Diagnostic of *f(R)* under the *Om(z)* function

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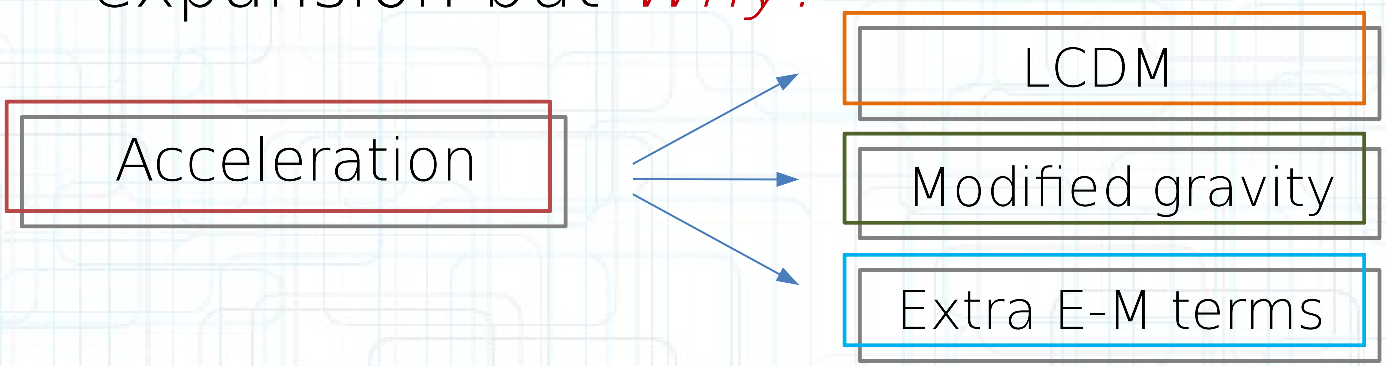
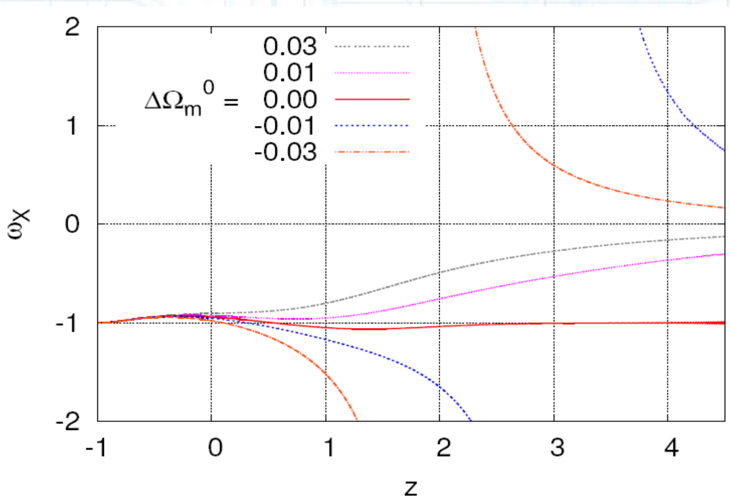
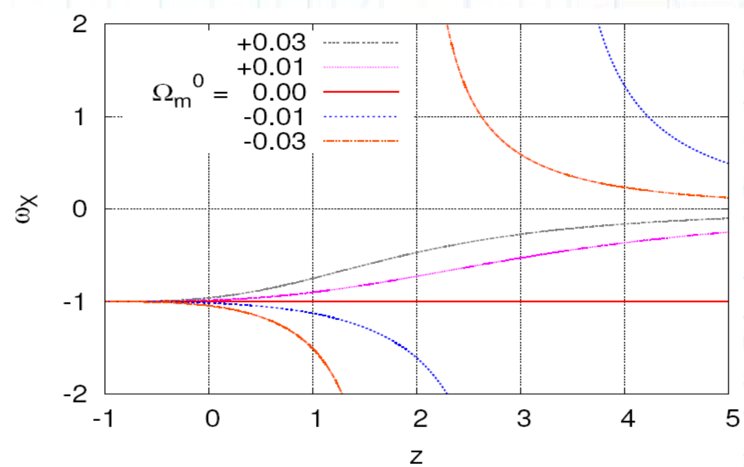
Introduction

- Ok… the Universe is in an accelerated expansion but *Why?*



We have a lot of answers, but now… *How?*





What is the *Om(z)* test?

