



TopMaglc

Magnons in Unconventional Magnets



Universität
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July 7th, 2026

Ferrons and Magnons: friends or foes?

Emmy
Noether-
Programm

DFG Deutsche
Forschungsgemeinschaft

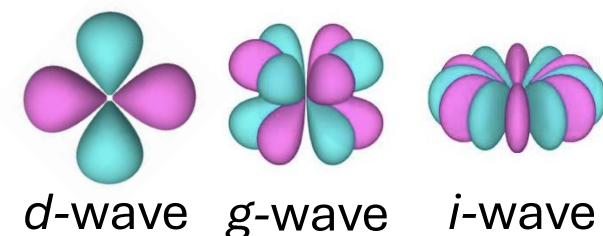
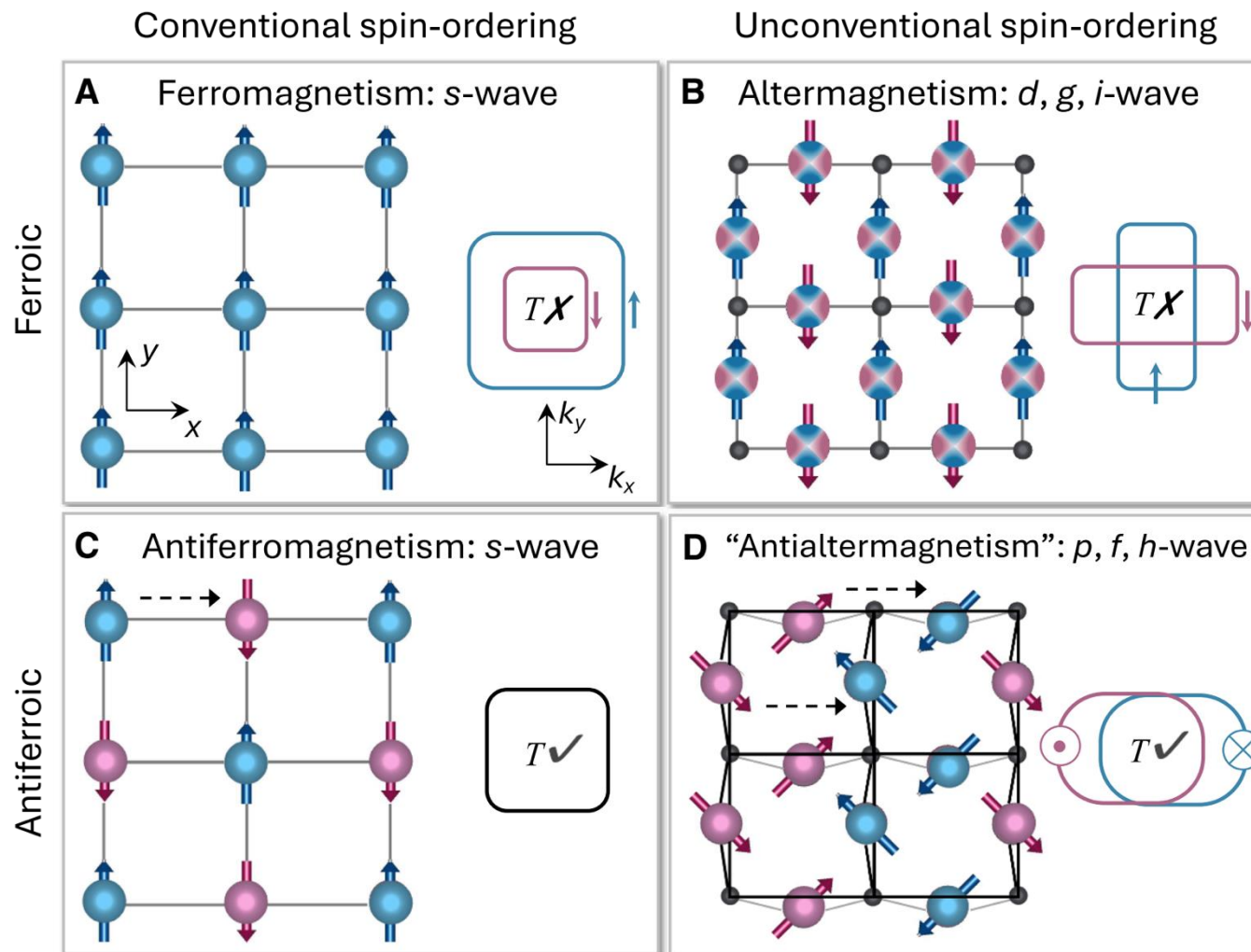


Unconventional Magnetism

Šmejkal, Sinova, Jungwirth, PRX 12, 031042 (2022) ; Jungwirth et al., Newton 1, 100162 (2025)

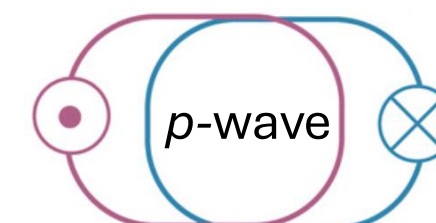
s-wave
spin active
GHz speeds
stray fields

spin inactive
THz speeds
no stray fields



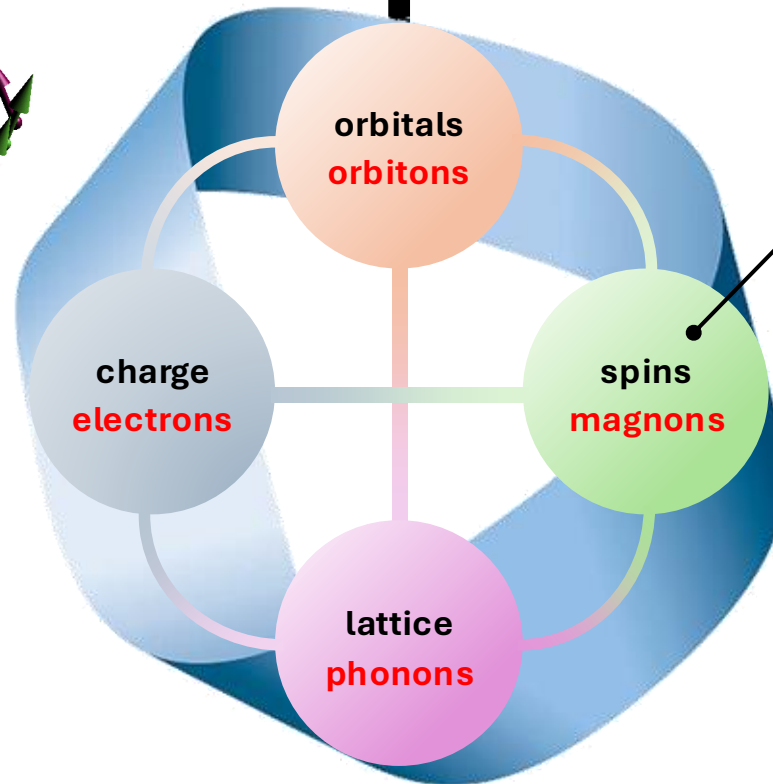
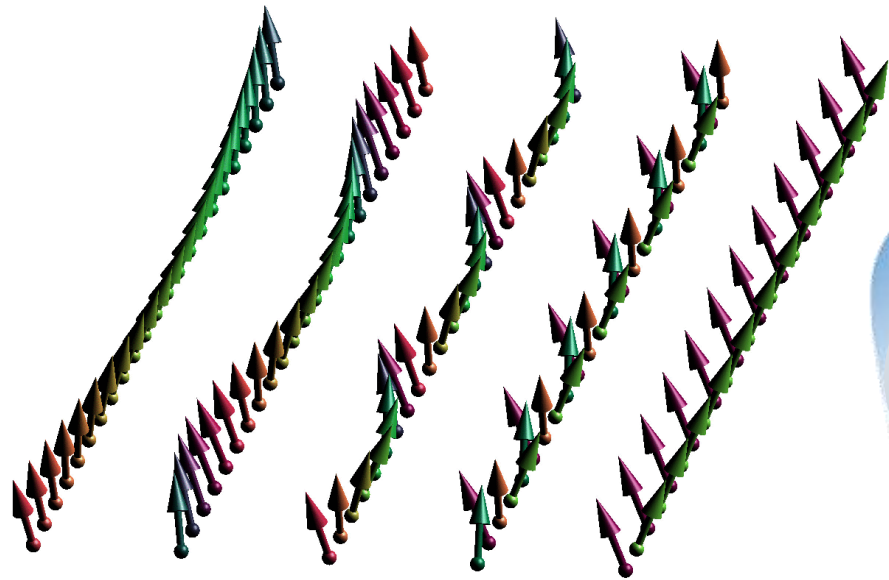
spin active
THz speeds
no stray fields
 $[C_{2\perp} || C_{4z}]$

Tt coplanar: $[C_{2\perp} || t]$



Hellenes et al.,
arXiv:2309.01607 (2023)

Unconventional Magnetism



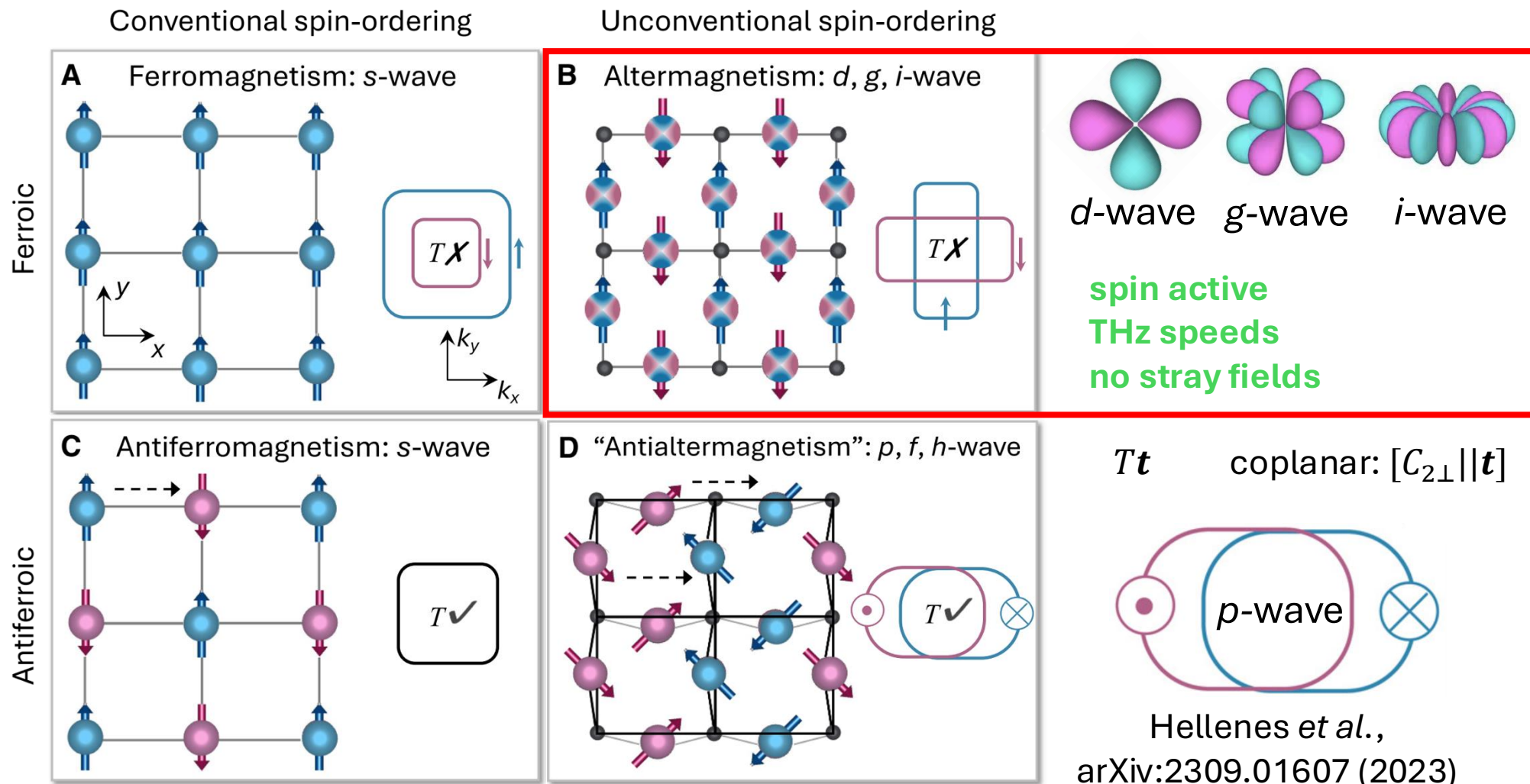
What happens to magnons?

Unconventional Magnetism

Šmejkal, Sinova, Jungwirth, PRX 12, 031042 (2022) ; Jungwirth et al., Newton 1, 100162 (2025)

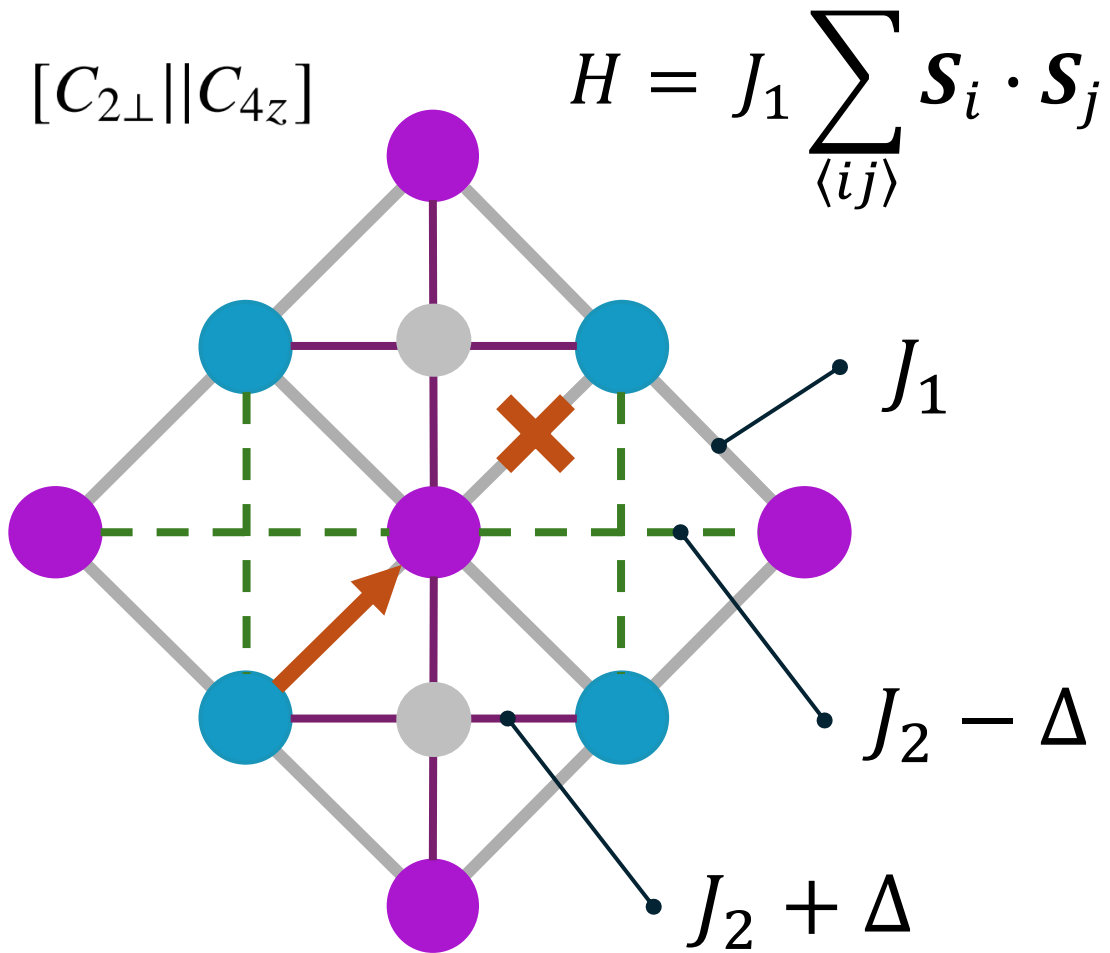
spin active
GHz speeds
stray fields

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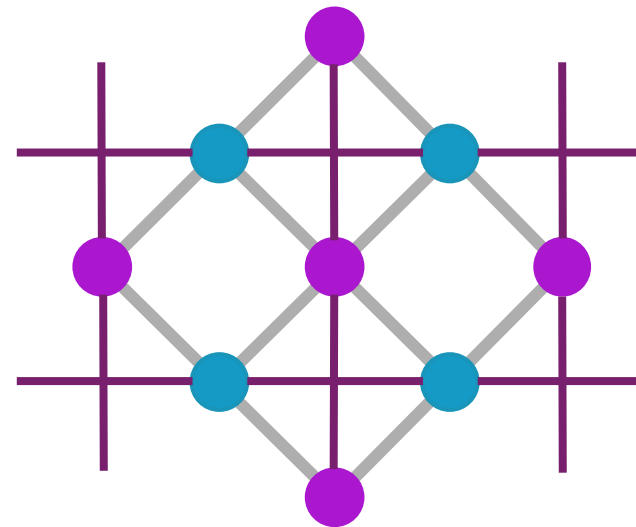


