

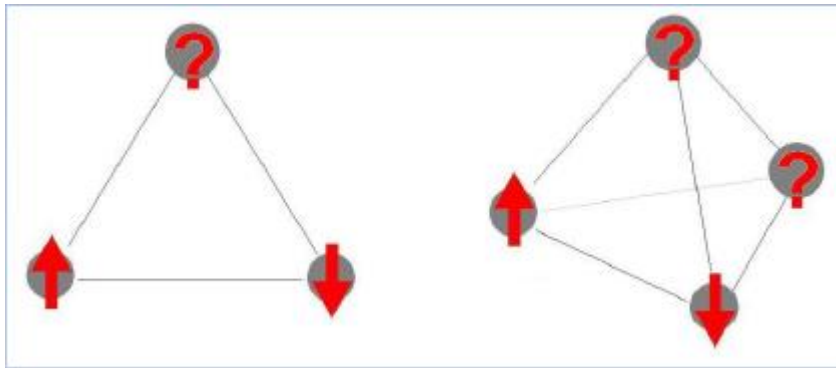
# ОСОБЕННОСТИ МАГНИТНОЙ СТРУКТУРЫ В СЛОИСТЫХ ФРУСТРИРОВАННЫХ ТРЕУГОЛЬНЫХ МАГНЕТИКАХ $M^+ABO_6$

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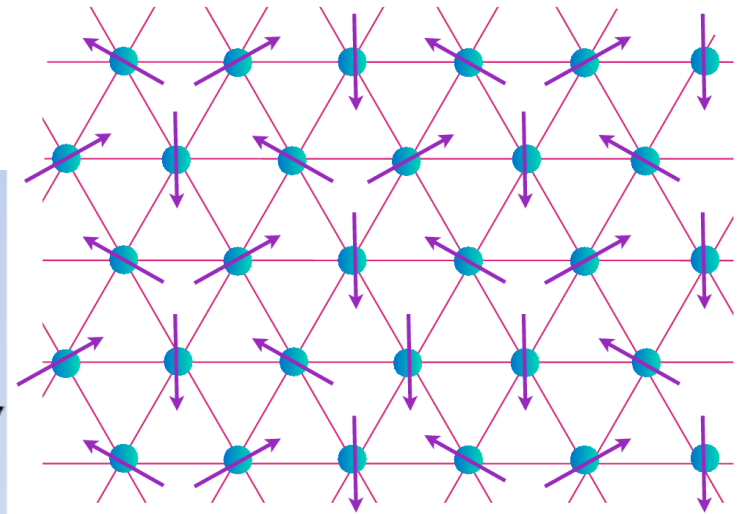
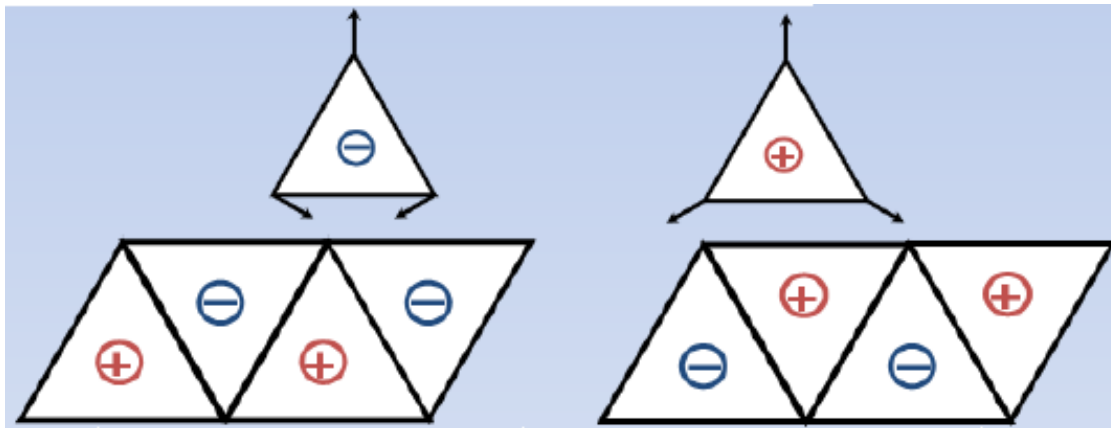
Кучугура М.Д., Курбаков А.И.  
ПИЯФ НИЦ КИ, СПбГУ



# Фрустрированные магнетики

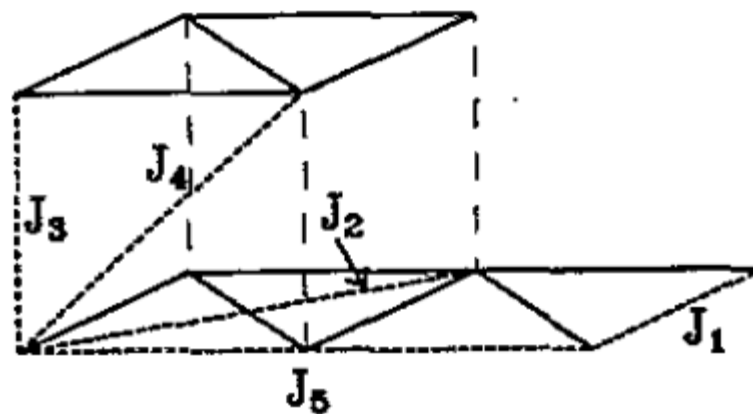


$$\mathcal{H} = -\frac{1}{2} \sum_{i \neq j} J_{ij} \mathbf{s}_i \mathbf{s}_j,$$

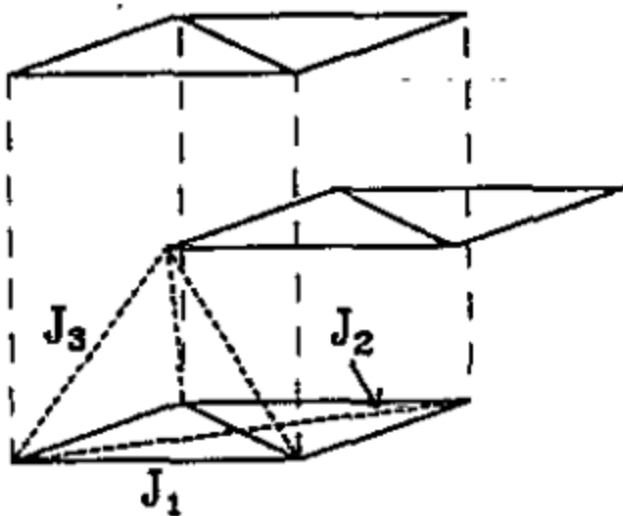


## 3d

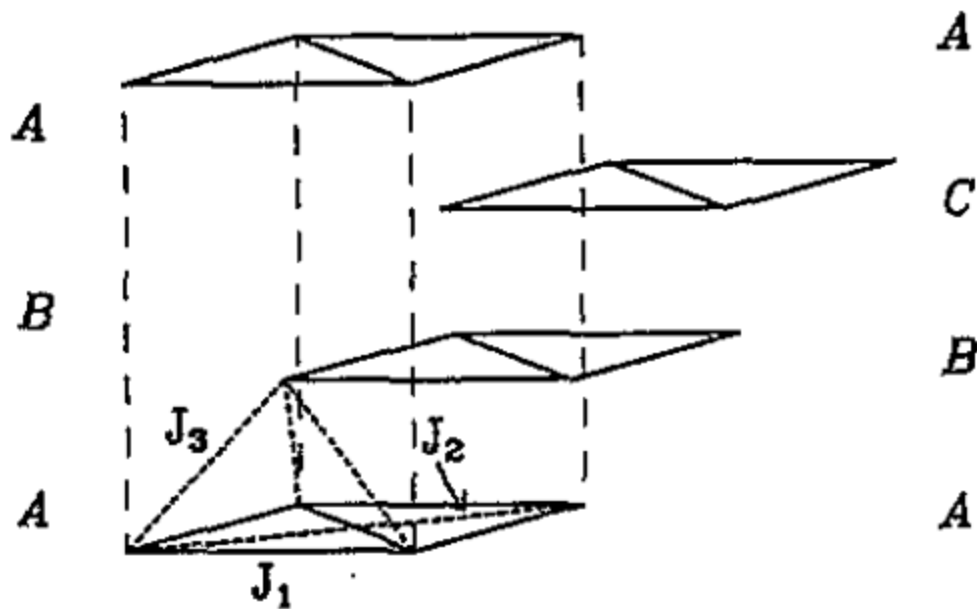
(a) ...AAA...



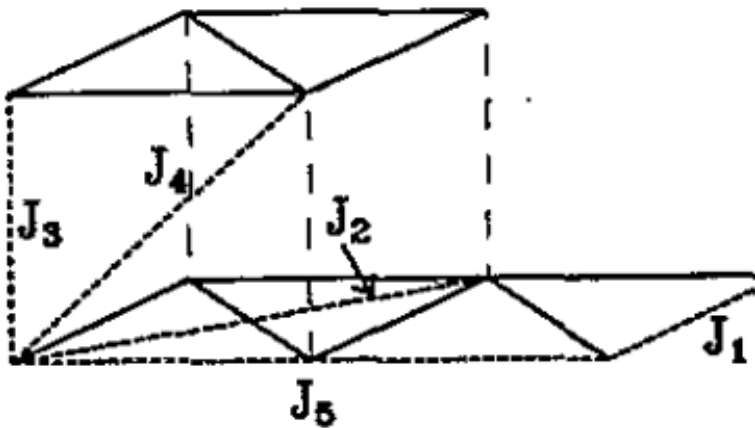
(b) ...ABAB...



