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Rotating superfluids in anharmonic traps: From vortex lattices to giant vortices

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We study a superfluid in a rotating anharmonic trap and explicate a rigorous proof of a transition from a vortex lattice to a giant vortex state as the rotation is increased beyond a limiting speed determined by the interaction strength. The transition is characterized by the disappearance of the vortices from the annulus where the bulk of the superfluid is concentrated due to centrifugal forces while a macroscopic phase circulation remains. The analysis is carried out within two-dimensional Gross-Pitaevskii theory at large coupling constant and reveals significant differences between 'soft' anharmonic traps (like a quartic plus quadratic trapping potential) and traps with a fixed boundary: In the latter case the transition takes place in a parameter regime where the size of vortices is very small relative to the width of the annulus whereas in 'soft' traps the vortex lattice persists until the width of the annulus becomes comparable to the vortex cores. Moreover, the density profile in the annulus where the bulk is concentrated is, in the 'soft' case, approximately gaussian with long tails and not of the Thomas-Fermi type like in a trap with a fixed boundary.

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