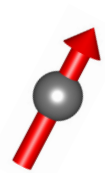
Bird's eye view of magnetic order

exchange couplings, magnetic model

synthetic magnets

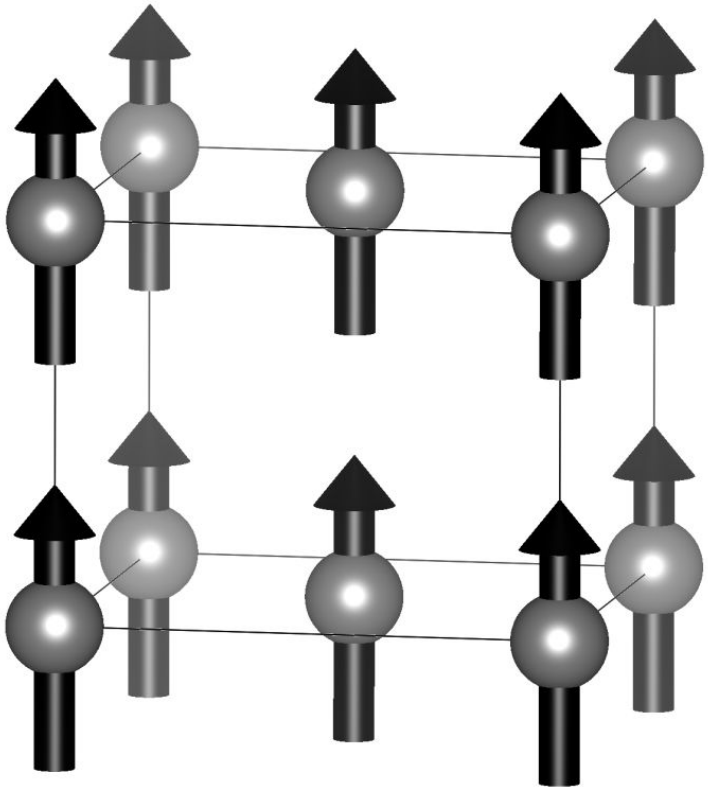
Werner Heisenberg



by Alexander Tsirlin, Leipzig University

Lecture 5: November 18, 2024

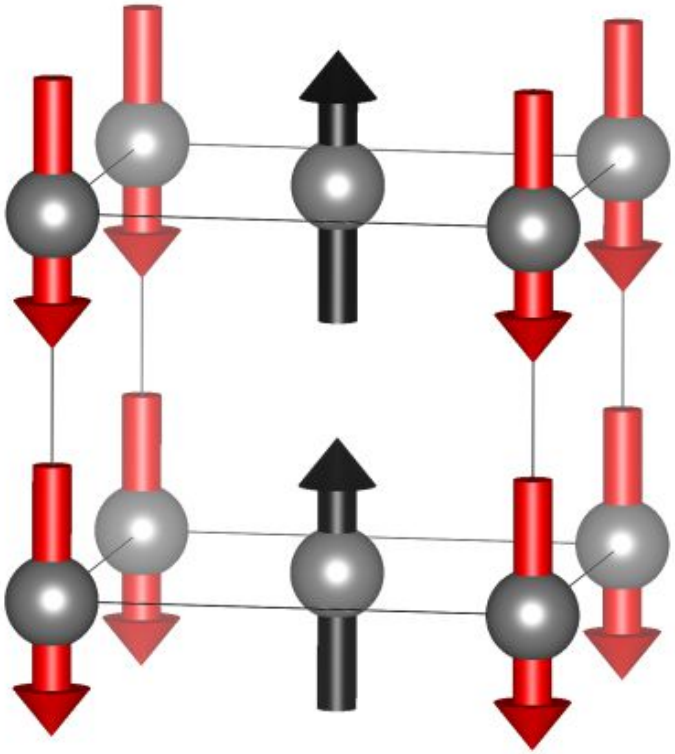
Ferromagnetic vs. antiferromagnetic



Ferromagnet

$M = M_s$

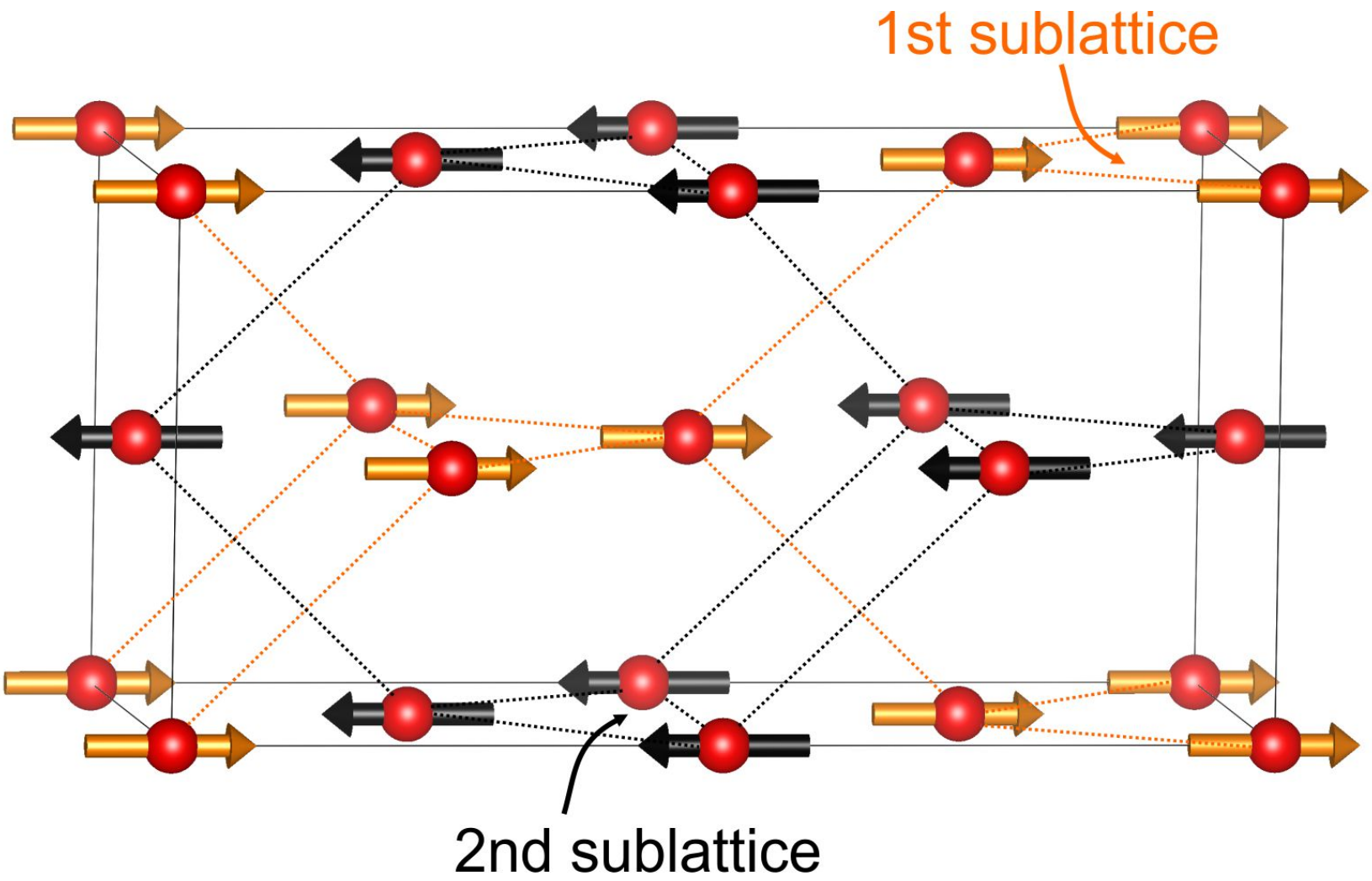
saturated magnetization



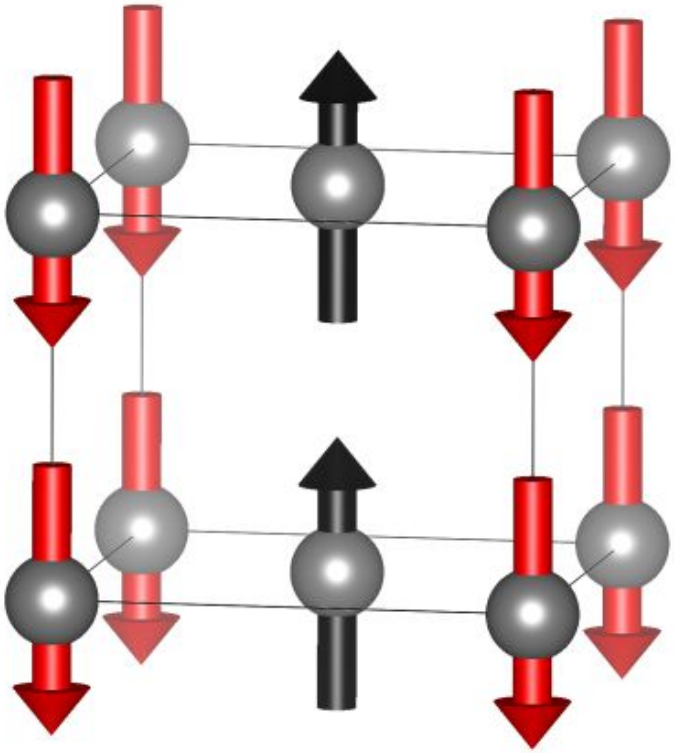
Antiferromagnet

$M = 0$

zero net magnetization


1st sublattice
2nd sublattice

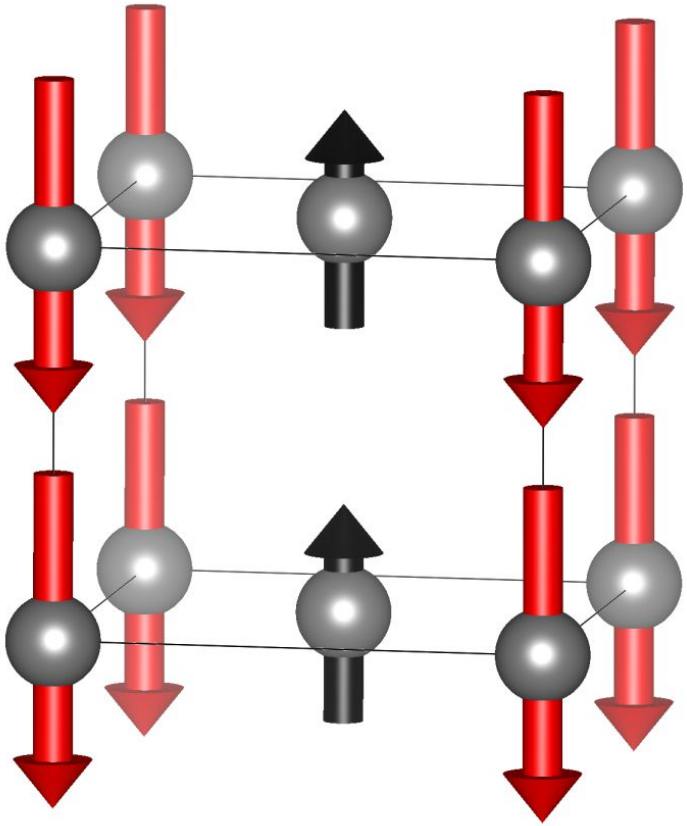
Antiferromagnetic vs. Ferrimagnetic



Antiferromagnet

$M = 0$

