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SCHOOL and CONFERENCE
on
COMPLEX SYSTEMS
and
NONEXTENSIVE STATISTICAL MECHANICS

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Random Resistor cum Tunneling-bond Network model : a Testing Lab for Percolative Complex Systems

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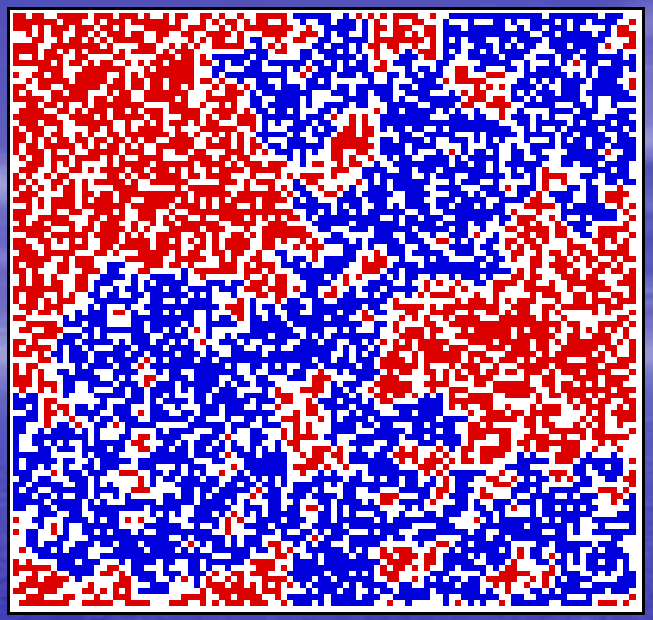
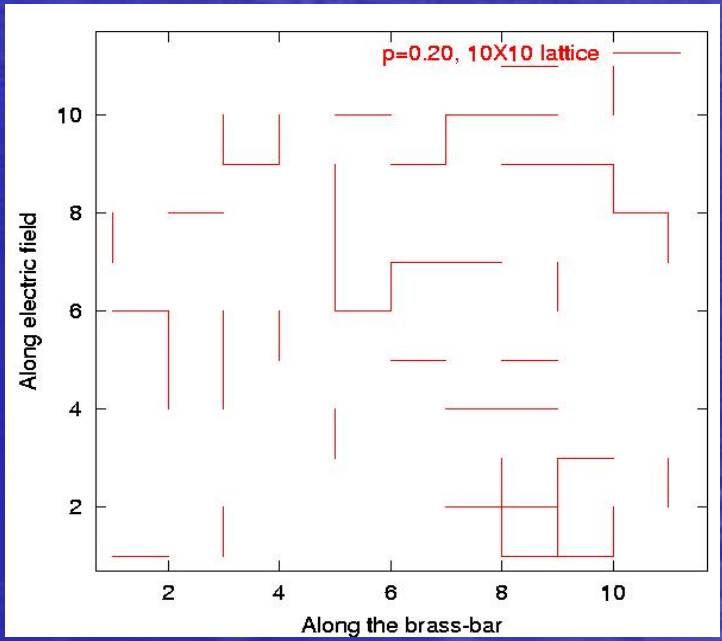
Composite Materials (complex materials)



- Made of multiple constituents, with different generalised susceptibilities, placed randomly within the host

- transport properties highly dependent on the geometrical connections among the conducting

Percolation technique is useful to model such systems



Random Resistor Network model (RRN) (classical)

Percolation threshold , $p_c = 0.5$

Linear steady response, exponential relaxation,

normal distribution of steady response within ensemble

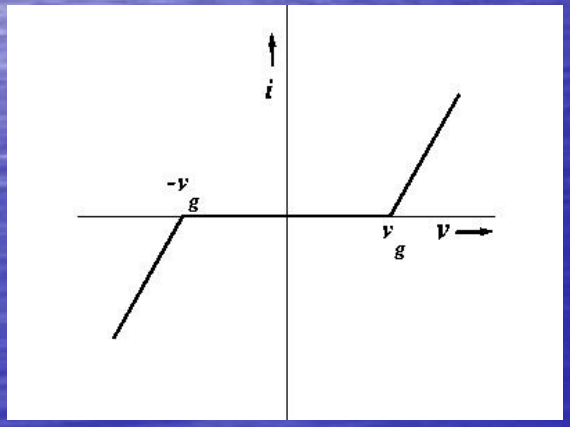
Experimental observations

- Ultra-low percolation threshold
- Nonlinearity in the bulk response, on both sides of the classical p_c; non-integer power-law in G(V) for small V
- Low temperature resistance minimum observed in quantum disordered substances
- Nonlinear dynamic response, $G(\omega) \sim \omega^{0.7}$ for low ω

