NH4.4/SM1.15
Statistics and pattern recognition applied to the spatio-temporal properties of seismicity

Convener: Stefania Gentili

Co-conveners: Rita Di Giovambattista, Álvaro González, Filippos Vallianatos

Chat time: Monday, 4 May 2020, 14:00–15:45 (Vienna time)

Welcome

- Welcome to the session NH4.4/SM1.15:

Statistics and pattern recognition applied to the spatio-temporal properties of seismicity

- In the following we show some slides summarizing the results for the session presentation. If you are interested, go to the presentations to have further details.

- Presentations will be available on this website until the end of May.

Chat Timetable

- A **text-based chat is scheduled on Monday, 4 May 2020, 14:00–15:45** (Vienna time) for further details see https://egu2020.eu/sharing_geoscience_online/how_to_use_the_chats.html
- During the live chat, all displays will be called in order of appearance in the **Display list** (next two slides) to give a 1-2 min summary of the work
- After the summary, we will have some time for questions/short discussion. In order to give enough time to all authors, there will be a maximum total time (summary+questions) of 8 minutes for each author.
- Once completed the summaries and questions for each author, we will leave some time at the end of the chat for further questions/short discussion.
- The presentations will be available until the end of May from this webpage and comments can be sent to the authors

Display list (chat) 1/2

Authors	Display	Abstract	Title
Peidong Shi, Léonard Seydoux, and Piero Poli	D2012	EGU2020-11655	Direct fault states assessment from wavefield properties: application to the 2009 L'Aquila earthquake
Giuseppe Petrillo, François Landes, Eugenio Lippiello, and Alberto Rosso	D2014	EGU2020-4676	The influence of the brittle-ductile transition zone on aftershock and foreshock occurrence
Matteo Taroni and Aybige Akinci	D2015	EGU2020-22578	Forecasting M≥5.0 earthquakes in Italy using a new adaptive smoothing seismicity approach
Zakaria Ghazoui, Jean-Robert Grasso, Arnaud Watlet, Corentin Caudron, Abror Karimov, Sebastien Bertrand, Yusuke Yokoyama, and Peter van der Beek	D2016	EGU2020-14510	Does the seismic cycle slip toward randomness?
Renata Rotondi and Elisa Varini	D2017	EGU2020-10098	Variations in the temporal evolution of seismicity pointed out by non-extensive statistical physics approach
Ilya Zaliapin and Yehuda Ben-Zion	D2018	EGU2020-12056	Quantifying preparation process of large earthquakes: Damage localization and coalescent dynamics
Yijian Zhou, Shiyong Zhou, Hao Zhang, Yu Hou, Weilai Pei, Longtan Wang, and Naidan Yun	D2020	EGU2020-3535	Stress State and Fault Strength Variation along Xiaojiang Fault Zone Revealed by Seismicity

