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New physics in the second Landau Level

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Clean two-dimensional electron systems subjected to perpendicular magnetic fields have a long history of revealing exotic ground states. A large number of these states are only possible in the presence of electron-electron interactions. Two notable examples of such collective ground states are the fractional quantum Hall liquids of the first two Landau levels and the electronic solids called the stripe and bubble phases forming beyond the first Landau level. These two classes of phases are simultaneously present and hence compete in the second Landau level. This talk will highlight our latest results on the evolution of the states of the second Landau level as the magnetic field is tilted away from the direction perpendicular to the sample. The challenging task of cooling to millidegree temperatures and in-situ tilting in this low temperature environment is achieved with a hydraulically driven rotator equipped with sintered Silver heat exchangers mounted onto the nuclear demagnetization stage of a dilution refrigerator. We found that the bubble states are rapidly destroyed with tilt and argue that such a behavior is consistent with the formation of an electronic solid. Furthermore, the well developed $\nu = 2+1/5$ and $2+4/5$ liquids are found to be driven insulating while the $2+1/3$ and $2+2/3$ states survive to the largest tilt angles accessible. The simplest interpretation of the rapid evolution of these states is that bubble phases melt into a classical Hall gas and the $\nu = 2+1/5$ and $2+4/5$ liquids solidify with tilt. Our data suggest that spin interaction plays an important role in the formation of these phases. In particular, we surmise that the bubble phases are not fully spin-polarized but most likely have a substantial antiferromagnetic order. These bubble phases could be first examples of antiferromagnetically ordered solids in a single layer two-dimensional electron system. This work was done in collaboration with J.S. Xia, C.L. Vicente, E.D. Adams, N.S. Sullivan, D.C. Tsui, H.L. Stormer, L.N. Pfeiffer, and K.W. West.