fullly compensated

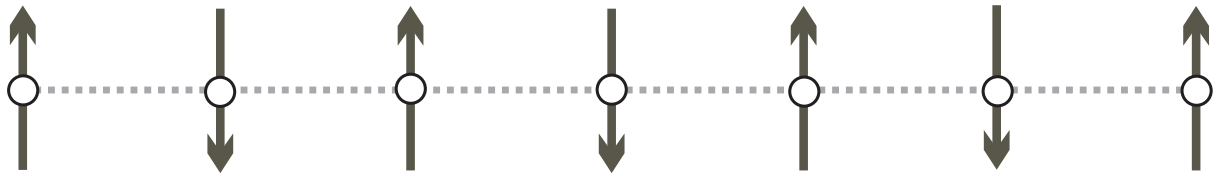


Ferrimagnet

$M \neq 0$

partially compensated

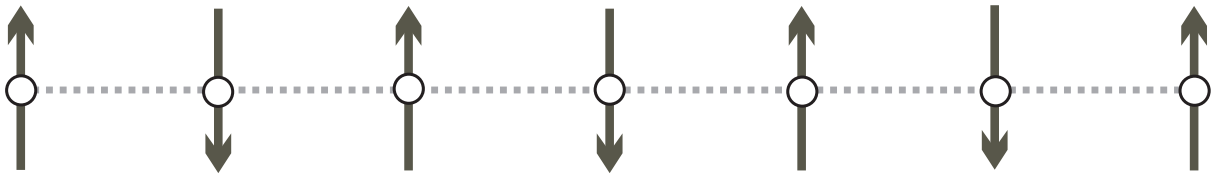
Commensurate vs. Collinear



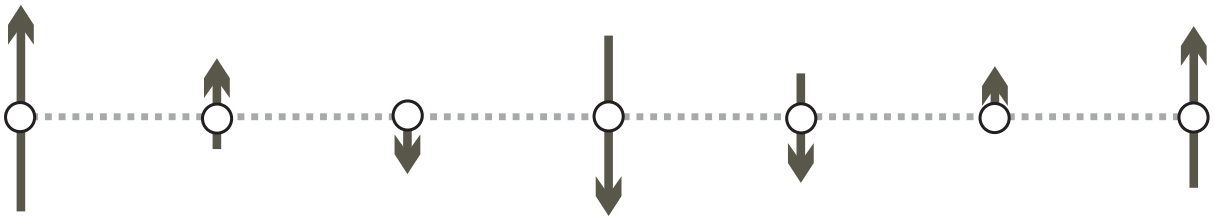
commensurate

collinear

Commensurate vs. Collinear

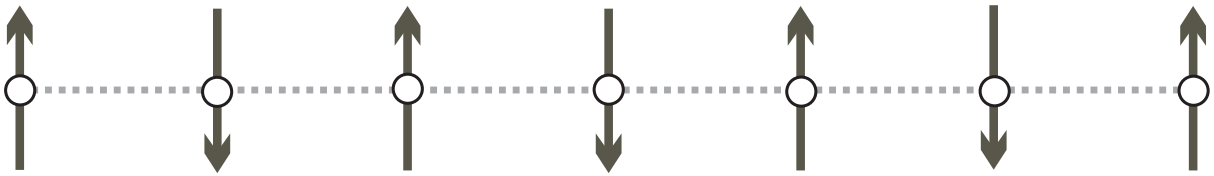


commensurate
collinear

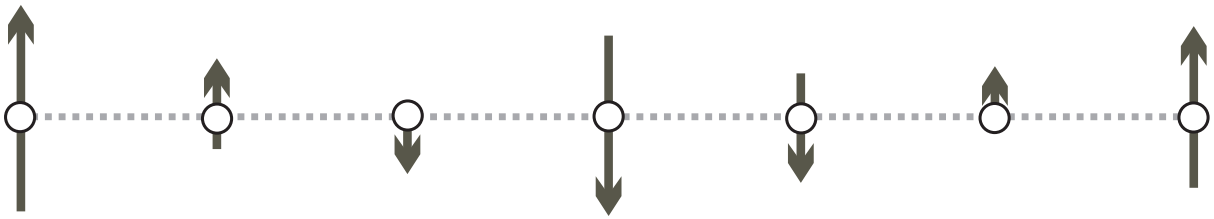


incommensurate
collinear

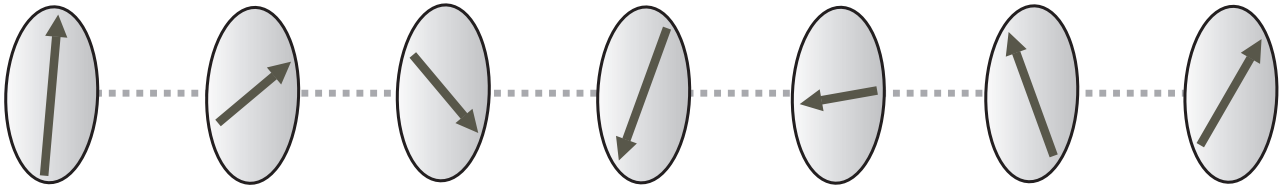
Commensurate vs. Collinear



commensurate
collinear

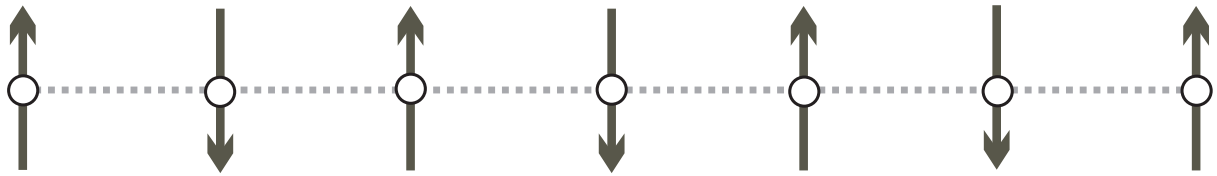


incommensurate
collinear

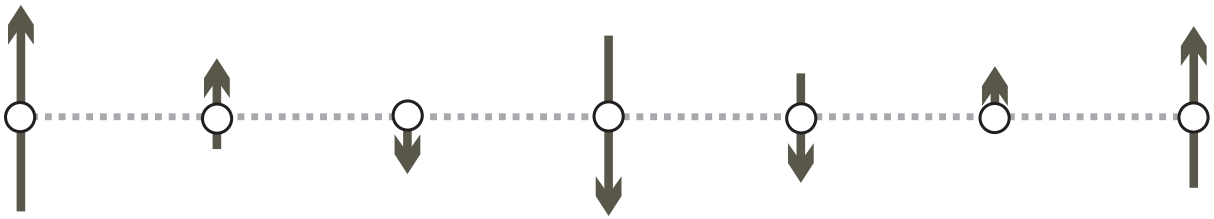


incommensurate
non-collinear

