Contribution ID : **19** Type : **Nuclear and Particle Astrophysics**

Superfluid Neutron Matter with a Twist

Thursday, 11 February 2021 11:30 (15)

Superfluid neutron matter is a key ingredient in the composition of neutron stars. The physics of the inner crust is largely dependent on that of its S-wave neutron superfluid which has an effect on pulsar glitches and the neutron star cooling. Moreover, with recent gravitational-wave observations of neutron star mergers, the need for an equation of state for the matter of these compact stars is further accentuated and a model-independent treatment of neutron superfluidity is important. Ab initio techniques developed for finite systems can be guided to perform extrapolations to the thermodynamic limit and attain this model-independent extraction of various quantities of infinite superfluid neutron matter. To inform such an extrapolation scheme, we performed calculations of the neutron $^1S_0$ pairing gap using the model-independent odd-even staggering in the context of the particle-conserving, projected BCS theory under twisted boundary conditions. While the practice of twisted boundary conditions is standard in solid state physics and has been used repeatedly in the past to reduce finite-size effects, this is the first time it is employed in the context of pairing. We find that a twist-averaging approach results in a substantial reduction of the finite-size effects, bringing systems with $N > 50$ within a 2% error margin from the infinite system. This can significantly reduce extrapolation-related errors in the extraction of superfluid neutron matter quantities.

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