Some Scenario of Holographic Dark Energy Interacting with Modified Chaplygin Gas in Five Dimensional Kaluza-Klein Cosmology

9.1 Introduction

Now a days it is strongly accepted that our universe is undergoing an accelerated phase of expansion in the present epoch. Many prominent results of the cosmological observation like Type SNeIa supernovae (Riess), CMB (Cosmic Microwave Background) anisotropies, the large scale structure of the universe(LSS), Baryon Acoustic Oscillations, WMAP (Wilkinson Microwave Anisotropy Probe) Sachs-Wolfe effects and SDSS supports the facts for the cosmic acceleration with direct and the indirect evidence. Not only the above mentioned surveys, some other new cosmological results like Planck, Atacama Cosmology Telescope (ACT), South Pole Telescope Sunyaev-Zel'dovice (SPT-SZ) survey have measured the temperature and polarization of CMB to exquisite precision, are also supporting this fact. Also we know that dark energy (DE) is responsible to produce sufficient acceleration in late time evolution of the universe with positive energy density and negative pressure. Some of the important claimants of DE are tachyons, phantom , k-essence, quintom, quintessence, chaplygin gas, braneworld , holographic DE and new agegraphic DE models along with the other four elements i.e. dark matter, baryons, radiation and nutrinos. But so far there is no direct detection of such exotic fluids. Although the literature is now flooded with hundreds of models of DE, but hitherto, we still know little about the physical nature of the dark energy and till today we are not in a state to provide an exactly clear statement about the origin of the evolution of our universe. When we study different literatures and philosophical point of views we found that different minds provide different opinions about our universe. Due to this reason the most challenging problem to us is to understand the late time acceleration of the universe.

In this connection if we accept that Einstein was correct with his general theory of relativity to explain accelerated expansion of the universe could also be explain by negative pressure working against gravity. The belief of Einstein to the static universe let him to think about negative pressure which will stop the attraction of gravity. However, we know that we have accelerating non static universe. From the above observational data analysis, it can be estimated that the amount of negative pressure in our universe, which we call it as dark energy is still one of the intriguing question and left free space for new speculations.

Several authors have been extensively used Chaplygin gas model in different context on cosmology due to the reason that its predictions are consistent with the observational findings. Also, it gives a unified picture of dark matter and dark energy to discuss new cosmological models in different ways. So it considered as a prospective candidate for dark energy model which was introduced in aerodynamics in 1904. The equation of state for Chaplygin gas is $p = -\frac{A}{\rho}$, where p and ρ are respectively pressure and energy density and A is a positive constant. An extension of this equation of state is generalized Chaplygin gas, a unification of dark energy and dark matter is given by $p = -\frac{A}{\rho^\alpha},\ \alpha \geq 1$. However, observational data is not consistent with this model and so it was extended to modified Chaplygin gas model. The equation of state for modified Chaplygin gas is given by

$$p = A\rho - \frac{B}{\rho^\alpha},\ \alpha \geq 1 \tag{9.1}$$

The problem of dark energy can also be described in the context of holographic principle which states that the number of degrees of freedom of a bounded physical system is finite and related directly to the bounding area of the system which is not scaled by its volume. In recent years, the holographic principle which has its root in quantum gravity is incorporated in cosmology to track the dark energy content of the universe. The idea behind the foundation of holographic principle is that the entropy of a given system doesnot depend upon the volume, but rather on the surface area surrounding it. For the entropy of the universe holographic principle establishes an upper limit. Cohen et al. found that there exists a relationship between an ultraviolet (UV) cutoff and an infrared (IR) cutoff, in a quantum field theory due to the limit set by forming a black hole, so we have $L^3\rho_\Lambda \leq LM_P^2$ where ρ_Λ is the vacuum energy density and $M_p = (8\pi G)^{-\frac{1}{2}}$ is the reduced Planck mass. In cosmological context, the holographic energy density corresponds to the dark energy density. By saturating the inequality and considering the whole universe into action the maximum value of L is obtained such that the holographic energy density is given by $\rho_\Lambda = 3c^2M_P^2L^{-2}$ where c is free dimensionless parameter.