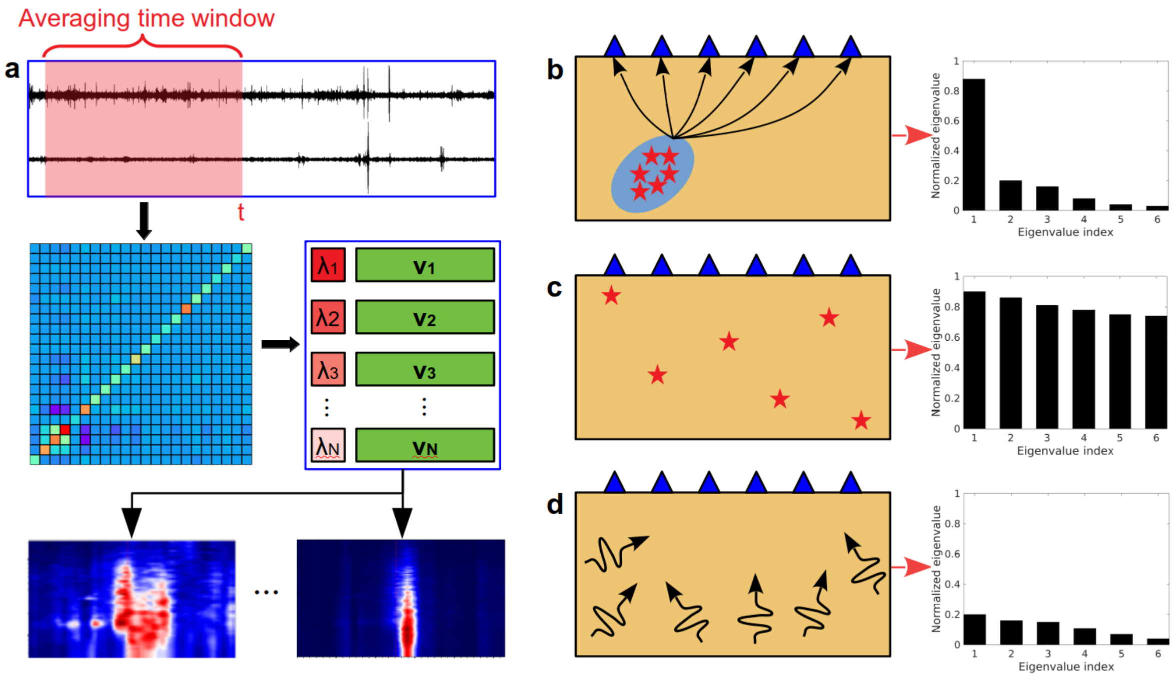
Display list (chat) 2/2

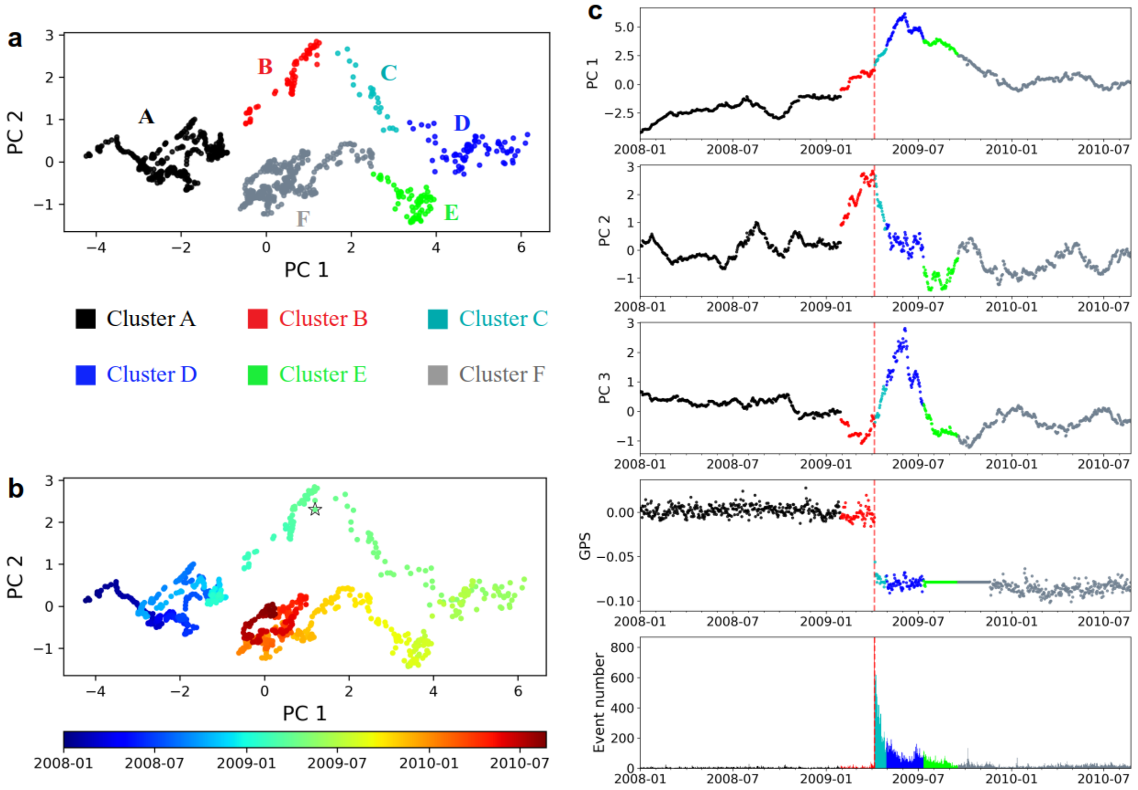
Authors	Display	Abstract	Title
Yifan Yin, Stefan Wiemer, Edi Kissling, Federica Lanza, and Bill Fry	D2022	EGU2020-4051	Seismic rate change as a tool to investigate remote triggering of the 2010-2011 Canterbury earthquake sequence, New Zealand
Álvaro González, Isabel Serra, and Álvaro Corral	D2024	EGU2020-13309	The global statistical distribution of time intervals between consecutive earthquakes
Gianfranco Cianchini and the SAFE Team	D2026	EGU2020-22588	Geosystemics View of Earthquakes
Polyzois Bountzis, Tasos Kostoglou, Vasilios Karakostas, and Eleftheria Papadimitriou	D2028	EGU2020-4788	A study of earthquake clustering in central Ionian Islands through a Markovian Arrival Process
Stefania Gentili and Rita Di Giovambattista	D2029	EGU2020-8184	How strong will be the following earthquake?
Rita Di Giovambattista, Giovanna Calderoni, and Antonio Rovelli	D2030	EGU2020-22596	Spatio-temporal variations of source parameters in the nucleation zone of the 6 April 2009, Mw 6.1 L'Aquila Earthquake
Jordi Baro, Joern Davidsen, and Álvaro Corral	D2031	EGU2020-4948	Topological properties of aftershock clusters in a viscoelastic model of quasi-brittle failure

Summarizing slides

Direct fault states assessment from wavefield properties: application to the 2009 L'Aquila earthquake

Peidong Shi[1*], Leonard Seydoux[1], Piero Poli[1]



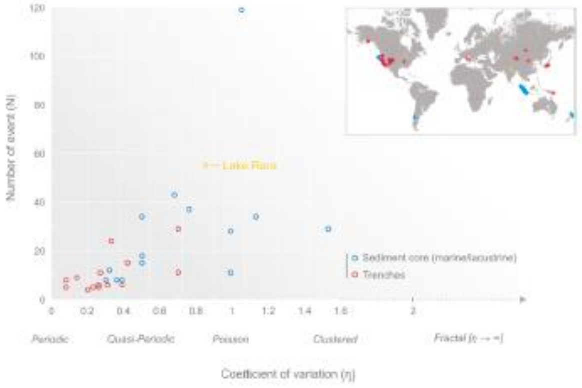


Continuous wavefield → **Wavefield features + machine learning** → **Temporal evolution of fault states**

Does the seismic cylce slip towards randomness?

Zakaria Ghazoui*, Jean-Robert Grasso, Arnaud Watlet,
Corentin Caudron, Abror Karimov, Sebastien Bertrand, Yusuke Yokoyama,
and Peter van der Beek

Cov and Paleoseismic Biais?



Research Questions

- To which statistical distribution does the longest continuous paleoseismic Himalayan record (Lake Rara sediment core, Nepal) best fit?

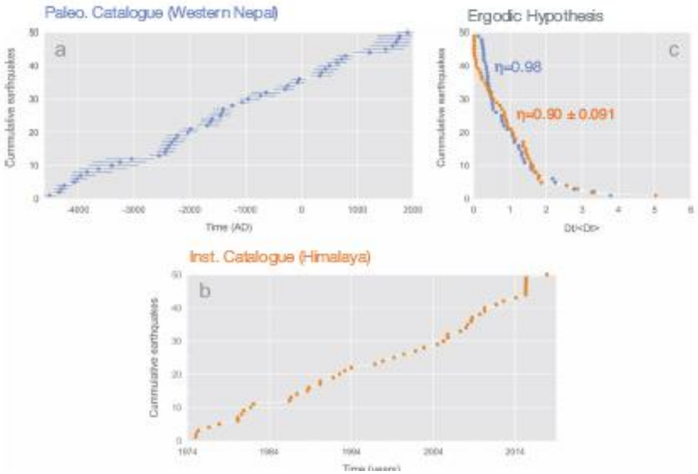
- When testing the ergodic hypothesis, is there a similiarity of inter-event time distribution between the instrumental data (whole Himalaya) and the paleoseismic data (Lake Rara sediment core, Nepal)?

