Astrobiological Studies on Extremophiles and Its Application for Desertification Control

Fengyuan Zhuang[1], Yongding Liu[2]

1. School of Astronautics, Beihang University, Beijing, CHINA; E-mail: *zhuangfy@buaa.edu.cn*
2. Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, CHINA; E-mail: *liuyd@ihb.ac.cn*

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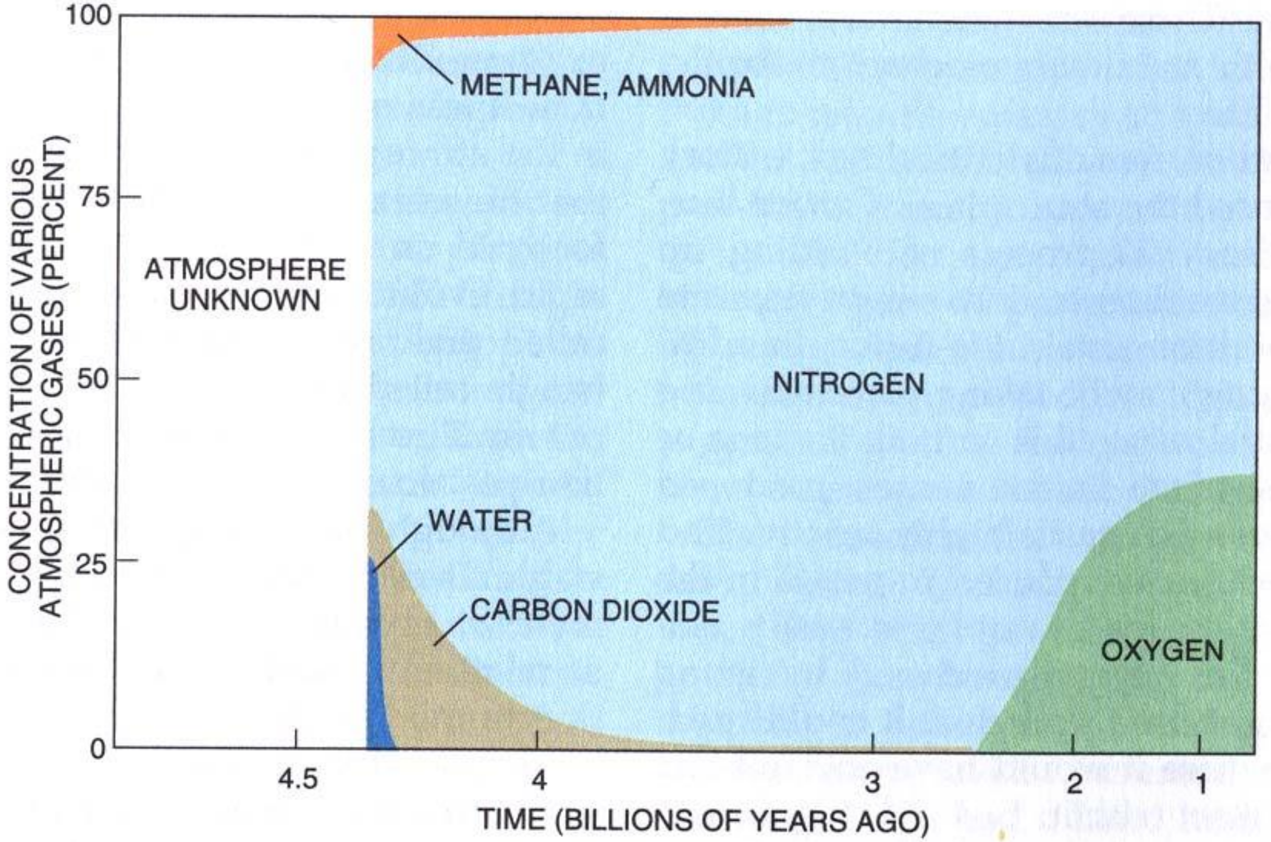
Astrobiology is the study of the origin, evolution and distribution of life in the context of cosmic evolution.

Cyanobacteria are one kind of **Extremophiles**, appeared on the early Earth (From 3.5Ga to 2.1 Ga ago), **use photosynthesis to make their own food, and** have tolerance to desiccation, cold and hot weather, nutrient starvation and ionizing radiation, and live everywhere on Earth from desert to alkaline, salinity and acidity aquatic environments .

