Cosmic-Ray Extremely Distributed Observatory*: the new beginning - BACKUP

Piotr Homola □

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

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

CREDO Visegrad Workshop, Opava, 21-23.11.2019

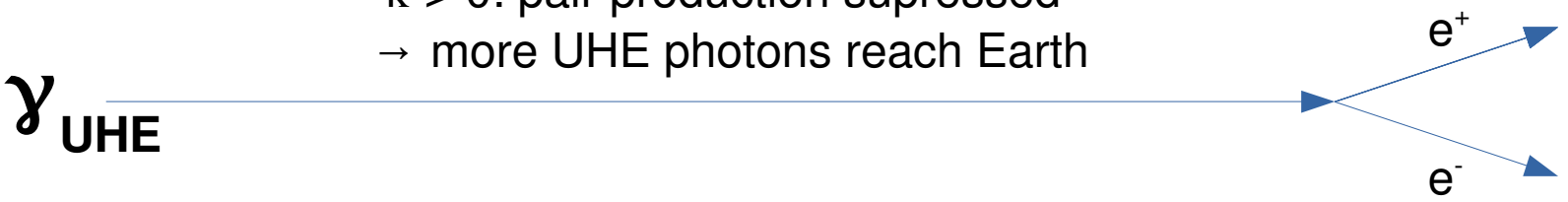
CRE and Lorentz Invariance Violation

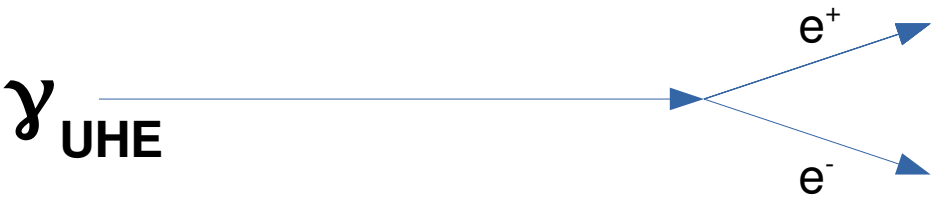
Modified dispersion relation of a photon:

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

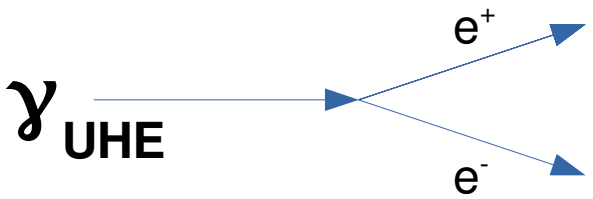
limits from gamma-ray astronomy,
98% C.L. (Klinkhamer & Schreck, 2008):
$6 \times 10^{-20} > \kappa > -9 \times 10^{-16}$

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



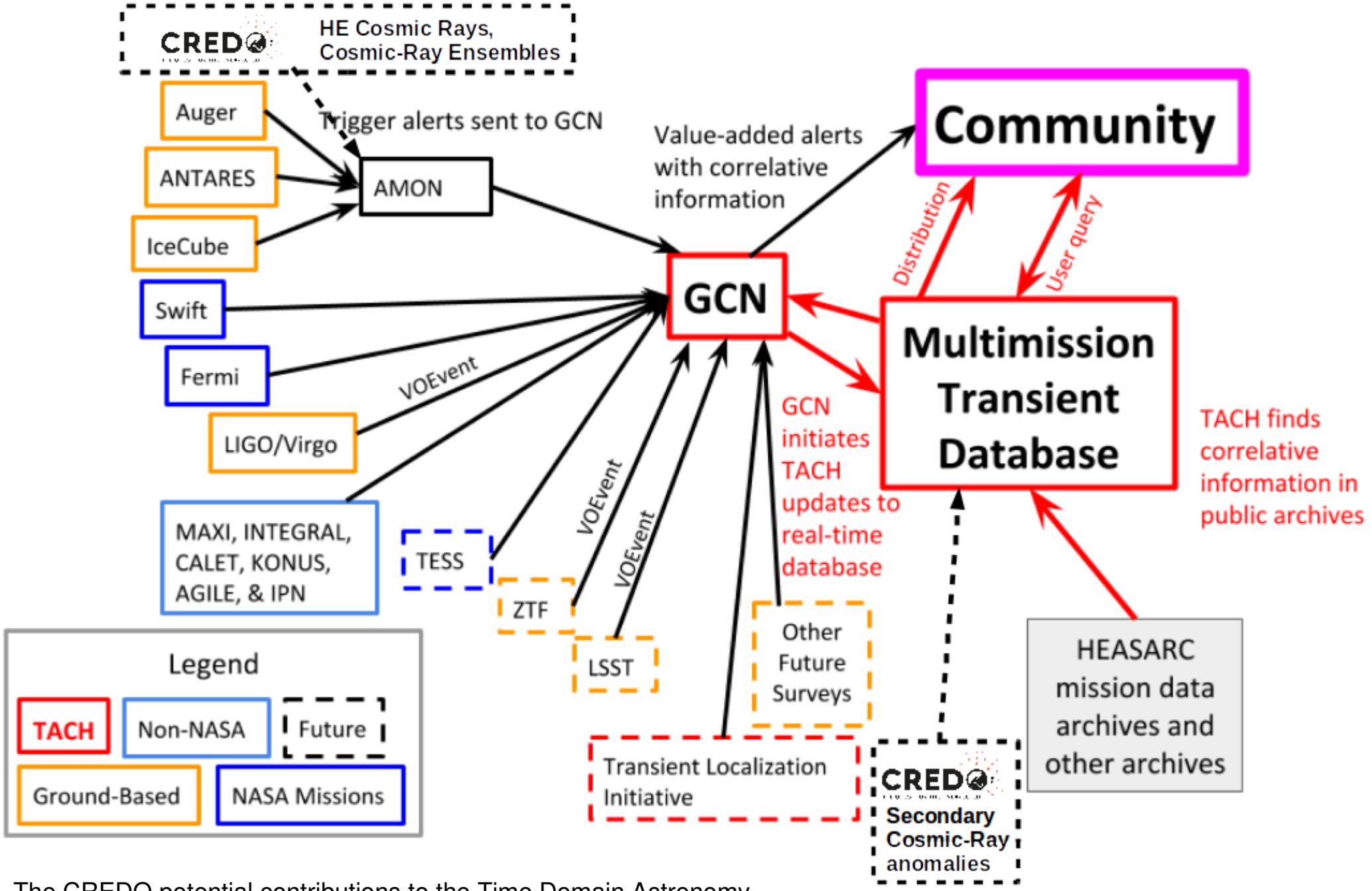


$\kappa = 0$: „normal" pair production



$\kappa < 0$: 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 $\kappa < 0$!

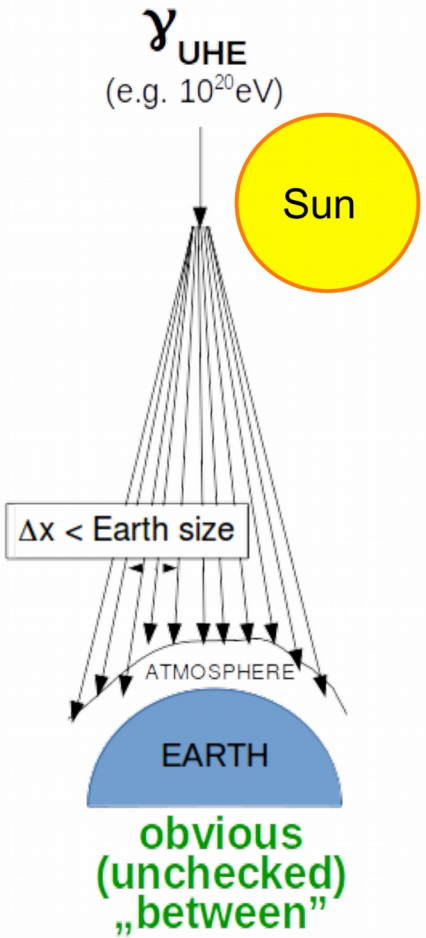


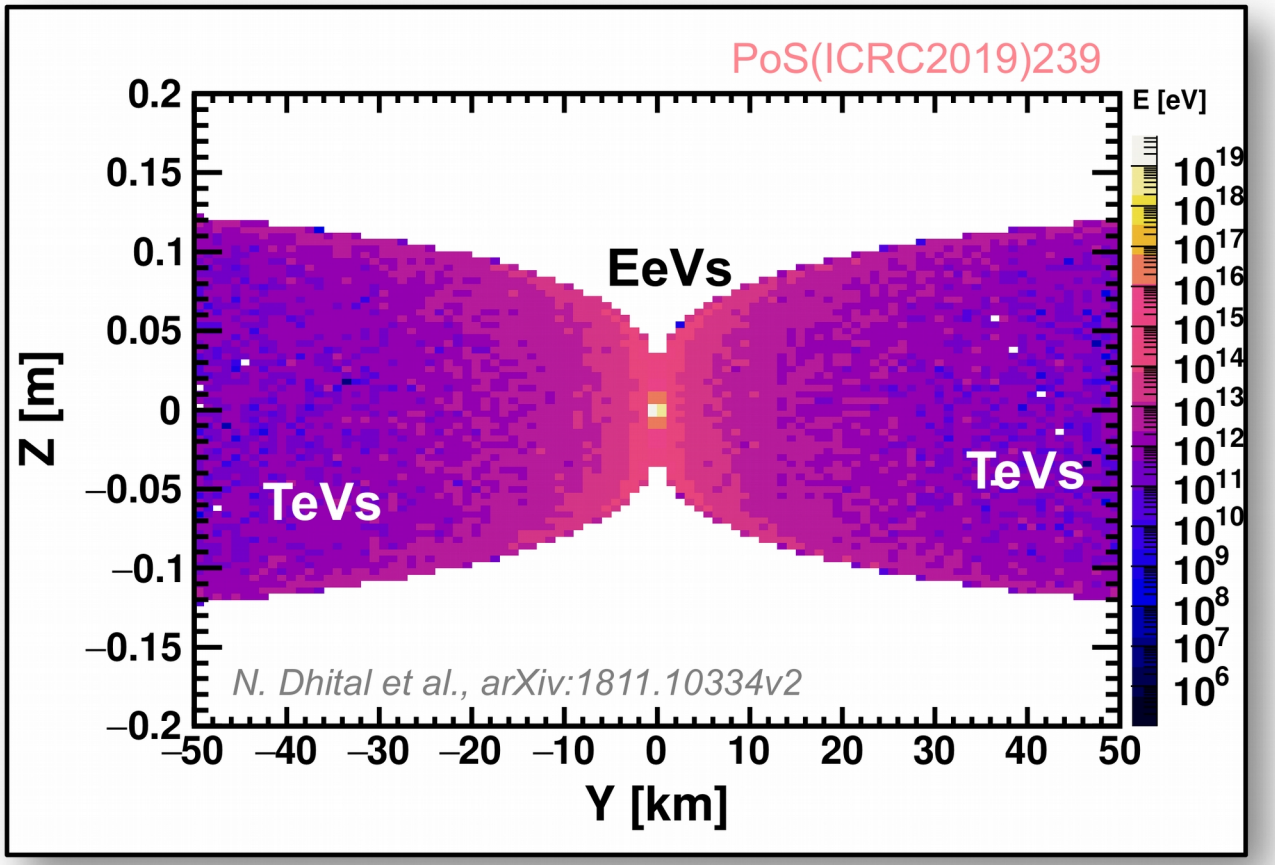
The CREDO potential contributions to the Time Domain Astronomy Coordination Hub (TACH), a new NASA initiative (the CREDO logo has been positioned in two distinct places on top of the slide by Judith Racusin, NASA, from her invited talk at the New Era of Multi-Messenger Astrophysics Conference, Groningen, March 2019).

Example of CRE : Preshower near the Sun

> First calculations by *W. Bednarek* (1999) low energies not treated → extent ~ **tens of km** at the top of the atmosphere.

