A stride down the quantum materials roadmap

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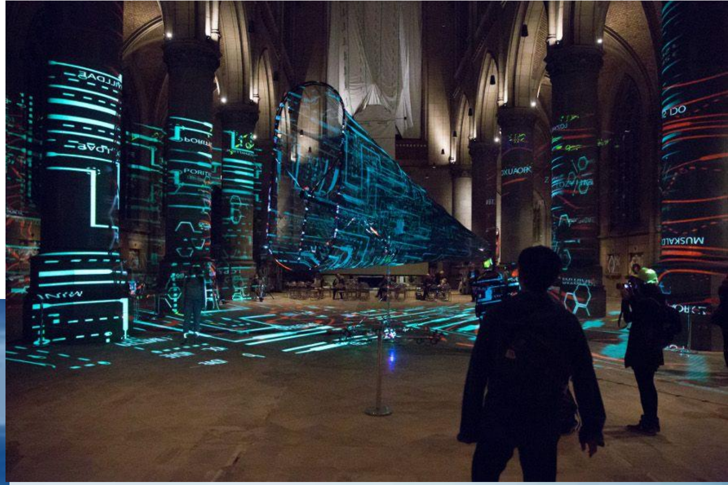

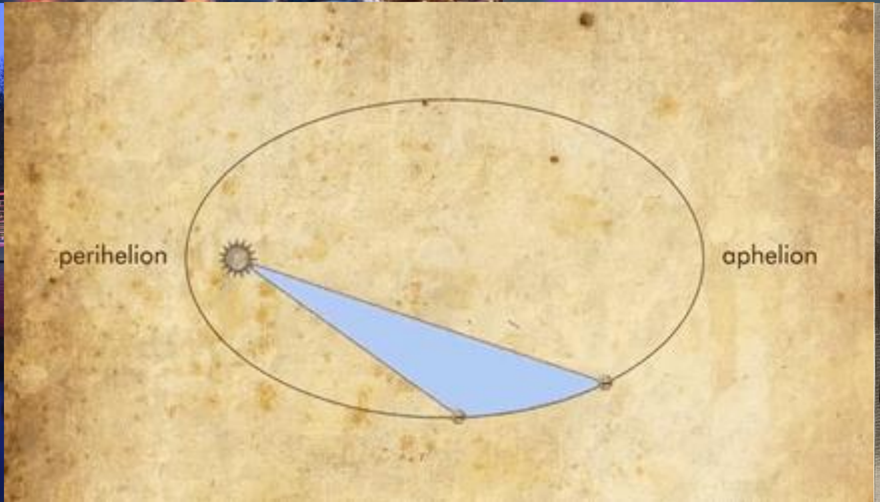


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Journal of Physics: Materials

ROADMAP

The 2021 quantum materials roadmap

Feliciano Giustino[1,2], Jin Hong Lee[3], Felix Trier[3], Manuel Bibes[3], Stephen M Winter[4], Roser Valentí[4], Young-Woo Son[5], Louis Taillefer[6,7], Christoph Heil[8], Adriana I Figueroa[9], Bernard Plaçais[10], QuanSheng Wu[11], Oleg V Yazyev[11], Erik P A M Bakkers[12], Jesper Nygård[13], Pol Forn-Díaz[14,15], Silvano De Franceschi[16], J W McIver[17], L E F Foa Torres[18], Tony Low[19], Anshuman Kumar[20], Regina Galceran[9], Sergio O Valenzuela[9,21], Marius V Costache[9], Aurélien Manchon[22], Eun-Ah Kim[23], Gabriel R Schleder[24,25], Adalberto Fazzio[24,25] and Stephan Roche[9,21]

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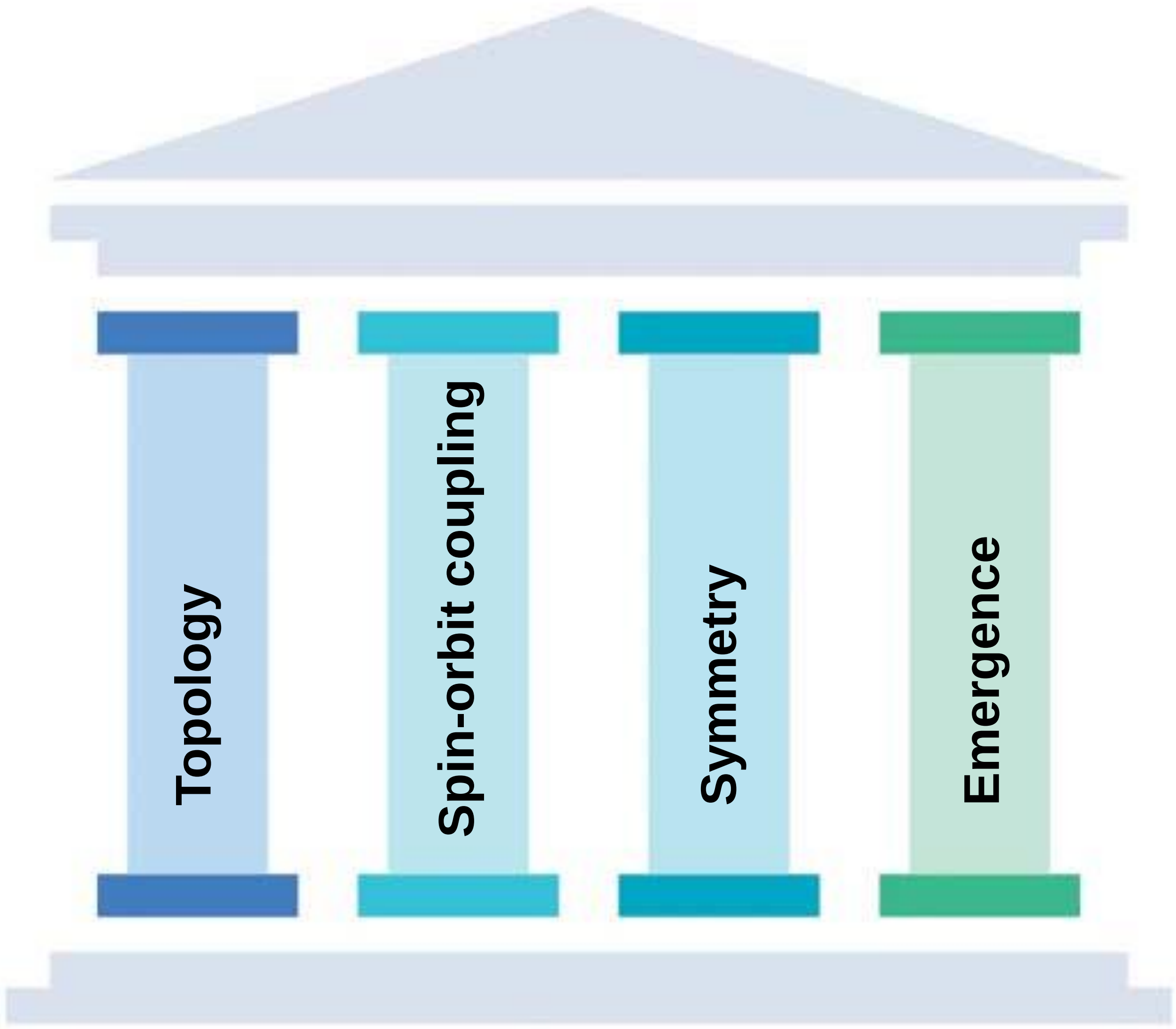
What are quantum materials?

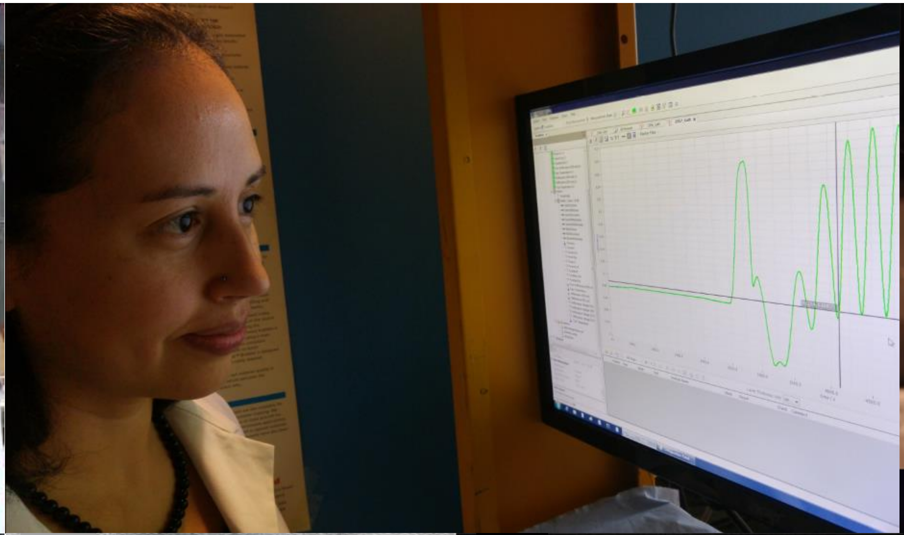
- Nature isn't classical and if you want to make a simulation of nature, you'd better make it quantum mechanical and it's a wonderful problem, because it doesn't look so easy

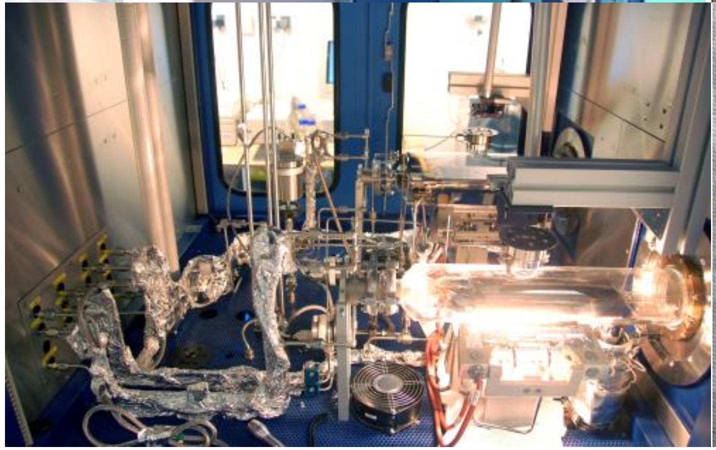
Richard Feynman 1981

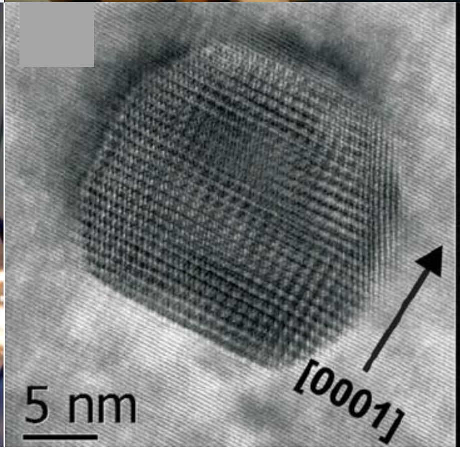

Topology
Spin-orbit coupling
Symmetry
Emergence

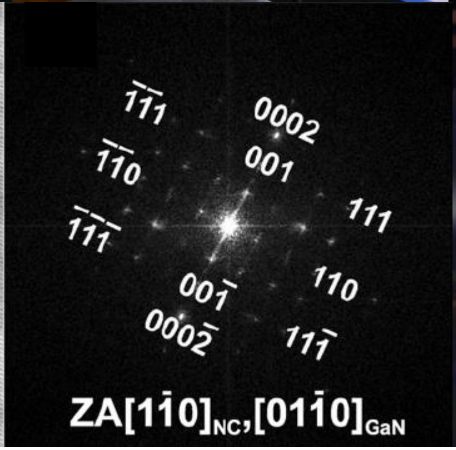

Kitaev Materials
(Un)Conventional superconductors: dressed and/or engineered
Topological states of matter
Quantum (conventional) materials: The next decade and beyond
Spin-orbit coupling + spin torque materials
Axion and Chern insulators
Beyond graphene 2D materials

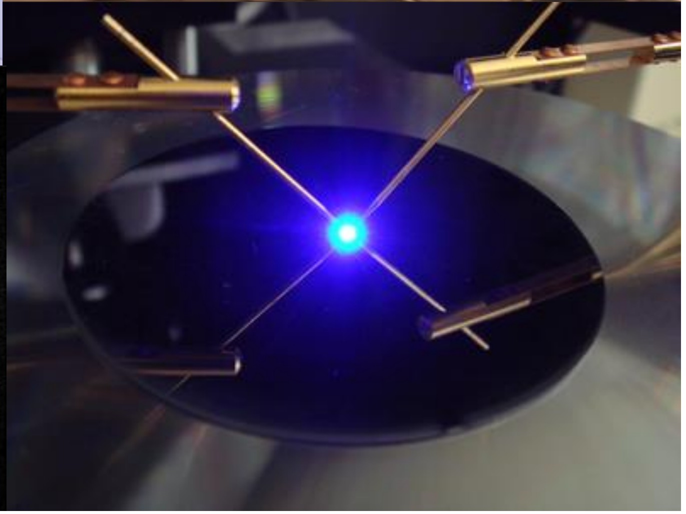
Long tradition: crystal growth and extended characterization



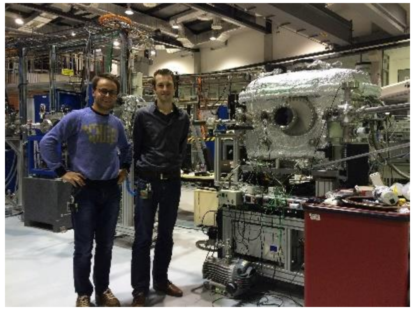


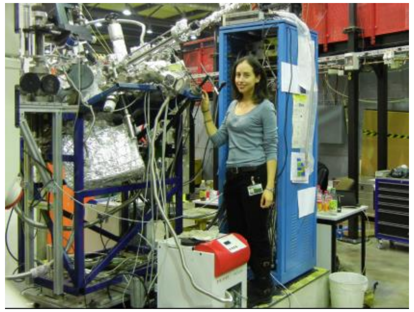


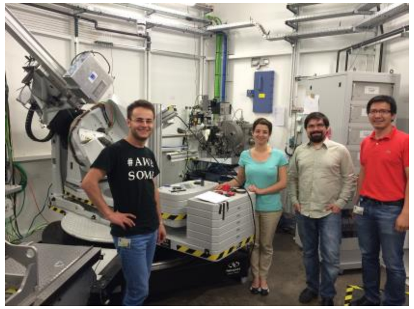




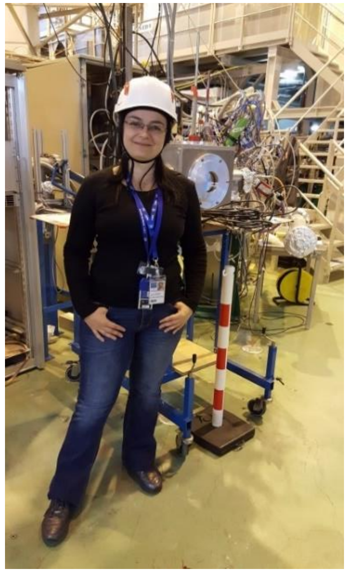
Characterization - synchrotrons







ISOLDE-CERN: Mössbauer, channeling



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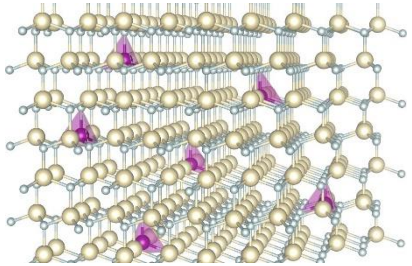
SOLEIL-Paris: XAS, XES

(Ga,Mn)N

[x up to 6% in MOVPE and up to 10% in MBE]

without band carriers



DMS → (Ga,Mn)N spin filters, resonant structures

W. Stefanowicz,...AB, Phys.Rev.B **81**, 125210 [2010]
J. Suffczyński,...AB, Phys.Rev.B **83**, 235210 [2011]
M. Sawicki,...AB, Phys.Rev.B **85**, 205204 [2012]
G. Kunert,...AB,...Appl.Phys.Lett. **101**, 0224213 [2012]
S. Stefanowicz,...AB,... Phys.Rev.B **88**, 081201(R) [2013]
R. Adhikari,...AB, Phys.Rev.B **91**, 205204 [2015]
T. Dietl,...AB,..., Rev.Mod.Phys **87**, 1311 [2015]
D. Sztenkiel, ...AB,..., Nat.Commun. **7**, 13232 [2016]

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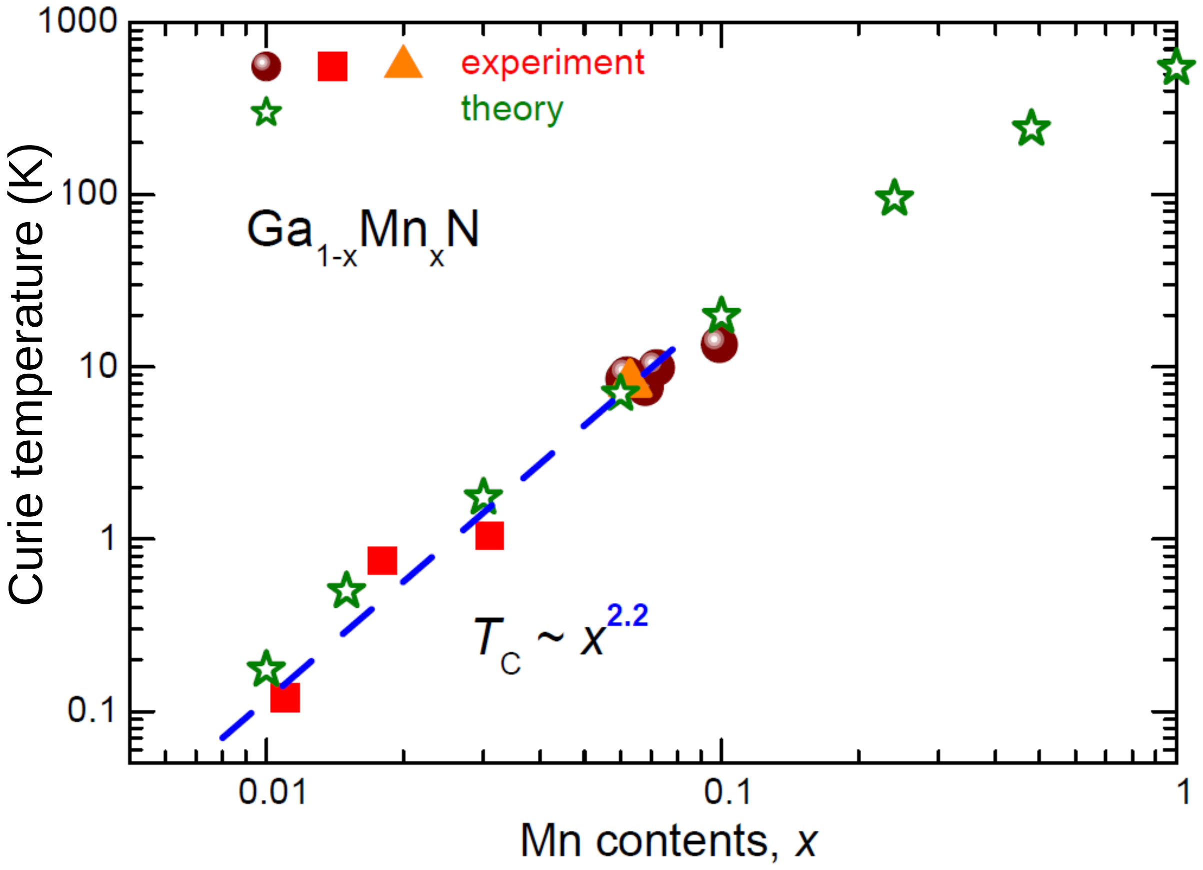
(Ga,Mn)N – T_C – Experiment *vs.* TBA + MonteCarlo

