2026 SCEC Community Stress Drop Validation Workshop
20 January 2026
Invited communication

FEAR
Fault Activation and Earthquake Rupture

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Kinematic source characterization of micro-earthquakes induced in BedrettoLab fault activation experiments

Supino Mariano[1], Cocco Massimo[1], Meier Men-Andrin[2], Tinti Elisa[3], Mosconi Francesco[3], Poggiali Giulio[3], Valentin Gischig[4], Rinaldi Antonio Pio[4], Massin Frederick[4], Clinton John[4], Scarabello Luca[4], Selvadurai Paul[4], Luca Dal Zilio[5], Florian Amann[6], Stefan Wiemer[4] and Domenico Giardini[2]

1 Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy
2 ETH Zürich, Institute of Geophysics, Earth Sciences, Zürich, Switzerland
3 Sapienza Universitá di Roma, Dipartimento di Scienze della Terra, Rome, Italy
4 ETH Zürich, Swiss Seismological Service, Zürich, Switzerland
5 Nanyang Technological University, Earth Observatory of Singapore, Singapore
6 RWTH Aachen University, Lehrstuhl für Ingenieurgeologie und Hydrogeologie, Aachen, Germany

INGV

ETH zürich SAPIENZA Università di Roma Schweizerischer Erdbebendienst / Service Sismologique Suisse / Servizio Sismico Svizzero / Swiss Seismological Service ETH zürich Earth Observatory of Singapore RWTH Aachen University