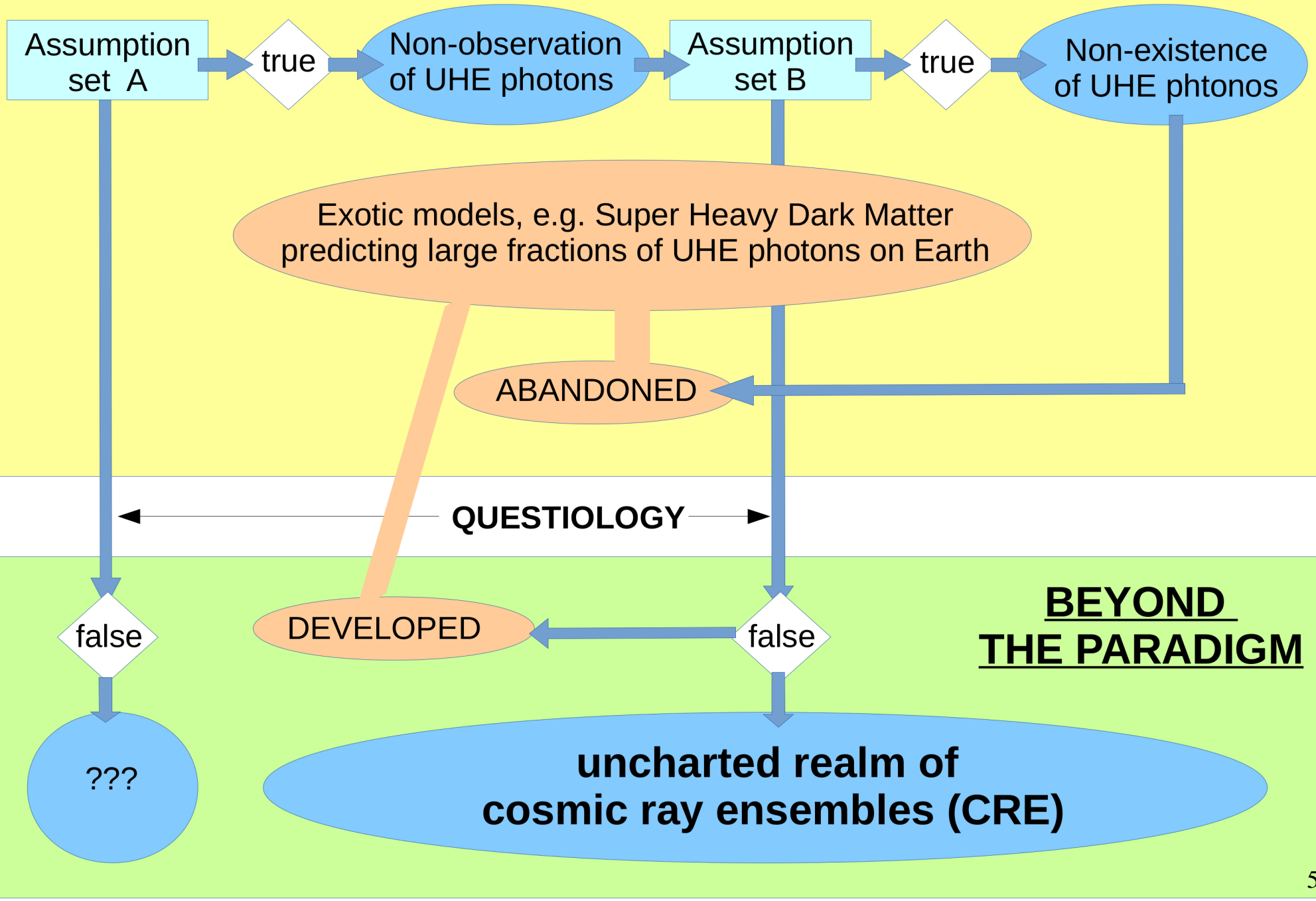
> New simulations: all energy spectrum → extent ~ **thousands of km** at the top of the atmosphere.





Typical particle/energy distribution at the top of atmosphere for 100 EeV photon interacting close to the Sun (3 $R_\odot$)

Ultra-high energy cosmic ray (UHECR) PARADIGM



The CREDO Detector App, status 10th September 2019

selected statistics (by S. Stuglik)

- 3 286 288 detections
- 6 297 724 device pings (sums up to 973 years looking for particles)
- 7811 users with at least 1 detection
- 11061 devices
- 2714 teams
- ~27 GB data storage in JSON files

- First Light in Quantum Gravity Previewer,
  The first experiment on the CREDO infrastructure!
- https://credo.science/quantum-gravity-previewer/

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.

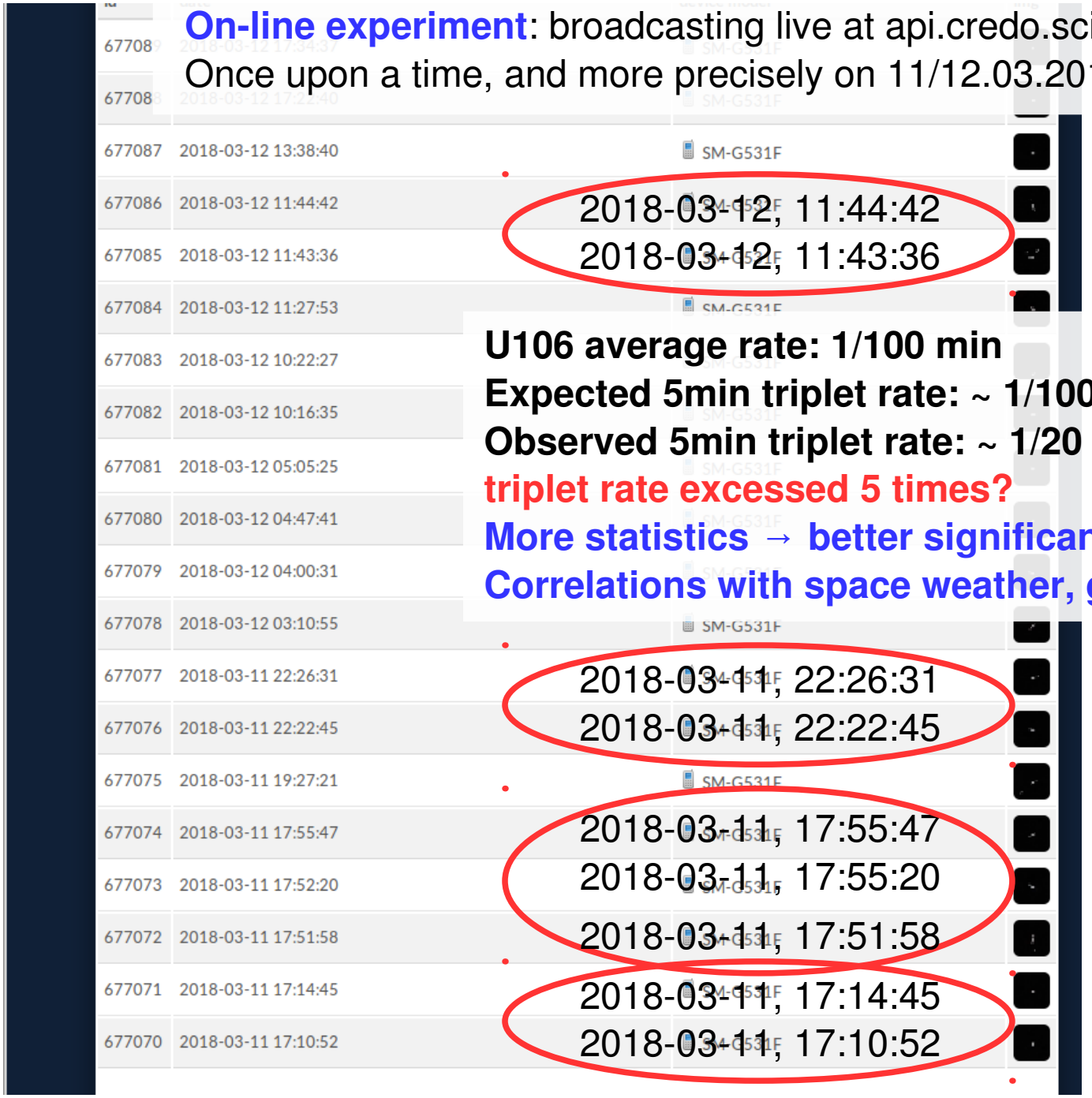
UC Davis Chancellor May Announces Emily Galindo and Rahim Reed to Fill Interim Leadership Roles
March 13, 2018

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

→ predicted by Quantum Gravity

Quantum Gravity Previewer 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?

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3 min 49 s (a triplet!)

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2018-03-11, 17:10:52

3 min 53 s

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

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

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

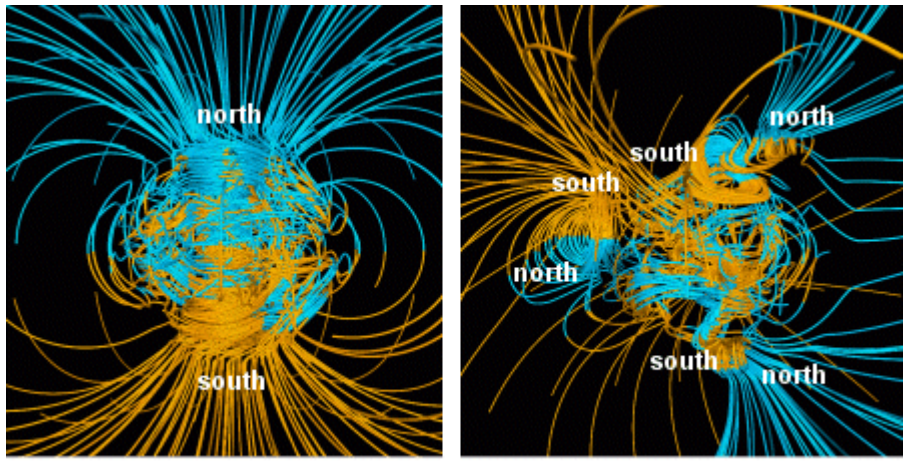
unique signature **fishing (ongoing)** ✓

… potential and beyond

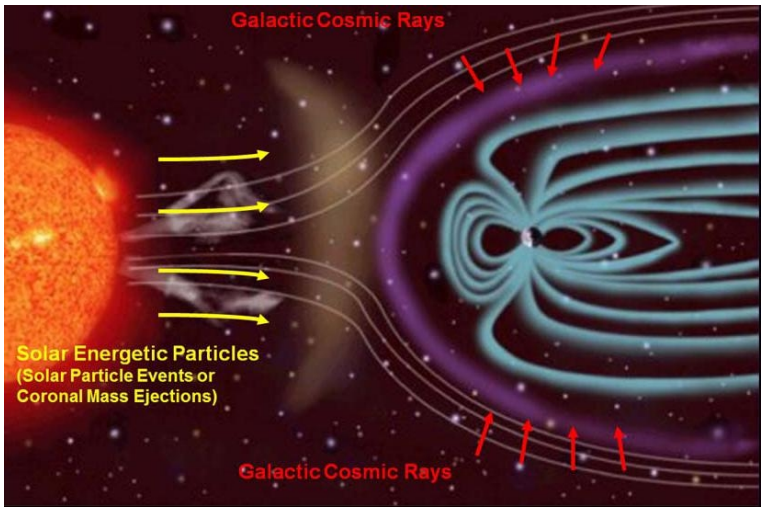
→ interdisciplinarity

Cosmic Rays and earthquake early warning?

Wikipedia: „Geomagnetic 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?

OCTOBER 2018

VOLUME 319, NUMBER 4

SCIEN
AMEI

ON THE COVER
Three mathematicians spent several years and 146 pages proving that the "spectral gap" problem—the question of whether materials have a gap between their lowest energy level and first excited state—is undecidable. To reach this conclusion, the researchers investigated the computer science of Turing machines, the mathematics of bathroom floor tiles and the foundations of quantum physics.
Illustration by Mark Ross Studios.