- Ferromagnetic interaction
- Character of *sp-d* hybridization

  → scaling dependence

- Monte Carlo with exchange integrals from tight-binding
- FM superexchange



M. Sawicki,...AB, Phys.Rev.B **85**, 205204 [2012]

S. Stefanowicz,...AB,... Phys.Rev.B **88**, 081201(R) [2013]

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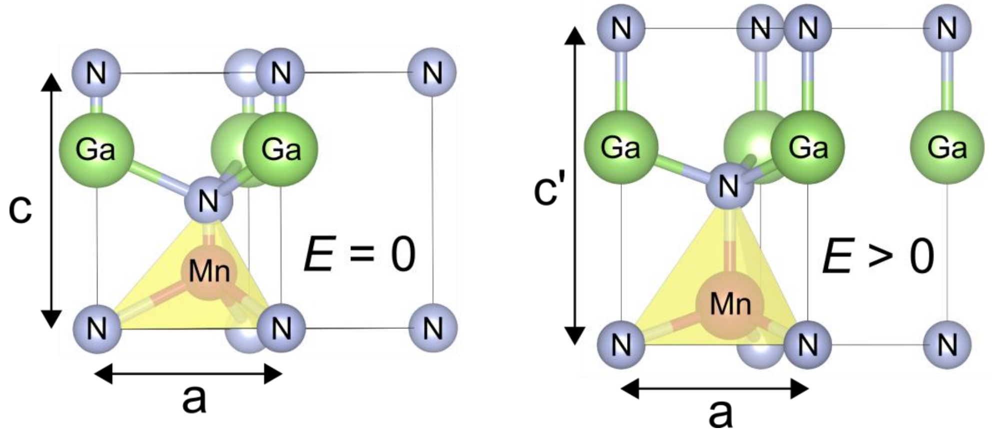
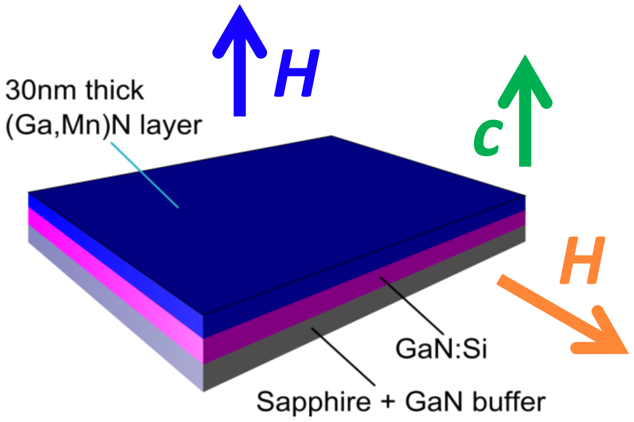
Electric field modulation of magnetism in (Ga,Mn)N



D. Sztenkiel, …AB,… Nat. Commun. **7**, 13232 [2016]



Magnetic anisotropy in (Ga,Mn)N

$$H = H_{CF} + H_{JT} + H_{TR} + H_{SO} + H_{Z}$$

Tetrahedral crystal field

Jahn-Teller splitting

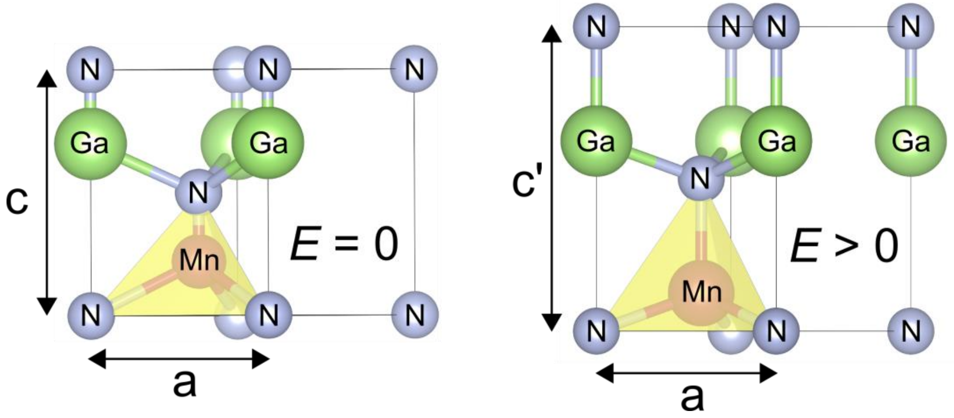
Trigonal distortion

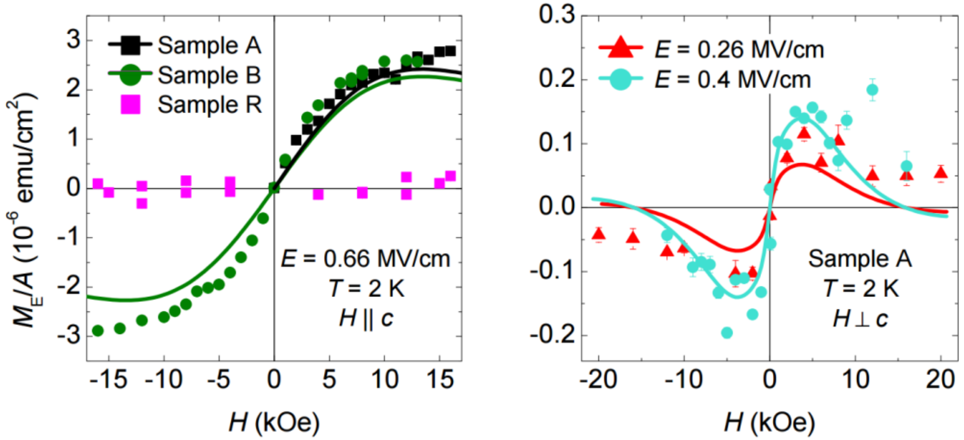
Spin-orbit coupling

Zeeman splitting

$$H_{TR} \propto \xi = c/a - \sqrt{8/3}$$

In (Ga,Mn)N → $\xi < 0$ → $M(H \perp c) > M(H \| c)$





W. Stefanowicz,...AB, Phys.Rev.B **81**, 125210 [2010]

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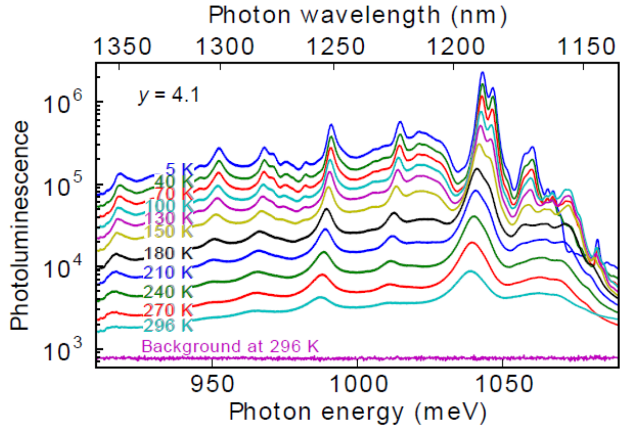
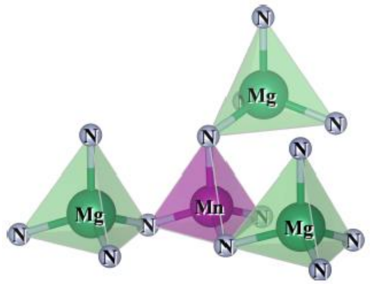
(Ga,Mn)N:Mg



complexes → Centers for solotronics and quantum computing

complexes →
Photonics:
[(Al)Ga,Mn)]N:Mg-
based infrared lasers

Optimized DUV LEDs



T. Devillers,...,AB, Sci. Rep. **2**, 722 [2012]

T. Devillers,...,AB, Appl. Phys. Lett. **103**, 211909 [2013]

G. Capuzzo,...,AB, Sci. Rep. **7**, 426972 [2017]

D. Kysylychyn,...,AB, Phys. Rev. B **97**, 245311 [2018]

A. Nikolenko,...AB, Crystals **9**, 235 [2019]

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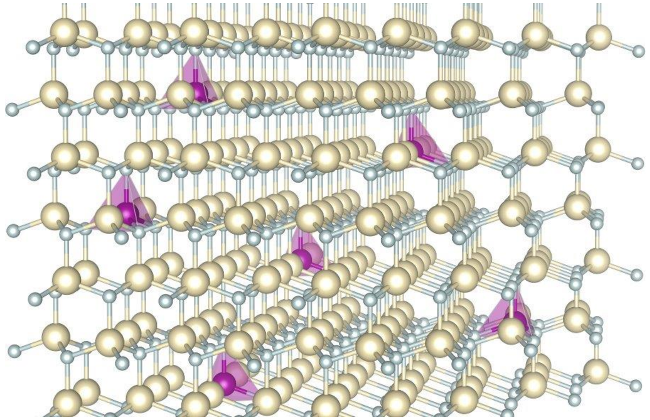
(Ga,Mn)N:Mg – $MnMg_k$ complexes



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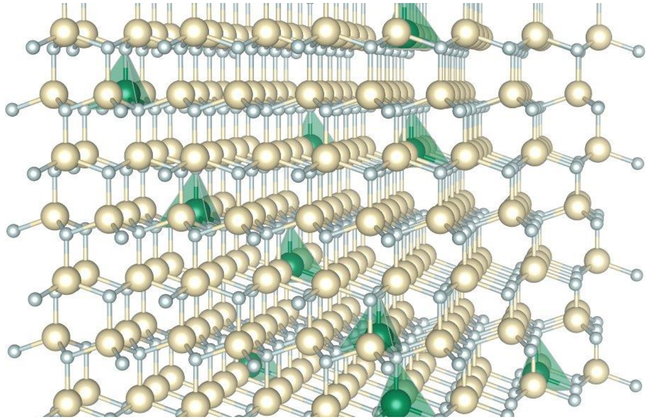
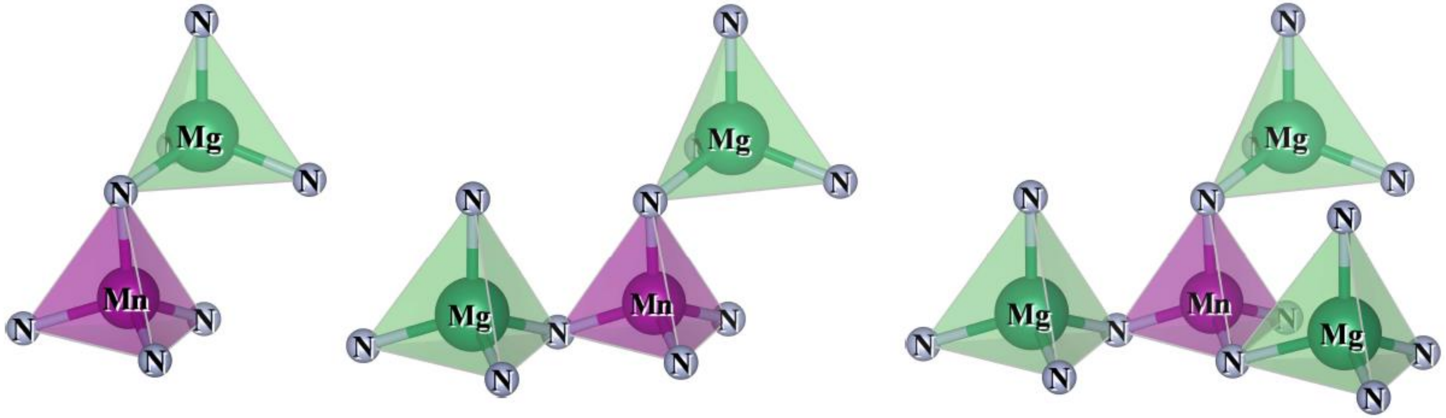


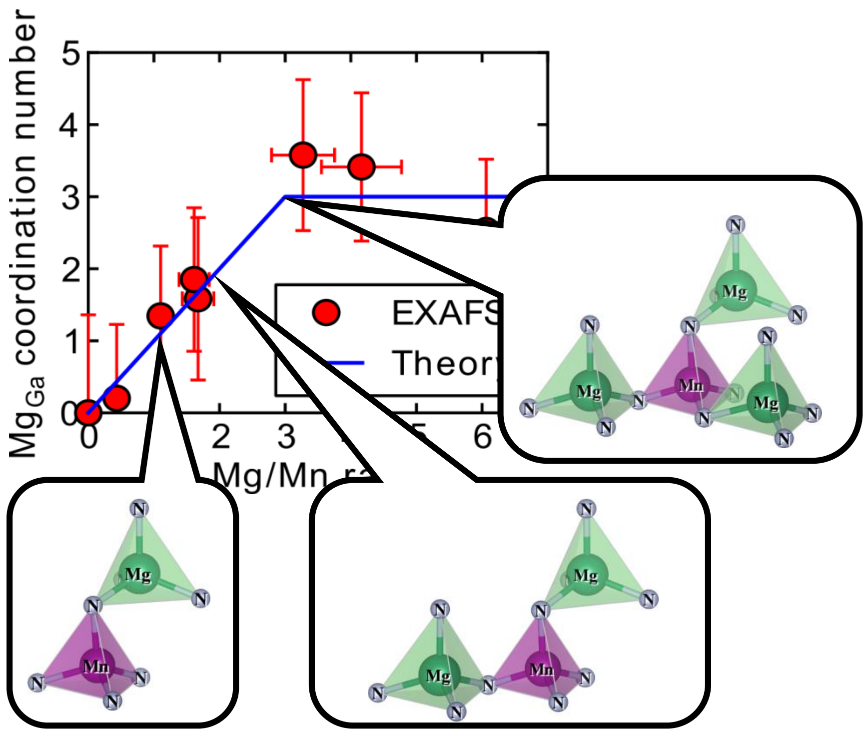
(Ga,Mn)N

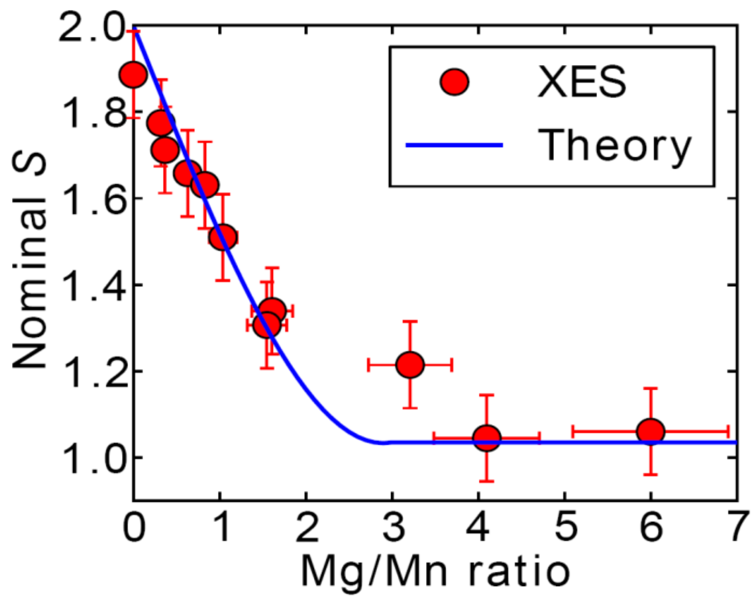
(Ga,Mg)N



MnMg (-0.51eV) $MnMg_2$ (-0.58eV) $MnMg_3$ (-0.21eV)

(Ga,Mn)N:Mg – control over charge and spin state





charge: **Mn^{3+}** → **Mn^{5+}**

spin: ***S* =2** → ***S* =1**

T. Devillers,...,AB, Sci. Rep. **2**, 722 [2012]

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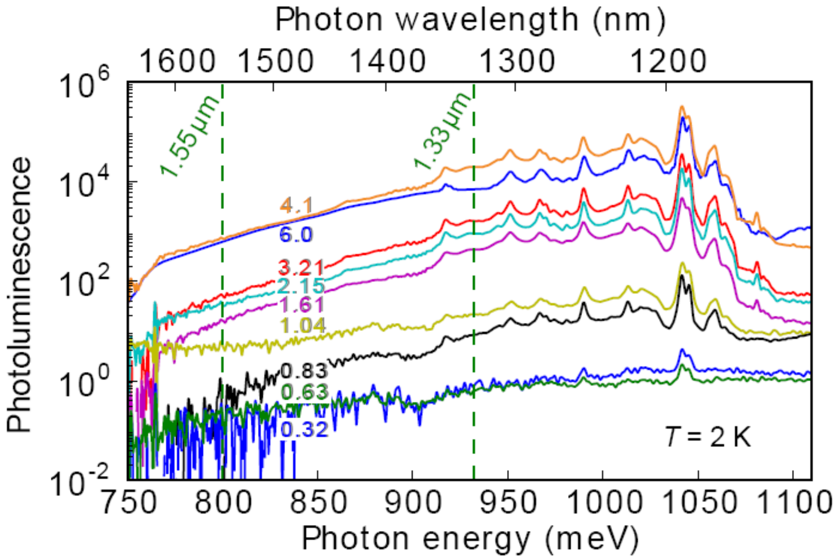
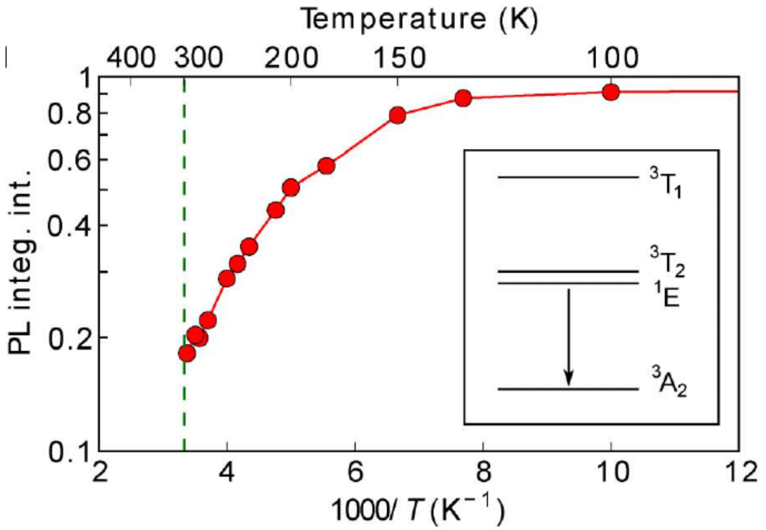
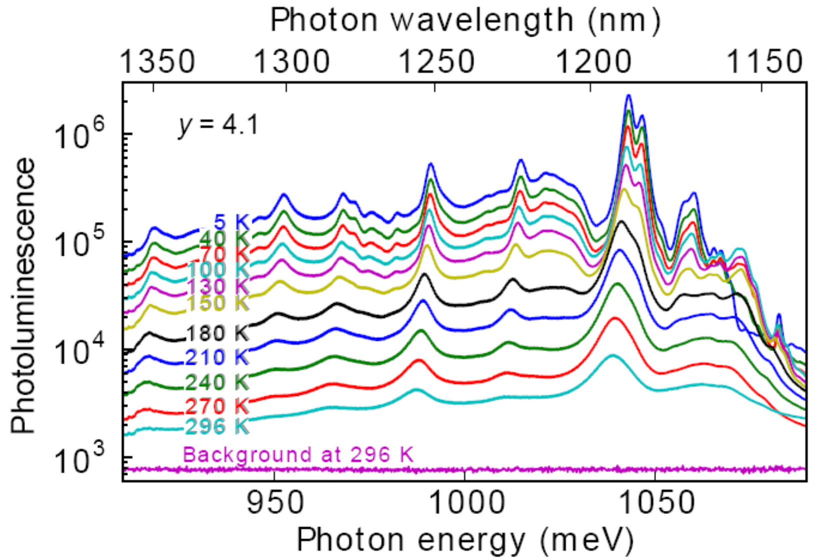
(Ga,Mn)N:Mg – and emitting in the IR







\ IR emission

\ up to room temperature

T. Devillers,...,AB, Sci. Rep. **2**, 722 [2012]

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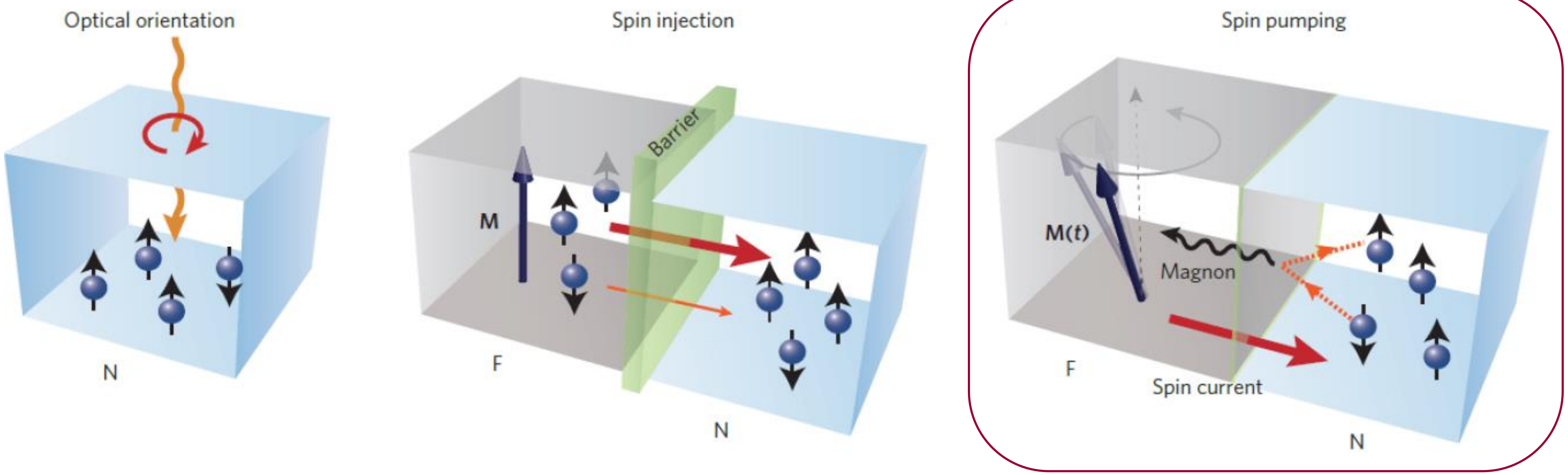
Generation of spin currents