- Do we find similarities in inter-event time distribution for different paleoseismic catalogues originating from different tectonic settings?

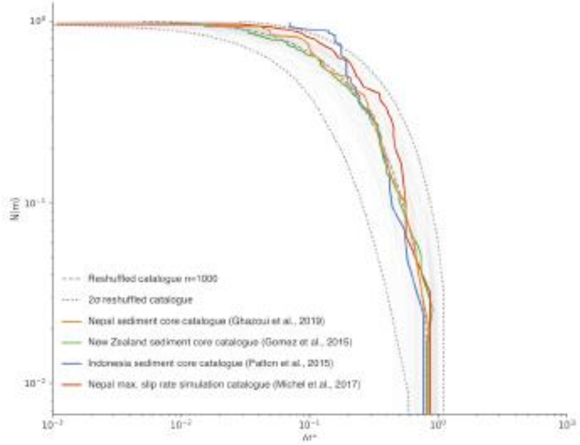
- Is there a universal distribution (paleo. and inst. data considered)?

- Where does this leave us in terms of seismic hazard?

Paleo. vs. Instrumental Data - Nepal and Himalaya



Paleo. Inter-event Time Distribution - Distinct Tectonic Settings

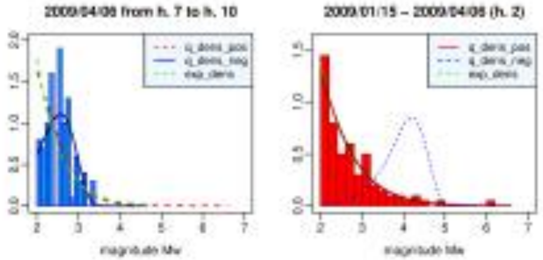


Variations in the temporal evolution of seismicity pointed out by non-extensive statistical physics approach

R. Rotondi G. Bressan E. Varini

Aim: to study a **'descriptor'** of the criticality of a seismogenic system and to interpret its variations as indicator of seismic phase change

- we have estimated the q-exponential distributions in both sub-additive and super-additive case **on time windows of 100 events shifted at each event**
- the value of the q entropic index (and of the entropy) is significantly less than its average value since long time (even years) before the strongest shocks



Examples of (left) $q < 1$ and (right) $q > 1$ q-exponential distributions

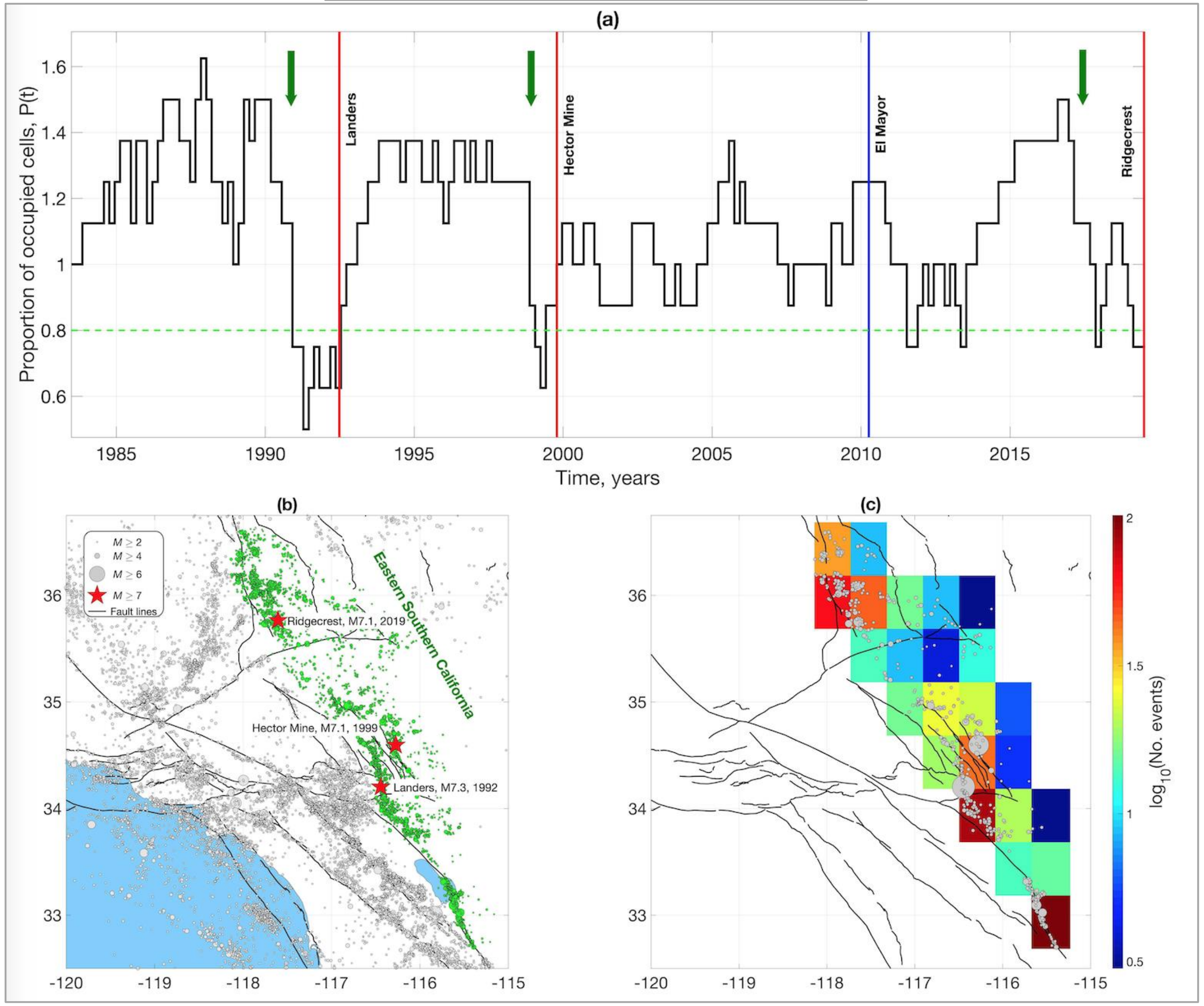
Quantifying preparation process of large earthquakes:

