Quantum Spin Liquids 2025
Experimental Enigmas & Theoretical Challenges • 6–10 October 2025 • Budapest, Hungary

Prevalence of highly dynamic magnetism in langbeinites

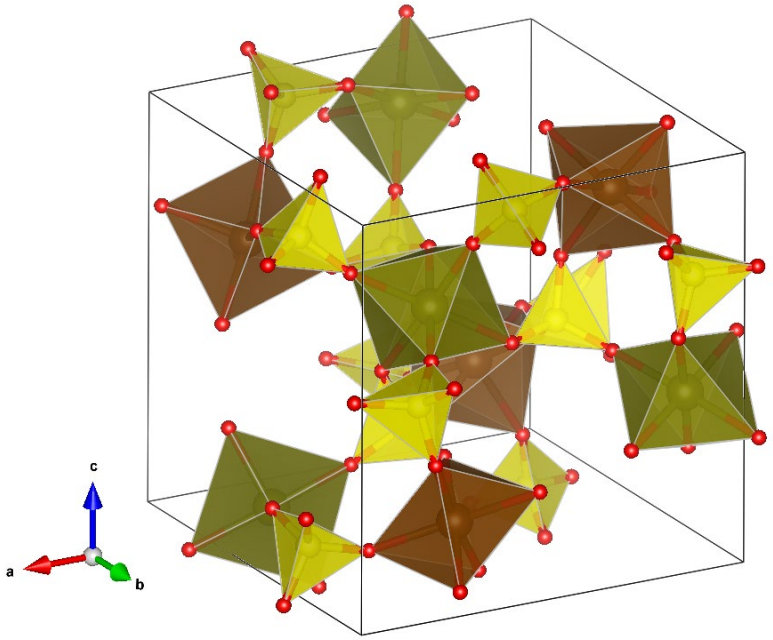
Ivica Zivkovic

EPFL

IQM

en.wikipedia.org/wiki/Langbeinite

$K_2Mg_2(SO_4)_3$



- $P2_13$ cubic structure (non-centrosymmetric)
- two octahedral sites for metal ions
- a tetrahedral site for an anion
- a cation

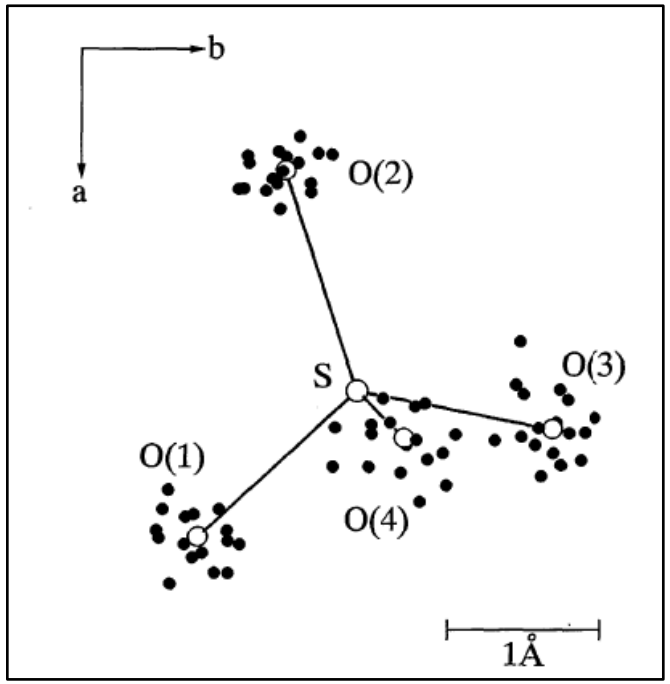
Hikita, JPSJ 49, 1421 (1980)

Table I. Classification of the types of phase transitions in langbeinite-type crystals.

Classification	Transition scheme	Crystal (Abbreviated name)	T_3(°C)	T_2(°C)	T_1(°C)	Ref.
Group I	$P2_13$	$(NH_4)_2Cd_2(SO_4)_3$ (ACS)			−181	2)
	↓					
	$P2_1$	$Tl_2Cd_2(SO_4)_3$ (TCS)	−181	−153	−145	3)
	↓					
	$P\bar{1}$	$Rb_2Cd_2(SO_4)_3$ (RCS)	−205*	−170	−144	8)
	↓					
	$P2_12_12_1$	$K_2Zn_2(SO_4)_3$ (KZS)	−186**	?***	−136	*
Group II	$P2_13$	$K_2Mn_2(SO_4)_3$ (KMS)			− 82	9, 20)
	↓					
	$P2_12_12_1$	$K_2Cd_2(SO_4)_3$			159	7)
Group III	No Transition	$(NH_4)_2Mn_2(SO_4)_3$ (AMS)				6)
		$Tl_2Mn_2(SO_4)_3$ (TMS)				6)

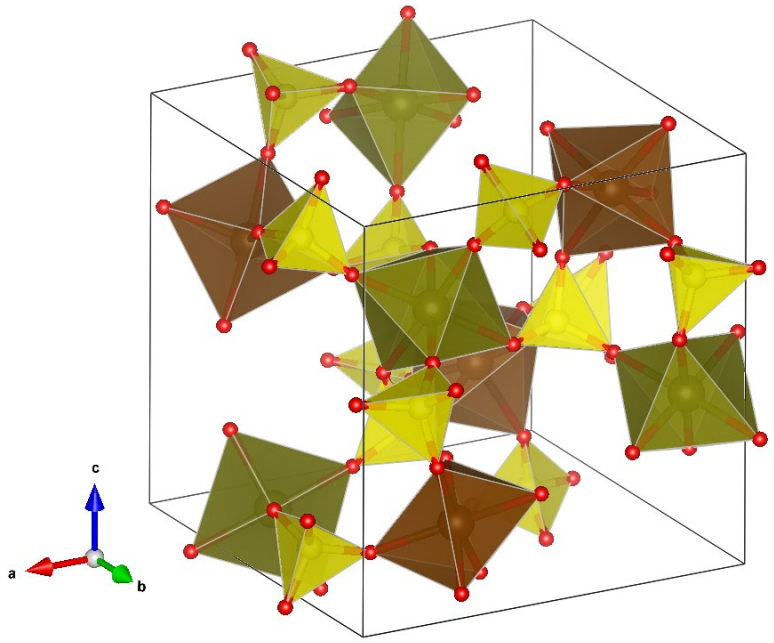
* present authors: to be published, ** determined by optical and dielectric measurements, *** undetermined.

- ferroelastic and ferroelectric properties
- role of XO4 disorder

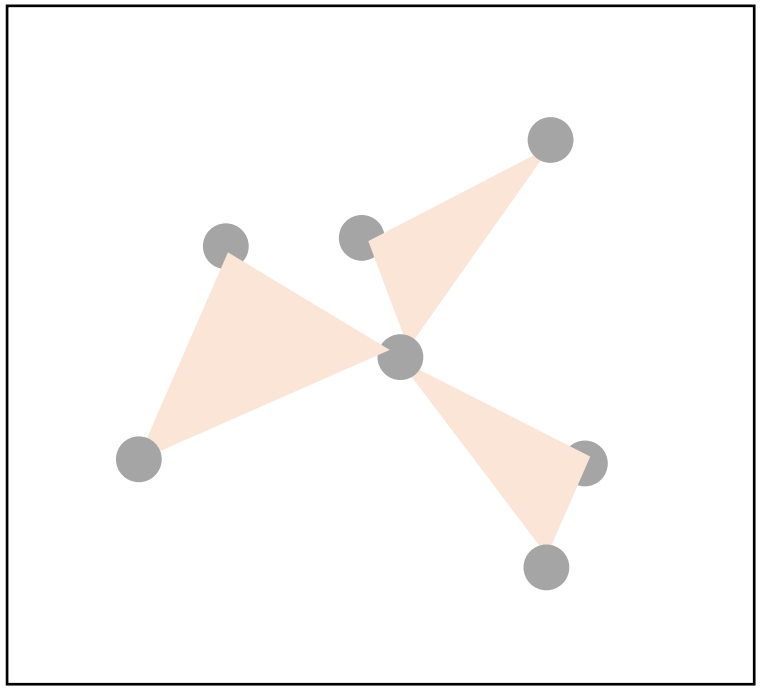


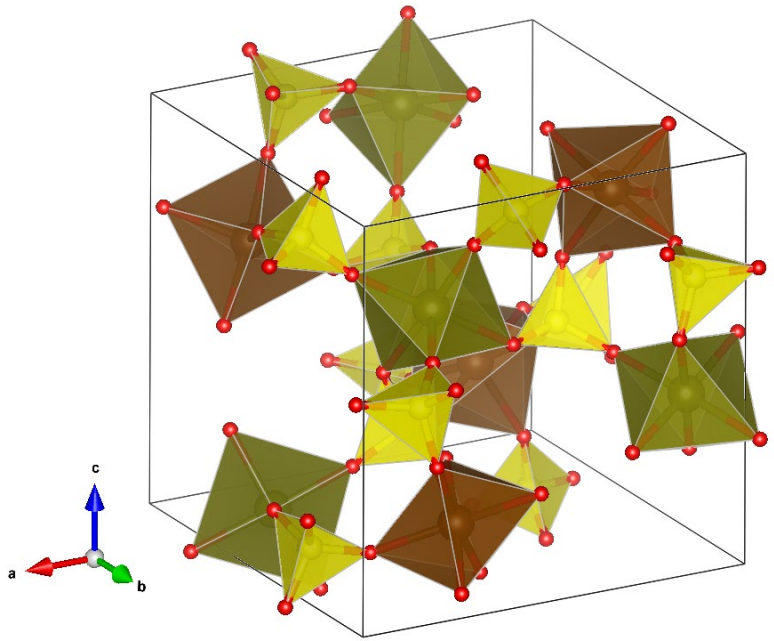
Moriyoshi, JPSJ 64, 4726 (1995)

- double trillium lattice



- connectivity of the trillium lattice





- connectivity of the trillium lattice

MnSi (Mn trillium lattice)

- *p*-induced QPT
- skyrmions

Non-Fermi-liquid nature of the normal state of itinerant-electron ferromagnets

C. Pfleiderer*, S. R. Julian† & G. G. Lonzarich†

* *Physikalisches Institut, Universität Karlsruhe, D-76128 Karlsruhe, Germany*
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Nature 414,427 (2001)

Skyrmion Lattice in a Chiral Magnet

S. Mühlbauer,[1,2] B. Binz,[3] F. Jonietz,[1] C. Pfleiderer,[1]* A. Rosch,[3]
A. Neubauer,[1] R. Georgii,[1,2] P. Böni[1]

Science 323, 915 (2009)

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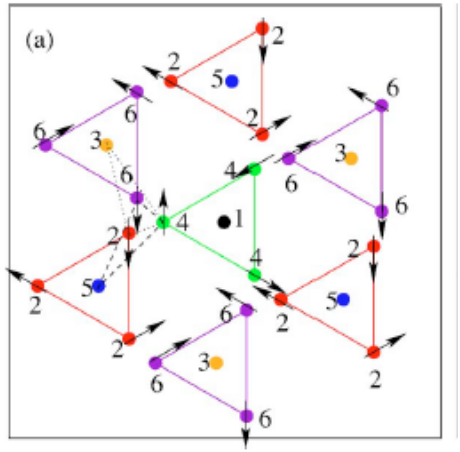

PHYSICAL REVIEW B 74, 224441 (2006)

Geometric frustration inherent to the trillium lattice, a sublattice of the B20 structure

John M. Hopkinson* and Hae-Young Kee†
60 St. George Street, University of Toronto, Toronto, Ontario, Canada
(Received 5 October 2005; revised manuscript received 28 August 2006; published 29 December 2006)

PHYSICAL REVIEW B 78, 014404 (2008)

Fate of partial order on trillium and distorted windmill lattices

Sergei V. Isakov,[1] John M. Hopkinson,[2] and Hae-Young Kee[3,4]
[1]*Institute for Theoretical Physics, ETH Zurich, CH-8093 Zurich, Switzerland*
[2]*Brandon University, Brandon, Manitoba, Canada R7A 6A9*
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[4]*Korea Institute for Advanced Study, Seoul 130-722, Republic of Korea*
(Received 3 April 2008; revised manuscript received 3 June 2008; published 2 July 2008)

PHYSICAL REVIEW B **112**, 104429 (2025)

Classification of spin-$\frac{1}{2}$ fermionic quantum spin liquids on the trillium lattice

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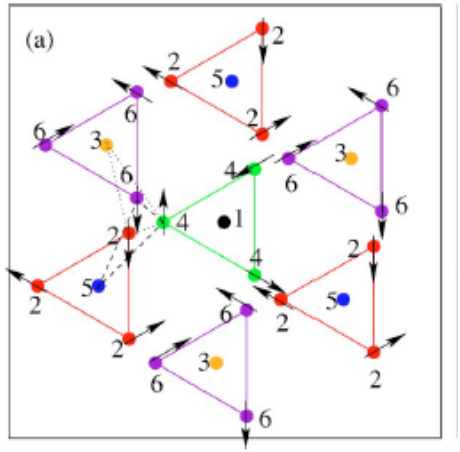
[2]*Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany*

(Received 14 November 2024; revised 9 June 2025; accepted 17 July 2025; published 19 September 2025)

We study fermionic quantum spin liquids (QSLs) on the three-dimensional trillium lattice of corner-sharing triangles. We are motivated by recent experimental and theoretical investigations that have explored various classical and quantum spin liquid states on similar networks of triangular motifs with strong geometric frustration. Using the framework of projective symmetry groups (PSG), we obtain a classification of all symmetric Z_2 and U(1) QSLs on the trillium lattice. We find two Z_2 spin-liquids, and a single U(1) spin-liquid that is proximate to one of the Z_2 states. The small number of solutions reflects the constraints imposed by the nonsymmorphic symmetries in the space group of the trillium lattice. Using self-consistency conditions of the mean-field equations, we obtain the spinon band-structure and spin structure factors corresponding to these states. All three of our spin liquids are gapless at their saddle points: one of the two Z_2 QSLs is nodal, while the U(1) case hosts a spinon Fermi surface. One of our Z_2 spin liquids hosts a stable gapless nodal star that is protected by projective symmetries against additions of further neighbor terms in the mean-field ansatz. We comment on directions for further work.



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$K_2Mg_2(SO_4)_3$ → 2-: SO_4, WO_4, MoO_4, SeO_4, CrO_4, BeF_4
3-: PO_4, AsO_4
4-: SiO_4

majority of 2+ ions (Cu not possible?)

Na, Rb, Cs, Tl, NH_4 / Sr, Ba

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Formula
$Na_2Mg_2(SO_4)_3$
$K_2Mg_2(SO_4)_3$
$Rb_2Mg_2(SO_4)_3$
$Cs_2Mg_2(SO_4)_3$
$(NH_4)_2Mg_2(SO_4)_3$
$Tl_2Mg_2(SO_4)_3$
$K_2CaMg(SO_4)_3$
$K_2Ca_2(SO_4)_3$
$Rb_2Ca_2(SO_4)_3$
$Cs_2Ca_2(SO_4)_3$
$Tl_2Ca_2(SO_4)_3$
$(NH_4)_2Ca_2(SO_4)_3$
$(NH_4)_2V_2(SO_4)_3$
$K_2Mn_2(SO_4)_3$
$Rb_2Mn_2(SO_4)_3$
$Cs_2Mn_2(SO_4)_3$
$(NH_4)_2Mn_2(SO_4)_2$
$Tl_2Mn_2(SO_4)_3$
$K_2Fe_2(SO_4)_3$
$Rb_2Fe_2(SO_4)_3$
$Tl_2Fe_2(SO_4)_3$
$(NH_4)_2Fe_2(SO_4)_3$[52]
$K_2Co_2(SO_4)_3$
$Rb_2Co_2(SO_4)_3$
$Cs_2Co_2(SO_4)_3$
$(NH_4)_2Co_2(SO_4)_3$
$Tl_2Co_2(SO_4)_3$
$K_2Ni_2(SO_4)_3$
$Rb_2Ni_2(SO_4)_3$
$Cs_2Ni_2(SO_4)_3$
$(NH_4)_2Ni_2(SO_4)_3$
$Tl_2Ni_2(SO_4)_3$
$Rb_2Cu_2(S_{04})_3$
$Cs_2Cu_2(S_{04})_3$
$Tl_2Cu_2(S_{04})_3$
$K_2Zn_2(SO_4)_3$
$Rb_2Zn_2(S_{04})_3$
$Cs_2Zn_2(S_{04})_3$
$Tl_2Zn_2(S_{04})_3$
$K_2Cd_2(SO_4)_3$
$Rb_2Cd_2(SO_4)_3$
$(NH_4)_2Cd_2(SO_4)_3$
$Tl_2Cd_2(SO_4)_3$