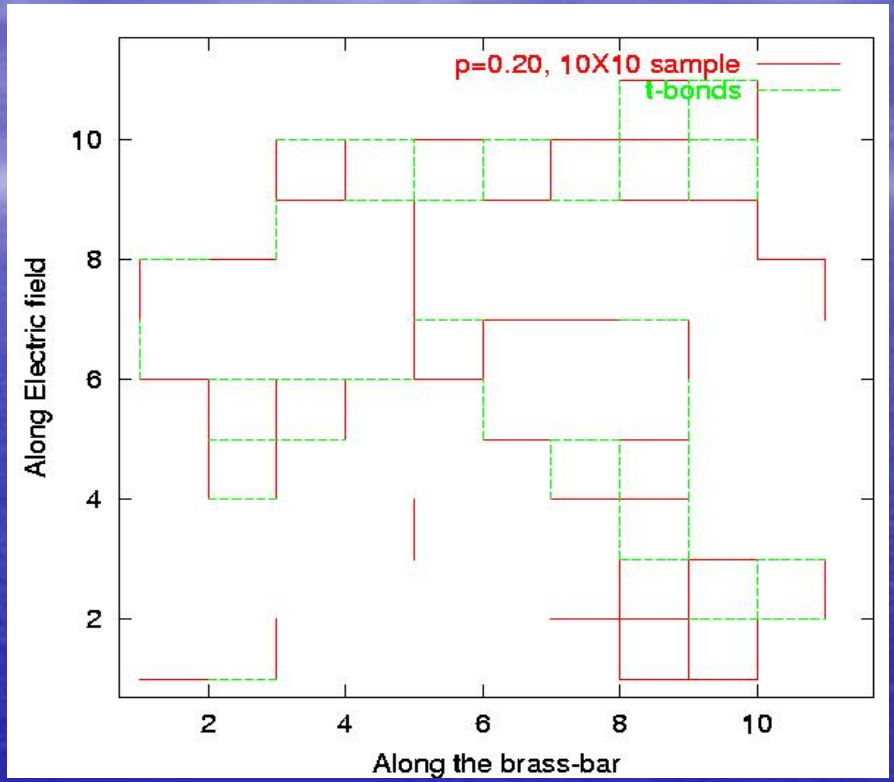
Random Resistor cum Tunneling-bond Network model (RRTN) (Semi-quantum)

Sen and Kar Gupta, LNP, 1994
Kar Gupta and Sen, PRB, 57, 3375 (1998)

- Correlated-random bonds
- phenomenological tunneling between two nearest -neighbour RRN bonds



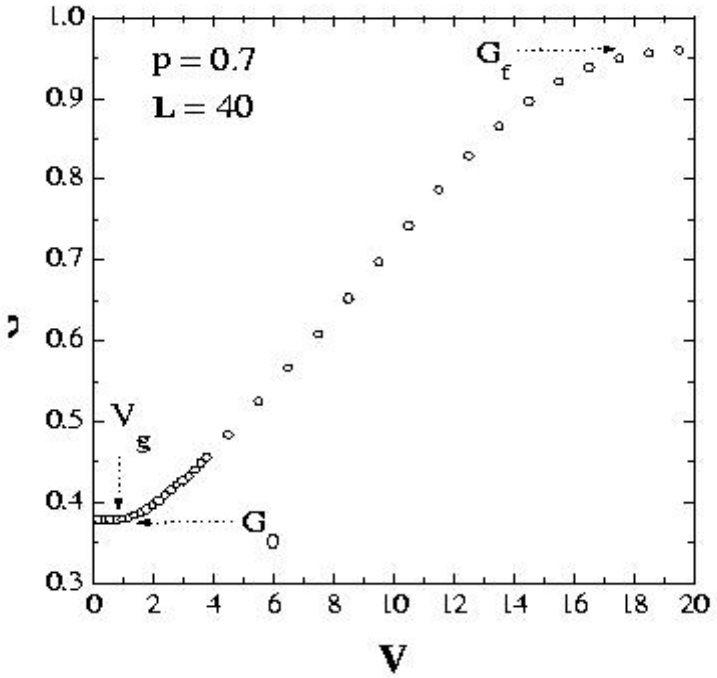
Almost a theorem for observing **nonlinearity**



