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Distinctive diffusive properties of swimming planktonic copepods in different environmental conditions*

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Abstract. Suspensions of small planktonic copepods represent a special category in the realm of active matter, as their size falls within the range of colloids, while their motion is so complex that it cannot be rationalized according to basic models of self-propelled particles. Indeed, the wide range of individual variability and swimming patterns resemble the behaviour of much larger animals. By analysing hundreds of three-dimensional trajectories of the planktonic copepod *Clausocalanus furcatus*, we investigate the possibility of detecting how the motion of this species is affected by different external conditions, such as the presence of food and the effect of gravity. While this goal is hardly achievable by direct inspection of single organism trajectories, we show that this is possible by focussing on simple average metrics commonly used to characterize colloidal suspensions, such as the mean square displacement and the dynamic correlation functions. We find that the presence of food leads to the onset of a clear localization that separates a short-time ballistic from a long-time diffusive regime. Such a benchmark reflects the tendency of *C. furcatus* to remain temporally feeding in a limited space and disappears when food is absent. Localization is clearly evident in the horizontal plane, but is negligible in the vertical direction, due to the effect of gravity. Our results suggest that simple average descriptors may provide concise and useful information on the swimming properties of planktonic copepods, even though single organism behaviour is strongly heterogeneous.

1 Introduction

Motion behaviour reveals the dynamic adaptations of an organism to a changing environment. Movement can have direct consequences on the fitness of the individual, but it can also affect the population and metapopulation levels [1, 2]. The first model used to simulate the organism movement was the random walk (see, *e.g.*, refs. [3, 4]). However, this was demonstrated insufficient to represent biological systems that are intrinsically characterized by a high degree of complexity. As such, animal movement may display regular patterns that cannot be assimilated to random walks [5, 6]. In some instances, the emergence of regularities depends on the considered timescale and might manifest an adaptive behaviour for organism's survival. Indeed, movement is crucial for organism's life and represents a tradeoff between searching for food and mates, and escaping from predators (see [7] and references therein). In water, movement is constrained by the medium since friction is higher as compared to the air in terrestrial environments. Therefore, water acts as a selective force favoring specific organismal morphologies, *e.g.* [8], and reduces significantly animal's speed. Notwithstanding this constraint, small planktonic metazoans, living in the water at the edge between viscous and inertial environments [9], display a large suite of swimming behaviour [10, 11]. The various motion patterns of planktonic copepods, the most numerous animals at sea, have been categorised in two prevalent modes, *i.e.* "ballistic" and "diffusive" [12]. In many active systems, these two modes interplay on different time and length scales, and are often tangled with intermittent individual dynamics, so as to optimise target search [13–16]. Intermittency in planktonic copepod trajectories has been, indeed, observed in recent experiments, which also unveiled the presence of regularities

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