he would at all consider an official invitation. The salary was not insultingly low; when in 1871 Sir William Thomson invited Helmholtz to become the first Cavendish Professor in Cambridge the stipend he could offer was not much more than £700. A possible — and to my mind the most probable — explanation for Max Müller's declining the invitation on behalf of Helmholtz without consulting him is that, at the time, Max Müller was regarded as perhaps the most distinguished and internationally best known scholar in Oxford, and he may have felt that Helmholtz would outshine him. He effectively vetoed the invitation to avoid this risk.

Would Helmholtz have accepted the chair? It appears at first sight that he approved of Max Müller's action but the relevant passage in the German original (*"Ich finde es also ganz in der Ordnung . . ."*) sounds less definite than the English version. Then there is the passage omitted by Koenigsberger in the quotation above and marked differences between his version and the rendering of the same letter in the biography of Anna von Helmholtz (Helmholtz's wife) by her daughter, Ellen von Siemens-Helmholtz. The passage in the Koenigsberger version "but they could raise . . . not come on those terms" appears in the Anna von Helmholtz biography as "and that Professor Max Müller had told them assuredly that I would not accept the offer". The original of the letter cannot be found. The Archives of the Akademy of the German Democratic Republic (formerly the Berliner Adademie des Wissenschaften) in East Berlin has only Helmholtz's scientific papers and correspondence. The personal papers remained originally in the family but were transferred to a green safe at the academy which survived the allied bombing attack of 3 February 1945 and was still in its place in 1947. Subsequently the safe was opened, its contents disappeared and we shall probably never know the exact wording of Helmholtz's letters.

One can only speculate whether, but for Max Müller, Helmholtz would have become Professor of Experimental Philosophy in Oxford, how the Clarendon Laboratory would have fared under him and whether 50 years of neglect would have been avoided. For the sad truth is that Clifton's lofty aim "to aid . . . as far as in me lies, in securing and maintaining for the University a reputation in science befitting the dignity of Oxford" remained unfulfilled.

In preparing this article I was greatly helped by the late Professor W. Haberditzl (Humboldt Universität), by Dr Christa Kirsten (Director of the Archives of the Akademie der DDR) and by Dr and Mrs Hermann von Siemens (München). □

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Low-temperature physics

Persistent currents in liquid ^{3}He

from Peter McClintock

If you once start liquid ^{3}He moving round a circle, it will continue to flow indefinitely without any further assistance and without slowing down at all, according to a recent experiment at Cornell University. The work in question, which was carried out by P.L.Gammel and J.D. Reppy of Cornell in collaboration with H.E. Hall of the University of Manchester, is reported in *Physical Review Letters* (**52**, 121; 1984).

A feature that liquid ^{4}He, liquid ^{3}He and the electron gas in certain metals have in common is that, as a result of a low-temperature transition, they seem to lose all their viscosity and are then able to flow without friction and thus without any dissipation of energy. The critical temperatures for the onset of this so-called superfluid behaviour ranges from only 2 mK in liquid ^{3}He to about 20 K in a metallic alloy. In each case, below the transition temperature the fluid seems to divide into two distinct but freely intermingling fractions: a normal fluid component, much like any other liquid, and a superfluid component that exhibits the dissipationless flow properties.

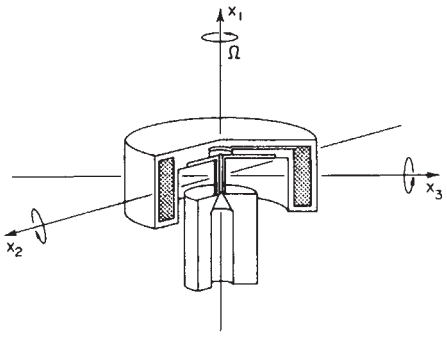

Fig.1 Schematic diagram of the ac gyroscope. The ^{3}He fills the shaded cross-section of the cap of the mushroom via the hollow stem. Drive and detection electrodes (not shown) oscillate the mushroom about any of the axes X_1, X_2 and X_3, and monitor the amplitude of oscillation. By movement of the entire cryostat the mushroom can be rotated at a steady angular velocity Ω about axis X_1.

One of the best ways to demonstrate that a superfluid flows without friction is to show that, once it has been set to flow around a closed circuit, it keeps going without any diminution of velocity. (The flow of a normal liquid in such an experiment would gradually slow down.) However, whereas it is relatively easy to demonstrate persistent currents in a superconductor, it is not so simple in superfluids.

