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Magnetic protection from space radiation for manned Mars exploration

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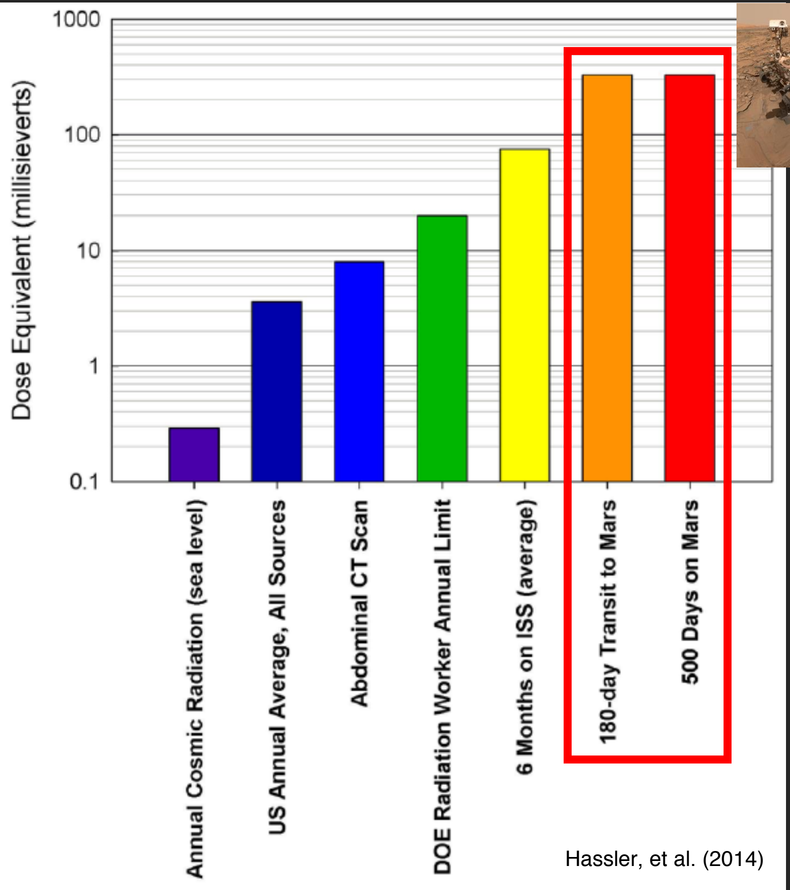
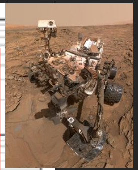
Abstract
We propose radiation protection using Martian local magnetic field to protect human crews on the Martian surface. Mars has no inherent global magnetic field, but there is a local crustal magnetic field in the southern hemisphere. The Martian local magnetic field can change trajectories of space radiation and reduce harsh radiation exposure of human crews since the space radiation is mainly composed of protons and experience the Lorentz force. To validate the radiation protection using Martian local magnetic field, we have simulated the trajectories of energetic protons and obtained the impact rate on the Martian surface.

Introduction

Observations by NASA's Curiosity rover have revealed that human crews could have harsh radiation exposure on the Martian surface.

