# Report on the first-year postgraduate studies.

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The following results of first-year postgraduate studies are presented:

- *Anharmonic corrections to the electrostatic energy of a Coulomb crystal*, A.I. Chugunov and D.A. Baiko, Physica A, **352** (2005), pp. 397-408.

  Model calculations of the electrostatic energy of body-centered-cubic and face-centered-cubic Coulomb crystals are presented. The electrostatic energy is calculated using a pair distribution function of ions in the harmonic approximation. This distribution function is shown to be in a good agreement with the function derived by the Monte Carlo method in the high-temperature classical limit ($T \gg \hbar\omega_\mathrm{p}$, $\omega_\mathrm{p}$ being the ion plasma frequency). It is also in a good agreement with the distribution function obtained by the path integral Monte Carlo method in the low-temperature quantum limit ($T \ll \hbar\omega_\mathrm{p}$). First- and second-order anharmonic corrections to the electrostatic energy are analyzed in a wide temperature range, from the high-temperature classical regime to the low-temperature quantum regime. For typical conditions in the envelopes of neutron stars and the cores of white dwarfs the anharmonic corrections to the electrostatic energy do not exceed a few percent of the electrostatic energy of harmonic lattice.

- *Shear Viscosity and Oscillations of Neutron Star Crust*, A.I. Chugunov and D.G. Yakovlev, Astronomy Reports, **49** (2005) pp. 724738 (Translated from Astronomicheskii Zhurnal, **82** (2005), pp. 814829).

  We calculate the electron shear viscosity of dense matter (determined by Coulomb electron collisions) in a wide range of parameters typical for white dwarf cores and neutron star crusts. In the density range from $\sim 10^3$ g cm$^{-3}$ to $10^7 - 10^{10}$ g cm$^{-3}$ we consider the matter composed 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 proton charge over the nucleus. Numerical values of the viscosity are approximated by an analytic expression convenient for applications.

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

- *Envelope oscillations of neutron stars* (paper in preparation)

  Using the approximation of plane-parallel layer we study eigenmodes of acoustic oscillations of high multipolarity, $l \sim 100 - 1000$, localized in the envelope of a neutron star. For $l \gtrsim 300$ modes of two types are present. Modes of the first type are localized at the outer layers of envelope, but the modes of the second type are localized at the vicinity of outer/inner crust boundary. The second type modes are associated with softening of the equation of state after neutron drip point. For $l \sim 100$ the difference between the mode types became negligible and all modes are localized in a whole of envelope.

  We compare modes of the accreted and ground state envelope. The mode features are qualitatively same. For the ground state envelope we employ two accurate models (with phase transitions associated with beta-captures) and the model with smooth dependence of matter parameters. The eigen oscillation frequencies are the same (with accuracy $\sim 1\%$) of all models of ground state envelope.

- *Phonon thermal conductivity of dense matter* (unpublished)

  Calculations of the phonon thermal conductivity are presented. The phonon-phonon and phonon-electron interactions are included. For the low temperatures, the phonon thermal conductivity dominates over the electron conductivity across a very strong magnetic field. The calculations should be improved by accurate studies of freezing of electron-phonon umklapp processes.

- *The electron conductivities: studies of umklapp freezing. First step* (unpublished) The theory of electron-phonon conductivity for the cold dense matter is suggested. The previous calculations (see, e.g., A.Y. Potekhin, D.A. Baiko, P. Hensel, D.G. Yakovlev, Astron. Astrophys. 346 (1999) 345) were made for not very low temperatures at which the main contribution into electron scattering comes from umklapp processes and the electrons could be considered as almost free. However, at low temperatures umklapp processes become localized near intersections of the electron Fermi surface and the boundaries of Brillouin zones. Near these lines, the electron dispersion relation has gaps due to interaction of electrons with periodic lattice structures. The presence of these gaps freezes out the umklapp processes. This freezing was included into the calculations 'by hands' (O.Y. Gnedin, D.G. Yakovlev, A.Y. Potekhin, Mon. Not. Roy. Astron. Soc. 324 (2001) 725) assuming its exponential temperature dependence.

In our calculations the electron energy gaps are considered in the weak coupling approximation, which is justifies because of large electron Fermi energy. The electron electrical conductivity is calculated using the variation method. This approach is traditionally used for studying transport properties of degenerate plasmas in astrophysics and gives accurate results.

The results of numerical studies which will be performed at the nearest future are required for simulating structure and evolution of neutron stars and white dwarfs.