Cosmic Ray radiation dosimetry on ground and in space

Italian-Argentine collaboration

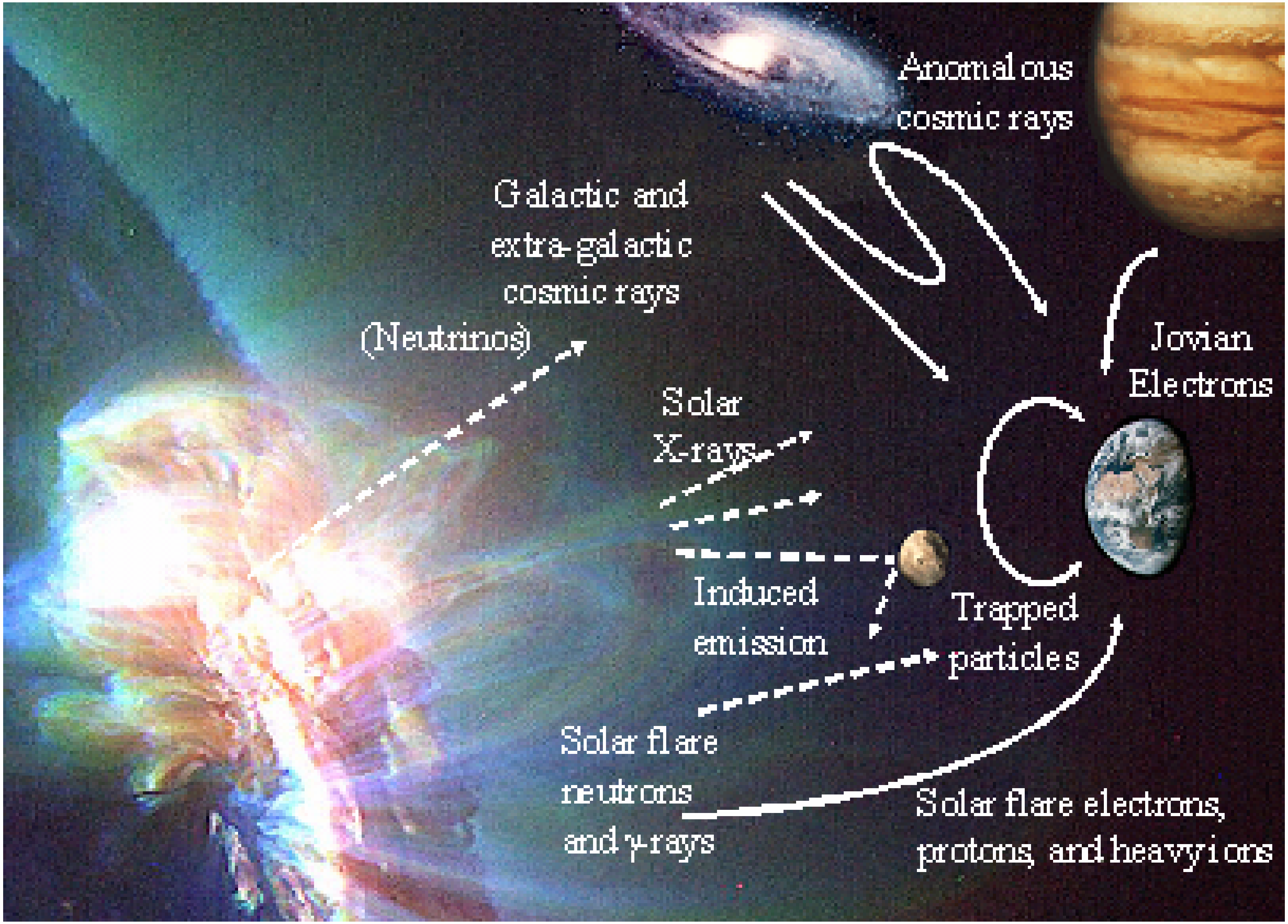
Ecole Internationale d'Astrophisique Chalonge-De Vega

Citè Universitaire de Paris- Casa Argentina

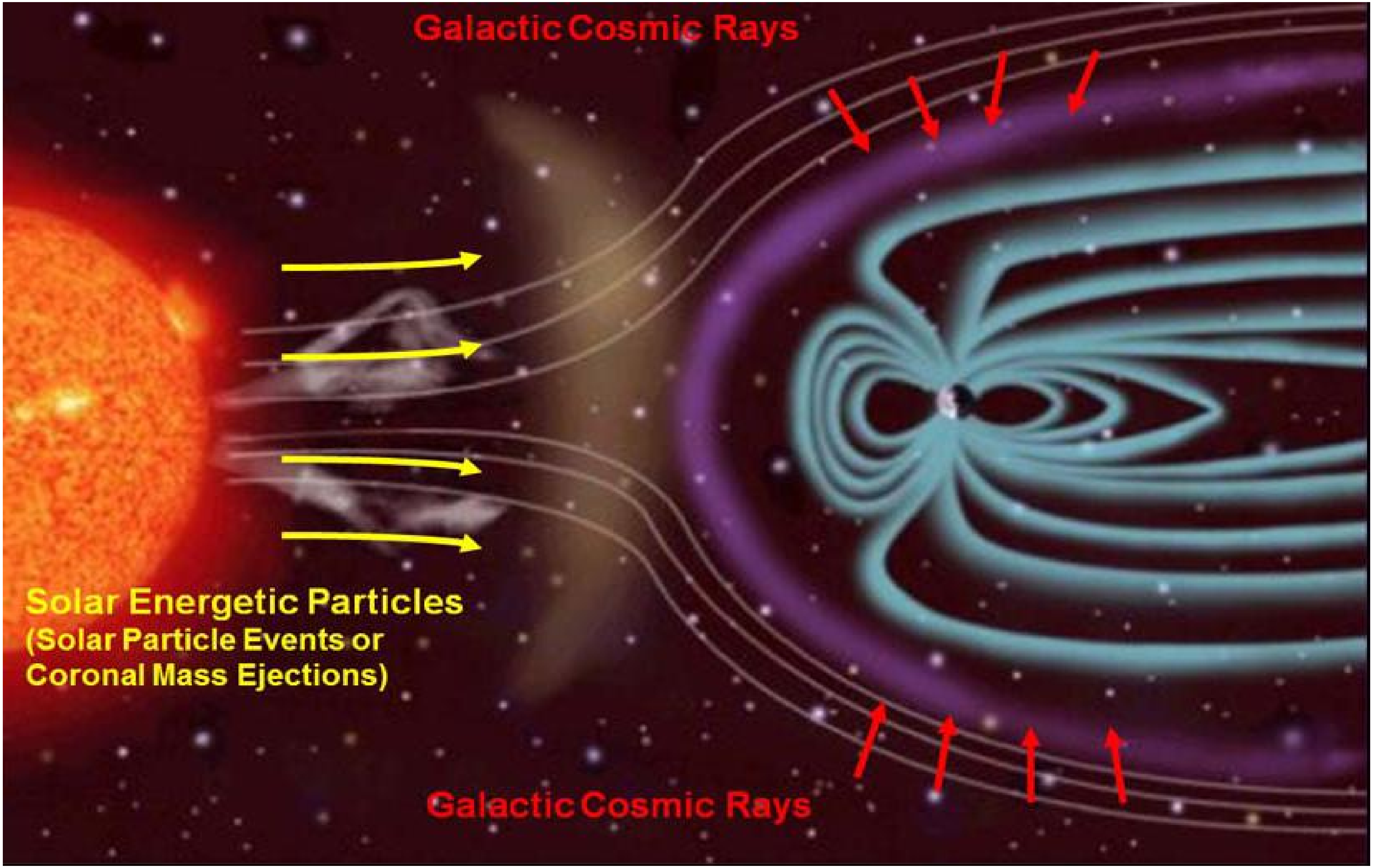
23 November 2017

Alba Zanini INFN Sezione di Torino, Italy

Radiation Dosimetry on ground and in space

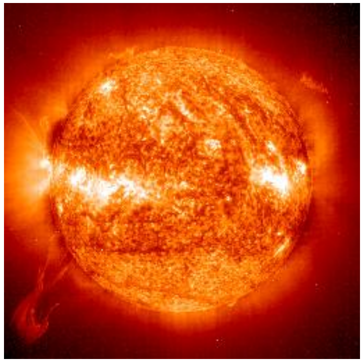


Origine dei raggi cosmici



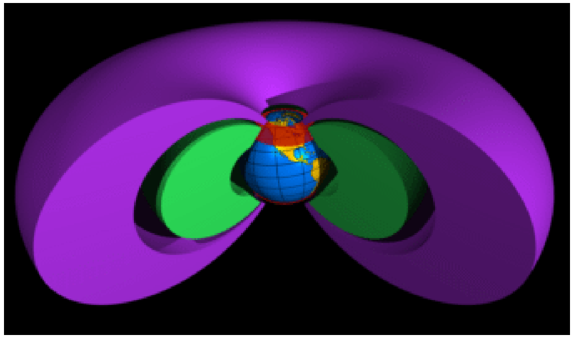
Primary radiation

- **Galactic Cosmic Radiation (GCR)** consists of completely ionised atomic nuclei (**from protons up to high Z)**. Heavy Charged Particles (HCP) have their origin outside the solar system and are accelerated to extremely high energies.



- **Solar particle-event radiations (SPE)** are in general large clouds of charged particles (mainly **protons and helium nuclei** in a wide range of energy) released from the sun by gigantic eruptions during solar storms
.
- **Geomagnetically Trapped Radiation** (Van Allen Belts) consists of

  electrons with E > 0.5 MeV,
  protons with E > 10 MeV
  helium nuclei.



Primary radiation

Primary cosmic rays are produced in supernovae explosions and accelerated by shock waves
Cosmic ray flux on Earth is modulated by solar activity

Higher solar activity correspond to lower cosmic ray flux

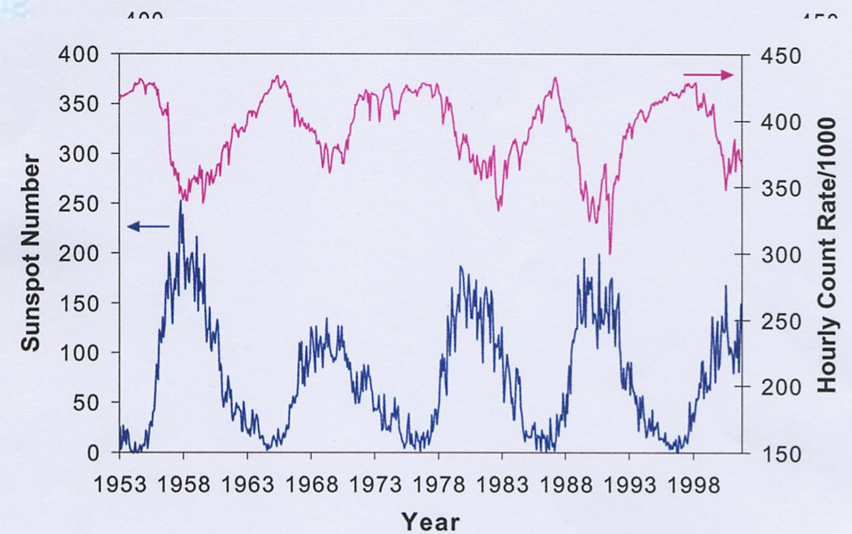
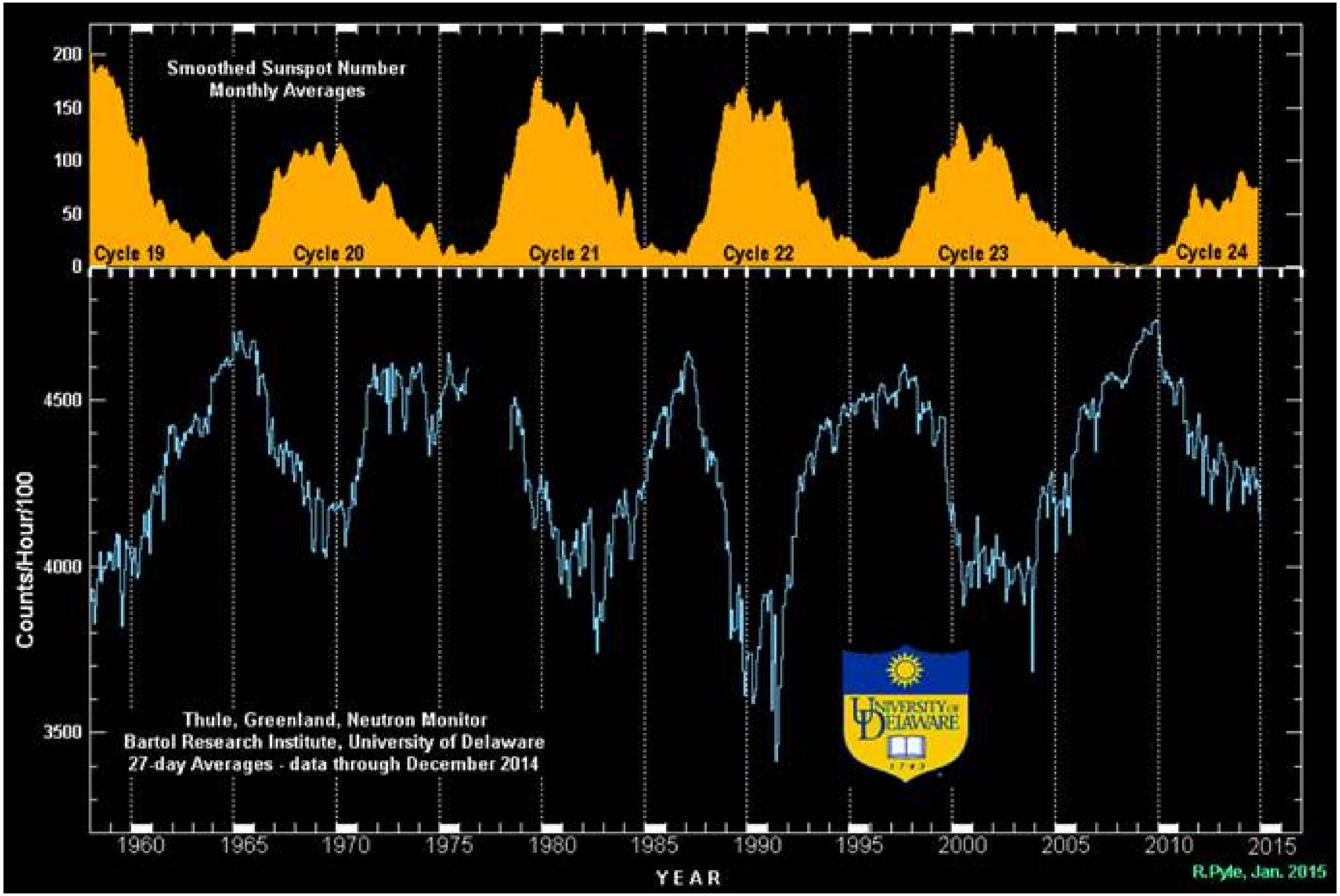


Figure 1.1 Plot of sunspot number and neutron count rate versus date. (—) Sunspot number per month (which is an indication of the activity of the sun);[3] (—) Monthly average of the hourly neutron count from the Climax, Colorado ground-based neutron monitor (which detects variations in the intensity of the cosmic ray neutrons which penetrate the Earth's atmosphere).[4]

Il vento solare scherma i raggi cosmici primari



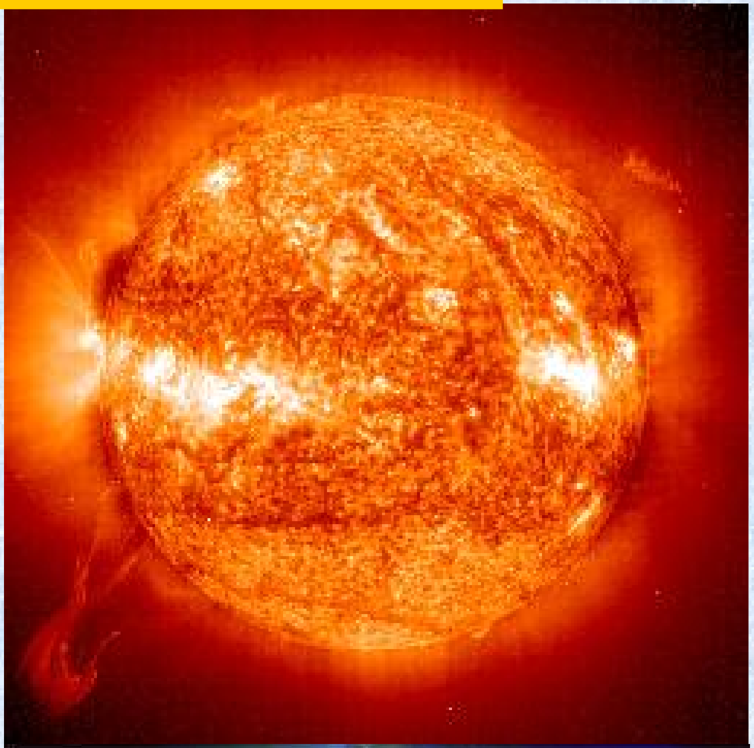
L'attività solare si misura in base al numero di macchie solari

La variazione del flusso dei raggi cosmici si misura con i neutron monitor

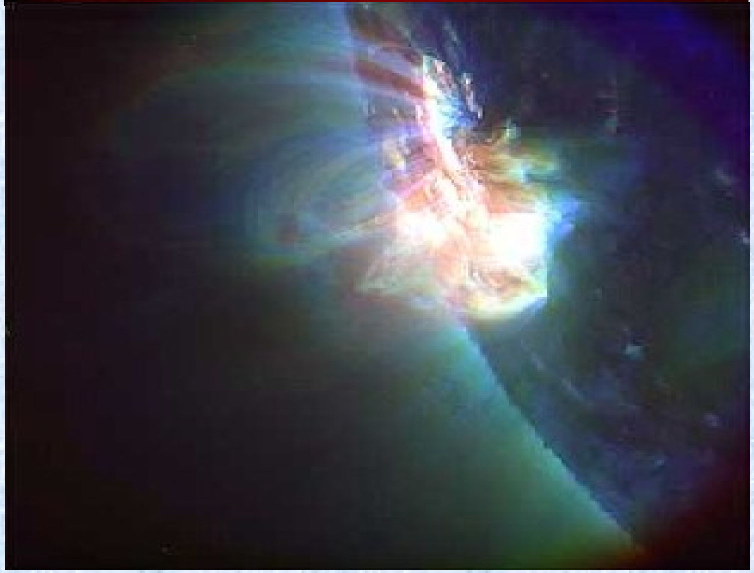
Mc Murdo Antarctic Station- Delaware University

Solar particle events

Solar particle-event radiations (SPE) are in general large clouds of charged **particles** (mainly protons and helium nuclei in a wide range of energy) **released from the sun by gigantic eruptions during solar storms**.



During the Apollo programme,between the manned missions 16 and 17, one of the largest solar particle-events occurred (August 4-9, 1972).



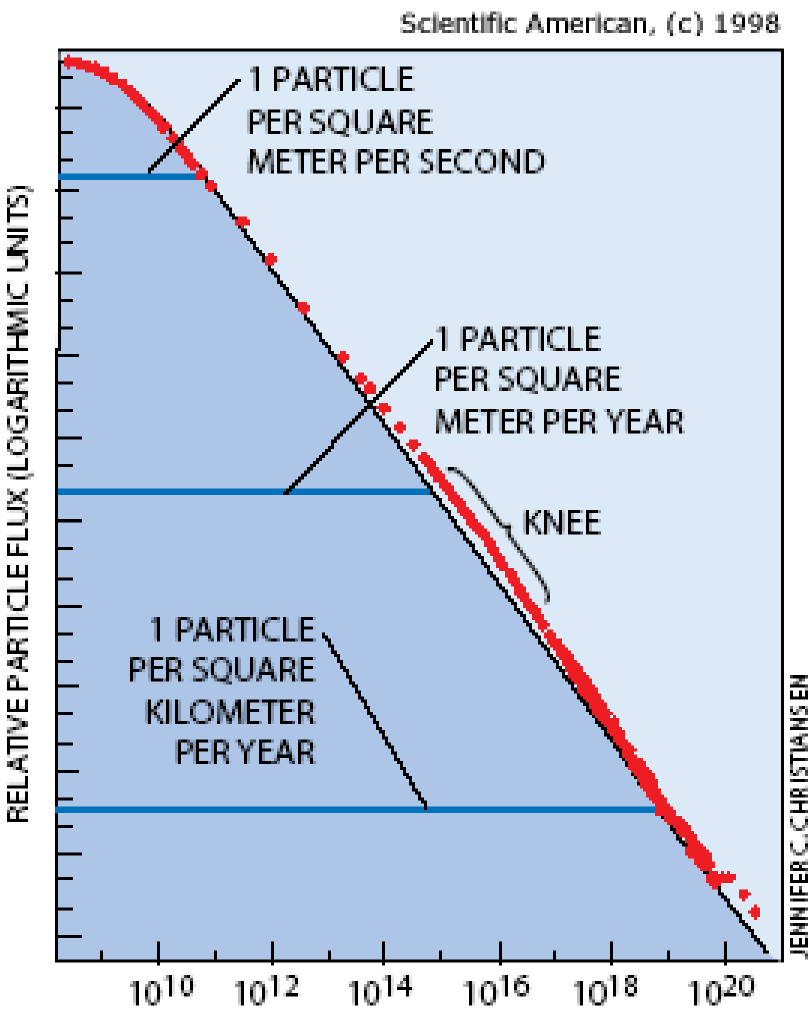
Radiation doses to the crew inside the thinly shielded lunar module or during extravehicular activities during such an event would have been extremely serious.

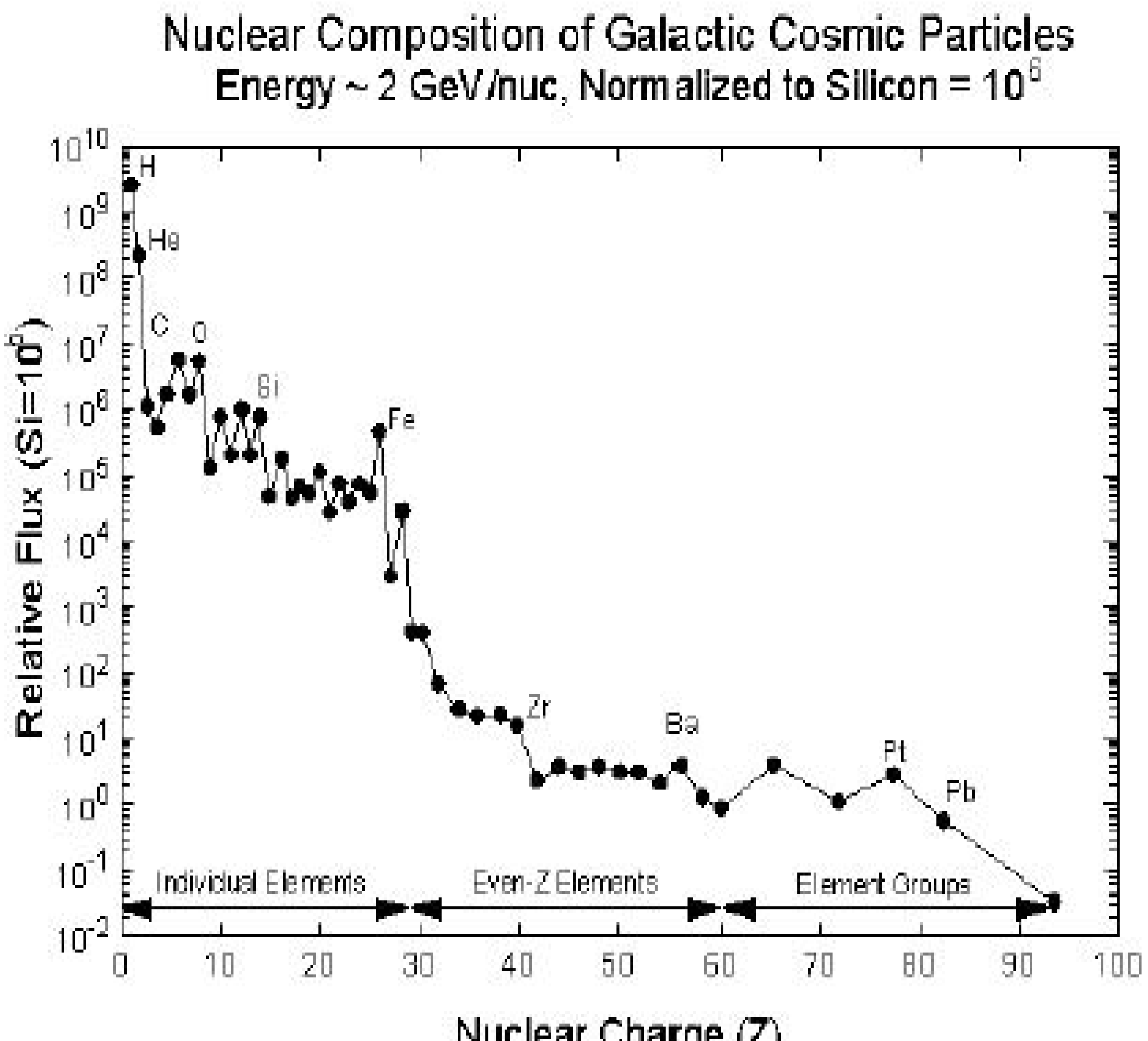
Primary radiation

ORIGINE: *Black Holes, Neutron stars, Pulsars, Supernovae, Active Galactic Nuclei, Quasars, Big Bang……*

COMPOSIZIONE RAGGI COSMICI PRIMARI: *87% protoni, 11% particelle alfa 2% nuclei pesanti*

