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Forbush phenomenon and the rains in the Amazon

Newton Silva de Lima

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Newton Silva de Lima. Forbush phenomenon and the rains in the Amazon. Doctoral. Manaus - Brasil, France. 2019. <hal-02895544>

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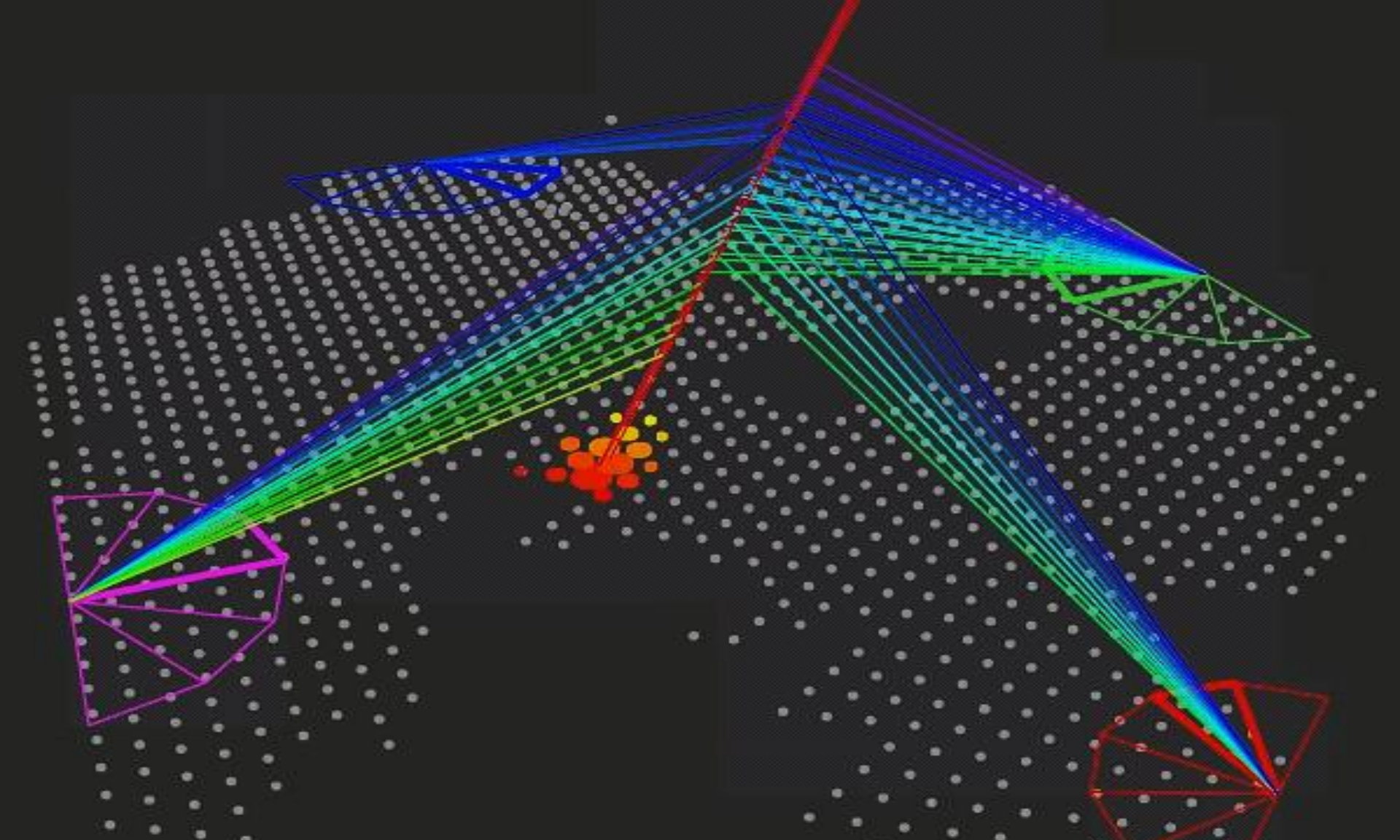
Submitted on 9 Jul 2020

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Fenômeno FORBUSH e as chuvas na Amazônia

Forbush phenomenon and the rains in the Amazon

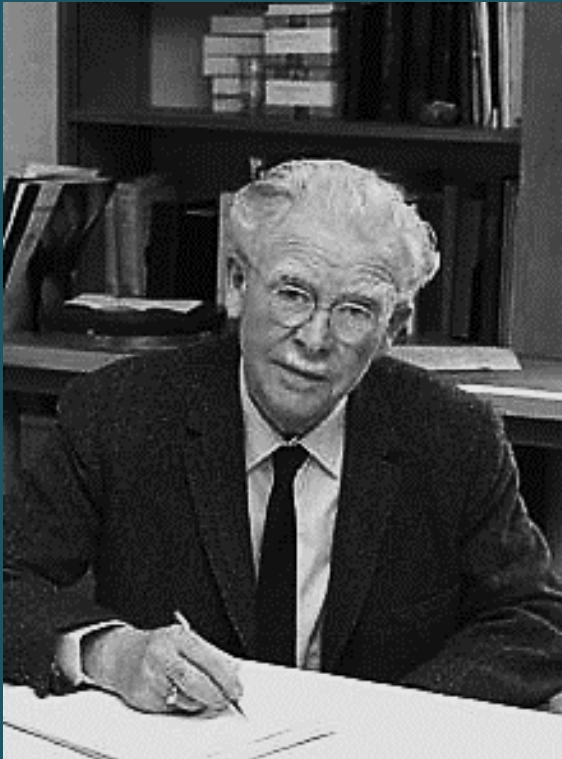
NEWTON SILVA DE LIMA
ULBRA/SEDUC-AM

• Summary

- *Phenomenon FORBUSH*
- *Cosmic Shower*
- *Cherenkov Light Timeline*
- *Standard Model of Elementary Particles*
- *Theory*
- *Detectors*
- *Simulation*
- *Observation Station (1-2-3-4)*
- *Interaction at sea level*
- *Investigation*

Observations with operational research on the connection of the 11-year Solar Cycle and the El Niño and La Niña phenomena and rainfall in the Amazon (1980-2030).

- Phenomenon *FORBUSH*



Scott Ellsworth Forbush (1904-1984)

The increase in the intensity of solar cosmic rays is often followed by a decrease in the extra solar cosmic rays. This effect is known as Forbush reduction (Scott Ellsworth Forbush), which occurs due to the solar wind that carries the Sun's magnetic field, with (coronal mass ejection - *CME*) and thus, protects the earth from cosmic radiation.

Phenomenon FORBUSH

- Cosmic Rays

They are highly energetic nuclei that cross our universe

- Composition

About 87% of the observed cosmic rays are Hydrogen nuclei, 12% are Helium nuclei and the rest are heavier elements such as Carbon and Iron

- Velocity

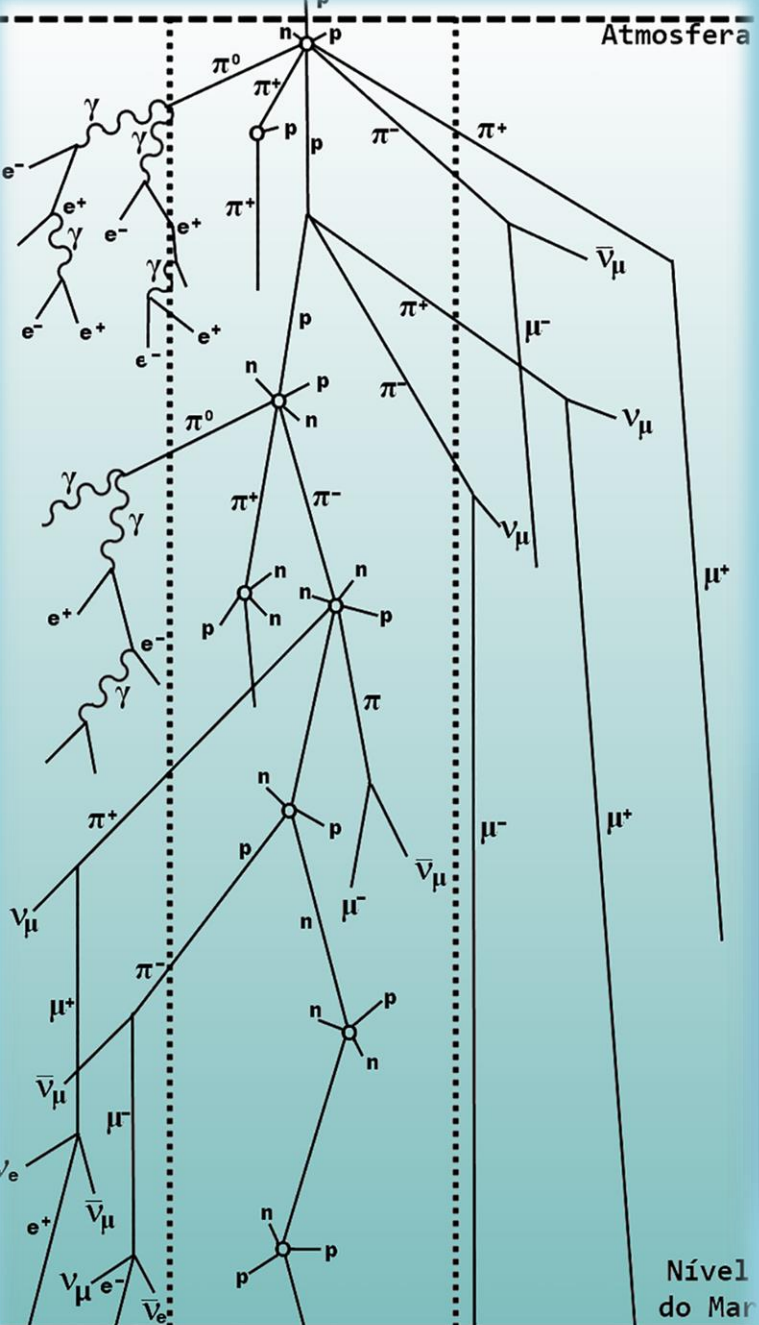
Close to light in a vacuum

- Energy

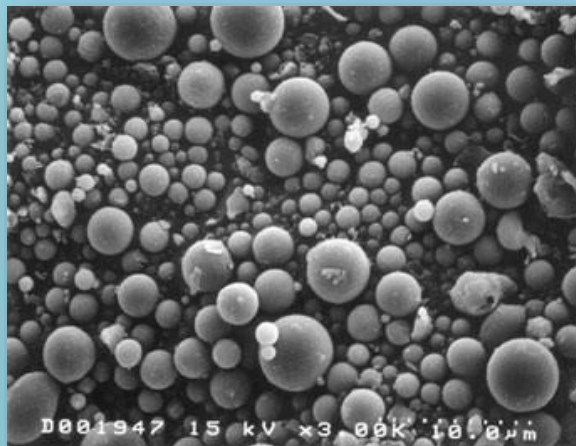
- of a tennis ball with $v = 57 \text{ m / s}$ for a mass of $0.0000000000000001 <$ than the tennis ball.

Chuveiro Cósmico “cosmic shower”

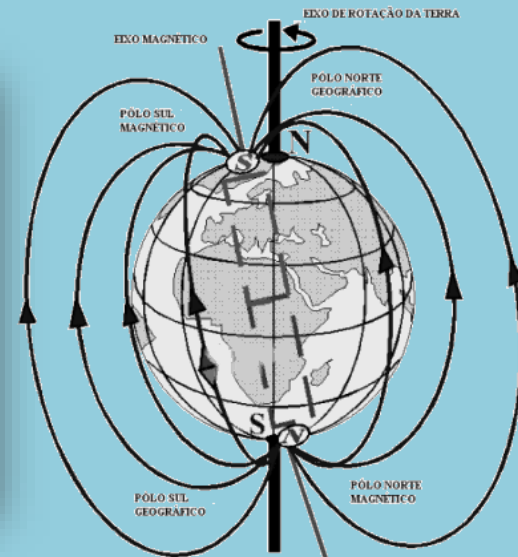
The cosmic bomber is more intense at the poles and smaller in the equatorial region, due to its alignment with the Earth's magnetic field.



Componente Eletron Fotônica Componente Hadronica Componente Muonica



Aerosol of 10 -100 μm
2.000 x increased



Chuveiro Cósmico e a cobertura de nuvens

“cosmic shower and the cloud cover”



Henrik Svensmark

Division of Solar System Physics at the Danish National Space Institute (DTU Space) | Copenhagen.

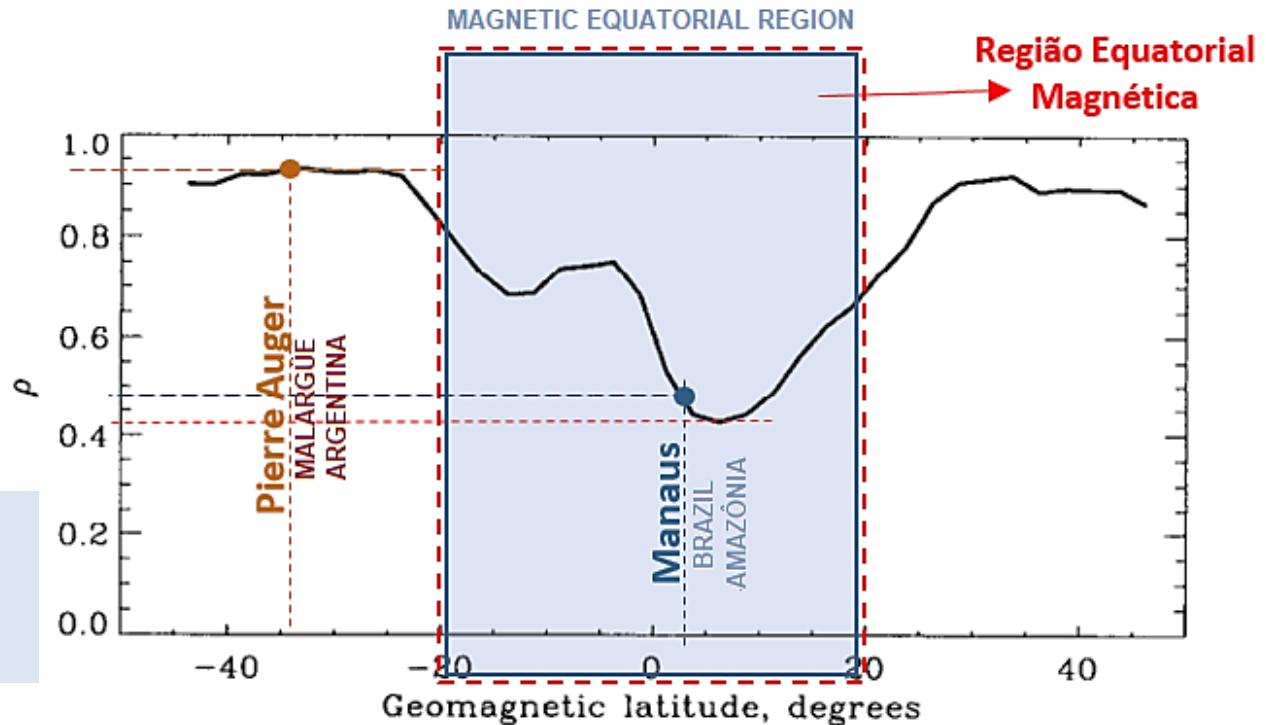


Fig. 5. Latitude profile of zonal average values of the correlation between the cosmic ray flux and the cloud cover over the oceans. The zonal averages have been derived corresponding to geomagnetic latitudes (dipole field with pole at 78.5°N 291°E).

Source: H. Svensmark, E. F. Christensen. *Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships*. *Journal of Atmospheric and Solar-Terrestrial Physics*, 59, 11 (1997) 1225.

Cherenkov Light Timeline



1900

Marie Curie



1932

Pavel Alekseyevich Cherenkov



Ilia Mikhailovitch Frank



Pierre Curie



Igor Yevgenyevich Tamm

1958
Nobel Prize

Source: Pierre Auger Observatory

Modelo Padrão das Partículas Elementares

Standard Model of Elementary Particles

			três gerações da matéria (férmions)			interações / partículas mensageiras (bósons)	
			I	II	III		
massa			=2.2 MeV/c ²	=1.28 GeV/c ²	=173.1 GeV/c ²	0	=124.97 GeV/c ²
carga			2/3	2/3	2/3	0	0
spin			1/2	1/2	1/2	1	0
			u up	c charm	t top	g glúon	H higgs
			=4.7 MeV/c ²	=96 MeV/c ²	=4.18 GeV/c ²	0	
			-1/3	-1/3	-1/3	0	
			1/2	1/2	1/2	1	
			d down	s strange	b bottom	γ fóton	
			=0.511 MeV/c ²	=105.66 MeV/c ²	=1.7768 GeV/c ²	=91.19 GeV/c ²	
			-1	-1	-1	0	
			1/2	1/2	1/2	1	
			e elétron	μ múon	τ tau	Z bóson Z	
			<1.0 eV/c ²	<0.17 MeV/c ²	<18.2 MeV/c ²	=80.39 GeV/c ²	
			0	0	0	±1	
			1/2	1/2	1/2	1	
			ν_e neutrino do elétron	ν_μ neutrino do múon	ν_τ neutrino do tau	W bóson W	

Atom

p próton

$$p = u+u+d = 2/3+2/3-1/3 = +1$$

$$n = u+d+d = 2/3-1/3- 1/3 = 0$$

n nêutron

QUARKS

LÉPTONS

BÓSONS DE GAUGE

BÓSONS VETORIAIS

BÓSONS ESCALARES

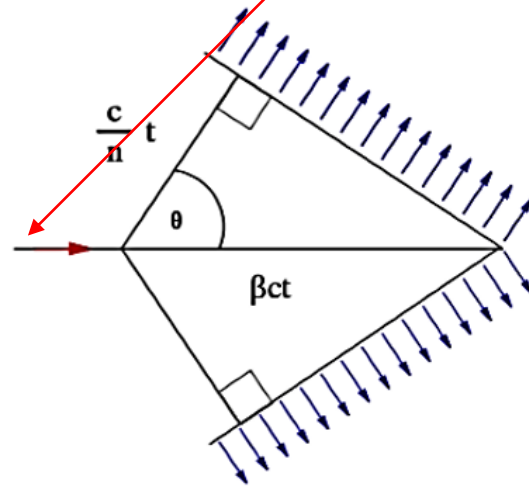
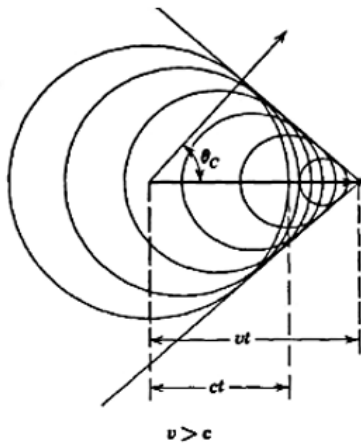
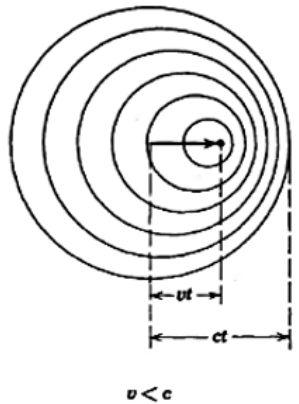
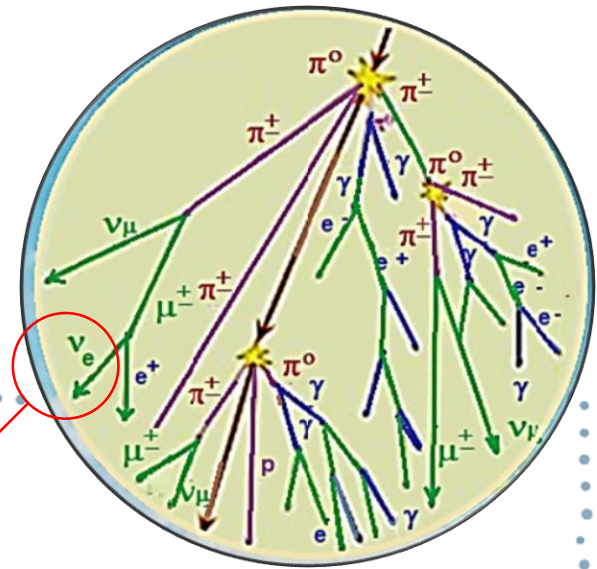
Curiosity

alphabet soup = 1 atom
(2u + 1d + 1e + 3g)
Hydrogen ¹H

Breath

2,6 mL O₂ = 1,2x10⁻⁴ mol
3,2x10²¹ u + 3,2x10²¹d + 1,0x10¹⁹e + 3,2x10²¹ g
(320.000.000.000.000.000.000 [320 Zeta(10²¹)] u = d = g + 10.000.000.000.000.000.000 [10 Exa (10¹⁸)] e)

Teoria (Theory)



$$\cos \theta_c = \frac{1}{\beta_n}$$

$$\beta_n = \frac{vn}{c}$$

Endler, 2010; Takeda, 2018

“Os raios cósmicos galácticos são as principais fontes de ionização na atmosfera mais baixa”.

