ABSTRACT

Our investigation in this thesis entitled “CHAPLYGIN GAS MODEL AS A COSMOLOGICAL MODEL” consists of nine chapters.

In **Chapter 1**, we discussed about the basic definitions related to standard cosmology, dark energy and Chaplygin gas. We presented the Friedmann Robertson Walker universe and Bianchi type universes and their field equations. We discussed the various types of Chaplygin gas equation of states. The motivation and physical relevance of the investigations presented in the next chapters are described in the light of related work of other authors.

In **Chapter 2**, we investigated the unified model of dark energy and dark matter considering generalized cosmic Chaplygin gas. In presence of perfect fluid we studied the homogeneous anisotropic Bianchi type-I universe with generalized cosmic Chaplygin gas. For large values of the scale factor we have $\rho \cong (C+1)^{\frac{1}{(1+\alpha)}}$ and for this value of ρ we get, $p = -\rho$. We determined the physical quantities such as expansion scalar θ, the mean anisotropy Δ, the shear scalar σ^2 and the deceleration parameter q. In the limit when $t \to \infty$ we found that the value of shear scalar σ^2 tends to zero. Corresponding to the isotropic limit the shear scalar is decreasing function of the cosmic time . We observe that at late time when $t \to \infty$, Δ tends to finite quantity which shows that our model has transition from initial anisotropy to isotropy at present epoch. For large values of the scale factor the deceleration parameter is negative, so our model universe is an accelerating one which supports

the present observational findings that due to the dark energy component the present universe is accelerating. Also we determined the values of the statefinder parameters for the large values of the scale factor which characterizes the properties of dark energy.

In **Chapter 3**, we studied the Bianchi Type-I universe filled with the fluid with equation of state $p = \omega\rho$ as well as generalized cosmic Chaplygin gas simultaneously. At present time t_0 we determined the value of the energy density for generalized cosmic Chaplygin gas. It is observed that for $\omega_0 > -1$, scalar field $\dot{\phi}^2 > 0$, giving positive kinetic energy and for $\omega_0 < -1$, $\dot{\phi}^2 < 0$, giving negative kinetic energy. The values of $\omega_0 > -1$ and $\omega_0 < -1$ represents the case of quintessence and phantom fluid dominated universe respectively. When $t \to 0$, $H^{-1} \to D_0$ and $t \to \infty$, $H^{-1} \to \infty$ and thus in the present case galaxies will not disappear when $t \to \infty$. It is observed that if the fluid behaves like generalized cosmic Chaplygin gas and fluid with equation of state $p = \omega\rho$ simultaneously then the accelerated growth of scale factor of future universe for time $t_0 < t < \infty$ with no future singularity can be obtained.

In **Chapter 4**, we considered within the framework of Friedmann Roberton Walker metric, a model of the universe filled with generalized cosmic Chaplygin gas and another fluid with barotropic equation of state. We observe by considering the mixture of these two fluid models, its role in accelerating phase of the universe valid from the radiation era to ΛCDM for $-1 \leq \omega \leq 1$ and the radiation era to quintessence model for $\omega < -1$. The statefinder parameters describe the evolution of the universe in different phases for these two fluid models. For cosmic acceleration $q < 0$ and since $y > 0$ we get, $x + \omega < -1/3$, where x represents the ratio of fluid pressure to energy density and y represents the ratio of the energy density of the barotropic fluid to that of Chaplygin gas. For different values of ω we get different scenarios. For $-\frac{1}{3} < \omega < \frac{2}{3}$ the Chaplygin gas represents the dark energy and the barotropic fluid represents the dark matter. For $-1 < \omega < -\frac{1}{3}$ the barotropic fluid represents the dark energy. In this case the Chaplygin gas can represent both dark energy or dark matter depending on the values of the other parameters and the ratio of the energy densities of the two fluid. For $\omega < -1$ the model represents phantom energy.

In **Chapter 5**, entitled "Generalized Cosmic Chaplygin Gas Model Interacting in Non-Flat Universe" we studied generalized cosmic Chaplygin gas model to obtain the equation of state of generalized cosmic Chaplygin gas energy density which interacts with cold dark matter in Friedmann-Robertson-Walker non-flat universe. By considering $Q = \Gamma\rho_\Lambda$, where Γ is the decay rate, an interaction between generalized cosmic Chaplygin gas energy density and cold dark matter, we obtained the equation of state for the interacting generalized cosmic Chaplygin gas energy density. Assuming the decay rate $\Gamma = 3b^2(1+r)H$, where b^2 is the coupling constant and r is the ratio of the energy densities, we obtained the effective equation of state parameter. By considering $B < 0$ we get $\omega_\Lambda^{eff} < -1$ which can describe the phantom field interacting generalized cosmic chaplygin gas dark energy and which also supports the latest observational data.

