Advanced Sensing of Earthquakes [through piezo-electric and magnetic LENR; AI; machine learning & satellites]

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I am honoured to be allowed to give this seminar at a venue of the Italian Senate in 2024

- I privately presented this novel proposal about advanced sensing of earthquakes in 2012 to Professor Luciano Maiani who was then in-charge of Risks in Italy. Nothing happened!

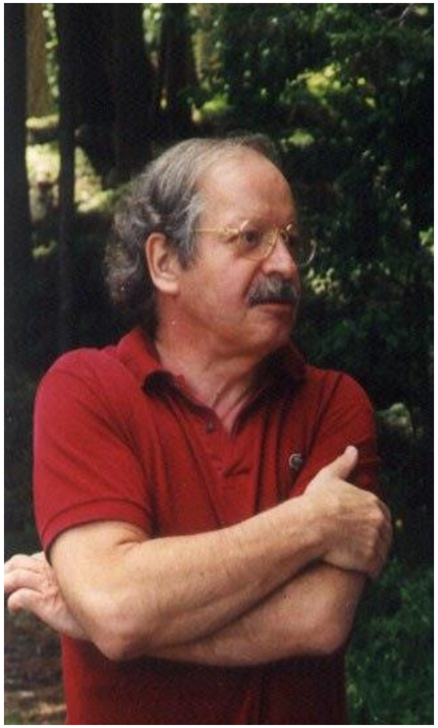
- In 2016, I gave a seminar to the physicists and geologists at U. of Perugia, after a series of devastating earthquakes in Umbria & in Amatrice and pointed out a perfect venue for such an underground laboratory in Rocca Paolina, Perugia. No one listened!

- It is not an exaggeration to say that had one of these devices were in place within a 100 Kilometers of the epicenter of the Amatrice EQ, neutron sensing would have given us a one week prior warning.

Some further back history

- The previous experimental work on this subject was done by a group from Politecnico di Torino led by Professor A. Carpinteri.
- The theoretical work was pioneered by Giuliano Preparata in a seminal paper in 1991 in Milano. The piezo-electric aspect –along with the notion of electro-strong interaction- was subsequently developed and applied to the advanced sensing of EQ's by Allan Widom, John Swain and myself in Boston and in Perugia.
- In my naivety I wrongly presumed that as both theoretical and experimental breakthroughs were essentially made in Italy, I shall see overwhelming support from my Italian colleagues and those in positions of decision making and over public resources.

Giuliano Preparata and Allan Widom
Two pioneers of piezo-nuclear reactions



All very clever people are heretics
but not all heretics are clever
(Emilio del Giudice)

Earthquakes (during my stay) in Lazio and Umbria

I witnessed a Fireman begging forgiveness from a young girl whom he was not in time to save…

We as physicists/geologists –so far- have ben limited to closing down buildings and have engineers/technicians evaluate the damage ….

But as physicists and geologists we can do more: much more

- When a student would ask me what is physics really about, my short answer has always been:

A good physicist is a problem solver

- To follow my own advice, let us look at what the problem about advanced sensing of an Earthquake might be.
- Let us focus on sensing through various emissions:
- Acoustic
- Electro-magnetic
- Neutrons

I have given it the acronym: AMEN

AMEN I

In an Earthquake (EQ), we have three types of emissions of waves:

(i) Acoustic: tremors at frequencies that animals are sensitive to lead them to begin running and hiding themselves prior to the arrival of an EQ; [*the Last to reach the surface]*

(ii) Electromagnetic: these are EM emissions we can detect accurately only through instruments: usually not our eyes or other senses; [*the Second to reach the surface*]

(iii) Neutrons: these are emissions produced in nuclear reactions (LENR) in the gut of the EQ.[*the First, perhaps weeks before, to reach the surface]*

AMEN II

Let me repeat what I wrote in the last slide

[all verified experimentally by the Torino group]:

- Acoustic waves reach us the last

  [perhaps a few hours to a day

  before the apex of the EQ]

- EM waves reach us before

  [perhaps 3 to 4 days earlier]

- Neutrons reach us first

  [perhaps a week or more

  ahead of the apex of the EQ]

AMEN III

- There are several interesting scientific facts about AMEN.
- First they are united in the sense that they are all waves (or oscillations).
- A difference lies in their frequency (inversely proportional to the time period of the wave): how many times a given wave repeats itself in a second.
- Acoustic is a pressure wave and has the lowest frequency (used e.g., in gravitational wave antennas) and thus has the highest time period.
- The EM wave has a much higher frequency.
- Nuclear reactions that produce neutrons have an enormously large frequency.
    - And they arrive at different times [la chiave]

AMEN IV

- Theoretically, that acoustic waves are produced, every physicist and geologist would agree.
- After all in an EQ, there are tremendous pressures created that would of course generate acoustic waves.

- The EM and neutron wave emissions are “new” in this field (but known elsewhere for a long time) that we need to understand and exploit.
- To discuss EM and neutrons we need to know what materials there are within the Earth that might generate them. This brings us to the subject of *Smart materials*.

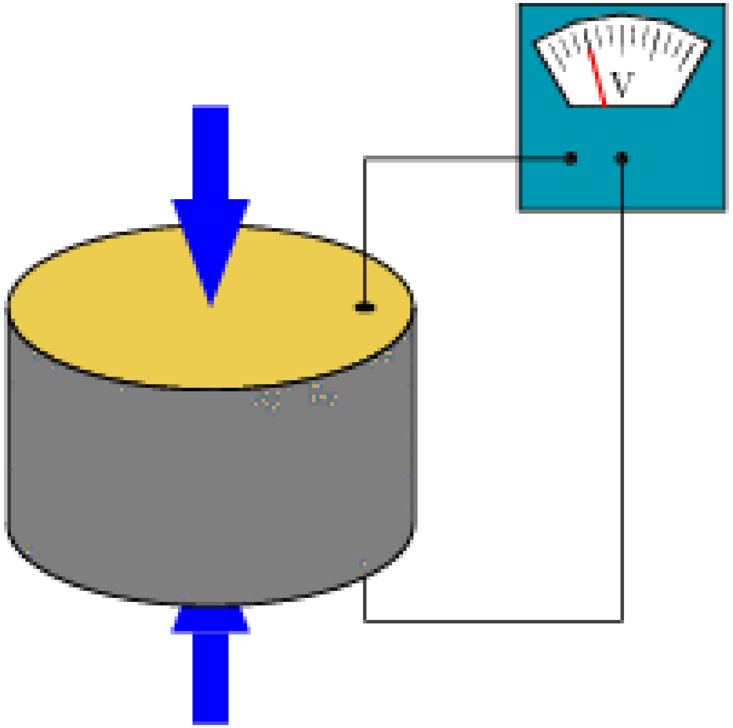
Smart Materials

Let me first discuss -in very simple terms- as to what is involved through some examples of what physicists call "smart" materials:

(i) Pyroelectrics
(ii) Piezo-electrics.
(iii) Piezo-magnetics

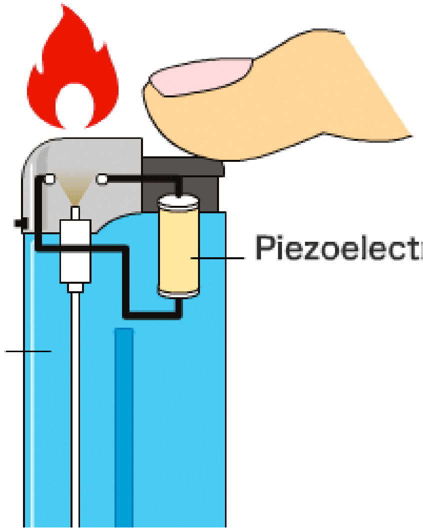
Rocks containing Quartz are piezo-electric & magnetite is piezo-magnetic: hence they are both very important for EQ's. [Marble is not!]

