Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics B 929 (2018) 438–451

NUCLEAR PHYSICS B

www.elsevier.com/locate/nuclphysb

Physical condition for the slowing down of cosmic acceleration

Ming-Jian Zhang [b], Jun-Qing Xia [a,*]

[a] *Department of Astronomy, Beijing Normal University, Beijing 100875, China*
[b] *Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Science, P.O. Box 918-3, Beijing 100049, China*

Received 22 August 2017; received in revised form 8 February 2018; accepted 26 February 2018
Available online 28 February 2018
Editor: Hong-Jian He

Abstract

The possible slowing down of cosmic acceleration was widely studied. However, judgment on this effect in different dark energy parameterizations was very ambiguous. Moreover, the reason of generating these uncertainties was still unknown. In the present paper, we analyze the derivative of deceleration parameter $q'(z)$ using the Gaussian processes. This model-independent reconstruction suggests that no slowing down of acceleration is presented within 95% C.L. from the Union2.1 and JLA supernova data. However, $q'(z)$ from the observational $H(z)$ data is a little smaller than zero at 95% C.L., which indicates that future $H(z)$ data may have a potential to test this effect. From the evolution of $q'(z)$, we present an interesting constraint on the dark energy and observational data. The physical constraint clearly solves the problem of why some dark energy models cannot produce this effect in previous work. Comparison between the constraint and observational data also shows that most of current data are not in the allowed regions. This implies a reason of why current data cannot convincingly measure this effect.

* Corresponding author.
E-mail address: xiajq@bnu.edu.cn (J.-Q. Xia).

https://doi.org/10.1016/j.nuclphysb.2018.02.020

1. Introduction

Multiple experiments have consistently confirmed the cosmic late-time accelerating expansion. Contributions to this pioneering discovery contain the type Ia supernova (SNIa) [1,2], large scale structure [3], cosmic microwave background (CMB) anisotropies [4], and baryon acoustic oscillation (BAO) peaks [5]. One theoretical paradigm to describe the acceleration is the exotic dark energy with repulsive gravity. In the dark energy doctrine, a large number of phenomenological models were invented in terms of equation of state (EoS) $w(z)$. In particular, the Chevallier–Polarski–Linder (CPL) [6,7] model has attracted great attention. As well as the dynamical theory, kinematics is another way to understand the cosmic acceleration. The deceleration parameter $q(z) < 0$ is just a direct expression of the phase transition of accelerating expansion. Instead, $q(z) > 0$ is a symbol of the decelerating expansion.

Recently, the authors in Ref. [8], in the prior of CPL parameterization, found that deceleration parameter $q(z)$ may be changing from negative to positive, or has been achieved a positive value. It means that the cosmic acceleration may have already peaked and we are currently witnessing its slowing down at $z \lesssim 0.3$. The slowing down of acceleration (hereafter SA) has caused wide public concern. More and more observational data and dark energy parameterized models were focused in the subsequent investigations [9–12]. Including the two comprehensive studies [13,14], they generally believed that the speculation of SA was ambiguous. Specifically, some models can lead to the SA, while some ones cannot. Meanwhile, some observational data can cause the SA, while some data cannot. For example, using the Lick Observatory Supernova Search (LOSS) sample [15] or Union2 compilation, the SA phenomenon is evidenced [13,16]. While for the joint light-curve analysis (JLA) compilation [17], they prefer an eternal acceleration [14]. We note that the unconvincing results essentially lie in the model-dependence. Consequently, a model-independent test is really necessary to better understand the cosmic evolution.

In our recent work [18], we presented a model-independent analysis on this interesting subject, using the powerful Gaussian processes (GP) technique. Unlike the parameterization constraint, this approach does not rely on any artificial dark energy template. It is thus able to faithfully model the cosmology. Modifying the public code GaPP (Gaussian Processes in Python) invented by Seikel et al. [19], we studied the deceleration parameter with abundant data including luminosity distance from Union2, Union2.1 compilation and gamma-ray burst, and Hubble parameter from cosmic chronometer and baryon acoustic oscillation peaks. The GP reconstructions suggest that no SA is detected within 95% C.L. from current observational data.

However, the reason of why some models can lead to the SA, while some ones cannot, is still not available. To solve this problem, we deduce the derivative of deceleration parameter to draw a picture on it. Our goal in the present paper, on the one hand, is to reconstruct the derivative of deceleration parameter by GP method to further test the SA. On the other hand, we try to provide a physical condition or constraint on the dark energy and observational data, to answer why some models or current data cannot present the SA.

In Section 2, we first introduce the methodology including some theoretical basics on the SA, the GP approach and relevant data. We then present the reconstruction result from current data in Section 3. The possible physical condition is analyzed in Section 4 before we discuss conclusions in Section 5.

2. Methodology

In this section, we briefly deduce the theoretical formulas for the SA, and then describe the reconstruction method and observational data used in the present work.