Magnons on the checkerboard lattice

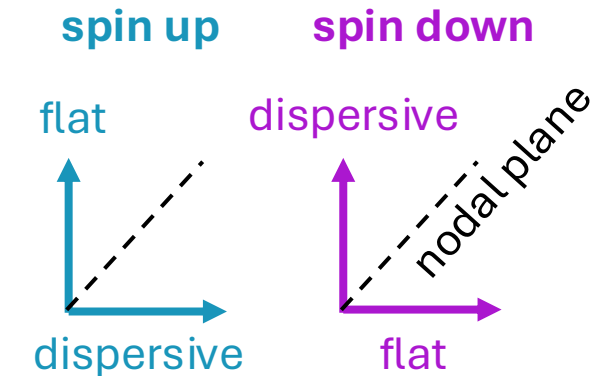
Eto, Gohlke, Sinova, Mochizuki, Chernyshev, **AM**, PRB 112, 094442 (2025)



- No PT symmetry
 - No $T\tau$ symmetry
- } spin splitting

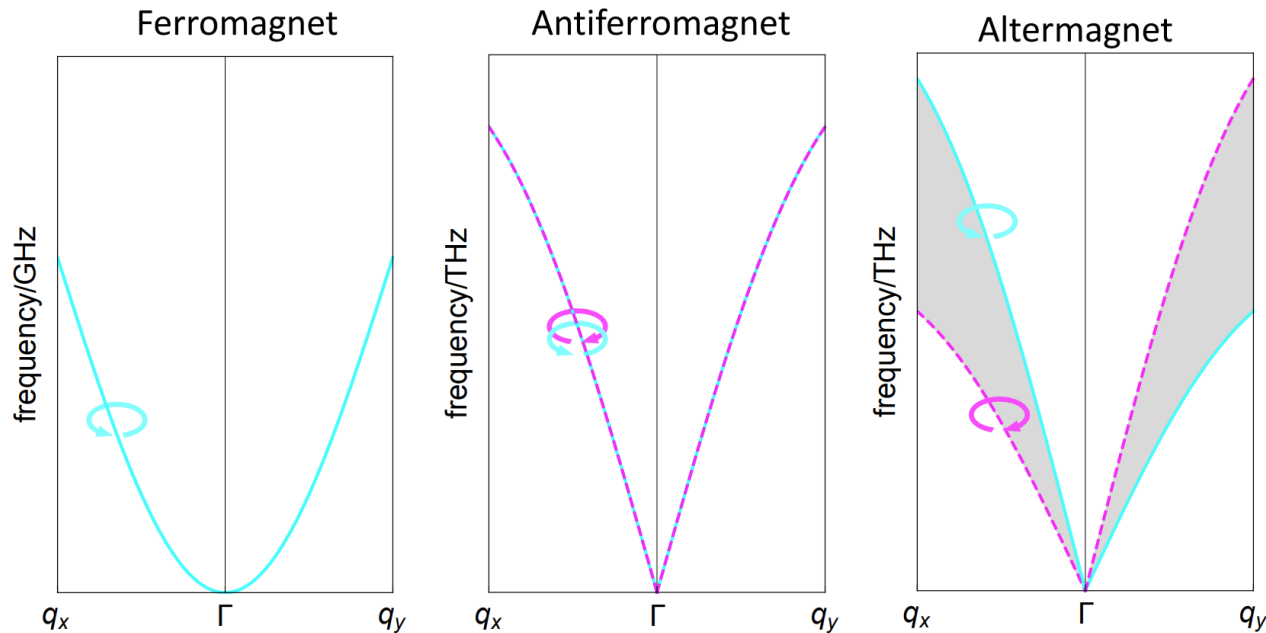


ferromagnetic chains in perpendicular directions



Magnetic excitations in altermagnets

Spin (or chirality) split magnon bands

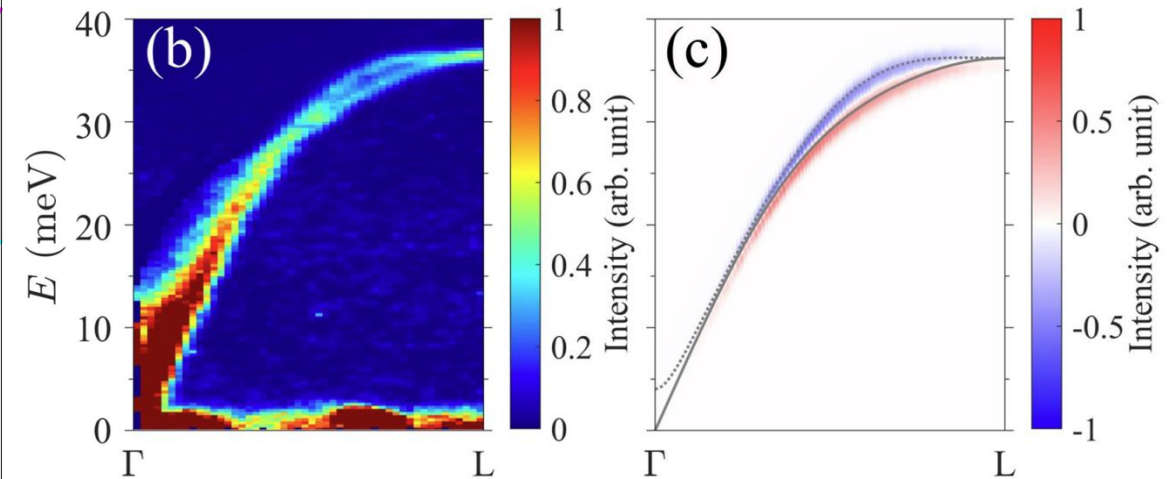


Šmejkal *et al.*, Phys. Rev. Lett. **131**, 256703 (2023)

Gohlke, Corticelli, Moessner, McClarty, **AM**, PRL 131, 186702 (2023)

Gomonay *et al.*, Spintronics **2**, 35 (2024)

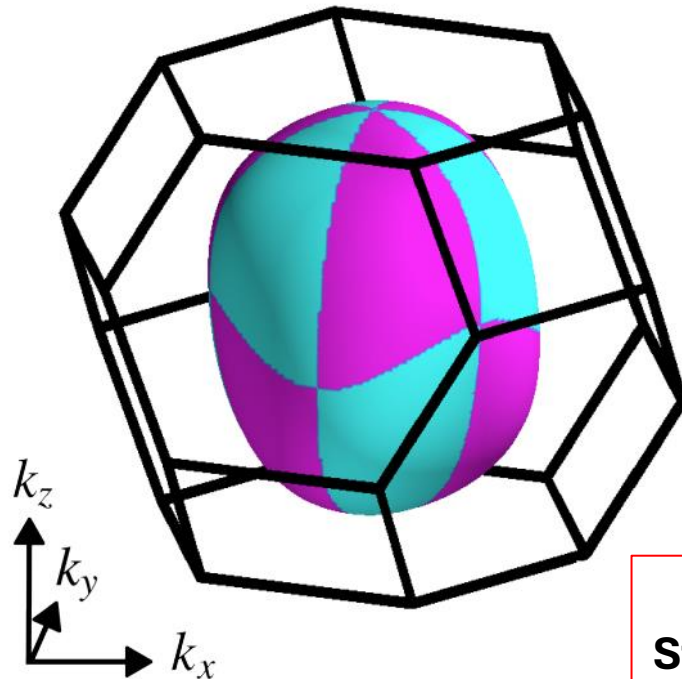
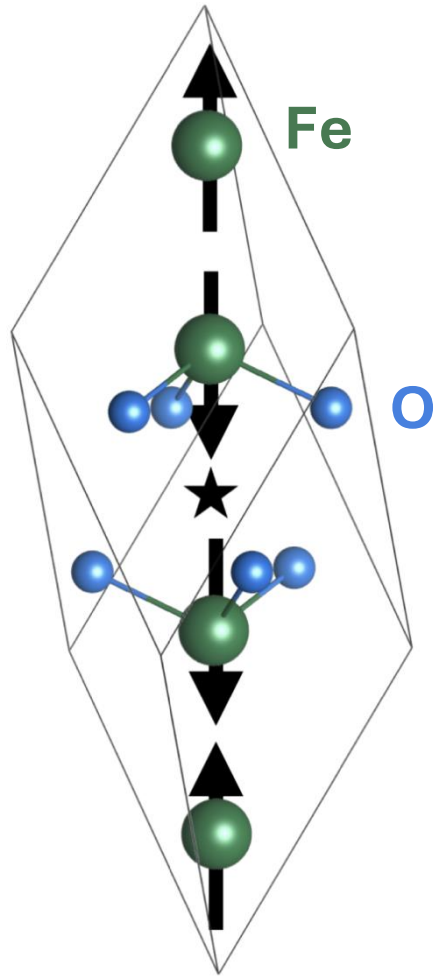
Material: MnTe



Liu *et al.*, Phys. Rev. Lett. **133**, 156702 (2024)

Hematite ($\alpha\text{-Fe}_2\text{O}_3$) is an altermagnet

Hoyer, Stavropoulos, Razpopov, Valenti, Šmejkal, *AM*, PRB 112, 064425 (2025)



Rhea Hoyer



Libor Šmejkal

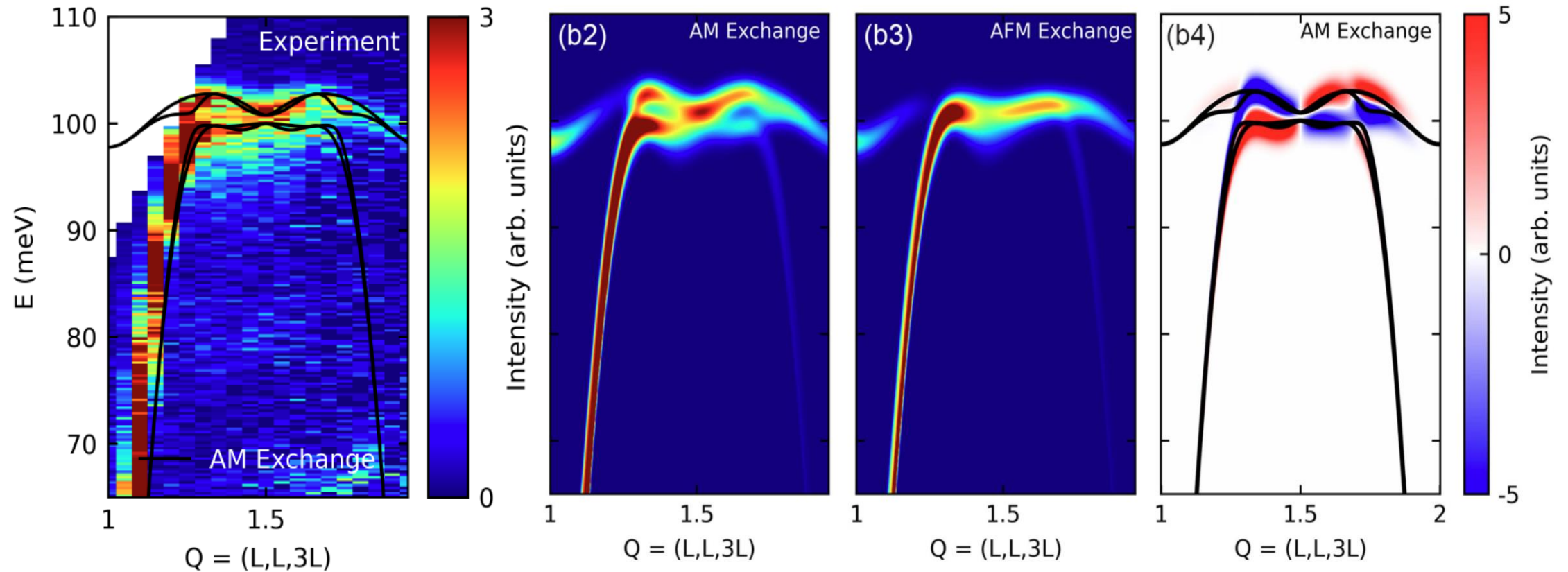


Roser Valenti

Poster:
Strain effects in hematite

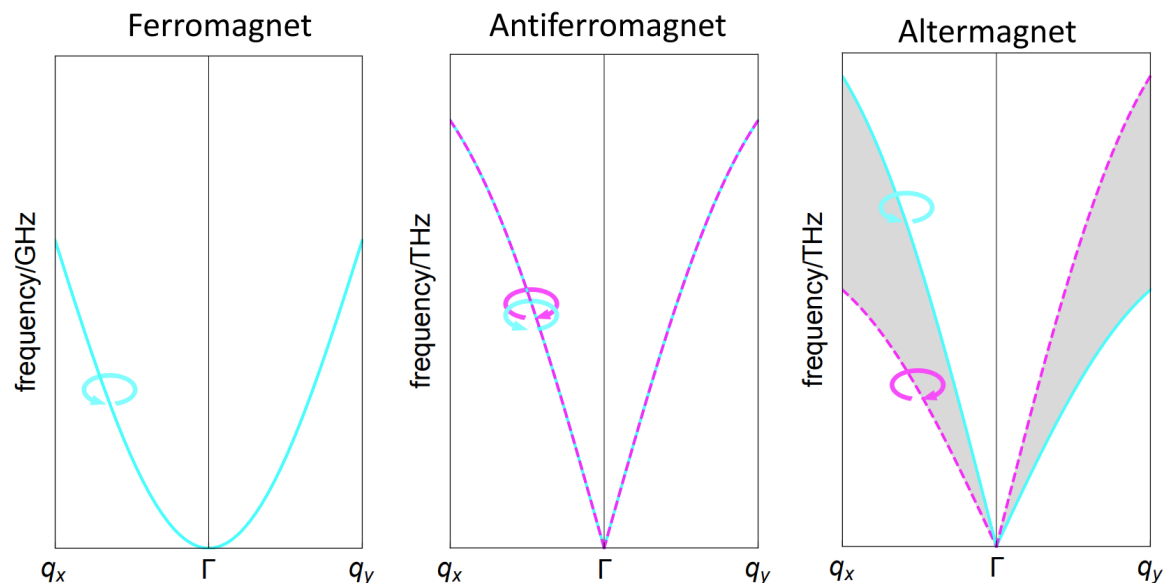
Panagiotis Stavropoulos
Aleksandar Razpopov

Hematite ($\alpha\text{-Fe}_2\text{O}_3$) is an altermagnet



Sun *et al.*, Phys. Rev. Lett. 135, 186703 (2025)

Classes of collinear magnets



Šmejkal *et al.*, Phys. Rev. Lett. **131**, 256703 (2023)

$$H = \sum_{\langle ij \rangle} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j$$

Are magnons stable at zero temperature?