Several authors have studied holographic model for DE on the basis of the holographic principle proposed by Fischler and Susskind. Recently the interaction of holographic DE with or without varying G has been studied in order to explain the current status of the universe. Some authors also studied the interaction between the generalized second law of thermodynamics and holographic DE. In the framework of general relativity Adabi et al. discussed the correspondence between Chaplygin gas scalar field and ghost dark energy model. Using holographic DE model Karami and Fehri found the evolution equation as well as equation of state parameters with Granda and Oliveros cut-off. Jamil et al. also, using Granda-Oliveros cut-off, studied the holographic dark energy model in the framework of Brans-Dicke gravity theory. Pasqua et al. investigated the HDE model using Granda-Oliveros cut-off, modified holographic Ricci dark energy model as well as they investigated a model containing higher derivatives of the Hubble parameter in the context of CS modified gravity. Setare studied the holographic dark energy in FRW universe considering a scalar field which describes the Chaplygin gas cosmology. He discussed holographic dark energy model interacting generalized Chaplygin gas in FRW universe. Chattopadhyay and Debnath discussed the correspondence between holographic dark energy and variable modified Chaplygin gas. Jamil established the correspondence between holographic dark energy and modified variable Chaplygin gas and viscous generalized Chaplygin gas. Naji studied the correspondence between holographic dark energy density interacting generalized cosmic Chaplygin gas model in flat FRW universe. WU et al. considered holographic dark energy as dark energy component and cold dark matter with $\omega_{dm} = 0$ as a unification of generalized Chaplygin gas model. WU et al. studied modified Chaplygin gas as an interacting holographic dark energy model. Sarkar has discussed holographic dark energy model with linearly varying deceleration parameter and generalized Chaplygin gas dark energy model in Bianchi type-I universe. Kiran et al., Reddy et al., have studied Bianchi type minimally interacting holographic dark energy models in Brans-Dicke and Saez-Ballester theories of gravitation. Santhi et al. have investigated LRS Bianchi type-V universe with variable modified Chaplygin gas in Brans-Dicke scalar-tensor theory of gravitation. Rao and Sireesha have studied axially symmetric holographic dark energy model with generalized Chaplygin gas in Brans-Dicke Theory of gravitation. Santhi et al. have discussed spherically symmetric universe with holographic dark energy and generalized Chaplygin gas in Brans-Dicke theory of gravitation. Huang studied the holographic dark energy in spatially closed non-flat universe. Adhav et al. have studied the anisotropic and homogeneous Bianchi type-I universe filled with interacting dark matter and holographic DE. Oliveros and Acero studied the cosmological evolution of a holographic DE model with a non-linear interaction between the DE and dark matter components in FRW type flat universe. Nastase obtained the holographic dark energy model from a cosmological constant generated by generic quantum gravity effects giving a minimum length. Khurshudyan considered the models of the accelerated expanding large scale universe containing a generalized holographic dark energy with a Nojiri-Odintsov cut-off. Setare presented model by extra dimensions built on the DGP brane-world scenario. Ghose et al. in the framework of compact Kaluza-Klein cosmology studied the holographic dark energy interacting generalized Chaplygin gas.

In this modern era we seem that peoples are more interested to study higher dimensional case since, the solutions of Einstein's field equation in higher dimensional space times are believed to be physical relevance possibly at extremely early times before the universe underwent the compactification transition. So it is necessary for us to study the cosmological problems by considering higher dimensional spacetime to unify gravity with other interactions. Witten, Appelquist et al., Chodos and Detweller, and Marciano were attracted to the study of higher dimensional cosmology because it has physical relevance to the early times before the universe has undergone compactification transitions.Kaluza and Klein used an extra dimension to unify gravity and electromagnetism to the usual four dimension spacetime. The idea of five dimension has been used by many authors for studying the cosmological models as well as particle physics. Later two versions of this theory was developed of which one is compact (fifth dimension is lenght like and it is very small) and another is non-compact (fifth dimension is mass like). In non-compact Kaluza-Klein theory we need not to insert matter because the matter is induced in 4D by 5D vacuum theory. In 5D the curvature of spacetime induces effective properties of matter in 4D. Due to unavoidable practical limits it has been difficult to prove the existence of an extra dimension experimentally, but its effect is observed . In multi-dimensional physics and the Kaluza−Klein theory extensive works brought forth the concept of the Universe comprising more than four dimensions, which were large at the early universe stage, but later became too small to be measured experimentally with available data. In higher dimensional RW type of homogeneous cosmological model, the dimensionality has a marked effect on the time temperature relation of the universe and our universe appears to cool more slowly. To establish a relation between dark energy model and Kaluza−Klein cosmology the idea of Holographic Dark Energy has been incorporated. Sharif and Khanum have discussed modified holographic dark energy in Kaluza˘Klein cosmology and evaluated the equation of state parameter as well as the equation of evolution. Darabi studied the non-compact, non-Ricci Kaluza˘Klein theory and coupled the flat universe with non-vacuum states of the scalar field. Sharif and Jawad studied varying G in non-flat Kaluza˘Klein universe with Modified holographic dark energy. In this paper we study some scenario of holographic dark energy interacting with modified chaplygin gas in five dimensional Kaluza−Klein cosmology. We also studied the correspondence between interacting modified Chaplygin gas and holographic phantom. In the next sections we presented the stability of the model with some discussions which will be beneficial for further investigation.

