

Putting Momentum Under the Microscope

A new method lets quantum gas microscopes measure not only where atoms are but also how they move.

By **Ryan Wilkinson**

By imaging individual atoms in ultracold atomic gases, so-called quantum gas microscopes (QGMs) have become indispensable for exploring quantum many-body physics. But although they can reveal an atom's position, they typically cannot also reveal its momentum. Now a team led by Nigel Cooper at the University of Cambridge in the UK has devised an approach that lets QGMs simultaneously observe both an atom's position and its momentum, albeit with some shared blur [1]. These snapshots could uncover features invisible to position-only QGMs, such as energy flow, local temperature, and the swirling motion of quantum fluids.

According to the Heisenberg uncertainty principle, both the position and momentum of a quantum particle cannot be known with unlimited precision. In 1965, theorists showed that this principle does not prevent a single experiment from obtaining approximate measurements of both quantities at once. Cooper and his colleagues have demonstrated how to turn that six-decade-old concept into a novel capability for QGMs. In their newly proposed method, light pulses and

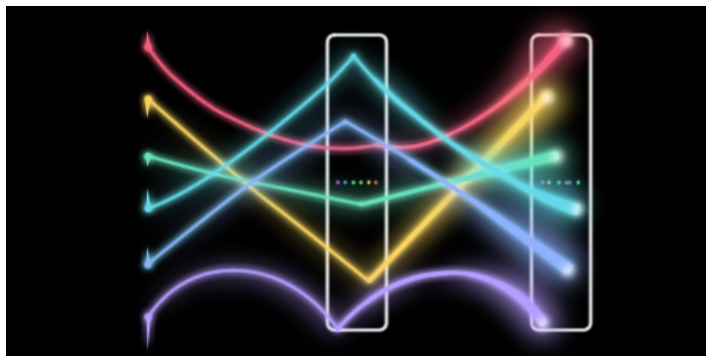
magnetic fields convert information about an atom's momentum into a form that QGMs can capture alongside the atom's position.

The researchers distinguish between two operational modes. In the first, an atom's position and momentum are jointly measured and share a loss in precision caused by the uncertainty principle. In the second, the QGM still measures an atom's position, but it also extracts some statistical measure related to the atom's momentum—characterizing its mean velocity or its mean energy, for example—without the precision trade-off. “Our technique can be directly implemented in state-of-the-art QGM setups,” Cooper says. “It offers a new lens through which to view nonequilibrium dynamics and correlated quantum phases.”

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REFERENCES

1. N. R. Cooper *et al.*, “Phase-space microscopes for quantum gases: Imaging conjugate variables and momentum-weighted densities,” *Phys. Rev. Lett.* **137**, 173402 (2026).



Credit: N. R. Cooper/University of Cambridge; adapted by APS