ENERGIA: *varia su quasi 14 ordini di grandezza (10^8 eV – 10^{21})*



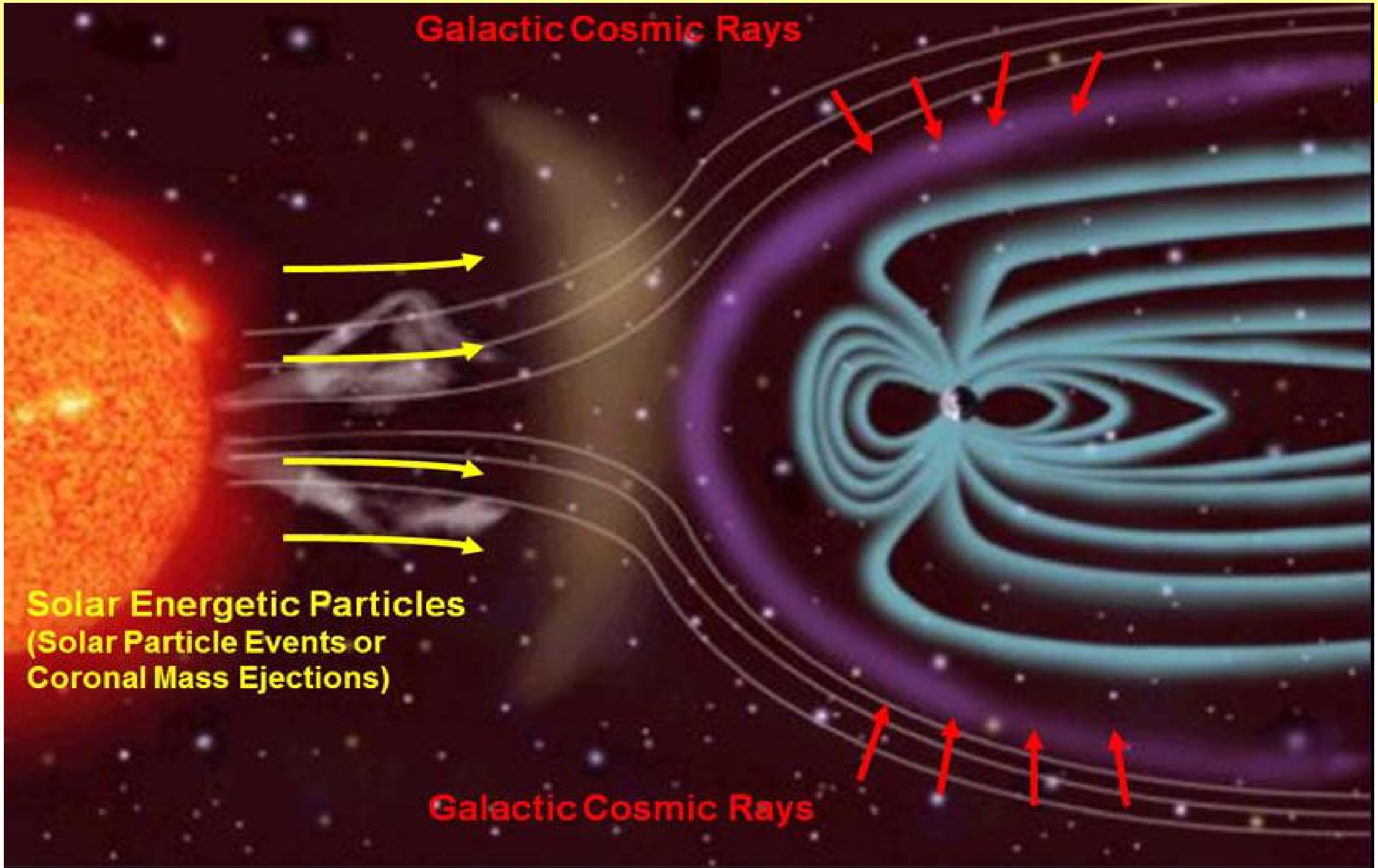


IL CAMPO MAGNETICO SOLARE

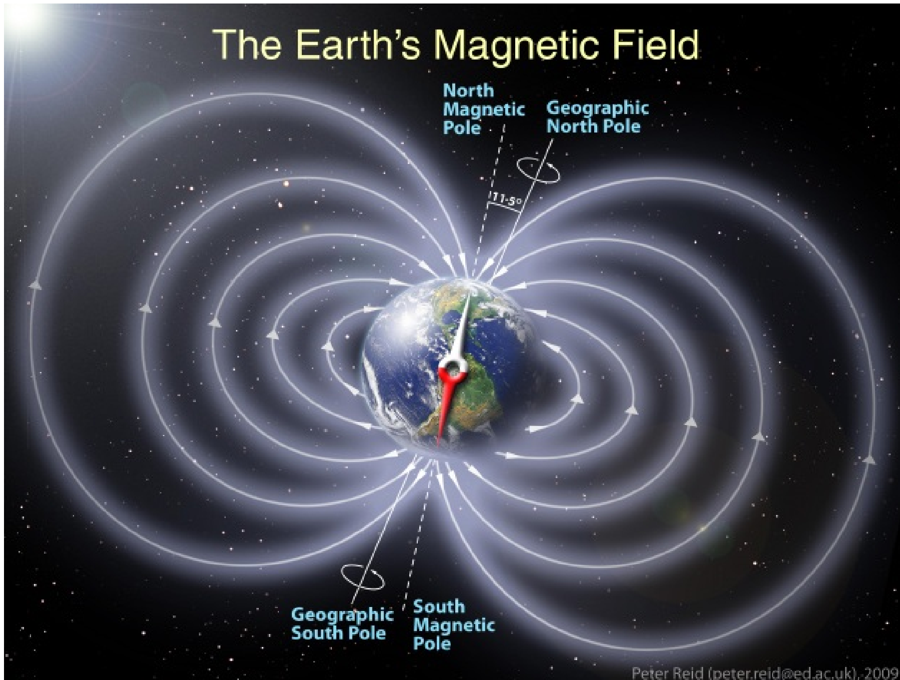
The Sun has a strong magnetic field carried out well beyond Pluto by the solar wind and known as the Heliosphere.

This field slows and tends to exclude lower-energy particles ($E < 10^9$ eV = 1 GeV).

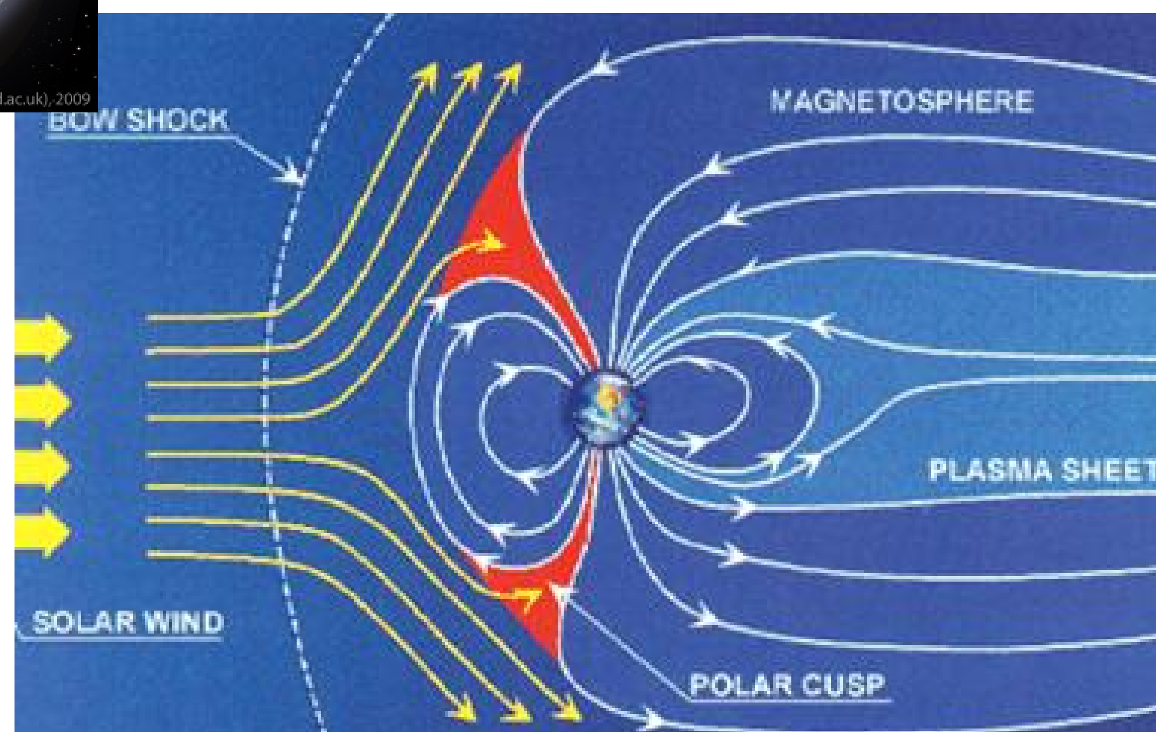
Solar activity varies on an 11-year cycle; this seems to strongly affect particles with energies less than about 10 GeV.



IL CAMPO MAGNETICO TERRESTRE



Costituisce uno schermo contro i raggi cosmici primari. Interagisce con il campo magnetico solare. La massima efficacia schermante si ha quando sono opposti ed è 20 volte maggiore di quando i due campi sono allineati

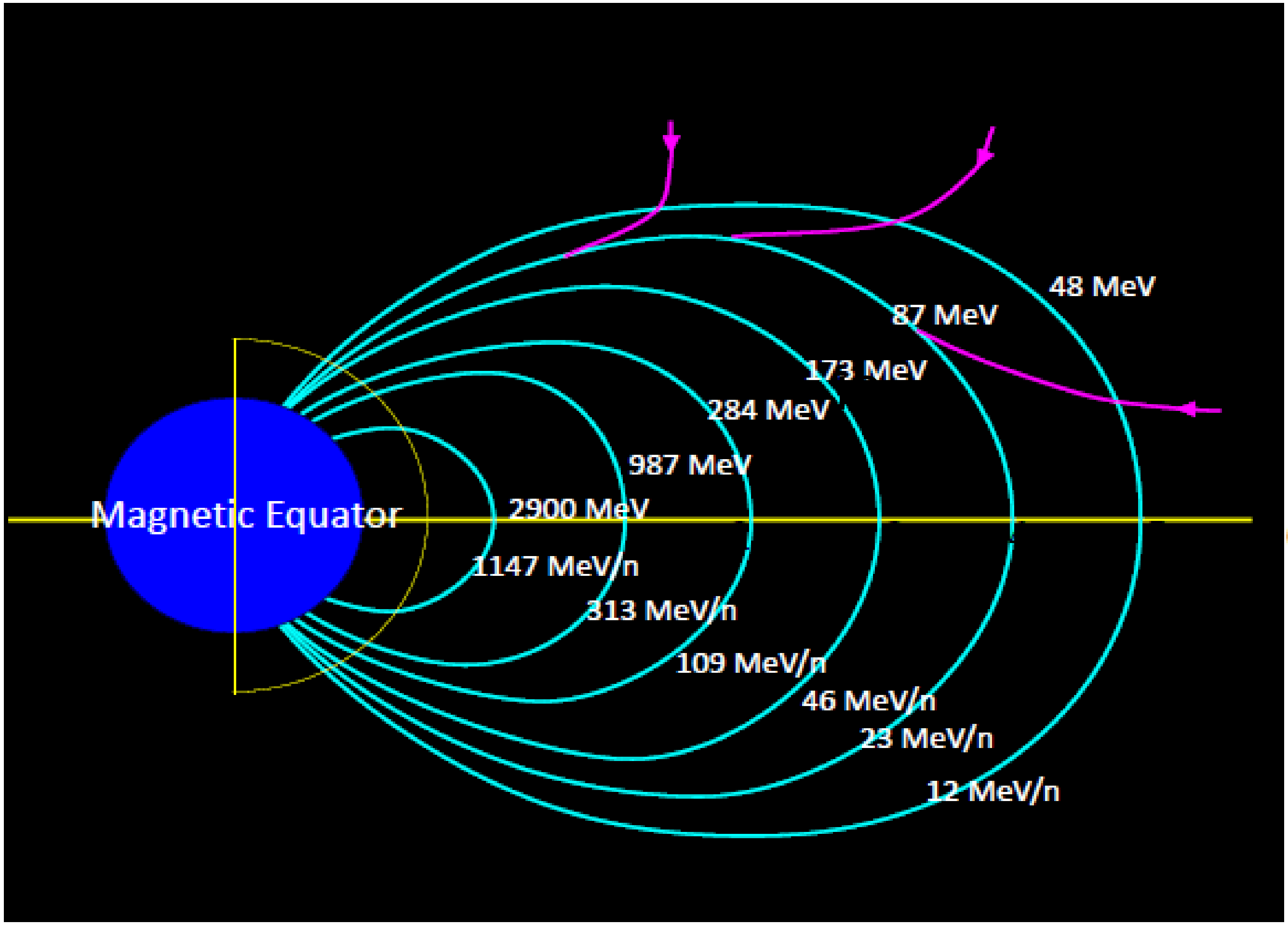


Solar-terrestrial magnetic fields

Magnetic Rigidity

Total Energy Required to Penetrate the Magnetosphere

(CUT OFF)



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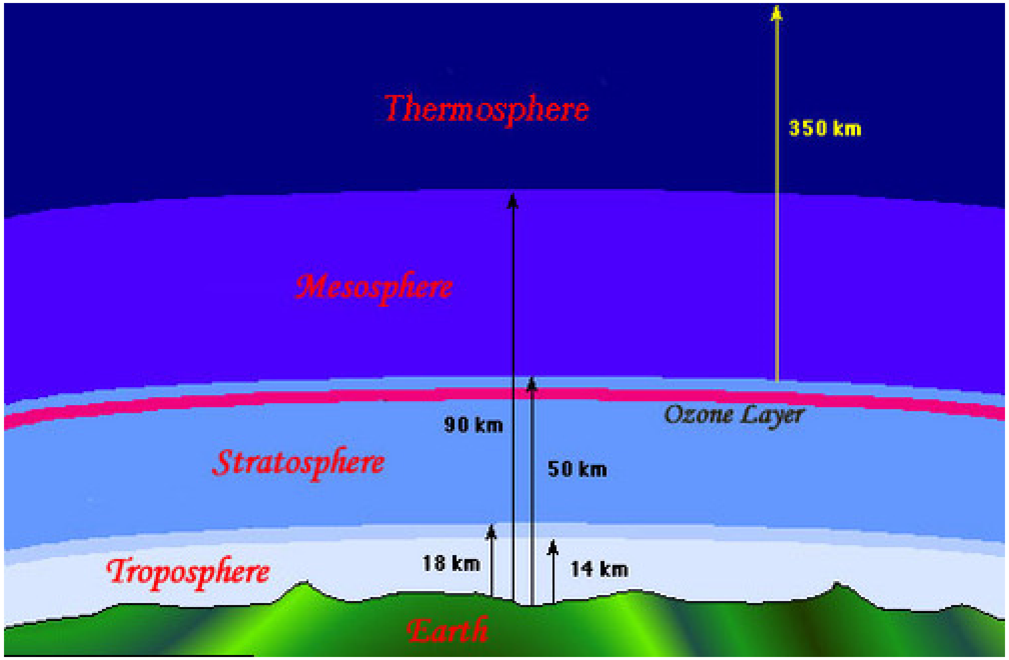
The geomagnetic cutoff rigidity is a concept that describes the geomagnetic shielding provided by the earth's magnetic field against the arrival of charged cosmic ray particles from outside the magnetosphere.

7

L'atmosfera terrestre

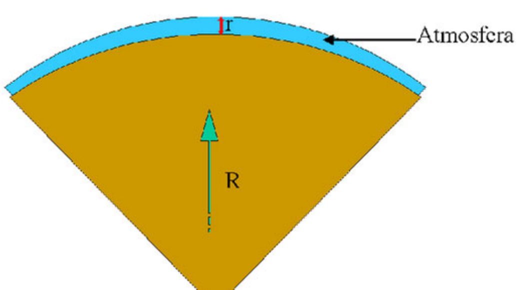


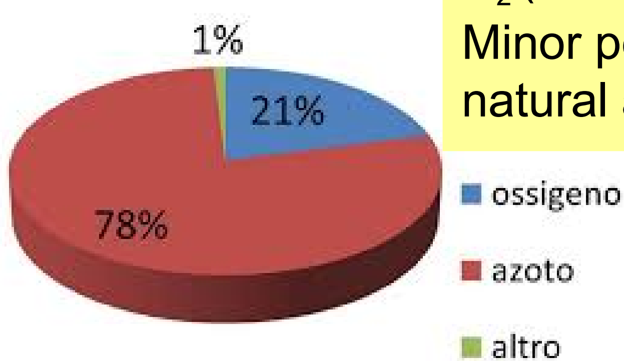
COMPOSIZIONE IN DETTAGLIO DELL'ATMOSFERA ATTUALE

ELEMENTI	SIMBOLO	%
Azoto	N_2	78%
Ossigeno	O_2	21%
Argon	A	0,90%
Anidride Carbonica	CO_2	0,03
Neon	Ne	0,002
Elio	He	tracce
Metano	CH_4	tracce
Cromo	Kr	tracce
Biossido di Azoto	N_2O	tracce
Idrogeno	H_2	tracce
Ozono	O_3	tracce
Xenon	Xe	tracce
Acqua	H_2O	variabile

L'atmosfera terrestre

R = raggio terrestre medio ≅ 6360 Km
r = spessore atmosfera ≅ 500 Km

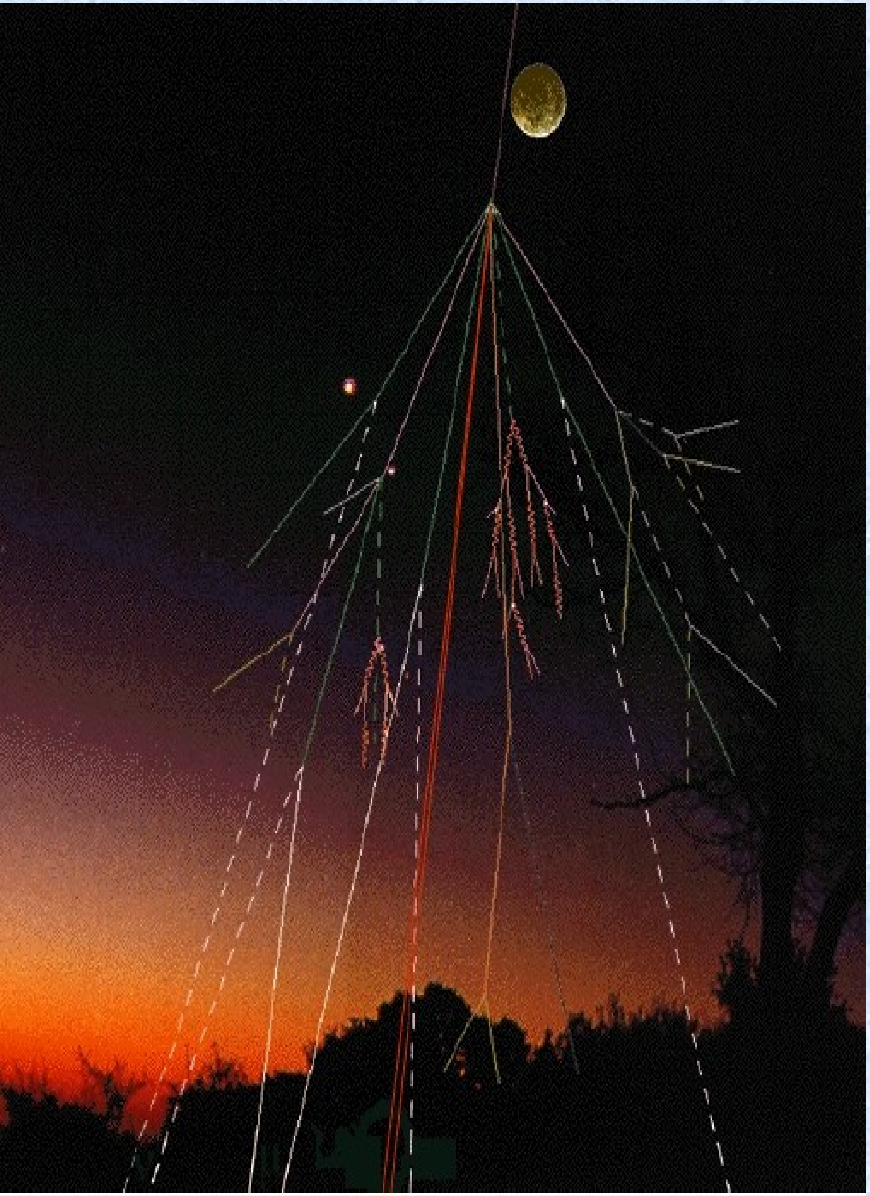




La composizione dell'aria

The atmosphere is mainly composed by N_2 (78%), O_2 (20%) and some rare gases. Minor percentages of other gases (both natural and anthropogenic origin).

Secondary radiation in atmosphere



It is produced by interaction of primary cosmic rays with atmospheric nuclei: O(21%) N (78%) Ar(1%)

The atmospheric cascade is characterized by:

:

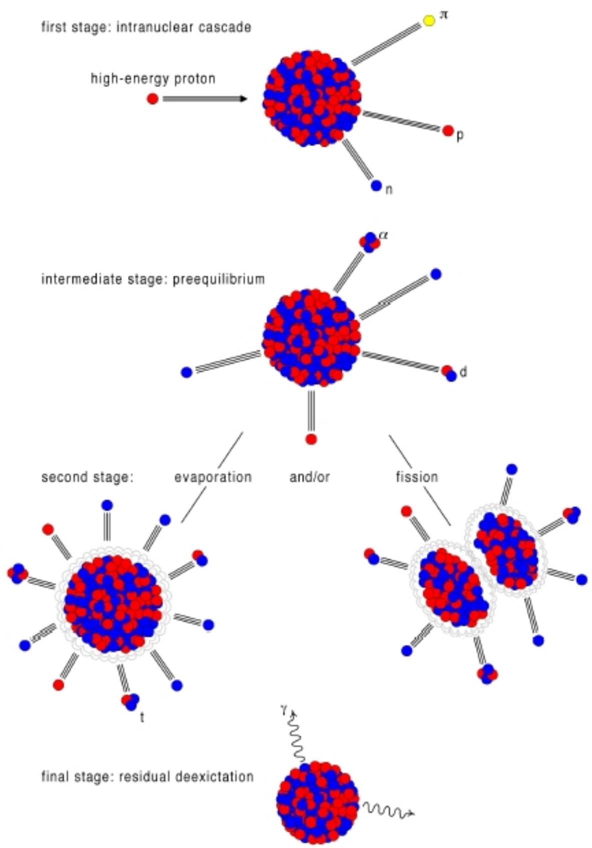
1. N component (nucleonic component) particles subjected to strong interaction

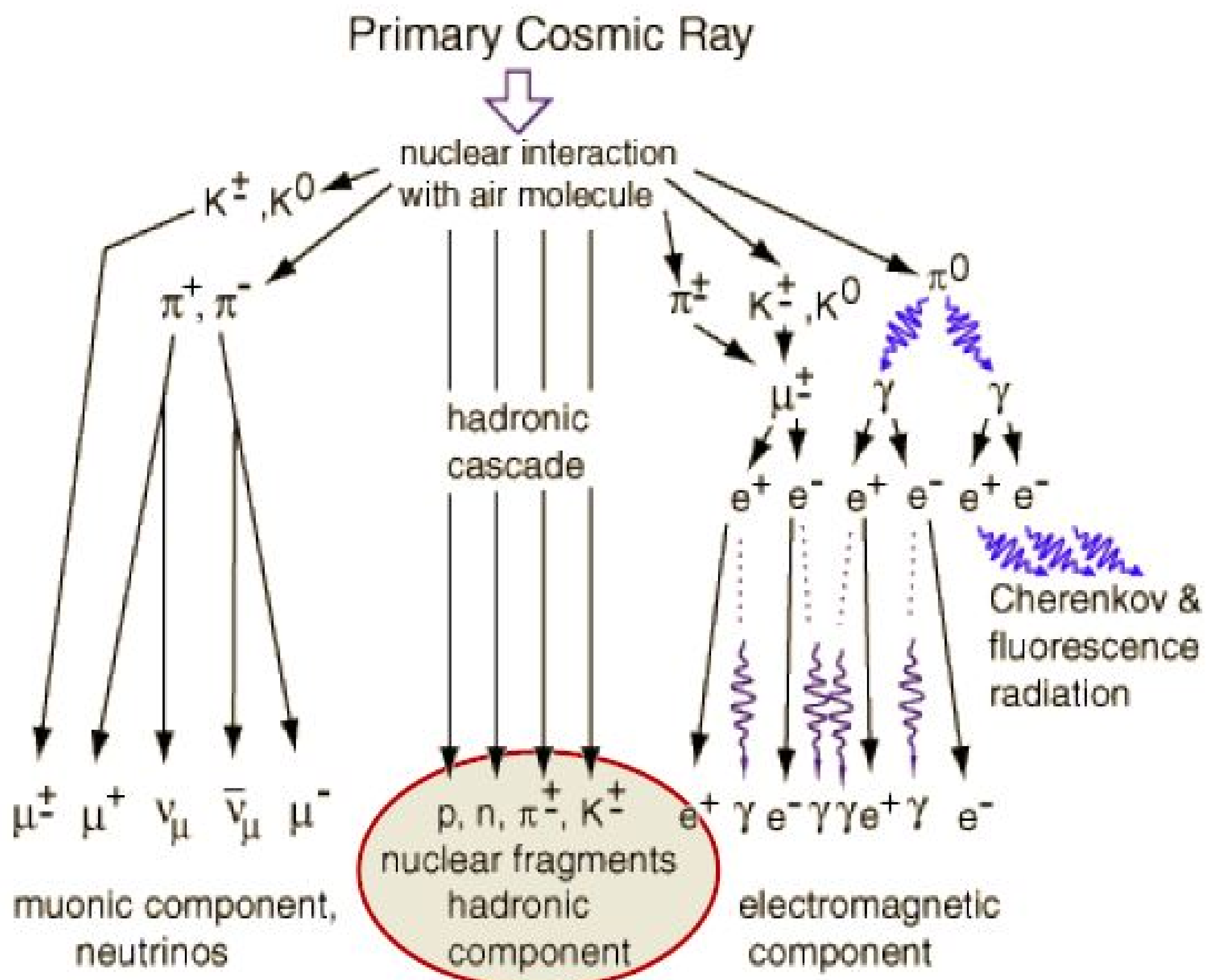
2.Soft component (electromagnetic component)
Electrons ,positrons,electromagnetic

3. Hard component (muon component).

CASCATA ATMOSFERICA SECONDARIA

L'interazione dei raggi cosmici primari con i nuclei dell'atmosfera terrestre (N, Ar, O, H, ...) crea un flusso di raggi cosmici secondari.

