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FRW Viscous Cosmological Model with Time Periodically Varying Deceleration Parameter In $\mathbf{f(R,T)}$Gravity

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Abstract. This research paper investigates the dynamics of a Friedmann–Robertson–Walker cosmological model characterized by perfect fluid pressure and barotropic bulk viscous pressure. By obtaining exact solutions to Einstein's field equations with a time-varying periodic deceleration parameter, the study reveals periodic behaviour in most parameters, attributed to the influence of a cosine function in the deceleration parameter. The analysis delves into the physical and dynamical implications of this model, particularly highlighting how negative pressure contributes to the late-time expansion of the universe.

Keywords: bulk viscous fluid, time period, decelerating parameter, accelerating expansion.

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1. Introduction and preliminaries

Recent observational evidence, notably from Riess et al. (1998) [1] confirms that our universe is expanding at an accelerating rate. This accelerated expansion, particularly the "dark energy era"(Weinberg 1998) [2] , presents a significant cosmological puzzle. The driving force behind this acceleration is thought to be a mysterious entity with huge negative pressure. Numerous candidates have been proposed to explain dark energy, including the cosmological constant, quintessence, phantom energy, tachyon fields, and Chaplygin gas (Tegmark et al. 2004 [3]; Padmanabhan et al. 2002 [4]; Bento et al. 2002 [5]; Nojiri et al. 2003 [6]). Another intriguing epoch in the universe's history is the inflationary phase, a period of rapid expansion preceding the radiation-dominated era. Proposed in the early 1980s, inflation addresses shortcomings of the standard Big Bang model (Guth 1981 [7]; Linde 1983 [9], 1994 [8]). While Planck observations have provided constraints on inflationary parameters, direct observational evidence remains elusive. Modified gravity theories offer a compelling framework to explain both early and late-time acceleration. These theories, such as f(R) gravity, Gauss–Bonnet gravity (f(G)), and f(T) gravity, modify Einstein's general relativity. For instance, replacing the Einstein–Hilbert action with a function f(R) of the Ricci scalar R can yield cosmic acceleration. Copeland et al. provide a comprehensive review of f(R) gravity, while Bamba et al. [10]. review dark energy models with early

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inflation and late-time acceleration. Harko et al. (2011) [11] introduced f(R,T) gravity, a modified theory incorporating both the Ricci scalar R and the trace T of the energy-momentum tensor Reddy et al. (2012, 2013) [12, 13] investigated LRS Bianchi type-II and type-III cosmological models within this framework. Santhikumar et al. (2017) [15] studied accelerating cosmological model in f(R,T) gravity. Explaining the current accelerating expansion and the transition from a decelerating past is crucial in cosmological modeling. A varying deceleration parameter offers a mechanism to describe this phase transition in isotropic and anisotropic universe models. The deceleration parameter quantifies the rate at which the universe's expansion slows down. Studies of oscillating universe models with quintom matter demonstrate alternating phases of deceleration and acceleration, with a periodically varying Hubble parameter and keeps positive for time periodic deceleration parameter (TPVDP) (M. Shen and L. Zhao, 2014) [16]. Time periodically varying deceleration parameter models within f(R,T) gravity, investigated by Aktas and A?lin (2017) [17], show vanishing string tension density in a cyclic universe scenario. N. Ahmed and Alamri (2019) [18] suggest that the late-time acceleration could arise from a negative cosmological constant with a TPVDP. Hulka and Singh (2022) [19] find that positive energy density and negative pressure throughout the universe's evolution guarantee late-time expansion. Motivated by these investigations, this paper explores a Friedmann-Robertson-Walker viscous cosmological model with a TPVDP within the framework of f(R,T) gravity. The paper is structured as follows: Section 2: Brief reviews on f(R,T) gravity and its field equations of the model. Section 3: Presents solutions to the field equations. Section 4: Analyzes the physical properties of the model. Section 5: conclusions.

