Cosmic-Ray Extremely Distributed Observatory*: novel astrophysical potential and beyond

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Piotr Homola□

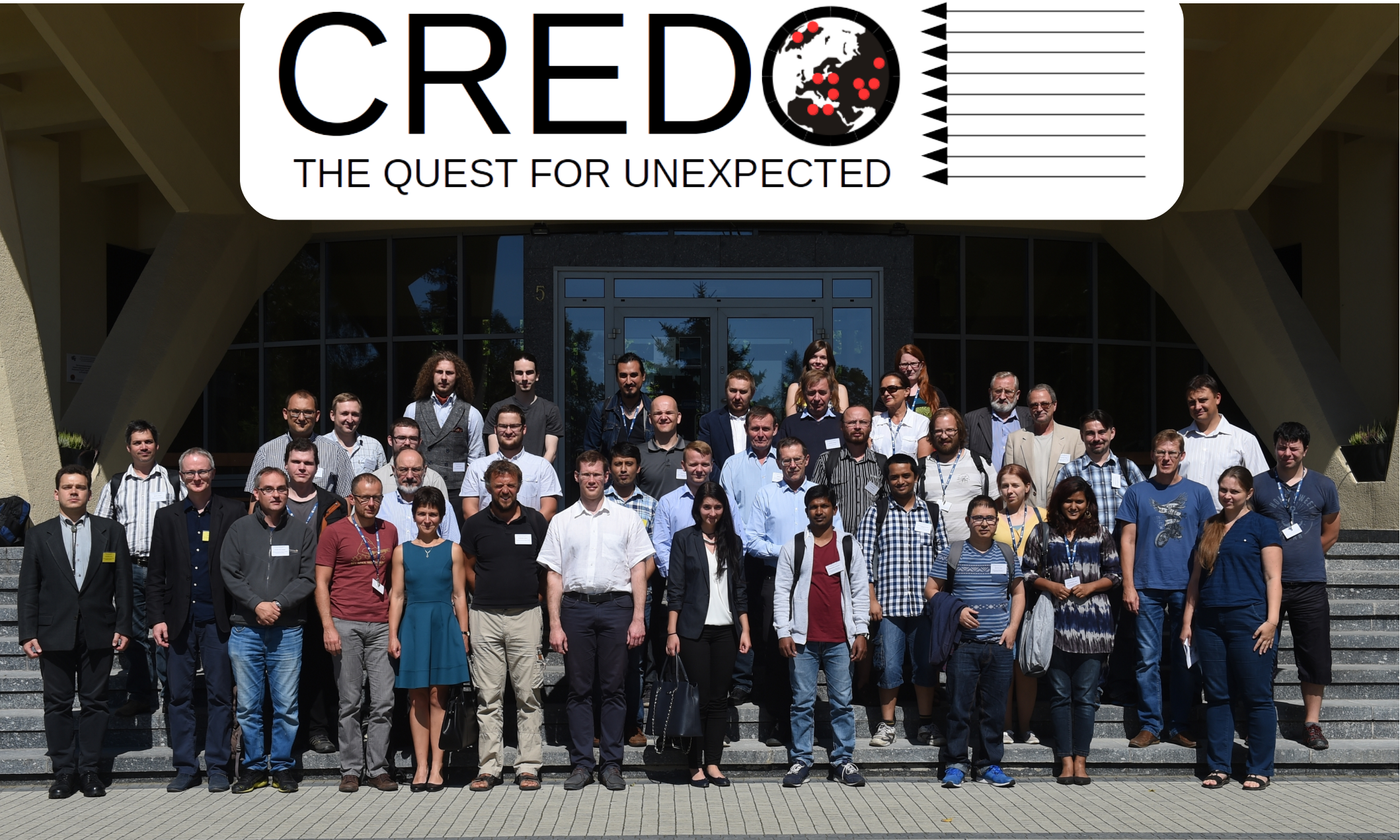
□) Institute of Nuclear Physics
Polish Academy of Sciences, Kraków, Poland
*) http://credo.science

take home:
$N_{ATM} >= 1$!

CREDO Project Meeting, Comenius University, Bratislava, 19.03.2018

CREDO

THE QUEST FOR UNEXPECTED



CREDO The 1st Anniversary Symposium
IFJ PAN Kraków, 30th August 2017

fot. Jan Zych

We simply love cosmic rays...

Particles coming to Earth from Space

1912. Electroscopes discharge faster with increasing altitude → rays of extraterrestrial origin: V. Hess (Nobel prize 1936).

1932. Discovery of antimatter (positron): C. Anderson (Nobel prize 1936).

1937. Discovery of muons: S. Neddermeyer and C. Anderson → particle physics begins.

1938. Extensive air showers (EAS) → $E > 10^{15}$ eV: P. Auger

1962. First EAS at 10^{20} eV: J. Linsley
→ what and why can have so huge energies???

.... high time for a next breakthrough?

… and we love them all :)

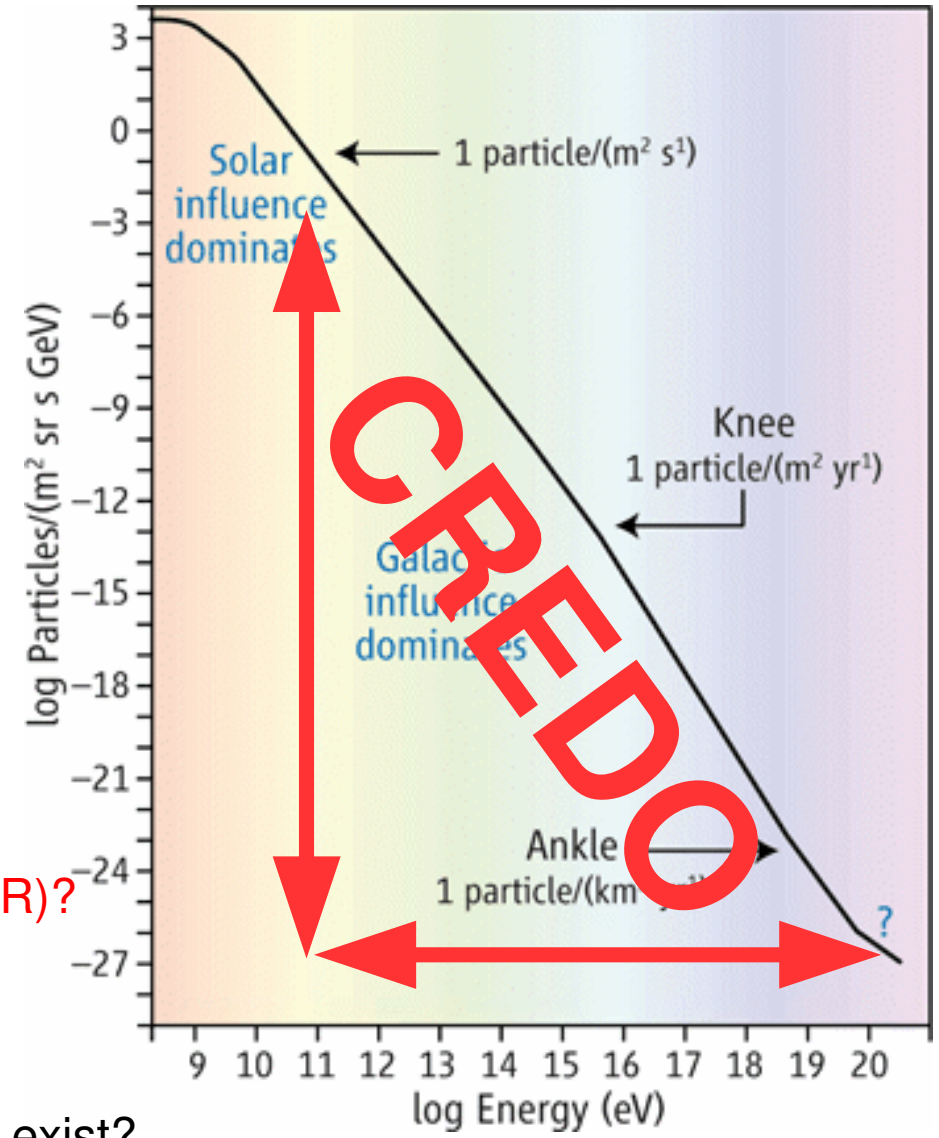
Ranges:
energy: > 10 orders of magnitude
flux: > 30 orders of magnitude
→ diverse physics (sources)
→ diverse detection techniques

Flux rapidly decreases with energy (~10^{-3}),
Highest energies → the most demanding challenges:

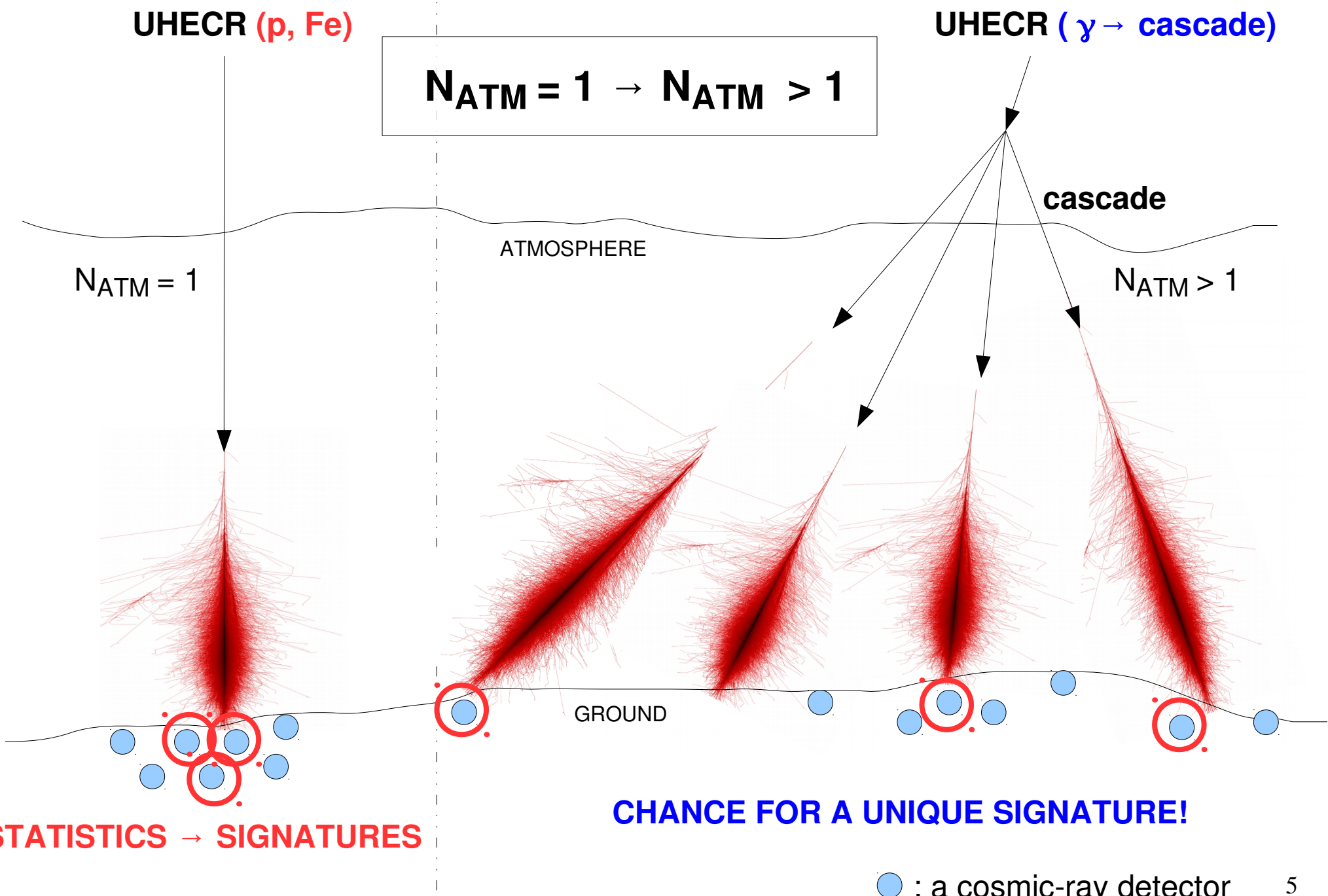
→ technical:
extremely low flux (at E=10^{20}eV
1 particle / km^2 millenium), but now:
the Pierre Auger Observatory (~3000 km^2)

→ scientific:
What are Ultra-High Energy Cosmic Rays (UHECR)?
Where they come from?
How do they propagate?

Do photons of very high energies (above 10^{15} eV) exist?



Generalized detection of cosmic rays: $N_{ATM} >= 1$



$N_{ATM} > 1$ motivated by data! (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)

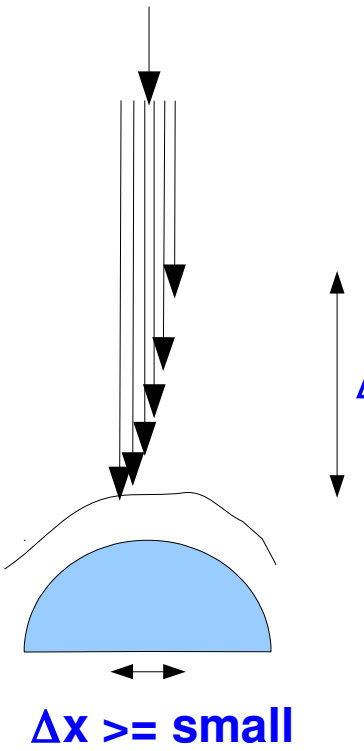
A series or burst of 32 extensive air showers of estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 150 000 such showers in a period of 18 months between October 1980 and April 1982.

PACS numbers: 94.40.Pa, 96.Rc, 95.30.-k

Forgotten (!) treasure (?) no. 1

PH: Correlated cosmic rays?

$N_{ATM} > 1$?



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

$N_{ATM} > 1$ motivated by data! (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 Sept[illegible] 1983)

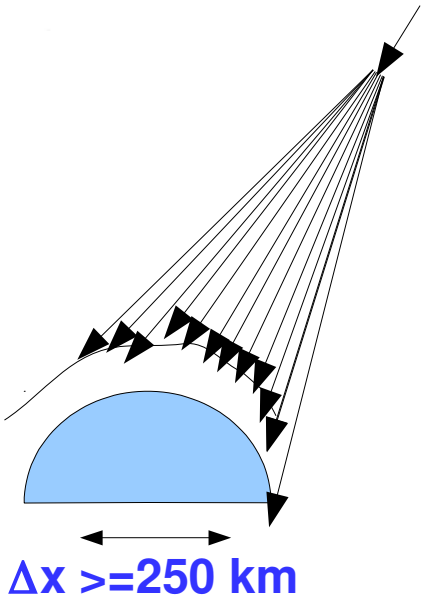
The authors report on an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations separated by 250 km. The event lasted for 20 s. This event was the only one of its kind detected in three years of observation. The duration and structure of this event is different from a recently 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

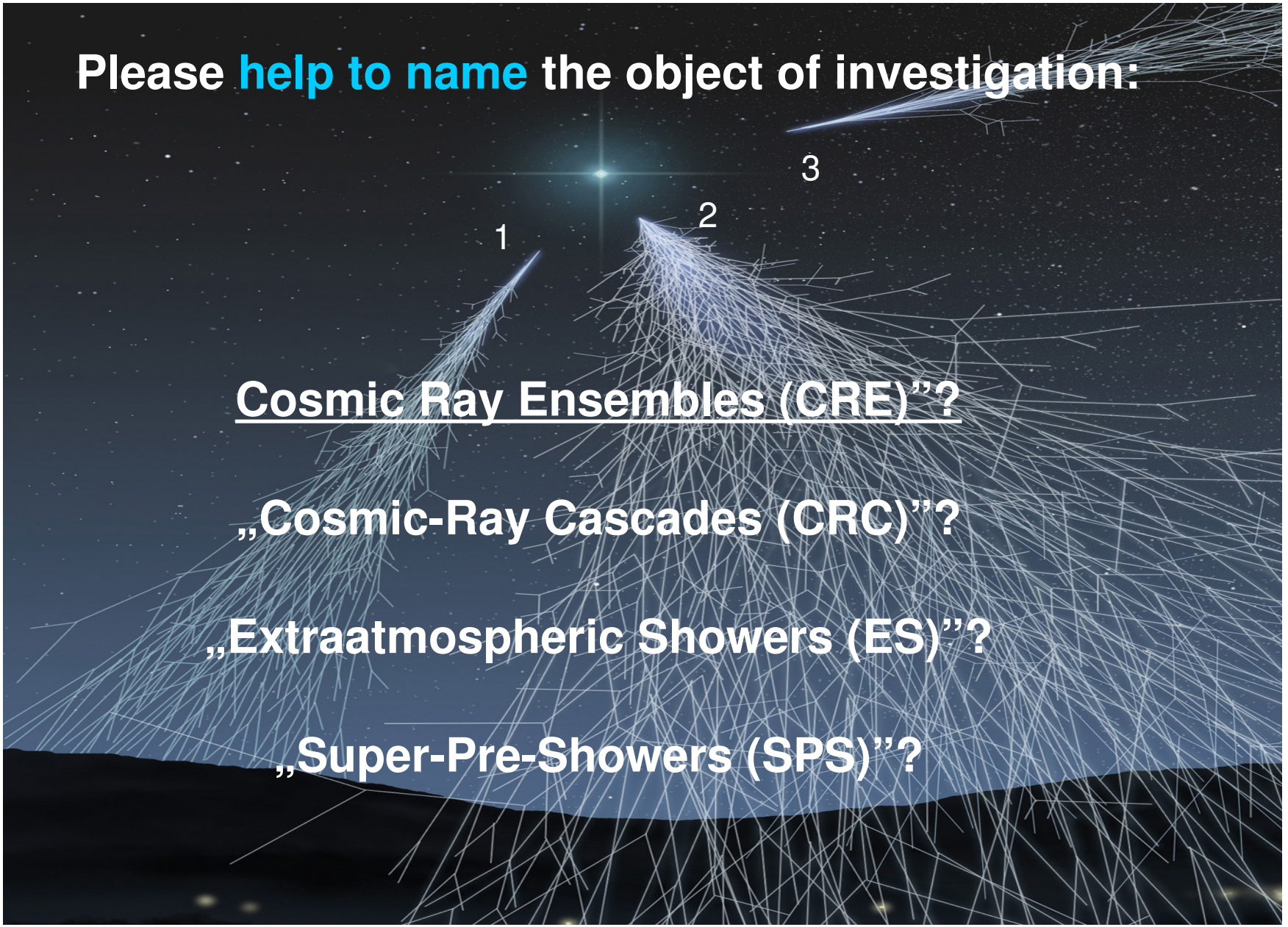
Forgotten (!) treasure (?) no. 2

PH: Correlated cosmic rays?

