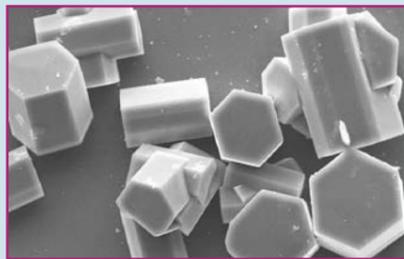


# Fake ice and levitation

Although cirrus clouds affect our climate, we don't really know how the tiny ice crystals in them scatter light. Now Zbigniew Ulanowski and Evelyn Hesse say cirrus can be studied in the laboratory.



Artificial ice crystals.

**T**hin and wispy they might be, but cirrus clouds have a profound influence on the Earth's climate. You may be surprised to know cirrus can have a sizeable overall warming effect – despite being composed mainly of very cold ice crystals. Cirrus reflects heat back towards the Earth's surface. And since higher temperatures can lead to more cirrus, potentially causing even higher temperatures, these clouds may have a positive feedback on our climate. These days global climate models are pretty comprehensive, but cirrus clouds are not very accurately represented, partly because scientists don't know enough about how the tiny ice crystals in the clouds scatter light. Our work should help change that.

## A down-to-earth approach

Typically, researchers collect images of cirrus, and measure the clouds' light scattering properties from aircraft. Paul Kaye and his group at the University of Hertfordshire developed the Small Ice Detector, an aircraft-mounted instrument that can measure ice crystals in cirrus directly. But there might be an easier way to investigate light scattering. Instead of having to take complex equipment into ice clouds, we wanted to investigate cirrus in the laboratory. The controlled environment in a lab gets rid of some of the uncertainties of field measurements, and using artificial crystals is much easier than studying volatile and changeable ice microcrystals. Fake ice and exotic-

sounding techniques like levitation make a lab study possible, but first we needed to put together an interdisciplinary team. Zbigniew knew about light scattering and Evelyn brought expertise ranging from experimental charged particle and surface physics to computer modelling. Materials scientist Rajam Chandrasekhar, several chemists,

and diligent undergraduate Ian Tongue, worked on growing crystals. The Met Office's Anthony Baran offered his knowledge of light scattering in the atmosphere and cirrus-climate interactions.

## Artificial ice

Our first task was to create artificial ice crystals, as no suitable substitutes existed. Ice crystals in cirrus, while not as complex as snowflakes, have a wide variety of shapes, ranging from highly symmetric to irregular, and they come in a broad range of sizes. We had to reproduce as much of this diversity as possible. After a lot of work, involving superconducting magnets, crystal growth in gels and glass-blowing techniques, as well as a great deal of trial and error, we developed two main 'ice-analogues'. These were fine glass fibres with hexagonal cross-sections, and crystals with shapes, sizes and optical properties closely mimicking atmospheric ice. Unlike real ice, these materials exist at room temperature and do not change their shape and size under normal conditions, making them a lot easier to study. Rajam produced a variety of crystals, including simple shapes such as hexagonal columns or platelets and more complex ones such as rosettes. Our straightforward methods for making the crystals should be easily reproducible in other labs.

## Halos

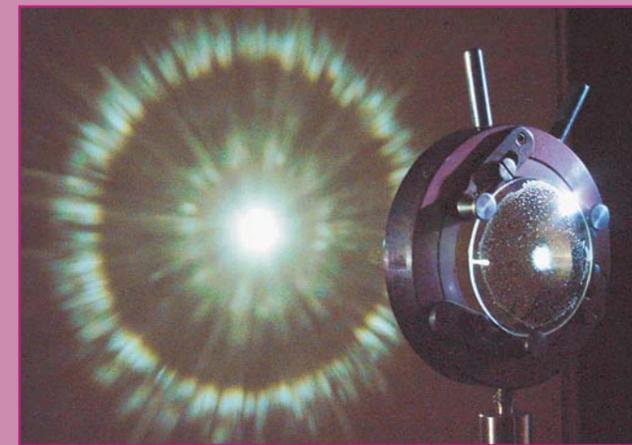
Have you ever noticed the circles, arcs and spots of coloured or white light formed when sunlight or moonlight strikes thin ice-clouds? These beautiful halos, which are characteristic of cirrus, are produced when ice crystals bend rays of light. Halos come in a variety of shapes, with names ranging from the prosaic to the evocative, such as the 22-degree halo, the circumzenithal arc, sundogs, sun-pillars and the Parry arc. Last September we showed that the new ice analogues do indeed resemble real ice when crystals grown by Ian Tongue produced realistic halo displays – apparently the first time this has ever been achieved in a laboratory.