Formula
$K_2Mn_2(BeF_4)_3$[11]
$K_2Mg_2(BeF_4)_3$[72]
$(NH_4)_2Mg_2(BeF_4)_3$[72]
$KRbMg_2(BeF_4)_3$[72]
$Rb_2Mg_2(BeF_4)_3$[72]
$Tl_2Mg_2(BeF_4)_3$[72]
$K_2Ni_2(BeF_4)_3$[72]
$Rb_2Ni_2(BeF_4)_3$[72]
$Tl_2Ni_2(BeF_4)_3$[72]
$K_2Co_2(BeF_4)_3$[72]
$(NH_4)_2Co_2(BeF_4)_3$[72]
$Rb_2Co_2(BeF_4)_3$[72]
$Tl_2Co_2(BeF_4)_3$[72]
$RbCsCo_2(BeF_4)_3$[72]
$K_2Zn_2(BeF_4)_3$[72]
$(NH_4)Zn_2(BeF_4)_3$[72]
$Rb_2Zn_2(BeF_4)_3$[72]
$Tl_2Zn_2(BeF_4)_3$[72]
$RbCsZn_2(BeF_4)_3$[72]
$K_2Mn_2(BeF_4)_3$[72]
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$(NH_4)_2Mn_2(BeF_4)_3$[72]
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$Rb_2MnCd(BeF_4)_3$[72]
$RbCsMnCd(BeF_4)_3$[72]
$Cs_2MnCd(BeF_4)_3$[72]
$(NH_4)_2Cd_2(BeF_4)_3$[72]
$Rb_2Cd_2(BeF_4)_3$[72]
$Tl_2Cd_2(BeF_4)_3$[72]
$RbCsCd_2(BeF_4)_3$[72]
$Cs_2Cd_2(BeF_4)_3$[72]
$RbCsCdCa(BeF_4)_3$[72]
$Rb_2Ca_2(BeF_4)_3$[72]
$RbCsCa_2(BeF_4)_3$[72]
$Cs_2Ca_2(BeF_4)_3$[72]
$Cs_2Mg_2(BeF_4)_3$

Formula
$LiCs_2Y_2(PO_4)_3$[73]
$LiRb_2Y_2(PO_4)_3$[74]
$K_2YTi(PO_4)_3$[1]
$K_2ErTi(PO_4)_3$[1]
$K_2YbTi(PO_4)_3$[1]
$K_2CrTi(PO_4)_3$[1]
$(NH_4)(H_3O)Ti^{III}Ti^{IV}(PO_4)_3$[75]
$K_2Ti_2(PO_4)_3$[76]
$Rb_2Ti_2(PO_4)_3$[76]
$Tl_2Ti_2(PO_4)_3$[76]
$Na_2FeTi(PO_4)_3$[77]
$Na_2CrTi(PO_4)_3$[77]
$K_2Mn_{0.5}Ti_{1.5}(PO_4)_3$[78]
$K_2Co_{0.5}Ti_{1.5}(PO_4)_3$[78]
$Rb_4NiTi_3(PO_4)_6$[79]
$K_2AlTi(PO_4)_3$[80]
$K_2TiYb(PO_4)_3$[81]
$Li_2Zr_2(PO_4)_3$[82]
$K_2(Ce, ..., Lu)Zr(PO_4)_3$[83]
$Rb_2FeZr(PO_4)_3$[84]
$K_2FeZr(PO_4)_3$[85]
$K_2YZr(PO_4)_3$[87]
$K_2GdZr(PO_4)_3$[87]
$K_2YHf(PO_4)_3$[88]
$Li(H_2O)_2Hf_2(PO_4)_3$[89]
$K_2BiHf(PO_4)_3$[90]
$Li(H_2O)_2Zr_2(PO_4)_3$[82]
$K_2AlSn(PO_4)_3$
$K_2CrSn(PO_4)_3$
$K_2InSn(PO_4)_3$
$K_2FeSn(PO_4)_3$
$K_2YbSn(PO_4)_3$
$K_4Al_3Ta(PO_4)_6$[91]
$K_4Cr_3Ta(PO_4)_6$[91]
$K_4Fe_3Ta(PO_4)_6$[91]
$K_4Tb_3Ta(PO_4)_6$
$K_4Fe_3Nb(PO_4)_6$[91]
$KBaEr_2(PO_4)_3$[93]
$RbBaEr_2(PO_4)_3$[93]
$CsBaEr_2(PO_4)_3$[93]
$(Rb,Cs)_2(Pr,Er)Zr(PO_4)_3$[93]
$KCsFeZrP_3O_{12}$
$CaFe_3O(PO_4)_3$[95]
$SrFe_3O(PO_4)_3$[95]

$PbFe_3O(PO_4)_3$[95]
$KSrFe_2(PO_4)_3$[96]
$Pb_{1.5}V^{IV}_2(PO_4)_3$
$K_2TiV(PO_4)_3$[98]
$BaTiV(PO_4)_3$[98]
$KBaV_2(PO_4)_3$[98]
$Ba_{1.5}V_2(PO_4)_3$[98]
$Ba_{1.5}Fe^{3+}_2(PO_4)_3$[99][100]
$KSrSc_2(PO_4)_3$[101]
$Rb_{0.743}K_{0.845}Co_{0.293}Ti_{1.707}(PO_4)_3$[102]
$K_2BiZr(PO_4)_6$[103]
$KBaSc_2(PO_4)_3$[104]
$KBaRZrP_2SiO_{12}$[2]
$KBaYSnP_2SiO_{12}$[2]
$KBaFe_2(PO_4)_3$[105]
$KBaCr_2(PO_4)_3$[106]
$Rb_2FeTi(PO_4)_3$[107]
$KBaMgTi(PO_4)_3$[108]
$KPbMgTi(PO_4)_3$[108]
$RbBaMgTi(PO_4)_3$[108]
$RbPbMgTi(PO_4)_3$[108]
$KSrMgZr(PO_4)_3$[108]
$KPbMgZr(PO_4)_3$[108]
$KBaMgZr(PO_4)_3$[108]
$RbSrMgZr(PO_4)_3$[108]
$RbPbMgZr(PO_4)_3$[108]
$RbBaMgZr(PO_4)_3$[108]
$CsSrMgZr(PO_4)_3$[108]
$Ba_3In_4(PO_4)_6$[109]
$Ba_3V_4(PO_4)_6$[110]
$KPbCr_2(PO_4)_3$[111]
$KPbFe_2(PO_4)_3$[111]
$K_4NiHf_3(PO_4)_6$[112]

Phosphate silicates

substance	for
$K_2Sn_2(PO_4)_2SiO_4$[113]	
$K_2Zr_2(PO_4)_2SiO_4$[113]	
$Cs_2Zr_2(PO_4)_2SiO_4$[114]	
$CsKZr_2(PO_4)_2SiO_4$[114]	

Vanadates [edit]

The orthovanadates have fou

	formul
Formula	g/mol
$LiBaCr_2(VO_4)_3$[115]	593.0
$NaBaCr_2(VO_4)_3$[115]	609.1
$AgBaCr_2(VO_4)_3$[115]	694.0

Arsenates [edit]

substance	fo
$K_2ScSn(AsO_4)_3$[116]	6
$Zr_2NH_4(AsO_4)_3·H_2O$[117]	6

Selenates [edit]

Langbeinite structured doubl
and ammonia to form a pyros

substance	for
$(NH_4)_2Mn_2(SeO_4)_3$[119]	57

Molybdates [edit]

substance	fo
$Cs_2Cd_2(MoO_4)_3$[120]	97
$Rb_2Co_2(MoO_4)_3$	76
$Cs_2Co_2(MoO_4)_3$[121]	
$Cs_2Ni_2(MoO_4)_3$[122]	86
$(H_3O)_2Mn_2(MoO_4)_3$[123]	62
$K_2Mn_2(MoO_4)_3$[124]	

Tungstates [edit]

substance	formu
$Rb_2Mg_2(WO_4)_3$[125]	963.06
$Cs_2Mg_2(WO_4)_3$[125]	1057.9

$K_2Mg_2(SO_4)_3$ → 2-: **SO_4**, WO_4, **MoO_4**, SeO_4, CrO_4, BeF_4
3-: **PO_4**, AsO_4
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majority of 2+ ions (Cu not possible?)

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$Rb_2Ca_2(SO_4)_3$
$Cs_2Ca_2(SO_4)_3$
$Tl_2Ca_2(SO_4)_3$
$(NH_4)_2Ca_2(SO_4)_3$
$(NH_4)_2V_2(SO_4)_3$
$K_2Mn_2(SO_4)_3$
$Rb_2Mn_2(SO_4)_3$
$Cs_2Mn_2(SO_4)_3$
$(NH_4)_2Mn_2(SO_4)_2$
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$Rb_2Cu_2(S_{04})_3$
$Cs_2Cu_2(S_{04})_3$
$Tl_2Cu_2(S_{04})_3$
$K_2Zn_2(SO_4)_3$
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$Rb_2MnCd(BeF_4)_3$[72]
$RbCsMnCd(BeF_4)_3$[72]
$Cs_2MnCd(BeF_4)_3$[72]
$(NH_4)_2Cd_2(BeF_4)_3$[72]
$Rb_2Cd_2(BeF_4)_3$[72]
$Tl_2Cd_2(BeF_4)_3$[72]
$RbCsCd_2(BeF_4)_3$[72]
$Cs_2Cd_2(BeF_4)_3$[72]
$RbCsCdCa(BeF_4)_3$[72]
$Rb_2Ca_2(BeF_4)_3$[72]
$RbCsCa_2(BeF_4)_3$[72]
$Cs_2Ca_2(BeF_4)_3$[72]
$Cs_2Mg_2(BeF_4)_3$

Formula
$LiCs_2Y_2(PO_4)_3$[73]
$LiRb_2Y_2(PO_4)_3$[74]
$K_2YTi(PO_4)_3$[1]
$K_2ErTi(PO_4)_3$[1]
$K_2YbTi(PO_4)_3$[1]
$K_2CrTi(PO_4)_3$[1]
$(NH_4)(H_3O)Ti^{III}Ti^{IV}(PO_4)_3$[75]
$K_2Ti_2(PO_4)_3$[76]
$Rb_2Ti_2(PO_4)_3$[76]
$Tl_2Ti_2(PO_4)_3$[76]
$Na_2FeTi(PO_4)_3$[77]
$Na_2CrTi(PO_4)_3$[77]
$K_2Mn_{0.5}Ti_{1.5}(PO_4)_3$[78]
$K_2Co_{0.5}Ti_{1.5}(PO_4)_3$[78]
$Rb_4NiTi_3(PO_4)_6$[79]
$K_2AlTi(PO_4)_3$[80]
$K_2TiYb(PO_4)_3$[81]
$Li_2Zr_2(PO_4)_3$[82]
$K_2(Ce, ..., Lu)Zr(PO_4)_3$[83]
$Rb_2FeZr(PO_4)_3$[84]
$K_2FeZr(PO_4)_3$[85]
$K_2YZr(PO_4)_3$[87]
$K_2GdZr(PO_4)_3$[87]
$K_2YHf(PO_4)_3$[88]
$Li(H_2O)_2Hf_2(PO_4)_3$[89]
$K_2BiHf(PO_4)_3$[90]
$Li(H_2O)_2Zr_2(PO_4)_3$[82]
$K_2AlSn(PO_4)_3$
$K_2CrSn(PO_4)_3$
$K_2InSn(PO_4)_3$
$K_2FeSn(PO_4)_3$
$K_2YbSn(PO_4)_3$
$K_4Al_3Ta(PO_4)_6$[91]
$K_4Cr_3Ta(PO_4)_6$[91]
$K_4Fe_3Ta(PO_4)_6$[91]
$K_4Tb_3Ta(PO_4)_6$
$K_4Fe_3Nb(PO_4)_6$[91]
$KBaEr_2(PO_4)_3$[93]
$RbBaEr_2(PO_4)_3$[93]
$CsBaEr_2(PO_4)_3$[93]
$(Rb,Cs)_2(Pr,Er)Zr(PO_4)_3$[93]
$KCsFeZrP_3O_{12}$
$CaFe_3O(PO_4)_3$[95]
$SrFe_3O(PO_4)_3$[95]

$PbFe_3O(PO_4)_3$[95]
$KSrFe_2(PO_4)_3$[96]
$Pb_{1.5}V^{IV}_2(PO_4)_3$
$K_2TiV(PO_4)_3$[98]
$BaTiV(PO_4)_3$[98]
$KBaV_2(PO_4)_3$[98]
$Ba_{1.5}V_2(PO_4)_3$[98]
$Ba_{1.5}Fe^{3+}_2(PO_4)_3$[99][100]
$KSrSc_2(PO_4)_3$[101]
$Rb_{0.743}K_{0.845}Co_{0.293}Ti_{1.707}(PO_4)_3$[102]
$K_2BiZr(PO_4)_6$[103]
$KBaSc_2(PO_4)_3$[104]
$KBaRZrP_2SiO_{12}$[2]
$KBaYSnP_2SiO_{12}$[2]
$KBaFe_2(PO_4)_3$[105]
$KBaCr_2(PO_4)_3$[106]
$Rb_2FeTi(PO_4)_3$[107]
$KBaMgTi(PO_4)_3$[108]
$KPbMgTi(PO_4)_3$[108]
$RbBaMgTi(PO_4)_3$[108]
$RbPbMgTi(PO_4)_3$[108]
$KSrMgZr(PO_4)_3$[108]
$KPbMgZr(PO_4)_3$[108]
$KBaMgZr(PO_4)_3$[108]
$RbSrMgZr(PO_4)_3$[108]
$RbPbMgZr(PO_4)_3$[108]
$RbBaMgZr(PO_4)_3$[108]
$CsSrMgZr(PO_4)_3$[108]
$Ba_3In_4(PO_4)_6$[109]
$Ba_3V_4(PO_4)_6$[110]
$KPbCr_2(PO_4)_3$[111]
$KPbFe_2(PO_4)_3$[111]
$K_4NiHf_3(PO_4)_6$[112]

Phosphate silicates

substance	for
$K_2Sn_2(PO_4)_2SiO_4$[113]	
$K_2Zr_2(PO_4)_2SiO_4$[113]	
$Cs_2Zr_2(PO_4)_2SiO_4$[114]	
$CsKZr_2(PO_4)_2SiO_4$[114]	

Vanadates [edit]

The orthovanadates have fou

	formul
Formula	g/mol
$LiBaCr_2(VO_4)_3$[115]	593.0
$NaBaCr_2(VO_4)_3$[115]	609.1
$AgBaCr_2(VO_4)_3$[115]	694.0

Arsenates [edit]

substance	fo
$K_2ScSn(AsO_4)_3$[116]	6
$Zr_2NH_4(AsO_4)_3·H_2O$[117]	6

Selenates [edit]

Langbeinite structured doubl
and ammonia to form a pyros

substance	for
$(NH_4)_2Mn_2(SeO_4)_3$[119]	57

Molybdates [edit]

substance	fo
$Cs_2Cd_2(MoO_4)_3$[120]	97
$Rb_2Co_2(MoO_4)_3$	76
$Cs_2Co_2(MoO_4)_3$[121]	
$Cs_2Ni_2(MoO_4)_3$[122]	86
$(H_3O)_2Mn_2(MoO_4)_3$[123]	62
$K_2Mn_2(MoO_4)_3$[124]	

Tungstates [edit]

substance	formu
$Rb_2Mg_2(WO_4)_3$[125]	963.06
$Cs_2Mg_2(WO_4)_3$[125]	1057.9

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

site mixing

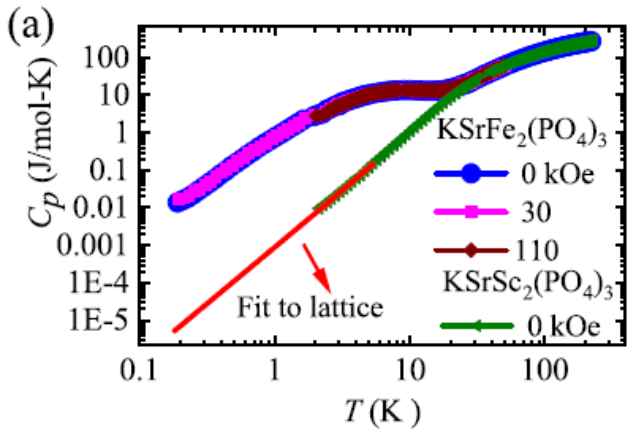
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

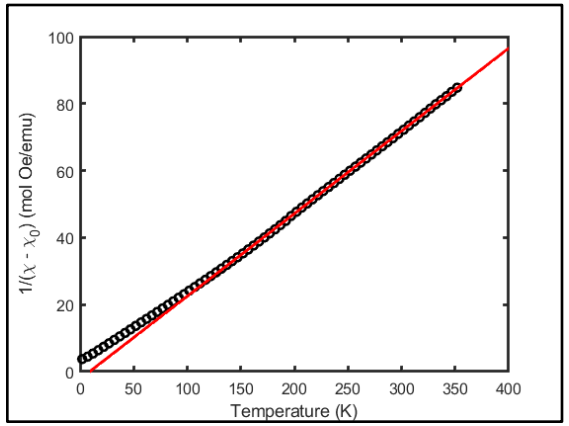
ordering around 10K

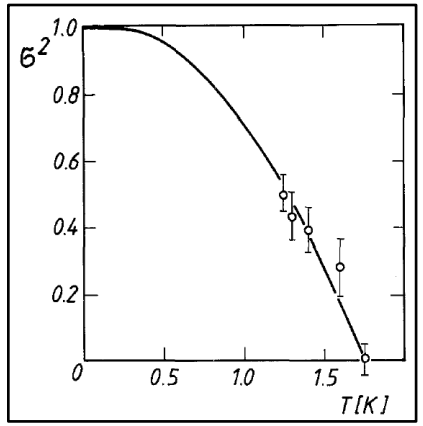
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

