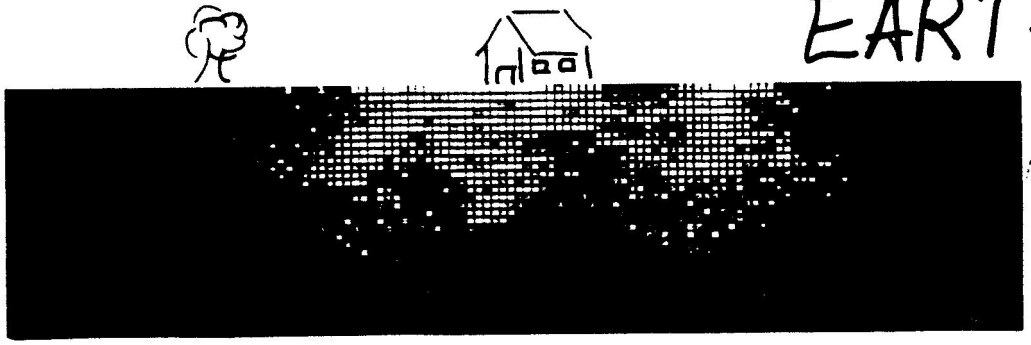
AVALANCHES

James P. Sethna, Sivan Kartha
Jim Krumhansl, Olga Perković
Bruce Roberts, Joel Shore K.D.
UIUC, Cornell University

Daniel S. Fisher, Yehuda Ben-Zion
Deniz Ertaş, Sharad Ramanathan, K.D.
UIUC, Harvard University

John Carpenter, Robert White, Amit Mehta
Ali Vanderveld, Sharon Loverde, Alex Traveset UIUC

