Experimental evidence of the statistical equilibrium of large scales in hydroelastic wave turbulence

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Understanding the emergence of statistical equilibrium in out-of-equilibrium systems is of great significance, as it allows the application of statistical mechanics tools and methods. In this work, we present the first experimental evidence of statistical equilibrium at large scales in hydroelastic turbulent waves driven by small-scale random forcing. The wave field statistics, fully resolved in space and time at scales larger than the forcing scale, exhibit remarkable agreement with the predictions of Rayleigh-Jeans equilibrium spectra over more than a decade. Furthermore, we calculate the effective temperature, entropy, and heat capacity of this nonequilibrium system, demonstrating that classical thermodynamic concepts can effectively describe large-scale statistical equilibrium in turbulent systems.

The corresponding experimental set-up is shown Figure 1 and consist in a square tank, filled with water and covered by an elastic sheet made of silicone rubber. The waves are produced by a shaker fed with a bandpass Gaussian white noise signal. The vertical deformations of the sheet are either measured in a single point thanks to a laser Doppler velocimeter, or are fully resolved in space and time using the Fourier Transform Profilometry method [1]. Hydroelastic waves are highly relevant for practical applications of great importance. In oceanography, they provide a good approximation of waves propagating on the ice-covered ocean surface. The recent development of very large floating structures, such as floating airports, mobile of shore bases, and large floating solar panel farms, further highlights the need for a better understanding of these waves. In both cases, ocean swell can act as small-scale forcing, leading to complex large-scale dynamics. This work has been submitted to PRL [2].

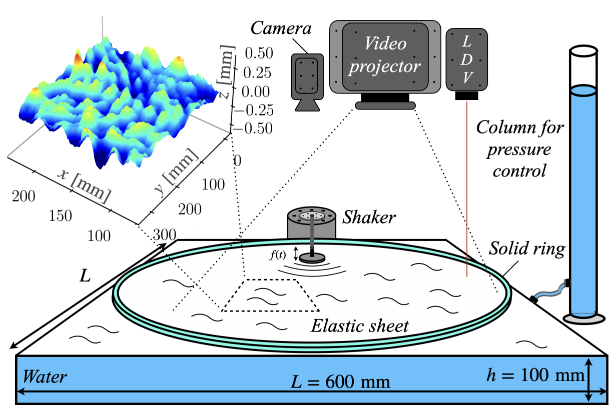

Figure 1. Scheme of the experimental device.

Références

1. P. J. Cobelli, A. Maurel, V. Pagneux, and P. Petitjeans, *Exp. Fluids*, **46**, 1037 (2009).
2. M. Vernet and E. Falcon, *Phys. Rev. Lett.*, **Submitted**, (2025).

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