Cyanobacteria are important research objects for Astrobiology from life origin, study on early Earth, to the space life exploration, space application.

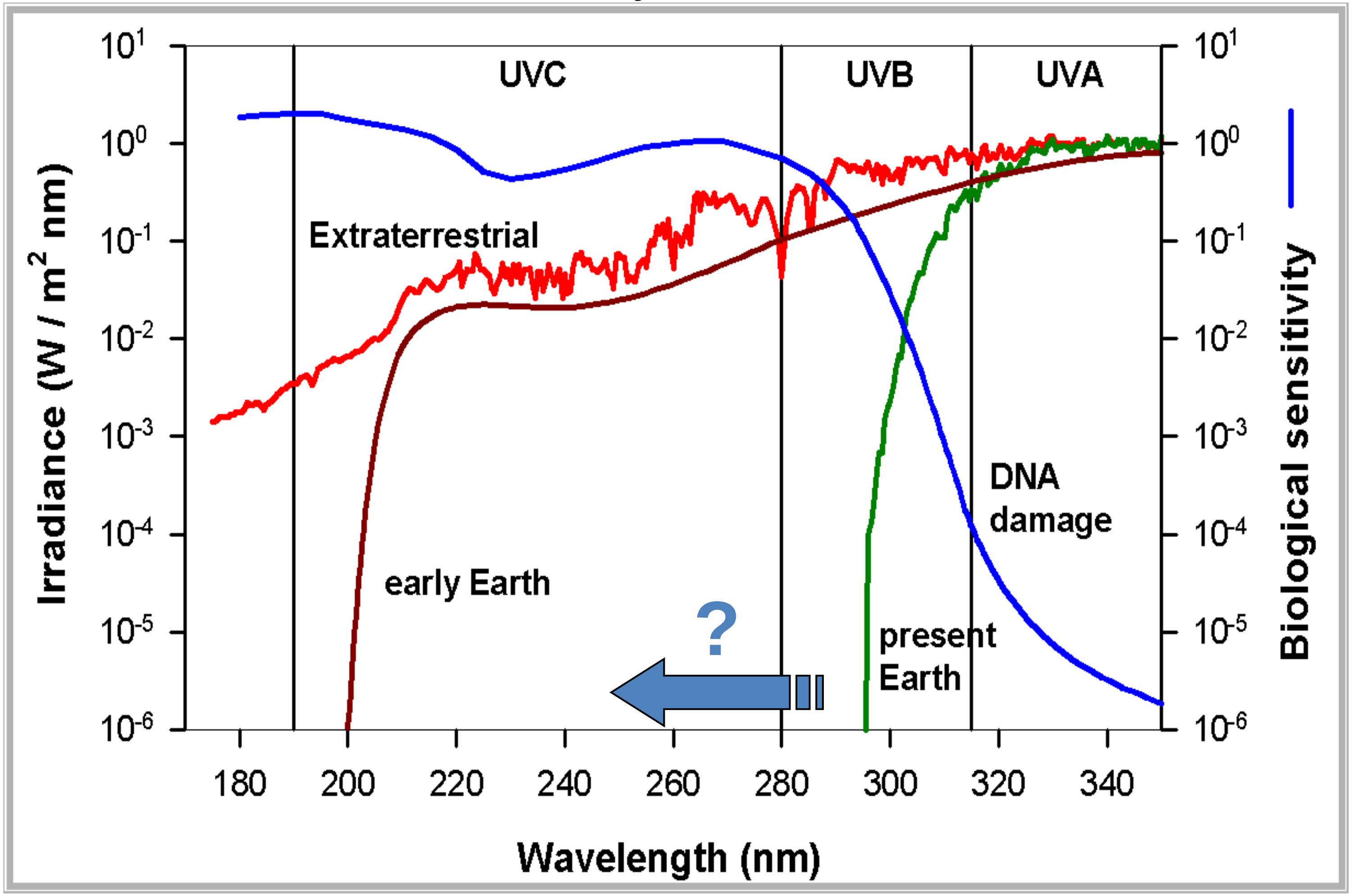
http://astrobiology.com/1998/04/what-is-astrobiology.html

The atmosphere of the early Earth



Cyanobactria are important for the early Earth Environment change:
Form of Soil on surface of Earth, the Concentration of components of atmosphere, UV radiation on surface of Earth

