A Candidate for the On-Off Switch for Inviscid Shear Instability

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Prof. Dowling is an internationally recognized expert on the atmospheric dynamics and thermodynamics of planetary atmospheres, and principal architect of the EPIC atmospheric model, used by NASA and researchers around the world to model the atmospheres of Jupiter, Saturn, Uranus, and Neptune.

ABSTRACT: Strong shears are ubiquitous in gas-giant atmospheres and in Earth's oceans and atmosphere. Necessary and sufficient conditions for instability of inviscid shears have not yet been found despite over a century of effort inaugurated by Rayleigh's inflection-point theorem of 1880. The 1-eqn. theory is conservation of quasigeostrophic potential vorticity; in the geophysical fluid dynamics context this is the Charney-Obukhov equation and in the non-neutral plasma context it is the Hasagewa-Mima equation. Arnol'd's energy-Casimir method applied to baroclinic shears yields two stable branches, the first of which includes the familiar Rayleigh, Kuo, Charney-Stern, and Fjortoft stability theorems as special cases. The second branch is less well known, but appears to be more relevant to most zonal jets in nature. Neither theorem is nondimensionalized, and I will show that the appropriate nondimensional number is the analogue of the Mach number for Rossby waves (vorticity waves), "Ma", such that the two stability branches reduce to "Ma" < 0 and 1 < "Ma" (negative "Ma" corresponds to downstream intrinsic wave speed), and hence concatenate into a compact result: shear flows are stable for (1 / "Ma") < 1. A recent postulate is that the shock of Rossby waves at a critical line is the on-off switch for inviscid shear instability itself. For Jupiter, "Ma" ~ 1 has been inferred via an empirical vortex-tube-stretching analysis of the Great Red Spot, yielding an abyssal wind profile that correctly anticipated Juno's deep-wind gravity results. For Saturn, the reference frame for which "Ma" = 1 yields a planetary rotation period of 10h 34m, which was recently confirmed by ring-wave analysis and is the most accurate value to date.

ALL ARE WELCOME!