Piezoelectric Solids



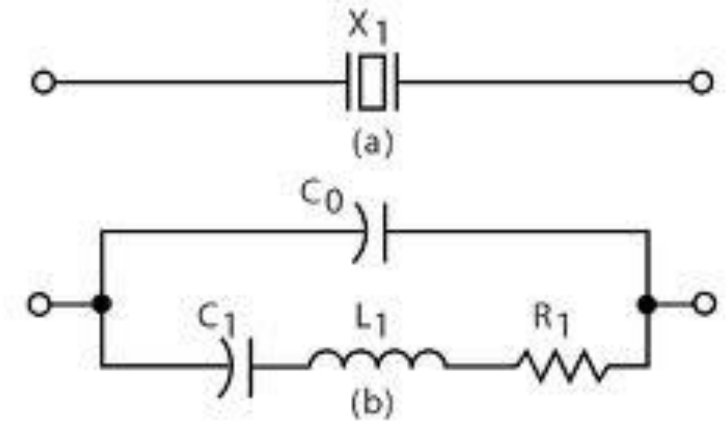
Strains in a crystal produce voltages across the crystal and vice versa.

Piezoelectric Solids II



The strain Produces a voltage.
The voltage produces a spark.

Piezoelectric Solids III
(Atomic Clocks are quartz oscillators)



In the equivalent circuit, C_0 represents the geometric capacitance of the upper arm. C_1 represents the quartz oscillator spring constant and L_1 represents the oscillator mass in the mechanical lower arm circuit element. The resistance R_1 represents the slight mechanical oscillator damping due to mechanical viscosity.

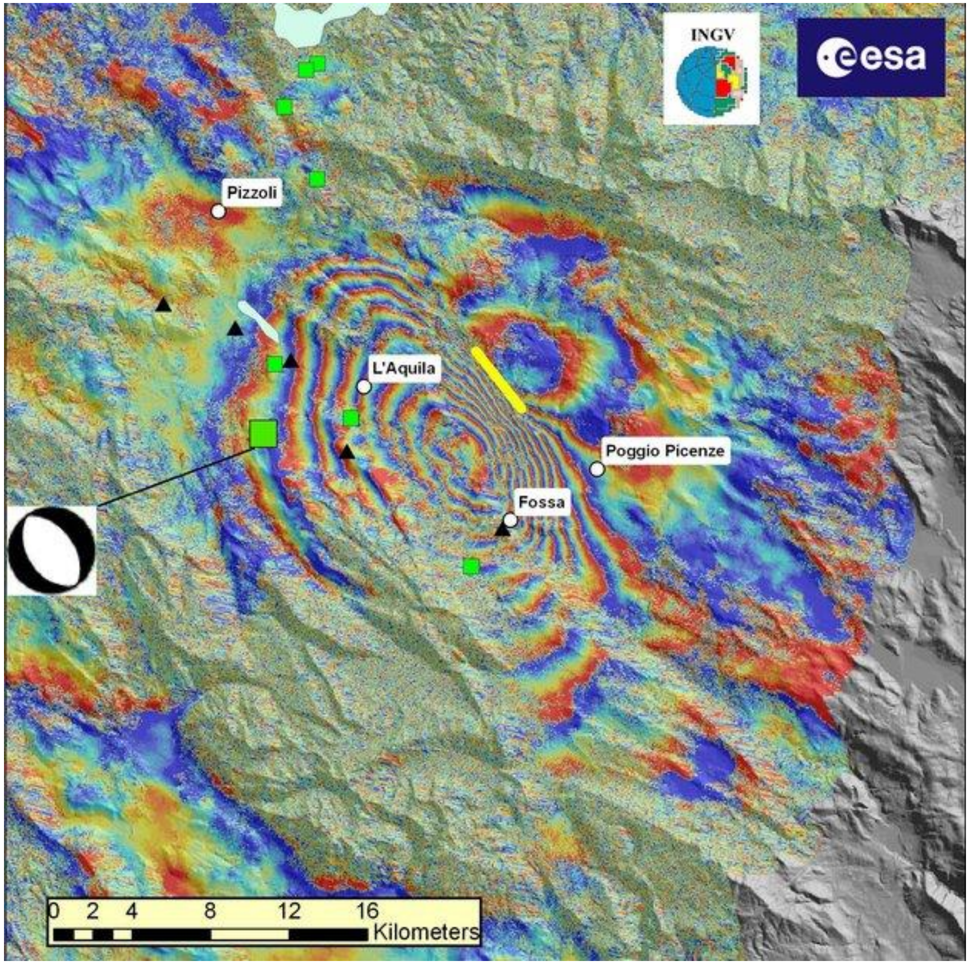
Earthquake Lights I

Japanese Earthquake Takes Place around the times of the visible light

Earthquake Lights II

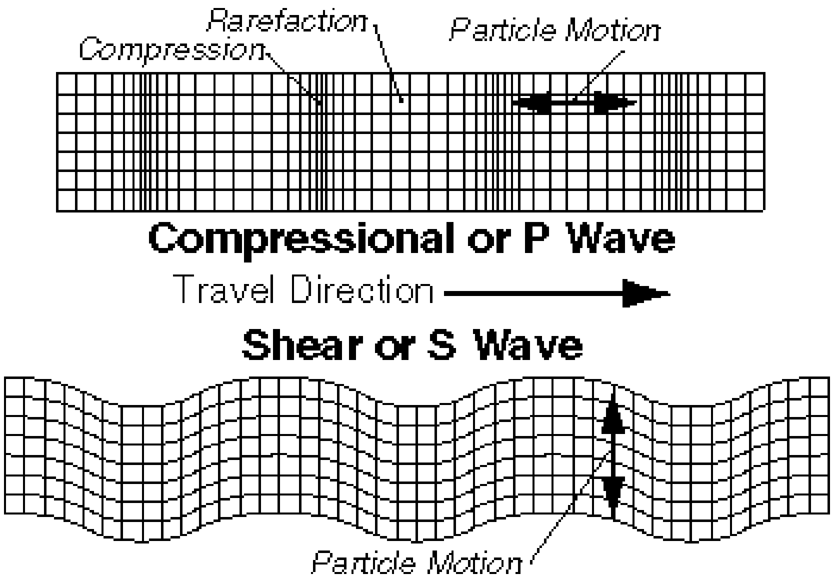
Day and Night Earthquake Lights

Earthquake Lights III



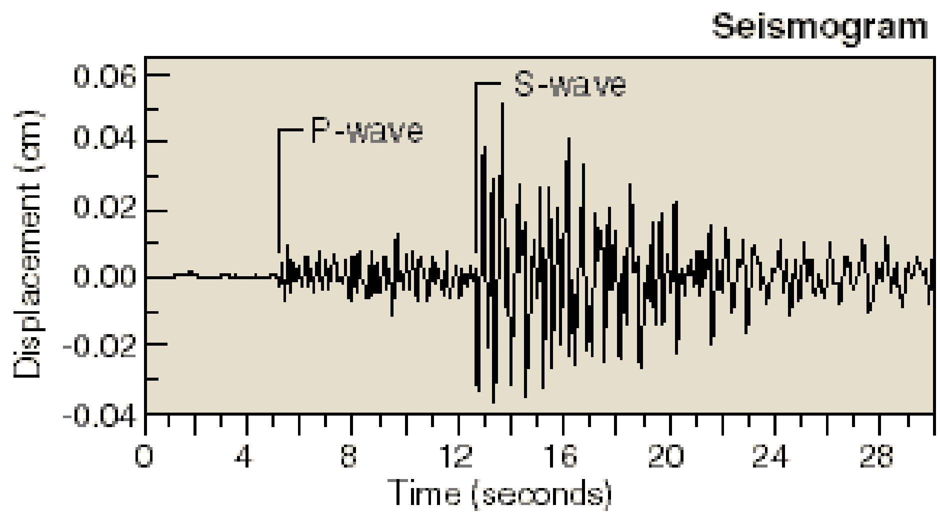
Satellite Pictures of the L'Aquila Region Around the Time of the 2009 Earthquake

