Cosmic Rays as a clue constraint in Exoplanet Habitability

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Cosmic Rays irradiance on exoplanets play an important role in habitability. Specially, atmospheric shielding is a key parameter as it determines the flux of radiation on planetary surfaces. In this project, we estimate the flux of cosmic rays for diverse selected exoplanets in their habitable zones to evaluate their potential habitability. We consider different atmospheric configurations to simulate the interactions of Cosmic Rays and obtain their flux at the surface. These preliminary results will help us to better understand the role of Cosmic Rays in the emergence of life.

Introduction

Cosmic Rays (C.R.) are energetic fundamental particles that interact with a planetary atmosphere, undergo hadronic and electromagnetic interactions and produce a surface radiation, which could impact the habitats of potential ecosystems on the planet.

Atmosphere and planetary magnetic field are two key factors in protecting the surface from radiation.

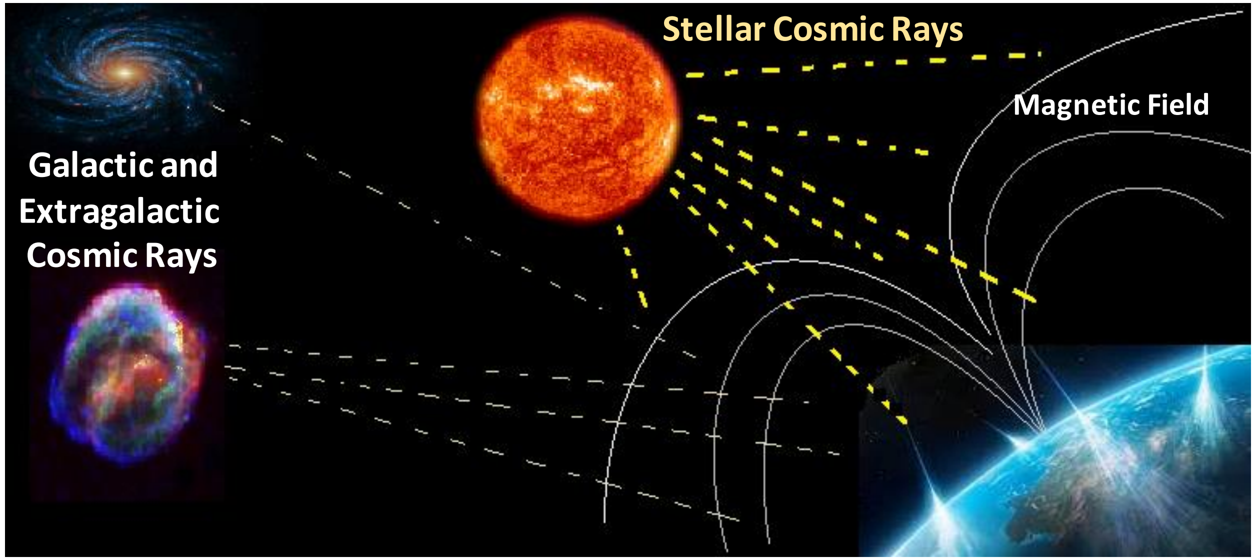


Fig. 1. Representation of the outer space rays hitting the Earth magnetic field (Irma Riádigos).

Methodologies

For our study we have chosen the following Earth-like exoplanets with their corresponding host stars:

1. ***The climate GCM-1D model is used to obtain the atmospheric profiles using as an input the exoplanets characteristics: stellar flux received, planet-star distance, eccentricity, orbital period, gravity, etc.***
2. ***Then, Cosmic Rays propagation in the atmospheres is simulated using AIRES software.***
3. ***Magnetic field information is so far unknown for all bodies under consideration. So, we assume a magnetic field intensity similar to that on Earth.***

	GJ 9827		Gliese 667	Kepler 438	Kepler 452	Kepler 1638	Kepler 62
Stars	(K)		(M)	(K)	(G)	(G)	(K)
Exoplanets	b y c		c	b	b	b	f
Gravity ($\frac{m}{s^2}$)	10,959	11,016	12,896	10,125	?	?	?
Surface Pressure (bar)	1	1	1,4	1	?	?	?
Surface Temperature (K)	305	305	289	360	265	304	208

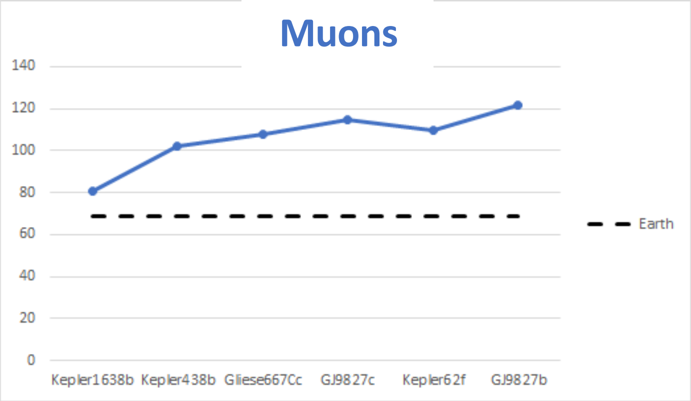
? = Not confirmed data that had to be estimated

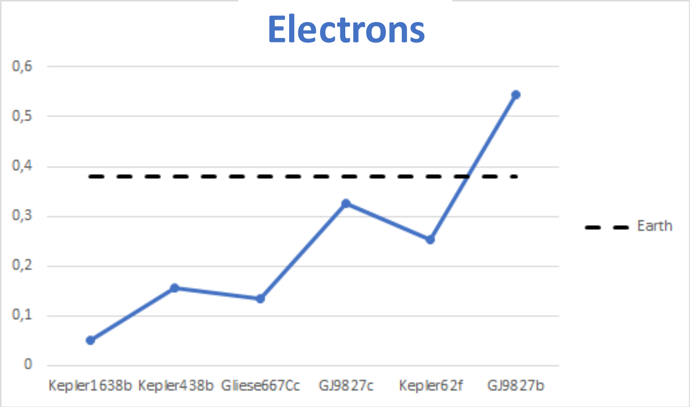
Fig. 2. Spectral types of the hosts (indicated inside the star) of our exoplanets (indicated with the corresponding letter under the stars) and the main data of them (Alberto Pelaez).