J. Sinova,…T. Jungwirth, Rev. Mod. Phys. **87**, 1213 [2015]

I. Žutic and H. Dery, Nat. Mater. **10**, 647 [2011]

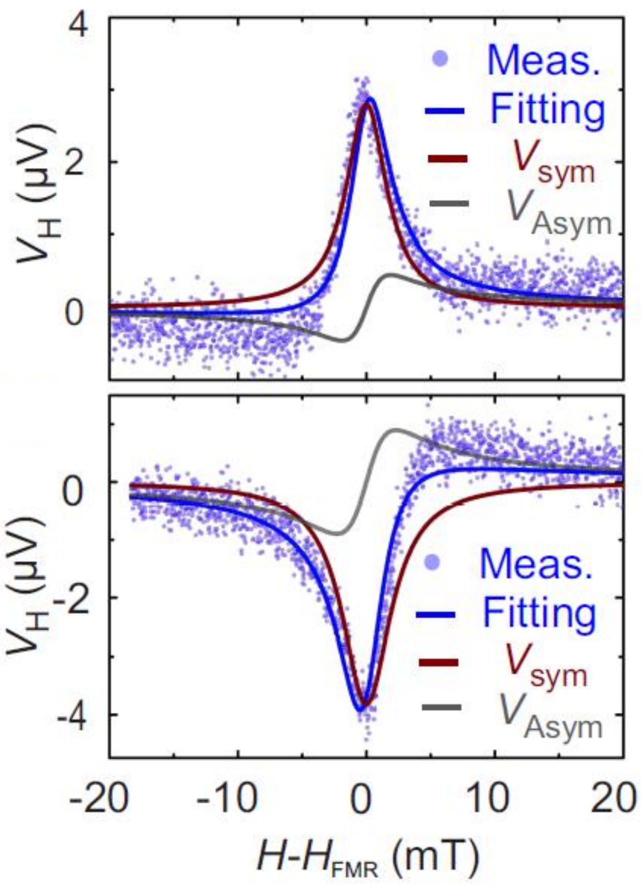
Y. Tserkovnyak *et al.*,
Phys. Rev. Lett. **88**, 117601 [2002]

E. Saitoh *et al.*,
Appl. Phys. Lett. **88**, 182509 [2006]

Estimation of spin Hall angle θ_{HA} in *n*-GaN:Si

$$\theta_{SH} = \left(\frac{\hbar}{2e}\right) \frac{V_{ISHE}\,(d_N\sigma_N + d_F\sigma_F)}{w\sigma_N \tanh\left(\frac{d_N}{2\lambda_N}\right) j_s^0}$$

- Function of:
  - spin current density j_s^0
  - inverse spin Hall voltage V_{ISHE}



- $\theta_{HA} = 3.03 \times 10^{-3}$ for *n*-GaN:Si
- 10> than other semiconductors like *e.g.*: Si, Ge, ZnO, *n*-GaAs

R. Adhikari,…..,AB, Phys. Rev. B **94**, 085205 [2016]

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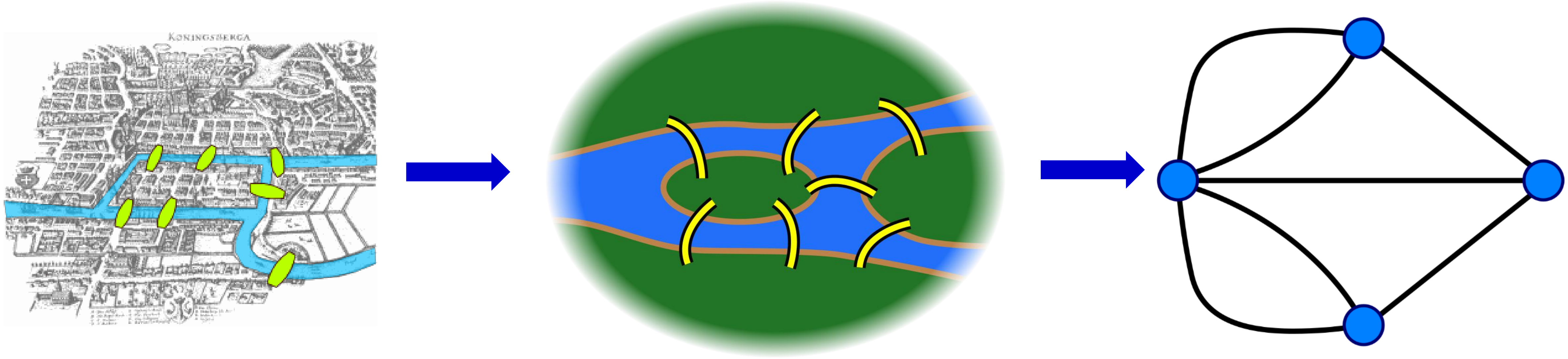
$Sn_{(1-x)}[Mn_{(x)}]Te$

a crystalline topological insulator

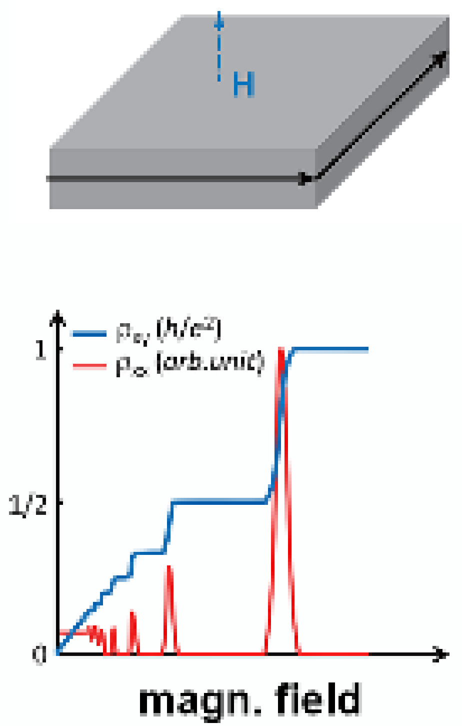
Königsberg bridges: the birth of topology

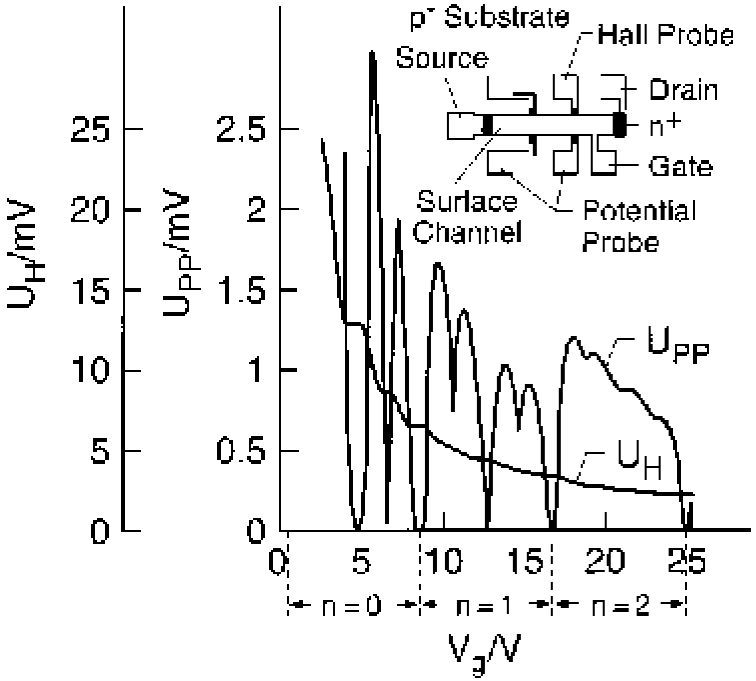


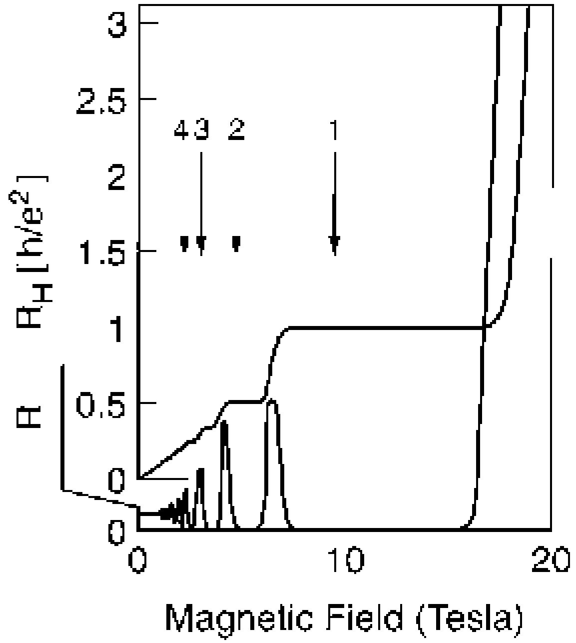
■ Leonhard Euler [1736] → solution with network diagrams [vertices and arcs]

Topology in condensed matter physics

[integer] quantum Hall effect

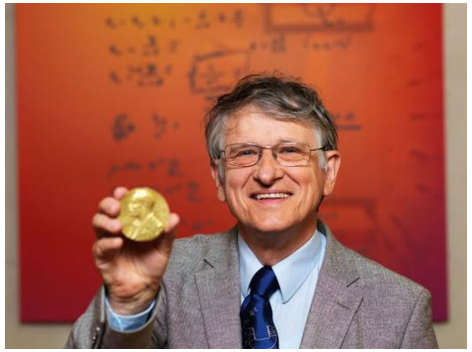






K. von Klitzing *et al.*, Phys. Rev. Lett. **45**, 494 [1980]

K. von Klitzing *et al.*, Annu. Rev. Condens. Mater. **8**, 13 [2017]



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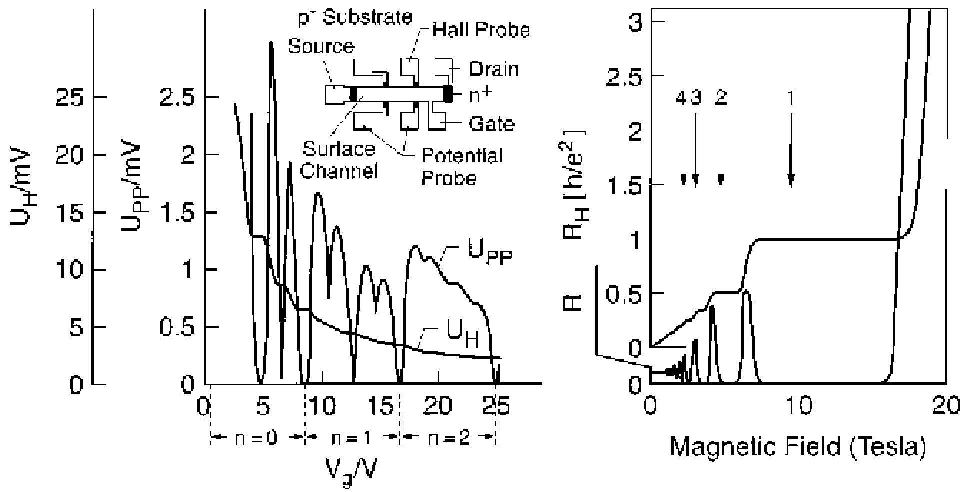
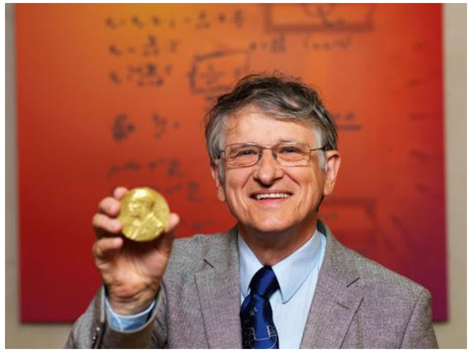
Relevant for metrology → IQHE → resistance standard

Integer quantum Hall effect – topologically protected phase

- Response function characterized by topological invariant $n \in \mathbb{Z}$
- Hall conductance $\sigma_{xy} = \left(\frac{ne^2}{h}\right)$
  - ☐ n → number of Landau levels under Fermi level





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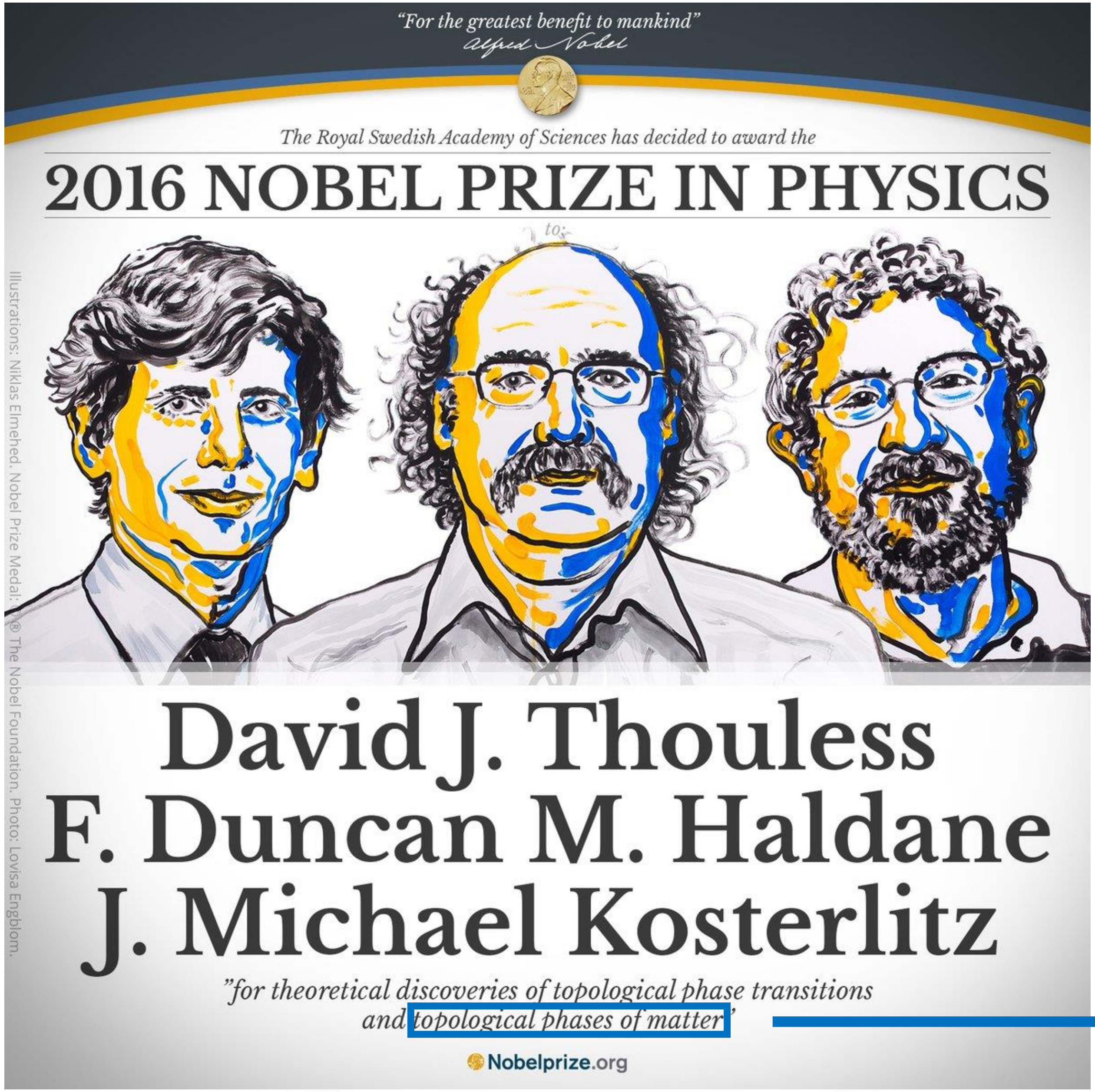
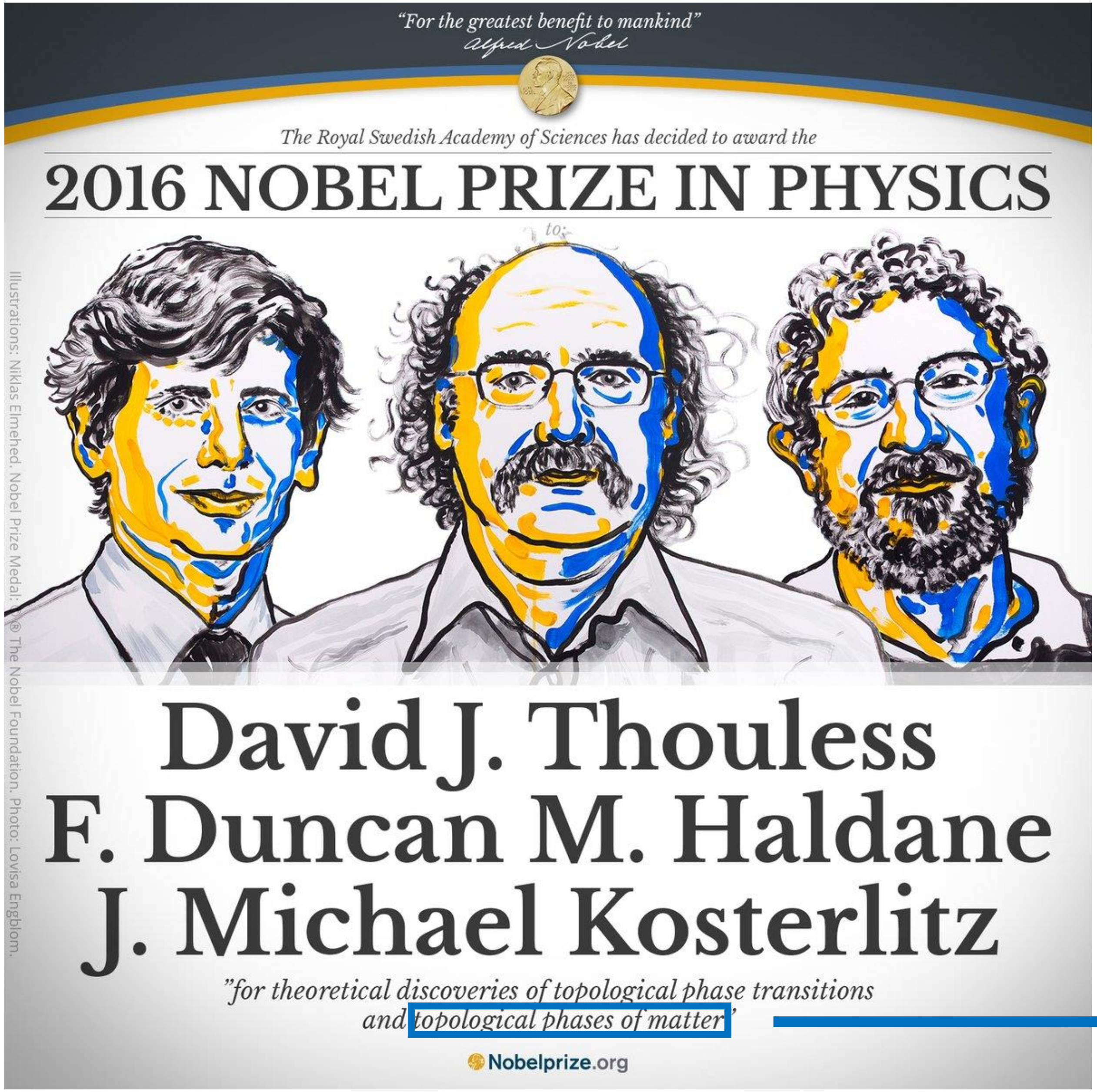


$$C = \frac{1}{2\pi}\int d^2\boldsymbol{k}\mathcal{F}_b$$

- Quantization of Hall conductance
- Odd under time-reversal symmetry $\mathcal{T}$
  - symmetry breaking → non-trivial states
- High magnetic fields required

Symmetry protected topological phases of matter

D.J. Thouless *et al.*, Phys. Rev. Lett. **49**, 405 [1982]



$$C = \frac{1}{2\pi}\int d^2\boldsymbol{k}\mathcal{F}_b$$

- Quantization of Hall conductance
- Odd under time-reversal symmetry $\mathcal{T}$
  - symmetry breaking → non-trivial states
- SOC → topological insulators with preserved $\mathcal{T}$

M.Z. Hasan and C.L. Kane, Rev. Mod. Phys. **82**, 041004 [2010]
M. König *et al.*, Science **318**, 766 [2007]

Symmetry protected topological phases of matter

D.J. Thouless *et al.*, Phys. Rev. Lett. **49**, 405 [1982]

Chiral edge states as dissipationless channels

- Chern number $\mathcal{C}$ → number of dissipationless channels
- Topological insulators → $\mathcal{C} = \pm 1$ → only time-reversal $\mathcal{T}$ protects the topology
- Challenge → $|\mathcal{C}| > 1$

