MULTI-PARAMETRIC INVESTIGATION OF PRE-SEISMIC ORIGIN PHENOMENA THROUGH THE USE OF RDF TECHNOLOGY (RADIO DIRECTION FINDING) AND THE MONITORING OF RADON GAS STREAM (RN_{222})

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ABSTRACT

Through this work the authors want to establish the existence of a possible correlation between the increase in the Radon gas stream (Rn_{222}) (JP Toutain et al., 1999) and the detection of radio-recorded anomalies in crustal level in the Apennines in central Italy and seismic activity recorded in the same area where the numerous faults and micro-faults, also capable of generating potentially destructive earthquakes, in the last 2 months (August-September 2019) are dynamically active. The study is focused on the observation of transient variations between the gas flow Radon (Rn_{222}), (G. Giuliani et al. 2012), as measured by gamma of the Permanente Foundation G. Giuliani, sensors and the measurement of the electromagnetic field "in continuous "and broadband by the Radio Emissions Project, scientific research project, founded in 2007 by Gabriele Cataldi and Daniele Cataldi for the study of Electromagnetic Seismic Precursors (ESPs).

Keywords: RDF systems, earthquake prevision, Gas Radon, Central Italy.

INTRODUCTION

It was 1890 when the British geologist John Milne, inventor of the eponymous horizontal seismograph, a professor at the Imperial College of Engineering in Tokyo and founder of the Seismological Society of Japan (SSJ), in his work entitled "Earthquakes in connection with electric and magnetic phenomena "(J. Milne, 1890), described some electrical phenomena magnetic and related to seismic activity. It was the first scientific publication ever in which they were described a series of electromagnetic phenomena, about one hundred years later, the international scientific community renamed as "Electromagnetic Seismic Precursors" or ESPs.

This small but necessary introduction represents the first milestone in a long and complex path that scientists have built over the decades and that, to date, has not yet been completed. Currently, the lack of a global coordination center able to establish a standard methodological approach through which to address research on Electromagnetic Seismic Precursors (ESPs), has inevitably produced a fragmentation of resources, the objectives to be achieved and a consequent lack of homogeneity of the methodologies research used and the results obtained.

In 2007, Gabriele Cataldi and Daniel Cataldi founded a scientific research project (Radio Emissions Project) dedicated to monitoring and study of Electromagnetic Seismic Precursors (ESPs) and, in the course of a few years, they have developed an innovative electromagnetic tracking method (G. Cataldi, 2019), who was able to provide valuable data on the pre-seismic electromagnetic anomalies, meaning by this term also electromagnetic phenomena of solar origin and those of geomagnetic nature (G. Cataldi et al., 2013-2019; D. Cataldi et al., 2014-2019; V. Straser, 2011-2012; Straser V. et al., 2014-2019).

The Rn_{222} (discovered since 1899), is the only gaseous element decay product of dell'Uranio238 family. Gas noble, unstable, radioactive, odorless, colorless, tasteless, with half-life of 3.824 days, has an atomic weight = 222, atomic number = 86, density = 9,73kg/m3, a melting point = 202°K, the boiling point = 211.3°K, a critical point = 103.85°C/6,28Mpa, enthalpy of vaporization = 16,4kJ/mol, electronegativity = 2.2, conductivity = 0,00364W ends/(m · K), energy of first ionization = 1037kJ/mol, covalent radius = 145pm, within van der Waals = 220pm and an electronic configuration = [Xe] 4f145d106s26p6. It is the

product of immediate Radio226 decay.
Gioacchino Giampaolo Giuliani (Permanent Foundation G. Giuliani - NPO) monitors the gas flow Rn_{222} since 2002 by using automated devices (gamma detectors named PM-4 and PM-2) designed to continuously monitor the vertical Rn_{222} coming up from the subsoil, two to transport and diffusion mechanisms. The range detectors Consists in a plastic scintillator, NE110 or NE102 with a volume of 800 or 600 cm3; on opposite walls of the scintillator, are applied four or two photomultipliers (Photonis xp3462b) with a gain of ≈ 2 · 106. Rn_{222} atoms coming from the subsoil penetrated the box lead and decay, producing, as secondary products, Pb214 and Bi214 Which, in turn, decay by emitting photons range.
The electromagnetic monitoring "continuously" Broadband and gas flow monitoring Rn_{222} are two search methods that have resulted in potentially relevant data from a predictive profile than conventional research methods, and the authors believe that to develop a new seismic prediction method that is able to disengage from seismometric data is necessary to realize an innovative seismic prediction method can provide measurements of the phenomena that precede the seismic event; phenomena intimately connected to the seismogenic mechanism, and the electromagnetic monitoring joined to the Rn_{222} gas monitoring can certainly be two good candidates to realize a method of seismic prediction projected into the future.
This paper will present the first results of the multi-parametric monitoring method (electro-magnetic-chemical), first in Italy and Europe, which has been able to identify with a notice of 24 hours the region of Central Italy in that on October 12, 2019 at 12:29:55 (UTC) has been a ML3.1 earthquake.

Methods and Data

To carry out this study, the authors analyzed the concentration of Radon gas (Rn_{222}) and monitored the electromagnetic environmental activities through three multi-parametric monitoring stations located between Tuscany, Abruzzo and Lazio:

- First station: radon Station (Rn_{222}) located in Ripa-Fagnano (Lat. + 42.265663N, Long. + 13.583765E). It is equipped with a gamma detector, capable of recording variations of the gas hourly flow Rn_{222} in a radius of action for small and medium grade Richter events, amounting to 0-50 km. Always a sensor for monitoring the electromagnetic "continuous" broadband, implemented with RDF technology (Radio Direction Finding) in Ripa Fagnano-station has been installed. The technology developed by the Radio Emissions Project, for the monitoring of the pre-seismic radio emissions, it is able to identify the target arrival direction (azimuth) of the electromagnetic signals picked up between the band SELF (Super-Extremely-Low-Frequency: 0 <f <3Hz) and the first portion of the band LF (Low-Frequency; 30 <f≤300kHz) reaching 96kHz (total bandwidth ≈ 96kHz; 0 <f≤96 kHz) with a resolution <1Hz, an analog-to-digital conversion 24-bit and a digital sampling to 192kHz. The multi-parametric station is positioned in an area of high seismic risk (as visible in Fig. 1).

- Second Station: radon Station (Rn_{222}) located in pairs (AQ) (Lat. + 42.367509N, Long. + 13.342659E). It is equipped with a gamma detector, capable of recording the gas hourly flow variation Rn_{222} in a range for small and medium Richter scale events, pariah 0-50 km.

- Third Station: Pontedera RDF station (PI) (Lat. + 43.672479N, Long. 10.640259E +) (Fig. 7); Located 286 km away (NW) from the two radon stations considered in this study and located in the province of L'Aquila (Ripa Fagnano-: Lat. + 42.265663N, Long. + 13.583765E; Coppito: Lat. + 42.367509N, Long. + 13.342659E). The Pontedera RDF station (PI) has the same technical characteristics of the RDF station Ripa-Fagnano (AQ).