$N_{ATM} > 1$?

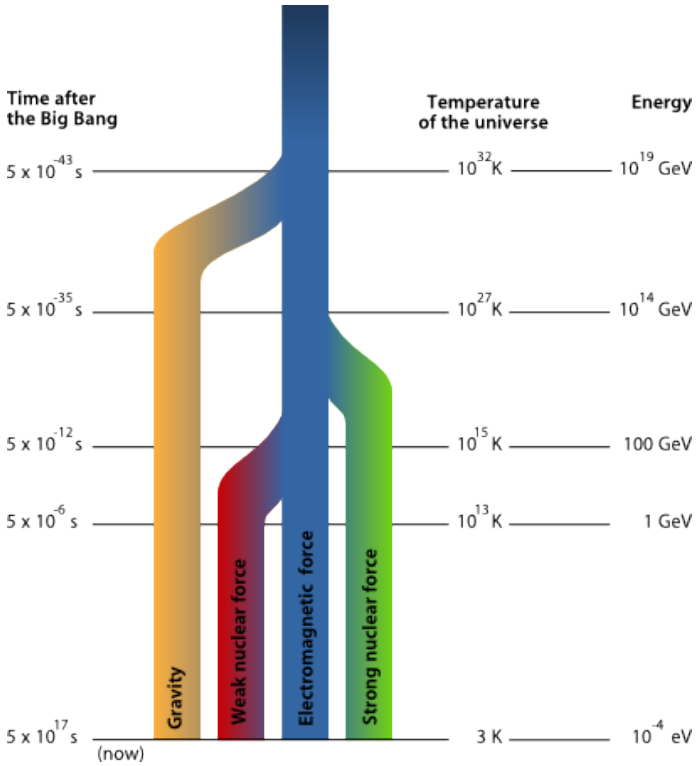


$N_{ATM} > 1$: new subfield of astroparticle physics!



N_{ATM} >= 1 mission (briefly)

Scenarios AND Fishing



CREDO: the first $N_{ATM} >= 1$ observatory

Cosmic-Ray Extremely Distributed Observatory

Status March 2016: „an idea"

Central database/interface: access to everything for everybody

CREDO SCHEMATIC

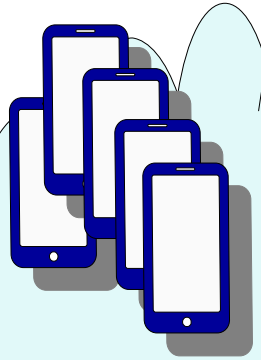
Data Acquisition Interfaces

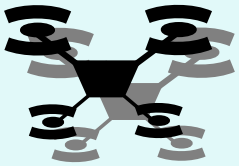
Data Access and RT Alert Interface

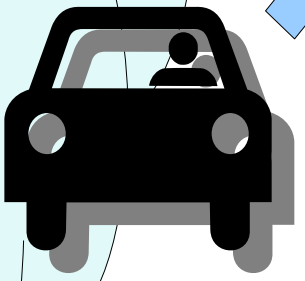
CREDO Computing Infrastructure

For Data Storage and Processing

Data Export Interface (experiment specific, common protocol)







Sensor Networks

- aggregated Data Analysis → **Science** (or **Nature** :)

Pierre Auger Observatory
Baikal-GVD
Atlas CERN
MAGIC/CTA, ….

Potentially...

Citizen Science! But ... science must be real

Citizen science

From Wikipedia, the free encyclopedia

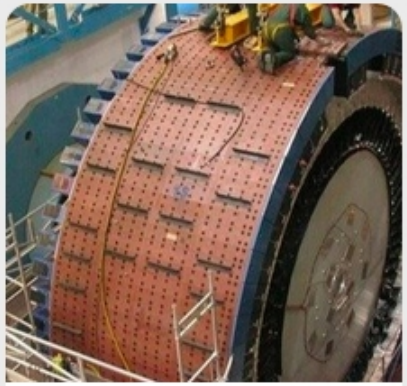
Citizen science (**CS**) (also known as **crowd science**, **crowd-sourced science**, **civic science**, **volunteer monitoring** or **networked science**) is scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Citizen science is sometimes described as "public participation in scientific research", participatory monitoring and participatory action research.[1]

CITIZEN SCIENCE **IS NOT** OUTREACH!

PUBLICATIONS!

CO-AUTHORS!

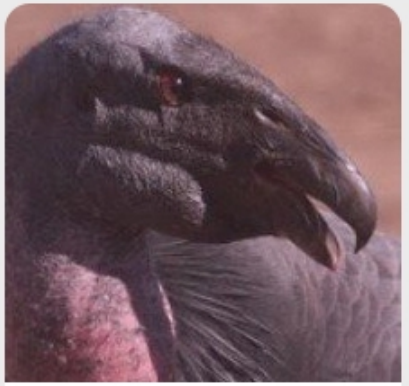
Citizen science: where to start? Zooniverse.org

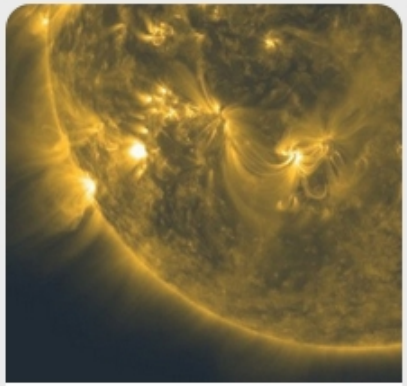

HIGGS HUNTERS


PENGUIN WATCH


CHICAGO WILDLIFE WATCH


FLOATING FORESTS

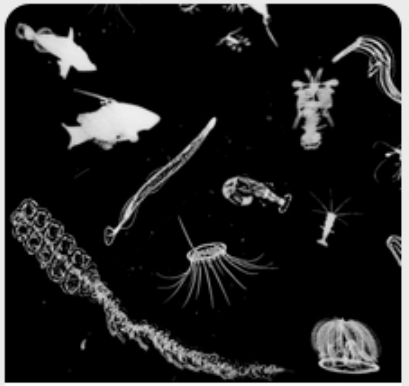

CONDOR WATCH


SUNSPOTTER


DISK DETECTIVE


OPERATION WAR DIARY


RADIO GALAXY ZOO


PLANKTON PORTAL

New affiliation type: “amateur”

Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 26 January 2016 (MN LATEX style file v2.2)

Planet Hunters X.
KIC 8462852 – Where’s the flux? ⋆†

T. S. Boyajian[1], D. M. LaCourse[2], S. A. Rappaport[3], D. Fabrycky[4], D. A. Fischer[1], D. Gandolfi[5,6], G. M. Kennedy[7], H. Korhonen[8,9], M. C. Liu[10], A. Moor[11], K. Olah[11], K. Vida[11], M. C. Wyatt[7], W. M. J. Best[10], J. Brewer[1], F. Ciesla[12], B. Csák[13], H. J. Deeg[14,15], T. J. Dupuy[16], G. Handler[17], K. Heng[18], S. B. Howell[19], S. T. Ishikawa[20], J. Kovács[13], T. Kozakis[21], L. Kriskovics[11], J. Lehtinen[22], C. Lintott[23], S. Lynn[24], D. Nespral[14,15], S. Nikbakhsh[22,25], K. Schawinski[26], J. R. Schmitt[1], A. M. Smith[27], Gy. Szabo[11,13,28], R. Szabo[11], J. Viuho[22], J. Wang[1,29], A. Weiksnar[20], M. Bosch[2], J. L. Connors[2], S. Goodman[2], G. Green[2], A. J. Hoekstra[2], T. Jebson[2], K. J. Jek[2], M. R. Omohundro[2], H. M. Schwengeler[2], A. Szewczyk[2]

[1]*Department of Astronomy, Yale University, New Haven, CT 06511, USA*
[2]*Amateur Astronomer*
[3]*Department of Physics, and Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[4]*Department of Astronomy and Astrophysics, University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA*
[5]*Dipartimento di Fisica, Universitá di Torino, via P. Giuria 1, I-10125, Torino, Italy*
[6]*Landessternwarte Königstuhl, Zentrum für Astronomie der Universität Heidelberg, Königstuhl 12, D-69117 Heidelberg, Germany*

.SR] 25 Jan 2016

wyborcza.pl
KRAKÓW

to be available soon...

1 ZDJĘCIE

Projekt Credo (credo.ifj.edu.pl)

Krakowscy astrofizycy mają pomysł, chcą

PolskieRadio.pl | WIADOMOŚCI | JEDYNKA | DWÓJKA | TRÓJKA | CZWÓRKA | POLSKIE RADIO 24 | ...

PolskieRadio.pl | Trójka

Trójwymiar

ostatnia aktualizacja:
30.08.2017 20:40

Eksperyment kosmiczny. Telefon w służbie nauki

TRÓJKA

Dzięki specjalnej aplikacji CREDO Detector każdy smartfon może, dzię
swojemu modułowi GPS, stać się częścią programu mającego na celu
ciemnej materii.

AUDIO | 1 plik

03'13 +

Eksperyment kosmiczny. Telefon w służbie nauki (Trójwymiar/Trójka)

pap Nauka w Polsce

TYGODNIK POWSZECHNY

AUTORZY | BLOGI | ARCHIWUM | REDAKCJA | WYDAWCA | FUNDACJA | KUP PRE

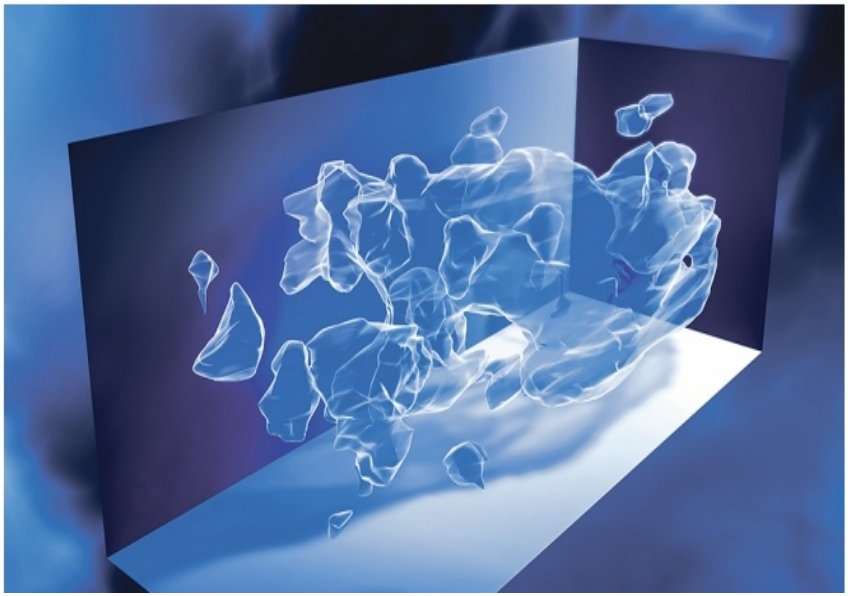
MENU

STRONA GŁÓWNA » NAUKA » BŁYSKI CIEMNEJ MATERII

BŁYSKI CIEMNEJ MATERII

MICHAŁ KRUPIŃSKI - | 25.07.2017 | CZYTA SIĘ 8 MINUT

Eksperyment polskich naukowców ma pomóc wyjaśnić, czym jest ciemna materia – jeden z najbardziej zagadkowych składników wszechświata. Każdy będzie mógł w nim wziąć udział – wystarczy mieć smartfon z GPS-em.



Nauki medy

ytków: krzy

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likacji
rody na

GPS,
owcom
a cząstka

ać o
echniki

„I do think CREDO has a unique capability of entering in and exploring a completely uncharted realm of science." Mikhail V. Medvedev

Media about us

2017

- CREDO Anniversary Symposium 2017

Telefon w służbie nauki

Od dziś każdy może za pomocą smartfona poszukać ciemnej materii

Od środy każdy może za pomocą smartfona poszukać ciemnej materii

Chcą znaleźć ciemną materię. Potrzebny milion ochotników ze smartfonami

Badaj kosmos smartfonem i wspieraj rozwój nauki

Badaj kosmos smartfonem i pracuj na Nobla – naukowcy z PK w projekcie CREDO

Rocznicowe seminarium CREDO w Instytucie Fizyki Jądrowej w Krakowie, 30-31.08.2017

- CREDO Inaguration

TVP3 Kraków – Kronika, EVENING NEWS – Smartfonowe obserwatorium

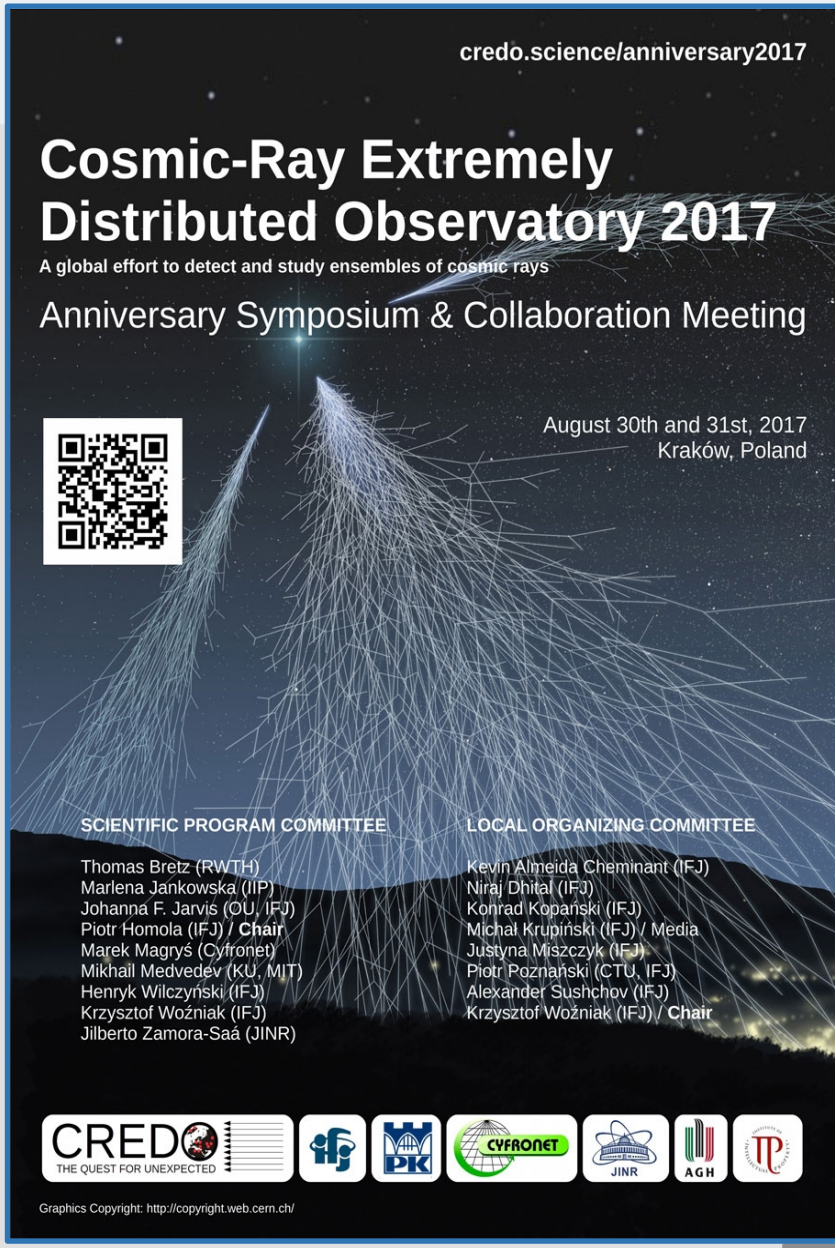
RMF24, Projekt CREDO: Pożycz nauce smartfona, może dostaniesz..... Nobla

Gazeta Wyborcza, Masz smartfona? Zostań odkrywcą, obserwuj promieniowanie kosmiczne

Radio Eska, Prace astrofizyków z Krakowa

Radio Kraków, Każdy może przyczynić się do ważnego odkrycia naukowego. Wystarczy... telefon komórkowy

Start projektu CREDO i jego możliwe implikacje dla rozwoju astrofizyki



http://credo.science/media-about-us/, 25.09.2017 r.

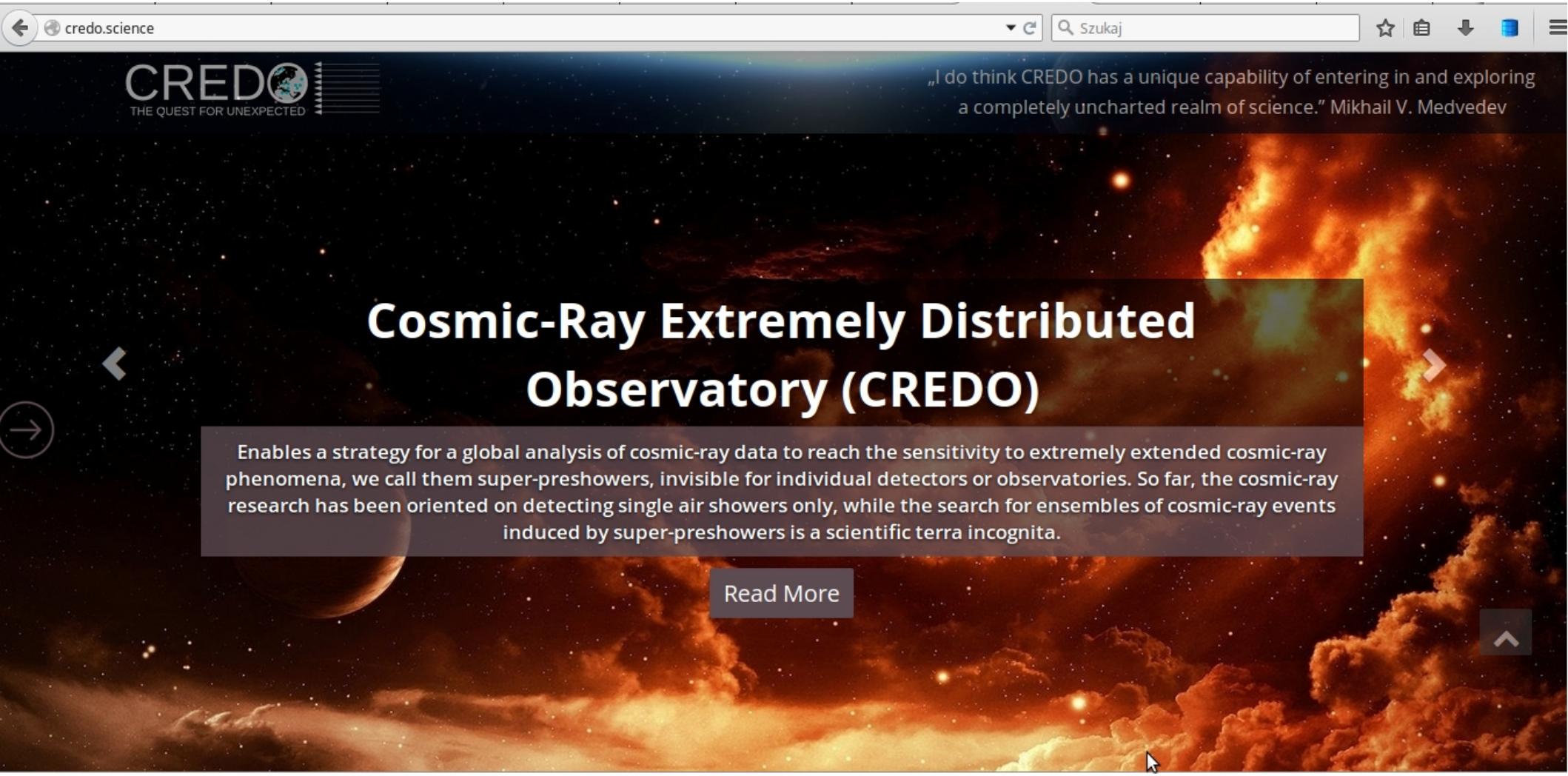
Public engagement / citizen science: a tool

new era in science:
Smart Science?

