A comparison of the silent base flow and vortex sound analogy sources in high speed subsonic jets

S. Sinayoko A. Agarwal

University of Cambridge, UK

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Outline

Introduction

Laminar jet

Turbulent jet

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How can we define the sound sources?

$$\mathbf{N}\mathbf{q} = 0$$

$$\mathbf{L}\mathbf{q}' = \mathbf{s}$$

$$\mathbf{q} = \overline{\mathbf{q}} + \mathbf{q}'$$

The silent base flow sources

M. E. Goldstein
On identifying the true sources of aerodynamic sound.
Journal of Fluid Mechanics, 526:333–347, 2005.

The silent base flow sources

- M. E. Goldstein
  On identifying the true sources of aerodynamic sound.
  Journal of Fluid Mechanics, 526:333–347, 2005.
- S. Sinayoko, A. Agarwal, and Hu Z.
  Flow decomposition and aerodynamic noise generation.
  Journal of Fluid Mechanics,668:335–350, 2011.

Radiation criterion: $k = \omega / c_\infty$.

“Lighthill” silent base flow sources

Density formulation

Dependent variables

$$\mathbf{q} = \{\rho, \rho\mathbf{v}, \pi\}$$

“Lighthill” silent base flow sources

Density formulation

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Sound sources

$$f_{1i}' = -\frac{\partial}{\partial x_j}\left(\overline{\rho}\,\widetilde{v}_i\widetilde{v}_j\right)'$$

$$\widetilde{v}_i = \overline{\rho v_i}/\overline{\rho}$$

“Doak” silent base flow sources

Total enthalpy formulation

P. Doak
Fluctuating Total Enthalpy as the Basic Generalized Acoustic Field.
Theoretical and Computational Fluid Dynamics, Vol. 10, No. 1-4, Jan. 1998, pp. 115–133.

Dependent variables

$$\mathbf{q} = \{h + v^2/2, \mathbf{v}, S\}$$

“Doak” silent base flow sources

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Dependent variables

$$\mathbf{q} = \{h + v^2/2, \mathbf{v}, S\}$$

Sound sources

$$f'_{2i} = -\left(\overline{\mathbf{\Omega}} \times \overline{\mathbf{v}}\right)'_i$$

Dominant source in laminar jet: shear noise

S. Sinayoko and A. Agarwal.
The silent base flow and the sound sources in a laminar jet.
Journal of the Acoustical Society of America,131:1959–1968, 2012.

Dominant source 1

$$f'_{1zz} \approx \rho_\infty \frac{\partial}{\partial z} \left(v_0 \widetilde{v}_z \right)'$$

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Dominant source in laminar jet: shear noise

S. Sinayoko and A. Agarwal.
The silent base flow and the sound sources in a laminar jet.
Journal of the Acoustical Society of America,131:1959–1968, 2012.

Dominant source 1

$$f'_{1zz} \approx \rho_\infty \frac{\partial}{\partial z} \left(v_0 \widetilde{v_z} \right)'$$

Source 2 definition

$$\overline{\Omega} = \frac{\partial \bar{v}_z}{\partial r} - \frac{\partial \bar{v}_r}{\partial z}$$
$$f'_{2z} = \bar{v}_r \, \overline{\Omega}$$
$$f'_{2r} = -\bar{v}_z \, \overline{\Omega}$$

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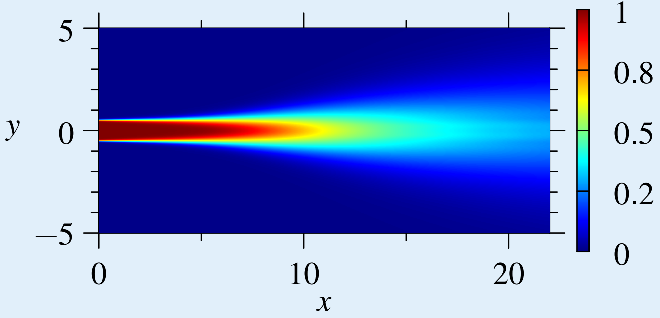
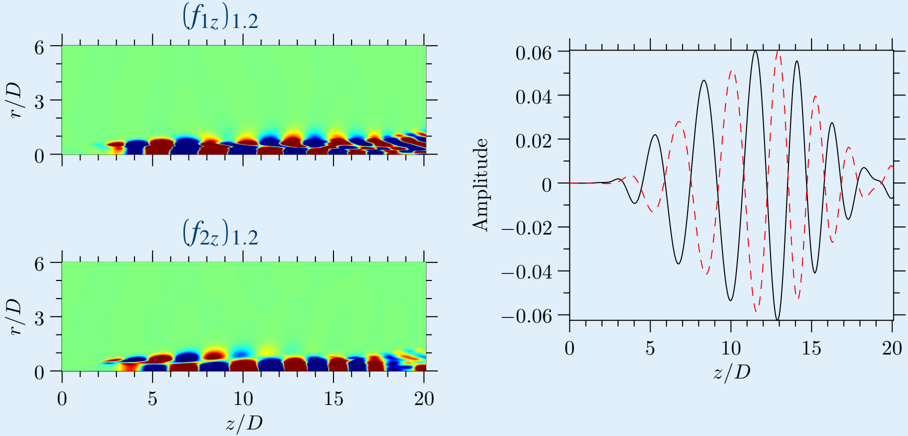
Flow description



