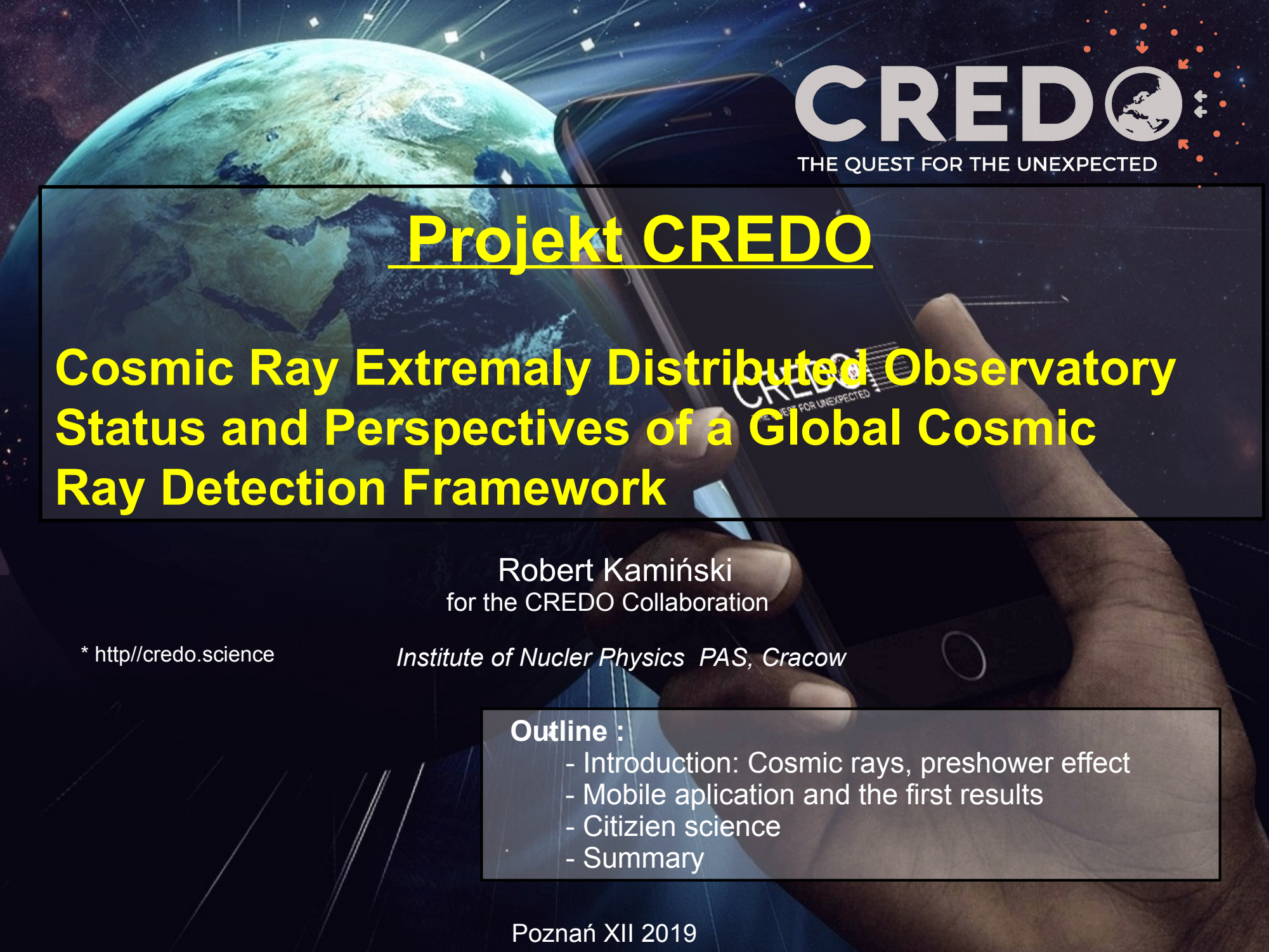


Projekt CREDO

Cosmic Ray Extremaly Distributed Observatory Status and Perspectives of a Global Cosmic Ray Detection Framework

Robert Kamiński
for the CREDO Collaboration

* http//credo.science

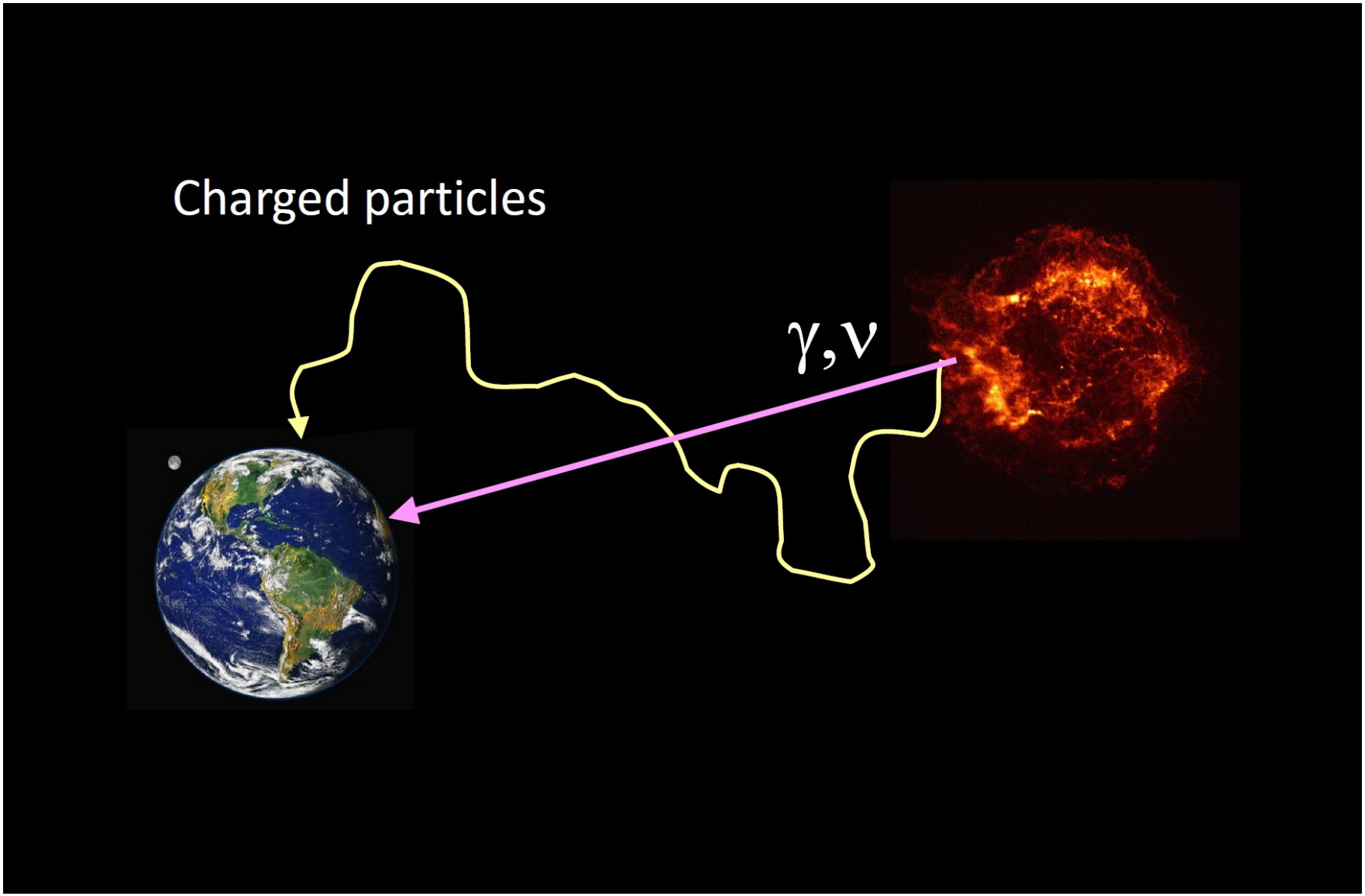
Institute of Nucler Physics PAS, Cracow

Outline :

- Introduction: Cosmic rays, preshower effect
- Mobile aplication and the first results
- Citizien science
- Summary

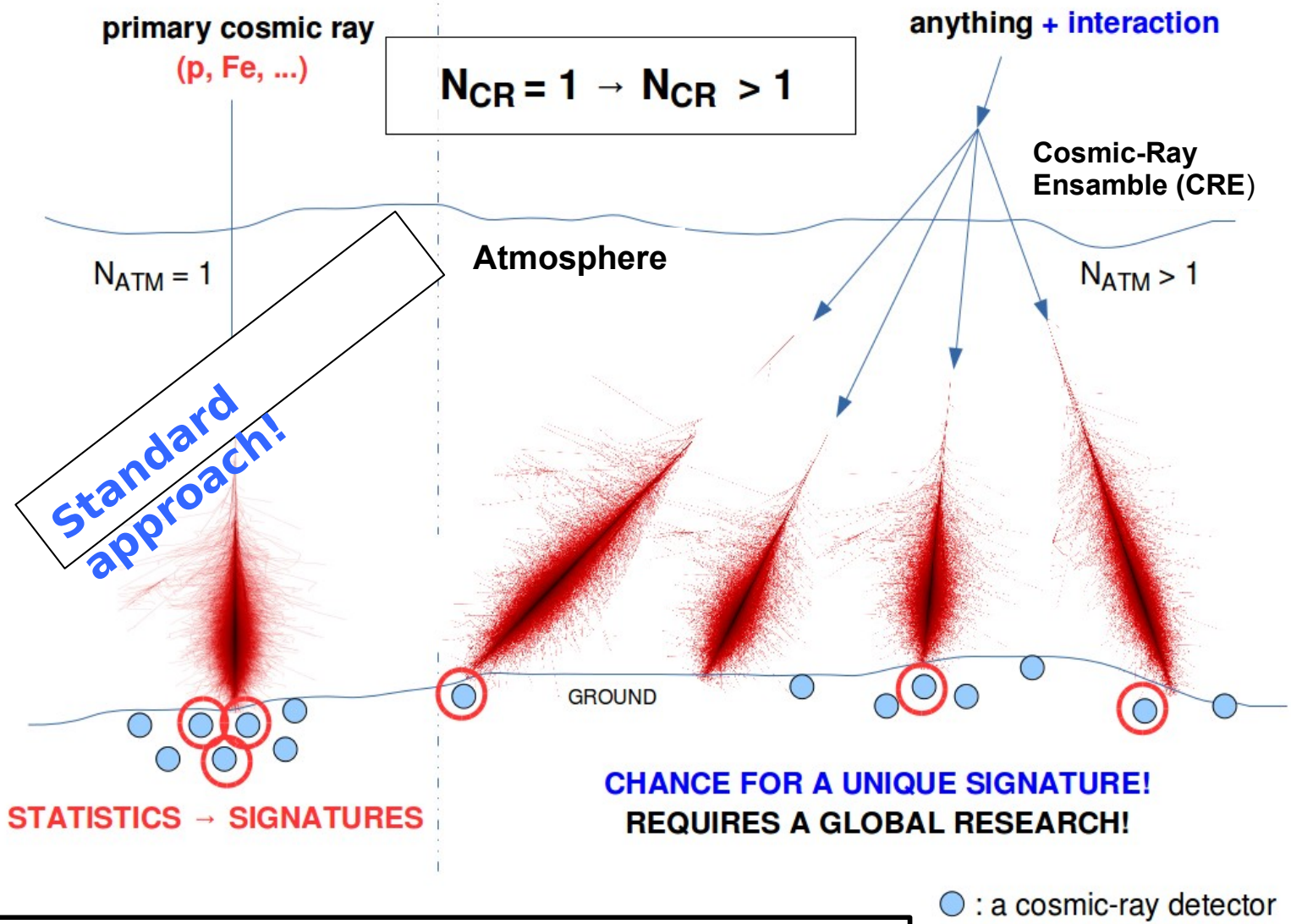
Poznań XII 2019

Charged cosmic rays vs. gamma rays



Motivation: looking for Cosmic Ray Ensambles (CRE)

