Abstract

The interstellar medium is the space between the galaxies that is filled with matter and intense radiations. The matter coupled with the intense radiations gets ionized to form the plasma state. It is well known that about 99% of the ISM is in the plasma state (mostly hydrogen (91%), helium (8.9%), and other heavier element (0.1%)) and remaining 1% is of micron-submicron size dust grain in solid state. The dust grains are generally composed of Silicates, Graphites, Amorphous Carbons and Carbonaceous compounds, Polycyclic Aromatic Hydrocarbon (PAH) molecules, Silicon Carbides, Magnesium Sulfides, and so forth. The geometrical dust grain size varies from micron to submicron $(10^{-2}-10^{-9})\,m$*. These dust grains can be both positively and negatively charged depending upon its interaction with the surrounding plasma environs. The interaction of dust grains with other charged particles can excite various types of waves, oscillations, and instabilities in the plasma medium. The presence of dust particulate in the plasmas is termed as "dusty plasmas" if* $R << a_d < \lambda_D$ *where,* R *is the dust grain size,* a_d *is the average intergrain distance, and* λ_D *is the Debye length. Some of the examples of dusty plasmas in space are dust molecular clouds (DMCs), interplanetary space, Comets, Planetary rings, and so on.*

DMCs are the dense sites of ISM known as stellar nurseries for stars, planets, compact astrophysical objects like white dwarfs, neutron stars, etc. The dust-to-gas in the DMC increases by 20%-30% from the canonical ISM value of 1%. This is due to the presence of larger size dust grains $(0.1-10\,\mu m)$ *in the DMCs for which self –gravity comes into play. As a result, abundance of dust grains increases locally in the DMC. Star are formed in such sites due to Jeans instability. In other words, only the volumes of the DMC that exceeds the corresponding critical Jeans length undergo gravitational collapse, and subsequently bounded astrophysical objects are formed.*

In this compiled thesis, we have used fluid dynamical approach to study the waves and instabilities excited in various astronomical environs. In fluid dynamics, the characteristic mean free path is asymptotically zero (characteristic length/system length ~ 0). The proposed thesis herein, is centered around the gravitational instability triggered in gravitating fluidic systems, when the internal thermal (outward) force field is not sufficient to prevent the gravitational (inward) force field, hence, leading to gravitational collapse.

In chapter 1, we give an overview of the plasmas, dusty plasmas, and their physical properties. The existence of dusty plasma in various domains of the Universe is briefly *mentioned. The dynamical mechanisms behind the excitation of various types of dust mode in dusty plasmas are concisely highlighted. The importance of dust in DMCs related to Jeans instability and star formation is discussed. The viscoelastic behaviour of dusty plasma is precisely reviewed. Such behaviour, in reality, is relevant to various compact astrostructures and their circumvent environs, such as the white dwarf stars, neutron stars, Jovian planetary interior structures, etc.*

In Chapter 2, we semi-analytically study the evolutionary excitation dynamics of the gravitational instability in a self-gravitating viscoelastic non-thermal polytropic complex fluid on the astro-scales of space and time. We apply a generalized gravitating hydrodynamic model in the concurrent presence of buoyancy, thermal fluctuations, volumetric expansion, and so forth. A normal mode (local) analysis yields a quadratic linear dispersion relation with a unique set of multi-parametric coefficients. The analytical reliability is checked by comparing with the existing reports on purely ideal inviscid nebular fluid and non-ideal viscoelastic fluids in isolation. The stabilizing (destabilizing) and accelerating (decelerating) factors of the instability are illustratively explored. The instability features are judged in the light of both impure non-ideal viscoelastic fluid and pure ideal inviscid nebular fluid scenarios.

In Chapter 3, the nonlinear evolutionary dynamics of gravitational instability of the model mentioned in Chapter 2 is semi-analytically investigated on the Jeansian scales of space and time. A nonlinear normal mode (local) analysis yields a Korteweg-de Vries (KdV) equation with a unique set of multi-parametric coefficients. We provide a numerical platform to demonstrate how the KdV dynamics excites an interesting spectral class of compressive solitary chain patterns as the evolutionary eigenmodes having atypical dynamical behaviour. Their diversified characteristic features are explained elaborately alongside phase-plane analysis. Various stabilizing (destabilizing) and accelerating (decelerating) factors of the instability are illustratively explored together with a validated reliability checkup. The relevancy of our investigated results in the context of super-dense compact astro-objects, and their circumvent atmospheres is summarily outlined.

In Chapter 4, a generalized magnetohydrodynamic (g-MHD) meanfluidic model is theoretically constructed to analyze the gravitational instability dynamics excitable in a spherical complex astrocloud on the non-relativistic classical astroscales of space and time. It concurrently includes the effects of viscoelasticity, buoyancy, polytropicity, volumetric thermal expansion, and so forth. A spherical normal mode analysis yields a unique form of a generalized linear cubic dispersion relation. It is interestingly found that *the magnetic field in the presence of adopted non-ideality effects in the spherical astrocloud acts as a destabilizing agent. It sets out a new theoretic support to the existent various astronomic observations on the magnetic field acting as a cloud destabilizing agency in the presence of geometrical curvature (spherical) effects widely prereported in the literature.*

In Chapter 5, we investigate the dynamics of the dust acoustic wave (DAW, low-fugacity) and the dust Coulomb wave (DCW, low-fugacity) in self-gravitating magnetized viscoelastic spherical dusty astroclouds. It consists of the inertial dust grains with variable charge alongside the non-thermal electrons and ions in a generalized hydrodynamic framework. A spherical wave analysis yields a unique generalized quadratic dispersion relation. The fluctuations are free from the viscoelasticity effects in the weakly coupled limit (WCL) against the strongly coupled limit (SCL). The distinctive WCL-SCL scenarios are explicitly compared. The results show correlative consistencies in real astronomic circumstances sketchily.

In Chapter 6, the stability effects of the inner crust regions against the local collective perturbations in non-rotating neutron stars is proposed. It consists of the viscoelastic heavy neutron-rich nuclei, superfluid neutrons, and degenerate quantum electrons. A normal spherical mode analysis yields a generalized linear dispersion relation multiparametrically mimicking the inner crust features of neutron stars. A hybrid gravito-nucleo-acoustic (GNA) instability mode is found to be excited. The stabilizing (destabilizing) and accelerating (decelerating) agencies of the GNA instability is discussed. It is found that the high-K *regions are the more unstable spectral windows indicating that the GNA mode plays a dominant role in the inner crust zone towards the local stability. Its fair reliability is indicated in light of the recent astronomic observed scenarios. It could be useful to explore acoustic mode signatures in non-rotating neutron stars, and similar other compact astrophysical objects.*

In Chapter 7, we put forward the overall summary of the compiled thesis with some futuristic directions.

Keywords: Gravitational instability, star-formation, DMC, viscoelasticity, DAW, DCW, compact astrophysical object.