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NODE Neural ODEs for magnetic holographic QCD phase diagram

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The QCD phase diagram is essential for understanding strongly interacting matter under extreme conditions, with important implications for cosmology, neutron stars, and heavy-ion experiments. We present a novel holographic QCD model utilizing neural ordinary differential equations (ODEs) to map the QCD phase diagram under magnetic field B, baryon chemical potential μ_B, and temperature T. By solving the inverse problem of constructing the theory from Lattice QCD data, we find an unprecedented rich phase structure at finite B. Particularly, it uncovers the existence of multiple critical endpoints (CEPs) at strong magnetic fields. For example, under $B = 1.618\,\mathrm{GeV}^2$, there are two CEPs locating at ($T_C = 87.3\,\mathrm{MeV},\ \mu_C = 115.9\,\mathrm{MeV}$) and ($T_C = 78.9\,\mathrm{MeV},\ \mu_C = 244.0\,\mathrm{MeV}$). Surprisingly, the critical exponents vary based on the CEP's location. Our findings significantly enhance our understanding of the QCD phase structure and provide concrete predictions for validation at upcoming facilities like FAIR, JPARC-HI, and NICA.

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