EFM With Field in 111 Starting With Random and Ground Initial States

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Overview

The effective field method was used to 2000 iterations to determine the 0 temperature states of the 12x12x12 3D FCC kagome lattice while being subjected to a changing magnetic field along the 111 direction. The field was either incremented or decremented in steps of 0.0001. There were 4 cases studied:

1. **Increasing** magnetic field in the **111** direction from **0.00 to 0.05**, with an initial spin configuration that was a **ground state** with theta = 0.206275 and phi = 3.11867.
2. **Increasing** magnetic field in the **111** direction from **0.00 to 0.05**, with an initial spin configuration that was **randomly generated**.
3. **Decreasing** magnetic field in the **111** direction from **0.05 to 0.00**, with an initial spin configuration that was a **ground state** with theta = 0.206275 and phi = 3.11867.
4. **Decreasing** magnetic field in the **111** direction from **0.05 to 0.00**, with an initial spin configuration that was **randomly generated**.

Analysis that was performed on the resulting data included the following:

- Plots of magnetization versus field
- Plots of energy versus field
- Animations of the characteristic 6 spins
- Animations of a subsection of the lattice
- Determination of the number of "unique" spins that populate the lattice
- Determination of the components of the unique spins
- Plots of azimuth and zenith angles of the A, B, C, spins w.r.t. the plane of the 111 normal vector

RUN 1: Increasing Field, Ground State

Steps persist in the energy graphs. This can probably be fixed by increasing precision. A sudden drop in energy occurs at field 0.006. This corresponds to the spin configuration snapping into a planar state, where the applied field vector intersects the plane. The angle of intersection is not perpendicular, but looks close to it. Once in the planar state, the spins gradually align with the field, and nothing else interesting happens.

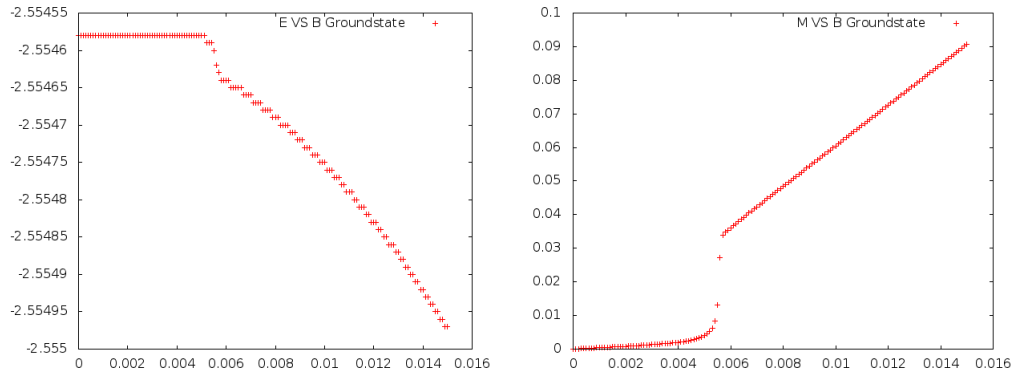

Figure 1: Energy vs increasing field and Magnetization versus increasing field

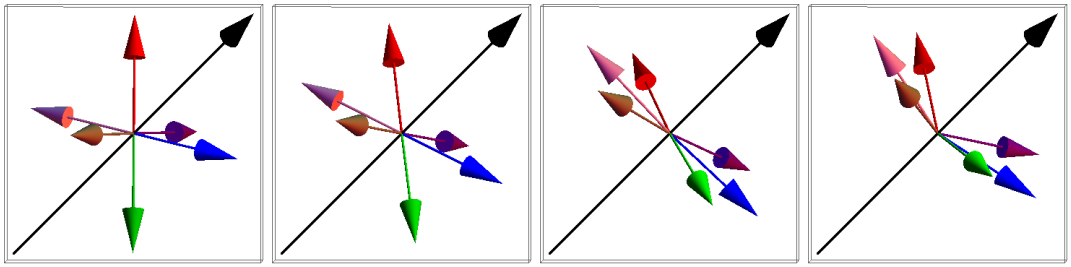

Figure 2: Snapshots of the 6 characteristic spins of the lattice at B=0, B=0.0052, B=0.0077, and B=0.05

0.0000	6	0.0050	6	0.0100	6	0.0150	6	0.0200	6	0.0250	6	0.0300	6	0.0350	6	0.0400	6	0.0450	6
0.0001	6	0.0051	6	0.0101	6	0.0151	6	0.0201	6	0.0251	6	0.0301	6	0.0351	6	0.0401	6	0.0451	6
0.0002	6	0.0052	6	0.0102	6	0.0152	6	0.0202	6	0.0252	6	0.0302	6	0.0352	6	0.0402	6	0.0452	6
0.0003	6	0.0053	6	0.0103	6	0.0153	6	0.0203	6	0.0253	6	0.0303	6	0.0353	6	0.0403	6	0.0453	6
0.0004	6	0.0054	6	0.0104	6	0.0154	6	0.0204	6	0.0254	6	0.0304	6	0.0354	6	0.0404	6	0.0454	6
0.0005	6	0.0055	6	0.0105	6	0.0155	6	0.0205	6	0.0255	6	0.0305	6	0.0355	6	0.0405	6	0.0455	6
0.0006	6	0.0056	28	0.0106	6	0.0156	6	0.0206	6	0.0256	6	0.0306	6	0.0356	6	0.0406	6	0.0456	6
0.0007	9	0.0057	6	0.0107	6	0.0157	6	0.0207	6	0.0257	6	0.0307	6	0.0357	6	0.0407	6	0.0457	6
0.0008	12	0.0058	6	0.0108	6	0.0158	6	0.0208	6	0.0258	6	0.0308	6	0.0358	6	0.0408	6	0.0458	6
0.0009	8	0.0059	6	0.0109	6	0.0159	6	0.0209	6	0.0259	6	0.0309	6	0.0359	6	0.0409	6	0.0459	6
0.0010	6	0.0060	7	0.0110	6	0.0160	6	0.0210	6	0.0260	6	0.0310	6	0.0360	6	0.0410	6	0.0460	6
0.0011	6	0.0061	6	0.0111	6	0.0161	6	0.0211	6	0.0261	6	0.0311	6	0.0361	6	0.0411	6	0.0461	6
0.0012	6	0.0062	6	0.0112	6	0.0162	6	0.0212	6	0.0262	6	0.0312	6	0.0362	6	0.0412	6	0.0462	6
0.0013	6	0.0063	6	0.0113	6	0.0163	6	0.0213	6	0.0263	6	0.0313	6	0.0363	6	0.0413	6	0.0463	6
0.0014	6	0.0064	6	0.0114	6	0.0164	6	0.0214	6	0.0264	6	0.0314	6	0.0364	6	0.0414	6	0.0464	6
0.0015	6	0.0065	7	0.0115	6	0.0165	6	0.0215	6	0.0265	6	0.0315	6	0.0365	6	0.0415	6	0.0465	6
0.0016	6	0.0066	6	0.0116	6	0.0166	6	0.0216	6	0.0266	6	0.0316	6	0.0366	6	0.0416	6	0.0466	6
0.0017	6	0.0067	6	0.0117	6	0.0167	6	0.0217	6	0.0267	6	0.0317	6	0.0367	6	0.0417	6	0.0467	6
0.0018	6	0.0068	7	0.0118	6	0.0168	6	0.0218	6	0.0268	6	0.0318	6	0.0368	6	0.0418	6	0.0468	6
0.0019	6	0.0069	6	0.0119	6	0.0169	6	0.0219	6	0.0269	6	0.0319	6	0.0369	6	0.0419	6	0.0469	6
0.0020	6	0.0070	6	0.0120	6	0.0170	6	0.0220	6	0.0270	6	0.0320	6	0.0370	6	0.0420	6	0.0470	6
0.0021	6	0.0071	6	0.0121	6	0.0171	6	0.0221	6	0.0271	6	0.0321	6	0.0371	6	0.0421	6	0.0471	6
0.0022	6	0.0072	6	0.0122	6	0.0172	6	0.0222	6	0.0272	6	0.0322	6	0.0372	6	0.0422	6	0.0472	6
0.0023	6	0.0073	6	0.0123	6	0.0173	6	0.0223	6	0.0273	6	0.0323	6	0.0373	6	0.0423	6	0.0473	6
0.0024	6	0.0074	6	0.0124	6	0.0174	6	0.0224	6	0.0274	6	0.0324	6	0.0374	6	0.0424	6	0.0474	6
0.0025	6	0.0075	6	0.0125	6	0.0175	6	0.0225	6	0.0275	6	0.0325	6	0.0375	6	0.0425	6	0.0475	6
0.0026	6	0.0076	6	0.0126	6	0.0176	6	0.0226	6	0.0276	6	0.0326	6	0.0376	6	0.0426	6	0.0476	6
0.0027	6	0.0077	6	0.0127	6	0.0177	6	0.0227	6	0.0277	6	0.0327	6	0.0377	6	0.0427	6	0.0477	6
0.0028	6	0.0078	6	0.0128	6	0.0178	6	0.0228	6	0.0278	6	0.0328	6	0.0378	6	0.0428	6	0.0478	6
0.0029	6	0.0079	6	0.0129	6	0.0179	6	0.0229	6	0.0279	6	0.0329	6	0.0379	6	0.0429	6	0.0479	6
0.0030	6	0.0080	6	0.0130	6	0.0180	6	0.0230	6	0.0280	6	0.0330	6	0.0380	6	0.0430	6	0.0480	6
0.0031	6	0.0081	6	0.0131	6	0.0181	6	0.0231	6	0.0281	6	0.0331	6	0.0381	6	0.0431	6	0.0481	6
0.0032	6	0.0082	6	0.0132	6	0.0182	6	0.0232	6	0.0282	6	0.0332	6	0.0382	6	0.0432	6	0.0482	6
0.0033	6	0.0083	6	0.0133	6	0.0183	6	0.0233	6	0.0283	6	0.0333	6	0.0383	6	0.0433	6	0.0483	6
0.0034	6	0.0084	6	0.0134	6	0.0184	6	0.0234	6	0.0284	6	0.0334	6	0.0384	6	0.0434	6	0.0484	6
0.0035	6	0.0085	6	0.0135	6	0.0185	6	0.0235	6	0.0285	6	0.0335	6	0.0385	6	0.0435	6	0.0485	6
0.0036	6	0.0086	6	0.0136	6	0.0186	6	0.0236	6	0.0286	6	0.0336	6	0.0386	6	0.0436	6	0.0486	6
0.0037	6	0.0087	6	0.0137	6	0.0187	6	0.0237	6	0.0287	6	0.0337	6	0.0387	6	0.0437	6	0.0487	6
0.0038	6	0.0088	6	0.0138	6	0.0188	6	0.0238	6	0.0288	6	0.0338	6	0.0388	6	0.0438	6	0.0488	6
0.0039	6	0.0089	6	0.0139	6	0.0189	6	0.0239	6	0.0289	6	0.0339	6	0.0389	6	0.0439	6	0.0489	6
0.0040	6	0.0090	6	0.0140	6	0.0190	6	0.0240	6	0.0290	6	0.0340	6	0.0390	6	0.0440	6	0.0490	6
0.0041	6	0.0091	6	0.0141	6	0.0191	6	0.0241	6	0.0291	6	0.0341	6	0.0391	6	0.0441	6	0.0491	6
0.0042	6	0.0092	6	0.0142	6	0.0192	6	0.0242	6	0.0292	6	0.0342	6	0.0392	6	0.0442	6	0.0492	6
0.0043	6	0.0093	6	0.0143	6	0.0193	6	0.0243	6	0.0293	6	0.0343	6	0.0393	6	0.0443	6	0.0493	6
0.0044	7	0.0094	6	0.0144	6	0.0194	6	0.0244	6	0.0294	6	0.0344	6	0.0394	6	0.0444	6	0.0494	6
0.0045	7	0.0095	6	0.0145	6	0.0195	6	0.0245	6	0.0295	6	0.0345	6	0.0395	6	0.0445	6	0.0495	6
0.0046	6	0.0096	6	0.0146	6	0.0196	6	0.0246	6	0.0296	6	0.0346	6	0.0396	6	0.0446	6	0.0496	6
0.0047	6	0.0097	6	0.0147	6	0.0197	6	0.0247	6	0.0297	6	0.0347	6	0.0397	6	0.0447	6	0.0497	6
0.0048	6	0.0098	6	0.0148	6	0.0198	6	0.0248	6	0.0298	6	0.0348	6	0.0398	6	0.0448	6	0.0498	6
0.0049	6	0.0099	6	0.0149	6	0.0199	6	0.0249	6	0.0299	6	0.0349	6	0.0399	6	0.0449	6	0.0499	6

