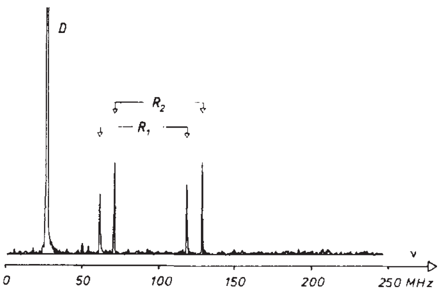

Fig. 1 Muon procession frequencies derived from the measured μSR time-histogram for 2-methyl-1,3-butadiene, with an external field of 1 kG. R_1 and R_2 originate from muonium-substituted radicals (after Roduner *et al., Chem. Phys. Lett.* **57**, 37; 1978).

decay, which leads preferentially to positron emission along the instantaneous muon spin direction, and appropriately located positron detectors give a direct observation of the time evolution of the muon polarisation.

Chemically the most interesting possibility is the formation and subsequent behaviour of the atomic species muonium ($Mu \equiv \mu^+ e^-$). Muonium has a similar size and ionisation potential to the hydrogen atom, and a mass some nine times less. It therefore would be expected to behave like a superlight hydrogen isotope, providing possibilities for observing dramatic H/Mu isotope effects in chemical reaction kinetic studies (compared with the relatively staid hydrogen-deuterium difference). Indeed, measurements of rate constants for the reaction $Mu + Br_2$ is the gas phase (Fleming *et al., J. Chem. Phys.* **64**, 1281; 1976), and Mu in aqueous solutions (Percival *et al., Chem. Phys. Lett.* **47**, 11; 1977; Jean *et al., Chem. Phys. Lett.* **57**, 293; 1978) have demonstrated the chemical similarity of H and Mu, although a detailed interpretation of observed isotope effects has been frustrated by the realisation that much of the previously accepted H atom data must now be reassessed. A new development reported at the Rorschach meeting concerns the direct observation of muonium-substituted radicals in solution. Although measurement of muonium rate constants obviously may imply the formation of such radicals, it is only recently that they have been observed directly in a μSR experiment (Roduner *et al., Chem. Phys. Lett.* **57**, 37; 1978). In muonium-substituted radicals the observed frequency spectrum is dependent on the coupling of the muon spin with those of nearby nuclei and unpaired electrons, leading to characteristic spectra. A typical example is shown in Fig. 1, corresponding to radicals $CH_2{=}C(CH_3)CHCH_2Mu$ and $CH_2MuC(CH_3)CH{=}CH_2$. Hyperfine coupling parameters are derived from the spectra, and the large isotope effects compared with the analogous hydrogenous radicals are related to equilibrium structure and vibrational and rotational motions of the radical species. The implications of this work for reaction rate theory and radiation chemistry are substantial, the importance of the μSR technique lying in its unique sensitivity—since only one muon may be in the sample at any one time, reactions are pseudo-first order, and the reacting muonium species can in principle be identified unambiguously from its depolarisation behaviour.

Why then, this apparently sudden activity in condensed matter applications of the muon? The answer undoubtedly lies in the availability of high quality muon beams at the new meson factories in North America, the USSR and Western Europe (though not, one notes, in the UK, although the proton synchrotron of the so-called spallation neutron source at the Rutherford Laboratory may yet provide a world ranking source). A striking feature of these facilities is the overall tendency towards 'applied' research, most markedly demonstrated by the Muon Spin Rotation technique itself. At the recent meeting for example, investigations using μSR included, in addition to purely chemical work, studies of the electronic structure of impurities in metals and magnetic materials, the behaviour of μ^+ and muonium in insulators and semiconductors, and the study of defects in radiation-damaged materials. As usual the biochemists have been quick to assess the potential of the technique in their own work. The proceedings are to be published in a volume of *Hyperfine Interactions* early in the new year, and this will doubtless serve to acquaint a larger audience with the possibilities of the technique for the first time. Already preliminary plans are in hand for a second international meeting, most probably to be held in Vancouver in 1980. □

