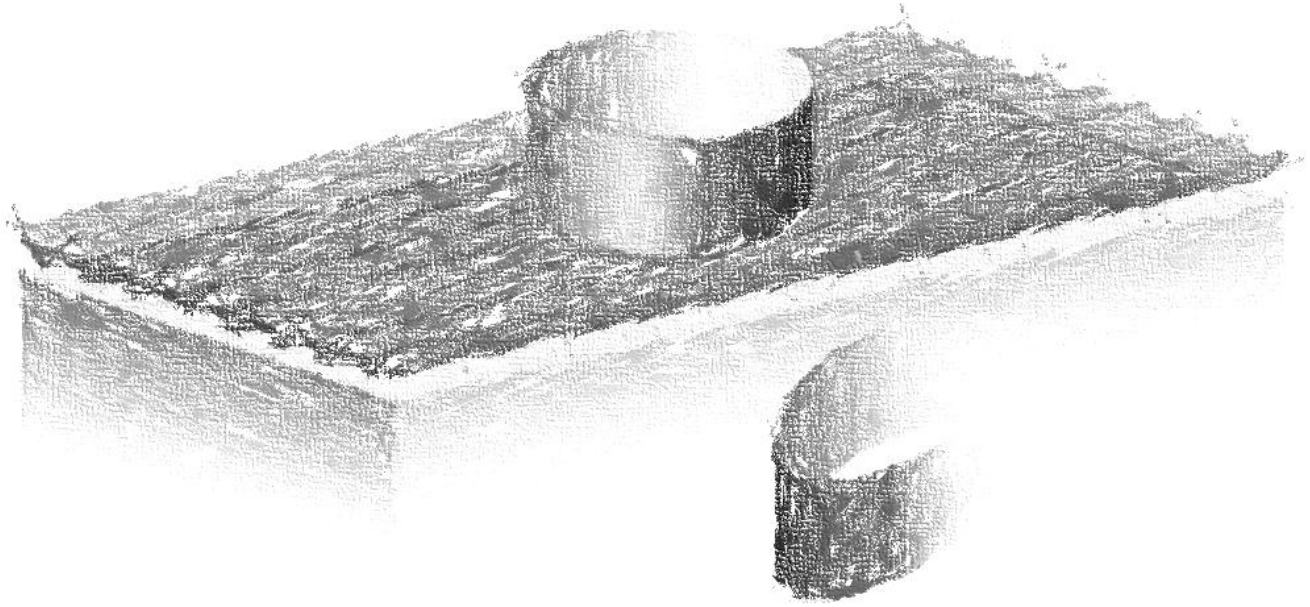
Topological insulators

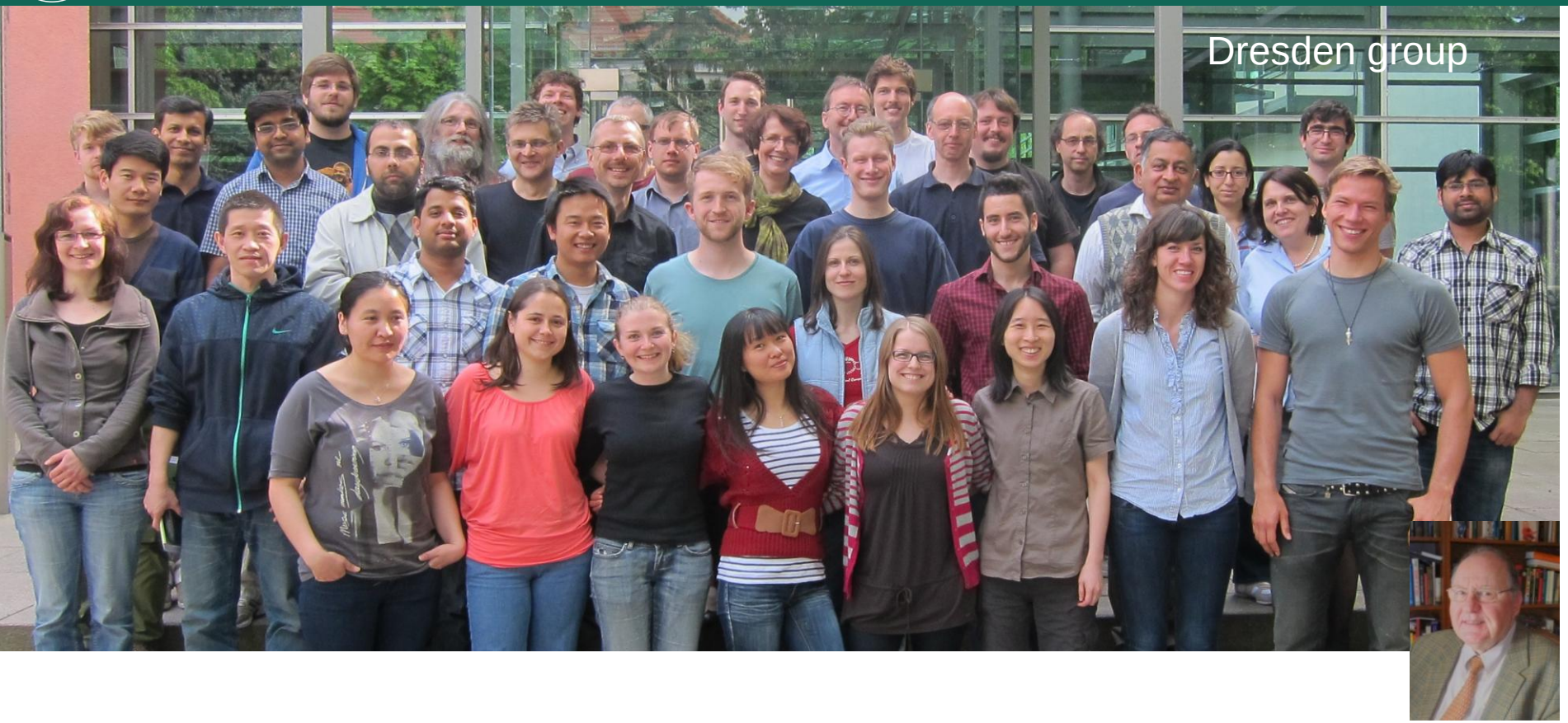


Claudia FELSER, Binghai YAN,

Shekkar Chandra, Stas Chadov, Lukas Müchler, Martin Jansen, Jürgen Kübler, Shou-Chen Zhang, Xiaoliang Qi, Yulin Chen

www.superconductivity.de

Co-workers in Dresden and elsewhere



Shou-Cheng Zhang et al., Stanford

Yulin Chen et al. Oxford

Stuart Parkin et al. IBM Almaden

Paul Canfield, Ames Lab.

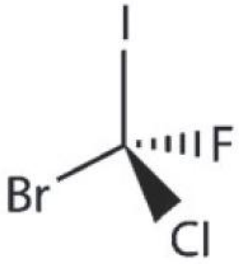
SPP 1666

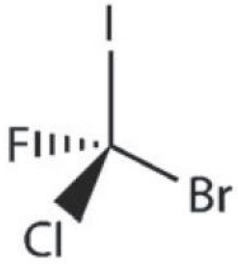
Deutsche Forschungsgemeinschaft DFG

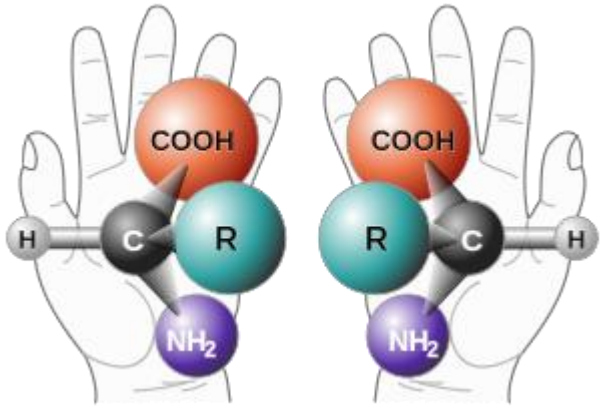
erc

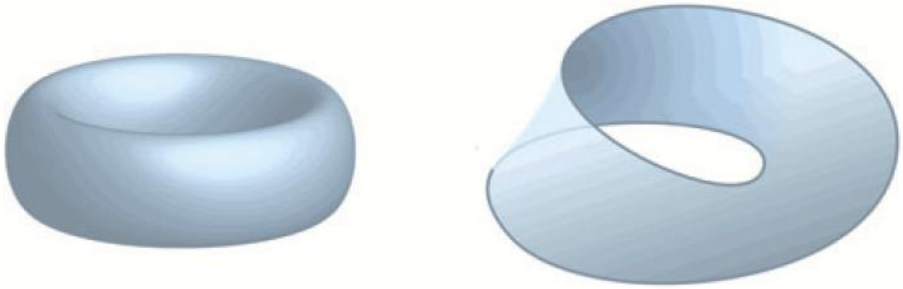
Topology in chemistry

Molecules with different chiralities can have different physical and chemical properties



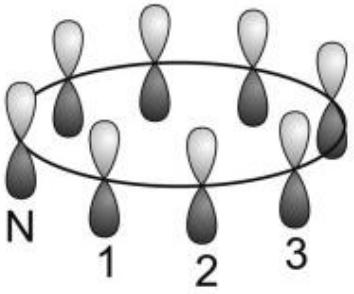






Topologically interesting compounds are 4n aromatics with Möbius geometry, whereas normal 4n compounds are anti-aromatic

Hückel and Möbius aromaticity



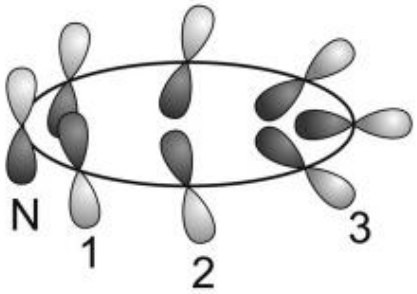
secular equation

$$\begin{vmatrix} \alpha-E & \beta & \cdots & \beta \\ \beta & \alpha-E & \beta & \\ & & & \beta \\ \beta & \cdots & \beta & \alpha-E \end{vmatrix}$$

$$E_j = \alpha + 2\beta \cos \frac{2\pi j}{N}$$

N: number p-orbitals
E_j: π MO energies
j = 0,1,2,3 ··· (N-1)
α : Coulomb integral
β : Resonance integral

Möbius Annulenes



secular equation

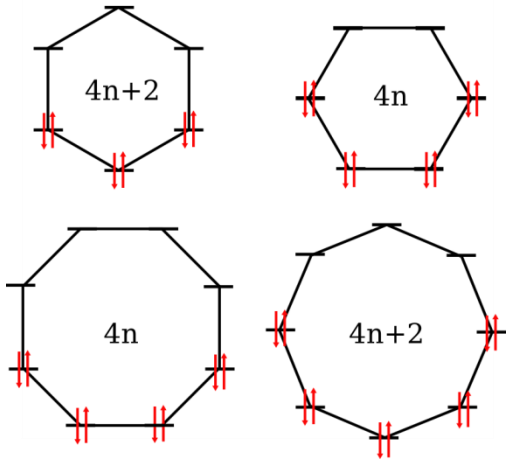
$$\begin{vmatrix} \alpha-E & \beta & \cdots & -\beta \\ \beta & \alpha-E & \beta & \\ & & & \beta \\ -\beta & \cdots & \beta & \alpha-E \end{vmatrix}$$

$$E_j = \alpha + 2\beta \cos \frac{\pi(2j+1)}{N}$$

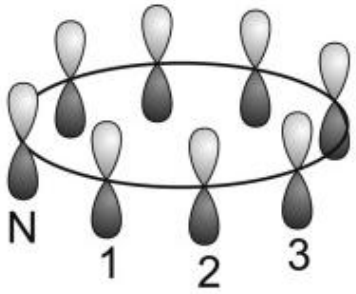
Magic electron numbers

Hückel:
4n+2 aromatic
4n antiaromatic

Möbius
4n aromatic
4n+2 antiaromatic



Hückel and Möbius aromaticity



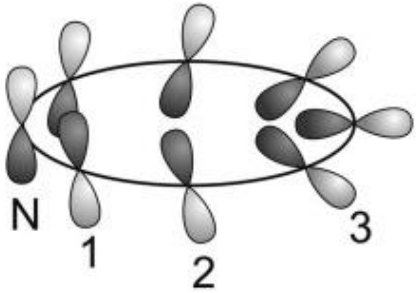
ORGANIC CHEMISTRY

Aromatics with a twist

Rainer Herges

The properties of flat aromatic molecules are well known to chemists, but some non-planar aromatics remain a mystery. A molecule that can twist into a Möbius band on command might shed light on their features.

Möbius Annulenes



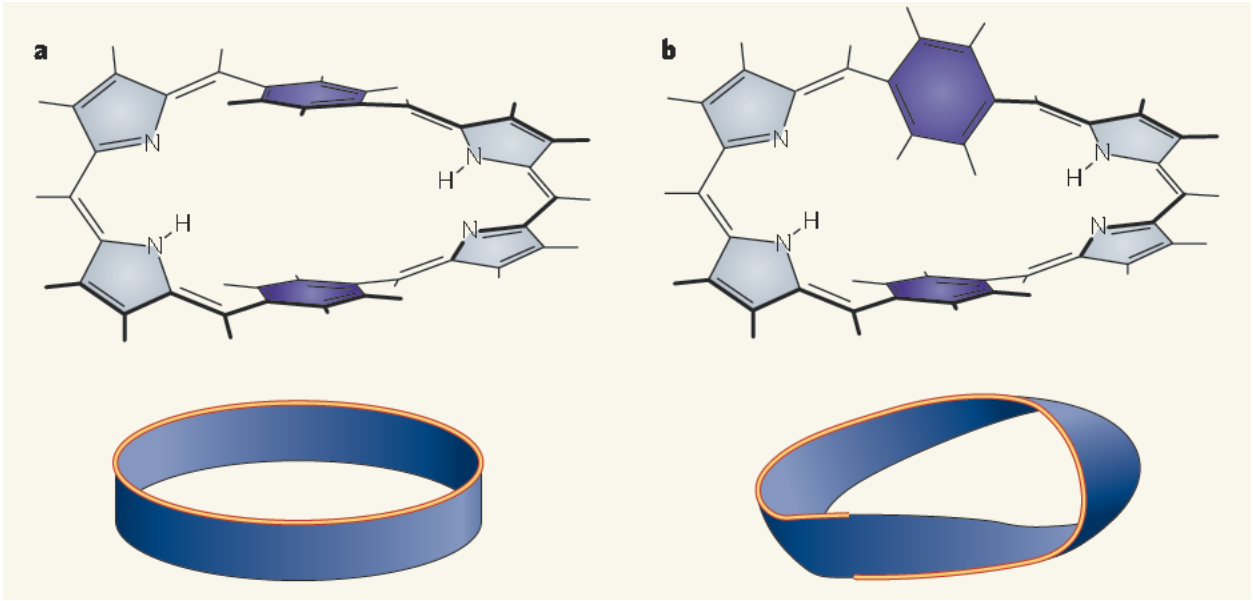
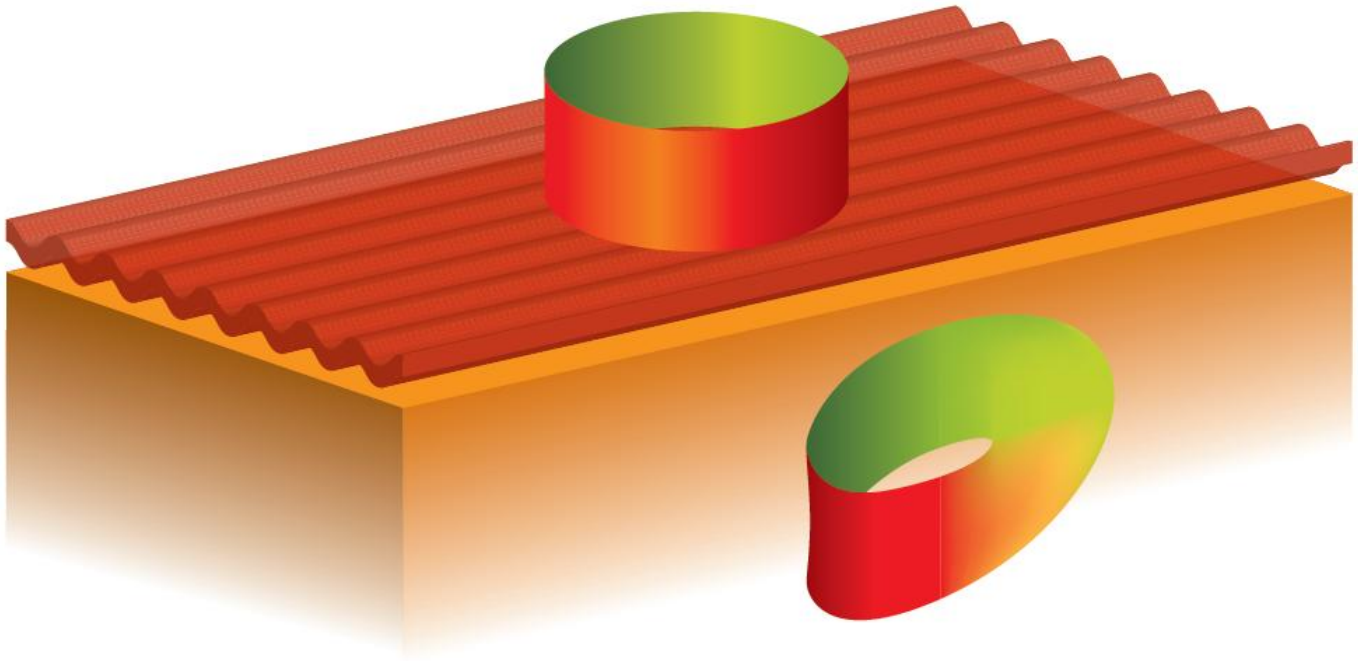
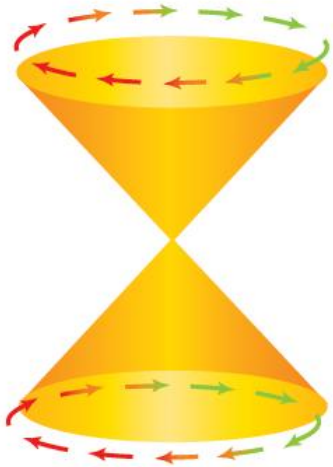


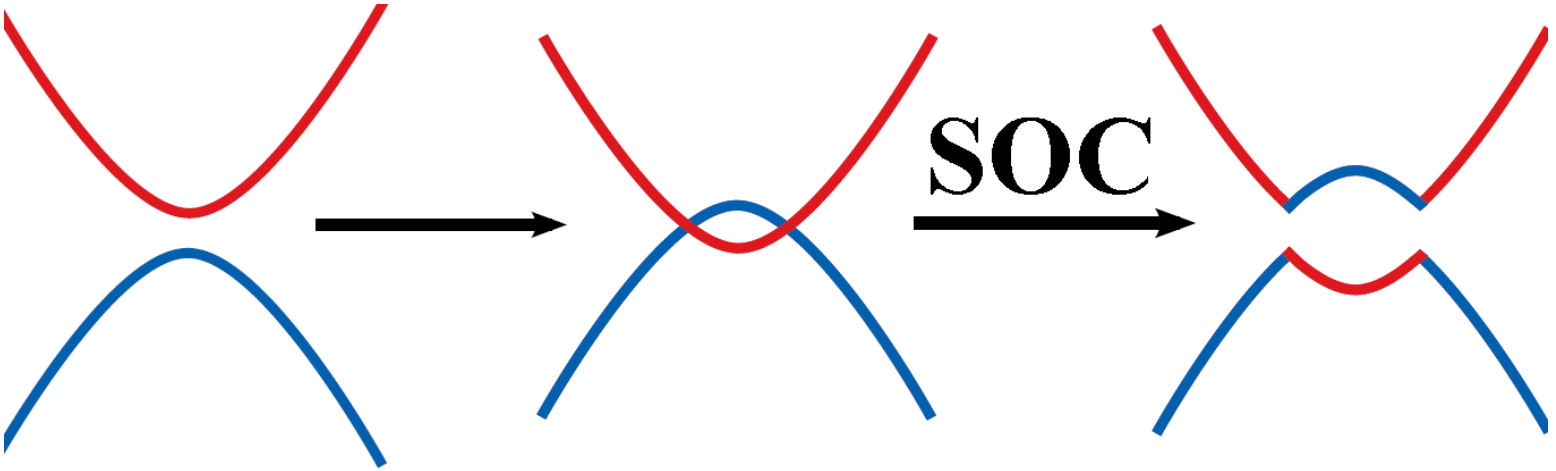
Figure 2 | A molecular topological switch. Latos-Grażyński and colleagues[1] have made a compound that is antiaromatic in nonpolar solvents, but not in polar solvents. **a**, In nonpolar solvents, the two benzene rings (purple) in the molecule are parallel, and the molecule is a two-sided, non-twisted band. **b**, In polar solvents, the upper benzene ring twists by 90°, so that the molecule becomes a one-sided, Möbius structure. This conformational change alters the aromaticity of the molecule.

