Universität zu Köln

Skyrmions in $SrRuO_3$ based heterostructures?

University of Cologne| Institute of Physics II | Lena Wysocki | 11/21/2018

SPINTRONICS

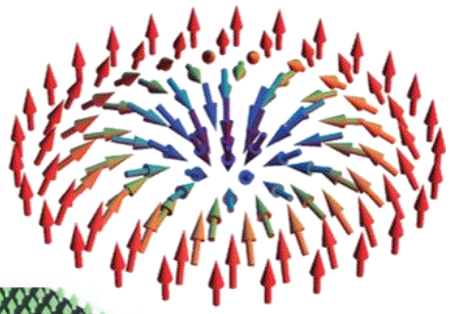
Skyrmionics gets hot

Stefan Krause and Roland Wiesendanger

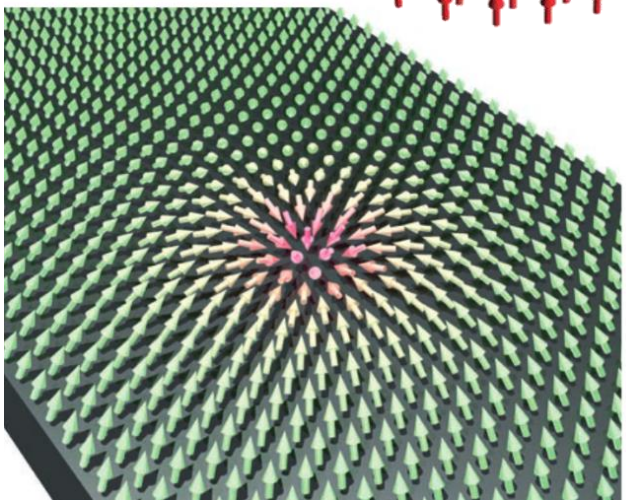
Observed at room temperature
-> ambient conditions

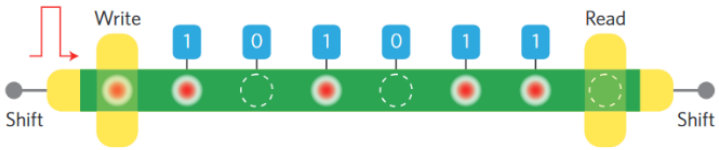
Manipulation by electric currents
-> enables application

Size in the nm range
-> high information density



Topological protection
-> stability/reliability

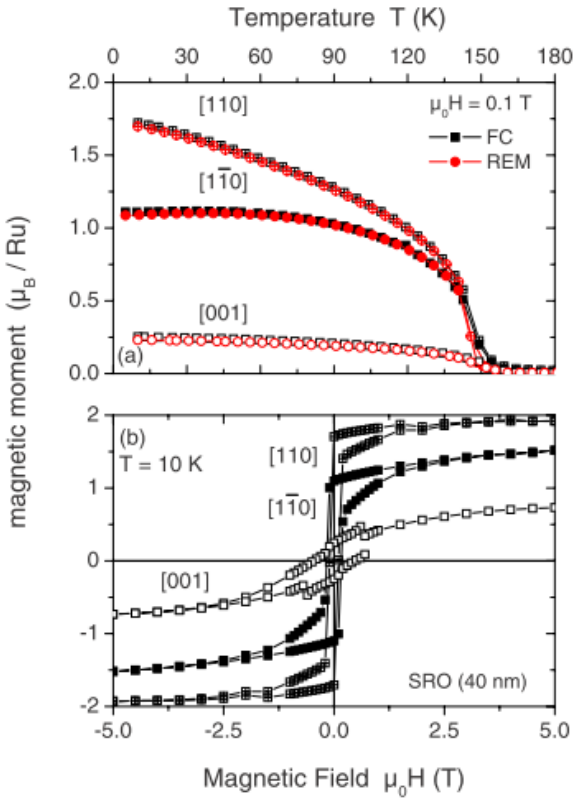




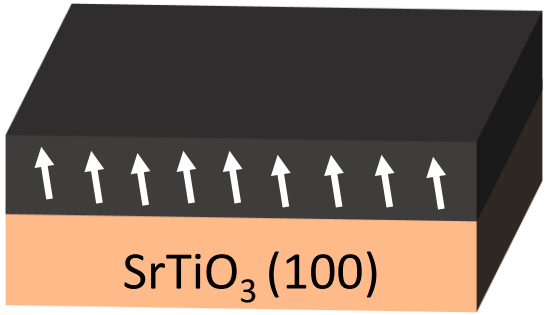
Krause, Wiesendanger. Nature Materials,15(2016)

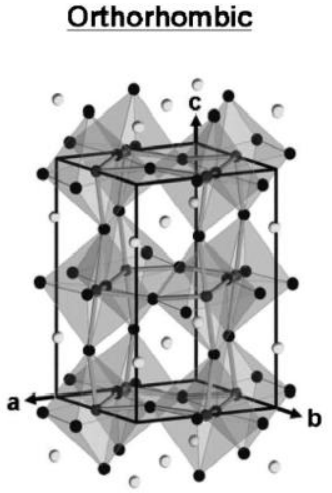
$SrRuO_3$ based multilayers

$SrRuO_3$

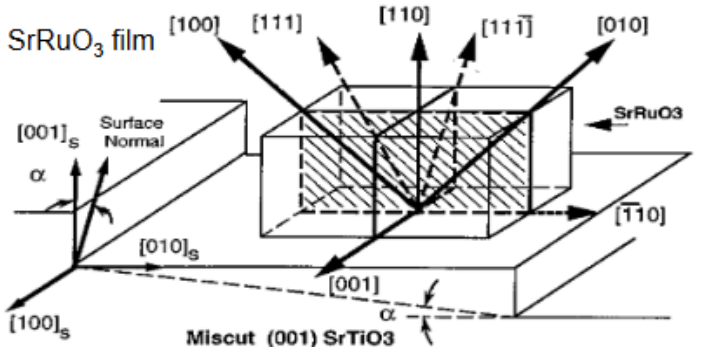


M. Ziese, I. Vrejoiu, D. Hesse, PRB 81, 184418 (2010)





Choi et al., Science 306, 1005 (2004)



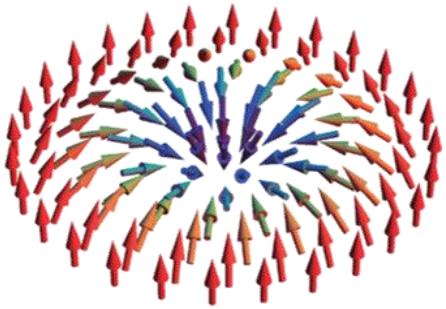
Gan et al., APL 85, 5297 (1999)

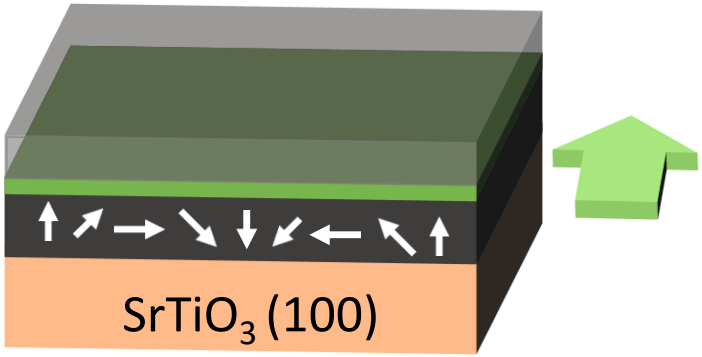
$SrRuO_3$ based multilayers

$SrRuO_3$ + $SrIrO_3$

5d *Iridium*
-> strong SOC

skyrmions?



