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The space road to UHECR observations: challenges and expected rewards

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Significant progress has been made in the last decade in the field of Ultra-High-Energy Cosmic Rays (UHECRs), thanks to the operation of large ground-based detectors and to the renewed theoretical interest that they triggered. While multi-messenger astronomy is rapidly developing worldwide, the sources of the charged messengers, namely the cosmic rays, are still to be determined, and the acceleration process to be understood. Even at the highest energies, the particle deflections by intervening magnetic fields appear to be too large to allow direct identification, at least with the current statistics. Concentrating on the highest energies has the advantage to reduce the number of sources, thanks to the so-called GZK effect, and thus potentially reduce source confusion. However, the very low flux of UHECRs in the GZK range requires huge detectors to be deployed. Alternatively, a single instrument could be used to significantly increase the current statistics if it could be operated from space, looking down to the nadir to detect the fluorescence light of UHECR-induced air showers over a huge volume of atmosphere. In addition, such a space mission would cover the whole celestial sphere and allow to draw the first complete map of UHECRs with essentially uniform coverage and systematics. Such a program has been undertaken by the JEM-EUSO Collaboration. In this talk, I will review the major steps taken along this road to space, including ground-based experiments and balloon flights. I will also present the future planned missions, on a super-pressure balloon as well as in/on the ISS. Finally, I will discuss the current efforts to extend the science case of such a mission to high-energy neutrino astronomy, complementing the ground-based neutrino detectors, and address the interesting issue of high-altitude UHECR shower, which only a space mission could observe.

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