Effects of Site Disorder on An Effective Spin-1/2 Triangular-Lattice Antiferromagnet Ba$_3$CoSb$_2$O$_9$

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Overview

1. Why $\text{Ba}_3\text{CoSb}_2\text{O}_9$? Why doping with Sr?

2. Results and discussions

3. Summary

2. Heisenberg coupling $J (\sim 18K)$ is quite appropriate $T_N = 3.8K$

Space group: P63/mmc

Dzyaloshinskii–Moriya (DM) effect.

1. The DM effect is a contribution to the total magnetic exchange interaction between two neighboring magnetic spins.

\[ H_{DM} = D_{ij} \cdot (S_i \times S_j) \quad D_{ij} \propto (r_i \times r_j) \]

2. It can cause weak ferromagnetic behavior in an antiferromagnet.
Ba$_3$CoSb$_2$O$_9$, Up up down (UUD) phase

H.D. Zhou, et al. PRL 109, 267206 (2012);

Intrinsic quantum effects: The linear and nonlinear spin-wave theories (SWTs) are inadequate to explain intrinsic linewidth broadening and high-intensity continuum.
Recent studies on RbFe(MoO$_4$)$_2$ show that the site disorder even on non-magnetic site could affect the UUD phase.

Ba$_{2.8}$Sr$_{0.2}$CoSb$_2$O$_9$, crystal structure

<table>
<thead>
<tr>
<th></th>
<th>Pure</th>
<th>Doped</th>
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</thead>
<tbody>
<tr>
<td>$a$</td>
<td>5.85475(3)</td>
<td>5.85236(4)</td>
</tr>
<tr>
<td>$b$</td>
<td>5.85475(3)</td>
<td>5.85236(4)</td>
</tr>
<tr>
<td>$c$</td>
<td>14.4498(1)</td>
<td>14.4583(1)</td>
</tr>
<tr>
<td>$\alpha$</td>
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<td>90</td>
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<tr>
<td>$\beta$</td>
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<td>90</td>
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<tr>
<td>$\gamma$</td>
<td>120</td>
<td>120</td>
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</tbody>
</table>
The transition temperature is 2.9K, lower than pure sample.
Ba$_{2.8}$Sr$_{0.2}$CoSb$_2$O$_9$, DC and AC susceptibility

For comparison, in pure sample
\[ \theta_{cw} = -75.11 \text{K} \]
\[ \theta = \theta_{cw}/T_N = -25.9 \]
\[ \mu_{\text{eff}} = 4.67 \mu_B \]

Yoshihiro Doi et al 2004 J. Phys.: Condens. Matter 16 8923
The UUD phase becomes weak or likely to disappear.
Summary

Results:
1. The transition temperature decreases by doping Sr
2. The UUD phase becomes weak or likely to disappear. **Order by site disorder!**
3. Doped sample has stronger quantum fluctuations. Interesting when compared with upper result.

Future plan:
1. Conduct elastic neutron scattering measurement and solve the magnetic structure at zero and finite fields
2. Conduct inelastic neutron scattering measurement to study the effects of site disorder on spin dynamics
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