

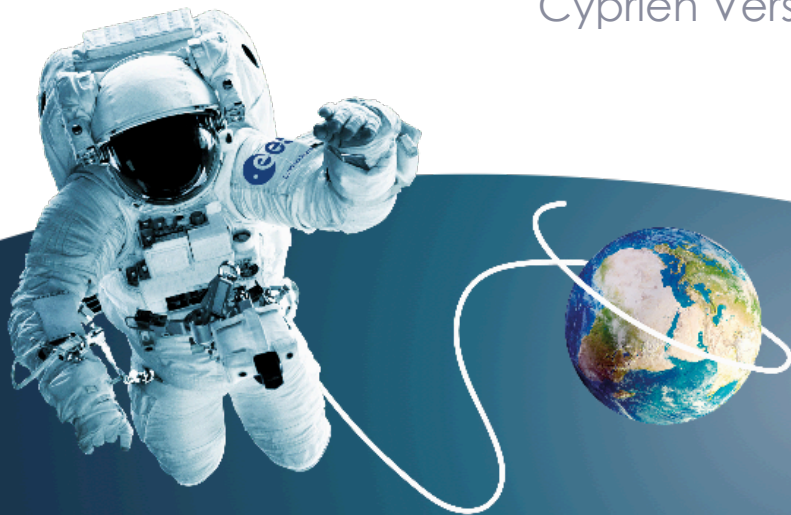


An experimental device for studies on cyanobacteria at low pressure, in the frame of BLSS

Cyprien Verseux, Tiago Ramalho, Malte Duckhorn, Jonathan Determann, Michael Smagin and Christiane Heinicke

ZARM, University of Bremen, Germany

November 4th 2020



Atmosphere

CO₂, N₂

Regolith

P, S, Mg, Fe, Ca, Na, K, Mn, Cr, Ni, Mo, Cu, Zn and other micronutrients

Water sources

Ice caps, subsurface ice, atmosphere, hydrated minerals, ...

