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Beer bottle whistling: a stochastic Hopf bifurcation[1] EDOUARD BOUJO, CLAIRE BOURQUARD, YUAN XIONG, NICOLAS NOIRAY, CAPS Laboratory, MAVT Department, ETH Zurich — Blowing in a bottle to produce sound is a popular and yet intriguing entertainment. We reproduce experimentally the common observation that the bottle "whistles", i.e. produces a distinct tone, for large enough blowing velocity and over a finite interval of blowing angle. For a given set of parameters, the whistling frequency stays constant over time while the acoustic pressure amplitude fluctuates. Transverse oscillations of the shear layer in the bottle's neck are clearly identified with time-resolved particle image velocimetry (PIV) and proper orthogonal decomposition (POD). To account for these observations, we develop an analytical model of linear acoustic oscillator (the air in the bottle) subject to nonlinear stochastic forcing (the turbulent jet impacting the bottle's neck). We derive a stochastic differential equation and, from the associated Fokker-Planck equation and the measured acoustic pressure signals, we identify the model's parameters with an adjoint optimization technique. Results are further validated experimentally, and allow us to explain (i) the occurrence of whistling in terms of linear instability, and (ii) the amplitude of the limit cycle as a competition between linear growth rate, noise intensity, and nonlinear saturation.

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