Damage localization and coalescent dynamics

Ilya Zaliapin
Department of Mathematics and Statistics
University of Nevada, Reno

Yehuda Ben-Zion
Department of Earth Sciences
University of Southern California

Localization of earthquake damage



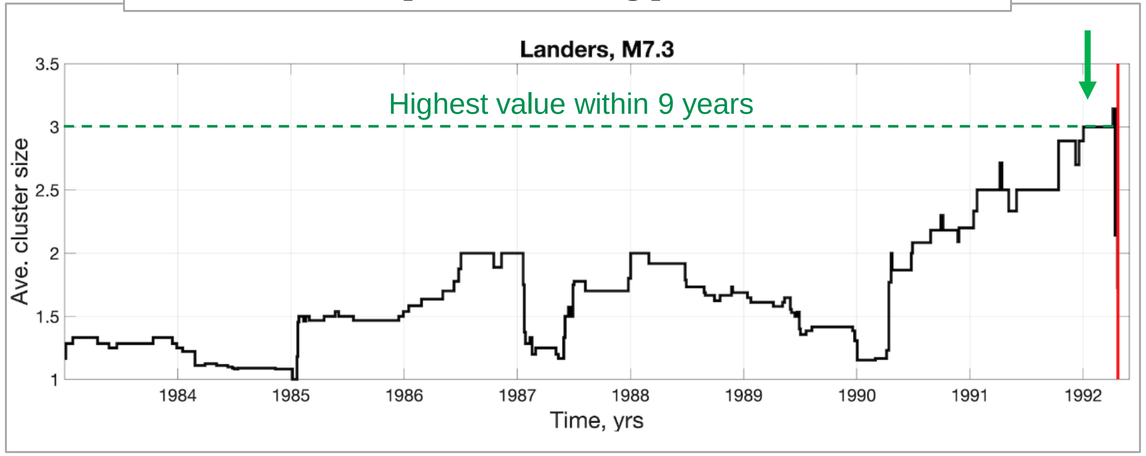
Main Findings:

(1) Generation of rock damage around the eventual rupture zones of M>7 earthquakes in SoCal and Baja.

(2) Progressive localization patterns 2-3 yr before M>7 earthquakes.

(3) Rapid coalescence of small events into clusters in the final year before the large events.

Increase of earthquake clustering prior to Landers, M7.3



Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

ETH zürich

EGU2020-4051

Seismic rate change as a tool to investigate remote triggering of the 2010-2011 Canterbury earthquake sequence, New Zealand

Yifan Yin, Stefan Wiemer, Edi Kissling, Federica Lanza, and Bill Fry

In sparsely instrumented places, careful event discovery reveal diverse seismic response of the crust to major subduction-zone events. In this study, by adding micro-seismicity, we found that the North Canterbury plain undergoes seismic quiescence before the 2010 Darfield Earthquake. Dilatations produced by 2009 Dusky Sound Earthquake concentrate on north of north Canterbury Plain, provides ideal stress change for the Darfield Earthquake.

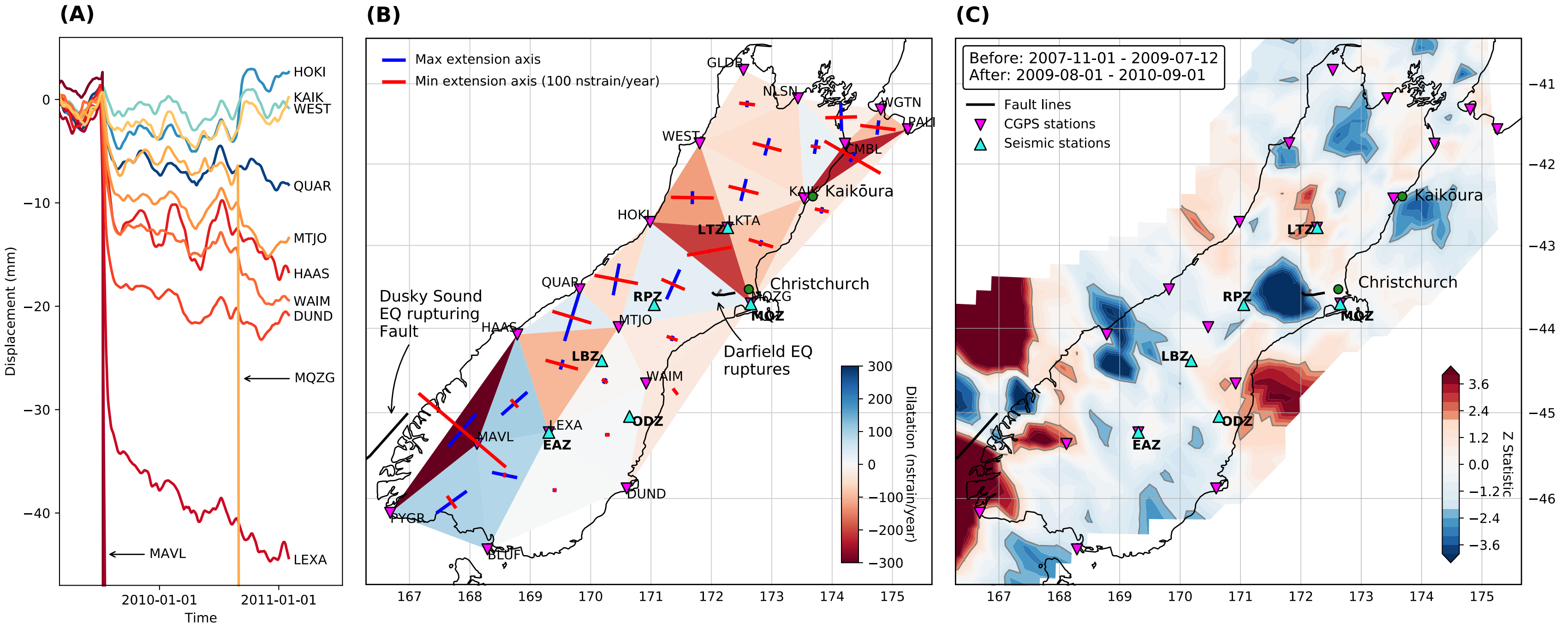


Figure. (A) East-west detrended GPS displacement. (B) Areal dilatation after Dusky Sound Earthquake (C) Z statistic same as fig 4C with insignificant region toned out. The thick pale grey lines shows the fast-moving plate-boundary faults (Litchfield et al., 2014)

