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Analytical solutions of spherical structures with relativistic corrections

M. Z. Bhatti[1,a], **S. Ijaz**[1,b], **Bander Almutairi**[2,c], **A. S. Khan**[3,d]

[1] Department of Mathematics, University of the Punjab, Quaid-i-Azam Campus, Lahore 54590, Pakistan
[2] Department of Mathematics, College of Science, King Saud University, P.O.Box 2455, 11451 Riyadh, Saudi Arabia
[3] Institute of Advanced Study, Shenzhen University, Shenzhen 518060, Guangdong, China

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Abstract This paper analyzes the characteristic of a non-static sphere along with anisotropic fluid distribution in the background of modified $f(\mathcal{G})$ theory. Conformal Killing vector is a productive constraint for computing reliable results for modified field equations. The occurrence of conformal Killing vector indicates the existence of symmetries in spacetime and it permits us to choose the coordinates that reduce the number of independent variables. Subsequently, for different conformal Killing vector choices, we obtain several types of precise analytical solutions for both non-dissipative and dissipative systems. We compute the matching conditions in the context of $f(\mathcal{G})$ gravity. In addition to this, we apply specific constraints to the matching conditions in an attempt to determine the significant results. Further, we proceed our investigation by utilizing quasi-homologous condition and vanishing complexity factor condition. Finally, we summarize all the important results which may help to understand the properties of astrophysical objects.

1 Introduction

Several notions introduced to explain the cosmic evolution, but general theory of relativity (GR) stood out among all of them. Many investigations and findings, including the bending of light around massive objects, the precession of Mercury's orbit, time dilation effects, and the detection of gravitational waves, extensively verified and confirmed GR [1]. Gravitational waves are kind of waves that sweep through spacetime, which are produced by the acceleration of massive celestial bodies like black holes or neutron stars. They transmit energy away from the system in the form of ripples in spacetime. The Laser Interferometer Gravitational-Wave Observatory LIGO [2,3] experiment identified the gravitational waves. It is the basis of our understanding of gravity on cosmological scales, describing the motion of massive celestial objects such as stars, galaxies, and even the entire universe.

GR deals with the evolution of the cosmos, beyond the big-bang, but GR is unable to explain their initial events or the causes. Understanding the birth of the universe and the nature of its initial singularity require a theory that includes gravity and quantum physics. The observable phenomena of dark matter (DM) and dark energy (DE) were not adequately explained by GR. These ideas developed to explain gravitational effects on galactic and cosmic scales. The factors and characteristics of DE along with DM are yet unresolved, and research into their origin and behavior is still proceeding.

To deal with these issues, modified theories [4–12] were presented, for instance the Brans–Dicke theory [13–15], which extends GR by including a scalar field. Brans and Dicke [16] proposed this theory with the aim of providing an alternative framework for understanding gravitational interactions. Numerous applications of the Brans–Dicke theory analyzed, including cosmological objects, the physical characteristics of BHs etc. This theory is also associated with other different theories, which might involve higher-dimensional and scalar-tensor theories (STTs). The STTs [17–23] examined in cosmology and modified gravity scenarios. These theories analyze the universe's expansion and the evolution of cosmic objects. Moreover, STTs explored in the realm of DE, expressing many possible explanations for the rapid expansion of cosmos. Modified $f(\mathcal{R})$ theories [24–30] presented as an alternative explanation for the phenomena that include DE and cosmic accelerating expansion. The pre-

[a] e-mail: mzaeem.math@pu.edu.pk (corresponding author)
[b] e-mail: seeratijaz400@gmail.com
[c] e-mail: baalmutairi@ksu.edu.sa
[d] e-mail: samadkhan_80@yahoo.com

dictions regarding how gravity will behave can be based on the precise form of $f(\mathcal{R})$ theories. Observational constraints and instabilities are significant deficiencies for $f(\mathcal{R})$ theories. Bhatti et al. [31–33] worked out to under stand the dynamical behavior of self-gravitating compact structures with an anisotropic environment with $f(R, T)$ theory. They applied radial perturbation scheme studied the effects of extra curvature terms which appear due to modified $f(R, T)$ gravity model in both the Newtonian and Post Newtonian eras.

Modified Gauss–Bonnet (GB) theory is also familiar as modified $f(\mathcal{G})$ theory. Noriji and Odintsov [34–37] proposed this modified theory, in which the gravitational action of GR is modified by using generalized function $f(\mathcal{G})$ instead of Ricci scalar $\mathcal{R}$. In this gravity, $\mathcal{G}$ is the GB invariant which is also known to be topologically invariant in four dimensions, which is written as $\mathcal{G} = \mathcal{R}^2 - 4\mathcal{R}_{\lambda\nu}\mathcal{R}^{\lambda\nu} + \mathcal{R}_{\lambda\gamma\nu\xi}\mathcal{R}^{\lambda\gamma\nu\xi}$, where, $\mathcal{R}_{\lambda\gamma\nu\xi}$ and $\mathcal{R}_{\lambda\nu}$ defined as the Riemann tensor and Ricci tensor, respectively. In addition to the potential consequences of modified GB theory, higher-order variables that influence spacetime curvature may cause novel gravitational effects, such as gravitational lensing. Moreover, this theory may cause a variety of fascinating cosmological phenomena in higher-dimensional brane-world methodologies [38–40].

Based on $f(\mathcal{G})$ theory, new sorts of BH solutions, such as those with scalar hair or non-singular center analyzed. These solutions might possibly provide fresh perspectives on the mathematical nature of BHs and the general relativistic singularity challenges. Solar system tests are a significant way of evaluating predictions of $f(\mathcal{G})$ theory, which may help in revealing the information on the nature of gravity and the history of cosmos. The $f(\mathcal{G})$ theory predicts variations to the Friedmann equations, which explain the growth of the universe. Observations of cosmic microwave background radiation or the large-scale structure of the cosmos might possibly put them under evaluation [41].

Nojiri et al. [42,43] analyzed the universe's evolution whenever it undergoes transition from a phase of deceleration to accelerated expansion, or vice versa. These transitions retain tremendous interest since they may provide information on how the universe behaves within the parameters of modified theories. Along with this, they demonstrated that the ΛCDM, i.e., Lambda cold dark matter, may provide an explanation for such theories. Felice et al. [44,45] found that when a wide range of model parameters were considered, these models satisfied all the constraints of the solar system. Additionally, to assess the accuracy of the $f(\mathcal{G})$ models, several experiments were performed on the solar system, including light deflection, Earth perihelion shift, gravitational redshift, and light retardation. Paul et al. [46] identified cosmic results and studied various phases of growth that are allowed in higher derivative theories. They used the modified theories as an exploratory model to examine the past, present, and forecast future evolution. It turns out that all of the simulations investigated, are capable of analyzing the universe's present rapid phase of expansion. Myrzakulov et al. [47] evaluated numerous cosmological solutions in the framework of $f(\mathcal{G})$ theory. To do so, the inhomogeneous factors in the Equation of State (EoS) of a perfect fluid might lead to late-time acceleration. Moreover, they established the distinct solutions in $f(\mathcal{G})$ theory. Bhatti et al. [48] examined the unstable behavior of compact star in modified GB gravity by using adiabatic approach. They also studied the standard representation and scalar tensor representations of $f(G, T)$ gravitation and introduced a two set of novel matching conditions in both representation to better understand the behavior of this modified theory in the presence of boundaries or interfaces [49]. Yousaf et al. [50–52] investigated behavior of gravastar via theoretically and graphically, which is alternative compact object to black hole, under the influence of different modified gravity theories.

Bamba et al. [53] explored bounce cosmology in $f(\mathcal{G})$ theory along with the stability of the solutions in the reconstructed model. In addition to that, they effectively evaluated the $f(\mathcal{G})$ gravity model in an analytical manner, in which late-time cosmos acceleration and early-time bounce are possible. Abbas et al. [54] focused to determine analytical solutions for compact objects with anisotropic gravitational static sources. Moreover, they utilized the Krori and Barua metric for resolving Einstein field equations (EFEs) with anisotropic fluid distribution and the power law model of $f(\mathcal{G})$ theory. They also examined the compact star's regularity and stability. Odintsov and Oikonomou [55] studied gravitational baryogenesis by developing an analogy between the GB invariant and the baryonic current. Meanwhile, determined the baryon to entropy ratio based on the GB terms by considering the observational constraints. Antoniou et al. [56] looked at the possible existence of typical BH solutions alongside scalar hair, which particularly emphasizes the restrictions of the prior no-hair theorems. They additionally investigated the solutions of entropy, scalar charge and horizon area.

Munyeshyaka et al. [57] examined cosmic perturbations in modified GB gravity by utilizing the $(1+3)$ covariant formalism. They explained scalar and vector gradient functions and calculated the evolution equations for them. Koussour et al. [58] analyzed a holographic DE model with an anisotropic and homogeneous cosmos of Bianchi type I in the context of $f(\mathcal{G})$ theory. They discovered precise solutions to the field equations with the assumption that the parameter of deceleration fluctuates with cosmic time. Bajardi and Agostino [59] obtained the theory's point-like Lagrangian and associated equations of motion by considering a flat Friedmann–Lemaître–Robertson–Walker metric. The Noether symmetry approach utilized to identify effective functions. In addition, they studied at the cosmological properties of the $f(\mathcal{R}, \mathcal{G})$ model in the presence of matter fields.

The Killing vector field (KVF) [60] is a vector field on a manifold that retains the metric tensor at every point along the vector field. The KVF is related to spacetime symmetries in GR. The curvature of spacetime is intrinsically associated with the distribution of matter and energy in space. The geometrical structure is described by the metric tensor, which precisely defines the structures that the KVF retain. The EFEs are differential equations that are associated with the curvature of spacetime. These are particularly nonlinear equations that are complex to resolve. The simplest way is to use spacetime symmetries to simplify the equations. If spacetime enables a KVF, then this vector field yield a set of spacetime isometries. It leads to an array of transformations that preserve the invariance of metric tensor. These isometries may be utilized for simplifying the EFEs, leading to breakthroughs in the study of spacetime appears in various physical phenomena.

A conformal Killing vector (CKV) on a manifold is a particular kind of vector field that keeps the metric structure up to a scale factor. In a nutshell, it is a vector field that retains angles and distances between points despite enabling the manifold's overall dimension to differ. The CKV have several major applications in GR, and provide a substantial function in the study of asymptotically flat spacetime. These functions are EFEs solutions corresponding to flat Minkowski space at the point of infinity. The CKV permit the description of conserved factors such as mass, angular momentum and electric charge.

Böhmer et al. [61,62] identified that traversable wormholes exhibit precisely defined solutions under specified circumstances of non-static spherical symmetry in their structure. They found novel family of simple analytical approaches corresponding to anisotropic objects alongside conformal motion. These results can be considered to examine the physical properties of compact anisotropic objects. It is essential to study the effects of physical variables such as energy density, mass, pressure gradient, and force related to the star in order to find a physically applicable solutions [63–65]. Manjonjo et al. [66] analyzed the static spherical metric corresponding to the CKV and obtained analytical solutions of EFEs admitting conformal symmetries for different fluid distributions. Further, they demonstrated that the results satisfied the barotropic EoS.

The goal of this manuscript is to extend the work of Herrera et al. [67] in the framework of $f(\mathcal{G})$ gravity. To accomplish our objective, we determine specific solutions that yield one-parameter group of conformal motions in general. Depending on the choice of vector field, there will probably be a pair of different categories of solutions. We will explore the dissipative and non-dissipative cases for each of these categories individually. In particular, one of these categories is related to the facts with vector field parallel to four-velocity, while the other is related to the case with vector field perpendicular to four-velocity.

This manuscript is organized as follows: Sect. 2 presents the basic formulism of $f(\mathcal{G})$ theory and significant properties of the fluid. In Sect. 3, we discuss kinematical variables for non-static spherically symmetric spacetime. We also determine the mass function, structure scalars, and junction conditions. Section 4 deals with the numerous analytical solutions under the constraint $\mathbb{Y}_{TF} = 0$ along with $\sigma = 0$ for both the non-dissipative and dissipative systems. Eventually, we summarize our findings in Sect. 5.

2 Field equations in $f(\mathcal{G})$ gravity

In this section, we consider the equations of motion for $f(\mathcal{G})$ gravity. The action integral for $f(\mathcal{G})$ theory [68] is given as

$$S = \int \left(\mathcal{R} + \frac{1}{\kappa} f(\mathcal{G}) + l_m\right)\sqrt{-g}d^4x, \tag{1}$$

where $\mathcal{R}$, g, l_m, and $\kappa = \frac{8\pi G}{c^4}$ are the Ricci scalar, the determinant of the metric tensor, the Lagrangian density of matter distribution and the coupling constant. For simplicity, we consider relativistic units, i.e., $c = G = 1$. The field equations for $f(\mathcal{G})$ theory are

$$\mathcal{R}_{\lambda\nu} - \frac{1}{2}g_{\lambda\nu}\mathcal{R} = 8\pi\mathbb{T}_{\lambda\nu},$$

where the term $\mathbb{T}_{\lambda\nu}$ is defined as

$$\mathbb{T}_{\lambda\nu} = T^{(m)}_{\lambda\nu} + T^{(\mathcal{G})}_{\lambda\nu},$$

here, $T^{(m)}_{\lambda\nu}$ and $T^{(\mathcal{G})}_{\lambda\nu}$ represent anisotropic matter and the modified correction terms of theory, respectively. The anisotropic fluid distribution can be described by

$$T^{(m)}_{\lambda\nu} = \mu\mathcal{V}_\lambda\mathcal{V}_\nu + Ph_{\lambda\nu} + \Pi_{\lambda\nu} + q(\mathcal{V}_\lambda\mathcal{N}_\nu + \mathcal{N}_\lambda\mathcal{V}_\nu), \tag{2}$$

along with

$$P = \frac{P_r + 2P_\perp}{3}, \quad h_{\lambda\nu} = g_{\lambda\nu} + \mathcal{V}_\lambda\mathcal{V}_\nu,$$
$$\Pi_{\lambda\nu} = \Pi\left(\mathcal{N}_\lambda\mathcal{N}_\nu - \frac{1}{3}h_{\lambda\nu}\right), \quad \Pi = P_r - P_\perp,$$

where μ, P_r, $P_\perp$ denote the energy density, radial pressure and tangential pressure, respectively. The heat flux, the projection tensor, the anisotropic factor, the anisotropic tensor, the four-velocity and the unit four-vector along the radial direction reflected by $q^\lambda = q\mathcal{N}^\lambda$, $h_{\lambda\nu}$, Π, $\Pi_{\lambda\nu}$, $\mathcal{V}^\lambda$ and $\mathcal{N}^\lambda$, respectively. We define four-velocity and a unit four-vectors as

$$\mathcal{V}^{\lambda}=\left(\frac{1}{A},0,0,0\right),\quad \mathcal{N}^{\lambda}=\left(0,\frac{1}{B},0,0\right). \tag{3}$$

