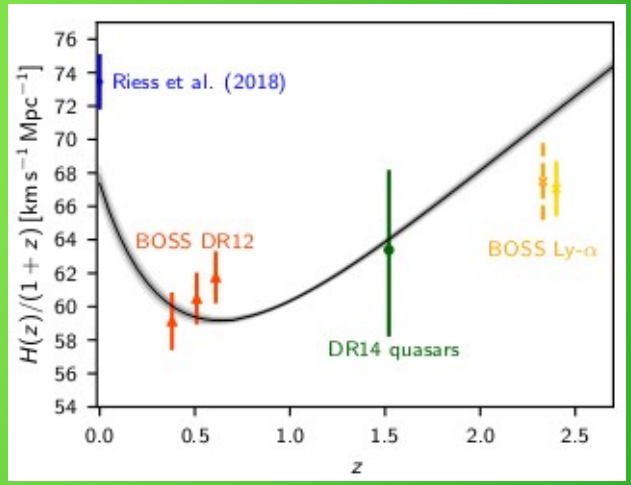
Experimental puzzle



H0LiCOW, 2019

- Different experiments give different values for today's value of the Hubble parameter [5.3 sigma if combined with H0LiCOW]
- Possible unknown systematics?
- New kind matter? Dark Radiation: Riess et al, 2017
- New theory of gravity? f(R), Horndeski, BeyH, etc.
  - Scalar tensor theories
  - Massive (bi-)gravity theories, …



Planck coll., 2018

Minimal theories of gravity

- Extra dof tend to be constrained at several scales (ST theories: Chameleon, Veinshtein mechanisms)
- It is minimal: a theory with only two gravity degrees of freedom
- The idea is to break 4D-diffeo-invariance (but not 3D diffeo) at very large cosmological scales
- Standard GR is recovered at short scales (in space & time) compared to cosmological ones

Type I and II theories

- Type I: can be recasted as GR + coupling to matter. It possesses an Einstein frame
- Type II: it does not have an Einstein frame
- We consider in the following type-II theories
- Matter is minimally coupled with gravity in type-II

Recipe for type II theory

- Start from GR Hamiltonian in ADM variables
- Perform a canonical transformation to a new frame
- Introduce a cosmological constant in the new frame
- We add a gauge fixing term as to keep dof to be two
- Perform inverse canonical transformation to non-GR theory
- Add matter minimally

Type-II theory Hamiltonian

[ADF, Doll, Mukohyama 2020, to appear in JCAP]

- After following the previous recipe

$$H=\int d^3x\Big[N\,H_0(\gamma,\pi)+N^i H_i(\gamma,\pi)+N\sqrt{\gamma}\,M_p^2 V(\phi)+\sqrt{\gamma}\,\lambda_C\left(M_p^2\phi-\frac{\pi^{ij}}{\sqrt{\gamma}}\gamma_{ij}\right)$$
$$+\lambda_\phi\pi_\phi+\sqrt{\gamma}\,M_p^2\lambda_{gf}\nabla^2\phi$$

- It can be interpreted as addition of non-dynamical 3D scalar
- One free function available. When V goes to constant then GR is recovered
- Number of phase space variables: 2x6 [from γ_{ij}]+2 [from ϕ] = 14
- 3 1st class constr + 4 2nd class constr.: 14 - 2x3 -1x4 = 4. 4/2=2 dof

Type-II theory Lagrangian

- Via a Legendre transformation we get the gravity Lagrangian

$$\mathscr{L}=N\sqrt{\gamma}\left[\frac{M_p^2}{2}\left[R+K_{ij}K^{ij}-K^2-2V(\phi)\right]-\frac{\lambda_{gf}}{N}M_p^2\nabla^2\phi-\frac{3M_p^2\lambda^2}{4}-M_p^2\lambda(K+\phi)\right]$$

- Consider now cosmology adding standard matter fields
- Friedmann equations

$$3M_p^2H^2=\rho+\rho_\phi,\qquad \rho_\phi=M_p^2(V-\phi V_{,\phi})+\frac{3}{4}M_p^2V_{,\phi}^2$$

$$\frac{\dot{H}}{N}=\frac{1}{4M_p^2}(\rho+P)(3V_{,\phi\phi}-2)$$

Conclusions

- Tensions in cosmology: hint for modified gravity theories?
- We build up a minimal theory
- Minimal distance from GR: 2 dof.
- 1 extra function V
- Dynamics different from GR at large cosmological scales: non trivial phenomenology