Supplementary Table S1a. Refined atomic structure parameters of the PM phase at 6.5 K in ***C***2/c.

Site	Type	Coordinates			U_{iso} [Å^2]	Occu-pancy	Multiplicity
		x	y	z			
Mn1	Mn	0	0.3957(15)	0.25	0.001(1)	1	4
Mn2	Mn	0.3178(5)	0.4160(11)	0.1878(9)	0.001(1)	1	8
Mn3	Mn	0.3262(5)	0.0244(10)	0.1349(9)	0.001(1)	1	8
P1	P	0.4170(4)	0.1763(7)	0.4114(7)	0.001	1	8
P2	P	0.1606(4)	0.2400(9)	0.1298(7)	0.001	1	8
O1	O	0.5164(3)	0.2870(7)	0.0901(7)	0.0016(6)	1	8
O2	O	0.4238(3)	0.0648(7)	0.2935(6)	0.0016(6)	1	8
O3	O	0.3453(4)	0.2734(7)	0.3659(5)	0.0016(6)	1	8
O4	O	0.0841(3)	0.3922(6)	0.4431(6)	0.0016(6)	1	8
O5	O	0.3361(3)	0.2383(7)	0.0283(7)	0.0016(6)	1	8
O6	O	0.2025(3)	0.0916(7)	0.1748(6)	0.0016(6)	1	8
O7	O	0.2016(3)	0.3725(7)	0.2120(5)	0.0016(6)	1	8
O8	O	0.0727(3)	0.2349(6)	0.1557(6)	0.0016(6)	1	8
O9	O	0.2390(4)	0.0816(7)	0.4675(7)	0.0016(6)	1	8
O10	O	0.0760(4)	0.0154(8)	0.3445(8)	0.0016(6)	1	8
D1	D	0.0209(4)	0.2188(7)	0.0022(7)	0.021(2)	1	8
D2	D	0.2653(3)	0.1484(7)	0.4164(6)	0.018(2)	1	8
D3	D	0.2031(4)	0.1289(6)	0.5228(6)	0.006(2)	1	8
D4	D	0.0665(3)	0.0984(8)	0.2836(6)	0.019(2)	1	8
D5	D	0.4652(3)	0.4515(7)	0.1364(5)	0.017(2)	1	8

Supplementary Table S1b. Refined atomic structure parameters of the FM phase at 3.4 K in ***C***2'/c'.

Site	Type	Coordinates			U_{iso} [Å^2]	Occu-pancy	Multiplicity
		x	y	z			
Mn1	Mn	0	0.3995(9)	0.25	0.001(1)	1	4
Mn2	Mn	0.3173(3)	0.4070(7)	0.1862(5)	0.001(1)	1	8
Mn3	Mn	0.3247(3)	0.0286(6)	0.1344(6)	0.001(1)	1	8
P1	P	0.4192(3)	0.1810(5)	0.4078(5)	0.001	1	8
P2	P	0.1600(2)	0.2366(5)	0.1289(4)	0.001	1	8
O1	O	0.5132(2)	0.2808(5)	0.0827(5)	0.0009(3)	1	8
O2	O	0.4236(2)	0.0684(4)	0.2941(4)	0.0009(3)	1	8
O3	O	0.3450(2)	0.2697(4)	0.3705(3)	0.0009(3)	1	8
O4	O	0.0856(2)	0.3900(4)	0.4449(4)	0.0009(3)	1	8
O5	O	0.3377(2)	0.2356(4)	0.0324(4)	0.0009(3)	1	8
O6	O	0.2005(2)	0.0957(5)	0.1727(4)	0.0009(3)	1	8
O7	O	0.2004(2)	0.3647(4)	0.2089(4)	0.0009(3)	1	8
O8	O	0.0760(2)	0.2341(4)	0.1568(4)	0.0009(3)	1	8
O9	O	0.2417(3)	0.0801(5)	0.4682(4)	0.0009(3)	1	8
O10	O	0.0767(3)	0.0134(5)	0.3529(5)	0.0009(3)	1	8
D1	D	0.0244(2)	0.2201(4)	0.0093(5)	0.024(1)	1	8
D2	D	0.2647(2)	0.1561(4)	0.4145(4)	0.015(1)	1	8
D3	D	0.2025(2)	0.1288(4)	0.5232(4)	0.010(1)	1	8
D4	D	0.0635(2)	0.0917(6)	0.2830(4)	0.022(1)	1	8
D5	D	0.4675(2)	0.4509(4)	0.1406(4)	0.020(1)	1	8

Supplementary Table S1c. Refined atomic structure parameters of the FM phase at 4.5 K in ***C***2'/c'.

