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Gluon propagation in cold quark matter: soft gluon self-energy at next-to-leading-order

At high densities and low temperatures, matter composed of quarks and gluons exists as a deconfined plasma known as quark matter. Recent analyses of neutron-star (NS) observations suggest that the cores of the heaviest NSs could be dense enough to contain cold quark matter (CQM). Densities in NS cores are lower than what is required for perturbation theory. Despite this, perturbation theory is an important tool in understanding the high-density limit of CQM.

At non-zero densities, observables can be expressed as a sum of Feynman diagrams similar to quantum field theory in vacuum. However, the naive expansion in the number of loops in the diagrams breaks down at non-zero densities with the appearance of seemingly uncanceled infrared (IR) divergences. This can be remedied by an all-loop-order resummation procedure, where the dynamics of long-wavelength (soft) gluons are described by an effective theory known as hard-thermal-loop (HTL) effective theory.

One of the most fundamental observables for NS applications is the pressure of CQM, which has recently been computed to next-to-next-to-next-to-leading-order for soft gluons using HTL effective theory. In addition, transport coefficients, such as thermal conductivity and viscosity, are interesting due to their connection to NS observations. To compute higher-order corrections to these quantities, it is necessary to determine the gluon self-energy, which describes the effect of interactions on gluon propagation.

Recently, the contribution from short-wavelength (hard) gluons to the self-energy of soft gluons in CQM was determined at next-to-leading-order (NLO). The remaining contribution from soft gluons, known as the HTL-resummed self-energy, is computed in my thesis using HTL effective theory. When both contributions are considered, all IR divergences cancel, and the NLO self-energy is found to be gauge-dependent in contrast with the gauge-independent leading-order self-energy. The computation provides a basis for computing higher-order corrections to transport coefficients in CQM and serves as a step towards higher-order computations in HTL effective theory.