For comoving coordinates, these vectors satisfy the relation

$$\mathcal{V}^{\lambda}\mathcal{V}_{\lambda}=-1,\quad \mathcal{N}^{\lambda}\mathcal{N}_{\lambda}=1,\quad \mathcal{N}^{\lambda}\mathcal{V}_{\lambda}=0. \tag{4}$$

The expression for energy–momentum tensor in $f(\mathcal{G})$ theory is formulated by using the variational principle as

$$\begin{aligned}T^{(\mathcal{G})}_{\lambda\nu}=&\frac{1}{\kappa}\{f_{\mathcal{G}}(4\mathcal{R}_{\lambda\alpha}\mathcal{R}^{\alpha}_{\nu}-2\mathcal{R}\mathcal{R}_{\lambda\nu}\\&-2\mathcal{R}_{\lambda\alpha\beta\gamma}\mathcal{R}^{\alpha\beta\gamma}_{\nu}+4\mathcal{R}_{\lambda\alpha\nu\gamma}\mathcal{R}^{\alpha\gamma})\\&+\frac{1}{2}g_{\lambda\nu}f(\mathcal{G})-2\mathcal{R}g_{\lambda\nu}\nabla^2 f_{\mathcal{G}}\\&+2\mathcal{R}\nabla_{\lambda}\nabla_{\nu}f_{\mathcal{G}}-4\mathcal{R}^{\alpha}_{\lambda}\nabla_{\nu}\nabla_{\alpha}f_{\mathcal{G}}\\&-4\mathcal{R}^{\alpha}_{\nu}\nabla_{\lambda}\nabla_{\alpha}f_{\mathcal{G}}+4\mathcal{R}_{\lambda\nu}\nabla^2 f_{\mathcal{G}}\\&+4g_{\lambda\nu}\mathcal{R}^{\alpha\gamma}\nabla_{\alpha}\nabla_{\gamma}f_{\mathcal{G}}-4\mathcal{R}_{\lambda\alpha\nu\gamma}\nabla^{\alpha}\nabla^{\gamma}f_{\mathcal{G}}\}.\end{aligned} \tag{5}$$

Here, $f_{\mathcal{G}}$ depicts $\frac{df(\mathcal{G})}{d\mathcal{G}}$, $\nabla^2=\nabla^{\lambda}\nabla_{\lambda}$ is the d'Alembert operator and ∇_{λ} is the covariant derivative. The non-static interior spacetime is given as

$$\begin{aligned}ds^2=&-A^2(t,r)dt^2+B^2(t,r)dr^2\\&+R^2(t,r)(d\theta^2+\sin^2\theta d\phi^2).\end{aligned} \tag{6}$$

The modified field equations for spacetime described in Eq. (6) is expressed as

$$\begin{aligned}8\pi\{T^{(m)}_{00}+T^{(\mathcal{G})}_{00}\}=&\left(2\frac{\dot{B}}{B}+\frac{\dot{R}}{R}\right)\frac{\dot{R}}{R}-\left(\frac{A}{B}\right)^2\\&\times\left[2\frac{R''}{R}+\left(\frac{R'}{R}\right)^2-2\frac{B'}{B}\frac{R'}{R}-\left(\frac{B}{R}\right)^2\right],\end{aligned} \tag{A1}$$

$$8\pi\{T^{(m)}_{01}+T^{(\mathcal{G})}_{01}\}=-2\left(\frac{\dot{R}'}{R}-\frac{\dot{B}}{B}\frac{R'}{R}-\frac{\dot{R}}{R}\frac{A'}{A}\right), \tag{A2}$$

$$\begin{aligned}8\pi\{T^{(m)}_{11}+T^{(\mathcal{G})}_{11}\}=&-\left(\frac{B}{A}\right)^2\left[2\frac{\ddot{R}}{R}-\left(2\frac{\dot{A}}{A}-\frac{\dot{R}}{R}\right)\frac{\dot{R}}{R}\right]\\&+\left(2\frac{A'}{A}+\frac{R'}{R}\right)\frac{R'}{R}-\left(\frac{B}{R}\right)^2,\end{aligned} \tag{A3}$$

$$\begin{aligned}8\pi\{T^{(m)}_{22}+T^{(\mathcal{G})}_{22}\}=&\frac{8\pi}{sin^2\theta}\{T^{(m)}_{33}+T^{(\mathcal{G})}_{33}\}\\=&-\left(\frac{R}{A}\right)^2\left[\frac{\ddot{B}}{B}+\frac{\ddot{R}}{R}-\frac{\dot{A}}{A}\left(\frac{\dot{B}}{B}+\frac{\dot{R}}{R}\right)+\frac{\dot{B}}{B}\frac{\dot{R}}{R}\right]\\&+\left(\frac{R}{B}\right)^2\left[\frac{A''}{A}+\frac{R''}{R}-\frac{A'}{A}\frac{B'}{B}+\left(\frac{A'}{A}-\frac{B'}{B}\right)\frac{R'}{R}\right].\end{aligned} \tag{A4}$$

where, dot and prime show the derivative with respect to time t and radius r, respectively. The non-zero component of energy momentum tensor for usual matter are

$$\begin{aligned}&T^{(m)}_{00}=\mu A^2,\quad T^{(m)}_{01}=-qAB,\quad T^{(m)}_{11}=P_rB^2,\\&T^{(m)}_{22}=P_{\perp}R^2,\quad T^{(m)}_{33}=sin^2\theta T^{(m)}_{22}.\end{aligned} \tag{7}$$

Also, the non-vanishing component of energy momentum tensor for $f(\mathcal{G})$ theory is defined in Appendix.

3 Kinematical variables and mass function

The four-acceleration, the expansion scalar and shear tensor of the fluid are given as

$$\begin{aligned}&a_{\lambda}=\mathcal{V}_{\lambda;\nu}\mathcal{V}^{\nu},\quad \Theta=\mathcal{V}^{\lambda}{}_{;\lambda},\\&\sigma_{\lambda\nu}=\mathcal{V}_{(\lambda;\nu)}+a_{(\lambda}\mathcal{V}_{\nu)}-\frac{1}{3}\Theta h_{\lambda\nu}.\end{aligned} \tag{8}$$

We derive the four-acceleration and its scalar "a" after substituting the values in Eq. (8), which can be expressed as

$$a_{\lambda}=a\mathcal{N}_{\lambda},\quad a=\frac{A'}{A}\frac{1}{B}. \tag{9}$$

The expansion scalar is evaluated by using Eqs. (8) and (6) as

$$\Theta=\frac{1}{A}\left(2\frac{\dot{R}}{R}+\frac{\dot{B}}{B}\right). \tag{10}$$

The non-zero components of $\sigma_{\lambda\nu}$ from Eqs. (6) and (8) along its scalar value can be expressed as

$$\sigma_{11}=\frac{2}{3}B^2\sigma,\quad \sigma_{22}=\frac{-1}{3}R^2\sigma,\quad \sigma_{33}=Sin^2\theta\sigma_{22}, \tag{11}$$

$$\sigma^{\lambda\nu}\sigma_{\lambda\nu}=\frac{2}{3}\sigma^2, \tag{12}$$

here,

$$\sigma=\frac{1}{A}\left(\frac{\dot{B}}{B}-\frac{\dot{R}}{R}\right). \tag{13}$$

The mass function introduced by Misner and Sharp [69], which is used for describing the mass distribution in a spherical spacetime. For the metric mentioned in Eq. (6), it can be expressed as

$$m(t,r)=\frac{R^3}{2}\mathcal{R}_{23}^{23}=\frac{R}{2}\left[\left(\frac{\dot{R}}{A}\right)^2-\left(\frac{R'}{B}\right)^2+1\right]. \quad (14)$$

Next, D_R and D_T define proper radial derivative and proper time derivative which is expressed as

$$D_T=\frac{1}{A}\frac{\partial}{\partial t},\quad D_R=\frac{1}{R'}\frac{\partial}{\partial r}. \quad (15)$$

Furthermore, U is referred to the collapsing fluid's velocity and can be defined with respect to the proper time derivative of the areal radius as

$$U=D_T R.$$

Here, U may be negative when fluid is collapsing. The function $m(t,r)$ using the collapsing velocity, which is evaluated as

$$E\equiv\frac{R'}{B}=\left(1-\frac{2m}{R}+U^2\right)^{\frac{1}{2}}. \quad (16)$$

By using Eq. (16), we can write Eq. (B1) as

$$4\pi q=-\frac{1}{2AB}\left[f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4\right]+E\left[\frac{1}{3}D_R(\Theta-\sigma)-\frac{\sigma}{R}\right]. \quad (17)$$

Using modified field equations along with proper derivatives of Eq. (14), the expressions for the function of mass $m(t,r)$, which is expressed as

$$D_T m=-4\pi\left\{U\left[P_r-\frac{1}{\kappa}\left(\frac{(\mathcal{G}f_{\mathcal{G}}-f)}{2}+\frac{1}{B^2}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_5+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_6)\right)\right]+\left(q+\frac{1}{\kappa AB}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4)\right)E\right\}R^2, \quad (18)$$

and

$$D_R m=4\pi\left[\mu+\frac{1}{\kappa}\left(\frac{(\mathcal{G}f_{\mathcal{G}}-f)}{2}-\frac{1}{A^2}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_1+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_2)\right)+\left(q+\frac{1}{\kappa AB}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4)\right)\frac{U}{E}\right]R^2. \quad (19)$$

After the integration of Eq. (19), we get

$$m=\int_0^r 4\pi\left[\mu+\frac{1}{\kappa}\left(\frac{(\mathcal{G}f_{\mathcal{G}}-f)}{2}-\frac{1}{A^2}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_1+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_2)\right)+\left(q+\frac{1}{\kappa AB}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4)\right)\frac{U}{E}\right]R^2R'dr. \quad (20)$$

Performing certain computations, we find the expression for $m(t,r)$ as

$$\frac{3m}{R^3}=4\pi\mu-\frac{4\pi}{R^3}\int_0^r R^3\left\{D_R\mu-\frac{3}{R}\left[\frac{1}{\kappa}\left(\frac{(\mathcal{G}f_{\mathcal{G}}-f)}{2}-\frac{1}{A^2}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_1+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_2)\right)+\frac{U}{E}\left(q+\frac{1}{\kappa AB}(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3+f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4)\right)\right]\right\}R'dr. \quad (21)$$

The additional terms that resulted from $f(\mathcal{G})$ theory in the aforementioned mass function formulation are corresponding to the basic characteristic of the spherically symmetric distribution of fluid, that include heat dissipation as well as change in energy density.

3.1 Structure scalars

In this subsection, we determine the structure scalar $\mathbb{Y}_{TF}$ [70–73], which are chosen to define the complexity of the system. Before computing the structure scalar, we calculate the Weyl scalar by use of the Weyl tensor that can be expressed as

$$\mathbb{E}_{\lambda\nu}=\mathbb{C}_{\lambda\mu\nu\gamma}\mathcal{V}^{\mu}\mathcal{V}^{\gamma}, \quad (22)$$

where $\mathbb{C}_{\lambda\mu\nu\gamma}$ denotes the Weyl tensor. In spherically symmetric spacetime, the magnetic part must vanishes but its electric part reveals the importance of the Weyl tensor. The non-zero components of Eq. (22) are

$$\mathbb{E}_{11}=\frac{2}{3}B^2\mathcal{E},\quad \mathbb{E}_{22}=-\frac{1}{3}R^2\mathcal{E},\quad \mathbb{E}_{33}=\mathbb{E}_{22}\sin^2\theta, \quad (23)$$

where Weyl scalar is indicated by $\mathcal{E}$ and is calculated for spacetime (6) as

$$\mathcal{E}=\frac{1}{2A^2}\left[\frac{\ddot{R}}{R}-\frac{\ddot{B}}{B}-\left(\frac{\dot{R}}{R}-\frac{\dot{B}}{B}\right)\left(\frac{\dot{A}}{A}+\frac{\dot{R}}{R}\right)\right]+\frac{1}{2B^2}\left[\frac{A''}{A}-\frac{R''}{R}+\left(\frac{B'}{B}+\frac{R'}{R}\right)\left(\frac{R'}{R}-\frac{A'}{A}\right)\right]-\frac{1}{2R^2}. \quad (24)$$

It is interesting to note that the electric component of the Weyl tensor could also be expressed as

$$\mathbb{E}_{\lambda\nu} = \mathcal{E}\left(\mathcal{N}_\lambda\mathcal{N}_\nu - \frac{1}{3}h_{\lambda\nu}\right). \tag{25}$$

In order to illustrate the key characteristics of the matter distribution, Herrera and his collaborators [70] constructed structure scalars on the basis of splitting of Riemann tensor [74]. Because of these structure scalars, we can analyze the complexity of the self-gravitating systems. To determine the complexity factor, let us express the tensor $\mathbb{Y}_{\lambda\nu}$ [75] as

$$\mathbb{Y}_{\lambda\nu} = R_{\lambda\alpha\nu\beta}\mathcal{V}^\alpha\mathcal{V}^\beta. \tag{26}$$

The tensor $\mathbb{Y}_{\lambda\nu}$ may be expressed in terms of $\mathbb{Y}_T$ and $\mathbb{Y}_{TF}$, which describe the trace and the trace-free component of the Riemann tensor as

$$\mathbb{Y}_{\lambda\nu} = \frac{1}{3}\mathbb{Y}_T h_{\lambda\nu} + \mathbb{Y}_{TF}\left(\mathcal{N}_\lambda\mathcal{N}_\nu - \frac{1}{3}h_{\lambda\nu}\right). \tag{27}$$

By using Eq. (26), we calculated trace and trace-free parts of the electric part of Riemann tensor [76], which is expressed as

$$\mathbb{Y}_T = 4\pi(3P_r^{(D)} - 2\Pi^{(D)} + \mu^{(D)}), \quad \mathbb{Y}_{TF} = \mathcal{E} - 4\pi\Pi^{(D)}. \tag{28}$$

Further, by using the modified field equations with the combination of Eqs. (14) and (24), we have

$$\frac{3m}{R^3} = 4\pi(\mu^{(D)} - \Pi^{(D)}) - \mathcal{E}. \tag{29}$$

Equation (28) along with Eqs. (21) and (28), yield

$$\mathbb{Y}_{TF} = -8\pi\Pi^{(D)} + \frac{4\pi}{R^3}\int_0^r R^3\left\{D_R\mu - \frac{3}{R}\left[\frac{T_{00}^{(\mathcal{G})}}{A^2} + \frac{U}{E}\left(q^{(D)}\right)\right]\right\}R'dr, \tag{30}$$

where $\mu^{(D)}$, $P_r^{(D)}$, $\Pi^{(D)}$ and $q^{(D)}$ are defined in Appendix. Equations (A4)–(A2) and the formula for $\mathcal{E}$, transform Eq. (27) as

$$\mathbb{Y}_{TF} = \frac{1}{A^2}\left[\frac{\ddot{R}}{R} - \frac{\ddot{B}}{B} + \frac{\dot{A}}{A}\left(\frac{\dot{B}}{B} - \frac{\dot{R}}{R}\right)\right] + \frac{1}{B^2}\left[\frac{A''}{A} + \frac{A'}{A}\left(\frac{B'}{B} + \frac{R'}{R}\right)\right]. \tag{31}$$

The complexity of matter distribution has been measured by using the scalar function $\mathbb{Y}_{TF}$. It has been explained by the notion that it reveals the most significant detail regarding the distribution of matter by observing the pressure anisotropy as well as energy density inhomogeneity. A number of the solutions will be discussed in the coming sections using the condition $\mathbb{Y}_{TF} = 0$.