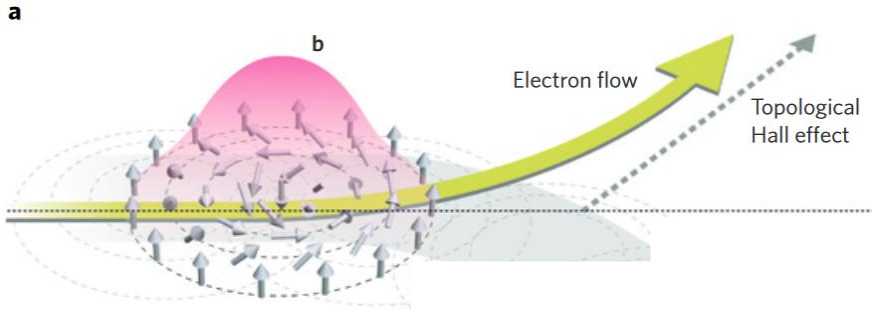


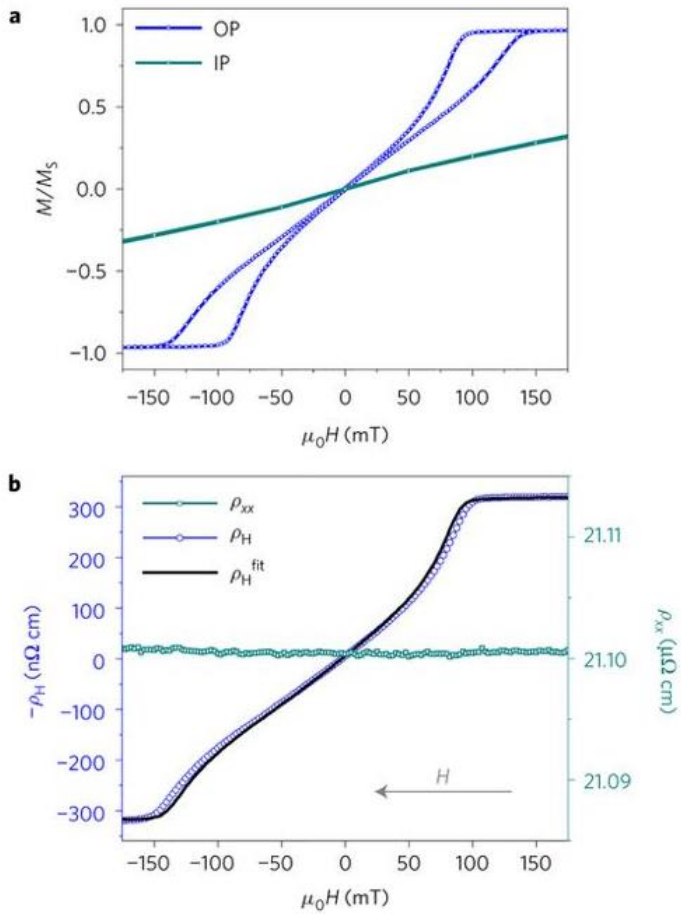
$$\boldsymbol{H}_{DMI} = -\boldsymbol{D}_{ij}(\boldsymbol{S}_i \times \boldsymbol{S}_j)$$

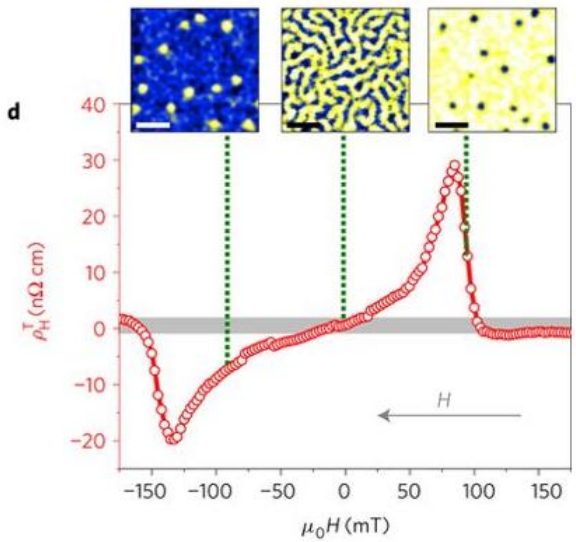
THE: Fingerprint of skyrmions

$$\rho_{Hall} = R_0 B_z + R A M_z + \rho^{\mathrm{THE}}$$

Nagaosa, Tokura Nature Nanotechnology, Volume 8 (2013)



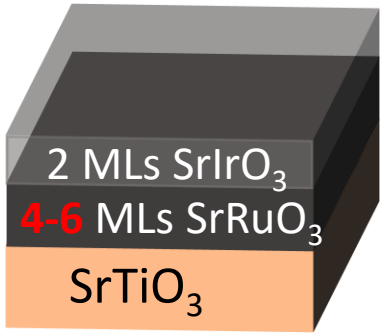


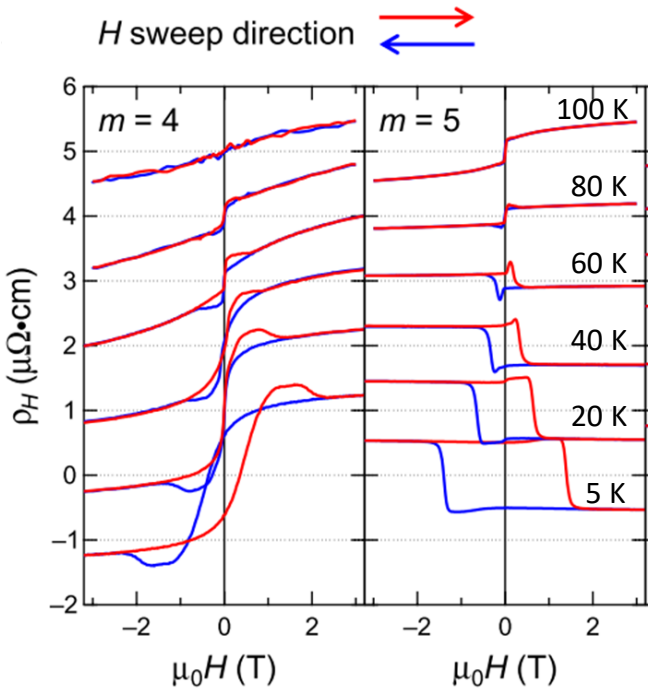


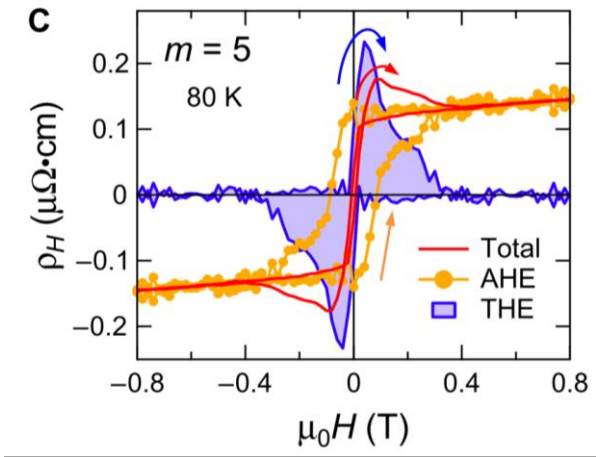
Tunable room-temperature magnetic skyrmions in Ir/Fe/Co/Pt multilayers
Soumyanarayanan et al., Nature Materials **16**,898-904(2017)

