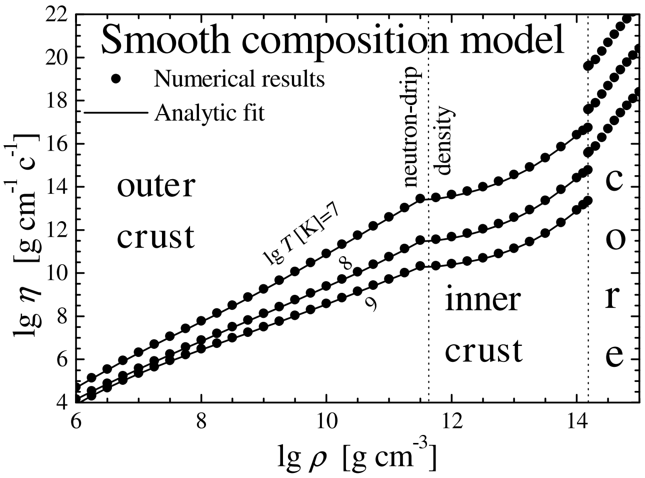
Shear viscosity of a strongly non-ideal Coulomb plasma and oscillations of neutron star crust

A. I. Chugunov *, D. G. Yakovlev †



We have calculated the shear viscosity of dense matter (determined by Coulomb electron collisions) in a wide range of parameters typical for cores of white dwarfs and envelopes of neutron stars. In the density range from $\sim 10^3$ g cm^{-3} to $10^7 - 10^{10}$ g cm^{-3} we have considered the plasma of widely spread astrophysical elements from H to Fe. For higher densities, $10^{10} - 10^{14}$ g cm^{-3}, we employ the ground-state nuclear composition, taking into account finite sizes of atomic nuclei and the distribution of the proton charge over an atomic nucleus. Results of numerical calculations are approximated by an analytic expression which is convenient for practical applications. The figure presents numerical results (thick dots) and analytic approximation (lines) for three temperatures $T = 10^7$, 10^8, 10^9 K. The figure is extended from the neutron star crust into the core (where the density $\rho \geq 1.5 \times 10^{14}$ g cm^{-3}). The viscosity in the core is about three orders of magnitude higher than in the crust, because atomic nuclei (very efficient electron scatterers) are absent in the core, and the electrons scatter there off strongly degenerate protons.

Using the approximation of a plane-parallel layer, we have calculated frequencies and eigenmodes (the profiles of hydrodynamical velocity and of variations of density and pressure) as well as viscous damping times of oscillations of high multipolarity $l \sim 500 - 1000$, localized in the outer crust of a neutron star. For instance, at $l \sim 500$ the oscillations have frequencies $f \gtrsim 40$ kHz and are localized not deeper than 300 m under the surface. When the crust temperature decreases from 10^9 K to 10^7 K, the damping time of oscillations (with a few radial nodes) decreases from ~ 1 year to $10 - 15$ days.

The work was partly supported by the Russian Leading Scientific Schools (grant 1115.2003.2), by the Dynasty Foundation and the RFBR (grant 05-02-16245).

*E-mail: andr.astro@mail.ioffe.ru
†E-mail: yak.astro@mail.ioffe.ru