Public contribution (**co-authorship!**) to scientific success:

Level 1. supporting the growth → larger collaboration = better science
Level 2. data acquisition → more devices = better science
Level 3. data analysis → advanced members = better science
Level 4. education → deeper involvement = better science
Level 5. experience → **practical philosophy** = better science

Visit credo.science...



… and contribute to CREDO science.

CREDO
THE QUEST FOR UNEXPECTED

facebook /credo.science

Level 1:

growth/scale generation

http://credo.science
https://play.google.com/store/
apps/details?id=
science.credo.credomobiledetektor

CREDO
THE QUEST FOR UNEXPECTED

CREDO detector

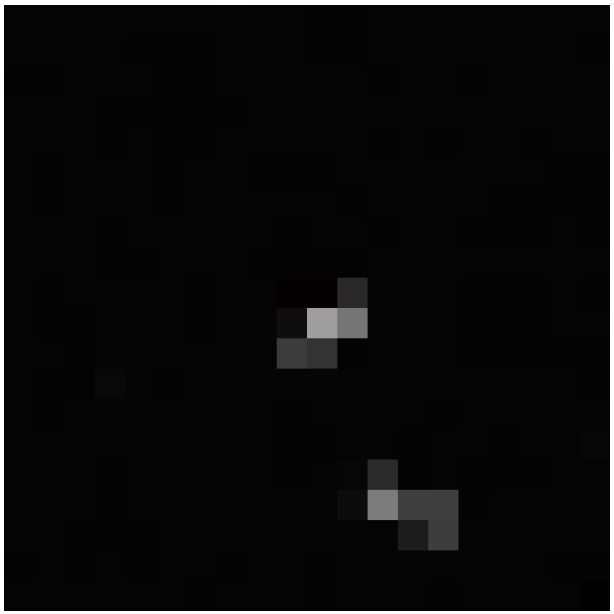
Level 2:

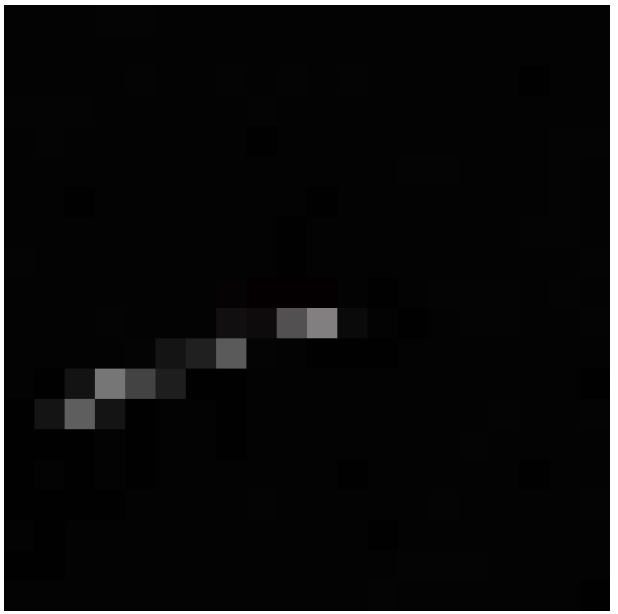
data acquisition

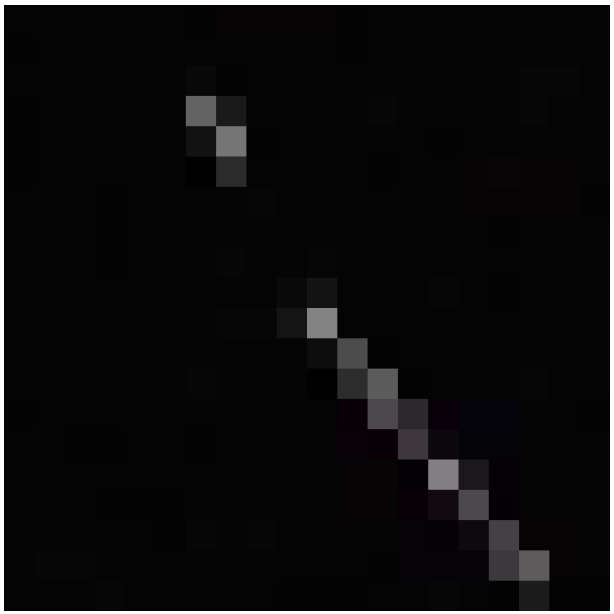
CREDO Detector: examples

User: „Piotr Homola”, https://api.credo.science/user/29
Team: „IFJ”
Device: Smasung Galaxy Grand Prime, model SM-G531F
System: Android 5.1.1
Average detection rate: ~1/hr

Example images:





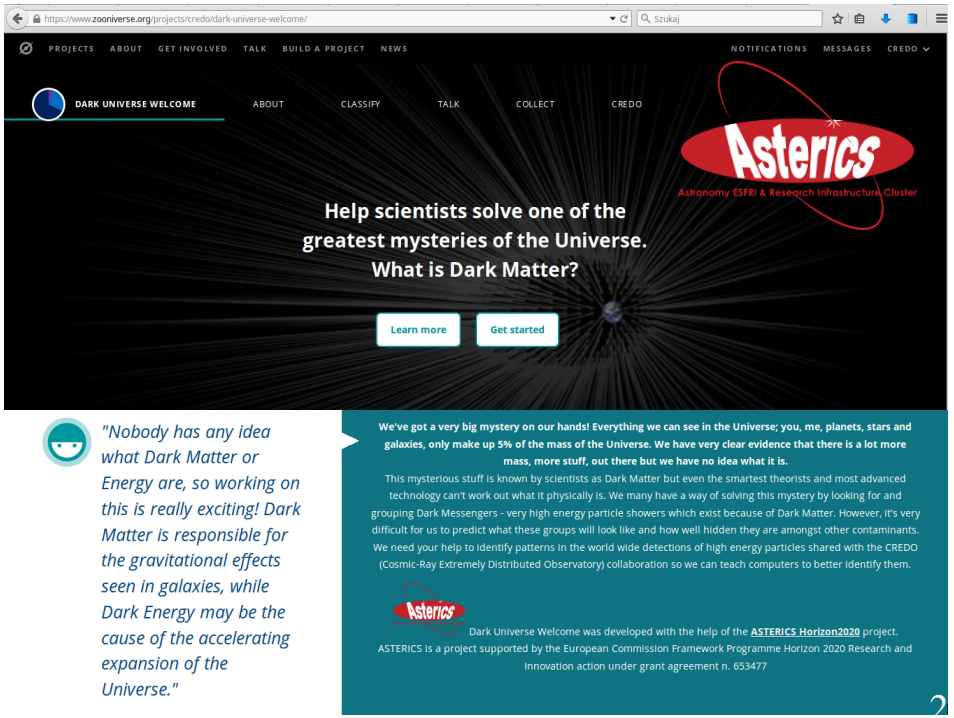


CREDO

THE QUEST FOR UNEXPECTED

Dark Universe Welcome

kategoria wiekowa: 7+



"Nobody has any idea what Dark Matter or Energy are, so working on this is really exciting! Dark Matter is responsible for the gravitational effects seen in galaxies, while Dark Energy may be the cause of the accelerating expansion of the Universe."

We've got a very big mystery on our hands! Everything we can see in the Universe; you, me, planets, stars and galaxies, only make up 5% of the mass of the Universe. We have very clear evidence that there is a lot more mass, more stuff, out there but we have no idea what it is.

This mysterious stuff is known by scientists as Dark Matter but even the smartest theorists and most advanced technology can't work out what it physically is. We many have a way of solving this mystery by looking for and grouping Dark Messengers - very high energy particle showers which exist because of Dark Matter. However, it's very difficult for us to predict what these groups will look like and how well hidden they are amongst other contaminants. We need your help to identify patterns in the world wide detections of high energy particles shared with the CREDO (Cosmic-Ray Extremely Distributed Observatory) collaboration so we can teach computers to better identify them.

Asterics

Dark Universe Welcome was developed with the help of the **ASTERICS Horizon2020** project. ASTERICS is a project supported by the European Commission Framework Programme Horizon 2020 Research and Innovation action under grant agreement n. 653477

2

Level 3:

data analysis

Public engagement as a scientific tool

The match: “IFJ” vs. “Team Rzezawa”

Discipline: **catching secondary cosmic ray particles with mobile devices with CREDO Detector**

When? 16.11.2017, 11:00 – 12:00

Where? IFJ PAN, Gimanzjum Publiczne Rzezawa, Poland, world

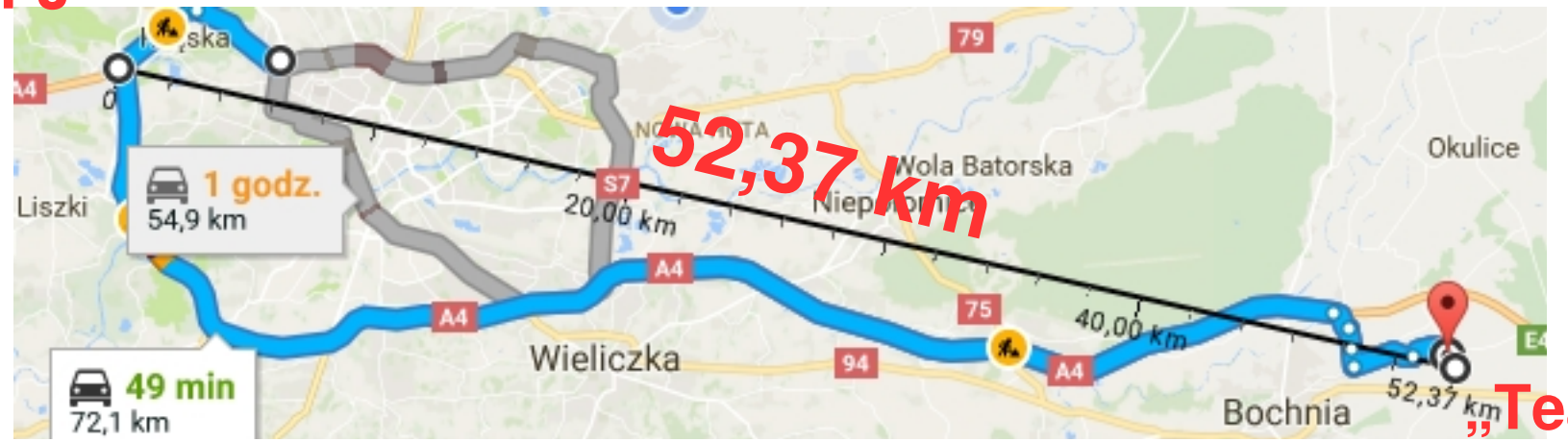
Transmitted live: CREDO YouTube Channel

Number of registered players: 32:30

Number of catched particles: 12:4

Final score: -135 do -257

„IFJ”



„Team Rzezawa”

Level MAX: fun and emotions

Warunki powodzenia projektu:

- Zaangażowanie klienta 15,5%
- Wsparcie Kierownictwa 13,9%
- Jasne określenie wymagań 13,0%
- Właściwe planowanie 9,6%
- Realistyczne analizowanie 8,2%
- Mniejsze odstępy miedzy punktami kontrolnymi 7,7%
- Odpowiedzialność 5,3%
- Jasno sprecyzowane cele 2,9%
- Ciężko pracujący pracownicy 2,4%
- Inne 13,9%

IPMA international project management association

… potential and beyond

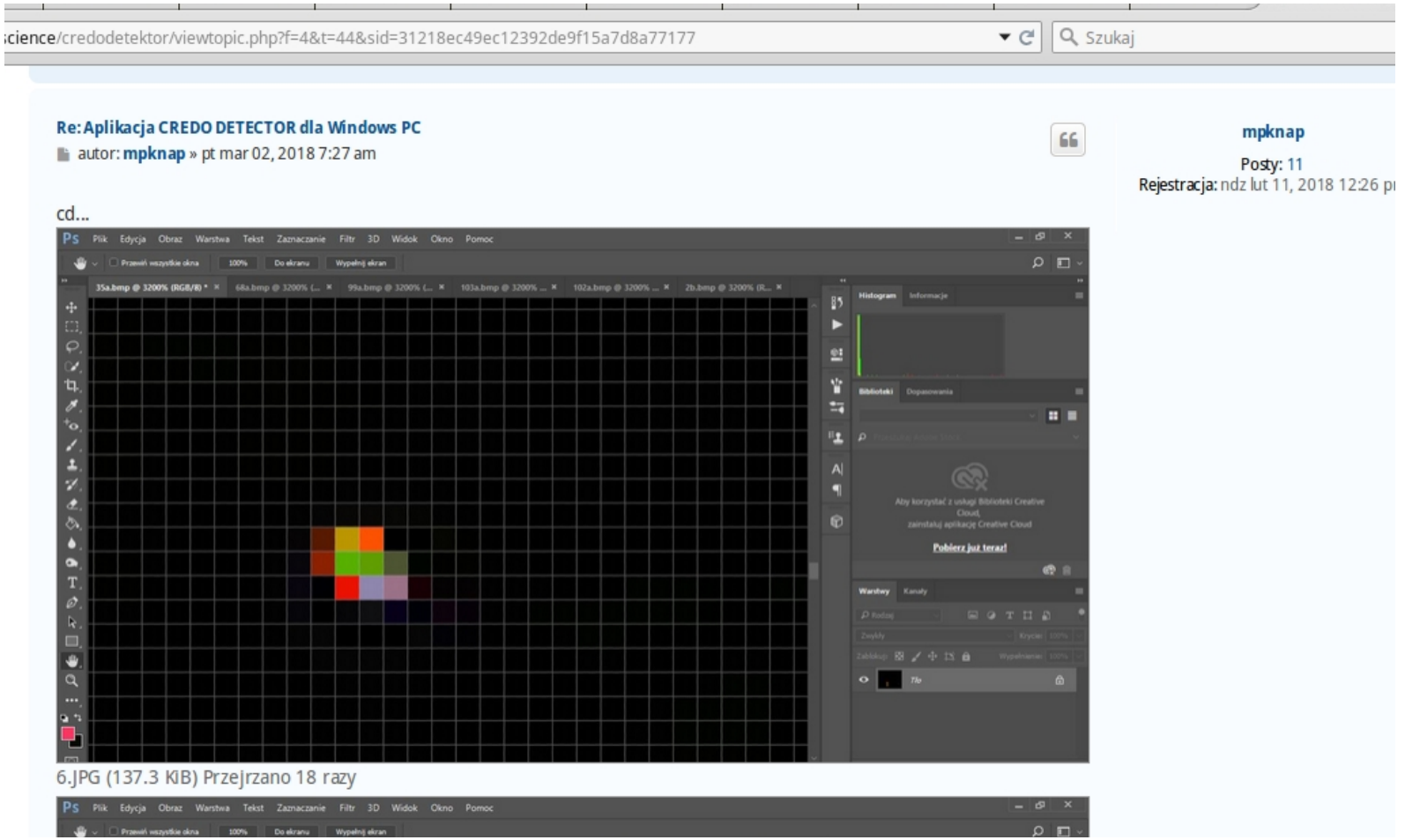
CREDO attracts... e.g. Ukrainian youth

ca. 250,000 talented youth! ca. 20% technical/scientific!

→ CREDO invited to discuss partnership!

