Cosmic-rays and earthquake prediction? Towards a multi-messenger strategy with the Cosmic-Ray Extremely Distributed Observatory

K. Almeida Cheminant[1,*] for the CREDO Collaboration[†]

1) *Institute of Nuclear Physics Polish Academey of Sciences, Radzikowskiego 152, Kraków, Poland*

*) *presenter*
†) website: http://credo.science

corresponding author: kevin.almeida-cheminant@ifj.edu.pl

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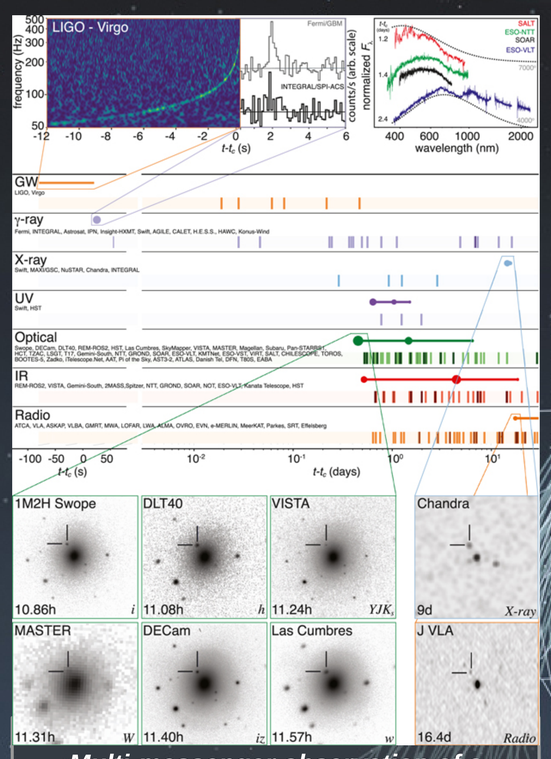
SUMMARY

The Cosmic-Ray Extremely Distributed Observatory (CREDO) is an astroparticle physics experiment focusing on the detection of cosmic-rays on worldwide scales via both research expertise and citizen science. Thanks to the smart-phone application we have developed, cosmic-ray particles can be detected worldwide at minimal costs by non-scientists. Because these particles are charged, they are strongly influenced by electromagnetic (including geomagnetic) field variations. Although we have yet to find a significant relation between such variations, cosmic-ray rates and earthquakes, the scientific literature seems to open questions regarding the capability to predict seismic movement via both electromagnetic and cosmic-ray precursors. In fact, strange behaviours of cosmic-ray rates have been observed in leading cosmic-ray research collaborations hours before Chile's earthquake in 2010 and although we cannot conclude any link between such rate and the earthquake with enough confidence, we believe that the cosmic-ray channel of observation may give a potentially serious opportunity to predict seismic activity and save human lives. By developing citizen science participation, the CREDO experiment aims at collecting large amount of data on a world scale and at strengthening the collaboration between various fields of science by encouraging a multi-messenger strategy.

MULTI-MESSENGER ASTRONOMY



Multi-messenger observation of a neutron star merger in August 2017
B.P. Abbot et al., Astr. J. Let. 848-2 (2017)

In astronomy, the detection of one particular event via multiple channels of observation can reveal informations about different physical mechanisms but also strengthen our understanding of how these mechanisms might be connected to one another. The range spanned by the electromagnetic spectrum (more than 20 orders of magnitude) and the opacity of the Universe to certain wavelengths has lead the astronomical community to build various telescopes focusing on different frequencies and has enforced a collaboration with other experiments (gravitational waves, cosmic-rays and neutrinos) in order to improve our grasp on the physical processes occuring in the Universe. The cross-correlation of datasets coming from distinct experiments can be done in two ways:

