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Emergent phenomena and magnetism in high-density electron gases in $SrTiO_3$

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$GdTiO_3/SrTiO_3$ interfaces grown by molecular beam epitaxy exhibit mobile carrier densities that are remarkably well predicted by the electrostatic requirements of the compensation of the polar discontinuity at the interface. Carrier densities are $\sim$3x10^{14} cm^{-2}, or $\sim$0.5 electron per surface unit cell. By sandwiching few-unit-cell-thick $SrTiO_3$ layers between $GdTiO_3$, carrier concentrations in the $SrTiO_3$ approach densities under which on-site Coulomb interactions may appear. By changing the width of the quantum well, the 3D electron density can be varied, which allows for a systematic study of interaction effects. In this presentation, we discuss evidence for short-range Coulomb interactions, and associated phenomena, in ultrathin, confined the $SrTiO_3$ quantum wells containing extreme charge densities. We show that narrow $SrTiO_3$ quantum wells exhibit ferromagnetism at low temperatures, as evidenced by a hysteresis in the magnetoresistance. The Curie temperature scales with the thickness of the $SrTiO_3$ quantum well. We discuss evidence for on-site Mott-Hubbard-type correlation physics in the temperature-dependent transport in metallic quantum wells. With increasing 3D carrier densities we observe a correlation-induced mass enhancement, followed by a transition to a correlated insulator at the highest 3D densities. We also discuss the role of disorder in the insulating state. This work was done in collaboration with Pouya Moetakef, Clayton A. Jackson, Leon Balents, Jim Allen, Jimmy Williams and David Goldhaber-Gordon.