3.2 Junction conditions

In this subsection, we consider the Vaidya-metric as exterior spacetime which is described as

$$ds^2 = -\left[1 - \frac{2M(\nu)}{r}\right]d\nu^2 - 2drd\nu + r^2(d\theta^2 + sin^2\theta d\phi^2), \tag{32}$$

where $M(\nu)$ and ν denote the total mass and retarded time, respectively. The general interior spacetime and exterior Vaidya spacetime matching on the boundary surface, $r = r_\Sigma$ =constant. Next, we have to satisfy the Darmois matching condition [77], so the continuity of the first and second fundamental forms, across the boundary, give

$$m(t, r) \overset{\Sigma}{=} M(\nu), \tag{33}$$

$$\left\{2\left(\frac{\dot{R}'}{R} - \frac{\dot{B}}{B}\frac{R'}{R} - \frac{\dot{R}}{R}\frac{A'}{A}\right)\right\}_\Sigma = \left\{-\frac{B}{A}\left[2\frac{\ddot{R}}{R} - \left(2\frac{\dot{A}}{A} - \frac{\dot{R}}{R}\right)\frac{\dot{R}}{R}\right] + \frac{A}{B}\left[\left(2\frac{A'}{A} + \frac{R'}{R}\right)\frac{R'}{R} - \left(\frac{B}{R}\right)^2\right]\right\}_\Sigma. \tag{34}$$

In Eq. (34), both sides are equal on the boundary surface, and then using Eqs. (A2) and (A3) in Eq. (34), we have

$$q_\Sigma = \left(P_r - \frac{1}{2\kappa}(\mathcal{G}f_\mathcal{G} - f)\right)_\Sigma. \tag{35}$$

Finally, the matching across boundary of Eqs. (6) and (32) formulates the Eq. (33) as well as Eq. (35). So, Eq. (33) represent that the function $m(t, r)$ and the total mass $M(\nu)$ are equal to each other across Σ. Subsequently, Eq. (35) express that the heat flux is equal to radial pressure and higher-curvature terms at the Σ.

3.3 Quasi-homologous evolution

Here, we identify the constraint that has been chosen to fulfil the requirement for the most basic form of evolution. To do so, we rewrite the Eq. (A3) as

$$D_R\left(\frac{U}{R}\right) = \frac{4\pi}{E}\left[q + \frac{1}{\kappa AB}(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)\right] + \frac{\sigma}{R}. \tag{36}$$

After integration of Eq. (36), we obtain

$$U=\tilde{a}(t)R+R\int_0^r\left[\frac{4\pi}{E}\left(q+\frac{1}{\kappa AB}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right)+\frac{\sigma}{R}\right]R'dr. \tag{37}$$

Putting the value of the integration function $\tilde{a}(t)$, the Eq. (37) produces

$$U=\frac{U_\Sigma}{R_\Sigma}R-R\int_r^{r_\Sigma}\left[\frac{4\pi}{E}\left(q+\frac{1}{\kappa AB}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right)+\frac{\sigma}{R}\right]R'dr. \tag{38}$$

Consequently, Eqs. (37) and (38) provide $U=R$, which is a common characteristic of homologous evolution [78–80]. If two integral terms cancel one another or when the fluid is adiabatic with $\sigma=0$, we achieve

$$U=\tilde{a}(t)R. \tag{39}$$

The "homologous evolution" terminology is accomplished to describe the relativistic structures which satisfy the expression as

$$\frac{R_1}{R_2}=constant. \tag{40}$$

Equation (40) illustrates that the evolution structure of matter distribution corresponds with the homologous condition throughout its evolution. Here, R_1 and R_2 denote the areal radii of two concentric shells described by $r=r_1=constant$, and $r=r_2=constant$, respectively. We can write the quasi-homologous condition by using the Eq. (38) in Eq. (B1) which implies

$$\frac{4\pi}{R'}\left[Bq+\frac{1}{\kappa A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right]+\frac{\sigma}{R}=0. \tag{41}$$

3.4 The transport equation

When the gravitational collapse of a dissipative system in thermodynamics happens, the transport equation (TE) will be used in the diffusion approximation [81,82]. The TE yields the temperature of the dynamically collapsing fluid and it is a generalized differential equation that deals with several aspects of transportation, such as fluid dynamics, heat transmission, and mass transfer. The heat flux for the transport equation becomes

$$\tau h^{\lambda\nu}\mathcal{V}^{\xi}q_{\nu;\xi}+q^{\lambda}=-\kappa h^{\lambda\nu}(T_{,\nu}+Ta_{\nu})-\frac{1}{2}\kappa T^2\left(\frac{\tau\mathcal{V}^{\nu}}{\kappa T^2}\right)_{;\nu}q^{\lambda}, \tag{42}$$

where κ represents the thermal conductivity, τ and T represent the relaxation time and temperature, respectively. The TE contains one independent factor. This factor can be extracted from Eq. (42) by reducing it with the vector, which seems unit-space like $\mathcal{N}^{\lambda}$, as

$$\tau\mathcal{V}^{\lambda}q_{,\lambda}+q=-\kappa(\mathcal{N}^{\lambda}T_{,\lambda}+Ta)-\frac{1}{2}\kappa T^2\left(\frac{\tau\mathcal{V}^{\lambda}}{\kappa T^2}\right)_{;\lambda}q. \tag{43}$$

We may obtain TE's truncated version as

$$\tau\mathcal{V}^{\lambda}\dot{q}_{,\lambda}+q=-\kappa(\mathcal{N}^{\lambda}T_{,\lambda}+Ta). \tag{44}$$

where τ describes ephemeral processes that take place earlier in relaxation. While their accomplishments are applicable at all time scales, they are notably crucial for time scales in the range of τ or $<\tau$. The TE's truncated version is helpful to provide the formulation of T for some peculiar models.

4 Conformal motions: exact solutions

Despite the fact that the major goal of this work is to examine dissipative and adiabatic systems. In an attempt to balance out overall perspective, we deal with the metric described in Eq. (6), acknowledge the CKV, and satisfy the equation

$$\mathcal{L}_{\mathcal{X}}g_{\lambda\nu}=2\psi g_{\lambda\nu}\rightarrow\mathcal{L}_{\mathcal{X}}g^{\lambda\nu}=-2\psi g^{\lambda\nu}, \tag{45}$$

here $\mathcal{L}_{\mathcal{X}}$ represents Lie derivative of $\mathcal{X}$, also ψ treated as function of t and r. When ψ is constant equivalent to a homothetic Killing vector. The most inclusive formulation of Eq. (45) is

$$\mathcal{X}=\varepsilon(t,r)\partial_t+\upsilon(t,r)\partial_r. \tag{46}$$

where ε and υ are the functions of t and r. Next, we discuss dissipative and non-dissipative cases under some restrictions one by one.

4.1 Non-dissipation with vector field orthogonal to four-velocity

Let us, consider the scenario where the vector field $\mathcal{X}^{\delta}$ orthogonal to the four-velocity V^{δ} and $q=0$. From Eq. (45), we have

$$\mathcal{L}_{\mathcal{X}}g_{\lambda\nu}=2\psi g_{\lambda\nu}=\mathcal{X}^{\delta}\partial_{\delta}g_{\lambda\nu}+g_{\lambda\delta}\partial_{\nu}\mathcal{X}^{\delta}+g_{\nu\delta}\partial_{\lambda}\mathcal{X}^{\delta}. \tag{47}$$

Using Eq. (47), we evaluate the following equations as

$$\psi = \frac{A'}{A}\mathcal{X}^1, \tag{48}$$

$$\psi = (\mathcal{X}^1)' + \frac{B'}{B}\mathcal{X}^1, \tag{49}$$

$$\psi = \frac{R'}{R}\mathcal{X}^1, \tag{50}$$

and

$$\mathcal{X}^1_{,t} = \mathcal{X}^1_{,\theta} = \mathcal{X}^1_{\phi} = 0. \tag{51}$$

From Eqs. (48) and (50), we obtain

$$A = k(t)R, \tag{52}$$

here $k(t)$ is function of integration. Through re-parametrization t, we might set k to be equivalent to 1. Then, we can express

$$A = \varrho R, \tag{53}$$

where ϱ is a unit constant. The derivative with respect to time of Eq. (49) along with Eq. (50) and further using Eq. (51), can formulated as

$$\frac{B}{W(r)} = \varrho\eta_1(t)R, \tag{54}$$

where $W(r)$ is function of integration, we may set W equivalent to 1 by re-parametrizing r, while $\eta_1(t)$ is an arbitrary function. Thus, we have

$$B = \varrho\eta_1(t)R. \tag{55}$$

Putting back Eqs. (53) and (55) in Eq. (A2) with $q = 0$, we obtain

$$\frac{\dot{B}'}{B} - \frac{2\dot{B}B'}{B^2} = \frac{1}{2}(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4). \tag{56}$$

After integrating the Eq. (56), the solution reads

$$B = \frac{1}{\xi(t) + J(r) + I_1(t,r)},$$
$$A = \varrho R = \frac{\eta(t)}{\xi(t) + J(r) + I_1(t,r)}, \tag{57}$$

here, $J(r)$, $\xi(t)$, and $I_1(t,r)$ are integration functions of their arguments. Further, $\eta(t) \equiv \frac{1}{\eta_1(t)}$ and $I_1 = -\int\int \frac{1}{2B}(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)dtdr$. We may see that these arbitrary functions $\eta(t)$, $\xi(t)$, $J(r)$ and $I_1(t,r)$ may exist in the further discussed models. Then, the modified field equations become

$$8\pi\mu = -\frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{(\xi + J + I_1)^2}{\eta^2} \times \left[f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2 + \frac{\dot{\eta}^2}{\eta^2} - \frac{4\dot{\eta}(\dot{\xi} + \dot{I}_1)}{\eta(\xi + J + I_1)} + \frac{3(\dot{\xi} + \dot{I}_1)^2}{(\xi + J + I_1)^2} + \varrho^2\right] + 2(J'' + I_1'')(\xi + J + I) - 3(J' + I_1')^2, \tag{58}$$

$$8\pi P_r = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{(\xi + J + I_1)^2}{\eta^2} \times \left[\eta^2(f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6) + \frac{\dot{\eta}^2}{\eta^2} + \frac{2\dot{\eta}(\dot{\xi} + \dot{I}_1)}{\eta(\xi + J + I_1)} - \frac{3(\dot{\xi} + \dot{I}_1)^2}{(\xi + J + I_1)^2} + \frac{2(\ddot{\xi} + \ddot{I}_1)}{(\xi + J + I_1)} - \frac{2\ddot{\eta}}{\eta} - \varrho^2\right] + 3(J' + I_1')^2, \tag{59}$$

$$8\pi P_\perp = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{(\xi + J + I_1)^2}{\eta^2} \times \left[\varrho^2(f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8) + \frac{\dot{\eta}^2}{\eta^2} - \frac{3(\dot{\xi} + \dot{I}_1)^2}{(\xi + J + I_1)^2} + \frac{2(\ddot{\xi} + \ddot{I}_1)}{(\xi + J + I_1)} - \frac{\ddot{\eta}}{\eta}\right] + 3(J' + I_1')^2 - 2(J'' + I_1'')(\xi + J + I_1). \tag{60}$$

Using the results of Eq. (57) in the junction conditions which are described in Eqs. (33) and (35) on hypersurface, we have the solutions as

$$\dot{R}^2_\Sigma + \varrho^2(R^2_\Sigma - 2MR_\Sigma - \varpi R^4_\Sigma) = 0, \tag{61}$$
$$2\ddot{R}_\Sigma R_\Sigma - \dot{R}^2_\Sigma - \varrho^2(3\varpi R^4_\Sigma - R^2_\Sigma) = 0, \tag{62}$$

where $\varpi \equiv J'(r_\Sigma)^2$. Basically, Eq. (62) is the time derivative of Eq. (61), so we only consider the Eq. (61). Thus, we could express Eq. (61) as

$$\dot{R}^2_\Sigma = \varrho^2 R^4_\Sigma[\varpi - V(R_\Sigma)], \tag{63}$$

with

$$V(R_\Sigma) = \frac{1}{R^2_\Sigma} - \frac{2M}{R^3_\Sigma}. \tag{64}$$

From the integration of the Eq. (63), we obtain

$$\varrho(t - t_0) = \pm\int \frac{\sqrt{27}}{\sqrt{z(z+6)(z-3)^2}}dz = \pm 2\tanh^{-1}\frac{\sqrt{3z}}{\sqrt{z+6}}, \tag{65}$$

with $z \equiv \frac{R_\Sigma}{M}$. We evaluate the solutions from Eq. (65) which is expressed as

$$R_\Sigma^{(I)} = \frac{6M\tanh^2[\frac{\varrho}{2}(t-t_0)]}{3-\tanh^2[\frac{\varrho}{2}(t-t_0)]}, \tag{66}$$

and

$$R_\Sigma^{(II)} = \frac{6M\coth^2[\frac{\varrho}{2}(t-t_0)]}{3-\coth^2[\frac{\varrho}{2}(t-t_0)]}. \tag{67}$$

The quasi-homologous condition in adiabatic system illustrates that $\sigma = 0$ in the fluid, from which Eq. (13) demonstrates that

$$\frac{\dot{B}}{B} = \frac{\dot{R}}{R} \Rightarrow \eta(t) = constant \equiv \eta_0. \tag{68}$$

Using Eq. (68), we can write metric functions as

$$A = \frac{\eta_0}{\xi(t)+J(r)+I_1(t,r)}, \quad B = \frac{1}{\xi(t)+J(r)+I_1(t,r)},$$
$$R = \frac{\eta_0}{\varrho[\xi(t)+J(r)+I_1(t,r)]}. \tag{69}$$

Then putting back Eq. (69) in Eq. (30) in addition to the condition $\mathbb{Y}_{TF} = 0$, we get

$$\frac{A''}{A} - \left(\frac{R'}{R}+\frac{B'}{B}\right)\frac{A'}{A} = 0. \tag{70}$$

