Chapter 8

Concluding Remarks and Future Aspects

The thesis entitled "A study on Bianchi type-III, VI, IX cosmological models in Sen-Dunn scalar-tensor theory of gravitation" is accordingly concluded in each chapter. The results obtained throughout the research are summarized as follows:

- The first chapter is the introductory part, reviewing Einstein's general theory of relativity, Sen-Dunn's theory of gravity, Bianchi space-time, Dark energy, various cosmological contexts related to the work in this thesis, and the literature review of multiple types of research.

- In the second chapter, the existence of the dark energy model is examined with a unique form of scale factor that exhibits variable deceleration parameters. The dark energy model is obtained by considering Bianchi type-VI_0 space-time in the Sen-Dunn scalar-tensor theory of gravitation, considering some plausible physical conditions. The energy density of the model is characterized as a positively decreasing function of time, and the EoS parameter signifies the existence of dark energy. Also, the statefinder parameter suggests that the model approaches the ΛCDM model. Finally, the expression of the cosmological parameters is presented and analyzed, which is compatible with the present observational results.

- In the third chapter, the effect of bulk viscous nature in the cosmos is presented for the anisotropic Bianchi type-IX space-time. The behaviour of the isotropic pressure, effective pressure and the energy density for the model tends to zero as time increases. The coefficient of bulk viscosity is physically compatible with all three conditions. The deceleration parameter is always negative, representing the accelerating universe and attaining the fastest expansion rate at $q = -1$. The energy conditions for the viscous model are all satisfied throughout the universe's evolution. The model gradually approaches the ΛCDM model.

- In the fourth chapter, the dynamical behaviour of the dark energy with negative pressure is observed, taking an electromagnetic field into account for the Bianchi type-VI_0 cosmological model. The deceleration parameter shows the transit from a positive to a negative phase, indicating the early decelerated to accelerated expansion of the universe. The electromagnetic field for the model decreases with time and the negative pressure well indicates the presence of dark energy in the model. The violation of the SEC also states that the dark energy component exhibits the universe's acceleration. The EoS parameter and the statefinder parameter represent the ΛCDM model favouring the dark energy paradigm.

- In the fifth chapter, the behaviour of the energy density, isotropic pressure, effective pressure and the bulk viscosity coefficient are discussed considering the bilinear varying deceleration parameter for Bianchi type-III model in Sen-Dunn theory. The universe's expansion in the derived cosmological model evolves from the initial singularity and follows the standard big-bang model. The deceleration parameter shows the signature flip property. Thus indicating the transit from early decelerating to the present accelerating universe. The model's energy density, pressure, expansion scalar, and shear scalar tend to be zero for a large time. The bulk viscosity of the universe decreases in the late times and sustains the anisotropic nature throughout its evolution. The model of the universe also approaches the ΛCDM model.

- In the sixth chapter, another form of bilinear varying deceleration parameter is considered to study Bianchi type-IX space-time in the presence of an electromagnetic field. The model does not tend to isotropy for large values of time in the presence of the magnetic field. The exponential expansion is observed for the values of $\alpha > 0$, and for $\alpha > 1$ indicates the super-exponential expansion. The energy density, expansion scalar, and shear scalar tends to zero in the presence of a magnetic field with negative pressure.The energy condition shows phantom model characteristics that might co-exist in the large-scale universe.

- In the seventh chapter, the Bianchi type-III model with a time-dependent deceleration parameter presents the accelerating universe. The model is expanding, shearing, non-rotating and anisotropic throughout the evolution admitting initial singularity at $t = 0$. The energy density, pressure, and expansion scalar tend to zero, indicating an empty space in the late times in the presence of the magnetic field. The current model derived in this chapter also approaches the standard ΛCDM model as characterised by the state-finder parameter.

The result of this thesis illustrates the expansion of the universe from deceleration to acceleration. The cause of the universe's acceleration is well reflected due to the existence of dark energy. The vacuum energy or the cosmological constant may be taken into account that contributes to the existence of dark energy, which serves the cosmic acceleration. Also, it can be observed from the study that the early universe was highly viscous than at late times. The mathematical models acquired in this research mostly approaches the standard ΛCDM model, which is in good agreement with the recent astronomical observation. Furthermore, the observed cosmological parameters for the models obtained in this research are well-acknowledged of the universe's behaviour and ultimate destiny.
As per the scope of the study, some of the future aspects that can be carried out are:

- To investigate the cosmic evolution of the universe with another model of Bianchi Type space-time in the Sen-Dunn scalar-tensor theory of gravitation. As here only three type of Bianchi Type space-time is considered to study the cosmological model of the universe.

- Further study on higher dimensional space-time considering various cosmological contexts in Sen-Dunn's theory of gravitation may derived different physical properties of the cosmological model of the universe.

- Also, further study of anisotropic Bianchi Type cosmological models with other alternate theories of gravitation can be carried out to understand the cosmic evolution.