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Realization of non-symmorphic Dirac cones in PbFCl materials

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While most 3D Dirac semimetals require two bands with different orbital character to be protected, there is also the possibility to find 3D Dirac semimetals that are guaranteed to exist in certain space groups. Those are resulting from the non-symmoprhic symmetry of the space group, which forces the bands to degenerate at high symmetry points in the Brillouin zone. Non-symmorphic space groups can force three- four, six and eight fold degeneracies which led to the proposal to find 3D Dirac Semimetals as well as new quasiparticles in such space groups [1,2]. Problematic for realizing this types of Dirac materials is that they require and odd band filling in order to have the Fermi level located at or also near by the band crossing points. Therefore, although the first prediction for using non-symmoprhic symmetry to create a Dirac material was made in 2012 [1], it took almost four years for an experimental verification of this type of Dirac crossing [3]. In this talk I will introduce the material ZrSiS that has, besides other Dirac features, a Dirac cone protected by non-symmorphic symmetry at about 0.5 eV below the Fermi level and was the first material where this type of Dirac cone was imaged with ARPES [3]. I will then proceed to discuss ways to shift this crossing to the Fermi edge and finally show an experimental verification of a fourfold Dirac crossing, protected by non-symmorphic symmetry, at the Fermi energy. [1] Young, S.M., Zaheer, S., Teo, J.C., Kane, C.L., Mele, E.J. and Rappe, A.M., 2012. Phys. Rev. Lett., 108(14), p.140405. [2] Bradlyn, B., Cano, J., Wang, Z., Vergniory, M.G., Felser, C., Cava, R.J. and Bernevig, B.A., 2016. Science, p.aaf5037 [3] Schoop, L.M., Ali, M.N., Straßer, C., Topp, A., Varykhalov, A., Marchenko, D., Duppel, V., Parkin, S.S., Lotsch, B.V. and Ast, C.R., 2016. Nat. comm., 7.