Earthquake Sounds and Seismic Waves I

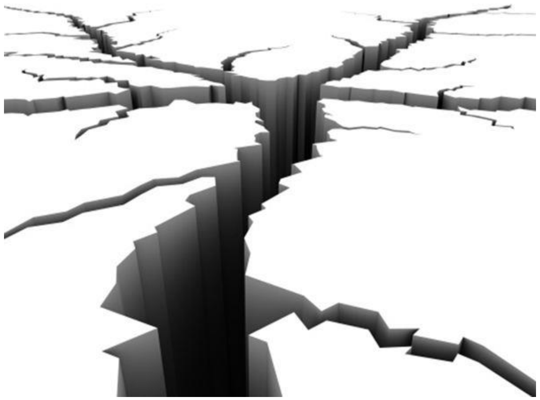


Seismic Waves can describe compression (P wave) strain or shear (S wave) strain.

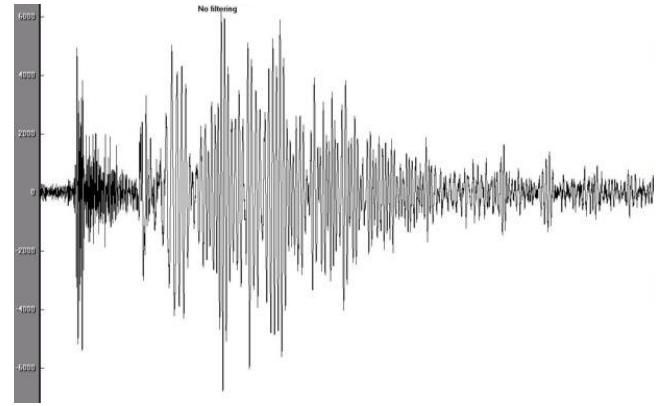
P waves travel faster than do S waves.



Earthquake Sounds and Seismic Waves II



Fracture produced sound.



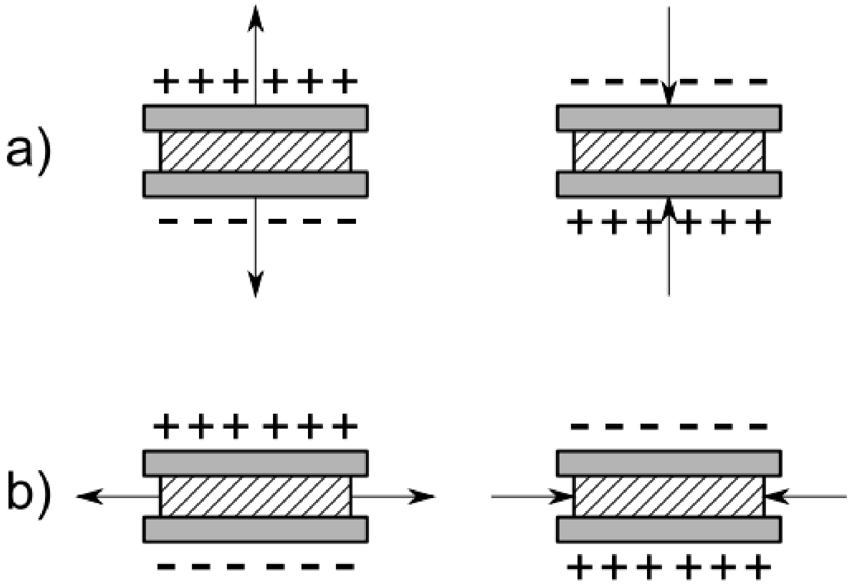
Fractured Granite Stone from a Mechanical Engineering Laboratory
Politecnico di Torino

Thermodynamics I

$$du = Tds - \mathbf{P} \cdot d\mathbf{E} - \boldsymbol{\sigma} : d\mathbf{w}$$

$$\beta_{i,jk} = \left(\frac{\partial P_i}{\partial w_{jk}} \right)_{\mathbf{E},s} = \left(\frac{\partial \sigma_{jk}}{\partial E_i} \right)_{\mathbf{w},s}$$

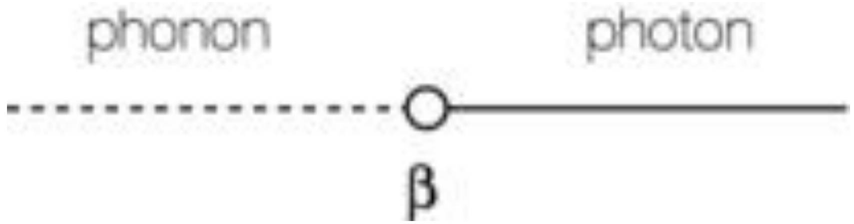
u = energy per unit volume
T = temperature
s = entropy per unit volume
$\mathbf{P}$ = polarization
$\mathbf{E}$ = electric field
$\boldsymbol{\sigma}$ = stress tensor
$\mathbf{w}$ = strain tensor
$\boldsymbol{\beta}$ = piezoelectric coefficient



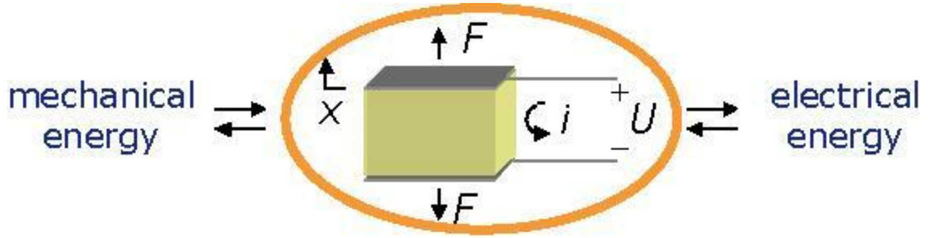
Thermodynamics II

$$\beta_{i,jk} = \left(\frac{\partial P_i}{\partial w_{jk}}\right)_{\mathbf{E},s} = \left(\frac{\partial \sigma_{jk}}{\partial E_i}\right)_{\mathbf{w},s}$$

