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Fundamental properties of fracture and seismicity in a non extensive statistical physics framework.

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A fundamental challenge in many scientific disciplines concerns upscaling, that is, of determining the regularities and laws of evolution at some large scale, from those known at a lower scale. Earthquake physics is no exception, with the challenge of understanding the transition from the laboratory scale to the scale of fault networks and large earthquakes. In this context, statistical physics has a remarkably successful work record in addressing the upscaling problem in physics. It is natural then to consider that the physics of many earthquakes has to be studied with a different approach than the physics of one earthquake and in this sense we can consider the use of statistical physics not only appropriate but necessary to understand the collective properties of earthquakes [see Corral 2004, 2005a,b,c;]. A significant attempt is given in a series of works [Main 1996; Rundle et al., 1997; Main et al., 2000; Main and Al-Kindy, 2002; Rundle et al., 2003; Vallianatos and Triantis, 2008a] that uses classical statistical physics to describe seismicity. Then a natural question arises. What type of statistical physics is appropriate to commonly describe effects from fracture level to seismicity scale??
The application of non extensive statistical physics offers a consistent theoretical framework, based on a generalization of entropy, to analyze the behavior of natural systems with fractal or multi-fractal distribution of their elements. Such natural systems where long - range interactions or intermittency are important, lead to power law behavior. We note that this is consistent with a classical thermodynamic approach to natural systems that rapidly attain equilibrium, leading to exponential-law behavior. In the frame of non extensive statistical physics approach, the probability function p(X) is calculated using the maximum entropy formulation of Tsallis entropy which involves the introduction of at least two constraints (Tsallis et al., 1998). The first one is the classical normalization of p(X). The second one is based on the definition of the expectation value which has to be generalized to the "q-expectation value", according to the generalization of the entropy [Abe and Suzuki, 2003]. In order to calculate p(X) we apply the technique of Langrange multipliers maximizing an appropriate functional and leading t maximization of the Tsallis entropy under the constraints on the normalization and the q-expectation value.
It is well known that the Gutenberg-Richter (G-R) power law distribution has to be modified for large seismic moments because of energy conservation and geometrical reasons. Several models have been proposed, either in terms of a second power law with a larger b value beyond a crossover magnitude, or based on a magnidute cut-off using an exponential taper. In the present work we point out that the non extensivity viewpoint is applicable to seismic processes. In the frame of a non-extensive approach which is based on Tsallis entropy we construct a generalized expression of Gutenberg-Richter (GGR) law [Vallianatos, 2008]. The existence of lower or/and upper bound to magnitude is discussed and the conditions under which GGR lead to classical GR law are analysed. For the lowest earthquake size (i.e., energy level) the correlation between the different parts of elements involved in the evolution of an earthquake are short-ranged and GR can be deduced on the basis of the maximum entropy principle using BG statistics. As the size (i.e., energy) increases, long range correlation becomes much more important, implying the necessity of using Tsallis entropy as an appropriate generalization of BG entropy. The power law behaviour is derived as a special case, leading to b-values being functions of the non-extensivity parameter q. Furthermore a theoretical analysis of similarities presented in stress stimulated electric and acoustic emissions and earthquakes are discussed not only in the frame of GGR but taking into account a universality in the description of intrevent times distribution. Its particular form can be well expressed in the frame of a non extensive approach. This formulation is very different from an exponential distribution expected for simple random Poisson processes and indicates the existence of a nontrivial universal mechanism in the generation process. All the aforementioned similarities within stress stimulated electrical and

acoustic emissions and seismicity suggests a connection with fracture phenomena at much larger scales implying that a basic general mechanism is “actively hidden” behind all this phenomena [Vallianatos and Triantis, 2008b]. Examples from S.Aegean seismicity are given.

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