Nonequilibrium dynamics of α-$RuCl_3$ - a time-resolved magneto-optical spectroscopy study

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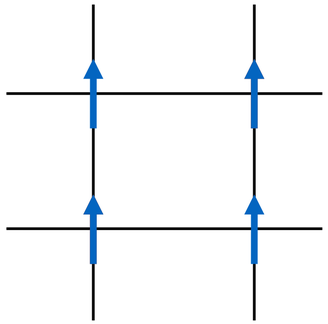
Heisenberg model

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

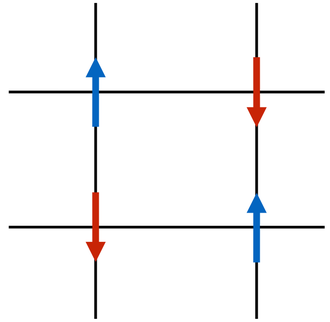
Ferromagnet

$J < 0$

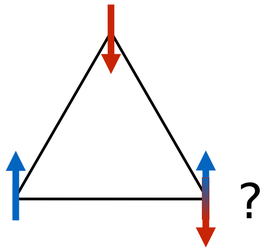


Antiferromagnet

$J > 0$



Frustrated magnets



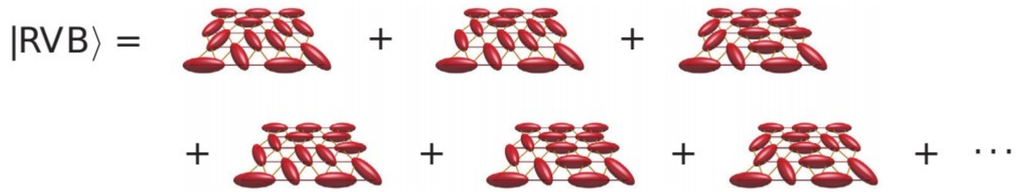
G. H. Wannier, Physical Review 79, 357 (1950)

Classical degeneracy → Non-zero entropy at T=0

Reseonating valence bonds (RVB)

P. W. Anderson, Materials Research Bulletin 8, 153 (1973)

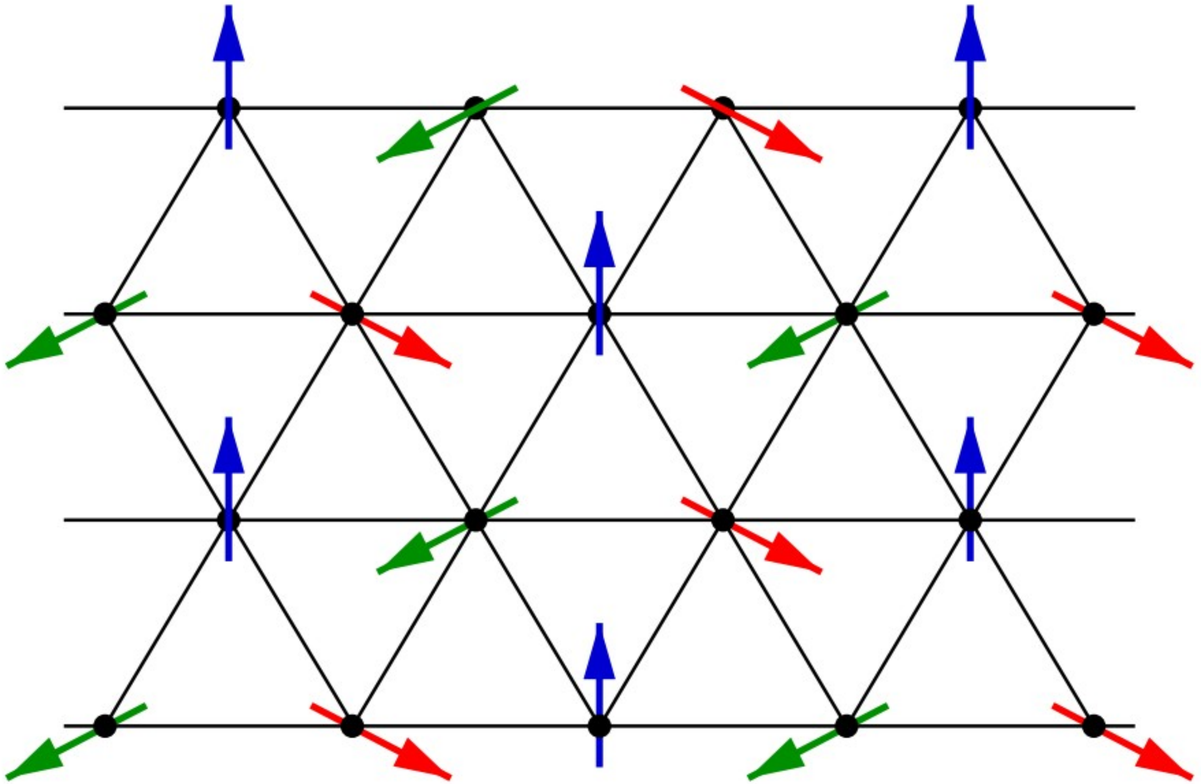
P. Fazekas and P. W. Anderson, Philosophical Magazine 30, 423 (1974)



