Liquid-crystalline patterns in vibrated granular rods

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Granular particles are known to order under vibration in liquid-crystalline structures similar to those of microscopic thermal particles [2, 3]. In the present work [1] we study the behaviour of vibrated granular rods confined in a quasi-2D circular cavity. Depending on particle aspect ratio κ and packing fraction η different liquid-crystalline phases appear: isotropic, tetratic and smectic. We show that some properties of the granular system can be explained by mean-field theories of thermal particles. In particular the stabilization of the tetratic phase for relatively long particles can be understood if we look at the system in terms of clustering, which is particularly enhanced with respect to equilibrium systems due to dissipation. Additionally many other aspects show the non-equilibrium behaviour characteristic of these kind of systems. For instance the vorticity of the velocity field plays an important role [4] and is highly interconnected with the ordering of rods. On the one hand smectic structures are very sensitive to vorticity, which tends to break these domains. Consequently the smectic does not appear as a global stable phase but as fluctuations where local regions with high smectic order emerge and disappear during the experiment. This dynamic effect is represented in figure 1 where the uniaxial order parameter q_2 is shown for an experiment presenting smectic ordering. In the top-right panel the time evolution of q_2 shows an unstable behaviour presenting abrupt changes in the order parameter. In the top-left panel a representative particle configuration of this experiment is shown where the local smectic order parameter is superimposed. On the other hand the tetratic phase seems to be very stiff against vorticity and tetratic order reaches a steady state. In contrast to the smectic case, the tetratic is able to form a global phase with four stable point defects located symmetrically within the cavity. In figure 1 we can see how the tetratic order parameter q_4 is very stable in time (bottom-right panel) in experiments presenting tetratic phase. Also a particle configuration with the local tetratic order parameter superimposed is shown in the bottom-left panel. Here the four point defects appear very clearly.

Apart from the one component system we have also investigated mixtures of rods with different aspect ratios. An interesting result is that mixtures of rods with significant difference in aspect ratio present segregation. This segregation occurs between two phases with different orientational ordering which usually consists of long particles exhibiting nematic order and short ones presenting a gas-like isotropic phase. A particle configuration is shown in figure 2.

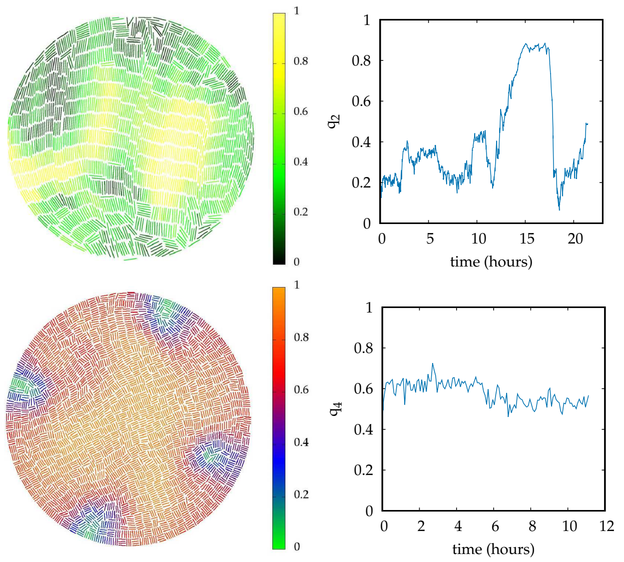

Figure 1: **Top-left**: Smectic configuration with the local smectic field superimposed. **Top-right**: Uniaxial order parameter as a function of time for an experiment with smectic fluctuations. **Bottom-left**: Tetratic configuration with the local tetratic field superimposed. **Bottom-right**: Tetratic order parameter as a function of time.

Figure 2: Phase separation in a mixture with particles of $\kappa_1 = 14$ and $\kappa_2 = 4$.

[1] *Clustering in vibrated monolayers of granular rods*, M. González-Pinto, F. Borondo, Y. Martínez-Ratón y E. Velasco, arXiv:1701.05154v1 [cond-mat.soft] (2017)

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[4] *Swirling motion in a system of vibrated elongated particles*, I. S. Aranson, D. Volfson and L. S. Tsimring, Phys. Rev. E **75**, 051301 (2007).