SPACE::TALK #02

Kozmické žiarenia zblízka

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Kozmické žiarenie zblízka

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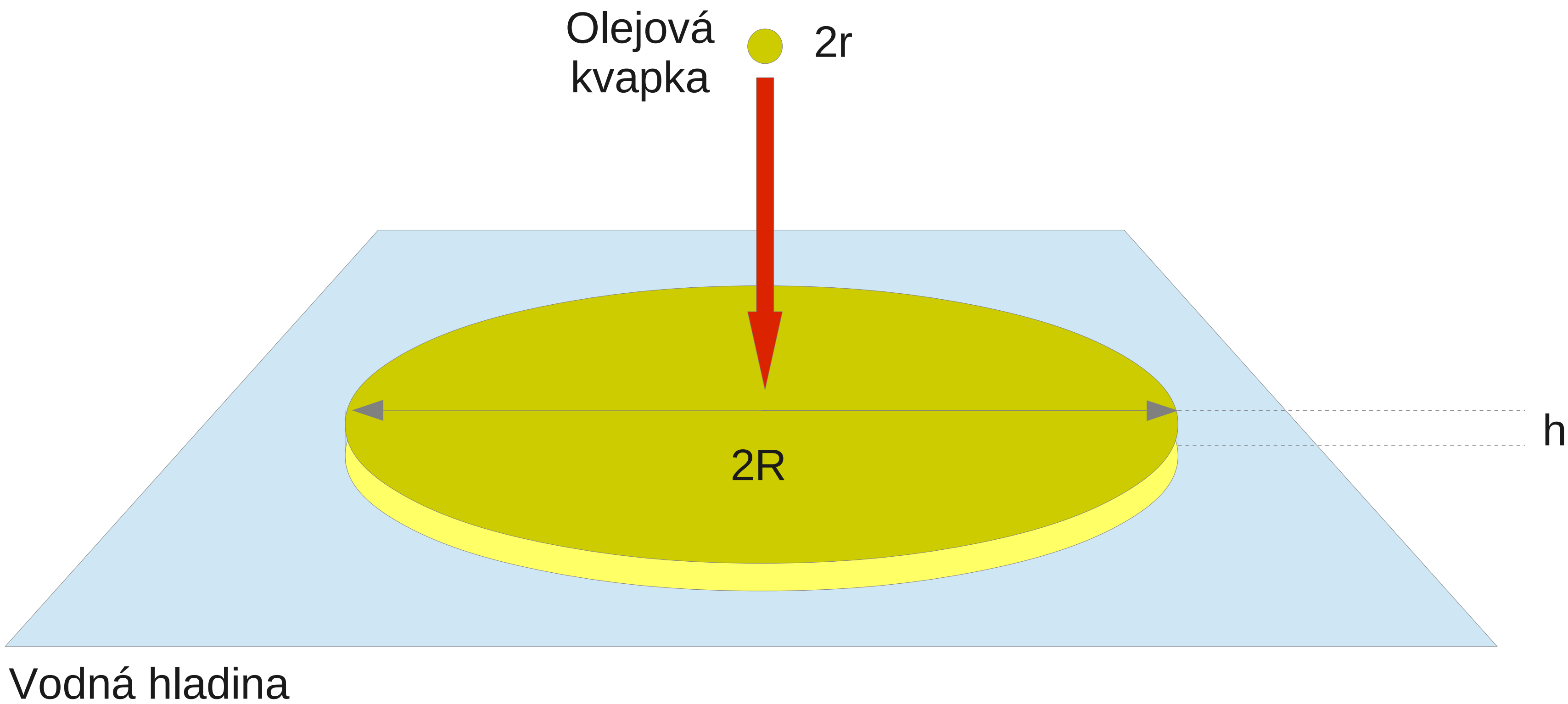
Space::TALK

2. máj 2019, Košice

Čo je kozmické žiarenie?

Čo je malé?
Na aké najmenšie časti môžeme rozložiť veci?



:: Kvapôčka oleja je malá guľočka s priemerom 0.5 mm
:: Na vodnej hladine vytvorí ~kruh s priemerom 25 centimetrov
:: Na vodnej hladine vytvorí „kruhový valec“ s výškou jednej molekuly oleja
rozmer molekuly je → **~tri miliardtiny metra**

- Aký malý je atóm?
- Koľko atómov obsahujú veci okolo nás?
- Aké veľké je jadro atómu voči rozmerom celého atómu?

Predmety okolo nás sa skladajú z najmenších stavebných blokov nazývaných častice.

Kozmické žiarenie tvoria častice prichádzajúce z vesmíru

Môžeme kozmické žiarenie vidieť voľným okom?

Sileye-2 experiment, MIR

Credit M. Casolino

- Astronauti pozorujú svetelné záblesky (jeden záblesk raz za približne 4 až 7 minút)
- MIR ~0,13 LF/min

  LF = light flashes

- Apollo ~0,23 LF/min
- Skylab ~1,3 LF/min
- Sileye-2, helma v ktorej astronaut nevidí svetlo zahŕňajúca detektor častíc
- Výsledky zverejnené v článku
  M. Casolino et al., Space travel - Dual origins of light flashes seen in space, Nature 422, 680, 2003, DOI: 10.1038/422680a

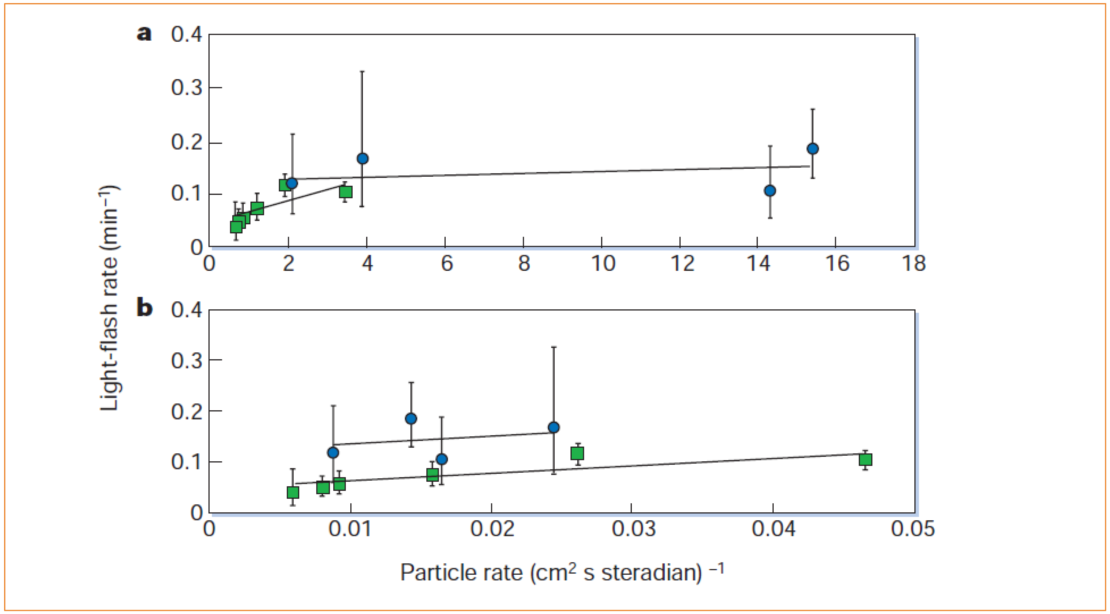


Figure 1 Rate of occurrence of light flashes on board the Mir space station as a function of particle rate for all particles and for relativistic nuclei inside (circles) and outside (squares) the South Atlantic Anomaly. **a,** Plot of light-flash rate against proton rate; **b,** light-flash rate against particle rate for particles with linear-energy transfer of >20 keV μm^{-1}. Linear fits for each region are shown. Data are from the Sileye-2 experiment[1], in which astronauts wore light-excluding helmets integrated with cosmic-ray particle-flux detectors, enabling the frequency of flashes to be recorded as a function of background flux and orbit position.

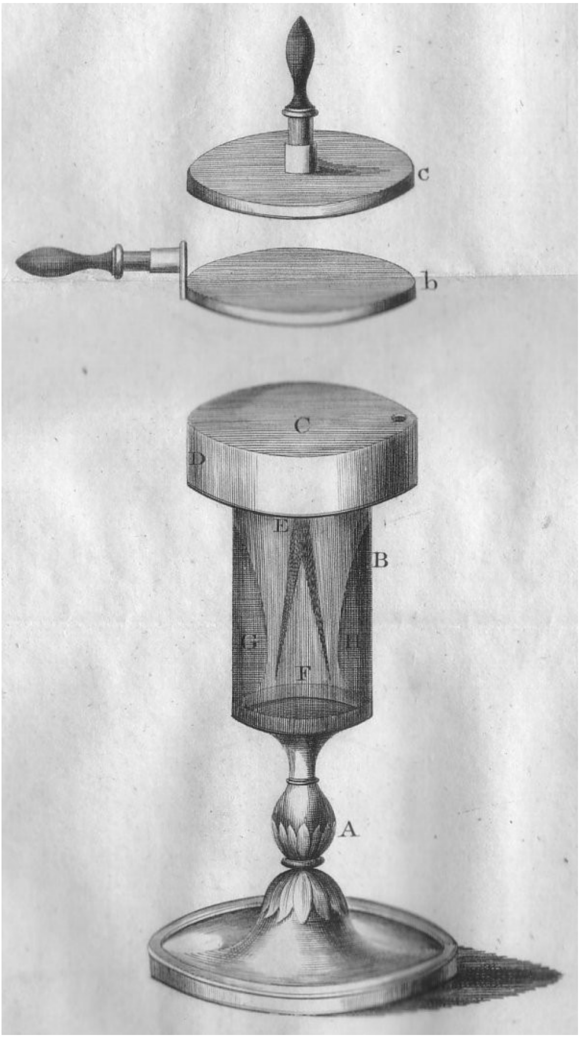
Prekvapivo, kozmické žiarenie môžeme vidieť voľným okom.

Ak sme na orbite Zeme.

Kozmické žiarenie – začiatok príbehu

1785 *Charles Coulomb* - nabité teleso (vo vzduchu) sa po čase stane elektricky neutrálnym

1787 *Abraham Bennet* – elektroskop (dve tenké pásky zlata na bavlnených vláknach) sa postupne bez akéhokoľvek vonkajšieho zásahu vybíja



1900 Charles Thomson Rees Wilson – ionizácia vzduchu vonkajším žiarením spôsobuje vybíjanie elektroskopu

Záver: žiarenie spôsobujúce vybíjanie elektroskopu pochádza zo zeme – problém vyriešený.

Naozaj?

Kozmické žiarenie – objav

1912 *Victor Hess*

Dokonalejší elektroskop s ktorým meral ionizáciu na rôznych výškach.

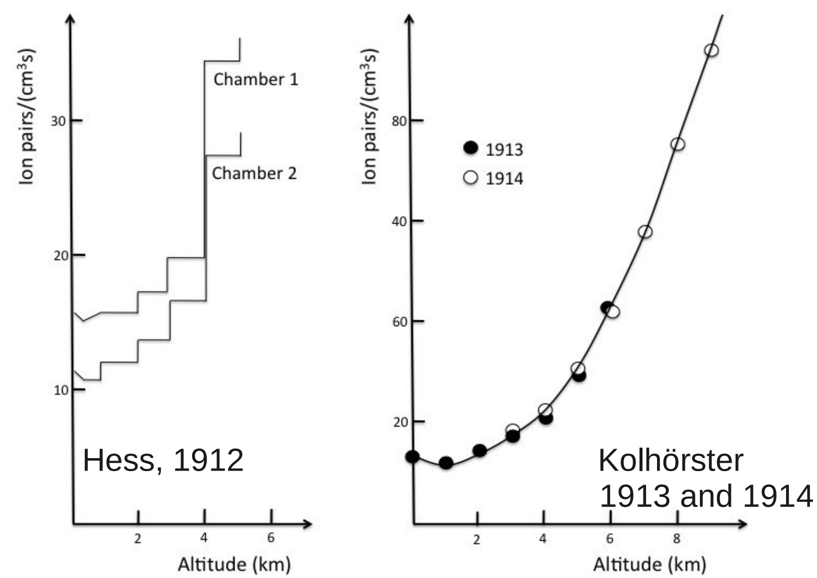
10 letov, z nich 5 letov v noci

Rovnaké výsledky – **ionizácia vo výškach od 2000 m.n.m rastie**

17. apríla 1912 počas zatmenia Slnka – rovnaký záver. Slnko tiež nie je zdrojom ionizujúceho žiarenia.

Žiarenie prichádza z vesmíru – termín Kozmické žiarenie zaviedol Robert Millikan

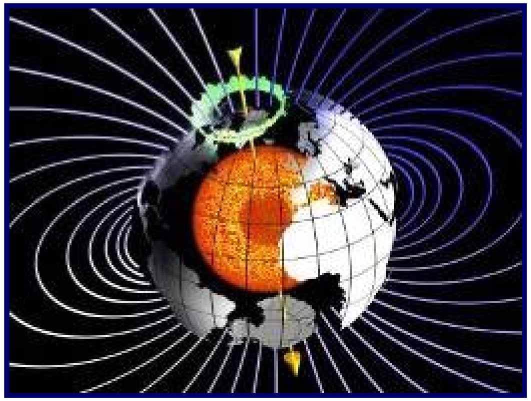
Nobelova cena v roku 1936.



Credit: Alessandro De Angelis

Kozmické žiarenie – míľniky

1932 Carl D. Anderson – objav pozitrónu v kozmickom žiarení



1933 Sir Arthur Compton - intenzita radiácie závisí na geomagnetickej šírke

1937 Street a Stevenson - objav miónu v kozmickom žiarení, 207 krát ťažší než elektrón

1938 Pierre Auger a Roland Maze - žiarenie v detektoroch vzdialených od seba 20m (neskôr 200m) prichádza v "rovnaký" moment

Objav EAS

- článok v *Reviews of Modern Physics*

  Auger P., Ehrenfest P., Maze R., Daudin J., Fréon F
  A., Extensive Cosmic-Ray Showers, *Rev. Mod. Phys.* 11, 288–291, 1939

  - http://rmp.aps.org/abstract/RMP/v11/i3-4/p288_1

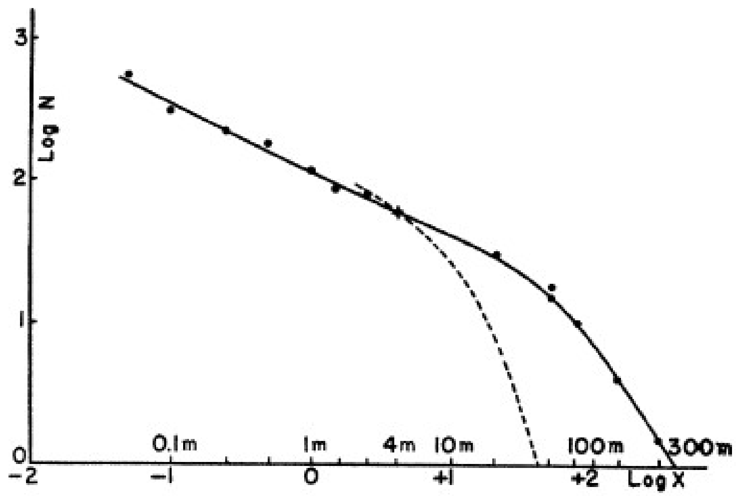


FIG. 1. Results with two parallel and horizontal counters.

Credit: Pascalou petit [CC BY-SA 3.0]

Credit: Julius Silver [CC BY-SA 4.0]

JULY-OCTOBER, 1939 REVIEWS OF MODERN PHYSICS VOLUME 11

Extensive Cosmic-Ray Showers

PIERRE AUGER
In collaboration with
P. EHRENFEST, R. MAZE, J. DAUDIN, ROBLEY, A. FRÉON
Paris, France

INTRODUCTION

IT is generally admitted that the soft group present at sea level is almost entirely due to the effects of mesotrons, that is to their decay electrons and their collision electrons. These electrons should then give rise in the lower atmosphere to local showers, the intensity of which should increase very slowly with the altitude, in the same way as the hard group (mesotrons).

But we know that the increase of the soft group with altitude is very rapid, so we must admit that electrons of another origin than that indicated above are adding their effects to those of the decay and collision electrons from mesotrons. It seems natural to suppose that they represent the end effects of the showers that the primary particles, probably electrons, which enter the high atmosphere produced there. If this is the case, we should be able to recognize it by the existence of a "coherence" of these shower particles, the multiple effects of a single initial particle remaining bound in time and in space.

We have shown the existence of these extensive showers[1] and studied their properties with counters and Wilson chambers partly at sea level, and partly in two high altitude laboratories, Jungfraujoch (3500 m) and Pic du Midi (2900 m).

LONG DISTANCE COINCIDENCES

If two or three counters are arranged in coincidence in free air, a small number of coincidences is observable, due to "air showers" and this number decreases quickly when the horizontal distance of the counters is increased. Schmeiser and Bothe have studied these local showers with counter separations up to half a meter.[2] If the distance is increased further, the number of coincidences decreases much more slowly, and for distances of the magnitude of ten meters, there remains a quite measurable effect, although small.[1, 3] In order to continue this study efficiently, it is then necessary to use a coincidence system with a very good resolving power, especially in the use of two counters. The apparatus employed in the present work registered only multiple kicks which happened within the time lag of 10^{-6} second.[4] The "background" or accidental coincidences can be calculated by the formula:[*]

$$N=\frac{n^x\tau^{(x-1)}}{60^{(x-2)}},$$

where N is the number of accidental coincidences per hour, if n is the number of single kicks in the counters per minute, x the number of counters, τ the resolving time in seconds. For instance with two large counters of 200 square centimeters, we had a background of about 1 per hour, in high altitudes. With three counters, the background is always negligible.

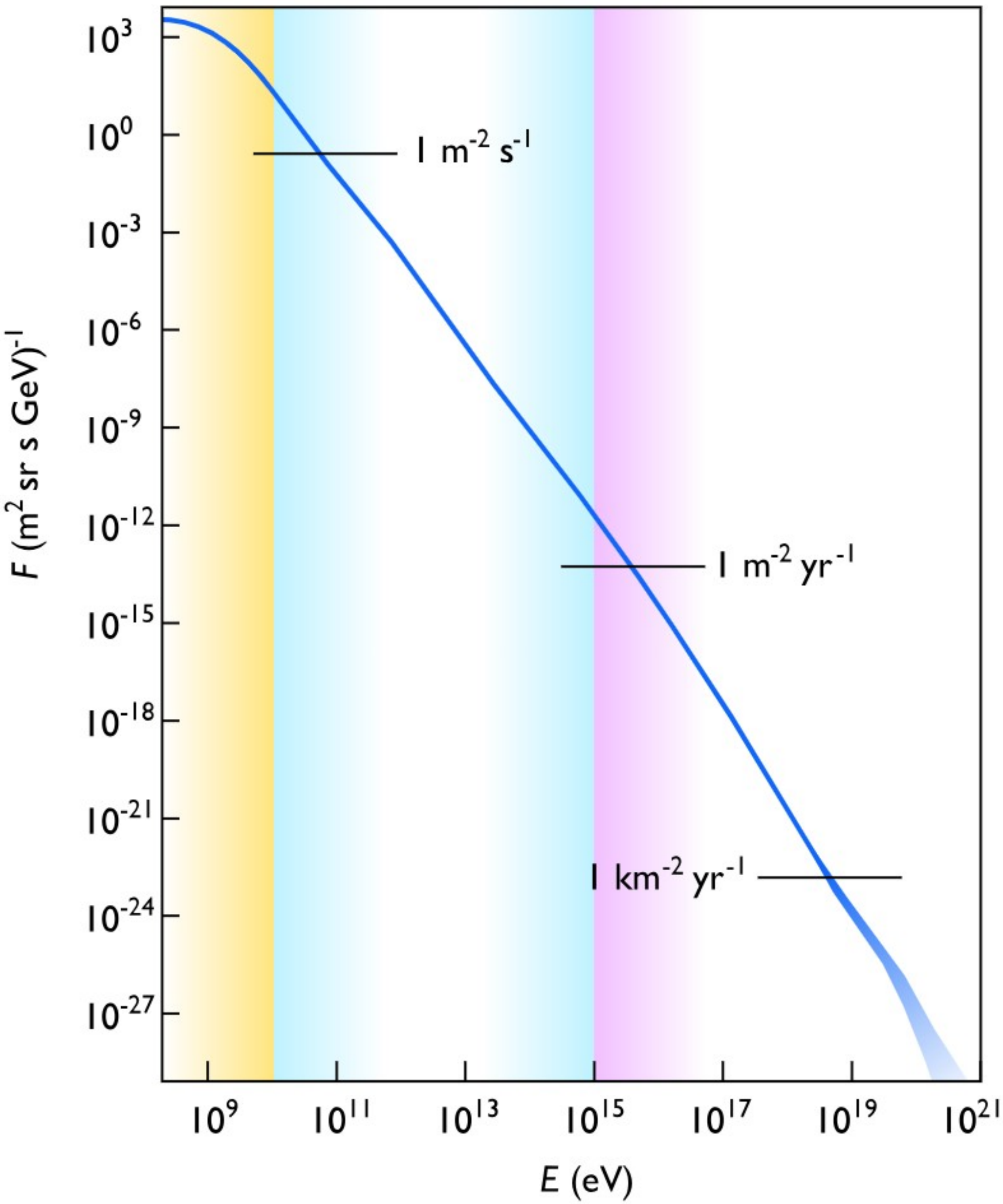
With the simplest arrangement of two parallel and horizontal counters placed at progressively increasing distances,[5] we could obtain the results given here in logarithmic scale (Fig. 1). The greatest distance was 300 m, we did not think it wise to try greater distances, because of the uncertainty of the simultaneity in the single kicks in the counters, coming from distant particles of the same showers. The time difference can be of the same order of magnitude as the resolving power, since the showers are not necessarily vertical.

[1] P. Auger, R. Maze, T. Grivet-Meyer, Comptes rendus **206**, 1721 (1938); P. Auger and R. Maze, Comptes rendus **207**, 228 (1938); P. Auger, R. Maze, P. Ehrenfest, Jr., and A. Fréon, J. de phys. et rad. **10**, 39 (1939).
[2] W. Bothe *et al.*, Physik. Zeits. **38**, 964 (1937).
[3] W. Kohlhörster, I. Matthes, E. Weber, Naturwiss. **26**, 576 (1938).
[4] R. Maze, J. de phys. et rad. **9**, 162 (1938).
[*] Instead of this equation, many writers (e.g. C. Eckart and F. R. Shonka, Phys. Rev. **53**, 752 (1938)) use an expression equivalent to

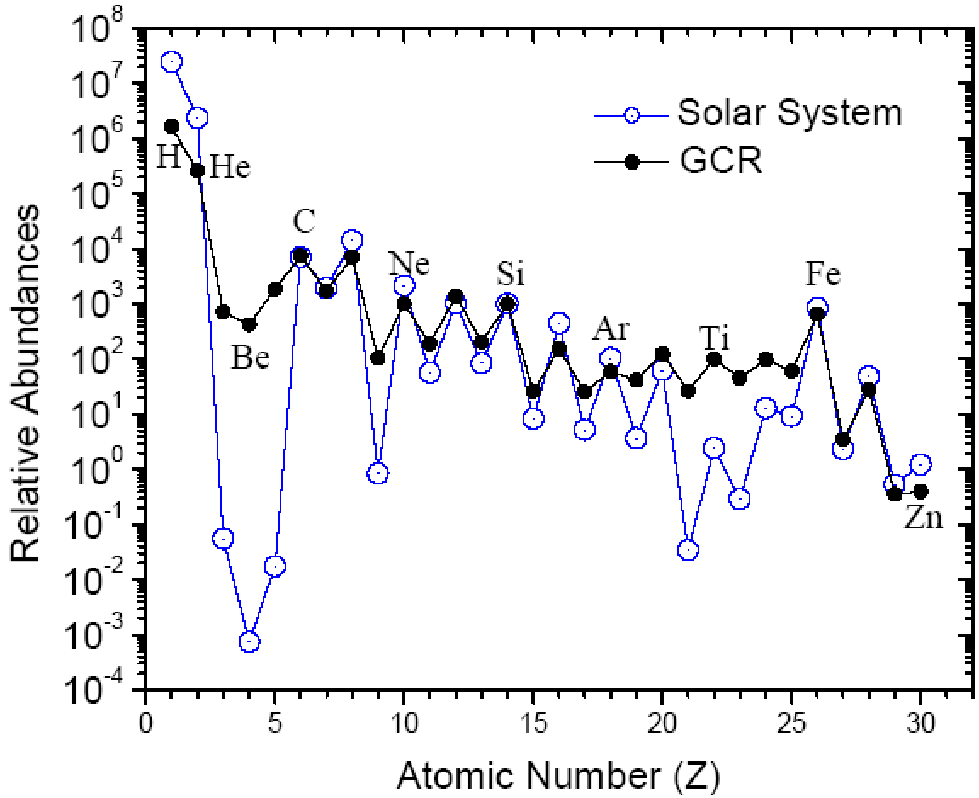
$$N=x\frac{n^x\tau^{(x-1)}}{60^{(x-2)}}$$

differing from that here given by a factor of x.
[5] P. Auger, R. Maze, and Robley, Comptes rendus **208**, 1641 (1939).

Kozmické žiarenie – spektrum



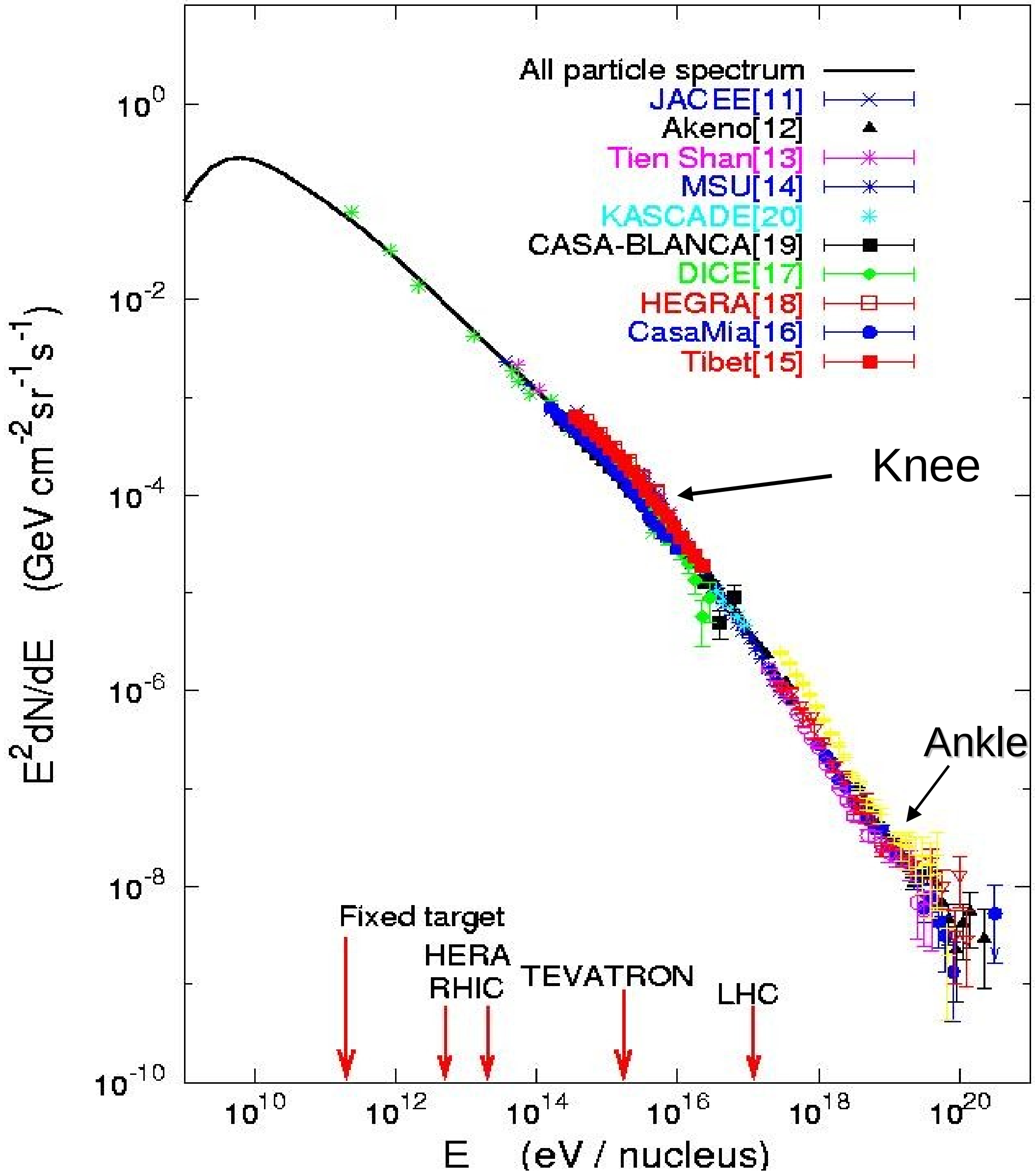
Credit: Sven Lafebre [CC BY-SA 3.0]



www.srl.caltech.edu/ACE/ACENews/ACENews83.html [CC BY 4.0]

- 10 rádov v energii 30 rádov v intenzite
- Podobné zloženie kozmického žiarenia a hmoty v Slnečnej sústave

Kozmické žiarenie – spektrum



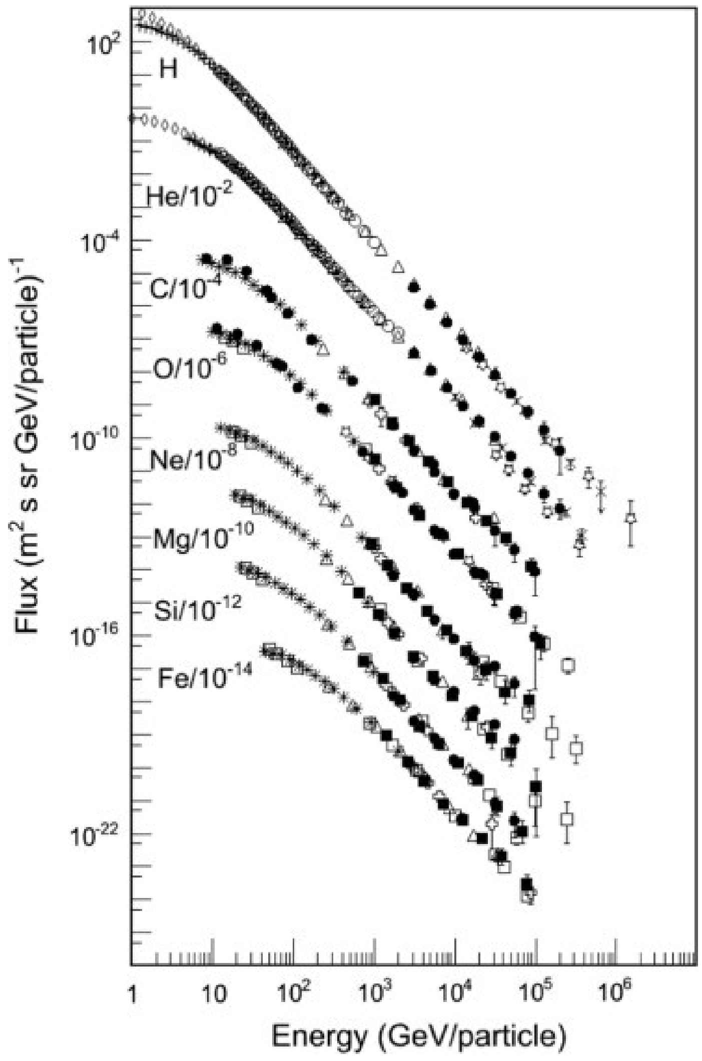


Fig. 5. Differential energy spectra from direct measurements of proton-to-Fe elements as a function of energy per particle. AMS diamonds; BESS [24] crosses; ATIC-2 open triangles; CREAM-1 filled circles; CREAM-2 filled squares; JACEE x; RUNJOB stars; HEAO-3 asterisks; CRN open crosses; TRACER open squares.

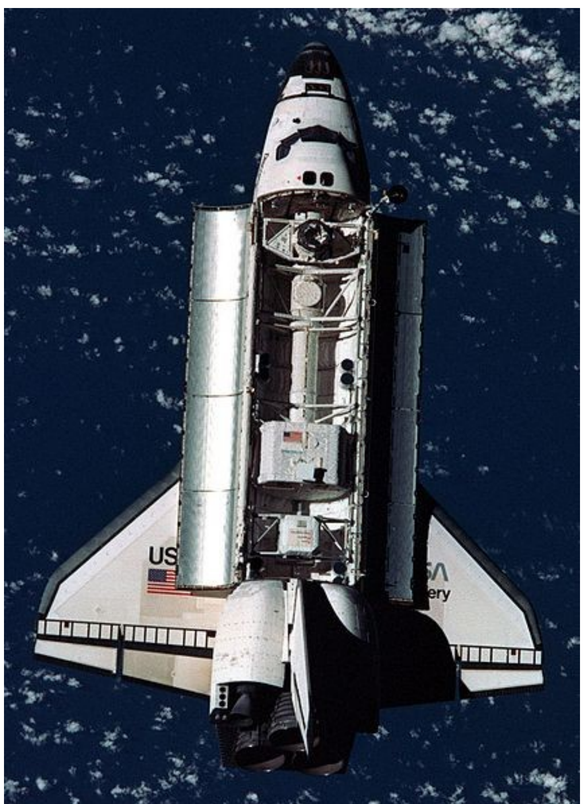
Direct measurements of cosmic rays using balloon borne experiments, Astroparticle Physics, Vol. 39–40, 76–87, 2012

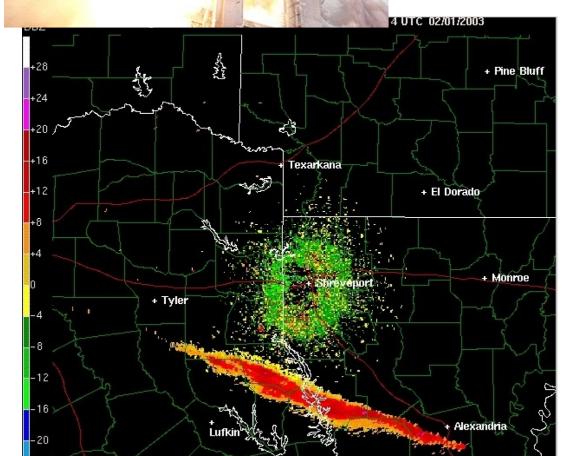
AMS – najpresnejšie meranie spektier KŽ

... príbeh, ktorý takmer neskončil dobre

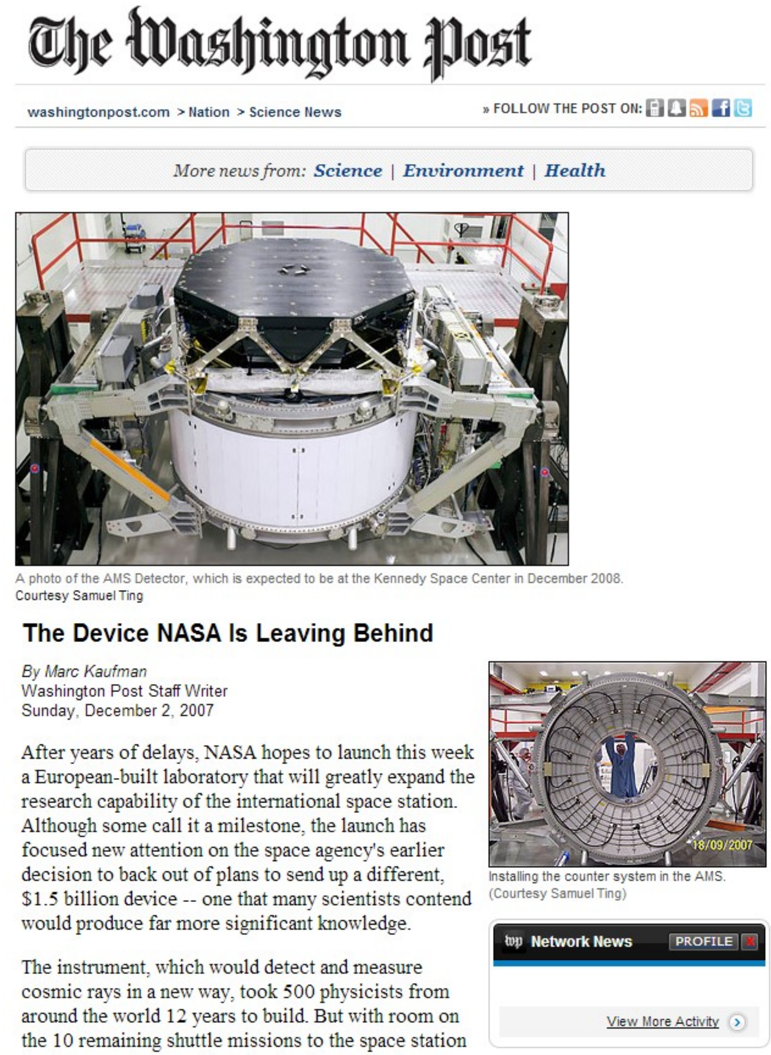
Samuel Ting – návrh AMS experimentu v roku 1995
Nobelova cena v roku 1976 za objav za J/ψ častice

- Let na Space Shuttle Discovery / STS-91 - jún 1998
  - let k stanici Mir
  - stanovený limit pre pomer hélia a antihélia na 1.1×10^{-6}
  - najpresnejšie spektrá p, He atď.





- havária STS Columbia
  – február 2003



The Washington Post

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A photo of the AMS Detector, which is expected to be at the Kennedy Space Center in December 2008.
Courtesy Samuel Ting

The Device NASA Is Leaving Behind

By Marc Kaufman
Washington Post Staff Writer
Sunday, December 2, 2007

After years of delays, NASA hopes to launch this week a European-built laboratory that will greatly expand the research capability of the international space station. Although some call it a milestone, the launch has focused new attention on the space agency's earlier decision to back out of plans to send up a different, $1.5 billion device -- one that many scientists contend would produce far more significant knowledge.

The instrument, which would detect and measure cosmic rays in a new way, took 500 physicists from around the world 12 years to build. But with room on the 10 remaining shuttle missions to the space station in short supply, many fear that it will remain forever warehoused on Earth, becoming the most sophisticated and costly white elephant of the space era.

As a result, the imminent launch of the $1 billion Columbus laboratory -- the kind of scientific workspace that the station's backers always said would be its reason for being -- will take place under something of a cloud.

Installing the counter system in the AMS.
(Courtesy Samuel Ting)

Network News PROFILE

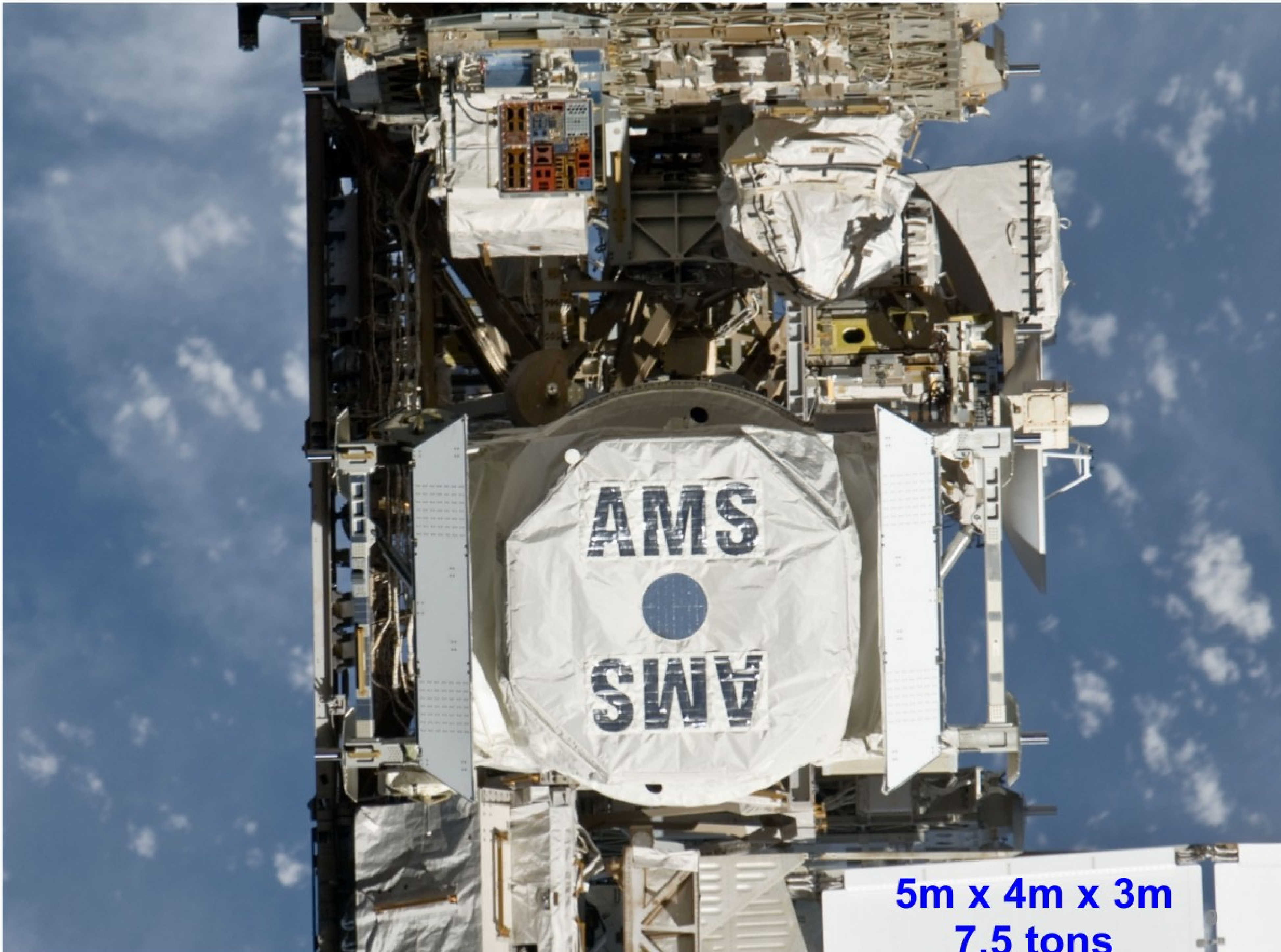
View More Activity

http://www.washingtonpost.com/wp-dyn/content/article/2007/12/01/AR2007120100760.html

AMS-02 – presné meranie kozmického žiarenia na ISS

STS 133 :: pôvodne posledný plánovaný let raketoplánov
STS 134 :: schválený v júni 2008
STS 134 :: 16. máj 2011

- ISS
- 1.5 mld $
- 6,717 kg, 2.0–2.5 kW
- predpokladaná doba meraní ~10 rokov
- vedecké ciele: antihmota, tmavá hmota, kozmické žiarenie



S. Ting, The Alpha Magnetic Spectrometer on the International Space Station, ICRC 2013

AMS – The Fight for Flight

https://youtu.be/OzX0q665_cM

AMS – p , He spektrá

PRL **114,** 171103 (2015)

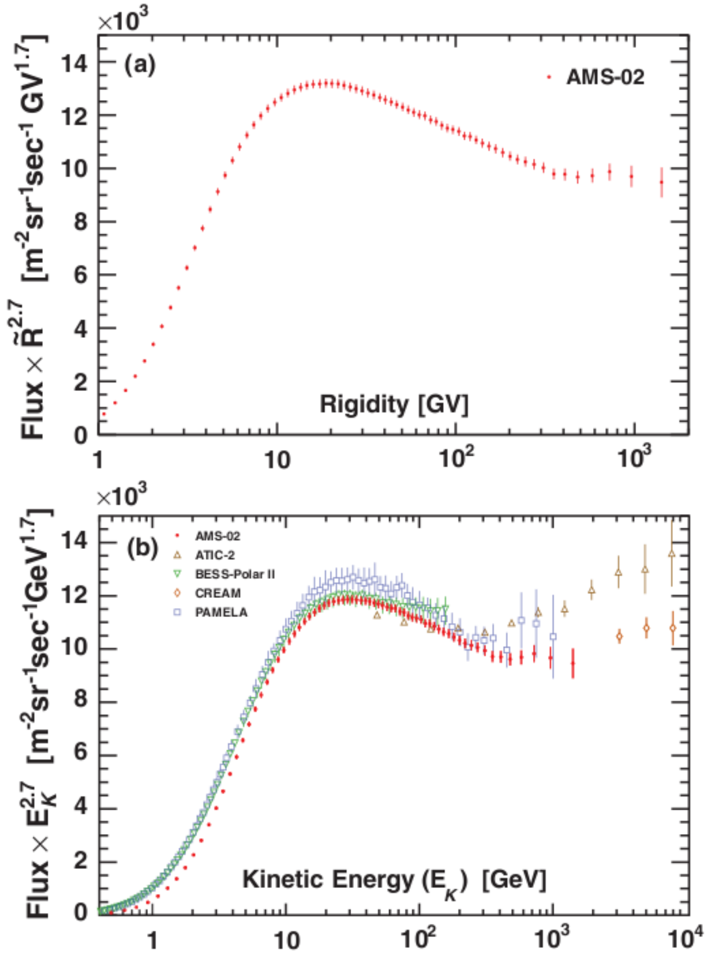


FIG. 3 (color). (a) The AMS proton flux multiplied by $\tilde{R}^{2.7}$ and the total error as a function of rigidity. (b) The flux as a function of kinetic energy E_K as multiplied by $E_K^{2.7}$ compared with recent measurements [3–6]. For the AMS results $E_K \equiv \sqrt{\tilde{R}^2 + M_p^2} - M_p$ where M_p is the proton mass.

PRL **115,** 211101 (2015)

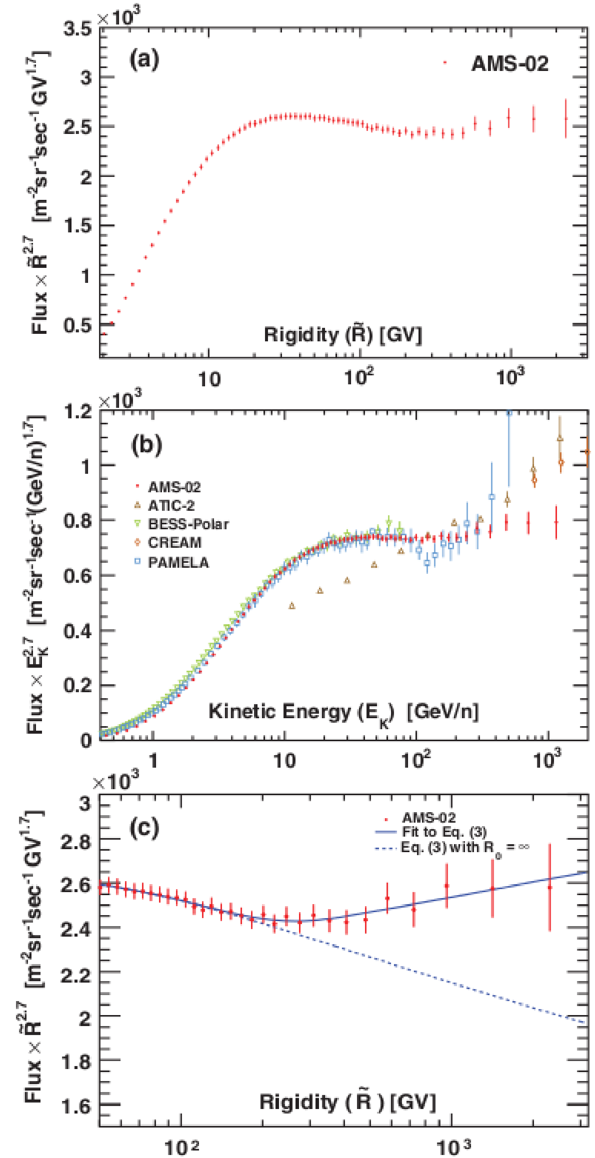
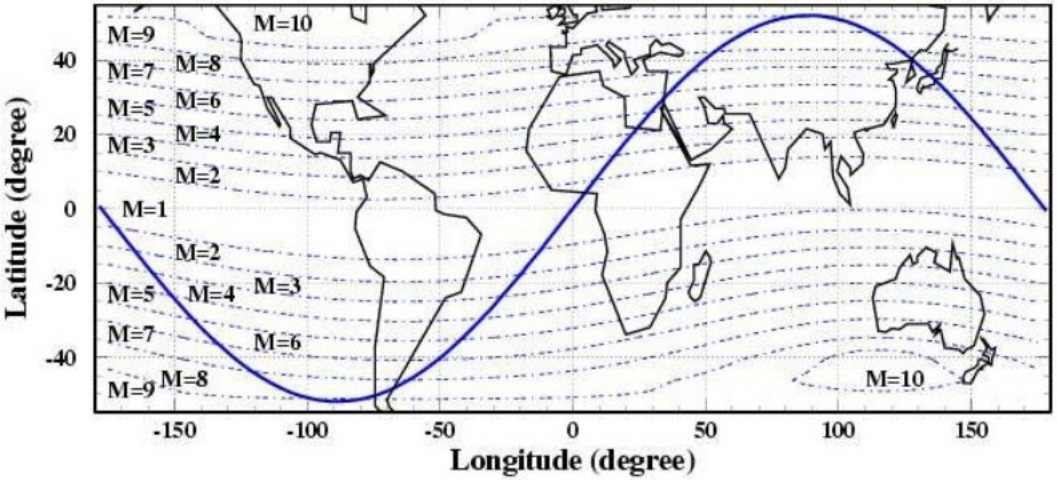


FIG. 1 (color). (a) The AMS helium flux [22] multiplied by $\tilde{R}^{2.7}$ with its total error as a function of rigidity. (b) The flux as a function of kinetic energy per nucleon E_K multiplied by $E_K^{2.7}$ compared with measurements since the year 2000 [3–6]. For the AMS results $E_K \equiv (\sqrt{4\tilde{R}^2 + M^2} - M)/4$ where M is the ^{4}He mass as the AMS flux was treated as containing only ^{4}He. (c) Fit of Eq. (3) to the AMS helium flux. For illustration, the dashed curve uses the same fit values but with R_0 set to infinity.