Again, using Eq. (69) in Eq. (70), we accomplish

$$J(r)+I_1(t,r) = \mathbb{P}_1(t)r + \mathbb{P}_2(t), \tag{71}$$

here, $\mathbb{P}_1$ and $\mathbb{P}_2$ are the arbitrary functions of t. After substituting Eq. (69) in Eq. (66), we obtain an arbitrary function $\xi^{(I)}(t)$ as

$$\xi^{(I)}(t) = \frac{\eta_0\{3-\tanh^2[\frac{\varrho}{2}(t-t_0)]\}}{6\varrho M\tanh^2[\frac{\varrho}{2}(t-t_0)]} - \mathbb{P}_1 r_\Sigma - \mathbb{P}_2. \tag{72}$$

Using Eqs. (71) and (72) with Eq. (69), the modified field equations for $f(\mathcal{G})$ theory is expressed as

$$\begin{aligned}8\pi\mu =& -\frac{1}{2}(\mathcal{G}f_\mathcal{G} - f)\\ &+ \frac{\{3\eta_0\coth^2[\frac{\varrho}{2}(t-t_0)] - \eta_0 - 6\varrho M\mathbb{P}_1(r_\Sigma - r)\}^2}{36\varrho^2M^2\eta_0^2}\\ &\times\left[(f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2) + \varrho^2\right]\\ &+3\left[\frac{\cosh[\frac{\varrho}{2}(t-t_0)]}{2M\sinh^3[\frac{\varrho}{2}(t-t_0)]} + \frac{\dot{\mathbb{P}_1}(r_\Sigma - r)}{\eta_0}\right]^2 - 3\mathbb{P}_1^2,\end{aligned} \tag{73}$$

$$\begin{aligned}8\pi P_r =& \frac{1}{2}(\mathcal{G}f_\mathcal{G} - f)\\ &+\left[\frac{\{3\eta_0\coth^2[\frac{\varrho}{2}(t-t_0)] - \eta_0 - 6\varrho M\mathbb{P}_1(r_\Sigma - r)\}^2}{36\varrho^2M^2}\right]\\ &\times(f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6) - \frac{3\dot{\mathbb{P}_1}^2(r_\Sigma - r)^2}{\eta_0^2}\\ &-\frac{3\cosh[\frac{\varrho}{2}(t-t_0)]\dot{\mathbb{P}_1}(r_\Sigma - r)}{M\eta_0\sinh^3[\frac{\varrho}{2}(t-t_0)]} - \frac{4M^2\ddot{\mathbb{P}_1}(r_\Sigma - r)}{\varrho\eta_0}\\ &\times\left[3\coth^2[\frac{\varrho}{2}(t-t_0)] - \frac{1}{3} - \frac{2\varrho M\mathbb{P}_1(r_\Sigma - r)}{\eta_0}\right]\\ &-\frac{1}{9M^2} - \frac{\varrho^2\mathbb{P}_1{}^2(r_\Sigma - r)^2}{\eta_0^2} - \frac{3\varrho\mathbb{P}_1(r_\Sigma - r)}{2\eta_0 M\sinh^4[\frac{\varrho}{2}(t-t_0)]}\\ &+3\mathbb{P}_1^2 + \frac{2\varrho\mathbb{P}_1(r_\Sigma - r)}{3\eta_0 M},\end{aligned} \tag{74}$$

$$\begin{aligned}8\pi P_\perp =& \frac{1}{2}(\mathcal{G}f_\mathcal{G} - f)\\ &+\left[\frac{\{3\eta_0\coth^2[\frac{\varrho}{2}(t-t_0)] - \eta_0 - 6\varrho M\mathbb{P}_1(r_\Sigma - r)\}^2}{36\eta_0^2M^2}\right]\\ &\times(f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8) - \frac{3\dot{\mathbb{P}_1}^2(r_\Sigma - r)^2}{\eta_0^2}\\ &-\frac{3\cosh[\frac{\varrho}{2}(t-t_0)]\dot{\mathbb{P}_1}(r_\Sigma - r)}{M\eta_0\sinh^3[\frac{\varrho}{2}(t-t_0)]} - \frac{4M^2\ddot{\mathbb{P}_1}(r_\Sigma - r)}{\varrho\eta_0}\\ &\times\left[3\coth^2[\frac{\varrho}{2}(t-t_0)] - \frac{1}{3} - \frac{2\varrho M\mathbb{P}_1(r_\Sigma - r)}{\eta_0}\right]\\ &+3\mathbb{P}_1^2 + \frac{\eta_0 - 6\varrho M\mathbb{P}_1(r_\Sigma - r)}{4M^2\eta_0\sinh^4[\frac{\varrho}{2}(t-t_0)]}\\ &+\frac{\eta_0 - 3\varrho M\mathbb{P}_1(r_\Sigma - r)}{3M^2\eta_0\sinh^2[\frac{\varrho}{2}(t-t_0)]}.\end{aligned} \tag{75}$$

In order to calculate the expansion scalar, we utilize the metric functions of model I, which can be expressed as

$$\Theta = \frac{3\cosh[\frac{\varrho}{2}(t-t_0)]}{2M\sinh^3[\frac{\varrho}{2}(t-t_0)]} + \frac{3\dot{\mathbb{P}_1}(r_\Sigma - r)}{\eta_0}. \tag{76}$$

With the help of the Eqs. (67) and (69), we get

$$\xi^{(II)}(t) = \frac{\eta_0\{3-\coth^2[\frac{\varrho}{2}(t-t_0)]\}}{6\varrho M\coth^2[\frac{\varrho}{2}(t-t_0)]} - \mathbb{P}_1 r_\Sigma - \mathbb{P}_2. \tag{77}$$

Moreover, we derive the modified field equations with additional curvature terms by using Eqs. (69), (71) and (77) that can be expressed as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\{3\eta_0\tanh^2[\frac{\varrho}{2}(t-t_0)]-\eta_0-6\varrho M\mathbb{P}_1(r_\Sigma-r)\}^2}{36\varrho^2M^2\eta_0^2}\times\left[(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+\varrho^2\right]+3\left[\frac{\sinh[\frac{\varrho}{2}(t-t_0)]}{2M\cosh^3[\frac{\varrho}{2}(t-t_0)]}+\frac{\dot{\mathbb{P}}_1(r_\Sigma-r)}{\eta_0}\right]^2-3\mathbb{P}_1^2, \quad (78)$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\left[\frac{\{3\eta_0\tanh^2[\frac{\varrho}{2}(t-t_0)]-\eta_0-6\varrho M\mathbb{P}_1(r_\Sigma-r)\}^2}{36\varrho^2M^2}\right]\times(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)-\frac{3\dot{\mathbb{P}}_1^2(r_\Sigma-r)^2}{\eta_0^2}-\frac{3\sinh[\frac{\varrho}{2}(t-t_0)]\dot{\mathbb{P}}_1(r_\Sigma-r)}{M\eta_0\cosh^3[\frac{\varrho}{2}(t-t_0)]}-\frac{4M^2\ddot{\mathbb{P}}_1(r_\Sigma-r)}{\varrho\eta_0}\times\left[3\tanh^2[\frac{\varrho}{2}(t-t_0)]-\frac{1}{3}-\frac{2\varrho M\mathbb{P}_1(r_\Sigma-r)}{\eta_0}\right]-\frac{1}{9M^2}-\frac{\varrho^2\mathbb{P}_1^2(r_\Sigma-r)^2}{\eta_0^2}-\frac{3\varrho\mathbb{P}_1(r_\Sigma-r)}{2\eta_0M\cosh^4[\frac{\varrho}{2}(t-t_0)]}+3\mathbb{P}_1^2+\frac{2\varrho\mathbb{P}_1(r_\Sigma-r)}{3\eta_0M}, \quad (79)$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\left[\frac{\{3\eta_0\tanh^2[\frac{\varrho}{2}(t-t_0)]-\eta_0-6\varrho M\mathbb{P}_1(r_\Sigma-r)\}^2}{36\eta_0^2M^2}\right]\times(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)-\frac{3\dot{\mathbb{P}}_1^2(r_\Sigma-r)^2}{\eta_0^2}-\frac{3\sinh[\frac{\varrho}{2}(t-t_0)]\dot{\mathbb{P}}_1(r_\Sigma-r)}{M\eta_0\cosh^3[\frac{\varrho}{2}(t-t_0)]}-\frac{4M^2\ddot{\mathbb{P}}_1(r_\Sigma-r)}{\varrho\eta_0}\times\left[3\tanh^2[\frac{\varrho}{2}(t-t_0)]-\frac{1}{3}-\frac{2\varrho M\mathbb{P}_1(r_\Sigma-r)}{\eta_0}\right]+3\mathbb{P}_1^2+\frac{\eta_0-6\varrho M\mathbb{P}_1(r_\Sigma-r)}{4M^2\eta_0\cosh^4[\frac{\varrho}{2}(t-t_0)]}+\frac{\eta_0-3\varrho M\mathbb{P}_1(r_\Sigma-r)}{3M^2\eta_0\cosh^2[\frac{\varrho}{2}(t-t0)]}. \quad (80)$$

We assume $\varpi=0$ in Eq. (61) and get

$$R_\Sigma^{(III)}=2M\cos^2[\frac{\varrho}{2}(t-t_0)]. \quad (81)$$

When $\varpi=0$, we have $J'(r_\Sigma)^2=0$, and we determine $\mathbb{P}_1^2=0$. Therefore, we may write the functions as

$$A=\frac{\eta_0}{\xi(t)+\mathbb{P}_2}\quad B=\frac{1}{\xi(t)+\mathbb{P}_2}\quad R=\frac{\eta_0}{\varrho[\xi(t)+\mathbb{P}_2]}. \quad (82)$$

The function $\xi^{(III)}(t)$, using Eqs. (81) and (82), transforms into

$$\xi^{(III)}(t)=\frac{\eta_0}{2\varrho M\cos^2[\frac{\varrho}{2}(t-t_0)]}-\mathbb{P}_2. \quad (83)$$

The equations of motion in terms of $f(\mathcal{G})$ for the functions which is mentioned in Eqs. (82) and (83) are produced as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{1}{4\varrho^2M^2\cos^4[\frac{\varrho}{2}(t-t_0)]}\times(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+\frac{3-2\cos^2[\frac{\varrho}{2}(t-t_0)]}{4M^2\cos^6[\frac{\varrho}{2}(t-t_0)]}, \quad (84)$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\eta_0^2}{4\varrho^2M^2\cos^4[\frac{\varrho}{2}(t-t_0)]}(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6), \quad (85)$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{1}{4M^2\cos^2[\frac{\varrho}{2}(t-t_0)]}(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)+\frac{1}{4M^2\cos^4[\frac{\varrho}{2}(t-t_0)]}. \quad (86)$$

Furthermore, if we assume $M=0$, the solution of Eq. (61) can be evaluated as

$$R_\Sigma^{(IV)}=\frac{1}{\sqrt{\varpi}\cos[\varrho(t-t_0)]}, \quad (87)$$

and

$$R_\Sigma^{(V)}=\frac{1}{\sqrt{\varpi}\sin[\varrho(t-t_0)]}. \quad (88)$$

We determine the $\xi^{(IV)}(t)$ and $\xi^{(V)}(t)$ from the areal radius at Σ which is mentioned in Eqs. (87) and (88) as

$$\xi^{(IV)}(t)=\frac{\eta_0}{\varrho}\sqrt{\varpi}\cos[\varrho(t-t_0)]-\sqrt{\varpi}r_\Sigma-\mathbb{P}_2, \quad (89)$$

and

$$\xi^{(V)}(t)=\frac{\eta_0}{\varrho}\sqrt{\varpi}\sin[\varrho(t-t_0)]-\sqrt{\varpi}r_\Sigma-\mathbb{P}_2. \quad (90)$$

Case: $\xi^{(IV)}(t)$

The modified field equations for the function $\xi^{(IV)}(t)$ are

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\left[\frac{\sqrt{\varpi}}{\varrho}\cos[\varrho(t-t_0)-\frac{\mathbb{P}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]^2$$

$$
\begin{aligned}
&\times(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+3\varpi-3\mathbb{P}_1^2\\
&-2\varpi\cos^2[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\\
&\times\left[2\sqrt{\varpi}\cos[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&+\frac{3\dot{\mathbb{P}}_1^{\,2}}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)^2\\
&+\frac{6\dot{\mathbb{P}}_1\sqrt{\varpi}}{\varrho}\sin[\varrho(t-t_0)]\left(1-\frac{r}{r_\Sigma}\right),
\end{aligned}\tag{91}
$$

$$
\begin{aligned}
8\pi P_r=&\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)\\
&+\left[\sqrt{\varpi}r_\Sigma\cos[\varrho(t-t_0)]-\mathbb{P}_1r_\Sigma\left(1-\frac{r}{r_\Sigma}\right)\right]^2\\
&\times(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)-3\varpi+3\mathbb{P}_1^2\\
&-\frac{3\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\left[2\sqrt{\varpi}\sin[\varrho(t-t_0)]+\frac{\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&-\frac{2\ddot{\mathbb{P}}_1}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)\\
&\times\left[\sqrt{\varpi}\cos[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]+\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\\
&\times\left[4\sqrt{\varpi}\cos[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right],
\end{aligned}\tag{92}
$$

$$
\begin{aligned}
8\pi P_\perp=&\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)\\
&+\left[\sqrt{\varpi}\cos[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]^2\\
&\times(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)-3\varpi+\varpi\cos^2[\varrho(t-t_0)]\\
&-\frac{3\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\left[2\sqrt{\varpi}\sin[\varrho(t-t_0)]-\frac{\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&-\frac{2\ddot{\mathbb{P}}_1}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)\left[\sqrt{\varpi}\cos[\varrho(t-t_0)]\right.\\
&\left.-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]+3\mathbb{P}_1^2\\
&+2\sqrt{\varpi}\mathbb{P}_1\cos[\varrho(t-t_0)]\left(1-\frac{r}{r_\Sigma}\right).
\end{aligned}\tag{93}
$$

