PRELIMINARY QUANTIFICATION OF FREELY EXPLORING *ATTA INSULARIS*

CUANTIFICACION PRELIMINAR DE LA EXPLORACION LIBRE EN *ATTA INSULARIS*

A. Reyes, G. I. Rodríguez and E. Altshuler†

Group of Complex Systems and Statistical Physics, Physics Faculty, University of Havana, Havana 10400, Cuba; ealtshuler@fisica.uh.cu†.
† corresponding author

Ants are social insects that typically use pheromone traces to self-organize long foraging lines without any centralized organization [1]. However, a very basic question arises: how does a single ant explores new territories without any chemical or "topographical" clues? To the authors knowledge, the question is unanswered in the literature. In this paper, we offer a preliminary quantification of the free exploration of the Cuban leaf-cutter ant *Atta insularis* (known as *bibijagua* in Cuba) [2–6].
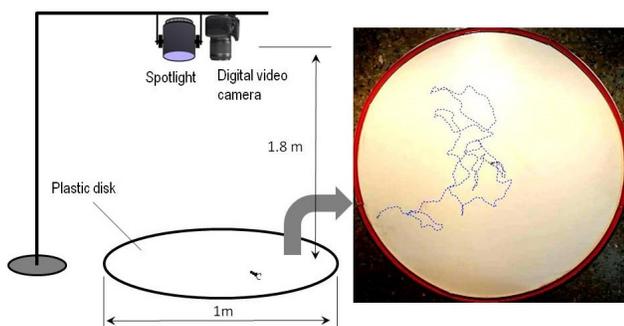

Figure 1. Experimental setup. Left panel: sketch of the experimental set up. The camera was a CANON EOS Rebel T3. Videos were taken at 25 frames per second, with a resolution of 4272 pixels × 2848 pixels. Right panel: Actual photogram of the experimental arena, where an experimental trajectory of a single ant is represented as a dotted line. The starting point of the trajectory is at the geometrical center of the circular arena.

A typical experiment can be described as follows. A single individual of *Atta insularis* is collected from a foraging line in natural conditions, immediately taken to the laboratory, and released at the center of a 1-meter-diameter circular area made of white plastic. The trajectory of the ant is then followed by a digital camera located 1.8 meters above the center of the arena, until the ant reaches the edge of the circular platform. The illumination is provided by a 250-watt incandescent lamp located near the camera, equipped with a light diffusor, as sketched in the left panel of Fig.1. (Our setup does not produce temperatures or illuminations on the arena bigger than the maxima experienced by ants out of the nest in natural conditions). Once the experiment has finished, the ant is released back in its natural foraging area. The experiment is replicated for several individuals collected

in the same way, thoroughly cleaning the plastic arena with ethanol between repetitions.

Images were averaged and the result was subtracted from each photogram, in order to distinctly visualize the moving object (i.e., the ant), on an immobile and homogeneous background. Then, images were binarized using an appropriately threshold, so the ant trajectory can be easily converted into a list of positions and times. The right panel of Fig.1 shows a typical trajectory.
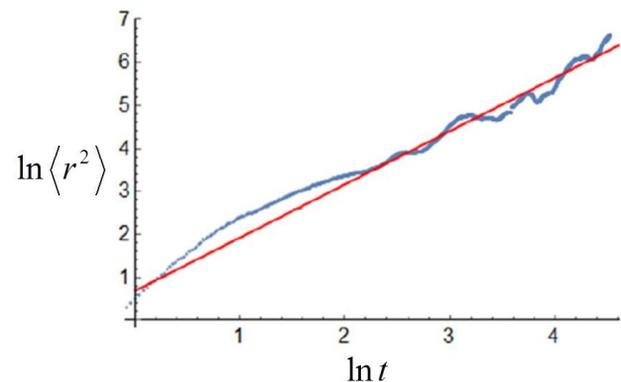

Figure 2. Mean Squared Displacement (MSD). The figure shows the logarithm of the MSD of the ants against the logarithm of time. This figure includes the data from a sample of 25 experiments with individual ants. The straight line corresponds to a Log-Log graph of the power law $\langle r^2 \rangle \sim t^\gamma$ where the exponent $\gamma = 1.24 > 1$, suggests *super-diffusion*.

