ASTR/ATOC-5410: Fluid Instabilities, Waves, and Turbulence

Project description   November 14, 2016, Axel Brandenburg

Strato-Rotational Instability (SRI)

Analogous to the magneto-rotational instability (MRI), the presence of stratification provides a restoring force and can lead to instability; see Rüdiger et al. (2016) for a recent paper on the subject and with many references.

Background

You may use analytic or numerical approaches, for example by adapting a related setup for the PENCIL CODE in cylindrical coordinates; see the bottom of the page `http://lcd-www.colorado.edu/~axbr9098/teach/PencilCode/MixedTopics.html`

Project details

1. Review the analysis of Molemaker et al. (2001) and put it in perspective of recent work.

2. Rüdiger et al. (2016) defined the Froude number as $\mathrm{Fr} = \Omega_{\mathrm{in}}/N$, where Ω_{in} is the angular velocity of the inner cylinder and $N = \sqrt{-g\,\mathrm{d}\ln\rho/\mathrm{d}z}$ is the buoyancy frequency. Compare their instability condition

$$0.3 < \mathrm{Fr} < 5.5 \tag{1}$$

   with earlier work in the literature.

3. Compute the stability map as a function of Reynolds and Froude numbers. Plot growth rates also separately versus Reynolds and Froude numbers.

4. Discuss the behavior for flat rotation curves and compare with other rotation laws.

5. Discuss differences with the so-called "Zombie vortex instability" of Marcus et al. (2015).

References

Marcus, P. S., Pei, S., Jiang, C.-H., Barranco, J. A., Hassanzadeh, P., & Lecoanet, D., "Zombie vortex instability. I. A purely hydrodynamic instability to resurrect the dead zones of protoplanetary disks," *Astrophys. J.* **808**, 87 (2015).

Molemaker, M. J., McWilliams, J. C., & Yavneh, I., "Instability and Equilibration of Centrifugally Stable Stratified Taylor-Couette Flow," *Phys. Rev. Lett.* **86**, 5270-5273 (2001).

Rüdiger, G., Seelig, T., Schultz, M., Gellert, M., Harlander, U., & Egbers, C., "The stratorotational instability of Taylor-Couette flows of moderate Reynolds numbers," *J. Fluid Mech.* submitted, arXiv:1610.02907 (2016).