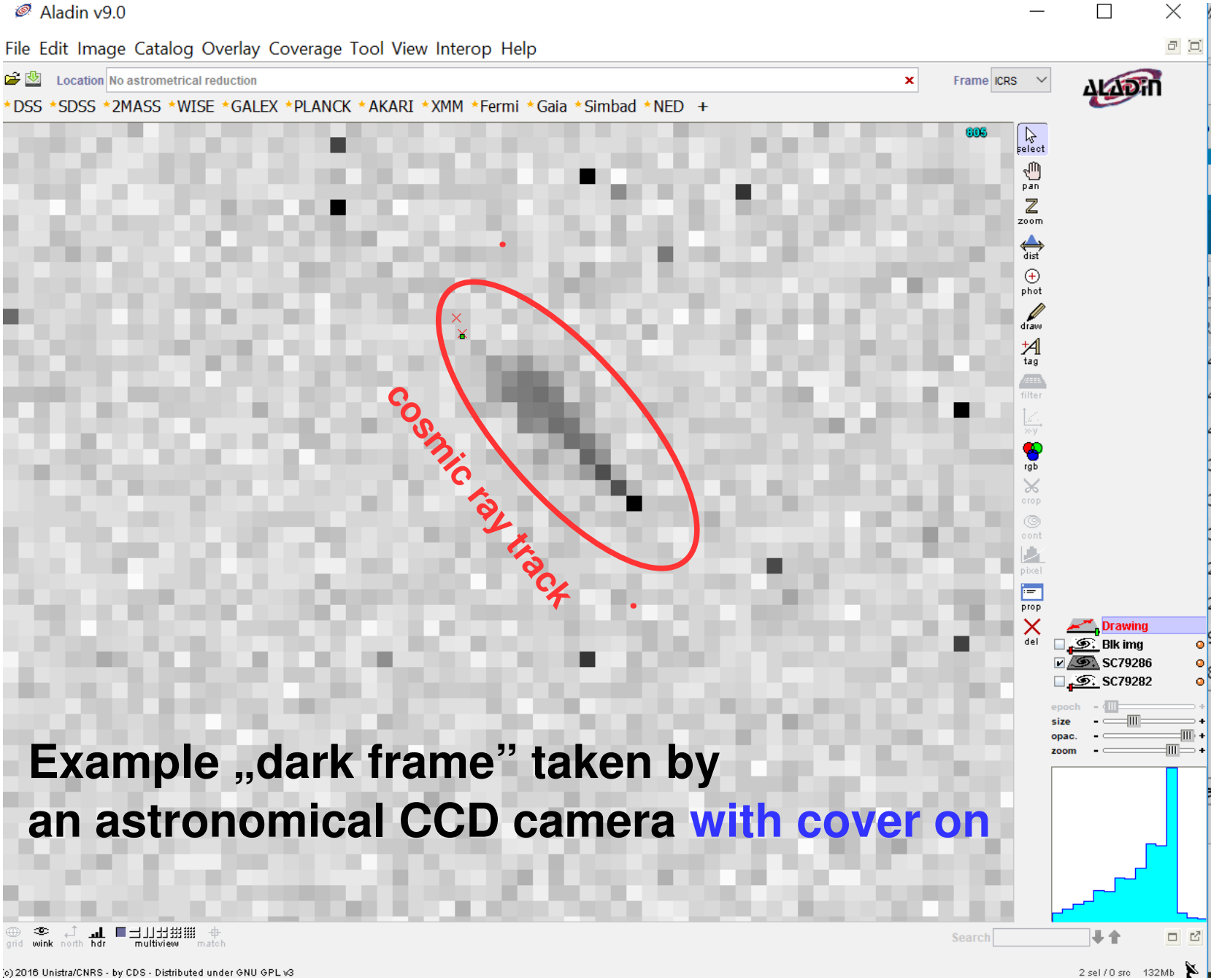
CREDO attracts... also non-experts

→ **PC application to catch particles with an internet camera, by a 41-year old science enthusiast!**



https://credo.science/credodetektor/viewtopic.php?f=4&t=44

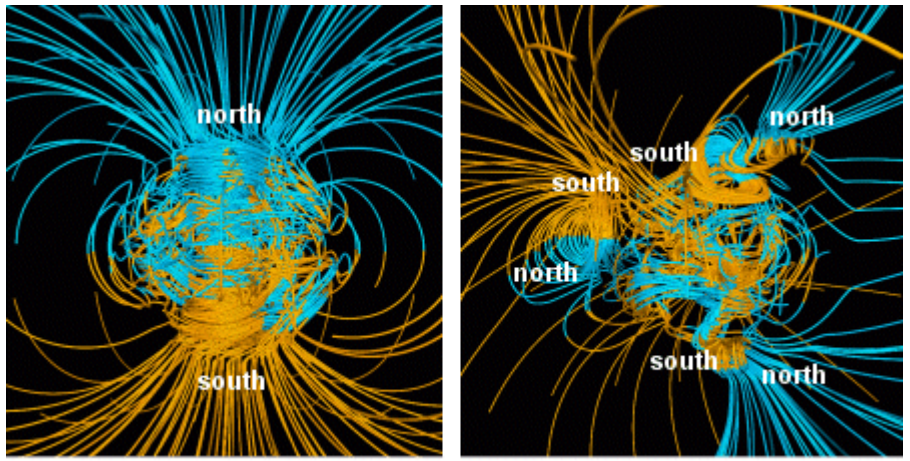
CREDO attracts... astronomers!



Credit & idea by Massimo Ramella (INAF)

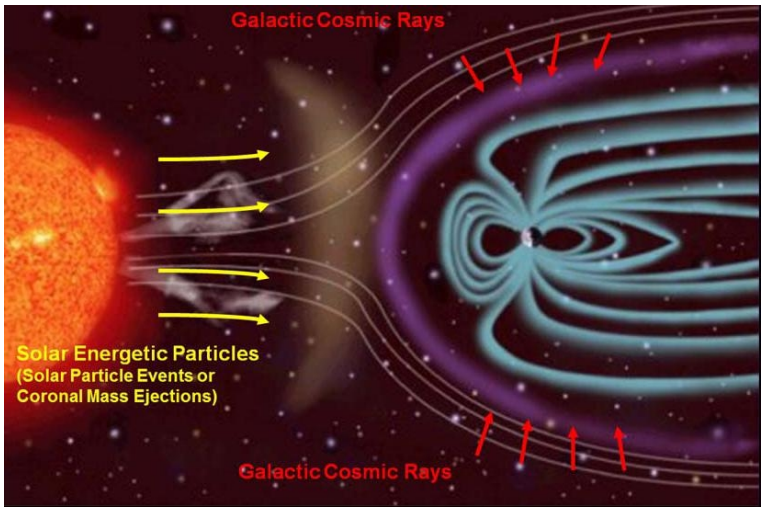
CREDO and p. 18: interdisciplinary opportunities

Wikipedia: „Geomagnetic reversal”



between reversals during a reversal

Wikipedia: „Health threat from cosmic rays”



Earth outer core: Liquid (molten iron)
→ geomagnetism
↓
Impulse (tidal forces)
→ hydrodynamics: waves
↓
→ Mechanical wave upwards (slow, hours?)
→ Electromagnetic wave („instant”, ms)
↓
Local geomagnetic field vector changes
AND seismic effect might occur!
↓
Variation of the CR rate!
↓
Earthquake precursors?

CREDO

THE QUEST FOR UNEXPECTED

Scientific diversity: BIO

[Livescience.com, October 11, 2016]

On a Long Trip to Mars, Cosmic Radiation May Damage Astronauts' Brains

… and how can cosmic rays affect us on Earth?

Imagine a global network of cosmic ray detectors and global data on EEG...

Quantum Gravity with gamma astronomy

https://www.ucdavis.edu/news/gamma-ray-delay-may-be-sign-new-physics

UCDAVIS

Quick Links

ABOUT US ADMISSIONS ACADEMICS RESEARCH CAMPUS LIFE NEWS

Gamma Ray Delay May Be Sign of 'New Physics'

Delayed gamma rays from deep space may provide the first evidence for physics beyond current theories.

The MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescope found that high-energy photons of gamma radiation from a distant galaxy arrived at Earth four minutes after lower-energy photons, although they were apparently emitted at the same time. If correct, that would contradict Einstein's theory of relativity, which says that all photons (particles of light) must move at the speed of light.

"Everybody's very excited," about this result, said Daniel Ferenc, a physics professor at UC Davis and a member of the MAGIC collaboration. Ferenc cautioned that the results need to be repeated with other gamma-ray sources and that a simpler explanation had not been ruled out. But, "it shows that such measurements are possible," he said.

The researchers propose that the delay could be caused by photons interacting with "quantum foam," a type of structure of space itself. Quantum foam is predicted by quantum gravity theory, an attempt to unite quantum physics and relativity at cosmic scales.

UC Davis Chancellor May Announces Emily Galindo and Rahim Reed to Fill Interim Leadership Roles
March 13, 2018

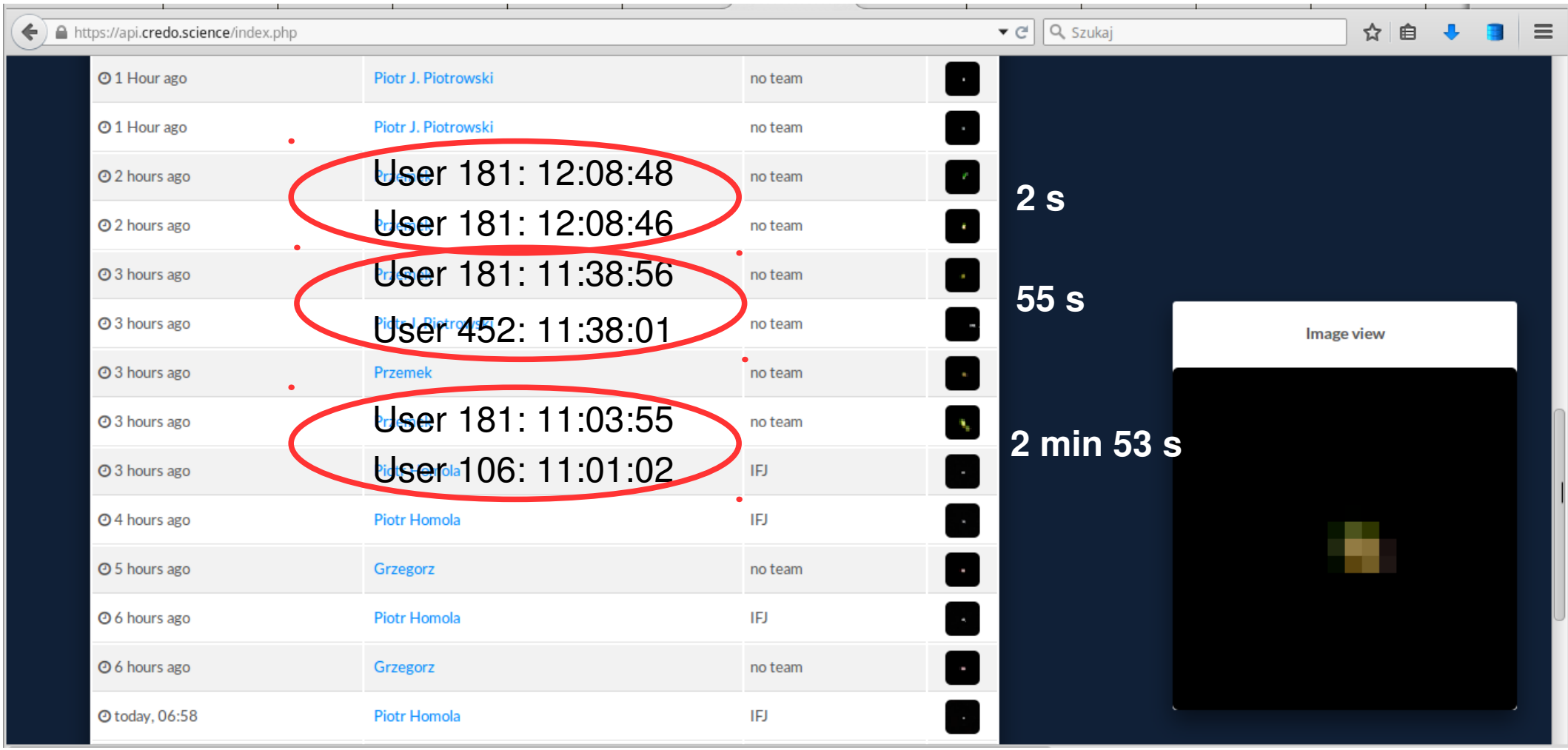
→ 4 min. delay could be the signature of a special space structure: Quantum foam

→ predicted by Quantum Gravity

Quantum Gravity with smartphones!

On-line experiment: broadcasting live at api.credo.science

Once upon a time, and more precisely on 16.03.2018, around 11:00 CET...



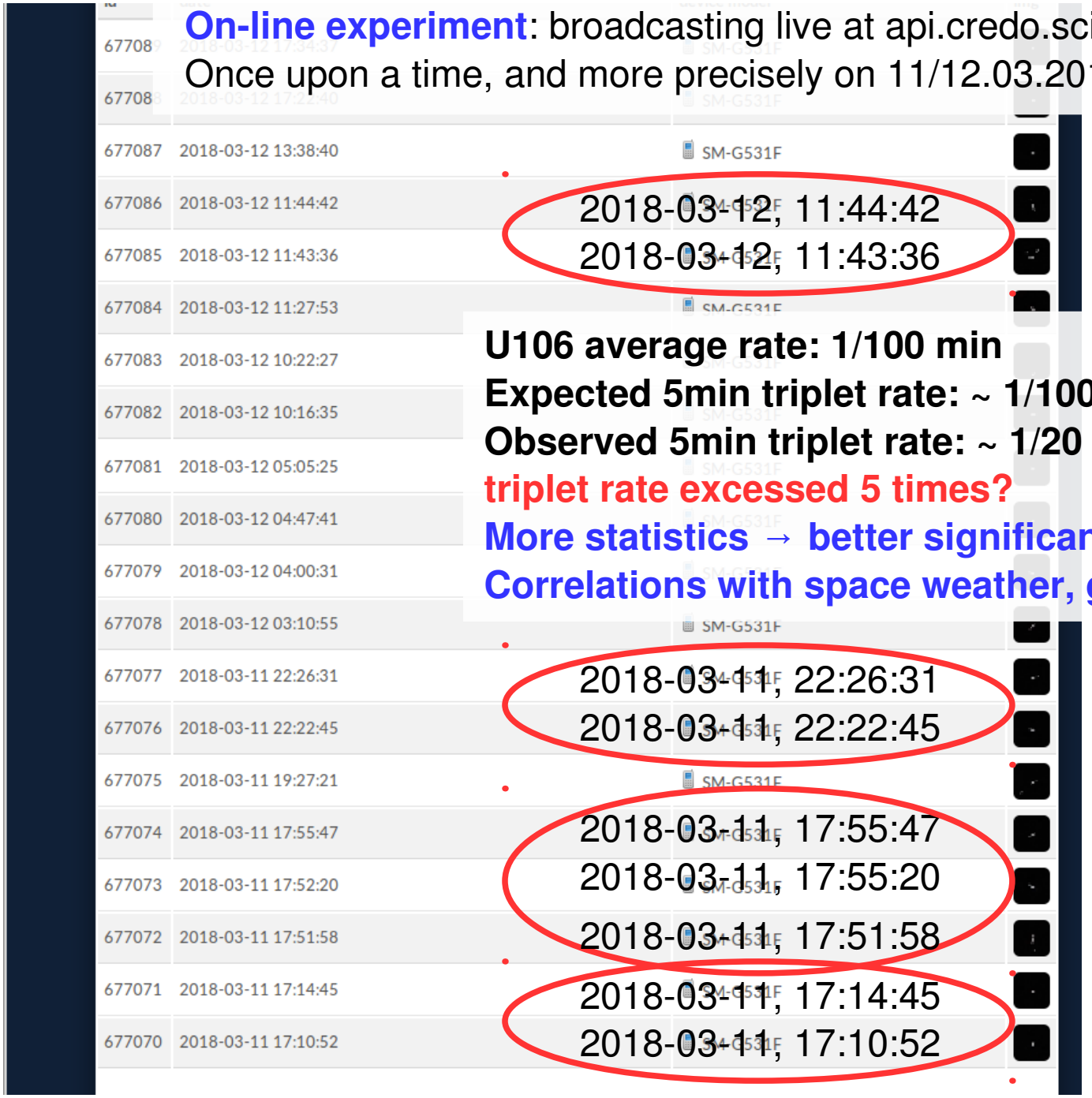
Expected vs. Observed?

doublet / triplet / multiplet rate, duration of doublets,

distance between the multiplet detection sites, geographical alignment of the lines, ...

Quantum Gravity with a smartphone!

On-line experiment: broadcasting live at api.credo.science
Once upon a time, and more precisely on 11/12.03.2018, at user's 106 house...



2018-03-12, 11:44:42
2018-03-12, 11:43:36

1 min 6 s

U106 average rate: 1/100 min
Expected 5min triplet rate: ~ 1/100 days
Observed 5min triplet rate: ~ 1/20 days
triplet rate excessed 5 times?
More statistics → better significance
Correlations with space weather, geomagnetic changes?

2018-03-11, 22:26:31
2018-03-11, 22:22:45

3 min 46 s

2018-03-11, 17:55:47
2018-03-11, 17:55:20
2018-03-11, 17:51:58

3 min 49 s (a triplet!)

2018-03-11, 17:14:45
2018-03-11, 17:10:52

3 min 53 s

success guaranteed?

Mission

N_{ATM} >= 1 → scenarios + fishing / Education

Strategy

Spread globally & grow giant → „1 million colleagues”

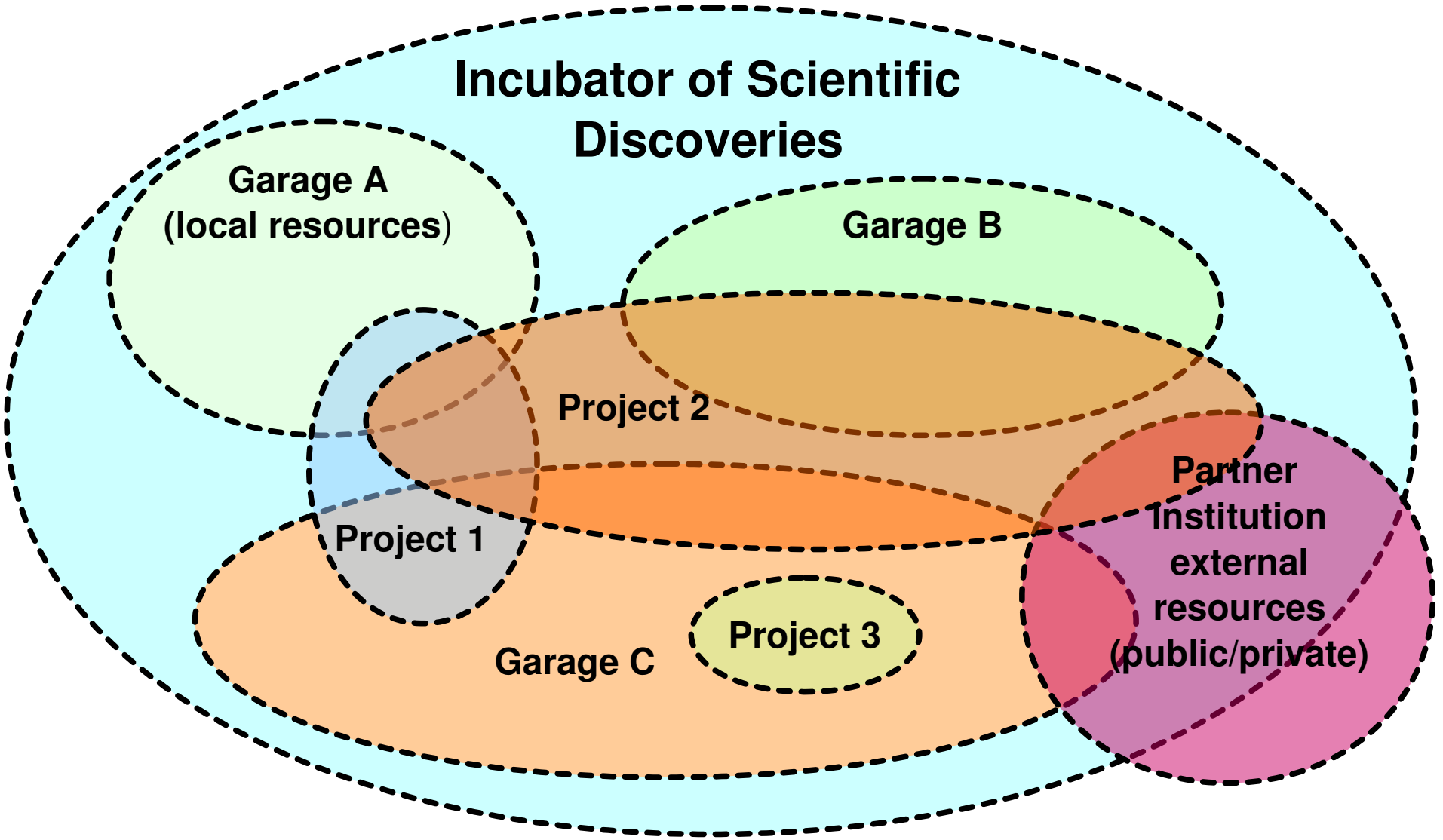
Tactics

- tools: variety of detectors / citizen science
- users: young + old
- training: discoverology