- disorder + nonlinear
- p_{ct} =0.181
- v_g develops V_g for the bulk

Static G-V characteristics

- **Lower linear region for $V < V_g$**
- **Sigmoidal region for $V > V_g$**
- **Upper linear region for $V >> V_g$**



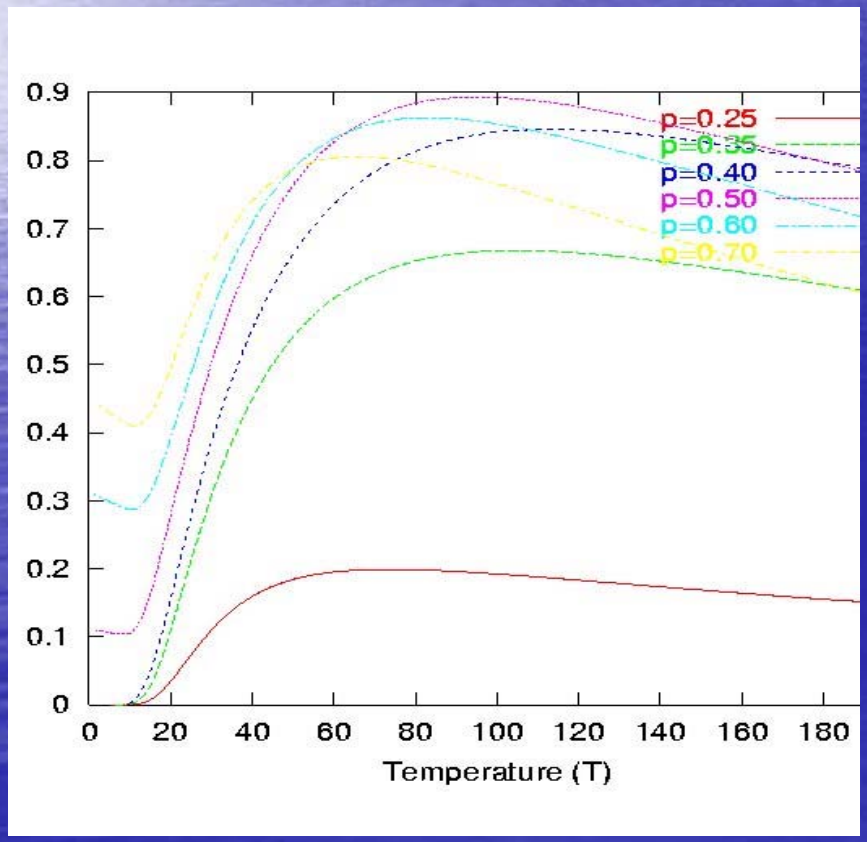
Kar Gupta and Sen, PRB, 57, 3375 (1998)