- Sahni, Shafieloo and Starobinsky. (2014, 2012, 2008) proposed a test in order to distinguish LCDM from modified gravity models.
- They use the Om(z) function given by:

$$Om(x) \equiv \frac{h^2(x) - 1}{x^3 - 1}$$

with

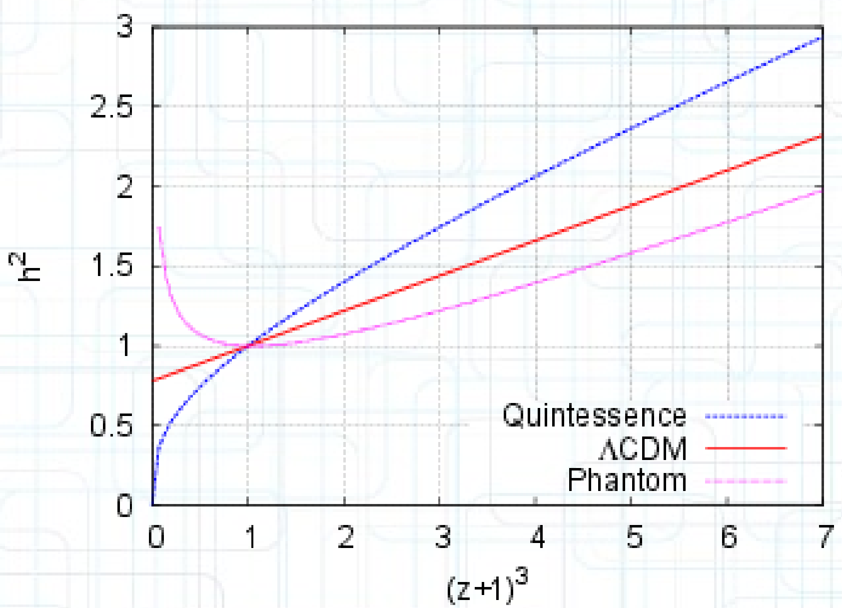
$$x = 1 + z$$

$$h(x) = H(x)/H_0$$

$$h^2(x) = \Omega_{0m} x^3 + (1 - \Omega_{0m}) x^\alpha$$

$$\alpha = 3(1 + w)$$

- Quintessence $\omega = 0.7$
- LCDM $\omega = 1.0$
- Phantom $\omega = -1.3$



What is the *Om(z)* test?

- What the Om(z) function can tell us about the cosmology?

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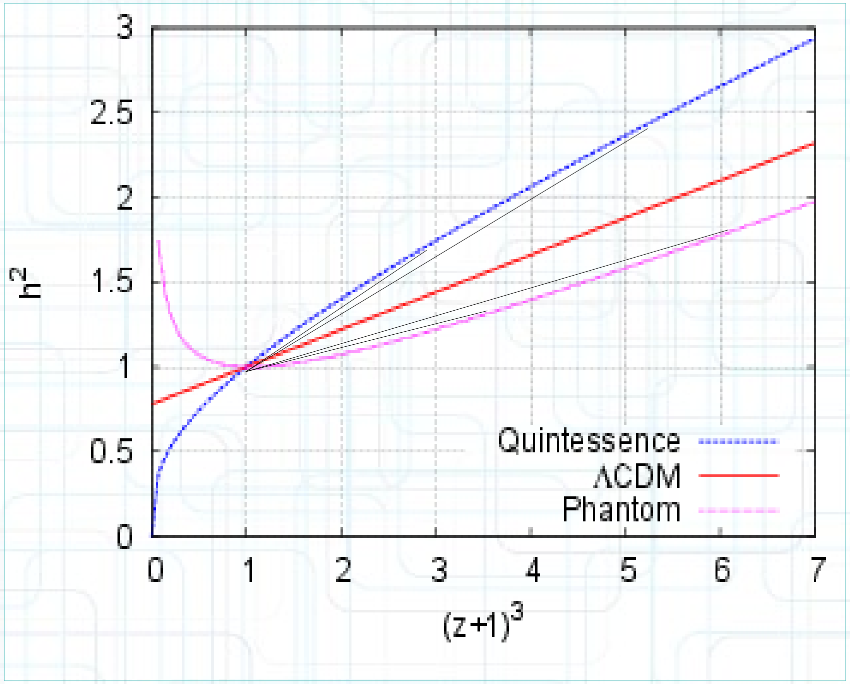