S=5/2

Boya, APL Mater. 10, 101103 (2022)

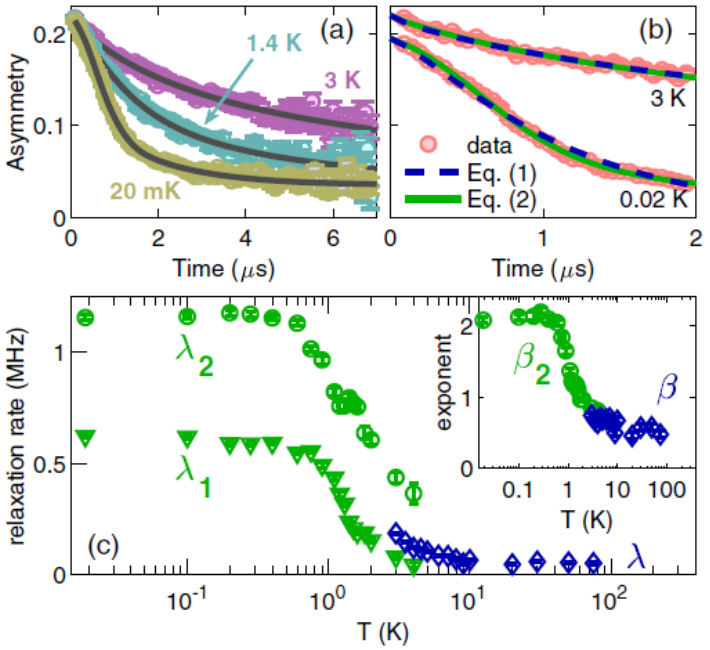


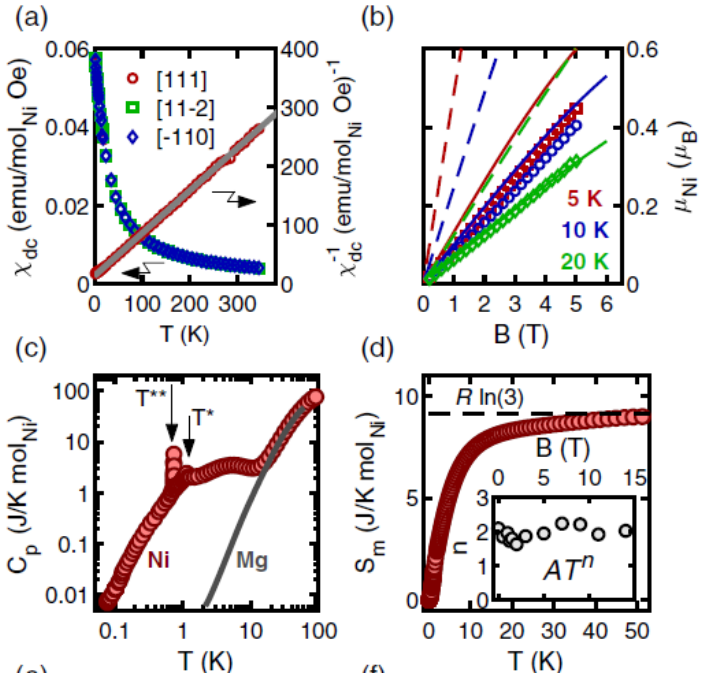


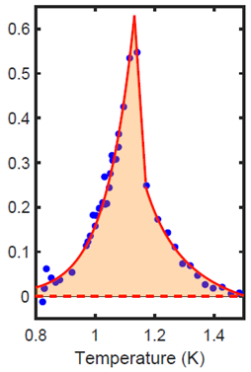


Oelkrug et al., PhysChemMinerals 16, 246 (1988)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

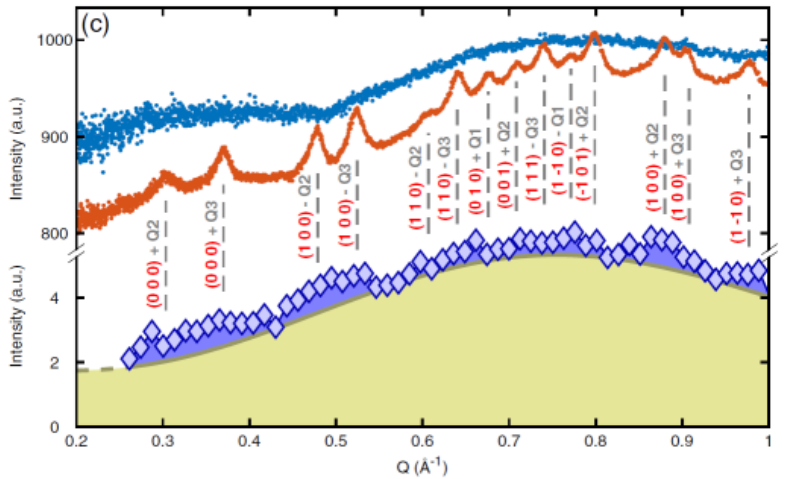






- Curie-Weiss T > 50K (S = 1, g = 2.3)
- θ = -18K

- ordering below 1K
- only 1% of entropy release
- 3 *q*-vectors

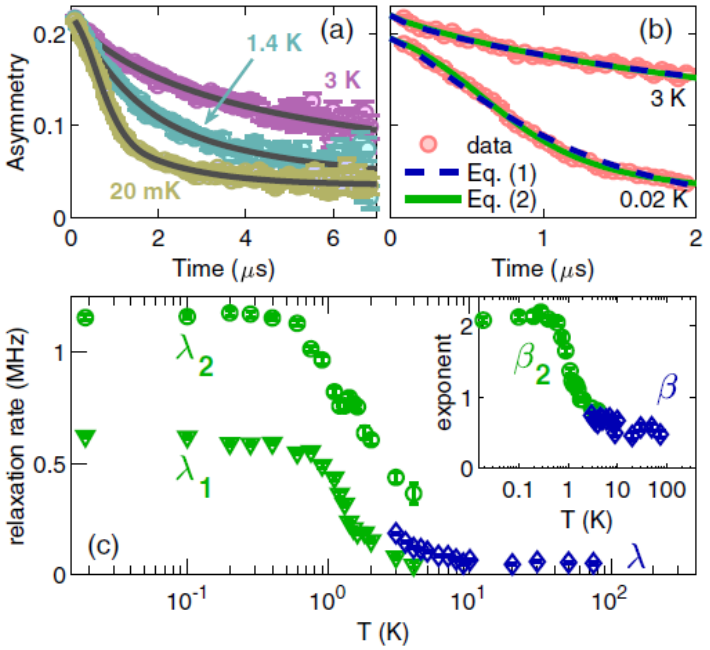


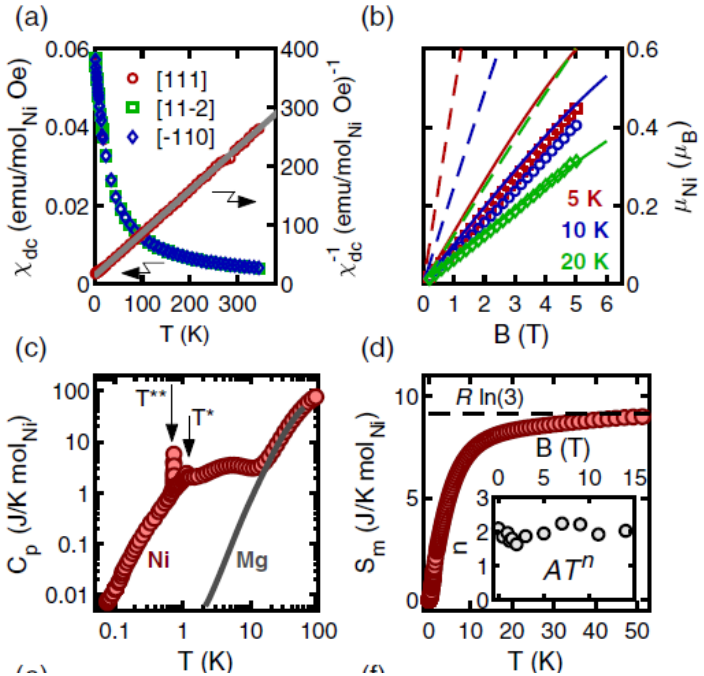
Zivkovic, PRL 127, 157204 (2021)

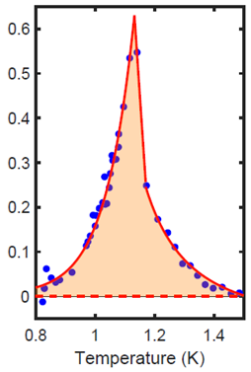
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

pressure

wiggles

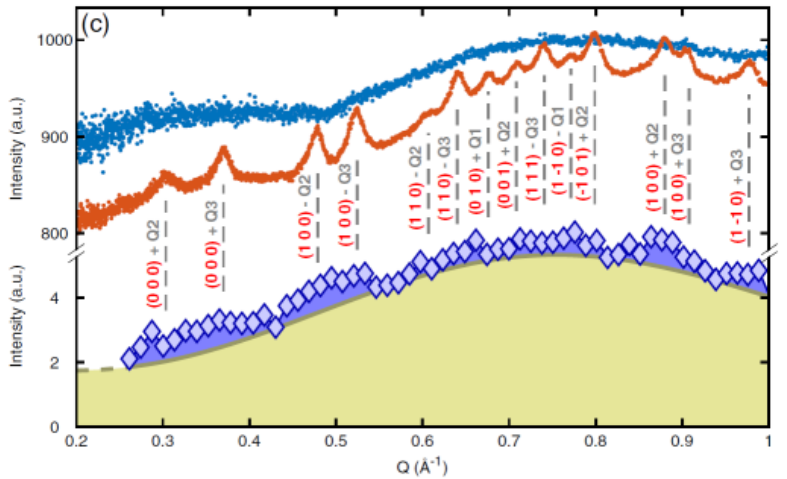






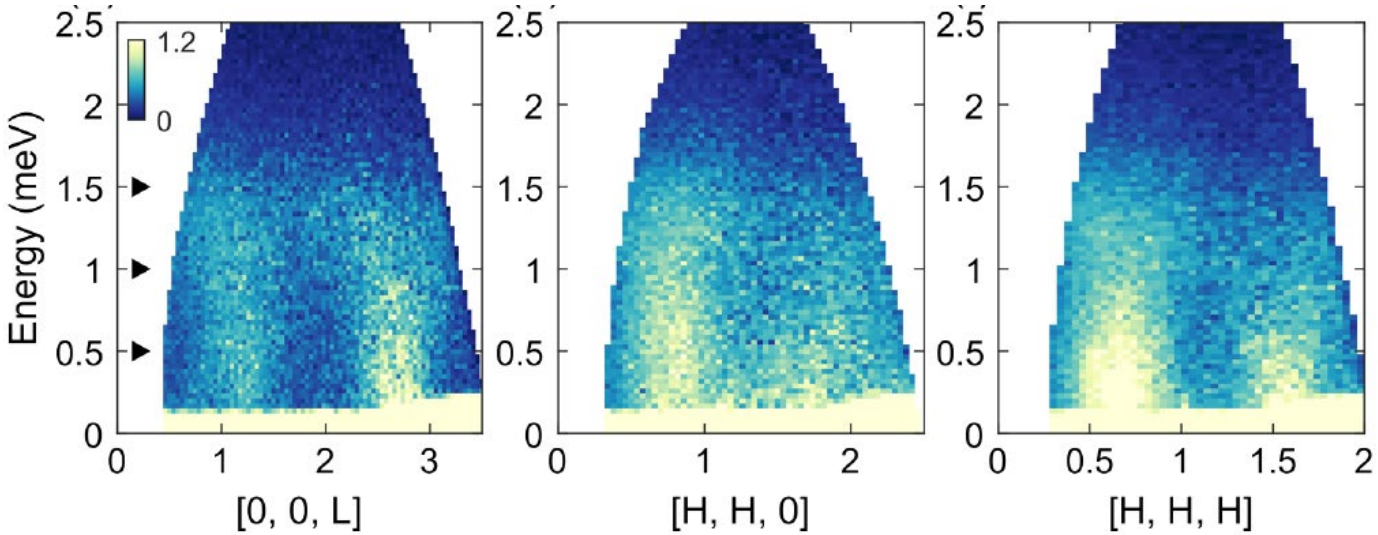
- Curie-Weiss T > 50K (S = 1, g = 2.3)
- θ = -18K

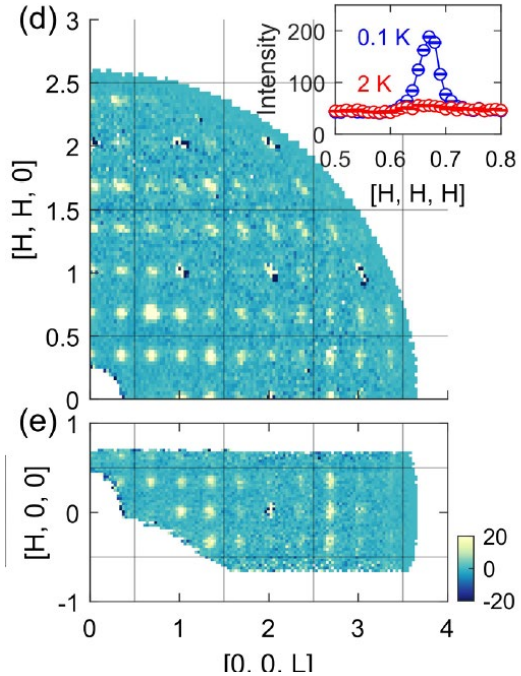
- ordering below 1K
- only 1% of entropy release
- 3 *q*-vectors

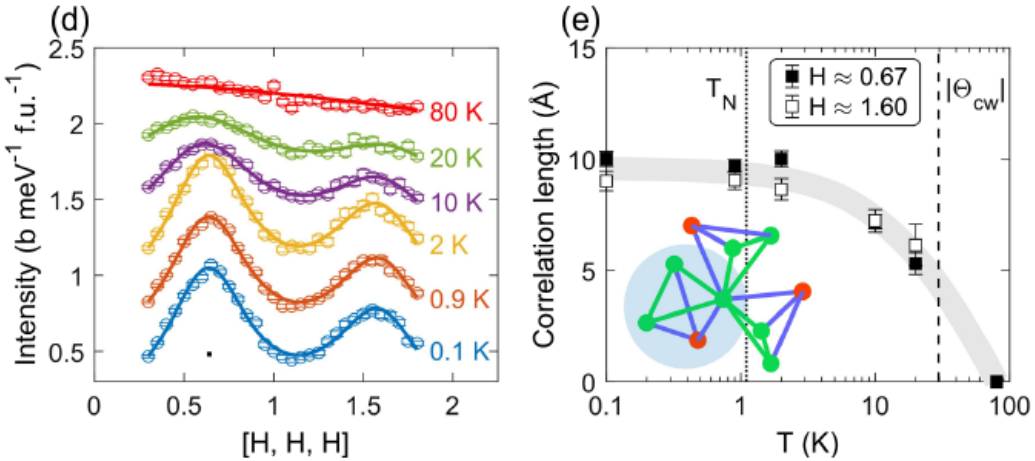


Zivkovic, PRL 127, 157204 (2021)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

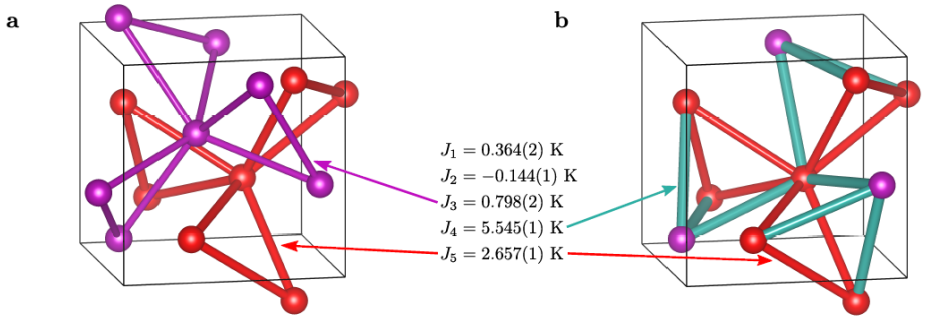




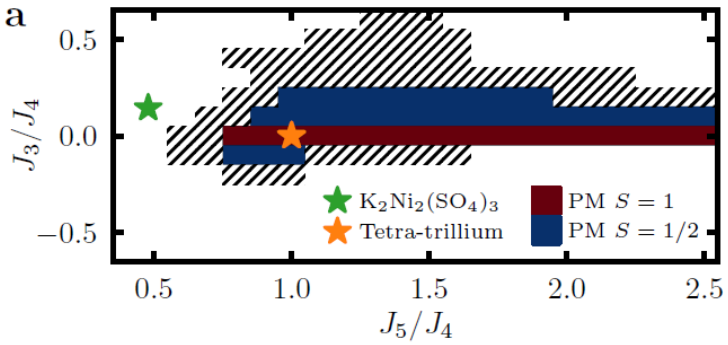


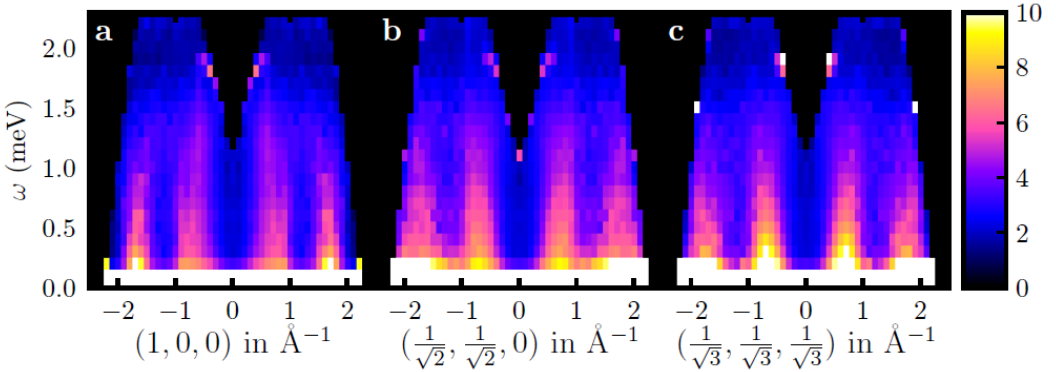
Yao, PRL 131, 146701 (2023)

