Contribution ID: **6** Type: **Talk**

Geometric low-rank approximation of incompressible fluids on the sphere

Thursday, September 4, 2025 2:30 PM (30 minutes)

We discuss an evolving low-rank approximation of the vorticity solution of the Euler equations describing the flow of a two-dimensional incompressible ideal fluid on the sphere. Such problem can be approximated by the so-called Zeitlin model, an isospectral Lie-Poisson flow on the Lie algebra of traceless skew-Hermitian matrices. We propose an approximation of Zeitlin's model based on a time-dependent low-rank factorization of the vorticity matrix and evolve a basis of eigenvectors according to the Euler equations. In particular, we show that the approximate flow remains isospectral and Lie-Poisson and that the error in the solution, in the approximation of the Hamiltonian and of the Casimir functions only depends on the approximation of the vorticity matrix at the initial time. After a suitable time discretization, the computational complexity of solving the approximate model is shown to scale quadratically with the order of the vorticity matrix and linearly if a further approximation of the stream function is introduced.

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Session Classification: Afternoon Session