An alternative way to obtain dark energy from f(R) theory

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Differing from the ordinary scalar-tensor theory, the effect of dark energy is accounted for what the curved space and time acting. We combine the new 307 Union supernova Ia samples, the shift parameter of the Cosmic Microwave Background (CMB) given by the three-year Wilkinson Microwave Anisotropy Probe observations (WMAP), the baryon acoustic oscillation (BAO) measurement from the Sloan Digital Sky Survey (SDSS) and age estimates of 35 galaxies, as well as the X-ray of galaxies, to constrain the minimum-coupling f(R) theory. The character of the effective dark energy is analyzed.

The minimum-coupling f(R) theory

$$S=\frac{1}{2k^2}\int d^4x\sqrt{-g}\,f(R)+S_{matter}$$

$$f(R)=R-\beta R^{-n}$$

Equivalent Equation of State

$$w_{eff}=-1+\frac{2(1+z)}{3H}\frac{dH}{dz}$$

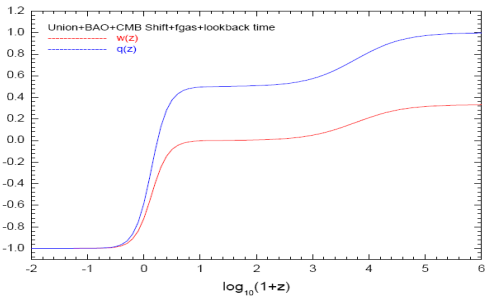
Deceleration factor

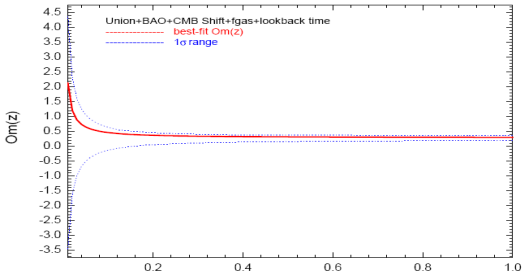
$$q=-1+\frac{1+z}{H}\frac{dH}{dz}$$

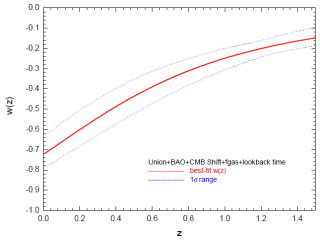
Om(z) diagnostic

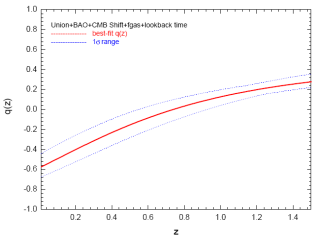
$$Om(z)=\frac{E^2(z)-1}{(1+z)^3-1}$$

Varun Sahni, Arman Shafieloo, Alexei A. Starobinsky. 0807.3548









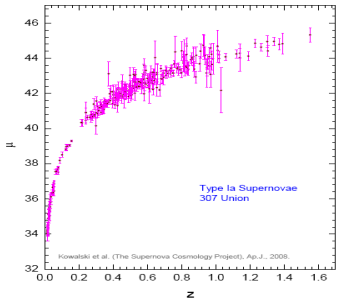
Supernova Ia

Luminosity distance

$$d_L(z)=\frac{c(1+z)}{H_0}\int_0^z\frac{dz'}{E(z')}$$

Distance modulus

$$\mu(z)=m-M=5\log_{10}\left(\frac{d_L(z)}{Mpc}\right)+25$$



Baryon Acoustic Oscillation (BAO)

$$A=\sqrt{1-\Omega_{D0}}\,E(z_{BAO})^{-1/3}\left[\frac{1}{z_{BAO}}\int_0^{z_{BAO}}\frac{dz'}{E(z')}\right]^{2/3}=0.469\left(\frac{n_s}{0.98}\right)^{-0.35}\pm0.017$$

CMB Shift

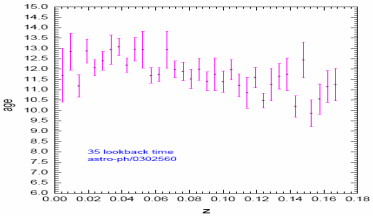
$$R=\sqrt{1-\Omega_{D0}}\int_0^{z_{CMB}}\frac{dz'}{E(z')}=1.70\pm0.03$$

Lookback time

$$t_o(P)=\frac{1}{H_0}\int_0^{\infty}\frac{dz'}{(1+z')E(z')}$$

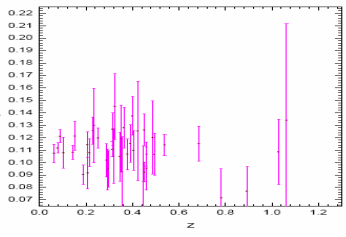
Total expanding age of the universe

$$t_L(z;P)=\frac{1}{H_0}\int_0^{z}\frac{dz'}{(1+z')E(z')}$$



X-ray gas observation

$$f(z)=\frac{b\Omega_b}{(1+0.19\sqrt{h})}\left[\frac{d_A^{SCDM}(z)}{d_A^{m}(z)}\right]^{1.5}$$

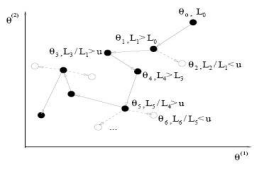


Markov Chain Monte Carlo

Metropolis algorithm(1953)

$r = \min[1, P(X')/P(X_n)]$

$$X_{n+1}=\begin{cases}X' & \text{if } \xi < r\\ X_n & \text{otherwise}\end{cases}$$



Conclusion: From the combination of the new 307 Union supernova Ia samples, the shift parameter of CMB given by WMAP3, the BAO measurement from the SDSS and age estimates of 35 galaxies, as well as the X-ray of galaxies, f(R) model is constrained tightly. The effective dark energy is likely a quintessence, which is propelling the current universe to accelerate. The equation of state of DE reveals the universe has orderly experienced three stages: radiation, matter, dark energy.