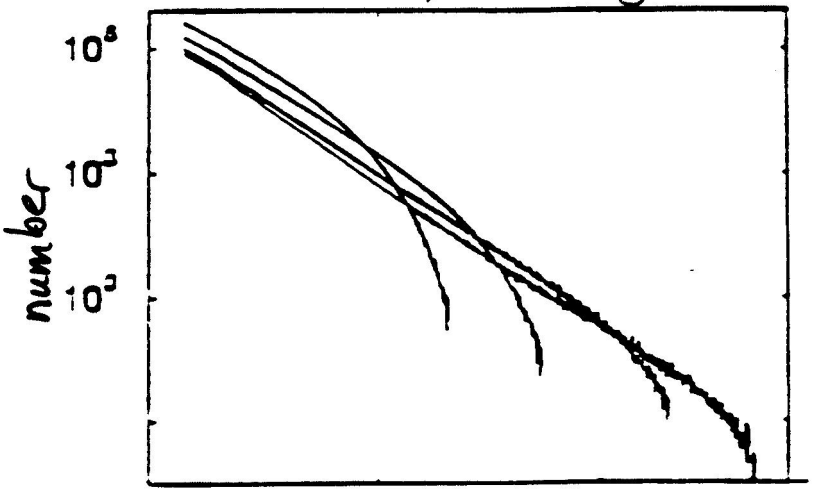
EARTHQUAKES

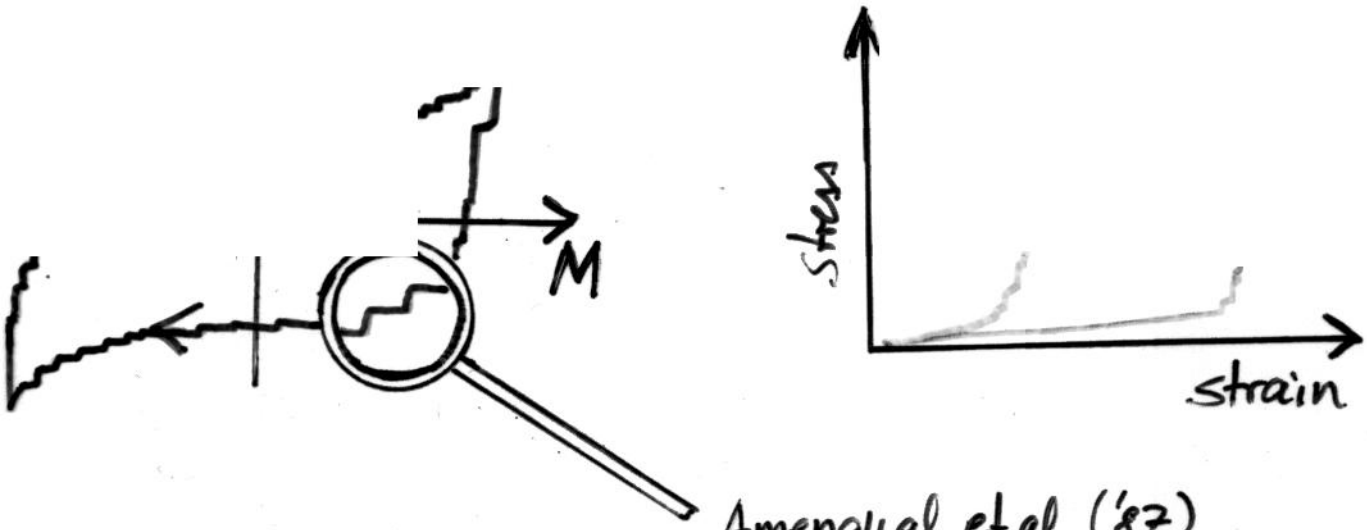


POPULATION BIOLOGY

(David Nelson UIUC,
Nadav Shnerb, Yuval Oreg, Harvard,

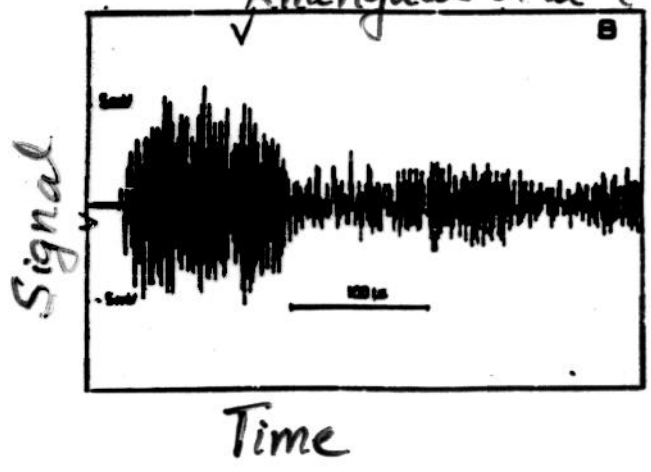
disorder induced critical & behavior





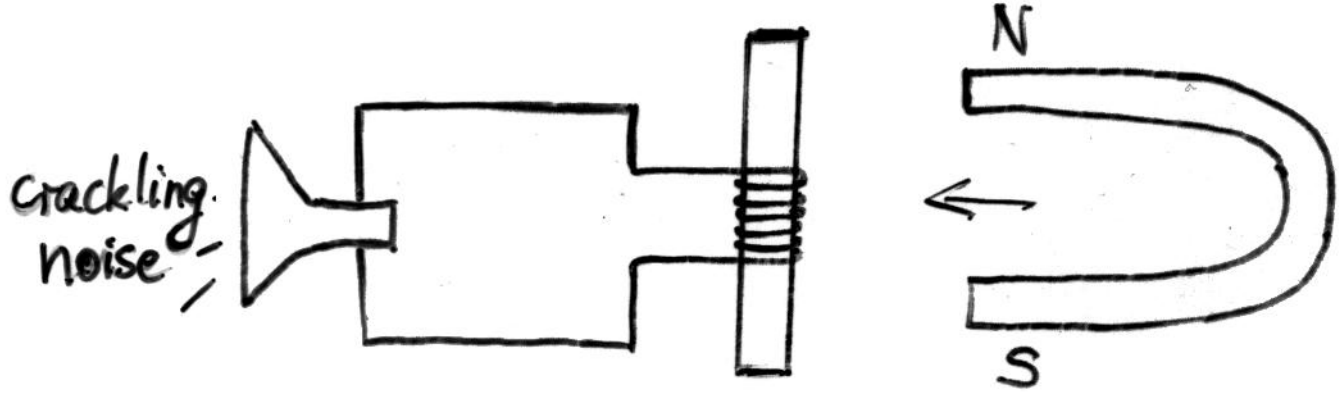
Amengual et al ('87)