Spin liquids: fractional excitations with topological properties

L. Savary and L. Balents, Reports on Progress in Physics 80, 016502 (2017)

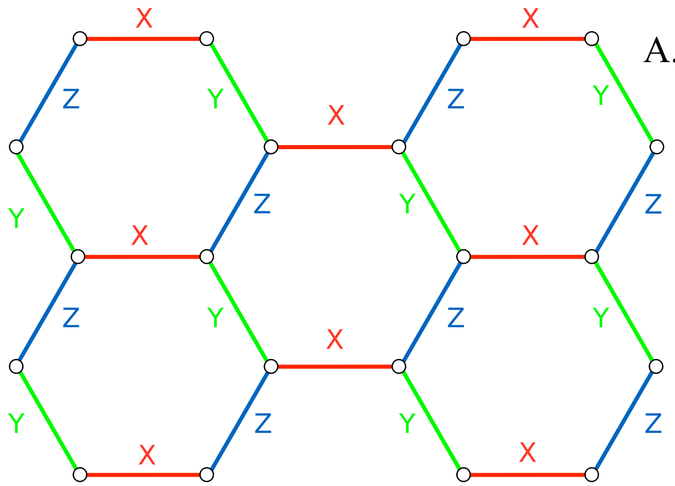
Frustrated magnets: long-range order



Non-collinear ground state of the Heisenberg model on a triangular lattice

Frustration from anisotropic interactions: Kitaev model

$$\mathcal{H} = K \sum_{\langle ij \rangle^{\gamma}} S_i^{\gamma} S_j^{\gamma} = K \sum_{\langle ij \rangle^{\mathrm{x}}} S_i^x S_j^x + K \sum_{\langle ij \rangle^{\mathrm{y}}} S_i^y S_j^y + K \sum_{\langle ij \rangle^{\mathrm{z}}} S_i^z S_j^z$$

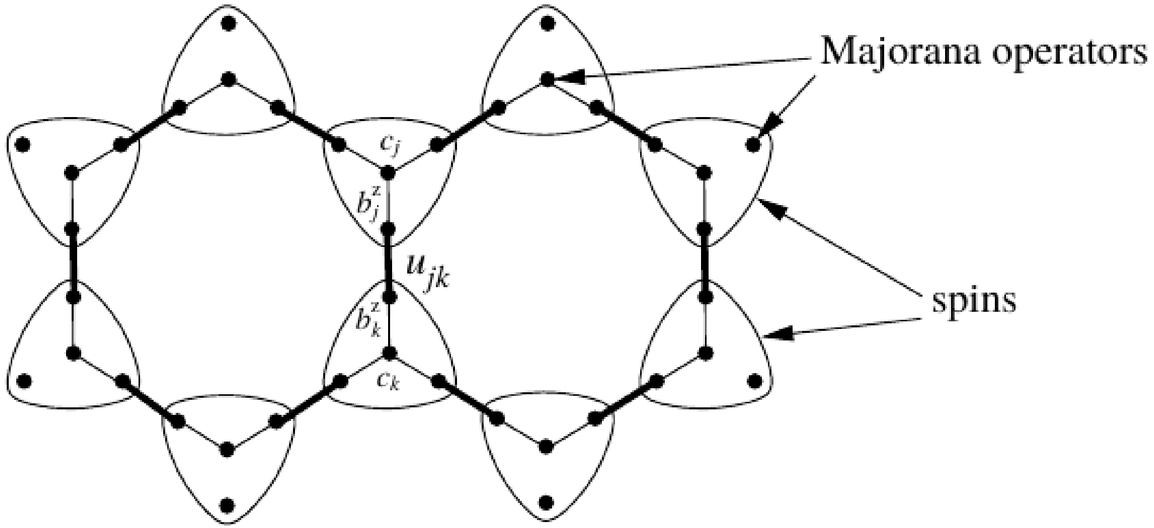


A. Kitaev, Annals of Physics 321, 2 (2006), January Special Issue

Exact solution for S=1/2

Kitaev model: Majorana fermions

$$\mathcal{H} = K \sum_{\langle ij \rangle^\gamma} S_i^\gamma S_j^\gamma = K \sum_{\langle ij \rangle^{\mathrm{x}}} S_i^x S_j^x + K \sum_{\langle ij \rangle^{\mathrm{y}}} S_i^y S_j^y + K \sum_{\langle ij \rangle^{\mathrm{z}}} S_i^z S_j^z$$

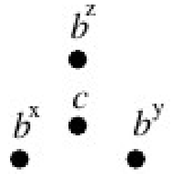


Free fermion model!