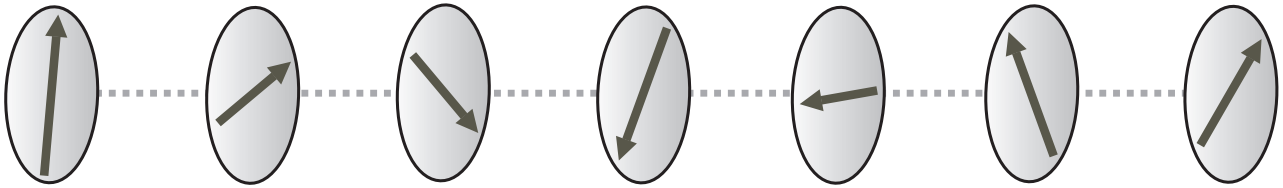
Commensurate vs. Collinear



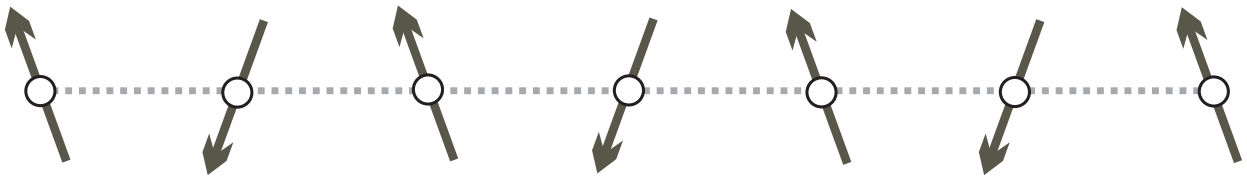
commensurate
collinear



incommensurate
collinear

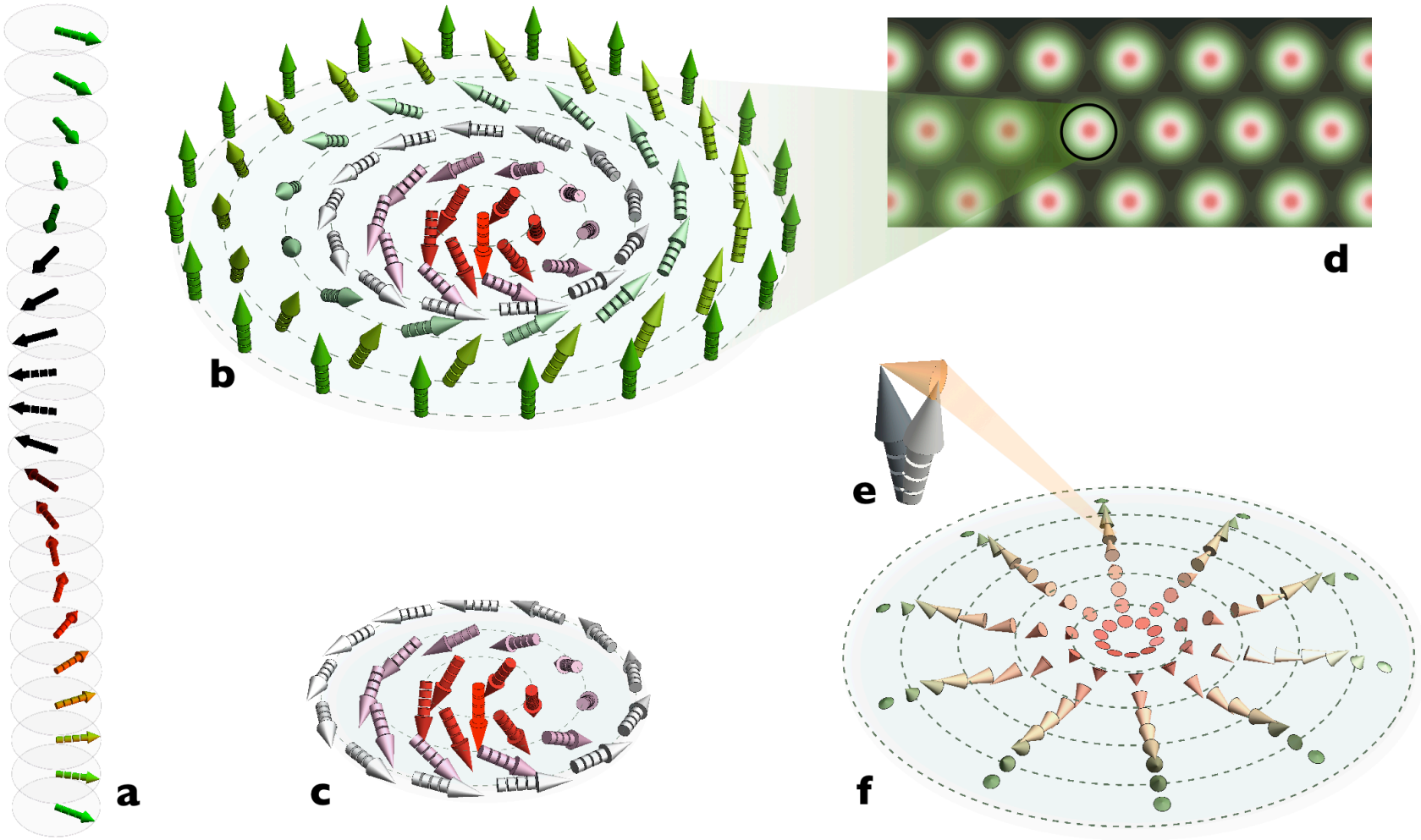


incommensurate
non-collinear



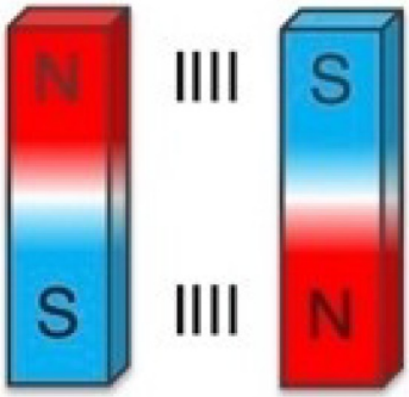
commensurate
non-collinear

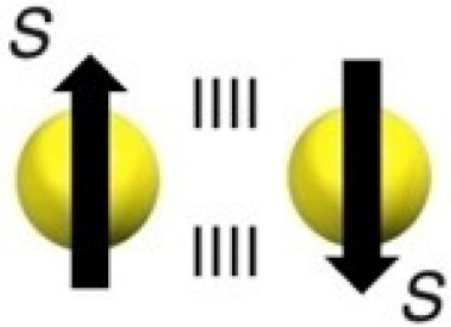
Spin textures: skyrmions



Helical magnetic structures may turn into finite objects, **skyrmions**, that can be used for information storage

Dipole-dipole interaction

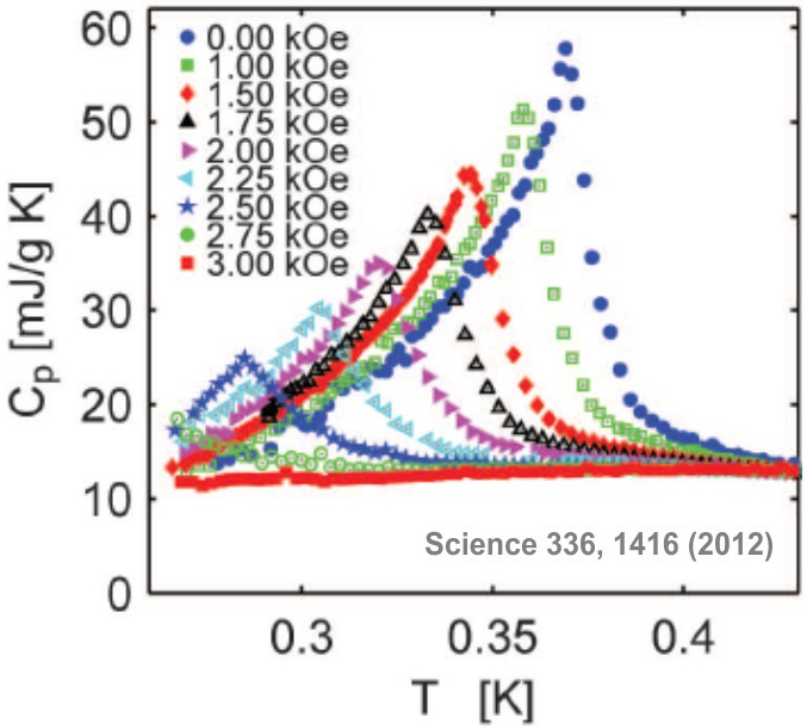


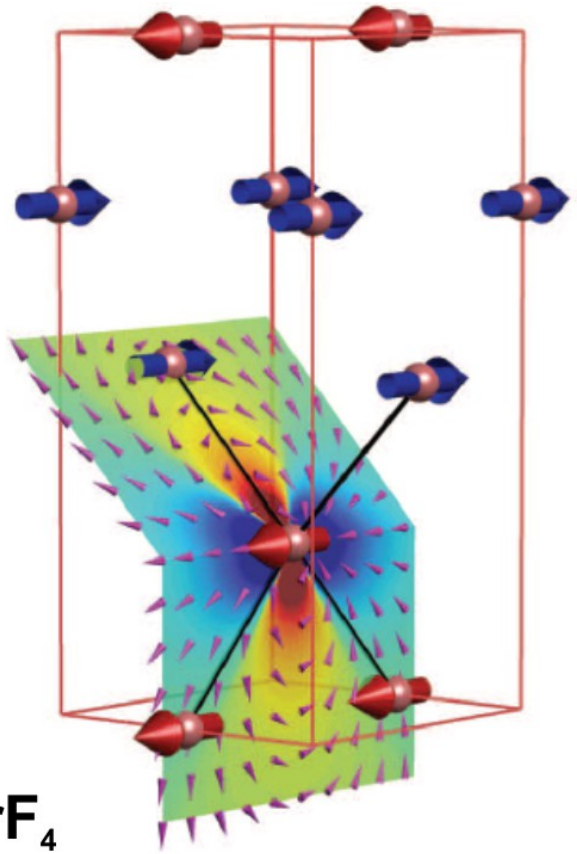


Chem. Eur. J. 29, e202203421 (2022)

Dipole-dipole interaction

milli-K range!