Atmospheric Electricity in the Planetary Boundary Layer

William A. Hoppel, R. V. Anderson, and John C. Willett Naval Research Laboratory

Letter | Published: 14 February 1959

Cosmic Radiation and the Weather

EDWARD P. NEY

Nature **183**, 451–452(1959) | Cite this article

76 Accesses | 156 Citations | 19 Altmetric | Metrics

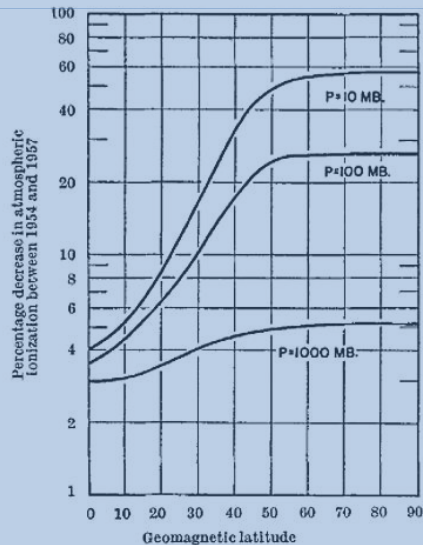


Fig. 2. Percentage reduction in atmospheric ionization during the last solar cycle. The percentage change is calculated with respect to the value of the ionization at sunspot minimum in 1954

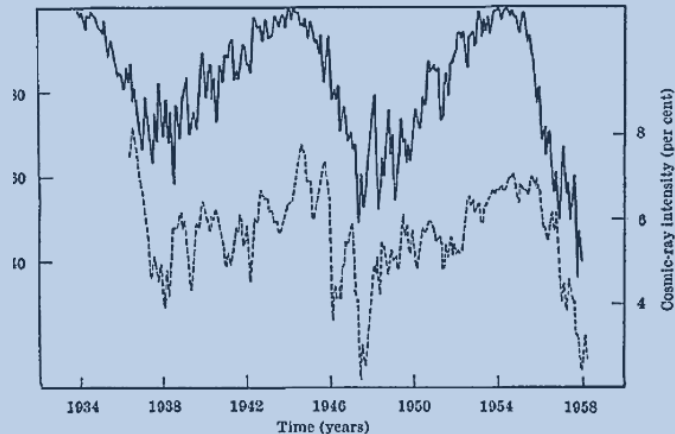
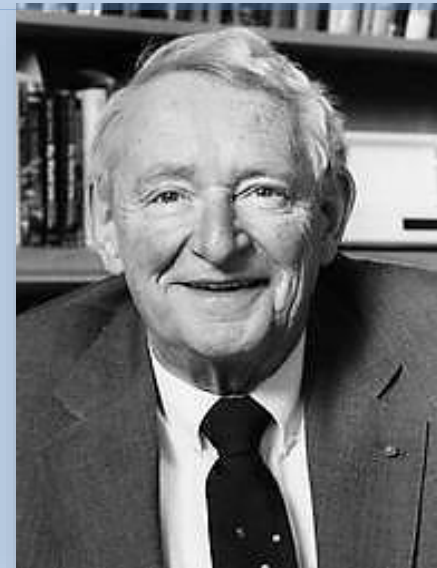


Fig. 1. Forbush's results ref. (1) showing the inverse correlation of cosmic-ray intensity and solar activity. —, Sunspot numbers; ---, cosmic-ray intensity



Source: Frank B. McDonald, 2012, Feb.6.

“Raios C3smicos podem afetar o tempo e o clima”

“Cosmic rays can affect weather and climate” p. 451 – Nature 183 | 1959.

Phenomenon Forbush

- *Significant coronal mass ejection (CME) from the Sun to Earth.*
- *The FORBUSH phenomenon is the decrease in cosmic rays by CME.*
- *The number of particles that reach sea level, on average, is one particle per second in each square centimeter.*

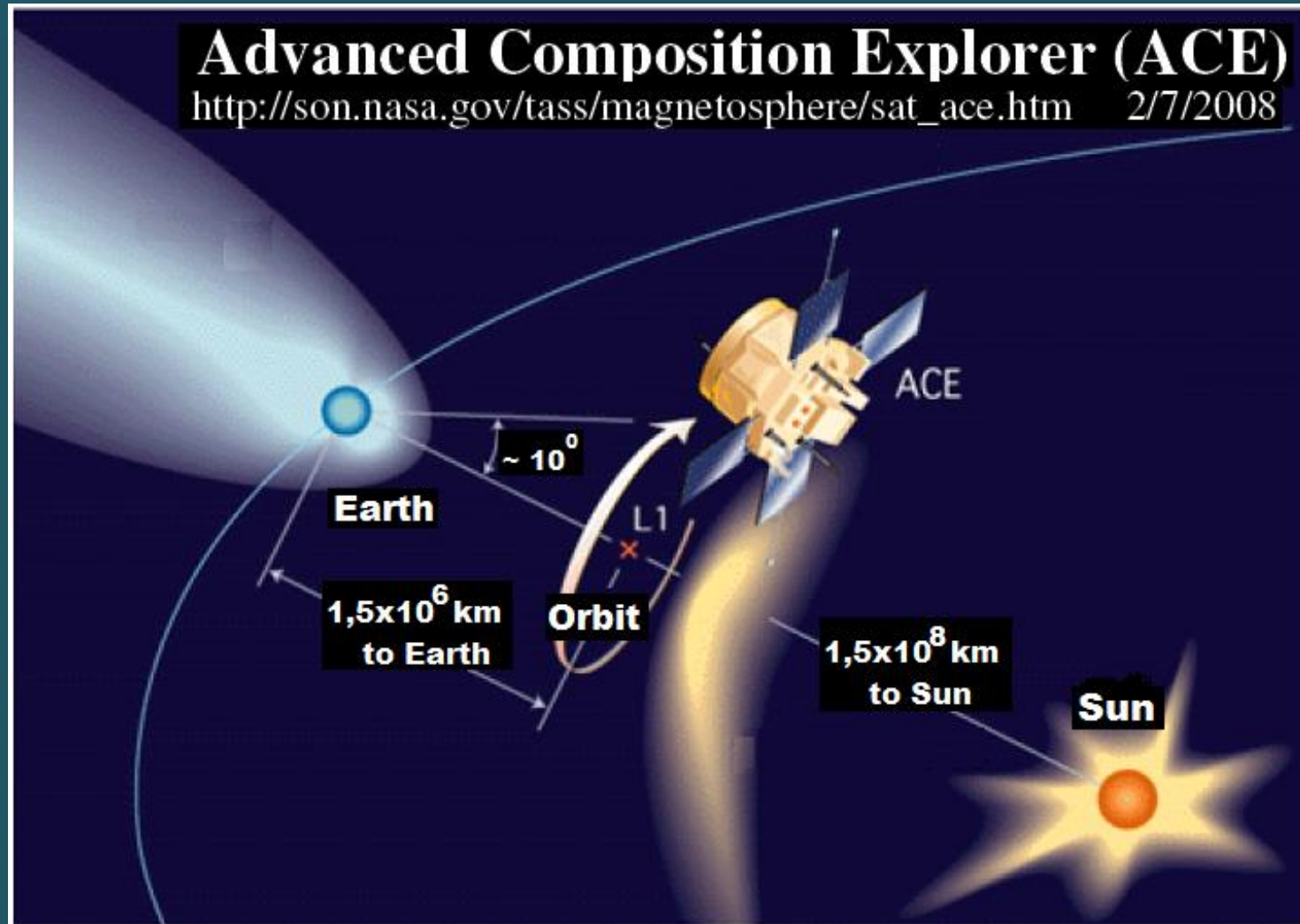
Phenomenon FORBUSH

- **Detectors (Embedded)**
- ACE – Advanced Composition Explorer
- CGRO - Compton Gamma Ray Observatory (Colapso)
- ISS – AMS (Alpha Magnetic Spectrometer)

- **Detectors (Observation Station)**
- Haverah Park
- Kascade
- **Pierre Auger**
- IceCube

- **Simulation and Research**

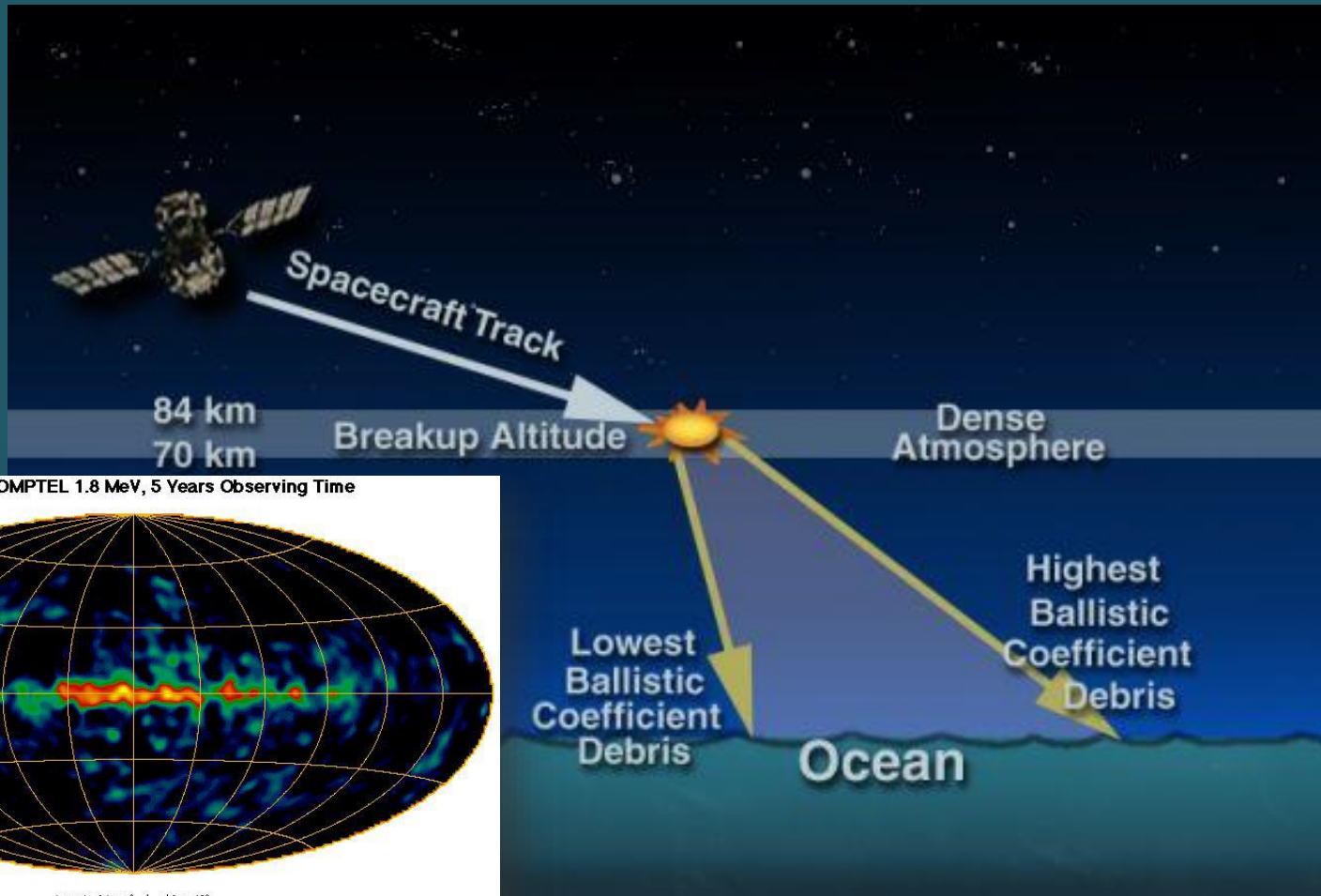
Embedded in Satellite



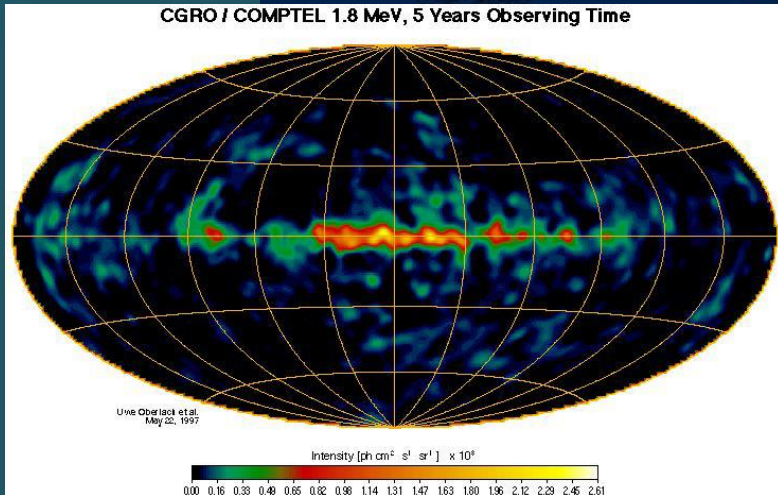
Embedded in Satellite

CGRO - Compton Gamma Ray Observatory

The CGRO Mission(1991 - 2000) - The Imaging Compton Telescope (COMPTEL)



CGRO / COMPTEL 1.8 MeV, 5 Years Observing Time




Embedded in ISS

International Spatial Station – ISS / AMS (Alpha Magnetic Spectrometer)

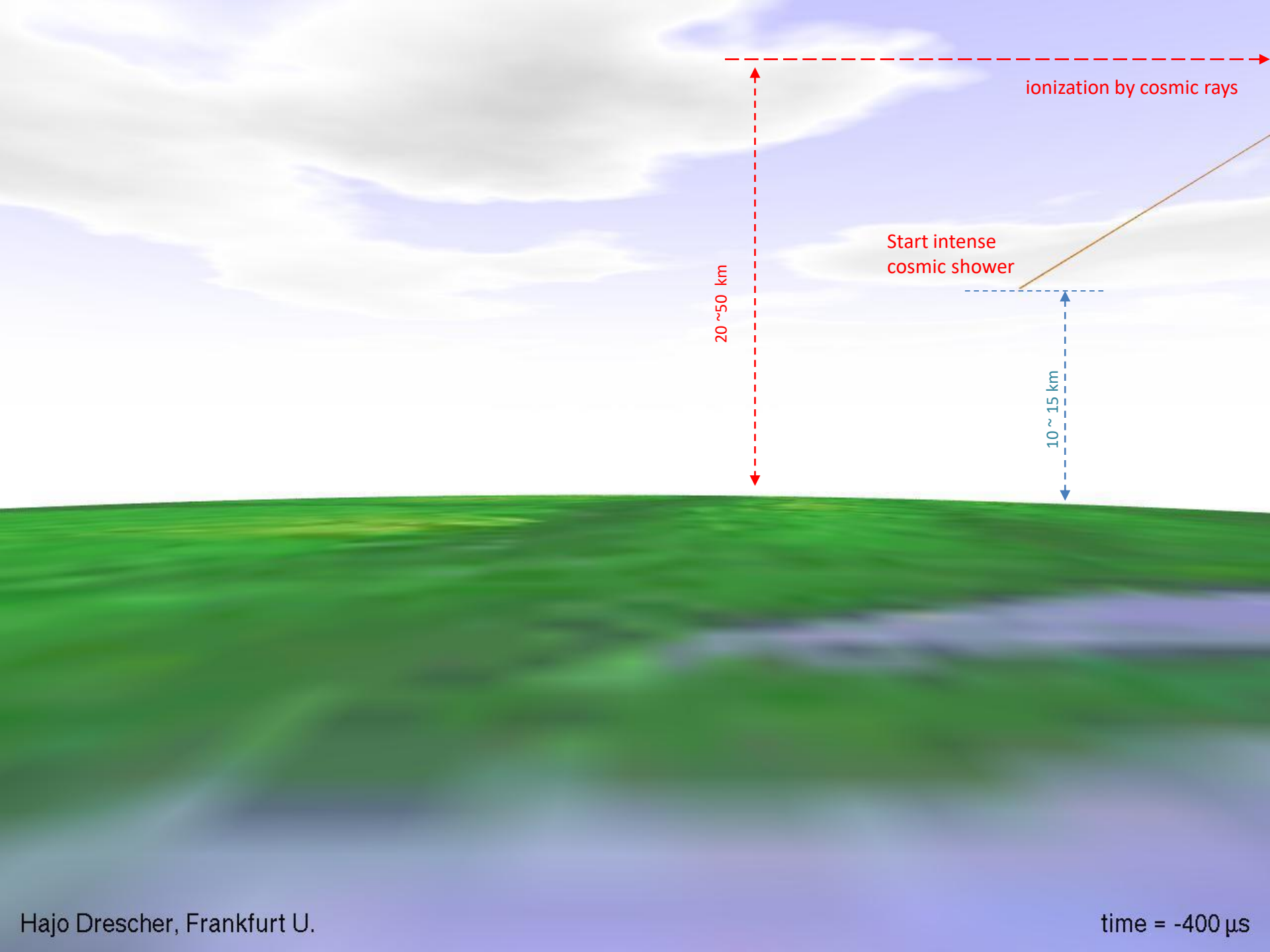


Simulation

SIMULAÇÃO



Como um chuva de Raios C3smicos interage com a Atmosfera?
How does a shower of Cosmic Rays interact with the Atmosphere?

