Nonlinear Cosmological Probes of Screening Mechanisms in Modified Gravity

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Scalar-Tensor Theories
with Chameleon or Symmetron screening mechanisms

\[ F_\phi = -M \alpha_\phi \nabla \phi, \quad \alpha_\phi = \frac{d \log A(\phi)}{d \phi} \]

\[ \tilde{g}_{\mu\nu} = A^2(\phi) g_{\mu\nu} \]
Extremely tight constraints on Modified Gravity from experiments at small scales!

$10^{-3}$ cm extra dimensions? 1AU 1kpc 1Mpc 1000Mpc

GR Modified Gravity?
Large Scale Structure Formation: deviations from GR must be small

\[ \mathcal{L}_{\text{ModGrav}} = R - \alpha R^\beta \]

Supernovae + Large Scale Structures + CMBR + Baryon Oscillations

Decelerated Expansion

Accelerated Expansion

Amargui, Elgaroy, DFM, A&A
Structure formation probes deviations from GR

Structure formation dependence on coupling and range

\[ \frac{G_{\text{eff}}(r)}{G} = 1 + 2\beta^2 e^{-r/\lambda_\phi} \]

Stronger coupling \(\rightarrow\) bigger deviations from LCDM

\[ \frac{G_{\text{eff}}}{G} = \begin{cases} 1 & r \gg \lambda_\phi \\ 1 + 2\beta^2 & r \ll \lambda_\phi \end{cases} \]

Larger range \(\rightarrow\) large scale deviations from LCDM

Short range

\[ \Delta P(k)/P(k) \]

Long range

\[ \Delta P(k)/P(k) \]

Structure formation dependence on the screening scale

\[ \frac{G_{\text{eff}}}{G} = 1 + \frac{2\beta^2 \phi^2 / \phi_0^2}{1 + \frac{a^2}{\lambda^2 k^2}} \]

**Low density region**

\[ V(\phi) \]

\[ \phi \neq 0 \rightarrow \text{Unscreened} \]

**High density region**

\[ V(\phi) \]

\[ \phi = 0 \rightarrow \text{Screened} \]

Symmetron screening

Very difficult to differentiate between Chameleon and Symmetron

Gronke, Llinares, DFM, A&A
Symmetron Unique Feature
Symmetron Domain Walls

$V_{\text{eff}}(\phi)$

Linares & DFM, PRL
Probing Symmetron with Local Power Spectrum

\[
\frac{P_{\text{full}} - P_{\text{static}}}{P_{\text{static}}}
\]

\( (32,0.64) \)
\( (32,32,64) \)
\( (32,64,64) \)
\( (32,96,64) \)
Summary

- If one wants probe Modified Gravity then:
  - one should look at structure formation
  - Effects are stronger within the fifth force range and proportional to the coupling
  - Nonlinear regime is the most interesting!

- If one wants to probe screening mechanisms then:
  - Global observables may not do the job
  - Only local observables with an environmental dependence can be smoking guns