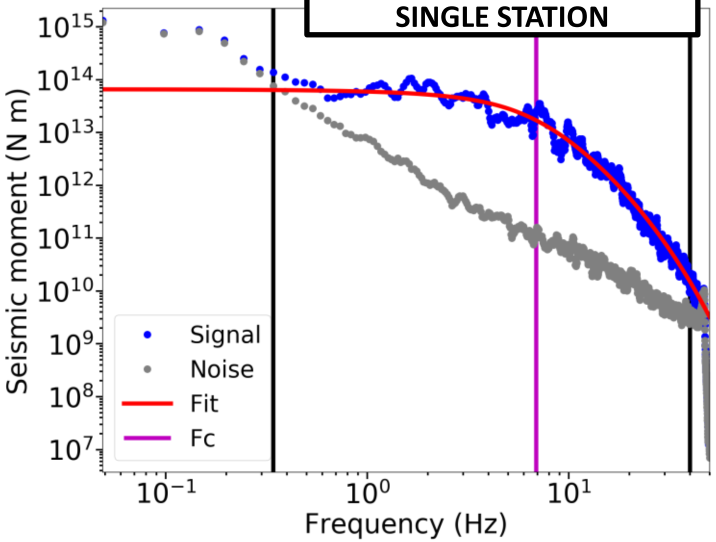
Spectral inversion method

Seismic moment and corner frequency joint PDF

Method SPAR by Supino et al., 2019 | doi

A — INVERTED OBSERVATION : DISPLACEMENT SPECTRUM

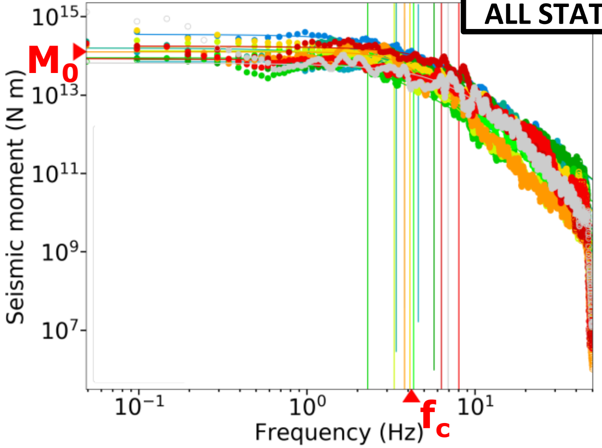
SINGLE STATION



C — EVENT SOLUTION

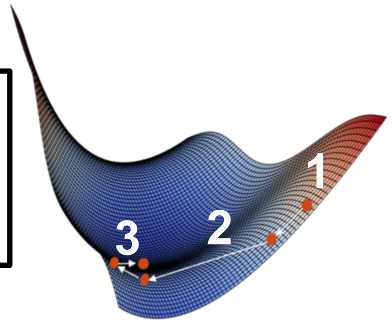
Inverse-variance weighted average

ALL STATIONS



B — PROBABILITY DENSITY FUNCTION OF SOURCE PARAMETERS $\boldsymbol{m}$

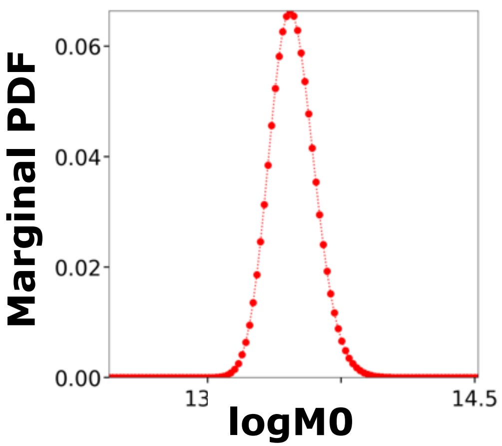
B.1 Find the a-posteriori joint PDF $\sigma_M(\boldsymbol{m})$ maximum $\boldsymbol{m}^*$ with MC global optimization

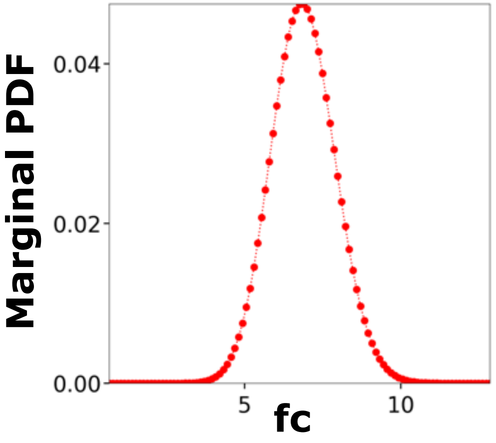


1. Random perturbation
2. Local minimization
3. Metropolis criterion

B.2 Evaluate $\sigma_M(\boldsymbol{m})$ around $\boldsymbol{m}^*$

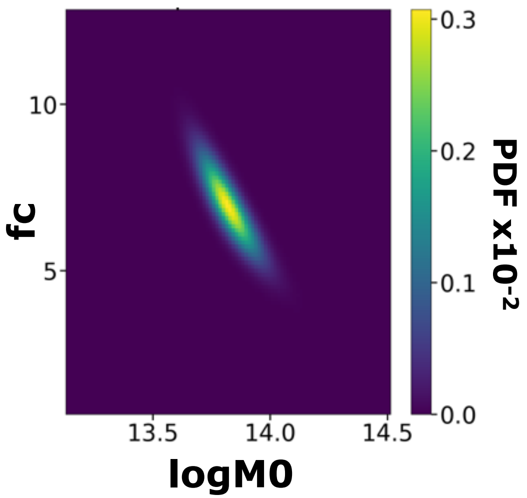
B.3 Evaluate marginal PDFs, mean and variance of source parameters