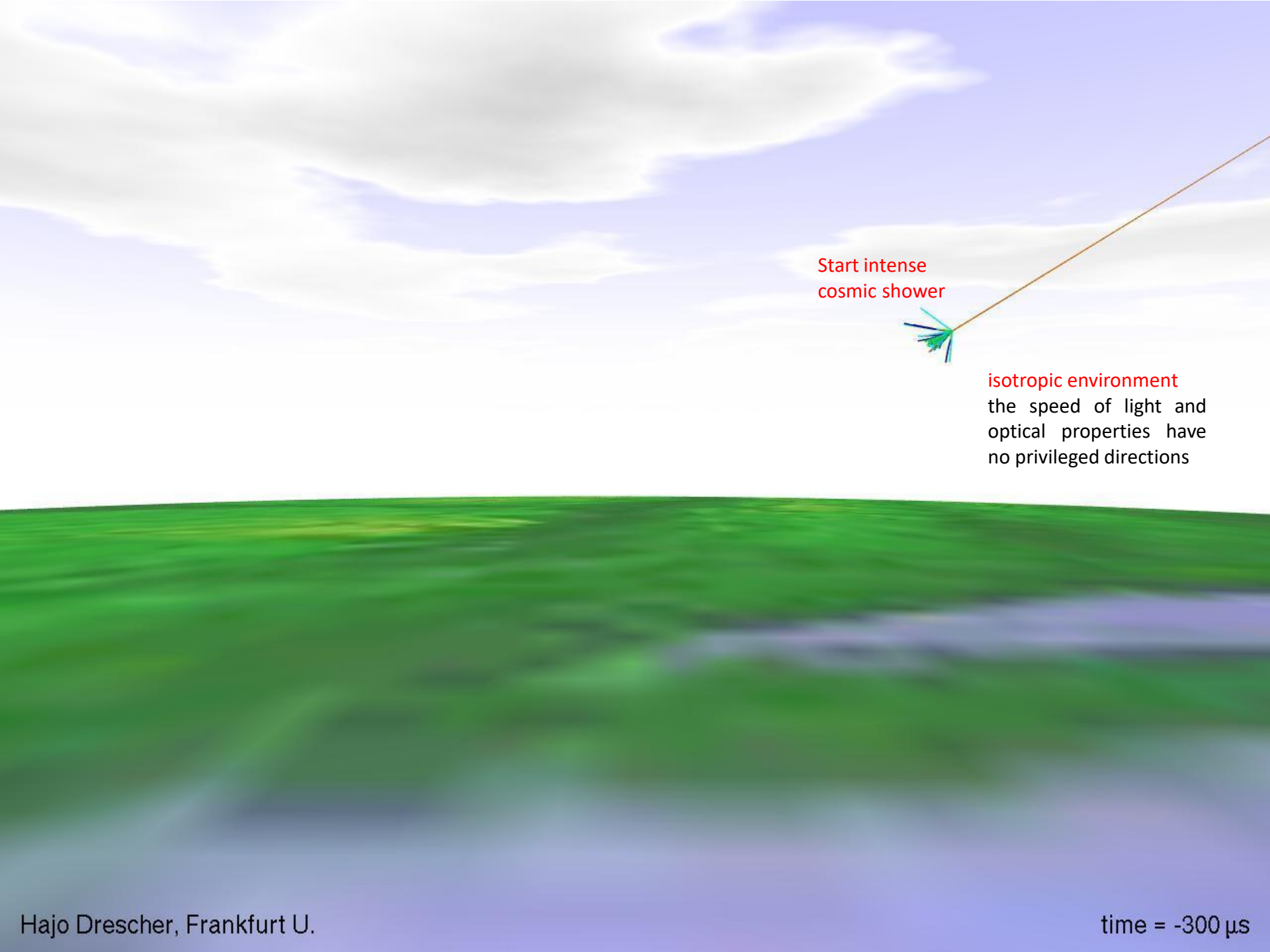


ionization by cosmic rays

20 ~ 50 km

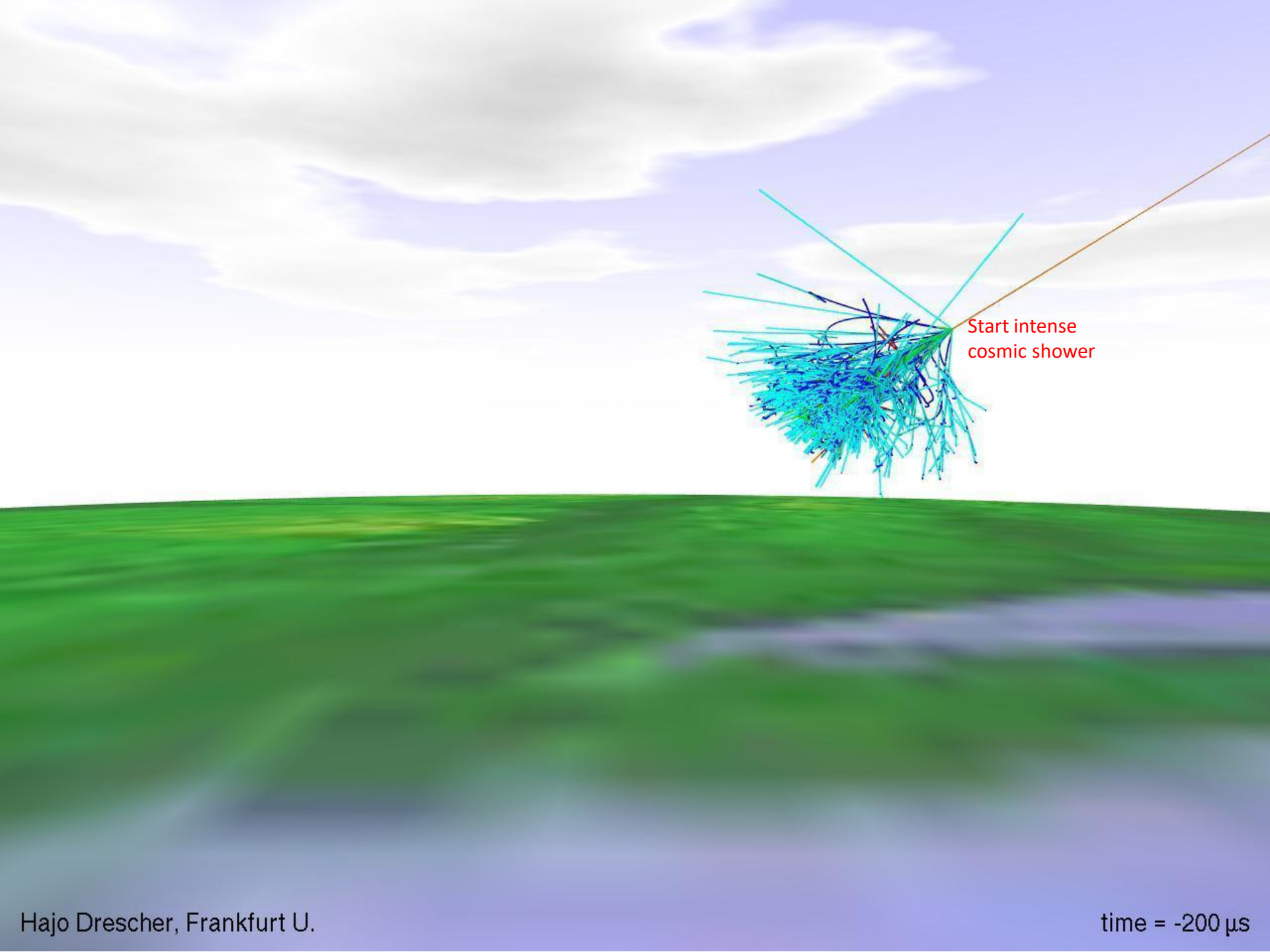
Start intense
cosmic shower

10 ~ 15 km

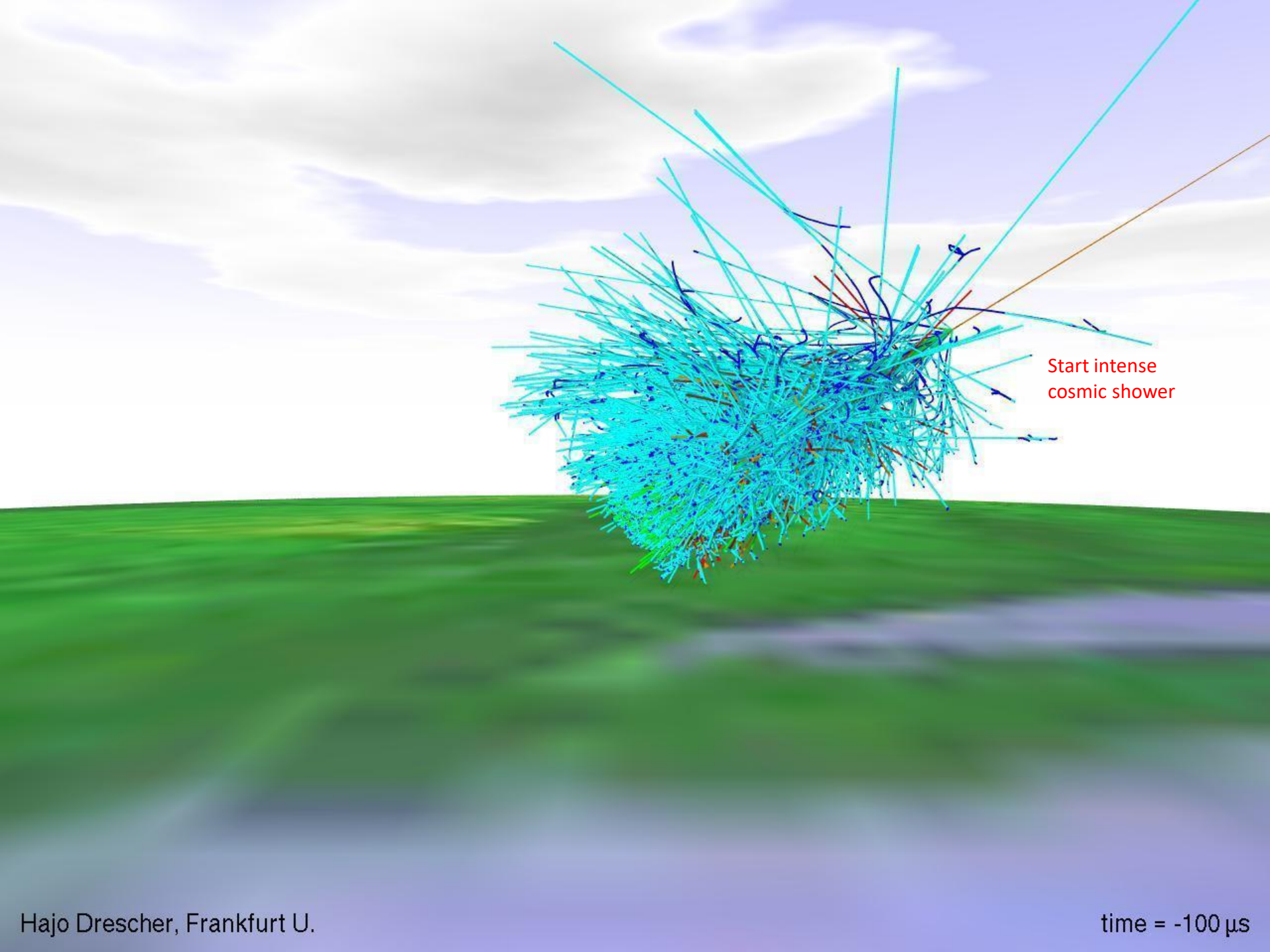


Start intense
cosmic shower

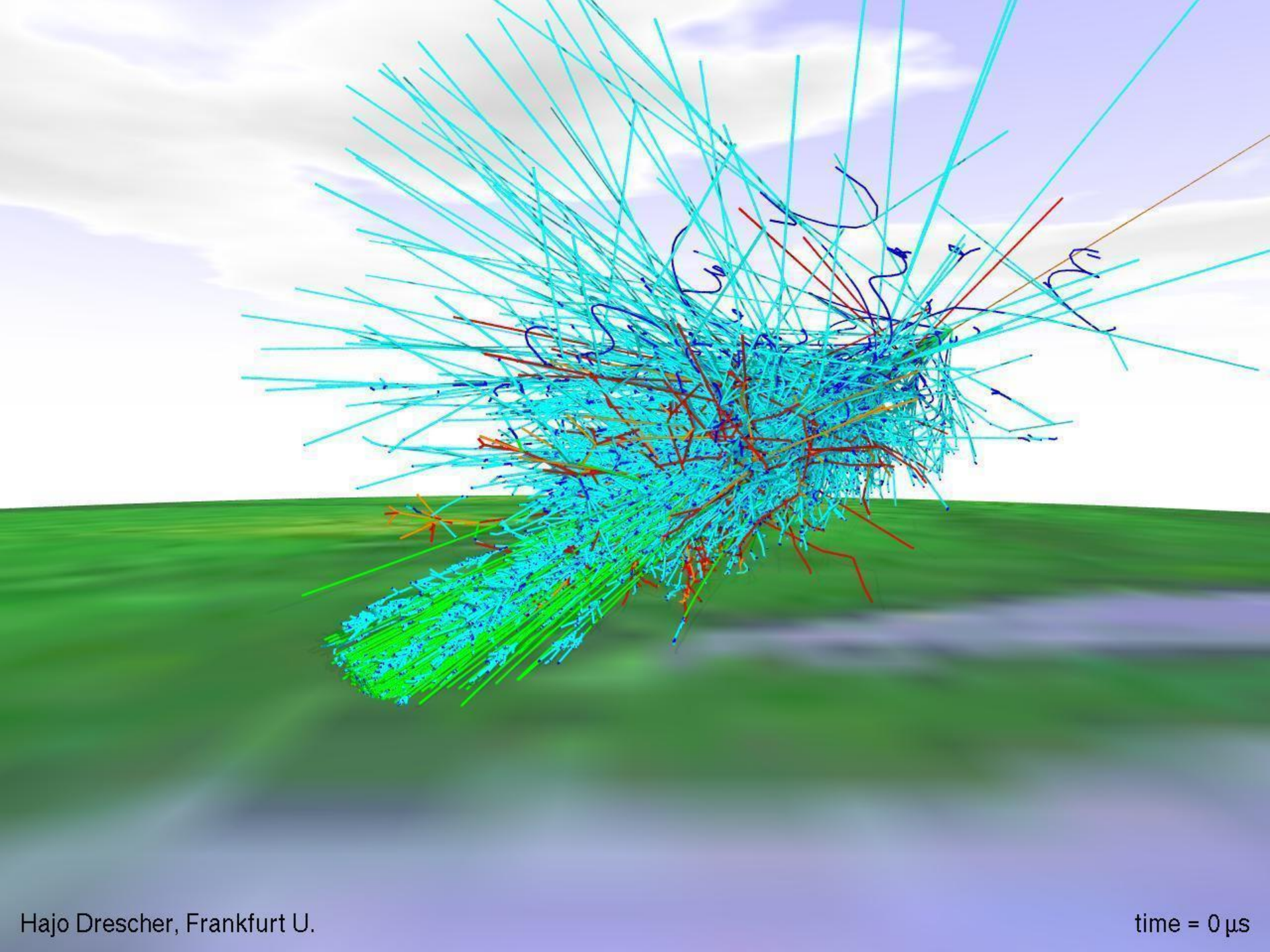
isotropic environment
the speed of light and
optical properties have
no privileged directions

