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**Majorana-time-reversal symmetries: a fundamental principle for sign-problem-free quantum Monte Carlo** ZI-XIANG LI, YI-FAN JIANG, HONG YAO, Institute for Advanced Study, Tsinghua University — A fundamental open issue in physics is whether and how the fermion-sign-problem in quantum Monte Carlo (QMC) can be avoided generically. Here, we show that Majorana-time-reversal (MTR) symmetries can provide a unifying principle to avoid the fermion-sign-problem in interacting fermionic models. By systematically classifying Majorana-bilinear operators according to the anti-commuting MTR symmetries they respect, we rigorously proved that there are two and only two *fundamental* symmetry classes which are sign-problem-free and which we call “Majorana-class” and “Kramers-class”, respectively. Novel sign-problem-free models in the Majorana-class include interacting topological superconductors and interacting models of charge-4e superconductors. We believe that our MTR unifying principle could shed new light on sign-problem-free QMC simulation on strongly-correlated systems and interacting topological matters.

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