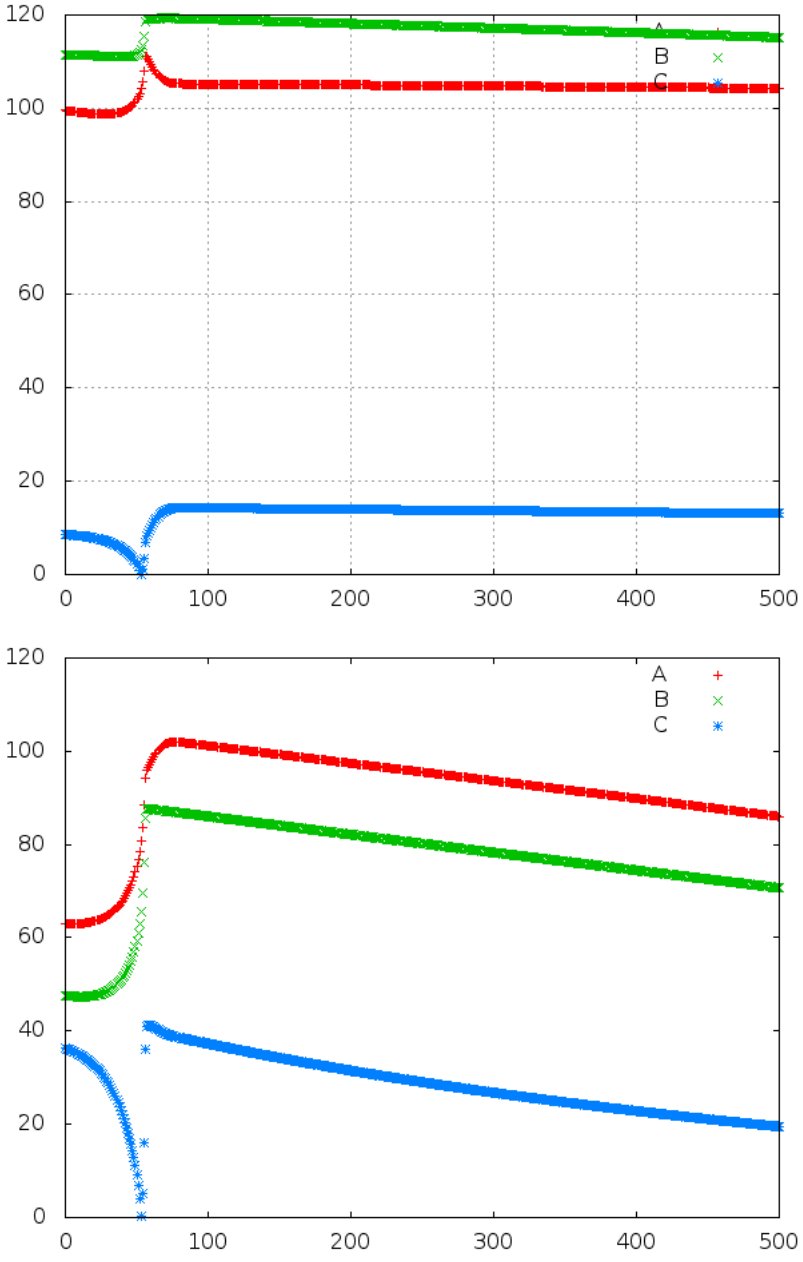

Figure 3: The angles are those between a chosen vector lying in the plane intersected by 111, and a projection of each of the A, B, and C spins. Azimuthal angles are followed by zenith angles.

RUN 2: Decreasing Field, Ground State

Steps persist in the energy graphs. Increasing precision can probably fix this. Unlike the case where the field was increased, a sudden transition does not occur within the spin configuration when decreasing the field. The field is initially at its highest, and the spins are partially aligned with the field. As the field is lowered, the spins gradually relax to a planar state, and do not return to the ground state that is typically observed at near zero or zero field.