Interface-driven topological Hall effect in $SrRuO_3$-$SrIrO_3$ bilayer

Jobu Matsuno,[1]* Naoki Ogawa,[1] Kenji Yasuda,[2] Fumitaka Kagawa,[1] Wataru Koshibae,[1] Naoto Nagaosa,[1,2] Yoshinori Tokura,[1,2] Masashi Kawasaki[1,2]







additional contribution to the Hall effect

-> topological Hall effect

-> indication for noncollinear magnetic order

J. Matsuno et al., Sci. Adv. 2, e1600304 (2016)

Interface-driven topological Hall effect in $SrRuO_3$-$SrIrO_3$ bilayer

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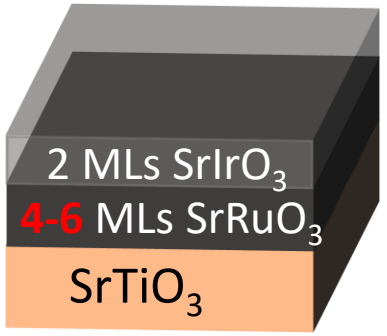
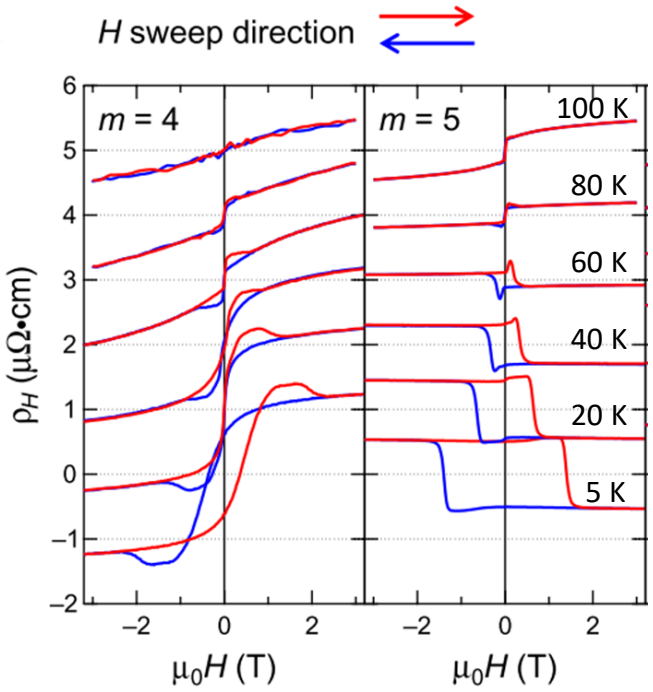
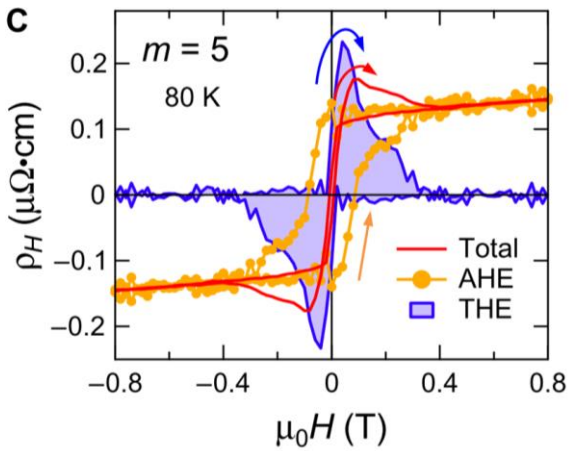
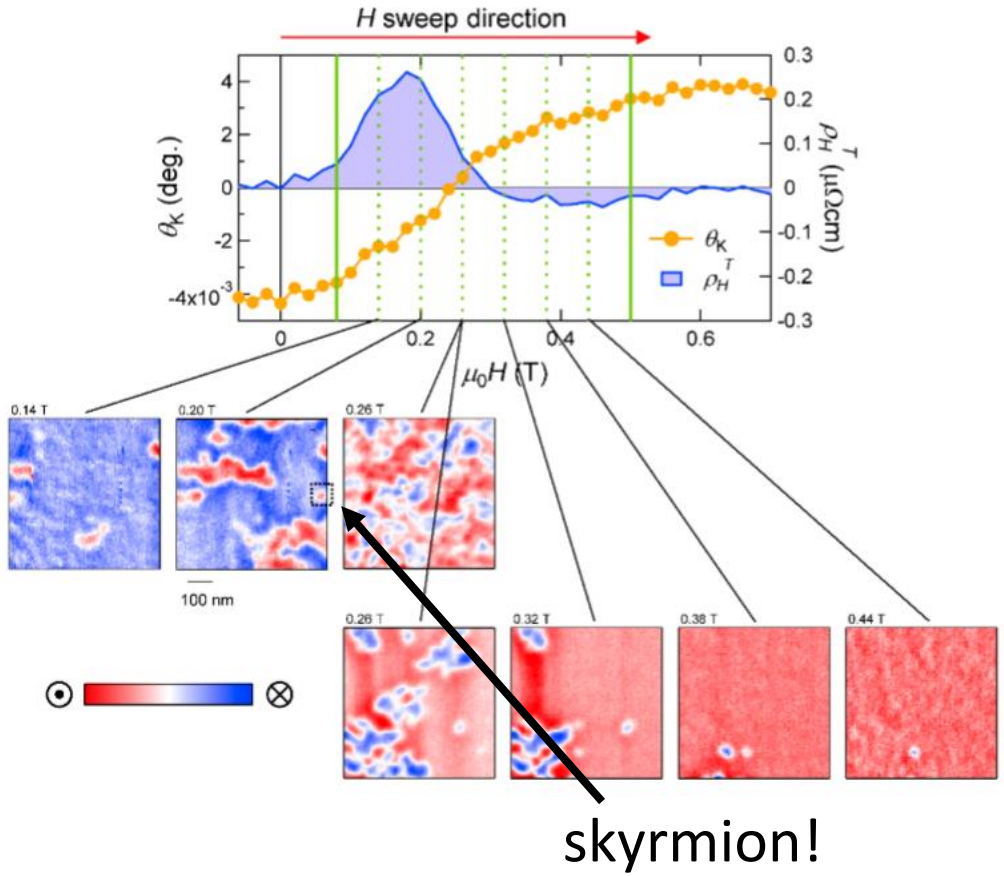








skyrmion!

