

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

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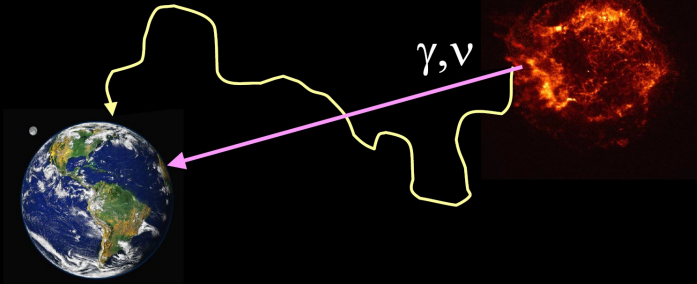
* <http://credo.science>

Outline :

- Introduction: Cosmic rays, preshower effect
- Mobile application and the first results
- Citizen science
- Summary

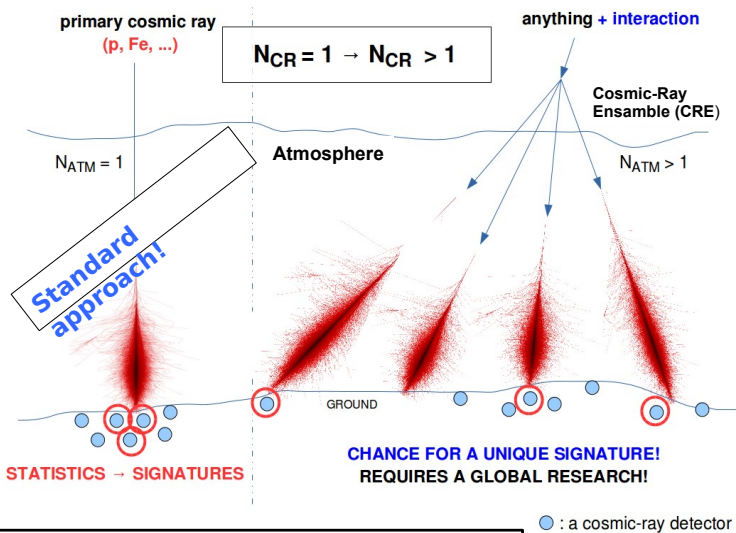
Charged cosmic rays vs. gamma rays

Charged particles



Motivation: looking for Cosmic Ray Ensembles (CRE)

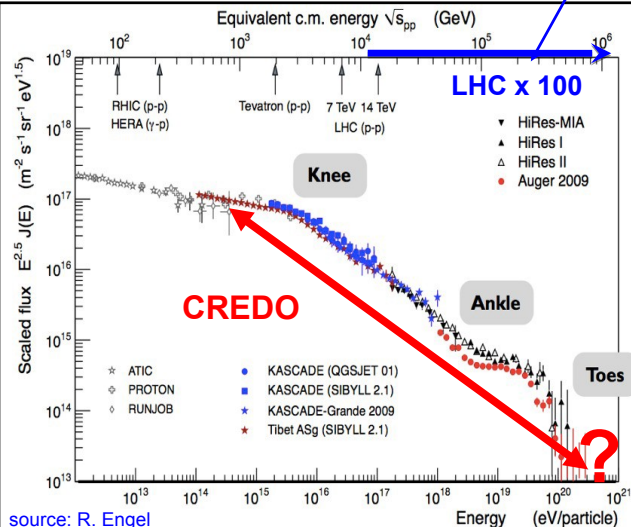
... many air showers and individual particles arriving simultaneously to the Earth ($N_{CR} > 1$)



CREDO strategy: Looking for multiple air showers correlated in time

The Ultra-High-Energy Cosmic Ray mystery

Particle physics beyond
the reach of colliders



> 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*

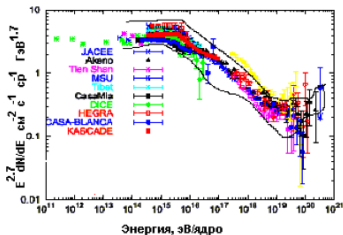
now: rather the efficiency limit of particle acceleration by sources

source: R. Engel

knee, ankle and toes:

MEPHI, High Energy Astrophysics. Lecture 1: Cosmic rays

Knee in CR spectrum



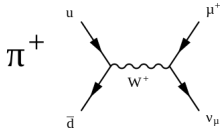
- Knee was discovered by Kulikov
- and Khristiansen in data of MSU
- Experiment in 1958
- It was confirmed by all new
- independent experiments

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

muons

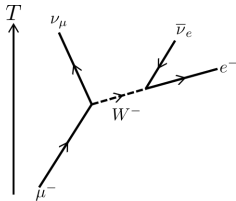
pions, e.g. $\pi^+ = u\bar{d}$, $M = 139 \text{ MeV}$, average life time $\tau = 2.6 \times 10^{-8} \text{ s}$, pion decay:

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$



muons: $M = 105.66 \text{ MeV}$, average life time $\tau = 2.2 \times 10^{-6} \text{ s} \rightarrow 660 \text{ m}$, decay:

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

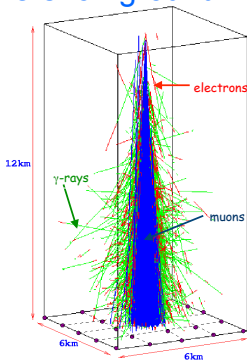


Cosmic rays

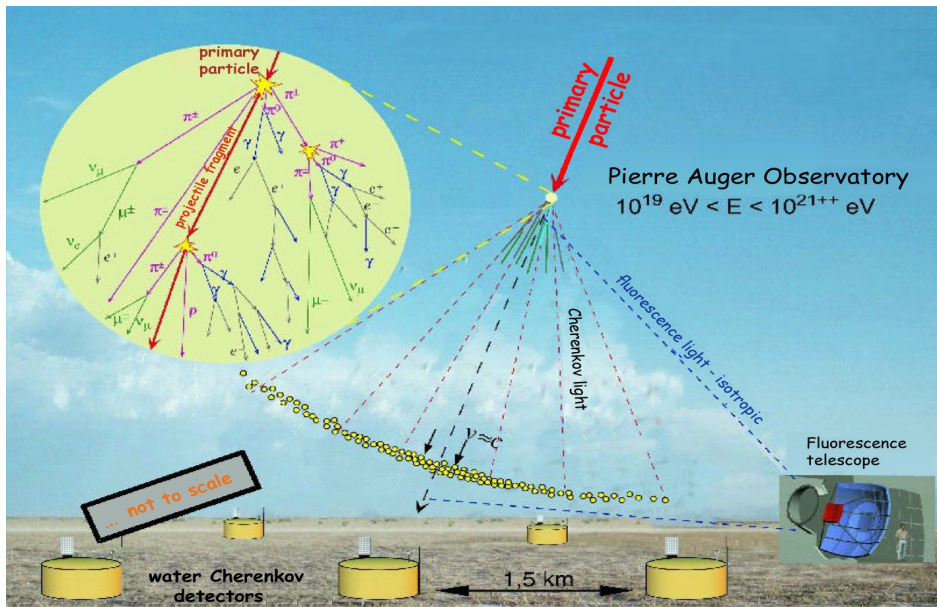
MEPHI, High Energy Astrophysics. Lecture 1: Cosmic rays

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^{10-11} photons, electrons and positrons in area 20-50 km². It is enough to have detectors with area of few m² per km². 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.

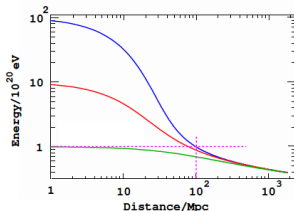
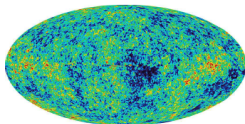


Big atmospheric showers: ($N_{\text{ATM}} = 1$)



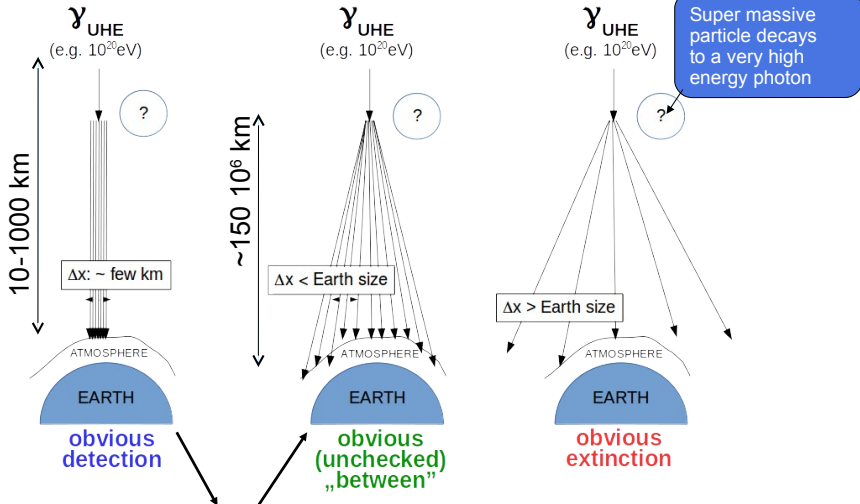
Energy limit for cosmic particles, GZK effect

Greisen-Zatsepin-Kuzmin Effect



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.



$N_{\text{cr}} > 1$ 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.

