High energy astrophysical hazards for habitability

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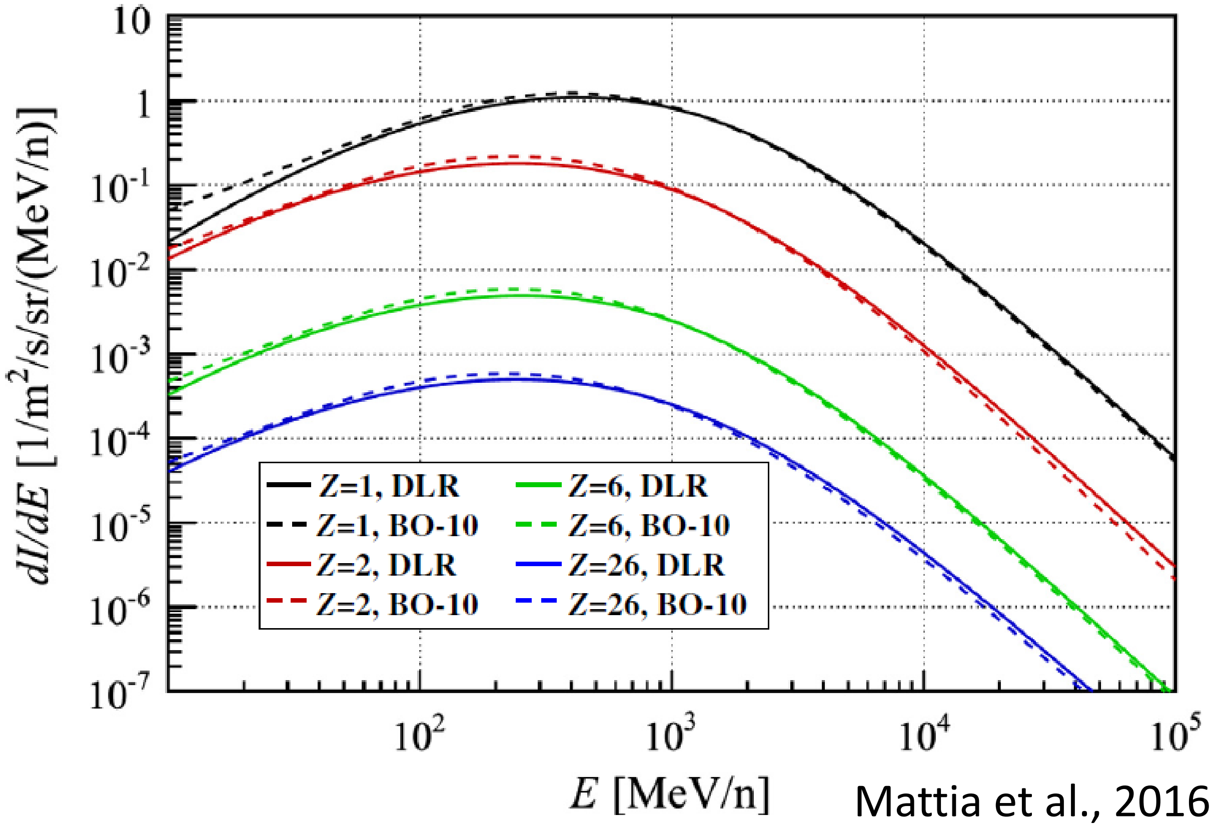
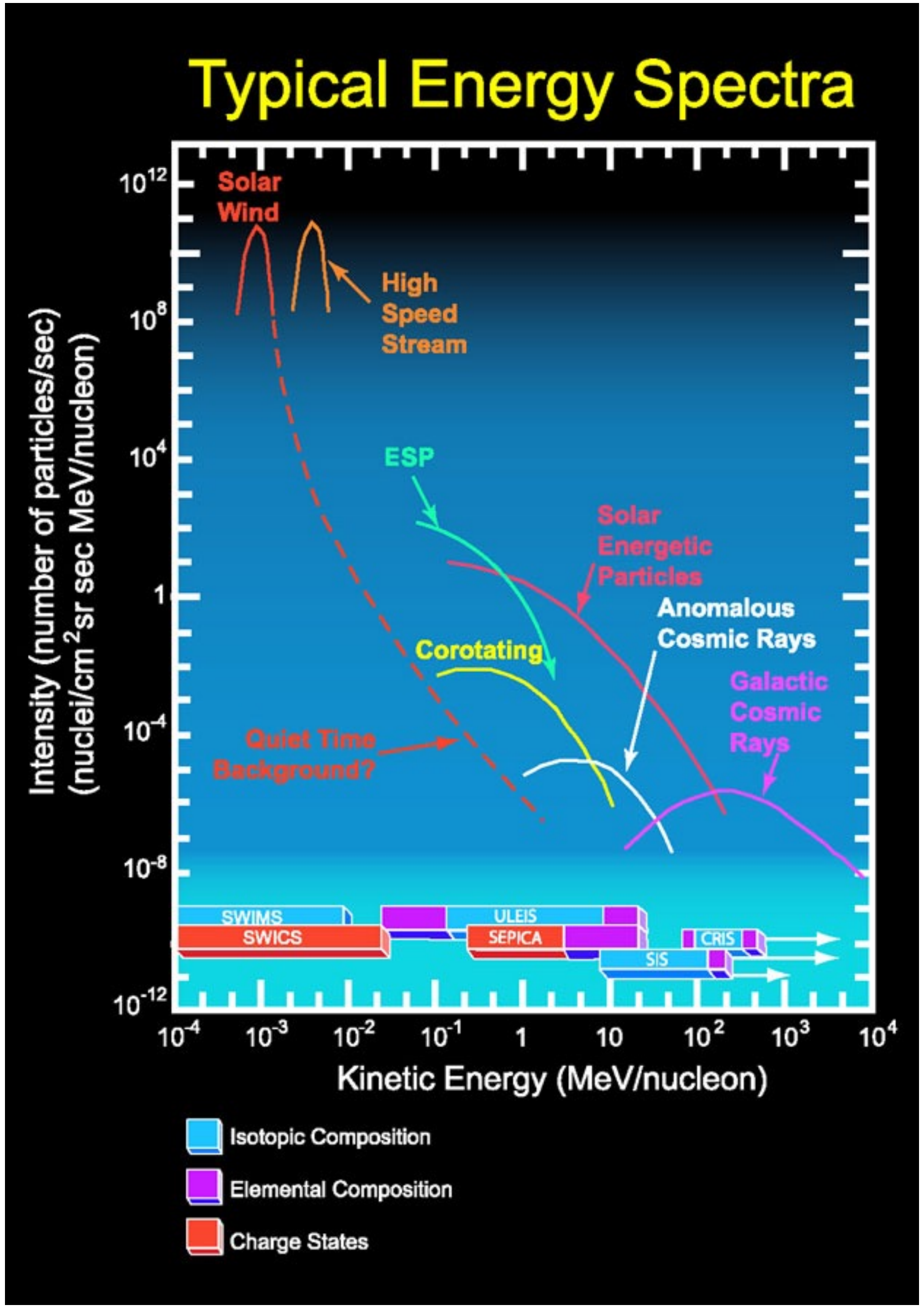
Introduction