The global statistical distribution of time intervals between consecutive earthquakes

Álvaro González
Isabel Serra
Álvaro Corral
www.geonaut.eu

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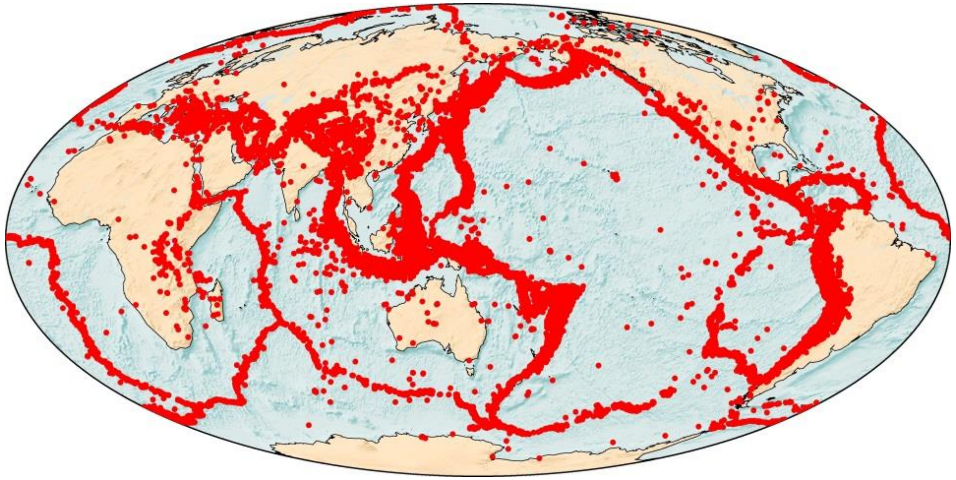
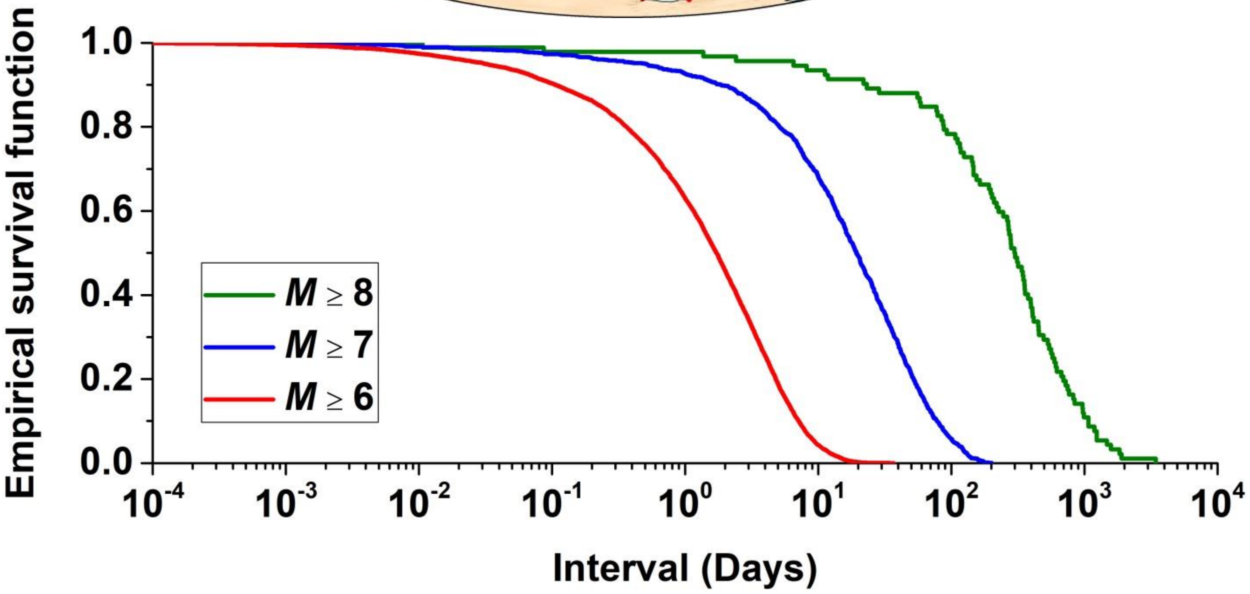
GFZ
Helmholtz-Zentrum
POTSDAM





