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Wave-kinetic description of planetary wave interaction with a zonal jet

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Nonlinear interaction between mean flow and eddies is believed to be the origin of Jupiter and Saturn's zonal, banded jets, but due to its partly turbulent nature, the phenomenon remains extremely challenging to describe theoretically. Here, quasi-geostrophic zonal jet formation in the presence of Ekman damping is studied by treating the eddy field as a 'sea' of planetary wavepackets. A quantum-mechanical tool, the Wigner function, is used to rigorously construct an equation for the evolution of wavepacket density in phase space. Interpretation of the flux of eddy potential vorticity $\overline{v'q'}$ in terms of the density of wavepackets then allows a complete description of the interaction of planetary waves with an arbitrary zonal flow.

Analytical arguments, combined with a simple numerical model, give an intuitive picture of jet formation as a feedback process between zonal flow and eddies. It is also found that when the contribution of the zonal flow to the total mean potential vorticity gradient is taken into account, a broadband distribution of planetary waves can cause a finite amplitude jet to become asymmetric, and eventually barotropically unstable.