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Cylindrically Symmetric Generalized Ghost Pilgrim Dark Energy Cosmological Univers

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Abstract. The solution of the cylindrically symmetric Einstein Rosen universe is investigated and occupied with generalized ghost pilgrim dark energy and matter. To obtain the exact solutions of Einstein's field equations, we discussed the GGPDE model and determined the EoS parameter, Regions of the model to be identified by the $\omega_d - \dot{\omega}_d$ plane analysis , Phantom and quintessence phases to be discussed by state finder, and Stability of the model to be discussed by squared speed of sound. The physical properties of the model are discussed. The results obtained are to be useful with the current observations.

Keywords: phantom, quintessence, Stability, cylindrically, symmetric.

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Introduction

The present challenging problem shows that the universe is expanding rapidly. It is big mystic problem today. Through supernova $I_{a,}$ the expansion phenomenon of the universe was explained by authors (Riess et al. [1]; Permutter et al [2]; Copeland et al. [3]).The Negative pressure of the universe causes e accelerating expansion of the universes caused Dark Energy The galactic curved and structure formation of the universe was explained by the absence of pressure, the dark matter. Several dark energy models have been proposed by many authors which can be characterized by the equation of parameter ω. For fine-tuning there are many cosmological constants are considered for dark energy like holographic (Cohen et al.[4]; Hooft [5]), Pilgrim (Wei [6]), k-essence (Armendariz [7]), h-essence (Wei [8]), phantom (Caldwell [9]), quintom (Guo et al.[10]), quitessence (Ratra e.al., [11]), tachyon (Sen [12]), dilation (Gasperini et al. [13]), and DBIessence (Gumjudpai et al. [14]; Martin et al. [15]) etc.

It is observed the ordinary ghost Dark energy model only the leading term (i.e., H) has been deliberated and sub leading term (i.e, H^2) is introduced by "Cai et al.[16]" in the ordinary ghost

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dark energy it helps to describing early-stage evolution of the universe and the energy density is called generalized ghost dark energy density defined as $\rho_\wedge = a_1 H + b_1 H^2$. The vacuum energy from the Veneziano ghost field in QCD is obtained as H+O(H^2) (Zhitnitsky [17]), it shows the accelerated expansion of the universe. Several authors (Karami [18]; Malekjani [19];) has been developed different cosmological parameters like Eos parameter, deceleration, investigated different, state finder and squared speed of sound, etc. The stability of this type of model has been investigated by authors 'Ebrahimi and Sheykhi [20]'. Therefore, the Generalized Ghost Pilgrim Dark Energy(GGPDE) is defined as (Sharif and Nazir [21]) $\rho_\wedge = \left(\alpha_1 H + \alpha_2 H^2\right)^\beta$.

Vijayashanti et al. [22] studied bianchi type GGPDE and Anisotropic GGPDED respectively. Tazmin[23] studied GGPDE with Sign-Changeable Integration. Sharif et at[24] developed GG-PDE in f(R,T) gravity. Prianka et al. [25] studied GGPDE in Saez-Ballester theory. Wajihajavad et al. [26] studied Interacting GGDE anisotropic scalar field models. Bharali et al. [27] studied dynamics of GGPDE. By the motivation of all the above study of researchers, we studied in this reach article 'cylindrically symmetric GGPDE'. The physical and general properties are also discussed.

1. Metric and field equations

The Einstein Rosen metric is in the form

$$ds^2 = e^{(2A-2B)}\left[dt^2 - dr^2\right] - r^2 e^{-2B} d\psi^2 - e^{2B} dz^2 \tag{1}$$

where A and B are time dependent only and $x^1 = r,\ x^2 = \varphi,\ x^3 = z\ and\ x^4 = t.$

The field equation is

$$R_{ij} - \frac{1}{2} R g_{ij} = -8\pi\left(T_{ij} + \overline{T}_{ij}\right). \tag{2}$$

Since the momentum of energy is conservative

$$\left(T_{ij} + \overline{T}_{ij}\right)_{;j} = 0 \tag{3}$$

Here, R_{ij} is the Ricci tensor, g_{ij} is metric tensor, R is Ricci scalar.

Take $8\pi G = c = 1$.

The EMT for DE and DM are given by

$$T_i^j = diag\,[1,0,0,0]\,\rho_m \tag{4}$$

$$\overline{T}_i^j = diag\,[\rho_d,\ -p_d, -p_d, -p_d] = diag\,[1,\ -\omega_d, -\omega_d, -\omega_d]\,\rho_d \tag{5}$$

where $\rho_m,\ \rho_d$ are ED of DM and DE , p_d is pressure of DM,

The EoS parameter of DE is defined by

$$\omega_d = \frac{p_d}{\rho_d} \tag{6}$$

The ED for dark energy $\overline{T}_i^j$ can be reduced to

$$\overline{T}_i^j = diag\,[1,\ -\omega_d, -\left(\omega_d + \delta\right), -\left(\omega_d + \delta\right)]\,\rho_d \tag{7}$$

Here, δ is skewness parameter deviated from ω_d on y and z axes.

