Mach Cones in Dusty Plasmas: "Shocked" to be a wake?

Supersonic jets create audible (and sometimes visible [Fig. 1]) "sonic booms"; ships create distinctive wakes [Fig. 2]; and microscopic dust grains create "multiple Mach cones" as they move through a layer of ionized dust [Fig. 3]. Initially, the multiple Mach cones were ascribed to the behavior of nonlinear shocks in an elastic material. But are these Mach cones nonlinear shocks, or linear wakes?

The Mach cones are created when a charged grain of dust moves along the surface of a thin dusty plasma. The wake consists of several cone-like structures, termed "Mach cones" by the experimentalists who first observed them. (Mach cones are commonly created by objects moving faster than the speed of sound; and here the speed of sound is only a few centimeters per second!) The Mach cones are readily visualized, and were reproduced on the year 2000 calendar and directory of the APS.

However, Dubin has now shown that the Mach cones are actually a complicated pattern arising from simple linear waves; the cones represent the superposition of many waves, each of which follows the linear dispersion relation for sound waves in the dusty plasma layer. The theory is similar to the classic analysis of the wake behind a moving ship - the "Kelvin wedge". One benefit of this theory is that several difficult-to-measure plasma parameters (the Debye shielding length and the charge on the dust grains) can be inferred from the angular shape and spacing of the Mach cones.

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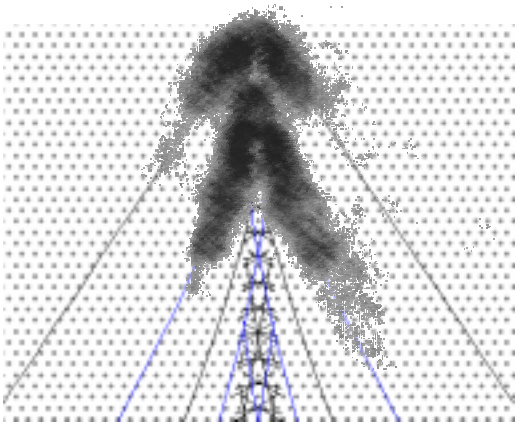
1)The nonlinear mach cone behind an f-18, made visible by condensing water vapor in the shock.

2)The linear wake behind a ship (the Kelvin wedge)



3)The 'multiple mach cones' formed by a moving charge in a dusty plasma, superimposed on a linear theory for the locations of wave crests (black lines) and troughs (blue lines).