The graphene bilayer consisting of mutually rotated layers shows a rich physics, including both a large angle electronic decoupling of the constituent layers, and a small angle regime characterized by an emergent long length scale, the moiré length, and dramatic changes in the density of states near the Dirac point [1]. In this work we present tight-binding results for a complete range of twist angles (θ), demonstrating the existence of a small angle limit in which the system becomes self-similar with θ, i.e., reduction of θ leads to no changes in electronic properties when scaled by system size N. This regime is characterized by a zero mode consisting of states strongly localized on the AA patches of the lattice. In addition we present a low energy gauge theory of this self-similar regime, and demonstrate that it yields good agreement with the tight-binding results.