Barkhausen noise



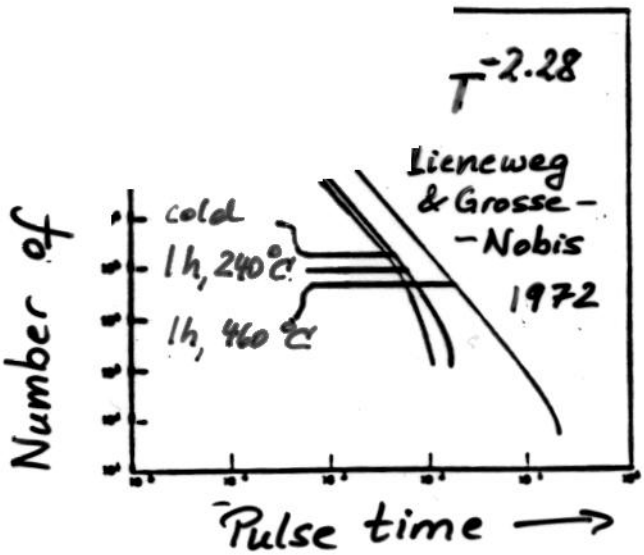
Acoustic Emission

Barkhausen Noise

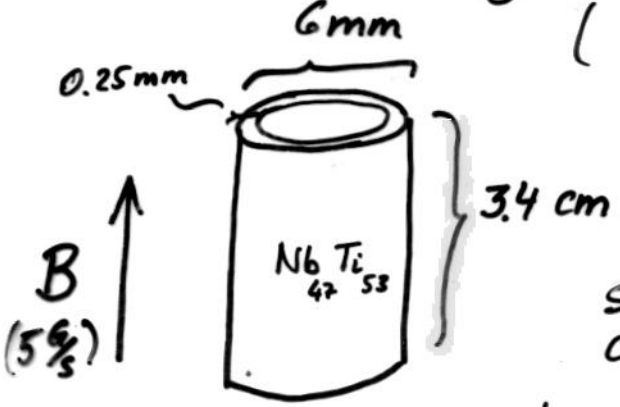


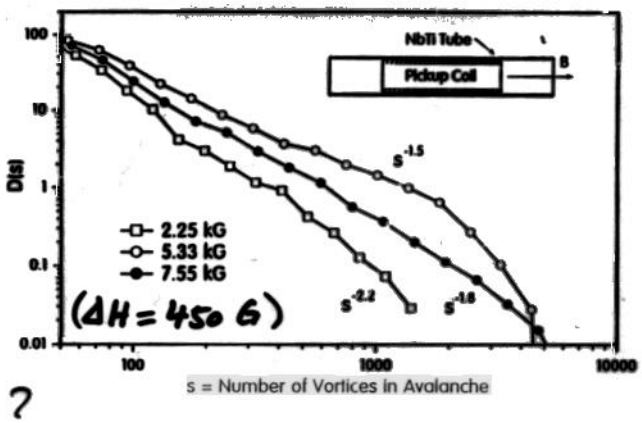
)

Distribution of Pulsetimes (or areas)
⇓
POWERLAWS with cutoff



2) Superconducting Vortex Avalanches:
(S. Field, F. Nori, X. Ling)

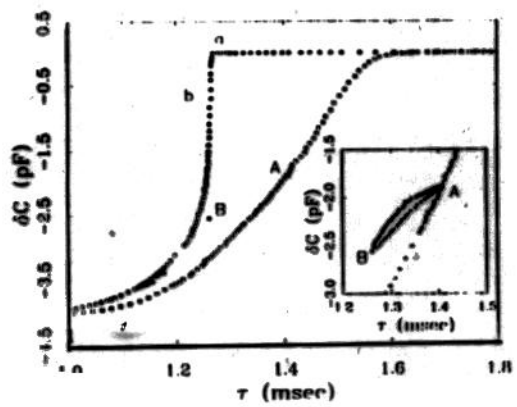


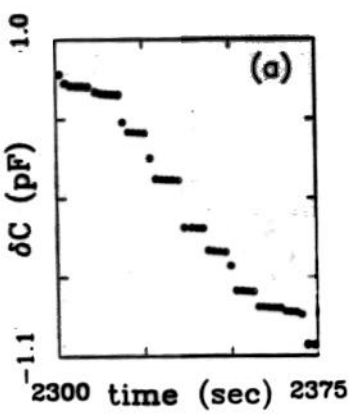


self-organized critical
or
plain old critical ?

