f(R) Modified Gravity

Cosmological & *Solar-System Tests*

Je-An Gu 顧哲安

臺灣大學梁次震宇宙學與粒子天文物理學研究中心
Leung Center for Cosmology and Particle Astrophysics (LeCosPA), NTU

Collaborators : *Wei-Ting Lin* 林韋廷 @ Phys, NTU

Dark Energy Working Group @ LeCosPA & NCTS-FGCPA

f(R) Modified Gravity (MG):

$$S_g = \frac{1}{16\pi G} \int d^4x \sqrt{-g}[R + f(R)]$$

Cosmological Test

Local Test

Cosmic Expansion **Cosmic Structure** **Solar-System Test**

$f(R)$ Modified Gravity (MG): $S_g = \dfrac{1}{16\pi G}\int d^4x\sqrt{-g}\,[R + f(R)]$

Cosmological Test | **Local Test**

Cosmic Expansion **Cosmic Structure** **Solar-System Test**

"**designer $f(R)$**"

Reconstruct $f(R)$
for given expansion history $H(t)$,
parametrized via **CPL $w_{eff}(z)$**:

$$w_{CPL}(z) = w_0 + w_a\, z/(1+z)$$

with observational constraints:

(1) $w_{eff} = \text{constant} = -0.980 \pm 0.053$ (68% CL)

(2) $w_0 = -0.93 \pm 0.13,\ \ w_a = -0.41^{+0.72}_{-0.71}$ (68% CL)

$\Rightarrow$ construct

$$f\left(R; \{w_0, w_a, f_{ini}, q_j\}\right)$$

f_{ini} : initial condition of $f(R)$
q_j : other cosmological parameters

f(R) Modified Gravity (MG): $S_g = \dfrac{1}{16\pi G} \int d^4x \sqrt{-g}\,[R + f(R)]$

Cosmological Test

Local Test

Cosmic Expansion

Cosmic Structure

Solar-System Test

"designer f(R)"

Reconstruct $f(R)$
for given expansion history $H(t)$,
parametrized via **CPL** $w_{eff}(z)$:

$$w_{CPL}(z) = w_0 + w_a\, z/(1+z)$$

with observational constraints:

(1) $w_{eff} = \text{constant} = -0.980 \pm 0.053$ (68% CL)

(2) $w_0 = -0.93 \pm 0.13$, $w_a = -0.41^{+0.72}_{-0.71}$ (68% CL)

$\Rightarrow$ construct

$$f(R; \{w_0, w_a, f_{ini}, q_j\})$$

---

f_{ini} : initial condition of $f(R)$

q_j : other cosmological parameters

❖ Observational constraint
(Giannantonio et al, 2009):

$$1 \le \Psi/\Phi < 1.996$$

$$1 \le G_{eff}/G < 1.403$$

for $z = 0$ & $k = 0.01\,h/\text{Mpc}$.

❖ Constraint on

f(R) MG with
Chameleon Mechanism

$$-10^{-15} < f_R \le 0$$

$$0 \le R f_{RR} < 2/5$$

f(R) Modified Gravity (MG): $S_g = \dfrac{1}{16\pi G}\int d^4x\sqrt{-g}\,[R + f(R)]$

Cosmological Test

Local Test

Cosmic Expansion

Cosmic Structure

Solar-System Test

"**designer $f(R)$**"

Reconstruct $f(R)$
for given expansion history $H(t)$,
parametrized via **CPL $w_{\mathrm{eff}}(z)$**:

$$w_{CPL}(z) = w_0 + w_a\, z/(1+z)$$

with observational constraints:

(1) $w_{\mathrm{eff}} = \text{constant} = -0.980 \pm 0.053$ (68% CL)

(2) $w_0 = -0.93 \pm 0.13,\ w_a = -0.41^{+0.72}_{-0.71}$ (68% CL)

$\Rightarrow$ construct

$$f\big(R; \{w_0, w_a, f_{ini}, q_j\}\big)$$

❖ Observational constraint
(Giannantonio et al, 2009):

$$1 \le \Psi/\Phi < 1.996$$

$$1 \le G_{\mathrm{eff}}/G < 1.403$$

for $z = 0$ & $k = 0.01\, h/\mathrm{Mpc}$.

• The existence of
the designer $f(R; \{w_0, w_a, f_{ini}\})$ models
which pass the cosmic-structure test
would require fine-tuning of initial condition f_{ini}.

❖ Constraint on

$f(R)$ MG with
Chameleon Mechanism

$$-10^{-15} < \ f_R \ \le 0$$

$$0 \ \ \le Rf_{RR} < 2/5$$

f_{ini} : initial condition of $f(R)$

q_j : other cosmological parameters

f(R) Modified Gravity (MG): $S_g = \dfrac{1}{16\pi G}\int d^4x\sqrt{-g}\,[R+f(R)]$

Cosmological Test

Local Test

Cosmic Expansion

Cosmic Structure

Solar-System Test

"designer f(R)"

Reconstruct $f(R)$
for given expansion history $H(t)$,
parametrized via **CPL** $w_{\text{eff}}(z)$:

$$w_{CPL}(z) = w_0 + w_a\, z/(1+z)$$

with observational constraints:

(1) $w_{\text{eff}} = \text{constant} = -0.980 \pm 0.053$ (68% CL)

(2) $w_0 = -0.93 \pm 0.13,\ w_a = -0.41^{+0.72}_{-0.71}$ (68% CL)

$\Rightarrow$ construct

$$f\big(R; \{w_0, w_a, f_{ini}, q_j\}\big)$$

f_{ini} : initial condition of $f(R)$
q_j : other cosmological parameters

❖ Observational constraint
(Giannantonio et al, 2009):

$$1 \le \Psi/\Phi < 1.996$$
$$1 \le G_{\text{eff}}/G < 1.403$$

for $z = 0$ & $k = 0.01\,h/\text{Mpc}$.

● The existence of
the designer $f(R; \{w_0, w_a, f_{ini}\})$ models
which pass the cosmic-structure test
would require fine-tuning of initial condition f_{ini}.

● Among the designer $f(R; \{w_0, w_a, f_{ini}\})$ models,
only those closely mimicking **GR + Λ** (in all the 3 tests)
can pass the solar-system test.

● The solar-system test **rules out**
the frequently studied $w_{\text{eff}} = -1$ $f(R; f_{ini})$ models
that are distinct from **ΛCDM** in Ψ/Φ, G_{eff}/G.

❖ Constraint on

f(R) MG with
Chameleon Mechanism

$$-10^{-15} < \ f_R \ \le \ 0$$
$$0 \ \ \le \ Rf_{RR} < 2/5$$