Volunteer Measurements as the Next Evolution Stage of BOINC

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Intro – the New Hype: “Citizen Science” & crowd computing

Hundreds projects and consortia even …

<u>The main principle</u> here is <u>the paradigm shift:</u>

to go from the passive “volunteer computing” (widely used now in many fields of sciences) to other volunteer actions under guidance of scientists:

- “volunteer measurements”,
- “volunteer data processing and visualization”,
- “volunteer data mining”, etc.

The main components of the idea

The Volunteer Measurements should be carried out:

- by ordinary people – not scientists only!
- by easily accessible measuring units – like modern smartphones with sensors (with camera, accelerometer, magnetometer, GPS, microphone, heart-rate monitor!, … etc.)
- in unobtrusive way – in (semi-)automatic regimes like in BOINC!

The Main Expectations

- **leverage the available "crowdsource" resources**: hardware (personal CPUs + sensors) and "brain-ware" (brains, manual operation of sensors),
- **get huge number of volunteers** (millions) as targets for personal health monitoring (temporally or during their whole life),
- obtain the **new scientific "quality"** from these **huge "quantities"**,
- **involve ordinary citizens** (like pupils and students, please see the next slides) in scientific process,
- **report to the society** about the current scientific activities and priorities.

Background - Our Last (Student) Projects

- My Green City (2012) global Volunteer Measurements –>

  Use Case for Monitoring Environmental Conditions and their Effects on Personal Health

Usual traffic jam in Kyiv

- How to Make Old Age More Comfortable, Less Boring and Active for Your Nearest and Dearest (2013) personal (local) Volunteer Measurements –>

  Use Case for Personal Health Monitoring

(C) S.Chernbumroong, S.Cang, A.Atkins, H.Yu, *Expert Systems with Applications*, (2012)

«My Green City» project (2012)

Motivation: while **vehicle exhaust** is one of **the most dangerous sources of air pollution** in cities, **global attempts** to assess how emissions impact local city ecology **have proven ineffective**.

Aims:

- to estimate **personal dosage** of accumulated dangerous emissions – by **personal air health monitor**,
- to determine **real-time distribution of pollutants** by vehicle exhausts in cities – by **virtual online air pollution map**.

Methods:

(1) **wearable personal cheap sensors** with GPS-enabled smart phones;
(2) **community-wide installation of sensors** near available traffic web-cameras **for real time monitoring** the dangerous factors (gases, noise, ...) for different parameters (seasons, rush hours, weather, ...).

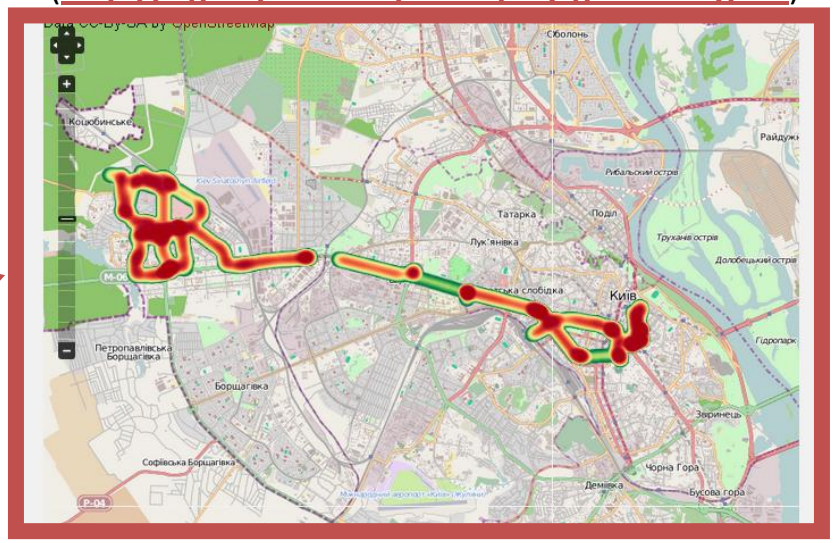
«My Green City» - Methods

The technical implementation is based on integration of pollution data by **vehicle emissions sensor** (CO-gas-USB logger) and location data by **GPS-navigator in ordinary smart phones** for:

- **estimation of personal dosage** of accumulated dangerous emissions – **personal air health monitor**;

- continuous air pollution **data processing** and **construction** of **interactive air pollution map** (see below **"My Green City"** pilot project).

