Emergence of Majorana bound states in a Kitaev spin liquid beyond quantum criticality

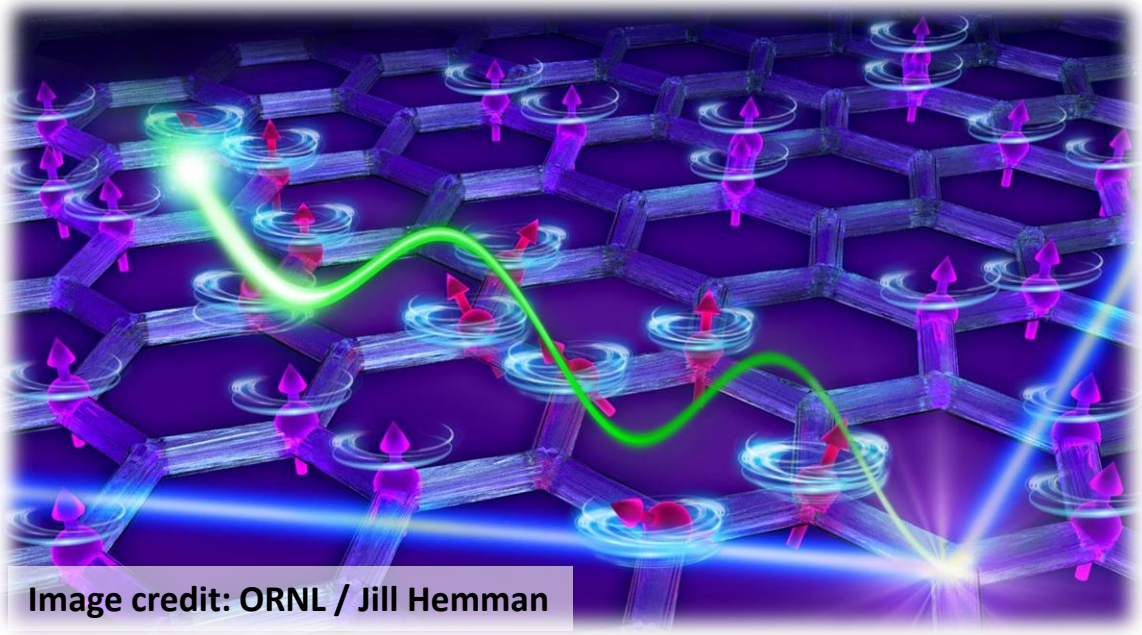

Image credit: ORNL / Jill Hemman

→ arXiv:1910.00800

Dirk Wulferding
Youngsu Choi
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Chan Hyeon Lee
Peter Lemmens
Clément Faugeras
Yann Gallais
Kwang-Yong Choi

IPKM & LENA, TU Braunschweig
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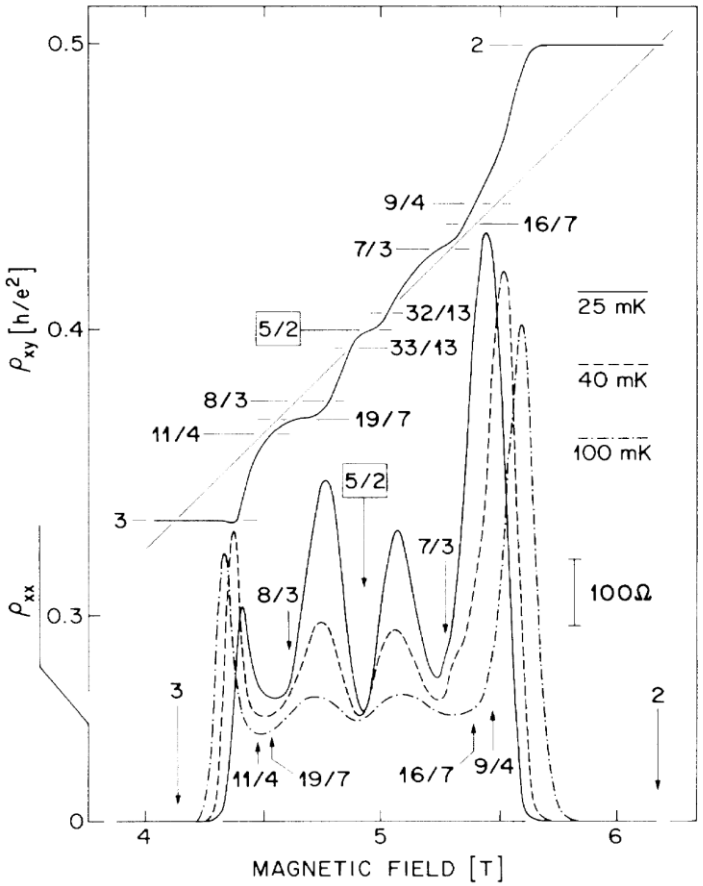
LNCMI-CNRS Grenoble, France
Chung-Ang Univ. Seoul, Korea
MPK / POSTECH, Korea

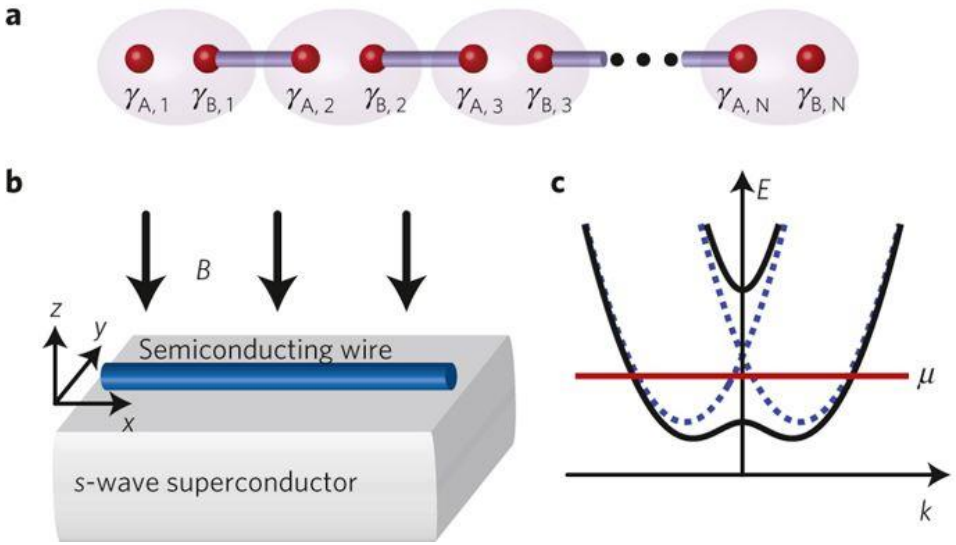
Optical Spectroscopy / Metrology Group

The hunt for non-Abelian quasi-particles

FQHE at ν=5/2

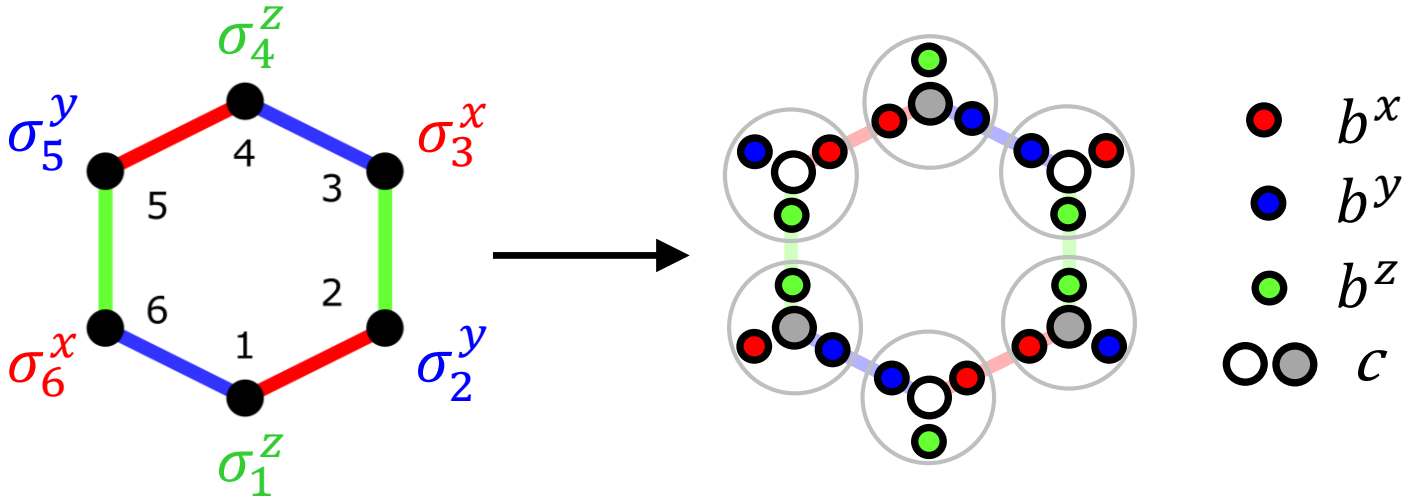


Willett, et al., PRL **59**, 1776 (1987).



Alicea, et al., Nat. Phys. **7**, 412 (2011).

Kitaev honeycomb magnets – a promising route towards Majorana fermionic excitations



A. Kitaev, Ann. Phys. **321**, 2 (2006).

$$H_K = -J_{xx} \sum_{xx-link} \sigma_i^x \sigma_j^x - J_{yy} \sum_{yy-link} \sigma_i^y \sigma_j^y - J_{zz} \sum_{zz-link} \sigma_i^z \sigma_j^z$$

$$H_K = -J_a \sum_{<i,j>a} \sigma_i^a \sigma_j^a \longrightarrow H_K = -iJ_a \sum_{<i,j>a} u_{i,j}^a c_i \; c_j$$

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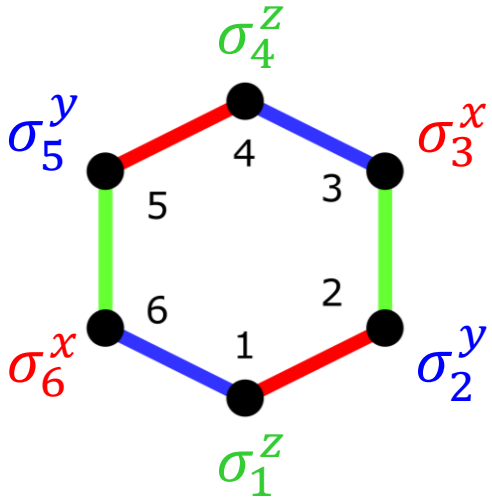

