Смена знака спиновой киральности в моногерманидах (моносилицидах) переходных металлов

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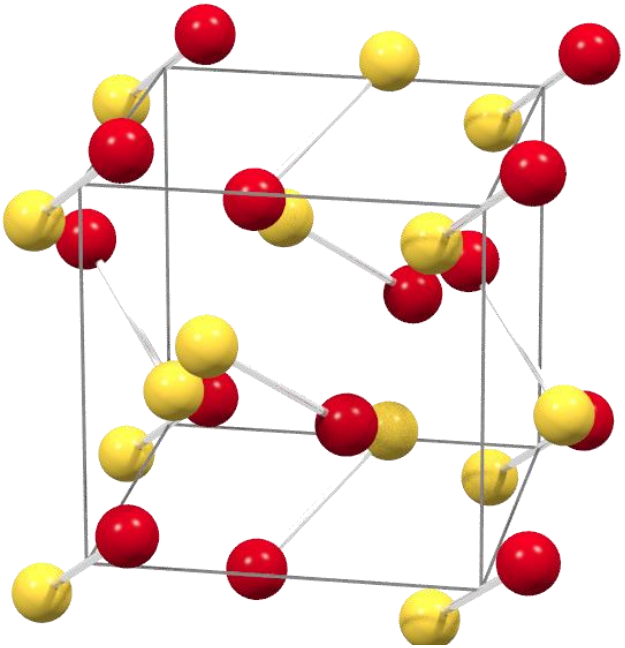
B20 structure



Examples

MnSi, FeSi, CoSi

$Mn_{1-y}Fe_ySi$, $Mn_{1-y}Co_ySi$, $Fe_{1-x}Co_xSi$

MnGe, FeGe, CoGe

$Mn_{1-y}Fe_yGe$, $Fe_{1-y}Co_yGe$, $Mn_{1-y}Co_yGe$

Si(Ge)

Me

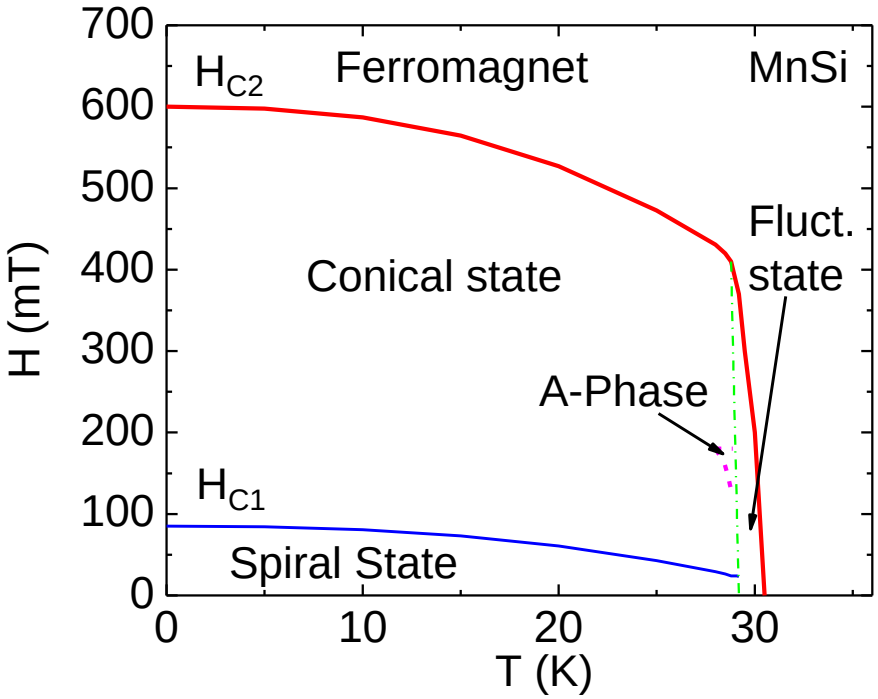
- B20-type cubic
- Space group $P2_13$, $a \approx 4.6 – 4.8$ Å
- 4 Me and 4 Si atoms are inside a unit cell

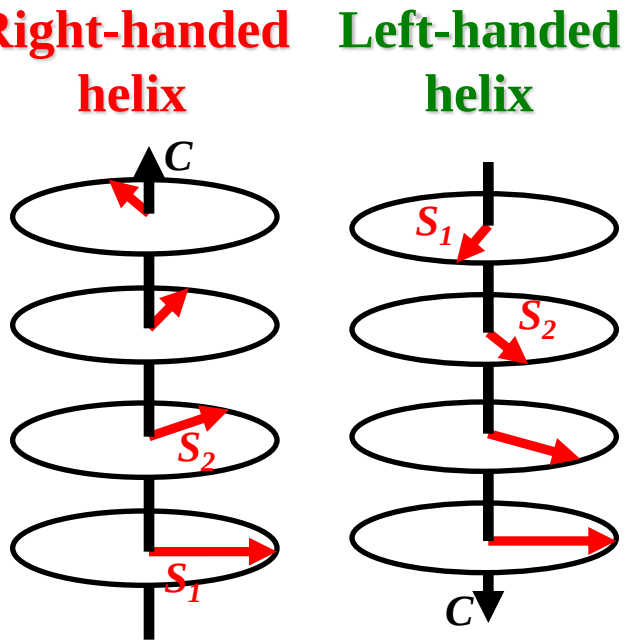
positions (u,u,u), (1/2+u,1/2-u,u), (1/2-u,-u,1/2+u), (-u,1/2+u,1/2+u)

with $u_{Mn} = 0.138$ and $u_{Si} = 0.845$

B-T phase diagram in B20 compounds

[1] Y. Ishikawa, G. Shirane, J.A. Tarvin, M. Kohgi, Phys.Rev.B 16 (1977) 4956.





