The Effects of Precipitating Solar Energetic Protons in the Martian Atmosphere

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What is Particle Precipitation?

The Basics

- highly energetic electrons, protons, neutrons, and ions
- Accelerated into atmosphere
- Cause chemical changes in the atmosphere
- geomagnetic polar regions

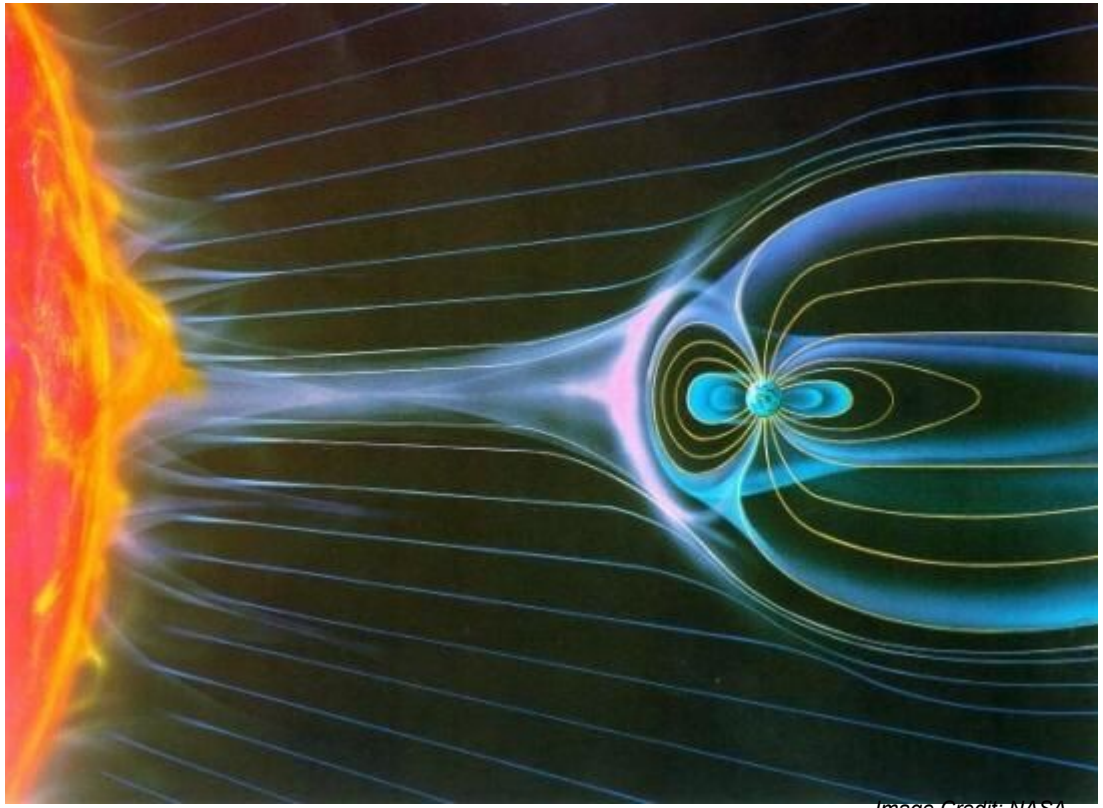

Image Credit: NASA

Where do these highly energetic particles come from?

