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Mega et al. Reply — Source link

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Mega *et al.* Reply: Any scaling measure, including the diffusion entropy (DE) method, when applied to the earthquake time series, may yield anomalous scaling for a variety of reasons, of stationary and nonstationary nature. Let us discuss first the *stationary sources* of anomalous diffusion: the non-Poisson distribution $\psi(\tau^{[m]}) \propto 1/(\tau^{[m]})^{\mu}$ of the time distances between one earthquake swarm and the following (see [1]), and the Pareto's law, $p(n) \propto n^{-\gamma}$, with $p(n)$ denoting the probability of a swarm of n earthquakes. The process with the smallest power index determines the asymptotic scaling δ, revealed by the DE method. In Ref. [1] we proposed a value of μ close to 2 so as to account for $\delta = 0.94$. The authors of [2] considered a generalized Poisson (GP) model [with an exponential $\psi(\tau^{[m]})$] and $\gamma = 2.25$ [3], and found $\delta = 0.92$. According to Ref. [4], the scaling is $\delta = 1/(\gamma - 1)$ if $2 < \gamma < 3$, $\delta = 0.5$ for $\gamma > 3$ and $\delta = 1$ for $\gamma < 2$, yielding $\delta = 0.8$ in this case. This theoretical prediction is supported by Fig. 1, which also shows that to obtain $\delta = 0.99$ we should use $\gamma = 1.25$ [5], which is even smaller than the value proposed in [2]. This proves that Pareto's law is not responsible for the anomalous diffusion generated by seismic fluctuations. Let us now discuss the *nonstationary sources* of anomalous diffusion. The recent work of our group shows that a drift on the diffusing variable $x(t)$ with a derivative whose absolute value is larger (smaller) than 1, yields $\delta = 1$ (0). This is why in [1] we mentioned the possibility of relating $\delta = 1$ to a slow geological drift, which would make the main shocks predictable. However, we assigned to the GP $\psi(\tau^{[m]})$ the form of an inverse-power law, while maintaining the assumption that these times are unpredictable. Another nonstationary source of anomalous diffusion is the Omori's law. According to the continuous random walk prescriptions [4], the diffusing variable should increase logarithmicaly in time (thereby producing localization) after an extended transition to scaling, with an index close to $\delta = 1$. We think that the discrepancy between Fig. 1 of [2], yielding $\delta = 0.94$, and Fig. 1 of this Reply, producing $\delta = 0.8$, is due to the adoption in Ref. [2] of an Omori's process with an extremely slow transient. This is confirmed by Fig. 2(a) of Ref. [2], which can be interpreted as a manifestation of the Omori's process with the time scale of months.

In conclusion, the value $\delta = 0.94$ emerging from the real seismic data might be generated by an Omori's process with the time scale larger than a few months. Since Omori's law generally acts at shorter time scales, we consider the non-Poisson model of [1] a plausible way to account for the extended memory revealed by the DE analysis. We define the main shocks as those processes that cancel the memory of the earlier seismic activity. This yields no correlation among the $\tau^{[m]}$'s, while it predicts a strong time correlation among seismic events, if they are selected only on the basis of magnitude. Thus, the results of Fig. 2 of Ref.[2] reinforce our perspective rather than weakening it.

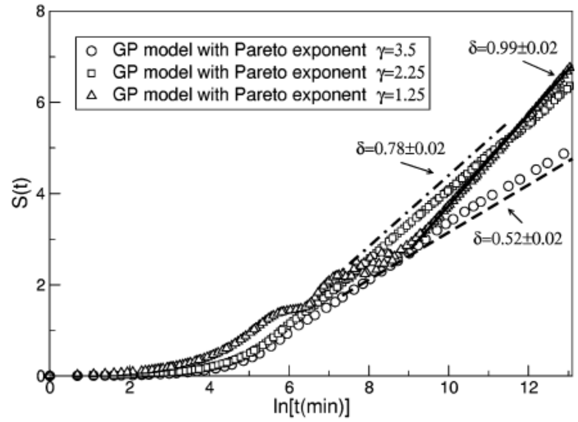

FIG. 1. DE analysis for different synthetic series generated with the GP model and three different exponents of the Pareto law, i.e., $\gamma = 3.5, 2.25, 1.25$. We report also the corresponding values of δ obtained by fitting the asymptotic behavior, i.e., $\delta = 0.52, 0.78, 0.99 \pm 0.02$.

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[1] M. S. Mega *et al.*, Phys. Rev. Lett. **90**, 188501 (2003).
[2] A. Helmstetter and D. Sornette, preceding Comment, Phys. Rev. Lett. **92**, 129801 (2004)
[3] In the literature Pareto's law is referred to as the cumulative distribution.
[4] P. Grigolini *et al.*, Fractals **9**, 439 (2001).
[5] The γ range in Ref. [1] was 3 ± 0.2 and not 3 ± 0.7 as erroneously reported due to a misprint.