Interactive air pollution map for Kiev (http://dg.imp.kiev.ua/slinca/my-green-city/CO).



«My Green City» - Feasibility Check

To check feasibility of this proposal the student pilot project "My Green City" was implemented with construction of air pollution map for Kiev (Ukraine).

It became one of the **15 global finalists** in **Google Science Fair 2012**.
Judges selected 15 projects out of >10000 of others, sent out from more than 100 countries around the world.

"My Green City" team: Milena Klimenko, Nikita Gordienko, Alexey Kozlov (left to right) with their consultant and curator - IDGF-member Dr.Yuri Gordienko (behind them)

The social incentive behind this pilot project can briefly be expressed by the slogan:
"From volunteer scientific calculations to volunteer scientific measurements".

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«My Green City» - Conclusions for Practice

By integrating location-based data from these sensors scientists can develop tools (**personal air health monitor** and online **virtual air pollution map**) that allows persons and communities to make **real time estimations** about **the actual impact** of vehicle emissions **on a city environment**.

For municipal authorities: these tools could **improve** overall **city traffic planning** and **city management accountability**.

For people: these tools could stimulate **better personal planning** and implement **healthier behavior** due to

- the greater public **awareness** of **air pollution distribution** by **virtual air pollution map**;
- the **targeted estimation** of **personal dosage** of accumulated dangerous emissions by **personal air health monitor**.

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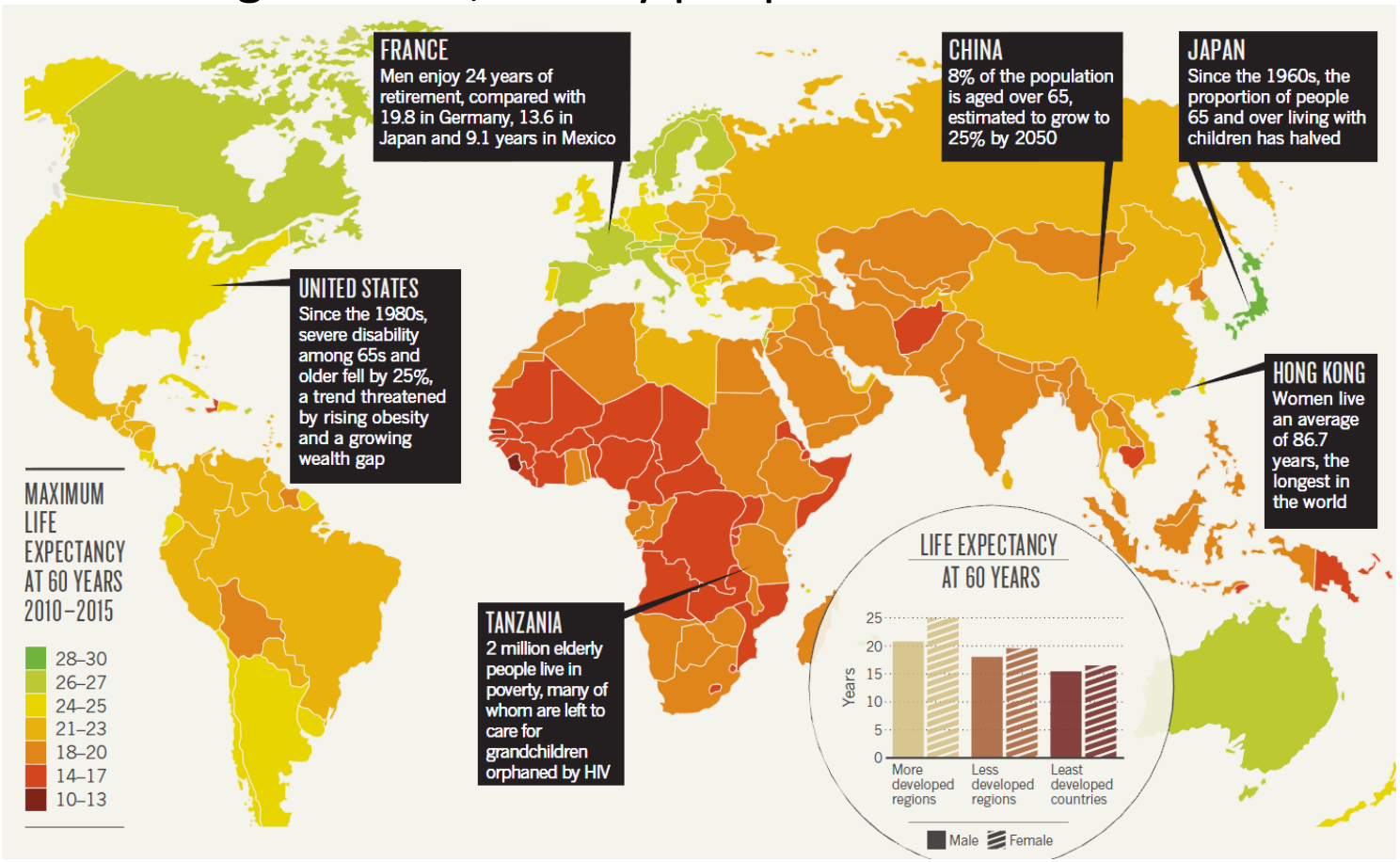
«How to Make Old Age More Comfortable, Less Boring and Active for Your Nearest and Dearest» (2013)