J. Matsuno et al., Sci. Adv. 2, e1600304 (2016)

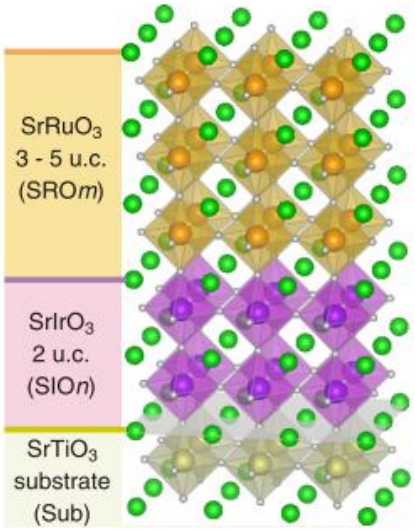
nature COMMUNICATIONS

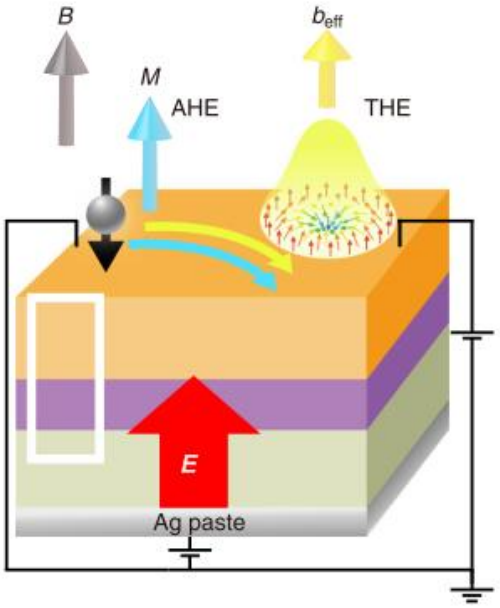
ARTICLE

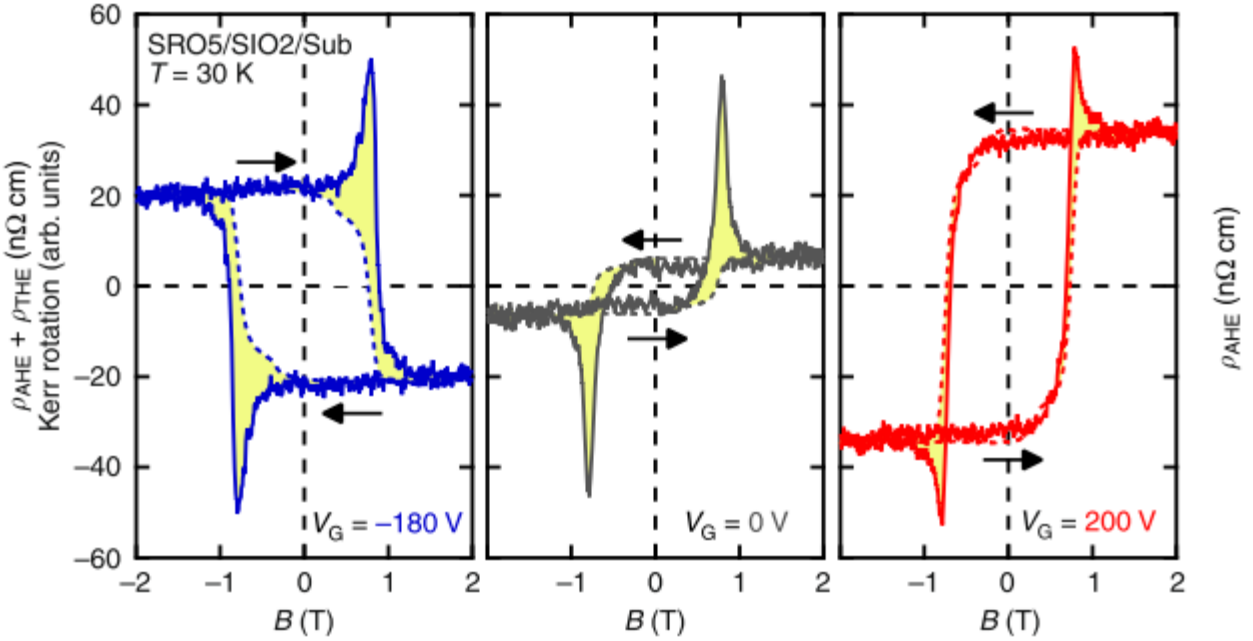
DOI: 10.1038/s41467-017-02629-3 OPEN

Electric-field control of anomalous and topological Hall effects in oxide bilayer thin films

Yuki Ohuchi[1], Jobu Matsuno[2], Naoki Ogawa[2], Yusuke Kozuka[1], Masaki Uchida[1], Yoshinori Tokura[1,2] & Masashi Kawasaki[1,2]







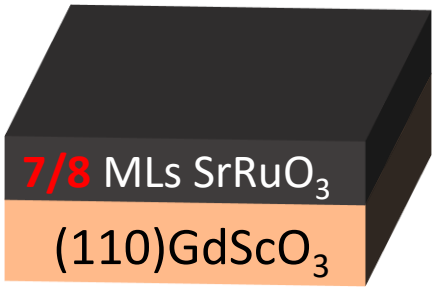
Ohuchi et. al, Nature Communications **9**, 213 (2018)

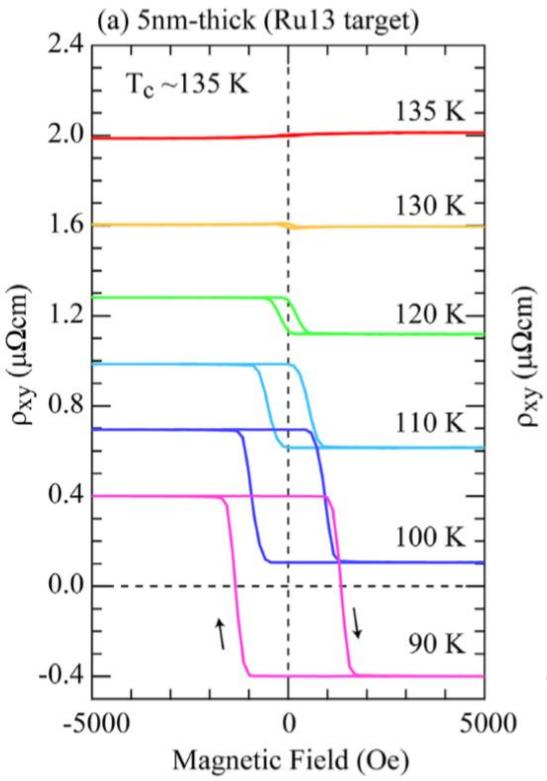
physica status solidi b
www.pss-b.com

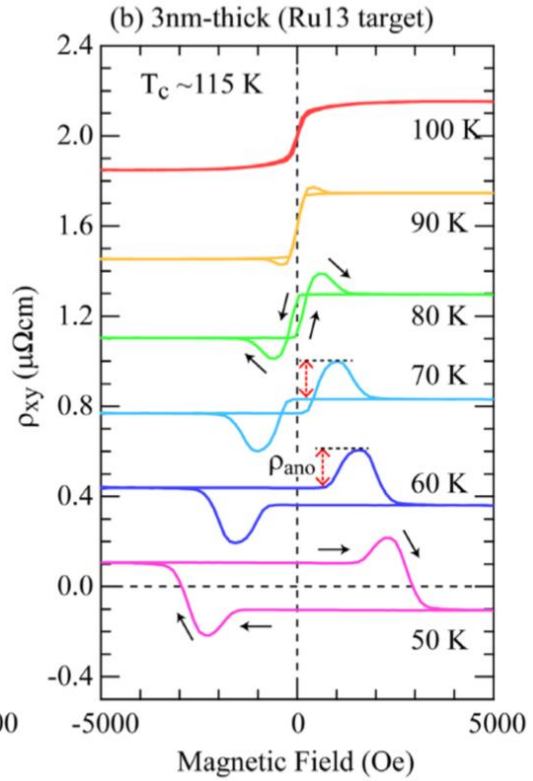
July 2018

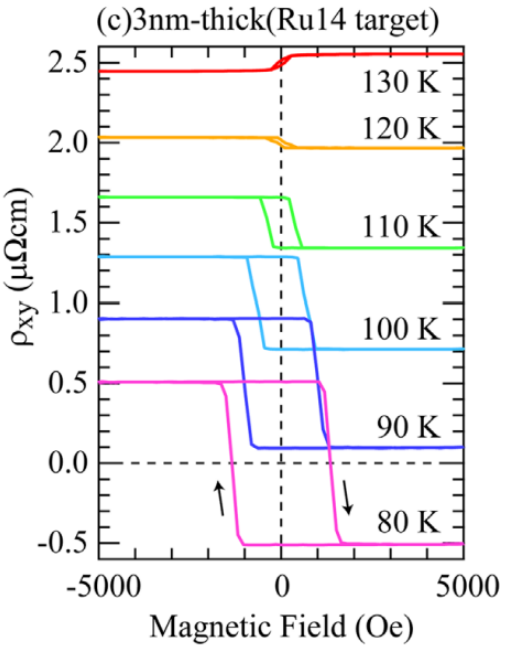
Defect-Induced Anomalous Transverse Resistivity in an Itinerant Ferromagnetic Oxide