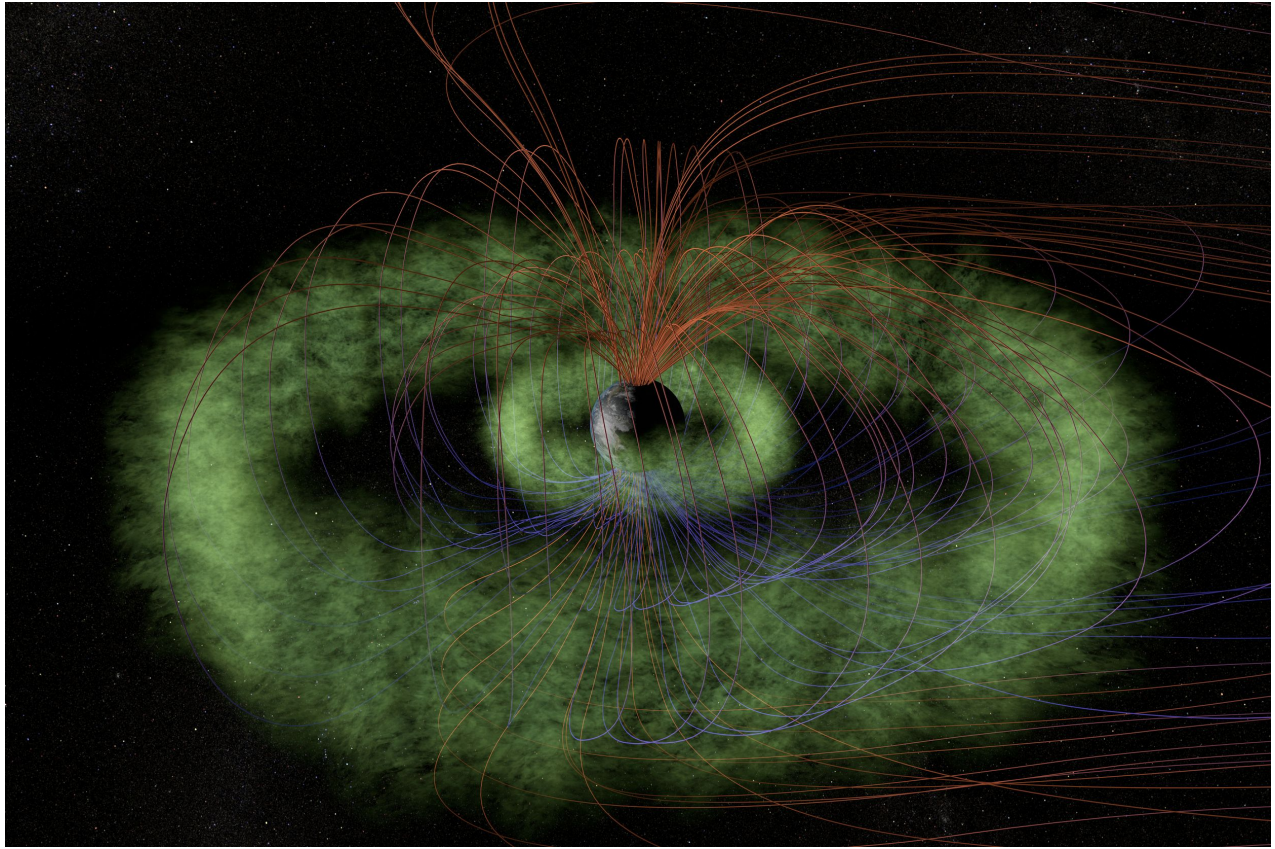

Image credit: T. Benesch and J. Carns for the NASA Science Mission Directorate

