HEP-Astroparticle Experiments to Improve the Radiation Health Risk Assesment for Humans in Space Missions

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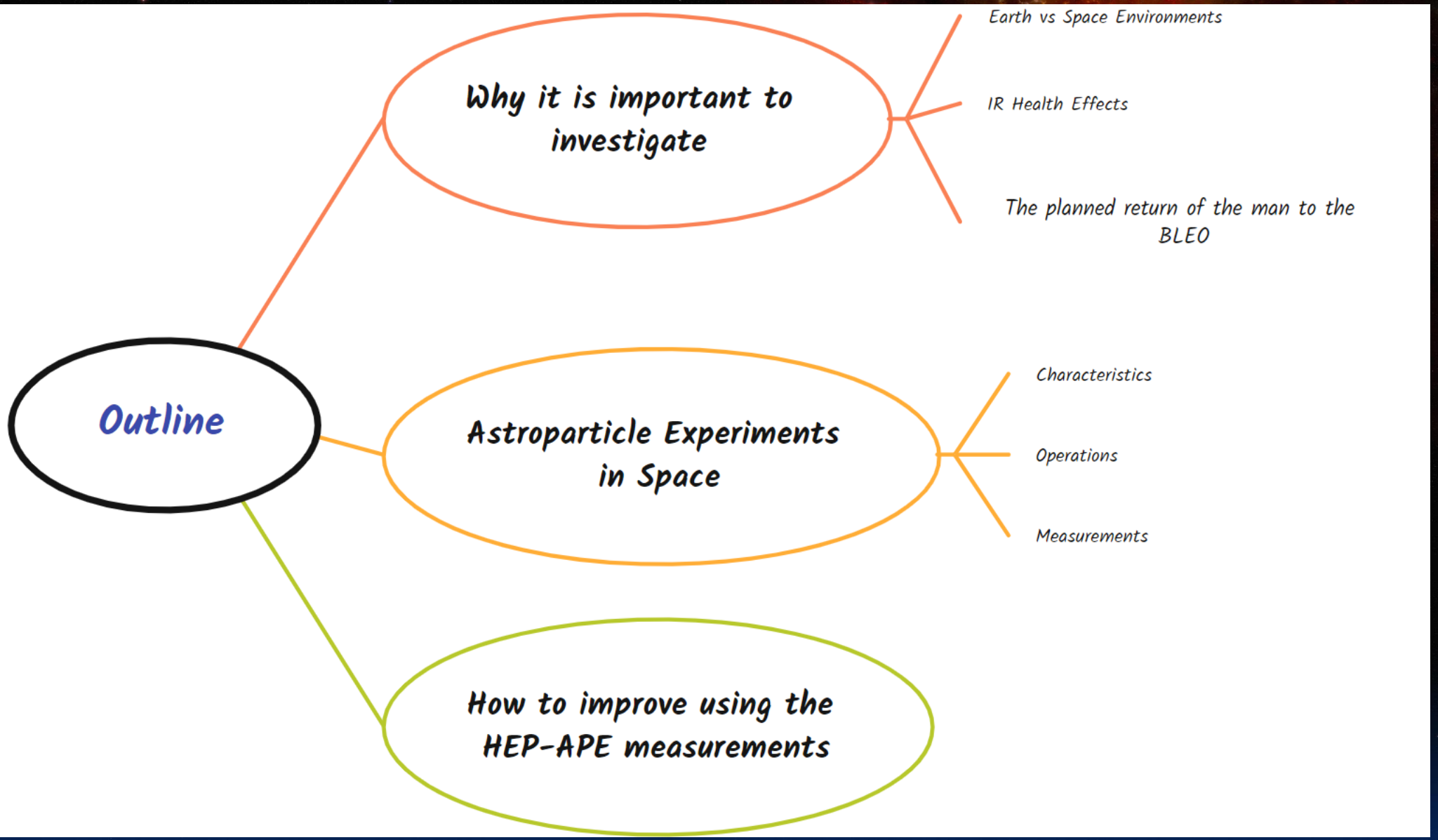
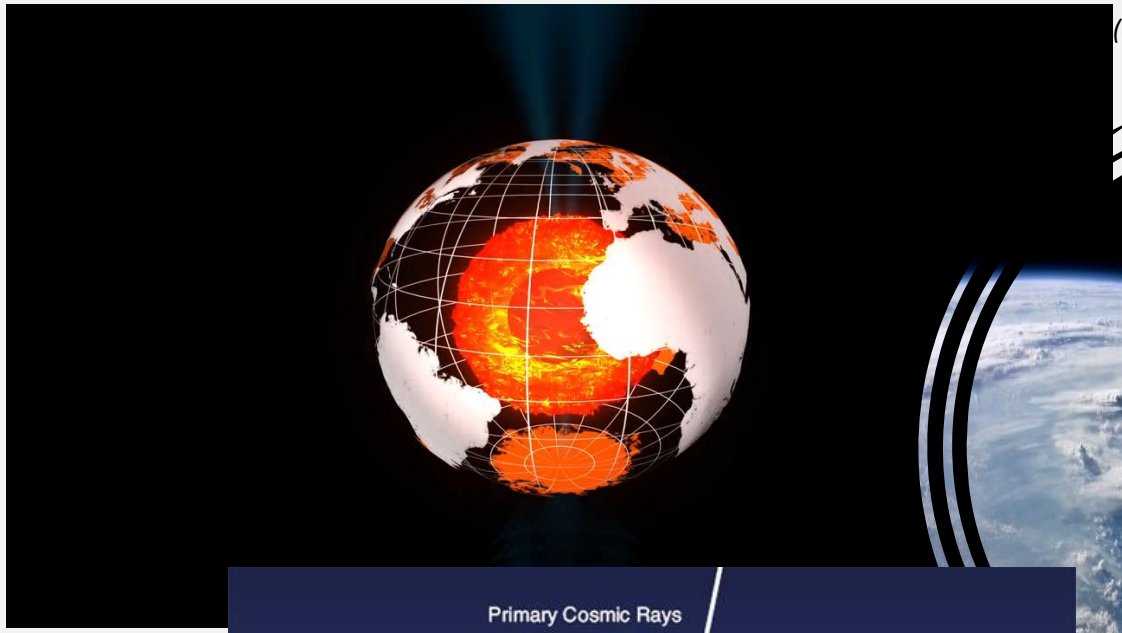
We gratefully acknowledge the strong support from the AMS collaboration and from the Italian Space Agency (ASI) within the agreement *ASI-INFN n. 2019-19-HH.0.*


Outline
Why it is important to investigate
Earth vs Space Environments
IR Health Effects
The planned return of the man to the BLEO
Astroparticle Experiments in Space
Characteristics
Operations
Measurements
How to improve using the HEP-APE measurements