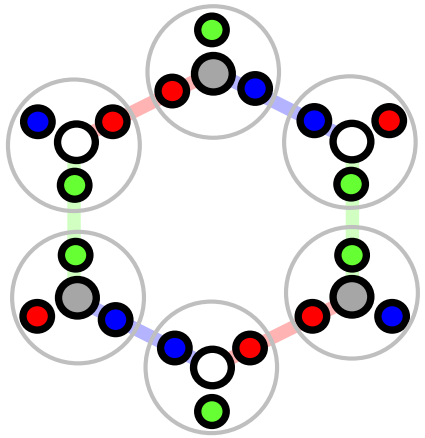

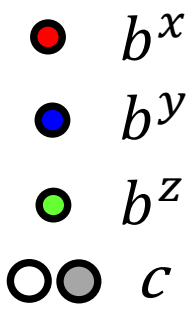

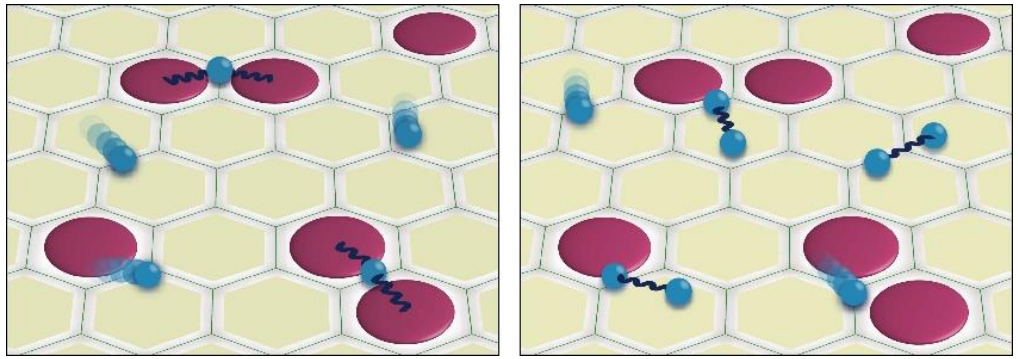

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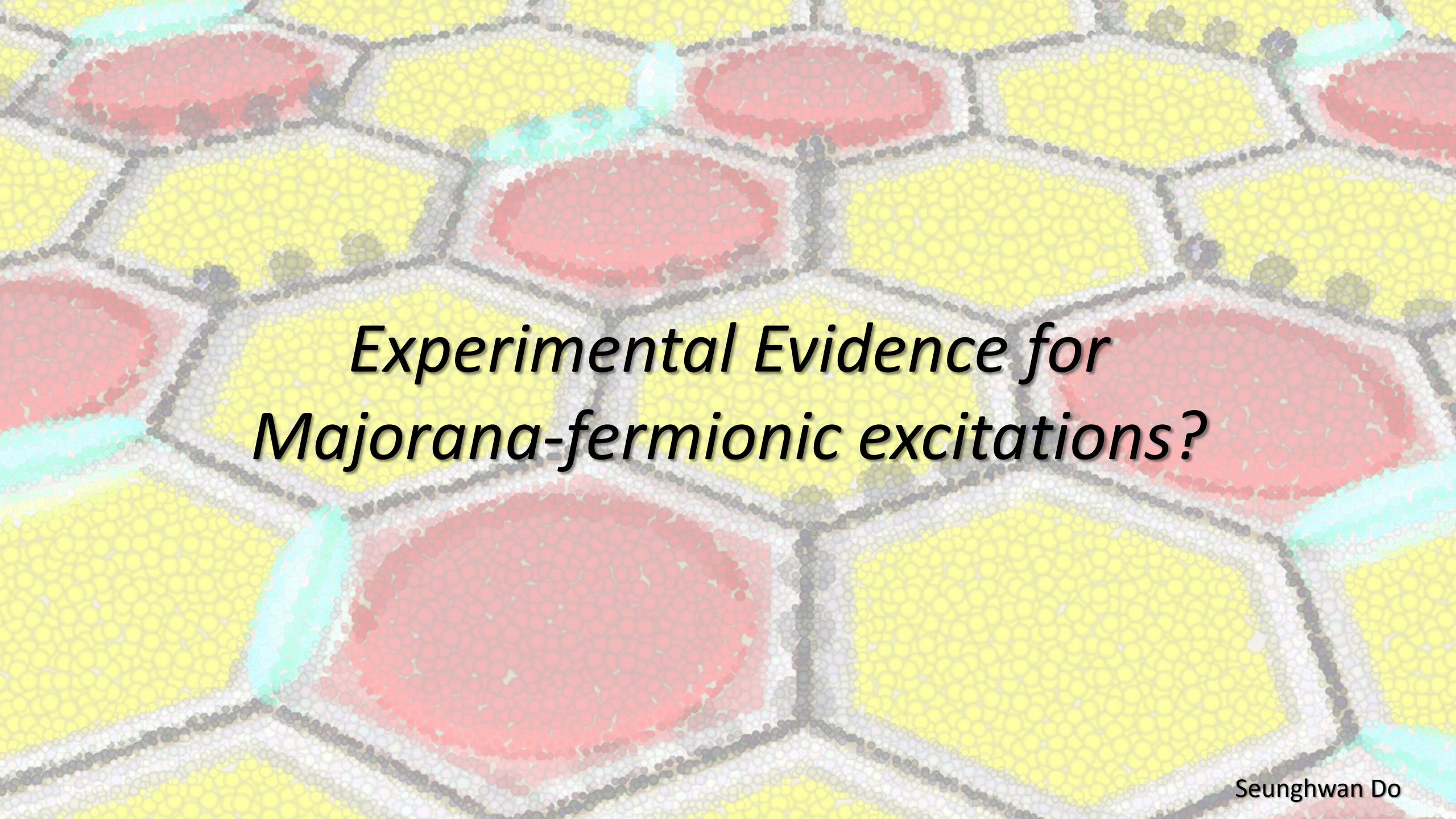
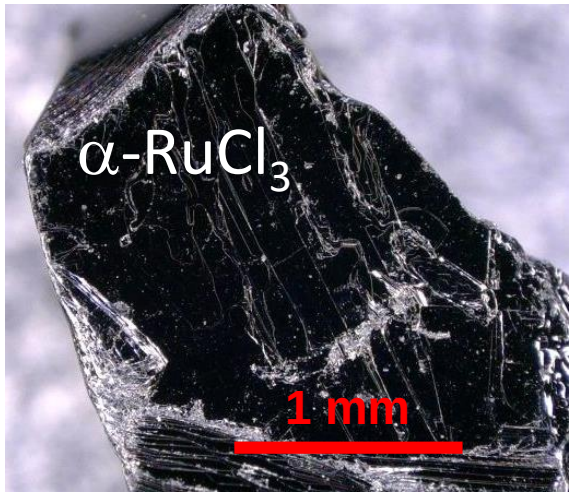
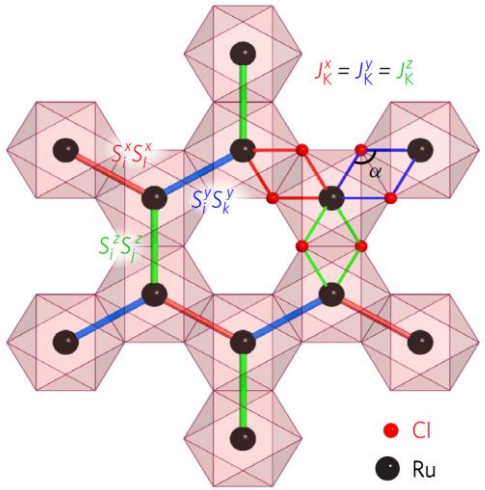
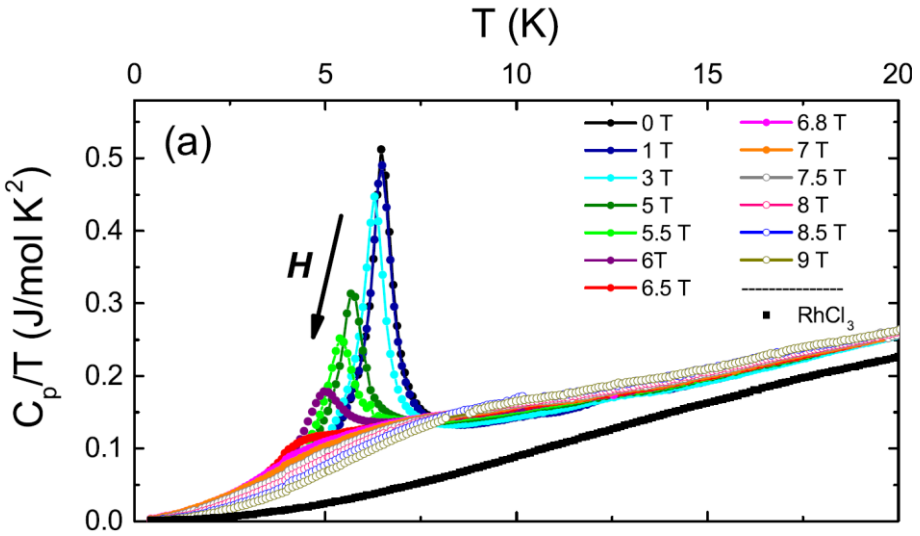


Seunghwan Do

α-$RuCl_3$ – a close realization of a Kitaev honeycomb magnet







Wolter, et al., Phys. Rev. B **96**, 041405 (2017).

Kitaev candidates vs. Kitaev model:

$H = H_K + J + \Gamma + \ldots$

Sandilands, et al., PRL **114**, 147201 (2015).
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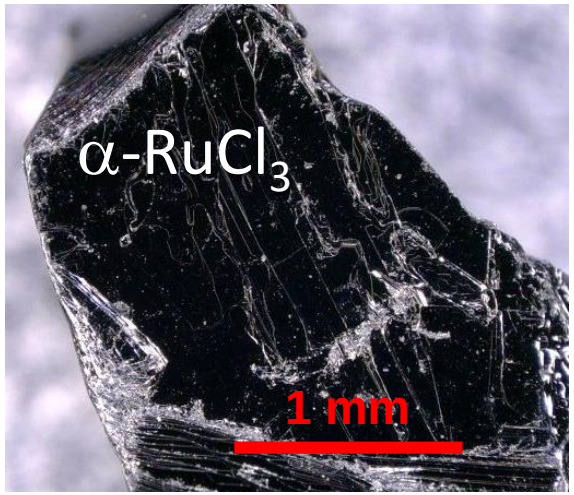

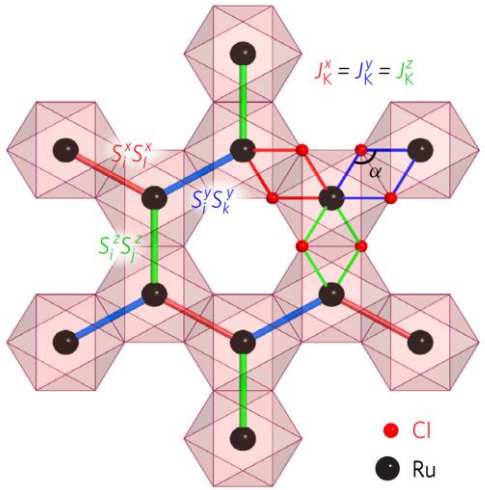

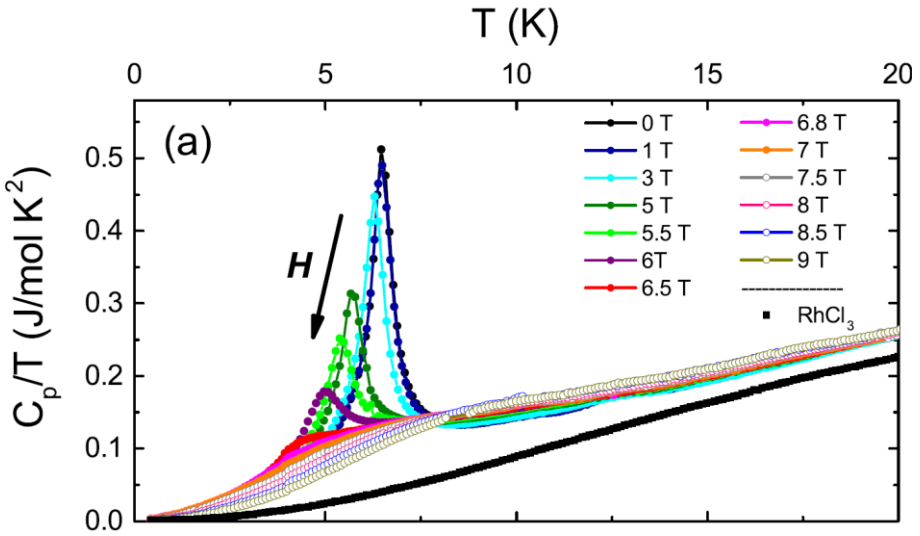

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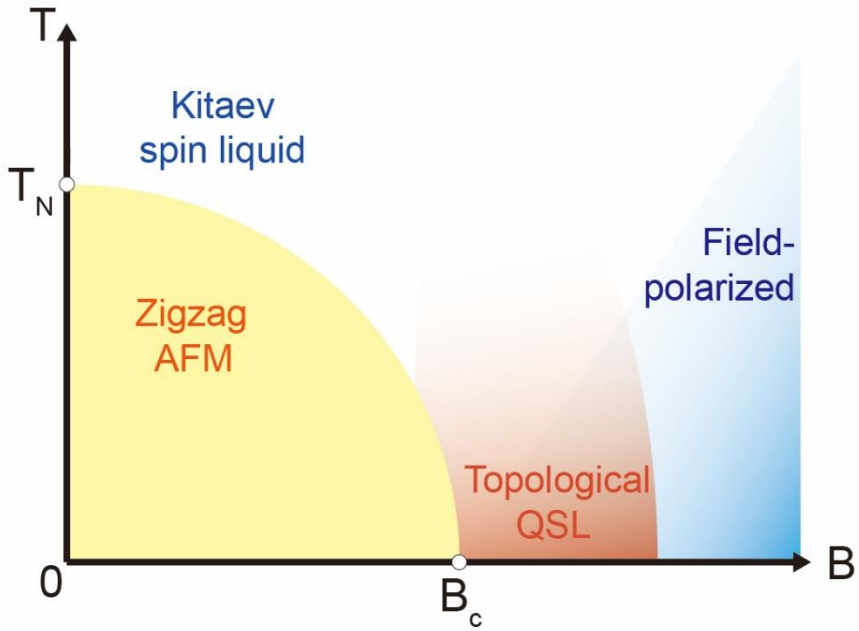

