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Phase diagram and edge excitations of the $\nu = 0$ quantum Hall state in graphene[1]

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The interaction-induced broken-symmetry incompressible quantum Hall states in graphene at integer and fractional filling factors have by now been firmly established in transport and compressibility measurements. However, identifying their precise nature (e.g., how the symmetry is broken) still remains a tough challenge: on the experimental side, transport and compressibility probes do not provide direct information about the physical order; on the theoretical side, the presence of additional to spin discrete degrees of freedom, valleys, results in a variety of competing phases in this multicomponent system. As the prime example of this rich behavior, I will present a generic phase diagram for the intriguing $\nu = 0$ state, obtained within the framework of quantum Hall "ferromagnetism." The diagram consists of the canted antiferromagnetic, ferromagnetic, charge-density-wave (charge-layer-polarized), and Kekulé (interlayer-coherent) phases in monolayer (bilayer). I will then discuss the edge excitations of the $\nu = 0$ state. Remarkably, the edge excitations are nonuniversal (e.g., can be gapped or gapless) and crucially depend on which phase is realized in the bulk of the system. Besides being of considerable theoretical interest, these unprecedented properties simultaneously allow one to infer about the nature of the phases from the transport experiments. I will present arguments based on this analysis and existing data why the insulating $\nu = 0$ state realized in real bilayer (and possibly, monolayer) graphene is likely to be canted antiferromagnetic. Finally, I will mention how this theoretical framework can be generalized to fractional quantum Hall states in graphene, which could shed light on some of the puzzling features of the recent experiments.

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