Functional renormalization group approach to some problems of condensed matter physics

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This short scientific report explores superfluid phase transitions in quantum matter, focusing on the application of functional renormalization group (FRG) methods to understand these phenomena. The key points I will stick to are

1. **Modern State of Phase Transitions in Quantum Matter:** The report begins with an overview of the current understanding and significance of phase transitions in quantum matter (atomic gases), highlighting recent advancements and ongoing challenges in the field.

2. **Theoretical Framework - Functional Renormalization Group**: The FRG is introduced as a powerful theoretical tool for studying phase transitions. Its ability to handle complex, nonperturbative effects makes it ideal for analyzing the scale dependence of coupling constants in quantum systems.

3. **Critical Properties in Large Spin Fermionic Systems**: The study specifically examines the phase transition to superfluid order in SU(N) symmetric fermionic systems. This is achieved by modeling the system using a bosonic field theory that accounts for fluctuations in the order parameter.

4. **Nonperturbative Analysis of Couplings**: The FRG method is used to nonperturbatively track the scale dependence of the theory's couplings, providing insights into how these couplings evolve near the critical point.

5. **Fluctuation-Induced First-Order Phase Transition**: One of the key results is the identification of a first-order phase transition induced by fluctuations. The nature of this transition varies with the coupling strength:

- Weak-Coupling Regime: In this regime, the order parameter exhibits a small jump, leading to an almost continuous phase transition.

- Strong-Coupling Regime: Here, the transition is marked by a significant discontinuity in the order parameter, making the phase change more distinct and detectable.

The findings on the possible fluctuation-induced first-order phase transition enhance the theoretical framework and may provide a deeper insight into the behavior of large spin fermionic systems near critical points.