The emergent fine-structure constant in quantum spin ice is large

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Condensed matter systems provide alternative `vacua' exhibiting emergent low-energy properties drastically different from those of the standard model. A case in point is the emergent quantum electrodynamics (QED) in the fractionalized topological magnet known as quantum spin ice, whose magnetic monopoles set it apart from the familiar QED of the world we live in. Here, we show that the two greatly differ in their fine-structure constant α, which parametrizes how strongly matter couples to light: α_{QSI} is more than an order of magnitude greater than $\alpha_{\mathrm{QED}}\approx 1/137$. Furthermore, α_{QSI}, the emergent speed of light, and all other parameters of the emergent QED, are tunable by engineering the microscopic Hamiltonian. We find that α_{QSI} can be tuned all the way from zero up to what is believed to be the \textit{strongest possible} coupling beyond which QED confines. In view of the small size of its constrained Hilbert space, this marks out quantum spin ice as an ideal platform for studying exotic quantum field theories and a target for quantum simulation. The large α_{QSI} implies that experiments probing candidate condensed-matter realizations of quantum spin ice should expect to observe phenomena arising due to strong interactions.

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