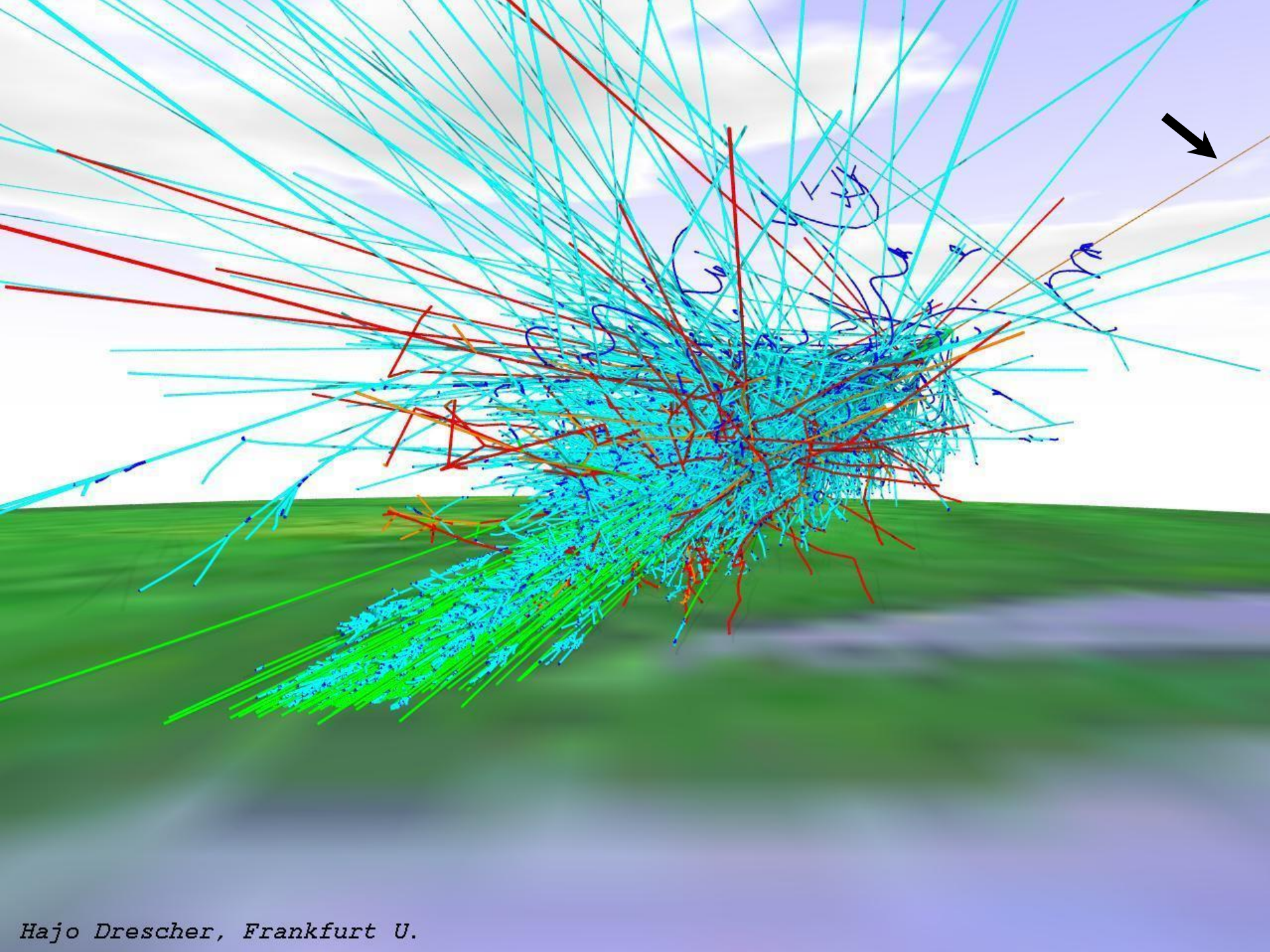


Start intense
cosmic shower



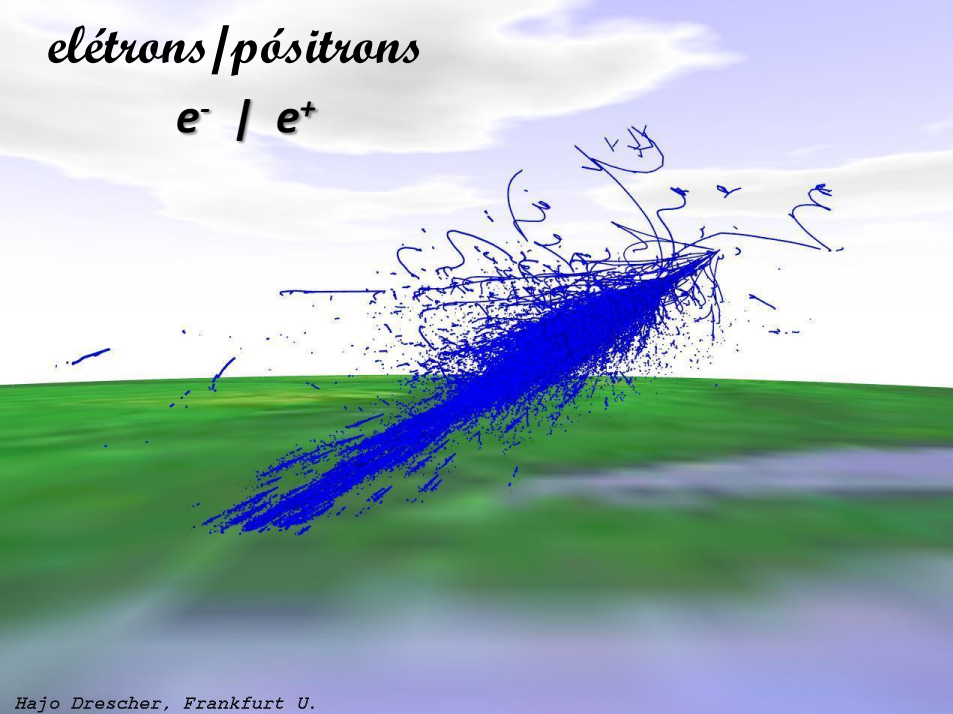
Start intense
cosmic shower





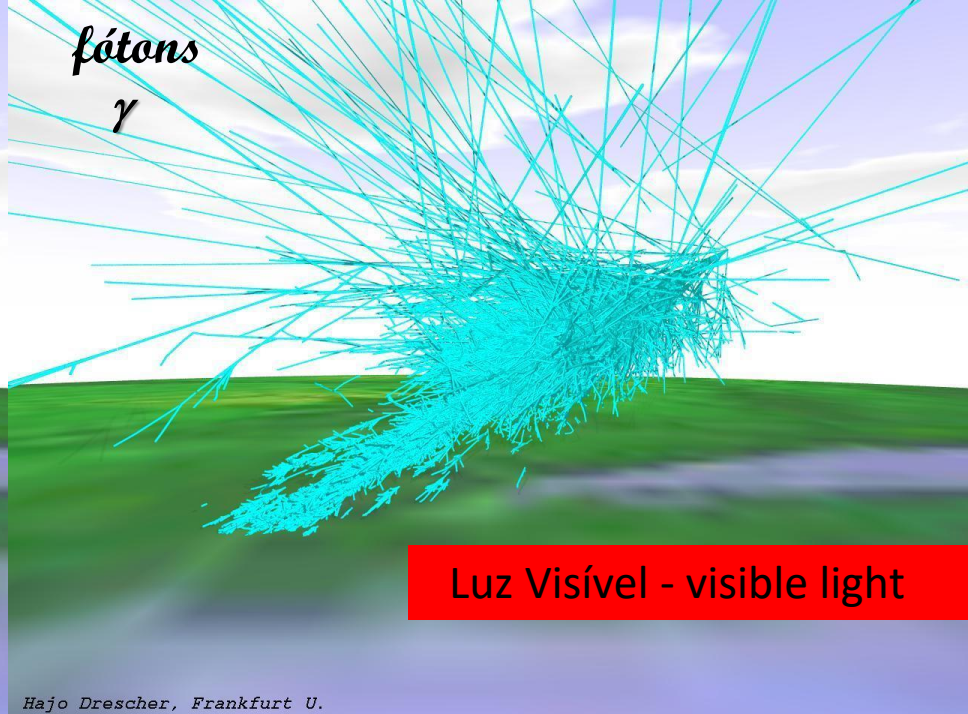
Hajo Drescher, Frankfurt U.

elétrons / pósitrons
 e^- / e^+



Hajo Drescher, Frankfurt U.

fótons
 γ

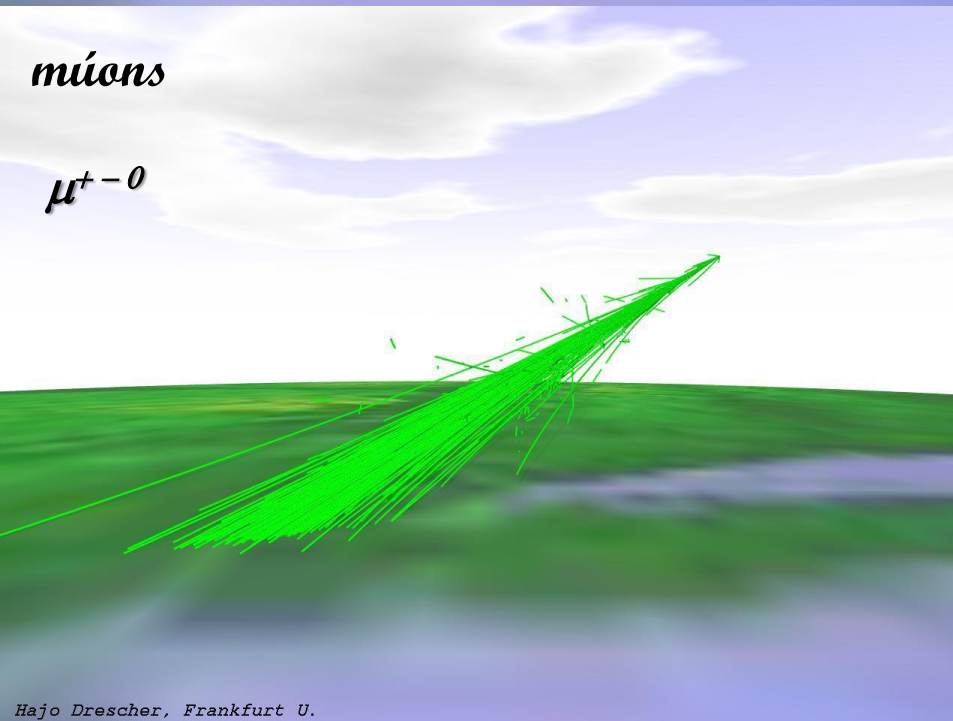


Luz Visível - visible light

Hajo Drescher, Frankfurt U.

múons

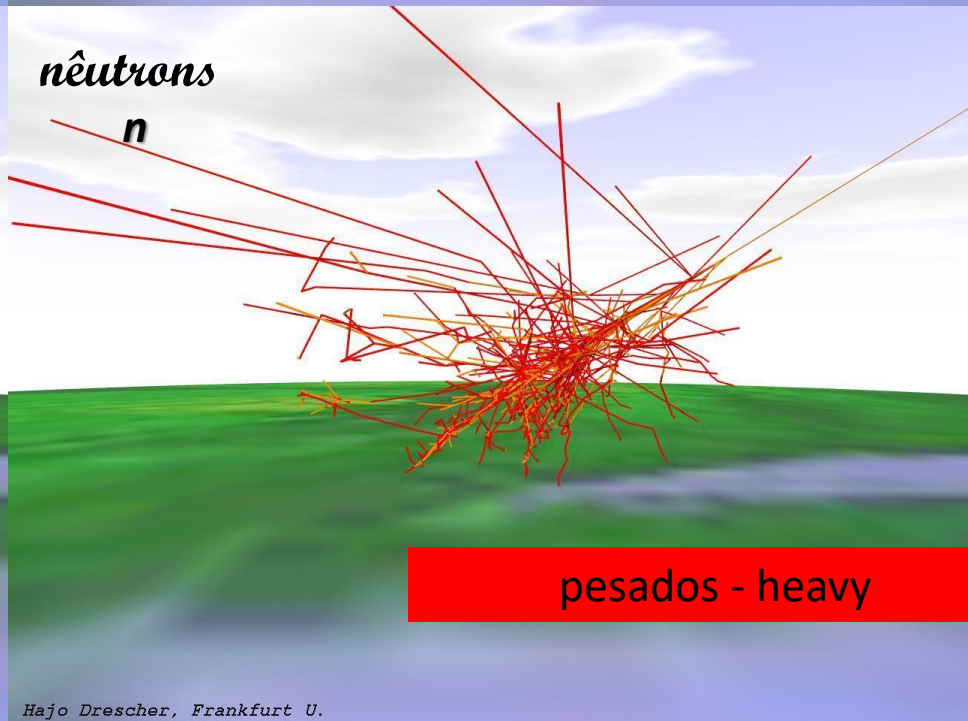
$\mu^+ - 0$



Hajo Drescher, Frankfurt U.

nêutrons

n



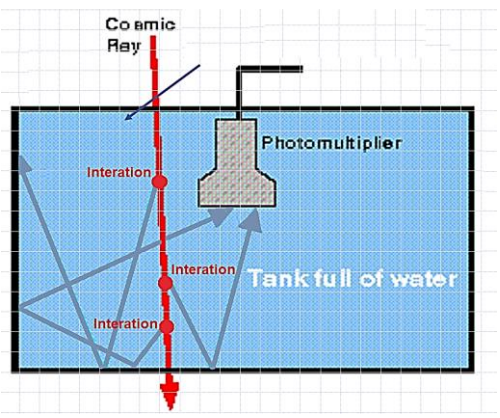
pesados - heavy

Hajo Drescher, Frankfurt U.

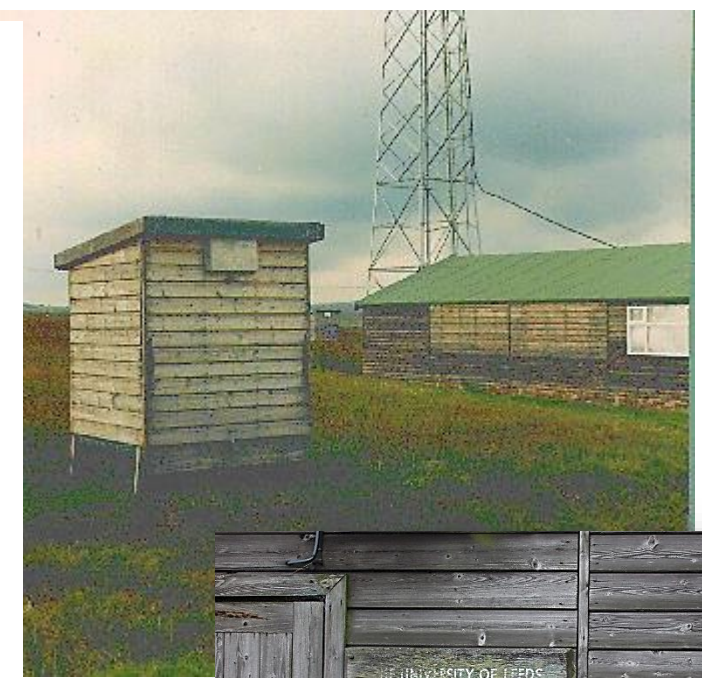
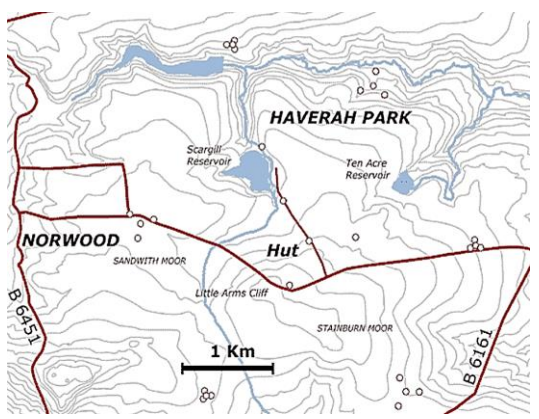
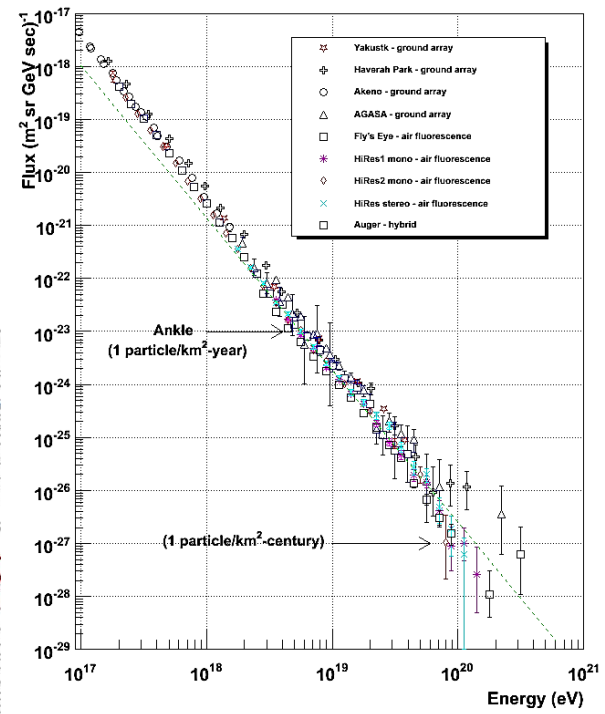


Haverah Park

Was operated by the *Physics Department of the University of Leeds* (1970-1993) north Yorkshire Moors in the United Kingdom
Situated on 12 square kilometers of farmland



Cosmic Ray Spectra of Various Experiments

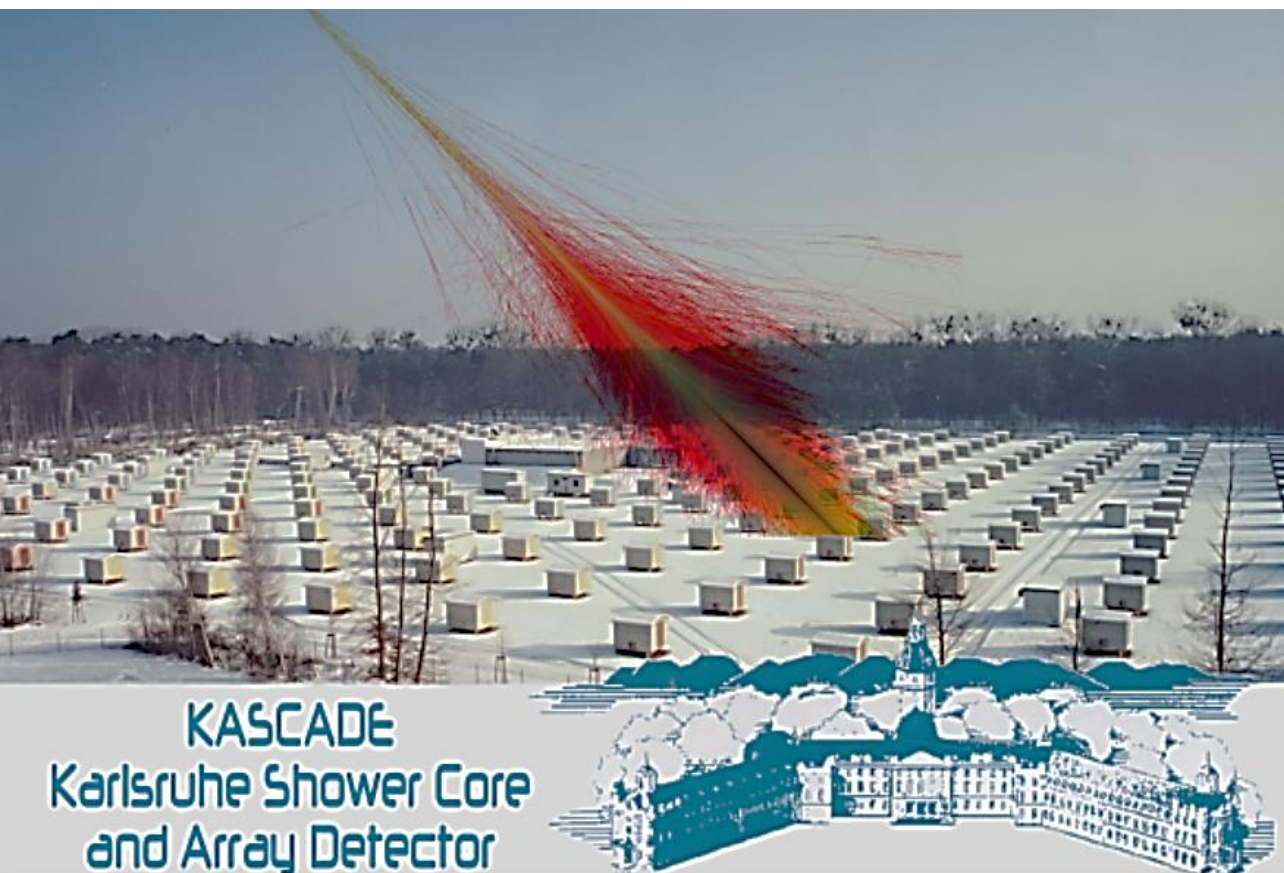


Kascade

KIT- Karlsruhe Institute of Technology (since 1825)

Campus North - National Large-scale Laboratory - Helmholtz Association

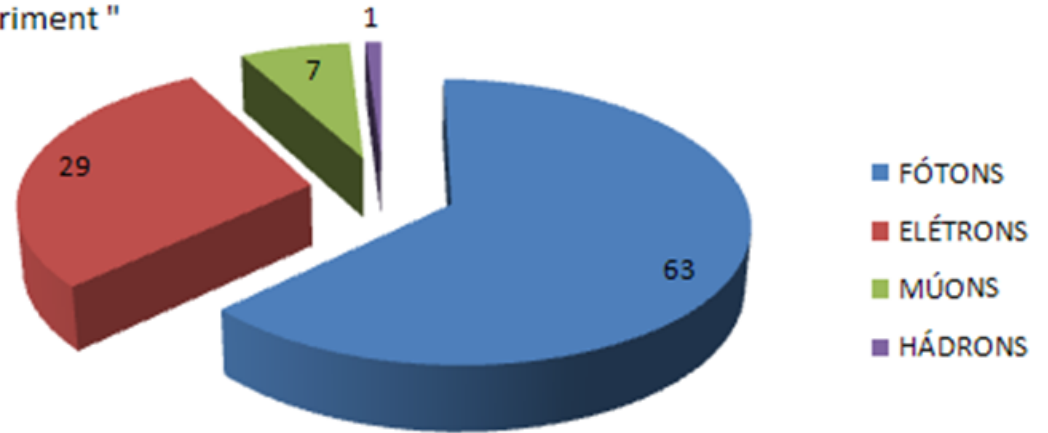
250 estações de superfície – 30 antenas de RF (40 – 80 MHz)

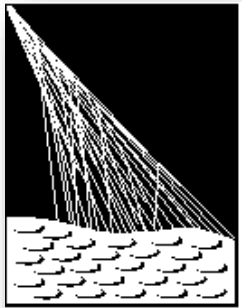




Cascade in relation to sea level

The KASCADE Collaboration, " Electron, Muon and Hadron Lateral Distributions Measured in Air-Showers by the KASCADE Experiment "