By eqs. (1), (4) and (7) The field eq. (2) can reduced to the following equations

$$\left(\dot{B}\right)^2 = \left(-\omega_d \rho_d\right) e^{(2A-2B)} \tag{8}$$

$$\ddot{A} + \left(\dot{B}\right)^2 = \left(-\left(\omega_d + \delta_y\right)\rho_d\right) e^{(2A-2B)} \tag{9}$$

$$\ddot{A} + \left(\dot{B}\right)^2 - 2\left(\ddot{B}\right) = \left(-\left(\omega_d + \delta_z\right)\rho_d\right) e^{(2A-2B)} \tag{10}$$

$$\left(\dot{B}\right)^2 = -(\rho_m + \rho_d)\; e^{(2A-2B)} \tag{11}$$

$$\frac{1}{e^{(2A-2B)}}\left(\frac{\dot{\dot{A}}}{r}\right) = 0 \tag{12}$$

By the law of conservation for DM and DE can be reduced as

$$\begin{gathered}\dot{\rho_m} + \left(\dot{A} - \dot{B}\right)\left[2 + e^{(-2A+2B)}\right]\rho_m - \;\dot{\rho_d} + \left\{\left(\dot{A} - \dot{B}\right)^{\cdot}\left(2 + (1+\omega_d)\, e^{(-2A+2B)}\right) + \right.\\ \left. + \left(\omega_d + \delta_y\right) r^{-2} e^{2B} + \left(\omega_d + \delta_z\right) e^{-2B}\right\}\rho_d = 0\end{gathered} \tag{13}$$

Here, overhead dot stands for ODE w.r.t t

2. Solution of the filed equations

The filed equations (8)–(12) form is a system of five independent equations with six unknowns A,B , $\rho_d,\ \rho_m,\ \omega_d\ and\ \delta$. The system is initially undetermined. So, we can require extra physical conditions to solve the above equations.
The DM and DE components are

$$\dot{\rho_m} + \left(\dot{A} - \dot{B}\right)\left[2 + e^{(-2A+2B)}\right]\rho_m = 0 \tag{14}$$

$$\dot{\rho_d} = \left\{\left(\dot{A} - \dot{B}\right)^{\cdot}\left(2 + (1+\omega_d)\, e^{(-2A+2B)}\right) + \left(\omega_d + \delta_y\right) r^{-2} e^{2B} + \left(\omega_d + \delta_z\right) e^{-2B}\right\}\rho_d \tag{15}$$

By eq. (12)

$$A = constant = \vartheta(say) \tag{16}$$

By Berman (1983) applying the law of variation for the Hubbles parameter with constant decelerating parameter.
The average scale factor for Einstein–Rosen metric is

$$a = \left(re^{2A-2B}\right)^{\frac{1}{3}} \tag{17}$$

The special Volume V is

$$V = \sqrt{(-g)} = re^{2A-2B} \tag{18}$$

The mean Hubble's parameter H is

$$H = \frac{1}{3}\left(\frac{\dot{V}}{V}\right) = \left(\frac{\dot{a}}{a}\right) = \frac{2}{3}\left(\dot{A} - \dot{B}\right) = \frac{2}{3}\left(-\dot{B}\right) \tag{19}$$

We considered the relation

$$H = \frac{k_1}{(a)^n} \tag{20}$$

where k_1 and n are non-negative constants.

The decelerating parameter is q is

$$q = -\frac{a\,\ddot{a}}{(\dot{a})^2} \tag{21}$$

By Eq. (19) and (20) $\left(\frac{\dot{a}}{a}\right) = H = \frac{k_1}{(a)^n}$, we have

$$\dot{a} = k_1 a^{(1-n)} \tag{22}$$

$$\ddot{a} = k_1^2(1-n)a^{(1-2n)} \tag{23}$$

Using Eqs. (21)–(23), the "q" is reduced to

$$q = n - 1 \quad \text{for } n \neq 0, \qquad\qquad q = -1 \text{ for } n = 0. \tag{24}$$

