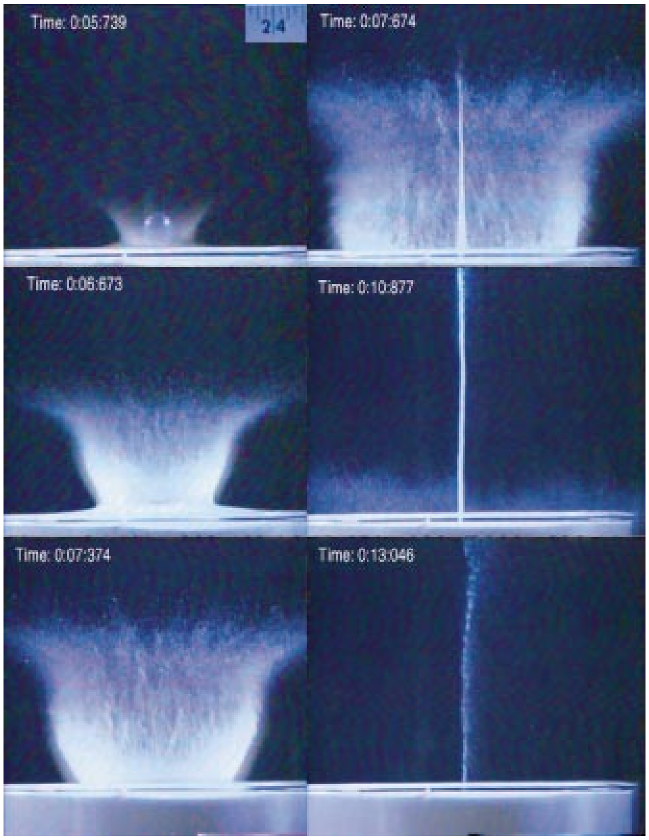


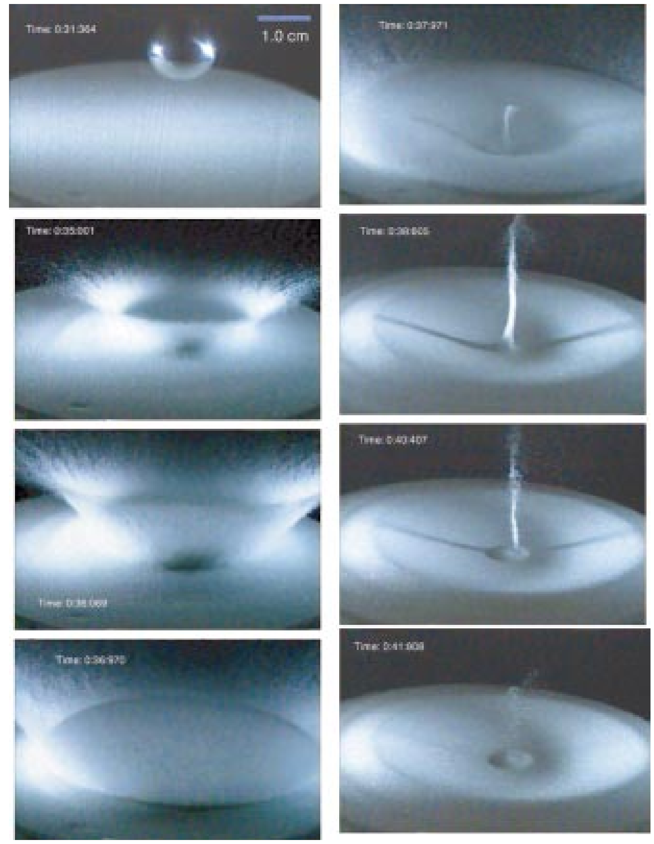


## Granular Jetting

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When a solid sphere impacts on a deep layer of granular medium, it generates an ejecta sheet and a transient axisymmetric crater. The gravity-driven radial collapse of this crater generates a pressure spike as the cavity closes. This pressure spike drives up a narrow granular jet along the axis of symmetry.

The sequences in the above figures show such a granular jet generated by the impact of a lead sphere at impact speed 5.5 m/s. The ball has a diameter of 1.34 cm and the density of 11.5 g/cm$^3$. The highly monodisperse spherical glass beads have diameter of 0.079 mm and density of 2.48 g/cm$^3$. The impacting sphere produces a deep cylindrical cavity in the sand. This cavity subsequently collapses radially under the gravity-induced ''hydrostatic'' pressure. The sand converges axisymmetrically towards the center of the cavity. Due to the relatively small compressibility of the granular medium, the radial velocity diverges as $1/r$ when the cavity closes. This inertial focusing produces a large dynamic pressure-spike driving up the sand in a narrow jet along the axis of symmetry. This new phenomenon suggests that a singularity in the surface tension force (which is absent for dry granular medium here) is not necessary to produce such jets and raises the question whether the inertial focusing is the sole mechanism. Our experiments will be useful in separating the effects of surface tension and inertial focusing,[1,2] on the tuning of singular fluid jets. More importantly, they give insights into the constitutive properties of flowing granular media at high shear rates. The tuning of the granular jet does not depend on the layer depth as in the fluids case,[2] however, the granular jet height is strongly dependent on the grain size of the granular medium. We get the highest jets using the finest granular media for the same impact velocity.

The quantity we use to characterize the ''singularity'' or jetting event is the maximum height attained by the jet $H_j$. The maximum height of the granular jet is found to depend on the impact velocity, gravity, and the effective viscosity of the granular medium through a simple product of the Reynolds and Froude numbers.[3]

[1]J. Shin and T. A. McMahon, ''The tuning of a splash,'' Phys. Fluids A **2**, 1312 (1990).
[2]B. W. Zeff, B. Kleber, J. Fineberg, and D. P. Lathrop, ''Singularity dynamics in curvature collapse and jet eruption on a fluid surface,'' Nature (London) **403**, 401 (2000).
[3]S. T. Thoroddsen and A. Q. Shen, ''Granular jets,'' Phys. Fluids **13**, 4 (2001).