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Magnetic interactions and spin dynamics of the ^{53}Cr in the orthosilicate host crystals

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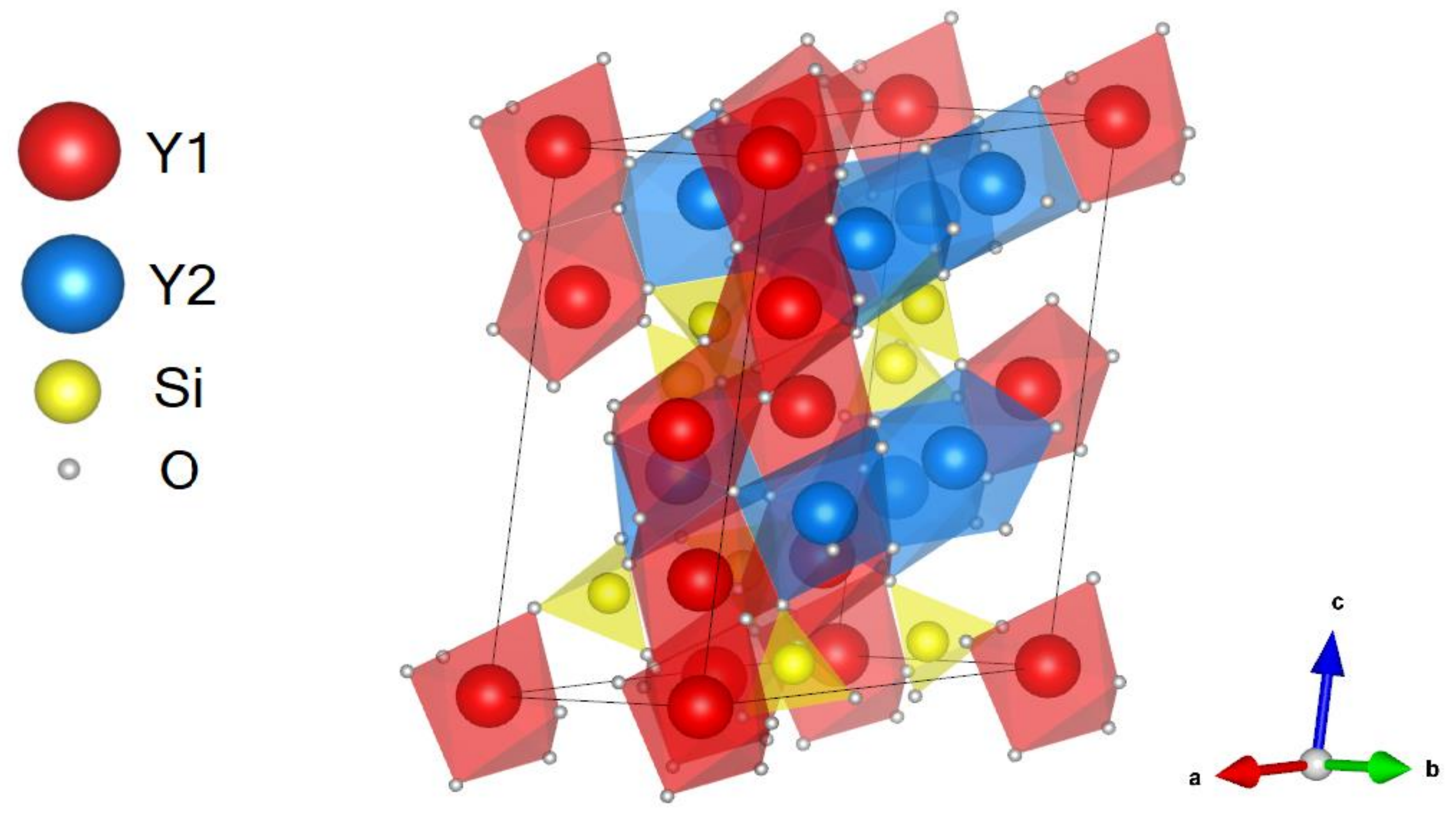
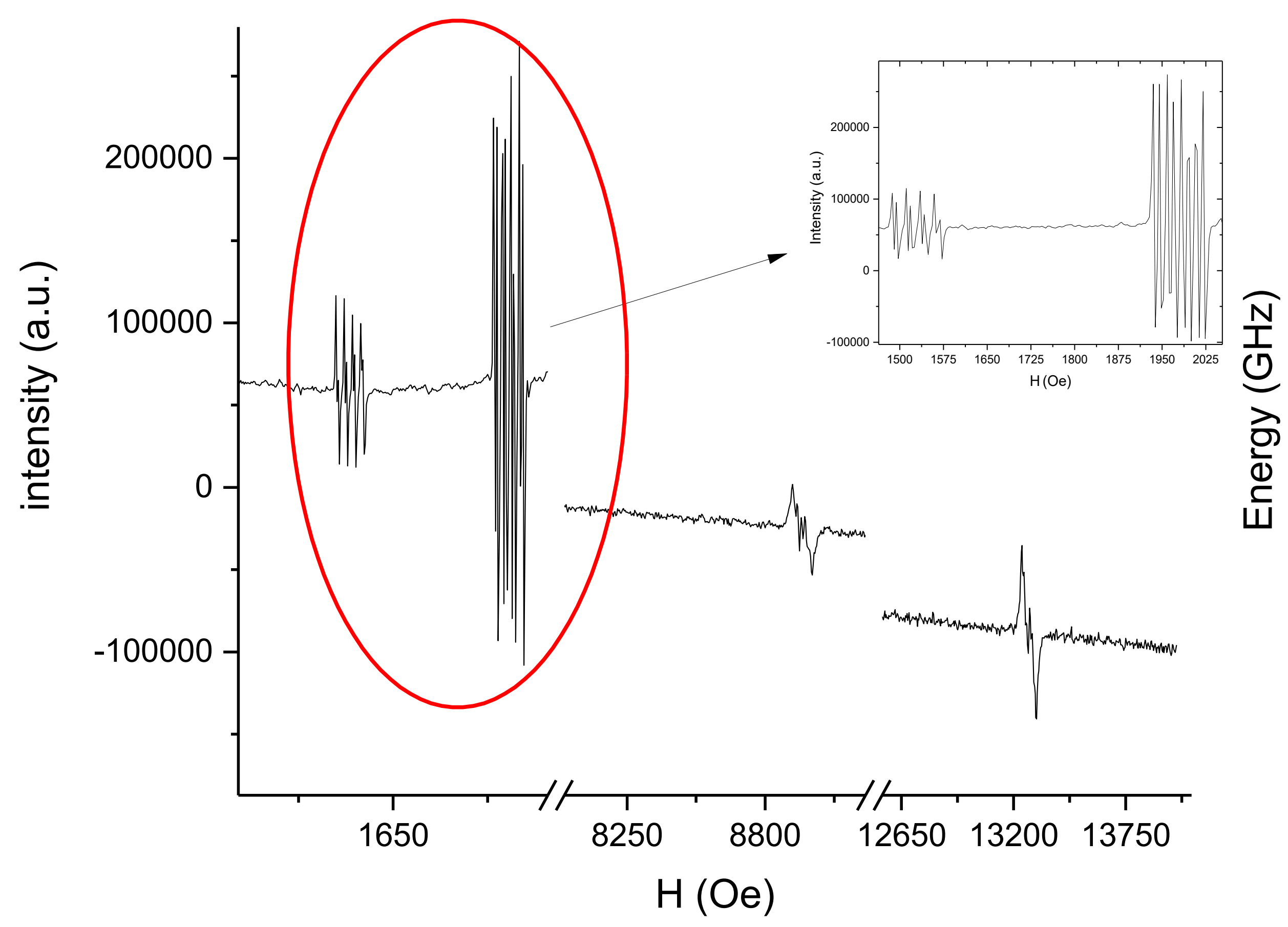
$^{53}Cr^{3+}$:$Y_2{}^{28}SiO_5$ monocrystals are considered as promising materials for quantum memory applications[1,2]. By using the isotopically pure impurity ions $^{53}Cr^{3+}$ the high density of optical resonance medium is achieved. Also, the inhomogeneous linewidth of the resonance transition can be decreased if the host crystal is formed with monoisotopic ^{28}Si compare to silicon with natural abundance due to the non-zero nuclear spin I = 1/2 of ^{29}Si isotope and its interaction with nuclear and electron spin of the $^{53}Cr^{3+}$ impurity ions.