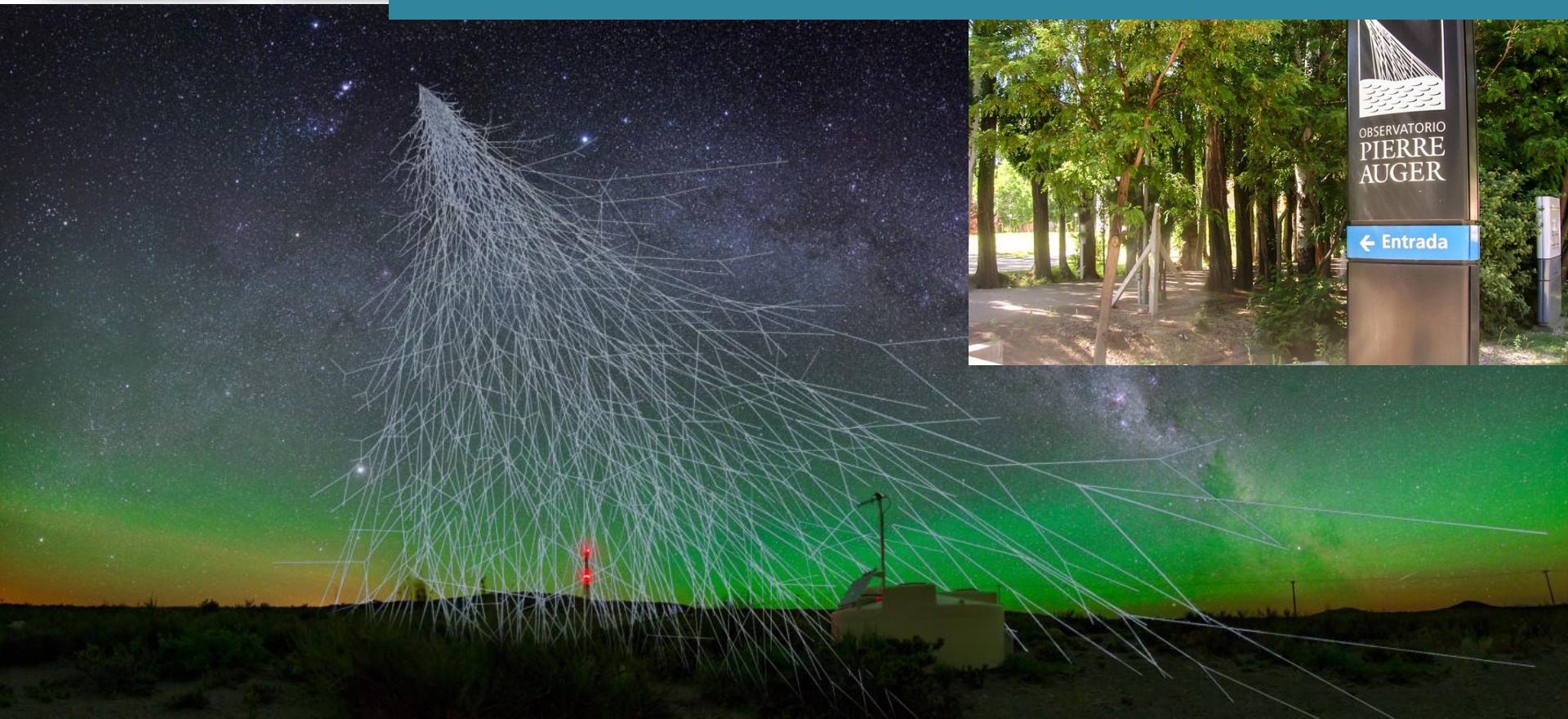


**PIERRE
AUGER**
OBSERVATORY



1899-1993

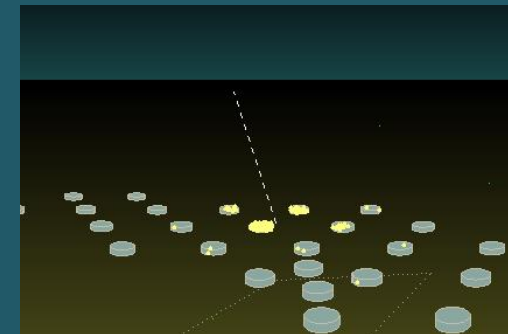
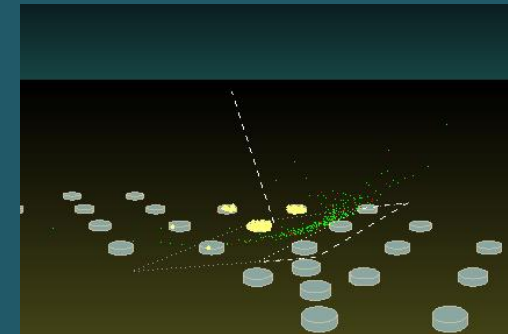
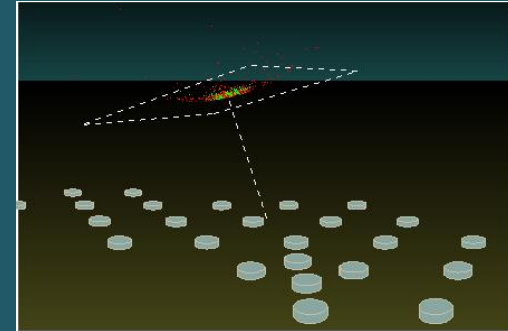
PIERRE AUGER OBSERVATORY | Malargüe – Argentina (Mendoza)



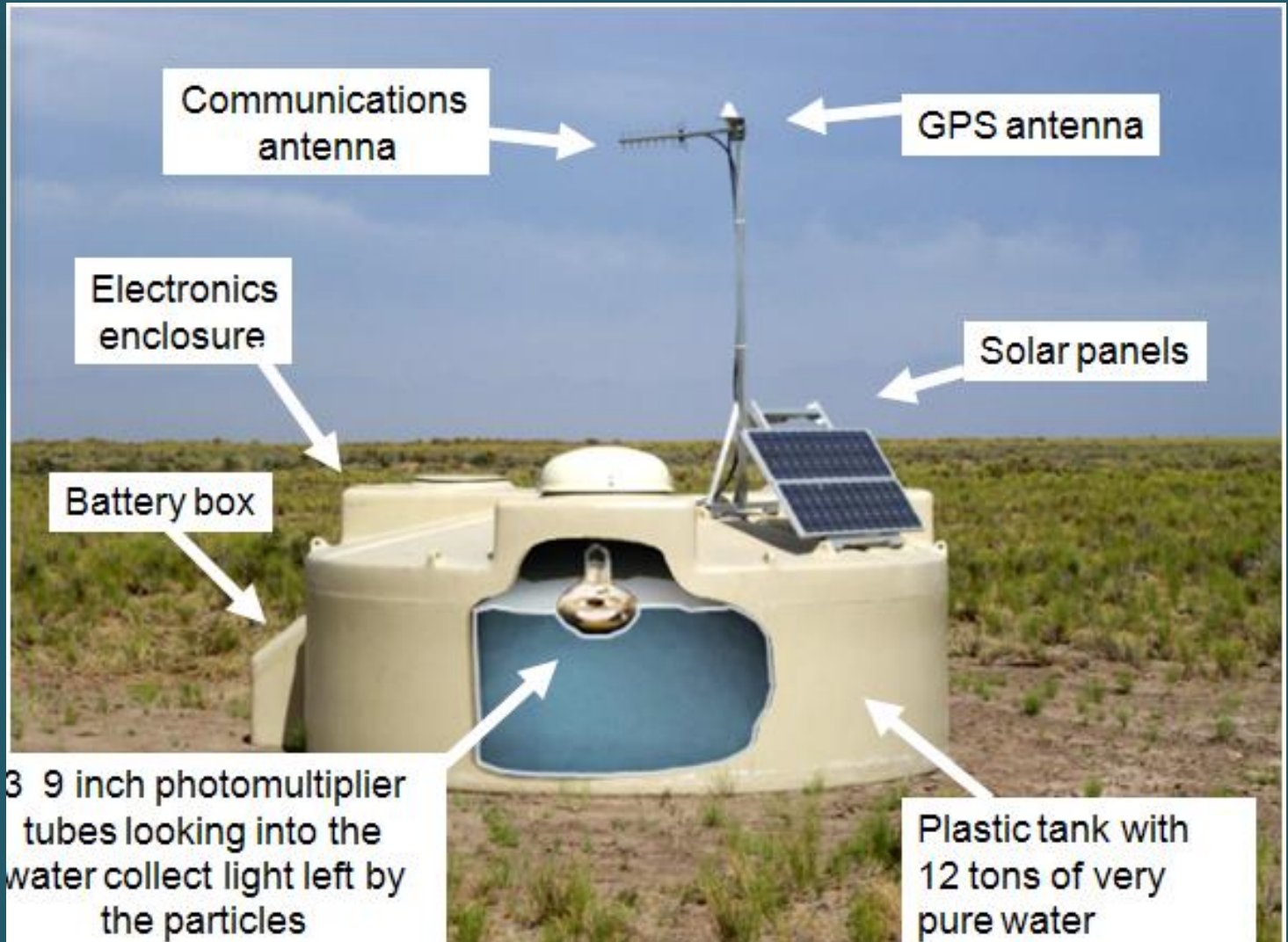
Pierre Auger (<http://www.auger.org/>)

Cheronkov Effect

1.600 tanks (3000 km² area)

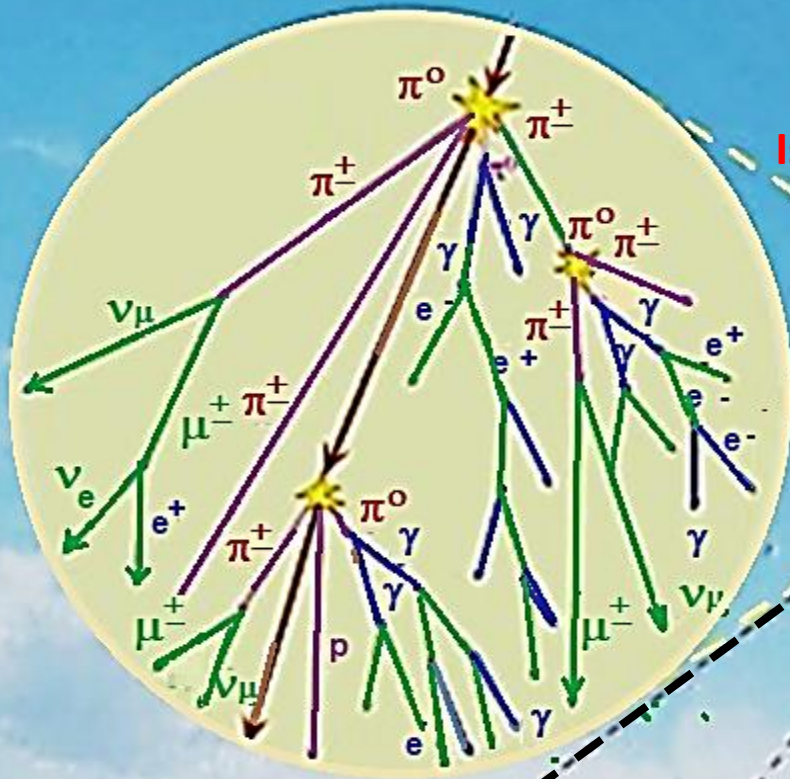


Surface Station - devices

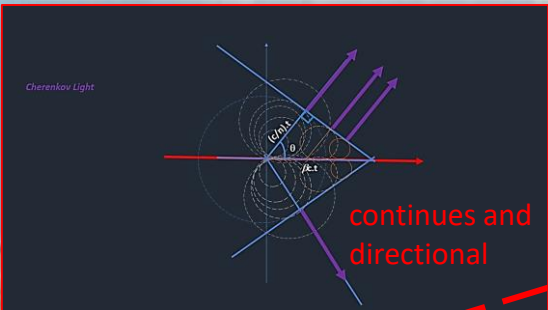
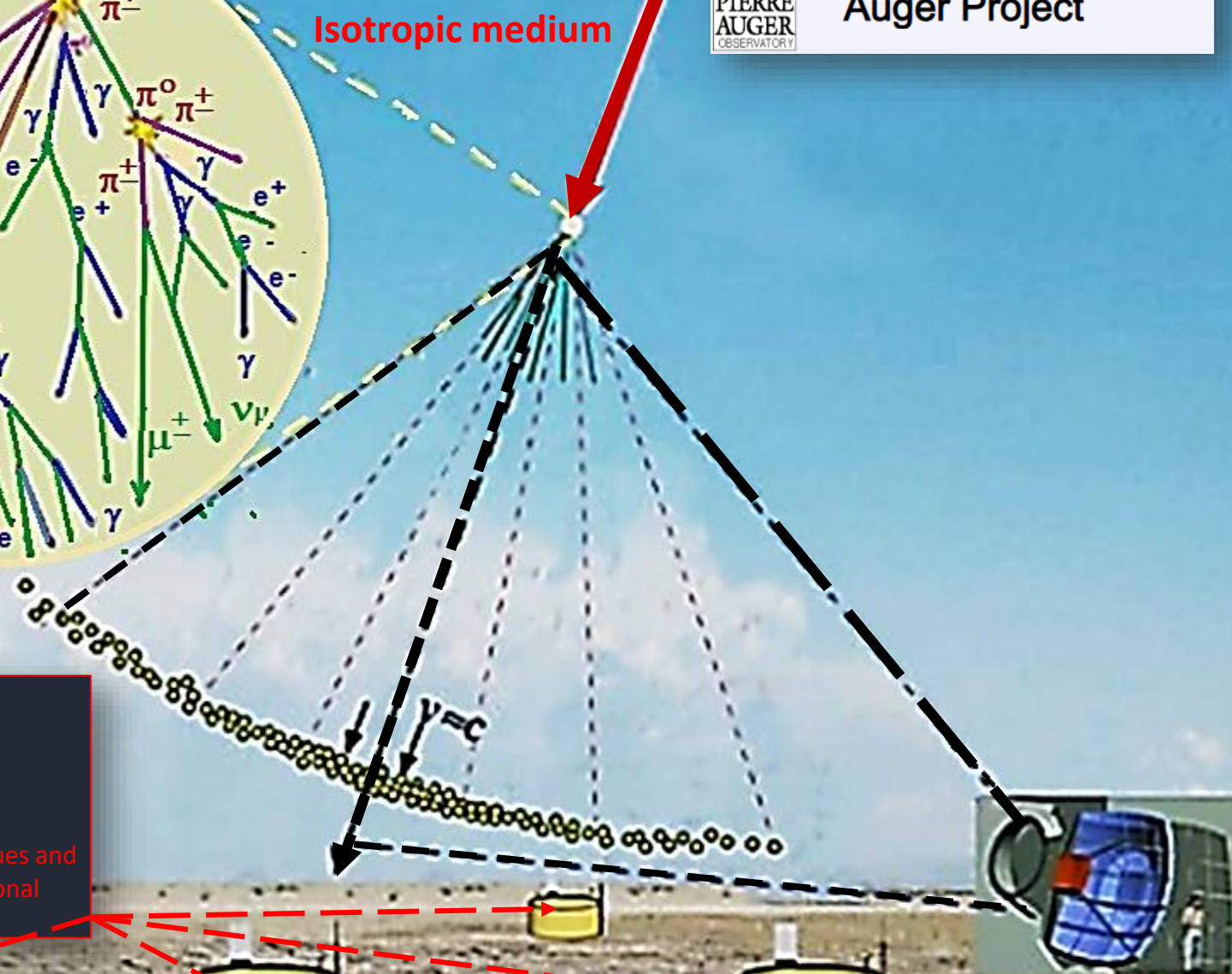




A Cherenkov Radiation Detector for the Auger Project



Isotropic medium





**A Cherenkov Radiation
Detector for the
Auger Project**



PIERRE AUGER OBSERVATORY | Malargüe – Argentina (Mendoza)

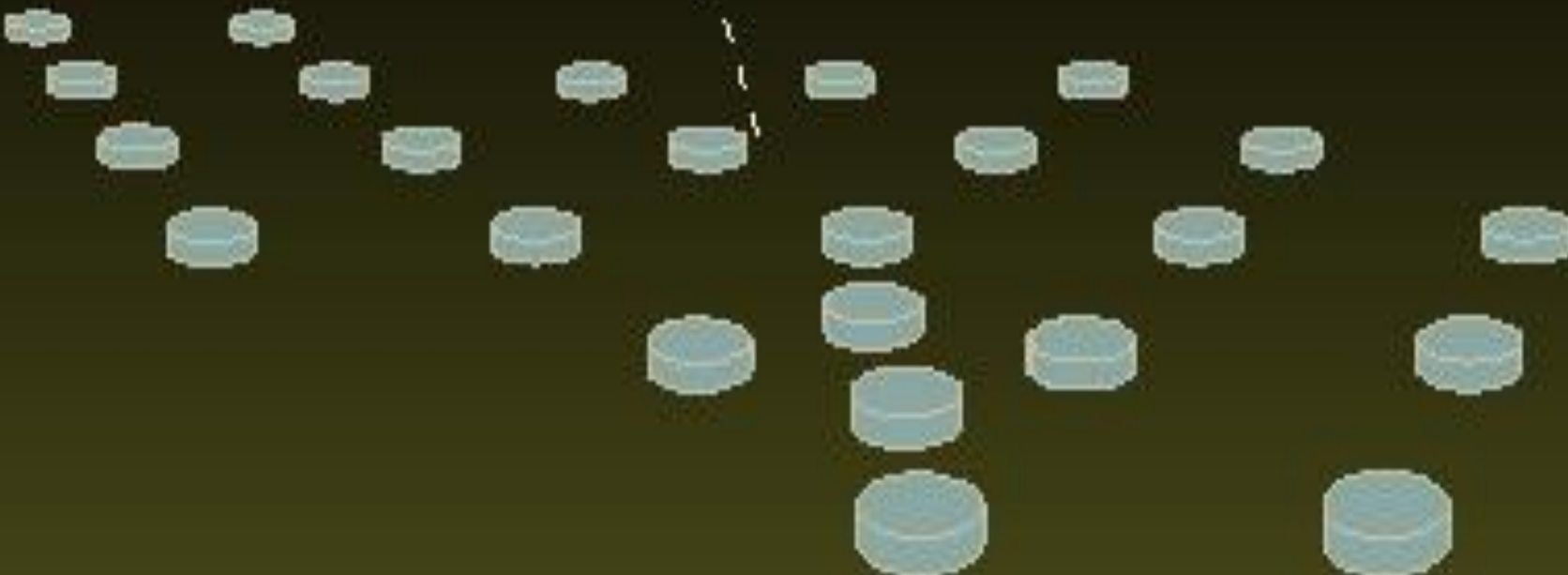
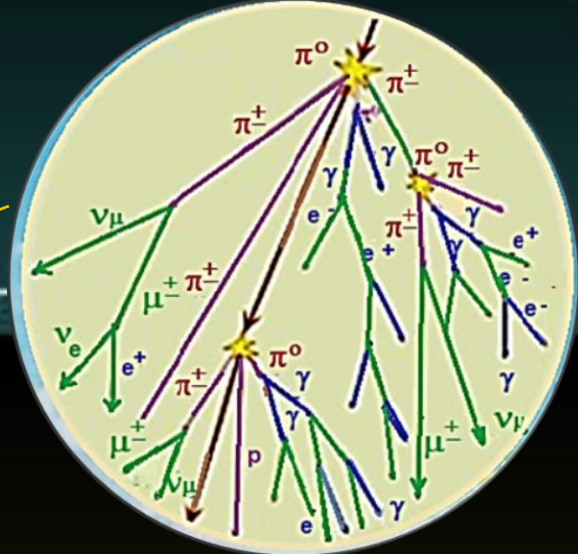
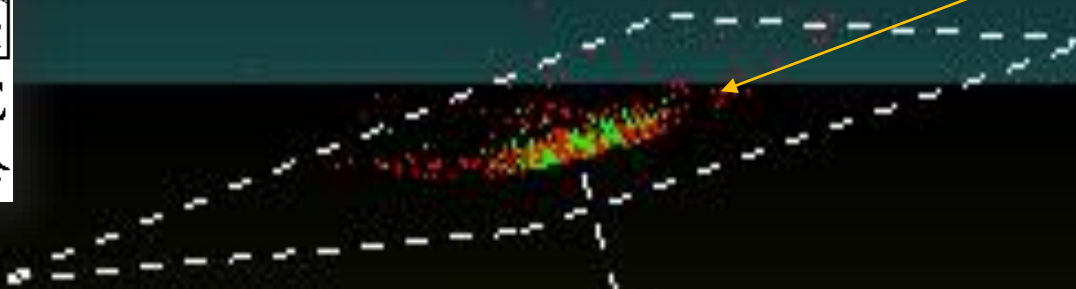


