Crackling Noise and Random Field Ising Model at Finite Temperature

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1.) Abstract

Cracking noise in response to a changing external conditions is found in many nonequilibrium systems with disorder. We simulate Barkhausen noise in disordered ferromagnets at finite temperature as a prototypical example of crackling noise systems. Using the non-equilibrium random field Ising model (RFIM) one finds power law scaling in the noise power spectrum at zero temperature near a critical disorder. At low enough temperatures and finite ramprate of the external driving field, a crossover from the zero temperature scaling behavior to equilibrium noise is seen at high frequencies. In this work we focus on comparing the simulation results to recent experiments on noise in relaxor ferroelectrics.

2.) Zero Temperature Random Field Ising Model

- Model for describing crackling noise
- Consist of N spins on a hypercubic lattice
- Random is field is governed by a disorder parameter R
- Gives power law scaling of power spectrum (figure 2)

$$\mathcal{H} = -J\sum_{\langle i,j\rangle} s_i s_j - \sum_i (H + h_i) s_i$$

The Hamiltonian of the RFIM, with a random field h_i.

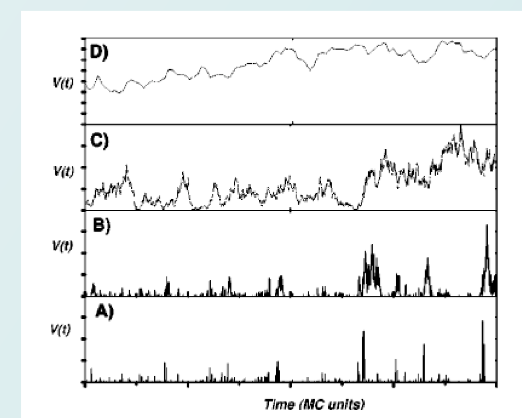

Fig 1.) Voltage Signal and Avalanches increasing the ramprate from a A) to D).

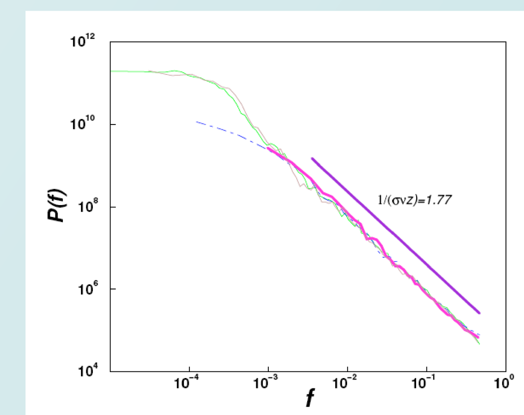

Fig 2.) Power spectrum at critical disorder for various sweep rates at zero temperature.

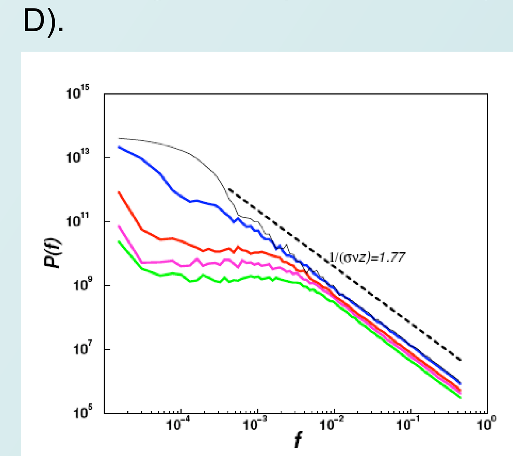

Fig 3.) Power law scaling of power spectrum at various disorders.