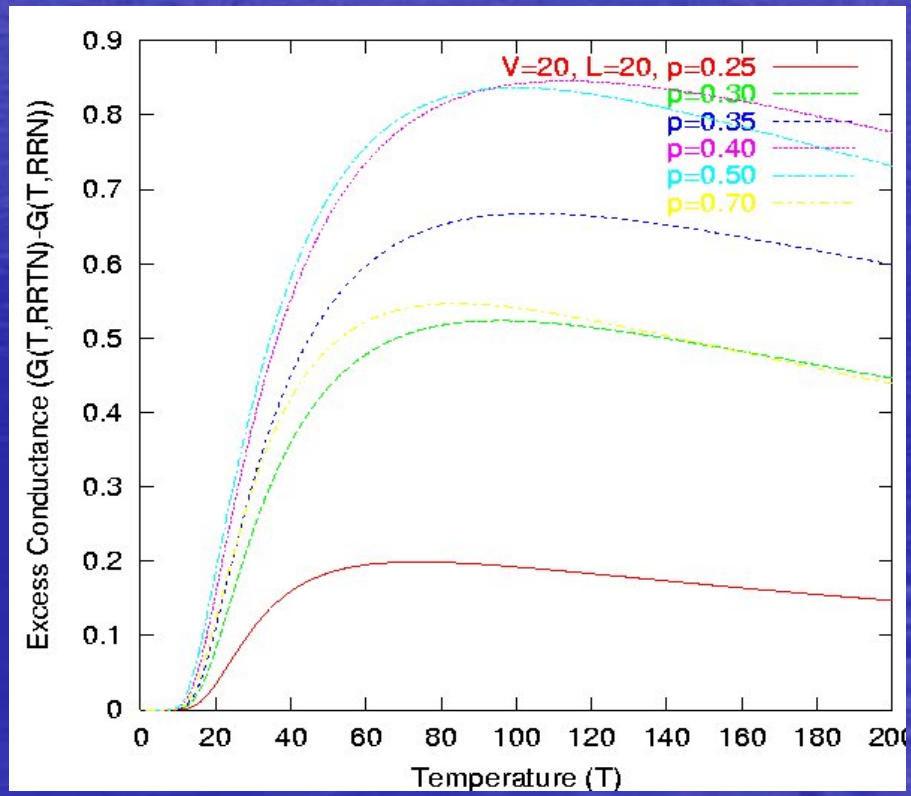
Variable Range Hopping Conduction study through RRTN model

A K Sen and S Bhattacharya, in Proc. NATO Adv. Res. Workshop, CMDS10, NATO Sci. Ser. II. Math. Phys. Chem., 158, Eds. D Bergman, E Inan (Kluwer Acad. Publ., Dordrecht 2004), pp. 367-373.

Explicit temperature dependence in the microscopic bonds:

$g_o = 1/(1+a_0 T)$, $g_t = 10 \exp(-100/T)$





Ensemble averaging:

One needs to handle an ensemble averaged quantity in statistical mechanics.

- ✓ Ergodic hypothesis

- ✓ **Question is:** whether averaging over all sorts of disorder is meaningful?

- ✓ **Procedure:** Calculate (**normalised**) Fluctuation,: $\kappa^2 = (\langle I^2 \rangle - \langle I \rangle^2)/\langle I \rangle^2$

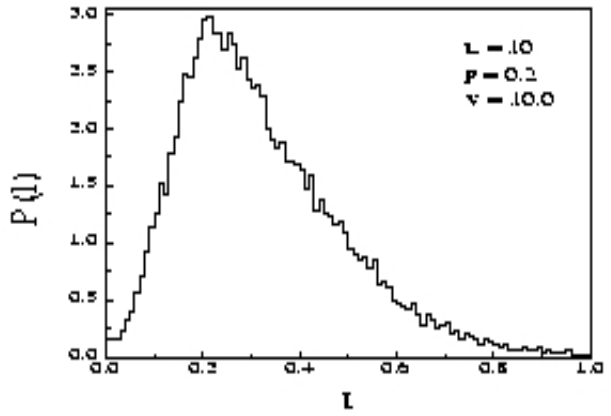
- ✓ Investigate on **self-averaging** property: :

If, $\kappa(L)$ is **almost constant** with L, then non-self-averaging

- ✓ **why electric field rather than voltage ?**

Histogram P(I) for p=0.2, L=20

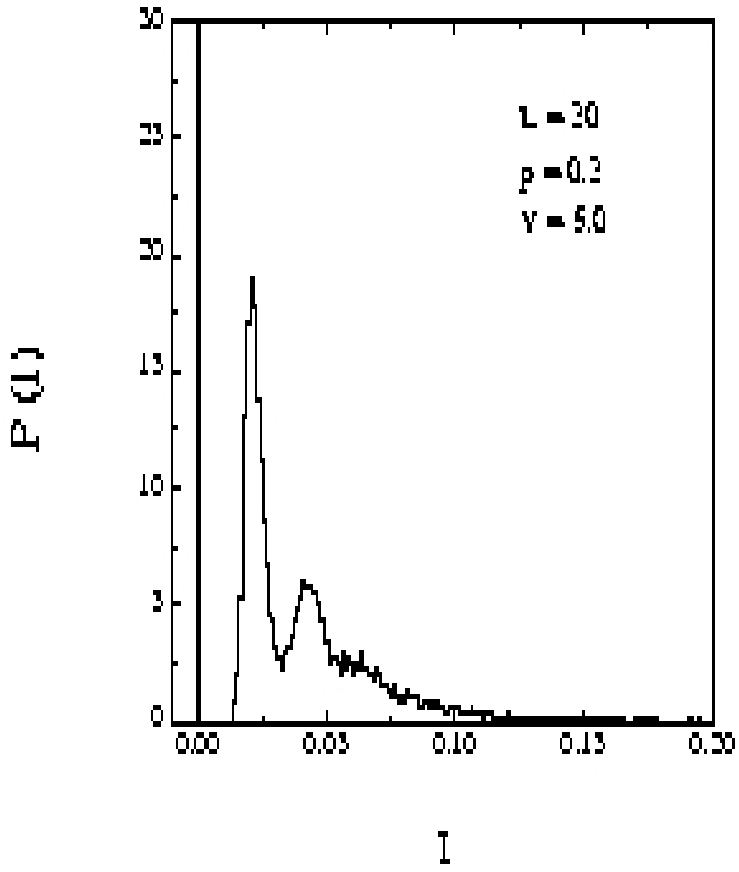
PRB, 57, p3375 (1998)



