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Fact versus formula in the power spectra of complex systems

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More than 100 years ago, Thomson and Tait's classic "Treatise on Natural Philosophy" cautioned its readers against "considering the formula and not the fact as physical reality". Deciding what the facts actually _were_, however, was left as an exercise for the reader ... Complex systems offer many examples [1] of the ambiguity Thomson and Tait were trying to point out. This presentation will be about a formula-the "1/f" spectral shape seen in many areas of physics including climate science; and an empirical fact-the growth of rescaled range originally seen in river time series and now known as the Hurst effect.

It is well known that Mandelbrot kicked off the study of long range dependence (LRD) in the mid 1960s [2] with a stationary model for 1/f noise and the Hurst effect. This fractional Gaussian model is now so well known that it is often seen as synonymous with both 1/f noise and the Hurst effect. However Mandelbrot himself was aware that there were other models that produced 1/f noise, including a family [3-6] which he called "conditionally stationary", with power law distributions of times between switching of states. Late in his life he re-emphasised the clear contrasts between their behaviour and that of fGn. I will explain why these other models are also physically interesting, and will show why real systems including climate examples may potentially map more closely to one or the other, or may in fact combine both aspects. I will also discuss his proposals for distinguishing between the models and how they may be implemented.

[1] Watkins, Bunched Black Swans, Geophys Res. Lett, 2013
[2] Graves et al, A Brief History of Long Memory, arXiv:1406.6018 [stat.OT]
[3] Berger and Mandelbrot, "A New Model for Error Clustering in Telephone Circuits", IBM Technical Journal, July 1963.
[4] Mandelbrot, "Self-similar error clusters in communications systems, and the concept of conditional stationarity", IEEE Trans. on Communications Technology, COM-13, 71-90, 1965.
[5] Mandelbrot, "Time varying Channels, 1/f noises, and the Infrared Catastrophe: Or why does the low frequency energy sometimes seem infinite ?", IEEE Communication Convention, Boulder, Colorado, 1965.
[6] Mandelbrot, "Some Noises With 1/f Spectrum, a Bridge Between Direct Current and White Noise", IEEE Trans. Inf. Theory, 13(2), 289, 1967.