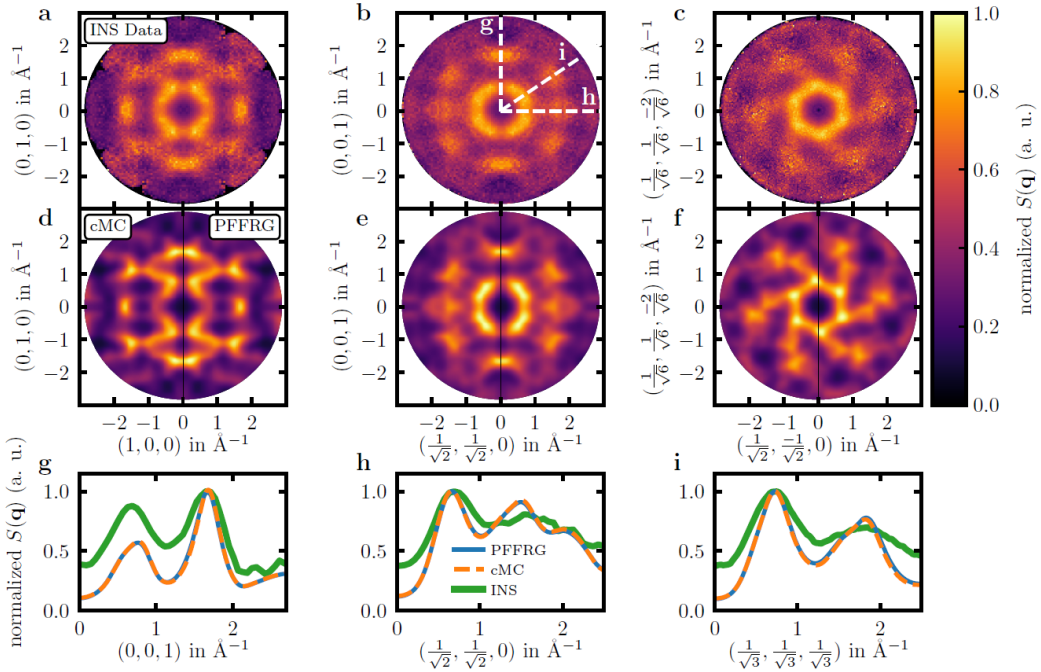
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		



Tetra-trillium lattice

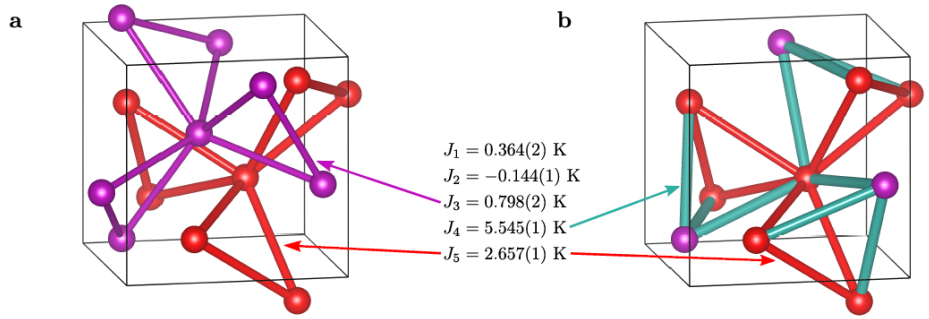




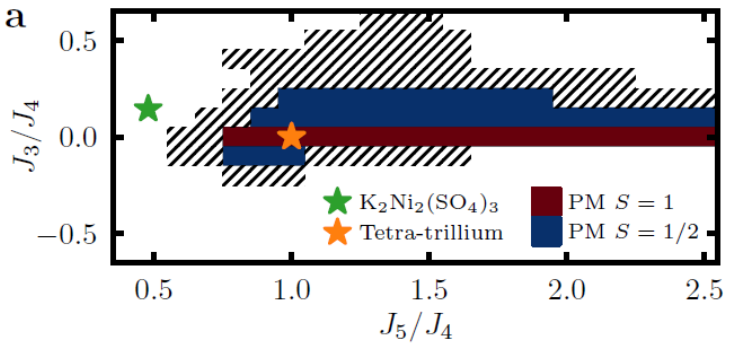


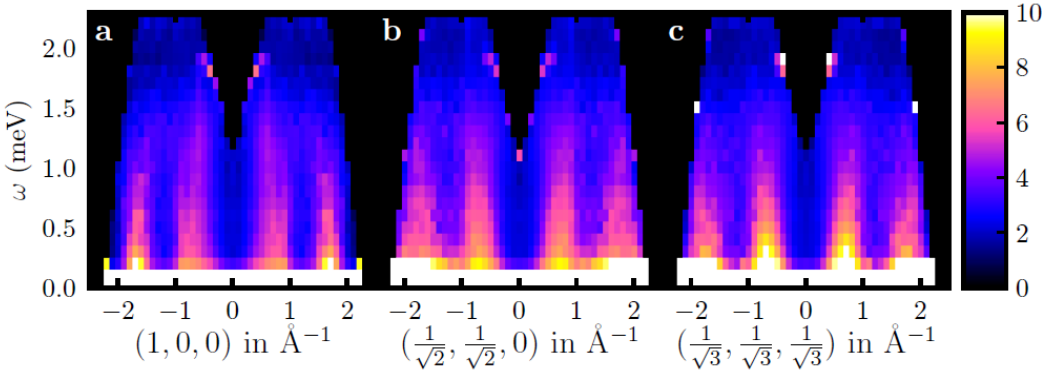
Gonzalez, Nature Commun. 15, 7191 (2024)

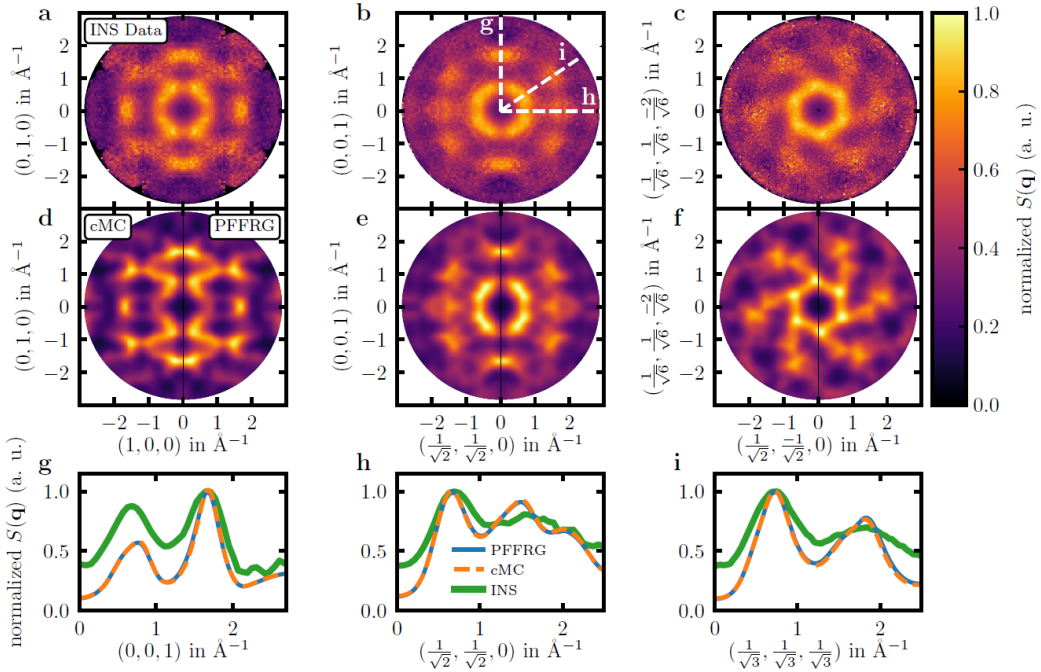
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		



Tetra-trillium lattice



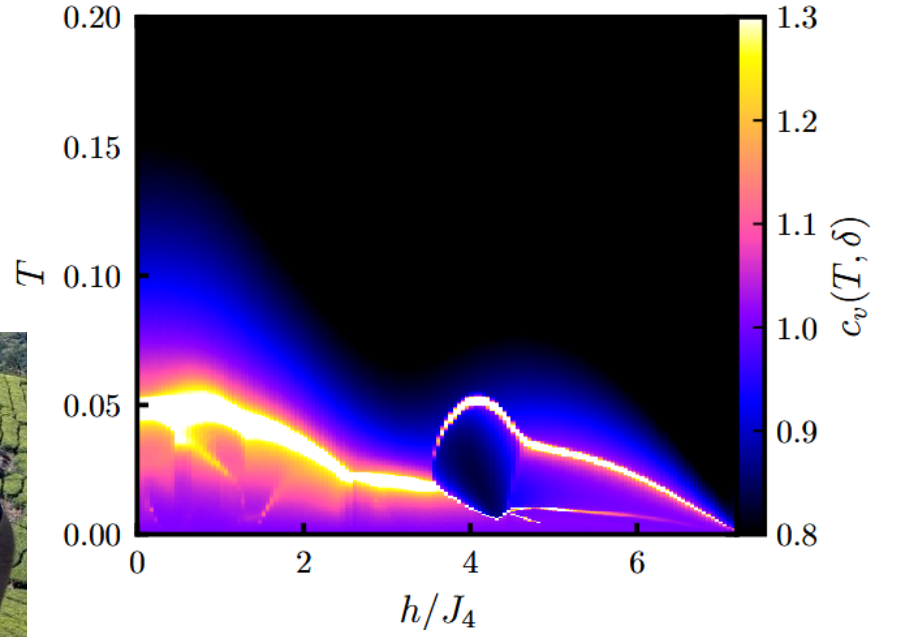




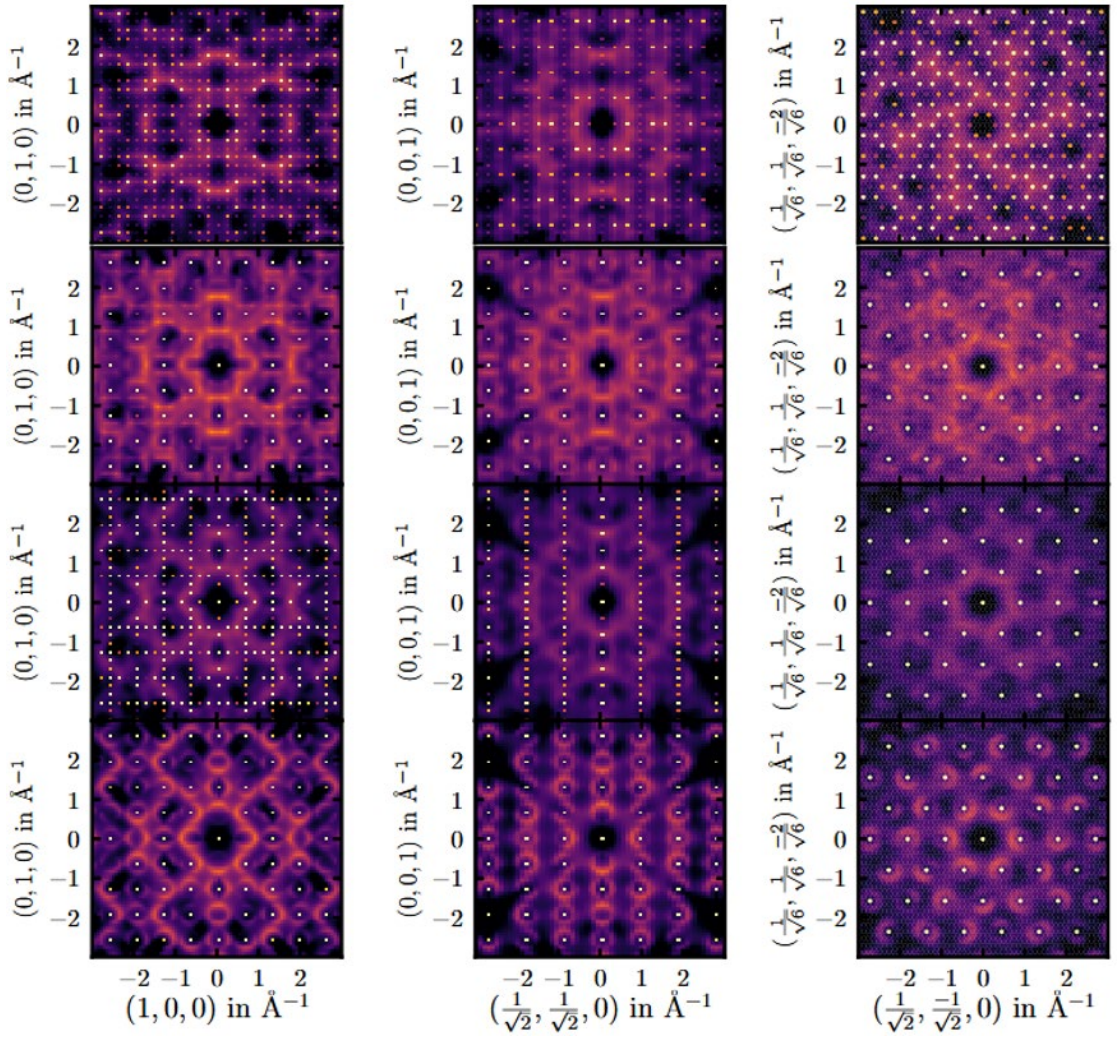
Gonzalez, Nature Commun. 15, 7191 (2024)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