H₂O

Cyanobacteria

NH₄⁺,
Organics,
Leached minerals

Recycling

**Heterotrophs,
Plants**

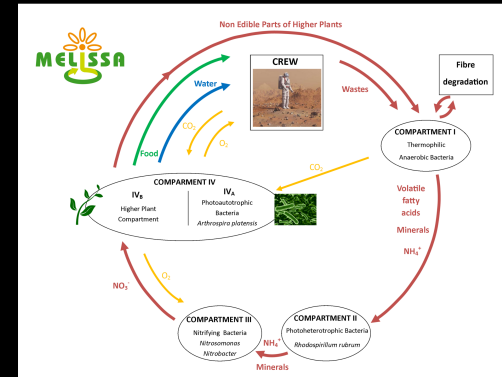
Organic material,
CO₂, H₂O

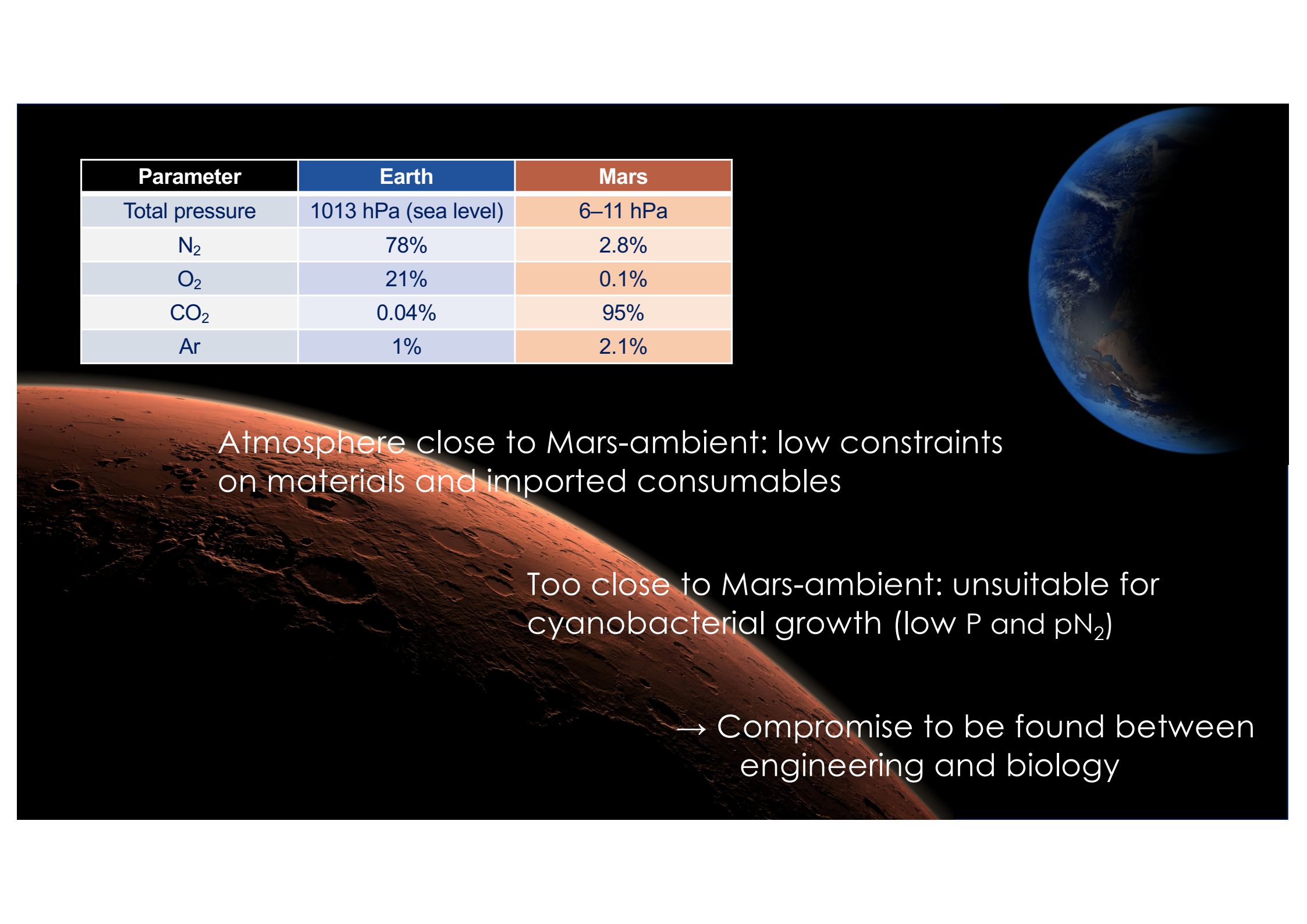
Energy, heat

Solar radiation

(Crew activity)

Metabolic and
manufacturing waste





Parameter	Earth	Mars
Total pressure	1013 hPa (sea level)	6–11 hPa
N ₂	78%	2.8%
O ₂	21%	0.1%
CO ₂	0.04%	95%
Ar	1%	2.1%

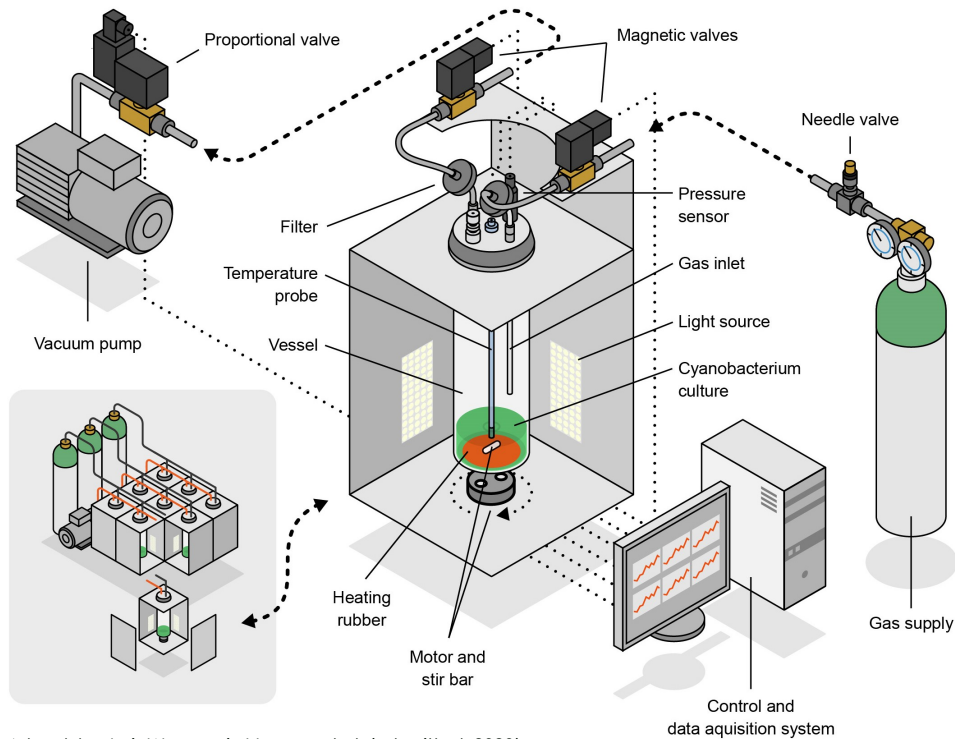
Atmosphere close to Mars-ambient: low constraints on materials and imported consumables

Too close to Mars-ambient: unsuitable for cyanobacterial growth (low P and pN₂)