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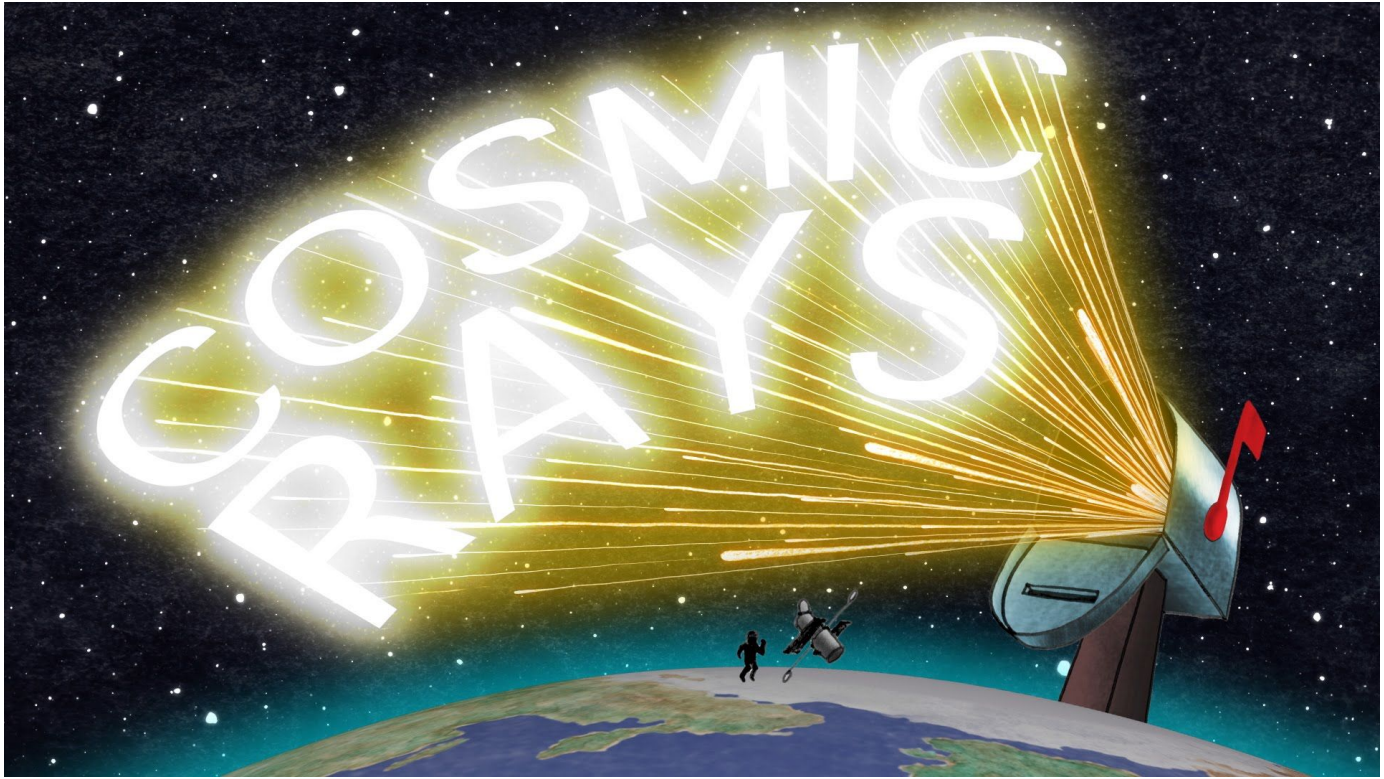

