

Weakly-Rotating Self-Gravitating Fluids: Flow Generation via Catastrophic Loss of Equilibrium

Nana Shatashvili^{a, b}, Lasha Gudushauri^{a, c}, Gigla Shekiladze^d, Swadesh Mahajan^e

e-mail: nana.shatashvili@tsu.ge

^a Department of Physics, Faculty of Exact and Natural Sciences, Javakhishvili Tbilisi State University, 1, Chavachavadze ave, Tbilisi 0179, Georgia

^b Andronikashvili Institute of Physics, TSU, 6, Tamarashvili st. Tbilisi 0177, Georgia

^c E. Kharadze Georgian National Astrophysical Observatory, Abastumani 0301, Georgia

^d Department of Physics, University of Florida, Gainesville, Florida, 32611, USA

^e Institute for Fusion Studies, The University of Texas at Austin, Austin, Tx 78712, USA

In present study, we explored the self-gravity driven flow generation in slowly rotating neutral fluid/gas found in various astrophysical settings. The self-gravitating system, obeying what we call Gravito-magnetic field equations (closely resembling the Maxwell-Lorenz system of electrodynamics), follow a trajectory similar to that of its electromagnetic counterpart, and can be analyzed in terms of the Beltrami-Bernoulli equilibrium whose principal part is the Double Beltrami equation that the velocity field obeys. Because of the similarity in the governing equations, the system dynamics is worked out exactly in parallel to the methods developed for investigating catastrophic relaxation in stellar plasmas [1-3]. In the latter a more “complex” equilibrium state, on slow changes in the environment, can lose its equilibrium (catastrophe), and transform to a less complex state with a very different energy mix from the original. It is shown that a similar transformation in the weakly rotating self-gravitating fluid/gas will convert much of its gravitation energy into kinetic energy in the flow – we show that the self-gravity provides the energy for flow generation. Since flows are a perennial ingredient of high-energy astrophysical systems, the energy transformation processes revealed in present study, can advance our understanding of a variety of them. Some particularly relevant examples are: macro-scale flows / structures in galaxies, accretion discs, and the dynamics and stability of a rotating star / its atmosphere.

Work is partially funded by Shota Rustaveli GNSF grant project No FR-22-8273

References

- [1] Ohsaki, S., Shatashvili, N.L., Yoshida, Z. and Mahajan, S.M. *Magnetofluid coupling: eruptive events in the Solar Corona. **Astrophys. J.**, 559 (1) (2001) L61-L65.*
- [2] Ohsaki, S., Shatashvili, N.L., Mahajan, S.M. and Yoshida, Z. *Energy transformation mechanism in the solar atmosphere associated with magnetofluid coupling: explosive and eruptive events. **Astrophys. J.**, 570 (2002) 395–407.*
- [3] Saralidze, E., Shatashvili, N.L., Mahajan, S.M., Dadiani, E. *Catastrophic formation of macro-scale flow and magnetic fields in the relativistic gas of binary systems. **Astrophys. Space Sci.**, 370(6) (2025) 64-75.*