Rintaro Eto



Masahito
Mochizuki



Matthias
Gohlke



Jairo
Sinova



Sasha
Chernyshev

$$H = \sum_{\langle ij \rangle} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j$$

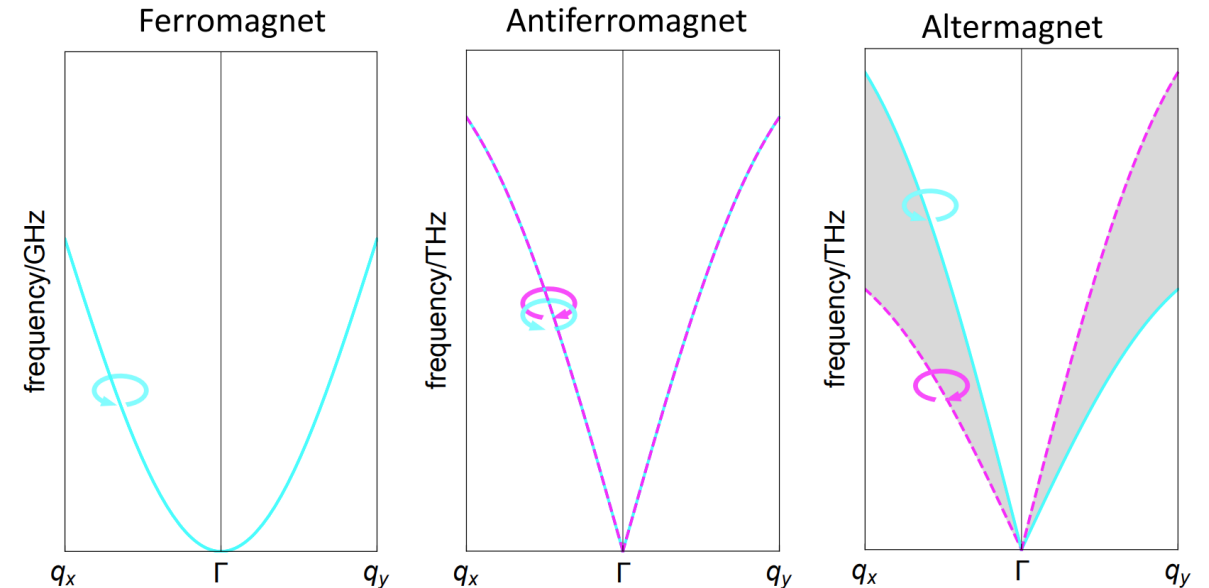
➤ Holstein-Primakoff transformation:

$$S_i^+ = \sqrt{2S - a_i^\dagger a_i} a_i \quad S_i^+ = b_i^\dagger \sqrt{2S - b_i^\dagger b_i}$$

$$S_i^- = a_i^\dagger \sqrt{2S - a_i^\dagger a_i} \quad S_i^- = \sqrt{2S - b_i^\dagger b_i} b_i$$

$$S_i^z = S - a_i^\dagger a_i \quad S_i^z = b_i^\dagger b_i - S$$

$$H = H_0 + H_2 + H_4 + H_6 + \dots$$

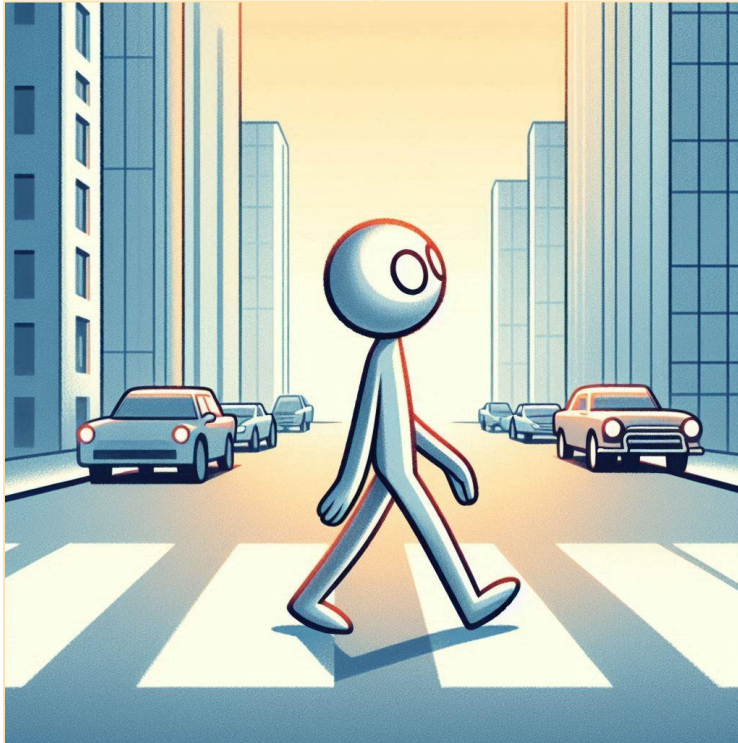


Šmejkal *et al.*, Phys. Rev. Lett. **131**, 256703 (2023)

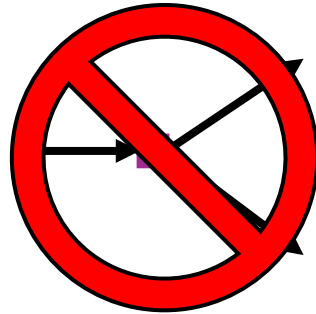
$$H_2 = \sum_{\mathbf{k}} (\epsilon_{\mathbf{k},\uparrow} \alpha_{\mathbf{k},\uparrow}^\dagger \alpha_{\mathbf{k},\uparrow} + \epsilon_{\mathbf{k},\downarrow} \beta_{\mathbf{k},\downarrow}^\dagger \beta_{\mathbf{k},\downarrow})$$

Many-body effects

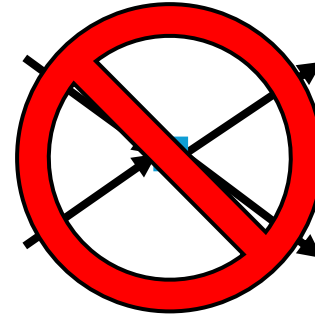
$$H = H_0 + H_2 + H_3 + H_4 + \dots$$



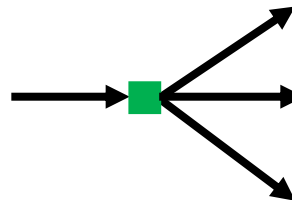
One-in-two-out:



Two-in-two-out:



One-in-three-out:

$$H = \sum_{\langle ij \rangle} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j$$




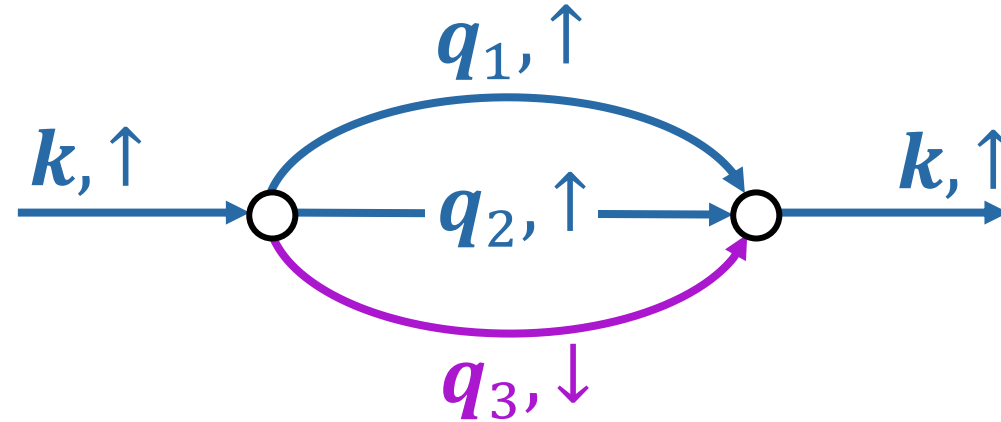
Three-magnon decay physics

Conserved:

- energy
- momentum
- spin

Not conserved:

- number of magnons



$$\varepsilon_{k,\uparrow} = \varepsilon_{q_1,\uparrow} + \varepsilon_{q_2,\uparrow} + \varepsilon_{k-q_1-q_2,\downarrow}$$

Review of magnon decay physics: Zhitomirsky, Chernyshev, Rev. Mod. Phys. 85, 219 (2013)

Magnon stability in collinear magnets

Eto, Gohlke, Sinova, Mochizuki, Chernyshev, **AM**, PRB 112, 094442 (2025)

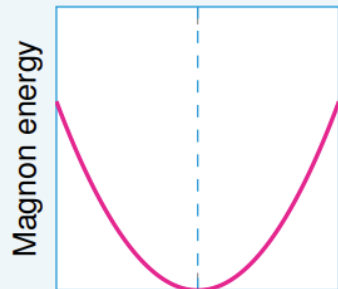
a

Class (i)

s-wave spin splitting of magnons

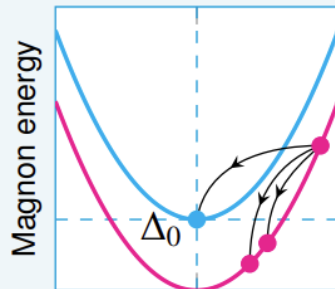
ferromagnet

ferrimagnet



Momentum

stable

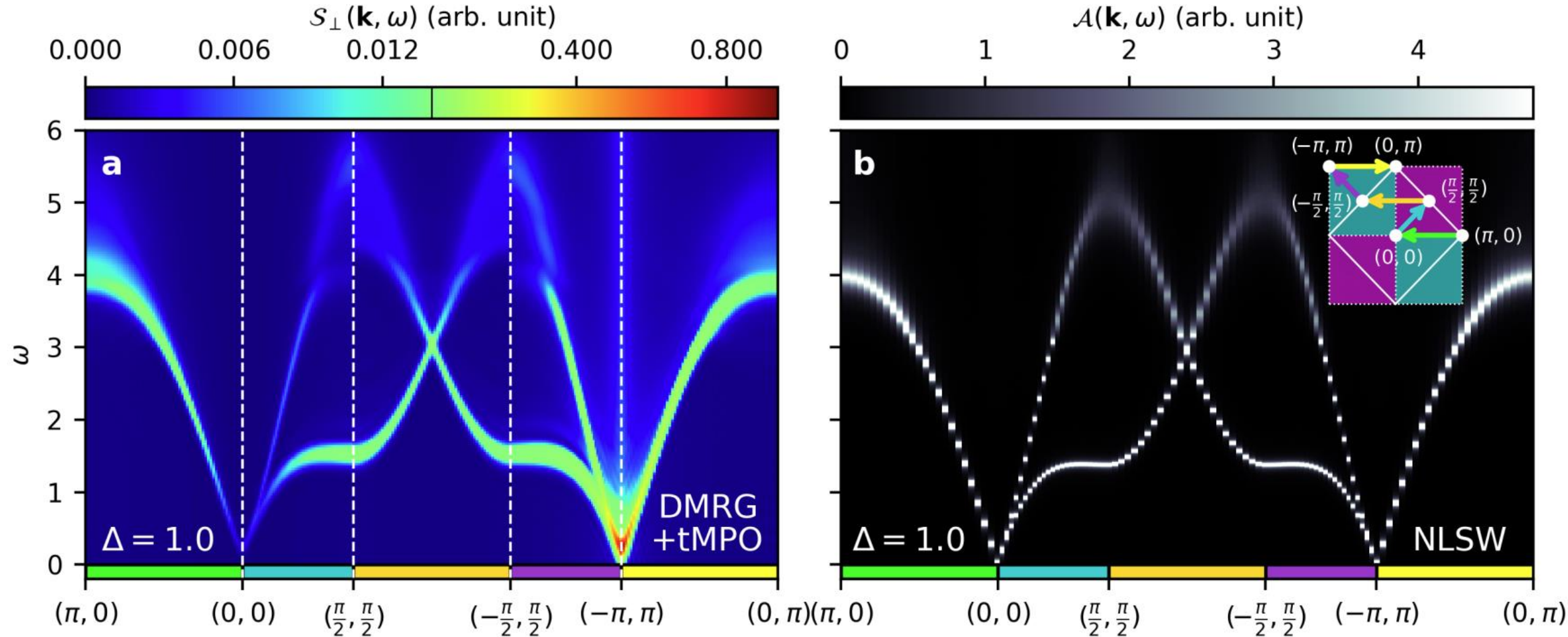


Momentum

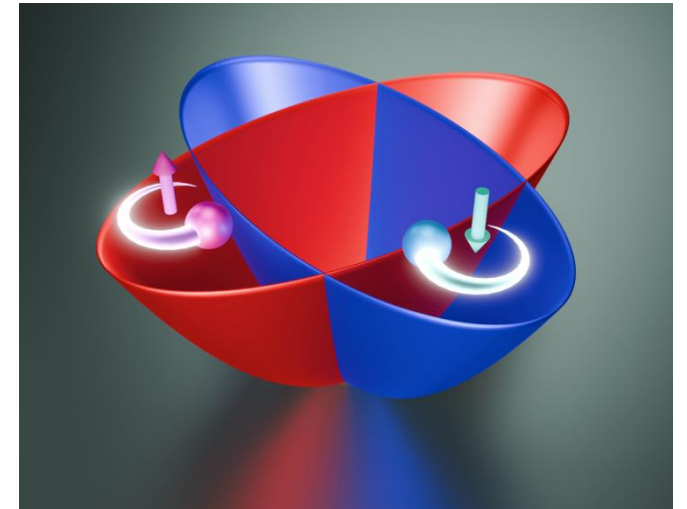
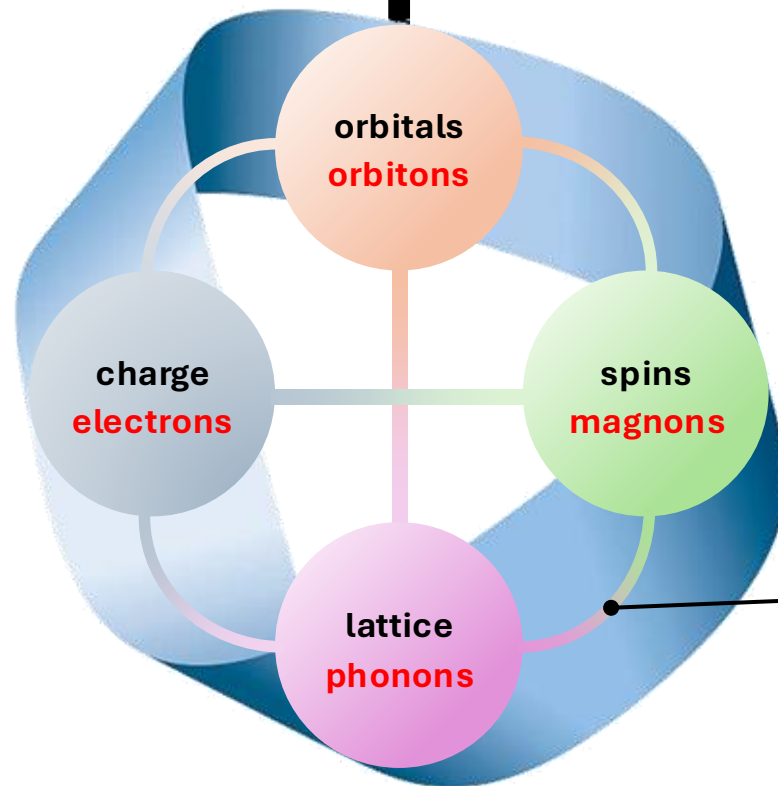
stable lower branch*
unstable upper branch

Nonperturbative versus perturbative

Eto, Gohlke, Sinova, Mochizuki, Chernyshev, *AM*, PRB 112, 094442 (2025)



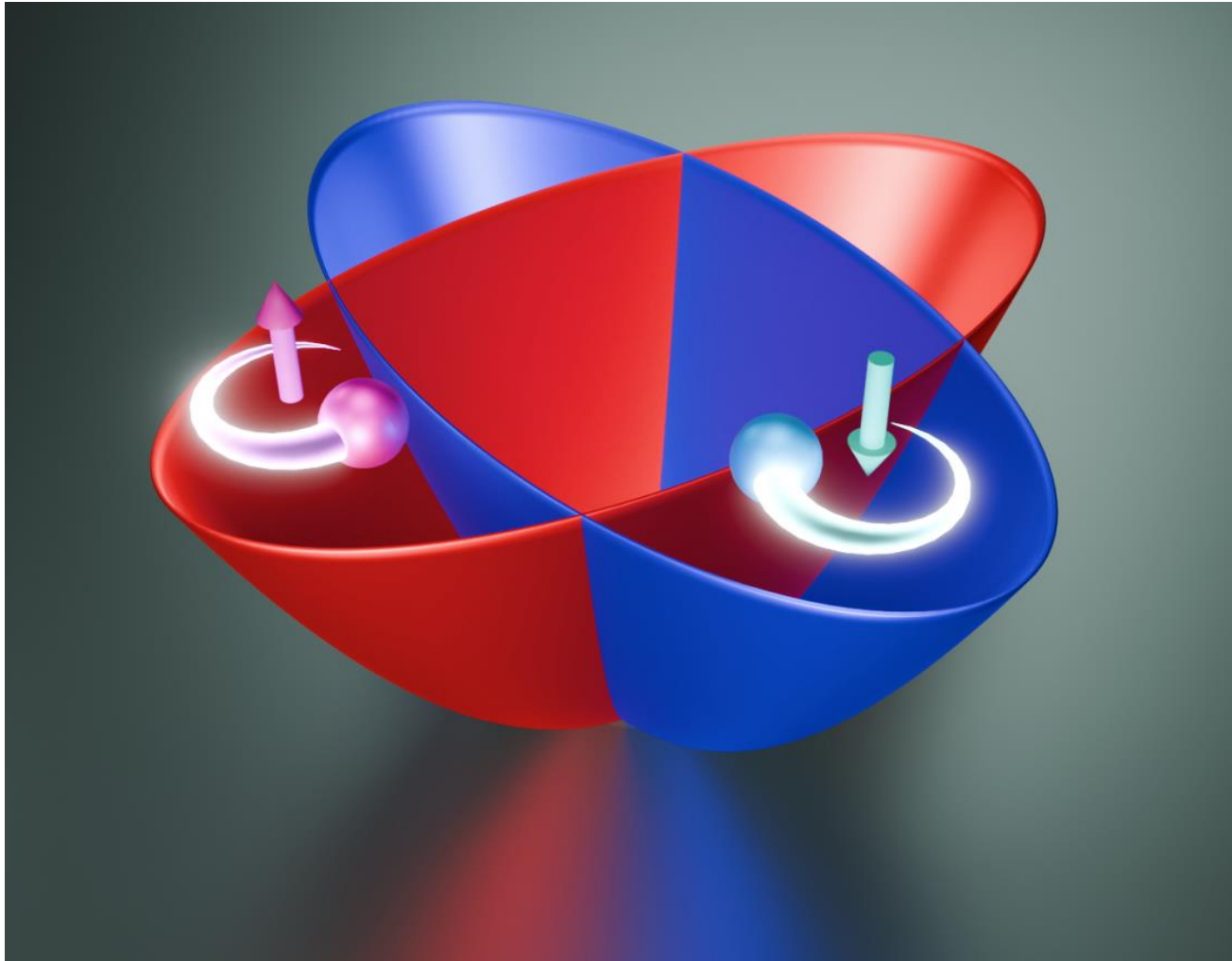
Unconventional Magnetism



Can we transfer the symmetry breaking to the lattice?