PRL **106,** 106802 (2011) PHYSICAL REVIEW LETTERS week ending 11 MARCH 2011

Topological Crystalline Insulators

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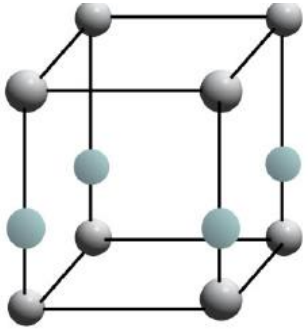
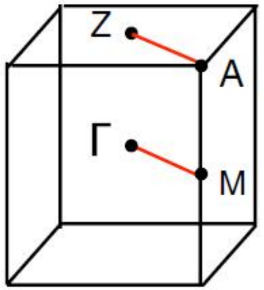
Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

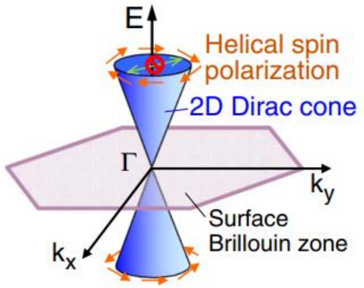
Topology protected by mirror symmetry $\mathcal{M}$





Topological crystalline insulators

- Crystal point group symmetries accounted for
- Presence of surfaces → crystal symmetry breaking
- TCI → counterpart of TI in systems without SOC
  - e^- orbital degree of freedom → role similar to spin



Y. Ando *et al.*, J. Phys. Soc. Jap. **82**, 102001 [2013]

- TI → linear dispersion of Dirac surface states
  - protection: time-reversal invariant
  - single Dirac cone
- TCI → quadratic band degeneracy
  - protection: crystal [point-group] symmetry
  - mirror $\mathcal{M}$ symmetry → two independent topological invariants C_t and $C_{\mathcal{M}}$
  - four Dirac cones

Liang Fu, Phys. Rev. Lett. **106**, 106802 [2011]
Su-Yang Xu *et al.*, Nature Commun. **3**, 1192 [2012]

nature COMMUNICATIONS

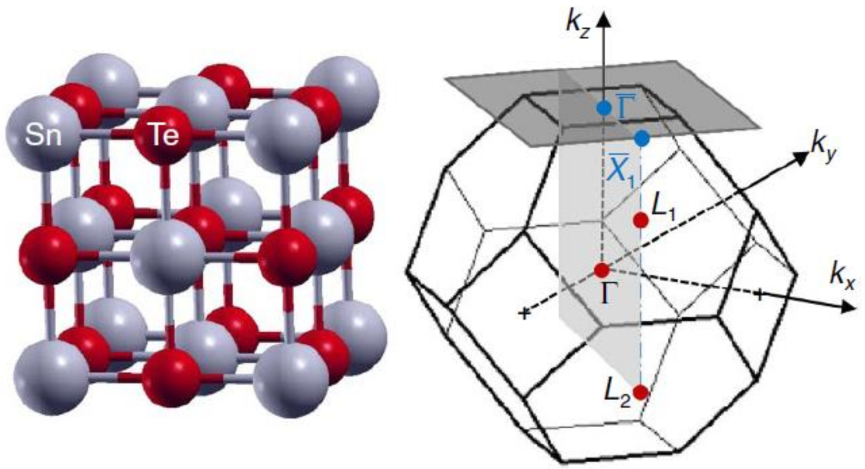
ARTICLE

Received 23 Feb 2012 | Accepted 21 Jun 2012 | Published 31 Jul 2012

DOI: 10.1038/ncomms1969

Topological crystalline insulators in the SnTe material class

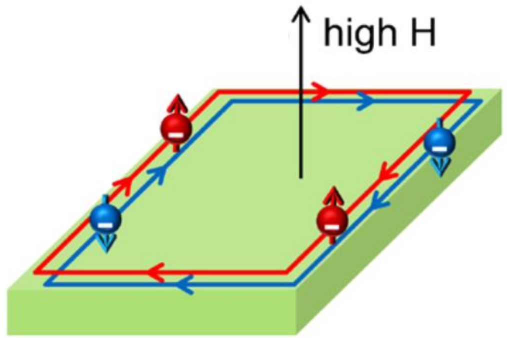
Timothy H. Hsieh[1], Hsin Lin[2], Junwei Liu[1,3], Wenhui Duan[3], Arun Bansil[2] & Liang Fu[1]



- $|C_{\mathcal{M}}| \neq 0 = 2$
- [one isotropic Dirac surface state $\bar{\Gamma}$]+ [three anisotropic at $\bar{M}$]
- Majorana-like excitations stabilized at surface steps

P. Sessi *et al.*, Science **354**, 1269 [2016]

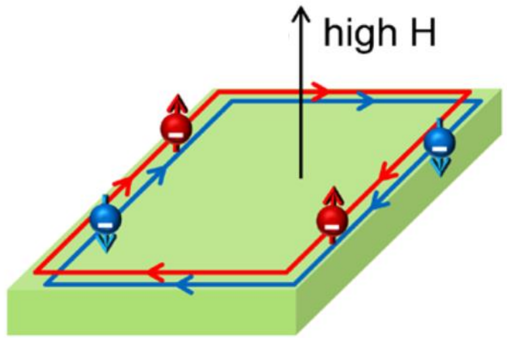
Chiral edges as dissipationless channels



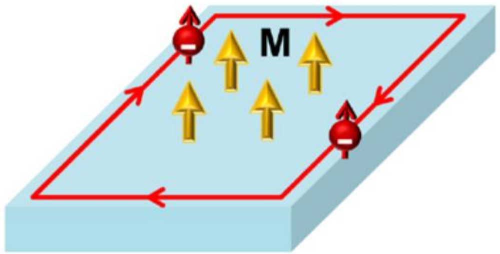
QHE

- 2D electron gas
- high magnetic field required

By adding magnetic elements



QHE
- 2D electron gas
- high magnetic field required



QAHE
- magnetic topological insulator
- intrinsic ***M***
- no magnetic field required

C.Z. Chang *et al*., Science **340**, 6129 [2013]

Ferromagnetic insulator with $|C| \neq 0$:

→ [intrinsic anomalous Hall effect and QHE] & [geometric Berry phase] → QAH states

→ quantization of Hall conductance σ_{xy} in the absence of external field

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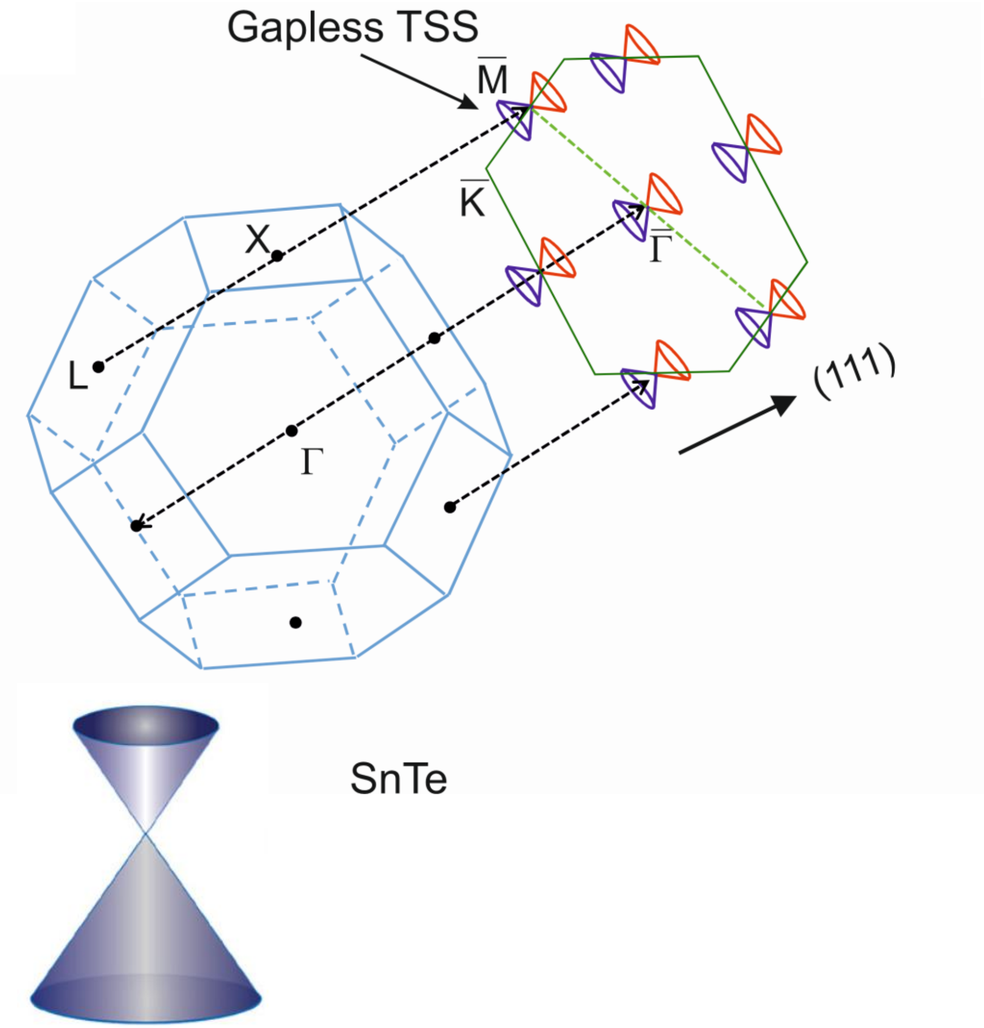
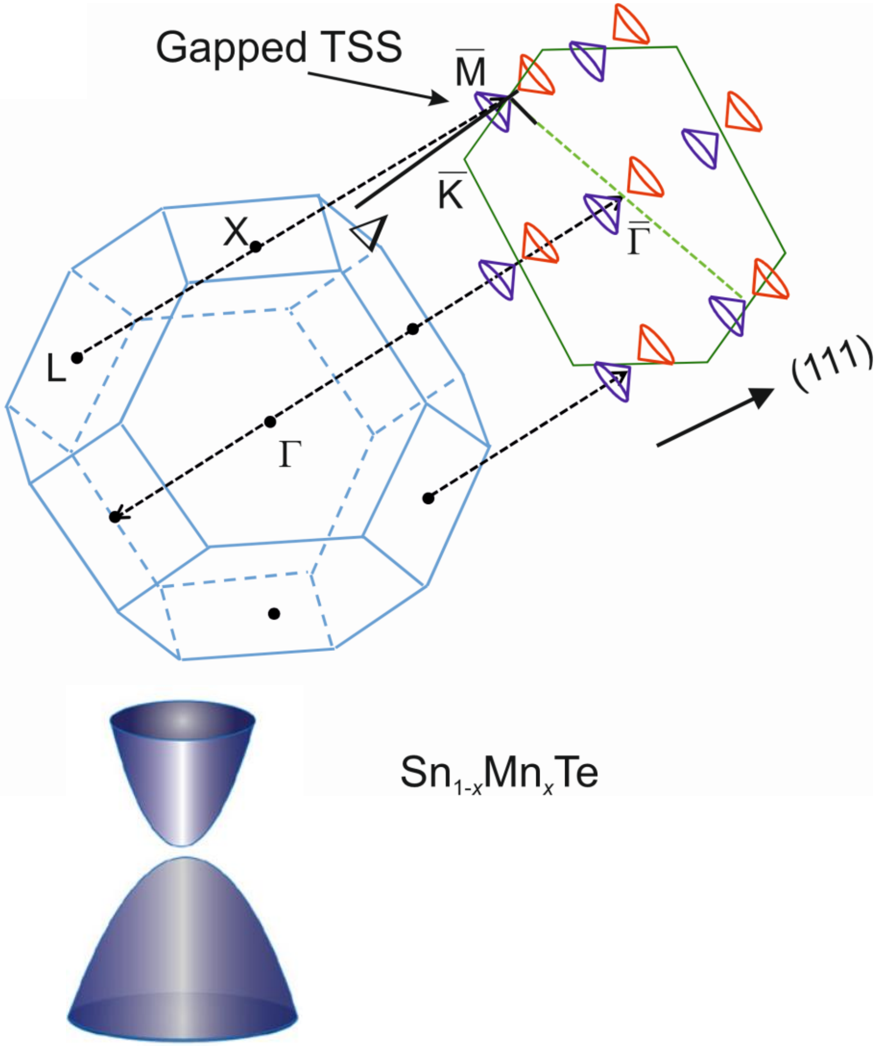
N. Nagaosa *et al*., Rev. Mod. Phys. **82**, 1539 [2010]

Effect of Mn doping on SnTe band structure





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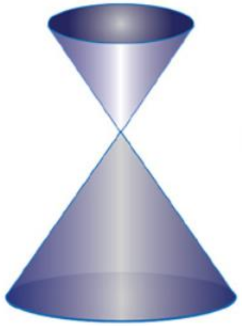
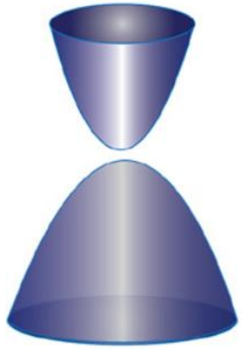
SnTe *vs.* $Sn_{1-x}Mn_xTe$

- **SnTe**



  - ☐ narrow band-gap [direct, ~0.18 eV]
  - ☐ thermoelectric material
  - ☐ *p*-type conductivity, $p \sim 10^{20}$ cm^{-3}

- **$Sn_{1-x}Mn_xTe$**



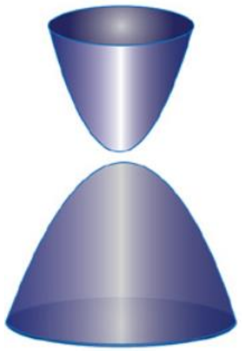
  - ☐ dilute magnetic semiconductor
  - ☐ carrier-mediated ferromagnetism [RKKY]

G. Tan *et al.*, J. Am. Chem. Soc. **35**, 137 [2015]

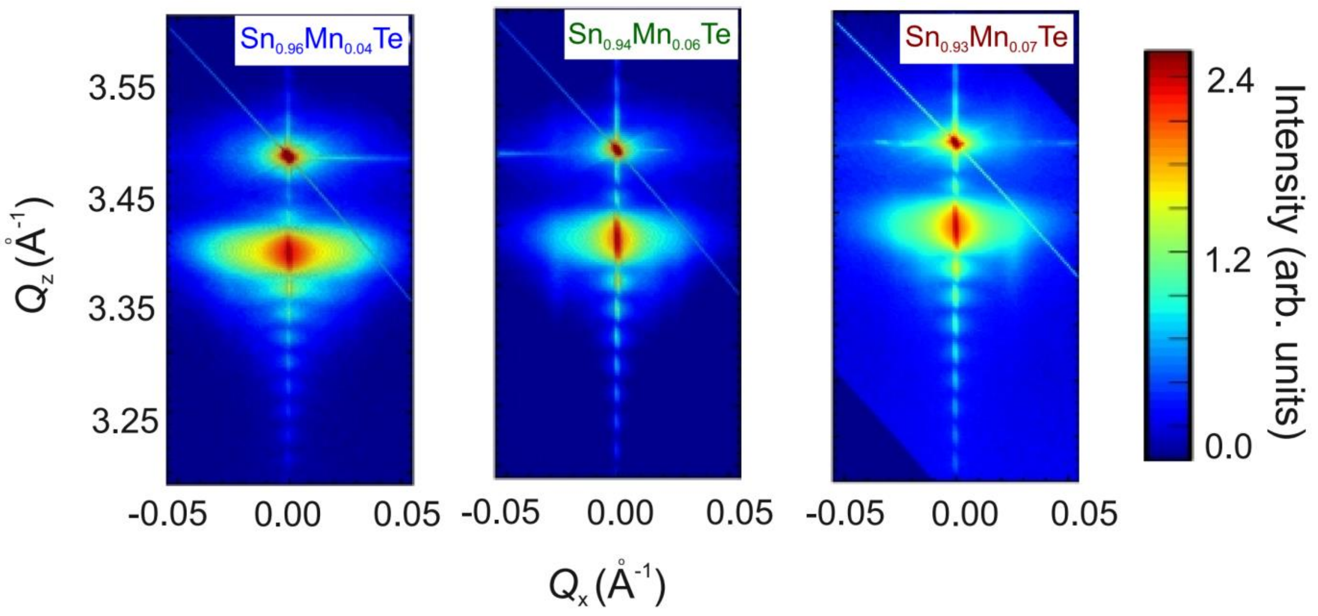
Mn doping and topology in SnTe

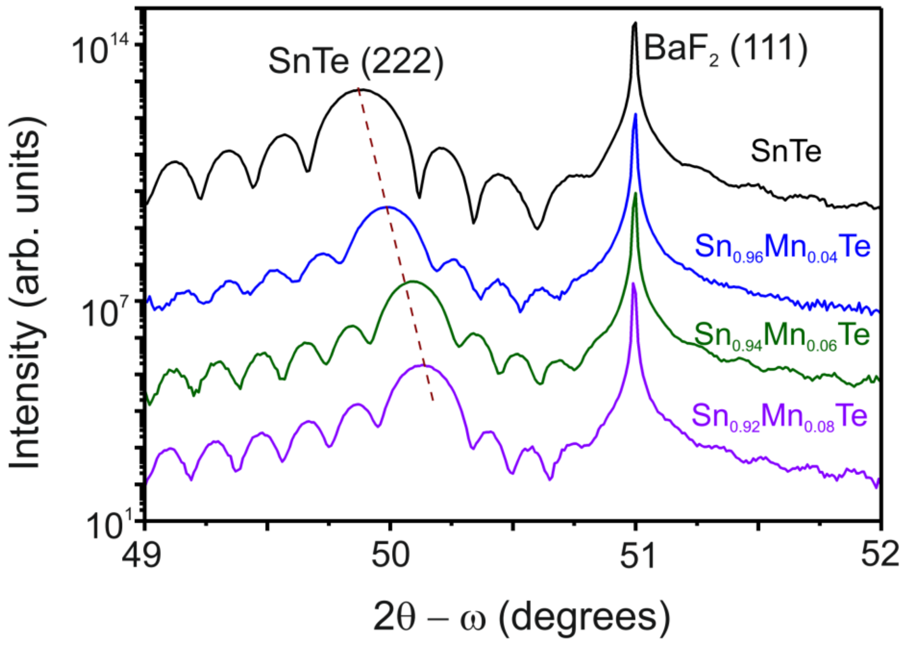
- **$Sn_{1\text{-}x}Mn_xTe$**
  - ☐ gapped Dirac cones at the time-reversal invariant momenta [TRIM] points $\bar{\Gamma}$ and $\bar{M}$
  - ☐ total Chern number → $C_{\mathrm{tot}} = C_{\mathrm{T}} + C_{\mathrm{M}}$
  - ☐ QAHE in ferromagnetic SnTe [predicted]
  - ☐ 4 dissipationless chiral edge channels

- **Criteria for QAH states**
  - ☐ ferromagnetic ordering
  - ☐ emergence of AHE
  - ☐ perpendicular magnetic anisotropy
  - ☐ sample thickness *vs*. decay length of topological surface states



$Sn_{1-x}Mn_xTe(111)$ – structural characterization





- ☐ $Sn_{1-x}Mn_xTe(111)$ strained on $BaF_2(111)$ substrate
- ☐ Mn incorporated into SnTe lattice
- ☐ no evidence of secondary phases
- ☐ Mn concentration follows Vegard‘s law

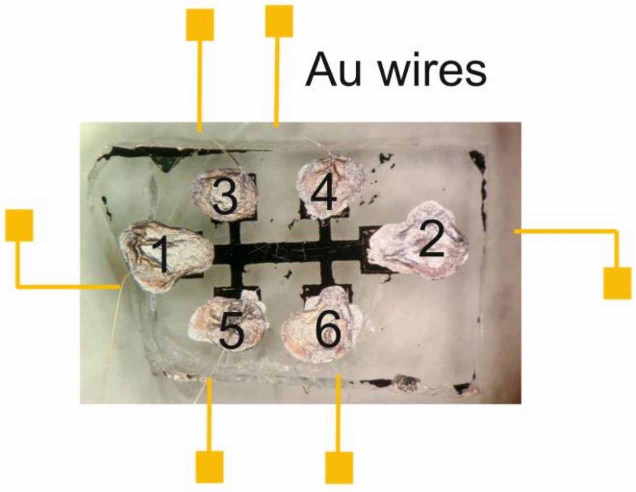
JKU

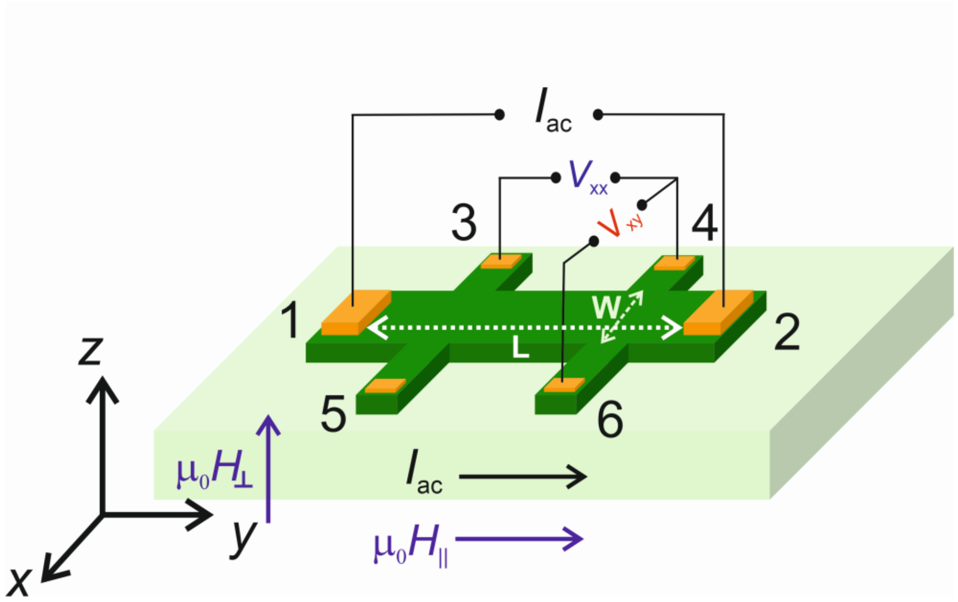
R. Adhikari,…., and AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – electronic properties