3) Capillary Condensation of He in porous material:
(M.P. Lilly, P.T. Finley, R.B. Hallock)

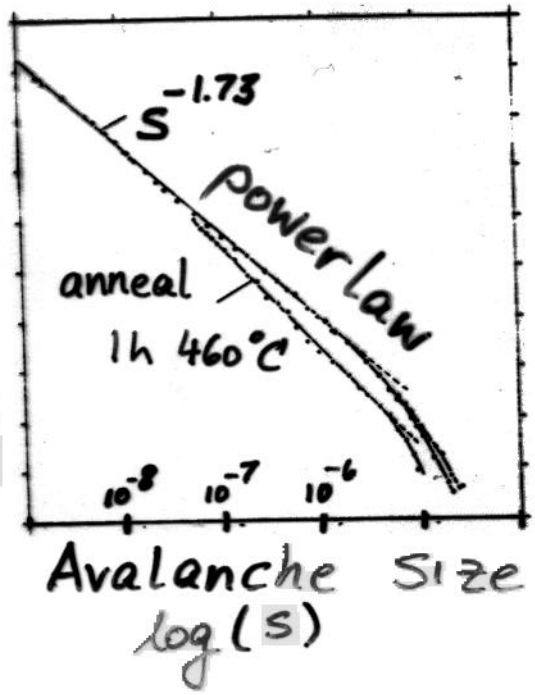
step structure: avalanches





T = 1.52 K, 2000 Å pore diameter

- Superconductors (P. Adams; S Field, with F Nori)
- Liquid He invading Nuclepore (Hallock, Lilly) (Wootters '99)
- Rupture in fibrous materials
- earthquakes



Experiment

Lieneweg and Grosse Nobis (1972)
(Barkhausen, 81% Ni Fe)

BROAD RANGE OF Avalanche Sizes, Durations "Self Similar"

WHY ?

SOC Urbach Madison Markert '95 (PRL)
Zapperi Cizeau Durin, Stanley PRB '98, Narayan PRL'9

PLAIN OLD CRITICALITY !

WHAT TRANSITION ?

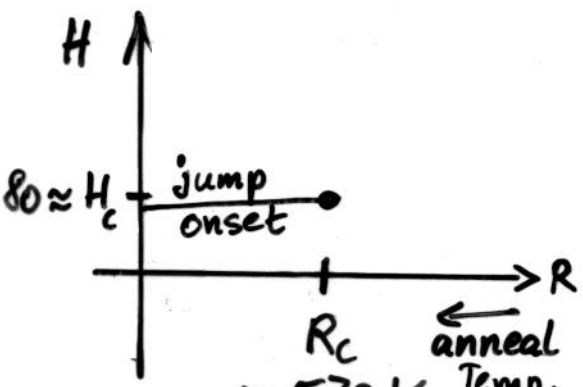
TRANSITION:

Experiment:

(A. Berger, (Irvine) Argonne)

R

CHANGE ANNEALING TEMP.