D-wave axial phonons

Bendin, **AM**, Mertig, Neumann, arXiv:2511.08357, PRL accepted (2026)



MARTIN-LUTHER
UNIVERSITÄT
HALLE-WITTENBERG



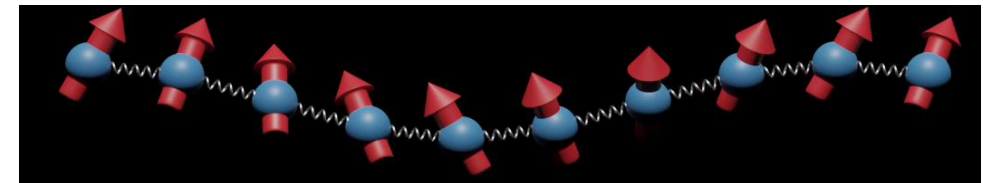
Hannah
Bendin



Ingrid
Mertig



Robin
Neumann



D-wave axial phonons

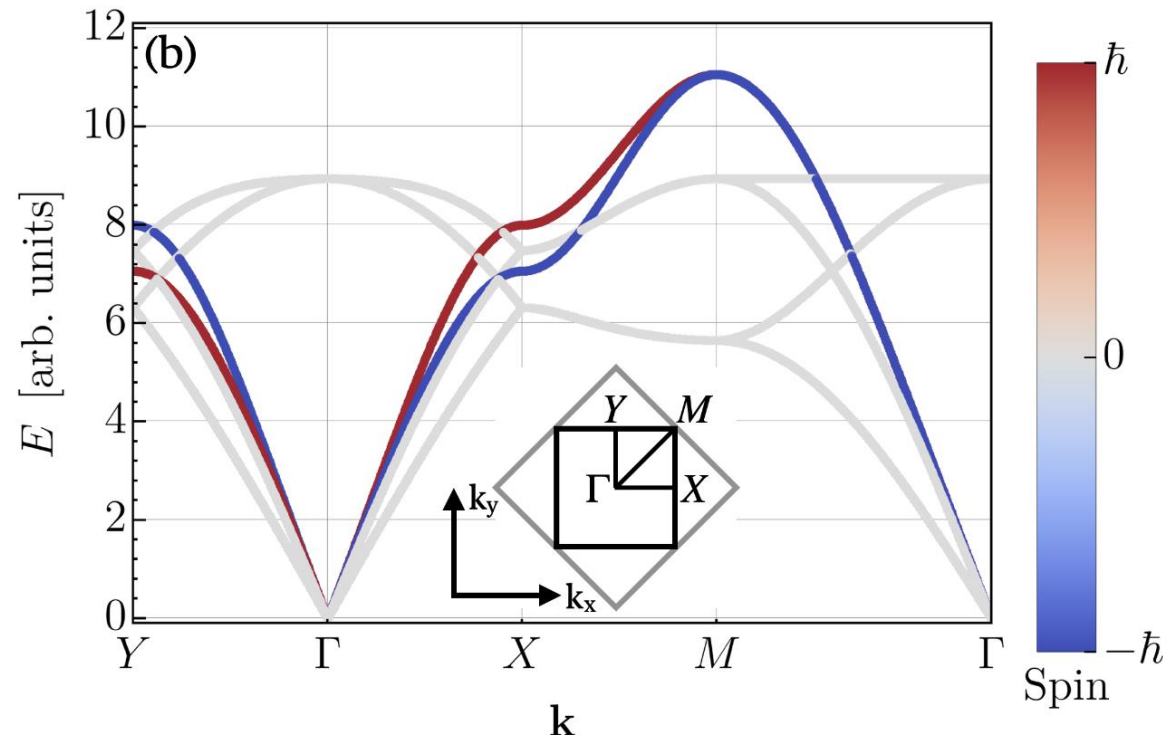
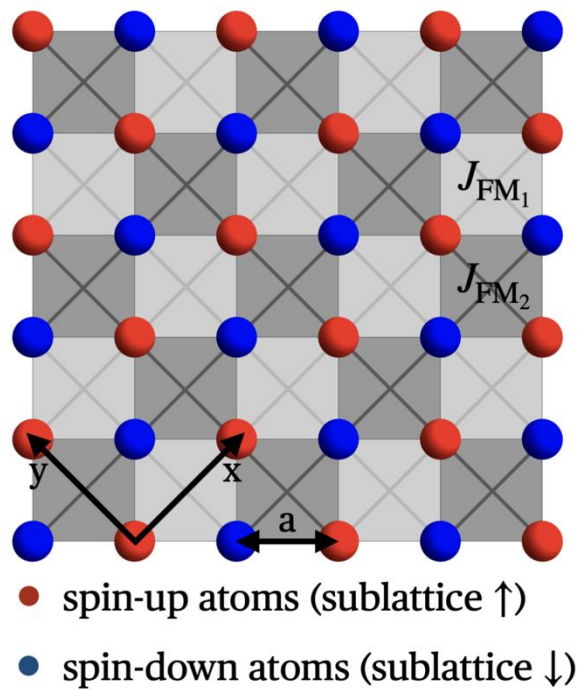
Bendin, AM, Mertig, Neumann, arXiv:2511.08357, PRL accepted (2026)

Spin Hamiltonian

$$\hat{H}_m = -\frac{J_{\text{AFM}}}{2} \sum_{\langle i,j \rangle} \mathbf{S}_i \cdot \mathbf{S}_j - \frac{J_{\text{FM}_1}}{2} \sum_{\langle\langle i,j \rangle\rangle_1} \mathbf{S}_i \cdot \mathbf{S}_j - \frac{J_{\text{FM}_2}}{2} \sum_{\langle\langle i,j \rangle\rangle_2} \mathbf{S}_i \cdot \mathbf{S}_j$$

Coupling to phonons via SOC

$$\hat{H}_{\text{DMI}} = \sum_{i,j} \mathbf{D}_{ij} \cdot (\mathbf{S}_i \times \mathbf{S}_j)$$



D-wave axial phonons

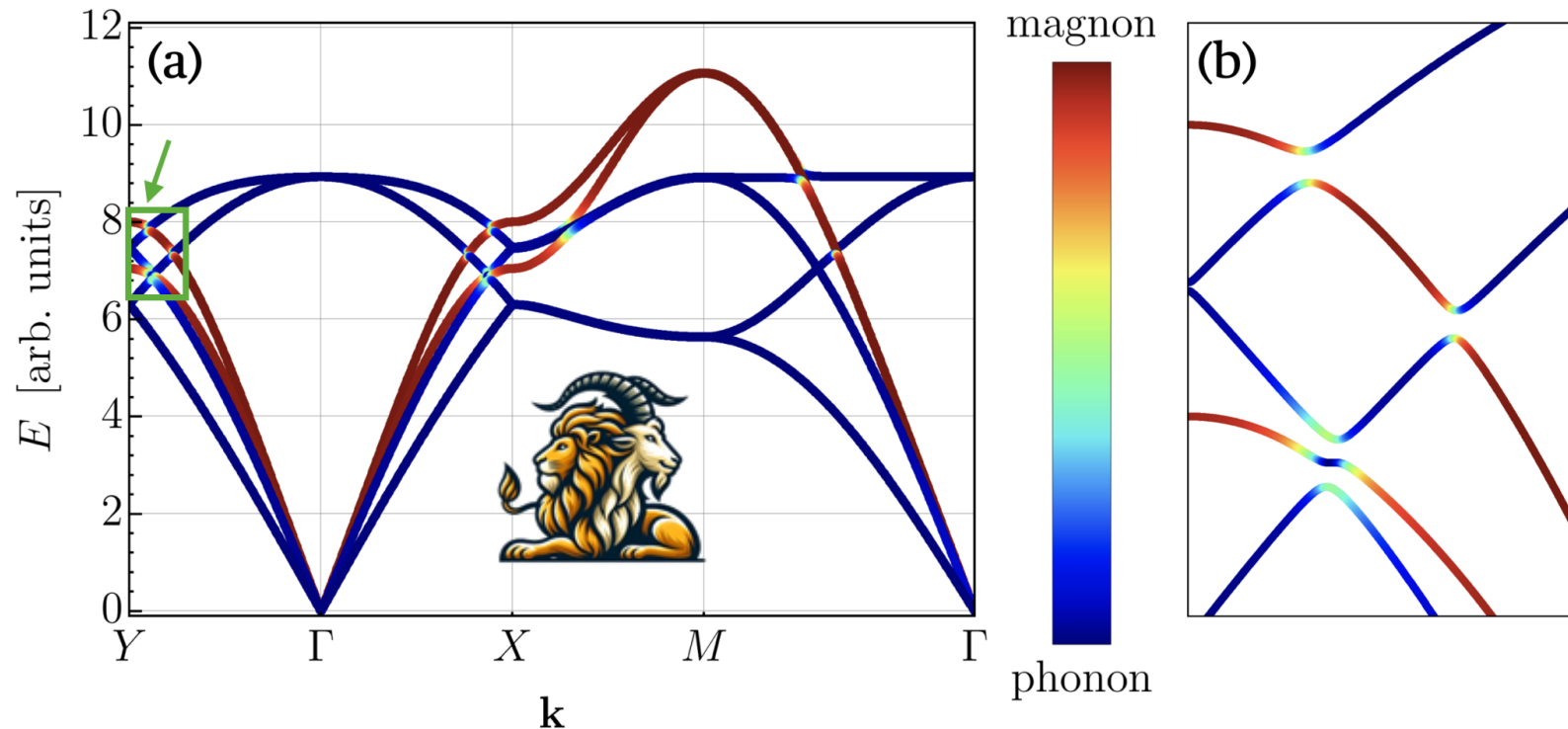
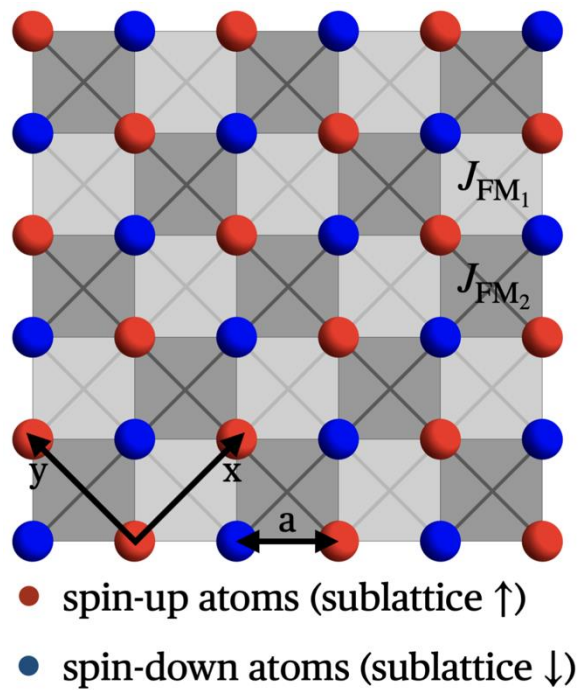
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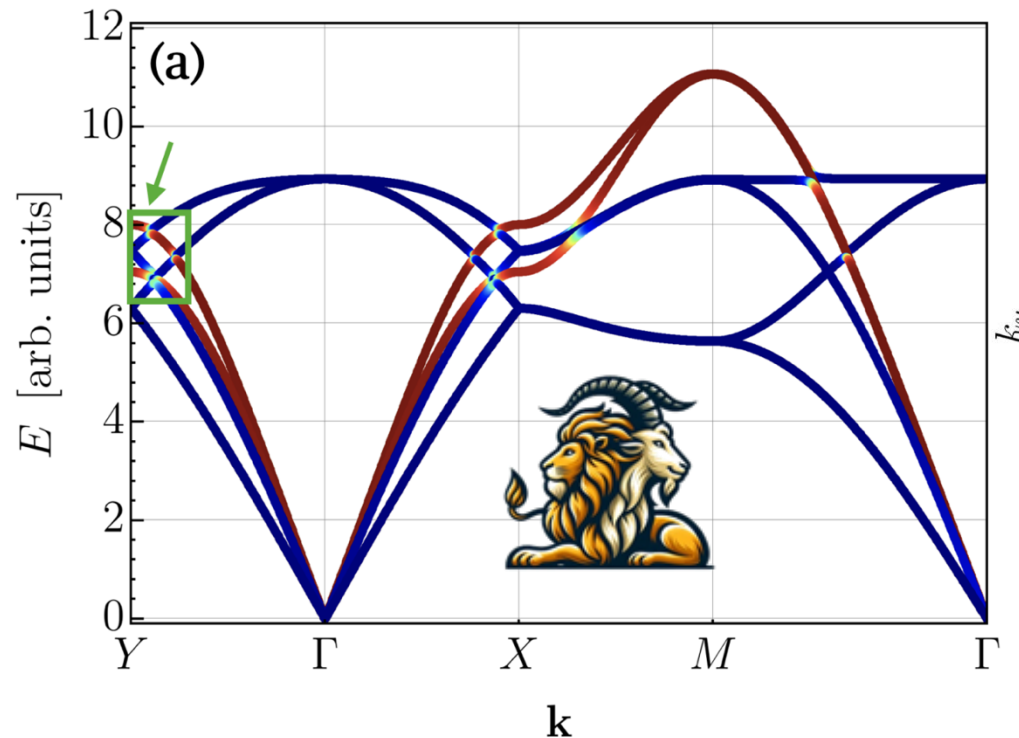
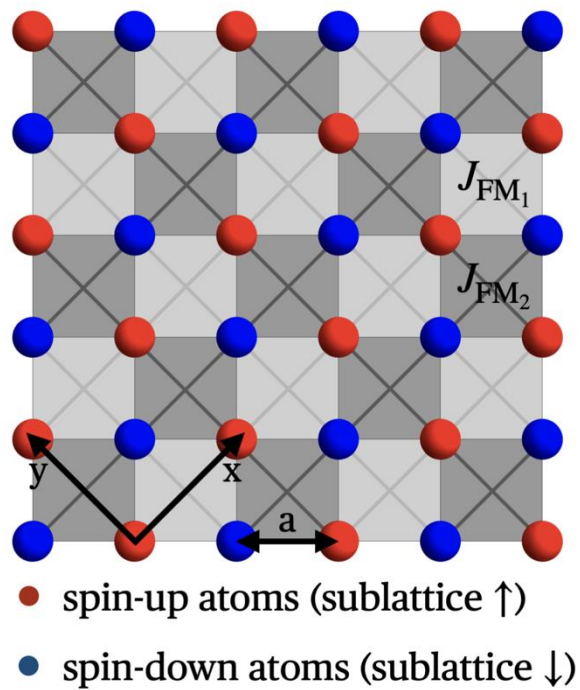