Protónové spektrá

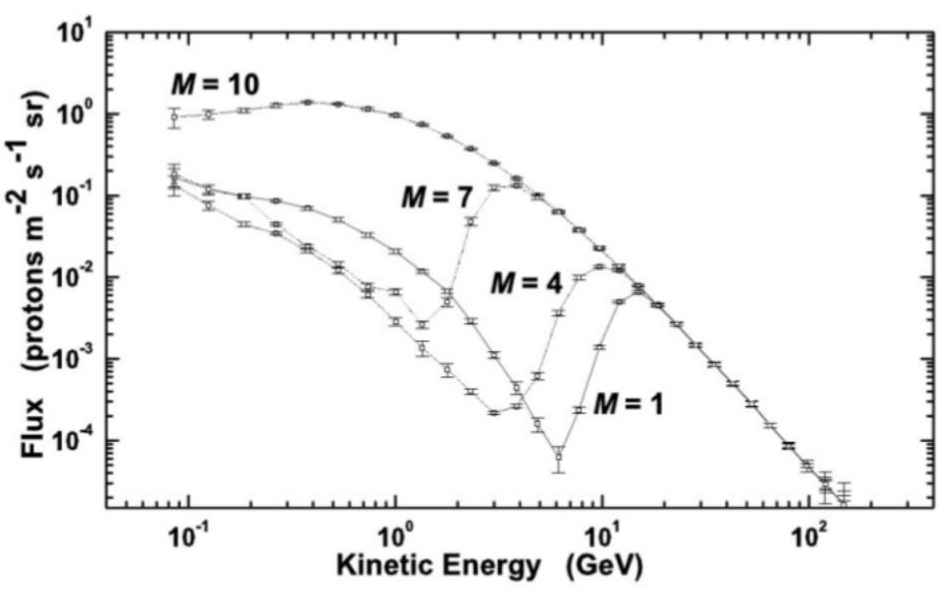
orbita ISS, závislosť na geomagnetickej šírke



The 10 geomagnetic regions (M) covered by AMS-01, defined in Table 1, are shown on the background of the Earth surface. A typical trajectory of AMS-01 detector on board of the space shuttle, at an altitude of about 400 km, is also plotted. The space shuttle trajectory shifts with time and covers almost uniformly the Earth surface inside a geographic latitude $\Theta \leq 51{,}6^{\circ}$.

Region (M)	CGM latitude θ_M (rad)
1	$\lvert\theta_M\rvert \leq 0.2$
2	$0.2 \leq \lvert\theta_M\rvert \leq 0.3$
3	$0.3 \leq \lvert\theta_M\rvert \leq 0.4$
4	$0.4 \leq \lvert\theta_M\rvert \leq 0.5$
5	$0.5 \leq \lvert\theta_M\rvert \leq 0.6$
6	$0.6 \leq \lvert\theta_M\rvert \leq 0.7$
7	$0.7 \leq \lvert\theta_M\rvert \leq 0.8$
8	$0.8 \leq \lvert\theta_M\rvert \leq 0.9$
9	$0.9 \leq \lvert\theta_M\rvert \leq 1.0$
10	$\lvert\theta_M\rvert \geq 1.0$

Table 1. Geomagnetic regions covered by AMS-01 measurements and kinetic energies corresponding to the dip for each geomagnetic zone (see [*AMS Collaboration*, 2000a; *AMS Collaboration*, 2002]). The regions are dened using the Corrected Geomagnetic latitude (CGM).

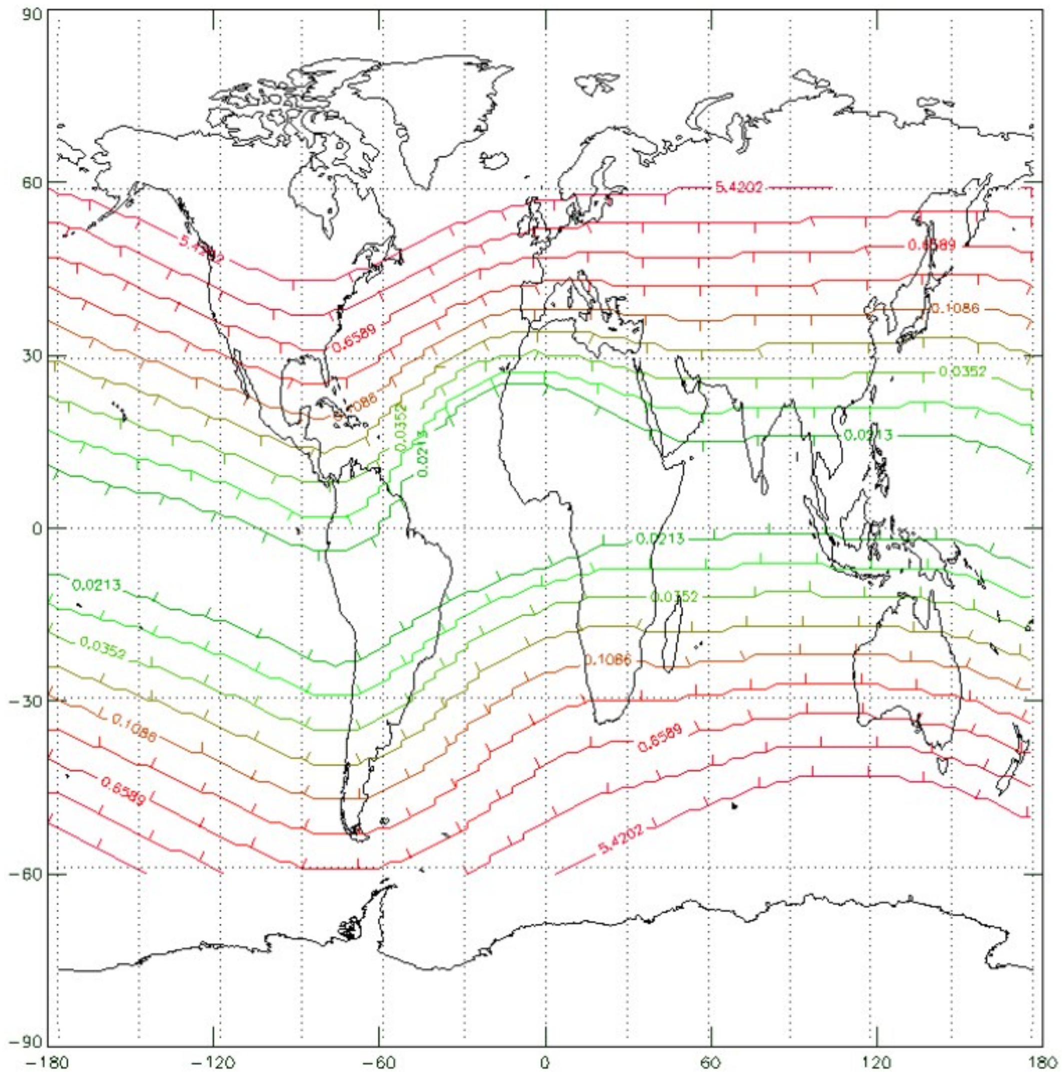


Left down panel: Normalized fluxes per units of solid angle are shown for the geomagnetic regions M = 1, 4, 7 and 10 as functions of the proton kinetic energies.

All figures are from: *Bobik P., Boella G., Boschini M. J., Gervasi M., Grandi D., Kudela K., Pensotti S., Rancoita P. G., Magnetospheric transmission function approach to disentangle primary from secondary cosmic ray fluxes in the penumbra region, JGR, 111, Issue A5, A05205, 2006*

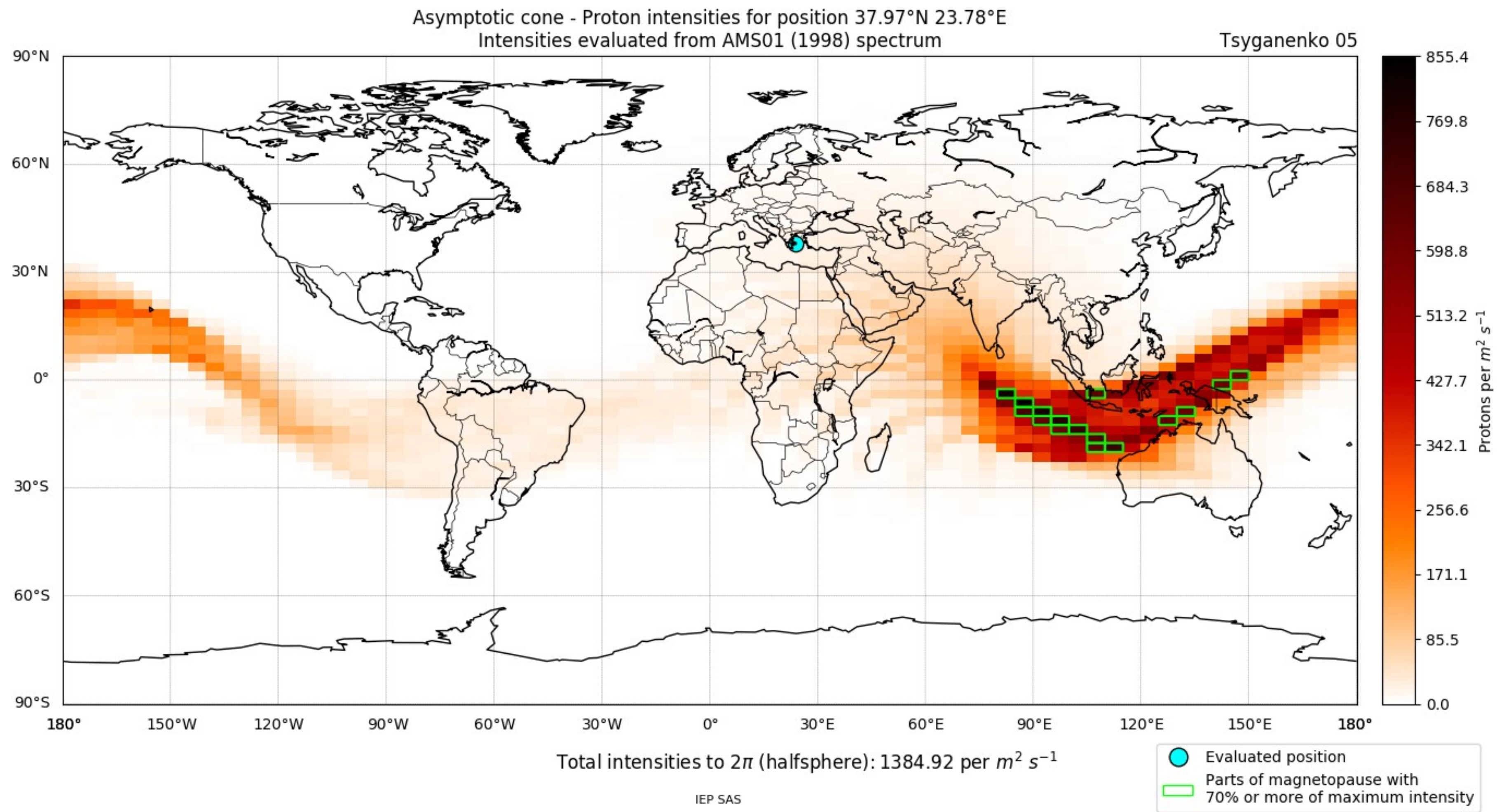
Integrálne protónové spektrá
orbita ISS, závislosť na geomagnetickej šírke

AMS downward proton total flux in $(m^2\ s\ sr\ MeV)^{-1}$
- evaluated from spectra published in article *Protons in near earth orbit, Physics Letters B, Volume 472, Issues 1-2, 13 January 2000, Pages 215-226*



COR model

Cut-Off Rigidity model (COR model) - model pre simulácie prechodu kozmického žiarenia magnetosférou Zeme

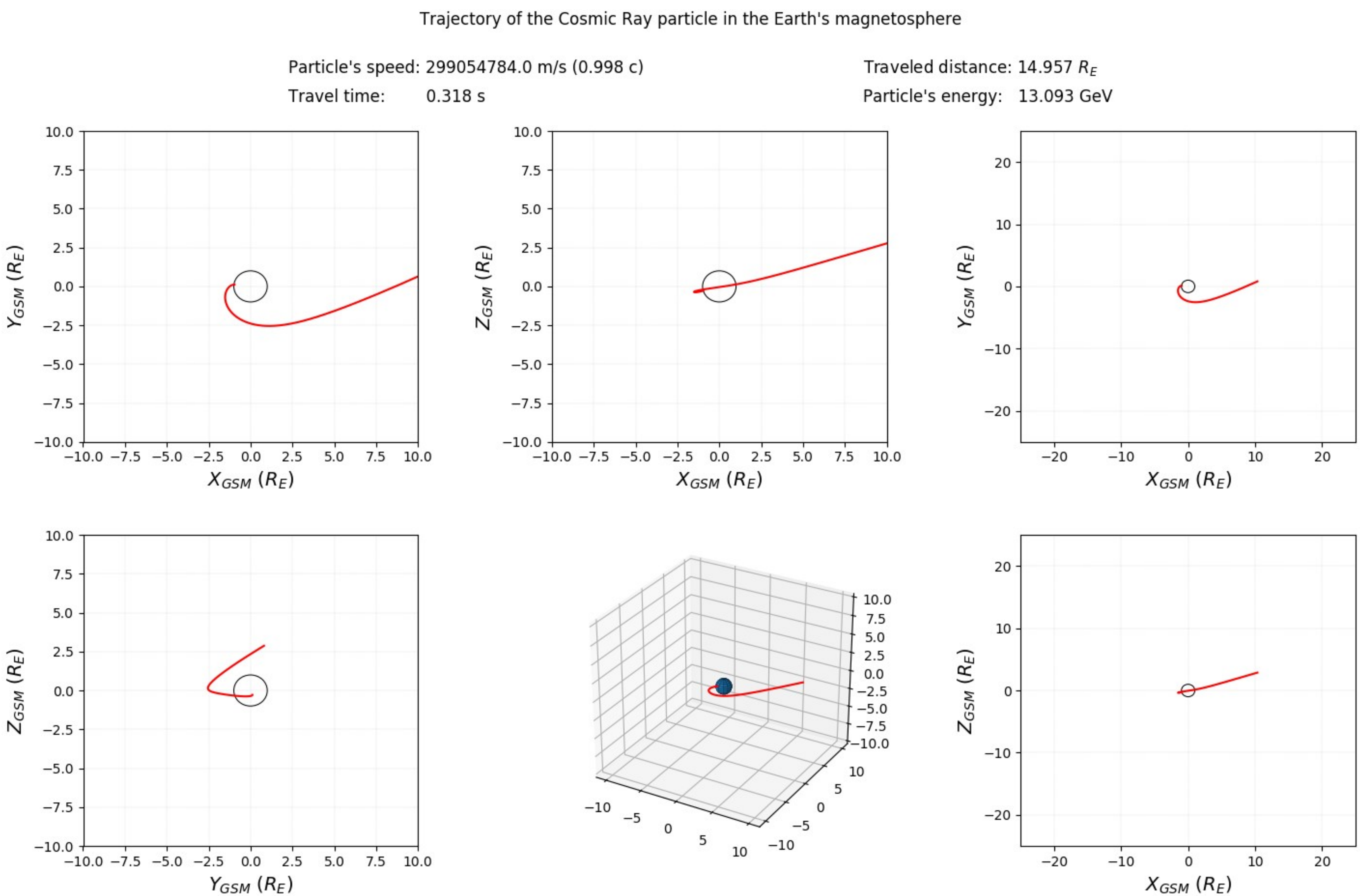


COR model:
Pavol Bobik and Marian Putis
Institute of Experimental Physics, SAS

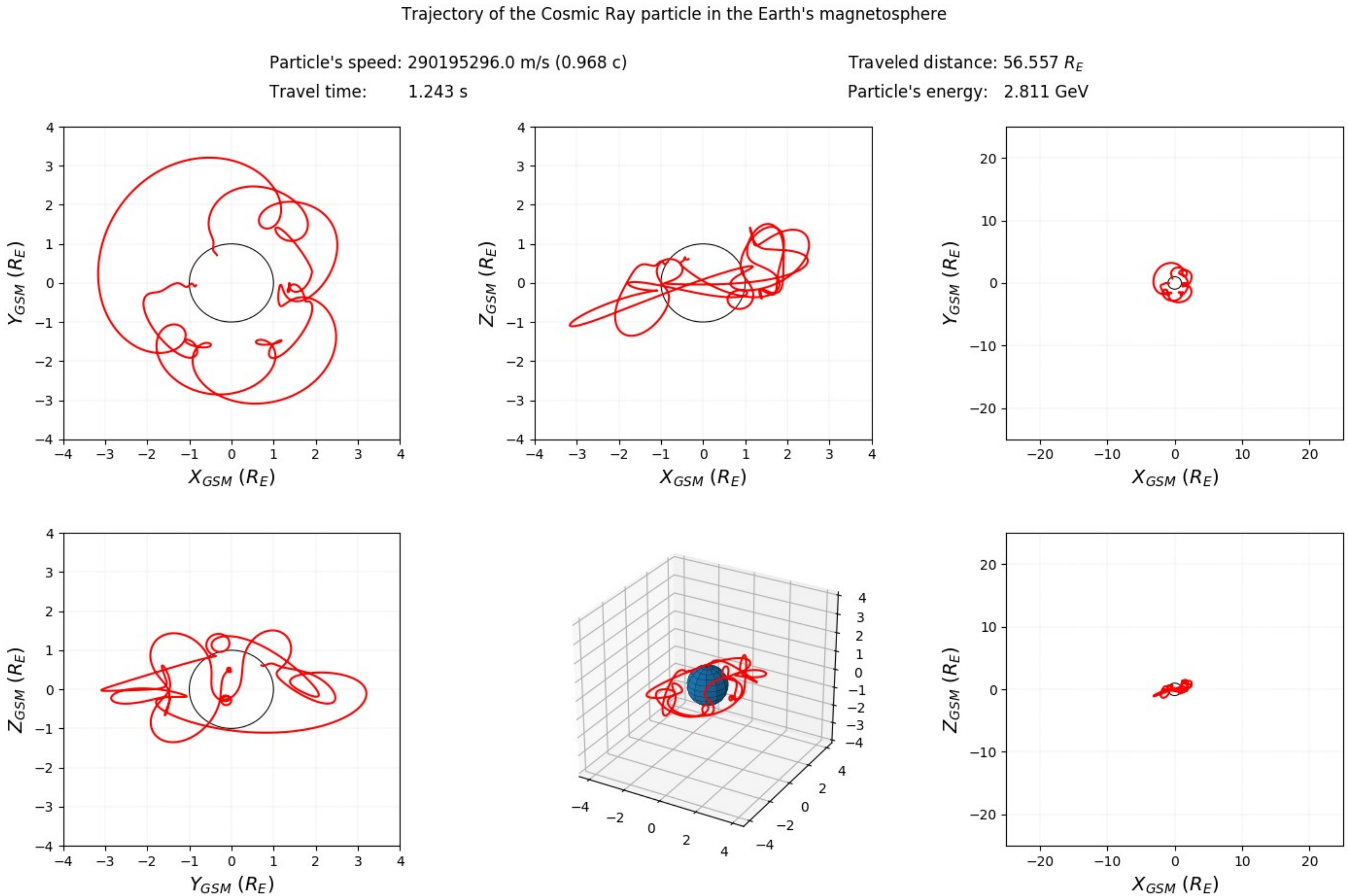
Simulations management system and web framework:
Daniel Gecasek, Michal Vrabel and Jan Genci
Technical University of Kosice

Patricipation on visualisation module:
Martin Vasko and Ivan Bernat
Technical University of Kosice

COR model


Trajectory of the Cosmic Ray particle in the Earth's magnetosphere
Particle's speed: 299054784.0 m/s (0.998 c)
Travel time: 0.318 s
Traveled distance: 14.957 R_E
Particle's energy: 13.093 GeV
X_{GSM} (R_E)
Y_{GSM} (R_E)
Z_{GSM} (R_E)

COR model


Trajectory of the Cosmic Ray particle in the Earth's magnetosphere
Particle's speed: 290195296.0 m/s (0.968 c)
Travel time: 1.243 s
Traveled distance: 56.557 R_E
Particle's energy: 2.811 GeV
Y_{GSM} (R_E)
X_{GSM} (R_E)
Z_{GSM} (R_E)
X_{GSM} (R_E)
Y_{GSM} (R_E)
X_{GSM} (R_E)
Z_{GSM} (R_E)
Y_{GSM} (R_E)
Z_{GSM} (R_E)
X_{GSM} (R_E)

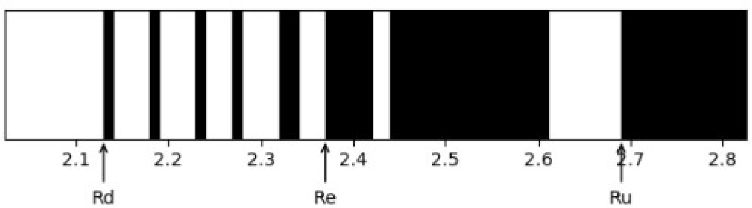
COR model

Geological position: 40.21°N 287.79°E

2010/01/10 00:00:00

YYYY/MM/DD HH:MM:SS

Direction ID: 000



$\Delta R = 0.01$

Rd = 2.13 GV

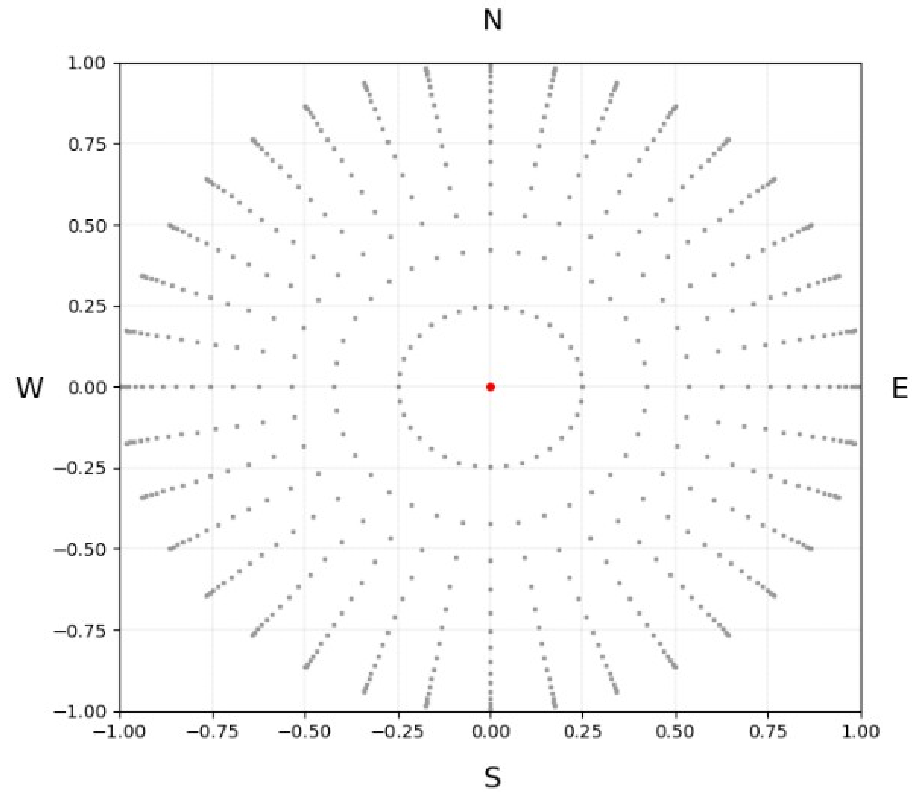
Re = 2.37 GV

Ru = 2.69 GV

Model: Tsyganenko 05

$\theta = 0.0°$

$\varphi = 0.0°$



The spectrum of allowed and forbidden rigidities (left panel)
The incoming direction is signed by the red point (rigth panel)

IEP SAS

0 /576 > »

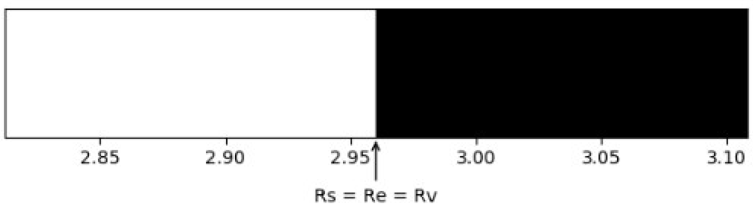
COR model

Geological position: 40.21°N 287.79°E

2010/01/10 00:00:00

YYYY/MM/DD HH:MM:SS

Direction ID: 576



ΔR = 0.01

Rd = 2.96 GV

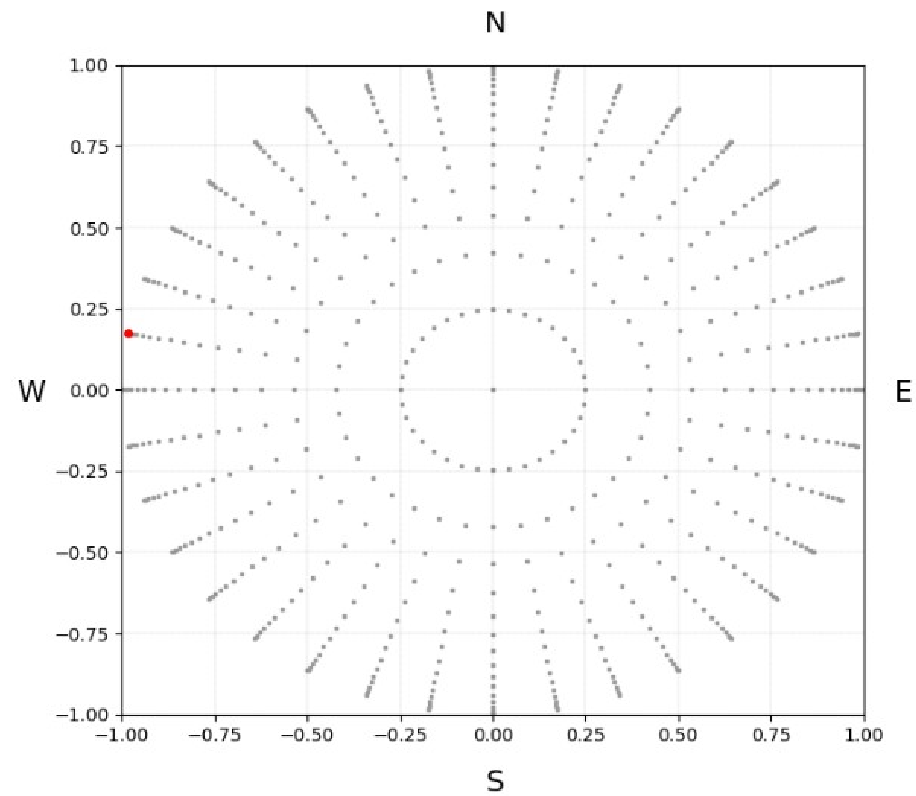
Re = 2.96 GV

Ru = 2.96 GV

Model: Tsyganenko 05

θ = 88.21°

φ = 350.0°



The spectrum of allowed and forbidden rigidities (left panel)
The incoming direction is signed by the red point (rigth panel)

IEP SAS

« < 576 /576

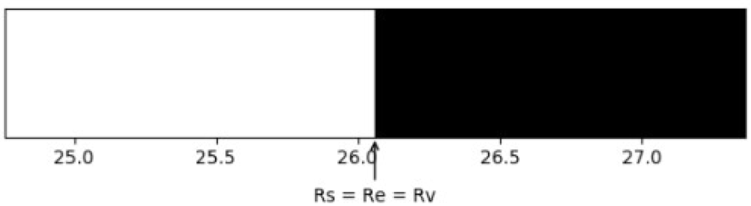
COR model

Geological position: 40.21°N 287.79°E

2010/01/10 00:00:00

YYYY/MM/DD HH:MM:SS

Direction ID: 559



ΔR = 0.01

Rd = 26.06 GV

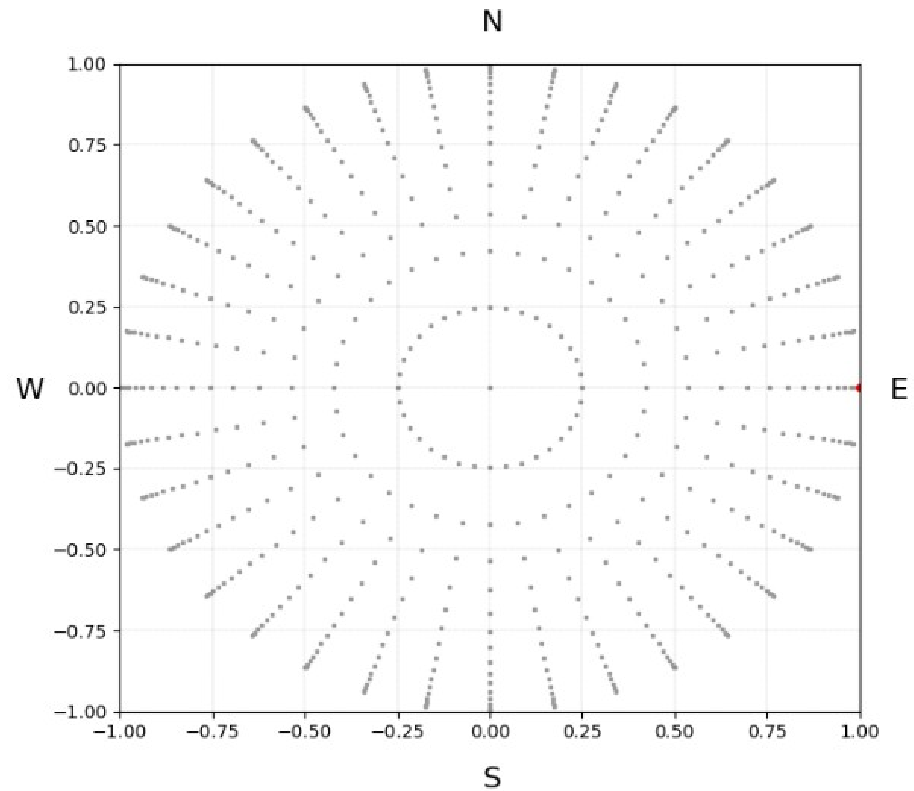
Re = 26.06 GV

Ru = 26.06 GV

Model: Tsyganenko 05

θ = 88.21°

φ = 180.0°

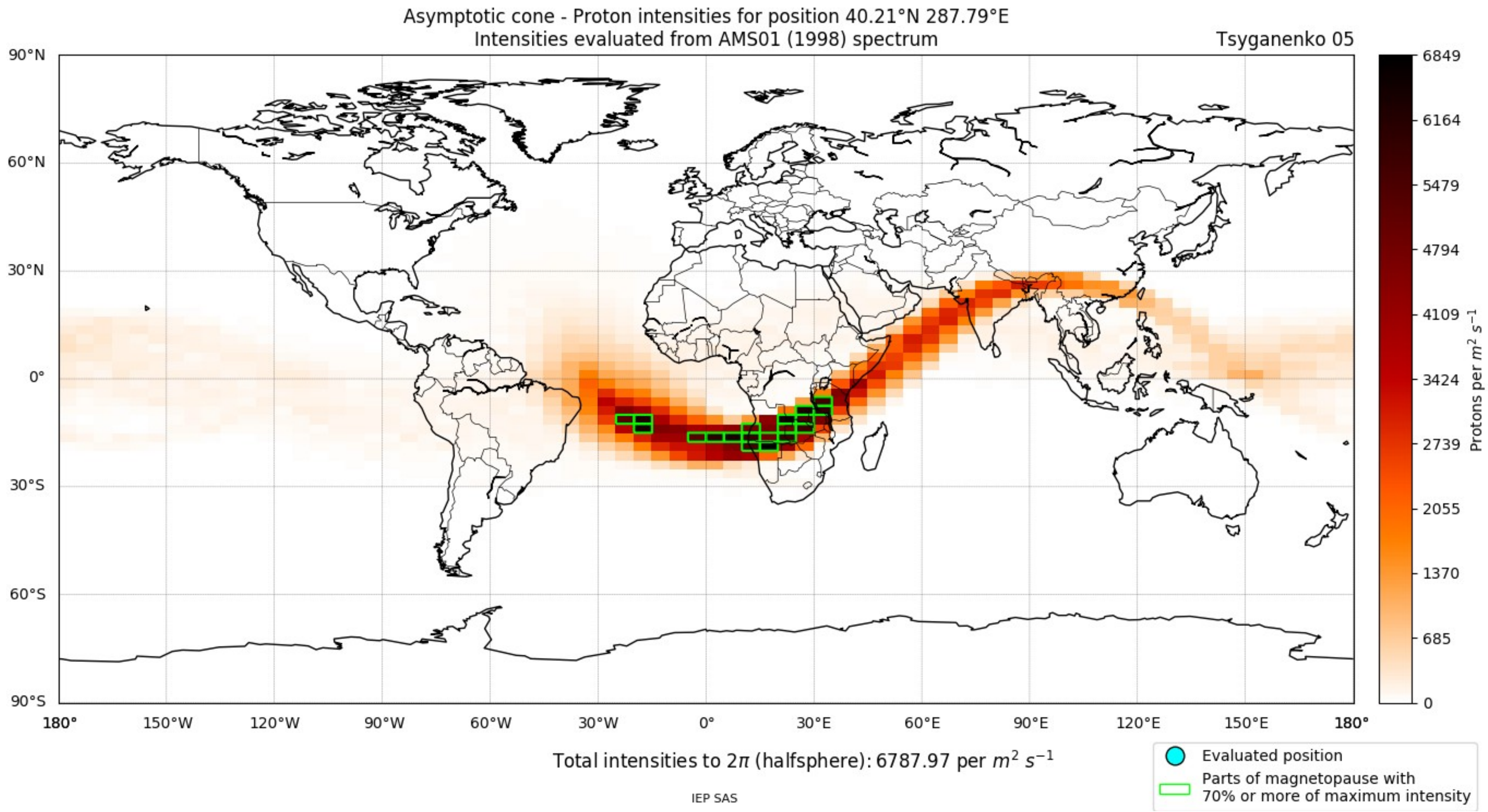


The spectrum of allowed and forbidden rigidities (left panel)
The incoming direction is signed by the red point (rigth panel)

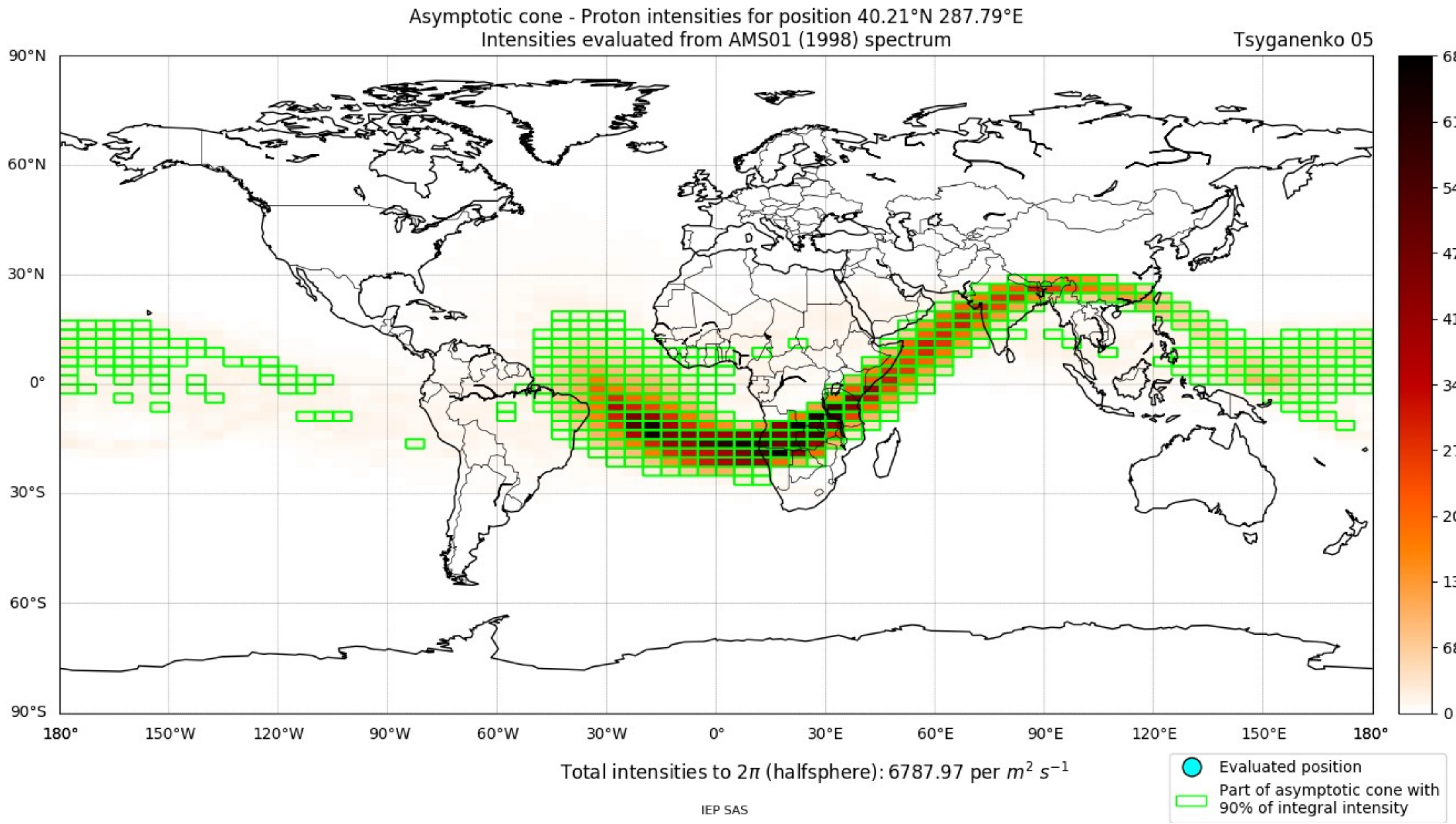
IEP SAS

« < 559 /576 > »

COR model


Asymptotic cone - Proton intensities for position 40.21°N 287.79°E
Intensities evaluated from AMS01 (1998) spectrum
Tsyganenko 05
90°N
60°N
30°N
0°
30°S
60°S
90°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
6849
6164
5479
4794
4109
3424
2739
2055
1370
685
0
Protons per $m^2\ s^{-1}$
Total intensities to 2π (halfsphere): 6787.97 per $m^2\ s^{-1}$
IEP SAS
Evaluated position
Parts of magnetopause with
70% or more of maximum intensity

COR model



Asymptotic cone - Proton intensities for position 40.21°N 287.79°E
Intensities evaluated from AMS01 (1998) spectrum
Tsyganenko 05
90°N
60°N
30°N
0°
30°S
60°S
90°S
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150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
6849
6164
5479
4794
4109
3424
2739
2055
1370
685
0
Protons per m^2 s^{-1}
Total intensities to 2π (halfsphere): 6787.97 per m^2 s^{-1}
IEP SAS
Evaluated position
Part of asymptotic cone with 90% of integral intensity

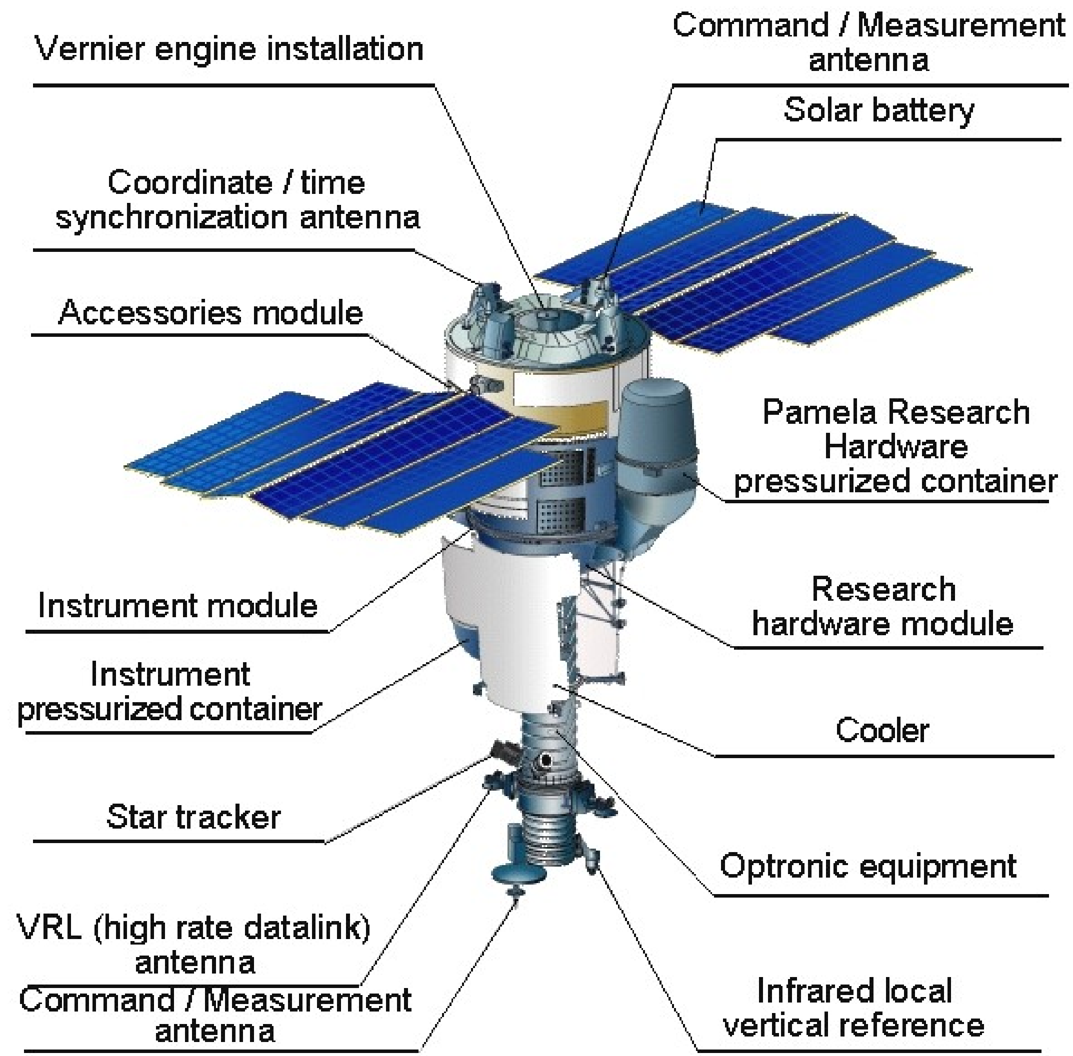
PAMELA : Príbehy vedy, skôr a lacnejšie

a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics

Rusko, Talianska, Nemecko, Švédska misia

Štart : 15. jún 2006
Nosič : Soyuz-FG
Platforma : Resurs DK1

Výsledky skôr ako AMS za výrazne nižšiu cenu



Vol 458 | 2 April 2009 | doi:10.1038/nature07942 nature

LETTERS

An anomalous positron abundance in cosmic rays with energies 1.5–100 GeV

O. Adriani[1,2], G. C. Barbarino[3,4], G. A. Bazilevskaya[5], R. Bellotti[6,7], M. Boezio[8], E. A. Bogomolov[9], L. Bonechi[1,2], M. Bongi[2], V. Bonvicini[8], S. Bottai[2], A. Bruno[6,7], F. Cafagna[7], D. Campana[4], P. Carlson[10], M. Casolino[11], G. Castellini[12], M. P. De Pascale[11,13], G. De Rosa[4], N. De Simone[11,13], V. Di Felice[11,13], A. M. Galper[14], L. Grishantseva[14], P. Hofverberg[10], S. V. Koldashov[14], S. Y. Krutkov[9], A. N. Kvashnin[5], A. Leonov[14], V. Malvezzi[11], L. Marcelli[11], W. Menn[15], V. V. Mikhailov[14], E. Mocchiutti[8], S. Orsi[10,11], G. Osteria[4], P. Papini[2], M. Pearce[16], P. Picozza[11,13], M. Ricci[17], S. B. Ricciarini[2], M. Simon[15], R. Sparvoli[11,13], P. Spillantini[1,2], Y. I. Stozhkov[5], A. Vacchi[8], E. Vannuccini[2], G. Vasilyev[9], S. A. Voronov[14], Y. T. Yurkin[14], G. Zampa[8], N. Zampa[8] & V. G. Zverev[14]

Prvé meranie s jasným nárastom počtu pozitrónov voči očakávanému spektru pochádzajúcemu zo sekundárnej produkcie v Galaxii.

Antiparticles account for a small fraction of cosmic rays and are known to be produced in interactions between cosmic-ray nuclei and atoms in the interstellar medium[1], which is referred to as a 'secondary source'. Positrons might also originate in objects such as pulsars[2] and microquasars[3] or through dark matter annihilation[4], which would be 'primary sources'. Previous statistically limited measurements[5–7] of the ratio of positron and electron fluxes have been interpreted as evidence for a primary source for the positrons, as has an increase in the total electron+positron flux at energies between 300 and 600 GeV (ref. 8). Here we report a measurement of the positron fraction in the energy range 1.5–100 GeV. We find that the positron fraction increases sharply over much of that range, in a way that appears to be completely inconsistent with secondary sources. We therefore conclude that a primary source, be it an astrophysical object or dark matter annihilation, is necessary.