Feynman Diagram



Engineering Diagram



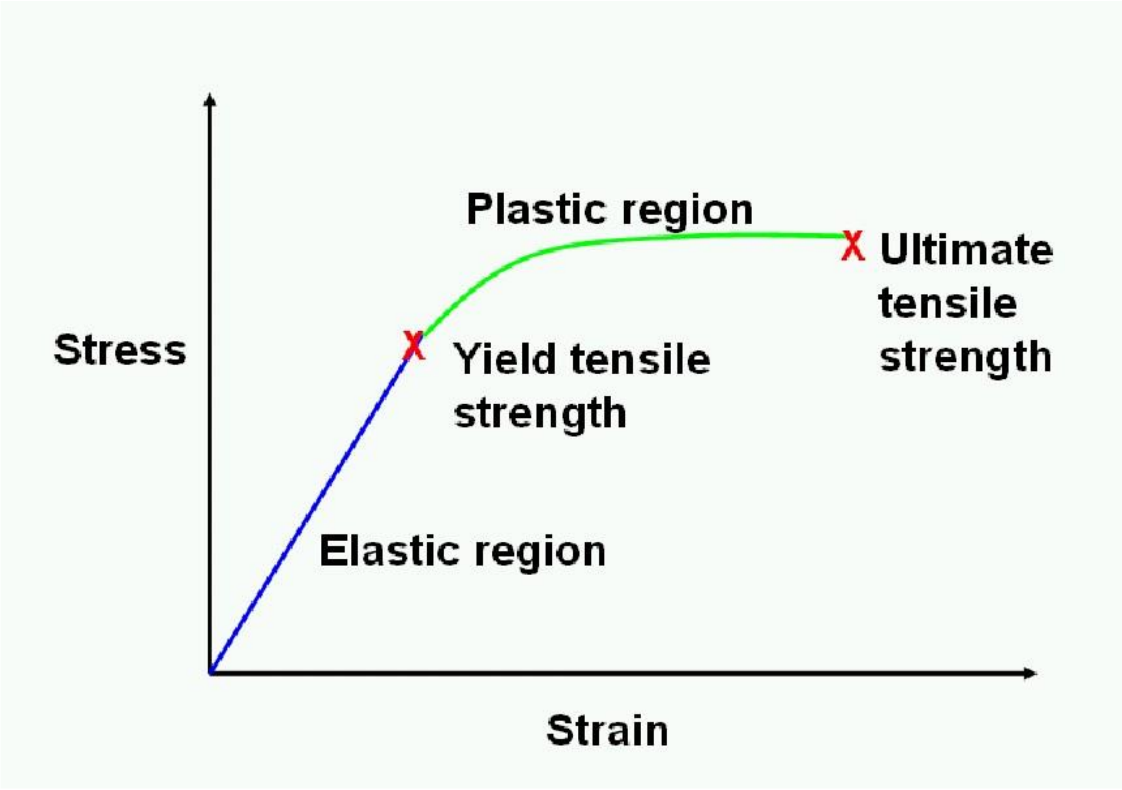
$$\text{Mechanical Power} = Fv = F\frac{dx}{dt}$$

$$\text{Electrical Power} = Ui = U\frac{dq}{dt}$$

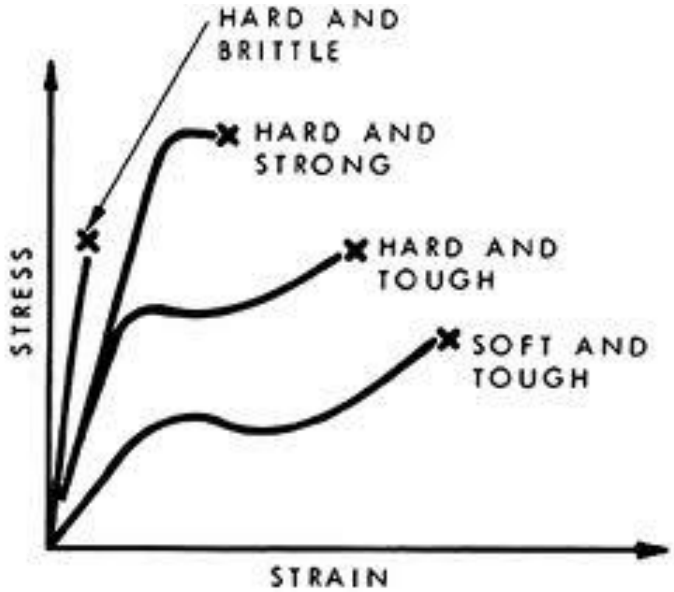
Tensile Strength I

σ_F = tensile strength of a material beyond which the material fractures
If the matter is held together by Coulombs law, then in order of magnitude the electric fields E_F associated with fracture is determined.