Daisuke Kan and Yuichi Shimakawa*





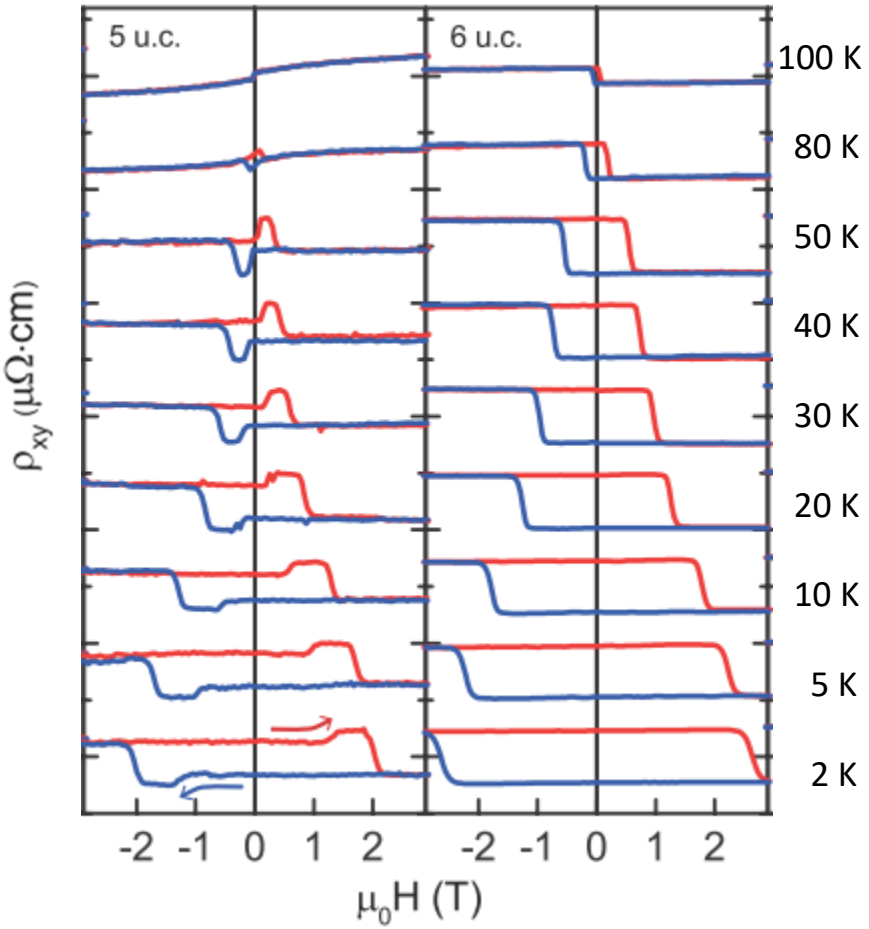


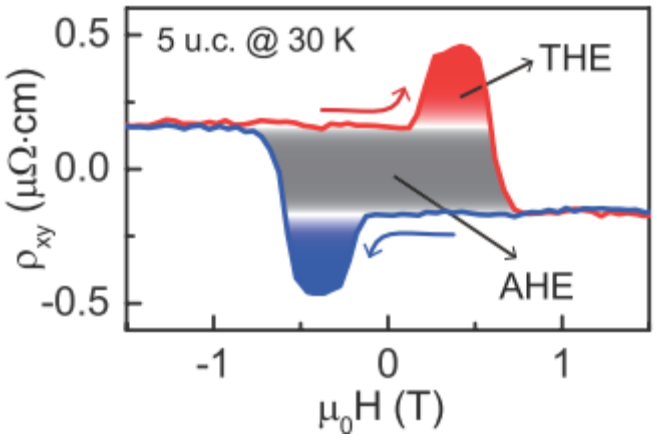


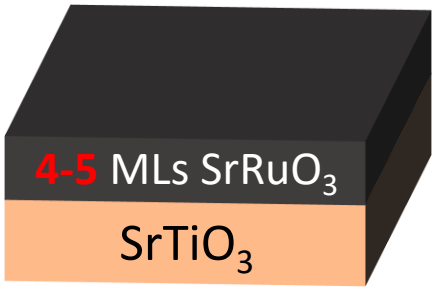
Kan and Shimakawa, Phys.Status Solidi B 2018, 1800175

Emergence of robust 2D skyrmions in $SrRuO_3$ ultrathin film without the capping layer

Byungmin Sohn,[1,2] Bongju Kim,[1,2,*] Se Young Park,[1,2] Hwan Young Choi,[3] Jae Young Moon,[3] Taeyang Choi,[4] Young Jai Choi,[3] Tae Won Noh,[1,2] Hua Zhou,[5] Seo Hyoung Chang,[4,†] Jung Hoon Han,[6,‡] and Changyoung Kim[1,2,§]





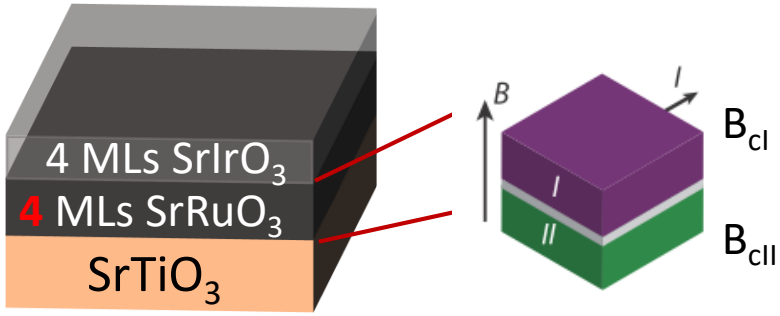


Sohn et al. , arXiv:1810.01615vl

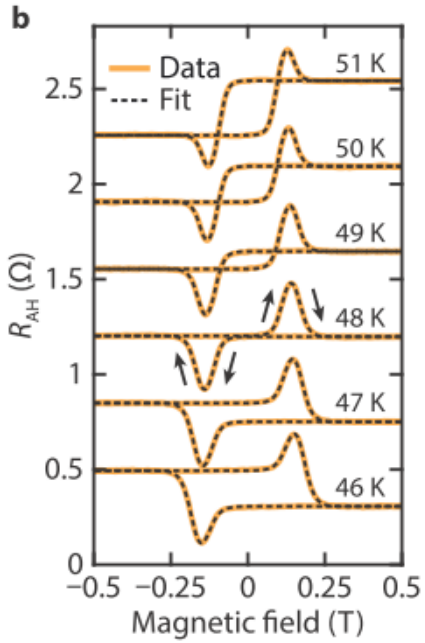
Berry phase engineering at oxide interfaces

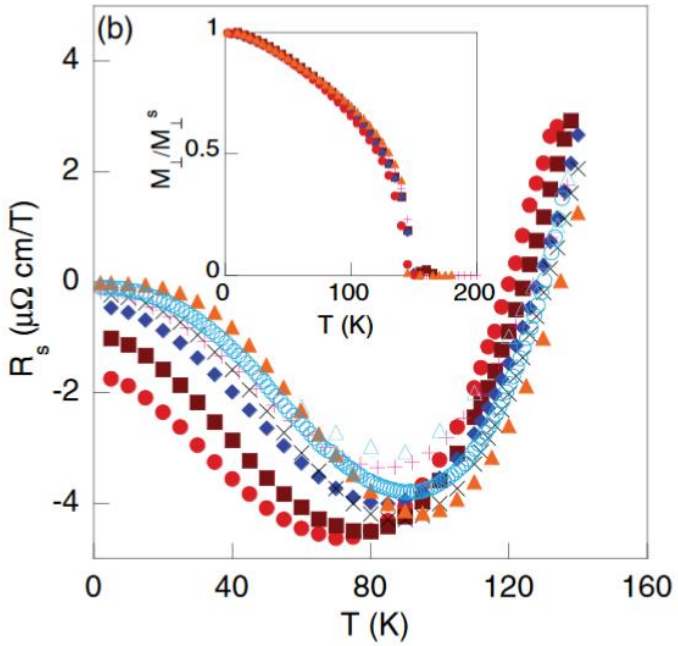
Dirk J. Groenendijk,[1,*] Carmine Autieri,[2,3,†] Thierry C. van Thiel,[1,†] Wojciech Brzezicki,[2,3] Nicolas Gauquelin,[4] Paolo Barone,[2] Karel H. W. van den Bos,[4] Sandra van Aert,[4] Johan Verbeeck,[4] Alessio Filippetti,[5,6] Silvia Picozzi,[2] Mario Cuoco,[2,7] and Andrea D. Caviglia[1,‡]

12th of October 2018



$$\rho_{anomalous\ Hall} = R_A M_z$$





Haham et al., Physical Review B 84, 174439 (2011)