→ Compromise to be found between engineering and biology



Atmos: a low-pressure PBR

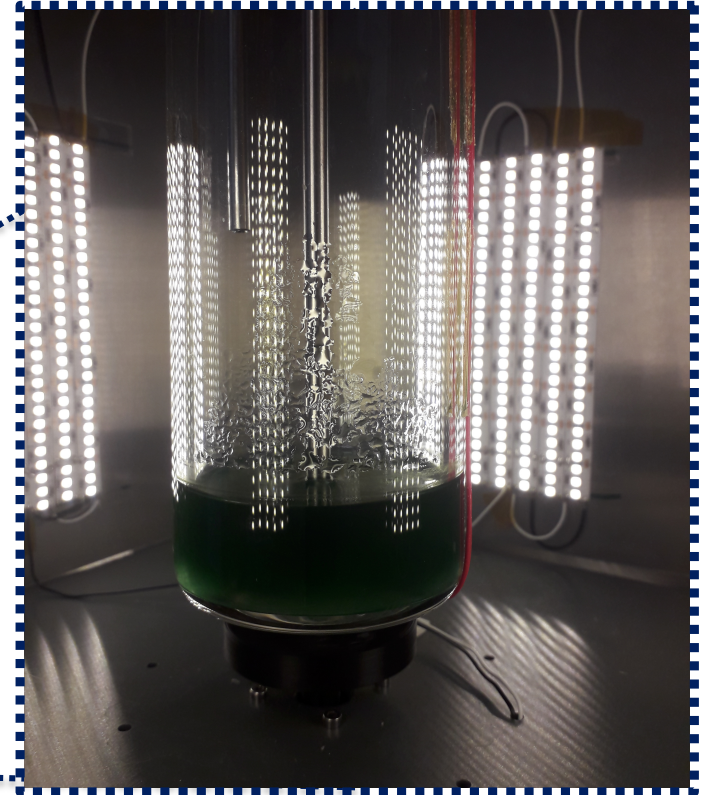
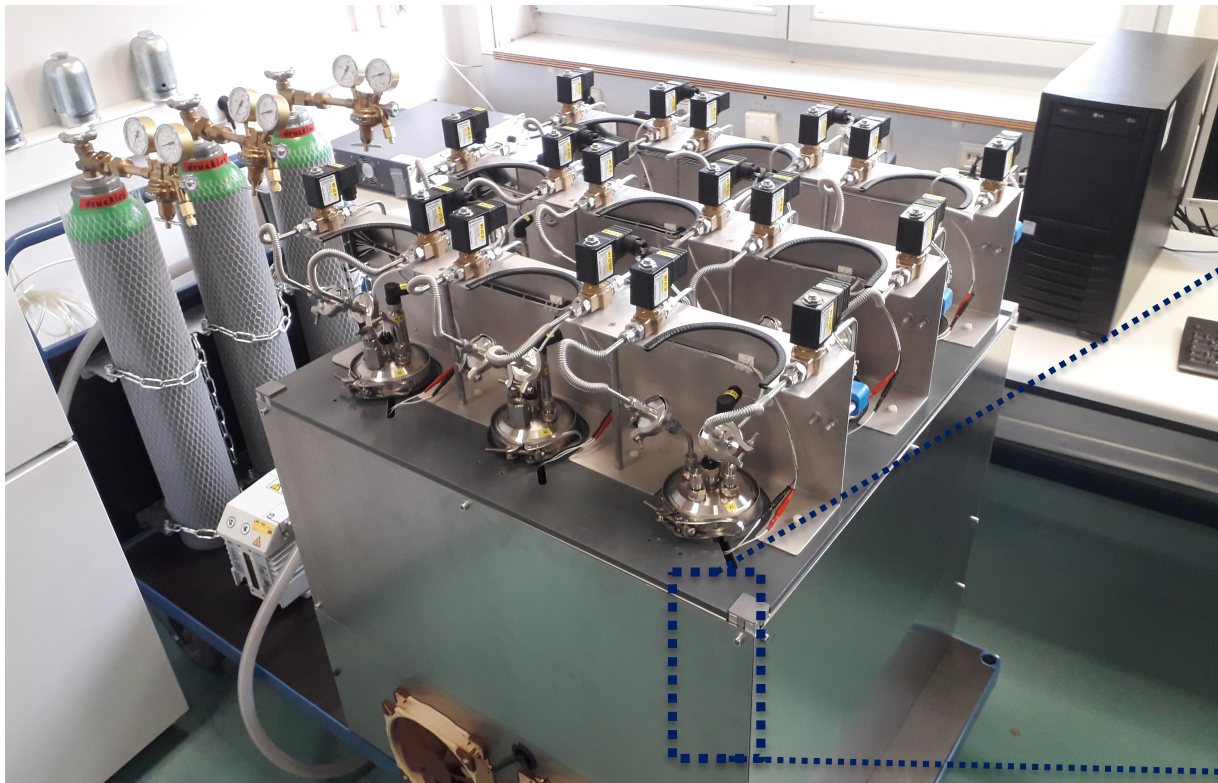


Artwork by Joris Wegner, in Verseux et al. (submitted, 2020).

- Accurate control of atmospheric conditions at low pressure.
- Some specifications:
 - 9 vessels, ca. 1L each.
 - Gas composition: can differ between rows.
 - Pressure, gas renewal: each vessel regulated individually.
 - Sampling at low pressure without interruption.
 - Also: adjustable stirring speed, light intensity, heating...
 - Computer-controlled.



Atmos: a low-pressure PBR

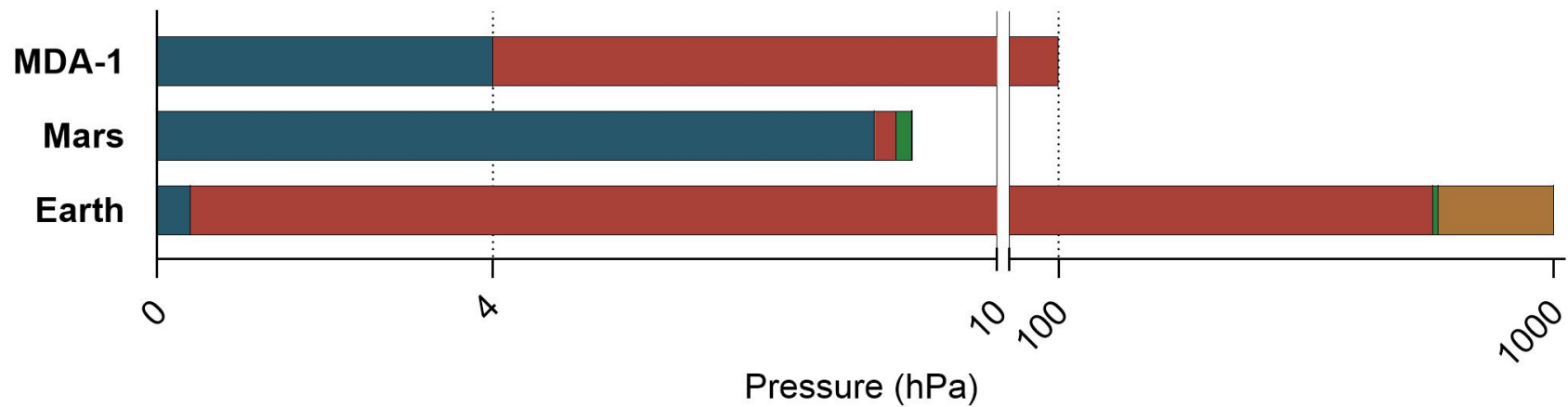




MDA-1

Mars-derived atmosphere 1

Atmosphere	Pressure (hPa)	CO ₂	N ₂	Ar	O ₂
MDA-1	100	4%	96%	0%	0%
Mars	6–11	95%	2.8%	2.1%	0.1%
Earth	1013 (sea level)	0.04%	78%	1%	21%