B-field induced behavior



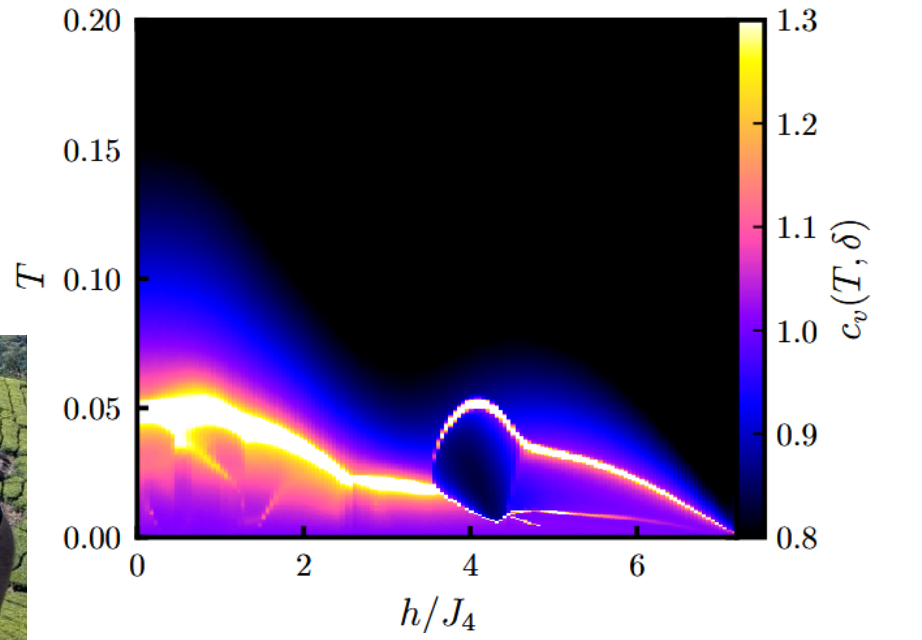
B

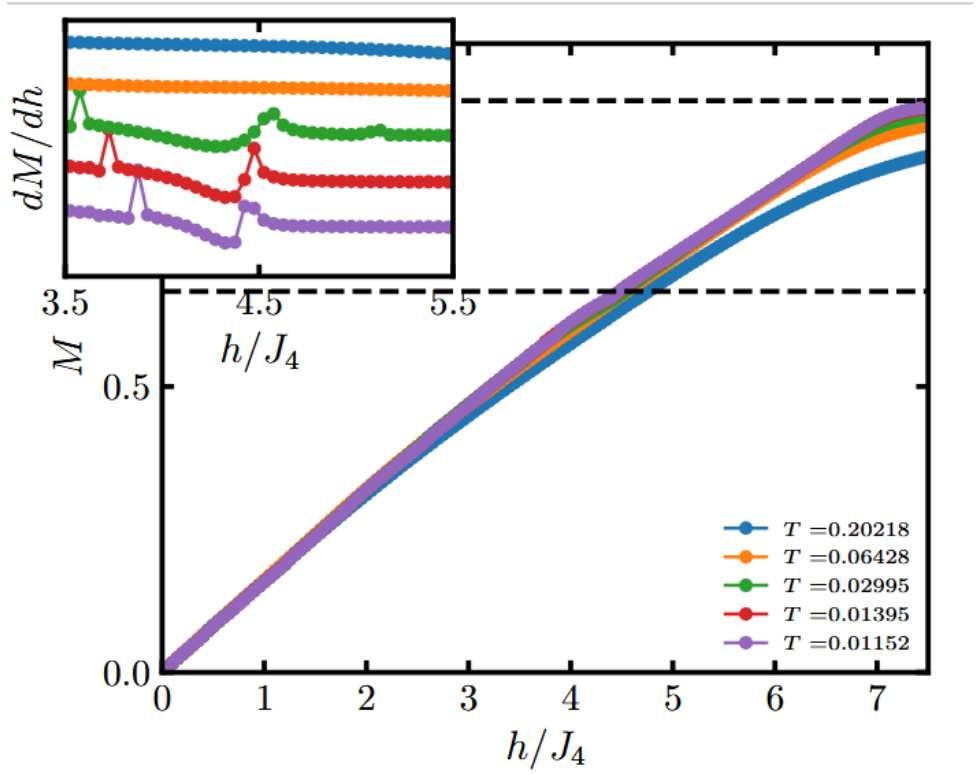


Gonzalez, unpublished

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

B-field induced behavior

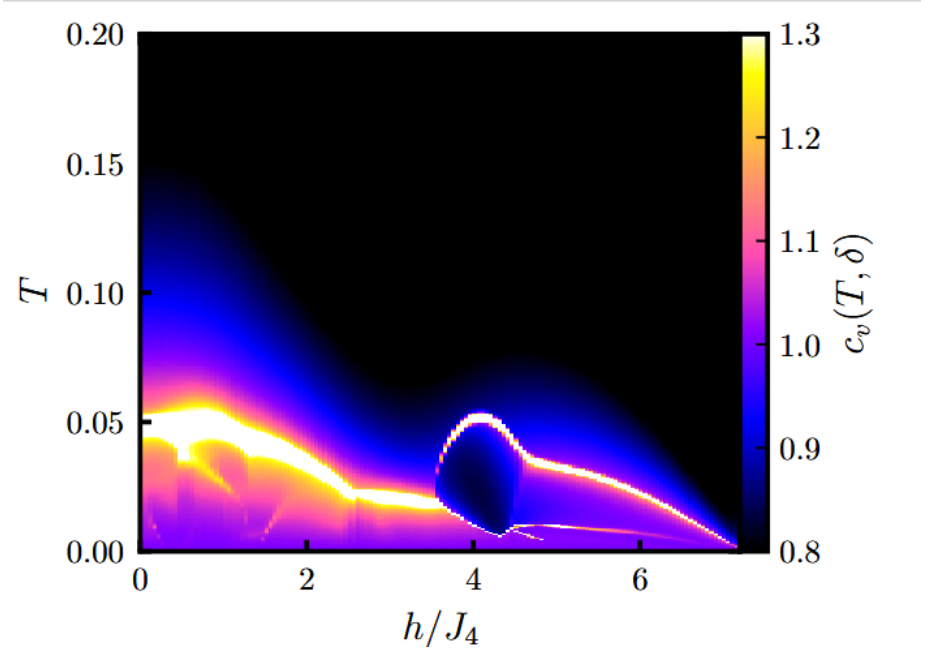


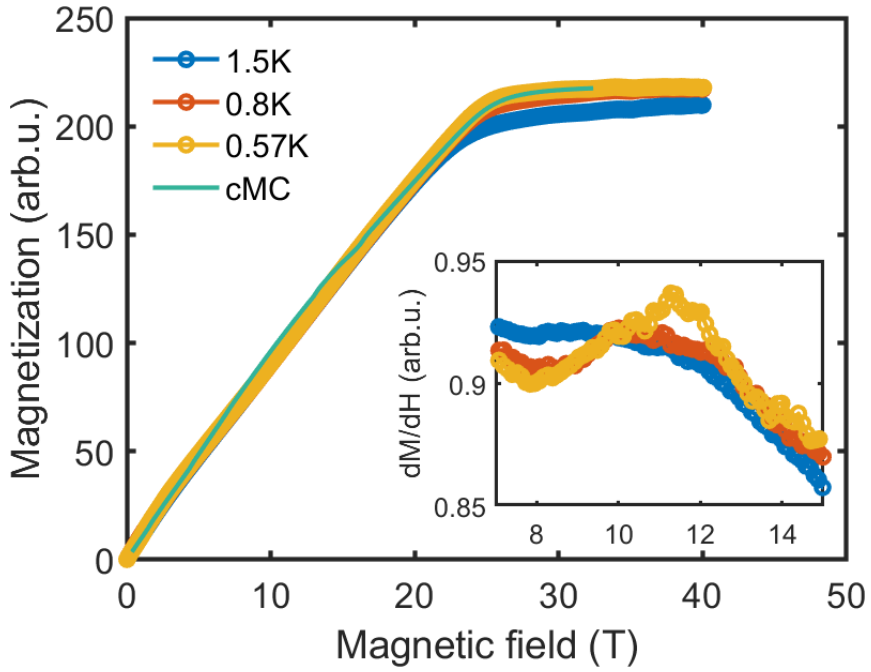


Gonzalez, unpublished

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

B-field induced behavior

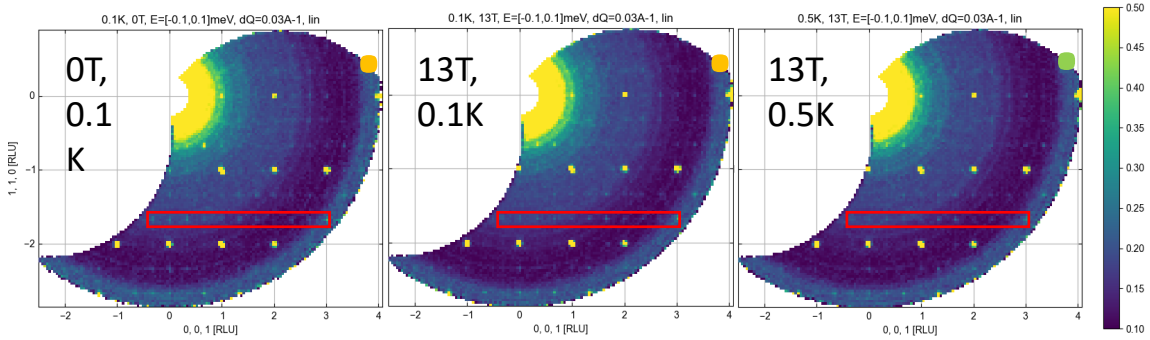


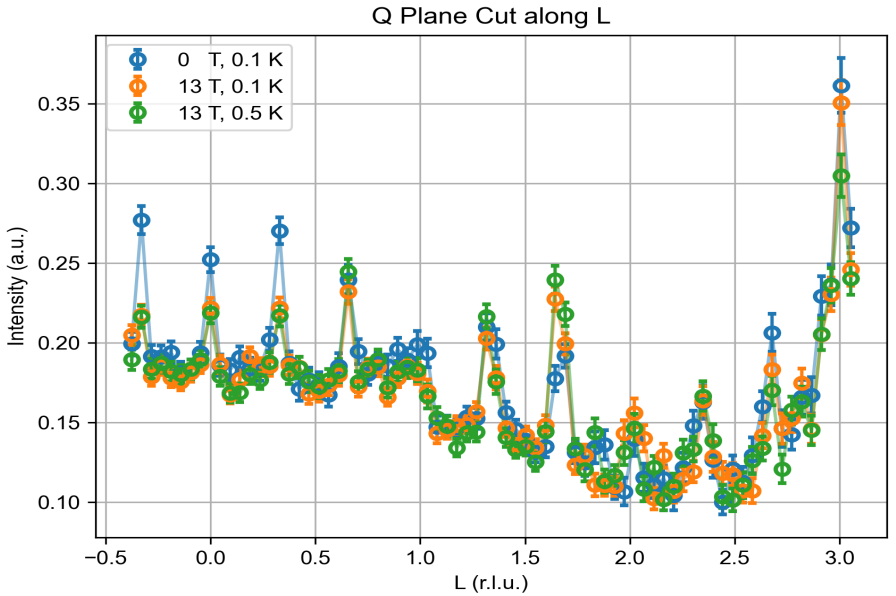


Gonzalez, unpublished

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

B-field induced behavior

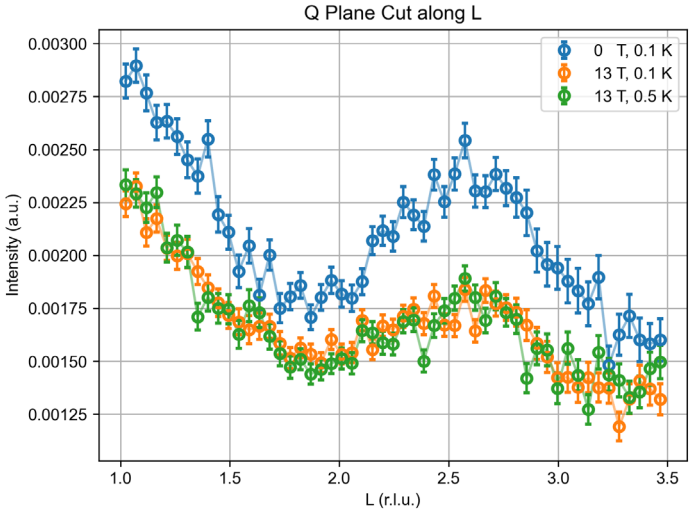




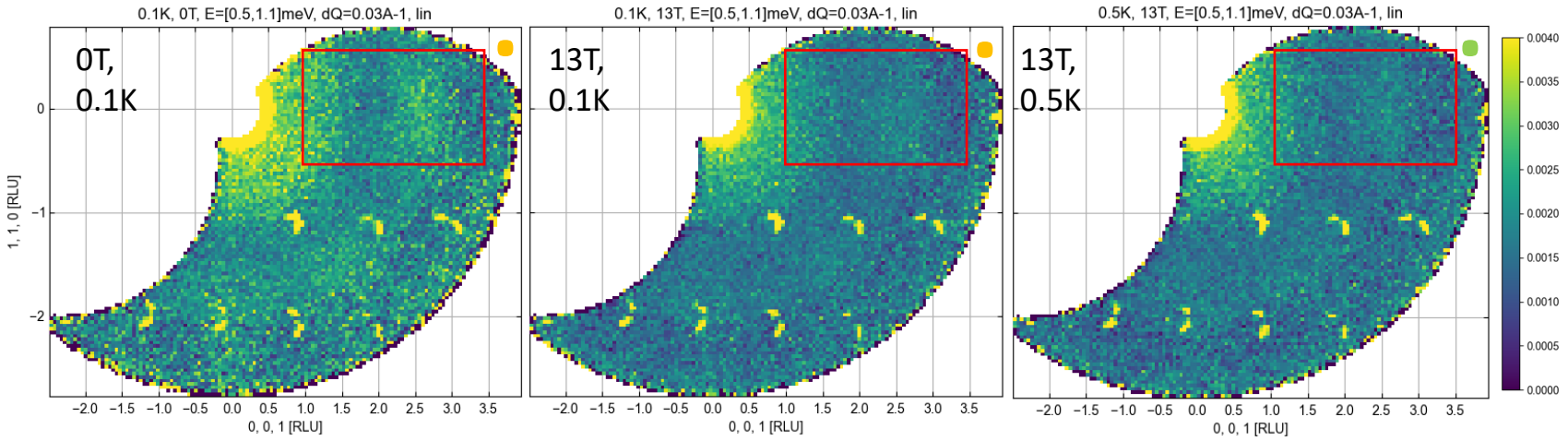
width=0.03Å^{-1}, minPixel=0.03Å^{-1}, E=[-0.1,0.1]meV

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

B-field induced behavior

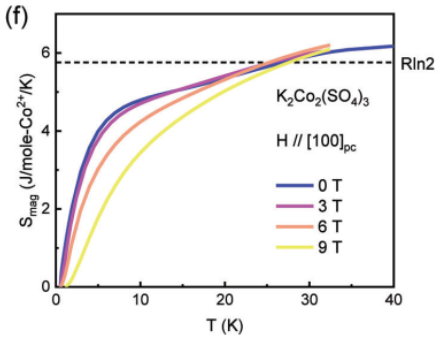


width=1Å^{-1}, minPixel=0.03Å^{-1},
E=[0.5,1.1]meV



2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

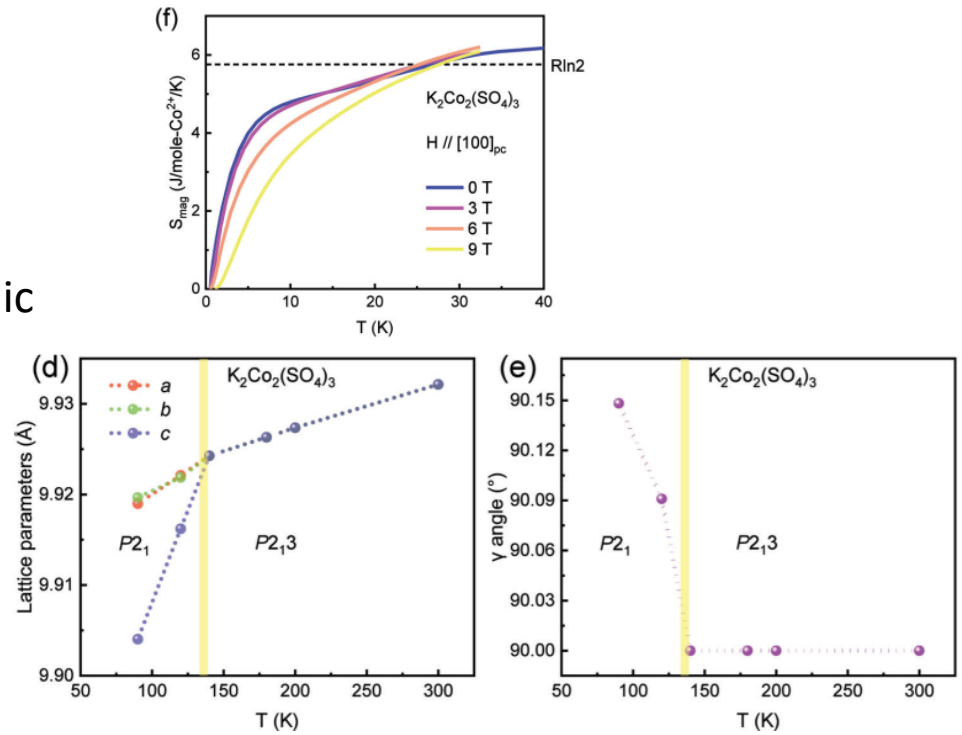
- spin crossover
  $S=3/2 \rightarrow S=1/2$



Xu, Adv.Electron.Mater. 2400308, (2024)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

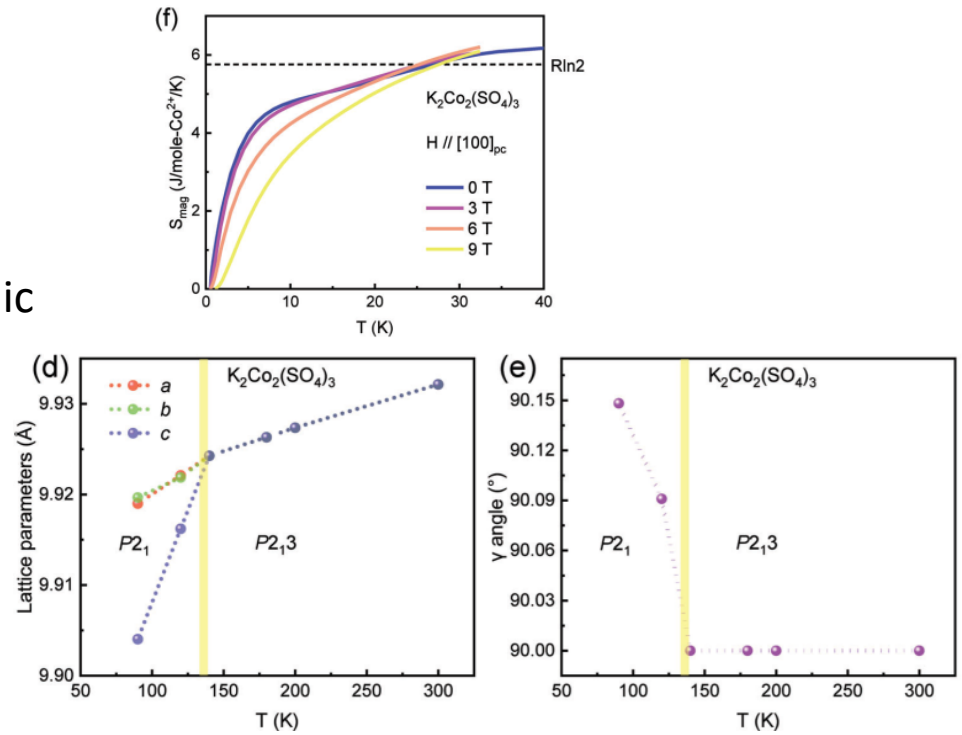
- spin crossover
  S=3/2 → S=1/2
- cubic → monoclinic
  (chiral, polar)