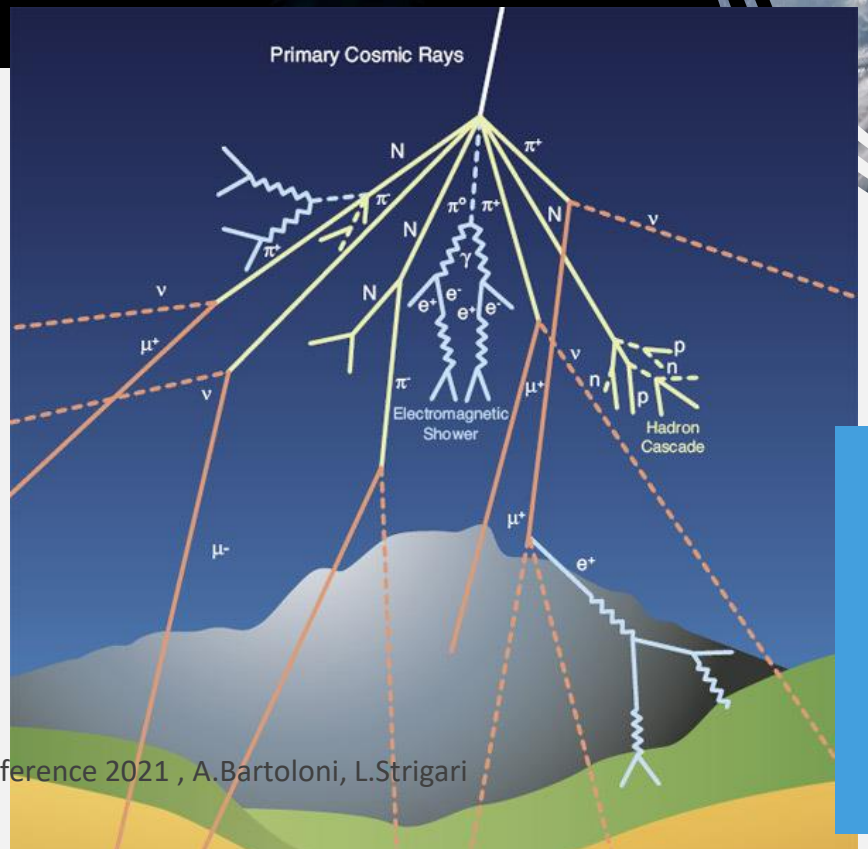
(credit : ESA)

Cosmic Rays Interactions with the geo-magnetosphere

Earth is a cocoon !!!

Magnetosphere stops/deflects 99.9% of charged particles

the Earth Atmosphere is equivalent to a metal shielding 1 meter thick



(credit : CERN)

The annual cosmic ray "dose" at sea level is about **0.3 mSv**

<10% of "Natural Background Radiation"
(Radon, Soils, Foods, ..)

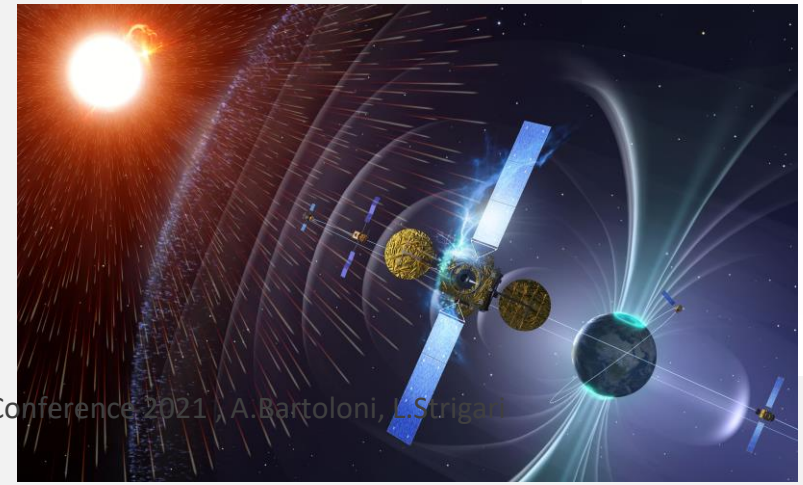
Space Radiation Environment

Human Space activities must cope with the high radiation environment of outer space.

Space Radiation composition

- Galactic Cosmic Rays **(GCR)**
- Particle emitted by the Sun **(SEP)** during isolated events
- Particle trapped in Earth's magnetic field **(Radiation Belt)**

None of the 3 components is constant in time, mainly due to the solar activity



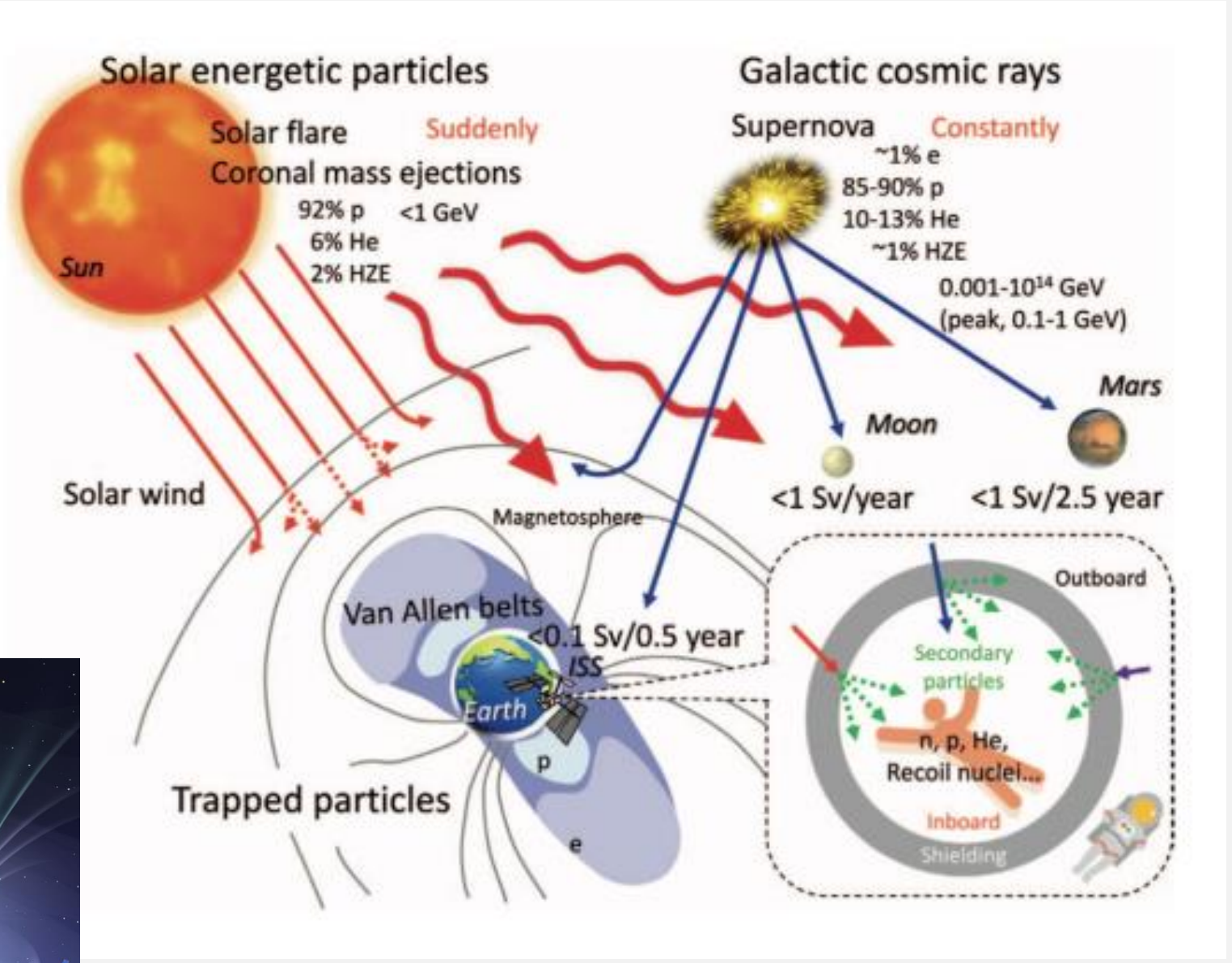


Image courtesy of European Space Agency (ESA)