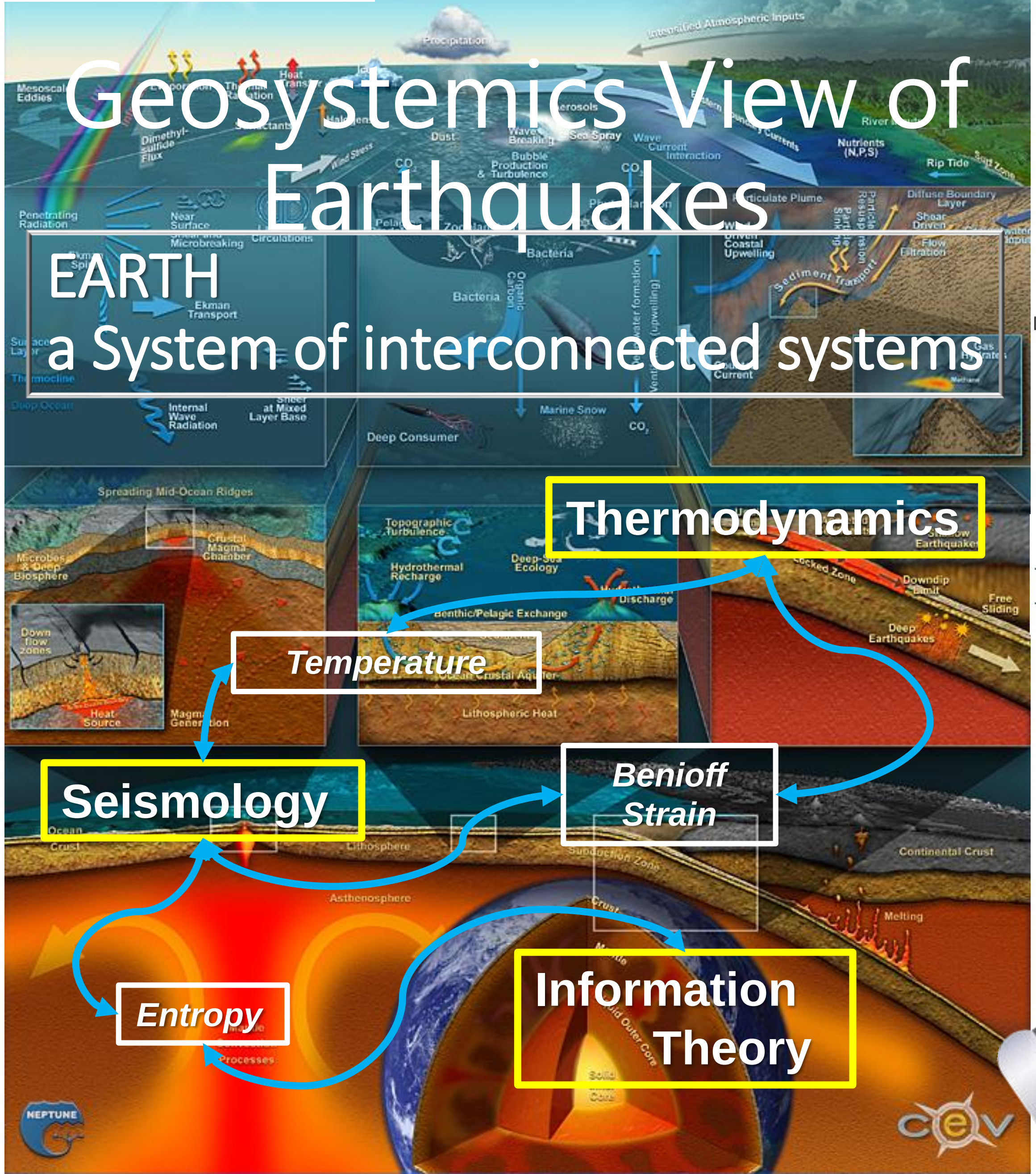
Goals:

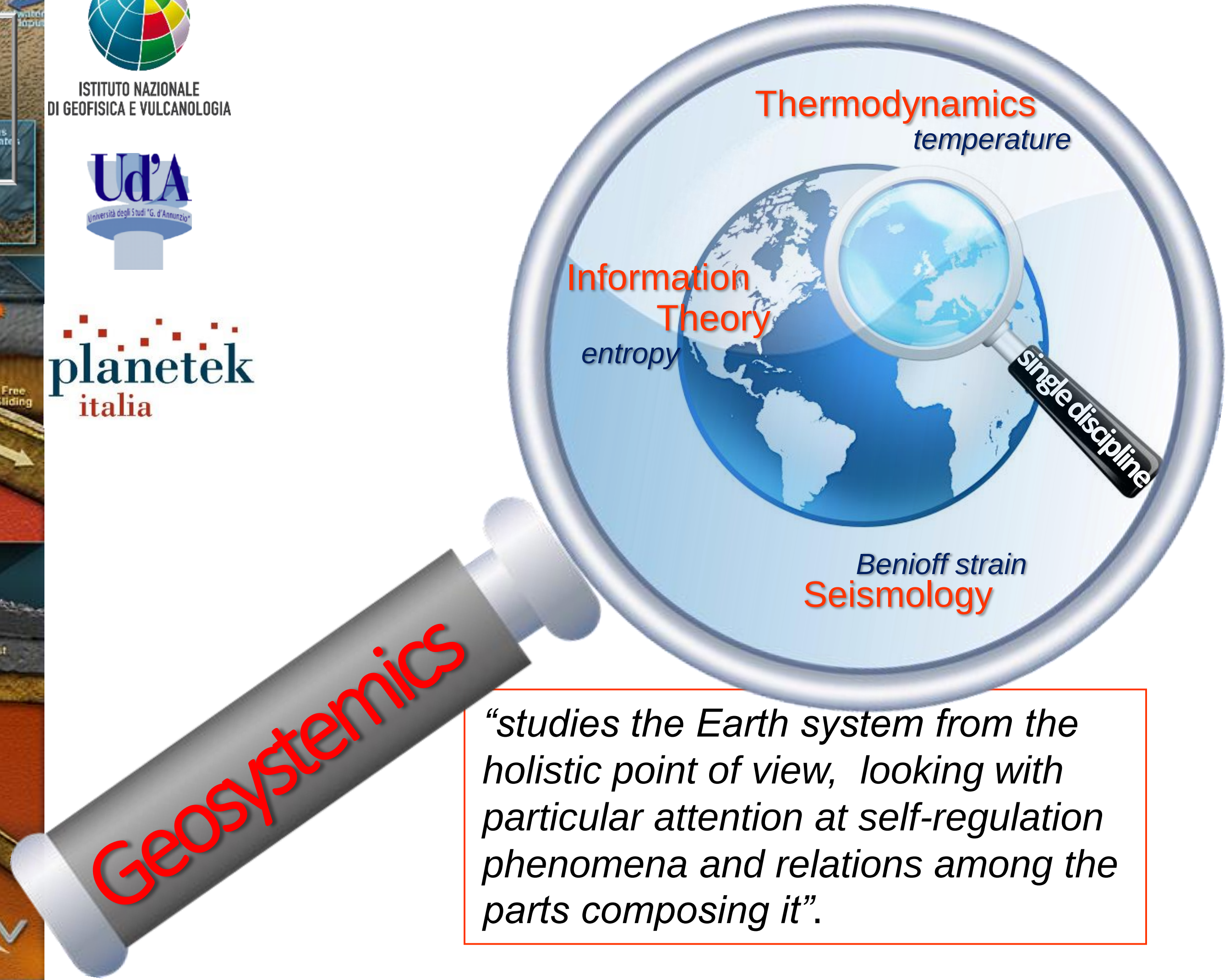
- **Which statistical distribution best fits the data?**
- **Is there a universal distribution?**
- **Can Poissonian occurrence be rejected for the whole series of the largest earthquakes?**

Geosystemics View of Earthquakes

INGV Team: Angelo De Santis - Lucilla Alfonsi - Saioa A. Campuzano - Claudio Cesaroni - Gianfranco Cianchini - Giorgiana De Franceschi - Anna De Santis - Dedalo Marchetti - Loredana Perrone - Alessandro Piscini - Dario Sabbagh - Maurizio Soldani - Luca Spogli
UNIChieti Team: Luca Martino - Mario Luigi Rainone
Planetek srl Team: Cristoforo Abbattista - Leonardo Amoruso - Marianna Carbone - Francesca Santoro
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA
Ud'A
planetek italia

EARTH
a System of interconnected systems





"studies the Earth system from the holistic point of view, looking with particular attention at self-regulation phenomena and relations among the parts composing it".