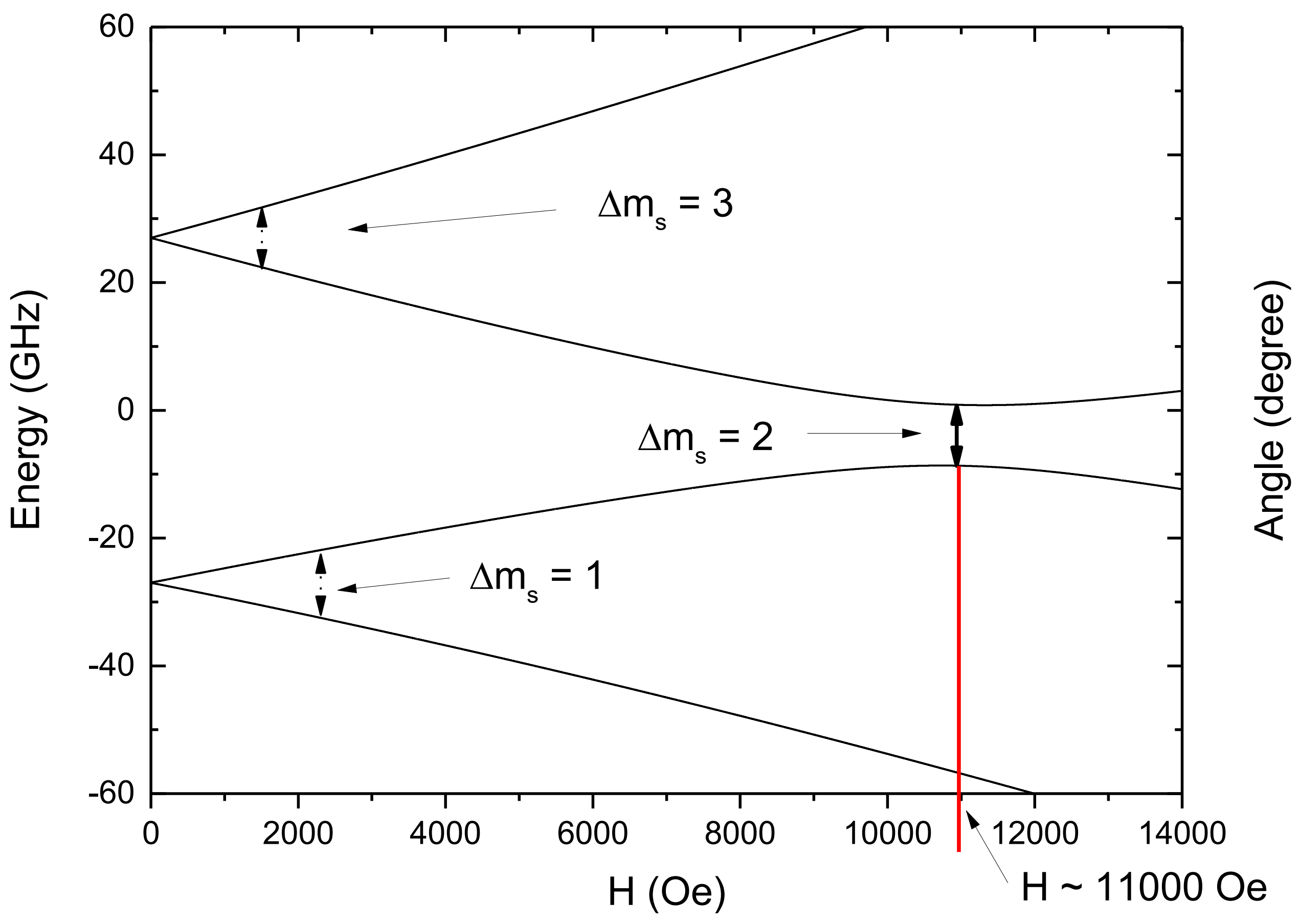


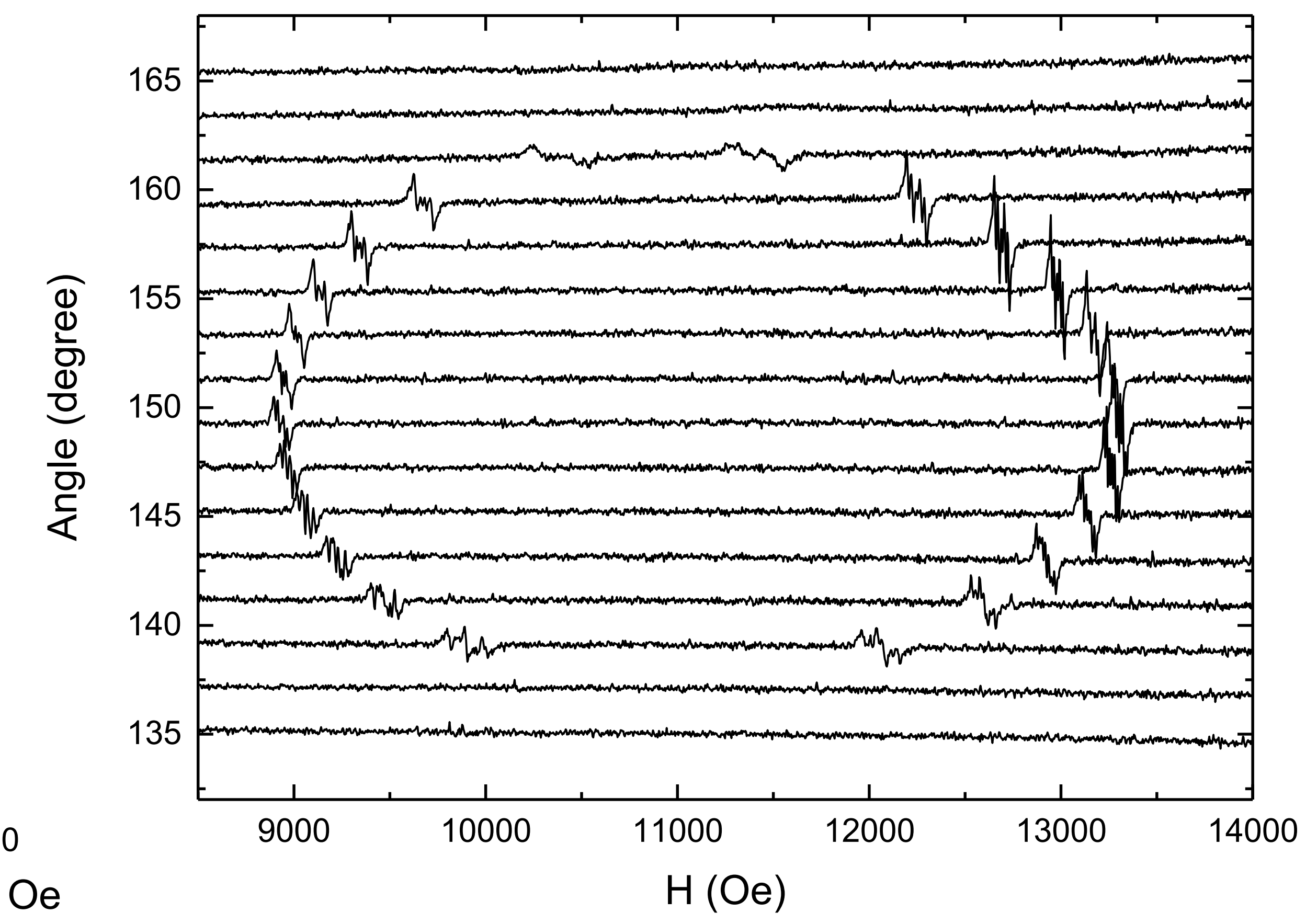
Y_2SiO_5 belongs to monoclinic symmetry group $C_{2/c}$ with two Y positions: Y1 [YO_7] and Y2 [YO_6]. Cr^{3+} ions substitute Y^{3+} ions in Y2 site.

Lattice parameters[3]			
a, Å	b, Å	c, Å	β,°
10.41	6.721	12.49	102.65

Cr has 4 stable isotopes: ^{50}Cr (4.345%), ^{52}Cr (83.789%), ^{53}Cr (9.501%) and ^{54}Cr (2.365%). ^{53}Cr has I = 3/2.