Potential

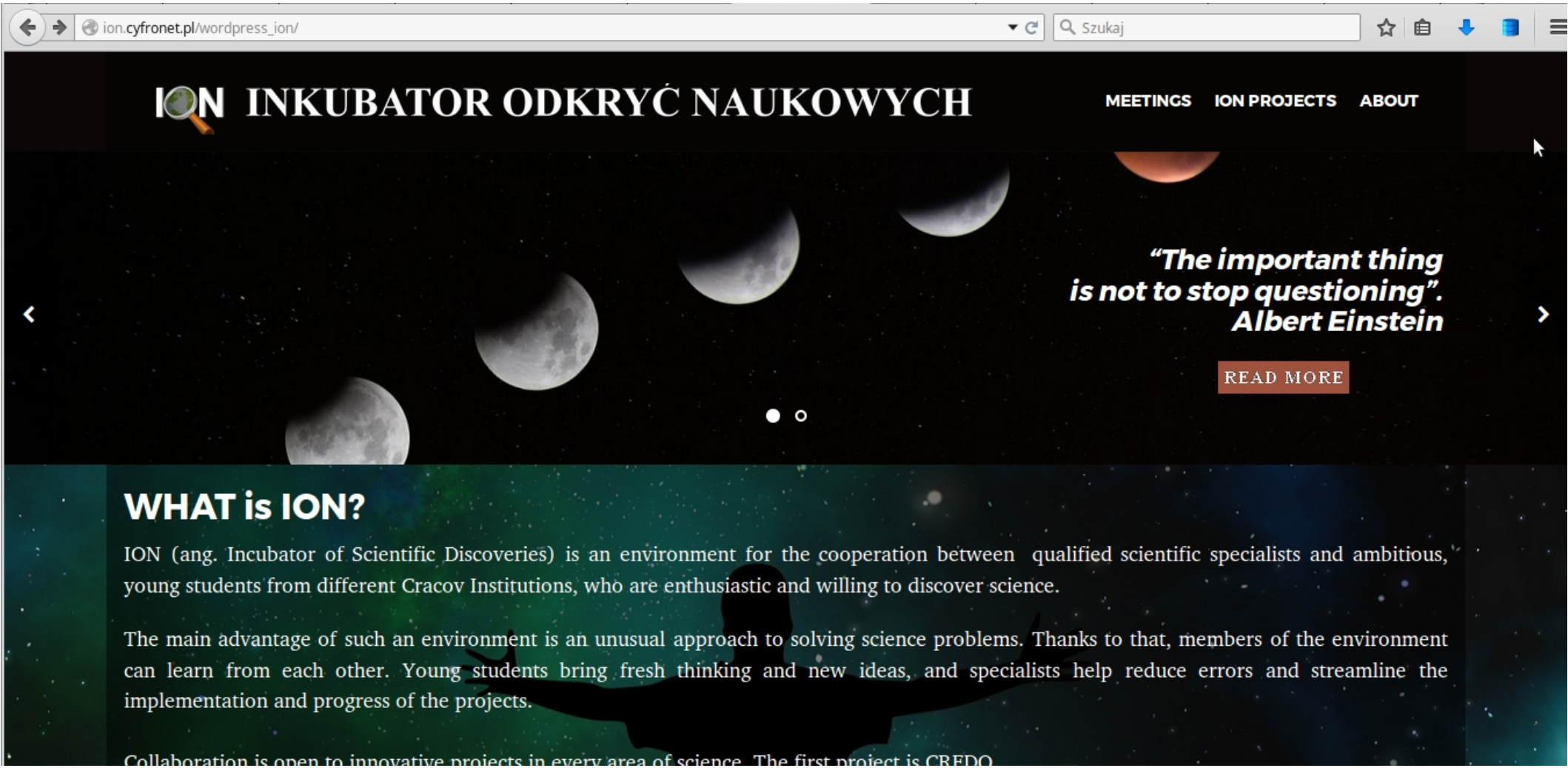
- multidimensional: **beyond astrophysics, beyond science**

Incubator of Scientific Discoveries: vision



Resources: money, space, tools, skills, competencies, advise, ...
Projects!: team, goal, road map, budget, action, reports, **continuity** → **discoveries!**
Distributed = access to more resources = **synergy** = better chance for discoveries.

Incubator of Scientific Discoveries



Begin your journey to the Nobel Prize early...

Example upcoming training:"**Mentality of discoverers**" **[psychology]**

Incubator: Discovery training

Incubator role:

discoveries! (scientific **think tank**)

↓

Training required

… but no „**discovery education**”

↓

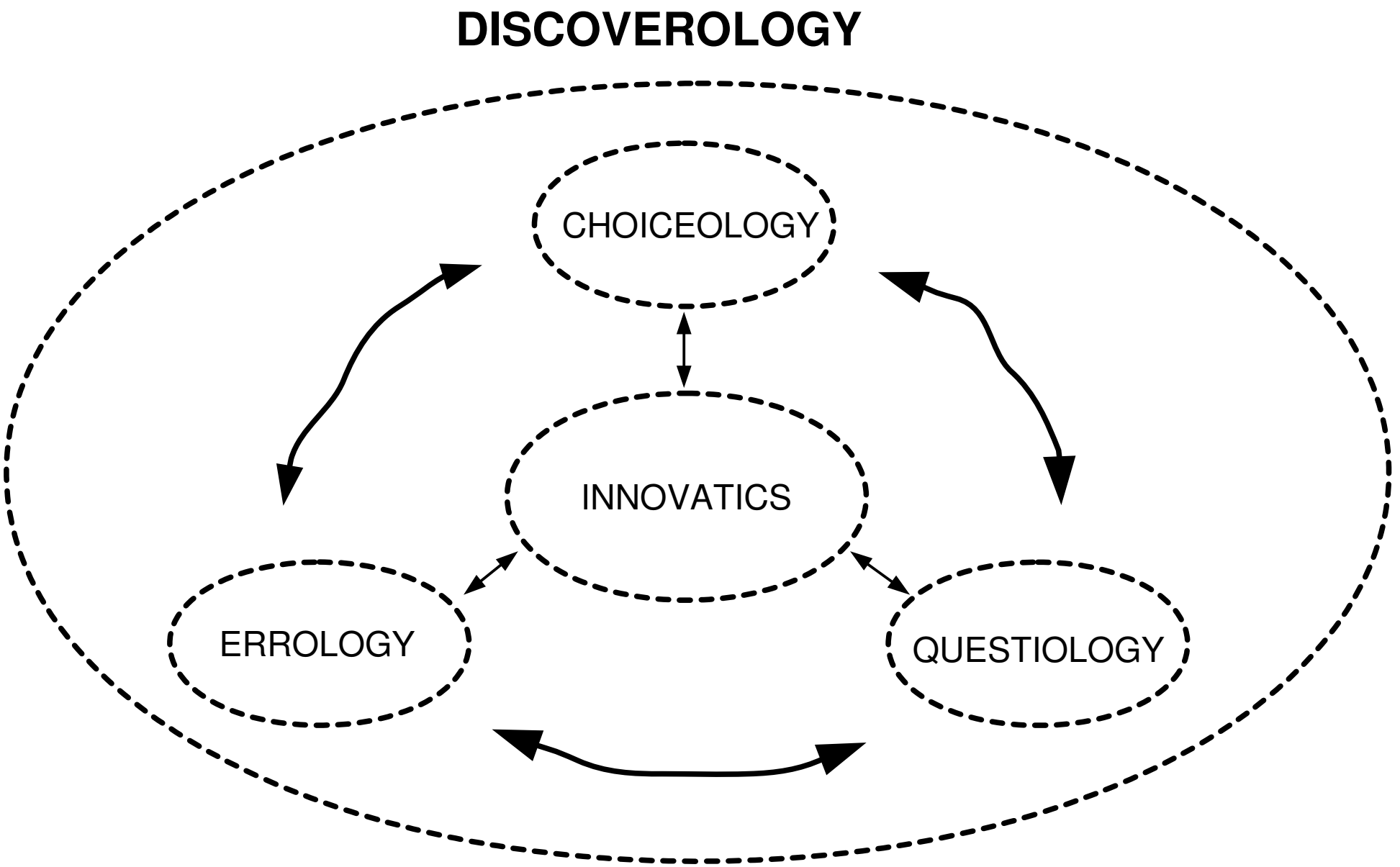
Consequtive approximation method...

→ doing science (real discovery-oriented projects)

→ **remove obstacles for independent thinking**

→ practice the **art of asking questions**

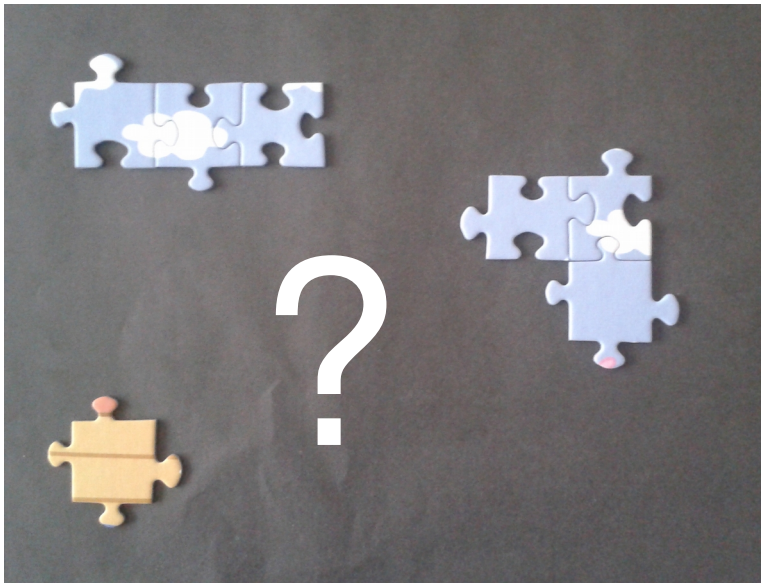
Training to discoveries or... discipline?



from: P. Homola, “Introduction to Discoverology”, chapter in “AI: Law, Philosophy & Geoinformatics”, 2018

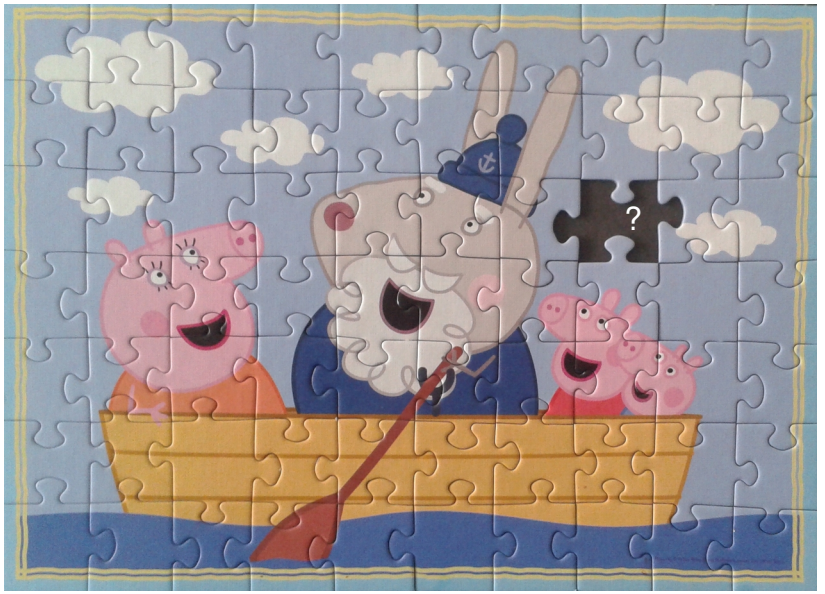
CHOICEOLOGY: what do I do?

UNIVERSE A



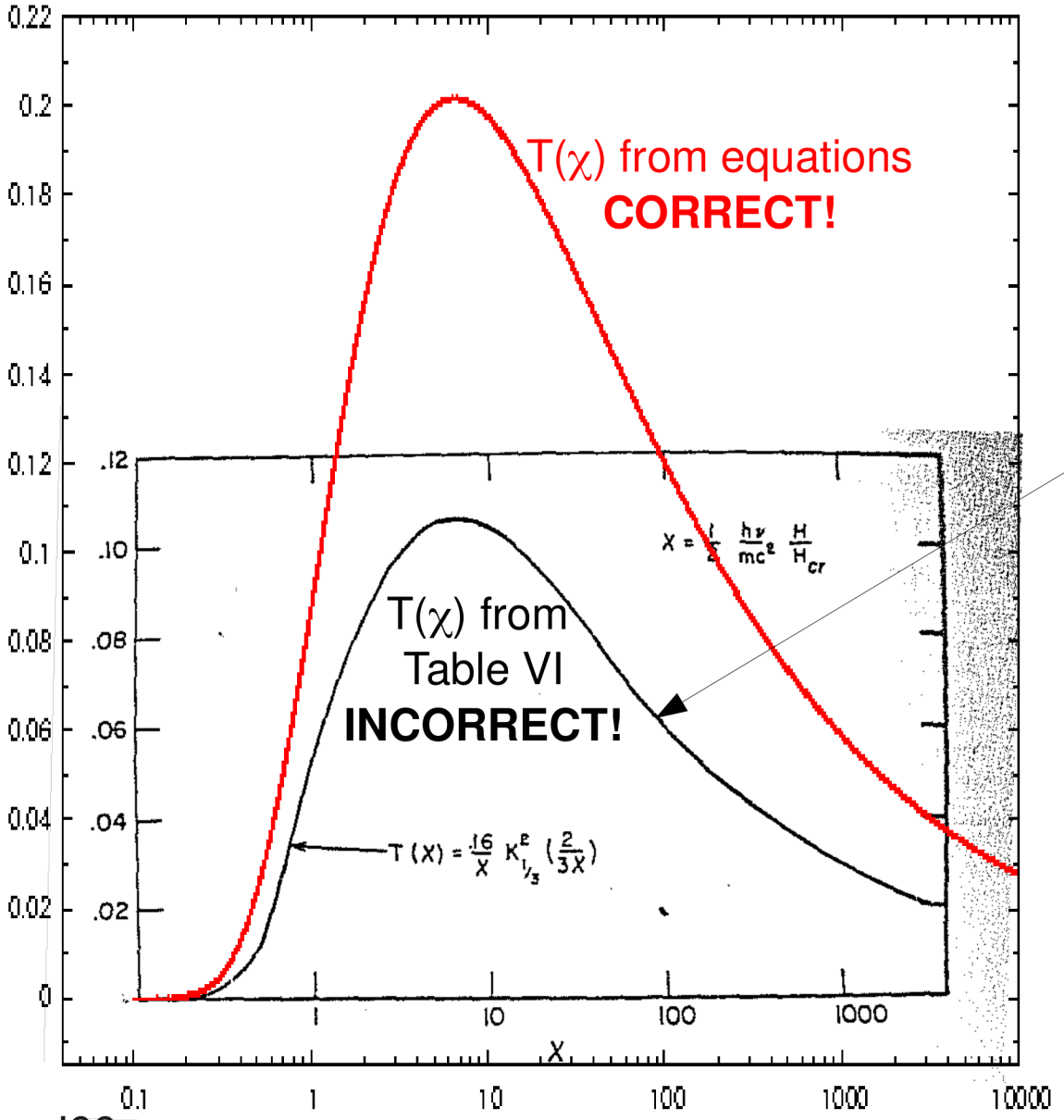
or

UNIVERSE B



?

ERROLOGY: do I do well?



Erber '66:

FIG. 9. The magnetic pair production function $T(\chi)$; compare (3.4a-d).

Erber '66:

TABLE VI. The magnetic pair production function $T(\chi)$.

χ	$T(\chi)$
0.2	2×10^{-4}
0.3	2.2×10^{-3}
0.4	6.6×10^{-3}
0.7	0.026
1.2	0.055
3.0	0.094
5.0	0.10
6.0	0.10
7.0	0.10
9.0	0.10
15	0.099
30	0.085

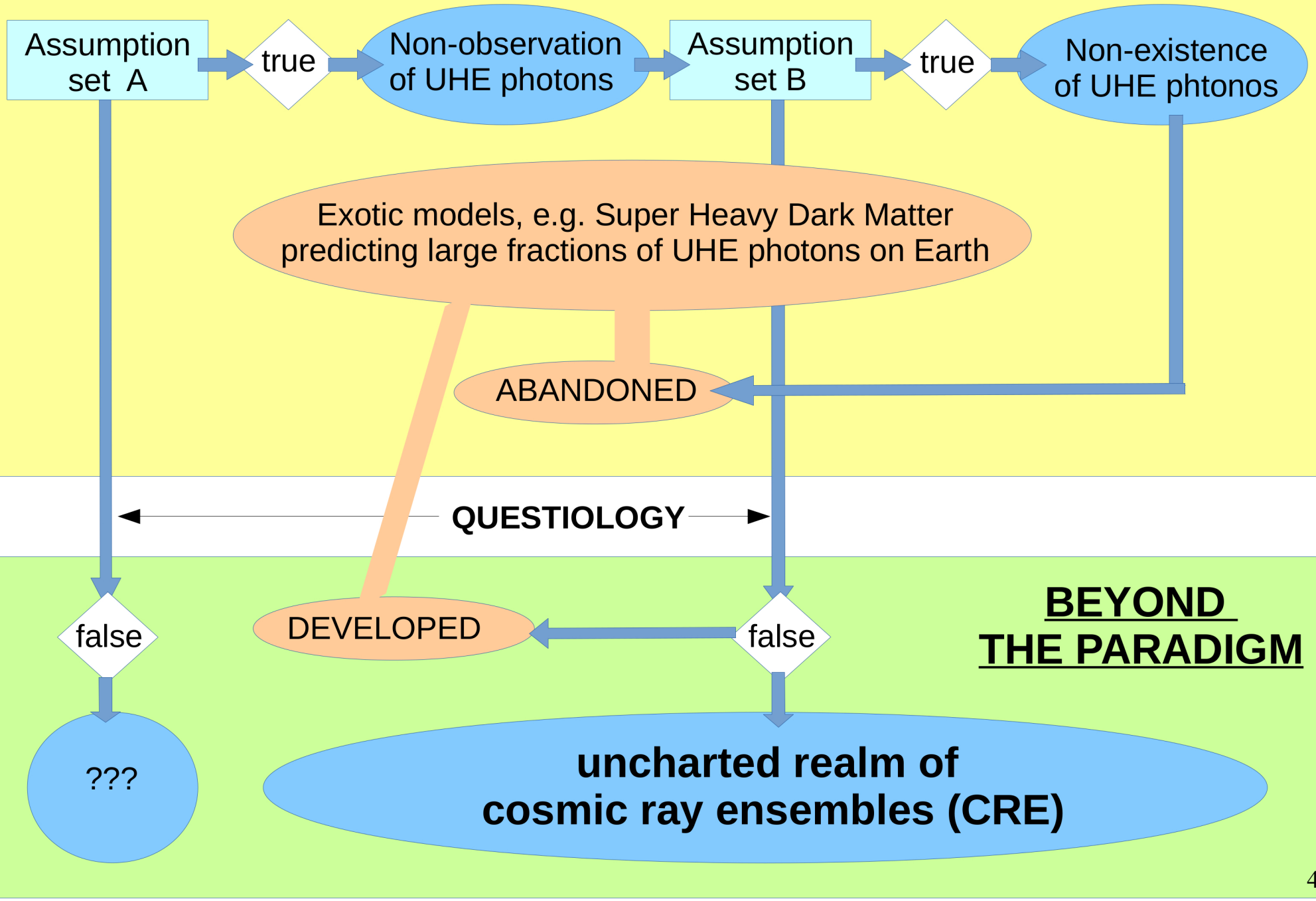
INCORRECT!