We discuss the field equations and their solutions in the next section. Then we consider the interaction of holographic modified Chaplygin gas in section 9.3 In section 9.4 we studied the correspondence of the holographic phantom interacting Modified Chaplygin gas. In section 9.5 we introduce the squared speed of sound for modified Chaplygin gas. We summarize the physical interpretations of our results in section 6 and the last section is concluding remarks.

9.2 Field equations and their Solutions

The five dimensional Kaluza-Klein cosmology spacetime metric is given by

$$ds^2 = dt^2 - R^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right) + \left(1-kr^2\right)d\psi^2\right] \qquad (9.2)$$

where $R(t)$ is the scale factor and $k = -1, 0, 1$ for the closed, flat and open universe respectively. The Kaluza-Klein universe is filled with perfect fluid having energy-momentum tensor

$$T_{\mu\nu} = (p+\rho)u_\mu u_\nu - pg_{\mu\nu} \qquad (\mu, \nu = 0, 1, 2, 3, 4), \qquad (9.3)$$

where u_μ is the five velocity vector such that $u^\mu u_\mu = 1$, ρ is the density and p is the pressure of the cosmic fluid. The Einstein field equation is

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = kT_{\mu\nu} \qquad (9.4)$$

where $R_{\mu\nu}$ is the Ricci tensor, R is the Ricci scalar.

For flat universe $k = 0$ the Einstein's field equation for the metric (9.2) becomes

$$\rho = 6\frac{\dot{R}^2}{R^2} \tag{9.5}$$

$$p = -3\frac{\ddot{R}}{R} - 3\frac{\dot{R}^2}{R^2} \tag{9.6}$$

where $H = \frac{\dot{R}}{R}$ is the Hubble's parameter. The covariant derivative of five dimensional energy momentum tensor $T^{\mu\nu}_{;\nu} = 0$ yields the continuity equation

$$\dot{\rho} + 4H\left(p + \rho\right) = 0 \tag{9.7}$$

In five dimensions using the equation of state $p = \omega\rho$ the equation of continuity reduces to

$$\dot{\rho} + 4H\rho\left(1 + w\right) = 0 \tag{9.8}$$

We assume that the universe is dominated by two kinds of fluids with total energy density as $\rho = \rho_\Lambda + \rho_m$ where ρ_Λ and ρ_m represent dark energy density and matter density with $w_m = 0$. The continuity equations for interacting dark energy models are

$$\dot{\rho}_m + 4H\rho_m = Q \tag{9.9}$$

$$\dot{\rho}_\Lambda + 4H\rho_\Lambda\left(1 + w_\Lambda\right) = -Q \tag{9.10}$$

where Q is the interaction between dark energy and dark matter.

9.3 Interacting holographic modified Chaplygin gas model:

Let $Q = \Gamma\rho_\Lambda$ be the interaction quantity which denotes the ratio of the energy densities for the two fluids with r, i.e. $r = \rho_m/\rho_\Lambda$ and Γ is the decay rate of modified Chaplygin gas component into Cold Dark Matter (CDM). The effective equation of state parameters are

$$w_\Lambda^{eff} = w_\Lambda + \frac{\Gamma}{4H} \qquad and \qquad w_m^{eff} = -\frac{1}{r}\frac{\Gamma}{4H} \tag{9.11}$$

The continuity equations are given by

$$\dot{\rho}_\Lambda + 4H\rho\Lambda(1 + w_\Lambda^{eff}) = 0 \tag{9.12}$$

$$\dot{\rho}_m + 4H\rho(1 + w_m^{eff}) = 0 \tag{9.13}$$

The Friedmann equation in flat Kaluza-Klein universe in terms of Hubble parameter is

$$H^2 = \frac{1}{6}\left[\rho_\Lambda + \rho_m\right] \tag{9.14}$$

where $M_p^2 = 1$. The density parameters are

$$\Omega_m = \frac{\rho_m}{\rho_{cr}}, \qquad \Omega_\Lambda = \frac{\rho_\Lambda}{\rho_{cr}} \tag{9.15}$$

where $\rho_{cr} = 6H^2$.