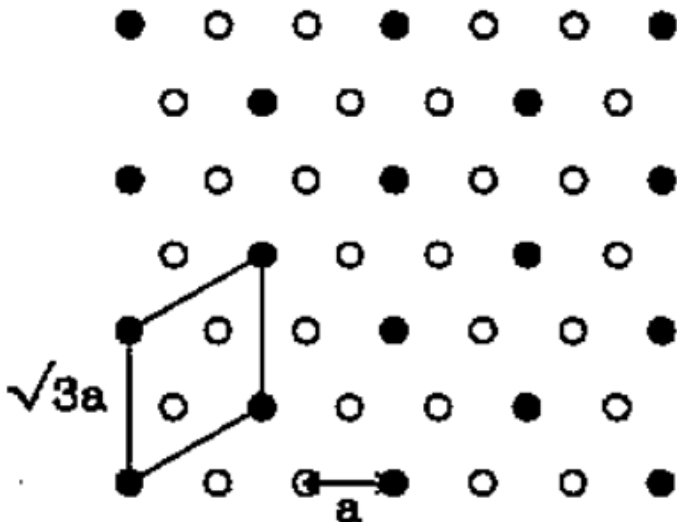
(c) ...ABCABC...



(a) ...AAA...

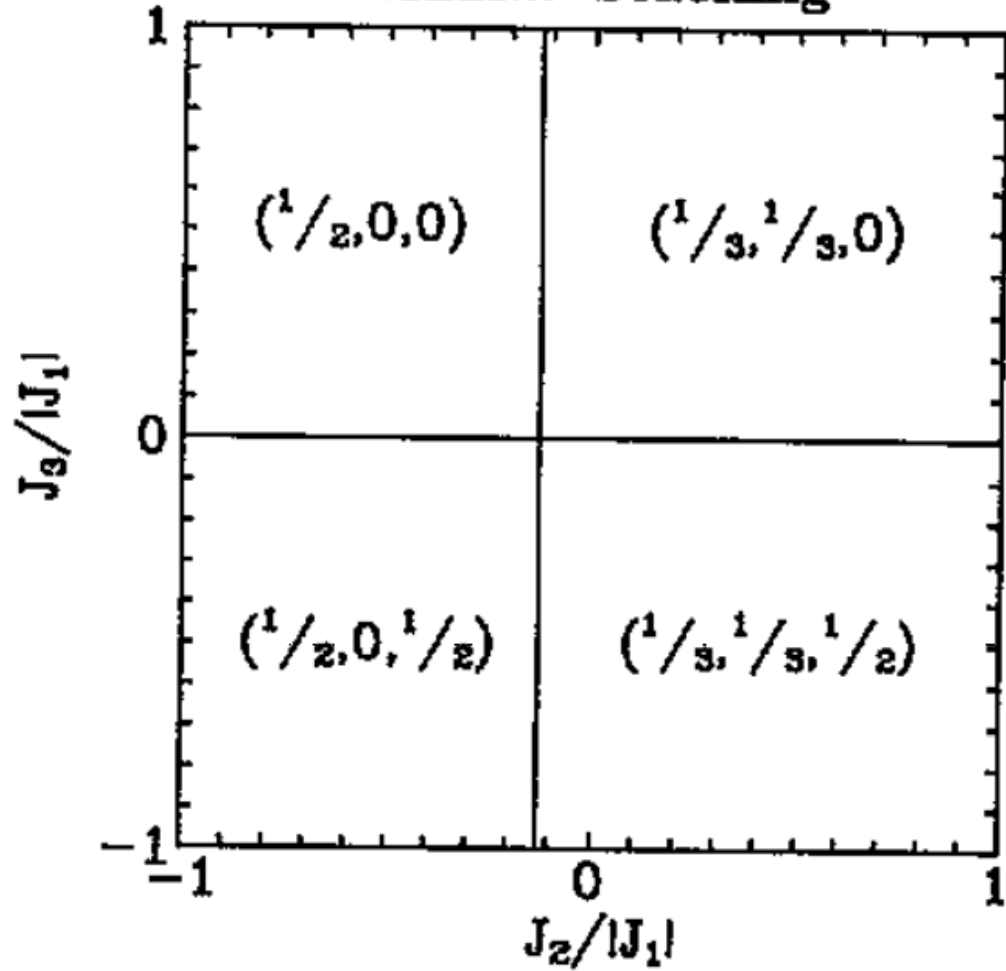


○○○○○ Unoccupied  
●●●●● Occupied

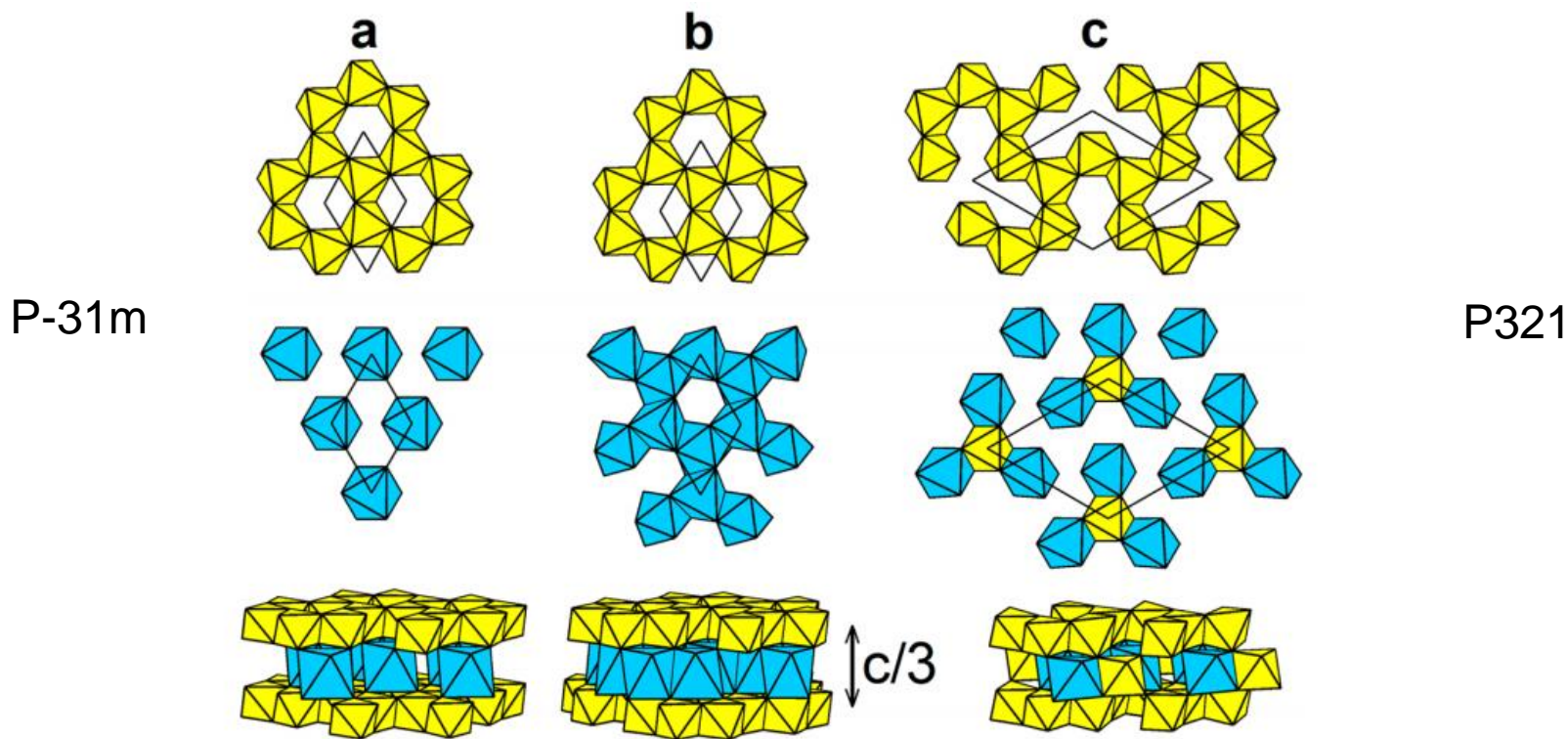


$$\bar{q} = \left(\frac{1}{s}, \frac{1}{s}, 0\right)$$

...AAA... Stacking



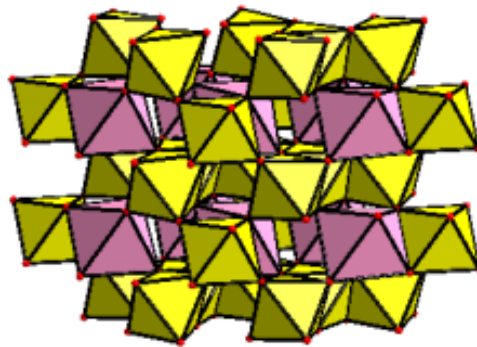
# $MnSb_2O_6$ возможные формы



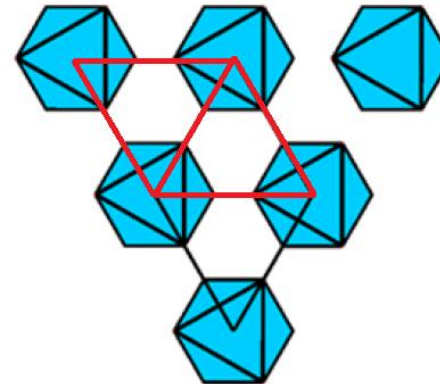
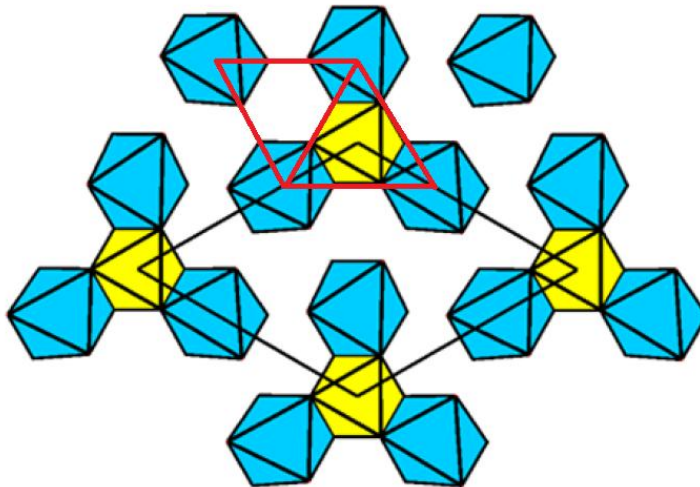
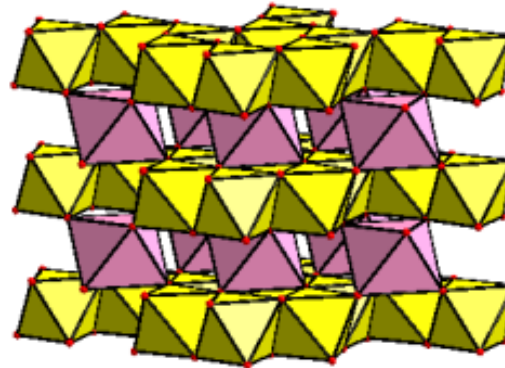
**Figure 1.** Polyhedral presentation of the crystal structures of (a)  $CaSb_2O_6$  ( $P\bar{3}1m$ ),<sup>45</sup> (b)  $NaSbO_3$  ( $Na_2Sb_2O_6$ ,  $R\bar{3}$ ),<sup>46</sup> and (c)  $MnSb_2O_6$  ( $P321$ ). (Top row) Layer of  $SbO_6$  octahedra, (middle row)  $MO_6$  octahedra ( $M = Ca^{2+}$ ,  $Na^+$ , or  $Mn^{2+}$ ), and (bottom row) layer stacking pattern.

# Различия в кристаллических структурах

*P321*

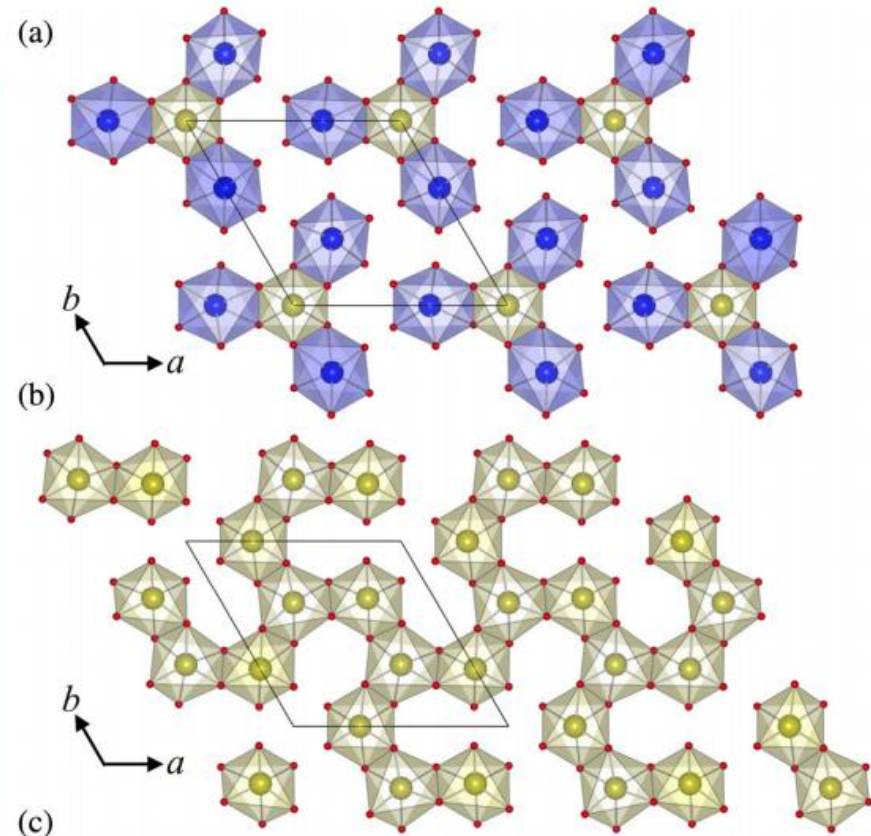
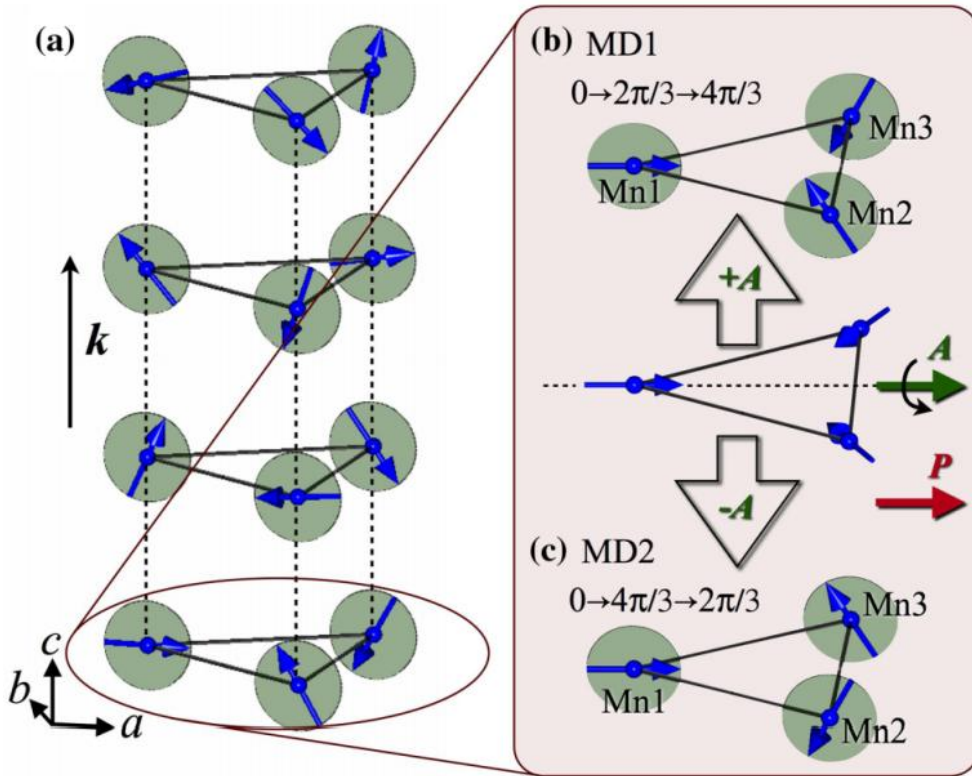


*P-31m*



# $MnSb_2O_6$

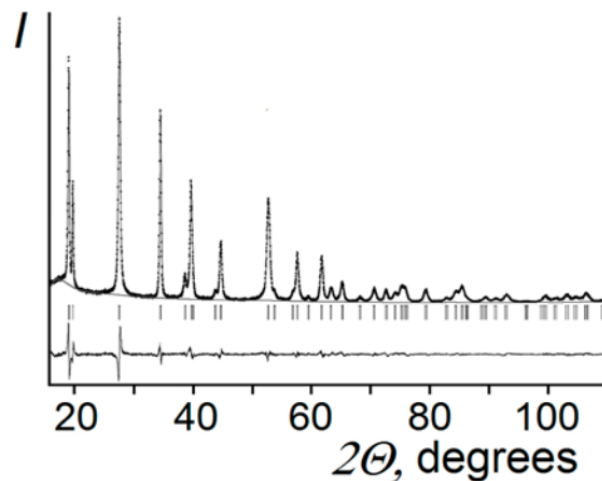
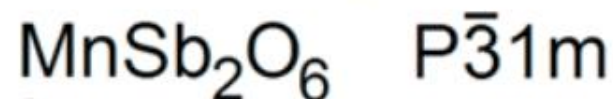
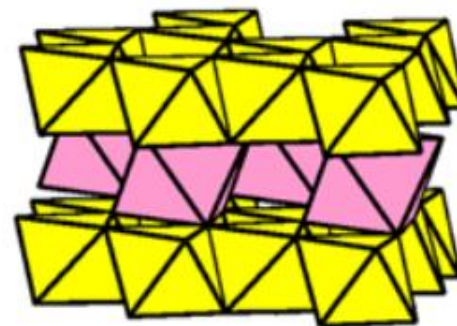
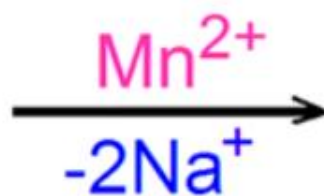
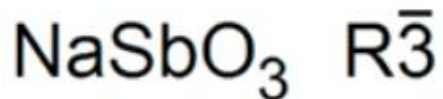
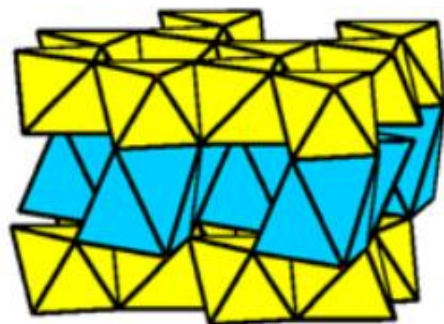
P321