$N_{\text{ATM}} > 1$: 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)

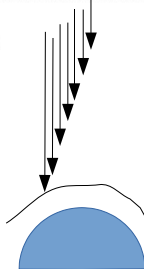
A series or burst of 32 extensive air showers with an estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 11 extensive showers in a period of 18 months between October 1980 and April 1982.

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

Cosmic ray group?

$N_{\text{ATM}} > 1$?

$\Delta x \geq \text{small}$



Year = 1981

$N_{\text{obs}} = 32$

$N_{\text{exp}} = 1$

$E = 3 \times 10^{15} \text{ eV}$

$N_{\text{ATM}} > 1$: 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

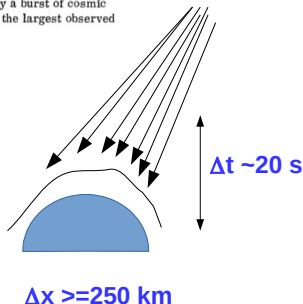
(Received 14 September 1983)

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

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

Cosmic ray group?

$N_{\text{ATM}} > 1$

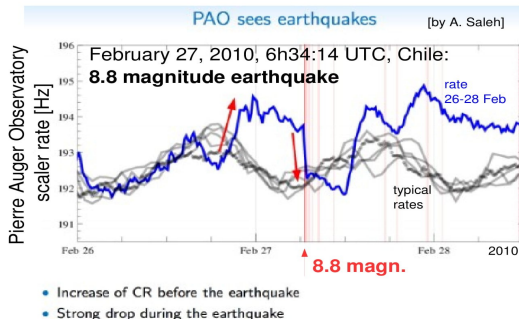
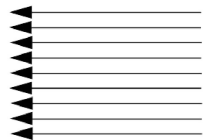


CREDO



THE QUEST FOR UNEXPECTED

Scientific diversity: GEO



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

2,7 billion people

**Science as a service to
the human community?**

Even the smallest chance to
save lives

= a must check!

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

For more information visit CREDO.science



"I think CREDO has a unique capability of entering in and exploring a completely uncharted realm of science."

Mikhail V. Medvedev

Cosmic-Ray Extremely Distributed Observatory

The Cosmic Ray Extremely Distributed Observatory (CREDO) collaboration is an ongoing research project involving scientists and the public from around the world. Our objective is to answer one of the most fundamental questions in the Universe – What is dark matter?

[Read More](#)



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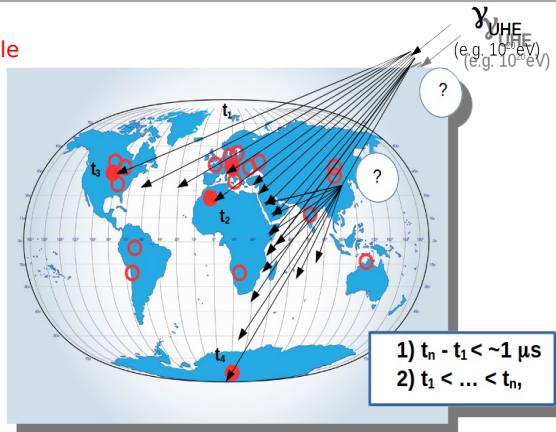
CREDO PROJECT

Cosmic-ray Extremal Distributed Observatory

CREDO's main idea:

creating a global network of particle detectors!

How?...

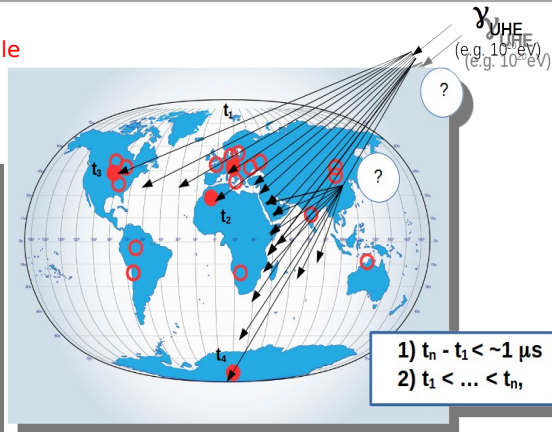


Cosmic-ray Extremal Distributed Observatory

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How?...



Code of application is public on GitHub:

<https://github.com/credo-science>

Different version available:

CREDO-PC-Windows, CREDO-Desktop-Det., Raspberry-Pi...

Slide 7

DID YOU KNOW THAT YOU HAVE
**AN INTERGALACTIC
PARTICLE DETECTOR
RIGHT IN YOUR
POCKET?**

Install CREDO Detector app for Android
and hunt for the deeply hidden
treasures of the Universe.