In terms of density parameters equation (9.14) becomes

$$\Omega_m + \Omega_\Lambda = 1 \tag{9.16}$$

From equation (9.15) and (9.16) we get,

$$r = \frac{1 - \Omega_\Lambda}{\Omega_\Lambda} \tag{9.17}$$

The equation of state of modified Chaplygin gas is given by

$$p = A\rho - \frac{B}{\rho^\alpha}, \ \alpha \geq 1 \tag{9.18}$$

where ρ and p are the energy density and pressure respectively and A and B are positive constants. The energy density for modified Chaplygin gas in five-dimensional cosmology is given by

$$\rho_\Lambda = \left[\frac{B}{1 + A} + \frac{C}{R^{4(1+A)(1+\alpha)}}\right]^{\frac{1}{1+\alpha}} \tag{9.19}$$

The equation of state parameter ω_Λ are given by

$$w_\Lambda = \frac{p_\Lambda}{\rho_\Lambda} = A - \frac{B}{\rho_\Lambda^{\alpha+1}} = A - \frac{B}{\frac{B}{1+A} + \frac{C}{R^{4(1+A)(1+\alpha)}}} \tag{9.20}$$

$$w_\Lambda^{eff} = A - \frac{B}{\frac{B}{1+A} + \frac{C}{R^{4(1+A)(1+\alpha)}}} + \frac{\Gamma}{4H} \tag{9.21}$$

For a holographic correspondence for modified Chaplygin gas in Kaluza-Klein cosmology the energy density is

$$\rho_\Lambda = 3c^2\pi^2 L^2 \tag{9.22}$$

But in flat Kaluza-Klein Universe the infrared cutoff of the universe L is equal to the apparent horizon (R_a), which coincides with Hubble horizon (R_H). The apparent horizon (R_a) is given by

$$R_a = \frac{1}{H} = R_H = L \tag{9.23}$$

L is defined as $L = Rr(t)$, where R is scale factor and $r(t)$ is relevant to the future event horizon of the universe.

From equations (9.19) and (9.26) we get,

$$L = \frac{H\sqrt{2\Omega}}{c\pi} \tag{9.24}$$

Let us consider the decay rate as

$$\Gamma = 4b^2\left(1+r\right)H \tag{9.25}$$

where b^2 is coupling constant. Using equation (9.15), (9.25) in equation (9.21) we get,

$$w_\Lambda^{eff} = A - \frac{B}{\left(6H^2\Omega_\Lambda\right)^{1+\alpha}} + \frac{b^2}{\Omega_\Lambda} \tag{9.26}$$

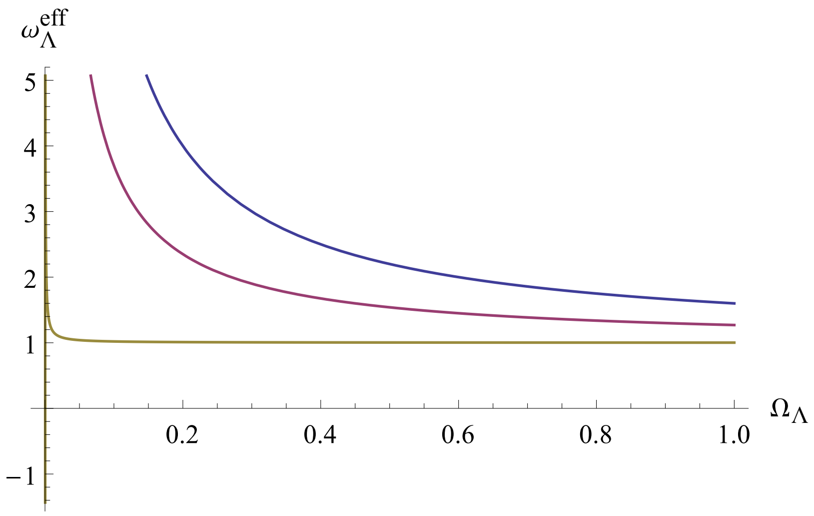

Figure-1 : Variation of ω_Λ^{eff} vs. Ω_Λ , $A = 1$, $B = 1$, $\alpha = 1$ and $b^2 = 0.6$, $b^2 = 0.27$, $b^2 = 0.002$

