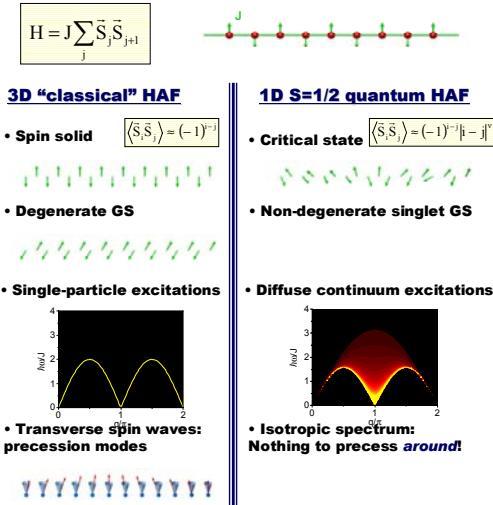


Transverse and longitudinal excitations in weakly-coupled quantum S=1/2 chains



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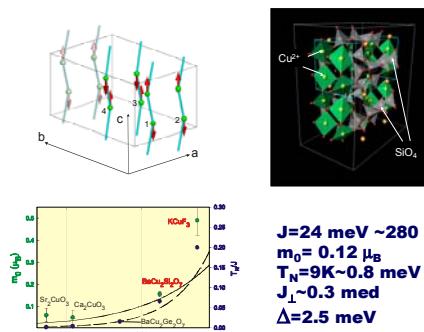
• Classical vs. quantum HAF



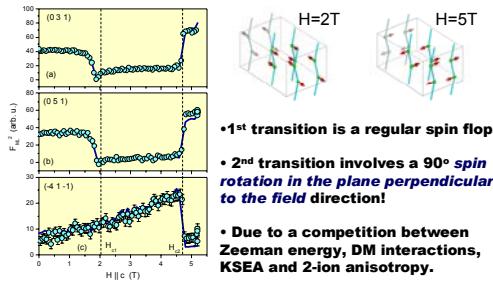
• Dimensional crossover: quasi-1D

- LRO is restored by arbitrary weak inter-chain interactions.
- Spectrum contains both spin waves and continuum.
- MF/RPA theory:
 - Continuum has a gap 2Δ (Δ is the spin wave gap at the RPA "magic" transverse wave vector).
 - There is a longitudinal "spin wave".
- Common sense:
 - Continuum has a pseudogap.
 - The "longitudinal mode" is damped and *is no more than a "bump" in the continuum*.

• BaCu₂Si₂O₇: a great model system



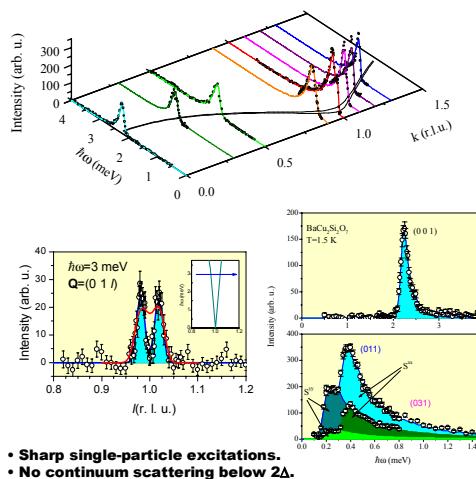
• Exotic spin rotation transitions



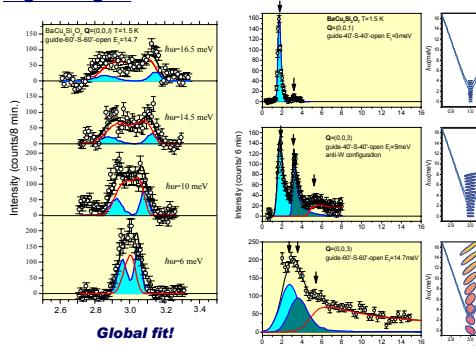
The low-field transition can be used to perform polarization analysis with unpolarized neutrons!

• Transverse spectrum

Low energies

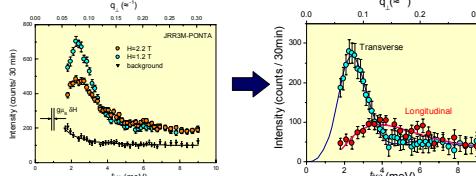


High energies



- Single-particle **and** continuum excitations.
- Quantitatively consistent with chain-MF/RPA theory.
- Continuum has a **pseudogap** $\Delta_c = 2\Delta$.
- Well described by a "truncated Müller Ansatz" function.

• Poor man's polarization analysis



• Unpolarized neutrons do carry polarization information

$$\frac{d^2\sigma}{d\Omega dE'} \propto \frac{|\vec{k}|}{k} F(\vec{q})^2 \frac{1}{2\pi\hbar} e^{i\vec{q}\cdot\vec{r}} \frac{1}{N} \langle S_i^+(\vec{t}) S_i^-(\vec{t}) \rangle dt$$

• For $Q=(0,0,1)$:

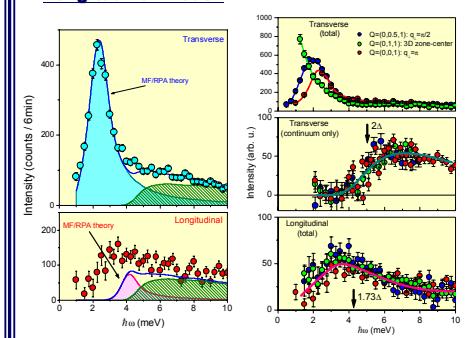
$$\frac{d\sigma}{dQdE'} \propto S^{xx} + S^{yy} = 2S^z \quad H < H_{c1}$$

$$\frac{d\sigma}{dQdE'} \propto S^{xx} + S^{yy} = S^z + S^{\perp} \quad H > H_{c1}$$

- Zeeman and DM energies are much smaller than the relevant energy of inter-chain interactions.
- Point-by-point data analysis is robust and insensitive to resolution effects.

• Longitudinal spectrum

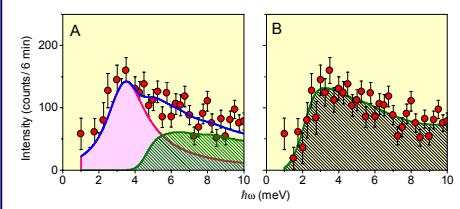
Longitudinal mode?



• The longitudinal mode in **chain-MF/RPA theory fails** to account for low-energy longitudinal scattering.

• **Longitudinal scattering is Q_z -independent**, like continuum scattering in the transverse channel, but unlike scattering by the strongly dispersive transverse spin waves.

Two models...



• The longitudinal mode is 4 times **stronger**, has a **smaller gap** and has a substantial **intrinsic width**... ... in which case it **can not be separated from the continuum**, and is just a "bump" on its lower bound.

• A single truncated Müller ansatz function describes the data very well, assuming a smaller (pseudo)gap $\Delta_c \sim \Delta$ for the longitudinal continuum.

... same conclusion:

There is no longitudinal mode in BaCu₂Si₂O₇

The longitudinal mode is an artifact of the MF/RPA approach:

- It exists for a single chain in a static external staggered field.
- The chain-MF approximation carries it over into the quasi-1D problem...
- ...but by ignoring dynamic inter-chain correlations...
- ...fails to provide a decay mechanism.

• Customary false-color plots

Useless but pretty

