

Demonstration of a persistent current in superfluid atomic gas

One of the most remarkable properties of macroscopic quantum systems is the phenomenon of persistent flow. Current in a loop of superconducting wire will flow essentially forever. In a neutral superfluid, like liquid helium below the lambda point, persistent flow is observed as frictionless circulation in a hollow toroidal container. A Bose-Einstein condensate (BEC) of an atomic gas also exhibits superfluid behavior. While a number of experiments have confirmed superfluidity in an atomic gas BEC, persistent flow, which is regarded as the “gold standard” of superfluidity, had not been observed. The main reason for this is that persistent flow is most easily observed in a topology such as a ring or toroid, while past BEC experiments were primarily performed in spheroidal traps.

Using a combination of magnetic and optical fields, we were able to create an atomic BEC in a toroidal trap, with the condensate filling the entire ring. Once the BEC was formed in the toroidal trap, we coherently transferred orbital angular momentum of light to the atoms (using a technique we had previously demonstrated) to get them to circulate in the trap. We observed the flow of atoms to persist for a time more than twenty times what was observed for the atoms confined in a spheroidal trap. The flow was observed to persist even when there was a large (80%) thermal fraction present in the toroidal trap. These experiments open the possibility of investigations of the fundamental role of flow in superfluidity and of realizing the atomic equivalent of superconducting circuits and devices such as SQUIDs.

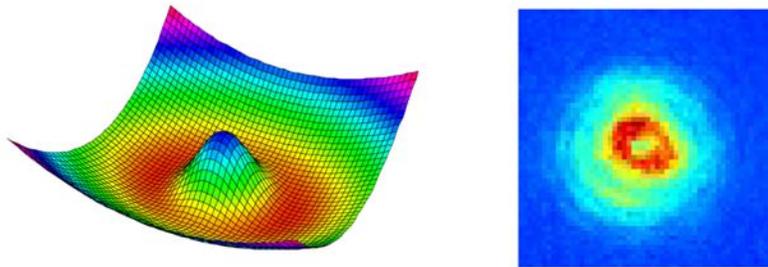
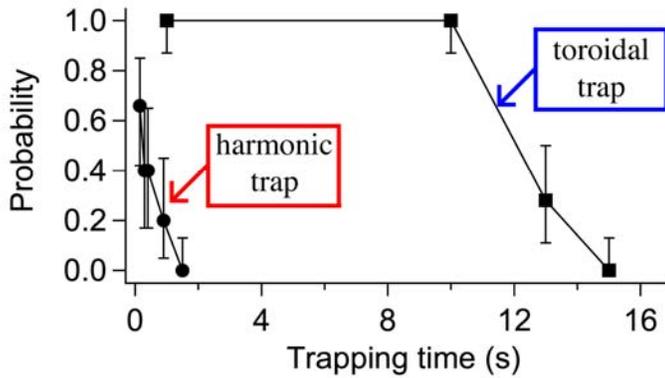


Figure 3.4: **Lower left:** Toroidal potential for the atoms. **Lower right:** time-of-flight image showing the donut shape characteristic of an atomic cloud with quantized rotation. **Upper:** the difference in persistence of flow when the trap is toroidal (with plug) compared to spheroidal (without plug).

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