Case: $\xi^{(V)}(t)$

For the function $\xi^{(V)}(t)$, we have the following physical parameters

$$
\begin{aligned}
8\pi\mu=&-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)\\
&+\left[\frac{\sqrt{\varpi}}{\varrho}\sin[\varrho(t-t_0)-\frac{\mathbb{P}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]^2\\
&\times(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)-3\mathbb{P}_1^2+3\varpi\\
&+\frac{6\dot{\mathbb{P}}_1\sqrt{\varpi}}{\varrho}\cos[\varrho(t-t_0)]\left(1-\frac{r}{r_\Sigma}\right)\\
&-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\\
&\times\left[2\sqrt{\varpi}\sin[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&-2\varpi\sin^2[\varrho(t-t_0)]+\frac{3\dot{\mathbb{P}}_1^{\,2}}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)^2,
\end{aligned}\tag{94}
$$

$$
\begin{aligned}
8\pi P_r=&\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)\\
&+\left[\sqrt{\varpi}r_\Sigma\sin[\varrho(t-t_0)]-\mathbb{P}_1r_\Sigma\left(1-\frac{r}{r_\Sigma}\right)\right]^2\\
&\times(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)-3\varpi+3\mathbb{P}_1^2\\
&-\frac{3\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\left[2\sqrt{\varpi}\cos[\varrho(t-t_0)]+\frac{\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&-\frac{2\ddot{\mathbb{P}}_1}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)\left[\sqrt{\varpi}\sin[\varrho(t-t_0)]\right.\\
&\left.-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]+\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\\
&\times\left[4\sqrt{\varpi}\sin[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right],
\end{aligned}\tag{95}
$$

$$
\begin{aligned}
8\pi P_\perp=&\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)\\
&+\left[\sqrt{\varpi}\sin[\varrho(t-t_0)]-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]^2\\
&\times(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)-3\varpi+\varpi\sin^2[\varrho(t-t_0)]\\
&-\frac{3\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\left[2\sqrt{\varpi}\cos[\varrho(t-t_0)]-\frac{\dot{\mathbb{P}}_1}{\varrho}\left(1-\frac{r}{r_\Sigma}\right)\right]\\
&-\frac{2\ddot{\mathbb{P}}_1}{\varrho^2}\left(1-\frac{r}{r_\Sigma}\right)\left[\sqrt{\varpi}\sin[\varrho(t-t_0)]\right.\\
&\left.-\mathbb{P}_1\left(1-\frac{r}{r_\Sigma}\right)\right]+3\mathbb{P}_1^2\\
&+2\sqrt{\varpi}\mathbb{P}_1\sin[\varrho(t-t_0)]\left(1-\frac{r}{r_\Sigma}\right).
\end{aligned}\tag{96}
$$

In the Eqs. (91)–(96), we choose the relation between the constants η_0, r_Σ, and ϱ such that $\frac{\eta_0}{r_\Sigma}=\varrho$. In this case, we examined the non-dissipation system using Eq. (47) and then determined the metric functions. We utilized Eq. (57) in junction conditions which are mentioned in Eqs. (33) and (35) to simplify it into a single differential equation. Next, to find models I and II, we use some approaches such as $\sigma=0$ and $\mathbb{Y}_{TF}=0$. To determine further models, consider two scenarios, $\varpi=0$ and $M=0$, with the same approaches as mentioned before. Due to extra curvature terms, the radial pressure at the boundary surface does not equal to zero in model III, but it does in GR [67]. It is noteworthy that the expansion scalar is homogeneous and positive, which is expressed in Eq. (76).

4.2 Dissipation with vector field orthogonal to four-velocity

In this subsection, we assume the dissipation case when $\mathcal{X}^\delta$ orthogonal to $\mathcal{V}^\delta$. Hence, from Eq. (47), we formulate

$$
A=\varrho R,\quad \eta(t)B=\varrho R.\tag{97}
$$

Thus, implying Eq. (97) in Eq. (A2) with dissipative case, we produce

$$\frac{\dot{B}'}{B}-2\frac{B'}{B}\frac{\dot{B}}{B}=4\pi\left[qAB+\frac{1}{\kappa}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right]. \quad (98)$$

The solution of Eq. (98) is given as

$$B=\frac{1}{\xi(t)+J(r)-4\pi\int\int(qA+\frac{1}{\kappa B}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)dtdr}, \quad (99)$$

thus

$$A=\varrho R=\frac{\eta(t)}{\xi(t)+J(r)-4\pi\int\int(qA+\frac{1}{\kappa B}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)dtdr}, \quad (100)$$

here there are two integration functions, $\xi(t)$ and $J(r)$. Using Eq. (97) in Eq. (30) along with the condition $\mathbb{Y}_{TF}=0$, we have

$$\frac{1}{\eta^2}\left(\frac{\ddot{\eta}}{\eta}+\frac{\dot{\eta}\dot{B}}{\eta B}-\frac{\dot{\eta}^2}{\eta^2}\right)+\frac{B''}{B}-2\left(\frac{B'}{B}\right)^2=0. \quad (101)$$

In aiming to solve Eq. (101), we could take into account

$$\left(\frac{\ddot{\eta}}{\eta}+\frac{\dot{\eta}\dot{B}}{\eta B}-\frac{\dot{\eta}^2}{\eta^2}\right)=0, \quad (102)$$

and

$$\frac{B''}{B}-2\left(\frac{B'}{B}\right)^2=0. \quad (103)$$

After integration, the Eq. (103) can express, in the form

$$B=-\frac{1}{\zeta(t)r+\varsigma(t)}, \quad (104)$$

where both ζ and ς are the functions of t. Thus, computing the r-derivative of Eq. (102), the solution becomes $\varsigma=\frac{\zeta}{\varrho}$. So, we can write Eq. (104) as

$$B=-\frac{\varrho}{\zeta(t)(\varrho r+1)}. \quad (105)$$

After substituting Eq. (105) in Eq. (102), the solution of Eq. (102) is determined as

$$\eta(t)=\mathcal{P}_3e^{\mathcal{P}_4\int\zeta dt}, \quad (106)$$

here $\mathcal{P}_3$ and $\mathcal{P}_4$ are integration constants. Next, from Eq. (106), we have

$$\frac{\dot{\eta}}{\eta}=\mathcal{P}_4\zeta. \quad (107)$$

After using the Eqs. (100), (105), and (106), we evaluate the modified field equations under the influence of $f(\mathcal{G})$ theory that can be written as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho r+1)^2}{\varrho^2\mathcal{P}_3^2e^{2\mathcal{P}_4\int\zeta dt}}\times\left[f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2+\varrho^2-4\mathcal{P}_4\dot{\zeta}+\frac{3\dot{\zeta}^2}{\zeta^2}+\mathcal{P}_4^2\zeta^2\right]-3\zeta^2, \quad (108)$$

$$4\pi q=-\frac{\zeta\dot{\zeta}(\varrho r+1)}{\varrho\mathcal{P}_3e^{\mathcal{P}_4\int\zeta dt}}-\frac{\zeta^2(\varrho r+1)^2}{2\varrho^2\mathcal{P}_3e^{\mathcal{P}_4\int\zeta dt}}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4), \quad (109)$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho r+1)^2}{\varrho^2}(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)-\frac{\zeta^2(\varrho r+1)^2}{\varrho^2\mathcal{P}_3^2e^{2\mathcal{P}_4\int\zeta dt}}\left[\varrho^2-\frac{2\ddot{\zeta}}{\zeta}+\frac{3\dot{\zeta}^2}{\zeta^2}+\mathcal{P}_4^2\zeta^2\right]+3\zeta^2, \quad (110)$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho r+1)^2}{\varrho^2\mathcal{P}_3^2e^{2\mathcal{P}_4\int\zeta dt}}\times\left[\varrho^2(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)-\frac{3\dot{\zeta}^2}{\zeta^2}+\frac{2\ddot{\zeta}}{\zeta}-\mathcal{P}_4\dot{\zeta}\right]+3\zeta^2. \quad (111)$$

Next, we assume the quasi-homologous condition which is described in Eq. (41), then feeding back Eq. (109) in Eq. (41), we obtain

$$4\pi qA\frac{B^2}{B'}+\frac{B}{2B'}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)=\frac{\dot{\eta}}{\eta}. \quad (112)$$

If we impose the shear-free condition ($\sigma=0$), then $\dot{\eta}=0$, which further implies that $\mathcal{P}_4=0$. Thus, from the Eq. (106), it seems obvious that the function $\eta(t)$ may be expressed as $\mathcal{P}_3$. Next, the metric functions can be determined as

$$B=-\frac{\varrho}{\zeta(\varrho r+1)},\quad A=-\frac{\mathcal{P}_3\varrho}{\zeta(\varrho r+1)},\quad R=-\frac{\mathcal{P}_3}{\zeta(\varrho r+1)}. \quad (113)$$

With regard to the $f(\mathcal{G})$ theory, the equations of motion can be interpreted as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho r+1)^2}{\varrho^2\mathcal{P}_3^2}$$

$$\times\left[f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2+\varrho^2+\frac{3\dot{\zeta}^2}{\zeta^2}\right]-3\zeta^2, \quad (114)$$

$$4\pi q=-\frac{\zeta\dot{\zeta}(\varrho\, r+1)}{\varrho\mathcal{P}_3}-\frac{\zeta^2(\varrho\, r+1)^2}{2\varrho^2\mathcal{P}_3}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4), \quad (115)$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho\, r+1)^2}{\varrho^2}(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)$$
$$-\frac{\zeta^2(\varrho\, r+1)^2}{\varrho^2\mathcal{P}_3^2}\left[\varrho^2-\frac{2\ddot{\zeta}}{\zeta}+\frac{3\dot{\zeta}^2}{\zeta^2}\right]+3\zeta^2, \quad (116)$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\zeta^2(\varrho\, r+1)^2}{\varrho^2\mathcal{P}_3^2}$$
$$\times\left[\varrho^2(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)-\frac{3\dot{\zeta}^2}{\zeta^2}+\frac{2\ddot{\zeta}}{\zeta}\right]+3\zeta^2. \quad (117)$$

Next, from the matching condition that is mentioned in Eq. (34), we evaluate the function ζ as

$$\frac{2\ddot{\zeta}}{\zeta}-3\left(\frac{\dot{\zeta}}{\zeta}\right)^2+\frac{2\varrho_1\dot{\zeta}}{\zeta}=\varrho^2-3\varrho_1^2, \quad (118)$$

with $\varrho_1\equiv\frac{\varrho\mathcal{P}_3}{\varrho\, r_\Sigma+1}$. For integration, first we assume $u=\frac{\dot{\zeta}}{\zeta}$, which reduce Eq. (118) into the Ricatti equation as

$$2\dot{u}-u^2+2\varrho_1\, u=\varrho^2-3\varrho_1^2. \quad (119)$$

The solution of Eq. (119) turns out

$$u=\varrho_1+\sqrt{\varrho^2-4\varrho_1^2}\tan\left[\frac{\sqrt{\varrho^2-4\varrho_1^2}}{2}(t-t_0)\right]. \quad (120)$$

Thus, from the Eq. (120), the function $\zeta(t)$ is given as

$$\zeta(t)=\varrho_2e^{\varrho_1 t}\sec^2\left[\frac{\sqrt{\varrho^2-4\varrho_1^2}}{2}(t-t_0)\right], \quad (121)$$

here ϱ_2 is an integration constant. Furthermore, we need to find the temperature, so we will use the transport equation. Then, the notion of $T(t,r)$ becomes

$$T(t,r)=\frac{(\varrho\, r+1)}{4\pi\kappa\varrho\,\mathcal{P}_3}\left[\frac{\tau r(\dot{\zeta}^2+\zeta\ddot{\zeta})}{\mathcal{P}_3}-\dot{\zeta}\ln(\varrho\, r+1)\right]$$
$$+\frac{\zeta(\varrho\, r+1)}{\varrho\,\kappa\mathcal{P}_3}\left[\tau\mathbb{M}-\mathbb{N}\right]+T_0(t). \quad (122)$$

Where

$$\mathbb{M}=\int\frac{\varrho}{\zeta(\varrho\, r+1)}\left[\frac{\zeta^2(\varrho\, r+1)^2}{8\pi\varrho^2\mathcal{P}_3}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right]^{\cdot}dr,$$

$$\mathbb{N}=\int\frac{1}{8\pi}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)dr.$$

Further, $\mathcal{P}_3$ is the constant and $T_0(t)$ is the function of integration.

In the aforementioned case, we utilized the condition ($\mathbb{Y}_{TF}=0$) to specify our solutions. Next, the function $\zeta(t)$ is implemented to represent the physical parameters, as one can observe in Eqs. (114)–(117). Further, the function $\zeta(t)$ is evaluated from the junction condition that is described in Eq. (35). Moreover, we implemented some additional limits to reduce the complexity of our models. Finally, from the transport equation, we compute the expression for temperature $T(t,r)$ in the presence of additional curvature terms in Eq. (122).

4.3 Non-dissipation with vector field parallel to four-velocity

In this subsection, we discuss the non-dissipative system in the framework of $\mathcal{X}^\delta$ that is parallel to the four-velocity $\mathcal{V}^\delta$. Taking into account the aforementioned condition, we consider Eq. (47), so that

$$A=BD(r),\quad R=rB,\quad \psi=\frac{\dot{B}}{B},\quad \mathcal{X}^0=1, \quad (123)$$

here, $D(r)$ is function of integration. Also, by using Eq. (123), we get

$$ds^2=B^2(t,r)[-D^2(r)dt^2+dr^2+r^2(d\theta^2+\sin^2\theta d\phi^2)]. \quad (124)$$

Using Eq. (123) in Eq. (A2) along with the condition $q=0$, we achieve

$$\frac{\dot{A}'}{A}-2\frac{\dot{A}}{A}\frac{A'}{A}=\frac{1}{2}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4). \quad (125)$$

The integration of Eq. (125) yields

$$A=\frac{1}{\xi(t)+J(r)+I_2(t,r)}, \quad (126)$$

also, we get

$$B=\frac{1}{D(r)[\xi(t)+J(r)+I_2(t,r)]},$$
$$R=\frac{r}{D(r)[\xi(t)+J(r)+I_2(t,r)]}, \quad (127)$$

here $I_2=-\int\int\frac{1}{2A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)dtdr$. Hence, we can conclude that the arbitrary functions of their arguments are represented by ξ, D, J, and I_2. Next, the matching of the mass functions of inner and outer spacetime, which is mentioned in Eq. (33) along with Eq. (127), can be expressed as

$$\dot{R}_\Sigma^2=\varrho^2R_\Sigma^4[\vartheta-V(R_\Sigma)], \tag{128}$$

where

$$\varrho^2\equiv\frac{D_\Sigma^2}{r_\Sigma^2},\quad \vartheta\equiv(J')_\Sigma^2D_\Sigma^2,$$
$$V(R_\Sigma)=\frac{2\sqrt{\vartheta}}{R_\Sigma}(1-\alpha_1)+\frac{\alpha_1}{R_\Sigma^2}(2-\alpha_1)-\frac{2M}{R_\Sigma^3}, \tag{129}$$

with $\alpha_1\equiv\frac{D'_\Sigma r_\Sigma}{D_\Sigma}$. Next, using the Eqs. (35) and (127), we get

$$2\ddot{R}_\Sigma R_\Sigma-\dot{R}_\Sigma^2-3\vartheta\varrho^2R_\Sigma^4-4\varrho^2\sqrt{\vartheta}R_\Sigma^3(\alpha_1-1)$$
$$-\varrho^2R_\Sigma^2\alpha_1(\alpha_1-2)=0. \tag{130}$$