The results presented here are based on the data set collected by the PAMELA satellite-borne experiment[9] between July 2006 and February 2008. More than 10^9 triggers were accumulated during a total acquisition time of approximately 500 days. From these triggered events, 151,672 electrons and 9,430 positrons were identified in the energy interval 1.5–100 GeV. Results are presented as positron fraction—that

Table 1 | Summary of positron fraction results

Rigidity at spectrometer (GV)	Mean kinetic energy at top of payload (GeV)	Extrapolated $\frac{\phi(e^+)}{(\phi(e^+)+\phi(e^-))}$ at top of payload
1.5–1.8	1.64	$(0.0673^{+0.0014}_{-0.0013})$
1.8–2.2	1.99	(0.0607 ± 0.0012)
2.2–2.7	2.44	(0.0583 ± 0.0011)
2.7–3.3	2.99	(0.0551 ± 0.0012)
3.3–4.1	3.68	(0.0550 ± 0.0012)
4.1–5.0	4.52	(0.0502 ± 0.0014)
5.0–6.1	5.43	(0.0548 ± 0.0016)
6.1–7.4	6.83	(0.0483 ± 0.0018)
7.4–9.1	8.28	(0.0529 ± 0.0023)
9.1–11.2	10.17	$(0.0546^{+0.0029}_{-0.0028})$
11.2–15.0	13.11	$(0.0585^{+0.0030}_{-0.0031})$
15.0–20.0	17.52	$(0.0590^{+0.0040}_{-0.0041})$
20.0–28.0	24.02	(0.0746 ± 0.0059)
28.0–42.0	35.01	(0.0831 ± 0.0093)
42.0–65.0	53.52	$(0.106^{+0.022}_{-0.023})$
65.0–100.0	82.55	$(0.137^{+0.048}_{-0.043})$

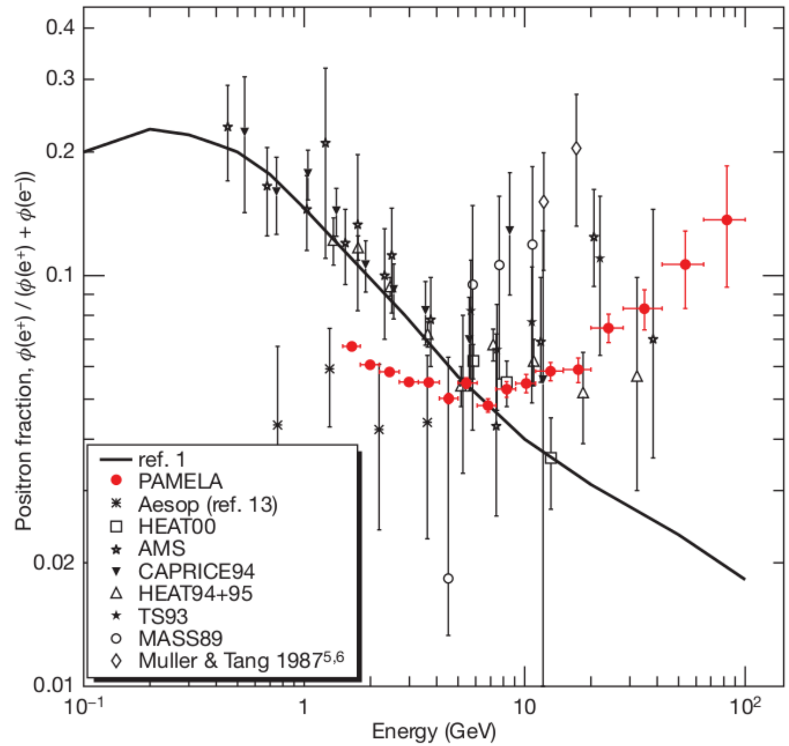


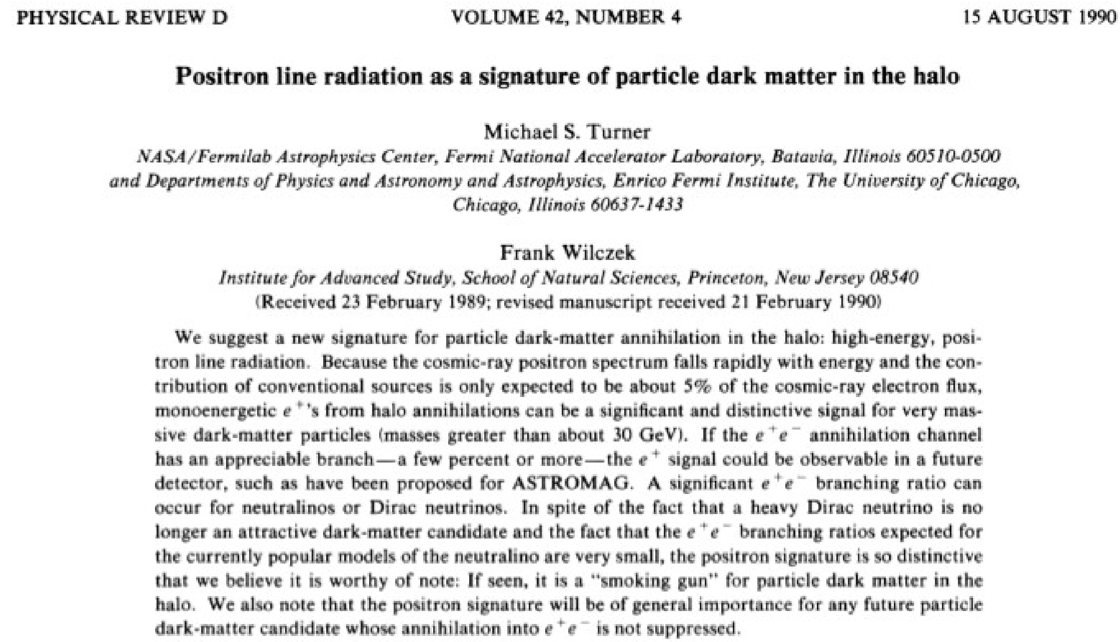
Figure 2 | PAMELA positron fraction with other experimental data and with secondary production model. The positron fraction measured by the PAMELA experiment compared with other recent experimental data (see refs 5–7, 11–13, 30, and references within). The solid line shows a calculation[1] for pure secondary production of positrons during the propagation of cosmic rays in the Galaxy without reacceleration processes. Error bars show 1 s.d.; if not visible, they lie inside the data points.

Tmavá hmota

?

Kandidáti – priveľa kandidátov

- hnedí trpaslíci
- neutrína
- čierne diery
- častice
    - WIMP
    - ...


PHYSICAL REVIEW D VOLUME 42, NUMBER 4 15 AUGUST 1990

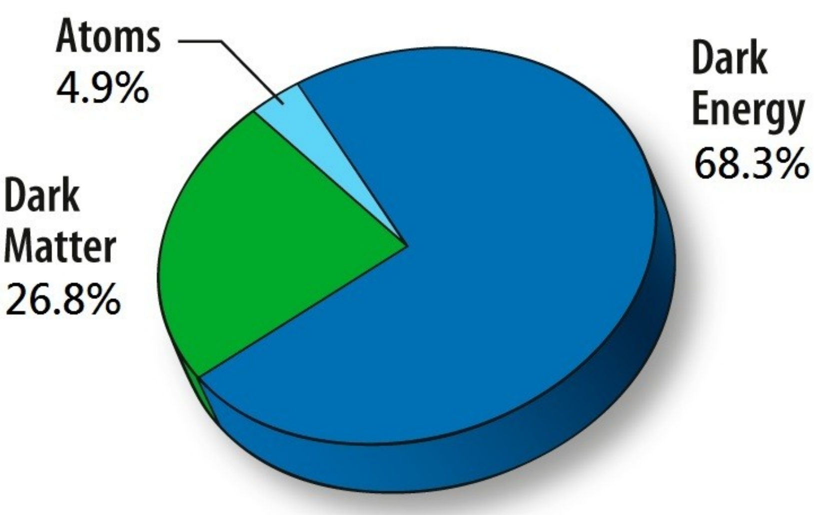
Positron line radiation as a signature of particle dark matter in the halo

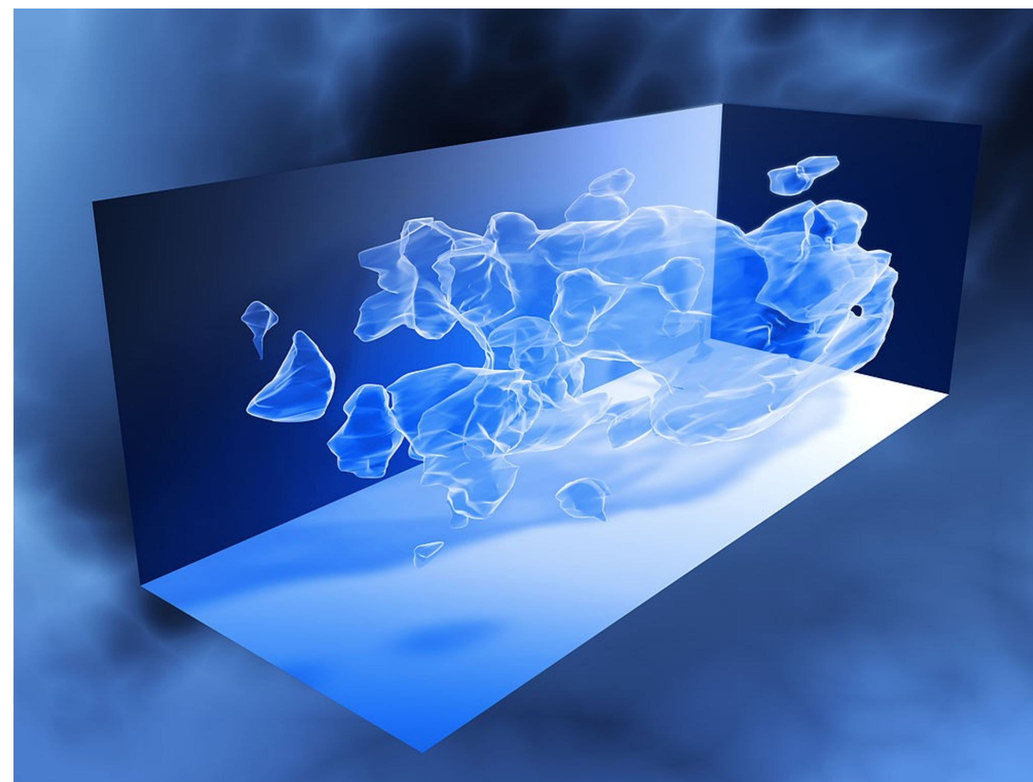
Michael S. Turner
NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500 and Departments of Physics and Astronomy and Astrophysics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433

Frank Wilczek
Institute for Advanced Study, School of Natural Sciences, Princeton, New Jersey 08540
(Received 23 February 1989; revised manuscript received 21 February 1990)

We suggest a new signature for particle dark-matter annihilation in the halo: high-energy, positron line radiation. Because the cosmic-ray positron spectrum falls rapidly with energy and the contribution of conventional sources is only expected to be about 5% of the cosmic-ray electron flux, monoenergetic e^+'s from halo annihilations can be a significant and distinctive signal for very massive dark-matter particles (masses greater than about 30 GeV). If the e^+e^- annihilation channel has an appreciable branch—a few percent or more—the e^+ signal could be observable in a future detector, such as have been proposed for ASTROMAG. A significant e^+e^- branching ratio can occur for neutralinos or Dirac neutrinos. In spite of the fact that a heavy Dirac neutrino is no longer an attractive dark-matter candidate and the fact that the e^+e^- branching ratios expected for the currently popular models of the neutralino are very small, the positron signature is so distinctive that we believe it is worthy of note: If seen, it is a "smoking gun" for particle dark matter in the halo. We also note that the positron signature will be of general importance for any future particle dark-matter candidate whose annihilation into e^+e^- is not suppressed.

http://journals.aps.org/prd/issues/42/4





The PAMELA Positron Excess from Annihilations into a Light Boson

Ilias Cholis,[1] Douglas P. Finkbeiner,[2] Lisa Goodenough,[1] and Neal Weiner[1]
[1] *Center for Cosmology and Particle Physics, Department of Physics, New York University, New York, NY 10003*
[2] *Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138*
(Dated: April 30, 2009)

Recently published results from the PAMELA experiment have shown conclusive evidence for an excess of positrons at high ($\sim 10 - 100$ GeV) energies, confirming earlier indications from HEAT and AMS-01. Such a signal is generally expected from dark matter annihilations. However, the hard positron spectrum and large amplitude are difficult to achieve in most conventional WIMP models. The absence of any associated excess in anti-protons is highly constraining on models with hadronic annihilation modes. We revisit an earlier proposal, wherein the dark matter annihilates into a new light ($\lesssim$ GeV) boson ϕ, which is kinematically constrained to go to hard leptonic states, without anti-protons or π^0's. We find this provides a very good fit to the data. The light boson naturally provides a mechanism by which large cross sections can be achieved through the Sommerfeld enhancement, as was recently proposed. Depending on the mass of the WIMP, the rise may continue above 300 GeV, the extent of PAMELA's ability to discriminate between electrons and positrons.

http://arxiv.org/abs/0810.5344

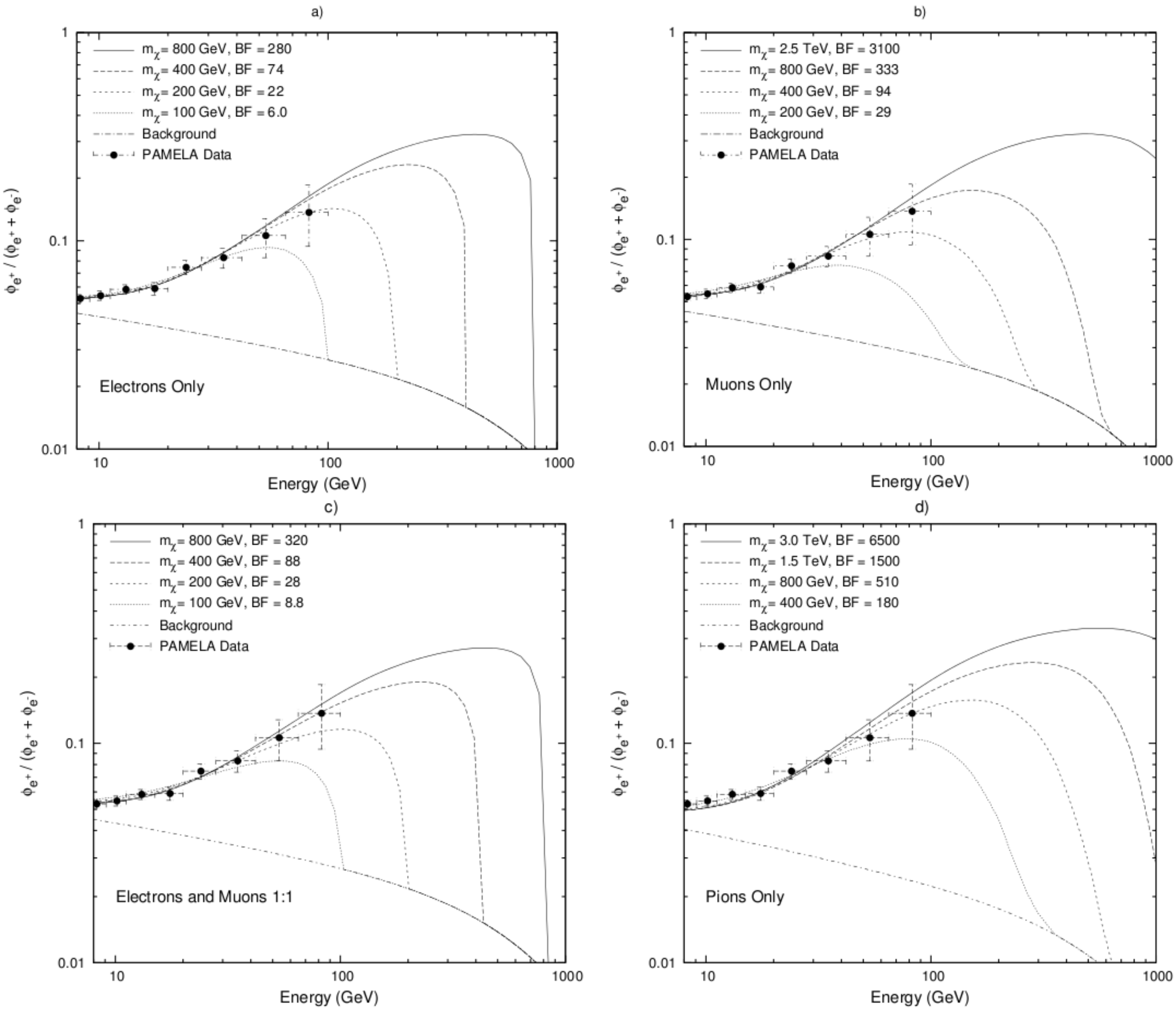
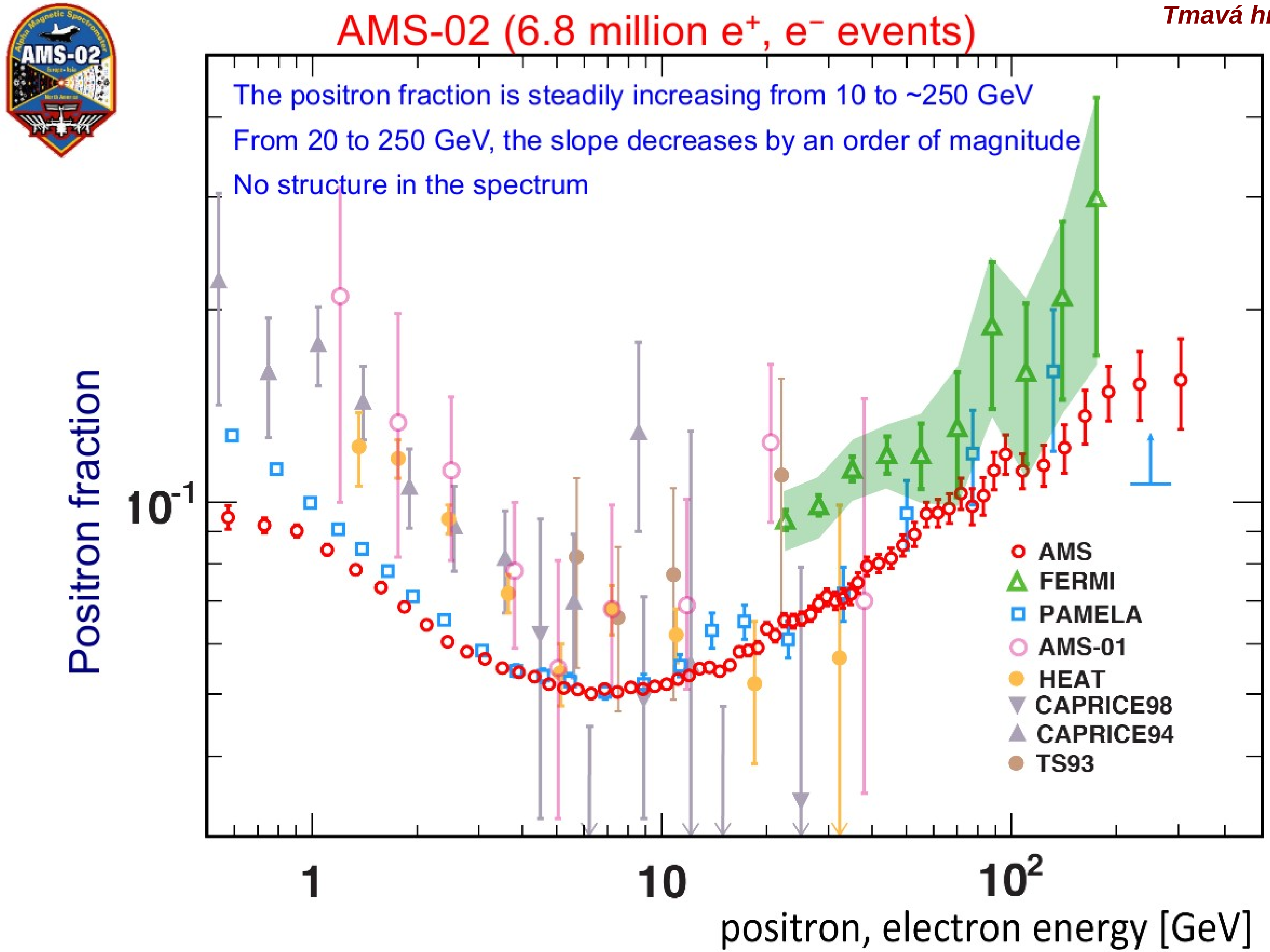


FIG. 2: The positron fraction as a function of energy for the four annihilation modes considered here: $\chi\chi \to \phi\phi$, followed by, (a) $\phi \to e^+e^-$, (b) $\phi \to \mu^+\mu^-$, (c) $\phi \to e^+e^-$, $\mu^+\mu^-$ (1:1), (d) $\phi \to \pi^+\pi^-$. The boost factor is defined relative to a cross section $\langle \sigma v \rangle = 3 \times 10^{-26} \mathrm{cm}^3\mathrm{s}^{-1}$ and $\rho_0 = 0.3\,\mathrm{GeV cm}^{-3}$. Such a boost reasonably can arise from a Sommerfeld enhancement, without appeals to substructure.

I. Cholis et al., http://arxiv.org/abs/0810.5344



S. Ting, The Alpha Magnetic Spectrometer on the International Space Station, ICRC 2013

PRL **113,** 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

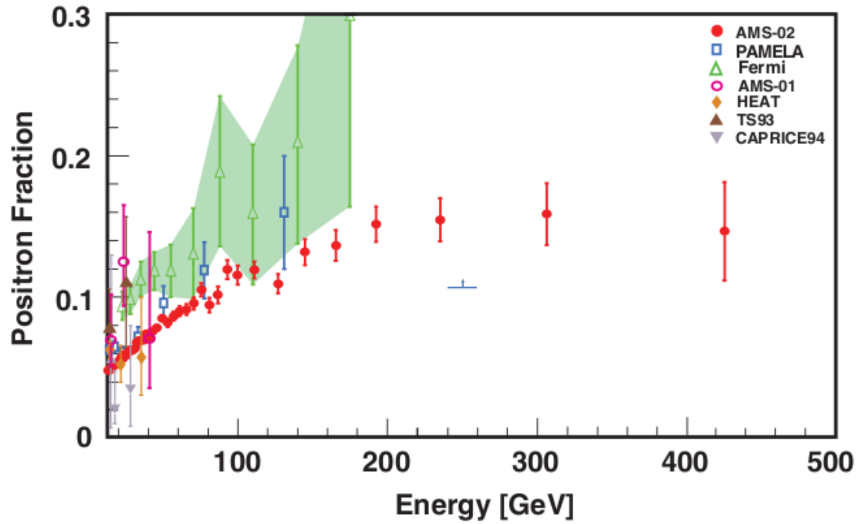


FIG. 3 (color). The positron fraction above 10 GeV, where it begins to increase. The present measurement extends the energy range to 500 GeV and demonstrates that, above ∼200 GeV, the positron fraction is no longer increasing. Measurements from PAMELA [21] (the horizontal blue line is their lower limit), Fermi-LAT [22], and other experiments [17–20] are also shown.

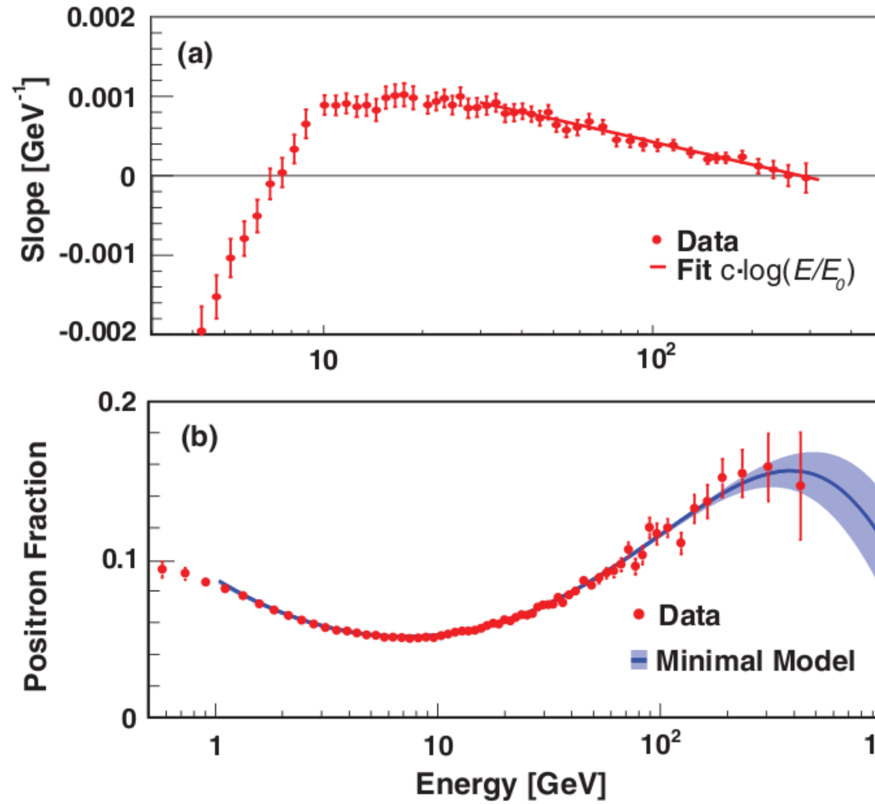


FIG. 4 (color). (a) The slope of the positron fraction vs energy over the entire energy range (the values of the slope below 4 GeV are off scale). The line is a logarithmic fit to the data above 30 GeV. (b) The positron fraction measured by AMS and the fit of a minimal model (solid curve, see text) and the 68% C.L. range of the fit parameters (shaded). For this fit, both the data and the model are integrated over the bin width. The error bars are the quadratic sum of the statistical and systematic uncertainties. Horizontally, the points are placed at the center of each bin.

AMS 02 : Čaká sa na väčšiu štatistiku ...

Voyager :: Najdlhšia cesta v dejinách ľudstva
Tam kde ešte nikdy nik nebol

Titan IIIE, V1, 5. september 1977

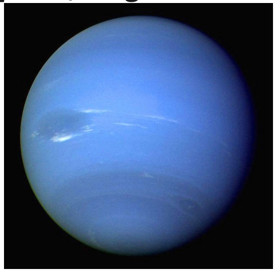
Voyager 1

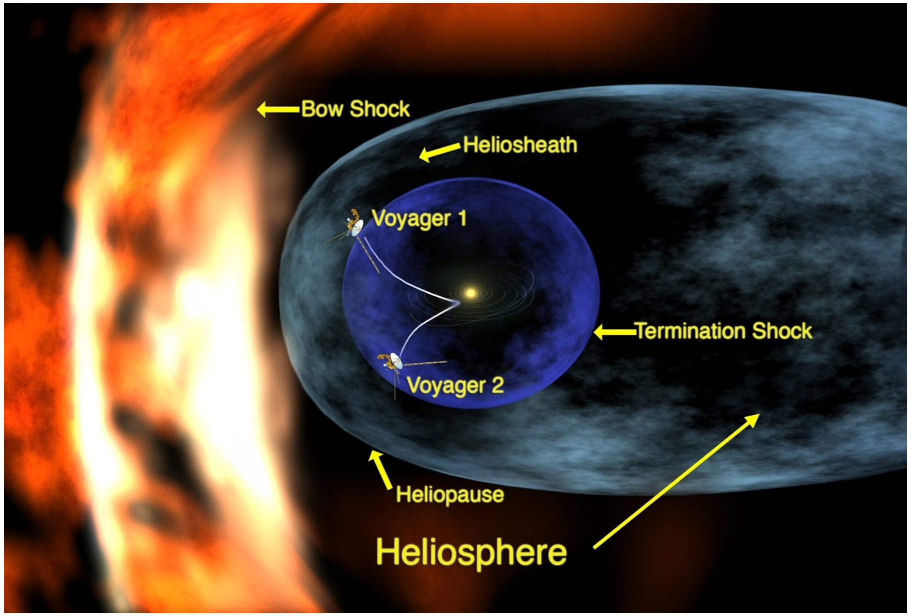
V1, Jupiter, apríl 1979

V1, Saturn, November 1980

V2, Urán, január 1986

V2, Neptún, august 1989





Aktuálne V1 vo vzdialenosti

~22 miliárd kilometrov

40 rokov na ceste

Funkčný do roku **2025**

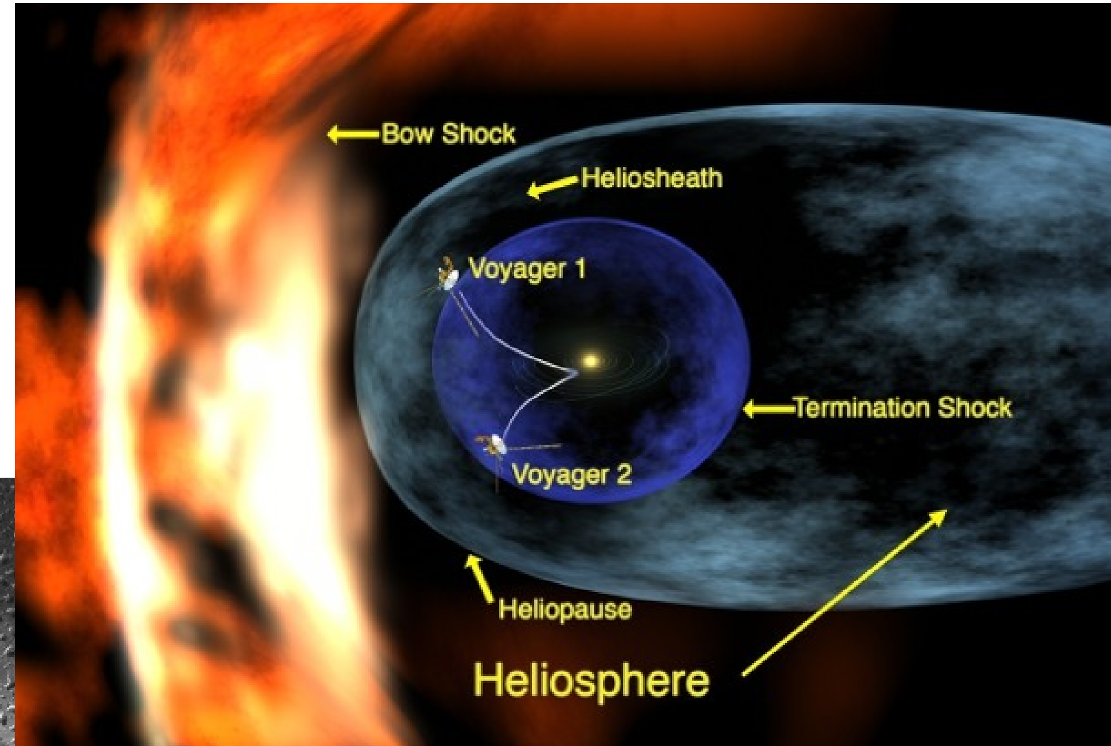
Voyager :: hranice heliosféry

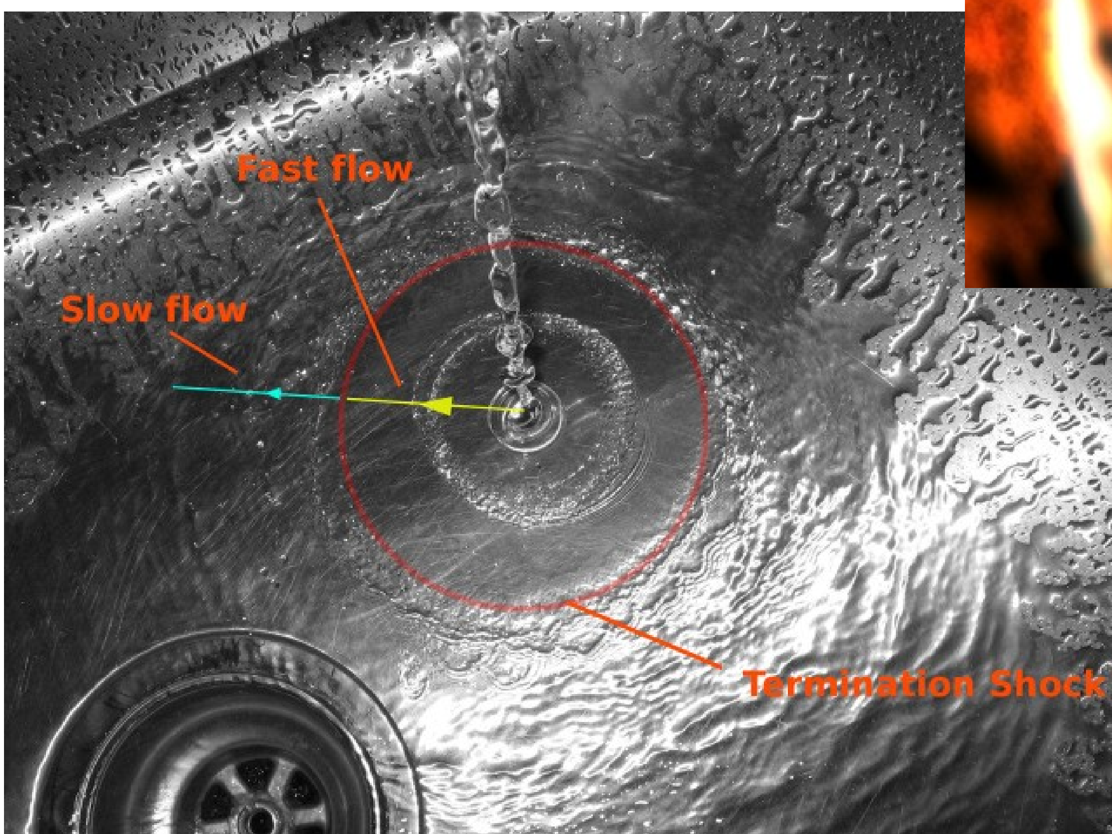
Heliosféra, magnetická bublina obklopujúca naše Slnko do vzdialenosti násobne väčšej než je vzdialenosť Pluta od Slnka.

Tri základné hranice medzi heliosférou a medzihviezdnym priestorom.

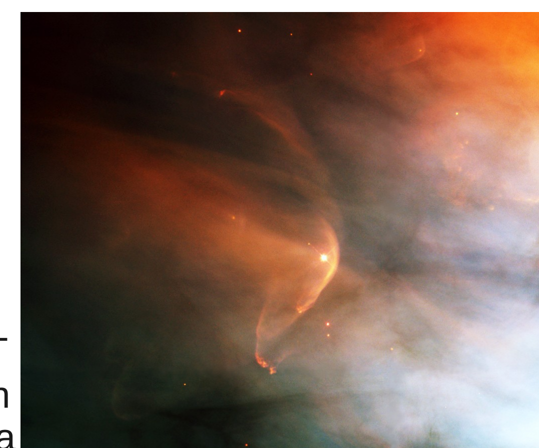
Termination shock, najbližší k Slnku, v slovenčine terminačná rázová vlna, je hranica kde rýchlosť slnečného vetra skokovo prechádza z nadzvukovej do podzvukovej rýchlosti. Oddeľuje priestor v okolí Slnka kde sa slnečný vietor pohybuje rýchlosťou približne 400 kilometrov za sekundu. Za terminačnou rázovou vlnou nasleduje oblasť nazývaná **heliosheat (héliosférická obálka)** kde sa slnečný vietor postupne spomaľuje z rýchlosti približne 100 kilometrov za sekundu na ktorú klesol hneď za terminačnou rázovou vlnou. Heliosférickú obálku končí **heliopauza**, hranica kde je slnečný vietor zastavený medzihviezdnym materiálom.

Heliosféra :: Klasická predstava





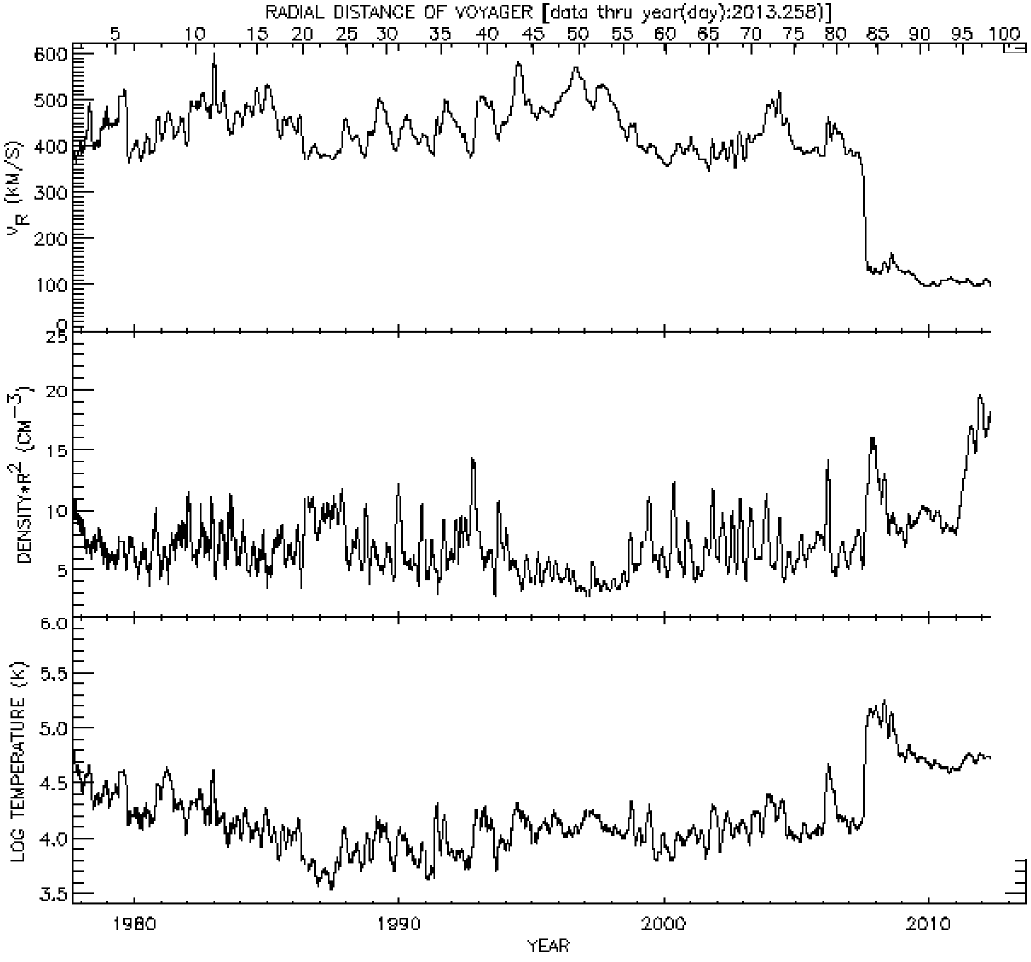
Keďže sa Slnko a s ním celá heliosféra pohybujú voči centru Galaxie a tým voči medzihviezdnému prostrediu, vzniká pri jeho interakcii s heliosférou takzvaný **bow shock**, **oblúková rázová vlna** (názov podľa predku lode, kde vzniká podobná vlna) kde spomaľuje materiál medzihviezdného prostredia voči heliosfére.

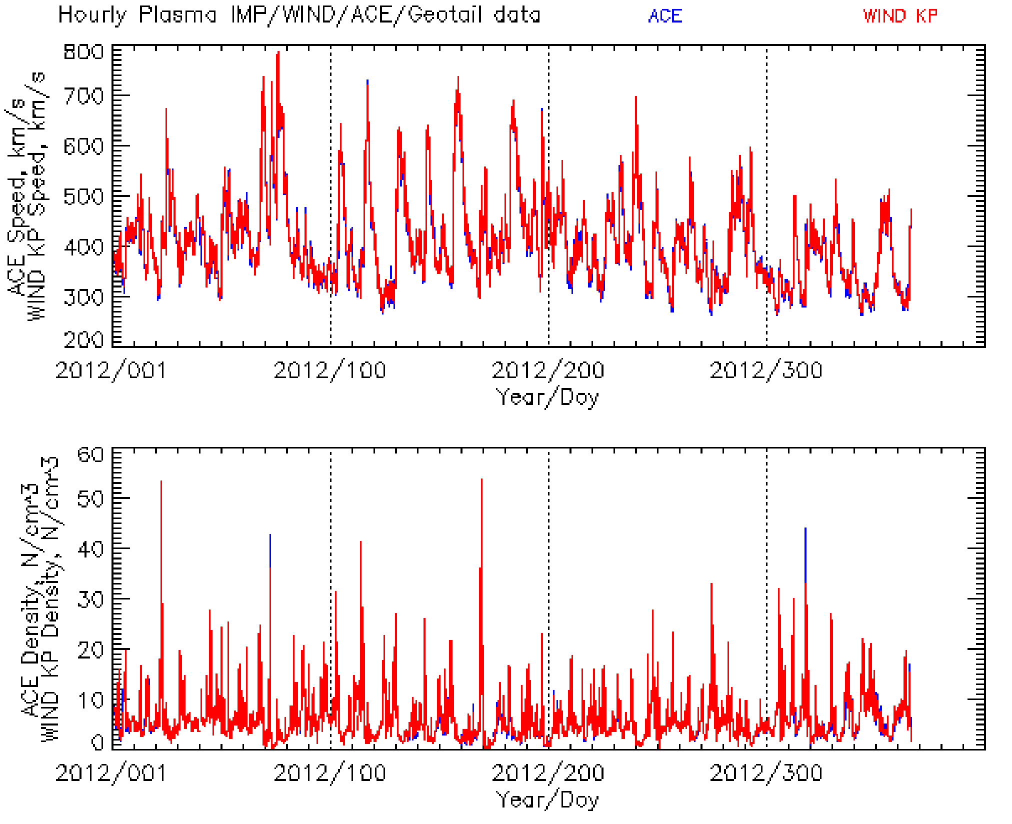


HST
Orion
hmlovina

Medziplanetárny priestor

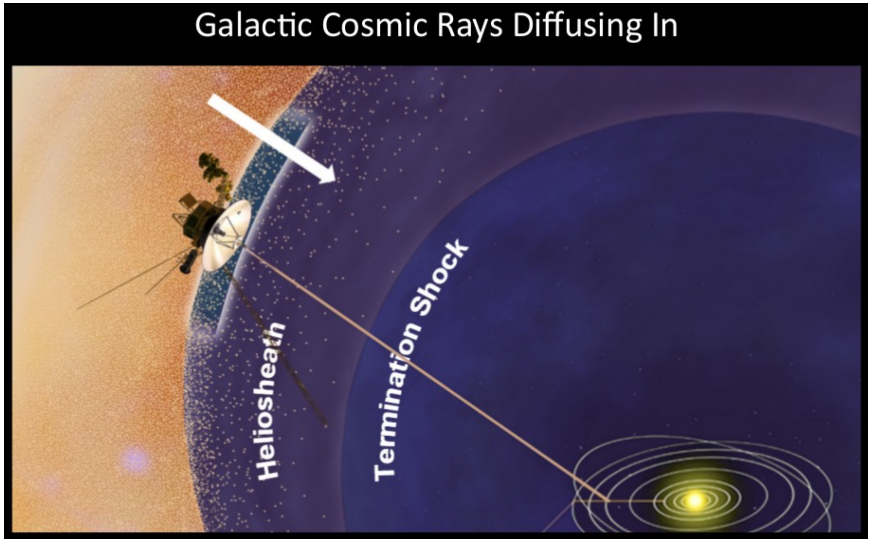
Rýchlosť slnečného vetra – príliš sa s r nemení
Hustota častíc 5 – 10 častíc/cm^3 na 1 AU, klesá s r^2

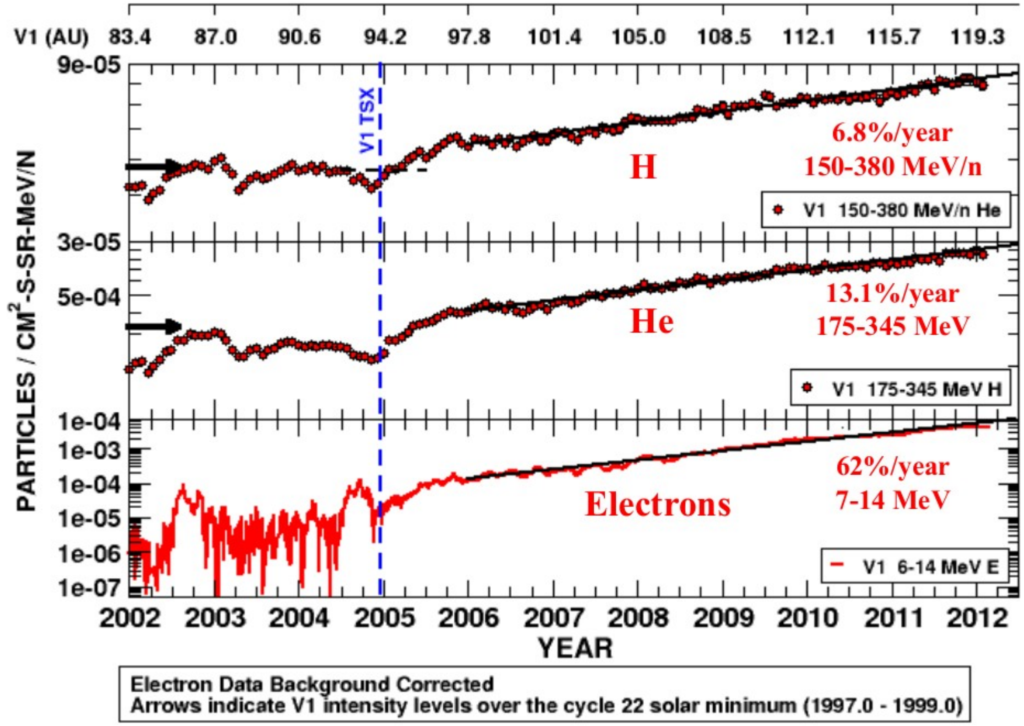




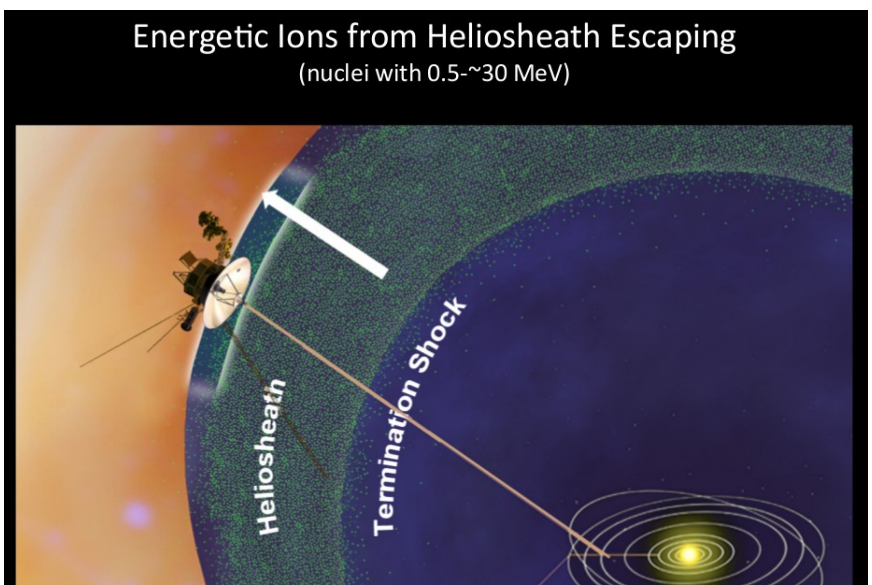
http://omniweb.gsfc.nasa.gov/
http://web.mit.edu/afs/athena/org/s/space/www/voyager/voyager_data/voyager_data.html

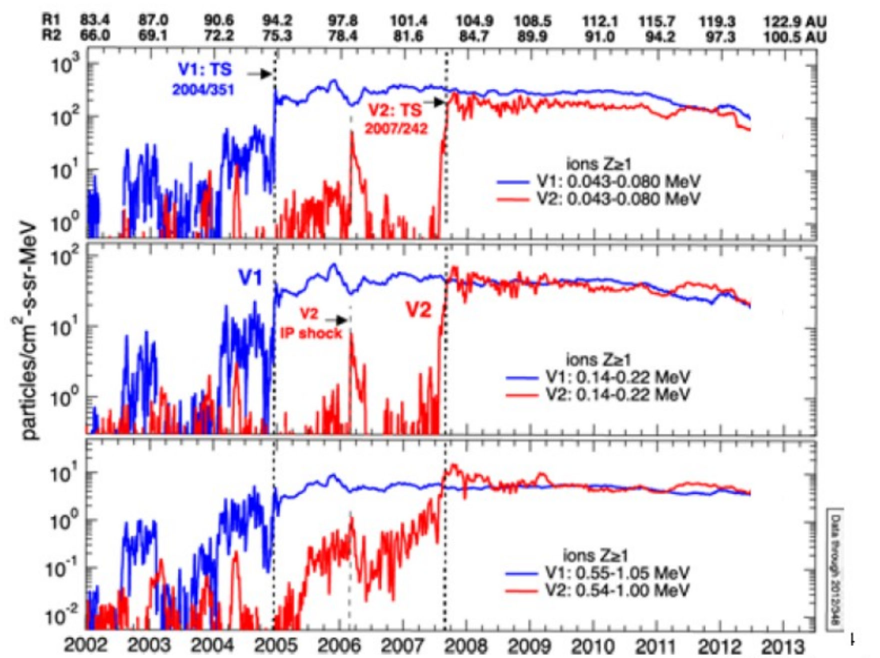
Voyager :: hranice heliosféry





McDonald et al. 2012

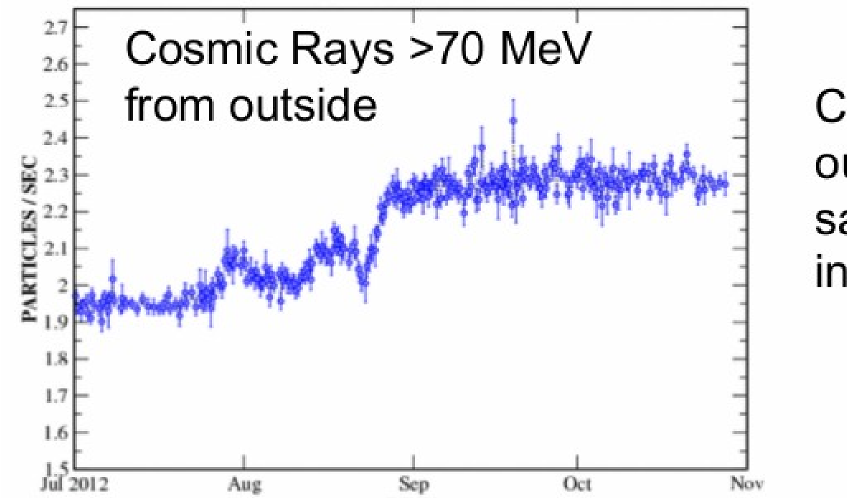




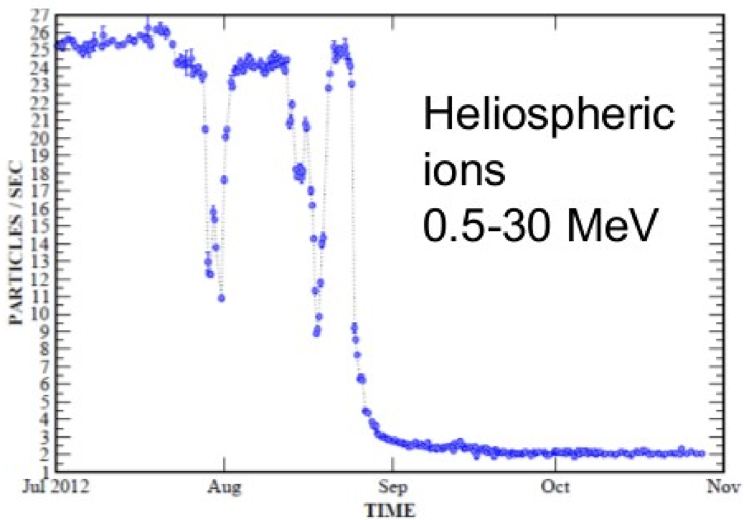
Edward Stone, Voyager 1 at the Edge of Interstellar Space; an Overview, ICRC 2013

LECP Decker et al.

