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# ELECTRON CONDUCTION OPACITY FOR DENSE STELLAR PLASMAS

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RESUMEN: Se calcula la conductividad térmica de la materia densa tanto para el estado de metal líquido como para el estado cristalino. El cálculo del estado de metal líquido toma en cuenta el mejor conocimiento disponible sobre el factor de estructura iónico en el límite clásico a alta temperatura y el apantallamiento dieléctrico producido por los electrones degenerados. El cómputo del estado cristalino incluye la forma precisa del factor de Debye-Waller.

ABSRTACT: Thermal conductivity of the dense matter is calculated for the liquid metal state as well as for the crystalline lattice state. The calculation for the liquid metal state takes account of the best knowledge available on the structure factor of the ions in the high-temperature, classical limit and the dielectric screening due to degenerate electrons. The calculation for the crystalline lattice state takes account of the accurate form of the Debye-Waller factor.

*Key words*: ATOMIC PROCESSES - DENSE MATTER

## I. INTRODUCTION

In the deep interiors of evolved stars where densities are sufficiently high, energy transport is generally due to degenerate electrons. In this paper we report on the recent advancements in the calculations of the thermal conductivity of dense matter (Itoh et al. 1983; Mitake, Ichimaru, and Itoh 1984; Itoh et al. 1984).

We consider the case that the atoms are completely pressure-ionized. We further restrict ourselves to the density-temperature region in which electrons are strongly degenerate. This condition is expressed as

$$T \ll T_F = 5.930 \times 10^9[[1 + 1.018(\frac{Z}{A})^{\frac{2}{3}}\rho_6^{\frac{2}{3}}]^{\frac{1}{2}} - 1] \ \ [K], \tag{1}$$

where $T_F$ is the Fermi temperature, $Z$ the atomic number of the nucleus, $A$ the mass number of the nucleus, and $\rho_6$ the mass density in units of $10^6 gcm^{-3}$ . The state of the ionic system is determined by the parameter

$$\Gamma \equiv \frac{Z^2 e^2}{akT} = 2.275 \times 10^{-1} \frac{Z^2}{T_8} \left(\frac{\rho_6}{A}\right)^{\frac{1}{3}}, \tag{2}$$

where $a = [3/(4\pi n_i)]^{1/3}$ is the ion-sphere radius, and $T_8$ the temperature in units of $10^8 K$ . The ionic system is in the liquid state for $\Gamma < 178$ , and in the crystalline lattice sate for $\Gamma > 178$.

## II. RESULTS

The thermal conductivity in the liquid metal state is obtained as

$$\kappa = 2.363 \times 10^{17} \frac{\rho_6 T_8}{A} \frac{1}{[1 + 1.018(Z/A)^{2/3} \rho_6^{2/3}] < S >} \quad [ergscm^{-1}s^{-1}K^{-1}], \tag{3}$$

where $< S >$ is determined by the static structure factor of the ionic system and the longitudinal dielectric function of the relativistically degenerate electrons. Examples of the calculated $< S >$ values are shown in Figures 1-4. The solid curves correspond to the results obtained by Itoh et al.(1983), whereas the dashed curves correspond to the results obtained by Yakovlev and Urpin (1981).