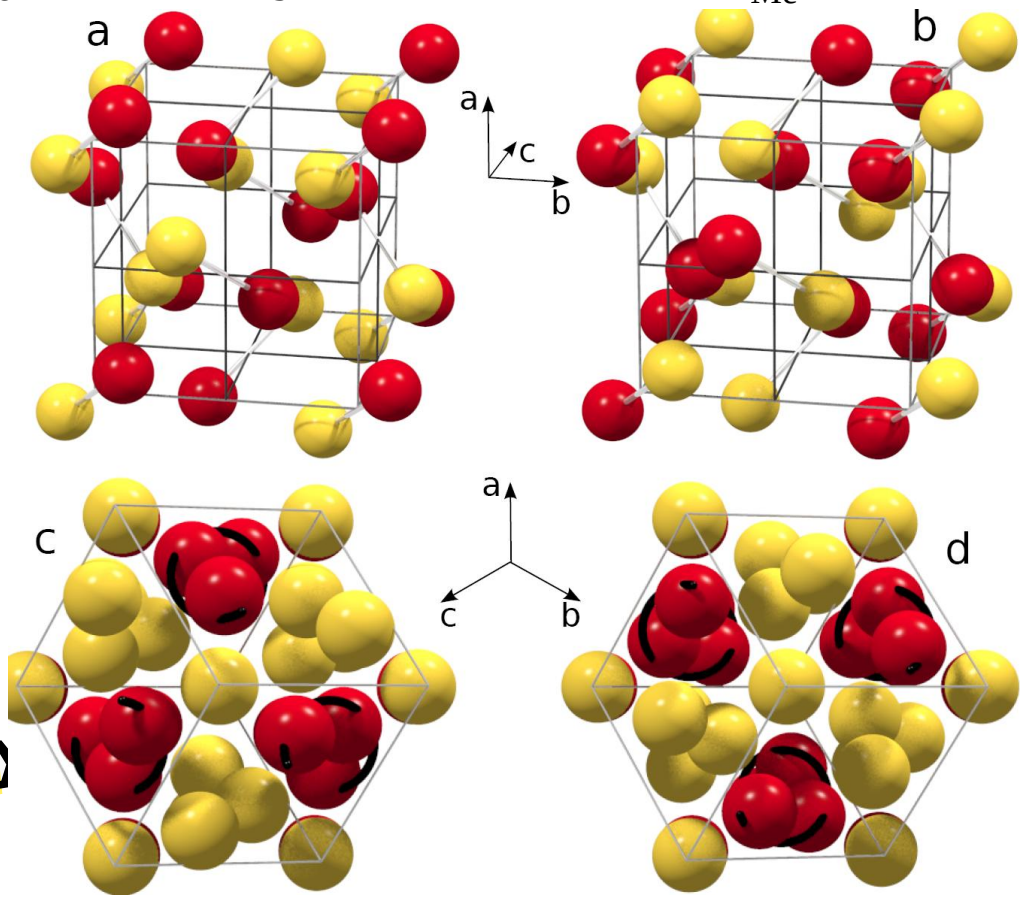
Characteristic parameters:

T_C, S, k, H_{C1}, H_{C2}

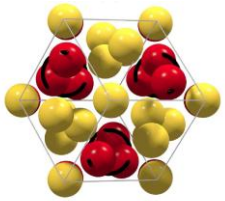
What is structural chirality?

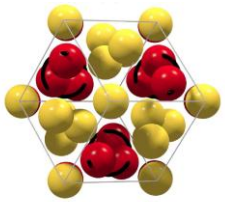
(u,u,u), (1/2+u,1/2-u,u), (1/2-u,-u,1/2+u) (-u,1/2+u,1/2+u)
with
$u_{Me} = 0.138$ и $u_{Si} = 0.845$.

(u,u,u), (1/2+u,1/2-u,u), (1/2-u,-u,1/2+u) (-u,1/2+u,1/2+u)
with $u_{Me} = 0.862$ и $u_{Si} = 0.155$.

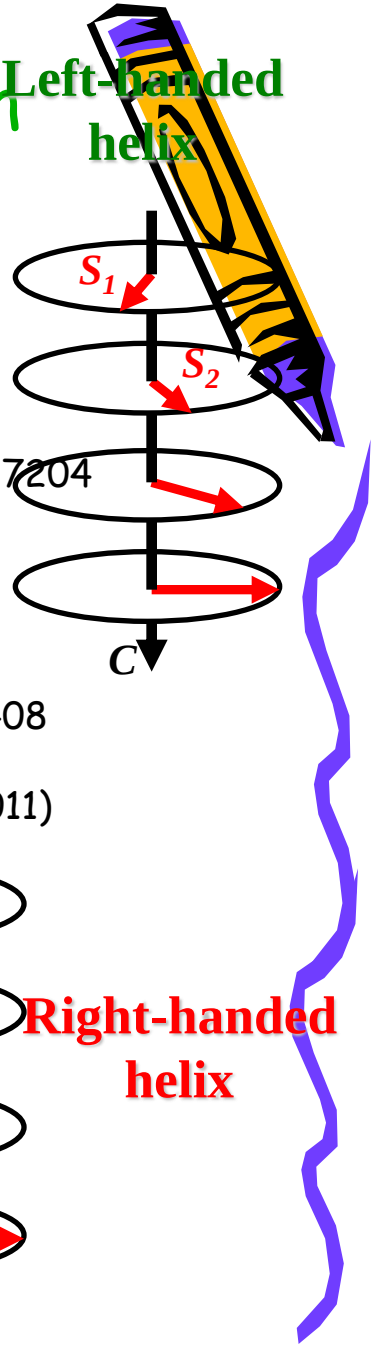


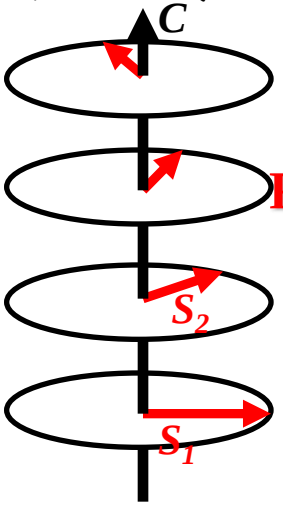
Crystal chirality and magnetic chirality in $Fe_{1-x}Co_xSi$ and $Mn_{1-y}Fe_ySi$





