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Superflow instabilities of atomic fermion superfluids in an optical lattice GANESH RAMACHANDRAN, ARUN PARAMEKANTI, Department of Physics, University of Toronto, Toronto, Ontario, Canada M5S 1A7, A.A. BURKOV, Department of Physics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1 — We study the superfluid phase of the one-band attractive Hubbard model as a prototype of a strongly correlated fermionic superfluid on a lattice. We characterize its collective mode and compute the sound velocity and "roton" gap within a generalized random phase approximation (GRPA). At strong coupling, we perform a spin wave analysis of the appropriate pseudospin model, with our GRPA results matching onto the spin wave results. With our two-pronged understanding of the collective mode, we examine breakdown of superfluidity due to imposed supercurrent. We find several mechanisms of superflow breakdown - depairing, Landau or dynamical instabilities. The most interesting is a charge modulation dynamical instability distinct from those previously studied in Bose superfluids. The associated charge order can be of two types: (i) a commensurate checkerboard modulation driven by softening of the roton mode at the Brillouin zone corner, or (ii) an incommensurate modulation arising from flow-induced finite-momentum pairing of Bogoliubov quasiparticles. We map out a dynamical phase diagram showing critical flow momentum of the leading instability, and point out implications for experiments on cold atom superfluids in an optical lattice.

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