Astrophys Space Sci
DOI 10.1007/s10509-013-1723-8

ORIGINAL ARTICLE

Particle motion in the Schwarzschild-Quintessence space-time

EnKun Li · Yu Zhang

Received: 29 September 2013 / Accepted: 27 November 2013

Abstract The influence of free static spherically symmetric quintessence on particle motion in the Schwarzschild-quintessence space-time has been studied by numerical calculation. In the Schwarzschild space-time, the particle motion can be determined by an effective potential. However, this potential is dependent on the quintessence's state parameter w_q. We find that when the quintessence's state parameter w_q is in the range of $[-\frac{1}{3}, 0]$, the massive particle's motion is just like that in the Schwarzschild space-time. And when $-1 \leqslant w_q < -\frac{1}{3}$, a maximum unstable circular orbit exists for every L, and no matter how small L is, the scattering state exists, which leads to the accelerating expansion of our universe. The exists of the maximum orbit can even explain why galaxies is in a ball.

Keywords Particle motion · Quintessence · Effective potential · Accelerating expansion

1 Introduction

It is well known that our universe is undergoing a period of accelerated expansion phase, which is supported by the present observations from SNe Ia (Riess et al. 1998; Perlmutter et al. 1999), WMAP (Bennett et al. 2003), SDSS (Tegmark et al. 2004) and X-ray (Allen et al. 2004). Data from these observations show that the present universe contains more than 70 % of unknown nature—"dark energy", whose negative pressure drives current expansion. In order to explain it, various theories and models have been put forward. The simplest model is the Einstein's cosmological constant (Sahni and Starobinsky 2000; Peebles and Ratra 2003) with a state parameter $w_q = -1$. However, this model leads to a theoretical problem called the "fine-tuning" problem (Weinberg 1989). This causes more dark energy paradigm, such as the dynamical scalar field quintessence (Ratra and Peebles 1988; Wetterich 1988; Liddle and Scherrer 1999), phantom (Caldwell 2002; Caldwell et al. 2003), quintom (Feng et al. 2005; Guo et al. 2005), chameleon fields (Khoury and Weltman 2004), k-essence (Armendariz-Picon et al. 2000, 2001; Chiba et al. 2000), tachyon field (Padmanabhan 2002), dilaton dark energy (Gasperini et al. 2002) and so on. Besides, some unified (Bento and Bertolami 2004; Wang et al. 2005) or coupled (Brookfield et al. 2006) dark energy models have been proposed. More detailed information of dark energy models can be found in (Copeland et al. 2006).

So far, there are so many people have worked on combine the dark energy momentum tensor with Einstein equation (Chernin et al. 2002; González-Díaz 2001, 2002; Kiselev 2003). Among them, Kiselev (2003) chooses a free parameter, characterizing that the energy momentum tensor of the quintessence under the condition of additivity and linearity, and then he presented a static spherically-symmetric exact solution of Einstein equation describing black hole surrounded by quintessence. According to Kiselev (2003), the energy-momentum tensor of the quintessence in the static spherically symmetric state can be written as

$$
\begin{aligned}
T_t^t &= \rho_q(r), \\
T_i^j &= \rho_q(r)\beta\left[-\big(1+3B(r)\big)\frac{r_i r^j}{r_n r^n} + B(r)\delta_i^j\right],
\end{aligned}
\tag{1}
$$

E.K. Li · Y. Zhang (✉)
Faculty of Science, Kunming University of Science and Technology, Kunming, Yunnan 650500, People's Republic of China
e-mail: zhangyu_128@126.com