2. Brief reviews on f(R,T) gravity and its field equations of the model

Assuming the universe to be homogeneous and Isotropic, the FRW metric can be written as

$$ds^2 = -dt^2 + a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\left(\mathrm{d}\theta^2 + \sin^2\theta \mathrm{d}\varnothing^2\right)\right] \tag{1}$$

where a(t) is the scale factor of the universe and k $= -1, 0, +1$ represents the model for open, flat and closed universe respectively

The filed Eg. of f(R,T) gravity are driven from Hilbert–Einstein type variational principal by taking the action

$$S = \frac{1}{16k}\left[\int \{f(R,T) + L_m\}\sqrt{-g}\, d^4x\right] \tag{2}$$

where f(R,T) is an orbitrary function of the Ricci scalar "R"."T" is the trace of stress-energy tensor of the matter " T_{ij}" and "L_m" is the matter Lagrangian density

we define the stress energy tensor of the matter as

$$T_{\mathrm{ij}} = \frac{-2}{\sqrt{g}}\frac{\delta(\sqrt{-g}L_m)}{\delta 8^{\mathrm{ij}}} \tag{3}$$

And its trace by T $= 8^{\mathrm{ij}}$ T_{ij} respectively

By Assursing that $L_m$of matter depends only on the metric tensor components 8_{ij} and not on its derivatives, we obtain

$$T_{\mathrm{ij}} = g_{\mathrm{ij}}L_m - 2\frac{\partial L_m}{\partial 8^{\mathrm{ij}}} \tag{4}$$

Now by varying the action " S" of the gravitational field with respect to the metric tensor components g^{ij},we obtain the field equation of f(R,T) gravity as

$$f(R,T)R_{\mathrm{ij}}-\frac{1}{2}f(R,T)g_{\mathrm{ij}}+\left(g_{\mathrm{ij}}\boxdot-\nabla_i\nabla_j\right)f_R(R,T)=8\pi T_{\mathrm{ij}}-f_T(R,T)T_{\mathrm{ij}}-f_T(R,T)\theta_{\mathrm{ij}} \quad (5)$$

$$\text{where } \theta_{\mathrm{ij}}=T_{\mathrm{ij}}+g_{\mathrm{ij}}L_m-2g^{\mathrm{lk}}\frac{\partial^2 L_m}{\partial g^{\mathrm{ij}}\partial g^{\mathrm{lm}}} \quad (6)$$

$$\text{where } f_R=\frac{\delta f(R,T)}{?\mathrm{R}},\ f_{T=}\frac{\delta f(R,T)}{?\mathrm{T}} \text{ and } \boxdot=\nabla^i\nabla_i \quad (7)$$

∇_i is the covariant derivative and T_{ij} is the standard matter energy-momentum tensor derived from Lagrawgian L_m. It may be noted that when f(R,T)≡ f(R) the eq. 5 yields, the field equation of f(R) gravity.

The problem of the perfect fluid described by an energy density ρ, effective pressure and four velocity-u^i is complicated since that is no unique definition of the matter Lagrangian. However, here, we assume that the stress energy tensor of the matter is given below

and the matter Lagrangian can be taken as $L_m=-\overrightarrow{p}$ and we have

$$u^i\nabla_i\nabla_j=0,\ u^iu_j=1 \quad (8)$$

With the use of equation (6) , we obtain for the variation of stress energy tensor of perfect fluid the expression

$$\theta_{\mathrm{ij}}=-2T_{\mathrm{ij}}-\overrightarrow{p}g_{\mathrm{ij}} \quad (9)$$

Generally, the field equations also depends through the tensor θ_{ij}, on the physical nature of the matter field. Hence, in the case of f(R,T) gravity depends on the nature matter source,we obtain serval theoretical models corresponding to each choice of f(R,T)

Assusing

$$f(R,T)=R+2f(T) \quad (10)$$

as a first choice where f(T) is an arbitrary function of the trace of stress-energy of matter.

We get the gravitational field equation of f(R,T) gravity from equation (5) as

$$R_{\mathrm{ij}}-\frac{1}{2}Rg_{\mathrm{ij}}=8\pi T_{\mathrm{ij}}-2f^1(T)T_{\mathrm{ij}}-2f^1(T)\theta_{\mathrm{ij}+f(T)g_{\mathrm{ij}}} \quad (11)$$

Where the prime denotes differentiation with respect to the argument.