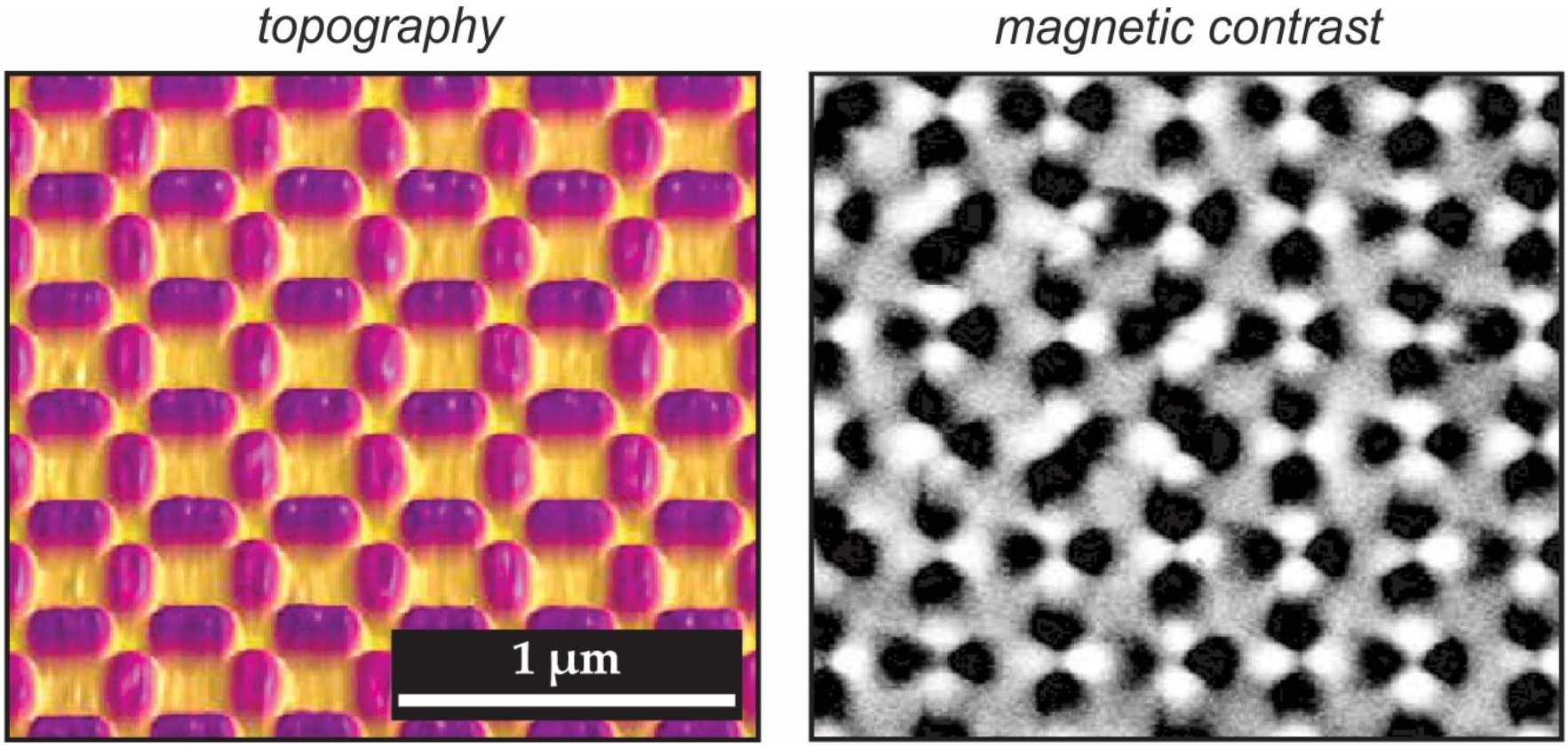




$LiErF_4$

Material / Technology

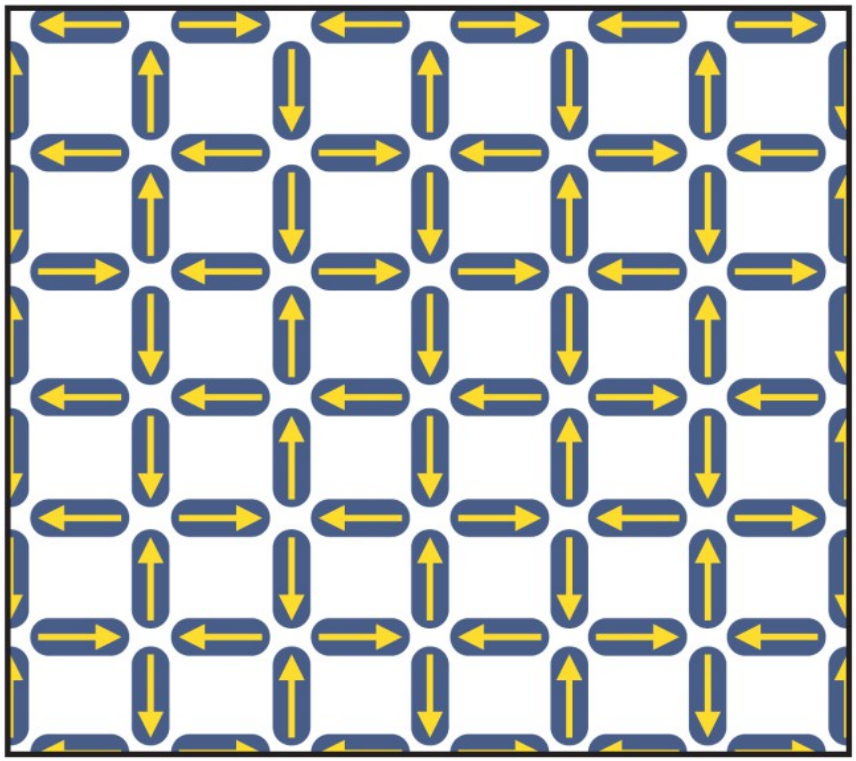
synthetic magnets

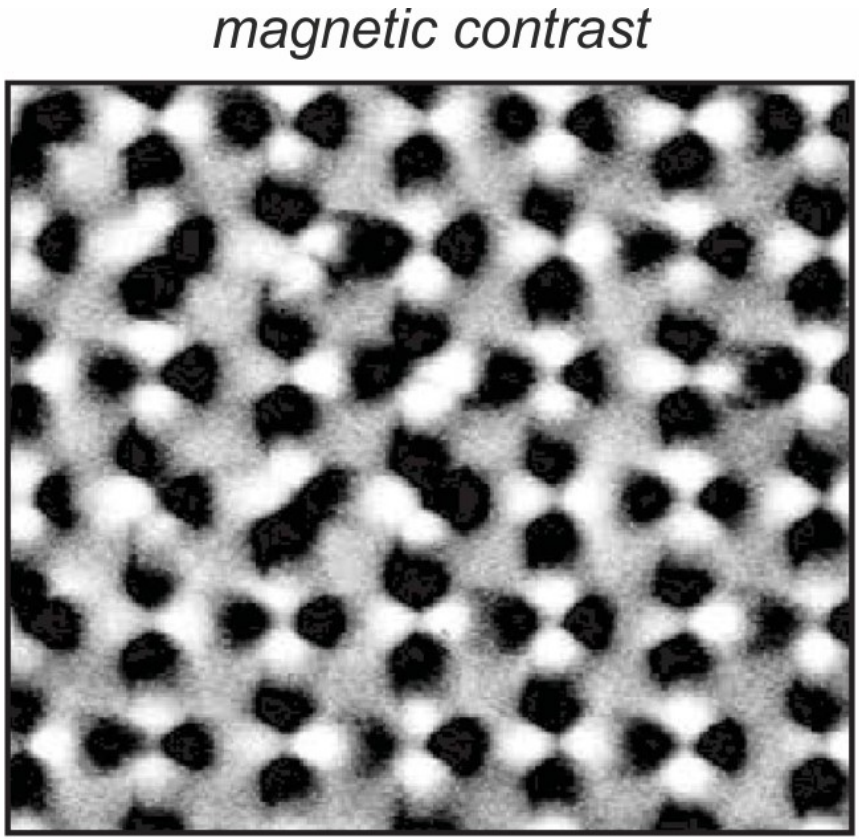


Nanosized islands made of a ferromagnetic Ni-Fe alloy

Large moments $\longrightarrow$ strong dipole-dipole interactions

Phys. Today 69(7), 54 (2016)





