Non-abelian gauge theories with Majorana fermions in two dimensions

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Text books usually only deal with the Schwinger model and the 't Hooft model as examples of gauge theories coupled to fermions in two dimensions. SU(N) gauge theories coupled to massless fermions in two Euclidean dimensions (one space and one time) exhibit interesting physical properties and is currently an active area of study. These theories can be studied using a Hamiltonian formalism or a Lagrangian formalism. When the fermions are in a Dirac representation, the infra-red limit of these theories have a conformal sector described by a Wess Zumino Witten model. Theories with a single massless Majorana fermion can either have a mass gap or not. For example, when the Majorana fermion is in an integer representation, J, of SU(2) gauge theory; the spectrum has a gap of J=1,2 and the spectrum is masless if $J > 2$. There is no gauge field topology in two dimensions but there is a mod-2 fermion index that results in robust zero modes that are stable under gauge field perturbations. Such a mod-2 index is present only when N is even and the Majorana fermion is in the adjoint representation. In such theories, fermion boundary conditions (periodic and anti-periodic) and gauge field boudary conditions (non-trivial twist) on a torodial lattice affect the physical results. For example with N=2, there are four different partition functions, Z(A,T), Z(P,T), Z(A,N) and Z(P,N). A and P are anti-periodic and periodic boundary condtions respetively and T and N correspond to trivial and non-trivial twist. One can rigorously show that Z(P,T) and Z(A,N) are zero. The necessity to sum over boundary conditions is a new feature of such theories. With that in place one can show that the Z2 chiral symmetry is explicitly broken at finite volume. This result is independent of whether the theory has a mass gap or not and this is surprising. When one studies these theories using the Discrete Light Cone Hamiltonian, one can see evidence for the massless spectrum even before one takes the continuum limit. This is also surprising since there is no symmetry generating current unlike theories with Dirac fermions. I would like to present a comprehensive summary of all these results.