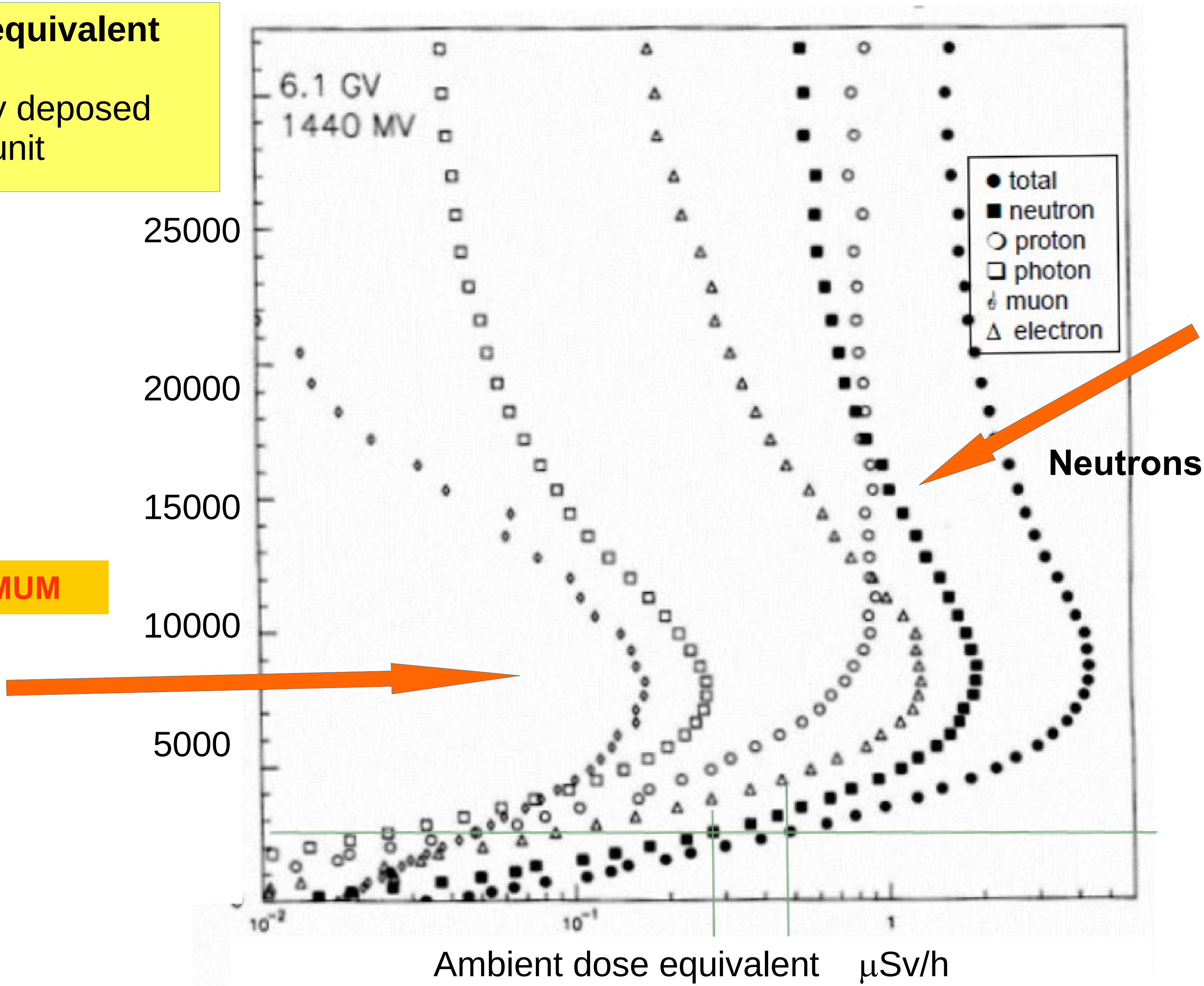




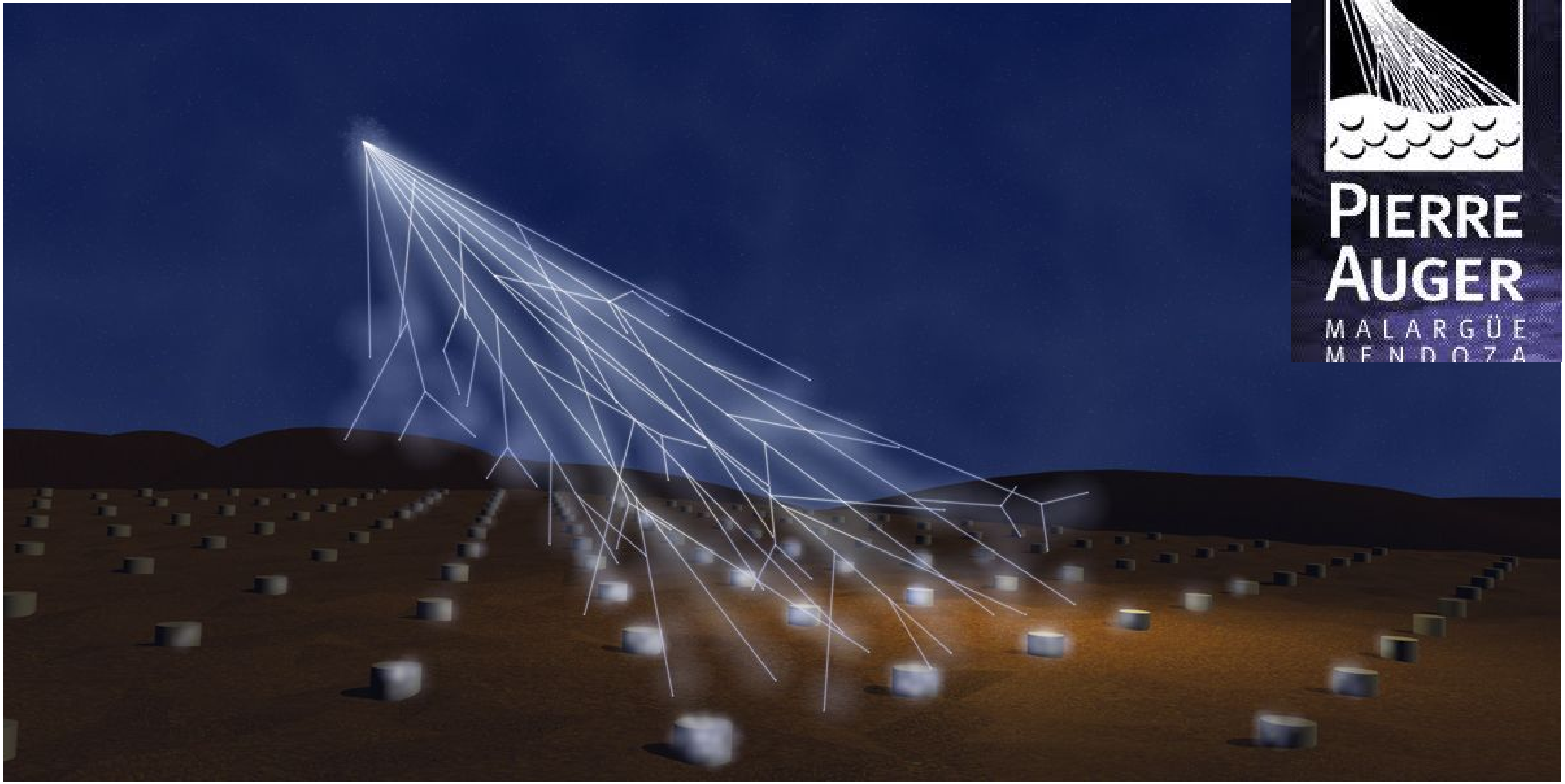
Composizione della radiazione secondaria e dipendenza dall'altitudine

Ambient dose equivalent
Sv [J/kg]
Radiation energy deposed in mass unit

PFOTZER MAXIMUM



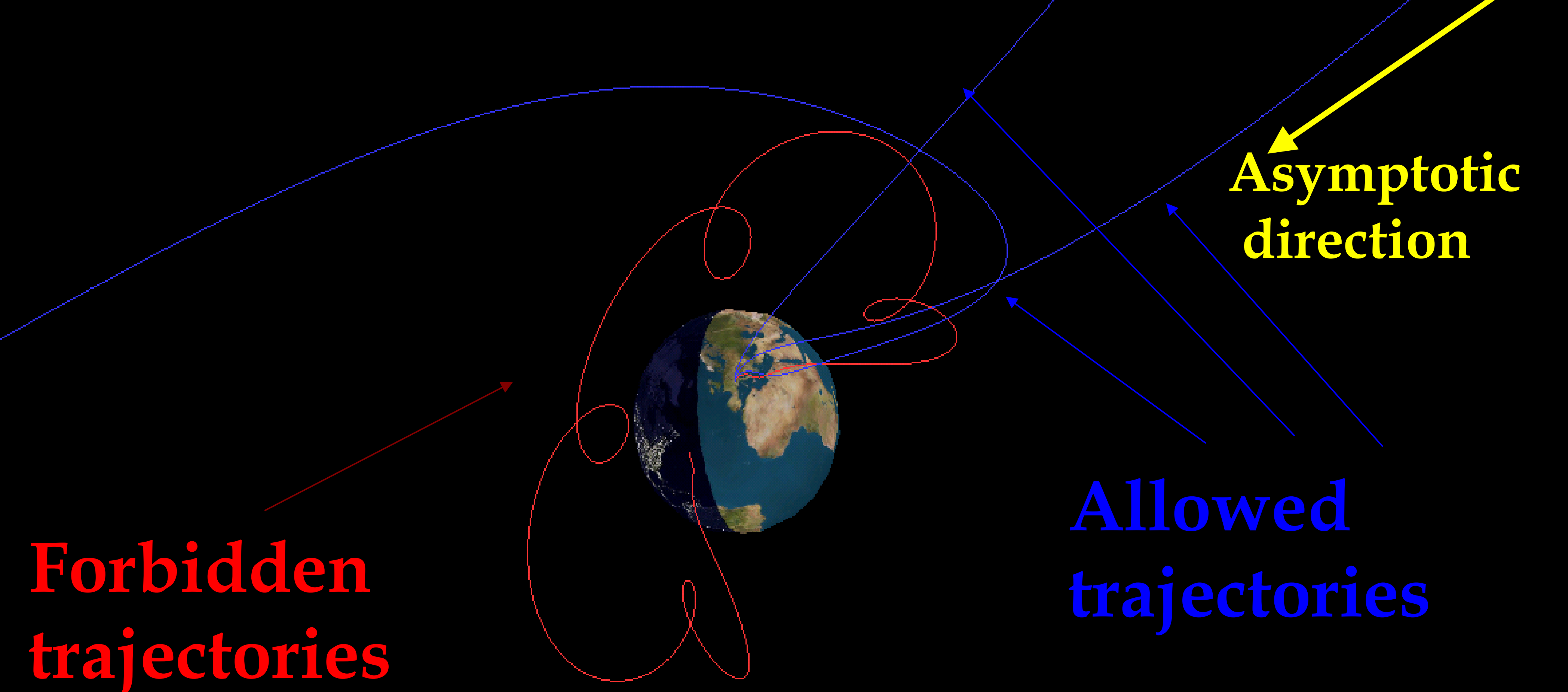
Osservatorio Pierre Auger - Mendoza,Argentina



A set of 1660 water Cherenkov particle detector stations is spread over 3000 km^2

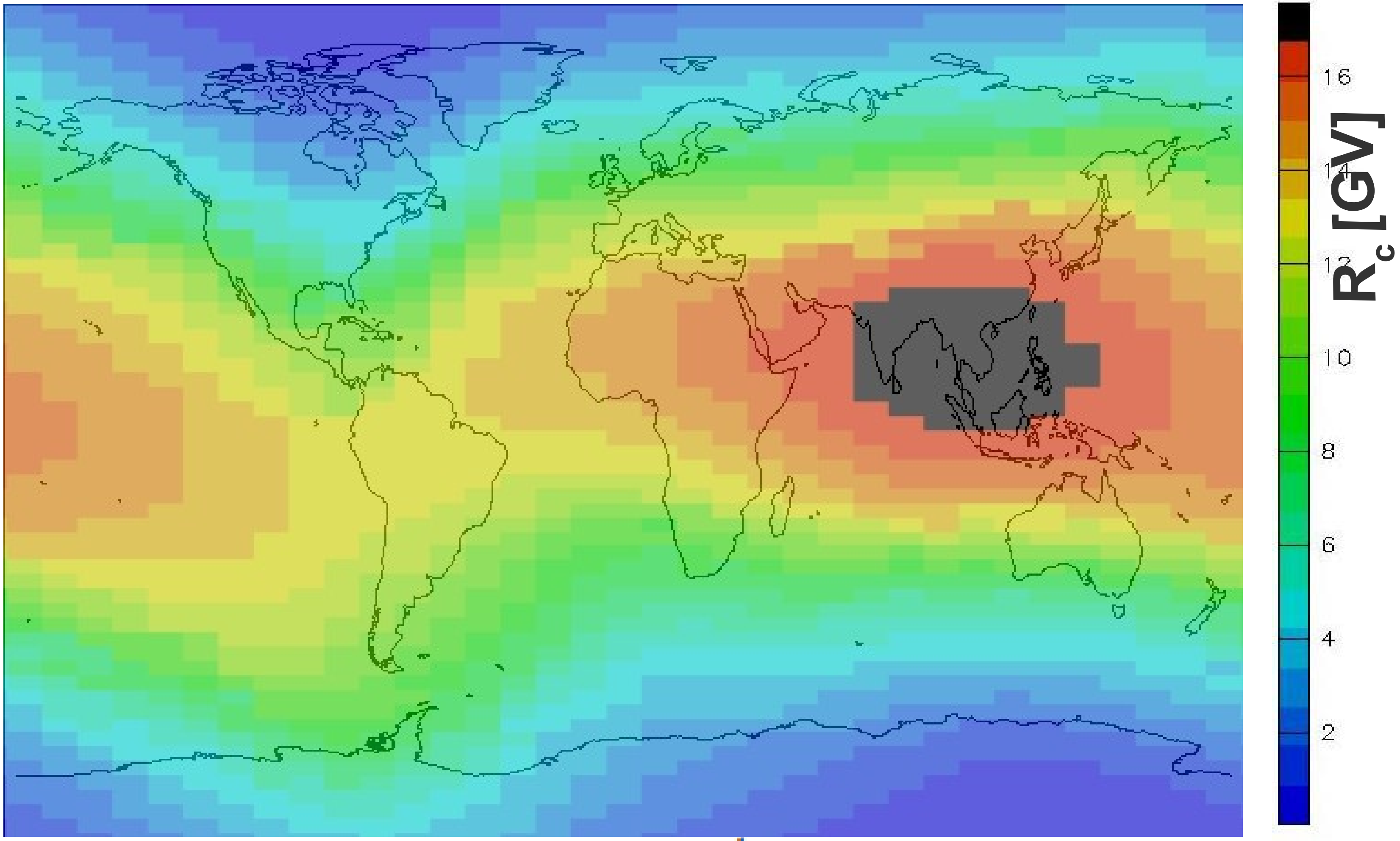
Pierre Auger (1899-1993) discovered in1938, with detectors on the Alps, the cosmic ray shower

Cosmic ray access to a position



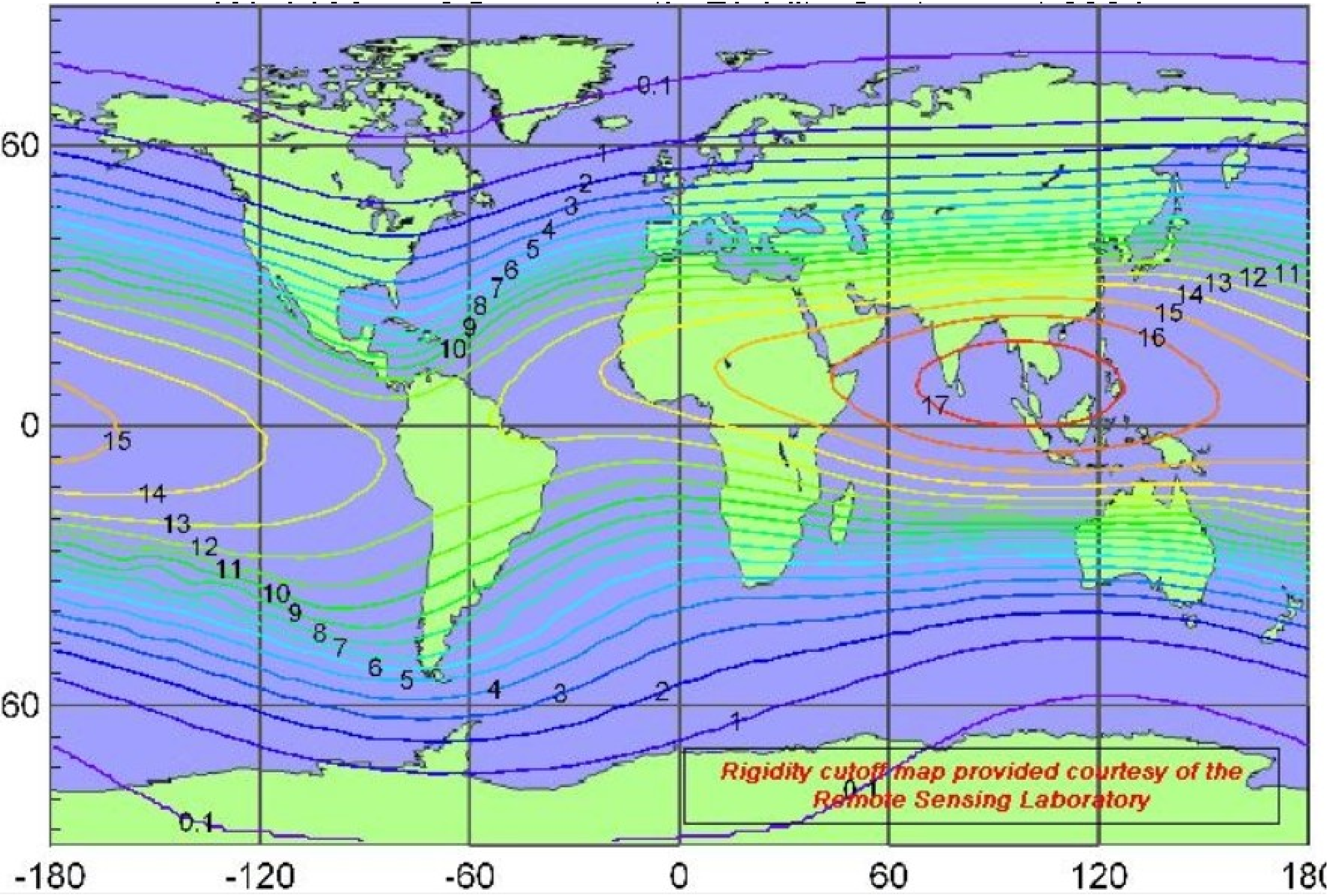
$$R = p/qc$$

Cutoff Rigidities vs position



$$P_c = 14.9 \cos^4 \lambda_m,$$

where λ_m is the geomagnetic latitude and the constant 14.9 reflects the magnitude of the Earths dipole moment here taken to be 8.0×10^{25} EMU.



60
0
60
-180
-120
-60
0
60
120
180
0.1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Rigidity cutoff map provided courtesy of the Remote Sensing Laboratory

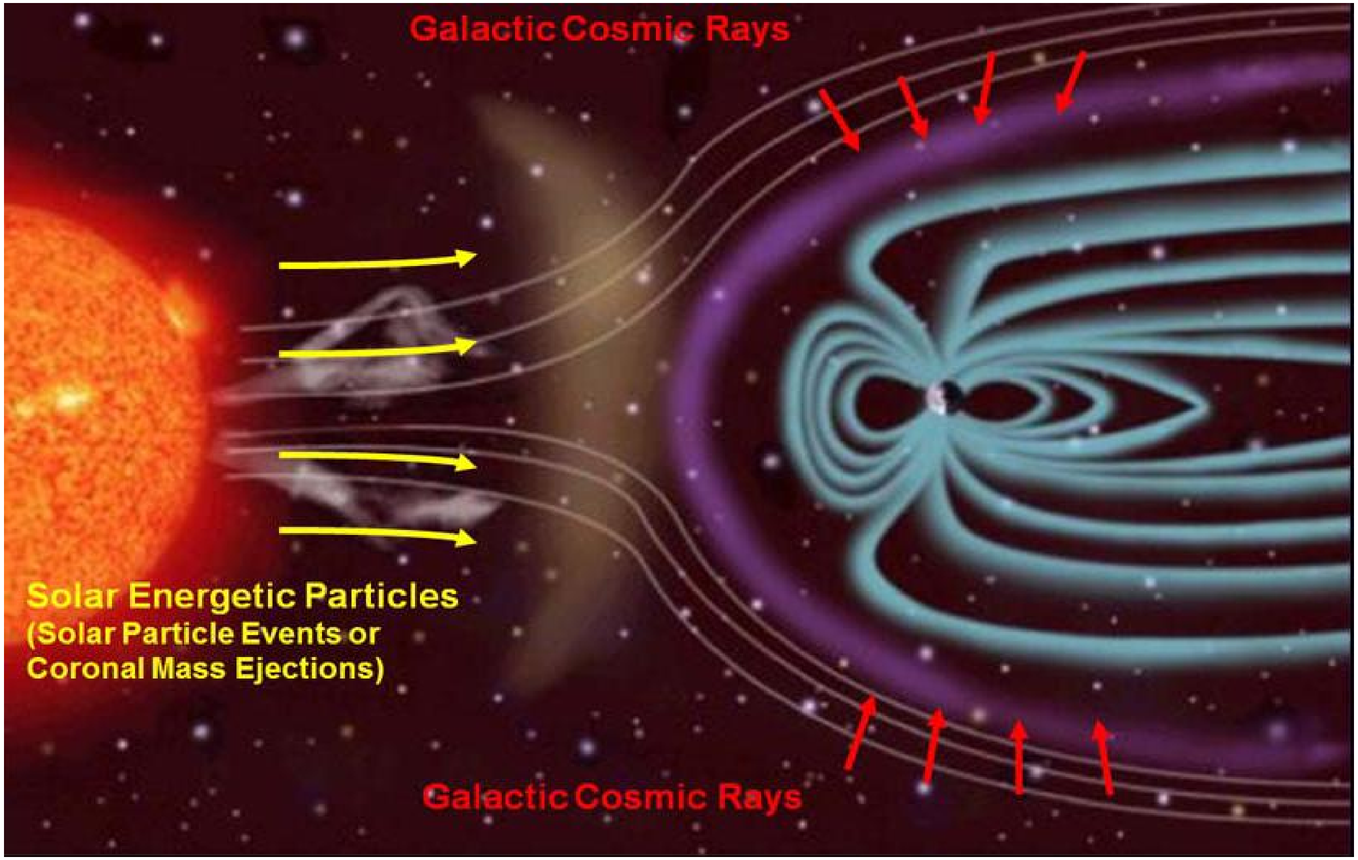
LA TERRA E PROTETTA DALLA RADIAZIONE COSMICA PRIMARIA

DAL VENTO SOLARE

DAL CAMPO MAGNETICO SOLARE

DAL CAMPO MAGNETICO TERRESTRE

DALL'ATMOSFERA TERRESTRE

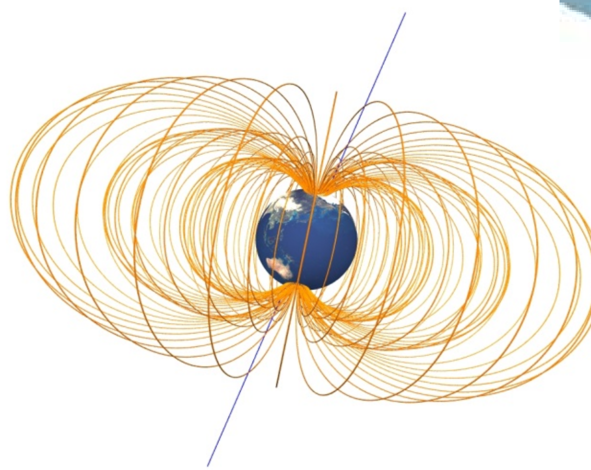


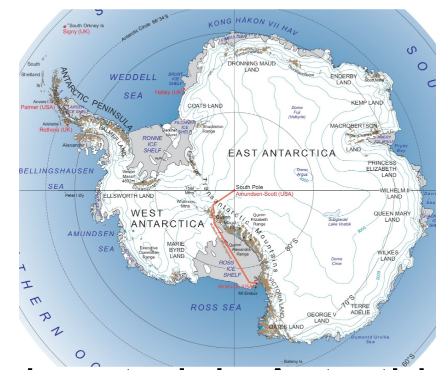
Variabilità della radiazione cosmica secondaria

1) ALTITUDINE:
a grandi altezze l'atmosfera è più rarefatta e quindi il suo effetto assorbente e schermante viene meno.

Laboratori ad alta quota

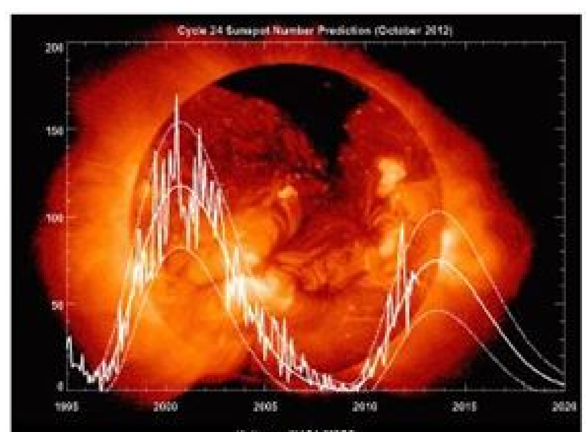
2) LATITUDINE:
A causa della forma del campo geomagnetico.