$$\sigma_F = \frac{E_F^{\ 2}}{4\pi}$$

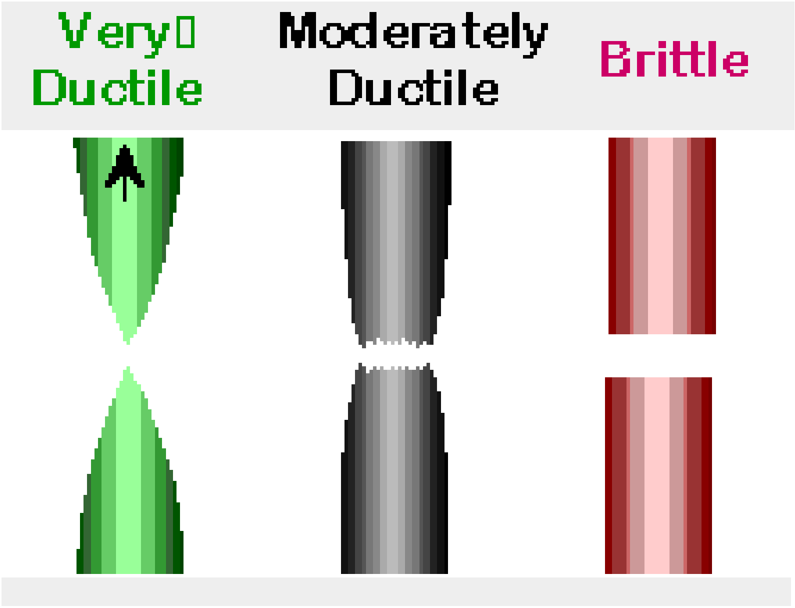


Tensile Strength II



Brittle Fracture
Tensile Stress

$$\sigma_F = \frac{E_F^{\ 2}}{4\pi}$$

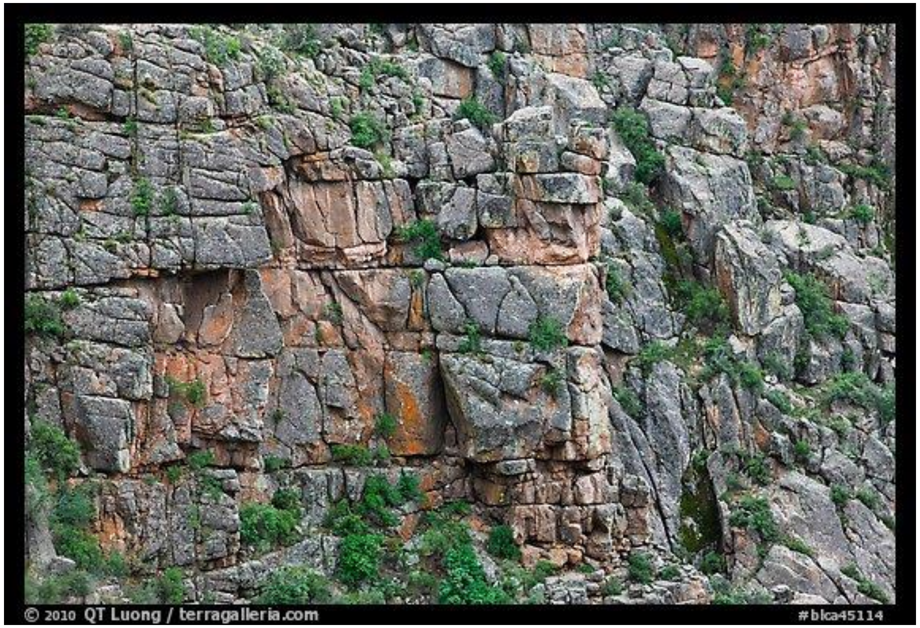


Micro-Cracks and Brittle Fracture I

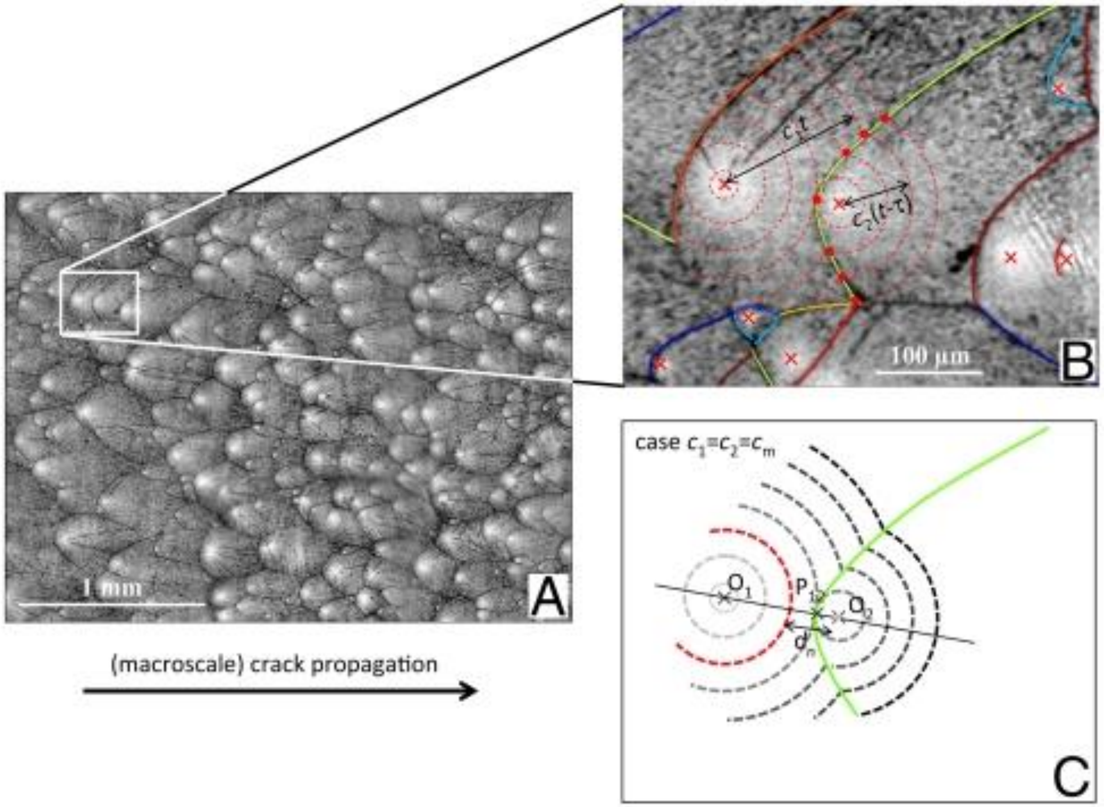
Understanding fast macro-scale fracture from micro-crack post mortem patterns

C. Guerra, J. Scheibert, D. Bonamy, D. Dalmas

Proc Natl Acad Sci USA **109,** 190 (2012)

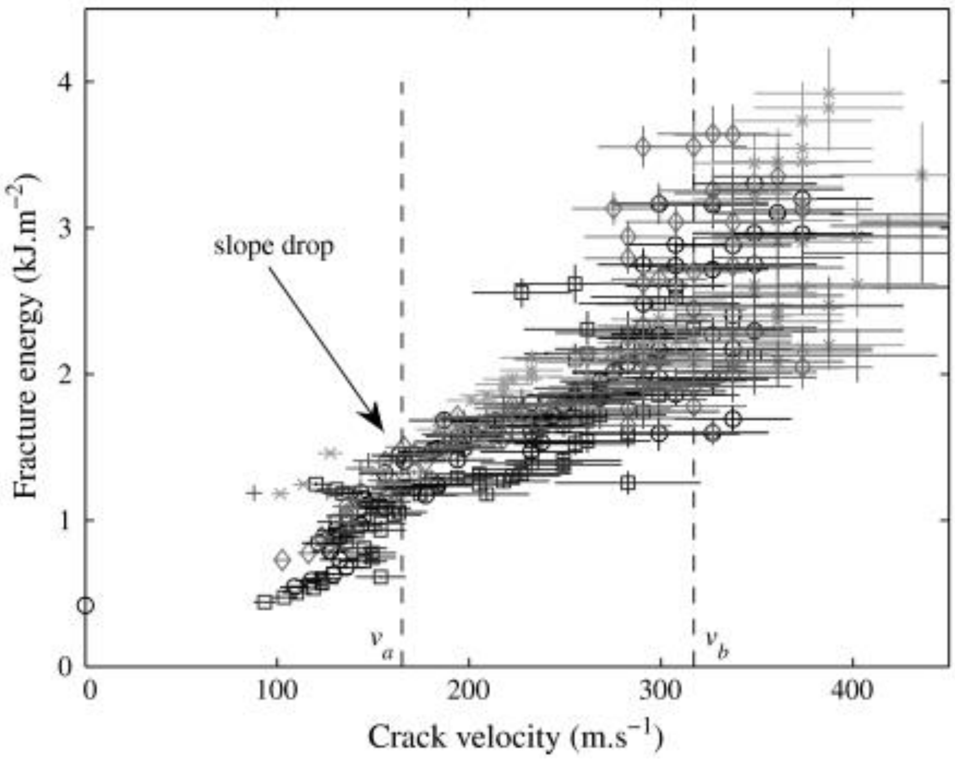


Micro-Cracks and Brittle Fracture II



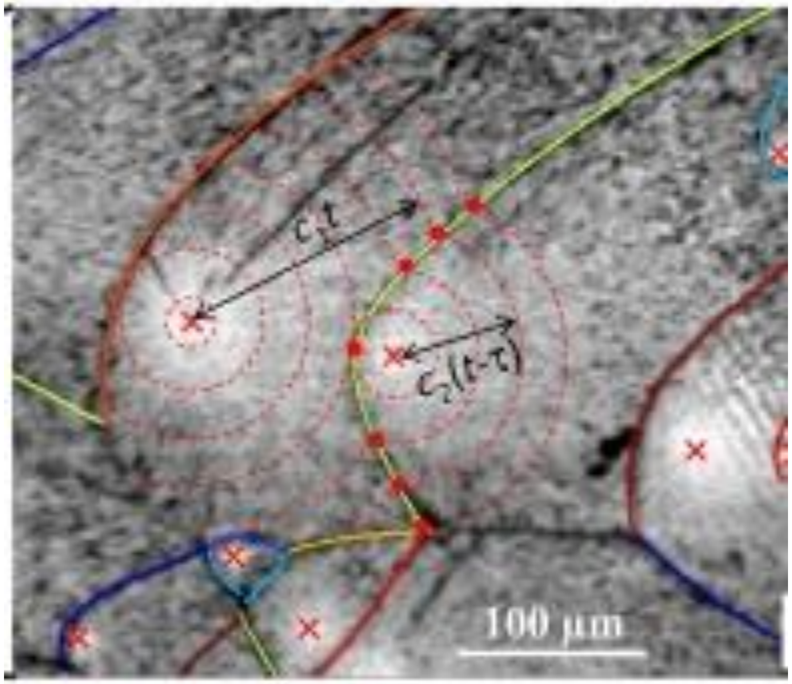
Micro Cracks on a Length Scale of 100 microns