If the matter source is a perfect fluid then the field equations become

$$R_{\mathrm{ij}}-\frac{1}{2}g_{\mathrm{ij}}R=8\pi T_{\mathrm{ij}}+2f^1(T)T_{\mathrm{ij}}+\left[2\overrightarrow{p}f^{'}(T)+f(T)\right]g_{\mathrm{ij}} \quad (12)$$

Using co-moving coordinates and particular choice of the function given by (Herko et. al. 2011)

$$f(T)=\mu T,\ \mu \text{ is constant} \quad (13)$$

$$R_{\mathrm{ij}}-\frac{1}{2}8_{\mathrm{ij}}R=8\pi T_{\mathrm{ij}}+2\mu T_{\mathrm{ij}}+\left[2\overrightarrow{p}\mu+\mu T\right]g_{\mathrm{ij}} \quad (14)$$

3. Field equations

Using Equation & we obtain

$$2\frac{\ddot{a}}{a}+\left(\frac{\dot{a}}{a}\right)^2+\frac{k}{a^2}=(8\pi+3\mu)\overrightarrow{p}-\mu\rho \quad (15)$$

$$3\left(\frac{\dot{a}}{a}\right)^2+3\left(\frac{k}{a^2}\right)=-(8\pi+3\mu)\rho+\mu\overrightarrow{p} \tag{16}$$

where an overhead dot denotes differentials with respect to t.

Solution and the Model

From the above two independent field Equations & the field equations are highly non-linear in nature and therefore we use the following placesible physical condition

(i) For baratropic fluid the combined effect of proper pressure and the barotropic bulk viscous pressure can be expressed as

$$\overrightarrow{p}=p-3H=\epsilon\rho \tag{17}$$

$$\text{where } p=\in_0\rho,\quad 0\leqslant\in_0\leqslant 1 \tag{18}$$

(ii) We use the time periodically varying decleration parameter (TPVDP) of the form [16]

$$q=m\,Cos(nt)-1 \tag{19}$$

where m and n are positive constants. This type of deceleration parameter is known as TPVDP. The deceleration parameter play a role in determine the nature of the constructed

models of the Universe i.e decelerating (*or*) accelerating in nature. According to the range values of "q" the universe exhibits the expansion in the following way [20, N.Hulke et.al (2020)], [21, G.P.Singh et.al (2020)].

$q>0$: Decelerating expansion

$q=0$: Expansion with constant rate

$-1<q<0$: Accelerating power law expansions

$q=-1$: Exponential expansion / de sitter expansion

$q<-1$: Super exponential expansion.

From the consideration form of "q" in Eg(20), the deceleration parameter shows periodic nature due to the presence of cos(nt).

The deceleration parameter "q" lies in the interval $-(m+1)\leqslant q\leqslant(m-1)$.

Here we observed that

(i) For m=0, the deceleration parameter q=–1 and the universe exhibits exponential expansion de sitter expansion.

(ii) For m $\in(0,1)$, the deceleration parameter "q" becomes negative and leades to decelerated expansion in the periodic way.

(iii) For m=1, q lies in the interval $[-2,0]$ it indicates that the universe enolves from expension with constant rate to super exponential expansion in a periodic way followed by accelerating power law expansion to de sitter expansion.

(iv) For $m>1$, phase transition taken place from deceleratives phase to accelerations phase in a periodic way where the universe starts will a deceleratives expansion and evolves to super exponential expansion.

By N. Hulke (2022) [19] the following are rang of the parameter m for fixed "n" values.

n	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
Inter of m	$0.34 \leqslant m \leqslant 0.64$	$0.35 \leqslant m \leqslant 0.66$	$0.37 \leqslant m \leqslant 0.69$	$0.39 \leqslant m \leqslant 0.74$	$0.43 \leqslant m \leqslant 0.82$	$0.49 \leqslant m \leqslant 0.94$	$0.59 \leqslant m \leqslant 1.11$	$0.74 \leqslant m \leqslant 1.39$	$1.02 \leqslant m \leqslant 1.93$	$1.70 \leqslant m \leqslant 3.20$