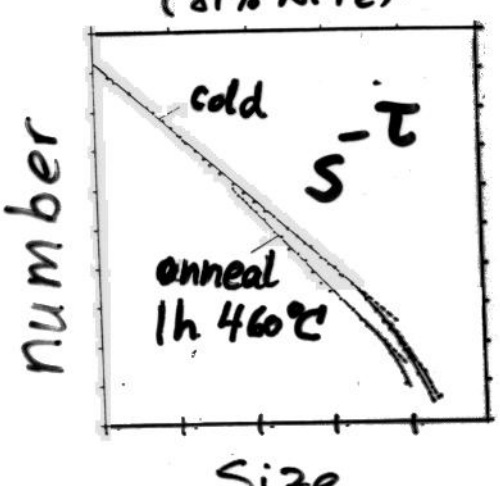


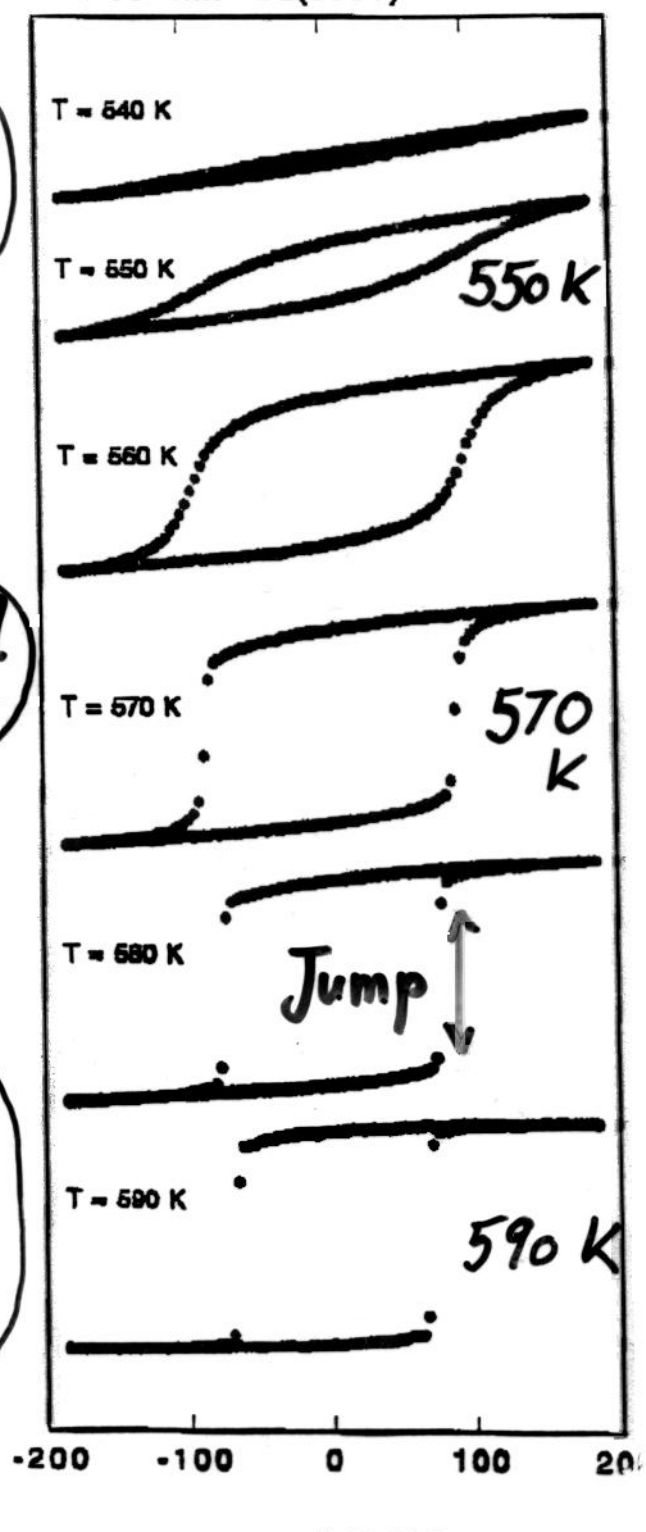
Smooth loops

"critical loop"

loops with jump

Barkhausen pulses (?)
(81% Ni Fe)