T(χ) from equations significantly larger than in Table VI of the standard reference Erber '66.

Taking T(χ) values from Table VI leads to an **underestimation** of pair production probability [!].

Mistake mentioned in:
→ Homola et al. 2005
→ Klein 2006

Ultra-high energy cosmic ray (UHECR) PARADIGM



Intellectual property of a giant collaboration?
Intellectual property regarding a scientific breakthrough?
Superior management for science & civilizational development?
Known contribution (=share) of each member?

→ CREDO Inc.

→ Inc.: selfsustainable business in: science, education, toys, AI, power banking, computer science, social science era → media, advanced electronics (smart-sci-phones), nanotech, information security, space research: satellites, seismology, cosmic health, **science breakthrough quest as business (fundamental drive)**

- processing towards a breakthrough is beneficial!

Scale is the driver: openess & transparency

→ shareholders, governments, institutions, companies, private
→ shares: money or in-kind (like, detection, buy, analyze, play, …)

Advantages: scalable, one-of-a-kind, global, stock market for visibility, activation/synergy engine, operational flexibility, discoverology as intellectual formation engine, playing on a breakthrough as a beneficial process itself

Contras:?

Summary v. 2

Ensembles of Cosmic Rays (Cosmic-Ray Cascades, Super Pre-Showers):

- Unprobed and easily accessible information channel about Universe!

[*terra incognita* but... might be a desert]

Cosmic-Ray Etremely Distributed Observatory:

- the pioneer receiver, already operating, stay tuned!

CREDO „ more than 1 million" potential:

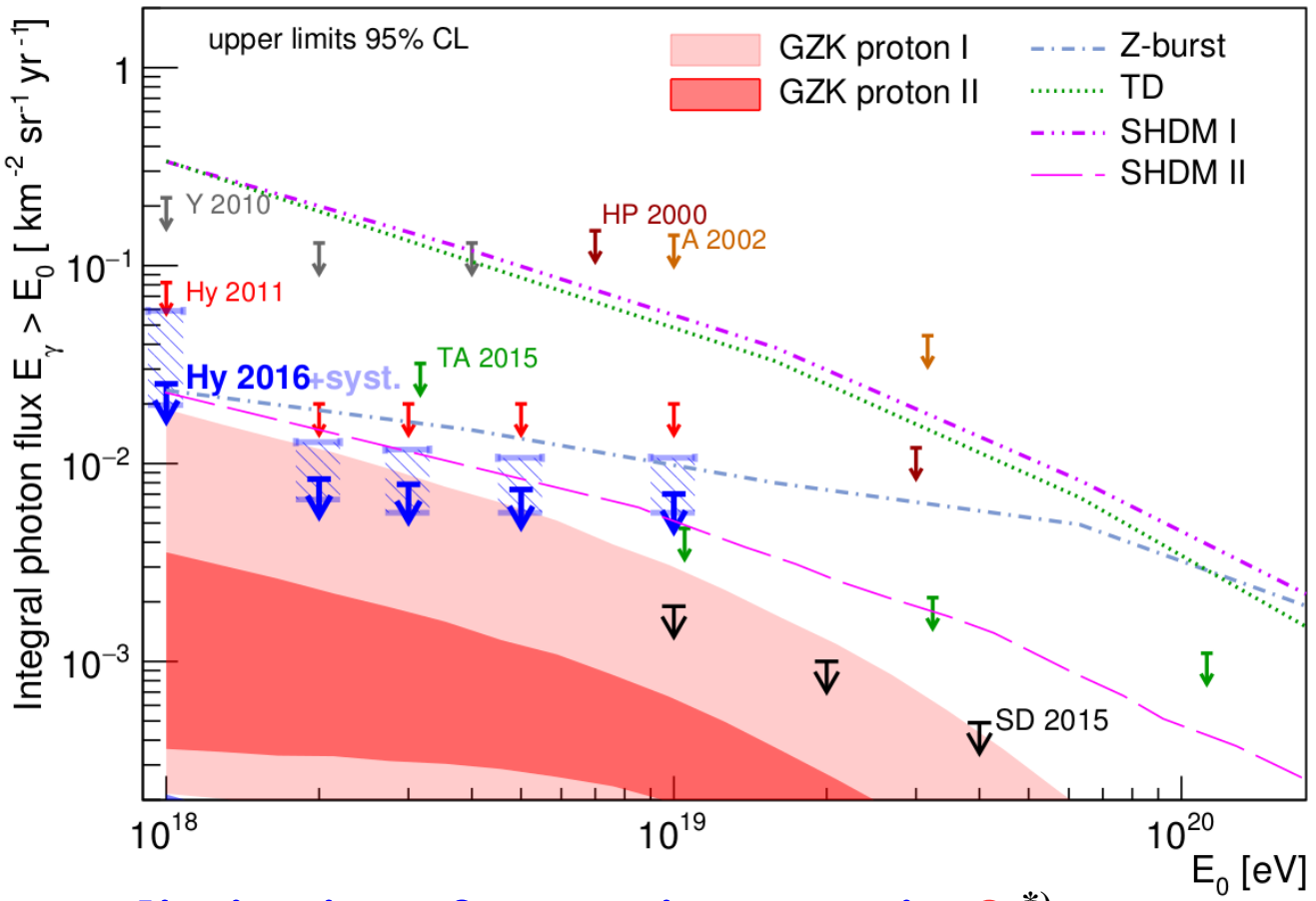
- top science motivation with super easy method
- data everywhere and for free
- massive data requires massive participation
- cheap massive detectors (toys?) possible
- mulitdisciplinary (astro, geo, bio)

…. **to engage even the youngest** science enthusiasts

Do UHE photons reach Earth?

UHECR COMPOSITION PARADIGM

At the highest energies photon fractions < 1%



→ **Severe limitations for exotic scenarios?** *)

→ **and for (special) Lorentz Invariance Violation?** *)

*) **Understand well**: limits apply to single photons, **assume no screening** eg. within exotic models of interactions, structure of a photon and the spacetime structure that could manifets at UHE...

Experimental evidence about γ_{UHE}

γ_{UHE} —no interactions / screening→ **Earth**

NOT OBSERVED

γ_{UHE} —unexpected interactions, screening, ...→ **ELECTROMAGNETIC CASCADES (SUPER-PRE-SHOWERS)** → **Earth**

NOT TRIED SO FAR...

↓

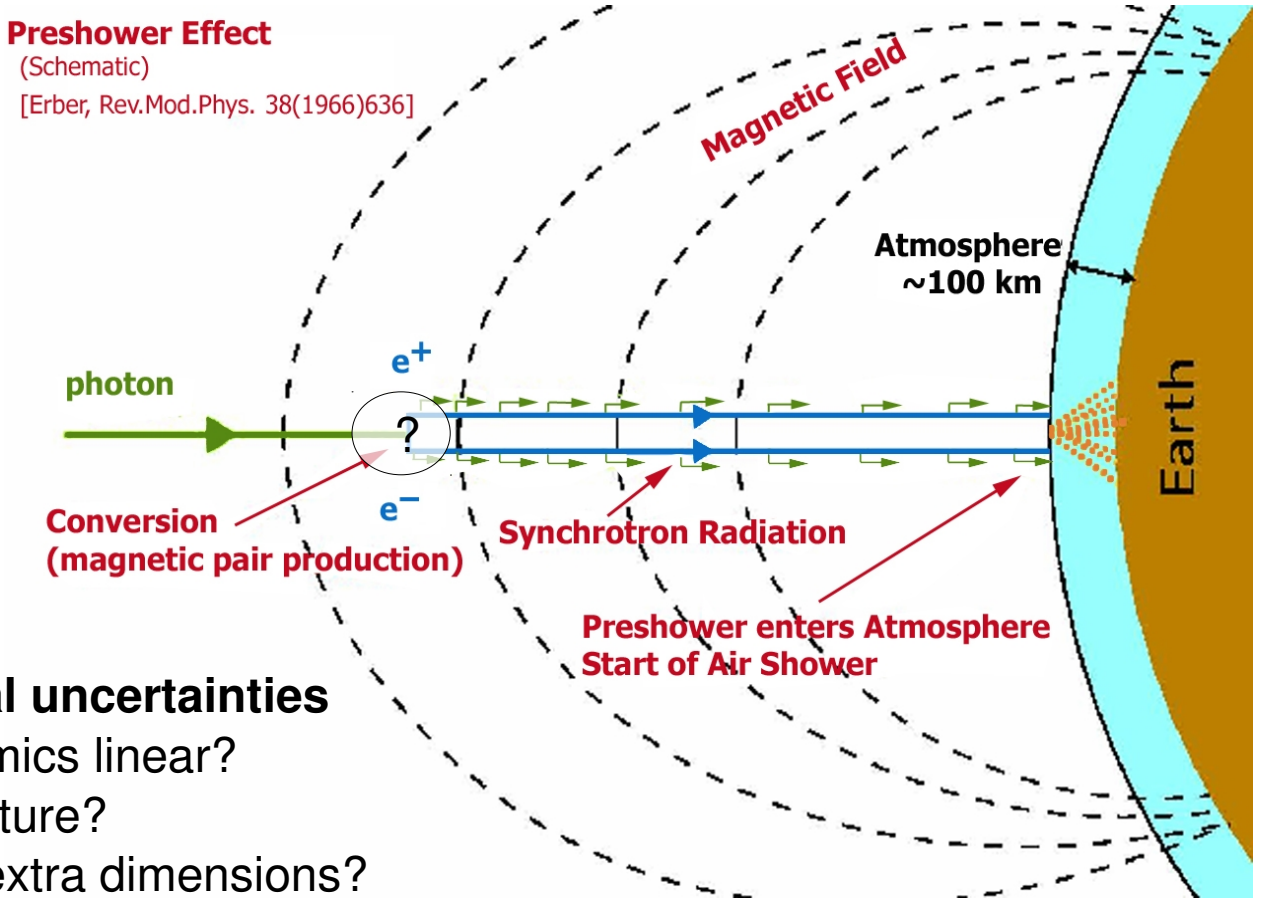
CREDO!

(Super-)preshowers: a must to study UHE photons

(super-)preshower:

→ contains typically **(>1000)** 100 particles

→ created at around **(>10000)** 1000 km a.s.l.)



? : **fundamental uncertainties**

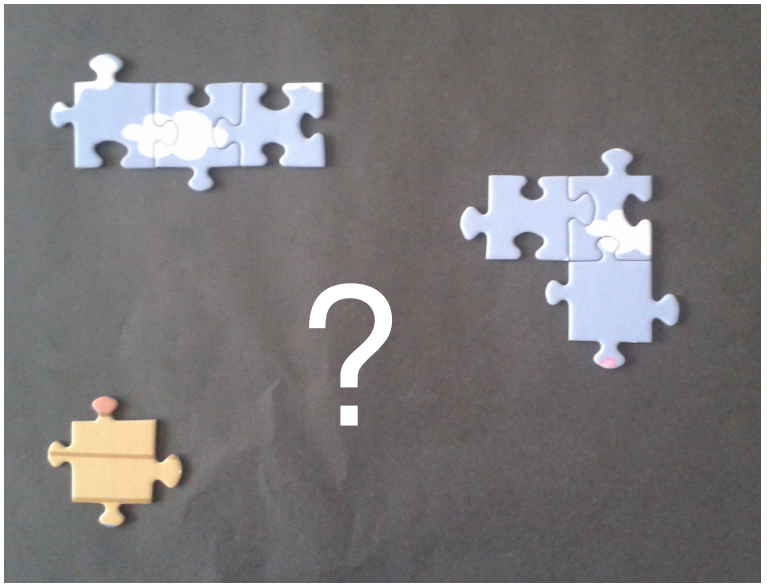
- electrodynamics linear?
- photon structure?
- spacetime: extra dimensions?

$N_{ATM} > 1$, type A, not observed?

Jak popularyzować naukę?

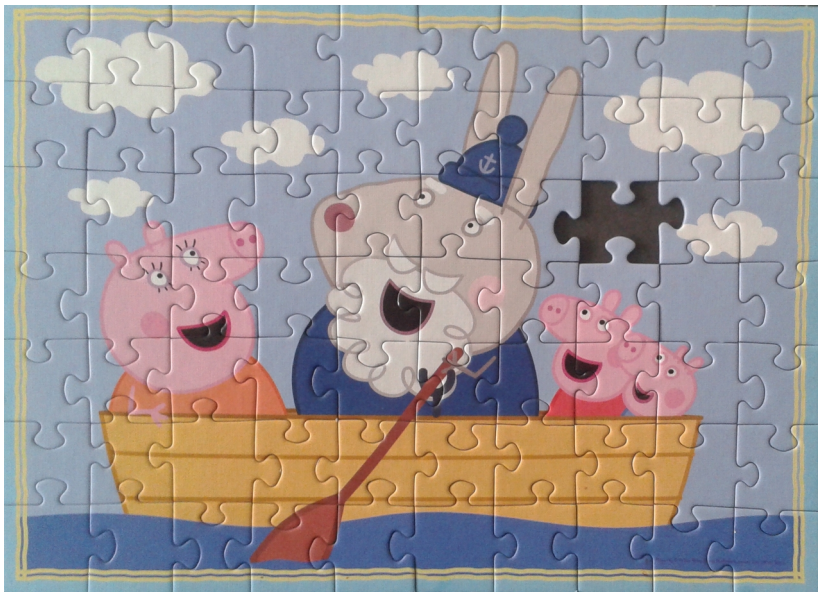
Więcej niewiedzy niż wiedzy?
Obszar niewiedzy rośnie
szybciej niż obszar wiedzy?

a)



Więcej wiemy niż nie wiemy?
Wiemy prawie wszystko?

b)



Popularyzacja nauki:

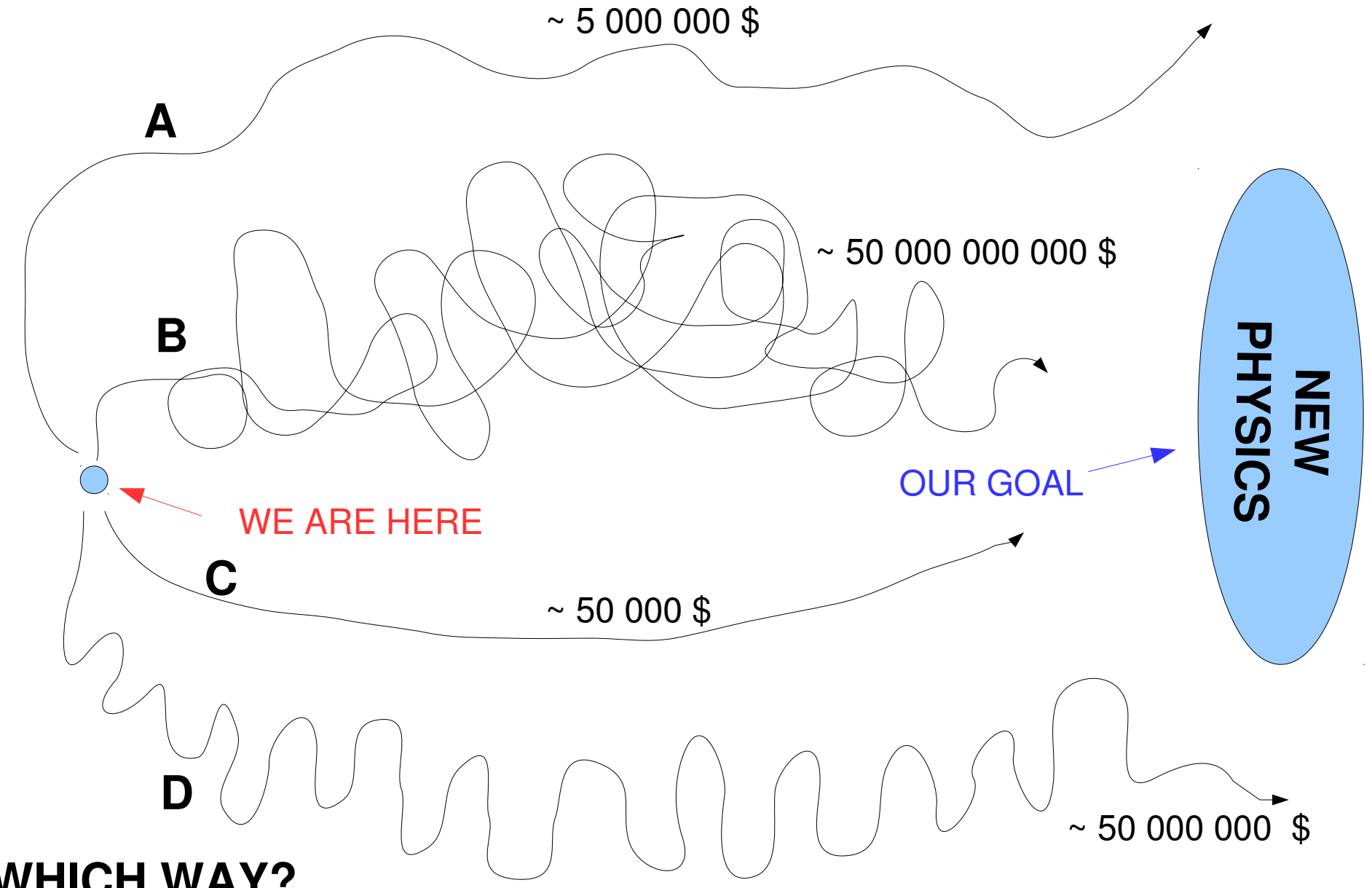
→ świadomość dostępnych zasobów wiedzy

→ **świadomość niewiedzy (wyzwań, zagadek)**

brakuje popularyzacji (informacji o) NIEWIEDZY?

zwłaszcza jeśli żyjemy w świecie typu a) …?

