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Bounds on the entanglement entropy of droplet states in the XXZ spin chain

We consider a class of one-dimensional quantum spin systems on the finite lattice $\Lambda \subset \mathbb{Z}$, related to the XXZ spin chain in its Ising phase. It includes in particular the so-called droplet Hamiltonian. Remarkably, the attractive, nearest-neighbor interaction implies the existence of thresholds in the spectrum of the corresponding Hamiltonians: clustering of spins with the same orientation is energetically favorable and a lowest band may be identified, the "droplet band". It should be emphasized that, generically, droplet states are neither Gaussian, nor ground states of our system. The entanglement entropy of these energetically low-lying states over a bipartition $\Lambda = B \cup B^c$ is investigated and proven to satisfy a logarithmic bound in terms of $\min\{n, |B|, |B^c|\}$, where n denotes the maximal number of down spins in the considered state. Upon addition of any (positive) random potential the bound becomes uniformly constant on average, thereby establishing an area law. The proof is based on spectral methods: a deterministic bound on the local (many-body integrated) density of states is derived from an energetically motivated Combes–Thomas estimate. (Joint work with S. Warzel)