$^{53}Cr^{3+}(0.005\%)$:$Y_2{}^{28}SiO_5$ T=290K plane ac f = 9.474897 GHz


Energy level scheme of electron spin transitions for Cr^{3+} plane *ac*

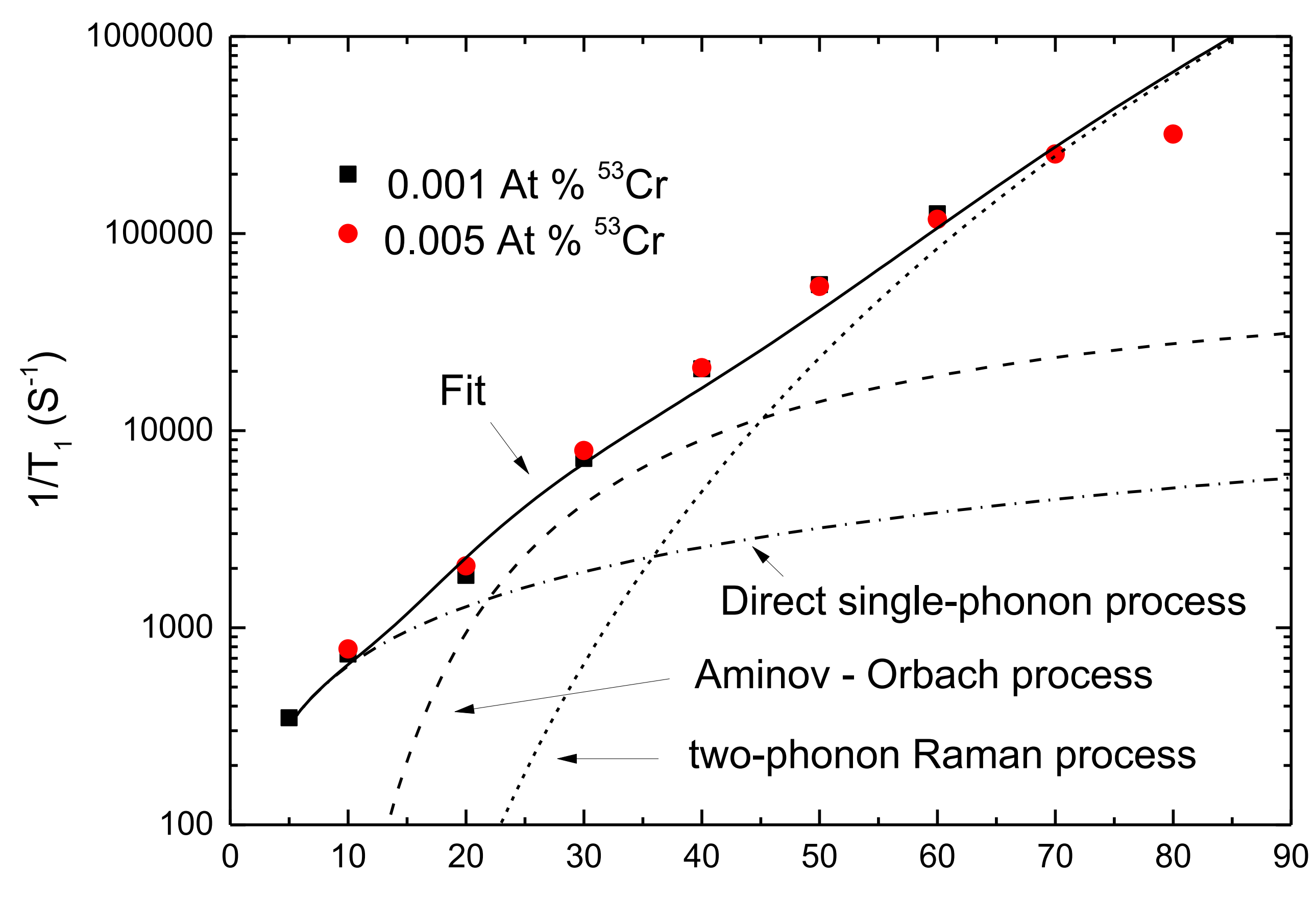

Orientational dependencies of interdoublet transitions in plane *ac*

In order to analyze experimental orientational dependencies the following Hamiltonian was used[4]:

$$\mathcal{H} = \mu_{\beta e}(\mathbf{H}\cdot\mathbf{g}\cdot\mathbf{S}) + \mathbf{S}\cdot\mathbf{D}\cdot\mathbf{S} + \mathbf{S}\cdot\mathbf{A}\cdot\mathbf{I} - \mu_{\beta n}g_n(\mathbf{H}\cdot\mathbf{I})$$