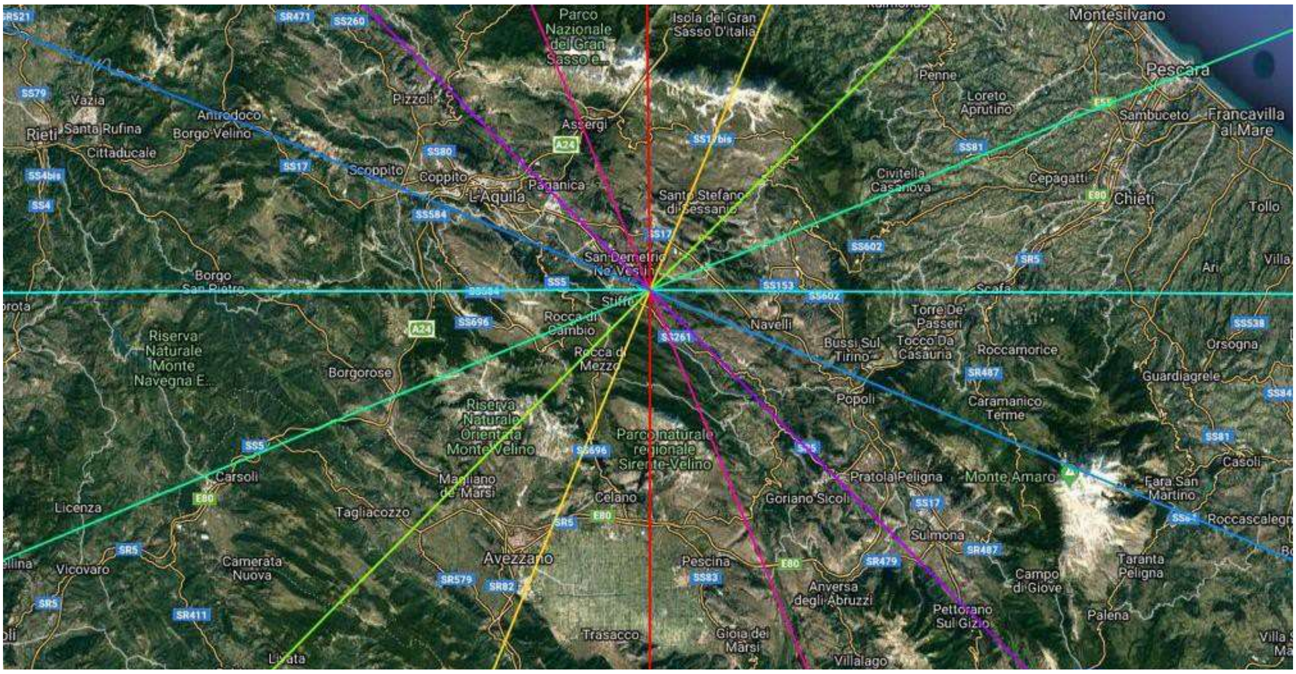

Fig. 1 – Colorimetric map of RDF system located at the monitoring station of Rapa-Fagnano (AQ). The In geographical map above the azimuth references RDF system they were included (Radio Direction Finding) located at the electromagnetic monitoring station "continuously" broadband installed at Ripa-Fagnano (AQ): The colors indicate the axial azimuth / spatial origin of the electromagnetic signals detected by the RDF station. Credits: Radio Emissions Project.

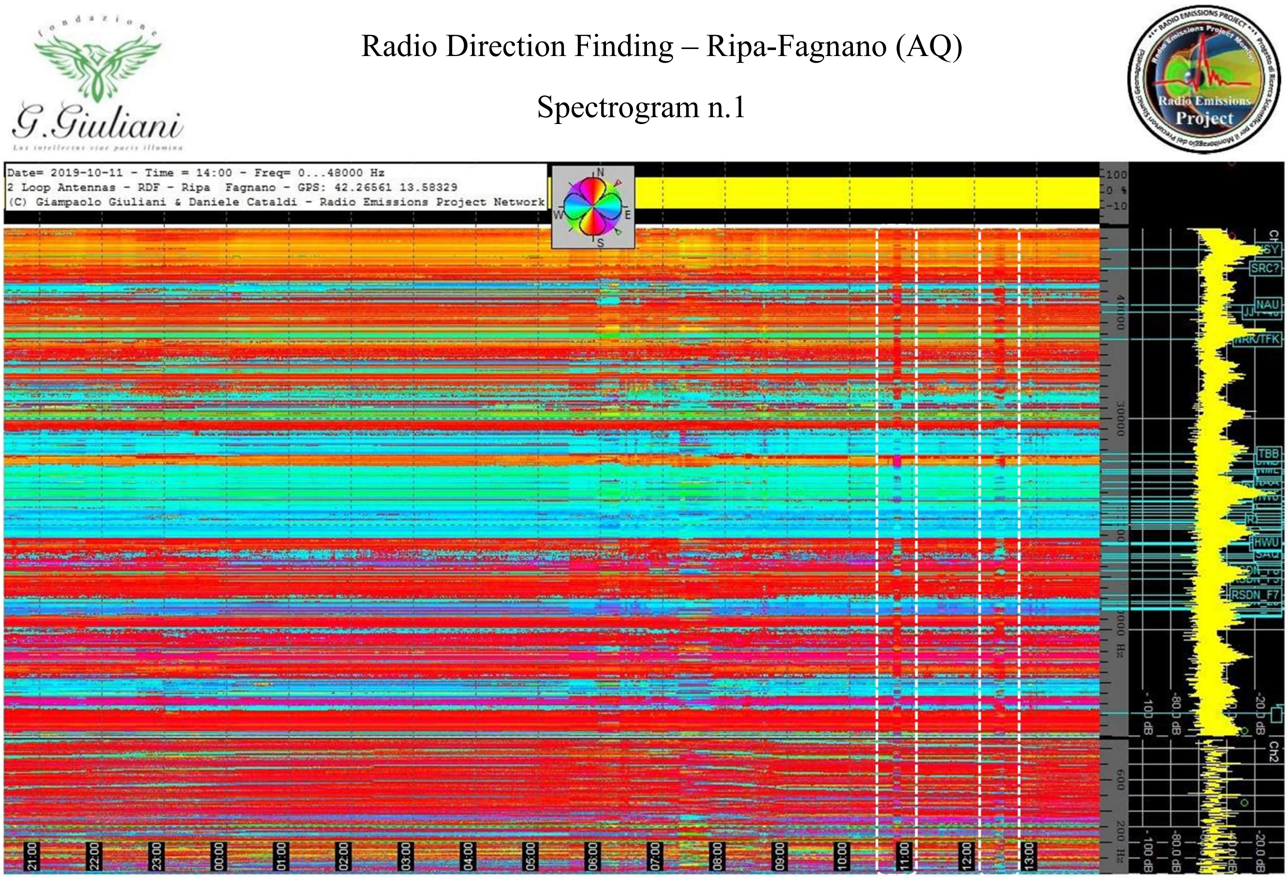

***Fig. 2 – Electromagnetic anomalies recorded** by the RDF station Ripa-Fagnano. At the top is visible the recorded dynamic spectrogram between 10 and October 11, 2019 in which are visible increase of peaks (within the areas surrounded by the white dotted line) recorded between 10:45 and 24:25 UTC UTC with azimuth 90° -180° (NS) and 330 ° -150 ° (NNE - SSW) and sull'azimut 290° -110° (approximately EW) (For 25 and 24 hours before the earthquake). Credits: Radio Emissions Project; Permanent Foundation G. Giuliani.*

The RDF station Ripa-Fagnano is in operation 24 hours on 24 and 7 days out of 7 and is active since October 6, 2019. The electromagnetic amplification system is located only 4 meters away from the sensor range for the measurement of Rn_{222} gas. The experimentation of the multi-parametric "RDF-Rn_{222}" system aims, for the first time, at least on the Italian territory, to highlight any changes in the environmental electromagnetic field that can find correlations with the thermodynamic energy variations detected through variations in the concentration of Rn_{222} to behind the faults. More in detail, it is placed in relation to each other the characteristics of the environmental electromagnetic background and concentration variations on the hourly moving average Rn_{222}. It is conceivable that the crustal movements favor the propagation velocity of the gas Rn_{222} through the earth's crust and the surface; as well as the increase of the tectonic stress, also responsible of crustal subsidence, may generate radiofrequency and piezomagnetico piezoelectric effect.

According to the authors, the detection of a correlation between the local seismic activity, the pre-seismic increments Rn_{222} gas and the detection of pre-seismic radio emissions (having consistent with azimuth seismic events themselves) is confirmed precisely through the theory of plate tectonics on a small scale (not more than 1000km).

The analysis of the data obtained from the two monitoring systems (RDF and Rn_{222}) showed that the RDF station Ripa-Fagnano (AQ) 11 October 2019 recorded a series of electromagnetic anomalies between 10:45 UTC and 12:25 UTC having azimuth 90° -180° (axis NS), 330° -150° (NNW axis - SSW) and sull'azimut 290°-110° (EW axis approximately). The electromagnetic anomalies have had an intensity higher than the normal variation of the natural electromagnetic background (Fig. 2). In the same time period, the gas detection station Radon situated in pairs (AQ), highlighted a number of anomalies on the moving average of the concentration of Rn_{222} (Fig. 4). What has been said is also observed from the graphs of Rn_{222} also relative to the second sensor (Fig. 5) and the azimuth shown in the spectrogram of the RDF system (Fig. 2b) in which the azimuth and the bluish purple denote the geographical area of the sensor Coppito radon, borderline (Fig. 3).

