# MSL/RAD Radiation Measurements on the Surface of Mars on the Way to Solar Maximum – New Findings & Updates

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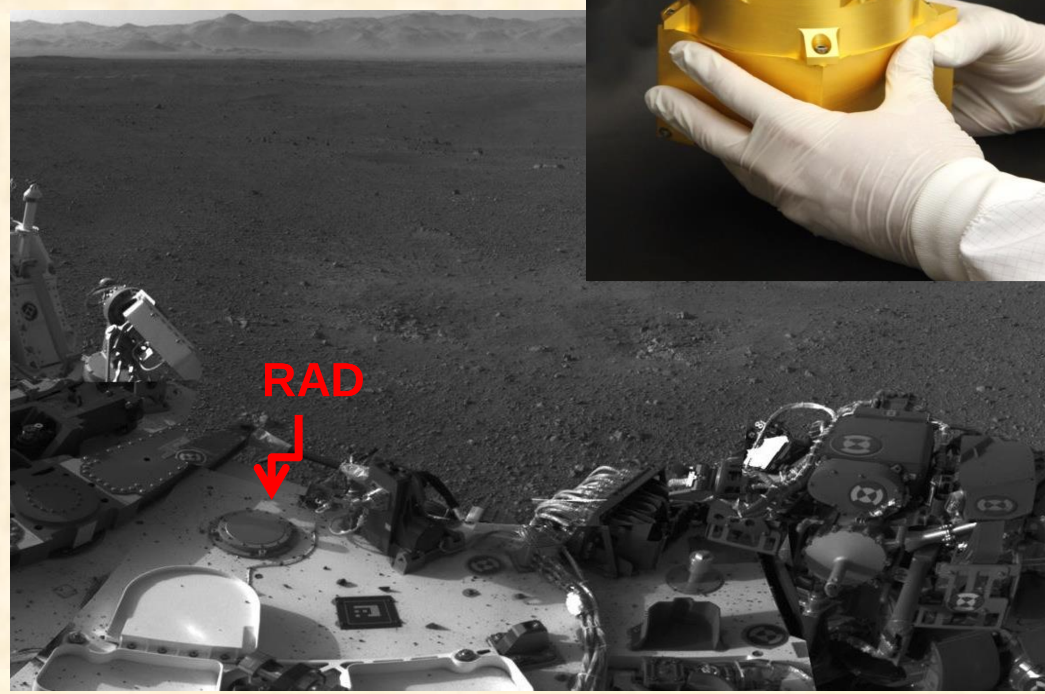
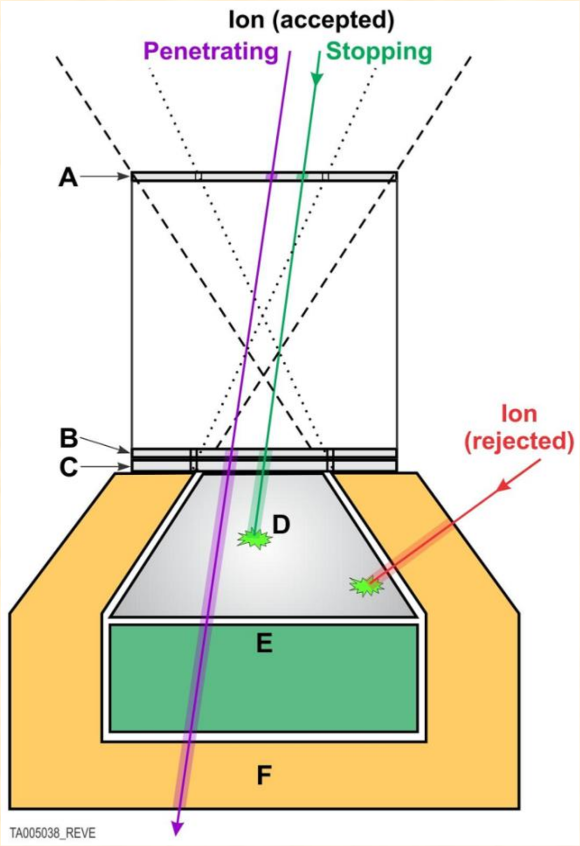
# The Radiation Assessment Detector (RAD)