SEISMOLOGY

Earthquakes in the Sky

The best early warnings of a big disaster may appear 180 miles above the ground, a controversial new theory says

By Erik Vance

Illustration by Maria Corte

Workshop on Observatory Synergies for Astroparticle physics and Geoscience

11-12 February 2019
IPGP
Europe/Paris timezone

- Overview
- Call for Abstracts
- Timetable
- Apply for a Grant
- Contribution List
- Speaker List
- Book of Abstracts
- Registration
- Participant List
- Venue
- Information

Timetable

Mon 11/02 | **Tue 12/02** | All days

Print | PDF | Full screen | Detailed view | Filter

09:00

Speed-of-light Seismology and Earthquake Early Warning Systems — *J-P Montagner et al.*
Amphithéâtre, IPGP 09:00 - 09:20

Time and frequency transfer over telecommunication fiber networks: a new research infrastructure for geoscience and astroparticle physics? — *P-E Pottie*

Geophysical noise in the Virgo gravitational wave antenna — *Irene Fiori*
Amphithéâtre, IPGP 09:40 - 09:55

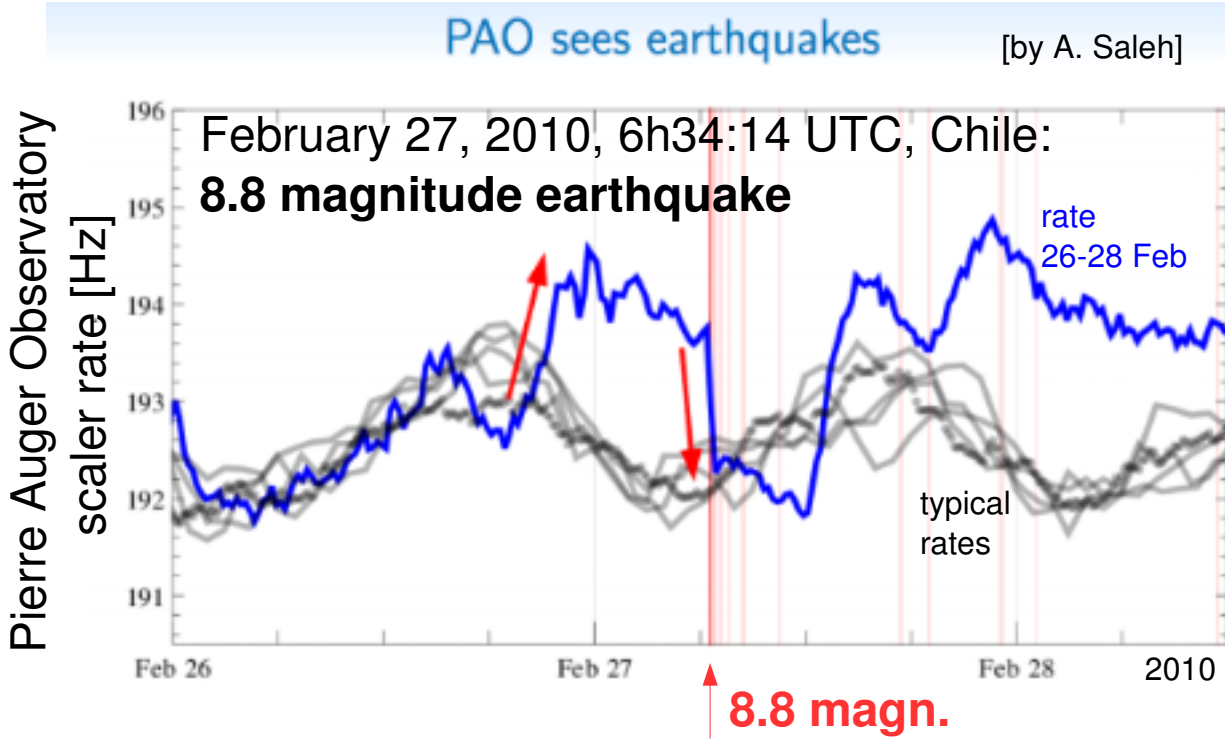
10:00

Seismic characterization of GW detector sites using an array of wireless geophones — *Soumen Koley*
Amphithéâtre, IPGP 09:55 - 10:10

CREDO

THE QUEST FOR THE UNEXPECTED

Scientific diversity: GEO



- 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]:

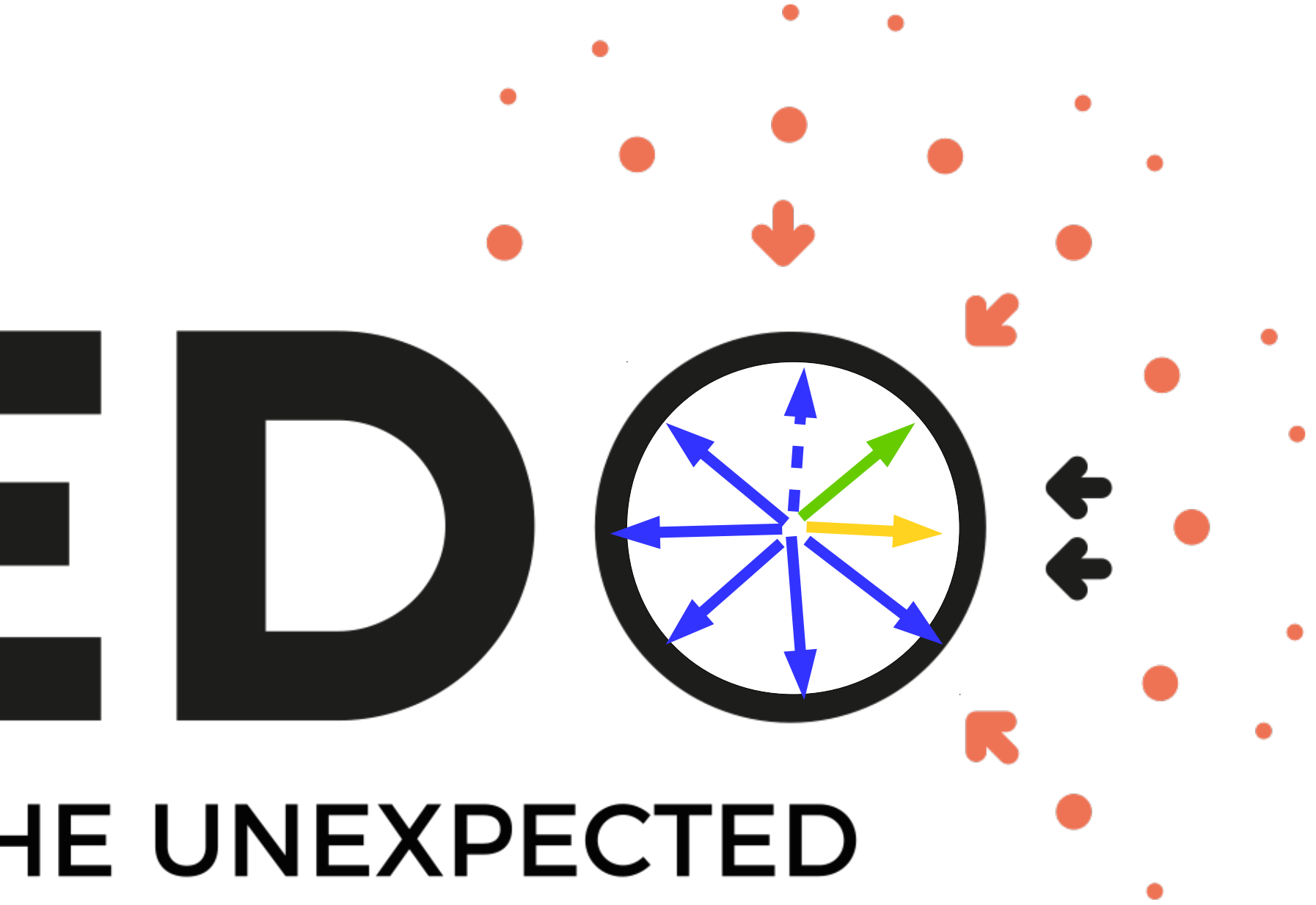
2,7 billion people

Science as a service to the human community?

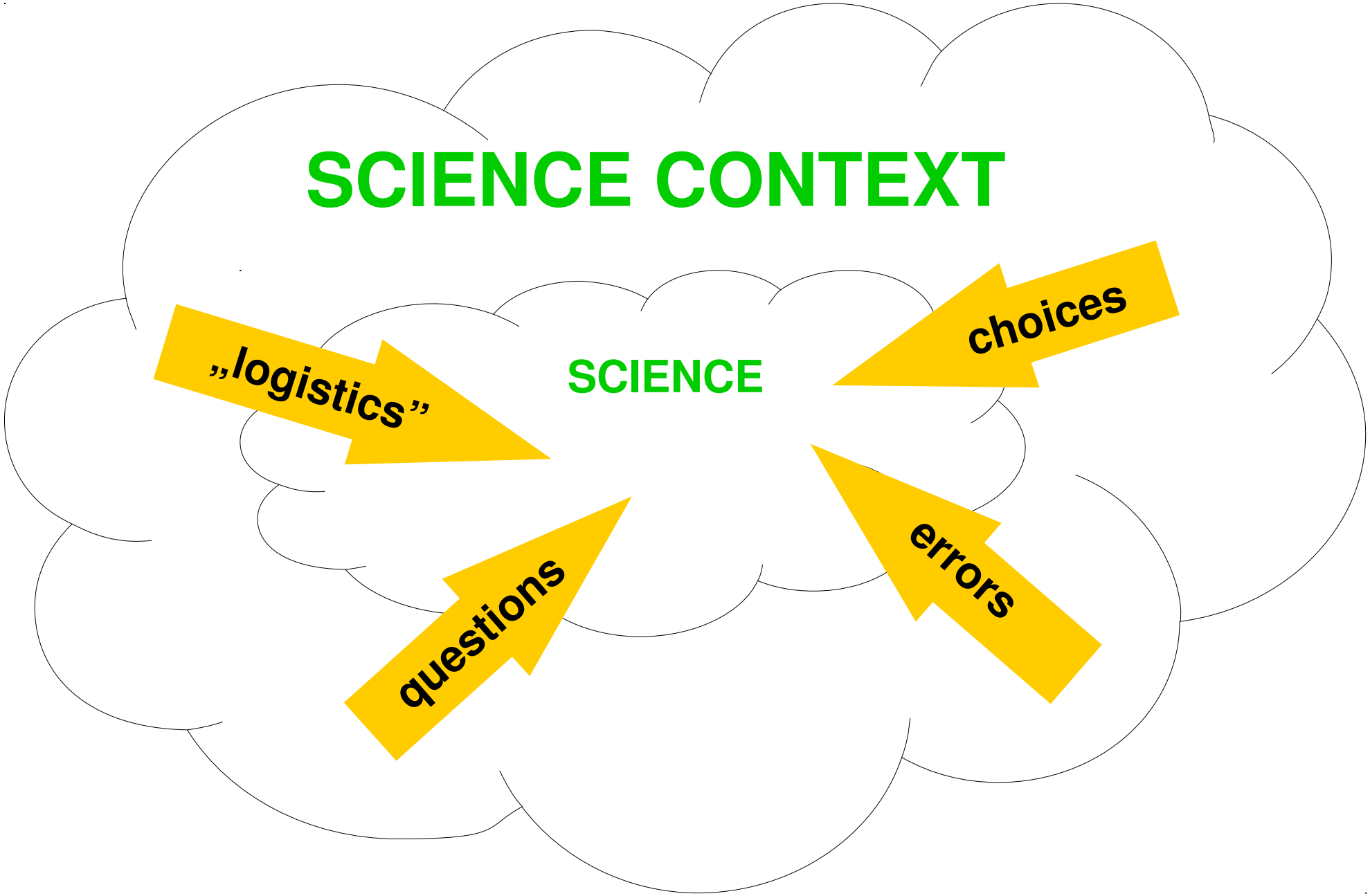
Even the smallest chance to save lives

= **a must check!**

CREDO: astro/geo multimessenger infrastructure!