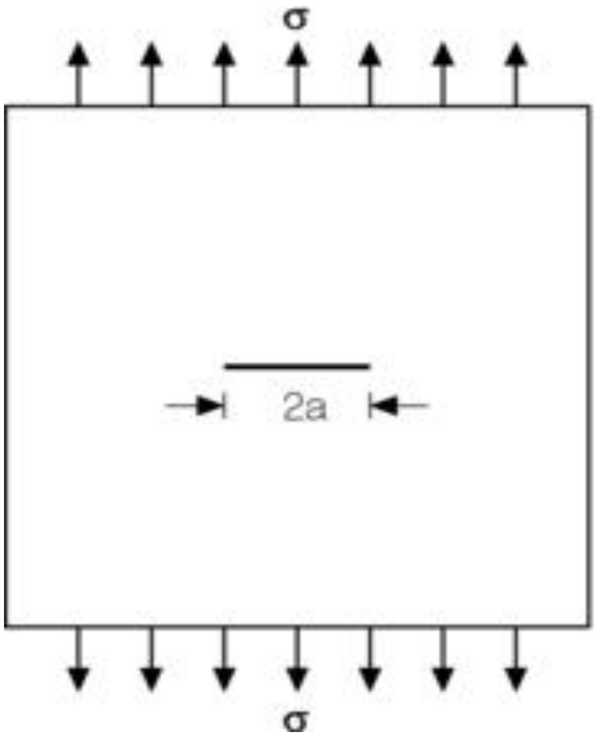
Micro-Cracks and Brittle Fracture III



Micro Crack Energy per Unit Area is Related to The speed of Micro Crack Propagation Speed

Micro-Cracks and Brittle Fracture IV





Physical Micro Crack

Cartoon Drawing

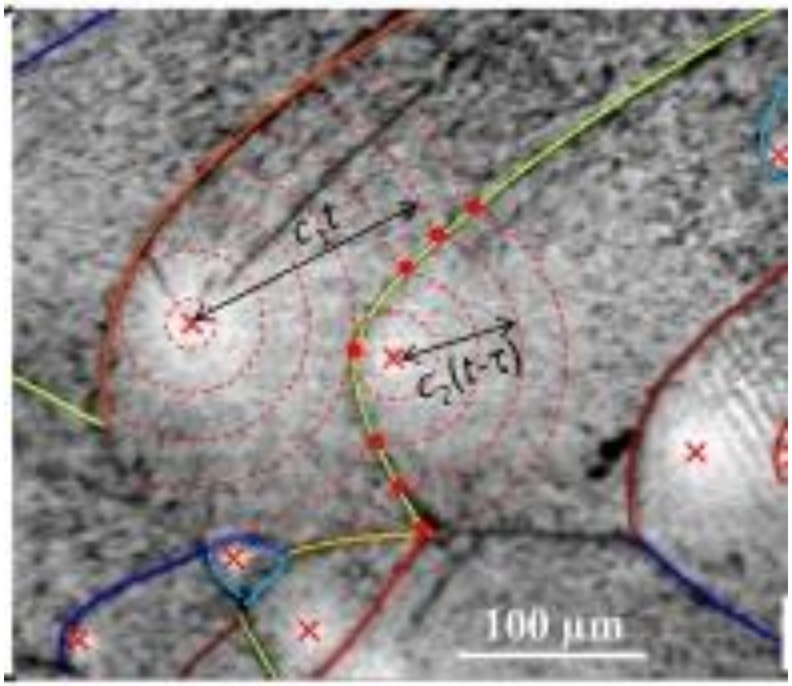
Micro-Cracks and Brittle Fracture V

Y = Young's Modulus
ν = Poisson Ratio
γ_s = surface tension
a = crack width
σ_F = tensile fracture stress

$$u = \gamma_s a = Min_b \left(4\gamma_s b - \pi b^2 \left[\frac{(1-\nu^2)\sigma_F{}^2}{Y} \right] \right)$$

$$a = \frac{2\gamma_s}{\pi} \left(\frac{Y}{(1-\nu^2)\sigma_F{}^2} \right)$$

$$\sigma_F = \sqrt{\frac{2\gamma_s Y}{\pi(1-\nu^2)a}}$$



Neutron Production Within Micro Cracks I: (lavoro sperimentale da Politecnico di Torino)

Indian Academy of Sciences Sadhana **37.** 59 (2012).

Electromagnetic and neutron emissions from brittle rocks failure: Experimental evidence and geological implications

A CARPINTERI[1], G LACIDOGNA[1], O BORLA[1,2],
A MANUELLO[1] and G NICCOLINI[3]

[1]Politecnico di Torino, Department of Structural Engineering and Geotechnics, Corso Duca degli Abruzzi 24 – 10129 Torino, Italy

[2]National Institute of Nuclear Physics, INFN Via Pietro Giuria 1 – 10125 Torino, Italy

[3]National Research Institute of Metrology, INRIM Strada delle Cacce 91 –10135 Torino, Italy

Neutron Production Within Micro Cracks II: [lavoro teorico fatto in Perugia e Boston]

J. Phys. G: Nucl. Part. Phys. **40,** 015006 (2013).

Neutron production from the fracture of piezoelectric rocks

A Widom[1], J Swain[1] and Y N Srivastava[2]

[1] Physics Department, Northeastern University, Boston MA, USA
[2] Department of Physics, University of Perugia, Perugia, Italy

Neutron Production Within Micro Cracks III:

$$\dot{\mathbf{p}} = e\mathbf{E}$$

$$\overline{p^2} = \frac{e^2 E^2}{\omega_0{}^2}$$

$$Mc^2 = m^2c^4 + c^2\overline{p^2}$$

$$M = m\sqrt{1 + \left(\frac{E^2}{E_0{}^2}\right)}$$

$$E_0 = \left(\frac{mc^2}{|e|}\right)\frac{\omega_0}{c} = \frac{(mc^2/|e|)}{\lambda}$$

p = electron momentum
e = **-**|*e*| = electron charge
E = field
m = vacuum electron mass
M = Electron renormalized mass within the micro-crack
ω_0 = resonant field frequency
E_0 = threshold electric field

