Additional information for the paper:

Similarity of fluctuations in correlated systems: The case of seismicity

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ABSTRACT

Additional information as well as Tables of experimental data are provided. Furthermore, we proceed to additional clarifications of some points discussed in the main text.

In Section I and II we explain the data used, and provide some clarifications on the data analysis. In Section III, we provide an example showing how $\Pi(\phi)$ varies when approaching a mainshock.

I. THE DATA USED

We first clarify that the seismic energy E released during an earthquake (which is itself proportional to the seismic moment M_0) is related to the magnitude M through $E \sim 10^{cM}$ where c is a constant around 1.5 [1]

The following earthquake catalogues have been used: For the San Andreas fault system, the Southern California Earthquake catalogue (SCEC) available from http://www.data.scec.org/ftp/catalogs/SCSN/, and for Japan, the Japan Meteorological Agency (JMA) catalogue. As for the worldwide seismicity (WWS) we used the data available from http://www.seismology.harvard.edu/CMTsearch.html. The magnitude (M) thresholds $M \geq 2.0$, $M \geq 3.5$, and $M > 5.7$ have been considered for SCEC, Japan, and WWS, respectively to

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ensure data completeness (i.e., to obey the well known magnitude-frequency relation) for the periods studied.

II. DATA ANALYSIS

All the seismic data have been analyzed in the natural time-domain, i.e., in a similar fashion as shown in Fig. 1 of the main text. The seismic moment M_0 was obtained from the magnitude M as follows:

For **Japan**, the following approximate formulae, obtained from a fit to Fig. 5.3 of Ref. [2], have been used:

$M_w=0.701M_J+1.47$ for $M_J<5$,

$M_w=0.916M_J+0.40$ for $5\leq M_J<6$,

$M_w=1.07M_J-0.509$ for $6\leq M_J<7.3$,

$M_w=1.345M_J-2.56-0.0472/(M_J-8.3)$ for $7.3\leq M_J$,

where M_J stands for the magnitude reported by JMA and M_w stands for the moment magnitude. Then M_0 was obtained through the relation $M_0\approx 10^{1.5\,M_w}$.

For **SCEC**, we followed the procedure explained in Refs. [3, 4]. As for **WWS**, the M_0 values are directly accessible at the aforementioned http address.

III. CALCULATIONS SUPPORTING THE SUGGESTION THAT $\Pi(f)$ OR κ_1 MAY BE CONSIDERED AS AN ORDER PARAMETER

As a precise example we consider below the example of the M=6.6 mainshock that occurred in Greece on May 13, 1995 with an epicenter at 40.18^o N 21.71^oE, i.e., in the Grevena-Kozani area, which is the strongest EQ in the Greek area during the last 20 years.

This EQ was preceded by two SES activities on April 18 & 19, 1995, excerpts of the recordings of which have been published in Ref. [5] or in Ref. [6]. Thus, we focus our calculations on the EQs that occurred during the period April 18 – May 13, 1995 within the region $N_{39.2}^{40.5}E_{20.3}^{22.0}$ surrounding the epicenter of the mainshock. These earthquakes are tabulated in Table 1, where the local magnitude M_L is given for each event.

The calculation is carried out as follows: Using, for each EQ, the M_L value given in Table 1, we find the corresponding seismic moment M_0 (in dyn.cm) through the relation [7]:

$$\log_{10}(M_0) = (0.99 \pm 0.04)M_L + (18.1 \pm 0.15)$$

The resulting M_0 values of all the events (numbered 1 to 18 in Table 1) that preceded the main shock are plotted in the natural time domain in Fig. 1, in a similar fashion as in Fig. 1(b) of the main text (recall that the latter figure shows only the events numbered (nr.) 1 to 11).