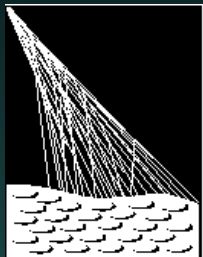
Alignment of tanks



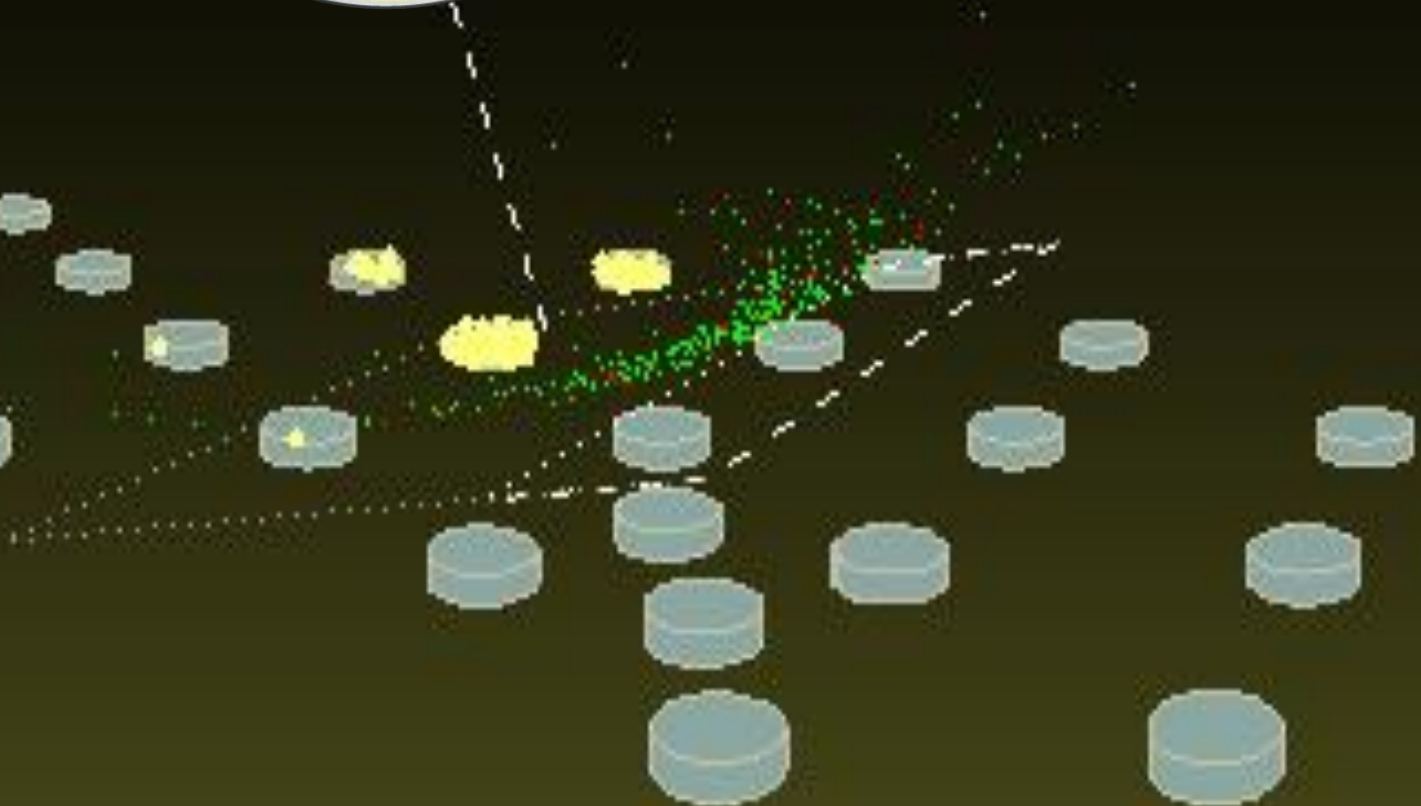
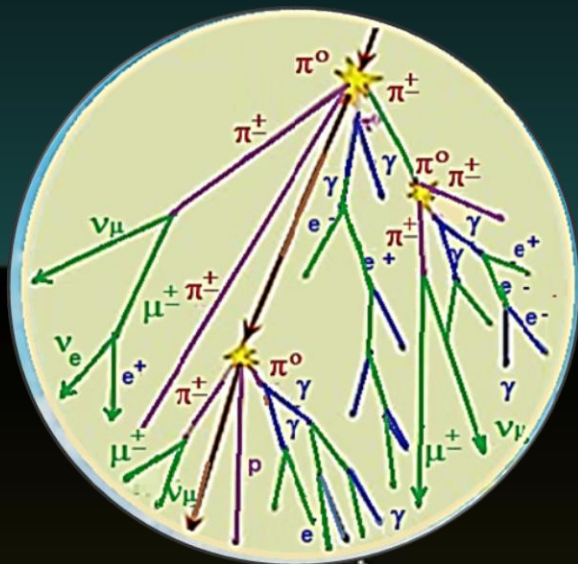


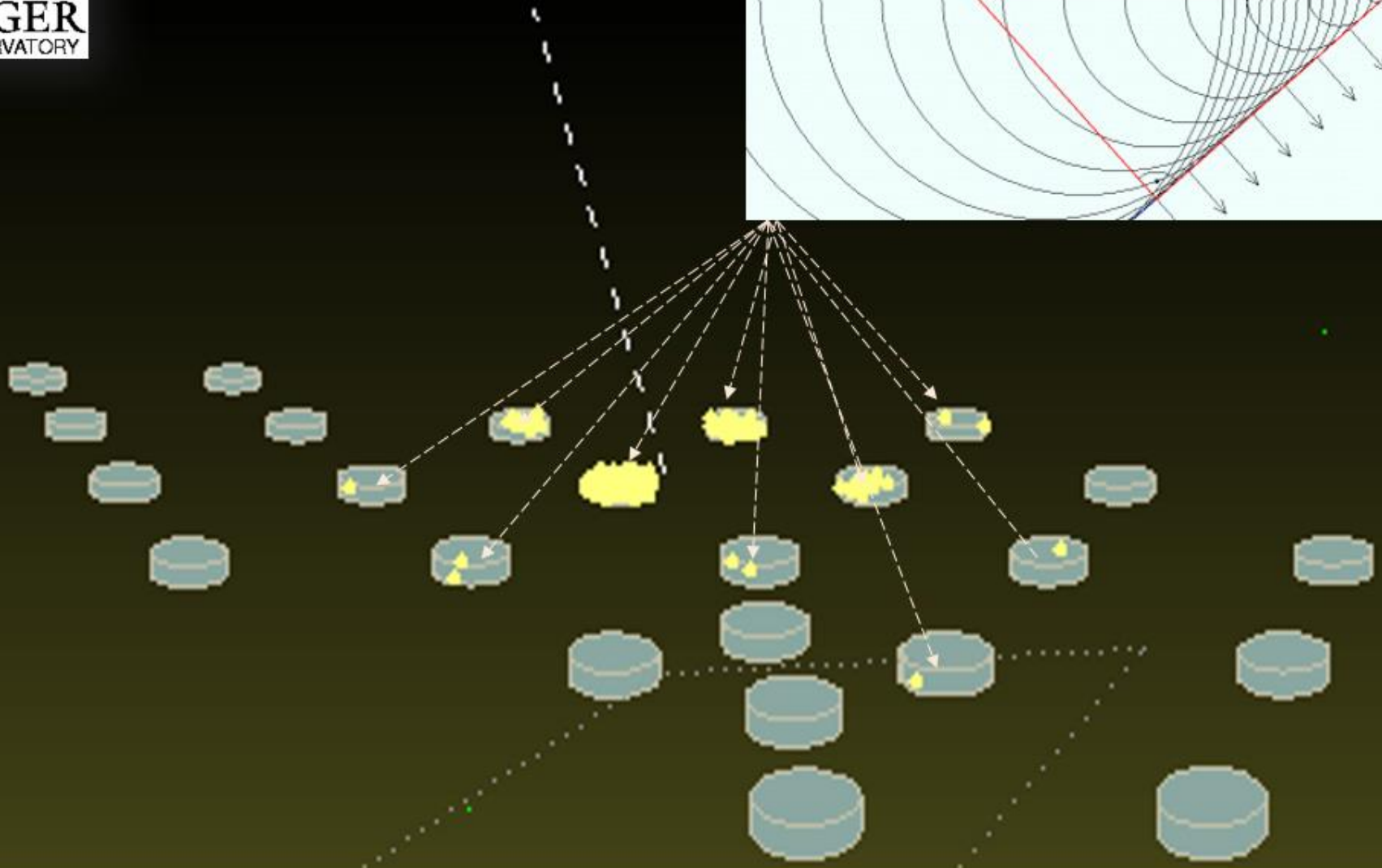
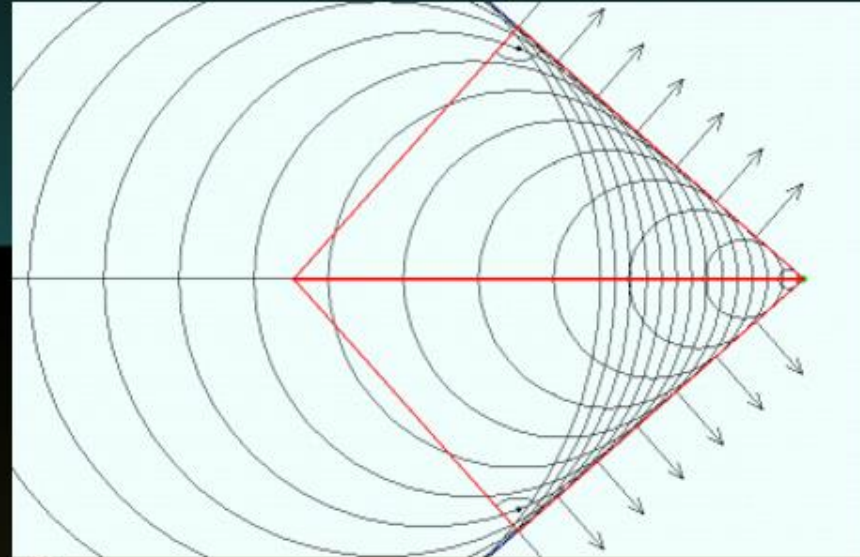
PIERRE
AUGER
OBSERVATORY



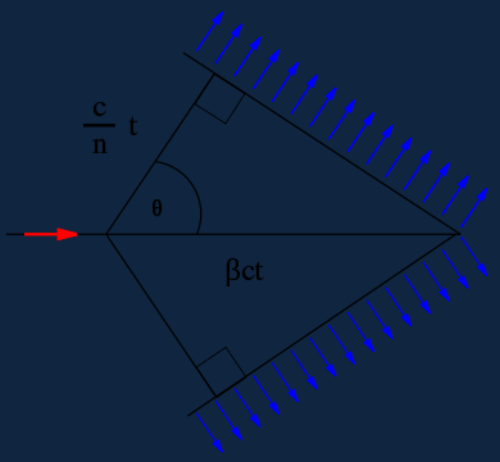
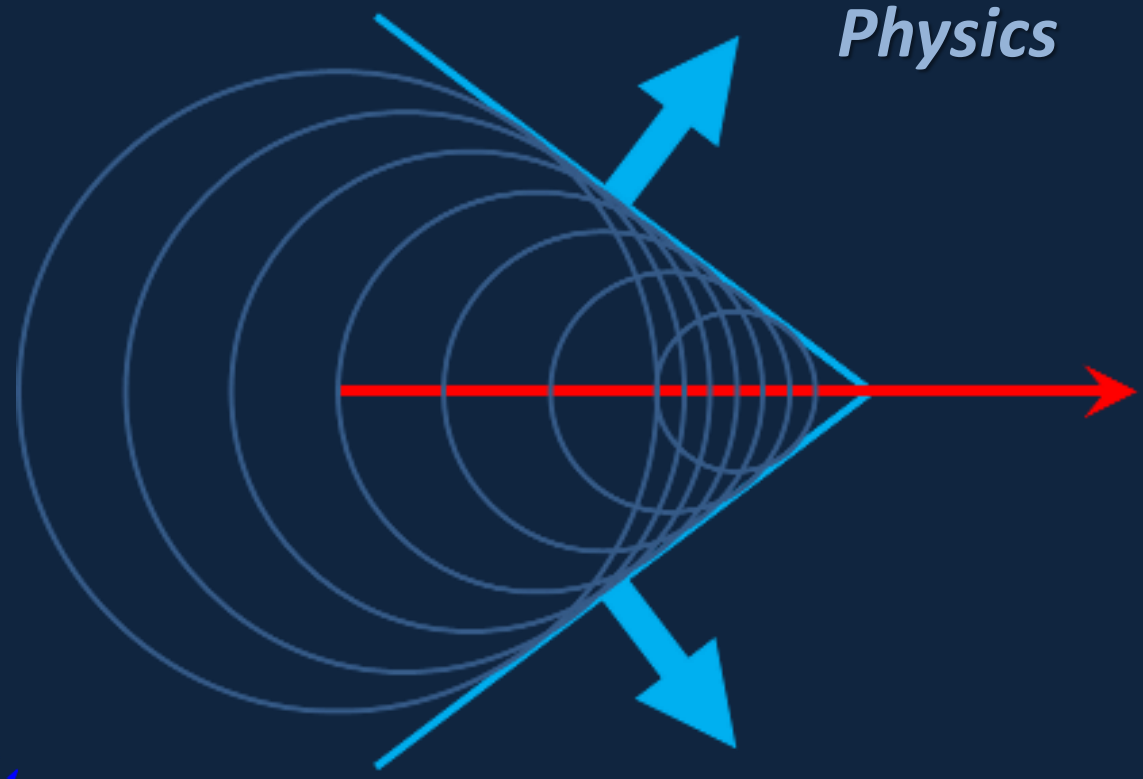


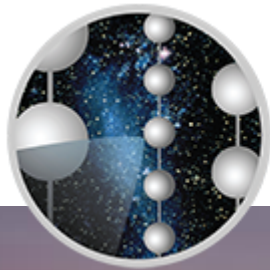
PIERRE
AUGER
OBSERVATORY





Cherenkov Light Physics





ICECUBE

SOUTH POLE NEUTRINO OBSERVATORY



O IceCube Neutrino Observatory na Estação Polar *Amundsen – Scott* na Antártica.
São milhares de sensores localizados sob o gelo antártico, distribuídos por um quilômetro cúbico.

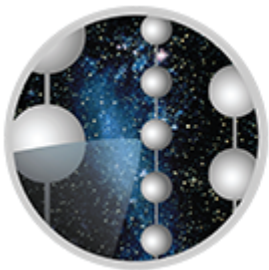


Roald Engelbregt Gravning *Amundsen* (1872-1928)



Robert Falcon *Scott* (1868-1912)

Source: [https://icecube.wis.edu/IceCube Neutrino Observatory](https://icecube.wis.edu/IceCube%20Neutrino%20Observatory)



ICECUBE

SOUTH POLE NEUTRINO OBSERVATORY

radio/microwave

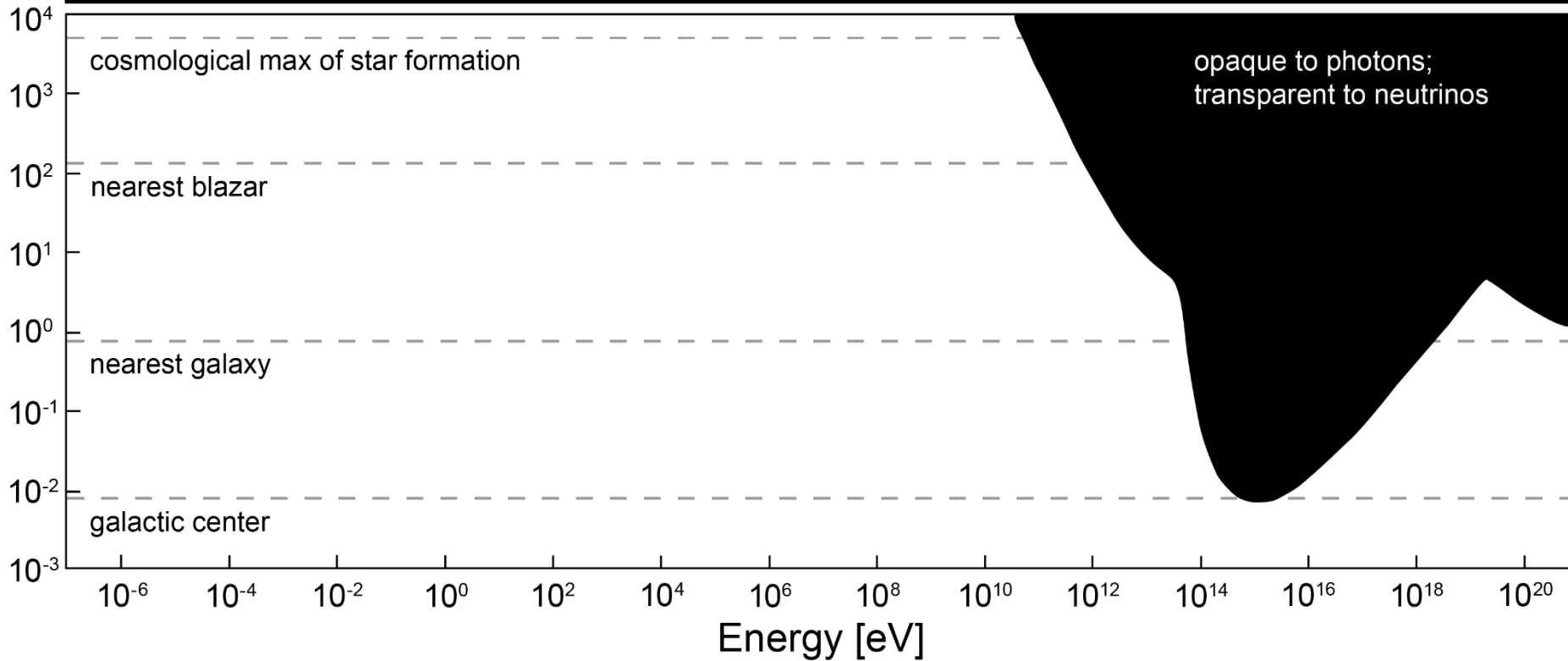
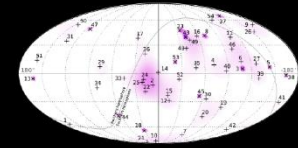
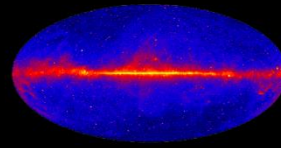
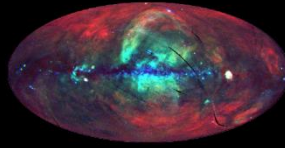
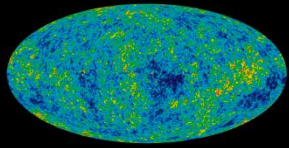
infrared/optical