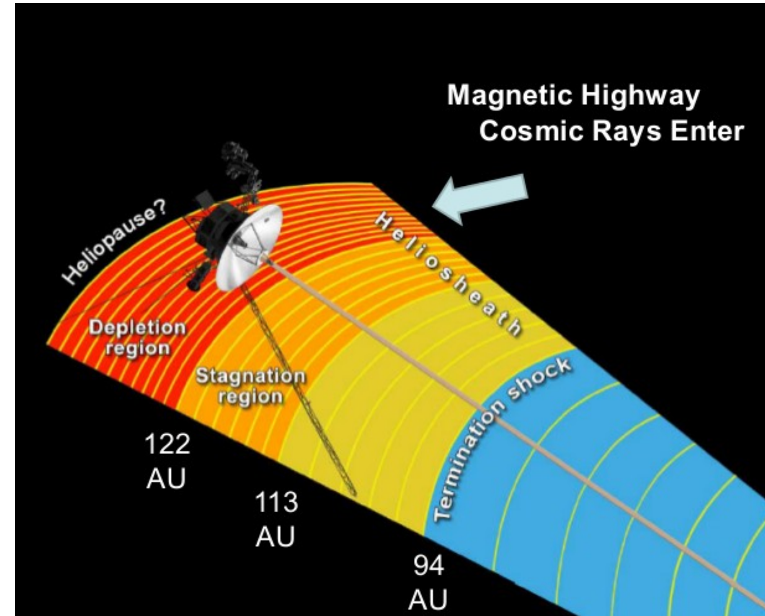
Voyager :: hranice heliosféry

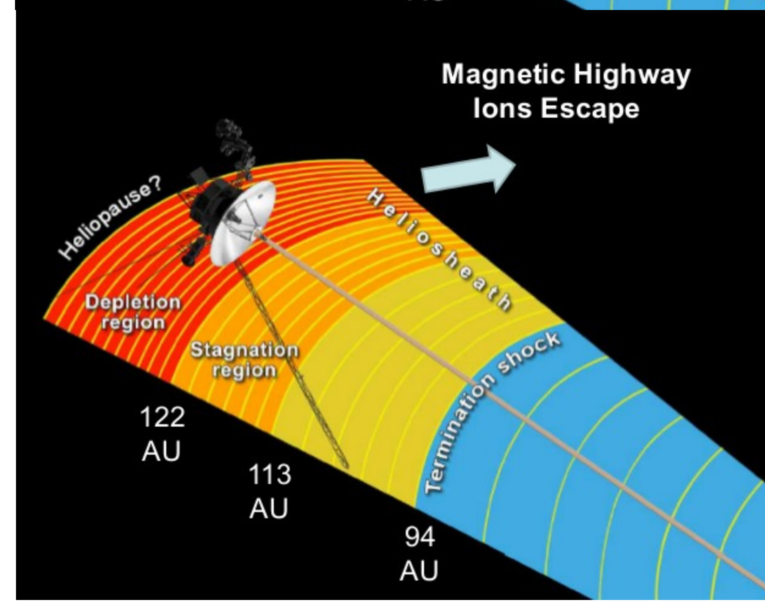


Cosmic rays from outside increased at same time as ions from inside escaped



Is Voyager 1 in interstellar space, or in a new region inside that is depleted of heliospheric ions and connected to interstellar space outside?





Edward Stone, Voyager 1 at the Edge of Interstellar Space;
an Overview, ICRC 2013

Magnetická diaľnica

V auguste 2012 Voyager 1 prešiel heliopauzou. Hranicou oddeľujúcou heliosféru od medzihviezdného prostredia. Pozorované intenzity energetických iónov a elektrónov sa výrazne (skokovito) zmenili

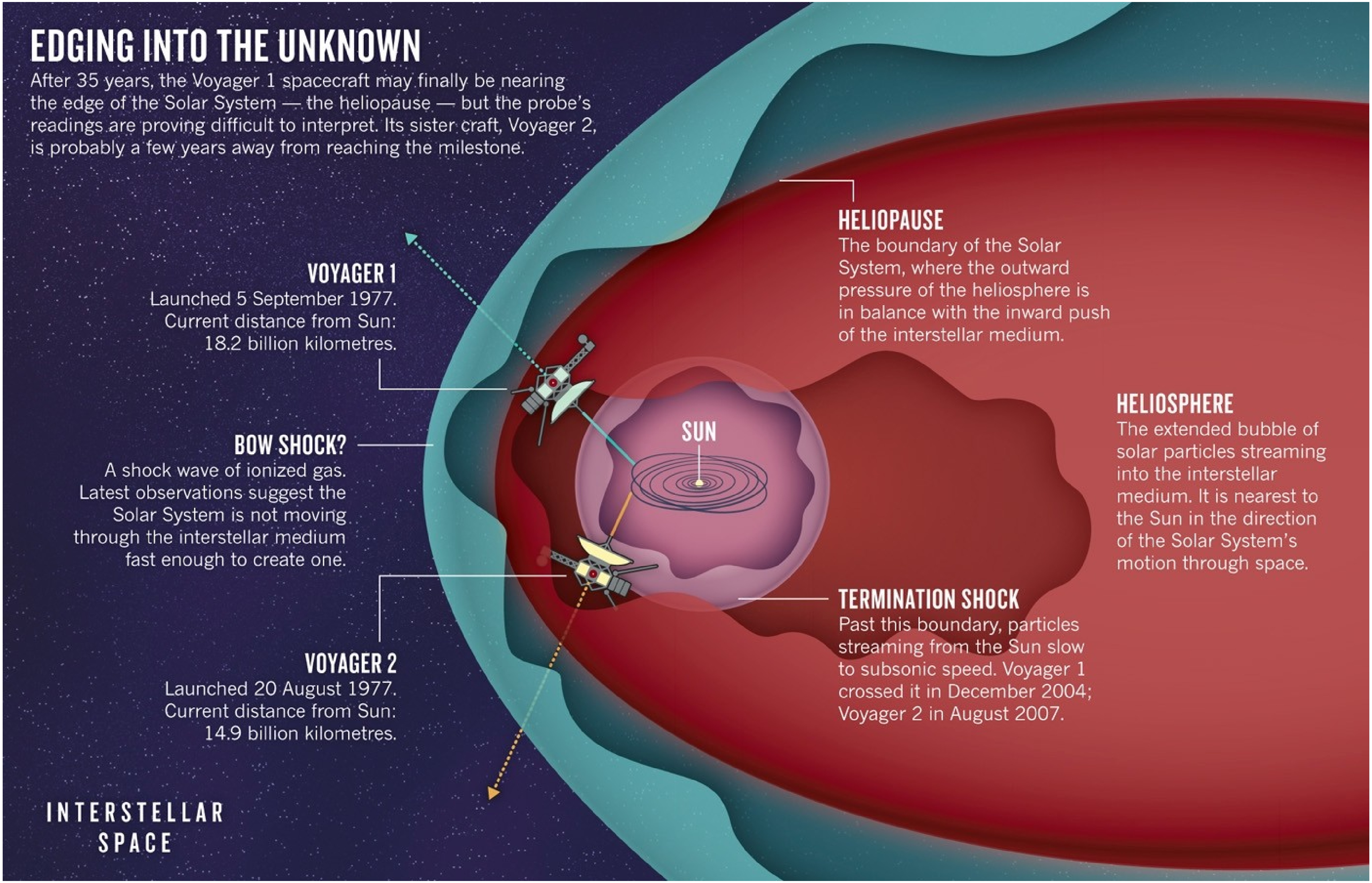
- pri protónoch s energiami nad 70MeV zaznamenal niekoľkonásobný nárast intenzity
- pri elektrónoch s energiami 6-100 MeV zaznamenal nárast intenzity
- pri protónoch s energiami 7-60MeV zaznamenal pokles intenzity

Za heliopauzou však Voyager nezaregistroval žiadnu zmenu orientácie magnetického poľa.

Zdá sa, že Voyager prešiel do nového regiónu na pomedzí heliosféry a medzihviezdného prostredia. Región, ktorý „slúži“ ako "magnetická diaľnica" pre nízkoenergetické ióny unikajúce z heliosféry a pre galaktické kozmické žiarenie z medzihviezdneho prostredia.

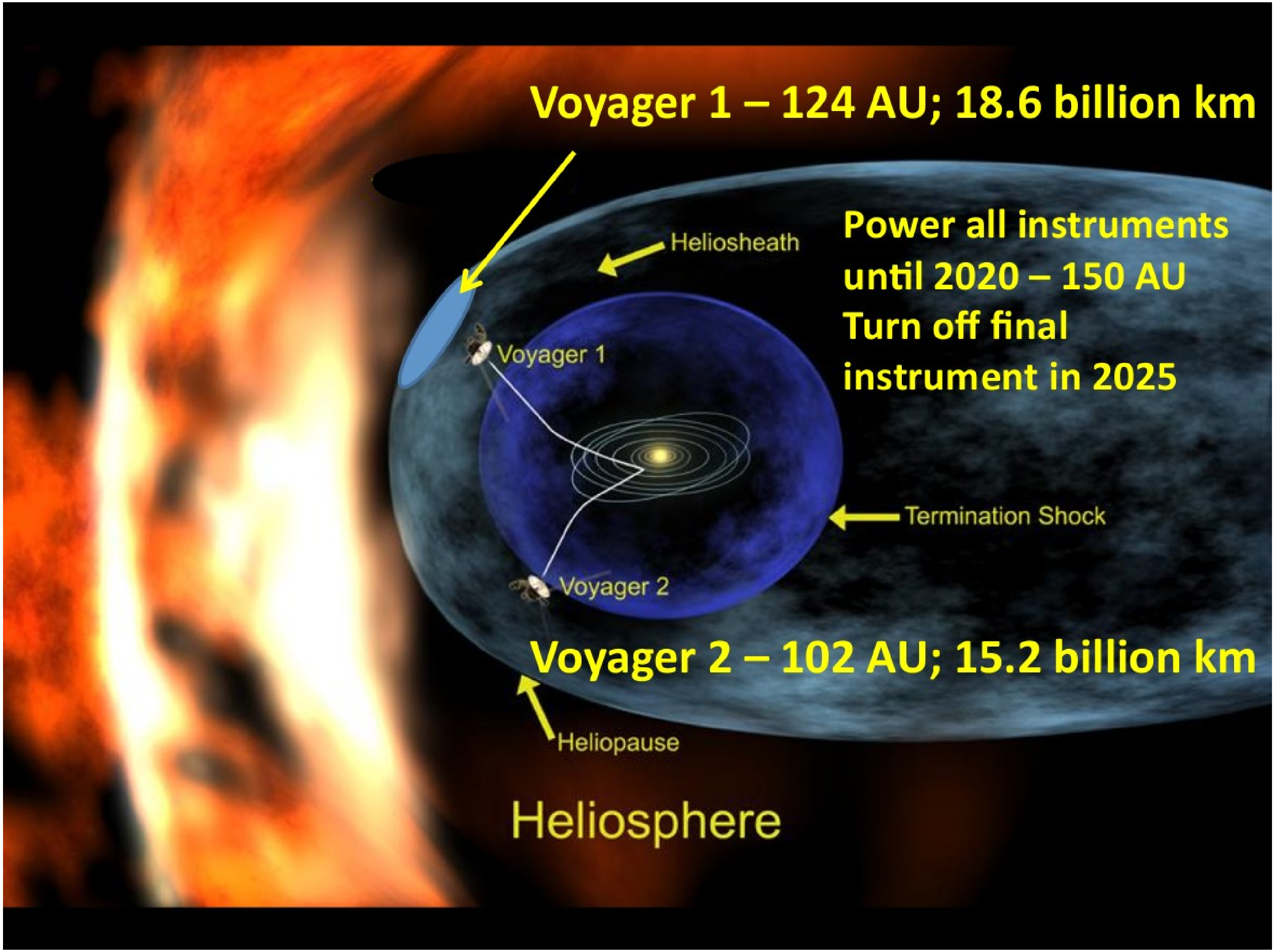
Hustota častíc je za heliopauzou 40 násobná.

Na titulnej stránke Science 12. júla 2013



Voyager's long goodbye, NATURE, 05 September 2012
http://www.nature.com/news/voyager-s-long-goodbye-1.11348

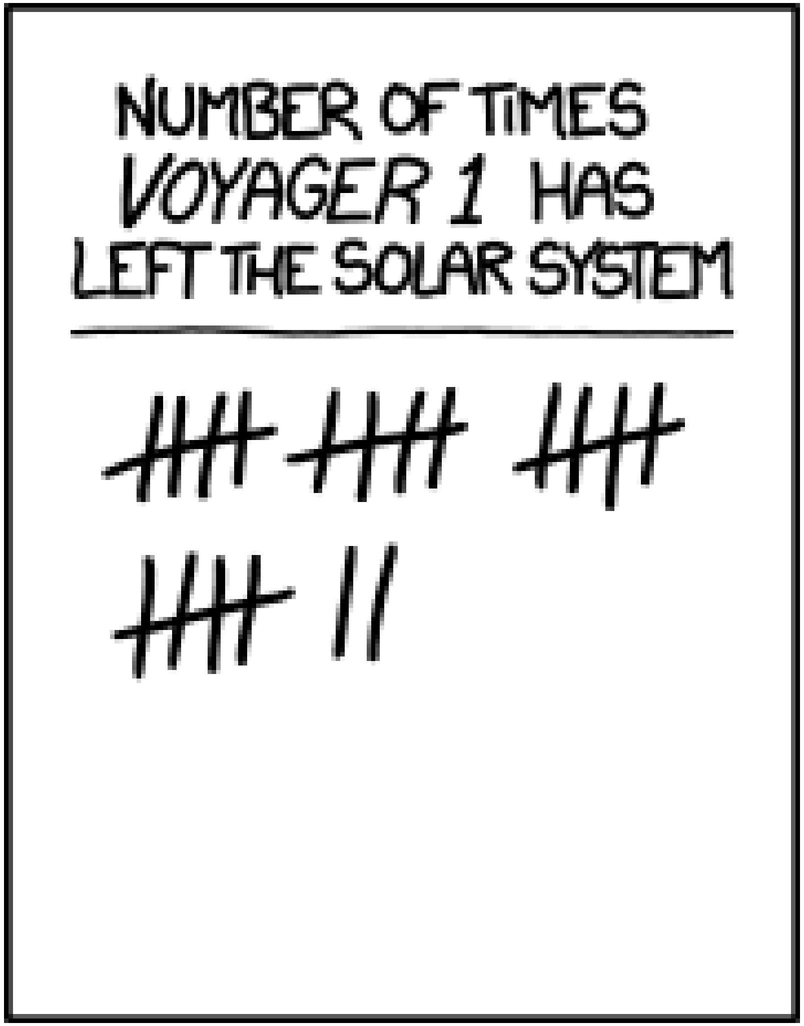
Voyager :: hranice heliosféry



Edward Stone, Voyager 1 at the Edge of Interstellar Space;
an Overview, ICRC 2013

Medzihviezdný priestor

„in situ“ meranie : Voyager interstellar mission (VIM)

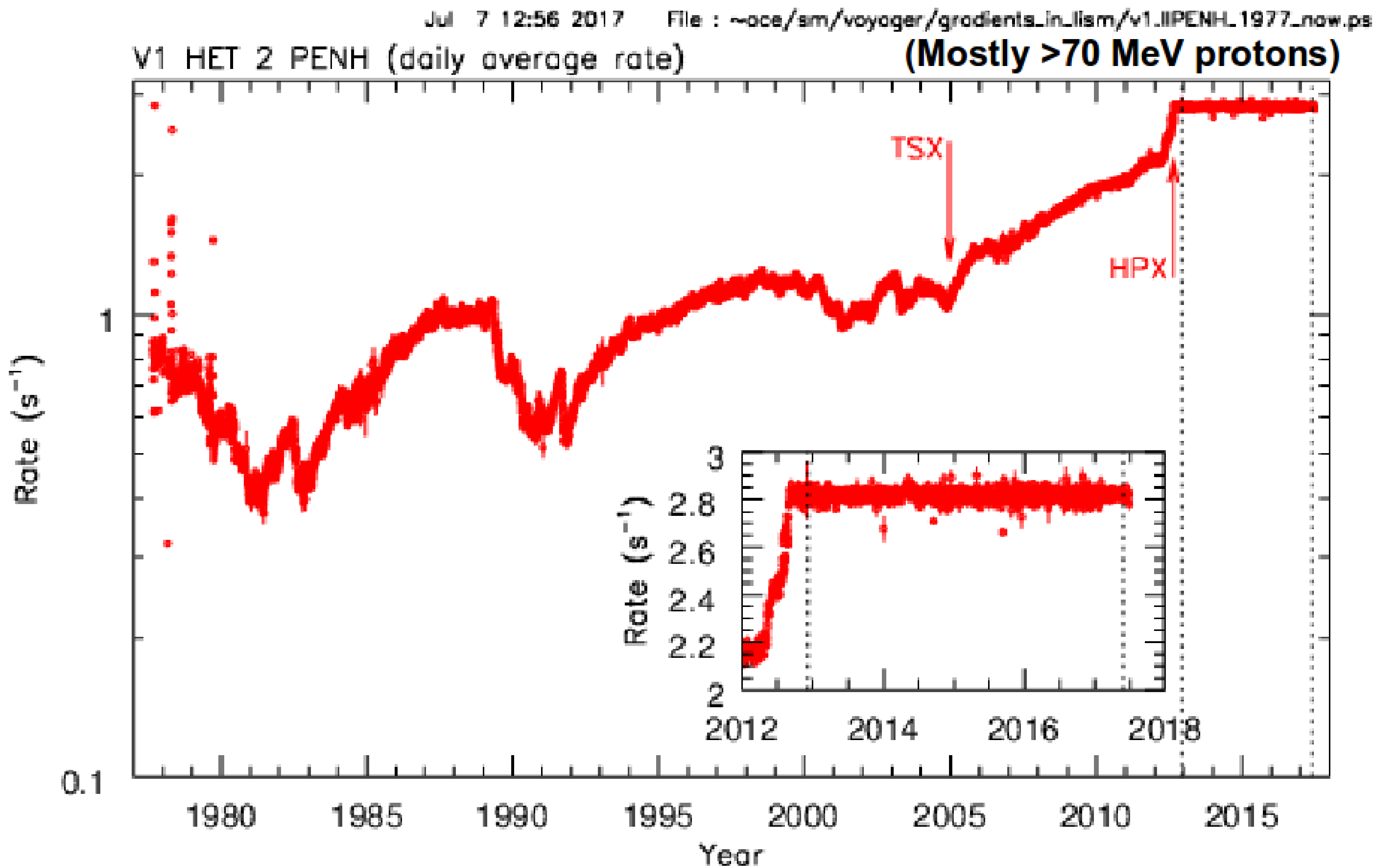


The team has talked so many times about the impending departure into interstellar space that office doors around mission control are decorated with a photo of a forlorn-looking Voyager with the quote:

“Whenever people stop paying attention to me, I pretend to leave the Solar System.”

Voyager: Outward bound, Nature, 22 May 2013
http://www.nature.com/news/voyager-outward-bound-1.13040

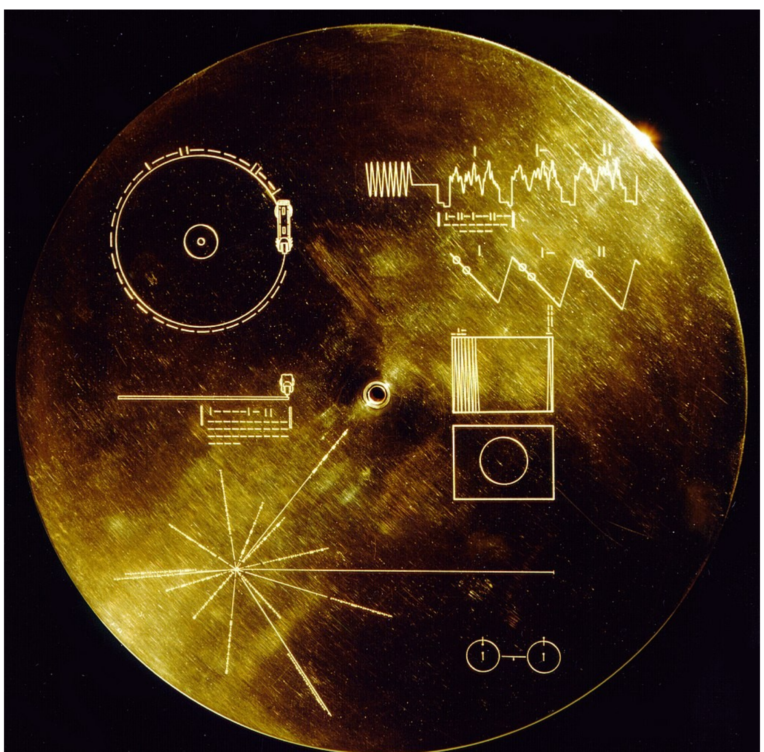
Medzihviezdny priestor

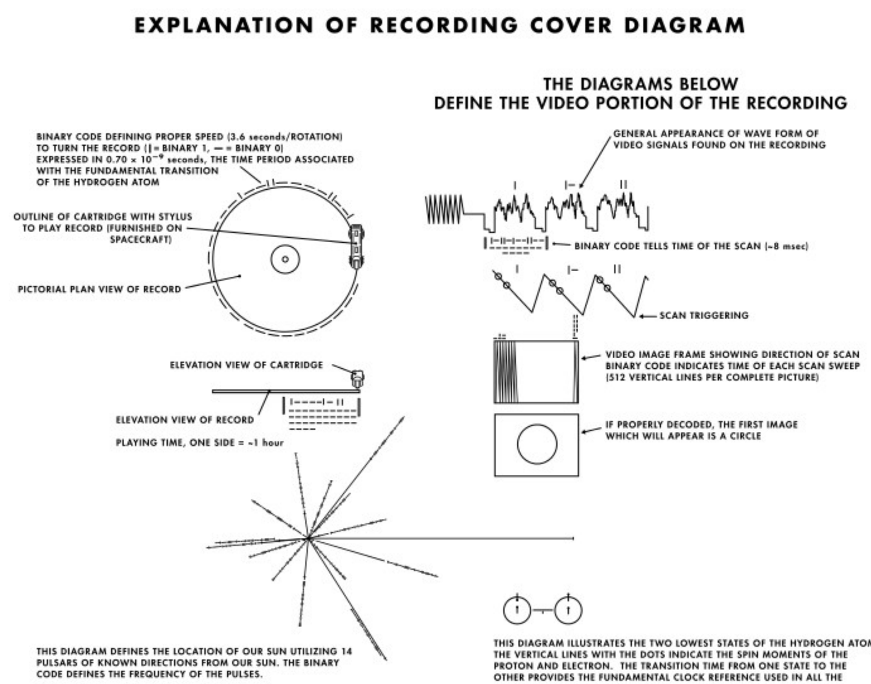


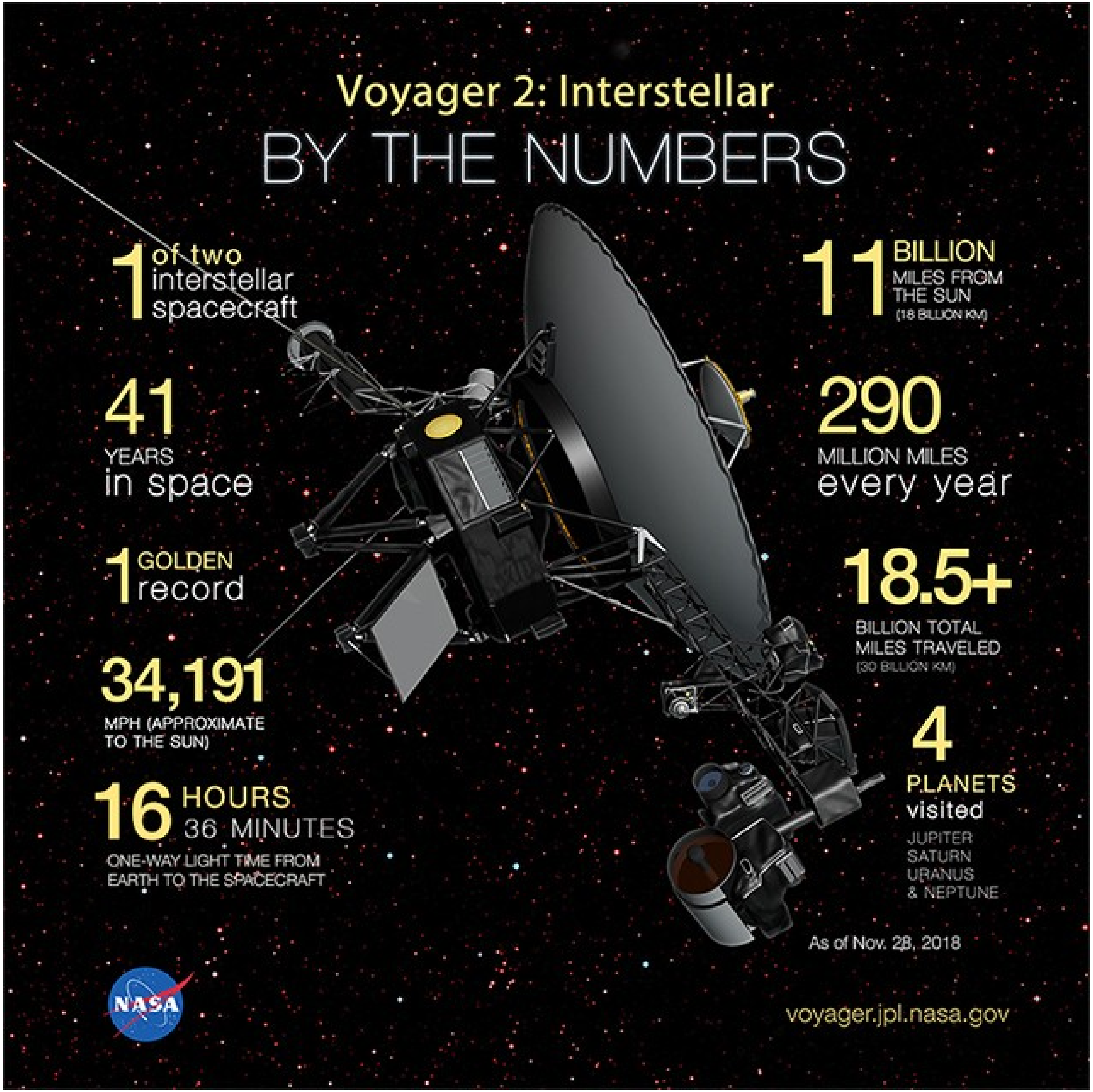
Black vertical dotted lines mark period for radial gradient results.

Voyager 1 & 2

- Najvzdialenejší ľudskou rukou vyrobený objekt V1
- Najdlhšie fungujúce vesmírne sondy
- Jediná sonda, ktorá navštívila Urán a Neptún V2
- Prvé fungujúce sondy v medzihviezdnom priestore V1 & V2
- Dve z piatich sond opúšťajúcich Slnečnú sústavu






Voyager 2: Interstellar
BY THE NUMBERS
1 of two interstellar spacecraft
41 YEARS in space
1 GOLDEN record
34,191 MPH (APPROXIMATE TO THE SUN)
16 HOURS 36 MINUTES
ONE-WAY LIGHT TIME FROM EARTH TO THE SPACECRAFT
11 BILLION MILES FROM THE SUN (18 BILLION KM)
290 MILLION MILES every year
18.5+ BILLION TOTAL MILES TRAVELED (30 BILLION KM)
4 PLANETS visited
JUPITER
SATURN
URANUS
& NEPTUNE
As of Nov. 28, 2018
NASA
voyager.jpl.nasa.gov

Credit: NASA

Propagation of Cosmic rays in the Heliosphere

Parker transport equation

Propagation in the heliosphere is described by Parker (1965) equation:

$$\frac{\partial U}{\partial t} = \nabla \cdot (\underbrace{\mathbf{K}^{\mathbf{S}} \cdot \nabla U}_{} - \underbrace{\mathbf{V}_{\mathbf{sw}} U}_{} - \underbrace{\langle \mathbf{v}_{\mathbf{D}} \rangle U}_{}) + \underbrace{\frac{1}{3}(\nabla \cdot \mathbf{V}_{\mathbf{sw}}) \frac{\partial}{\partial T}(\alpha T U)}_{}$$

U is Cosmic Rays number density per unit interval of kinetic energy

Diffusion	Convection	Drift	Energetic Loss
Small Scale magnetic Field irregularity	Solar wind moving out from the Sun	Large scale magnetic field structure	Due to adiabatic expansion of the solar wind

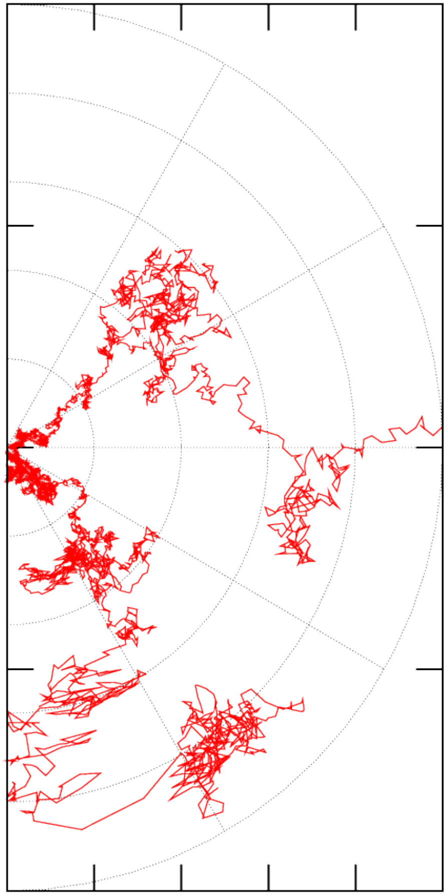
Propagation of CR in the heliosphere is described by Parker (1965) equation:

$$\frac{\partial U}{\partial t} = \nabla\cdot(\mathbf{K^S}\cdot\nabla U - \mathbf{V}_{\mathbf{sw}}U - \langle\mathbf{v_D}\rangle U) + \frac{1}{3}(\nabla\cdot\mathbf{V}_{\mathbf{sw}})\frac{\partial}{\partial T}(\alpha T U)$$

A Monte Carlo Approach - *Ito's lemma, see e.g. Gardiner, 1985*

The 2D **Hel**iosphere **Mod**ulation Monte Carlo Code: **HelMod**

Stochastic Differential Equations (SDE)



$$dr = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 K_{rr})dt - \frac{\partial}{\partial \mu}\left(\frac{K_{r\mu}\sqrt{1-\mu^2}}{r}\right)dt + (V_{\rm sw} + v_{d_r})dt + (2K_{rr})^{1/2}R_r\sqrt{dt}$$

$$d\mu = -\frac{1}{r^2}\frac{\partial}{\partial r}\left(rK_{\mu r}\sqrt{1-\mu^2}\right)dt + \frac{\partial}{\partial \mu}\left(K_{\mu\mu}\frac{1-\mu^2}{r^2}\right)dt - \frac{1}{r}v_{d_\mu}\sqrt{1-\mu^2}dt$$
$$+\frac{-2K_{r\mu}}{r}\left(\frac{1-\mu^2}{2K_{rr}}\right)^{1/2}R_r\sqrt{dt} + \frac{1}{r}\left((1-\mu^2)\frac{K_{\mu\mu}K_{rr}-K_{r\mu}^2}{0.5K_{rr}}\right)^{1/2}R_\mu\sqrt{dt}$$

$$dT = -\frac{\alpha_{\rm rel}T}{3r^2}\frac{\partial V_{\rm sw}r^2}{\partial r}dt$$

2-Dimensional set of SDEs

Details of HelMod modulation code, and how to compute the SDE, could be found in [Bobik et al. Ap.J. 2012, 745:132]

HelMod – selected results

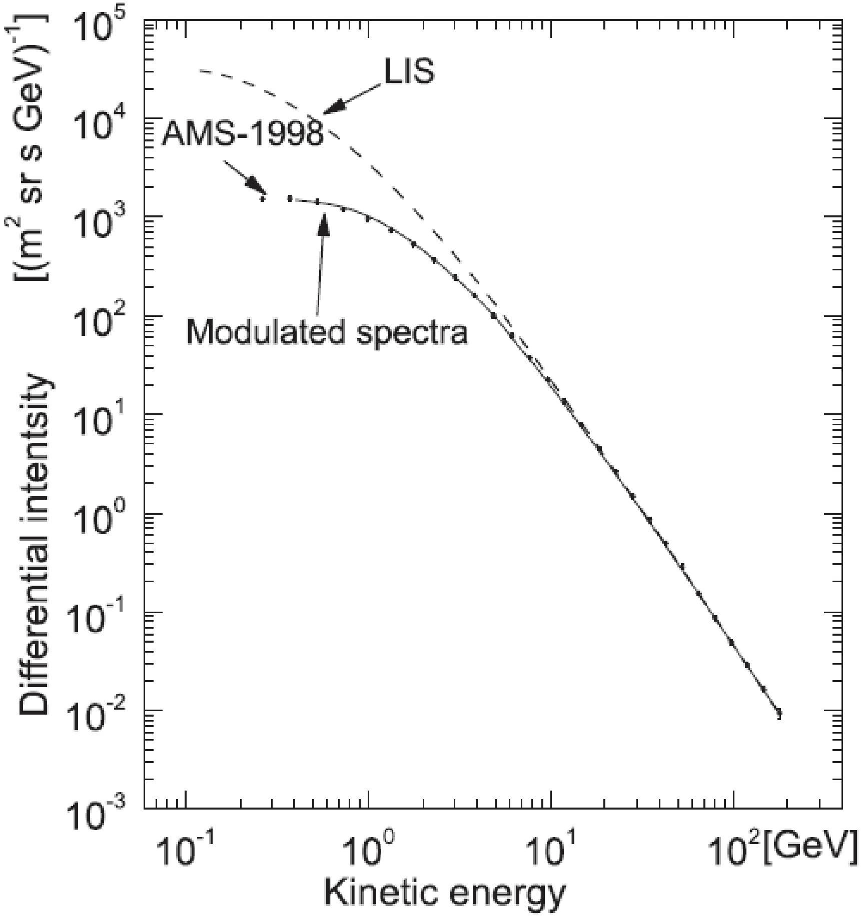


Figure 8. Differential intensity determined with the HelMod code (continuous line) compared to the experimental data of AMS–1998; the dashed line is the LIS (see the text).

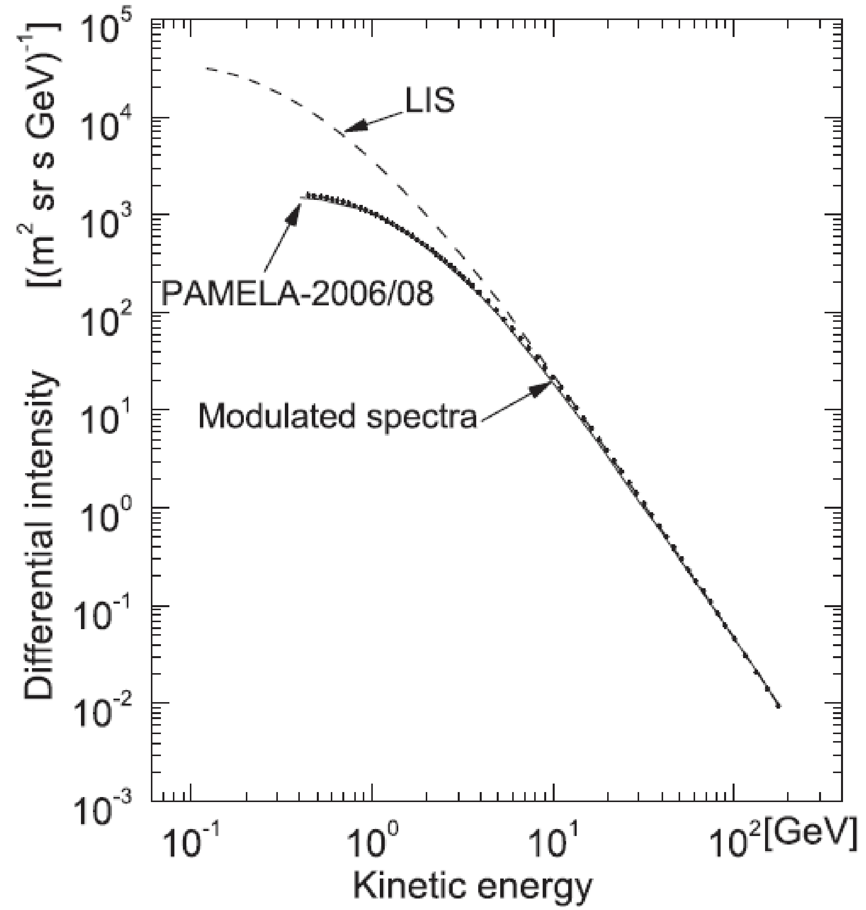


Figure 10. Differential intensity determined with the HelMod code (continuous line) compared to the experimental data of PAMELA–2006/08; the dashed line is the LIS (see the text).

Bobik P. et al., Systematic Investigation of Solar Modulation of Galactic Protons for Solar Cycle 23 Using a Monte Carlo Approach with Particle Drift Effects and Latitudinal Dependence, The Astrophysical Journal, Volume 745, Issue 2, 21 pp. , 2012

Porovnanie metód riešenia Parkerovej rovnice
- distribúcia Kozmického žiarenia v Heliosfére

- štandardné riešenia sa líšia

$$\frac{\partial U}{\partial t} = -\nabla \cdot (U\vec{V}) + \nabla \cdot \left[\tilde{K} \cdot \nabla U\right] + \frac{(\nabla \cdot \vec{V})}{3} \frac{\partial}{\partial T} \left(\alpha_{\mathrm{rel}} T U\right)$$

$$\frac{\partial f}{\partial t} = -\nabla \cdot (f\vec{V}) + \nabla \cdot \left[\tilde{K} \cdot \nabla f\right] + \frac{(\nabla \cdot \vec{V})}{3p^2} \frac{\partial}{\partial p} \left(p^3 f\right)$$

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Space Physics

TECHNICAL REPORTS: METHODS

10.1002/2015JA022237

Key Points:
- Quantitative comparison of backward-forward-in-time cosmic rays transport Monte Carlo methods
- Estimation of systematic error of both methods for spectra at 1 AU for energies above 1 GV
- Backward-in-time method is suited for predicting modulated spectra for high-precision experiments

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Citation:
Bobik, P., et al. (2016), On the forward-backward-in-time approach for Monte Carlo solution of Parker's transport equation: One-dimensional case, *J. Geophys. Res. Space Physics*, *121*, doi:10.1002/2015JA022237.

On the forward-backward-in-time approach for Monte Carlo solution of Parker's transport equation: One-dimensional case

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Abstract The cosmic rays propagation inside the heliosphere is well described by a transport equation introduced by Parker in 1965. To solve this equation, several approaches were followed in the past. Recently, a Monte Carlo approach became widely used in force of its advantages with respect to other numerical methods. In this approach the transport equation is associated to a fully equivalent set of stochastic differential equations (SDE). This set is used to describe the stochastic path of quasi-particle from a source, e.g., the interstellar space, to a specific target, e.g., a detector at Earth. We present a comparison of forward-in-time and backward-in-time methods to solve the cosmic rays transport equation in the heliosphere. The Parker equation and the related set of SDE in the several formulations are treated in this paper. For the sake of clarity, this work is focused on the one-dimensional solutions. Results were compared with an alternative numerical solution, namely, Crank-Nicolson method, specifically developed for the case under study. The methods presented are fully consistent each others for energy greater than 400 MeV. The comparison between stochastic integrations and Crank-Nicolson allows us to estimate the systematic uncertainties of Monte Carlo methods. The forward-in-time stochastic integrations method showed a systematic uncertainty <5%, while backward-in-time stochastic integrations method showed a systematic uncertainty <1% in the studied energy range.

IF= 3,318 Q1P

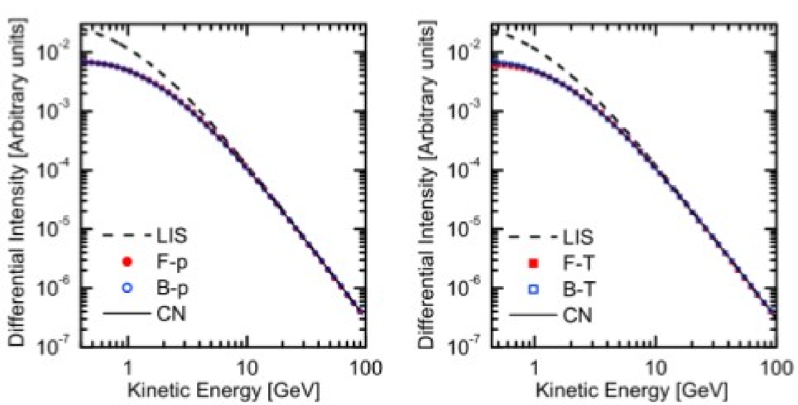

Figure 2. Particle differential intensity, in arbitrary units, at 1 AU evaluated by Monte Carlo and Crank-Nicolson methods. The LIS is shown as dashed line. CN is reported with black solid line. (left) **B-p** (blue round) and **F-p** (red round) solutions. (right) **B-T** (blue square) and **F-T** (red square) solutions.

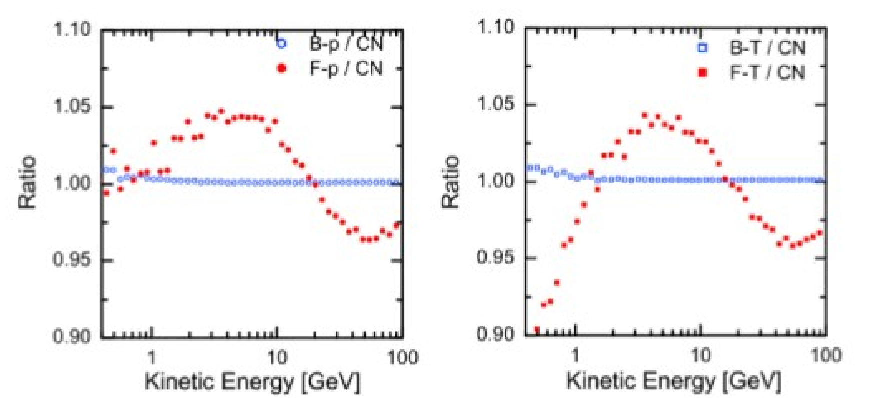

Figure 3. Ratio between Monte Carlo and CN solutions. (left) **B-p** over CN (blue round) and **F-p** over CN (red round) solutions. (right) **B-T** over CN (blue square) and **F-T** over CN (red square).

Modely propagácie KŽ heliosférou

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **470**, 1073–1085 (2017) doi:10.1093/mnras/stx1202

Advance Access publication 2017 May 16

An analytically iterative method for solving problems of cosmic-ray modulation

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[2]*Institute of Experimental Physics, Watsonova 47, 04001 Kosice, Slovakia*

Accepted 2017 May 11. Received 2017 May 11; in original form 2017 February 13

ABSTRACT

The development of an analytically iterative method for solving steady-state as well as unsteady-state problems of cosmic-ray (CR) modulation is proposed. Iterations for obtaining the solutions are constructed for the spherically symmetric form of the CR propagation equation. The main solution of the considered problem consists of the zero-order solution that is obtained during the initial iteration and amendments that may be obtained by subsequent iterations. The finding of the zero-order solution is based on the CR isotropy during propagation in the space, whereas the anisotropy is taken into account when finding the next amendments. To begin with, the method is applied to solve the problem of CR modulation where the diffusion coefficient κ and the solar wind speed u are constants with an Local Interstellar Spectra (LIS) spectrum. The solution obtained with two iterations was compared with an analytical solution and with numerical solutions. Finally, solutions that have only one iteration for two problems of CR modulation with u = constant and the same form of LIS spectrum were obtained and tested against numerical solutions. For the first problem, κ is proportional to the momentum of the particle p, so it has the form $\kappa = k_0\eta$, where $\eta = \frac{p}{m_0 c}$. For the second problem, the diffusion coefficient is given in the form $\kappa = k_0\beta\eta$, where $\beta = \frac{v}{c}$ is the particle speed relative to the speed of light. There was a good matching of the obtained solutions with the numerical solutions as well as with the analytical solution for the problem where κ = constant.

Key words: methods: analytical – Sun: heliosphere – cosmic rays.

