A novel mechanism of ordering in a coupled driven system: vacancy induced phase separation

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We study a coupled driven system where two different species of particles, along with some vacancies or holes, move in a landscape whose shape fluctuates with time. The movement of the particles is guided by the local shape of the landscape, and this shape is also affected by the presence of different particle species. The nature of this coupling plays a crucial role in the formation of long range order in the system. When a particle species pushes the landscape in the same (opposite) direction of its own motion, it is called an aligned (a reverse) bias. Aligned bias promotes ordering while reverse bias destroys it. In the absence of vacancies, the system reduces to the previously studied light-heavy model for which different kinds of ordered and disordered phases were observed. These phases could be explained as a competition or cooperation between aligned bias and reverse bias coming from different particle species. This interplay is expected to remain unaffected even when vacancies are present since vacancies do not impart any kind of bias on the landscape. However, we find that the presence of vacancies effectively weakens the reverse bias and this significantly changes the outcome of the competition between the two bias types. As a result, novel ordered phases emerge which were not seen before. We analytically calculate the new phase boundaries within the mean field approximation. We show that even when the aligned bias is weaker than the reverse bias, it is possible to find long range order in the system. We discover two new phases where the particle species showing weak aligned bias phase separate and the other species with strong reverse bias stays mixed with the vacancies. We call these phases finite currents with partial phase separation (FPPS) and vacancy induced phase separation (VIPS). The landscape beneath the phase separated species takes the form of a macroscopic hill or valley in the FPPS phase. However, in the VIPS phase it has a shape similar to a plateau whose height scales as the square root of the system size. The landscape of the remaining part of the system is disordered in both these phases.