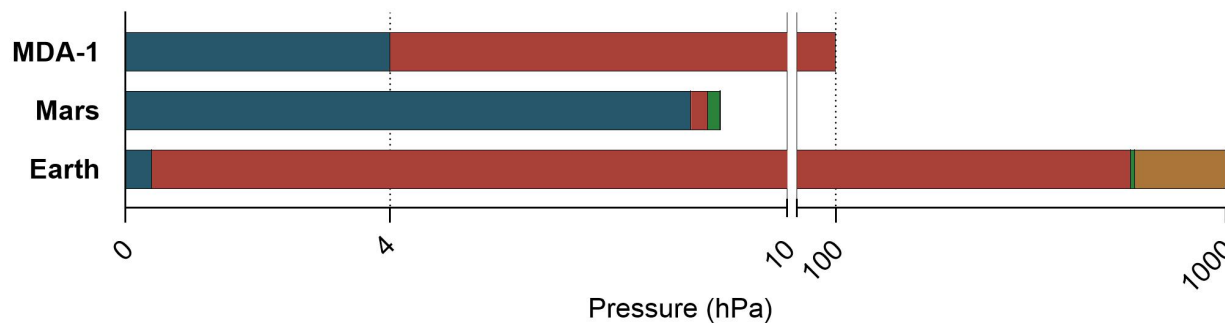




MDA-1

Mars-derived atmosphere 1

Atmosphere	Pressure (hPa)	CO ₂	N ₂	Ar	O ₂
MDA-1	100	4%	96%	0%	0%
Mars	6–11	95%	2.8%	2.1%	0.1%
Earth	1013 (sea level)	0.04%	78%	1%	21%



Gases from the Martian atmosphere

- non-limiting CO₂ (4 hPa)
- limiting, but exploitable, pN₂ (compromise: low total P)

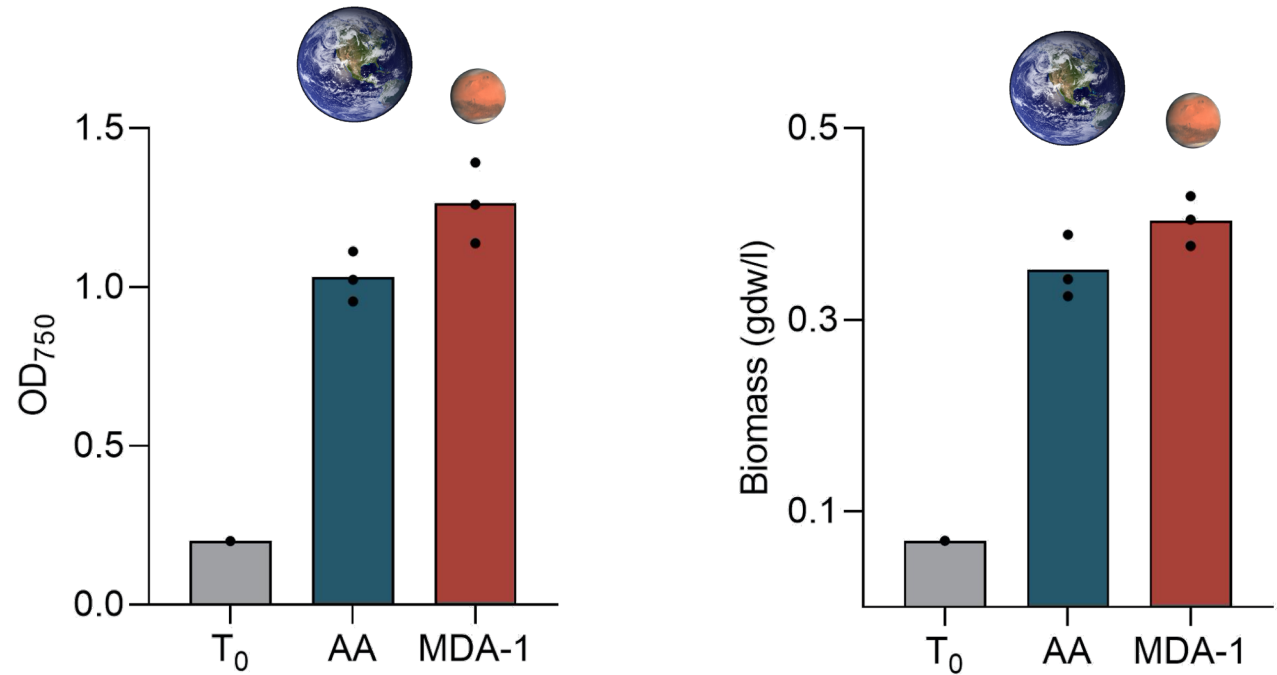
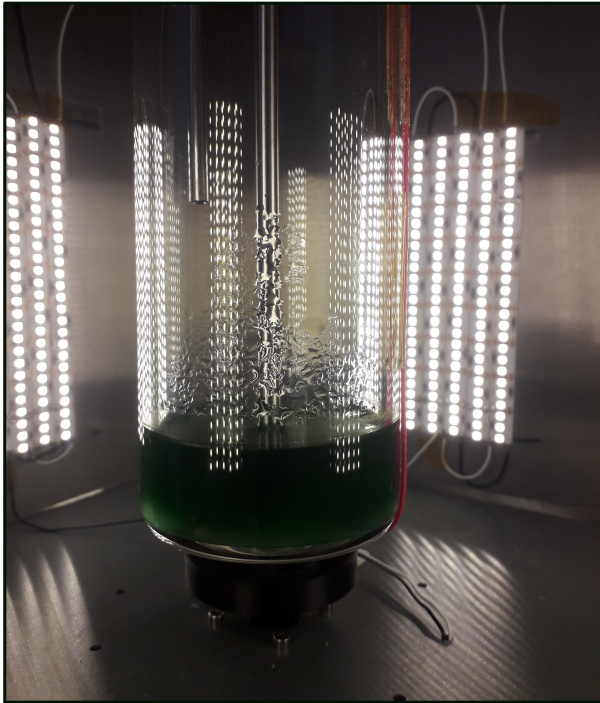
→ ***In situ* resource utilization**