Image Credit: Veronica Bindi

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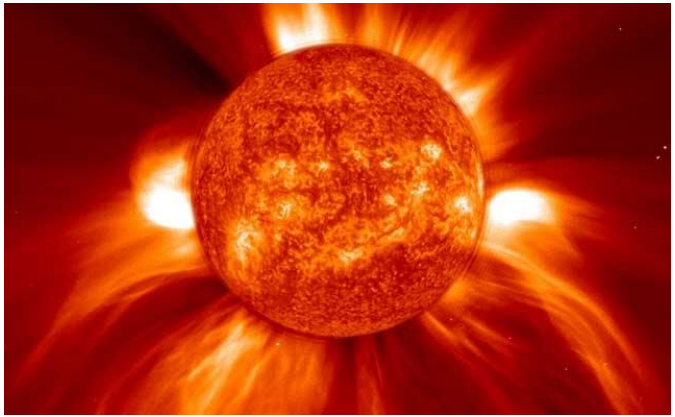
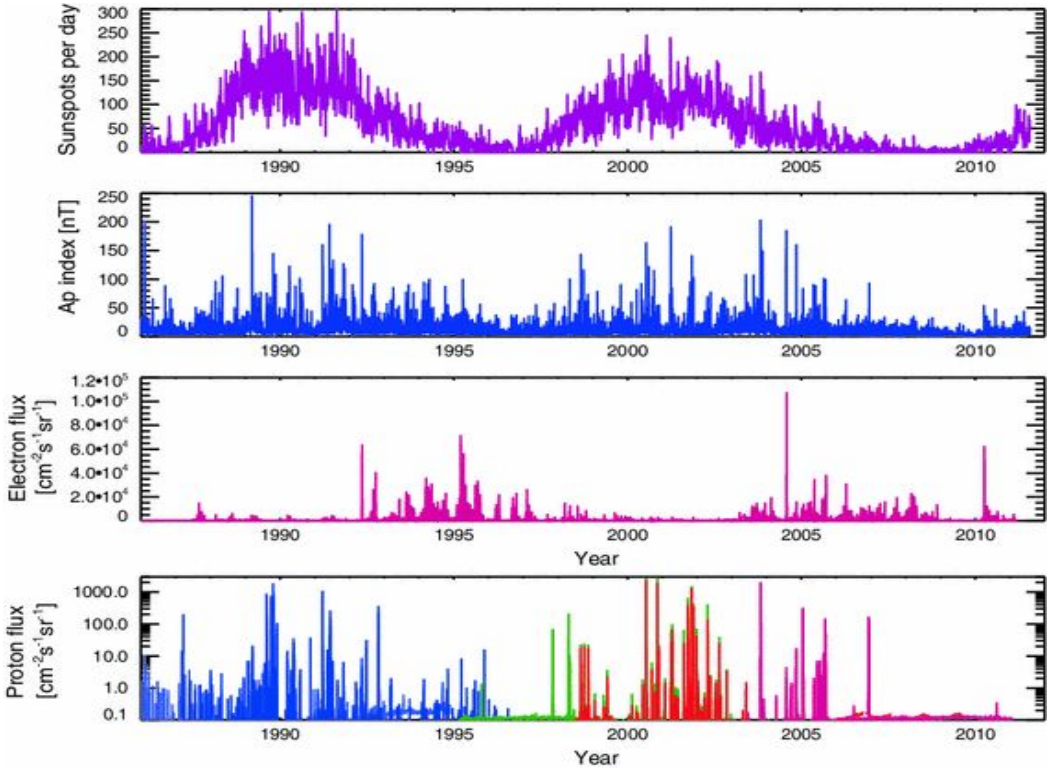