Clearly for n=0.01 & $0.34 \leqslant m \leqslant 0.64$ reshows us $q < 0$ it represent the model is accelerating in nature for n=0.10 & $1.70 \leqslant m \leqslant 3.20$, the model show phase transion from decelerating phase to accelerating phase. Here q is from positive to negative. Hence the complete phase transition scenario of the model is discussed in this range only. In order to obtaion the Hubble parameter from equation we used the relation between Hubble parameter and deceleration parameter on

$$q = \frac{1}{\mathrm{dt}}\left(\frac{1}{H}\right) - 1 \tag{20}$$

Hubble parameter

$$H = \frac{\dot{a}}{a} \tag{21}$$

Deceleration parameter

$$q = \frac{-a\ddot{a}}{\dot{a}^2} \tag{22}$$

By Eq (19) & (21) we have

$$H = \frac{w}{m\mathrm{Sin(nt)} + nl} \tag{23}$$

where "l" is integration constant and we obtain

$$a(t) = c \cdot \exp\left\{\frac{2}{\sqrt{nlm - m^2}} \tan^{-1}\left(\frac{nl\tan\left(\frac{\mathrm{nt}}{2}\right) + m}{\sqrt{nlm - m^2}}\right)\right\} \tag{24}$$

where c is integration constant

$$\mathrm{ds}^2 = -\mathrm{dt}^2 + c^2 \cdot \exp\left\{\frac{4}{\sqrt{nlm - m^2}} \tan^{-1}\left(\frac{nl\tan\left(\frac{\mathrm{nt}}{2}\right) + m}{\sqrt{nlm - m^2}}\right)\right\} \times \times \left[\frac{\mathrm{dr}^2}{1 - kr^2} + r^2\left(\mathrm{d}\theta^2 + \sin^2\theta d\varnothing^2\right)\right] \tag{25}$$

4. Physical properties of the model

Eq (25) represents FRW Viscous fluid model. Using equation (15)–(18) & (23), (24) Density

$$\rho = \left[\frac{1}{\varepsilon - (8\pi + 3\mu)}\right]\left[3\left(\frac{\dot{a}}{a}\right)^2 + 3\left(\frac{k}{a^2}\right)\right] \tag{26}$$

$$\rho = \left[\frac{3}{\varepsilon - (8\pi + 3\mu)}\right]\left[\left(\frac{n}{n\sin nt + nl}\right)^2\right] + + k\left[\mathrm{c} \cdot \exp\left\{\frac{2}{\sqrt{nlm - m^2}} \tan^{-1}\left(\frac{nl\tan\left(\frac{\mathrm{nt}}{2}\right) + m}{\sqrt{nlm - m^2}}\right)\right\}\right]^{-1} \tag{27}$$

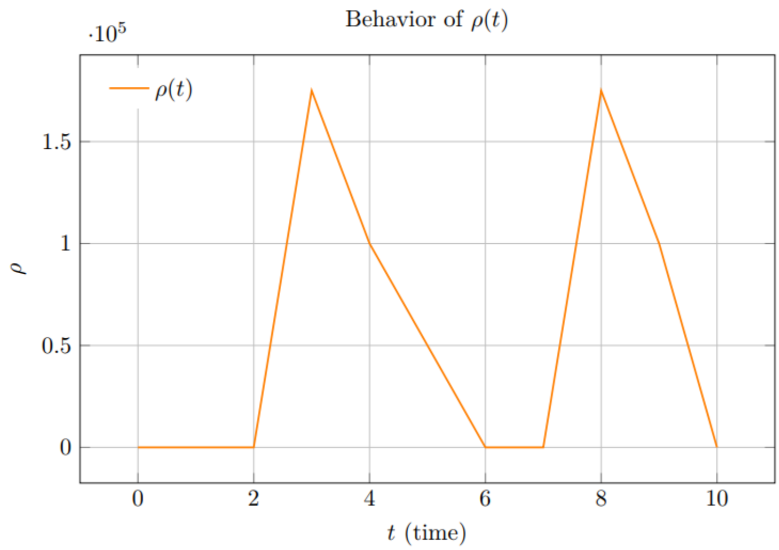

Fig. 1. Energy Density ρ Vs. Time t

The behavior energy density ρ(t) of from the Fig. 1 is the term involving sin(nt) introduces oscillations in the function. The exponential term in the denominator influences the decay or growth, depending on the parameter values. Certain values of t may lead to singularities (e. g., when the denominator of trigonometric terms approaches zero).