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Superfluid ^{3}He in narrow cylinders

from Dieter Vollhardt

SUPERFLUID ^{3}He is a fascinating liquid —it has an unusually large number of internal degrees of freedom, it is inherently anisotropic and displays uncommon magnetic properties. There exist three superfluid phases: A, A_1 and a B phase which all differ in their spin-configurations. The A phase, in particular, can be characterised by two unit vectors: (1) the vector **l**, which describes the angular momentum of a ^{3}He–^{3}He Cooper pair and which is the anisotropy axis affecting, for example, flow motion of the liquid, and (2) the vector **d**, describing the spin part of the underlying wavefunction (if S is the total spin of a Cooper pair then $\mathbf{d}{\cdot}S$ is a constant of motion).

Both vectors are thus internally defined directions, which characterise the degrees of freedom of the superfluid and which will form vector fields defined throughout the whole sample. Given a container and external fields, **l** and **d** will form a configuration such as to minimise the energy of the system. For this to occur several conditions, which usually all compete with each other, have to be optimised: (1) **l** must be perpendicular to any wall, (2) **d** and **l** want to be as straight as possible because bending costs energy; (3) **d** wants to be perpendicular to an external magnetic field because of the susceptibility anisotropy and finally **l** and **d** want to be parallel due to the nuclear dipole interaction in a ^{3}He–^{3}He pair. It is this very energy that leads to the unusual magnetic properties of superfluid ^{3}He, which become particularly evident in nuclear magnetic resonance (NMR) experiments. The bulk A phase hence shows not only a transverse resonance frequency which is strongly shifted away from the Larmor frequency but also a longitudinal resonance! By means of NMR experiments one can then indirectly obtain information about the **l** and **d** configuration in a sample, because **d** will oscillate in the potential provided by the **l**-vector, giving rise to particular resonances. Of all textures the coupled **l** and **d** fields can build up, those which are non-uniform and show textural defects and singularities are of particular interest. Quite generally the topics of defects and singularities in condensed matter physics and their classification has been of great theoretical interest for the past 2 years (see, for example, Toulouze & Kleman, *J. Phys. Lett.* (*Paris*) **37**, L-149; 1976).

While some experimental work on non-uniform textures (without singularities) has been done already the first experimental studies which specifically deal with singular textures have only recently been reported (Saunders *et al. Phys. Rev. Lett.* **40**, 1278; 1978; Gould & Lee, *Phys. Rev. Lett.* **41**, 967; 1978).

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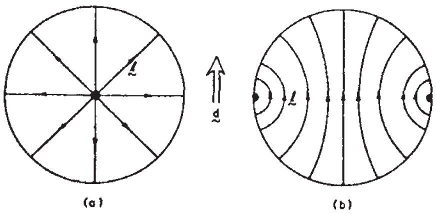

Fig. 1 Two possible planar textures of the **l** vector confined in a long cylinder. *a*, Modified de Gennes disgyration with the **l** vector strictly radial, giving a singularity in the centre, and the **d** vector uniform. *b*, The 'Pan-Am' texture with two singularities on the walls. **d** is again uniform (from Gould and Lee, *op. cit.*).

By a rare coincidence both groups carried out NMR measurements of A-phase textures in the same type of very narrow cylinders (2 μm diameter). In the experiments an external static magnetic field was applied parallel to the cylinder axes with rf fields parallel and transverse to this to measure the longitudinal and transverse resonances. In addition, Gould and Lee also reported measurements of a transverse resonance with the external magnetic field perpendicular to the cylinders. The confinement of the superfluid in these narrow cylinders has drastic consequences for possible **d** and **l** textures. As bending of **l** and **d** usually takes place over a distance of typically 10 μm, such a deformation will cost quite a lot of energy if it happens over a length of 2 μm, even more energy than to have a singularity somewhere in the plane of the cylinder. The only known non-singular texture that would fit into a cylinder, the so-called Mermin-Ho vortex, can be shown to require too much bending energy to be a favourable candidate, so that the only possible textures must bear singularities. With a magnetic field parallel to the cylinder one would thus *a priori* expect planar textures with **d** uniform across the sample (in the plane of the cylinder cross section) and the **l**-field looking somewhat as in Fig. 1.

