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Chiral Waves on the Fermi-Dirac Sea: Quantum Superfluidity and the Axial Anomaly EMIL MOTTOLA, ANDREY SADOFYEV, Los Alamos Natl Lab — As a result of the axial anomaly, massless fermions at zero temperature define a relativistic quantum superfluid. Corelated fermion/anti-fermion pair excitations of the Fermi-Dirac sea propagate as gapless Chiral Density Waves (CDWs), i.e. axion-like acoustic modes of an irrotational and dissipationless Hamiltonian perfect fluid. In D=2 the chiral superfluid effective action is identical to that of the Schwinger model as $e \to 0$, with the CDW acoustic mode precisely the Schwinger boson. This identity holding also at zero chiral chemical potential implies that the Dirac vacuum itself may be viewed as a quantum superfluid state. The CDW collective boson is massless as a result of a novel, non-linear realization of Goldstone's theorem extended to this case of symmetry breaking by an anomaly. We give a new local form of the axial anomaly effective action in any even D spacetime, consistent with superfluidity, and show that its quantization is required by the anomalous Schwinger terms in fermion current commutators. In massless QED_4 this collective Nambu-Goldstone mode appears as a massless pole in the axial anomaly triangle diagram, and is responsible for the macroscopic non-dissipative currents of the Chiral Magnetic and Chiral Separation Effects.

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