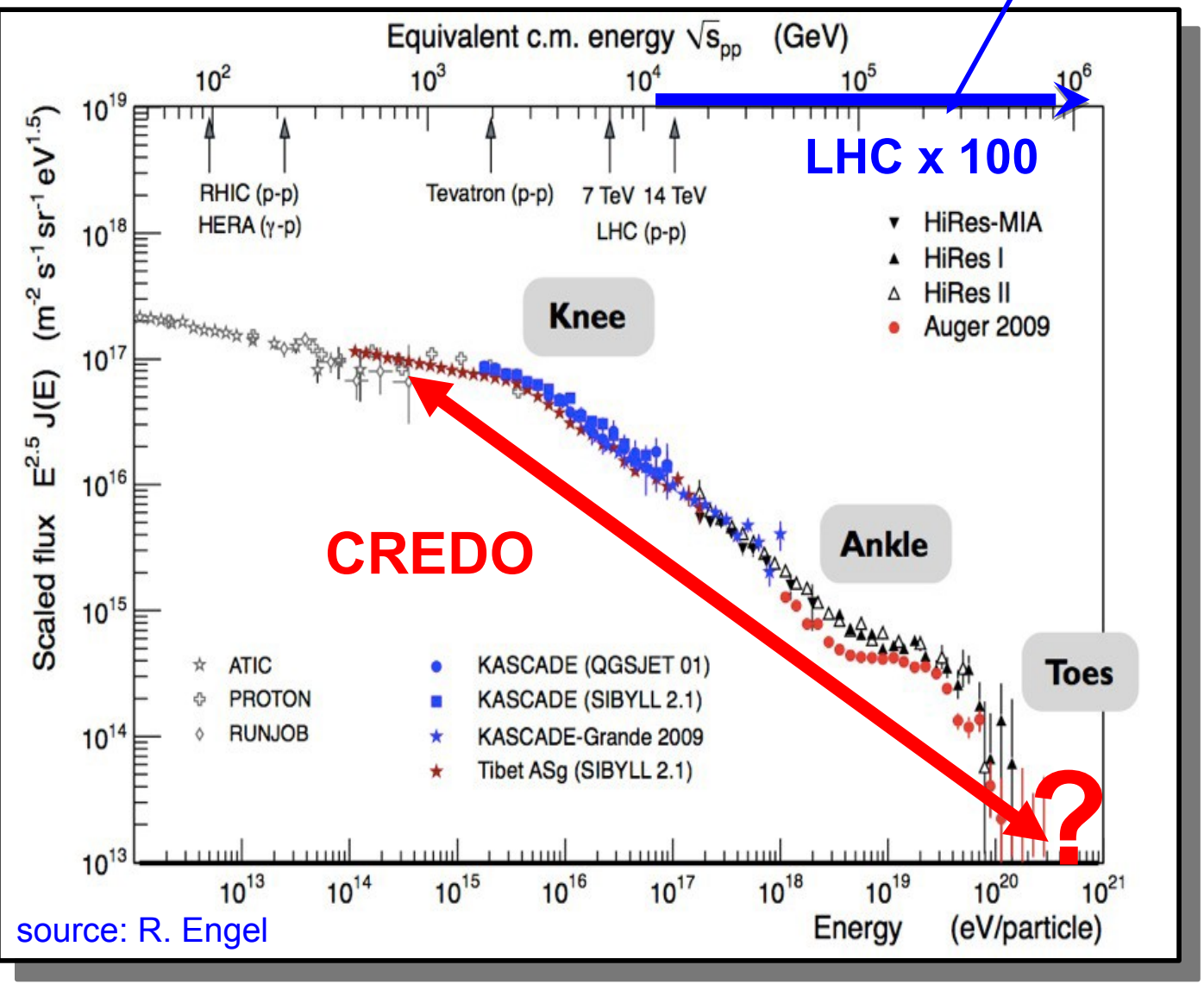
... many air showers and individual particles arriving simultaneously to the Earth ($N_{CR} > 1$)



CREDO strategy: Looking for multiple air showers correlated in time

The Ultra-High-Energy Cosmic Ray mystery

Particle physics beyond the reach of colliders



source: R. Engel

> What's their composition?

> Where do they come from?

→ *anisotropies weakly correlated to known possible sources: active galactic nuclei, gamma-ray burst,…*

> How do they reach such tremendous energies?

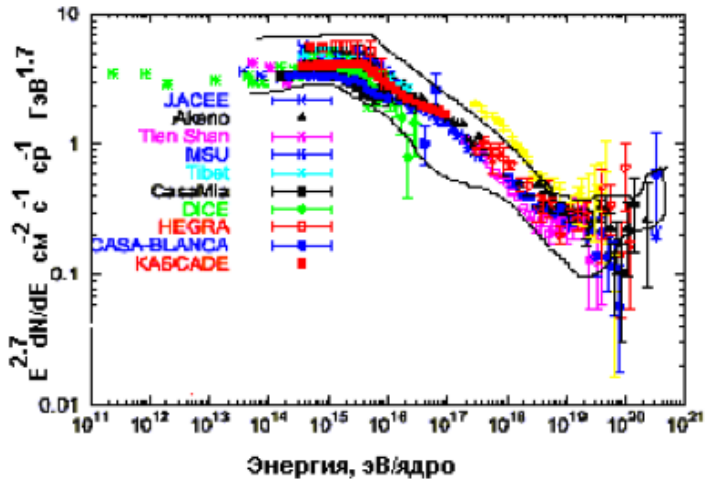
Spectrum suppression:

in the past: *the GZK cut-off*

now: *rather the efficiency limit of particle acceleration by sources*

knee, ankle and toes:

Knee in CR spectrum

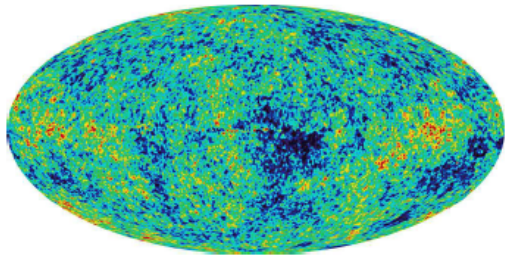


- Knee was discovered by Kulikov
- and Khristiansen in data of MSU
- Experiment in 1958
- It was confirmed by all new
- independent eperiments

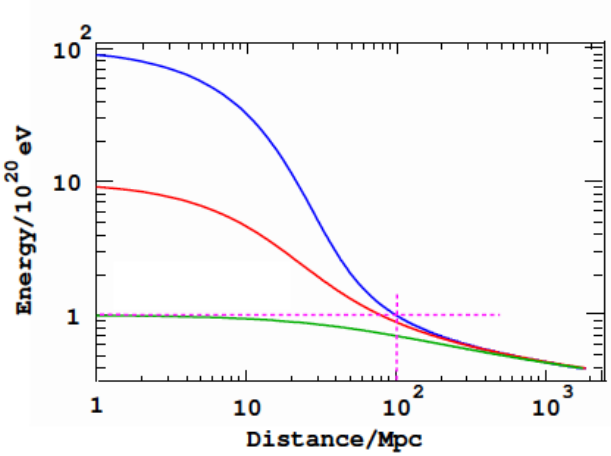
• For long time it was 2 explanations: astrophysical and particle physics one. In partile physics explanation it was assumed that either interaction changes or new particle dominates. Tevatron and LHC finally killed this interpretation.

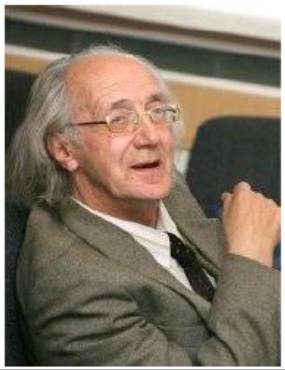
Energy limit for cosmic particles, GZK effect

Greisen-Zatsepin-Kuzmin Effect



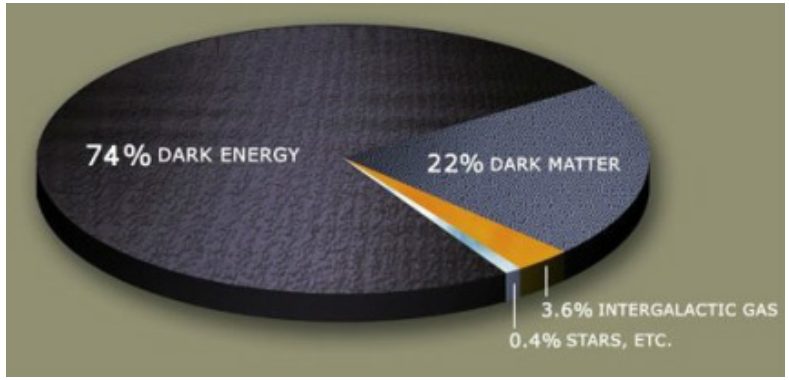
$$p + \gamma_{\mathrm{CMB}} \rightarrow N + \pi$$





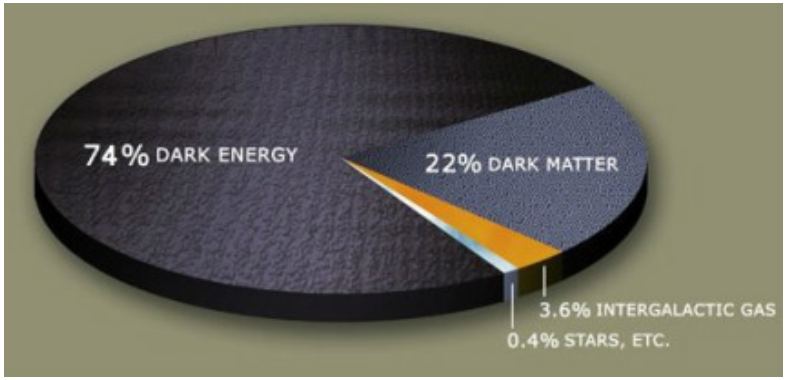
Where do they come from?