A new era in human space exploration is coming …

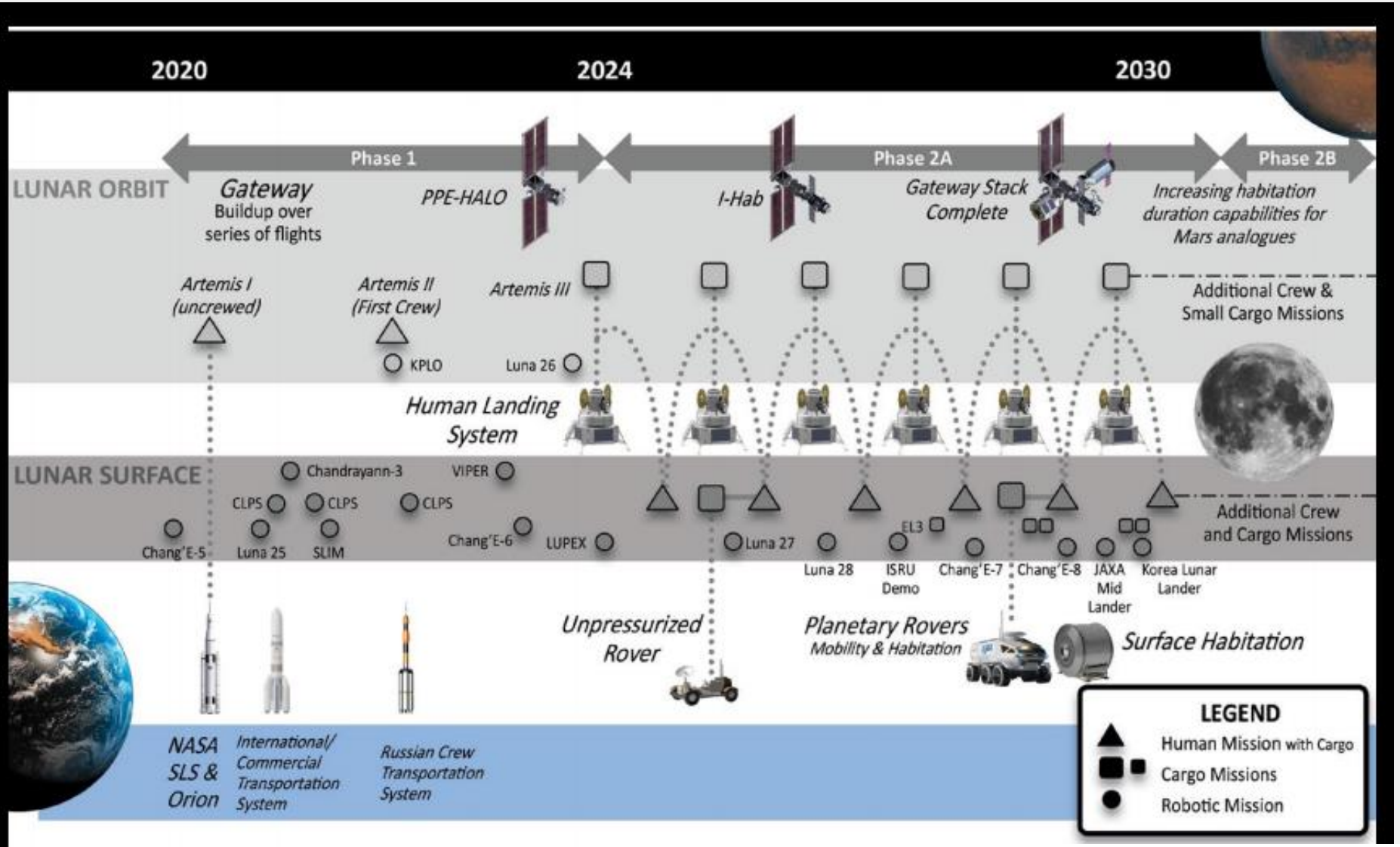


Figure 1. Updated ISECG Lunar Surface Exploration Scenario.

«Global Exploration Roadmap Lunar Surface Exploration Scenario update August 2020»

International Space Exploration Coordination Group (ISECG)

The **International Space Exploration Coordination Group** (ISECG) is a forum set up by 14 space agencies to advance the Global Exploration Strategy through coordination of their mutual efforts in space explor

Limits and concerns

The manned spaceflight especially the one beyond the LEO could represent a concern for the health of astronauts.

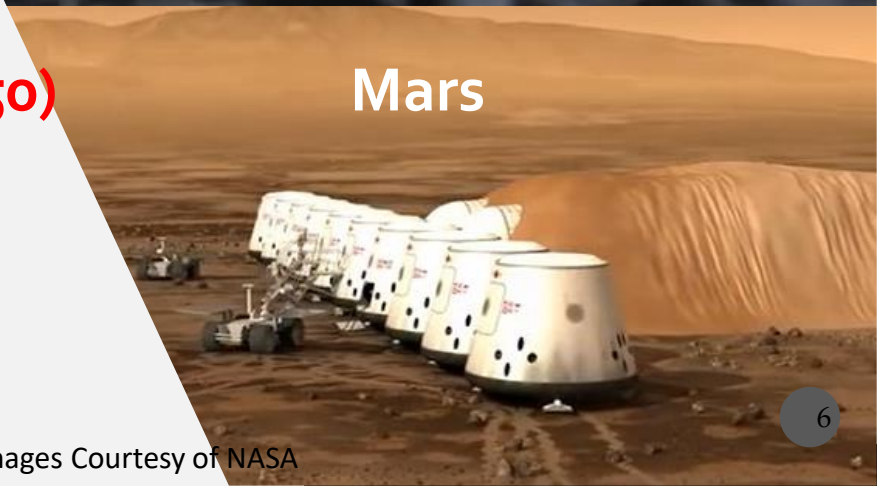
The limit in carrying out the missions are due to health effects

- short-term (<hours)
- acute effects (<months)
- late effects including severe toxicity

Radioprotection in space is a difficult jobs due to the presence of different species of particle and nuclei that present different characteristics in penetrating the barrier and shielding