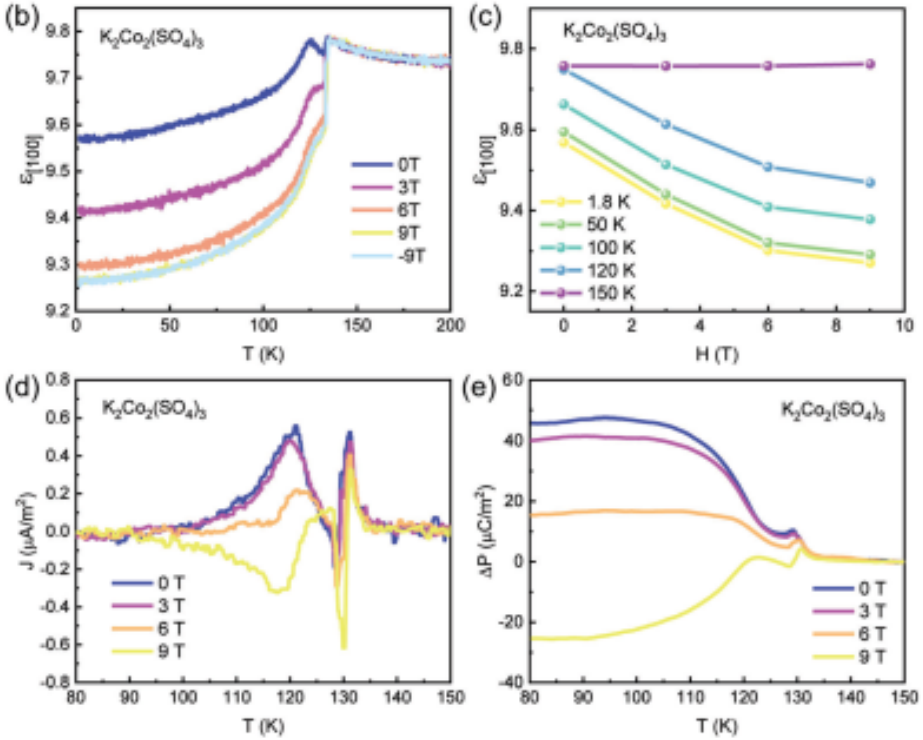


Xu, Adv.Electron.Mater. 2400308, (2024)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

- spin crossover
  S=3/2 → S=1/2
- cubic → monoclinic
  (chiral, polar)
- magneto-electric

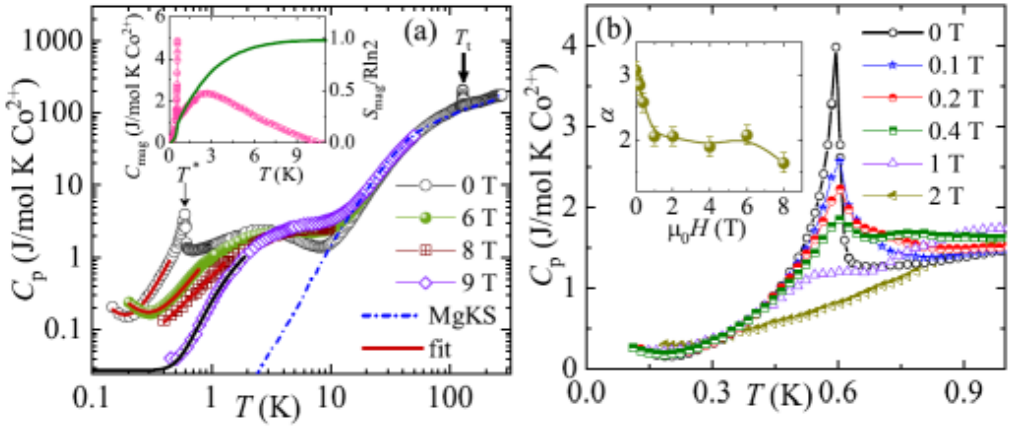


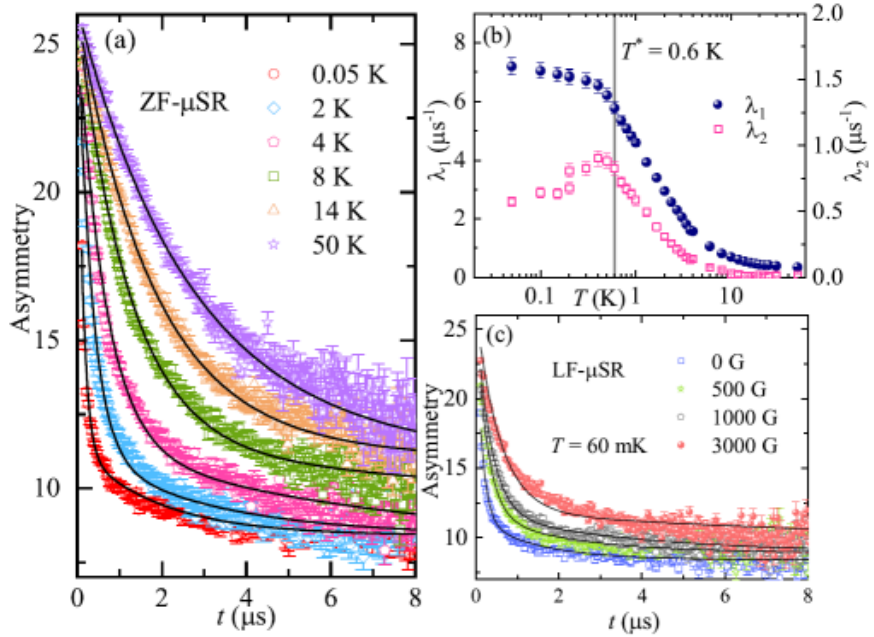


Xu, Adv.Electron.Mater. 2400308, (2024)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

- spin crossover
  S=3/2 → S=1/2
- cubic → monoclinic
  (chiral, polar)
- magneto-electric

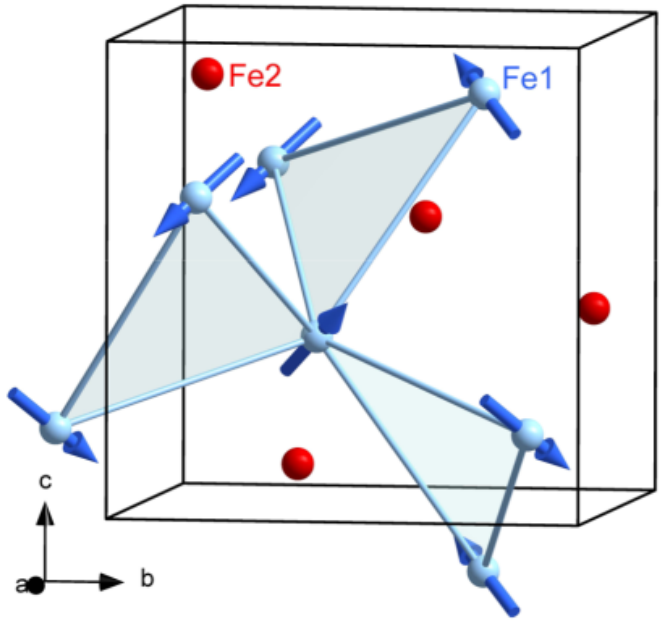




Magar, arxiv 2508.07687 (2025)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$		
$K_2Mn_2(SO_4)_3$		

- S=2, strong SOC
- cubic
- single Fe ordered moment
- magneto-caloric

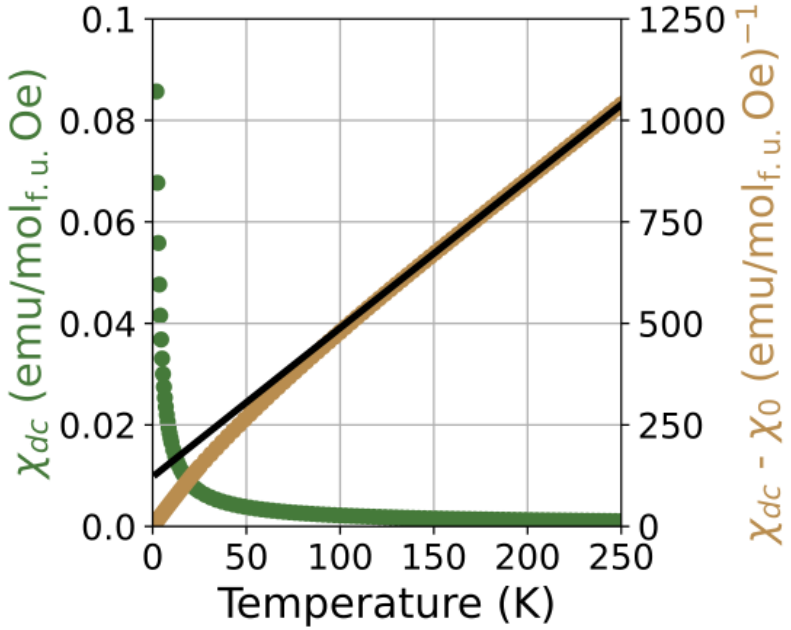


Kubickova, Chem.Mater. 36, 7016 (2024)

2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

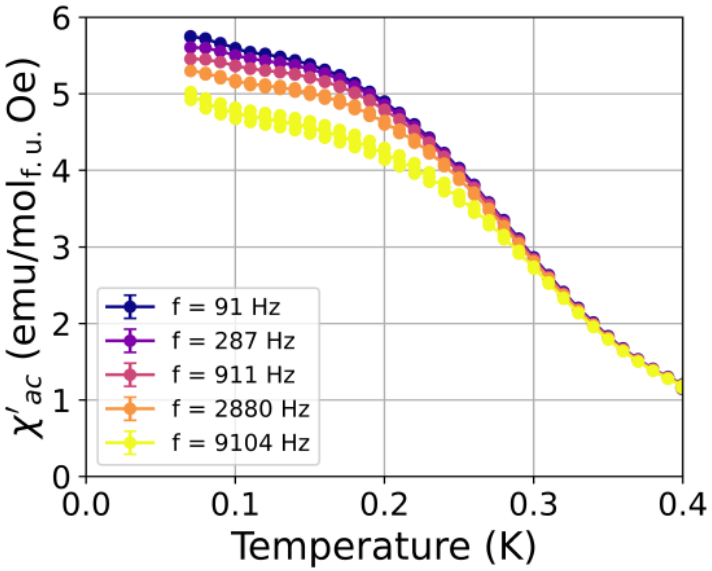
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