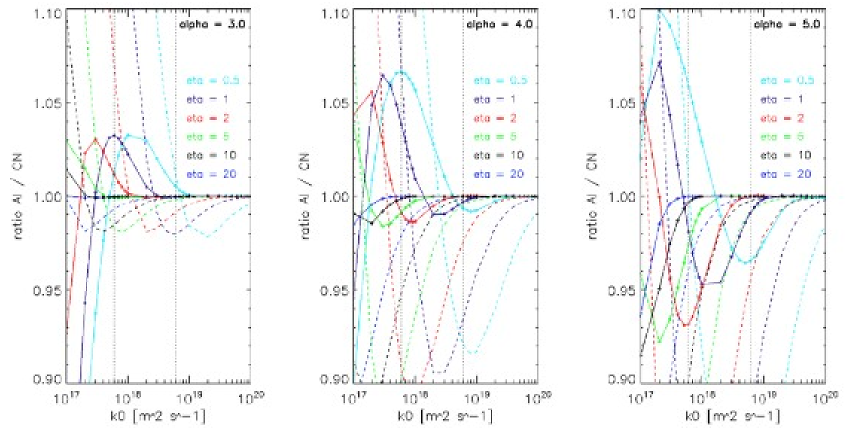


Figure 8. The comparison of the ratio of the AI and CN solutions for different diffusion coefficients k_0 and $\alpha = 3$ (left-hand panel), 4 (middle panel) and 5 (right-hand panel) at 1 au for $\eta = 0.5, 1, 2, 5, 10, 20$. Dashed lines represent the ratio AI(N_0)/CN and solid lines represent the ratio AI($N_0 + N_1$)/CN. AI and CN for $\kappa = k_0\beta\eta$ (for more details, see the text)

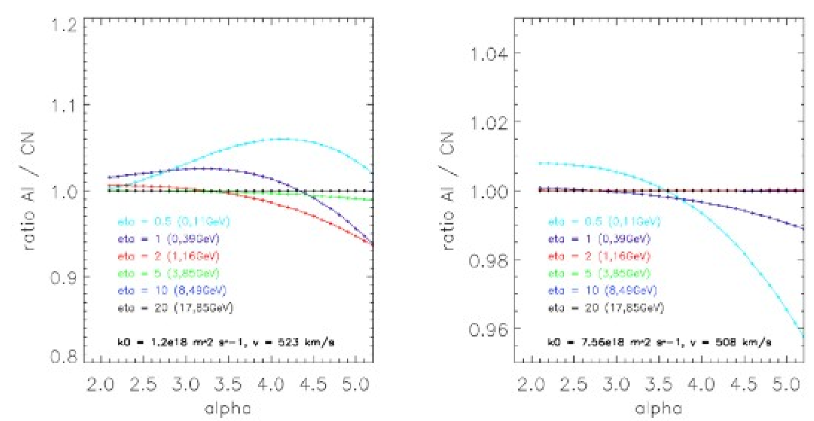
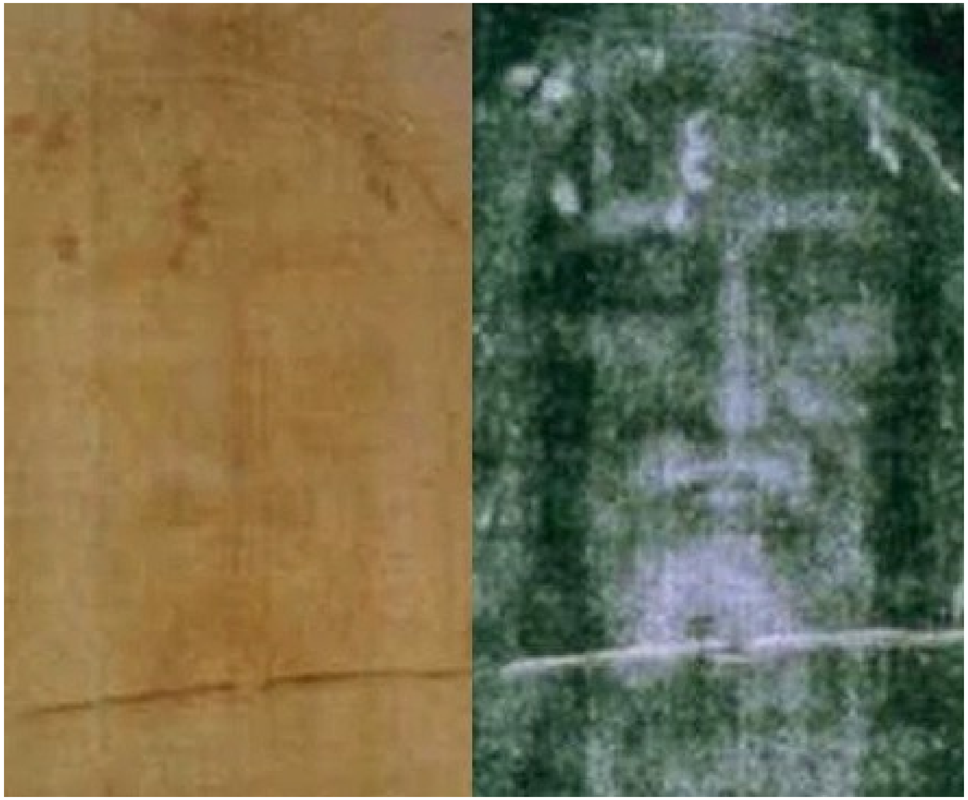


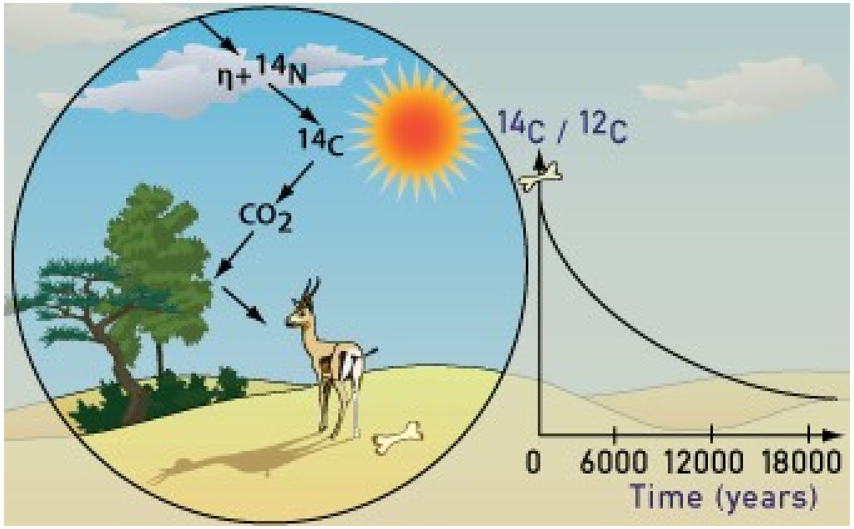
Figure 9. The comparison of the ratio of the AI and CN solutions as functions of the initial spectrum slope α at 1 au for two selected values of k_0. Solutions for $\kappa = k_0\beta\eta$ (for more details, see the text).

Turínske plátno
Zaujímavosti o kozmickom žiarení

Podľa tradície ide o ľanovú plachtu, do ktorej Jozef z Arimatey a Nikodém zabalili telo umučeného Ježiša Krista po tom, ako ho zložili z kríža.

Zdroj: http://sk.wikipedia.org/wiki/Turínske_plátno





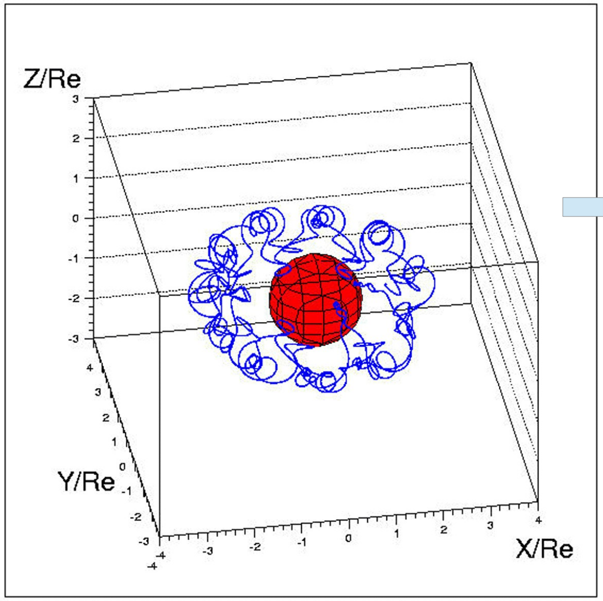
Zdroj: http://www.webexhibits.org/pigments/intro/dating.html

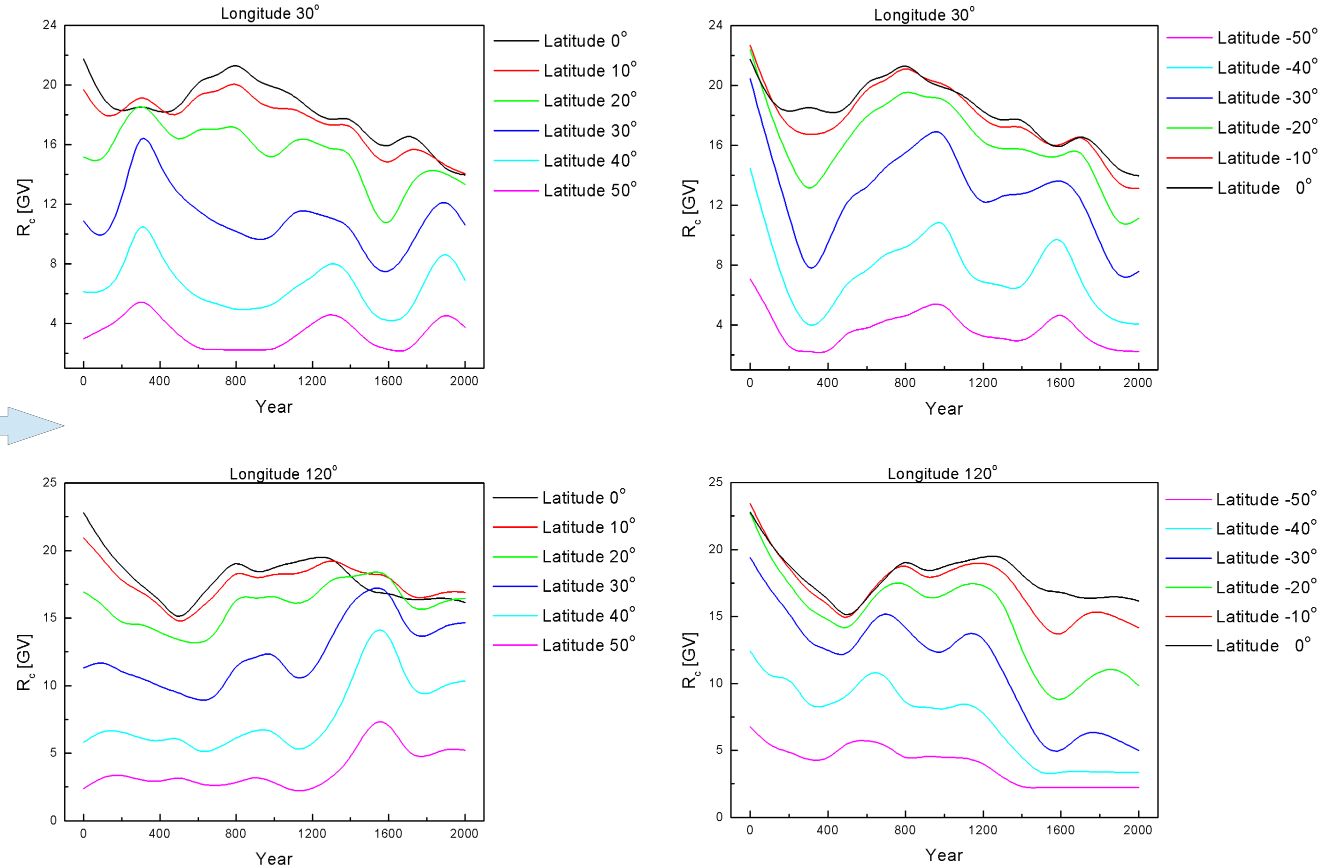
Avšak

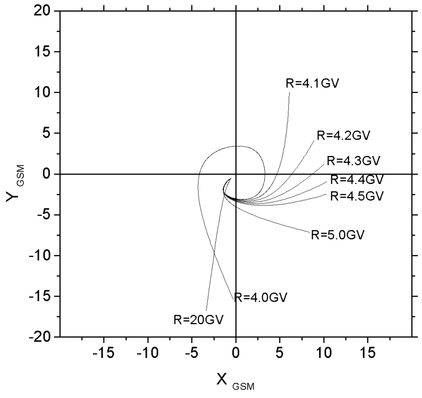
Intenzita kozmického žiarenia v okolí Zeme a priepustnosť magnetosféry sa mení

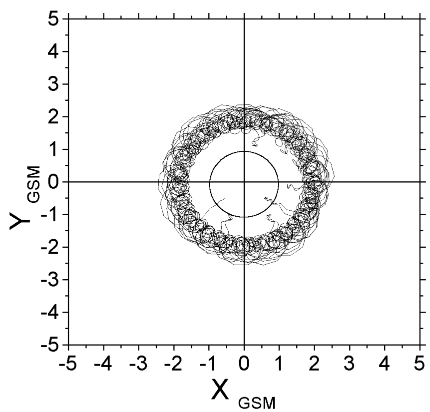
Turínske plátno

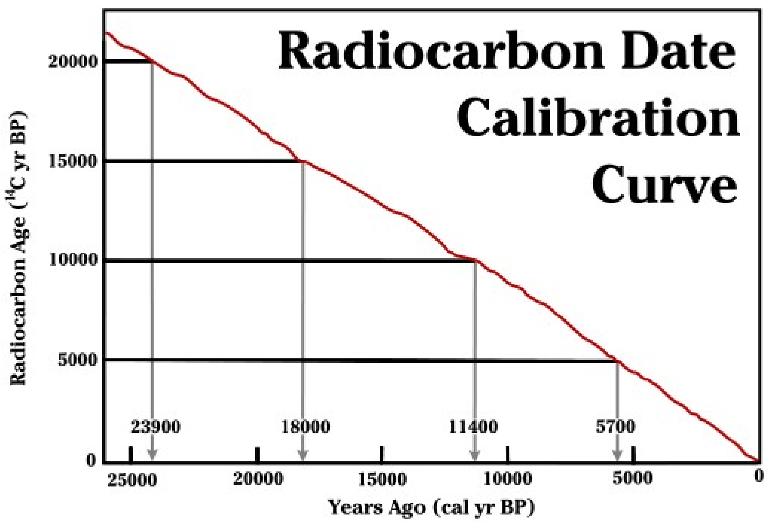
Zaujímavosť o kozmickom žiarení











Kudela, K.; Bobik, P., Long-Term Variations of Geomagnetic Rigidity Cutoffs, Solar Physics, Volume 224, Issue 1-2, pp. 423-431, 2004

Zdroj: IntCal04 Terrestrial radiocarbon age calibration". Radiocarbon 46: 1029-58, 2004

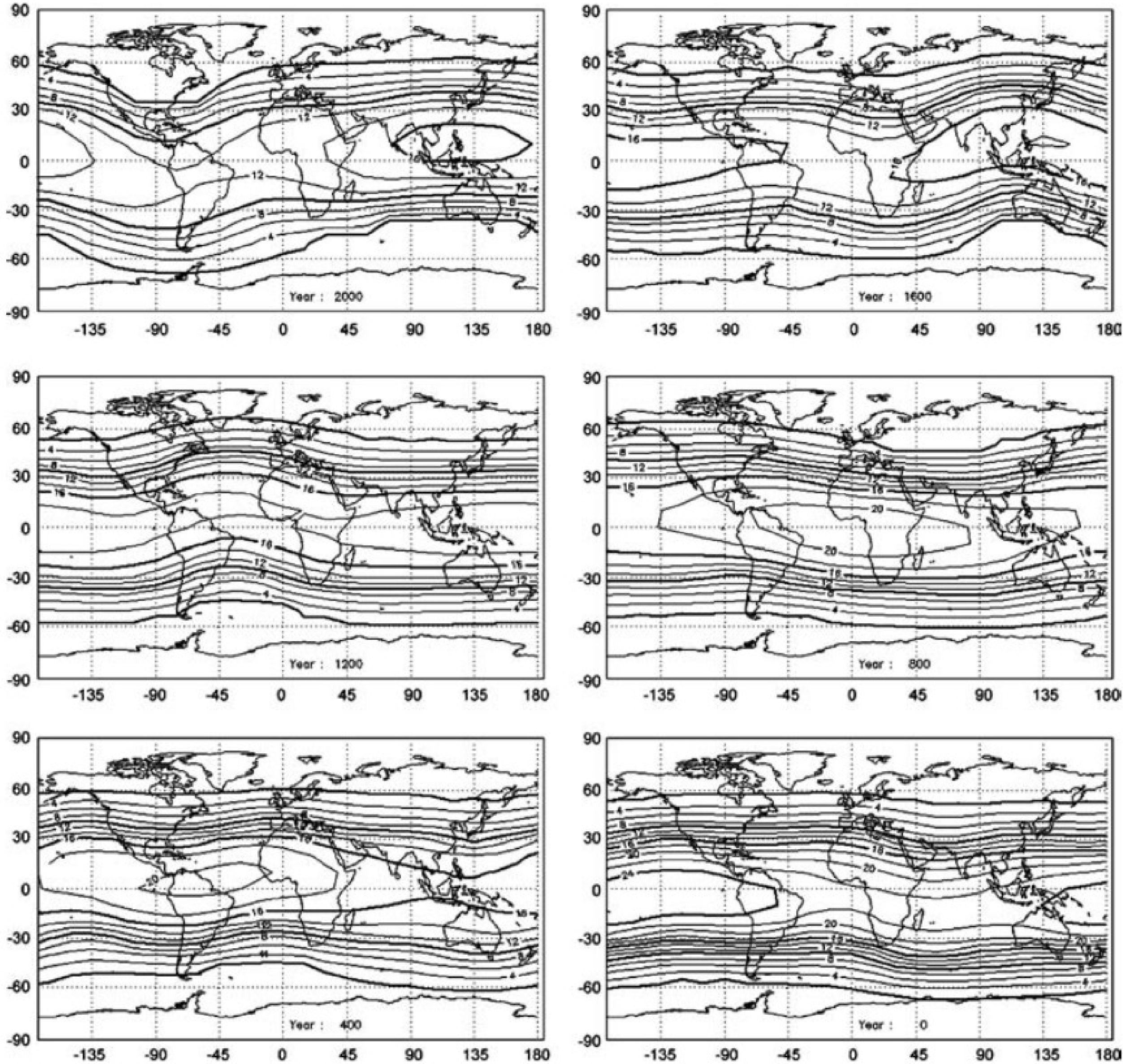
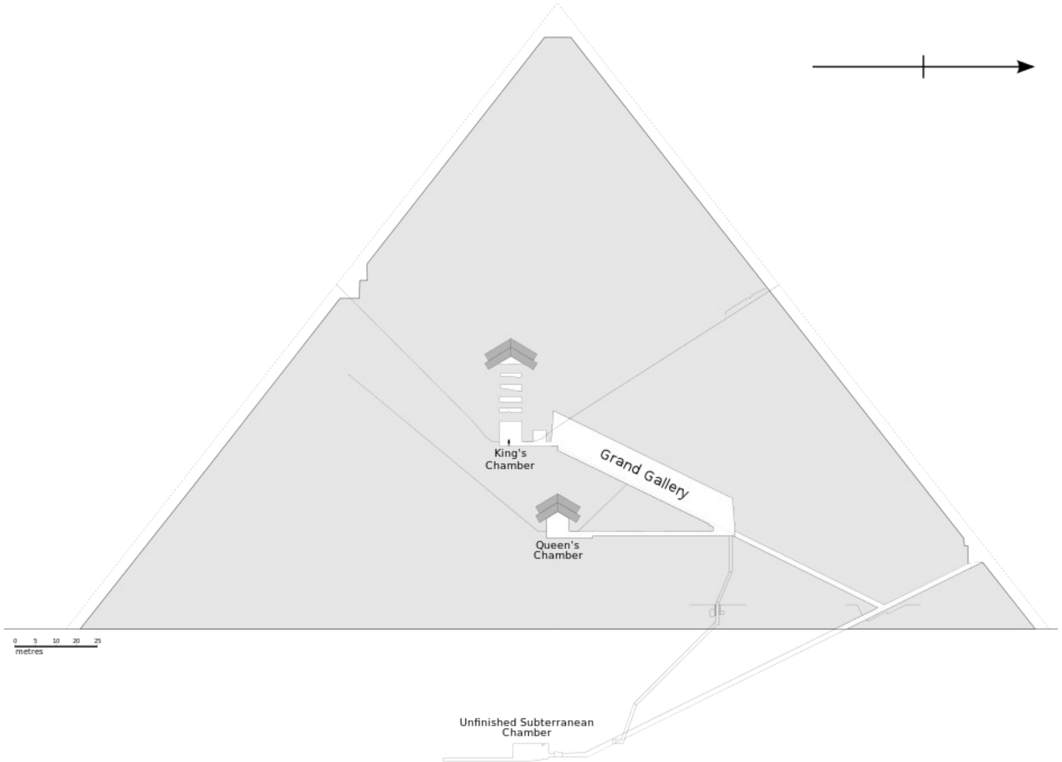


Figure 3. Contour maps of vertical cutoff rigidities estimated from the computations using the approximation $n = 2+$ in years 0, 400, 800, 1200, 1600 (coefficients from Hongre, Hulot, and Khokhlov, 1998) and for year 2000 using $n = 2+$ selection from IGRF model.

Kudela, K.; Bobik, P., Long-Term Variations of Geomagnetic Rigidity Cutoffs,
Solar Physics, Volume 224, Issue 1-2, pp. 423-431, 2004

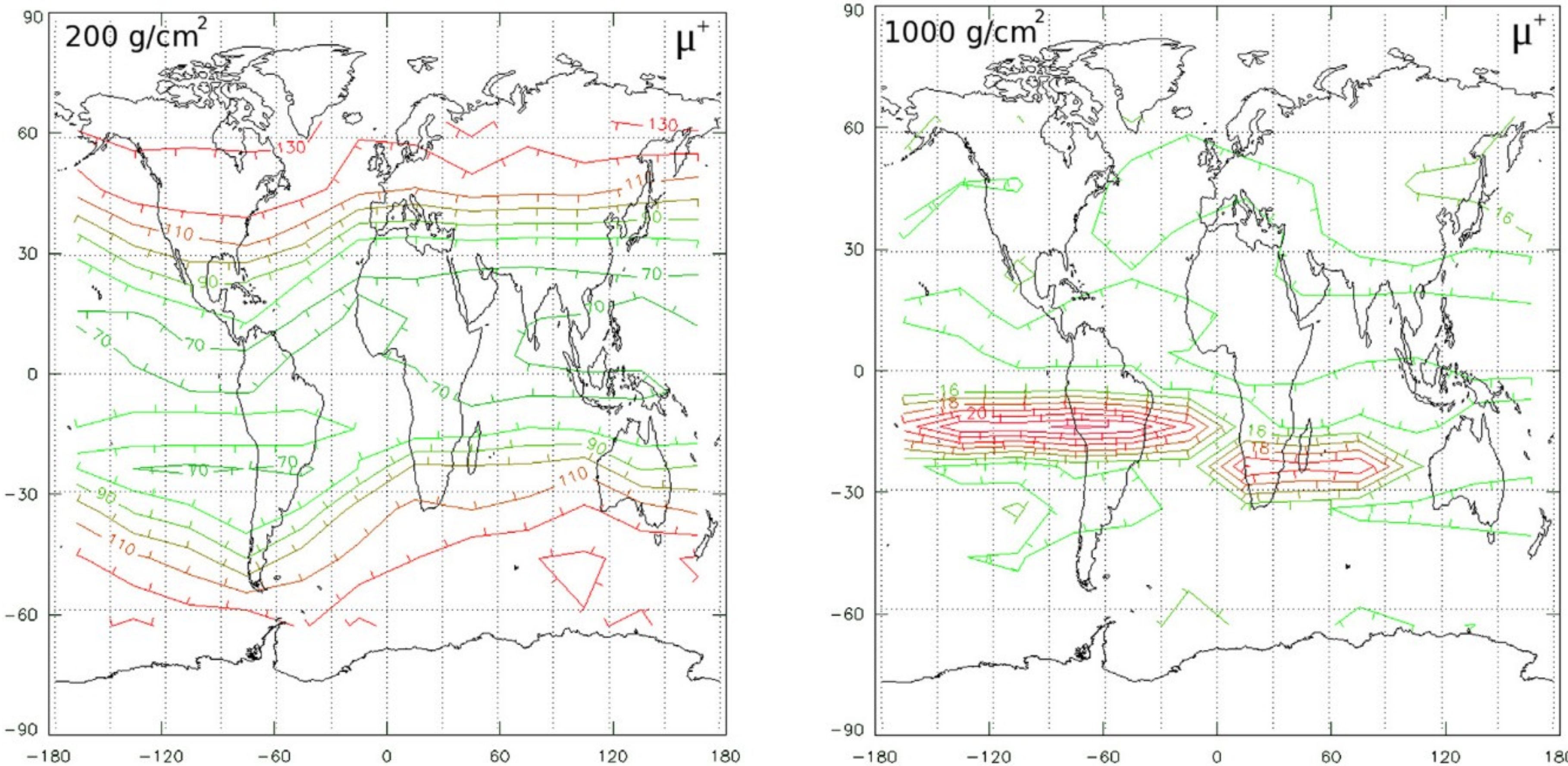
Miónová tomografia

- Projekt ScanPyramid – hľadanie priestorov a štruktúr vnútri pyramíd
- Jednou z použitých neinvazívnych techník je miónová tomografia
- Tri nezávislé experimenty na detekciu miónov, každý používa iný typ miónového detektora (jadrové emulzie, scintylátorové hodoskopy, plynový detektor)
- Discovery of a big void in Khufu’s Pyramid by observation of cosmic-ray muons, Kunihiro Morishima, et al., Nature volume 552, pages 386–390, 21 December 2017, arXiv:1711.01576v2
- Prázdny prestor nad Veľkou galériou s minimálnou dĺžkou 30 metrom a účinným prierezom podobným Veľkej galérii.
- A possible explanation of the void discovered in the pyramid of Khufu on the basis of the pyramid texts, Giulio Magli, arXiv:1711.04617v2



Credit: Jeff Dahl [CC BY-SA 4.0]

Miónová tomografia



Distribúcia Miónov^{+} na atmosférických hĺbkach 200 g/cm^2 a 1000 g/cm^2.

P.Bobika, K.Kudela, B.Pastircak, A.Santangelo, M.Bertaina, K.Shinozaki, F.Fenu, J.Szabelski, J.Urbar, Distribution of secondary particles intensities over Earth’s surface: Effect of the geomagnetic field, Advances in Space Research, Volume 50, Issue 7, 1 October 2012, Pages 986-996

Hľadanie zdrojov ultravysokoenergetických častíc

EUSO experimenty

P. Bobik

bobik@saske.sk

Web: http://space.saske.sk

Space::TALK

Ústav experimentálnej fyziky SAV, Oddelenie kozmickej fyziky

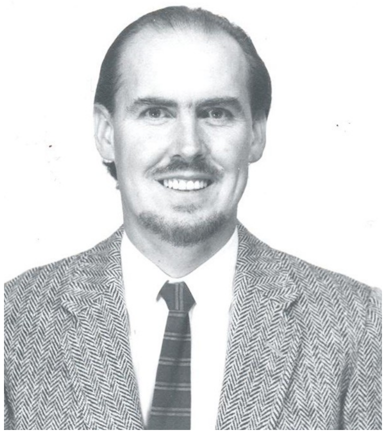
Odkiaľ – Kam – Prečo

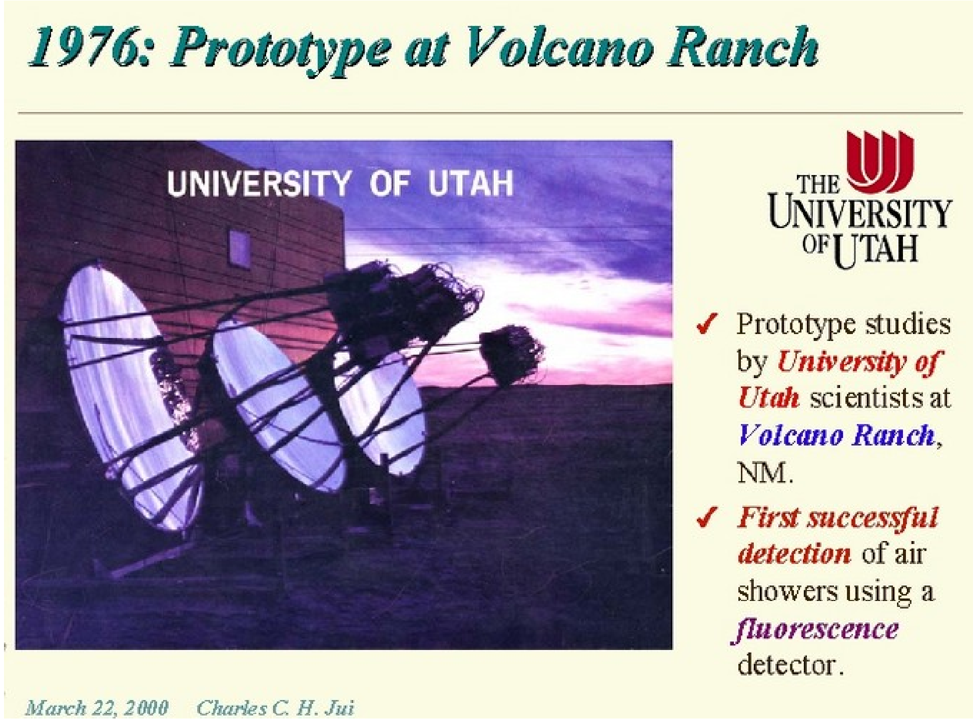
Prečo niekto minie ~miliardu dolárov a tisíce človeko-rokov práce na nájdenie odpovede na jednu otázku?

- Opodstatnenie experimentu / Zmysel misie
- Podstata experimentu, spôsob zberu dát
    - state of art, prvá misia plánujúca použitie Fresnelovej šošovky vo vesmíre (2,6 m, vyrobiteľná do 3,4 m s 10 nm presnosťou), kremíkové PMT na masívnej škále, prototyp celkovo aj na mnohých jednotlivých úrovniach celej mašinérie

Objav UHECR

- John D. Linsley
- Pole 19 scintilačných detektorov, Volcano Ranch, Albuquerque, New Mexico
- Začiatok pozorovaní v lete 1959
- 22. februára 1962, Linsley pozoroval atmosférickú spŕšku vytvorenú primárnou časticou s energiou viac než 16 Joulov





Oh-My-God particle

- Oh-My-God particle - 15 október 1991 – HiRes Fly's eye II, Dugway Proving Ground, Utah. Energia 3×10^{20} eV (51 J)
  - častica s kinetickou energiou rovnou basebalovej (142 gr) loptičke letiacej rýchlosťou 100 km/h či protón letiaci rýchlosťou 0.9999999999999999999999951c = pri ročnej ceste zaostane za fotónom len 46 nanometrov alebo 0.15 femtosekundy.

- z pohľadu častice - čas

Object	Distance[3] (light years)	Perceived Travel Time
Alpha Centauri	4.36	0.43 milliseconds
Galactic nucleus	32,000	3.2 seconds
Andromeda galaxy	2,180,000	3.5 minutes
Virgo cluster	42,000,000	1.15 hours
Quasar 3C273	2,500,000,000	3 days
Edge of universe	17,000,000,000	19 days

- z pohľadu častice – dĺžka „objektov“

Object	Rest Frame Thickness	Particle Frame Thickness
Earth's diameter	12,756 km	0.0399 mm
Solar system	80 AU	37 metres
Sun/Alpha Centauri	4.3 light years	127 km (79 miles)
Milky Way galaxy	30 kiloparsecs	2,895,000 km, about ten times the distance from the Earth to the Moon

http://www.fourmilab.ch/documents/OhMyGodParticle

Pohybová energia, čo to je?

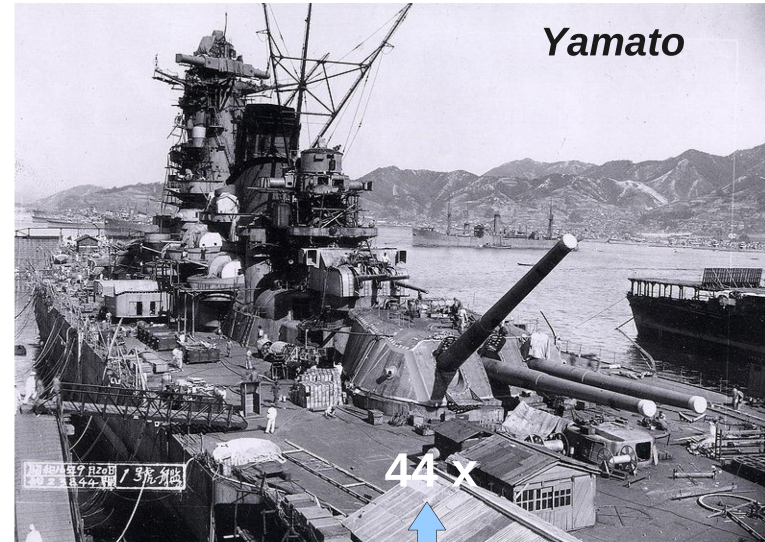
Bentley Continental GT

2320 kg, max. rýchlosť 318 km/h

110000 x

0,4 kg, 100 km/h

1064 x



Batillus supertanker

555 000 ton, dĺžka 414 metrov, bežná cestovná rýchlosť 30 km/h

≈

Airbus A380

575 ton, 945 km/h

Majme miniatúrnu guličku zo železa s váhou 1 gram

Nech sa pohybuje rovnakou rýchlosťou ako častice s ultravysokými energiami.

Je jej pohybová energia väčšia alebo menšia ako pohybová energia Airbusu A380?

Odpoveď : omnoho omnoho väčšia

- Cheopsova pyramída je približne 10 krát ťažšia ako supertanker Bautillus
- Ak by sa pohybovala **10 tisíc krát** rýchlejšie ako sa pohybuje Airbus A380 (za 15 sekúnd okolo Zeme)
- Potom bude mať pohybovú energiu rovnú jednogramovej železnej guľôčke pohybujúcej sa rýchlosťou častíc s ultravysokou energiou !!!

Kozmické žiarenie ultravysokých energií ma najviac energie vo vesmíre na jednotku hmotnosti

Zaujímavosť – UHECR a stabilita vesmíru

en.wikipedia.org/wiki/Large_Hadron_Collider#Safety_of_particle_collisions

Safety of particle collisions [edit source | edit beta]

Main article: Safety of high energy particle collision experiments

The experiments at the Large Hadron Collider sparked fears among the public that the particle collisions might produce doomsday phenomena, involving the production of stable microscopic black holes or the creation of hypothetical particles called strangelets.[99] Two CERN-commissioned safety reviews examined these concerns and concluded that the experiments at the LHC present no danger and that there is no reason for concern,[100][101][102] a conclusion expressly endorsed by the American Physical Society.[103]

The reports also noted that the physical conditions and collision events which exist in the LHC and similar experiments occur naturally and routinely in the universe without hazardous consequences,[101] including ultra-high-energy cosmic rays observed to impact Earth with energies far higher than those in any man-made collider.

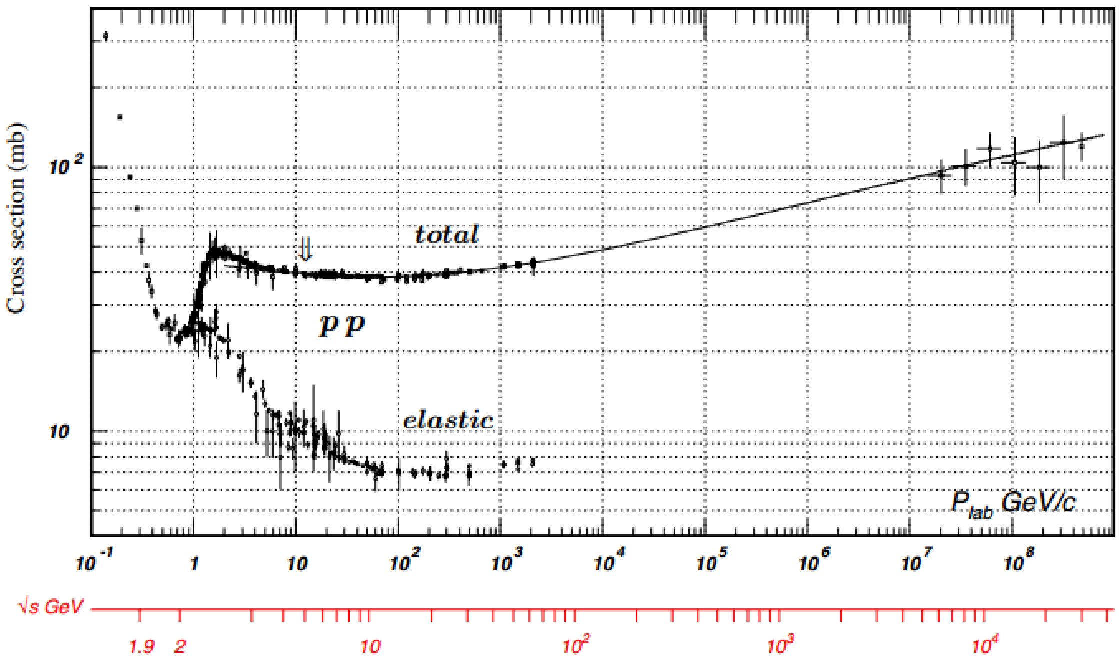
Zaujímavosť – UHECR a stabilita vesmíru

- Pri intenzite 1 častica / (m^2 s) sa mi na ploche 2×10^{28} m^2 zrazia 2 protóny s energiami 10^{20} eV každú sekundu
- Nad 10^{20} eV máme

  5×10^{-3} protónov / (km^2 sr rok)

  1.8×10^{-16} protónov / (m^2 sr s)

  resp. na 10^{16} m^2 sr za sekundu padnú 2 častice s energiou 10^{20} eV
- rádovo na $10^{16} \times 10^{28}$ m^2 prebehne jedna zrážka za jednu sekundu
  - 10^{44} m^2 je štvorec s hranou 10^{22} m čo je približne 10^6 sv. roku
- v celom vesmíre každú sekundu nastanú minimálne milióny takýchto zrážok



p-p cross section

http://pdg.lbl.gov/2009/reviews/rpp2009-rev-cross-section-plots.pdf

Pre 10^{20} eV menej ako 1 barn = 10^{-28} m^2

Poznámka : steradiány sme pre jednoduchosť zanedbali

Kozmické žiarenie ultravysokých energií

Kozmického žiarenia s ultravysokou energiou je extrémne málo.

Na ploche celého Slovenska približne jedna častica s ultravysokou energiou za deň !

Detektor s plochou ako územie Slovenska ?

Integrálne spektrum KŽ

1e10 eV	9.7e1	častíc / (m^2 sr s)
1e11 eV	1.9	častíc / (m^2 sr s)
1e12 eV	3.1e-2	častíc / (m^2 sr s)
1e13 eV	5.2e-4	častíc / (m^2 sr s)
1e14 eV	8.6e-6	častíc / (m^2 sr s)
1e15 eV	4.5	častíc / (m^2 sr rok)
1e16 eV	7.5e-2	častíc / (m^2 sr rok)
1e17 eV	1.2e-3	častíc / (m^2 sr rok)
1e18 eV	2.1e-5	častíc / (m^2 sr rok)
1e19 eV	3.4e-7	častíc / (m^2 sr rok)
1e20 eV	5.6e-3	častíc / (km^2 sr rok)

- nad kolenom približné hodnoty

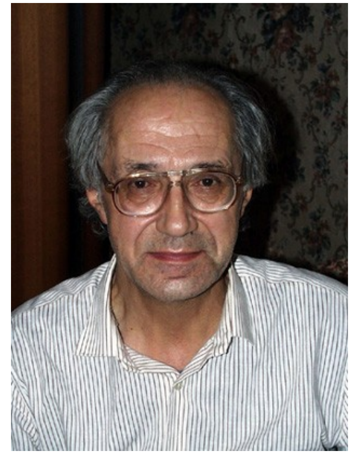
Koleno – nad kolenom sa sklon spektra zvačší

Členok – sklon spektra sa opäť zmenší

Záhada GZK efekt

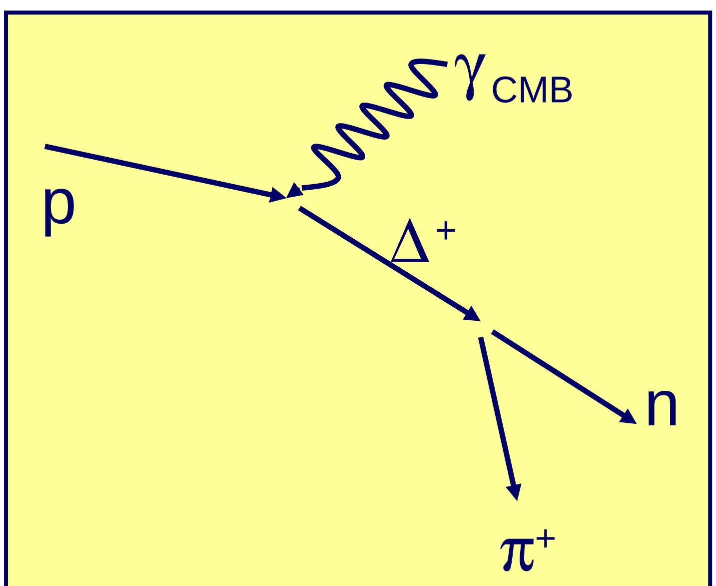
Kenneth
Greisen

George
Zatsepin



Vadim
Kuzmin

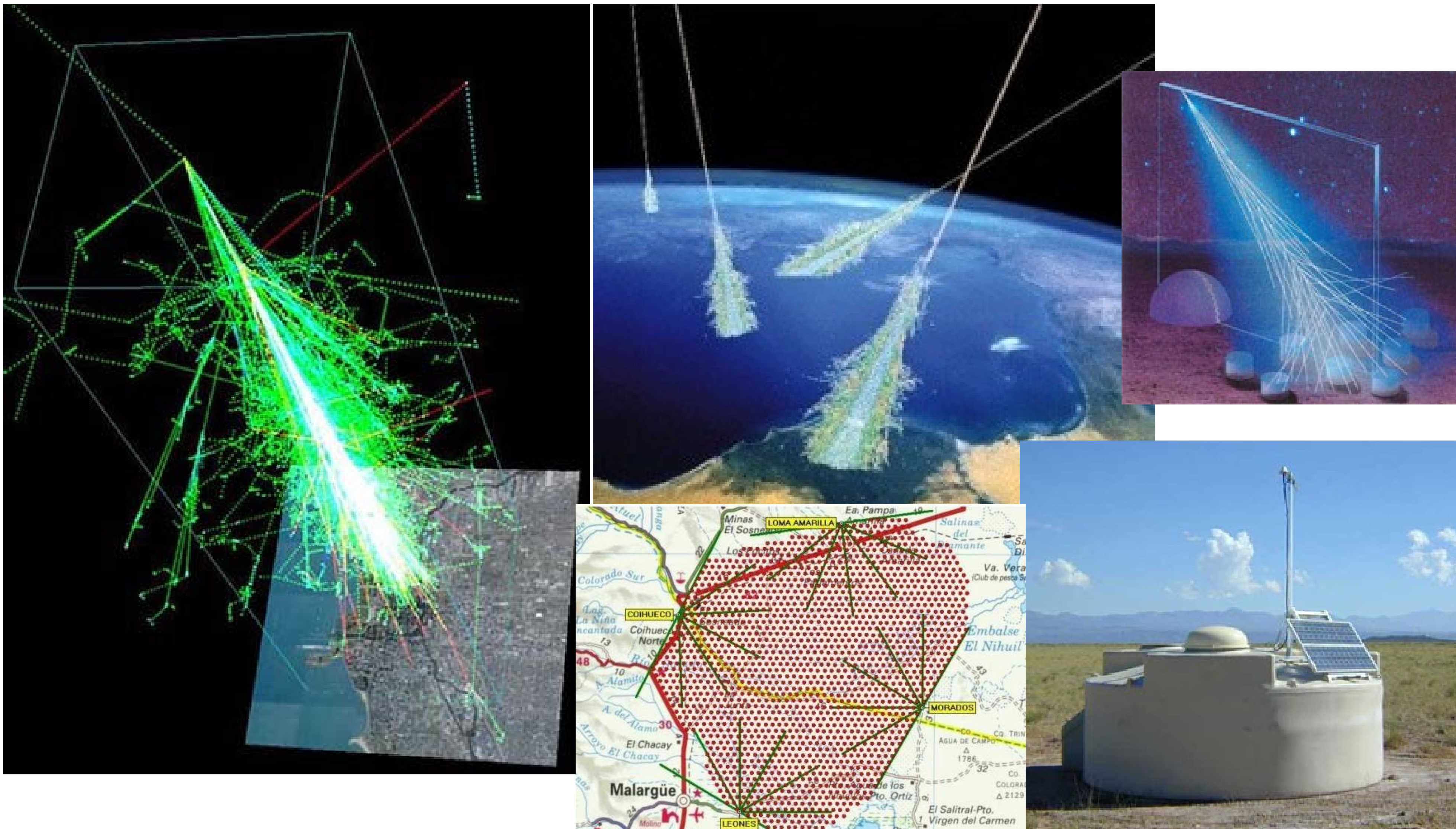
Greisen (1966) a,
nezávisle Zatsepin
& Kužmin (1966)



$$E_{th} = \frac{2m_N m_p + m_p^2}{4e} \to 5 \cdot 10^{19}\,\mathrm{eV}$$

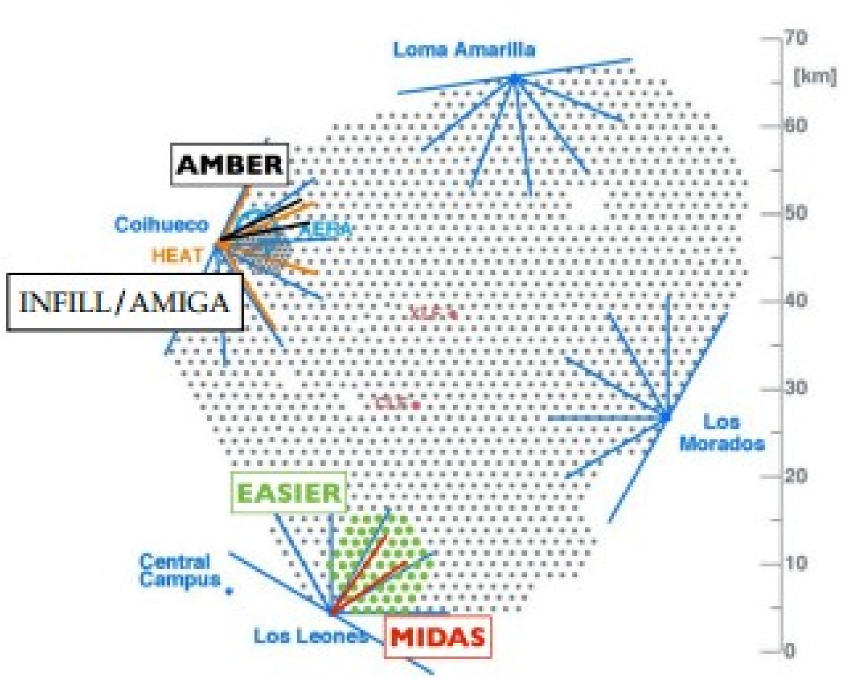
Rozpty kozmického žiarenia ultravysokých
energií na mikrovlnom pozadí vesmíru

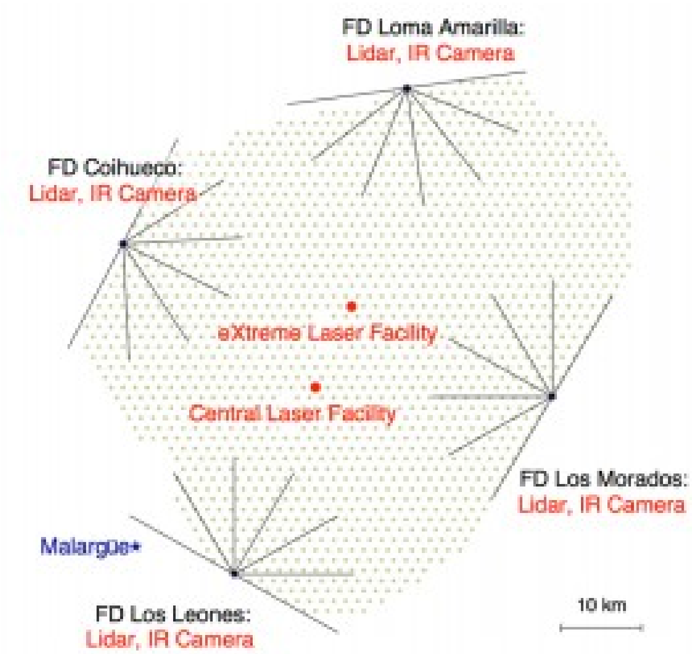
Kozmické žiarenie – registrácia UHECR
Pierre Auger Observatory