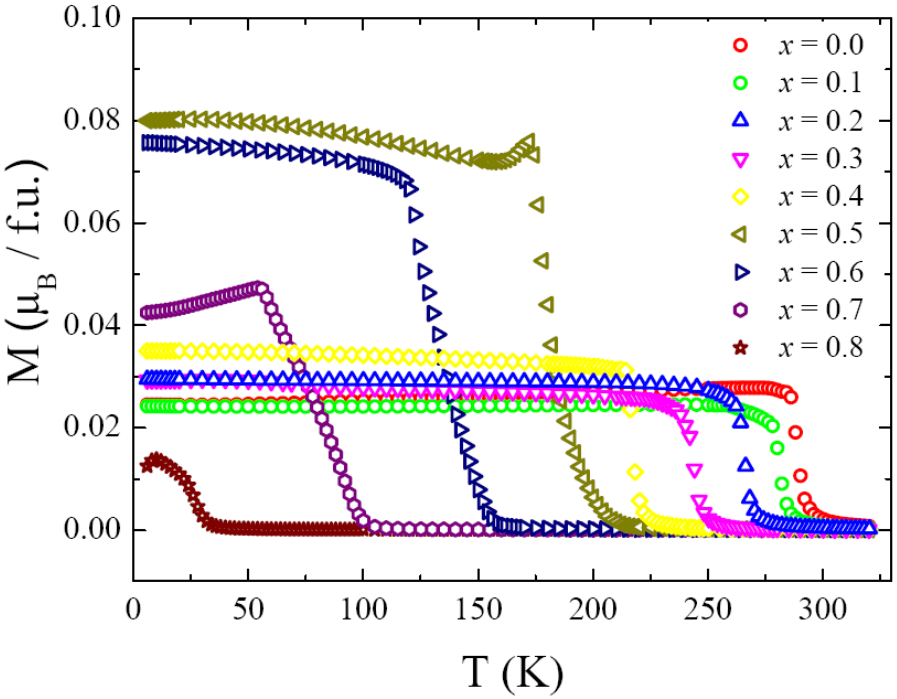
	Γ_c	γ_m	
$Fe_{1-x}Co_xSi$	(+1)	(-1)	*S. V. Grigoriev, et al, Phys. Rev. Lett. 102 (2009) 037204
$Mn_{1-y}Fe_ySi$	(+1)	(+1)	**S. V. Grigoriev, et al, Phys. Rev. B **81** (2010) 012408 ***V.A. Dyadkin, et al, Phys. Rev. B **84**, 014435 (2011)