Topological Insulator





Topological Insulator

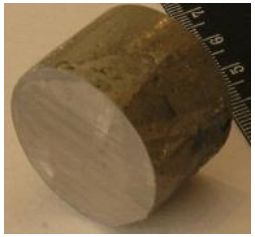


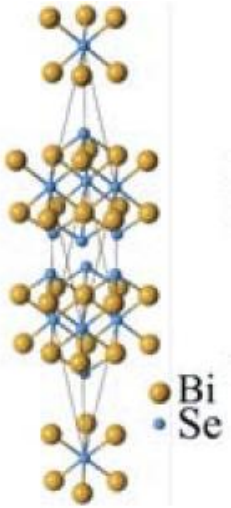
Topological insulators

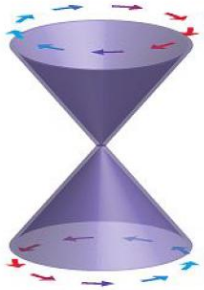
3D Topological Insulators

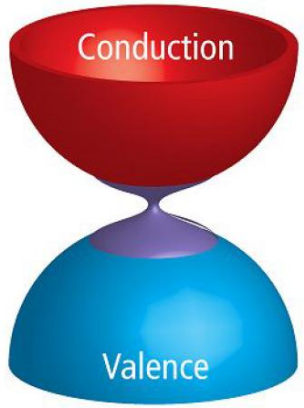
Bi-Sb alloys

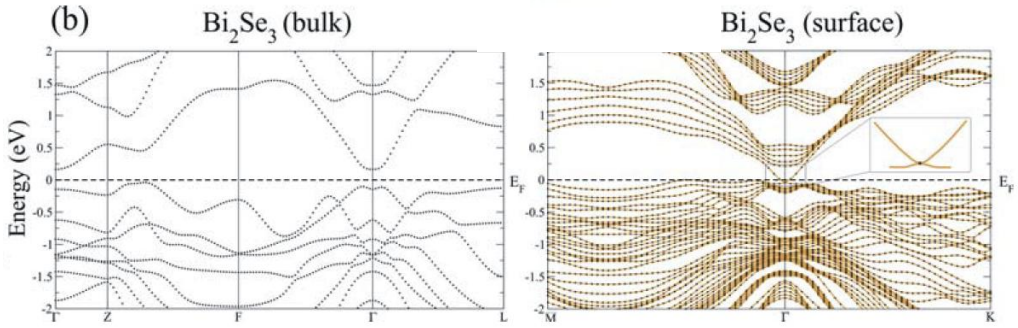
Bi_2Se_3 and relatives

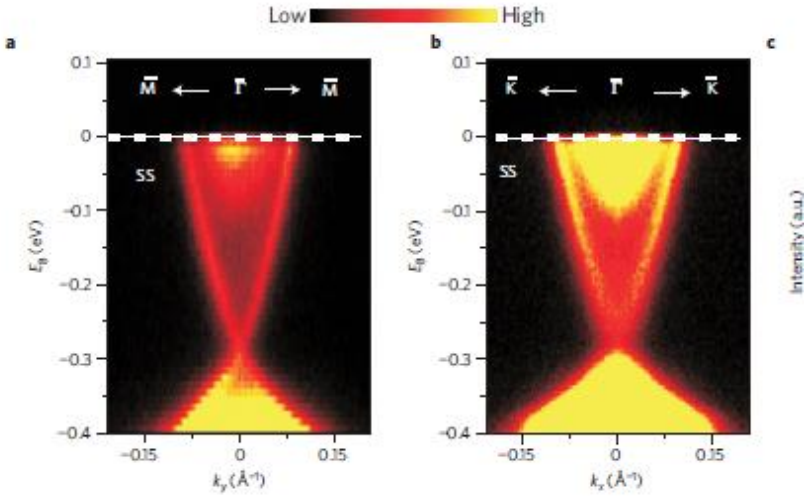










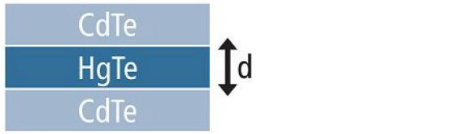


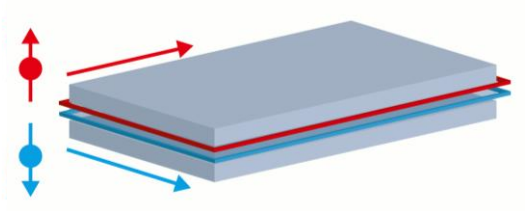
Moore and Balents, PRB 75, 121306(R) (2007)
Fu and Kane, PRB 76, 045302 (2007)
Murakami, New J. Phys. 9, 356 (2007)
Hsieh, et al., Science 323, 919 (2009)
Xia, et al., Nature Phys. 5, 398 (2009); Zhang, et al., Nature Phys. 5, 438 (2009)

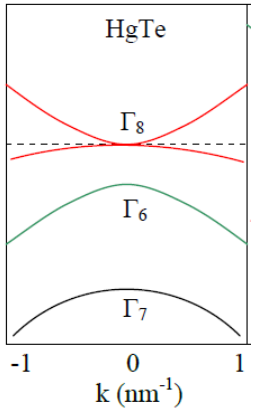
Topological insulators

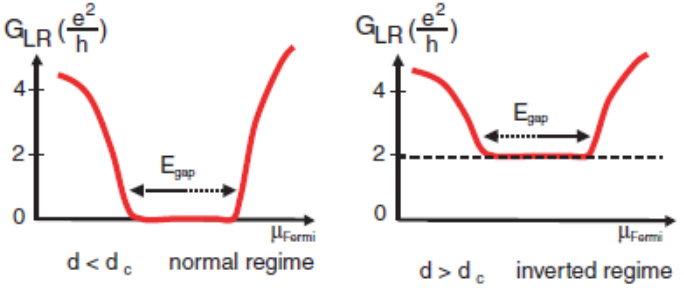
2D TI … prediction and realization

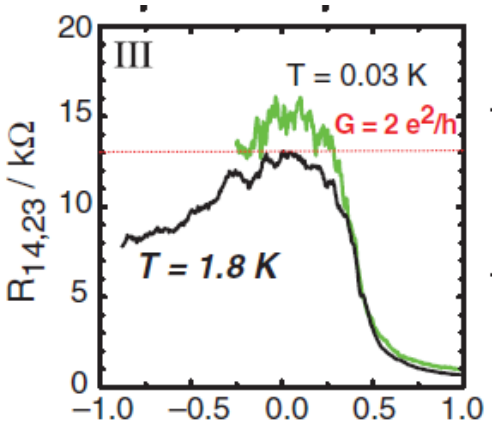
- HgTe and relatives
- Quantum well structure

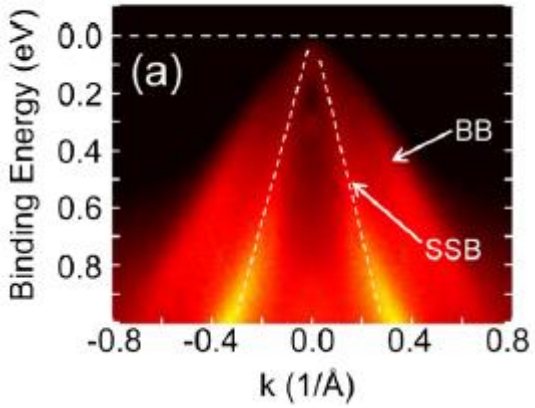


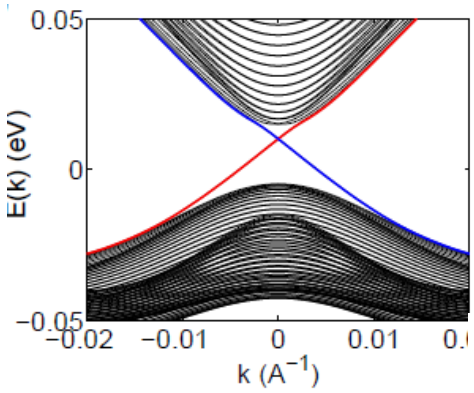








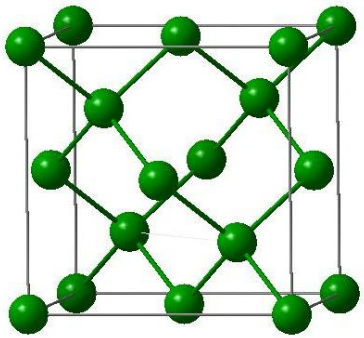


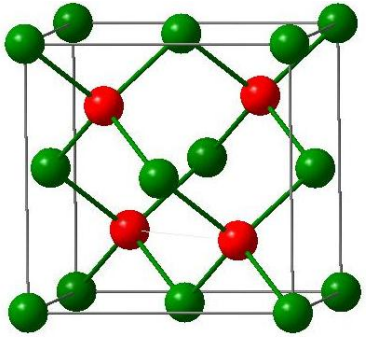


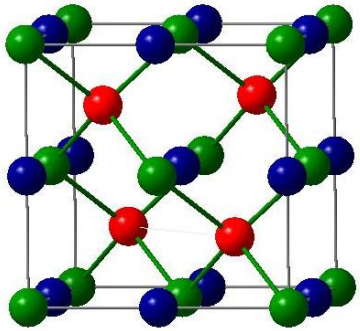
Kane and Mele, PRL 95, 146802 (2005)
Bernevig,et al., Science 314, 1757 (2006)
Bernevig, S.C. Zhang, PRL 96, 106802 (2006)
König, et al. Science 318, 766 (2007)

Heusler compounds

Diamond **ZnS** **Heusler XYZ $C1_b$**







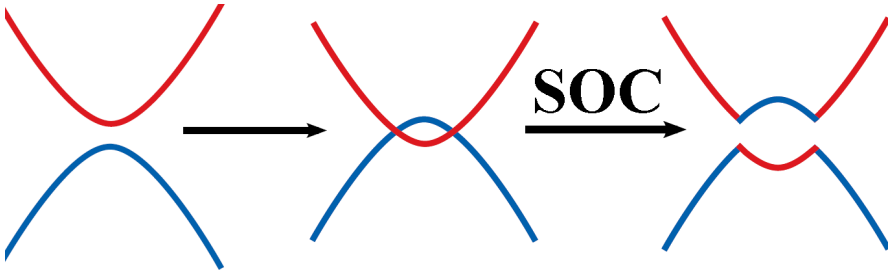
C 2.55	N 3.04
Si 1.90	P 2.19
Ge 2.01	As 2.18
Sn 1.96	Sb 2.05

H 2.20																	He
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne
Na 0.93	Mg 1.31											Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16	Ar
K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.60	Mo 2.16	Tc 1.90	Ru 2.20	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.10	I 2.66	Xe 2.60
Cs 0.79	Ba 0.89	Hf 1.30	Ta 1.50	W 1.70	Re 1.90	Os 2.20	Ir 2.20	Pt 2.20	Au 2.40	Hg 1.90	Tl 1.80	Pb 1.80	Bi 1.90	Po 2.00	At 2.20	Rn	
Fr 0.70	Ra 0.90																
		La 1.10	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.20	Gd 1.20	Tb 1.10	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.10	Lu 1.27	
		Ac 1.10	Th 1.30	Pa 1.50	U 1.70	Np 1.30	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.30	Cf 1.30	Es 1.30	Fm 1.30	Md 1.30	No 1.30	Lr 1.30	

Graf, Felser, Parkin, IEEE TRANSACTIONS ON MAGNETICS 47 (2011) 367

Graf, Felser, Parkin, Progress in Solid State Chemistry 39 (2011) 1

spin orbital coupling counts



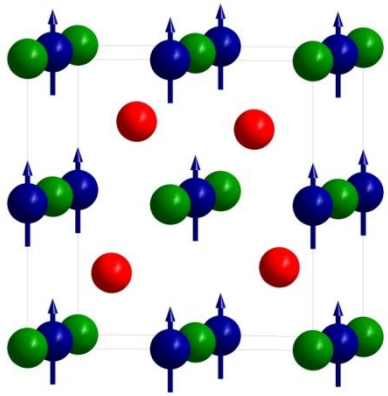
XYZ Heusler compounds

H 2.20																	He
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne
Na 0.93	Mg 1.31											Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16	Ar
K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.60	Mo 2.16	Tc 1.90	Ru 2.20	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.10	I 2.66	Xe 2.60
Cs 0.79	Ba 0.89		Hf 1.30	Ta 1.50	W 1.70	Re 1.90	Os 2.20	Ir 2.20	Pt 2.20	Au 2.40	Hg 1.90	Tl 1.80	Pb 1.80	Bi 1.90	Po 2.00	At 2.20	Rn
Fr 0.70	Ra 0.90																
		La 1.10	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.20	Gd 1.20	Tb 1.10	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.10	Lu 1.27	
		Ac 1.10	Th 1.30	Pa 1.50	U 1.70	Np 1.30	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.30	Cf 1.30	Es 1.30	Fm 1.30	Md 1.30	No 1.30	Lr 1.30	

$\lambda_{SOC} \sim Z^2$ for valence shells

Counting Electrons

From wide to low band gap semiconductor



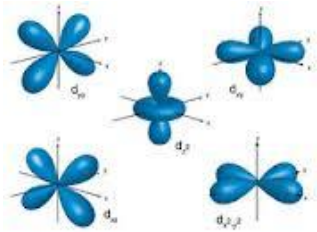
Ga As

3 + 5 = 8

2 s
6 p

Li Mg As

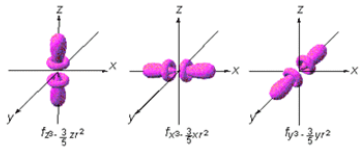
1 + 2 + 5 = 8



Zr Ni Sn

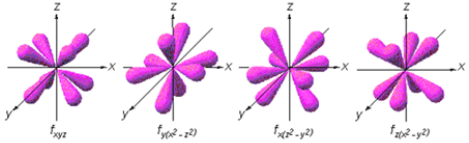
10 d

4 + 10 + 4 = 18



RE Pt Bi

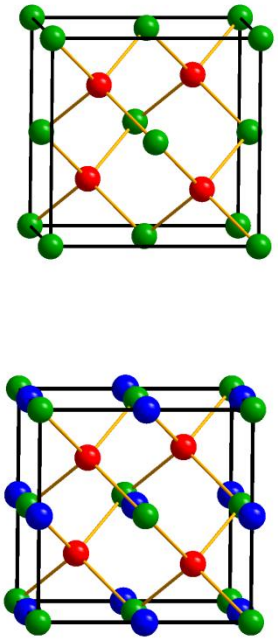
14 f

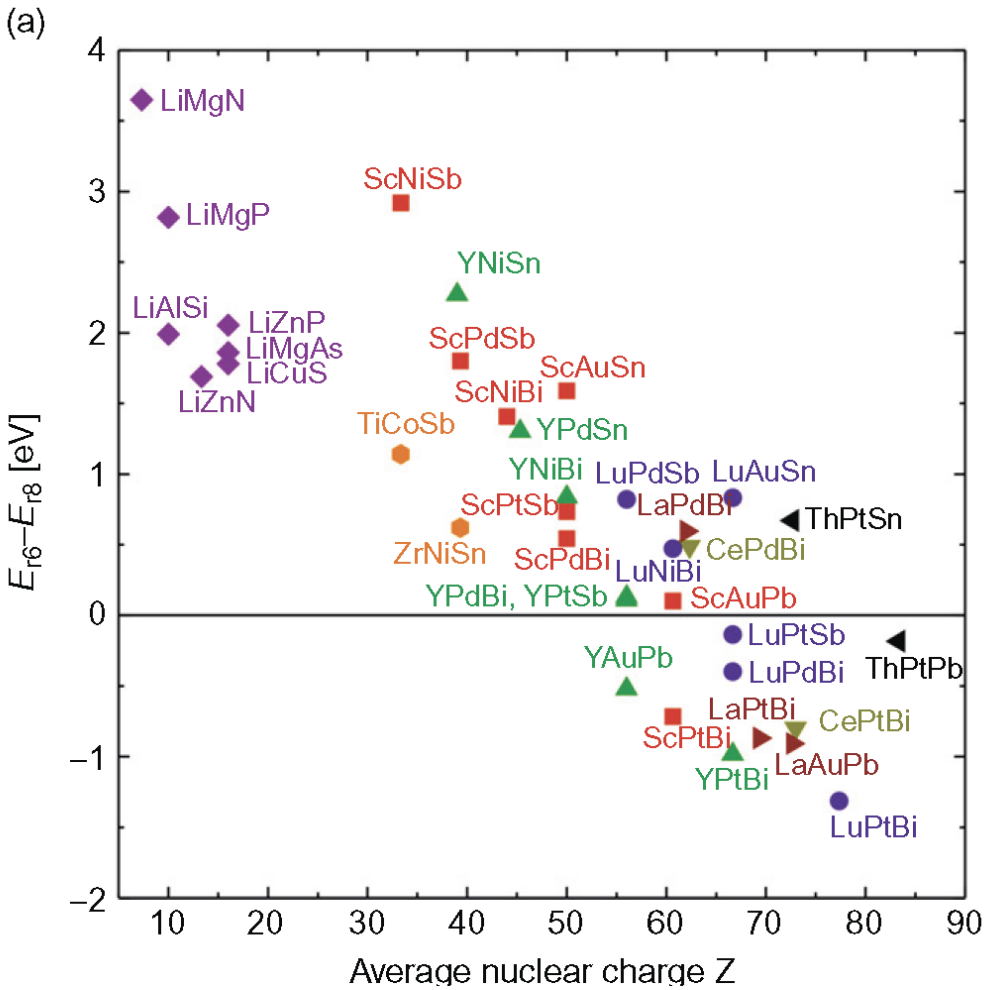


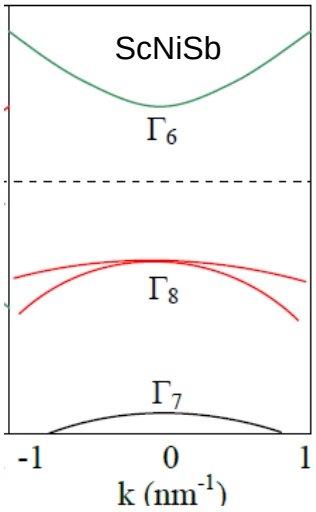
3 (+f^n) + 10 + 5 = 18 + n

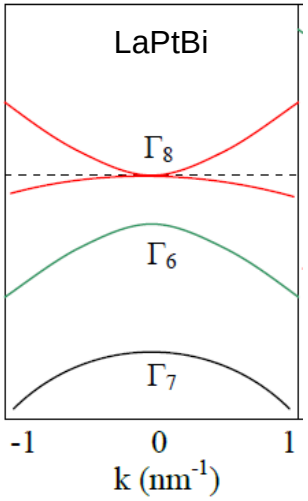
Graf, Felser, Parkin, Progress in Solid State Chemistry 39 (2011) 1
Kandpal et al., J. Phys. D **39** (2006) 776

Predicting new Compounds









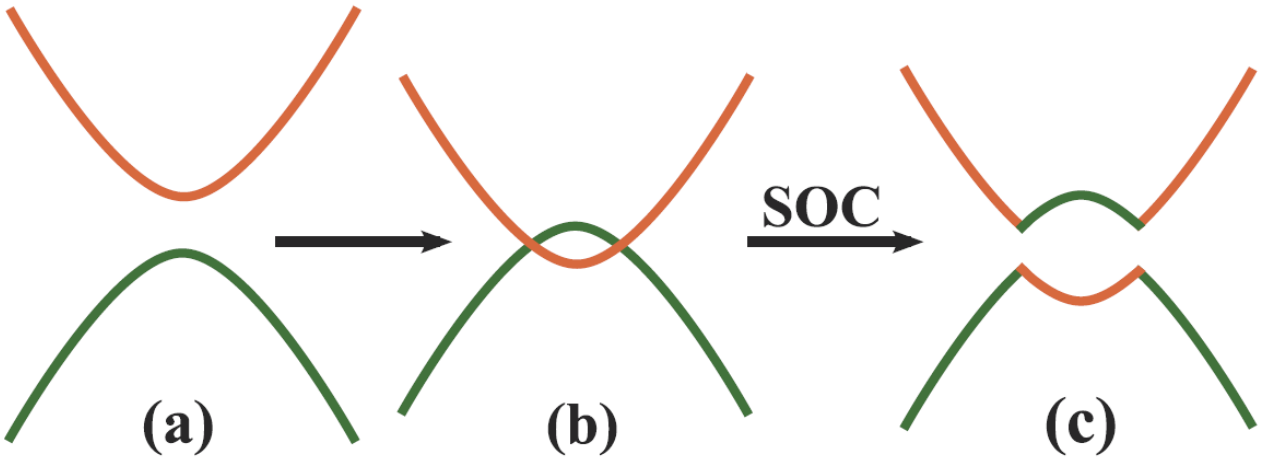
Graf, Felser, Parkin, Progress in Solid State Chemistry (2011)
Chadov, Qi, Kübler, Zhang, Felser Nature Mat. 9 (2010) 541, arXiv:1003.0193

Trivial and topological insulators

Trivial semiconductor
CdS

Topological Insulator
Without spin orbit coupling

Topological Insulator
Withspin orbit coupling

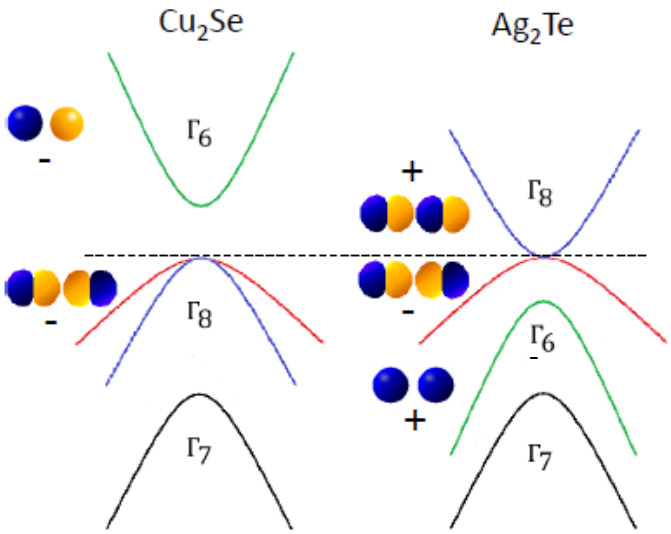


Sufficient condition:

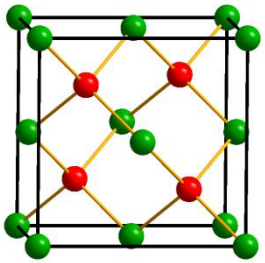
Parity change

Centro symmetric ➡ Eigenvalues

Noncentro sym. ➡ Z2 classification

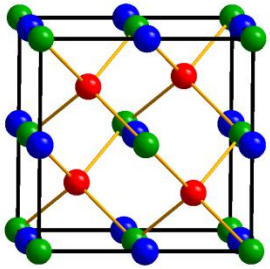


Structure to Property



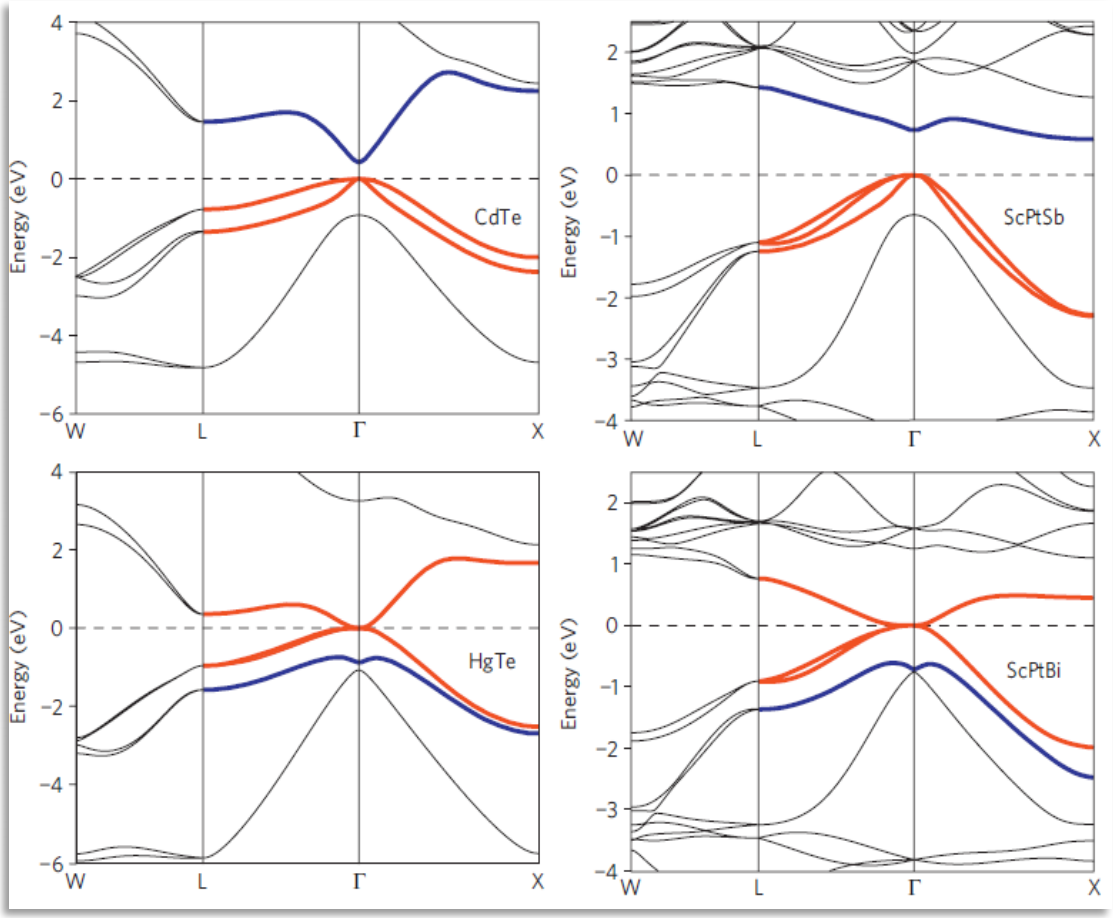
CdTe

HgTe



ScPtSb

ScPtBi



Chadov, Qi, Kübler, Zhang, Felser Nature Mat. 9 (2010) 541, arXiv:1003.0193

Multifunctional topologic insulators

Magnetism and heavy fermion-like behavior in the RBiPt series

P. C. Canfield, J. D. Thompson, W. P. Beyermann, A. Lacerda, M. F. Hundley, E. Peterson, and Z. Fisk
Los Alamos National Laboratory, Los Alamos, New Mexico 87545

H. R. Ott
ETH, Zurich, Switzerland

J. Appl. Phys. **70** (10), 15 November 1991

Multifunctional properties

- RE: Gd Magnetism and TI
  - Antiferromagnetism with GdPtBi
- RE: Ce
  - complex behaviour of the Fermi surface
- RE: Yb Kondo insulator and TI
  - YbPtBi is a super heavy fermion with the highest γ value

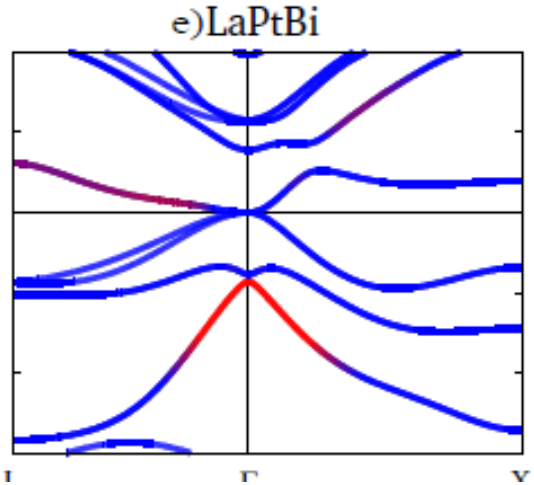
10 + 3 (+f^n) + 5 = 18

Chadov, Qi, Kübler, Zhang, Felser Nature Mat. 9 (2010) 541

Non centro symmetric Superconductor

Multifunctional properties

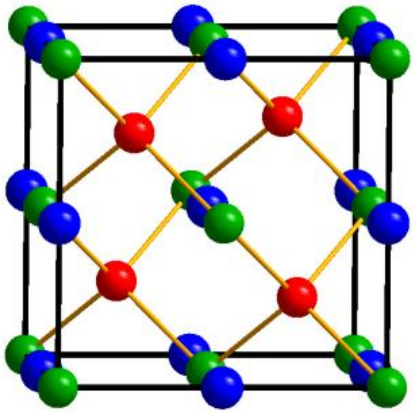
- RE: La Superconductivity and TI
  - LaPtBi is superconductor
  - p-type semiconductors
  - with a band inversion
  - without inversion symmetry and
  - low charge carrier concentration n = $6*10^{18}cm^{-3}$



Pt — RE — Bi

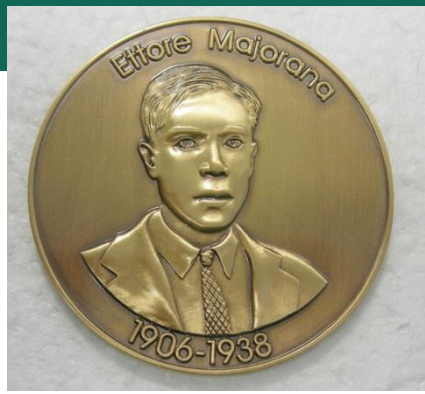
10 + 3 (+f^n) + 5 = 18

Goll *et al.* Physica B 403 1065 (2008)



Chadov, Qi, Kübler, Zhang, Felser Nature Mat. 9 (2010) 541

Hunting Majorana



Wikipedia: A Majorana fermion, also referred to as a Majorana particle, is a **fermion that is its own antiparticle**. They were hypothesised by Ettore Majorana in 1937. The term is sometimes used in opposition to a Dirac fermion, which describes fermions that are not their own antiparticles. No elementary fermions are known to be their own antiparticle, though the nature of the neutrino is not settled and it might be a Majorana fermion.

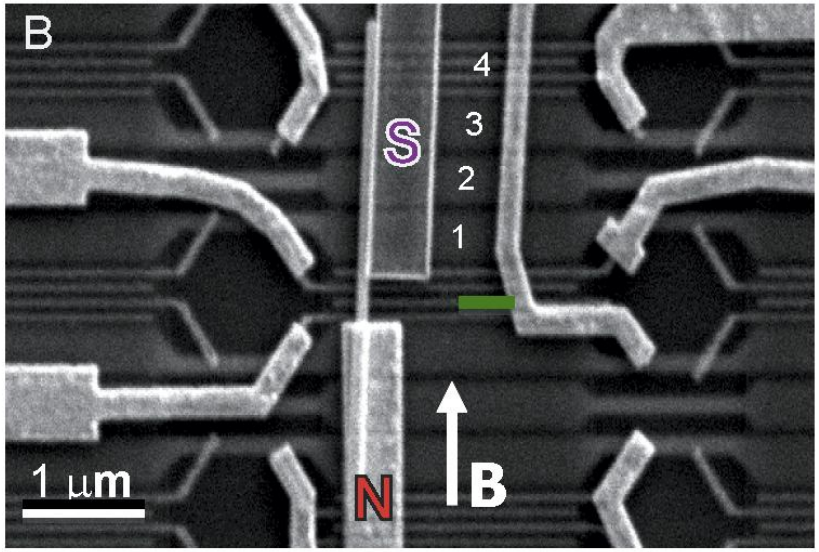
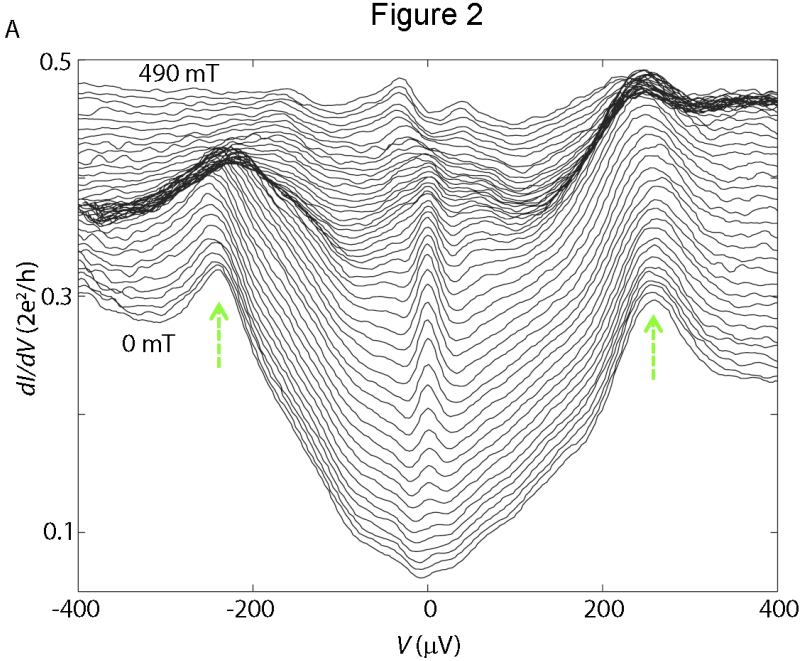
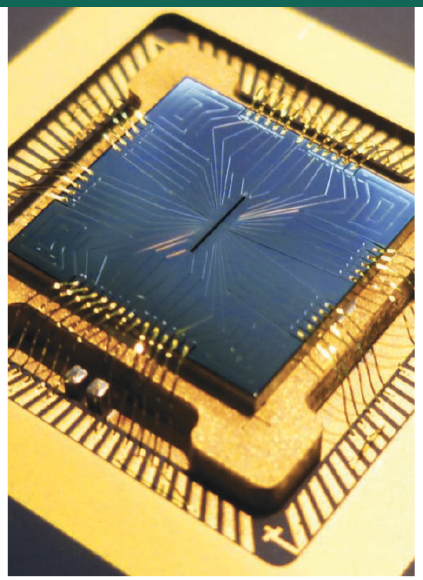


Figure 2



Mourik et al. Science 336 (2012) 1003



SPECIAL SECTION

INTRODUCTION

The Future of Quantum Information Processing

Topological phenomena

topological structure in the physical system, which are thus usually universal and robust against perturbations.

- flux quantization in superconductors
- Hall conductance quantization in the Quantum Hall states
- topological insulators and topological superconductors

Quantum entanglement

essential for quantum information and quantum computation

The understanding of quantum entanglement provides a *new probe to the physical properties of the many-body systems* compared to the conventional response properties such as conductivity, spin susceptibility, etc.

What is the relation between quantum entanglement and topological states of matter?

Xiaoliang Qi

sciencemag.org

A number of qubit types have been proposed and experimentally realized that satisfy at least some of these crite-

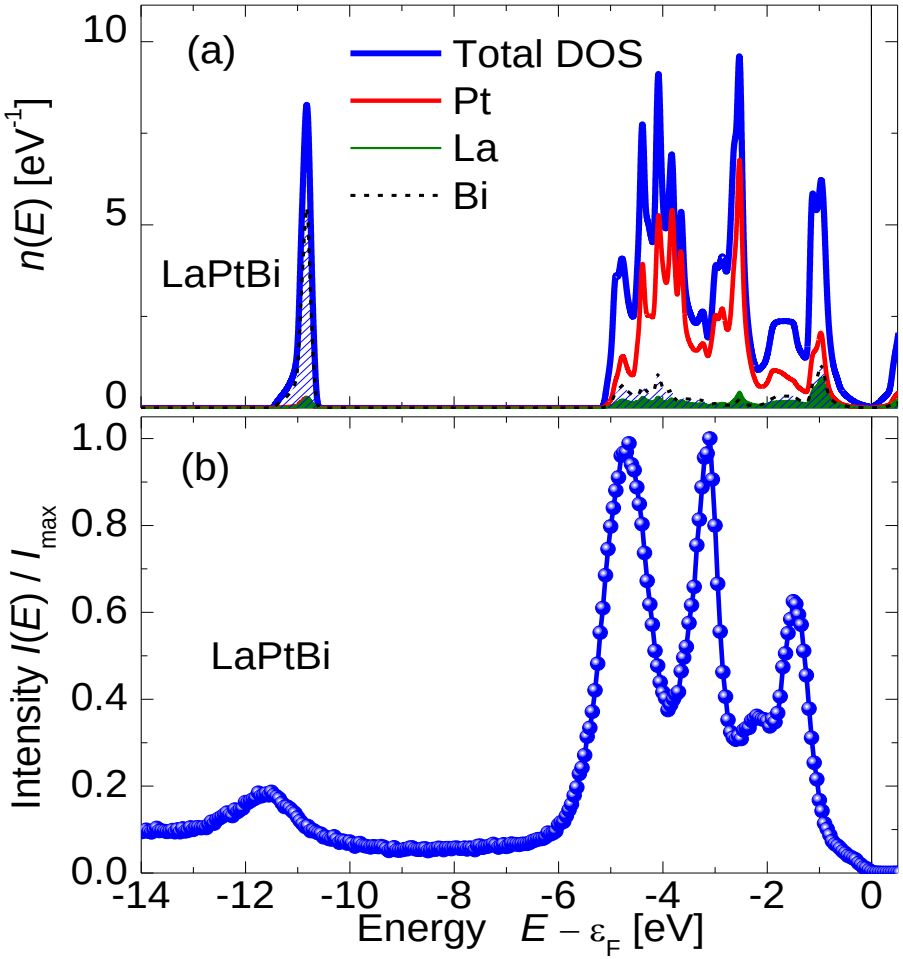
Quantum Information Processing

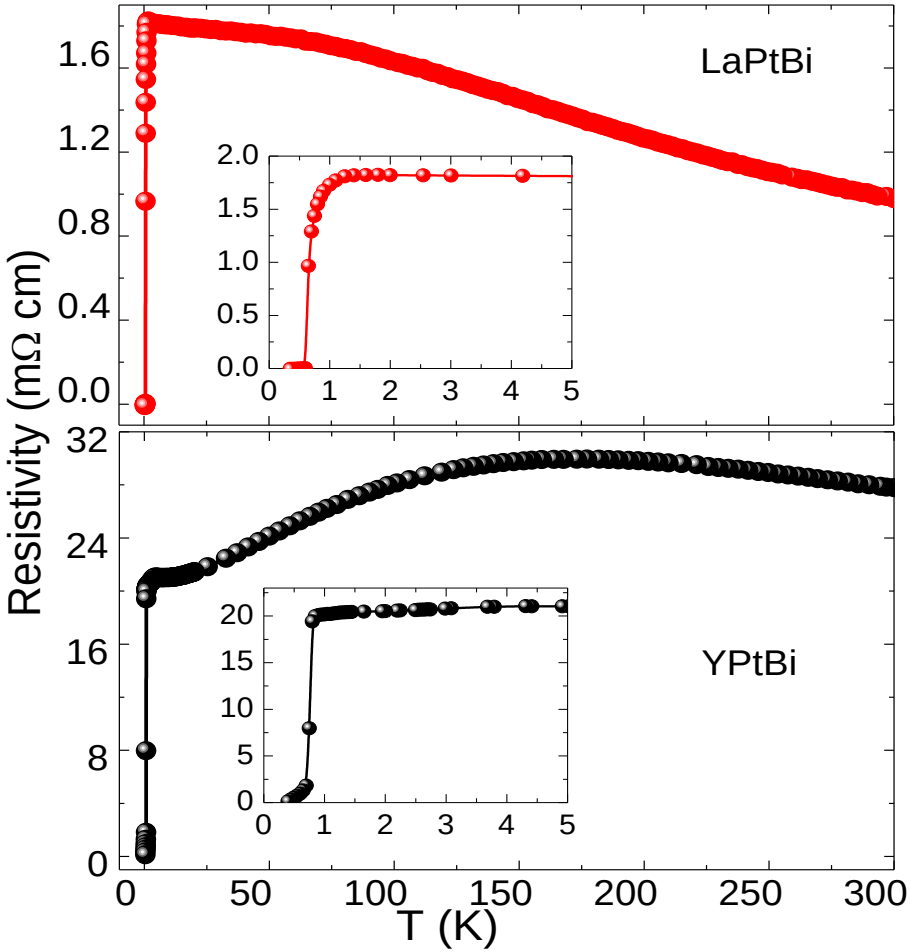
CONTENTS

Reviews

Topolocical Insulator + Superconductor

Hard X-ray Photoemission





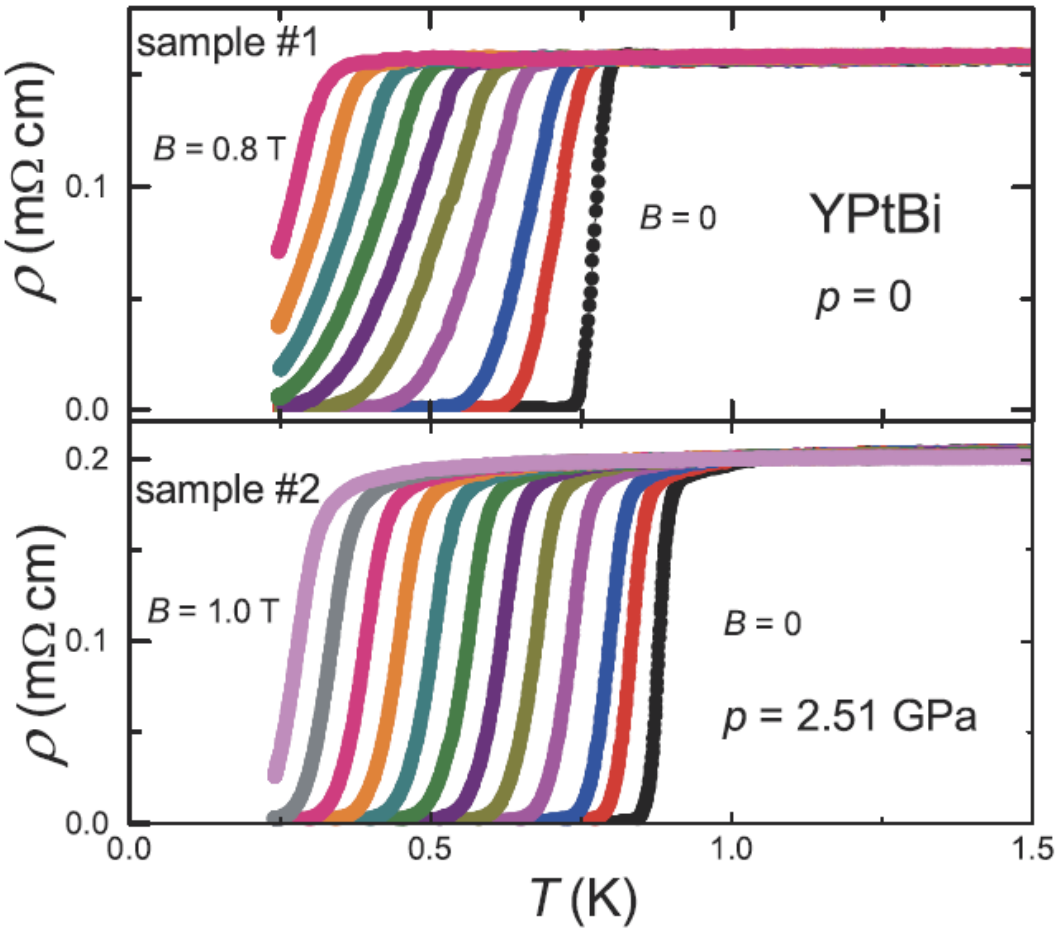
Shekkar et al. J. Appl. Phys. 113 17E142 (2013)

YPtBi

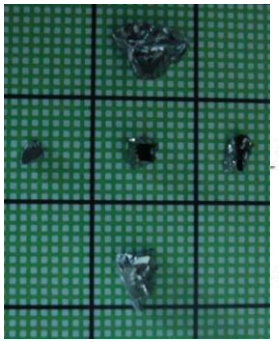
PHYSICAL REVIEW B **86**, 064515 (2012)

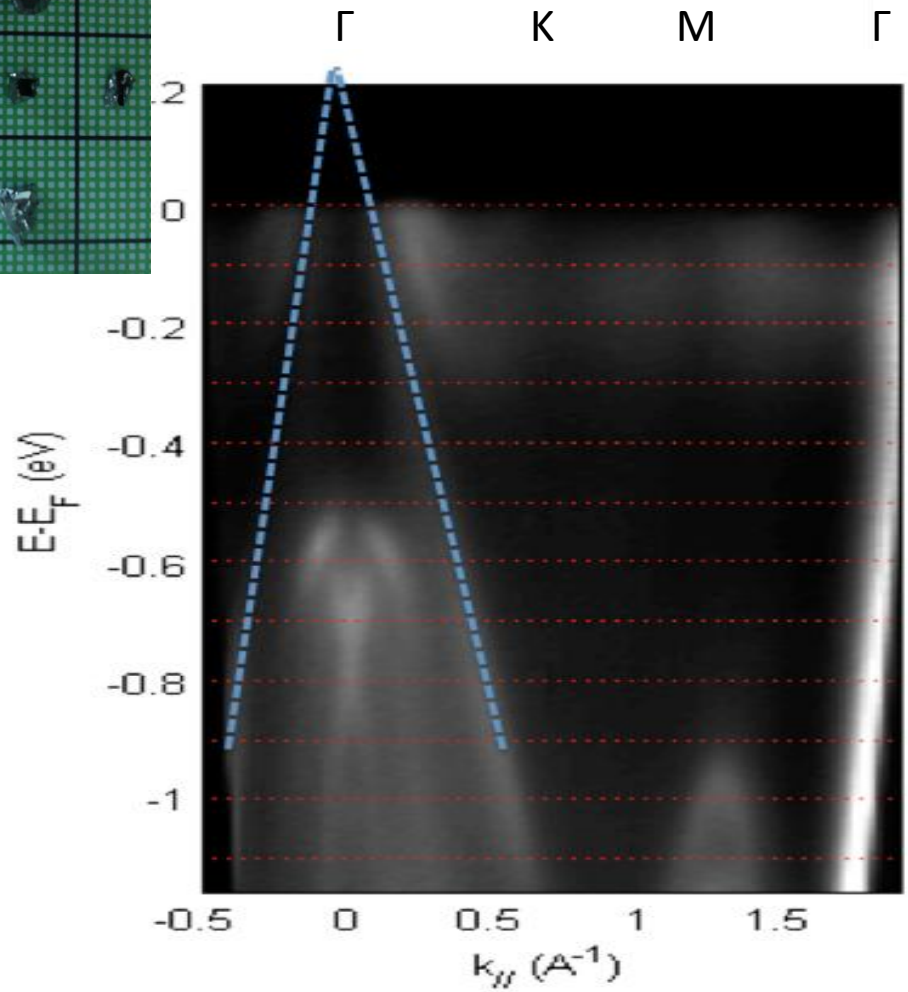
Superconductivity in noncentrosymmetric YPtBi under pressure

