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Non-extensive Entropic Analysis in pre-catastrophic signals: the pre-seismic Signals Case

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In the recent years, there has been a very wide effort to acquire unified, and where possible universal descriptions, of classes of phenomena from traditionally distinct scientific areas. This effort has proven especially fruitful in the study of pre-catastrophic phenomena, since these demonstrate a multitude of universal characteristics. In that sense, timeseries from pre-seismic electromagnetic emissions recorded before major earthquakes, preictal EEG recordings before epilepsy seizures, recordings from major geomagnetic storms and other pre-catastrophic phenomena, they all seem to share common mathematical and statistical features. In the present work, we employ the non-extensive entropic analysis technique in order to study pre-seismic electromagnetic signals that were recorded before the earthquake in Athens, Greece in September 1999. Our aim is to determine which of the non-extensive entropies when applied to that kind of signals, can give as a safer precursor of an upcoming seismic event. Beyond the obvious importance of such a potential precursor, any conclusions of the present work can be immediately transferred back to other catastrophic phenomena such as epilepsy. The entropic form that we use is the well known non-extensive (Tsallis) entropy, defined as:

$$S_q = \frac{1 - \sum_i p_i^q}{1 - q} \quad (1)$$

For q=1, Eq. (1) reduces to the standard Boltzmmann-Gibbs entropy, that is:

$$S_{BG} = -\sum_i p_i ln p_i \quad (2)$$

The timeseries that we analyze is a scalar voltage timeseries. It is treated with the following algorithm:

1) The global maximum and minimum voltage that appear on the timeseries are calculated.

2) A normal partitioning of the voltage range is defined.

3) For temporal windows of predefined size we calculate the probability distribution p_μ of finding a measurement in the given temporal window, within the ìth voltage bin.

4) Having calculated the distributions as a function of time, we are able to calculate entropic functions as a function of time.

The choice of the “suitable” entropic functional is a rather subtle and arbitrary process since given a probability distribution we can calculate any entropy. However, we decided to employ the Tsallis entropies since in the vast related literature they have been shown to describe well phenomena of criticality and phase transitions. The seismic phenomenon thus, a critical process par excellence, is an excellent candidate to be treated within the non-extensive framework. Our analysis concludes that as the electromagnetic signal approaches the earthquake time, a sharp rise in all entropies appears. This rise however is most predominant in entropic measures of the Tsallis family with low values of q (for q = 0.5 the rise in entropy is of the order of 2). Thus, these entropies appear to be an excellent measure of complexity of the signal as we approach the main seismic event. Furthermore, preliminary results from the corresponding analysis in epileptic EEG signals in both human and mice, demonstrate similar behavior. Therefore, the universality that has been widely demonstrated in the literature is also observed within the present work.

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