plication in a very large shower-star as evidence for photons from the decay of neutral mesons whose number was comparable with the number of charged mesons.[3] Our shower-stars do not show such striking multiplication, perhaps because the energies involved are lower. Some of the shower particles from stars may be electrons produced in the plates by photons from neutral mesons

In Table I 45 showers are listed which do not have two or more heavy tracks. Some of these are probably immediate products of nuclear explosions which have only one or no slow fragments emerging from the plate, but since some show the typical form of small electron cascades it is unlikely that all are formed in this way. We estimate that about 16 of these showers originate at the point of a nuclear explosion and about 29 do not. If these showers were caused by a primary electronic component, which was even 10 percent as numerous as the proton component,[4] the number of energetic showers observed in our cloud chamber would be approximately equal to the number of nuclear explosions caused by protons. There are actually about 25 of the latter (including "showers" which we estimated to have unobserved heavy tracks concealed in the plates) and one or two energetic electron showers. We conclude that primary electrons are rare, or non-existent, as is generally considered to be the case, and that the small showers observed must arise in some way from the nuclear interactions of the primary protons. One expansion showed two small showers coming from the second plate which project back to a common point in the first (carbon) plate, the angle between them being 40°, a type of event which suggests the neutral meson hypothesis.

* Work performed at Brookhaven National Laboratory under the auspices of the AEC.

[1] Flights were made by General Mills, Inc., Project Skyhook, sponsored by the ONR.

[2] The cloud chamber has been described by Shutt, Johnson, and Thorndike, Rev. Sci. Inst. **20**, 398 (1949).

[3] Camerini, Coor, Davies, Fowler, Lock, Muirhead, and Tobin, Phil. Mag. **40**, 1073 (1949). Kaplon, Peters, and Bradt, Phys. Rev. **76**, 1735 (1949). P. Freier and E. P. Ney, Phys. Rev. **77**, 337 (1950).

[4] Janossy, Rossi, and Hulsizer, Nature **163**, 246 (1949).

## Erratum: X-Ray and Gamma-Ray Reflection Properties from 500 X Units to Nine X Units of Unstressed and of Bent Quartz Plates

[Phys. Rev. **77**, 475 (1950)]

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On p. 482, column 1 of the text the statement is made that $t=w_1=w_4$. This should read: $t=w_1=w_2$. The text material is otherwise correct.

Equation (18), p. 485, is not complete as it stands. It should read:

$$\exp[\mu_0 t_0/\gamma_0]R' = r_0 d_H(|F_H|/V)\lambda/2\cos\theta_B \cdot\left[\frac{1+\cos^2 2\theta_B+2l_0^2(1+\cos^4 2\theta_B)}{1+\cos 2\theta_B+l_0^2(1+\cos^3 2\theta_B)}\right]. \quad (18)$$

On p. 485, bottom of column 1, the words *electron vector* should read *electric vector*.

In Fig. 3, the boxes represent the *maximum* spread in the experimental data, and not the probable errors as stated in the text.

## The Thermal Rayleigh Disk in Liquid He II*

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During early discussions regarding the validity of formulas for radiation pressure[1] and associated properties of second sound, it became apparent that a Rayleigh disk[2] experiment might constitute an additional crucial test of the two-fluid hypothesis[3–5] for liquid He II. Measurements of this nature are being conducted at the Cryogenics Laboratory of the National Bureau of Standards and the positive effects observed thus far have been in full conformity with the currrent concepts[3,4] of the second sound mechanism. In addition to allowing a more detailed examination of the quantum hydrodynamics of liquid He II, the Rayleigh disk method provides an absolute measure of second sound intensity, dependent only upon such fundamentals as the kinetic energy and the geometry.

The singular feature of second sound in liquid He II is of course the basically thermal nature of the propagation. Ordinary acoustical sources cannot generate second sound waves, nor can ordinary microphones detect them; thermal methods are customarily employed instead.[6] This situation may be rationalized on the basis of the current two-fluid hypothesis for He II. Whereas the oppositely directed momenta (and particle velocities) of the component fluids logically constitute zero net momentum,[4,5] the internal mass transport establishes a net heat flow with an associated temperature fluctuation.

Although detectors of the microphone class (either pressure or velocity type) cannot recognize this process, the mechanical device known as the Rayleigh disk can and does resolve the existent internal convection. This disk can detect second sound as well as ordinary (sound) because it responds to particle velocity squared, rather than to mere particle velocity. The disk accordingly recognizes the existence of a kinetic energy density within the second sound as pictured on the two-fluid basis.

A thin circular mirror ($\frac{1}{2}$-in. diam.) has been suspended vertically within the second sound field by a thin torsion wire. The mirror orientation was adjusted for equilibrium conditions (in the absence of second sound) to make a 45° angle with the axis of wave propagation. The second sound field was then set up within a horizontally oriented cavity, and the mirror deflections observed for conditions of resonance. The sharp response of the mirror disk (and deflection of a reflected light beam) as the system was tuned through resonance verifies the internal mass flow and its associated kinetic energy density.

The wave velocity determined in this manner from critical resonance frequencies (half-wave-length fixed) is in essential agreement as a function of temperature with the results of earlier purely thermal methods.[6,7] Measurements can be extended quite close to the $\lambda$-point where velocities of less than 1 m/sec. have been observed.

The maximum torque set up at resonance can be measured directly, knowing the torsion constant of the system (from the observed period of free oscillation). Since, furthermore, the resonance response is regular and symmetrical, band width determinations are practicable. The associated reinforcement factor $Q$ combined with the known periodic heating rate (introduced uniformly over one end-wall of the cavity) leads to an estimate of the actual heat flow density at the location of the disk.

By comparison of the observed dependence of the torque on the temperature with theoretical predictions based on modifications of the classical Rayleigh formula,[2] the individual roles of normal fluid and superfluid in deflecting the disk can be examined. Space does not permit giving expressions for the separate torques, but should *both* fluids contribute it can be shown that the resultant torque $\tau$ would be

$$\tau=(4/3)a^3\rho(\rho_n/\rho_s)[\dot{H}^2/(\rho ST)^2]. \quad (1)$$

Here $a$ is the radius of the disk. The properties of liquid He II enter through the entropy $S$ and total density $\rho$; also $\rho_n$ is the density of the normal fluid, $\rho_s$ that of the superfluid. $T$ denotes the ambient absolute temperature and $\dot{H}$ the heat flow density. A similar expression holds for the contributions by each individual fluid component.

Thus far Eq. (1) has been checked only near the $\lambda$-point, but there the agreement seems complete. The significance of this verification however is that *superfluid is providing the predominant*