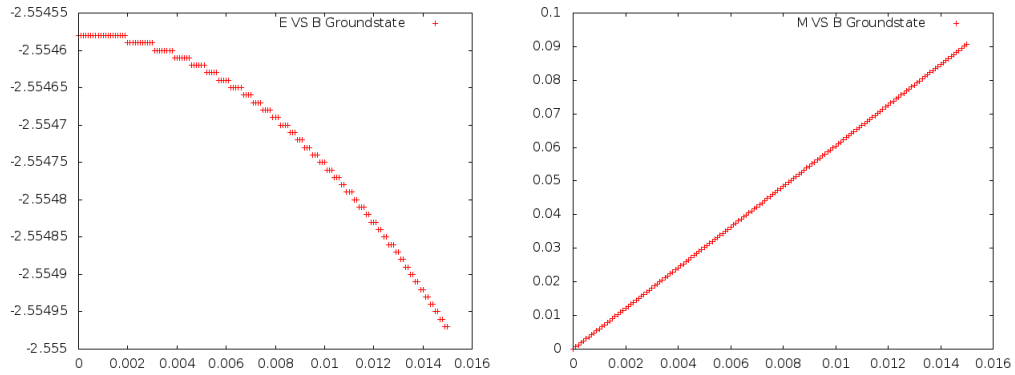

Figure 4: Energy vs decreasing field and Magnetization versus decreasing field

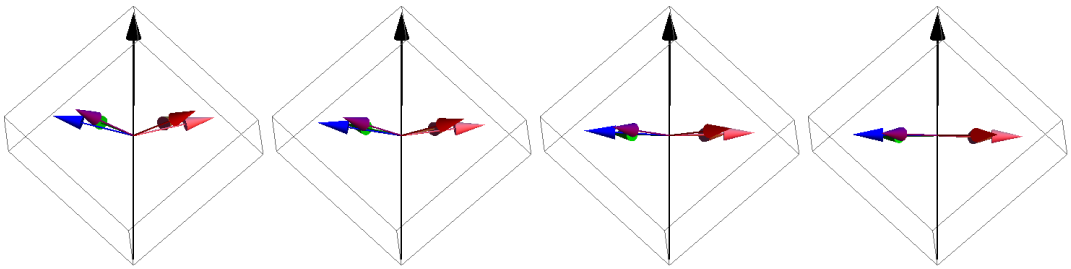

Figure 5: Snapshots of the 6 characteristic spins of the lattice at B=0.05, B=0.0309, B=0.01, and B=0.00

0.0500	6	0.0450	6	0.0400	6	0.0350	6	0.0300	6	0.0250	6	0.0200	6	0.0150	6	0.0100	6	0.0050	6
0.0499	6	0.0449	6	0.0399	6	0.0349	6	0.0299	6	0.0249	6	0.0199	6	0.0149	6	0.0099	6	0.0049	6
0.0498	6	0.0448	6	0.0398	6	0.0348	6	0.0298	6	0.0248	6	0.0198	6	0.0148	6	0.0098	6	0.0048	6
0.0497	6	0.0447	6	0.0397	6	0.0347	6	0.0297	6	0.0247	6	0.0197	6	0.0147	6	0.0097	6	0.0047	6
0.0496	6	0.0446	6	0.0396	6	0.0346	6	0.0296	6	0.0246	6	0.0196	6	0.0146	6	0.0096	6	0.0046	6
0.0495	6	0.0445	6	0.0395	6	0.0345	6	0.0295	6	0.0245	6	0.0195	6	0.0145	6	0.0095	6	0.0045	6
0.0494	6	0.0444	6	0.0394	6	0.0344	6	0.0294	6	0.0244	6	0.0194	6	0.0144	6	0.0094	6	0.0044	6
0.0493	6	0.0443	6	0.0393	6	0.0343	6	0.0293	6	0.0243	6	0.0193	6	0.0143	6	0.0093	6	0.0043	6
0.0492	6	0.0442	6	0.0392	6	0.0342	6	0.0292	6	0.0242	6	0.0192	6	0.0142	6	0.0092	6	0.0042	6
0.0491	6	0.0441	6	0.0391	6	0.0341	6	0.0291	6	0.0241	6	0.0191	6	0.0141	6	0.0091	6	0.0041	6
0.0490	6	0.0440	6	0.0390	6	0.0340	6	0.0290	6	0.0240	6	0.0190	6	0.0140	6	0.0090	6	0.0040	6
0.0489	6	0.0439	6	0.0389	6	0.0339	6	0.0289	6	0.0239	6	0.0189	6	0.0139	6	0.0089	6	0.0039	6
0.0488	6	0.0438	6	0.0388	6	0.0338	6	0.0288	6	0.0238	6	0.0188	6	0.0138	6	0.0088	6	0.0038	6
0.0487	6	0.0437	6	0.0387	6	0.0337	6	0.0287	6	0.0237	6	0.0187	6	0.0137	6	0.0087	6	0.0037	6
0.0486	6	0.0436	6	0.0386	6	0.0336	6	0.0286	6	0.0236	6	0.0186	6	0.0136	6	0.0086	6	0.0036	6
0.0485	6	0.0435	6	0.0385	6	0.0335	6	0.0285	6	0.0235	6	0.0185	6	0.0135	6	0.0085	6	0.0035	6
0.0484	6	0.0434	6	0.0384	6	0.0334	6	0.0284	6	0.0234	6	0.0184	6	0.0134	6	0.0084	6	0.0034	6
0.0483	6	0.0433	6	0.0383	6	0.0333	6	0.0283	6	0.0233	6	0.0183	6	0.0133	6	0.0083	6	0.0033	6
0.0482	6	0.0432	6	0.0382	6	0.0332	6	0.0282	6	0.0232	6	0.0182	6	0.0132	6	0.0082	6	0.0032	6
0.0481	6	0.0431	6	0.0381	6	0.0331	6	0.0281	6	0.0231	6	0.0181	6	0.0131	6	0.0081	6	0.0031	6
0.0480	6	0.0430	6	0.0380	6	0.0330	6	0.0280	6	0.0230	6	0.0180	6	0.0130	6	0.0080	6	0.0030	6
0.0479	6	0.0429	6	0.0379	6	0.0329	6	0.0279	6	0.0229	6	0.0179	6	0.0129	6	0.0079	6	0.0029	6
0.0478	6	0.0428	6	0.0378	6	0.0328	6	0.0278	6	0.0228	6	0.0178	6	0.0128	6	0.0078	6	0.0028	6
0.0477	6	0.0427	6	0.0377	6	0.0327	6	0.0277	6	0.0227	6	0.0177	6	0.0127	6	0.0077	6	0.0027	6
0.0476	6	0.0426	6	0.0376	6	0.0326	6	0.0276	6	0.0226	6	0.0176	6	0.0126	6	0.0076	6	0.0026	6
0.0475	6	0.0425	6	0.0375	6	0.0325	6	0.0275	6	0.0225	6	0.0175	6	0.0125	6	0.0075	6	0.0025	6
0.0474	6	0.0424	6	0.0374	6	0.0324	6	0.0274	6	0.0224	6	0.0174	6	0.0124	6	0.0074	6	0.0024	6
0.0473	6	0.0423	6	0.0373	6	0.0323	6	0.0273	6	0.0223	6	0.0173	6	0.0123	6	0.0073	6	0.0023	6
0.0472	6	0.0422	6	0.0372	6	0.0322	6	0.0272	6	0.0222	6	0.0172	6	0.0122	6	0.0072	6	0.0022	6
0.0471	6	0.0421	6	0.0371	6	0.0321	6	0.0271	6	0.0221	6	0.0171	6	0.0121	6	0.0071	6	0.0021	6
0.0470	6	0.0420	6	0.0370	6	0.0320	6	0.0270	6	0.0220	6	0.0170	6	0.0120	6	0.0070	6	0.0020	6
0.0469	6	0.0419	6	0.0369	6	0.0319	6	0.0269	6	0.0219	6	0.0169	6	0.0119	6	0.0069	6	0.0019	6
0.0468	6	0.0418	6	0.0368	6	0.0318	6	0.0268	6	0.0218	6	0.0168	6	0.0118	6	0.0068	6	0.0018	6
0.0467	6	0.0417	6	0.0367	6	0.0317	6	0.0267	6	0.0217	6	0.0167	6	0.0117	6	0.0067	6	0.0017	6
0.0466	6	0.0416	6	0.0366	6	0.0316	6	0.0266	6	0.0216	6	0.0166	6	0.0116	6	0.0066	6	0.0016	6
0.0465	6	0.0415	6	0.0365	6	0.0315	6	0.0265	6	0.0215	6	0.0165	6	0.0115	6	0.0065	6	0.0015	6
0.0464	6	0.0414	6	0.0364	6	0.0314	6	0.0264	6	0.0214	6	0.0164	6	0.0114	6	0.0064	6	0.0014	6
0.0463	6	0.0413	6	0.0363	6	0.0313	6	0.0263	6	0.0213	6	0.0163	6	0.0113	6	0.0063	6	0.0013	6
0.0462	6	0.0412	6	0.0362	6	0.0312	6	0.0262	6	0.0212	6	0.0162	6	0.0112	6	0.0062	6	0.0012	6
0.0461	6	0.0411	6	0.0361	6	0.0311	6	0.0261	6	0.0211	6	0.0161	6	0.0111	6	0.0061	6	0.0011	6
0.0460	6	0.0410	6	0.0360	6	0.0310	6	0.0260	6	0.0210	6	0.0160	6	0.0110	6	0.0060	6	0.0010	6
0.0459	6	0.0409	6	0.0359	6	0.0309	6	0.0259	6	0.0209	6	0.0159	6	0.0109	6	0.0059	6	0.0009	6
0.0458	6	0.0408	6	0.0358	6	0.0308	6	0.0258	6	0.0208	6	0.0158	6	0.0108	6	0.0058	6	0.0008	6
0.0457	6	0.0407	6	0.0357	6	0.0307	6	0.0257	6	0.0207	6	0.0157	6	0.0107	6	0.0057	6	0.0007	6
0.0456	6	0.0406	6	0.0356	6	0.0306	6	0.0256	6	0.0206	6	0.0156	6	0.0106	6	0.0056	6	0.0006	6
0.0455	6	0.0405	6	0.0355	6	0.0305	6	0.0255	6	0.0205	6	0.0155	6	0.0105	6	0.0055	6	0.0005	6
0.0454	6	0.0404	6	0.0354	6	0.0304	6	0.0254	6	0.0204	6	0.0154	6	0.0104	6	0.0054	6	0.0004	6
0.0453	6	0.0403	6	0.0353	6	0.0303	6	0.0253	6	0.0203	6	0.0153	6	0.0103	6	0.0053	6	0.0003	7
0.0452	6	0.0402	6	0.0352	6	0.0302	6	0.0252	6	0.0202	6	0.0152	6	0.0102	6	0.0052	6	0.0002	6
0.0451	6	0.0401	6	0.0351	6	0.0301	6	0.0251	6	0.0201	6	0.0151	6	0.0101	6	0.0051	6	0.0001	6