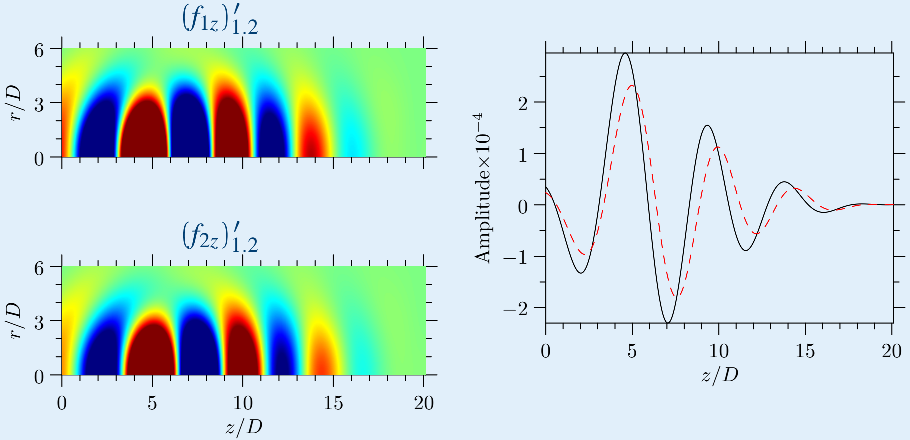
Mean flow excited at two frequencies:

$$\omega_1 = 2.2, \qquad \omega_2 = 3.4, \qquad \Delta\omega = 1.2.$$

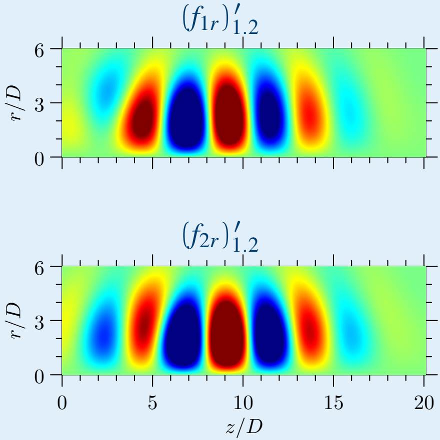
Laminar jet: unfiltered axial sources

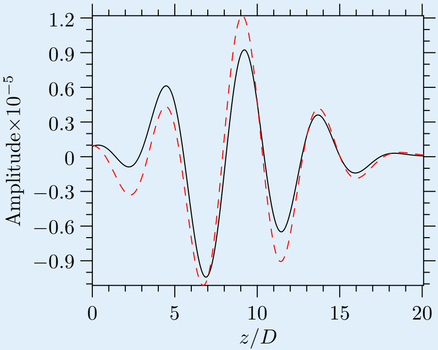


Laminar jet: filtered axial sources



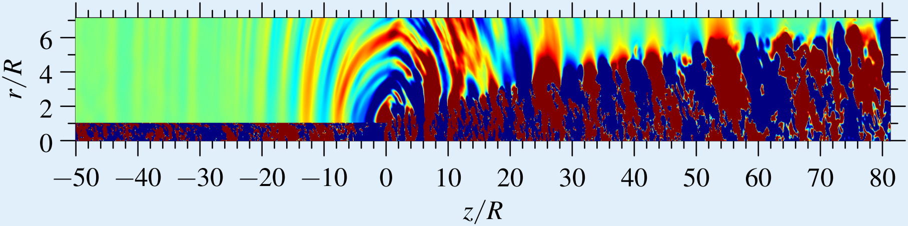
Laminar jet: filtered radial sources



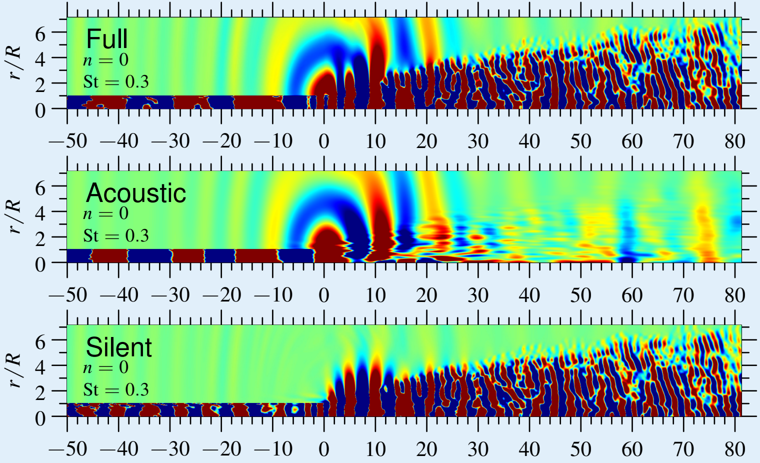


Outline

Turbulent jet: density fluctuations



Turbulent jet: flow decomposition ($n = 0, St = 0.3$)