D-wave axial phonons

Bendin, **AM**, Mertig, Neumann, arXiv:2511.08357, PRL accepted (2026)

Spin Hamiltonian

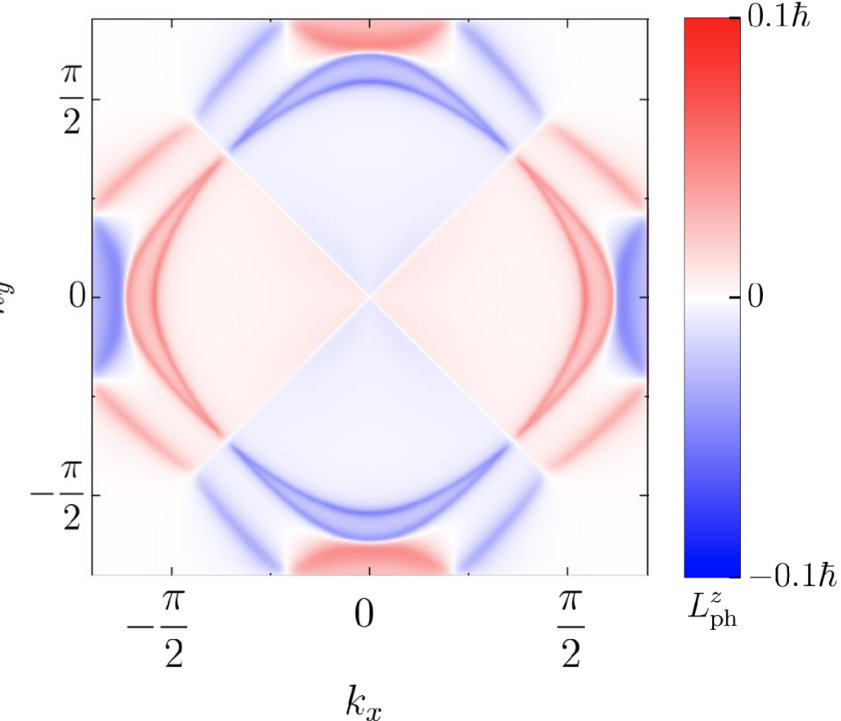
$$\hat{H}_m = -\frac{J_{\text{AFM}}}{2} \sum_{\langle i,j \rangle} \mathbf{S}_i \cdot \mathbf{S}_j - \frac{J_{\text{FM}_1}}{2} \sum_{\langle\langle i,j \rangle\rangle_1} \mathbf{S}_i \cdot \mathbf{S}_j - \frac{J_{\text{FM}_2}}{2} \sum_{\langle\langle i,j \rangle\rangle_2} \mathbf{S}_i \cdot \mathbf{S}_j$$



Coupling to phonons via SOC

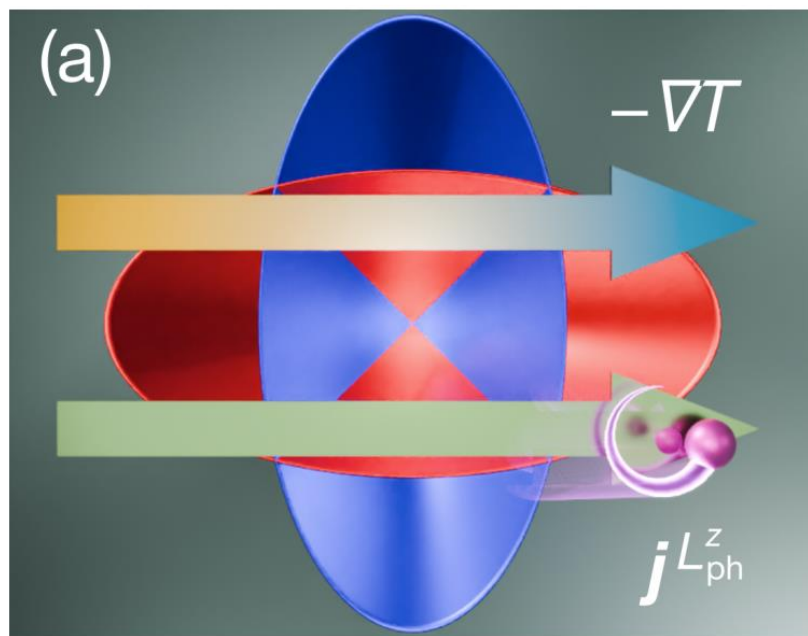
$$\hat{H}_{\text{DMI}} = \sum_{i,j} \mathbf{D}_{ij} \cdot (\mathbf{S}_i \times \mathbf{S}_j)$$

Phonon angular momentum



Phonon Angular Momentum Splitter

Bendin, AM, Mertig, Neumann, arXiv:2511.08357, PRL accepted (2026)



spin Seebeck-like geometry

spin splitter-like geometry

spin Seebeck-like geometry

Phonon angular momentum transport: $j_a^c = \chi_{ab}^c(-\nabla_b T)$ extrinsic: $O(\tau^1)$

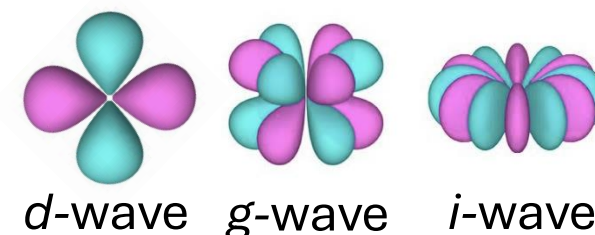
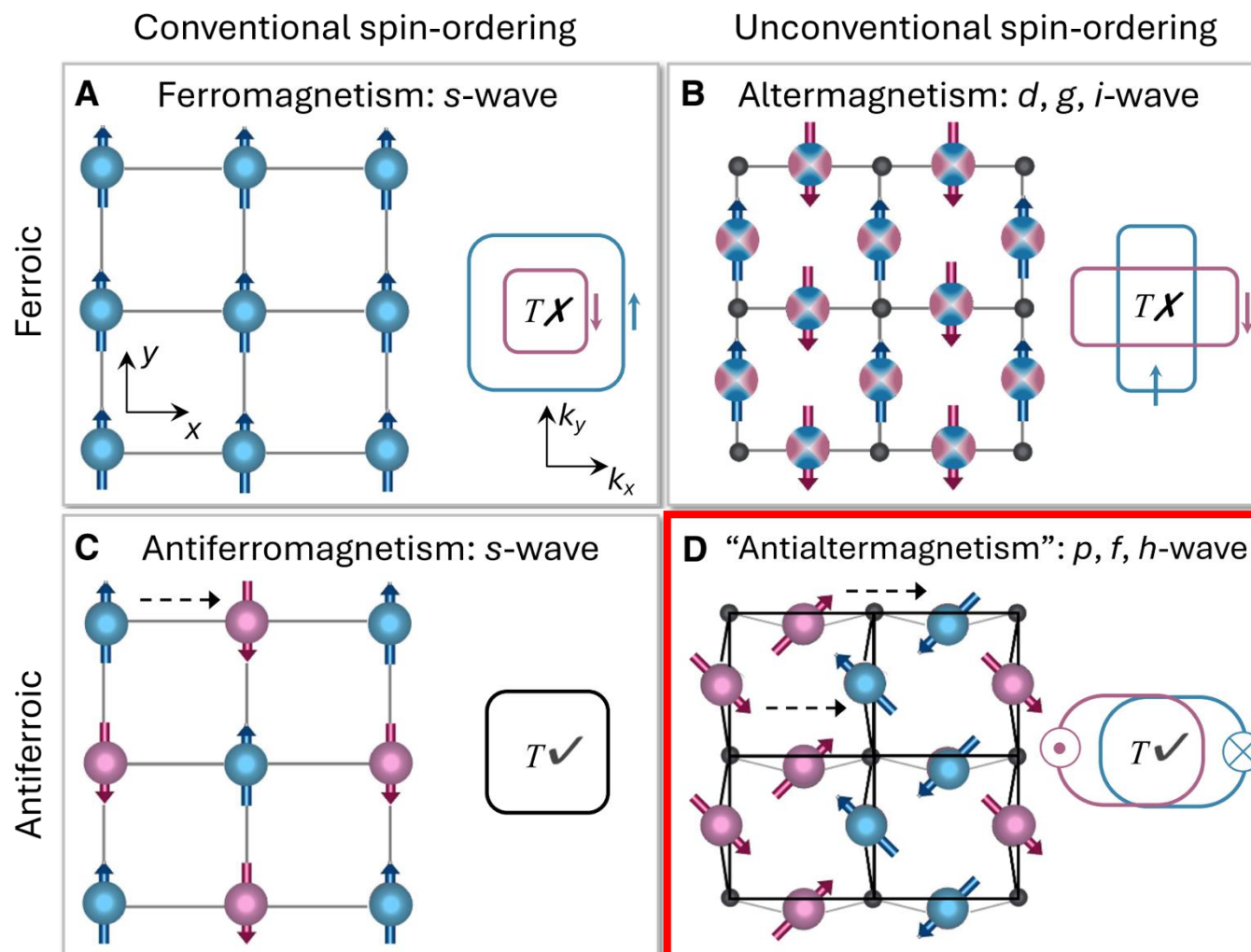
electronic spin splitter effect: González-Hernández, Šmejkal, Výborný, Yahagi, Sinova, Jungwirth, Železný, PRL 126, 127701 (2021)

Unconventional Magnetism

Šmejkal, Sinova, Jungwirth, PRX 12, 031042 (2022) ; Jungwirth et al., Newton 1, 100162 (2025)

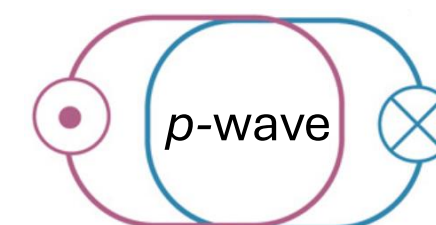
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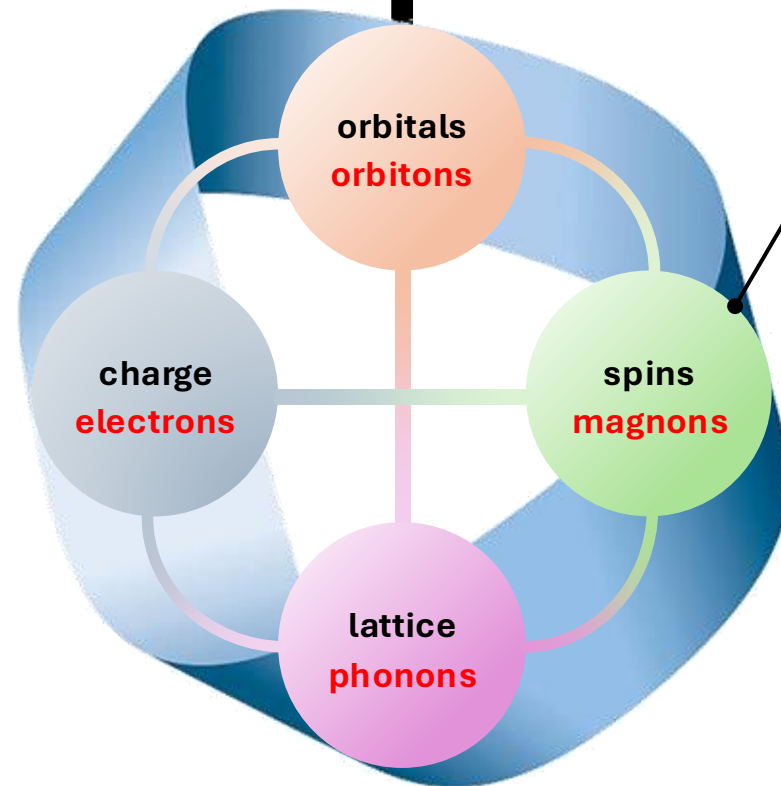
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Tt coplanar: $[C_{2\perp} || t]$



Hellenes et al.,
arXiv:2309.01607 (2023)

Unconventional Magnetism



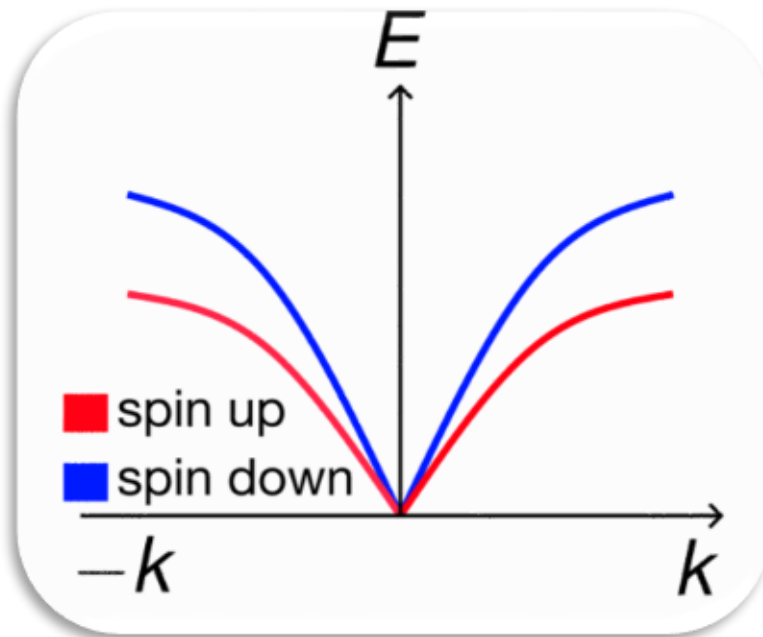
How do magnons look like in odd-parity magnets (antialtermagnets)?

Magnons in odd-parity-wave magnets

Neumann, Jaeschke-Ubiergo, Zarzuela, Šmejkal, Sinova, **AM**, arXiv:2603.05415 (2026)

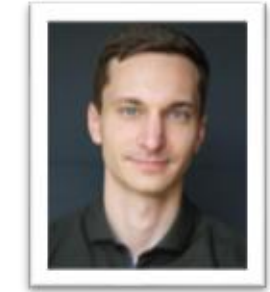
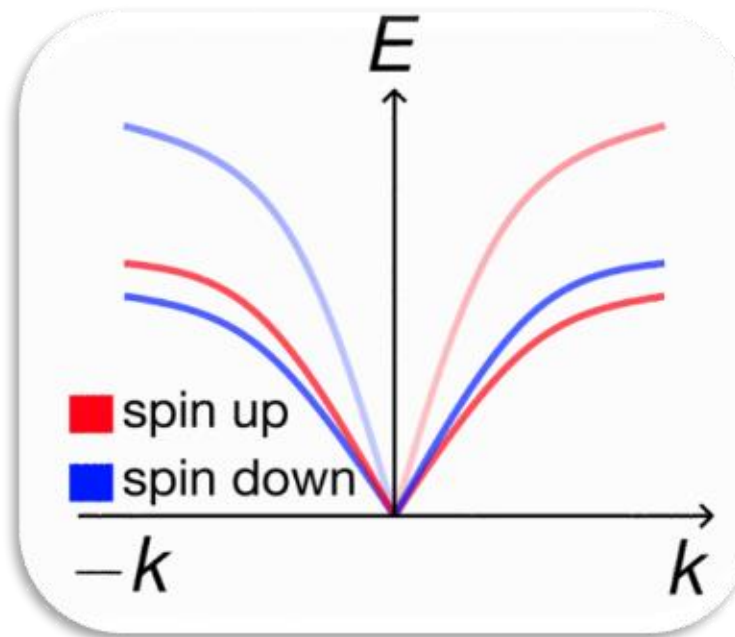
Altermagnet

(even parity-wave splitting)



Antialtermagnet

(odd parity-wave splitting)