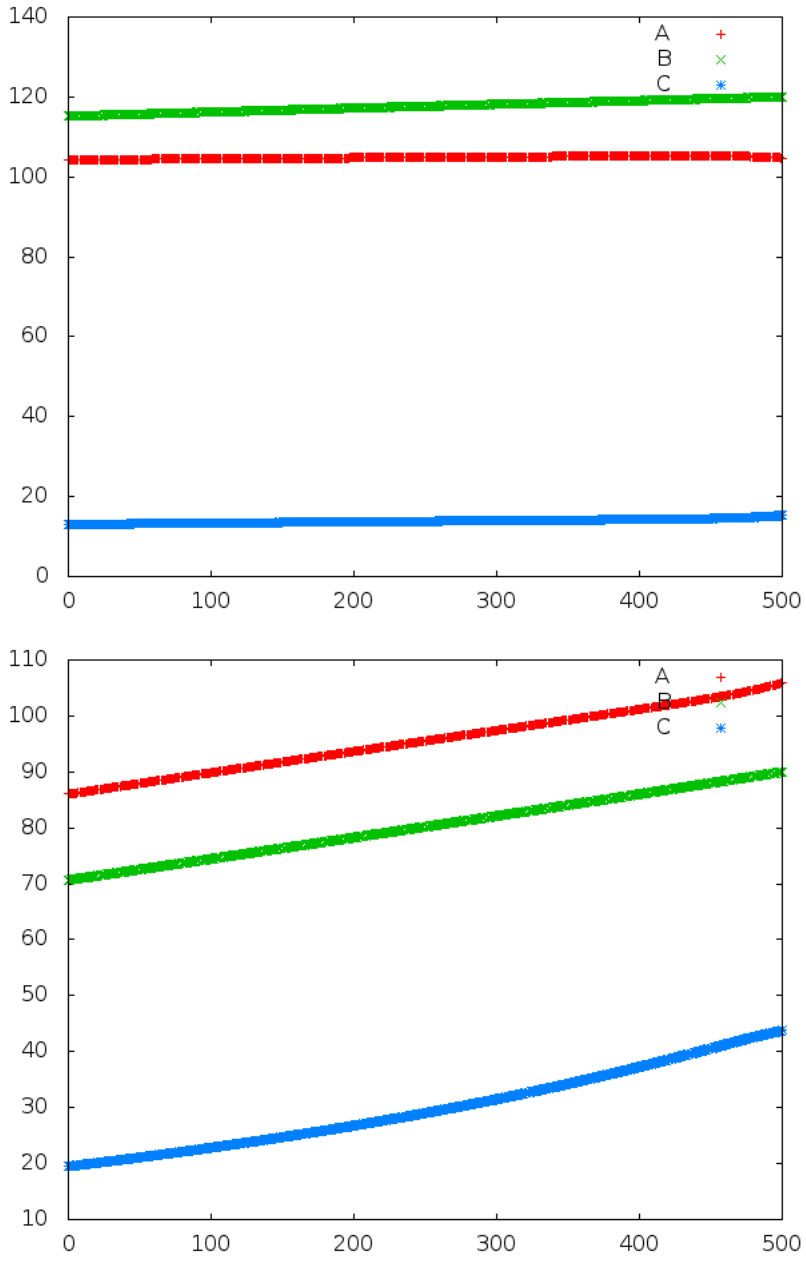

Figure 6: The angles are those between a chosen vector lying in the plane intersected by 111, and a projection of each of the A, B, and C spins. Azimuthal angles are followed by zenith angles.

RUN 3: Increasing Field, Random State

Very similar to run 1, where the lattice starts off at a ground state configuration and snaps into a planar configuration, followed by gradual alignment with the field. Note: the first data point in the energy and magnetization plots were removed since it was much higher than any other points on the graph, which caused the plot to become flattened in order to fit the entire range of data onto the same plot. This is likely due to the fact that 2000 iterations is insufficient for the energy to be minimized, and so starting from a random initial configuration causes the energy of the lattice at the first field value (B=0) to be much higher than the ground state since it has yet to become a ground state.