Exponential tail

Power-law tail

Non self-averaging depends on the nature of the tail in P(I)

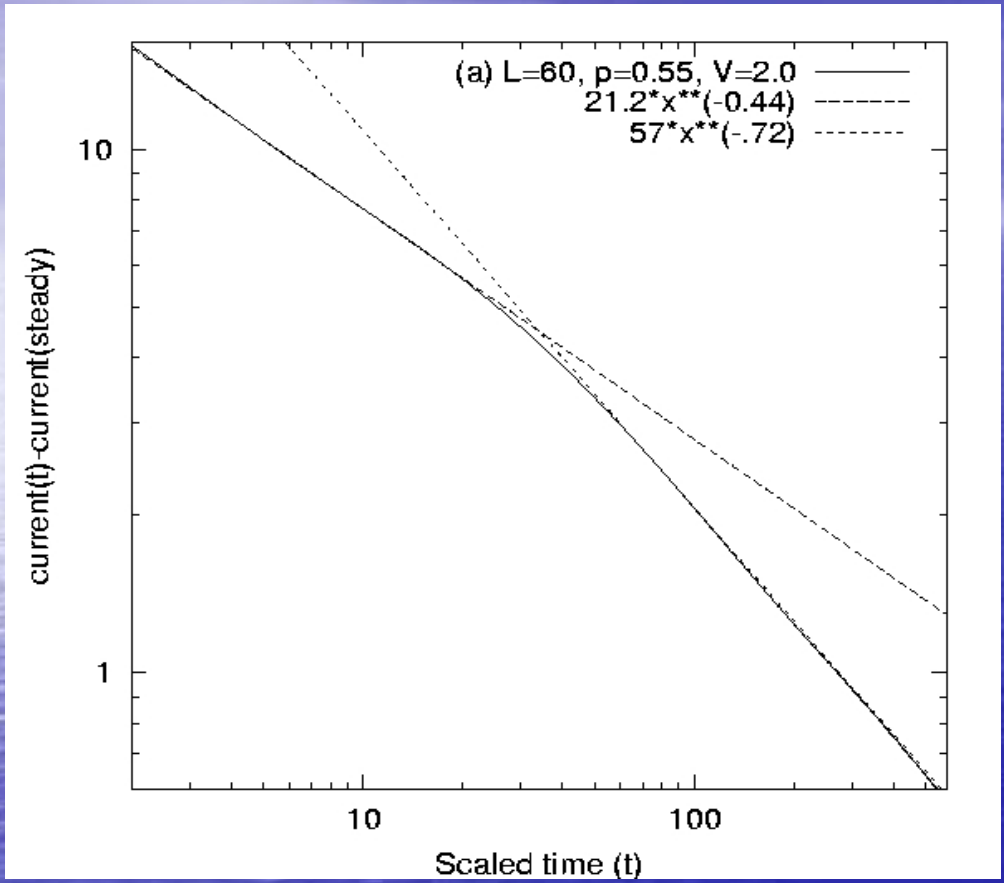


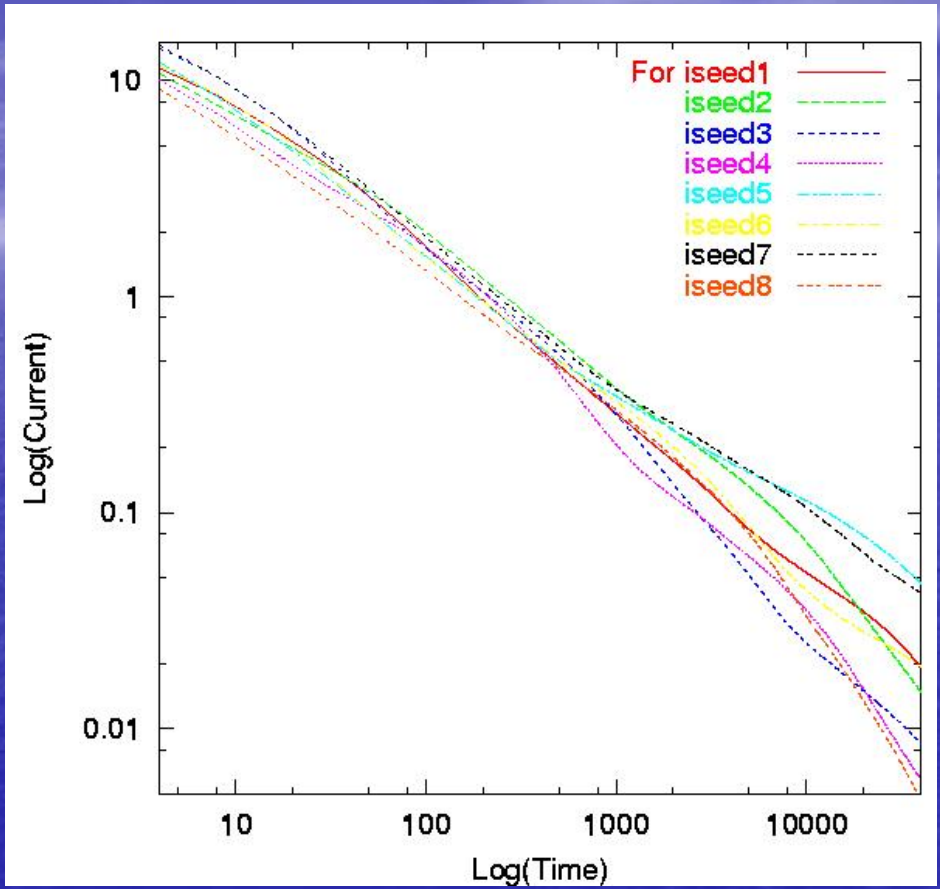
Main qualitative results on averaging:

The steady state response is non-self-averaging

