Abstract

Most of the conventional matter composed of protons and neutrons in the universe can be studied with the fluid dynamical approach. To explore a system of particles by applying the equations of fluid dynamics, one should be able to consider the system as a continuum. According to the continuum hypothesis, a fluid element is spatiotemporally invariant, though the molecules incessantly collide with each other. So, the molecular mean free path of the system must be very small compared to the macroscopic length scale of the system, so that a molecule can undergo many collisions with the neighbours without causing any noticeable effect on the dynamics of the fluid element. Various fluid-dynamical models have been proposed to explore the stellar structures and their evolution. However, some key realistic stellar parametric factors are still overlooked in the previous model formalisms. The motivation and drive behind the thesis presented here is the stellar perspectives of fluid structurization and evolution with some sensible stellar parametric factors previously remaining unaddressed and unexplored. This thesis focally aims at describing the equilibrium solar (and hence, sun-like stellar) plasma structure in the plasma-wall interaction physics based gravito-electrostatic sheath (GES) model fabric, with a couple of observationally significant stellar fluid properties.

In ***Chapter-1****, a brief introductory review of diverse fluids, with their wide realm of existence in the cosmos is presented. The key physical mechanisms in the bounded structure formation processes are highlighted. The fundamental insights of the plasma sheath in the laboratory as well as astrophysical spatiotemporal scales are depicted. Ultimately, the structure of the Sun is looked into in different model approaches.*

In ***Chapter-2****, the basic equilibrium solar plasma properties are explored in the fabric of a refined GES-model. Here, the idealistic GES-model is revaluated by a proper inclusion of the realistic solar-plasma structuring key factors in the model governing equations, such as the non-thermal κ-distributed electron population, magneto-activity, and turbulent nature of the solar plasma fluid. A precise numerical analysis of the model equations yields an interesting feature of the solar interior plasma (SIP) volume that it shrinks with an increase in the electron non-thermality. This result can be explicated by looking into the collisional nature variation of the electrons with the fluid ions for different κ-values. The spatial variation of the electric potential is found to be independent of the electron non-thermality effects. The entire non-thermal solar plasma*

flow dynamics is studied by analysing the Mach number and current density profiles with their sensitivities to the various relevant parametric variations. A comparative evaluation of the key results from our present model analysis with the available literature is performed finally.

*In **Chapter-3**, the spatial uniformity variation of the various basic equilibrium properties of the newly structured polytropic turbomagnetic GES-model based solar plasma system is studied. Numerical analysis of the model equations is performed to plot the inhomogeneity scale length of the key solar plasma properties such as gravity, electric potential, electric field, Mach number, and electric current density for various electronic non-thermality levels as well as relative temperatures of the plasma constitutive species. It is found that the SIP self-gravity and electric current density show abrupt uniformity transition, against the solar wind plasma (SWP) gravity, electric potentials and fields in the SIP and SWP, Mach number in the SIP and SWP, and the SWP electric current density, that follow gradual uniformity transition.*

*In **Chapter-4**, the internal structure of the κ-modified polytropic turbomagnetic GES-model based bounded solar plasma system is explored. The self-structurization of the constitutive plasma medium is studied by looking into the electron population behaviours in the SIP, and the electric field and self-gravity gradients with their corresponding field values against the Jeans-normalized heliocentric radial distance. A sharply defined and dense self-gravity dominated region is revealed to exist from* $\xi = 0 - 0.2\,\lambda_J$*.This region is analogous to the solar core, as in the standard solar model.*

*In **Chapter-5**, the plasma wall interaction physics based GES-model of the Sun is restructured methodically by a proper inclusion of the realistic negative ionic species for the first time. The solar plasma system is assumed to be consisted of the Maxwell-Boltzmann distributed inertialess electrons, gravito-electrostatically coupled with the positive-negative ionic inertial fluids, via the Poisson equations. Numerical analysis of the basic governing equations of the tri-component plasma system (electron, proton, and negative ion) in steady-state reveals that the bounded solar plasma volume shrinks with an increase in the negative ion concentration in the constitutive SIP medium. This GES-shrinking behaviour is not sensitive to the mass of the negative ions and temperature of the plasma constituents. This unique SIP feature can be explained by the shielding nature between the opposite polarity plasma constituents. The spatial variation of the electric potential is found to be insensitive to the negative ion concentration, their mass*

and plasma constituent temperature in both the SIP and SWP. The solar plasma flow dynamics is analysed with the Mach number and current density profiles for various relevant physical parametric variations. In the SWP, the sonic transition of the Mach number is found to be sensitive to the positive ion-to-electron temperature ratio. The current density shows sensitiveness to the negative ion density as well as the positive ion-to-electron temperature ratio in both the SIP and SWP. The self-organization of the SIP constituents is explored with their spatial density and density gradient profiles. The deviation of the diverse realistic negative ion modified SIP from the ideal quasi-neutrality is examined with the colour-spectral profiles in a defined colour phase space. Finally, a comparative assessment of the results from our model analysis with the previously available literature is performed.

In ***Chapter-6****, the GES-model based solar plasma system with diverse negative ionic species is revisited. The self-organization of mass and net electric charge distribution in the bounded SIP is studied with the spatial gradient profiles of the self-gravity and electric fields. A particular location with the negative ion density insensitive gravity gradient is revealed in the SIP. The dynamical behaviour of the constituent fluid elements with variation in their mass and electric charge is thoroughly portrayed in the gravito-electrostatic interaction phase space. The SIP constitutive material clumping nature is revealed herewith. This unique clumping property, reported here for the first time, clearly stands well with the observational result in the fact that the heavy negative ion formation is not favoured in the SIP.*

In ***Chapter-7****, the crucial conclusive remarks of the entire research are summarized along with a clear depiction of all the possible future directions. Lastly, two appendices (****Appendix: A-B****), directly linked to the above-mentioned topics, are added. The appendices present the Bohm sheath criterion in the non-thermal GES structure as well in the GES structure with diverse negative ionic species.*

Key words: Fluid, Sun, GES-model, solar plasma, solar wind, non-thermality.