- RAD has been measuring the radiation environment on Mars on board NASA's Curiosity rover since August 2012, now spanning ***one whole solar cycle***
- Knowledge of the radiation environment is crucial for the planning of ***future human exploration of Mars***
- Exposure to radiation from Galactic Cosmic Rays (***GCRs)*** and Solar Energetic Particles (***SEPs***) remains one of the major risks for manned spacce flight

# The Radiation Assessment Detector (RAD)

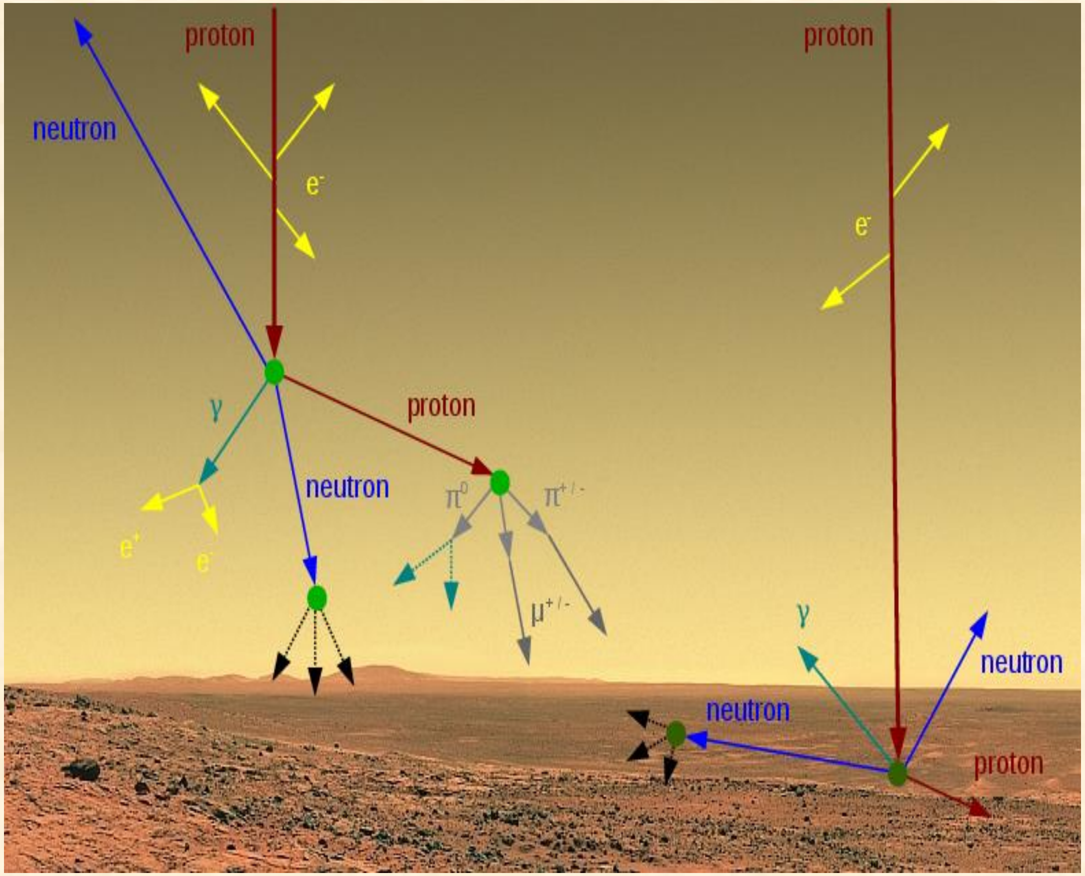
- The RAD Sensor Head consists of the following detectors
  - Three 300 μm thin Si detectors (***A, B, C***),
  - CsI scintillator (***D***),
  - Plastic (tissue-equivalent) scintillator (***E***),
  - Plastic scintillator (***F***) used for anti-coincidence
- The coincidence of detectors ***A&B*** defines the acceptance angle for charged particle detection
  - A&B FOV ~***30°*** from zenith
- ***D & E*** are used to detect ***neutral particles*** (in anti-coincidence with detectors C & F)