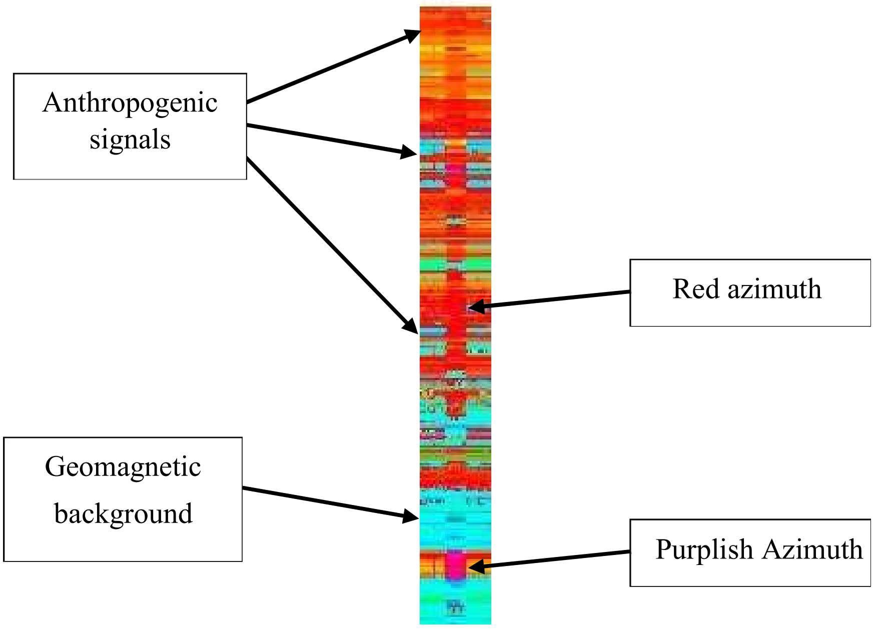

Fig. 2b *– Particular electromagnetic increase recorded by the RDF system located at the Ripa-Fagnano station (AQ). The increases have appeared 25 and 24 hours before the occurrence of the earthquake considered in this study. Credits: Radio Emissions Project.*

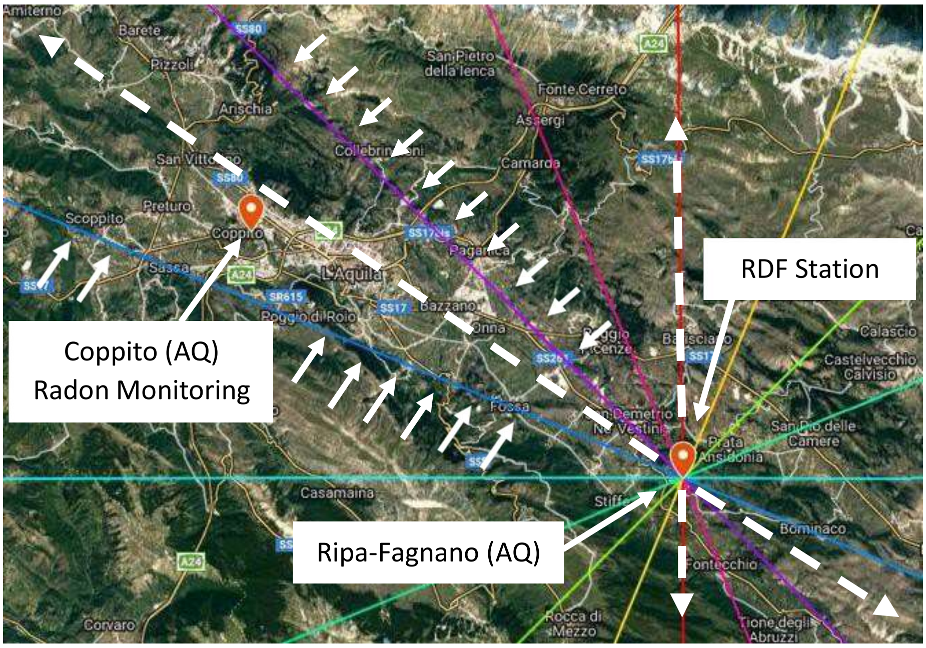

*Fig. 3 – **Indications azimuth derived from readings of RDF-station Ripa Fagnano (AQ).** In the map above the colorimetric range-azimuth of RDF station it is visible located in Ripa-Fagnano (AQ). The white arrows show the azimuth directions detected in the spectrogram acquired in Fig. 2 with respect to Coppito (dashed white ray radon stations - Rn_{222}) and Ripa-Fagnano. The vertical dashed white ray indicates, however, the azimuth associated with the color red. Credits: Radio Emissions Project; Permanent Foundation G. Giuliani.*

Radon (Rn_{222}) detection station n.1 – Coppito AQ.

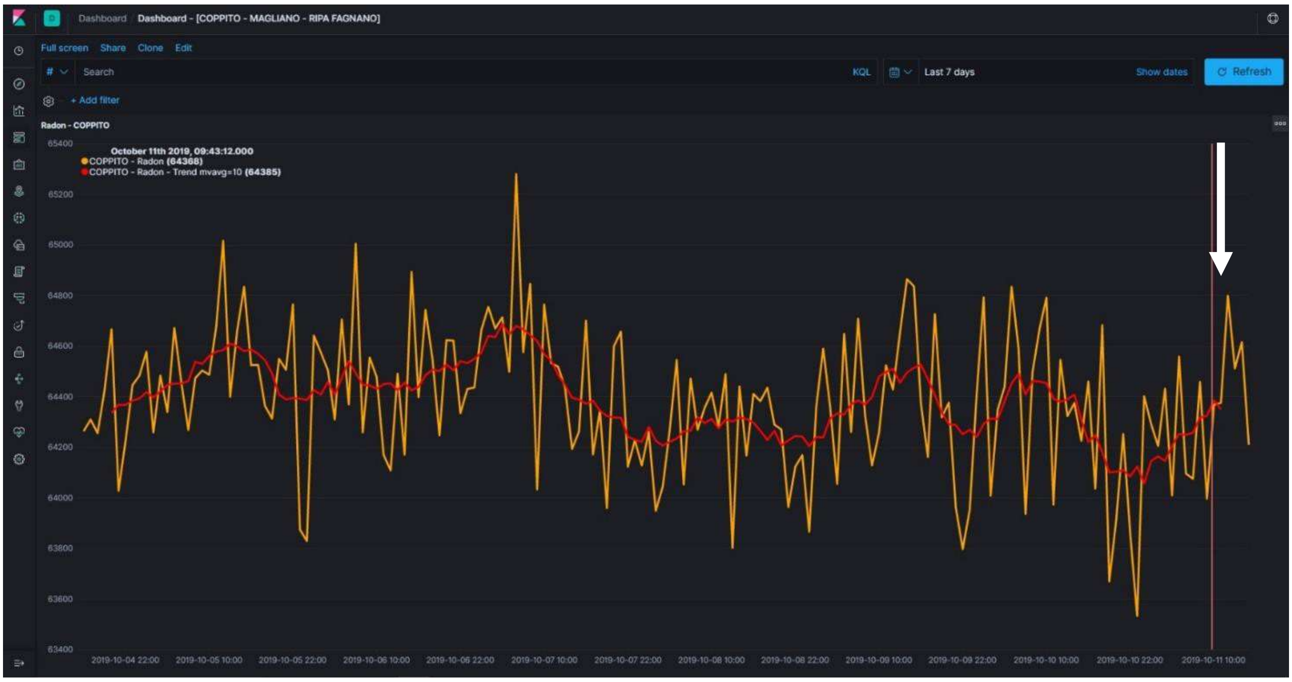

*Fig. 4 – **Gas Concentration Rn_{222} recorded between 4 and October 11, 2019 by the first detector located in pairs range (AQ).** The top graph shows the variation of the concentration of gas Radon (Rn_{222}) recorded by the range sensor located at the Coppito station (AQ). The recording was acquired between 10 and October 11, 2019. The vertical white arrow represents the time marker coincides with the first radio-anomaly recorded at 10:45 am UTC from RDF station located at Ripa-Fagnano (AQ). (See spectrogram of Fig. 2) Credits: Permanent Foundation G. Giuliani.*

In other words, the monitoring data showed that the increase in the counting rate of Rn_{222} registered at the Coppito station (AQ) coincided temporally with the electromagnetic increase (the first) recorded through the RDF station Ripa-Fagnano; also the azimuth indicated by the RDF station was compatible with that of the gas monitoring station Rn_{222} of torque (AQ) (Fig. 3-4). The data related to the gas concentration Rn_{222} of torque (AQ) are confirmed by a second Rn_{222} gas detector, always located at Coppito (AQ). The graphs of the two sensors (Fig. 4-5) are coincident with each other.

