Department of Physics
Condensed Matter Physics
Clarendon Laboratory, Parks Road, Oxford OX1 3PU

UNIVERSITY OF OXFORD

CONDENSED MATTER SEMINAR

Thursday 26th of January at 2.15pm

"From 3D Dirac to Weyl fermions"

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3D Dirac semimetals are promising materials for both (i) applications, due to their unusual magnetotransport properties, and (ii) the discovery of new phenomena. The main focus of our research is the exploration of new related phases through control of the band structure. Examples are the stabilisation of topological crystalline insulator states through the introduction of gaps and Weyl fermion excitations through time reversal symmetry breaking. We employ a range of techniques to study these phases including transport, magneto-torque, neutron scattering and scanning tunnelling microscopy.

In the first part of the talk I will focus on our recent results on a family of 3D Dirac electron materials – the inverse perovskites A_3BO (A=Ca, Sr, Eu / B=Pb, Sn). We exploit quantum oscillations to extract band structure properties, establishing the existence of Dirac electron excitations in the Ca and Sr members of the family, some of which are topological crystalline insulators. Intriguingly this class of materials opens up the possibility of introducing bulk magnetism in the Eu compounds, creating a complex low temperature magnetic phase diagram. I will discuss the implications for the stabilisation of Weyl fermions via time reversal symmetry breaking and the possibility to tune topological phases via laboratory-strength magnetic fields.

The wish to directly image the related topological surface states in magnetic fields via spectroscopic imaging scanning tunnelling microscopy (SI-STM) has lead us to the investigation of related 'Dirac line node' materials. ZrSiS is one of the first example materials explored in detail, hosting a 'nodal line' and an unusual surface state. We used SI-STM to study the bulk and surface state properties, being able to access both real and momentum space information. This allows us to confirm the existence of a nodal line in the material with quasiparticle lifetimes characteristic of Dirac electron excitations. We furthermore visualise the unusual surface state whose existence is enforced by the breaking of a non-symmorphic crystal symmetry. Beyond the immediate implications for ZrSiS in itself, a key value of the result is the characterisation of the experimental signatures of a non-magnetic 'Dirac line node' material as a benchmark for our ongoing research on a magnetic variant, on which I will comment at the end of my talk.

Host: Prof Yulin Chen
Audrey Wood Seminar Room, Clarendon Laboratory