Pierre Auger Observatory

The world's largest cosmic ray observatory
In operation since 2004



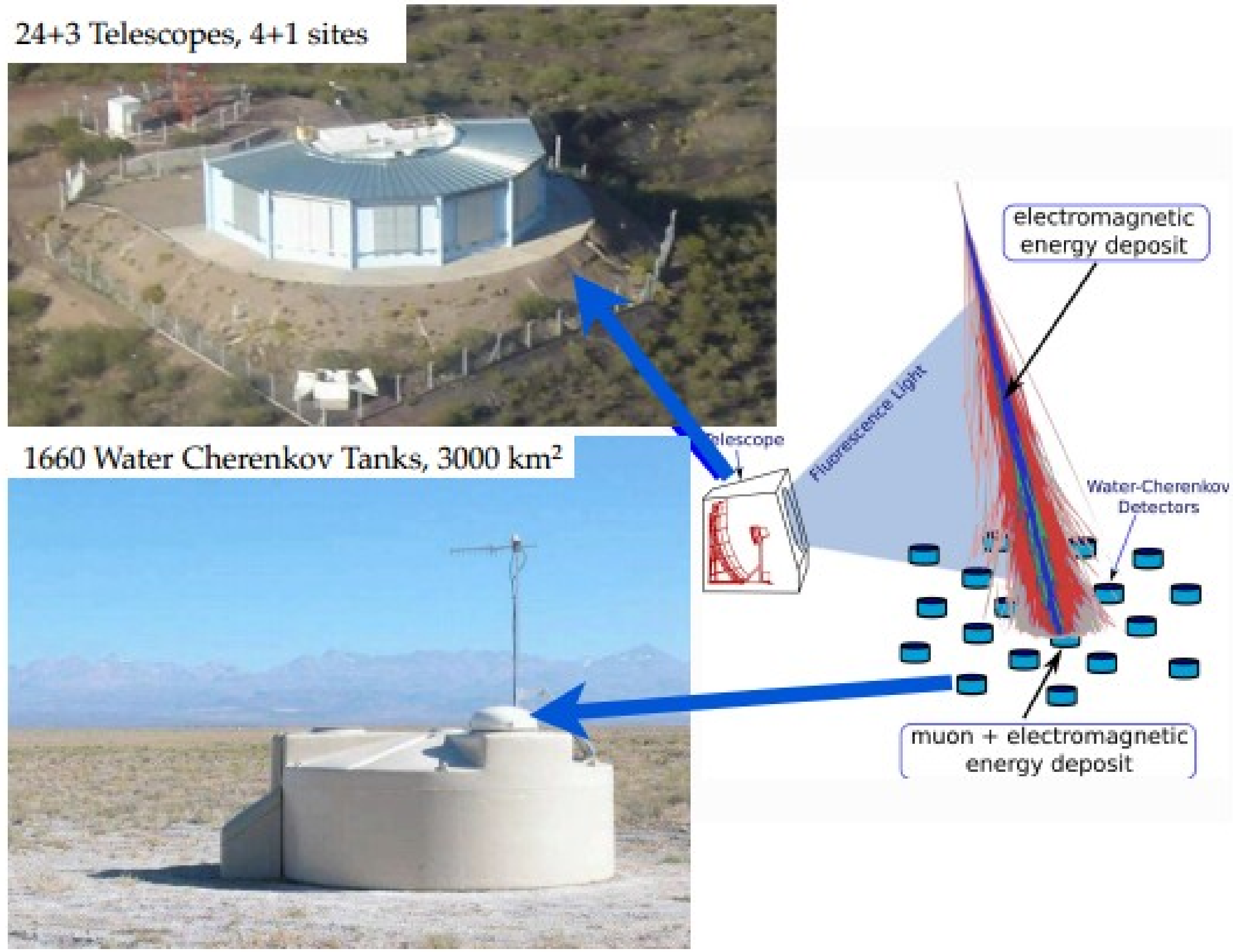


- Antoine LETESSIER-SELVON, Recent Highlights from the Pierre Auger Observatory, ICRC 2013

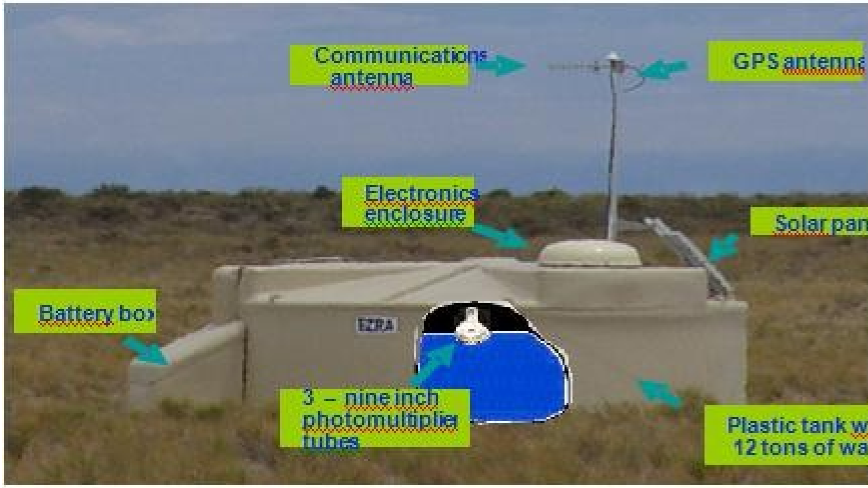
Pierre Auger Observatory

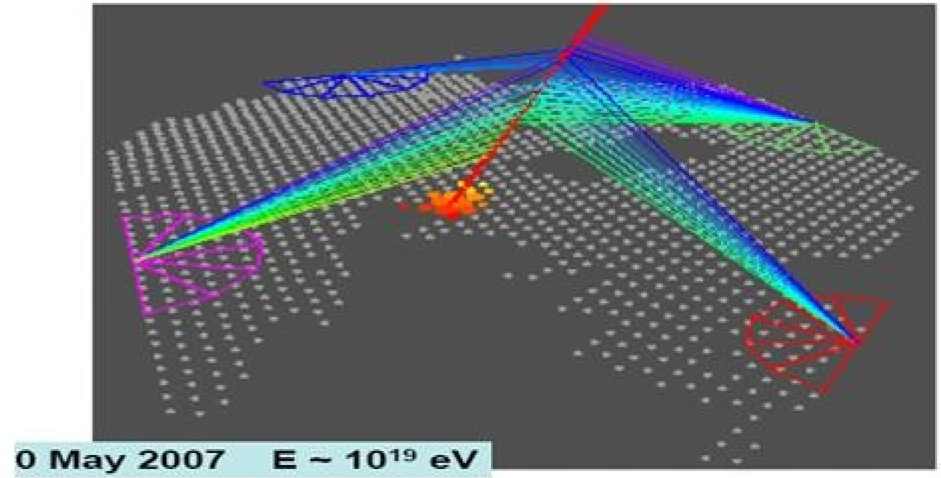
The world's largest cosmic ray observatory

The hybrid concept allows for a data-driven calibration of the ~100% duty cycle surface array using the calorimetric information from the fluorescence telescopes

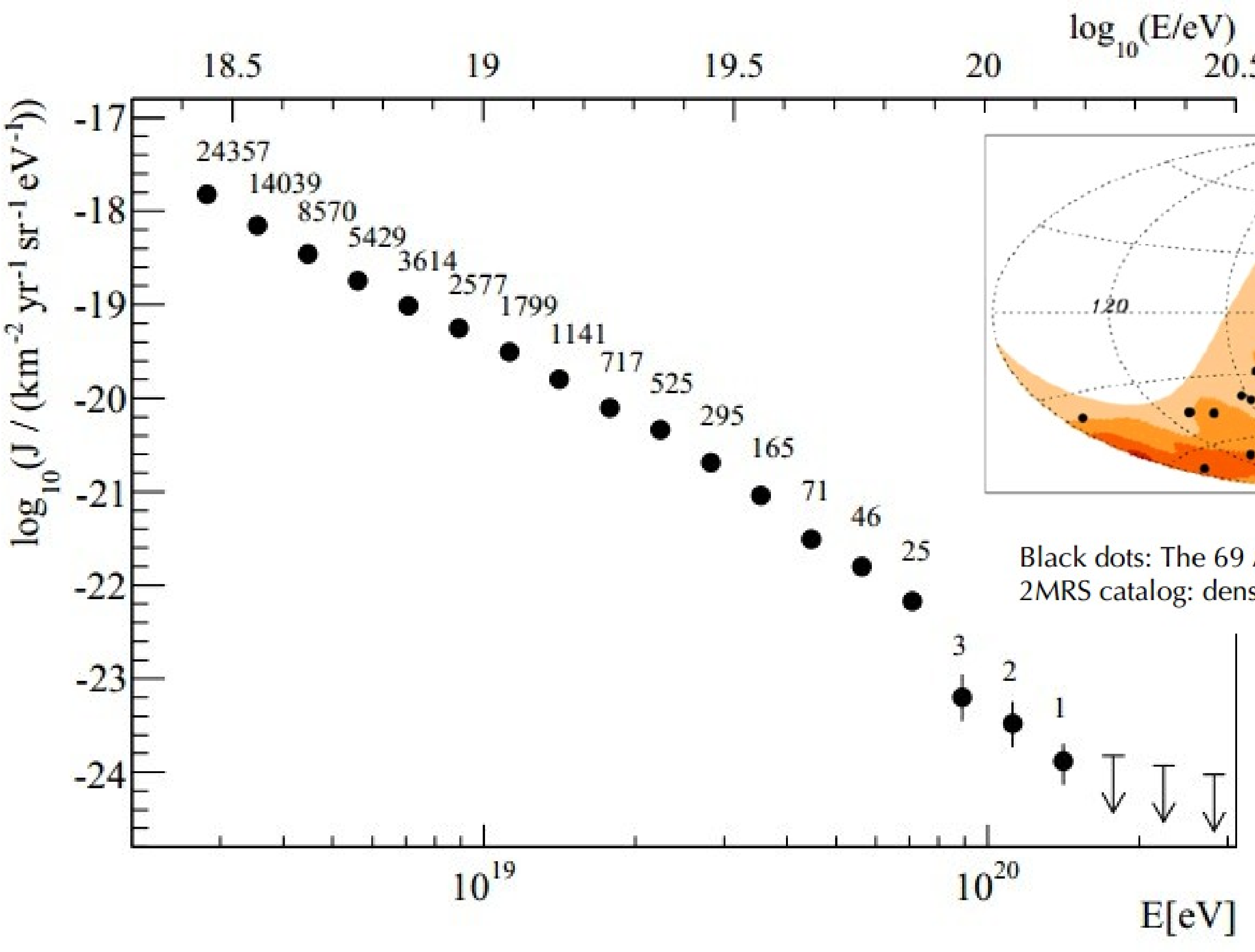


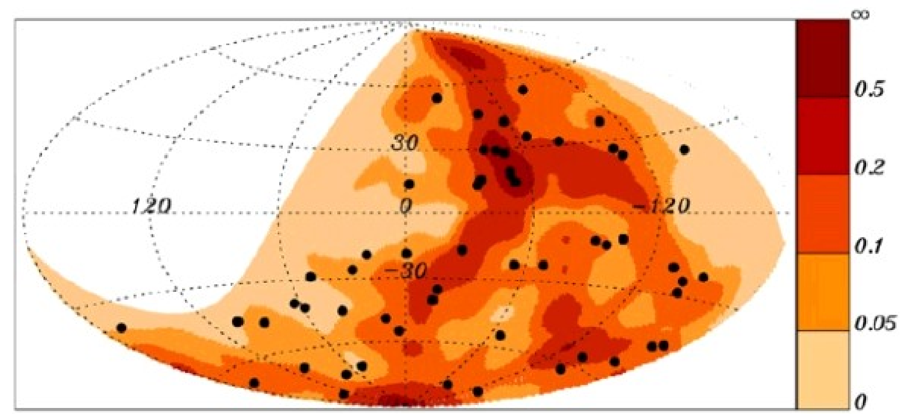
- Antoine LETESSIER-SELVON, Recent Highlights from the Pierre Auger Observatory, ICRC 2013





Približne 15 častíc / rok



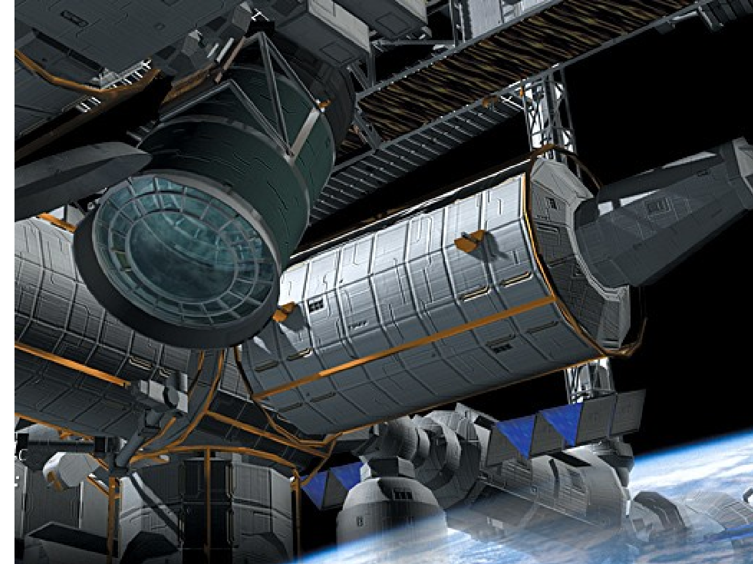


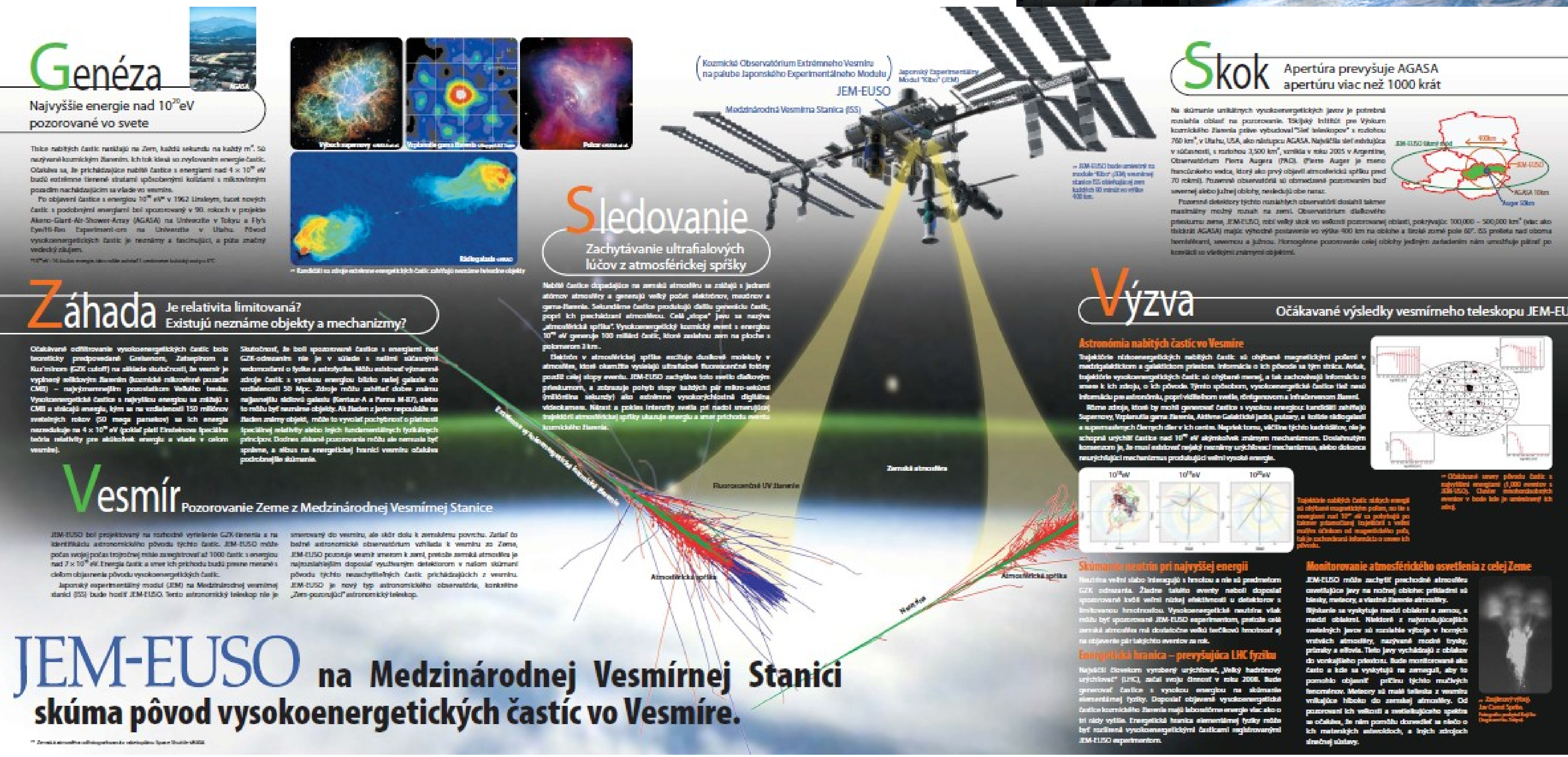
Black dots: The 69 Auger events with E>55EeV
2MRS catalog: density map with a 5° smoothing.

- Málo ?
- Riešenie ?

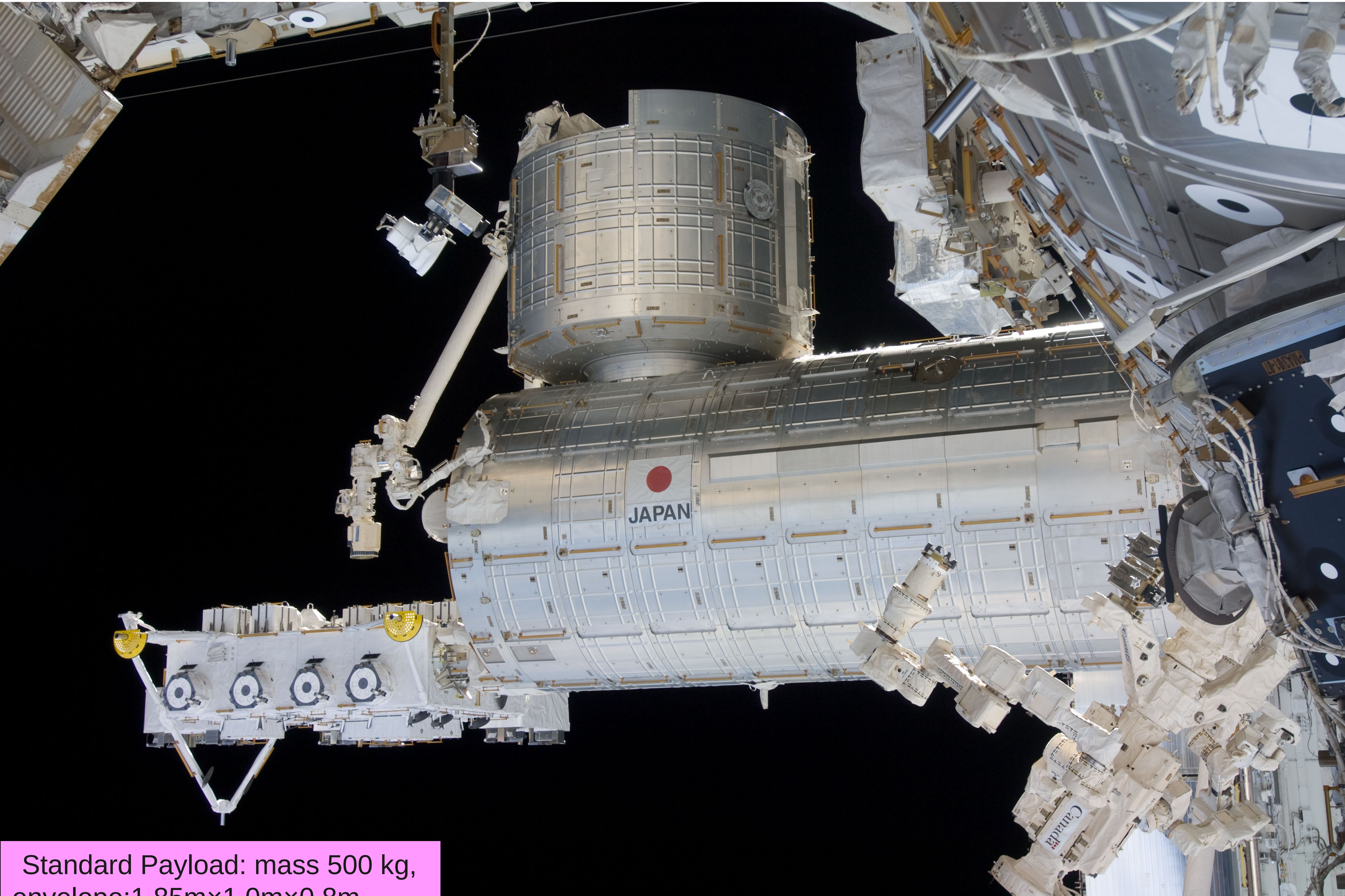
JEM-EUSO

- Kozmické Observatórium Extrémneho Vesmíru na palube Japonského Experimentálneho Modulu
- Projekt JAXA & ESA & NASA & Roskosmos,
- 16 členských krajín
  93 vedeckých inštitúcií

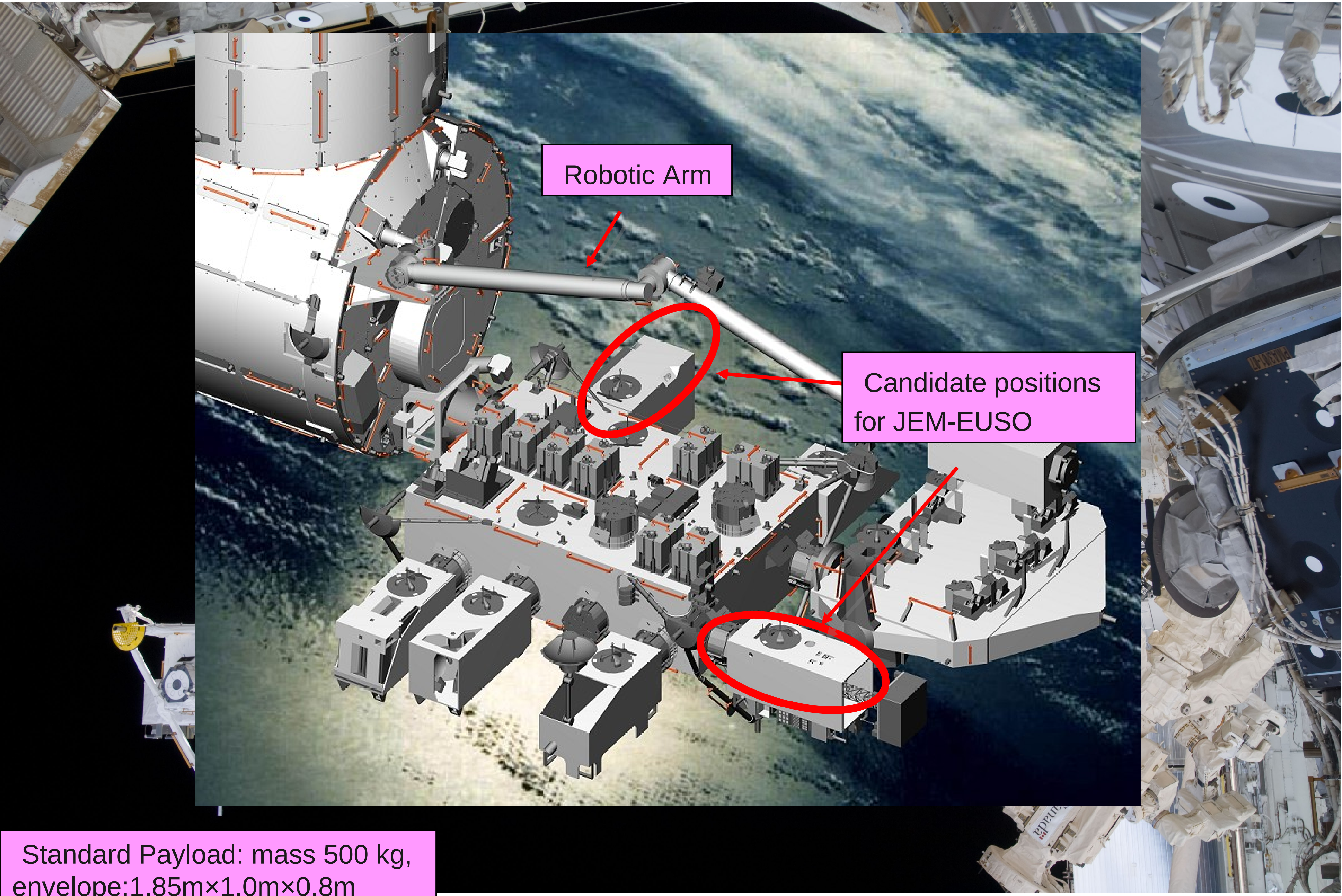




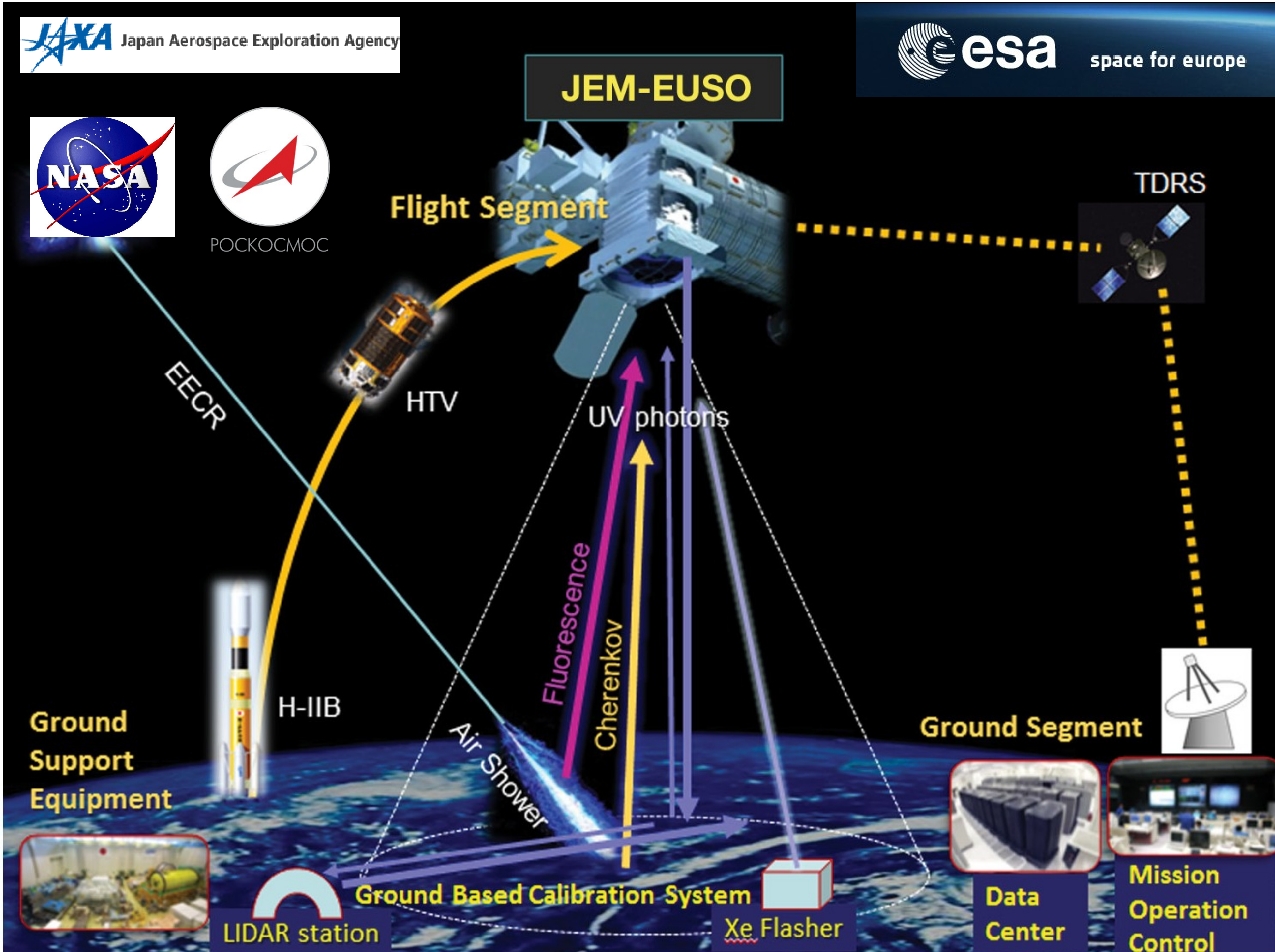
Medzinárodná vesmírna stanica ISS



Standard Payload: mass 500 kg,
envelope:1.85m×1.0m×0.8m



Standard Payload: mass 500 kg,
envelope:1.85m×1.0m×0.8m


Japan Aerospace Exploration Agency
esa
space for europe
JEM-EUSO
NASA
РОСКОСМОС
Flight Segment
TDRS
HTV
EECR
UV photons
Fluorescence
Cherenkov
H-IIB
Air Shower
Ground Support Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data Center
Mission Operation Control

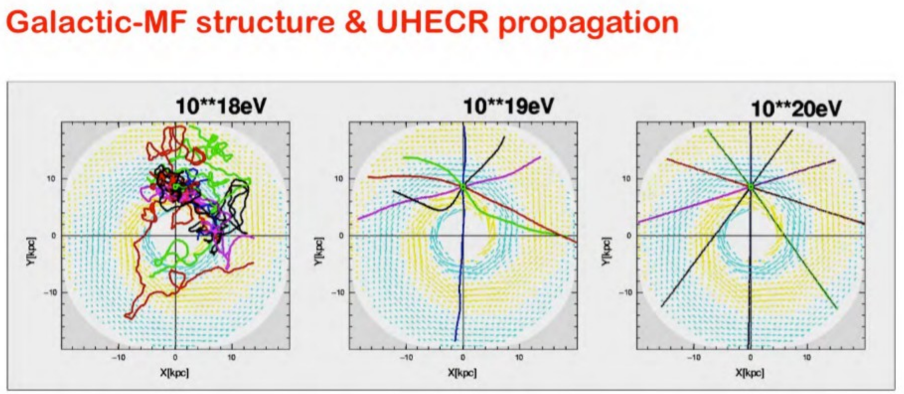
Základné parametre JEM-EUSO misie

Parameter	Value
Launch date	JFY 2016
Mission Lifetime	3+2 years
Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF#2
Mass	1938 kg
Power	926 W (op.) 352 W (non op.)
Data rate	285 kbps (+ on board storage)
Orbit	400 km
Inclination of the Orbit	51.6°
Operation Temperature	-10° to 50°

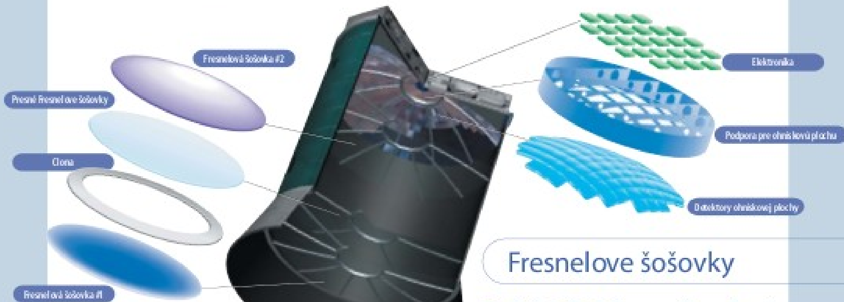
Čo JEM-EUSO hľadá

- *Zdroje kozmického žiarenia ultravysokých energií*
- *Neutrína ultravysokých energií*
- *Gamma žiarenie ultravysokých energií*
- *Galaktické a mimogalaktické magnetické polia*

Fyzika a Astrofyzika pre Energie > $5.\times10^{19}$ eV



Najnovšie Technológie v službách JEM-EUSO

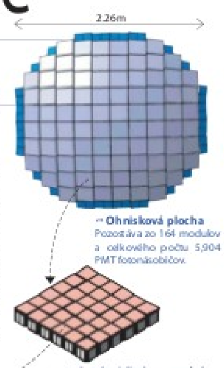


Zloženie

Detektory ohniskovej plochy

6,000 fotonásobičov

Ohnisková plocha je zakrivená s priemerom 2.26 m. 6000 1-palcových štvorcových multianódových rúriek fotonásobičov (PMTs) detektuje svetlo z rôznych miest v zemskej atmosfére. Predchádzajúce fotonásobiče (PMTs) mali obmedzenú fotosenzitívnu plochu približne 45%. JEM-EUSO a Hamamatsu Photonics spoločne vyvinuli fotonásobiče (PMTs), ktoré majú účinnú plochu 85%.



→ **Ohnisková plocha**
Pozostáva zo 164 modulov a celkového počtu 5,904 PMT fotonásobičov.

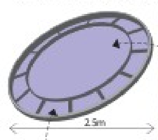
→ **Svetlocitlivý modul**
Pokrýva ohniskovú plochu s priemerom 2.26m s 5,904 PMT fotonásobičmi, z ktorých má každý 6 x 6 = 36 svetlocitlivých jednotiek.

→ **Fotonásobiče**
85% povrchu PMT fotonásobičov tvorí aktívna plocha, majúca 6 x 6 pixelov s celkovou plochou 26.2 mm štvorcových.

Fresnelove šošovky

Realizácia širokého zorného poľa pri nízkej hmotnosti

JEM-EUSO teleskop používa Fresnelove šošovky. Fresnelova šošovka je poloplochá šošovka, ktorá má kruhové drážky, ktoré eliminujú veľkú hmotnosť štandardných konvektívnych a konkávnych šošoviek. Tenkosť a ľahkosť Fresnelovej šošovky je nevyhnutnou podmienkou jej využitia vo vesmíre, pričom ponúka rovnaké optické funkcie ako hrubé a ťažké šošovky. JEM-EUSO používa dve zakrivené obojstranné Fresnelove šošovky z UV priepustného plastu a jednu mikromriežkovú Fresnelovu šošovku. Tento dizajn umožňuje najvyššiu účinnosť širokého zorného poľa. Veľkosť trojitej šošovky je 2.5 m v priemere, zložený zo stredovej 1.5 m časti a kruhového povrchu prstencových šošoviek.



→ Konfigurácia stredovej šošovky a prestencových šošoviek umožňuje vytvoriť väčšiu šošovku než aká môže byť vytvorená na jednom stroji.

Vypustenie

Transportný dopravník agentúry JAXA pre kozmickú stanicu (HTV) nesie JEM-EUSO

HTV bude vypustený H-IIB raketou (JAXA) ktorá prenesie JEM-EUSO k ISS. Robotické ramená na ISS umiestnia JEM-EUSO na JEM modul "Kibo."

→ Transportný dopravník kozmickej stanice (HTV) prilieta k ISS. ©JAXA

Porovnanie JEM-EUSO **s najväčšími pozemnými observatóriami**

	AGASA	HiRes	Auger	Telescope Array	JEM-EUSO
Organizácia	Tókijská Univerzita	Univerzita v Utahu	Medzinárodné konzorcium	Tókijská Univerzita a Univerzita v Utahu	Medzinárodné konzorcium
Miesto	Yamanashi, Japonsko	Utah, USA	Argentína	Utah, USA	Medzinárodná vesmírna stanica
Typ detektorov	Pozemná sieť	Fluorescenčný pozemný teleskop	Pozemná sieť + Fluorescenčný pozemný teleskop	Pozemná sieť + Fluorescenčný pozemný teleskop	Fluorescenčný vesmírny teleskop
Doba prevádzky	1990～2004	1997～2006	2005～	2007～	Vypustenie očakávané v 2013
Efektívna apertúra (km²·sr)	150	500	～7,000	760	125,000
Výskyt EHE udalostí (počet/rok)	1, experimenty ukončené	Menej ako 1 experimenty ukončené	50 (očakávané), 3 (pozorované)	10 (očakávané)	350 – 1,700 (očakávané)

JEM-EUSO misia

Výška	okolo 400km	Počet pixelov ohniskového povrchu	okolo 0.2 miliónov
Pozorovacia dĺžka a šírka	N51°- S51° × všetky dĺžky	Rozlíšenie na zemi	okolo 0.8 km
Zorné pole	60°	Strieda	12～25%
Apertúra (pozemná plocha)	0.2 miliónov km^2	Trvanie misie	3 (+2) rokov
Priemer teleskopu	2.5 m	Celková hmotnosť	～1.9 ton
Optický Systém	Dve zakrivené obojstranné Fresnelove šošovky a vysoko-presné Fresnelove šošovky	Príkon	< 1kW

Medzinárodní Partneri

Japonsko	RIKEN Konan Univ. Fukui Tech. Univ. Aoyama Gakuin Univ. Saitama Univ. NIRS Univ. Tokyo Tohoku Univ. ICRR, Univ. Tokyo KEK Chiba Univ. NAOJ ISAS/JAXA Kanazawa Univ. Nagoya Univ. STE Lab., Nagoya Univ. Yukawa Inst., Kyoto Univ. Kyoto Univ. Kobe Univ. Kinki Univ. Hiroshima Univ. Hokkaido Univ Tokyo Inst. Tech.
USA	NASA/MSFC UAH LBL, UCB UCLA Vanderbilt Univ. Univ. Arizona.
Francúzsko	APC-Paris 7 LAL, IN2P3-CNRS
Nemecko	MPI Munich Univ. Tuebingen MPI Bonn Univ. Erlangen LMU&MPQ
Taliansko	Univ. Florence Univ. Naples Univ. Palermo Univ. Rome "Tor Vergata" Univ. Turin INOA/CNR IASF-PA/INAF IFSI-TO/INAF INFN
Mexiko	ICN-UNAM BUAP UMSNH
Kórejska republika	Ehwa W. Univ. Yonsei Univ.
Rusko	SINP MSU Dubna JINR
Švajčiarsko	Neuchatel, CSEM IACETH
Španielsko	Univ. Alcalá
Poľsko	IPJ Podlasie Univ. Kielce Univ. Jagiellonian Univ.
Slovensko	Inst. Experimental Physics, Košice

Spolupáca JEM-EUSO

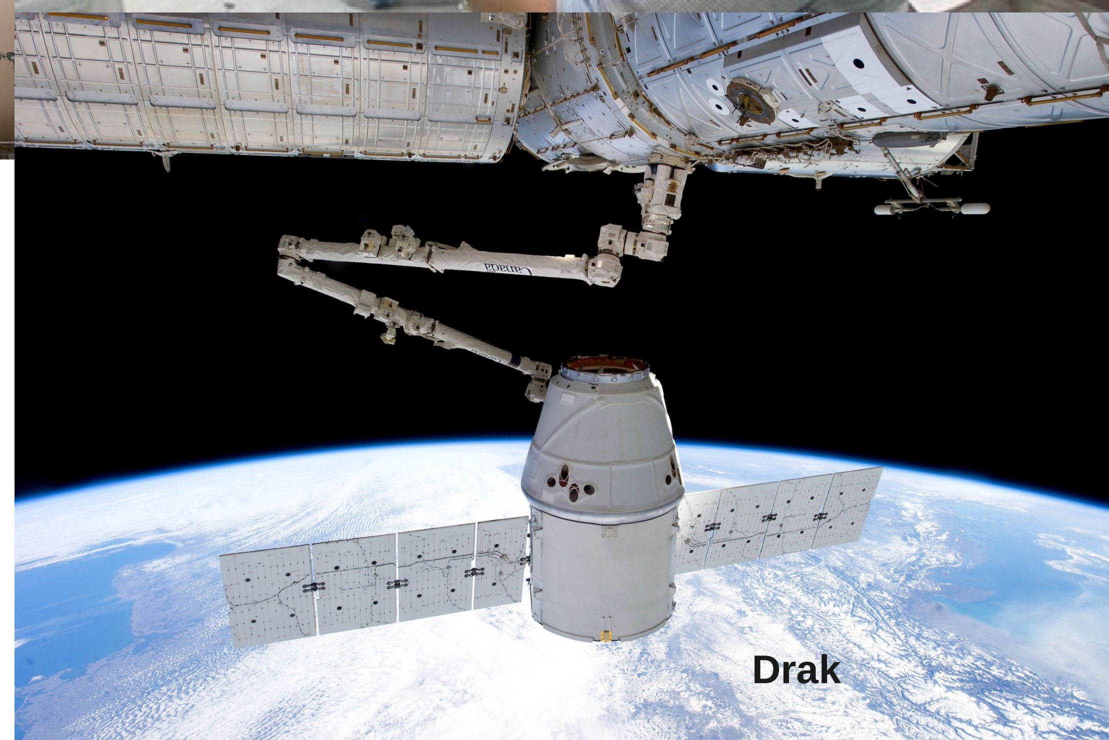
Japonsko
Computational Astrophysics Laboratory, RIKEN
2-1 Hirosawa, Wako, Saitama 351-0198 Japan
Tel: +81-48-467-9417 Fax: +81-48-467-4078
E-mail : jem-euso-staff@riken.jp URL : http://jemeuso.riken.jp/

Slovensko
Ústav Experimentálnej Fyziky, Košice
Watsonova 47, 040 01 Košice, Slovensko
Tel : +421 55 622 45 54 Fax: +421 55 633 62 92
E-mail : jem-euso@saske.sk URL : http://space.saske.sk/

Alternatíva k HII-B / HTV :: SpaceX / Falcon 9 / Dragon

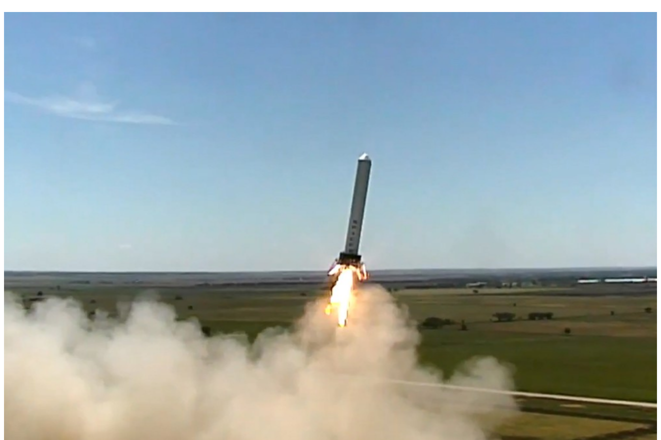
Sokol 9

Elon Musk

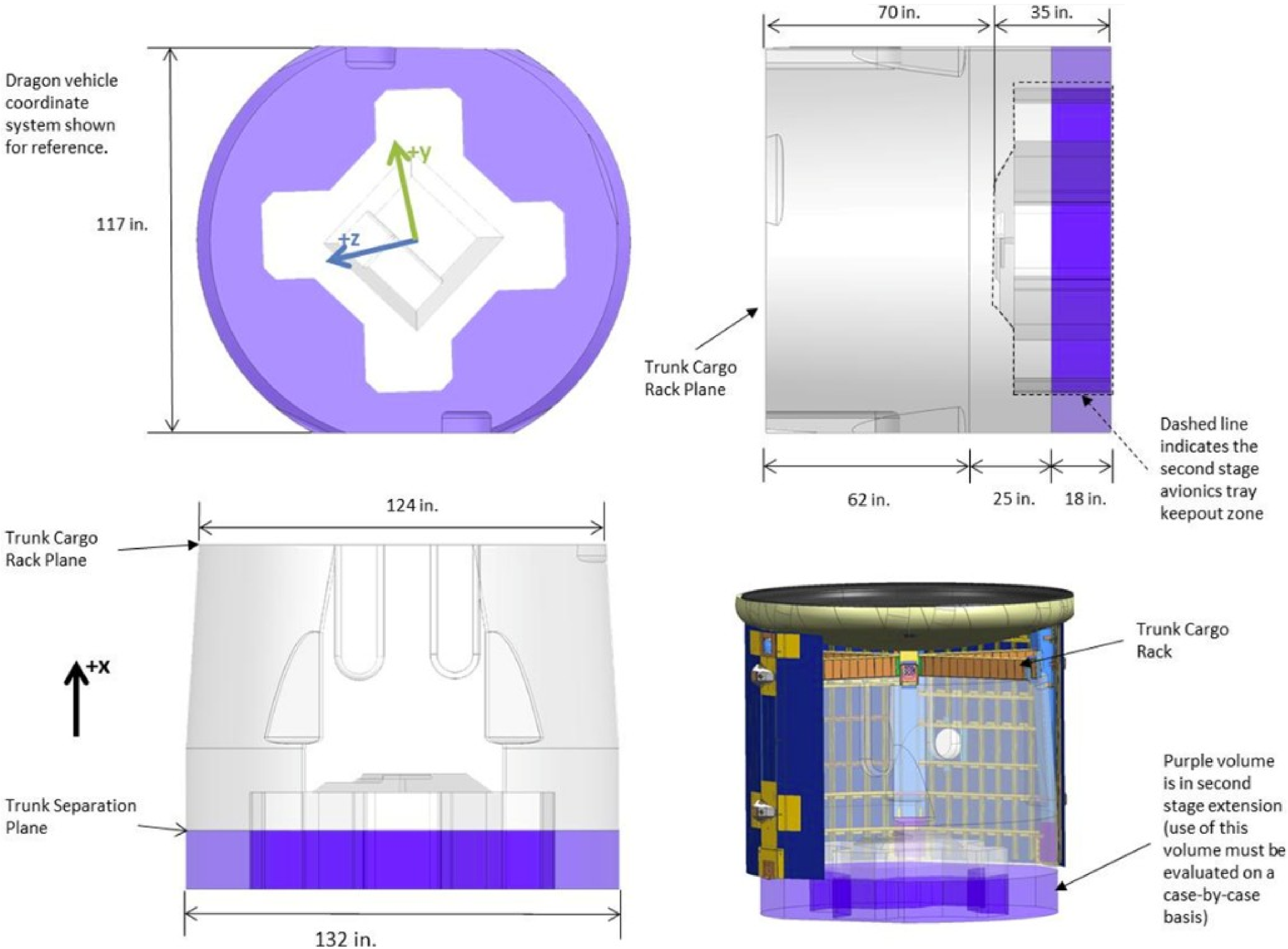


Drak

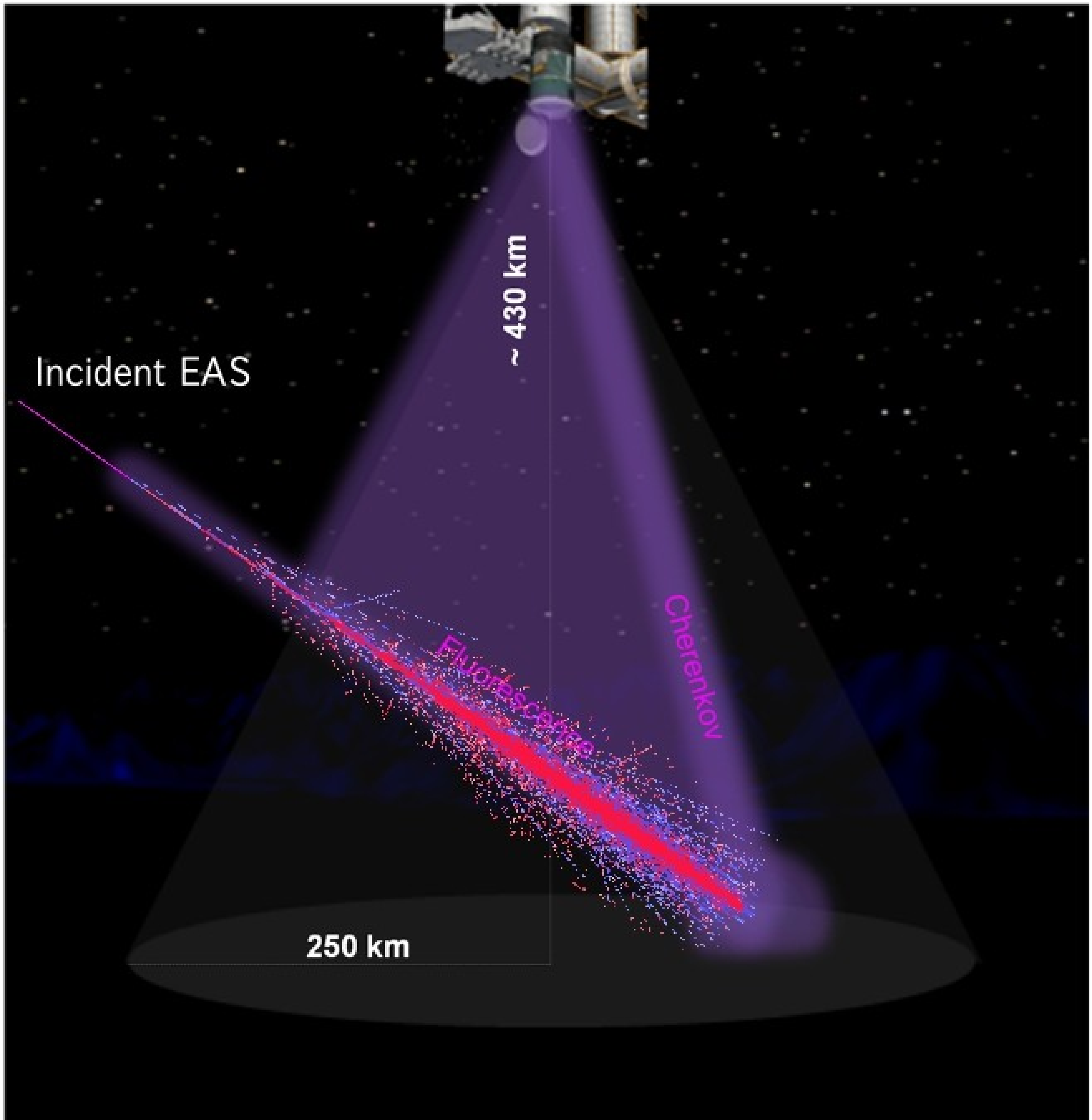
Lúčný koník



Kufor Draka

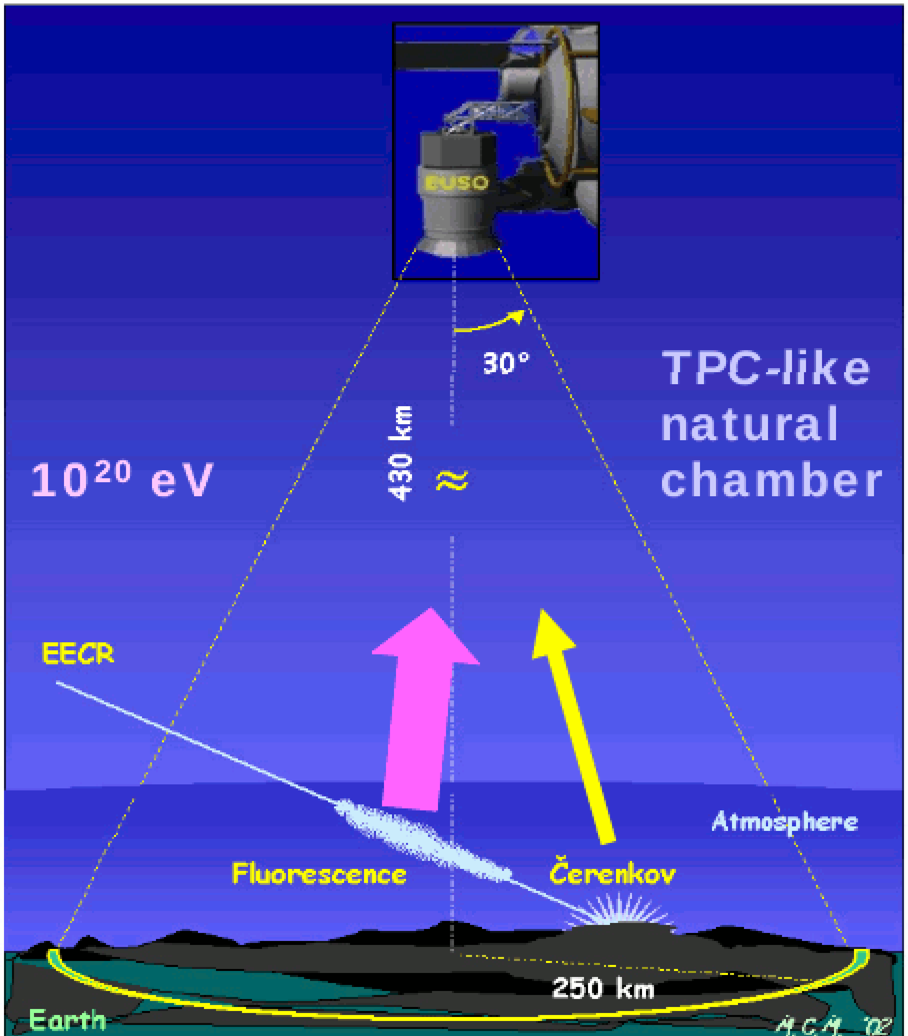

Dragon vehicle coordinate system shown for reference.
117 in.
+y
+z
70 in.
35 in.
Trunk Cargo Rack Plane
62 in.
25 in.
18 in.
Dashed line indicates the second stage avionics tray keepout zone
124 in.
Trunk Cargo Rack Plane
+x
Trunk Separation Plane
132 in.
Trunk Cargo Rack
Purple volume is in second stage extension (use of this volume must be evaluated on a case-by-case basis)