Where do they come from?

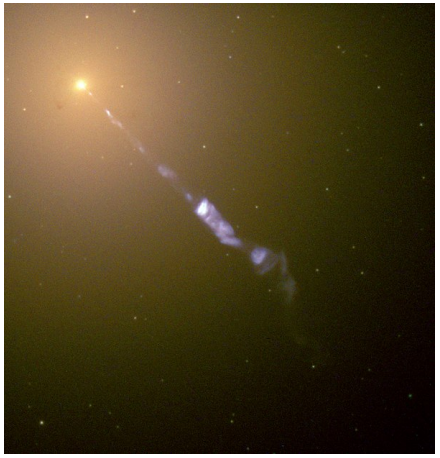


- Decay of dark matter particle?
- Active galactic nuclei?
- Gamma-ray bursts?

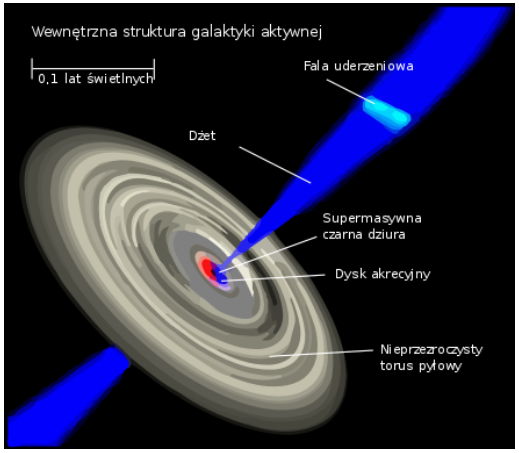
Where do they come from?



- Decay of dark matter particle?

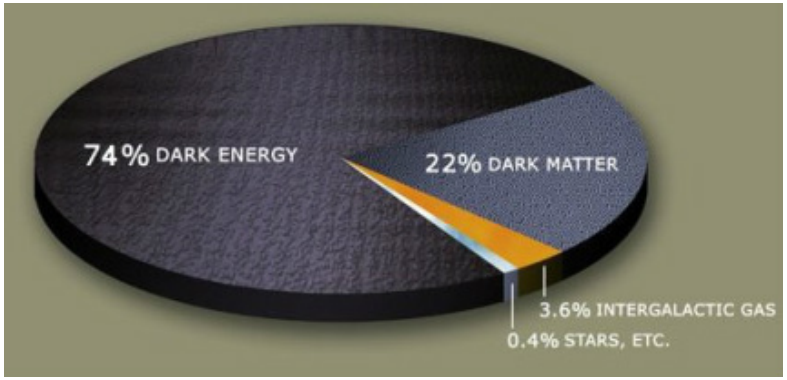


- Active galactic nuclei?

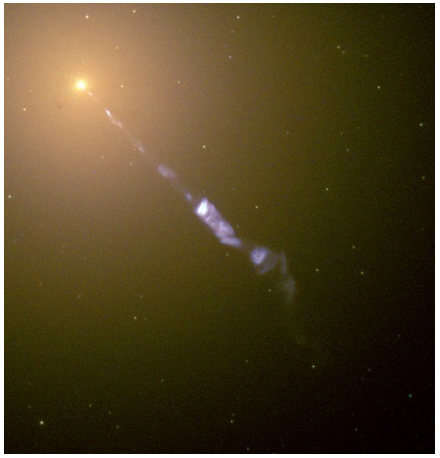


- Gamma-ray bursts?

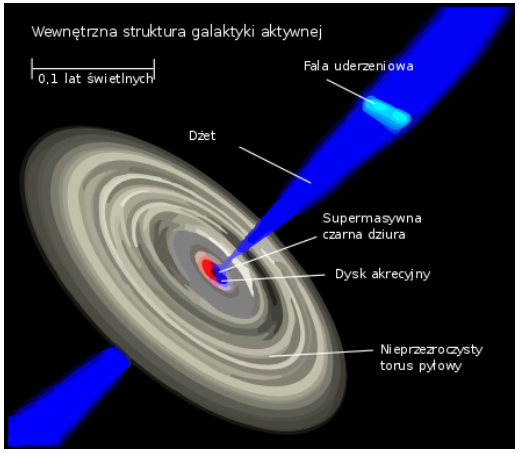
Where do they come from?

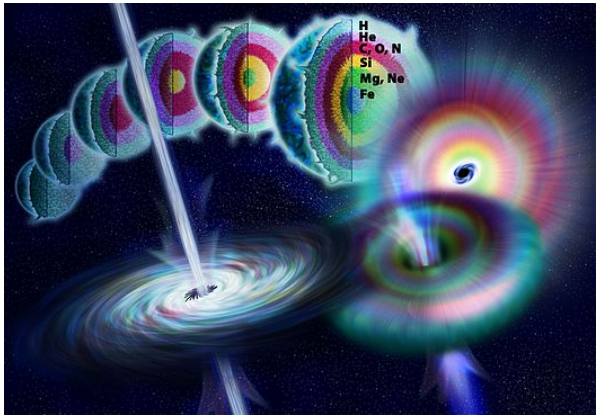


- Decay of dark matter particle?



- Active galactic nuclei?



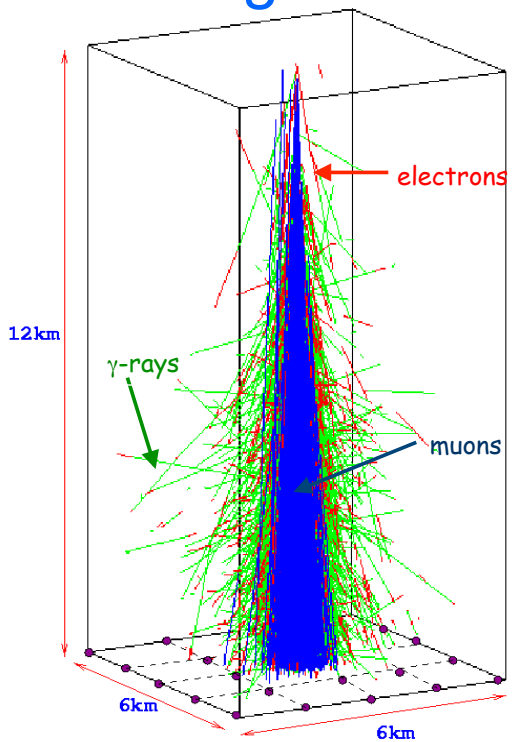


- Gamma-ray bursts?

Cosmic rays

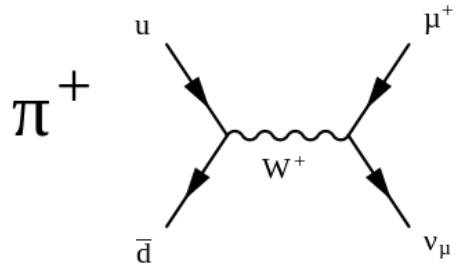
Detection of showers on ground

- Ground array measure footstep of the shower. Final particles at ground level are gamma-rays, electrons, positrons and muons.
- Typically $10^{10\text{-}11}$ photons, electrons and positrons in area 20-50 km^2. It is enough to have detectors with area of few m^2 per km^2. Number of low energy particles is connected to primary energy.
- Space/time structure of signal give information on arrival direction.
- Number of muons compared to number of electrons give information on primary particle kind.

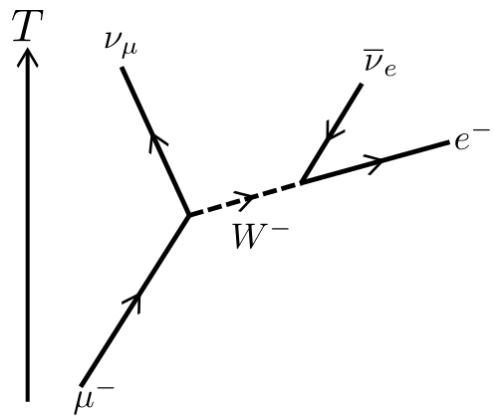


muons

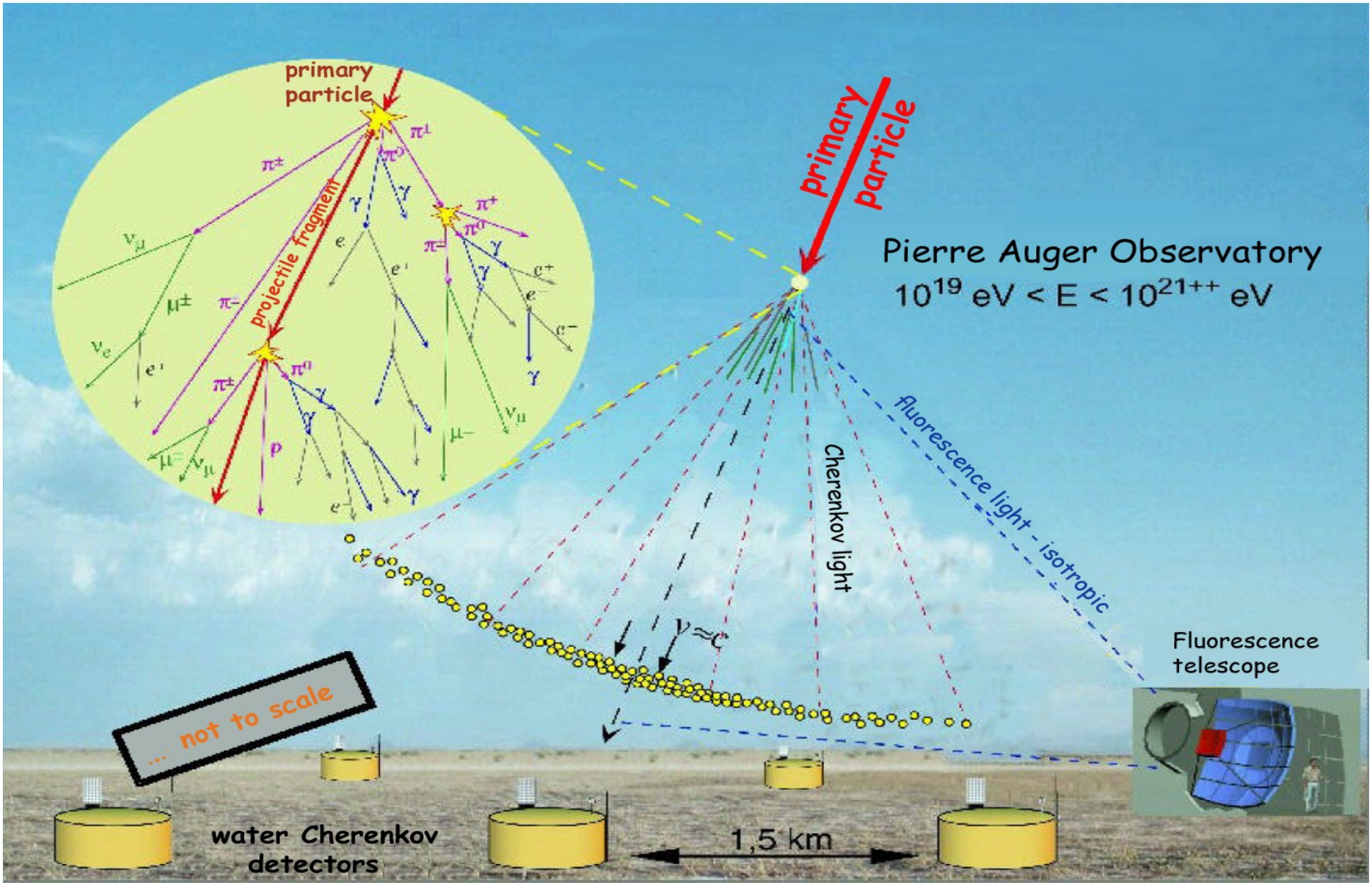
pions, e.g. $\pi^+ = u\bar{d}$, M = 139 MeV, average life time $\tau = 2.6 \times 10^{-8}$ s, pion decay: $\pi^+ \rightarrow \mu^+ + \nu_\mu$