The first parameter we measured was the position of the ants as time goes by, which was used to calculate the Mean Squared Displacement (MSD), shown in Fig.2. In the figure, it is included the data of 25 experiments (corresponding to 25 ants). The straight line fitting the data can be described as $\langle r^2 \rangle \sim t^\gamma$ with $\gamma = 1.24$ (here, r is the absolute distance from the ants to the center of the arena). Since the value of the exponent is bigger than 1, the motion can be classified as *super-diffusive* –i.e., there is a direction persistence beyond a pure random walk. Super-diffusive behavior is expected when animals move in an "anisotropic" environment. For example, bacteria moving "chemotactically" in a chemical gradient of nutrients, or "phototactically" in a light gradient

[7]. In the case of ants, we would expect a direction-biased walk if our arena was illuminated from one side (ants would try to escape from light), but that is not the case. A strongly super-diffusive behavior could be also expected if many ants were released on the arena at the same time, since they would chase each other due to the deposition of pheromone tracks –but that is neither our case–. The super-diffusive behavior we have found in isolated ants might be related to "direction memory" of the individuals, or perhaps a short range (but not long range) lack of memory ("Alzheimer walk", [8]). However, we have not quantified in detail the temperature and illumination homogeneities in the arena, so we cannot discard possible effects on the diffusivity. This will be done in the future.

The second element we have computed is the statistics of turn angles of the ant. The inset of Fig.3 illustrates how it was measured. First, the trajectory of one ant was divided into straight segments connecting two consecutive positions of the individual, separated by a time interval of 0.8 seconds (20 frames). The turn angle was defined as the deviation angle from one trajectory segment, to the next.

The main frame of Fig.3 shows the statistical distribution of the resulting angles, comprising all trajectories measured on 25 different experiments. It can be immediately seen that there is a dominance of small turn angles: most of the time, ants explore through smooth trajectories, and just eventually stop and perform a major turn. A further observation is that the average length of the right bars (especially near the center of the distribution) is significantly bigger than that of the left bars, i.e., left turns are more probable (due to our sign convention, it corresponds to a "thicker" right side of the statistical distribution shown in Fig.3). That opens the question if ants are "intrinsically left handed", so to speak.

example of these antecedents is illustrated in [10], also with *Temnothorax albipennis*, showing more left turns when ants explore new territories for the construction of a nest.

The continuous line in Fig.3 corresponds to a fit of a α-stable distribution (see, for example, [11]) which is able to reproduce the "power-law-like" tails of the bell-shaped distribution.

During exploration, every few seconds ants stop and perform bigger turns whose average is of the order of 90 degrees. In analogy with the "run-and-tumble" motion of *E. coli* [7,12–14] we define a "tumble" as a bigger turn and a *run* as the fast segment between two consecutive tumbles. Then, we have found that the statistical distribution in the durations of runs follows an exponential law, as "classically" expected for bacteria. However, more statistics must be collected to completely discard a power law.

In summary, we have preliminarily characterized the free exploration of a social insect (the Cuban endemic ant *Atta insularis*) using parameters typically used in the area of micro-swimmers. On the one hand, we have found a super-diffusive behavior in the individual ants –which implies a certain level of direction preference of unknown origin. Secondly, we have found clues indicating that free-exploring ants are slightly "left-handed", i.e., they prefer to turn left instead of right during exploration. These results –especially the latter– must be corroborated by a larger statistical sample of individuals, and should be extrapolated to other, non-social, insect species. Finally, the quantification of the temperature and illumination homogeneities must be performed in the future.
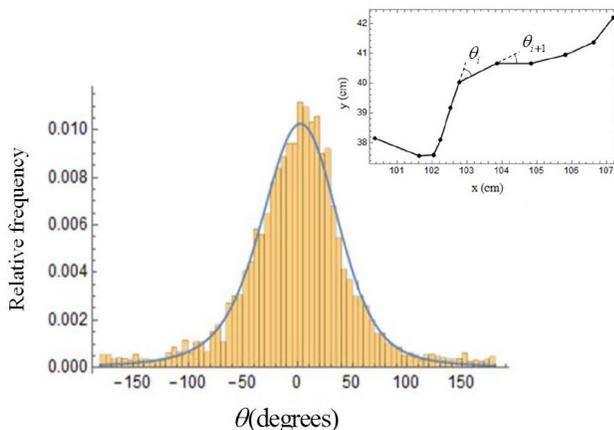

Figure 3. Frequency distribution of turn angles. The figure represents the statistical distribution of turn angles, and comprise the angles measured in all trajectories of all individual ants. The inset indicates how the turn angle is defined.

Some authors have proposed that this asymmetry can result in adaptive advantages. Studies with *Temnothorax albipennis* ants show that they apparently use their right eye more than the left eye to recognize reference points [9] (however, *Atta insularis* ants are practically blind , so they are not likely to use any reference points in our experiments). Another

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