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Radon (Rn_{222}) detection station n.2 – Coppito AQ.

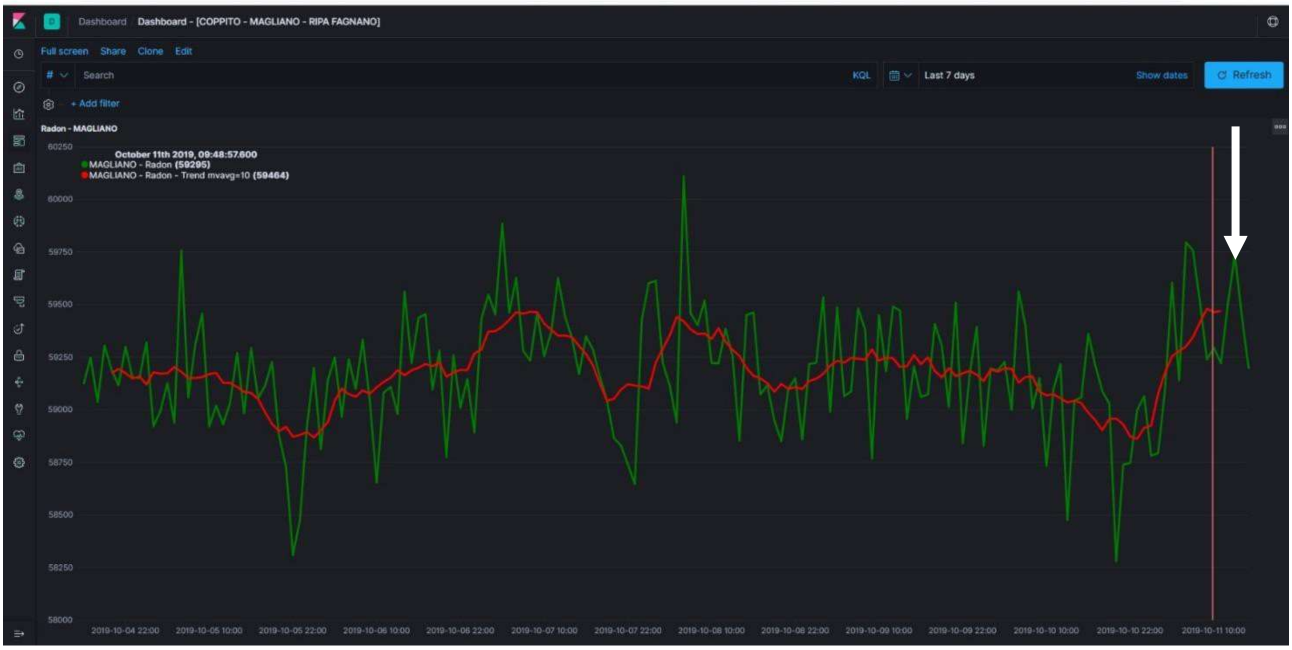

Fig. 5 – Gas Concentration Rn_{222} recorded between 4 and October 11, 2019 by the second detector located in pairs range (AQ). *At the top it is possible to observe the counting rate relative to the graph of Rn_{222} gas recorded by a second detector located in the range of Coppito monitoring station (AQ). The data confirm the reliability of the anomalies observed on the moving average of the two range sensors located in the east of L'Aquila. Credits: Permanent Foundation G. Giuliani.*

Between 23:00 of October 10, 2019 and 04:00 UTC on 11 October 2019, another RDF station Radio Emissions Project, located in Pontedera (PI), Italy, (Lat. 43.672479N, Long. 10.640259E) recorded electromagnetic increase peaks along the azimuth of torque (AQ) (Fig. 8) a few hours before the RDF station Ripa-Fagnano (AQ) observed the electromagnetic anomalies with direct azimuth toward Coppito (AQ) of which has discussed in the preceding pages (Fig. 2, 2b, 3). This figure is important in a context of the electromagnetic signal triangulation given that all the RDF stations have been able to receive, from different positions and distances, electromagnetic emissions having azimuth compatible with the Coppito radon station (AQ).

Data considered to achieve triangulation were as follows:

- Change the moving average of the counting rate of Rn_{222} Ripa-Fagnano (AQ).
- electromagnetic variations recorded by RDF-station Ripa Fagnano (AQ).
- electromagnetic Variations recorded from Pontedera RDF station (PI).

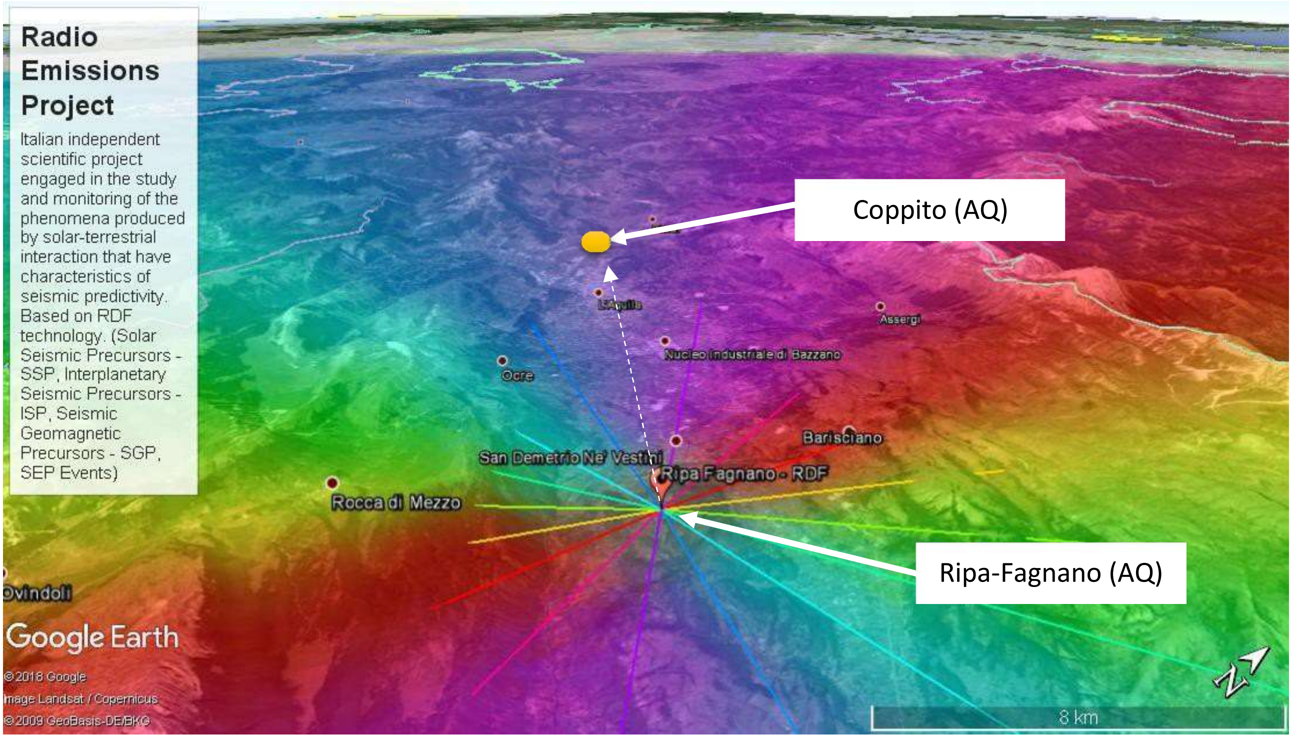

Fig. 6 – Italian Map RDF RDF system centered on the station-Ripa Fagnano (AQ).*At the top you can see the map of central Italy centered on multi-parametric monitoring of Ripa Fagnano-station (AQ). It was highlighted the colorimetric-azimuthal scale of the radio signals coming from Coppito (AQ) with respect to RDF station Ripa-Fagnano (AQ). Credits: Radio Emissions Project; Permanent Foundation G. Giuliani.*