THEORY

ZERO TEMPERATURE RANDOM FIELD ISING MODEL

$$\mathcal{H} = \sum_{ij} J_{ij} s_i s_j - \sum_i H s_i - \sum_i h_i s_i$$

Bond $J \equiv 1$; External field $H(t)$

Random field h_i at each site

"spins" or domains $s_i = \pm 1$

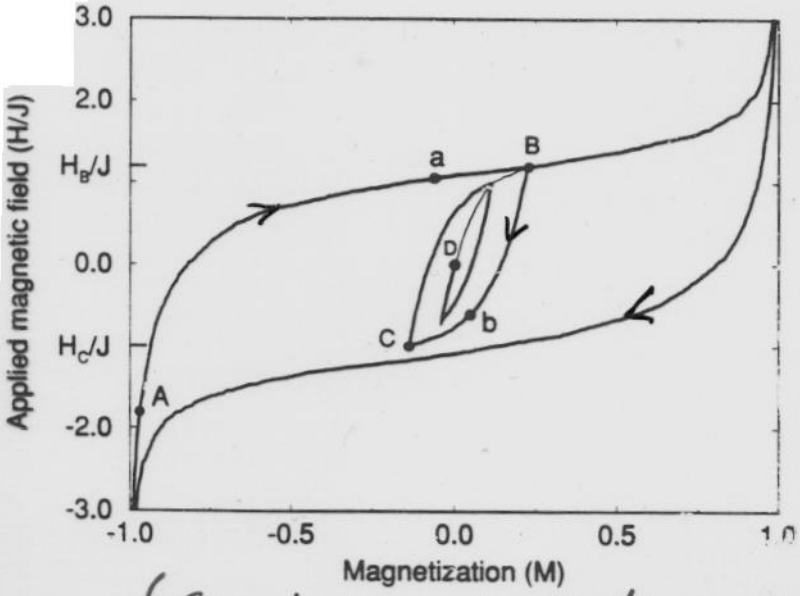
$H(t)$ swept up
from $-\infty$ to $+\infty$

s_i flips when local field $\sum_{nn} s_i + h_i + H(t)$ gets positive

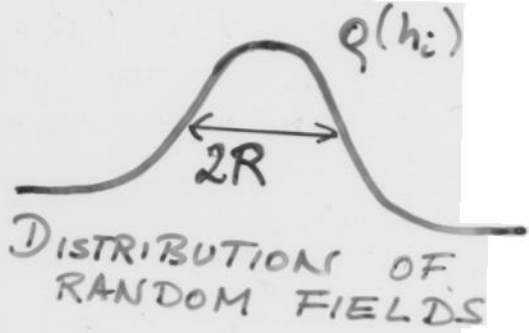
⊕ kicks neighbors

⇒ AVALANCHE

(Non-equilibrium!)



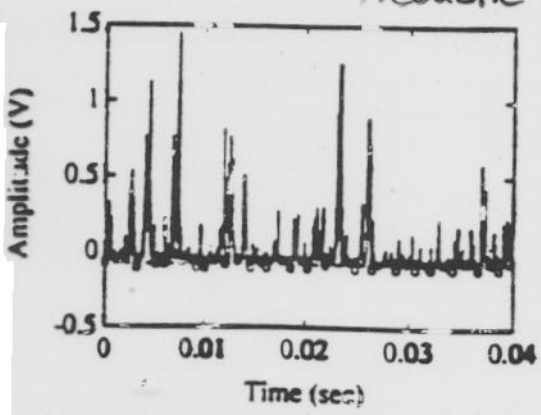
(Simulation in 3 dimensions)



Dynamics:

Each spin s_i flips, when local field: $J\sum_{(nn)} s_j + h_i + H$ changes sign.