Bulk viscour pressure

$$\overrightarrow{p} = \varepsilon\left(\left(\frac{3}{\varepsilon-(8\pi+3\mu)}\right)\left[\left(\frac{n}{n\sin\mathrm{nt}+\mathrm{nl}}\right)^2\right]+ \right. \\ \left. +\,\mathrm{k}\left[c\cdot\exp\left\{\frac{2}{\sqrt{\mathrm{nlm}-m^2}}\tan^{-1}\left(\frac{\mathrm{nl}\tan\left(\frac{\mathrm{nt}}{2}\right)+m}{\sqrt{\mathrm{nlm}-m^2}}\right)\right\}\right]^{-1}\right) \tag{28}$$

Pressure

$$p=\varepsilon_0\rho=\varepsilon_0\left(\left[\frac{3}{\varepsilon-(8\pi+3\mu)}\right]\left[\left(\frac{n}{n\sin\mathrm{nt}+nl}\right)^2\right]+ \right. \\ \left. +\,k\left[\mathrm{c}\cdot\exp\left\{\frac{2}{\sqrt{nlm-m^2}}\tan^{-1}\left(\frac{\mathrm{nl}\tan\left(\frac{\mathrm{nt}}{2}\right)+m}{\sqrt{nlm-m^2}}\right)\right\}\right]^{-1}\right) \tag{29}$$

The Behavior of p(t) from the Fig. 2 is the sine term causes periodic oscillations, which dominate the behavior at certain intervals. The exponential term in the denominator moderates the magnitude of pressure, depending on the constants n, l, m, n. Singularities may arise at specific t values due to the denominators in the equation becoming close to zero.

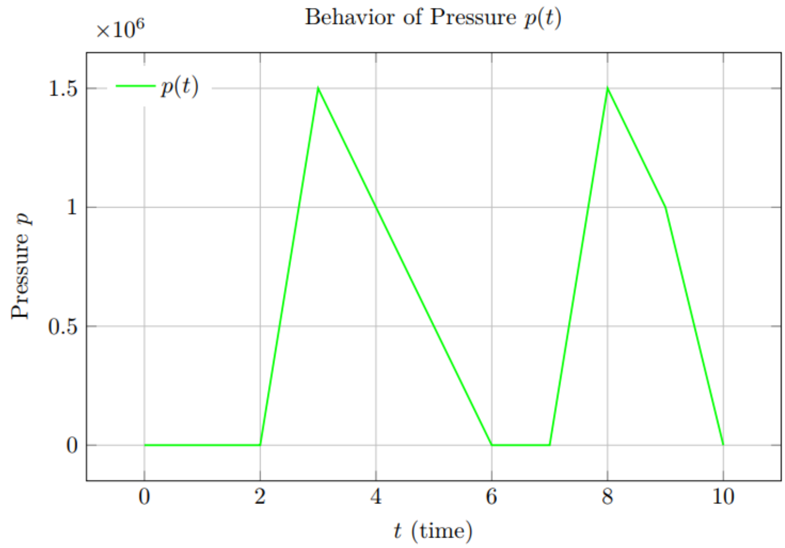

Fig. 2. Pressure p Vs. Time

Bulk viscous coefficient

$$\xi = \left(\frac{p-\varepsilon\rho}{3H}\right) = (\varepsilon_0 - \varepsilon) \times$$
$$\times \left(\frac{\left[\frac{3}{\varepsilon-(8\pi+3\mu)}\right]\left[\left(\frac{n}{n\sin nt+nl}\right)^2\right] + k\left[\mathrm{c}\cdot\exp\left\{\frac{2}{\sqrt{nlm-m^2}}\tan^{-1}\left(\frac{\mathrm{nl}\tan\left(\frac{\mathrm{nt}}{2}\right)+m}{\sqrt{nlm-m^2}}\right)\right\}\right]^{-1}}{3\ \frac{w}{\mathrm{m}\sin(\mathrm{nt})+nl}} \right) \tag{30}$$