For a superconductor, if one joins the two ends of a coil of superconducting wire and starts an electrical current flowing round the coil, both the presence and the strength of the current can readily be measured in terms of the magnetic field that is created. An experiment of this type has been run for more than a year without any measurable change occurring in the field produced by the circulating current.

A persistent flow current of superfluid ^{4}He is far more difficult to detect because the atoms, being neutral, create no associated magnetic field by their movement. Nevertheless, about fifteen years ago, J.D. Reppy of Cornell University developed a cunning technique capable of detecting the presence of persistent flows of this nature, based on what he called a superfluid gyroscope. His method exploits the propensity of gyroscopes to try to move at right angles to the direction in which they are being pushed. Thus, in a 'gyroscope' of superfluid flowing round a sensitively suspended torus, the existence of superflow is readily demonstrated if, upon turning the torus slightly about one diameter, it responds by trying to turn about another diameter, at right angles to the first. The Reppy gyroscope provides an outstandingly successful method for studying persistent currents in superfluid ^{4}He. It is much less easily applied to superfluid ^{3}He, partly because of the relatively small amount of liquid that can be cooled to the exceedingly low temperatures that are required.

Most people would have guessed that a superfluid ^{3}He gyroscope would, in practical terms, be quite impossible to set up. Nonetheless, what Gammel *et al.* have now devised — and operated successfully — is nothing less than a modified form of the original Reppy gyroscope. The strange instrument that they have created (see Fig.1), which they refer to as an 'ac gyroscope', consists, in essence, of a hollow 'mushroom' in which the head is made of epoxy and the (narrow) stem is made of springy beryllium–copper. The mushroom can be oscillated at small amplitude about any of the three axes X_1, X_2 or X_3, and the amplitudes are detected by sensors. The cap of the mushroom is filled with liquid ^{3}He through its hollow stem and the whole cryostat, which refrigerates the mushroom, is rotated (relatively rapidly) for a while about axis X_1, to try to set up a persistent current of ^{3}He around the circumference of the cap, and then brought to rest. To test whether a current persists, the mushroom is then oscillated at its resonant frequency about axis X_2: if there is a persistent current of ^{3}He, the gyroscope effect will cause, in addition, a small oscillatory motion about the axis at right angles, X_3. That is precisely what Gammel *et al.* have observed for the

B-phase of superfluid ^{3}He. They find that there is no observable decay of the persistent current over a period of an hour and have been able to deduce, on this basis, that the viscosity (if any) of the superfluid component is less than that of the normal fluid component by at least 10^8 — an enormous factor.

This is a very satisfying result, particularly in view of some aspersions previously cast on the superfluidity of the B-phase. Eisenstein and Packard (*Phys. Rev. Lett.* **49**, 564; 1982) had reported the observation of some dissipation apparently associated with the flow of ^{3}He-B through a narrow channel connecting two reservoirs. Although Brand and Cross subsequently proposed a plausible explanation of these effects in terms of events occurring in the reservoirs, rather than in the channel (*Phys. Rev. Lett.* **49**, 1959; 1982), there remained a lurking suspicion that perhaps ^{3}He-B was, in some way, not quite such a 'good' superfluid as ^{4}He or the electron gas in a superconductor. These residual doubts can now be laid to rest. □

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X-ray astronomy

Milestone for EXOSAT

from Mike Watson

EXOSAT, the European Space Agency's first satellite for X-ray astronomy, was launched in May last year and passed a second milestone in mid-December when the early scientific results were publicly presented at a special one-day session of a meeting at Florence*. The early phase of the EXOSAT mission was not free from problems, the sad demise of two of the four imaging X-ray detectors, for example, but also provided some pleasant surprises; the background levels for both the medium-energy experiment and the gas scintillator proportional counter were substantially below those expected. Judging by both the quality and quantity of results presented at the meeting in more than thirty papers, EXOSAT should fulfil its role of providing a major X-ray observational facility for Europe during the next three years.

EXOSAT has several novel features which give it important advantages over previous X-ray astronomy missions, as Peacock (European Space Research and Technology Centre, ESTEC) described. In particular, the sensitivity of the channel multiplier array imaging detectors in the soft X-ray/extreme UV permits studies of X-ray emissions in the 10–300 Å range — a part of the spectrum hitherto barely explored. Another important feature is the satellite's highly eccentric 90-hour orbit, which makes possible long uninterrupted observations important for the study of variability on time scales from hours to days characteristic of many galactic X-ray binaries. Real-time operation of the spacecraft from the European Space Operations Centre (ESOC) control centre in Darmstadt allows the entire payload to be used as a true X-ray observatory. This has proved enormously valuable in programmes coordinated with ground-based or International Ultraviolet Explorer studies and also allows EXOSAT to respond quickly to new phenomena such as X-ray transient outbursts. (60 per cent of observations made with EXOSAT in the first five months took advantage of this capability.)

