# Implications of Bulk-Viscous Dark Energy on the Expansion History of the Universe


B. Mostaghel, H. Moshafi, S.M.S. Movahed

Shahid Behehshti University, Tehran, Iran

Institute for Advances Studies in Basic Sciences , Zanjan, Iran

Institute for Research in Fundamental Sciences (IPM)



National Conference on Gravity & Cosmology

Jan 2016


## Introduction

According to recent cosmic observations our universe is experiencing an accelerating expansion. Despite of observational evidences from BAO, SN, CMB but underlying mechanism responsible for such acceleration is hidden. Many models have been proposed but the simplest one is a cosmological constant Λ, the model named ΛCDM.

We propose an alternative approach for acceleration. We assume vaccum energy as a viscous fluid.

Existence of a ghost field which is non-minimally coupled to geometry of space-time and acts like a generator of vacuum energy could explain viscous factor of vacuum. It's obvious from slow-roll condition of scalar field that mass of field should be order of $H_0$.

## Expansion History

Since the effect of model dominates in late time of expansion history we calculated luminosity distance for model to compare with distance modulus of Super Novae. We compared distance modulus of model with catalogure SNLS 3 of SN type Ia (Fig. 1).

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

$$d_L(z) = \frac{c}{H_0}(1+z)\int_0^z \frac{dz'}{\sqrt{\Omega_m(1+z')^3 + \Omega_{\text{vac}}(z')}}$$

| Parameter | Planck TT | JLA | HST |
|---|---|---|---|
| $\Omega_c h^2$ | $0.1201^{+0.0059}_{-0.0055}$ | $0.1178^{+0.0059}_{-0.0059}$ | $0.1131^{+0.0080}_{-0.0073}$ |
| $\Omega_m$ | $0.318^{+0.037}_{-0.033}$ | $0.304^{+0.025}_{-0.025}$ | $0.268^{+0.038}_{-0.038}$ |
| $\Omega_{\text{vac}}$ | $0.681^{+0.033}_{-0.037}$ | $0.696^{+0.025}_{-0.023}$ | $0.732^{+0.038}_{-0.038}$ |
| $H_0$ | $66.9^{+2.3}_{-2.4}$ | $67.9^{+2.3}_{-2.3}$ | $71.6^{+2.9}_{-3.7}$ |
| $\gamma$ | $0.644^{+0.155}_{-0.643}$ | $0.1288^{+0.0019}_{-0.0015}$ | $0.1502^{+0.0042}_{-0.0016}$ |
| $m_\phi / H_0$ | $2.805^{+0.463}_{-1.392}$ | $15.688^{+1.763}_{-1.556}$ | $11.201^{+1.941}_{-1.573}$ |

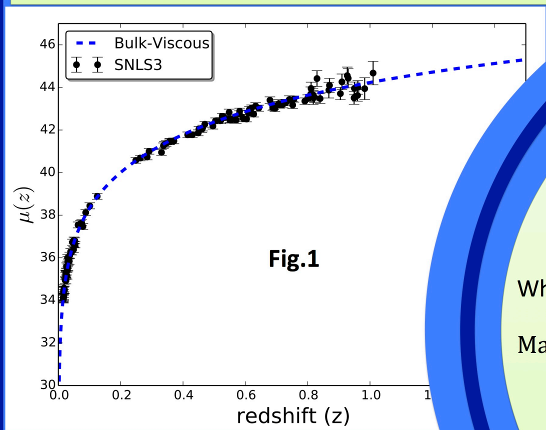


Fig.1

## Bulk-Viscous Dark Energy

Friedmann equation for this model is:

$$H = H_0\sqrt{\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_{\text{vac}}(a)}$$

$$\Omega_{\text{vac}}(a) = \Omega^0_{\text{vac}} + 9\gamma\sqrt{\Omega^0_{\text{vac}}}\ln(a) + \frac{81}{4}\gamma^2(\ln(a))^2$$

Which $\gamma = \frac{8\pi G_N}{3H_0^2}\zeta$ is dimensionless viscous coefficient.

Mass of field could be obtained as follows:

$$m_\phi \simeq H_0\sqrt{\frac{21}{2}(1-\Omega^0_{\text{vac}})} = 1.677H_0$$

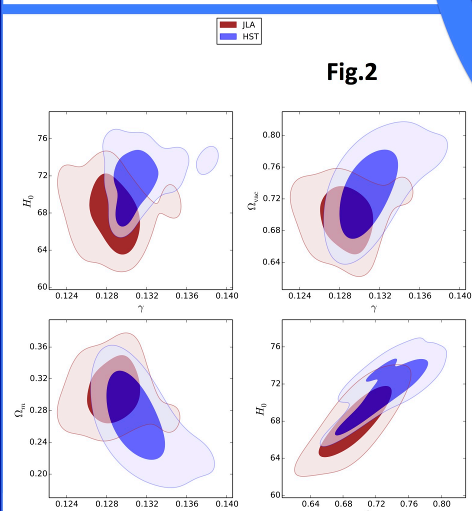


Fig.2

## Observational Constraints

This model has not effective signature in the universe and we expect to detect its footprints in late time expansion and large scale structure observations. So we performed a Maximum Likelihood Analysis by modification CAMB code and Monte Carlo code of CosmoMC by walking into parameter space :

$$\{\Theta_p\} : \Omega^0_{\text{vac}}, \gamma, \Omega_b h^2, \Omega_c h^2, H_0, \tau, A_s, n_s$$

You can see results for late-time data HST and JLA in Fig. 2 and Fig. 3.

Best values and ranges of parameters for confidence interval 68% based on HST, JLA and Planck 2015 data are summarized in table.

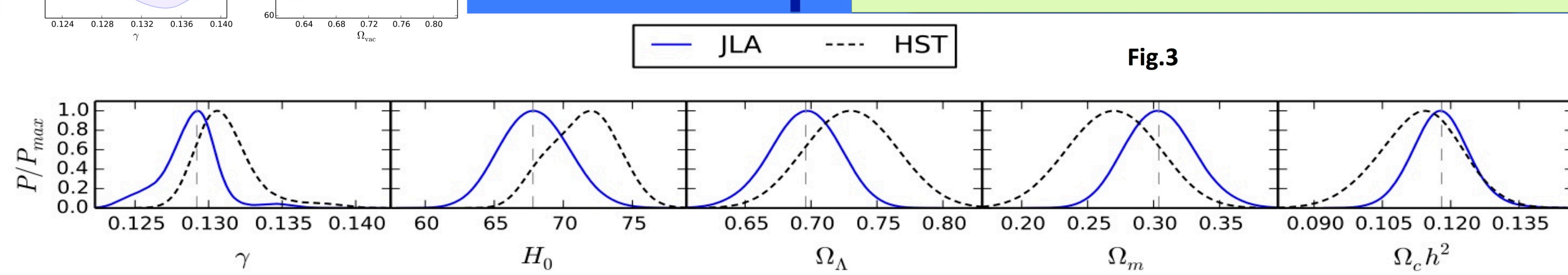


Fig.3