Abstract

The plasma is a unique state of matter rich in various collective waves, fluctuations and oscillations. The long-range interaction forces among the constituent species in any plasma system are responsible for exhibiting the plethora of collective phenomenological pattern formations both in equilibrium as well as in perturbation. The physical insights behind such phenomenological patterns are not fully understood so far to the best of our knowledge. The thesis presented here is motivated and driven by all those perspectives previously remaining unaddressed and unexplored. This compilation focally aims to describe a couple of new problems on plasma equilibrium and perturbation dynamics from a new realistic hydrodynamic continuum viewpoint extending from the laboratory confinement scales (Debye) to the astrophysical fluid scales (Jeans) of space and time.

*In **Chapter-1**, we briefly present an introductory overview of plasmas prevalent in diversified situations: laboratory to astrophysical scales. The different pattern formation and evolutionary structurization prevailing in such plasmas both in equilibrium and perturbation are briefed. The first part deals with the plasma sheath on laboratory scales and its applicability in gravito-electrostatic sheath (GES) on the Jeans scales of space and time. Similarly, the second part emphasizes on the nonlinear evolution of wave structural properties in dust molecular clouds (DMCs) of infinite spatial extension. Finally, the third part gives an overview of the solar plasma and associated evolutionary dynamics on the gravitational spatiotemporal scales.*

*In **Chapter-2**, we procedurally formulate a classical hydrodynamic model to see the equilibrium properties of planar plasma sheath in two-component magnetized bounded plasma on the laboratory scales of space and time. It incorporates the weak but finite electron-inertia instead of asymptotically inertialess electrons against the conventional scenarios. The effects of the externally applied oblique (relative to bulk plasma flow) magnetic field are judiciously accented. It is noticed that, the derived Bohm condition needed for the plasma sheath formation is modified conjointly by the electron-inertia and magnetic field. It is manifested that the electron-inertia in the presence of gyro-kinetic effects slightly enhances the ion-Mach threshold value (*$M_{i0} \geq 1.139$*) towards the sheath entrance, which is*

in contrast with the heuristic formalism ($M_{i0} \geq 1$) for the zero-inertia electrons. A numerical illustrative scheme on diverse non-trivial apposite arguments is parametrically constructed. The implication of the main findings are discussed alongside ameliorative scope.

*In **Chapter-3**, the equilibrium properties of planar plasma sheath in two-component quasi-neutral magnetized plasmas is studied methodologically in the framework of hydrodynamic model. It includes weak but finite electron-inertia incorporated via a regular perturbation of the electronic fluid dynamics only relative to a new smallness parameter, δ, assessing the weak inertial-to-electromagnetic strengths. The zeroth-order perturbation around δ leads to the usual Boltzmann distribution law, whereas the next higher-order yields the modified Boltzmann law describing the putative lowest-order electron-inertial correction of current interest. It is seen that the mutualistic action of electron-inertia amid gyro-kinetic effects slightly enhances the ion-flow Mach threshold value (typically, $M_{i0} \geq 1.140$), against the normal threshold value of unity for the inertialess electrons.*

*In **Chapter-4**, an analytical model to explore the weakly nonlinear gravito-electrostatic waves in a polytropic dust molecular cloud is proposed on the astrophysical scales of space and time. The considered situation is macroscopically a nonthermalized one due to the presence of the cold grains, and the mutually thermalized hot electrons and hot ions. A quasi-hydrostatic equilibrium in one-dimensional (1-D, Cartesian) is adopted with presumed global quasi-neutrality. The dust grain dynamics considered is such that exact gravito-electrostatic equilibrium is established with their first-order perturbed self-gravitational potential. A new gravito-electrostatically coupled pair of the modified Korteweg-de Vries (m-KdV) equations having unique self-consistent nonlinear sources is derived perturbatively. Interestingly, it is seen from the numerical analysis that the electrostatic fluctuations undergo bi-periodicity, while the self-gravitational counter parts retain uni-periodicity in phase space. Non-trivial aspects of the results relevant in space and astrophysical environments are summarily indicated.*

*In C**hapter-5**, the well-established gravito-electrostatic sheath (GES) model is re-examined in the presence of nonextensive nonthermal electrons and turbulence pressure (nonlinear logatropic pressure law) effects. It is demonstrated that the GES structure equations get drastically modified with the nonextensivity parameter (entropic index) arising* *due to thermostatistical behavior of the electronic dynamics in the presence of large-scale gradient forces. A numerical analysis in the platform of relevant solar plasma parameters is carried out to highlight the new changes in the equilibrium structure relative to the earlier idealized one on both the bounded (Sun) and unbounded (solar wind) scales. The nonextensive GES field strength for the bounded solar solution to exist is found to decrease by 21.67 % and the electrostatic potential by 30 %. Besides, the main implications and nontrivial applications are summarily outlined.*

*In C**hapter-6**, a linear stability analysis of a simple polytropic model for the solar wind dynamics based on the hydrodynamic equilibrium configuration is proposed. It incorporates data from the Advanced Composition Explorer (ACE) spacecraft at the very outset. Applying the usual variable-separation methodology on the dispersion relation, we obtain the linear growth rate of the fluctuations. It is seen that the growth rate is an explicitly nonlinear function of the variable polytropic index (α) and radial position (r) with respect to the considered center of the Sun. Furthermore, the growth of the fluctuations is found to be maximum near the solar corona, relative to that observed elsewhere in the solar plasma.*

*Similarly, in **Chapter-7**, the main conclusive remarks derived out of the entire compiled study are concisely summarized along with a clear indication to future scope.*

Finally, three appendices (Appendix: A-C) beyond the above compilation, are added to highlight the viscoelastic plasma sheath behavior, pulsational mode dynamics and magnetohydrodynamic (MHD) mode damping in the solar prominence plasma; respectively.