Dipolar Supersolids: A Novel Type of Josephson Junction Array

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Abstract: Supersolids, combining superfluidity and crystalline order, recently realized in dipolar gases, exhibit tunable self-induced Josephson junctions. Their unique dynamics offer potential novelties for quantum sensing and precision measurements in atomtronic-like devices.

Supersolids, a novel quantum state of matter proposed more than fifty years ago, uniquely combine superfluidity and crystalline order [1]. Recent advances with dipolar quantum gases have realized this fascinating state [2-4], revealing its profound potential to reshape our understanding of superfluid dynamics. Dipolar supersolids inherently exhibit a Josephson effect without requiring physical barriers, as each lattice site acts as a self-induced Josephson junction [5]. The coupling energy in these junctions depends on the so-called superfluid fraction [1], which was recently measured in our experiments and can be tuned continuously [5], offering unprecedented control over the system's collective behavior.

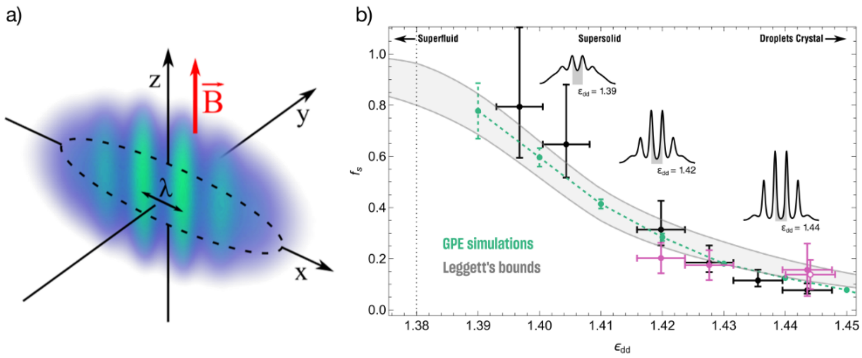

Fig. 1 Modulated density of a dipolar supersolid (a) with spacing λ and results for the superfluid fraction (b) measured through the Josephson effect, as a function of the interaction parameter ε_{dd} corresponding to different modulations (see insets).

The type of Josephson junction realized in a supersolid is fundamentally distinct from those in Bose-Einstein condensates (BECs) loaded into optical lattices. In supersolids, the dynamics are enriched by the interplay of many collective modes [6], offering a broader range of degrees of freedom and opening up novel possibilities for exploring quantum coherence and transport phenomena.

These findings highlight the potential of dipolar supersolids as natural analogs of Josephson junction arrays, with transformative implications for quantum sensing and precision measurements. By harnessing their unique properties, supersolid-based platforms could lead to groundbreaking advancements in technologies such as atomtronic SQUIDs and gyroscopes [7], paving new directions for sensing and fundamental physics.

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