Site	Type	Coordinates			U_{iso} [Å^2]	Occu-pancy	Multiplicity
		x	y	z			
Mn1	Mn	0	0.3973(11)	0.25	0.003(1)	1	4
Mn2	Mn	0.3181(3)	0.4111(8)	0.1857(5)	0.003(1)	1	8
Mn3	Mn	0.3250(4)	0.0255(7)	0.1334(6)	0.003(1)	1	8
P1	P	0.4194(3)	0.1813(6)	0.4091(5)	0.001	1	8
P2	P	0.1601(3)	0.2398(6)	0.1285(4)	0.001	1	8
O1	O	0.5125(2)	0.2860(5)	0.0825(5)	0.0012(5)	1	8
O2	O	0.4231(2)	0.0668(5)	0.2940(4)	0.0012(5)	1	8
O3	O	0.3459(2)	0.2730(5)	0.3677(4)	0.0012(5)	1	8
O4	O	0.0830(2)	0.3912(5)	0.4442(4)	0.0012(5)	1	8
O5	O	0.3368(2)	0.2375(5)	0.0319(5)	0.0012(5)	1	8
O6	O	0.2016(2)	0.0956(5)	0.1733(4)	0.0012(5)	1	8
O7	O	0.2016(2)	0.3660(5)	0.2127(4)	0.0012(5)	1	8
O8	O	0.0742(2)	0.2323(5)	0.1574(4)	0.0012(5)	1	8
O9	O	0.2402(3)	0.0785(5)	0.4703(5)	0.0012(5)	1	8
O10	O	0.0765(3)	0.0126(6)	0.3503(4)	0.0012(5)	1	8
D1	D	0.0246(2)	0.2221(5)	0.0092(4)	0.013(11)	1	8
D2	D	0.2638(2)	0.1524(5)	0.4143(4)	0.0173(1)	1	8
D3	D	0.2024(3)	0.1287(5)	0.5221(4)	0.015(1)	1	8
D4	D	0.0653(2)	0.0964(6)	0.2831(4)	0.017(1)	1	8
D5	D	0.4687(3)	0.4533(5)	0.1406(4)	0.024(1)	1	8