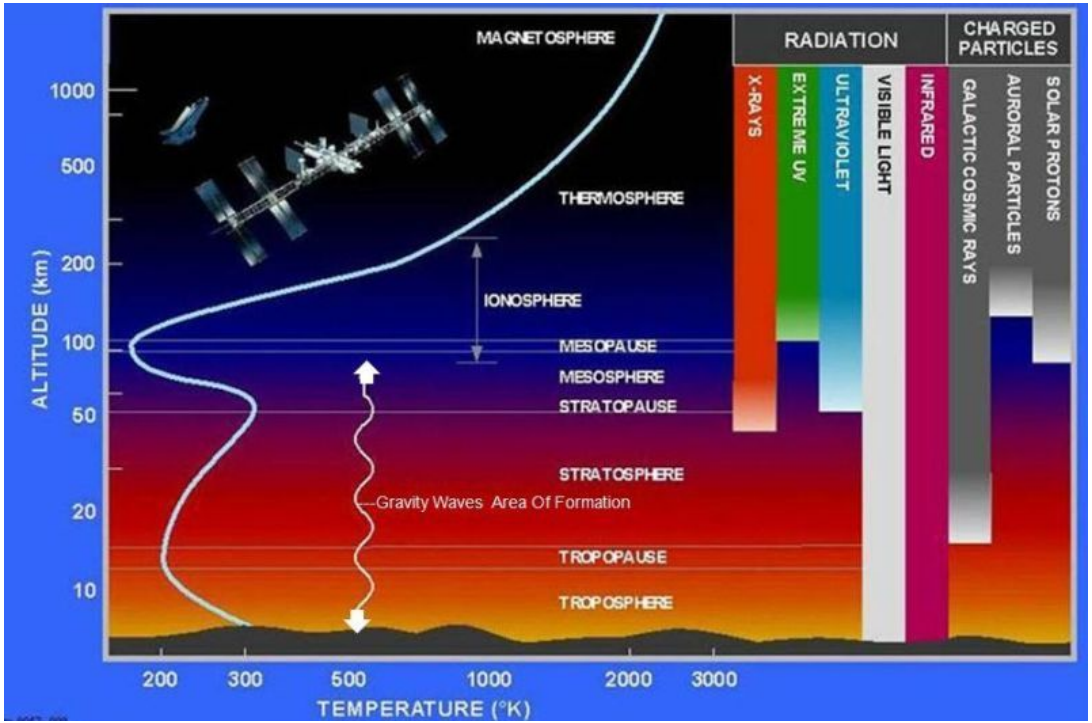
Image credit: NASA/ESA



Sinnhuber et al., 2012

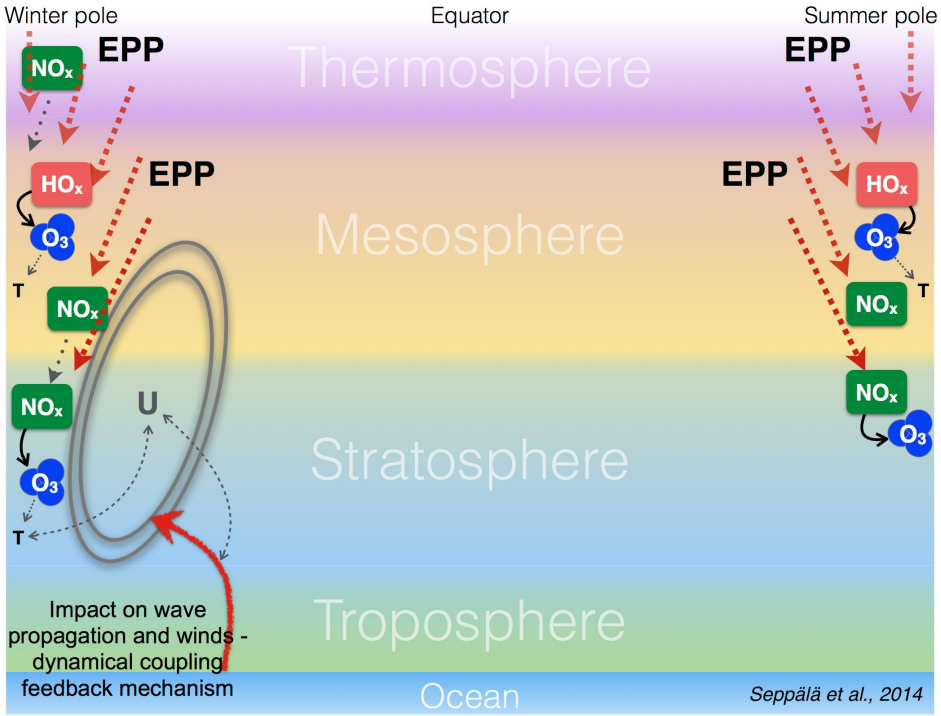
Where do these highly energetic particles come from?

- Auroral electrons: 1–10 keV, penetrate to ~80–130 km
- Solar Proton Events: 10's - 100's MeV, penetrate to mesosphere & upper stratosphere
- Galactic Cosmic Rays: several 100 MeV far into the EeV range, penetrate to lower stratosphere and sometimes reach the surface