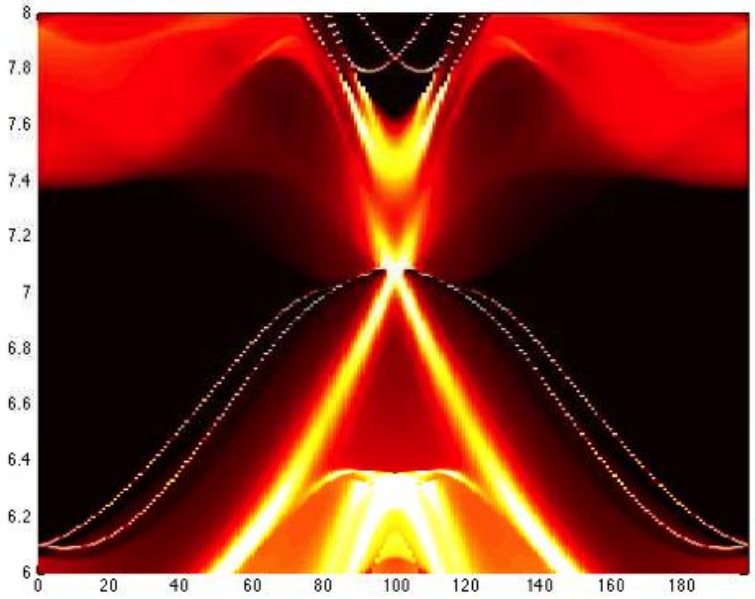
T. V. Bay,[1] T. Naka,[2] Y. K. Huang,[1] and A. de Visser[1,*]

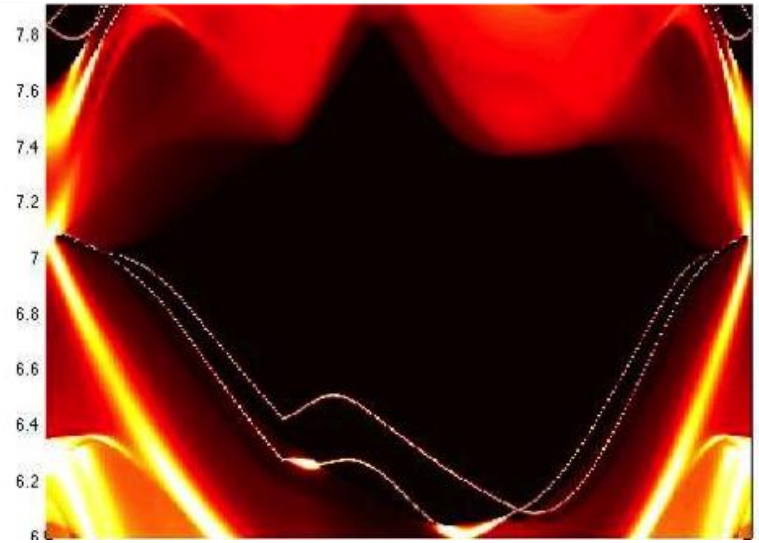


YPtBi ARPES and Theory



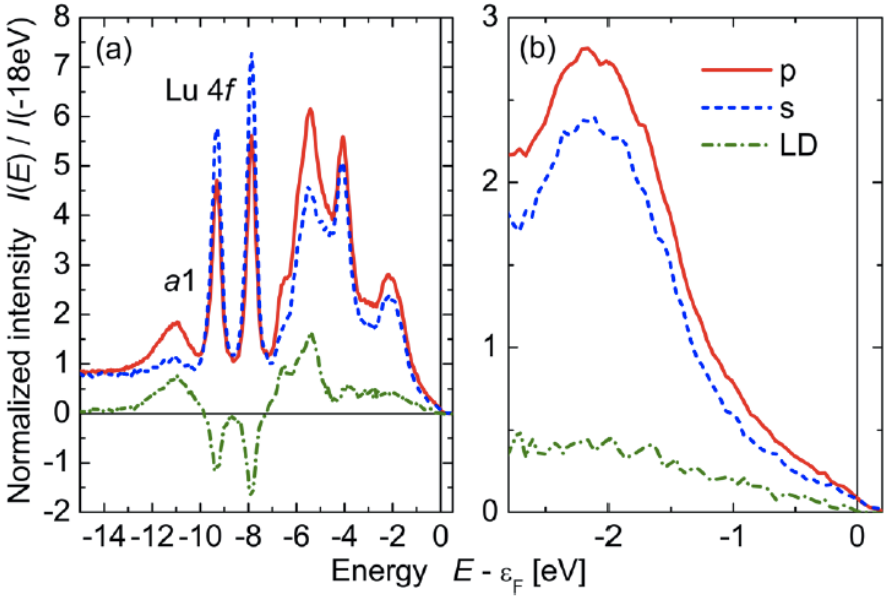


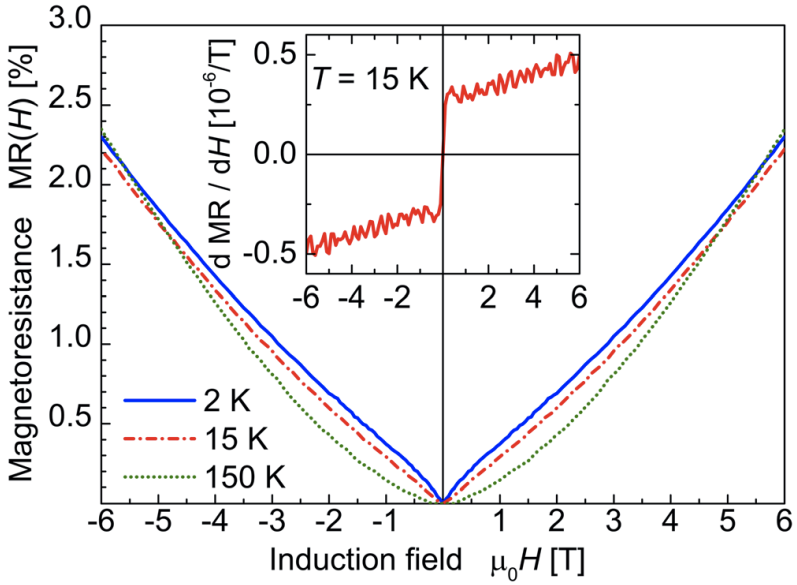




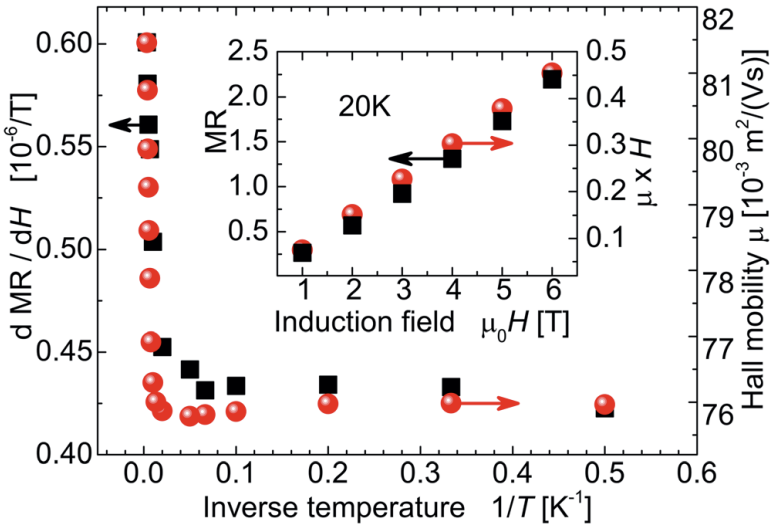
Collaboration with Yulin Chen, Oxford

Zero band gap





Polarization dependent valence band spectra and linear MR of PtLuSb

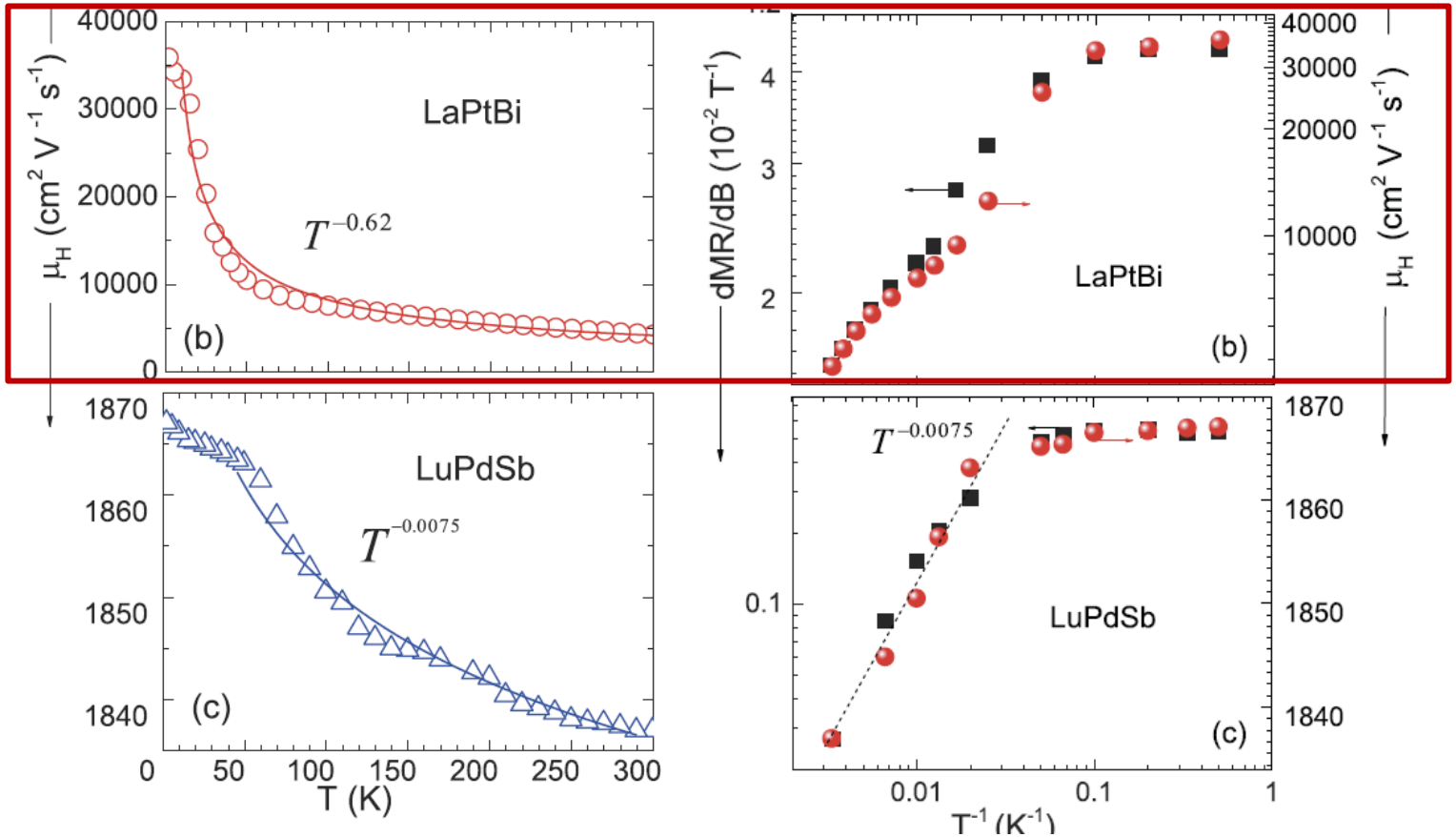


Ouardi et. al. Appl. Phys. Lett. 99, 211904 (2011).
Ouardi et. al. Appl. Phys. Lett. 98, 211901 (2011).
Shekhar, C. et. al. Appl. Phys. Lett. 100, 2152109 (2012).

Linear MR and ultrahigh mobilty

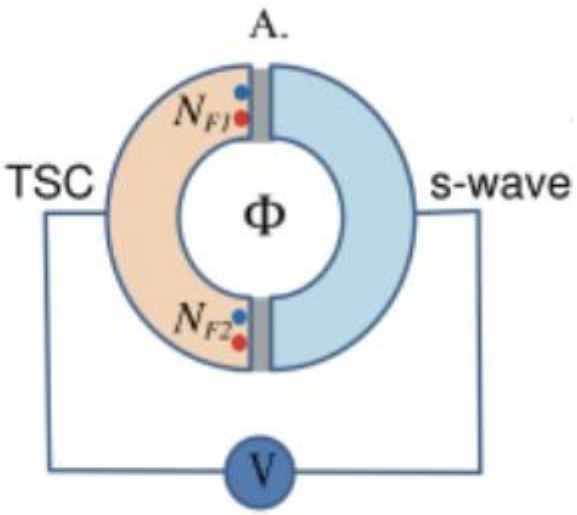
Weak localisation

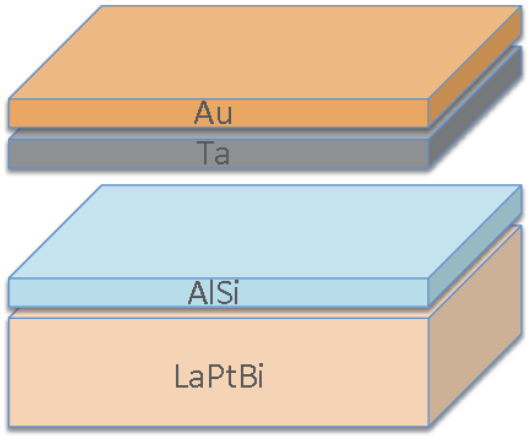
A close relation between the linear MR and the Hall mobility for this class of materials

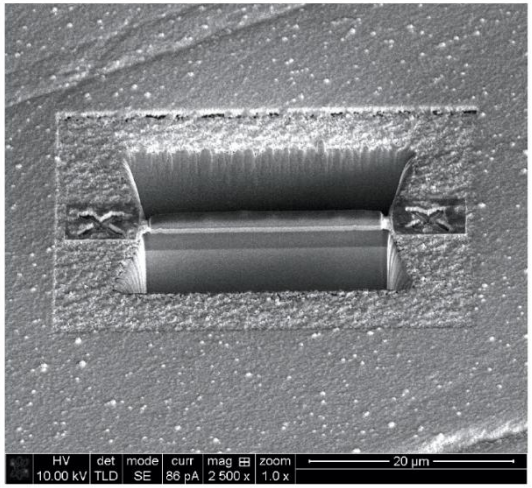


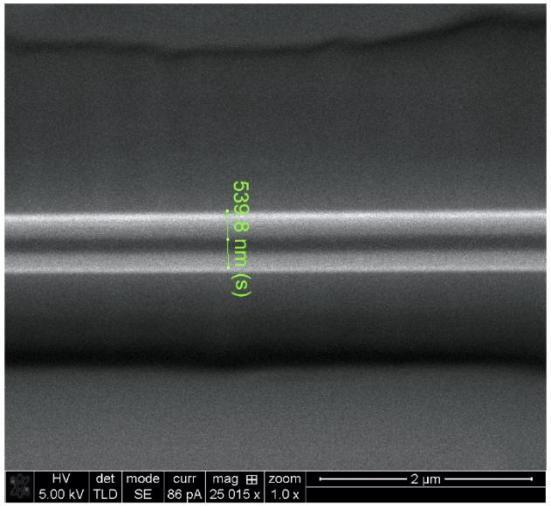
Ouardi et. al. Appl. Phys. Lett. 99, 211904 (2011).
Ouardi et. al. Appl. Phys. Lett. 98, 211901 (2011).
Shekhar, C. et. al. Appl. Phys. Lett. 100, 2152109 (2012).
Shekkar et al. PRB 86, 155314 (2012)

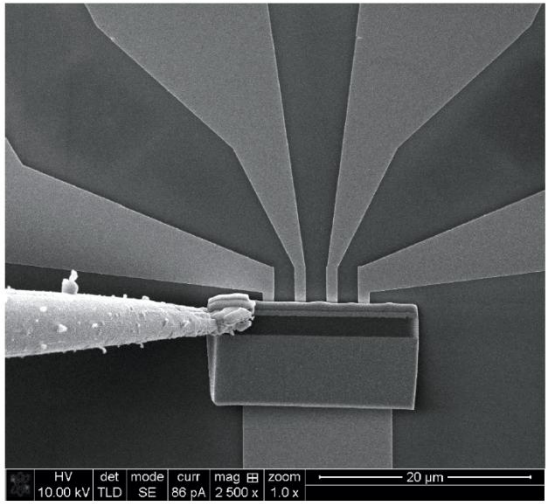
Hunting Majorana

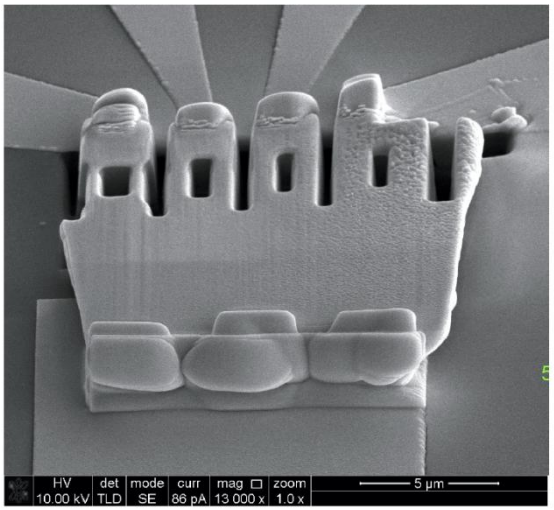








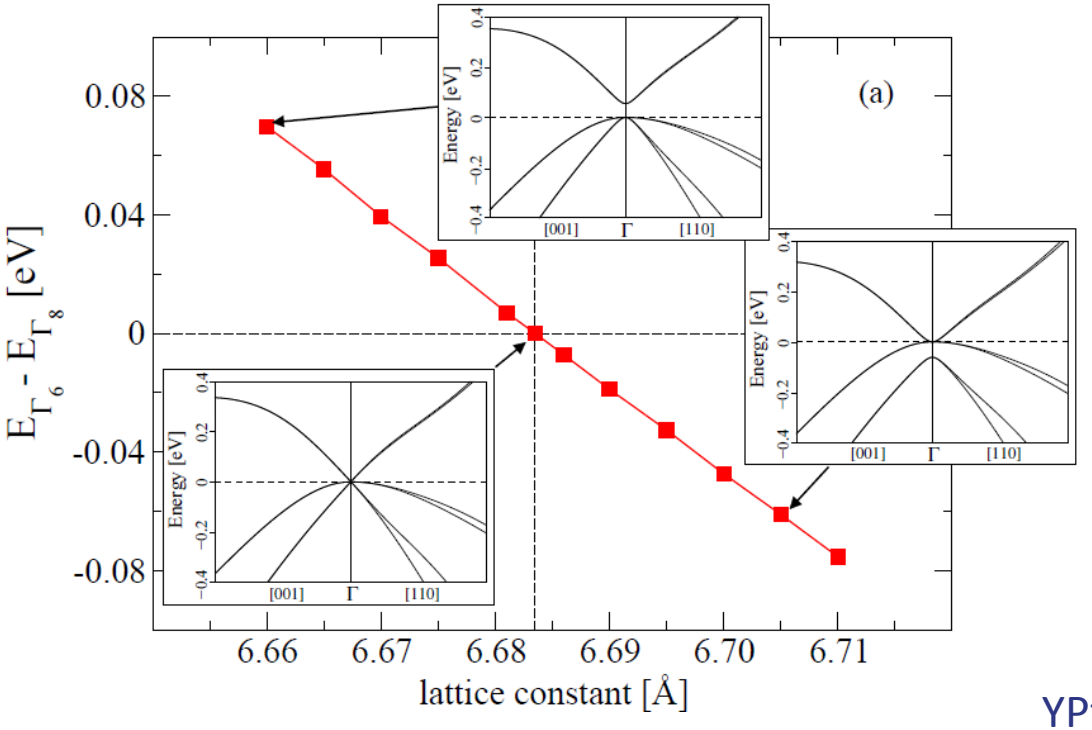


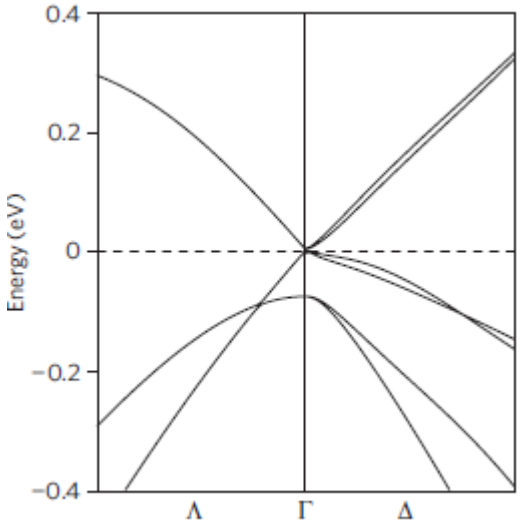


Ebke, Reiss, Wernsdorfer, Felser et al. unpublished

Quantum phase transition

- Taking the borderline compound **YPtSb** at a quantum critical line/point
- Applying strain: A gap will be opened and the Dirac cone stays in the gap
- Critical thickness for the quantum well structure