*Schematic of the RAD sensor head*

# Radiation Environment on Mars

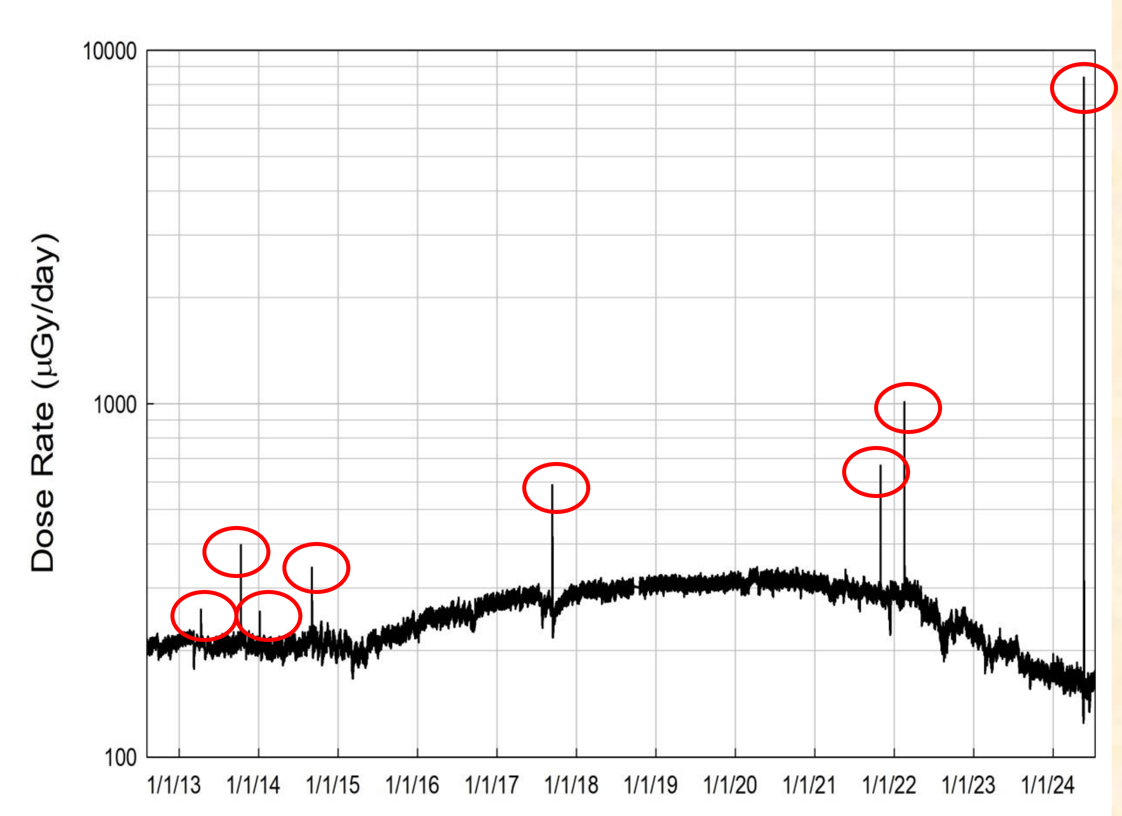
- Radiation environment on the surface of Mars differs greatly from Earth
- Mars lacks a global magnetic field and its ***atmosphere*** is very ***thin***
- ***GCRs*** and high-energy ***<u>SEPs</u>*** can propagate deep into the atmosphere and soil and interact with the nuclei → intense radiation field of ***charged and neutral particles*** on the surface
- Protons need ~***150 MeV*** to reach the surface!