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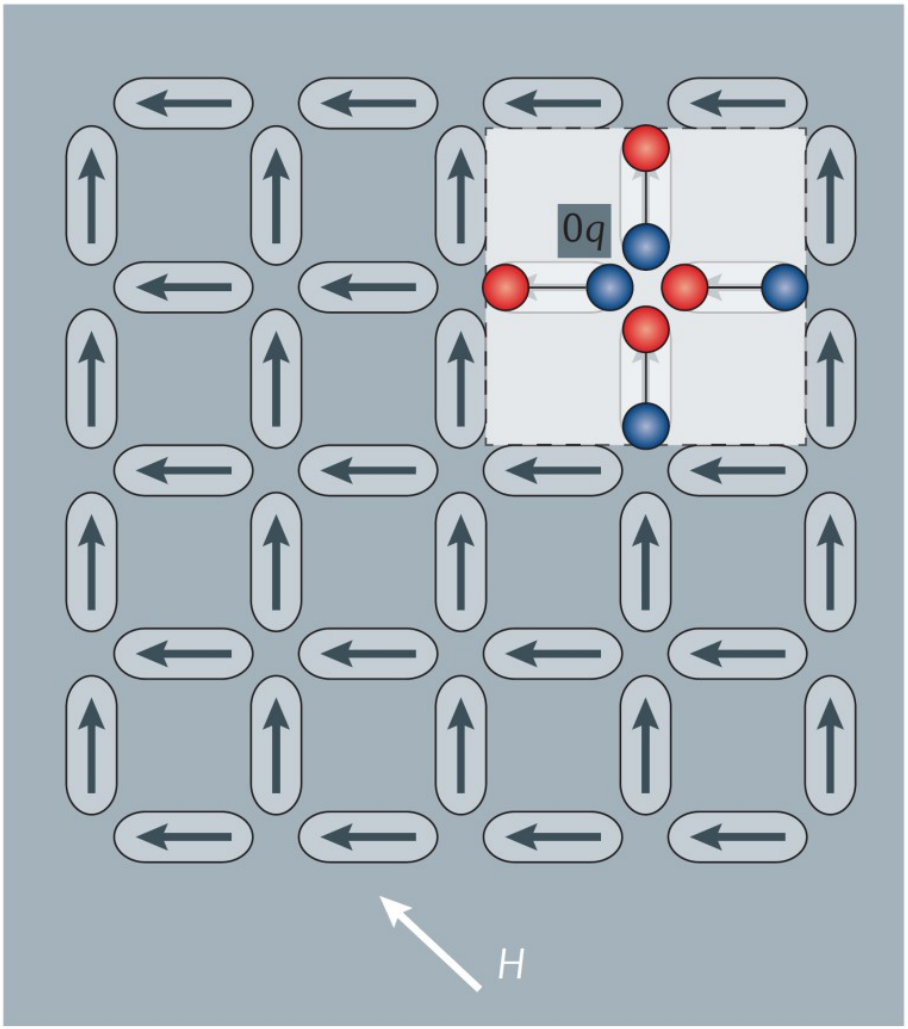
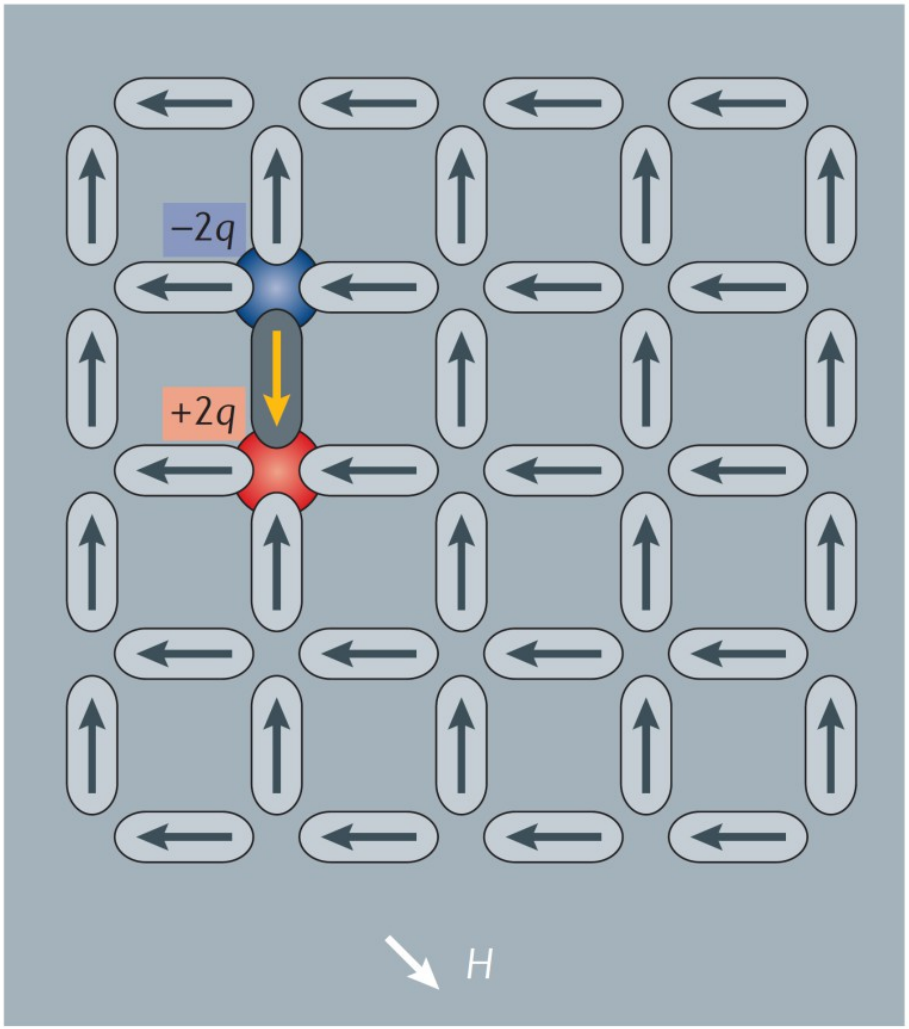
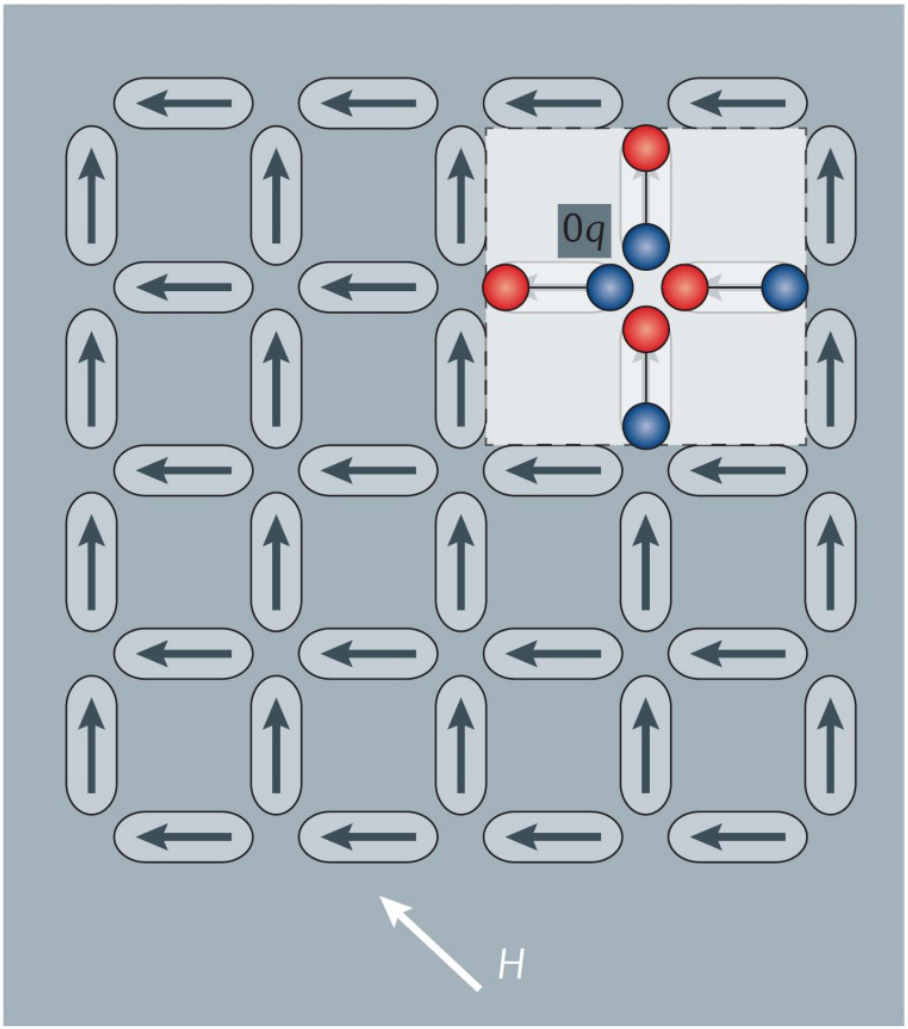
Magnetic monopole?

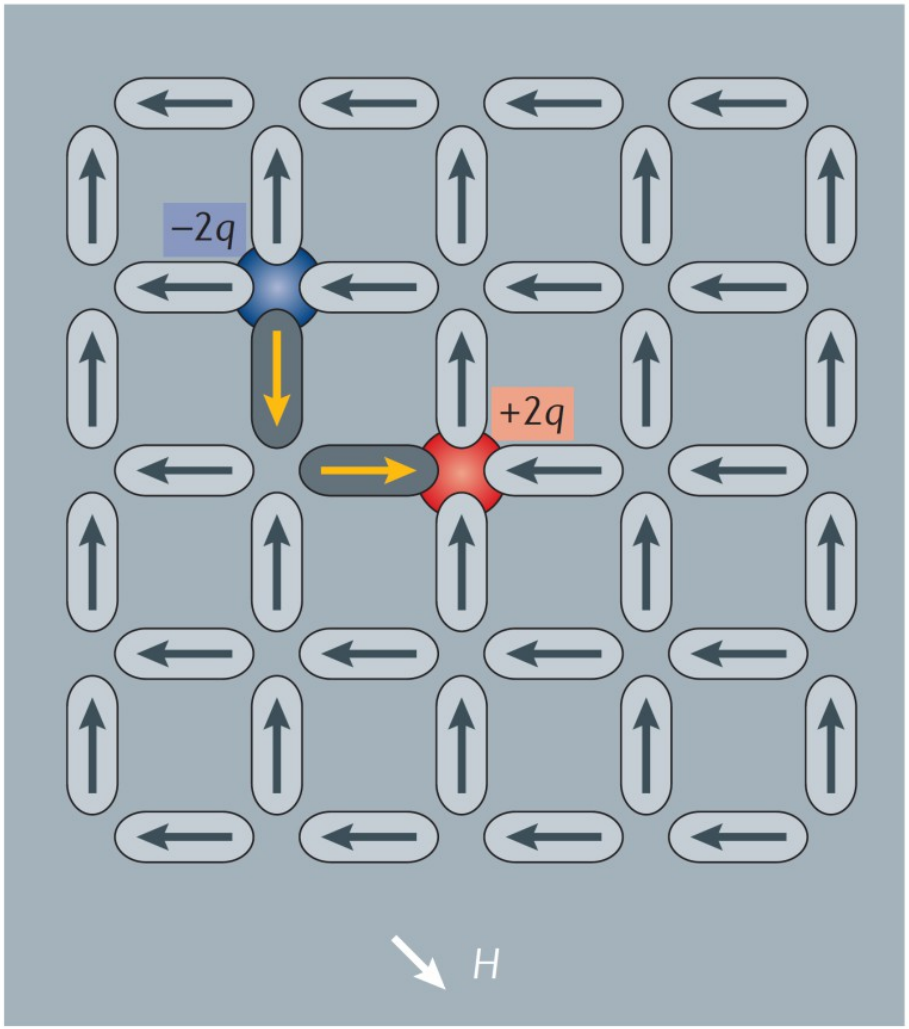




Nature Rev. Phys. 2, 13 (2020)

Magnetic monopole?





