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Symmetry-breaking transitions in dusty plasma clusters[1]

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We consider a cluster of n identical charged particles which repel each other through a Debye (i.e., a shielded Coulomb or Yukawa) potential and which are confined by a two-dimensional biharmonic well. In the strong-coupling regime, the particles' arrangement is determined by n, the Debye parameter κ, and the well anisotropy α [1-3]. For large α, the particles lie in a one-dimensional straight-line configuration. As α is reduced, the cluster undergoes a transition to a two-dimensional configuration via the zigzag instability [2,3]. In the opposite limit of an isotropic well, the ground state configuration is "circular." In particular, for $n = 6$ or 8 particles, the isotropic configuration has a single particle in the center which is surrounded by the remaining $n - 1$ particles. Since the zigzag and isotropic configurations have differing symmetries, the symmetry of the zigzag configuration must be broken in order to transition to the isotropic configuration. We have determined the symmetry-breaking mechanism by experimentally characterizing dusty plasma clusters as the anisotropy of the potential well is varied. For $n = 6$ and 8 particles, we find that the zigzag configuration becomes a finite 2-chain, which zigzags a second time to produce a 4-chain thereby pushing one particle into the center of the cluster. For $n = 10$ particles, the 2-to-4-chain instability pushes two particles inside the cluster, giving the expected (2,8) isotropic ground-state configuration.

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