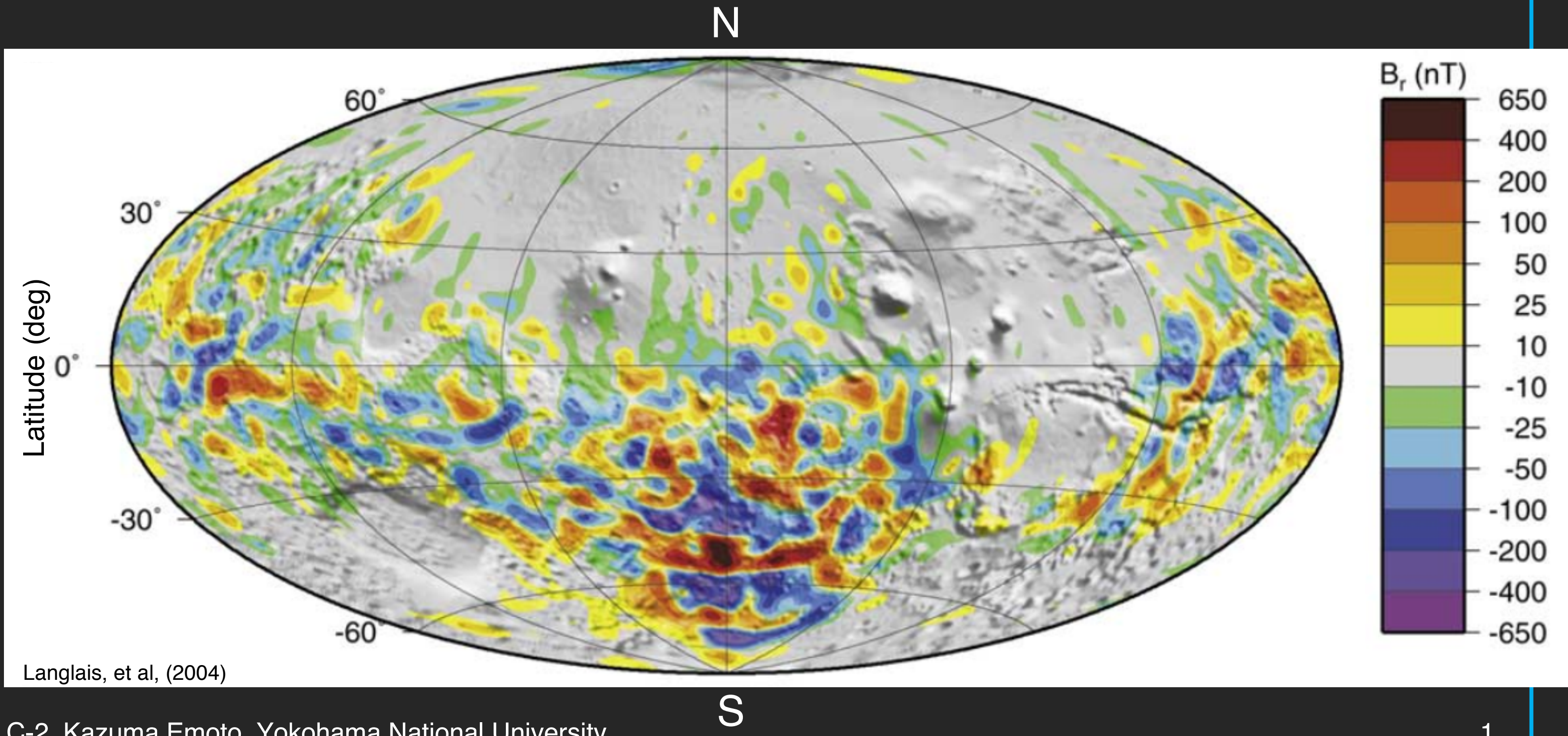


Hassler, et al. (2014)



The high radiation exposure originates the thin atmosphere and the lack of intrinsic magnetic field.

However, Mars has local crustal magnetic fields as shown below. Since the space radiation is composed of protons and other charged particles, local magnetic fields can change their trajectories through the Lorentz force. There could be safe places where the space radiation cannot reach, and human crews could be protected from the radiation exposure.



Langlais, et al, (2004)

Numerical model

We construct three-dimensional model to simulate Martian radiation environment as shown on the right figure.