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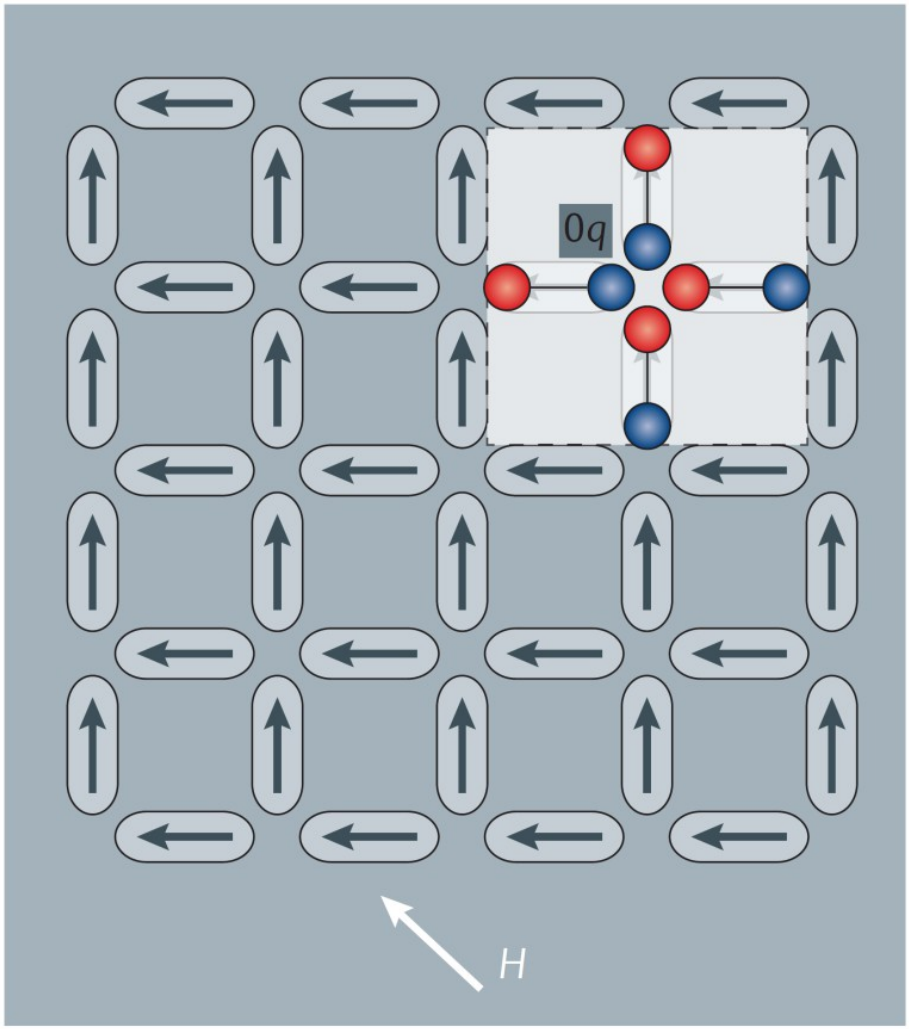
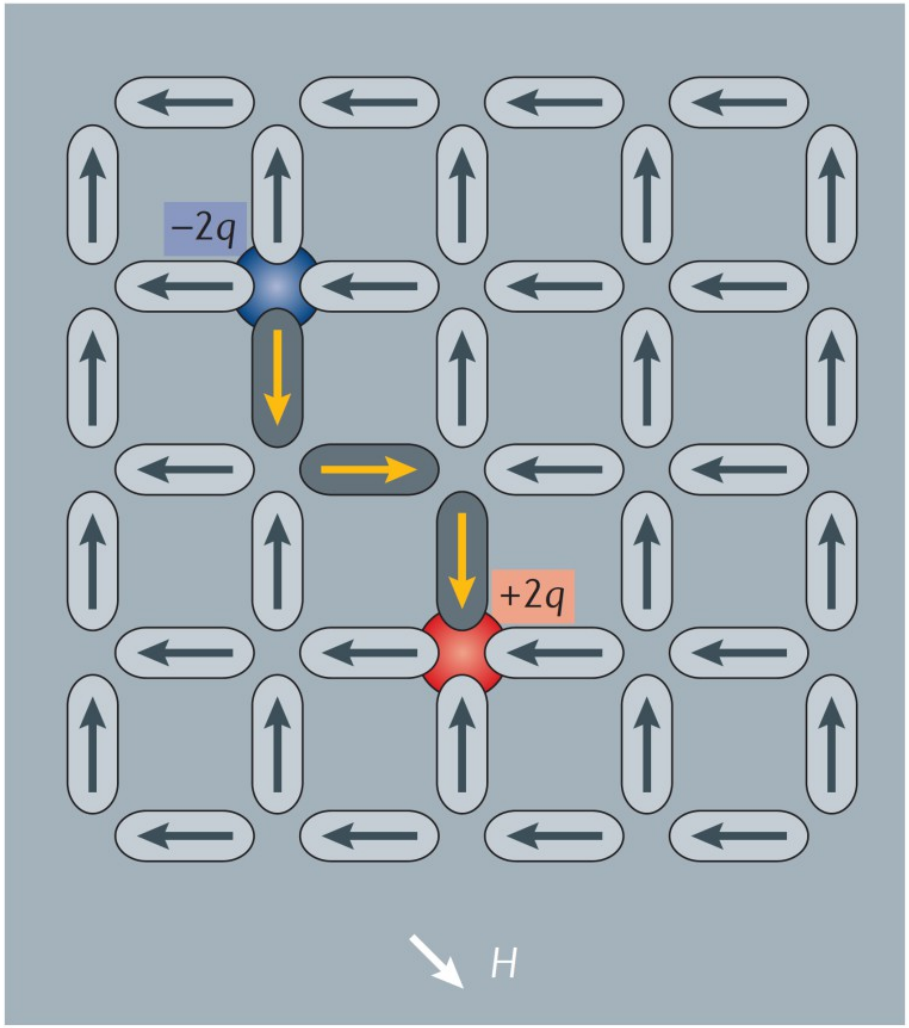
Magnetic monopole?





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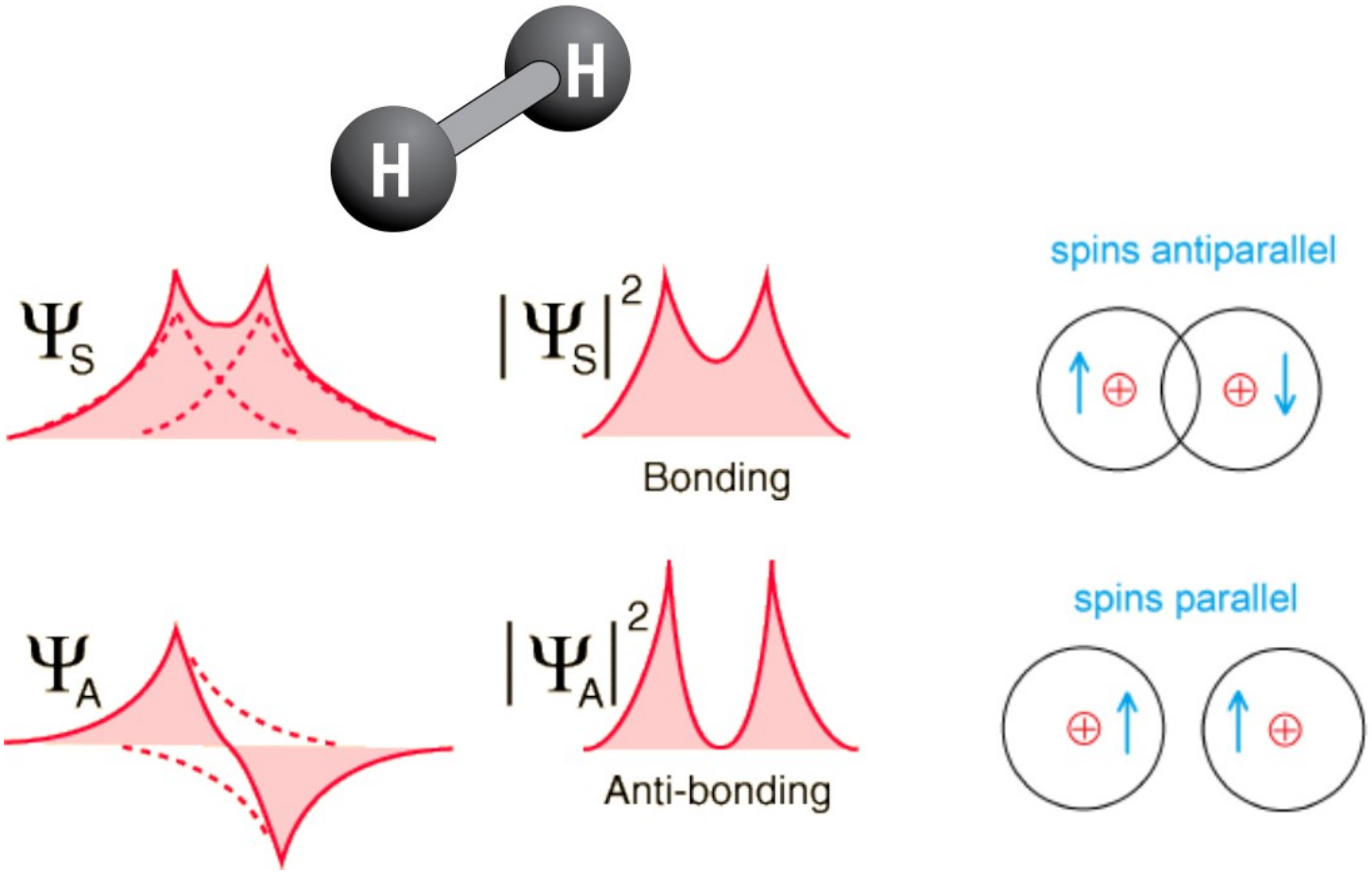
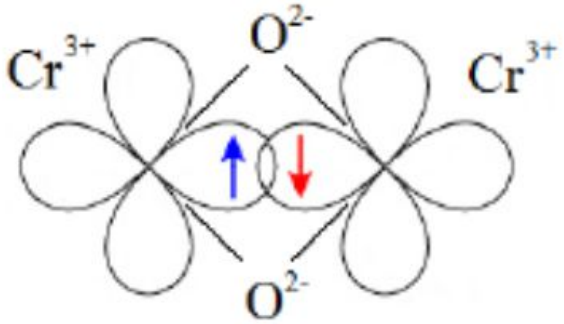