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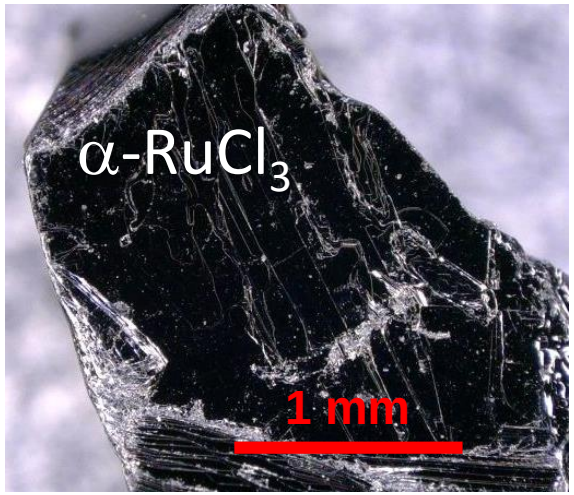
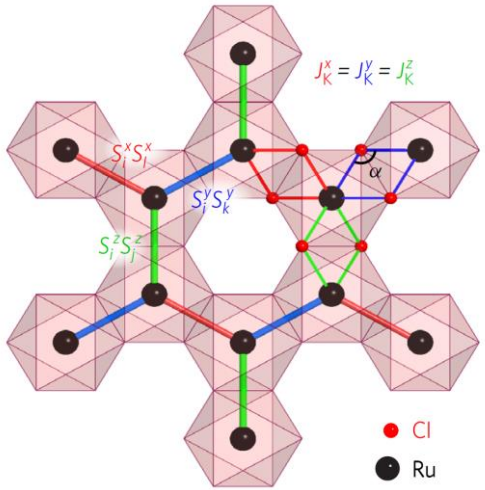
α-$RuCl_3$ – thermodynamic fingerprints of fractionalization





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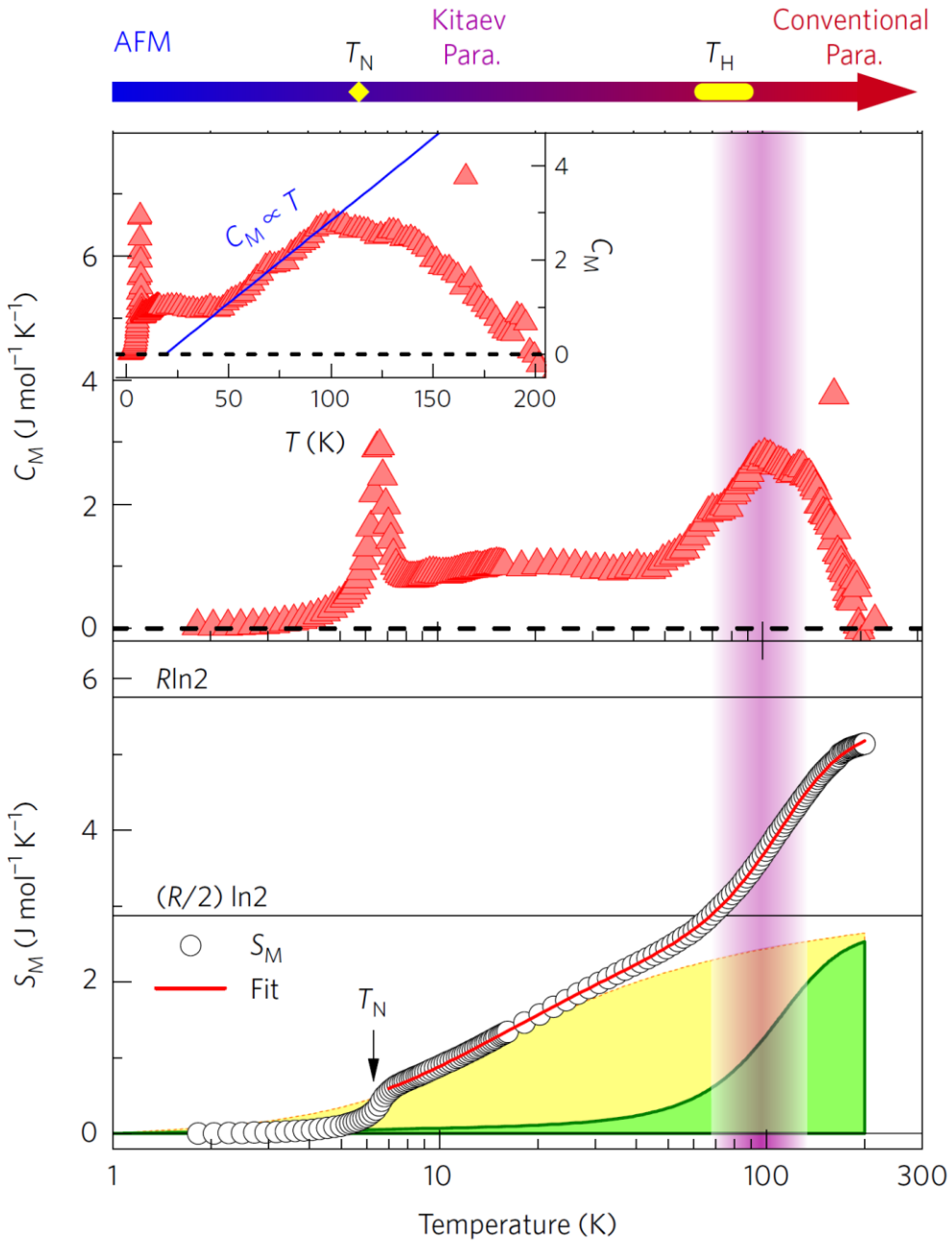

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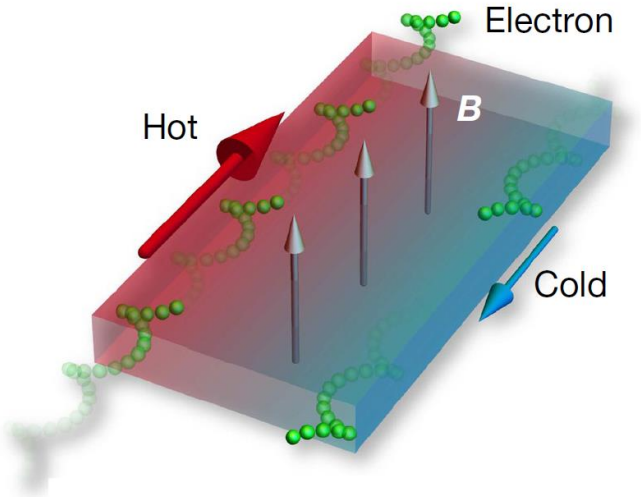
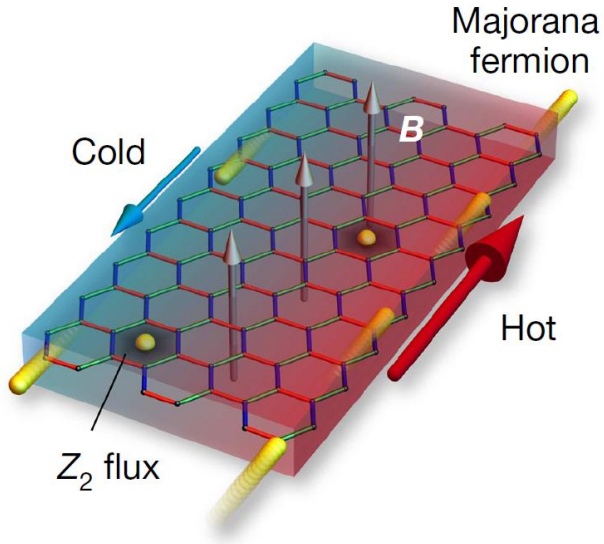
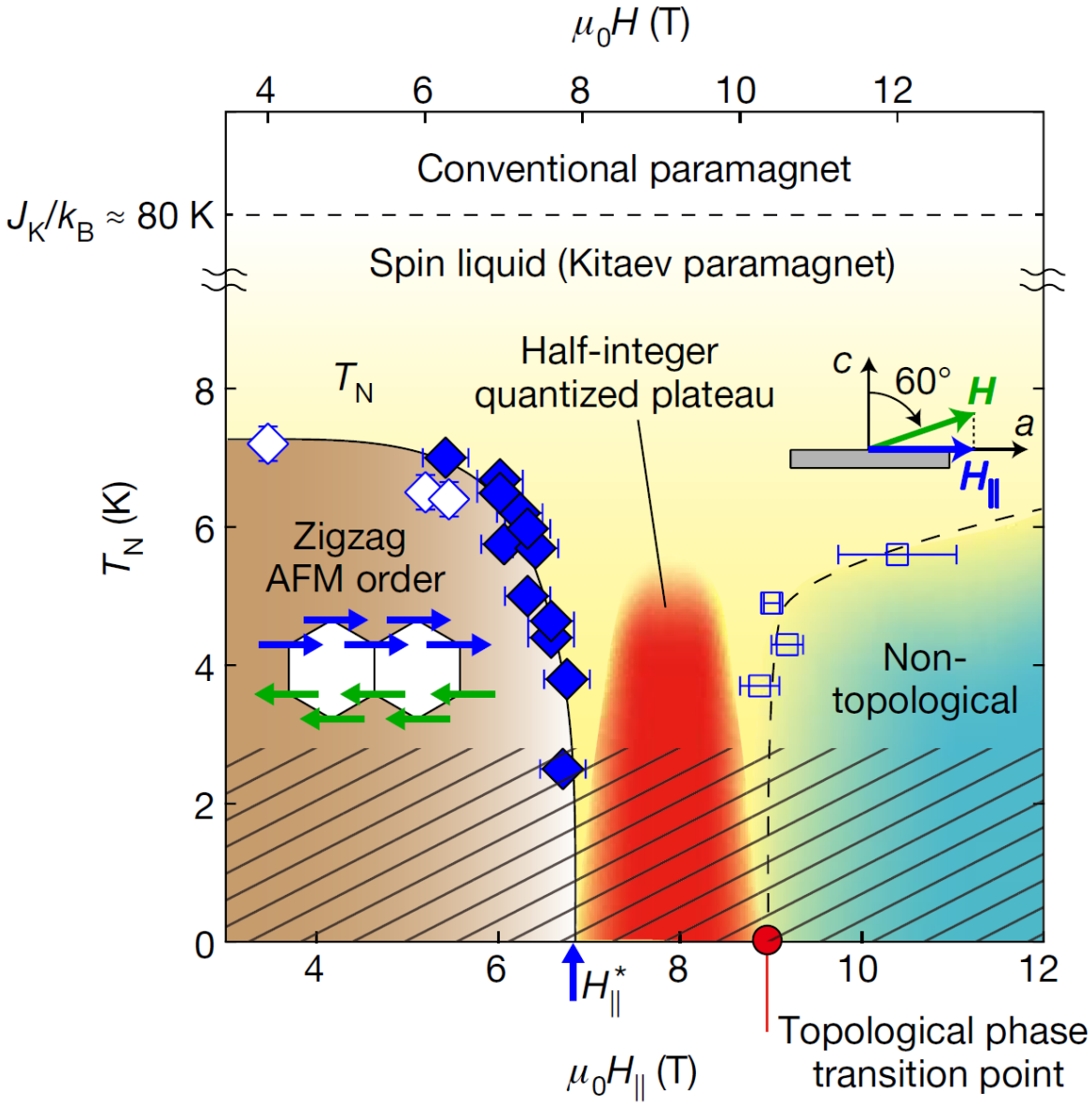
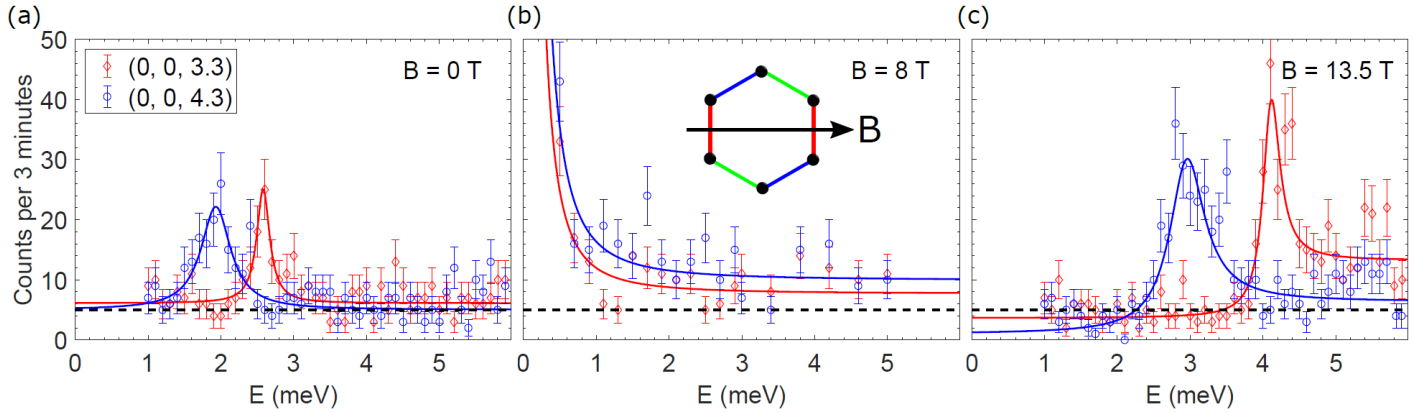


