Non-equilibrium Power-law Dynamics and Strong Memory Effects (novel Hysteretic Response) in Nonlinear Complex Systems

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We use the paradigm of electrical response and breakdown in random metallic networks in the presence of fully correlated 'tunneling' bonds with non- zero thresholds. We call it a Random Resistor cum Tunneling-bond Network (RRTN) model. Our model shows some relevance in many mechanical, hydro- dynamical, biological etc. systems (e.g., the re-binding dynamics of some heme-proteins after the dissociation of most of its CO and O2 ligands). The breakdown and its dynamics with two power-law (non-Debye) relaxations, is quite intriguing [our work: Europhys. Lett. v.71, p.797 (2005)], both in many experiments and in the RRTN model, away from any criticality. We do also observe the failure of the self-averaging process (in general, of the Central Limit theorem) concommitant with the power-law domains.

Such a power-law dynamics away from any criticality indicates long-range statistical correlations, and appearence of a strong memory effect. This usually means existence of dynamical hsyteresis phenomena. In our study, we have investigated on the intriguing variation in the shape and the area of the dynamical I-V loops with an external ac voltage of only one period. As expected, due to non-linearity, one finds multiple Fourier-modes in the loops. To cite just one important aspect, we find the formation of some secondary loops outside of the main one (also seen in the hysteresis of the optical Kerr-intensity with magnetic nano-dots on Cu(001) surface), where nonlinearity plays an important role in the response. Semi-empirical theoretical explanation is being sought in terms of some non-extensive, generalized q-entropy of Tsallis (generalization of the ideas on loss of information, initiated by Shannon etc. from the Kolmogorov 'school').