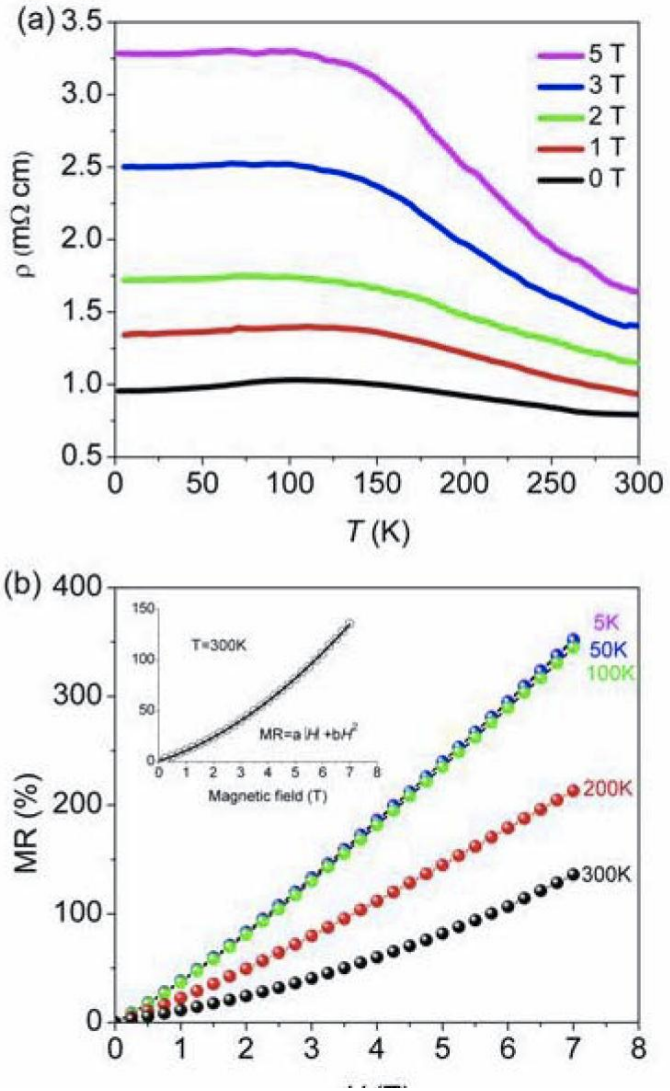




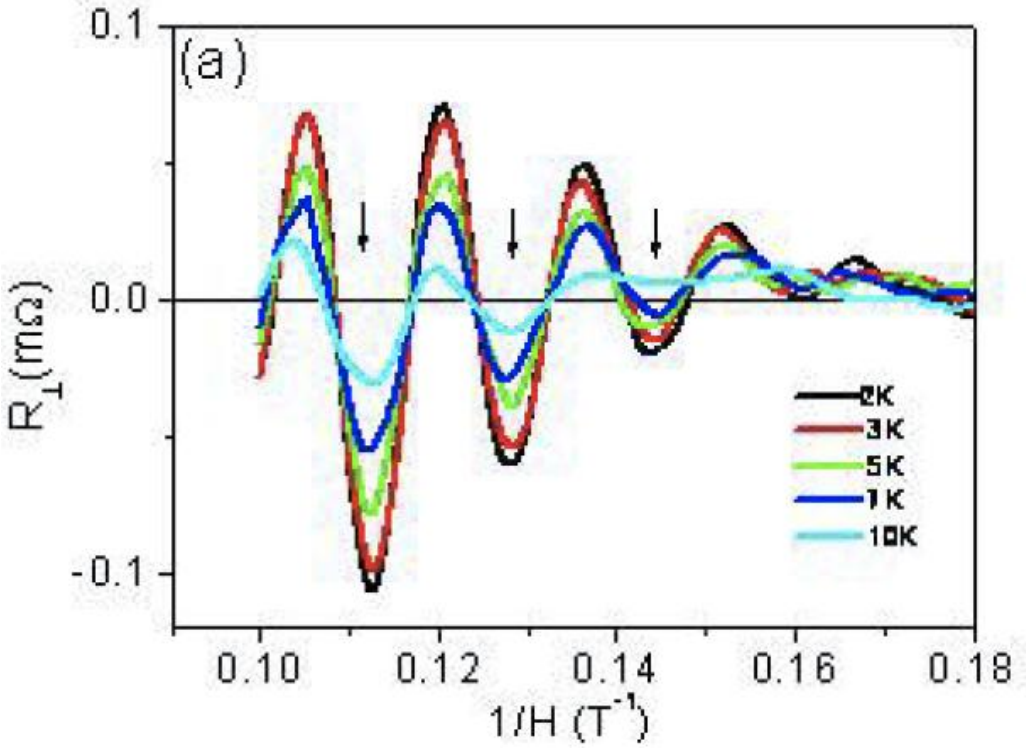
YPtSb is an excellent piezoelectric
arXiv:1107.5078 (Vanderbilt, Rabe)

Chadov, Qi, Kübler, Zhang, Felser Nature Mat. 9 (2010) 541

Zero band gap

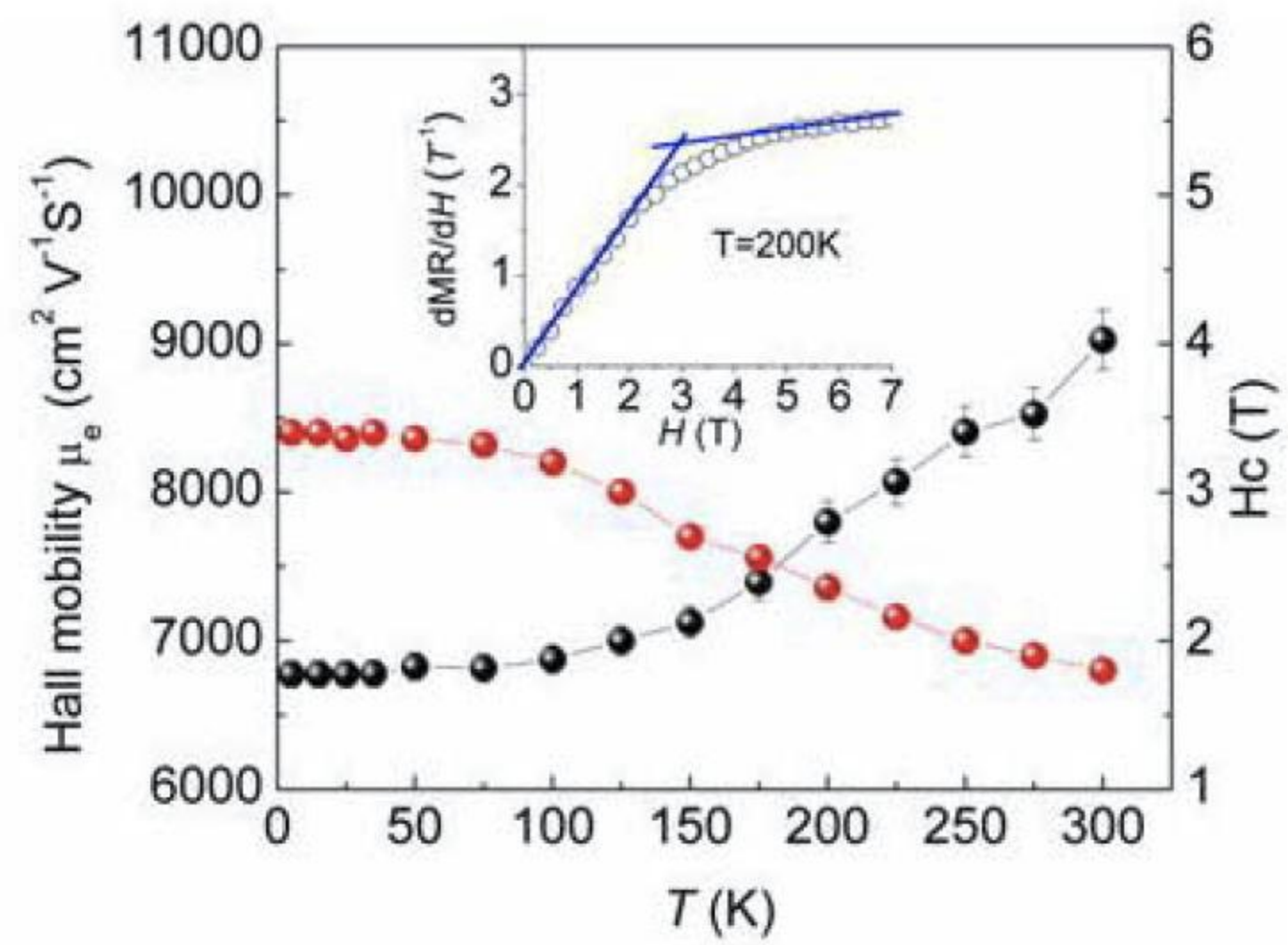


Large Linear Magnetoresistance and Shubnikov-de Hass Oscillations in Single Crystals of YPdBi Heusler Topological Insulators



Wang et al. Science Report (2013)

Zero band gap

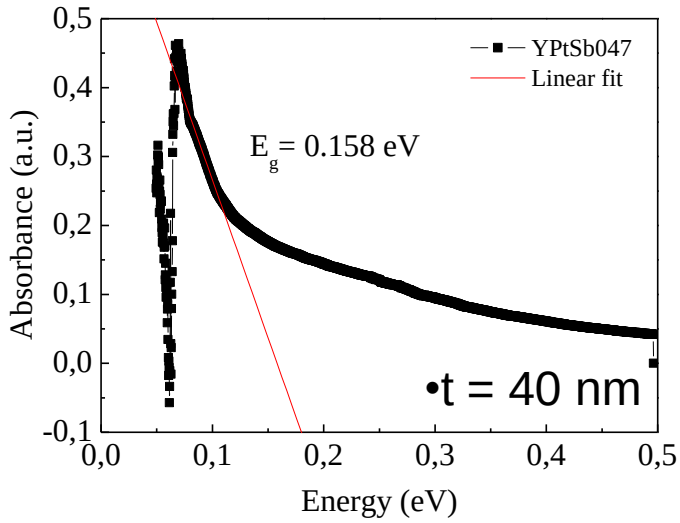


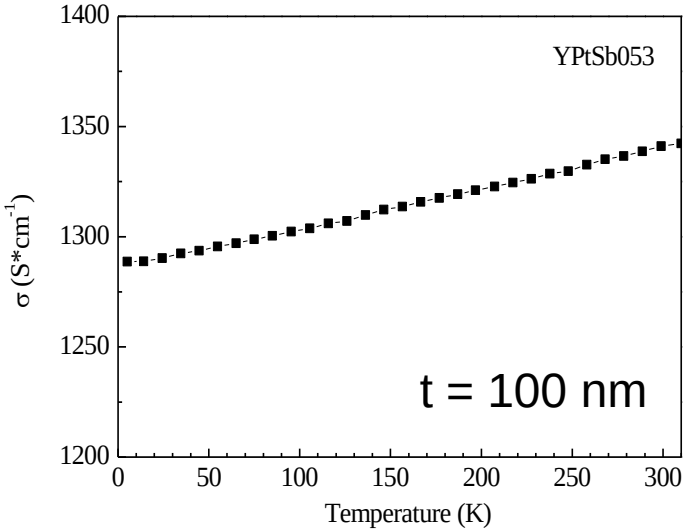
Wang et al. Science Report (2013)

Small Bandgap in YPtSb

Infrared spectroscopy. band gap predicted theoretically and observed from bulk material (0.16 eV).

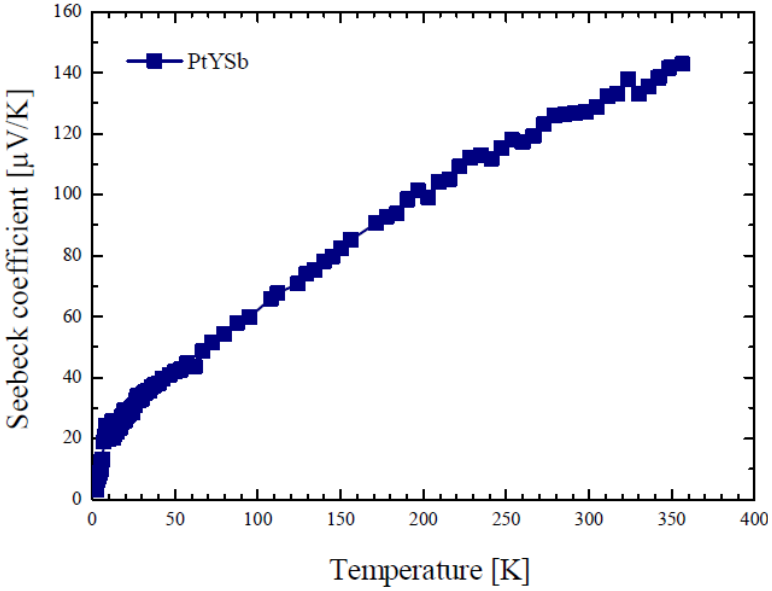
Temperature dependence of the conductance indicates a semiconducting behavior. Hall effect shows a carrier concentration is in the order of 10^{19} cm^{-3} and the mobility is around 380 cm^2/Vs.

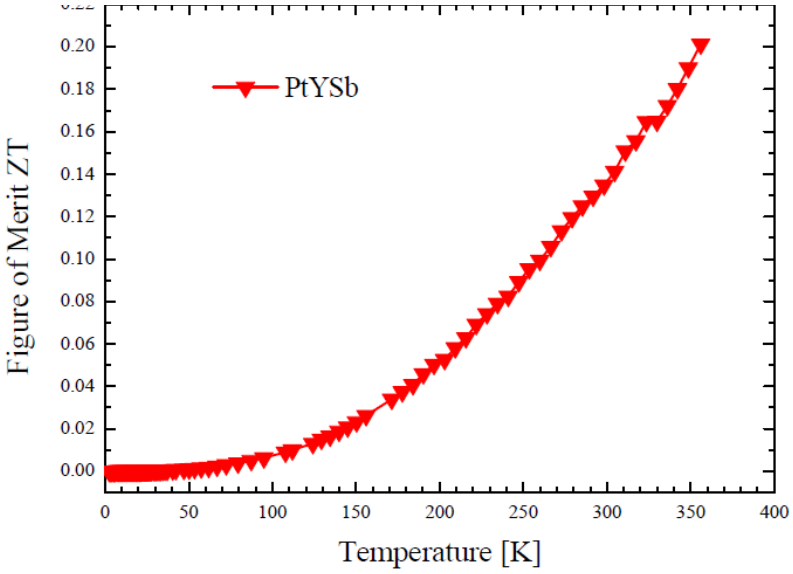


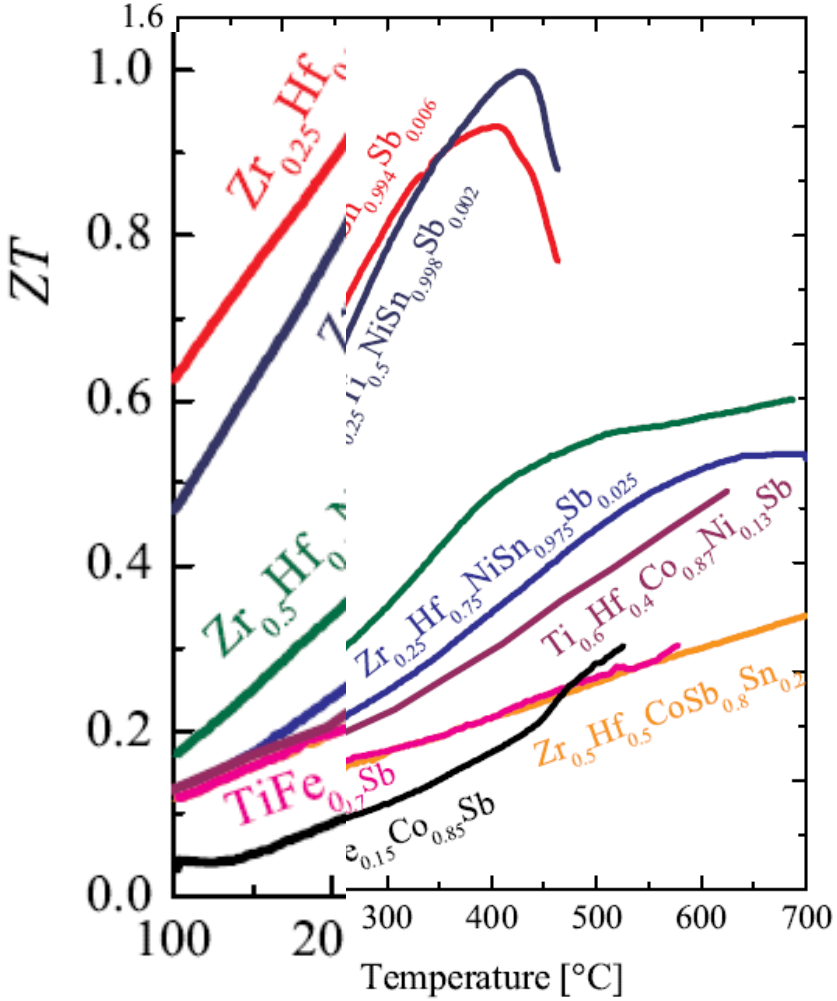


Shan Rong *et al*, Phys. Status Solidi RRL 7 (2013) 145

Good TI are good thermoelectrics

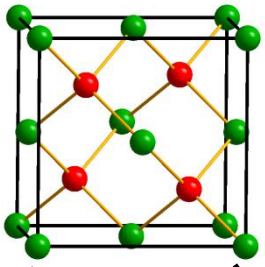




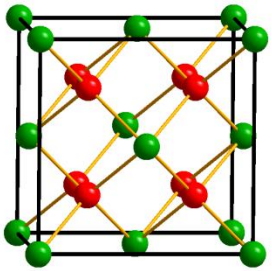


Ouardi, et al., Appl. Phys. Lett. 99 (2011) 211904.

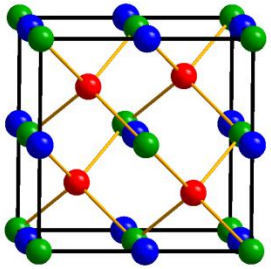
Distorted Structure to Property



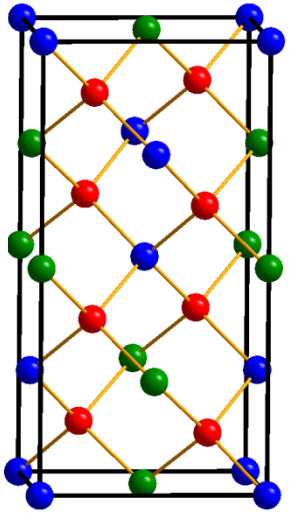
HgTe



α Ag_2Te

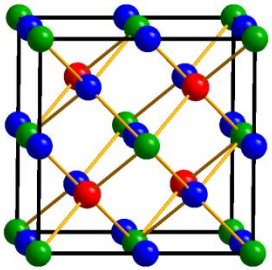


LaPtBi

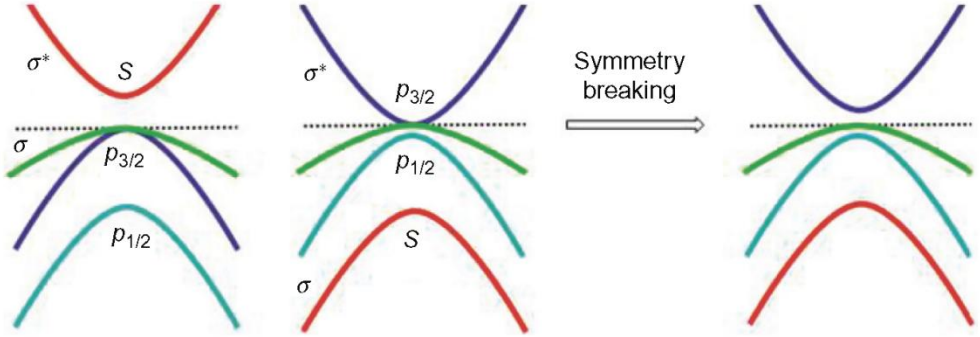


$AuTlS_2$

β Ag_2Te

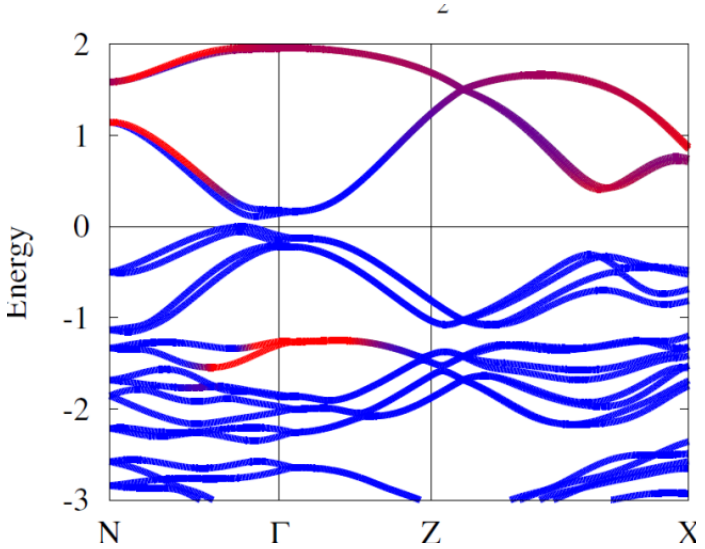


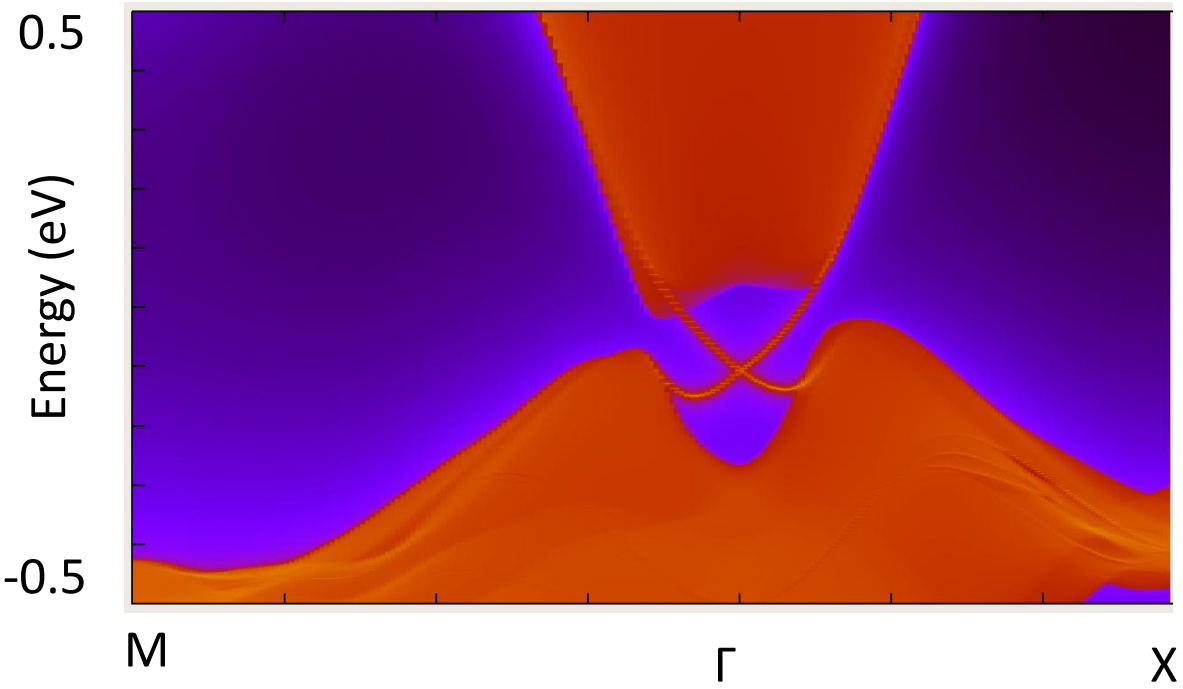
Li_2AgSb



Surface states

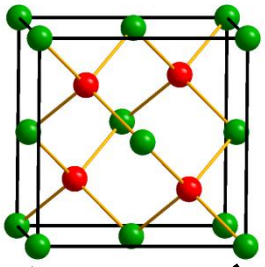
$AuTlS_2$





Müchler, Zhang, Chadov, Yan, Kübler, Zhang, Felser, Angewandte Chemie **124** 7333 (2012)

structure to property



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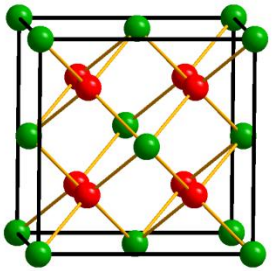
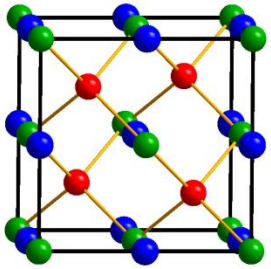
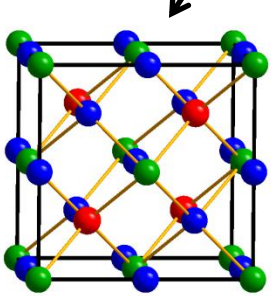