Magnetotransport

- ☐ lithographically designed Hall bars
- ☐ ac lock-in
- ☐ $1.8\ \mathrm{K} \leq T \leq 300\ \mathrm{K}$
- ☐ $-7\ \mathrm{T} \leq \mu_0 H \leq +7\ \mathrm{T}$

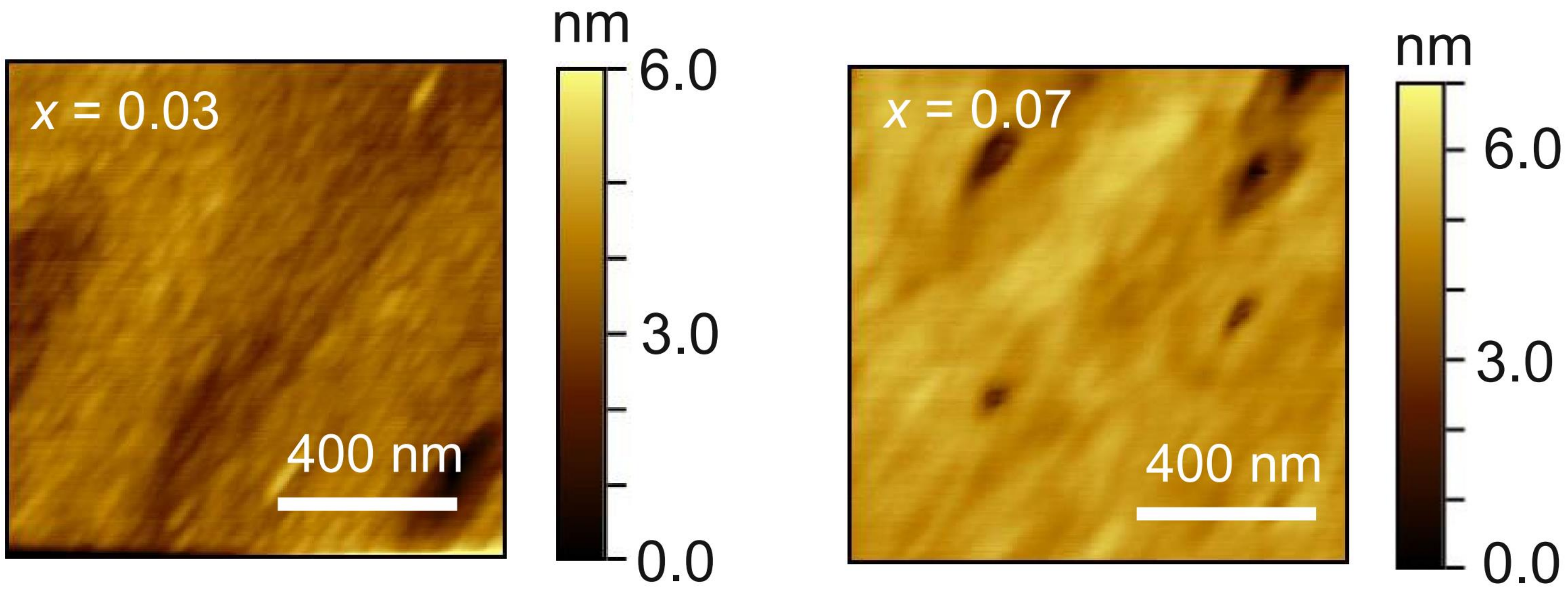




R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

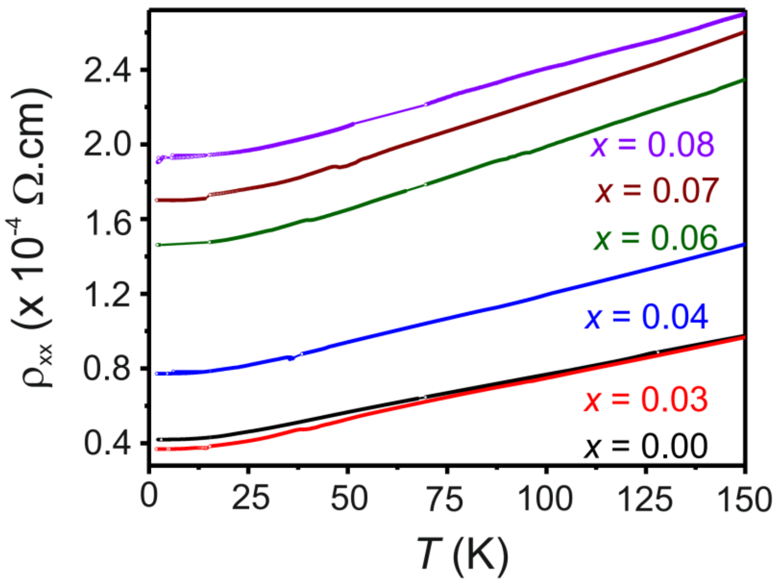
$Sn_{1-x}Mn_xTe$ samples

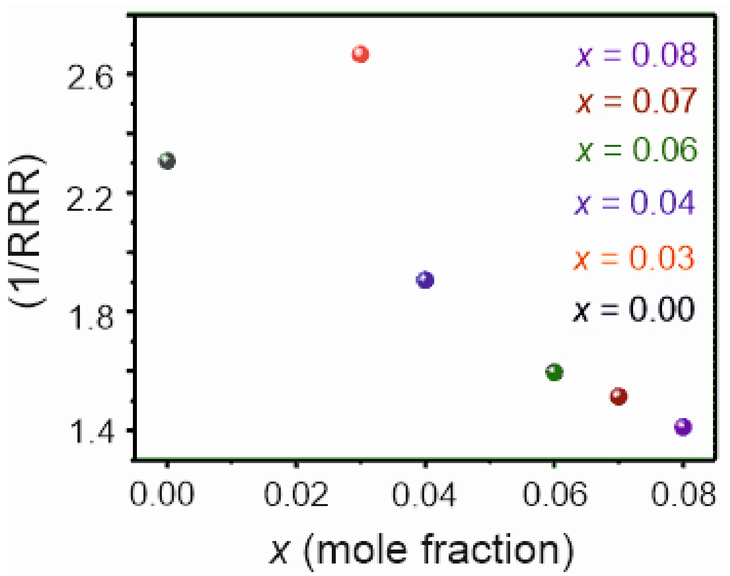
- **Epitaxial $Sn_{1-x}Mn_xTe(111)$**
  - ☐ molecular beam epitaxy
  - ☐ substrates: $BaF_2(111)$ → $\mathcal{M}$ symmetry and $\mathcal{T}$ invariance
  - ☐ thickness: 30 nm → adjusted to decay length of surface states; high crystallinity
  - ☐ x = 0.00; 0.03; 0.04; 0.06; 0,07 and 0.08



$Sn_{1-x}Mn_xTe(111)$ – resistivity

- ☐ semi-metallic behaviour
- ☐ residual resistivity ratio [RRR]
- ☐ disorder increases with Mn content





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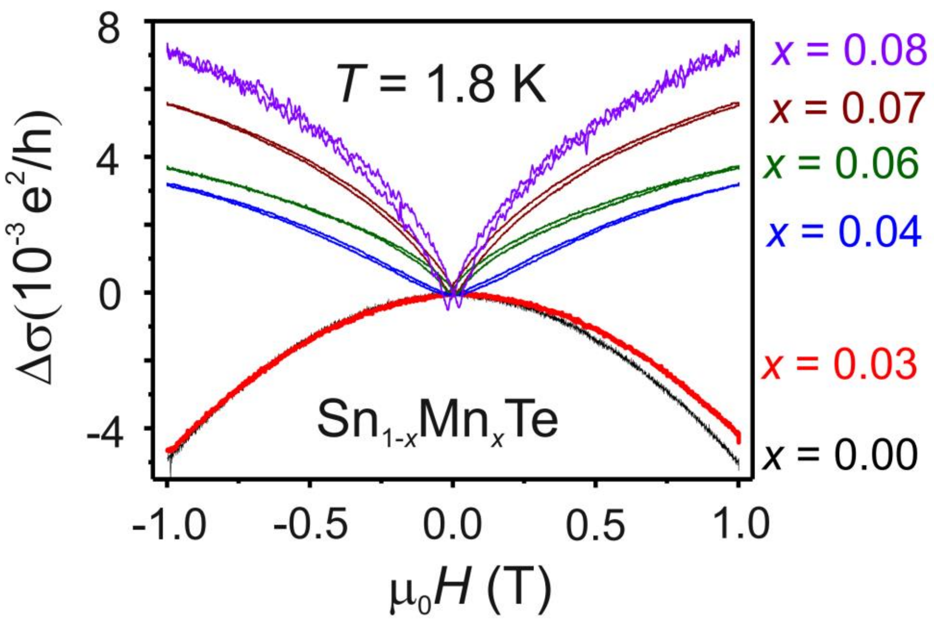
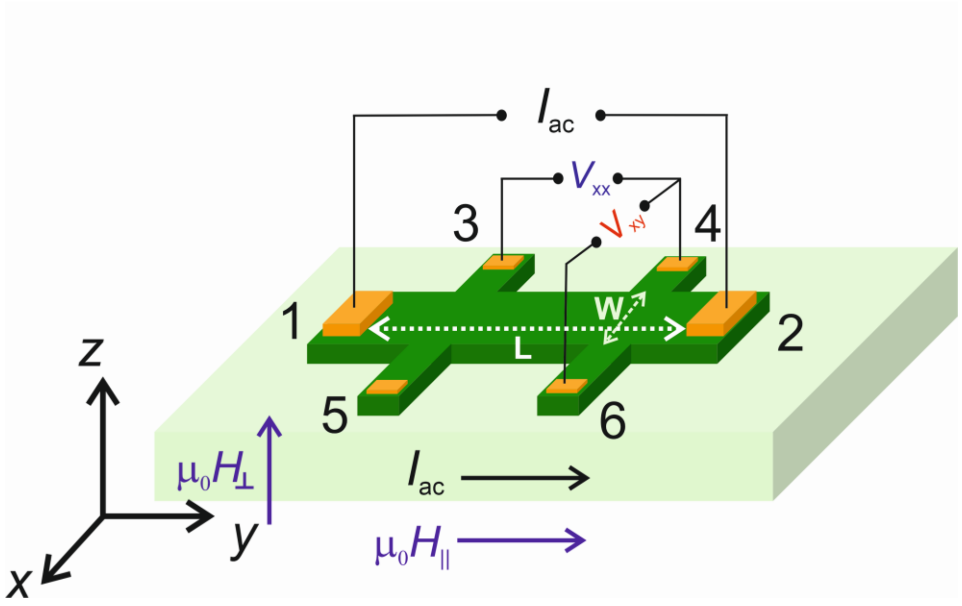
R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – magnetoconductance

$$\sigma_{xx} = \left(\frac{L}{W}\right)\left[R_{xx}\left(\frac{e^2}{h}\right)\right]$$



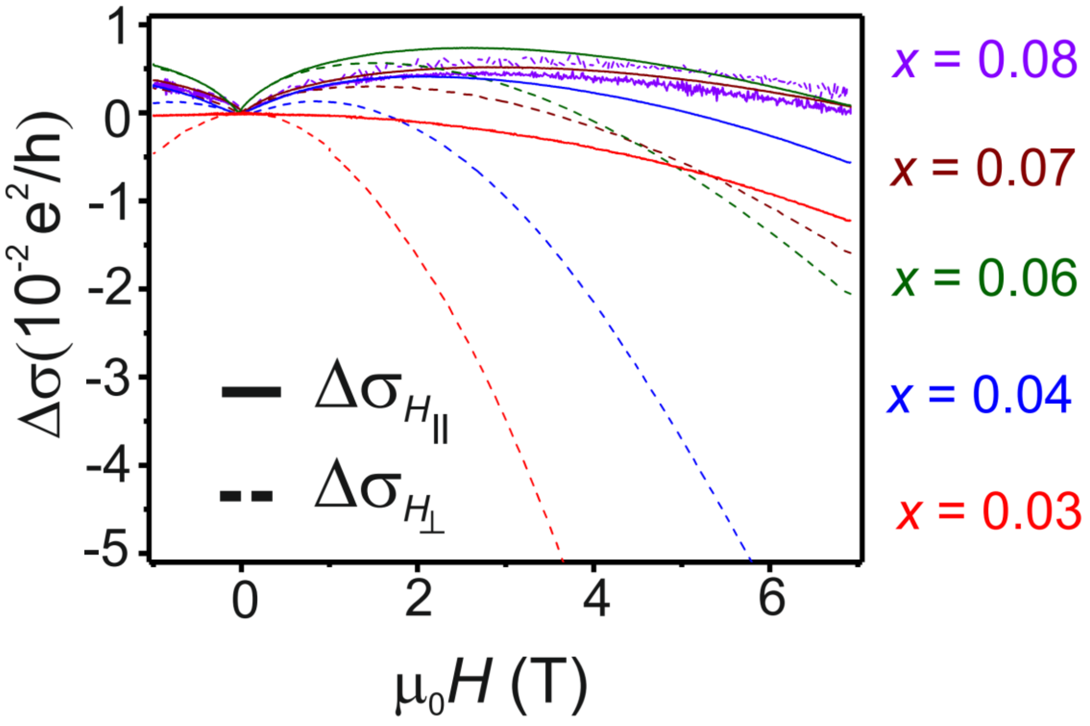


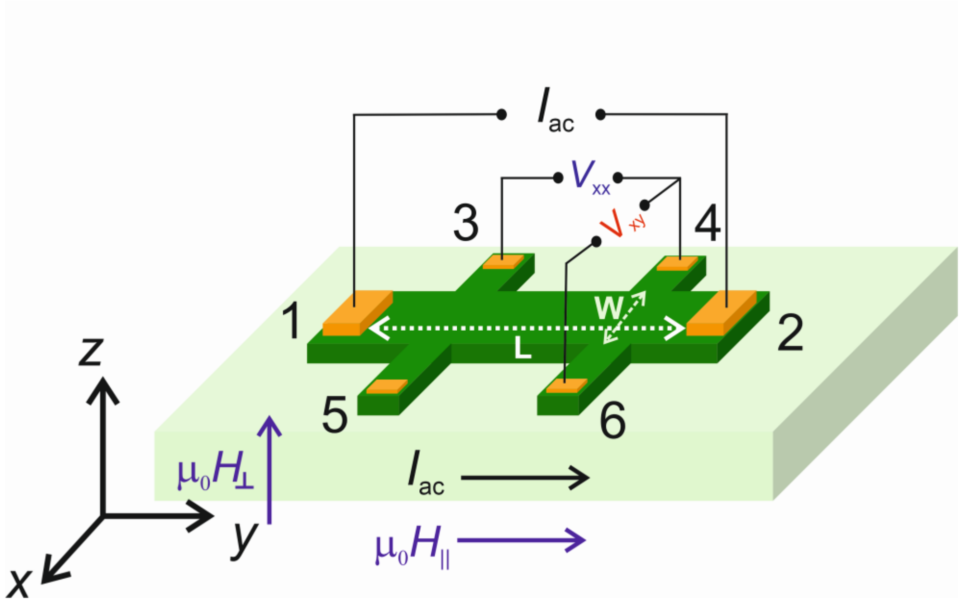
$$\Delta\sigma = [\sigma_{xx}(H) - \sigma_{xx}(0)]\left(\frac{e^2}{h}\right)$$

R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – magnetoconductance → PMA

Emergence of perpendicular magnetic anisotropy [PMA]

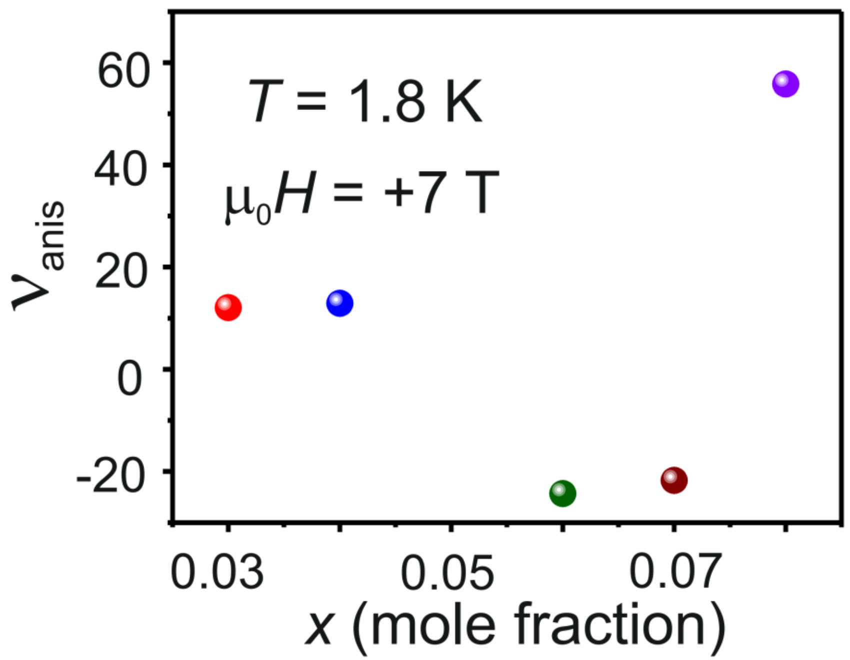




R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – magnetoconductance → PMA

Emergence of perpendicular magnetic anisotropy [PMA]



$$\nu_{\text{anis}} = \frac{\Delta\sigma_{H_\perp}}{\Delta\sigma_{H_\parallel}}$$

