EVIDENCE OF THE NATURE OF ROTATING LIQUID HELIUM*

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Earlier experiments by Hall¹ and also by Walm-sley and Lane² on the angular momentum content of rotating liquid helium II have involved measure-ments of torque required to set a vessel of liquid into equilibrium rotation. Integrating the resultant torque-time measurements over the angular acceleration (or deceleration) period yielded thereby a measure of the angular mo-mentum acquired by the helium. Since further-more an integration over the volume of the vessel was involved, such methods produced composite, over-all data.

The present method³ permits investigating both the time and position dependence of liquid helium II circulation within a rotating vessel by suspend-ing a movable Rayleigh disk device within such a system. Besides thus providing both instantaneous and local observations, the sensitivity of such a probe to individual fluid component motions permits in fact a still further resolution; the special case of zero response, for example, uniquely specifies each fluid component as stationary.

The liquid helium II sample investigated resides within a cylindrical shaped glass vessel (just under 5 cm inner diameter) rotated axially about the vertical; a small (½ mm) aperture at the lower (tip) extremity connects the region with the outer helium bath for filling purposes, etc. A “sta-tionary support” is provided inside the container for the disk suspension system which, although not rotating, is equipped (rack and pinion) for position adjustment along the vessel radius. The disk probe (3-mm diameter) is suspended by a quartz fiber (torsion constant ~ 10⁻⁶ dyne-cm/deg) to present an angle of 45° to the rotational flow direction. Resultant angular deflections from equilibrium orientation (tending to turn the disk across the flow) are observed as displacements of a narrow light beam reflected from the (silvered) disk surface and focused upon an optical scale. The present observations are for a vessel rotation rate of 2 rpm.

The results of this investigation include the following principal findings:

(a) A delay interval of several minutes elapses between setting the container suddenly into rota-tion from rest and initial response of the disk to the liquid helium II system. In contrast, the disk responds immediately to stopping rotation of the vessel. Thus liquid helium II appears to acquire a “rigidity” in rotation which is absent when sta-tionary.

(b) A linear relationship between such delay interval and radial position of the disk indicates that the circulatory motion propagates as a “ro-tation front” slowly inward from the moving wall of the container with a definite velocity.

(c) Steady-state angular deflections, reached after roughly one-half hour buildup time from initial response, obey a parabolic dependence upon radial distance from the axis.

(d) Finally, steady-state deflections depend markedly upon temperature. Upon cooling through the λ point the apparent rotational flow drops abruptly from the helium I value to zero, indica-ting no circulation at all. With reduction of tem-perature further into the helium II region circu-lation reappears, however, and builds up mono-
tonically to the helium I value toward the lower temperature limit ($T - 1^\circ K$).

The "rotation front" propagation phenomenon (b) is illustrated in Fig. 1, where response delay times (min) are plotted versus radial distance (cm) to the disk midpoint from the rotation axis. For a temperature of $2.0^\circ K$ (and vessel rotation rate of 2 rpm), the observed slope indicates an apparent "rotation front" velocity radially inward of about 2 mm/sec. Furthermore, observation that the intercept (zero time lapse) falls inside the liquid helium region indicates the liquid "circulation front" first disturbs the extreme edge of the disk.

The unexpected temperature dependence (d) is illustrated in Fig. 2, where fluid circulation is plotted versus temperature ($^\circ K$) for a fixed disk location (1.84 cm from axis of rotation). Observed results are expressed most directly as an effective density ratio ($\rho_{\text{eff}}/\rho_\lambda$), representing the fraction of fluid evidently carried into rotation with the vessel; the ratio measures the observed torque normalized to the helium I value (at the $\lambda$ point). Clearly a marked dependence of temperature exists, characterized by a sharp drop evidently to zero circulation immediately below the $\lambda$ point. A general (approximate) resemblance may be noted between this curve for effective density ratio and the well-known temperature dependence of superfluid concentration ($\rho_S/\rho$). Such behavior might be interpreted (but possibly oversimplified) to indicate that under these circumstances superfluid rotates whereas normal fluid does not.

