Emergent Su(2) symmetry : the missing link to the pseudo-gap puzzle

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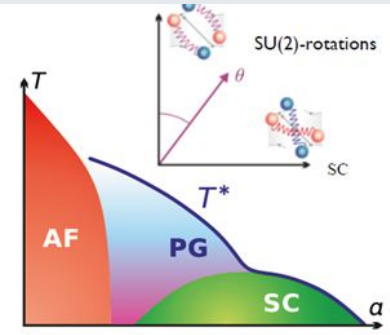
The concept of symmetries governing the behaviour of physical states is maybe the most robust in theoretical physics. From the formation of nuclei to the Higgs-Boson the symmetries are fundamental in the determination of every emerging state in high energy physics. It would be quite remarkable if a phenomenon as complex as high temperature superconductivity would be governed as well by an overall emergent symmetry. Suggestions about the existence of a pseudo-spin symmetry in the background of the physics of superconducting cuprates have been introduced since the early days of these compounds and has been revived over the years in different contexts. In all cases, the main simple idea is that one can rotate the d-wave superconducting state towards another state of matter degenerate in energy. The physics is then controlled solely by the powerful constraint of the emergent symmetry. A vast region of the phase diagram is then dominated by fluctuations between those states. Here, we argue that an emerging SU(2) symmetry connecting the d-wave superconducting state with a d-wave charge order is the main ingredient of the physics of superconducting cuprates.



Phase diagram of superconducting cuprates as a function of the hole doping level. Upon doping, the materials evolve from an insulating antiferromagnetic state (AF) to a strongly correlated metallic state governed the mysterious pseudo-gap (PG) phase, out of which superconductivity (SC) emerges. The insert sketches the SU(2) pseudo-spin connecting the d-wave superconducting Cooper pairs (2-electron pairs) with d-wave excitons (electron-hole pairs)

This emergent SU(2) symmetry allows us to understand the origin of the mysterious pseudo-gap phase out of which superconducting emerges. We give a new theoretical account of the physics of the pseudo-gap phase in terms of the emergence of local patches of particle-hole pairs generated by SU(2) symmetry fluctuations. The proliferation of these local patches accounts naturally for the robustness of the pseudo-gap phase to disturbances like disorder or magnetic field and is shown to gap out part of the Fermi surface, leading to the formation of the Fermi arcs. Most noticeably, we show that these patches induce a modulated charge distribution on the Oxygen atoms, in remarkable agreement with recent X-ray and STM observations. Within such a framework, we further propose a comprehensive study of the collective S=1 excitations observed by inelastic neutron scattering in both the superconducting state and also in the pseudo-gap regime. In addition, we highlight the existence a S=0 excitation with charge ±2 (η-mode), due excitations between the d-wave superconducting singlet pairing channel to a d-wave charge channel. This η- boson is likely to correspond to the mysterious excitation reported by electronic Raman scattering in the A1g Channel a long time ago. In more recent developments of our model, the emergent SU(2) symmetry can further generate « collateral » orders which typically break discret symmetries. The breaking of fourfold rotation symmetry enhances an electronic nematic susceptibility, whereas the breaking of both time reversal and parity symmetries induce a phase bearing similarities with a loop current order.

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