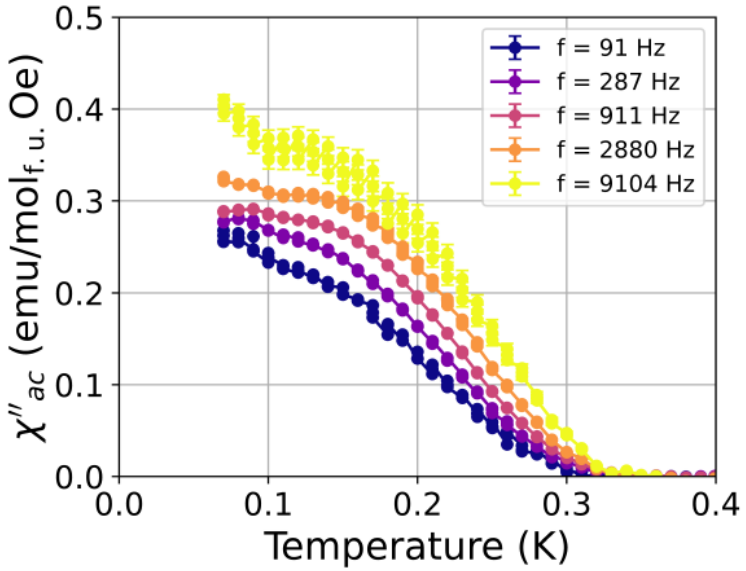
Berna Esmer

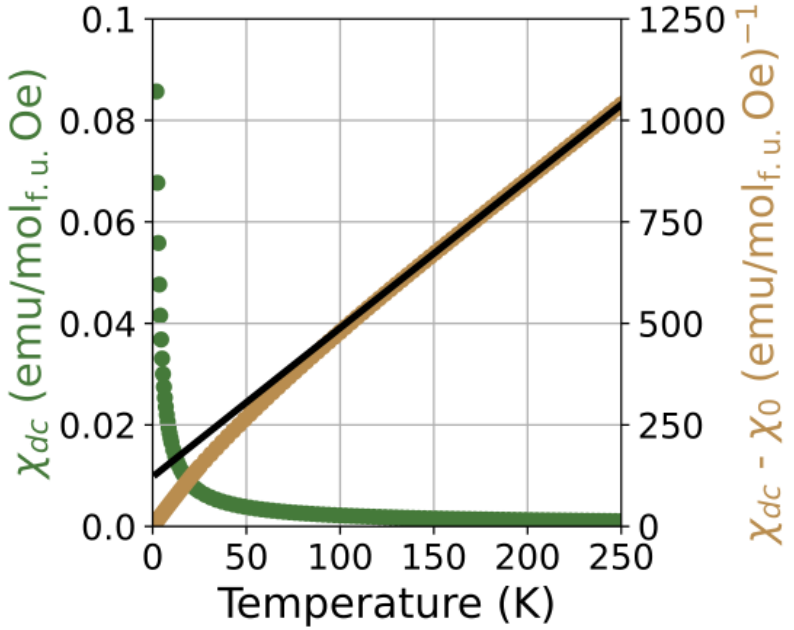


2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

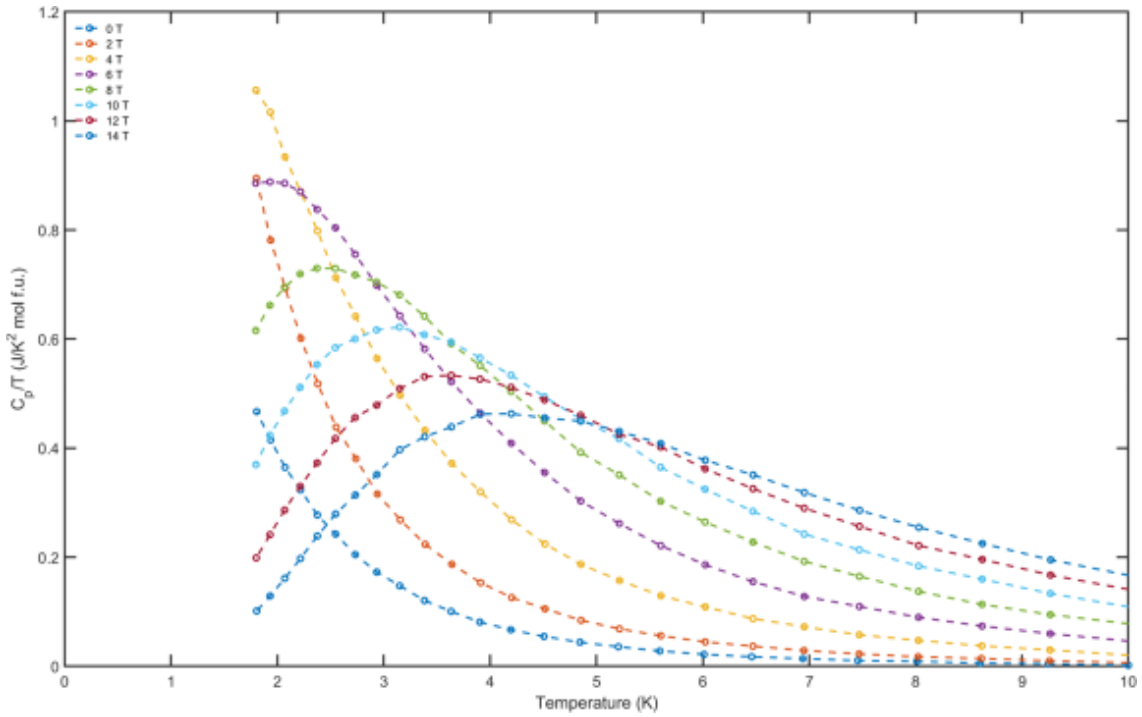
Berna Esmer

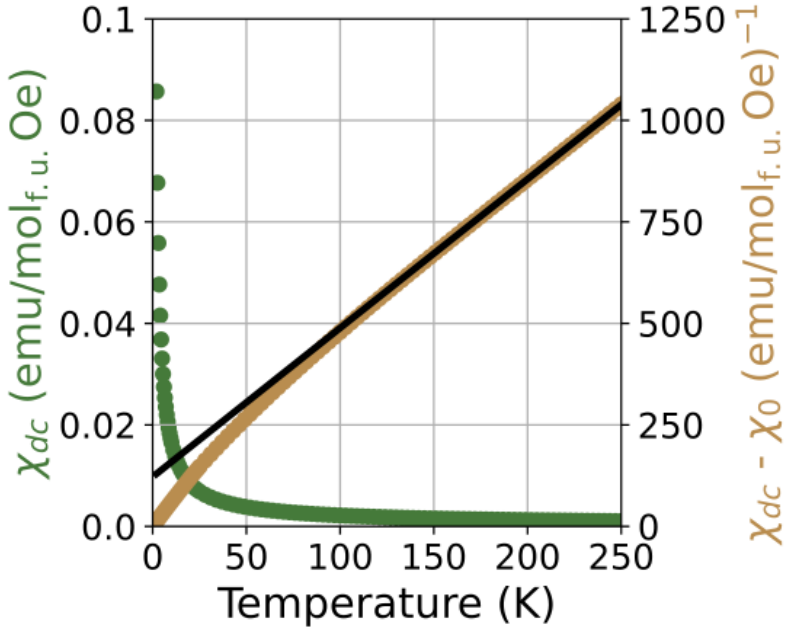






2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	



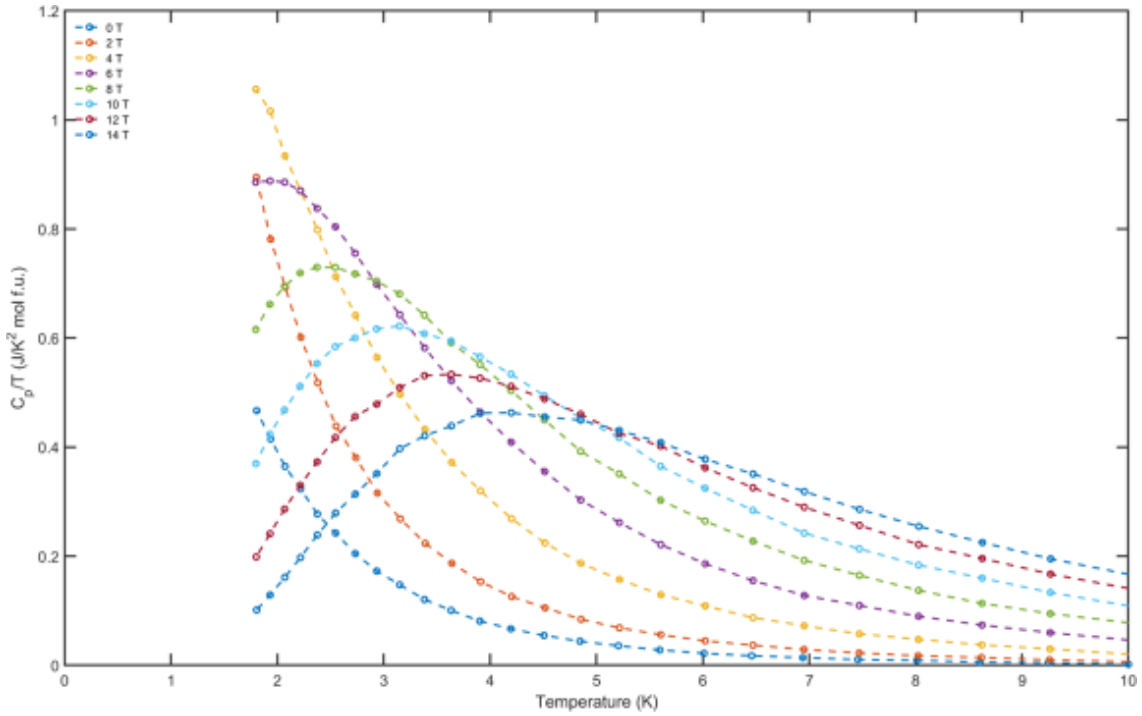


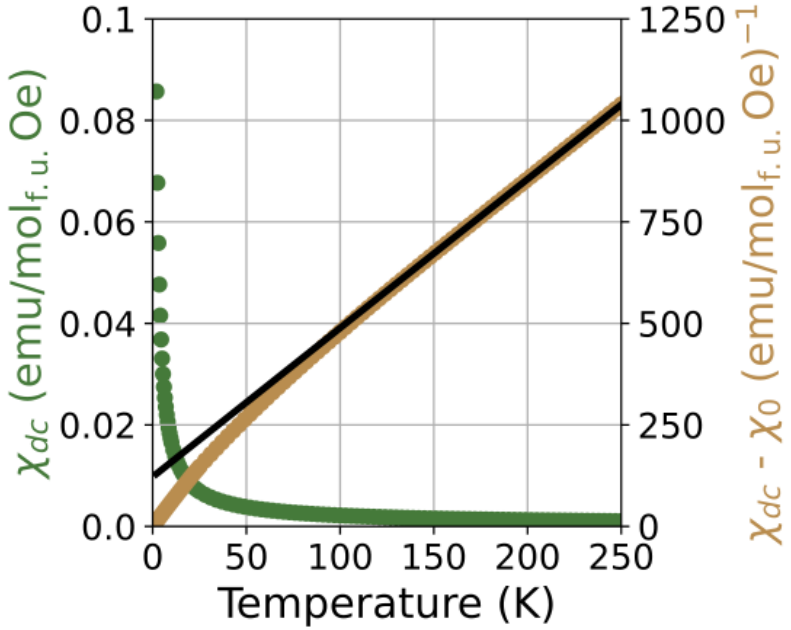
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

$K_2Ti_2(PO_4)_3 \rightarrow K_{2-x}Ti_2(PO_4)_3$

1x S=1/2 / f.u. → <1x S=1/2 / f.u.

Curie-Weiss: $C \sim ng^2S(S+1)$, n=?, g=?



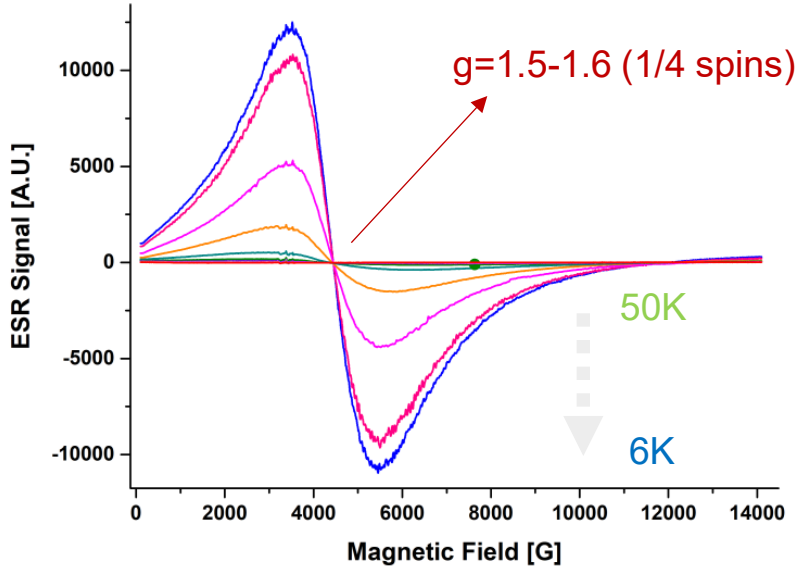


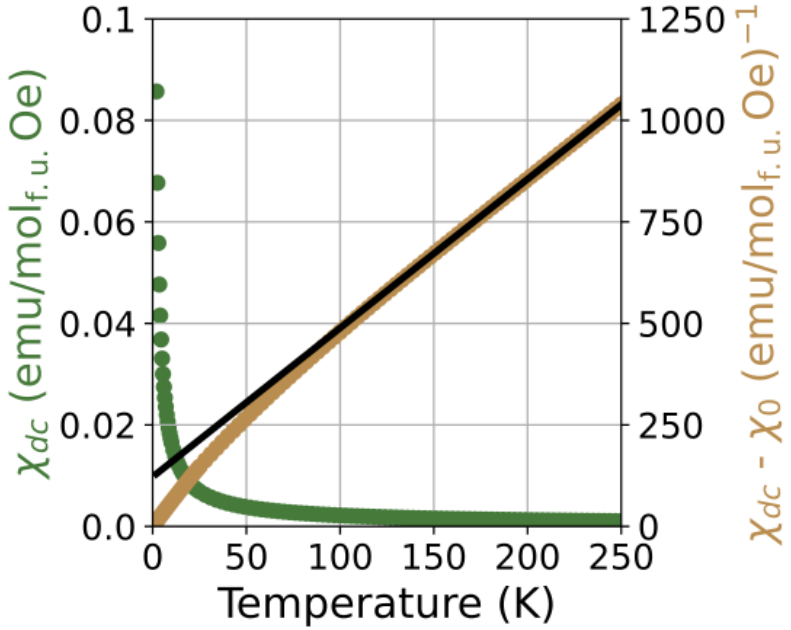
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

$K_2Ti_2(PO_4)_3 \rightarrow K_{2-x}Ti_2(PO_4)_3$

1x S=1/2 / f.u. → <1x S=1/2 / f.u.

Curie-Weiss: $C \sim ng^2S(S+1)$, n=?, g=?





2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

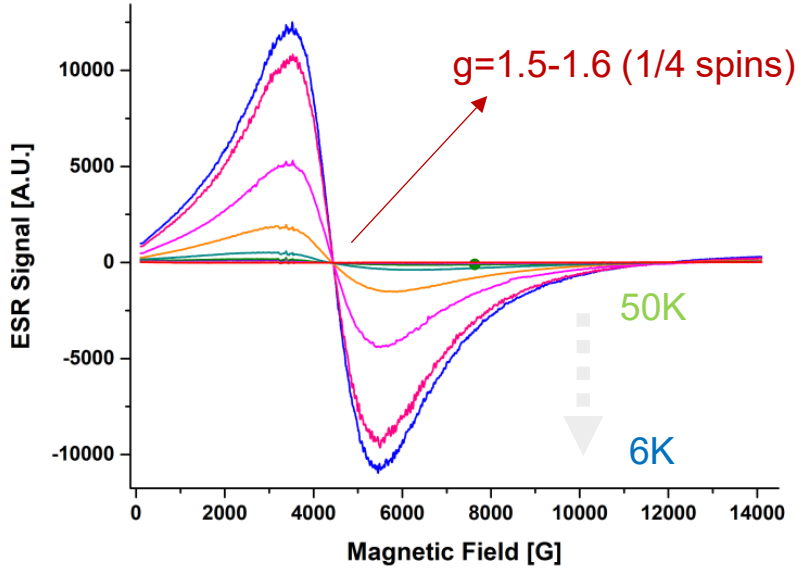
$K_2Ti_2(PO_4)_3 \rightarrow K_{2-x}Ti_2(PO_4)_3$

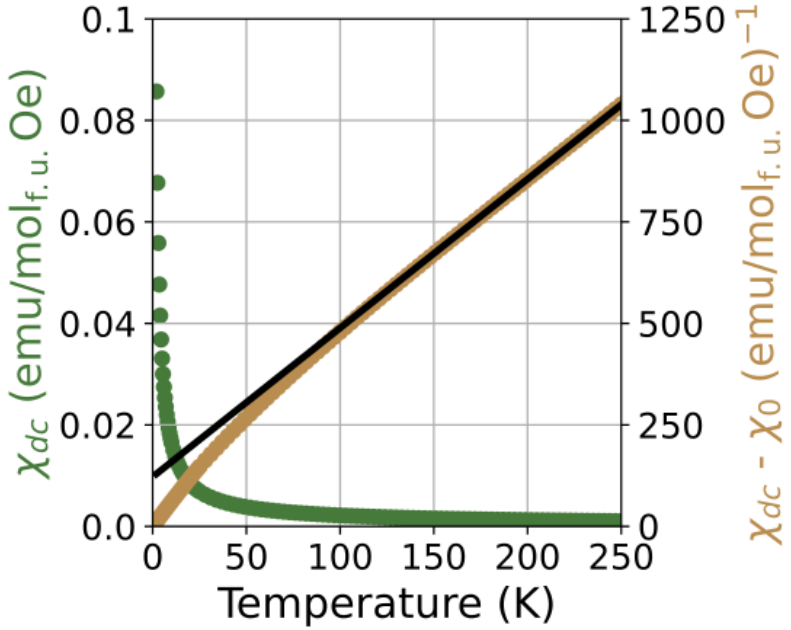
1x S=1/2 / f.u. → <1x S=1/2 / f.u.

Curie-Weiss: $C \sim ng^2S(S+1)$, n=?, g=?

d(Ti1 – O) = 1.925/1.954 Ang

d(Ti2 – O) = 1.993/2.021 Ang





2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

$K_2Ti_2(PO_4)_3 \rightarrow K_{2-x}Ti_2(PO_4)_3$

1x S=1/2 / f.u. → <1x S=1/2 / f.u.

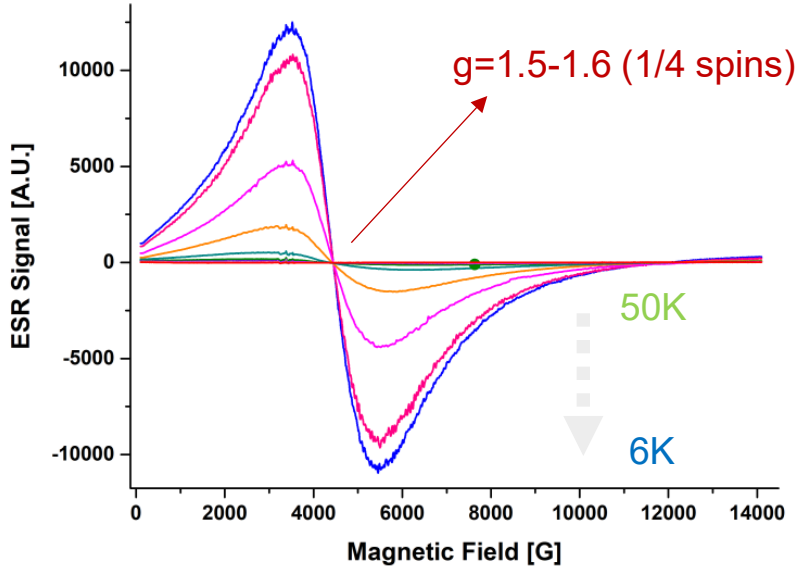
Curie-Weiss: $C \sim ng^2S(S+1)$, n=?, g=?

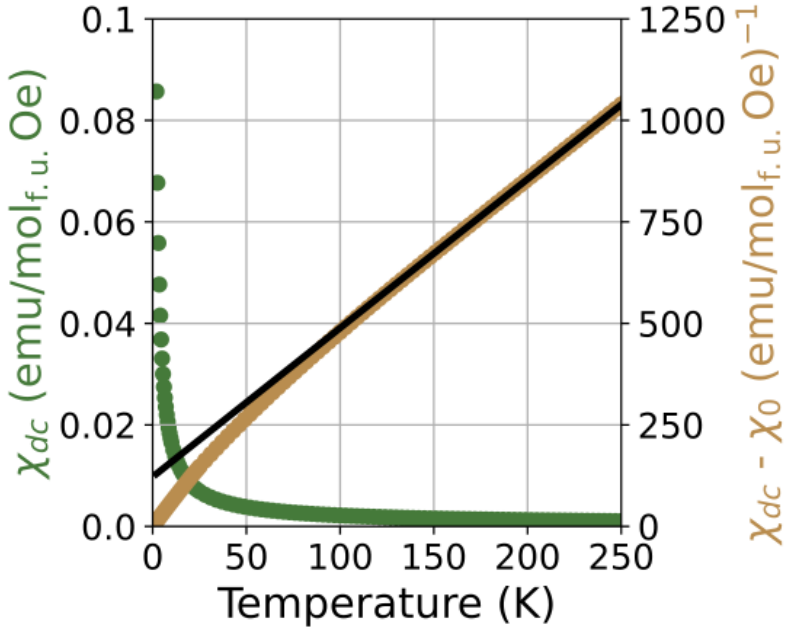
d(Ti1 – O) = 1.925/1.954 Ang

d(Ti2 – O) = 1.993/2.021 Ang

DFT

Ti2 yz	0.20189
Ti2 xy	0.20047
Ti2 xz	0.20034





2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

$K_2Ti_2(PO_4)_3 \rightarrow K_{2-x}Ti_2(PO_4)_3$

1x S=1/2 / f.u. → <1x S=1/2 / f.u.

