PAUL SCHERRER INSTITUT

PSD Mini Symposium

Novel Materials

Tuesday, October 8, 2019

10:00 to 11:15, WBGB 019

10:00: Highlight – 30min
Spin fluctuation induced Weyl semimetal state in the paramagnetic phase of EuCd2As2 proved by ARPES
Junzhang Ma, *S. M. Nie, J. Jandke, T. Shang, M. Y. Yao, M. Naamneh, M. Medarde, J. Mesot, C. Mudry, M. Muller, Y. G. Shi, T. Qian, H. Ding, and M. Shi*

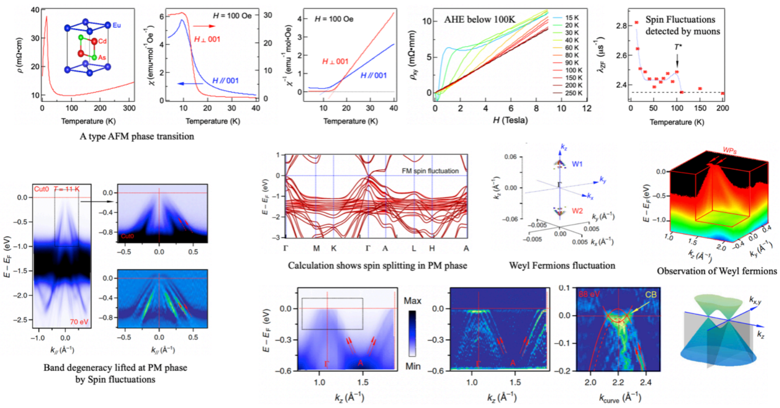

Fig.1 FM Spin fluctuation induced band splitting and the discovery of magnetic Weyl semimetal states.

10:30 Coffee break

10:50: Talk – 20min
Single spin-polarised Fermi surface in SrTiO3 thin films
Eduardo B. Guedes, *S. Muff, M. Fanciulli, A. P. Weber, M. Caputo, Z. Wang, N. C. Plumb, M. Radovic, J. Hugo Dil*

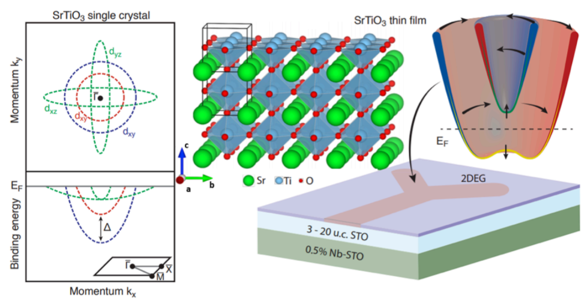

Figure 1. The spin-polarised 2DEG on SrTiO₃ crystals and thin films.

Spin fluctuation induced Weyl semimetal state in the paramagnetic phase of $EuCd_2As_2$ proved by ARPES

J.-Z. Ma[1], S. M. Nie[2], J. Jandke[1], T. Shang[1], M. Y. Yao[1], M. Naamneh[1], M. Medarde[3], J. Mesot[1], C. Mudry[4], M. Muller[4], Y. G. Shi[5], T. Qian[5], H. Ding[5], and M. Shi[1]

[1] Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[2] Department of Materials Science and Engineering, Stanford University, Stanford, CA 94305, USA
[3] Laboratory for Multiscale Materials Experiments, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland
[4] Condensed Matter Theory Group, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[5] Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

In this talk I will give an introduction to Angel Resolved Photoemission Spectroscopy (ARPES) at first. Then I will focus on one project we have finished recently that we firstly observed the long-awaited magnetic Weyl Semimetal state in the paramagnetic phase of $EuCd_2As_2$ family. Weyl fermions as emergent quasiparticles can arise in Weyl semimetals (WSMs) in which the energy bands are nondegenerate, resulting from inversion or time-reversal symmetry breaking. Nevertheless, experimental evidence for magnetically induced WSMs is scarce. Here, using photoemission spectroscopy, we observe that the degeneracy of Bloch bands is already lifted in the paramagnetic phase of $EuCd_2As_2$. We attribute this effect to the itinerant electrons experiencing quasi-static and quasi long-range ferromagnetic fluctuations. Moreover, the spin-nondegenerate band structure harbors a pair of ideal Weyl nodes near the Fermi level [1]. Hence, we show that long-range magnetic order and the spontaneous breaking of time-reversal symmetry are not essential requirements for WSM states in centrosymmetric systems and that WSM states can emerge in a wider range of condensed matter systems than previously thought.

