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Intermediate phases of the two dimensional electron fluid between the Fermi liquid and the Wigner crystal

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We study the consequences of Coulomb interactions in a 2D system undergoing a putative first order phase transition as a function of density. In two dimensions (2D), near the critical density, the system is universally unstable to the formation of new intermediate phases, which we call "microemulsion phases". They consist of an intermediate-scale mixture of regions of the two competing phases. A corollary is that there can be no direct transition as a function of density from a 2D Wigner crystal to a uniform electron liquid. Rather, there must always exist intermediate electronic micro-emulsion phases, and an accompanying sequence of continuous phase transitions. Among the intermediate electronic phases which we find are a variety of bubble phases and liquid crystalline phases. The existence of these phases can be established in the neighborhood of the phase boundaries on the basis of an asymptotically exact analysis. They likely occur in clean Si MOSFETs and p-GaAs heterojunctions in the range of densities in which an "apparent metal to insulator transition" has been observed in existing experiments. We also point out that, in analogy with the Pomaranchuk effect in ^{3}He, the Wigner crystal phase has higher spin entropy than the Fermi liquid phase, leading to an increasing tendency towards electronic crystallization with increasing temperature and with magnetic field parallel to the film. Finally we discuss the consequences of this effect for the temperature and the magnetic field dependences of the resistance of strongly correlated electron liquids and for the drag effect in p-GaAs double layers.