muons: M = 105.66 MeV, average life time $\tau = 2.2 \times 10^{-6}$ s $\rightarrow$ 660 m, decay: $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$

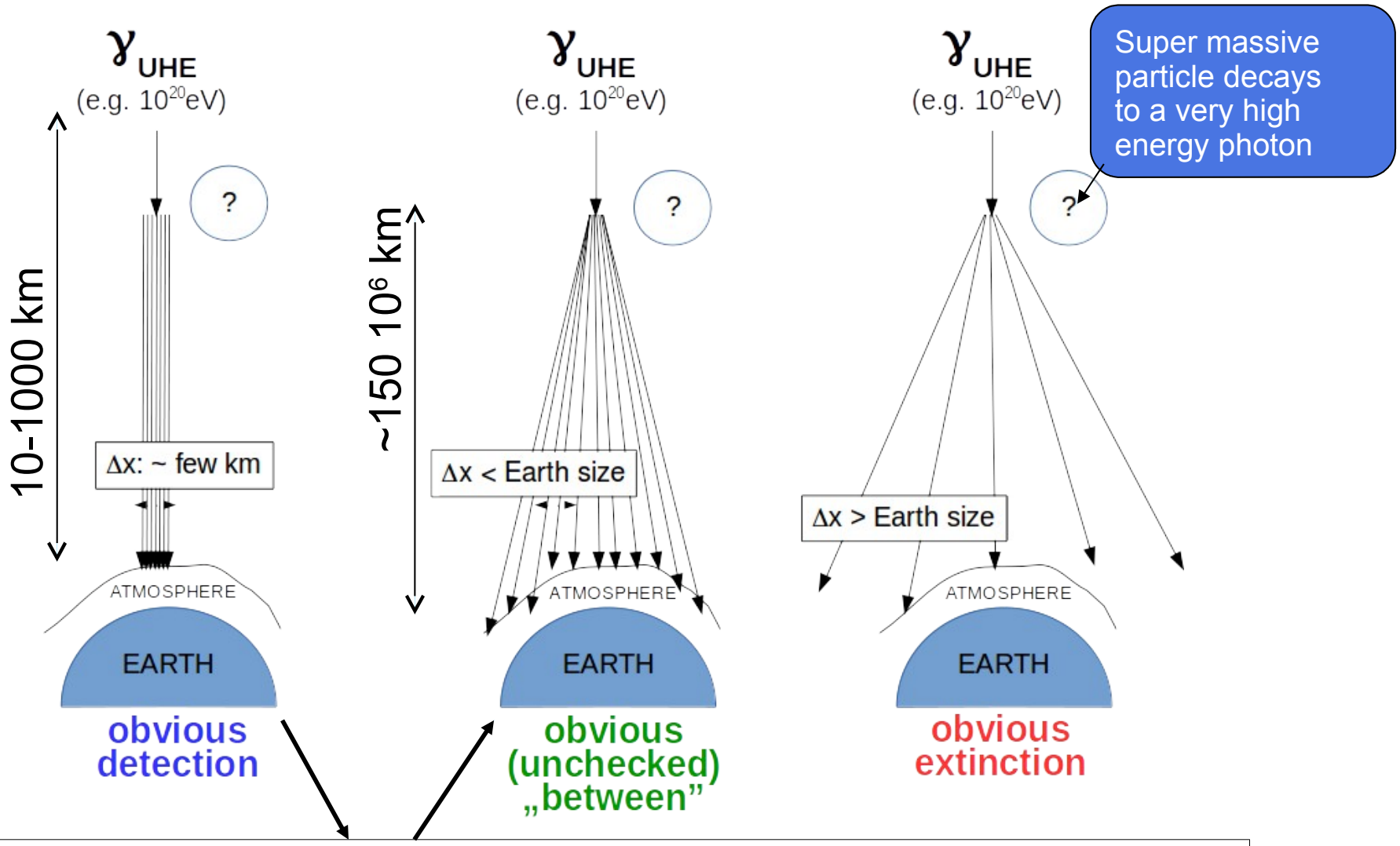


Big atmospheric showers: (N_{ATM} = 1)



Classes of CRE

Multiple scenarios: are possible based on the distance between the interaction point and the Earth's atmosphere, and the nature of the interaction.



$N_{cr} > 1$ scenario have been reported in the literature:

G.R. Smith et al., Phys. Rev. Lett. 50 (1983) 2110;177; D.J. Fegan and B. McBreen, Phys. Rev. Lett. 51 (1983) 2341

but they have not been observed repeatedly until now.

$N_{ATM} > 1$: data in literature ! (1)

VOLUME 50, NUMBER 26 PHYSICAL REVIEW LETTERS 27 JUNE 1983

Possible Observation of a Burst of Cosmic-Ray Events in the Form of Extensive Air Showers

Gary R. Smith, M. Ogmen, E. Buller, and S. Standil
Physics Department, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

(Received 7 April 1983)

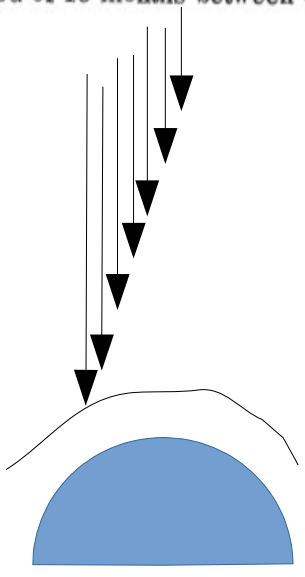
A series or burst of 32 extensive air showers of estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 1[illegible] such showers in a period of 18 months between October 1980 and April 1982.

PACS numbers: 94.40.Pa, 94.40.Rc, 95.30.-k

Hidden treasure 1

Cosmic ray group?

$N_{ATM} > 1$?



$\Delta x >=$ small

Year = 1981
$N_{obs} = 32$
$N_{exp} = 1$
$E = 3x10^{15}eV$

$N_{ATM} > 1$: Data in literature (2)

VOLUME 51, NUMBER 25 PHYSICAL REVIEW LETTERS 19 DECEMBER 1983

Observation of a Burst of Cosmic Rays at Energies above 7×10^{13} eV

D. J. Fegan and B. McBreen
Physics Department, University College Dublin, Dublin 4, Ireland
and
C. O'Sullivan
Physics Department, University College Cork, Cork, Ireland
(Received 14 September 1983)

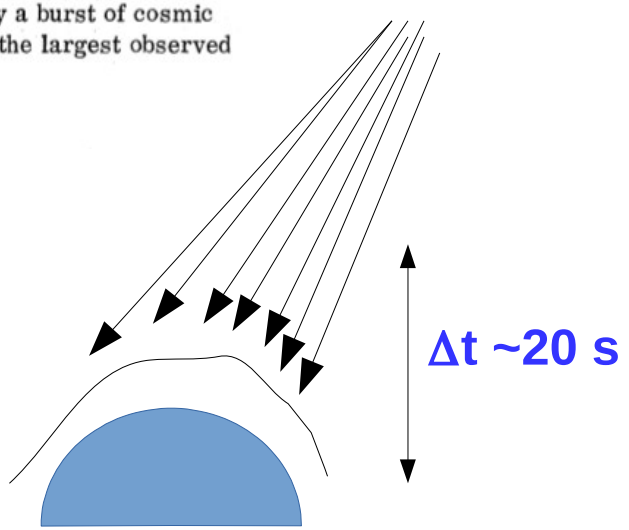
The authors report on an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations separated by 80 km. The event lasted for 20 s. This event was the only one of its kind detected in three years of observation. The duration and structure of this event is different from a recently reported single-station cosmic-ray burst. The simultaneity of the coincident event suggests that it was caused by a burst of cosmic gamma rays. There is a possibility that this event may be related to the largest observed glitch of the pulsar in the Crab Nebula.

PACS numbers: 94.40.Pa, 95.85.Qx, 97.80.Jp

Hidden treasure (?) nr 2

Cosmic ray group?

$N_{ATM} > 1$?



