by the Curie law and the experimentally determined value for pure He^3.[1,2] Points to the left of the maximum in Fig. 1, indicated by bars, were calculated under this assumption, the extremities of each bar corresponding to the limits imposed above on the susceptibility per atom. Points to the right of the maximum, indicated by crosses and corresponding to higher He^3 concentrations, were calculated under the assumption that the susceptibility per He^3 atom is the same as for pure He^3. Our measurements indicate that this assumption is approximately correct for high He^3 concentrations.

The open circles in Fig. 1 represent the T_λ measurements of Daunt and Heer[5] and the solid circle represents a T_λ determination made by us from thermal relaxation time measurements. Daunt's points fall close to the phase curve, easily within our experimental error. These points were measured by observing the warmup rate of a container of solution connected thermally to the helium bath through a fine capillary. The λ point was identified as that point at which the rate of warmup of the solution decreased suddenly due to the disappearance of the creeping film. However, since at any point below the phase curve in Fig. 1 there is a phase of low He^3 concentration which is below its λ point, we think it quite likely that Daunt has in fact measured one side of this phase curve, the low He^3 concentration phase disappearing as the curve is crossed during the warmup.

We hope to obtain shortly a more accurate phase diagram, and perhaps an answer to the question raised in the preceding paragraph, by working with solutions of other concentrations. A complete report on these findings will be reported later.

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Nuclear Resonance Experiments on Pure He^3 Under Pressure*

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PRELIMINARY measurements using nuclear magnetic resonance techniques[1,2] have been made on the density of He^3 at 1.2°K as a function of pressure, and on the nuclear susceptibility of He^3 as a function of pressure between 0.2°K and 1.2°K.

TABLE I. Density of He^3 as a function of pressure at 1.2°K.

Pressure (atmospheres)	Volume susceptibility (arbitrary units)	Density[a] (grams per cc)
0	1.00	0.0815
0.62	1.02	0.0831
0.97	1.04	0.0847
3.75	1.12	0.0913
6.89	1.20	0.0978
10.8	1.24	0.101
21.7	1.34	0.109
32.8	1.40	0.114

[a] Density values are relative to the value at zero pressure as measured by Kerr.[3]

Densities were determined from measurements as a function of pressure of the strength of the nuclear resonance absorption signal from a He^3 sample of constant volume. Pressures were transmitted to the sample through the compressed vapor above it. Since at 1.2°K, where these measurements were made, the susceptibility of liquid He^3 at its saturated vapor pressure is known to deviate from the Curie value by no more than 5%,[1,2] while measurements reported below indicate that if anything, the deviation becomes smaller as the pressure is increased. The error introduced by assuming the density to be directly proportional to the strength of the observed absorption signal should be no more than 5% at the highest pressures, and proportionately less at lower pressures.

An independent check on the density data, accurate to about 5%, was made by measuring the quantity of He^3 required at each pressure point to fill the constant-volume sample container. Agreement between results of the two methods was quite good.

Results of the density measurements are tabulated in Table I. The error in the values given there should be less than $\pm 2\%$, excluding the possible error discussed above due to changes in the susceptibility per atom as the pressure is increased. Since only relative values of the density could be measured by the method used, the data are normalized to the known value of the density of He^3 at 1.2°K under its saturated vapor pressure.[3] The coefficient of isothermal compressibility at 1.2°K is determined graphically from these data to be about 3% per atmosphere for He^3 under its saturated vapor pressure, a value approximately three times the corresponding value for He^4. Using this value for the compressibility, the velocity of sound at 1.2°K in liquid He^3 at its saturated vapor pressure is calculated, from the classical formula, to be 195 meters per second, about $\frac{4}{5}$ the velocity in He^4.

For each pressure point, the sample was cooled to 0.2°K and changes in the volume of the compressed vapor above the sample were observed as the system warmed up to 1.2°K. In this way it was determined that the change in density of liquid He^3 at any pressure is less than 1% for all temperatures between 0.2°K and 1.2°K. Hence, the data tabulated in Table I hold,

within the accuracy of their measurement, for all temperatures between 0.2°K and 1.2°K.

Measurements on the temperature dependence of the nuclear susceptibility of He^3 are being extended as a function of pressure up to the melting pressure. Preliminary data indicate that deviations from the Curie susceptibility law becomes less pronounced as the pressure is increased, the deviation at a given temperature being approximately a linear function of the average interatomic spacing as determined from the density data presented above. The temperature at which the susceptibility has fallen to 80% of the Curie value is about 0.45°K for He^3 under its saturated vapor,[2] and is about 0.33°K for He^3 under 22 atmospheres pressure.