- The health risks to astronauts from space radiation are a major problem for space exploration, perhaps representing a limiting factor on the maximum mission length under current risk acceptance levels.
- The main sources of radiation in space are the galactic cosmic rays (GCR) and solar particle events (SPE).
- The GCR consist of high-energy protons, helium nuclei, and heavy nuclei with energies extending to more than 10 GeV/amu (long –term changes)
- SPEs are largely protons with energies up to a few hundred MeV with a small helium and heavy ion component (short and long term changes).

- The energy spectrum of each source determines their range in shielding material and the human body.
- The amount of radiation received by astronauts depends on several factors including position in the solar cycle, and mission duration.



Mattia et al., 2016



NASA – ACE Brochure

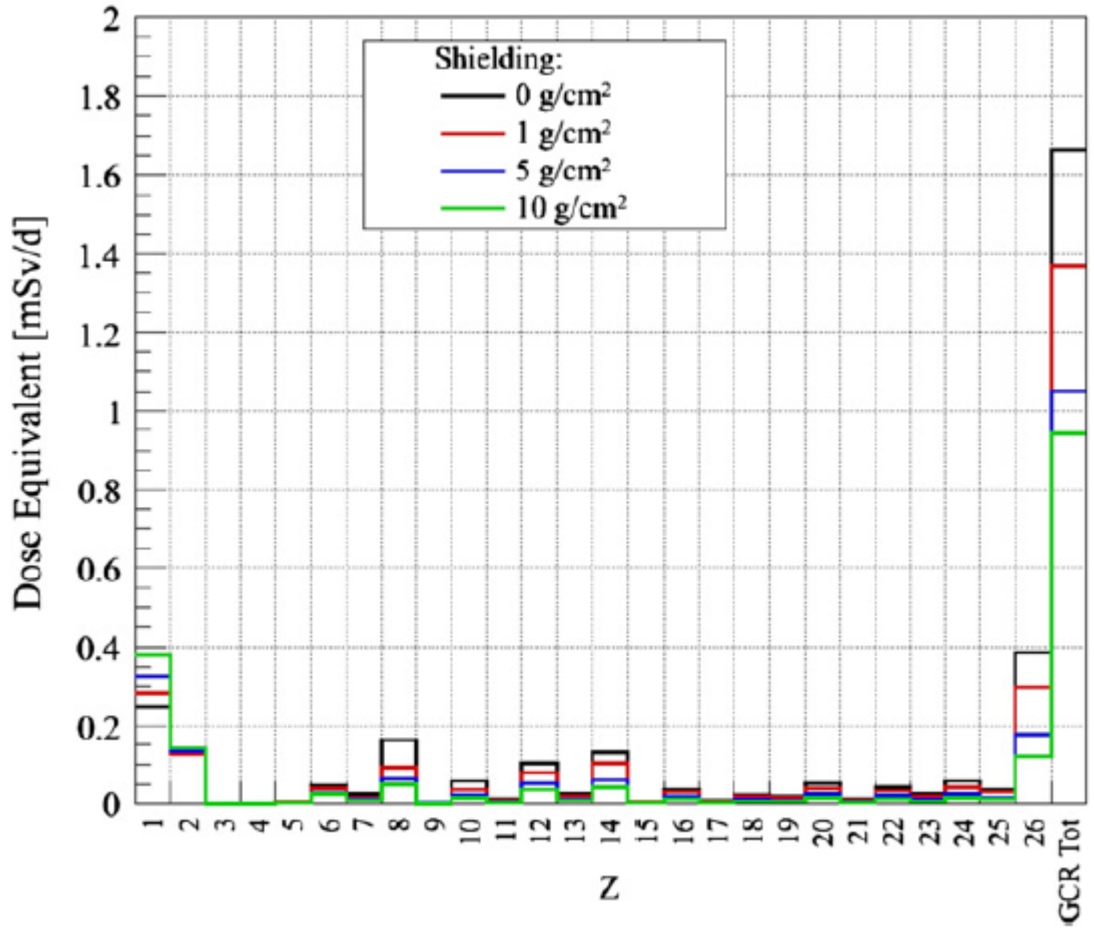
Career dose limits for space personnel quoted in NASA Technical Standard 2007 for year, are

52 cSv for a 25 year old male;
37 cSv for a 25 year old female;
72 cSv for a 35 year old male
55 cSv for a 35 year old female.

Cruise phase exposures to SEPs

Would have delivered to unshielded crews blood forming organs (BFO) doses of 411, 110 and 62cSv during three large SEP events (August,1972; November, 1960, and February,1956 Simonsen et al. (1990))

Cruise phase exposures to GCRs



McKenna-Lawlor et al., 2012

The dose level to be incurred over a year in interplanetary space near Earth, approaches the dose limits defined for 25year old personnel (Schwadron et al.(2010))


2029 - Mission to Mars

- In this work we evaluated the GCR and SEP contribution to the «radiation heath risk» during an hypotethical manned Mars mission in the next solar maximum (2029).
- In order to determine the dose rate, we calcuated:

1. The radiation sources and effects from both the Solar particle fluxes and GCR;
2. The Radiation sources and effects from long term - Solar particle fluence;
3. The Ionizing dose;
4. The linear energy transfer (LET);
5. The equivalent Dose Rate.