In order to find the specific models, we take $\alpha_1=1$, and then Eq. (128) can be expressed as

$$\dot{R}_\Sigma^2=\varrho^2R_\Sigma^4\left\{\vartheta-\frac{1}{R_\Sigma^2}+\frac{2M}{R_\Sigma^3}\right\}. \tag{131}$$

After applying the case $\alpha_1=1$ in Eq. (130), we obtain the same solution as Eq. (63), which is expressed as

$$2\ddot{R}_\Sigma R_\Sigma-\dot{R}_\Sigma^2-3\vartheta\varrho^2R_\Sigma^4+\varrho^2R_\Sigma^2=0. \tag{132}$$

Feeding back Eq. (127) in Eq. (30) along with condition $\mathbb{Y}_{TF}=0$, we accomplish

$$\frac{J''+I_2''}{J'+I_2'}-\frac{1}{r}+\frac{2D'}{D}=0. \tag{133}$$

Equation (133) can be written as

$$\frac{\epsilon'}{\epsilon}-\frac{1}{r}+\frac{2D'}{D}=0, \tag{134}$$

with $\epsilon\equiv J'+I_2'$. The integration of Eq. (134) yields

$$\epsilon=\frac{\mathbb{P}_4(t)r}{D^2}. \tag{135}$$

The solution of Eq. (135) is evaluated as

$$J+I_2=\mathbb{P}_4(t)\int\frac{r}{D^2}dr+\mathbb{P}_5(t), \tag{136}$$

here $\mathbb{P}_4$ and $\mathbb{P}_5$ are arbitrary functions of t. Further, we assume

$$D(r)=\mathcal{P}_6r, \tag{137}$$

here, $\mathcal{P}_6$ is treated as a constant. Next, using Eq. (136), we get

$$J+I_2=\mathbb{P}_5(t)+\mathbb{P}_7(t)\ln r, \tag{138}$$

where, $\mathbb{P}_5$ and $\mathbb{P}_7$ are the integration functions of t. If we solve Eq. (131), we obtain $R_\Sigma^{(VII)}$ as

$$R_\Sigma^{(VII)}=\frac{6M\tanh^2[\frac{\varrho}{2}(t-t_0)]}{3-\tanh^2[\frac{\varrho}{2}(t-t_0)]}. \tag{139}$$

Using the Eqs. (127) and (139), we can find the function $\xi^{(VII)}(t)$, which is expressed as

$$\xi^{(VII)}(t)=\frac{\eta_0\{3-\tanh^2[\frac{\varrho}{2}(t-t_0)]\}}{6\varrho M\tanh^2[\frac{\varrho}{2}(t-t_0)]}-\mathbb{P}_5-\mathbb{P}_7\ln r_\Sigma. \tag{140}$$

We utilized the functions that are expressed in Eqs. (138) and (140) with Eqs. (127) and (128). Further, We calculate the physical variables, which can be read as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_\mathcal{G}-f)+\left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{6\varrho M}+\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]$$
$$\times(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]}{4M^2\sinh^4[\frac{\varrho}{2}(t-t_0)]}$$
$$+\frac{\{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1\}^2}{36M^2}-3\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|$$
$$\times\left[\frac{\coth[\frac{\varrho}{2}(t-t_0)]}{M\sinh^2[\frac{\varrho}{2}(t-t_0)]}-\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]-3\varrho^2\mathbb{P}_7^2$$
$$+\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\left[\left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{3M}+\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right],\right. \tag{141}$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_\mathcal{G}-f)+r^2\times\left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{6M}+\varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]^2$$
$$\times(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)+3\varrho^2\mathbb{P}_7^2-\frac{1}{9M^2}$$
$$+\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\left[\left[\frac{3\coth[\frac{\varrho}{2}(t-t_0)]}{M\sinh^2[\frac{\varrho}{2}(t-t_0)]}-3\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]\right.$$
$$+\ddot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\left[\left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{3\varrho M}\right.\right.$$
$$\left.+2\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]+\varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|$$
$$\times\left[\frac{(3\coth^2[\frac{\varrho}{2}(t-t_0)]-1)(3\coth^2[\frac{\varrho}{2}(t-t_0)]-5)}{6M}\right.$$
$$\left.-\varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right], \tag{142}$$

$$8\pi P_{\perp} = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{6M} + \varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8) + \frac{2\coth^2[\frac{\varrho}{2}(t-t_0)]+1}{12M^2\sinh^2[\frac{\varrho}{2}(t-t_0)]} + \dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| \times \left[\frac{3\coth[\frac{\varrho}{2}(t-t_0)]}{M\sinh^2[\frac{\varrho}{2}(t-t_0)]} - 3\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\right] + \ddot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| \times \left[\frac{3\coth^2[\frac{\varrho}{2}(t-t_0)]-1}{3\varrho M} + 2\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right] + 3\varrho^2\mathbb{P}_7^2 + \ln\left|\frac{r}{r_\Sigma}\right|\frac{\varrho\mathbb{P}_7(3\coth^2[\frac{\varrho}{2}(t-t_0)]-1)}{2M\sinh^2[\frac{\varrho}{2}(t-t_0)]}. \quad (143)$$

We used $\varrho^2 \equiv \mathcal{P}_6^2$ in Eqs. (141)–(143). Next, if we consider $\vartheta = 0$ and $\alpha_1 = \frac{1}{2}$ in Eq. (128), then the Eq. (128) can be written as

$$\dot{R}_\Sigma^2 = \varrho^2 R_\Sigma^4\left[\frac{2M}{R_\Sigma^3} - \frac{3}{4R_\Sigma^2}\right]. \quad (144)$$

The integration of Eq. (144) gives

$$R_\Sigma^{(VIII)} = \frac{4M}{3}(1+\sin\tilde{t}). \quad (145)$$

With $\tilde{x} \equiv \frac{\sqrt{3}\varrho}{2}(t-t_0)$. If we further choose $D(r) = \mathcal{P}_1\sqrt{r}$ with $\mathcal{P}_1$ = constant. After integration, Eq. (133) may be expressed as

$$J(r) + I_2(t,r) = \mathbb{P}_2(t)r + \mathbb{P}_3(t), \quad (146)$$

where, $\mathbb{P}_2$ and $\mathbb{P}_3$ are the functions of t. Assume that $\vartheta = 0$, we have $J'(r_\Sigma)^2 = 0$. The function $\mathbb{P}_2$ must vanish. Next, the physical variables with modified correction terms yield

$$8\pi\mu = -\frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{9}{16\varrho^2M^2(\sin\tilde{x}+1)^2} \times (f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2) + \frac{27}{64M^2(\sin\tilde{x}+1)^2} \times \left[\frac{3\cos^2\tilde{x}}{(\sin\tilde{x}+1)^2} + \frac{r_\Sigma}{r}\right], \quad (147)$$

$$8\pi P_r = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{9rr_\Sigma}{16\varrho M^2(\sin\tilde{x}+1)^2} \times (f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6) + \frac{27}{64M^2(\sin\tilde{x}+1)^2}\left[1 - \frac{r_\Sigma}{r}\right], \quad (148)$$

$$8\pi P_{\perp} = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \frac{9r_\Sigma}{16r\varrho M^2(\sin\tilde{x}+1)^2} \times (f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8) + \frac{27}{64M^2(\sin\tilde{x}+1)^2}. \quad (149)$$

Moreover, we consider $M = 0$ and $\alpha_1 = 1$, then Eq. (128) is evaluated as

$$\dot{R}_\Sigma^2 = \varrho^2 R_\Sigma^4\left[\vartheta - \frac{1}{R_\Sigma^2}\right]. \quad (150)$$

The integration of Eq. (150) gives

$$R_\Sigma^{(IX)} = \frac{1}{\sqrt{\vartheta}\cos[\varrho(t-t_0)]}, \quad (151)$$

$$R_\Sigma^{(X)} = \frac{1}{\sqrt{\vartheta}\sin[\varrho(t-t_0)]}. \quad (152)$$

Using Eqs. (151) and (152), we may find the functions $\xi^{(IX)}(t)$ and $\xi^{(X)}(t)$ as

$$\xi^{(IX)}(t) = \frac{\sqrt{\vartheta}\cos[\varrho(t-t_0)]}{\varrho} - \mathbb{P}_5 - \mathbb{P}_7\ln r_\Sigma, \quad (153)$$

$$\xi^{(X)}(t) = \frac{\sqrt{\vartheta}\sin[\varrho(t-t_0)]}{\varrho} - \mathbb{P}_5 - \mathbb{P}_7\ln r_\Sigma. \quad (154)$$

After using Eqs. (146), (153), and (154) along with Eqs. (127) and (128), the corresponding set of modified field equations read as

Case: $\xi^{(IX)}(t)$

The physical parameters for the function $\xi^{(IX)}(t)$ yield

$$8\pi\mu = -\frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + \left[\sqrt{\vartheta}\cos[\varrho(t-t_0)] + \mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2) + 3\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| \times \left[\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| - 2\sqrt{\vartheta}\sin[\varrho(t-t_0)]\right] + 3\vartheta - 2\vartheta\cos^2[\varrho(t-t_0)] + \varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right| \times \left[2\sqrt{\vartheta}\cos[\varrho(t-t_0)] + \varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right] - 3\varrho^2\mathbb{P}_7^2 - 2\sqrt{\vartheta}\cos^2[\varrho(t-t_0)], \quad (155)$$

$$8\pi P_r = \frac{1}{2}(\mathcal{G}f_{\mathcal{G}} - f) + r^2\left[\sqrt{\vartheta}\cos[\varrho(t-t_0)] + \varrho\mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6) - 3\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| \times \left[\dot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right| - 2\sqrt{\vartheta}\sin[\varrho(t-t_0)]\right] + 2\ddot{\mathbb{P}}_7\ln\left|\frac{r}{r_\Sigma}\right|\left[\left[\frac{\sqrt{\vartheta}\cos[\varrho(t-t_0)]}{\varrho} + \mathbb{P}_7\ln\left|\frac{r}{r_\Sigma}\right|\right]\right.$$

$$- \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right| \left[\varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right| + 4\sqrt{\vartheta} \cos[\varrho(t-t_0)]\right] - 3\vartheta + 3\varrho^2 \mathbb{P}_7^2, \quad (156)$$

$$8\pi P_\perp = \frac{1}{2}(\mathcal{G} f_\mathcal{G} - f) + \left[\sqrt{\vartheta} \cos[\varrho(t-t_0)] + \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_7 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_8) - 3\vartheta + \vartheta \cos^2[\varrho(t-t_0)] + 3\varrho^2 \mathbb{P}_7^2 + 3\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \times \left[2\sqrt{\vartheta} \sin[\varrho(t-t_0)] - \dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] + 2\ddot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \left[\frac{\sqrt{\vartheta} \cos[\varrho(t-t_0)]}{\varrho} + \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] - 2\varrho \mathbb{P}_7 \sqrt{\vartheta} \cos[\varrho(t-t_0)] \ln \left|\frac{r}{r_\Sigma}\right|. \quad (157)$$

Case: $\xi^{(X)}(t)$

The equations of motion in the context $f(\mathcal{G})$ gravity can be read as

$$8\pi \mu = -\frac{1}{2}(\mathcal{G} f_\mathcal{G} - f) + \left[\sqrt{\vartheta} \sin[\varrho(t-t_0)] + \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_1 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_2) + 3\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \times \left[\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| - 2\sqrt{\vartheta} \cos[\varrho(t-t_0)]\right] + 3\vartheta - 2\vartheta \sin^2[\varrho(t-t_0)] + \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right| \left[2\sqrt{\vartheta} \sin[\varrho(t-t_0)] + \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] - 3\varrho^2 \mathbb{P}_7^2 - 2\sqrt{\vartheta} \sin^2[\varrho(t-t_0)], \quad (158)$$

$$8\pi P_r = \frac{1}{2}(\mathcal{G} f_\mathcal{G} - f) + r^2 \left[\sqrt{\vartheta} \sin[\varrho(t-t_0)] + \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_5 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_6) - 3\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \times \left[\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| - 2\sqrt{\vartheta} \cos[\varrho(t-t_0)]\right] + 2\ddot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \left[\frac{\sqrt{\vartheta} \sin[\varrho(t-t_0)]}{\varrho} + \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] - \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right| \left[\varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right| + 4\sqrt{\vartheta} \sin[\varrho(t-t_0)]\right] - 3\vartheta + 3\varrho^2 \mathbb{P}_7^2, \quad (159)$$

$$8\pi P_\perp = \frac{1}{2}(\mathcal{G} f_\mathcal{G} - f) + \left[\sqrt{\vartheta} \sin[\varrho(t-t_0)] + \varrho \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right]^2 \times (f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_7 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_8) - 3\vartheta + 3\varrho^2 \mathbb{P}_7^2 + 3\dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \times \left[2\sqrt{\vartheta} \cos[\varrho(t-t_0)] - \dot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] + 2\ddot{\mathbb{P}}_7 \ln \left|\frac{r}{r_\Sigma}\right| \times \left[\frac{\sqrt{\vartheta} \sin[\varrho(t-t_0)]}{\varrho} + \mathbb{P}_7 \ln \left|\frac{r}{r_\Sigma}\right|\right] - 2\varrho \mathbb{P}_7 \sqrt{\vartheta} \sin[\varrho(t-t_0)] \ln \left|\frac{r}{r_\Sigma}\right| + \vartheta \sin^2[\varrho(t-t_0)]. \quad (160)$$

In this section, we begin with the non-dissipative case, i.e., $q = 0$. After, utilizing Eq. (123) in Eq. (A2), we get Eq. (125). The solution of Eq. (125) specifies the metric variables. In fact, by computing the Eq. (33) along with Eq. (127), we obtain the differential equation whose solution constructs model VII with additional curvature factors. Further, if we assume $\vartheta = 0$ and $\alpha_1 = \frac{1}{2}$ in Eq. (128), then their solution provides the Eq. (145). Next, the vanishing complexity factor condition ($\mathbb{Y}_{TF} = 0$) along with Eq. (145) used to determine the model $VIII$. At the end, the model IX and X are evaluated when we consider $M = 0$ in Eq. (128). The solutions of models IX and X describe the properties of the compact objects.