Groenendijk et al. , arXiv:1810.05619vl

Berry phase engineering at oxide interfaces

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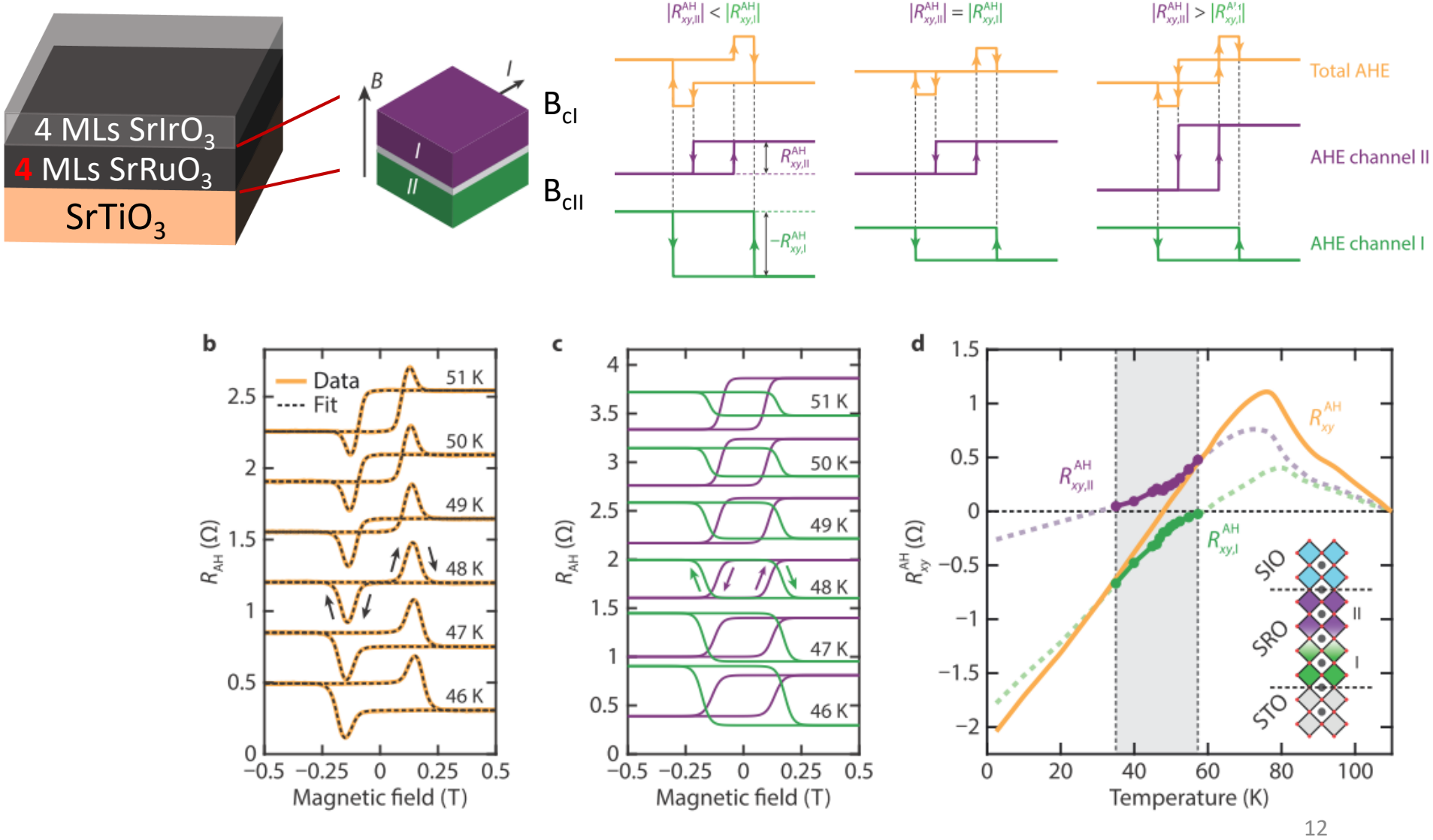
12th of October 2018



Groenendijk et al. , arXiv:1810.05619vl

nature materials

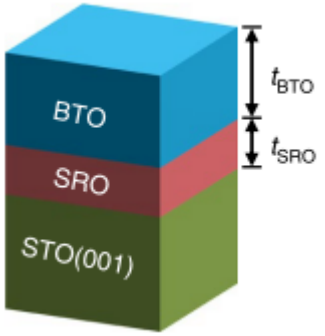
ARTICLES

https://doi.org/10.1038/s41563-018-0204-4

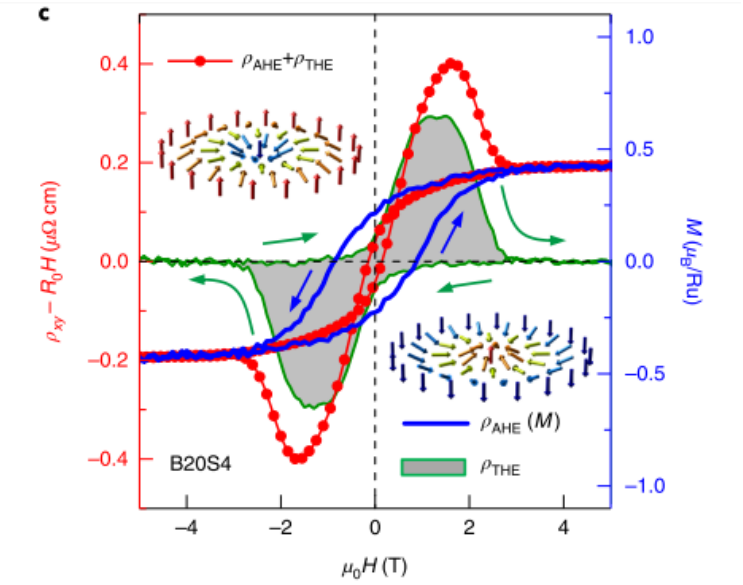
November 2018

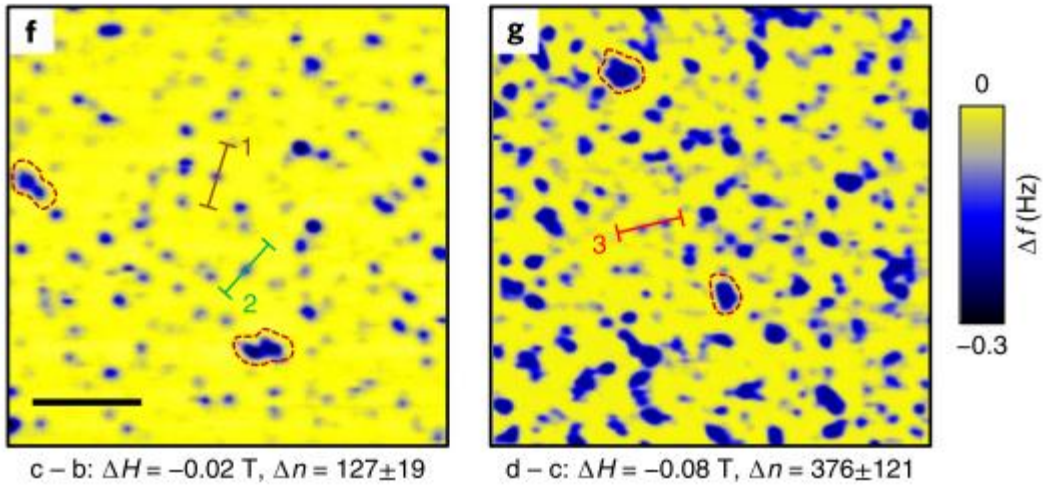
Ferroelectrically tunable magnetic skyrmions in ultrathin oxide heterostructures

Lingfei Wang[1,2*], Qiyuan Feng[3,4,8], Yoonkoo Kim[5,8], Rokyeon Kim[1,2,8], Ki Hoon Lee[1,2,8], Shawn D. Pollard[6], Yeong Jae Shin[1,2], Haibiao Zhou[1,2,3], Wei Peng[1,2], Daesu Lee[1,2], Wenjie Meng[3], Hyunsoo Yang[6], Jung Hoon Han[7], Miyoung Kim[5], Qingyou Lu[3,4*] and Tae Won Noh[1,2*]