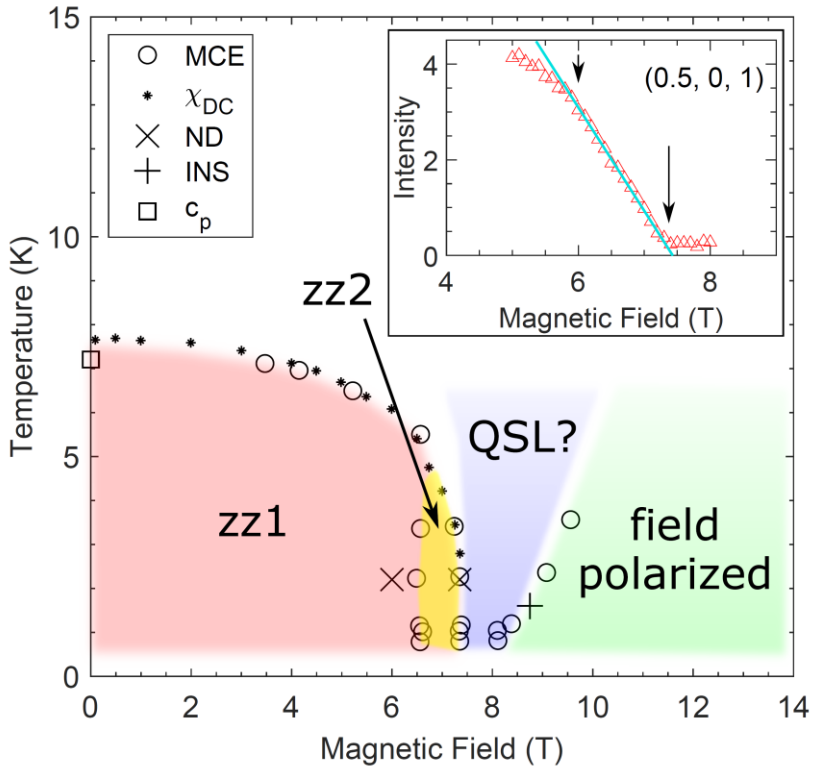




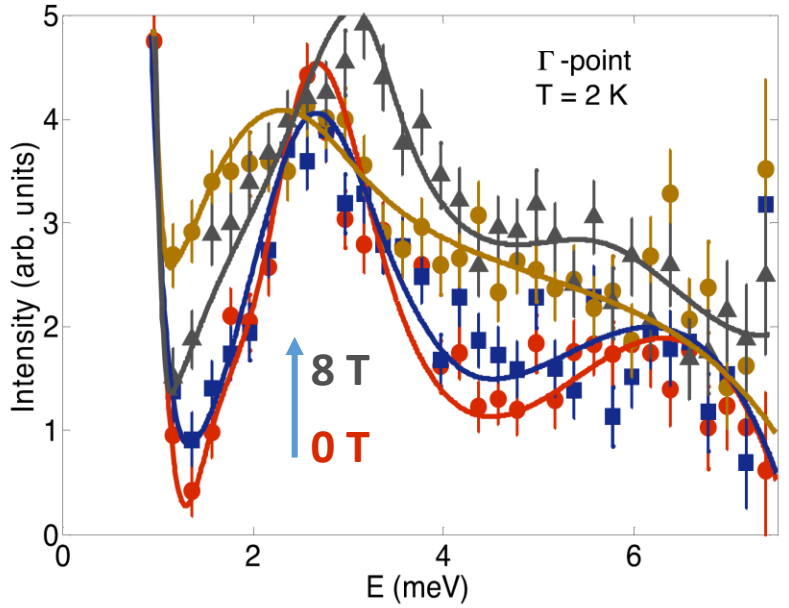
Kasahara, et al., Nature **559**, 227 (2018).

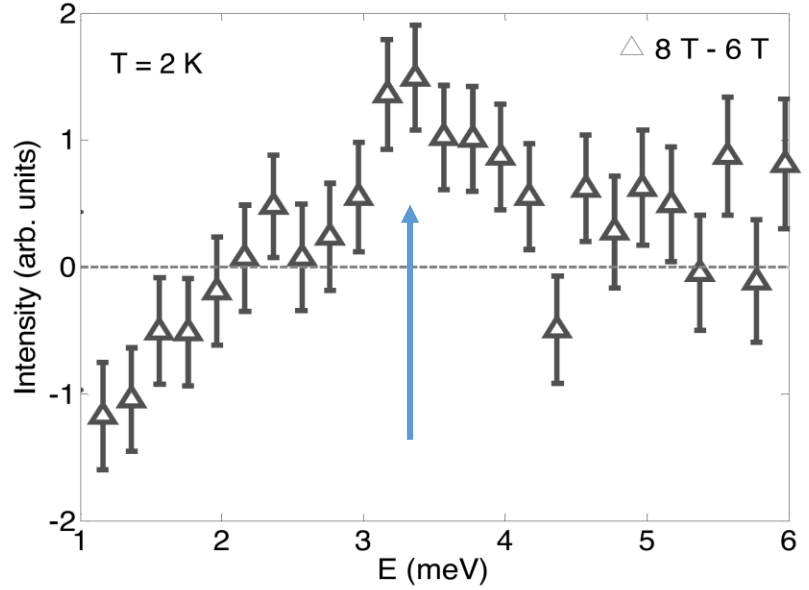
α-$RuCl_3$ – spectroscopic fingerprints for an intermediate phase





Novel excitation in intermediate phase?
Possibly Majorana bound state?

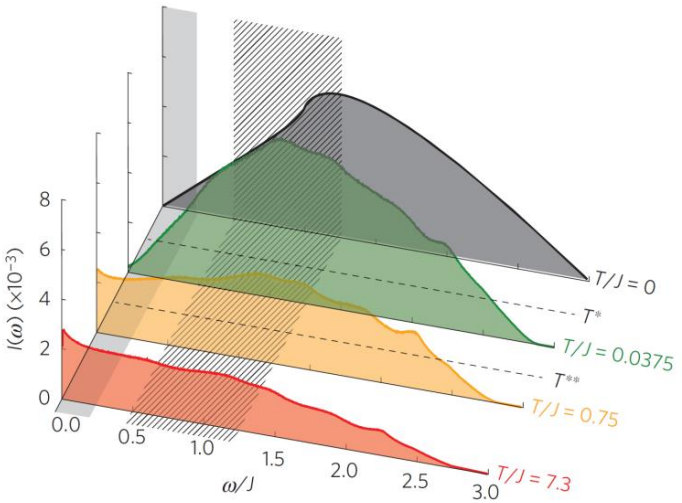


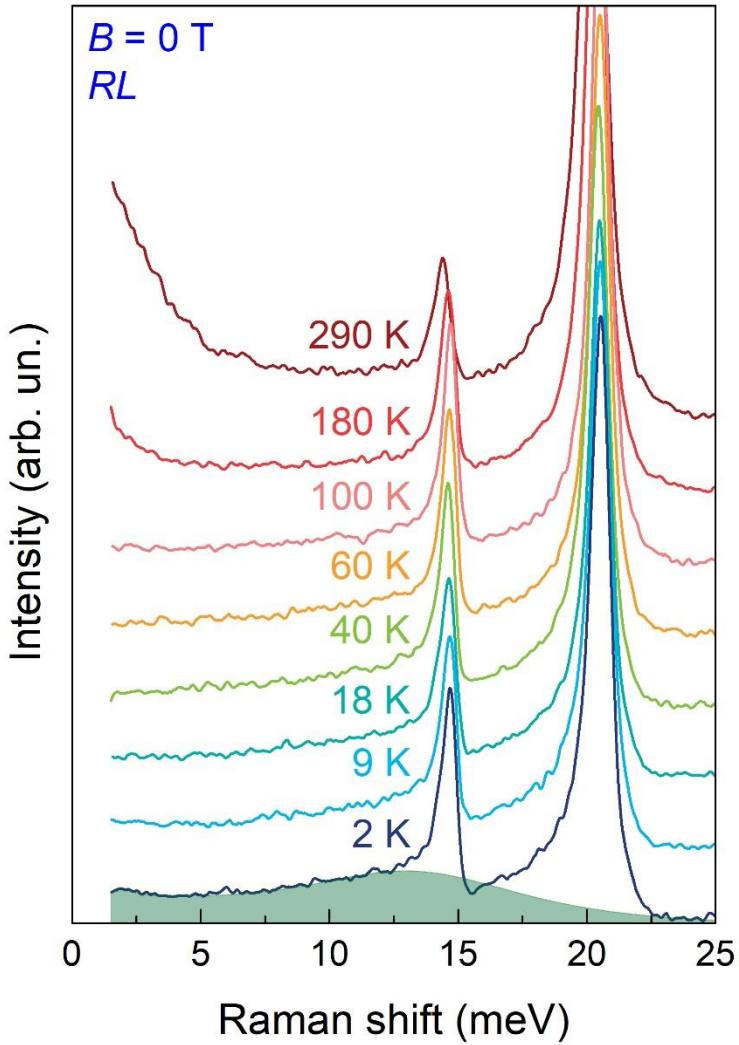


Balz, et al., PRB **100**, 060405(R) (2019).

Banerjee, et al., npj Quantum Mater. **3**, 8 (2018).