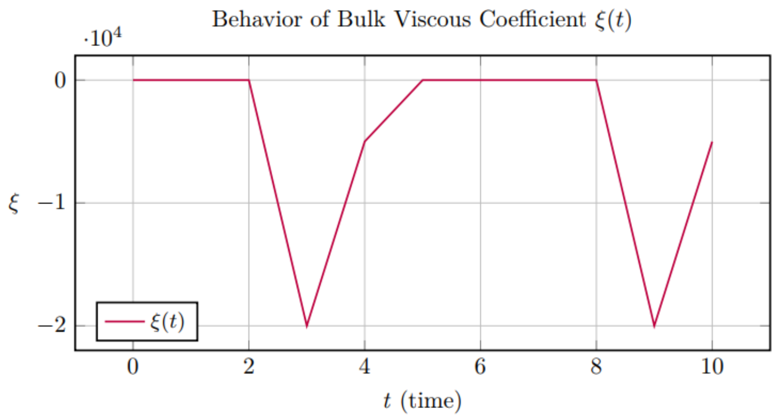

Fig. 3. Bulk viscous coefficient $\xi(t)$ Vs. Time t

The Behaviour of Bulk Viscous Coefficient $\xi(t)$, from the Fig. 3 is the interplay of pressure p , density ρ, and the oscillatory nature of sin(nt) introduces both periodic and nonlinear variations. The denominator msin(nt)+nl may approach zero at specific points, leading to spikes or singularities in $\xi(t)$. The exponential term moderates the coefficient, while the sin(nt) dependent term introduces periodicity.

Now we discuss the physical nature of the universe represented by eq. (26)–(30). In these two cases universe has a finite life time. It starts a Big bang at t=0. The energy density the scale factor of the universe diverse on finite time, so that the universe has a Big**gd** (Caldwel et al., 2003) [22]. Also as $t \longrightarrow \infty$ the energy density, Pressure, the hubbles parameter, Coefficient of Bulk viscous, viscous pressure vanish. It can be seen that the late times the deceleration parameter because negative. So that the universe accelerates which is in accordance with the recent scenario of accelerated expansion of the universe. It may also be observed that the energy density is always positive irrespective of the fact that the curvature k is positive (or) not.

5. Conclusion

This paper investigated a Friedmann–Robertson–Walker cosmological model within the framework of f(R,T) gravity, as formulated by Harko et al. The model incorporates a time-periodically varying deceleration parameter and considers the pressure of a perfect fluid. Exact solutions to the field equations were obtained using the time-periodically varying deceleration parameter proposed by Ming and Lang. A barotropic equation of state relating the metric potential and bulk viscous pressure was employed to obtain a determinate solution. The resulting cosmological model describes a spatially expanding, non-rotating, and non-singular universe. By fixing the constant parameter n, we observed distinct behaviours of the deceleration parameter. For n = 0.01, the deceleration parameter remains negative throughout the universe's evolution, indicating perpetual acceleration. Conversely, for n = 0.10, the universe undergoes periodic transitions between decelerating and accelerating phases. The Hubble parameter was calculated based on the deceleration parameter, reflecting the universe's expansion history. The key findings of this study are: The choice of a time-periodically varying deceleration parameter leads to periodic behavior in almost all cosmological parameters investigated. The model demonstrates the possibility of a universe transitioning between phases of deceleration and acceleration. The specific behaviour of the universe's expansion is sensitive to the choice of model parameters, highlighting the importance of observational constraints. Future work could explore the implications of this model for structure formation, the cosmic microwave background radiation, and the nature of dark energy.

References

[1] A.G.Riess, A.V.Filippenko, P.Challis, A.Clocchiatti, A.Diercks, P. M.Garnavich, et al., Observational evidence from supernovae for an accelerating universe and a cosmological constant, *The Astronomical Journal*, **116**(1998), no. 3, 1009.

[2] S.Weinberg, The cosmological constant problem, *Reviews of Modern Physics*, **61**(1989), no. 1.

[3] M.Tegmark, M.A.Strauss, M.R.Blanton, AK.bazajian, S.Dodelson, H.Sandvik,et al., Cosmological parameters from SDSS and WMAP, *Physical Review D*, **69**(2004), no. 10, 103501. DOI: 10.1103/PhysRevD.69.103501

[4] T.Padmanabhan, Accelerated expansion of the universe driven by tachyonic matter, *Physical Review D*, **66**(2002), no. 2, 021301. DOI: 10.1103/PhysRevD.66.021301

[5] M.C.Bento, O.Bertolami, A.A.Sen, Generalized Chaplygin gas, accelerated expansion, and dark-energy-matter unification, *Physical Review D*, **66**(2002), no. 4, 043507. DOI: 10.1103/PhysRevD.66.043507

[6] S. I.Nojiri, S. D.Odintsov, Modified gravity with negative and positive powers of curvature: Unification of inflation and cosmic acceleration, *Physical Review D*, **68**(2003), no. 12, 123512. DOI: 10.1103/PhysRevD.68.123512

[7] A. H.Guth, Inflationary universe: A possible solution to the horizon and flatness problems, *Physical Review D*, **23**(1981), no. 7, 347.