10 K

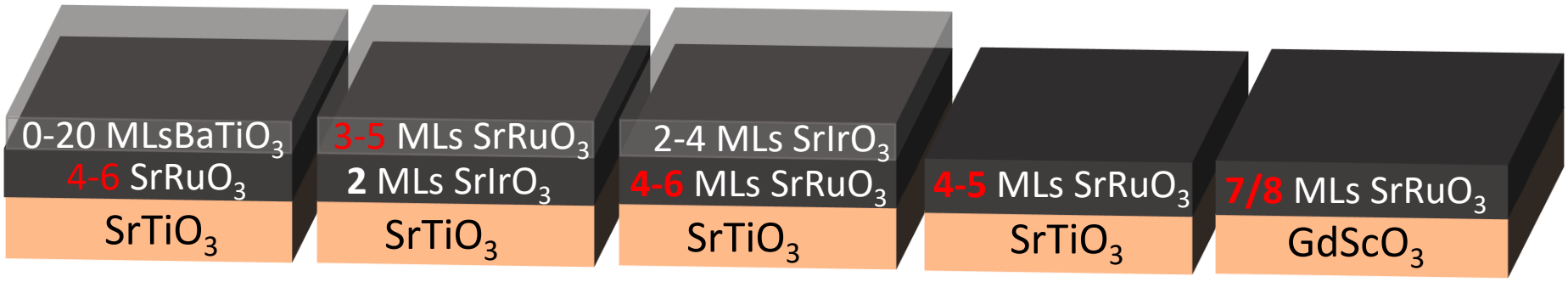




Summary

skyrmions

Noh group | Kawasaki group | Kim group



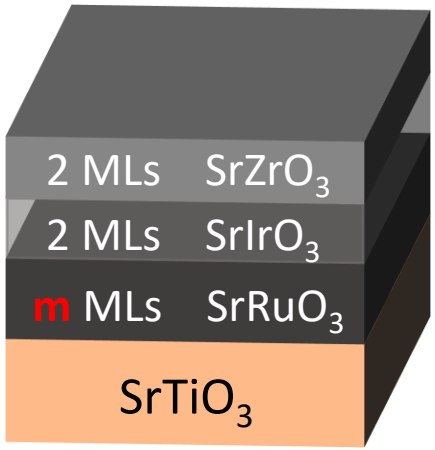
Caviglia group

Kan and Shimakawa

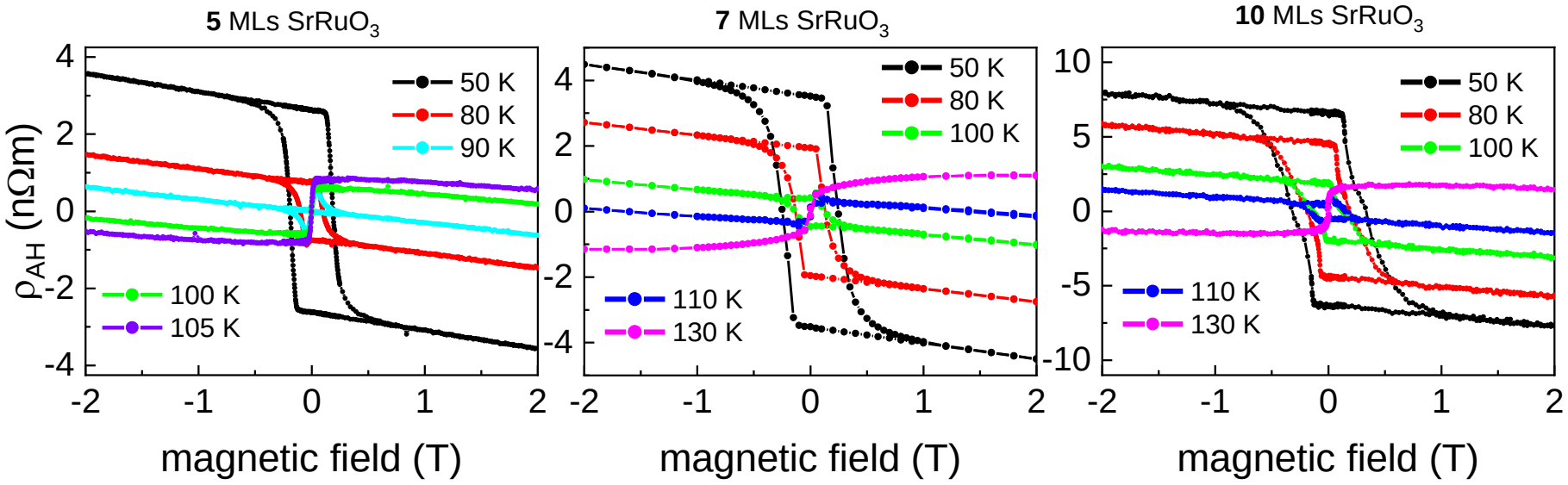
bandstructure modifications -> influence on AHE

Asymmetric multilayers with varying $SrRuO_3$ layer thickness:

$6\cdot[\mathbf{m}\ MLs\ SrRuO_3/\ 2\ MLs\ SrIrO_3/\ 2\ MLs\ SrZrO_3]$



Multilayers: Hall resistivity

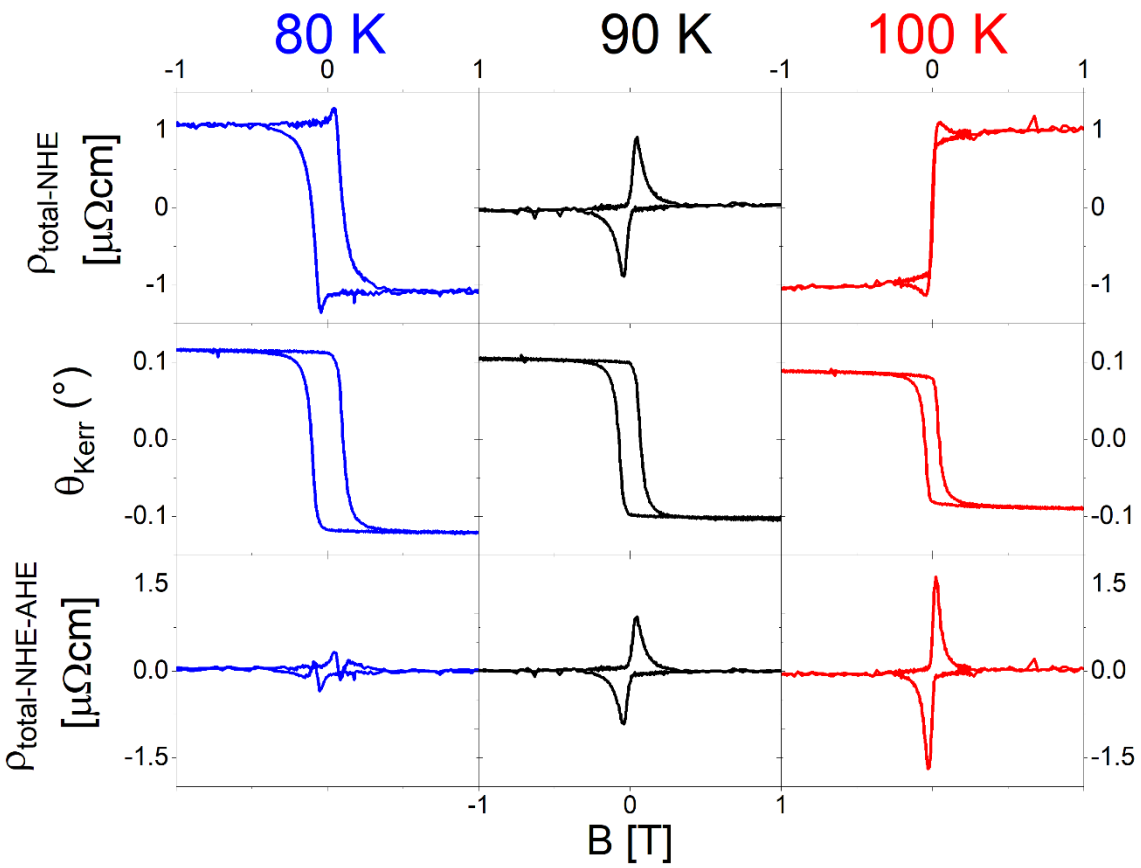


linear contribution:
ordinary Hall effect

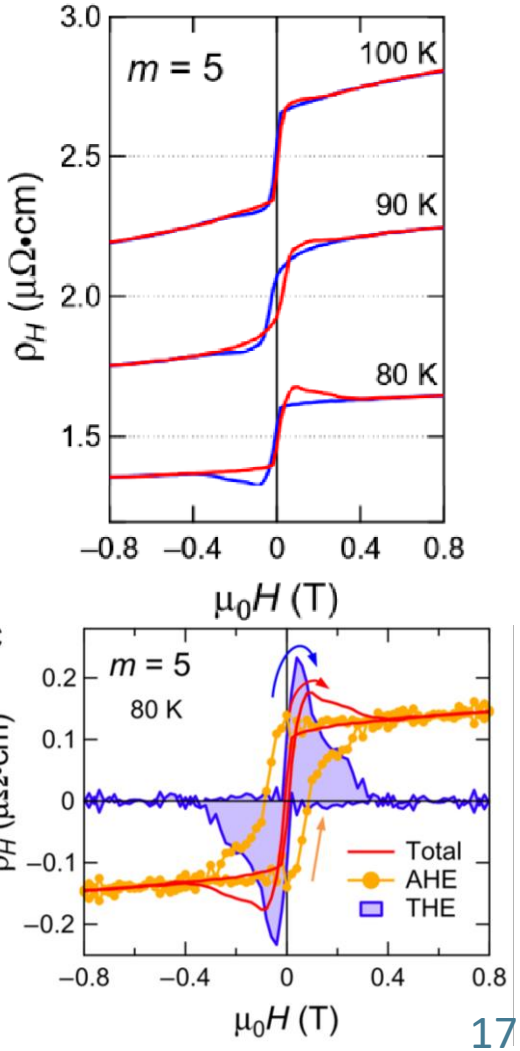
hysteresis shape:
anomalous Hall effect

Our multilayers vs bilayers

6*(**5** MLs $SrRuO_3$/2 MLs $SrIrO_3$/2 MLs $SrZrO_3$)