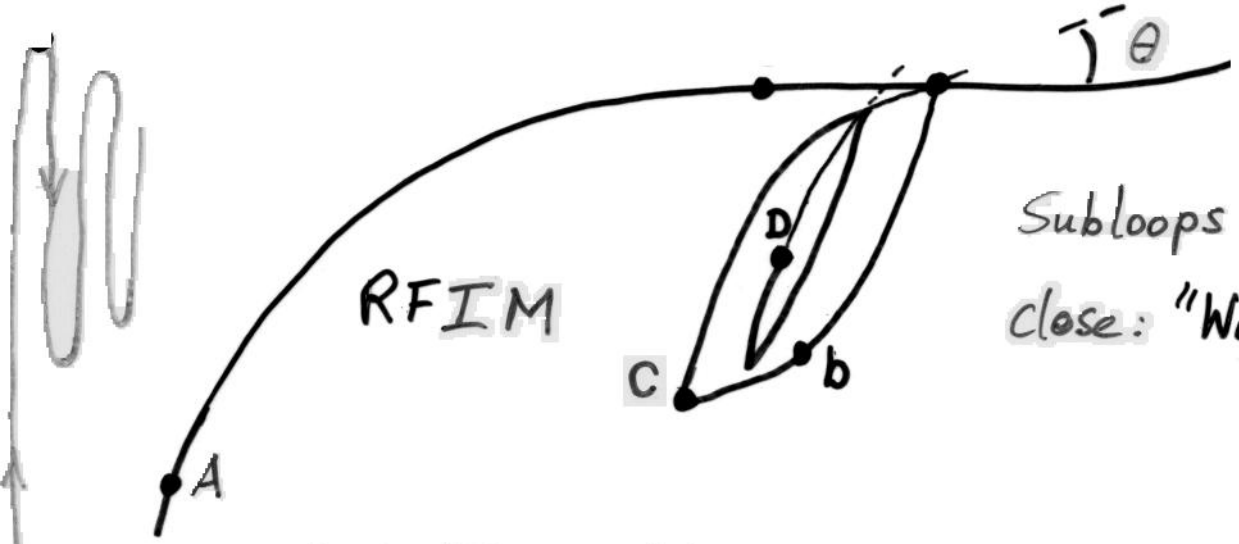
⇒ Avalanches ≙ Barkhausen noise, Acoustic emission



(Meisel & Cote 1992)

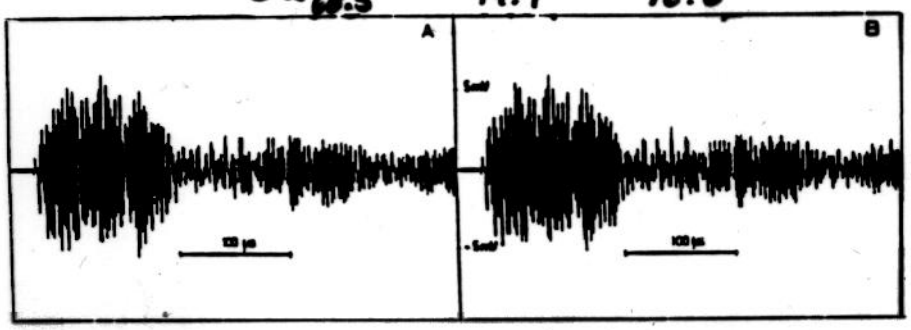
Avalanche model, but not self-organized

RY



Subloops close: "Wiping out"

$Cu_{68.5}\ Zn_{14.9}\ Al_{16.6}$



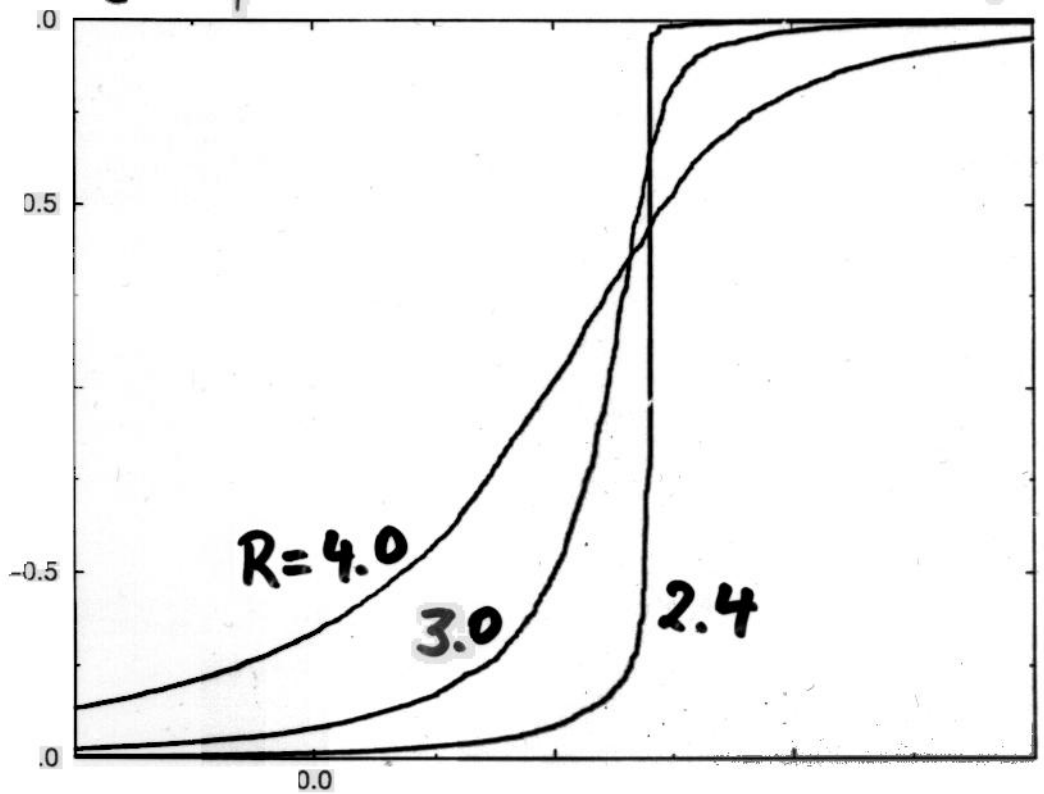
Avalanches repeat amazingly well !