Mission Definition

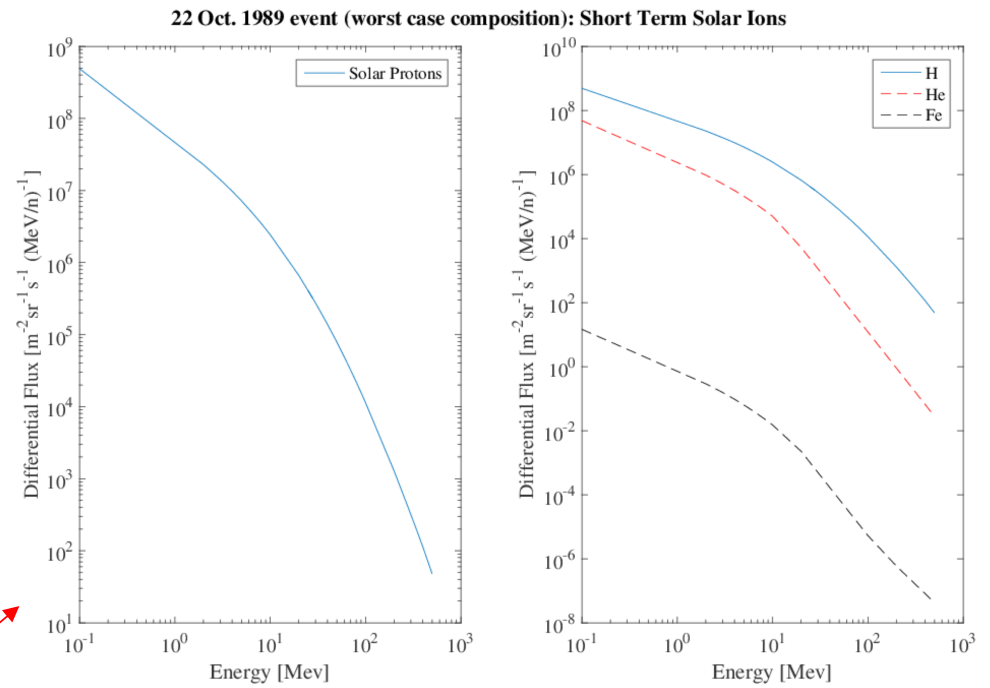
Scenario	Duration (Days)	Deep Space (Days)	Surface stay (Days)
Mars swingby	600	600	0
Mars Short surface stay	430	400	30
Mars Long surface stay	1000	400	600

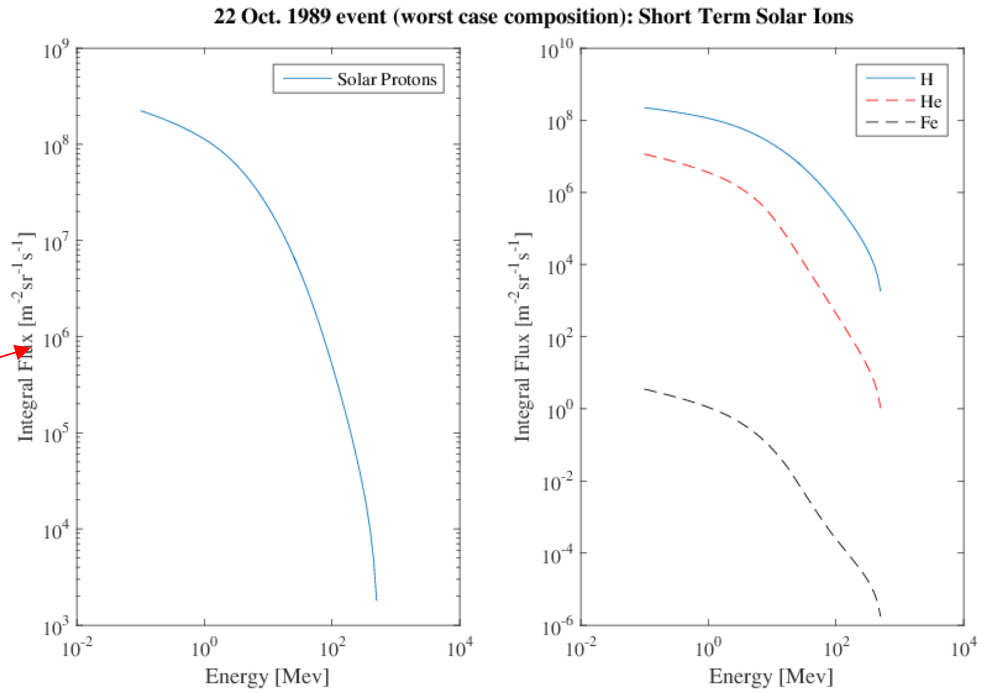
- **Table 2:** Early scenarios for manned Mars exploration (McKenna-Lawlor et al., 2012)

- We set a Mission to Mars lasted for 400 days;
- We set the launching on 01/01/2029, corresponding to the next Solar Maximum;

Radiation sources and effects
Solar particle fluxes.