Solar UV Radiation for Early Earth and Present Earth



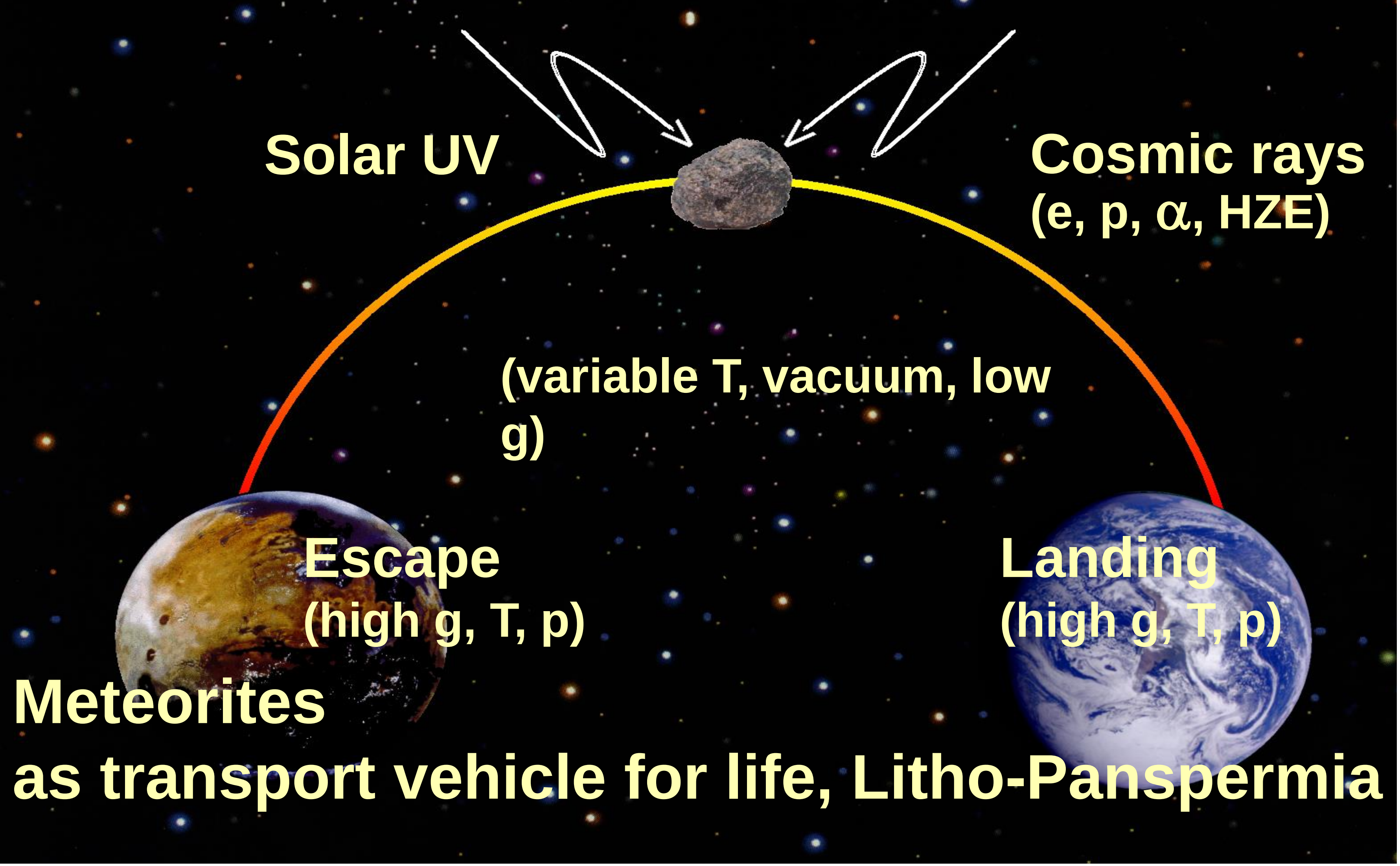
Cyanobactria are important for the early Earth Environment change: Form of Soil on surface of Earth, the Concentration of components of atmosphere, UV radiation on surface of Earth

Pictured above are two kinds cyanobacteria from the Bitter Springs chert of central Australia, a site dating to the Late Proterozoic原生代的, about 850 million years old. On the above is a colonial chroococcalean form, and on the bottom is

