APPENDIX-A

NONLINEAR PULSATIONAL EIGENMODES OF A COLLISIONAL DUST MOLECULAR CLOUD

A theoretical evolutionary model leading to the excitations of nonlinear pulsational eigenmodes in a planar (1-D) collisional dust molecular cloud (DMC) with fluctuating charge on the astrophysical scale is constructed. It is a self-gravitating multi-fluid model consisting of the Boltzmann distributed warm electrons and ions, and the inertial cold dust grains with partial ionization. The grain-charge behaves as a dynamical variable owing mainly to the attachment of the electrons and ions to the grain-surfaces randomly. The adopted technique is centered around a mathematical model based on new solitary spectral patterns within the hydrodynamic framework. The collective electrostatic and self-gravitational fluctuation dynamics are governed by driven Korteweg-de Vries (*d*-KdV) and Korteweg-de Vries (KdV) equations obtained by a standard multiscale analysis, respectively. The sensitive dependence of the eigenmode amplitudes on diverse relevant plasma parameters is discussed. The findings are relevant to space and astrophysical environments.

The nonlinear electrostatic fluctuations of the collisional DMC is governed by the following *d*-KdV equation in a reduced form resulting from the perturbative treatment over the closed set of the basic plasma structure equations, expressed with all the usual notations as,

$$\frac{\partial \Phi_1}{\partial T} + A_1 \Phi_1 \frac{\partial \Phi_1}{\partial X} + B_1 \frac{\partial^3 \Phi_1}{\partial X^3} = C_1 \Phi_1^2 \frac{\partial \Phi_1}{\partial X}, \tag{A1}$$

where, $A_1 = -\mu$, $B_1 = \dfrac{m_d^2 n_{do} G \mu}{e^2 (n_{eo} - n_{io})}$, $C_1 = -\dfrac{(e n_{eo} - e n_{io})}{n_{dco}^2 \mu}$. (A2)

Thus, the electrostatic eigenmodes are collectively governed by equation (A1) having a self-consistent nonlinear source term arising due to collisional grain-charge fluctuation dynamics. The effect of grain mass appears in B_1, and so, the third term in equation (A1) represents the grain inertial outcome on the fluctuation dynamics.

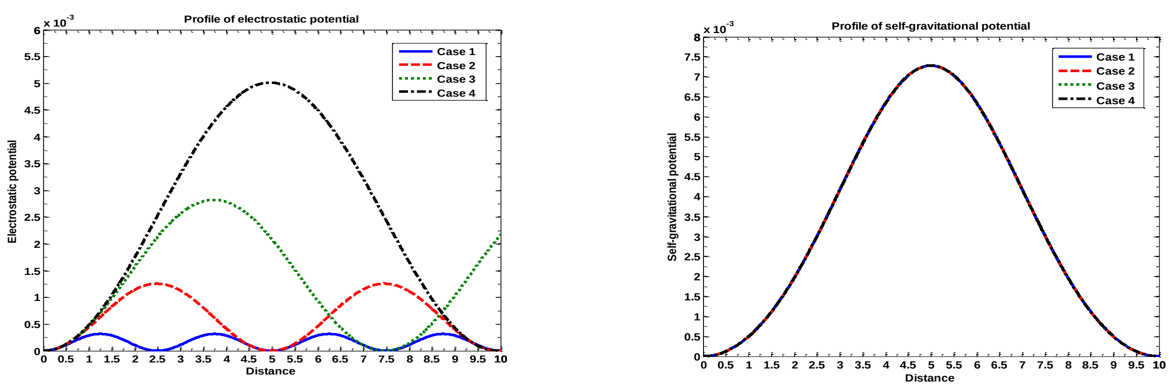
Similarly, the self-gravitational fluctuations is governed by the KdV equation given as,

$$\frac{\partial \Psi_1}{\partial T} + A_2 \Psi_1 \frac{\partial \Psi_1}{\partial X} + B_2 \frac{\partial^3 \Psi_1}{\partial X^3} = 0, \tag{A3}$$

where, $A_2 = \frac{\mu m_d \left(1 - n_{dno}\mu^2\right)^2}{e\left(n_{do}\mu^2 - 1\right)^3} + \frac{1}{2en_{dno}\mu}$, $B_2 = \frac{n_{do}\left(1 - n_{dno}\mu^2\right)^2}{2\mu n_{dno}^2}$. (A4)

