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Stratified Taylor-Couette flow: nonlinear dynamics. (English) Zbl 07423161

Summary: A series of experiments on stratified Taylor-Couette flow in short aspect ratio wide-gap annuli found an intriguing and not-well-understood dynamics: nonlinear coherent structures appearing and disappearing periodically, along with density layering reminiscent of staircase profiles. A detailed numerical study is presented of the nonlinear dynamics near onset of instability in this setting, which explains most of the characteristics found in the experiments. The simulations show that centrifugal instability of the boundary layer on the inner rotating cylinder produces jets of angular momentum forming Taylor cells that are compressed axially due to the strong stratification. These cells are not axisymmetric from the onset, but are in fact two sets of Taylor cells displaced axially that meet in localized azimuthal defect regions where the cells are patched together; the whole structure is a rotating wave with azimuthal wavenumber $n = 1$. The presence of endwalls in this short aspect ratio annulus is critical for the understanding of the dynamics. Their impact cannot be accounted for in idealized axially periodic models. Another key ingredient is the role played by the symmetries of the system. Although the axial reflection symmetry is weakly broken by centrifugal buoyancy effects, following instability there are various branches of solutions corresponding to the different ways the system’s symmetries may be broken.

MSC:
76E06 Convection in hydrodynamic stability
76U05 General theory of rotating fluids
76D50 Stratification effects in viscous fluids
76M99 Basic methods in fluid mechanics

Keywords:
Taylor-Couette flow; centrifugal instability; pattern formation; Galerkin-Fourier expansion; Chebyshev collocation method

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References:

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