α Ag_2Te

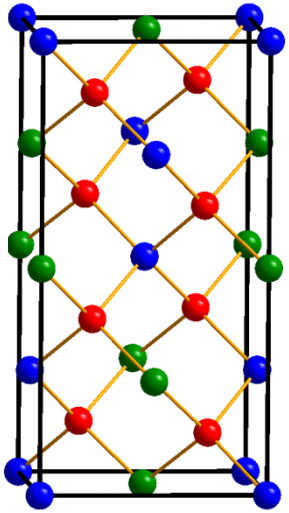


LaPtBi

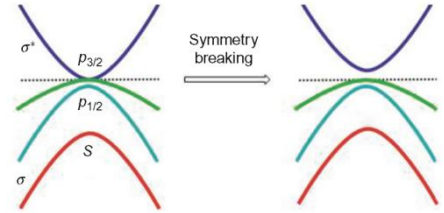


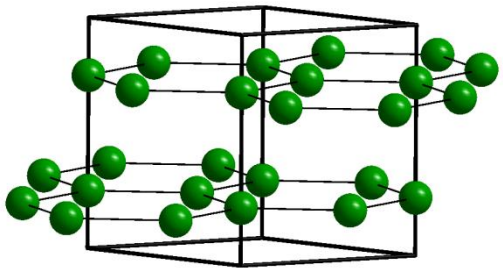
Li_2AgSb

β Ag_2Te

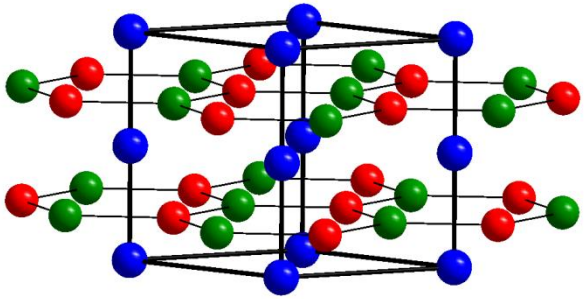


$AuTlS_2$



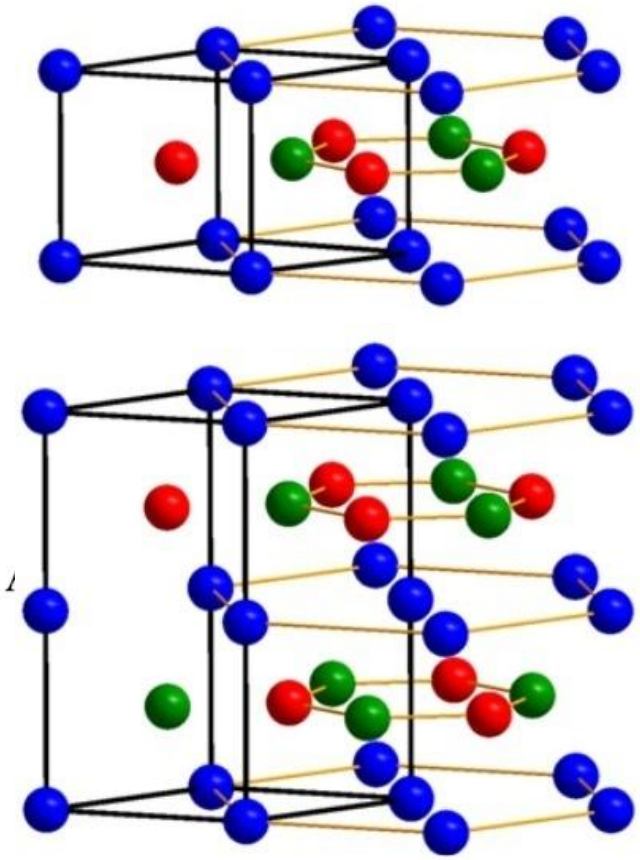


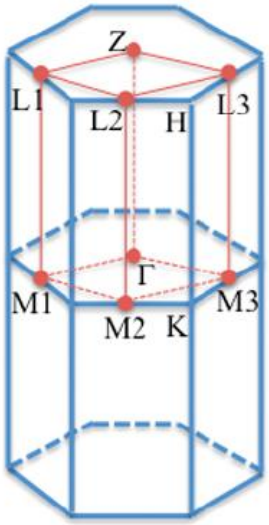
Graphite



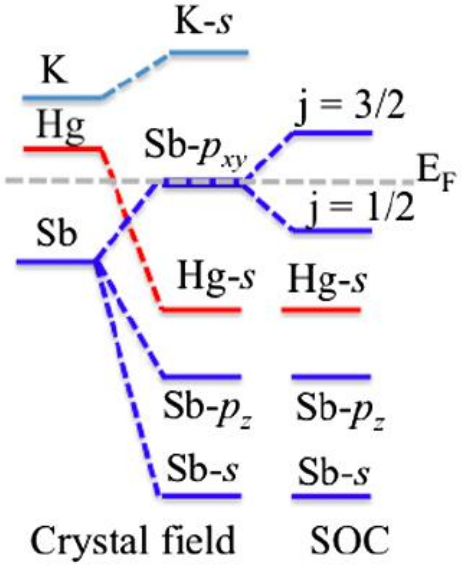
KHgSb

Honeycomb: Weak TI

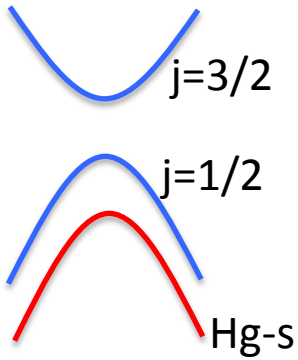




(c)



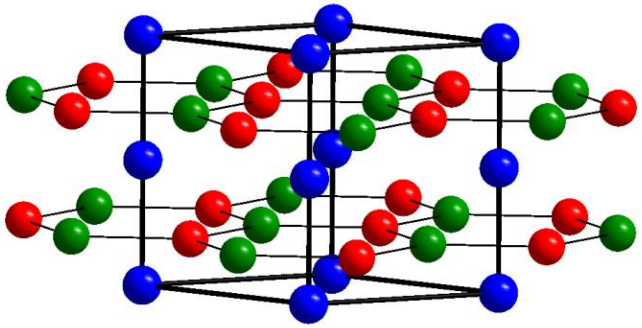
(d)

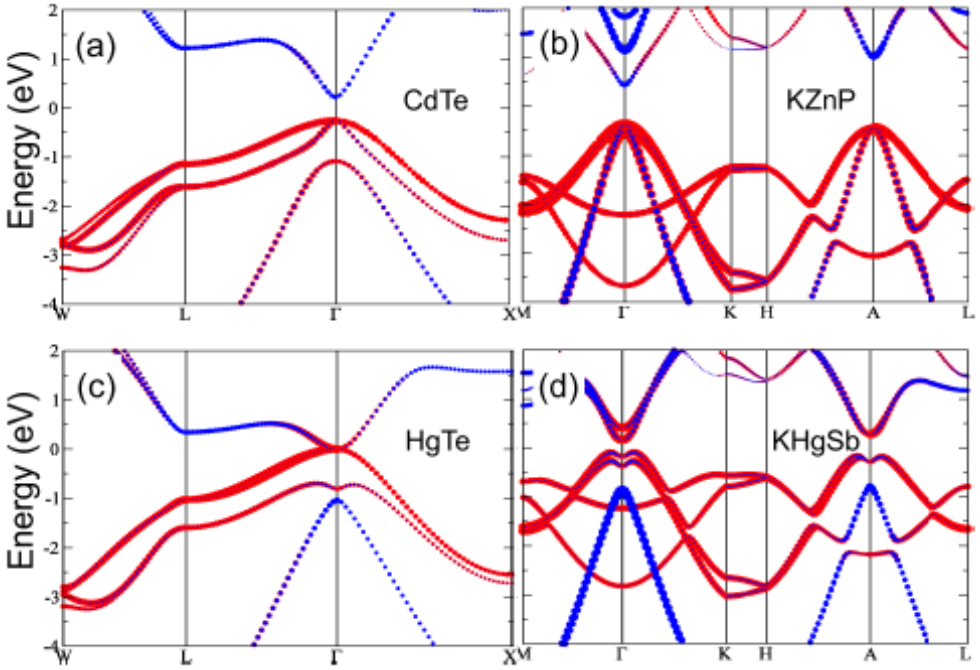


Yan, Müchler, Felser, Phys. Rev. Lett. 109 (2012) 116406

Zhang, Chadov, Müchler, Yan, Qi, Kübler, Zhang, Felser, Phys. Rev. Lett. 106 (2011) 156402

Honeycomb from sp^3 to sp^2

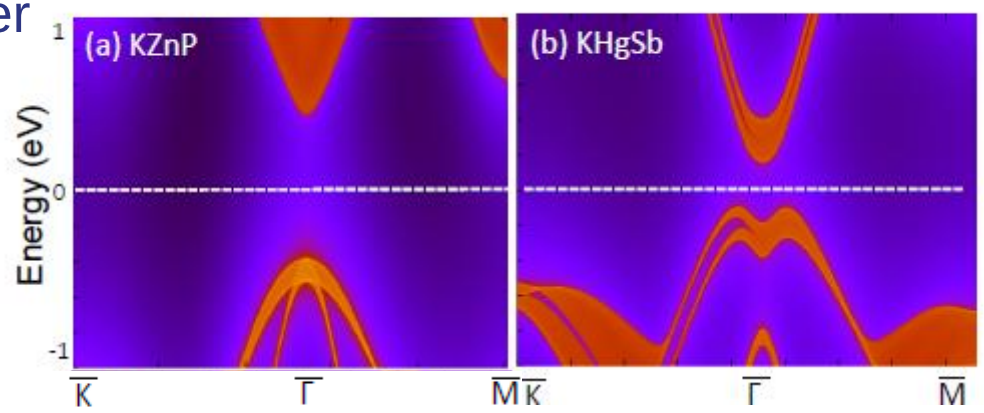




Band inversion is found in the heavier compounds

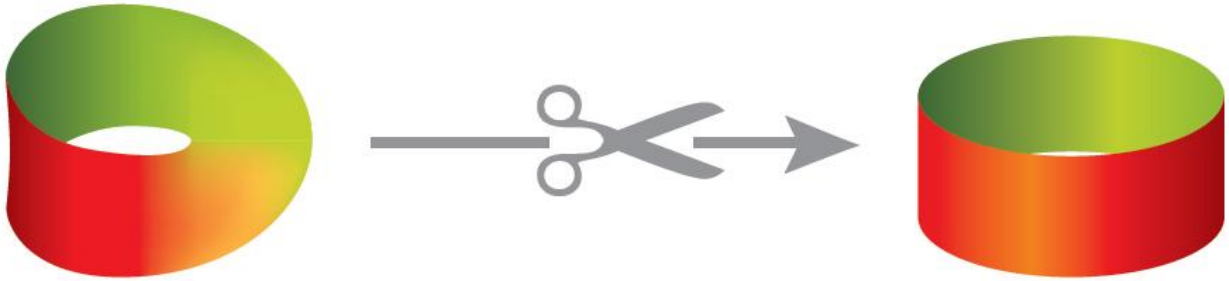
No surface state? Why ?

→ Interaction between the two layers in the unit cell and two Dirac Cones

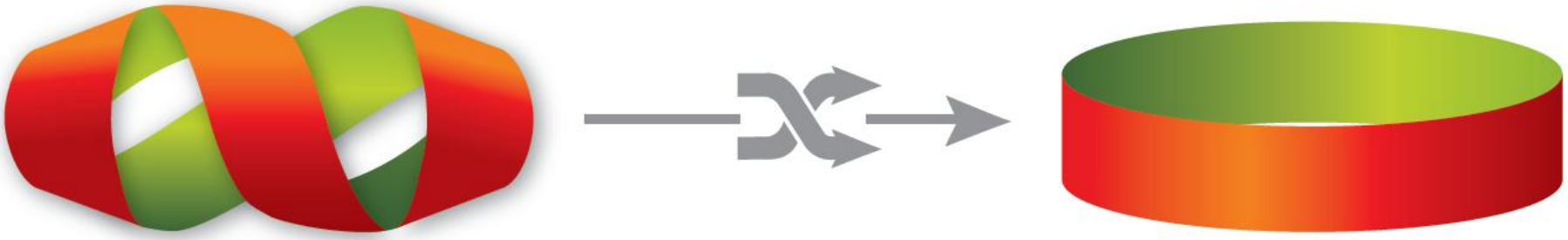


Zhang et al., Phys. Rev. Lett. 106 (2011) 156402 and Yan et al. Phys. Rev. Lett. 109, 116406 (2012)

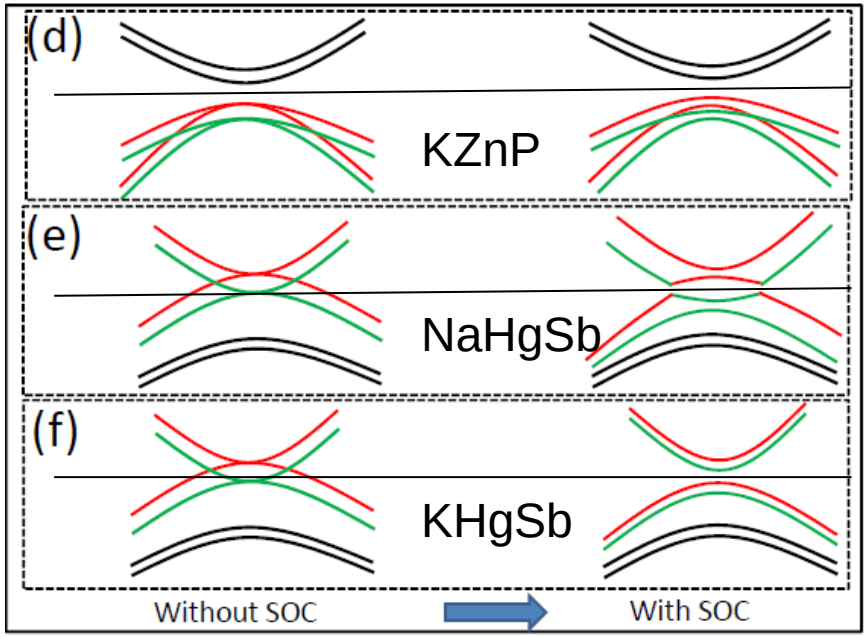
a)



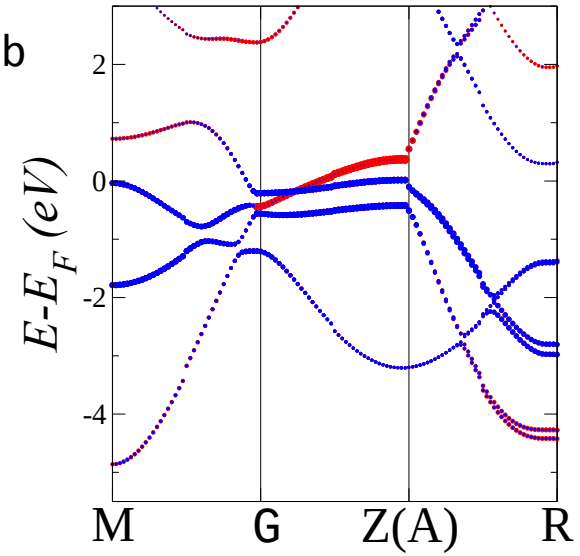
b)



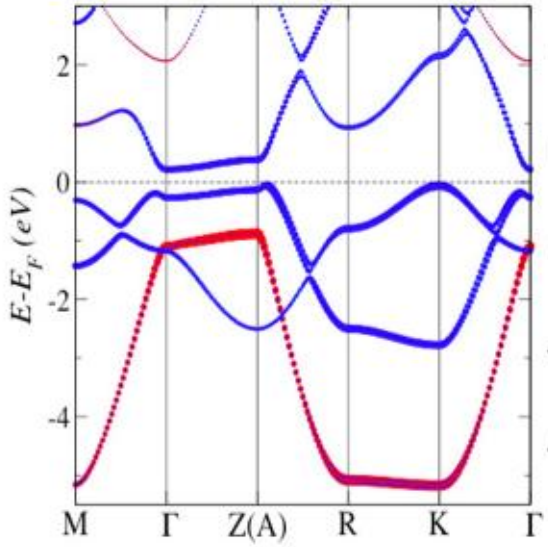
Honeycomb from sp^3 to sp^2



NaHgSb

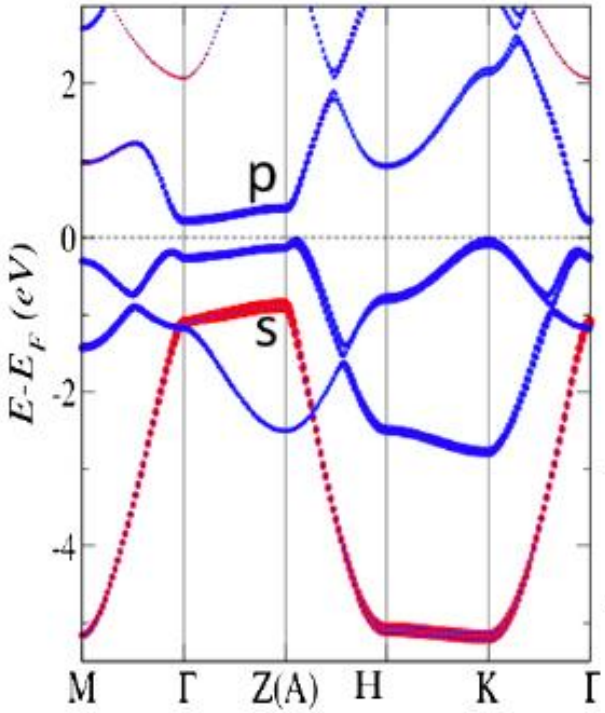


KHgSb

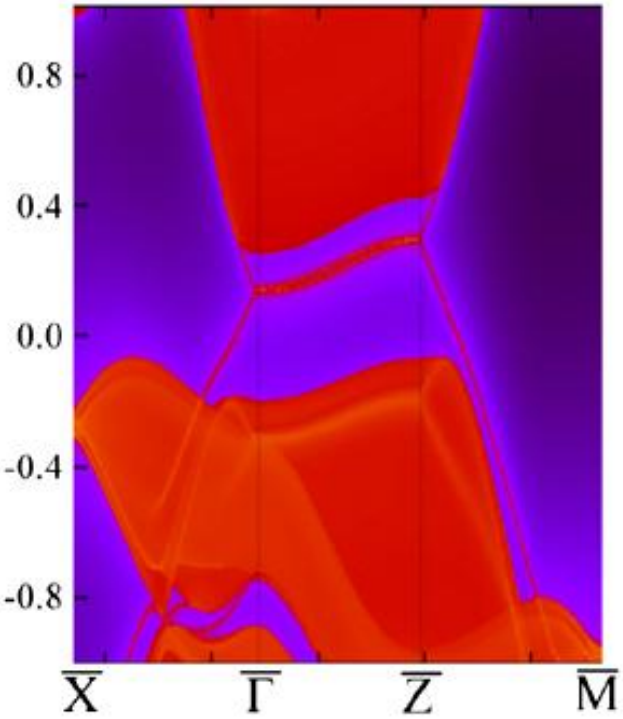


Zhang, Chadov, Müchler, Yan, Qi, Kübler, Zhang, Felser, Phys. Rev. Lett. 106 (2011) 156402 arXiv:1010.2195v1