x150-200

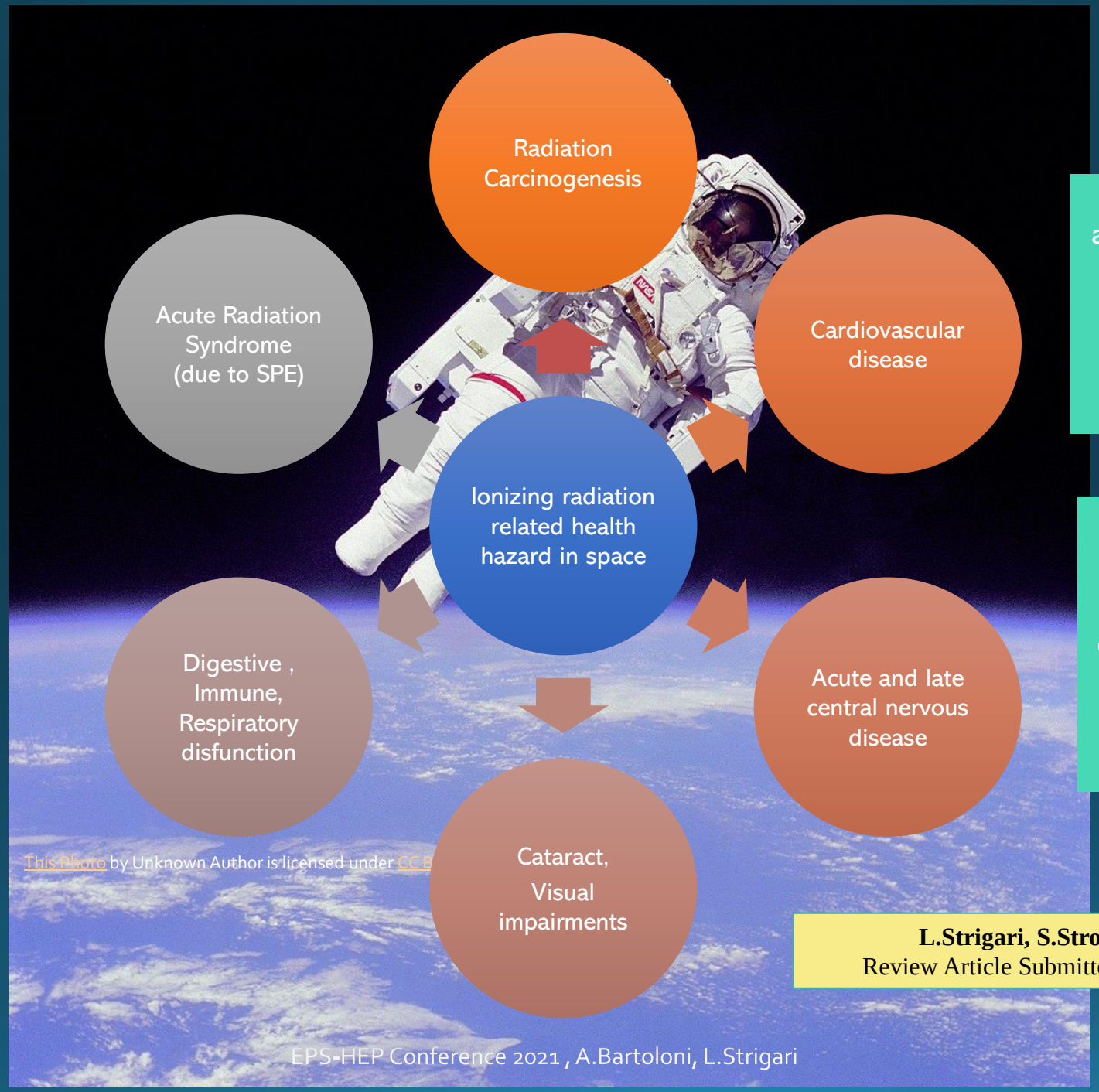
x300-400



x250 (x750)

Images Courtesy of NASA

Ionizing radiation exposures is one of the main concern for astronaut's health involved in exploratory missions to the Moon and Mars due to the high doses of radiation expected during the flight and on the surface



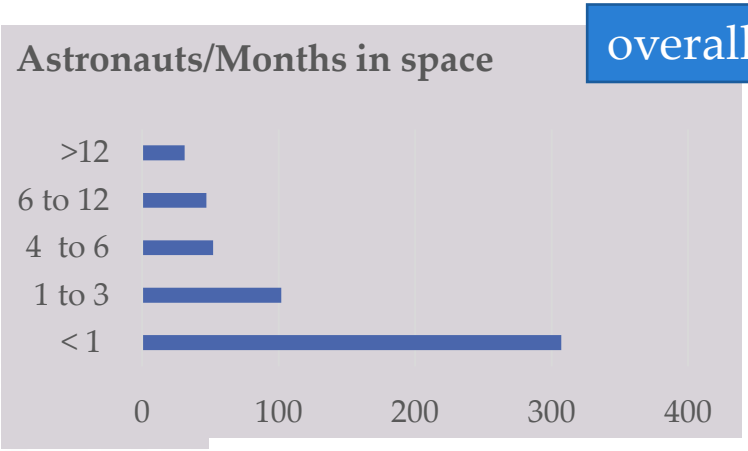
The radiation health hazard assessments in exploratory space missions requires the evaluation of the dose effects models in order to quantify the expected damage in the forecast astronaut's exposition scenario.

To complete this task the charged particle data taken by the high energy particle experiments can be useful to increase knowledge in many part of the risk assessment phases

L.Strigari, S.Strolin, A.G. Morganti, A. Bartoloni
Review Article Submitted to Frontiers in Public Health Journal

IR Effects on Human Health (Space vs Earth)

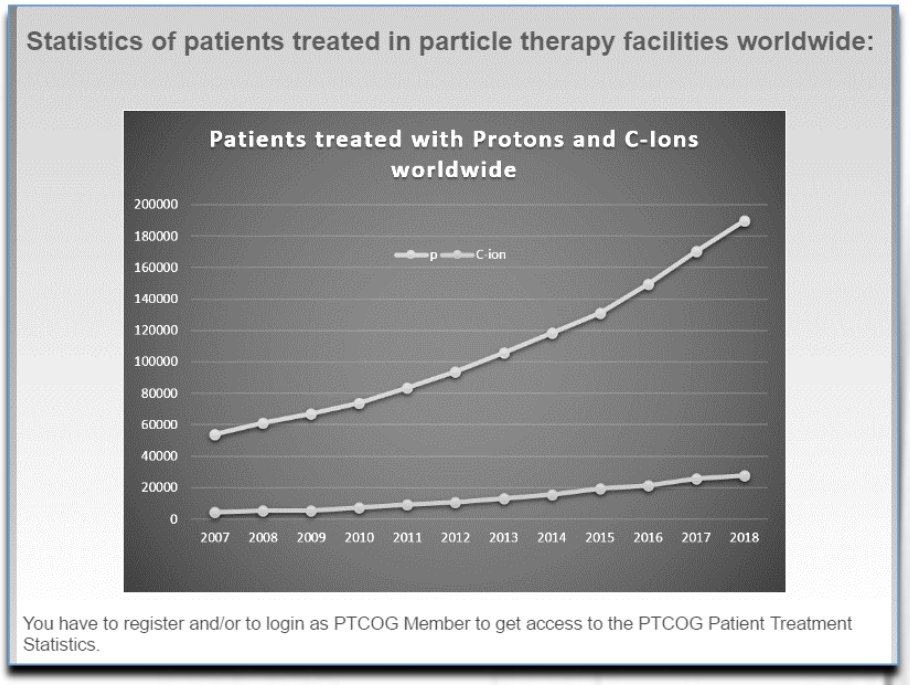
IR effects are based on a limited number of astronauts



BLEO

Total Space Radiation Dose (mGy)	<0.2	0.2–1.99	2–3.99	4–10.99	≥11	Total
# Astronauts	14	19	11	15	14	73
# Cancer Deaths	2	2	1	0	2	7
# Cardiovascular Disease Deaths	1	4	1	1	0	7
# Accident Deaths	6	5	0	0	1	12
# Other Deaths	1	0	1	0	1	3
# Unknown Deaths	1	0	0	3	1	5
Mean Medical Dose (SD)	2.4 (6.4)	27.7 (13.6)	34.4 (20.8)	29.1 (15.6)	32.5 (21.7)	25.1 (19.4)
Mean Year at Birth (SD)	1932.6 (4.1)	1931.7 (5.2)	1931.6 (2.5)	1932.2 (4.4)	1931.5 (3.3)	1931.9 (4.1)
Mean Age at Entry into Astronaut Corps (SD)	31.6 (2.7)	32.2 (3.4)	33.0 (2.5)	31.8 (2.8)	32.5 (2.2)	32.2 (2.8)
Mean Follow up Time (SD)	29.3 (23.6)	40.3 (15.0)	46.4 (12.9)	50.7 (7.8)	48.1 (7.5)	42.8 (16.1)
Total Group Person Years	409.9	766.5	510.1	760.8	673.4	3120.8
Mean Age at Death (SD)	57.7 (23.8)	65.7 (15.9)	64.5 (14.9)	78.2 (19.9)	74.9 (10.2)	65.2 (19.1)
Mean Current Age of Living Astronauts (SD)	79.9 (2.9)	82.1 (3.9)	84.9 (3.1)	83.6 (3.6)	83.8 (2.3)	83.4 (3.4)