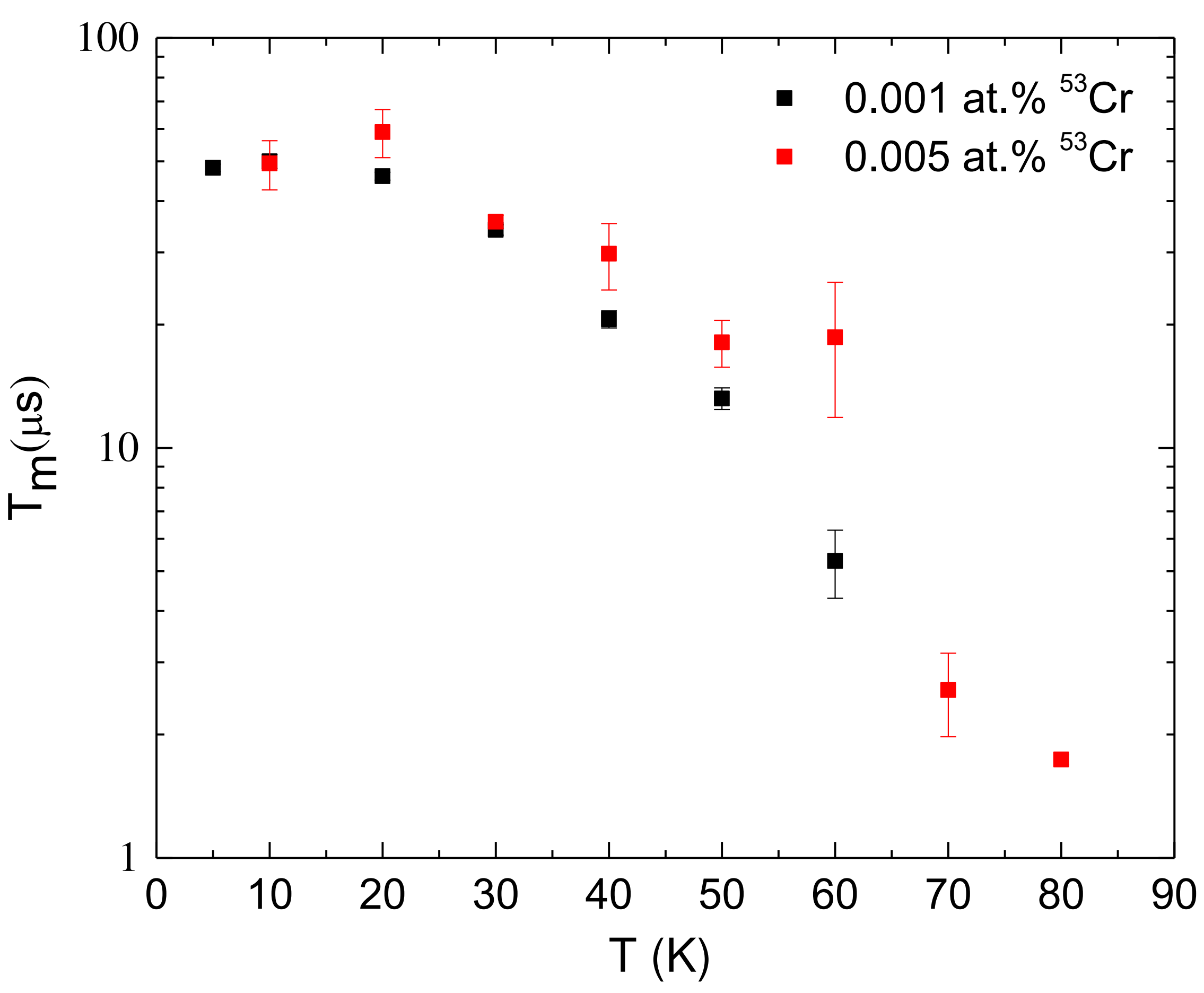
Model parameters:

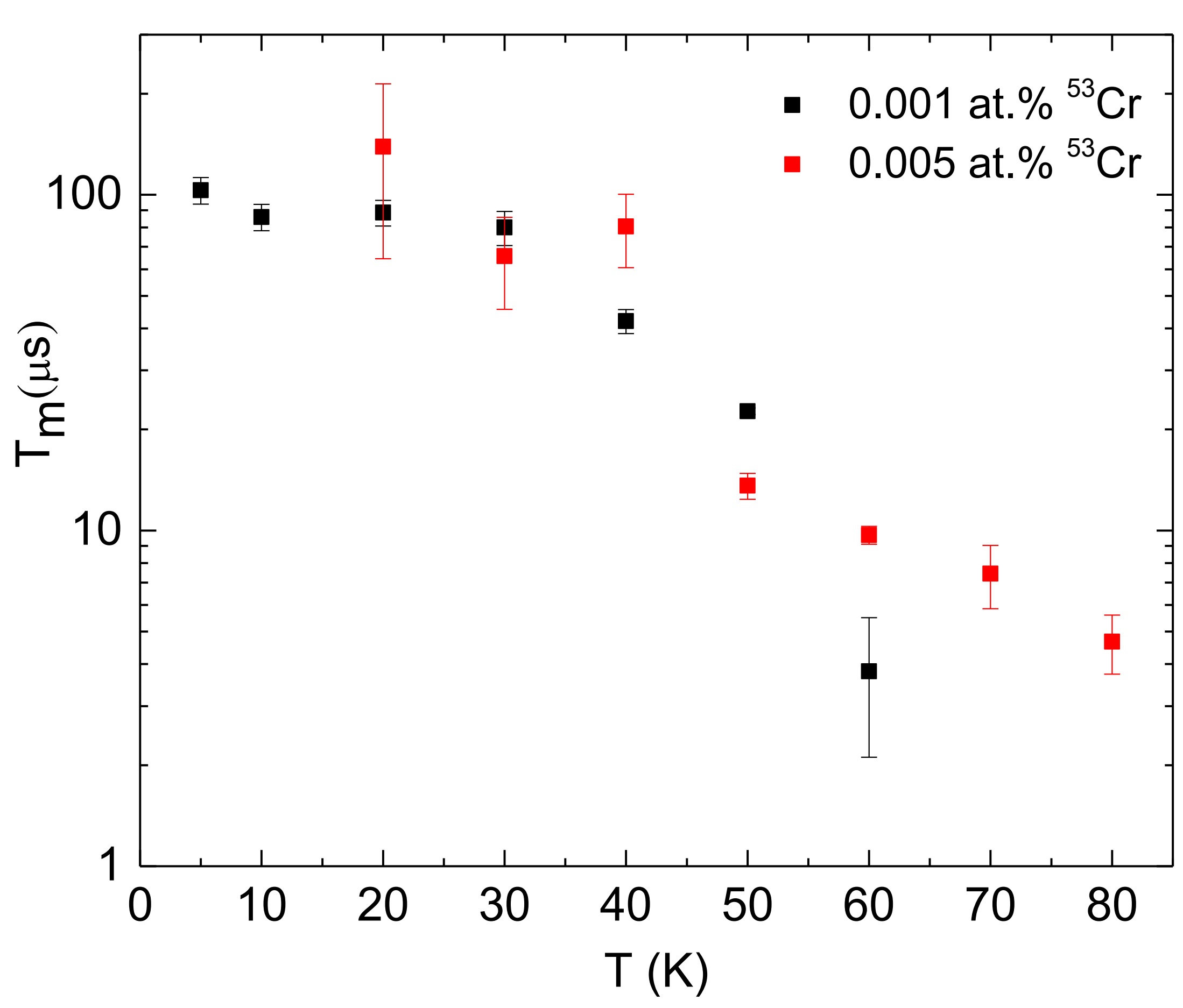
g: $g_x = g_y = g_z = 1.967$; **A:** $A_x = A_y = A_z = 52.4$ MHz; **D:** $D_x = -3.162$ GHz, $D_y = -13.758$ GHz, $D_z = 16.921$ GHz