Robin R.
Neumann



Rodrigo
Jaeschke-
Ubiergo



Ricardo
Zarzuela

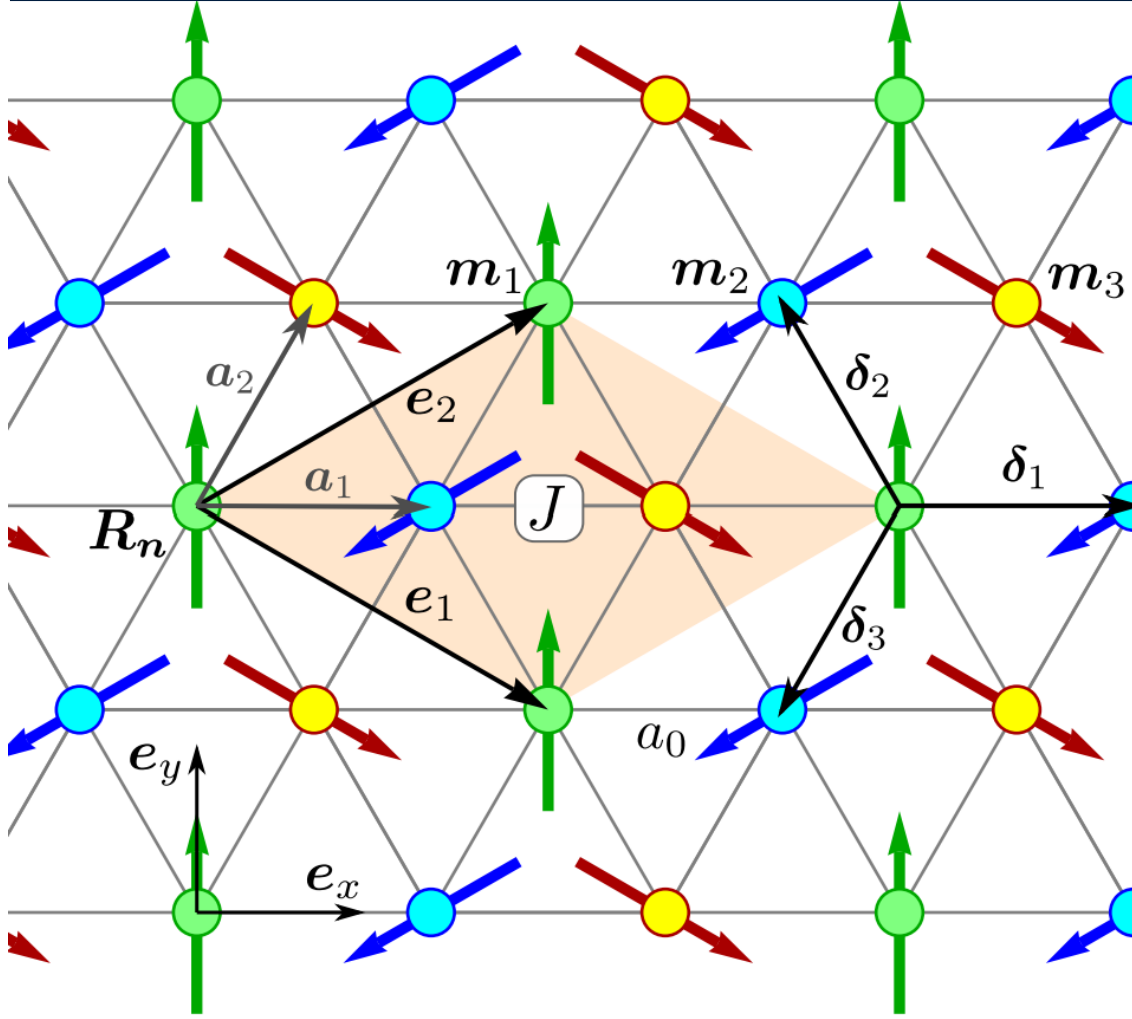


Libor
Šmejkal



Jairo
Sinova

F-wave magnons on triangular lattices



Volodymyr
Kravchuk



Kostiantyn
Yershov



Bastián
Pradenas



Jeroen
van den Brink



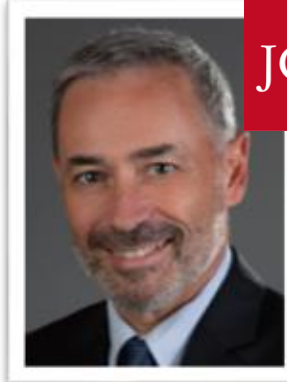
Robin
Neumann



Rodrigo
Jaeschke-Ubiergo



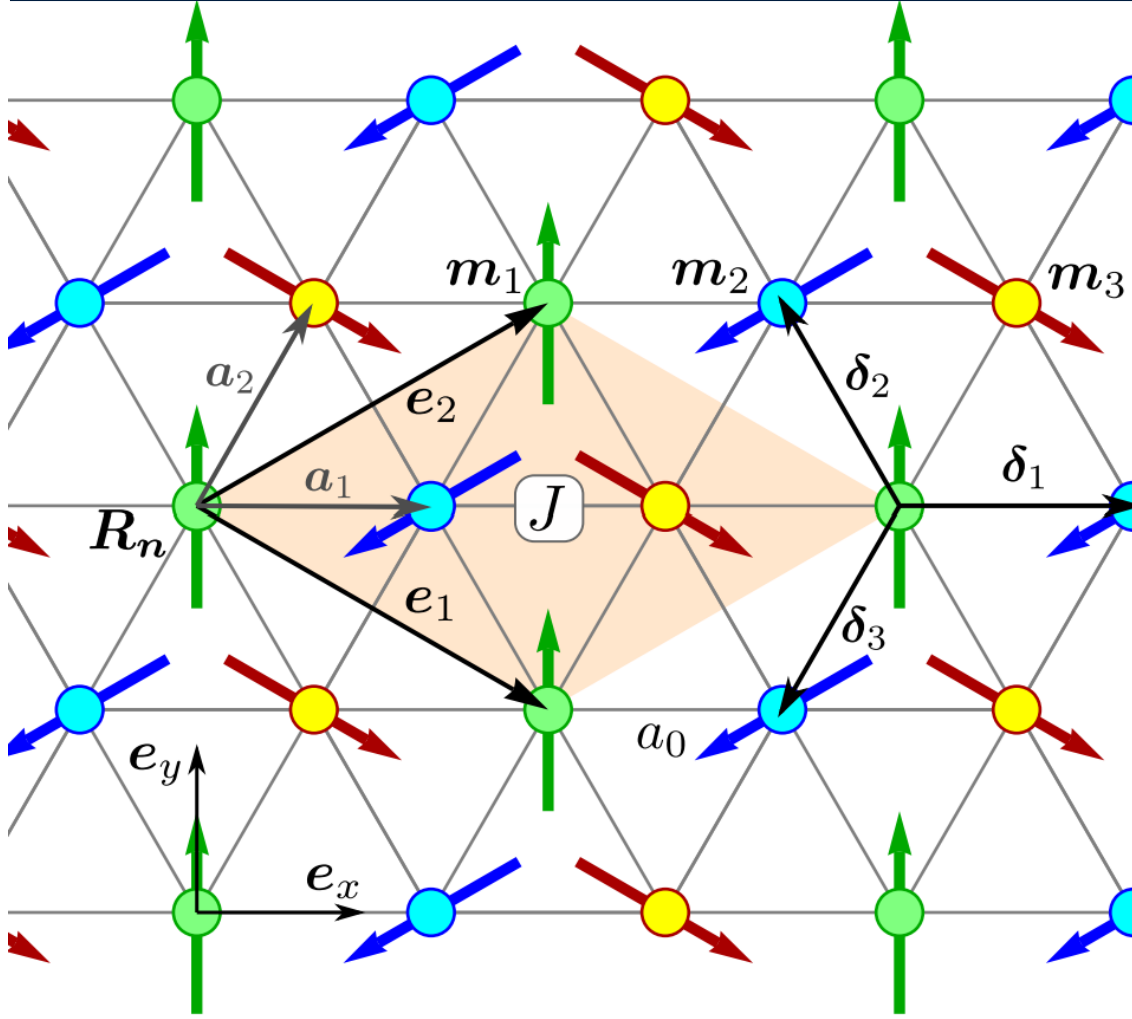
Ricardo
Zarzuela



Jairo
Sinova

Kravchuk, Yershov, Pradenas, Neumann, Jaeschke-Ubiergo, Zarzuela, Sinova, van den Brink, *AM*, arXiv:2605.22614 (2026)

F-wave magnons on triangular lattices



$$\mathcal{H} = \frac{J}{2} \sum_{\langle r_n, r'_n \rangle} \mathbf{m}(r_n) \cdot \mathbf{m}(r'_n)$$

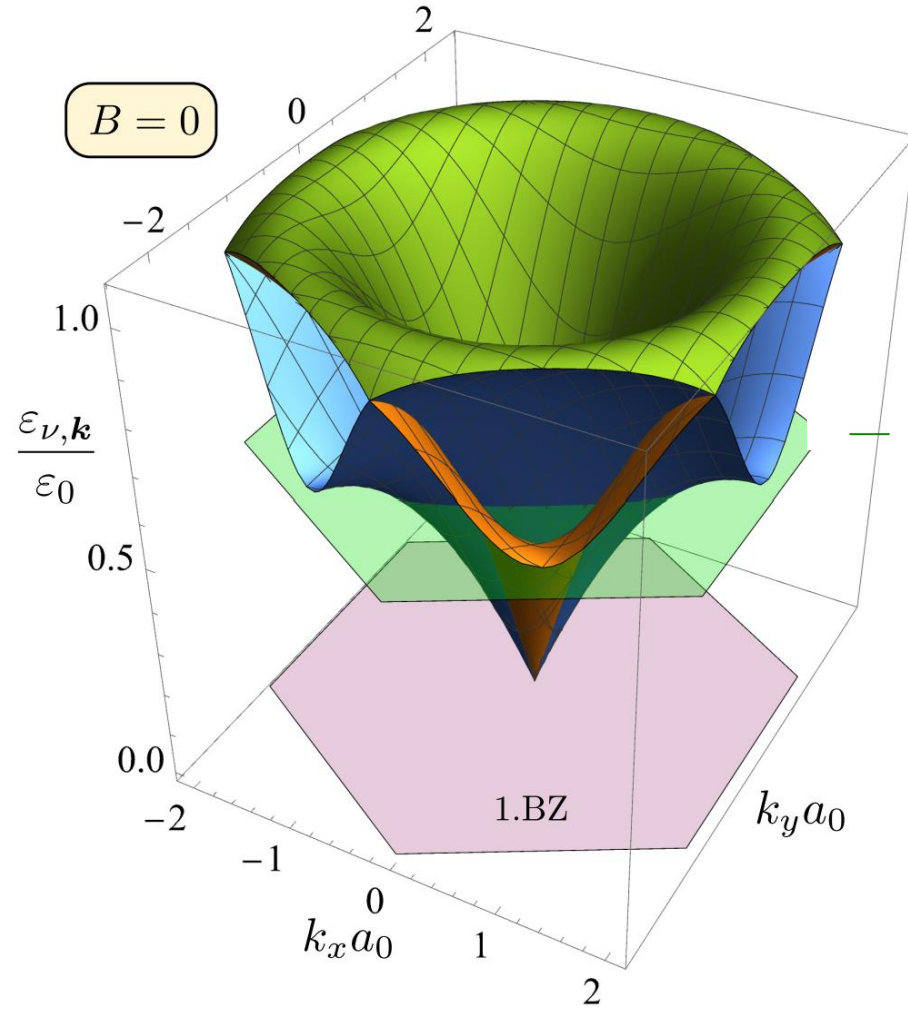
Linear spin-wave theory:

$$\varepsilon_{\pm 1, \mathbf{k}} = \varepsilon_0 \sqrt{\left(1 - \frac{\Omega_{\mathbf{k}}^{\pm}}{2}\right) \left[1 - \Omega_{\mathbf{k}}^{\pm} \begin{pmatrix} 1 \\ \end{pmatrix}\right]}$$

$$\varepsilon_{0, \mathbf{k}} = \varepsilon_0 \sqrt{(1 - \Omega_{\mathbf{k}}^c) [1 + \Omega_{\mathbf{k}}^c (2 \quad)]}$$

Kravchuk, Yershov, Pradenas, Neumann, Jaeschke-Ubiergo, Zarzuela, Sinova, van den Brink, **AM**, arXiv:2605.22614 (2026)

F-wave magnons on triangular lattices



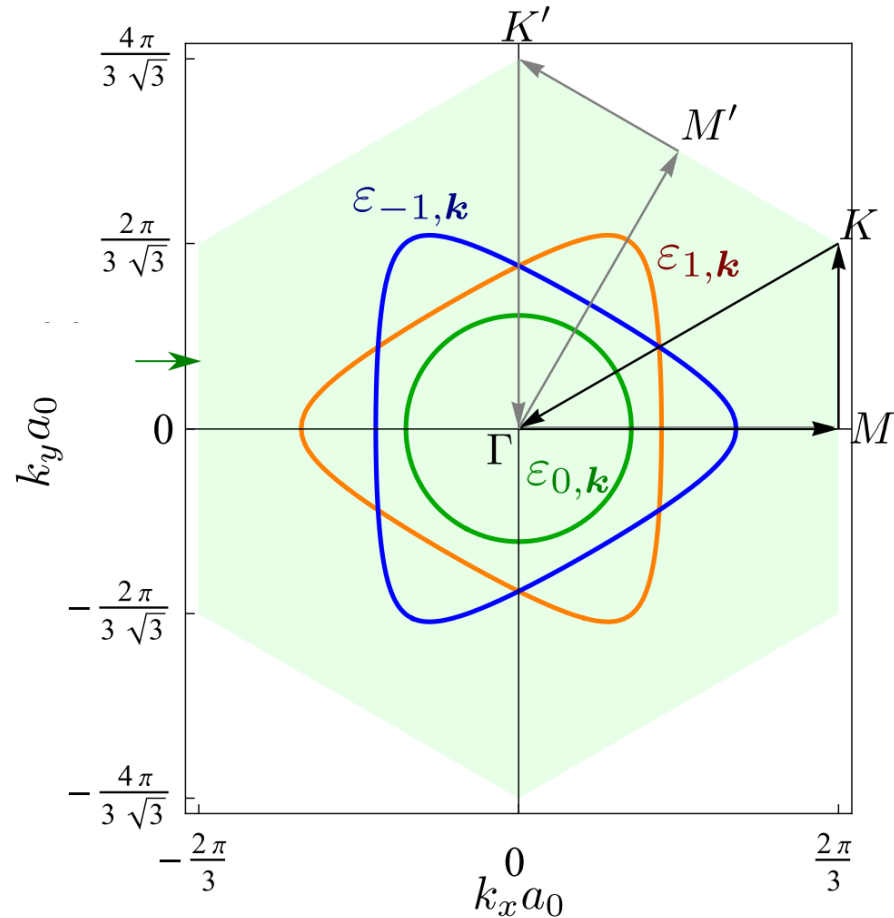
$$\mathcal{H} = \frac{J}{2} \sum_{\langle \mathbf{r}_n, \mathbf{r}'_n \rangle} \mathbf{m}(\mathbf{r}_n) \cdot \mathbf{m}(\mathbf{r}'_n)$$

Linear spin-wave theory:

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$$\varepsilon_{0, \mathbf{k}} = \varepsilon_0 \sqrt{(1 - \Omega_{\mathbf{k}}^c) [1 + \Omega_{\mathbf{k}}^c \begin{pmatrix} 2 & \\ & \end{pmatrix}]}$$

F-wave magnons on triangular lattices



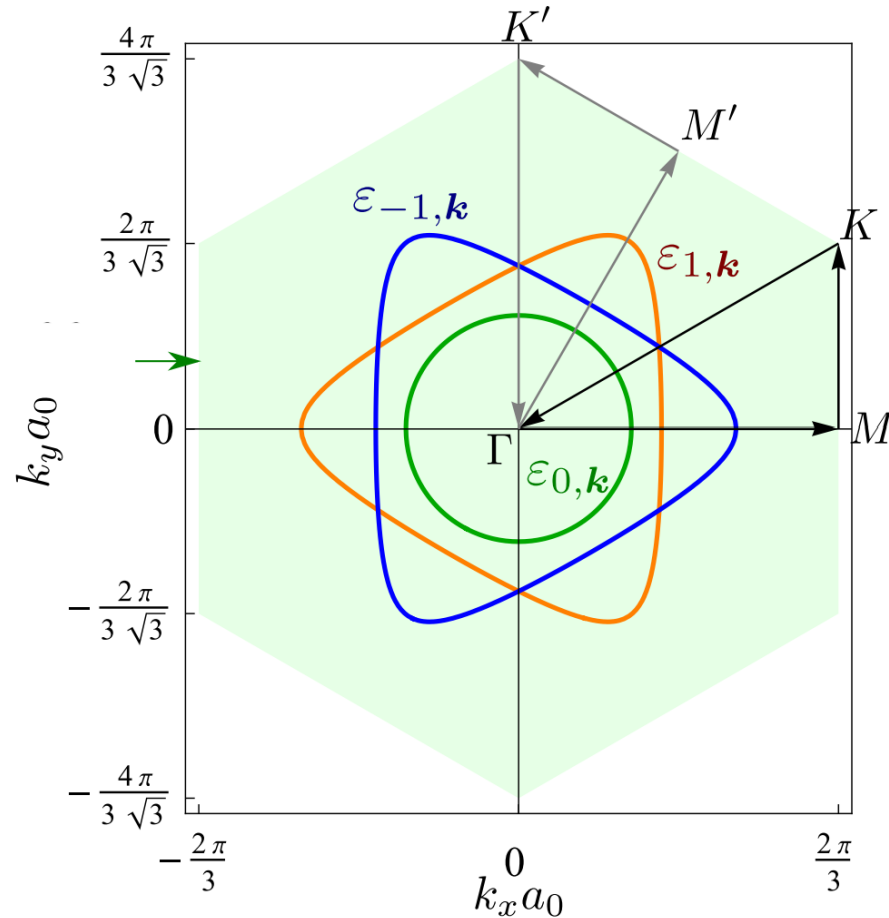
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F-wave magnons on triangular lattices



$$\mathcal{H} = \frac{J}{2} \sum_{\langle \mathbf{r}_n, \mathbf{r}'_n \rangle} \mathbf{m}(\mathbf{r}_n) \cdot \mathbf{m}(\mathbf{r}'_n) - \mu_s B \sum_{\mathbf{r}_n} m_z(\mathbf{r}_n)$$