Problem: the human population become older and will continue to do so in the coming decades; elderly people suffer from various diseases



(C) Tony Scully, Demography: To the limit, *Nature* 492, S2–S3 (2012).

«How to Make Old Age More Comfortable, Less Boring and Active for Your Nearest and Dearest» (2013)

Motivation:

elderly people suffer from various diseases, which progress can be monitored by decrease of mobility (!)

Aim:

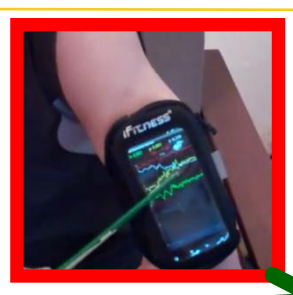
explore the use of sensors in the usual smartphone to monitor the health of older people by analysis of their locomotor activity

Method:

use **embedded personal sensors** (accelerometers) with GPS-enabled smart phones **for real time monitoring** the motion pattern (mean, standard deviation, skewness, curtosis, ...) for different types of motion (sleep, walk, run, …).

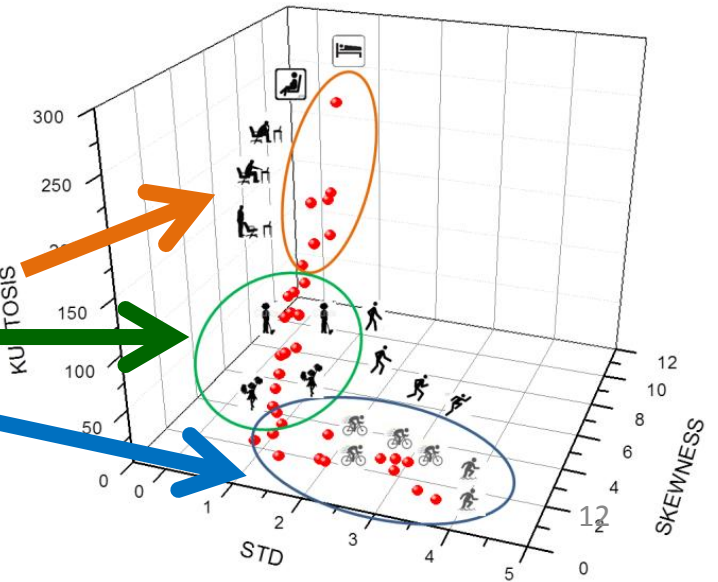
«How to Make Old Age More Comfortable…» – Methods

The technical implementation: integration of personal measurement **tools** and attachment points:
(a) **smartphone** with G-sensor **on the arm** (during writing, web-surfing, etc.);
(b) **on the leg** during cycling (walking, running, etc.);
(c) **"smart watch"** - arm wrist device ez430 (Texas Instruments) with accelerometer and wireless data broadcasting unit to a PC.



