Video: Zombie vortices in protoplanetary disks and their roles in star and planet formation

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The understanding of the early stages of planet formation from a disk of orbiting particles is an ongoing challenge for astrophysics and planetary science. Dr. Marcus will address the importance of instabilities in the particle disk as a link in the planetary formation chain.

Without instabilities, gas around a forming protostar remains in orbit, and the final star cannot form; dust grains cannot accumulate to form planets; and the compositions of meteorites cannot be explained. Unfortunately, the Keplerian motion within a disk is assumed by most astrophysicists to be stable by Rayleigh's theorem because the angular momentum of the disk increases with increasing radius.

Dr. Marcus will show that there is a new purely hydrodynamic instability that is violent and destabilizes the protoplanetary disk, filling it with turbulence. The essential ingredients of the new instability are rotation, shear, and vertical density stratification, so the instability can occur in stratified Boussinesq (or fully compressible) Couette flows. The new instability occurs at critical layers where neutrally-stable eigenmodes are singular in the inviscid limit (but finite, with a width that scales as the Reynolds number Re to the -1/3 power when viscosity is present) and requires an initial finite-amplitude perturbation. In a flow initialized with weak Kolmogorov noise with initial Mach number Ma, when Ma > Re-1/2 (~10-7 in a protoplanetary disk) the instability will be triggered and create turbulence and large-volume and large-amplitude vortices that fill the disk. When the initial perturbation is an isolated vortex, the vortex triggers a new generation of vortices at the nearby critical layers. After this second generation of vortices grows large, it triggers a third generation. The triggering of subsequent generations continues ad infinitum in a self-similar manner creating a 3D lattice of turbulent 3D vortices.

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