Diluted Random Impurities Destabilise 3D Semi-metallic Phases

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Dirac/Weyl semimetals (DWSMs) are novel three-dimensional gapless electronic phases, featuring unique topological properties [1]. The simplest DWSMs exhibit one or more two- (Weyl) or four-fold (Dirac) degenerate isotropic linear-band touchings at their Fermi levels. Their point-like Fermi surfaces are typically robust due to crystal symmetries or topological constraints and experimental realisations of these systems were already reported [2]. Such materials are incompressible semimetals with a quadratically vanishing density of states (DoS), in the absence of impurities or disorder.

A recurrent question on 3D nodal fermionic systems concerns the possibility of having a lifting of the density of states (DoS) induced by translation-invariance breaking perturbations. Early results [3] predicted disorder to be irrelevant above two dimensions, but more recent and seemingly contradictory field-theoretically [4,5] and numerical studies [6,7] have shown this matter to be much more subtle than previously expected.

Combining analytical techniques with ultra-high-resolution numerical simulations [8], we show that dilute spherical impurities can lead to a finite zero-energy DoS at the node of a 3D DWSM, destabilising the semi-metallic phase even for small impurity concentrations. This effect is driven by low-energy resonances occurring for impurities close to but not precisely fine-tuned at 'magical values' at which zero-energy bound states are formed. These near-critical impurity configurations give statistical significance to these zero-energy modes leading to a diffusive metallic phase. The present results are to be published soon [9], where additional discussions and further details may be found.

References

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Figures

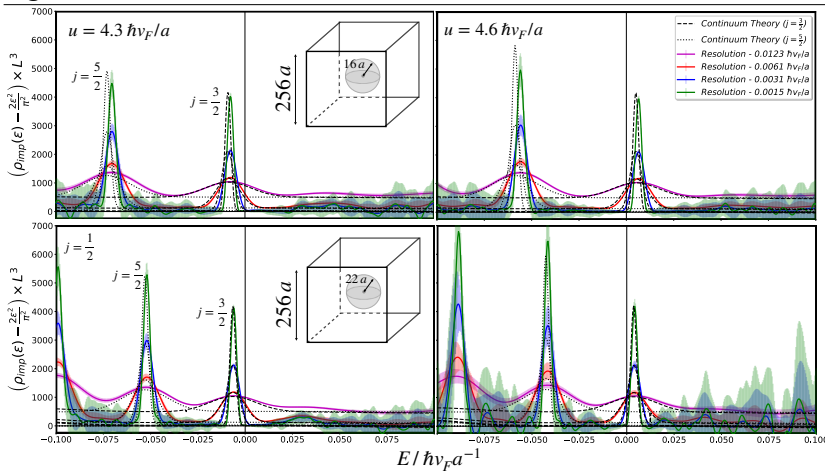

Figure 1: Comparison between the correction to the DoS due to near-critical spherical impurities in a cubic lattice model of an 8-valley Dirac Model [5,8]. The coloured curves were obtained using a high-resolution Chebyshev Kernel Polynomial Method. The black lines were gotten from an analytical theory based on phase-shift calculations done in the regime of highly diluted impurities.