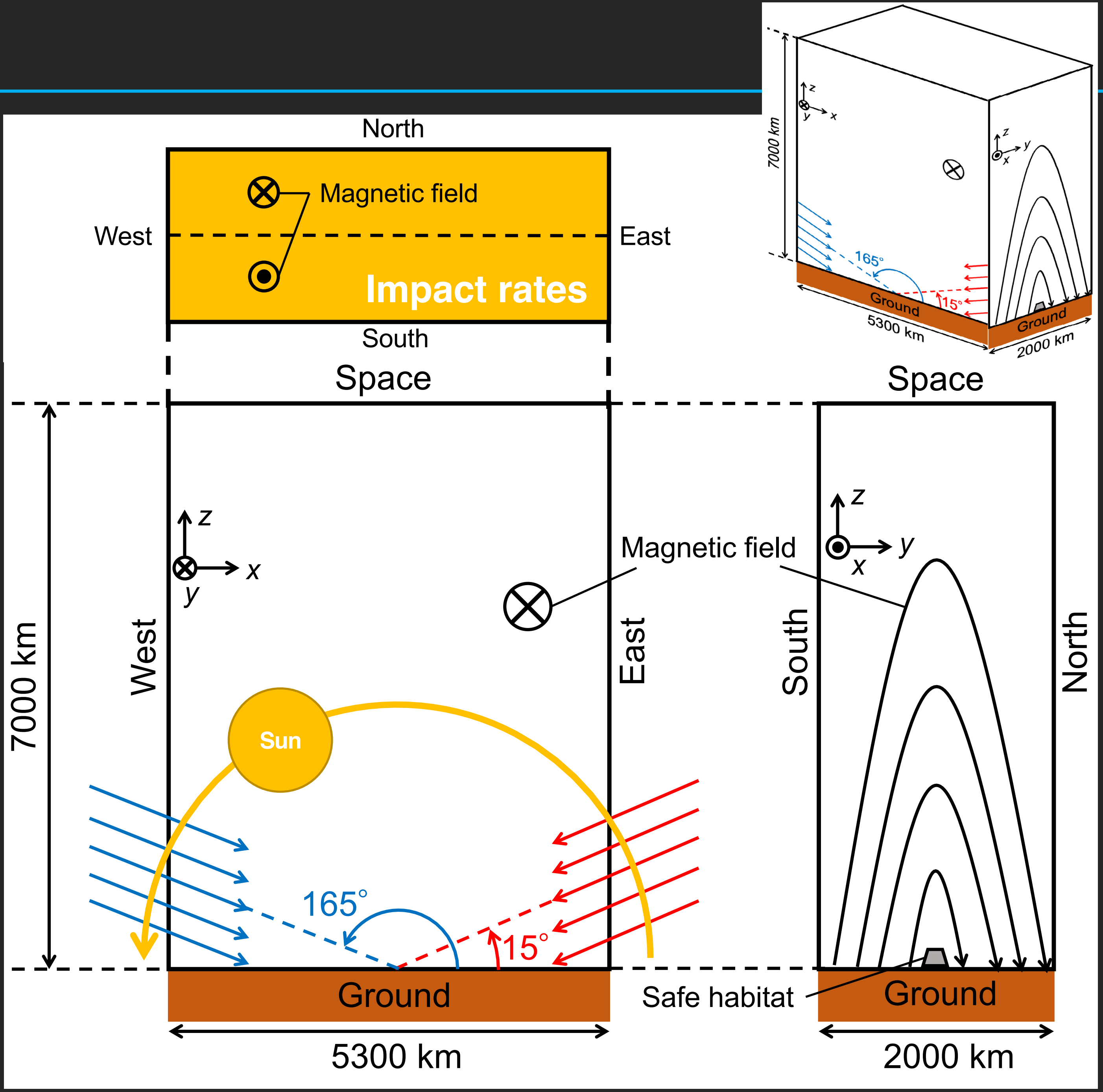
The magnetic field distribution is calculated solving maxwell's equation as