Inversion - recovery T_1 measurements

$$T_1^{-1} = AT + BT^7 + Cexp(-\frac{\Delta}{T})$$

A = 64 $s^{-1}K^{-1}$, B = $0.3\cdot10^{-7}$ $s^{-1}K^{-7}$,
C = $0.85\cdot10^5$ s^{-1}, Δ = 90K


Two-pulse echo decay T_m measurements


Carr - Purcell - Meiboom - Gill method T_m measurements

Each point was found by echo approximation with following equation[4]:

$$A = A_0 exp\left(-\frac{2\tau}{T_m}\right)^{\alpha}$$, here α = 1.8

[1] S. Welinski, A. Tiranov, M. Businger, A. Ferrier, M. Afzelius, P. Goldner, Phys. Rev. X 10, 031060 (2020). DOI: 10.1103/PhysRevX.10.031060
[2] N. Kukharchyk, D. Sholokhov, O. Morozov, S. L. Korableva, A. A. Kalachev, P. A. Bushev, Optics Express 28, pp. 29166-29177 (2020). DOI: 10.1364/OE.400222
[3] B.A. Maksimov, Yu.A. Kharitonov, V.V. Ilyukhin, N.V. Belov, Sov. Phys. Dokl. 13, 1188-1190 (1969).
[4] Sukhanov, A.A., Tarasov, V.F., Likerov, R.F. *et al. Appl Magn Reson* (2021). DOI: 10.1007/s00723-021-01366-7

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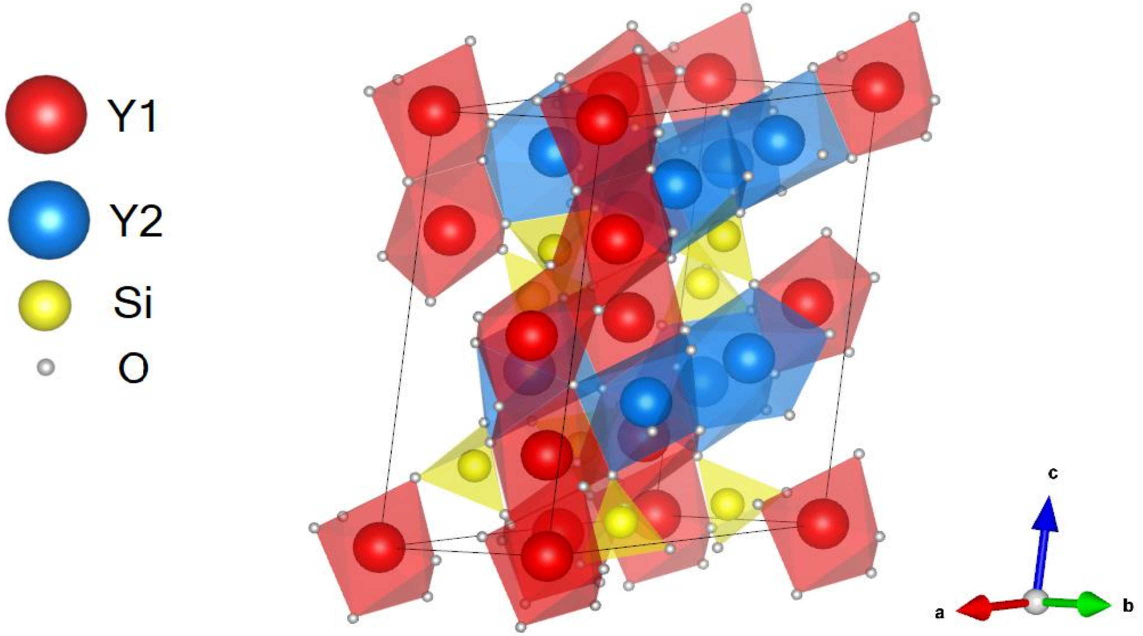

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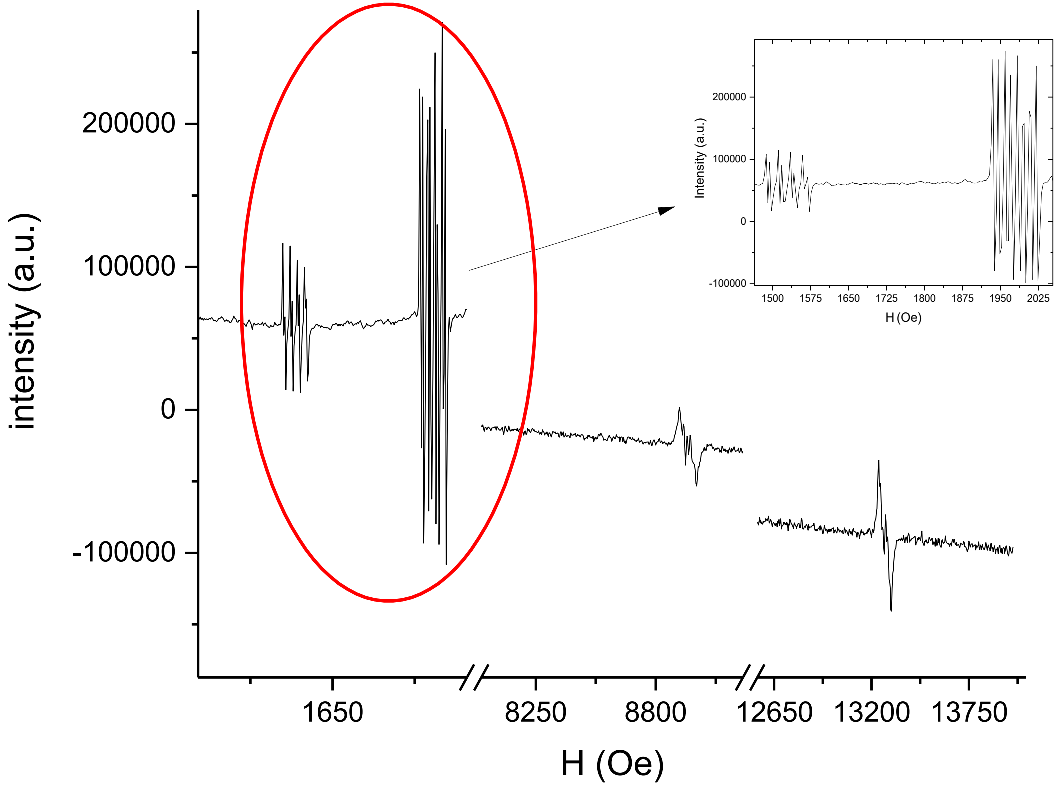