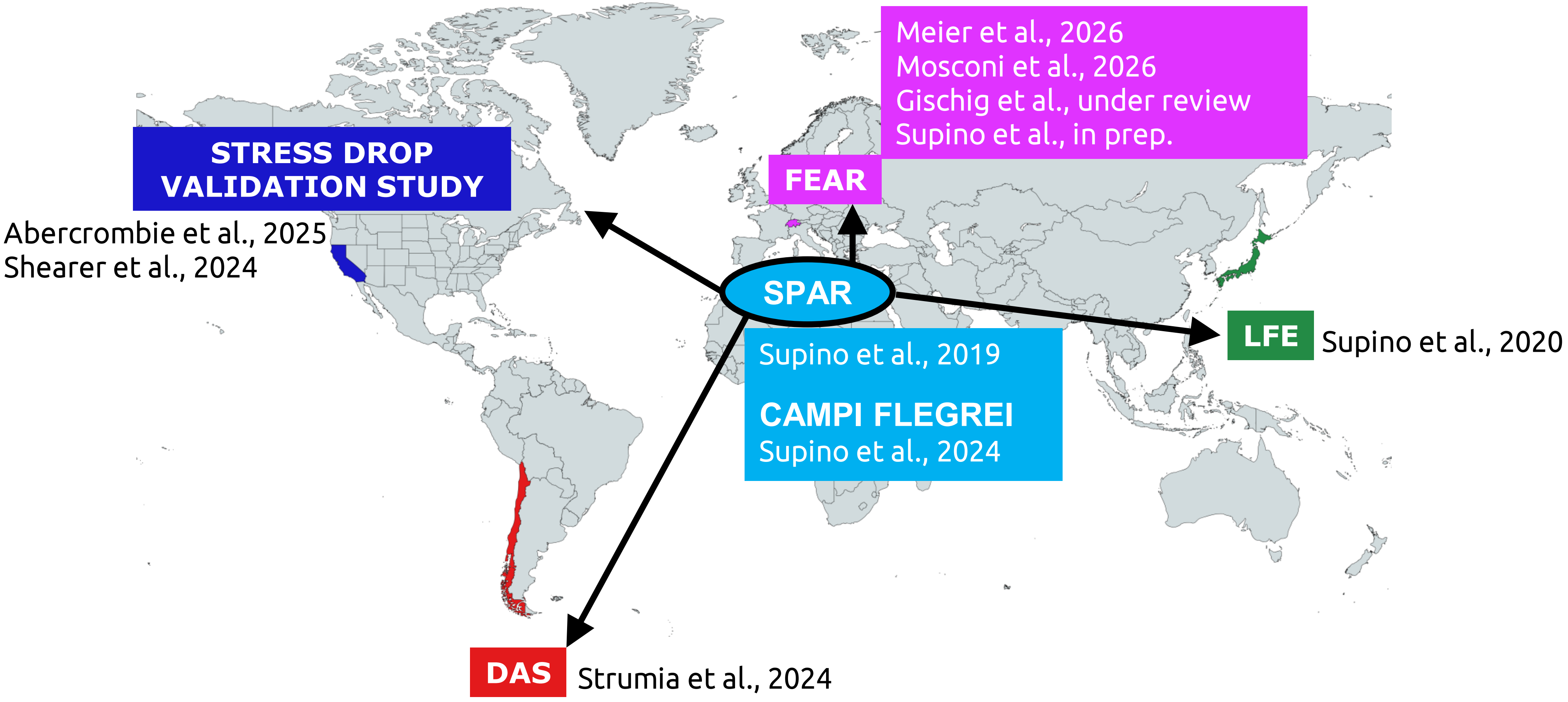


Joint PDF $\sigma_M(\boldsymbol{m})$

CORRELATION ρ = - 0.86

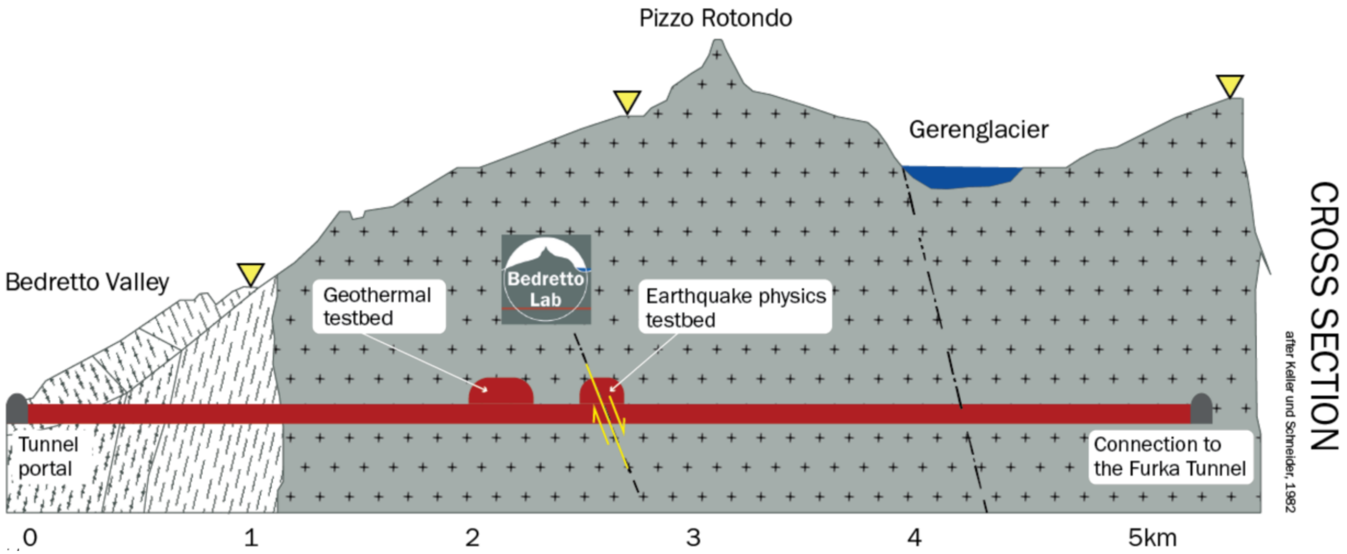


SPAR main applications
Different type of Earthquakes | Tectonic settings | Data

