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Advanced Research in Statistical Mechanisms of Seismic Movements -Earthquake Statistical Distributions-

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Introduction. Seismic risk and hazard is an important issue of the modern age. Material losses and human casualities produced by earthquakes are expected to be reduced by assessing the seimic risk and hazard, and by mitigation of the earthquake effects. Seismology and seimological engineering, as modern branches of the earthquake science, make promising, to some extent, the earthquake prediction and protection against earthquake effects, which may be disasterous sometime. In such applicative endeavours, seismology employs fundamental results of the basic science of the earthquakes, like focus mechanisms, propagation of seismic waves, local effects of seismic movements, and, especially, statistical distributions of earthquakes. Recently, non-linear effects in earthquake mechanisms also gained a certain importance.

Though featuring a large variety, and, almost an individuality sometime, the seismic movements seem, however, to exhibit certain regularities too, in spite of their great diversity. A few regularity patterns in occurrence and character of the seimic movements have been documented along the time, like the Gutenberg-Richter relationship, recurrence time, magnitude distribution, excedence law, Omori's law and the related, few, experimental observations associated to the seismic activity accompanying a major shock, like foreshocks and aftershocks. The present research project is devoted to further investigating such items. It is based on recent progress made along such lines of research,[1] and aims at further developing the investigation of such issues.

Objectives and relevance

1. A model of accumulating seismic energy in a localized focus has recently been put forward,[1] which relates the mean recurrence time to the seismic energy. The objective aims at extending this model to other geometries of the seismic foci, and to test the applicability of the model to the statistical description of the earthquakes. The relevance of this objective consists in its relating, on the basis of the physical principles, two main parameters of earthquake occurrence - the seismic energy and the mean recurrence time.

2. A time distribution has been advanced recently for main, regular earthquakes,[1] viewed as sequential probabilistic phenomena. It leads, together with the sesimic focus model and the Gutenberg-Richter relationship, to energy and magnitude distributions, recurrence law, and the mean recurrence time as function of magnitude. The objective aims at further developing this probabilistic mechanism, to investigate the role played by the seismicity rate, and to search for connection to power-type laws derived by other mechanisms. The relevance of the objective consists in assessing the critical role of the seismicity parameter, especially in estimating the mean

[1] B.-F. Apostol, PhD thesis, University of Bucharest (2005); B.-F. Apostol, Phys. Lett. **A318** 545 (2003); B.-F. Apostol, Phys. Lett. **A235** 363 (1997)

recurrence time, the errors involved in such an estimation, and, possibly, the profound meaning of the exponent of the power laws.

3. A generalization of Omori's law is envisaged, as based on a self-replication mechanism underwent by an original, generating distribution. The generalization may lead to power-type distributions singular in origin, exponent one included. The relevance originates in providing a statistical mechanism (perhaps the only one available) for Omori's type power laws, with direct application to the associated regime of seismic events accompanying a major seismic shock, both as foreshocks and aftershocks.[2]

4. The self-consistency of the mechanism generating associated events, self-replication included, may require a self-generating original distribution which is given by an exponential law. It leads to the original Omori's law with exponent unity, as stated originally in 1894 for seismic aftershocks. The relevance consists in the generality of the mechanism.

5. The generality of the mechanism producing associated seismic events may lead to time, magnitude, etc distributions of Omori's type for accompanying seismic activity. The corrresponding exponential laws for generating distributions in magnitude or in inverse of energy may serve for analyzing the empirical Bath law as well as the rate of releasing energy in aftershocks, respectively. The relevance arises from the fact that such predictions are amenable to empirical tests.

Apart from focal mechanisms and statistical distributions, the effects of major seismic movements depend critically on the particular regime of propagation of the seismic waves. In this context, the present project may undertake additional objectives, as follows:

6. Examination of the amplification factors in the oscillatory motion on approaching the resonance. This objective is based on previous work on amplification factors at resonance,[3] the relevance being related to further contributing toward assessing the local effects of the earthquakes.

7. Detailed characterization of elastic waves in anisotropic bodies. Recently, special geometries of perovskite-type seem to have been identified for manganese and iron silicates in thermal and pressure conditions at the outer boundary of the inner core of the Earth, which may suggest a uniaxial elastic body. The elasticity of such bodies has been investigated previously,[4] laying ground for a more refined analysis. The relevance stems from the highly non-linear character of the dispersion relations of these waves, which may lead to particular physical effects.

8. Elastic waves in complex, heterogeneous structures may exhibit the phenomenon of localization. Such a phenomenon has ben identified recently in surface seismic waves as bearing possibly a relevance on the seismograms coda. The transport of energy proceeds in this case by diffusion, much alike particles diffusion. Non-linear contributions to diffusion process showed recently the possibility of self-organized spatial patterns, characterized by slowly moving "waves fronts".[5, 6] The objective aims at further analyzing such non-linear processes of diffusion, with relevance to slow re-distribution and transport of seismic energy on Earth's surface.

9. Seismic waves propagate according to geometric rays theory, which is equivalent to a standard approach known as quasi-classical approximation for waves. A new method has recently been devised[7] to derive the asymptotic formulae for rays propagation, which is amenable to including higher-order effects of dispersion, as well as wave refraction, diffraction, reflexion, etc. The objective aims at such generalizations and developments, with relevance in enhancing the capabilities of the powerful rays method in seismic waves propagation.

10. New results have been obtained recently[8] in the non-linear effects of the anharmonic (cubic) corrections to wave equation. It has been shown that such non-linearities affect appreciably the plane waves, driving them, over very large distances and times, in non-physical, singular movements. Dynamic amplification factors have been estimated as due to such effects, and new

resonance phenomena have been identified in coupling longitudinal and transversal waves. The objective aims at further developing these methods in order to investigate more complex situations, especially non-linear coupling between waves propagating in different directions. The relevance consists in contributing to a better understanding of the role played by non-linearities in seismic movements.

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