[1] J. -Z. Ma, et al. *Science Advances* **5**, eaaw4718 (2019).

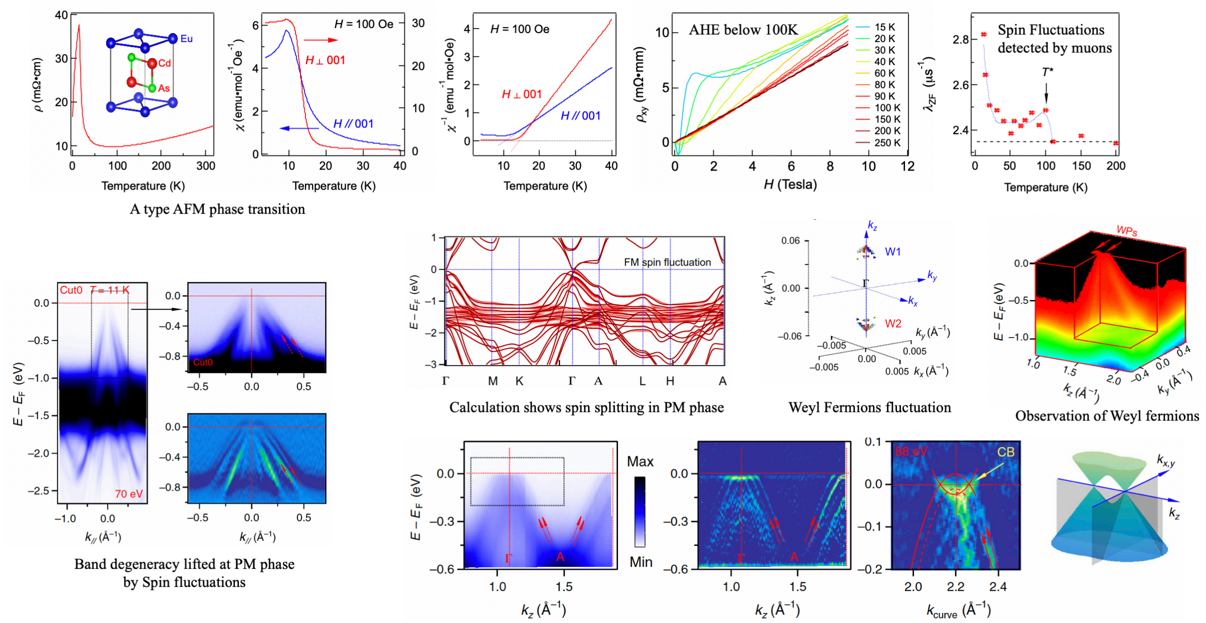

Fig.1 FM Spin fluctuation induced band splitting and the discovery of magnetic Weyl semimetal states.

Single spin-polarised Fermi surface in $SrTiO_3$ thin films

Eduardo B. Guedes[1,2], Stefan Muff[1,2], Mauro Fanciulli[1,2], Andrew P. Weber[1,2], Marco Caputo[1,2], Zhiming Wang[3], Nicholas C. Plumb[2], Milan Radovic[2], J. Hugo Dil[1,2]

[1] Ecole Polytechnique Federale de Lausanne, 1015 Lausanne, Switzerland
[2] Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
[3] Ningbo Institute of Materials Technology and Engineering, Ningbo 315201, Peoples Republic of China

The 2-dimensional electron gas (2DEG) formed at the surface and interfaces of $SrTiO_3$ [1,2,3] has attracted great interest because of its fascinating physical properties and promise as a novel electronic platform [4,5], but up to now has eluded a stable way to tune its properties. Using angle-resolved photoemission spectroscopy with and without spin resolution we here show that the band filling can be modified by growing thin $SrTiO_3$ films on $SrTiO_3$(001) substrates with different Nb doping levels. This results in a single spin-polarised 2D Fermi surface in a superconducting system [6], which can be used as platform for Majorana physics. Based on our results it can furthermore be concluded that the 2DEG does not extend more than 3 unit cells into the film and that its properties are strongly affected by the dielectric response of the system.