Δx >=250 km

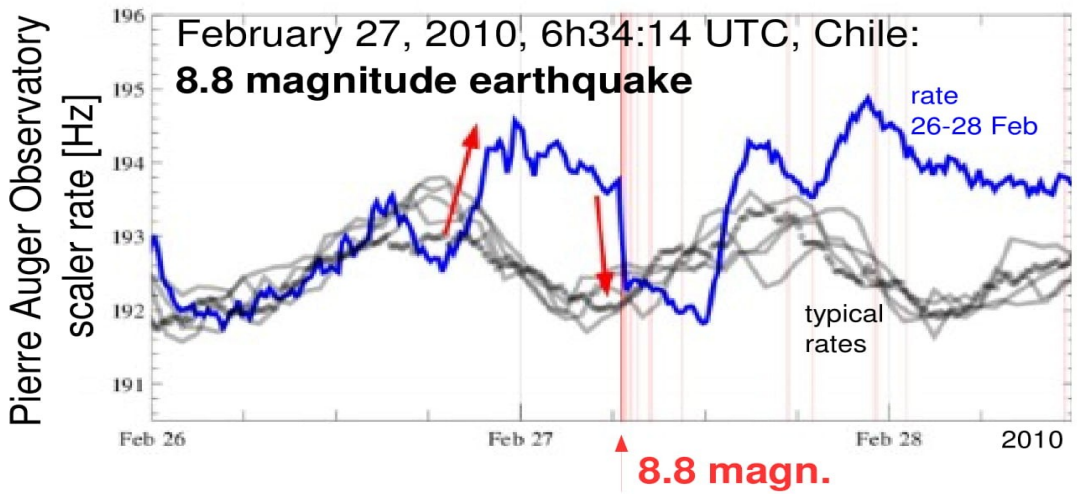
CREDO for Geo, cosmic rays vs earthquakes

CREDO

THE QUEST FOR UNEXPECTED

Scientific diversity: GEO

PAO sees earthquakes [by A. Saleh]



- Increase of CR before the earthquake
- Strong drop during the earthquake

→ **CREDO-earthquakes task** [already existing]

Inhabitants of territories threatened by earthquakes [= potential CREDO public egagement target]:

2,7 billion people

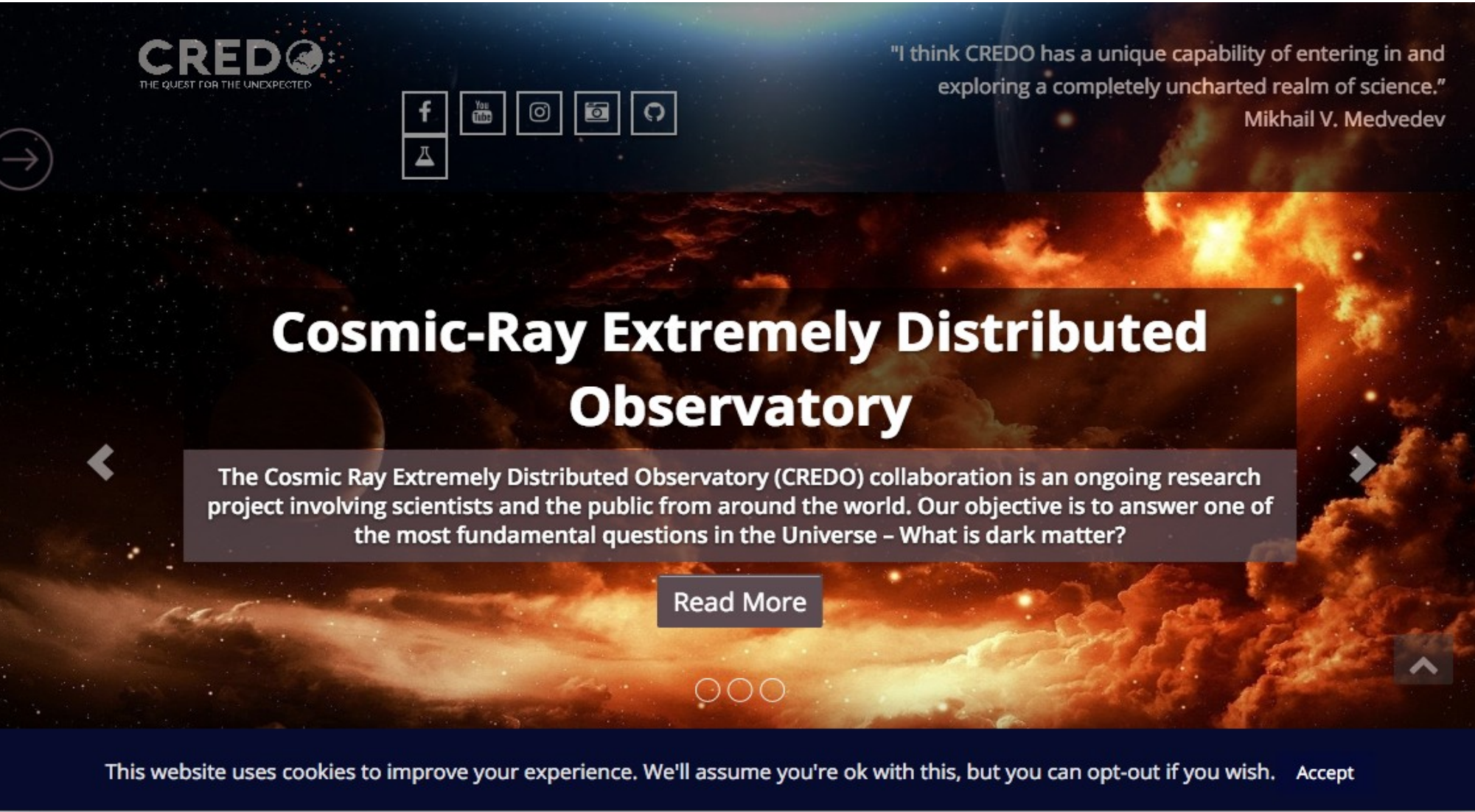
Science as a service to the human community?

Even the smallest chance to save lives

= **a must check!**

62

For more information visit CREDO.science



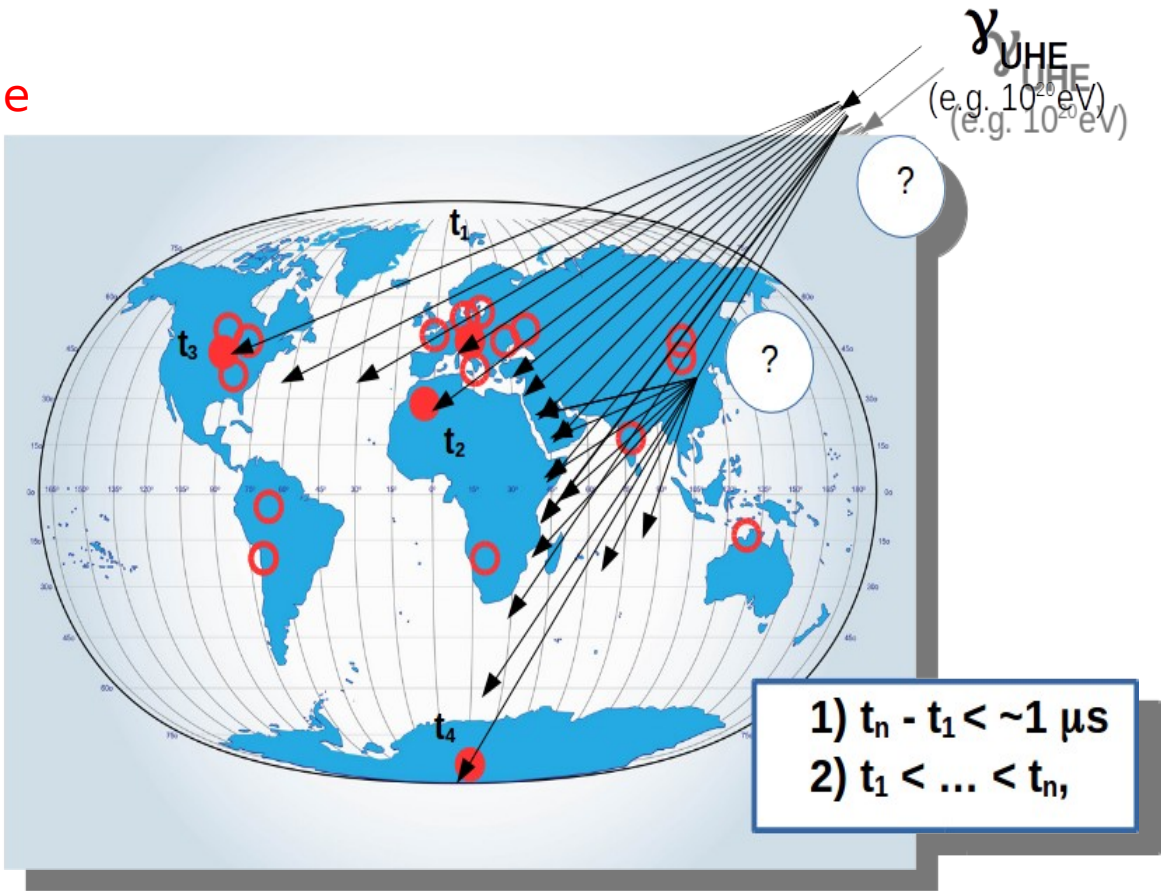
CREDO PROJECT

Cosmic-ray Extremaly Distributed Observatory

CREDO's main idea:

creating a global network of particle detectors!

How?...



Cosmic-ray Extremaly Distributed Observatory

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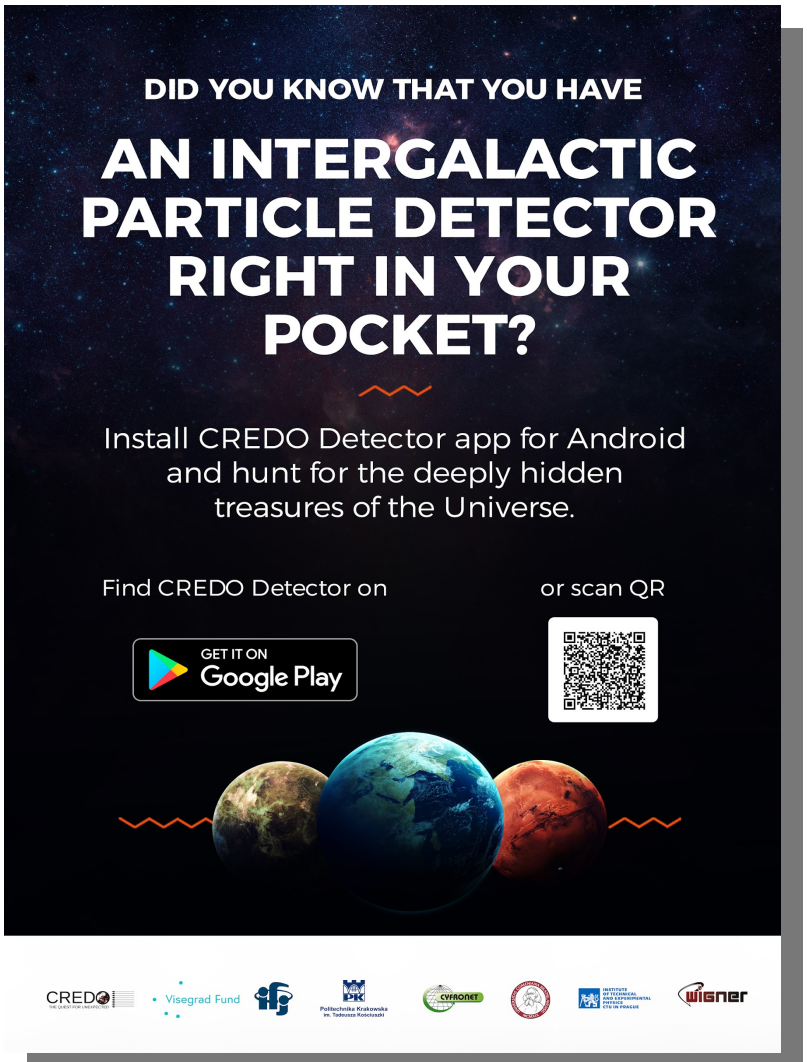