Raman-spectroscopic fingerprints of fractionalized excitations in Kitaev magnets





J. Knolle, et al., PRL **113**, 187201 (2014).
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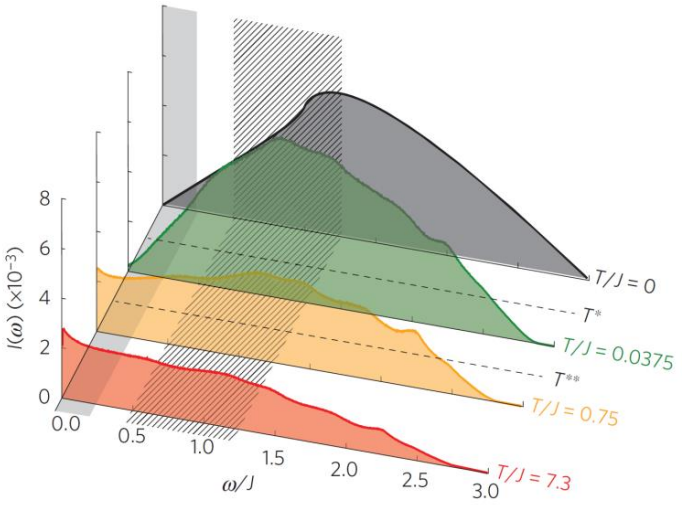

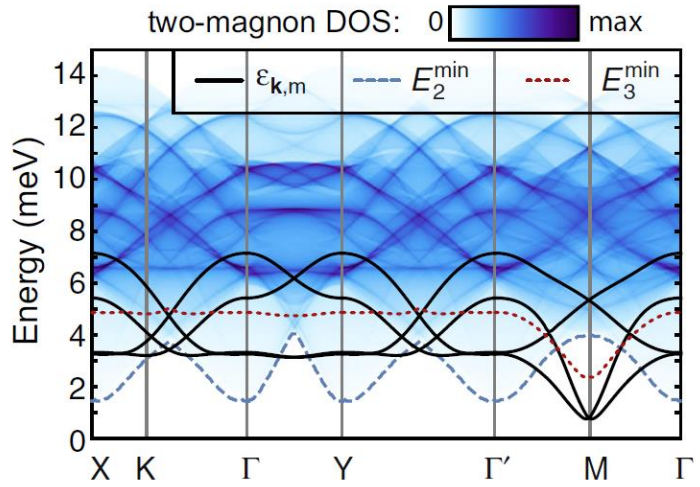

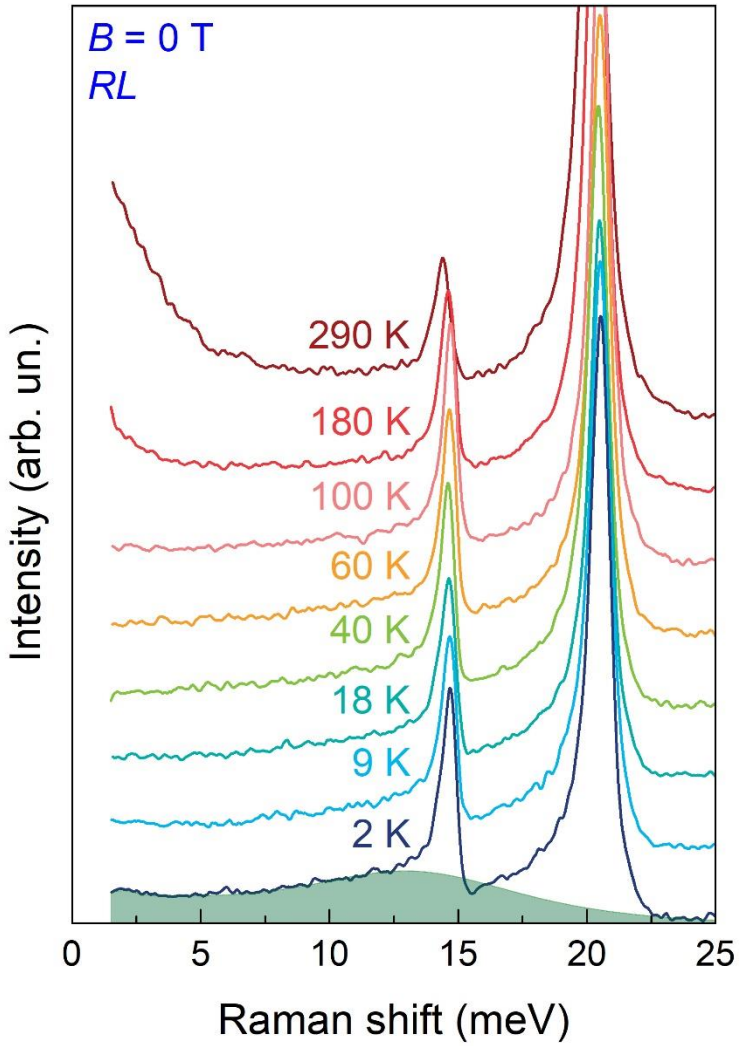

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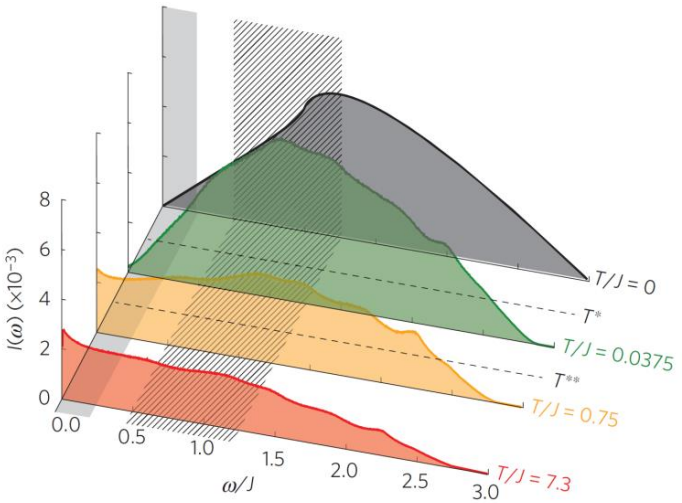

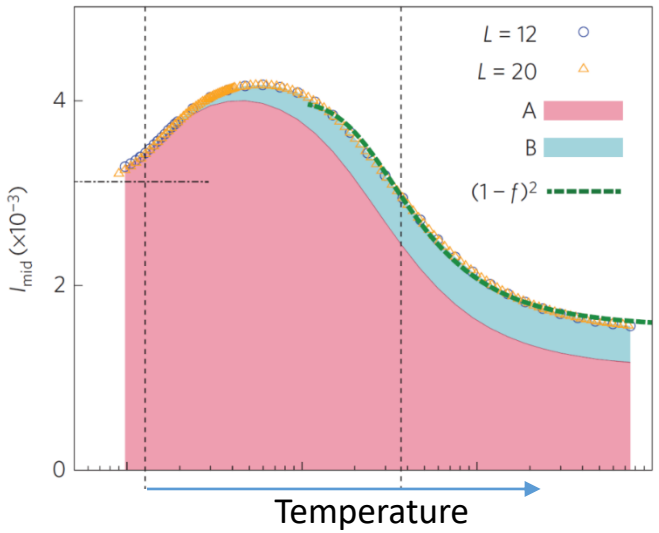

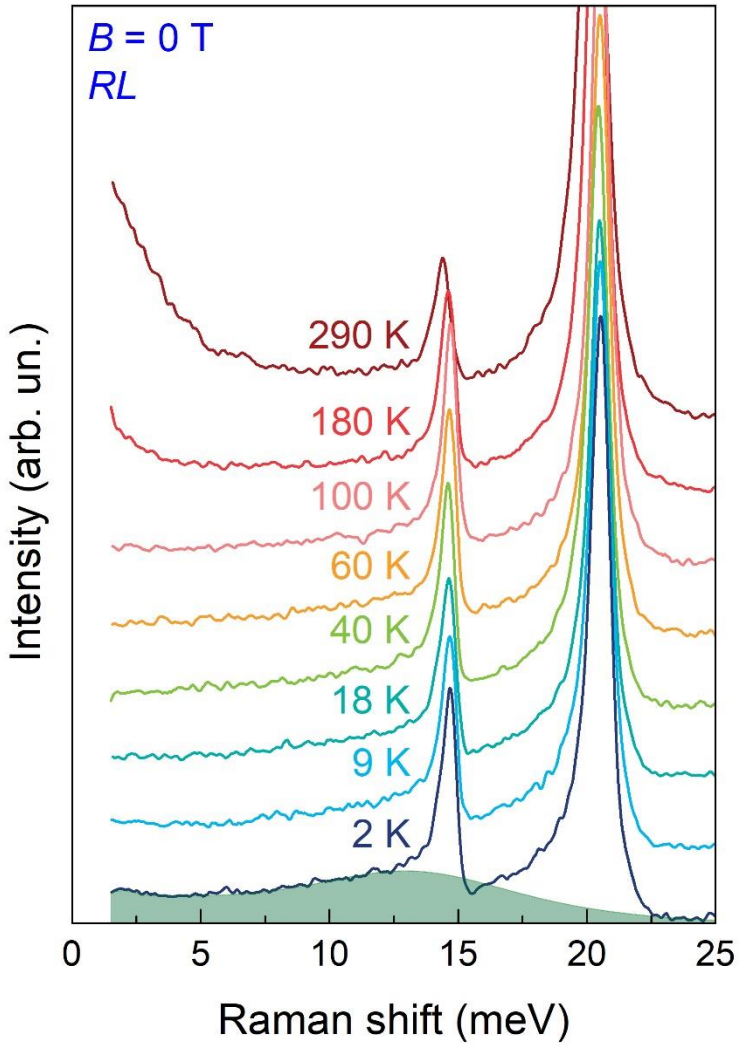

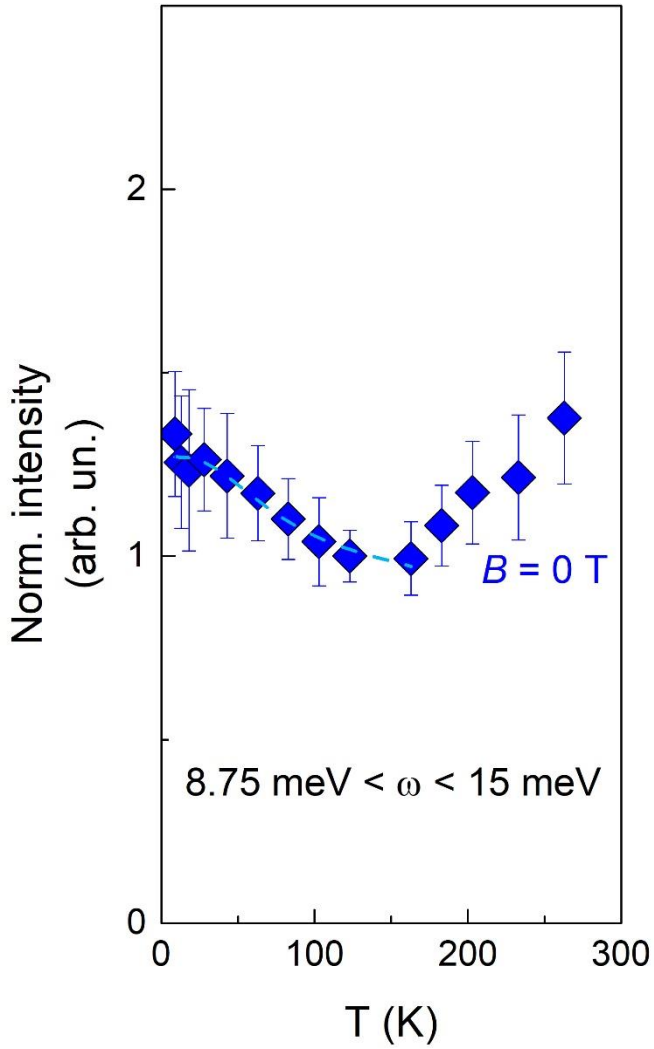

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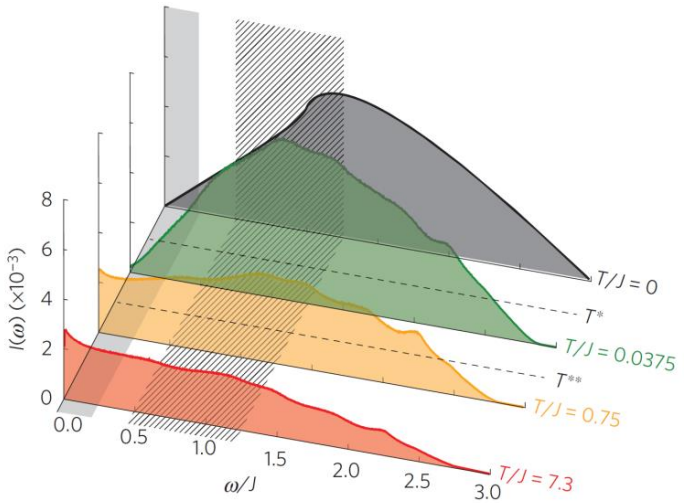