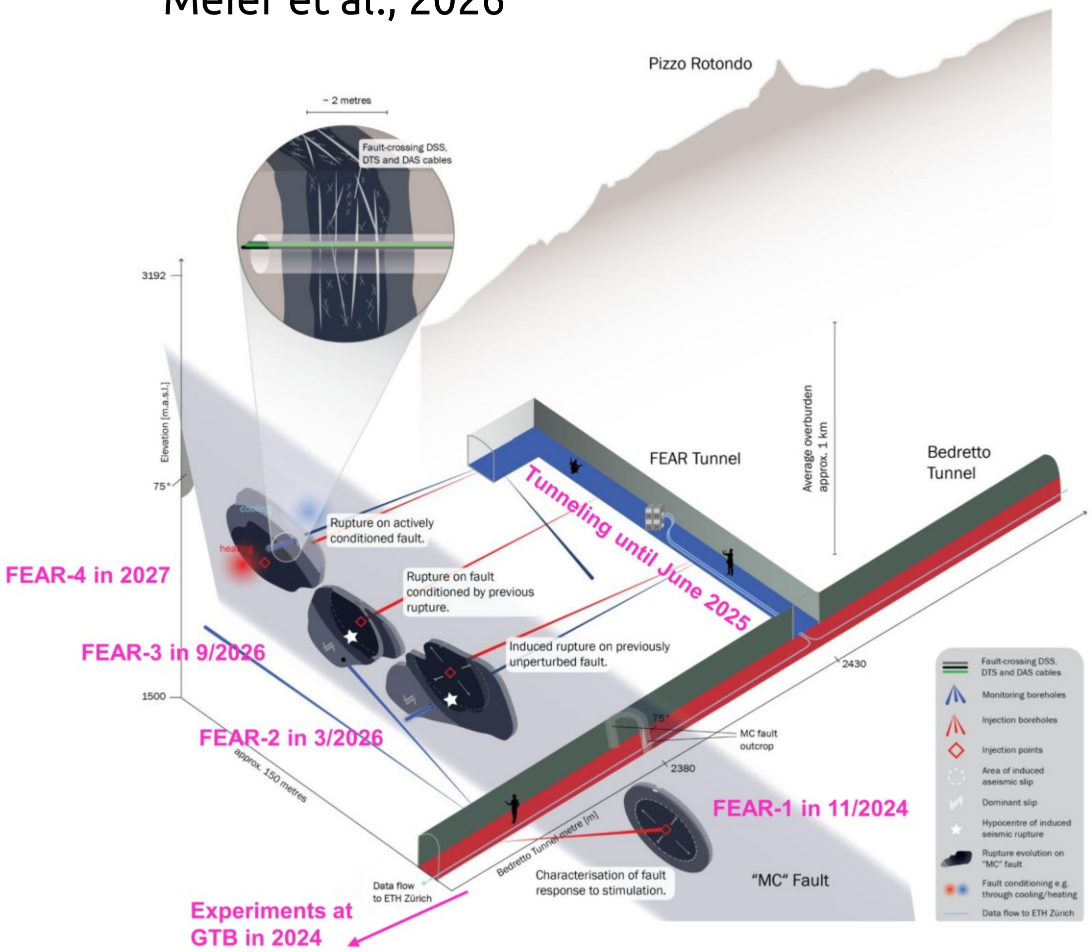


BedrettoLab and FEAR

BedrettoLab and FEAR Data



Meier et al., 2026



We use seismic data recorded at BedrettoLab, an underground research facility in Ticino (Switzerland).