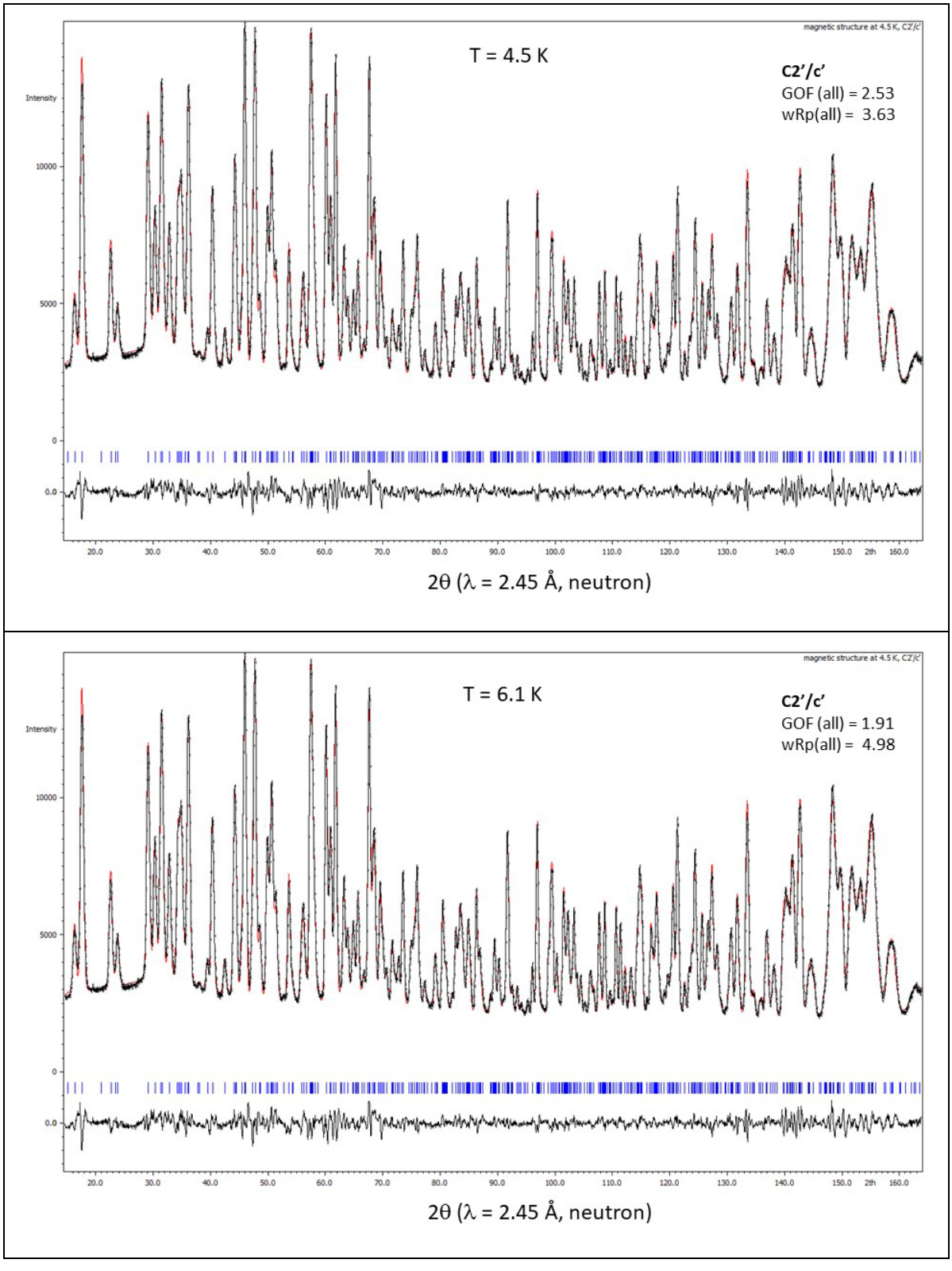
Supplementary Table S1d. Refined atomic structure parameters of the FM phase at 6.1 K in ***C***2'/c'.

Site	Type	Coordinates			U_{iso} [Å^2]	Occu-pancy	Multiplicity
		x	y	z			
Mn1	Mn	0	0.4044(16)	0.25	0.005(4)	1	4
Mn2	Mn	0.3201(5)	0.4074(12)	0.1842(8)	0.014(3)	1	8
Mn3	Mn	0.3235(6)	0.0281(11)	0.1318(9)	0.016(3)	1	8
P1	P	0.4195(4)	0.1869(9)	0.4081(7)	0.006(2)	1	8
P2	P	0.1599(4)	0.2386(10)	0.1294(7)	0.005(2)	1	8
O1	O	0.5115(3)	0.2831(8)	0.0808(7)	0.005(1)	1	8
O2	O	0.4236(3)	0.0678(7)	0.2922(6)	0.005(1)	1	8
O3	O	0.3451(4)	0.2722(8)	0.3674(5)	0.005(1)	1	8
O4	O	0.0843(3)	0.3908(7)	0.4462(6)	0.005(1)	1	8
O5	O	0.3366(3)	0.2350(8)	0.0335(7)	0.005(1)	1	8
O6	O	0.2025(3)	0.0985(8)	0.1728(6)	0.005(1)	1	8
O7	O	0.2007(3)	0.3641(8)	0.2123(5)	0.005(1)	1	8
O8	O	0.0749(3)	0.2316(8)	0.1591(6)	0.005(1)	1	8
O9	O	0.2417(4)	0.0764(8)	0.4709(7)	0.005(1)	1	8
O10	O	0.0765(4)	0.0147(9)	0.3504(7)	0.005(1)	1	8
D1	D	0.0253(4)	0.2229(7)	0.0107(7)	0.015(2)	1	8
D2	D	0.2629(3)	0.1521(7)	0.4143(6)	0.013(2)	1	8
D3	D	0.2020(4)	0.1269(7)	0.5208(6)	0.018(2)	1	8
D4	D	0.0663(3)	0.0957(9)	0.2824(6)	0.022(2)	1	8
D5	D	0.4679(4)	0.4524(8)	0.1426(6)	0.032(2)	1	8