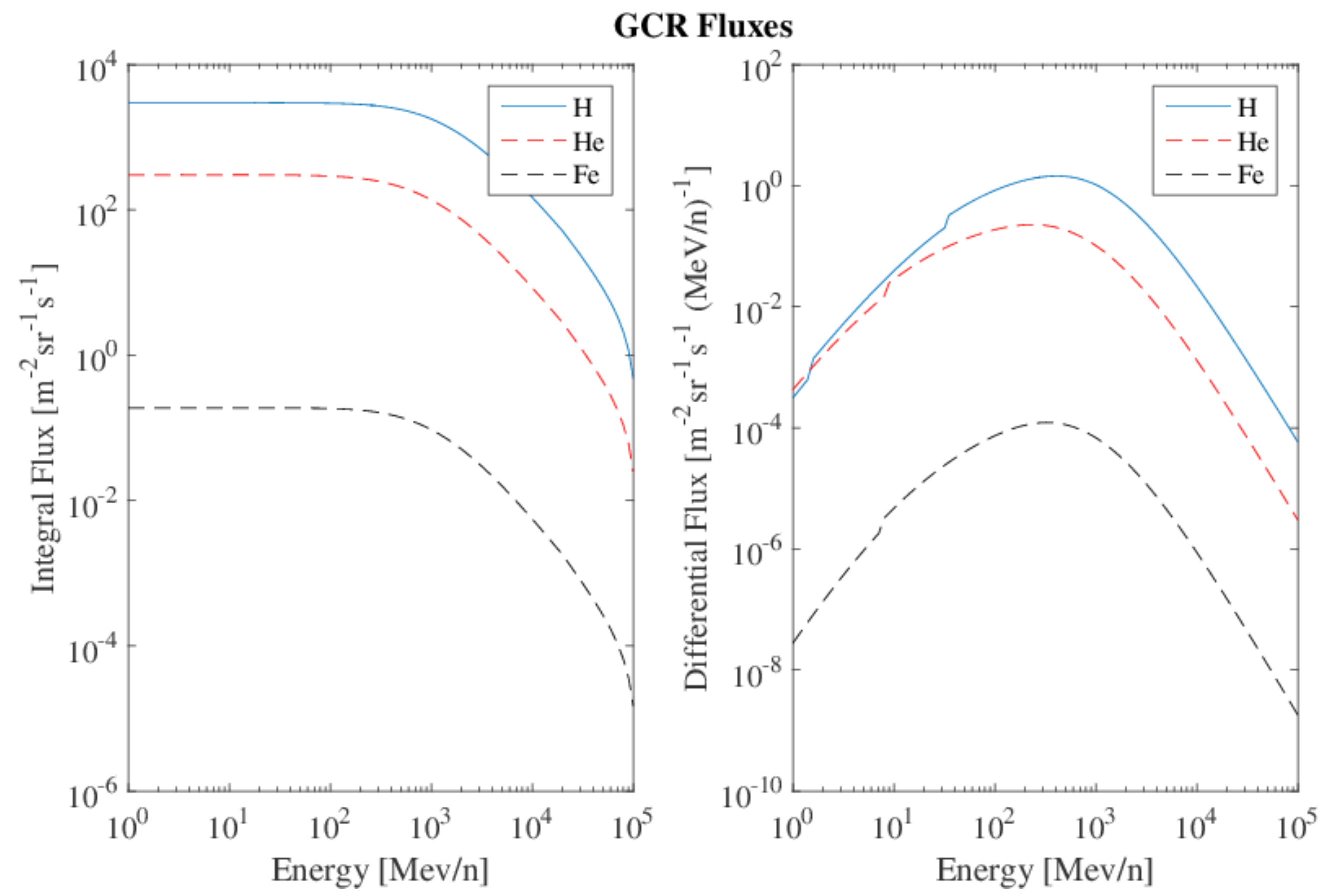
- We used the Xapsos et al. (2000) model;
- The ion range is from Hydrogen to Iron;
- We assume to be in the worst possible case: October 1989 flare-flux composition-like;
- Short term proton flux;
- Short term ion flux.





