East European Journal of Physics. **4**. 0–2 (2026)

DOI: 10.26565/2312-4334-2026-4-00 ISSN 2312-4334

BIANCHI V COSMOLOGICAL MODEL WITH STRANGE QUARK MATTER IN $f(R)$ GRAVITY

Neeru Goyal[a], **Anil Kumar Yadav**[b]

[a] *Department of Mathematics, Vidya Bharati Mahavidyalya, Camp, Amravati, 444601, India*

[b] *Department of Mathematics, Rajarshee Shahu Science College, Chandur Rly, Di.Amravati, 444904, India*

[c] *Department of Mathematics, Vidya Bharati Mahavidyalya, Camp, Amravati, 444601, India*

[*] *Corresponding Author e-mail: mathsvbmvpk@gmail.com*

Received May 25, 2024; revised July 7, 2024; accepted December Month XX, 20XX

In this research, we have studied behaviors of quark matter and strange quark matter which exist in f (R) gravity in presence of Bianchi type universe. In order to obtain a deterministic solution, we have considered the scale factor which is a combination of two factors: the one is the usual power law expansion and the second one is an exponential function. Effect of the curvature function f(R) is also observed on dynamical parameters.Finally we discussed our physical solutions.

Keywords: *$f(R)$ Gravity; Quark matter; Strange quark matter; Bianchi V space time*

PACS: 04.50.Kd, 04.20.Jb

1. INTRODUCTION

In this research, we have studied behaviors of quark matter and strange quark matter which exist in f (R) gravity in presence of Bianchi type universe. In order to obtain a deterministic solution, we have considered the scale factor which is a combination of two factors: the one is the usual power law expansion and the second one is an exponential function. ...

2. THE FORMALISM OF *F(R)* THEORY OF GRAVITY

In this research, we have studied behaviors of quark matter and strange quark matter which exist in f (R) gravity in presence of Bianchi type universe. In order to obtain a deterministic solution, we have considered the scale factor which is a combination of two factors: the one is the usual power law expansion and the second one is an exponential function. ...

3. SOLUTIONS OF QUARK MATTER IN $f(R)$ GRAVITY

In this research, we have studied behaviors of quark matter and strange quark matter which exist in f (R) gravity in presence of Bianchi type universe. In order to obtain a deterministic solution, we have considered the scale factor which is a combination of two factors: the one is the usual power law expansion and the second one is an exponential function. ...

4. DISCUSSION AND CONCLUSION

In this research, we have studied behaviors of quark matter and strange quark matter which exist in f (R) gravity in presence of Bianchi type universe. In order to obtain a deterministic solution, we have considered the scale factor which is a combination of two factors: the one is the usual power law expansion and the second one is an exponential function. ...

ORCID

Neeru Goyal, https://orcid.org/0000-0007-0283-0584; **Anil Kumar Yadav**, https://orcid.org/0000-0002-5174-5542

REFERENCES

[1] S. Nojiri, S.D. Odintsov, and V.K. Oikonomou, Physics of the Dark Universe, **29**, 100602 (2020). https://doi.org/10.1016/j.dark.2020.100602.

[2] D. Paul, S. Kalita, and A. Talukdar, International Journal of Modern Physics D, **32**(4), 2350021 (2023), https://doi.org/10.1142/S0218271823500219.

[3] M.I. Khan, S. Qayyum, T. Hayat, M.I. Khan, and A. Alsaedi, "Entropy optimization in flow of Williamson nanofluid in the presence of chemical reaction and Joule heating," International Journal of Heat and Mass Transfer, **133**, 959–967 (2019). https://doi.org/10.1016/j.ijheatmasstransfer.2018.12.168

[4] I. Zehra, M.M. Yousaf, and S. Nadeem, "Numerical solutions of Williamson fluid with pressure dependent viscosity," Results in Physics, **5**, 20–25 (2015). https://doi.org/10.1016/j.rinp.2014.12.002

Cite as: N. Goyal, A.K. Yadav, East Eur. J. Phys. 4, 0 (2026), https://doi.org/10.26565/2312-4334-2026-4-00

© N. Goyal, A.K. Yadav, 2026; CC BY 4.0 license

[5] K. Subbarayudu, S. Suneetha, and P.B.A. Reddy, "The assessment of time dependent flow of Williamson fluid with radiative blood flow against a wedge," Propulsion and Power Research, **9**(1), 87–99 (2019). https://doi.org/10.1016/j.jppr.2019.07.001

[6] A.M. Megahed, "Williamson fluid flow due to a nonlinearly stretching sheet with viscous dissipation and thermal radiation," Journal of the Egyptian Mathematical Society, **27**(1), 12 (2019). https://doi.org/10.1186/s42787-019-0016-y

[7] R.E. Rosensweig, *Ferrohydrodynamics*, (Cambridge University Press, New York, USA, 1985).