Find CREDO Detector on

or scan QR

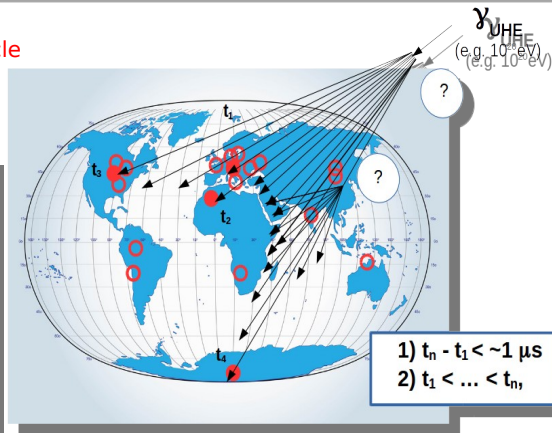


Cosmic-ray Extremal Distributed Observatory

CREDO's main idea:

creating a global network of particle detectors!

How?...



+ small type of scintillator detectors,

PoS(ICRC2019)428

+ connecting **existing observatories** to the network

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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

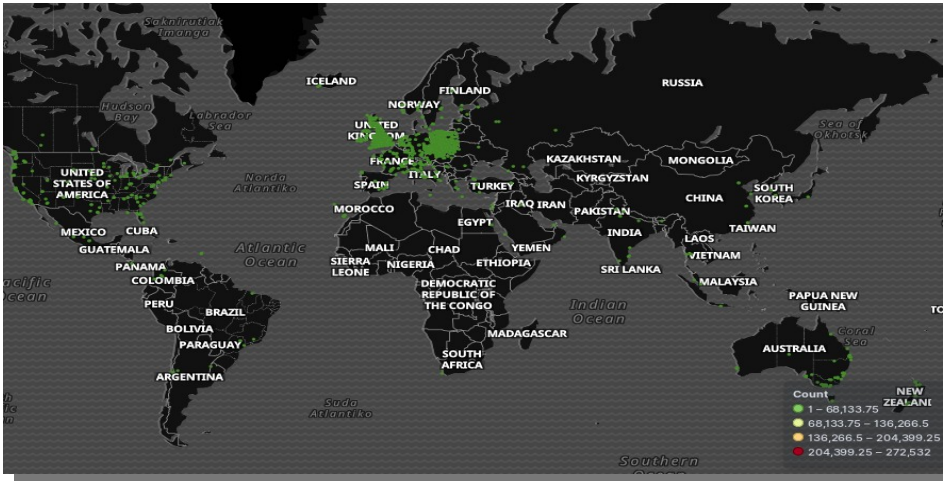
STIMULATES CITIZEN SCIENCE !

* 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 ($\sim 10^6$ 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:

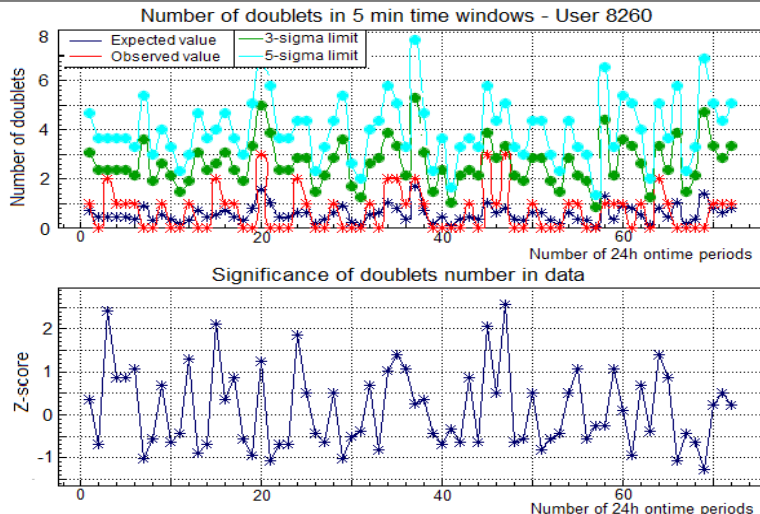
<https://api.credo.science/web/>



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)



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



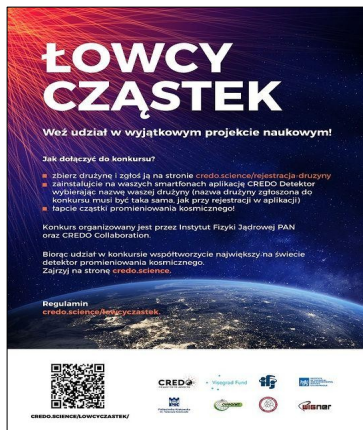
The CREDO heart :)

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!

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**xtrêmeley
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



Visegrad meeting Opava 2019

**HAVE A NICE STAY IN OPAVA
AND AT THE UNIVERSITY OF SILESIA
AND A FRUITFULL CONFERENCE!!**

LET'S ENJOY ASTROPHYSICS!

Děkuji za pozornost!