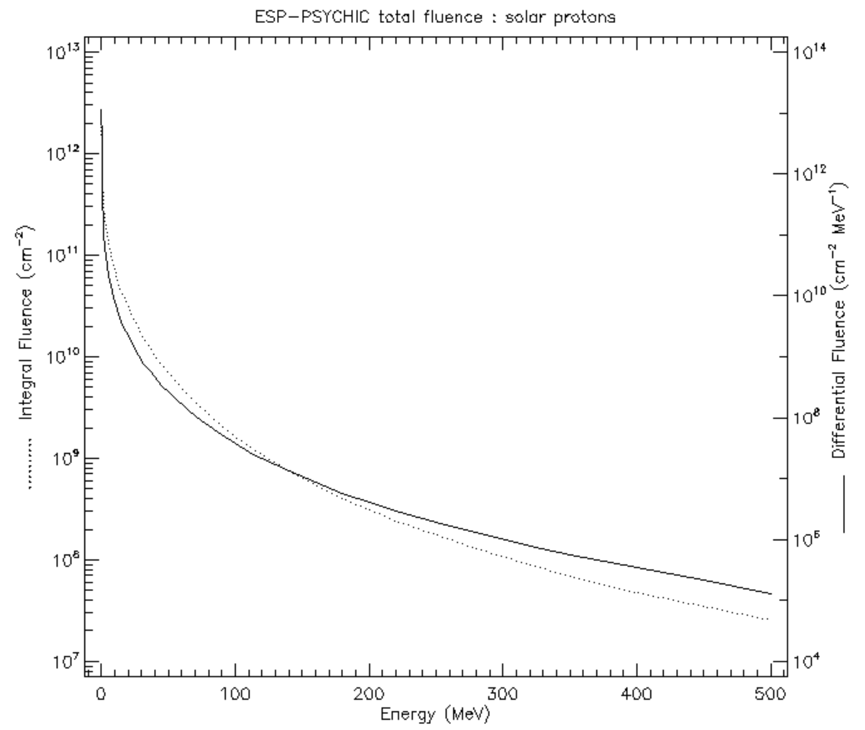
Radiation sources and effects
GCR Spectra.

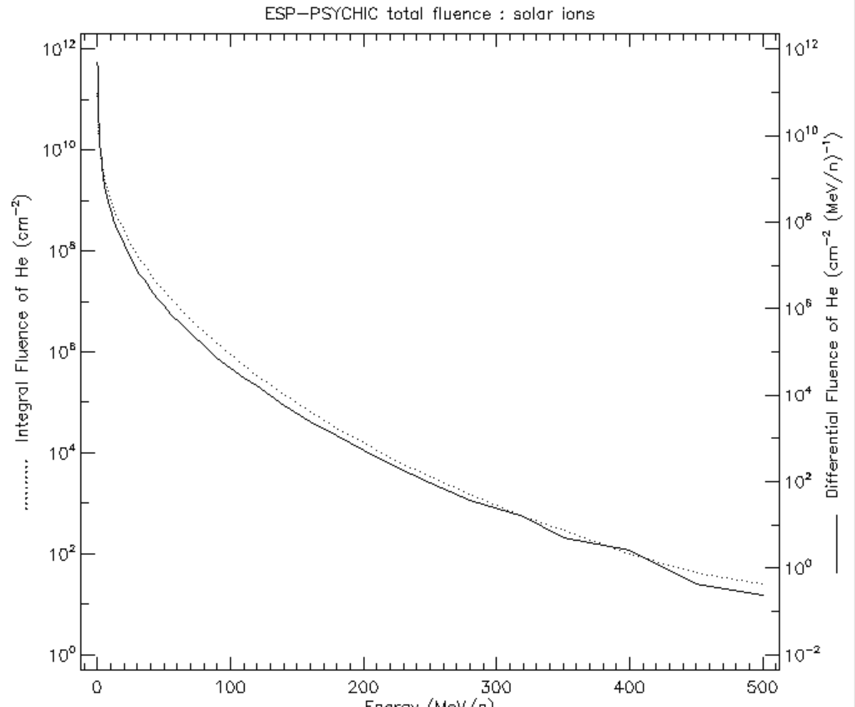
- We used the ISO standard 15390 model for the mission epoch;
- The ion range is from Hydrogen to Iron;
- We assume to be in the worst possible case: October 1989 flare-flux composition-like;
- We take into account GCR + fully ionized anomalous component (M=2);
- Ions Spectrum.



Radiation sources and effects
Long term - Solar particle fluence.