$$S^x = ib^x c, \;\; S^y = ib^y c, \;\; S^z = ib^z c$$

Majorana fermions:

$$c_j^2 = 1, \;\; c_i c_j = -c_j c_i, \;\; i \neq j$$

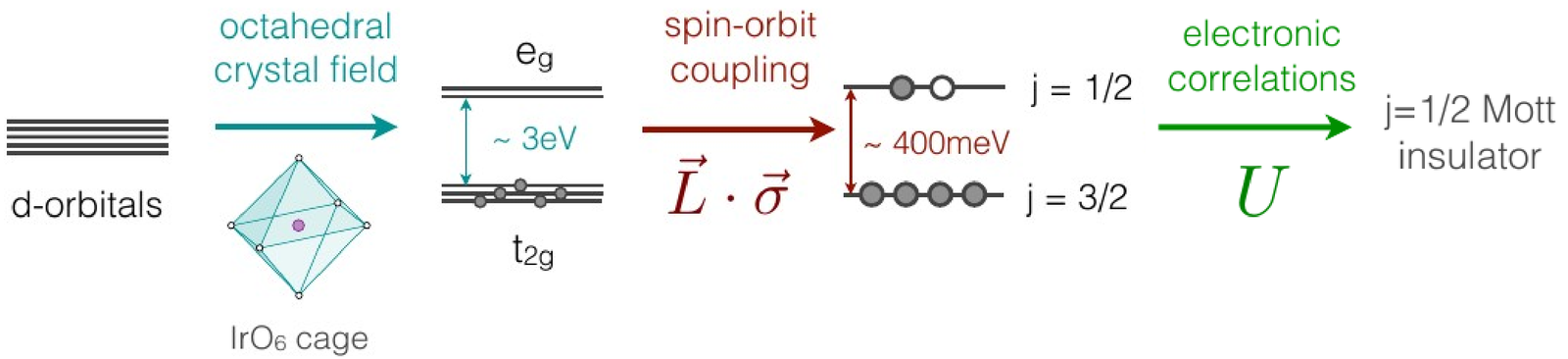


The excitations acquire non-Abelian statistics in magnetic field: a path towards topological quantum computation

А. Китаев, А. Шень, М. Вялый
КЛАССИЧЕСКИЕ И КВАНТОВЫЕ ВЫЧИСЛЕНИЯ

4. Анионы. Анионы — это особые возбуждения в двумерных квантовых системах, в частности, в двумерной электронной жидкости в магнитном поле. Один из авторов (А. К.) считает этот подход наиболее интересным (поскольку он же его и придумал [32]), поэтому опишем его более подробно.

Realization of Kitaev model: d^5 metals



$$|j_{1/2}\rangle = \begin{cases} \frac{1}{\sqrt{3}}(-|xy,\uparrow\rangle - \mathrm{i}|xz,\downarrow\rangle - |yz,\downarrow\rangle) & (m_j = +\frac{1}{2}) \\ \frac{1}{\sqrt{3}}(|xy,\downarrow\rangle + i|xz,\uparrow\rangle - |yz,\uparrow\rangle) & (m_j = -\frac{1}{2}) \end{cases}$$

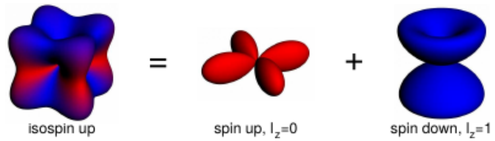
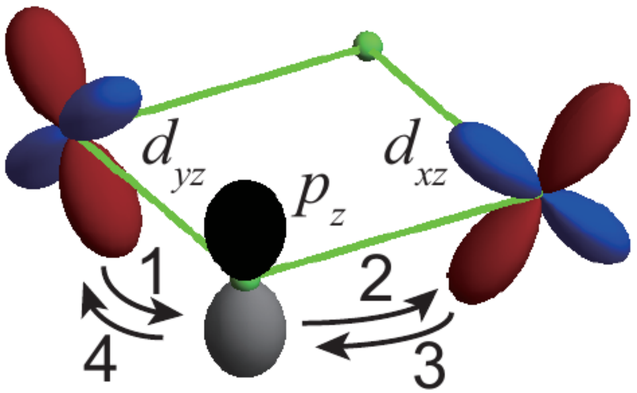


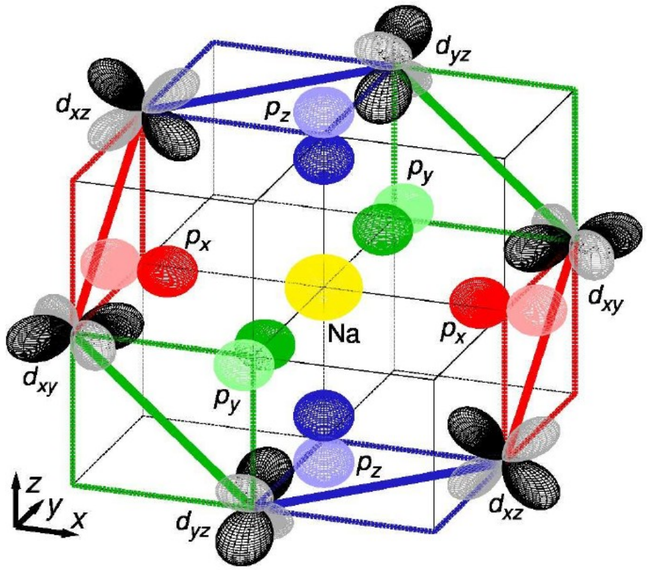
FIG. 1: (Color online) Density profile of a hole in the isospin up state (without tetragonal distortion). It is a superposition of a spin up hole density in $|xy\rangle$-orbital, $l_z = 0$, (middle) and spin down one in $(|yz\rangle + i|xz\rangle)$ state, $l_z = 1$, (right).