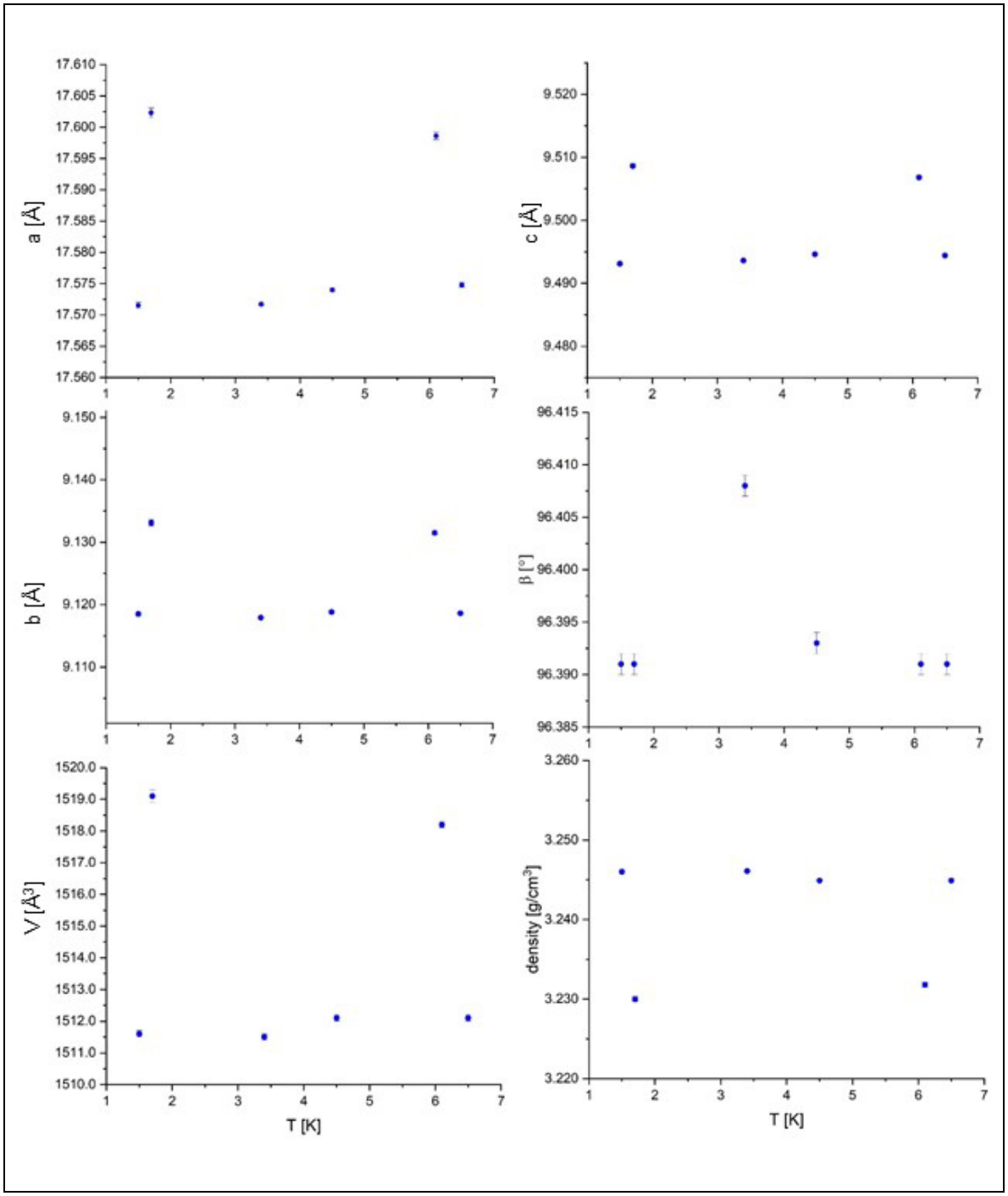
Supplementary Table S1e. Refined atomic structure parameters of the incommensurate AFM phase at 1.5 K in ***P***2_1/c.1'($\alpha 0 \gamma$)*00s*.