Empirical analysis of historical data

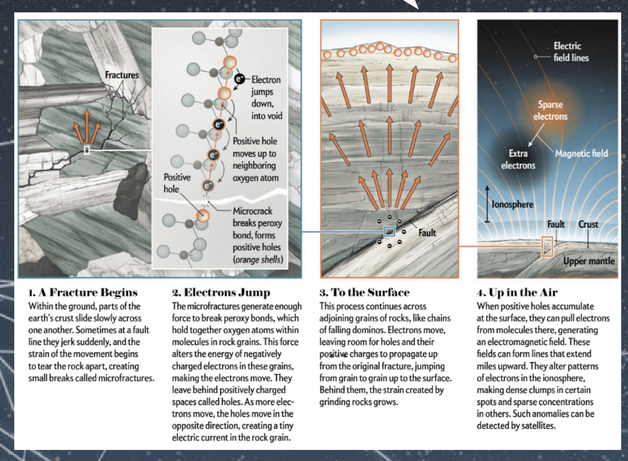
System of trigger alert to notify other experiments

THE COSMIC-RAY CHANNEL

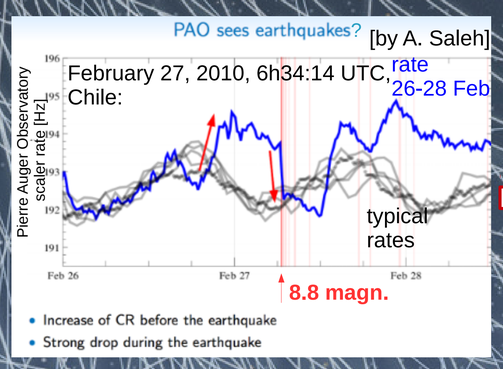
Cosmic-rays are particles (mainly protons) that are created in astrophysical processes such as supernovae and travel through space close to the speed of light. Because they are charged particles, they are highly sensitive to electromagnetic fields. Most potential precursors that can be found in the literature are related to electromagnetic field variations, whether they have solar or geological origins. Consequently, cosmic-rays can be used as a channel of observation to probe the correlation between these variations and seismic activity. In fact, cosmic-rays have already been considered for such study.

Some physical processes that may have considerable impact on the cosmic-ray rate can be seriously considered!

Seismic activity
↓
Inverse magnetostrictive effect
↓
Local geomagnetic field vector changes
↓
Variation of the CR rate
↓
Earthquake precursors?



Scientific American – October 2018



The observation of unusual cosmic-ray rate prior to the 2010 Chile earthquake may indicate a connection between cosmic-rays and earthquakes OR simply be a statistical ghost. It is necessary to study the possibility of such relationship when so many lives are at stake. The cosmic-ray channel is a **must-check!**

MULTI-MESSENGER STRATEGY: THE ESSENCE OF EARTHQUAKE PREDICTION RESEARCH

The search for earthquake precursors that could possibly warn authorities of important seismic activity and help decrease the number of casualties has been going on for several decades and its results has divided the scientific community regarding its feasibility. Despite the existence of articles presenting opposite points of view about the possibility to predict earthquakes, the multi-messenger approach has played an important role in ameliorating our understanding of potential connection between physical and geological phenomena. By cross-correlating datasets of different nature (sunspots, air pressure, solar wind velocities, electron density, polar light, etc.), the multi-messenger strategy has worked as a safegard against *statistical ghosts* by analyzing two types of earthquake precursors:

ACTIVE
Precursors that are believed to trigger earthquakes

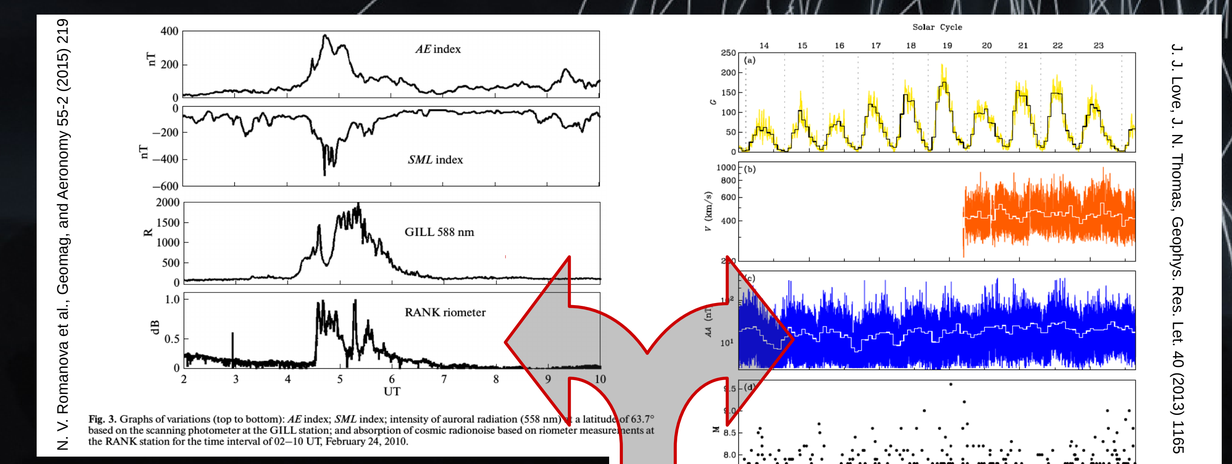
PASSIVE
Observable effects from geological activity prior to an earthquake

''*A pair of unusual events can represent an opportunity for new insight, provided that the temporal relationship of the events has a valid causal explanation.*'' J. J. Love, J. N. Thomas, Geophys. Res. Let. 40 (2013) 1165

→ the COSMIC-RAY channel could strengthen the search for causality between two distinct physical effects and offer an additional safegard.

THE COSMIC-RAY EXTREMELY DISTRIBUTED OBSERVATORY

The Cosmic-Ray Extremely Distributed Observatory (**CREDO**) is an experiment started in 2016 aimed at using the cosmic-ray channel to probe terrestrial and cosmic phenomena by providing a world-scale set-up of cosmic-ray detectors of various sizes and costs and via the collaboration of leading astroparticle experiments. One of CREDO key aspect is to offer a new channel of observation in the quest for unexpected phenomena. In the context of earthquake prediction research, it can offer an additional observable at minimal costs and on a global scale. Once the worldwide scale is reached, the radiation monitoring will bring chances to cross-correlate the cosmic effects with transient changes in other available databases.



N. V. Romanova et al., Geomag. and Aeronomy 55-2 (2015) 219

J. J. Love, J. N. Thomas, Geophys. Res. Let. 40 (2013) 1165

Fig. 3. Graphs of variations (top to bottom): *AE* index; *SML* index; intensity of auroral radiation (558 nm) at a latitude of 63.7° based on the scanning photometer at the GILL station; and absorption of cosmic radionoise based on riometer measurements at the RANK station for the time interval of 02–10 UT, February 24, 2010.

Figure . Time series of (a) monthly sunspot group number G (yellow) and annual averages (black), (b) universal-day averages of near-Earth solar wind velocity V (orange) and annual averages (white), (c) universal-day averages of the geomagnetic-activity index AA (blue) and annual averages (white), and (d) global earthquake magnitudes, shown here for $M \geq 7.5$.

COSMIC-RAY CHANNEL?

Track observed in camera sensors

The active use of citizen-science is an essential feature of the CREDO experiment. It provides mutual benefits to researchers and non-scientists by engaging an active collaboration between the two. From data acquisition to data analysis, the educational benefits are remarkable. In this endeavour, the CREDO mission is based on an intense, multi-level public engagement, employing e.g. smartphones equipped with an application that enables particle detection (e.g. the CREDO Detector app for Android), we emphasize that the enthusiasm for citizen-science that we already experience with CREDO, might bring scientific and societal fruits on unprecedented scale when directed to the earthquake prediction task: a mission that could save lives. With more than 6000 users spread around the globe, the extensive search for natural phenomena involving cosmic-rays can be pursued.

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CREDO
THE QUEST FOR THE UNEXPECTED