We now calculate the values of $\Pi(\phi)$, for $0< \phi \leq 0.5$, as they evolve with the occurrence of each new event after the previous events. The resulting values – calculated on the basis of Eq.(1) of the main text just by replacing E_k with $(M_0)_k$ – are plotted with the (red) crosses in Fig. 2. In the same figure, we also plot (blue solid line, labelled theory), for the sake of comparison, the $\Pi(\phi)$ values calculated from Eq.(2) of the main text. An inspection of this figure shows that since the EQ nr.9 (which occurred on May 2, see Table 1) the crosses start to gradually approach the solid line. Finally, they almost coincide upon the occurrence of the EQ nr. 12 (i.e., on May 10 and hence only 3 days before the main shock). Then the corresponding κ_1 value (see Fig. 3 of the main text) is close to 0.070, as predicted by Eq.(4) of the main text (cf. the κ_1 value seems to deviate somewhat from this value of 0.070 only upon the occurrence of the EQs nr. 16 and 17, which interestingly took place only a few minutes before the main shock). The last case of Fig. 2 depicts what happens upon the occurrence of the mainshock: The $\Pi(\phi)$ curve then exhibits an *abrupt* change and turns to a straight line almost parallel to the horizontal axis, i.e., $\Pi(\phi) \approx 1.0$ (cf. an abrupt change also appears for κ_1 as discussed in Fig. 3 of the main text). This is exactly the change that motivated us to consider $\Pi(\phi)$ (or κ_1) as an order parameter.

We emphasize that a behavior similar to that found above, is verified [3, 4] when studying the data related to *all* the strong EQs with $M \geq 6.0$ that occurred in Greece, (i.e., within the area $N_{36.5}^{41.5} E_{19.0}^{26.0}$), during the 15 year period 1988-2002. All the data (i.e., seismic data in a similar fashion as in Table 1, as well as the date of the relevant SES activities) that are necessary to repeat the corresponding calculations, can be found in Refs.[3] and [4].

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Table 1. All EQs within $N_{39.2}^{40.5}E_{20.3}^{22.0}$ that occurred after the SES on April 18 and 19, 1995 until the 6.6 *(Ms* from the United States Geological Survey (USGS) site: http://neic.usgs.gov/neis/epic/epic.html) main shock at Kozani-Grevena on May 13, 1995. The following data are available from the site of the National Observatory of Athens (NOA): http://www.gein.noa.gr

No.	Year	Mon.	Day	Hour	Min	Second	Lat.	Long.	Depth	*ML*
1	1995	Apr.	27	15	16	55.3	39.5	21.13	10	2.9
**)	1995	Apr.	28	20	3	16.7	39.19	20.35	17	3.5
2	1995.	Apr.	30	6	508	24.8	39.79	20.72	29	3
3	1995	Apr.	30	7	50	32.14	40.44	21.85	3	3.8*)
4	1995	Apr.	30	21	12	42.6	40	20.66	5	3.3
5	1995	Apr.	30	23	24	54.7	39.81	20.5	10	2.8
6	1995	Apr.	30	23	46	42.5	39.58	20.58	5 .	2.9
7	1995	May	1	1	49	55.5	39.89	20.74	5	3
8	1995	May	1	22	47	21.1	39.9	21.01	5	2.9
9	1995	May	2	15	52	18.6	39.55	20.58	5	3.8
10	1995	May	5	2	58	5.8	39.38	20.35	10	2.8
11-	1995	May	7	5	19	50.3	40.12	20.52	5	2.9
12	1995	May	10	O	1	4.2	40.34	21.79	10	2.9
13	1995	May	10	15	23	2.4	39.28	21.69	10	2.9
14	1995	May,	10	18	24	56.3	39.91	20.72	5	2.9
15	1995	May	11	9	14	24.1	39.94	21.28	10	3.1
16	1995	May	l3	8	42	12.3	40.07	21.75	5	3.7
17	1995	Mav	l3	8	43	18.7	40.02	21.77	5	4
18	**1995**	**May**	**l3**	**8**	**47**	**17**	**40.18**	**21.71**	**39**	**6.1**

*) This event is not reported by NOA but comes from USGS with *ML* (THE).

**) This is just in the boundary of the region selected. Note that if the calculation includes this event but disregards the aforementioned (*) one. i.e.. *ML* (THE) = 3.8, a collapse of the spectra. is again observed on May 10, 1995.

Table 2. The M_L magnitude along with the corresponding M_0 values for the EQs in Table1.

