PROCEEDINGS OF SCIENCE

CREDO.science ↔ global citizen science

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The scientific project CREDO (Cosmic Ray Extremely Distributed Observatory) is a fast growing research project based almost entirely on citizen science. It is intended to have a global reach and involve all people regardless of age, gender and education. The combination of serious scientific goals, which are outlined in this article, and the method of public participation by all stakeholders is innovative and has proven to be effective in blurring the differences between scientists and the rest of society. The differences between scientists and the rest of society were apparent for decades and could be seen even at the level of the language used by scientists, which is for the most part incomprehensible to others. The synergy between science and society can have an optimistic future for many fields of science, and this synergy is already beginning to bear scientific and social fruit, which is clear in the example of the CREDO project. The planned scope of CREDO's operation—a global scope, i.e., around the world—is an important factor, with CREDO's first scientific project having so many scientific goals and with such broad social involvement. This makes CREDO a pioneer of such activities, as is described in this article. In shaping its activities, CREDO needs, however, in addition to substantive and organizational support, examples from other scientists and non-scientists in the field of citizen science—such as, for example, those at the Engaging Citizen Science Conference 2022. At this conference people from many areas of life met and shared their experiences, and one could see that the activity within citizen science is already well defined and becoming commonplace. This short article presents the principles of operation, goals and methods of the CREDO project.

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1. CREDO project: goals and activities

The project CREDO (see CREDO.science) was established at the Institute of Nuclear Physics of the Polish Academy of Sciences in Cracow in 2018, and its operation is to record cosmic rays (cr) non-stop all over the Earth. The aim is detection of global cr air showers that may indicate the existence of, for example, still unknown massive or very energetic particles, study of the structure of the universe and, for example, linking changes in cr registration with upcoming earthquakes. This is the first cr research project with such a global reach and with such a wide range of scientific opportunities. This project is already gaining and maintaining its global reach thanks to the working method—citizen science (CS)—which is not an added element to the project, but the essence of its operation from the very beginning. At the current stage, registration is carried out using cameras in popular smartphones with the free CREDO application for Android and IoS installed. Thanks to this, such global registration is very cheap and available to all inhabitants of the Earth. In July 2021, almost 50 scientific institutions from 19 countries started cooperation with CREDO, over a dozen million data from registration under CS was collected, in which several thousand users of the CREDO application participated. However, the registrations will be of full scientific significance only when millions of interested persons are registered simultaneously all over the Earth for a period of at least several months (years).

In accordance with the principles of CS in CREDO, all data is completely available worldwide for anyone. All persons, regardless of their education, age and other individual characteristics, who in any way participated in the collection/analysis of data may be co-authors of serious scientific publications devoted to this data. All these works are carried out under the supervision of professional scientists from around the world, guaranteeing their credibility and high quality.

From a sociological point of view, this access to science and participation in its production "live" with all non-scientists in the CS project clearly reduces the existing cognitive and sociological gap between scientists and the rest of society. This opens up a range of options for choosing the direction of education for the youngest and facilitates the development of scientific careers for those who are more interested.

2. CREDO and other astrophysics projects

What is the difference in the research objectives and research method adopted by CREDO?

2.1 Scientific goals

The scientific goal is to study secondary cosmic rays in the form of a cr cone with a radius of about one kilometer on the Earth's surface caused by primary cosmic radiation (over 90% are protons) with different energies. These energies can significantly exceed (by several orders of magnitude) the largest achievable in human-built accelerators. The main imperfection of these cr showers is their low statistics—especially for extremely high energies. Thus, the way out of this situation is to significantly increase the recording area by deploying detectors all over the Earth [1, 2]. Even the largest professional cr observatories, such as Pierre Auger or Ice Cube, have not done this so far.

Researching cr on such large surfaces opens the way to registration not of individual cr but entire groups of them coming simultaneously from one source away from the Earth, even thousands of millions of km (see Fig. 1). Such a registration would require searching for an

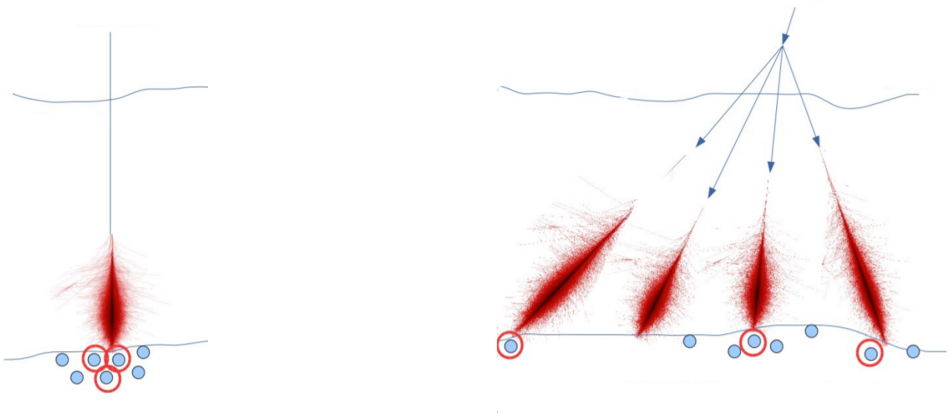

Figure 1: Left—single air shower; right—a bunch of simultaneous air showers

answer to the question about the source of such radiation, and it would give a chance to study both the micro-world of particles (e.g., dark matter) and the structure of space time. All these issues are not achievable by other observatories—although large—local on the Earth scale.

2.2 Research method

How to distribute such a large number (hundreds of millions) of detectors all over the Earth? First of all, they must be cheap and easy to use. Moreover, they must be distributed together with a description of (at least) the scientific basis presented in a short and understandable way by non-scientists.

