Instabilities in fusion plasmas: Interface dynamics and flow fields structure

Snezhana I. Abarzhi [1,2], Dan V. Ilyin [1]
[1] California Institute of Technology, [2] The University of Western Australia
e-mail (speaker): snezhana.abarzhi@gmail.com

Interfaces and mixing and their far from equilibrium dynamics couple micro to macro scales, and are ubiquitous to occur in plasmas in high energy density regimes. Inertial confinement fusion, stellar evolution, and nanofabrication are few examples of many processes to which dynamics of interfaces is directly relevant. This talk presents the rigorous theory of the stability of the interface – a phase boundary broadly defined. [1,2,3,4]

We directly link the structure of macroscopic flow fields to microscopic interfacial transport, quantify the contributions of macro and micro stabilization mechanisms to interface stability, and discover the plasma instabilities never previously discussed. In ideal and realistic fluids, the interface stability is set primarily by the interplay of the macroscopic inertial mechanism balancing the destabilizing acceleration, whereas microscopic thermodynamics and heat flux create vortical fields in the bulk. By linking micro to macro scales, the interface is the place where balances are achieved. [1,2,3,4]

Figure 1 illustrates the dependence of the growth-rates (ω) on the magnitude of the acceleration (G) for the conservative dynamics with zero thermal heat flux (CDG) and with thermal heat flux in the advection, diffusion and low Mach processes ($CDG(A)(D)(M)$), and for the accelerated Landau-Darrieus (LDG) and Rayleigh-Taylor (RT) dynamics. For strong accelerations, the growth-rate of the conservative dynamics (CDG) in ideal fluids is the largest and is asymptotic for the advection, diffusion and low Mach dynamics ($CDG(A)(D)(M)$) in realistic fluids. Furthermore, for strong accelerations, the growth-rates of the dynamics in ideal and realistic fluids ($CDG(A)(D)(M)$) are greater than the growth-rates of the Landau-Darrieus (LDG) and Rayleigh-Taylor (RT). [1,2,3,4]

References

[1] S.I. Abarzhi *et al*, Proc. Natl. Acad. Sci. USA **116**, 18218 (2019)
[2] D.V. Ilyin, S.I. Abarzhi, Springer Nat. Appl. Sci. **4**, 197 (2022)
[3] D.V. Ilyin, S.I. Abarzhi, Phys. Lett. A **426**, 127827 (2022)
[4] S.I. Abarzhi, Front. Appl. Math. Stat. **10**, 1517619 (2024)

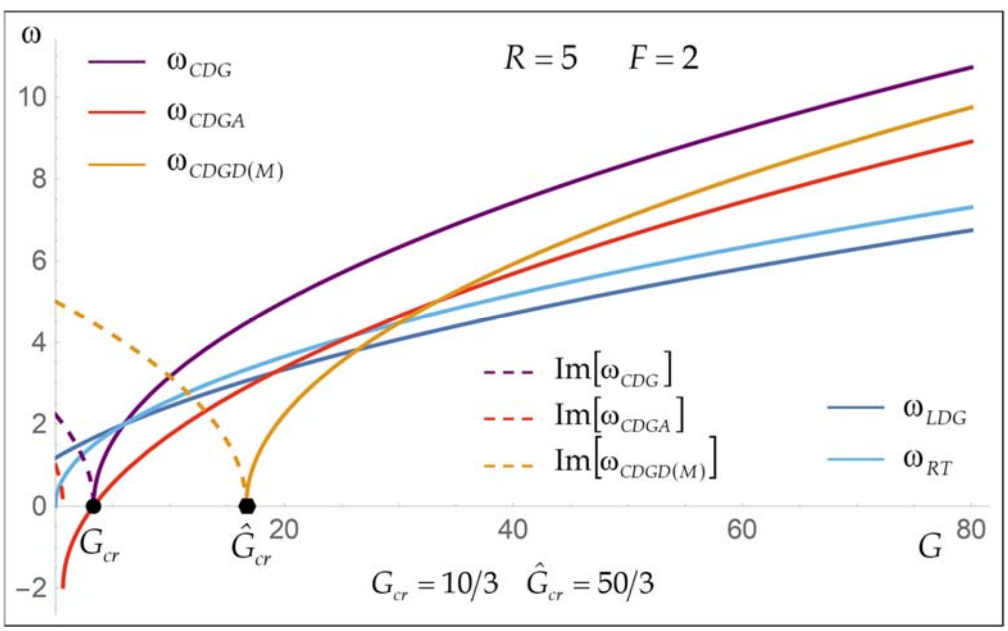

Figure 1. Dependence of the growth-rates (ω) on the acceleration magnitude (G) at some values of the density ratio (R) and thermal heat flux parameter (F) for the conservative dynamics with zero thermal heat flux (CDG) and with thermal heat flux in the advection, diffusion and low Mach processes ($CDG(A)(D)(M)$), and for the accelerated Landau-Darrieus (LDG) and Rayleigh-Taylor (RT) dynamics. The values are dimensionless and are scaled with the length scale of the initial perturbation, the magnitude of the ablation velocity, and the internal energy. The energy perturbations are seeded by the thermal heat flux. [1-4].