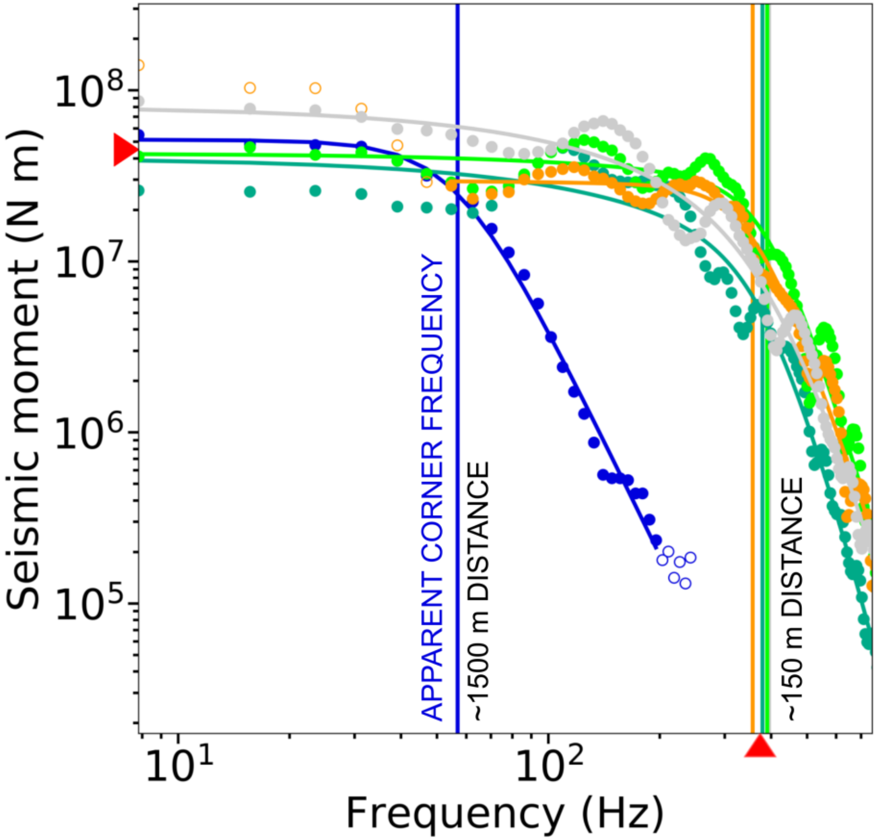
We analyze the 6 largest events ($-1 \leq Mw \leq -0.1$) occurred during the 2024 fluid injection experiments conducted in the framework of the FEAR ERC Synergy project.

Seismic stations were available extremely close to the target faults, with distances starting from ~100 meters.

Seismic phases were manually picked and earthquake locations manually revised by the SED ETH Zurich team.

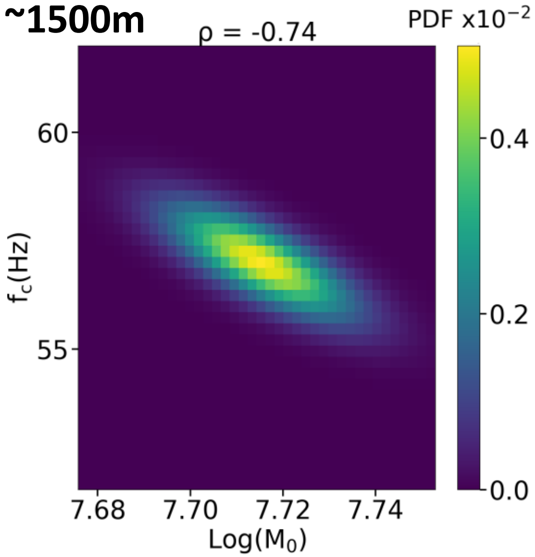
[Figures from fear-earthquake-research.org]

