Editorial – Scanning Khufu's Pyramid with Atmospheric Muons

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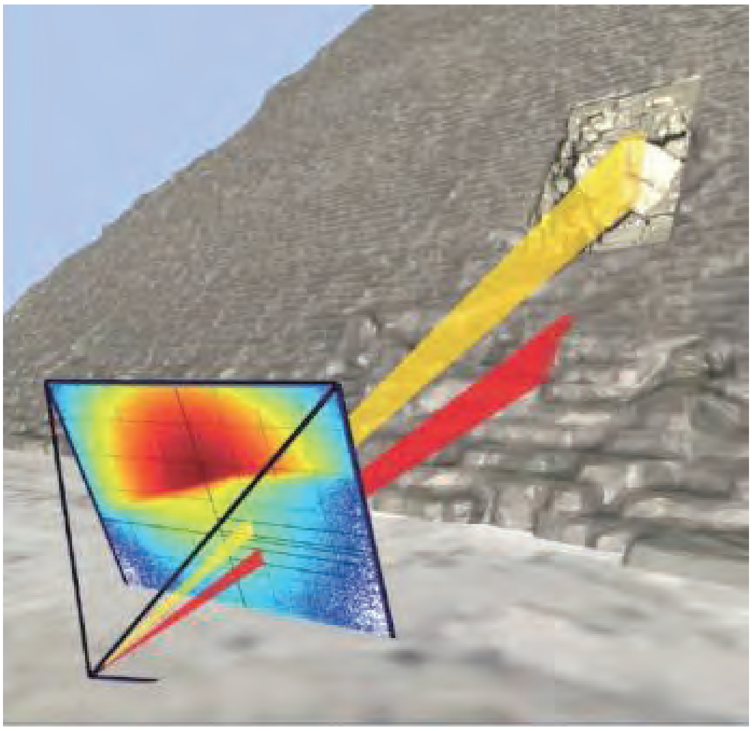

Detection of muons with the help of telescopes from CEA/Irfu outside the pyramid. The higher rate of muons indicates the presence of a cavity in the pyramid.

In a publication in Nature in December 2017 [1], teams of the ScanPyramids project [2] announced the discovery of a hitherto unknown big void in Khufu's Pyramid in Egypt, also known as the Great Pyramid of Giza or the Pyramid of Cheops [3]. The void was found by scanning the internal structure of the pyramid using the abundant flux of atmospheric muons. The technique is known as muon radiography by analogy with X-ray radiography. Three different muon detection techniques familiar in particle physics research confirmed the large void.

The muon flux at sea level is the result of interactions of cosmic ray particles with atoms in the upper atmosphere, creating a shower of subatomic particles. While most other components of the shower are attenuated in the atmosphere, muons arrive at sea level at a rate of about 10,000 muon/m^2/sr every minute. Penetrating the pyramid from many directions, muons are partially absorbed revealing a three-dimensional count rate pattern which reflects the density of the pyramid's construction material. A large hole in the pyramid would result in a higher muon count rate than expected.

The first evidence of a void above the Queen's chamber was found using nuclear emulsion film detectors installed in the chamber at two positions, 10 m apart. These detectors are particularly suited for a setup deep inside the pyramid, because they are compact and do not need electrical power. The highly sensitive photographic film allows recording of three-dimensional trajectories of the traversing muons. Comparing the measured count rates of muons traversing the emulsion with those from Monte Carlo simulations, the known large structures inside the pyramid were clearly visible, establishing confidence in the detection technique. Unexpectedly, the data also showed a higher muon count rate in a region above and almost parallel to the Grand Gallery. The observation was confirmed using the different detection technique of scintillator hodoscopes also installed in the Queen's chamber at two locations. Traversing muons generate scintillation light in the elements of the hodoscopes, thus allowing the reconstruction of their trajectories. The recorded data were found to be consistent with the observation using the emulsion technique. Data recorded using a third detection technique with micro-pattern gaseous detectors filled with an Argon mixture installed in a setup outside the pyramid also confirmed the observation. According to the authors, this was the first time that the interior of a pyramid had been measured using external detectors.

The three independent detection techniques, each with different systematics, established with high confidence the discovery of the void with a cross section similar to that of the Grand Gallery and a length of at least 30 m. The purpose of the void is not known yet, however, quoting the authors: "…. *these findings show how modern particle physics can shed new light on the world's archaeological heritage*".

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References

[1] Nature 552, 386-390 (21 December 2017), doi:10.1038/nature24647
[2] Website of the ScanPyramids project: http://www.scanpyramids.org
[3] Wikipedia: https://en.wikipedia.org/wiki/Great_Pyramid_of_Giza