Forces on an Electron in a Micro-Crack

Neutron Production Within Micro Cracks IV:

$$M = m\sqrt{1 + \left(\frac{4\pi\sigma_F}{E_0{}^2}\right)}$$

$$N = m\sqrt{1 + \left(\frac{E}{E_0}\right)^2}$$

$$E_0 = \left(\frac{mc^2}{|e|}\right)\frac{\omega_0}{c}$$

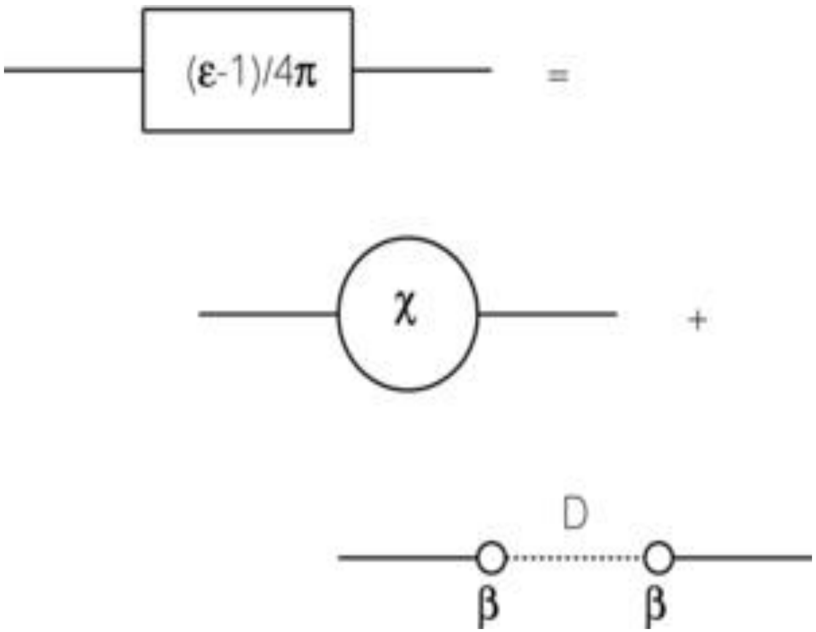
$$\sigma_F \sim 10^8 \ \frac{\text{erg}}{\text{cm}}$$

$$E \sim 10^5 \ \text{Gauss}$$

$$E_0 \sim 10^3 \ \text{Gauss}$$

Piezoelectric Sound Coupling to Electromagnetic Fields determines the frequency ω_0 .

The electron mass renormalization is very large. $(M/m) \sim 10^2$.



Deduction

Granite is a Piezoelectric Solid

Earthquake Lights and Sound Depend on Piezoelectricity

Laboratory Rock Fracturing is a Small Scale Earthquake

Hydraulic Fracturing Depends on Granite Rock Crushing

Micro-Cracks are Formed During Brittle Fracture

There is Neutron Production and Microwave Radiation

Magnetic Rocks

- The analysis of magnettite or magnetic rocks in general is a bit more complex but it has been completed:
- **Meccanica, Volume 50 (2015) 1205**
  - ***Photo-disintegration of the iron nucleus in fractured magnetite rocks with magnetostriction***
- A. Widom, J. Swain , Y. N. Srivastava
- Incidentally, there are huge unexplored applications of Electro Strong processes towards

(i) the unsolved problem of nuclear waste and

(ii) production of radio-isotopes for medicine.

Experimental Work: Politecnico I

- Several years of their work on the subject can be found in a book
  - **Acoustic, Electromagnetic, Neutron Emissions from Fracture and Earthquakes**
  - **Editors: A. Carpinteri, G. Lacidogna, Amedeo Manuello**
  - **Springer (2015)**
- In the following I show you one of their continuous monitoring of AMEN signals for three years in an underground laboratory 100 meters deep in order to reduce cosmic neutron and man made EM and acoustic signals.
- In 3 years they were able to study 342 EQ over M=1.8 scale in an area of 100 Km from their device.
- Shown data are from a M=3.2 EQ on April 11, 2015 that occurred near Torino.
- Data were obtained after a comprehensive statistical analysis and signal processing of AMEN (N. B. This can now be done quickly & more comprehensively by AI & machine learning in 2024)

Experimental Work: Politecnico II

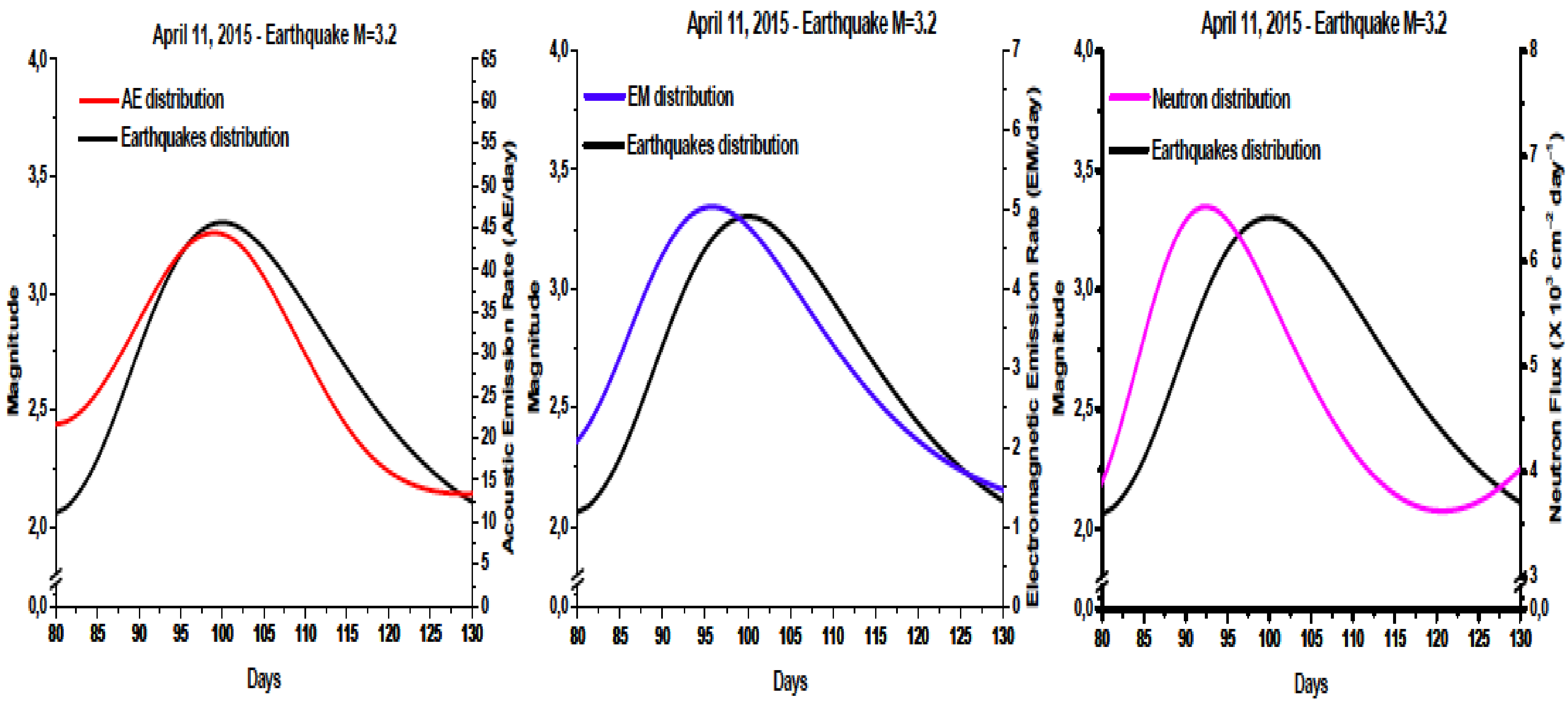


Fig. 1a-c: Anticipated and differently shifted Gaussian distributions of AE/EME/NE events for the earthquake of April, 11 2015

Near Future Prospects I

It is my hope –not just a dream- that very soon, with a concentrated program about AMEN (acoustic; electro-magnetic and neutron emissions), we can predict with fair certainty the arrival of an Earthquake and thus help the public cope with overwhelming disasters caused by an Earthquake.