Multi-parametric moment analysis: **activities can be classified** in more details, i.e. divided into groups (colored ellipses) with the similar values of the acceleration distribution parameters:

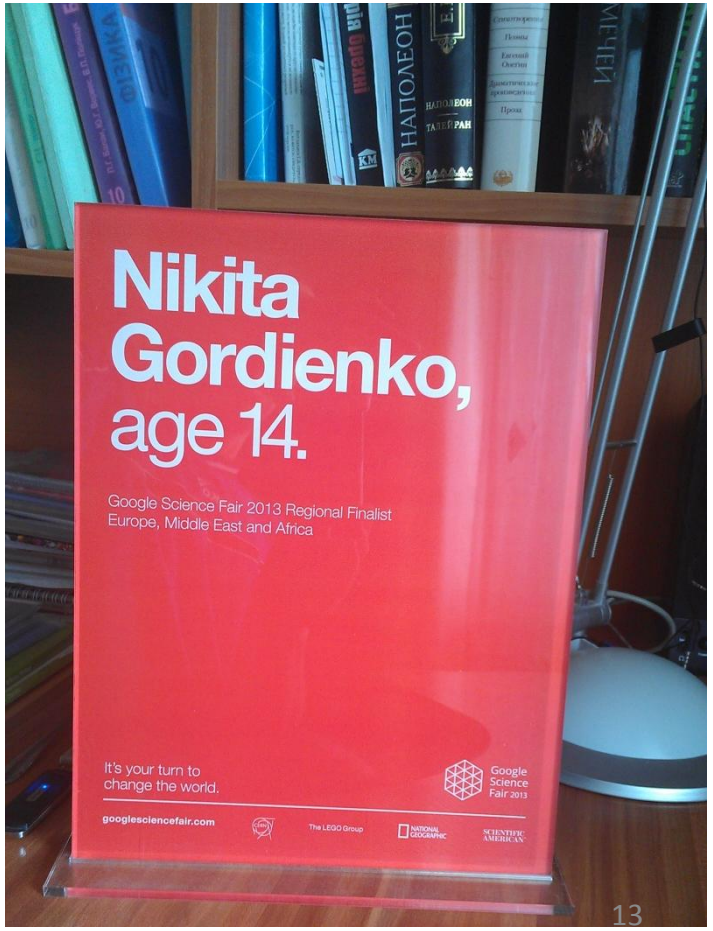
- **passive** (web surfing, read, sleep) (**brown ellipse**),
- **moderate** (writing, sitting) (**green ellipse**),
- **active** (sports, housework, walking) (**blue ellipse**)



«How to Make Old Age More Comfortable…» – Feasibility Check

To check feasibility of this idea: the student project "How to Make Old Age More Comfortable, Less Boring and Active for Your Nearest and Dearest" was implemented.

It became one of the **90 regional finalists** in **Google Science Fair 2013**. Judges selected 90 projects out of >10000 of others, sent out from more than 100 countries around the world.



The social incentive behind this pilot project can briefly be expressed by the slogan:
"From general volunteer scientific measurements to personal volunteer scientific measurements".

«How to Make Old Age More Comfortable…» – Implications for Practice

The tests shown that some essential features of health and activity patterns can be distinguished and classified.
By analysis of sensor (accelerator) data scientists can develop tools (**personal activity monitor**) that allow persons and communities to make **real time estimations** of the **actual locomotor activity decrease** and subsequent **health decay**.

For health care authorities, these tools could **improve** overall **elderly care** and stimulate personal **online elderly care services**.

For general public, these tools could stimulate closer attention to locomotor activity and its automated monitoring due to

- the greater **public awareness** of **dangerous locomotor activity decrease** and probable subsequent **health decay**;
- the **targeted estimation** of **personal** dangerous decrease of **locomotor activity** by **personal activity monitor**.

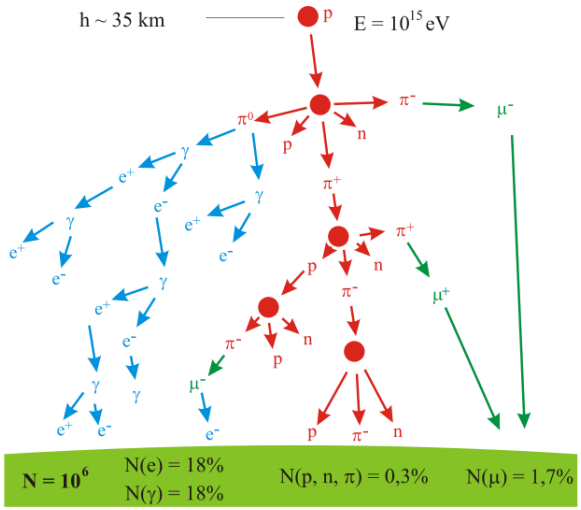
What's next?