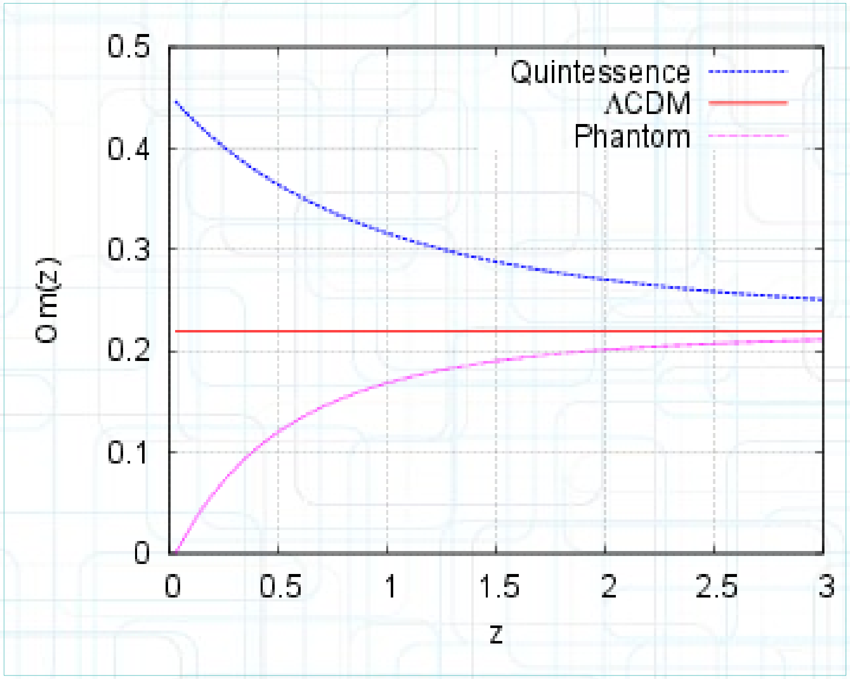

$$Omh^2(z_i; z_j) = \frac{h^2(z_i) - h^2(z_j)}{(1+z_i)^3 - (1+z_j)^3}$$

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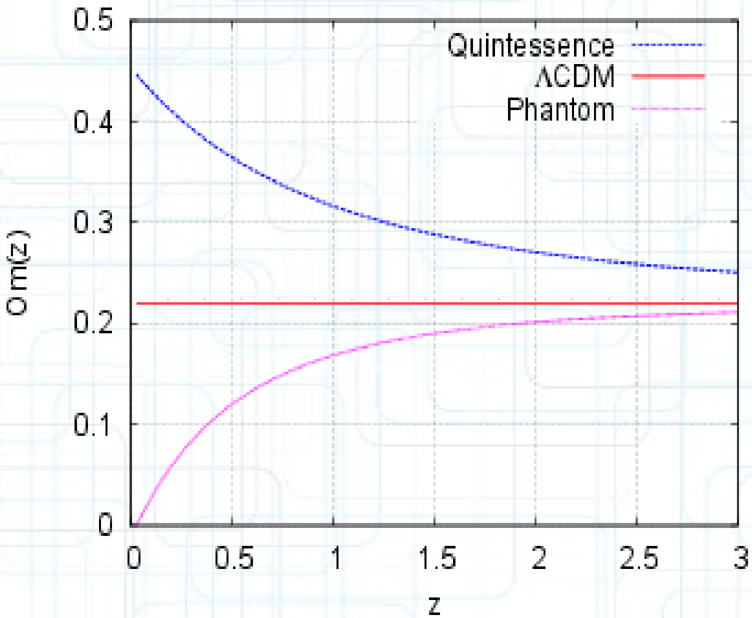


We can apply this test to different models by using BAO's results to z=0.57 and z=2.34. The two-point Omh^2 relation give us:

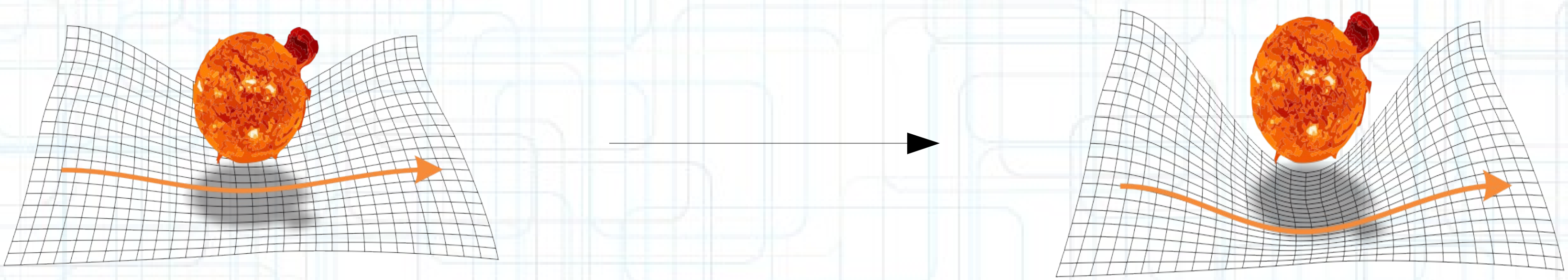
$$Omh^2(z_1;z_2) = 0.124 \pm 0.045,$$
$$Omh^2(z_1;z_3) = 0.122 \pm 0.01,$$
$$Omh^2(z_2;z_3) = 0.122 \pm 0.012,$$

ΛCDM → $Omh^2 = 0.1426$

Approach to f(R)

- f(R) theories are the most straightforward way to extend the Hilbert-Einstein action

$$S[g_{ab},\psi] = \int \frac{f(R)}{2\kappa}\sqrt{-g}\, d^4x + S_{\rm matt}[g_{ab},\psi]$$



$$G_{ab} = \frac{1}{f_R}\Big[f_{RR}\nabla_a\nabla_b R + f_{RRR}(\nabla_a R)(\nabla_b R) - \frac{g_{ab}}{6}\Big(R f_R + f + 2\kappa T\Big) + \kappa T_{ab}\Big] \; .$$

4th order

$$\Box R = \frac{1}{3 f_{RR}}\left[\kappa T - 3 f_{RRR}(\nabla R)^2 + 2f - R f_R\right]$$

Approach to f(R)

- Modified Friedmann equations in f(R)

$$\begin{cases} H^2 = -\dfrac{1}{f_{RR}}\left[f_{RR}H\dot{R} - \dfrac{1}{6}(Rf_R - f)\right] - \dfrac{\kappa T^t_t}{3f_R} \\ \dot{H} = -H^2 - \dfrac{1}{f_R}\left[f_{RR}H\dot{R} + \dfrac{f}{6} + \dfrac{\kappa T^t_t}{3}\right] \end{cases}$$

- Trace →

$$\ddot{R} = -3H\dot{R} - \frac{1}{3f_{RR}}\left[3f_{RRR}\dot{R}^2 + 2f - f_R R + \kappa T\right]$$

f(R) models in our test.

- Starobinsky

$$f(R) = R + \lambda R_S\left[\left(1 + \frac{R^2}{R_S^2}\right)^{-q} - 1\right]$$

with $q = 2$, $\lambda = 1$ and $R_S = 4.17H_0^2$.