*Schematic of GCR protons propagating through the atmosphere and interacting with the nuclei of soil and atmosphere.*

# RAD Dose Rate Measurements over one Solar Cycle

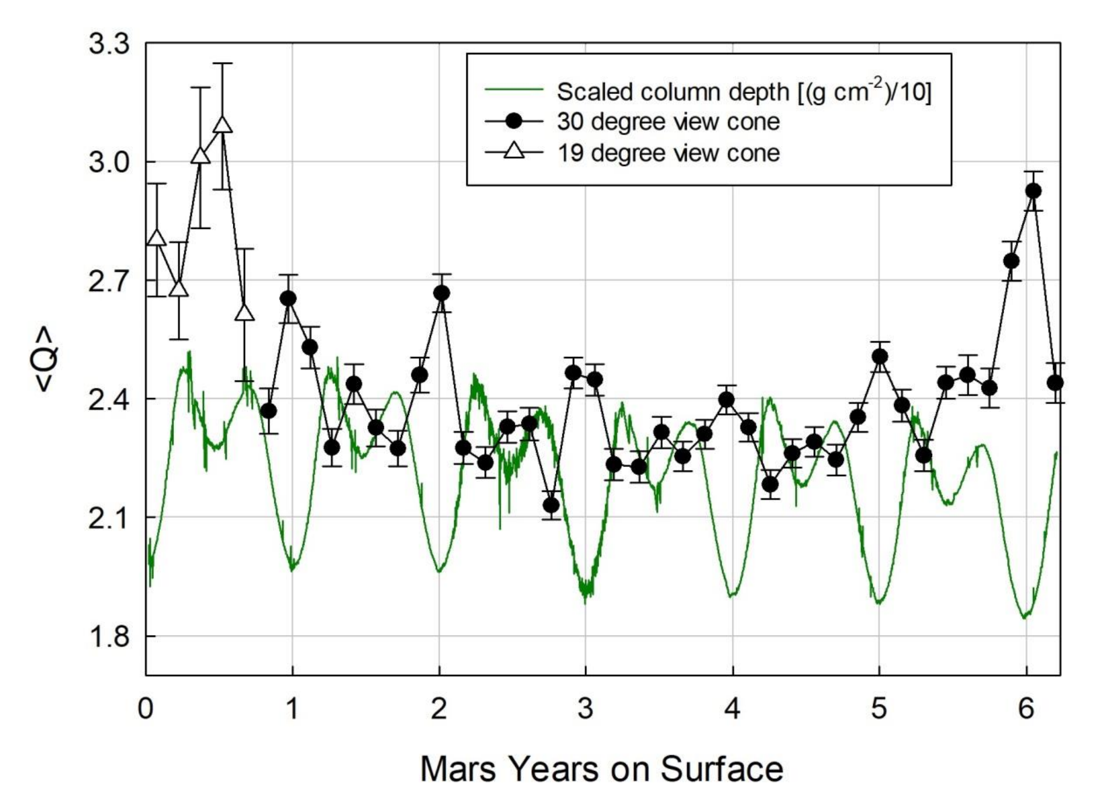
- Dose rates range from ~ ***340 µGy/day*** (solar min) to ~ ***160 µGy/day*** (current solar max)
- Previous solar max dose rates ***deeper*** than during end of last solar max (2012)
- Dose rates stem mainly from ***GCR***…
- … and vary with ***solar modulation & Martian pressure*** cycle
- RAD has detected ***eight SEP events*** so far (red circles)




*RAD dose rate measurements in tissue-equivalent plastic scintillator E. The eight solar events detected by RAD are highlighted in red.*