- ✓ at **low electric field** such that $E \leq 0.25$
  and at $p \cong p_{ct}$ (=0.18) ; we checked the result for p=0.2
- ✓ Temperature can not change the situation, unless p and E values determine the phase

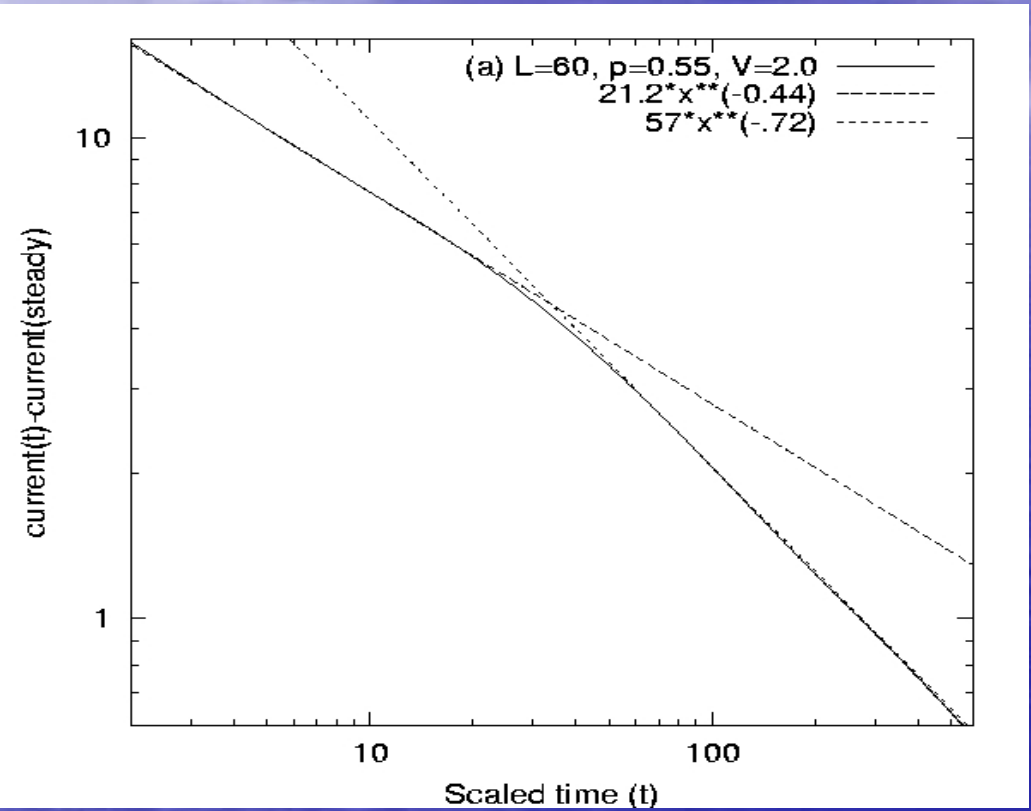
S. Bhattacharya and A. K. Sen, Europhys. Lett. 71, 797 (2005)