CHOICEOLOGY: example of practical philosophy



WHICH WAY?

Science: all; Philosophy: the most promising; Economy: cheap; Ethics: good for civiization

Why (mainly) very high energy photons interesting?

- they should exist

- they should initiate large scale cascades

- detection of large scale cascades unattempted

Photons as cosmic rays: astrophysical scenarios

Astrophysical scenarios

acceleration of nuclei (e.g. by shock waves)
+ „conventional interactions", e.g. with CMBR

- sufficently efficent astrophysical objects difficult to find
- small fractions of photons and neutrinos – mainly nuclei expected

??? Exotic scenarios (particle physics) **???**

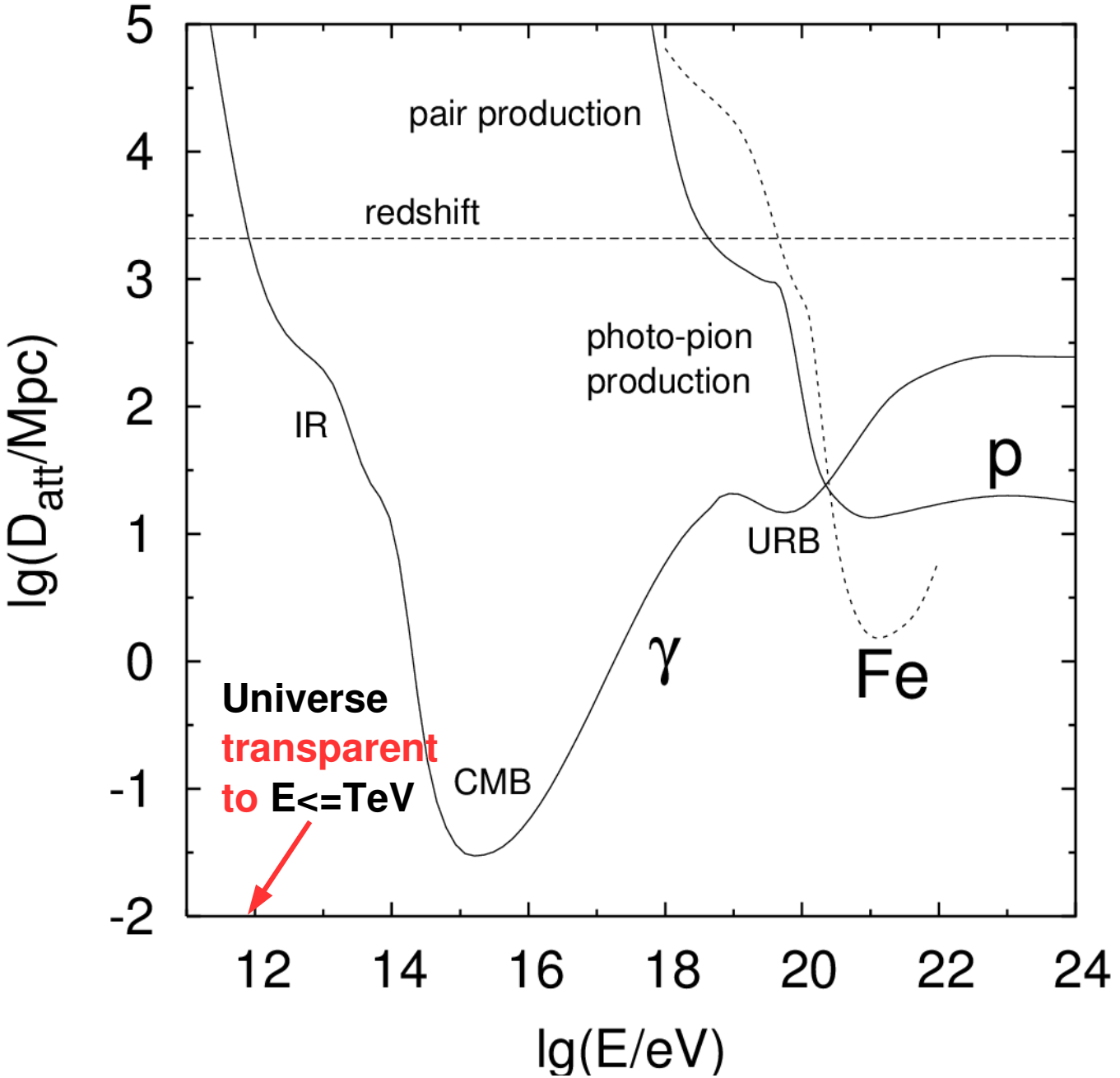
Decay or annihilation the early Universe relics
→ hypothetic supermassive particles of energies $\sim 10^{23}$ eV
→ decay to quarks and leptons → hadronization (mainly pions)

- large fraction of photons and neutrinos in UHCER flux

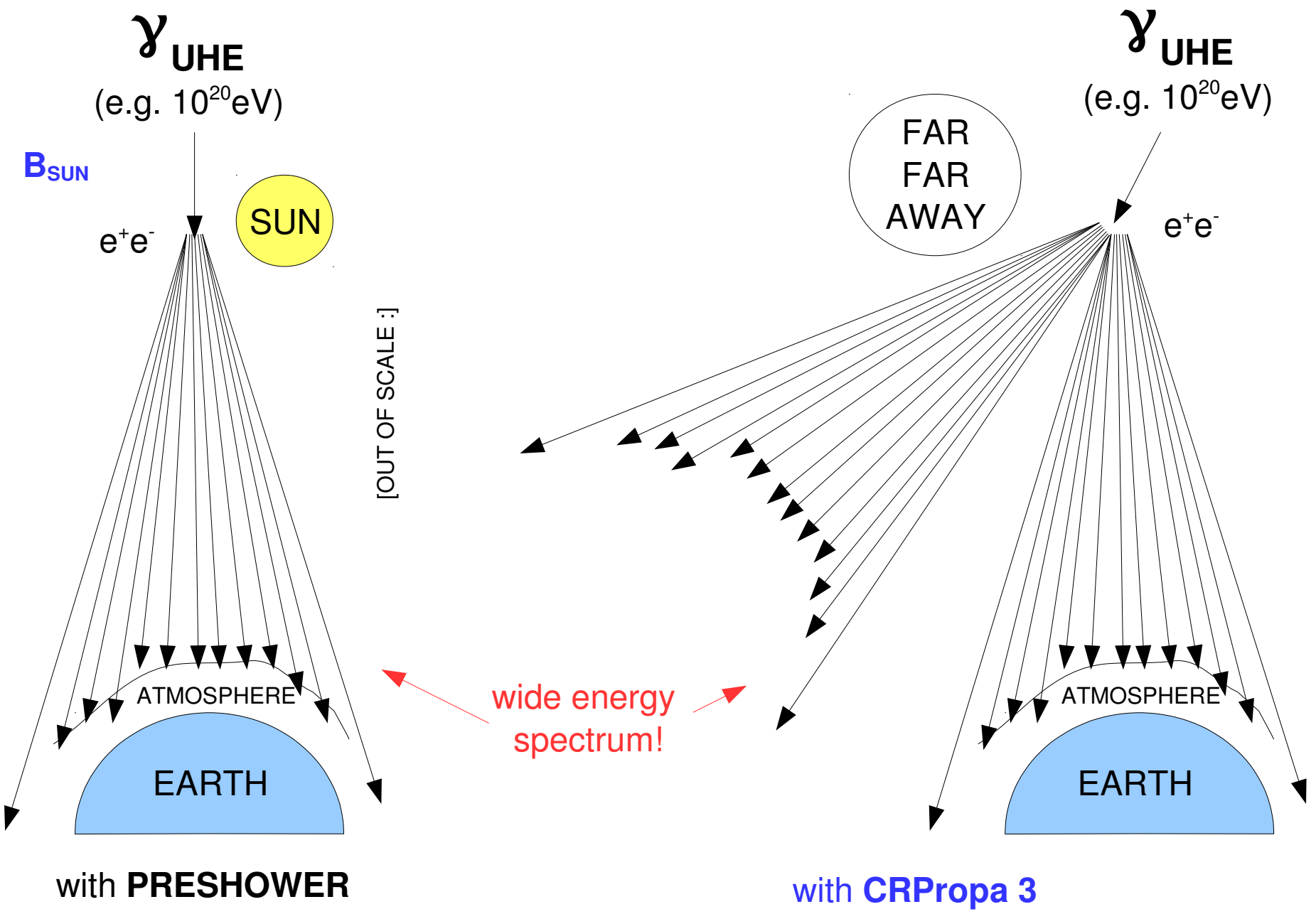
↓

not the case?

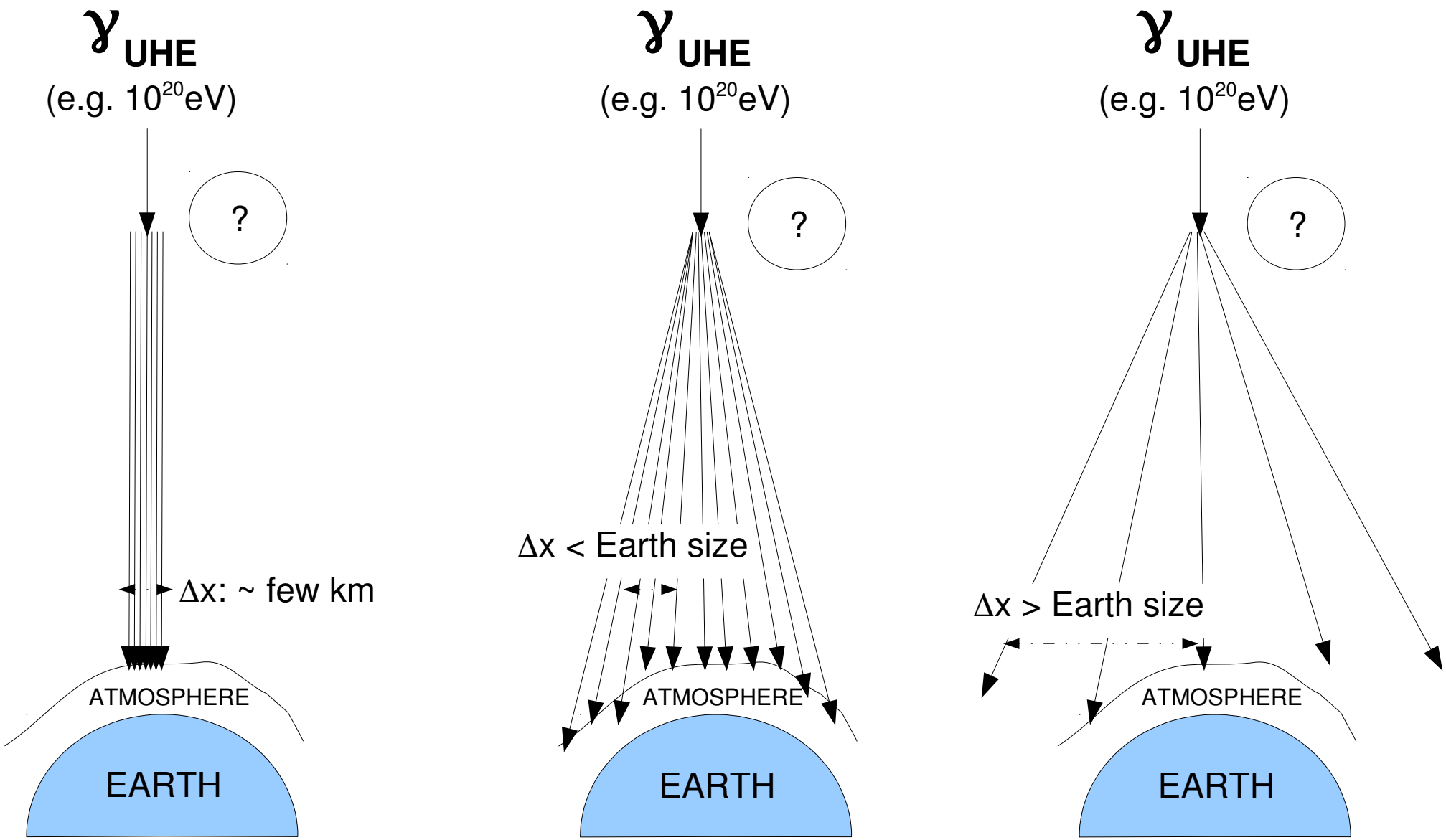
γ_{UHE} travelling through the Universe: paradigm



UHE photons → big cascades (classical examples)



N_{ATM} >= 1: untouched ground



Cosmic-Ray Ensembles (CRE): road map

Theoretical scenarios (ongoing)
non-exotic / exotic ✓

↓

CRE standalone simulations → particle distributions
at the top of the atmosphere (ongoing) ✓

↓

Air shower simulations (ongoing) ✓

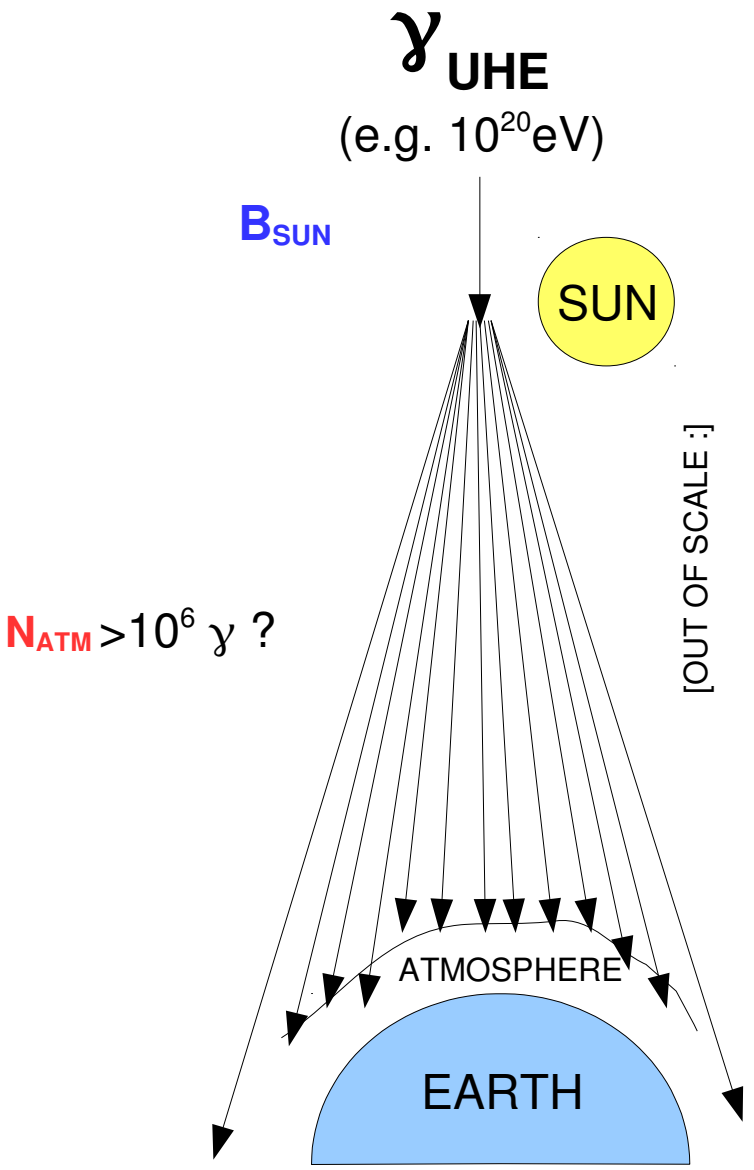
↓

Detector response (ongoing) ✓

↓

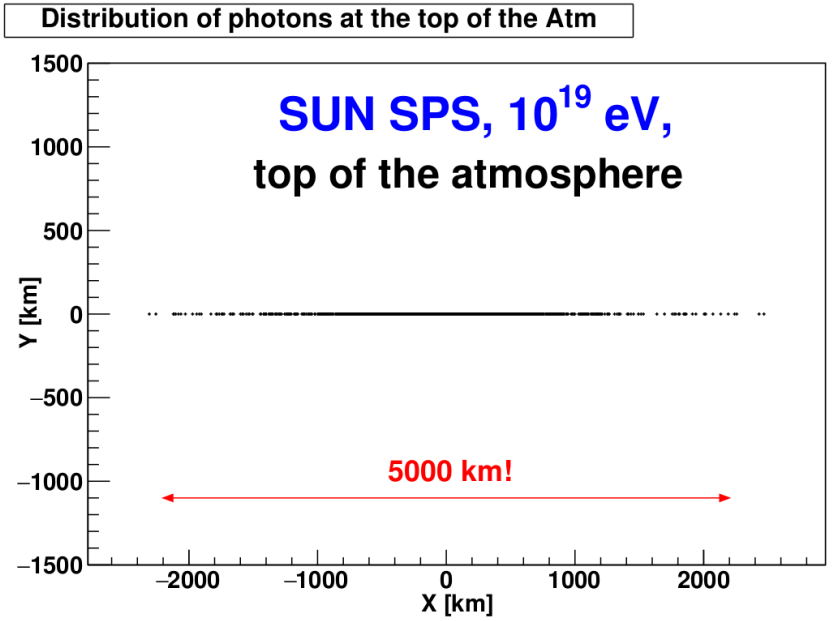
observation / upper limits

Super-preshowers (SPS) from the vicinity of the Sun



→ First calculations: W. Bednarek 1999
low energies not treated: extent ~ tens of km

→ N. Dhital, 2017
complete energy spectrum: extent
~ thousands of km



Distribution of photons ($E > 10^{13}$ eV) at the top of the atmosphere.
$E_\gamma = 10$ EeV, Impact parameter $= 2.5 R_S$.

