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A limitation on the asymptotic decay of vanishing spectral gaps

The spectral gap of quantum many-body systems is one of the most fundamental quantities determining much of the properties of the low-energy physics, and understanding its behavior is a particularly hard problem. Even in the case of a gapless system, where the spectral gap goes to zero as the system size increases, it is important to understand the rate at which it vanishes. For the case of finite-range, frustration free Hamiltonians on a spin lattice of arbitrary dimension, we show that in the gapless case, the spectral gap on regions of diameter n is at most $o\left(\frac{\log(n)^{2+\varepsilon}}{n}\right)$ for any positive ε. Any slower decay rate is ruled out, as it would imply a constant spectral gap, via a recursive strategy.