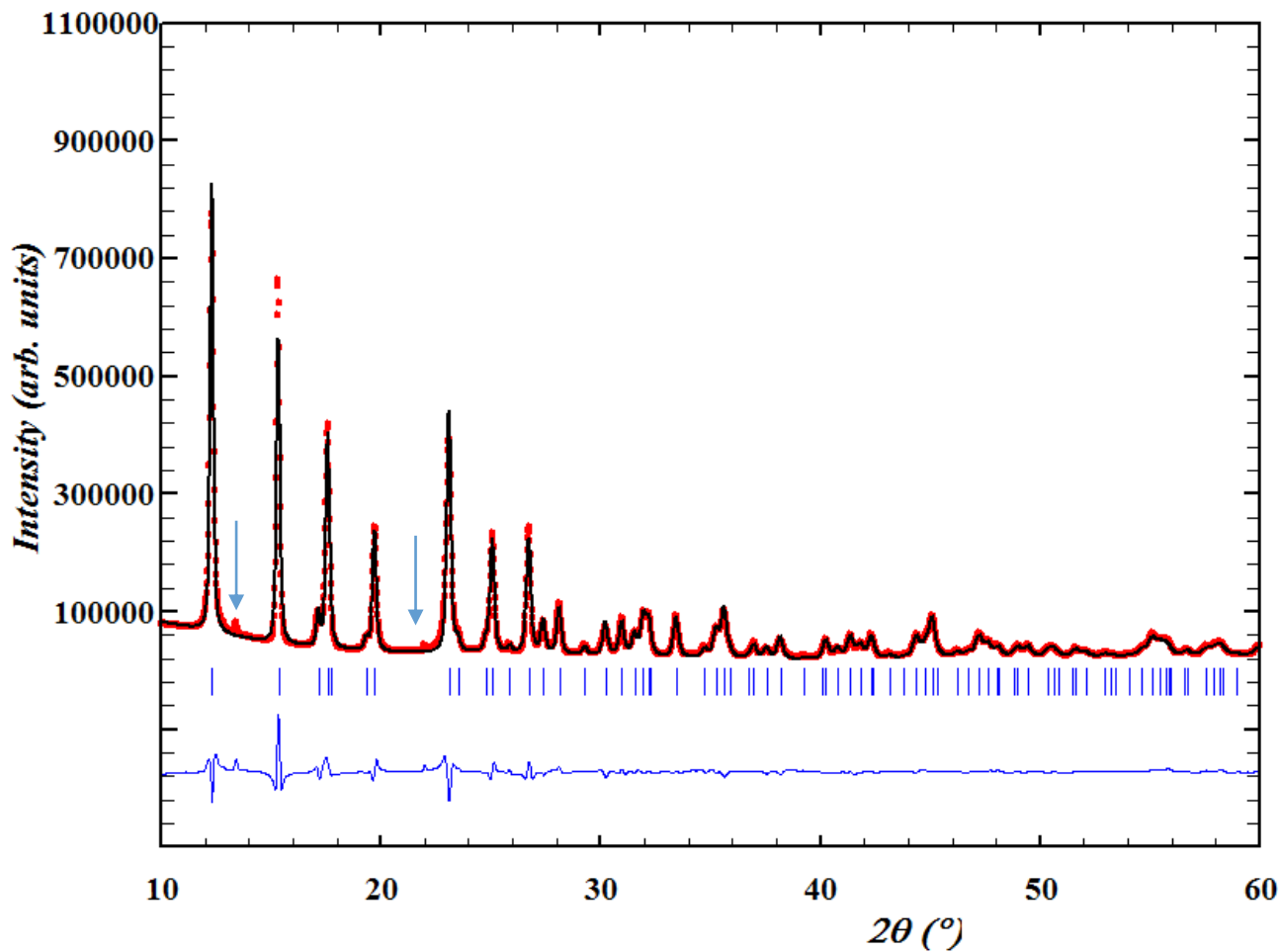
$MnSb_2O_6$  : A Polar Magnet with a **Chiral Crystal Structure** R. D. Johnson, K. Cao, L. C. Chapon, F. Fabrizi, N. Perks, P. Manuel, J. J. Yang, Y. S. Oh, S.-W. Cheong, and P. G. Radaelli PRL 111, 017202 (2013)

Magnetic Reversal of Electric Polarization with Fixed Chirality of Magnetic Structure in a Chiral-Lattice Helimagnet  $MnSb_2O_6$  M. Kinoshita, S. Seki, T.J. Sato, Y. Nambu, T. Hong, M. Matsuda, H.B. Cao, S. Ishiwata, and Y. Tokura PRL 117, 047201 (2016)

# Синтез





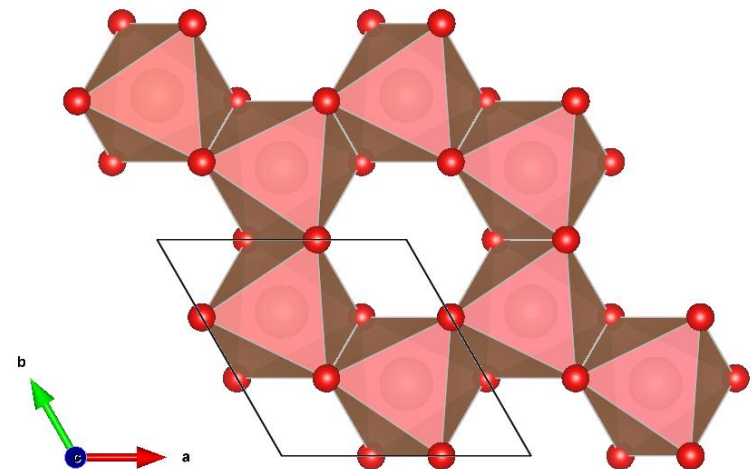
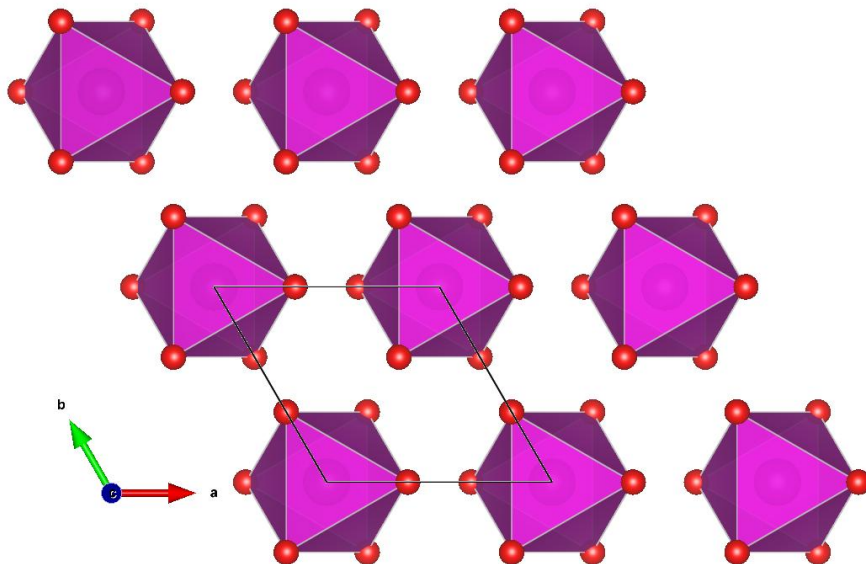
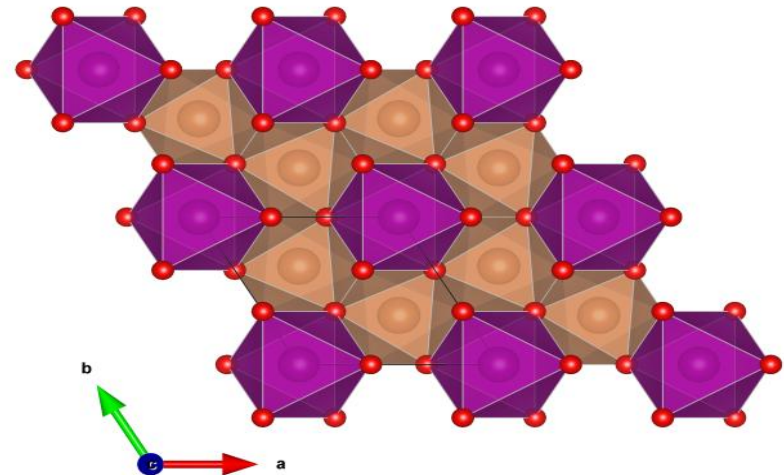
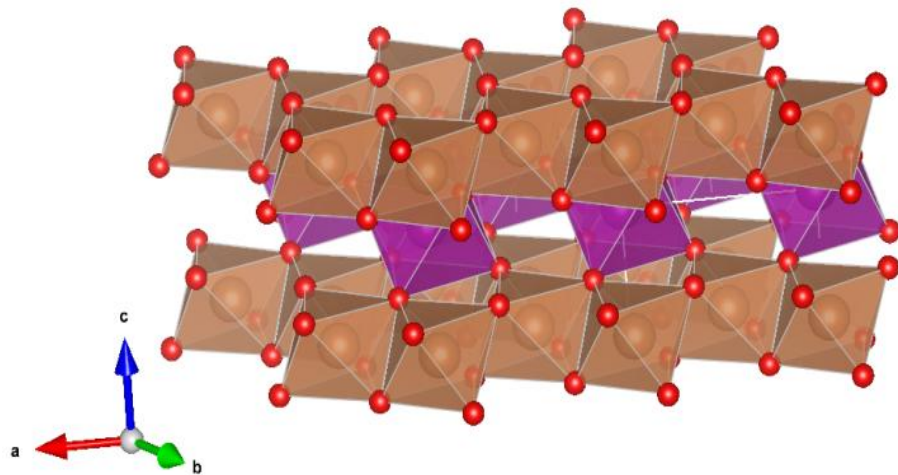