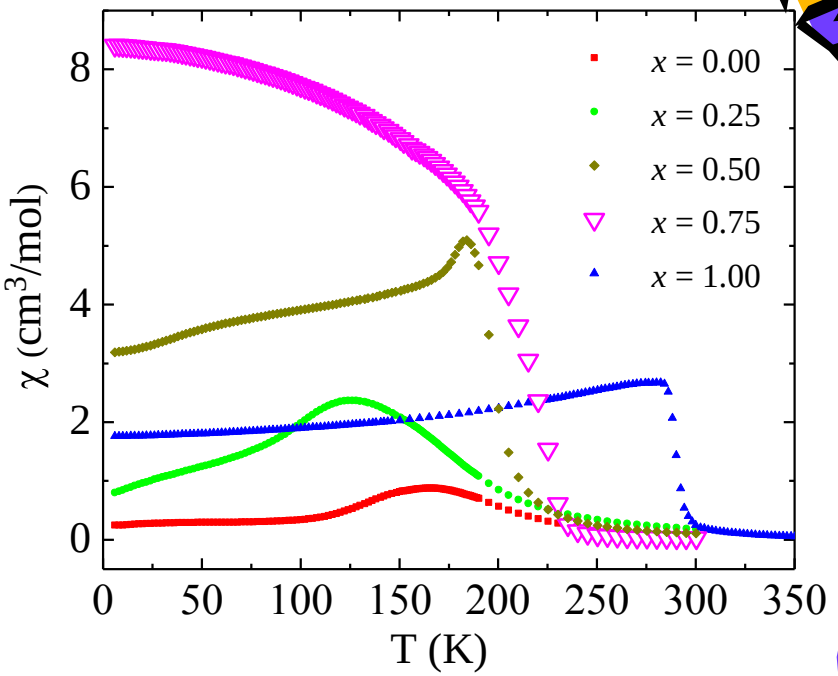




Right-handed helix

Magnetization measurements in $Fe_{1-x}Co_xGe$ and $Mn_{1-x}Fe_xGe$

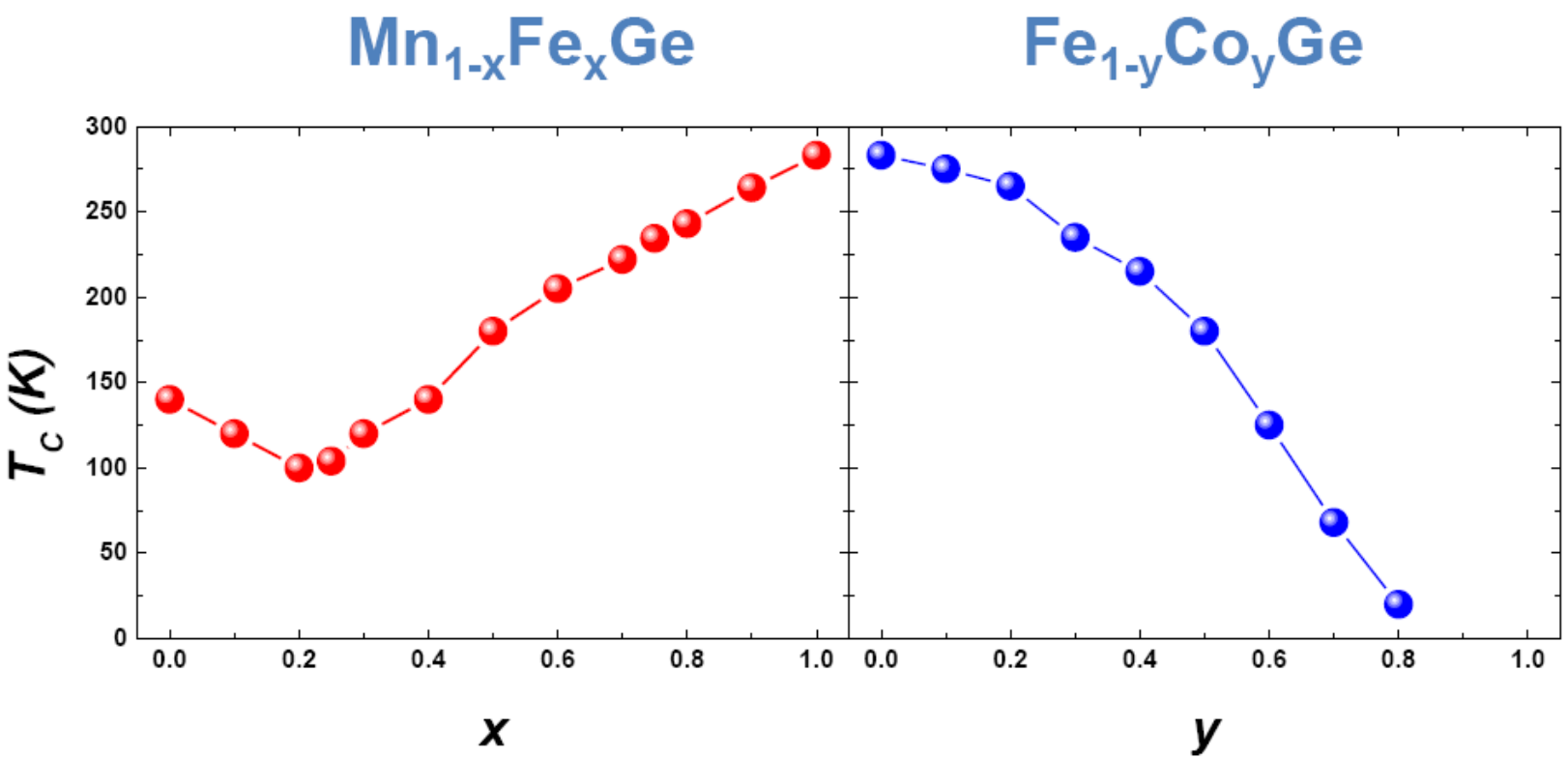




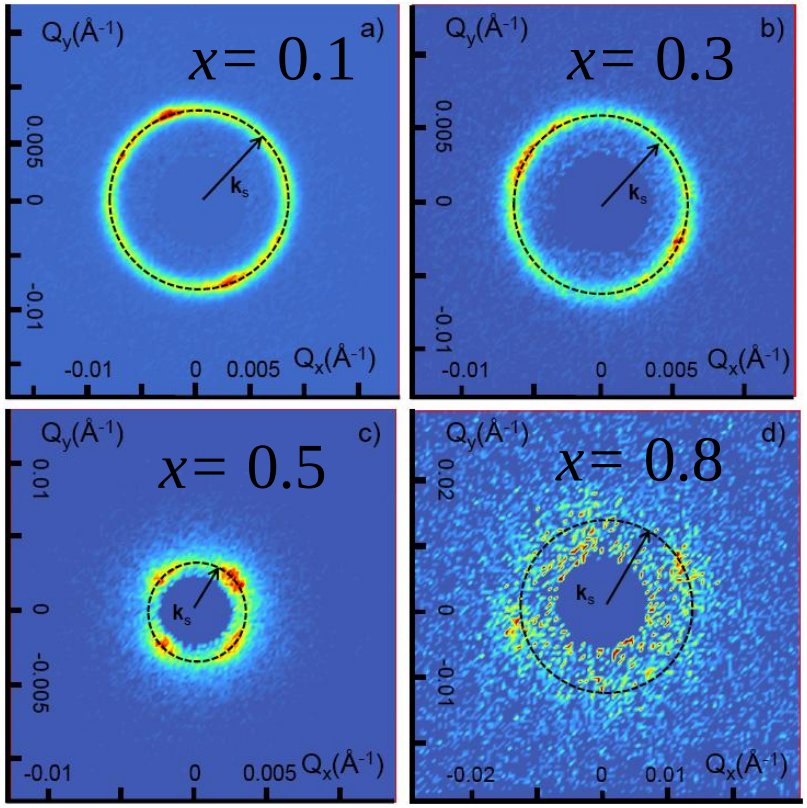
Samples: **$Mn_{1-y}Fe_yGe$ (0,0.1… -.. 1.0)**
$Fe_{1-y}Co_yGe$ (0,0.1… -.. 1.0)
(A.V. Tsvyashchenko, Institute for High Pressure Physics, Troitsk, Russia)

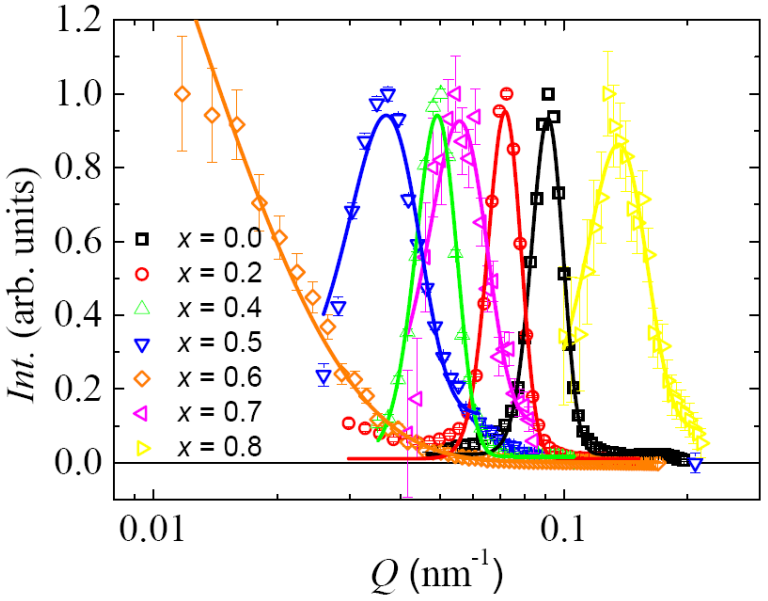
Susceptibility measurements

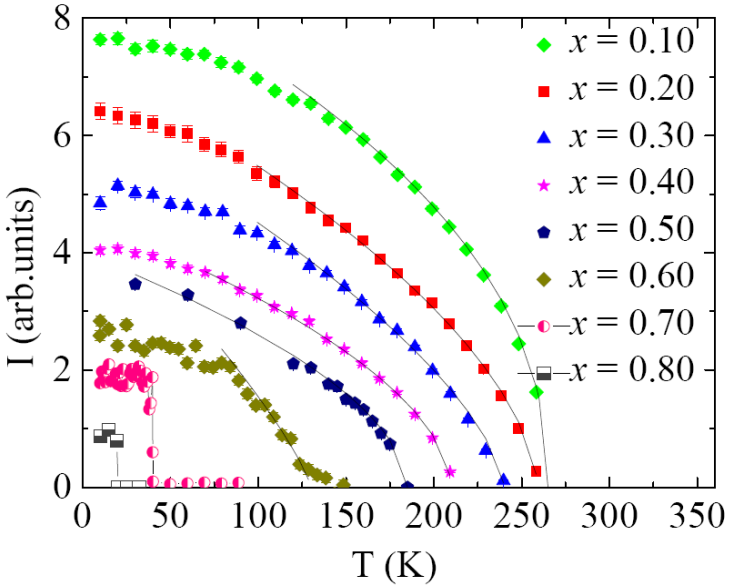
Ordering temperature T_C in $Mn_{1-x}Fe_xGe$ and $Fe_{1-x}Co_xGe$



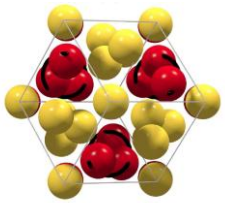
Small angle neutron scattering on the powder samples $Fe_{1-x}Co_xGe$





