the case of comet Schwassmann-Wachmann I the occurrence of these bears no temporal association with perihelion passage, as would be expected if the comet was a single swarm of particles. An *ad hoc* increase in the number of swarms in an individual comet helps, but goes against the whole tenet of Occam's argument. Meteor studies indicate that Encke has made thousands of orbits around the Sun and this gives Encke a recent inner Solar System lifetime of at least 10,000 years. Long period comets are expected to have lifetimes easily up to ten times this value. The high surface area to mass ratio of the swarm comet would make it a large collision target for the meteoroids in the Solar System dust cloud and collisions with these particles would slowly dissipate the swarm. Also a hierarchy of particle sizes would lead to a conspicuous spreading of the swarm along its orbit over 10,000–100,000 years under the action of the Poynting–Robertson effect. Swarm comets would thus have shorter lives than icy nucleus comets—possibly too short to agree with meteor stream data.

Some Sun-grazing comets actually pass through the solar corona, and the dusty insulating layers surrounding an icy nucleus seem to be required to enable the comet to withstand the intense heat. Swarm particles would vapourise. Even though recondensation is possible, the gas content and thus cometary activity would be much reduced.

Arguments

These are some of the arguments that crop up in the debate—a debate which is not without its fair share of invective. For example, Whipple (*op. cit.*) dismisses the swarm hypothesis as 'totally unsatisfactory' and O'Dell (*The Study of Comets* part 2, NASA S.P. 393, 591; 1976) describes the swarm and nucleus models as 'the inconsistent and the unavoidable'. Lyttleton in his paper calls the icy nucleus model an 'invalid unacceptable hypothesis' to which has been added 'an elaborate set of ad hoc assumptions to try and escape the difficulties that the initial conjecture itself entails', a model which is 'ruled out at once by the principle due to Occam'. Before introducing the icy nucleus as a hypothesis 'it would be necessary to show with scientific certainty that specific cometary phenomena exist that are incapable of explanation by already available hypotheses'. In other words dust swarm out before icy nucleus in. But why? Surely hypotheses must be judged on their usefulness and not their historicity. Both can be subjected to the scientific rigour of checking and improvement. To quote Fellget: 'it is not permissible to go on copying the same assumptions from one publication to the next, while simply ignoring either the contrary evidence or the lack of positive evidence'. So the adherents of the swarm hypothesis must investigate explicitly how a swarm can accelerate as well as decelerate in its orbit, how it can split up, produce outbursts, and how it can exist as a specific entity for 10^4 to 10^5 years. Those who favour the icy nucleus must again carefully investigate processes which can produce the observed variation of coma size with heliocentric distance, the asymmetry of coma brightness, and the sometimes quickly varying spatial and temporal light condensations in it. But how can we satisfy Lyttleton?

He predicts that there is little possibility of this argument being resolved 'short of some startling optical development useable from Earth, or that the Earth should run directly into a long-period comet or a successful cometary mission has been carried out with equipment capable of finding the nucleus if it is there'. The second of these points

A liquid permanent magnet?

from P. V. E. McClintock

ACCORDING to A. J. Leggett (this issue of *Nature,* page 585) there is reason to believe that the A-phase of superfluid ^{3}He may display ferromagnetic properties. An isolated sample of the liquid would thus be surrounded by its own spontaneously created magnetic field in much the same way as a conventional steel permanent magnet, although the physical origins of this magnetism would be rather difficult.

The onset of superfluidity (below a temperature of 0.0026 K) in liquid ^{3}He is associated with the atoms forming themselves into pairs, each of which can be regarded as being in many ways rather like a giant diatomic molecule, with the two atoms orbiting around each other. A bulk sample of the liquid tries to arrange itself such that the angular momentum associated with each pair lies in the same direction, known as the l direction (giving rise to intriguing—and, as yet, unresolved—questions about the possible existence and magnitude of an intrinsic, macroscopic angular momentum for the liquid as a whole). In the A-phase the nuclei of the atoms in a pair are orientated parallel to each other and, because each nucleus carries a feeble magnetic moment, this might seem at first sight to offer the possibility of bulk ferromagnetic properties. It is known, however, that even in a very weak magnetic field the pairs of nuclei tend to align themselves in such a way that just as many lie antiparallel to the field as are parallel to it. One can be confident, therefore, that the liquid will not develop any intrinsic magnetic field through spontaneous ordering of the nuclei. What Leggett has done is to point to the possible existence of an entirely different mechanism in which it is the electrons of the ^{3}He atoms that might be able to produce magnetic effects.

It is well known that in a rotating diatomic molecule the electron shells tend to 'slip' a bit: the atoms forming the molecules do not orbit each other like rigid spheres. Thus, a little of the rotational angular momentum of a molecule gets transferred to the electrons around each of its two constituent atoms, producing electrical currents which in turn give rise to magnetic fields. For a conventional diatomic gas, however, the net magnetic field resulting from this phenomenon averages to zero because all the molecules are orientated at random relative to each other. (The effect may still be observed, though, from the broadening of nuclear magnetic resonance lines resulting from the randomly modified local magnetic field in which each nucleus finds itself.)

For ^{3}He-A, on the other hand, the 'molecules' form a highly ordered system, so that the magnetic contributions of different pairs will reinforce each other, producing a macroscopic magnetic field whose direction will depend on that of the l vector. Leggett estimates the magnitude of this field, and he reaches the conclusion that it should be detectable in a suitably designed experiment.

If superfluid ^{3}He-A is really ferromagnetic—and, on the basis of the simple 'giant diatomic molecule' model of the pairing, this conclusion seems to be almost inescapable—there will, as Leggett points out, be a number of interesting implications. Not least is the fact that the superfluid would apparently have been found endowed with yet another form of uniqueness: as being the only ferromagnetic liquid known in nature.

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