Using eq. (22), the average scale factor for two conditions obtained as

$$a = (c_1 t + c_2)^{\frac{1}{n}} \quad \text{for } n \neq 0 \tag{25}$$

$$a = c_3 e^{k_1 t} \quad \text{for } n = 0 \tag{26}$$

Where c_1, c_3 are constants and c_2 is integration constants
The ED of GGDE in terms of pilgrim dark energy is defined by (sharif et al. [28])

$$\rho_d = \left(\alpha_1 H + \alpha_2 H^2\right)^{\beta} \tag{27}$$

Where β pilgrim dark energy parameter
The state finder pair {r, s}are defined as (Sahni et al. [39])

$$r = \frac{1}{H^3}\left(\frac{\dddot{a}}{a}\right) \tag{28}$$

$$s = \frac{r-1}{3\left(q - \frac{1}{2}\right)} \tag{29}$$

The state finders represent the distance between CDM to DE model. If (r,s)=(1,0) indicate CDM limit and (r,s)=(1,1) indicate CDM. Also, if r<1 and s>0 represents the region of quintessence and phantom.
Square speed sound is obtained for this model is

$$v^2 = \frac{\dot{p}_d}{\dot{\rho}_d} \tag{30}$$

The stability of background evolution of the model is analyzed based on the sign of Squared speed sound. The (-)ve and (+)ve sign indicates the model is unstable and stable respectively..

$\omega_d - \dot{\omega}_d$ Plane analysis :

By Caldwell and Linder(2005) to estimate the nature of the quintessence scalar field DE model. The model splits into two regions i.e., If ω_d <0, $\dot{\omega}_d$ >0 the region of the model is the throwing region, where as ω_d <0, $\dot{\omega}_d$ <0 the region is the freezing region.

Case (i) : Model for $n \neq 0$ or $q \neq -1$

By Eqs(12), (16), (19) and (25)

$$B = \log\left(c_4(c_1 t + c_2)^{\left(\frac{-3}{2n}\right)}\right) \tag{31}$$

Where c_4 are constants

The metric (1) can be reduced to

$$ds^2 = c_4(c_1t+c_2)^{\left(\frac{3}{n}\right)}\left[e^{(2\upsilon)}\left[dt^2 - dr^2\right] - r^2 d\psi^2\right] - \frac{dz^2}{c_4(c_1t+c_2)^{\left(\frac{3}{n}\right)}} \tag{32}$$

By Eq. (20) and (25)
The Hubble's parameter,

$$H = \frac{k_1}{(a)^n} = \frac{k_1}{(c_1t+c_2)} \tag{33}$$

By eqs. (27) and (33) The ED is

$$\rho_d = \left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{\beta} \tag{34}$$

By Eq. (11) The MD is

$$\rho_m = \frac{c_5}{(c_1t+c_2)^{\left(2+\frac{3}{n}\right)}} - \left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{\beta} \tag{35}$$

Where $c_5 = \dfrac{3c_1}{2ne^{2\vartheta}c_4^2}$
By Eq. (8) and (31) the pressure is

$$p_d = \frac{c_5}{(c_1t+c_2)^{\left(2+\frac{3}{n}\right)}} \tag{36}$$

The EoS parameter is

$$\omega_d = \frac{p_d}{\rho_d} = \frac{c_5}{(c_1t+c_2)^{\left(2+\frac{3}{n}\right)}\left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{\beta}} \tag{37}$$

$$\dot{\omega}_d = \frac{-c_1c_5\left(2+\frac{3}{n}\right)}{(c_1t+c_2)^{\left(3+\frac{3}{n}\right)}\left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{\beta}} + \\ + \frac{c_1c_{5\beta}\left(\frac{\alpha_1k_1}{(c_1t+c_2)^2} - \frac{2\alpha_2{k_1}^2}{(c_1t+c_2)^3}\right)}{(c_1t+c_2)^{\left(2+\frac{3}{n}\right)}\left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{-\beta-1}} \tag{38}$$

The state finder pair { r, s}are defined as

$$r = \frac{1}{H^3}\left(\frac{\dddot{a}}{a}\right) = \frac{(1-2n)(1-n)c_1^3}{n^3k_1} \tag{39}$$

$$s = \frac{r-1}{3\left(q-\frac{1}{2}\right)} = \left[\frac{(1-2n)(1-n)c_1^3 - n^3k_1}{n^3k_1 3\left(n-\frac{3}{2}\right)}\right] \tag{40}$$

Square speed sound is obtained for this model is

$$v^2 = \frac{\dot{p}_d}{\dot{\rho}_d} = \frac{-c_1c_5\left(2+\frac{3}{n}\right)}{(c_1t+c_2)^{\left(3+\frac{3}{n}\right)}\left(\alpha_1 \frac{k_1}{(c_1t+c_2)} + \alpha_2\left(\frac{k_1}{(c_1t+c_2)}\right)^2\right)^{\beta-1}\left(\frac{-c_1\alpha_1k_1}{(c_1t+c_2)^2} - \frac{2c_1\alpha_2{k_1}^2}{(c_1t+c_2)^3}\right)} \tag{41}$$

