Neutron scattering Studies of Spin-Ladders

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Spin-ladders consists of two parallel antiferromagnetic chains of magnetic spin-1/2 ions (legs of ladder) coupled together (rungs of ladder). In the limit of strong rung coupling, the magnetic spectrum is dominated by the excitations of an antiferromagnetic dimer i.e. a gapped magnon mode; introduction of leg coupling modulates this mode but the gap remains. In the limit of weak rung coupling the excitations are similar to the multi-spinon continuum of the one-dimensional, spin-1/2, Heisenberg antiferromagnet. The gap remains in the presence of finite rung coupling but can be suppressed by cyclic exchange interactions. Inelastic neutron scattering of some spin-ladder compounds will be presented. $La_4Sr_{10}Cu_{24}O_{41}$ has strong rung coupling and its excitations consist of a gapped one-magnon mode and a two-magnon continuum, a substantial cyclic exchange reduces the gap and destroys the bound two-magnon excitations. In contrast $CaCu_2O_3$ has a weak rung interaction and a large cyclic exchange which drives the system gapless and quantum critical. At high energies the excitations resemble the multi-spinon continuum of the antiferromagnetic, spin-1/2 chain. At low energies however the excitations are gapless and quantum critical. Comparison to theory suggests that the spinons are bound by the rung coupling and the ladder is close to the Wess-Zumino-Novikov-Witten quantum critical point.