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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Magnetized Strange Quark Matter in Lyra Theory

Lyra Teoride Manyetize Acayip Kuark Madde

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Abstract

In this study, the Kasner universe, which is a homogeneous anisotropic universe, have been discussed. For the Kasner universe, the behavior of magnetized strange quark matter(MSQM) have been examined within the framework of the Lyra theory. The solutions of the field equations in Lyra theory have been obtained and examined with the help of graphics.

Keywords: Kasner metric, Lyra Theory, Magnetized strange quark.

Öz

Bu çalışmada, homojen anizotropik bir evren olan Kasner evreni ele alındı. Kasner evreni için manyetize acayip kuark madde(MAKM) davranışını Lyra teorisi çerçevesinde incelendi. Lyra teorisinde alan denklemlerinin çözümleri elde edilerek grafik yardımıyla irdelendi.

Anahtar kelimeler: Kasner metriği, Lyra Teori, Manyetize acayip kuark madde.

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1. INTRODUCTİON

The formation process of the universe is still being investigated by scientists today. There are many theories that try to explain the formation and evolution of the universe. However, the theory that best explains the evolution of the universe is known as the Big Bang Theory. According to the Big Bang theory, the universe began to expand by exploding from a hot and dense point 13.8 billion years ago. General Relativity Theory (GRT), which best explains the interaction between matter-energy and space-time, was put forward by Albert Einstein. These solutions were largely rejected until the first observational evidence for an expanding universe appeared in 1929. In 1998 and 1999, two independent research groups observed that the universe was expanding at an accelerating pace [1,2,3]. It was thought that dark energy might be responsible for this accelerated expansion. Although GRT tries to explain the universe in general on a large scale, it is insufficient to explain the dark energy that causes the accelerated expansion of the universe. Due to the lack of theoretical motivation, alternative theories have emerged [4,5,6]. In this study have been discussed Lyra theory.

Until about the mid-1900s, cosmic magnetic fields were generally viewed as unimportant. Only a few scientists, such as Biermann, Alfvén, Parker and Chandrasekhar, recognized the potential role of magnetism in the universe [7,8,9,10]. After that time, the magnetic field is thought to have an important place today. Magnetic fields play a crucial role in the physics of the interstellar medium in galaxies, but there are few observational studies of how they evolve over time [11,12].

Quark matter is one of the substances formed immediately after the Big Bang. In this study, Strange Quark Matter, one of the types of quark matter, have been discussed.

Hatkar et al., obtained Kasner solution, in a study they conducted in 2018 [13]. Özcan and Aktaş have studied MSQM in Lyra theory [14]. Kalkan and Aktaş have studied MSQM in $f(R,T)$ theory [15].

In this study, First of all, Kasner solutions are obtained in Lyra theory for MSQM. Then, the solutions will be acquired with the help of the equation of state(EoS) used for SQM. In conclusion, the graphs of the acquired solutions are iscrutinised.

2. MODİFİED FİELD EQUATİON İN KASNER UNİVERSE AND MAGNETİZED SQM

The modified field equations are as follows [4,16]:

$$R_{ik} - \frac{1}{2} g_{ik} R + \frac{3}{2} \phi_i \phi_k - \frac{3}{4} g_{ik} \phi_j \phi^j = T_{ik} \tag{1}$$

Where $R_{ik}, R, g_{ik}, T_{ik}$, and ϕ_i respectively Ricci tensör, Ricci scaler, metric tensör, energy momentun tensör, and displacement vector.

$$\phi_i = (0,0,0,\beta(t)) = \delta_i^4 \, \beta(t) \quad , i \in \{1,2,3,4\} \tag{2}$$

Kasner metric which is homogeneously anisotropic is

$$ds^2 = -dt^2 + t^{2k_1} dx^2 + t^{2k_2} dy^2 + t^{2k_3} dz^2 \tag{3}$$

Here, k_1, k_2, and k_3 are parameters. These parameters ensure

$$k_1 + k_2 + k_3 = s$$

and

$$k_1^2 + k_2^2 + k_3^2 = \theta$$

Parameters k_1, k_2, and k_3 will get be constants. As long as at least two of the three are different, space is anisotropic.