Low total P (100 mbar)

→ **Lower engineering constraints.**

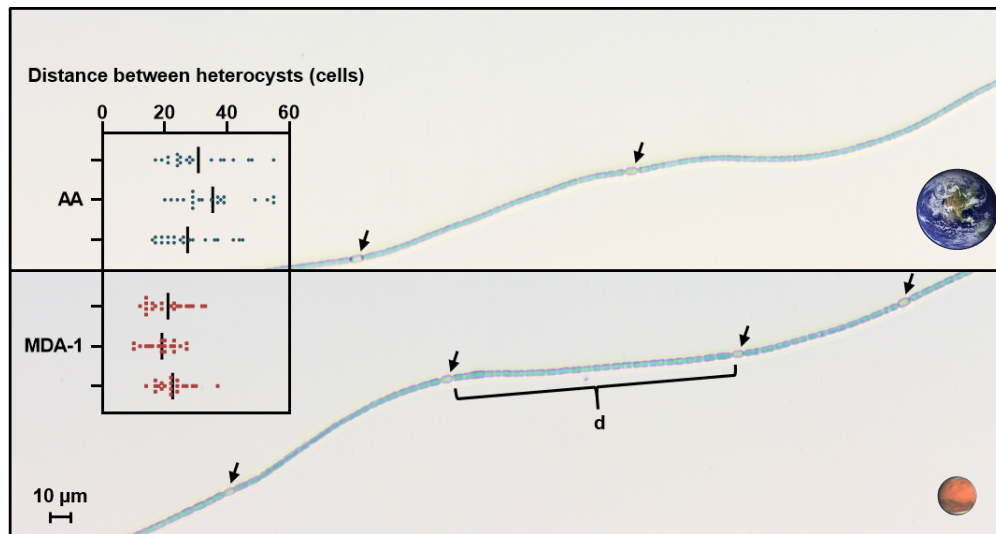


Vigorous growth of *Anabaena* sp. under MDA-1





Growth under MDA-1 induced physiological changes



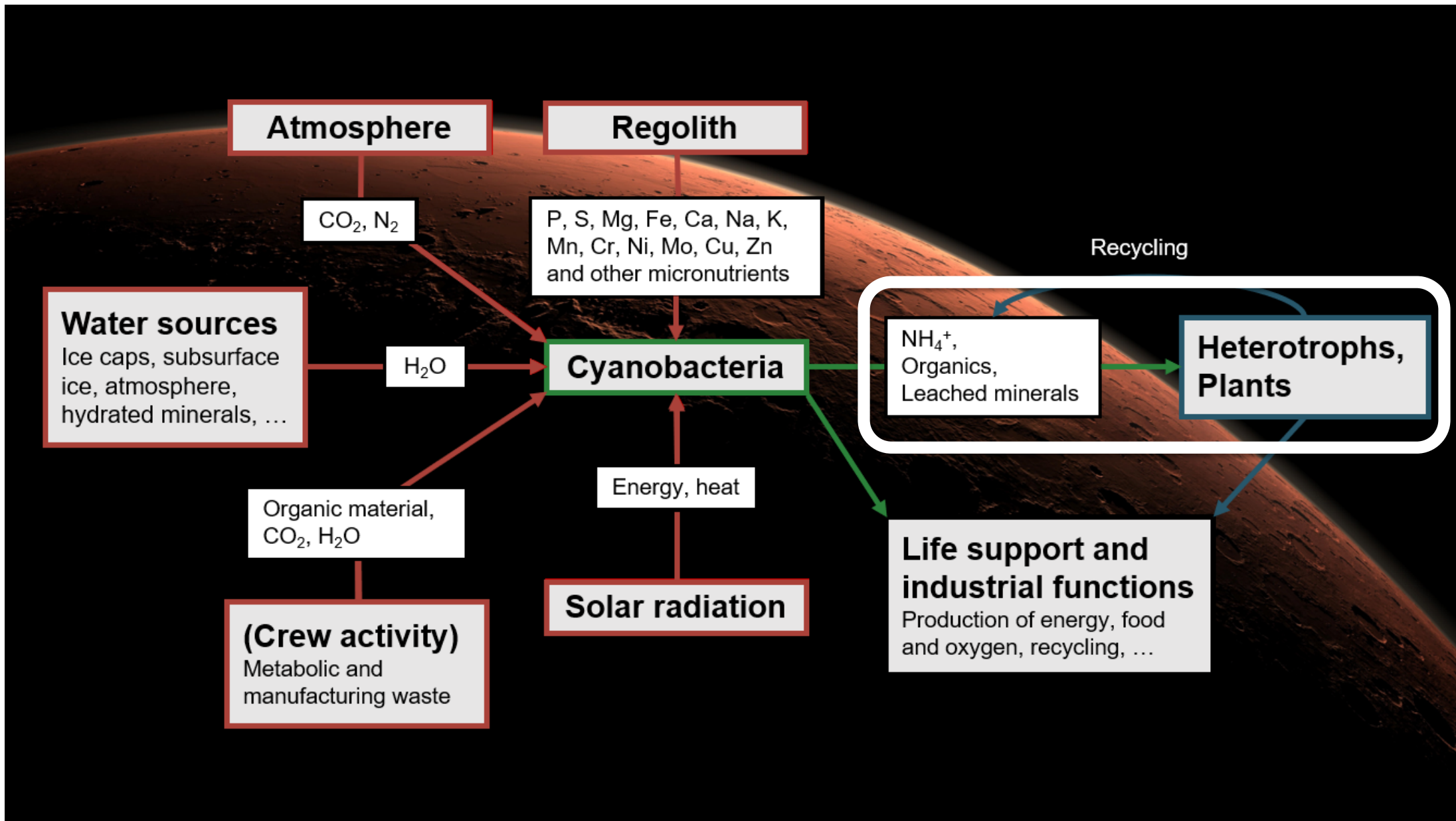
Physiological changes, as illustrated by:

← Reduced heterocyst spacing

↙ Reduced contents in soluble proteins

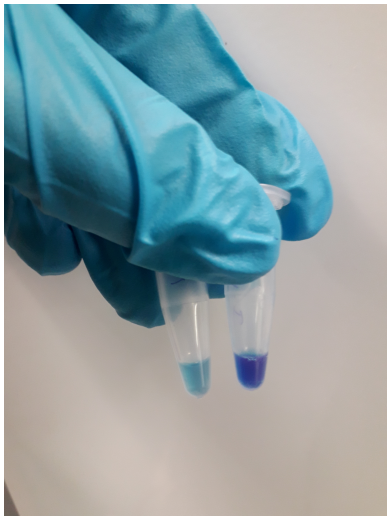
→ *Consequences for downstream applications?*

Atmosphere	Carbohydrates (A)	Soluble proteins (B)	A/B ratio
AA	21.8 (20.1–22.8)	22.4 (21.0–24.0)	0.97 (0.95–1.00)
MDA-1	22.1 (20.4–23.2)	18.3 (17.2–20.3)	1.2 (1.01–1.33)





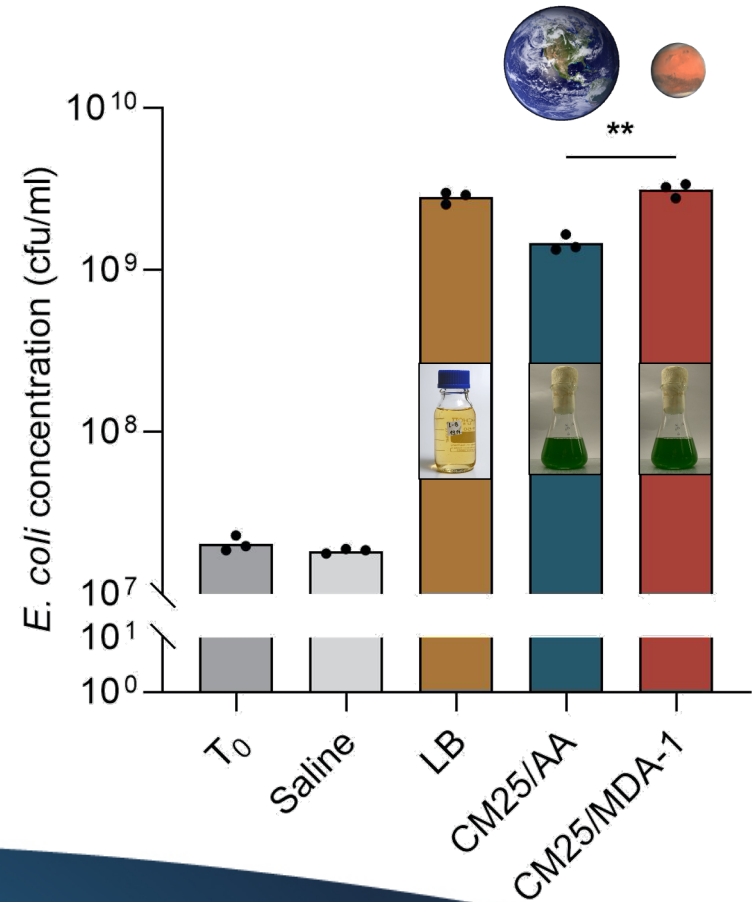
MDA-1 cyanobacterium extracts: remain suitable as a substrate for heterotrophs