All this sets very big tasks for CREDO employees, but as it has already been shown in the last few years, it is feasible and brings a large number of good results. The method of such work is the most generally understood form of citizen science.

In the case of CREDO, this method is based on the involvement of all people across the globe, without financial expenses and limitations due to age, education and place of residence. All information on how to download the application is available on the CREDO.science website in English. CREDO sends invitations to participate in data collection to many schools and educational institutions. After the application is loaded, anyone can use it at any time and place.

The registration frequency is on average one every few minutes. All data of a given registration —the shape of the trace in the matrix, time and place—are automatically sent by the application to the central database in Cracow, Cyfronet. These data are available to all interested parties from the moment of registration, and thus those interested can conduct statistics, analyze shapes, search for correlations and draw scientific conclusions from the data. The data itself is also an interesting source of educational research in, for example, schools.

The first and important element of registration research is to distinguish traces from the real secondary radiation cr from, for example, electronic noise and natural radiation of the Earth. This has to be done after the particle's trace has been recorded, and can be done by anyone— including non-scientists. Good data quality is guaranteed by filters (designed by specialized scientists) already present at the application level. It is mainly about time resolution and detector position (GPS).

Due to the complex process of analyzing millions of data and drawing conclusions from them, we still have to wait for the summary scientific results, but the first preliminary scientific results were published in, e.g., article [2]. The articles cited there present the CREDO project in terms of assumptions, methods and first results. One of the most recent scientific achievements is a proposal to analyze the intensity of secondary radiation recorded with smartphones for quick warning of impending earthquakes. This was initially described in an article [3].

3. CREDO now and for the future

Figure 2 shows a map of the world with specified places where noticeable activity of cr registration under the CREDO project is carried out. Most such places are of course in Europe, but one can see that many are scattered all over the world. "Users" are all—even individuals and, as groups, teams of users—for example, classes in schools or groups of 2 or more people from outside the schools.

At every stage of the development of the CREDO project, its activity is related to the promotion of science and scientific activity among all social groups, starting from primary schools for which the project organizes the so-called "Particle Hunters" competitions. Almost all data was collected by people from across society, including students from various schools as part of "Particle Hunters competitions" (in Poland for now). The annual Particle Hunters competition has proven to be very effective. In Poland, every year (since 2018), several dozen schools (groups of students (classes) and a teacher) participate in it. The duration of registration, frequency and number of participants are assessed. Every autumn, the activity of individual groups (schools) is assessed, the results are announced and the greatest achievements are awarded (number of registrations, number of hours).

Numerous series of lectures and conferences are conducted for all social groups. This allows us to receive feedback from the groups, which gives us the opportunity to constantly adjust the form and content of the CREDO presentation to social requirements globally and locally.

At the current stage of research (spring 2022), methods of registration other than a smartphone are being developed. These alternative methods are to be much more efficient (larger registration area) and allow for cr registration in several places separated by even several dozen meters. They are to cover more and more areas of the Earth (so far most of the registrations took place in Europe) and involve the international community not only in registration but also in the analysis of the obtained results.

An important aspect of the work of the CREDO project is to make this research as cheap as possible (as currently with the help of smartphones) and as interesting as possible for non-astrophysicists.

The forthcoming development plans for the CREDO project's activities include:

- continue to have participation in all important scientific conferences devoted to the astrophysics of cr,
- develop and disseminate cr detectors,
- disseminate knowledge about astrophysics among all social groups (talks, presentations, workshops, seminars, conferences),
- be involved in active participation in cr registration and in the analysis of data of other social groups, such as the blind and visually impaired.

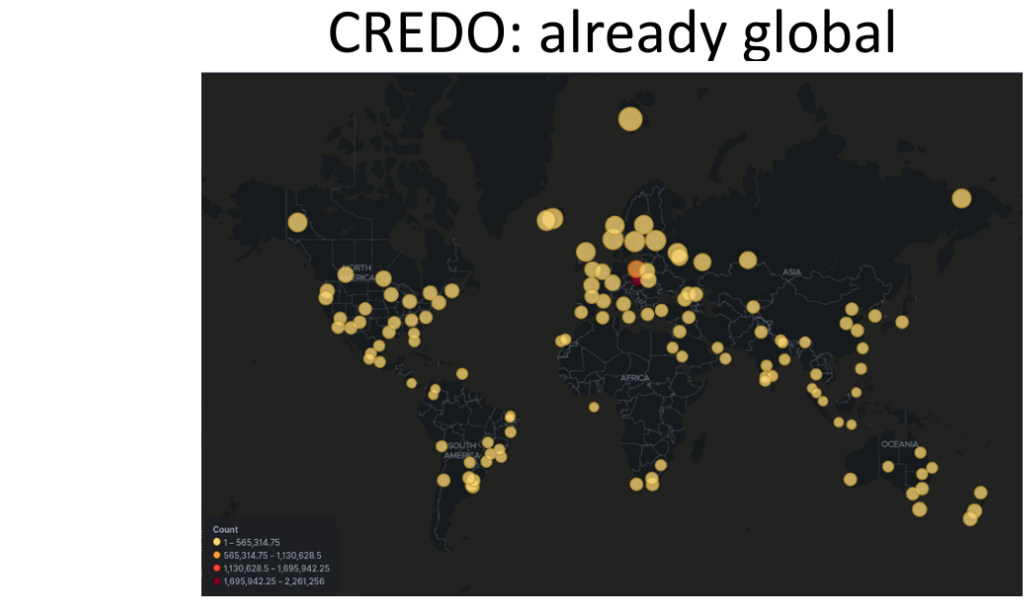

Figure 2: Map of the scientific links and activities of the citizen science of the CREDO project (state of art of the project for July 2021)

Acknowledgements

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References

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