G. Jackeli and G. Khaliullin, Phys. Rev. Lett. 102, 017205 (2009)

Realization of Kitaev model: d^5 metals



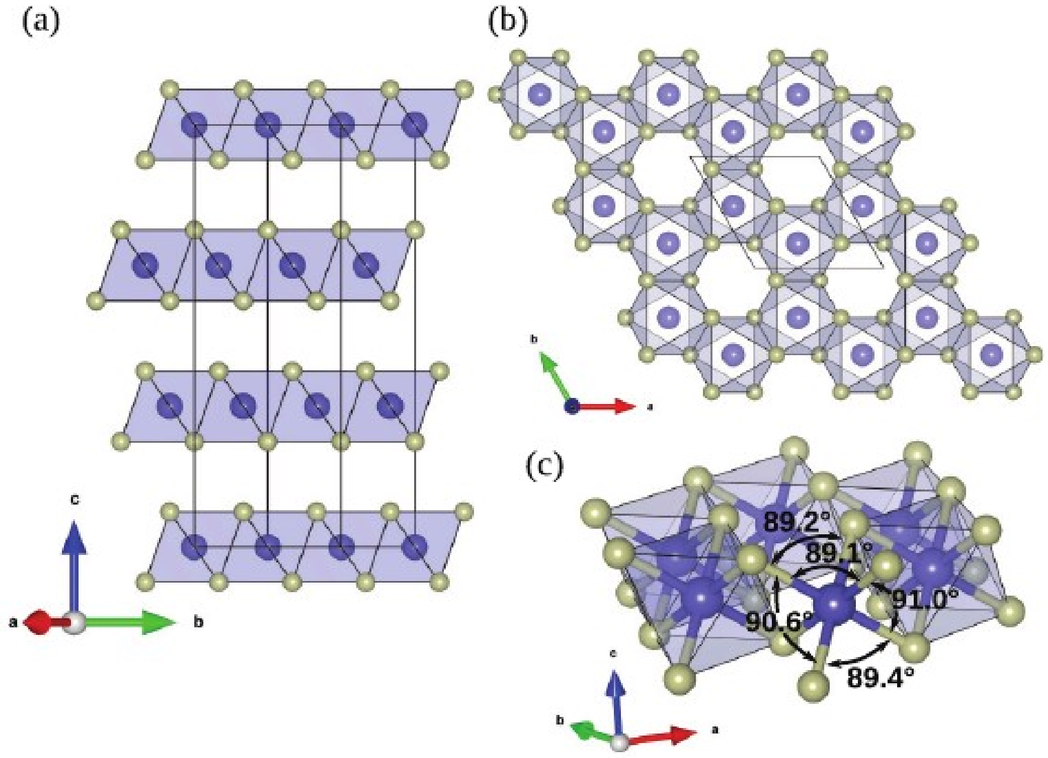
Only z-component of the pseudospin is interacting



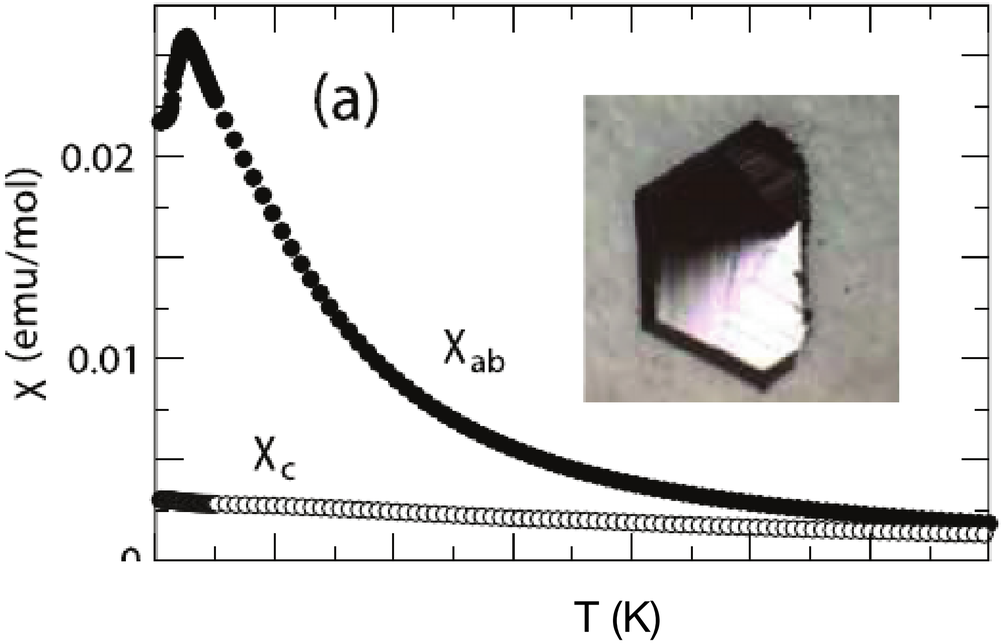
$$\mathcal{H} = K \sum_{\langle ij \rangle^\gamma} S_i^\gamma S_j^\gamma$$

