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Abstract

Lambda Perturbations and Instability of Keplerian Orbits in the Expanding Universe

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Abstract: Since the concept of Dark Energy (i.e., effective Lambda-term in the GR equations) became a commonly-accepted paradigm in cosmology, numerous authors analyzed its effects on the dynamics of celestial bodies. However, such calculations were usually done only in the framework of static Schwarzschild-deSitter metric, which does not possess the adequate cosmological asymptotics at infinity and, as a result, only the conservative perturbations of the orbits were taken into account. So, the aim of the present work is to use more realistic Robertson-Walker asymptotics and, thereby, to analyze also the nonconservative (secular) perturbations of Keplerian orbits. As a mathematical tool, we employ the modified Kottler metric, which was derived in our earlier paper [Yu.V. Dumin. Phys. Rev. Lett., v.98, p.059001 (2007)]. As follows from our analysis of motion of a test body in the field of a gravitating mass, the resulting perturbations of the Keplerian orbits depend on a complex interplay between three crucial parameters of the problem - the initial radius of the orbit, Schwarzschild and deSitter radii, - which differ from each other by many orders of magnitude. Namely, if Lambda-term is sufficiently small (i.e., the deSitter radius is large), then orbital perturbation is almost completely compensated by the gravitational attraction. Next, when the magnitude of Lambda increases, the corresponding secular perturbation becomes significant and can reach the rate of the standard Hubble flow [Yu.V. Dumin. Grav. & Cosmol., v.26, p.307 (2020)]. This fact may have important consequences for the long-term dynamics of planets and stellar binaries. At last, if the Lambda-term increases further, the perturbation becomes so strong that the original orbit is completely destroyed and the test body escapes to infinity (i.e., a kind of the "sling effect" takes place). This might be relevant, e.g., to the formation of the so-called "hypervelocity stars".

Keywords: relativistic celestial mechanics; Dark Energy; equations of motion