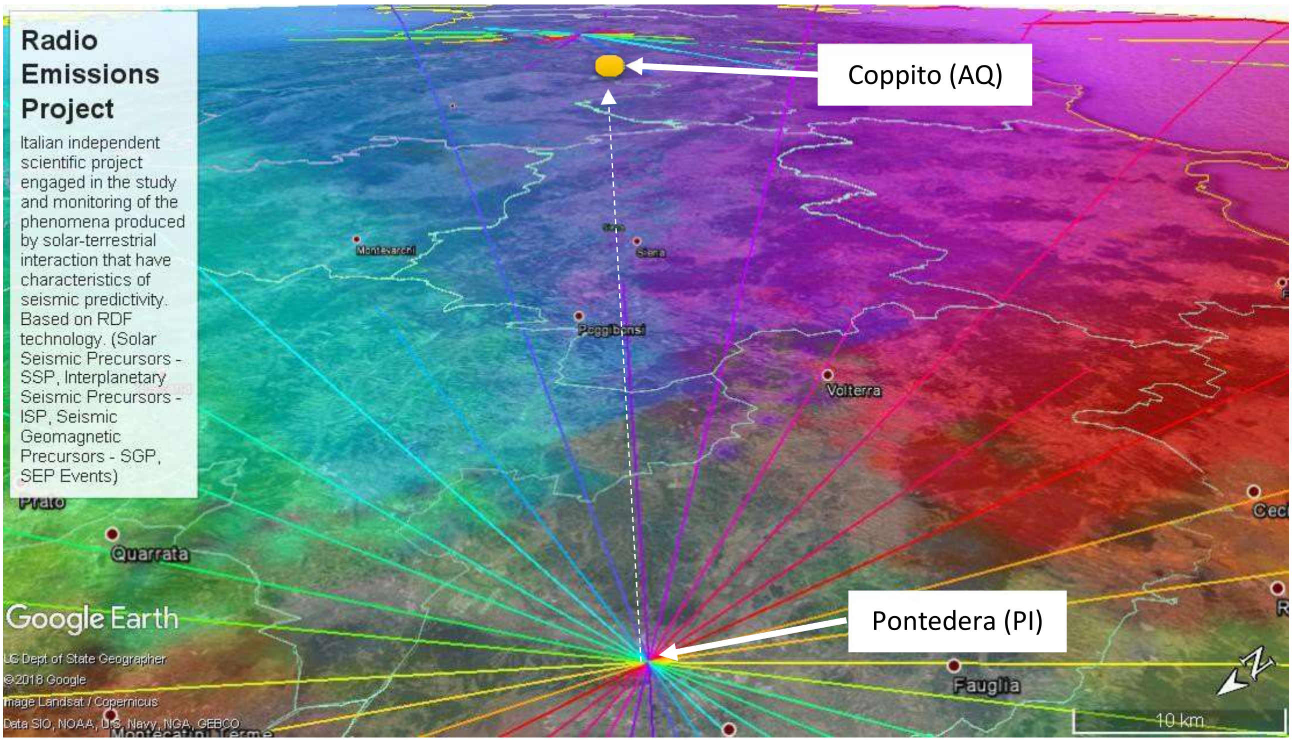

Fig. 7 – Italian Map of the RDF system centered on RDF station Pontedera (PI).*At the top you can see the map of central and northern Italian centered on the monitoring station of Pontedera (PI). It was highlighted the colorimetric-azimuthal scale of the radio signals coming from Coppito (AQ) with respect to the RDF station Pontedera (PI). Credits: Radio Emissions Project; Permanent Foundation G. Giuliani.*

Radio Direction Finding – Pontedera (PI)

Spectrogram n.2

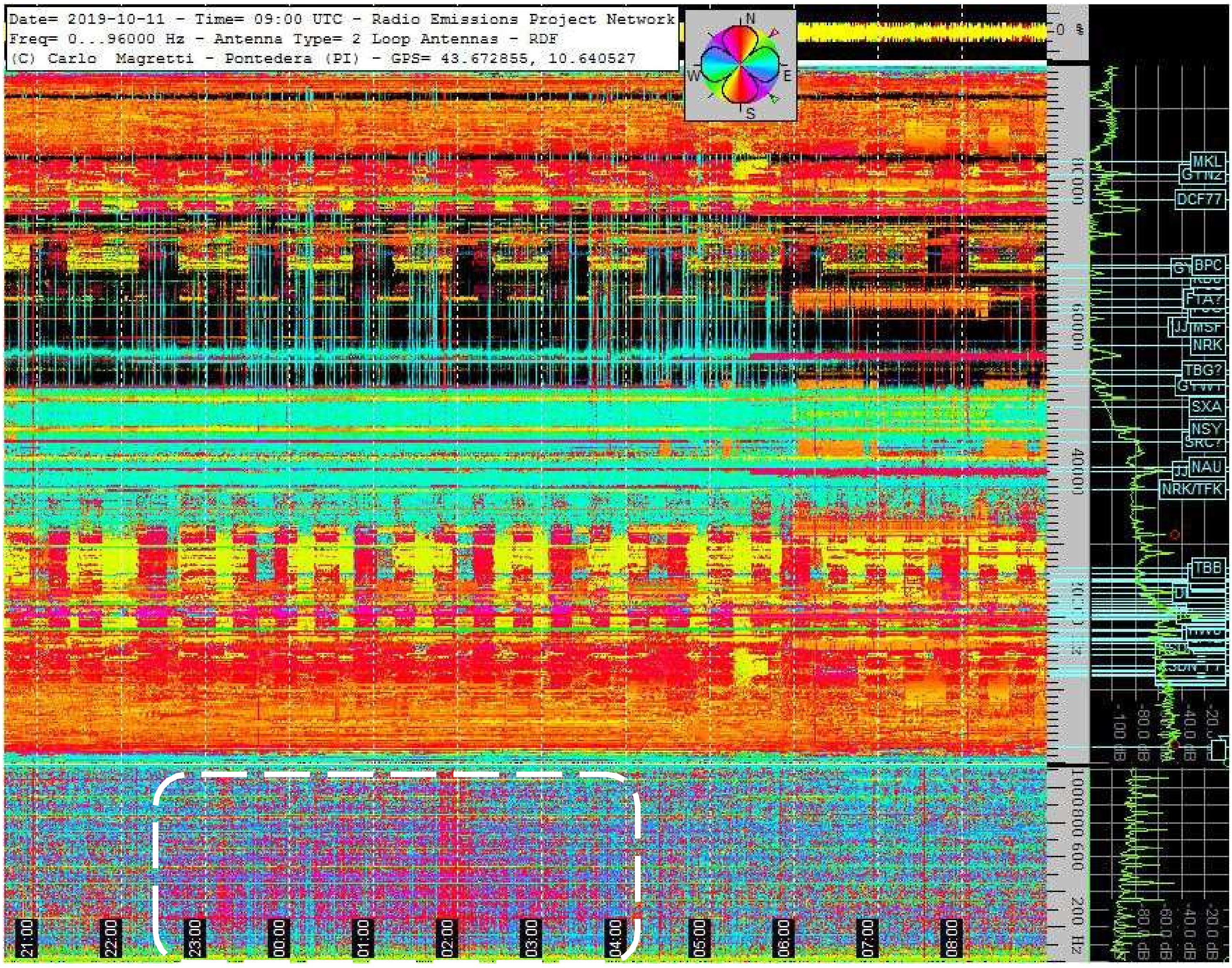

Fig. 8 – RDF Spectrogram recorded by the station of Pontedera (PI). *In the top it is visible the dynamic spectrogram recorded from Pontedera RDF station (PI) managed by Mr. Carlo Magretti (collaborator of Radio Emissions Project). The image highlights (inside the dashed white line) a clear increase in low frequency electromagnetic (electromagnetic background) between 0 and 1000 Hz, registered more than 36 hours before the earthquake considered in this study. Credits: Emissions Project Radio Network, Carlo Magretti.*

In this area of research is essential to consider that the correlation of data from multiple RDF stations located on Italian soil offer the ability to identify the geographic area from which the pre-seismic radio interference (Electromagnetic Seismic Precursors or ESPs are generated): a electromagnetic tracking method comparable (for targets) to the one used in 2011 to identify the seismic epicenter of M9 earthquake that was recorded in Japan (Ohta et al, 2013), but differs from that for the use of abnormalities streams on the counting rate of the Rn_{222} gas.