- The current project…
- Problems…
- Plans…
- Perspectives…

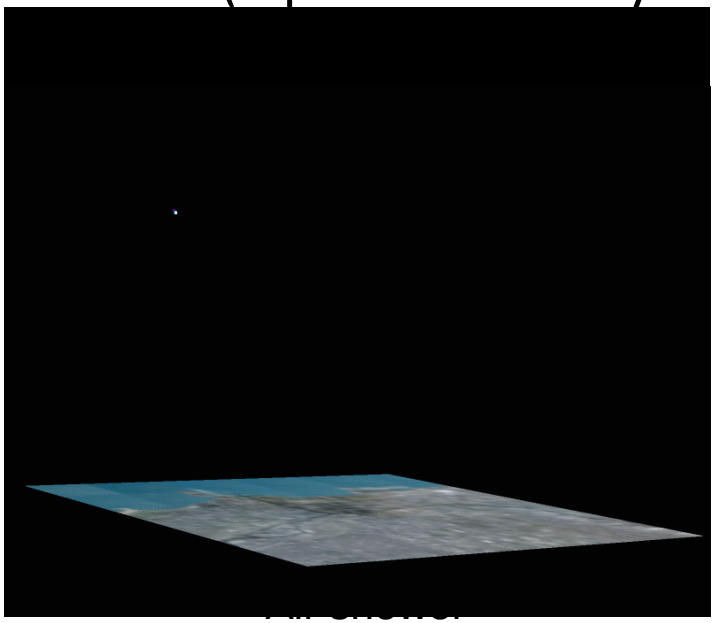
«System of Volunteer Scientific Measurements to Study Cosmic Rays» (2014-…)

Problem:

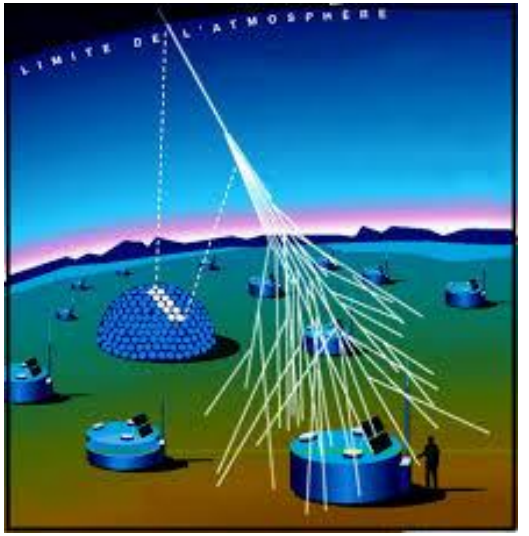
- cosmic rays (and “air showers” of elementary particles created by them) **affect** electronics, health, environment;
- their study is **expensive** (>$50 mln.) and limited in scale;
- the **most energetic** cosmic rays (>5×10^{19} eV) are **most important**, **but very rare** were observed (1 per month - by “Pierre Auger”).



“Air shower” created by cosmic rays



(computer simulation by COSMUS)



Cosmic-ray observatory “Pierre Auger” >$50 mln

«Volunteer Scientific Measurements to Study Cosmic Rays» (2014-…) - affect electronics

Cosmic rays have sufficient energy to **alter** the states of circuit components **in electronic integrated circuits**, **causing transient errors:**
- **corrupted data** in electronic memory devices,
- **incorrect performance** of CPUs, often referred to as "soft errors" (not to be confused with software errors caused by programming mistakes/bugs!).

Cosmic rays are suspected as a possible **cause of an in-flight incident in 2008:** Airbus A330 airliner of Qantas **twice plunged hundreds of feet after an unexplained** malfunction in its flight control system. **Many passengers and crew members were injured, some seriously**. The investigators determined that the airliner's flight control system had received **a data spike that could not be explained**, and that **all systems were in perfect** working order.