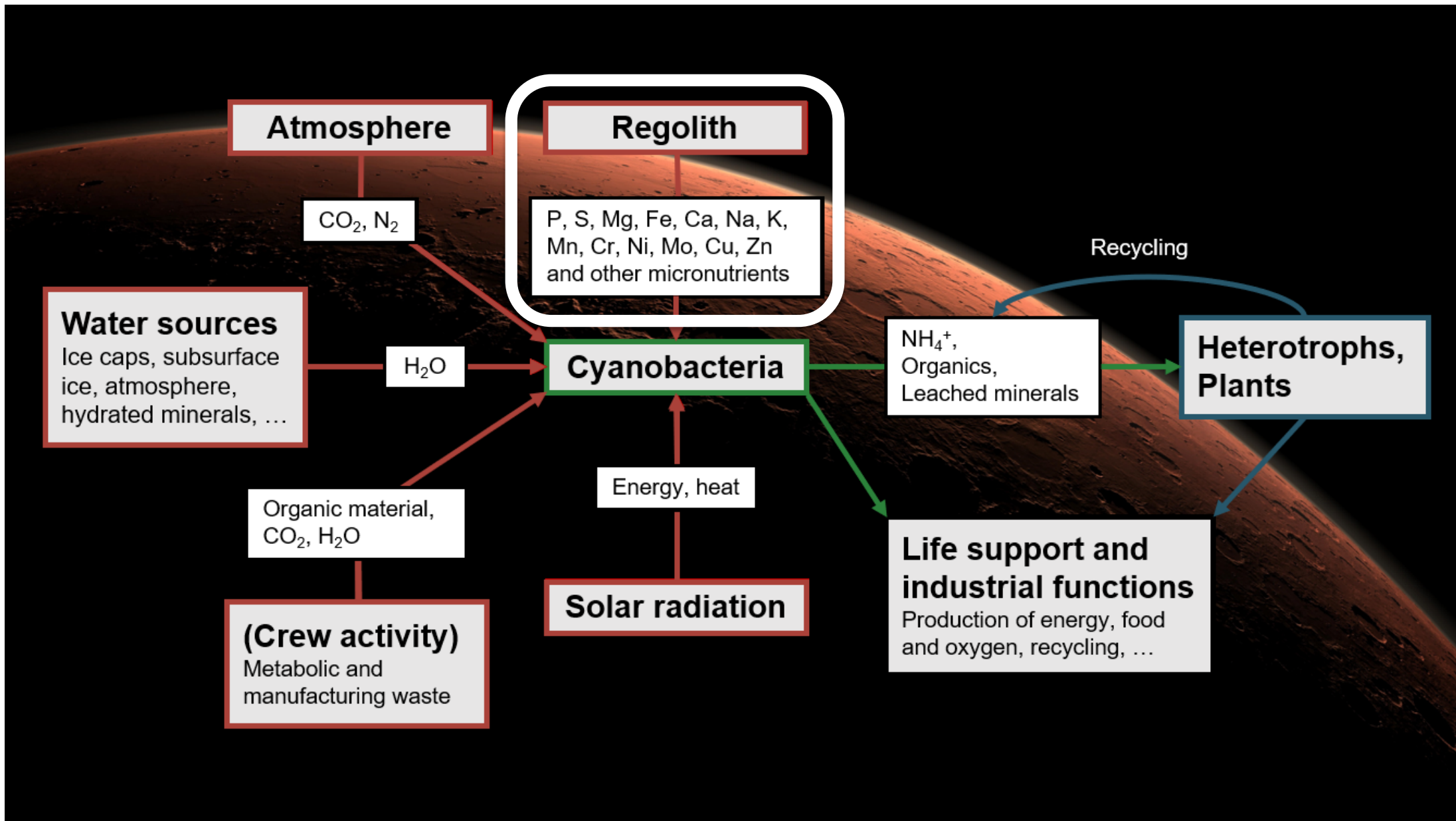


Dry biomass: ground,
resuspended at 25 g/L,
filtered.

Filtrate used as a substrate
to grow *E. coli* W.

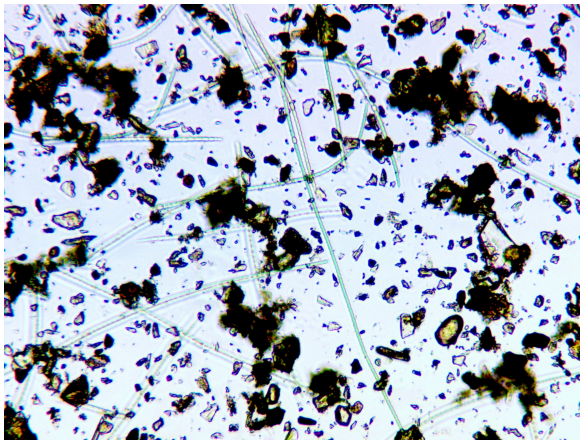
(Previous results, under AA: growth of various heterotrophs (several strains of *E. coli* and *B. subtilis*) and aquatic plants (*Lemna* sp.))