b

A Amengual, L.L. Mañosa, F Marko, C Picornell, C. Segui & V Torra, Thermochimica Acta 116, 195

Where does Return Point Memory Come from ?

Barkhausen noise in 3 dim
(samples at various disorders R)

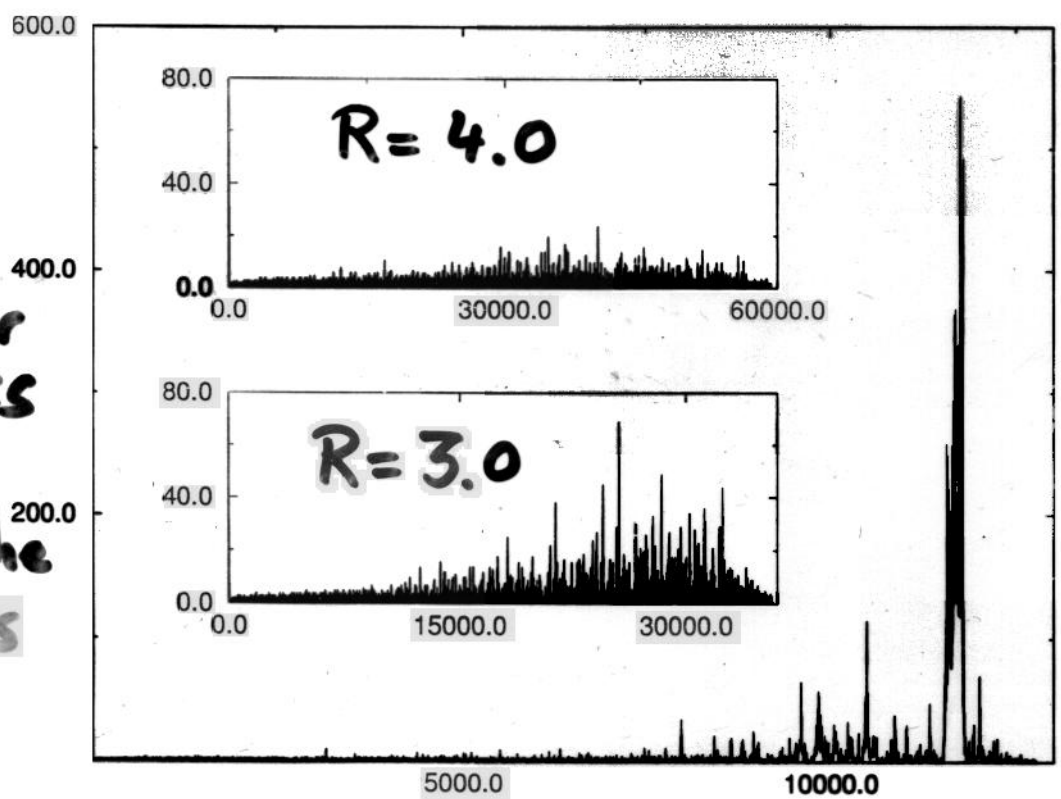


M

H

(40^3 system)

R_c 2.16 in 3 dim



area under peaks => avalanche sizes

R=2.4

Time Series