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Mixing and non-mixing behavior of three-dimensional granular flows in a spherical tumbler[1] MENGQI YU, PAUL UMBANHOWAR, JULIO OTTINO, RICHARD LUEPTOW, Northwestern Univ — We consider mixing of granular materials in the simplest three-dimensional (3D) flow geometry possible, that of a half-filled spherical tumbler rotated by less than 90° alternately about two perpendicular horizontal axes, as a prototype to investigate mixing under the competing influences of both stretching (during flow) and cutting & shuffling (upon changing the axis of rotation). In experiments, x-ray visualization of a tracer reveals persistent non-mixing regions, which have properties that are surprisingly consistent with predictions of a continuum model simulation and an idealized model based on the mathematics of piecewise isometries in which an object is cut, rearranged, and then reassembled into the same shape. Tracer particles are designed to either stay near the tumbler wall, which maps the properties of the outermost shell of the sphere, or, in contrast, to fully explore the 3D volume of the tumbler under the influence of collisional diffusion. The 3D trajectories indicate that mixing is enhanced when the particle travels across radial shells. Thus, 3D mixing can be predicted by models sampling 2D surfaces over a range of radii.

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