That public has supported the expensive research that we have enjoyed doing for decades at CERN, at Frascati and elsewhere.

It is time that we scientists did a pay back to the society.

Near Future Prospects II

Over the centuries, science has been able to

(i) Eradicate diseases that were considered incurable;

(ii) Found new ways to grow and conserve food to support 7+ billion of us on the Earth.

(iii) The above has been possible through three major routes:

- understanding and analyzing the physics of the problem;
- its technical application to a given phenomenon;
- obtaining the resources and using it efficiently for the public good.

Near Future Prospects III

- Umbria is frought with earthquakes. And in Perugia, we have the physics department united with geology. What more can one ask to deal with a problem that needs expertise from both?
- We can build a very low cost, small “underground” laboratory to provide a good shield against cosmics: Rocca Paolina. It can become a leader of a future Italian national grid of such centers.
- We have the best in high energy, nuclear and condensed matter physics; we have experts in gravitational wave antenna/detection…..
- I shall let the Geologists speak for themselves about their interest and participation

Near Future Prospects IV

- I first wrote about it in 2012 to Maiani: the Chief Scientist in-charge of Dipartimento della Protezione Civile in Italia.
- No one listened in 2012.
- In 2016, we had 3 advanced wave sensing devices available:(i)acoustic;(ii) electromagnetic & (iii) neutrons.
- In 2024, we have now extended it to a 6 prong sensing method. The extra 3 are: (iv) Earthquake lights; (v) over the horizon sensing of electric field & (vi) monitoring of it all -in real time- by passive AI after an inclusive machine training.
- Would someone pay attention now?

Perfect EQ Underground Lab to shield against cosmics:
Rocca Paolina, Perugia

Thank you for your attention

Supplementary Slides

[With notes for the curious]

Neutron production from fracturing rocks [WSS]: II

Examples of piezoelectrics: Bone, hair, quartz

$\mathcal{E}$	Electric field
w	Strain tensor
β	Piezoelectric constant

$$\mathcal{H}_{int} = -\int \beta_{ijk} E_i w_{jk} d^3\mathbf{r}$$

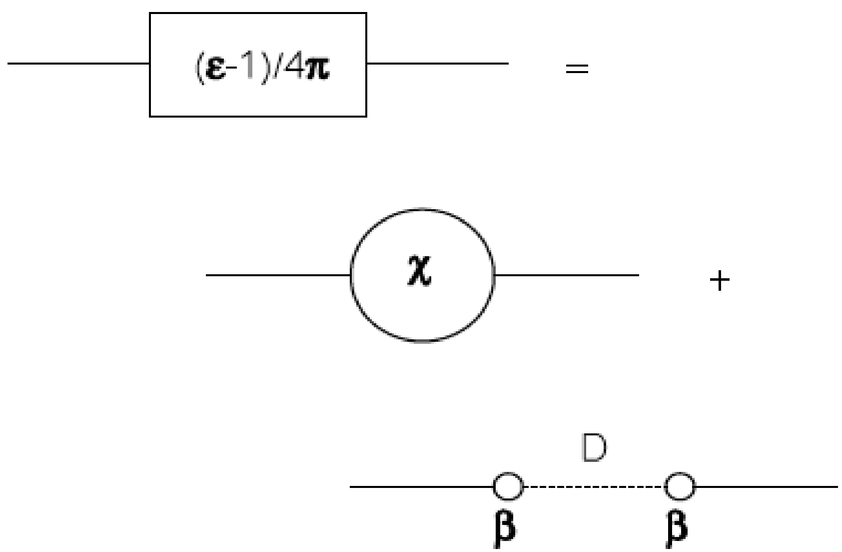
Neutron Production from the Fracture of Piezoelectric Rocks
[YS, A. Widom & J Swain: J. Phys. G: Nucl. Part. Phys. 40 (2013) 015006]

Neutron production from fracturing rocks [WSS]: III

$$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P},$$

$$\epsilon_{ij}(\zeta) = \delta_{ij} + 4\pi\tilde{\chi}_{ij}(\zeta),$$

$$\tilde{\chi}_{ij}(\zeta) = \chi_{ij}(\zeta) + \beta_{i,lk} D_{lknm}(\zeta)\beta_{j,nm}$$



- D_{ijkl} is the phonon propagator
- ε_{ij} is the dielectric response tensor; it appears in the polarization part of the photon propagator
- The Feynman diagram shows how the photon propagator is affected by β_{ijk}
- The above makes us understand why mechanical acoustic frequencies occur in the electrical response of piezoelectric materials

Neutron production from fracturing rocks [WSS]: IV

Numerical Estimates:

(i) v_s velocity of sound vs. c is ~ 10^{-5} hence ($\omega_{phonon}/\omega_{photon}$) ~ 10^{-5} for similar sized cavities

(ii) The mean electric field E ~ 10^{5} Gauss

(iii) The frequency of a sound wave is in the microwave range $\Omega \sim 3 \times 10^{10}$/sec.

(iv) The mean electron energy on the surface of a micro-crack under stress σ_F is about W ~ 15 MeV

(v) The production rate of neutrons for the above is

$$\Gamma(e^- + p^+ \to n + \nu_e) \sim 0.6 \text{ Hz} \qquad \varpi_2 \sim 10^{15} \frac{\text{Hz}}{\text{cm}^2} .$$

Magnetite I

- There are piezo-magnetic materials such as magnetite that we investigated. We were convinced of the phenomenon once Allan and I went to Carpinteri's lab where in front of us rocks were fractured.

- Evidence of neutrons along the line of fracture was evident (through various means of neutron detection: bubble chamber and others).

- On the surface of a magnetitie that had been fractured, we could see with our eyes white specs of Aluminum that had ben fractured.

- Iron being split into 2 Aluminum. Other new elements were produced: true evidence of fission.

- Stunning results.

Magnetite II

- As theorists, John Swain, Allan and I had a difficult problem. To break Iron, you need over 45 MeV of energy.
- What was the source of such a large energy and in amounts to cause a sufficent number of new materials?
- For the ignition of the weak Widom process on metallic hydrides, we werre contemplating just a few MeV electrons.
- This was the object of the Perugia experiment that never got completed

An Allegory I

Legend: has it that Asimov was discussing the following poem by Emerson with his friend Campbell:

"*If the stars should appear one night*
in a thousand years,
how would men believe and adore,
and preserve for many generations
the remembrance of the city of God!"

Ralph Waldo Emerson

Campbell said: "I think men will go mad"

Thus, was born Asimov's greatest story NIGHTFALL

An Allegory II

In Nightfall, Asimov invents a planet Lagash with six Suns: so there is always sunlight; never complete darkness

[and also the inhabitants never see the other stars]

Except! every 2059 years, when all the six Suns are aligned, there is perfect darkness.

All humanity goes mad and in efforts to procure light, they burn and destroy the whole planet.

They of course did not know the Law of Universal Gravitation and would be cured of this cyclic malady only after this knowledge.

An Allegory III

Another American, Mark Twain in his 1989 satirical book

" A Connecticut Yankee in King Arthur's Court"

recounts the story of an event befalling his hero (Hank), who is awaiting execution in prison. Sheer luck, that his date of execution in the year 528 a.d. coincides with that of a historical solar eclipse that Hank had been familiar with –in his other life. From prison, Hank sends Clarence –the messenger boy- to inform the King that he will blot out the Sun if he is executed….

Yet, another exquisite example of scientific knowledge overpowering ignorance.