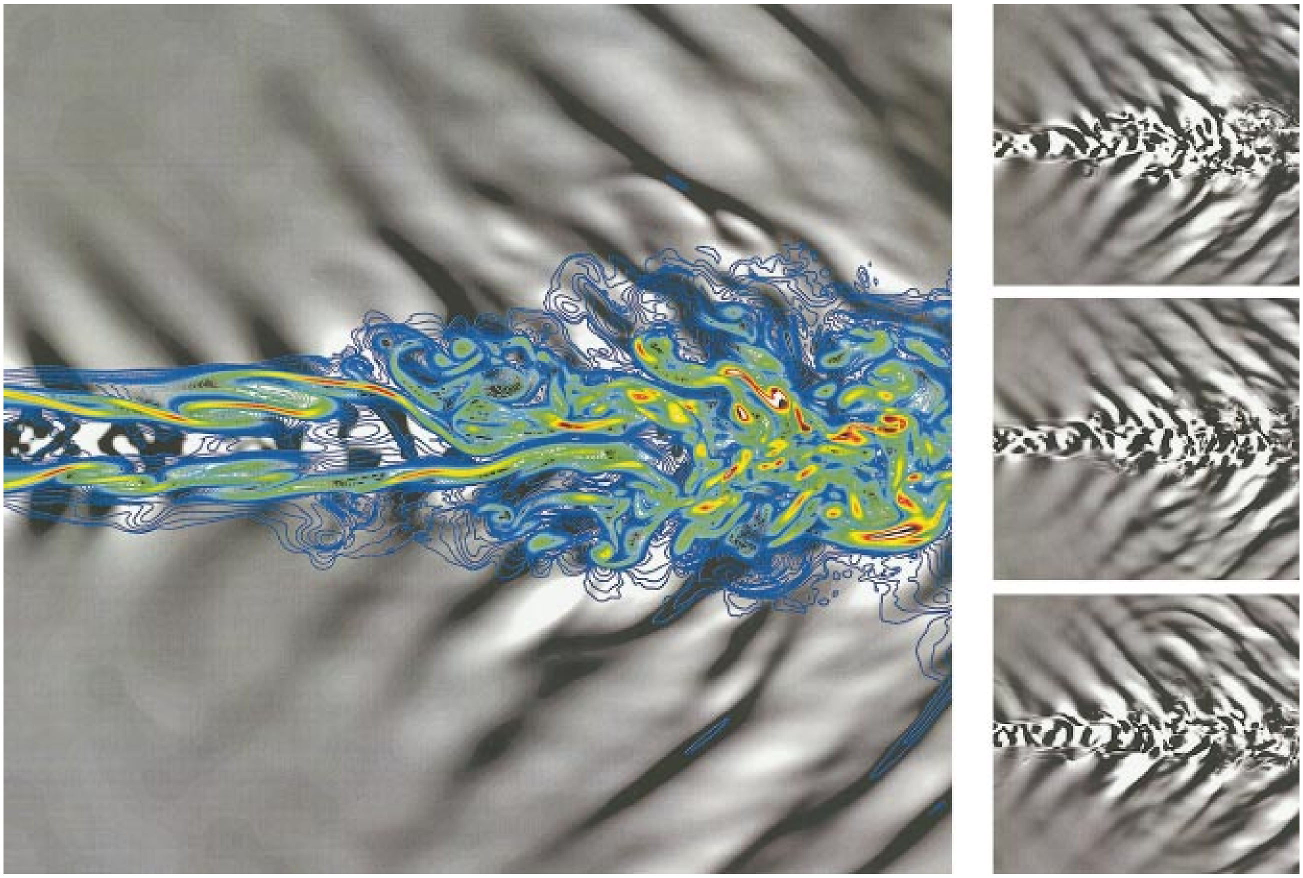

Mach Wave Radiation from a Jet at Mach 1.92

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The visualization shows a two-dimensional slice through the center of a Mach 1.92, Reynolds number 2000 round jet computed by direct numerical simulation. The simulation is discussed in detail by Freund, Lele, and Moin.[1] The jet turbulence is visualized with color contours of vorticity between $0U_c/r_o$ and $4.5U_c/r_o$, where U_c is the local centerline velocity and r_o is the nozzle radius. (The peak vorticity in this plane was $7.2U_c/r_o$ at the instant shown.) Despite the low Reynolds number, we see a range of turbulence scales in the flow. The grayscale levels shown are directly proportional to divergence of velocity between solid white which indicates $\nabla\cdot\mathbf{u}>0.017U_j/r_o$ and solid black which indicates $\nabla\cdot\mathbf{u}<0.017U_j/r_o$, where U_j is the jet nozzle velocity. In the sound field, narrow regions of compressions (dark) are typically separated by broader expansions (light) which suggests a nonlinear steepening process. Steepening in the far-field was investigated for this flow using weak shock theory.[1] The small visualizations, however, reveal that the dark regions appear to originate as already thin areas within the jet, as speculated by Ffowcs Williams *et al.*[2] who did not observe a significant increase in wave steepness at greater distances from a jet. This suggests a nonlinearity in the noise generation mechanism, though a quantitative investigation of this is necessary before any conclusions can be made. The role of nonlinearity in generating noise is being investigated.[3] The Mach waves all propagate at approximately 50° from the jet axis. Simultaneous visualization of the pressure and divergence of velocity (not shown) suggest that there are usually regions of high pressure at the origin of each Mach wave convecting at an appropriate supersonic velocity for the Mach angle, but as yet we have not identified consistent concrete events that spawn Mach waves.

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[1] J. B. Freund, S. K. Lele, and P. Moin, ''Direct numerical simulation of a Mach 1.92 turbulent jet and its sound field,'' AIAA J. **38**, 2023 (2000).
[2] J. E. Ffowcs Williams, J. Simson, and V. J. Virchis, ''Crackle: an annoying component of jet noise,'' J. Fluid Mech. **71**, 251 (1975).
[3] K. Mohseni, T. Colonius, and J. B. Freund, ''On the role of nonlinearity in Mach wave radiation in a Mach=1.92 jet,'' 39th Aerospace Sciences Meeting, Reno, NV, AIAA Paper 2001-0377, 2001.