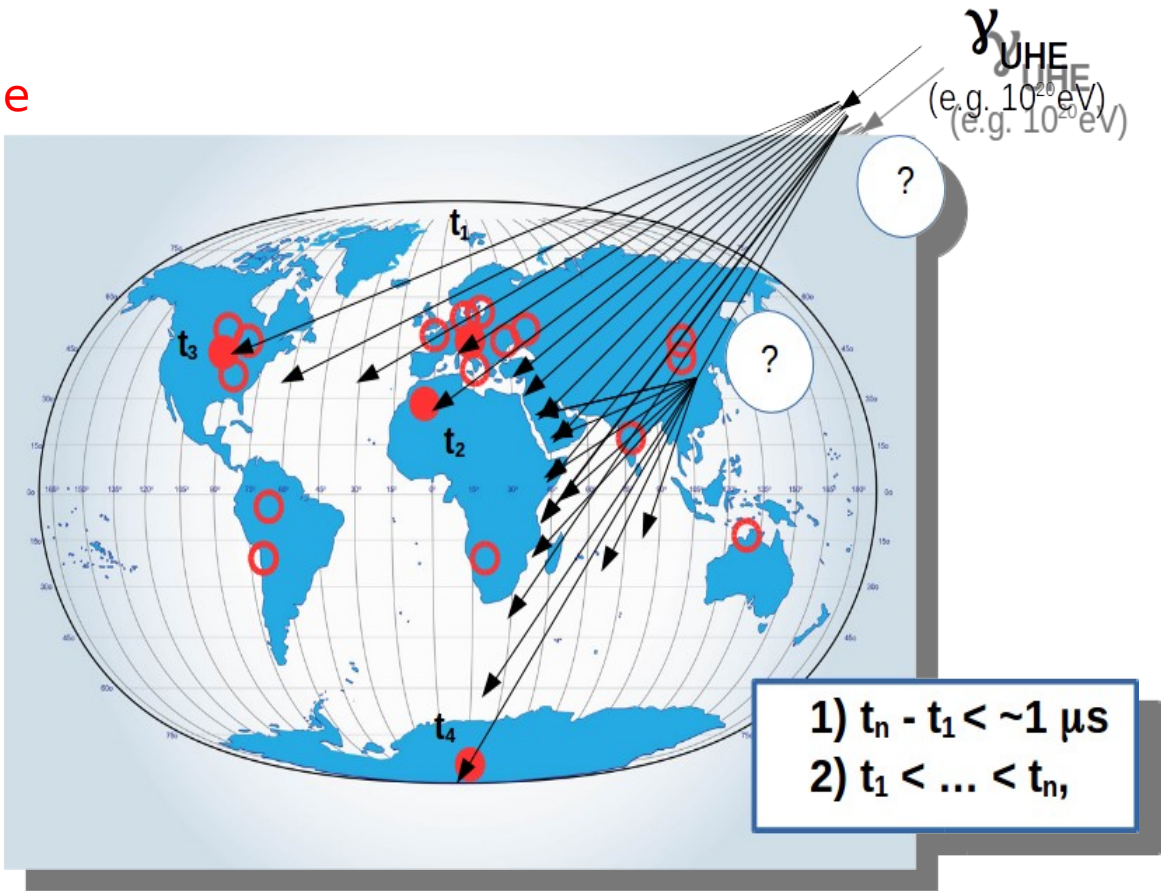

Code of application is public on GitHub:
https://github.com/credo-science
Different version available:
CREDO-PC-Windows, CREDO-Desktop-Det., Raspberry-Pi,...

Cosmic-ray Extremaly Distributed Observatory

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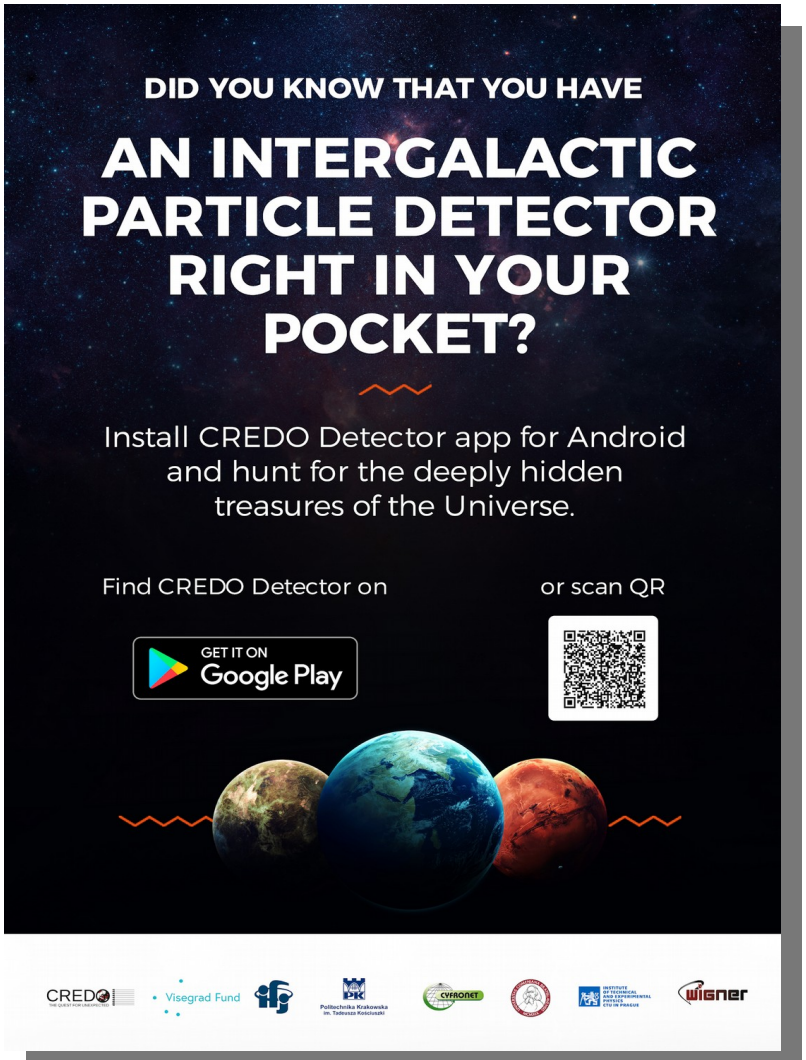
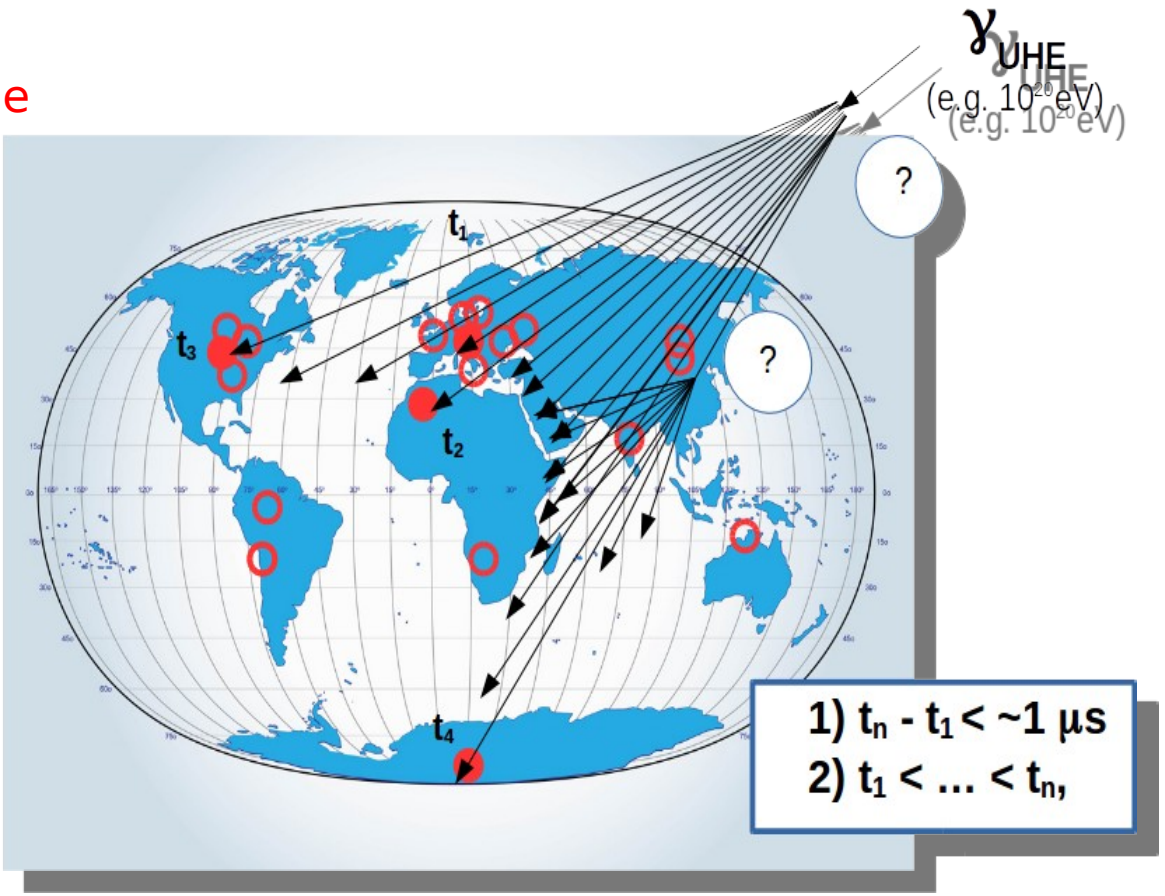




+ small type of scintilator detectors, PoS(ICRC2019)428

+ connecting **existing observatories** to the network

Code of application is public on GitHub:
https://github.com/credo-science
Different version available:
CREDO-PC-Windows, CREDO-Desktop-Det., Raspberry-Pi,...

Mobile application

> Smartphone application developed by CREDO collaboration, PoS(ICRC2019)367

Motivation: D. Groom, *Cosmic rays and other nonsense in astronomical CCD imagers*, Experimental Astronomy (2002) 14, 45

Principle:

particles hitting the camera sensors and triggering pixels by depositing energy*

> Detections are filtered to remove artifacts and stored in a central database (Cyfronet AGH-UST).