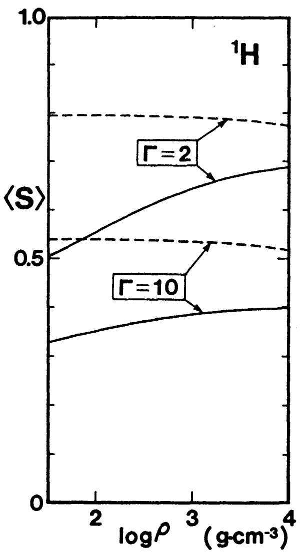


FIG.1

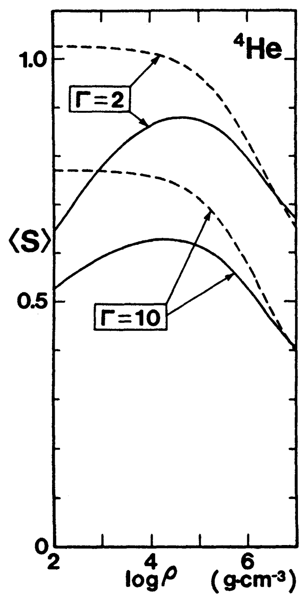


FIG.2

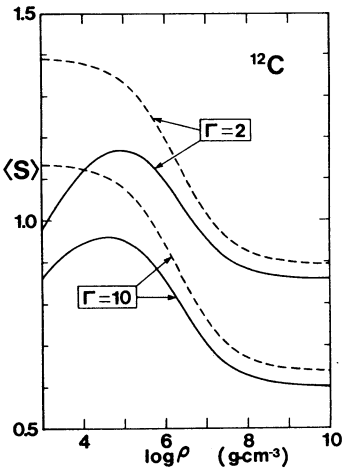


FIG.3

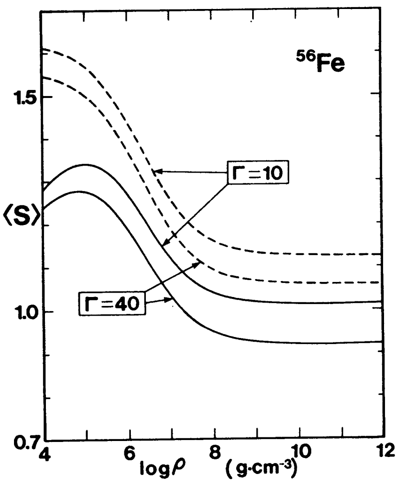


FIG.4

The discrepancy between the two calculations at relatively low densities is due to the fact that Yakovlev and Urpin (1981) neglected the screening due to degenerate electrons.

The thermal conductivity in the ideal crystalline lattice state is determined by the electron-phonon scattering process. The parameter $I_\sigma$ which is proportional to the thermal resistivity ( inversely proportional to thermal conductivity ) has the values shown in Figures 5-6. RY stands for the results obtained by Raikh and Yakovlev (1982). The other curves correspond to the results obtained by Itoh et al. (1984). The curves labeled as $e^{-2W} = 1$ correspond to the calculation in which the Debye-Waller factor is neglected. The other curves have been obtained by accurately taking into account the Debye-Waller factor. Raikh and Yakovlev (1983) neglected the Debye-Waller factor.

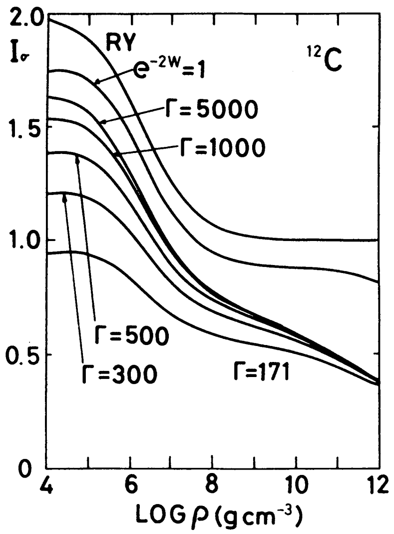


FIG.5

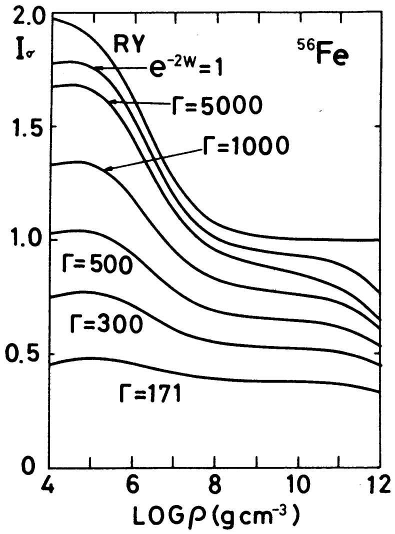


FIG.6

## III. CONCLUSION

Thermal conductivity of the dense matter has been calculated by taking into account the state of the art knowledge in statistical physics and solid state physics. The results presented in this paper have vital importance in building the models of the evolved stars.

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