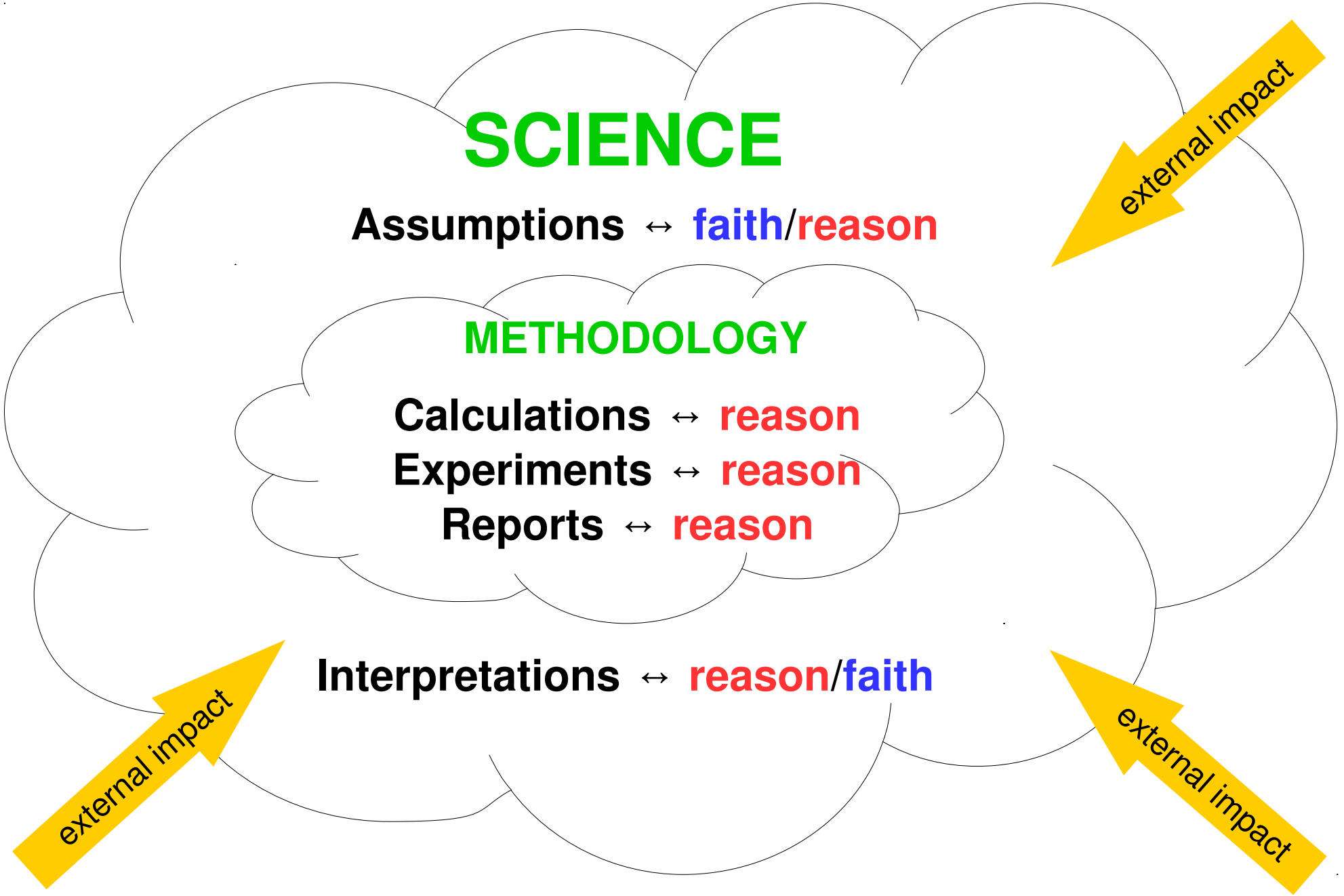


Science & “external” impact



Psychology, Sociology, Philosophy, Economics, Politics, …..

Science: reason & faith interplay?



CREDO

THE QUEST FOR THE UNEXPECTED

Success guaranteed?

Mission

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

Strategy

Spread globally & grow giant → „1 million scientific community”

Tactics

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

Potential

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

→ evokes **hot keywords** (big data, machine learning, AI, blockchain, decentralized autonomous organizations, cryptocurrency,...)

Why 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?

CREDO Theatre!

Trailer and Part I: CREDO YouTube, Part II: soon!

Fundament fundamentów - wyzwanie wyzwań

Czasoprzestrzeń jako scena

Gładka?

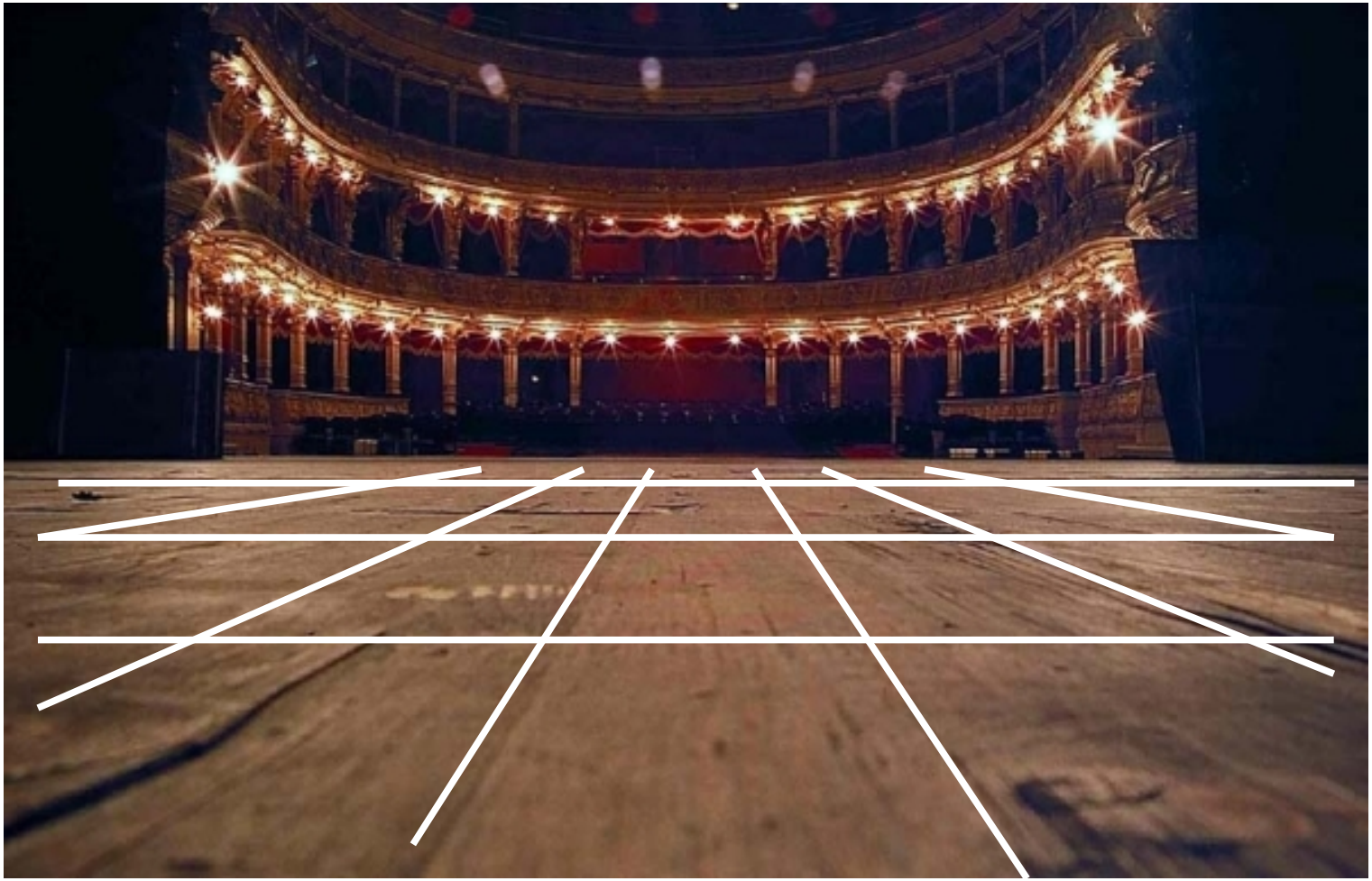
Fundament fundamentów - wyzwanie wyzwań

Czasoprzestrzeń jako scena

Dziury?

Fundament fundamentów - wyzwanie wyzwań

Czasoprzestrzeń jako scena



Sieć?

Fundament fundamentów - wyzwanie wyzwań

Czasoprzestrzeń jako scena

P / A N A ?

Big Wheel vs. Small Car (zespoły cząstek) jako testery sceny

Zespół promieni kosmicznych
o różnych energiach (CRE),
prędkość światła

START
(KOSMOS)

META
(ZIEMIA)

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CRE

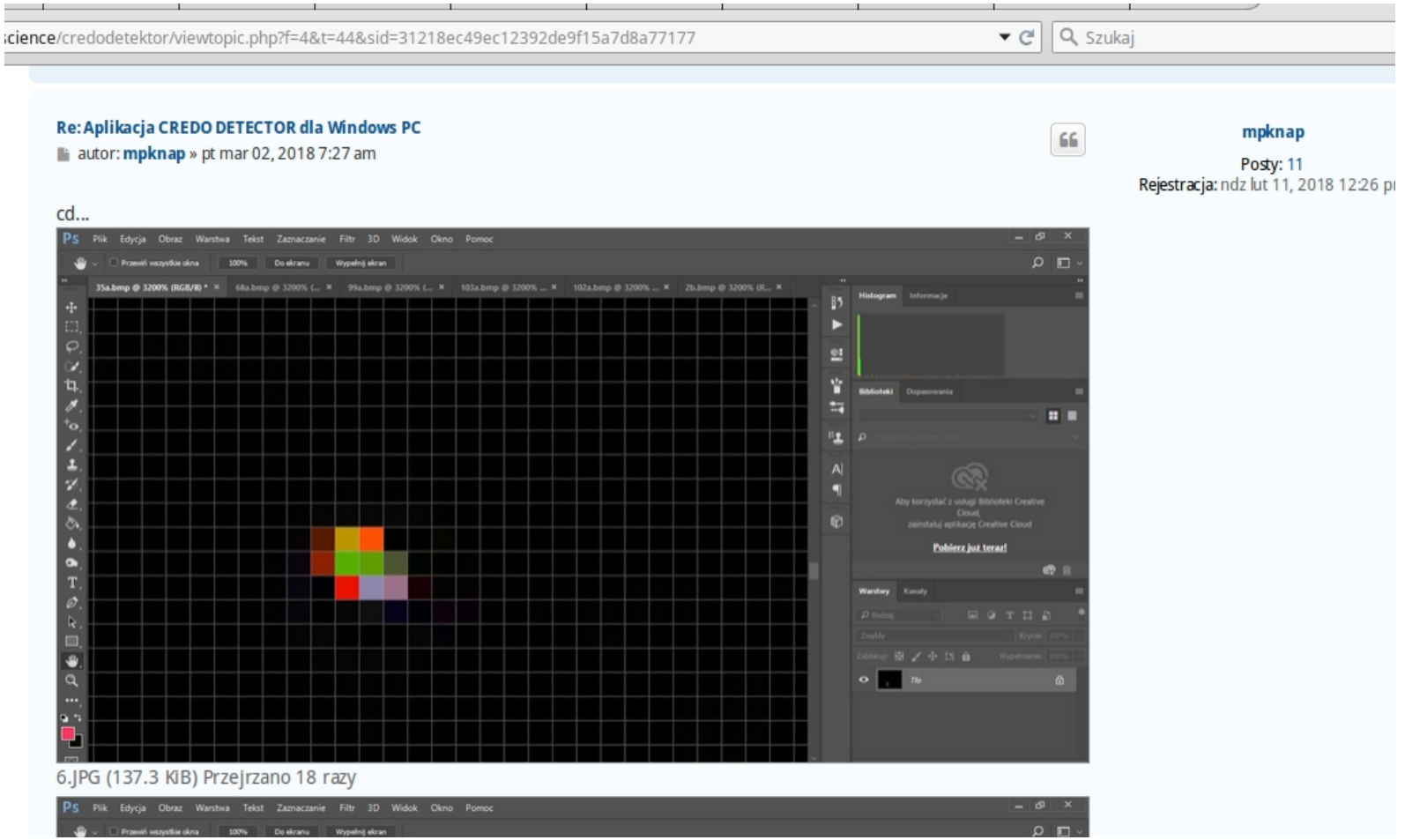
Zespół promieni kosmicznych o zróżnicowanych energiach (CRE): NOWY pomysł na testowanie struktury czasoprzestrzeni