Линия BM01 ESRF,  
Гренобль, Франция

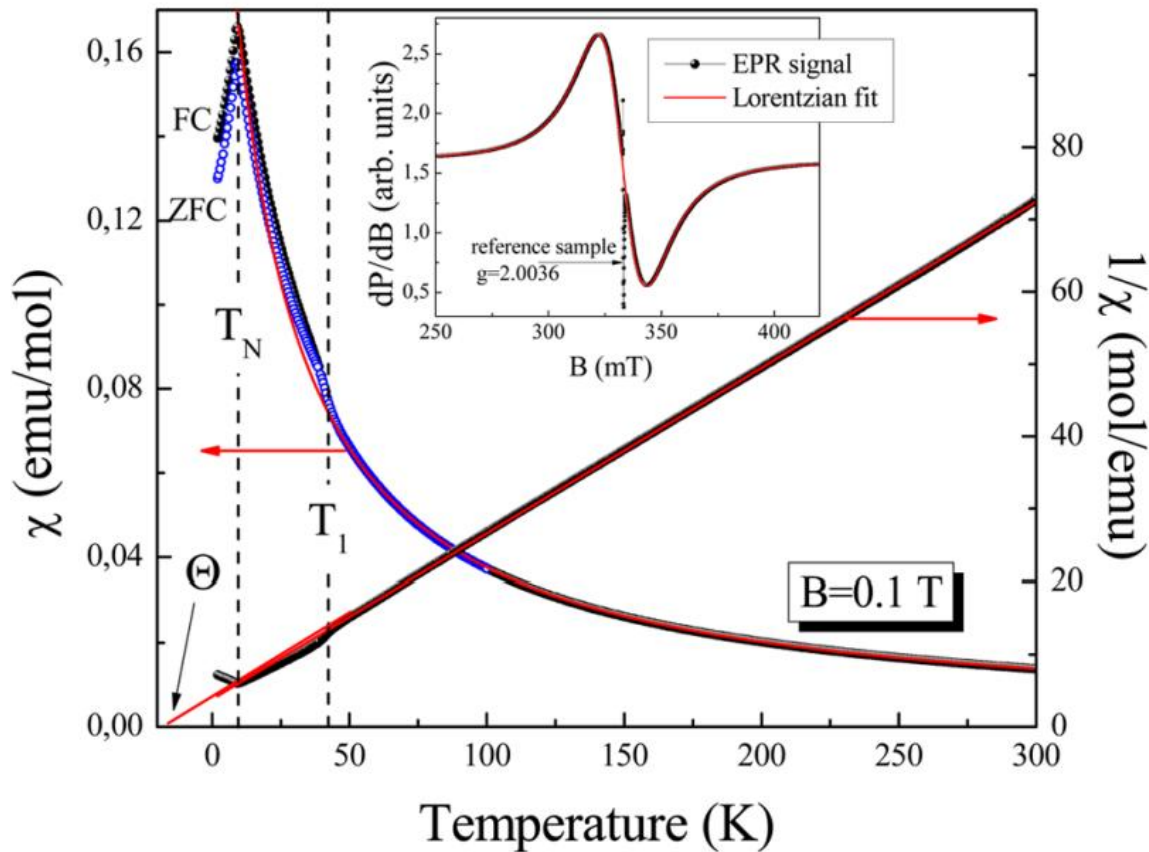
$$\lambda=0.6945 \text{ \AA}$$

Количество примеси  
не превышает 3%,  
 $\text{NaSbO}_3$

# $MnSb_2O_6$ новая структура



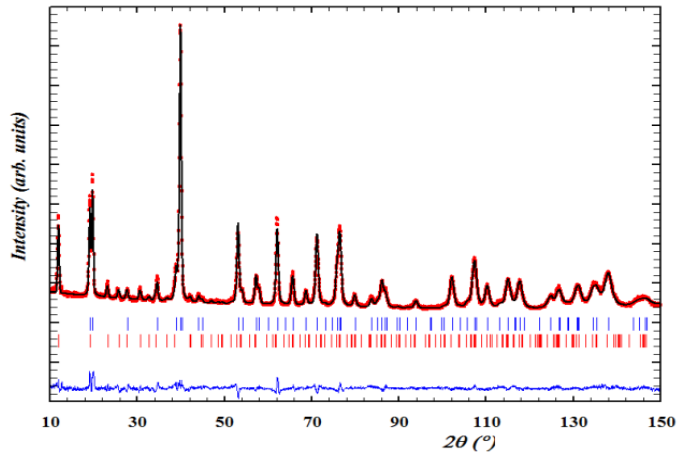
# Измерения магнитной восприимчивости



Магнитная  
восприимчивость  
 $\text{MnSb}_2\text{O}_6$  при  $B = 0.1$  T.

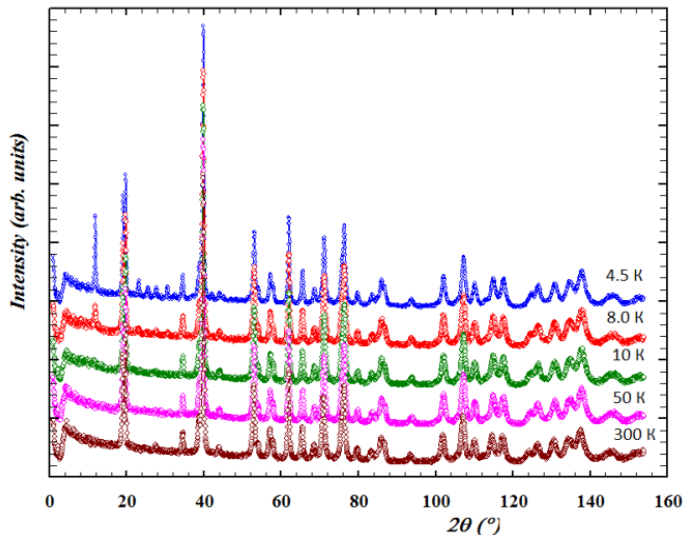
$$p_{\text{eff}} = 5.93 \mu_B$$
$$\theta = -23 \text{ K}$$

# Нейтронные данные



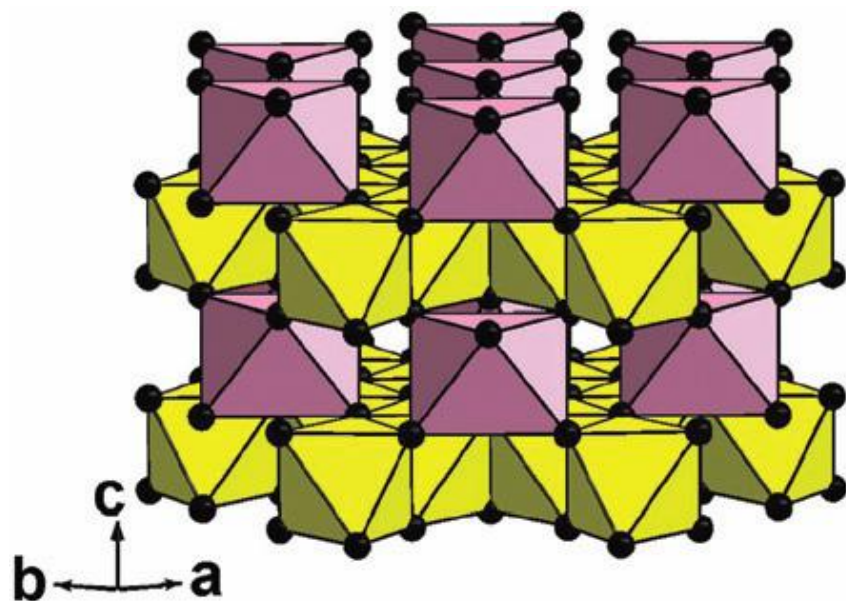
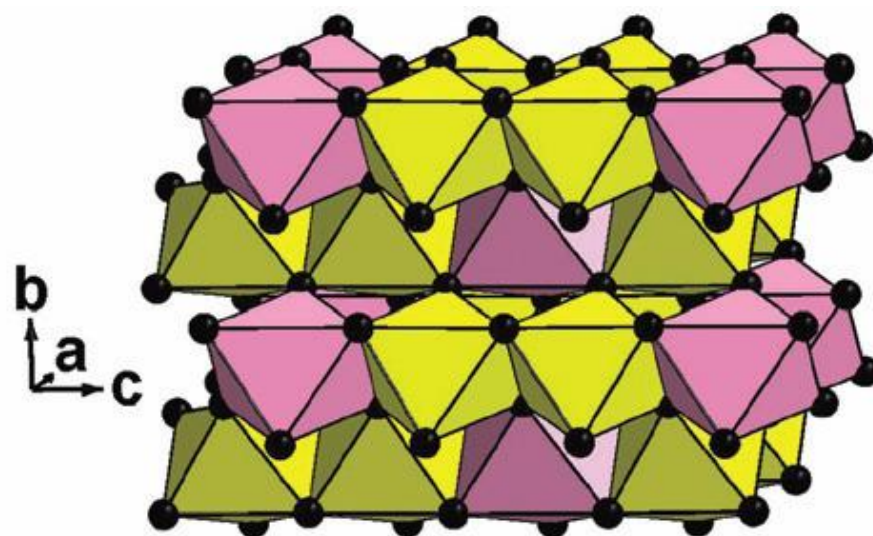
Измерения нового MnSb<sub>2</sub>O<sub>6</sub> проводились в ПИЯФ на дифрактометрах SSPD ( $\lambda = 1.753$  Å) при  $T = 300$  К и PD ( $\lambda = 1.366$  Å) при  $T = 4$  К, что для данного образца ниже температуры Нееля.