Linear spin-wave theory:

$$\varepsilon_{\pm 1, \mathbf{k}} = \varepsilon_0 \sqrt{\left(1 - \frac{\Omega_{\mathbf{k}}^{\pm}}{2}\right) \left[1 - \Omega_{\mathbf{k}}^{\pm} \left(1 - \frac{3B^2}{2B_0^2}\right)\right]} - \mu_{\pm 1, \mathbf{k}}^z B$$

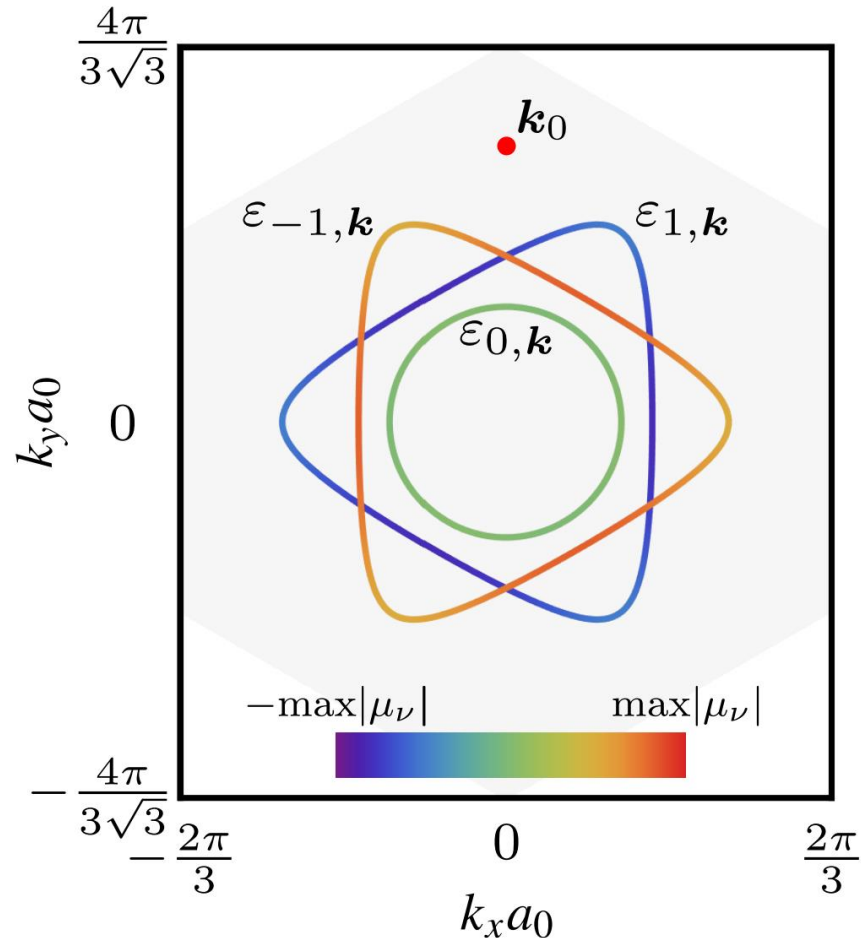
$$\varepsilon_{0, \mathbf{k}} = \varepsilon_0 \sqrt{(1 - \Omega_{\mathbf{k}}^c) [1 + \Omega_{\mathbf{k}}^c (2 - 3B^2/B_0^2)]} - \mu_{0, \mathbf{k}}^z B.$$

Magnon magnetic moment: $\mu_{\nu, \mathbf{k}} = -\partial_B \varepsilon_{\nu, \mathbf{k}}|_{B=0}$

$$\mu_{\pm 1, \mathbf{k}}^z = \frac{|g|\mu_B}{2} \left(\mp \Omega_{\mathbf{k}}^c + \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}} \right) \quad \mu_{0, \mathbf{k}}^z = -|g|\mu_B \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}}$$

Kravchuk, Yershov, Pradenas, Neumann, Jaeschke-Ubiergo, Zarzuela, Sinova, van den Brink, **AM**, arXiv:2605.22614 (2026)

F-wave magnons on triangular lattices



$$\mathcal{H} = \frac{J}{2} \sum_{\langle \mathbf{r}_n, \mathbf{r}'_n \rangle} \mathbf{m}(\mathbf{r}_n) \cdot \mathbf{m}(\mathbf{r}'_n) - \mu_s B \sum_{\mathbf{r}_n} m_z(\mathbf{r}_n)$$

Linear spin-wave theory:

$$\varepsilon_{\pm 1, \mathbf{k}} = \varepsilon_0 \sqrt{\left(1 - \frac{\Omega_{\mathbf{k}}^{\pm}}{2}\right) \left[1 - \Omega_{\mathbf{k}}^{\pm} \left(1 - \frac{3B^2}{2B_0^2}\right)\right]} - \mu_{\pm 1, \mathbf{k}}^z B$$

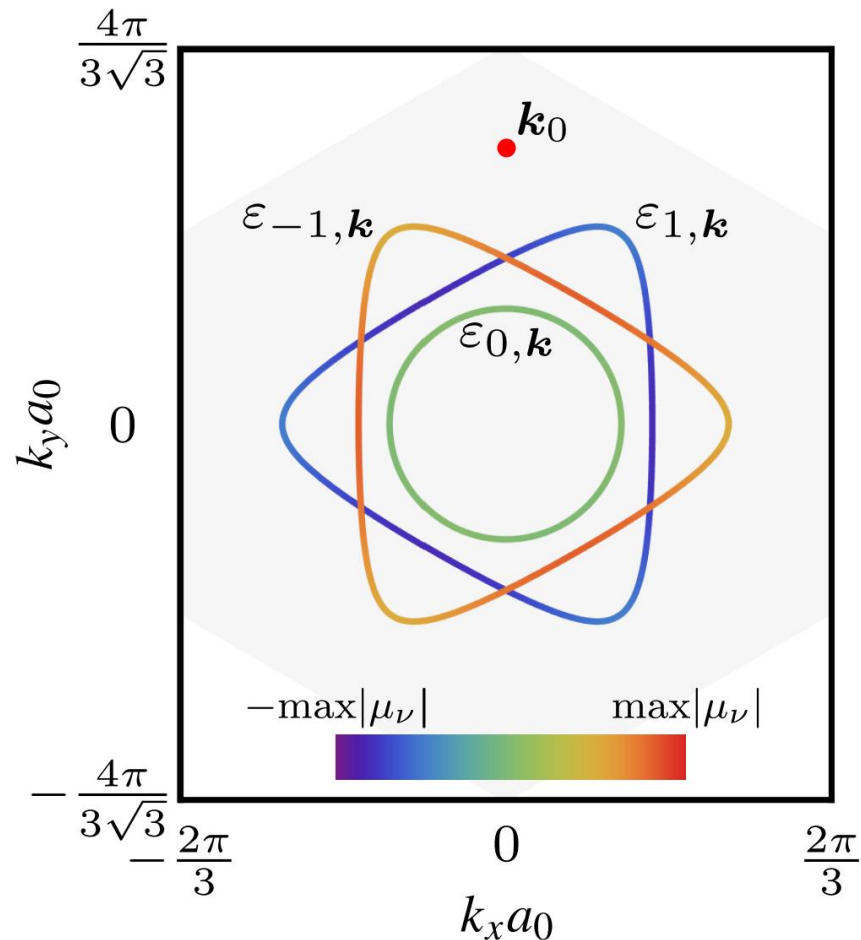
$$\varepsilon_{0, \mathbf{k}} = \varepsilon_0 \sqrt{(1 - \Omega_{\mathbf{k}}^c) [1 + \Omega_{\mathbf{k}}^c (2 - 3B^2/B_0^2)]} - \mu_{0, \mathbf{k}}^z B.$$

Magnon magnetic moment: $\mu_{\nu, \mathbf{k}} = -\partial_B \varepsilon_{\nu, \mathbf{k}}|_{B=0}$

$$\mu_{\pm 1, \mathbf{k}}^z = \frac{|g|\mu_B}{2} \left(\mp \Omega_{\mathbf{k}}^c + \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}} \right) \quad \mu_{0, \mathbf{k}}^z = -|g|\mu_B \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}}$$

Kravchuk, Yershov, Pradenas, Neumann, Jaeschke-Ubiergo, Zarzuela, Sinova, van den Brink, **AM**, arXiv:2605.22614 (2026)

F-wave magnons on triangular lattices



Magnon magnetic moment: $\mu_{\nu,k} = -\partial_B \varepsilon_{\nu,k}|_{B=0}$

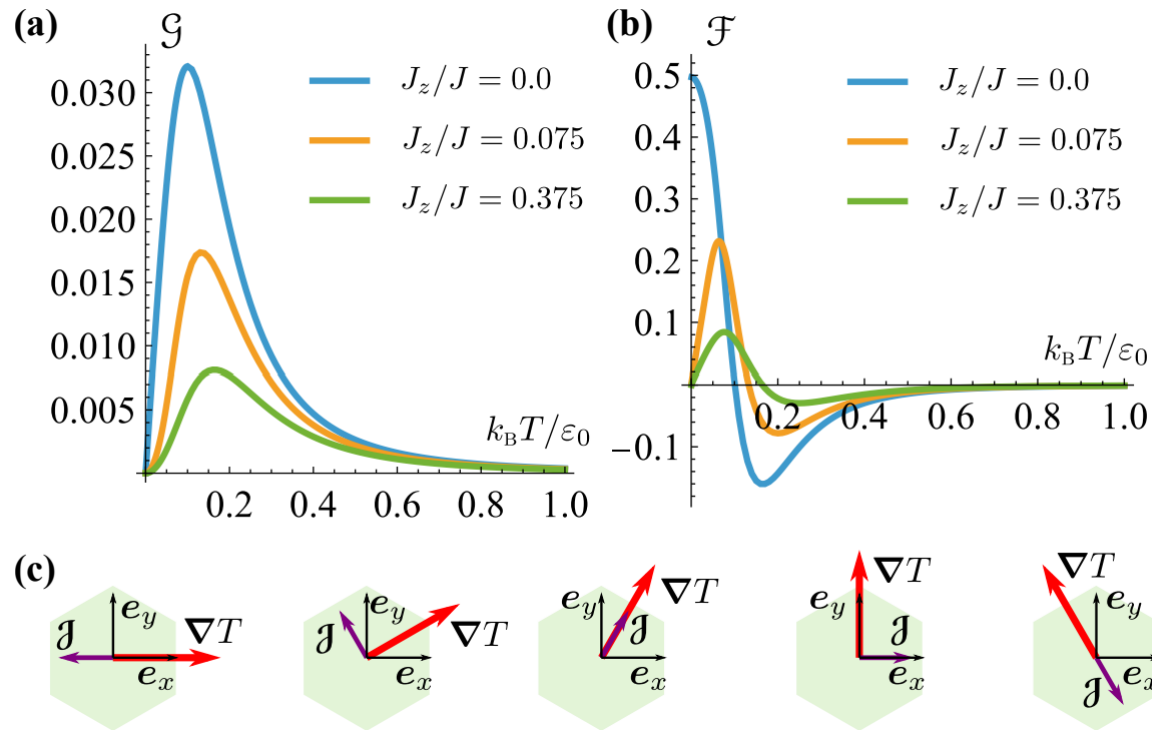
$$\mu_{\pm 1,k}^z = \frac{|g|\mu_B}{2} \left(\mp \Omega_k^c + \frac{\Omega_k^s}{\sqrt{3}} \right) \quad \mu_{0,k}^z = -|g|\mu_B \frac{\Omega_k^s}{\sqrt{3}}$$

Transport responses:

$$\mathcal{J}_\alpha = G_{\alpha\beta} \partial_\beta T + G_{\alpha\beta\gamma}^{(2)} \partial_\beta T \partial_\gamma T + \dots$$

$$M = F_\alpha \partial_\alpha T + F_{\alpha\beta}^{(2)} \partial_\alpha T \partial_\beta T + F_{\alpha\beta\gamma}^{(3)} \partial_\alpha T \partial_\beta T \partial_\gamma T + \dots$$

F-wave magnons on triangular lattices



Magnon magnetic moment: $\mu_{\nu, \mathbf{k}} = -\partial_B \varepsilon_{\nu, \mathbf{k}}|_{B=0}$

$$\mu_{\pm 1, \mathbf{k}}^z = \frac{|g| \mu_B}{2} \left(\mp \Omega_{\mathbf{k}}^c + \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}} \right) \quad \mu_{0, \mathbf{k}}^z = -|g| \mu_B \frac{\Omega_{\mathbf{k}}^s}{\sqrt{3}}$$

Transport responses:

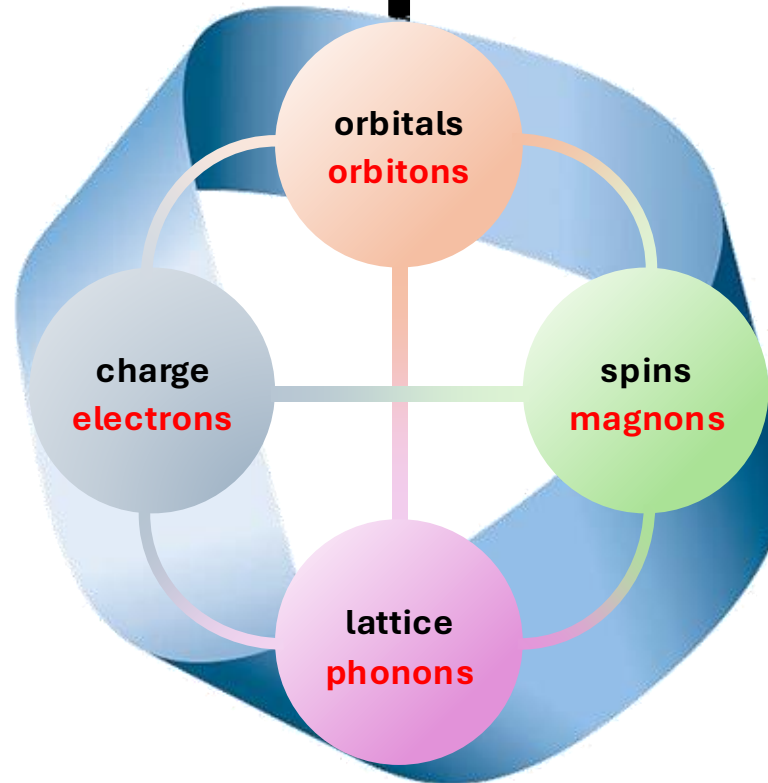
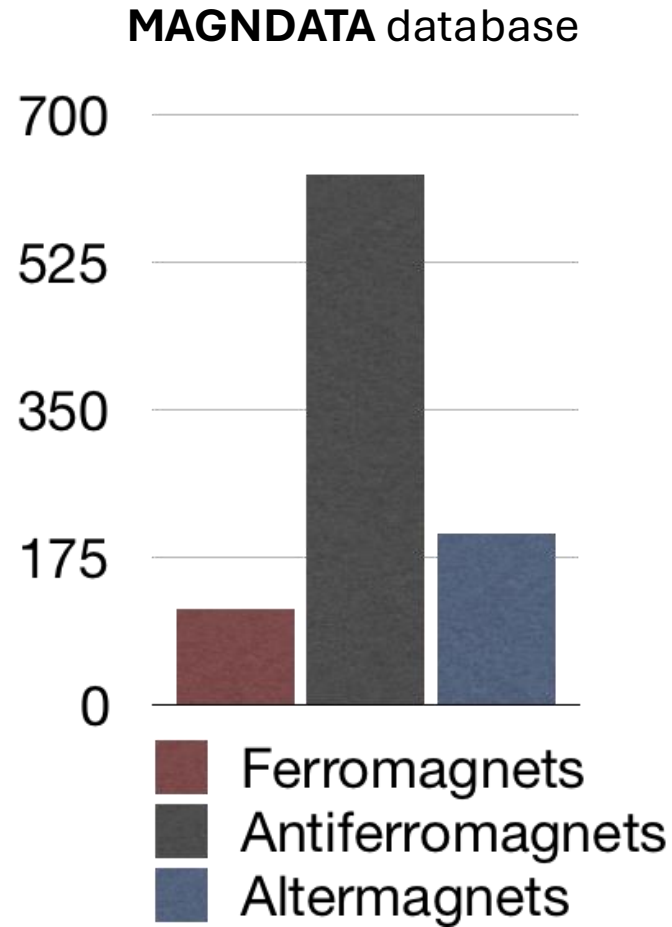
$$\mathcal{J}_{\alpha} = G_{\alpha\beta} \partial_{\beta} T + G_{\alpha\beta\gamma}^{(2)} \partial_{\beta} T \partial_{\gamma} T + \dots$$

$$M = F_{\alpha} \partial_{\alpha} T + F_{\alpha\beta}^{(2)} \partial_{\alpha} T \partial_{\beta} T + F_{\alpha\beta\gamma}^{(3)} \partial_{\alpha} T \partial_{\beta} T \partial_{\gamma} T + \dots$$