G. Jackeli and G. Khaliullin, Phys. Rev. Lett. 102, 017205 (2009)

Kitaev materials: ruthenium trichloride RuCl3



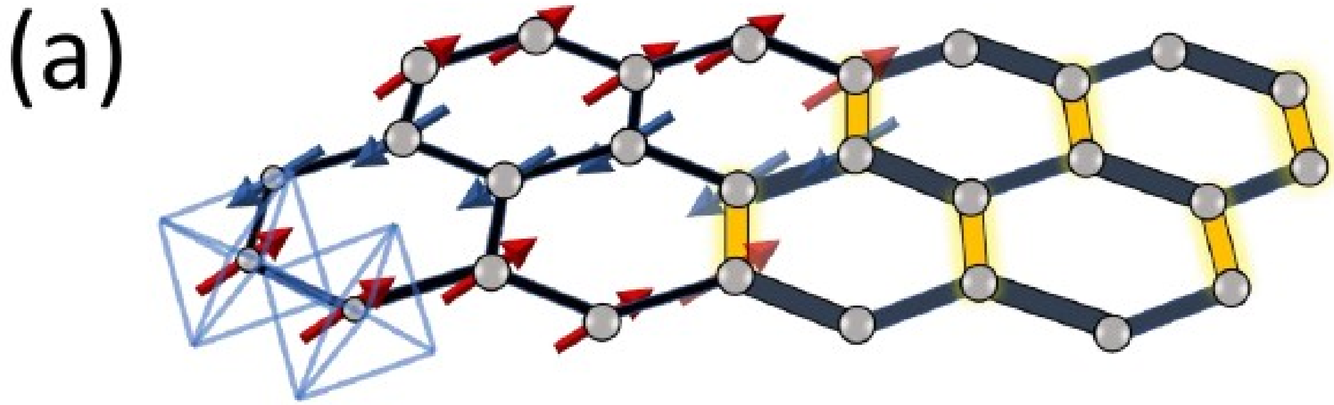
K. W. Plumb, J. P. Clancy, L. J. Sandilands, V. Vijay Shankar, Y. F. Hu, K. S. Burch, Hae-Young Kee, and Young-June Kim, Phys. Rev. B 90, 041112(R) (2014)



J. A. Sears, M. Songvilay, K. W. Plumb, J. P. Clancy, Y. Qiu, Y. Zhao, D. Parshall, and Young-June Kim, Phys. Rev. B 91, 144420 (2015)

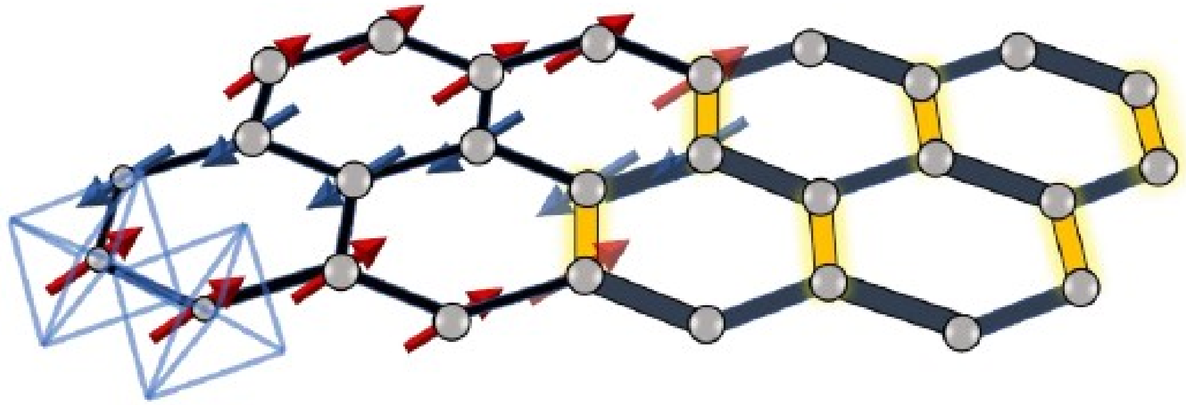
Также упорядочивается при 7K в коллинеарную зигзаг фазу