JEM-EUSO Observational Approach



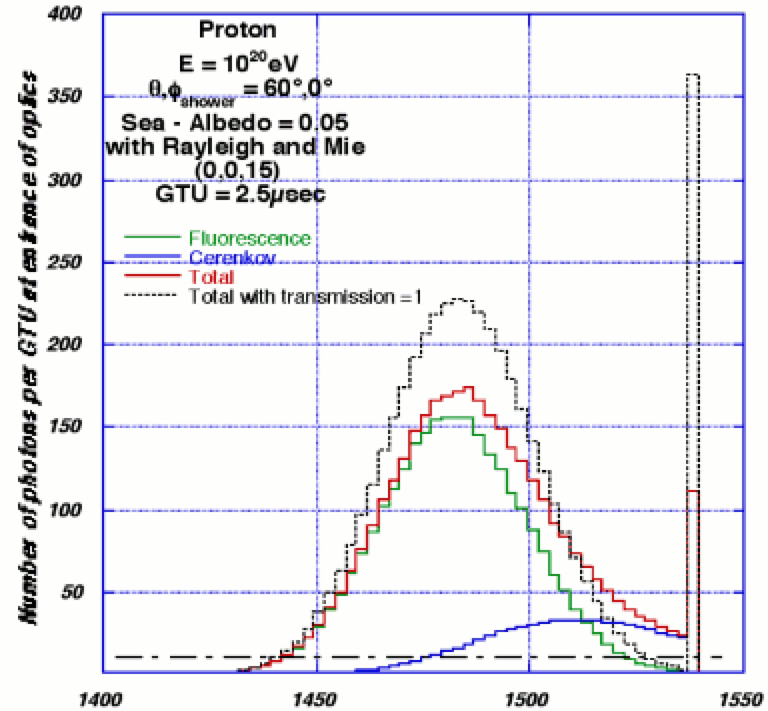
Principle of EUSO

- first *remote-sensing* from space, opening a new window for the highest energy regime

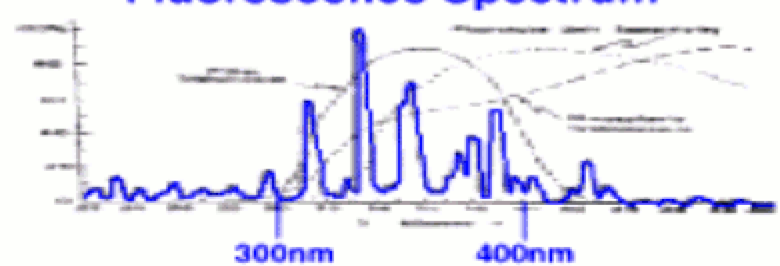


Cf: Ground-based arrays < 0.01 EUSO

(1) Scintillator array,(2)Fluorescence telescope array

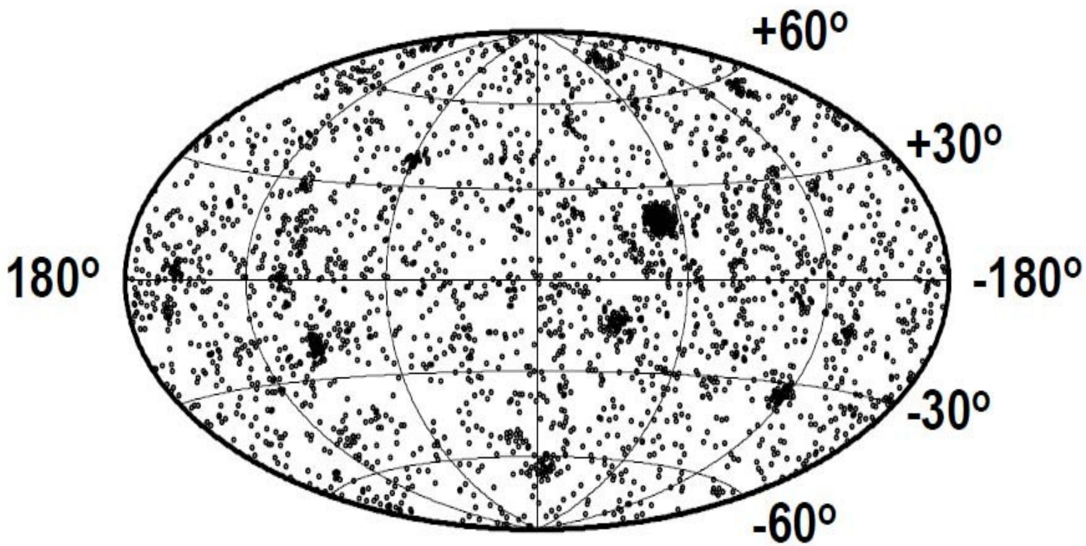


Fluorescence Spectrum

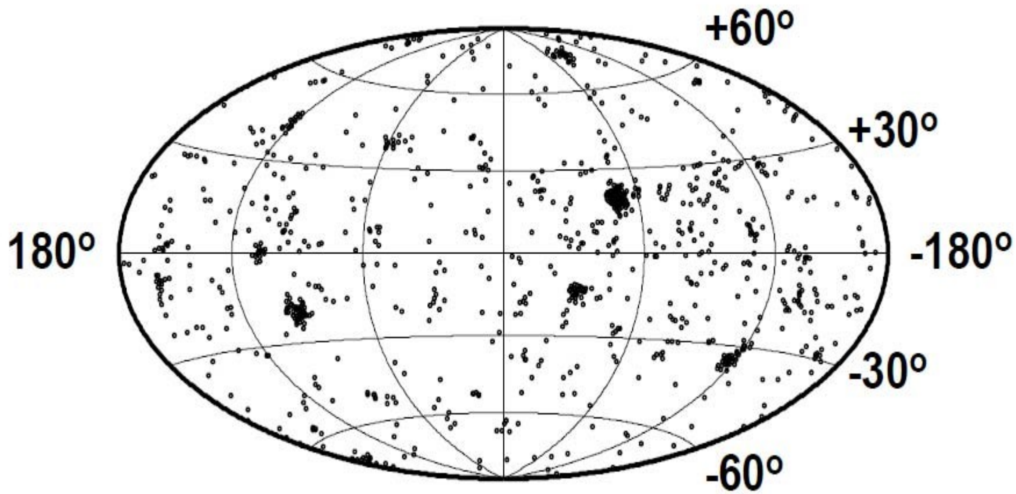


From College de France: better data now

Simulácia predokladajúca že zdrojmi sú Aktívne Jadrá Galaxií



3000 eventov
E > 5 10^{19}eV



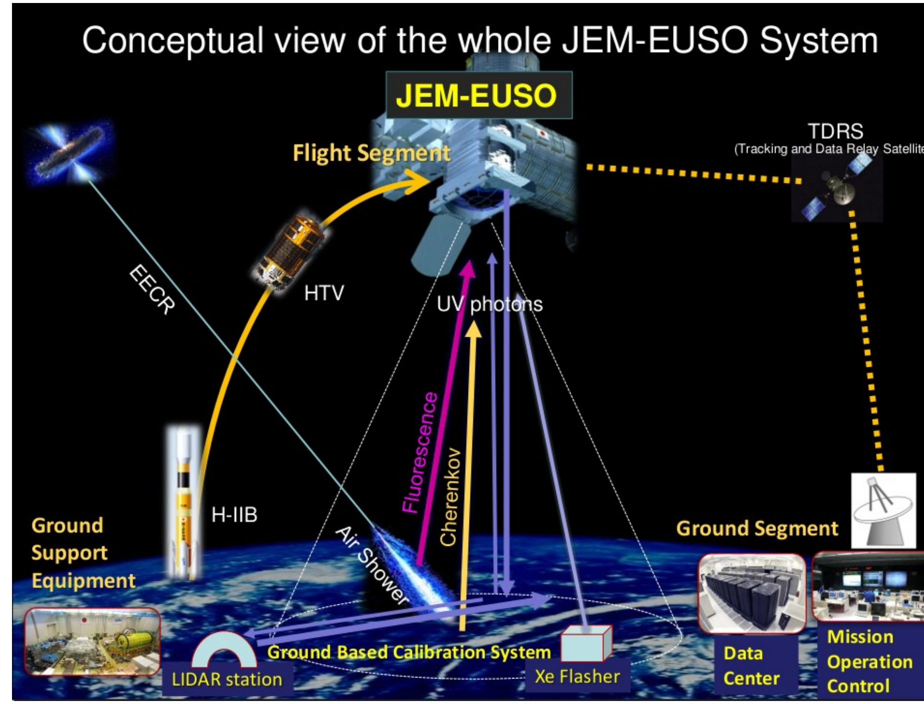
1000 eventov
E > 7 10^{19}eV

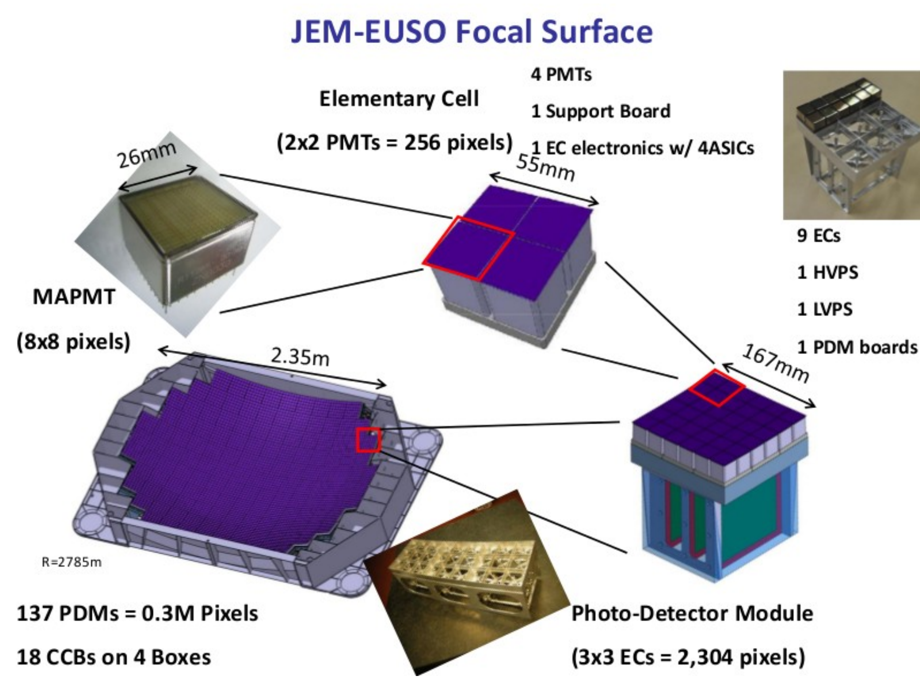
JEM-EUSO

- JEM-EUSO balón - stratosférický balón – 1 PDM, 2014

- JEM-EUSO TA, jar/2015

- JEM EUSO ISS - let po 2020

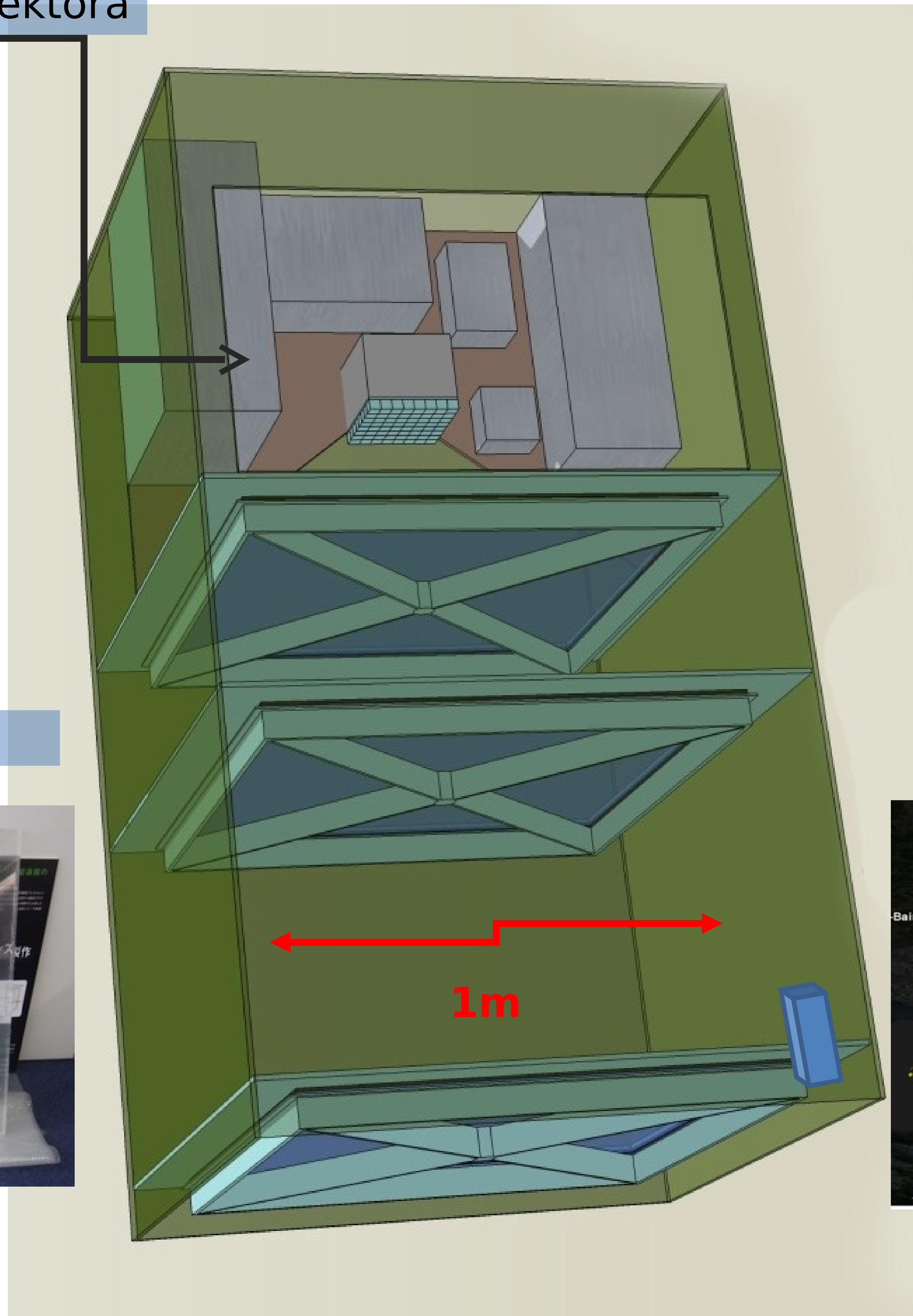




Elektronika detektora

EUSO balón

august 2014

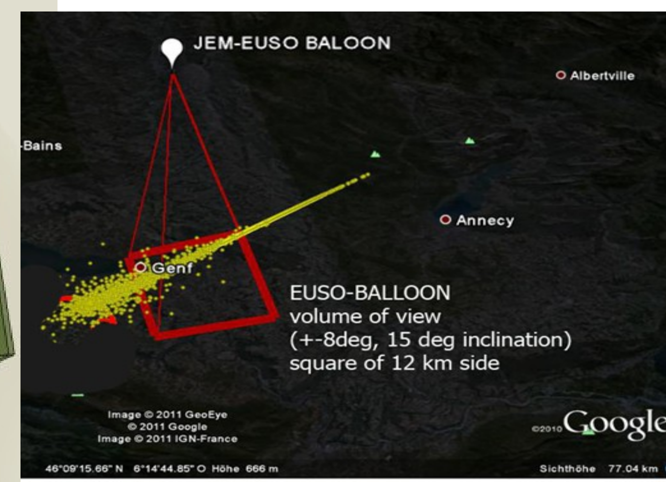


Šošovky

Prvý JEM-EUSO prekurzor experiment

- šošovky 1 m^2
- 1 PMD
~300 kg
- vodotesná gondola
- letová hladina ~38 km

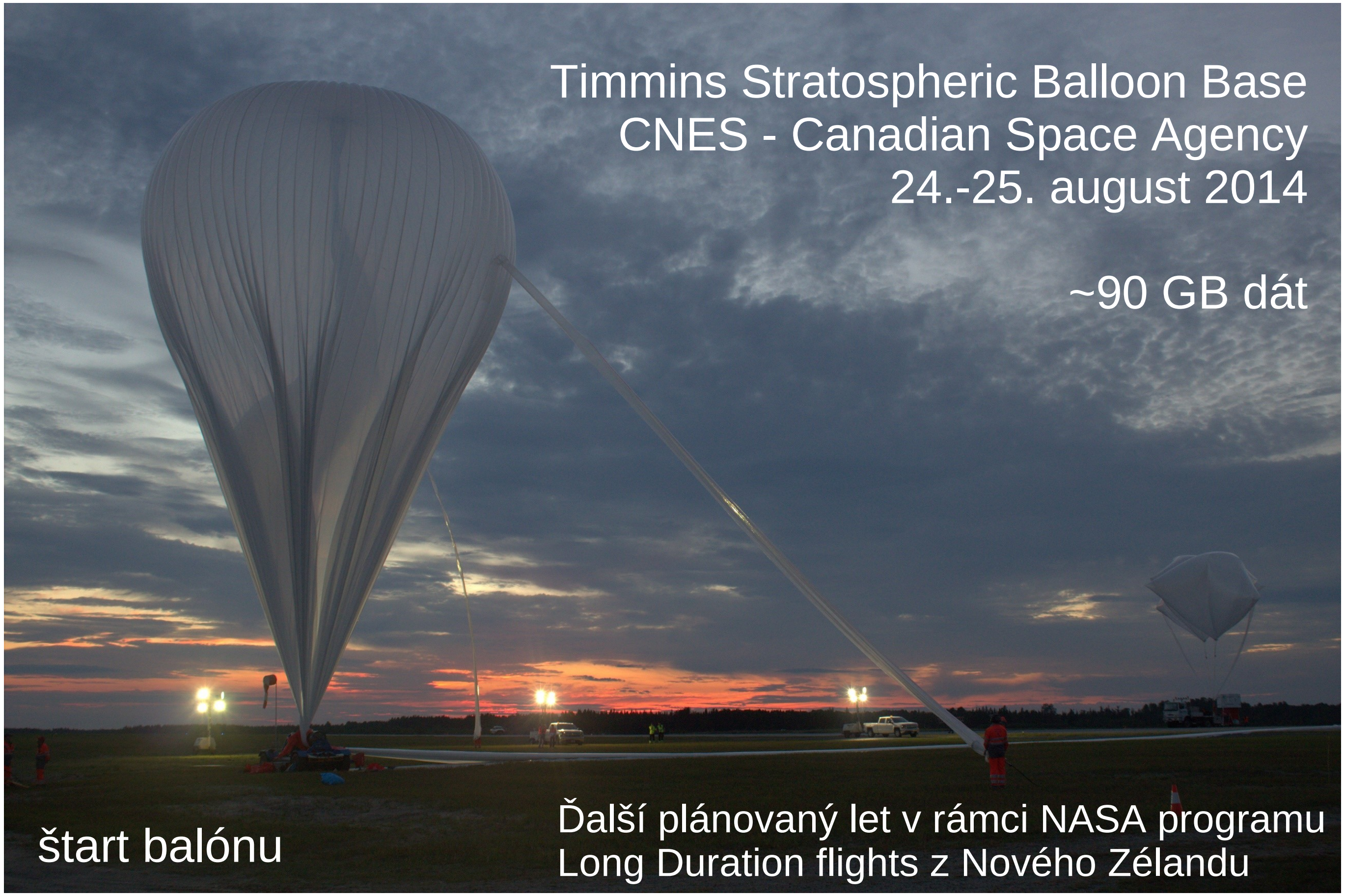
Výber z hlavných cieľov prekurzor experimentu
- overenie hw v podmienkach blízkych vesmírnym podmienkam
- meranie UV pozadia za rôznych pomienok
- verifikácia trigerovacej schémy experimentu



Simulácie


moving into the CU hall at Timmins 12.8.2014!

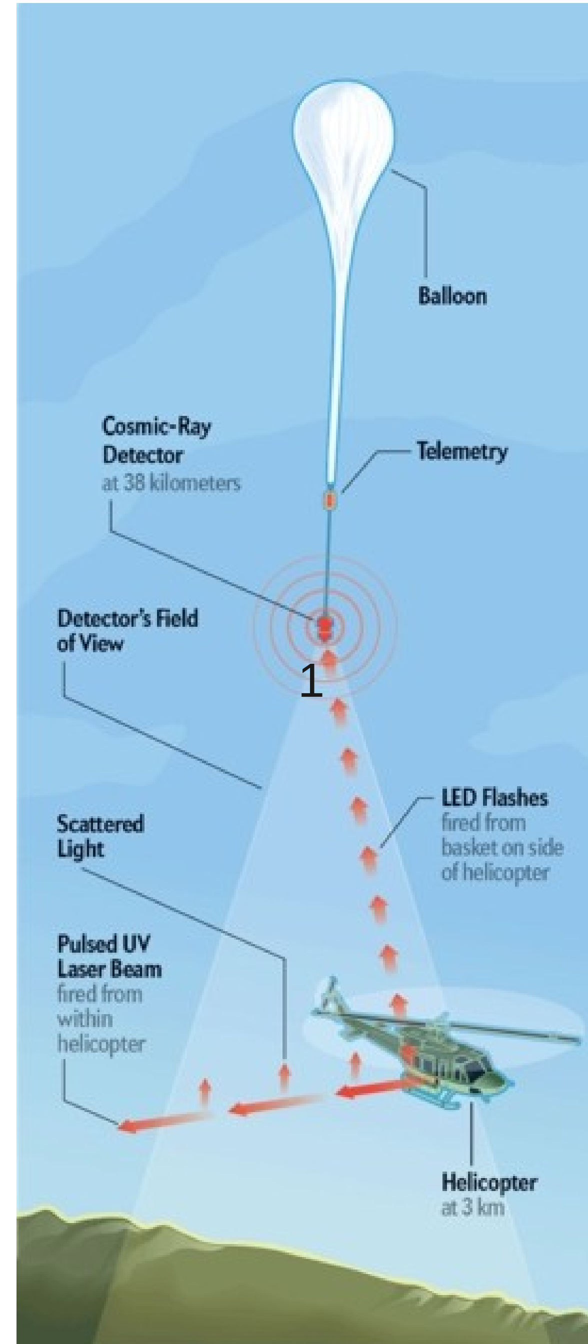

flight configuration : 18.8.2014



štart balónu

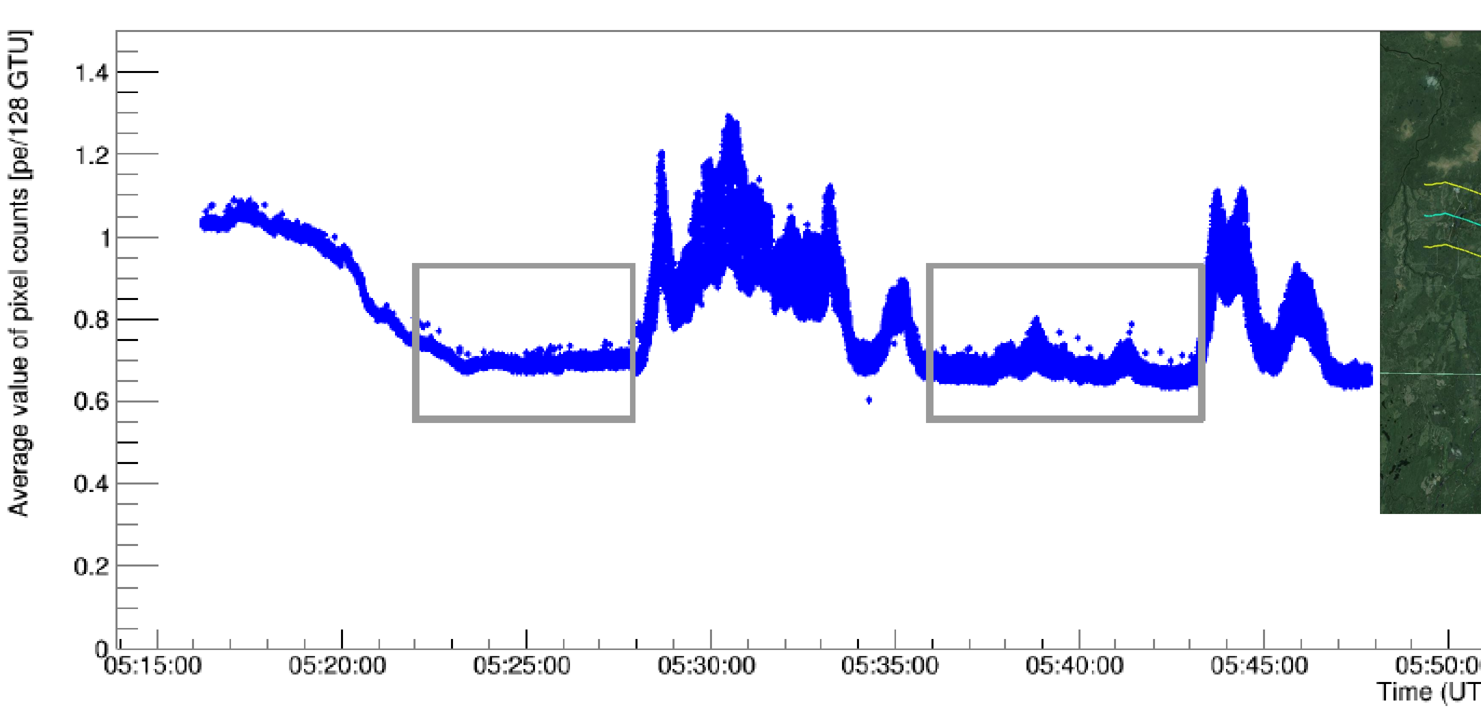
gondola v hangári

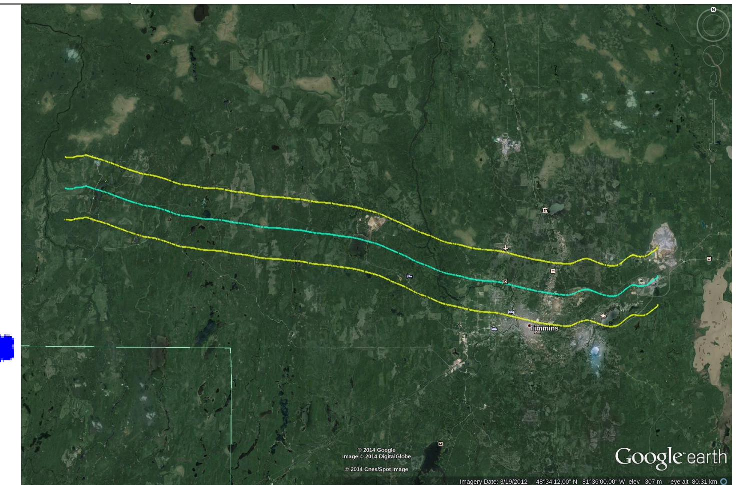
pristátie v jazere



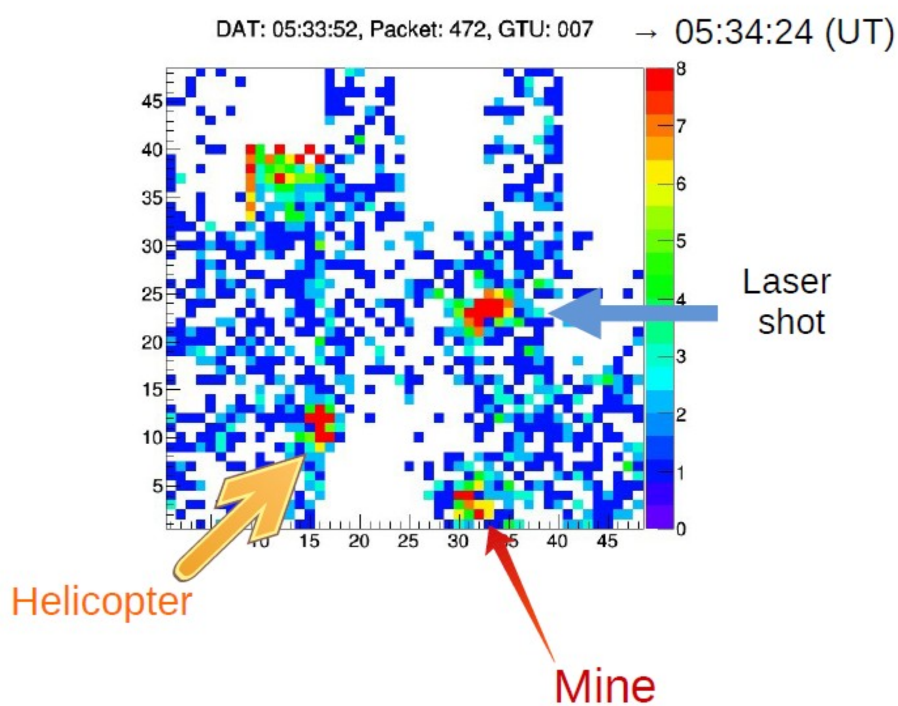
Článok v Scientific American:
Cosmic-RayTelescope Flies High

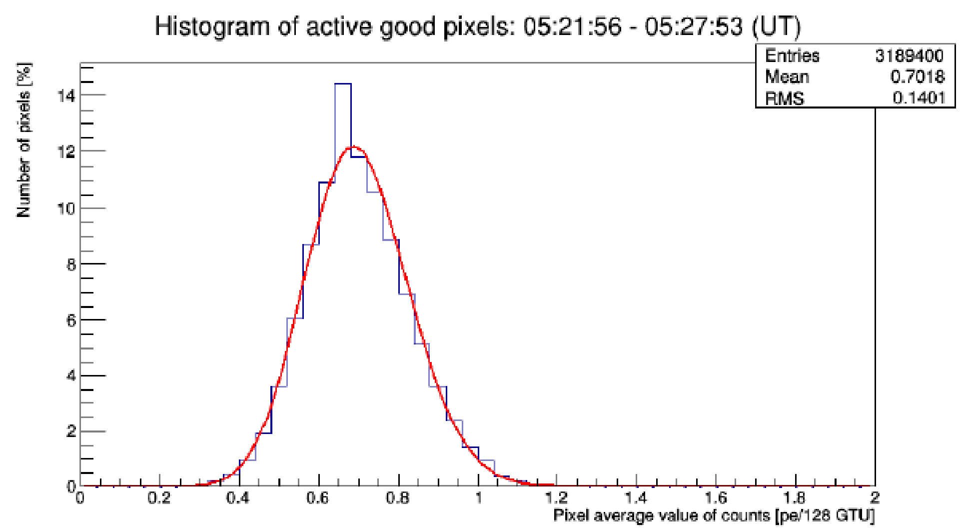
Spracovanie údajov z JEM-EUSO balónu





Prvé publikované výsledky ~jar/leto 2015





Fitted by Poisson distribution with $\lambda = 0.699$

Duty cycle estimation

UV light sources

If background 1500 ph/(m^2 ns sr) is allowed [in % of total time on orbit]

- sun
- moon

$\left.\right\}$ **~ 21-22 %**

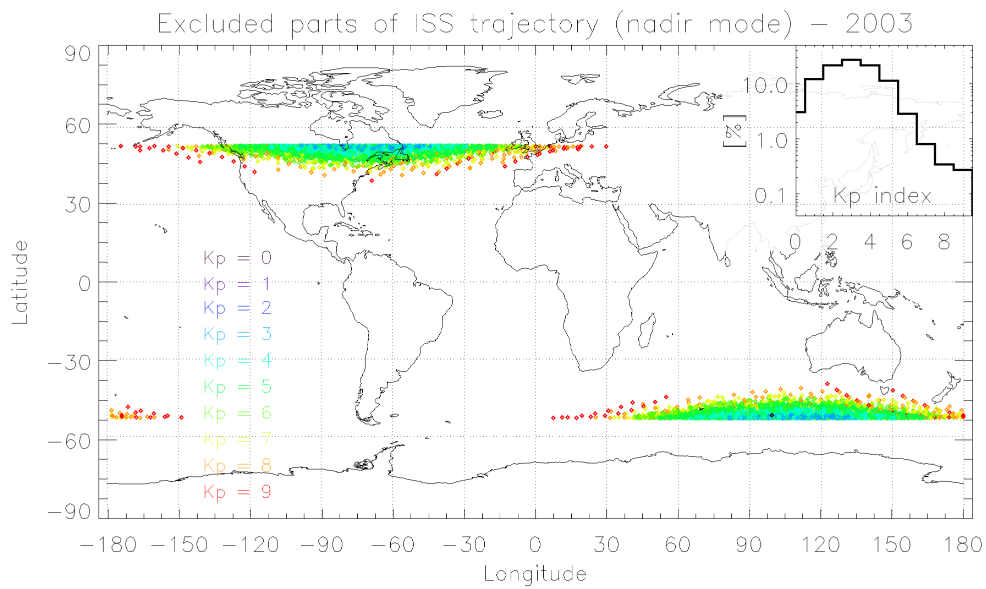
- airglow/nightglow
- zodiacal light
- integrated faint star light

$\left.\right\}$ **~ 20-21%**

- Boreal/austral auroras **~ 1%**
- South Atlantic anomaly **small**
- Lightning and TLEs **~ 2%**
- artificial sources (Anthropogenic / city light) **~ 9%**

Duty cycle estimation

Auroras effect on JEM-EUSO operational efficiency



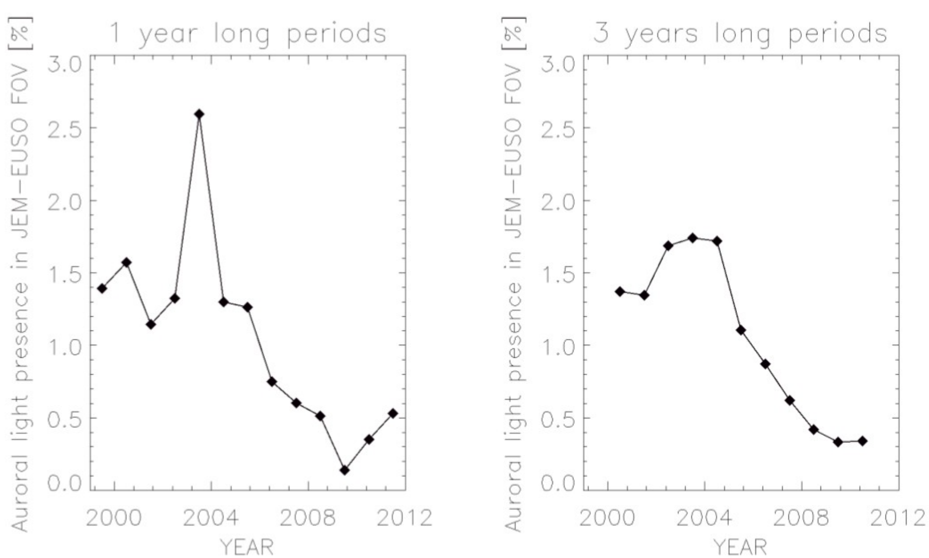
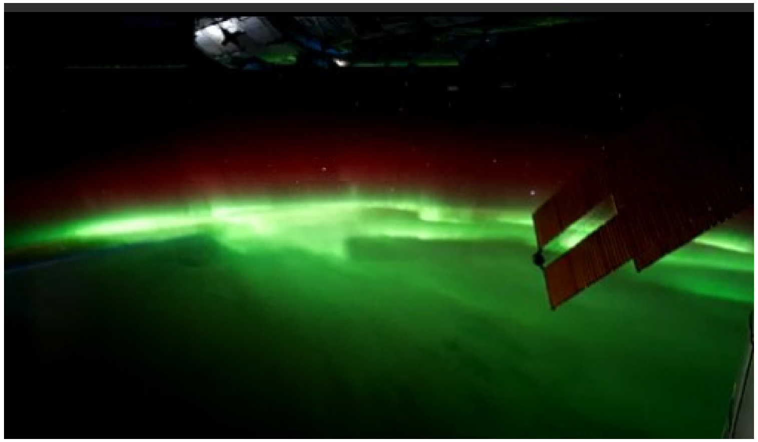
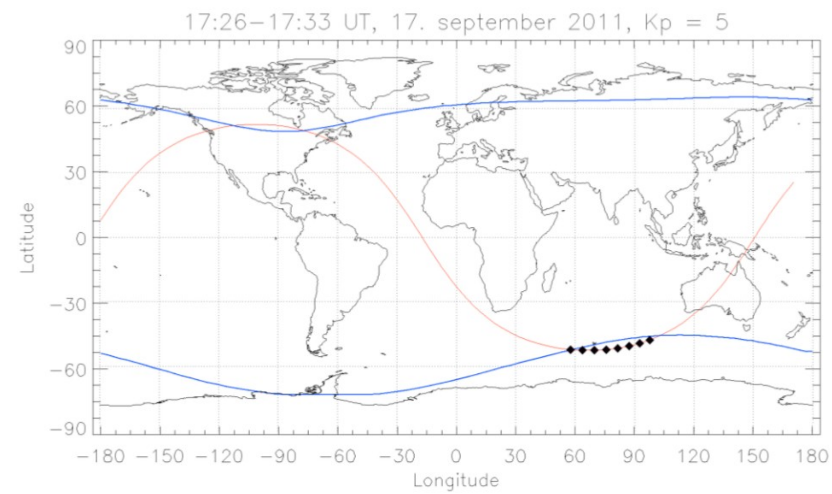


Figure 3: Left panel: Fraction of time f_{AL} in which auroral light restrain EAS measurements for one year long periods from 2000 to 2011. Right panel: Same as in the left panel, but integrating for 3-year periods.



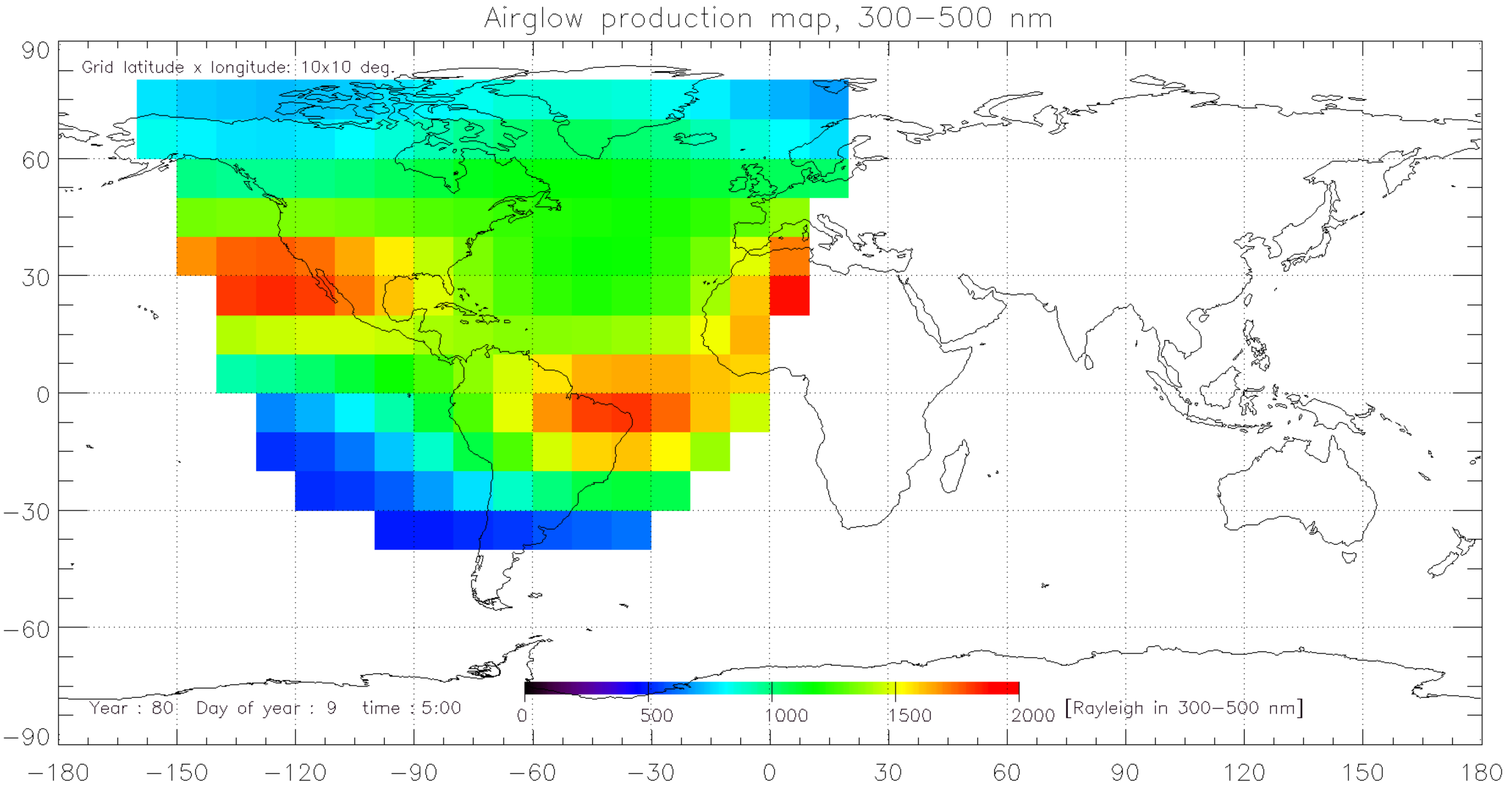


V rokoch 2017–2019 pravdepodobne ďalšie hlboké solárne minimum- **efekt aurororálneho svetla na meranie EAS ~ 1%** .

Advances in Space Research článok

Vývoj modelu UV pozadia

- skladá sa z modelov zdrojov svetla na nočnej strane Zeme a modelu radiačného transferu



AURIC model, D. J. Strickland et al. Journal of Quantitative Spectroscopy and Radiative Transfer 62 (1999) 689-742, doi:10.1016/S0022-4073(98)00098-3

Príklady výsledkov

Night time measurement of the UV background by EUSO-Balloon

Author(s): MACKOVJAK, Simon[1]
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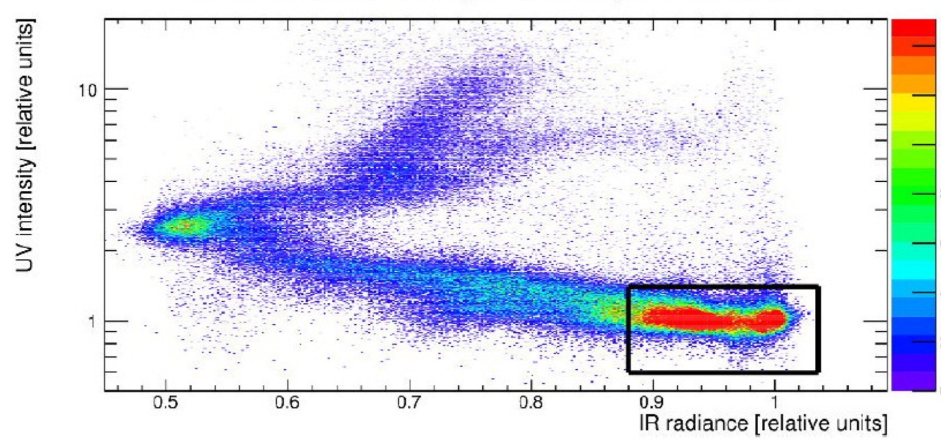
Precise characterization of the Earth night side UV background is essential for observation of the ultra-high-energy cosmic ray induced extensive air showers (EAS) from the space. We have analyzed data from the flight of EUSO-Balloon pathfinder mission that took place near Timmins (Canada) in the moonless night from 24^{th} to 25^{th} August 2014. The EUSO-balloon telescope imaged the UV background in the wavelength range 290–430 nm from the altitude ~38 km with a 1 m^2 refractor telescope with 11.5° field-of-view pointed in nadir direction. The UV data were complemented by the data of the Infrared (IR) camera onboard EUSO-balloon, which operated in the wavelength ranges 10.37–11.22 μm and 11.57–12.42 μm. We have combined the UV and IR images to study the upward UV radiance from the Earth surface and Earth atmosphere. This allowed us to estimate UV background in clear atmosphere conditions without man-made lights and also to investigate influence of clouds on the UV background values. The obtained UV intensity for clear atmosphere conditions is in a good agreement with previous BaBy and NIGHTGLOW balloon measurements. Comparison of the UV and IR images reveals a strong dependence of the upward UV radiance on the atmospheric conditions, so we discuss the possibility to use the UV albedo effect for characterization of the clouds. For estimating the observation efficiency of EAS from space by EUSO like detectors, it is important to determine the time variation of average UV background intensity, cloud distribution and local man-made light. Using available data, we also discuss these key factors that determine the observable time and area for EAS observation.