The correspondence between holographic dark energy and modified Chaplygin gas in Kaluza-Klein cosmology enables us to equate equations (9.23) and equations (9.26), which gives

$$C = R^{4(1+A)(1+\alpha)} \left[\left(3c^2\pi^2L^2\right)^{1+\alpha} - \frac{B}{1+A} \right] \tag{9.27}$$

For Kaluza-Klein Universe we have,

$$\dot{L} = HL - 1 \tag{9.28}$$

By considering the definition of holographic dark energy density ρ_Λ, and using equations (9.24) and (9.28) we get,

$$\dot{\rho}_\Lambda = 2\left(H - \frac{c\pi}{H\sqrt{2\Omega}} \right) \rho_\Lambda \tag{9.29}$$

Substituting this relation in equation (9.10) and using the definition $Q = \Gamma\rho_\Lambda$, we get

$$\omega_\Lambda = -\frac{3}{2} + \frac{c\pi}{2\sqrt{2}H^2\sqrt{\Omega_\Lambda}} - \frac{\Gamma}{4H} \tag{9.30}$$

From equation (9.11) we get,

$$\omega_\Lambda^{eff} = -\frac{3}{2} + \frac{c\pi}{2\sqrt{2}H^2\sqrt{\Omega_\Lambda}} \tag{9.31}$$

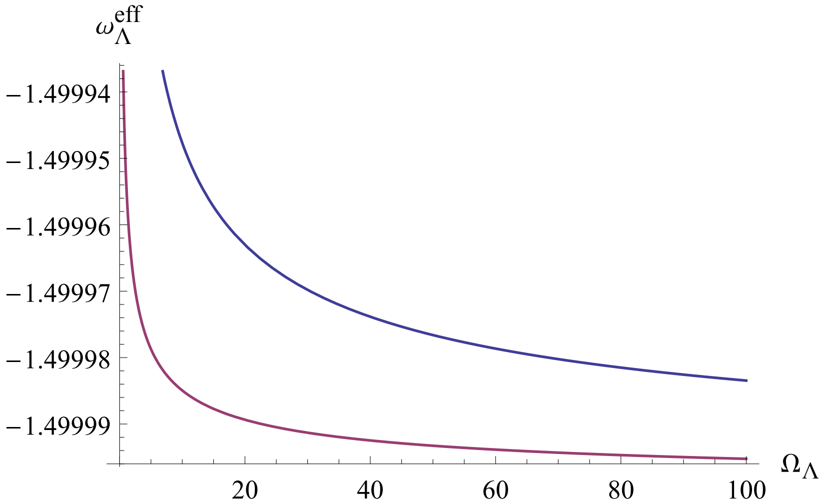

Figure-2 : Variation of ω_Λ^{eff} vs. Ω_Λ, when $c = 0.73$, $c = 0.21$

From equation (9.21) we obtain

$$B = \left(3c^2\pi^2L^2\right)^{1+\alpha}\left[A + \frac{3}{2} - \frac{c\pi}{2\sqrt{2}H^2\sqrt{\Omega_\Lambda}} + \frac{b^2}{\Omega_\Lambda}\right] \tag{9.32}$$

From equation (9.26) we get,

$$C = R^{4(1+A)(1+\alpha)}\left(3c^2\pi^2L^2\right)^{1+\alpha}\left[1 - \frac{1}{1+A}\left(A + \frac{3}{2} - \frac{c\pi}{2\sqrt{2}H^2\sqrt{\Omega_\Lambda}} + \frac{b^2}{\Omega_\Lambda}\right)\right] \tag{9.33}$$

9.4 The correspondence between interacting modified Chaplygin gas and holographic phantom :

The phantom energy density and pressure are given by

$$P\Lambda = \frac{1}{2}\dot{\phi}^2 + V(\phi) \tag{9.34}$$

$$\rho_\Lambda = \frac{1}{2}\dot{\phi}^2 - V(\phi) \tag{9.35}$$

The scalar potential and kinetic energy term are

$$V(\phi) = \frac{1}{2}(1 - w_\Lambda)\rho_\Lambda \tag{9.36}$$

$$\dot{\phi}^2 = (1 + w_\Lambda)\rho_\Lambda \tag{9.37}$$

Differentiating equation (9.14) with respect to cosmic time we get,

$$\dot{H} = \frac{\dot{\rho}}{12H} \tag{9.38}$$

where $\rho = \rho_\Lambda + \rho_m$ is the total energy density.