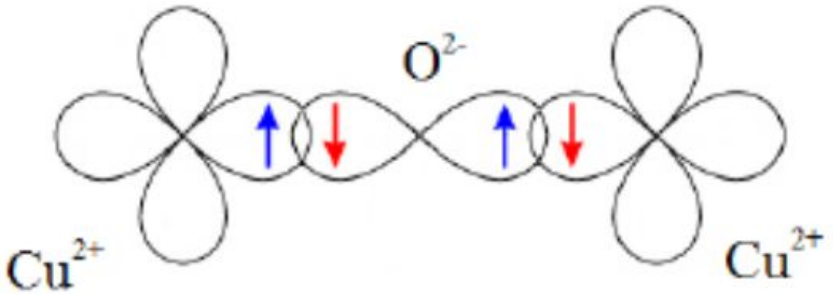
Same mechanism as the formation of a chemical bond

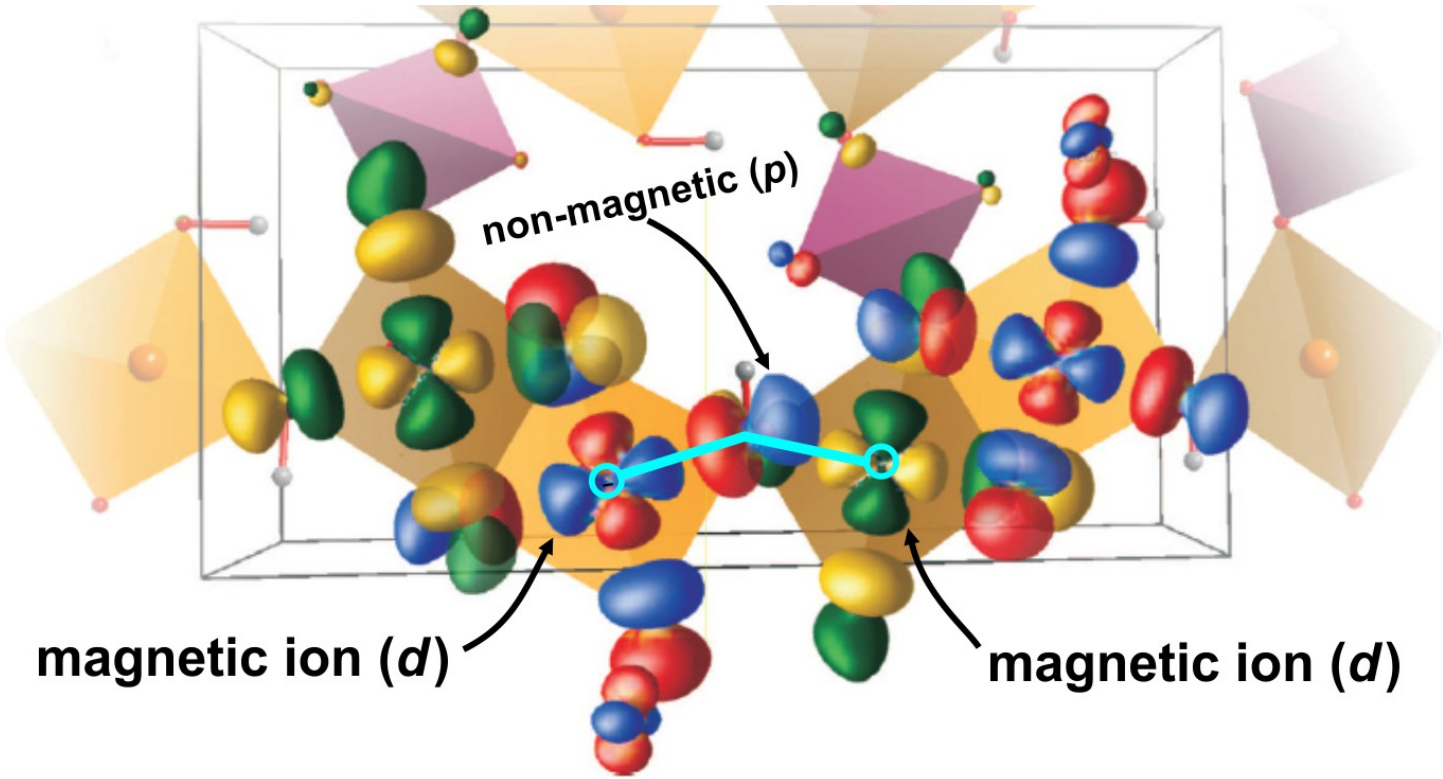
In spin space, $E \sim S_1 S_2 \quad \Rightarrow \quad \mathcal{H} = J \hat{\mathbf{S}}_1 \hat{\mathbf{S}}_2$

Direct exchange



Superexchange



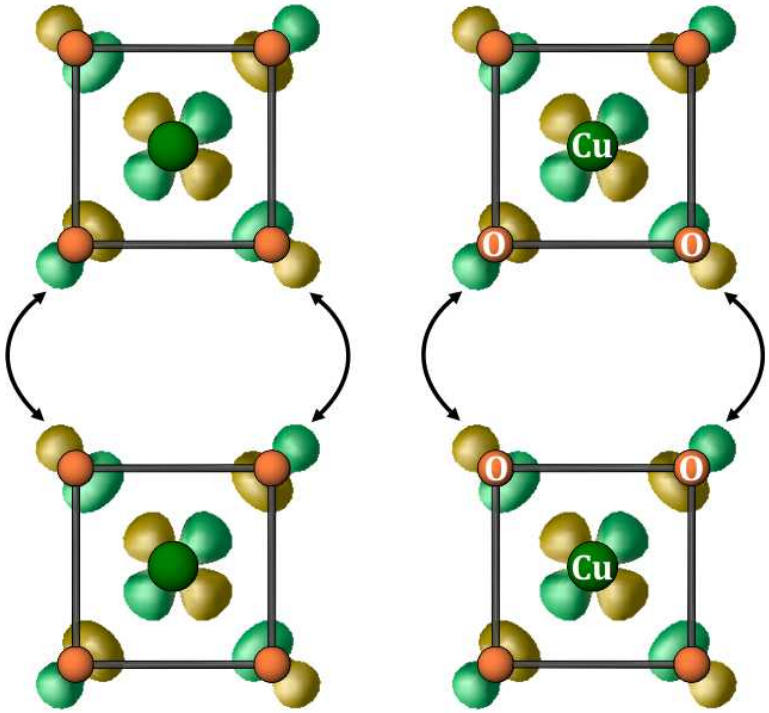


$Pb_2Cu(OH)_4Cl_2$

interatomic distance of 5.88 Å

$J \simeq 35\,\mathrm{K},\ T_N = 11\,\mathrm{K}$

[Phys. Rev. B 87, 064404 (2013)]