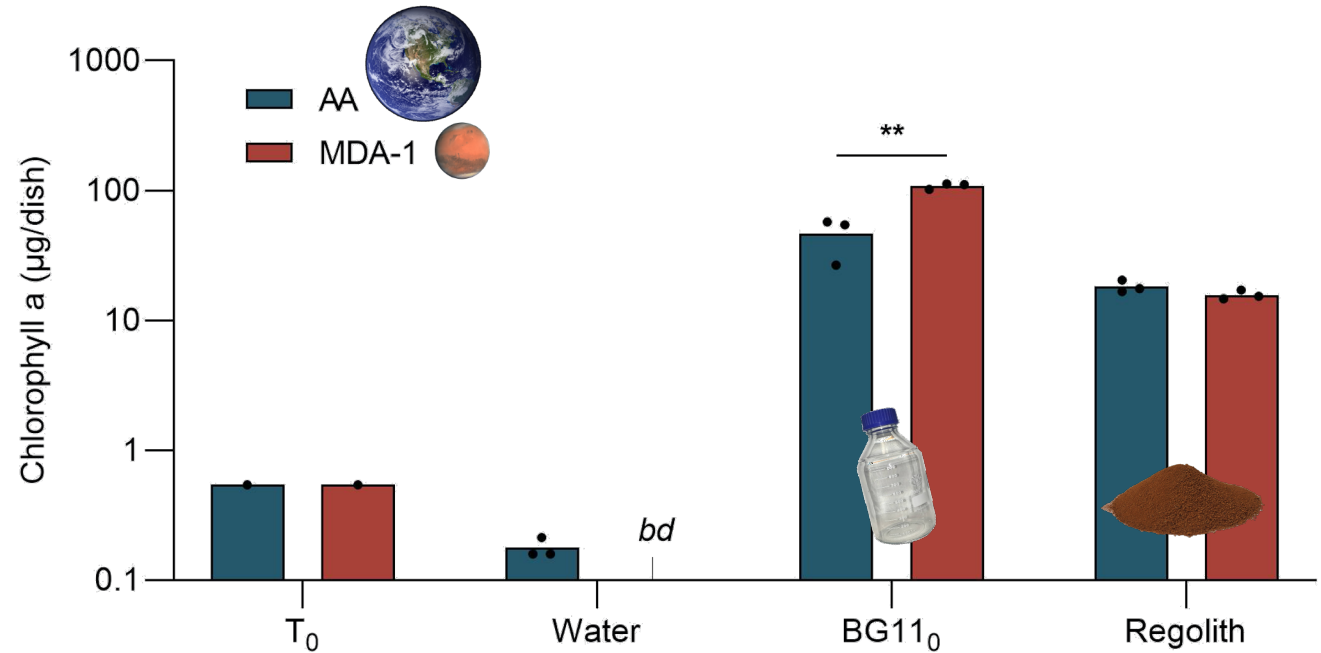




Cyanobacterial growth in regolith simulants: not impaired by MDA-1



Previous results, under AA: efficient growth of various cyanobacterium strains in various regolith simulants.



Growth in water and 5 g/mL regolith simulant (MGS-1)

In Atmos, with different setup: dish stack.



In short

- Cyanobacteria: suggested as a basis for ISRU-based BLSS.
- Atmospheric conditions influence feasibility and cost-effectiveness.
- We developed a low-pressure photobioreactor: Atmos. Collaborations welcome.
- First results: an N_2/CO_2 (96/4) atmosphere at 100 hPa is suitable for diazotrophic cyanobacterium growth in BLSS:
 - Vigorous growth of *Anabaena* sp.
 - Regolith-based growth not impaired.
 - Secondary producers seem not negatively affected.

MELISSA



MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE

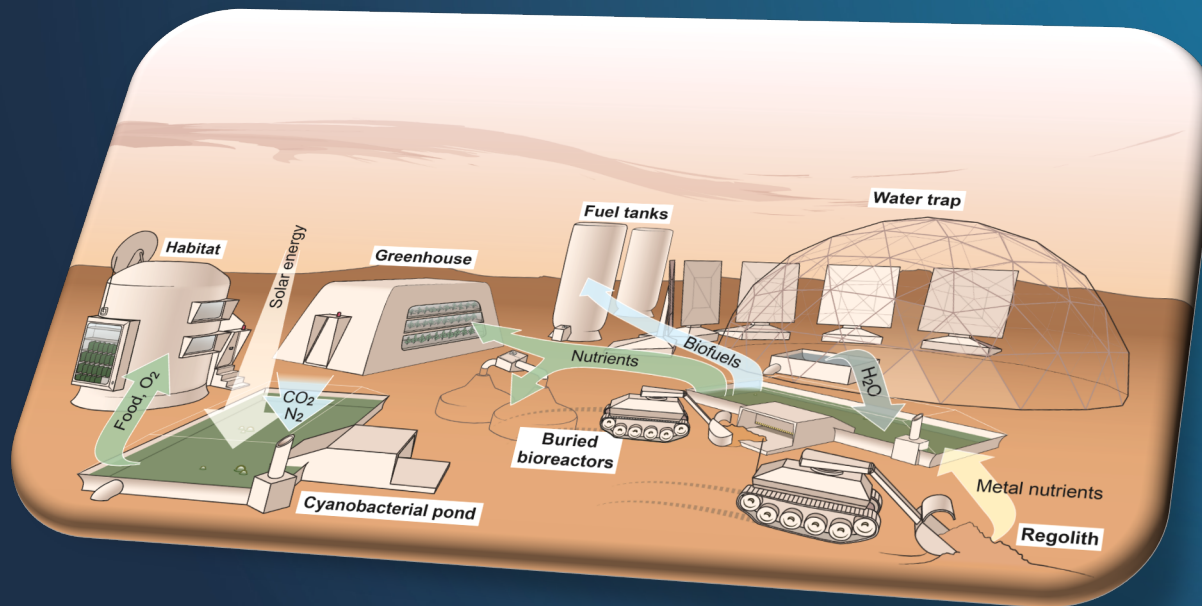
CENTER OF
APPLIED SPACE TECHNOLOGY
AND MICROGRAVITY



Unterstützt von / Supported by



Alexander von Humboldt
Stiftung / Foundation



THANK YOU.

Cyprien Verseux
ZARM, U. of Bremen

cyprien.verseux@zarm.uni-bremen.de

We are also grateful to:

- Prof. M. Avila (ZARM director)
- R. Mairose, M. Stadtlander, P. Prengel and K. Krömer (ZARM engineers)