Niska częstotliwość - niska energia - duża długość fali (duże „koła”),
→ niska czułość na strukturę czasoprzestrzeni

Wysoka częstotliwość - wysoka energia - krótka długość fali (małe „koła”),
→ wysoka czułość na strukturę czasoprzestrzeni

CREDO attracts... also non-experts

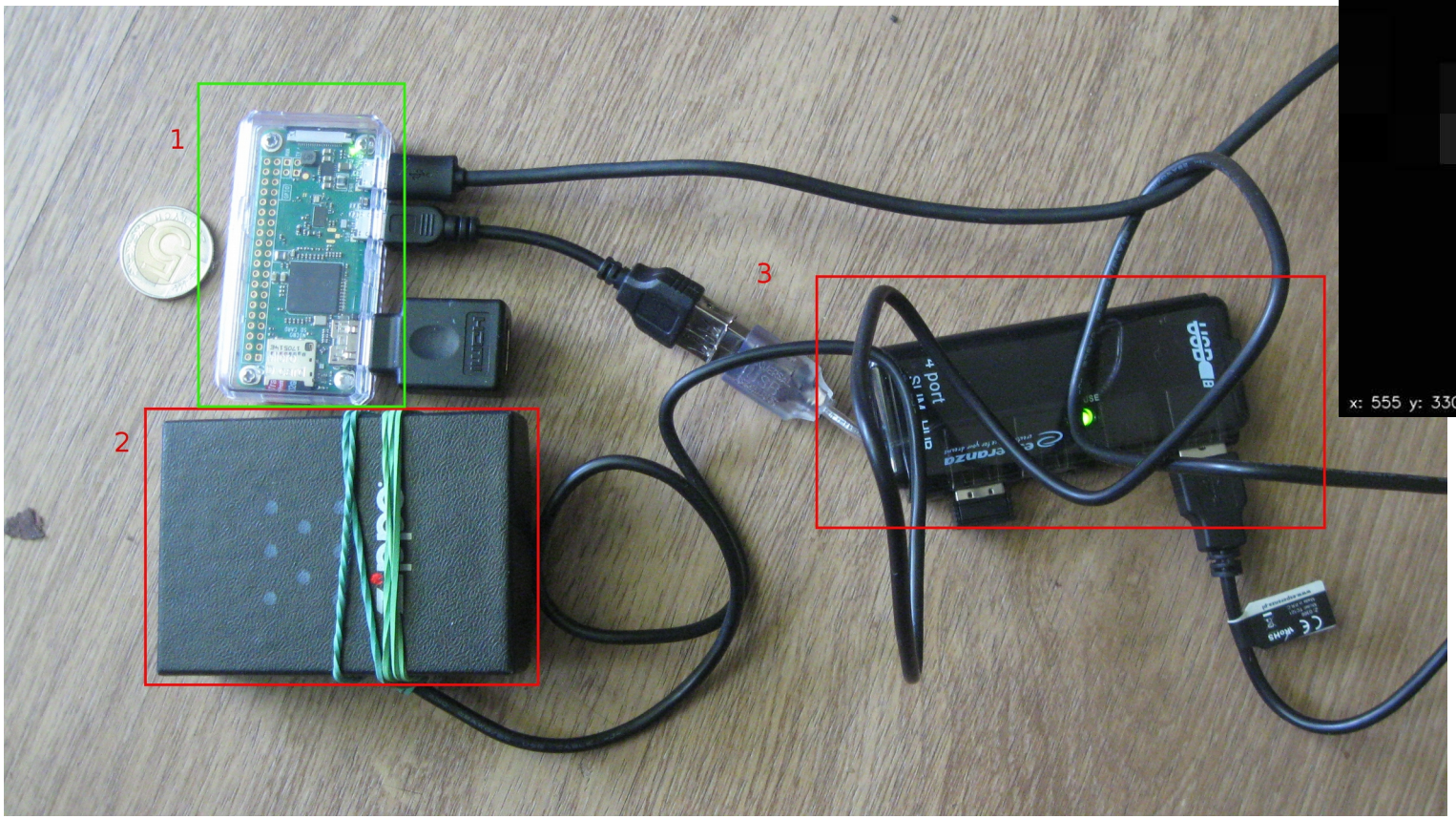
→ **PC application to catch particles with an internet camera, by a 41-year old science enthusiast!**



Info & download [author: Marek Knap]:
https://credo.science/credodetektor/viewtopic.php?f=3&t=45

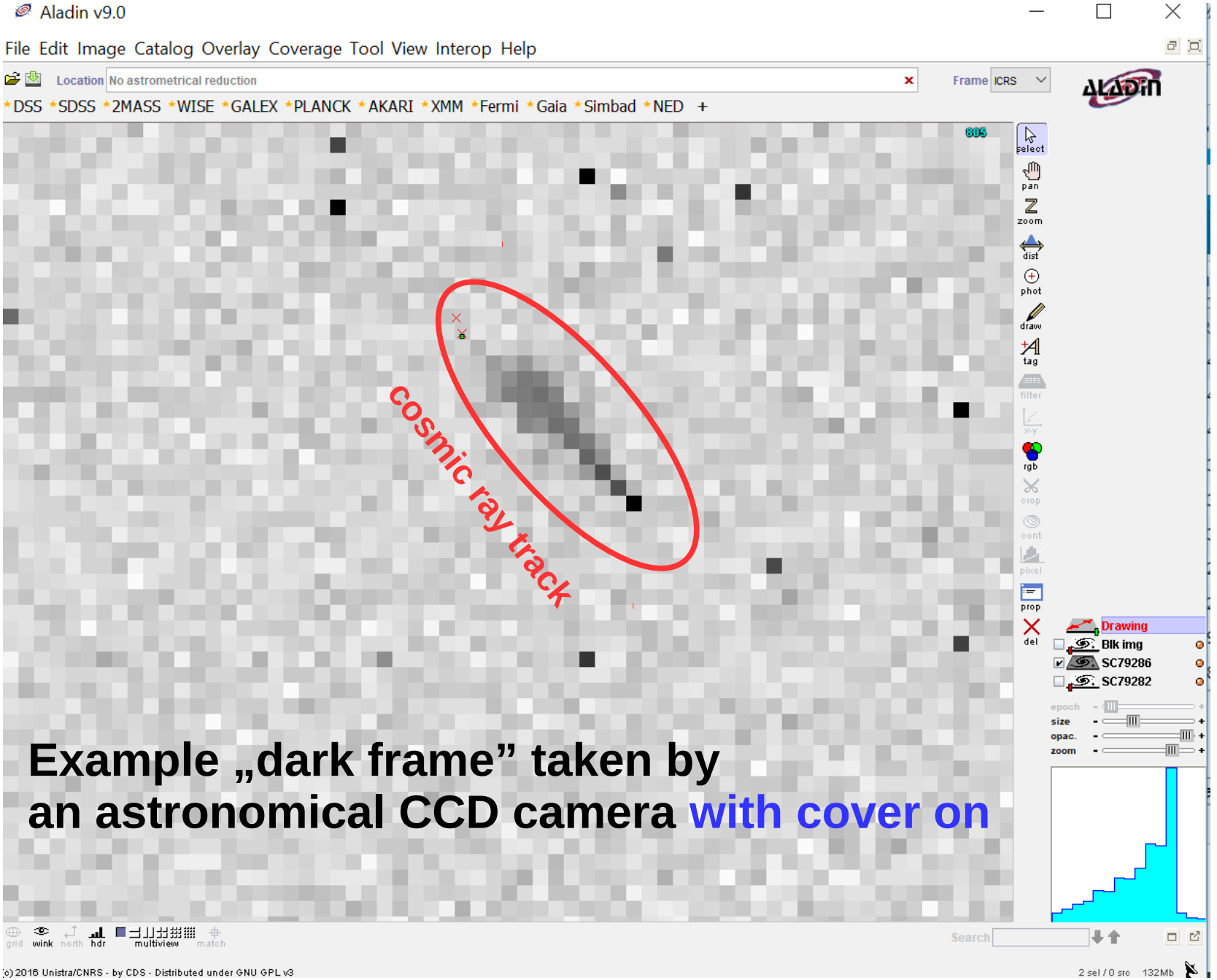
CREDO attracts... also non-experts

→ **PC application: linux version working with RasperryPi!**
By „TrueTom”



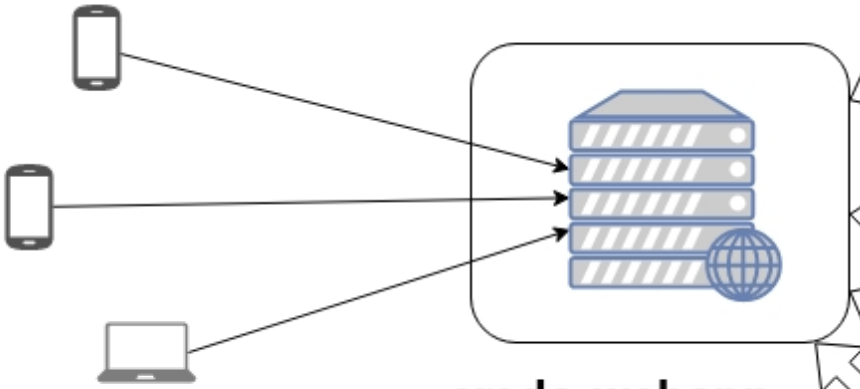
Info [author: Tomek/TrueTom]:
https://github.com/credo-science/Credo-detector-for-linux-desktop-and-Raspberry-Pi

CREDO attracts... astronomers!