Super-super-...-superexchange

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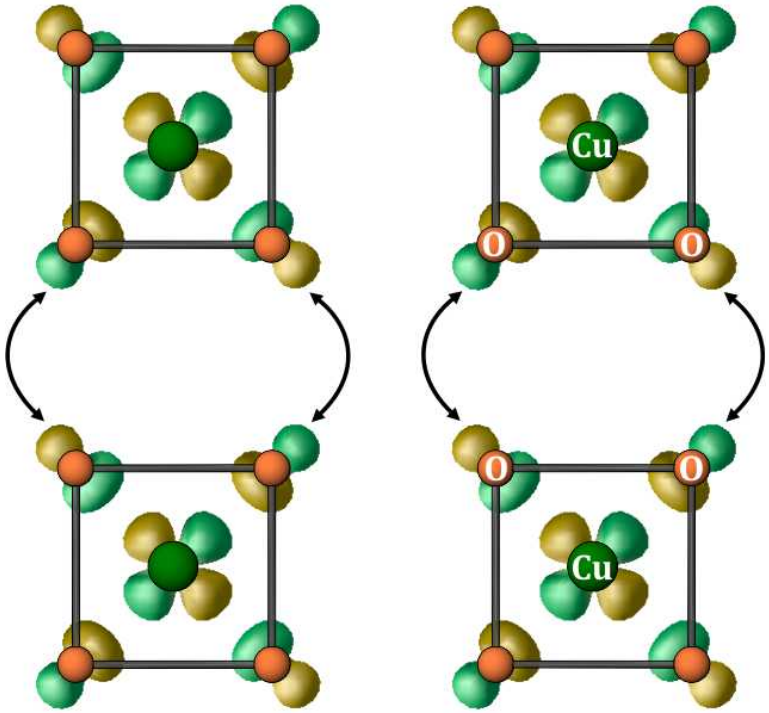
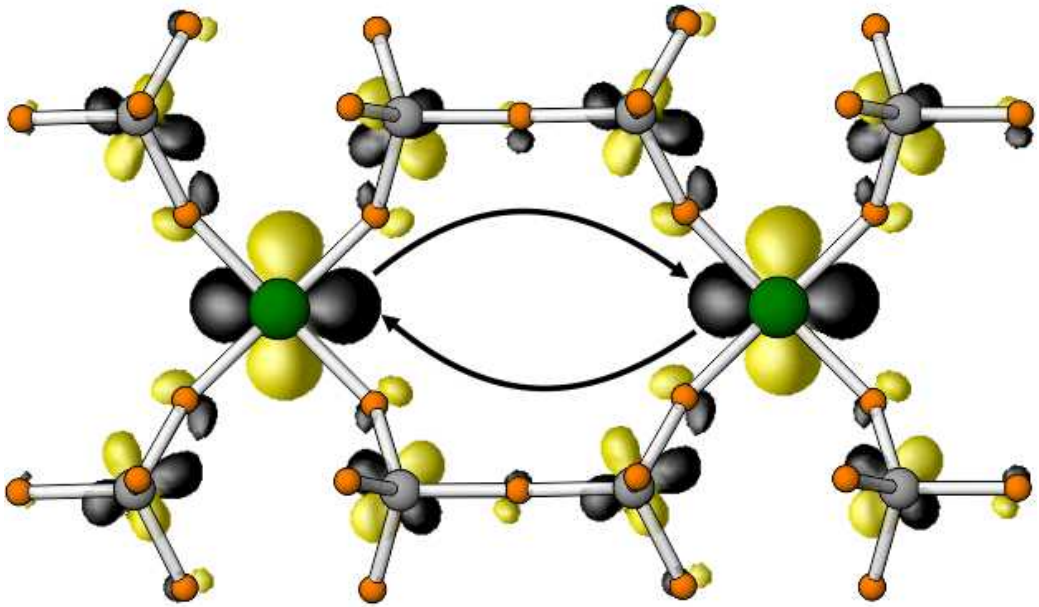




BaV_3O_8

interatomic distance of 7.43 Å

$J \simeq 38\,\mathrm{K},\ T_N = 6\,\mathrm{K}$

[Phys. Rev. B 89, 014405 (2014)]

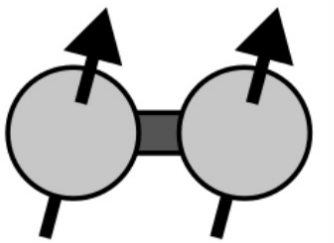
Person

Werner Heisenberg

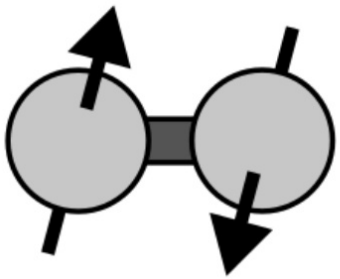
Werner Heisenberg
1901–1976

1932-33 Nobel prize in physics
"for the creation of quantum mechanics, the application of which has, *inter alia*, led to the discovery of the allotropic forms of hydrogen"

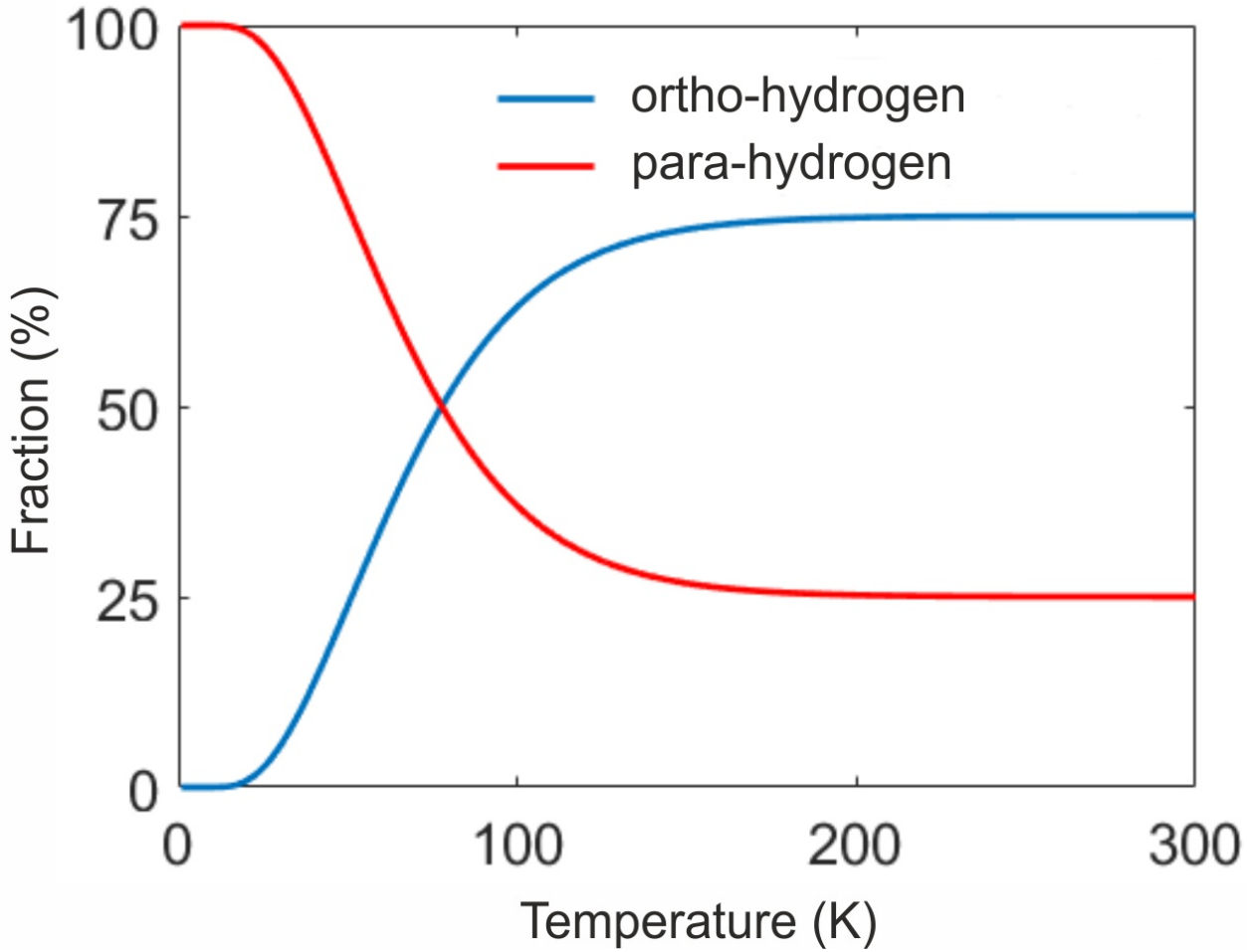
Spin isomers of hydrogen



ortho

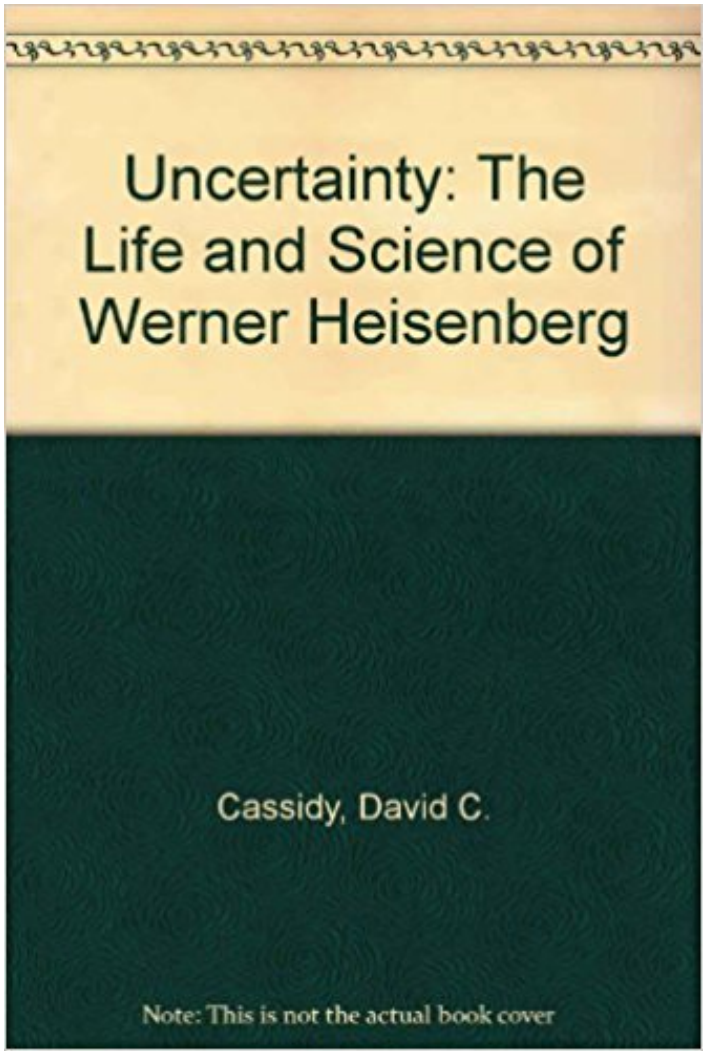


para



- 1927: predicted by Heisenberg
- 1929: observed experimentally (Harteck, Bonhoeffer)

Image credit: Schmidan (CC-BY-SA)



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1901–1976

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Heisenberg in retrospective

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- 1920–1923: physics studies and PhD at LMU
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- 1927–1942: professor in Leipzig
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Barbara Blum-Heisenberg at Uni Leipzig, 7.11.2024

Image credit: J. Haase