$N_{ATM} > 1$ → observable (line even 10000 km wide), **not yet tried**

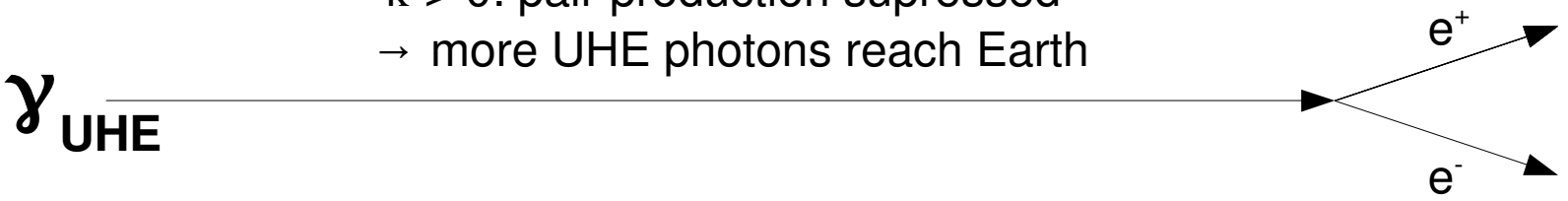
Motivation: Lorentz Invariance Violation

Modified dispersion relation of a photon:

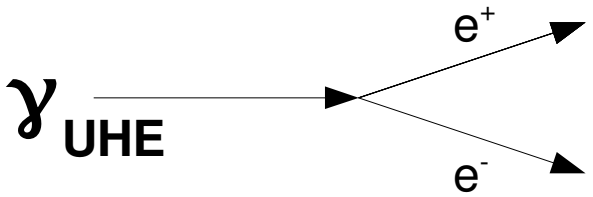
$$E_\gamma(\vec{k}) = \sqrt{\frac{(1-\kappa)}{(1+\kappa)}}|\vec{k}|$$

limits from gamma-ray astronomy,
98% C.L. (Klinkhamer & Schreck, 2008):
$6 \times 10^{-20} > \kappa > -9 \times 10^{-16}$

$\kappa > 0$: pair production supressed
→ more UHE photons reach Earth



$\kappa = 0$: „normal" pair production



$\kappa < 0$: pair production enhanced
(photon lifetime ~ 1 sec.!)
→ no UHE photons reach Earth

→ critical importance for the UHE photon search!
Observation of **photon cascades** would point to $\kappa < 0$!

Cosmic-Ray Ensembles (CRE): shortcut road map

Theoretical review (ongoing) ✓

↓

CRE standalone simulations → particle distributions at the top of the atmosphere (ongoing) ✓

↓

Air shower simulations (ongoing) ✓

↓

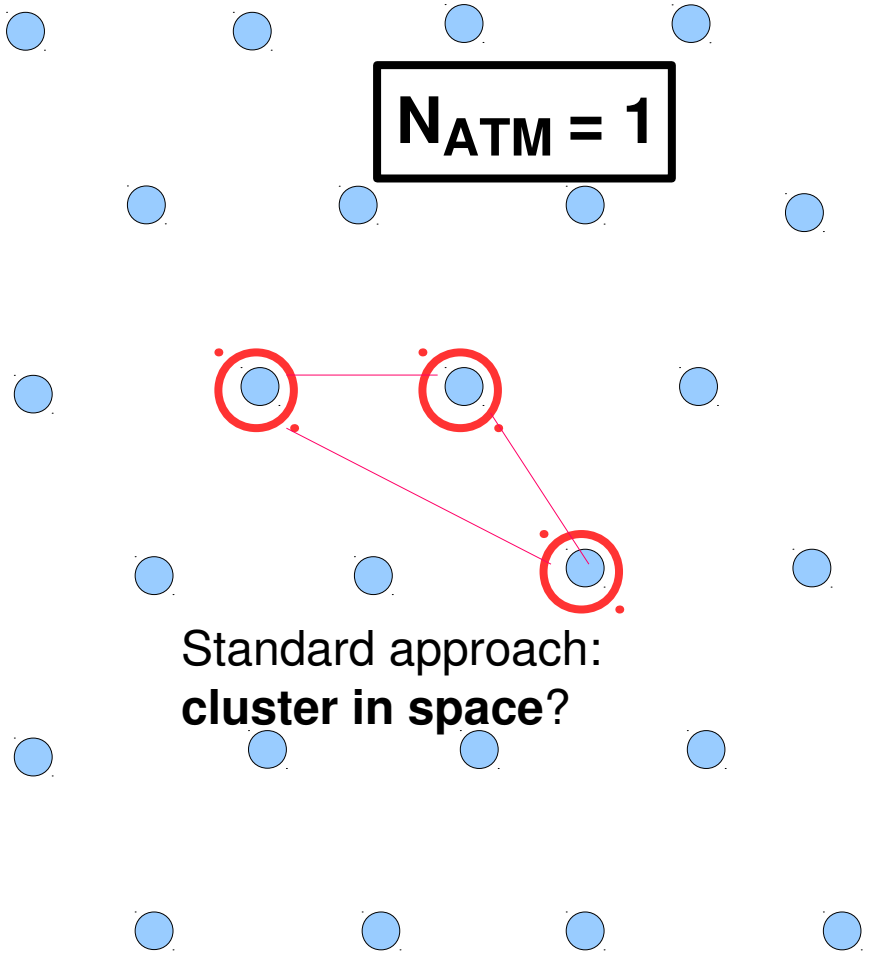
Detector response (ongoing) ✓

↓

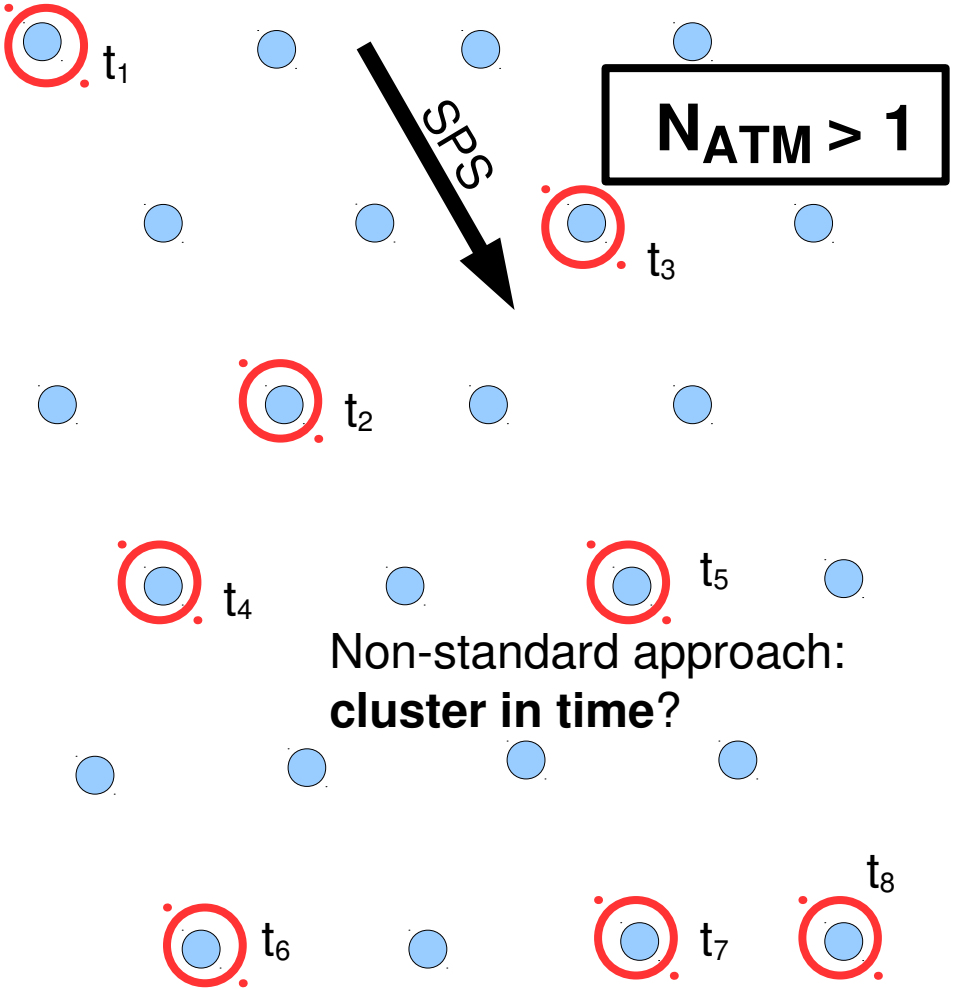
observation / upper limits

unique signature **fishing (ongoing)** ✓

A chance for a unique super-preshower signature



Standard approach:
cluster in space?

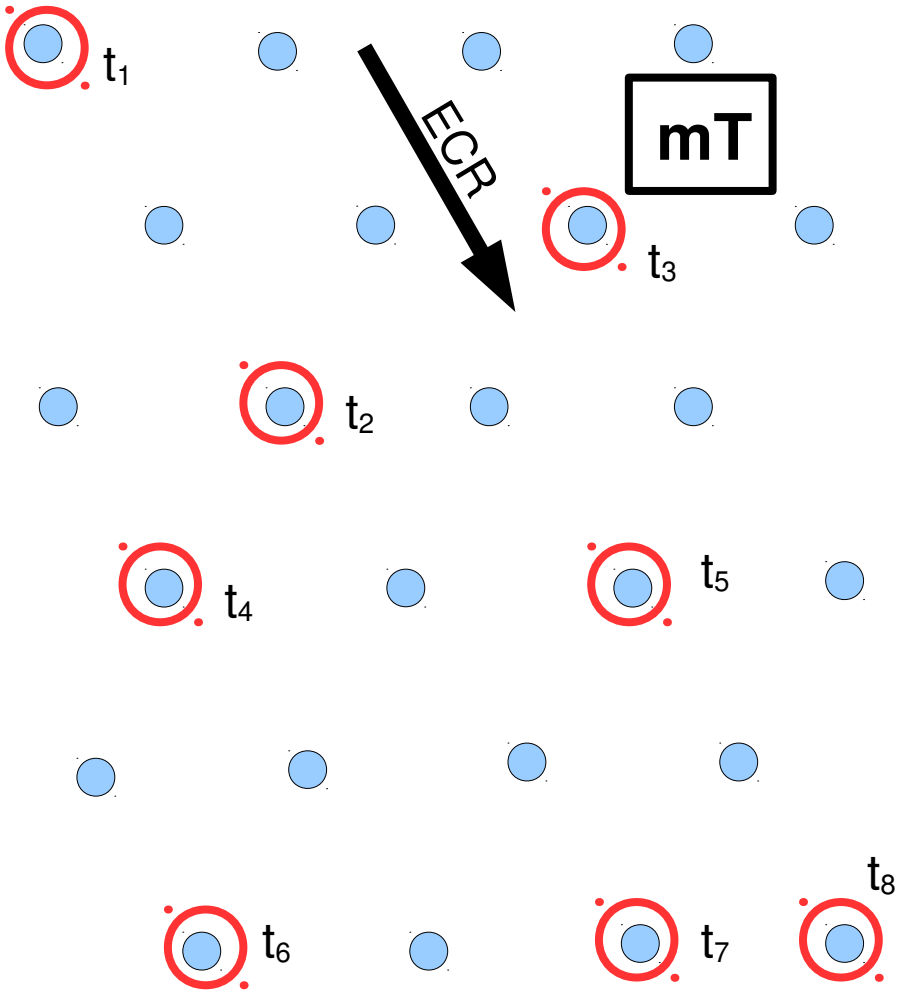


Non-standard approach:
cluster in time?

1) $t_n - t_1 <$ ~1 μs
2) $t_1 < \ldots < t_n$,

: a cosmic-ray detector

mT: NEW & EASY trigger for CRE



1) $t_n - t_1 < \sim 1\ \mu s$
2) $t_1 < \ldots < t_n$,

mT (multiTrigger)

Chance for a statistical coincidence for n=30, assuming trigger rate 100 Hz:

$P_{acc} = \sim 10/30! * 0.16^{30} =$ ridiculously small chance

sensitivity to $n_{LOW} < n < 30$

n_{LOW} =?

Does CREDO match the APPEC Roadmap 2017-26?

www.appec.org/roadmap

Szukaj

Home | About | Consortium | Research | Roadmap | News | Contact

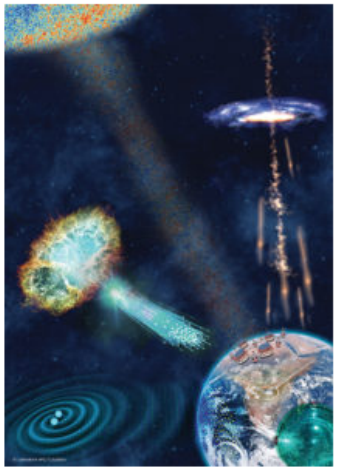
[Launched: 9th Jan 2018, Brussels]

European Astroparticle Physics Strategy 2017-2026

The Astroparticle Physics European Consortium (APPEC) are proud to announce the launch of the latest European Astroparticle physics strategy (2017-2026).

Download the European Astroparticle Physics Strategy 2017-2026

Astroparticle physics is the fascinating field of research at the intersection of astronomy, pahttp://www.appec.org/wp-content/uploads/2017/08/APPEC-Strategy-Book-Proof-23-Nov-2.pdfrticle physics and cosmology. It simultaneously addresses challenging questions relating to the micro-cosmos (the world of elementary particles and their fundamental interactions) and the macro-cosmos (the world of celestial objects and their evolution) and, as a result, is well-placed to advance our understanding of the Universe beyond the Standard Model of particle physics and the Big Bang Model of cosmology.



Apart from promoting cooperation and coordination, a crucial APPEC activity is to formulate, update and realise the European astroparticle physics strategy. Building on earlier strategies released in 2008 and 2011, APPEC started a new roadmap process. The APPEC Scientific Advisory Committee (SAC) provided valuable contributions to the scientific part of the roadmap, followed by contributions from the agencies. In April 2016 the APPEC General Assembly, in close cooperation with the SAC, organised a very well-attended and animated two-day Town Meeting in Paris open to the entire astroparticle physics community. This provided the

APPEC: 21 recommendations → „CREDO match summary": >=12

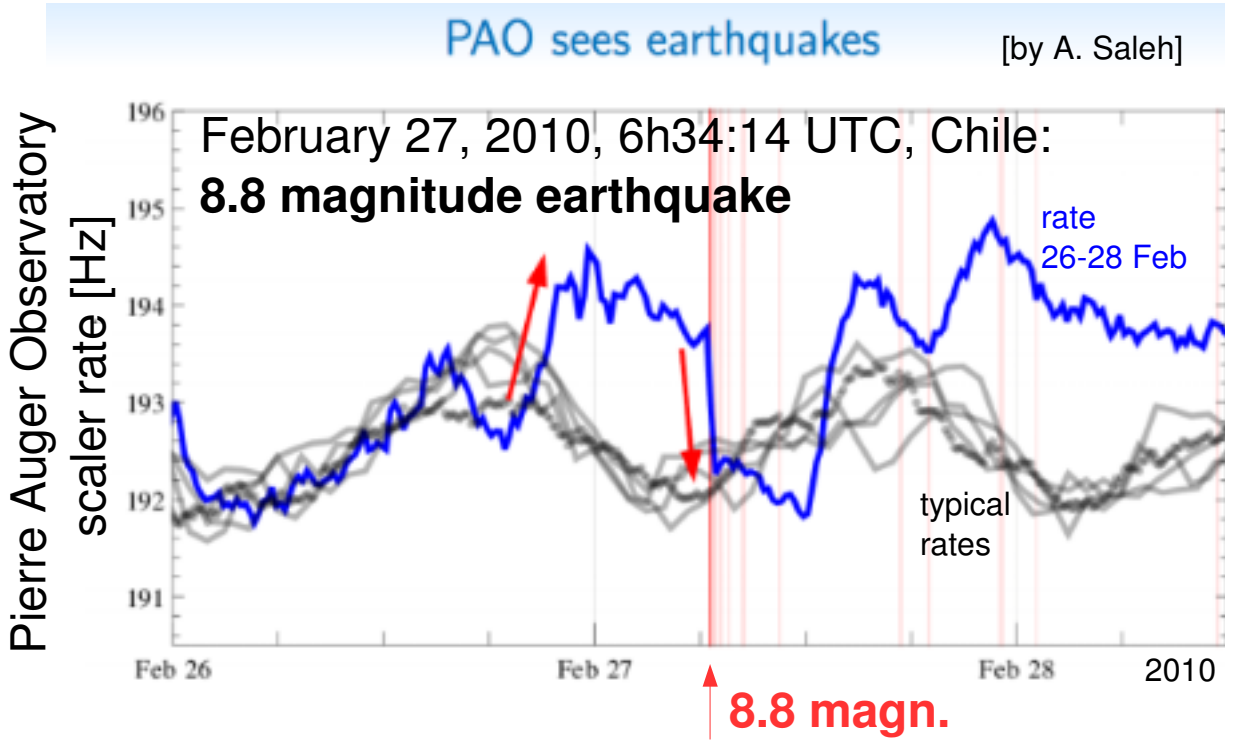
<u>APPEC Office about the „CREDO match summary":</u>

This is a valuable document **we can keep for the implementation of the roadmap** that is starting now. […] Your interpretation of outreach is fascinating. [...] Here you mean a systematic, long-term involvement, providing a software to support it: great! [...] it is a modern and efficient approach in engaging people of every age in Physics that **APPEC cannot miss**.

CREDO

THE QUEST FOR UNEXPECTED

Scientific diversity: GEO



→ **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!**

Experimental Cosmology & Quantum Gravity!

T. Jacobson, S. Liberati, and D. Mattingly, Annals Phys. 321 (2006) 150

Lorentz violation at high energy: concepts, phenomena and astrophysical constraints

Ted Jacobson [a], Stefano Liberati [b], David Mattingly [c]

[a] *Department of Physics, University of Maryland, USA*

[b] *International School for Advanced Studies and INFN, Trieste, Italy*

[c] *Department of Physics, University of California at Davis, USA*

extensive review). A partial list of such "windows on quantum gravity" is

- sidereal variation of LV couplings as the lab moves with respect to a preferred frame or directions
- cosmological variation of couplings
- cumulative effects: long baseline dispersion and vacuum birefringence (e.g. of signals from gamma ray bursts, active galactic nuclei, pulsars, galaxies)
- new threshold reactions (e.g. photon decay, vacuum Čerenkov effect)
- shifted existing threshold reactions (e.g. photon annihilation from blazars, GZK reaction)
- LV induced decays not characterized by a threshold (e.g. decay of a particle from one helicity to the other or photon splitting)
- maximum velocity (e.g. synchrotron peak from supernova remnants)
- dynamical effects of LV background fields (e.g. gravitational coupling and additional wave modes)