We expect to obtain more accurate data on each phase of the experiments reported here, and an attempt will be made to extend the measurements to solid He^3

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Galactic Radio Emission and the Energy Released in Nuclear Collisions of Primary Cosmic-Ray Protons

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THE energy density of cosmic radiaton in our galaxy is about 1 ev/cc, and if this is fairly uniformly distributed over the galactic disk and halo,[1,2] the total energy is 10^{54}–10^{55} ergs in the disk and 10^{55}–10^{56} ergs in the halo. The total radio power emitted both by our galaxy and $M31$ in halo[3] and disk is of the order of 10^{37} ergs/sec.[4,5] No detailed power-frequency spectra are yet available, and this is computed by using power levels near 100 Mc/sec and assumed band widths of about 500 Mc/sec. There is strong evidence suggesting that the general mechanism of radio emission is the synchrotron mechanism. If the mean magnetic fields in disk and halo are 10^{-5} and 2×10^{-6} gauss, respectively, the electron and positron energies demanded to produce appreciable power between 10 Mc/sec and 1000 Mc/sec (with a tail below 10 Mc/sec) lie in the ranges 250 Mev to 2.5 Bev in the disk and 560 Mev to 5.6 Bev in the halo. We shall suppose that these particles are produced following nuclear collisions between cosmic-ray protons and the interstellar hydrogen atoms[6,7] and that their energies may be modified by Fermi collision processes. Collisions with atoms other than H will be neglected. Energy losses by quantum processes will overpower the gain by Fermi collision processes below about 300 Mev,[8] and these may provide a natural cutoff for the radio emission.

The lifetime against nuclear collision for a cosmic-ray proton in the disk $(\sigma nc)^{-1}$ is 1.6×10^{15} seconds if $\sigma=4\times10^{-26}$ cm^2 and $n=0.5$. The number of protons having energies such that the decay electrons and positrons have energies suitable for emission in the radio range can be specified only if both the low-energy end of the cosmic-ray spectrum and the particle multiplicities as a function of energy in high-energy collisions are accurately known. The form of the cosmic-ray spectrum $[N(>E)\propto E^{-1.5}$ with a flattening and perhaps a cutoff near 1 Bev$]$[9] is such that a simple integration shows that the majority of the energy is contained in protons of energies between 1 and 100 Bev. We can make the approximation that the equivalent total number of protons is $10^{54}/\bar{E}$, where $\bar{E}\simeq4.3\times10^{-3}$ erg. Particle multiplicities in collisions in this energy range are more difficult to calculate, though energy considerations suggest that the majority of proton collisions in the range 1–100 Bev will give rise to electrons and positrons through π-meson and neutron decay having energies of about 100 Mev—5 Bev (at sufficiently high energies they will obtain about $\frac{1}{6}$ of the meson energy and $\frac{1}{2}$ of the neutron energy). For proton energies of 2.2 Bev, Fermi's calculations[10] show that an average of 1.1 electrons or positrons will be produced per collision. However, experiments suggest that statistical theory is not adequate at low energies, but that virtual excited states of the nucleons are important. The Fermi theory fails in the sense that in (n,p) collisions it predicts too few 2-meson processes, so that the number of electrons may be underestimated. For initial energies of 10 Bev and 100 Bev the Fermi theory gives maximum multiplicities of 5 and 11 mesons if the production of nucleon pairs (and K mesons) is neglected. In view of the uncertainties, it has not been thought worth while to calculate the relative probabilities of different final states for a given multiplicity.

We conclude that for this approximate treatment it is reasonable to suppose that about 5% of the available energy will be transformed to electron and positron energy in the required range. Thus the gain in electron-positron energy is

$$(10^{54}/\bar{E})\times(\bar{E}/20)\times6\times10^{-16}=3\times10^{37}\text{ ergs/sec.}$$

Thus, despite the uncertainties in the details, it appears that the rate of production of electron-positron energy is roughly balanced by the energy loss by synchrotron emission. The total energy which must currently reside in these particles can be estimated from work on other radio sources[11,12] to be 10^{52}–10^{53} ergs. If t_1 is the time taken to build up to this equilibrium, and t_2 is a time in which an electron will lose an appreciable fraction of