3.) Finite Temperature RFIM

- Uses Monte Carlo Glauber algorithm
- Voltage time series nearly identical
- Power spectrum is causally sensitive
- Use checkerboard update algorithm since avalanches are causal
- Crossover from zero temperature RFIM scaling at high frequencies (figure 4)

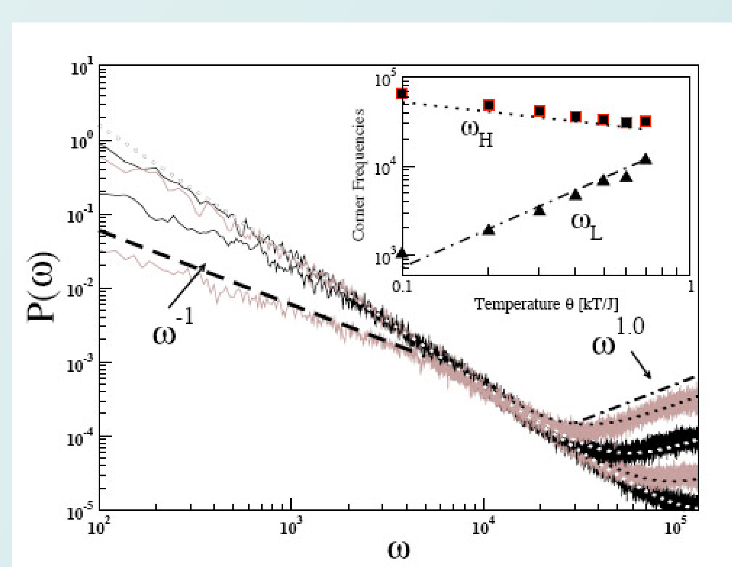

Fig 4.) There is crossover over from the ztneRFIM scaling at high frequency to equilbrium noise at high frequency.

4.) Relaxor Ferroelectrics

- PMN exhibits Barkhausen noise.
- Noise experiments are finite temperature and show power law scaling (figure 5).
- Simulations are being done show scaling similar to experiment and could give insight into the nature of the disorder (figure 6).

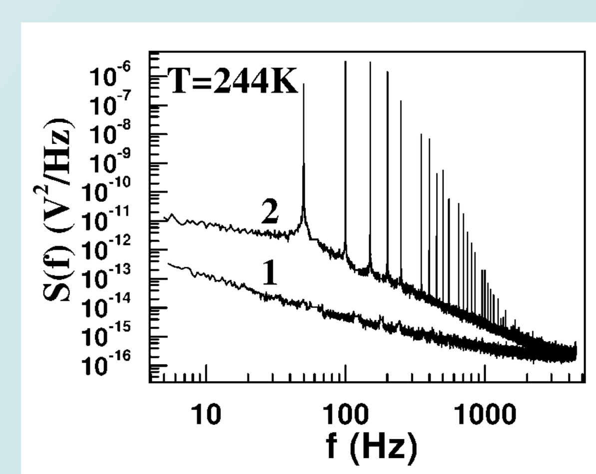

Fig 5.) Experimental power spectrum of Barkhausen noise in PMN in the relaxor phase. Exhibits approximately $1/f$ scaling.

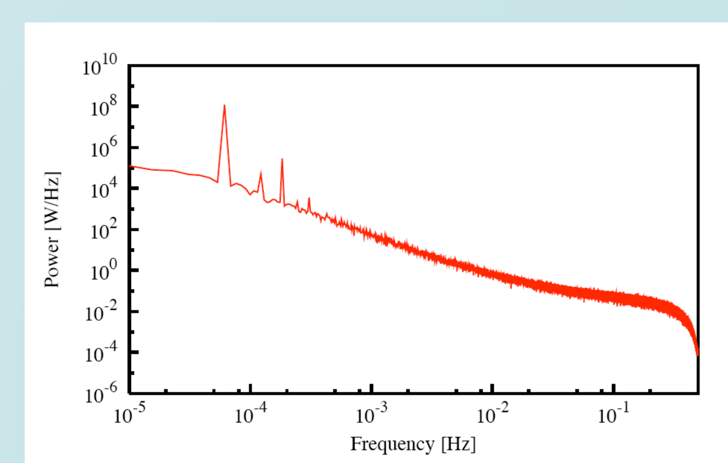

Fig 6.) Magnetization power spectrum at T = 0.3/J shows scaling similar to experiment.

Future prospects

- Further testing of PMN with the RFIM
- Finding other ferroelectrics which may obey the RFIM

References

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[2] Eugene V. Colla, Lambert K. Chao, M.B. Weissman "Barkhausen Noise in Relaxor Ferroelectric" , *Phys. Rev. Lett.* **88**, 17601-1(2002)
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