The azimuth from the Pisan RDF station, between the blue and violet, indicates precisely the azimuth passing through the center Italy (Fig. 9-11), as shown in Fig. 8. The above indicates the possibility of obtaining correlations on seismic epicentres RDF from different stations and abnormal variations observed Rn_{222} gas in the same geographical areas. In fact, 36 hours after having detected these electromagnetic anomalies (RDF) and the increase of the Radon gas (Rn222), which began more than 48 hours before, an earthquake of ML 3.1 was recorded at 19 Km from Coppito monitoring station (AQ) and from the area highlighted by the RDF system. The seismic data are as follows:

- Terremoto di magnitudo ML 3.1 registrato il 12-10-2019 alle 12:29:55 (UTC) a 2 km a Sud da

Capitignano (AQ); Lat. +42.5N; Long. +13.3E; (dati INGV).

Such a seismic event can be put in close correlation with the results of the multi-parametric monitoring just described.

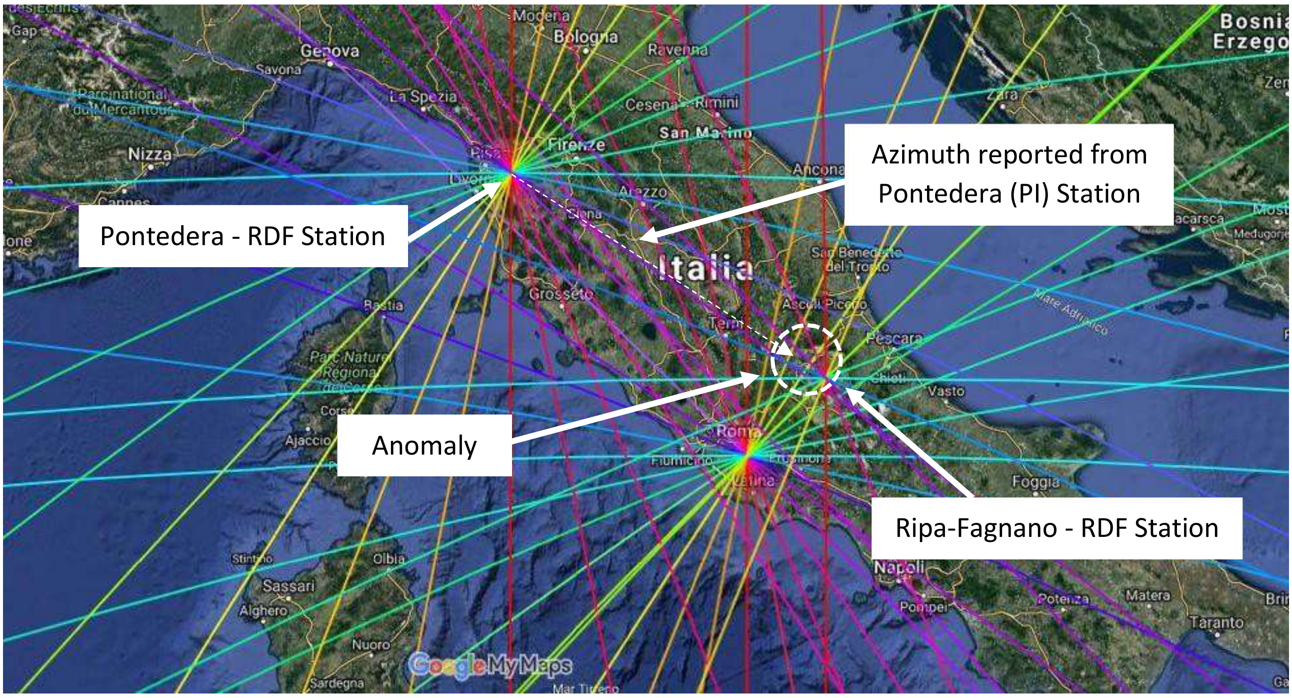

Fig. 9 – Italian Map RDF system (mapping) and the relative origin of the azimuth signals.*In the map at the top is put in highlights the azimuth purplish / bluish appeared on the spectrogram of the RDF station Pontedera (PI) that indicates precisely the direction of L'Aquila sub-urban area. Credits: Radio Emissions Project.*

As described above, relative to the area of L'Aquila basin, highlights what the authors consider the term "pre-seismic anomaly" and has the features to be identified as a flow variation in counting rate, the average gas Rn_{222} mobile 24 hours, correlated to the azimuth data of pre-seismic radio emissions captured through the RDF monitoring system.

The multi-parametric system showed well in advance (24 hours before) the area where, subsequently, was recorded on ML3.1 earthquake. This goal, although the first ever realized with a network of multi-parametric monitoring of this type, has produced encouraging results that should not be ignored. The analysis so far produced leads to a scientific reflection which is justified on the observed phenomenon: the increase on an average of flows of Rn_{222} observed by monitoring stations, and the coincident occurrence of electromagnetic signals having azimuth as the very area in which within a few hours occurred ML3.1 the earthquake, were affected by the dell ' thermodynamic energy of the Mantle, on the layer of Asthenosphere and Lithosphere connected to it. Continue stresses and fractures between Mantle and Lithosphere, it produces Rn_{222} ascent of the gas and increase in radio frequency values and the potential difference between the earth's crust and atmosphere.

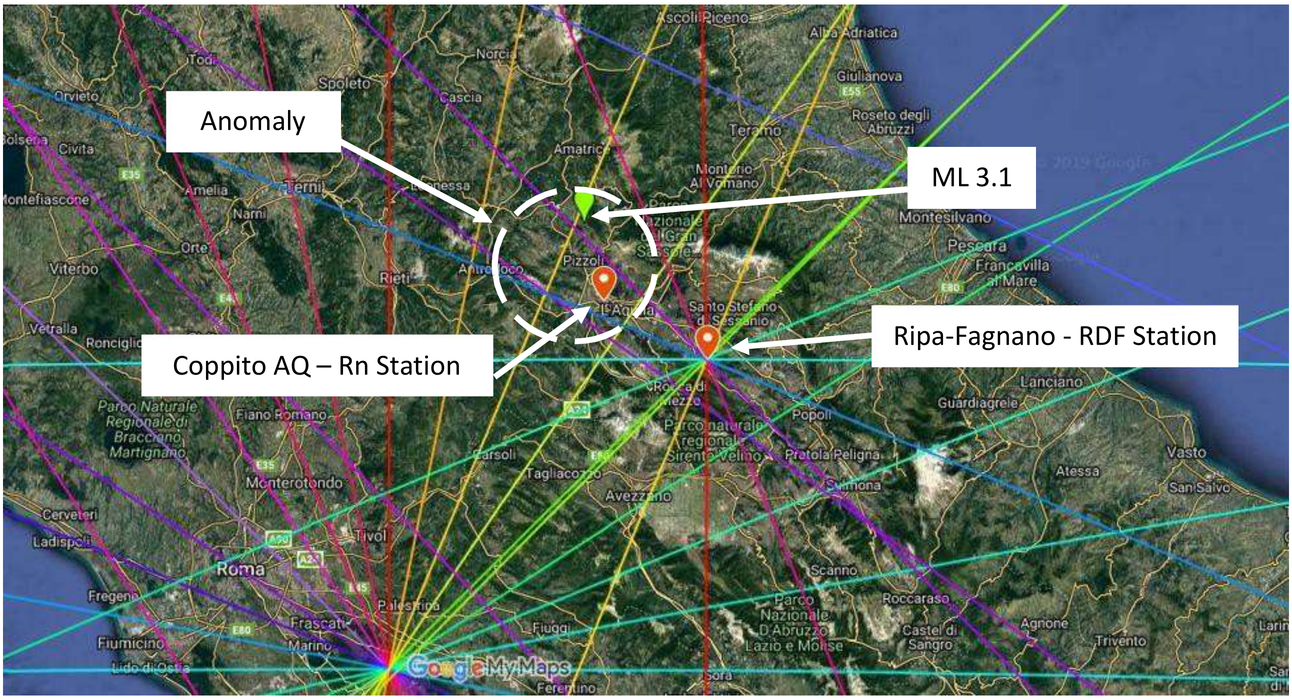

Fig. 10 – Colorimetric map of RDF-Rn$_{222}$ system installed in Central Italy. *In the map at the top is highlighted the epicenter seismic ML3.1 position in relation to the RDF detection stations and those dedicated to the gas monitoring Radon (Rn222). Credits: Radio Emissions Project.*