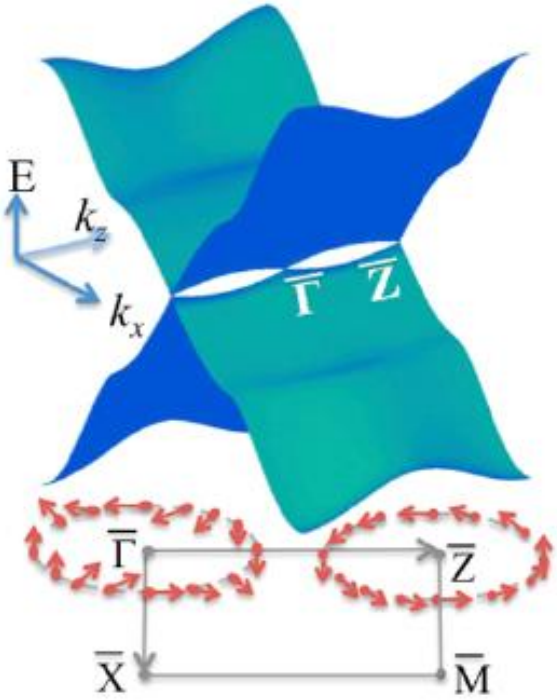
Honeycomb: weak TI



(a) Bulk



(b) Side surface



(c) Side surface

Yan, Müchler, Felser, Phys. Rev. Lett. 109 (2012) 116406

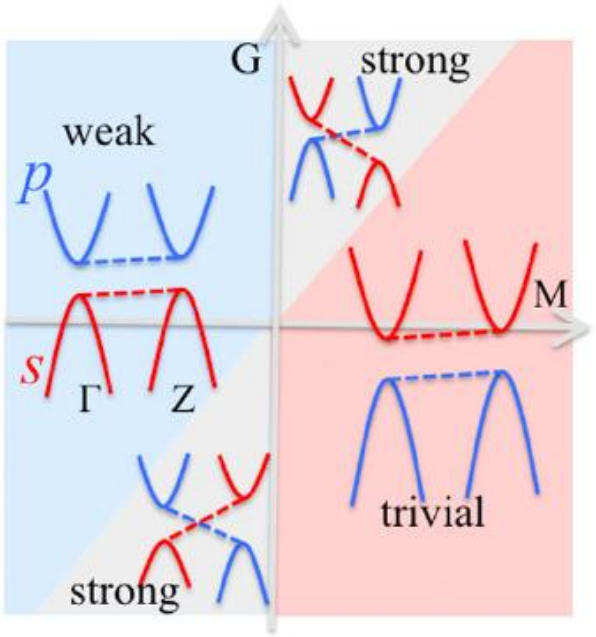
Zhang, Chadov, Müchler, Yan, Qi, Kübler, Zhang, Felser, Phys. Rev. Lett. 106 (2011) 156402

a large family of weak and strong TIs

BHZ model, minimal Hamiltonian

$$H(k) = \epsilon(k)\mathbb{I}_{4\times4} + \begin{pmatrix} M(k) & Ak_+ & & \\ Ak_- & -M(k) & & \\ & & M(k) & -Ak_- \\ & & -Ak_+ & -M(k) \end{pmatrix}$$

$$M(k) = M_0 - B\,k_{//}^2 - G\,k_z^2$$



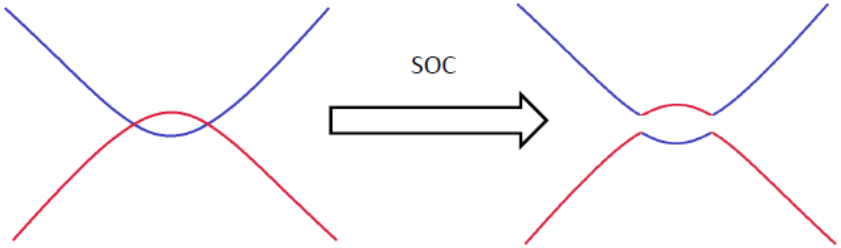
(a)

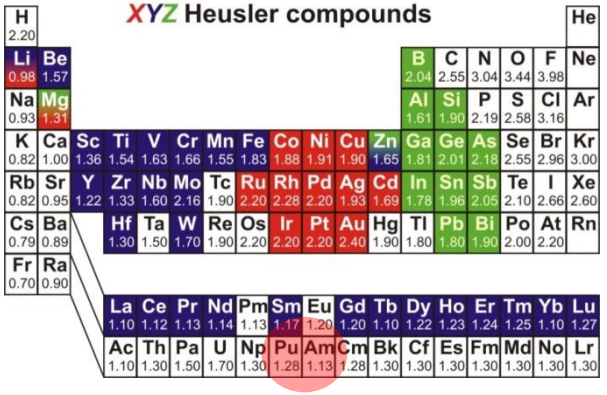
KHgSb	KHgAs	KHgP
NaHgSb	NaHgAs	NaHgP
LiHgSb	LiHgAs	LiHgP
KCdSb	KCdAs	KCdP
NaCdSb	NaCdAs	NaCdP
LiCdSb	LiCdAs	LiCdP

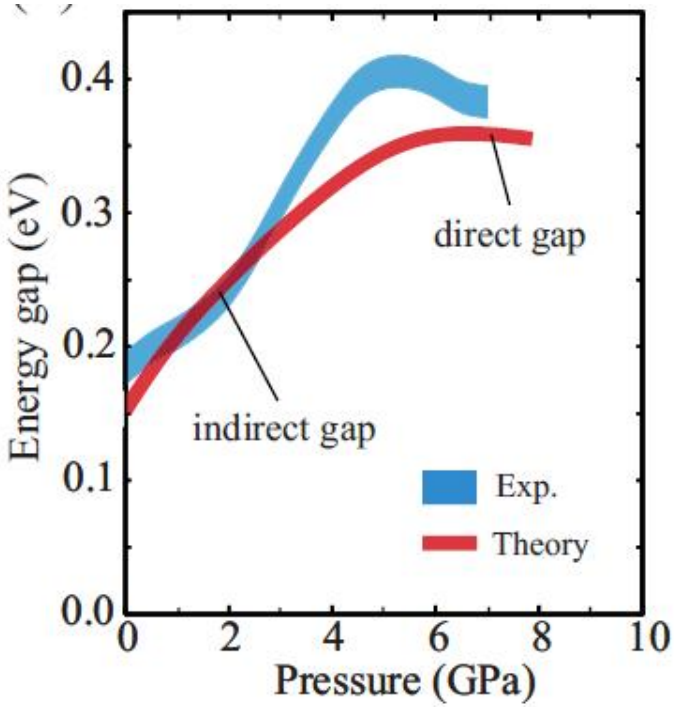
KAuTe	KAuSe
NaAuTe	NaAuSe
LiAuTe	LiAuSe
KAgTe	KAgSe
NaAgTe	NaAgSe
LiAgTe	LiAgSe

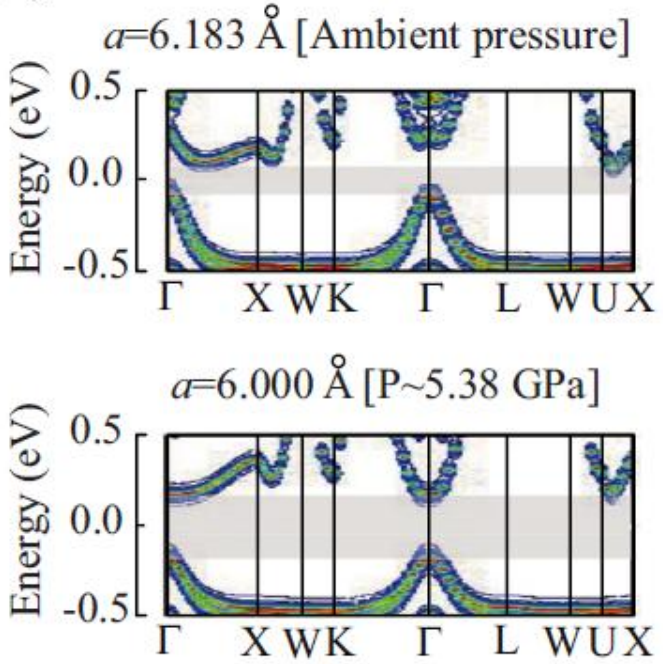
(b)

Pu with the largest SOC



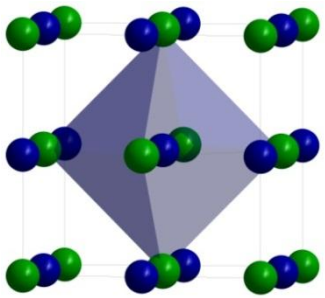






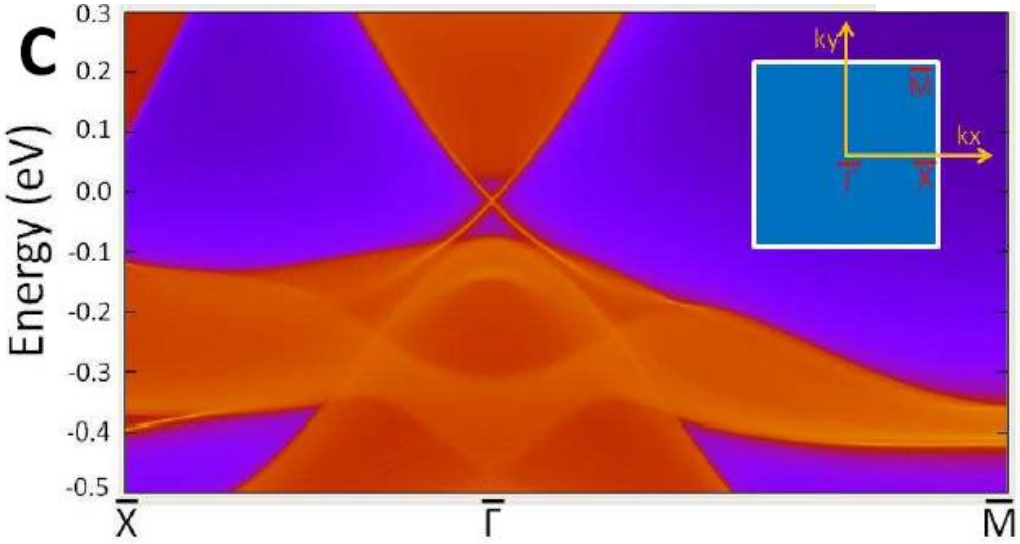
T. Gouder, P. M. Oppeneer, et al. Phys. Rev. B 72, 115122 (2005).
L. Müchler, et al, Angewandte Chemie **124** 7333 (2012)
Xiao Zhang, Haijun Zhang, Claudia Felser, Shou-Cheng Zhang, Science **335** (2012) 1464

PuTe and AmN, cubic 3D correlated TI



Topological Mott Insulator,
with a Dirac cone at Γ

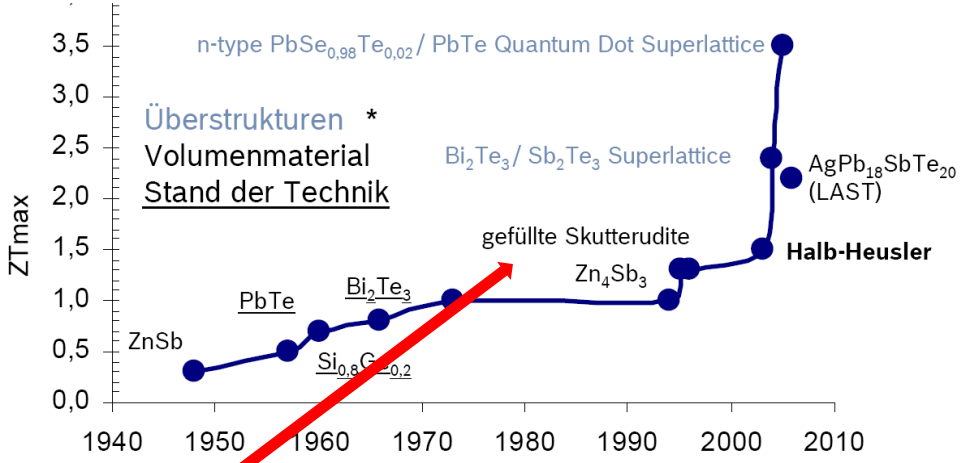
	E_g	Γ	$3X$	$4L$	Tot.
AmN	0.100eV	−	+	−	−
AmP	0.085eV	−	+	−	−
AmAs	0.080eV	−	+	−	−
AmSb	0.055eV	−	+	−	−
AmBi	0.040eV	−	+	−	−
PuSe	0.2eV	−	+	−	−
PuTe	0.178eV	−	+	−	−

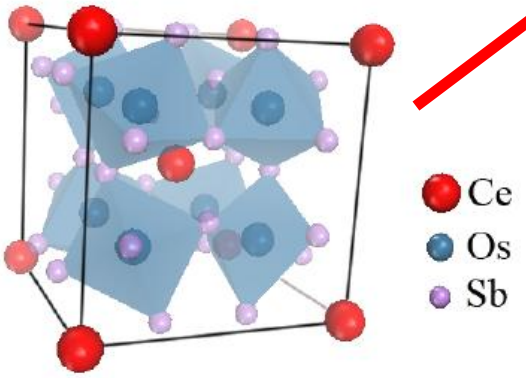


Band inversion between **d** and **f** bands of different parity
PuTe under pressure has a band gap up to 0.4 eV

Xiao Zhang, Haijun Zhang, Claudia Felser, Shou-Cheng Zhang, Science **335** (2012) 1464

Intrinsic Nanostructures …

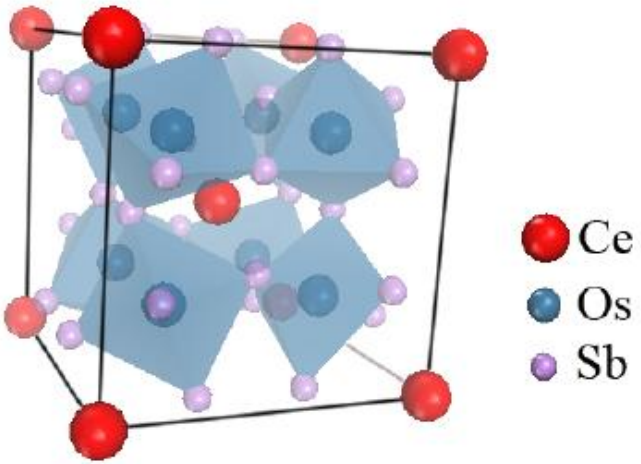




Kondo insulating behaviour in the filled skutterudite compound $CeOs_4Sb_{12}$

E D Bauer, A Ślebarski[1], E J Freeman, C Sirvent[2] and M B Maple

Skutterudites



Kondo insulating behaviour in the filled skutterudite compound $CeOs_4Sb_{12}$

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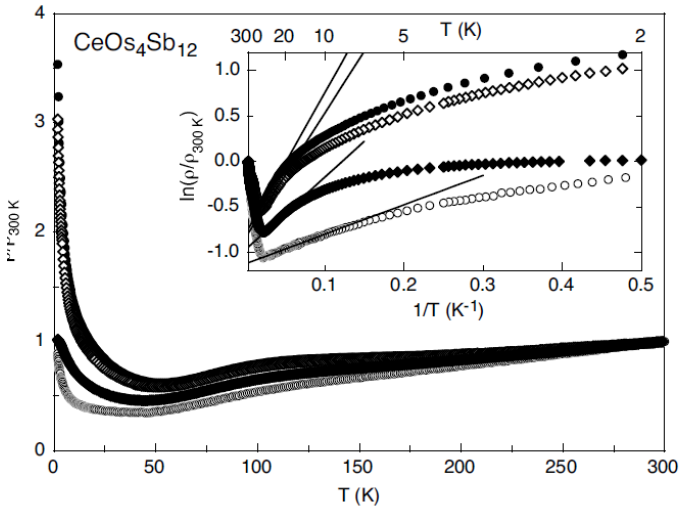
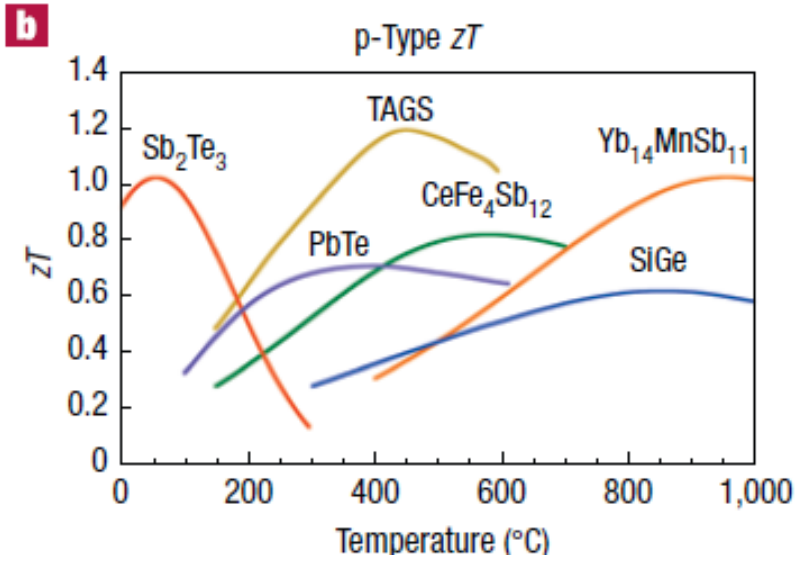


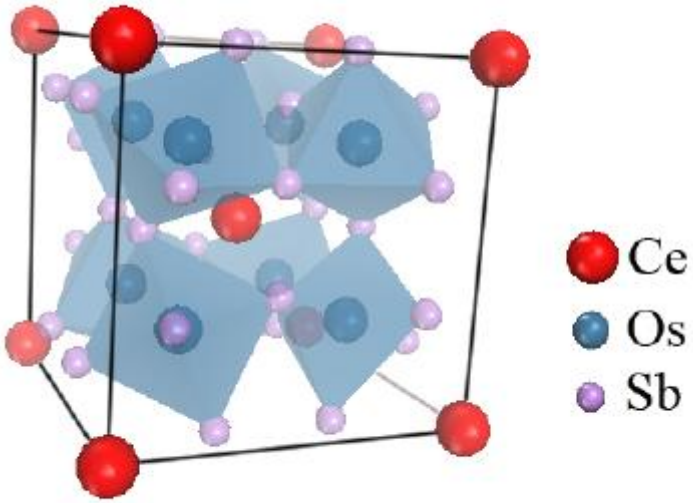
J. Phys.: Condens. Matter 13 (2001) 4495



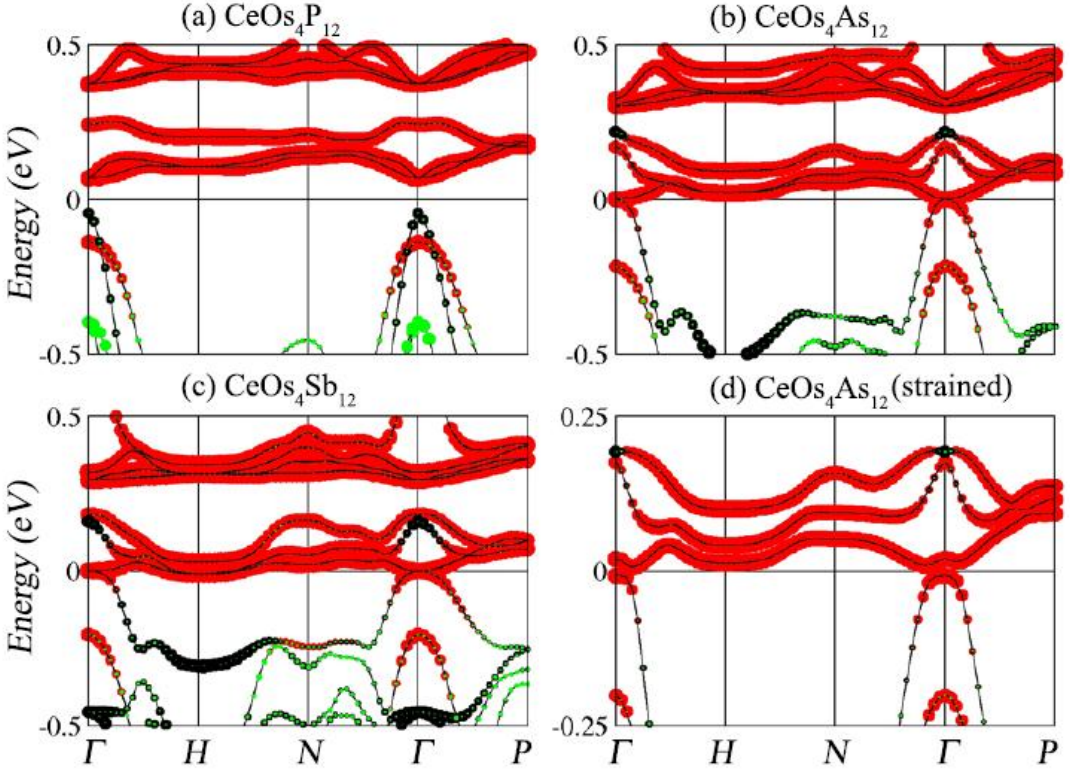
Superconductor
$PrOs_4Sb_{12}$

Review Thermoelectrica: G. J.Snyder, E. S. Toberer, Nat. Mat. 7 (2008) 105.

Skutterudites

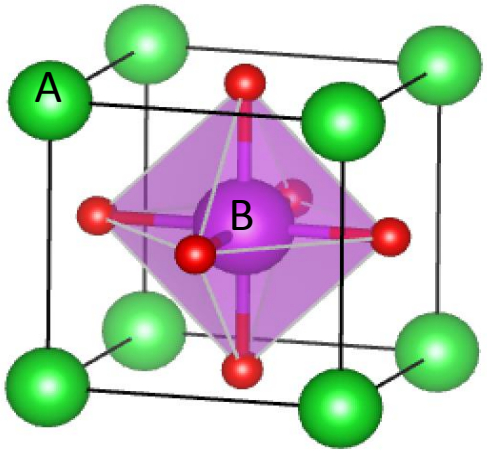


Band inversion between **d** and **f** bands of different parity



B. Yan, L Müchler, HJ Zhang, XL Qi,, SC Zhang, C. Felser, PRB 85 (2012) 165125, arXiv:1104.0641

Topological Perovskite Oxides



ABO_3

$BaBiO_3$ has a formal charge of +4 for Bi $6s^1$

BiO_6-octahedra are tilted 159.9◦ not 180◦

Bi^{5+} and Bi^{3+} lead to BiO_6 octahedra breathing in and out

Hole doped $BaBiO_3$ is superconducting with a maximum Tc is 34 K for $Ba_{0.6}K_{0.4}BiO_{3.8}$

$Ba_{1-x}K_xBiO_3$ (BKBO) crystallizes in the cubic structure

$0.375 < x < 0.5$ no breathing mode, but superconducting

Can perovskites exhibit topological quantum states?