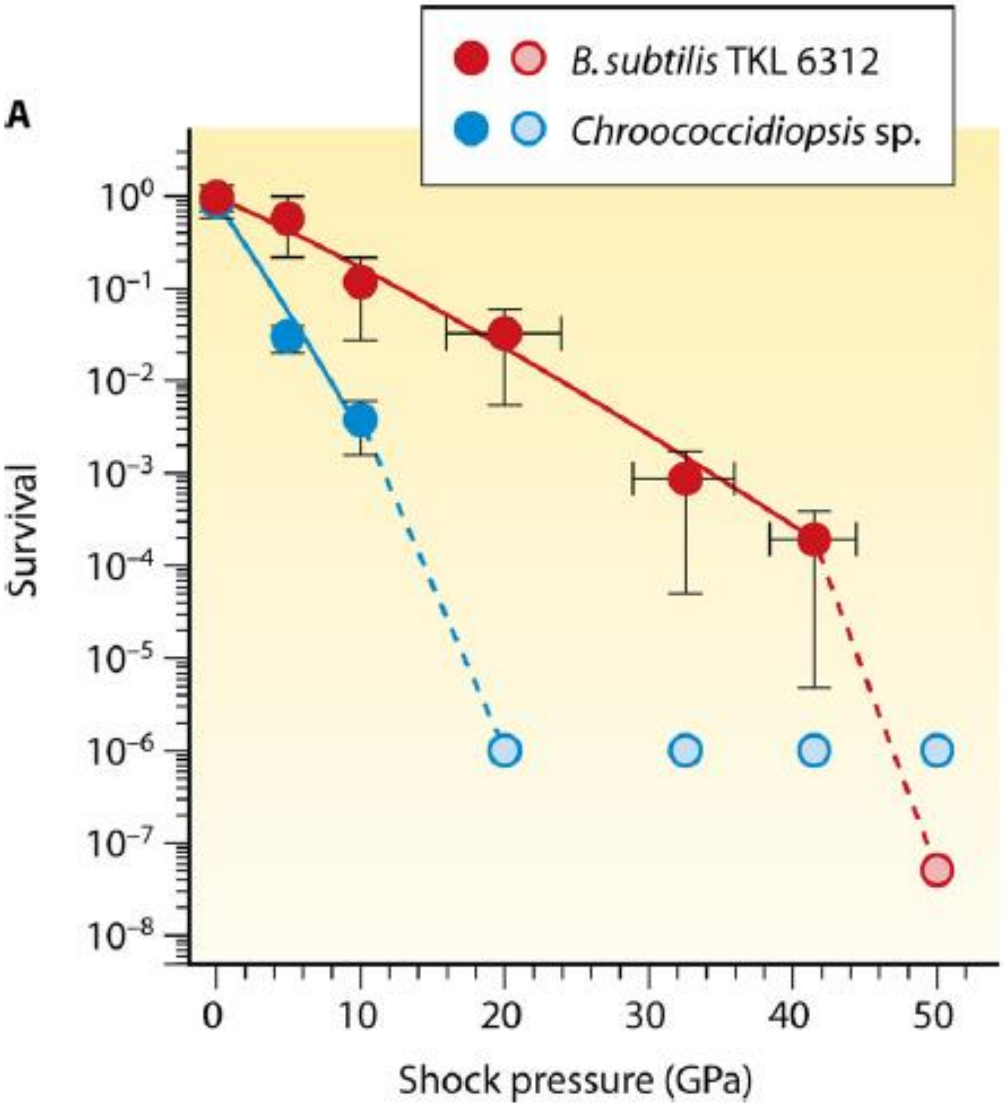
thefilamentous *Palaeolyngbya*.

Cynanobactria are one of earliest life on Earth,

Stromatolites are layered bio-chemical accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains by biofilm (microbial mates) of microorganisms, especially CYANOBAERIA. **Fossilized stromatolites provide ancient records of life (especially CYANOBACTERIA)on Earth by these remains, which might date from more than 3.5 billion years.**(The cyanobacteria have an extensive fossil record. The oldest known fossils, in fact, are cyanobacteria from Archaean rocks of western Australia, dated 3.5 billion years old.)