Credit & idea by Massimo Ramella (INAF)

Component diagram



User devices

- create new accounts
- send events
- request data exports

credo-webapp

- handle requests with new events
- handla data export requests
- basic visualization

python + django

Redis

- caching
- rate limiting
- leaderboards
- live detection filtering (hot pixels)

MariaDB

- user data and event storage
- authorative source of truth

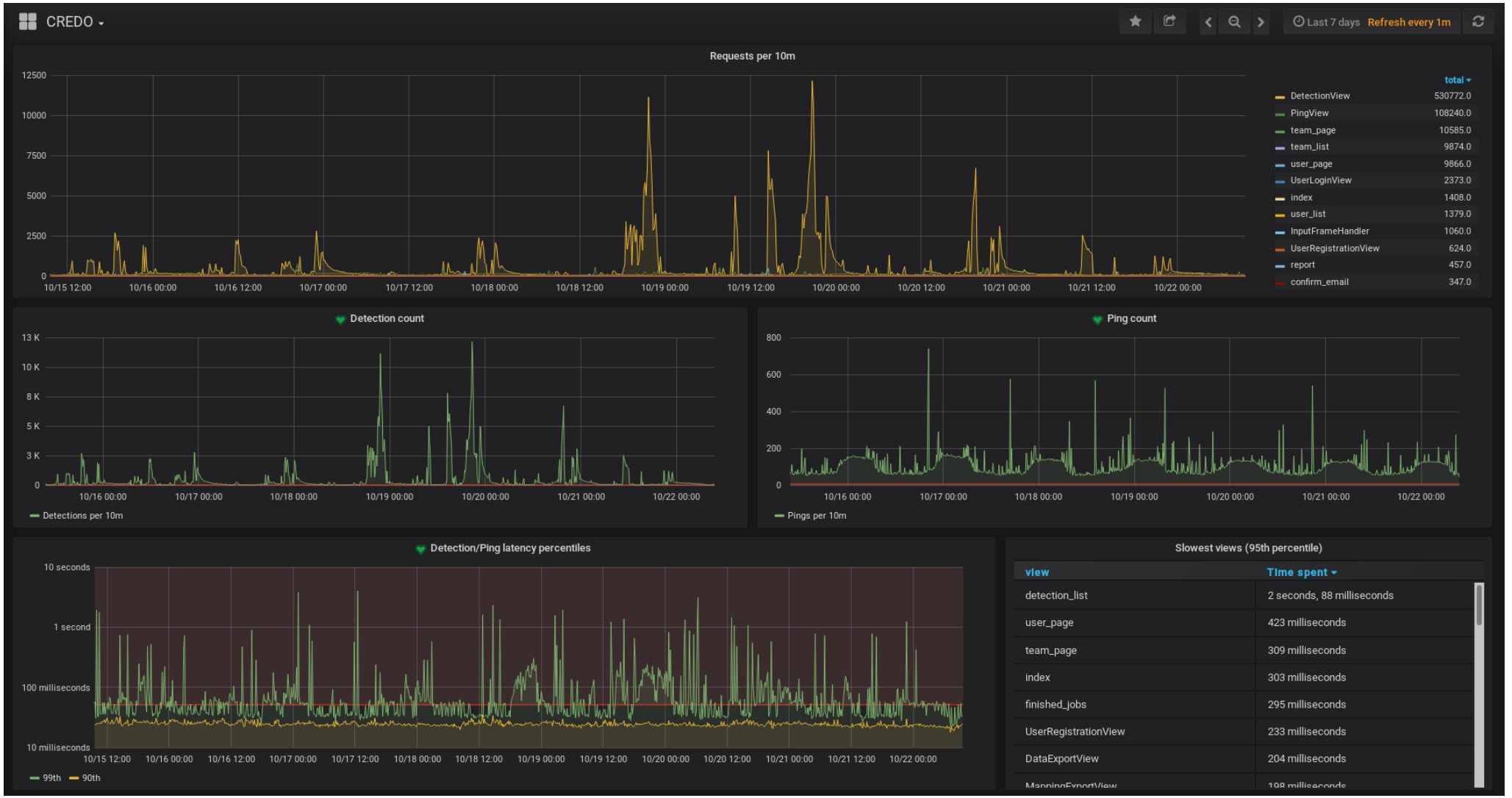
S3-compatible object storage

- data export storage
- backups

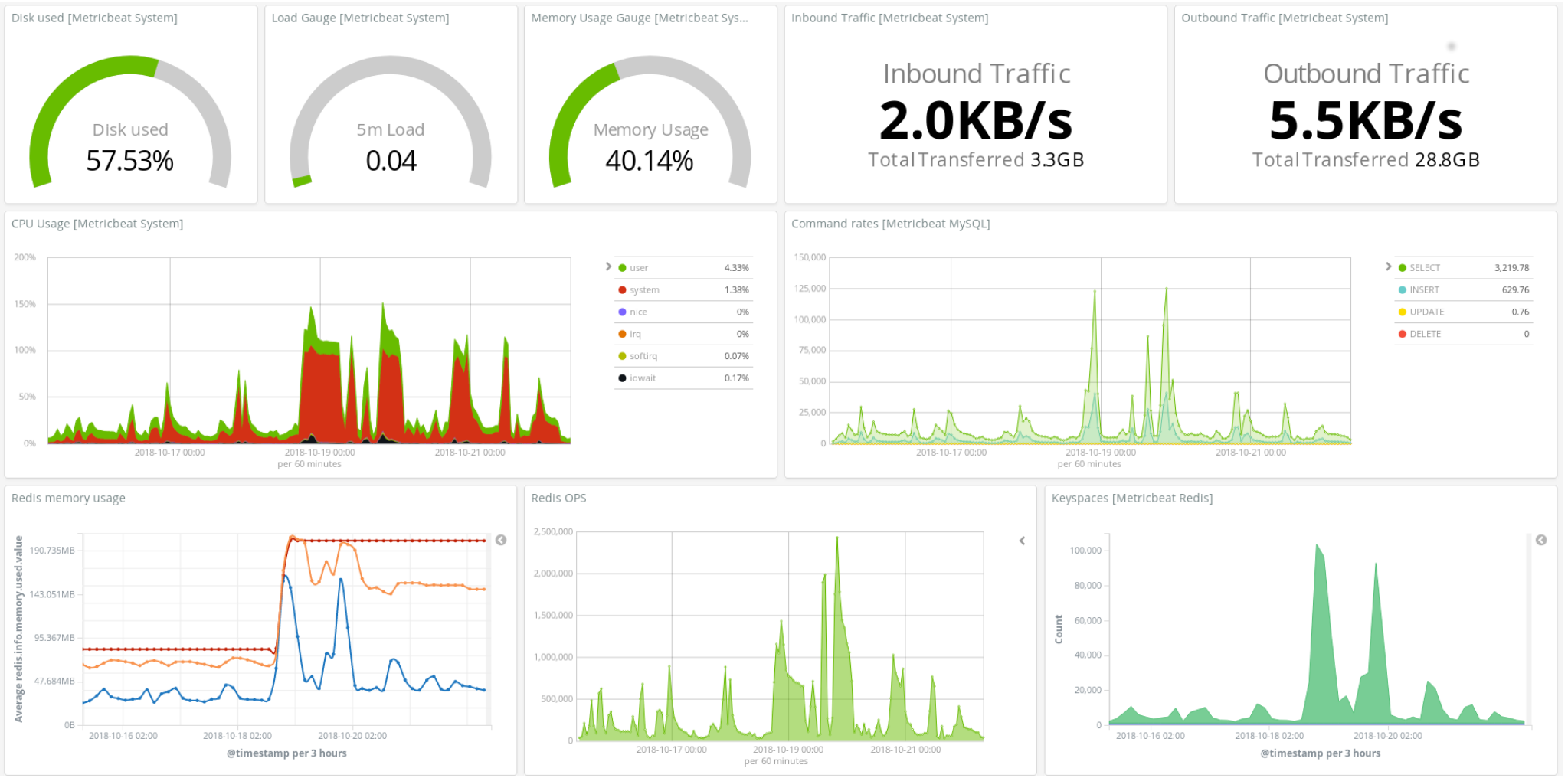
Other

- performance and server metrics
- monitoring

...



From: M. Pawlik et al, CGW'18



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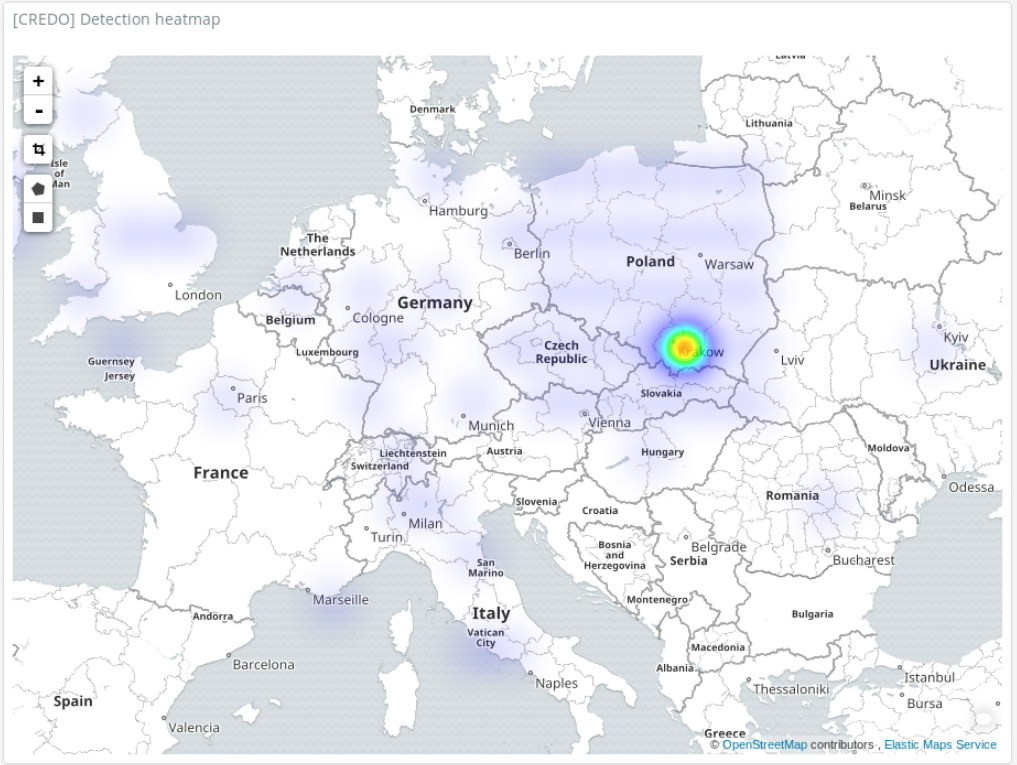
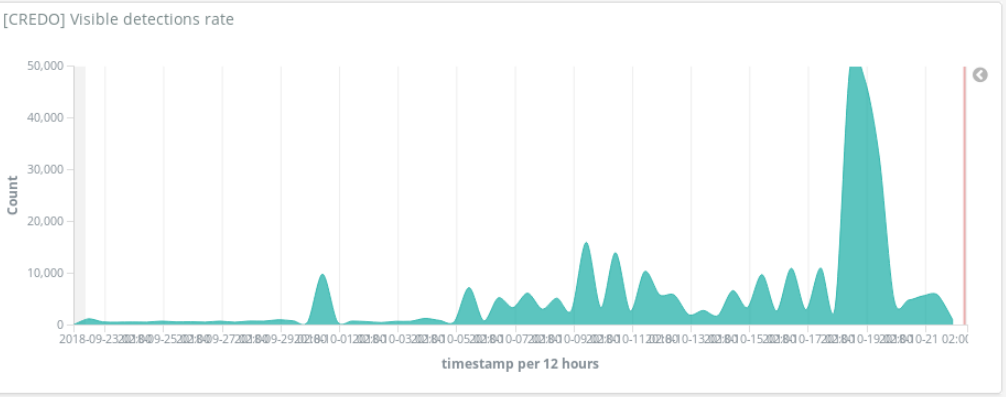
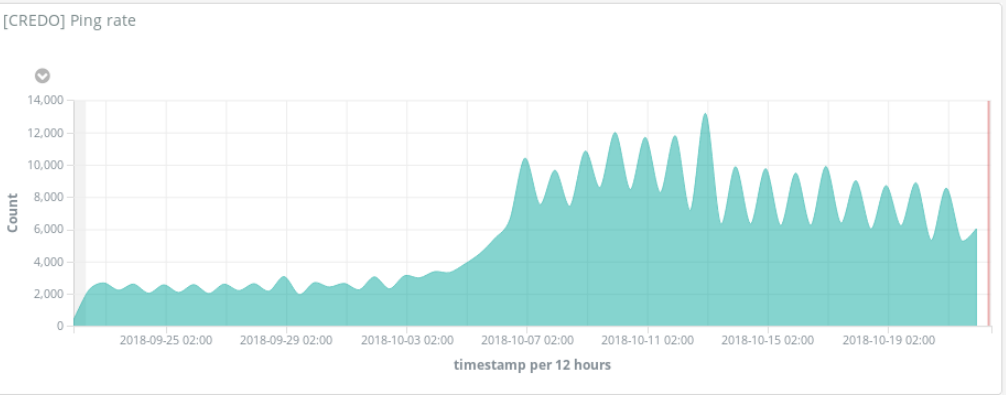