Laboratori in Antartide

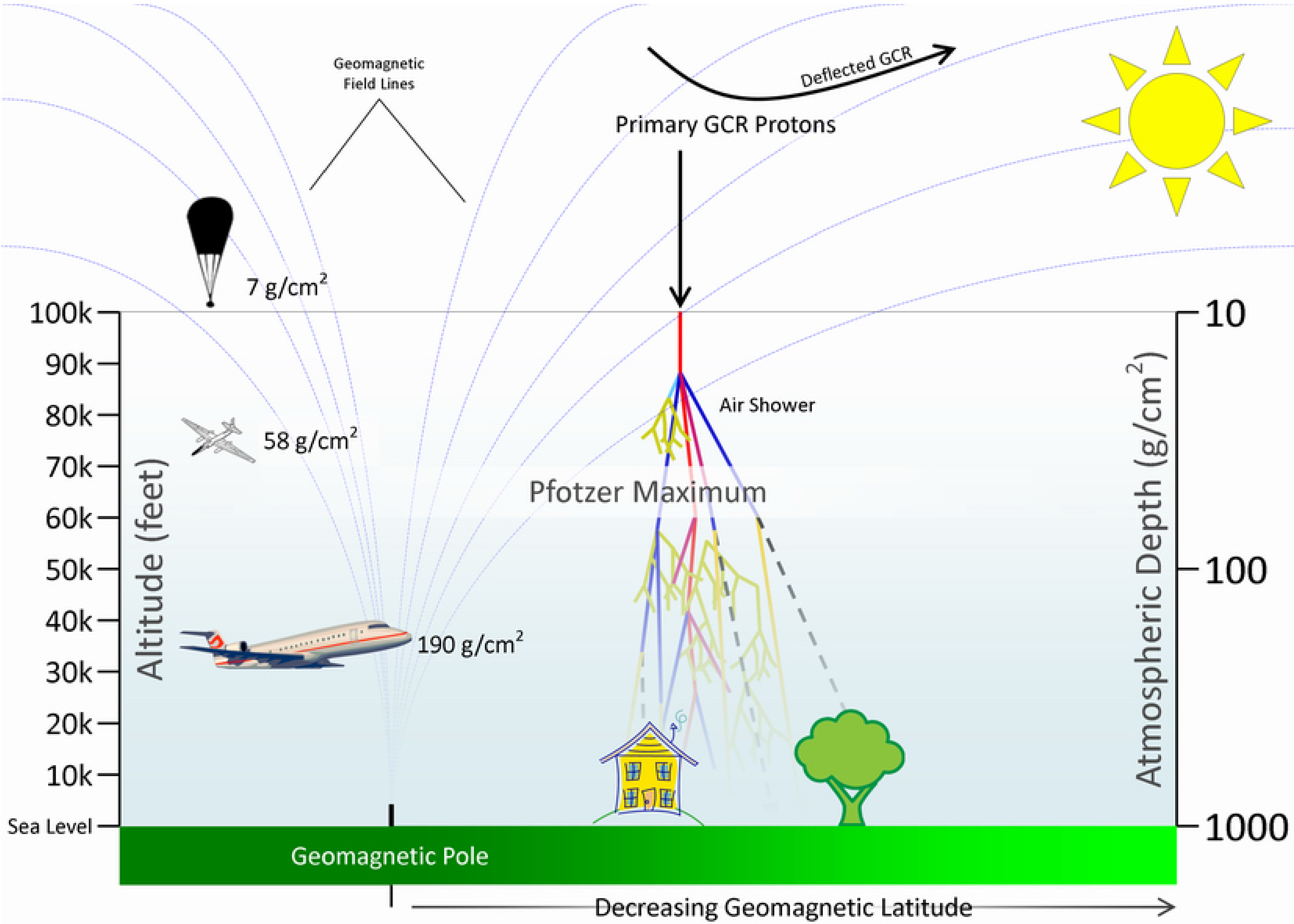
3) ATTIVITÀ SOLARE:
per via dell'influenza del vento solare sui raggi cosmici galattici ed extragalattici.



Variation of solar activity 11 years cycle

Periodi di bassa attività solare

Cosmic Ray Observation



Ionizing radiation dosimetry at High Altitude and Latitude

(on ground, at high altitude, in space)

1-CORA Project **(COsmic Rays in Antarctica** 2015-2020)

NFN, IAPS-INAF, IAA, UNLP

Base Marambio (Argentina, Antarctica)

2-CHINSTRAP **Base Concordia - Dome C (Italy-France)**

INFN, PNRA, IPEV, ONERA (Antarctica)

-
-

3-Chilecito **Monte Famatina (5000 m asl, Argentina)**

Laboratorio de Altura

CNR,UndeC,INFN

4- Ushuaia GAW Station

5-**Dosimetry onboard SABIA- MAR Satellite**

2021 ***CONAE, INFN, ASI***

6-HALCORD **INFN Torino-Trieste**

High altitude and latitude Cosmic Rays Dosimetry

- **Geomagnetic Field lowering in antarctica**
- **SAA deeping and increasing in Southern region**
- **Solar activity lowering**

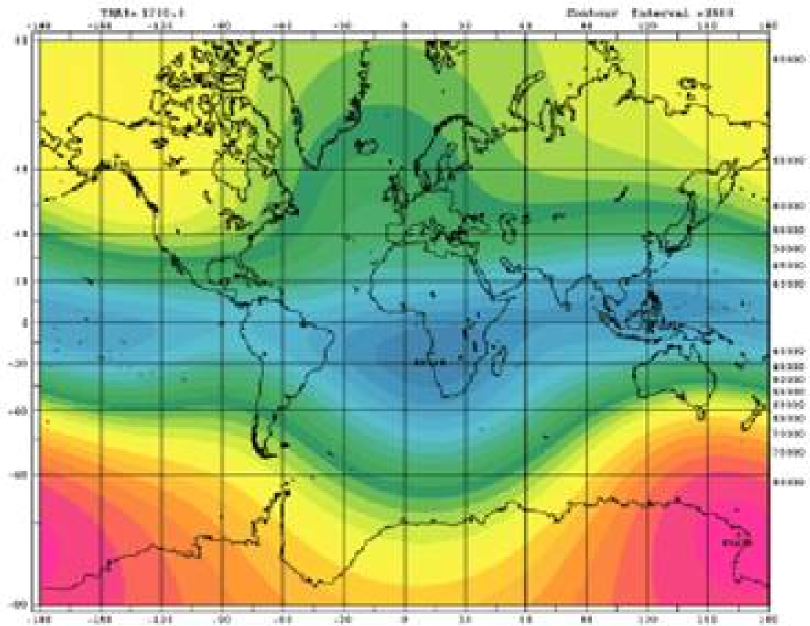
↓

- **Cosmic ray flux increasing**

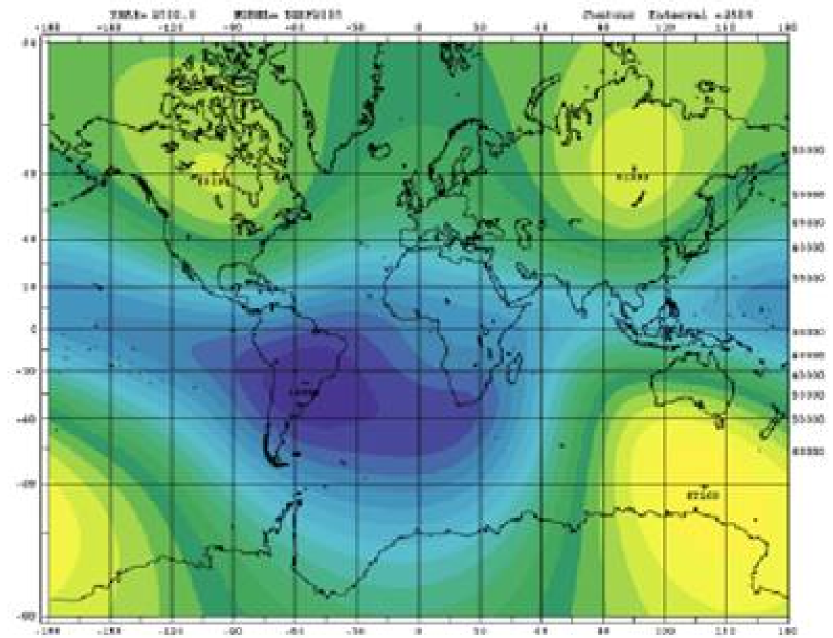
↓

Relevance of monitoring secondary cosmic radiation in Southern regions

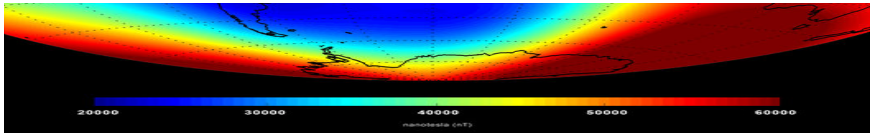
Variazione dell'ìintensità del Campo Magnetico Terrestre

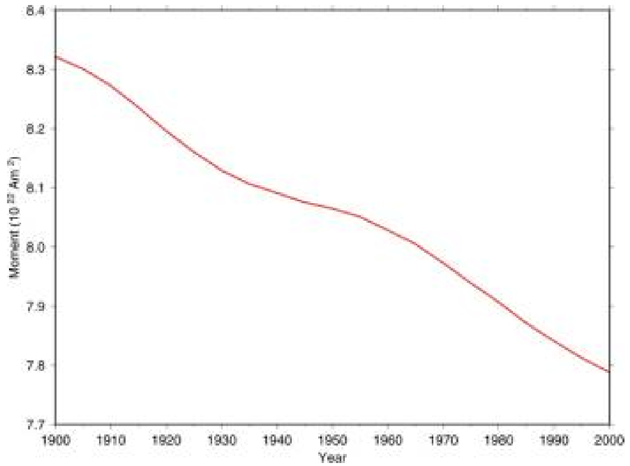


Campo magnetico terrestre 1600-1700



Campo magnetico terrestre 1900-2000





Variazione del Momento di Dipolo

Il Campo Magnetico terrestre è sensibilmente diminuito

Rajaram G., 2002; Rapid decrease in total magnetic field F at Antarctic stations - its relationship to core-mantle features. Antarctic Science 14 (l): 61-68.

Herbst, K.,et al.,2013; Influence of the terrestrial magnetic field geometry on the cutoff rigidity of cosmic ray particles. Ann.Geophys. 31:1637-1643

Korte, M., and Mandea M., 2008; Magnetic poles and dipole tilt variation over the past decades to millennia. Earth Planet Space 60: 937-948.

Decreasing of total magnetic field in Antarctica

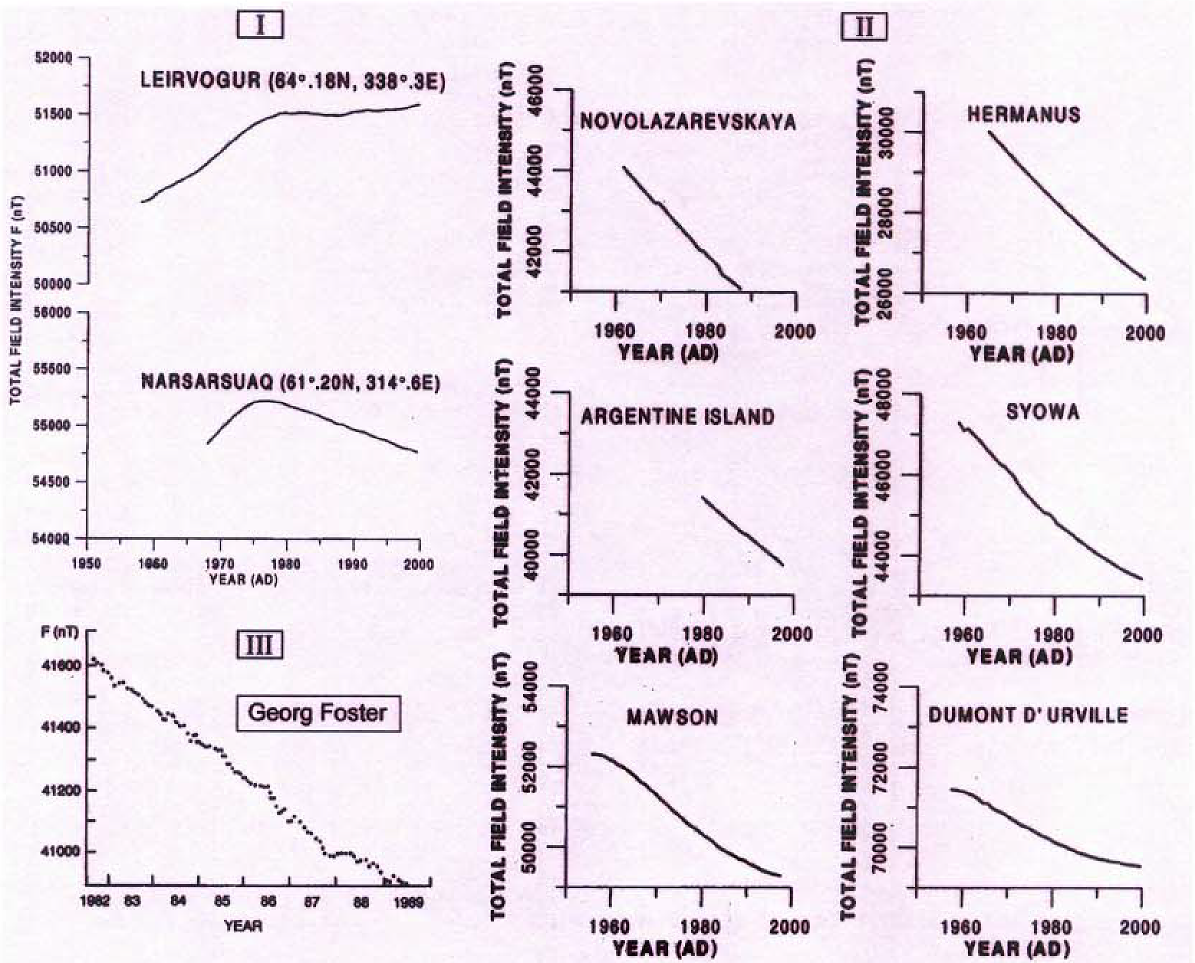
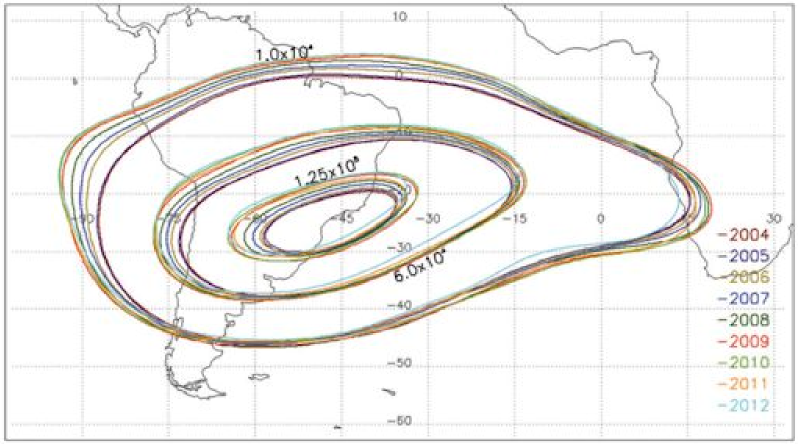
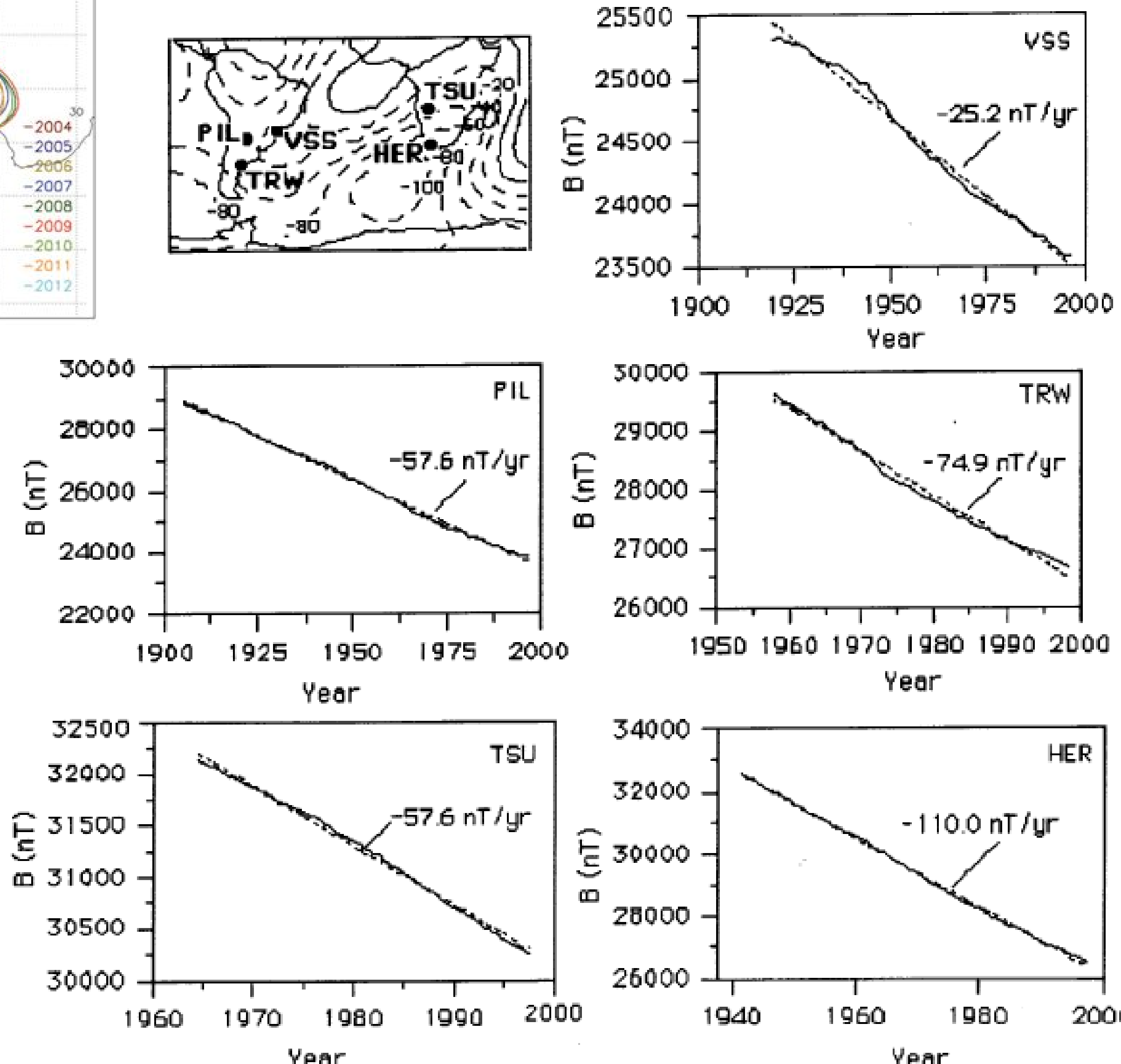


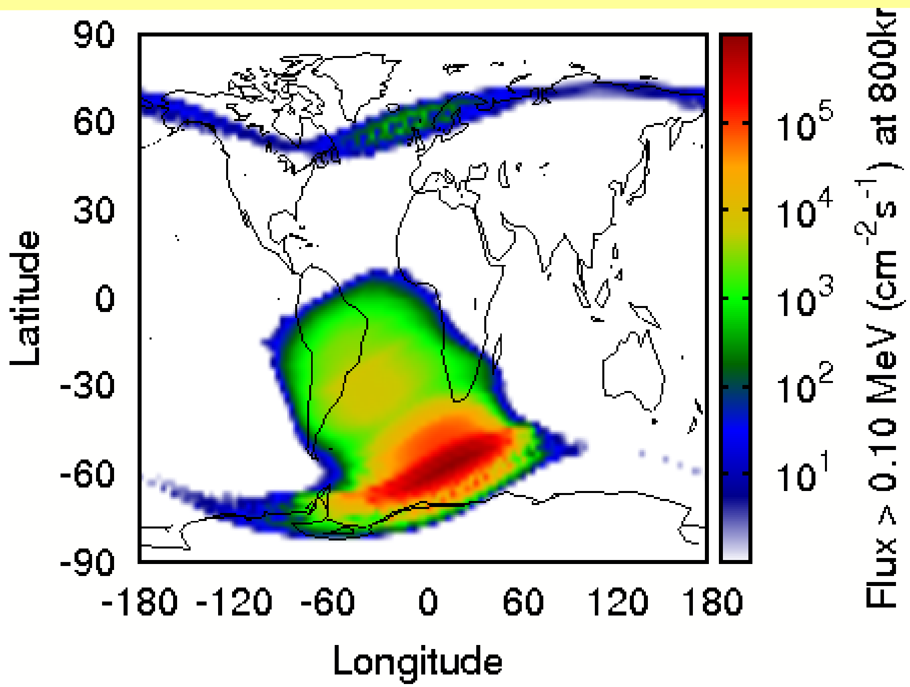
Fig. 1. Plots of F at various northern and southern stations. The bracket-I shows the F plots at two northern station Leirvogur and Narsarsuaq. Bracket-II show the plots at Novolazarevskaya, Hermanus, Argentine Island, Syowa, Mawson and Dumont d'Urville. Bracket-III shows the F plots at Georg Foster station (station closed) (from Rajaram et al., 2002).

Decrease of total magnetic field measured in stations around SAA (NASA)

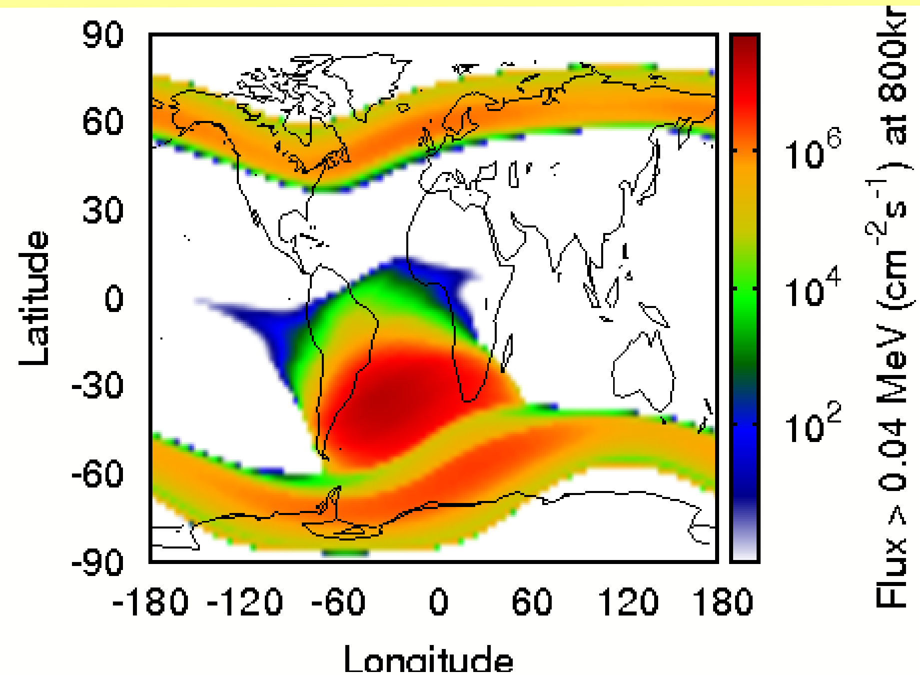




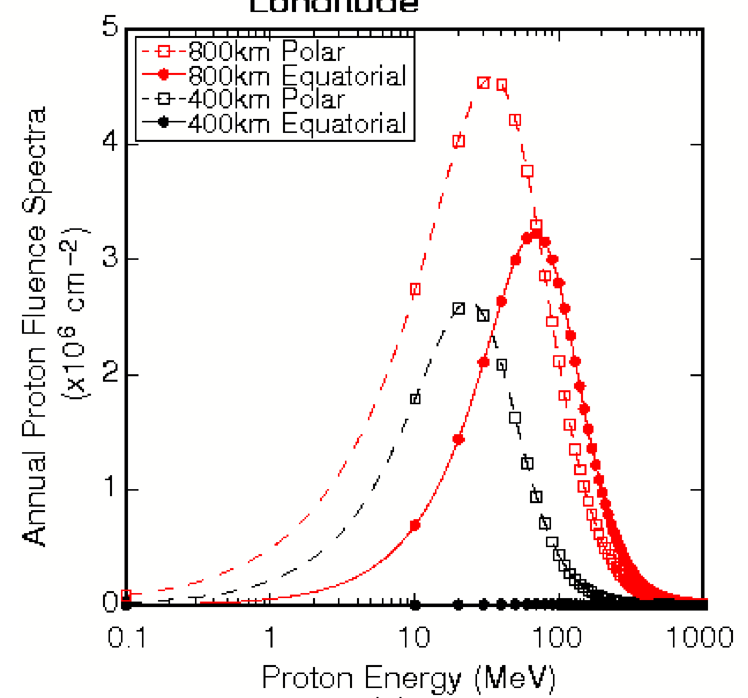
SAA proton -electron Flux on polar and equatorial orbits



(a)