> Analysis are run to search for peculiar signal signatures.

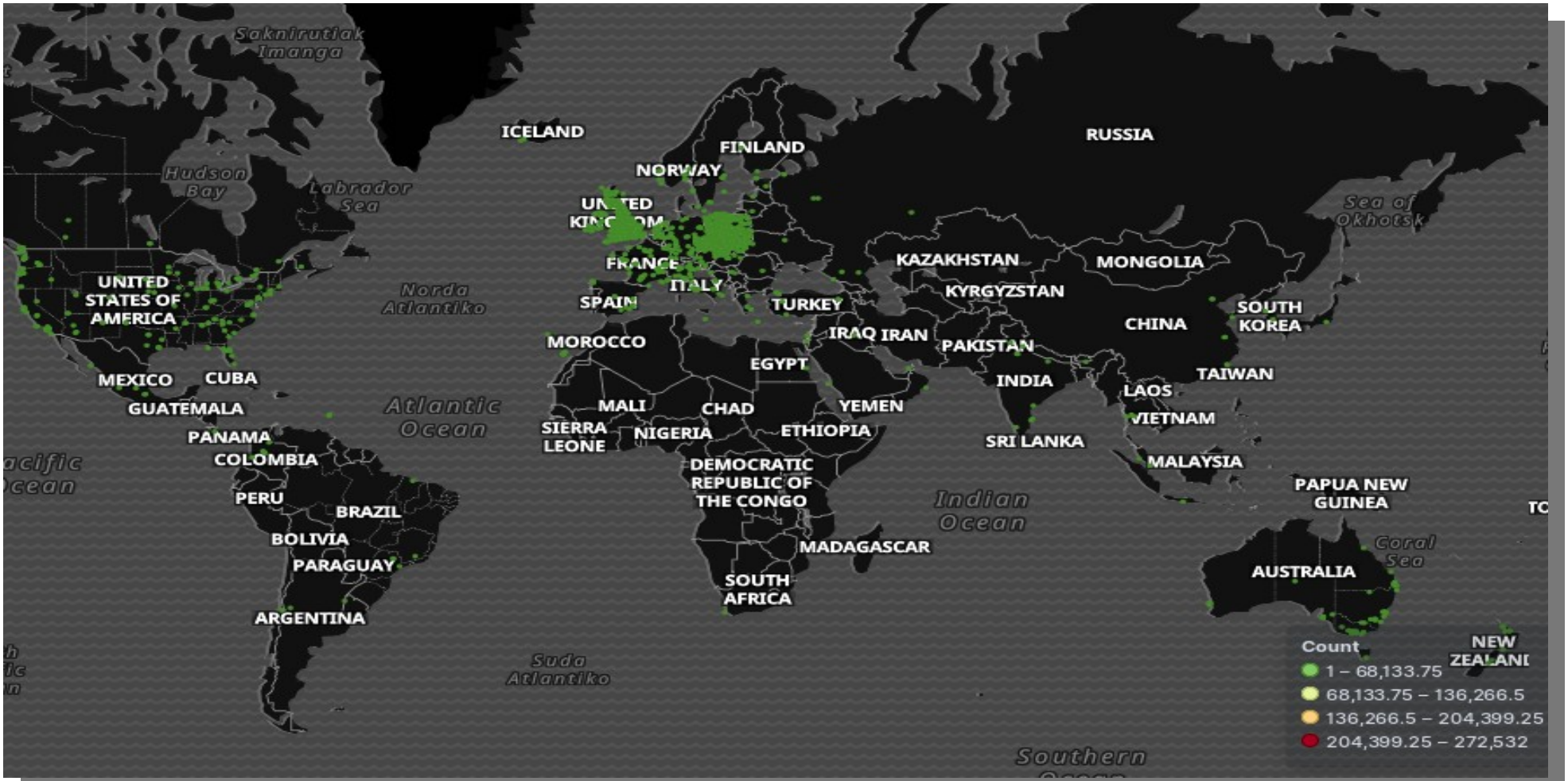
> Users can access the data they collected and see the results from the analysis run on their data

STIMULATES CITIZEN SCIENCE !

**The DECO/CRAFIS project* demonstrate discrimination between GeV cosmic-ray muon tracks and MeV electron, see Journal of Instrumentation 2016 11, P04019; M. Winter et al., Particle Identification In Camera Image Sensors Using Computer Vision, Astropart. Phys. (2019), 104, 92. However, large number of smartphones (~10^6 M. Unger and G. Farrar, [arXiv:1505.04777] are needed to reach the sensitivity comparable to the largest cosmic-rays observatories.)

Mobile application: we already reach the global scale !

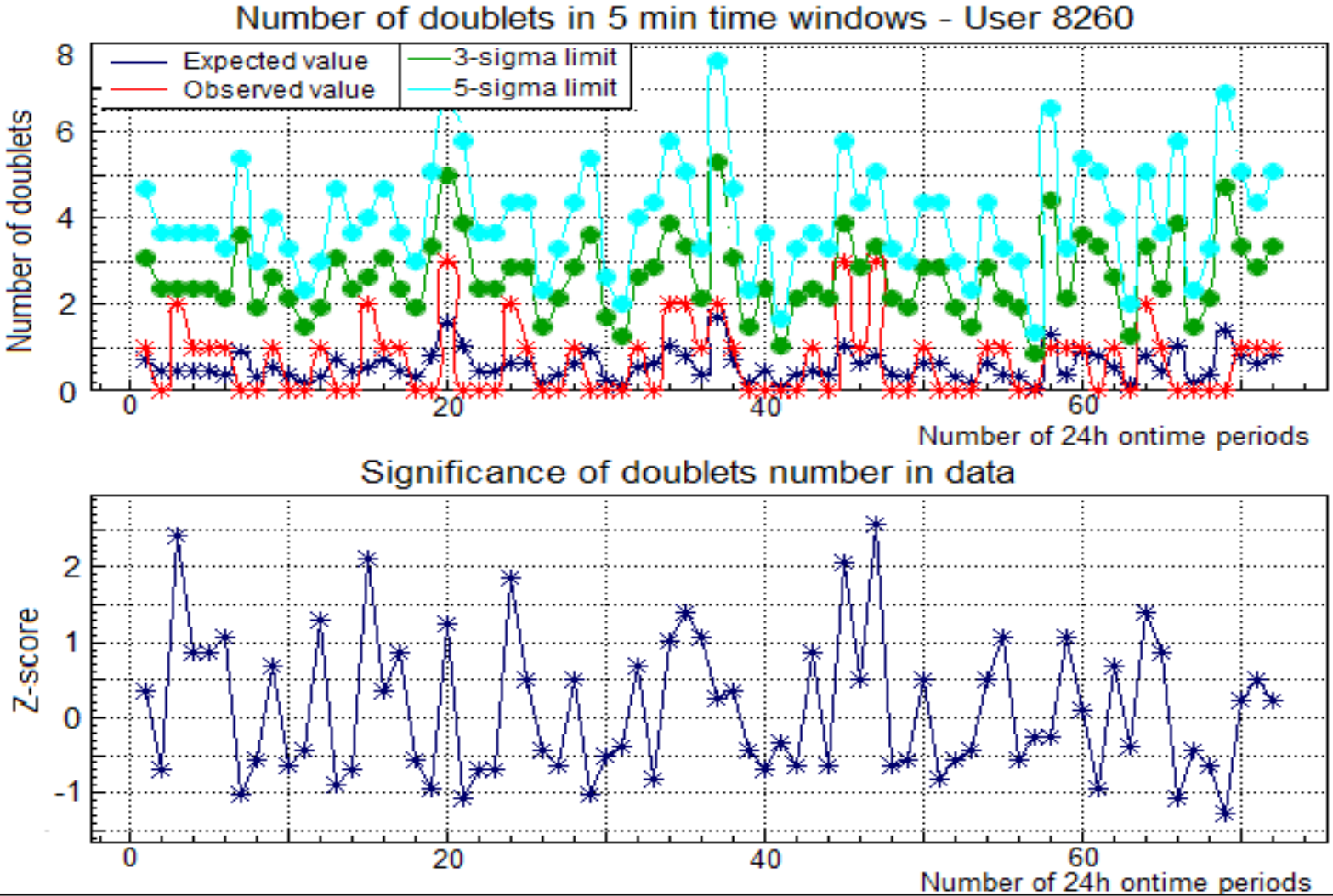
> Location of users since the launch based on data from:
https://api.credo.science/web/



Statistics from launch to July 25th 2019: > **7500 users** with at least 1 detections **~3 200 000 detections** App running time sums up to **947 years**

Example of analysis on data from individual users

> **First achievement (4.10.2018):** the signal from the first automatized, mass participation scientific experiment on the CREDO infrastructure