A study of earthquake clustering in central Ionian Islands through a Markovian Arrival Process

EGU General Assembly 2020

SCHOOL OF GEOLOGY A.U.TH.

P. Bountzis[1], T. Kostoglou[1], V. Karakostas[1] and E. Papadimitriou[1]
(1) Geophysics Department, School of Geology, Aristotle University of Thessaloniki, GR54124 Thessaloniki, Greece

- Detection of the main seismic clusters based on a temporal stochastic point process, MAP, combined with a density-based spatial clustering algorithm, DBSCAN
- Identified seismic excitations consistent with ones that have been derived by manually studied aftershock sequences
- Clustered component of seismicity is dominant in Central Ionian Islands due to the two main sequences (2014 Kefalonia doublet with $Mw6.1$ and $Mw6.0$ and the 2015 Lefkada $Mw6.5$ earthquake)

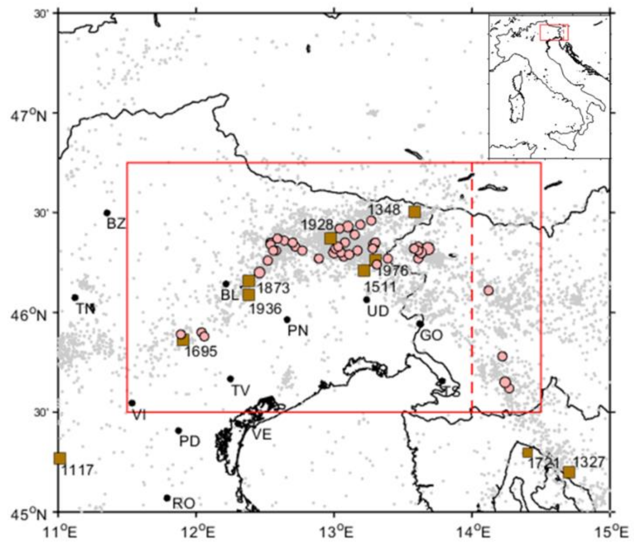
How strong will be the following earthquake?

S. Gentili and R. Di Giovambattista

MOTIVATION

PREDICTION OF A SECOND LARGE EARTHQUAKE BASED ON AFTERSHOCK SEQUENCE

The Database

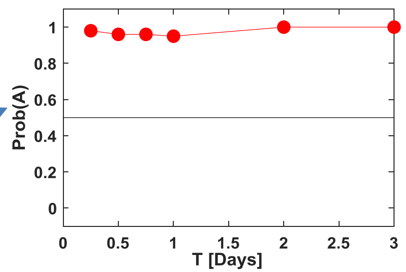


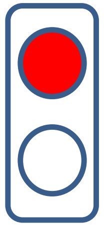
OGS Bulletins local catalogue : 30,000 earthquakes from 1977 to 2018. Pink rectangles: mainshocks. Brown squares: historical earthquakes

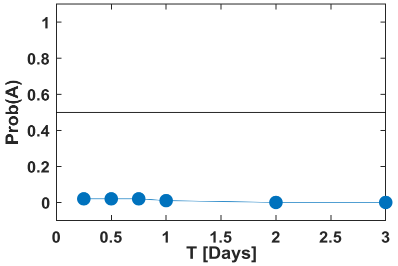
Pattern recognition in the first hours of clusters

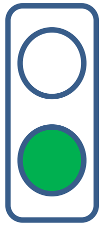
NESTORE

NExt **ST**rOng **R**elated **E**arthquake









Estimation of strong aftershock probability (A class) during cluster

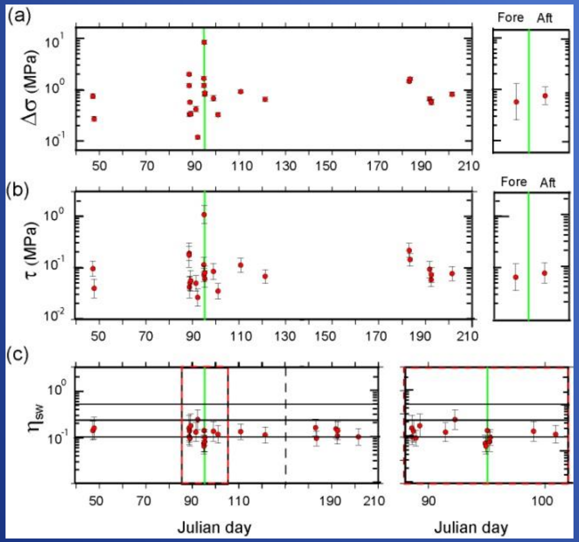
Spatio-temporal variations of source parameters in the nucleation zone of the 6 April 2009, M_w 6.1 L'Aquila Earthquake

G. Calderoni, A. Rovelli, and R. Di Giovambattista
Istituto Nazionale di Geofisica e Vulcanologia
EGU General Assemby 4-8 May 2020