Now using equations (9.9) and (9.10) we get,

$$\dot{\rho} = -4H(1 + w)\rho \tag{9.39}$$

where

$$w = \frac{w_\Lambda \rho_\Lambda}{\rho} = w_\Lambda \Omega_\Lambda \tag{9.40}$$

Substituting the value of $\dot{\rho}$ in equation (9.38), we obtain

$$w = -\frac{\dot{H}}{2H^2} - 1 \tag{9.41}$$

Using equations (9.40) and (9.41) the holographic energy equation of state is

$$w_\Lambda = -\frac{1}{\Omega_\Lambda}(1 + \frac{\dot{H}}{2H^2}) \tag{9.42}$$

Substituting the value of w_Λ in equations (9.36) and (9.37) we get,

$$V(\phi) = 3H^2(1 + \Omega_\Lambda) + \frac{3}{2}\dot{H} \tag{9.43}$$

$$\dot{\phi}^2 = 6H^2(1 - \Omega_\Lambda) - 3\dot{H} \tag{9.44}$$

9.5 Squared speed of sound in modified Chaplygin gas and stability of the model

The squared speed of sound is defined as

$$v_g^2 = \frac{dp_\Lambda}{d\rho_\Lambda} \tag{9.45}$$

Using equation (9.18) we have,

$$v_g^2 = A + \frac{B\alpha}{\rho^{\alpha+1}} \tag{9.46}$$

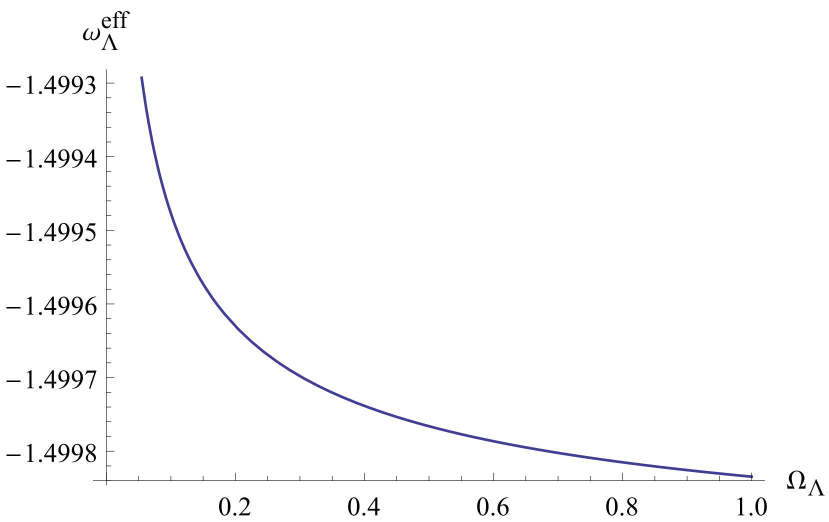

Figure-3 : Variation of v_g^2 vs. ρ, $A = 1$, $B = 1$, $\alpha = 1$

The squared speed of interacting holographic dark energy fluid is as

$$v_\Lambda^2 = \frac{dp_\Lambda}{d\rho_\Lambda} = \frac{\dot{p}_\Lambda}{\dot{\rho}_\Lambda} \tag{9.47}$$

where $\dot{p}_\Lambda = \dot{w}_\Lambda^{eff}\rho_\Lambda + w_\Lambda^{eff}\dot{\rho}_\Lambda$.

Using equation (9.31) we get,

$$\dot{w}_\Lambda^{eff} = -\frac{c\pi}{2\sqrt{2}H^4\Omega_\Lambda}\left[2\Omega_\Lambda H\dot{H} - \frac{c^2\pi^2\dot{H}}{H^3\sqrt{\Omega_\Lambda}}\right] \tag{9.48}$$

where $\dot{\Omega}_\Lambda = -2c^2\pi^2\frac{\dot{H}}{H^5}$.