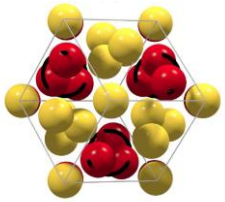


Crystal handedness and magnetic chirality in **FeGe**



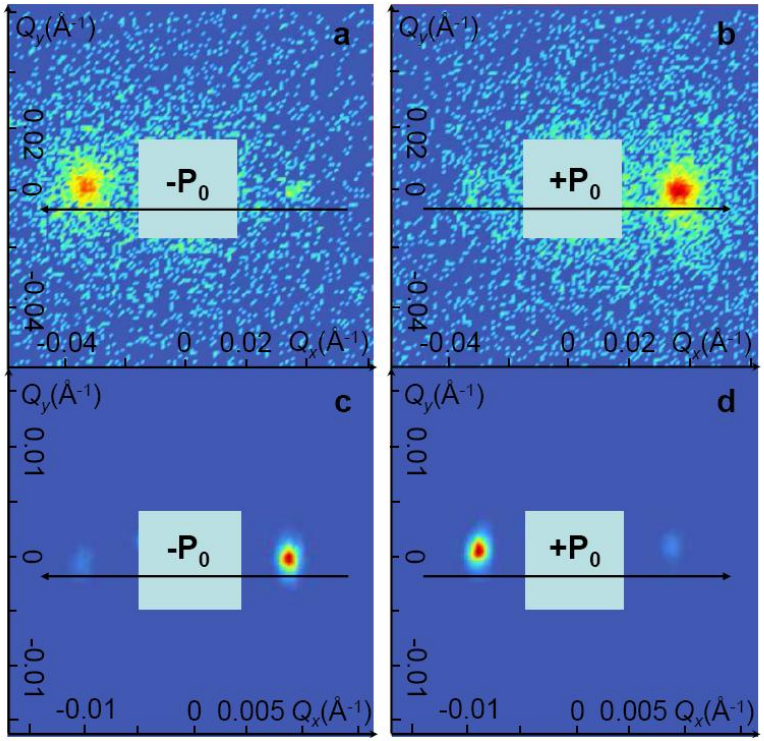
MnSi-etalon

$u_{Mn} = 0.135$
$u_{Si} = 0.845$



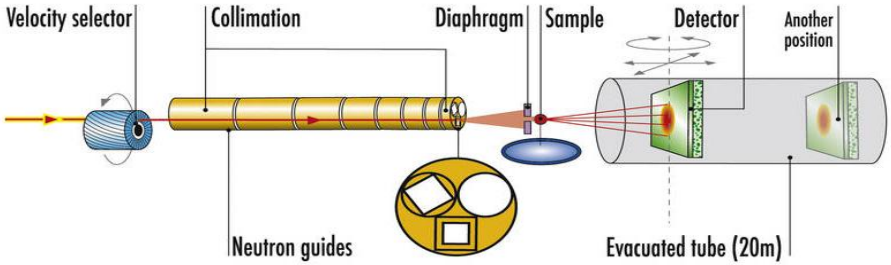
FeGe-sample

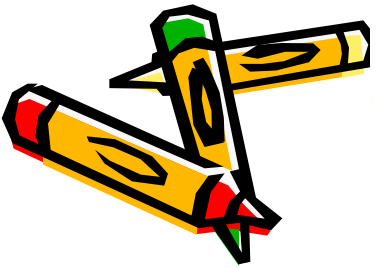
$u_{Fe} = 0.135$
$u_{Ge} = 0.845$

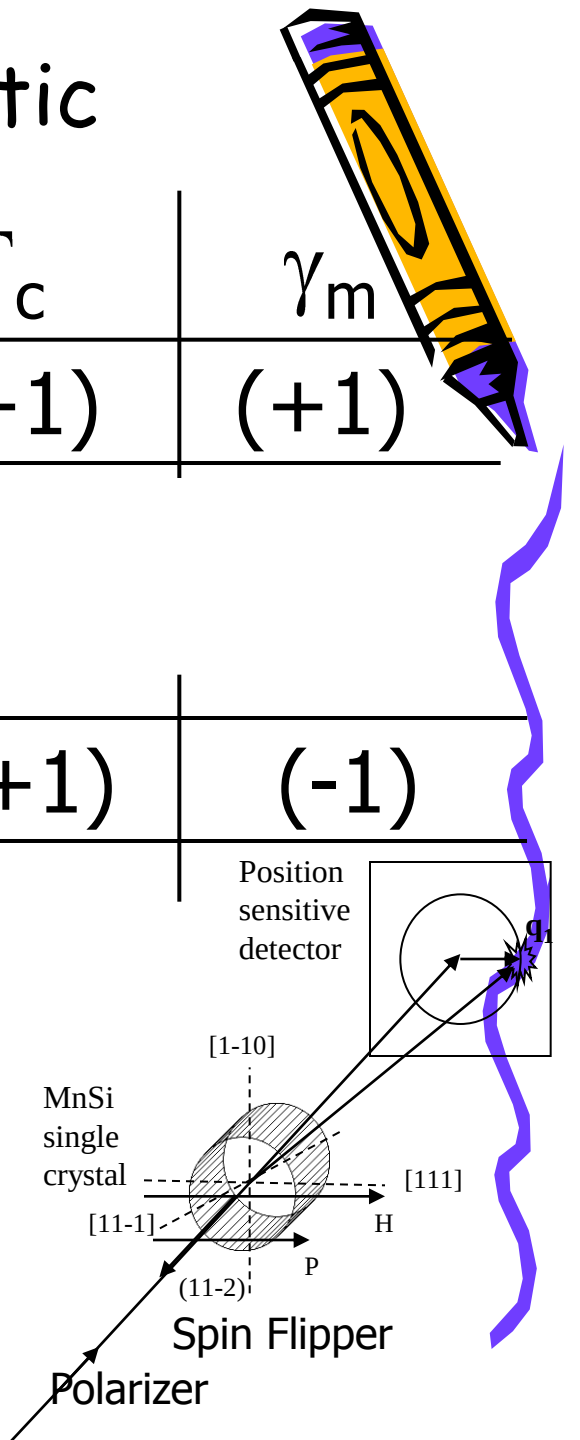


Γ_c	γ_m
(+1)	(+1)
(+1)	(-1)