[CREDO] Top users (detection count)

User ID	Detection count
8006	32,992
8003	23,956
6983	17,389
8001	14,114
6977	11,462
Other	234,060
	333,973

[CREDO] Top users (by on time)

User ID	On time	Ping count
4980	3 months	13,868
4125	3 months	13,457
157	2 months	9,139
1163	2 months	4,288
7358	a month	4,708
Other	5 years	302,462
	6 years	**347,922**

From: M. Pawlik et al, CGW'18

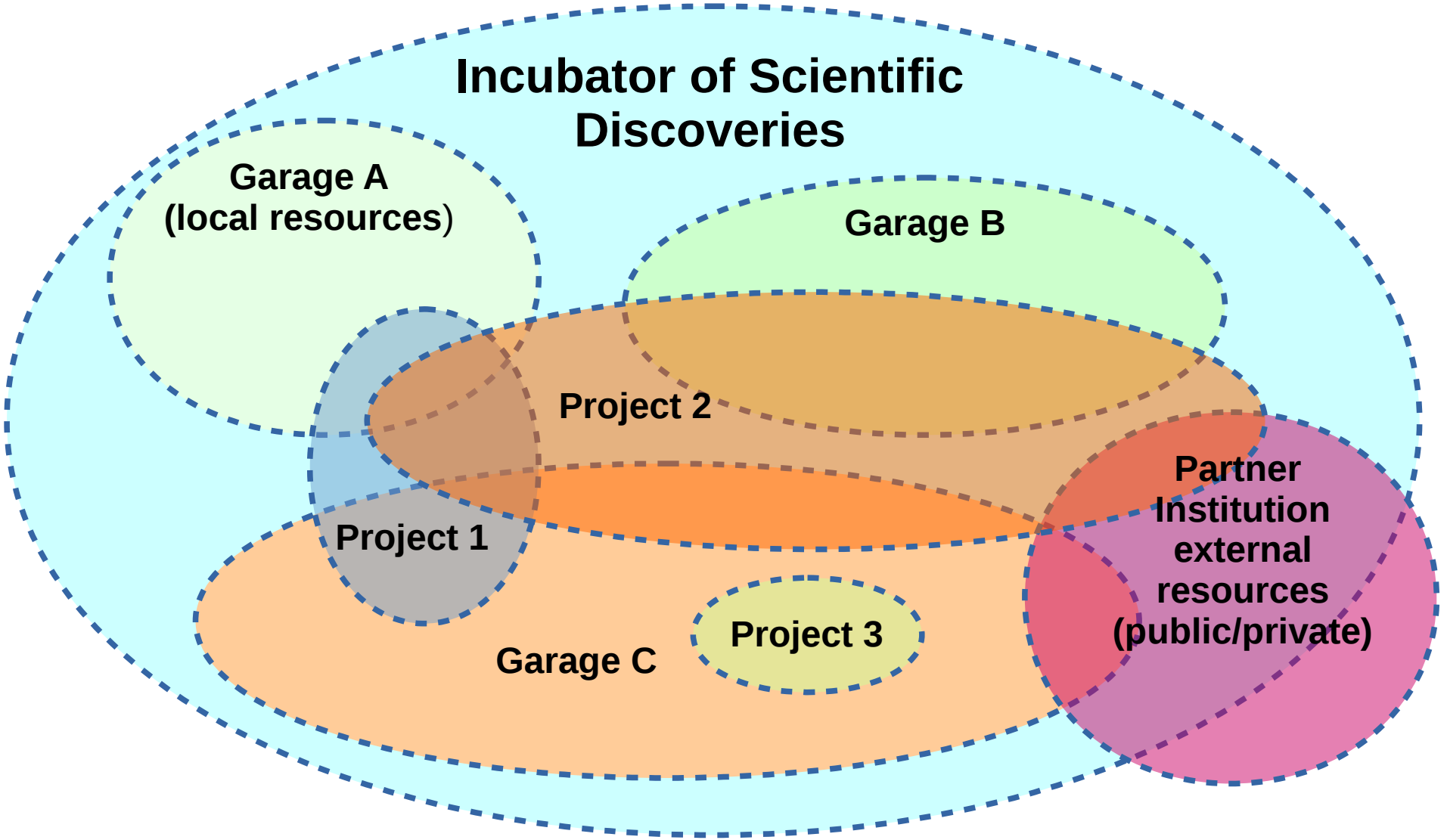
… as a gaming system enrooted in reality

- ambitious goals (spacetime structure, earthuake forewarning, biohazard alerting)
- tasks (detect, invite, educate, imagine ...)
- points (cryptocurrency: credos)
- profits (co-authorship, patent revenue, documented education/skills)
- gadgets (economy detectors, t-shirts, magnets...)
- distributed/decentralized (blockchain, cryptography)
- evolutive (self teaching, self defining)
- AI mamangement support (large scale!)
- crowdfunded

→ Participation!

Coming soon!

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.

Quantum Gravity Previewer with a smartphone!

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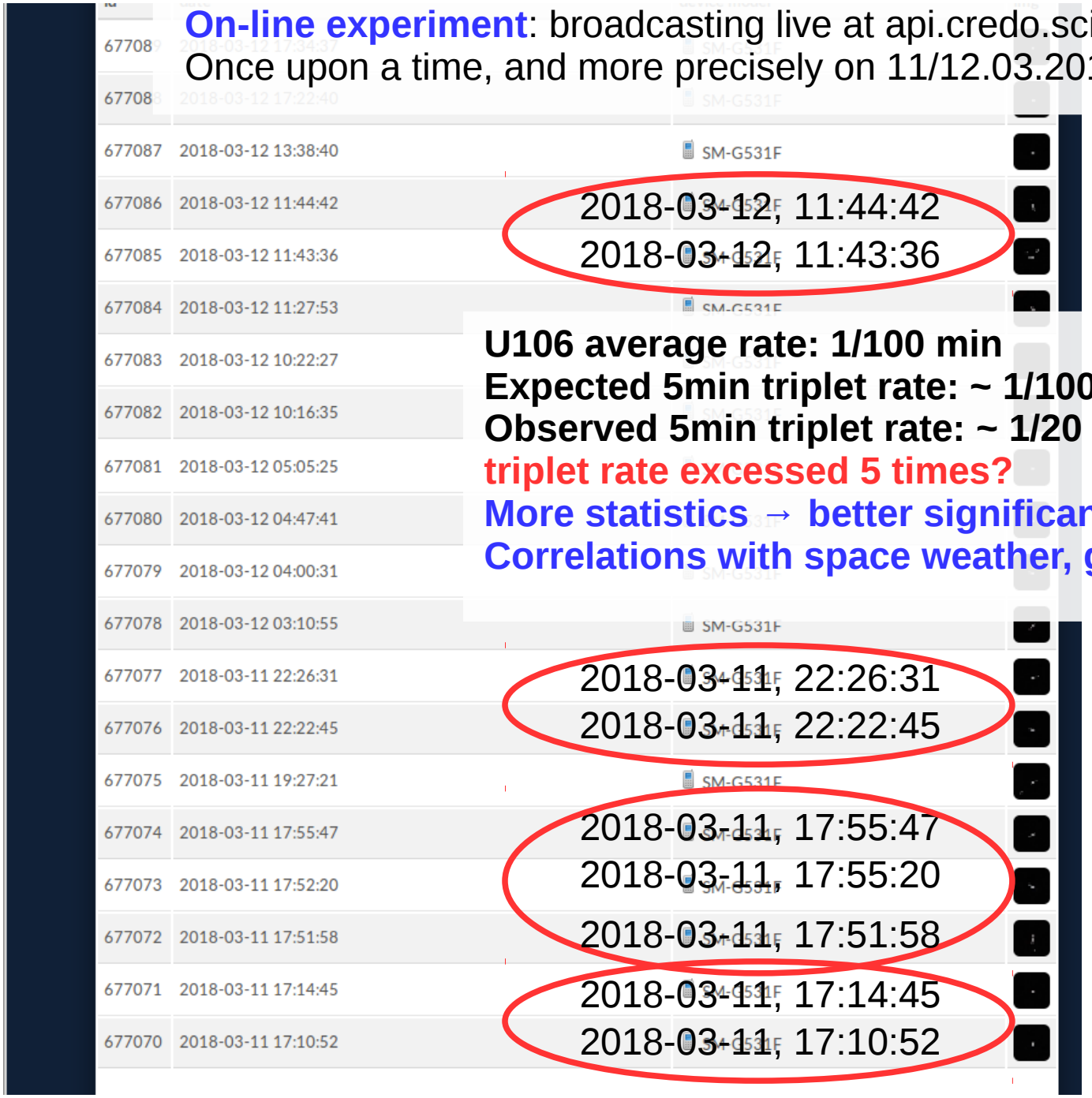

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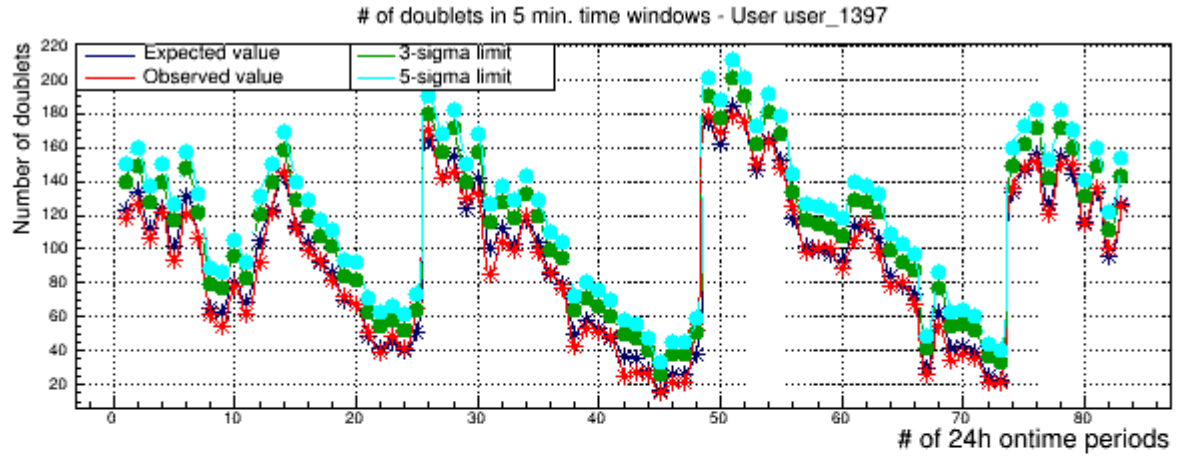
3 min 53 s

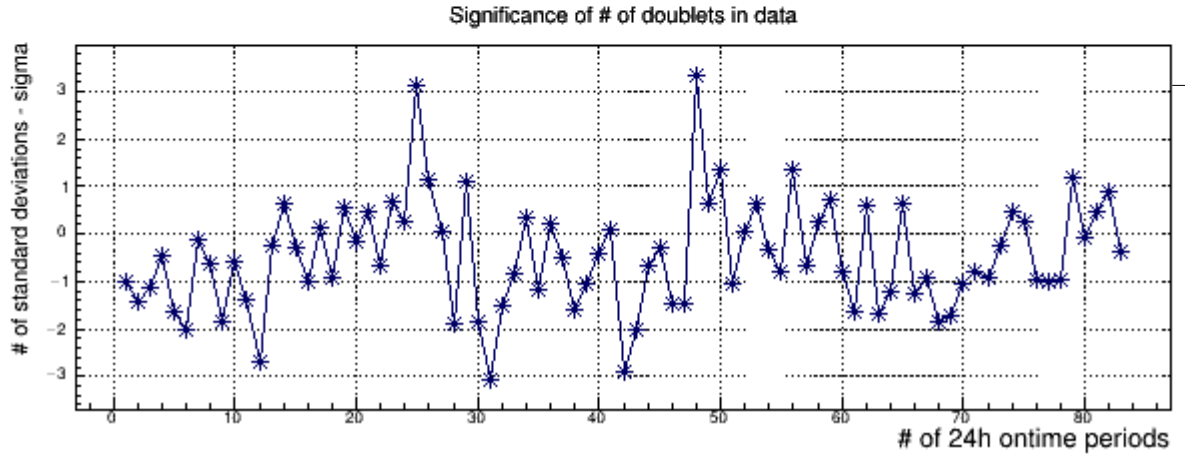
Quantum Gravity Previewer: online experiment!