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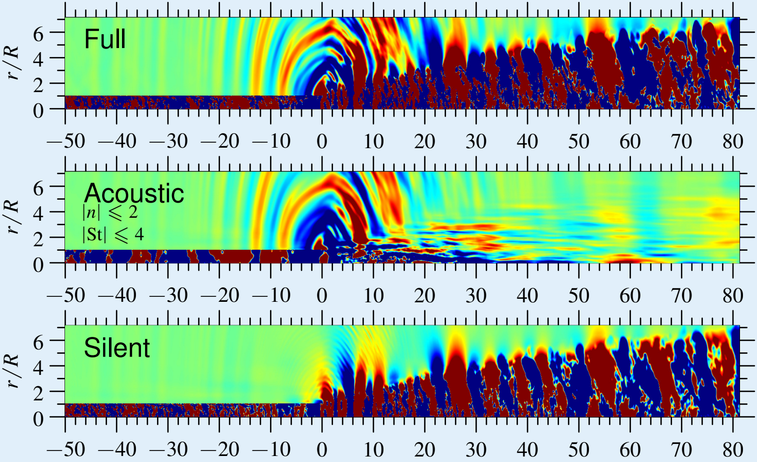
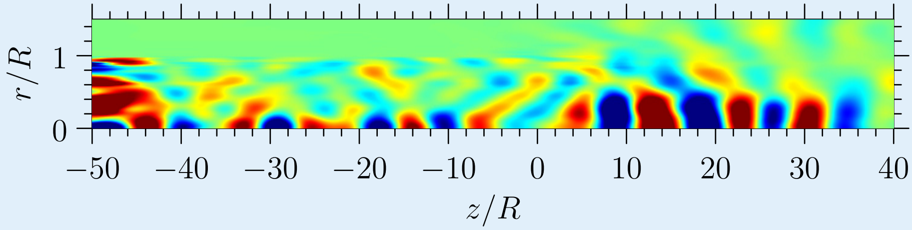
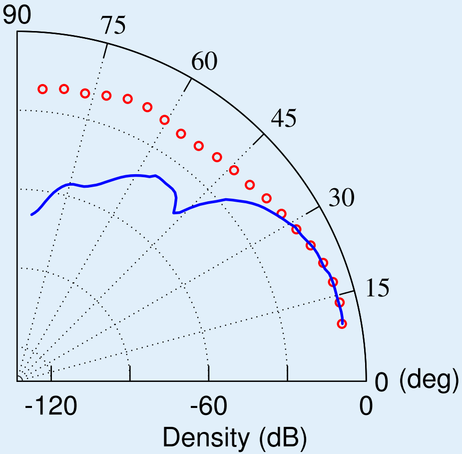
Turbulent jet: flow decomposition



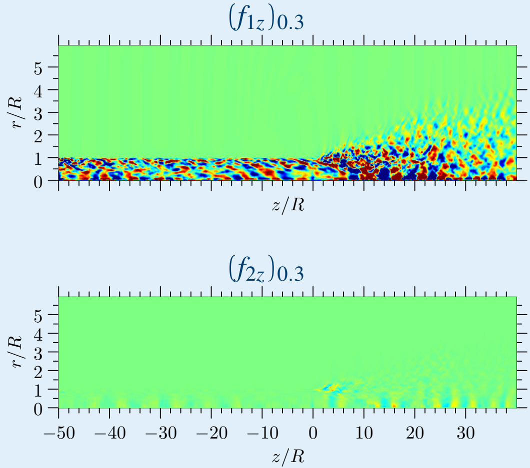
Turbulent jet: axial source $(f_{1zz})'_{0.3}$

