bars.[14] They are included here since no significant differences in ρ_s/ρ as measured by fourth sound in A-^{3}He and B-^{3}He are reported in Ref. 14 (or Yanof and Reppy[15]).

Combescot[13] has calculated ρ_s/ρ theoretically for the Balian-Werthamer state in the weak coupling limit. Although ^{3}He is not well described by weak-coupling calculations, Combescot has renormalized his results for us to account for strong-coupling effects[16] in a manner which works well for superconductors, by using a new temperature scale T_r such that

$$\frac{\Delta_{\rm BCS}(T)}{T}=\left(\frac{\Delta C_{\rm 3He}}{\Delta C_{\rm BCS}}\right)^{1/2}\frac{\Delta_{\rm BCS}(T_r)}{T_r},$$

where $\Delta C_{^3\rm He}/\Delta C_{\rm BCS}$ is the ratio of the specific heat jumps at T_c for ^{3}He and BCS, assumed to be 1.31,[17] and $\Delta_{\rm BCS}(T)$ is the weak-coupling energy gap. Then $\rho_s(T_r)_{\rm renormalized}=\rho_s(T)_{\rm weak\ coupling}$. Values of ρ_s/ρ obtained from Combescot's analysis, with $F_1=15.7$, are represented in Fig. 2 by the dashed line.

In conclusion, we are encouraged by the fine agreement between measurements of $\hat{\chi}_B$ obtained using pulsed NMR techniques and those obtained from an analysis of the continuous-wave NMR absorption spectra. The comparison of estimates of ρ_s/ρ we have made based on an analysis of the pulsed NMR susceptibilities with the values of ρ_s/ρ obtained in fourth-sound experiments and from a theoretical analysis further supports the validity of our results.

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Comment on Nuclear Shock Waves in Heavy-Ion Collisions

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Heavy-ion collisions are not likely to produce shock waves and baryon densities greater than twice the nuclear matter density, contrary to the conclusions of Scheid, Müller, and Greiner.

The hydrodynamics of high-energy heavy-ion collisions, studied recently by Scheid, Müller, and Greiner,[1] is of some interest, because high-density nuclear matter might have unusual properties. I mention the recent speculation that the compression might lead to a collapsed state of nuclear matter,[2] and also the possibility that pion condensation[3] might occur in nuclear matter at twice normal densities.[4] Scheid, Müller, and Greiner[1] and Wong and Welton[5] assume that the hydrodynamics is governed by formation of a shock wave.

The hydrodynamics of the compressed state depends crucially on the equation of state and the relative size of the mean free path of nucleons, compared to the size of the system. In this comment I wish to suggest a more realistic model than the one given by Ref. 1, which entirely changes the physical situation.

Equation of state.—Solution of the shock equations requires knowledge of the pressure as a function of density and internal energy (part of which may be heat). It is found that there is an upper limit to the maximum density achievable with a shock wave,[6] which for a gas having no internal degrees of freedom is a four-fold compression. This seems implicit in the equation following Eq. (9) of Ref. 1, but is not satisfied in the final results.

Turning to the details of the equation of state at zero temperature, the form assumed in Ref. 1 requires only 3 MeV per particle to double the density of ordinary nuclear matter. This is unreasonably low; already in a pure Fermi gas model 13 MeV per nucleon is required to double the density. A similar figure is found from the hard-core gas model[7] and from a mesonic model.[8] The realistic calculations of the nuclear equation of state by Negele and Vautherin[9] predict that a density doubling requires 16 MeV per nucleon. For an $^{16}O+^{16}O$ collision, this implies that the projectile lab energy should be of the order of 1 GeV.

Mean free path.—Numerical calculations for strong shock waves[10] show that the thickness of the transition region is typically 2.5λ, where λ is the mean free path of the particles prior to the collision. I estimate the mean free path by considering individual nucleons of the same velocity as the incident heavy ion. The mean free path is determined from the nucleon-nucleon cross section.[11] These are summarized in Table I for several energies.[12] It may be seen that the transition region will certainly encompass the whole nucleus, for such a light nucleus as ^{16}O.

TABLE I. Mean free path for $^{16}O+^{16}O$ kinematics.

$E_{c.m.}(^{16}O+^{16}O)$	E_{lab} per incident nucleon (MeV)	λ (fm)
100 MeV	12.5	7
600 MeV	80	2.0
2 GeV and higher	250	2.7

The conclusion is that heavy-ion collisions with enough energy to cause the nuclei to interpenetrate will more resemble gases passing through each other than droplets splashing on each other.

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