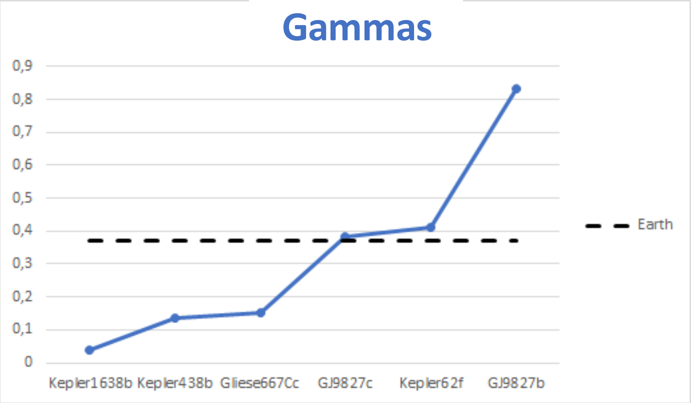
Results

Vertical fluxes in number of particles per square meter per second (top) and average energies (bottom) of muons, electrons/positrons and gamma rays, at sea/ground level with Energy E>1 GeV are shown. The corresponding flux values at Earth's surface are also represented (dotted lines – Dorman, 2013).

Flux $[m^2 s]^{-1}$

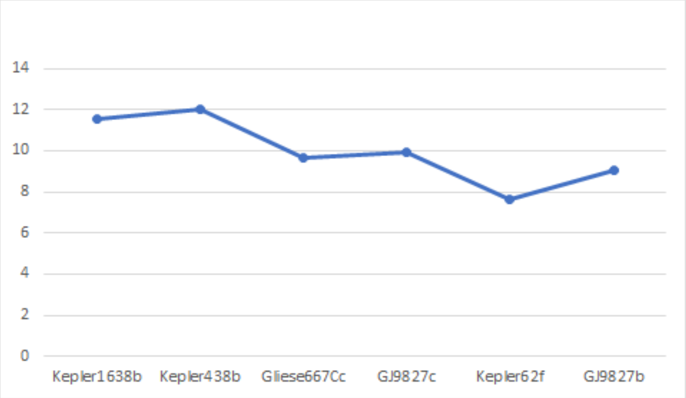


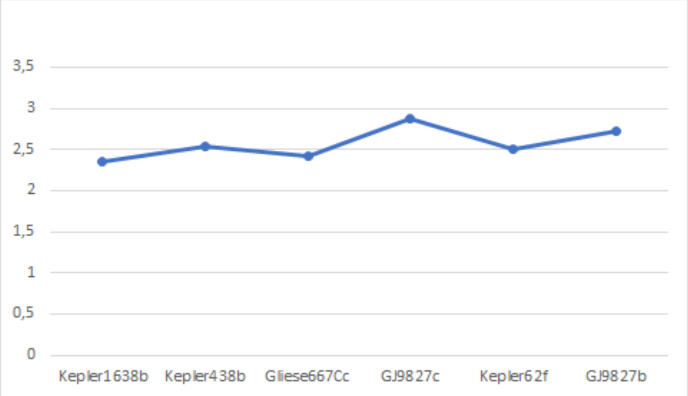


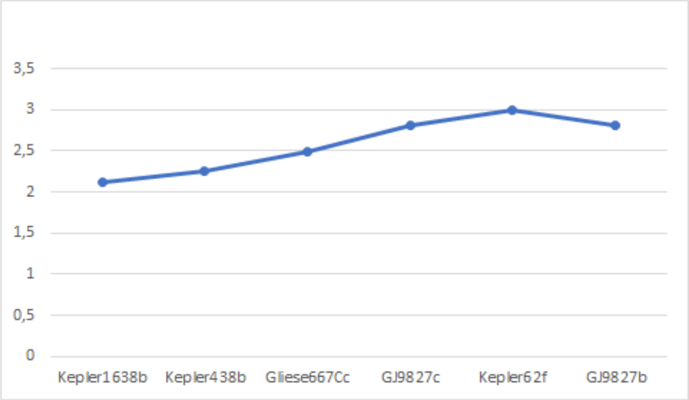


\+ Atmospheric Depth -

Average Energy [GeV]







Results

- ***The higher the atmospheric depth, the lower the surface particle flux seems to be.***
- ***Atmospheric composition seems not to be determinant. Models with only 25% O_2/75% N_2, 50% O_2/50% N_2 and 75% O_2/25% N_2 have been used so far.***
- ***Atmospheres are more compact at higher values than the Earth's gravity, this causes muons to travel less across this layer and reach the surface faster, so they don´t decay.***
- ***A higher atmospheric depth also translates into more energetic muons.***
- ***In the case of electrons (positrons) and gamma rays, their energy tend to slightly decrease with depth.***
- ***A magnetosphere similar or stronger than the one that shields the Earth will be enough to protect our 7 exoplanets from the radiation they receive.***

Impact and prospects for the future

We intend to pursue further improvements on our study, such as the use of 2D or 3D GCMs for the atmospheres, the extension of our exoplanet list and other chemical composition combinations, the seek of further exo-magnetospheric constraints or further testing of primary C.R. cascades.

- ***Some relevant references to this work are as follows:***

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