The effect of grain mass appears in A_2, and consequently, the first term in equation (A3) represents the grain inertial effect on the associated fluctuation dynamics. Here, Φ_1 and Ψ_1 are the normalized lowest-order perturbed electrostatic and self-gravitational potentials, respectively. Moreover, n_{e0}, n_{i0}, n_{dn0}, and n_{dc0} are the equilibrium population densities of the electrons, ions, neutral grains, and charged grains, respectively. The equilibrium dust density is $n_{do} = n_{dco} + n_{dno}$ and dust grain mass is m_d. Further, μ and G respectively are the fluctuation phase velocity (normalized by C_{ss}) and universal gravitational constant.

The exact evolutionary pictures of the gravito-electrostatic fluctuations, the KdV-family structures as displayed in figure A1, are obtained by numerical integration of equations (A1) and (A3) as an initial value problem under judiciously chosen astrophysical conditions. The details of the complete fluctuation patterns are presented in Ref. [1].



(a) (b)

Figure A1 *Profile of the normalized lowest-order perturbed (a) electrostatic and (b) self-gravitational potentials. The details of the input and initial values are discussed in Ref. [1].*

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1. Karmakar, P. K. and Borah, B. Nonlinear pulsational eigenmodes of a planar collisional dust molecular cloud with grain-charge fluctuation, *Eur. Phys. J. D* **67**, 187(1)-187(14), 2013.

APPENDIX-B

NEW OSCILLATORY FLUCTUATION PATTERNS IN SOLAR PLASMA

A simplified theoretical model is constructed to explore new stationary states of the nonlinear self-gravitational fluctuation dynamics of the solar plasma with the zero-inertia electrons against weakly nonlinear perturbation. It is based on the Jeans homogenization assumption. The joint action of space-charge polarization, sheath-formation, and bi-layer plasma-boundary interaction through gravito-electrostatic interplay in a spherically symmetric geometry is considered. Applying a standard multiscale technique, a unique form of the extended Korteweg-de Vries Burger (*e*-KdVB) equation with a new self-consistent linear sink is methodologically derived. The origin of the unique sink lies in the spherically symmetric inhomogeneous self-gravitational fluctuations contributed by the massive ions. A numerical shape-analysis with multi-parameter variation depicts the co-existence of two distinct classes of new eigenmode excitations. The numerical illustrations show that the fluctuations evolve as *oscillatory soliton-like* and *oscillatory shock-like* patterns in judicious plasma conditions under the adiabatic electronic response. Their oscillations, arising due to resonant and non-resonant coupling phenomena with the background spectral components, get gradually damped out due to the presence of the sink. This study allows us to conjecture that the model supports self-gravitational solitary (shock) waves having tails (fronts) composed of a sequence of slightly overlapping solitons with smoothly varying characteristic parameters. Our results are in agreement with earlier theoretical model predictions, on-board multispace satellite data and spacecraft observations.

The nonlinear self-gravitational potential fluctuations (η_1) of the ionized solar plasma within the gravito-electrostatic sheath (GES) model framework is governed by the *e*-KdVB equation in reduced normalized form (by standard astrophysical parameters) after systematic perturbative analysis over the basic closed GES model structure equations as given below,

$$\frac{\partial \eta_1}{\partial T} + \gamma_1 \eta_1 \frac{\partial \eta_1}{\partial X} + \gamma_2 \frac{\partial^3 \eta_1}{\partial X^3} + \gamma_3 \frac{\partial^2 \eta_1}{\partial X^2} + \gamma_4 \frac{\partial \eta_1}{\partial X} + \gamma_5 \eta_1 = 0, \tag{B1}$$

