Self-Induced Rayleigh-Taylor Instability in Granular Flows

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Abstract

Dry granular material flowing on rough inclines can experience a self-induced Rayleigh-Taylor (RT) instability followed by the spontaneous emergence of convection cells. For this to happen, particles are different in size and density, the larger particles are the denser but still segregate towards the surface. When the system is, as usual, initially made of two layers, dense particles above, a Rayleigh-Taylor instability develops during the flow. When the system is initially made of one homogeneous layer mixture, the granular segregation leads to the formation of an unstable layer of large-dense particles at the surface which subsequently destabilizes in a RT plume pattern. The unstable density gradient is only induced by the motion of the granular matter. This self-induced Rayleigh-Taylor instability and the two-layer RT instability are studied using two different methods, experiments and simulations. At last, contrarily to the usual fluid behavior where the RT instability relaxes to two superimposed stable layers of fluid, the granular flow evolves to a pattern of alternated bands with recirculation cells analogous to Rayleigh-Benard convection cells where segregation sustains the convective motion. An unstable state that is self-induced by the flow is unusual in fluid mechanics. It is interesting to note that this very simple system, flowing particles having different sizes and densities, brings the sufficient mechanisms to induce self-organisation, pattern formation and instability, features that are usually met in more complex systems like biological systems or complex chemical reactions.

Keywords: Rayleigh Taylor instability, Rayleigh Bénard instability, Granular Flow, Segregation, Self Organisation, Pattern Formation

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