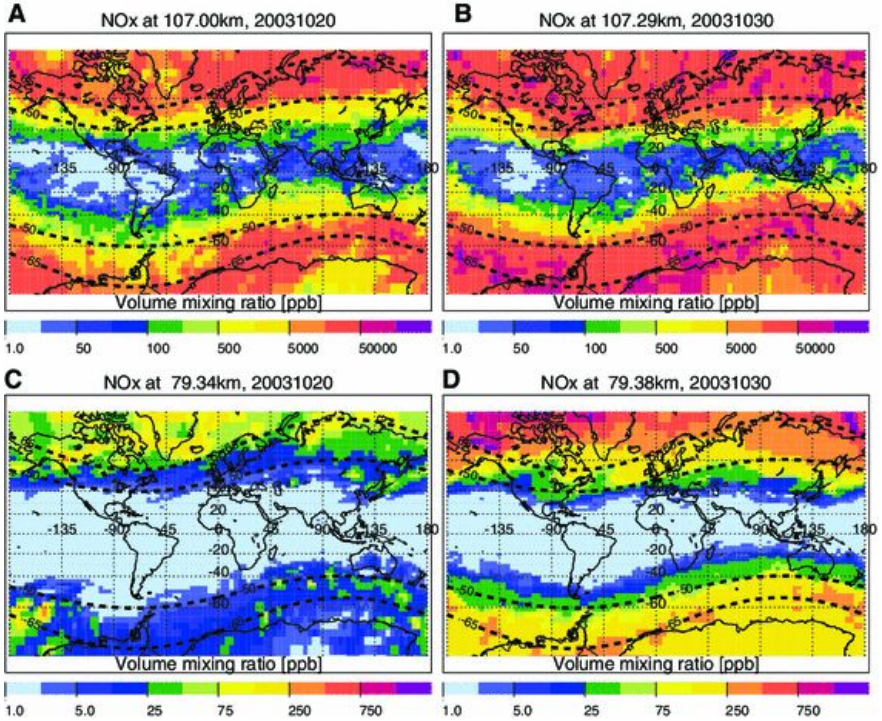


Credit: NASA

How is the Atmosphere Affected?



