Long-range effects of walls in schooling fish

Andreu Puy[1], Jordi Torrents[1], M. Carmen Miguel[2,3] and Romualdo Pastor-Satorras[1]
[1]Departament de Física, Universitat Politècnica de Catalunya, Campus Nord B4, 08034 Barcelona, Spain
[2]Departament de Física de la Matèria Condensada, Universitat de Barcelona, Martí i Franquès 1, 08028 Barcelona, Spain
[3]Institute of Complex Systems (UBICS), Universitat de Barcelona, Barcelona, Spain

Collective motion occurs when a system of self-propelled units exhibit spontaneous ordered movement. It is ubiquitous in the real world, arising in systems of many different scales [1, 2, 3]. Here, we approach the topic considering fish schools.

One major challenge in the field is to capture and quantify the interactions that drive the movement, both at the individual and collective level. This includes the cooperation between individuals and the responses to external elements, such as the presence of walls in a tank. Few works have tried to address the interactions with the walls, most of them investigating schools of only one or two fish [4, 5, 6, 7], finding short-range interactions decaying exponentially.

Here we use the tracking of trajectories of freely swimming fish in an experimental tank. The school consists on 40 individuals of black neon tetra (*Hyphessobrycon herbertaxelrodi*) swimming for three segments of 10 minutes of duration (1200 frames each). We have an example of the tracking (blue arrows) overlapped with an image of the experiment in g. 1, where the tank walls are displayed as a red rectangle.

We have analysed quantitatively the experimental interactions of schooling fish with the tank walls and find that wall forces in a fish school are long-range (see fig. 2), in contrast with experiments of one or two fish. We trace back the origin of the long range interactions to the transmission of information across the school. Moreover, we employ the interactions observed to build a random walk model of schooling fish in a tank and reproduce some key features of the system.

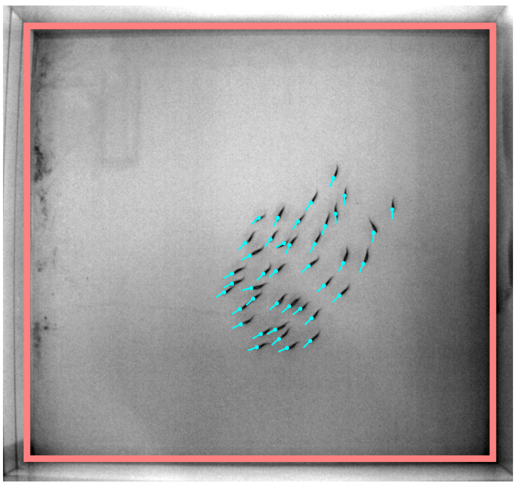
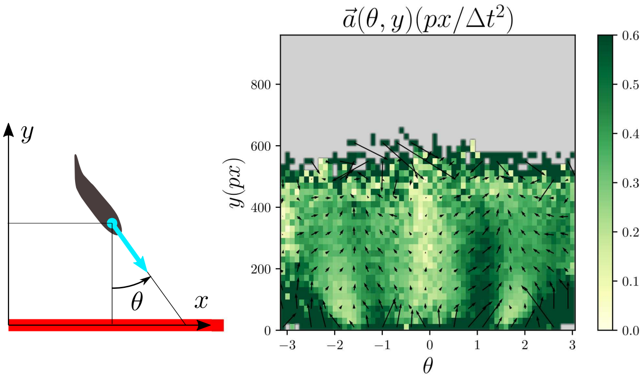


Fig. 1. The experiment consists on 40 black neon tetra free swimming in a tank. We display in blue arrows the tracking of the frame and in red the tank walls.



(a) (b)

Fig. 2. (a) We analyse the dependence of the wall interactions with the fish coordinates (x, y) and orientation θ with respect to the wall. (b) We find the wall interactions (measured by the acceleration of fish $\vec{a}$) to have a relevant influence at any point in the tank.

[1] Vicsek, T. & Zafeiris, A. Collective motion. *Physics Reports*. **517**, 71-140 (2012,8).

[2] Sumpter, D. Collective animal behavior. (Princeton University Press,2010)

[3] Ramaswamy, S. The Mechanics and Statistics of Active Matter. *Annual Review Of Condensed Matter Physics*. **1** pp. 323-345 (2010,4).

[4] Calovi, D., Litchinko, A., Lecheval, V., Lopez, U., Prez Escudero, A., Chat, H., Sire, C. & Theraulaz, G. Disentangling and modeling interactions in fish with burst-and-coast swimming reveal distinct alignment and attraction behaviors. *PLoS Computational Biology*. **14**, e1005933 (2018)

[5] Zienkiewicz, A., Ladu, F., Barton, D., Porfiri, M. & Di Bernardo, M. Data-driven modelling of social forces and collective behaviour in zebrafish. *Journal Of Theoretical Biology*. **443** pp. 39-51 (2018)

[6] Gautrais, J., Jost, C., Soria, M., Campo, A., Motsch, S., Fournier, R., Blanco, S. & Theraulaz, G. Analyzing fish movement as a persistent turning walker. *Journal Of Mathematical Biology*. **58**, 429-445 (2009)

[7] Gautrais, J., Ginelli, F., Fournier, R., Blanco, S., Soria, M., Chat, H. & Theraulaz, G. Deciphering interactions in moving animal groups. (Public Library of Science San Francisco, USA,2012)