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Neutron Superfluidity Deep in the Neutron Star Crust

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The free neutrons in a neutron star are thought to be paired in a superfluid. The critical temperatures and the density at which the neutron pairing gap closes, however, are poorly constrained. Neutron superfluid singlet pairing gap models that close in the core imply that free neutrons are superfluid throughout the entire crust, while gaps that close in the crust allow a layer of normal (unpaired) neutrons to form in the deep inner crust. During an outburst of accretion onto the neutron star, nuclear reactions heat the crust out of thermal equilibrium with the core. When accretion stops, the observed cooling of the neutron star thousands of days into quiescence probes the thermal properties of the inner crust. Deibel et al. (2016) found that a layer of low conductivity "nuclear pasta" at the crust-core boundary reduces the flow of heat into the core. With the core insulated by the pasta layer, the presence of normal neutrons will dominate the heat capacity of the inner crust and slow its cooling, causing the luminosity to decrease less rapidly after ~1000 days into quiescence. We compute a suite of cooling models to determine how well observations of cooling neutron star transients can constrain the density at which the gap closes.

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