Site	Type	Coordinates			U_{iso} [Å^2]	Occu-pancy	Multiplicity
		x	y	z			
Mn1	Mn	0.7272(11)	0.852(2)	0.745(3)	0.001	1	4
Mn2_1	Mn	0.4267(14)	0.662(4)	0.289(2)	0.001	1	4
Mn2_2	Mn	0.9369(13)	0.134(3)	0.337(2)	0.001	1	4
Mn3_1	Mn	0.4280(14)	0.253(3)	0.374(3)	0.001	1	4
Mn3_2	Mn	0.9197(14)	0.788(3)	0.353(3)	0.001	1	4
P1_1	P	0.3334(15)	0.451(3)	0.090(3)	0.001	1	4
P1_2	P	0.8298(16)	0.935(3)	0.083(3)	0.001	1	4
P2_1	P	0.5915(14)	0.489(3)	0.383(3)	0.001	1	4
P2_2	P	0.0888(13)	0.984(3)	0.364(3)	0.001	1	4
O1_1	O	0.2674(11)	0.540(2)	0.087(3)	0.001	1	4
O1_2	O	0.7528(12)	0.032(3)	0.077(3)	0.001	1	4
O2_1	O	0.3222(10)	0.313(2)	0.205(2)	0.001	1	4
O2_2	O	0.8351(10)	0.834(2)	0.195(2)	0.001	1	4
O3_1	O	0.4132(10)	0.510(3)	0.135(2)	0.001	1	4
O3_2	O	0.9010(11)	0.031(3)	0.129(3)	0.001	1	4
O4_1	O	0.6631(13)	0.631(3)	0.056(2)	0.001	1	4
O4_2	O	0.1688(12)	0.148(3)	0.063(2)	0.001	1	4
O5_1	O	0.4188(13)	0.491(3)	0.467(3)	0.001	1	4
O5_2	O	0.9138(13)	0.980(3)	0.467(3)	0.001	1	4
O6_1	O	0.5509(11)	0.350(3)	0.330(3)	0.001	1	4
O6_2	O	0.0454(11)	0.845(3)	0.335(3)	0.001	1	4
O7_1	O	0.5495(12)	0.609(3)	0.290(3)	0.001	1	4
O7_2	O	0.0466(14)	0.128(3)	0.281(2)	0.001	1	4
O8_1	O	0.6790(11)	0.481(3)	0.338(2)	0.001	1	4
O8_2	O	0.1714(12)	0.989(3)	0.355(2)	0.001	1	4
O9_1	O	0.5082(15)	0.319(3)	0.024(3)	0.001	1	4
O9_2	O	0.0133(14)	0.832(3)	0.037(3)	0.001	1	4
O10_1	O	0.6680(15)	0.276(2)	0.149(3)	0.001	1	4
O10_2	O	0.1757(15)	0.742(3)	0.137(3)	0.001	1	4
D1_1	D	0.2244(12)	0.518(3)	-0.0023(18)	0.001	1	4
D1_2	D	0.7264(12)	0.026(3)	-0.023(2)	0.001	1	4
D2_1	D	0.5398(11)	0.390(2)	-0.0221(19)	0.001	1	4
D2_2	D	0.0548(11)	0.871(2)	-0.023(2)	0.001	1	4
D3_1	D	0.4800(11)	0.413(2)	0.081(2)	0.001	1	4
D3_2	D	0.9921(12)	0.891(2)	0.085(2)	0.001	1	4
D4_1	D	0.7080(9)	0.214(2)	0.133(2)	0.001	1	4
D4_2	D	0.2265(10)	0.691(2)	0.141(2)	0.001	1	4
D5_1	D	0.6830(9)	0.362(2)	0.2312(16)	0.001	1	4
D5_2	D	0.1832(10)	0.821(2)	0.1997(18)	0.001	1	4

Supplementary Figure S2. Graphical representation of results from the last cycle of Rietveld calculations with HRNPD data of deuterated Mn-hureaulite at 4.5 K and 6.1 K with agreement factors. The calculated profile (red line) for the FM magnetic space group ***C***2'/c' well matched to the observed one (black line) at both temperatures point that this FM space group retains between T_1 and T_C.



Supplementary Figure S3. Lattice metrics between 6.5 K and 1.5 K along with the corresponding density values show relative strong jumps around magnetic phase transition temperatures T_1 and T_C.



Supplementary Figure S4. a) Graphical representation of results from Rietveld refinements with HRNPD data of deuterated Mn-hureaulite at 1.5 K with agreement factors. The profile (red line) calculated with the magnetic superspace group (MSSG) ***P***2_1/c.1'(α0γ)*00s* with a commensurate propagation vector, ***k***(0.5, 0, 0). This commensurate AFM model shows a much larger discrepancy from the observed profile, compared with the incommensurate model (Fig. 12 in the main text); **b**) Magnetic spin order in this commensurate AFM model.