$$\nabla \cdot \boldsymbol{B} = 0.$$

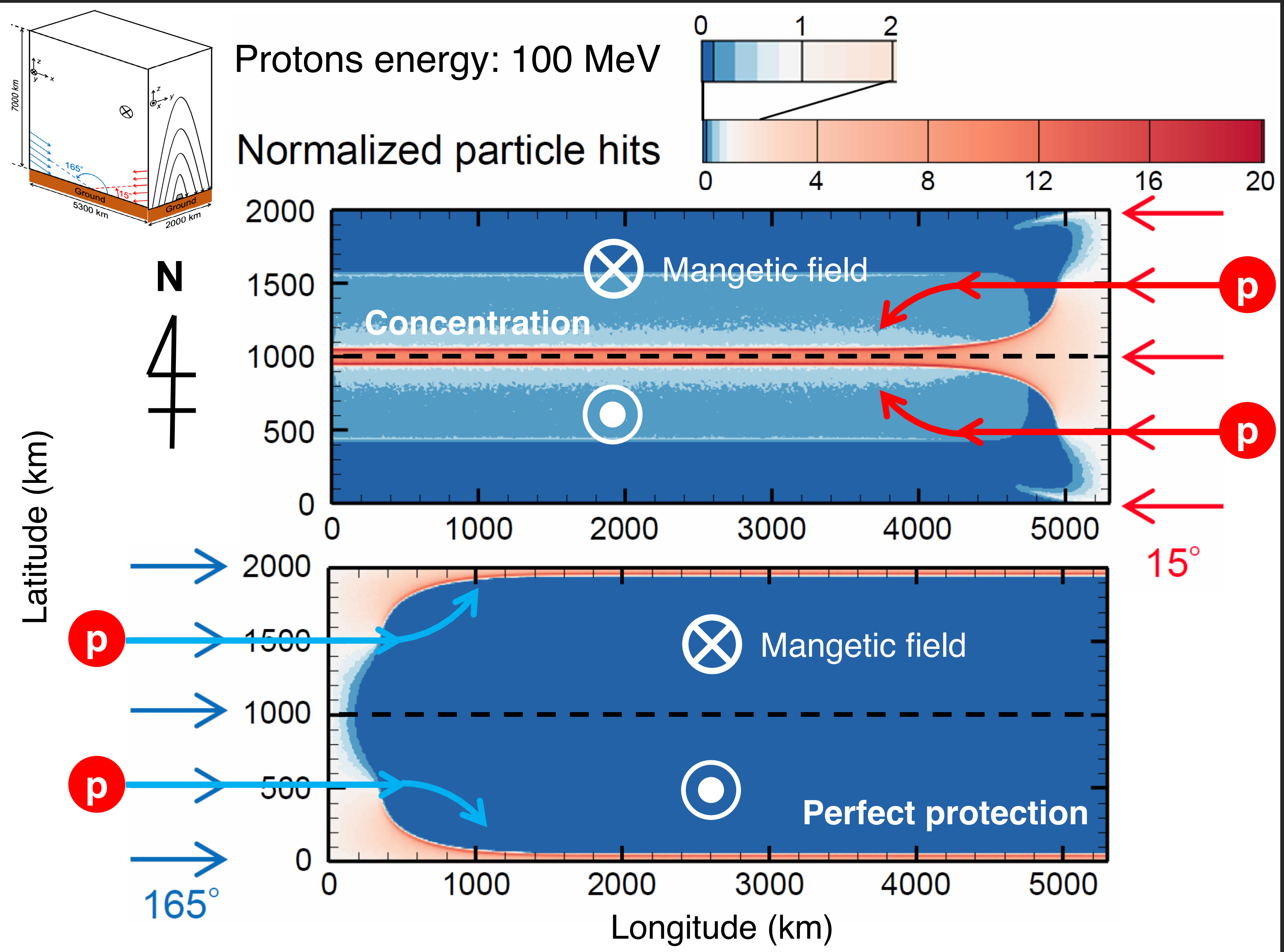
Particle trajectories are calculated solving relativistic equations of motion as

$$\frac{d(\gamma m \boldsymbol{v})}{dt} = q\boldsymbol{v} \times \boldsymbol{B}.$$

We obtain the impact rate on the Martian surface.



Impact rate of radiation on the Martian surface



- When the incident angle is 15°, protons concentrate around a latitude of 1000 km, and the radiation exposure increases significantly.
- On the other hand, when the incident angle is 165°, the protons are completely shielded around the latitude of 1000 km. Most places between magnetic poles could be safe habitats, and human crews can be protected from harsh radiation.
- Crews could also increase their protection from such risks by inhabiting areas with adjacent natural walls to the east, such as mountains or cliffs.

Conclusion

- Our numerical results show that Martian magnetic field can provide complete radiation shielding against particles incident from the west but concentrate those from the east. These results indicate that crews would only require radiation protection against particles incident from the east in particular, rather than from all directions.

- We expect that radiation exposure to humans could be reduced effectively by using the Martian magnetic field though we did not calculate their radiation doses in this study. A Martian magnetic field could therefore be used as a source of continuous and efficient radiation shielding.

- To realize this idea, it is necessary to strengthen the level of protection against radiation incident from the east by accurately measuring the incident directions of particles in the future. Moreover, we will conduct simulations in detail including the estimation of the radiation exposure in the Martian magnetic field.