in one direction and squeezed in the other as time passes — becoming highly elongated but retaining constant area.

Squeezing is a feature of classical, as well as quantum, mechanics. Both are underpinned by a general mathematical result known as the principle of the symplectic camel — named for an unfortunate beast who, bulging in one direction as he is squeezed in the other, cannot pass through the eye of a needle. It is, however, quantum theory that imposes a standard quantum limit on uncertainty through Heisenberg's principle. When the width of the probability distribution (or rather quasi-probability distribution, as it is not necessarily positive) in the narrowest direction falls below this limit, we speak of a squeezed state.

The picture of squeezing in position and momentum is relatively easy to grasp, but relating these variables to the states of spin-1 atoms is not a trivial task. As the spin components do not commute with each other, one might expect the sphere of total $(\langle S_x\rangle, \langle S_y\rangle, \langle S_z\rangle)$ values to replace the phase plane, but this turns out not to be the case. This is because the initial state — the same state used in the Berkeley experiment[3] — has $\langle \mathbf{S}\rangle = 0$. In the language of magnetism, it is nematic, having a definite axis but no dipole moment, such that $\langle [S_i, S_j]\rangle = 0$. Where then are the conjugate variables? Putting it another way, both $\langle S_x\rangle$ and $\langle S_y\rangle$ grow as the instability unfolds, and $\langle S_z\rangle$ is always zero. So what is squeezed?

The answer is that we need to consider the full algebra of observables associated with the three states of a spin-1 atom (this is the su(3) algebra familiar to particle physicists). The conjugate variables to S_x and S_y are quadrupole operators, and it is this 'hidden squeezing' that Hamley *et al.* have measured[1]. A microwave pulse can be used to effect a rotation in the internal space of these variables, converting a quadrupole component into a spin component that can be easily measured. From the uncertainty in the result, measured as a function of rotation angle, one can reconstruct a figure akin to Fig. 1b.

The result is a landmark in the characterization of the quantum state of atomic matter. It is natural to speculate that the same techniques could be used to measure novel magnetic order. For instance, by virtue of having interactions between spins of opposite sign to ^{87}Rb, a Bose condensate of ^{23}Na atoms is expected to have a nematic ground state that spontaneously chooses a quantization axis, with respect to which all atoms lie in the $S_z = 0$ state[4,5]. The deft manipulations of the atomic spin state demonstrated here suggest that this order will not remain hidden for long. ❒

Austen Lamacraft is in the Department of Physics at the University of Virginia, Charlottesville, Virginia 22904–4714, USA.
e-mail: austen@virginia.edu

References

1. Hamley, C., Gerving, C., Hoang, T., Bookjans, E. & Chapman, M. *Nature Phys.* **8,** 305–308 (2012).
2. Calabrese, P. & Cardy, J. *Phys. Rev. Lett.* **96,** 136801 (2006).
3. Sadler, L., Higbie, J., Leslie, S., Vengalattore, M. & Stamper-Kurn, D. *Nature* **443,** 312–315 (2006).
4. Ho, T. *Phys. Rev. Lett.* **81,** 742–745 (1998).
5. Ohmi, T. & Machida, K. *J. Phys. Soc. Jpn* **67,** 1822–1825 (1998).

Published online: 26 February 2012

DROPLET DYNAMICS

Suspended memory

One might expect dense suspensions to form droplets in much the same way as highly viscous fluids. Although this sounds intuitive, Marc Miskin and Heinrich Jaeger would argue otherwise, having assembled evidence to suggest that the particles in a suspension bring about strikingly different behaviour — tantamount to a new class of topological transition (*Proc. Natl Acad. Sci. USA* http://doi.org/hq9; 2012).

Experimenting with suspensions of varying density and viscosity, Miskin and Jaeger showed that the rate of detachment scaled with the radius of the neck of the forming droplet. Whereas high viscosity fluids are expected to exhibit linear scaling, the suspensions they tested showed sublinear scaling. Changing the experimental conditions, such as packing fraction and nozzle size, did little to recover the linear scaling — the exponent remained the same.

The first clue to what might be happening came when high-speed imaging revealed deformations in the surface of the neck. The authors noted that immediately before break-up, the thinning suspension was reduced to just two particles connected by a liquid stream. These observations prompted them to develop a new description for the process, based on the forces associated with the microscopic surface deformations.

© TURBO/CORBIS

The model incorporates the fact that the curvature of the neck's surface accommodates variations in packing — providing a built-in feedback mechanism between packing and pressure. This corroborates the picture suggested by high-speed imaging, and makes sense of experimental evidence downplaying the importance of viscous stresses on the observed scaling behaviour.

One of the more remarkable outcomes of the model is the prediction that droplets form as they would in pure, inviscid liquid when the particle size approaches that of the nozzle — rather than the opposite limit, in which the suspension more closely resembles a homogeneous fluid. This surprising prediction is borne out in Miskin and Jaeger's measurements. The particles create a pressure that matches the pressure in a pure liquid only when the mean curvature of their menisci approaches that of the forming droplet.

In this way, particle size shows up in the system as an intrinsic length scale that in turn encodes a memory of its initial conditions. This memory effect rules out the idea that suspension droplets are formed through a self-similar scaling mechanism — in stark contrast to the case for pure liquids — meaning that theories relying on the analogy do away with crucial details of what goes on near the nozzle tip.

ABIGAIL KLOPPER