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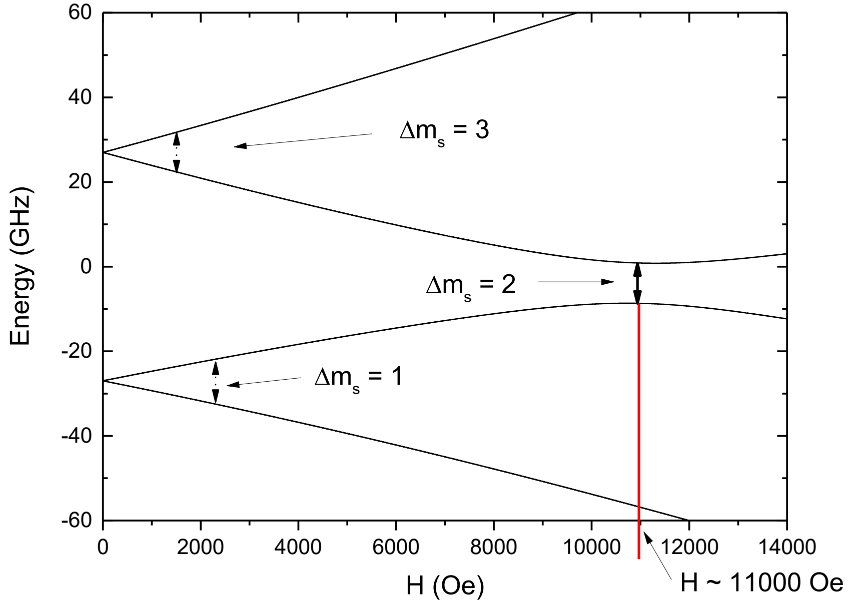

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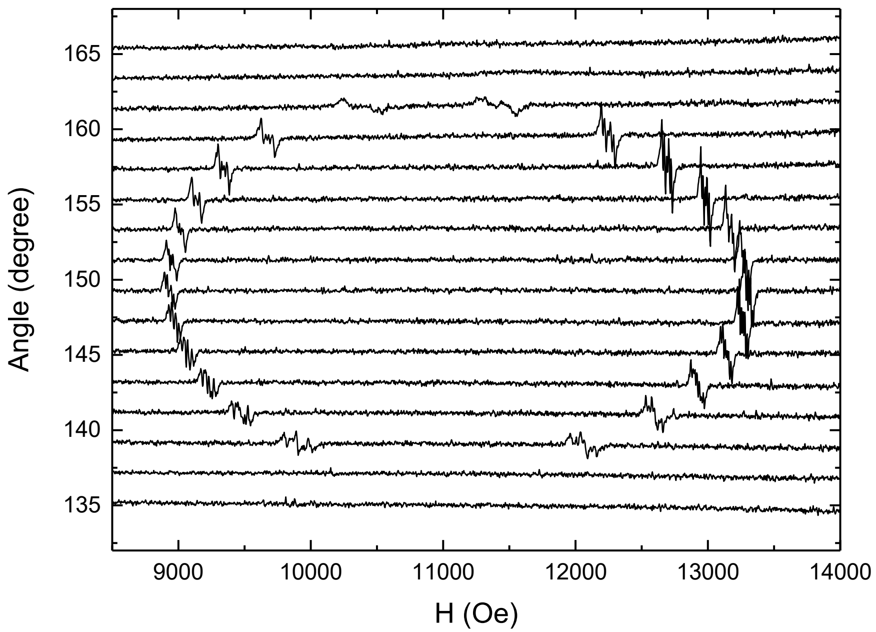

