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The neutron star crust in the liquid phase

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The crust and mantle of neutron stars are exceptional laboratories for the theoretical study of clustering in nuclear matter, and their specific transport properties are known to play an important role in many different observable phenomena, such as the thermal emission of X-ray pulsars, quasi-periodic oscillations, giant flares, pulsar glitches, just to cite a few.
Thanks to density functional theory, the composition and properties of crustal matter is relatively well known at zero temperature. The finite temperature problem has been much less addressed in the literature ; still, neutron stars are born hot, and the crustal ions as well as the non-spherical « pasta » nuclear clusters are in the liquid phase at all temperatures beyond about 10^10 K. In such a configuration, the ions are put into collective motion, the simplifying one-component Wigner-Seitz approximation is not valid, and the collective entropy contributions can strongly affect the thermodynamic and transport properties, as well as the composition of matter. This finite temperature modelling might also have some relevance in the late cooling stage of the neutron stars. Indeed, if the cooling is sufficiently fast, the crust composition might be frozen before the catalyzed configuration is reached. Notably, the cooling history of a neutron star is imprinted in the presence of impurities in the crustal lattice, that are at the origin of the highly resistive behavior of the crustal mantle.

In this contribution, I will present our latest results concerning the thermodynamic and transport properties of the neutron star crust in the liquid phase [1-5]. Concerning static properties, I will discuss the effect of going beyond the one-component plasma approximation and including a renormalization of the ion mass calculated in the hydrodynamic limit. Concerning transport, I will present analytical expressions for the anisotropic collision frequencies in the pasta phase using the Boltzmann equation in the relaxation time approximation, and numerical results for the associated electrical and thermal conductivities.

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4. H.Dinh Thi, A.F.Fantina, F.Gulminelli, The proto-neutron star inner crust in the liquid phase, A&A, submitted
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Auteur principal: Prof. GULMINELLI, Francesca (LPC/Ensicaen)

Orateur: Prof. GULMINELLI, Francesca (LPC/Ensicaen)

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