$$k=(1/3, 1/3, 1/5)$$

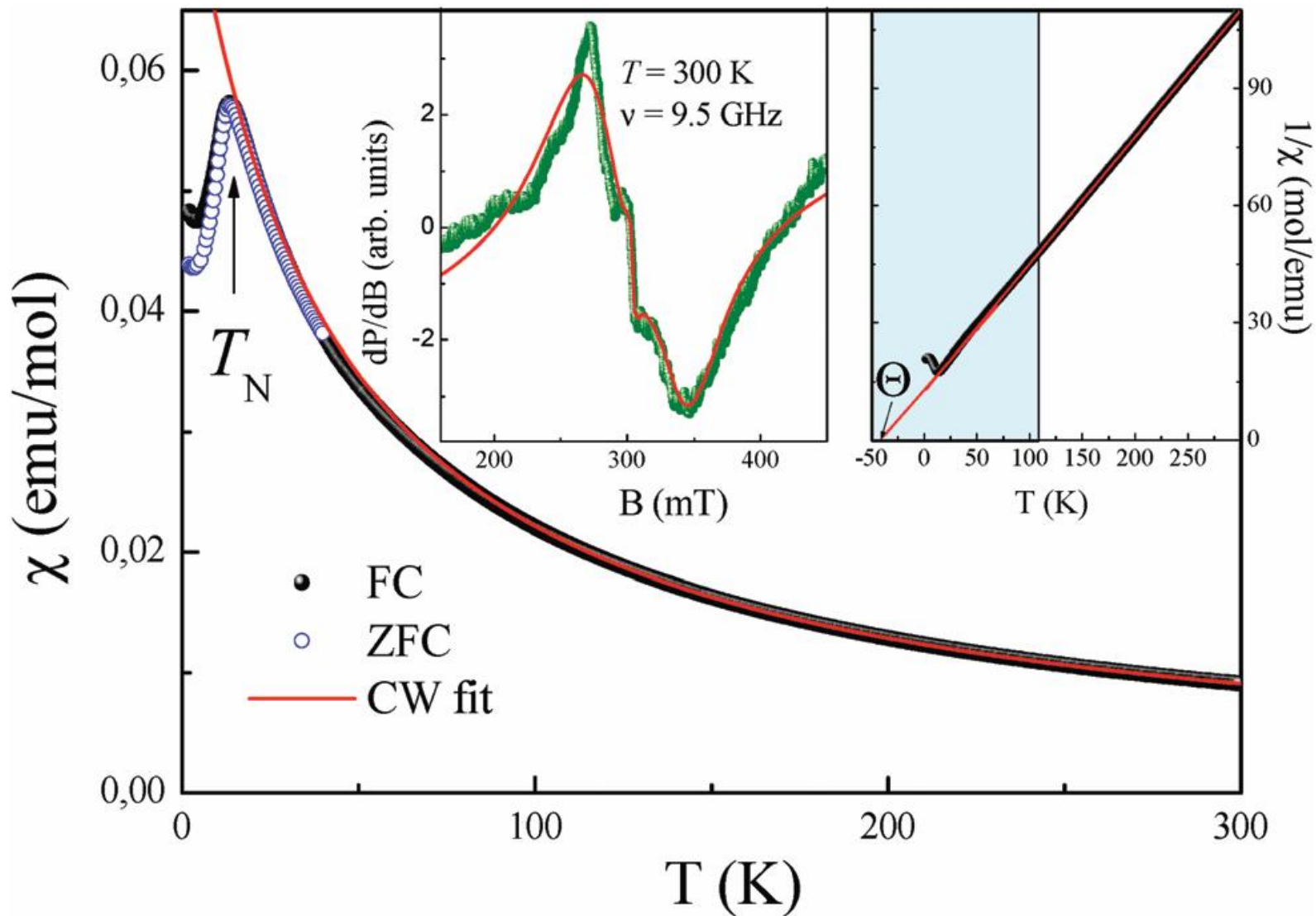


Эксперименты с большим разрешением были сделаны на дифрактометре SPODI ( $\lambda = 1.548$  Å) при  $T = 4 - 300$  К.

$$k = (0.327(2), 0.340(1), 0.196(1))$$

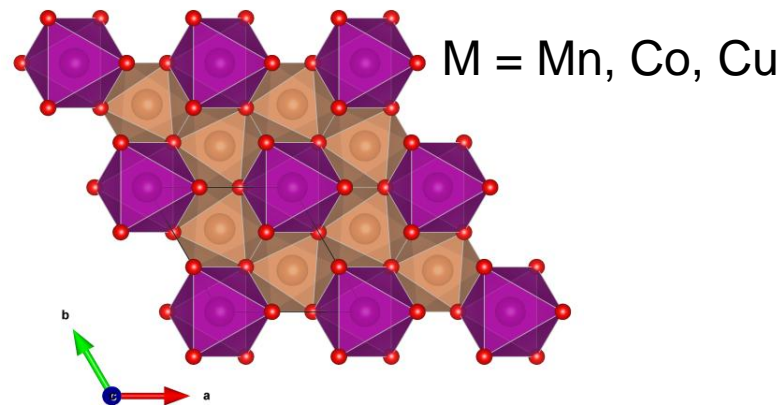
$M^+Sb_2O_6$  ( $M^+=Co, Cu, Ni$ )*P-31m**Trirutile  $P4_2/mnm$* 

# $\text{CoSb}_2\text{O}_6$



# $MSb_2O_6$

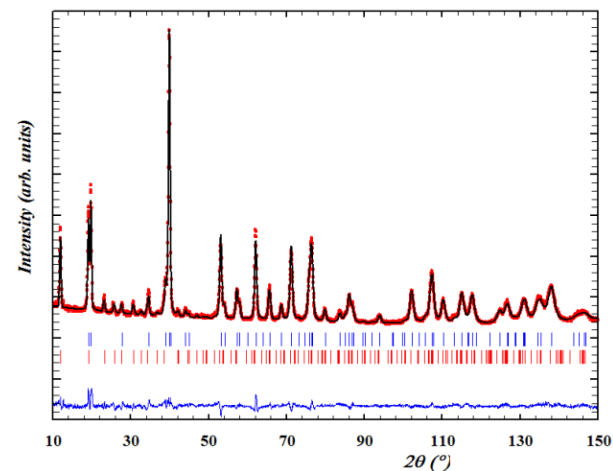
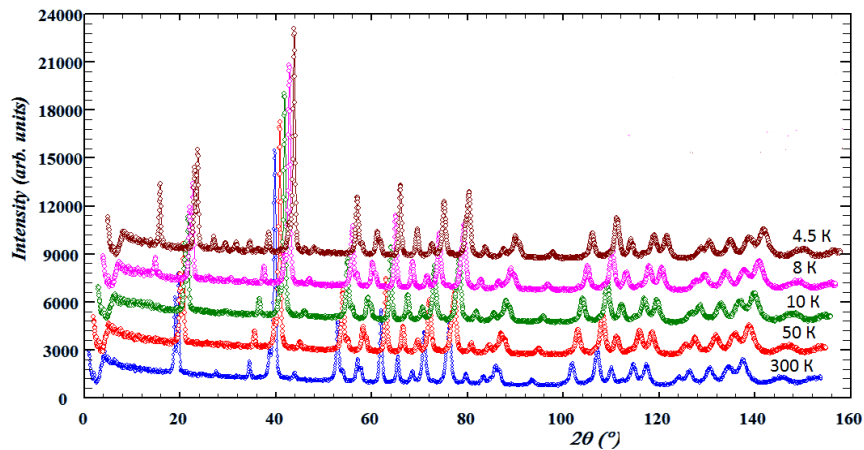
$P-31m$