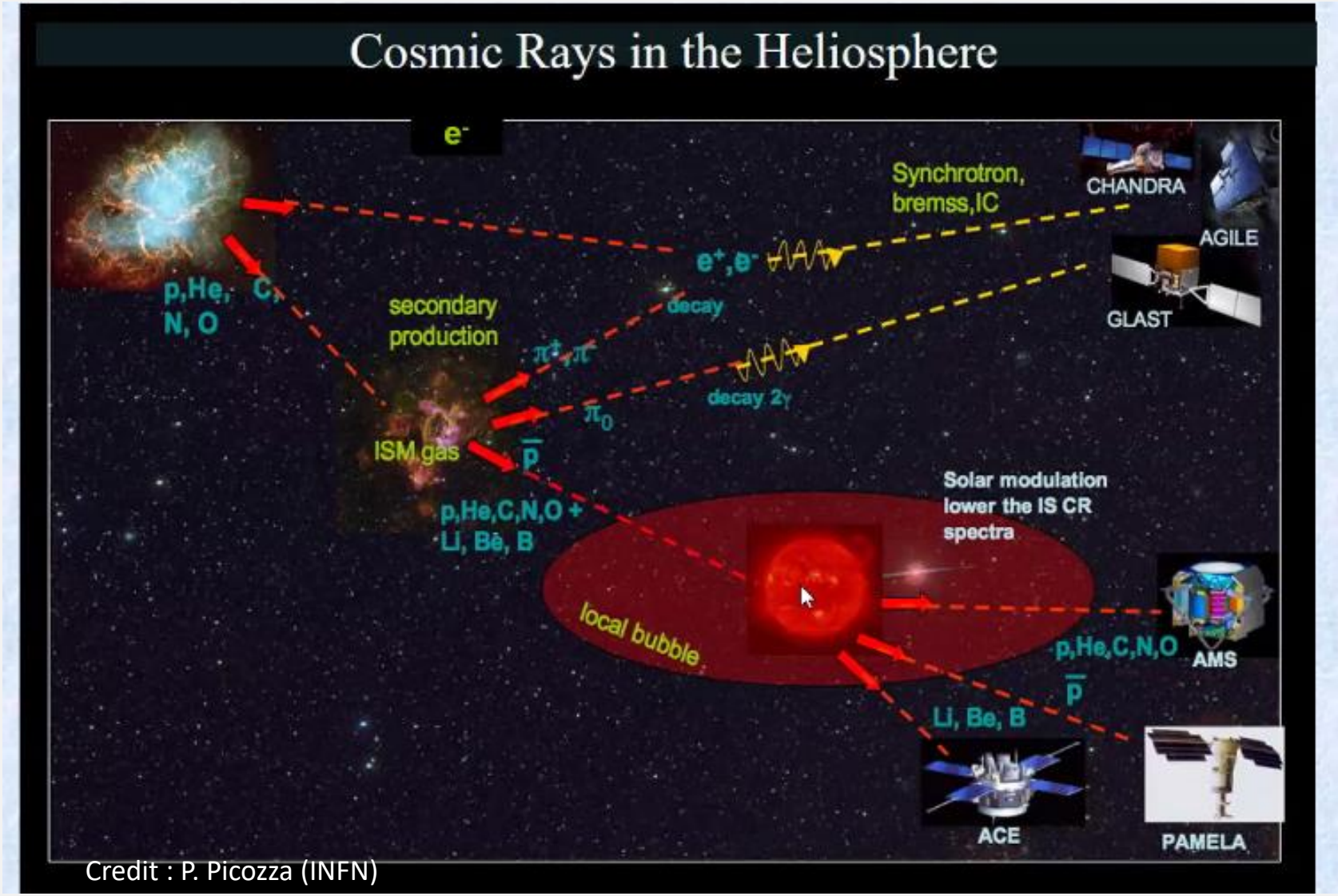
Table 1. Early astronaut cohort demographics binned by total space radiation dose category. SD = standard deviation.



Cosmic Ray Observatory

"A **cosmic-ray** observatory is a scientific installation built to detect high-energy-particles coming from space called **cosmic rays**.

This typically includes photons (high-energy light), electrons, protons, and some heavier nuclei, as well as antimatter particles.



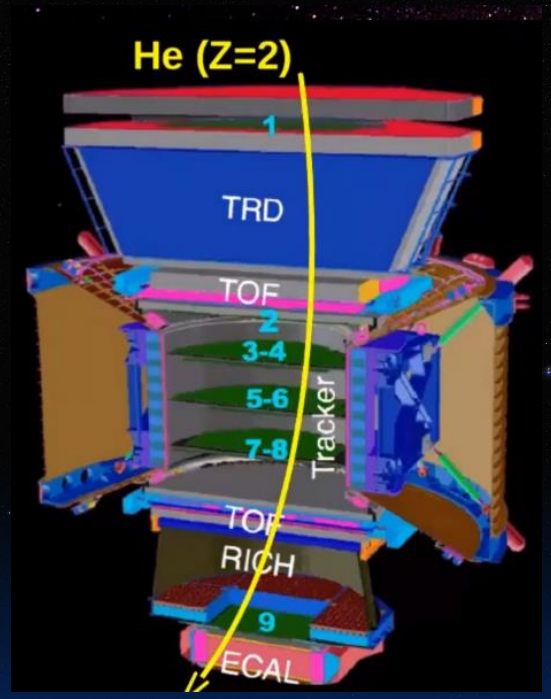
Credit : P. Picozza (INFN)

Principal Operating Cosmic Ray Space Detectors

International Space Station based

AMS02 – 2011

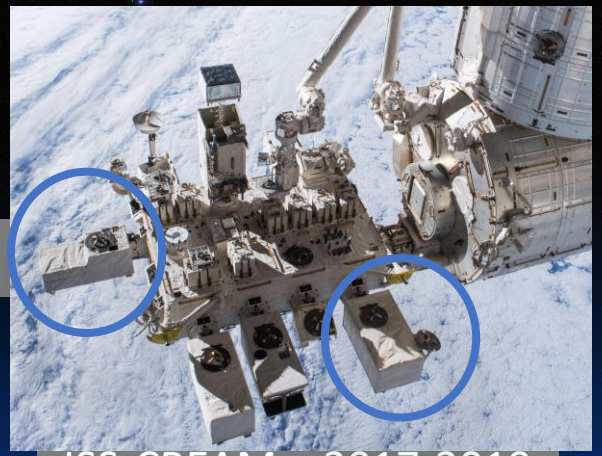
an ensemble of instruments each one designed to capture and measure the cosmic ray particles