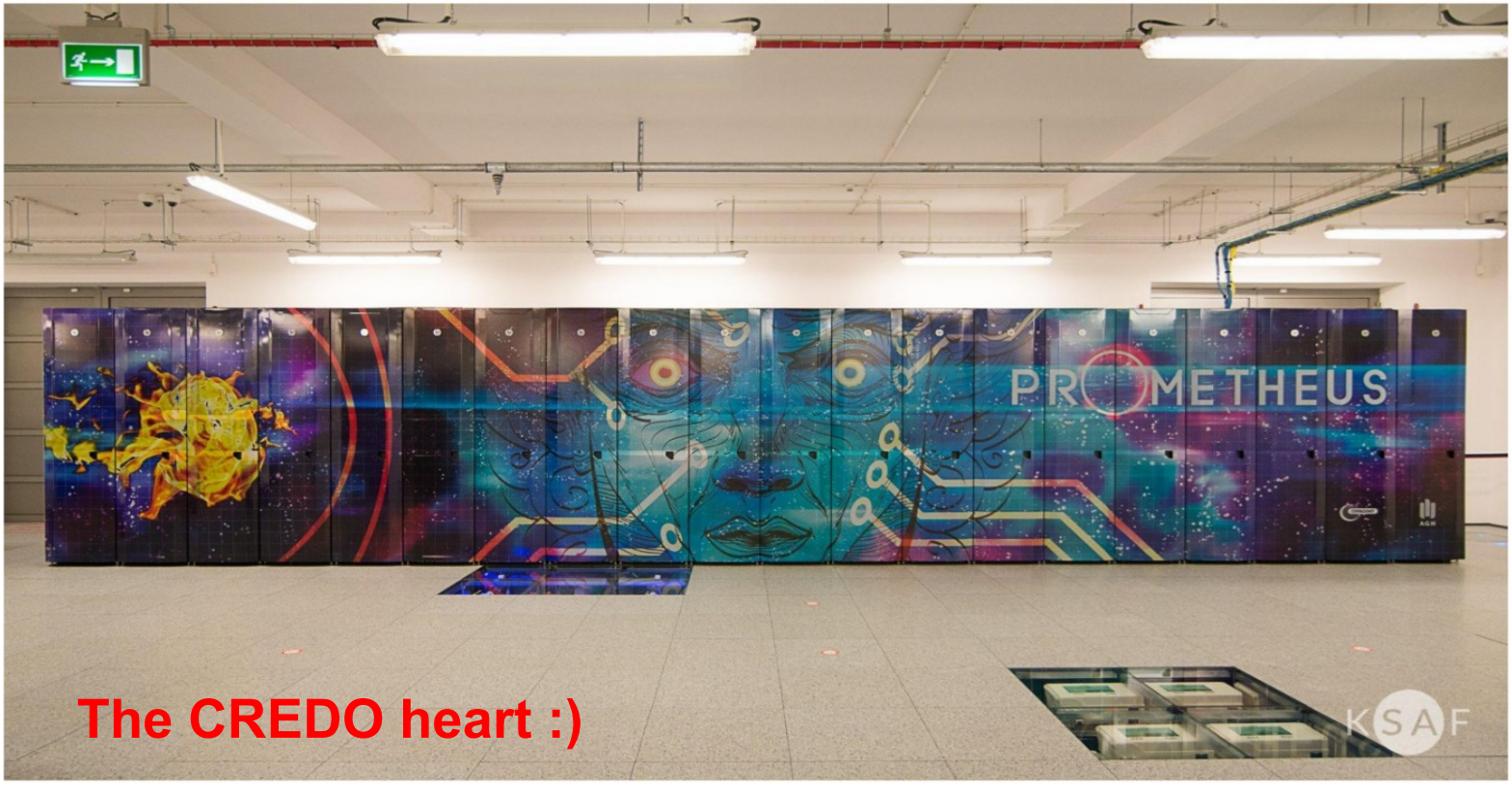


A significance of given doublet is calculated using scrambled technique, as described in *D.G. et al., Universe, 4(11) (2018) 111*.

Mainframe (AGH Univ., Krakow)

Visegrad Fund

2140 TFLOPS in CPUs + 256 TFLOPS in GPUs
2232 nodes, 53568 CPU cores, 279 TB RAM
10 PB usable disk space @ 180 GB/s

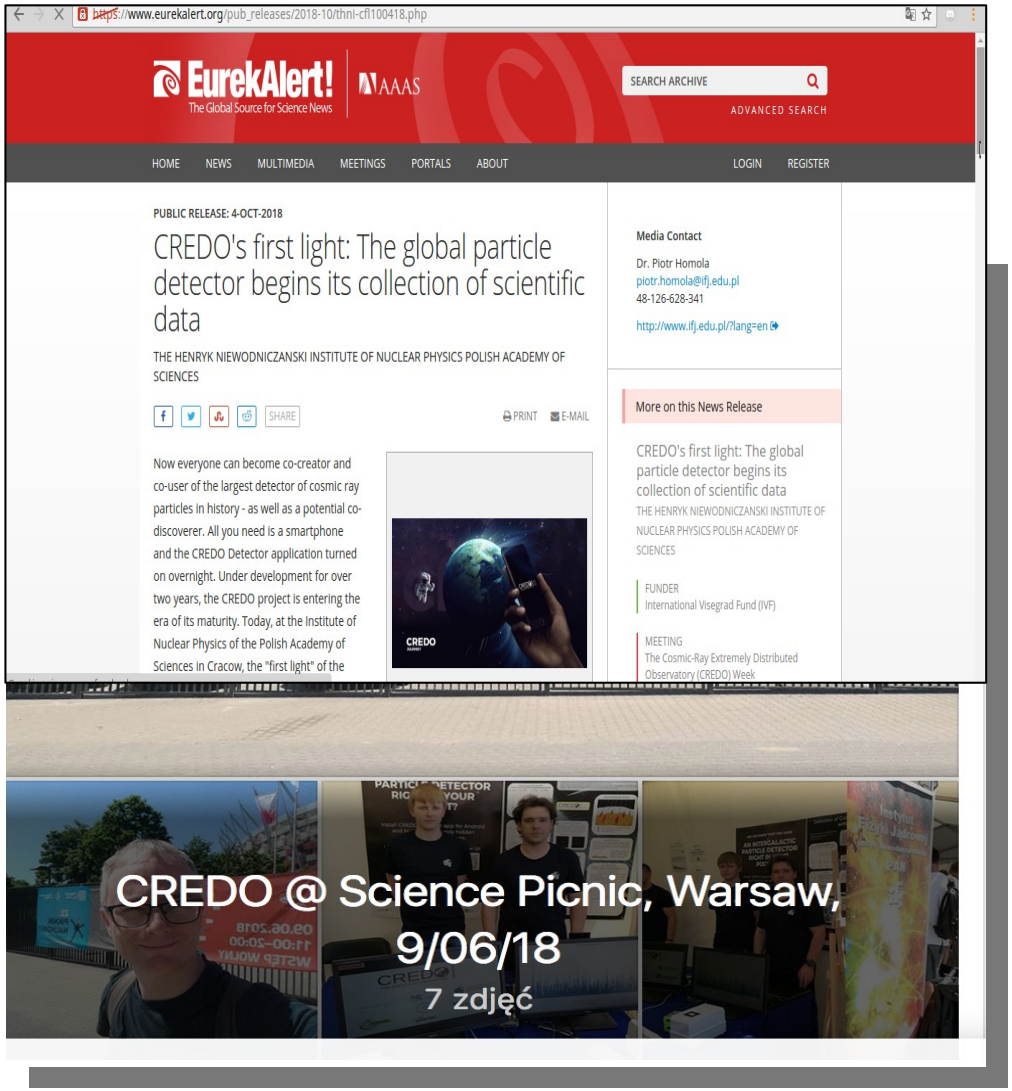


The CREDO heart :)

2.4 PFLOPS, #59 ON TOP500

Spreading the word...

> The second goal of CREDO involves a large number of participants (citizen science!)



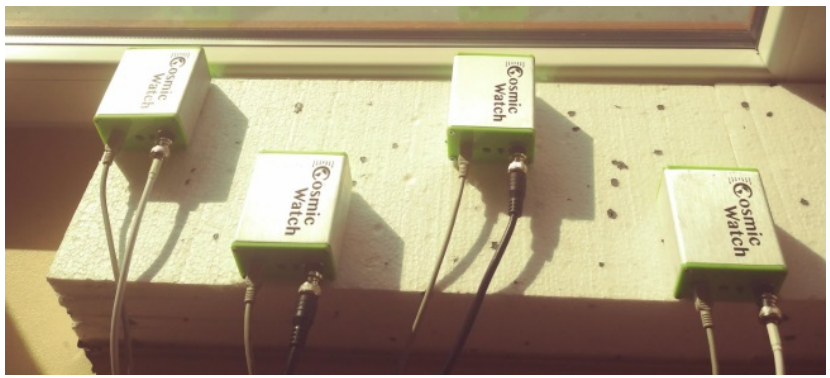
Particle Hunters League and Marathon!
Not only for schools!

https://credo.science/lowcyczastek

> Conferences: CREDO week,…
https://indico.ifj.edu.pl/event/213/

July 2019: ~ 1200 participants
from ~ 60 schools!

Pierwsza obserwacja pęku atmosferycznego przez CREDO (październik 2019)



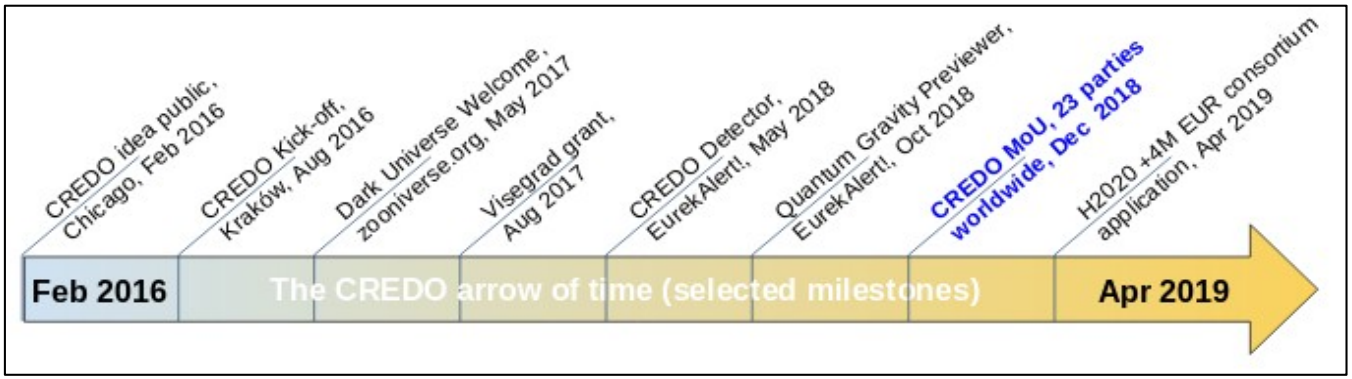
Conclusion

CREDO: a unifying, global cosmic-ray project: GeV – ZeV→ completing the closest accessible approach to GUT scale.

23 institutions representing **11 countries** [Australia (2),Czech Republic (2), Georgia (1), Hungary (1), Mexico (1), Nepal (1), Poland (8), Russia (1), Slovakia (1), Ukraine (2), USA (3)] are institutional members.

Many others ongoing projects:

- Ultra-high energy photon propagation simulations with CRPropa.
- Simulations of smartphone detectors' response to air showers.
- Calibration of smartphones for air showers and muons.
- Search for correlations between cosmic-rays and earthquakes on a global scale.
- "*Gamification*" for public outreach and development of low-price detectors



Conclusion2

What does **CREDO** mean?

Cosmic **R**ay **E**xtremeley
Distributed **O**bservatory

Conclusion2

What does **CREDO** mean?

Creative **R**esearch,

Conclusion2

What does **CREDO** mean?

Creative **R**esearch, **E**ducation

Conclusion2

What does **CREDO** mean?

Creative **R**esearch, **E**ducation and **D**evel**O**pment

Physics and astrophysics

Physics $\rightarrow$ astrophysics

Physics:

Physics:

Astrophysics:

Physics and astrophysics

Physics and astrophysics

Physics and astrophysics

Poznań XII 2019

MIŁEGO POBYTU W POZNANIU
OWOCNYCH DYSKUSJI,
DOBRYCH PREZENTACJI I ...
UDZIAŁU W PROJEKCIE CREDO!!!

CIESZMY SIĘ FIZYKĄ I ASTROFIZYKĄ!

Dziękuję za uwagę!