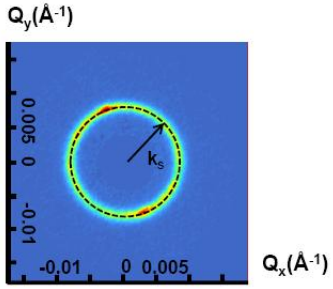
Experimental setup D22 (ILL)







Critical temperature T_C and spiral wavevector k in $Fe_{1-x}Co_xGe$



FeGe

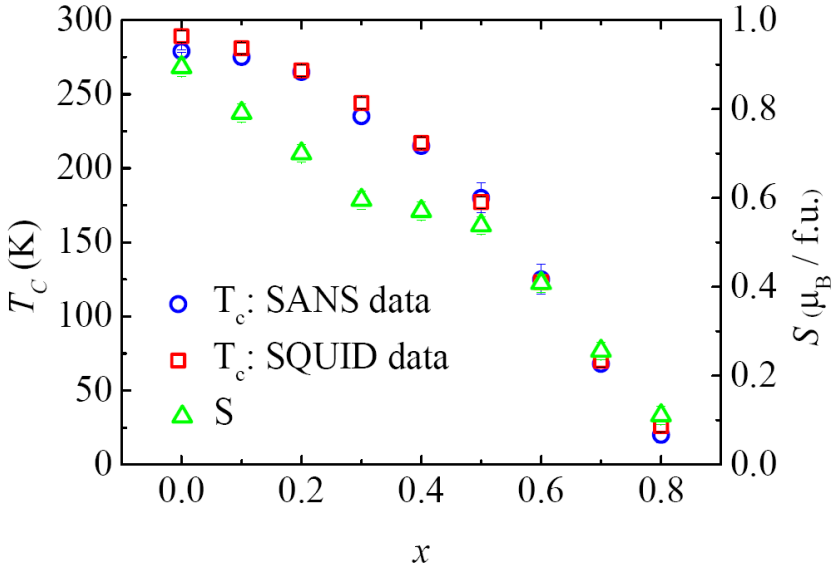
$\Gamma_c = +1$

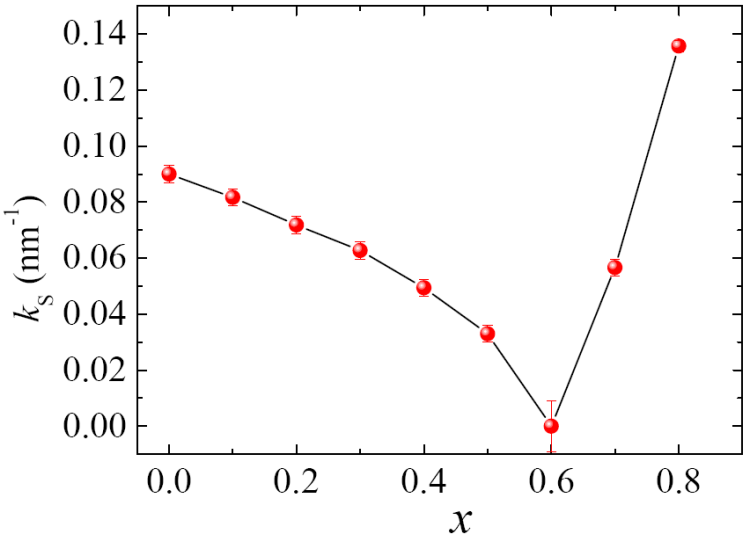
$\gamma_m = -1$

CoGe

$\Gamma_c = +1$

$\gamma_m = +1$





k -> 0, $x_c = 0.6$

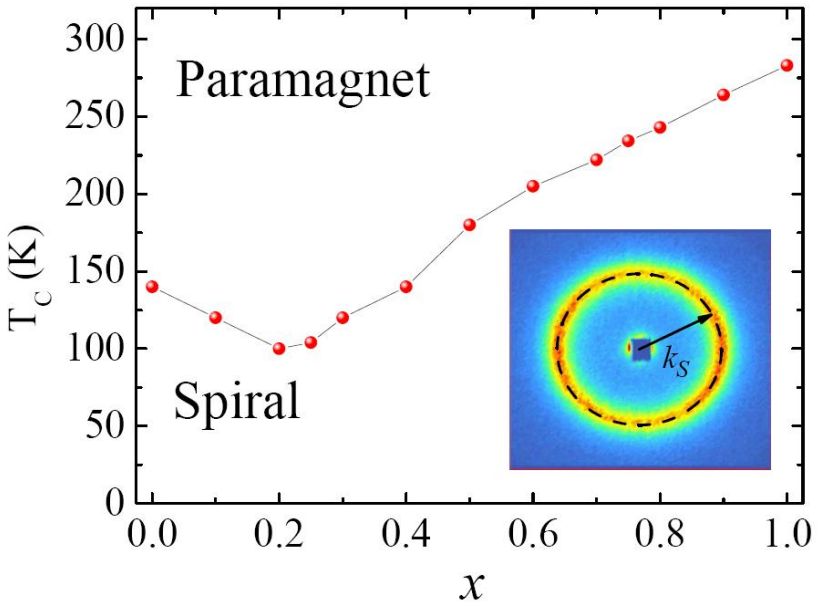
The wavevector k = 0, T_C = 140 K!!!

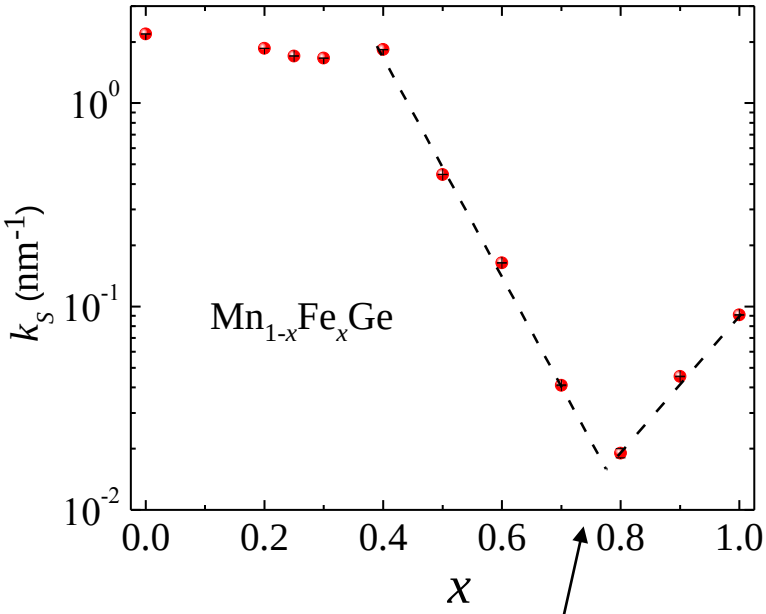
The system transforms to ferromagnet as well !

