Unified dynamic and aeroacoustic theories for the ring-mode coherent structures in all flow regions of a subsonic turbulent jet

Zhongyu Zhang[a] and Xuesong Wu[b]

Large-scale coherent structures (CS) are present on a turbulent circular jet and are known to constitute an important source of jet noise. These structures may be treated as wavepackets of instability modes supported by the time-averaged mean flow. The nonlinear evolution and acoustic radiation of such CS in the distinguished near-nozzle and the fully developed regions of a jet are described respectively[1,2]. The mechanism of envelope radiation was identified with the physical sound sources being attributed to the slowly breathing mean-flow distortion generated by the nonlinear interactions of CS. In the near-nozzle region, where the envelope length scale of the CS is comparable with the nozzle diameter, the CS resides in the thin shear layer developing from the lip line, and its nonlinear dynamics resembles that on a planar shear layer, which is only slightly affected by circular geometry, or circularity. Circularity causes a leading-order effect on acoustic radiation. One of the significant new features is the presence of an inner acoustic field in the potential core. The outer and inner acoustic fields interact with each other, and the equivalent sources of sound have to be determined along with the sound fields. In the developed region, the equivalent sound sources, on the contrary, can be pre-determined before the sound fields are analysed. As the jet develops downstream, the inner acoustic field gradually narrows and disappears. It is demonstrated that the present theory for nonlinear dynamics and acoustic radiation is valid from the near-nozzle to the developed regions, which describes the characteristics of both the outer (figures 1(a, b)) and inner (if present, figures 1(c)) acoustic fields. It thus stands as a unified theory.

---

[a] Lab. High-Speed Aerodynamics, Tianjin University, Tianjin, PRC
[b] Dep. Mathematics, Imperial College London, London, UK
[1] Zhang and Wu, *J. Fluid Mech.,* **940**, A39 (2022)
[2] Zhang and Wu, *Phy. Fluids,* **35**, 0141138 (2023)

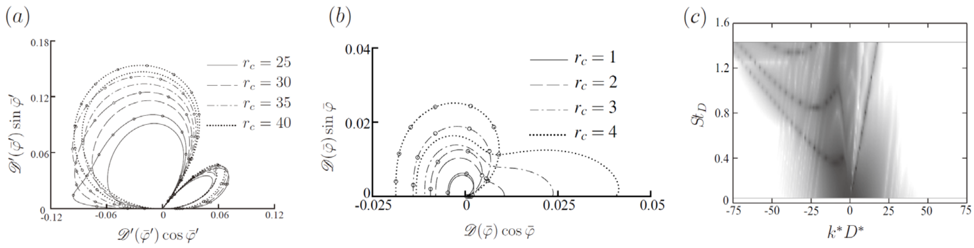

Figure 1: (a) The directivity of the outer acoustic field radiated from a modulated CS in the near-nozzle region. (b) The directivity of the outer acoustic field radiated from a modulated CS in the fully developed region. (c) The spectrum of the emitted acoustic pressure field in the potential core.