From equation (9.47) we get,

$$v_\Lambda^2 = w_\Lambda^{eff} - \frac{\dot{w}_\Lambda^{eff}}{4H(1+w)} \tag{9.49}$$

9.6 Physical Interpretations

We have investigated the behavior of holographic dark energy model with the interaction of modified Chaplygin gas by considering five-dimensional Kaluza-Klein universe. Introducing modified Chaplygin gas equation of state with the use of field equations we have calculated energy density and equation of state parameter in terms of scale factor. Here we have provided versatile cosmological discussion through various cosmological parameters and compare some of our results with the recent observational data. The summary of discussion is given below.

• **Interacting holographic modified Chaplygin gas model:** In our model the present value of $\omega_\Lambda^{eff} = -1$ is permitted for the coupling constant namely, $b^2 = 0.27$. Consequently the models with $b^2 < 0.27$ represent DE that behaves like phantom. Since the value of Ω_Λ is different at different epoch accordingly the corresponding value of coupling constant b^2 will change. The variations of w_Λ^{eff} with Ω_Λ clearly shown in the fig no. (1-3) with respect to the equation (9.26). Also, from equation (9.30) we see that the equation of state for the Modified holographic dark energy depends upon Hubble parameter H, dimensionless dark energy density Ω_Λ, the decay rate Γ and positive constant parameter c. But, according to the present status of the universe, it was observed that the value of $H = 1$ and $\Omega_\Lambda = 0.73$ and the observed value of c obtained from observational type Ia supernova is 0.21 and from the combined data of type Ia supernova, X-ray gas and BAO, the value of c is 0.73. Using these values of parameters we find that $\omega_\Lambda \leq -1/3$ for $c = 0.73$ and $\omega_\Lambda < -1$ for $c = 0.21$. From these ranges of the value of ω_Λ describe the accelerating expansion of the universe through dark energy as a driving force. And the holographic dark energy shows the transition from quintessence dark energy era to phantom dark energy era. Interestingly we also obtained the effective equation of state parameter w_Λ^{eff} for modified Chaplygin gas as given in equation (9.31) which satisfies phantom like equation and the variations of ω_{Λ}^{eff} and Ω_{Λ} for the two different values of c i.e. 0.73 and 0.21 are shown in fig. 4 and 5. So, we discussed the correspondence between interacting modified Chaplygin gas and holographic phantom with the construction of scalar potential and Kinetic energy. On the other hand we obtained the values of B and C as in equations (9.32) and (9.33) which are time dependent supporting to the recent studies of Setare.

• **The correspondence between interacting modified Chaplygin gas and holographic phantom :** From the values of scalar potential and kinetic energy are given by equations (9.43) and (9.44) we see that when $\Omega_{\Lambda} = -1$ then $V(\phi)$ is directly proportional to $\dot{H}$ and when $\Omega_{\Lambda} = 1$ then $\dot{\phi}^2$ is proportional to $\dot{H}$.

• **Squared speed of sound in modified Chaplygin gas and stability of the model :** From equation (9.48) we get, $\dot{w}_{\Lambda}^{eff} < 0$ and from equation (9.41) for phantom phase when $\dot{H} > 0$ then $1 + w < 0$, hence we get a negative value for the squared speed of interacting holographic fluid. From this fact the modified Chaplygin gas interacting with holographic fluid is instable. It is fair to claim that the simplicity and reasonable nature of holographic dark energy provide a more reliable framework for investigating the problem of dark dark energy compared with other models proposed in the literature. For instance, the coincidence problem is easily solved in some models of holographic dark energy based on this fundamental assumption that matter and holographic dark energy do not conserve separately, but matter energy density decays into holographic energy density. So finally we want to conclude that the Holographic dark energy is seems to be consistent with recent observational findings but required to constrain this model more precisely with careful study to get a results adapted with experimental observations for the accelerated expansion of the our universe.

9.7 Concluding Remarks

With the study of the correspondence between the holographic dark energy interacting with modified Chaplygin gas in the framework of five dimensional KK universe.

It may be pointed out that the modified Chaplygin gas is a single fluid model which unifies dark matter and dark energy. The modified chaplygin gas model is suitable for obtaining constant negative pressure at low density accomodating late acceleration and a radiation dominating era. Also the value of Eos parameter with modified Chaplygin lies in the acceptable range. So further study on holographic dark energy for the ultimate fate of the universe will be our next publication.