[8] A.Linde, Hybrid inflation, *Physical Review D*, **49**(1994), no. 2, 748.

[9] A.D.Linde, Chaotic inflation, *Physics Letters B*, **129**(1983), no. 3-4, 177–181.

[10] K.Bamba, S.Capozziello, S.I.Nojiri, S.D.Odintsov, Dark energy cosmology: the equivalent description via different theoretical models and cosmography tests, *Astrophysics and Space Science*, **342**(2011), no. 2, 155–228.

[11] T.Harko, F.S.Lobo, S.I.Nojiri, S.D.Odintsov, f(R, T) gravity, *Physical Review D. Particles, Fields, Gravitation, and Cosmology*, **84**(2011), no. 2, 024020. DOI: 10.1103/PhysRevD.84.024020

[12] D.R.Reddy, R.Santikumar, R.L.Naidu, Bianchi type-III cosmological model in f(R, T) theory of gravity. *Astrophysics and Space Science*, **342**(2012), 249–252. DOI: 10.1007/s10509-012-1158-7

[13] D.R.K.Reddy, SR.anthikumar, T. V.Pradeep Kumar, Bianchi type-III dark energy model in f(R, T) gravity, *International Journal of Theoretical Physics*, **52**(2013), 239–245. DOI: 10.1007/s10773-012-1325-1

[14] D.R.K.Reddy, R.Santhi Kumar, Some anisotropic cosmological models in a modified theory of gravitation. *Astrophysics and Space Science*, **344**(2013), 253–257. DOI: 10.1007/s10509-012-1304-2

[15] R.Santhikumar, B.Satyannarayana, Accelerating anisotropic cosmological model in f(R, T) theory of gravity. *Indian Journal of Physics*, **91**(2017), no. 10, 1293–1296. DOI: 10.1007/s12648-017-1017-z

[16] M.Shen, L.Zhao, Oscillating quintom model with time periodic varying deceleration parameter. C*hinese Physics Letters*, **31**(2014), no. 1, 010401. DOI:10.1088/0256-307X/31/1/010401

[17] C.Akta, S.Aygün, *Curr. Res. Int*, **11**(2017), no. 1.

[18] N.Ahmed, S.Z.Alamri, A cyclic universe with varying cosmological constant in f(R, T) gravity, *Canadian Journal of Physics*, **97**(2019), no. 10, 1075–1082.

[19] N.Hulke, G.P.Singh, B.K.Bishi, Bianchi-I cosmology with generalised Chaplygin gas and periodic deceleration parameter, *Indian Journal of Physics*, **96**(2022), no. 13, 4033–4049. DOI: 10.1007/s12648-022-02315-1

[20] N.Hulke, G.P.Singh, B.K.Bishi, Variable Chaplygin gas cosmologies in f(R, T) gravity with particle creation, *New Astronomy*, **77**(2020), no. 13, 101357.

[21] G. P.Singh, N.Hulke, A.Sing, Cosmological study of particle creation in higher derivative theory, *Indian Journal of Physics*, **94**(2020), no. 1, 127–141. DOI: 10.1007/s12648-019-01426-6

[22] R.R.Caldwell, M.Doran, Cosmic microwave background and supernova constraints on quintessence: concordance regions and target models, *Physical Review D*, **69**(2004), no. 10, 103517. DOI: 10.1103/PhysRevD.69.103517

Вязкая космологическая модель FRW с периодически изменяющимся во времени параметром замедления в $\mathbf{f(R,T)}$гравитации

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Аннотация. В этой исследовательской работе изучается динамика космологической модели Фридмана–Робертсона–Уокера, характеризующейся давлением идеальной жидкости и баротропным объемным вязким давлением. Получая точные решения уравнений поля Эйнштейна с изменяющимся во времени периодическим параметром замедления, исследование выявляет периодическое поведение большинства параметров, приписываемое влиянию косинусной функции в параметре замедления. Анализ углубляется в физические и динамические следствия этой модели, в частности, подчеркивая, как отрицательное давление способствует расширению Вселенной в поздние времена.

Ключевые слова: объемная вязкая жидкость, период времени, параметр замедления, ускоренное расширение.