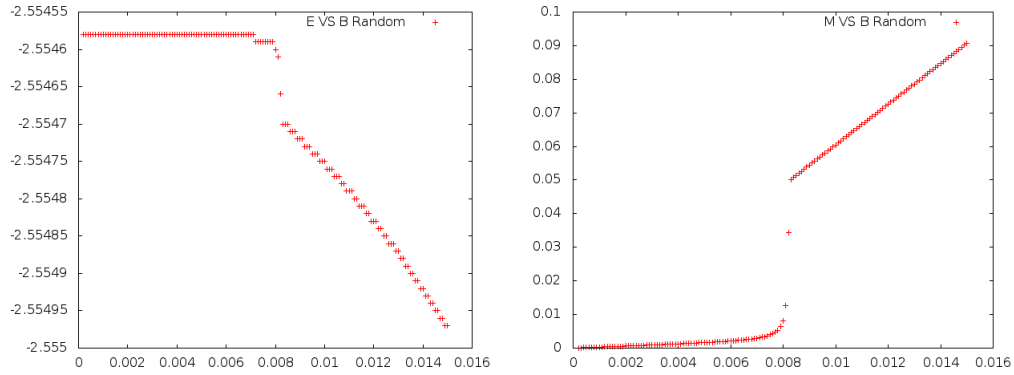

Figure 7: Energy vs increasing field and Magnetization versus increasing field

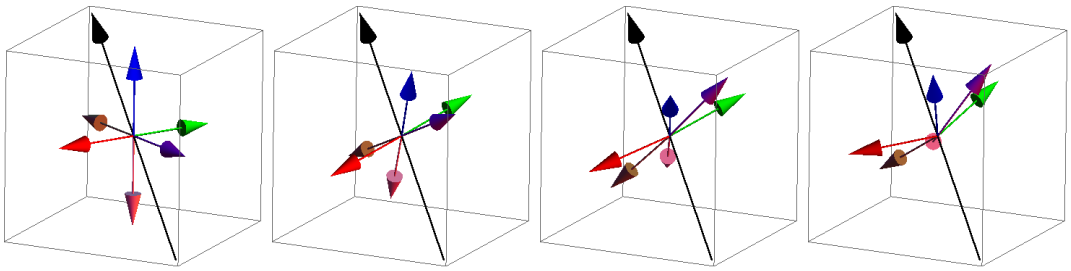

Figure 8: Snapshots of the 6 characteristic spins of the lattice

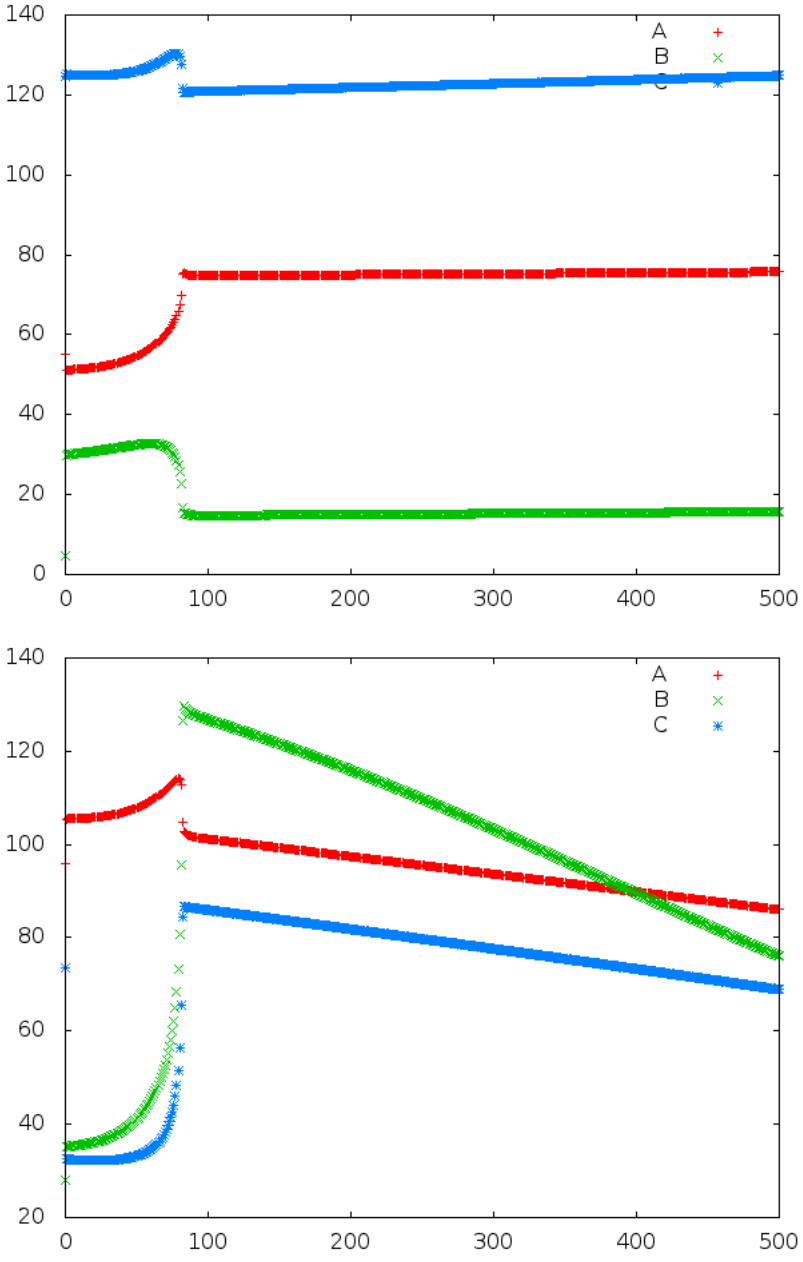

Figure 9: The angles are those between a chosen vector lying in the plane intersected by 111, and a projection of each of the A, B, and C spins. Azimuthal angles are followed by zenith angles.

0.0000	260	0.0050	6	0.0100	6	0.0150	6	0.0200	6	0.0250	6	0.0300	6	0.0350	6	0.0400	6	0.0450	6
0.0001	288	0.0051	6	0.0101	6	0.0151	6	0.0201	6	0.0251	6	0.0301	6	0.0351	6	0.0401	6	0.0451	6
0.0002	49	0.0052	6	0.0102	6	0.0152	6	0.0202	6	0.0252	6	0.0302	6	0.0352	6	0.0402	6	0.0452	6
0.0003	8	0.0053	7	0.0103	6	0.0153	6	0.0203	6	0.0253	6	0.0303	6	0.0353	6	0.0403	6	0.0453	6
0.0004	11	0.0054	6	0.0104	6	0.0154	6	0.0204	6	0.0254	6	0.0304	6	0.0354	6	0.0404	6	0.0454	6
0.0005	7	0.0055	7	0.0105	6	0.0155	6	0.0205	6	0.0255	6	0.0305	6	0.0355	6	0.0405	6	0.0455	6
0.0006	7	0.0056	7	0.0106	6	0.0156	6	0.0206	6	0.0256	6	0.0306	6	0.0356	6	0.0406	6	0.0456	6
0.0007	6	0.0057	6	0.0107	6	0.0157	6	0.0207	6	0.0257	6	0.0307	6	0.0357	6	0.0407	6	0.0457	6
0.0008	7	0.0058	6	0.0108	6	0.0158	6	0.0208	6	0.0258	6	0.0308	6	0.0358	6	0.0408	6	0.0458	6
0.0009	6	0.0059	7	0.0109	6	0.0159	6	0.0209	6	0.0259	6	0.0309	6	0.0359	6	0.0409	6	0.0459	6
0.0010	6	0.0060	7	0.0110	6	0.0160	6	0.0210	6	0.0260	6	0.0310	6	0.0360	6	0.0410	6	0.0460	6
0.0011	6	0.0061	6	0.0111	6	0.0161	6	0.0211	6	0.0261	6	0.0311	6	0.0361	6	0.0411	6	0.0461	6
0.0012	6	0.0062	6	0.0112	6	0.0162	6	0.0212	6	0.0262	6	0.0312	6	0.0362	6	0.0412	6	0.0462	6
0.0013	7	0.0063	6	0.0113	6	0.0163	6	0.0213	6	0.0263	6	0.0313	6	0.0363	6	0.0413	6	0.0463	6
0.0014	8	0.0064	6	0.0114	6	0.0164	6	0.0214	6	0.0264	6	0.0314	6	0.0364	6	0.0414	6	0.0464	6
0.0015	6	0.0065	6	0.0115	6	0.0165	6	0.0215	6	0.0265	6	0.0315	6	0.0365	6	0.0415	6	0.0465	6
0.0016	7	0.0066	6	0.0116	6	0.0166	6	0.0216	6	0.0266	6	0.0316	6	0.0366	6	0.0416	6	0.0466	6
0.0017	6	0.0067	6	0.0117	6	0.0167	6	0.0217	6	0.0267	6	0.0317	6	0.0367	6	0.0417	6	0.0467	6
0.0018	6	0.0068	6	0.0118	6	0.0168	6	0.0218	6	0.0268	6	0.0318	6	0.0368	6	0.0418	6	0.0468	6
0.0019	6	0.0069	6	0.0119	6	0.0169	6	0.0219	6	0.0269	6	0.0319	6	0.0369	6	0.0419	6	0.0469	6
0.0020	6	0.0070	6	0.0120	6	0.0170	6	0.0220	6	0.0270	6	0.0320	6	0.0370	6	0.0420	6	0.0470	6
0.0021	6	0.0071	6	0.0121	6	0.0171	6	0.0221	6	0.0271	6	0.0321	6	0.0371	6	0.0421	6	0.0471	6
0.0022	6	0.0072	6	0.0122	6	0.0172	6	0.0222	6	0.0272	6	0.0322	6	0.0372	6	0.0422	6	0.0472	6
0.0023	6	0.0073	6	0.0123	6	0.0173	6	0.0223	6	0.0273	6	0.0323	6	0.0373	6	0.0423	6	0.0473	6
0.0024	6	0.0074	6	0.0124	6	0.0174	6	0.0224	6	0.0274	6	0.0324	6	0.0374	6	0.0424	6	0.0474	6
0.0025	6	0.0075	6	0.0125	6	0.0175	6	0.0225	6	0.0275	6	0.0325	6	0.0375	6	0.0425	6	0.0475	6
0.0026	6	0.0076	6	0.0126	6	0.0176	6	0.0226	6	0.0276	6	0.0326	6	0.0376	6	0.0426	6	0.0476	6
0.0027	6	0.0077	6	0.0127	6	0.0177	6	0.0227	6	0.0277	6	0.0327	6	0.0377	6	0.0427	6	0.0477	6
0.0028	6	0.0078	6	0.0128	6	0.0178	6	0.0228	6	0.0278	6	0.0328	6	0.0378	6	0.0428	6	0.0478	6
0.0029	6	0.0079	6	0.0129	6	0.0179	6	0.0229	6	0.0279	6	0.0329	6	0.0379	6	0.0429	6	0.0479	6
0.0030	6	0.0080	6	0.0130	6	0.0180	6	0.0230	6	0.0280	6	0.0330	6	0.0380	6	0.0430	6	0.0480	6
0.0031	6	0.0081	6	0.0131	6	0.0181	6	0.0231	6	0.0281	6	0.0331	6	0.0381	6	0.0431	6	0.0481	6
0.0032	6	0.0082	45	0.0132	6	0.0182	6	0.0232	6	0.0282	6	0.0332	6	0.0382	6	0.0432	6	0.0482	6
0.0033	6	0.0083	6	0.0133	6	0.0183	6	0.0233	6	0.0283	6	0.0333	6	0.0383	6	0.0433	6	0.0483	6
0.0034	6	0.0084	6	0.0134	6	0.0184	6	0.0234	6	0.0284	6	0.0334	6	0.0384	6	0.0434	6	0.0484	6
0.0035	7	0.0085	6	0.0135	6	0.0185	6	0.0235	6	0.0285	6	0.0335	6	0.0385	6	0.0435	6	0.0485	6
0.0036	6	0.0086	6	0.0136	6	0.0186	6	0.0236	6	0.0286	6	0.0336	6	0.0386	6	0.0436	6	0.0486	6
0.0037	12	0.0087	6	0.0137	6	0.0187	6	0.0237	6	0.0287	6	0.0337	6	0.0387	6	0.0437	6	0.0487	6
0.0038	6	0.0088	6	0.0138	6	0.0188	6	0.0238	6	0.0288	6	0.0338	6	0.0388	6	0.0438	6	0.0488	6
0.0039	7	0.0089	6	0.0139	6	0.0189	6	0.0239	6	0.0289	6	0.0339	6	0.0389	6	0.0439	6	0.0489	6
0.0040	6	0.0090	7	0.0140	6	0.0190	6	0.0240	6	0.0290	6	0.0340	6	0.0390	6	0.0440	6	0.0490	6
0.0041	6	0.0091	6	0.0141	6	0.0191	6	0.0241	6	0.0291	6	0.0341	6	0.0391	6	0.0441	6	0.0491	6
0.0042	6	0.0092	6	0.0142	6	0.0192	6	0.0242	6	0.0292	6	0.0342	6	0.0392	6	0.0442	6	0.0492	6
0.0043	7	0.0093	6	0.0143	6	0.0193	6	0.0243	6	0.0293	6	0.0343	6	0.0393	6	0.0443	6	0.0493	6
0.0044	6	0.0094	6	0.0144	6	0.0194	6	0.0244	6	0.0294	6	0.0344	6	0.0394	6	0.0444	6	0.0494	6
0.0045	6	0.0095	6	0.0145	6	0.0195	6	0.0245	6	0.0295	6	0.0345	6	0.0395	6	0.0445	6	0.0495	6
0.0046	7	0.0096	6	0.0146	6	0.0196	6	0.0246	6	0.0296	6	0.0346	6	0.0396	6	0.0446	6	0.0496	6
0.0047	7	0.0097	6	0.0147	6	0.0197	6	0.0247	6	0.0297	6	0.0347	6	0.0397	6	0.0447	6	0.0497	6
0.0048	6	0.0098	6	0.0148	6	0.0198	6	0.0248	6	0.0298	6	0.0348	6	0.0398	6	0.0448	6	0.0498	6
0.0049	6	0.0099	6	0.0149	6	0.0199	6	0.0249	6	0.0299	6	0.0349	6	0.0399	6	0.0449	6	0.0499	6