5 MLs $SrRuO_3$/2 MLs $SrIrO_3$

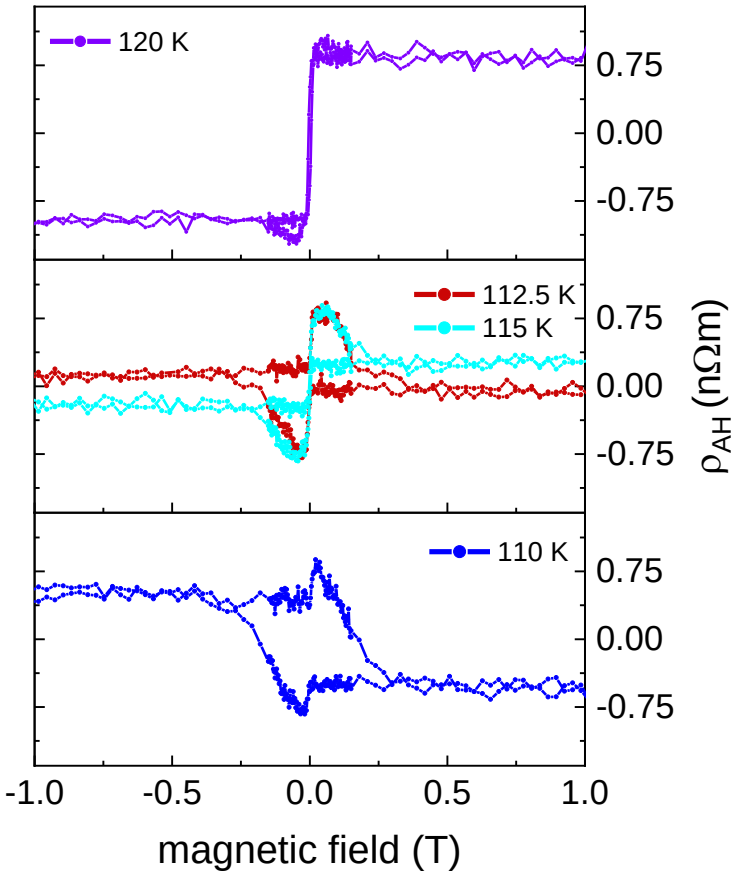


Measurements performed by Jörg and Ramil

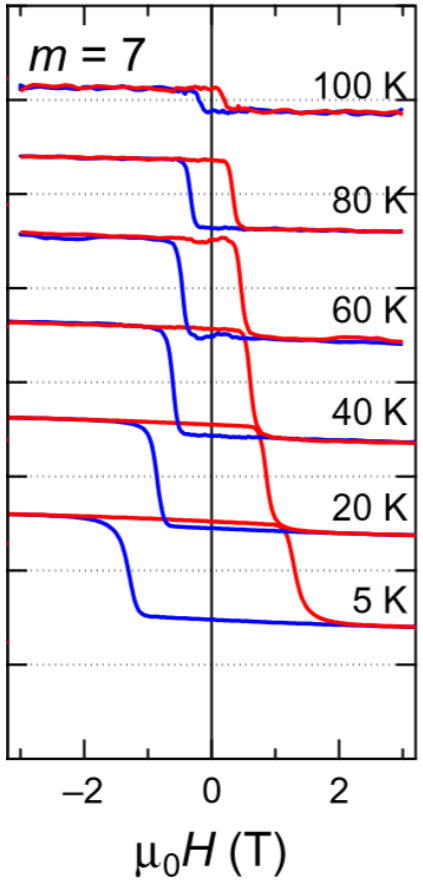
J. Matsuno et al., Sci. Adv. 2, e1600304 (2016)

Our multilayers vs bilayers

6*(**10** MLs $SrRuO_3$/2 MLs $SrIrO_3$/2 MLs $SrZrO_3$)



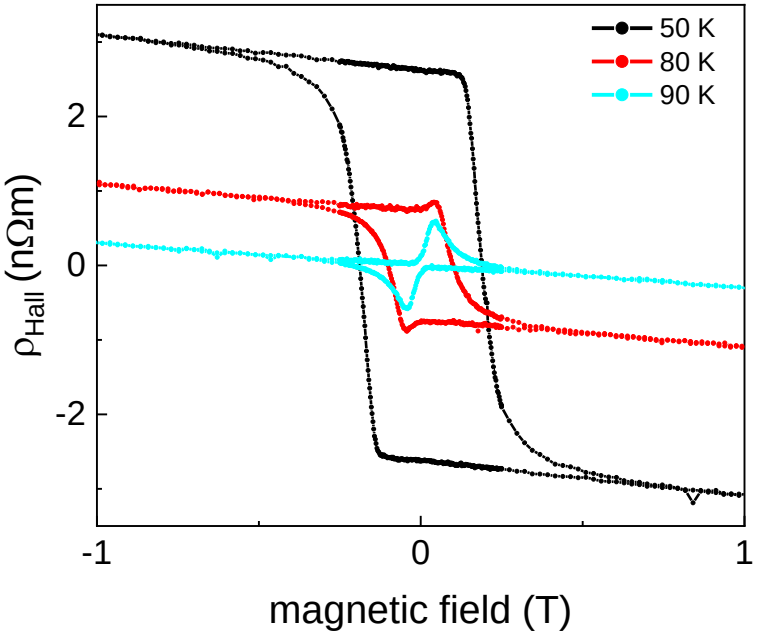
7 MLs $SrRuO_3$/2 MLs $SrIrO_3$

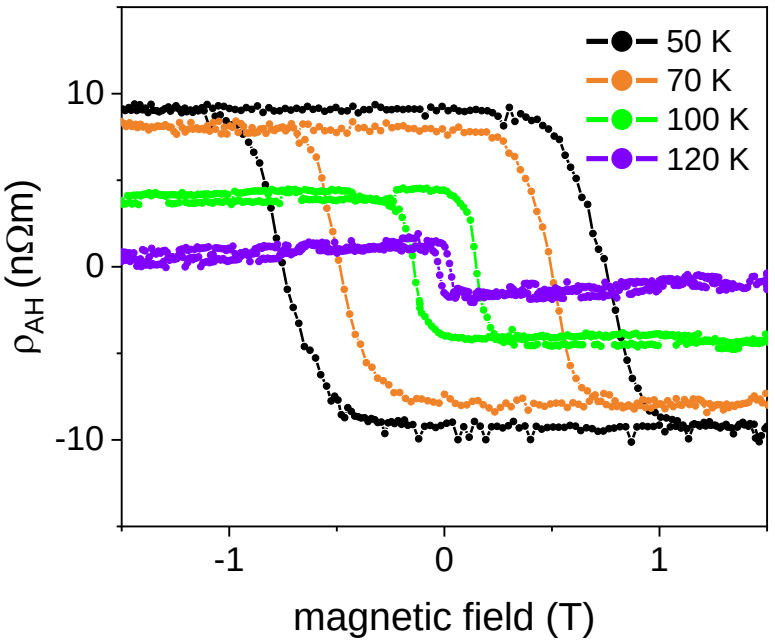


J. Matsuno et al., Sci. Adv. 2, e1600304 (2016)

Influence of the interface

Measurements performed by Jörg





Universität zu Köln

Thank your for your attention ☺