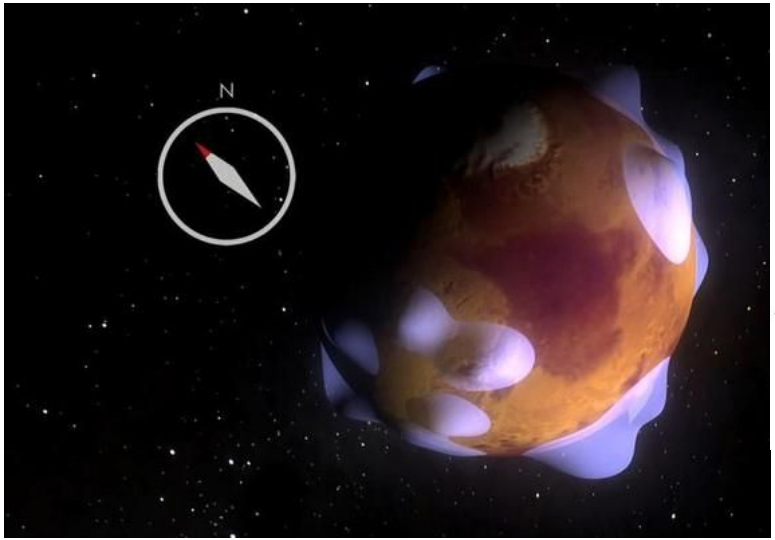
Seppälä et al., 2014



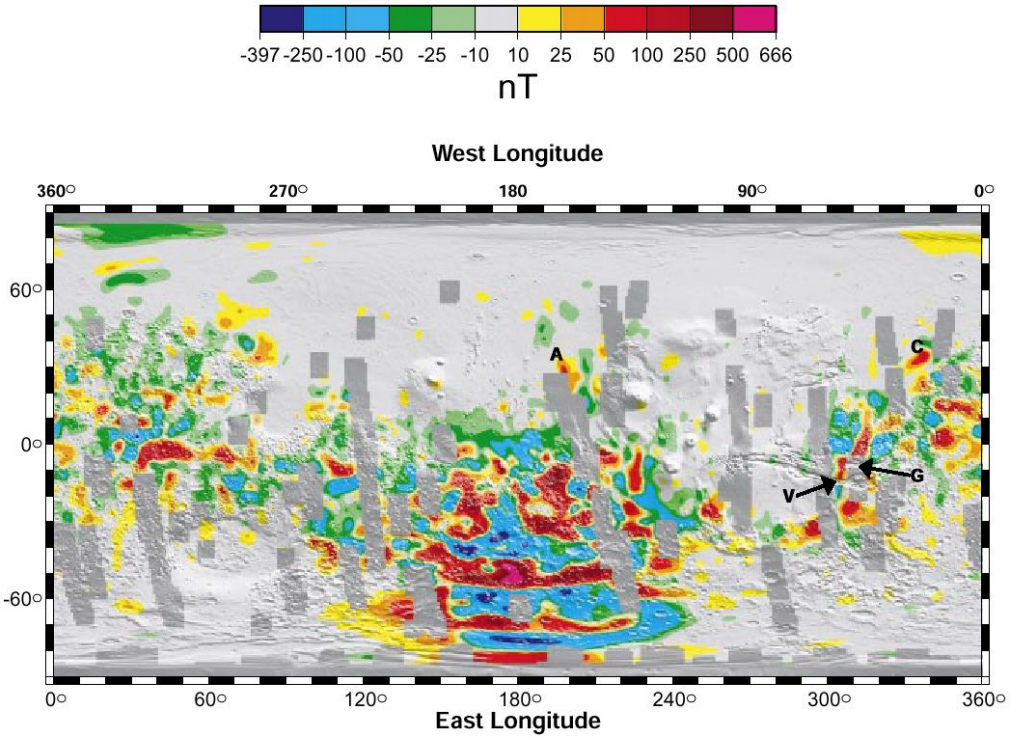
Sinnhuber et al., 2012

How Mars is Different?

- Weak, scattered crustal magnetic field
- Smaller in size
- More distant from the sun