RUN 4: Decreasing Field, Random State

Between the first two images of the 6 spins, there is little difference even though the field had changed by about 0.03. At 0.21, the 6 spins undergo sudden and rapid changes in orientation. Eventually, the 6 spins rest in a near planar state, and gradually relax to a full planar state at B=0. When referring to the spin chart, it's clear that trying to visualize the entire lattice by choosing 6 spins won't work, since there are far more than 6 spins for the majority of fields. An alternate approach was used, which involved looking at a small, manageable section of the entire lattice.

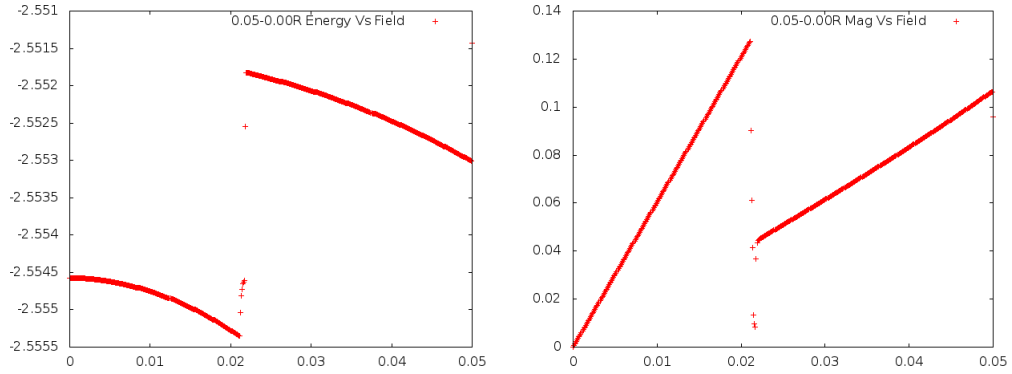

Figure 10: Energy vs decreasing field and Magnetization versus decreasing field

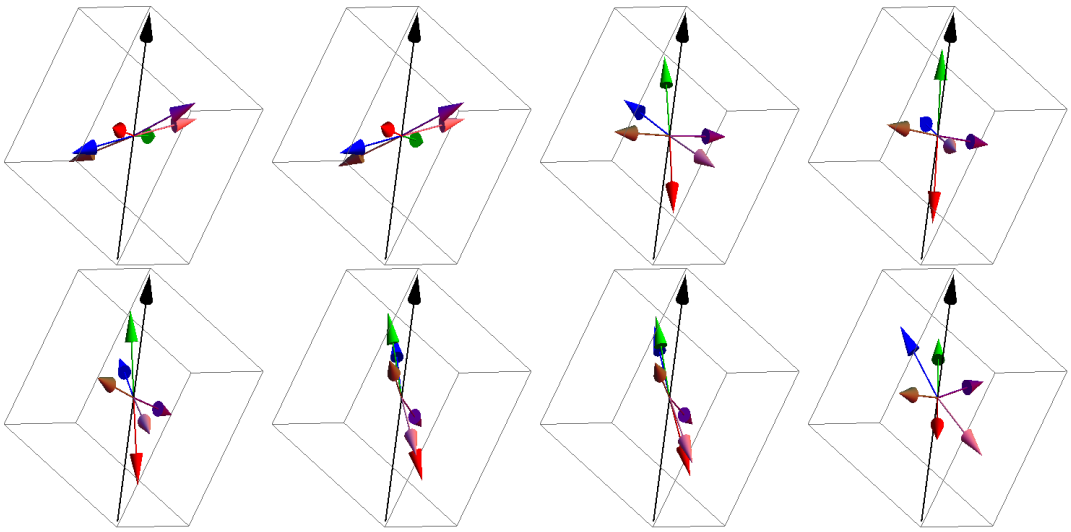

Figure 11: Snapshots of the 6 characteristic spins of the lattice over the course of increasing field