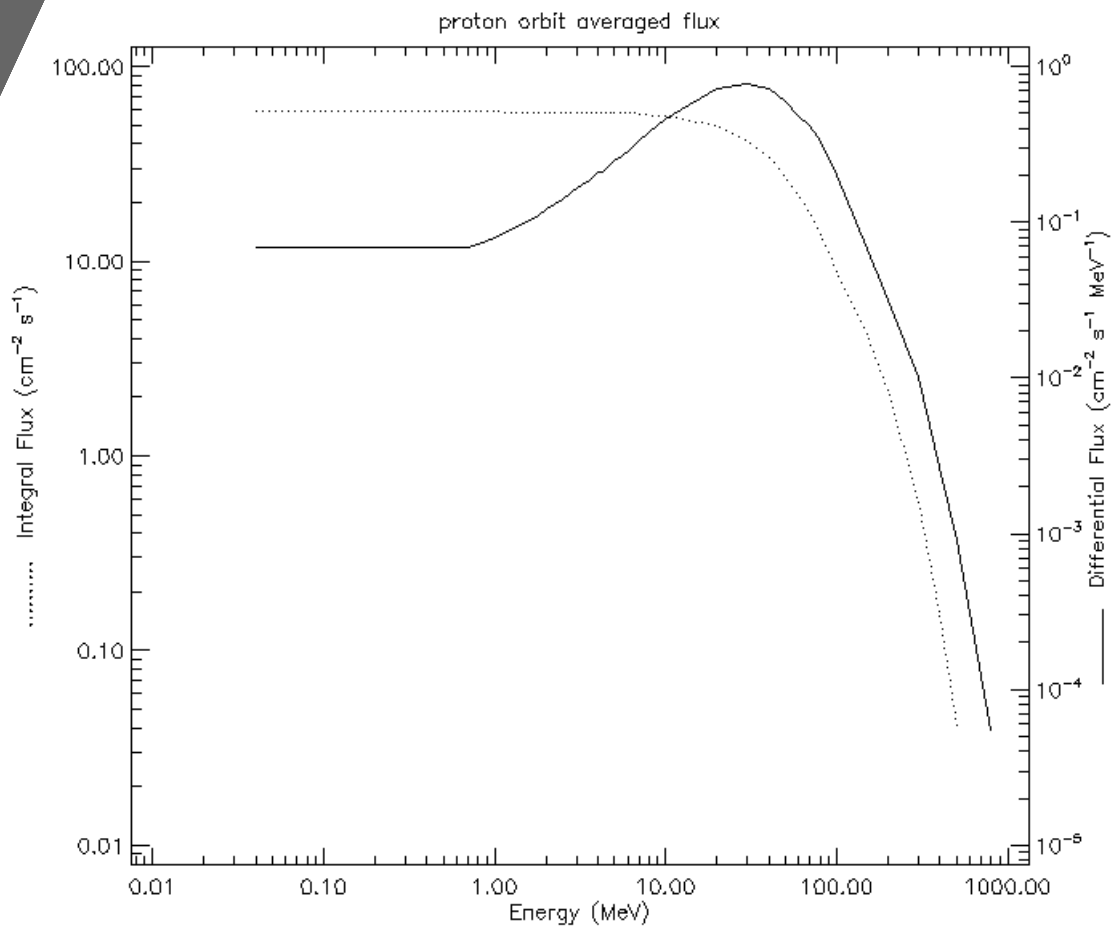
- We used the ESP Psychic model with 95% confidence level;
- The ion range is from Hydrogen to Iron;
- We assume to be in the worst possible case: October 1989 flare-flux composition-like;
- Long term proton flux;
- Long term ion flux.





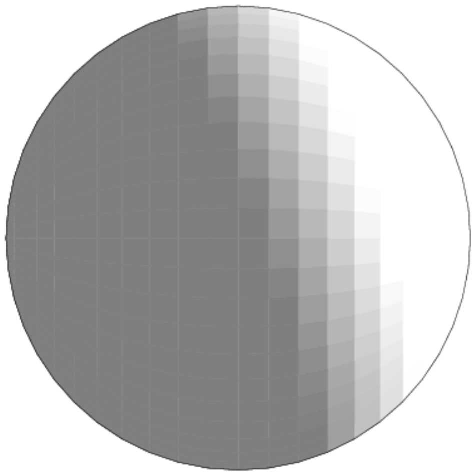
Radiation sources and effects
Shielded flux: MFLUX.

- We choose a shielding composed by 3.705 mm Aluminium from solar protons;
- We obtained a proton orbit averaged flux.



Radiation sources and effects Ionizing dose: parameters.

- We usedthe Shieldose-2 model;
- We choose a Aluminium sphere geometry 20 layers (1 mm thick each)
- Target material at the center of the sphere: Silicon.

