# Transport theory for a dilute Bose-Einstein condensate

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For a non-condensed (T>Tc) dilute monatomic gas of bosons, five slowly varying hydrodynamic variables govern the relaxation to equilibrium. These five variables correspond to quantities conserved during elastic collisions between the particles; the particle number, momentum (three components), and kinetic energy of the particles. Above Tc, relaxation is governed by three transport coefficients; shear viscosity, thermal conductivity, and bulk viscosity (which is zero for the dilute gas). Below the critical temperature Tc for Bose-Einstein condensation, the boson gas has six hydrodynamic modes, but the microscopic collision processes occur between Bogoliubov excitations (bogolons) and only four quantities are conserved; bogolon momentum and energy. The additional modes are due to the broken gauge symmetry and the presence of the condensate. Below Tc, relaxation to equilibrium is governed by six transport coefficients; shear viscosity, thermal conductivity, and four bulk viscosities (which appear to be negligible for a dilute BEC).

We have derived microscopic and macroscopic expressions for the six hydrodynamic modes of a dilute Bose-Einstein condensate; two transverse (shear) modes, and four longitudinal modes corresponding to first sound (elastic waves) and second sound (temperature waves). Our microscopic expressions include both the speed of the two types of sound and the rate of relaxation of the sound waves. The relaxation of both types of sound appears to be governed primarily by shear viscosity and thermal conductivity.

[1] L.E. Reichl and Erich D. Gust, “Transport Theory for a Dilute Bose-Einstein Condensate” (submitted to PRA).

[2] Erich D. Gust and L.E. Reichl, “Transport coefficients from the boson Uehling-Uhlenbeck equation,” Phys. Rev. E 87 042109 (2013).

[3] Erich D. Gust and L.E. Reichl, “Relaxation Modes and collision integrals for Bose-Einstein condensates,” J. Low Temp. Phys. 170 43 (2013).