Nonlinear steady-state magnetization:

$$M_{\max} \sim 1 \mu_B / \text{nm}^3$$

Unconventional Magnetism

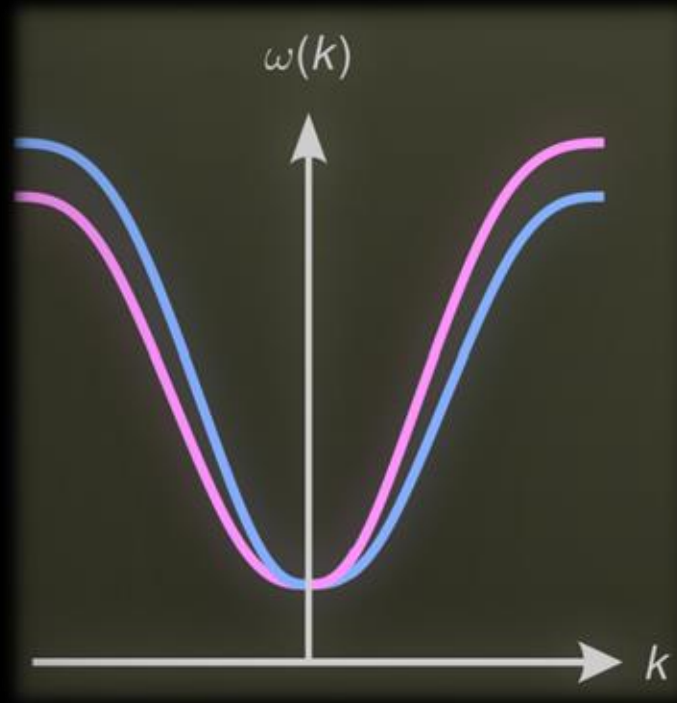


How can we increase the number of material candidates?

Jin, Neumann, Jaeschke-Ubiergo, Sinova, **AM**,
arXiv:2606.30214 (2026)

Poster:
P-wave magnons in nanotubes

P-wave magnetism



Zhejunyu Jin



Rodrigo Jaeschke-
Ubiergo



Robin Neumann



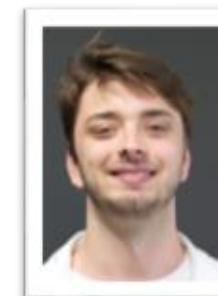
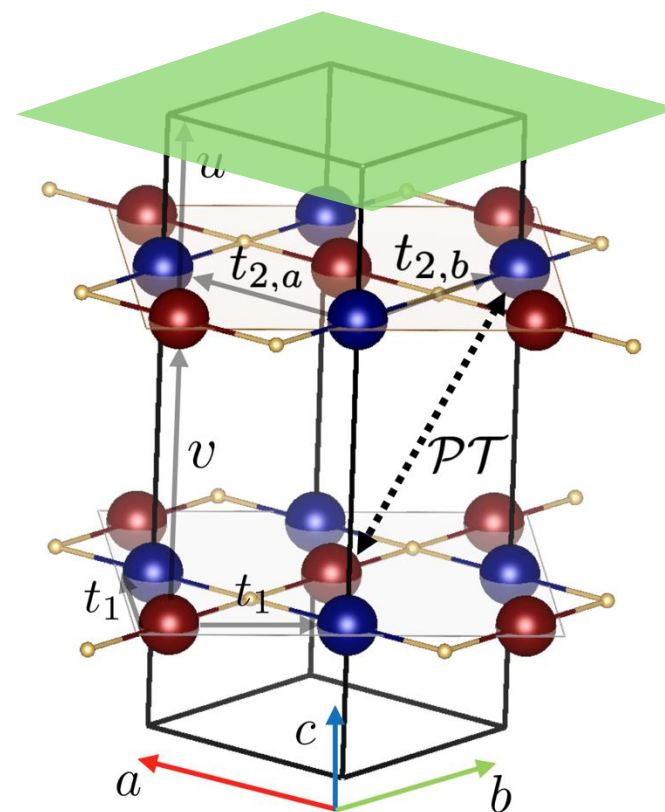
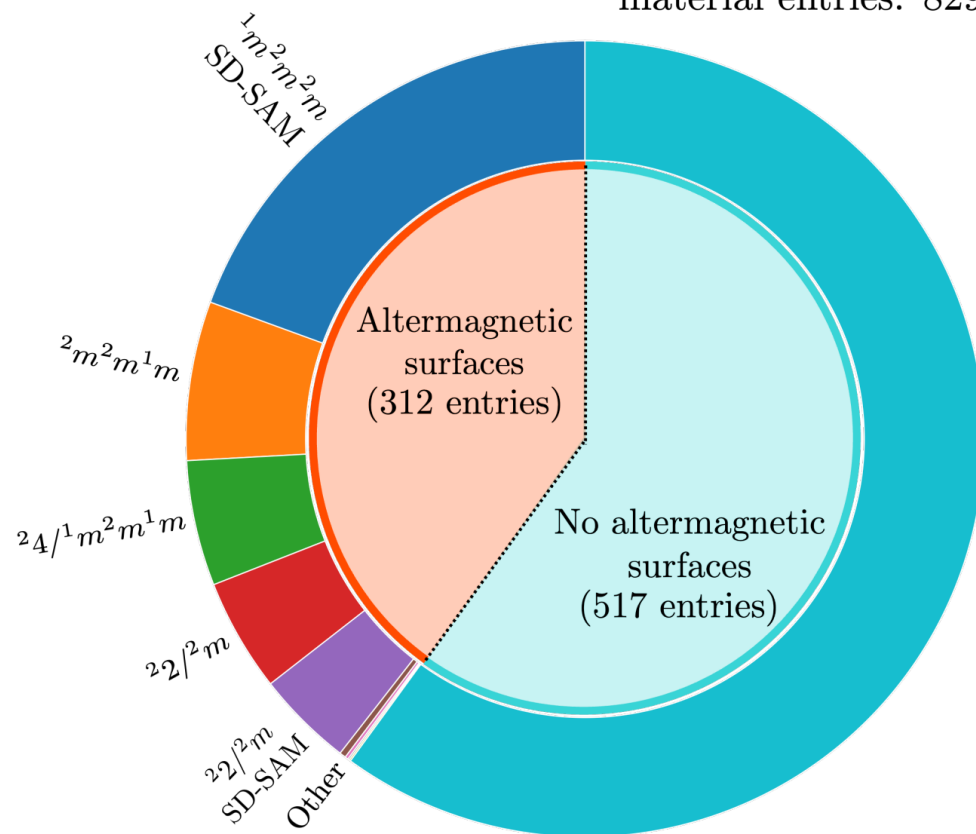
Jairo Sinova

Animation credit:
Robin R. Neumann

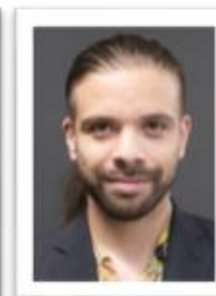
Emergent surface altermagnetism

Lange, Jaeschke-Ubiergo, Chakraborty, Verbeek, Šmejkal, Sinova, **AM**, arXiv:2602.08773 (2026)

Number of total
material entries: 829



Colin
Lange



Rodrigo
Jaeschke-
Ubiergo



Atasi
Chakraborty



Xanthe H.
Verbeek



Jairo
Sinova



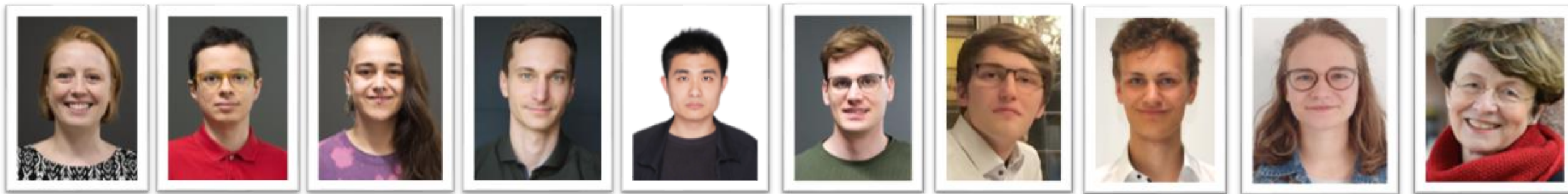
Libor
Šmejkal

Result of screening

Lange, Jaeschke-Ubiergo, Chakraborty, Verbeek, Šmejkal, Sinova, **AM**, arXiv:2602.08773 (2026)

No.	Material	Index	Normal	Surface spin	Laue group	Partial wave	Terrace domains
1	AgNiO ₂	1.50	[001] [010]	$\bar{1}$ $^2 2_z / ^2 m_z$	AFM SD-SAM		yes
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
208	NaMnP	0.627	[001] [1 $\bar{1}$ 0] [110]	$^2 4 / ^1 m ^1 m ^2 m$ $^2 m ^2 m ^1 m$ $^2 m ^2 m ^1 m$	<i>d</i> -wave <i>d</i> -wave <i>d</i> -wave		no
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
312	ZnV ₂ O ₄	1.24	[001] [1 $\bar{1}$ 0] [110]	$^2 2_z / ^2 m_z$ $2 / m$ $2 / m$	SD-SAM AFM AFM		yes

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Neumann

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Jin

Pieter M.
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Gieselmann

Anton
Plonka

Hannah
Bendin

Ingrid
Mertig



Colin
Lange

Rodrigo
Jaeschke-
Ubiergo

Atasi
Chakraborty

Xanthe H.
Verbeek

Jairo
Sinova

Libor
Šmejkal

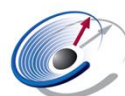
Rintaro
Eto

Masahito
Mochizuki

Matthias
Gohlke

Sasha
Chernyshev

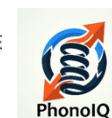
Funding



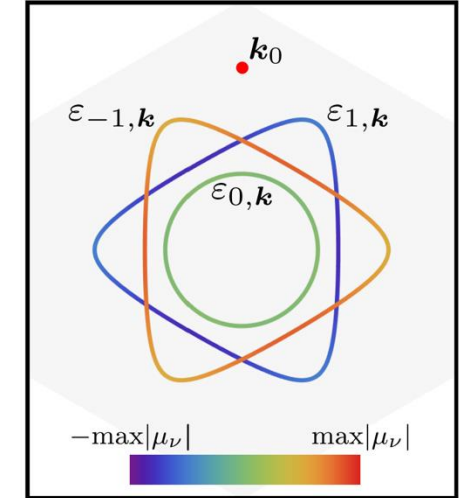
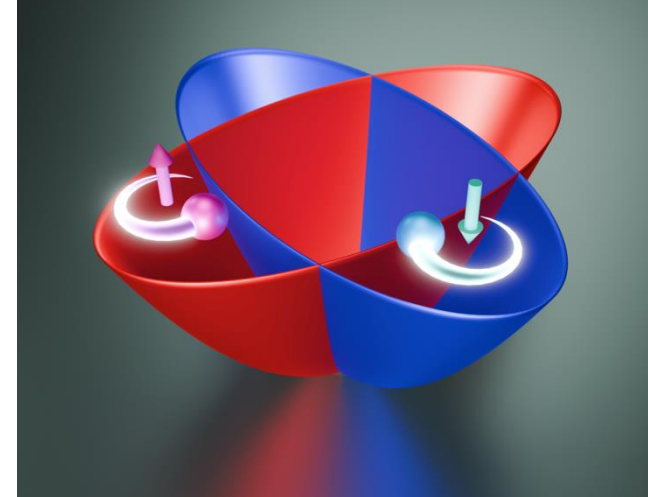
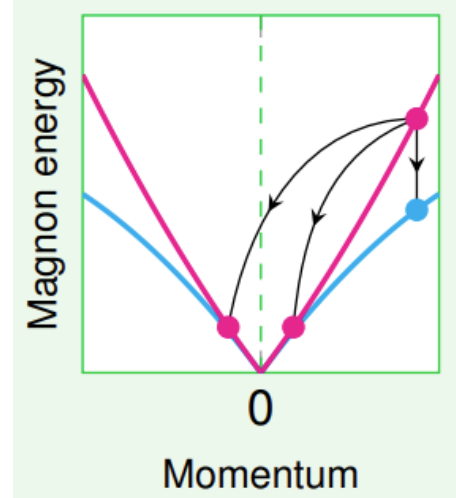
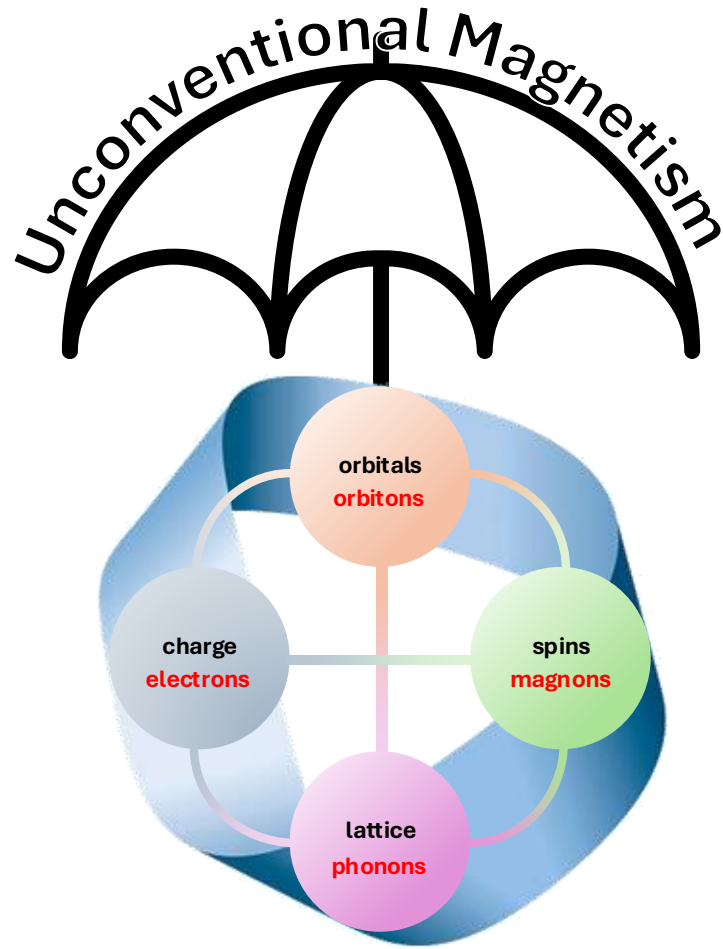
SPIN+X
SFB/TRR 173
Kaiserslautern • Mainz



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DES LANDES
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Unconventional magnetism governs magnon properties



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Lange, Jaeschke-Ubiergo, Chakraborty, Verbeek, Šmejkal, Sinova, **AM**, arXiv:2602.08773 (2026)

Kravchuk, Yershov, Pradenas, Neumann, Jaeschke-Ubiergo, Zarzuela, Sinova, van den Brink, **AM**, arXiv:2605.22614 (2026)