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Cutting and shuffling—Mixing in Spherical Tumblers RICHARD M. LUEPTOW, IVAN C. CHRISTOV, Northwestern University, GABRIEL JUAREZ, University of Pennsylvania, JULIO M. OTTINO, Northwestern University, ROB STURMAN, University of Leeds, STEPHEN WIGGINS, University of Bristol — Cutting and shuffling and the underlying mathematical formalism of piecewise isometries (PWIs) offer means to predict mixing of granular material in 3d tumblers. We have studied various mixing protocols for two-axis rotation of a spherical tumbler using a continuum model with a vanishingly-thin flowing layer (PWIs) and a realistic-thickness flowing layer. The PWIs describe the skeleton of the mixing emerging from the container shape, fill fraction, and rotation protocol. Mixing measures based on the center of mass of an ensemble of seed tracer particles and based on concentration variance provide similar results. Poor mixing occurs when the center of mass of the seed particles does not converge to the center of mass of the domain, but instead evolves toward a "limit cycle" due to symmetries in the rotation protocol. Good mixing occurs when the "limit cycle" is avoided. Comparison with simulations having a realistic flowing layer discerns the role of the flowing layer's thickness on mixing. The quality of mixing predicted by the center of mass measure based on the model with a vanishingly-thin flowing layer (PWIs) correlates with the quality of mixing predicted by the decay of concentration variance, allowing for fast optimization of mixing protocols using PWIs.

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