Monte Carlo Simulation for Molecular Viscosity Coefficients of Rotating Gases

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We study the molecular viscosity formula and viscosity coefficient to be used for the theory on angular momentum transfer of accretion disks. The present paper evaluates the molecular viscosity coefficients for a non-rotating gas, a rigidly rotating gas and a Keplerian rotating gas, separately, with use of the Monte Carlo direct simulation method. The results show that, as expected from our analytical study, with increasing Knudsen number Kn (mean free path of gas molecule/typical size of system) the viscosity coefficients are suppressed to very low levels. We also show the thermal conductivity coefficient. Thermal conduction occurs, due to rotation, also in a direction perpendicular to the temperature gradient. These are representative effects of rotation.

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According to the standard model of accretion disks, a typical accretion disk is in a turbulent state and its angular momentum is transported from inner parts to outer parts by the turbulent viscosity. Since it is unknown by what kind of formula the turbulent viscosity is expressed, the usual arguments use the molecular viscosity formula as it is. The viscosity formulas generally used are, however, applicable to non-rotating gases and do not take the effect of rotation into account.

With a rigidly rotating gas, the viscosity becomes isotropic and the magnitude of the viscosity coefficients depends on the mean free path of constituting molecules. A mean free path close to or larger than the typical size of a system in question, e.g. the thickness of a disk, decreases the viscosity coefficients to very low levels and increases the effect of anisotropy.

The present paper evaluates the molecular viscosity coefficients for a non-rotating gas, a rigidly rotating gas and a Keplerian rotating gas, separately, with use of the Monte Carlo direct simulation method. The results show that, as expected from our analytical study, with increasing Knudsen number Kn(mean free path of gas molecule/typical size of system) the viscosity coefficients are suppressed to very low levels. It has also been found that a stress appears in a direction perpendicular to the velocity gradient. We also show the thermal conductivity coefficient. Thermal conduction occurs, due to rotation, also in a direction perpendicular to the temperature gradient. These are representative effects of rotation.