Cumulative number of hit pairs („doublets”) within 5 min, in a single device, ~80 days

by Kevin Almeida Cheminant, for the CREDO Collaboration



expected from random
observed



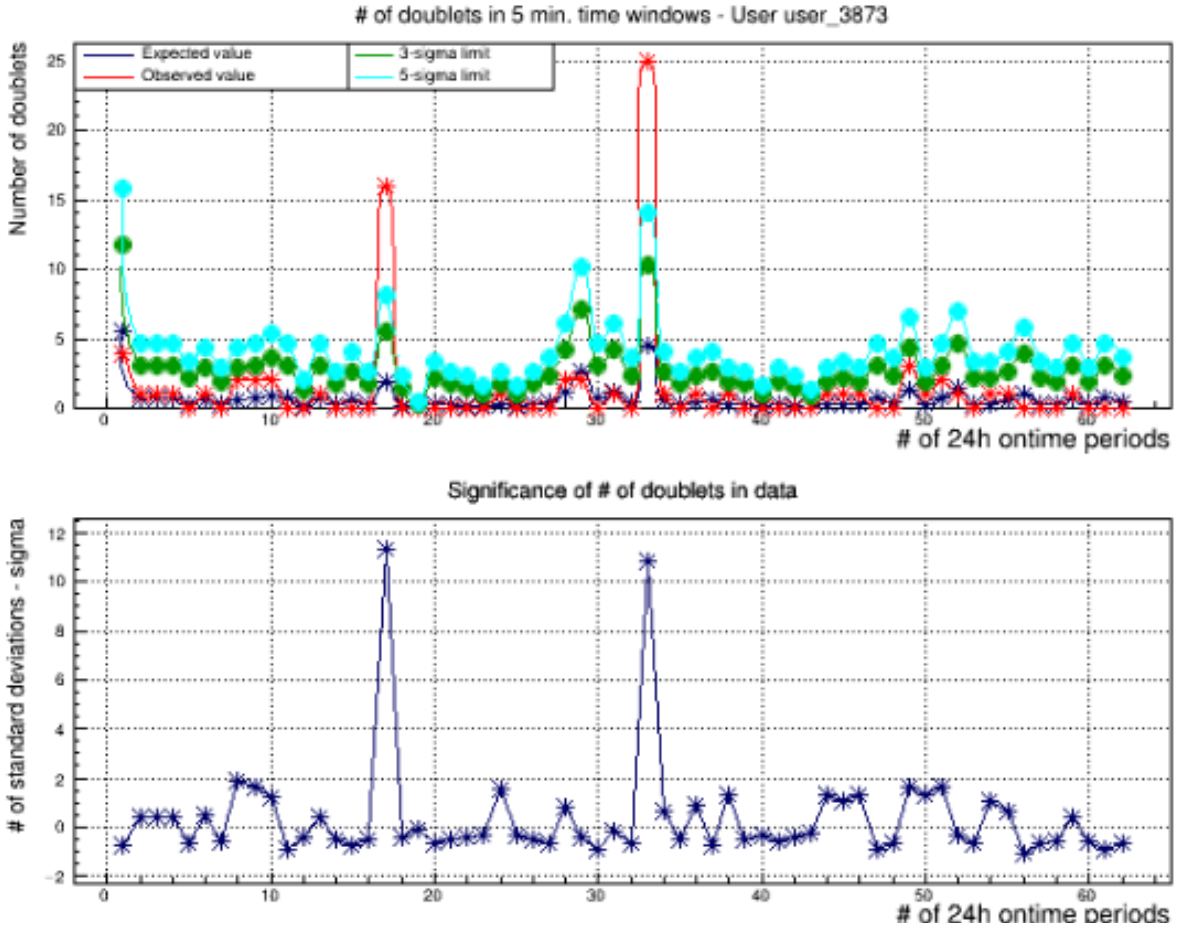
3σ
(significance)

The first experiment on CREDO infrastructure!
Running since 17.05.2018! First Light 4.10.2018!

Quantum Gravity Previewer: online experiment!

Cumulative number of hit pairs („doublets”) within 5 min, in a single device

by Kevin Almeida Cheminant, for the CREDO Collaboration



expected from random
observed

→ **10σ**
(significance)

Request zoom in, track back, investigate!
Privately, locally, and globally!
Get engaged!

Cosmic rays... any other surprises possible?

Particles (photons) 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?

the first paper on a CREDO scenario

status: submitted

Cosmic ray ensembles as signatures of ultra-high energy photons interacting with the solar magnetic field

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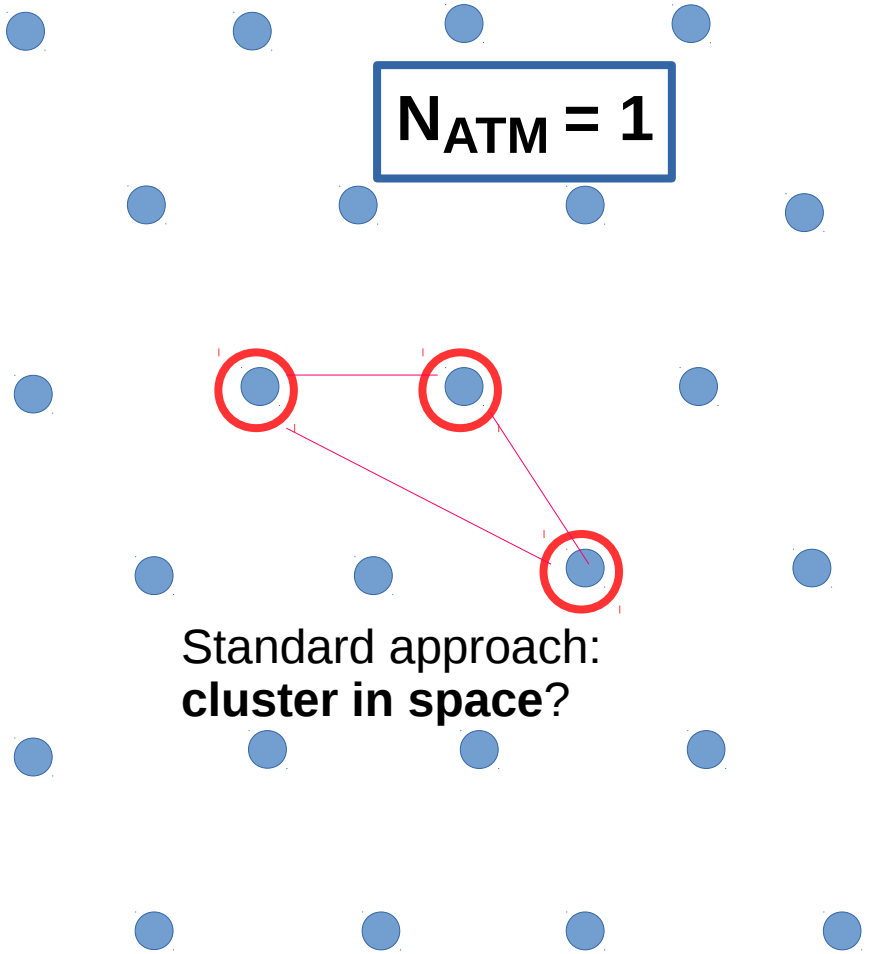
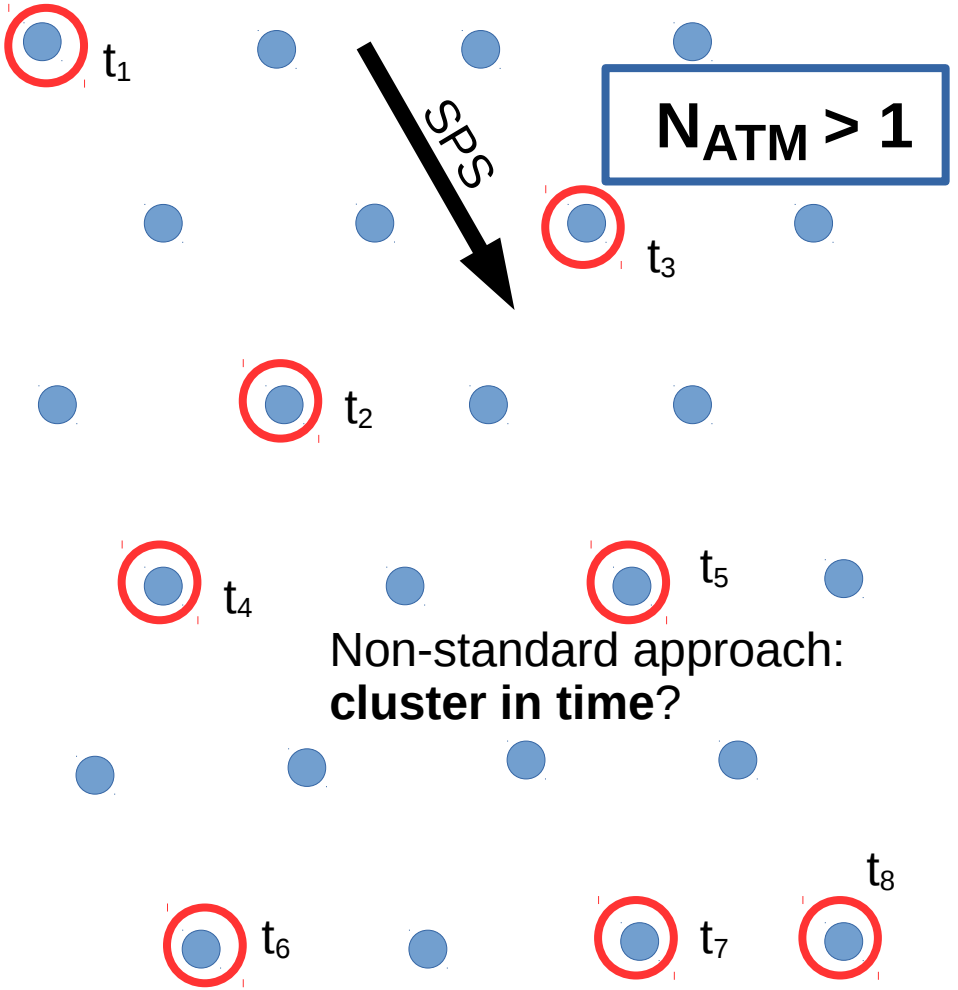
Propagation of ultra-high energy photons in the solar magnetosphere gives rise to cascades comprising thousands of photons. We study the cascade development using Monte Carlo simulations and find that the photons in the cascades are spatially extended over hundreds of kilometers as they arrive at the top of the Earth's atmosphere. We compare results from simulations which use two models of the solar magnetic field, and show that although signatures of such cascades are different for the models used, for practical detection purpose in the ground-based detectors, they are similar.

PACS numbers: 02.70.Uu, 13.85.Tp, 95.85.Ry

A chance for a unique CRE signature



Standard approach:
cluster in space?



Non-standard approach:
cluster in time?

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

● : a cosmic-ray detector