## Levitating crystals

The next challenge was to actually measure how the model ice particles scatter light. The crystals could not touch



Halo produced by moonlit cirrus cloud. The faintly coloured ring is at an angle of 22 degrees from the moon. You can also see two aircraft contrails, the upper one casting a shadow onto the thin layer of cirrus.



A Halo in the lab: bright patches produced by a few hundred crystals deposited on a glass circle combine into a ring with a 22-degree inner radius.

another object during the measurement without disturbing the reading – so we had to make them levitate. Since our team did not include a magician, we used a technique called electrodynamic levitation. Forces produced when electrodes are connected to a high voltage can counteract gravity acting on a microscopic object. We developed a novel levitation 'trap' that let us not only select and levitate single crystals but additionally – and this was crucial for the project – align the crystals in different orientations and then recover them from the trap for more analysis. We also built a 'laser diffractometer' that uses an array of optical fibres to collect and measure laser light scattered by single microscopic objects. The Met Office is already beginning to use our results to interpret satellite and aircraft data obtained from cirrus and to refine climate models.

Unexpectedly, the detailed

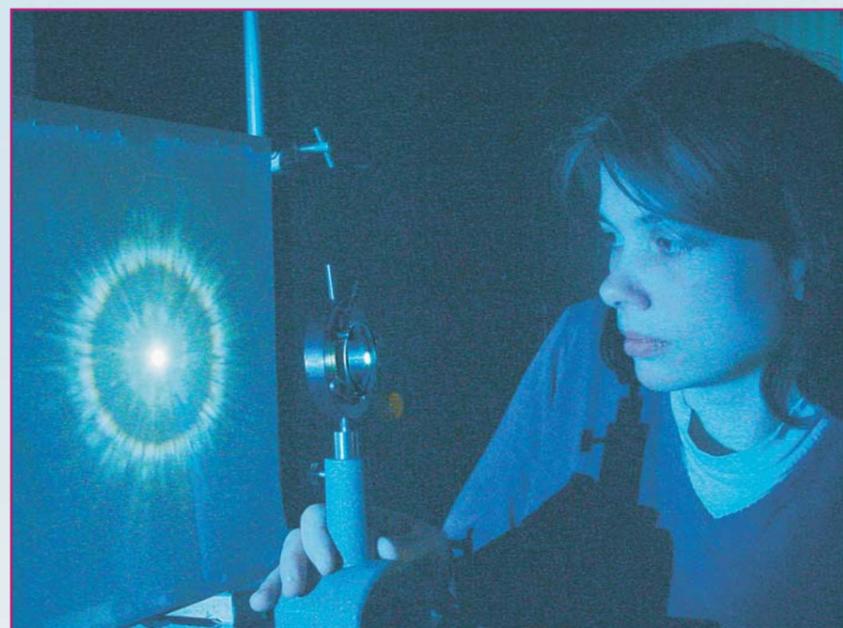
observations of our fake ice, which would not have been possible with real ice, inspired a new computational model describing how crystals scatter light. Tests using the ice analogues show the model is more accurate than the most widely used method for calculating scattering from cirrus crystals – the so-called Geometric Optics model. The new model, which we are still enhancing and improving, may eventually help make climate models more accurate.

Fortunately, NERC has extended our funding beyond the pilot stage, so our project is continuing. We will be able to apply the new techniques to tropical cirrus, which satellite observations and models suggest plays a very important role in the climate system. We will also be using electrodynamic levitation in a separate project studying single atmospheric aerosol particles.

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Physicist Evelyn Hesse examines a halo in the lab. Bright patches produced by a few hundred crystals combine into a ring with a 22-degree inner radius.