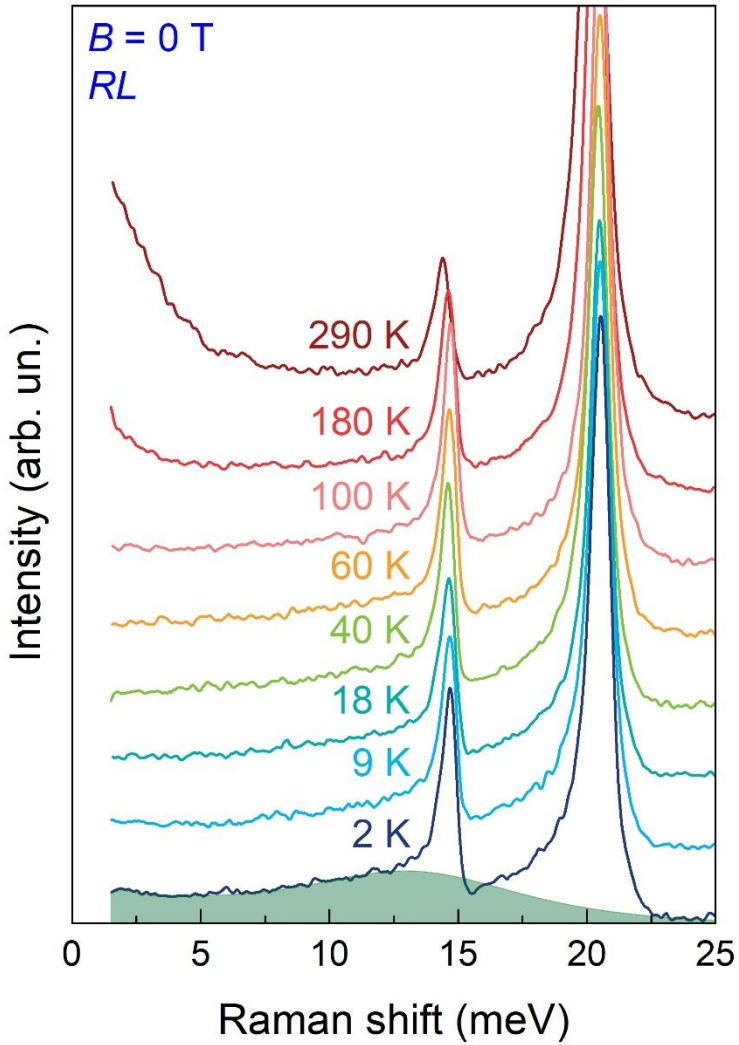

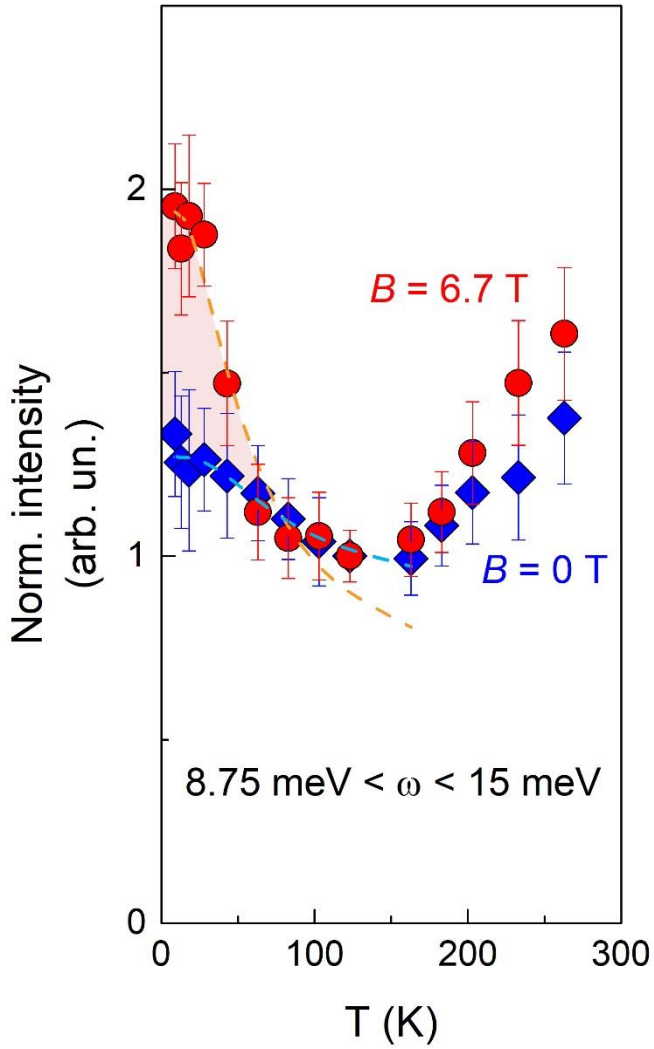

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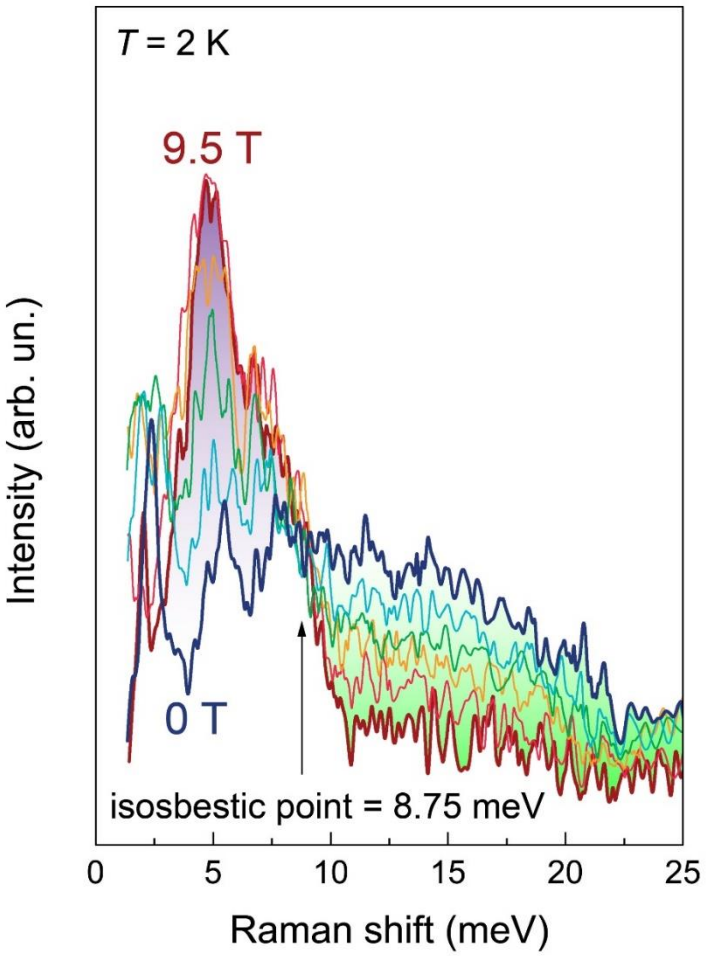
Spectral weight re-distribution & field-induced Majorana bound state

B-dependence



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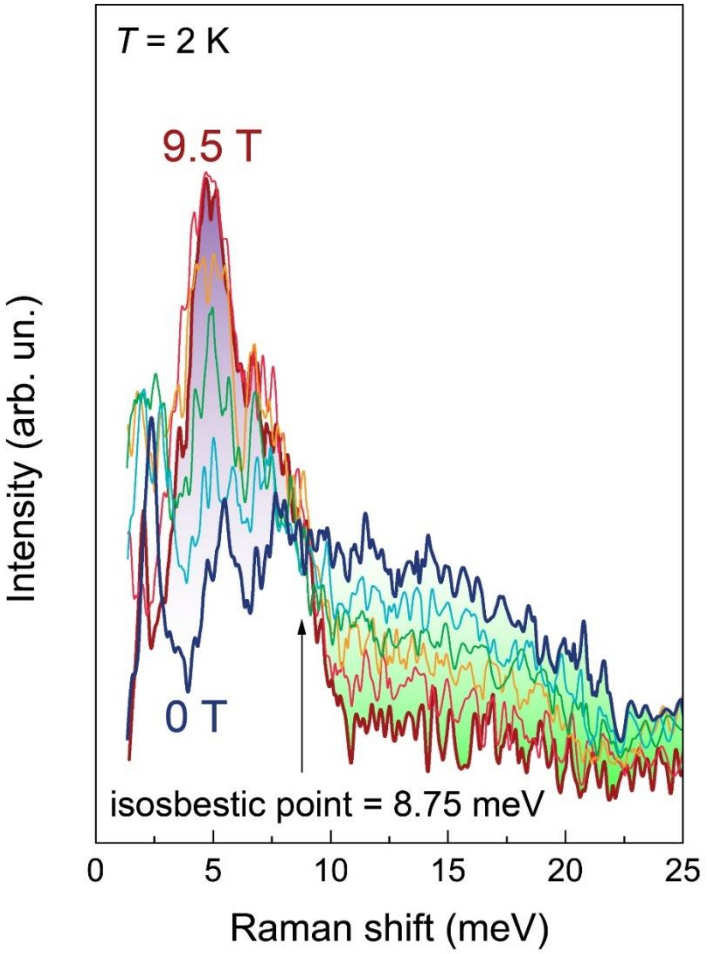
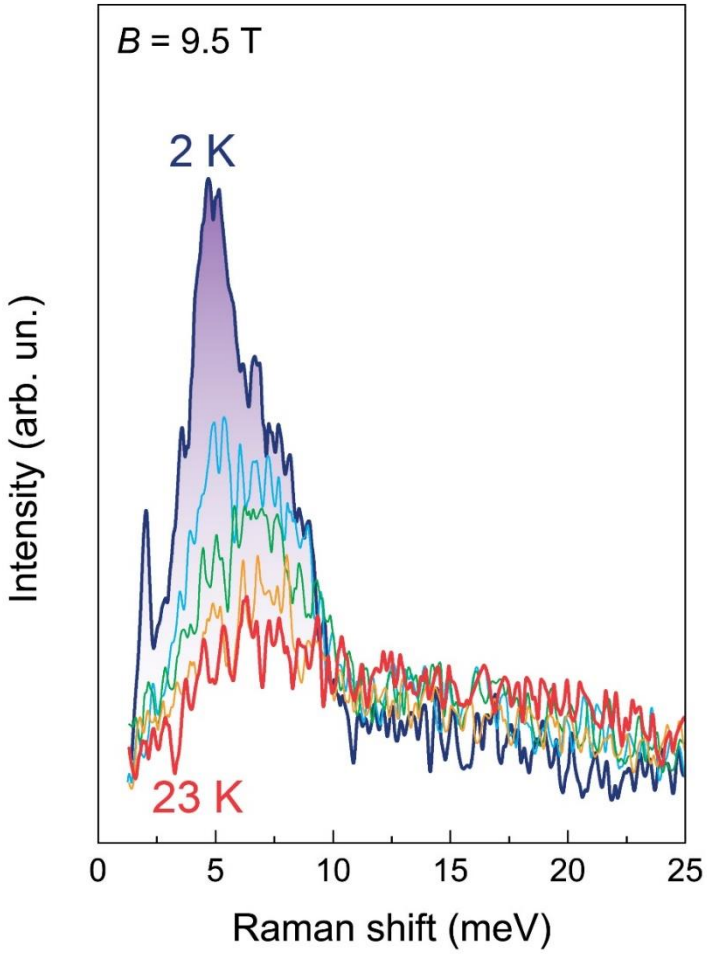