M_0 (N.m)	M_L
9.35×10^{13}	2.9
1.17×10^{14}	3.0
7.28×10^{14}	3.8
2.33×10^{14}	3.3
7.45×10^{13}	2.8
9.35×10^{13}	2.9
1.17×10^{14}	3.0
9.35×10^{13}	2.9
7.28×10^{14}	3.8
7.45×10^{13}	2.8
9.35×10^{13}	2.9
9.35×10^{13}	2.9
9.35×10^{13}	2.9
9.35×10^{13}	2.9
1.48×10^{14}	3.1
5.79×10^{13}	3.7
1.15×10^{15}	4.0
1.25×10^{19}	6.1

FIGURE CAPTIONS

Fig. 1. Plot in natural time of the events that preceded the mainshock of May 13, 1995 (see Table 1) (in similar fashion as Fig. 1(b) of the main text).

Fig. 2. The evolution of $\Pi(\phi)$(crosses in red) of the seismicity that occurred after the detection of the SES activity on April 18, 1995 until the mainshock of May 13, 1995. Figures (a) to (k) correspond to the $\Pi(\phi)$-values upon the occurrence of the EQs labeled 8 to 18, respectively. The corresponding EQs are given in Table 1. The (blue) solid lines are calculated from Eq.(2) of the main text.