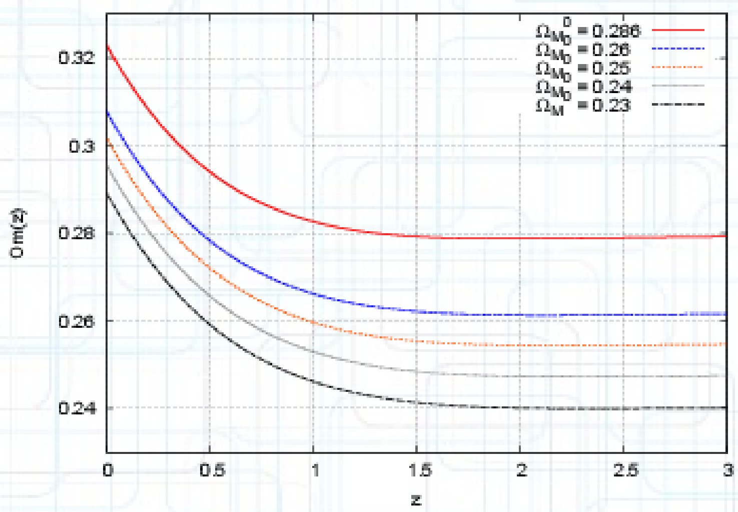
- Hu-Sawicki

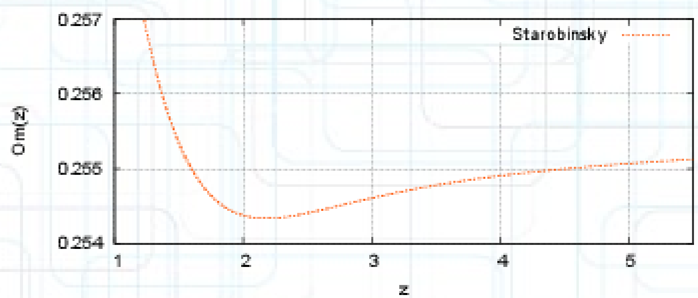
$$f(R) = R - R_{\rm HS}\frac{c_1\left(\frac{R}{R_{\rm HS}}\right)^n}{c_2\left(\frac{R}{R_{\rm HS}}\right)^n + 1}$$

$n = 4$, $c_1 \approx 1.25 \times 10^{-3}$,
$c_2 \approx 6.56 \times 10^{-5}$ and $R_{\rm HS} \approx 0.24H_0^2$

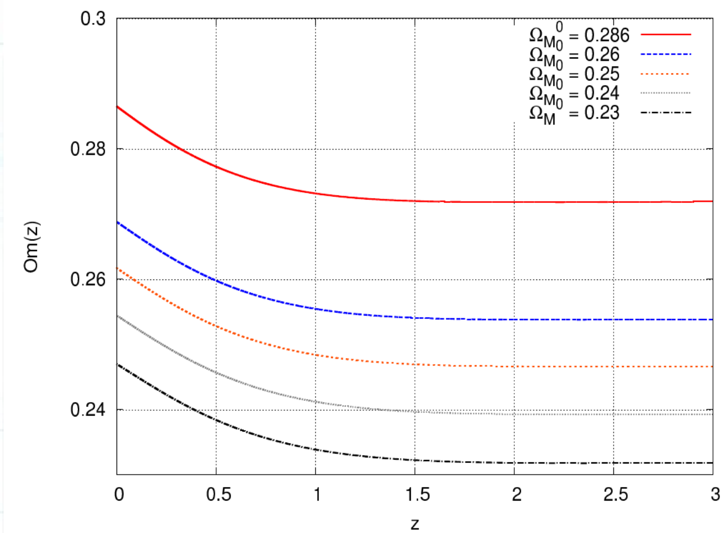
Results

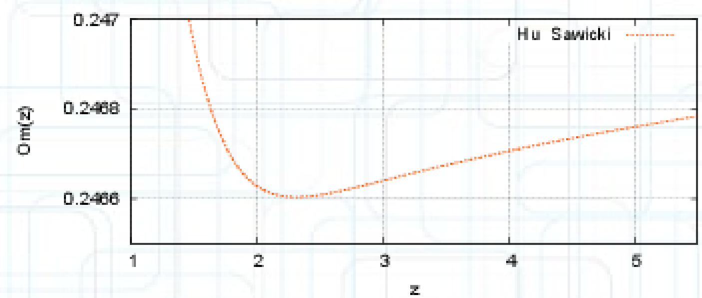
- Starobinsky





- Hu-Sawicki





Results

- The best value of the **Ω**m(z=0) for the f(R) models used in this work

Ω_m^0	(z_i, z_j)	$Omh^2(z_i, z_j)$	χ^2
	(z_1, z_2)	0.131	
0.24	(z_1, z_3)	0.123	0.041
	(z_2, z_3)	0.123	
	(z_1, z_2)	0.126	
0.25	(z_1, z_3)	0.123	0.013
	(z_2, z_3)	0.123	

$$Omh^2(z_1; z_2) = 0.124 \pm 0.045,$$
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ΛCDM

$$Omh^2 = 0.1426$$

Conclusion

Observations show that the Om(z) function it is NOT constant.

LCDM it is not able to pass the Om(z) function test.

f(R) gravity, in particular the models proposed by Starobinsky and Hu-Sawicki can provide a evolution of the Om(z) function that is in a better agreement with BAO's observations.

f(R) models present an evolution that looks flexible enough in order to explain the evolution of H.

Thanks!

“A novel theory is rarely or never a simple broadening about what is already known. Its understanding demands the reconstruction of the old theory and the compatibility with the previous facts. This is already a revolutionary process in itself which is rarely accomplished by a single person and never in one day.”

Thomas Kunh

The structure of scientific revolutions