Satellite Based

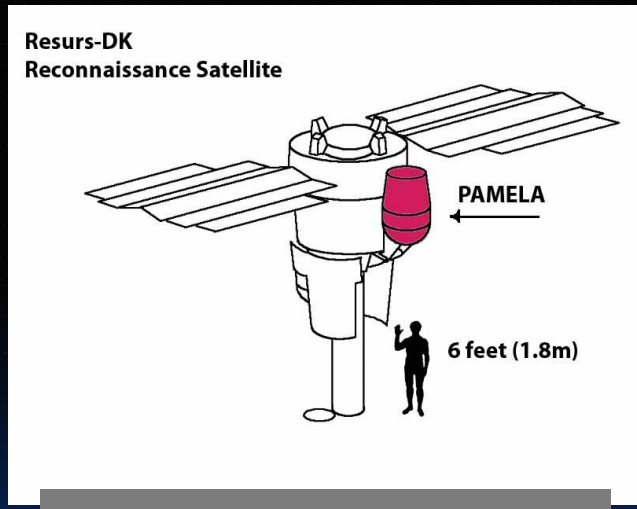
ACE - 1997

DAMPE - 2017



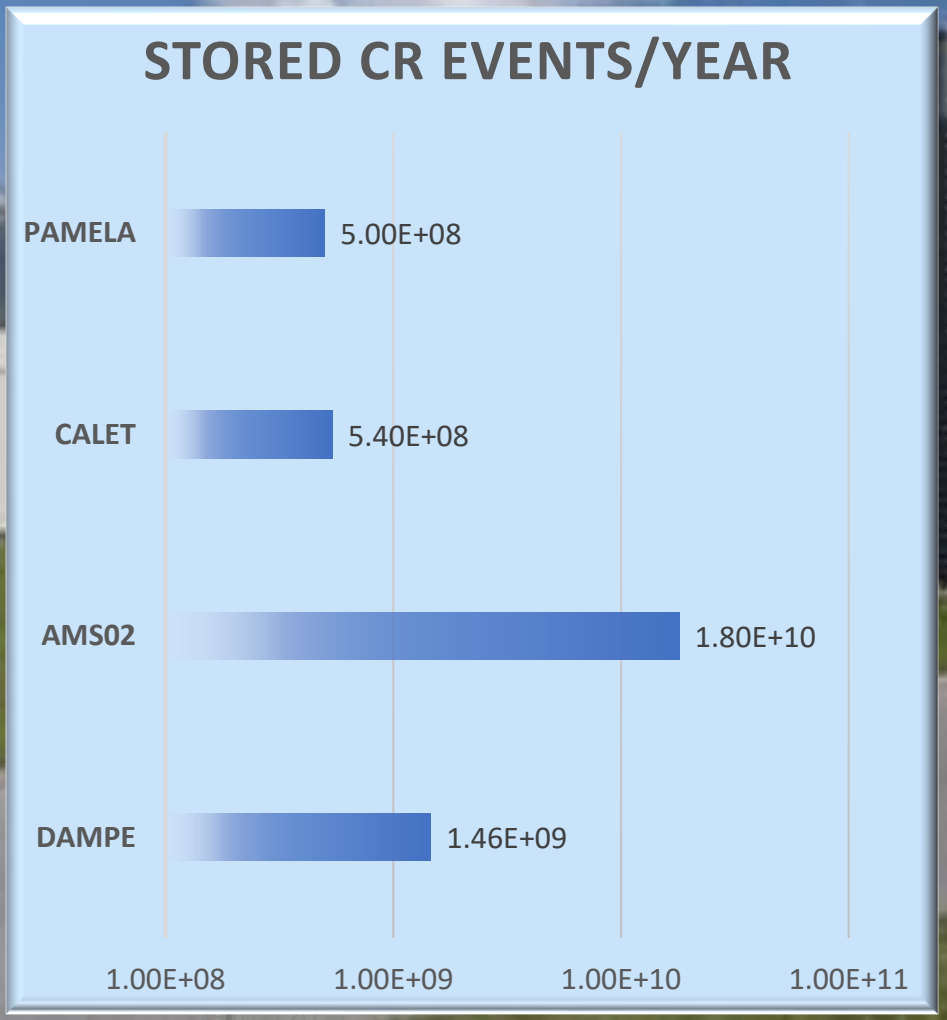
CALET - 2015

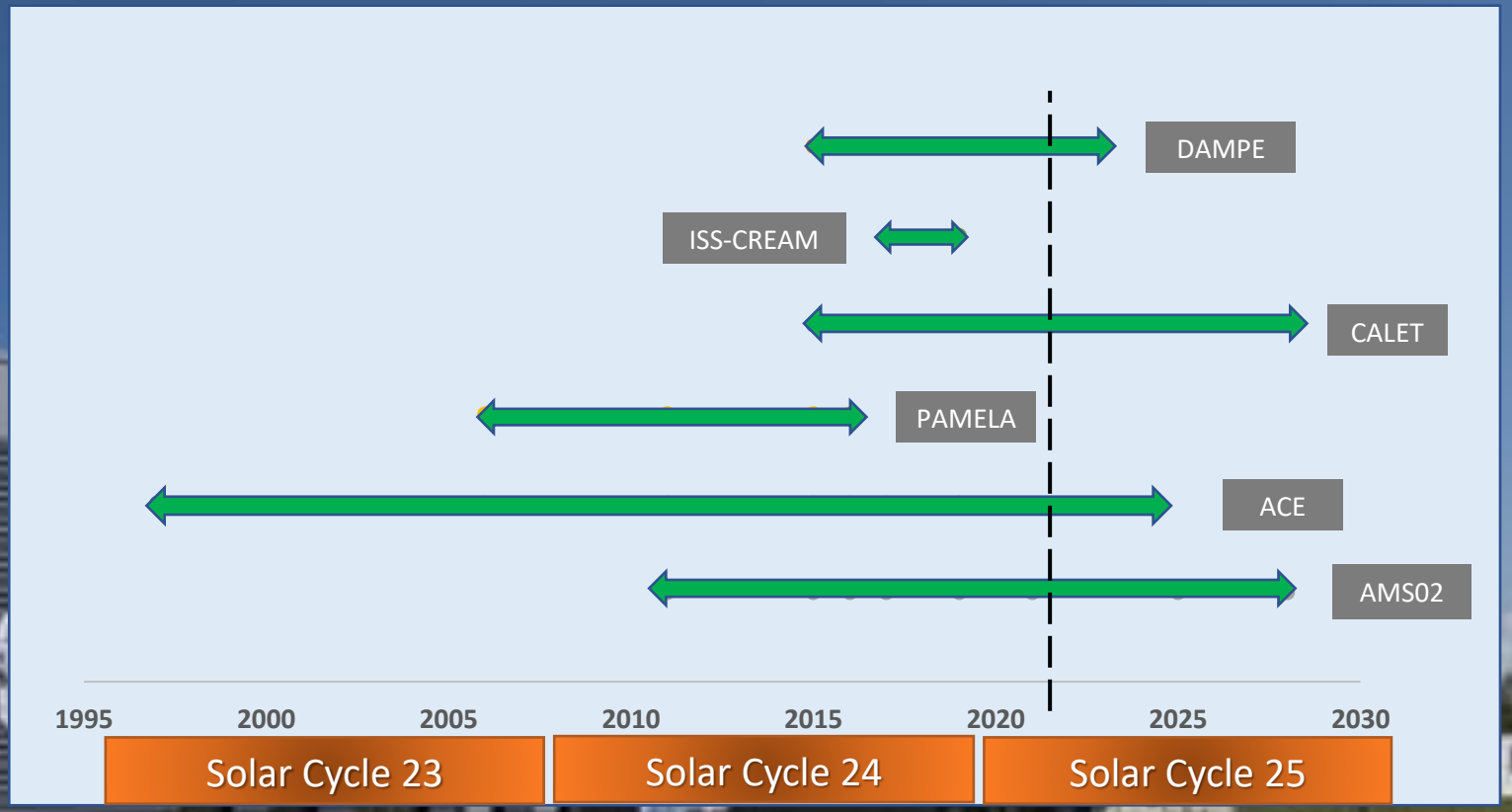
ISS-CREAM – 2017-2019



PAMELA – 2006-2016

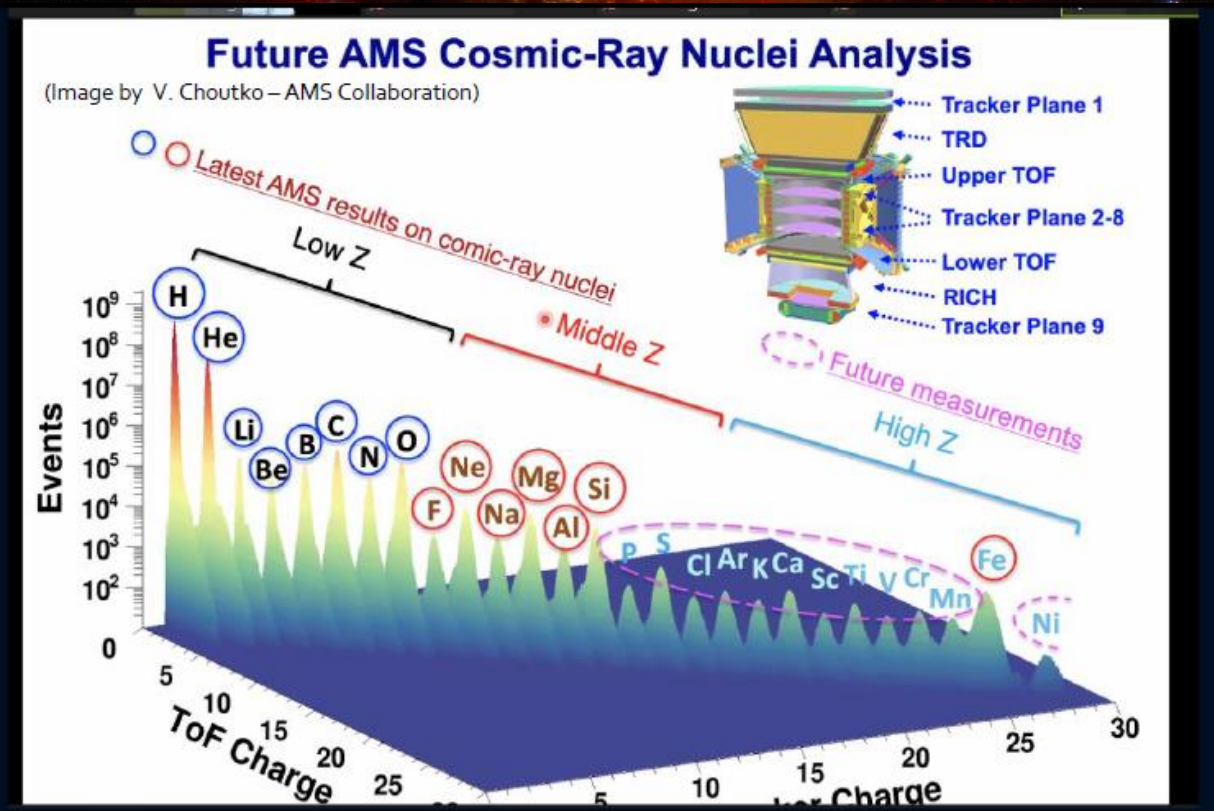
Missions Operations





Cosmic Ray Components Identification

e+,e-	ALL
p+,p-	ALL
D,He	ALL
Low-Z (<=8)	ALL (PAMELA up to Z=6)
Middle-Z	AMS02, CALET, ISS-CREAM, ACE, DAMPE
High-Z (>14)	AMS02, CALET, ISS-CREAM, ACE, DAMPE



Properties of Iron Primary Cosmic Rays: Results from the Alpha Magnetic Spectrometer

AMS Collaboration • M. Aguilar (Madrid, CIEMAT) et al. (Jan 29, 2021)

