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Spin coherent state representation of the Crow-Kimura and Eigen models of quasispecies theory

We present a spin coherent state representation of the Crow-Kimura and Eigen models of biological evolution. We deal with quasispecies models where the fitness is a function of Hamming distances from one or more reference sequences. In the limit of large sequence length N, we find exact expressions for the mean fitness and magnetization of the asymptotic quasispecies distribution in symmetric fitness landscapes. The results are obtained by constructing a path integral for the propagator on the coset $SU(2)/U(1)$ and taking the classical limit. The classical limit gives a Hamiltonian function on a circle for one reference sequence, and on the product of $2m-1$ circles for m reference sequences. We apply our representation to study the Schuster-Swetina phenomena, where a wide lower peak is selected over a narrow higher peak. The quadratic landscape with two reference sequences is also analyzed specifically and we present the phase diagram on the mutation-fitness parameter phase space. Furthermore, we use our method to investigate more biologically relevant system, a model of escape from adaptive conflict through gene duplication, and find three different phases for the asymptotic population distribution.