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$1/f$ noise and the low frequecy cutoff paradox

Starting with the work of Bernamont (1937) on resistance fluctuations, noisy signals of a vast number of natural processes exhibit $1/f$ power-spectrum. Such spectra are found in weather data, brain activity, currents of ion-channels and certain chaotic systems to name a few. The wide applicability of this spectrum resulted in conflicting theories distributed among many disciplines.

A unifying feature is that $1/f$ power spectrum is non-integrable at low frequencies implying that the total energy in the system is infinite, i.e. the spectral desnity is not normalizable. As pointed out by Mandelbrot (1950's) this infrared catastrophe suggests that one should abandon the stationary mind set and hence go beyond the widely applicable Wiener-Khinchin theorem for the power spectrum. Recent theoretical and experimental advances renewed the discussion on this old paradox, for example in the context of blinking quantum dots [1,2]. Importantly the removal of ensemble averaging in nano-scale measurement revealed time dependent spectrum, at least for nano-crystals.

In this talk ageing, intermittency, weak ergodicity breaking, and critical exponents of the sample power spectrum are discussed within a theoretical framework which hopefully provides new insights on the $1/f$ enigma [1,3]. A general theoretical framework based on non stationary but scale invariant correlation functions leads to an ageing Wiener-Khinchin theorem which replaces the standard spectral theory [3]. The non-integrable spectral density is reminiscent of the infinite invariant measure found in infinite ergodic theory.

References

[1] M. Niemann, H. Kantz, E. Barkai *Fluctuations of 1/f noise and the low frequency cutoff paradox* **Phys. Rev. Lett. 110**, 140603 (2013). M. Niemann, E. Barkai, and H. Kantz *Renewal theory for a system with internal states* **Mathematical Modelling of Natural Phenomena** (special issue on anomalous diffusion) 11 3 (2016) 191-239.

[2] S. Sadegh, E. Barkai, and D. Krapf $1/f$ *noise for intermittent quantum dots exhibits non-stationarity and critical exponents* **New. J. of Physics 16** 113054 (2014).

[3] N. Leibovich and E. Barkai, *Aging Wiener-Khinchin Theorem* **Phys. Rev. Lett. 115**, 080602 (2015). N. Leibovich, A. Dechant, E. Lutz, and E. Barkai *Aging Wiener-Khinchin theorem and critical exponents of* $1/f^{\beta}$ *noise* **Phys. Rev. E. 94**, 052130 (2016).