Evolution of Black Holes and Worm Holes Immersed in Generalized Chaplygin Gas Model

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ABSTRACT

In this paper we obtain analytical solutions of the evolution of mass of black holes and worm holes immersed in generalised Chaplygin gas (GCG) model and calculated the evolution of the mass of black hole and worm hole embedded in a universe filled with GCG. The GCG model represents the unification of dark matter and dark energy of the universe. For the equation of state (EOS) of the dark component in GCG model it is found that the mass of the black hole increases and the mass of the worm hole decreases as the universe expands and both the masses become constant when the dark energy component of the GCG model becomes dominant in universe.

KEYWORDS: Blackholes, Wormholes, Chaplygin Gas Model, Equation of State

I. INTRODUCTION

Recent observations from distant Type Ia supemovae as well as the combination of the anisotropies of the Cosmic Microwave Background Radiation and the mass-energy density estimates from galaxy clusters, weak lensing and large-scalar structure suggest that the universe is going through a phase of accelerated expansion . The cause for the mysterious acceleration is however some-kind of anti-gravitational force with negative pressure. Present observation indicates that about 96% energy density of the universe is dark out of which 73% energy density is for dark energy (DE) and 23% energy density for dark matter (DM). The first evidence for DM stemmed from observations of cluster of galaxies by Zwicky in 1933. From 1970 scientists began to realize that only large amount of dark matter could explain many of their observations. Scientists also realize that the existence of some unseen mass would also support theories regarding the structure of the Universe

Many cosmologists like to select the cosmological constant A, introduced by Einstien in his field equations, as a suitable candidate for dark energy because of its weired repulsive gravity . A number of dynamically evolving scalar field models of dark energy such as Quintessence, K-essence, Tachyon, Phantom etc. are also considered to explain the present accelerated expansion of the universe . Some other models have also been considered such as Quartessence, which proposes a unified fluid with the characteristics of both dark matter and dark energy .

The generalized Chaplygin gas (GCG) model is an interesting candidate for the unification of the dark matter and dark energy **.** In the GCG approach an exotic background duid is considered, described by the following equation of state

$$p_{ch} = -\frac{}{\rho_{ch}^{\alpha}} \qquad (1)$$

where *A* and n are positive constants with 0 < n N 1. The case n = 1 corresponds to the Chaplygin gas. The GCG model has been successfully confronted with many phenomenological tests such as Supernovae data, CMB data etc Regarding the latest supernova data, M. C. Bento et al. have shown that the GCG model is degenerated with a dark energy model involving a phantom like equation of state. They have also shown that GCG can be considered as a unique mixture of interacting dark matter and dark energy and because of the interaction there is a dow of energy from dark matter to dark energy.

II. THE FIELD MODELS AND SOLUTIONS

We start with the Einstein's equations coupled to the baryon, radiation and GCG duids. They read

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -8\pi G\left(T^{b}_{\mu\nu} + T^{r}_{\mu\nu} + T^{ch}_{\mu\nu}\right) \quad (2)$$

Where rb= 0, Tp=0 $T_{ch:p}$=0 (3)

The superscripts (subscripts) *b,r, ch* stand for baryon, radiation and the generalised Chaplygin gas. It is assumed that GCG represents non-relativistic cold dark matter and dark energy i.e. dark component of the universe. We assume a perfect fluid structure for the cosmic medium as a whole and also for each of the components so that
The Friedmann Robertson Walker (FRW) metric for a homogeneous and isotropic flat universe is given by

$ds' \quad -dt' + n'(t)[dr^2 + r^2 d8' + r \sin'8\, dQ^2]$ (4)

where a(t) is the scale factor and t represents the cosmic time.

Within the framework of FRW cosmology, insertion of equation (1) into the relativistic energy conservation equation, leads to an energy-density evolving as

$$\rho_{ch} = \left[A + \frac{B}{a^{3(1+\alpha)}}\right]^{\frac{}{1+\alpha}} \quad (5)$$

where *B* is a constant of integration which should be positive for a well-defined at all times.

From (1) and (5) we get Pressure Density of Chaplygin Gas as

$$p_{ch} = -\frac{Aa'*}{\left[B+Aa^{3(1+\alpha)}\right]^{\frac{\alpha}{1+\alpha}}} \quad (6)$$

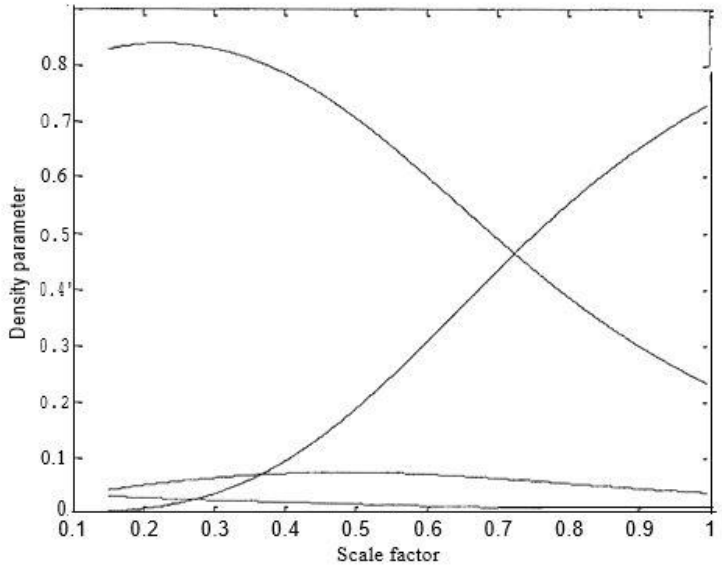
Now, for the entire history of the universe, we should have n›pg N —1. Again, for *mpp* < —1, the GCG behaves as phantom like DE. The DE accretion process for black hole and worm hole for *mf)p* < —1 has already been studied by P.Martin-Moruno . The mass of the black hole in this case decreases and the mass of the worm hole increases as the Hubble parameter increases as the universe expands in this case
. So, in this work, we take the case =*D*» — —1. In this case the energy density *ppp* can be split in a unique way as

$$\rho_{\Lambda} = -p_{\Lambda} = \frac{Aa^{3\alpha}}{\left[B+Aa^{3(1+\alpha)}\right]^{\frac{\alpha}{1+\alpha}}} \quad (7)$$