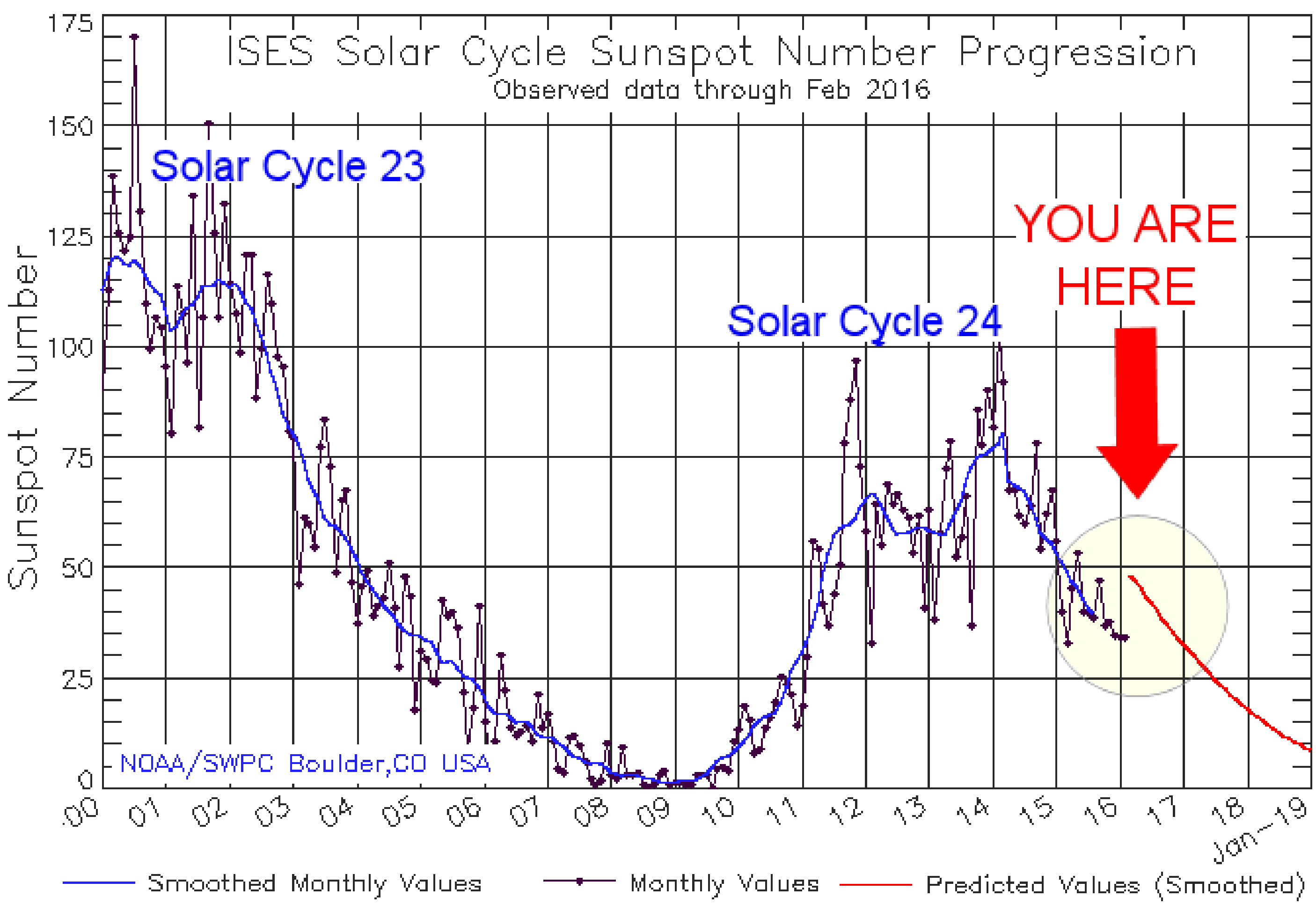


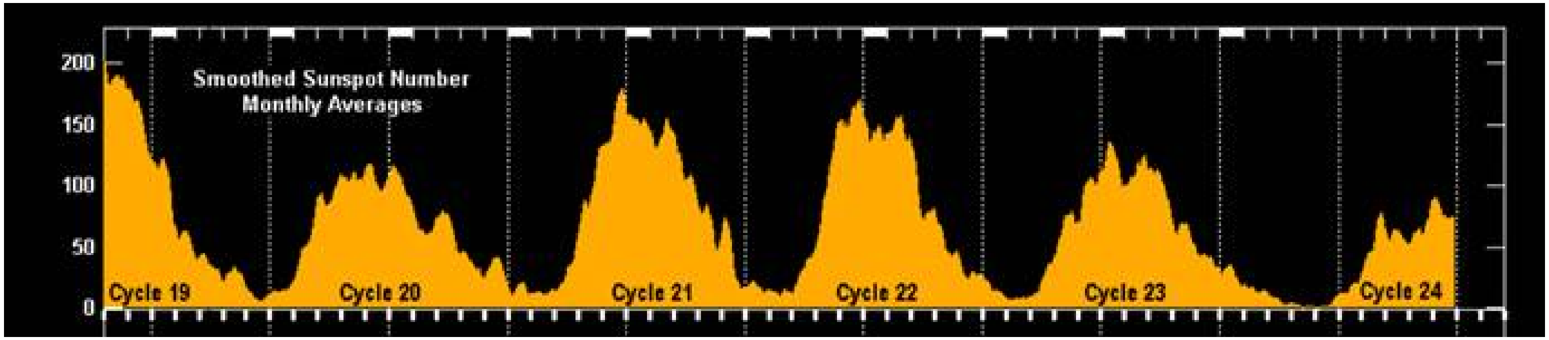
SPENVIS Simulation



(a)

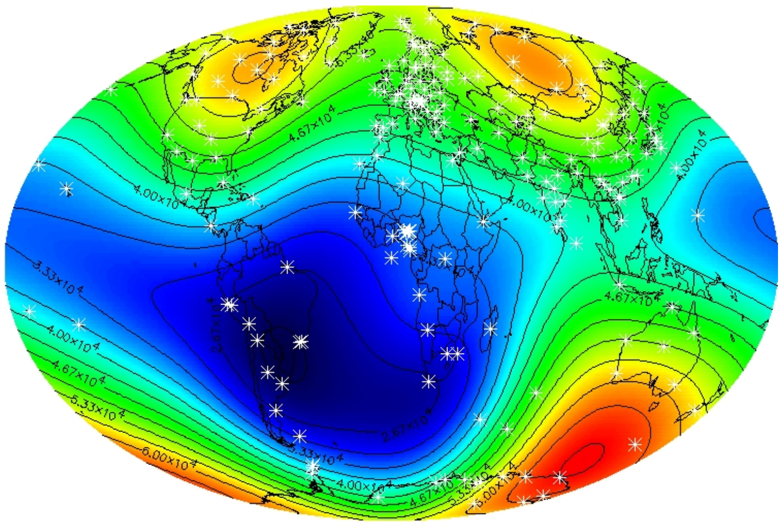
Decreasing solar Activity

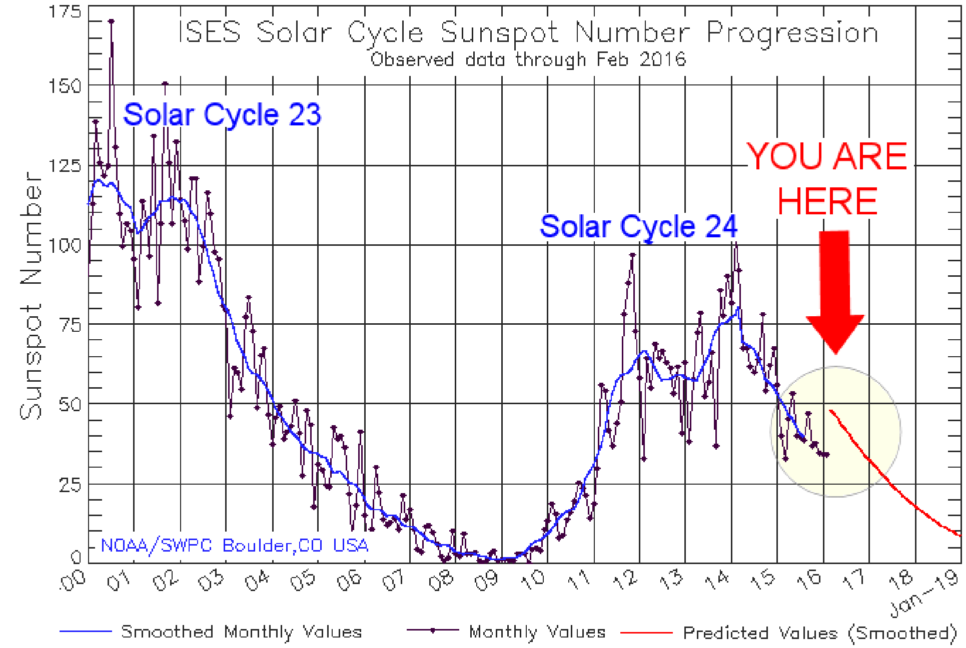




IL CAMPO MAGNETICO TERRESTRE

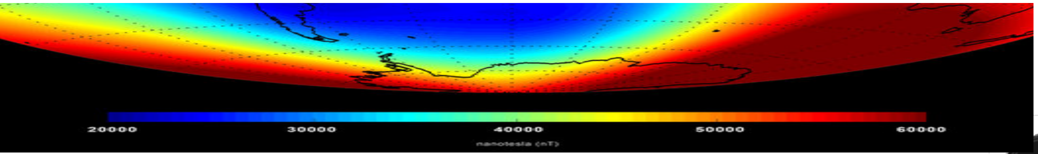
L' ATTIVITA SOLARE

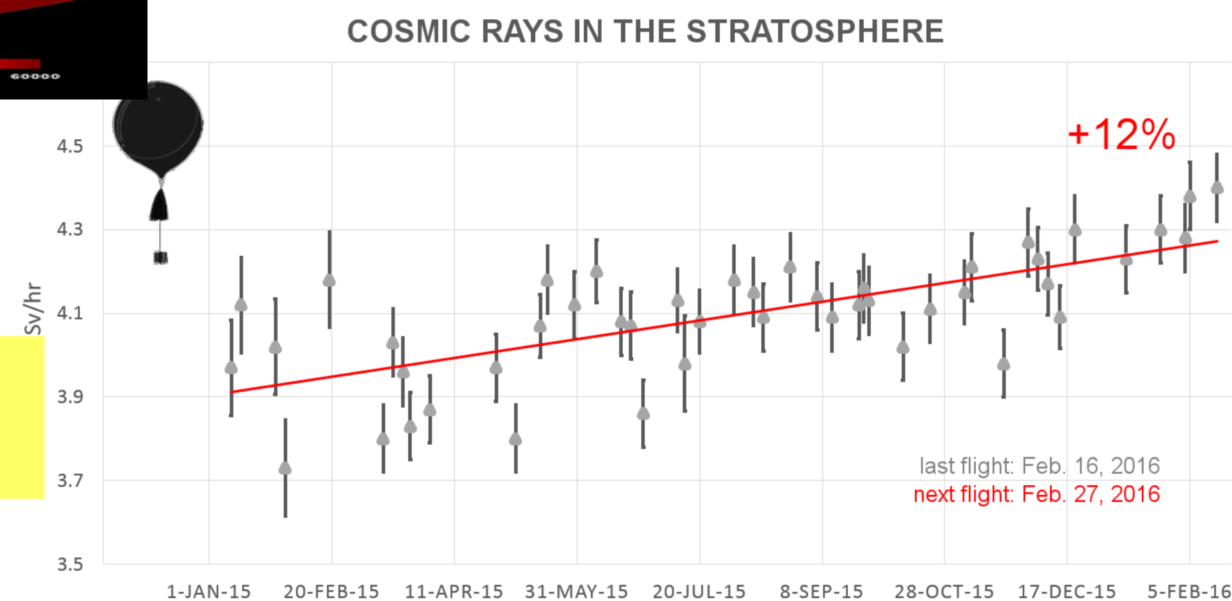




Il campo magnetico terrestre si sta indebolendo, in particolare nell'emisfero sud

L'attività solare sta diminuendo





AUMENTANO I RAGGI COSMICI

➢ Relationship between cosmic-ray intensities and atmospheric pressure

There is a relationship between the neutron dose rate and the atmospheric pressure in the monitoring period. The main component of the cosmic-ray measured at ground level is secondary cosmic-ray, and is attenuated by the air above the ground which acts as a shield. The cosmic-ray neutrons and the ionizing components measured at ground level vary according to an exponential attenuation law with the atmospheric pressure in the form of ~exp(-A·P).

$$N(Po + P) = N(Po) \exp(-aP).$$

- The largest deviations occur over Antarctica where ground level pressures are 20–40 hPa (hectoPascal) lower than the standard atmosphere (corresponding to a lower atmospheric mass). Secondary particle production rates in Antarctica are therefore 25–30% higher than values calculated by scaling Northern Hemisphere production rates with conventional scaling factors.

➢ Continued Decline of South Pole Neutron Monitor Counting Rate

John Bieber e al.

Journal of Geophysical Research: Space Physics
Volume 118, Issue 11, pages 6847–6851, November 2013

....At this time therefore we believe that there is a solid justification for a program to investigate in detail geomagnetic cutoff change at South Pole and its influence on the radiation environment

Rapid decrease in total magnetic field F at Antarctic stations - its relationship to core-mantle features

Antarctic** Science **14 (l), 61-68 (2002

GlRIJA RAJARAM, T. ARUN, WAY DHAR and A. G. PATIL
Indian Institute of Geomagnetism, Colaba, Mumbai 400 005, India

Comparison of the average quiet-time value of total intensity F for these years with values of F obtained at the same geographic location (interpolated from iso-intensity contours of *F* on World Magnetic Charts and IGRF Maps) for earlier years, suggestedover the last 75 years at this location, Fhas dropped from -49 000 nT in 1922, to -40 000 nT in 1996 i.e. -120 nT per year.

Lowering solar activity also in growing cycles (21-22-23-24)

Measurement sites in southern region at different altitude and latitude

Chacaltaya, Bolivia, 5200 m a.sl
16°21′12″S 68°07′53″W

Famatina, Argentina 5000 m a.s.l
28° 54' 56"S 67°31'0" W

Ushuaia Argentina, 0 m a.s.l
: 54°48′S 68°18′W

Marambio, Antartica 200 m asl
64°13' S ,56°43'W,

Dome C, Antartica 3300 m asl
75°06 S 123°20E,

Dosimetria della radiazione cosmica secondaria ad alta quota e ad alte latitudini

Mappatura dosimetrica nella regione australe:

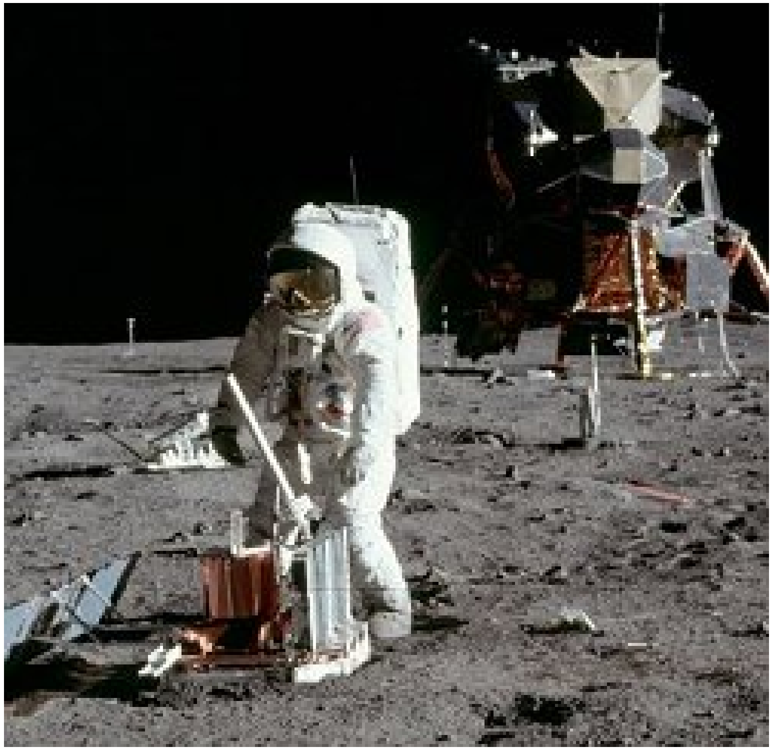
-Ushuaia (GAW station)
-Marambio (Antartide Argentina)
-Dome C (Antartide Francia-Italia)
-Monte Famatina (Argentina SAA)
-Chacaltaya (Bolivia)

→ DI GRANDE INTERESSE PER AGENZIE SPAZIALI NASA, ESA, ASI, CONAE

↓

- Correlazione dose da raggi cosmici secondari con:

- ✓ -Parametri geografici (latitudine , longitudine)
- ✓ -Composizione e dinamica dell'atmosfera
- ✓ -Attività solare (SPE, GLE)
- ✓ -Campo geomagnetico
- ✓ -Campo magnetico interplanetario



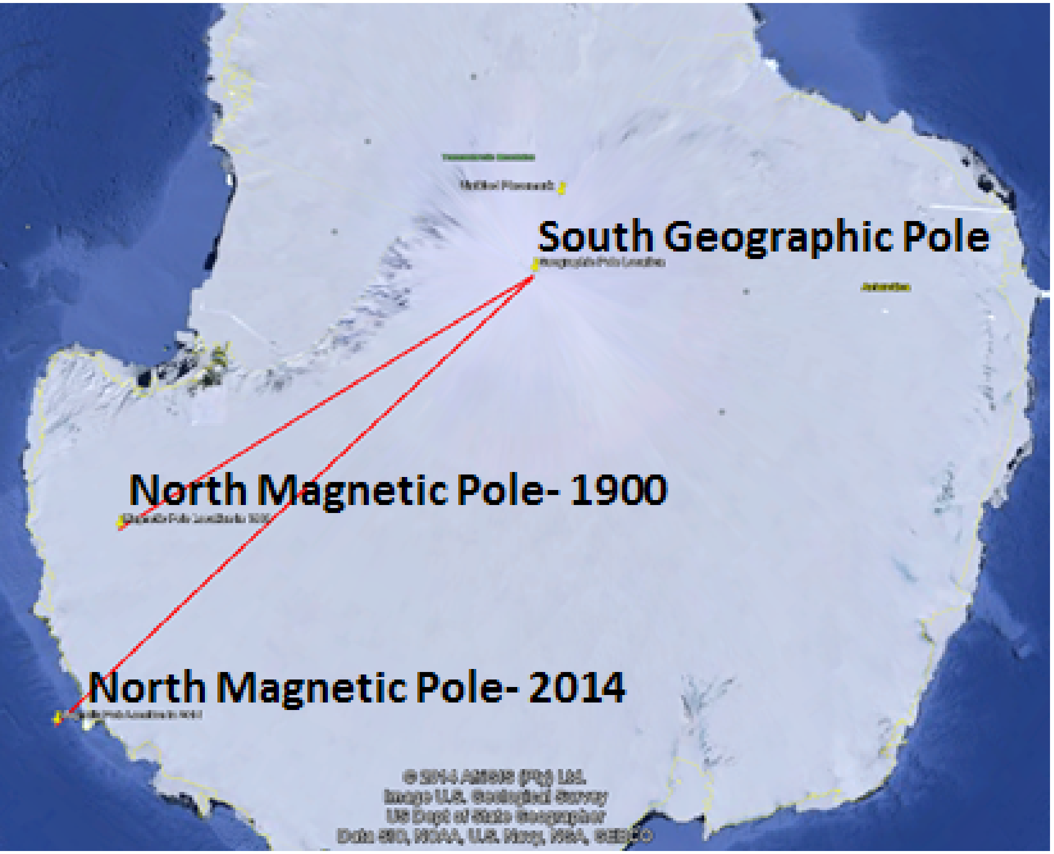
SHIELDING ASTRONAUTS FROM COSMIC RAYS

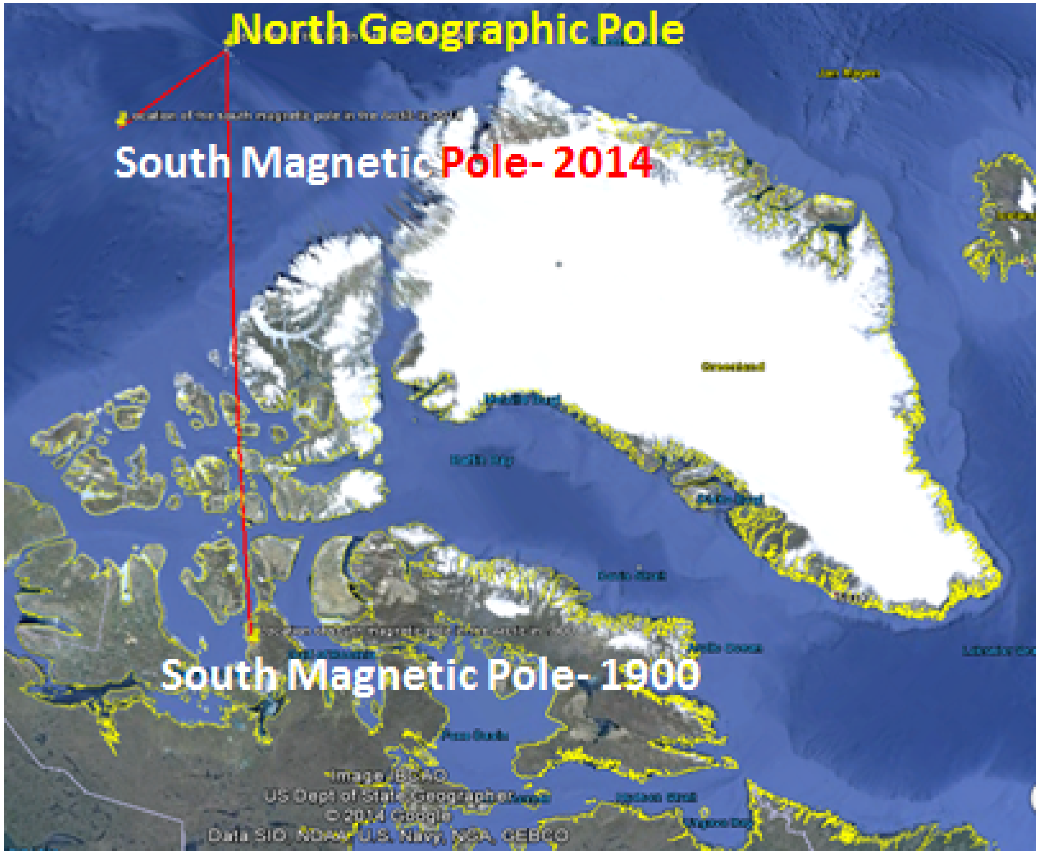
E. N. Parker
Dept. of Physics and Dept. of Astronomy and Astrophysics,
University of Chicago, Chicago, Illinois

The astronaut far removed from the magnetically enshrouded mass of Earth is subject to a continuing low dose rate of galactic cosmic radiation. Exposure for a year or more may be sufficient to induce a high incidence of cancer a decade or two later. Effective shielding of an astronaut by surrounding mass involves too much total mass to be practical for launching into space. Magnetic shielding requires transverse field of about 10^7 Gauss cm (to deflect particles up to 2 Gev). A dipole field of 10^5 Gauss with a characteristic scale of 2m or more would be required. However, there is evidence that the induced emf's from human residence in fields of the order of only 10^3 Gauss may be seriously injurious. There is very little information available on this subject. The alternative concept of inflating a magnetic dipole field with plasma is ill founded, and, in any case would serve only to reduce the Gauss cm of transverse field. Electrostatic shielding, charging the spacecraft to $+2x10^9$ volts, would have to contend with the surrounding sea of thermal electrons, perhaps with a guard potential of -10^3 volts. The power requirements to operate such a system are enormous.

We suggest that there may perhaps be a solution to the problem in the biomedical field, stimulating the human body to effective repair of the ongoing radiation damage by the cosmic rays. Unfortunately there is very little information available on this prospect. It may be our only hope.

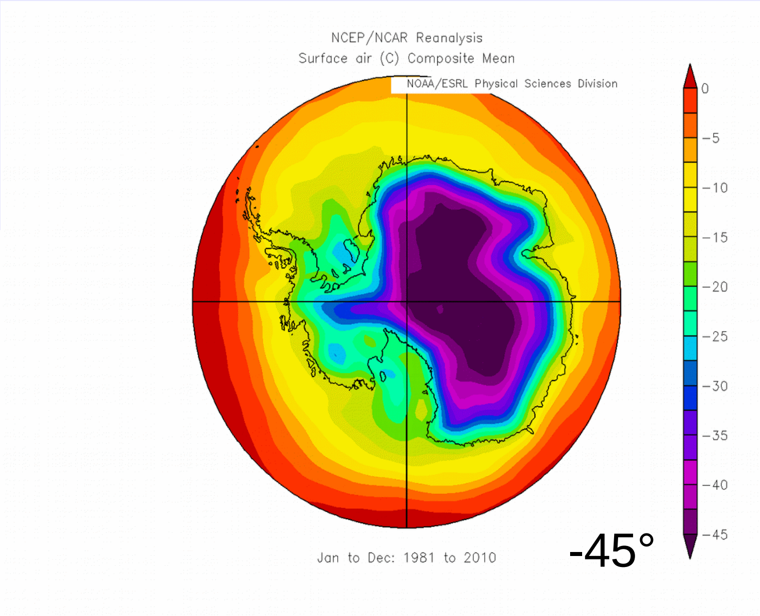
Differenze Artide -Antartide

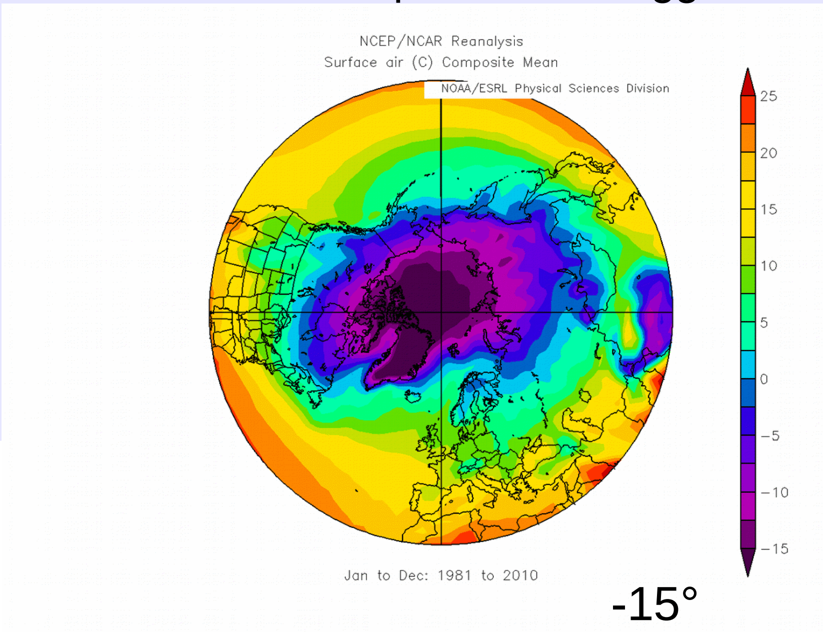




Artide – Antartide: differenze

REGIONE ANTARTICA	REGIONE ARTICA
Continente coperto di ghiaccio e circondato dall’oceano	Regione oceanica coperta di ghiaccio e circondata da continenti
Lo spessore di ghiaccio che ricopre il continente arriva fino a circa 4000 m → l’altitudine varia tra 0 m – 4000 m	Superficie relativamente piatta, basse altitudini
Clima più freddo, la differenza di temperatura rispetto alla regione artica diminuisce all’aumentare dell’altitudine	Il contenuto di umidità specifica è maggiore
Diminuzione più rapida del campo magnetico	





Confronto temperature superficiali Antartide – Artide → fino a 30°C di differenza

Collaboration

INFN
Section of Torino
Section of Bologna
- *LNF - Roma*
- **INAF** - *IAPS Roma*
- **IAA** - *Instituto Antártico Argentino*
- **UNLP** - *Universidad Nacional de La Plata*

- PROGETTO INFN **HALCoRD** **(**2017-2019)
- **(H**igh **A**ltitude and **L**atitude **Co**smic **R**ay **D**osimetry)

Agreement signed 23 April 2015 between italian and argentine institutions for a five years research program (2015 - 2020)

COLLABORATION AGREEMENT

BETWEEN

THE ISTITUTO NAZIONALE DI FISICA NUCLEARE - INFN, Italy

AND

ISTITUTO DI ASTROFISICA SPAZIALE E PLANETOLOGIA - IASP-INAF, Italy

AND

UNIVERSIDAD NACIONAL DE LA PLATA – UNLP, Argentina

AND

INSTITUTO ANTÁRTICO ARGENTINO - IAA, Argentina

CONCERNING THE EXECUTION OF A JOINT PROGRAM OF SCIENTIFIC RESEARCH AND EDUCATION

least six months prior to the expiration of the period of validity. If any Institution wishes to make an amendment to this Collaboration Agreement, the subject may be discussed and made valid through mutual consent.