[8] H.I. Andersson, and O.A. Valnes, "Flow of a heated ferrofluid over a stretching sheet in the presence of a magnetic dipole," Acta Mechanica, **128**, 39–47, (1998). https://doi.org/10.1007/BF01463158

[9] B.A. Pasha, G. Sowmya, V. Ramachandramurthy, and H.M. Nagesh, "Influence of Heat Source on Thin Film Flow of Ferrofluid Past an Unsteady Stretching Sheet," Journal of Mines Metals and Fuels, **71**(10), 1518–1525 (2023). https://doi.org/10.18311/jmmf/2023/35812

[10] E.E. Tzirtzilakis, "A mathematical model for blood flow in magnetic field," Physics of Fluids, **17**(7), 077103 (2005). https://doi.org/10.1063/1.1978807

[11] M.R.D. Garmroodi, A. Ahmadpour, M.R. Hajmohammadi, and S. Gholamrezaie, "Natural convection of a non-Newtonian ferrofluid in a porous elliptical enclosure in the presence of a non-uniform magnetic field," Journal of Thermal Analysis and Calorimetry, **141**(5), 2127–2143 (2019). https://doi.org/10.1007/s10973-019-09045-3

[12] N.H. Abu-Hamdeh, R.A.R. Bantan, F. Aalizadeh, and A. Alimoradi, "Controlled drug delivery using the magnetic nanoparticles in non-Newtonian blood vessels," Alexandria Engineering Journal, **59**(6), 4049–4062 (2020). https://doi.org/10.1016/j.aej.2020.07.010

[13] N.S. Anagandula, and N.K.S. Reddy, "Velocity and Thermal Slips Impact on the Williamson Fluid Flow above a Stretching Sheet in the Existence of Radiation and Inclined Magnetic Field," CFD Letters, **16**(7), 118–135 (2024). https://doi.org/10.37934/cfdl.16.7.118135

[14] A. Abbas, M.B. Jeelani, A.S. Alnahdi, and A. Ilyas, "MHD Williamson Nanofluid Fluid Flow and Heat Transfer Past a Non-Linear Stretching Sheet Implanted in a Porous Medium: Effects of Heat Generation and Viscous Dissipation," Processes, **10**(6), 1221 (2022). https://doi.org/10.3390/pr10061221

[15] M. Rashid, K. Ansar, and S. Nadeem, "Effects of induced magnetic field for peristaltic flow of Williamson fluid in a curved channel," Physica a Statistical Mechanics and Its Applications, **553**, 123979 (2020). https://doi.org/10.1016/j.physa.2019.123979

[16] M.V. Krishna, and B.V. Swarnalathamma, "Convective heat and mass transfer on MHD peristaltic flow of Williamson fluid with the effect of inclined magnetic field," AIP Conference Proceedings, **1728**, 020461 (2016). https://doi.org/10.1063/1.4946512

[17] A.M. Obalalu, S.O. Salawu, O.A. Olayemi, O.A. Ajala, and K. Issa, "Analysis of hydromagnetic Williamson fluid flow over an inclined stretching sheet with Hall current using Galerkin Weighted Residual Method," Computers & Mathematics With Applications, **146**, 22–32 (2023). https://doi.org/10.1016/j.camwa.2023.06.021

[18] Y.-X. Li, M.H. Alshbool, Y.-P. Lv, I. Khan, M.R. Khan, and A. Issakhov, "Heat and mass transfer in MHD Williamson nanofluid flow over an exponentially porous stretching surface," Case Studies in Thermal Engineering, **26**, 100975 (2021). https://doi.org/10.1016/j.csite.2021.100975

[19] M. Dhivua, and K. Vajravelu, "Heat transfer characteristics of a Williamson fluid flow through a variable porosity regime," International Journal of Ambient Energy, **44**(1), 2553–2568 (2023). https://doi.org/10.1080/01430750.2023.2258378

[20] M.S. Anwar, M.S. Alqarni, and M. Irfan, "Exploring the marvels of heat transfer: "MHD convection at a stagnation point in non-Newtonian fluid with yield stress and chemical reactions," Chinese Journal of Physics, **89**, 1299-1308 (2024). https://doi.org/10.1016/j.cjph.2024.01.030

[21] L.N. Trefethen, *Spectral Methods in MATLAB*, (Oxford University Mathematical Institute, Oxford, United Kingdom, 2000).

[22] D. Srinivasacharya, and K.H. Bindu, "Entropy generation in a micropolar fluid flow through an inclined channel with slip and convective boundary conditions," Energy, **91**, 72–83 (2015). https://doi.org/10.1016/j.energy.2015.08.014

[23] R.A. Alharbey, H. Mondal, and R. Behl, "Spectral Quasi-Linearization Method for Non-Darcy Porous Medium with Convective Boundary Condition," Entropy, **21**(9), 838 (2019). https://doi.org/10.3390/e21090838

[24] H. Mondal, and S. Bharti, "Spectral Quasi-linearization for MHD Nanofluid Stagnation Boundary Layer Flow due to a Stretching/Shrinking Surface," Journal of Applied and Computational Mechanics, **6**(4), 1058–1068 (2020). https://doi.org/10.22055/jacm.2019.30677.1766

[25] N. Rai, and S. Mondal, "Spectral methods to solve nonlinear problems: A review," Partial Differential Equations in Applied Mathematics, **4**, 100043 (2021). https://doi.org/10.1016/j.padiff.2021.100043

