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Activity out of a ferrogranular gas: How do ferrobots self-assemble and propagate?

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We report on the formation of active structures in a gas of mm-sized steel spheres when simultaneously exposed to a vertically shaking and a vertically oriented magnetic induction B_z. If a threshold of B_z is overcome, the steel spheres self-assemble to vertically oriented chains and three-dimensional clusters which autonomously wander on the vibrated vessel, and are therefore called ferrobots. They collide merge and split, but despite their complex dynamics the ferrobots arrange in an almost regular pattern. Its wavenumber k decreases with B_z, whereas its amplitude increases with B_z. Utilizing amplitude equations we characterize the emergence of ferrobots as a ferrogranular and active analog to the Rosensweig instability. By tracking the ferrobots their velocity distribution is shown to remain isotropic for all B_z, and to follow a stretched exponential form with a characteristic shape parameter of $\beta = 1.5$. The width of the velocity distribution increases up to $B_z \approx 15$mT before reaching a plateau. Mean-squared-displacement (MSD) measurements exhibit a ballistic and a diffusive regime. The lagtime for the onset of diffusive regime increases with B_z, indicating a progressively slower dynamics as the ferrobots become larger and mechanically stiffer, as a consequence of the externally induced dipole moments.

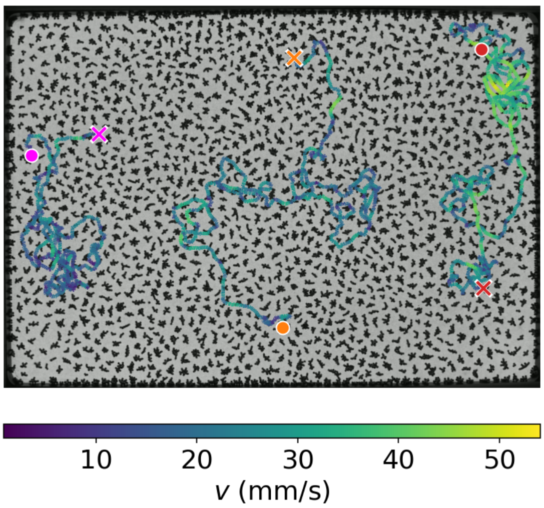

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Figure 1: Pattern of ferrobots at B_z= 17.99 mT, with an overlay of three exemplary tracks. The ◯ (×) mark start (end) of a trajectory, respectively. The color bar at the bottom indicates the average velocity over 0.17 s.

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