Ruthenium trichloride: zigzag ground state

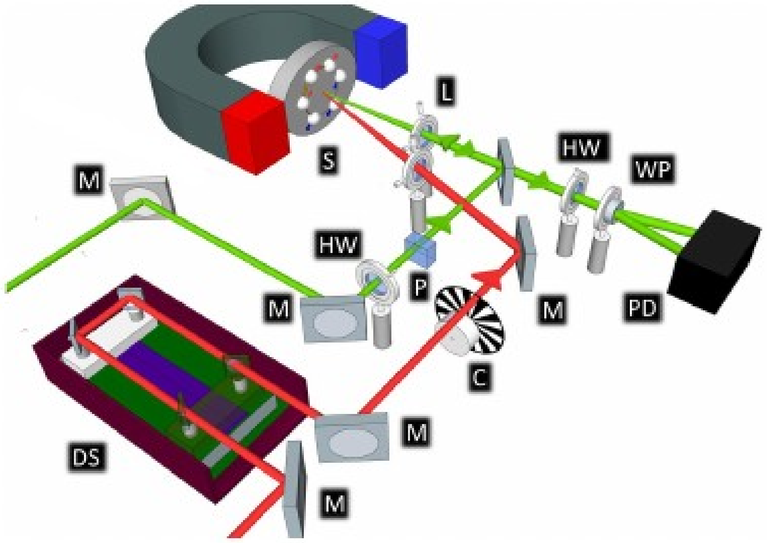


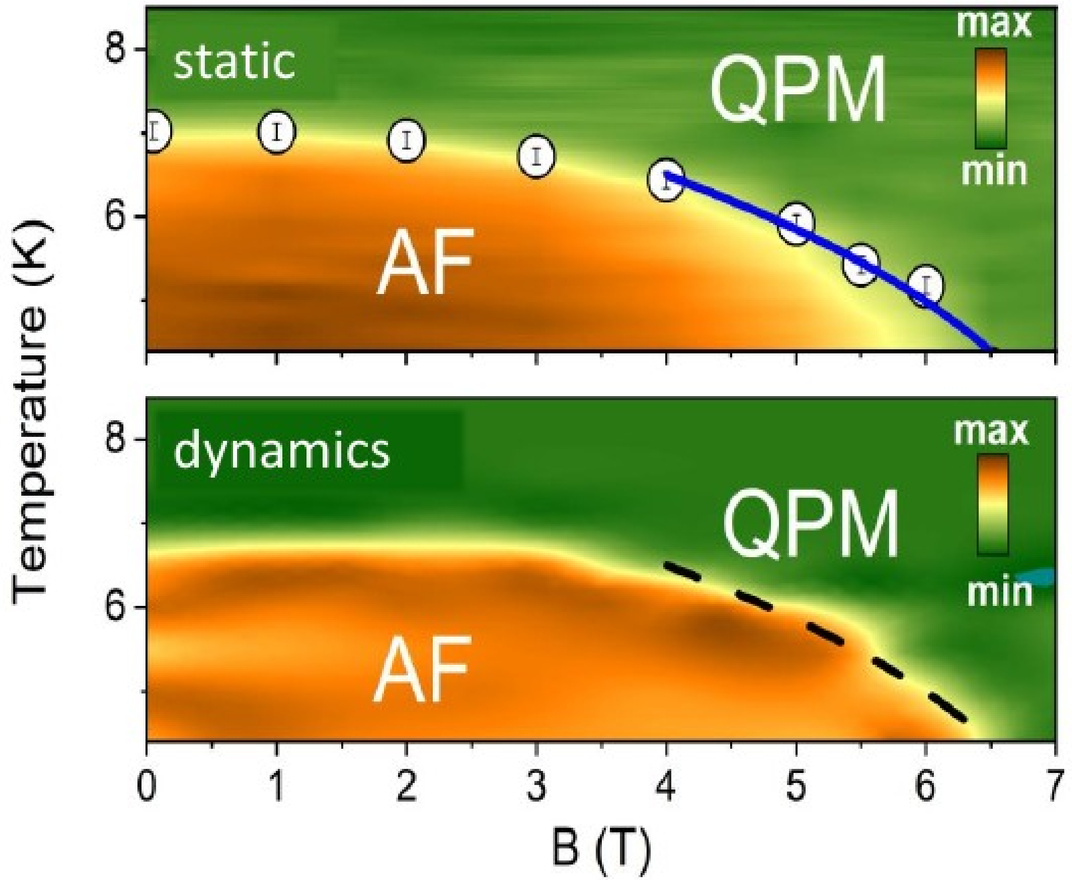
Ruthenium trichloride: B-T phase diagram

(a)



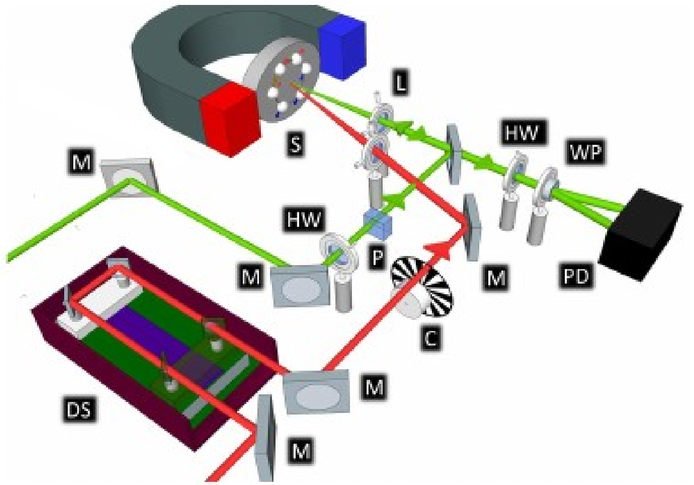
(c)





Magnetic linear dichroism

(c)