***x* = 0.08**

- contribution: surface states
- immune to disorder

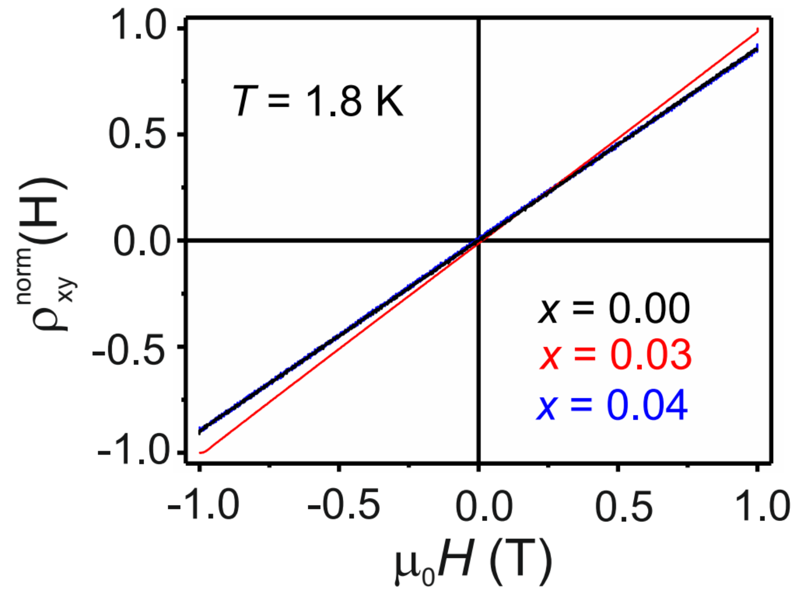
0.03 ≤ *x* ≤ 0.07

- contribution: (surface + bulk) states

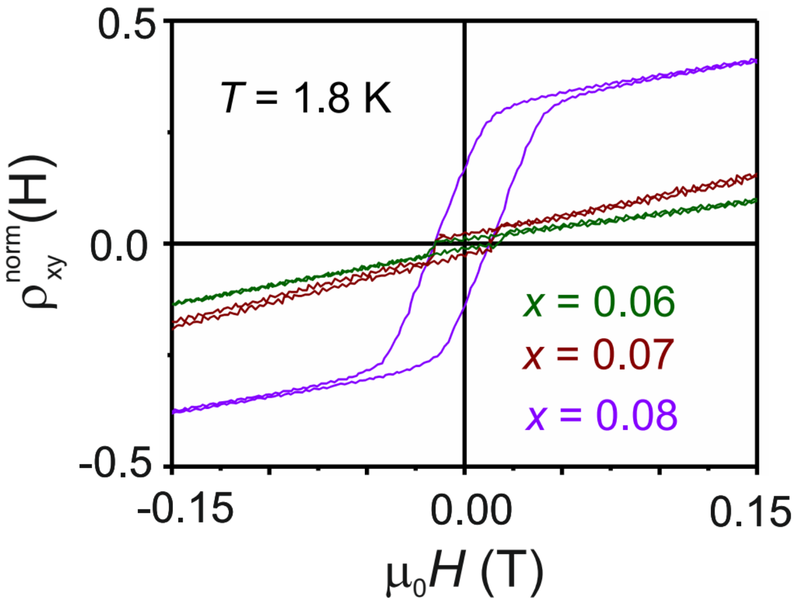
JKU R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – Hall resistivity → AHE

ordinary Hall effect



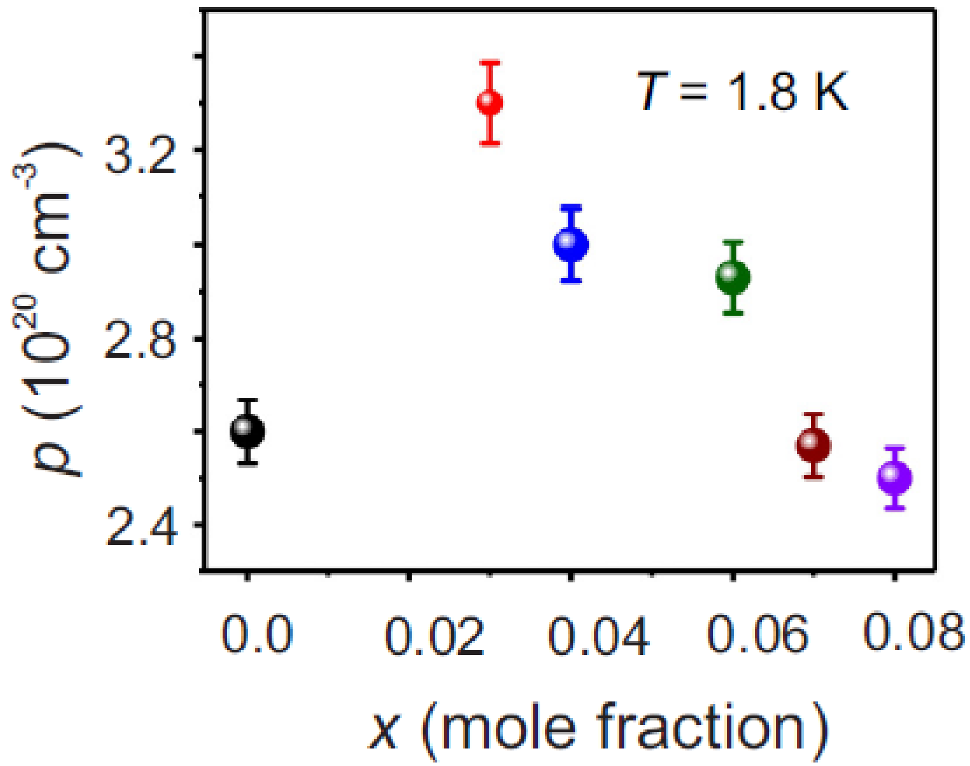
anomalous Hall effect

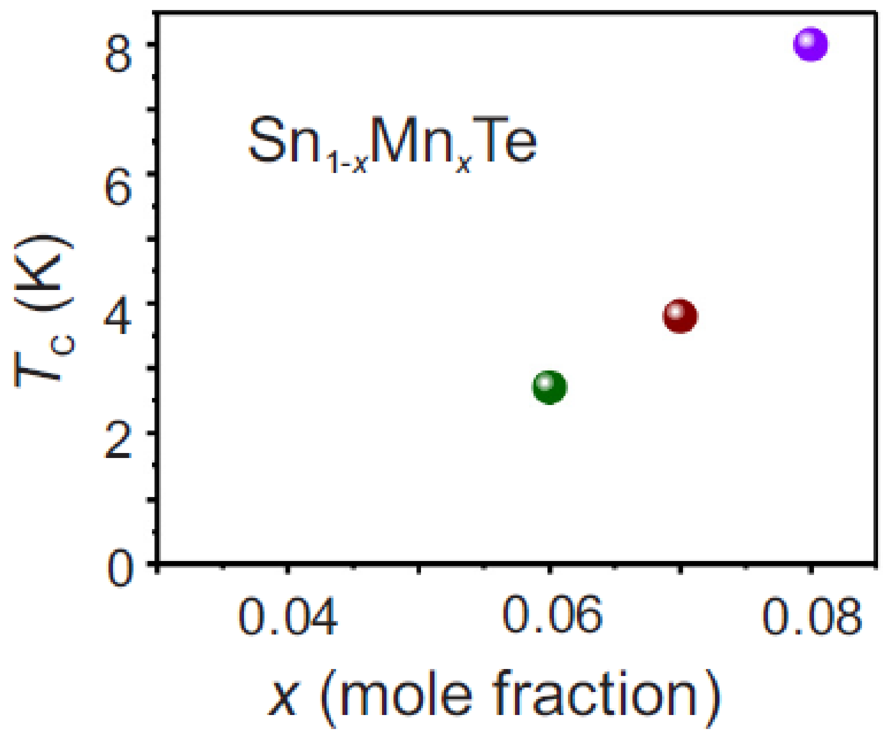


$$\rho_{xy}(H) = R_H H + \mu_0 R_{AH} M$$

JKU R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

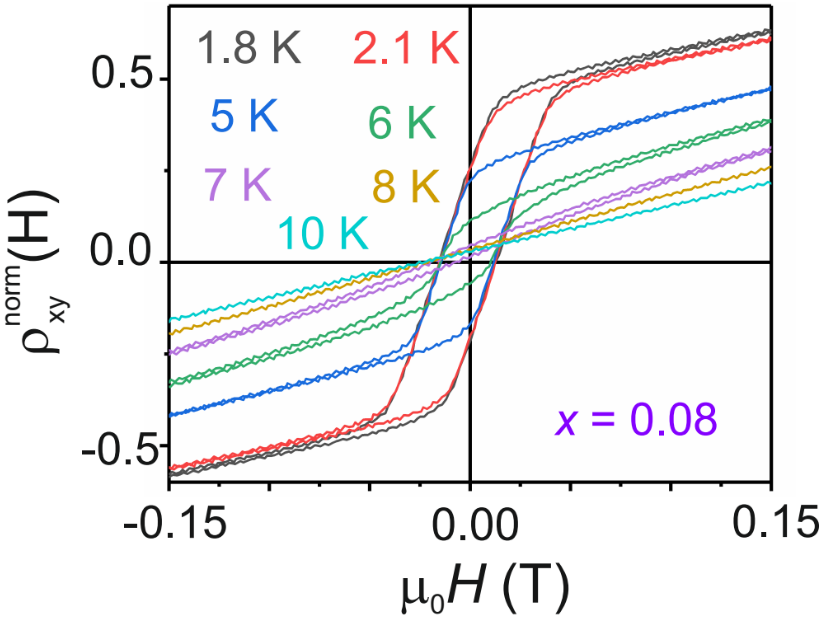
$Sn_{1-x}Mn_xTe(111)$ – T_c

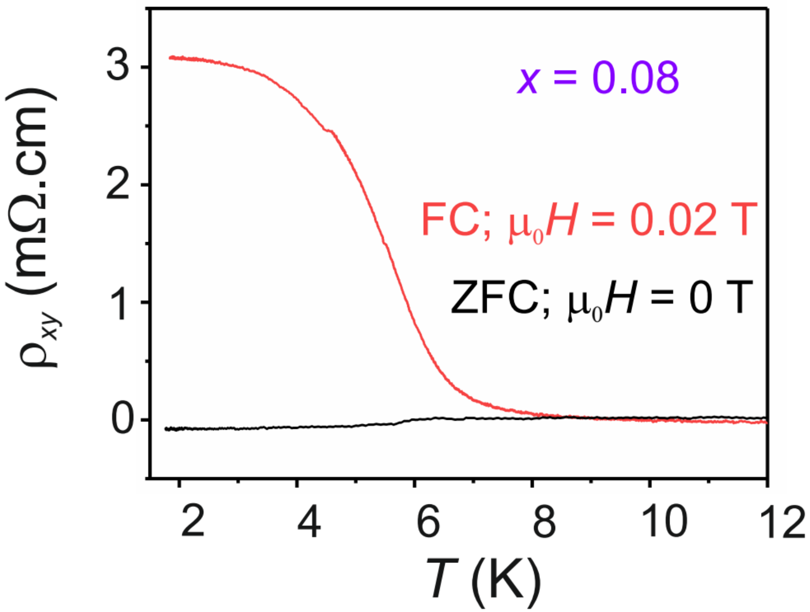




R. Adhikari,…., AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – Hall resistivity





- ☐ hysteretic anomalous Hall effect
- ☐ ferromagnetic order for $x \geq 0.06$
- ☐ carrier mediated FM
- ☐ highest T_C ~7.5 K for $x = 0.08$

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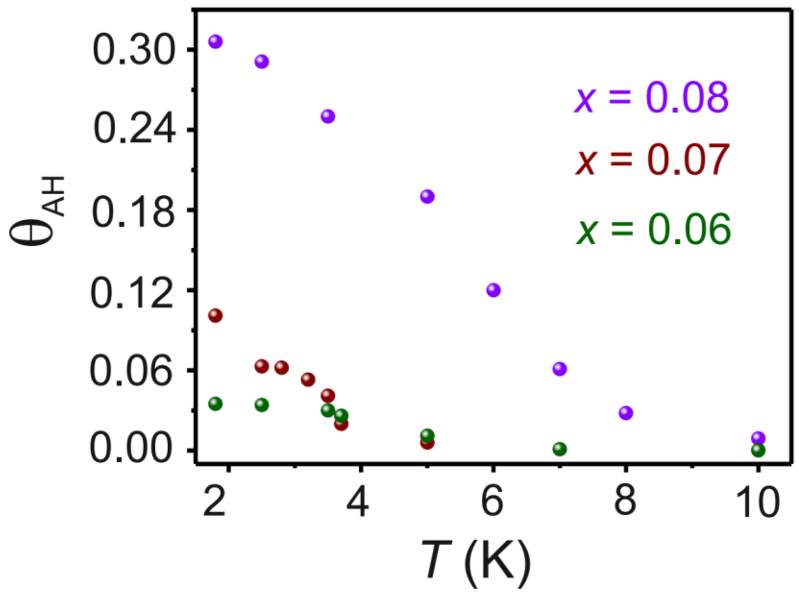
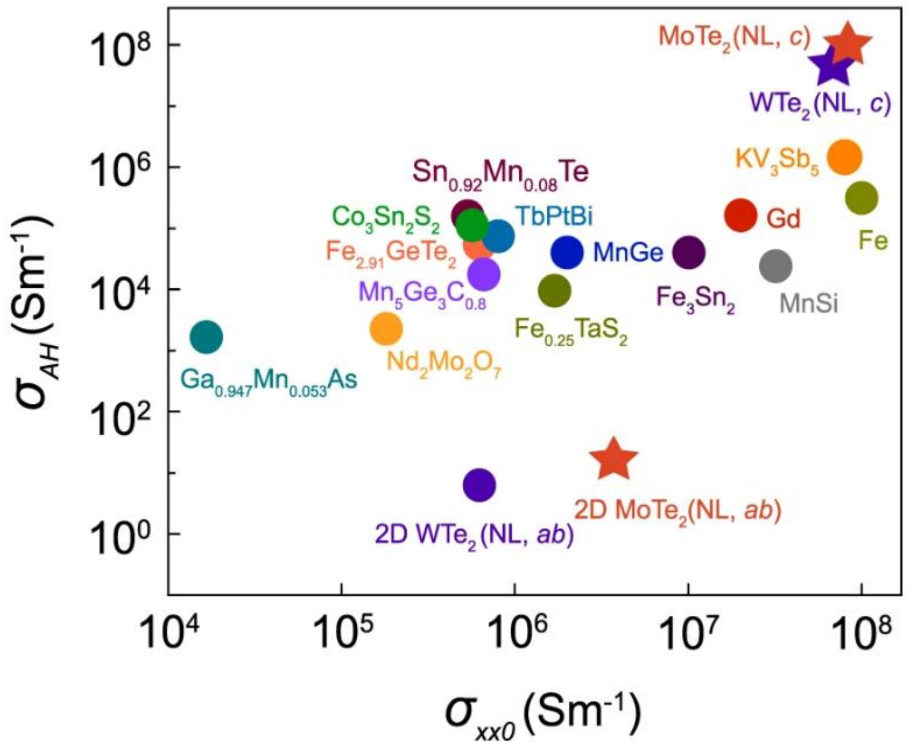
R. Adhikari,…., and AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – anomalous Hall angle



$$\theta_{AH} = \frac{\sigma_{xy}^{AH}}{\sigma_{xx}}$$



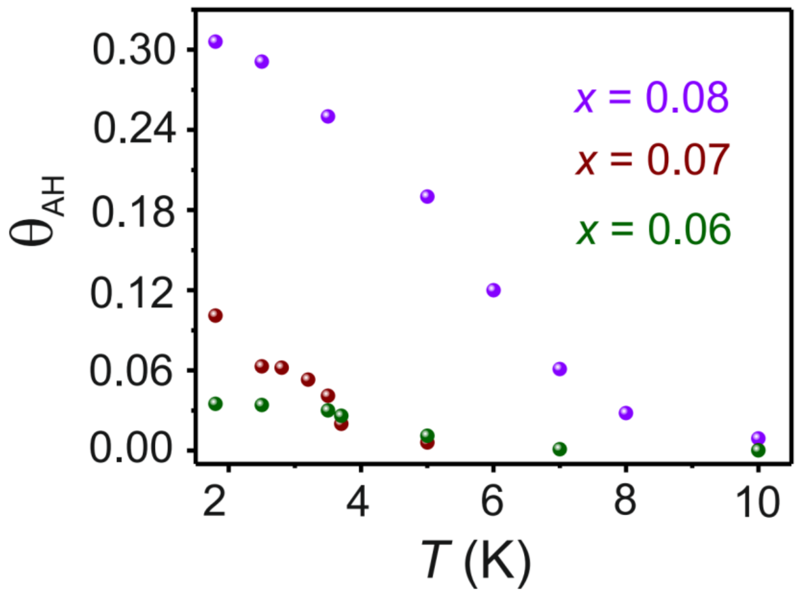
A. Tiwari *et al.* Nat. Commun. **12,** 2049 [2021]

- $\theta_{AH} = 0.3$ for $Sn_{0.92}Mn_{0.08}Te(111)$
  - $T = 1.8$ K, $\mu_0 H = +1$ T

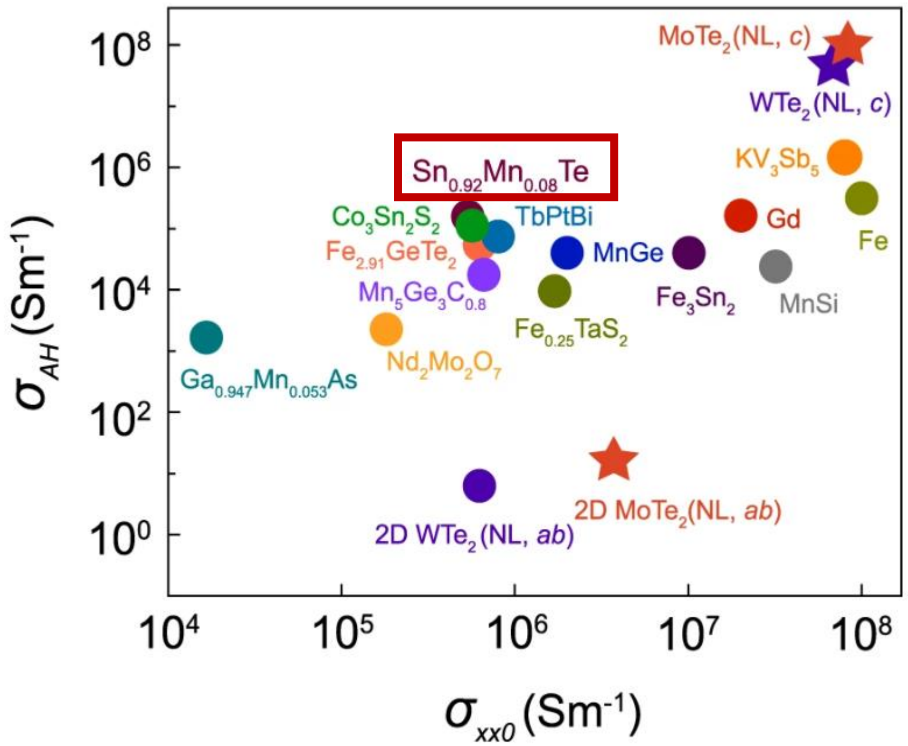
Among the highest reported for a magnetic topological insulator

JKU R. Adhikari,…., and AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – anomalous Hall angle



$$\theta_{\mathrm{AH}} = \frac{\sigma_{\mathrm{xy}}^{\mathrm{AH}}}{\sigma_{\mathrm{xx}}}$$



A. Tiwari *et al.* Nat. Commun. **12,** 2049 [2021]

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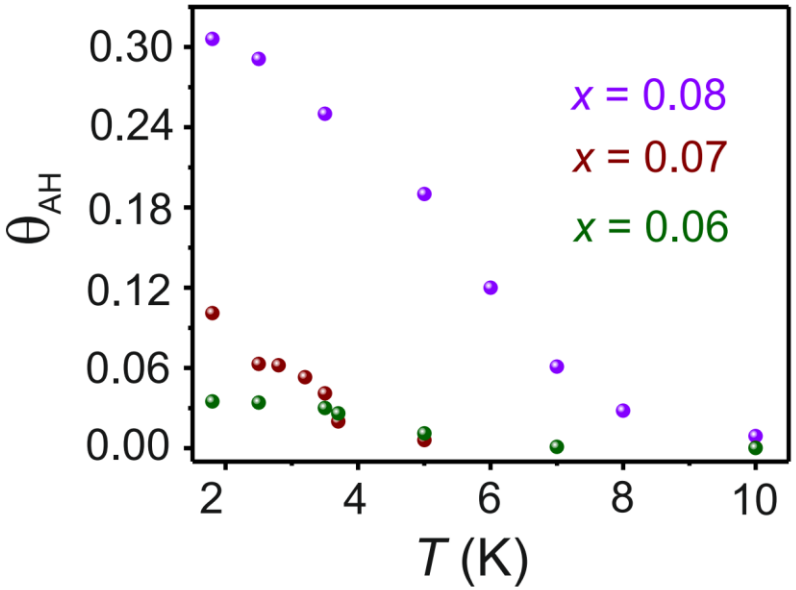
Among the highest reported for a magnetic topological insulator

R. Adhikari,…., and AB, Phys. Rev. B **100**, 134422 [2019]

$Sn_{1-x}Mn_xTe(111)$ – synopsis



$$\theta_{AH} = \frac{\sigma_{xy}^{AH}}{\sigma_{xx}}$$

- ☐ [carrier mediated] ferromagnetic ordering
- ☐ emergence of AHE
- ☐ PMA
- ☐ thickness adjusted to the decay length of topological surface states