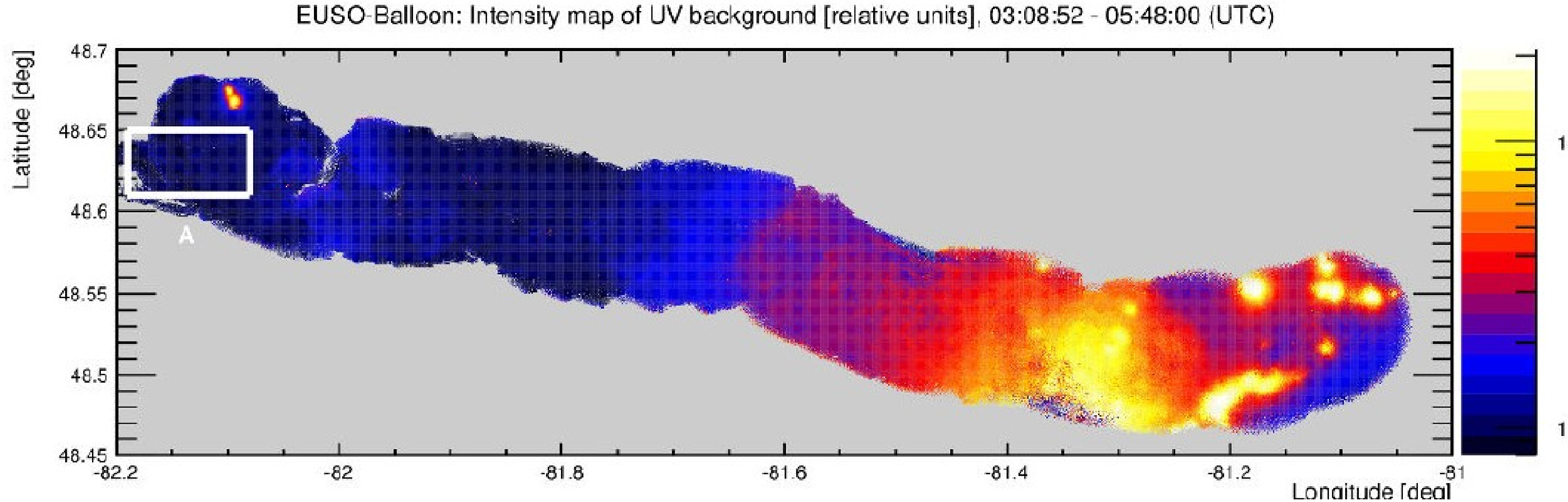
Main results

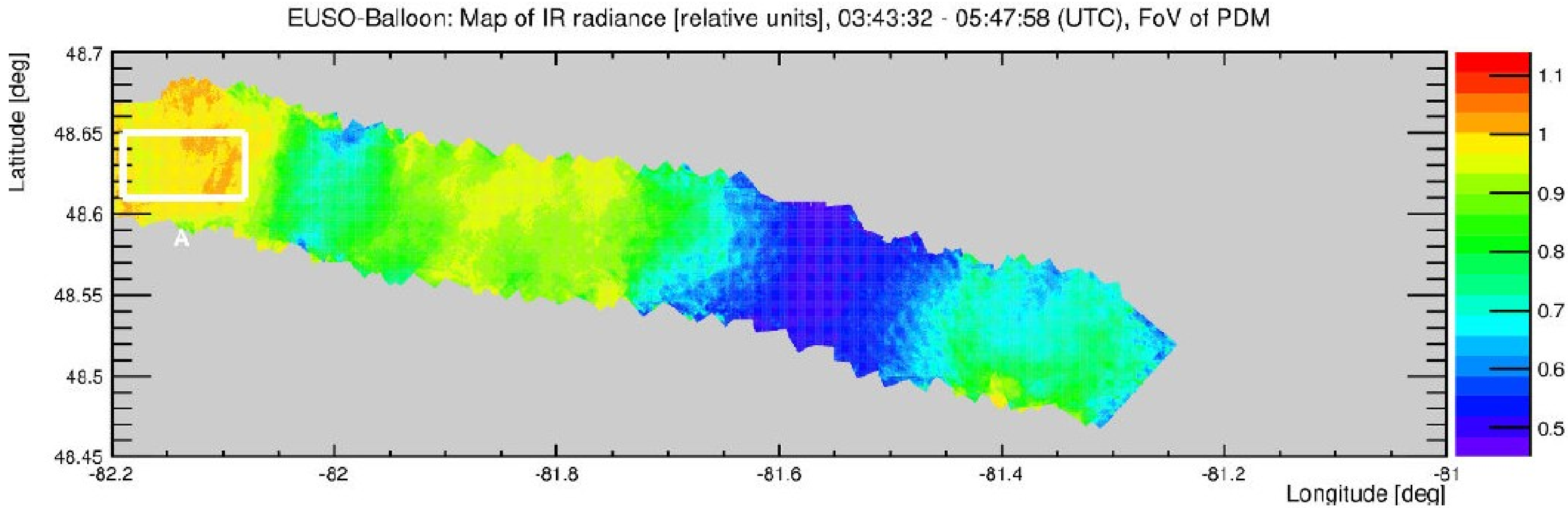
- EUSO-Balloon is the first mission that imaged the UV background in different atmospheric conditions, well monitored by dedicated Infrared Camera
- An anti-correlation between UV and IR up-going radiation was found and an evident dependence of the UV background on atmospheric conditions was revealed
- The tool for masking the regions affected by clouds and manmade light in the FoV is prepared to fulfill the requirements for a high quality detection of UHECR

Anti-correlation of UV background intensity with IR radiance



34^{th} International Cosmic Ray Conference (ICRC), July 30 to August 6, 2015, Hague, Netherlands





- The displayed values are relative to the mean value of *I* BG over reference area “A” (white box)
- Pixels with the lowest IBG and the highest IR radiance correspond to clear atmosphere
- The clouds have higher albedo than ground and increased IBG values
- The pixels affected by man-made lights (the city Timmins with

Príklady výsledkov

Pattern recognition study for different levels of UV background in JEM-EUSO experiment

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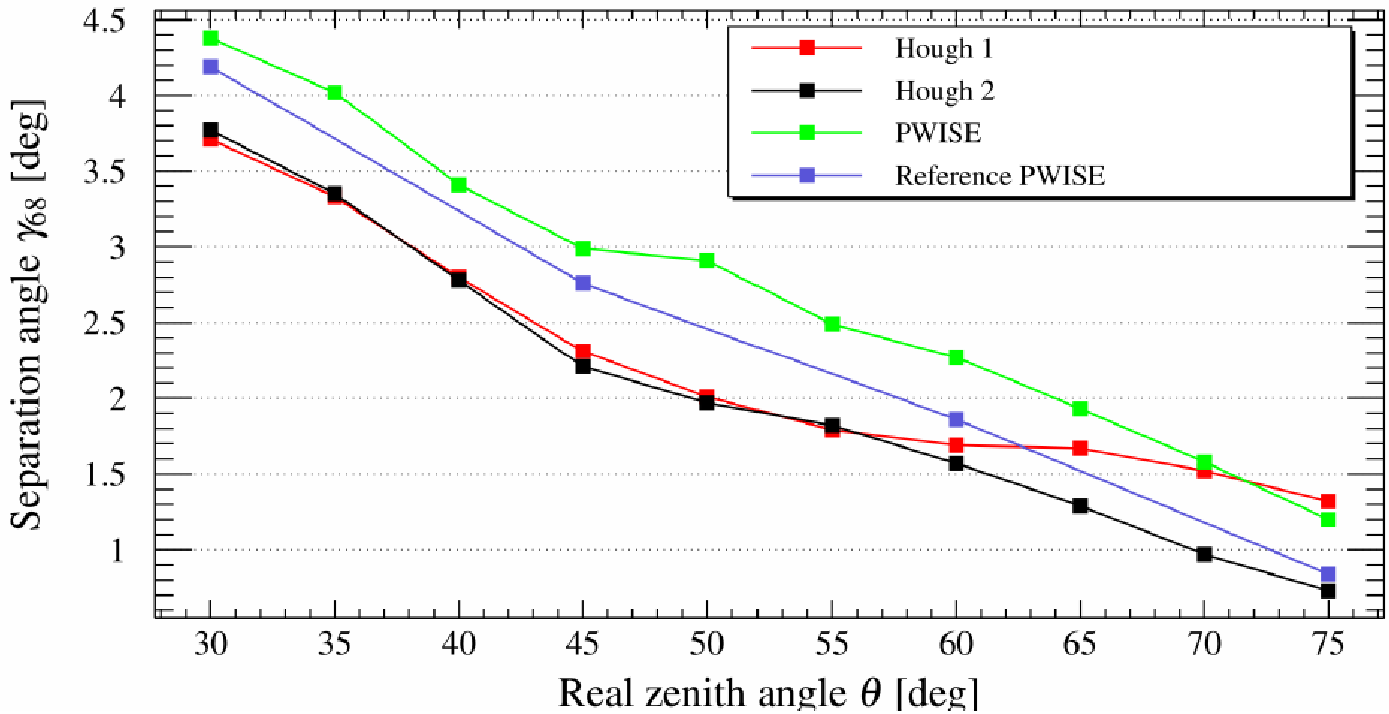
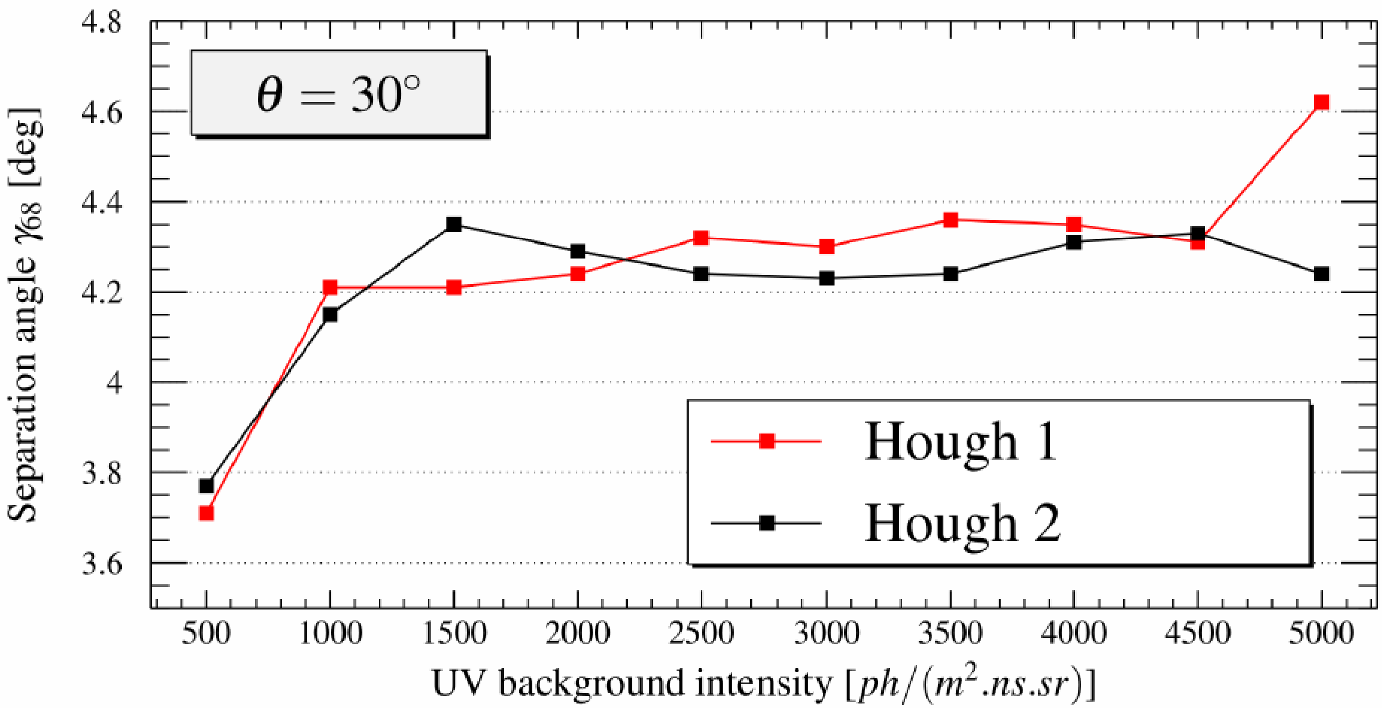
JEM-EUSO experiment will observe UV light created by extensive air showers initiated by ultra high energy cosmic rays (UHECR). Reconstruction of UHECR particle direction from detected signal depends also on the level of signal background, which can vary in time and with location.
We developed an alternative pattern recognition (PR) method based on Hough transformation besides to existing PR methods in JEM-EUSO software framework. The results of them, namely of PWISE method and Hough method were compared for the nominal UV background 500 ph/(m2 ns sr). Hough method was used to evaluate UHECR direction reconstruction ability for higher level of the UV backgrounds on the Earth's night side. The study what impact on fake trigger events rate come from varying background levels was performed, too.

34th International Cosmic Ray Conference (ICRC), July 30 to August 6, 2015, Hague, Netherlands



Hough 1
Hough 2
PWISE
Reference PWISE
Separation angle γ_{68} [deg]
Real zenith angle θ [deg]
4.5
4
3.5
3
2.5
2
1.5
1
30
35
40
45
50
55
60
65
70
75

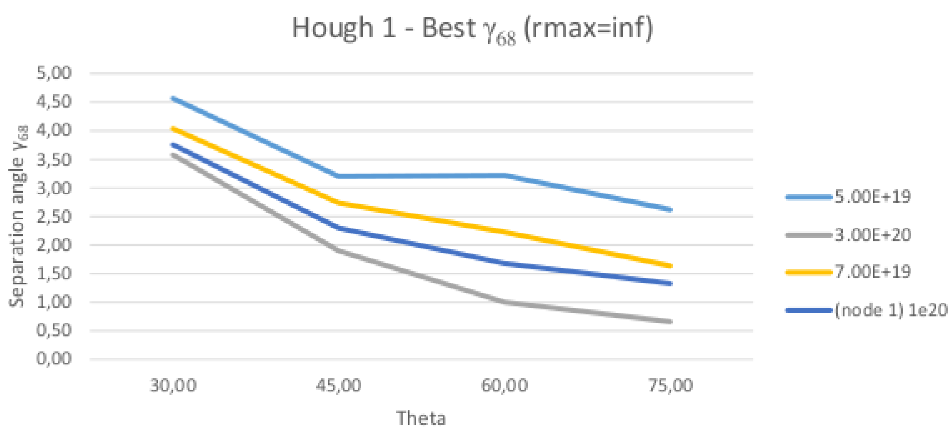


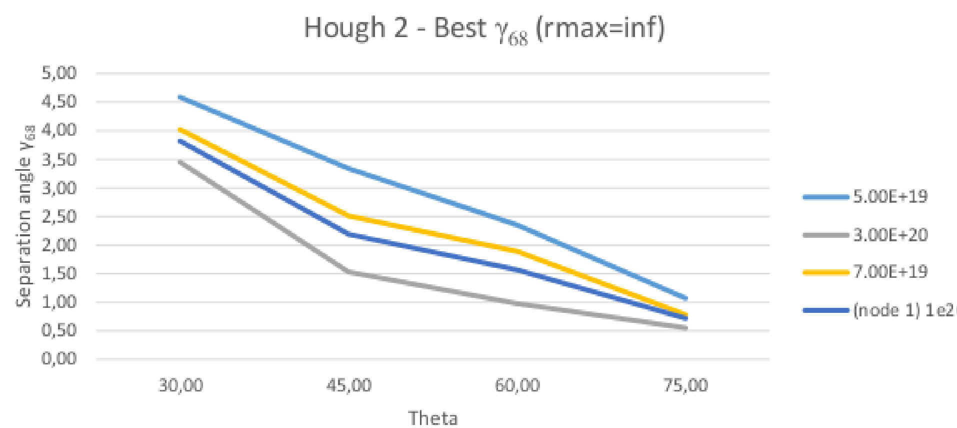
$\theta = 30°$
Hough 1
Hough 2
Separation angle γ_{68} [deg]
UV background intensity $[ph/(m^2.ns.sr)]$
4.8
4.6
4.4
4.2
4
3.8
3.6
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

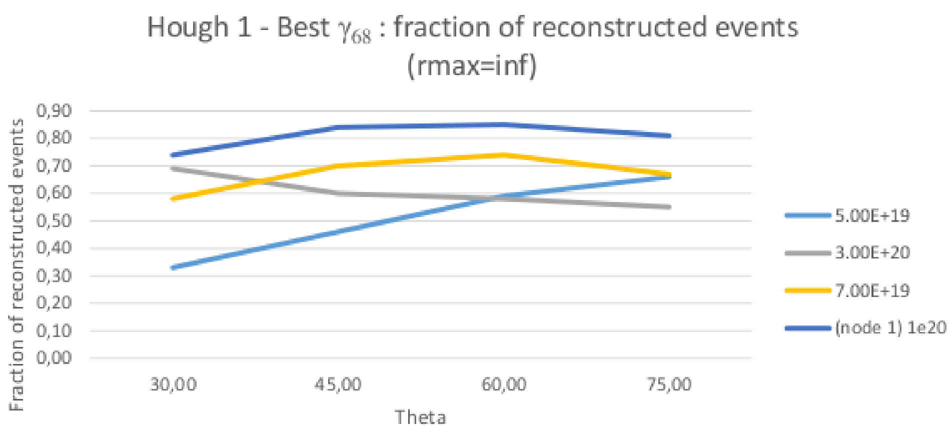
Príklady výsledkov

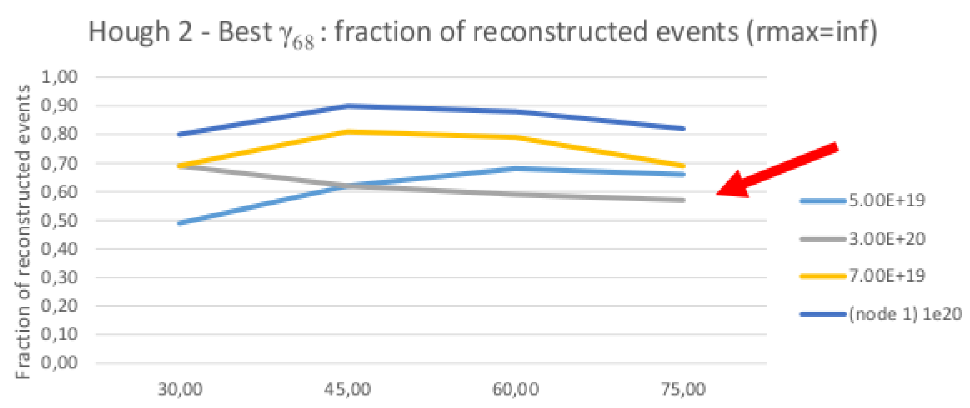
Precision of angular reconstruction (1)

energy of primary particle ... eV ; background **500** ph/(m² ns sr)







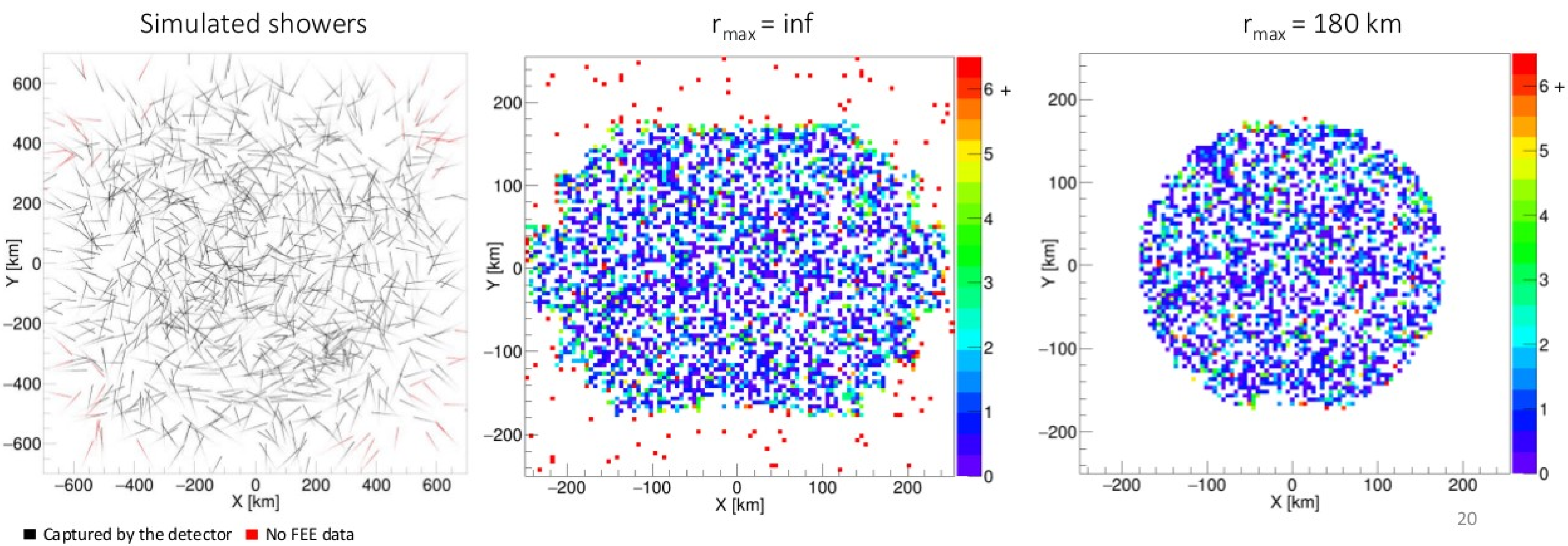


Príklady výsledkov

Precision of angular reconstruction (3)

energy of primary particle ... eV ; background **500** ph/(m^2 ns sr)

γ vs. position of shower maximum



20

M. Vrábel, The 18th International JEM-EUSO collaboration meeting @Stockholm, Sweden

Evaluation of scientific performance of JEM-EUSO mission with Space-X Dragon option

Author(s): Dr. SHINOZAKI, Kenji[1] ; Prof. SANTANGELO, Andrea[1]
Co-author(s): Mr. BAYER, Jörg [1] ; Dr. BERTAINA, Mario [2] ; Dr. BOBIK, Pavol [3] ; Dr. FENU, Francesco [2] ; Dr. GORODETZKY, Philippe [4] ; Mr. GUZMAN, Alejandro [1] ; Dr. HAUNGS, Andreas [5] ; Mr. IWOTSCHKIN, Elias [6] ; Prof. MEDINA TANCO, Gustavo [7] ; Dr. MERNIK, Thomas [6] ; Prof. NERONOV, Andrii [8] ; Prof. OLINTO, Angela [9] ; Dr. PASTIRCAK, Blahoslav [10] ; Dr. PUTIS, Marian [11] ; Prof. WIENCKE, Lawrence [12]

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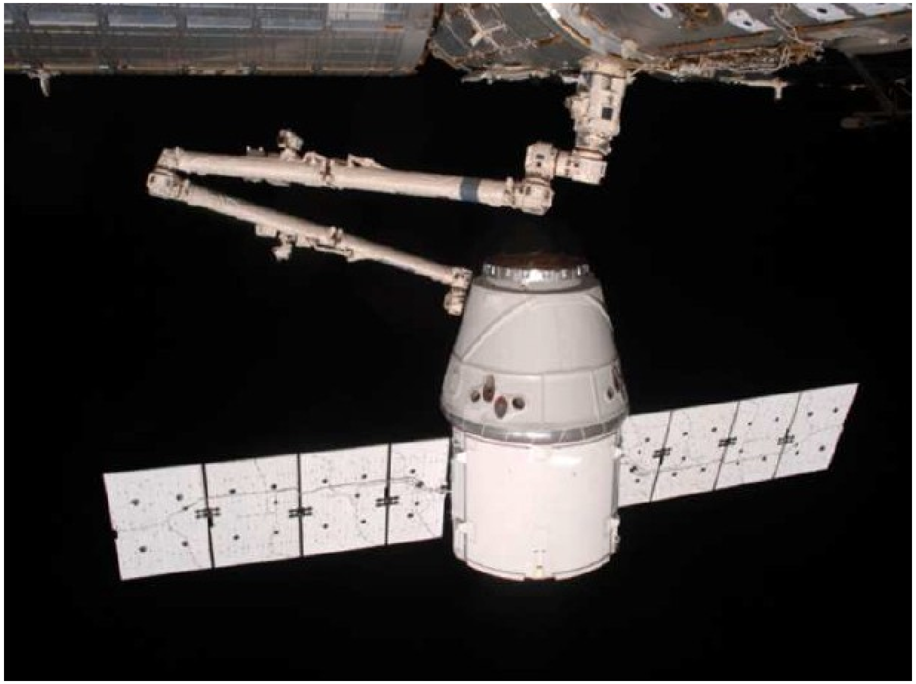
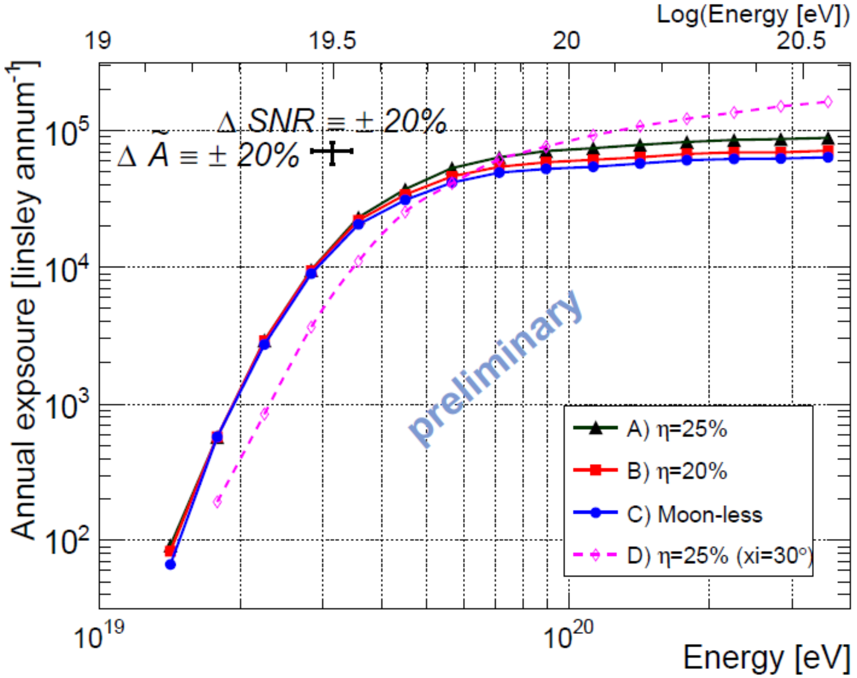
The Extreme Universe Space Observatory on-board the Japanese Experiment Module (JEM-EUSO) is a mission devoted to the observation of ultra-high energy cosmic rays (UHECRs) around and above the so-called Greisen-Zatseptin-Kuzimin energy at $\sim 5 \times 10^{19}$ eV. The origin of these enigmatically energetic cosmic rays remain an open question since their discovery more than 50 years ago. Very high statistics observations of UHECRs are essential to provide key information to answer this question. Very large exposure are indeed necessary to overcome their extremely low fluxes of an order of a few events per square kilometer per century. JEM-EUSO is designed to measure the extensive air showers induced by UHECRs using an super-wide field-of-view ultra-violet fluorescence telescope pointed downwards nighttime atmosphere. Orbiting onboard the International Space Station (ISS), JEM-EUSO rather uniformly covers the entire celestial sphere, allowing a thorough analysis of UHECR arrival direction distributions. In the present work, we introduce the current design of the JEM-EUSO telescope using the Space-X Falcon 9 as launcher and the Dragon as transport vehicle to the ISS. We then discuss the expected performances, and in particular the science of the search for the UHECR origin. Assuming the detector configuration based on the full-scale JEM-EUSO, the expected exposure and quality of arrival direction distribution analysis during the assumed mission lifetime are evaluated by simulation studies. We also preliminarily investigate an advanced scenario based on the use of silicon photomutiplers as focal surface detectors. Eventually we report the expected efficiency of UHECRs observation for these options including the expected sky map UHECRs.





EUSO-TA

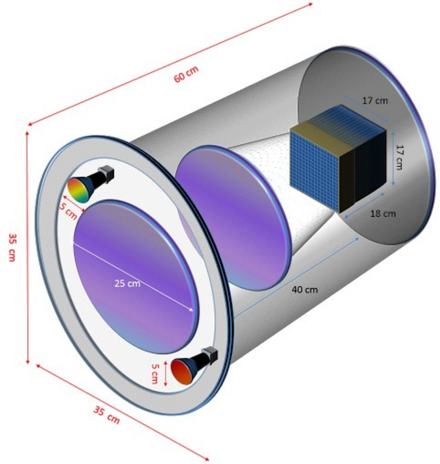
- Začiatok meraní: jar 2015
- Black Rock Mesa, Utah, pri Telescope Array experimente
- Vývoj a overenie funkčnosti hardvéru a softvéru, kalibrácia, pozorovanie pozadia pod vysokým zenitovým uhlom

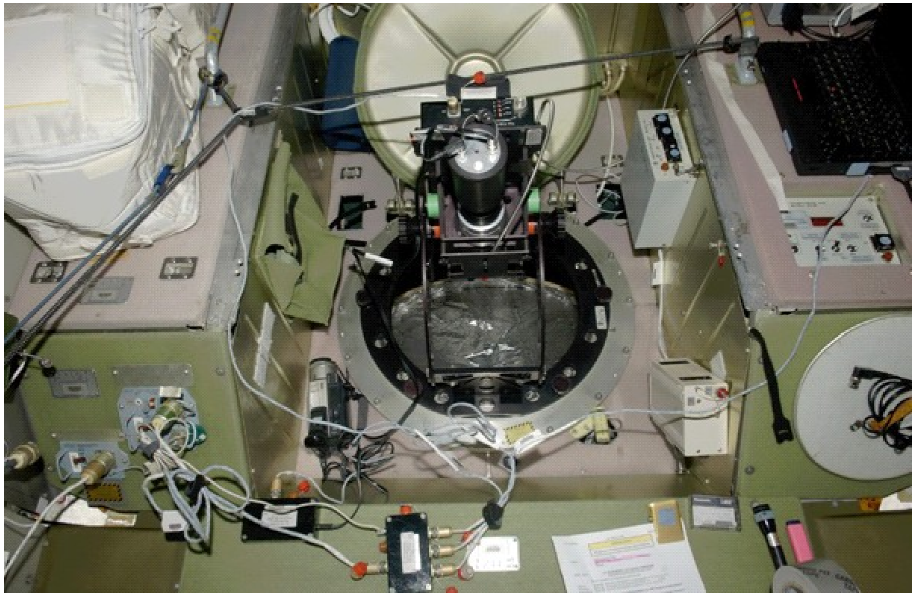
EUSO Super Pressure Balloon
EUSO-SPB

- Štart: apríl 2017
- Dĺžka letu: ~50 dní
- Letová výška: 36,6 km
- Hmotnosť vedeckého nákladu: ~600 kg
- Predpokladaný počet pozorovaných EAS: 100

Mini-EUSO

- Štart: koniec roka 2018
- Umiestnenie v UV priepustnom okne ISS
- Hmotnosť vedeckého nákladu: ~30 kg
- Pozorovanie
  - UV pozadia
  - TLE
  - bioluminiscencia

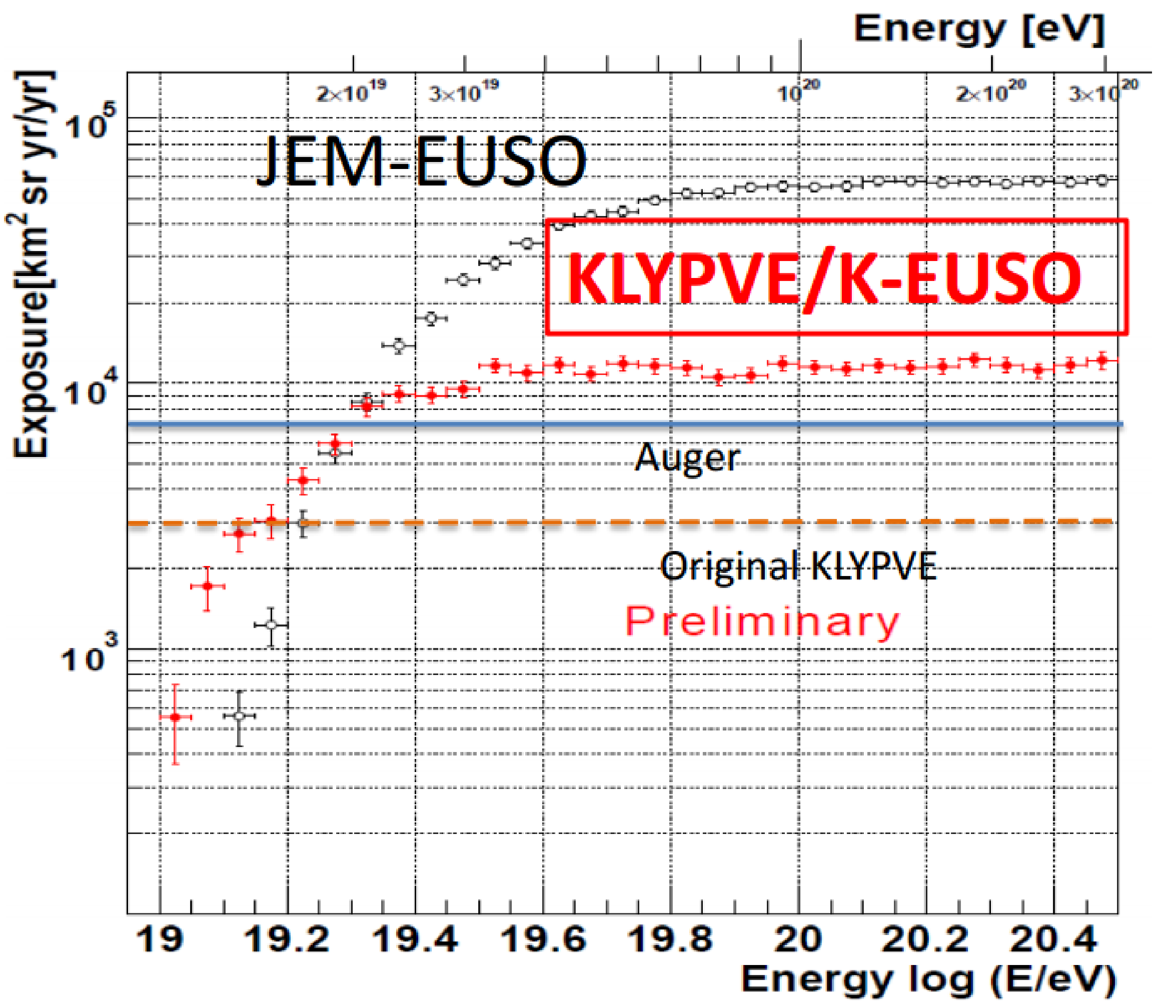




K-EUSO

- KLYPVE projekt
- Štart: 2020
- Meranie z ISS

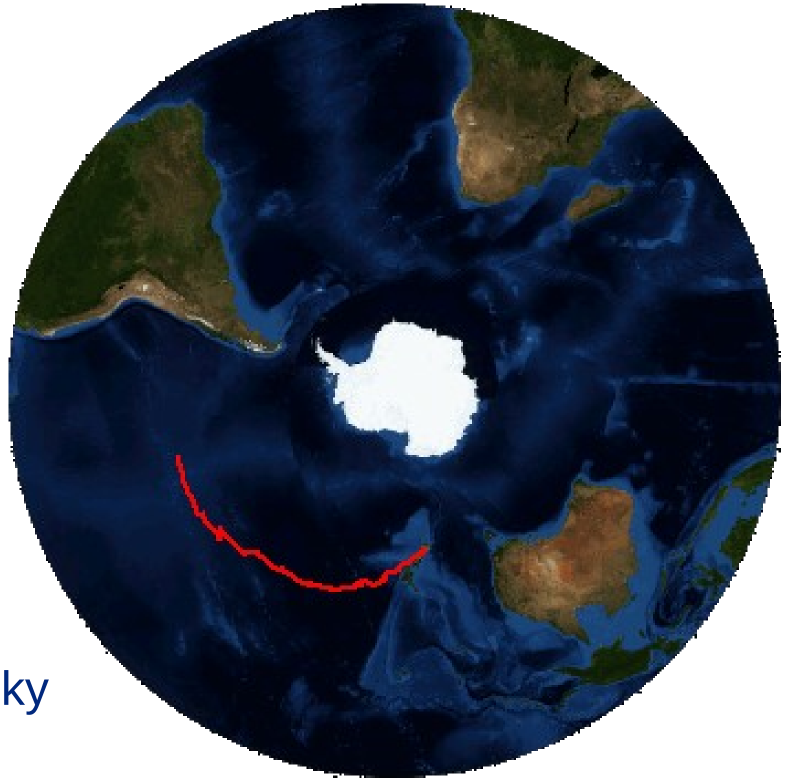
  2020-2024 (2026)
- Koncept založený na zrkadle (10 m^2)
- Ročná triggerovacia expozícia
  ~$1.2x10^4$ km^2 sr yr/yr (~ 1.7x viac než Auger: A(zenith<60^o)=7,000 km^2 sr yr/yr)



N.Sakaki, F. Fenu et al.
(ICRC2015 #647)

Oddelenie kozmickej fyziky

JEM-EUSO

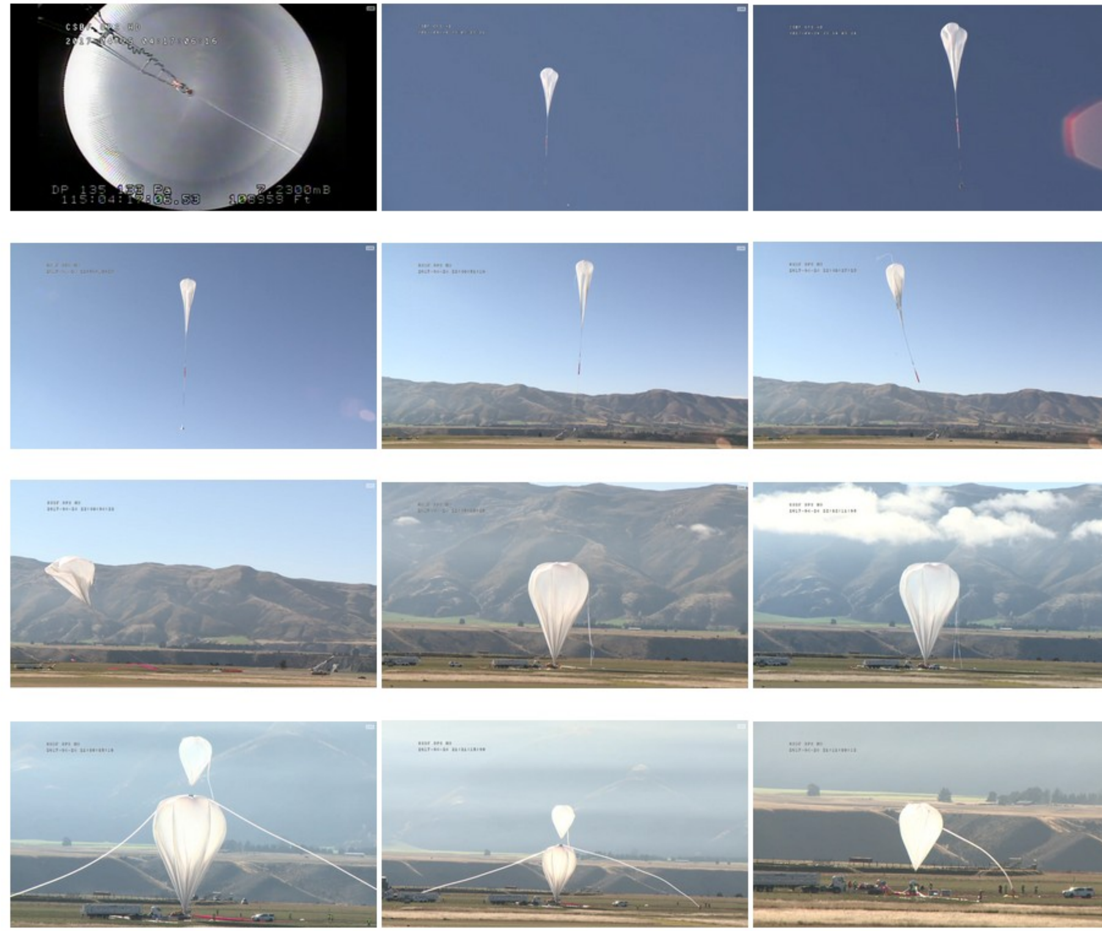


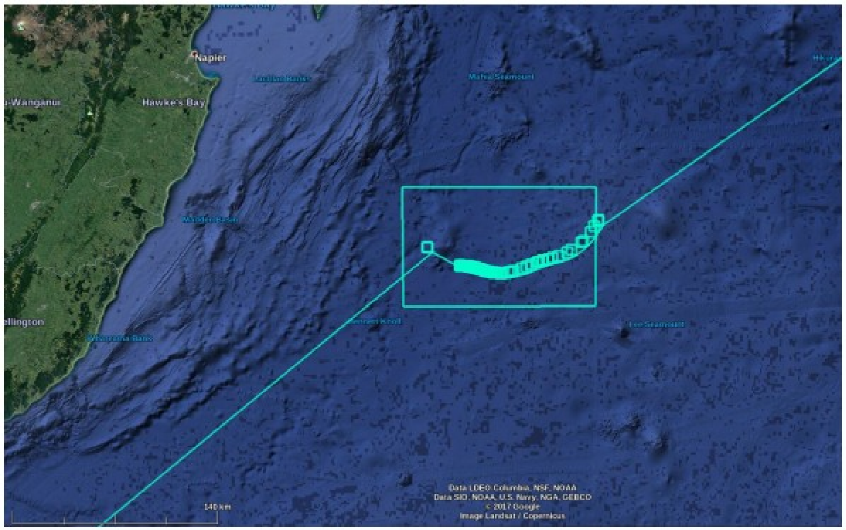
EUSO-SPB NASA balón

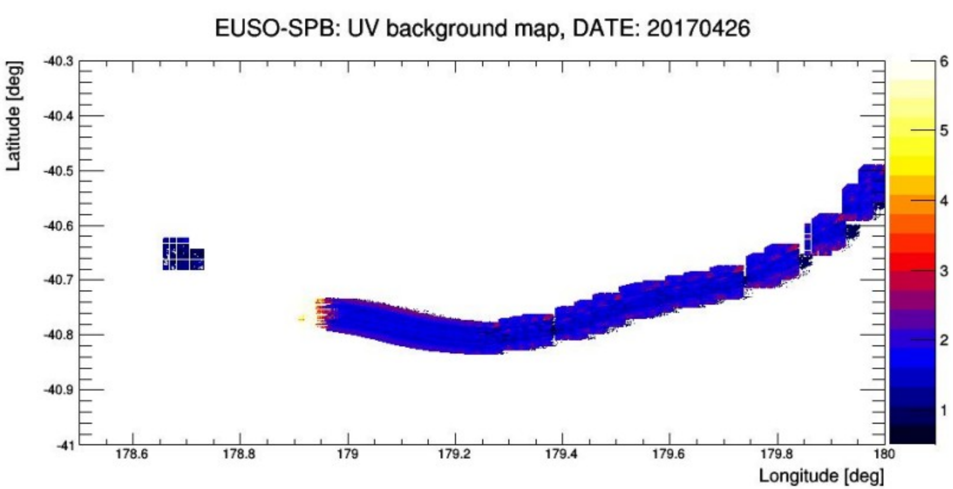
- štart 24. apríla 2017
- predpokladaná dĺžka letu 50 dní, pokus o 100 dňový rekordný let
- pád balónu po 12 dňoch, príčina zatiaľ neznáma
- detektor fungoval až do pádu do oceánu dobre
- prebieha vyhodnocovanie UV pozadia a hľadanie spŕšky

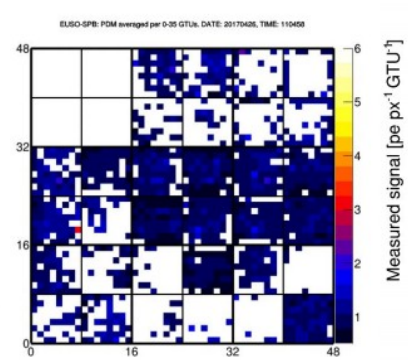
EUSO – SPB1

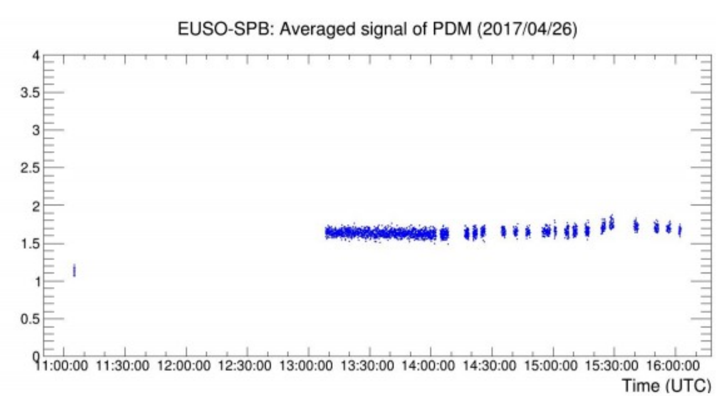
Ďalší štart 2019-2020





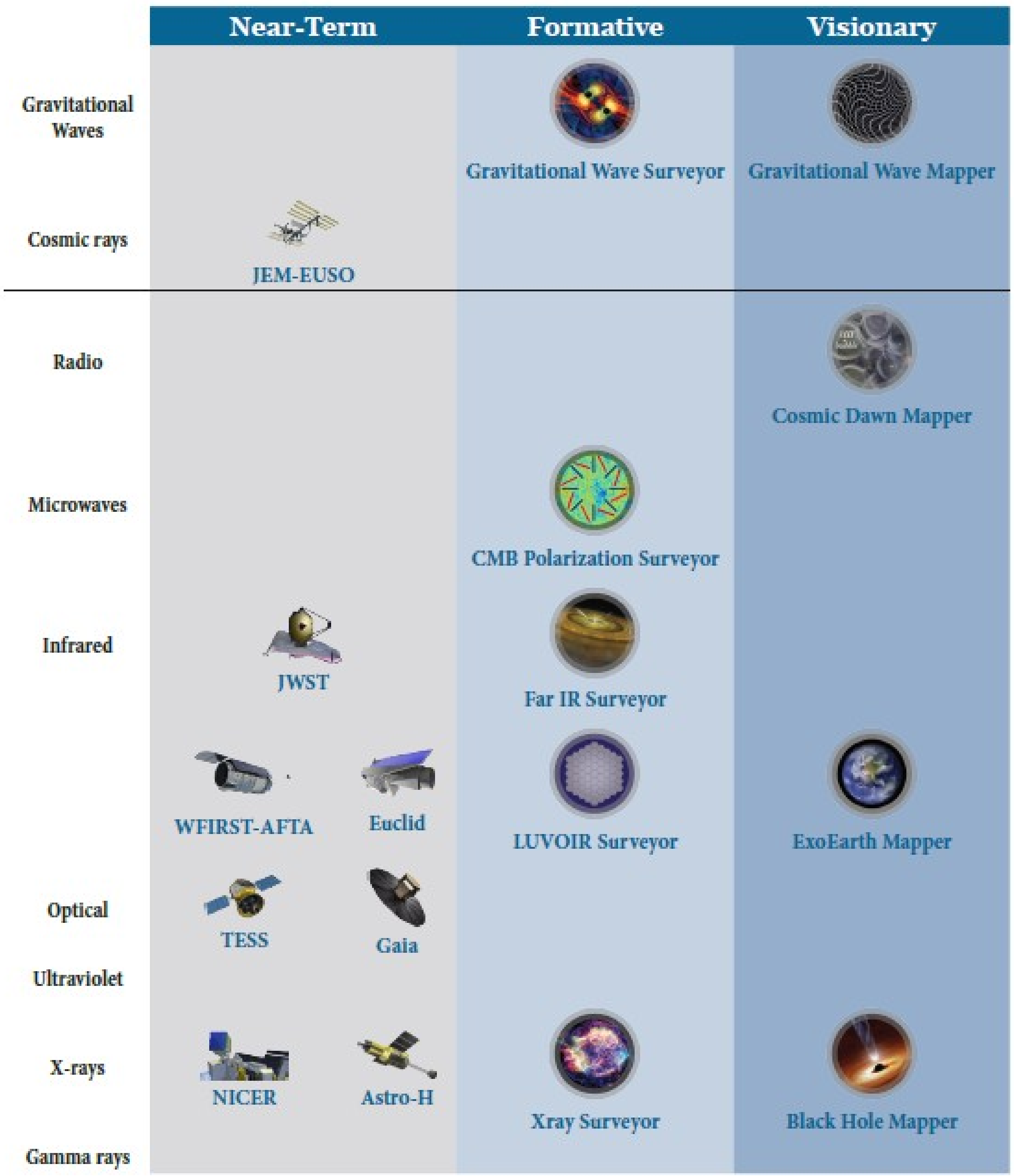






Š, Mackovjak, 22. JEM-EUSO general meeting, Tokyo 2017

2013 : NASA Astrophysics in the Next Three Decades



http://science.nasa.gov/media/medialibrary/2013/12/20/secure-Astrophysics_Roadmap_2013.pdf

2015 : štart v roku 2021?

Science, *Catching cosmic rays where they live,* 7. august 2015, vol. 349, 6248

„Another ISS detector, the Extreme Universe Space Observatory at the Japanese Experiment Module (JEM-EUSO) - now being considered for launch in 2021 - would look down on Earth with a wide-angle camera, watching for ultraviolet light produced by the showers of particles that ultrahigh-energy cosmic rays spawn when they hit the atmosphere.“

Ďakujem za pozornosť