RESEARCH INTERESTS

• Conformal Field Theory of the Integer Quantum Hall Plateau Transitions

One of the approaches towards the Conformal Field Theory (CFT) describing the II-nd order phase transition between the integer Quantum Hall (QH) plateaus is based on the supersymmetric technique for treating the quenched average of the random mass, random vector and scalar potentials. One could argue that the resulting PSL(2|2) WZNW model [1], as well as the related $SL(2,\mathbb{C})/SU(2)$ WZNW model [2], do not take into account a subtle effect in one of the $u(1)$ subalgebras leading to its spontaneous breaking. This effect, which I call "the zero-level effect", should be understood [3] first in the simpler case of the two-dimensional Dirac fermion model with random vector potential only, where the quenched average could be taken directly. There is a special value of the quenched coupling constant, corresponding to the threshold value of Refs. [4, 5, 6] at which the multifractal spectrum of the inverse participation ratios changes like in a localization transition. It would be interesting to interpret this transition from the CFT point of view. To this end we observe that the level of the $u(1)$ current algebra becomes zero at the threshold value of the coupling constant and all states created by the modes of the corresponding current are null states that presumably have to be removed from the space of states. This projection could be viewed as a CFT coset, which corresponds to the *freezing transition* in the work of [6] and seems to be an important first step for the identification of the ultimate CFT for the integer QH transitions. While it is almost certain that the quantum Hall plateau transitions are not in the universality class of the freezing transitions, it can be shown that the zero-level effect persists after taking into account (the quenched average over) the random mass and scalar potential. I anticipate that due to the above mentioned spontaneous breaking the (scalar potential's) IR fixed point does not have the entire affine symmetry of the UV one (cf. Ref. [7]) and the correct CFT for the Integer QH transitions can be obtained only after carefully applying the above projection to the CFT obtained in the supersymmetric approach, resulting in a certain coset CFT construction based on the PSL(2|2) or the $SL(2,\mathbb{C})/SU(2)$ model. This could give us some intuition about the possible coset CFT models for the integer QH transitions that should be identified within the classification scheme of Ref. [8].

• Conformal Field Theory Description of the Aharonov–Bohm Magnetization and Susceptibilities in Mesoscopic Quantum Hall States

The disk partition functions derived within the edge-state's CFT for mesoscopic QH systems can be used (in the thermodynamic limit) as a thermodynamic potential for the latter. When an Aharonov–Bohm (AB) type of flux is threading a mesoscopic disk QH sample the partition function should be periodic in the flux with period one flux quantum h/e (Bloch theorem). The derivative of the free energy with respect to the magnetic flux gives rise to an equilibrium persistent current which is proportional to the AB magnetization. The amplitudes of the magnetization and the corresponding susceptibility are universal, are not affected by impurities (due to the fixed chirality of excitations) and decay exponentially with increasing the temperature and/or the size of the sample [9, 10, 11]. These universal coefficients are unique characteristics of the QH universality classes allowing to distinguish between different QH states with the same filling factor. This approach has been used for the parafermion FQH states in the second Landau level [11], with filling factors $\nu = k/(k+2)$, showing that the above mentioned decay coefficients are qualitatively different from those in the Fermi or Luttinger liquid and do depend on the level k of the parafermion hierarchy. It would be interesting to apply the same scheme for the Jain series of plateaus with filling factors $\nu = n/(2np+1)$ where the theory says that the universal coefficients should be independent of the level n of the hierarchy while the experiments (see Ref. [12] and the Refs. therein) have shown the opposite. We hope that the analysis of the temperature behavior of the AB magnetization could shed more light on the puzzle in the tunneling experiments [12].

- ## Conformal Field Theory for the Edge States in the Jain series of Fractional Quantum Hall plateaus

The large-scale effective field theories for the fractional quantum Hall (FQH) effect are known [13, 14] to be (2+1) dimensional topological Chern–Simons theories which are in one-to-one correspondence with the rational conformal field theories (RCFT) on the (1 + 1) dimensional boundary. Due to the *universality* of the FQH effect these theories capture the long-range order of FQH systems allowing to classify all *universality classes* in terms of the RCFTs. Two of the most popular CFT schemes that have been developed for the principle series of plateaus (the Jain series) with filling factors $\nu = n/(2np + 1)$ are the multicomponent Luttinger liquid (described by the extended $\widehat{u(1)}^N$ current algebra models known as the K-matrix theories) [13, 15] and the $W_{1+\infty}$ minimal models [16]. In a recent series of experiments [17, 12], however, it was shown that the Luttinger liquid picture is at best incomplete or at worst wrong and could successfully describe only the Laughlin states with $\nu = 1/(2p + 1)$. On the other hand, while the role of $W_{1+\infty}$ symmetry is fairly fundamental for the FQH effect, the physical understanding of the absence of modular invariance in the $W_{1+\infty}$ minimal models is still missing. Therefore, as the two main approaches mentioned above could not be identified with the true CFT for the incompressible fractional quantum Hall states at the Jain filling factors, it is necessary to look for other RCFTs that could successfully describe the tunneling experiments. The CFT-based analysis of the I–V characteristics in the Aharonov–Bohm regime (like the one for the Luttinger liquid in Ref. [9]) could give important information about the RCFT that we are looking for. This could probably be realized by reducing neutral degrees of freedom (in terms of, say, affine CFT coset) within the multicomponent chiral Luttinger liquid model, inheriting in this way the electric properties of the latter, while changing dramatically its neutral ones.

- ## Other Topics

  - **Logarithmic Conformal Field Theories**
  - **Modular properties of affine coset and orbifold CFTs**
  - **Quantum Computing using fractionally charged quasiparticles in Quantum Hall qubits**
  - **Fractional Charges, Shot-Noise and Exclusion Statistics**
  - **Quantum Groups and $\mathbb{Z}_k$ parafermions**
  - **Classification of the $\widehat{u(1)}^N$ Modular Invariants**
  - **Non-Commutative Chern–Simons Theories**
  - **Riemann Zeta Function**

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