$$k = (1/3, 1/3, \alpha)$$

$$\alpha = 1/5 \text{ (Mn)}, 1/6 \text{ (Co)}$$

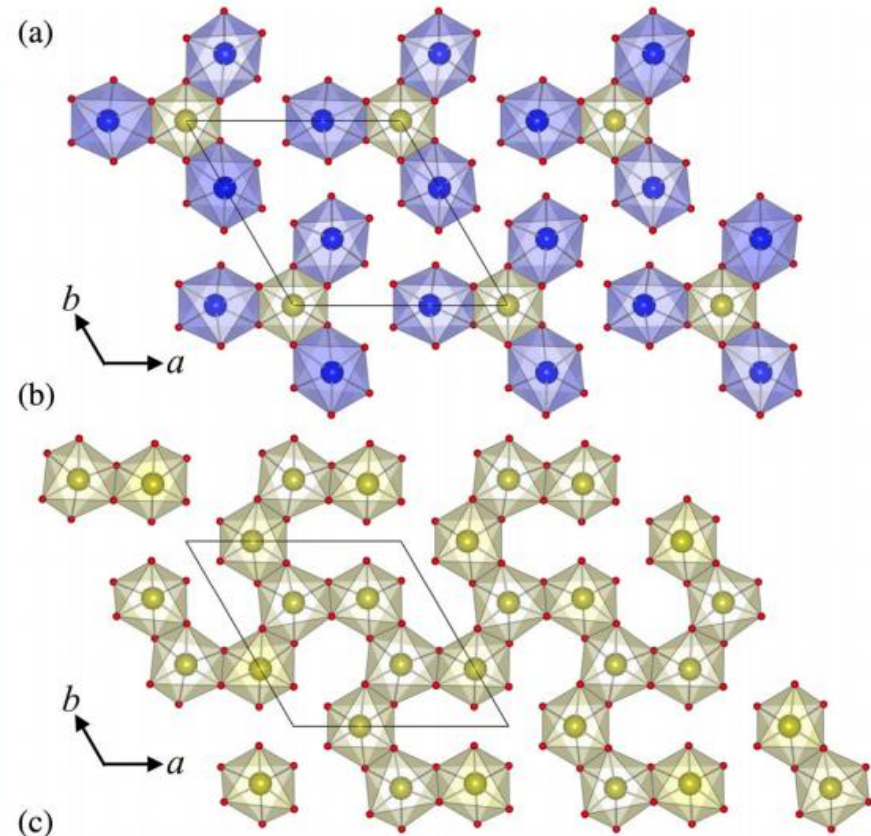
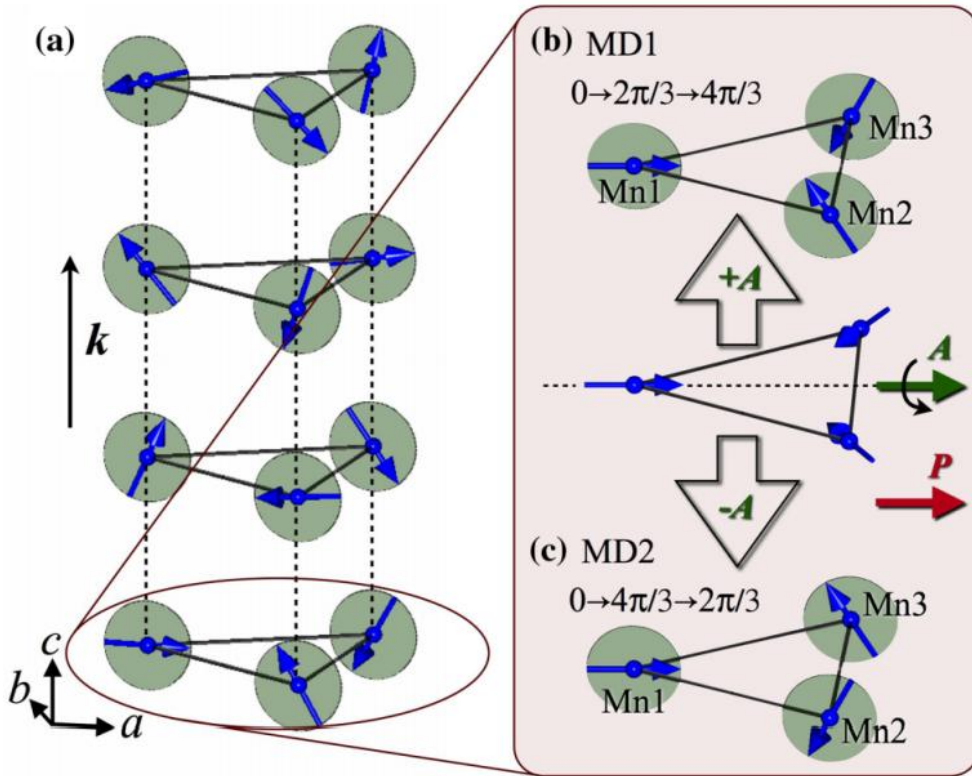
$$M = 0 \text{ (Cu)}$$



A.Yu. Nikulin, A.I. Kurbakov, M.D. Kuchugura et al.  
 Preparation and characterization of metastable trigonal  
 layered  $MSb_2O_6$  phases (M = Co, Ni, Cu, Zn, and Mg) and  
 considerations on  $FeSb_2O_6$   
*Dalton Trans.*, 2017, 46, 6059

# $MnSb_2O_6$

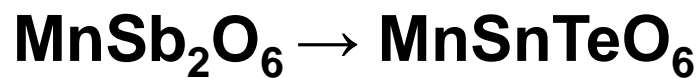
P321



$MnSb_2O_6$  : A Polar Magnet with a **Chiral Crystal Structure** R. D. Johnson, K. Cao, L. C. Chapon, F. Fabrizi, N. Perks, P. Manuel, J. J. Yang, Y. S. Oh, S.-W. Cheong, and P. G. Radaelli PRL 111, 017202 (2013)

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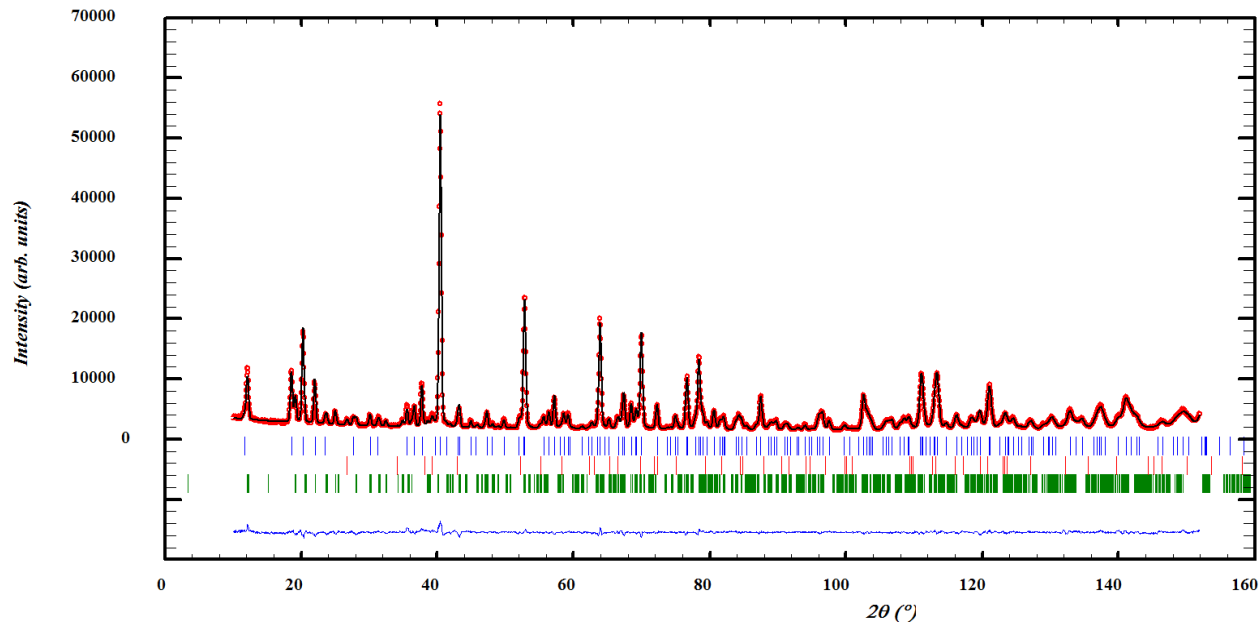




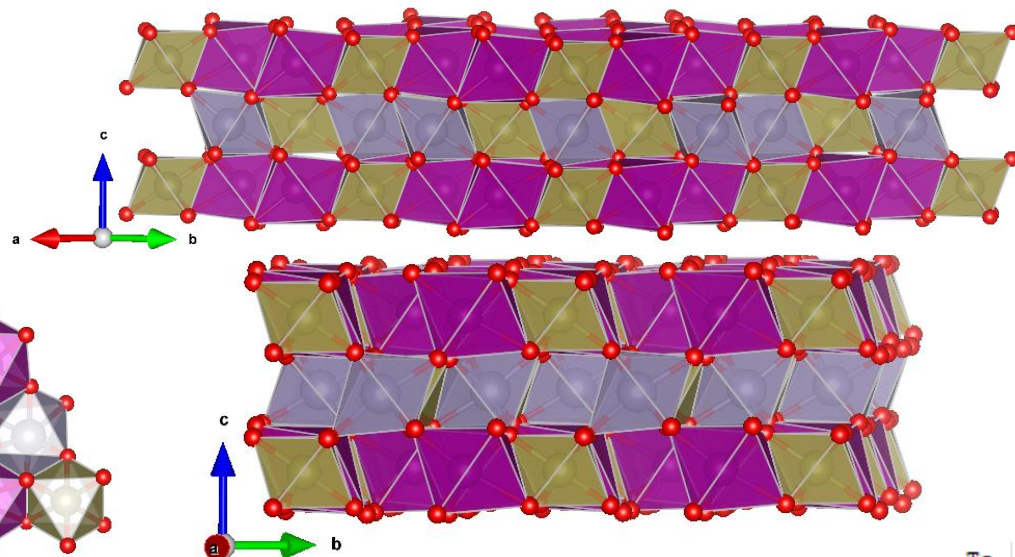
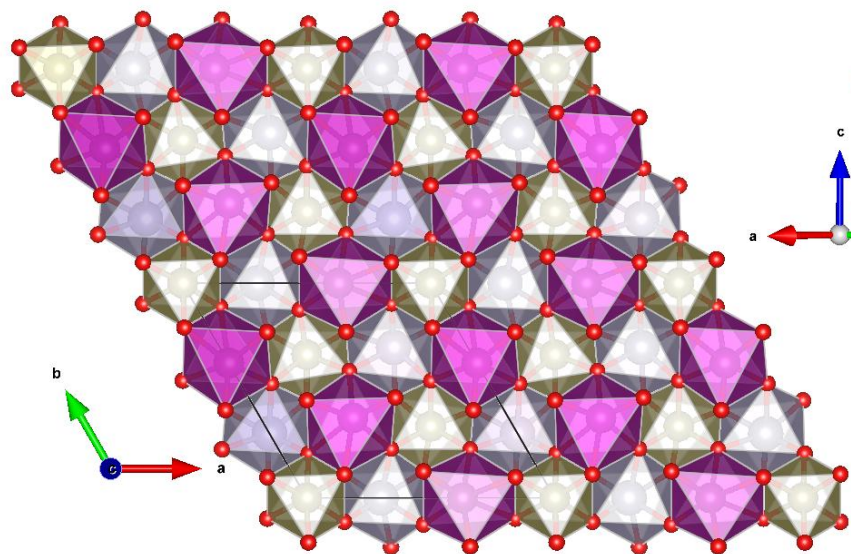
	$a, \text{Å}$	$c, \text{Å}$	$V, \text{Å}^3$
$\text{MnSb}_2\text{O}_6$	8.8011(3)	4.7241(1)	316.90
$\text{MnSnTeO}_6$	8.7822(8)	4.7928(1)	320.13

$$b_{\text{Sn}}(Z=50) = 0.62, \quad b_{\text{Te}}(Z=52) = 0.58 \cdot 10^{-12} \text{cm}$$

