A hundred years ago

In connection with the recent meeting of the French learned societies, Mr G. J. Symons writes from Paris as follows:—"M. Michel threw out a suggestion which appears to me likely to, or at any rate possibly may, be the means of averting the principal source of danger in crossing the Atlantic. I refer, of course, to icebergs in foggy weather and the total wrecks which occur from running on to them. It is well known that the proximity of icebergs is indicated by a diminution in the temperature of the sea. M. Michel's proposal is very simple: it is merely that Transatlantic steamers should carry a submerged electric thermometer, which might easily be arranged to ring a bell in any part of the vessel on the occurrence of whatever change of temperature might be decided upon."

from *Nature*, **11**, 476; April 15, 1875

like an ordinary viscous liquid and composed of thermal excitations in the liquid; and a 'superfluid' component, formed from the background liquid and closely associated with the atoms in the Bose condensate.

Suppose that superfluid helium is suddenly set into fairly slow motion along a tube. The thermal excitations rapidly come into equilibrium with the tube, and this is observed as a viscous slowing up of the normal component. But the velocity of the superfluid component does not change. This velocity is identified with the velocity of the condensate; any change in this velocity would imply a change in the velocity of all the atoms in the condensate simultaneously, and this process is believed to occur with negligible probability. The superfluid component is therefore observed to flow without friction.

Similar considerations apply to the motion of an object through superfluid helium. At low speeds it suffers a drag from only the normal fluid. Its effect on the condensate is to produce only an adiabatic deformation of the condensate wave friction, corresponding to frictionless potential flow of the superfluid component past the object. At very low temperatures, when there is practically no normal fluid, the object suffers negligible total drag.

This absence of drag is expected to apply only at sufficiently low velocities. As was pointed out, in effect, by Landau, it is energetically favourable for an object that is moving at a velocity exceeding a certain ('Landau') critical velocity to create a 'roton', which is one of the possible thermal excitations in the liquid. In 1970 E. H. Takken published a theory of the rate at which rotons can be produced in this way (*Phys. Rev.*, **A1**, 1220), and showed that an extremely large drag should set in above the Landau critical velocity.

In practice the Landau critical velocity for the creation of rotons is hardly ever observed, since another process, the creation of quantised superfluid vortices, usually sets in at a lower velocity. The creation of these vortices raises many interesting questions, which have not all been answered, but that is another story. The one situation where rotons do seem to be created was discovered by Rayfield (*Phys. Rev. Lett.*, **16**, 934; 1966; *Phys. Rev.*, **168**, 222; 1968), who showed that negative ions in helium at a high pressure can be accelerated to a limiting velocity that seems to be equal to the critical velocity for roton creation (about 50 m s^{-1}).

It is the drag on a moving negative ion at high pressures that has been investigated in detail by Phillips and McClintock. They have extended the earlier measurements by Rayfield and others, and they have measured the velocity with which the ions move in a very high electric field. They find that the drag on an ion moving at a velocity greater than the roton critical velocity is much less than was predicted by Takken, and they also find some unexpected features in the way in which vortex creation competes with roton creation in the drag process. It seems clear that Takken's theory is inadequate, and that we have another example of the fact that even after over thirty years of theoretical effort our understanding of critical velocities in superfluid helium is still far from complete.

Lunar duststorms

from David W. Hughes

One piece of apparatus left on the lunar surface by the Apollo 17 astronauts was a three-axis microparticle detector. This was designed to study the cosmic dust environment at the lunar surface to determine the nature and extent of luna ejecta produced by meteorite impacts at other spots on the Moon, to measure possible increases in flux produced by Earth focusing and to look for possible interstellar particles. Berg, Richardson, Rhee and Auer (Goddard Space Flight Center, Greenbelt, Maryland) present preliminary results from this experiment in their recent letter to *Geophysical Research Letters* (**1**, 289; 1974). The sensors are on three sides of a cube, one looking up, the other two looking along the lunar surface, pointing 25° north of east and 25° south of west respectively. The cube stands on four legs and is about 20 cm above the level of the lunar soil. The mass threshold is typically 10^{-13}g. The apparatus is on for 76% of the time, being switched off at the height of lunar day. 1,117 particles have been so far recorded during 203 days of observation.

One fascinating result from the analysis is that the particle event rate increases when the terminator (the day–night dividing line) passes over the apparatus. This increase starts some 40 h before sunrise and ends about 30 h after, the event rate typically increasing by a factor of 100 over the 'non-terminator' rate. The sunset effect is less consistent in time of appearance, duration and quality but is definitely present. Berg *et al.* rule out the direct effect of solar electromagnetic radiation as a cause because the event rate goes up long before the Sun illuminates the lunar region under consideration. Particles emanating directly from the Sun can also be discounted because the phenomenon always ends when the Sun is still rising in the sky. Rigorous thermal testing of the apparatus prior to launch also rules out temperature effects. The authors conclude that they are observing lunar surface particles, moving westward at sunrise and eastward at sunset, just as if a duststorm was sweeping across the lunar surface. This storm is along the terminator line, the dust particle moving always in the direction away from the Sun.

This could be a perfect example of electrostatic particle levitation and subsequent horizontal soil transport. It has been shown that solar ultraviolet radiation will raise the surface of the Moon to a potential of 20 to 40 volts and will give rise to a layer of high-electron density and electric field intensity that extends several centimetres above the lunar surface. This field is of the order of 60 V m^{-1} and can easily support small positively charged dust particles. Moving them bodily from place to place is another problem which requires some circumstance such as deviation of the potential of dust grains from the median value, this leading to the build-up of repulsive and attractive forces.

Dust movement could also be due to variations in the electrical surface charge with position on the lunar surface. This idea was first put forward by Criswell (*Geochim. Cosmochim. Acta.*, **3**, 2671; 1972) who suggested that large differences in the electrical surface charge could build up across light–dark boundaries due to the highly resistive nature of the lunar surface. If this is the cause of the duststorms the