Critical temperature T_C and spiral wavevector k in $Mn_{1-x}Fe_xGe$

MnGe
$\Gamma_c = +1$
$\gamma_m = +1$

FeGe
$\Gamma_c = +1$
$\gamma_m = -1$



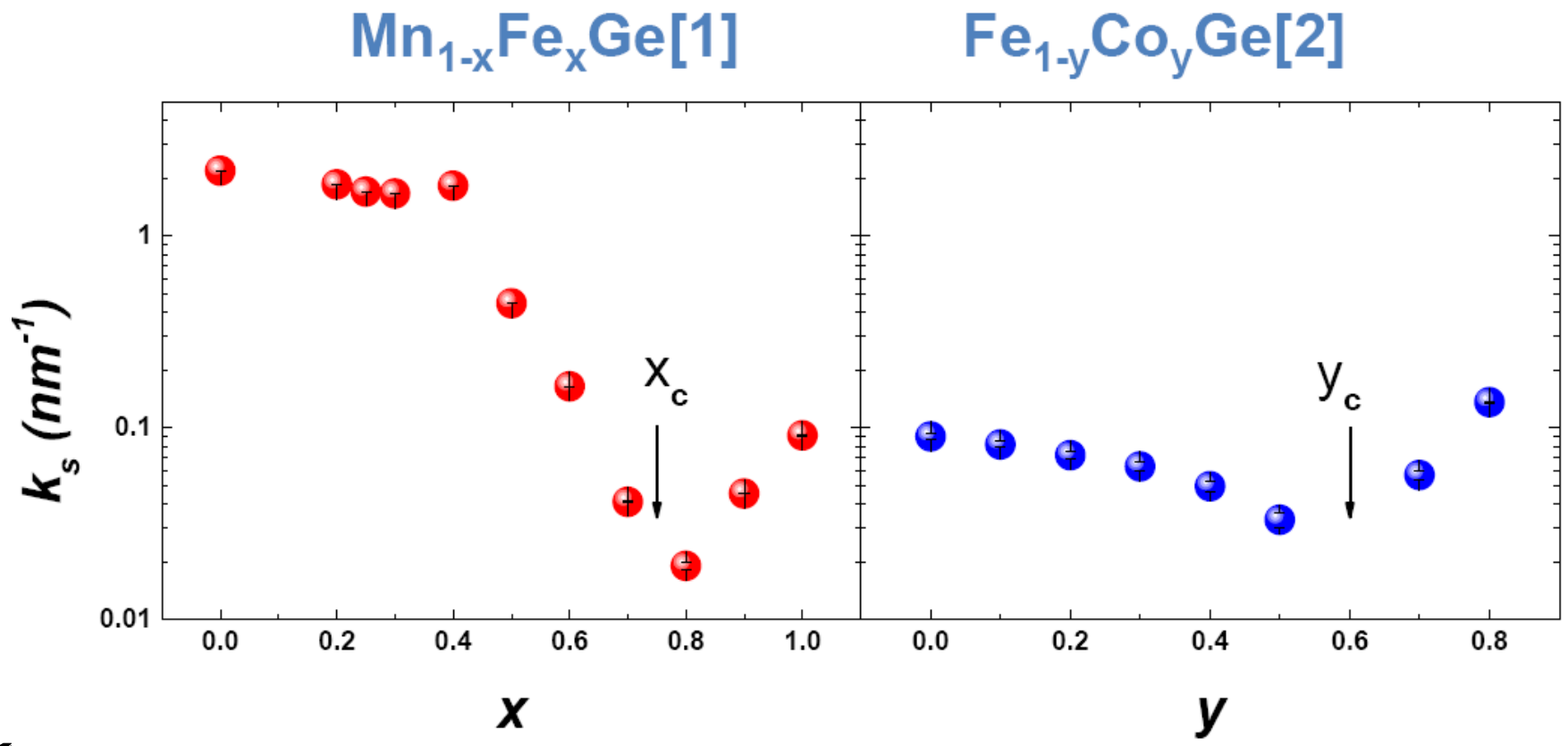


The wavevector k = 0, T_C = 240 K!!!
The system transforms to ferromagnet!

k -> 0, x_c = 0.75

S. V. G., N.M. Potapova, S.-A. Siegfried, V. A.Dyadkin, E. V. Moskvin, V. Dmitriev, D. Menzel, C. D. Dewhurst, D. Chernyshov, R. A. Sadykov, L. N.Fomicheva, and A. V. Tsvyashchenko, Phys. Rev. Lett. 110 (2013) 207201.
Shibata, X. Z. Yu, T. Hara, D. Morikawa, N. Kanazawa,K. Kimoto, S. Ishiwata, Y. Matsui and Y. Tokura, Nature Nanotechnology 8, 723-728 (2013).