# Radiation Quality Factor <Q>

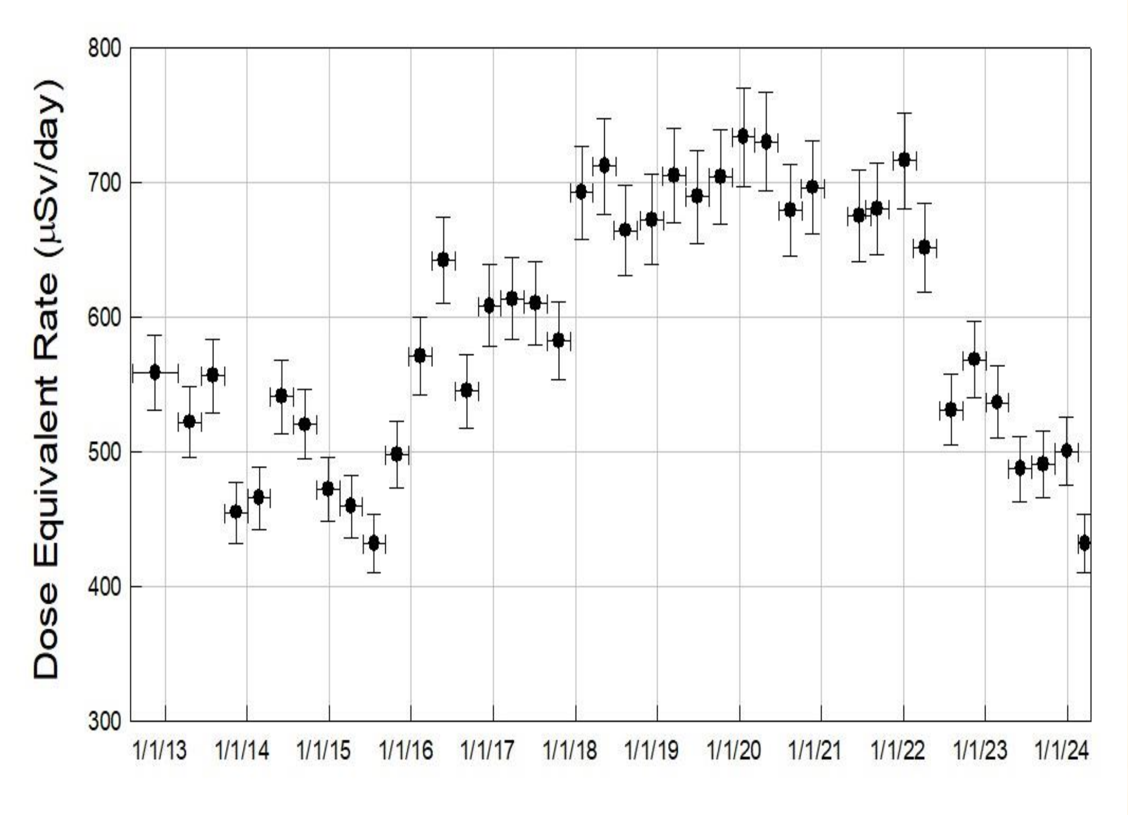
- <Q> is a measure for the ***biological effectiveness*** of the radiation field
- … calculated from RAD ***LET spectra*** and ***Q(LET)***
- <Q> is affected by both ***solar modulation*** and ***Martian pressure***
- Decrease in pressure leads to increase in <Q>
- Increase in solar modulation (solar max) leads to increase in <Q>
- ***<Q>*** ranges from ~ ***2.1*** (solar min) to ***3.1*** (solar max)




*(Green) Vertical column depth of Martian atmosphere. (Black) Average <Q> of the Martian radiation field.*

# Dose Equivalent Rate H

- Dose equivalent is the product of measured ***absorbed dose x <Q>***...
- … and provides a better insight into the radiation exposure ***relevant to astronaut health***
- Dose equivalent rates highest during solar min (***725 µSv/day***)...
- During solar max: ***425 - 450 µSv/day***




*RAD dose equivalent rates calculated from RAD absorbed dose rate measurements and <Q> of the radiation field.*

# RAD Acknowledgments

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