Logical explanations for findings (a), (b), and (c) follow directly in principle from an application of the Feynman concept of rotating liquid helium II, based on migrating quantized vortex distributions. Observed temperature dependence of finding (d) appears unaccountable, however, on the basis of either theory or (previous) experiment. According to Feynman's theory and Hall's measurements, for example, indicating rotation of both fluid components with a containing vessel, no temperature effect might be expected. According to Walmsley and Lane's measurements, on the other hand, indicating rotation of normal fluid alone, an increase of circulation with temperature might be anticipated. The actual observed behavior remains clearly oblique to such expectations. The possibility naturally exists at this juncture that some obscure phenomenon related to the method of measurement is responsible.

A paper now in preparation to describe fully the experiment and results will be submitted shortly.

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FIRST-ORDER TERRESTRIAL ETHER DRIFT EXPERIMENT USING THE MÖSSBAUER RADIATION

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Despite the general acceptance of the special theory of relativity, the Fitzgerald-Lorentz contraction theory and its ability to account for previous experiments have persisted. In particular, the extension of the Fitzgerald-Lorentz contraction theory by Ives\(^4\) appears to bring the contraction theory on a par with both the special and general theories of relativity. It has been pointed out\(^5\) that this impasse may be resolved by astronomical observations and satellite experiments designed to detect a variation in the one-way velocity of light with direction in space. The existence of such an observed variation, which may be considered to be synonymous with the existence of an ether, is allowed by the Fitzgerald-Lorentz contraction theory but not by the special theory. This note proposes a terrestrial experiment which has considerable sensitivity when the Mössbauer radiation is used and which permits a first-order test for a variation in the velocity of light with direction in space.

An electromagnetic radiator having a highly stable frequency, a frequency-selective absorber or filter, and a counter or other suitable detector are placed on a turntable, as shown in Fig. 1. Electrical connections to the counter or detector may be made through slip rings. If there is an ether and the velocity of the plane of the turntable through the ether is \(v\), then the time taken for the radiation to travel the distance \(s\) between radiator and absorber is

\[
\tau = \frac{s}{c - v \cos \theta},
\]

where \(c\) is the velocity of the radiation in the medium between radiator and absorber. When the table is rotated there is a variation in this time if \(v \neq 0\). As the time varies there is a change, \(-fd\tau\), in the phase of the radiation as received at the absorber, where \(f\) is the frequency of the radiation. The time rate of change of the phase corresponds to a change in frequency.

![Fig. 1. Arrangement for the detection of a one-way variation in the observed velocity of light.](image)

The relative change in frequency at the absorber, when \(v \ll c\), is then, to first order,

\[
\frac{\Delta f}{f} = \frac{d\tau}{dt} = \frac{\omega sv \sin \theta}{c^2} - \frac{v ds}{c^3 \frac{dt}{c}} \cos \theta - \frac{1}{c} \frac{ds}{dt},
\]

where \(\omega\) is \(d\theta/dt\), the angular velocity of the turntable. The last term is the Doppler shift. It and the second term may be minimized by using a rigid construction to insure that \(ds/dt\) is substantially zero.

If the linewidth of 1 part in \(10^{12}\) is not achievable with the Mössbauer radiation\(^6\) used for detecting a minimum change in frequency, \(s\) is made 1/\(10^6\) km and is constant, and \(\omega\) is \(60\pi\) rad/sec, corresponding to 1800 rpm, then an ether drift of about 5 km/sec is measurable. With a “least count” sensitivity of 3 parts in \(10^{13}\) estimated for the Mössbauer radiation\(^6\) and the above values for \(s\) and \(\omega\), an ether drift of about 0.0015 km/sec is measurable.

The axis of the table may be located anywhere...