4.4 Dissipation with vector field parallel to four-velocity

In this subsection, we assume that the vector field $\mathcal{X}^\delta$ parallel to $\mathcal{V}^\delta$ in combination with a dissipative system $q \neq 0$. Then, we have the same metric functions which have been described in Eq. (123). Thus, after substituting the Eq. (123) in Eq. (A2), we have

$$4\pi q AB + \frac{1}{2}(f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_3 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_4) = \frac{\dot{B}'}{B} - 2\frac{\dot{B}}{B}\frac{B'}{B} - \frac{\dot{B}}{B}\frac{D'}{D}. \quad (161)$$

After integration, the solution of Eq. (161) is obtained as

$$B = \frac{1}{D(r)\{\xi(t) + J(r) - \int\int [4\pi q B + \frac{1}{2A}(f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_3 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_4)] dt dr\}}, \quad (162)$$

$$A = \frac{1}{\xi(t) + J(r) - \int\int [4\pi q B + \frac{1}{2A}(f_{\mathcal{G}\mathcal{G}\mathcal{G}} \mathbb{Z}_3 + f_{\mathcal{G}\mathcal{G}} \mathbb{Z}_4)] dt dr}, \quad (163)$$

$$R=\frac{r}{D(r)\{\xi(t)+J(r)-\int\int[4\pi qB+\frac{1}{2A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)]dtdr\}}. \quad (164)$$

Here, $\xi(t)$ and $J(r)$ are functions of integration.

To attain another model, we apply the condition ($\mathbb{Y}_{TF}=0$). Putting the metric functions of Eqs. (162)–(164) in Eq. (31) produce

$$J'-\int[4\pi qB+\frac{1}{2A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)]dt=\frac{\varsigma(t)r}{D^2(r)}. \quad (165)$$

After integration, the Eq. (165) is obtained as

$$J-\int\int[4\pi qB+\frac{1}{2A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)]dtdr =\varsigma(t)\int\frac{rdr}{D^2(r)}, \quad (166)$$

where $\varsigma(t)$ is function of integration. Let us, taking time derivative of Eq. (165), we get

$$4\pi qB+\frac{1}{2A}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)=-\frac{\dot{\varsigma}(t)r}{D^2(r)}. \quad (167)$$

Using the Eqs. (162)–(164), the metric functions can be represented as

$$B=\frac{1}{D(r)[\xi(t)+\varsigma(t)\int\frac{rdr}{D^2(r)}]}, \quad (168)$$

$$A=\frac{1}{\xi(t)+\varsigma(t)\int\frac{rdr}{D^2(r)}}, \quad (169)$$

$$R=\frac{r}{D(r)[\xi(t)+\varsigma(t)\int\frac{rdr}{D^2(r)}]}, \quad (170)$$

Further, the combination of Eqs. (35), (168)-(170) and Eq. (A3) produce

$$D_\Sigma^2 S_\Sigma\left(\frac{1}{r_\Sigma}-\frac{D'_\Sigma}{D_\Sigma}-\frac{S'_\Sigma}{S_\Sigma}\right)\left(\frac{1}{r_\Sigma}-\frac{D'_\Sigma}{D_\Sigma}-3\frac{S'_\Sigma}{S_\Sigma}\right) -S_\Sigma\left(-2\frac{\ddot{S}_\Sigma}{S_\Sigma}+3\frac{\dot{S}_\Sigma^2}{S_\Sigma^2}+\varrho^2\right)=-\frac{2\dot{\varsigma}}{\varrho}, \quad (171)$$

where

$$\varrho\equiv\frac{D_\Sigma}{r_\Sigma},\quad S\equiv\xi(t)+\varsigma(t)\int\frac{rdr}{D^2(r)}. \quad (172)$$

To find the solution of Eq. (171), we consider

$$-2\frac{\ddot{S}_\Sigma}{S_\Sigma}+3\frac{\dot{S}_\Sigma^2}{S_\Sigma^2}+\varrho^2=\frac{2\dot{\varsigma}}{\varrho S_\Sigma}, \quad (173)$$

$$1-\alpha_1-\frac{r_\Sigma S'_\Sigma}{S_\Sigma}=0, \quad (174)$$

where $\alpha_1\equiv\frac{D'_\Sigma r_\Sigma}{D_\Sigma}$. Also, we can write Eq. (174) as

$$1-\alpha_1=\frac{\varsigma(t)}{\varrho^2 S_\Sigma}. \quad (175)$$

Using Eq. (175) after implying a time derivative, we compute

$$\frac{\varsigma(t)\dot{S}_\Sigma}{S_\Sigma^2}=\frac{\dot{\varsigma}(t)}{S_\Sigma}. \quad (176)$$

Using Eqs. (175) and (176) in Eq. (173), we get

$$2\frac{\ddot{S}_\Sigma}{S_\Sigma}-3\frac{\dot{S}_\Sigma^2}{S_\Sigma^2}+\frac{2\varrho\dot{S}_\Sigma(1-\alpha_1)}{S_\Sigma}-\varrho^2=0. \quad (177)$$

Further, we consider $x=\frac{\dot{S}_\Sigma}{S_\Sigma}$ for simplification. Then, we can say that the solution of Eq. (177) is the Ricatti equation, which is expressed as

$$\dot{x}-\frac{1}{2}x^2+\varrho(1-\alpha_1)x-\frac{\varrho^2}{2}=0. \quad (178)$$

The particular solution to Eq. (178) may be represented by as

$$x_0=\varrho(1-\alpha_1)\pm\varrho\sqrt{\alpha_1^2-2\alpha_1}. \quad (179)$$

The Eq. (178) by assuming $y=x-x_0$ is determined as

$$\dot{y}-\frac{1}{2}y^2+[\varrho(1-\alpha_1)-x_0]y=0. \quad (180)$$

The general solution of Eq. (180) produces

$$y=\frac{2\omega}{1+de^{\omega t}}, \quad (181)$$

here d is an integration constant and $\omega\equiv\varrho(1-\alpha_1)-x_0$. Now, we have to find the solution of Eq. (181) in terms of S_Σ, which can be evaluated as

$$S_\Sigma=\frac{\mathcal{P}e^{(2\omega+x_0)t}}{(1+de^{\omega t})^2}. \quad (182)$$

Furthermore, the equations of motion for $f(\mathcal{G})$ in the terms of $S_\Sigma(t,r)$ and $D(r)$ can be read as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+S^2(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+3\dot{S}^2 -D^2S^2\left[-\frac{2D''}{D}+3\left(\frac{D'}{D}\right)^2-2\frac{S''}{S}\right.$$

$$+3\left(\frac{S'}{S}\right)^2+2\frac{D'}{D}\frac{S'}{S}-\frac{4D'}{rD}-\frac{4S'}{rS}\bigg], \tag{183}$$

$$8\pi q=-DS^2(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)-2DS\dot{S}', \tag{184}$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+D^2S^2(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)+2\ddot{S}S-3\dot{S}^2+D^2S^2\bigg[\left(\frac{D'}{D}\right)^2+3\left(\frac{S'}{S}\right)^2+4\frac{D'}{D}\frac{S'}{S}-\frac{2D'}{rD}-\frac{4S'}{rS}\bigg], \tag{185}$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{D^2S^2}{r^2}(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)+2\ddot{S}S-3\dot{S}^2+D^2S^2\bigg[-\frac{D''}{D}+\left(\frac{D'}{D}\right)^2-2\frac{S''}{S}+3\left(\frac{S'}{S}\right)^2-\frac{D'}{rD}-\frac{2S'}{rS}\bigg]. \tag{186}$$

For the next model, we consider the case $x_0=-\varrho$ and $\omega=0$. By using these values in Eq. (182), we obtain the expression for S_Σ, which is expressed as

$$S_\Sigma=\tilde{\mathcal{P}}e^{\varrho t}, \tag{187}$$

with $\tilde{\mathcal{P}}\equiv\frac{\mathcal{P}}{(1+d)^2}$. Next, we consider the functions $D(r)$ and ϱ as

$$D(r)=\tilde{b}r^2,\quad \varrho=\tilde{b}r_\Sigma. \tag{188}$$

Using the Eq. (188), we have

$$\int\frac{rdr}{D^2(r)}=-\frac{r_\Sigma^2}{2\varrho^2r^2}. \tag{189}$$

By utilizing the Eq. (175), we get the expression for $\varsigma(t)$ as

$$\varsigma(t)=-\varrho^2\tilde{\mathcal{P}}e^{-\varrho t}. \tag{190}$$

We find the function $\xi(t)$ with the combination of Eqs. (172), (187), (189) and (190) as

$$\xi(t)=\frac{\tilde{\mathcal{P}}e^{-\varrho t}}{2}. \tag{191}$$

The final expression for the function $S(t,r)$ is

$$S^{(XI)}(t,r)=\frac{\tilde{\mathcal{P}}e^{-\varrho t}}{2}\left[1+\left(\frac{r_\Sigma}{r}\right)^2\right]. \tag{192}$$

For this particular model, the equations of motion in the influence of $f(\mathcal{G})$ theory are evaluated as

$$8\pi\mu=-\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\tilde{\mathcal{P}}^2e^{-2\varrho t}}{4r^2}(r^2+r_\Sigma^2)^2\times(f_{\mathcal{GGG}}\mathbb{Z}_1+f_{\mathcal{GG}}\mathbb{Z}_2)+\frac{3\tilde{\mathcal{P}}^2\varrho^2e^{-2\varrho t}}{4r^4}(5r^4+2r^2r_\Sigma^2+r_\Sigma^4), \tag{193}$$

$$8\pi q=-\frac{\varrho\tilde{\mathcal{P}}^2e^{-2\varrho t}}{4r^2r_\Sigma}(r^2+r_\Sigma^2)^2\times(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)-\tilde{\mathcal{P}}^2\varrho^2\exp^{-2\varrho t}(r^2+r_\Sigma^2)\frac{r_\Sigma}{r^3}, \tag{194}$$

$$8\pi P_r=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\varrho^2\tilde{\mathcal{P}}^2e^{-2\varrho t}}{r_\Sigma^2}(r^2+r_\Sigma^2)^2\times(f_{\mathcal{GGG}}\mathbb{Z}_5+f_{\mathcal{GG}}\mathbb{Z}_6)+\frac{\tilde{\mathcal{P}}^2\varrho^2e^{-2\varrho t}}{4r^4}(2r^2r_\Sigma^2-9r^4-r_\Sigma^4), \tag{195}$$

$$8\pi P_\perp=\frac{1}{2}(\mathcal{G}f_{\mathcal{G}}-f)+\frac{\varrho^2\tilde{\mathcal{P}}^2e^{-2\varrho t}}{r^2r_\Sigma^2}(r^2+r_\Sigma^2)^2\times(f_{\mathcal{GGG}}\mathbb{Z}_7+f_{\mathcal{GG}}\mathbb{Z}_8)+\frac{\tilde{\mathcal{P}}^2\varrho^2e^{-2\varrho t}}{4r^4}(2r^2r_\Sigma^2-9r^4-r_\Sigma^4). \tag{196}$$

The expression of total mass and temperature $T(t,r)$ for this specific model are determined as

$$m_\Sigma=\frac{e^{\varrho t}}{\tilde{\mathcal{P}}\varrho}, \tag{197}$$

$$T(t,r)=\frac{\tilde{\mathcal{P}}e^{-\varrho t}(r^2+r_\Sigma^2)}{2r^2}\times\bigg[\frac{1}{4\pi\kappa}\left(\frac{\tau\tilde{\mathcal{P}}\varrho^2r_\Sigma^2e^{-\varrho t}}{r^2}+\varrho\ln\left|\frac{r^2}{r^2+r_\Sigma^2}\right|\right)-\frac{1}{\kappa}(\tau\mathbb{H}+\mathbb{L})+T_0(t)\bigg], \tag{198}$$

with

$$\mathbb{H}=\int\frac{r_\Sigma}{\varrho\tilde{\mathcal{P}}e^{-\varrho t}(r^2+r_\Sigma^2)}\times\left[\frac{\varrho\tilde{\mathcal{P}}e^{-2\varrho t}(r^2+r_\Sigma^2)^2}{16\pi r^2r_\Sigma}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)\right]^{\cdot}dr,$$

and

$$\mathbb{L}=\int\frac{1}{8\pi}(f_{\mathcal{GGG}}\mathbb{Z}_3+f_{\mathcal{GG}}\mathbb{Z}_4)dr.$$

Here, $T_0(t)$ is the integration function. The expression for temperature that is mentioned in Eq. (198) is derived by using the Eq. (44).

In the aforementioned case, the condition $\mathbb{Y}_{TF}=0$ is implemented to obtain the metric variables that are mentioned in Eqs. (168)–(170). The junction conditions provided further constraints on functions $\xi(t)$ and $\varsigma(t)$. Ultimately, the functions $\xi(t)$ and $\varsigma(t)$ produced the expression for $S(t,r)$. Lastly, we evaluated the model XI in terms of the function $S(t,r)$. It is noteworthy that this model is anisotropic in pressure but isotropic in GR [67]. If $\mathcal{G} < 0$, the energy density is greater than pressure and will be treated as a positive quantity.

5 Conclusion

We studied a spherical symmetric collapsing fluid's distribution to correspond a system which is characterized by a dissipative fluid. This fluid may contains matter or radiation, that collapses in a symmetric way through the pull of its own gravity. The aforementioned scenario is extremely fascinating in astrophysics and cosmology because it helps to clarify the origins and growth of celestial structures. In the meantime, we observed by introducing CKV which yields a variety of solutions to modified field equations. In order to account for some modification under the influence of $f(\mathcal{G})$ gravity for usual non-static spherical fluid distributions, we implemented various constraints and obtained analytical solutions. Most of them have distinct physical meanings (for instance, $\mathbb{Y}_{TF} = 0$ or $\sigma = 0$).

We evaluated essential aspects of the complexity definition that discussed in [67]. In the context of $f(\mathcal{G})$ gravity and dissipative system, we set up structure scalar and defined $\mathbb{Y}_{TF}$ as a complexity factor that includes physical characteristics like energy density inhomogeneity, anisotropic pressure and modified terms. These entities reflect the complexity of the system. The work of several relativistic astrophysicists [83–87] emulated the justification for evaluating this type of assumption. Further, we examined anisotropic spherical symmetric solutions with shear-free backgrounds by considering the shear scalar to be zero, i.e., $\sigma = 0$. The aforementioned approach specifies the isotropic relative evolution focus on galaxy structures, although in the presence of a high gravitational background. Moreover, this approach might give rise to an indication of a naked singularity, opposing the widely understood cosmic theories.

We connected two distinct interior and exterior manifolds smoothly over a three-dimensional hypersurface by satisfying Darmois's conditions. If we discuss a non-dissipative system, the pressure gradient has no impact on the boundary. However, in the dissipative system, the radial pressure does not vanish across the hypersurface. The junction conditions specified in Eqs. (33) and (35) can possibly be reduced to a single differential equation. The solution of Eq. (61) generated a function that characterizes spherical symmetry. Further, we assumed shear-free and vanishing complexity factor conditions to evaluate the remaining variables. Under the context of $f(\mathcal{G})$ gravity, we proceeded with the results of models I and II. The physical parameters and positive energy densities have been identified in each model. These densities are singular-free, as are the physical parameters with higher curvature terms, as well as the exception of model I for $t = t_0$. Afterwards, we have examined the case $\varpi = 0$ with condition $\mathbb{Y}_{TF} = 0$ in order to construct the model III. For this model, the areal radius fluctuates between 0 and $2M$ across the boundary. This model's tangential pressure and energy density are homogenous and positive, whereas the pressure in radial direction didn't equal zero due to the extra curvature factors. Further, we studied the scenario $M = 0$. Models IV and V obtained from this particular scenario $M = 0$. They are some sort of "ghost stars", formed through a fluid dispersion that are unable to generate any gravitational pull across the boundary's surface.