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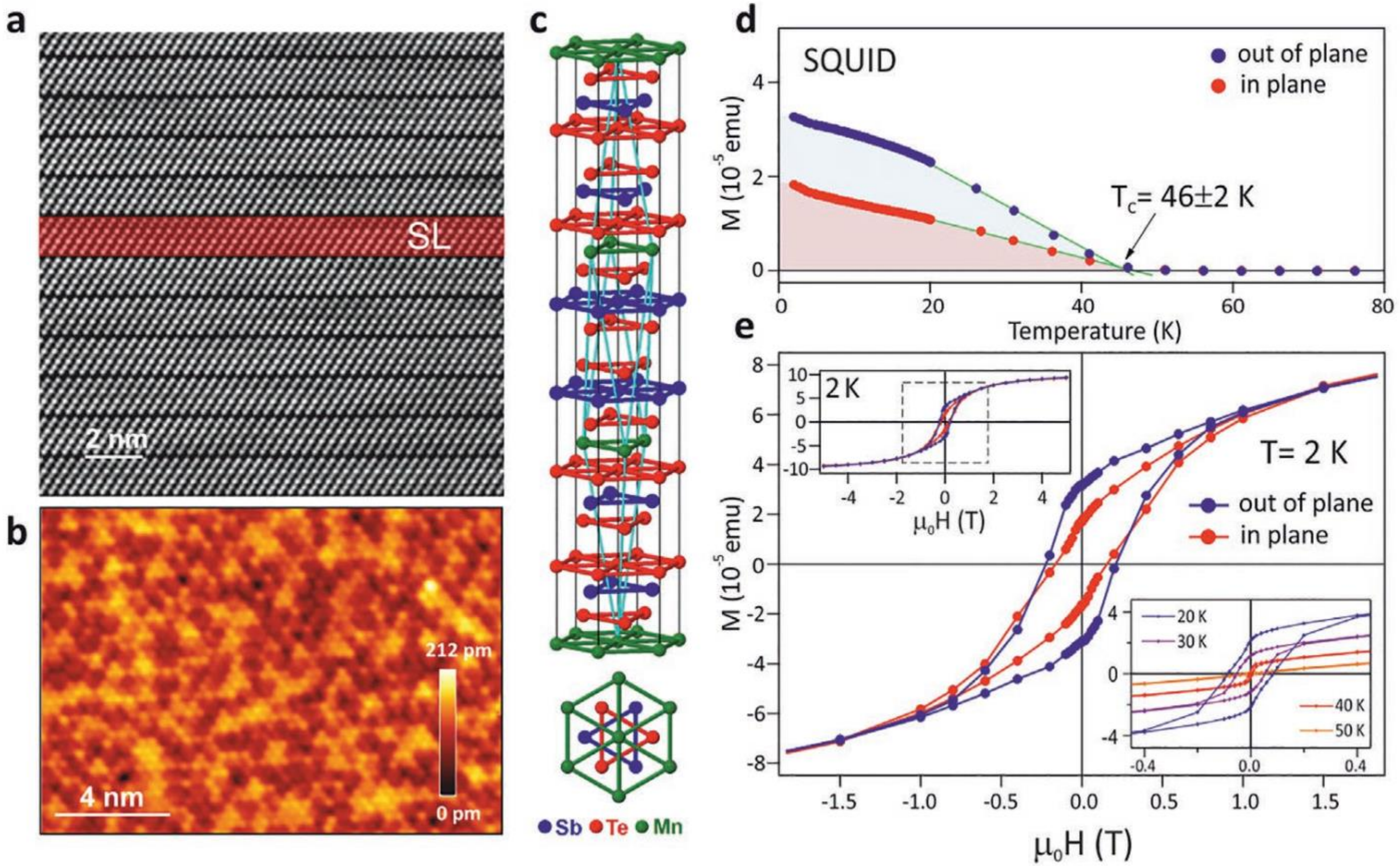
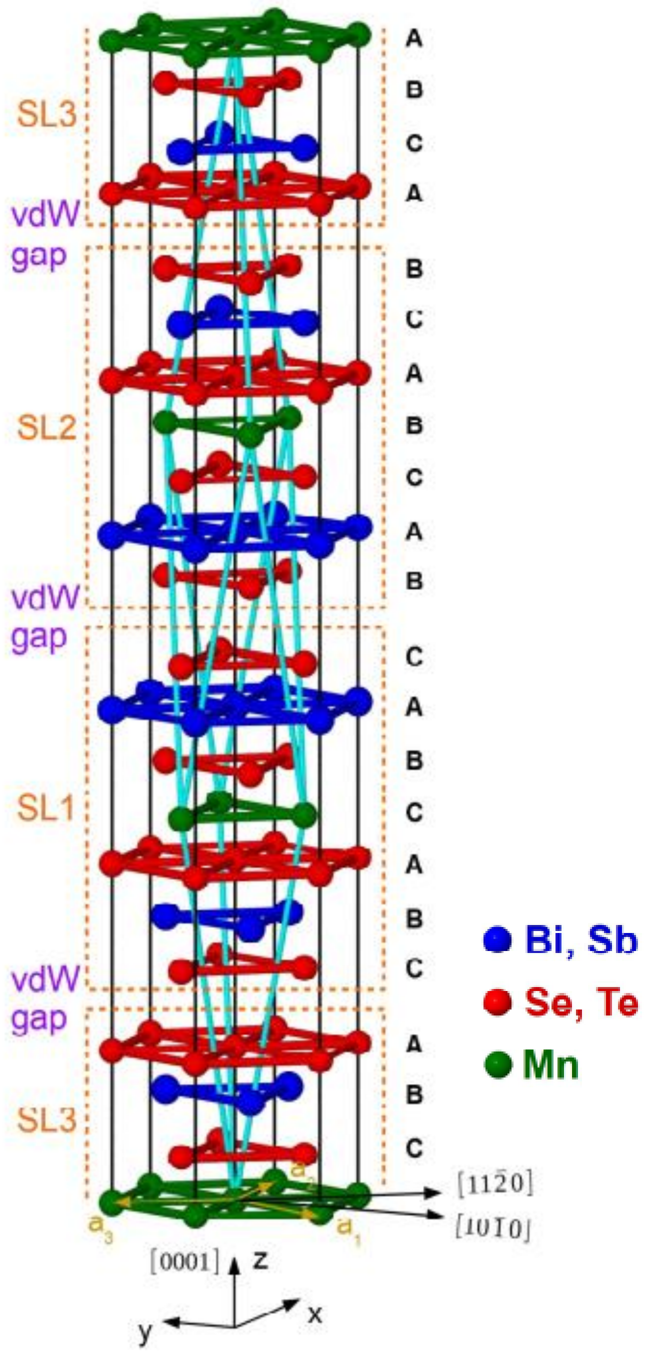
R. Adhikari,…., and AB, Phys. Rev. B **100**, 134422 [2019]

$MnSb_2Te_4$ – intrinsic MTI





S. Wimmer *et al*. Adv. Mater. **33**, 2102935 [2022]

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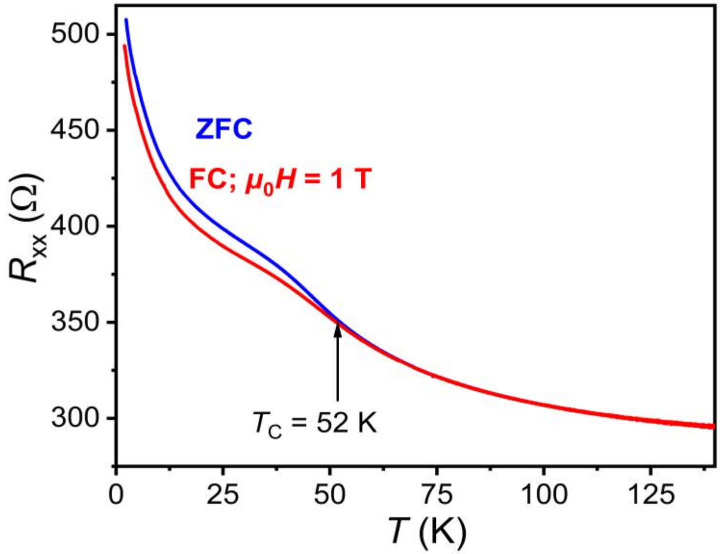
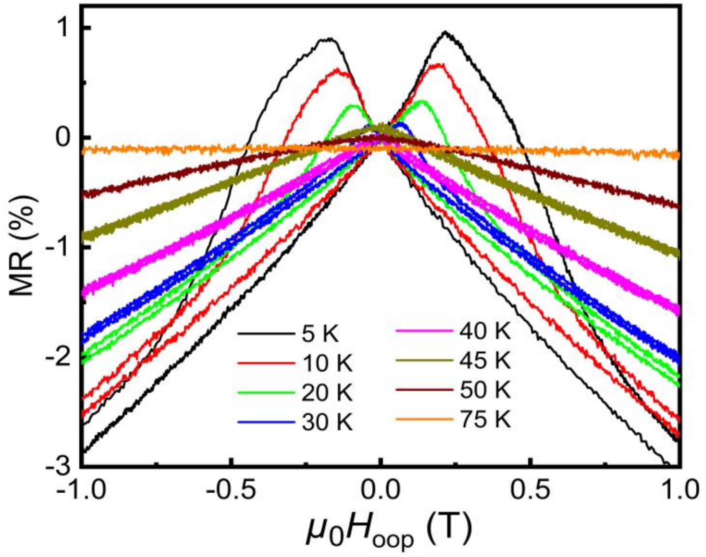
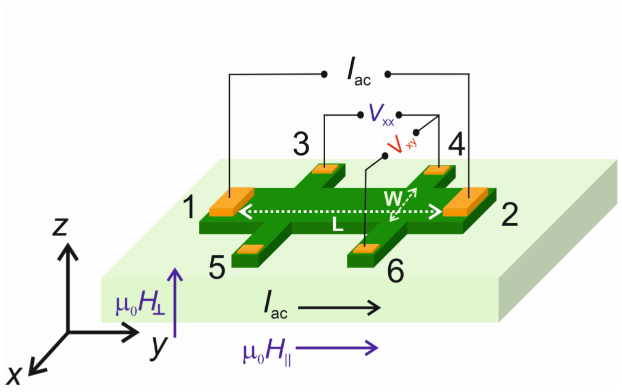
$MnSb_2Te_4$ – magnetotransport



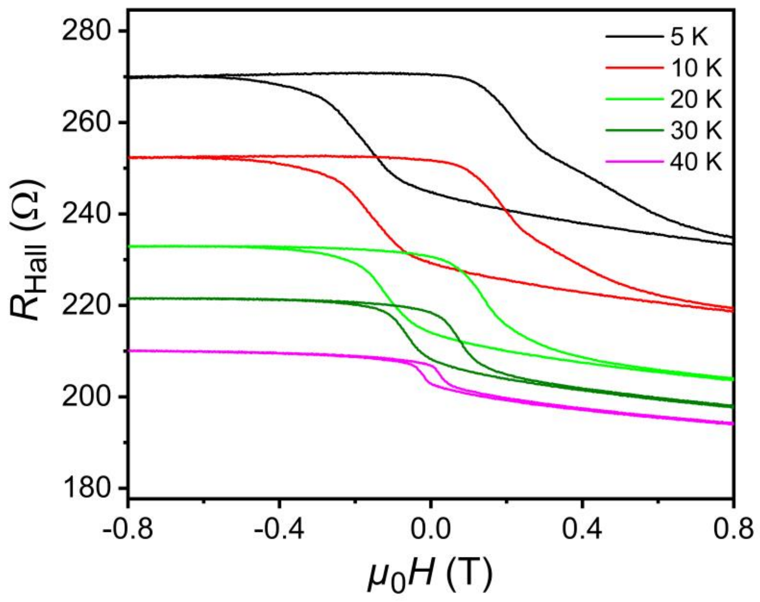


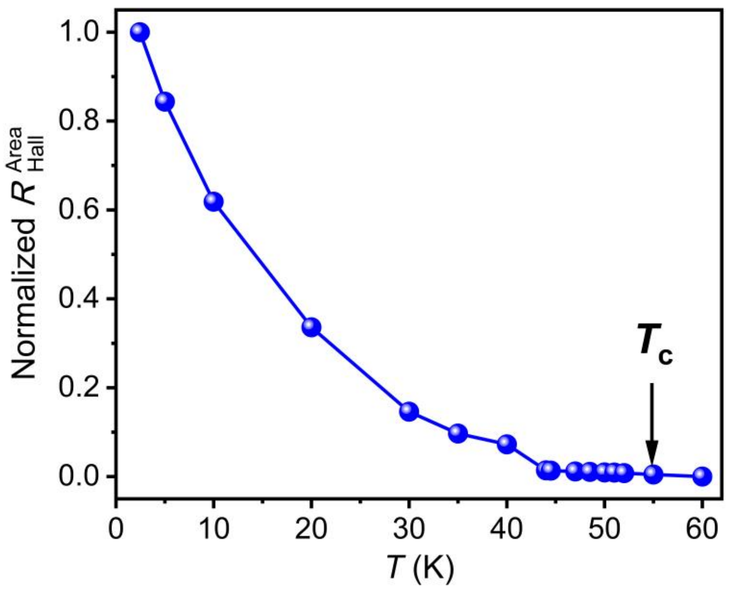


- ☐ Ferromagnetic ordering temperature T_C = 55 K
- ☐ Hysteretic butterfly magnetoresistance → spin-dependent transport

unpublished data

$MnSb_2Te_4$ – magnetotransport AHE

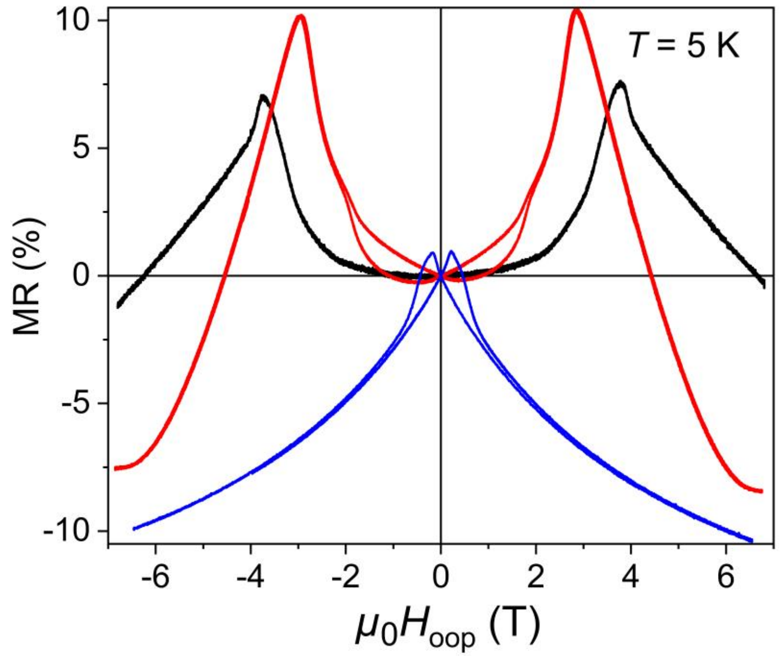




- □ AHE → pre-requisite for QAH in MTI
- □ T_C = 55 K → QAHE expected T > 4.2 K

unpublished data

$Mn(Bi,Sb_2)Te_4$ – evolution of interactions



$MnBi_2Te_4$

$Mn(Bi_{0.4}Sb_{0.6})_2Te_4$

$MnSb_2Te_4$

- □ $MnBi_2Te_4$ → antiferromagnetism
- □ $Mn(Bi_{0.04},Sb_{0.06})_2Te_4$ → canted antiferromagnetism
- □ $MnSb_2Te_4$ → ferromagnetism

JKU

unpublished data

Synopsis

- $Sn_{0.92}Mn_{0.08}Te$
  - Remarkable $\theta_{AH} = 0.3$
- $MnSb_2Te_4$
  - Intrinsic ferromagnetic TI → $T_C = 55$ K

Topology in condensed matter physics

- **Weyl equation for relativistic particles**

$$H_{\pm} = \pm c \begin{bmatrix} p_z & p_x - ip_y \\ p_x + ip_y & -p_z \end{bmatrix}$$

H. Weyl [1929]

- ☐ Solution → massless fermions with definite handedness or chirality
- ☐ Intended as model for elementary particles
  - ● 90 years → no Weyl fermions in high energy physics

AUGUST 15, 1937 PHYSICAL REVIEW VOLUME 52

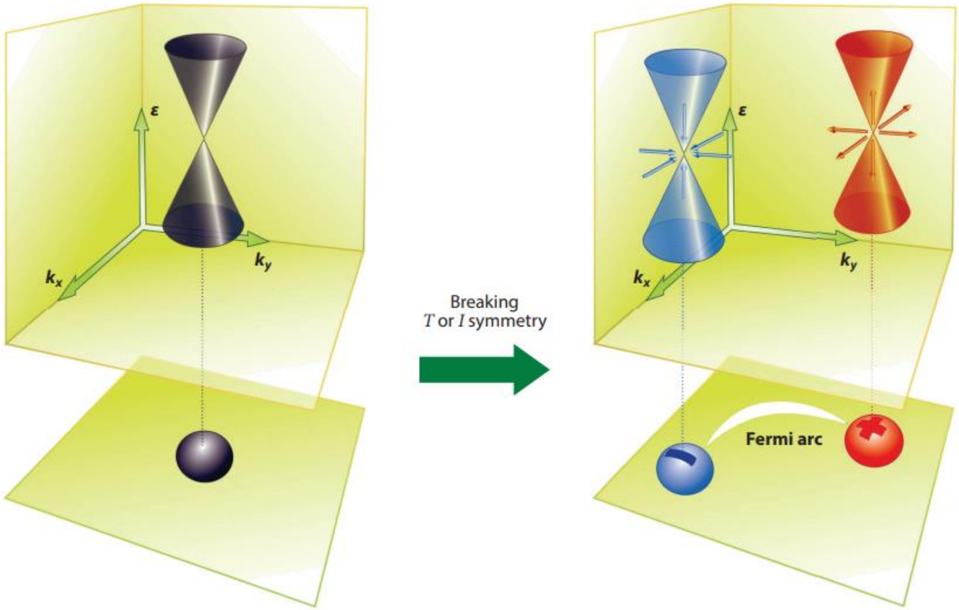
Accidental Degeneracy in the Energy Bands of Crystals

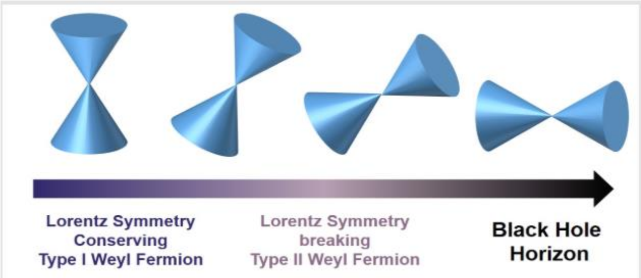
CONYERS HERRING
Princeton University, Princeton, New Jersey
(Received June 16, 1937)

C. Herring [1937]

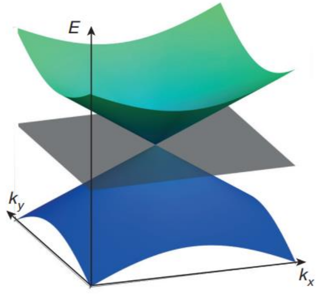
- ☐ Conditions for energy bands in solids to have the same energy
- ☐ Weyl equation in solid state physics
  - ● → will Weyl fermins emerge in low energy physics?