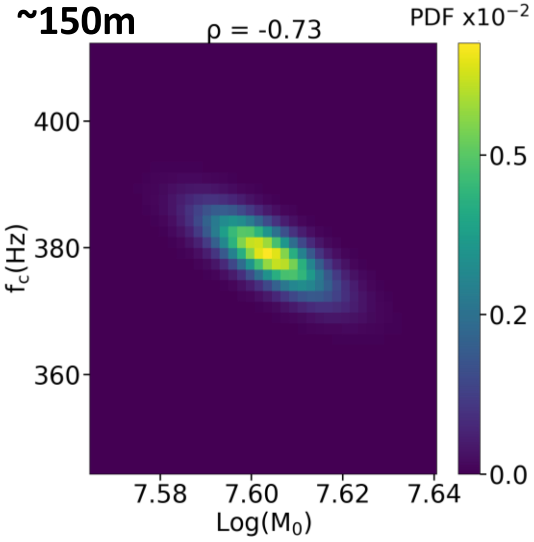
BedrettoLab and FEAR Results

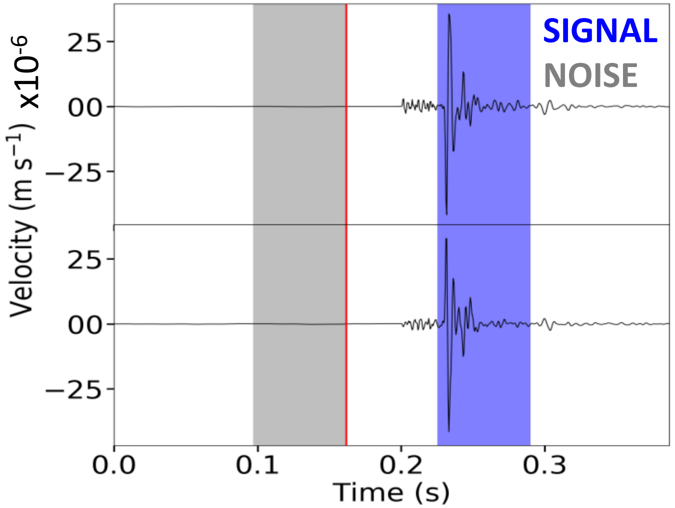


$$M_w = -0.97 \pm 0.04$$

$$f_C = 374 \pm 4\ \mathrm{Hz}$$



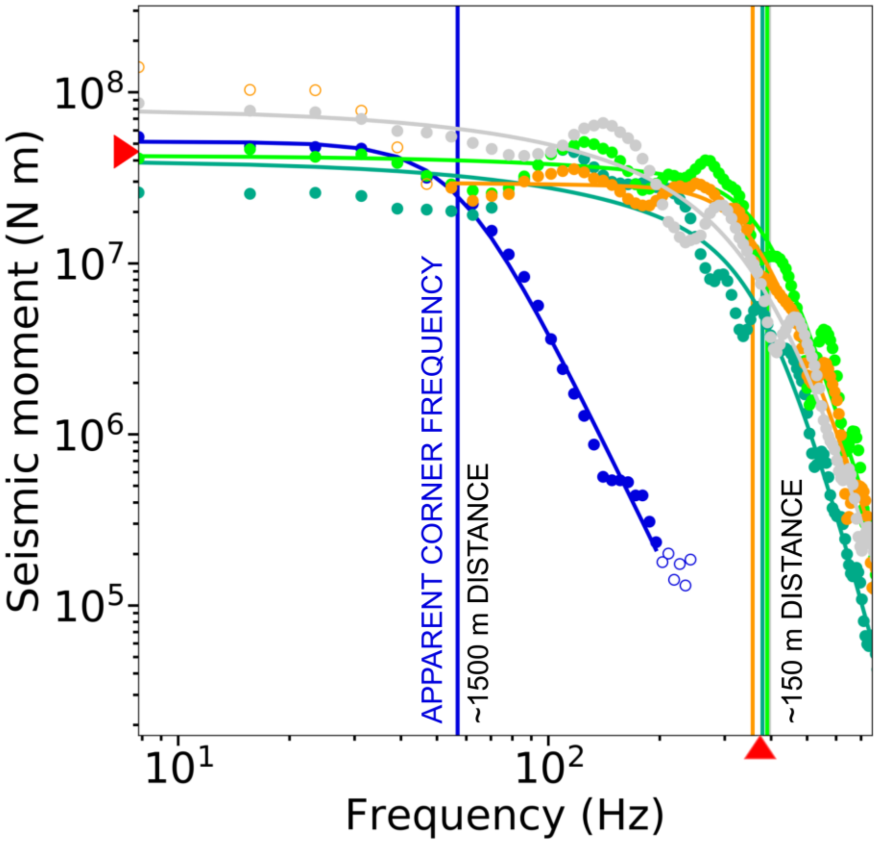




We observe a corner frequency **fc = 374 ± 4 Hz** from the raw signals recorded **at~150 m** distance for a magnitude Mw = -0.97 ± 0.04 event.
The same event recorded **at~1500 m** distance exhibit an apparent corner frequency **fc ~60 Hz**.