Published in: *Phys.Rev.Lett.* 126 (2021) 4, 041104

Properties of Heavy Secondary Fluorine Cosmic Rays: Results from the Alpha Magnetic Spectrometer

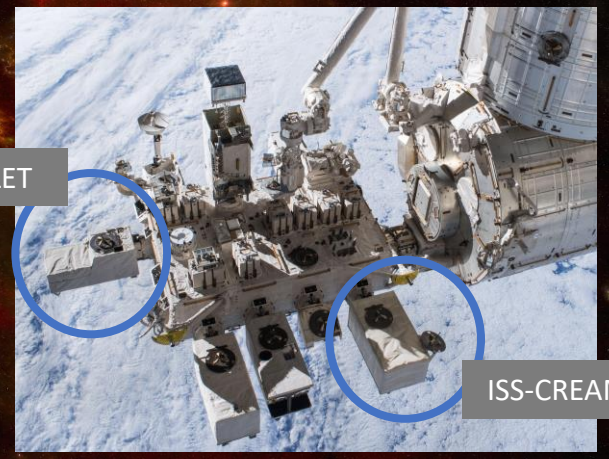
AMS Collaboration • M. Aguilar (Madrid, CIEMAT) et al. (Feb 25, 2021)

Published in: *Phys.Rev.Lett.* 126 (2021) 8, 081102

HEP-APE Energy Range

PAMELA

CALET - **1 GeV-10TeV**



CALET

ISS-CREAM

PAMELA - **50 MeV-2TeV**

ISS-CREAM - **1TeV-1PeV**

AMS02

AMS02 - **500 MeV-3TeV**

DAMPE - **5GeV-100TeV**

DAMPE

ACE

50 – 500 MeV

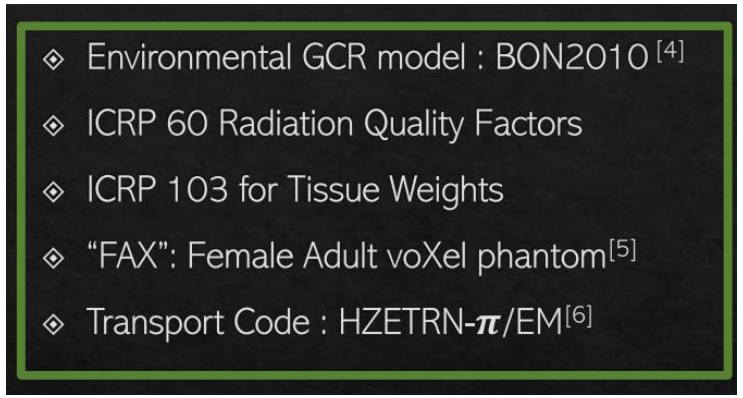
0.01 0.1 1 10 10^2 10^3 10^4 10^5 10^6 10^7

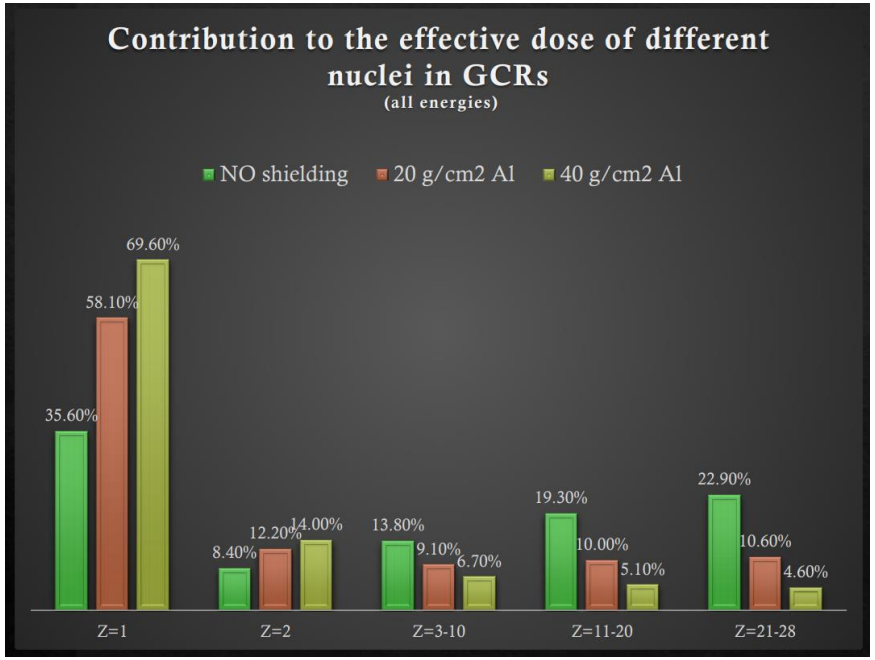
Energy (GeV)

