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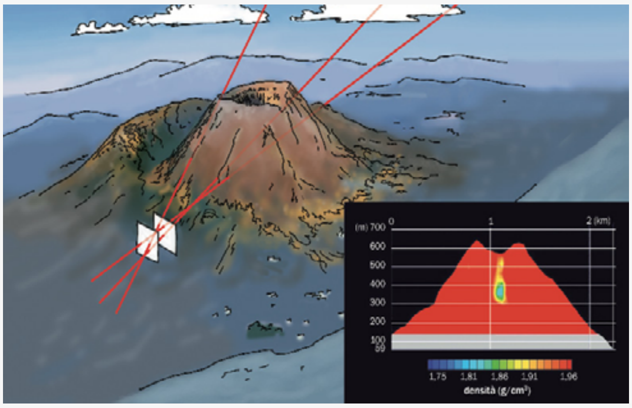

COSMIC PARTICLES FOR STUDYING VULCANOES

The Earth's surface is constantly being reached by muons, produced by the interactions of cosmic rays coming from space with atoms in Earth’s atmosphere. They are very energetic particles that are identical to electrons but with a mass 200 times higher, and it is precisely this characteristic of theirs that makes them so penetrating – capable, that is, of passing through matter while losing very little of their energy. After neutrinos, they are the most penetrating particles and, in any case, unlike neutrinos, they are not a source of astronomic information as they are only produced in the Earth’s atmosphere. They do constitute, however, a very powerful tool for investigating structures and objects on Earth. The ability to pass through very thick matter, including several kilometres of rock, makes it possible, in fact, to use muons to perform “muographies” of structures with large dimensions. These are very similar to radiographies, but have the advantage, compared to X-rays, of performing deeper probes.

The technique called muography was first used in the late 1960s by the Nobel prize for physics Luis Alvarez to search for hypothetical secret chambers inside the pyramid of Chefren. The study of pyramids with this technique has brought recently, in 2017, to the discovery of a secret chamber inside the Great Pyramid of Giza by a team of researchers on the international ScanPyramids project.

Starting in the 90s, this technique began to be applied for the study of volcanoes, initially in Japan and later in Italy, two countries that have similar geological phenomena: a high frequency of earthquakes and volcanic eruptions, and they are at the forefront of theoretical and experimental studies in these disciplines. In particular, the use of muons enables researchers to visualise magma conduits, or other internal structures, in the emerging part of volcanoes. Visualizations of this type are important diagnostic tools for understanding magma dynamics. One application of this technique was implemented at the beginning of 2015 by the MIUR MURAVES (MUon RAdiography of VESuvius) research group, a collaboration

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between INFN, INGV (National Institute for Geophysics and Volcanology), and the universities of Naples and Florence. It has enabled the installation of detectors for measurements on Stromboli and Mount Vesuvius. MURAVES is the evolution of the Mu-Ray prototype that was developed by INFN, and with which, in April 2013, a demonstration data acquisition was conducted on Mount Vesuvius. Placing the detector even deeper, the technique also enables the study of subterranean structures. The Neapolitan subsoil, where numerous cavities have been excavated in the tuffaceous rock since antiquity, provides an ideal situation for such study. The MURAVES project researchers have applied the same technique used on Mount Vesuvius to explore cavities surrounding the Bourbon tunnel, in the historic centre of Naples.
With the cosmic muons it is also possible to analyse smaller structures, making it possible to identify very dense objects, such as radioactive materials illegally transported in a container. Passing through the material, the muons lose energy but are also deflected by an angle that tends to be bigger, the greater the density of the material it has passed through. It is possible, therefore, to measure the deflection of the muon using two detectors that are placed, one above and one below the object to be studied, and measuring its direction before and after it has passed through the material. From the measurements recorded, thanks to a significant number of muons, it is possible to produce a three-dimensional tomography to reveal the denser objects inside the container. A prototype of this equipment was produced at the INFN Legnaro National Laboratories with very promising results.
The MURAVES project, already in data acquisition, will be fully underway in the spring of 2020, with the completion of four planned detectors, installed on Mount Vesuvius. ■