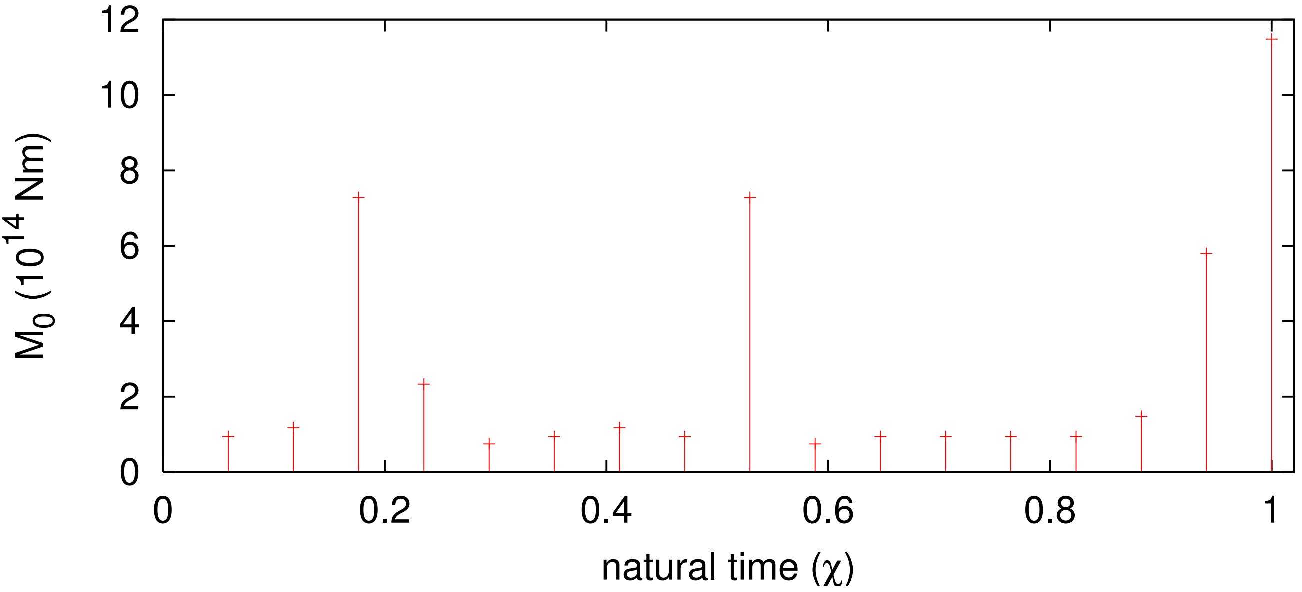

FIGURE 1

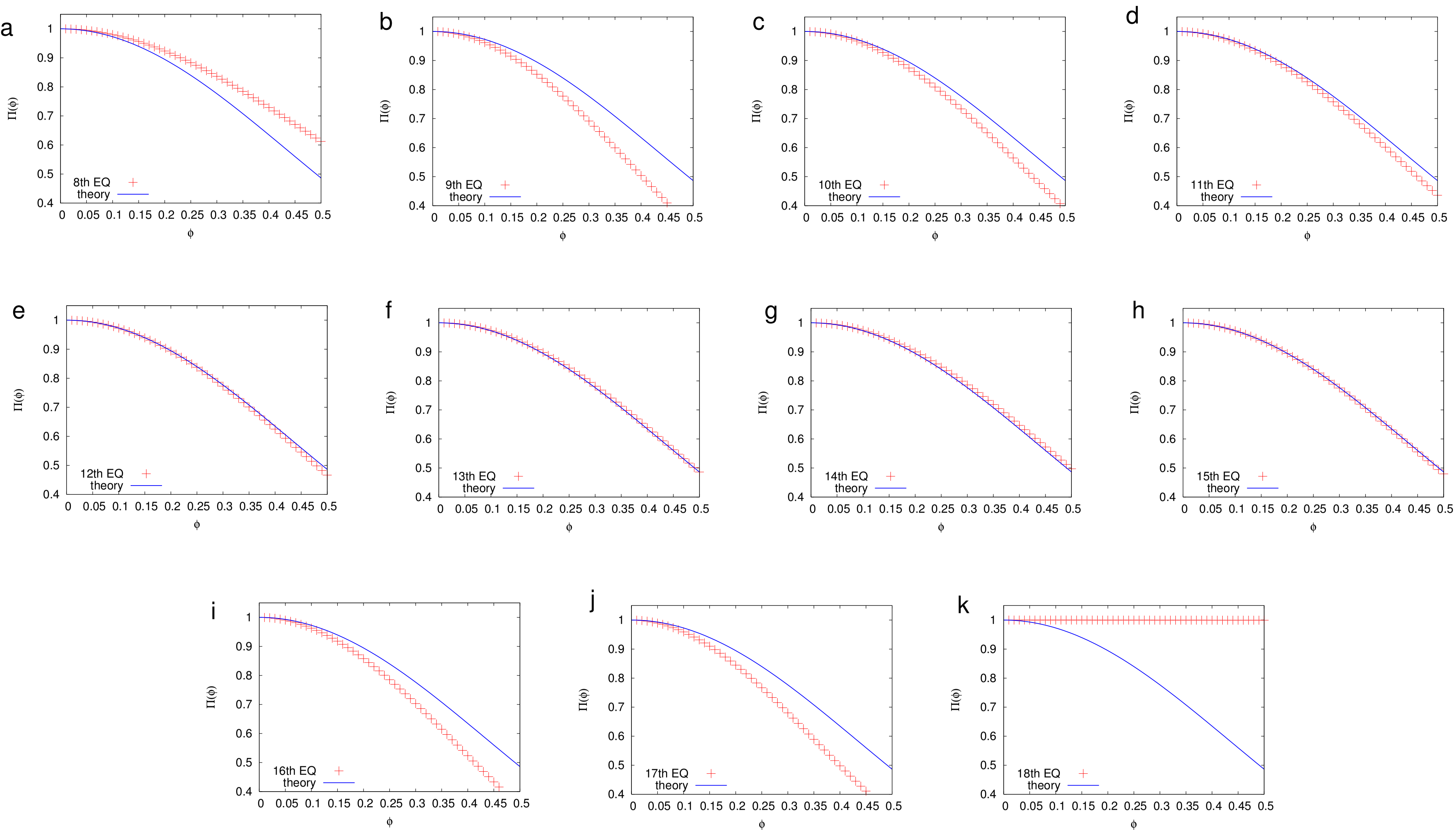
a
8th EQ
theory
b
9th EQ
theory
c
10th EQ
theory
d
11th EQ
theory
e
12th EQ
theory
f
13th EQ
theory
g
14th EQ
theory
h
15th EQ
theory
i
16th EQ
theory
j
17th EQ
theory
k
18th EQ
theory
Π(φ)
φ

FIGURE 2