0.0500	102	0.045	84	0.04	84	0.035	88	0.03	83	0.025	78	0.02	6	0.015	6	0.01	6	0.005	6
0.0499	92	0.0449	86	0.0399	82	0.0349	89	0.0299	82	0.0249	78	0.0199	6	0.0149	6	0.0099	6	0.0049	6
0.0498	86	0.0448	86	0.0398	88	0.0348	88	0.0298	82	0.0248	78	0.0198	6	0.0148	6	0.0098	6	0.0048	6
0.0497	86	0.0447	82	0.0397	88	0.0347	88	0.0297	82	0.0247	78	0.0197	6	0.0147	6	0.0097	6	0.0047	6
0.0496	86	0.0446	82	0.0396	90	0.0346	88	0.0296	82	0.0246	78	0.0196	6	0.0146	6	0.0096	6	0.0046	6
0.0495	90	0.0445	84	0.0395	88	0.0345	88	0.0295	80	0.0245	80	0.0195	6	0.0145	6	0.0095	6	0.0045	6
0.0494	86	0.0444	86	0.0394	90	0.0344	88	0.0294	80	0.0244	80	0.0194	6	0.0144	6	0.0094	6	0.0044	6
0.0493	88	0.0443	84	0.0393	90	0.0343	86	0.0293	80	0.0243	80	0.0193	6	0.0143	6	0.0093	6	0.0043	6
0.0492	86	0.0442	82	0.0392	84	0.0342	83	0.0292	82	0.0242	78	0.0192	6	0.0142	6	0.0092	6	0.0042	6
0.0491	88	0.0441	82	0.0391	86	0.0341	82	0.0291	80	0.0241	78	0.0191	6	0.0141	6	0.0091	6	0.0041	7
0.0490	88	0.044	85	0.039	86	0.034	84	0.029	80	0.024	78	0.019	6	0.014	6	0.009	6	0.004	6
0.0489	86	0.0439	84	0.0389	89	0.0339	84	0.0289	81	0.0239	80	0.0189	6	0.0139	6	0.0089	6	0.0039	6
0.0488	86	0.0438	82	0.0388	88	0.0338	84	0.0288	80	0.0238	81	0.0188	6	0.0138	6	0.0088	6	0.0038	6
0.0487	86	0.0437	82	0.0387	88	0.0337	84	0.0287	78	0.0237	80	0.0187	6	0.0137	6	0.0087	6	0.0037	6
0.0486	84	0.0436	82	0.0386	88	0.0336	84	0.0286	79	0.0236	82	0.0186	6	0.0136	6	0.0086	6	0.0036	6
0.0485	84	0.0435	82	0.0385	88	0.0335	84	0.0285	78	0.0235	80	0.0185	6	0.0135	6	0.0085	6	0.0035	6
0.0484	84	0.0434	82	0.0384	89	0.0334	86	0.0284	78	0.0234	82	0.0184	6	0.0134	6	0.0084	6	0.0034	6
0.0483	84	0.0433	84	0.0383	89	0.0333	88	0.0283	78	0.0233	83	0.0183	6	0.0133	6	0.0083	6	0.0033	6
0.0482	84	0.0432	82	0.0382	86	0.0332	88	0.0282	78	0.0232	83	0.0182	6	0.0132	6	0.0082	6	0.0032	6
0.0481	82	0.0431	82	0.0381	86	0.0331	88	0.0281	80	0.0231	84	0.0181	6	0.0131	6	0.0081	6	0.0031	6
0.0480	82	0.043	82	0.038	88	0.033	88	0.028	80	0.023	84	0.018	6	0.013	6	0.008	6	0.003	6
0.0479	82	0.0429	82	0.0379	88	0.0329	88	0.0279	80	0.0229	84	0.0179	6	0.0129	6	0.0079	6	0.0029	6
0.0478	84	0.0428	80	0.0378	95	0.0328	88	0.0278	78	0.0228	84	0.0178	6	0.0128	6	0.0078	6	0.0028	6
0.0477	84	0.0427	82	0.0377	95	0.0327	88	0.0277	78	0.0227	83	0.0177	6	0.0127	6	0.0077	6	0.0027	6
0.0476	86	0.0426	82	0.0376	96	0.0326	88	0.0276	82	0.0226	83	0.0176	6	0.0126	6	0.0076	6	0.0026	6
0.0475	86	0.0425	84	0.0375	96	0.0325	90	0.0275	82	0.0225	83	0.0175	6	0.0125	6	0.0075	6	0.0025	6
0.0474	86	0.0424	80	0.0374	98	0.0324	88	0.0274	82	0.0224	84	0.0174	6	0.0124	6	0.0074	6	0.0024	6
0.0473	86	0.0423	80	0.0373	98	0.0323	88	0.0273	83	0.0223	86	0.0173	6	0.0123	6	0.0073	6	0.0023	6
0.0472	90	0.0422	80	0.0372	96	0.0322	88	0.0272	84	0.0222	87	0.0172	6	0.0122	6	0.0072	6	0.0022	6
0.0471	86	0.0421	86	0.0371	96	0.0321	90	0.0271	91	0.0221	85	0.0171	6	0.0121	6	0.0071	6	0.0021	6
0.0470	82	0.042	88	0.037	94	0.032	90	0.027	91	0.022	99	0.017	6	0.012	6	0.007	6	0.002	6
0.0469	82	0.0419	88	0.0369	92	0.0319	90	0.0269	90	0.0219	110	0.0169	6	0.0119	6	0.0069	6	0.0019	6
0.0468	84	0.0418	88	0.0368	92	0.0318	88	0.0268	90	0.0218	50	0.0168	6	0.0118	6	0.0068	6	0.0018	6
0.0467	84	0.0417	88	0.0367	94	0.0317	88	0.0267	88	0.0217	29	0.0167	6	0.0117	6	0.0067	6	0.0017	6
0.0466	86	0.0416	88	0.0366	92	0.0316	86	0.0266	88	0.0216	9	0.0166	6	0.0116	6	0.0066	6	0.0016	6
0.0465	86	0.0415	86	0.0365	92	0.0315	86	0.0265	86	0.0215	11	0.0165	6	0.0115	6	0.0065	6	0.0015	6
0.0464	86	0.0414	88	0.0364	90	0.0314	86	0.0264	84	0.0214	9	0.0164	6	0.0114	6	0.0064	6	0.0014	6
0.0463	84	0.0413	84	0.0363	86	0.0313	86	0.0263	86	0.0213	9	0.0163	6	0.0113	6	0.0063	6	0.0013	6
0.0462	84	0.0412	82	0.0362	86	0.0312	86	0.0262	85	0.0212	10	0.0162	6	0.0112	6	0.0062	6	0.0012	6
0.0461	84	0.0411	82	0.0361	90	0.0311	86	0.0261	82	0.0211	8	0.0161	6	0.0111	6	0.0061	6	0.0011	6
0.0460	82	0.041	82	0.036	90	0.031	86	0.026	82	0.021	6	0.016	6	0.011	6	0.006	6	0.001	6
0.0459	82	0.0409	84	0.0359	90	0.0309	86	0.0259	82	0.0209	6	0.0159	6	0.0109	6	0.0059	6	0.0009	6
0.0458	84	0.0408	86	0.0358	90	0.0308	84	0.0258	82	0.0208	6	0.0158	6	0.0108	6	0.0058	6	0.0008	6
0.0457	84	0.0407	86	0.0357	89	0.0307	84	0.0257	80	0.0207	6	0.0157	6	0.0107	6	0.0057	6	0.0007	6
0.0456	86	0.0406	84	0.0356	90	0.0306	82	0.0256	80	0.0206	6	0.0156	6	0.0106	6	0.0056	6	0.0006	6
0.0455	86	0.0405	84	0.0355	90	0.0305	84	0.0255	80	0.0205	6	0.0155	6	0.0105	6	0.0055	6	0.0005	6
0.0454	86	0.0404	84	0.0354	90	0.0304	84	0.0254	82	0.0204	6	0.0154	6	0.0104	6	0.0054	6	0.0004	6
0.0453	86	0.0403	84	0.0353	90	0.0303	82	0.0253	82	0.0203	6	0.0153	6	0.0103	6	0.0053	6	0.0003	6
0.0452	86	0.0402	84	0.0352	92	0.0302	82	0.0252	82	0.0202	6	0.0152	6	0.0102	6	0.0052	6	0.0002	6
0.0451	86	0.0401	84	0.0351	90	0.0301	82	0.0251	78	0.0201	6	0.0151	6	0.0101	6	0.0051	6	0.0001	6