Flip of spin chirality in $Mn_{1-x}Fe_xGe$ and $Fe_{1-x}Co_xGe$ compounds

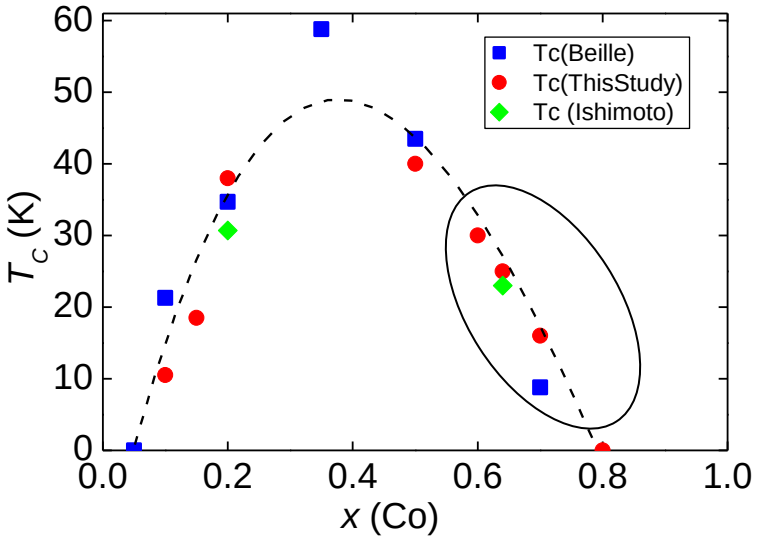


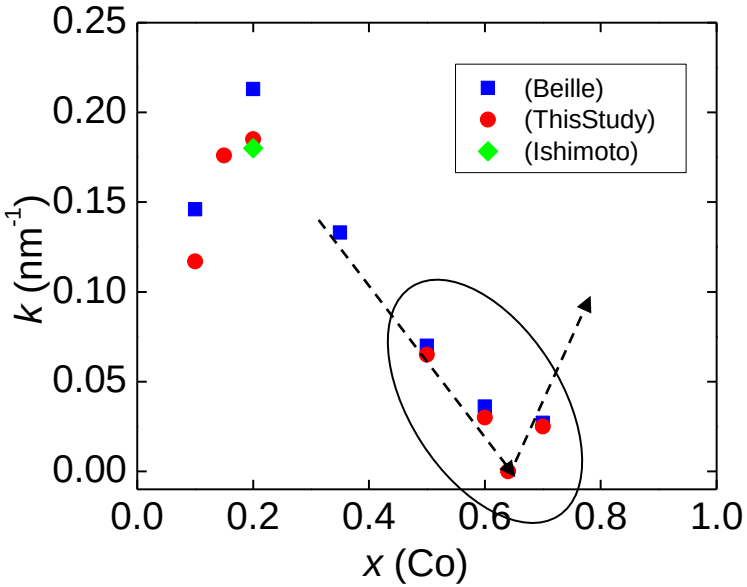
Crystallographic and magnetic chirality in $Fe_{1-x}Co_xSi$, $Mn_{1-y}Fe_ySi$, $Mn_{1-y}Fe_yGe$, $Fe_{1-x}Co_xGe$

	Γ_c	γ_m
$Fe_{1-x}Co_xSi$	(+1)	(-1)
$Mn_{1-y}Fe_ySi$	(+1)	(+1)
FeGe	(+1)	(-1)
MnGe	(+1)	(+1)
CoGe	(+1)	(+1)

Questions arise:

- Should we expect to observe flip of chirality in the $Fe_{1-x}Co_xSi$? Certainly we should because sign of DM interaction is different for the transition elements (Fe, Co). At what concentration x_c ?

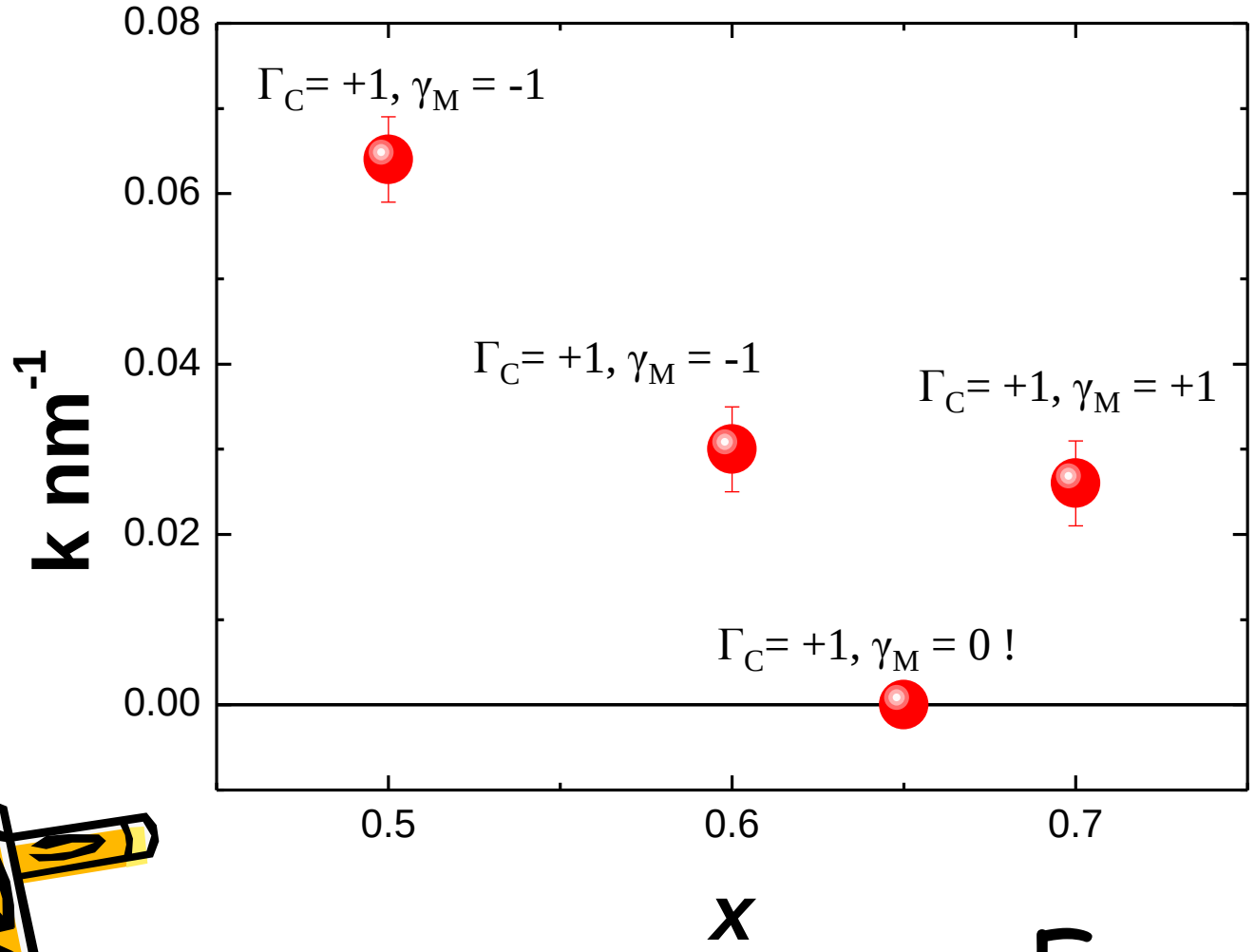




$Fe_{1-x}Co_xSi$

$k \to 0$, $x_c = 0.65$???

Crystal and spin helix chirality was measured x-ray single crystal diffraction and by polarized SANS at T = 3 K



$Fe_{1-x}Co_xSi$

Conclusions

- The spin flip is observed at $x = x_C$ for compounds $\mathbf{Mn_{1-y}Fe_yGe}$, $\mathbf{Fe_{1-x}Co_xGe}$, $\mathbf{Fe_{1-x}Co_xSi}$,
- The system becomes ferromagnetic at x_C.
- Theory: cubic anisotropy, when is comparable with the DM interaction, turns magnetic system of B20 crystals into ferromagnet.

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