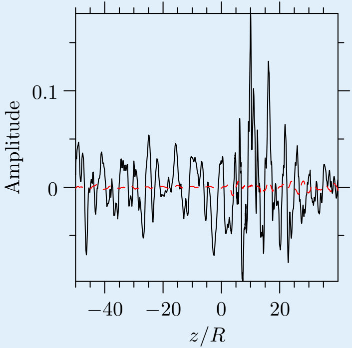


Turbulent jet: axial source $(f_{1zz})'_{0.3}$ validation

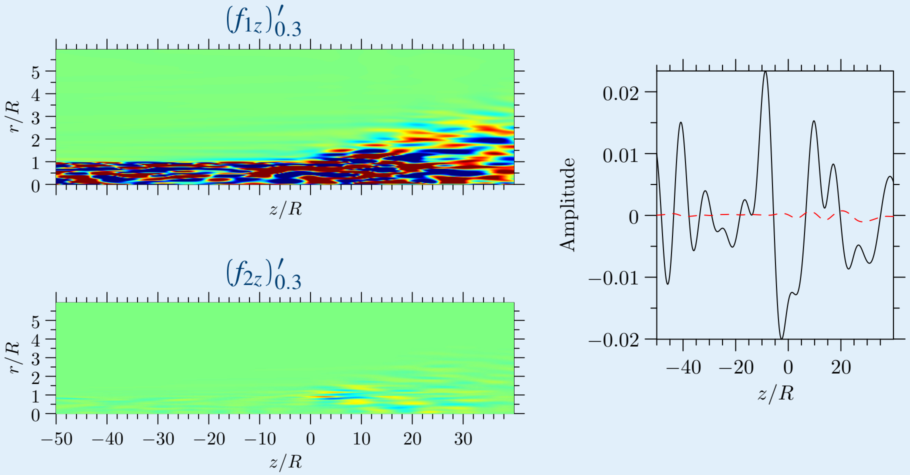


Turbulent jet: unfiltered axial sources

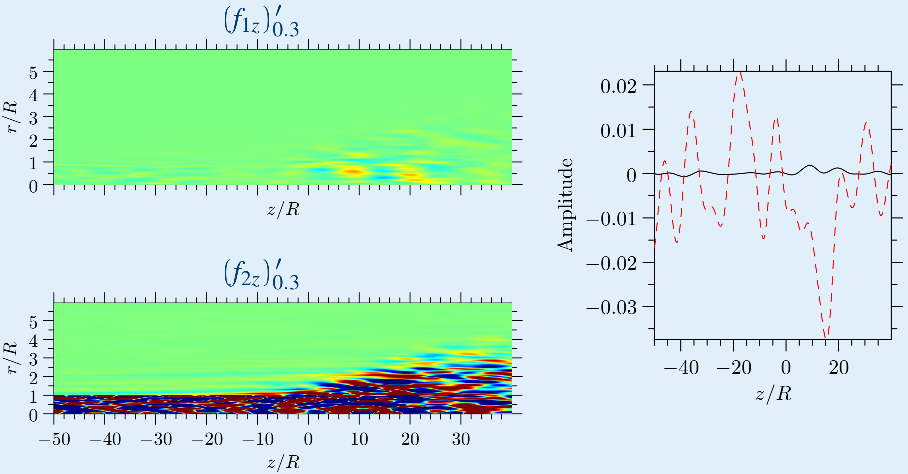




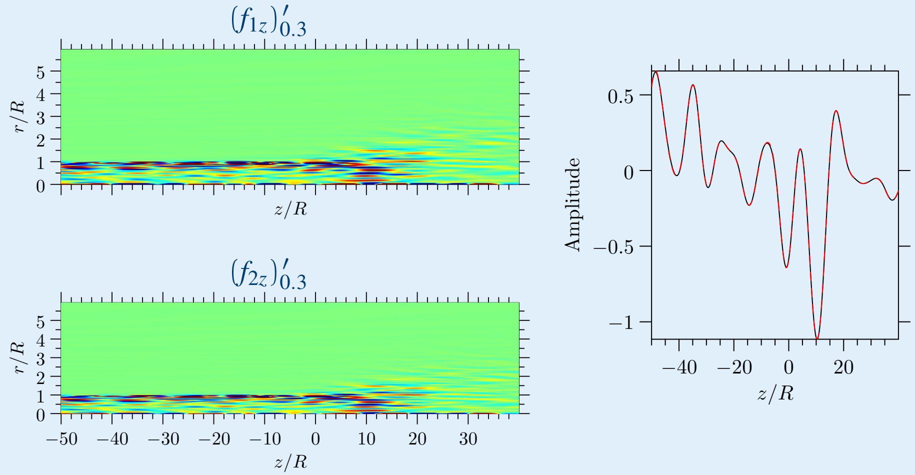
Turbulent jet: filtered axial sources



Turbulent jet: filtered radial sources



Turbulent jet: source divergence $\nabla f = \partial_z f_z + \partial_r f_r$



Conclusions

1. Vortex sound silent base flow sources
2. Laminar jet: the formulations are equivalent
3. Turbulent jet: the divergences are the same
4. Validated axial NRBF source for $n = 0$ and $St = 0.3$ for a fully turbulent jet

Thank you!