The biological effects of ionising radiation is a consequence of the energy transfer by ionization and excitation to body cells

GCR sensitivity analysis

- Identifications of CR components of the CR that are of interest for the computation of possible risks associated with the manned exploratory space missions in LEO and BLEO scenarios.
- Use of space radiation sensitivity studies we also recognised that they correspond with the data taken by the astroparticle experiments

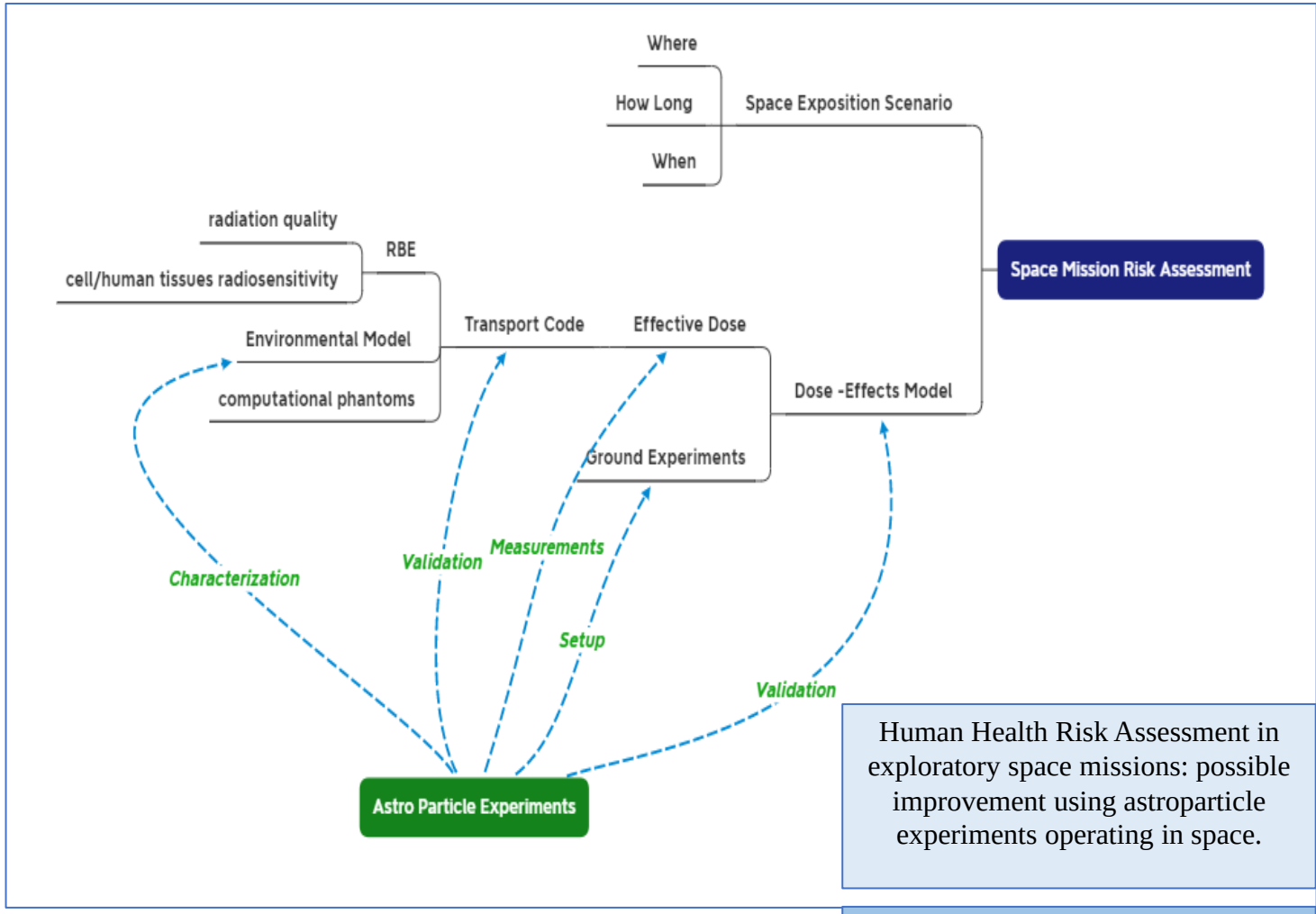




A. Bartoloni [a]*, L. Strigari[b]
SIF Conference 2019

Space Missions Risk Assessment Improvements

- ***Environmental Model Characterization:***
  - *Limited in data* at energies > 1Gev
  - Underestimation of the actual damage.
- ***Effective Dose Measurements:***
  - *to integrate the passive dosimeter measurement that do not take in account the time variations*
- ***Transport Code Validation***
  - *New cross sections and their validations are to be improved at high energy*
- ***Space Exposition Scenario Dose Computation***
  - *Montecarlo codes allows describe the effects of GCR particles interacting with cells, tissues/organs and astronauts, which can be modeled as geometries with increasing details and complexities.*
- ***Ground or Space based Experiment setup definition***



Human Health Risk Assessment in exploratory space missions: possible improvement using astroparticle experiments operating in space.

A. Bartoloni [a]*, L. Strigari[b]
Proceedings of GLEX-21-8.2.5 (ID:62186-2021)

Summary

- In the coming years there will be a great interest for space human mission non only to explore but also for a permanent presence of humans outside the geomagnetosphere
- Space Radiation is a main concern and the first one showstopper in many human exploration scenarios.
- Dose-Effects models should be improved and a synergy with the experience from the clinical field is crucial to perform this task
- Astroparticle Experiments are a principal source of information to perform this investigations complementary to what is usually done in the research field

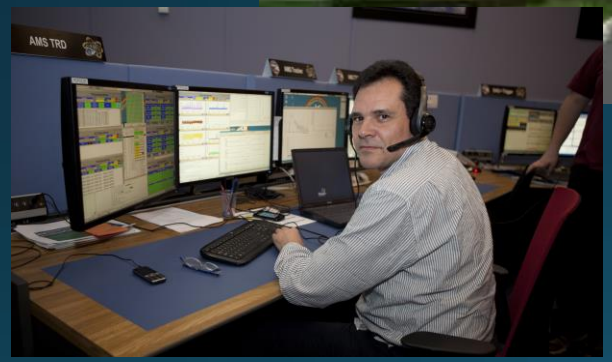
THANKS for the attention !!!

AMS INFN Roma-Sapienza Group

To address such problems a research collaboration on SPace RadioBiology (SPRB) is active since the 2017 between the INFN Roma-Sapienza AMS group and the Medical Physics Department of IRCCS University Hospital of Bologna (Italy)

The aim is to address the topic of space radiobiology by the comparison of possible effects

on the health of astronauts from particles and dangerous charged nuclei with the radiobiology experience in the clinical field where the ionizing radiations are used for therapy and diagnosis



If you are interested to collaborate on the SPRB with our research group please contact

alessandro.bartoloni@roma1.infn.it

POST-DOC open position in Roma-Sapienza !