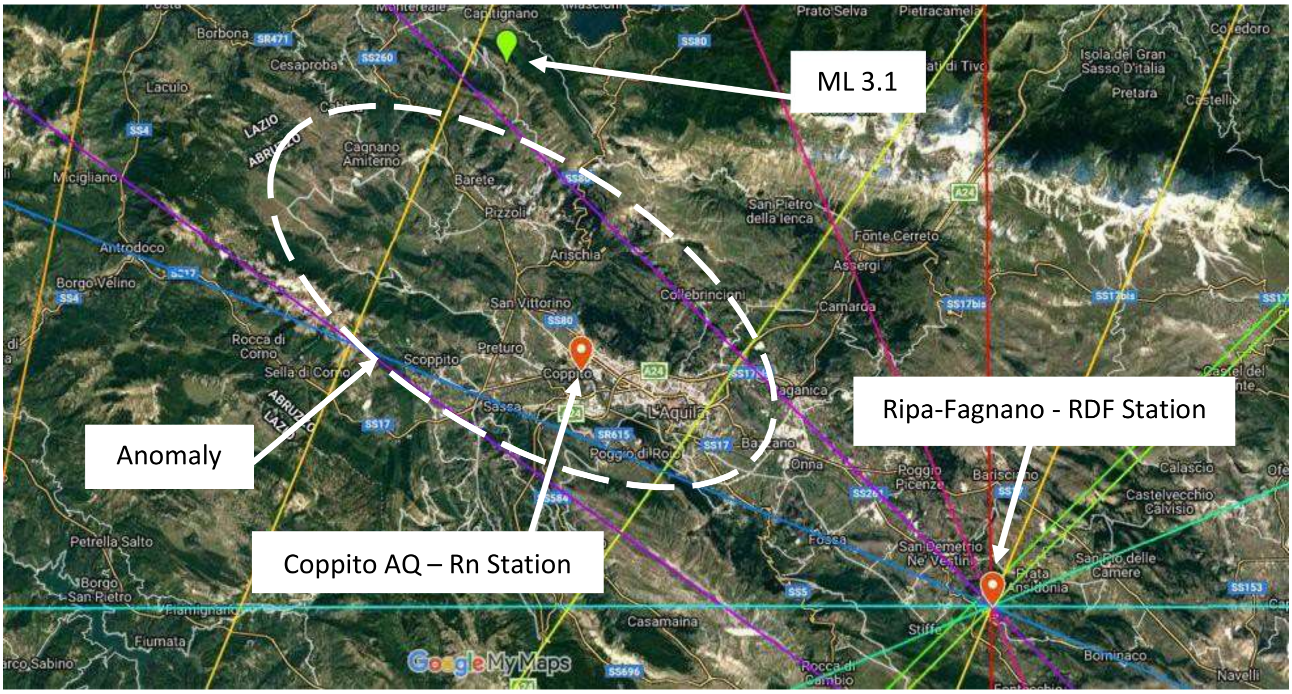

Fig. 11 – Geographical origin of the pre-seismic electromagnetic anomalies. *The white dashed line shows the geographic area where the RDF data showed the pre-seismic electromagnetic emission source. Credits: Radio Emissions Project.*

The deformation and fracture of the rocks present in the focal zone of the earthquake in the neighboring area and as a result of tectonic stress, induce the formation of dipoles electromagnetic (radio frequency) due to the movement of huge amounts of electric charges generated by the piezoelectric effect.

It follows that the particles electrically moving charges generate an electromagnetic field that can cross the Earth's crust and reach the surface without undergoing a drastic attenuation and be detectable through radio receivers. The radio frequency detected by RDF stations and the increments of Rn$_{222}$ flow would therefore be correlated to the increase of energy thermodynamic phenomena that produce stress on the basic tectonic mechanism, deformation of the earth's crust, the formation of microcracks, cracks on both local tectonic plates that continental and therefore, to sagging of these, release of small earthquakes, medium and strong intensity.

DISCUSSION

During the study, the authors worked on the identification of a cause that he could simultaneously explain the issue of Rn_{222} flow (increase) and the appearance of electromagnetic signals (Electromagnetic Seismic Precursors or ESPs) with azimuth as the very area where within a few hours, it occurred on ML3.1 earthquake. In this context it is important to consider the mechanical result of the lithosphere, which is subject to the continuous movements (geodynamic) that lead to the production of tectonic stress, which in turn is due to formation of microfractures that occur before an earthquake. This mechanism causes the ascent of Rn_{222} which therefore can be detected through the gamma detectors. In addition, the deformation and fracture of the rocks as a result of tectonic stress produce radiofrequency through the phenomenon of piezoelectricity. According to a study carried out in 2007 (Sgrigna et al., 2007), the volume of the earth's crust concerned issue pre-seismic electromagnetic due to the accumulation of tectonic stress, it has a much larger size than the volume of the affected earth's crust solely on the production of micro-fractures (focal area of the earthquake). Taking as reference an earthquake of magnitude 6 and considering the volumes involved, this ratio is> 200: 1 (**Fig. 12**).

Size of earthquake preparation zone (*r*) and precursor region (*R*) for 4.0 ≤ M ≤ 7.0		
Magnitude	**Radius (*r*) in Km**	**Radius (*R*) in Km**
4	0,1	52
5	2,5	141
6	6,0	380
7	41,3	1023

***Fig. 12 – Earthquake preparation area and Electromagnetic Seismic Precursors (ESPs) emission zone in comparison**. In the table above the dimensions (radius in km) of the earthquake preparation zone and that which contributes to the production of pre-seismic radiofrequency (ESPs) have been compared. Credits: V. Sgrigna, A. Buzzi, L. Conti. Seismo-induced effects in the near-earth space: Combined ground and space investigations as a contribution to earthquake prediction. Tectonophysics, 153-171. 2007.*

Subtracting the energy released by the seismic waves by the energy that theoretically is accumulated as a result of tectonic stress within the earthquake preparation zones, the result is that only a small part of the energy contained in the earthquake focal zone is converted into seismic waves . According to T. Lay and T. C. Wallace (T. Lay et al., 1995), only 1-10% of the energy and seismic moment contained in earthquake zones preparation is converted into seismic waves. It is therefore conceivable that the 90% (or more) of this energy, or part of it, can be converted to radiofrequency.
Taking as a reference an earthquake of magnitude 5, this has an energy and a seismic moment between 1012 and 1018 Nm (T. Lay et al., 1995). If we wanted to convert this mechanical moment (kg · m2 · s-2) in energy supplied in 1 second (W / s), the result would be equal to:

1.000.000.000 – 1.000.000.000.000.000 kW/s (1 kW/s = 1000 W/s)

that is:

$$\mathbf{10^{9} – 10^{15}\ kW/s\ o\ kJ\ (1\ Ws = 1\ J)}$$

Considering that it is not possible to quantify the energy losses of the system in terms of thermodynamic efficiency and the efficiency of energy conversion tectonic in other forms of energy, we assume that only 50% of the energy residual theorized by T. Lay and T. C. Wallace can be converted to radiofrequency. The result is as follows:

500.000 – 500.000.000.000 MW/s o MJ
(1 MW = 10^6 W; 1 MJ = 10^6 J)

These values represent the amount of energy that can be converted into radio frequency in one second. Converting it in W/h, we obtain as a result the amount of energy that can be supplied in the form of radiofrequency 1h:

