ensures that identical fermions cannot get close enough together to react. Flipping one nuclear spin to stop the molecules being identical can turn the reaction back on again[4]. The exquisite control of chemical reactants and molecular collision complexes should open up new vistas for chemistry involving ultracold molecules[5].

Why are molecules much harder to cool than atoms? Laser cooling is generally ineffective because molecules have a more complex internal structure than atoms. Two atoms that are already cold can sometimes be coaxed together using magnetic fields and light to make a molecule in its quantum ground (lowest-energy) state[6,7], but only a few species can be created this way. Stark deceleration, which uses a pulsed sequence of electric fields to slow a beam of polar molecules, provides a general technique for a variety of species[6]. However, the temperature of such molecules is still relatively high, about 50 mK, and the density in a molecular trap is very low. What has been missing is a method to cool the molecules further, and to increase their density — especially their phase-space density.

Stuhl *et al.* take advantage of the OH molecule's unusual properties. It has both an electric dipole moment, which means that it can be decelerated in a standard Stark decelerator, and an unpaired electron, which gives it a magnetic moment, so that it can be confined in a magnetic trap. The OH molecule's ground state has the useful property of being split into two quantum levels of nearly the same energy but with different parity quantum numbers. Molecules in the higher energy state are trapped, but those in the lower energy state are expelled from the trap. Evaporative cooling involves a slow reduction of the trap depth, allowing the warmer trapped molecules to escape while the cooler molecules achieve thermal equilibrium through collisions with one another that do not change their state. For evaporative cooling to work, the rate of such thermalizing collisions must remain high compared with the rate of loss collisions that convert the molecules to the untrapped lower energy state.

Evaporative cooling is not possible for most molecules because the ratio of thermalizing to loss collision rates is not favourable. But for OH and similar molecules, the upper state can survive for many collisions, allowing evaporative cooling to proceed. The theoretical model described by Stuhl *et al.* explains how two molecules in the upper state experience repulsive van der Waals forces when they are far apart, as a consequence of the opposite parity of the two ground-state levels of OH that have nearly the same energy. These repulsive forces ensure that fast thermalizing collisions occur while keeping the molecules far enough apart to prevent loss collisions.

Stuhl *et al.* lowered their effective trap depth by introducing a microwave-frequency 'knife' that converts trapped molecules to untrapped ones on the outer edges of the trap. By changing the microwave frequency, they could cut closer and closer to the centre of the trap, where the coldest molecules accumulate. Their tenfold decrease in temperature, with small molecular loss, implies a dramatic thousand-fold increase in phase-space density. The temperature may be even lower than reported, because in this low-temperature regime the molecules are at the limit at which temperature can be measured with the current apparatus.

This is an extremely promising advance in molecular cooling. The theoretical model suggests that evaporation should be even more effective as the molecules get colder. There is every reason to expect that an improved experimental apparatus could lower the temperature and increase the phase-space density enough to make a Bose–Einstein condensate from OH molecules. If the same degree of cooling can be achieved in OD, using deuterium (D, or ^{2}H), a quantum degenerate gas of fermions could also be observed.

It seems that evaporative cooling will soon join the method of associating two ultracold atoms as a way of making an ultracold molecule. Laser cooling of at least some species may not be far behind[8,9]. An era of doing real quantum science with ultracold molecules is now upon us. ■

Paul S. Julienne *is at the Joint Quantum Institute, NIST and the University of Maryland, Gaithersburg, Maryland 20899–8423, USA.*
e-mail: psj@umd.edu

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EARTH SCIENCE

Go with the lows

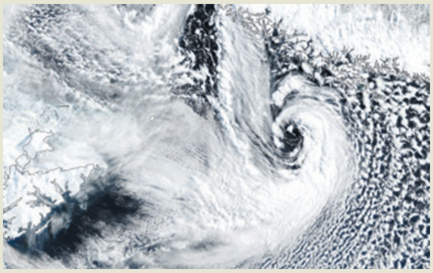
Before Father Christmas sets off from the North Pole, he will want to know if his flight will be disrupted by polar lows — storms (pictured) that afflict subpolar seas. Unfortunately for him, the effects of polar lows are not usually included in climate and seasonal forecasting models. Writing in *Nature Geoscience*, Condron and Renfrew report that they should be (A. Condron and I. A. Renfrew *Nature Geosci.* http://dx.doi.org/10.1038/ngeo1661; 2012).

Polar lows are typically too small (less than 250 kilometres in diameter) and fleeting (24–48 hours in duration) to be well resolved in global meteorological and climate models. Nevertheless, their intensity is often high enough to affect convection in the underlying ocean. Deep open-ocean convection is one of the mechanisms that renews the North Atlantic Deep Water, the main water mass that drives large-scale ocean circulation in the Atlantic Ocean.

Condron and Renfrew used state-of-the-art computational models to simulate circulation in the northeast Atlantic during 1978–98, in the presence or absence of polar lows. They found that models that incorporated the effects of the storms indicated more open-ocean convection, at greater depths, than those that omitted polar lows.

Furthermore, the strengths of two gyres — large systems of rotating ocean currents — in the region were more frequently high when the effects of polar lows were simulated. This in turn increased the renewal of deep water in the Greenland Sea, the transport of that water flowing south across the Greenland–Iceland–Scotland ocean ridge, and the northward movement of heat to Europe and North America.

The authors conclude that the effects of polar lows should be incorporated in ocean, climate and seasonal forecasting models. They also point out that the Intergovernmental Panel on Climate Change predicts that these storms will shift northwards in the future, and will occur less frequently than now. If so, this could greatly affect the deep waters of the North Atlantic, potentially reducing their southward flow. **Andrew Mitchinson**



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