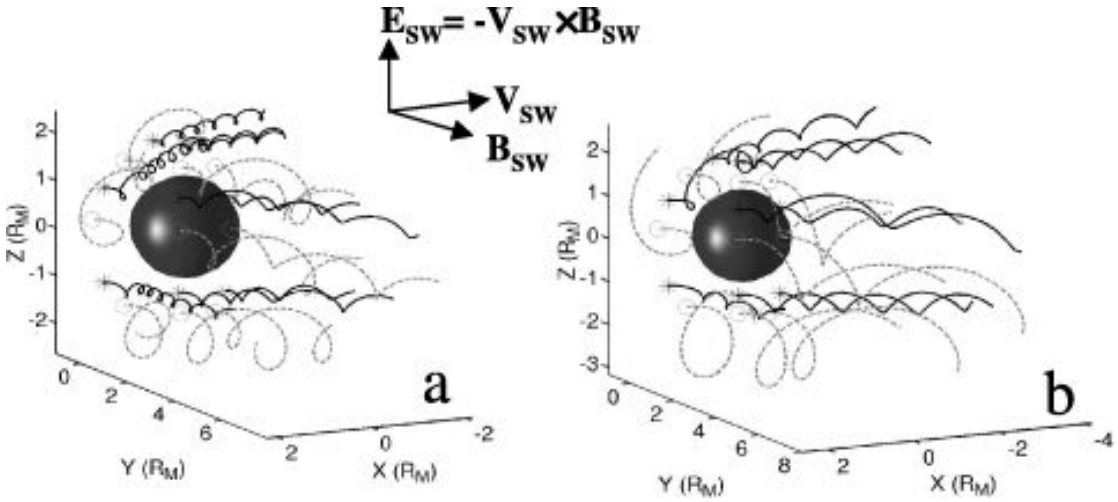
Credit: NASA



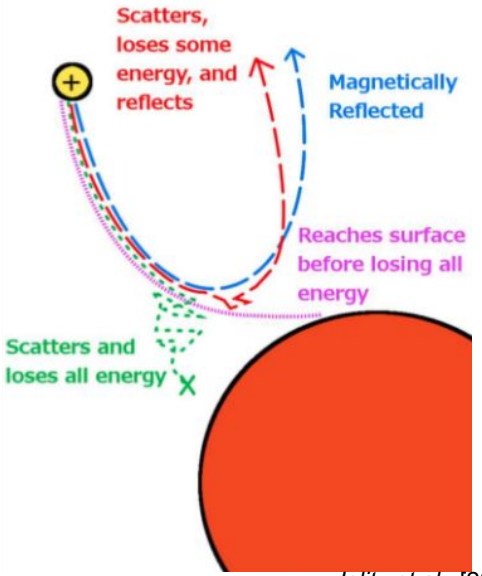
Purucker et al., 2000

Effects on the Martian Atmosphere

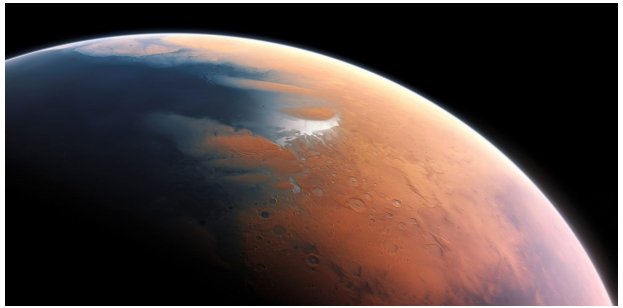
- Atmospheric heating
- Localized effects by crustal magnetic field
- Atmospheric Sputtering (animation)



Credit: Kallio, Janhunen 2001

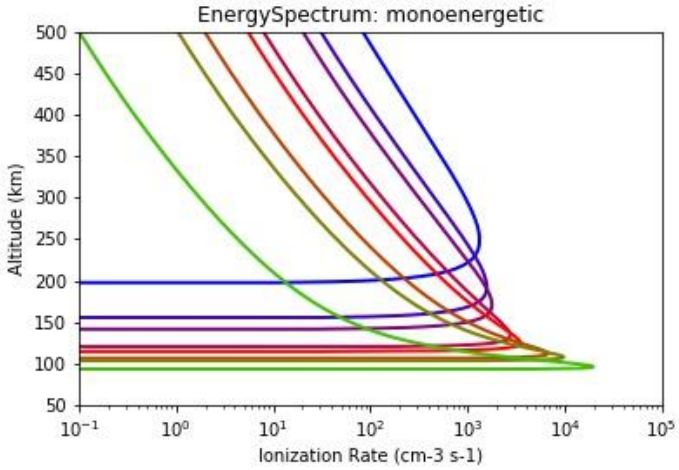


Jolitz et al., [2017]

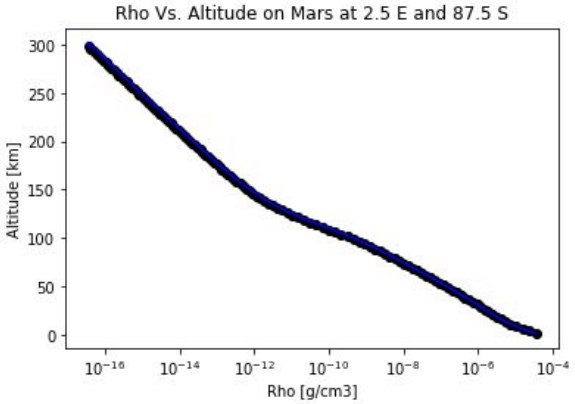


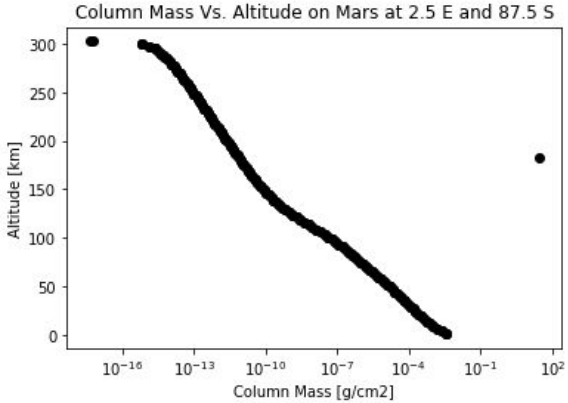
Credit: ESO/Wikimedia Commons

How the Code Works



- Uses NIST stopping power data
- Uses density of atmospheric elements to calculate column mass
- Inputs pre-determined energy of incident protons (in MeV)
- Calculates the incident energy flux, total energy dependent on mass & volume
- Outputs the total ionization result





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33: 1281. https://doi.org/10.1007/s10712-012-9201-3

Questions?