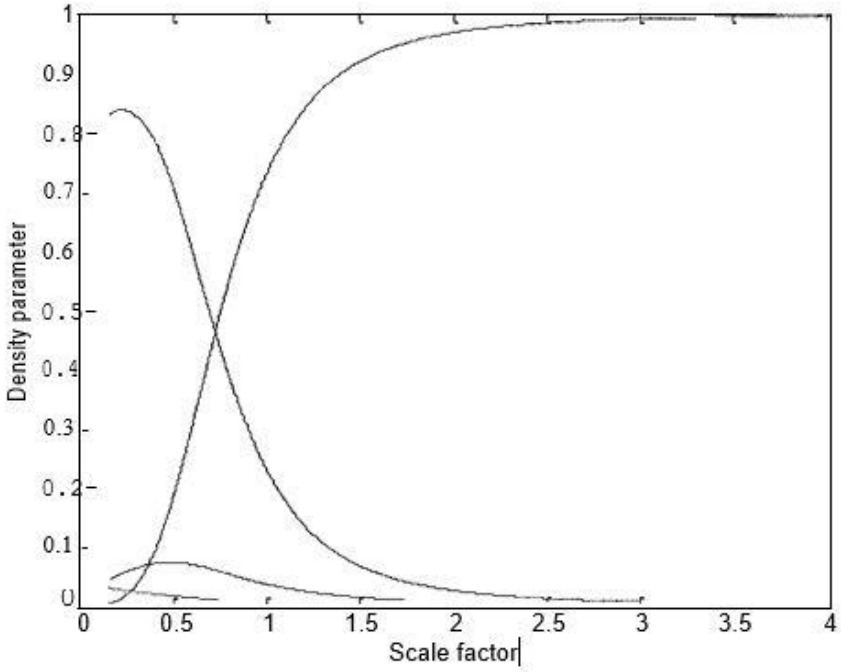
Hence, we obtain a Principal Mathematical Model Relation to plot evolutionary masses

III. Analysis and Mathematical Modelling

In the graph we represent the values of the density parameter of dark energy, dark matter, baryon and radiation respectively. We take the present value of the density parameters as $\tilde{n}_{b\,0}$ = .036, J2pp = .23, Algp —— .73, set it for the graph and a —— 0.2d



From the graph it is seen that the energy is transformed from the dark matter sector to the dark energy sector as the universe expands where the energy transforms from vacuum to matter sector is almost zero in *ACDM* model. Therefore the GCG model is quite different in this case from the *ACDM* model. We assume that no matter of black hole and worm hole is transformed from the dark matter to the dark energy of the universe as black hole and worm hole are not dynamically important for the universe



Again, it is seen from the graph that as the universe expands the dark energy component will dominate the energy density of the universe and the energy density of the dark component becomes constant.

IV. EVALUATION OF MASSES OF BLACKHOLE AND WORMHOLE

For the early universe the Chaplygin gas behaves like a pressure less dark matter due to large densities. Therefore we have for matter dominated universe

$$\rho_{ch} = \rho_{DM} = B^{\overline{1+\alpha}} a^{-3} \qquad \textbf{(8)}$$

As a well-defined mathematical relation

As the universe expands the mass of the black hole increases and the mass of the worm hole decreases as seen from the equations

$$m(t) = \frac{m_i}{1+m_i\sqrt{\frac{8\pi}{3G}}D\left\{\left[\left\{A+Ba^{-3(1+\alpha)}\right\}^{\frac{1}{1+\alpha}}+\rho_{b0}a^{-3}+\rho_{r0}a^{-4}\right]^{\frac{1}{2}}-(\rho_i)^{\frac{1}{2}}\right\}} \qquad (9)$$

$$M\{t\} = \frac{M_i}{1+M_i\sqrt{\frac{8\pi}{3G}}Q\left\{(\rho_i)^{\frac{1}{2}}-\left[\left\{A+Ba^{-3(1+\alpha)}\right\}^{\frac{1}{1+\alpha}}+\rho_{b0}a^{-3}+\rho_{r0}a^{-4}\right]^{\frac{1}{2}}\right\}} \qquad (10)$$

It is clearly evident Hubble parameter decreases as the universe expands. Therefore, the total energy density of the universe decreases as the universe expands. Again since the dark matter is diluted as the large amount of energy transfer from dark matter to dark energy for the evolution of the scale factor and we assume that no matter of black hole and worm hole is transformed from the dark matter to the dark energy of the universe, the mass of the black hole increases and the mass of the worm hole decreases as seen from theequations (9) and (10) obtained above.

In future the generalised Chaplygin gas behaves like a cosmological constant. From the graph it is clear that the dark energy component of the GCG will dominate the total energy density of the universe in future.

V. CONCLUSION

In this work we have seen that in four dimensional, homogeneous and isotropic universe, the mass of black hole increases and the mass of worm hole decreases as the universe expands in GCG model with equation of state ni = —1 with the assumption that no matter of black hole and worm hole is transformed to dark energy. When the energy density of the universe is dominated by the dark energy component of the universe the mass of the black holes and the worm holes become constants. The primordial black holes with maximum mass and worm holes with minimum mass will immerse in such a GCG fluid.

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