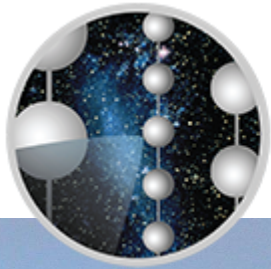
X-rays

gamma-rays

neutrinos

cosmic-rays





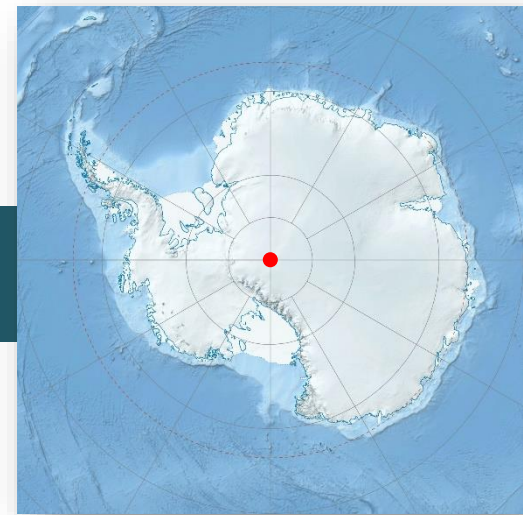
ICECUBE

SOUTH POLE NEUTRINO OBSERVATORY



IceCube drilling tower and hose reel in December 2009 | 2013

Source: <https://icecube.wis.edu/>
IceCube Neutrino Observatory



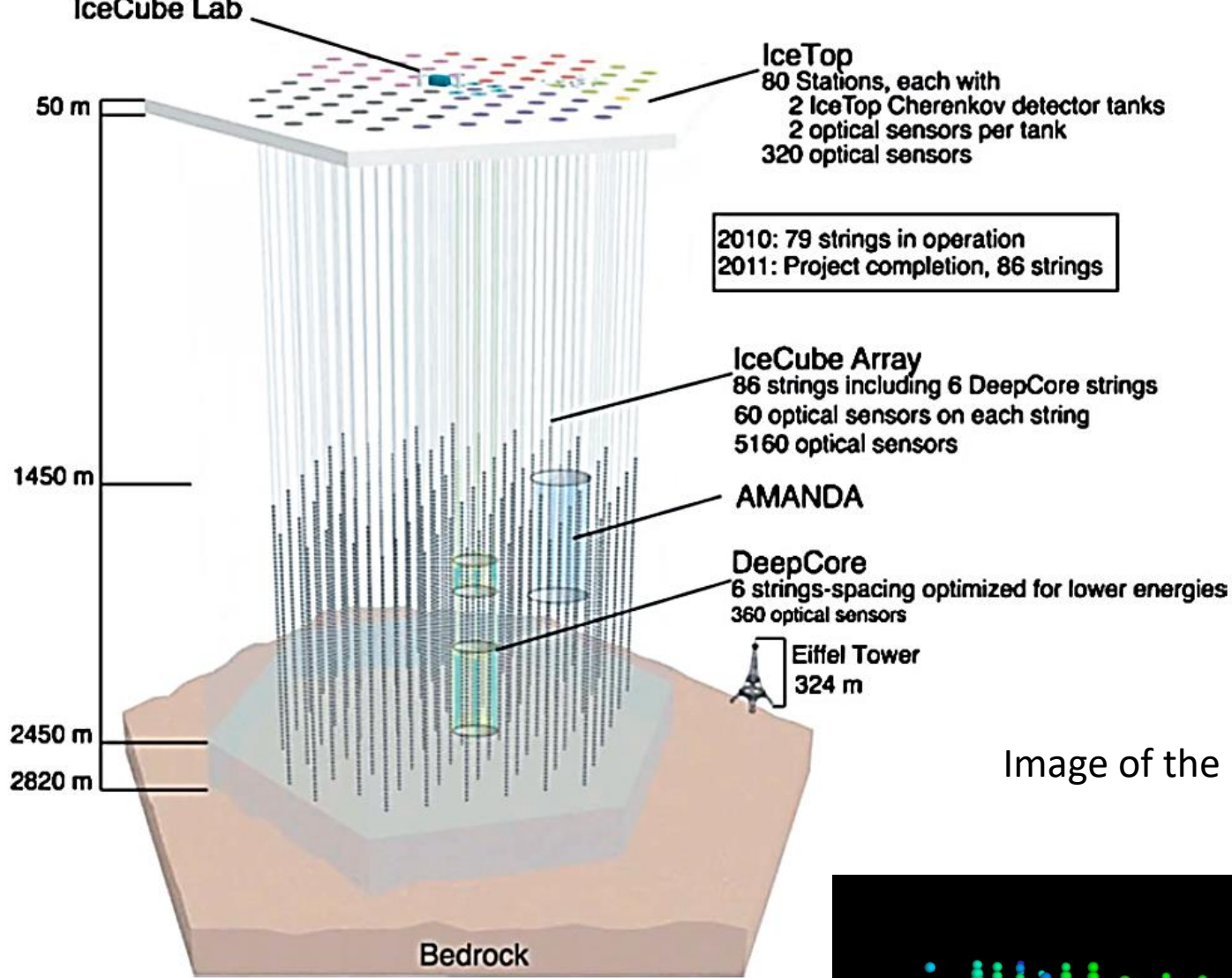
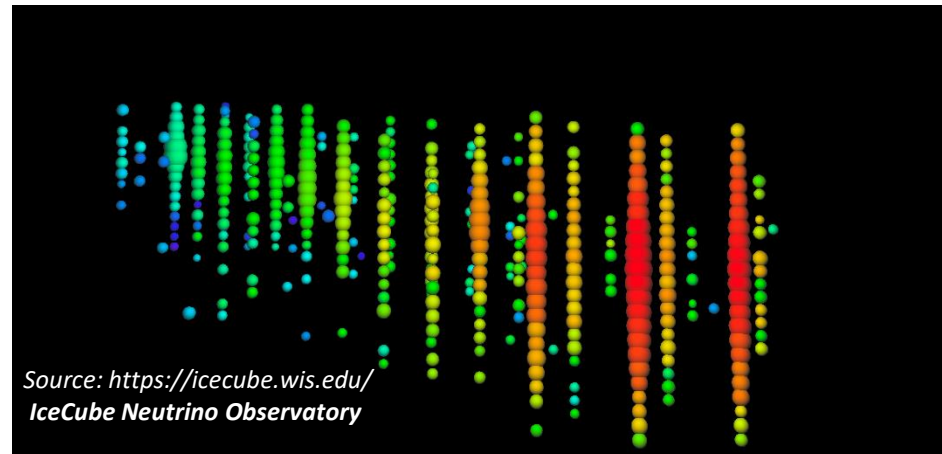
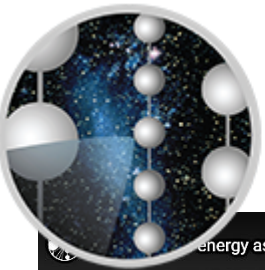


Image of the ice cube diagram.

Alert IC170922A was a muon neutrino with an estimated energy of ~ 300 TeV. Blazar TXS0506+06, a massive black hole shooting with powerful jets of high-energy particles pointing to Earth, is located within less 0.1 degrees from this neutrino and at a distance somewhere between 1.3 and 4.3 billion light years (redshift between 0.1 and 0.4).

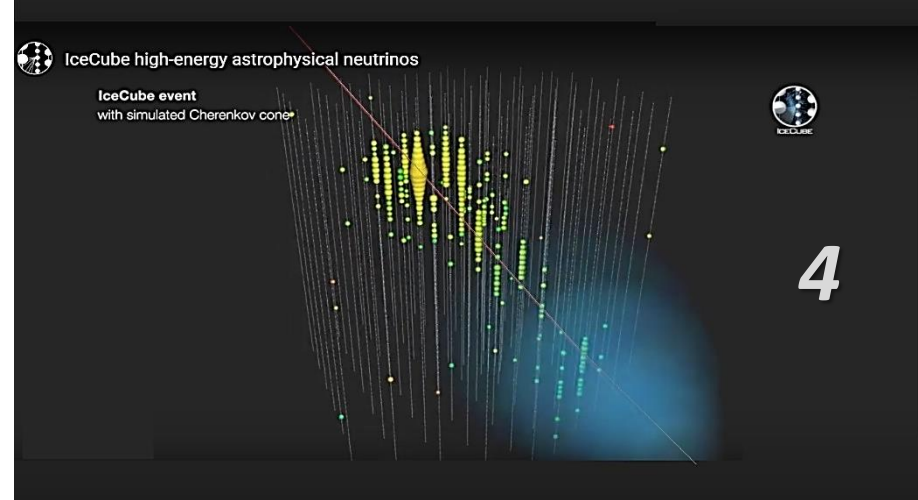
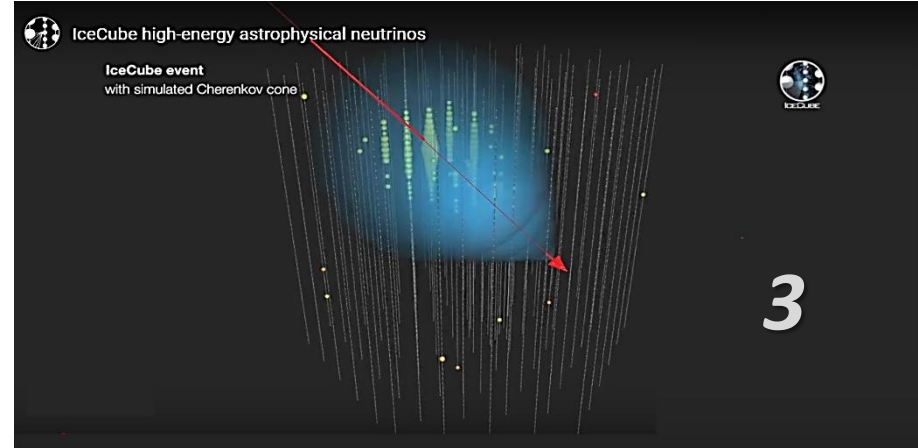
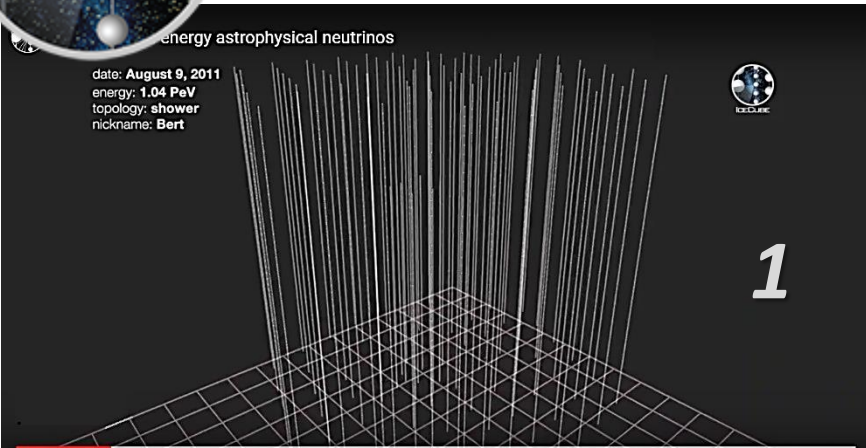


Source: <https://icecube.wis.edu/>
IceCube Neutrino Observatory



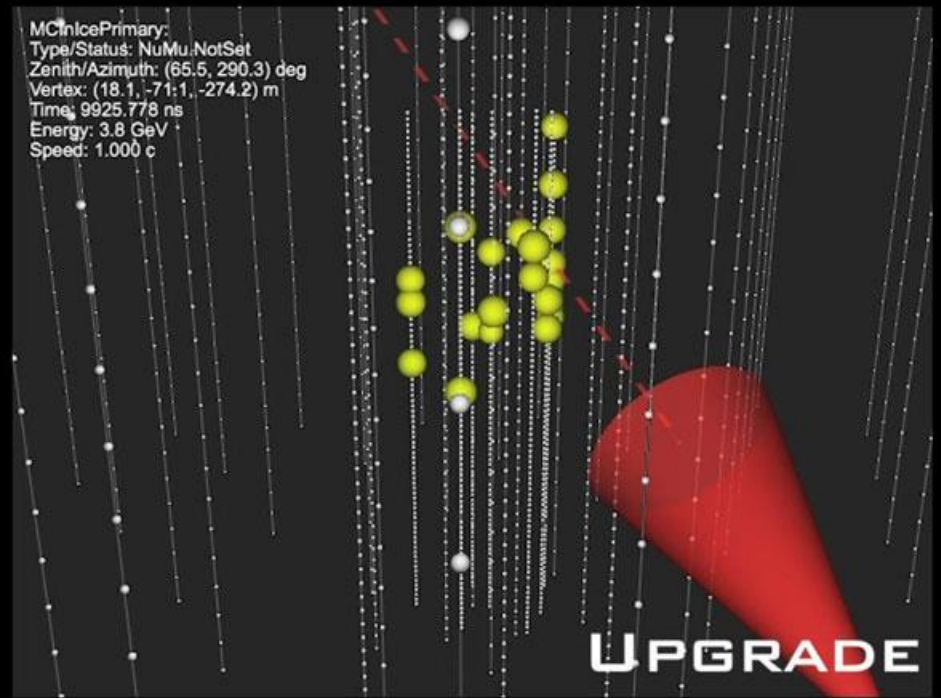
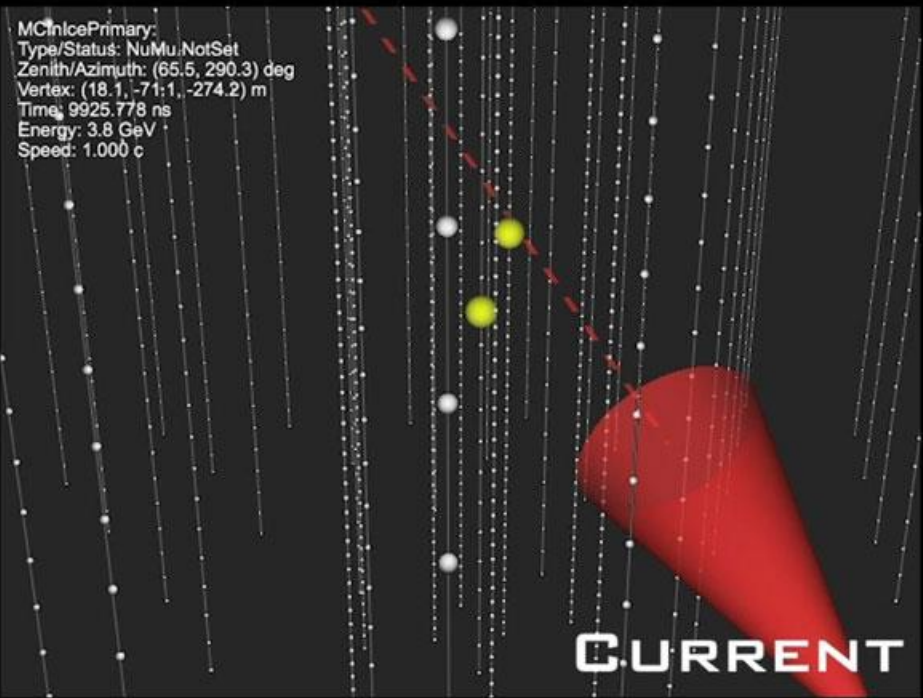
ICECUBE

SOUTH POLE NEUTRINO OBSERVATORY



"*Taklampa*," one of the Digital Optical Modules of IceCube's hole #85

Source: <https://icecube.wis.edu/>
IceCube Neutrino Observatory



Source: <https://icecube.wis.edu/>
IceCube Neutrino Observatory

Interaction at sea level

$h\nu$ (photon)

- **Shock and / or absorption section** (*photons*)

1 - Photoelectric Effect- Absorption ($h\nu < 5 \times 10^4$ eV)

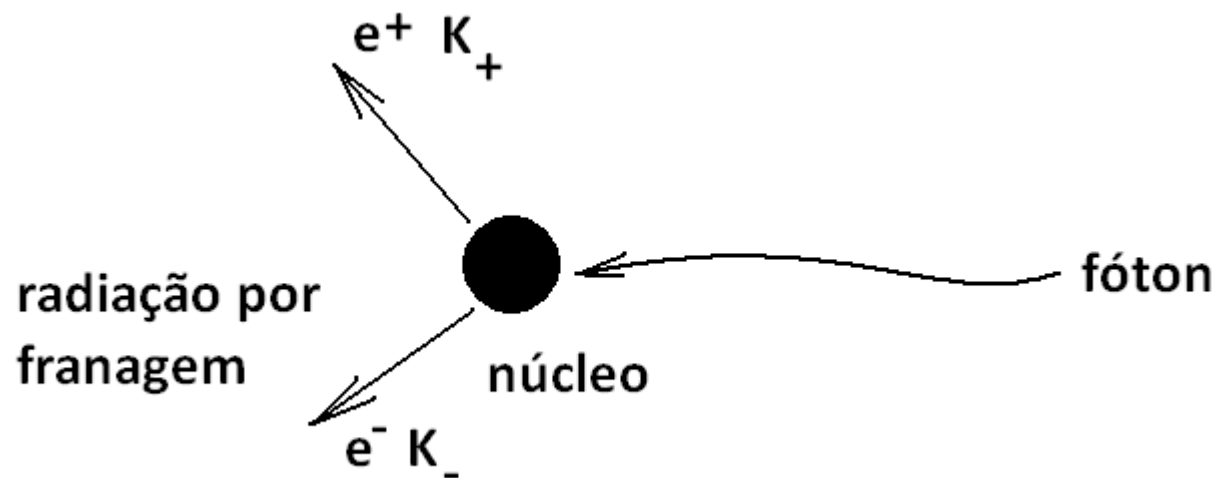
2 - Spreading – Shock (Thomson or Compton)

(5×10^4 eV $< h\nu < 5 \times 10^7$ eV)

