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

its energy, $t_1 \approx 3\times10^7$ to 3×10^8 years, and it is necessary that $t_2 \geqslant t_1$. For an electron, the rate of loss of energy

$$-dE/dt = 1.58\times10^{-15}H^2(E/mc^2)^2 - 4.8\times10^{-2}(v/c)^2(E/l)\ \text{ergs/sec.}$$

The second term represents the energy gained by Fermi collision processes; l is a distance of the order of the separation of the turbulent clouds, and v is their velocity. It has been shown previously that for the halo, for energies near 1 Bev, $dE/dt \geqslant 0$. Thus for the particles which originate in the disk but which diffuse into the halo, the flux can continuously build up, and perhaps gain considerable energy from the turbulent gas. Current estimates of v and l in the disk suggest that for the particles which remain in the disk the second term is small compared with the first and can be neglected. Thus, for example, if $E=5000$ Mev, the time taken to radiate an appreciable fraction of the energy is of the order of 10^7 to 10^8 years, so that $t_2 \approx t_1$.

These approximate arguments suggest that the radio emission from our galaxy, and perhaps from all normal galaxies, is a natural result of the presence of a cosmic-ray flux in the interstellar gas and magnetic field.

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Perturbation Treatment of the Nuclear Many-Body Problem

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It is generally believed that the results of treating the nuclear many-body problem by straightforward perturbation theory (based on replacing $\frac{1}{2}\sum\sum_{i\neq j}V_{ij}$ in the Hamiltonian by $\frac{1}{2}\sum_i U_i$ and treating the difference as a perturbation) indicate a poor convergence of the method.[1–3] A re-examination of Euler's original work[1] reveals the following situation.

Starting with an infinitely extended neutron-proton Fermi gas, imagine that nucleon-nucleon interactions are switched on. The resulting potential energy is, in first order, the expectation value $(\text{P.E.})^{(1)}$ of $\frac{1}{2}\sum\sum_{i\neq j}V_{ij}$ for the unperturbed Slater determinant. In second order, a correction $(\text{P.E.})^{(2)}$ appears, which expresses the result of correlations. The ratio $(\text{P.E.})^{(2)}/(\text{P.E.})^{(1)}$ (linear in the strength of the interaction) is a measure of the deviation from the uncorrelated state. Euler's formulas allow one to study this ratio as function of the density of the Fermi gas in the case when the interaction is a central, two-body, Gaussian potential of strength C and range a, acting in any one of the four two-particle states: triplet even, singlet even, triplet odd, singlet odd.

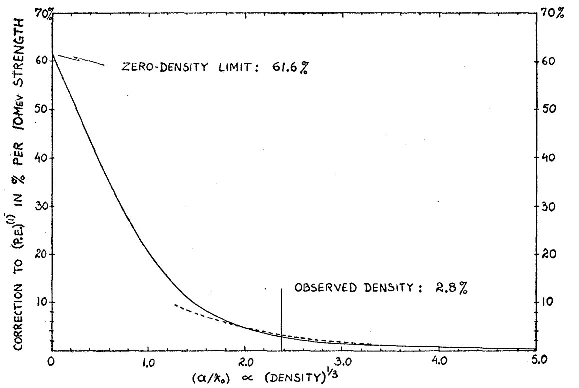

Fig. 1. Graph showing the damping out of correlations with increasing nuclear density. The ratio $(\text{P.E.})^{(2)}/(\text{P.E.})^{(1)}$ is plotted in percent per 10-Mev strength of a Gaussian interaction assumed to act in even states (full curve) or odd states (dotted curve). The abscissa, proportional to the cube root of the density, is the range of the Gaussian a, divided by $\lambda\!\!\!^{-}_0$ (the wavelength of the fastest particle in the Fermi gas, equal to $(8/9\pi)^{\frac{1}{3}}$ times the nuclear radius constant r_0).

At vanishingly small density (when the rare interactions that take place do so as essentially free two-body collisions), Euler's formulas give

$$\frac{(\text{P.E.})^{(2)}}{(\text{P.E.})^{(1)}} = \frac{1}{\sqrt{2}}\frac{C}{\hbar^2/Ma^2},$$

where M = nucleon mass. For a typical range $a=1.9\times10^{-13}$ cm (reference 2, p. 131), this gives $(\text{P.E.})^{(2)}/(\text{P.E.})^{(1)} = 61.6\%$ per 10 Mev of strength. This agrees with the expectation that a Born approximation treatment of free nucleon-nucleon collisions is inadequate.

Figure 1 shows how the above ratio decreases with increasing nuclear density. At the observed density, corresponding to a nuclear radius constant[4] $r_0=1.216\times10^{-13}$ cm, it is 2.8% per 10 Mev of strength—a decrease by a factor of 22. For a typical triplet-even strength (about 43.7 Mev, reference 2, p. 131), the correlation correction is then 12.2%. For the weaker singlet-even interaction (about 27.2 Mev), it is 7.6%.

The rapid damping-out of correlations with increasing density is due partly to the increasing average collision velocities and partly to the exclusion principle,