Observations close to the source as provided by BedrettoLab allows to observe source corner frequency and derive precise stress drop estimates from raw signals of microearthquakes.

BedrettoLab and FEAR Results



$\mathbf{M_w = -0.97 \pm 0.04}$

$\mathbf{f_C = 374 \pm 4\ Hz}$

$$\boldsymbol{r} = \frac{k}{f_C}$$

with $k = k(v_R)$

SOURCE RADIUS

SOURCE MODEL and PHASE

RUPTURE VELOCITY

$$\Delta\boldsymbol{\sigma} \propto \frac{M_0}{r^3}$$

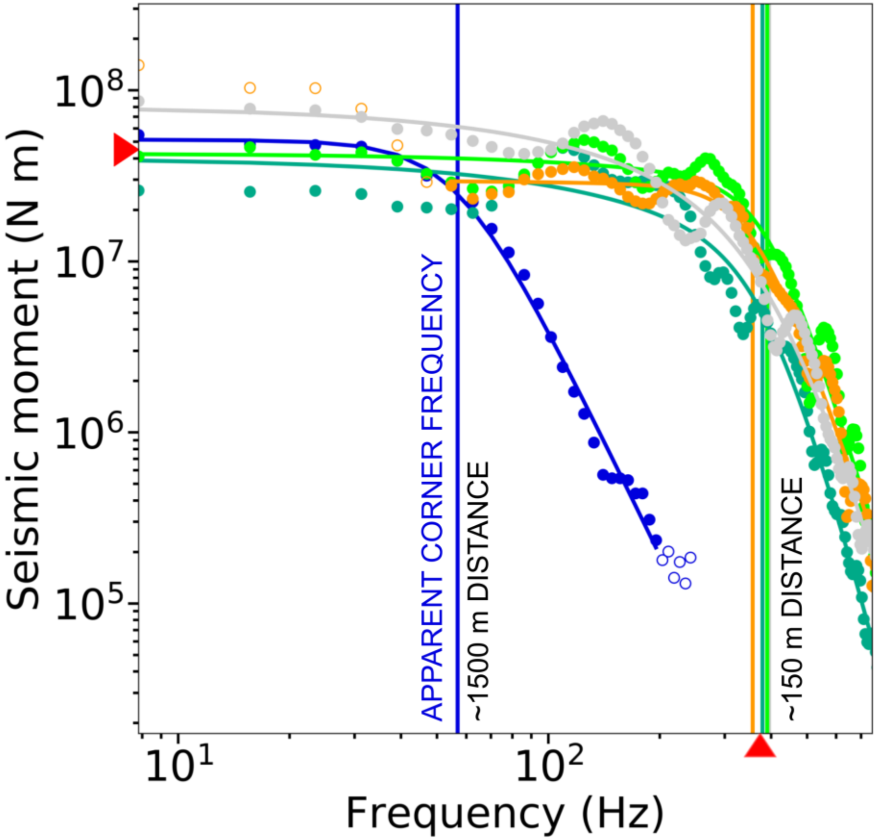
STRESS DROP

ASSUMING

$V_R = 0.9\ V_S$ and Kaneko and Shearer (2014)
circular source model | **k = 0.26**

$\Delta\boldsymbol{\sigma} = \mathbf{2.1 \pm 0.3}\ \boldsymbol{MPa}$

BedrettoLab and FEAR
Results



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V_R = 0.9 V_S and Kaneko and Shearer (2014)
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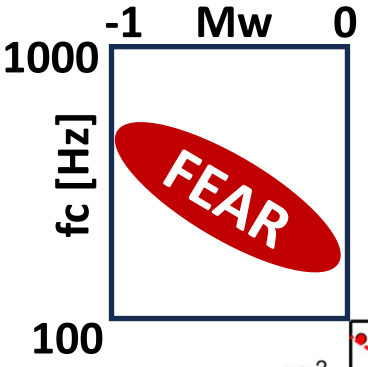
$\boldsymbol{\Delta\sigma = 2.1 \pm 0.3\ MPa}$