138,9 – 138.888.888,9 MW/h

It is an enormous amount of energy (between ~ 139 MW/h and ~ 138,889 GW/h), than if it were converted into radiofrequency would be able to propagate within the earth's crust and reach up to the surface. Laboratory experiments conducted on a few cubic centimeters of rock have found that during the creation of fractures in rocks, as a result of mechanical stress, it emitted a significant amount of radio waves (G. Hammer et al., 1985) through the phenomenon of piezoelectricity . This phenomenon is observed when crystals is applied on some of the mechanical stress in certain crystallographic directions: the opposite sides of the crystals we load instantly (Finkelstein et al., 1973). Studies confirming the production of radio frequency emitted by rocks placed under mechanical stress have also been conducted in recent years thanks to the funds allocated NASA (National Aeronautics and Space Administration) (F. Freund, 2002).
The existence of pre-seismic radio signals (defined by the authors as "Electromagnetic Seismic Precursors" or ESPs) is now an indisputable fact from the scientific point of view because these natural radio signals were detected through countless times of various radio detection stations type: the first literary work in which a description of these radio signals appears dates back to 1890 (J. Milne, 1890); nevertheless, in the next century (at least in the good half of the twentieth century) research on these unclaimed signals much success, until in the 90s the international scientific community has begun to reconsider positively these radio signals (P. Bernard, 1992; MJS Johnston, 1997).
Many authors have got to ensure that the bandwidth of these radio emissions is very wide: it extends from the lower limit of the known radio frequency (SELF band) to the VHF band; while, the intensity is greater at lower frequencies, reaching a maximum intensity between the band SELF and the first half of the ELF band ($0 < f \leq 15$ Hz) (G. Cataldi, 2019; G. Cataldi et al., 2013 -2 019; D. Cataldi et al., 2014-2019). This radio frequency can be easily monitored in order to understand the characteristics and the temporal evolution in relation to seismic activity, and because it is emitted from the focal zone of an earthquake and / or in the neighboring areas of the earth's crust subject to deformation due to tectonic stress, it is evident that through the use of an electromagnetic detection technology type radio-goniometric or RDF (Radio Direction Finding) is possible to obtain an indication of azimuthal seismic epicenter with respect to the electromagnetic detection station. The authors have experienced this type of technology from 2017 obtained very encouraging results.
Since the end of 2019 have supported this method also the monitoring of Radon gas stream (Rn_{222}) to assess whether it is possible to realize a multi-parametric monitoring system that has a common substrate: the creation of microfractures as a result of tectonic stress.
The Radon gas is a chemical element that has been used for the first time as seismic precursor in 1927 (K. Shoratoi, 1927), but the first real recording that has had an important echo within the scientific community was realized following the Tashkent earthquake in 1966 (A. Riggio et al., 2015). Although the ICEF (International Commission on Earthquake Forecasting) has stated that it is not obvious no significant correlation between the radon gas increases and seismic events; in our case the monitoring of the flow Rn_{222} has provided guidelines that were deemed correct, as confirmed by the RDF electromagnetic monitoring.
Certainly the opinion ICEF not contemplate the use of RDF technology confirming the creation of fractures in the subsurface, and this confirms that when using new media research you can get unexpected results. According to the authors, encouraging data about the use of radon as imminent

seismic activity indicator have been obtained, for example, against Radon gas flow measured before the M7.2 earthquake that was recorded in Kobe (Japan) on January 17 1995 (**Fig. 13**):

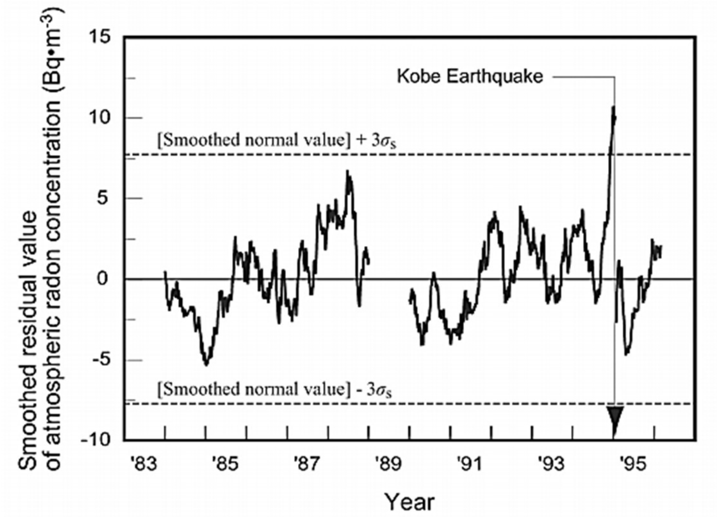

Fig. 13 – Concentrazione di gas Radon correlato al sisma M7.2 che fu registrato a Kobe il 17 Gennaio 1995. *Nel grafico in alto è possibile osservare la variazione della concentrazione di gas Radon che precedette il sisma M7.2 che fu registrato a Kobe nel 1995. Credits: Air radon concentration vs. time (by Kobe Pharmaceutical University) before the M=7.2 Kobe earthquake of January 17, 1995 (Kawada et al., 2007); A. Riggio et al., 2015.*

Allegri and his team (Allegri et al., 1983; Pulinets and Boyarchuk, 2004; Pulinets et al., 2007) analyzed the flow of gas Radon in central Italy between 1979 and 1980 in the sites of Rome and Rieti experiencing between June and in November 1980, an increase of + 25% of the Radon flux and + 170% of the baseline level, which preceded the M6.5 earthquake that was recorded in Irpinia (southern Italy) November 23, 1980 (**Fig. 14**):

Since the late '50s to today, they were made innumerable studies that confirmed a correlation between the increase of Radon gas flow and even destructive earthquakes. Today, the multi-parametric monitoring technique realized by the authors has resulted in very precise information on the epicenter of the seismic event ML3.1 which was registered on 12 October 2019 in Central Italy: RDF data confirmed the flow readings Rn_{222} of gas indicating that in that area was to be expected a seismic event; and this has occurred.

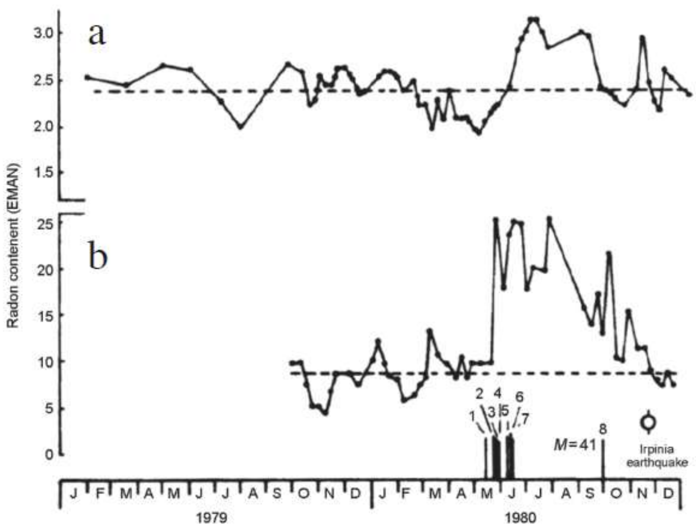

Fig. 14 – Concentrazione di gas Radon correlato al sisma M6.5 che fu registrato in Irpinia (southern Italy) il 23 Novembre 1980. *Nel grafico in alto è possibile osservare la variazione della concentrazione di gas Radon che precedette il sisma M6.5 che fu registrato in Italia nel 1980. The 1979-1980 series of the groundwater radon content at: a) Rieti station, b) Rome station. The vertical bars in the bottom panel show the seismic shocks. The length of the bars is proportional to the magnitude (modified from Pulinets and Boyarchuk, 2004). Credits: Allegri et al., 1983; Pulinets and Boyarchuk, 2004; Pulinets et al., 2007.*

the earth's crust as a result of tectonic stress. In Italy, for the first time, was carried out the first part of a network of innovative multi-parametric monitoring (located in Central Italy) that aims to analyze the pre-seismic electromagnetic phenomena and the gas flow for Rn_{222} understanding whether these data it is possible to develop a seismic prediction method based on the dynamics of the earth's crust. The first data that this multi-parametric monitoring network has provided allowed the authors to identify, with about 25 hours notice (for the RDF system) and 48 hours notice for the isotope flow detection system Rn_{222}, the geographical area in which it was then determined a ML3.1 earthquake. It is a result that in Italy is unprecedented.
What has just been said enables us to come to a conclusion: the energy potential of a high magnitude earthquake can certainly generate radio frequency that can be detected above the Earth's surface. Using the technology RDF (Radio Direction Finding) is currently individual can the geographic area from which these pre-seismic radio emissions are emitted.

Add to this the monitoring of Rn_{222} flow is clear that you can get further confirmation about the geographic area in which you can expect a seismic event. But it is obvious that to achieve this goal is essential to achieve a dense multi-parametric monitoring network destined for the monitoring of seismic precursors of electromagnetic and chemical type.

The researchers, all agree that the research to be undertaken in the coming months is to increase the number of multi-type detection stations, able to increase the number of correlated data in a forecasting context, based on this technique monitoring.

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