Can frequencies be predicted from mean flows?

L Tuckerman[1], S. Turton[2], Y. Bengana[1]

[1]PMMH, ESPCI Paris, PSL Research University; Sorbonne University Univ. Paris Diderot

[2]Massachusetts Institute of Technology

The von Karman vortex street is one of the most striking visual images in fluid dynamics. Immersed in a uniform flow of sufficient strength, a circular cylinder periodically sheds propagating vortices of alternating sign on either side of the "street". Although the von Karman vortex street can be simulated numerically with great accuracy, predicting its properties from general theoretical principles has proved elusive. It has been shown a linear stability analysis about the temporal mean yields an eigenvalue whose Real part is almost Zero and whose Imaginary part is very close to the vortex-shedding Frequency, a property which we call RZIF. However there has been no understanding of when and why the correct answer emerges from such an unorthodox procedure. Later work has shown that the mean flow and the frequency can be approximated without recourse to temporal simulation, by requiring that RZIF be satisfied, leading to a truncation called the Self Consistent Model (SCM). It has also been shown that this property can be generalized to flows with a broad spectrum, namely that the response at each frequency can be calculated by linearizing about the mean flow.

We have carried out a similar analysis of thermosolutal convection, which is driven by opposing thermal and solutal gradients. In a spatially periodic domain, branches of traveling waves and standing waves are created simultaneously by a Hopf bifurcation. We find that linearization about the mean fields of the traveling waves yields an eigenvalue which, like the cylinder wake, satisfies the RZIF property. In marked contrast, linearization about the mean field of the standing waves yields neither zero growth nor the nonlinear frequency. We show that this difference can be attributed to the fact that the temporal power spectrum for the traveling waves is peaked, while that of the standing waves is broad. We give a general demonstration that the frequency of any quasi-monochromatic oscillation can be predicted from its temporal mean. We show that the traveling waves are a solution to the SCM, but only very near threshold, whereas the RZIF property is satisfied far above threshold.

[l] Turton, Tuckerman, Barkley, Phys. Rev. E **91**, 043009 (2015).

[2] Barkley, Europhys. Lett. **75**, 750 (2006).

[3] Mantic-Lugo, Arriata, Gallaire, Phys. Rev. Lett. **113**, 084501 (2014).

[4] Beneddine, Sipp et al., J. Fluid Mech. **798**, 485 (2016).