This Collaboration Agreement is a mutual statement of intent between the Parties, who agree to make every reasonable effort to fulfil the intentions expressed herein.

For INFN

Prof. Fernando Ferroni
President
Date 23 APR. 2015

For IAPS-INAF

Prof. Pietro Ubertini
Director
Date

For Universidad Nacional de la Plata

Prof. Raul A. Perdomo
Rector
Date

For Instituto Antàrtico Argentino

Dr. Nestor R. Coria
Instituto Antartico Argentino
Director

Prof. Nestor Coria
Director
Date

Ushuaia GAW Station

Secondary cosmic ray dosimetry at high southern latitudes

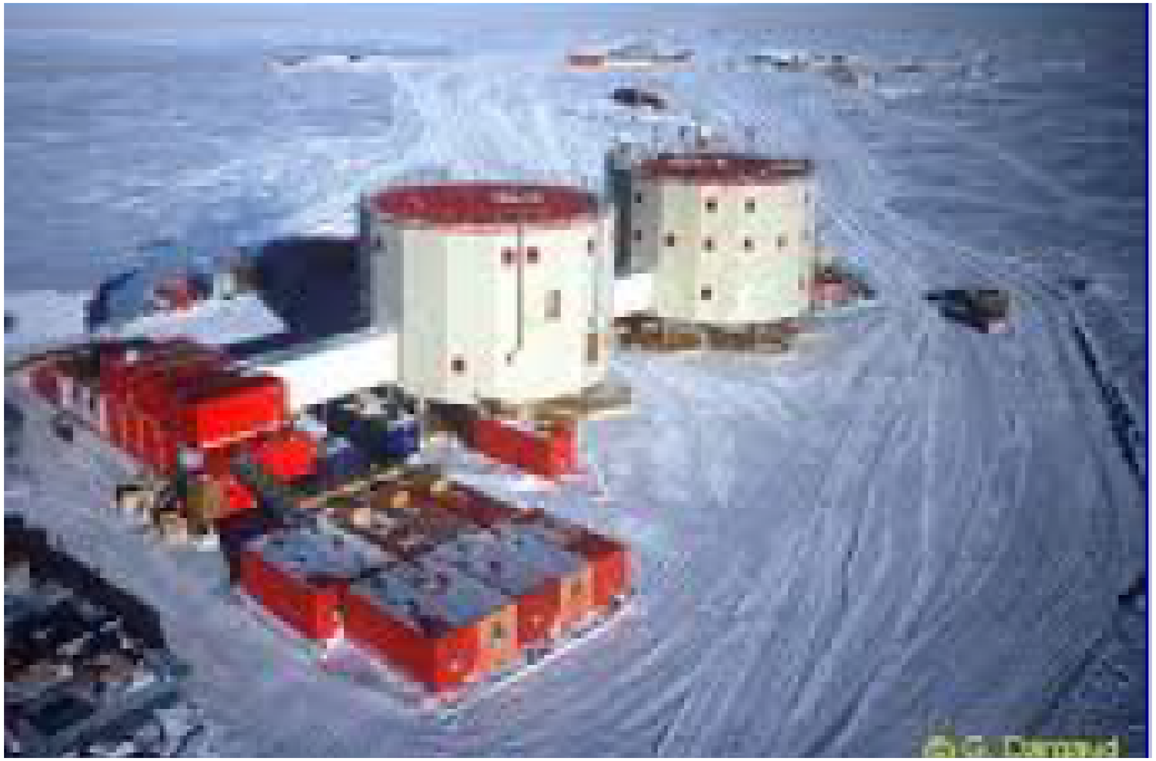
Alba Zanini ,Vicente Ciancio , Gustavo Di Giovan , Silvia Vernetto, Paolo Morfino , Alessandro Liberatore

In press

Marambio argentine antarctic base 2013-2015-2017 campaign

ANNUAL ANTARCTIC CONTINGENT
Since workers are known to be exposed to High LET radiation, a **CYTOGENETIC STUDY** is going to be performed before and after the Antarctic Campaigne by **UNLP Space Medicine Department.**

Dome C   Base Italo-Francese



Collaboration:

INFN Torino (Italy)

IPEV Paris (France)

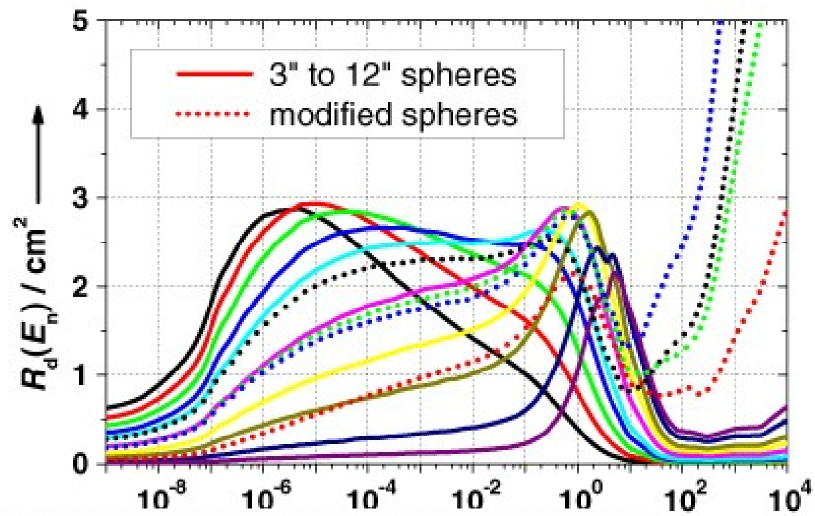
PNRA Rome (Italy)

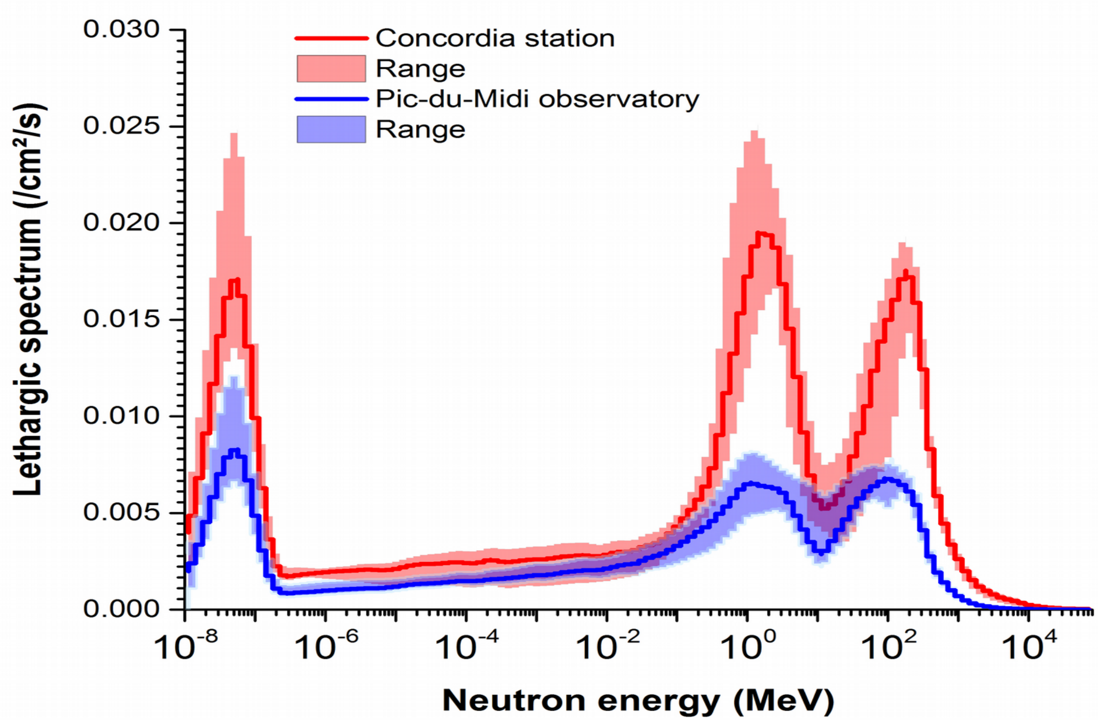
IAA   Buenos Aires (Argentine)

The CHINSTRAP project works with an high-energy extended neutron spectrometer at the **Concordia (Italy-France) station in Antarctic**.
The particularities of this location are unique (high altitude and proximity to the geomagnetic pole) and allow long-termeasurements dedicated to the study of the atmospheric natural radiative environment dynamics for Space Weather applications.
These data will complete the ones already obtained at the **Pic-du-Midi in France** and in the **Pico dos Dias in Brazil,** near the South Atlantic Anomaly.

CONAE

Bonner sphere system





Paleoclimatology

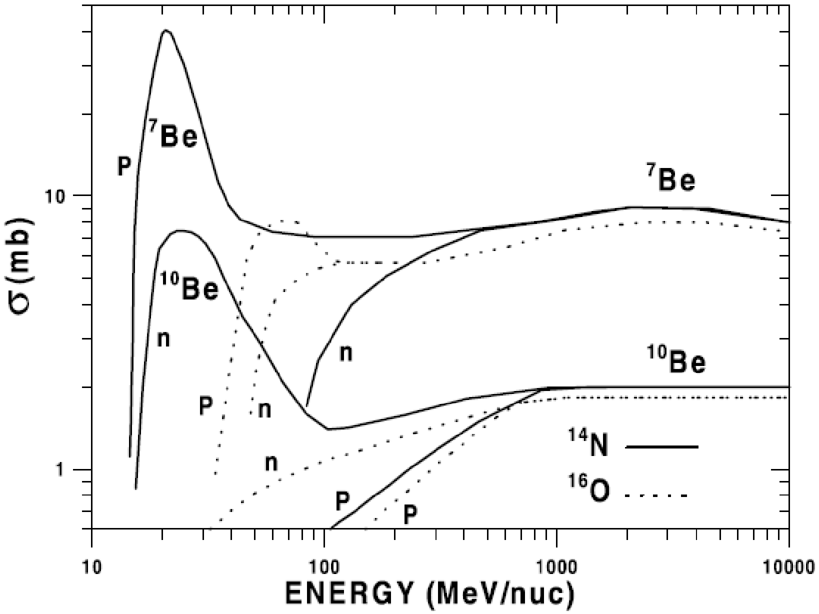
Cosmic nuclei

$N^{14}(n,p)\ 2Be^{7}$.

(half life 53.3 days)

$N^{14}(n,p)C^{14}$.
$^{16}O(n,3He)^{14}C$
$^{16}O(n,pd)^{14}C$
$^{16}O(n,n2p)^{14}C$

^{14}C half-life about 5730 yr



e 2. Cross sections for production of ^{7}Be and ^{10}Be from proton and neutron interactions wit
O. Solid and dashed lines above ~100 MeV/nuc are from the new cross sections formulation i
of *Webber et al.* [2003] based on higher energy data. Solid and dashed lines below ~100 MeV
om l

2 - 8 WEBBER AND HIGBIE: COSMIC RAY PRODUCTION OF COSMOGENIC NUCLEI

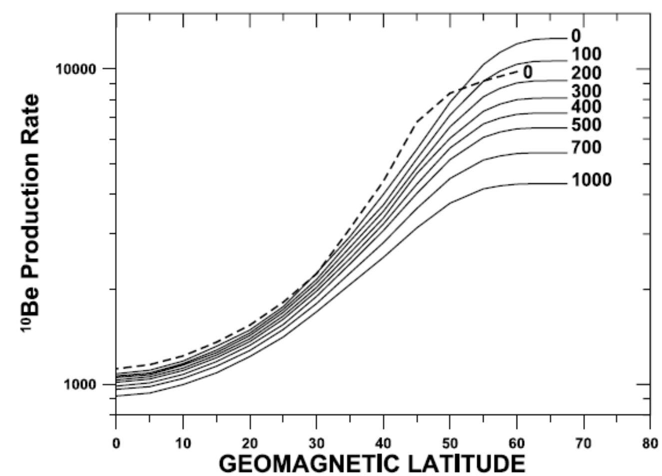


Figure 7. Total ^{10}Be production (in arbitrary units) in the atmosphere as a function of geomagnetic latitude and solar modulation level. The total ^{10}Be production from *Masarik and Beer* [1999] for a solar modulation φ = 0 normalized at a latitude of 30° is shown for illustration as a dashed line.

Table 1. Global, Polar (Geomagnetic Pole), and Equatorial (Geomagnetic Equator) Production Rates of the Five Cosmogenic Radiolsotopes for the Modern Conditions (the Geomagnetic Dipole Moment $M = 7.8 \cdot 10^{23}$ A m^2), for the Mean, Minimum, and Maximum Modulation Potentials: $\langle\phi\rangle = 650$, $\phi_{min} = 300$, and $\phi_{max} = 1200$ MV, Respectively[a]

	Global Production			Polar Production			Equatorial Production		
Isotope	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
^{7}Be	$6.5 \cdot 10^{-2}$	$8.5 \cdot 10^{-2}$	$4.8 \cdot 10^{-2}$	$1.45 \cdot 10^{-1}$	$2.2 \cdot 10^{-1}$	$9.1 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$2.3 \cdot 10^{-2}$	$1.9 \cdot 10^{-2}$
^{10}Be	$2.9 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$6.4 \cdot 10^{-2}$	$9.5 \cdot 10^{-2}$	$4.0 \cdot 10^{-2}$	$9.6 \cdot 10^{-3}$	$1.0 \cdot 10^{-2}$	$8.7 \cdot 10^{-3}$
^{14}C	1.6	2.07	1.2	3.42	5.02	2.21	$5.7 \cdot 10^{-1}$	$6.1 \cdot 10^{-1}$	$5.2 \cdot 10^{-1}$
^{22}Na	$5.4 \cdot 10^{-5}$	$6.9 \cdot 10^{-5}$	$4.0 \cdot 10^{-5}$	$1.15 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$7.5 \cdot 10^{-5}$	$1.8 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.6 \cdot 10^{-5}$
^{36}Cl	$2.5 \cdot 10^{-3}$	$3.3 \cdot 10^{-3}$	$1.85 \cdot 10^{-3}$	$5.6 \cdot 10^{-3}$	$8.5 \cdot 10^{-3}$	$3.5 \cdot 10^{-3}$	$8.3 \cdot 10^{-4}$	$8.8 \cdot 10^{-4}$	$7.5 \cdot 10^{-4}$

[a] The production rates are given in atoms/cm^2/s.

CHILECITO
LABORATORIO DE ALTURA

DiezAños UNdeC 20032013

90 ANNI 1923-2013

ices INTERNATIONAL CENTER FOR EARTH SCIENCES

http://www.undec.edu.ar/detalle.php?id=237

Por la actividad de lo Attaché Científico de Italia en Argentina, ing. Gabriele Paparo, el 29 de Abril de 2013, el prof. Louis NICOLAIS, Presidente del Consejo Nacional de Investigación (CNR) en Roma, Italia, y el profesor. Norberto Raúl Caminoa, Rector de la Universidad Nacional (UNDEC) Chilecito, Prov. La Rioja Argentina firmó, en la residencia del Embajador de Italia en Buenos Aires, un Acuerdo marco de cooperación científica y técnica entre las dos instituciones.

Las relaciones de cooperación se harán de la siguiente manera:

- Intercambio de docentes e investigadores.
- Investigaciones científicas.
- Intercambio de documentos y publicaciones científicas.
- Prácticas y visitas de los estudiantes.
- Participación en comités de evaluación.

Impulsar de manera conjunta el proy… …ncionamiento de una estación de altura (500… …iguientes temáticas:

1- Medi…

… a grandes alturas sobre el nivel del mar.

… …es a bajas presiones o a saltos de presiones

… …humana. En colaboración con el CADIC

3- Int… …ulcanismo.

4- Tra… …studio de la contaminación.

5- Med…

6- Deter… …tenido del radón en el suelo, con una metodología i… …en colaboración con el Distrito de Malargüe.(Prov. Mendoza)


Signature of UNDEC – CNR Agreement

Strumenti di misura da installare al Laboratorio de Altura sul Monte Famatina

- **Neutron Monitor modulare IAPS-INAF** — Variabilità cosmici primari
- **Rem counter Atomtex BDKN-03** — Flusso e dose neutronica (25 meV-14 MeV)
- **Rem counter Thermo** — Flusso e dose neutronica (25 meV-5GeV)
- **Gamma detector BDKG-04** — Dose X e gamma
- **Liulin LET spectrometer** — Dose totale
- **Bubble detectors** — Spettro neutronico (25 meV-14 MeV)
- **Magnetometro** — Variazione campo geomagnetico

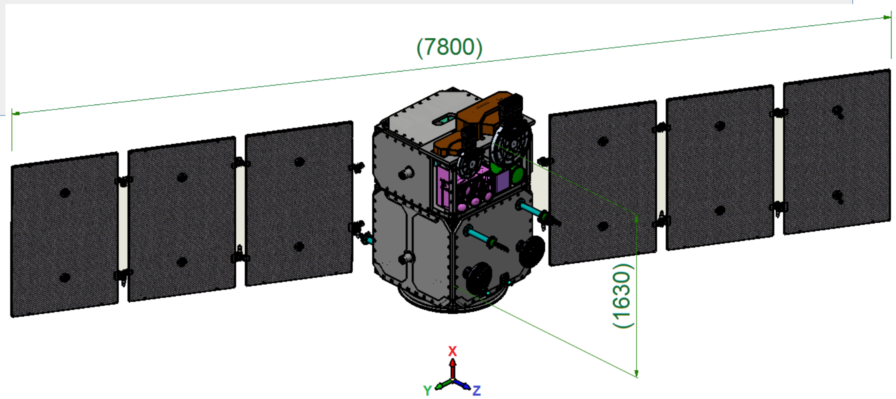
↓

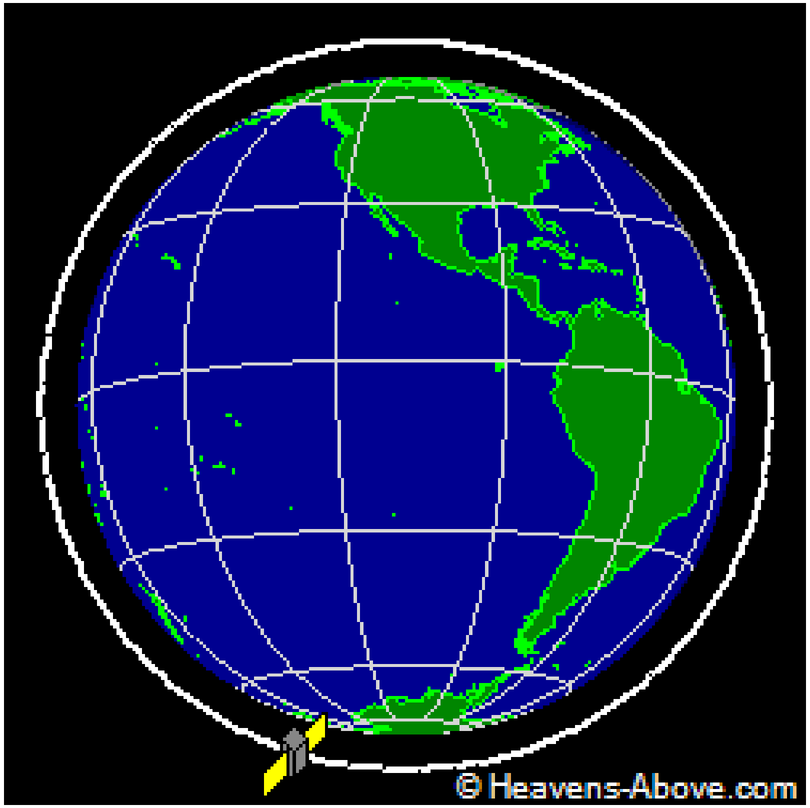
Dosimetria della radiazione ambientale
Correlazione con attività solare
Correlazione con campo magnetico

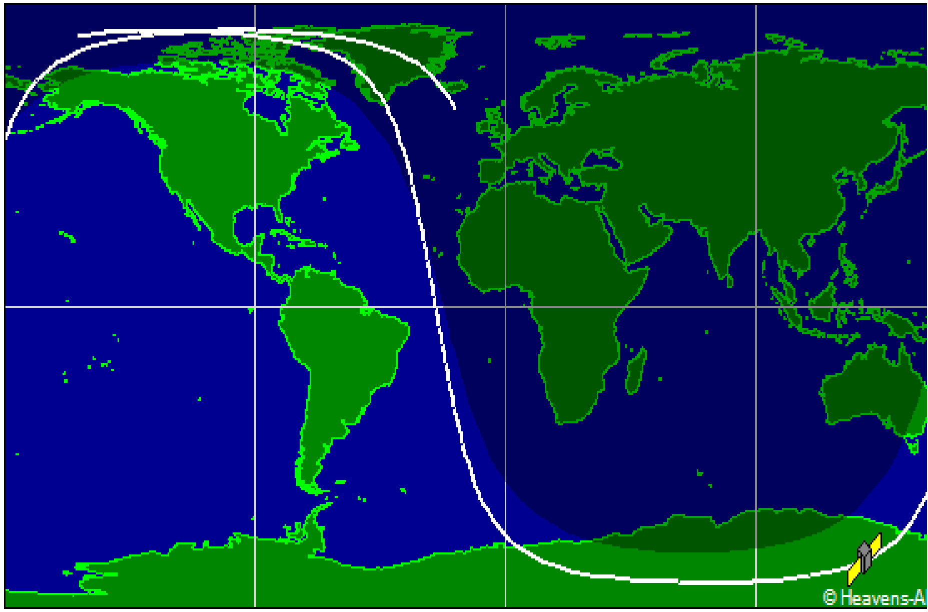
CONAE Comision Nacional de Activitades Espaciales

Liulin-AR dosimeter on board SABIA-Mar satellite
(launch 2020)

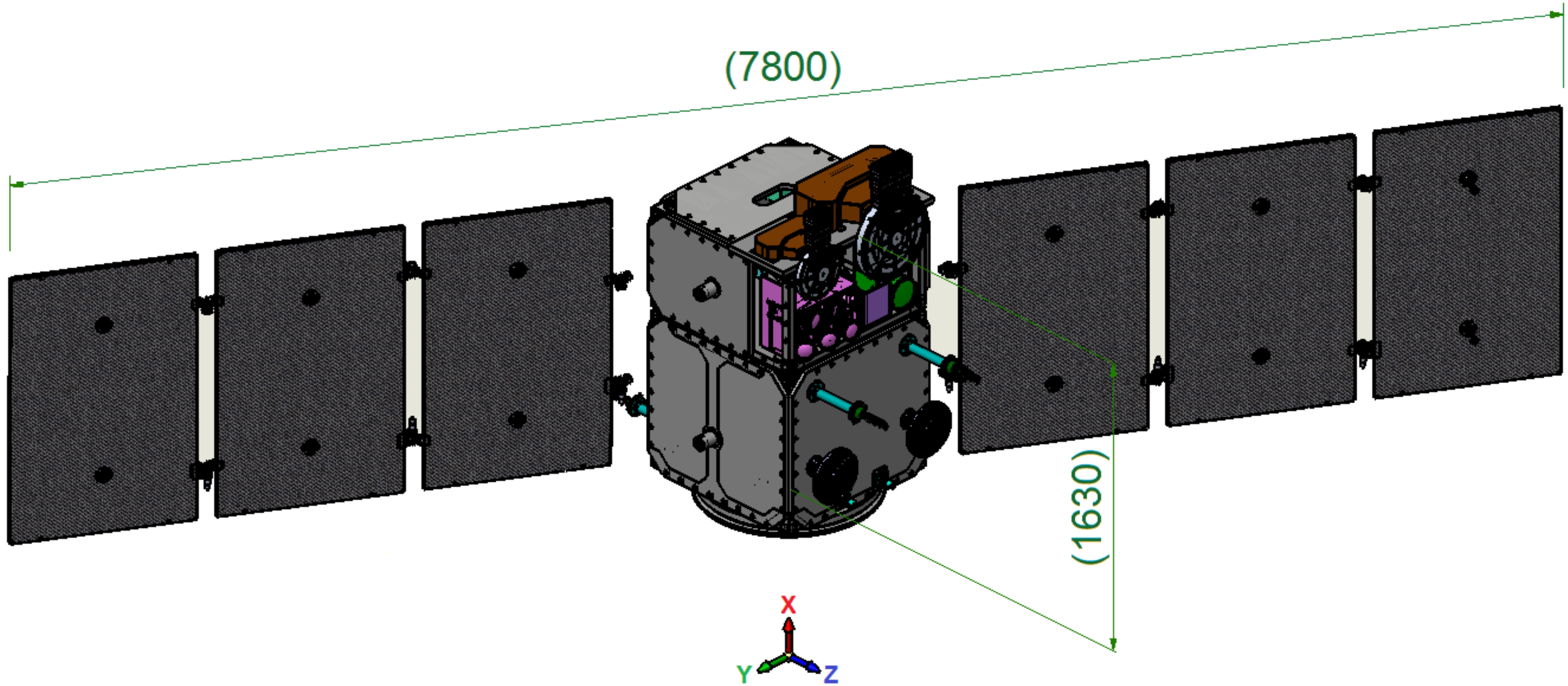
Polar orbit 654 km







SABIA-MAR satellite



Expected radiation environment on the SABIA-MAR orbit:

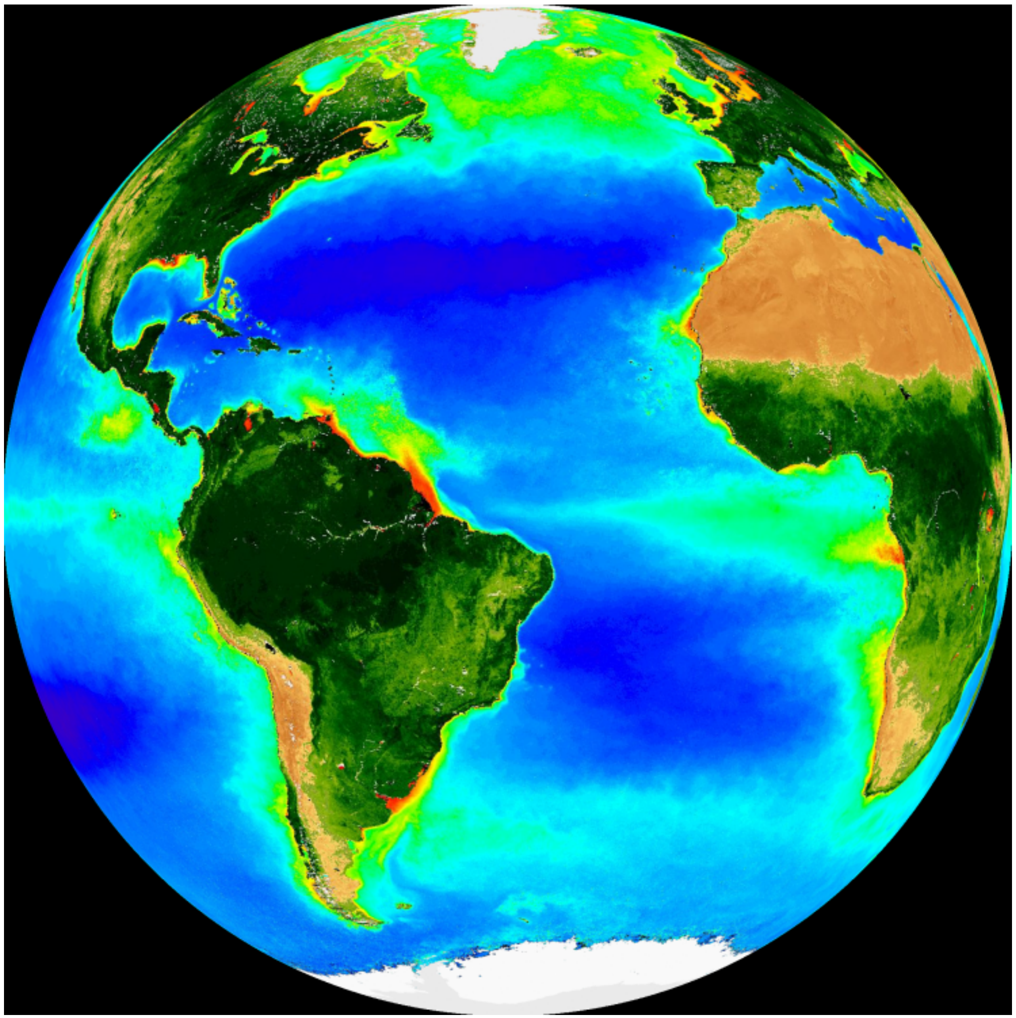
→ **Globally distributed GCR** particles and those derived from them;

→ **Protons in the SAA region** of the inner radiation belt (IRB);

→ **Relativistic electrons** and/or bremsstrahlung in the high latitudes of the orbit where the outer radiation belt (ORB) is situated

→ **Solar energetic particles (SEP**) in the high latitude orbit.