"Cosmic ray blitz: Space invaders that fry electronics"

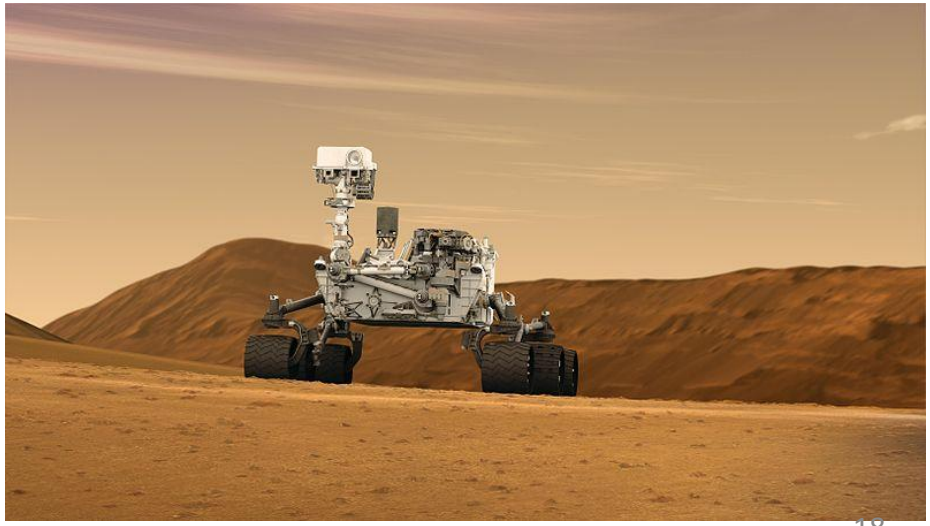
New Scientist, **28 September 2014**

«System of Volunteer Scientific Measurements to Study Cosmic Rays» (2014-…) - affect health

The **health threat from cosmic rays** is the danger posed by **galactic cosmic rays** and **Solar energetic particles to astronauts on interplanetary missions**.

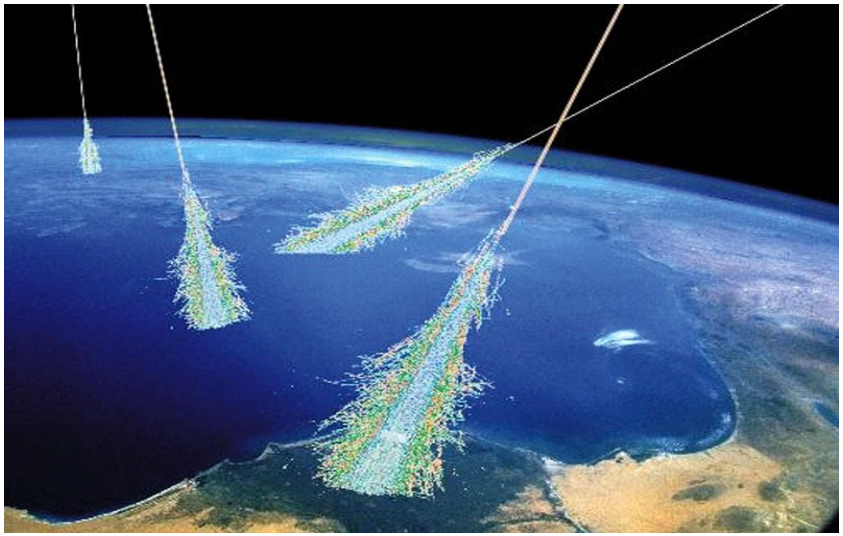
- **Galactic cosmic rays consist of** high energy **protons (85%), helium (14%)** and other high energy ions.
- **Solar energetic particles** consist of protons (mainly) accelerated by the Sun to high energies via proximity to solar flares and coronal mass ejections.

They are one of the most important barriers standing in the way of plans for interplanetary travel by crewed spacecraft.



«Volunteer Scientific Measurements to Study Cosmic Rays» (2014-…) - affect environment

A **role of cosmic rays** directly or via solar-induced **modulations in climate change** was suggested by Edward Ney (1959) and Robert Dickinson (1975). **Despite the opinion of over 97% of climate scientists against this notion**, the idea has been revived in recent years, most notably by Henrik Svensmark, who has argued that because **solar variations modulate** the cosmic ray flux on Earth, they would consequently **affect the rate of cloud formation and hence the climate**.



«System of Volunteer Scientific Measurements to Study Cosmic Rays» (2014-…)

Motivation: as far as cosmic rays affect electronics, they can be monitored by some available devices (like CMOS-camera chips)

Aims:

• to estimate possibility to identify “air showers” of elementary particles – by **personal** “air showers” **monitor**,

• to determine frequency and distribution of “air showers” in the densely populated cities – by massive involvement of “corporate” volunteers with creation of **virtual online map of** “air showers”.