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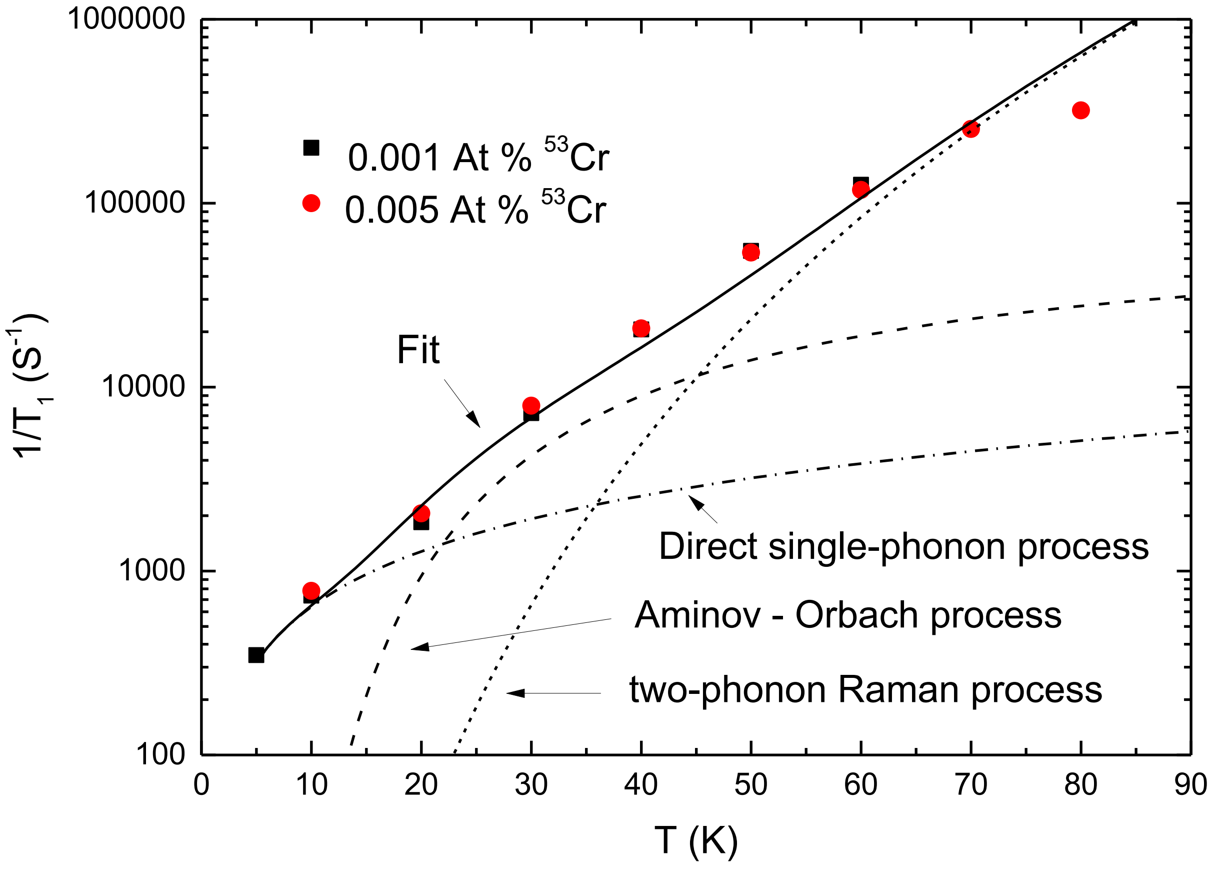
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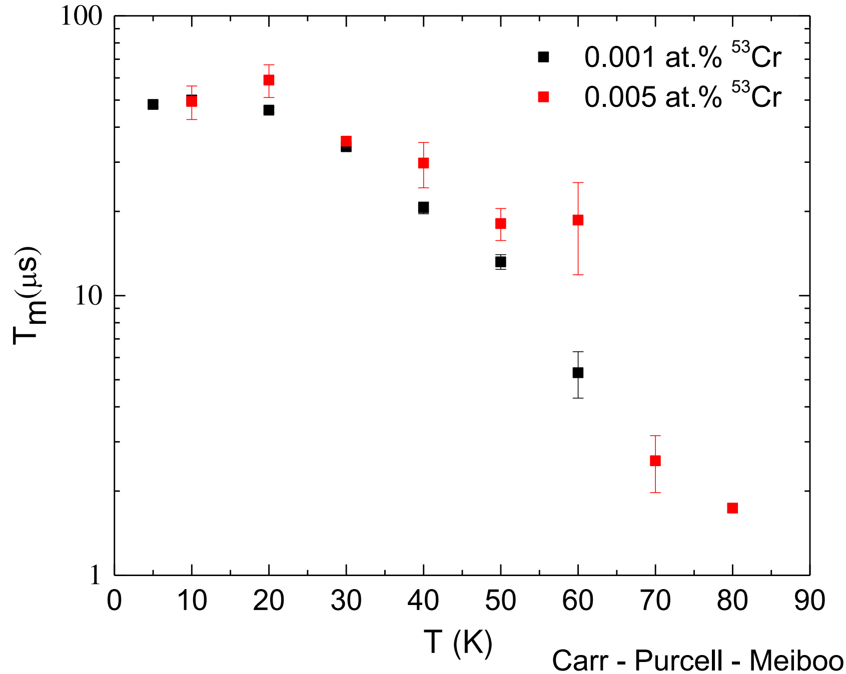
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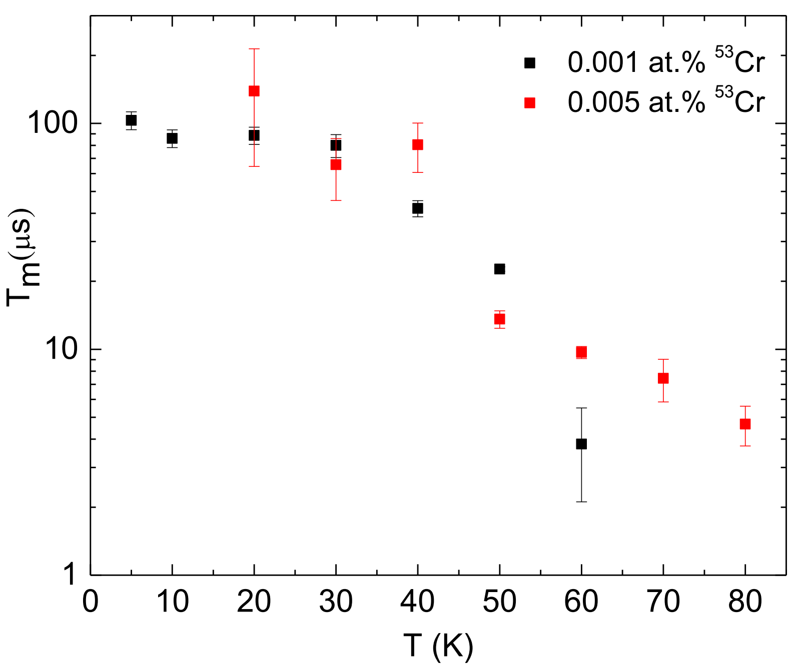
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