- Stable against against surface oxidization and degrading
- Multi-functionality, superconductivity, magnetic, ferroelectric
- Experiment fabrication

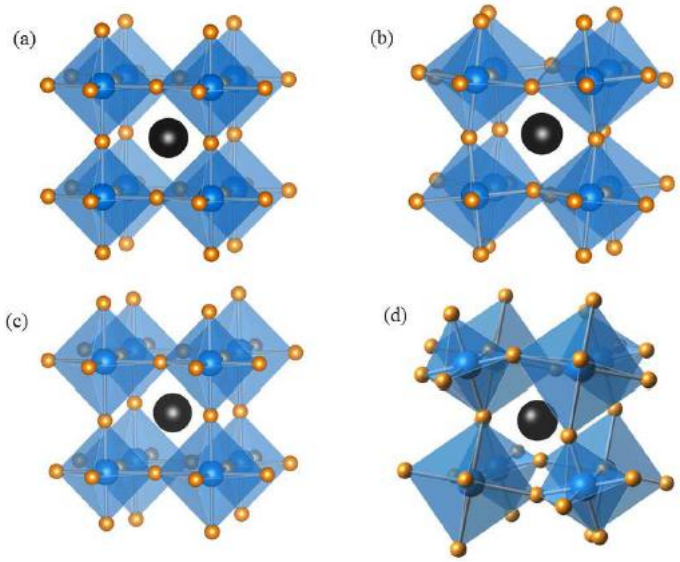
First example: $BaBiO_3$

The lone pair - $RbTlCl_3$

Inorganic Chemistry
Article
pubs.acs.org/IC

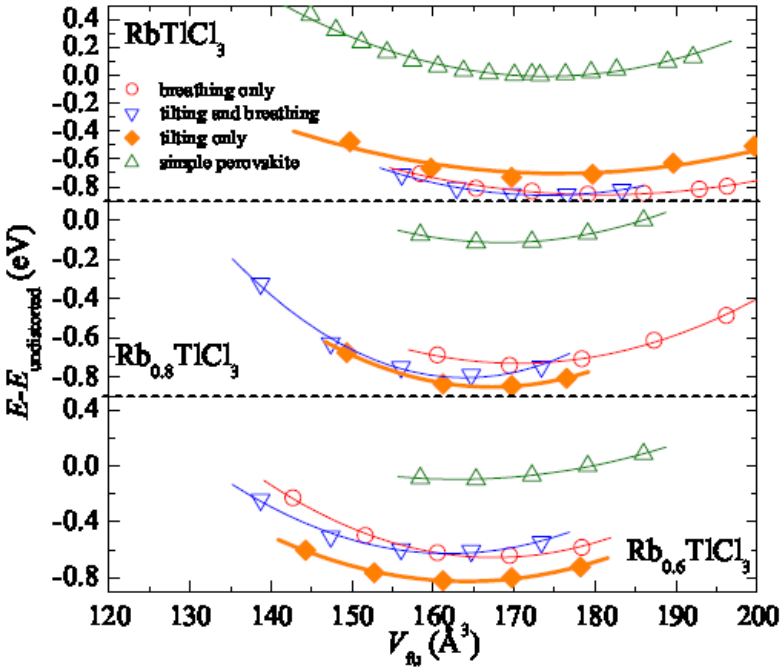
Lone Pair Effect, Structural Distortions, and Potential for Superconductivity in Tl Perovskites

Leslie M. Schoop,*[,†,‡] Lukas Müchler,[§] Claudia Felser,[§,∥] and R. J. Cava[†]



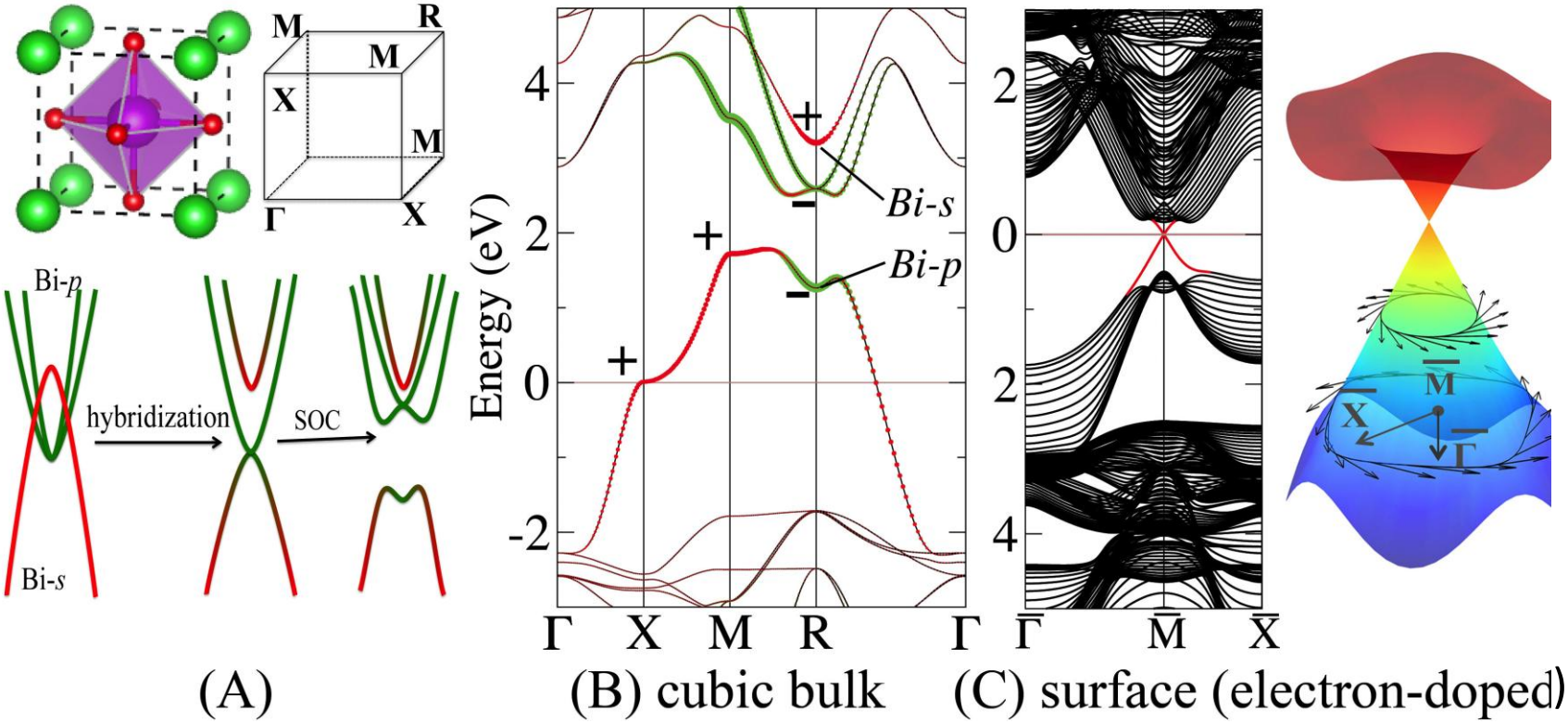
(a) Undistorted ideal
(b) Tilted octahedra
(c) Breathing no tilting
(d) Breathing and tilting

$RbTlCl_3$ has a formal charge of +2 for Tl $6s^1$



Oxide Topologic Insulator

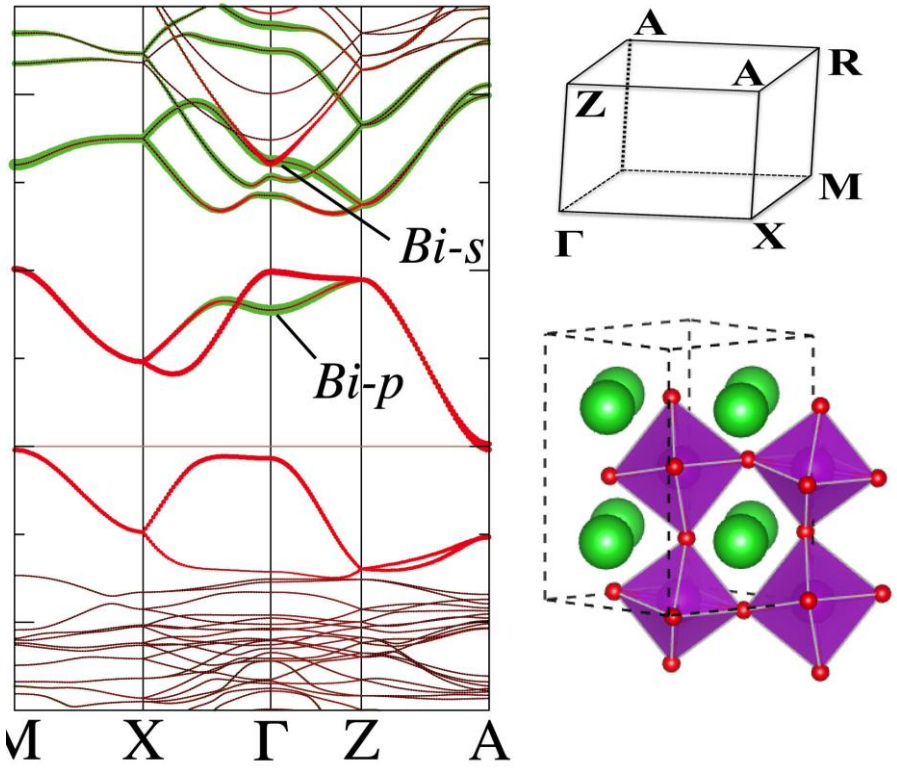
$BaBiO_3$ has a formal charge of +4 for Bi $6s^1$ $6s^2$



- **3D strong TI with Z_2 (1;111)**
- **Largest E_g of 0.7 eV among all known TIs**

Yan, Jansen, Felser, Nature Physics online.

Robust against lattice distortion

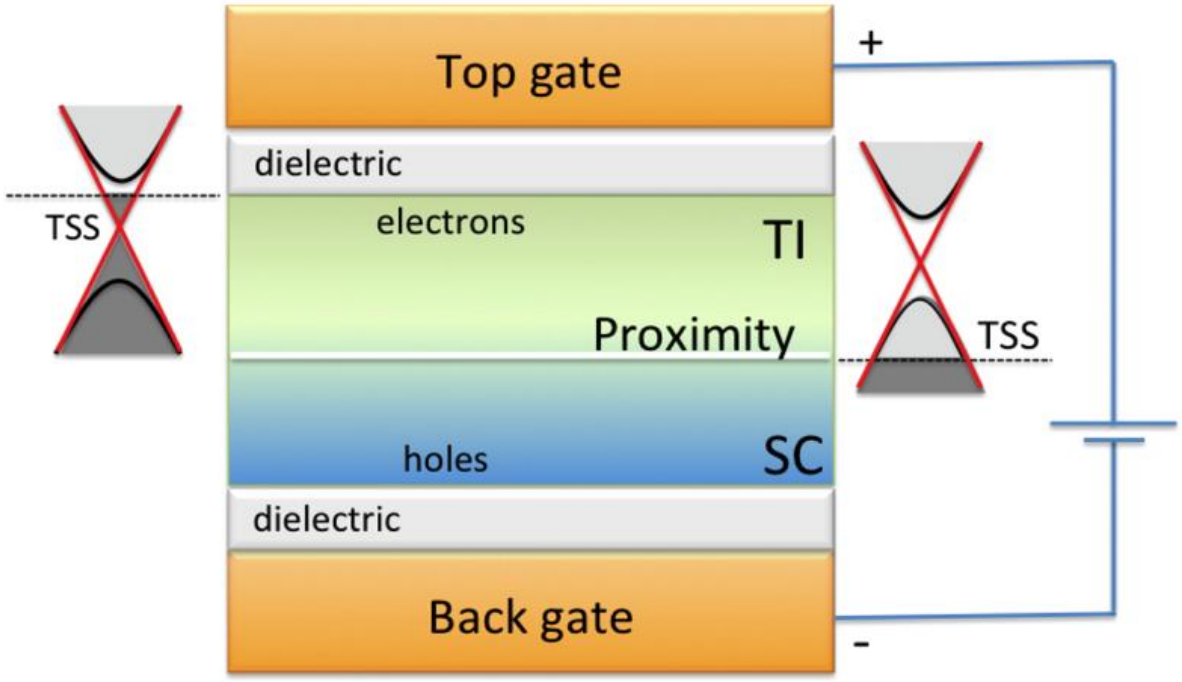


(D) monoclinic bulk

O-breathing
Octahedral distortion

TI + SC interface

A platform for Majorana fermions

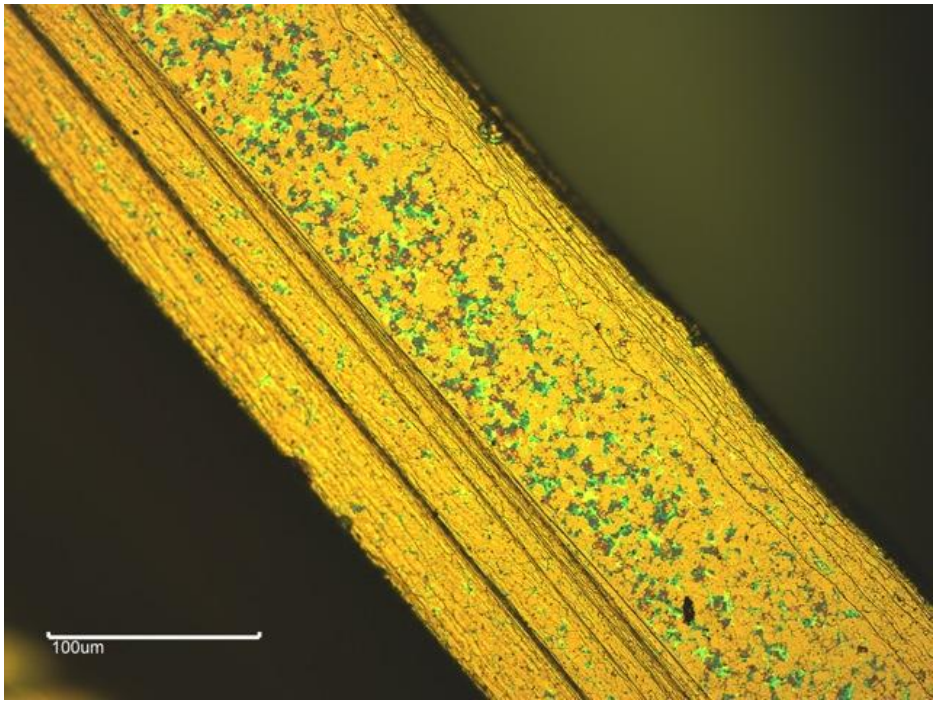


SC: p-type

TI: n-type

B. Yan, M. Jansen, C. Felser, Nature Physics, online

Mixed valent $BaBiO_3$

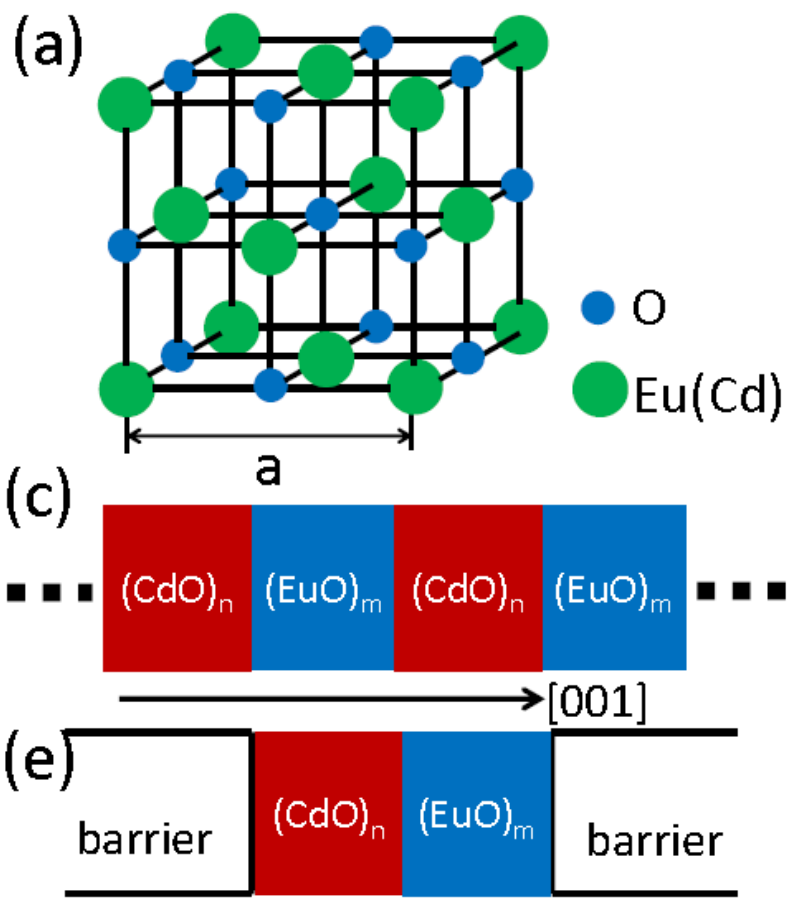


Single Crystals

Prediction in multilayer

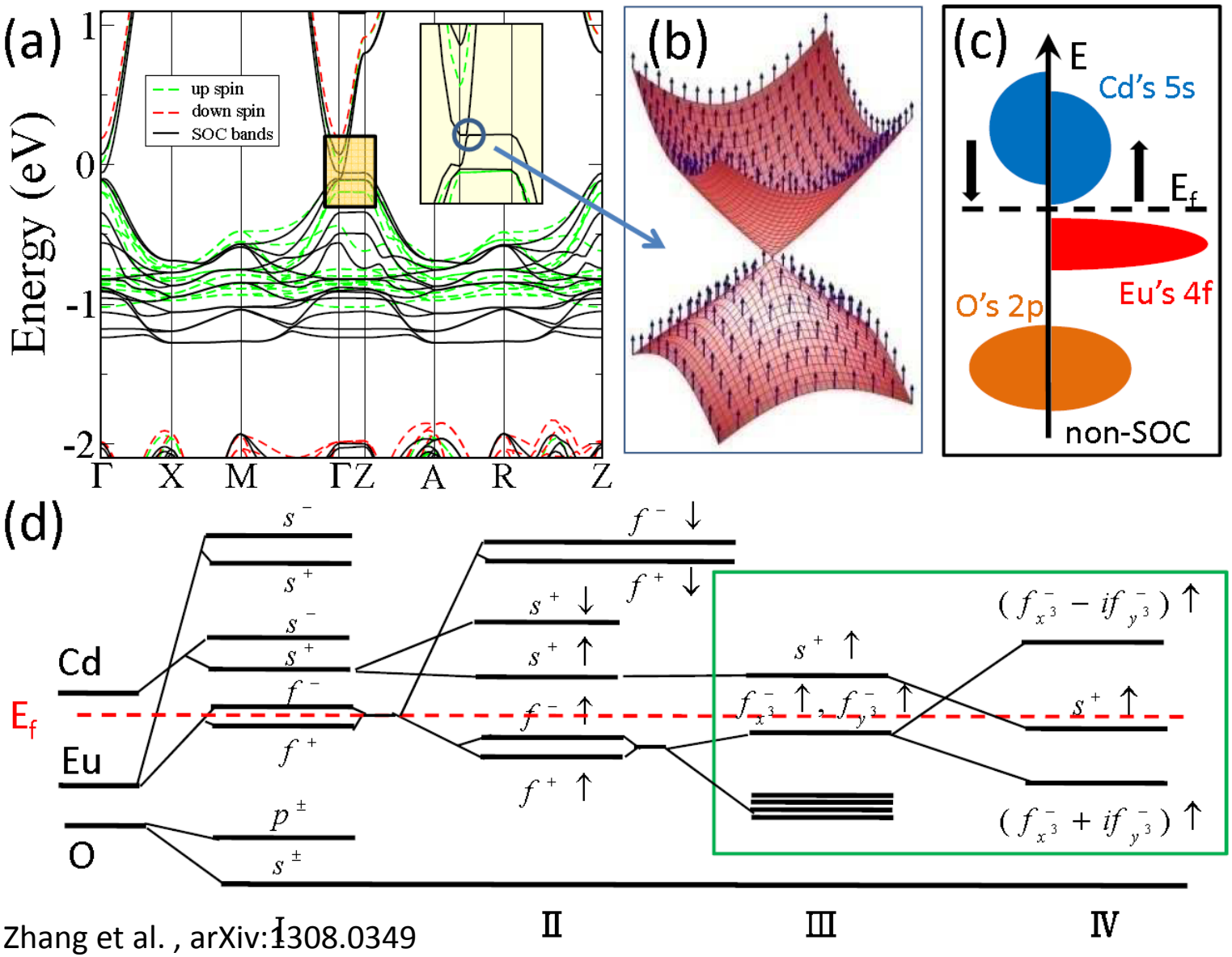
Topological States in Ferromagnetic CdO/EuO Quantum Well

Haijun Zhang, Jing Wang, Gang Xu, Yong Xu and Shou-Cheng Zhang
Department of Physics, McCullough Building, Stanford University, Stanford, CA 94305-4045, USA
(Dated: August 5, 2013)



Haijun Zhang et al. , arXiv:1308.0349

Prediction in multilayer



Haijun Zhang et al. , arXiv:1308.0349

Summary

Half Heusler as multifunctional TI

- Linear dispersion via ARPES
- TI plus superconductivity, Kondo, Magnetism

Correlated TIs with d – f inversion

- Skutterudites
- PuTe
- SmB_6 (Fisk) …

New oxide TI: $BaBiO_3$

- Large gap 0.7 eV
- Possible TI + SC interface
- Other s^2 systems such Tl^{+} Pb^{2+} Bi^{3+} for TI
- Other s^1 system stable against breathing for superconductivity such as $CsPbCl_2O$ or $BaPbO_2F$

What is next? Correlated oxides