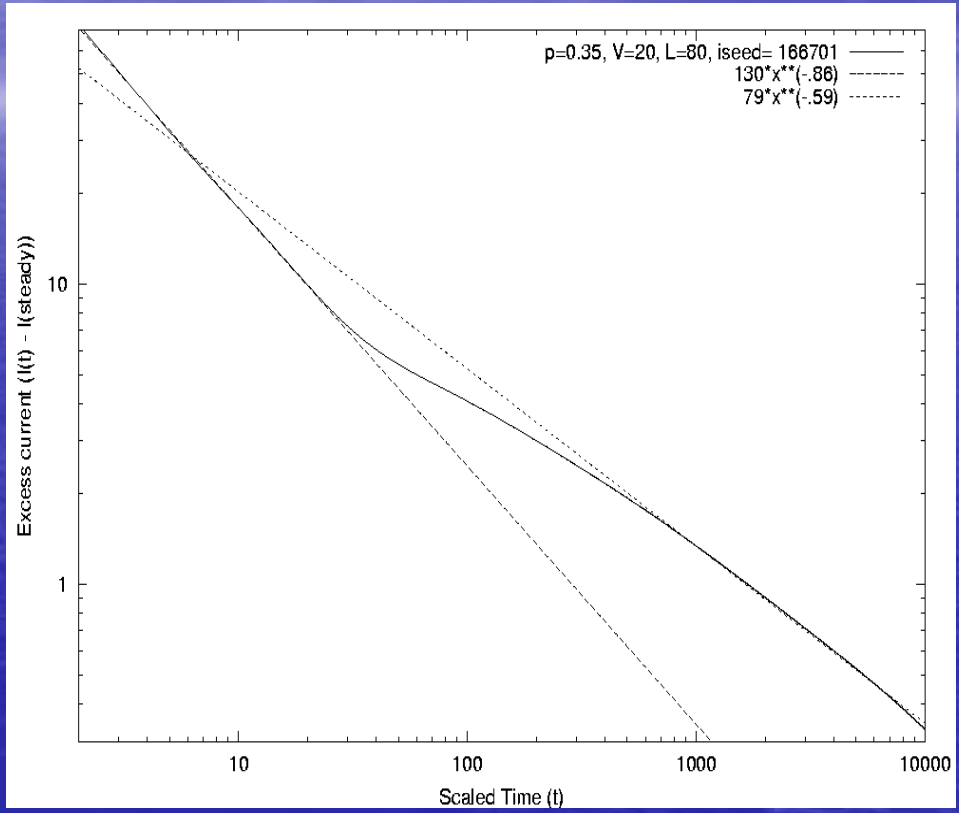




Too much fluctuation among the ensemble members even during dynamics

Early-stage power-laws in RRTN current dynamics





$\alpha_1 < \alpha_2$ $\alpha_1 > \alpha_2$

S. Bhattacharya and A. K. Sen, Europhys. Lett. 71, 797 (2005)

Thank you all !!!

for your kind
attention