Schwarzschild Black Holes surrounded by Quintessence and Non-Quintessence Fields

Saswati Roy[*] and Paramita Debnath[#]
Department of Physics
National Institute of Technology Agartala, Tripura, India - 799046

* saswati.roy@associates.iucaa.in
# paramitad777@gmail.com

The Schwarzschild solution successfully explains many astrophysical phenomena assuming that the surrounding spacetime is in vacuum. However, observations in cosmology, particularly those involving distant supernovae and cosmic microwave background radiation, indicate that the universe is undergoing an accelerated expansion. This phenomenon is attributed to an unknown component termed dark energy. One of the most compelling theoretical models for dark energy is quintessence, characterized by a spatially and temporally varying scalar field with negative pressure. Unlike a cosmological constant, quintessence allows for dynamical evolution and possible interaction with gravitational systems. This naturally raises an important question about how dark energy influences compact objects such as black holes. To address this, modified black hole solutions have been proposed in which the Schwarzschild spacetime is surrounded by a quintessence field. A static and spherically symmetric solution incorporating the effects of quintessence was made by Kiselev, whose model provides a useful framework for investigating the interplay between local gravitational fields and cosmological energy components.

In the presence of quintessence, the geometry of spacetime around a black hole is modified due to the influence of the surrounding scalar field. Photon orbits, ISCO radius, and stability of circular orbits are analysed for quintessence ($\omega = -1/3, -2/3$) including dark energy ($\omega = -1$), stiff fluid ($\omega = 1$), dust ($\omega = 0$), and radiation ($\omega = 1/3$). The resulting configuration retains spherical symmetry, but differs significantly from the vacuum Schwarzschild case.