Ideas of Methods:

(1) camera chips as **embedded** sensors in GPS-enabled smart phones;

(2) volunteer **communities in** densely populated locations **for real time monitoring** the “air showers” and analysis of their effects (on weather, environment, electronics, health).

«Volunteer Scientific Measurements to Study Cosmic Rays …» – Academic Solution

Pierre Auger Observatory - an international cosmic ray observatory designed to detect ultra-high-energy cosmic rays

Detect: 10^{17}–10^{21} eV cosmic rays

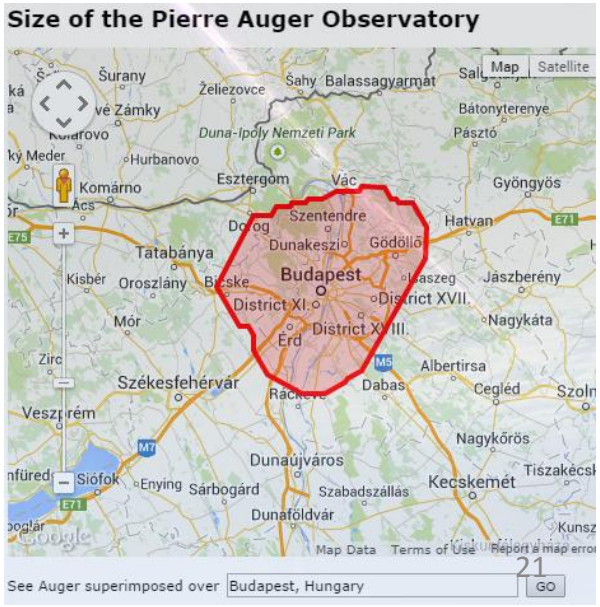
Detection area: 12 km^2

Staff: 500 scientists

Cost: >$50 mln

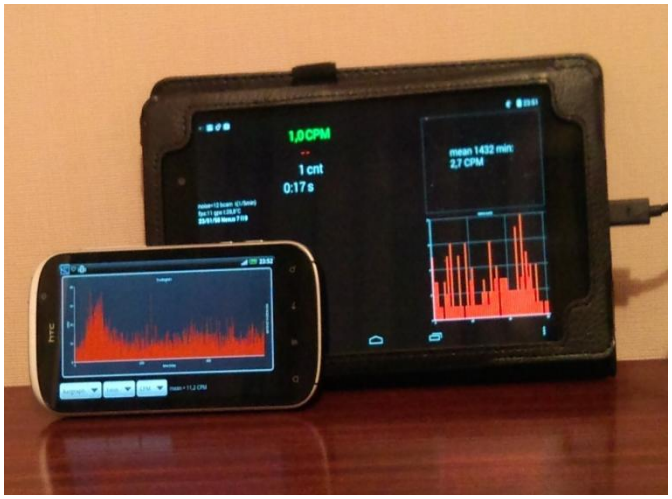
Installation Area: 3,000 km^2

(like Luxemburg, compare with Budapest)



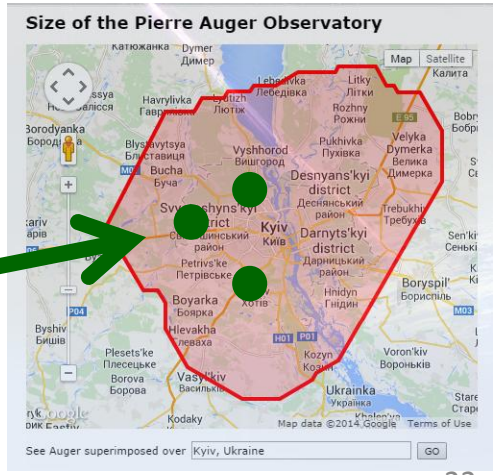
«Volunteer Scientific Measurements to Study Cosmic Rays …» – Our Method

The technical implementation is based on integration of data about registered flashes (by radiometric software) in **shielded camera chip**, **synchronised time** and **GPS-data** in ordinary smart phones/tablets/other gadgets:



Volunteer detector based on the usual smartphone/tablet

- to identify “air showers” of elementary particles – **personal “air shower” monitor**;
- to analyse the frequency and distribution of “air showers” in the densely populated cities – **virtual online map of** “air showers”.



