Divergence of the isospin asymmetry expansion of the nuclear equation of state

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We have extracted [1] from realistic chiral nuclear interactions the quadratic, quartic, and sextic terms in the isospin-asymmetry expansion of the equation of state of nuclear matter at finite temperature,

\[ F(T, \rho, \delta) \approx \sum_{n=0}^{N} A_{2n}(T, \rho) \delta^{2n}, \]  

from second-order many-body perturbation theory. In the bottom-right panel of Fig. 1, we observe that the quadratic coefficient \( A_2 \) describes well the global isospin asymmetry dependence from symmetric nuclear matter to pure neutron matter by comparing to the symmetry energy \( F_{\text{sym}} = F(T, \rho, \delta = 1) - F(T, \rho, \delta = 0) \). The higher-order terms, however, are shown to be large and alternating in sign (see the top-right and bottom-left panels of Fig. 1) at low temperature and high density, indicating a divergent series incompatible with the traditional assumption in Eq. (1). In Ref. [2] it was shown that at zero temperature an S-wave contact interaction gives an additional logarithmic contribution to Eq. (1) when
computed at second order in perturbation theory. Extracting this nonanalytic term leads to a significant improvement in the description of the free energy per particle at large isospin asymmetries. In future work these results will be used to study the crust-core transition density in neutron stars and the threshold density for the onset of direct URCA processes relevant for neutron star cooling.