By Eq. (8)–(10) and (31) we have the Skewness parameter is

$$\delta_y = 0 \tag{42}$$

and

$$\delta_z = \frac{3c_1^2 c_4}{ne^{2\vartheta}(c_1 t + c_2)^{\left(2+\frac{3}{n}\right)}\left(\alpha_1 \frac{k_1}{(c_1 t + c_2)} + \alpha_2\left(\frac{k_1}{(c_1 t + c_2)}\right)^2\right)^\beta} \tag{43}$$

Case (ii) : Model for $n = 0$ or $q = -1$
By Eqs. (12), (16), (19) and (25)
A = constant $= \vartheta$ and

$$B = \mathrm{c}_6 \mathrm{t} + c_7 \tag{44}$$

Where $c_6 = \frac{-3k_1}{2}$ and c_7 is integral constants
The metric (1) can be reduced to

$$ds^2 = e^{-2(\mathrm{c}_6\mathrm{t}+c_7)}\left[e^{(2\upsilon)}\left[dt^2 - dr^2\right] - r^2 d\psi^2\right] - \frac{dz^2}{e^{2\upsilon - 2(\mathrm{c}_6\mathrm{t}+c_7)}} \tag{45}$$

By Eqs.(20) and (25)
The Hubble's parameter

$$H = k_1 \tag{46}$$

By Eqs. (27) and (46) The ED is

$$\rho_d = \left(\alpha_1 k_1 + \alpha_2 (k_1)^2\right)^\beta \tag{47}$$

By Eq.(11) The MD is

$$\rho_m = -c_6^2 e^{2(\mathrm{c}_6\mathrm{t}+c_7-\upsilon)} - \left(\alpha_1 k_1 + \alpha_2 (k_1)^2\right)^\beta \tag{48}$$

By Eq.(8) and (44) the pressure is

$$p_d = -c_6^2 e^{2(\mathrm{c}_6\mathrm{t}+c_7-\upsilon)} \tag{49}$$

The EoS parameter is

$$\omega_d = \frac{p_d}{\rho_d} = \frac{-c_6^2 e^{2(\mathrm{c}_6\mathrm{t}+c_7-\upsilon)}}{\left(\alpha_1 k_1 + \alpha_2 (k_1)^2\right)^\beta} \tag{50}$$

$$\dot{\omega}_d = \frac{-2c_6^3 e^{2(\mathrm{c}_6\mathrm{t}+c_7-\upsilon)}}{\left(\alpha_1 k_1 + \alpha_2 (k_1)^2\right)^\beta} \tag{51}$$

Since $\omega_\mathrm{d}<0$, $\dot{\omega}_d<0$, so the region of the model is freezing region
The state finder pair {r, s} is

$$r = \frac{1}{H^3}\left(\frac{\dddot{a}}{a}\right) = 1 \tag{52}$$

$$s = \frac{r-1}{3\left(q - \frac{1}{2}\right)} = 0 \tag{53}$$

Clearly (r,s)=(1,0) indicate CDM limit so that the state finders represents the distance from CDM to dark energy model.

Square speed sound is obtained for this model is

$$v^2 = \frac{\dot{p}_d}{\dot{\rho}_d} = does\ not\ exist \tag{54}$$

By Eq.(8)–(10) and (44) we have the skewness parameter are

$$\delta_y = 0 \text{ and } \delta_z = 0 \tag{55}$$

Conclusions

We obtained the solution of cylindrically symmetric Einstein Rosen universe with GGPDE & DM. The aim of PDE shows interest as it indicates one of the opinions about the universe due to phantom energy in the late time. The volume of the model does not vanish throughout the evolution of the universe has no singularity. We identified with clearly evidence "q" is time dependent, we also discussed $\bigwedge$ with $\omega_d = -1$. The ω_d–$\dot{\omega}_d$ plane analyzed the throwing and freezing regions. The state finder splits the model into Phantom and Quintessence regions. The squared speed of sound indicates the stability of the universe . Since here ω_d is consistent it represents that the universe is accelerating. The model developed r-s plane possesses the region of Chaplayin gas models. At the end of conclusion, this model favors the PDE phenomenon. The results obtained are to be compatible with the present-day observations.

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Цилиндрически-симметричный обобщенный призрачный странник, темная энергия космологических вселенных

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Аннотация. Решение цилиндрически-симметричной вселенной Эйнштейна Розена исследовано и связано с обобщенной темной энергией и материей призрачного странника. Чтобы получить точные решения уравнений поля Эйнштейна, мы обсудили модель GGPDE и определили параметр EoS. Области модели, которые необходимо идентифицировать с помощью анализа плоскости $\omega_d - dot\omega_d$, Phantom и фазы квинтэссенции, которые будут обсуждаться с помощью средства поиска состояний, и стабильность модели, которая будет обсуждаться посредством квадрата скорости звука. Обсуждаются физические свойства модели. Полученные результаты будут полезны при текущих наблюдениях.

Ключевые слова: фантом, квинтэссенция, стабильность, цилиндрический, симметричный.