Bacterial survival in Martian conditions

G. Galletta$^{1,2}$, M. D'Alessandro$^3$, G. Bertoloni$^4$

$^1$Dept. Astronomy, University of Padua, Italy
$^2$CISAS “G. Colombo”, University of Padua
$^3$INAF, Padua Astronomical Observatory
$^4$Dept. Histology, Microbiology and Medical Biotechnologies, University of Padua
We present the results of some experiments performed in the Padua simulators of planetary environments, named LISA (Laboratorio Italiano di Simulazione Ambienti) used to study the limit of bacterial life on the planet Mars.

Projected in cooperation between: Dept. Astronomy, Dept. Histology, Microbiology and Medical Biotechnologies, Dept. Mechanical Engineering, University of Padua, Padua Astronomical Observatory - INAF (Italian National Institute for Astronomy) and CISAS “G. Colombo” (Center of Studies and Activities for Space).

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LISA’s goal: Before reaching the red planet with manned missions or with bio-packages, we may search in a less expensive way what kind of lifeforms may resist in such an extreme environment.

Caveats:

1 - lifeforms on a different planet may have a fully different combination of nucleic acids and aminoacids (LUCA hypothesis). We might not be able to recognize it.

2 - we don’t have (yet) neither Martian bacteria nor Martian soils to use for the tests. We use terrestrial surrogates! Maybe our conclusions are not applicable to Martian life, but are useful for contamination- or terraforming- studies.
Loading the samples in the 6 steel reaction cells of LISA
LISA performances

Temperature: \(-140 \leq T \leq 50 \, ^\circ\text{C}\) (Mars \(-136 \leq T \leq +27 \, ^\circ\text{C}\))
Pressure: \(10^{-4} \leq P \leq 2 \text{ bar}\) (Mars \(~7 \text{ mbar}\))
Atmosphere: any (Mars 95% CO\(_2\), 3% N\(_2\), etc.)
UVC flux \(~3-6 \text{ W/m}^2\)
Length of experiment: \(\geq 25\) hours LISA, no limit mini-LISA
LISA performances

Temperature: \(-140 \leq T \leq 50\, ^\circ C\) (Mars \(-136 \leq T \leq +27\, ^\circ C\))
Pressure: \(10^{-4} \leq P \leq 2\) bar (Mars \(~7\, mbar\))
Atmosphere: any (Mars 95% CO₂, 3% N₂, etc.)
UVC flux \(\sim 3-6\, W/m²\)
Length of experiment: \(\geq 25\) hours LISA, no limit mini-LISA

**Martian and LISA atmosphere:**

*Main components:*

<table>
<thead>
<tr>
<th></th>
<th>LISA</th>
<th>Martian</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>95.32%</td>
<td>95.5%</td>
</tr>
<tr>
<td>N₂</td>
<td>2.7%</td>
<td>3%</td>
</tr>
<tr>
<td>Ar</td>
<td>1.6-1.7%</td>
<td>1.6%</td>
</tr>
<tr>
<td>O₂</td>
<td>0.13-0.2%</td>
<td>0.13%</td>
</tr>
<tr>
<td>CO</td>
<td>0.08%</td>
<td>0.07%</td>
</tr>
</tbody>
</table>

*Minor components:*

<table>
<thead>
<tr>
<th></th>
<th>LISA</th>
<th>Martian</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>210 ppm</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>100 ppm</td>
<td></td>
</tr>
<tr>
<td>Ne</td>
<td>2.5 ppm</td>
<td>300 ppm</td>
</tr>
<tr>
<td>HDO</td>
<td>0.85 ppm</td>
<td></td>
</tr>
<tr>
<td>Kr</td>
<td>0.3 ppm</td>
<td>300 ppm</td>
</tr>
<tr>
<td>Xe</td>
<td>0.08 ppm</td>
<td>300 ppm</td>
</tr>
</tbody>
</table>

LISA performances

Temperature: \( -140 \leq T \leq 50 \degree C \) (Mars \( -136 \leq T \leq +27 \degree C \))
Pressure: \( 10^{-4} \leq P \leq 2 \text{ bar} \) (Mars \( \sim 7 \text{ mbar} \))
Atmosphere: any (Mars 95% CO\(_2\), 3% N\(_2\), etc.)
UVC flux \( \sim 3-6 \text{ W/m}^2 \)

Length of experiment: \( \geq 25 \text{ hours LISA, no limit mini-LISA} \)
(500 liter liquid nitrogen, refueling every Monday)
Samples analysis in the bio lab
Bacterial colonies grown after the Martian experiments

*Deinococcus radiodurans*

*Mycobacterium smegmatis*

*Bacillus nealsonii* ATCC 15077

*Bacillus pumilus* SAFR 032

*B. pumilus* DSMZ 27
Biological experiments

Cells, rich in liquid water, are killed in a few minutes

Martian "summer day" vegetative cells

23°C, CO₂, 7.5 mbar + UV
Biological experiments

Endospores: resting structures that allow some bacteria to survive harsh conditions.

Endospores have an higher resistance and may survive for hours.

Martian “summer day”
Biological experiments

Low temperatures increase the spore resistance to UV by ~1 order of magnitude

Martian “winter day”
UV light has the most lethal effect on cells and spores. However, some strains survive for hours on Mars. Dust blown by the wind may save them by deactivation.
Biological experiments

The survival of the “strong population” may be an effect of thickness.
Biological experiments

In absence of UV light spores survive for years

*B. Pumilus* SAFR 032 spores, -80°C, 1 bar, no UV
• Desiccation effect (water escape because of low pressure) may strongly decrease the survival of vegetative cells, but not of spores.

• In Martian environment, UV light has the most cytocidal effect. Atmospheric composition or temperature are not relevant to their survival.

• Vegetative cells are inactivated by UV light in few minutes, spores may survive for hours.

• Some bacterial strains, such as *B. pumilus* and *B. Nealsonii* resist for at least 6 hours to Martian conditions. In their sequenced DNA portion no mutations have been detected.

• A thin dust cover, or a dead cell layer may be sufficient to warrant the survival of the underlying spores.
• **Bacillus studies in space and on Mars:**
  R. Möller and co-workers  
  German Aerospace Center (DLR), Radiation Biology Division, Institute of Aerospace Medicine  
  Bacterial spores covered by dust survived in LISA up to 25 hours

• **Tardigrade survival in extreme conditions**
  L. Rebecchi, R. Bertolani and co-workers  
  University of Modena and Reggio Emilia, Department of Animal Biology, Modena  
  Small animals living in moss survived in mini-LISA
The two Fagi infect *Paenibacillus larvae* (gram-positive bacterium, pathogenic for bees)

Future works:

We expect your experiments!