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ORIGINAL ARTICLE

Preliminary limits on a logarithmic correction to the Newtonian gravitational potential in the solar system

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Abstract Using the supplementary advances of the perihelia provided by INPOP10a (IMCCE, France) and EPM2011 (IAA RAS, Russia) ephemerides, we obtain preliminary limits on a logarithmic correction to the Newtonian gravitational potential in the solar system. This kind of correction may originate from fundamental frameworks, like string theories or effective models of gravity due to quantum effects and the non-local gravity scheme. We estimate upper limit of Tohline-Kuhn-Kruglyak parameter λ and lower bound of Fabris-Campos parameter α, which parametrize the correction and connect each other by $\alpha\lambda = -1$. In our estimation, we take the Lense-Thirring effect due to the Sun's angular momentum and the uncertainty of the Sun's quadrupole moment into account. These two factors were usually absent in previous works. We find that INPOP10a yields the upper limit as $\alpha = -(0.66 \pm 5.82) \times 10^{-4}$ kpc^{-1} [or the lower limit as $\lambda = (0.15 \pm 8.76) \times 10^5$ kpc] while EPM2011 gives $\alpha = (0.52 \pm 1.74) \times 10^{-4}$ kpc^{-1} [or the lower limit as $\lambda = -(0.19 \pm 3.29) \times 10^5$ kpc]. The limits of $|\lambda|$ are greater than the result based on the rotation curves of spiral galaxies by about 3 orders of magnitude, indicating its effects might be screened in high density regions.

Keywords Logarithmic potential · Modified gravity · Ephemerides · Celestial mechanics

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1 Introduction

Gravitation is the first of the four known fundamental forces to be understood quantitatively and empirically. Newton's inverse-square law of gravity and Einstein's general relativity (GR) can explain and describe most of astronomical and astrophysical observations and phenomenon quite well. However, this triumph ceases when they are facing the flat rotation curves of spiral galaxies (e.g. Rubin and Ford 1970; Roberts and Whitehurst 1975; Sofue and Rubin 2001) without introducing dark matter and the present acceleration of the Universe (e.g. Riess et al. 1998; Perlmutter et al. 1999) without dark energy (see Lämmerzahl 2009, for a review about some of the open problems in gravitational physics). Nevertheless, the physical nature of dark matter and dark energy remains still unknown. Another way to solve the problems is to modify the theory of gravity and these modified theories can generate interesting astrophysical and cosmological consequences (for a recent review see Clifton et al. 2012, and references therein). Among these modification, one case is a logarithmic correction to the Newtonian gravitational potential, which may originate from fundamental frameworks, like string theories or effective models of gravity due to quantum effects (e.g. Soleng 1995; Shapiro et al. 2005; Capozziello et al. 2006) and the non-local gravity scheme (Hehl and Mashhoon 2009; Blome et al. 2010).

Mücket and Treder (1977) first considered a logarithmic correction to the Newtonian gravitational potential and calculated its resulting perihelion advance on a planet. The

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