Example of air shower in Kyiv

«Volunteer Scientific Measurements to Study Cosmic Rays …» – Our Prototype

Current technical implementation

hardware (tested)**:**

- HTC Amaze smartphone (8 Mpx),
- Nexus 7 tablet (1.2 Mpx),
- Nexus 7 tablet (5 Mpx),
- ASUS TF201 tablet (8 Mpx)

"brainware" (human actions needed):

- **volunteer should shield the camera!**

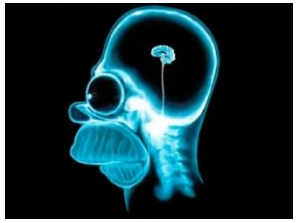
software (tested)**:**

- radiation counters (used for tests only),
- Sync Time (for time synchronization),
- E-mail submissions of logs,
- manual post-processing, analysing mapping "air showers"

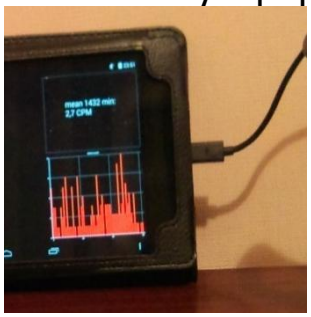
volunteer community (tested)**:**

- **>80 students are involved already** (in the Lab Works during "Distributed Computing Course" in National Technical University of Ukraine in Kyiv)

Current (Trivial) Workflow



A volunteer sets mobile for charging (!) … and shields the camera by a paper sheet (!)



App starts to detect flashes and send data to processing server (by e-mail at the moment)

The server processes data, analyze them and create online map (not ready at the moment, will be as BOINC-project)

«Volunteer Scientific Measurements to Study Cosmic Rays…» – Short Analysis

Comparison with other solutions

	«Pierre Auger» Observatory	External Sensor (Paspberry PI + sensor)	This BOINC-enabled "smartphone" solution
Size	**3000 км^2**	1 см^2	**4 мм^2**
Scalability	**<30%**	<10 times	**>1 mln. times (unlimited)**
Maximal Area (*n* – installations, *L* – min distance between)	**~3000 км^2** (*n*=1)	~1 см^2 (*n*=1)	**>10^6 км^2** (*n*=10^6 , $S \sim n*L^2$)
Staff (per installation)	**500 scientists**	1-3 scientists	**1 ordinary human ("Citizen Scientist")**
Cost	**>$50 000 000**	~$500	**<$200**

The main problems and lessons learned

- to leverage the available “crowdsource” resources (hardware and “brain-ware”) at this level **– feasible, if sensors are embedded already (integration with external sensors is hardly can be attractive for potential volunteers)**
- get huge number of volunteers (millions) **– feasible** as collaborators **(but see previous note)**, and **hardly feasible** for personal location and health data **due to privacy issues**
- obtain the new scientific “quality” from these huge “quantity” of data **– hardly feasible, because NO automation at the moment, but … porting to BOINC-environment should help!**
- involve ordinary citizens in scientific process **– feasible**
- report to society about the current scientific activities and priorities **– feasible and more after porting to BOINC-environment!**

Plans

- **BOINC-client** for Android and **BOINC-server-side** master application (or **Science Gateway** portal like **gUSE**) are needed (under development) for post-processing, analysing mapping “air showers”
- **Integration with embedded sensors** and automatic cooperation with them (**no manual operations!**).
- **Volunteer community management** (job submission, data storage and analysis, forum, etc.) at **BOINC-server**, especially, in corporative communities (like schools, colleges, universities) under **SZTAKI BOINC Desktop Grid** technology.
- **Report to society** about the current achievements at BOINC-server or portal (**Science Gateway** like **gUSE!**).

Possible Achievements

- Cosmic rays **can be investigated in any place**, not just in some parts of Earth
- The technology would **be very effective, if it will be automated** (again, for example, on the basis of BOINC)
- This method could **be very useful, if some small area will have many volunteers**; especially this technology will be effective in universities and other educational institutions (**Corporative/Community Crowd Computing?**)
- The project provides **an additional (NOT alternative!!!) way** to study cosmic ray (air showers) and their influence on civilization without huge installations, numerous high-qualified scientists, high basic and maintenance costs

Thank you
for your attention!

Under partial support and in cooperation with EU FP7 SCI-BUS project, contract no. RI-283481