

## Abstract

The purpose of this thesis is to construct a number of physically plausible models of black holes and compact stars based on Einstein's theory of General Relativity and then forecast the unknown interior features of these phenomena. The problems have been analysed/solved by employing some analytical as well as numerical techniques. We organize the whole thesis into nine chapters, described as follows:

The **first chapter** contains the introductory portion of the thesis in which the contents of the certain relevant topics namely, General theory of relativity, the modified theory of gravity, black holes, compact stars and concerning the problems in the subsequent chapters are briefly described.

In the **second chapter**, we analyze the null geodesics of regular black holes. As an application of null geodesics, we calculate the radius of photon sphere, gravitational bending of light, the angle of deflection for the photons and the shadow of BH. As an application of time-like geodesics we compute the innermost stable circular orbit (ISCO) and marginally bound circular orbit (MBCO) of the regular BHs .

In the **third chapter**, we derive proper-time Lyapunov exponent ( $\lambda_p$ ), coordinate-time Lyapunov exponent ( $\lambda_c$ ) and compute their ratio ( $\frac{\lambda_p}{\lambda_c}$ ) for a regular Hayward class of black hole. We show that, in the eikonal limit, the real and imaginary parts of quasi-normal modes (QNMs) is specified by the frequency and instability time scale of the null circular geodesics. Furthermore, we discuss the unstable photon sphere and radius of shadow for this class of black hole.

Of concern in the **forth chapter**, we analyze the behavior of relativistic spherical objects within the context of modified  $f(R, T)$  gravity considering Tolman VI spacetime. For this investigation, we have chosen three compact stars namely PSR J1614-2230, Vela X-1 and 4U 1538-52. In this theory the equation of pressure isotropy is identical to standard Einstein's theory. We have investigated the effort of coupling parameter ( $\beta$ ) on the local matter distribution.

In the **fifth chapter**, we have investigated the classical tests of General Relativity like precession of perihelion, deflection of light and time delay by considering a phenomenological astrophysical object like Sun, as a neutral regular Hayward black hole in Rastall gravity. We have tabulated all our results for some appropriate values

of the parameter  $\sigma$ . We have compared our values with  $\sigma = 0$ , which correspond to the Schwarzschild case.

In the **sixth chapter**, we have searched the existence of anisotropic and non-singular compact star in the  $f(R, T)$  gravity by taking into account the non-exotic equation of state (EoS). We assume the well known barotropic form of EoS that yields the linear relation between pressures and energy density.

The aim of the **seventh chapter** is to develop a new model for a spherically symmetric dark matter fluid sphere containing two regions: (i) Isotropic inner region with constant density and (ii) Anisotropic outer region. We solve the system of field equation by assuming a particular density profile along with a linear equation of state. The obtained solutions are well-behaved and physically acceptable which represent equilibrium and stable matter configuration.

In the **eighth chapter**, we calculate the principle Lyapunov exponent (LE) and Kolmogorov-Senai (KS) entropy for our rotating Kerr-Kiselev (KK) black hole. We found that the null circular geodesics has larger angular frequency than time-like circular geodesics ( $Q_o > Q_\sigma$ ) and has shortest orbital period ( $T_{\text{photon}} < T_{\text{ISCO}}$ ) among the all possible circular geodesics.

Finally, in the **ninth chapter**, we have discussed the summary and future scopes for all above chapters.

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