[26] W. Al-Kouz, C.S. Reddy, M.S. Alqarni, and B. Mahanthesh, "Spectral quasi-linearization and irreversibility analysis of magnetized cross fluid flow through a microchannel with two different heat sources and Newton boundary conditions," The European Physical Journal Plus, **136**(6), 645 (2021). https://doi.org/10.1140/epjp/s13360-021-01625-3

[27] E.E. Tzirtzilakis, and G.B. Tanoudis, "Numerical study of biomagnetic fluid flow over a stretching sheet with heat transfer," International Journal of Numerical Methods for Heat & Amp Fluid Flow, **13**(7), 830–848 (2003). https://doi.org/10.1108/09615530310502055

[28] H. Muzara, and S. Shateyi, "Magnetohydrodynamics Williamson Nanofluid Flow over an Exponentially Stretching Surface with a Chemical Reaction and Thermal Radiation," Mathematics, **11**, 2740 (2023). https://doi.org/10.3390/math11122740

[29] A. Srinu, K.S. Reddy and N. Amar, "Radiation and inclined magnetic field effects on Williamson fluid flow above a stretching sheet in the existence of velocity, thermal, and concentration slips", Partial Differential Equations in Applied Mathematics, **9**, 100611 (2024). https://doi.org/10.1016/j.padiff.2023.100611

[30] M. Faizan, M. Ajithkumar, M.V. Reddy, M.A. Jamal, B. Almutairi, N.A. Shah, and J.D. Chung, "A theoretical analysis of the ternary hybrid nano-fluid with Williamson fluid model," Ain Shams Engineering Journal, **15**, 102839 (2024). https://doi.org/10.1016/j.asej.2024.102839

[31] T. Salahuddin, and Muhammad Awais, "Thermal and solutal transport by Cattaneo-Christov model for the magnetohydrodynamic Williamson fluid with joule heating and heat source/sink," Heliyon, **10**, e29228 (2024). https://doi.org/10.1016/j.heliyon.2024.e29228

[32] Z. Liu, S. Li, T. Sadaf, S.U. Khan, F. Alzahrani, M.I. Khan, and S.M. Eldin, "Numerical bio-convective assessment for rate type nanofluid influenced by Nield thermal constraints and distinct slip features", Case Studies in Thermal Engineering, **44**, 102821 (2023). https://doi.org/10.1016/j.csite.2023.102821

КОСМОЛОГІЧНА МОДЕЛЬ Б'ЯНЧІ V З ДИВНОЮ КВАРКОВОЮ МАТЕРІЄЮ У f(R) ГРАВІТАЦІЇ

С.М. Варбе[a], **М.С. Паласпагар**[b], **П.П. Хаде**[c]

[a] *Департамент математики, Відья Бхарати Махавідьяля, Кемп, Амраваті, 444601, Індія*

[b] *Департамент математики, Науковий коледж Науковий коледж, Чандур Рлі, Ді.Амраваті, 444904, Індія*

[c] *Департамент математики, Відья Бхарати Махавідьяля, Кемп, Амраваті, 444601, Індія*

Представлено результати комп'ютерного моделювання виходу вторинних нейтронів та протонів при взаємодії протонів з енергією 50 МеВ з легкими ядрами - ^{12}C, ^{14}N та ^{16}O за допомогою кодуTALYS - 1.96 за замовчуванням. Важливість урахування випромінювання вторинних нуклонів: нейтронів та протонів є необхідним елементом при проведенні фундаметально-прикладних ядерних досліджень, таких як дозиметрія та радіаційна безпека. Як результат отримано значення повного перерізу утворення вторинних нейтронів та протонів, що вказують на суттєві відмінності в їх характеристиках від ядра-мішені. Для ядра ^{12}C поріг утворення нейтронів знаходиться в області 20 МеВ. Аналогічна характеристика для ^{14}N лежить в області до 10 МеВ, а для ^{16}O загальний переріз утворення нейтронів становить 17-18 МеВ. Максимальний вихід нейтронів на один падаючий протон спостерігається для ядра ^{16}O. Також було визначено загальний переріз утворення вторинних протонів та їх вихід. Як і у випадку з виходом нейтронів, ядро кисню демонструє найбільшу кількість вторинних протонів на протон, що дорівнює 1,47. Також були отримані розрахункові значення енергетичних спектрів вторинного випромінювання протонів та нейтронів. Максимальна середня енергія вторинних протонів спостерігається для ядра ^{14}N і становить 12,72 МеВ, тоді як для ядер ^{12}C та ^{16}O вона становить близько 10 МеВ. Аналіз спектрів вторинних нейтронів показав, що максимальною середньою енергією володіють нейтрони, що утворюються в результаті взаємодії з ядром азоту, тоді як енергії вторинних нейтронів, що утворюються на ядрах ^{12}C та ^{16}O, приблизно рівні (6,2 та 6,4 відповідно).

Ключові слова: $f(R)$ *гравітація, кваркова матерія, дивна кваркова матерія, простір-час Б'янкі V*