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Vortex couples in an axisymmetric large-scale flow

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The evolution of a self-propelling vortex couple is considered in an axisymmetric flow with constant potential vorticity (e.g., such flows may exist over isolated seamounts in the ocean). Using a point vortex approximation in the equivalent-barotropic quasi-geostrophic model, we found the system to be integrable due to conservation of the Hamiltonian and angular momentum that reduces the original four degrees of freedom to only two degrees of freedom similar to what is known for the system of three point vortices where there are four integrals.

When the dipole with zero angular momentum moves towards the center of the axisymmetric flow, the intensity of dipole does not change and its center passes the flow center at an angle described by a simple expression proportional to the angular rotation speed in the flow and inversely proportional to the dipole propagation speed. When the dipole has non-zero angular momentum, it approaches from the infinity with some offset from the direction towards the flow center. In the vicinity of the flow center the dipole intensity increases for one sign of the offset and decreases for the other sign of the offset depending also on the sign of the flow rotation. Correspondingly, the dipole center reaches the minimum distance from the flow center which is either larger than the offset or smaller than the offset value. Further from the flow center, the dipole may propagate in any direction very sensitive to the offset. In some parameter range there exist a region of trapped dipole motion which can not be reached from the infinity. In the vicinity of the separatrix chaotization of the couple propagation is expected.