SABIA-MAR satellite

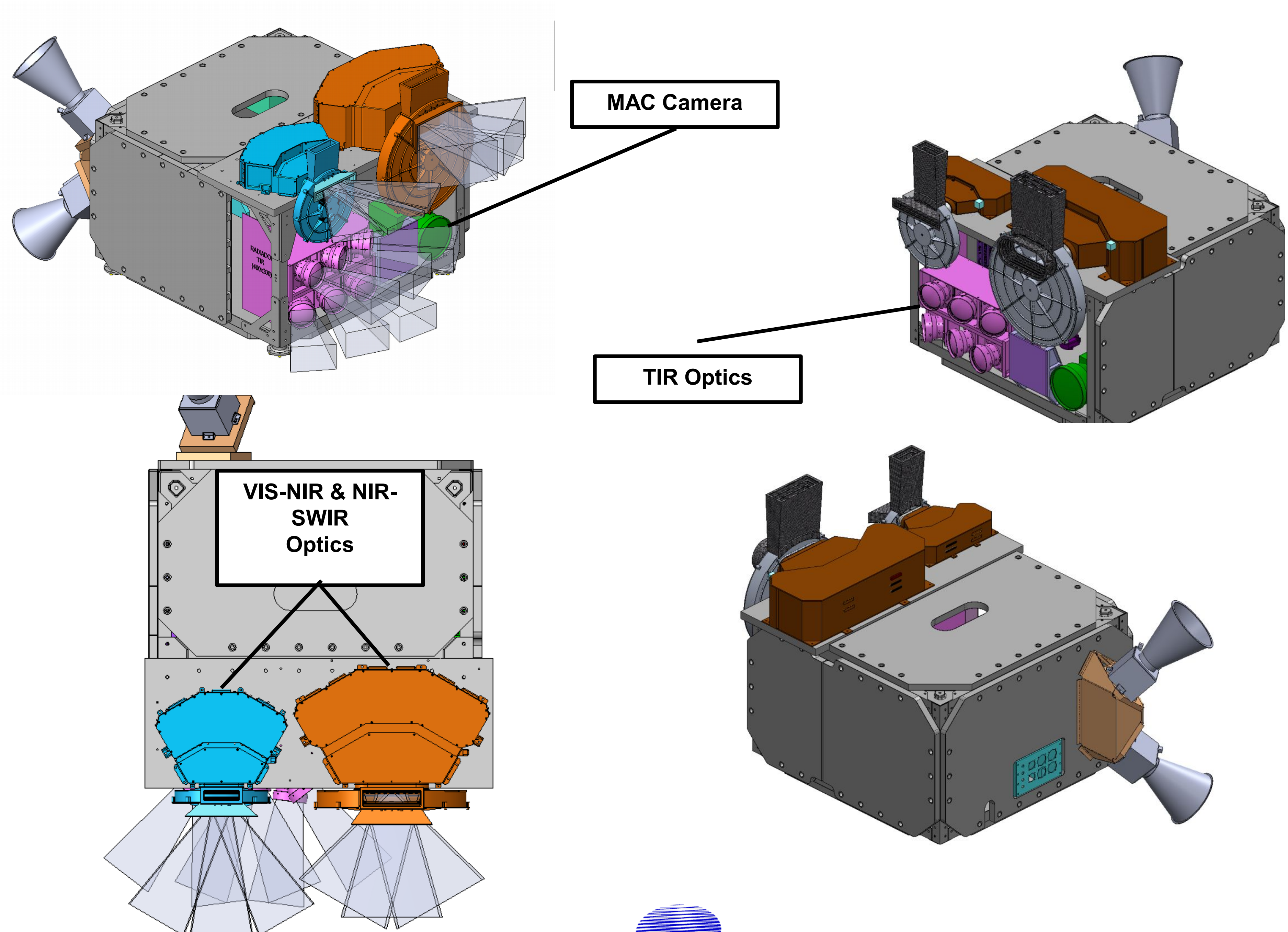


Products

- **Normalized Water leaving radiance maps** 5% uncertainty (0.5% in blue for open ocean)
- **Chlorophyll-*a* concentration Maps**
  30% uncertainty for open ocean with concentration in the range 0.01-10 mg/m3
- **Diffuse Attenuation coefficient Kd (490)**
  25% uncertainty on a daily time scale
- **Photosynthetic Available Radiation**
  20%, 15%, 10% on a daily-weekly-monthly time scales
- **Turbidity**
  35% uncertainty
- **Sea Surface Temperature**
  0.7^{o}C

CONAE

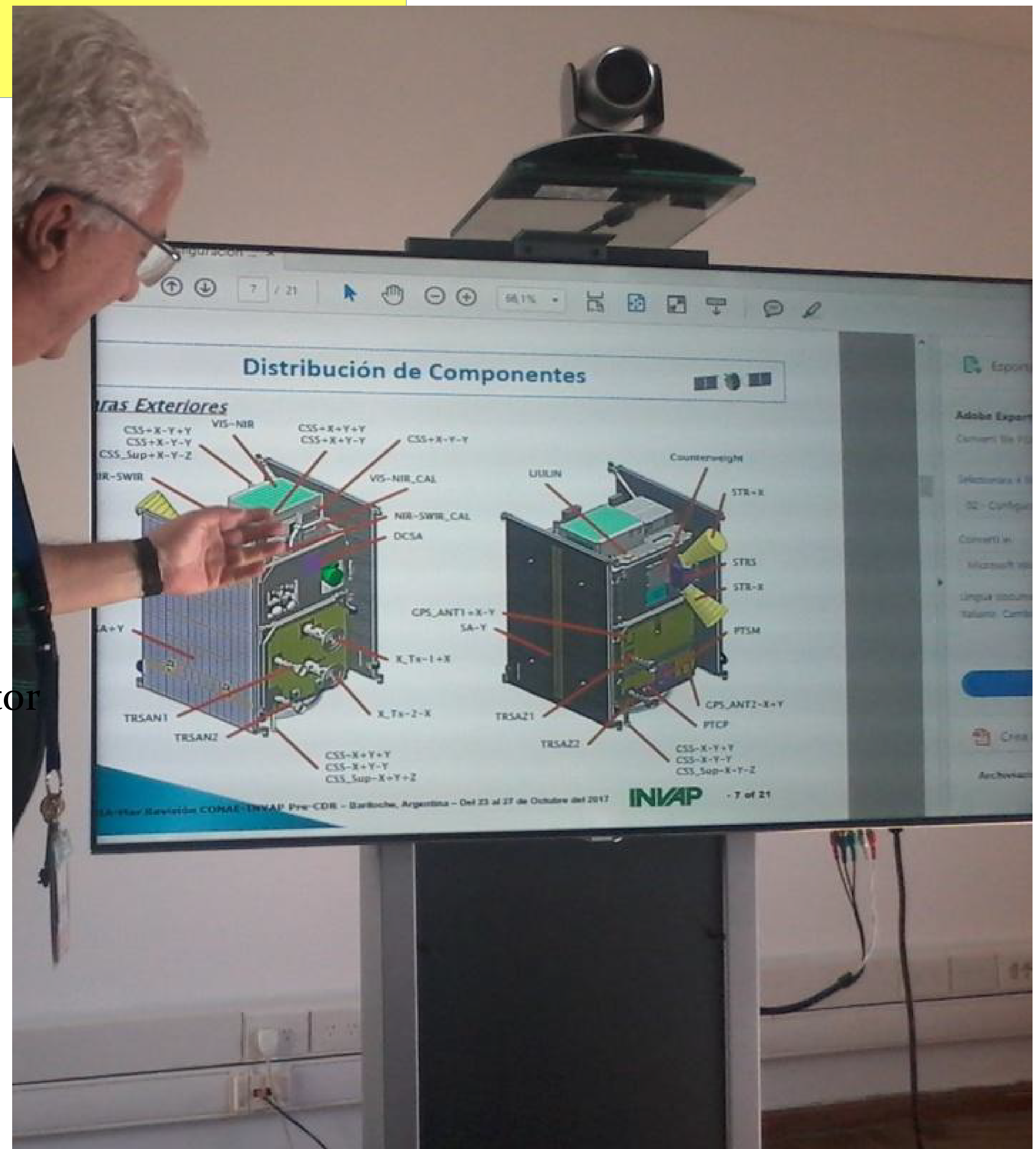
SABIA-Mar 1 – Payload Module



LIULIN -AR LET spectrometer on Sabia -MAR

Space radiation dosimetry

Early Alert



***6)* LET spectrometer Liulin I MUD-1**

256-channel active silicon semiconductor spectrometer developed at Solar-Terrestrial Influence Laboratory of Bulgarian Academy of Sciences.

- **Energy range:** 10 KeV -20 MeV
- **Sensitivity:**

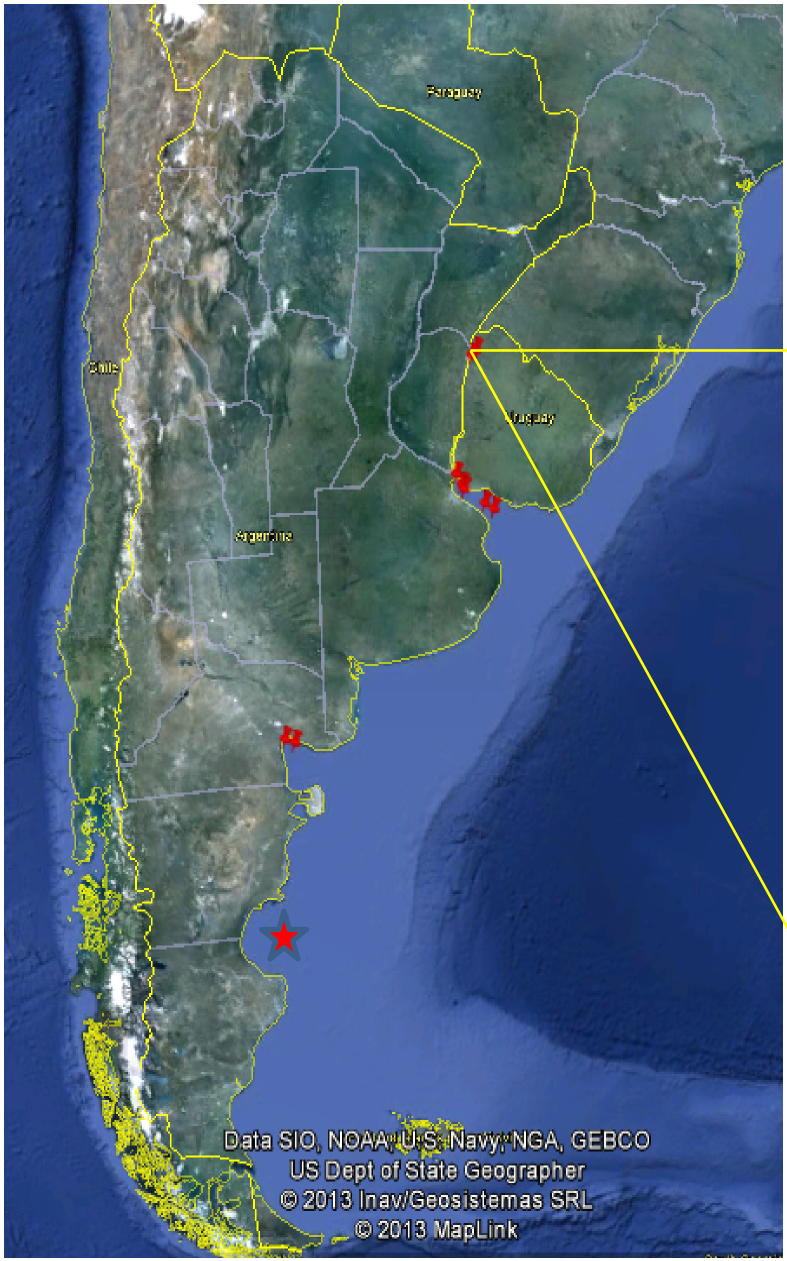
Dose rate 0.01 μSv/h - 10 mSv/h

- **Error:** 20%

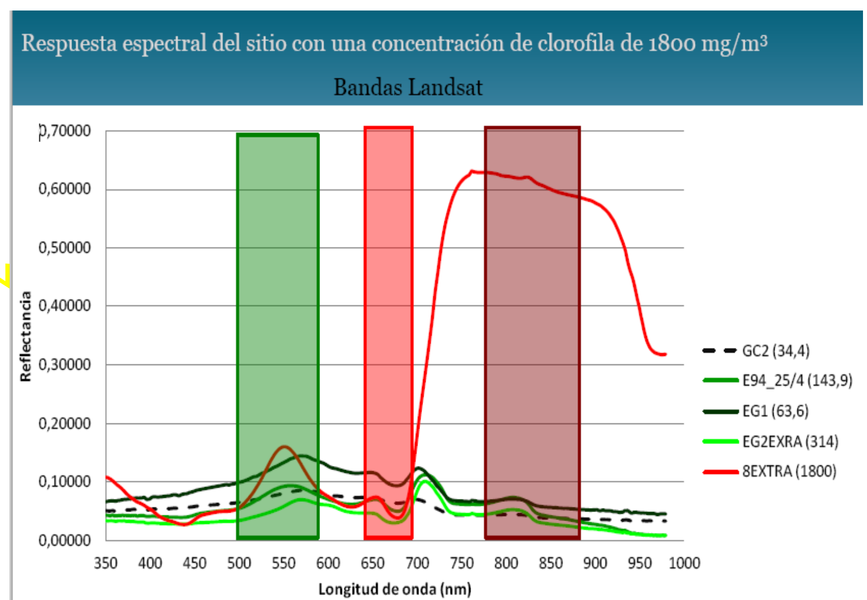
Launch Segment

- A Joint (CONAE&AEB) Request for Information [RFI] was released and addressed to all possible providers asking for launch availability, ROM price, fueling services at the launch base, possibility of insurance, etc.
- Until now, 11 proposals were received, 9 of them for a dedicated launch and 2 considering a dual launch, being SABIA-Mar 1 the primary payload. Proposals were received from: **Rockot [Eurockot], Dnepr [ISC Kosmotras], Vega [Arianespace], Falcon 9 [Space X], Soyuz [Arianespace], LM-2C/2D [CGWIC], Soyuz [JSC Glavkosmos], Minotaur C [OSC], Tsyklon 4 [ACS Alcantara].** Another proposal**, from Antrix,** expected to be received during 1st quarter this year.
- **The Phase 1 of the Proposals Evaluation is completed** (Antrix response to be added)
- Phase 2 of the Proposals Evaluation (interchanges with possible providers, environments and interfaces clarification, statement of work generation, etc.) going on.
- International Bid Tender release foreseen by Mission CDR time frame

In situ radiometric measurements in progress



With National & International Cooperation



CONAE

Satellite 2017 Confernce

11-16 May 2017

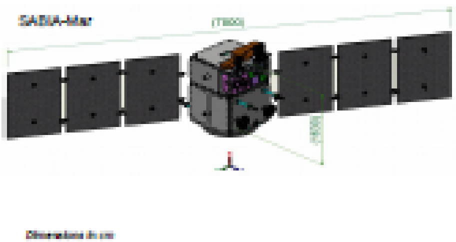
Barcelone

Liulin-AR spectrometer for radiation environment observation on SABIA-MAR 1 satellite

T. Dachev, Space Research and Technology Institute of Bulgarian Academy of Science, Sofia, Bulgaria
A. Zanini, Istituto Nazionale di Fisica Nucleare, Sez. Torino, Italy
M. Colazo, Comisión Nacional de Actividades Espaciales, Buenos Aires, Argentina
D. Caruso, Comisión Nacional de Actividades Espaciales, Buenos Aires, Argentina
M.Raboli, Comisión Nacional de Actividades Espaciales, Buenos Aires, Argentina
V. Ciancio, Universitad National de La Plata, La Plata, Argentina

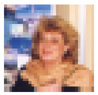
Abstract

The SABIA-Mar (Satélite Argentino Brasileño para Información del Mar) is a dual satellite joint Argentine-Brazilian Earth observation mission, which objective is to study the oceanic biosphere, its changes along time and how it is affected and reacts to human activity. The Argentinian SABIA-Mar 1 satellite planned to be launched at 702 km sun-synchronous circular orbit in 2021. The platform and the instruments for ocean color observation and sea surface temperature determination are developed and built in Argentina. A Liulin instrument for determination and quantification of the global distribution of the 4 possible primary sources of space radiation outside the satellite: galactic cosmic rays particles and their secondary products, energetic protons in the South Atlantic Anomaly region of the inner radiation belt, relativistic electrons and/or bremsstrahlung in the outer radiation belt and solar energetic particles, generated during solar particles events. The Liulin-AR instrument is a Liulin-type deposited energy spectrometer, which were successfully used in the period 2001-2016 in: five missions to the International space station, four low earth orbiting satellites and on the lunar Indian Chandrayaan-1 satellite. It is miniature spectrometer-dosimeter, which uses pulse analysis technique to obtain the energy deposited spectrum in single PIN diode with area of 2 cm^2 and thickness of 0.3 mm. The spectra are further used for calculation of the deposited in the silicon of the detector dose rate in micro Grey per hour and the flux of the particles. The Liulin -R dimensions are 10x40x20 mm and weight of 0.092 kg.



Recent Publications

1. SABIA-MAR (2009) Phase A, final Report; CONAE Document SB-010400-IA-00100 , Release A:1-48
2. Rabolli M, Torrusio S, Caruso D, (2017) CONAE, SABIA-Mar Mission Status Update.
3. Dachev T, Semkova J, Tomov T, Nikolaev I, et al, (2015) Overview the Liulin type instruments for space radiation measurement and their scientific results, Life sciences and Space Research 4:91-114
4. Dachev T, Tomov B, Matviichuk Y, Dimitrov P, Bankov N, Häder D,Horneck G, Reitz G,(2015) ISS radiation environment as observed by liulin type R3-DR2 instrument in October-November 2014. Aerospace Research in Bulgaria: 17-42
5. Semkova J, Koleva R, Bankov N, Malchev St, Petrov VM, Shurshakov VA, et al. (2013). Study of radiation conditions onboard the International Space Station by means of the Liulin-5 dosimeter. Cosmic Res.51:124– 132.
6. Damasso M, Dachev T, Falzetta G, Giardi M T, Rea G, Zanini A. (2009). The radiation environment observed by Liulin-Photo and R3D-B3 spectrum-dosimeters inside and outside Foton-M3 spacecraft. Radiation Measurements 44:263-273



Alba Zanini has her expertise in ionizing radiation dosimetry, both in medical and environmental field. In particular she developed original methods of passive dosimetry techniques for neutron spectrometry and dosimetry, suitable for space application, that were successfully employed on LEO orbits ESA satellites and on International Space Station. At present she collaborates with CONAE and IAA (Istituto Antartico Argentino) for a program of environmental radiatin dosimetry at high southern latitudes, in space and in Argentina Antarctic base Marambio
zanini@to.infn.it

Journal of Environmental Radioactivity 175-176 (2017) 1–9

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Environmental radiation dosimetry at Argentine Antarctic Marambio Base (64° 13′ S, 56° 43′ W): preliminary results

Alba Zanini [a,*], Vicente Ciancio [b], Monica Laurenza [c], Marisa Storini [c], Adolfo Esposito [d], Juan Carlos Terrazas [e], Paolo Morfino [f], Alessandro Liberatore [g], Gustavo Di Giovan [b]

[a] INFN Sez. Torino, Via P. Giuria 1, 10125 Torino, Italy
[b] Università National de La
[c] IAPS-INAF, Via del Fosso d
[d] LNF-INFN, Via E. Fermi 4(
[e] INAF-OATo, Strada Osserv
[f] Efesto S.a.r.l., 55 Avenue M
[g] Università degli studi di T

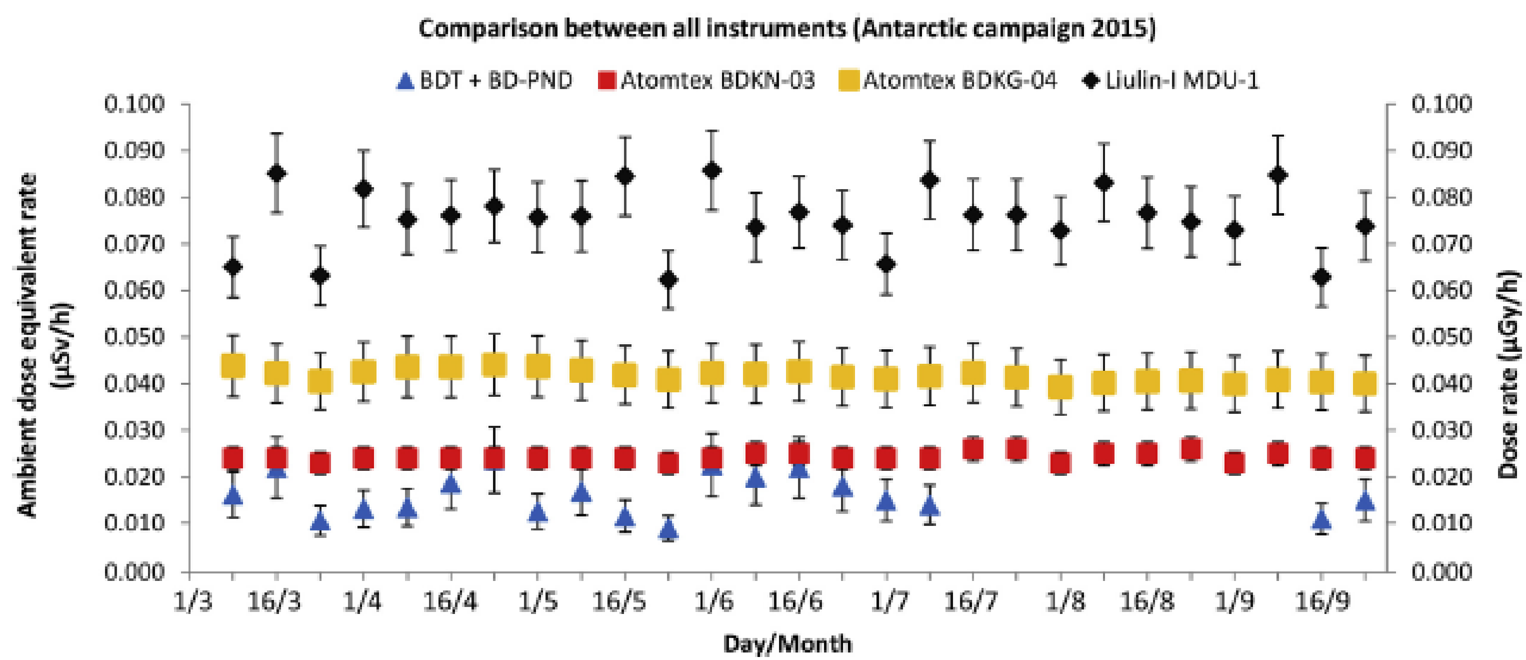
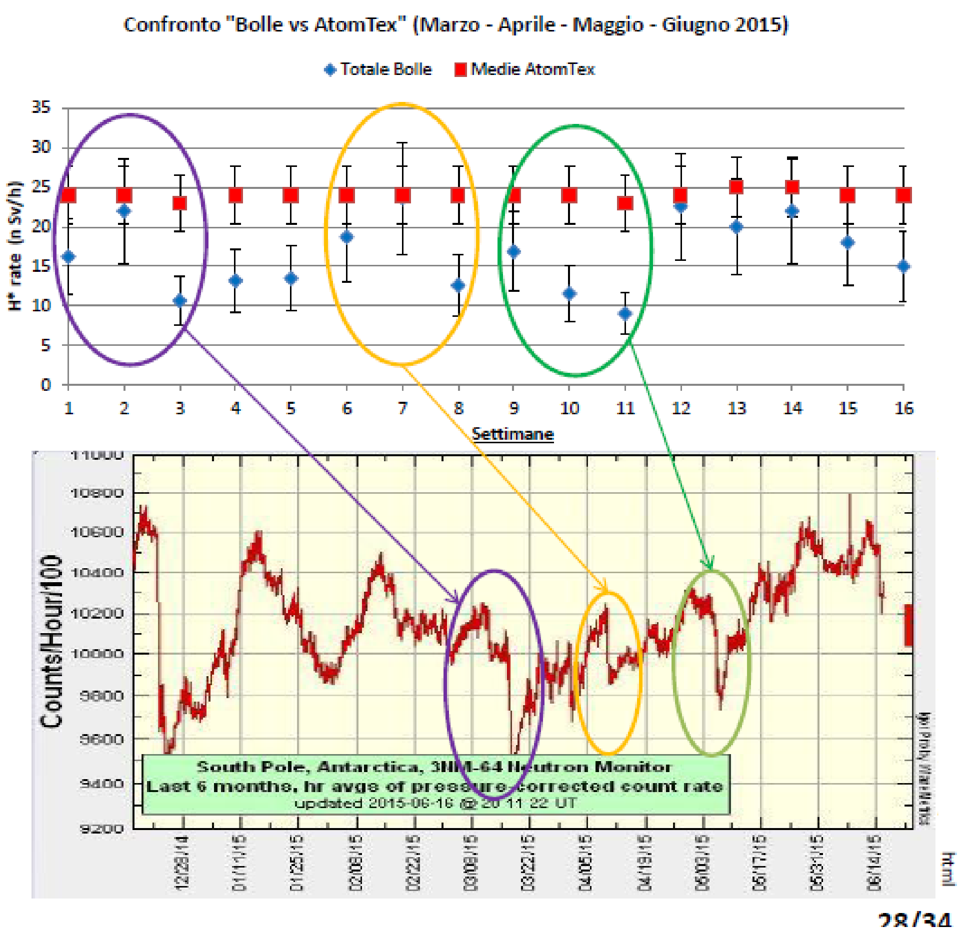


Fig. 7. Comparison between all instruments data measured in the period 1 March–20 September 2015 (8 days mean data) at Argentine Antarctic Marambio Base:
■Neutron ambient dose equivalent rate (µSv/h) measured by Atomtex BDKN-03;
▲Neutron ambient dose equivalent rate (µSv/h) (mean of BDT + mean of BD-PND) measured by Bubble detectors;
■X-γ dose rate (µGy/h) measured by Atomtex BDKG-04;
◆Dose rate (µGy/h) measured by Liulin-I MDU-1.