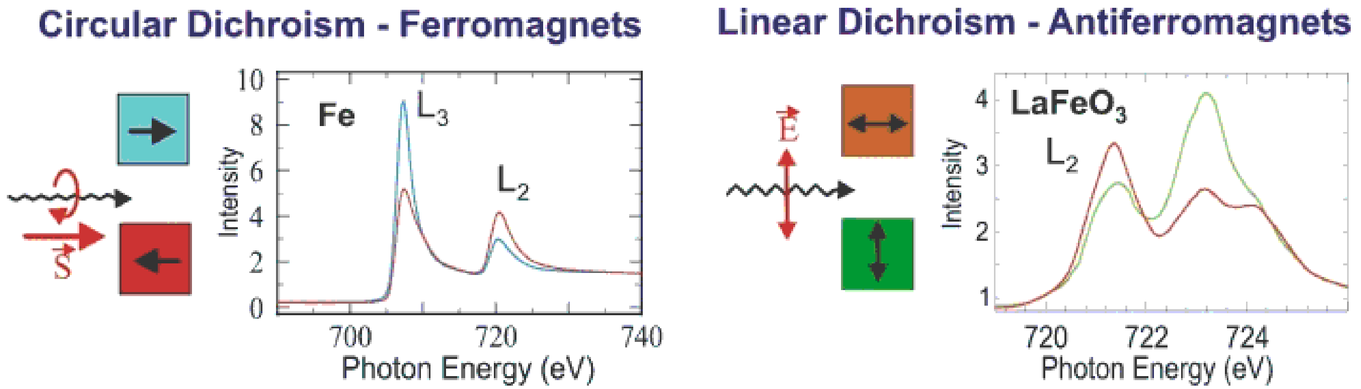
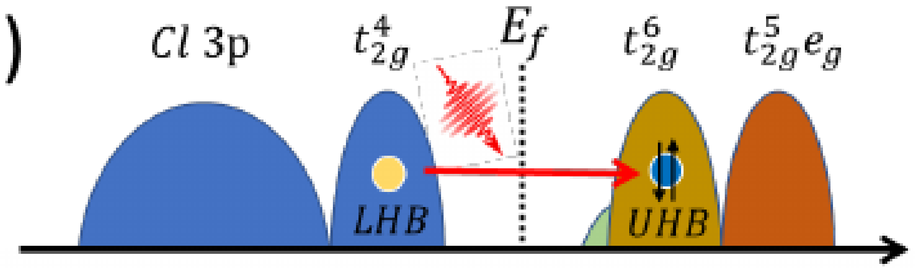
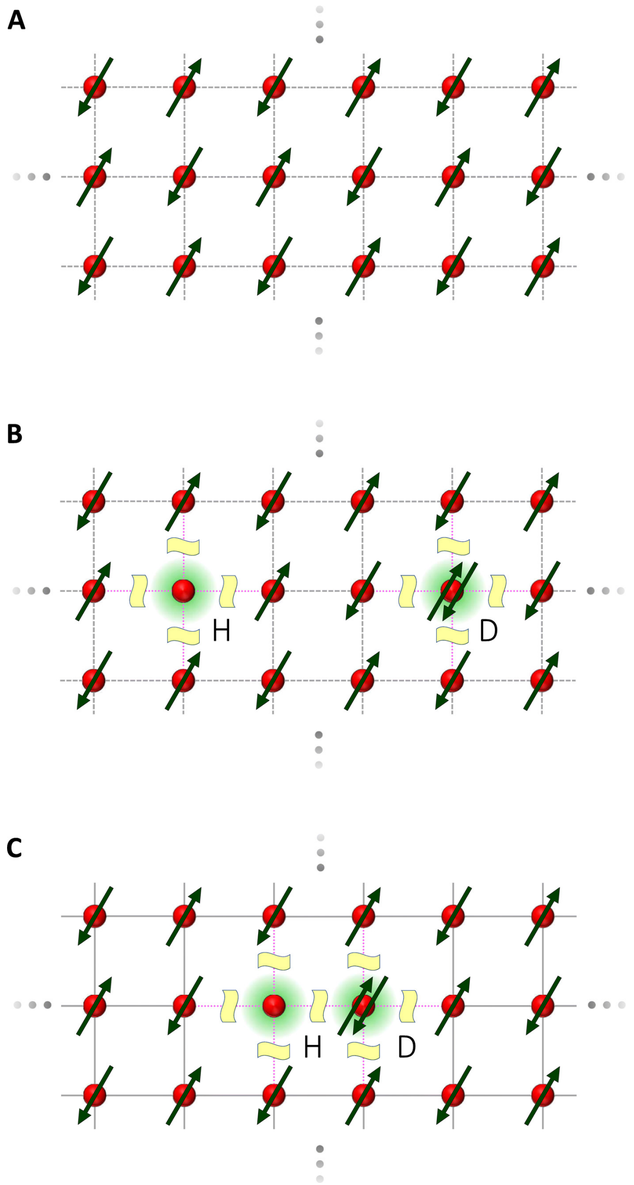


Fig. 1: Illustration of the size of magnetic dichroism effects. Note that the XMLD effect is large only in cases where the absorption edge exhibits multiplet structure.