Further, to construct the model VI, we assumed that the fluid is dissipative. Also, we applied some constraints ($\mathbb{Y}_{TF} = 0, \sigma = 0$) to diminish the complexity of the system. Next, we evaluated the function $\xi(t)$ from the integration of junction condition (35). Under the influence of $f(\mathcal{G})$ theory, the Eq. (44) permitted us to determine the expression for temperature that contained the notion of relaxation time τ. Further, if $\tau = 0$, it is associated with the steady dissipative case that takes into consideration the thermal evolution of galactic objects, especially the period preceding relaxation. Moreover, we construct models when the vector field is parallel to the four-velocity along with $q = 0$. The Eq. (128) has been integrated for different choices of the parameter. However, we chose $\alpha_1 = 1$ with the approach $\mathbb{Y}_{TF} = 0$ and obtained model VII. The areal radius across boundary expands from 0 to $3M$ in this model. For model VII, the signature of μ depends upon the behavior of extra curvature factors of $f(\mathcal{G})$ theory, and its singularity appears only at $t = t_0$. One can witness it from Eqs. (141)–(143). Moreover, if $\vartheta = 0$ and $\alpha_1 = \frac{1}{2}$, the solution of junction conditions yield model $VIII$. For model $VIII$, the areal radius across hypersurface fluctuates among 0 and $\frac{8M}{3}$. The system's energy density is greater than pressure which is applied in radial direction and is thus positive if $\mathcal{G} < 0$ as one can notice it from Eq. (147). Furthermore, if we consider $M = 0$ and $\alpha_1 = 1$ in Eq. (128), its solution produces the models IX and X. These models depict "ghost stars".

Lastly, for the parallel case, we considered $q \neq 0$. In this scenario, the corresponding values of metric variables are described in Eqs. (162)–(164). The vanishing complexity factor condition is utilized, which yield the Eqs. (168)–(170). Thus, the solution of the junction conditions generated some specific functions, which are expressed in Eq. (188). This case is further characterized by the choice of $\alpha_1 = 2$. This leads to the model XI, which is demonstrated in Eq. (192). In model XI, the total mass has a tendency to be infinite at $t = \infty$. Even though q approaches to zero and μ does not approaches to zero because of the impact of $f(\mathcal{G})$ theory.

Analytical models could provide the prediction of physical events. Based on specific choices of gravity, we could understand the significance of curvature, the interaction of geometry and matter, and the basic properties of gravity itself. These analytical solutions could characterize particular phases for self gravitating objects during the formation of compact bodies. Ultimately, our analytical solutions reduce to GR if we replace the generic function $f(\mathcal{G})$ with the Ricci scalar $\mathcal{R}$.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Utilizing Eq. (10) with Eq. (12), we could modify the Eq. (A2) as

$$4\pi q B + \frac{1}{2A}\left(f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3 + f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4\right) = \frac{1}{3}(\Theta - \sigma)' - \sigma\frac{R'}{R}. \tag{B1}$$

Some terms that are used in Eq. (29) are defined as

$$\mu^{(D)} = \mu + \frac{T_{00}^{(\mathcal{G})}}{A^2}, \quad q^{(D)} = q - \frac{T_{01}^{(\mathcal{G})}}{AB},$$
$$P_r^{(D)} = P_r + \frac{T_{11}^{(\mathcal{G})}}{B^2}, \quad P_\perp^{(D)} = P_\perp + \frac{T_{22}^{(\mathcal{G})}}{R^2}. \tag{B2}$$

Here, the non-zero component for the expression $T_{\lambda\nu}^{(\mathcal{G})}$ is evaluated as

$$T_{00}^{(\mathcal{G})} = \frac{1}{\kappa}\left[\frac{A^2}{2}(\mathcal{G} f_{\mathcal{G}} - f) - f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_1 - f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_2\right],$$
$$T_{01}^{(\mathcal{G})} = -\frac{1}{\kappa}\left[f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_3 + f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_4\right],$$
$$T_{11}^{(\mathcal{G})} = -\frac{1}{\kappa}\left[\frac{B^2}{2}(\mathcal{G} f_{\mathcal{G}} - f) + f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_5 + f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_6\right],$$
$$T_{22}^{(\mathcal{G})} = -\frac{1}{\kappa}\left[\frac{R^2}{2}(\mathcal{G} f_{\mathcal{G}} - f) + f_{\mathcal{G}\mathcal{G}\mathcal{G}}\mathbb{Z}_7 + f_{\mathcal{G}\mathcal{G}}\mathbb{Z}_8\right],$$
$$T_{33}^{(\mathcal{G})} = \sin^2\theta\, T_{22}^{(\mathcal{G})}, \tag{B3}$$

where

$$\mathbb{Z}_1 = \frac{4\mathcal{G}''}{R^2B^4}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2) + \frac{4\dot{\mathcal{G}}}{A^2B^3R^2} \times (A^2B^2\dot{B} - A^2\dot{B}R'^2 + 3B^2\dot{B}\dot{R}^2 + 2A^2\dot{R}R'B' - 2A^2B\dot{R}R'') + \frac{4\mathcal{G}'}{B^5R^2}(A^2B^2B' - 3A^2B'R'^2 + B^2B'\dot{R}^2 + 2A^2BR'R'' - 2B^2\dot{B}\dot{R}R'),$$

$$\mathbb{Z}_2 = \frac{4\mathcal{G}'^2}{B^4R^2}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2),$$

$$\mathbb{Z}_3 = \frac{4\dot{\mathcal{G}}'}{A^2B^2R^2}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2) + \frac{4\dot{\mathcal{G}}}{A^3B^2R^2}(A^2B^2A' + 3A'B^2\dot{R}^2 - A^2A'R'^2 + 2AB\dot{B}\dot{R}R' - 2AB^2\dot{R}\dot{R}') + \frac{4\mathcal{G}'}{A^2B^3R^2}(A^2B^2\dot{B} + B^2\dot{B}\dot{R}^2 - 3A^2\dot{B}R'^2 - 2ABA'\dot{R}R' + 2A^2BR'\dot{R}'),$$

$$\mathbb{Z}_4 = \frac{4\dot{\mathcal{G}}\mathcal{G}'}{A^2B^2R^2}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2),$$

$$\mathbb{Z}_5 = \frac{4\ddot{\mathcal{G}}}{A^4R^2}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2) + \frac{4\dot{\mathcal{G}}}{A^5R^2}(A^2B^2\dot{A} + 3B^2\dot{A}\dot{R}^2 - A^2\dot{A}R'^2 - 2AB^2\dot{R}\ddot{R} + 2A^2A'\dot{R}R') + \frac{4\mathcal{G}'}{A^3B^2R^2}(A^2B^2A' + A'B^2\dot{R}^2 - 3A^2A'R'^2 + 2AB^2R'\ddot{R} - 2\dot{A}B^2\dot{R}R'),$$

$$\mathbb{Z}_6 = \frac{4\dot{\mathcal{G}}^2}{A^4R^2}(A^2R'^2 - A^2B^2 - B^2\dot{R}^2),$$

$$\mathbb{Z}_7 = \frac{4R\ddot{\mathcal{G}}}{A^4B^3}(A^2BR'' - B^2\dot{B}\dot{R} - A^2BR') + \frac{4R\mathcal{G}''}{A^3B^4}(AB^2\ddot{R} - B^2\dot{A}\dot{R} - A^2A'R') + \frac{4R\dot{\mathcal{G}}'}{A^3B^3}(2A\dot{B}R' + 2BA'\dot{R} - 2AB\dot{R}') + \frac{4R\dot{\mathcal{G}}}{A^5B^3}(3B^2\dot{A}\dot{B}\dot{R} + A^2\dot{A}B'R'$$

$$
\begin{aligned}
&- A^2B\dot{A}R'' - A^2\dot{B}A'R' - AB^2\dot{B}\ddot{R} - 2ABA'^2\dot{R}\\
&+ 2A^2BA'\dot{R}' + A^2BA''\dot{R}\\
&- AB^2\ddot{B}\dot{R} - A^2\dot{R}A'B') + \frac{4R\mathcal{G}'}{A^3B^5}\\
&\times (3A^2A'B'R' - B^2\dot{B}\dot{R}A' - A^2BA'R''\\
&+ B^2\dot{A}\dot{R}B' - AB^2B'\ddot{R}\\
&- 2AB\dot{B}^2R' + 2AB^2\dot{B}\dot{R}' - A^2BA''R'\\
&- B^2\dot{A}\dot{B}R' + AB^2\ddot{B}R'),
\end{aligned}
$$

$$
\begin{aligned}
\mathbb{Z}_8 = &\frac{4\dot{\mathcal{G}}^2R}{A^4B^3}(A^2BR'' - B^2\dot{B}\dot{R} - A^2BR')\\
&+ \frac{4R\mathcal{G}'^2}{A^3B^4}(AB^2\ddot{R} - \dot{A}\dot{R}B^2 - A^2A'R')\\
&+ \frac{4R\dot{\mathcal{G}}\mathcal{G}'}{A^3B^3}(2A\dot{B}R' + 2BA'\dot{R} - 2AB\dot{R}').
\end{aligned}
$$

Appendix B: Dynamical analysis

We can formulate the non-zero components of Bianchi identities, $\mathbb{T}^{\lambda\nu}_{;\nu} = 0$, by utilizing the Eqs. (A4)–(A3), which produce

$$
\begin{aligned}
\mathbb{T}^{\lambda\nu}_{;\delta}\mathcal{V}_\lambda = &-\frac{1}{A}\left[\dot{\mu} + 2(\mu + P_\perp)\frac{\dot{R}}{R} + (\mu + P_r)\frac{\dot{B}}{B}\right]\\
&- \frac{1}{B}\left[q' + 2q\left(\frac{A'}{A} + \frac{R'}{R}\right)\right] + \mathcal{W} = 0, \qquad \text{(C1)}
\end{aligned}
$$

where,

$$
\begin{aligned}
\mathcal{W} = &\frac{1}{A}\left\{\frac{-1}{2}(\dot{\mathcal{G}}f_\mathcal{G} + \mathcal{G}\dot{f}_\mathcal{G} - \dot{f}) \right. \qquad (199)\\
&+ \frac{1}{A^2}\left[\frac{\partial}{\partial t}(f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2)\right]\\
&- \left(2\frac{\dot{A}}{A^3} - \frac{\dot{B}}{BA^2} - 2\frac{\dot{R}}{RA^2}\right)(f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2)\\
&- \frac{1}{B^2}\left[\frac{\partial}{\partial r}(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)\right]\\
&- \left(\frac{A'}{AB^2} - \frac{B'}{B^3} + 2\frac{R'}{B^2R}\right)(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)\\
&+ \frac{\dot{B}}{B^3}(f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6)\\
&\left.+ \frac{\dot{R}}{R^3}(f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8)\right\}.
\end{aligned}
$$

$$
\begin{aligned}
\mathbb{T}^{\lambda\nu}_{;\nu}\mathcal{N}_\lambda = &\frac{1}{A}\left[2q\left(\frac{\dot{B}}{B} + \frac{\dot{R}}{R}\right) + \dot{q}\right]\\
&+ \frac{1}{B}\left[\frac{(\mu + P_r)A'}{A} + P_r' + 2\frac{(P_r - P_\perp)R'}{R}\right]\\
&+ \mathbb{W} = 0, \qquad \text{(C2)}
\end{aligned}
$$

where

$$
\begin{aligned}
\mathbb{W} = &\frac{1}{B}\left\{\frac{-1}{2}(\mathcal{G}'f_\mathcal{G} + \mathcal{G}f_\mathcal{G}' - f') - \frac{A'}{A^3}(f_{\mathcal{GGG}}\mathbb{Z}_1 + f_{\mathcal{GG}}\mathbb{Z}_2)\right.\\
&+ \frac{1}{A^2}\left[\frac{\partial}{\partial t}(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)\right]\\
&- \left(\frac{\dot{A}}{A^3} - \frac{\dot{B}}{A^2B} - 2\frac{\dot{R}}{A^2R}\right)(f_{\mathcal{GGG}}\mathbb{Z}_3 + f_{\mathcal{GG}}\mathbb{Z}_4)\\
&- \frac{1}{B^2}\left[\frac{\partial}{\partial r}(f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6)\right]\\
&- \left(\frac{A'}{AB^2} - 2\frac{B'}{B^3} + 2\frac{R'}{B^2R}\right)(f_{\mathcal{GGG}}\mathbb{Z}_5 + f_{\mathcal{GG}}\mathbb{Z}_6)\\
&\left.+ \frac{R'}{R^3}(f_{\mathcal{GGG}}\mathbb{Z}_7 + f_{\mathcal{GG}}\mathbb{Z}_8)\right\}.
\end{aligned}
$$

After utilizing the Eqs. (9), (10), (15) and (16), we achieve

$$
\begin{aligned}
&\frac{1}{3}(P_r + 3\mu + 2P_\perp)\Theta + D_T\mu + ED_Rq\\
&+ \frac{2}{3}\sigma(P_r - P_\perp) + 2q\left(a + \frac{E}{R}\right) - \mathcal{W} = 0, \qquad \text{(C3)}\\
&D_Tq + \frac{2}{3}q(\sigma + 2\Theta) + a(\mu + P_r) + ED_RP_r\\
&+ 2\frac{E}{R}(P_r - P_\perp) + \mathbb{W} = 0. \qquad \text{(C4)}
\end{aligned}
$$

The previous equation might be reduced significantly using the mass function, Eqs. (14), (16) and (A3) can be read as

$$
D_TU = -4\pi P_rR - \frac{m}{R^2} + Ea - \frac{4\pi RT_{11}^{(\mathcal{G})}}{B^2}. \qquad \text{(C5)}
$$

Further, utilizing the factor a from Eq. (C5) into Eq. (C4), we accomplish

$$
\begin{aligned}
D_TU(\mu + P_r) = &-(\mu + P_r)\left[4\pi P_rR + \frac{m}{R^2} + \frac{4\pi RT_{11}^{(\mathcal{G})}}{B^2}\right]\\
&- E\left[D_Tq + 2q\left(\sigma + 2\frac{U}{R}\right) + \mathbb{W}\right]\\
&- E^2\left[\frac{2}{R}(P_r - P_\perp) + D_RP_r\right]. \qquad \text{(C6)}
\end{aligned}
$$

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