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Self-sustained shear driven dynamos

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A large Reynolds number matched asymptotic expansion is concerned for nonlinear 3D magneto-hydrodynamic (MHD) dynamo states driven by a shear. The theory has emerged out of a nice combination of the vortex-wave interaction theory by Hall & Smith (1991) and the resonant absorption theories for Alfven and cusp waves, developed in solar physics community. The dynamos are self-sustained, in the sense that they are maintained without any linear instability mechanism of the basic flow. There are two classes of dynamos can be sought. The first class of dynamos appears when we consider the similar scaling for both hydrodynamic and magnetic fields. In this case the dynamos must be supported by a small external magnetic field, but induce much bigger magnetic field. The external magnetic field can actually be switched off to yield the second class of dynamos, which is now purely driven by shear. The theory is tested using the unstable invariant solutions of the full MHD equations at finite Reynolds numbers. The dynamo solutions can be found by continuing the hydrodynamic solution branch of plane Couette flow. Using an external magnetic field as a homotopy parameter, the dynamo solutions can indeed be found even at zero-external magnetic field condition. Their asymptotic development can be excellently explained by the asymptotic theory.

References

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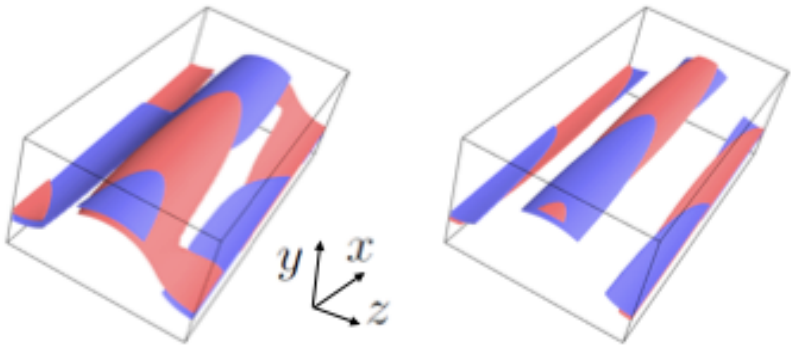

Figure 1: 50% streamwise vorticity (left) and current (right) of the self-sustained shear driven dynamo in plane Couette flow (the basic flow is u=y). The vortex/current sheet appears at the resonant position.