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Analytic continuation of path integral Monte Carlo data for the strongly coupled electron liquid

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Path integral Monte Carlo (PIMC) simulations are one of the few methods which can describe the many body effects of strongly coupled quantum systems. However, PIMC simulations yield imaginary time correlation functions (ITCF) that must be analytically continuated back to real time to extract dynamic information about the system. In this talk, we present three recent works that have successfully conducted analytically continuation for the finite temperature electron liquid. Each work uses a different approach: Bryan's maximum entropy method [https://arxiv.org/pdf/2503.20433], dual Newton optimization with entropic regularization [https://arxiv.org/abs/2501.01869], and PyLIT's regression method [submission in progress]. These works have explored data-driven Bayesian priors, resampling methods, non-linear grid spacing, new regularization terms, and different regularization weight selection procedures.

Since the analytic continuation amounts to an inverse Laplace transform of a function with poles, then, in theory the same information is present in either representation. However, in practice the inversion is difficult. Here, we also present investigations that have observes the same phenomena in both the imaginary and real time. We focus on observing a repeated roton (i.e. double roton) structure [submission in progress], differentiating which pair potential was used in PIMC simulation [https://arxiv.org/abs/2504.00737], and the satisfaction of sum rules [https://arxiv.org/pdf/2503.20433]. Note that there are no constraints enforcing these phenomena in the analytic continuation tools. For these three phenomena, we have find good agreement between real time and imaginary time representations.

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