Measuring the transverse NMR signal, both groups find two resonances where initially most of the weight lies in the higher frequency mode; however, this mode slowly decays into the lower mode over 40–60 min, which seems to imply a textural transition. The two groups measured somewhat different NMR frequencies and while the resonances of Gould and Lee proved to be temperature dependent (suggesting a temperature-dependent texture) the one of Saunders *et al.* did not depend on temperature. Their results for the longitudinal resonances are also different. Gould and Lee find a single, well defined, longitudinal resonance (temperature dependent) which does not change during the textural transition, while Saunders *et al.* do not observe any such resonance, which would be consistent with an axially symmetric texture. Whether the differences in the results can be explained by the different experimental setups (Gould and Lee for example, use Pomeranchuk cooling, Saunders *et al.* use nuclear demagnetisation) is unclear. The results, however, lead to the following conclusion: in both experiments the first texture seems to decay into a similar one, whose projection into the plane of the cylinder's cross section is about the same (so they give the same longitudinal resonance). The initial textures that would be fairly consistent with the NMR-resonances are the de Gennes disgyration in the case of Saunders *et al.* and a somewhat distorted 'Pan-Am' texture (Bruinsma & Maki, private communication) in the case of Gould and Lee. The deviations of the cylinder cross sections from a circular shape—they have a rounded hexagonal structure as can be seen on magnifications—probably need to be considered. The only alternative mechanism that could, at least qualitatively, account for a distortion of textures in the direction of the cylinder axes in both experiments and the temperature dependence in Gould and Lee's results seem to be superfluid currents in the cylinders.

To explain quantitatively what textures are responsible for the measured NMR resonances will not be an easy but most certainly a very rewarding task. It will provide us with new understanding of textures and singularities in superfluid ^{3}He, and beyond that in condensed matter systems. □

Germs from Mars?

from Arie J. Zuckerman

The health and environmental hazards of bringing to Earth surface soil samples from Mars, assuming that life exists on that planet, have been discussed for over a decade. On the one hand, views have been expressed that the risk of the spread of virulent Martian organisms to terrestrial life forms is so great that such an undertaking planned for the 1980s should be abandoned (see for example Young & De Vincenzi *Science* **186**, 496; 1974). In a recent cogent discussion of the problem (*COSPAR: Life Sciences and Space Research* XVI (eds Holmquist & Strickland) Pergamon, 1978) Martin Favero points out that adequate containment facilities for microorganisms are now available, although absolute security in a scientific sense is of course impossible to guarantee. It is therefore necessary to examine the risks in terms of possibilities.

Favero develops his argument for the unlikelihood of Martian microorganisms' causing harm as follows. If life exists on Mars such organisms would be adapted to low temperature fluctuations and virtually no oxygen or water in the atmosphere. It could reasonably be assumed that such organisms will be so adversely affected by the Earth's environment that Herculean scientific efforts will be required simply to maintain them. Counter arguments could be that terrestrial microorganisms survive under wide ranges of conditions, which is in principle true, and furthermore Martian organisms might remain unrecognised by the host's immune and other defence mechanisms thereby resulting in devastating infections. However, in general terms, microorganisms that have no association with man are not pathogenic, for example hydrogen bacteria, methane bacteria and blue-green algae. Another argument is that extraterrestrial microorganisms might be resistant to inactivation, for instance to heat. It is pointed out that heat which destroys carbon bonds will destroy Martian organisms. If they survived, it would be because their biology was not based on carbon, in which case they should not be pathogenic for forms of life whose biology is based on a carbon system. Finally, there is the potential risk of exchange of genetic material between Martian organisms and terrestrial forms of life. However, there is no evidence of efficient transfer in nature of genetic material between heterogeneous broad groups such as bacteria, algae, fungi, protozoa, higer plants and animals, and the probability of introducing genetic material from Mars to Earth seems insignificant.

This is the stuff of science fiction. Yet similarly conjectural risks had to be considered in the development of atomic energy, production of antibiotics and the use of live virus vaccines.

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