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Flux attachment and non-commutative geometry in the fractional quantum Hall effect: some open mathematical problems

"Holomorphic states"play a key role in model many-body fractional quantum Hall states, such as the Laughlin states. The origin of holomorpic structure is usually (incorrectly) explained as being a special property of the "lowest Landau level", but in fact derives from the non-commutative geometry of guiding centers of Landau orbits in any Landau level. The complex structure defines a metric that describes the shape of "flux attachment", which is a hidden variational parameter of the Laughlin state. The Laughlin and other even-more-interesting model states such as the non-Abelian Moore-Read and Read-Rezayi states have rich mathematical structure (for example they are Jack polynomials on genus-0 manifolds) but so far most quantitative information has come from numerical studies. The are a number of challenging problems that mathematical physics could usefully tackle. For example, the Laughlin states are the highest density states in the kernel of a "pseudopotential model" with close analogies to the the AKLT spin chain. Numerical studies clearly show that its excitation gap remains finite in the thermodynamic limit, but while a lower bound to the gaps of the AKLT model was found, this is lacking for the model for which the Laughlin state is the ground state. Other issues such as a modular-invariant formalism on the torus, and a Heisenberg as opposed to Schrodinger formulation appropriate for non-commutatve geometry will be discussed, if time permits.