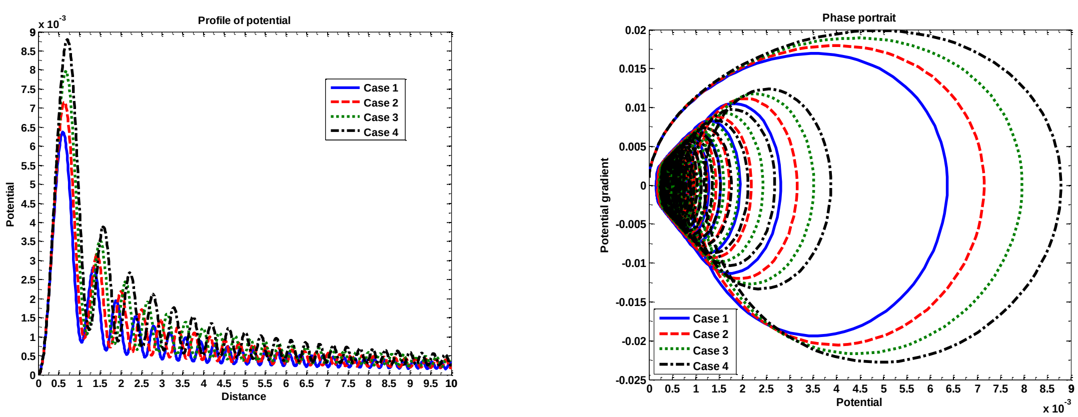
where,

$$\gamma_1 = Z = \left[(M_o - \mu)/\alpha - (M_o - \mu)^2\right], \quad \gamma_2 = \frac{\alpha + \left(\frac{\lambda_{De}}{\lambda_J}\right)^2 \{1 - (M_o - \mu)Z\}}{Z}, \quad \gamma_3 = \frac{2\alpha + \left(\frac{\lambda_{De}}{\lambda_J}\right)^2 2\{1 - (M_o - \mu)Z\}}{XZ},$$

$$\gamma_4 = \frac{X^3 (M_o - \mu) Z - \left(\frac{\lambda_{De}}{\lambda_J}\right)^2 2\mu T \{1 - (M_o - \mu)Z\} - 2\mu T \alpha}{X^2 Z \mu T}, \text{ and } \quad \gamma_5 = \frac{(M_o - \mu)}{\mu T}.$$

Here, $\alpha = (1 + \in_T)$ and $\in_T$ is the ratio of ion-to-electron temperatures (in eV). The notations M_0, T, and μ represent the normalized equilibrium ion flow Mach number, normalized time coordinate and the phase speed of the fluctuations, respectively. In addition, λ_{De} and λ_J represent the plasma Debye length and Jeans length scales, respectively.

To see the exact picture of the self-gravitational solar plasma fluctuations, equation (B1) is numerically solved (by RK-IV method) as an initial value problem under judiciously chosen plasma conditions to yield figure B1. The details are displayed in Ref. [1].



(a) **(b)**

Figure B1 *Spatial profile of the normalized lowest-order perturbed self-gravitational (a) potential and (b) phase portrait. The details of the input and initial values are discussed in Ref. [1].*

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1. Karmakar, P. K. and Borah, B. New self-gravitational oscillatory eigenmode patterns of solar plasma with Boltzmann-distributed electrons, *European Scientific Journal* **10**, 449-520, 2014.

SUMMARY OF
MINOR ACHIEVEMENT

Paper published in International Peer-reviewed Journal # 10

Peer-reviewed conference Proceedings # 02

Journal paper unpublished # 03

Workshop/Conference/Symposium (of National and International repute) participated for paper presentation # 12

Best poster award in *National Conference in Theoretical Physics (NCTP-2013)*, Department of Physics, Tezpur University, during 08-12 February, 2013 # 01

LIST OF PUBLICATIONS

A. International Refereed Journal:

1. Karmakar, P. K. and Borah, B. New nonlinear eigenmodes of self-gravitating spherical charged dust molecular cloud, *Physica Scripta* **86**, 025503(1)-025503(11), 2012.
2. Karmakar, P. K. and Borah, B. Nonlinear self-gravitational solar plasma fluctuations with electron inertia, *Contributions to Plasma Physics* **53**, 516-539, 2013.
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B. Conference proceedings:

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15. Karmakar, P. K. and Borah, B. Nonlinear fluctuation dynamics in self-gravitating spherical charged dust molecular cloud, in *Proceeding of the 27th National Symposium on Plasma Science and Technology* (Plasma-2012), Pondicherry University, Pondicherry, 2012, 156-160.