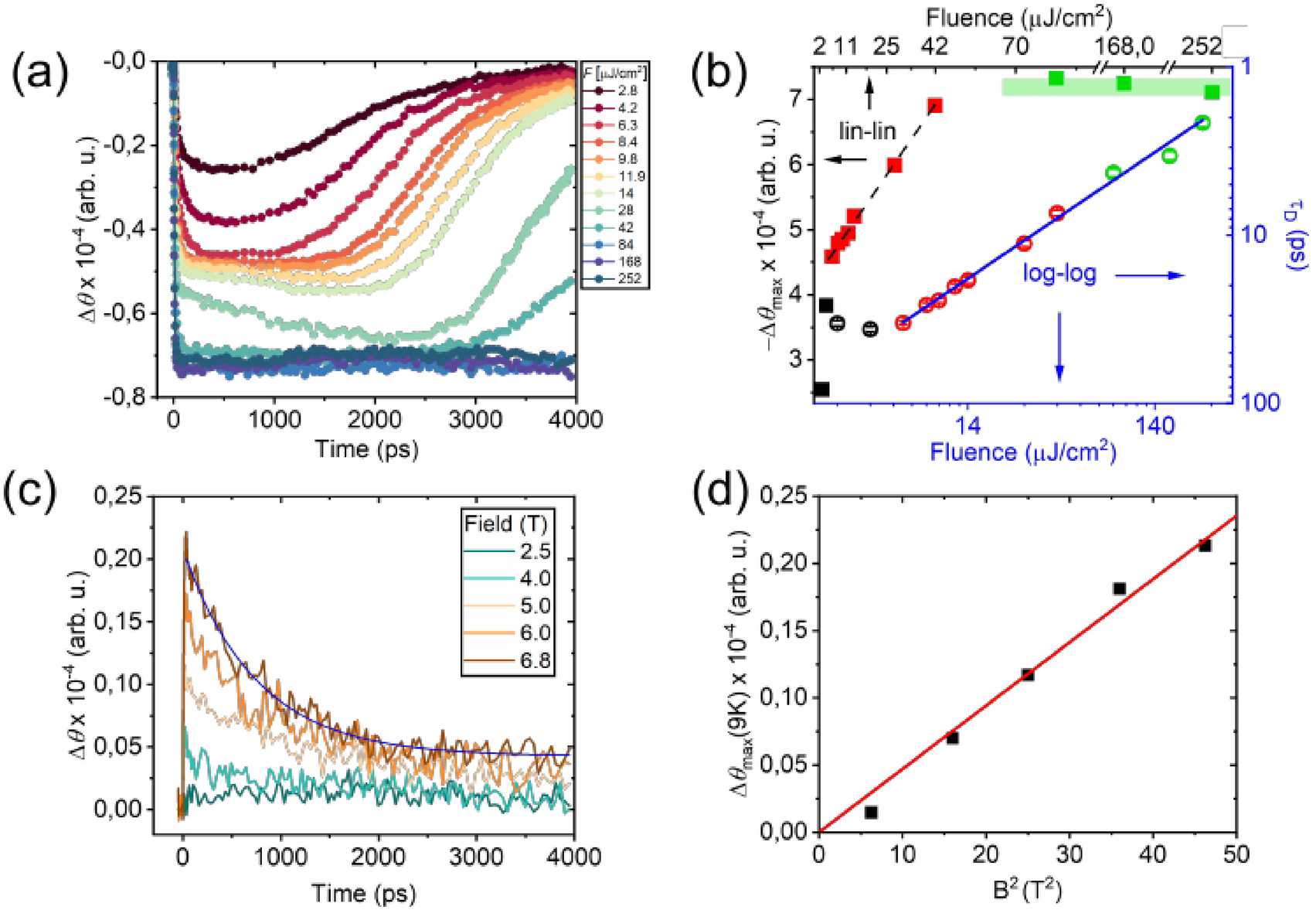
(b)



Pumped state



Pump-probe experiments



Обзоры

Модель Китаева и материалы	A. Kitaev, Annals of Physics 321, 2 (2006), January Special Issue
	Models and materials for generalized Kitaev Magnetism, Stephen M Winter et al, J. Phys.: Condens. Matter 29 493002 (2017)
	Kitaev Materials, Simon Trebst, 2017, arxiv:1701.07056
	Materials design of Kitaev spin liquids beyond the Jackeli-Khaliullin mechanism, Motome et al., 2020, arxiv:2001.03731
Спиновые жидкости	Lucile Savary and Leon Balents, Rep. Prog. Phys. 80 016502 (2017)
	M J P Gingras and P A McClarty, Rep. Prog. Phys. 77 056501 (2014)
Коррелированные системы со спин-орбитальным взаимодействием	William Witczak-Krempa, Gang Chen, Yong Baek Kim, Leon Balents, Annual Review of Condensed Matter Physics, 5:1, 57 (2014)
Магнонные распады	M. E. Zhitomirsky and A. L. Chernyshev, Rev. Mod. Phys. 85, 219 (2013)