Weyl semimetals



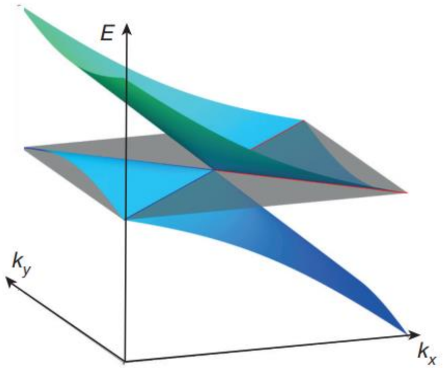


Type-I Weyl semimetals



TaAs, NbAs, NbP

Type-II Weyl semimetals



T_d-$MoTe_2$, T_d-WTe_2

B. Yan *et al.* Annu. Rev. Condens Mater. **8**, 337 [2017]

M. Z. Hasan *et al.* Annu. Rev. Condens Mater. **8**, 289 [2017]

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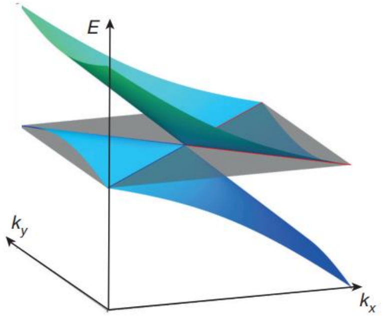
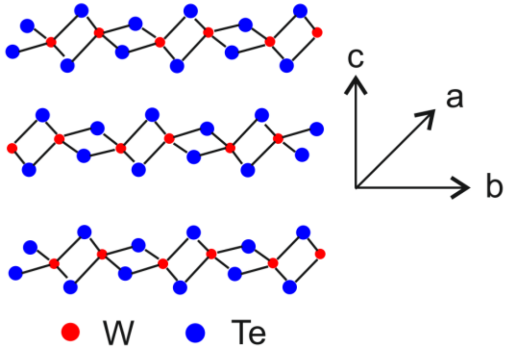
Type II Weyl semimetal – T_d-WTe$_2$



- ☐ Tilted electronic band structure
- ☐ Anysotropic magnetotransport
- ☐ Quantum anomalies – Adler-Bell-Jackiw or chiral anomaly
  - ● classical conservation laws broken at quantum level

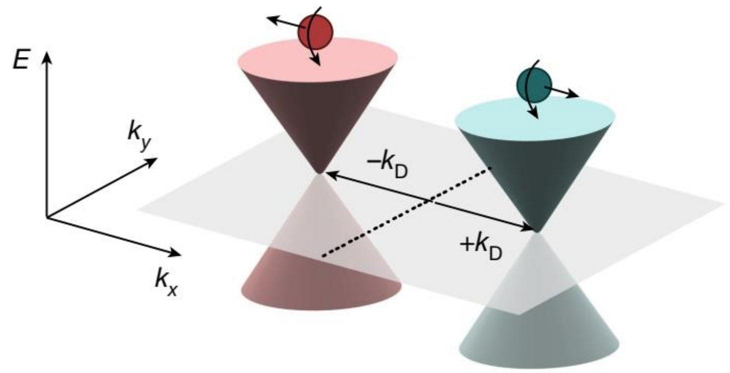


- ☐ van der Waals structure
- ☐ Insight into Weyl quasiparticles – massless, high mobility
- ☐ High-speed devices, THz photonics, emergent phenomena in 2D

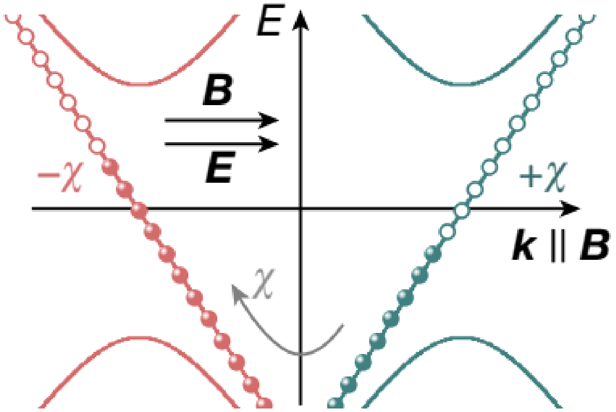
JKU

Soluyanov *et al*. Nature **527**, 495 [2015]

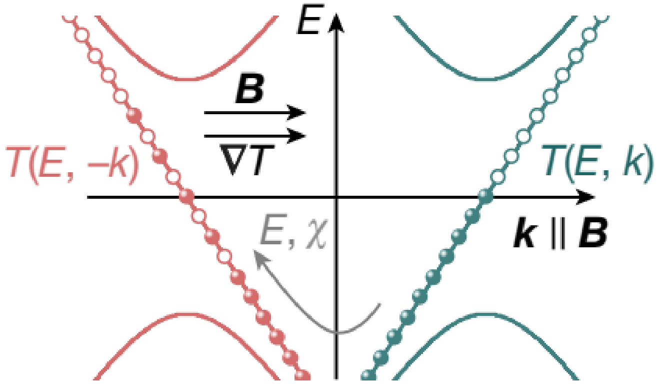
Weyl semimetal – quantum anomalies



Chiral anomaly

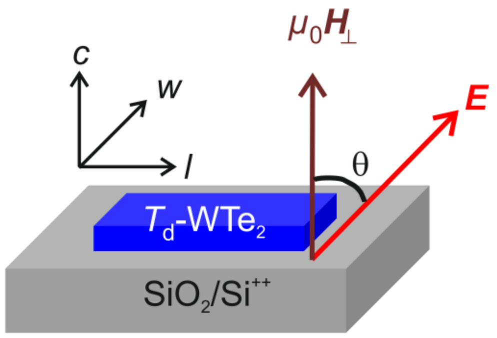


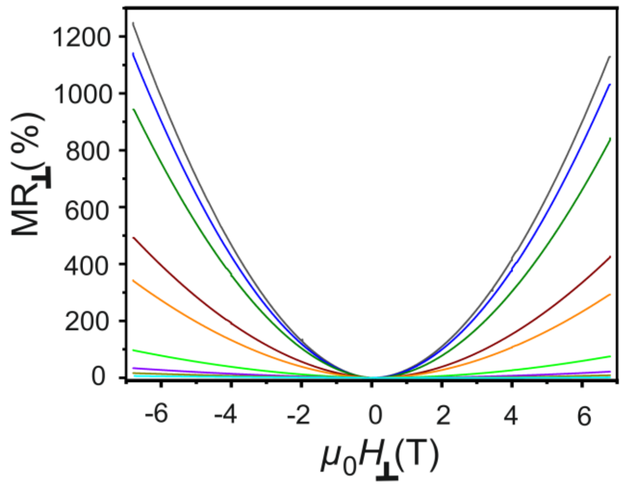
Axial-gravitational anomaly

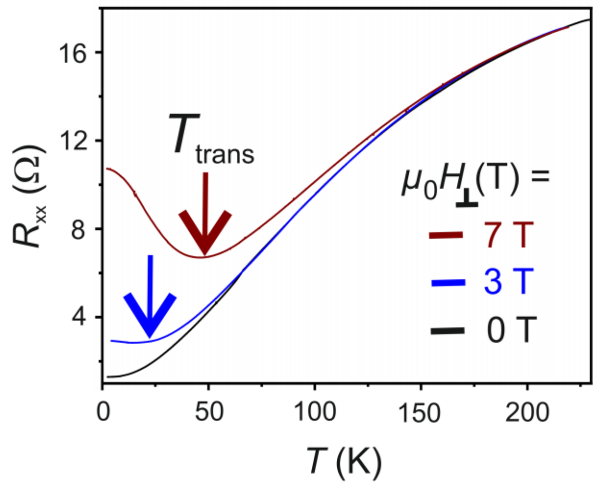


J. Gooth *et al*. Nature **547**, 324 [2017]

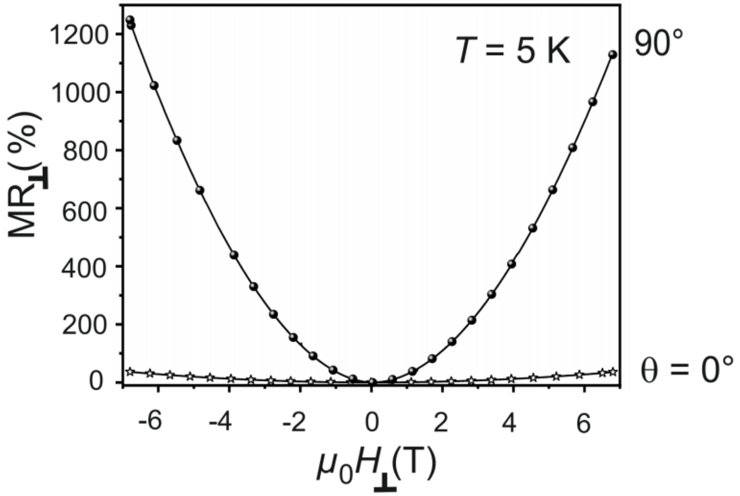
T_d-WTe_2 – perpendicular magnetic fields





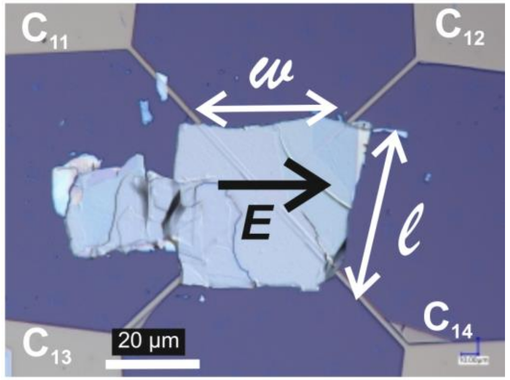


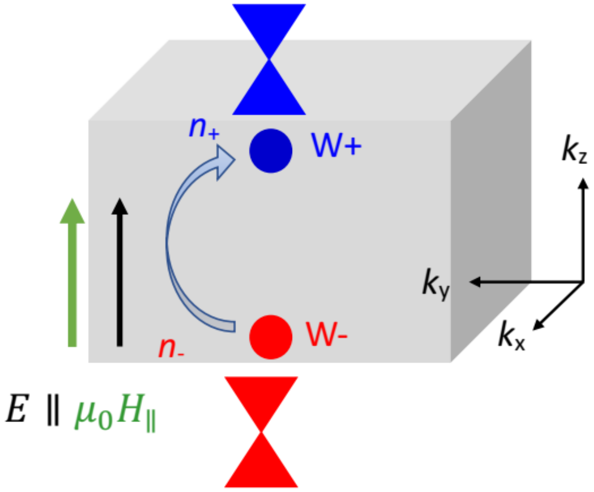
- ☐ Fermi liquid below 50 K
- ☐ Significant positive MR
  - ~1200%, due to charge compensation
  - → electron and hole pockets
- ☐ Anisotropic electronic properties

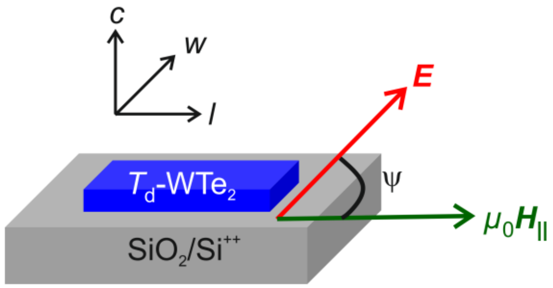


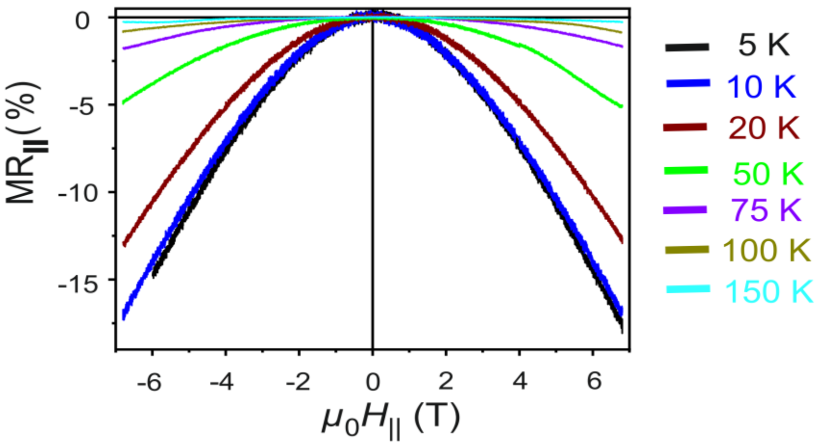
R. Adhikari *et al*. Nanomater. **11**, 2755 [2021]

T_d-WTe_2 – parallel magnetic fields and quantum anomaly



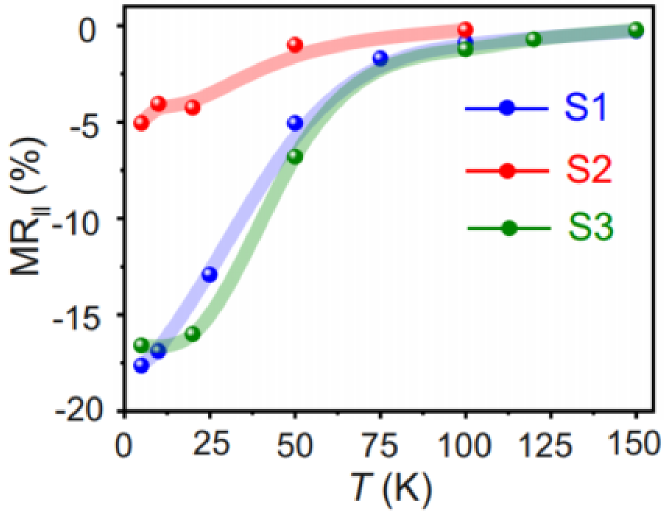


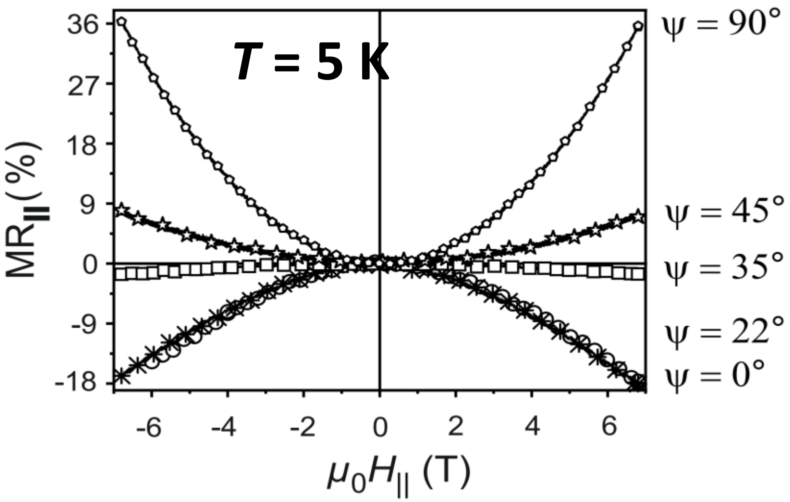




$(E \parallel \mu_0 H_\parallel) \parallel b$

Chiral anomaly up to 100 K





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Synopsis

- T_d-WTe_2
    - ☐ Large non saturating MR ~1200% at 5 K, 7 T
    - ☐ Charge compensation
    - ☐ Electron – hole pockets
    - ☐ Chiral anomaly up to 100 K

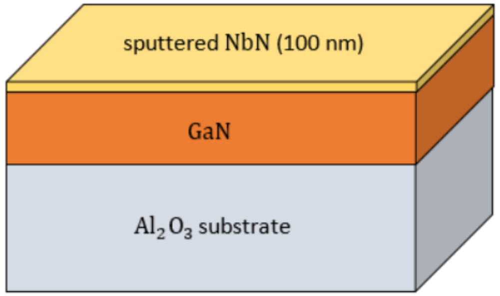
Back to superconductivity

- ☐ Perfect diamagnetism and zero resistivity
- ☐ Type I and type II superconductors
- ☐ Conventional and unconventional superconductors
- ☐ NBN: conventional, *s*-wave, BCS superconductor

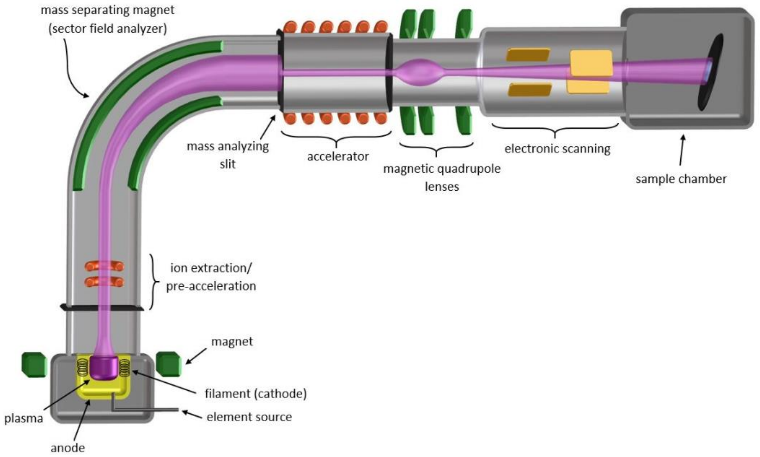
- ■ Why?

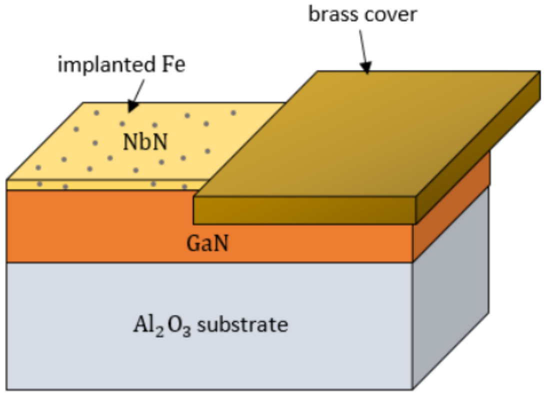
- ☐ Proximity effects and emergence
- ☐ Anderson-Higgs mechanism
- ☐ Yu-Shiba-Rusinov states
- ☐ Spin-triplet Cooper pairing
- ☐ Topological superconductivity
- ☐ Odd frequency superconductivity

Fe implanted NbN

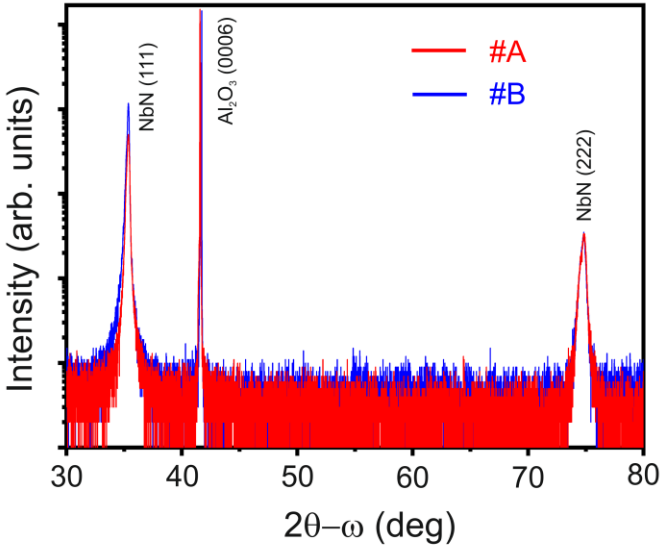


#A NbN





#B Fe:NbN



Collaborations:
CERN [ISOLDE];
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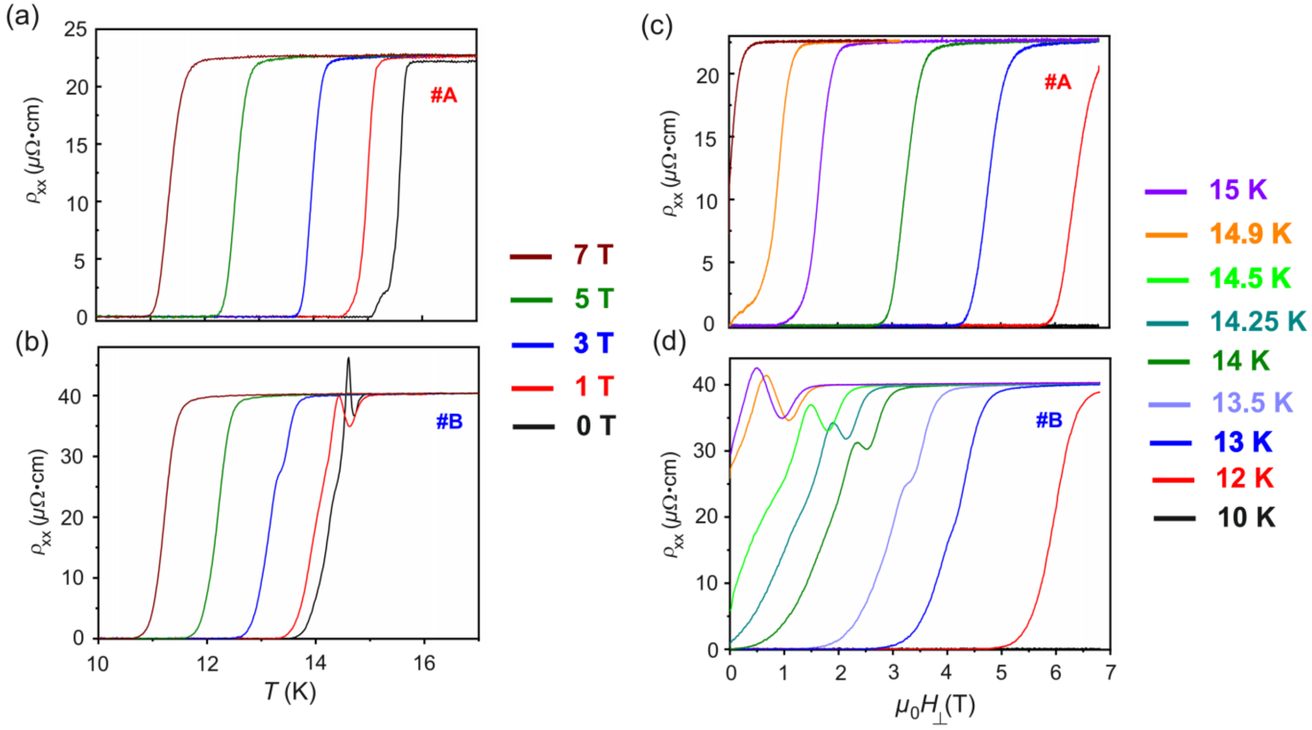
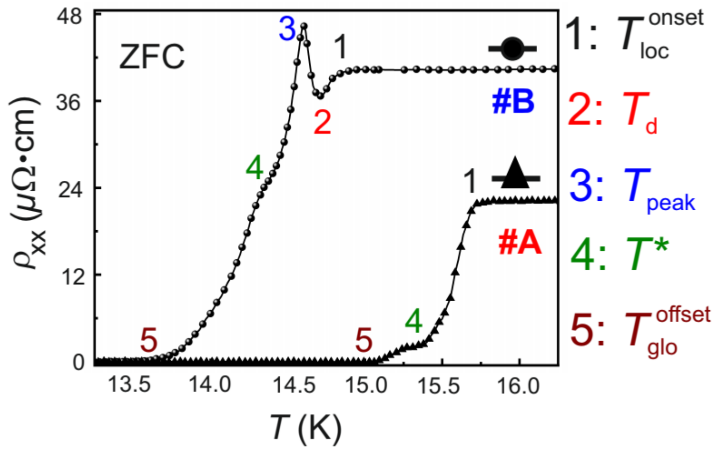
JKU

Fe implanted NbN - Magnetotransport





- ☐ T_C ~15 K
- ☐ Superconductivity persisting in Fe:NbN
- ☐ Re-entrant resistve behaviour in fe:NbN
  - Bosonic islands percolation

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Synopsis

- Fe:NbN
  - ☐ Superconductivity
  - ☐ Emergence of bosonic insulator state
  - ☐ N-shaped re-entrant resistive character of metal-to-superconductor transition