

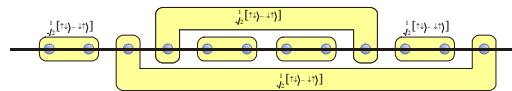
Scaling and dynamics in quantum spin chains with bond randomness

T. Masuda and A. Zheludev (ORNL), K. Uchinokura (RIKEN), S. Park and J.-H. Chung (NIST)

Random Singlet model and universality

$$\hat{H} = \sum_j J_i \bar{S}_j \bar{S}_{j+1} \quad |J_i| > 0, \langle J_i \rangle = J$$

- The $S=1/2$ spin chain is **critical** in the absence of disorder.
- Disorder is **relevant** in low-dimensional systems.
- Regardless of the details or strength of disorder, the low-energy properties of random-bond spin chains are as those in the **infinitely** disordered Random Singlet state:



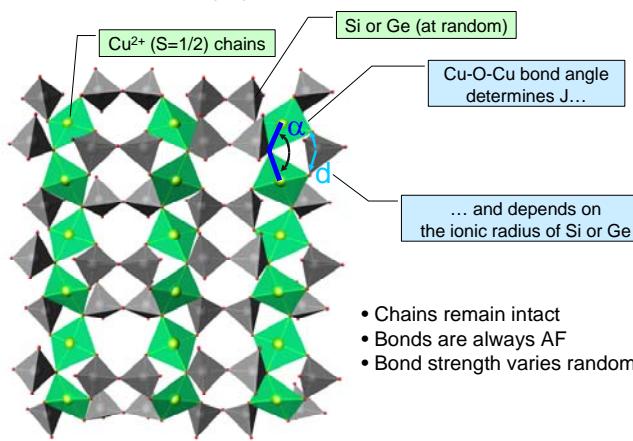
- Abundant weakly coupled large-scale singlets
- Divergent density of states at $\omega \rightarrow 0$: $n(\omega) \sim 1/\omega \ln^3 \omega$
- Universal scaling laws:

$$\chi(T) = \frac{1}{T \ln^2(\Omega_0/T)} \quad S(q, \omega) = \frac{1}{\omega \ln^3(\Omega_0/\omega)} F\left(|q - q_0| d \frac{\delta J}{J} \ln^2(\Omega_0/\omega)\right)$$

Doty, Fischer et al., 1992-1995 K. Damle, O. Motrunich and D. Huse, PRL 84, 3434 (2000)

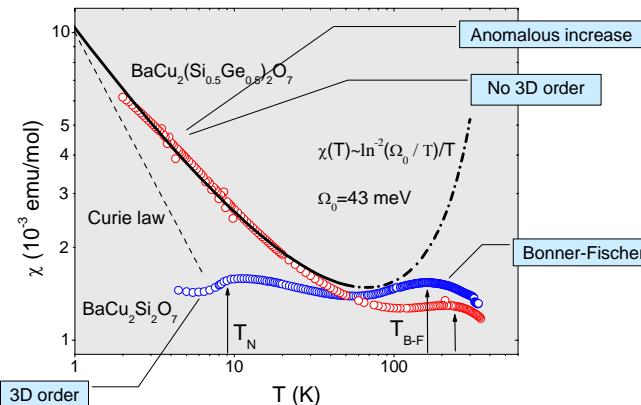
A family of model compounds

$BaCu_2(Si_xGe_{1-x})_2O_7$



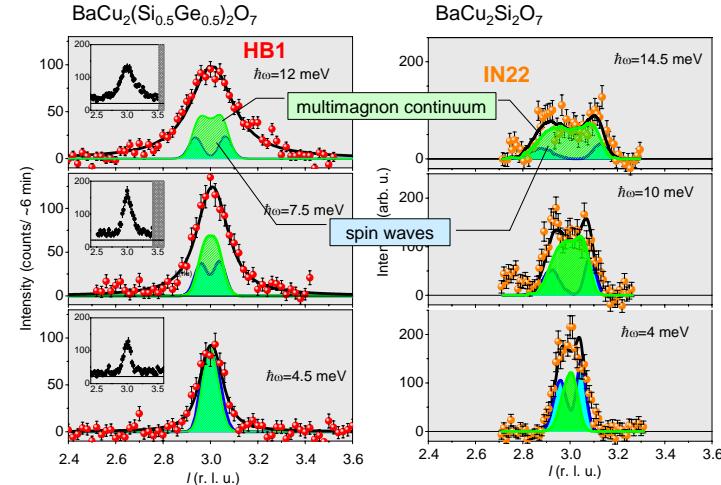
- $x=1$ $BaCu_2Si_2O_7$: $J=24$ meV $T_N=9.2$ K
- $x=0$ $BaCu_2Ge_2O_7$: $J=50$ meV $T_N=8.5$ K

X=0.5: bulk properties



- $\chi(T)$ increase observed in all $0 < x < 1$ compounds.
- Can be explained by divergent $n(\omega)$ in random chains.

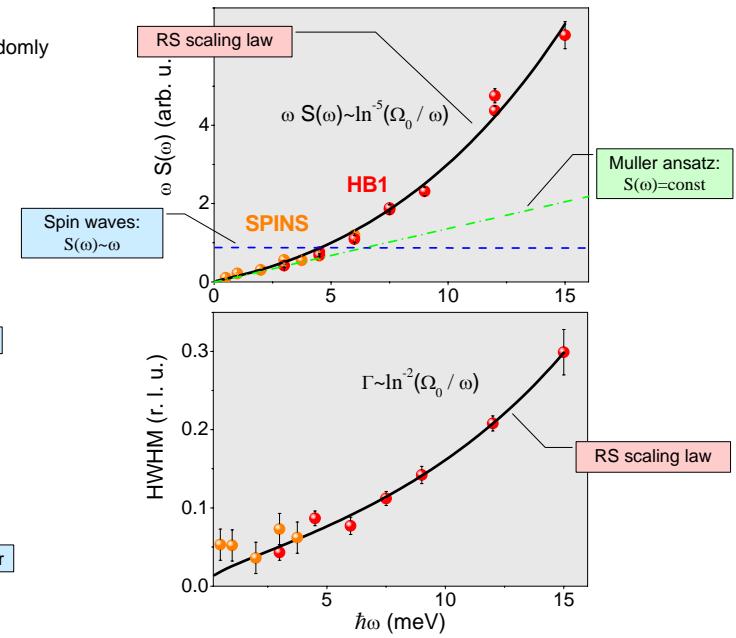
Nature of spin excitations



- Typical "top hat" shape
- Confined to $\hbar\omega > |q|v$ "wedge"
- Diffusive** propagation of **local excitations**
- Width determined by size of excitations

Scaling of the dynamic structure factor

- q -integrated intensity **increases** with energy!



- Scaling of HWHM allows to estimate $\delta J \sim 1$ meV

Conclusion

quenched disorder + quantum critical spin state
= universal scaling of spin dynamics