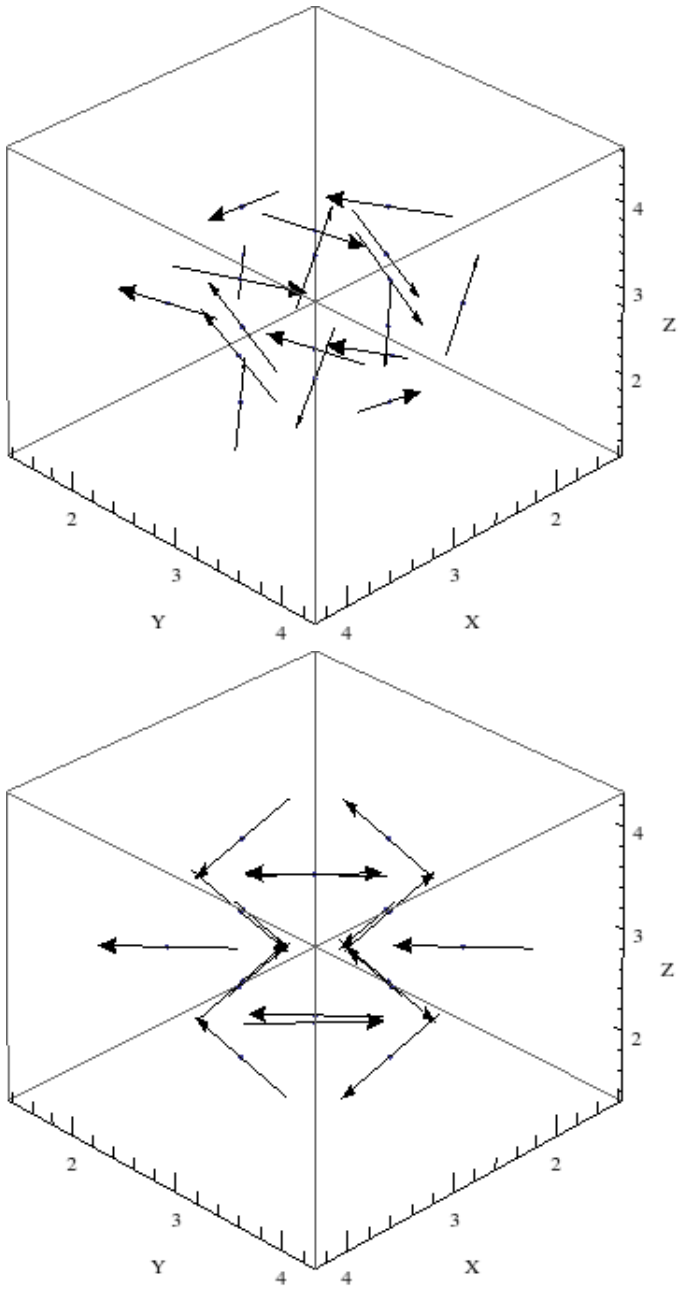

Figure 12: Visualization of a small section of the entire lattice used in RUN 3. The spins are initially highly disordered, until they snap into a final planar configuration.

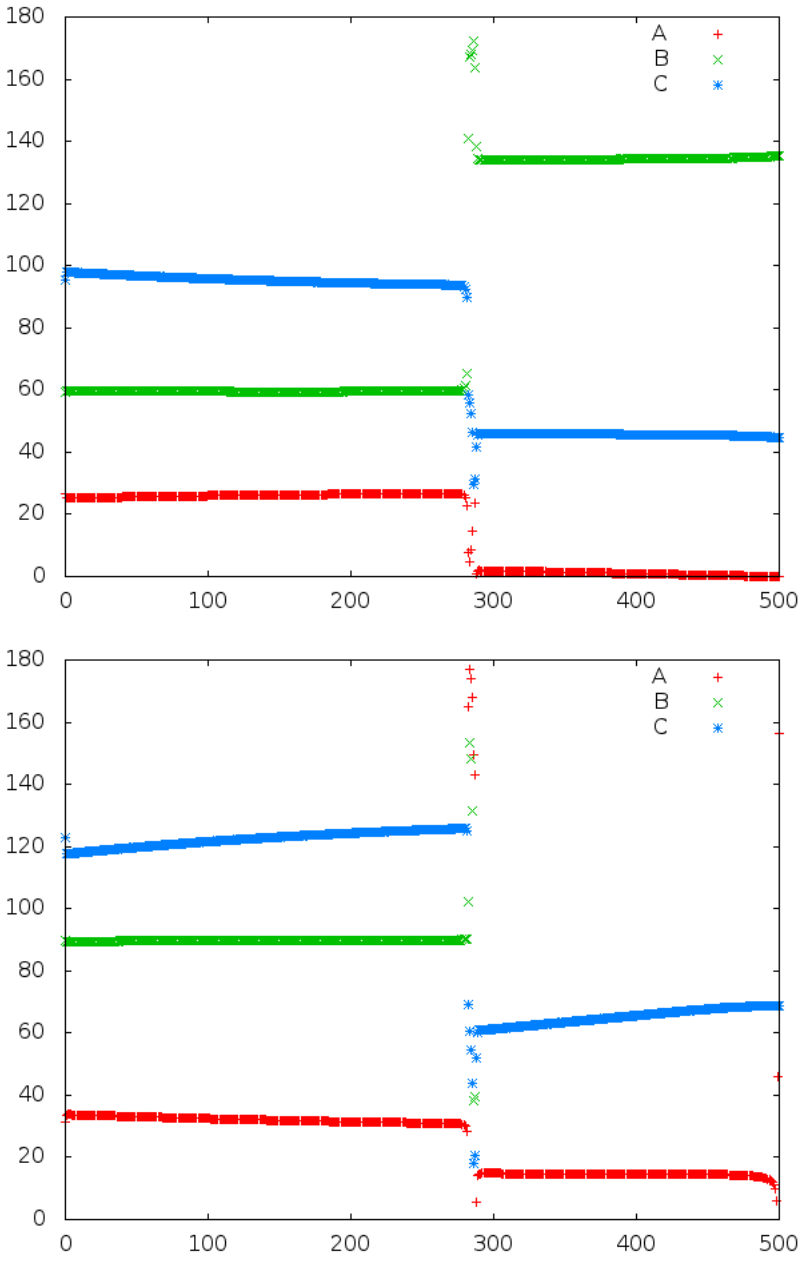

Figure 13: The angles are those between a chosen vector lying in the plane intersected by 111, and a projection of each of the A, B, and C spins. Azimuthal angles are followed by zenith angles.

Appendices

Appendix A - Finding Unique Spins

Overview This script finds all confxxxx.f90 files in the current directory, scans through each of them, and finds each unique spin that occurs within that conf file. The script outputs the name of the conf file followed by the number of unique spins that exist in that file, and each unique spin that exists in the file. A spin is considered unique when it has never been encountered before; that is, it does not already exist in a temporary file that stores all unique spins encountered for the current conf file. A spin is considered unique when it does not match any of the spins contained within this file up to some pre-determined decimal places. If the number of unique spins within the conf file surpasses a number of spins (specified by the first argument) the spins will not be added to resulting uniqueSpins.txt file.

```
#!/bin/bash
#findUnique.sh Andrew Way arw405@mun.ca

if [[ $# < 2 ]];then
echo "Usage: ./findUniqueRx.sh uniqueSpinLimit NumberOfCharacters"
echo "Exiting."
exit 1
fi
rm debug.txt
rm spinSummary.txt
rm spinFrequency.txt
touch spinSummary.txt
touch spinFrequency.txt
touch debug.txt
for i in conf*
do
    echo "Working on $i"
    confLength=‘cat $i | wc -l‘
    echo ‘cat $i | head -n 1 | tail -n 1‘ > uniqueTmp.txt
    for line in ‘seq 2 $confLength‘
    do
        text=‘cat $i | head -n $line | tail -n 1‘
   verdict="unique"
   spinA=‘echo $text | awk ’{print $1;}’ | cut -c1-$2‘
   spinB=‘echo $text | awk ’{print $2;}’ | cut -c1-$2‘
   spinC=‘echo $text | awk ’{print $3;}’ | cut -c1-$2‘
   #echo "$i $spinA $spinB $spinC" >> debug.txt
   USLength=‘cat uniqueTmp.txt | wc -l‘
   for j in ‘seq 1 $USLength‘
   do
      tmpSpin=‘cat uniqueTmp.txt | head -n $j | tail -n 1‘
          tmpSpinA=‘echo $tmpSpin | awk ’{print $1;}’ | cut -c1-$2‘
```

```
      tmpSpinB=‘echo $tmpSpin | awk ’{print $2;}’ | cut -c1-$2‘
      tmpSpinC=‘echo $tmpSpin | awk ’{print $3;}’ | cut -c1-$2‘
      if [ $tmpSpinA == $spinA ] && [ $tmpSpinB == $spinB ] && [ $tmpSpinC == $spinC ]
      then
     verdict="notUnique"
      fi
    #   echo "tmpSpins $tmpSpinA $tmpSpinB $tmpSpinC" >> debug.txt
   done
   if [ $verdict == "unique" ];then
      echo $text >> uniqueTmp.txt
   fi
    done
    USLength=‘cat uniqueTmp.txt | wc -l‘
    echo "Unique spins: $USLength"
    echo "$i : $USLength" >> spinSummary.txt
    if [[ $USLength -le $1 ]];then
   for j in ‘seq 1 $USLength‘
   do
      echo ‘cat uniqueTmp.txt | head -n $j | tail -n 1‘ >> spinSummary.txt
   done
   else
      echo "unique spin limit surpassed for $i" >> spinSummary.txt
   fi
   echo "$i $USLENGTH" >> spinFrequency.txt
   rm uniqueTmp.txt
done
```