T-dependence



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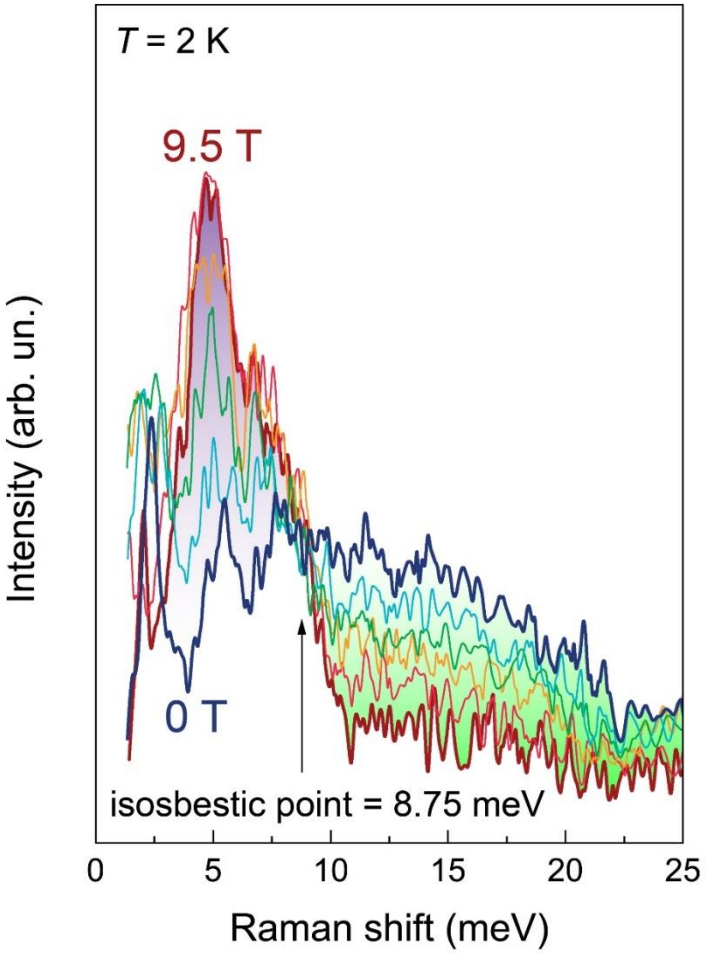

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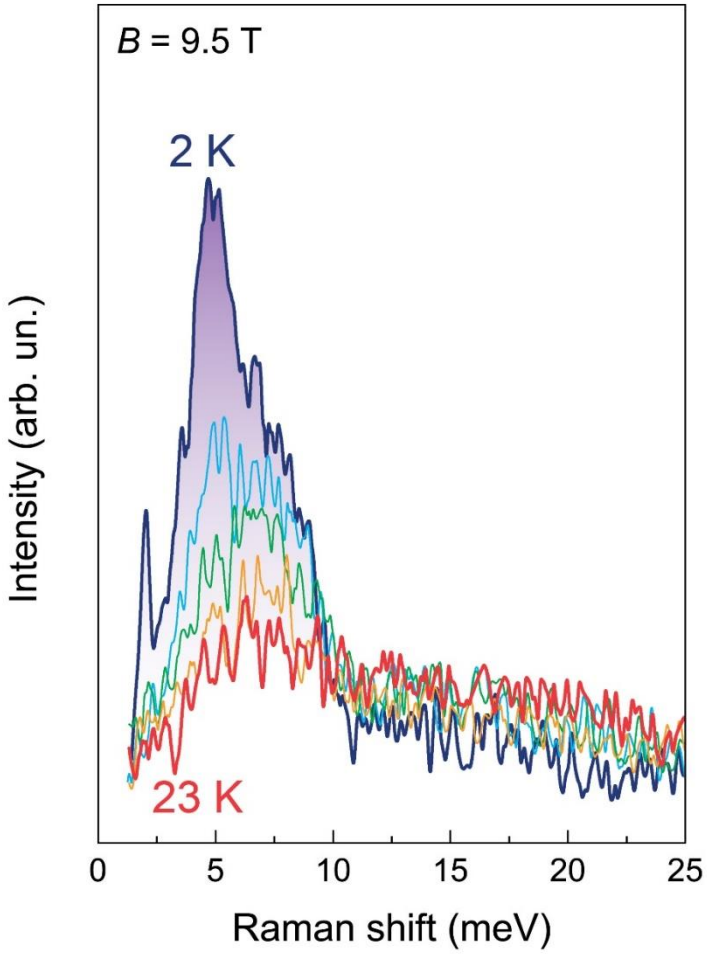
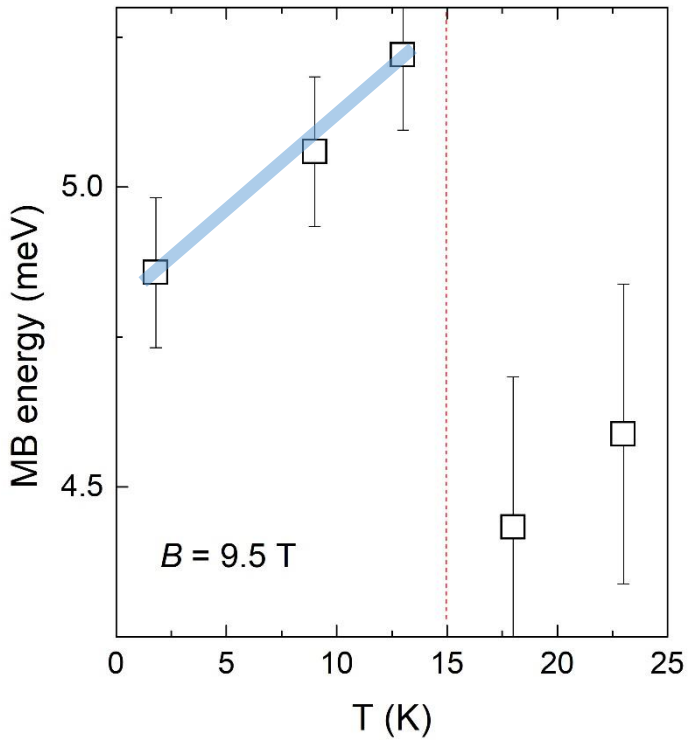
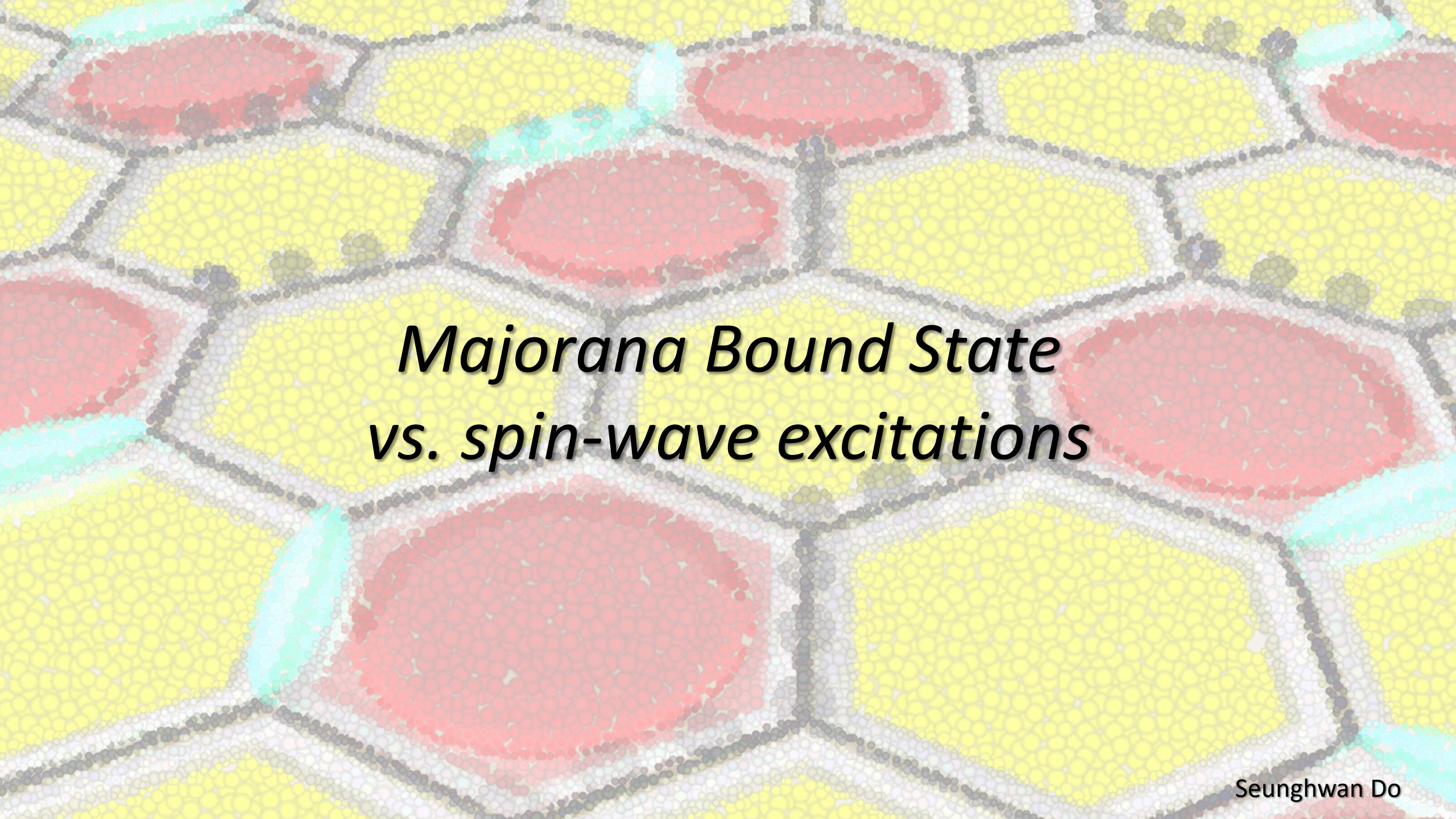




Transition around 15 K
→ binding energy ~ 1.3 meV



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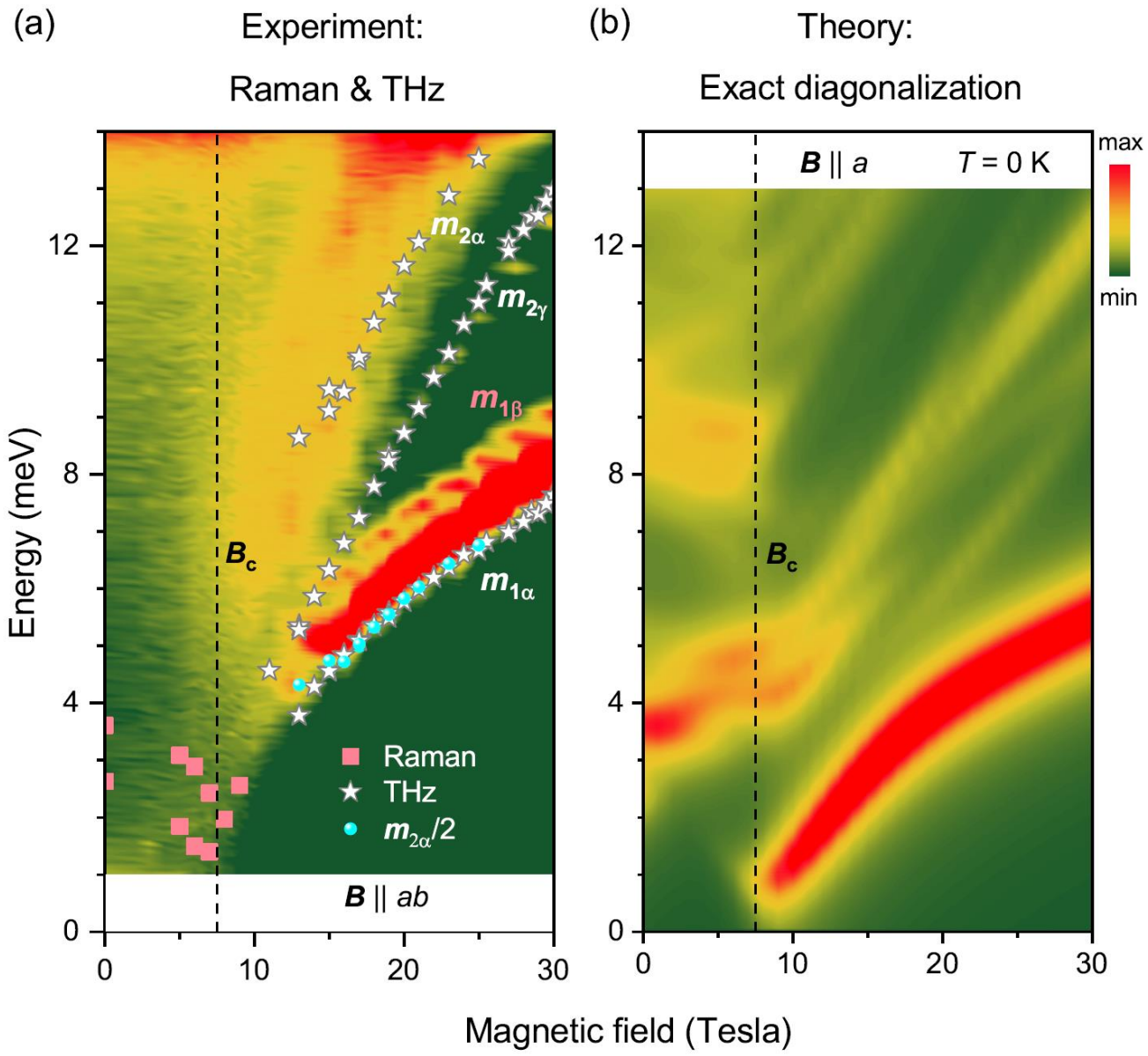
Majorana bound state vs. spin-wave excitations