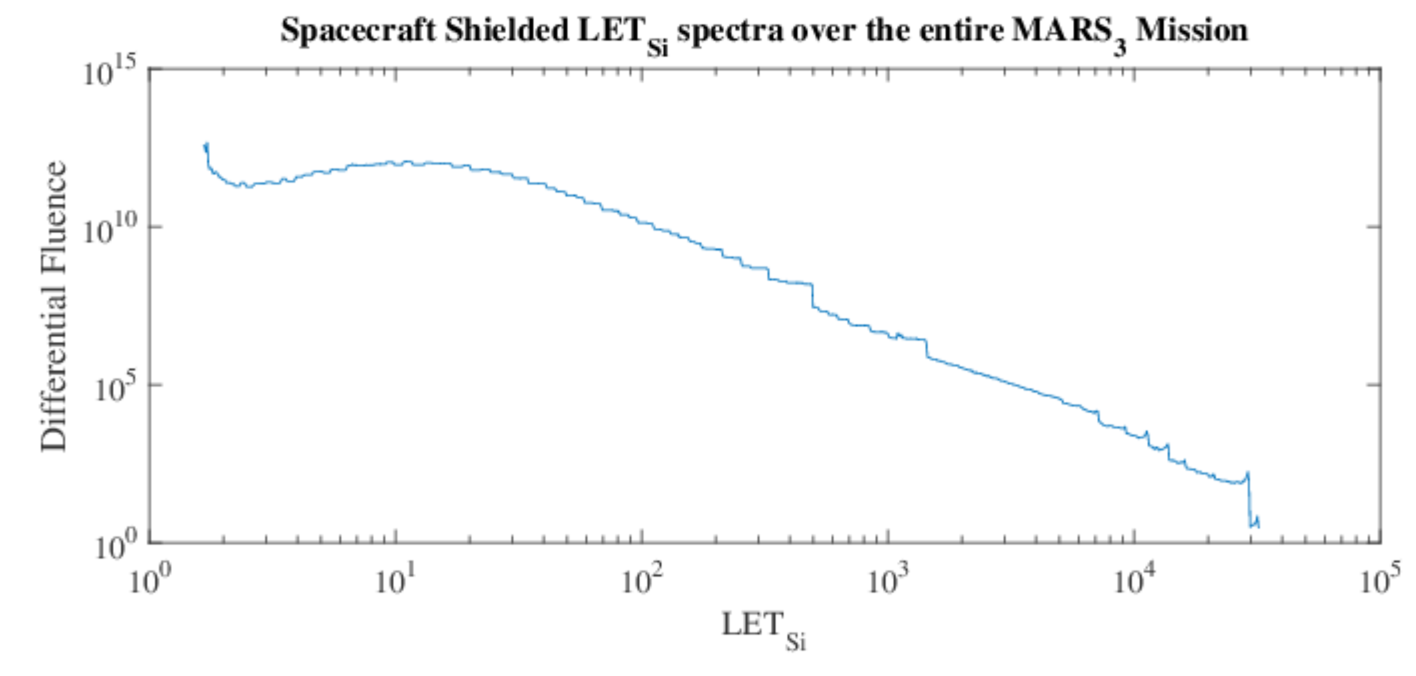


Short Term LET spectra

- For the chosen geometry, we obtained the LET spectra;
- By using the Benton et al. (2010) relation, we obtained the LET spctra in H_20
- The Dose rate is obtained by using the Benton and Benton (2001) relation:

Dose rate$= 4\pi \times 1.6 \cdot 10^{-9} \times LET_{H_2O}$

- We obtained the following dose rate for SEP and GCR for the whole interplanetary part of the mission:



	SEP Long Term	SEP Short Term	CGR
Dose rate	203 cSv	72 cSv	31,2 cSv/d

Summary and Conclusions

- We evaluated the GCR and SEP contribution to the «radiation heath risk» during an hypotethical manned Mars mission in the next solar maximum (2029);
- The values of SEP energy obtained are in agreement with results obtained by Cane et al. (1986), McKenna-Lawlor et al. (2012), Townsend et al. (2006) and Laurenza et al. (2009);
- As expected the SEP energy peak is around 30 MeV (Laurenza et al., 2009);
- **Es expected, the GCR effect represents the principal hazard for manned interplanetary missions also during a solar maximum period (SM);**
- **The long term SEP effect (203 cSv) during a SM period, despite being lower than GCR, is higher than the dose limit (72 cSv) for space personnel quoted by NASA (2007);**
- **The long term SEP effect represents an additional hazard for manned interplanetary missions that cannot be neglected expecially during a SM period;**
- Interestingly, a dramatic event like October 1989 flare-flux (**short temp SEP**) can produce by itself an equivalent dose rate of 72 cSv, **addressing a further health safety issue.**

Thank you
for your attention