Radial compression and expansion of a stratifying Yukawa cluster in a parabolic trap

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Experiments in dusty plasmas have shown that a single layer of particles can form a square bilayer when vertical confinement is weakened [1]. Earlier simulations of finite Yukawa clusters found that layering starts at the center and spreads outward [2].

We study how this transition changes the projected area of a Yukawa cluster in an axisymmetric harmonic trap. We use radial force balance to find the pressure and a local model to relate that pressure and the vertical confinement to the area per particle. We compare the model with numerical calculations at zero temperature. As the vertical trap frequency decreases, the denser square bilayer core grows into the surrounding monolayer, and the projected area decreases. For clusters with a developed bilayer core, a 1% decrease in vertical trap frequency reduces the area by about 0.4%. At fixed trap frequencies, a 1% increase in particle number increases the same area by about 0.5%.

The model also predicts radial self-similarity. At fixed vertical confinement and constant $N\Omega_r^2$, where N is the particle number and Ω_r is the radial trap frequency, the radius of the layered region scales approximately as $\sqrt{N}$. The density and height profiles for different cluster sizes nearly coincide when plotted against $r/\sqrt{N}$. The predicted area changes can be verified against the experimental data using images of dust clusters taken from above.

[1] Singh S, Bandyopadhyay P, Kumar K and Sen A 2023 *Phys. Plasmas* **30** 043706 URL http://dx.doi.org/10.1063/5.0147850

[2] Klumov B A 2023 *JETP Lett.* **118** 807–812 URL http://dx.doi.org/10.1134/S0021364023603366