ED: field-induced excitations well-described by conventional spin-waves

A. Sahasrabudhe, et al., arXiv:1908.11617 (2019).

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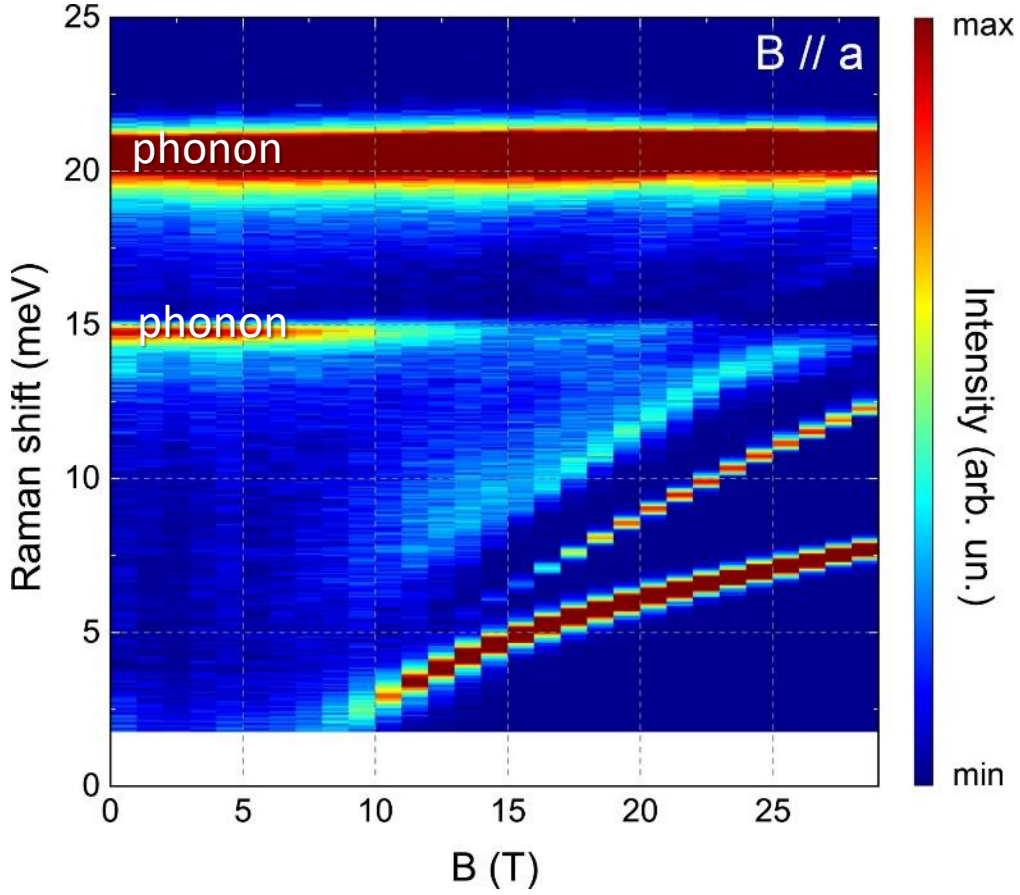
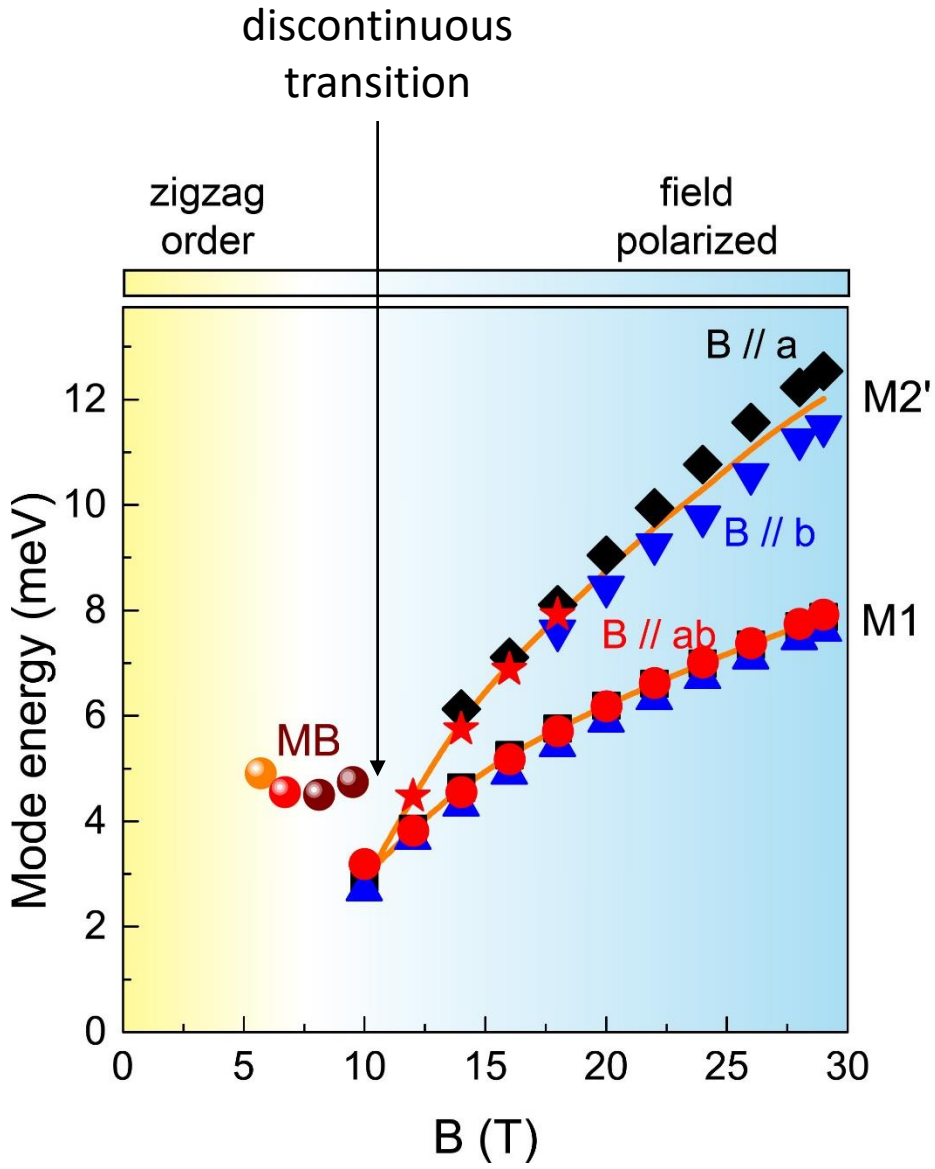
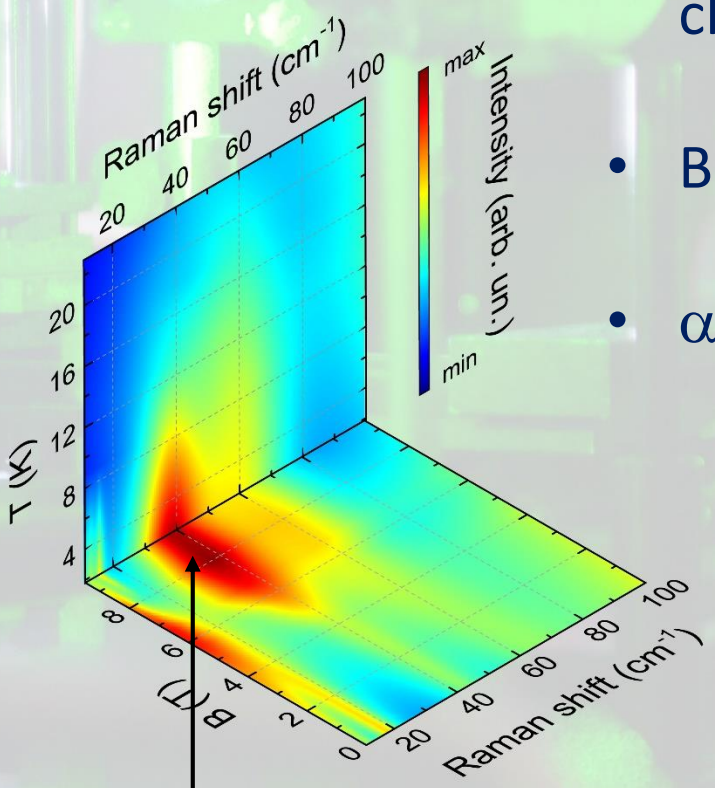




Summary

- Broad continuum of fractionalized excitations
- Quantum critical regime: new excitation with bound-state characteristics
- Binding energy ~ 1.3 meV
- α-$RuCl_3$ at $B = B_c$ is a promising platform to study Kitaev physics



Majorana bound state

→ arXiv:1910.00800

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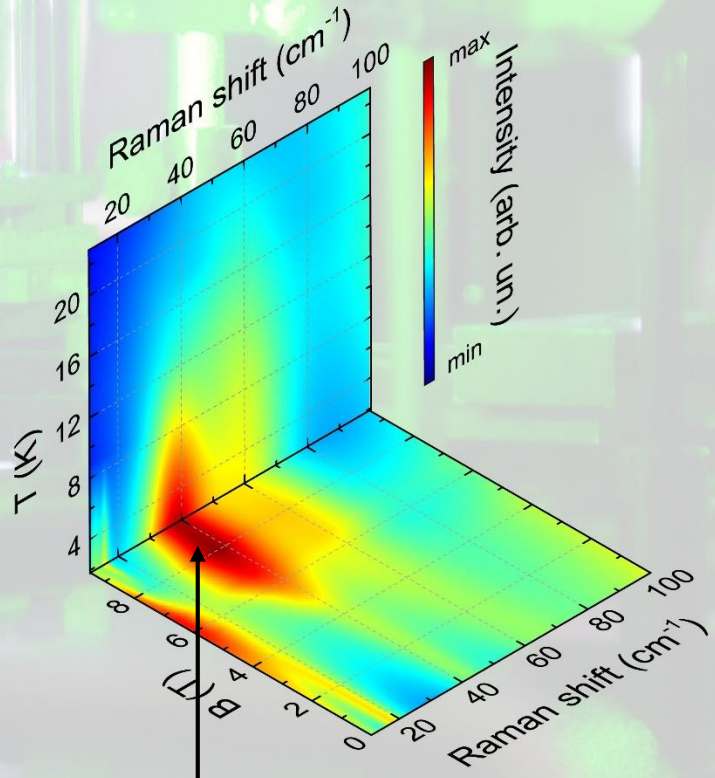
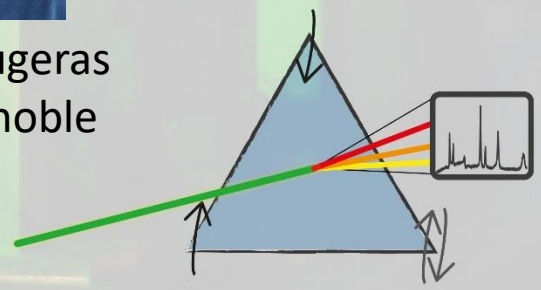


Majorana bound state



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