-Radiation dosimetry at Argentina Antarctic Marambio base
(200 m asl, 64°14′ S - 56°37′ W) and its correlation with cosmic ray variability
A.Zanini et al. 12th European Space Weather Week 23-27 November 2015

-Radiation dosimetry at high altitude and high latitude and correlation with cosmic ray variability
A.Zanini et al. SOHE 2016 28 May-1 June Rome



Environmental radiation dose at Marambio Base -2015

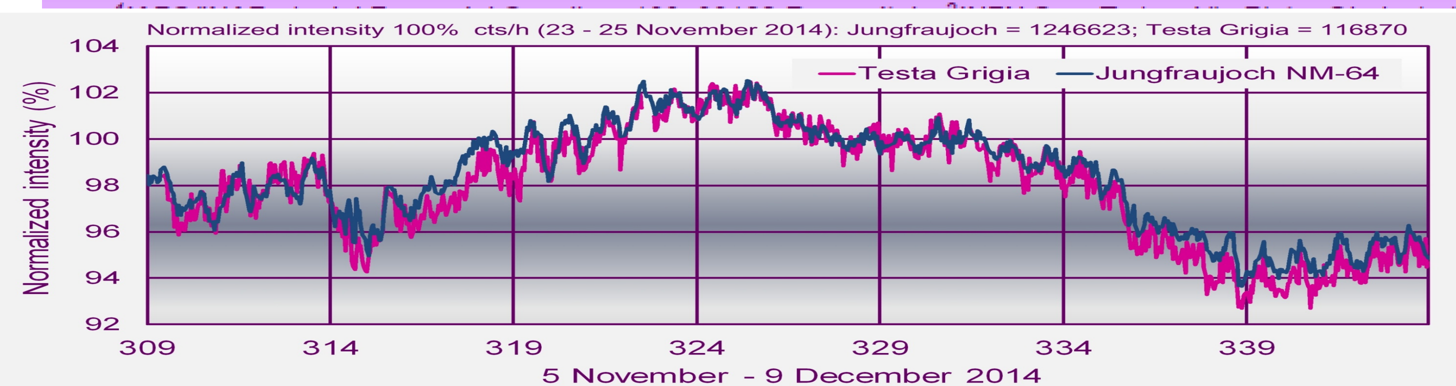
Table 2
Dose equivalent rate mean values (1 March-20 September 2015).

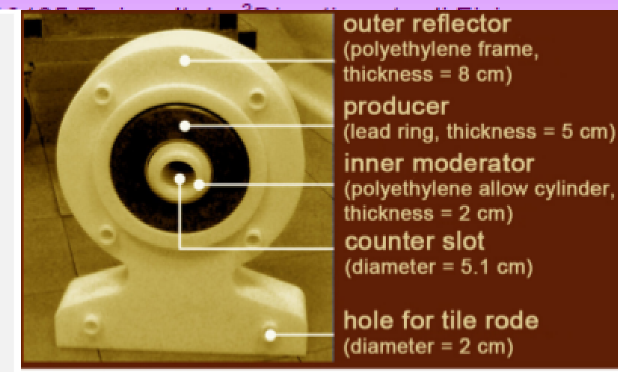
Instrument	Mean values	s.d.
Atomtex BDKN-03	*H* rate* (μSv/h)	
(neutrons)	0.024	0.002
Bubble detectors	*H* rate* (μSv/h)	
(neutrons)		
BDT	0.007	0.002
BD-PND	0.010	0.003
Sum (BDT + BD-PND)	0.017	0.005
Liulin-I MDU-1	*D rate* (μGy/h)	
(LET Spectrometer)	0.080	0.010
Atomtex BDKG-04	*D rate* (μGy/h)	
(X, γ)	0.042	0.003

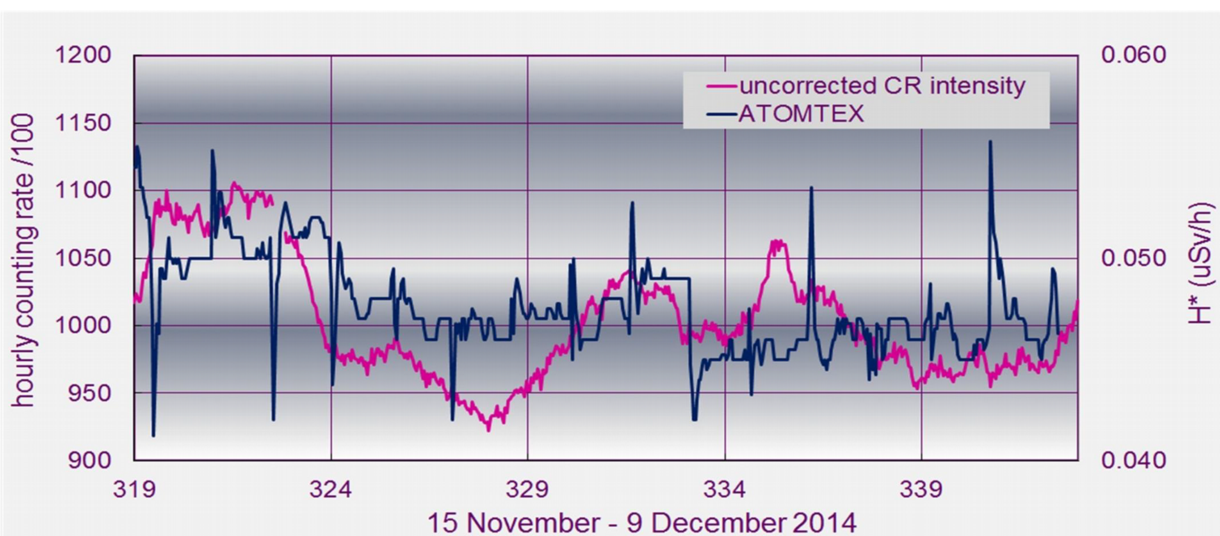
SESSION - NEUTRON MONITOR SCIENCE AS A FUNDAMENTAL TOOL FOR SPACE WEATHER

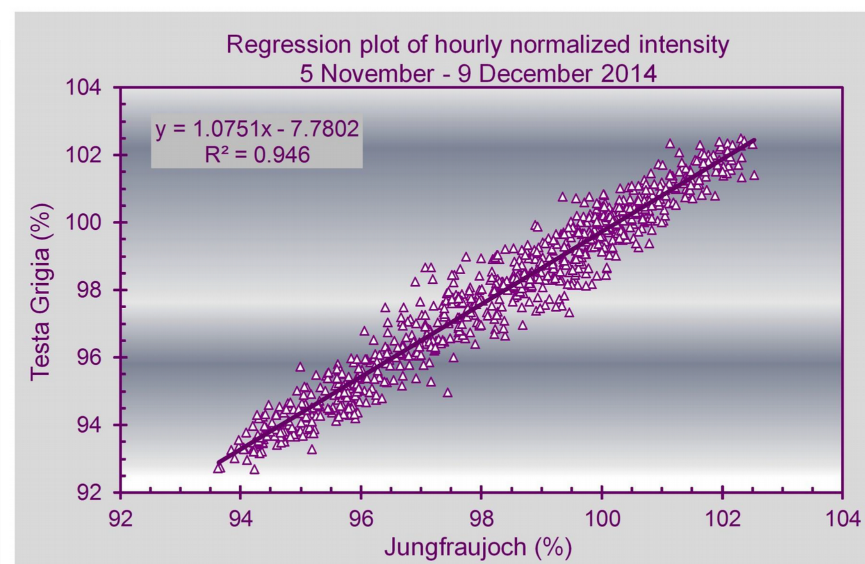
Multi-instrument radiation monitoring at the high altitude Testa Grigia Observatory

M. Laurenza[1], M. Storini[1], F. Signoretti[1], A. Zanini[2], P. Diego[1,3], S. Massetti[1], J. C. Terrazas[4], A. Liberatore[2], M.Chiti[5], A. Esposito[5]









Neutron Monitor
IAPS-INAF Roma

NM-64 He3 Portable Neutron Monitor:
Il "***M**odular **N**eutron **M**onitor*" (*MNM*)
è impiegato per misurare la variabilità
del flusso dei raggi cosmici primari.

- Formato da 23 moduli separati
- Lunghezza: 2,1 m
- Peso: 800 kg
- Contatore a 3He di tipo LND253773

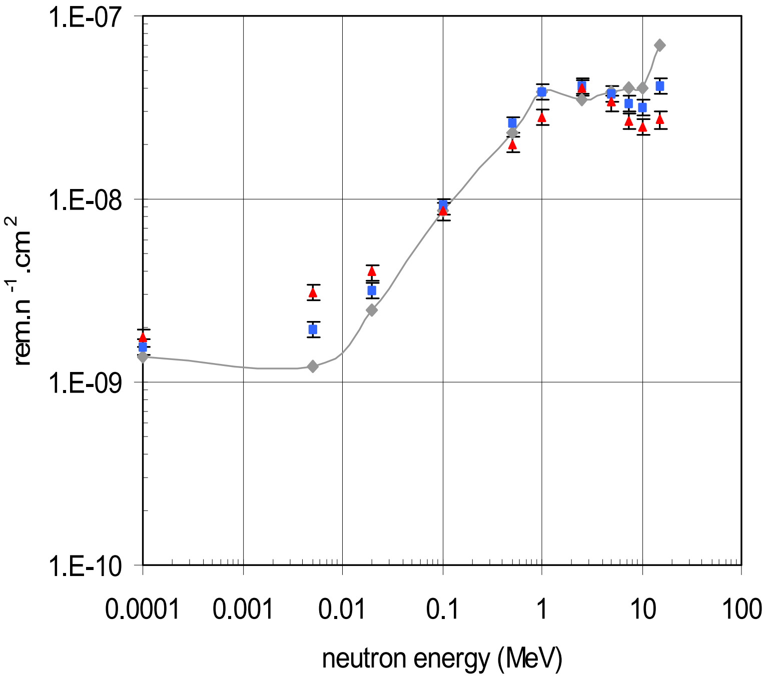
- Calibrazione effettuata all'osservatorio SVIRCO (Roma)
- In attività psso il Laboratorio Testa Grigia da ottobre 2014


MNM Neutron Monitor

Connections of the MNM

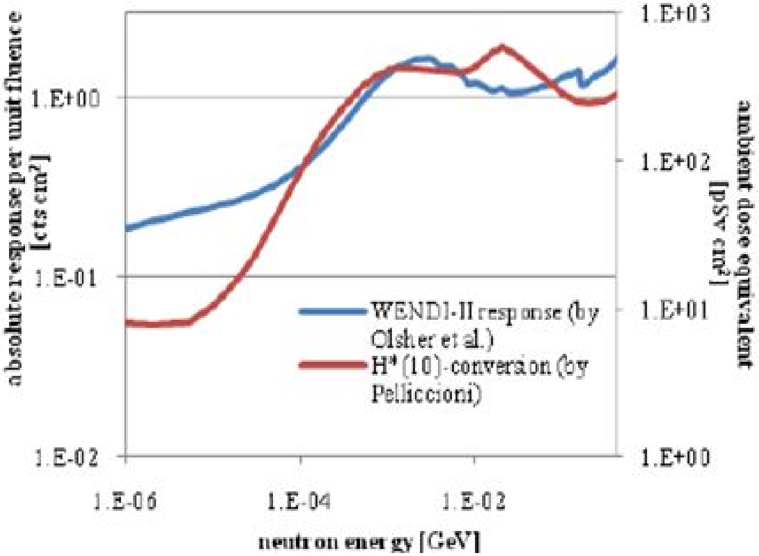
Rem Counter AtomTex

- AT1117M works with digital readout consisting of the processing unit (PU1 and/or PU2) with an internal Geiger-Muller counter:
- Neutron Radiation: neutron/s*cm
- Energy range: from 20 KeV up to 3 MeV
- n from 0.025 eV up to 14 MeV,
- α 3-7 MeV,
- β from 155 KeV up to 3,5 MeV.

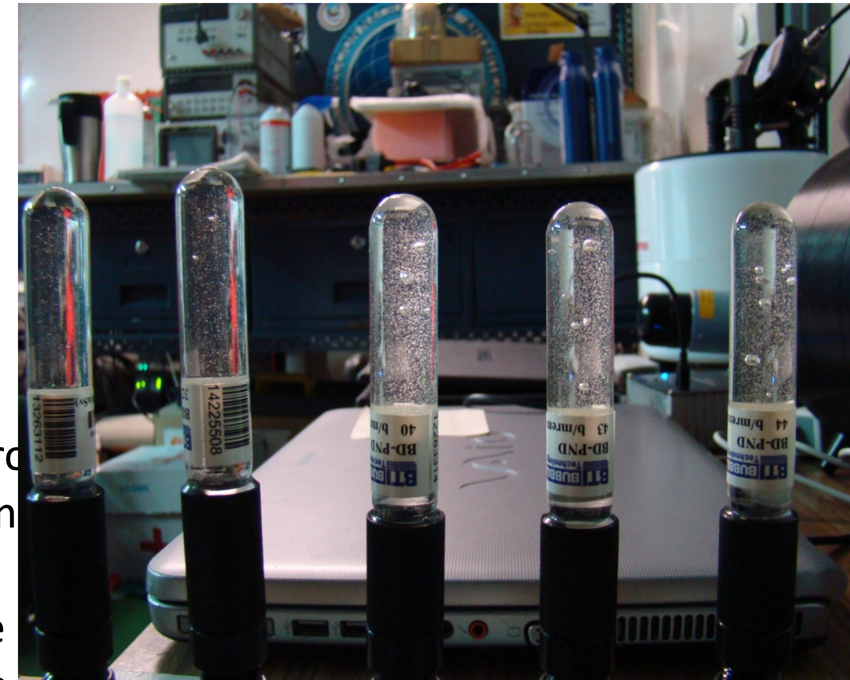


Extended FHT 762 Thermo

- Energy Range: 25MeV - 5GeV
- Linearity: ±20%
- (Angular dependence: ±20% in all directions)
- Sensitivity: Sensitivity: 0.84 cps/(µSv/h) Cf-252
- Temperature (Metric) Operating -30° to +50°C
- Pressure: 500 to 1500 hPa
- Relative Humidity: up to 90%,



Dosimetri a Bolle

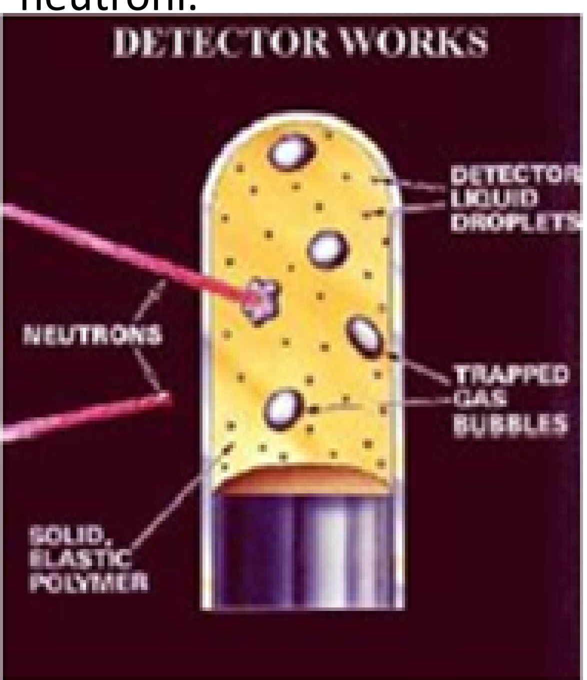


BDT: neutroni a basse energie (0,025 eV – 0,4 eV)

BD PND: neutroni ad alta energia (100 KeV – 20 MeV)

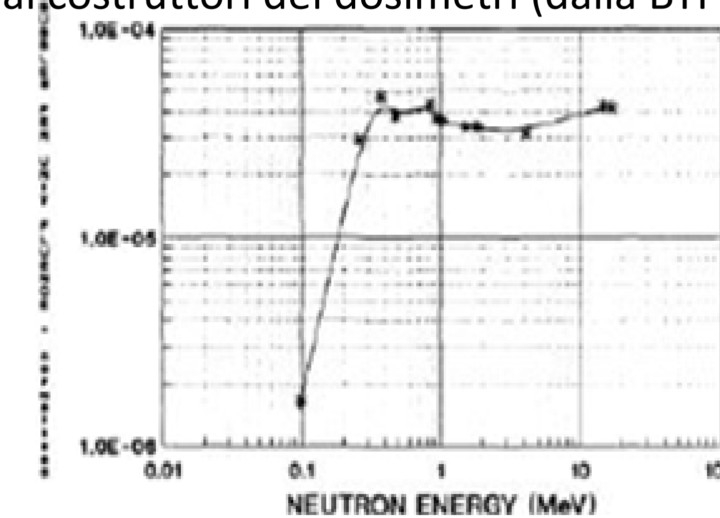
HANNO UN'ACCURATEZZA DEL 30%

Funzionamento: fiale di policarbonato contenente un polimer
elastico tessuto equivalente trasparente in cui sono presenti m
gocce di freon super riscaldato e termicamente metastabili.
L'interazione dei neutroni con il polimero provoca la creazione
protoni ($^{35}Cl + n \rightarrow {}^{35}S + p$) ed il conseguente rilascio di energia causa la formazione delle bolle. I dosimetri vengono attivati tramite la rimozione del cappuccio che mantiene pressurizzato il liquido all'interno. Richiudendo il tappo, le bolle spariscono. Quindi numero di bolle risulta proporzionale al numero di neutroni.



Per misurare la dose basterà quindi contare il numero di bolle createsi e usare i fattori di conversione forniti dai costruttori dei dosimetri (dalla BTI Bubble Technology Industries).

Vantaggi:
- insensibilità ai campi elettrici
- risposta angolare isotropa
- sono riutilizzabili



5) X- γ detector BDKG-04

- **Energy range:** 50 keV - 3 MeV.
- **Sensitivity:**

Dose rate 0.05 μSv/h - 10 mSv/h

- **Error:** 20%

Based on a scintillation plasticdetector(30x15)mm,sensitive to X and γ radiation

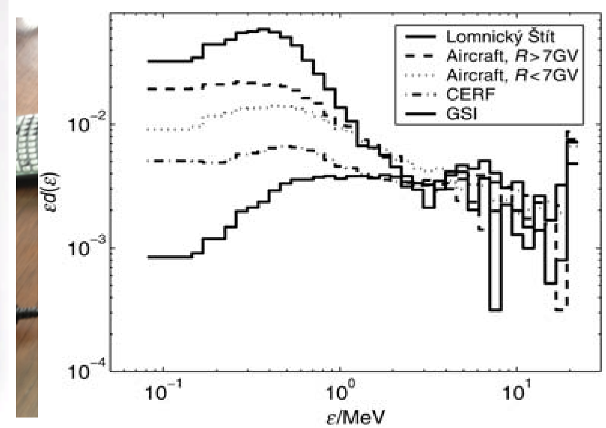
6) LET spectrometer Liulin I MUD-1

256-channel active silicon semiconductor spectrometer developed at Solar-Terrestrial Influence Laboratory of Bulgarian Academy of Sciences.

- **Energy range:** 10 KeV -20 MeV
- **Sensitivity:**

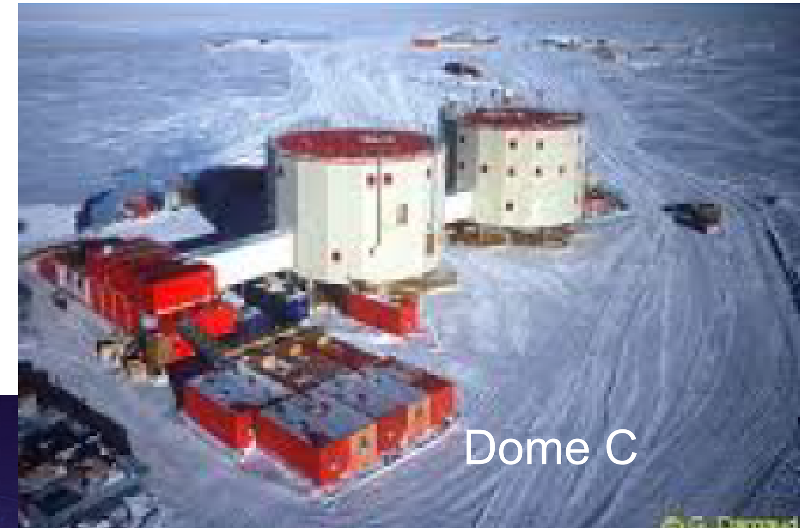
Dose rate 0.01 μSv/h - 10 mSv/h

- **Error:** 20%



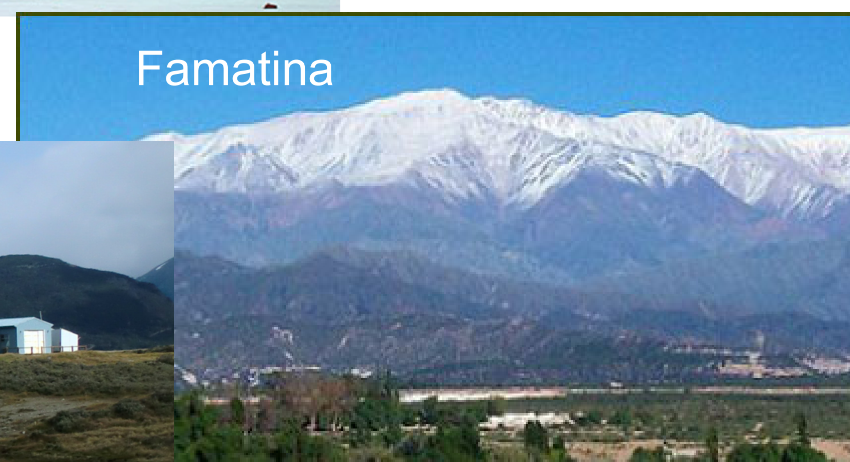
Liulin Detector response in various radiation environments


m
Marambio


Dome C


Chacaltaya


Testa Grigia


Famatina


Ushuaia

3 Novembre 2017
Ricevimento all’ambasciata italiana
a Buenos Aires

Da sin. a dx
1- Josè Kenny , addetto scientifico
2- l’ambasciatrice Teresa Castaldo
3-il segretario d’ambasciata Napolitano

Da sin. a dx
1-Antonio Meloni, presidente PNRA
2-Gabriele Paparo, 3-il presidente CONEA
4-il Prof Vicente Ciancio, 5-Alba Zanini

3 Novembre 2017
Incontro al CONAE
(Consorcio Nacional de activitades espaciales)

Da sx a dx
1- Ing. Corrado Varotto, presidente CONAE
2- Monica Rabolli
3-Gianrossano Giannini

La Plata

Thank you for your attention