In **Chapter 6**, we discussed the equation of state of generalized cosmic Chaplygin gas to obtain the Chaplygin gas energy density interacting cold dark matter in anisotropic Bianchi Type-I universe. We considered the continuity equations for dark energy as generalized Chaplygin gas and cold dark matter along with the interaction quantity as $Q = \Gamma\rho_\Lambda$, where Γ is the decay rate. We solved the Einstein's field equations and by assuming the decay rate $\Gamma = b^2(1+r)\left(\frac{\dot{V}}{V}\right)$, where b^2 is the coupling constant and r is the ratio of the energy densities, we found the effective equation of state of generalized cosmic Chaplygin gas. When the value of B becomes negative we get $\omega_\Lambda^{eff} < -1$, that corresponds to a universe dominated by phantom dark energy. Also, we determined the value of scalar field ϕ which is negative for negative values of B and corresponds to a phantom field.

In **Chapter 7**, we explored the cosmological solutions of Bianchi type-III universe filled with generalized cosmic Chaplygin gas. To find the solution we used the power law relation between average Hubble parameter H and average scale factor R given by Berman as $H = DR^{-m}$ where, $D > 0$ and $m \geq 0$. We get two models of the universe, i.e. the exponential model and power law model by the assumption of constant deceleration parameter. We investigated the generalized cosmic Chaplygin gas model of the universe for $m = 0$ and for $m \neq 0$ with small and large values of the scale factor. For $m = 0$ the generalized cosmic Chaplygin gas model of the universe with small scale factor is non-singular because exponential function is never zero, so there does not exist any physical singularity. For $m \neq 0$ with small values of the scale factors, the universe exhibits initial singularity. At the initial singularity the physical parameters ρ, p, θ, σ^2 and H tend to infinity whereas these parameters tend to zero as $t \to \infty$. By using sound speed we investigated the stability of the model and in both the cases for $m = 0$ and $m \neq 0$ we get $0 \leq C_s^2 \leq 1$, which shows that the model is completely stable.

In **Chapter 8**, we studied the cosmological solutions of Bianchi type-V universe filled with modified Chaplygin gas within the framework of Lyra's geometry using the relation between average Hubble parameter H and average scale factor R. The assumption of constant deceleration parameter leads to the exponential and power law model. In case of modified Chaplygin gas model of the universe i.e. the exponential model of the universe with small values of the scale factor corresponding to $m = 0$, the model is non-singular and hence there does not exist any physical singularity. The model is isotropic as the values of mean anisotropy parameter Δ and shear scalar σ^2 are zero. For large values of the scale factors, the physical quantities ρ, p and β remain constant and other parameters are same as well for small values of the scale factor. In case of power law model of the universe corresponding to $m \neq 0$ with small values of scale factors, the universe exhibits initial singularity of the point-type at $t = \left(-\frac{a_1}{mD}\right)$. The physical parameters ρ, p and β tend to zero as $t \to \infty$. In this case also the values of mean anisotropy parameter Δ and shear scalar σ^2 are zero which corresponds to the isotropic universe. In both the cases, $0 \leq C_s^2 \leq 1$ from which we can conclude that modified Chaplygin gas models of the universe within the framework of Lyra's geometry are completely stable.

In **Chapter 9**, we studied the correspondence between the holographic dark energy interacting with modified Chaplygin gas in the framework of five dimensional Kaluza-Klein universe. We considered the decay rate as $\Gamma = 4b^2(1 + r)H$ and obtained the effective equation of state parameter. Also we found the values of B and C which are time dependent. We discussed the correspondence between interacting modified Chaplygin gas and holographic phantom with the construction of scalar potential and Kinetic energy. From the values of scalar potential and kinetic energy we observed 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 $\dot{H}$. The modified chaplygin gas model is suitable for obtaining constant negative pressure at low density accomodating late acceleration and a radiation dominating era. Also we have found the value of equation of state parameter with modified Chaplygin lies in the acceptable range.