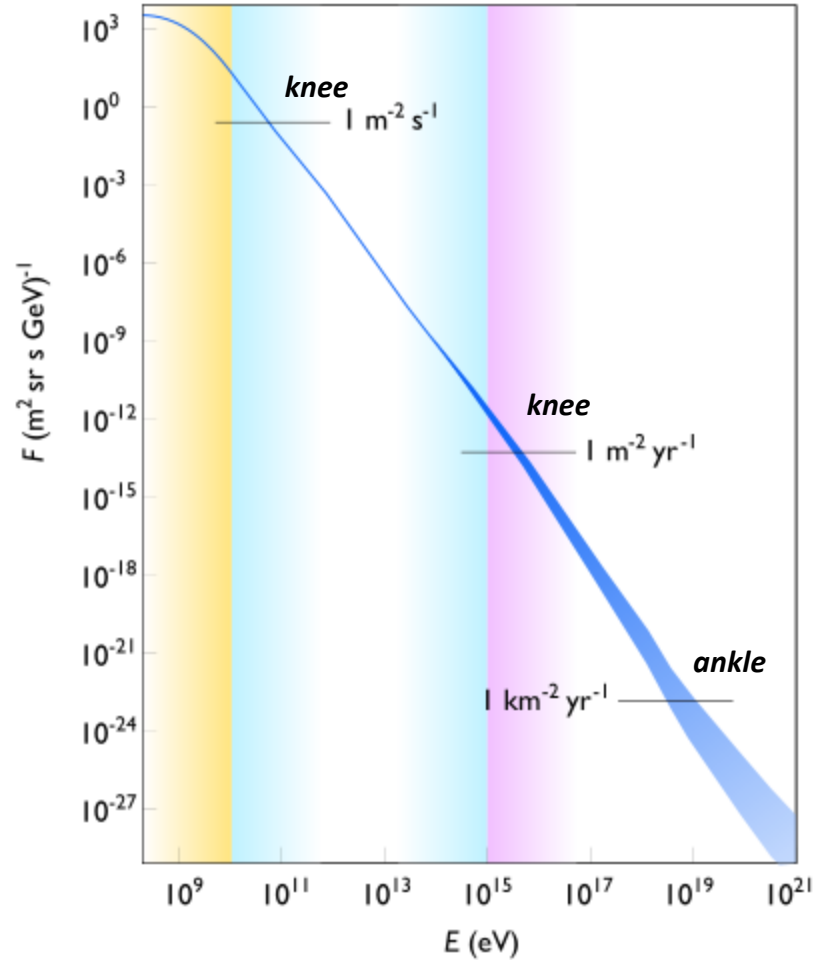
3 – Production of pairs – Shock $h\nu > 5 \times 10^7$ eV

(bremsstrahlung process)

Bremsstrahlung Process



Cosmic Ray Spectrum



Cosmic Ray Monitoring

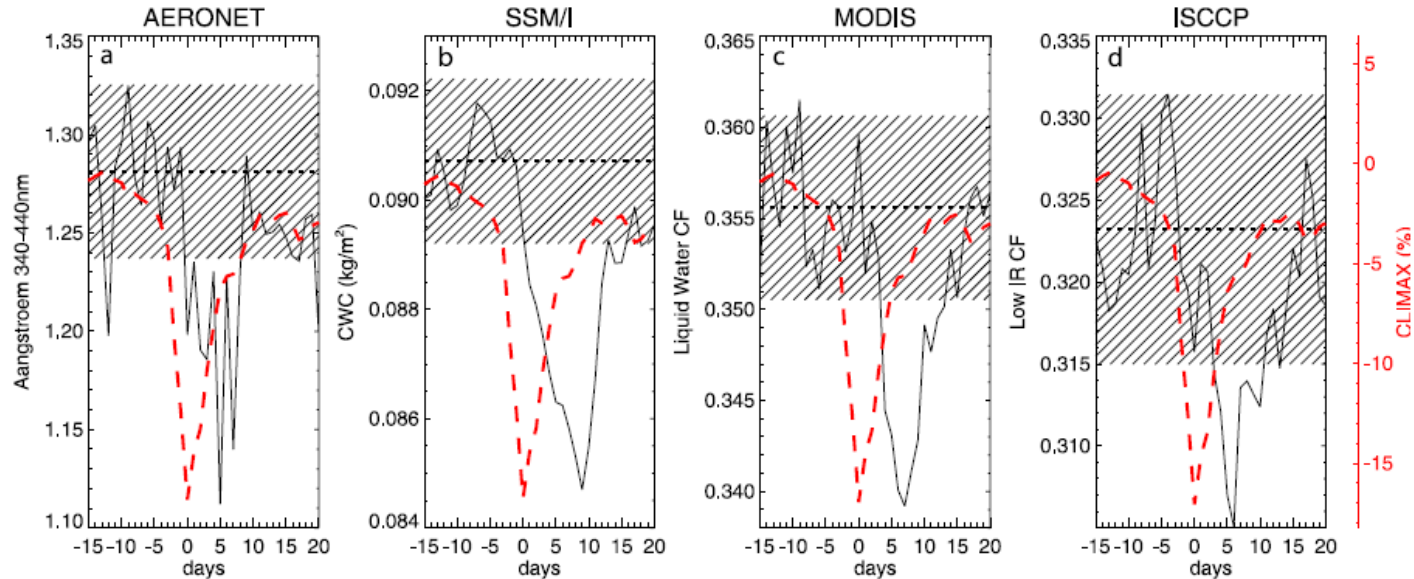


Figure 1. The evolution of (b) cloud water content (SSM/I), (c) liquid water cloud fraction (MODIS), and (d) low IR-detected clouds (ISCCP) is here averaged for the 5 strongest Forbush decreases that their data sets have in common (order numbers 1, 3, 4, 6, and 7 in Table 1) and is compared with (a) the corresponding evolution of fine aerosol particles in the lower atmosphere (AERONET). In (a) each data point is the daily mean from about 40 AERONET stations world-wide, using stations with more than 20 measurements a day. Red curves show % changes in GCR neutron counts at Climax. The broken horizontal lines denote the mean for the first 15 days before the Forbush minimum, and the hatched zones show $\pm 1\sigma$ for the data, estimated from the average variance of a large number of randomly chosen periods of 36 days of each of the four data sets. The effects on clouds and aerosols are not dominated by any single event among the 5 averaged. Examples of SSM/I data for several individual events are shown in the auxiliary material.

Source: H. Svensmark, E. F. Christensen. *Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships.* *Journal of Atmospheric and Solar-Terrestrial Physics*, 59, 11 (1997) 1225.

Cosmic Ray Monitoring

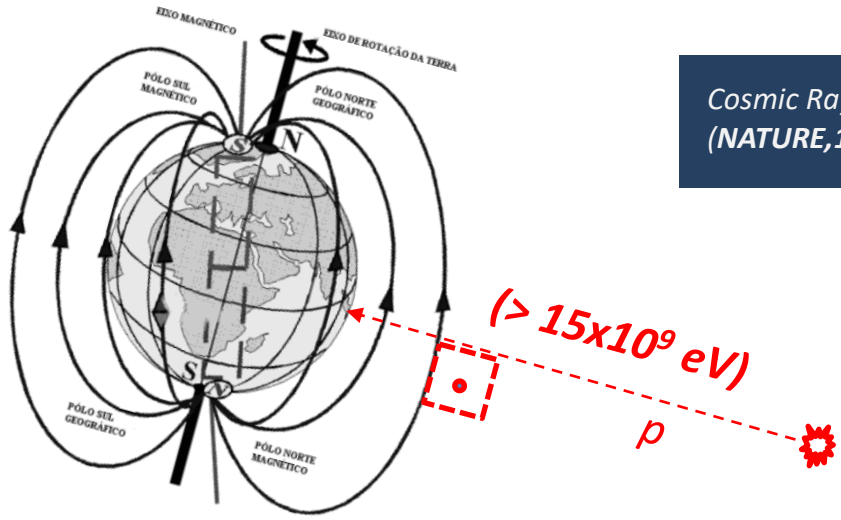
Table 1. Twenty-Six Solar Events in the Period 1987–2007 are Here Ranked According to Their Depression of Ionization in the Earth's Lower Atmosphere, Gauged as a Percentage of the Normal Overall Variation in Ionization During the Course of a Solar Cycle^a

Order	Date	Decrease (%)
1	31/10/2003	119
2	13/6/1991	87
3	19/1/2005	83
4	13/9/2005	75
5	15/3/1989	70
6	16/7/2000	70
7	12/4/2001	64
8	29/10/1991	56
9	9/7/1991	54
10	29/11/1989	54
11	10/11/2004	53
12	26/9/2001	50
13	25/3/1991	48
14	17/7/2005	47
15	25/9/1998	45
16	27/7/2004	45
17	10/9/1992	44
18	31/5/2003	44
19	25/11/2001	39
20	15/5/2005	38
21	28/8/2001	37
22	27/8/1998	36
23	10/5/1992	35
24	27/2/1992	33
25	18/2/1999	33
26	2/5/1998	28

Source:H. Svensmark, E. F. Christensen. *Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships.* *Journal of Atmospheric and Solar-Terrestrial Physics*, 59, 11 (1997) 1225.

Low influence of Cosmic Rays on the equatorial region

Cosmic Ray and the Weather
(NATURE,183)p. 451-452. 1959



Equator in the vertical direction

Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships. Journal of Atmospheric and Solar-Terrestrial Physics, 59, 11 (1997) 1225

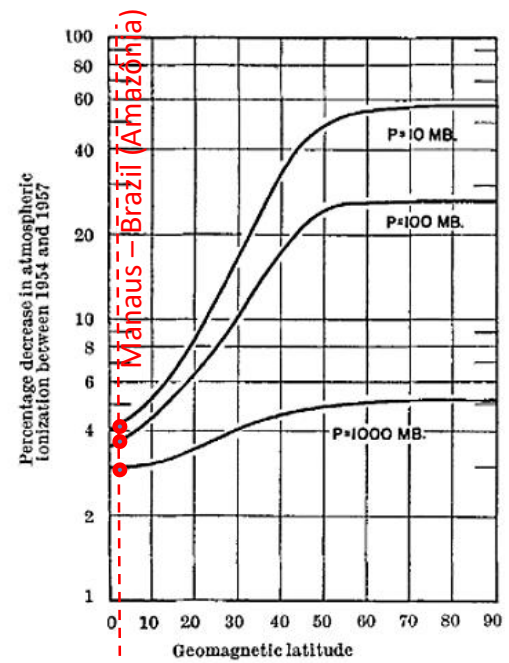


Fig. 2. Percentage reduction in atmospheric ionization during the last solar cycle. The percentage change is calculated with respect to the value of the ionization at sunspot minimum in 1954

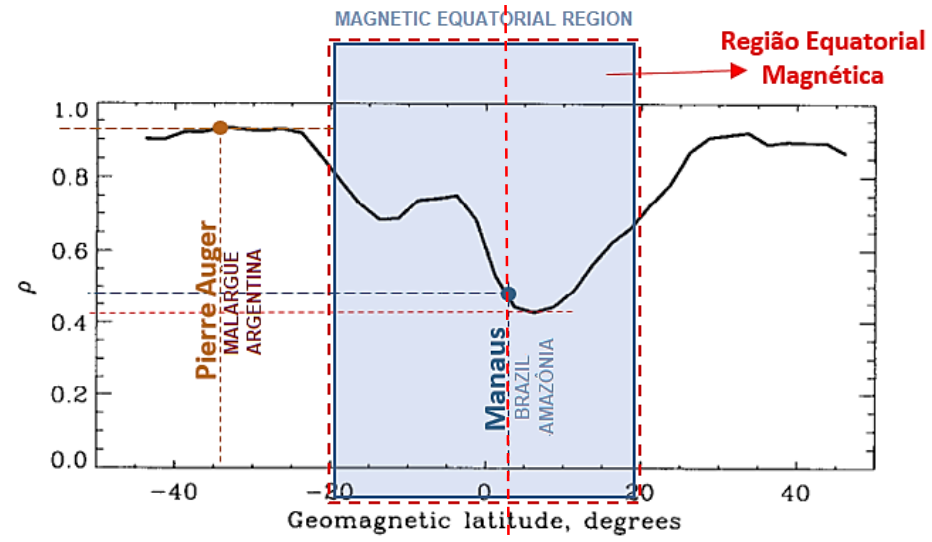


Fig. 5. Latitude profile of zonal average values of the correlation between the cosmic ray flux and the cloud cover over the oceans. The zonal averages have been derived corresponding to geomagnetic latitudes (dipole field with pole at 78.5°N 291°E).

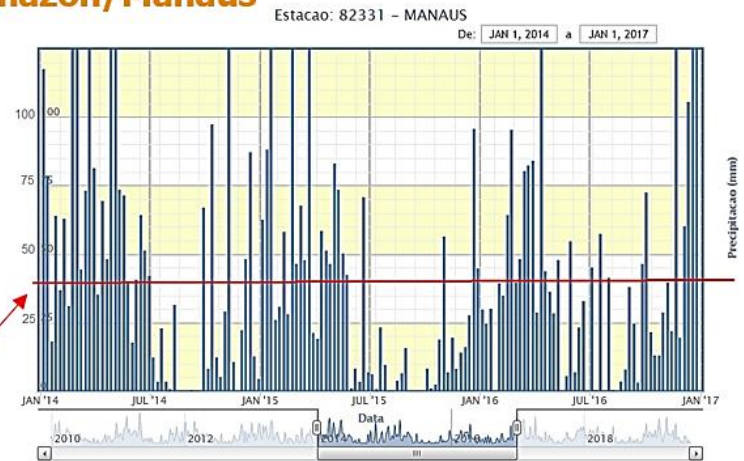
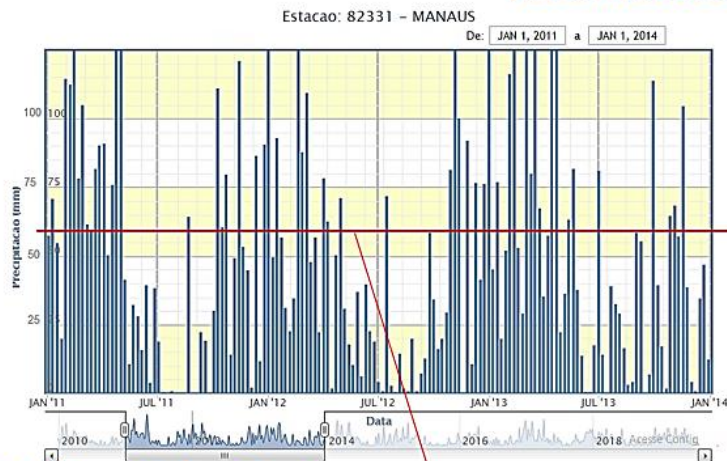
Observations with operational research on the connection of the 11-year Solar Cycle and the El Niño and La Niña phenomena and rainfall in the Amazon (1980-2030).

Newton Silva de Lima^{*††}, Eriberto Façanha^{*††}, Alan dos Santos Ferreira^{*}, Aldemir Malveira^{††}, José Cavalcante^{††}, Roseilson Souza do Vale[‡], Daniel Valentim Mansur⁺

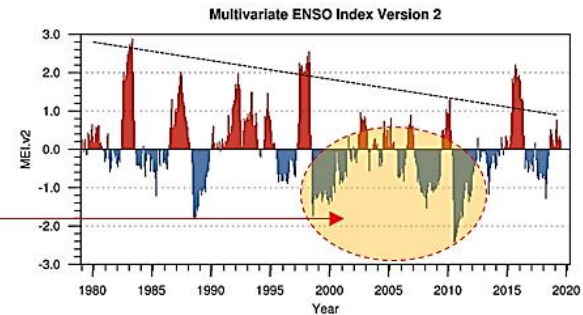
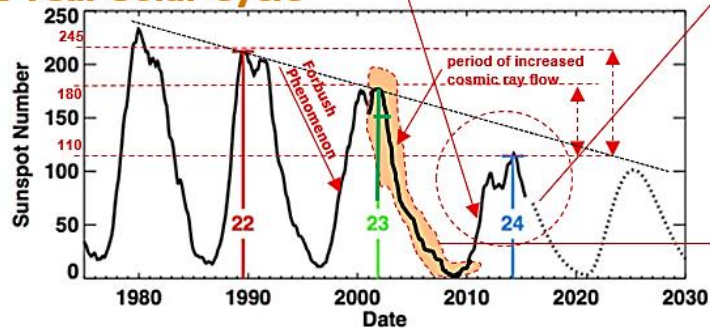
^{*}Lutheran University Center of Manaus (Geosciences - Mathematics) / [†]Federal University of Amazonas (Mathematics) / [‡]Federal University of West of Pará (Geosciences), ^{††}(Secretary of Education and Quality of Teaching of the State of Amazonas), ⁺Federal University of Juiz de Fora.



Accumulated rain – Amazon/Manaus



11 Year Solar Cycle



Observations with operational research on the connection of the 11-year Solar Cycle and the El Niño and La Niña phenomena and rainfall in the Amazon (1980-2030).

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^{*}Lutheran University Center of Manaus (Geosciences - Mathematics) / ^{††}Federal University of Amazonas (Mathematics)/

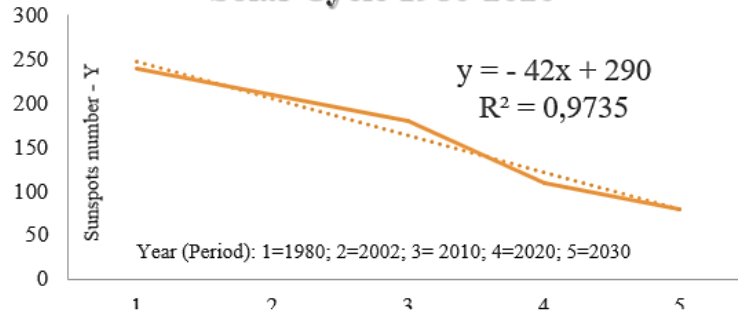
^{‡‡}Federal University of West of Pará (Geosciences), ^{††}(Secretary of Education and Quality of Teaching of the State of Amazonas), ^{*}Federal University of Juiz de Fora.

^{†††}Manaus (Brazil)/ [‡]Santarém (Brazil)/ [†]Juiz de Fora (Brazil)

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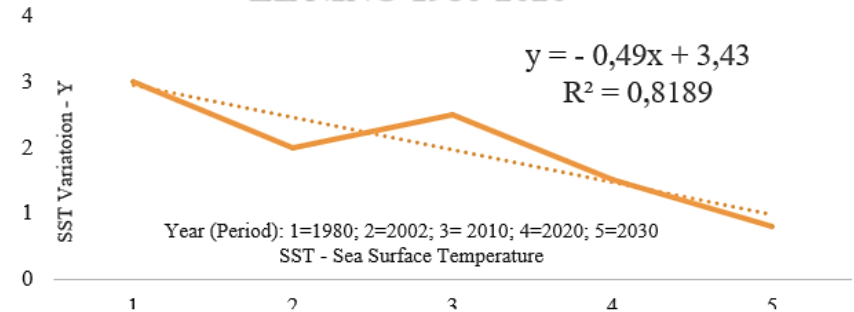
Solar Cycle 1980-2020



Regression Statistics	
R multiple	0,9913744
R-Square	0,982823202
R-square adjusted	0,977097602
Standard Error	10,18566944

Predicted Y	Residue
246,1153034	-6,11530335
209,4566858	0,543314217
165,4663447	14,5336553
117,8101419	-7,810141865
81,1515243	-1,151524298

EL NIÑO 1980-2020



Regression Statistics	
R multiple	0,898711725
R-Square	0,807682765
R-square adjusted	0,74357702
Standard Error	0,433541283

Predicted Y	Residue
2,906912164	0,093087836
2,484183519	-0,484183519
1,976909146	0,523090854
1,427361908	0,072638092
1,004633263	-0,204633263

Cosmic Ray Monitoring



Image Credit - Crédito da imagem: Jornal Acrítica – Manaus, BRAZIL 2010.

2010 Drought

Benjamin Constant – AM/Brazil



Image Credit - Crédito da imagem: Jornal Acrítica – Manaus, BRAZIL 2010.

2010 Drought— Manaus – AM/Brazil



Image Credit - Crédito da imagem: Jornal Acrítica – Manaus, BRAZIL 2010.

Thank you !



Image Credit - Crédito da imagem: Jornal Acrítica – Manaus, BRAZIL 2010.

Agradecimientos

acknowledgments

Volunteer researchers at Atmosphere Office 101 for their participation in fieldwork, collaborations and reading of texts.