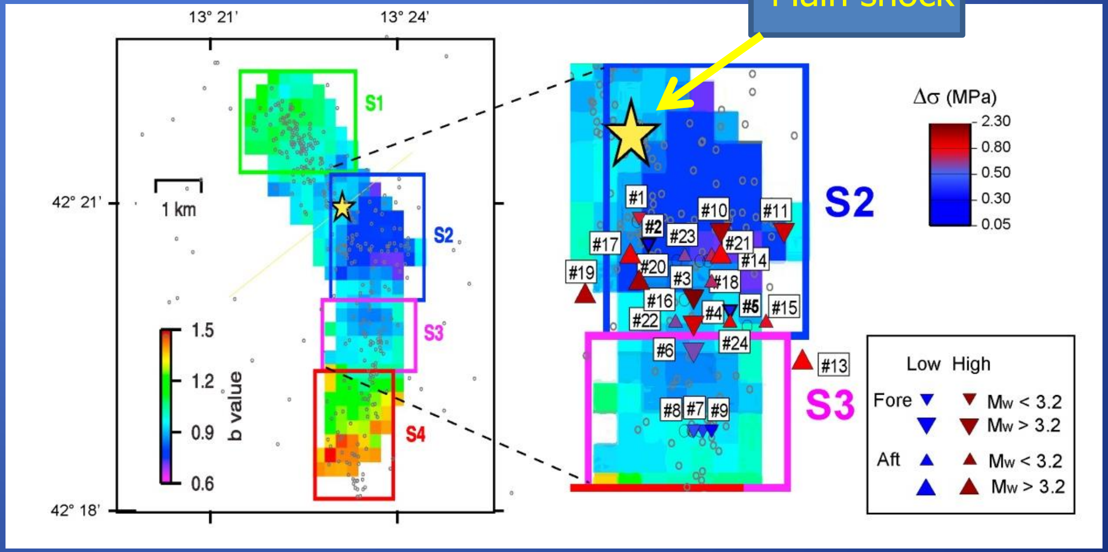

JGR Solid Earth
Research Article
Stress Drop, Apparent Stress, and Radiation Efficiency of Clustered Earthquakes in the Nucleation Volume of the 6 April 2009, M_w 6.1 L'Aquila Earthquake
Giovanna Calderoni, Antonio Rovelli, Rita Di Giovambattista
First published:13 September 2019 | https://doi.org/10.1029/2019JB017513

- ➢ Spatio-temporal variations of source parameters of clustered earthquakes located near the hypocenter of the M_w 6.1 L'Aquila earthquake.
- ➢Inter-event variability results in a factor of 10, well beyond the individual-event uncertainty.
- ➢The temporal change observed might be interpreted as a spatial variation due to the earthquake migration into the locked portion of the fault originating the main shock.

Temporal variations



Spatial variations



Topological properties of aftershock clusters in a viscoelastic model of quasi-brittle failure

Jordi Baró [a,b,*], Jörn Davidsen [a], Alvaro Corral [b]

[a] Complexity Science Group, Dept. of Physics and Astronomy, Univ. of Calgary, Calgary, AB, T2N 1N4, Canada.

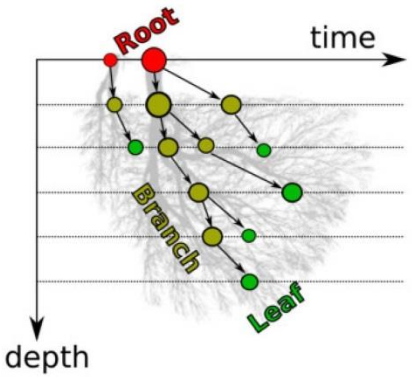
[b] Centre for Mathematical Research (CRM), Barcelona, 08193, Spain.

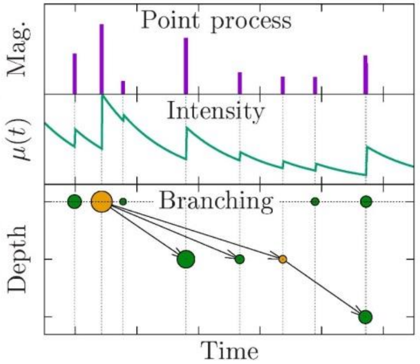
[*] jbaro@crm.cat

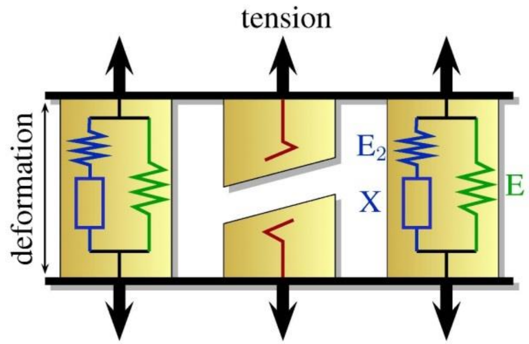
Material failure at different scales and processes can be modeled as an emergent feature of **micromechanical** systems in terms of **avalanche dynamics**. Among experimental observations, event-event triggering —**aftershocks**— is common in a common feature in seismological catalogs, acoustic emission experiments [*1*] and even other phenomena. In parallel, the statistical properties of triggering in such catalogs are often modeled as stochastic **epidemic branching** or **linear Hawkes** processes [*4,5*]. In the **micromechanical** approach, **viscoelastic** stress transfer and after-slip are among the proposed mechanism behind triggering and aftershocks.

Here we address a simple question:

Do aftershock sequences obtained in micromechanical models agree with the predictions and ideas behind the epidemic branching framework?







We introduce two **fibrous models** as prototypes of **viscoelastic fracture** [2] which (i) provide an analytical explanation to the acceleration of activity in absence of critical failure observed in acoustic emission experiments [*3*]; (ii) reproduce the typical spatio-temporal properties of triggering found in field catalogs, acoustic emission experiments; and (iii) agree with the one-to-one causality established in epidemic models, but display discrepancies with the branching topological properties predicted by stochastic models. These are probably caused by physical constrains and nonstationary parameters.

[1] J. Baró et al., *Phys. Rev. Lett.* 110 (8), 088702 (2013);
[2] J. Baró, J. Davidsen, *Phys. Rev. E* **97** (3), 033002 (2018);
[3] J. Baró, et al., *Phys. Rev. Lett.* **120** (24), 245501 (2018);
[4] J. Baró, *J. of Geophys. Res.: Solid Earth*, **125**, e2019JB018530 (2020);
[5] S. Saichev, et al., *Pure and App. Geoph.*, **162** (6), 1113-1134 (2005).

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