

CHAPTER-9

CONCLUSIONS AND FUTURE DIRECTIONS

The methodologies, works and results compiling this thesis offer our continuous efforts to understand various equilibrium electromagnetic characteristics, low-frequency wave phenomena and gravito-electrostatic interplay mechanisms prevailing in inhomogeneous self-gravitating astrophysical plasmas in different situations. We apply all the possible procedures, including both perturbative and nonperturbative techniques, to investigate the fluctuations and instabilities supported in such self-gravitationally confined systems in a wide-range of new parameter windows. Our findings may be helpful for understanding the propagation of gravito-electrostatic waves and instabilities in interstellar dense media in different realistic situations comprehensively. In addition, the analytical, numerical and graphical techniques may be exploited further to get in-depth microphysics and insights behind material transportation through gravito-electrostatic instabilities leading to fragmentation of molecular clouds into substructures, galactic units and other astrophysical object formation mechanisms. The main results drawn from the thesis works are concisely presented as follows.

1. We study the basic electromagnetic characteristics of inhomogeneous self-gravitating astrophysical clouds with the help of a new technique based on the modified Lane-Emden equation (m -LEE) of polytropic configuration. The multi-order extremization of the m -LEE solutions specifies the cloud surface boundary (CSB) existence at a radial point 8.58×10^{12} m relative to the cloud centre. It is shown that the CSB gets biased negatively due to the interplay of plasma-boundary wall interaction (global) and plasma sheath-sheath coupling (local) processes. Diversified application of our technique to neutron stars, other observed DMCs and double layers is presented with highlighted future scopes significant to other self-gravitating systems too.
2. We formulate exact non-local linear analysis for identifying the global gravito-electrostatic modes, discrete oscillations and associated instabilities in interstellar charged dust molecular cloud (DMC) sphere with mass-radius above the critical values. The realistic effects like equilibrium inhomogeneities, diverse gradient forces and dust flow-convection dynamics are

included in the analysis. We see that the entire cloud supports spectrally heterogeneous mixture of the Jeans and electrostatic modes. It is shown that the lowest-order non-rigid diffused cloud surface boundary (CSB) is the most unstable interfacial layer due to enhanced coupling strength of bipolar electrostatic repulsion and unipolar self-gravitational attraction. Three distinct and spatio-spectrally isolated classes of global eigenmodes-dispersive, nondispersive and hybrid types-are identified and characterized together with prolific features. Dispersive features are found prominent in the ultra-high k -regime; whereas, non-dispersive characteristics in the ultra-low k -regime. Numerical illustrations demonstrate that the grain-charge plays destabilizing influential role for the electrostatic fluctuations, but stabilizing role for the self-gravitational counterparts. In contrast, the grain-mass plays stabilizing influence for the former, but destabilizing influence for the latter. The results can be useful to realize complex nonlocal astrophysical fluctuations from a new perspective of plasma-wall interaction philosophy.

3. We investigate new spatiotemporal features of the excitation-evolution mechanism of gravito-electrostatic eigenmodes in self-gravitating astrophysical clouds by using both perturbative (multiscale analysis) and non-perturbative (Sagdeev pseudo-potential method) techniques. We use hydrodynamic fluid model to study the fluctuations excited in such clouds under different realistic conditions on the Jeans scales. The analytical and numerical analyses reveal that the fluctuations evolve as shocks, and solitons-like patterns. The work highlights on their formation mechanisms, distinctive features, and their tentative astrophysical applicability leading to prestellar cores, and other galactic unit formation mechanism. The exact results obtained in the investigations can rigorously be applied to explain diverse multispace satellite observations and experimental predictions made by others in space and astrophysical environments.
4. We methodologically study the various conserved quantities associated with the astrophysical clouds fluctuations governed by a KdV system. All the relevant classical conserved quantities associated with the constructed KdV system under translational invariance are analytically derived and numerically analyzed. It is found that the solitary mass, momentum and energy densities also evolve like solitary spectral patterns, but with different characteristic features, which remain conserved throughout the spatiotemporal scales of the concerned fluctuation dynamics.

5. The gravito-electrostatic fluctuation spectral patterns exist in a number of explored clouds, which have been testified by various spacecraft instrumentations, on-board multi-space satellite reports and experimental findings. Examples of such clouds are *Lynds 204 Complex*, *Barnard 68*, and so forth. The methodological analysis may also be extensively applied to study the observed data on the dynamics of jets and associated bow shocks on the galactic scales as observed in certain galaxies like M51, NGC 1068, NGC 5258, Circinus, Mrk 673, and so forth.

Finally, we would like to include some suggestions for future works. We have studied various equilibrium electromagnetic characteristics, low-frequency wave phenomena and gravito-electrostatic interplay mechanisms prevailing in inhomogeneous self-gravitating astrophysical plasmas in different situations, but under field-free conditions. One can rigorously extend the presented works by considering the effect of inhomogeneous magnetic field and thermal forces to get more realistic results. The adopted mathematical and numerical strategies may, however, be extended for further exploration on the gravito-electrostatic fluctuation dynamics with more necessary complications, such as grain rotations, full collisions, different inhomogeneous gradient forces, viscosity, grain-size distribution, diffusion, and so on, taken into account in different astrophysical and space environments.