The energy-momentum tensor for MSQM is

$$T_{ik} = \frac{h^2}{2} (2u_i u_k - g_{ik}) + u_i u_k \rho + p(u_i u_k - g_{ik}) - h_i h_k \tag{4}$$

where, h^2 is magnetic field, is energy density [17,18] . with the help of Eq. (1), Eq.(3) and Eq.(4), modified field equations in Lyra theory are obtained as follows:

$$\frac{k_2{}^2}{t^2}+\frac{k_2k_3}{t^2}+\frac{k_3{}^2}{t^2}-\frac{k_2}{t^2}-\frac{k_3}{t^2}+\frac{3\beta^2}{4}=-p+\frac{h^2}{2} \quad (5)$$

$$\frac{k_1{}^2}{t^2}+\frac{k_1k_3}{t^2}+\frac{k_3{}^2}{t^2}-\frac{k_1}{t^2}-\frac{k_3}{t^2}+\frac{3\beta^2}{4}=-p-\frac{h^2}{2} \quad (6)$$

$$\frac{k_1{}^2}{t^2}+\frac{k_1k_2}{t^2}+\frac{k_2{}^2}{t^2}-\frac{k_1}{t^2}-\frac{k_2}{t^2}+\frac{3\beta^2}{4}=-p-\frac{h^2}{2} \quad (7)$$

$$\frac{k_1k_2}{t^2}+\frac{k_1k_3}{t^2}+\frac{k_2k_3}{t^2}-\frac{3\beta^2}{4}=\rho+\frac{h^2}{2} \quad (8)$$

The EoS for strange quark matter is as follows:

$$p=\frac{\rho-4\,B_c}{3} \quad (9)$$

Where, B_c is bag constant [19]. Using Eq.(6) and Eq.(7),

$k_2=k_3$ is obtained. By solving equations (5)-(9) together, the following results are obtained:

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$k_2=k_3$ is obtained. By solving equations (5)-(9) together, the following results are obtained:

$$h^2=-\frac{(k_1+2k_3-1)(k_1-k_3)}{t^2}$$

$$p=-2B_c+\frac{(k_1+2k_3-1)(k_1+k_3)}{2t^2}$$

$$\rho=-2B_c+\frac{3(k_1+2k_3-1)(k_1+k_3)}{2t^2}$$

$$\beta^2=\frac{8}{3}B_c+\frac{4\left(-k_1{}^2+(-2k_3+1)k_1-3k_3{}^2+2k_3\right)}{3t^2}$$

3. CONCLUSION

In this study, the behavior of MSQM for Kasner solutions in lyra theory have been examined. In this section, the graphs for magnetic field, energy density and pressure obtained in section (2) will be examined.

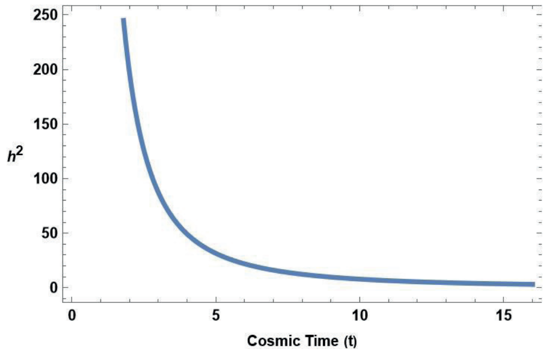

Fig 1. Change of magnetic field with time.

It is seen that the Kasner solutions of the magnetic field decrease over time.

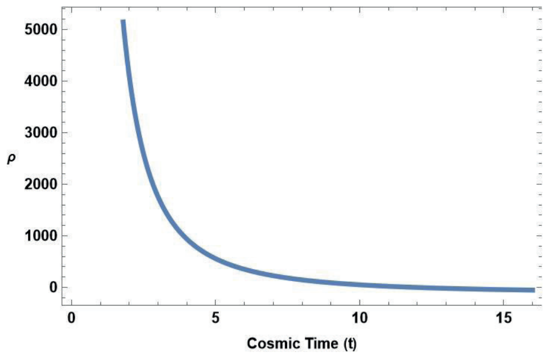

Fig 2. Change of energy density with time.

Density indicates the ratio of energy to volume. At the beginning of the universe, the density was infinite because the energy was concentrated in a region smaller than a point, and as the universe expanded, the density decreased. In this study, energy density has a positive value and decreases over time.

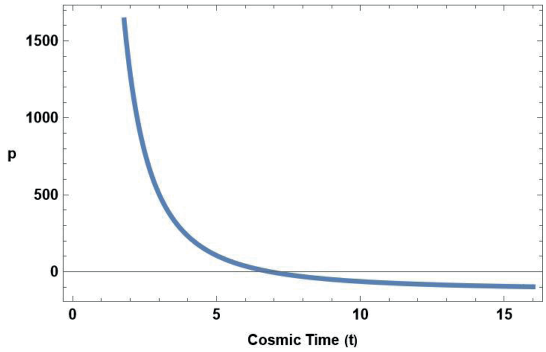

Fig 3. Change of pressure with time.

It has been observed that the pressure initially has a positive value and after a certain time it turns to a final negative value.

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