At the Florence meeting, the emphasis was on studies of galactic objects, particularly binary X-ray emitters of all types. The most dramatically variable objects in the X-ray sky are the X-ray transients which undergo intense outbursts paralleling those of classical novae.

Blisset (ESOC) and Peacock described two X-ray transients (4U1543–47 and V0332+53) which conveniently flared up during the first six months of the EXOSAT mission. X-ray outbursts from both sources were first noted by the Japanese Tenma satellite, but the flexibility of EXOSAT made it possible to obtain within a few days X-ray positions accurate enough for the optical counterparts of both transients to be quickly identified. Observations of the transient V0332+53 also revealed a coherent 4.4-s pulsation together with chaotic flaring activity down to millisecond time scales, behaviour characteristic of the black hole candidates Cyg X-1 and GX339–4. This observation may be especially important for our understanding of the black hole candidates, for the coherent 4.4-s pulsations are almost certainly the signature of a rotating magnetized neutron star.

Among other results on bright galactic X-ray sources, Parmar (ESOC) and Kahabka (Max Planck Institute, Garching) reported that the binary Her X-1 had undergone a transition into a low-flux state in which its normal X-ray characteristics seem to be absent, even though X-ray heating of the optical companion seems still to be taking place. Pietsch (Max Planck Institute, Garching) had a similar story to tell about 4U2129+47, which was undetectable during the EXOSAT observation.

The continuous 30-h EXOSAT observation of Cyg X-3 described by Willingale (University of Leicester) and Blisset was particularly impressive. The wealth of new features discovered in the X-ray light curve will be a challenge for models of this exotic system. X-ray bursters and bulge sources also featured, with presentations by Sztajno (Max Planck Institute, Garching) of the discovery of absorption dips in 4U1755–33 and by Turner (University of Leicester) of an unusual absorption feature in X-ray spectra of several bursts from 4U1636–536 obtained with the medium-energy experiment which could be due to iron absorption red-shifted by the strong gravitational field near the neutron star.

EXOSAT is also providing valuable data on cataclysmic variables, interacting binary systems involving accretion onto a white dwarf companion. Current interest centres on those systems, known as 'polars' and 'intermediate polars', containing a magnetized white dwarf with a field strong enough to ensure that accretion takes place primarily onto the magnetic polecaps.

Heise (Space Research Laboratory, Utrecht) announced the discovery of completely anomalous behaviour in the best-known polar, AM Her; the modulation of the soft X-ray flux at the 3.1-h binary period is almost exactly out of phase with the hard X rays, perhaps implying emission from two active magnetic poles. For EX Hya, a possible intermediate polar, Cordova (Mullard Space Science Laboratory/Los Alamos) showed the clear presence of a 67-min period together with a weaker modulation at the 98-min binary period in the soft X-ray light curve. Pietsch described observations of the established intermediate polar H2252–035 which suggest a 30 per cent orbital modulation of the X-ray flux as well as the well-known 805-s pulse period. Watson (University of Leicester) announced the discovery, during an optical outburst, of X-ray pulsations from the old nova GK Per, with a period of 351 s, which implies that the accreting white dwarf in this system must also have a substantial magnetic field and be yet another intermediate polar. The relative amplitude of the X-ray pulses from GK Per does not change as the mean X-ray flux varies, which may be an important clue to the geometry of the region at the magnetic polecap emitting X rays, as it is difficult to model this behaviour unless the scale-height of this region above the white dwarf surface is small.

EXOSAT's low-energy imaging detectors can be used in conjunction with filters to provide X-ray 'colours' in the important spectral region spanning the soft X-ray and extreme ultraviolet; this capability is particularly valuable for observations of single stellar objects, as was demonstrated by McKechnie (University of Leiden) and Heise. Heise also presented objective grating spectra of the hot white dwarf HZ 43 and AM Her which indicated the great potential of this instrumental combination. Some of the visually most impressive results were the images obtained of supernova remnants, and the value of spectro-

* The Seventh European Regional Astronomy Meeting was held in Florence on 12–16 December 1983.