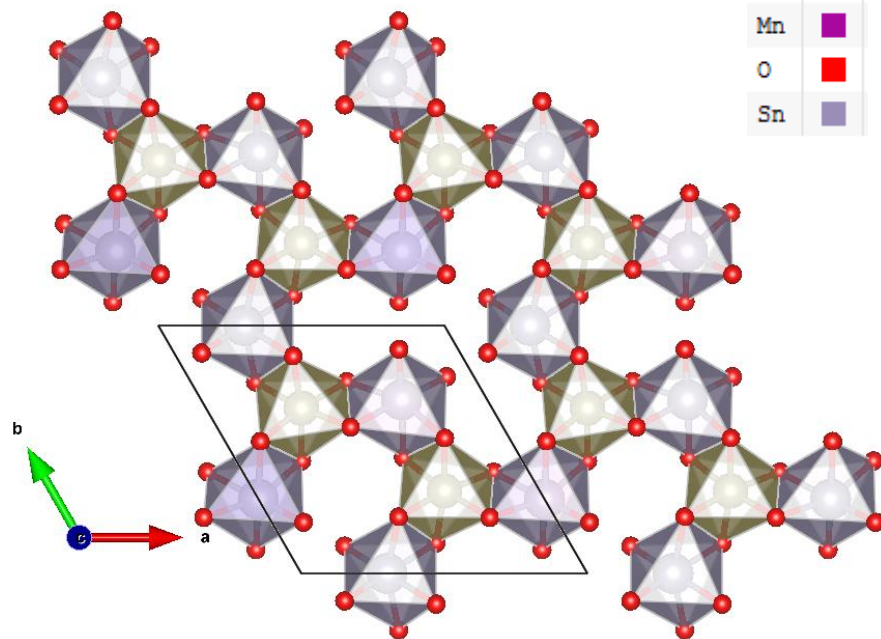
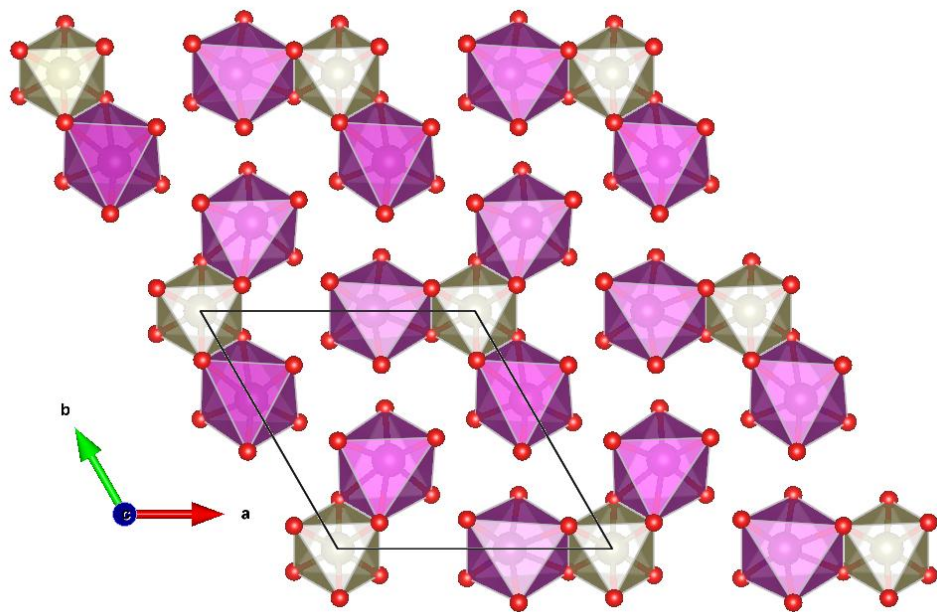
$$r_{\text{Sn}} = 0.69 \text{ Å}, \quad r_{\text{Te}} = 1.11 \text{ Å}$$

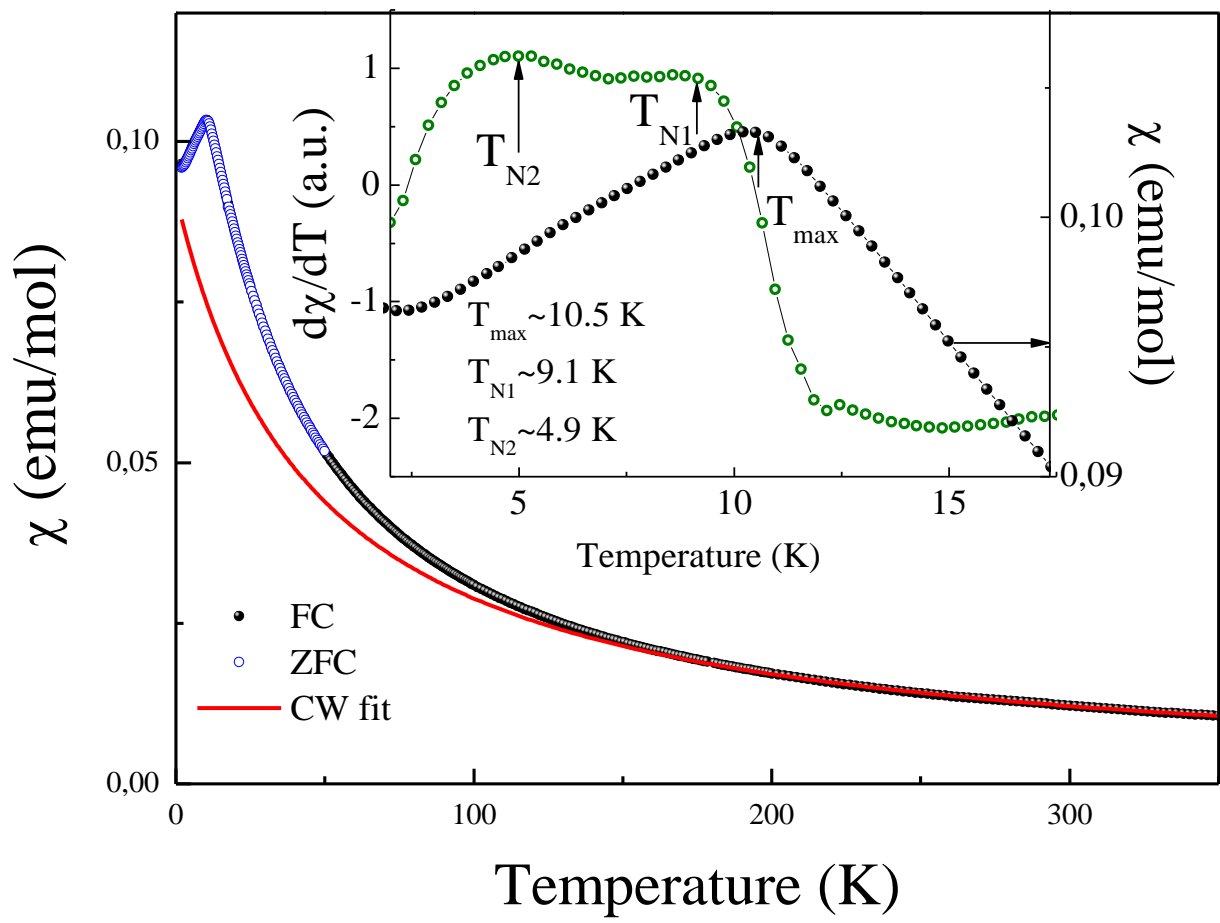


# MnSnTeO<sub>6</sub>

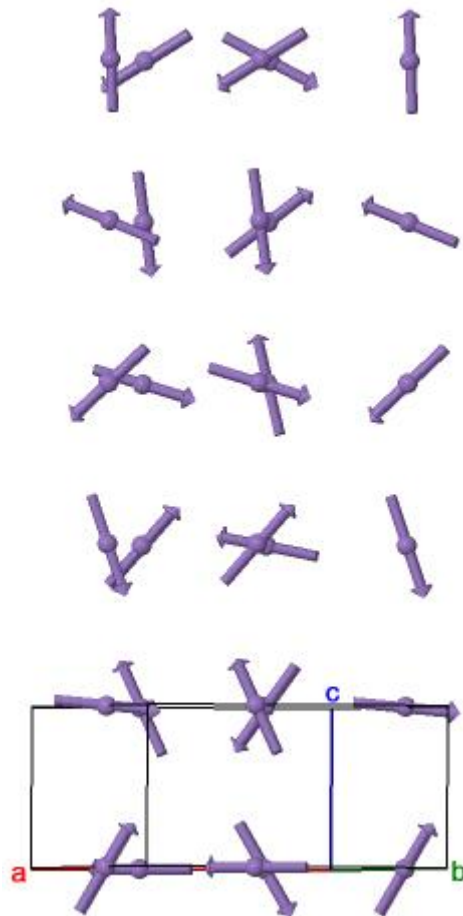


Te	
Mn	
O	
Sn	





# Magnetic structures of "triangular" compounds



$$\mathbf{k}=(0, 0, 0.182)$$

# Благодарности

**Anatoliy Senyshyn**

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**Elena Zvereva**

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Low Temperature and Superconductivity Dep.,  
RUSSIA*

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RUSSIA*

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