[1] N. Plumb et al., Phys. Rev. Lett. 113 (2014).
[2] C. Cancellieri et al., Nature Communications 7, (2016).
[3] A. F. Santander-Syro, Nature 469 (2011).
[4] N. Reyren et al., Science 317 (2007).
[5] J. A. Bert et al., Nature Physics 7(2011).
[6] J. F. Schooley, Phys. Rev. Lett. 12 (1964).

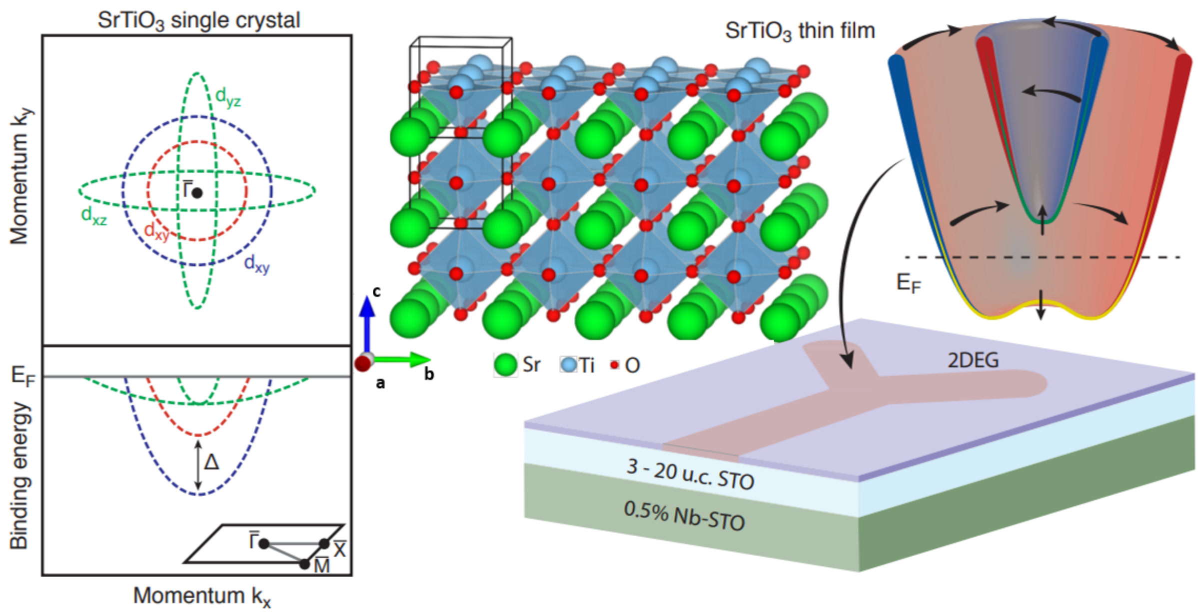

Figure 1. The spin-polarised 2DEG on $SrTiO_3$ crystals and thin films. (a) Schematics of the electronic structure of the 2DEG on STO crystals, consisting of two circular $3d_{xy}$-derived states (red and blue) and ellipsoidal $3d_{xz}$- and $3d_{yz}$-derived states (green). The inset shows the surface cubic Brillouin Zone. (b) llustration showing the crystal structure of STO and the STO film grown on 0.5 wt% Nb-doped STO substrate, along with the band structure of the hosted 2DEG. In this case, the Fermi level lies in the Zeeman gap at the SBZ centre, thus resulting in a single spin-polarised 2D Fermi surface. This band structure, along with the superconducting properties of STO, makes this material a 2D Majorana platform.