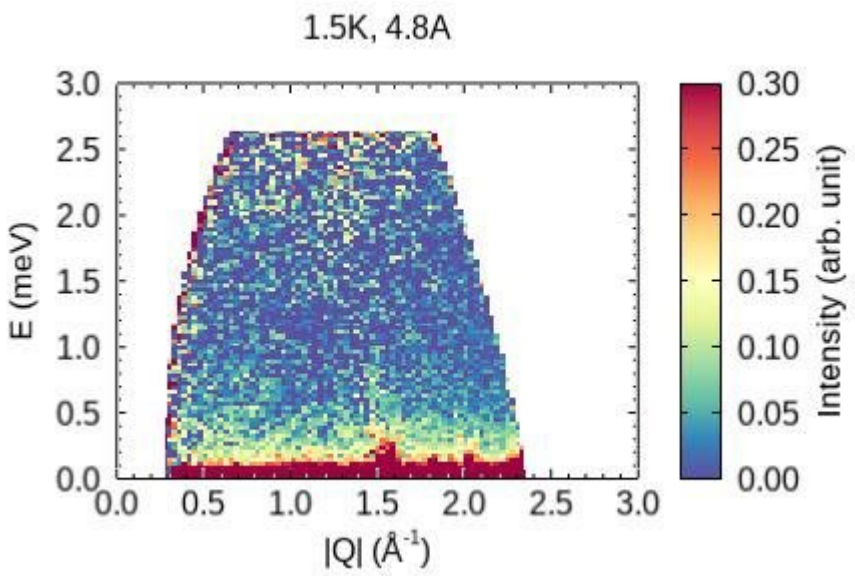
Curie-Weiss: $C \sim ng^2S(S+1)$, n=?, g=?

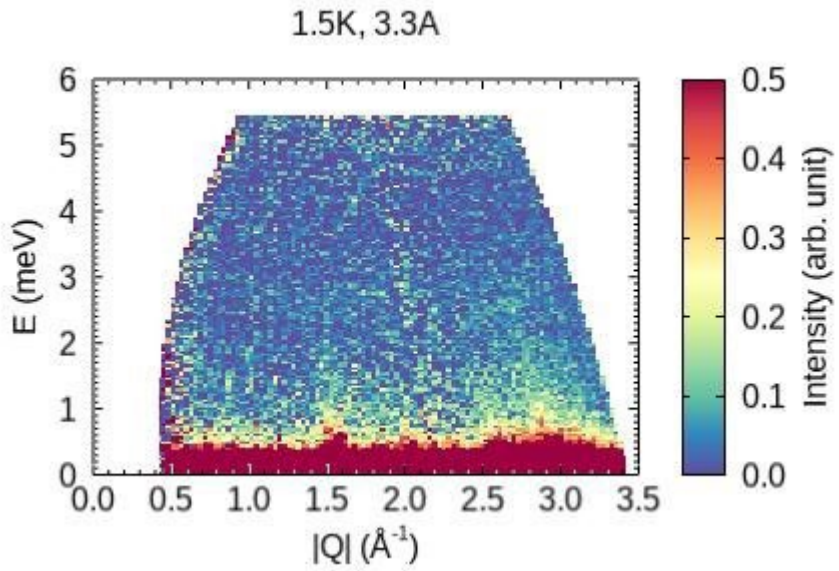
d(Ti1 – O) = 1.925/1.954 Ang

d(Ti2 – O) = 1.993/2.021 Ang

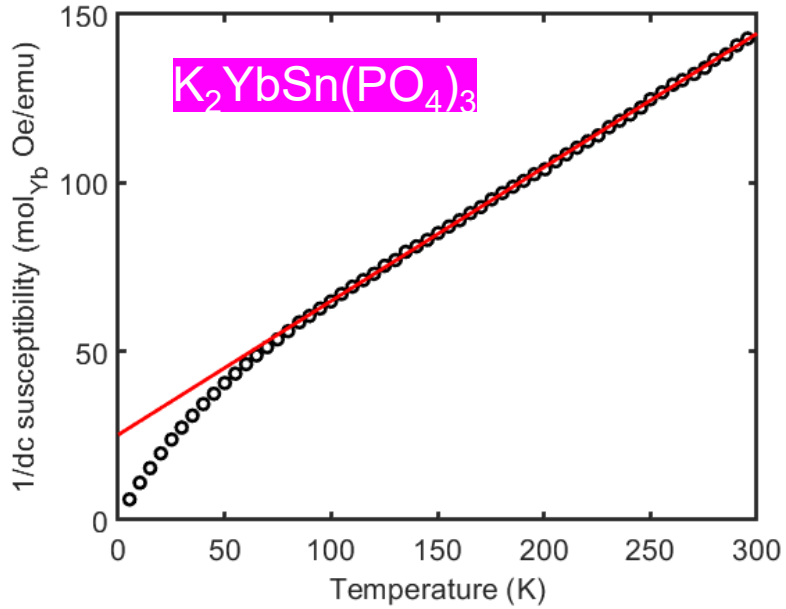
DFT

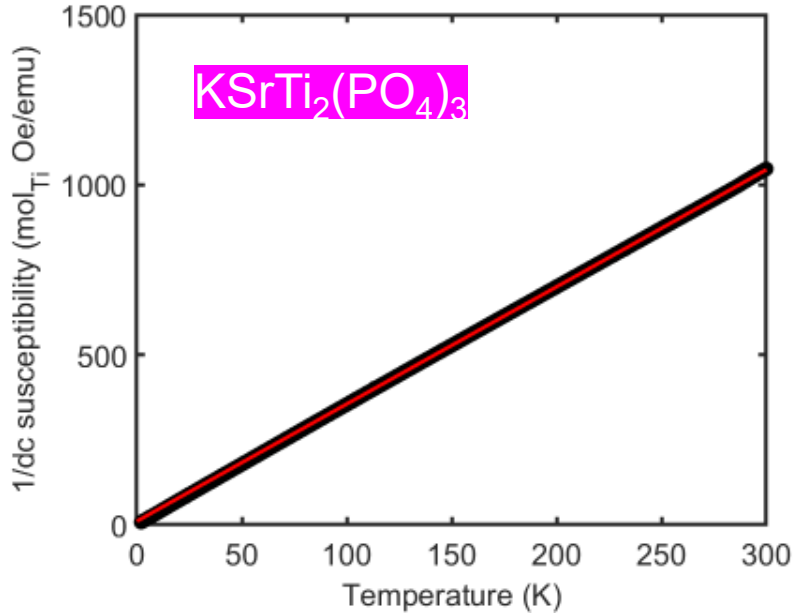
Ti2 yz	0.20189
Ti2 xy	0.20047
Ti2 xz	0.20034





2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	



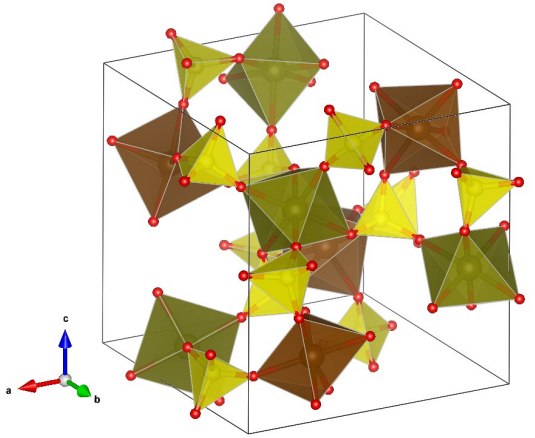


2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

site mixing (x-ray diffraction)

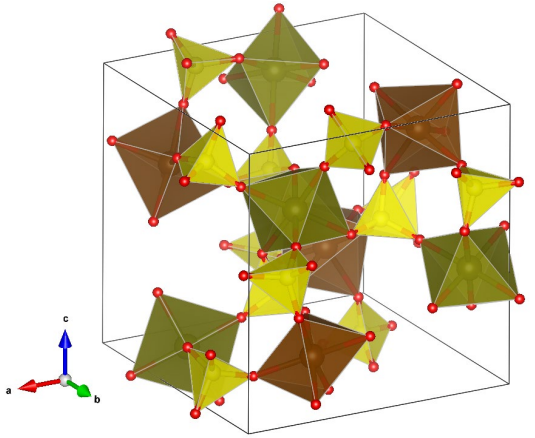
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

^{31}P NMR-MAS
(magic angle spinning)

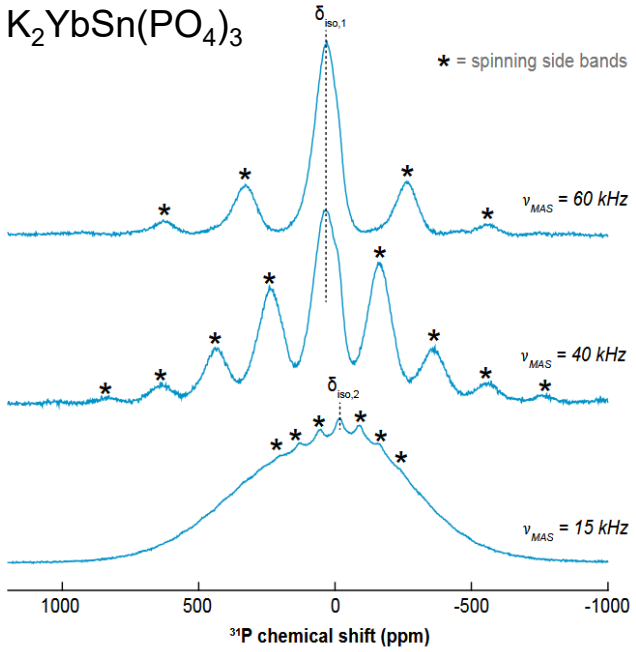


2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

^{31}P NMR-MAS
(magic angle spinning)

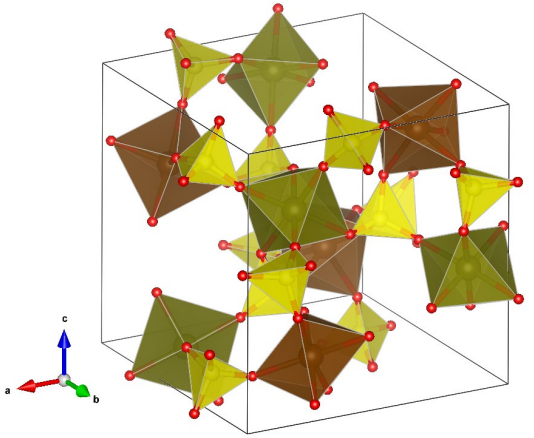


$K_2YbSn(PO_4)_3$

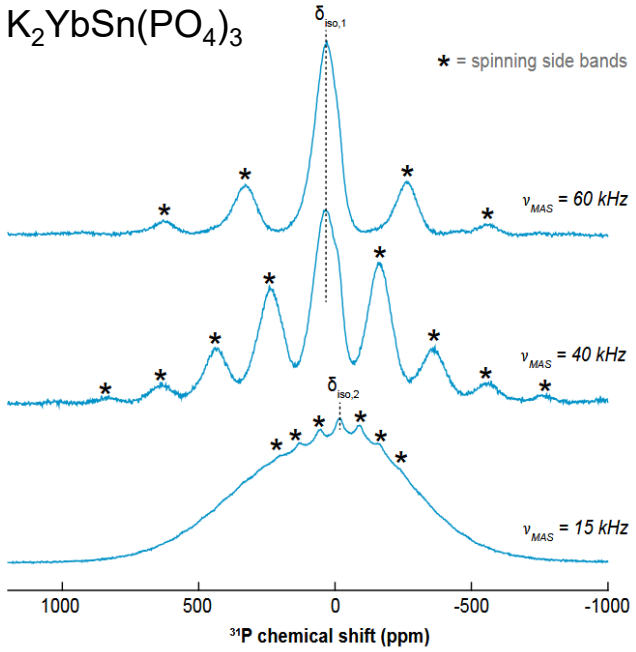


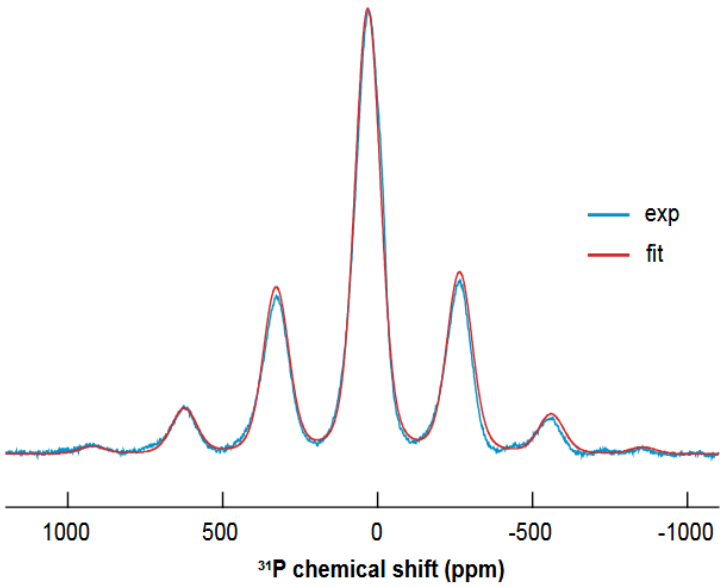
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

^{31}P NMR-MAS
(magic angle spinning)



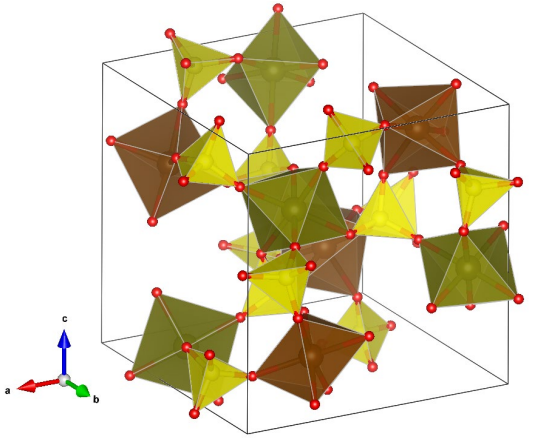
$K_2YbSn(PO_4)_3$



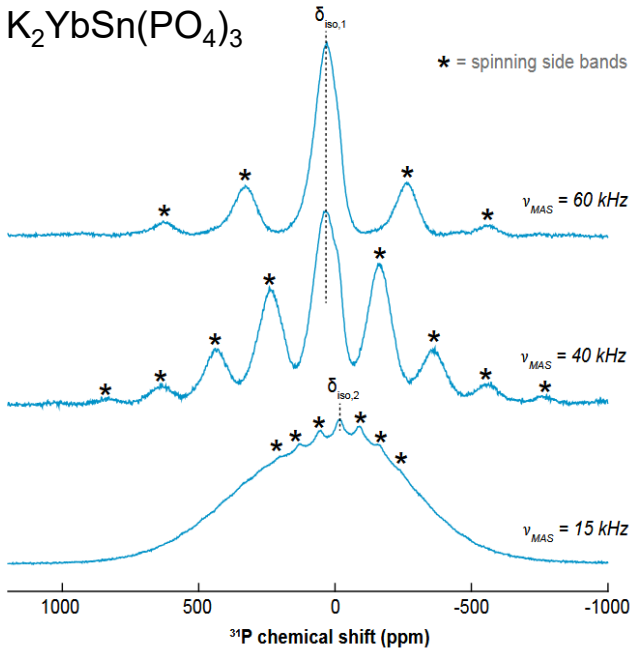


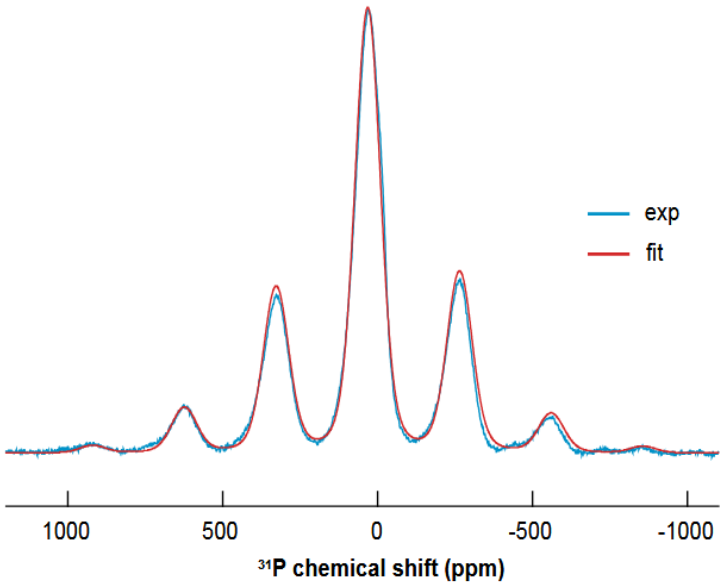
2-	3-	
	$K_2B^{3+}B'^{4+}(PO_4)_3$	$A^{+}A'^{2+}B^{3+}{}_2(PO_4)_3$
$K_2Ni_2(SO_4)_3$	$K_2CrTi(PO_4)_3$	$KBaCr_2(PO_4)_3$
$K_2Co_2(SO_4)_3$	$K_2FeSn(PO_4)_3$	$KSrFe_2(PO_4)_3$
$Cs_2Fe_2(MoO_4)_3$	$K_2Ti_2(PO_4)_3$	$KSrTi_2(PO_4)_3$
$K_2Mn_2(SO_4)_3$	$K_2YbSn(PO_4)_3$	

^{31}P NMR-MAS
(magic angle spinning)



$K_2YbSn(PO_4)_3$





$K_2Ti_2(PO_4)_3$