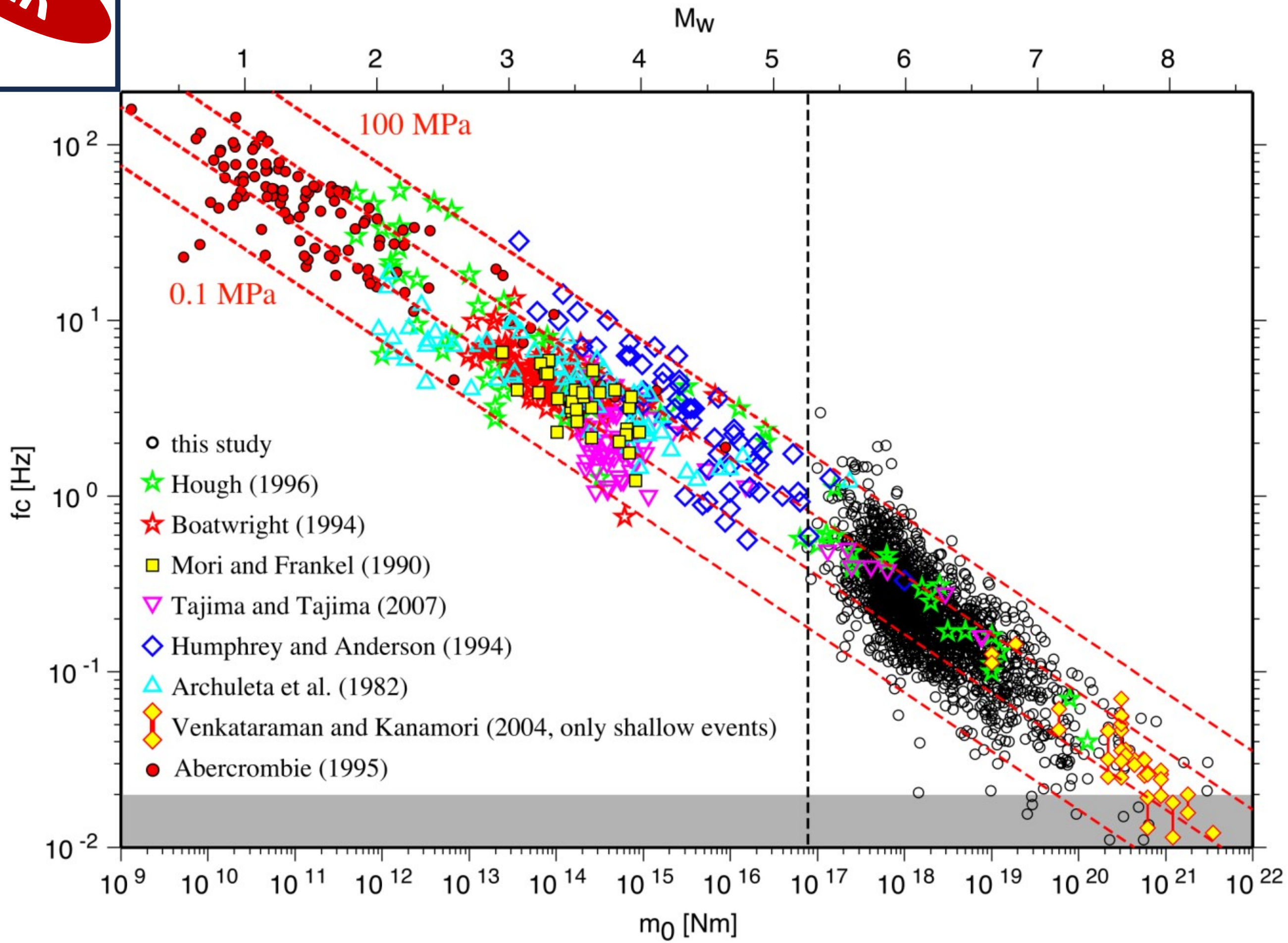
$\Delta\sigma$ from 6 main events between 1.0 and 4.5 Mpa

BedrettoLab and FEAR
Results

FEAR observations contribute to understand earthquake source scaling in terms of corner frequency and seismic moment, showing a stress drop of~MPa, as commonly observed for natural earthquakes.



Allmann and Shearer 2009, collection of corner frequency and seismic moment observed globally for natural earthquakes. Stress drop isolines assume Madariaga source model



The unique FEAR perspective (source-receiver distances from tens of meters up to kilometers) provide new evidences for:

- The importance of on-fault observatories to improve our understanding of seismic source and scaling processes
- The anelastic attenuation low-pass filtering significantly limiting the source information content for small-magnitude earthquakes.