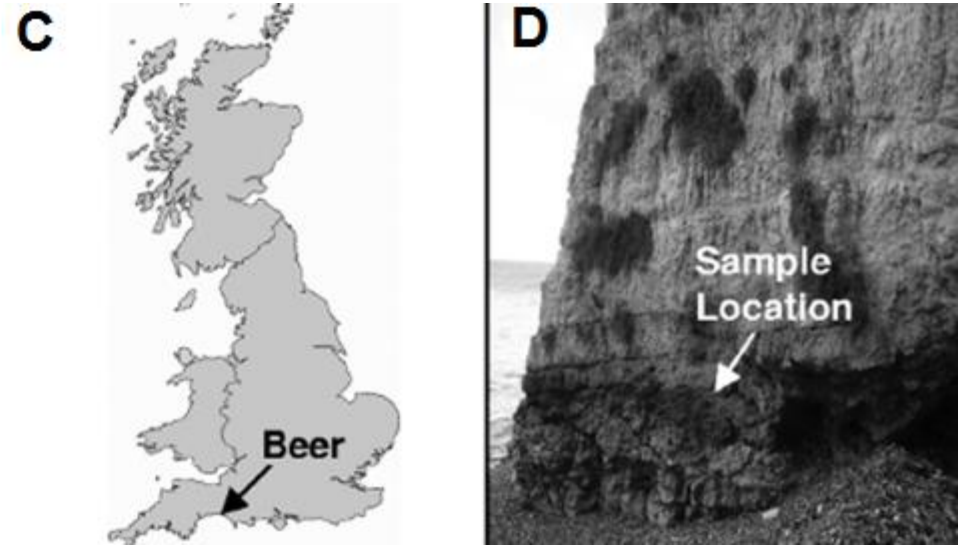


What kind of life can be transported via Meteorites between planets; Litho-Panspermia via Escape, Journey in space, and Landing. Cynnobactria may be these objects.



Survival as a function of applied shock pressure during shock recovery experiments with spores of *B. subtilis* TKL 6312 and cells of *Chroococcidiopsis* sp. One kind of Cyanobacteria. For simulation the escape process by impact, and ejction. *Chroococcidiopsis* sp. can sustain 10 Gpa Shock pressure.

Gerda Horneck MICROBIOLOGY AND MOLECULAR BIOLOGY REVIEWS, Mar. 2010, p. 121–156



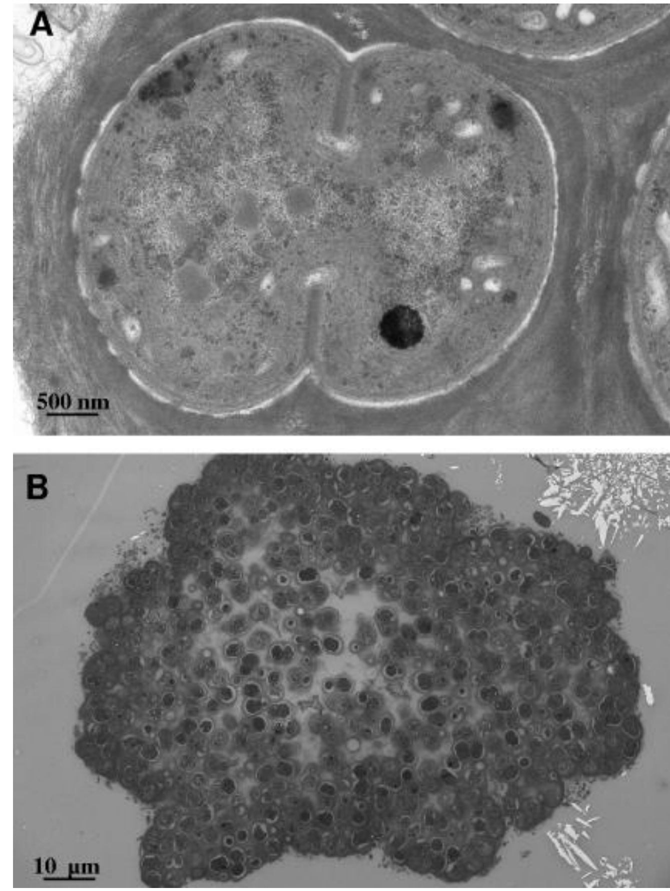
Natural Biofilms of Cyanobactria on rocks were exposured to Space, the Microbial Community dwelling rocks were cut into blocks with an upper surface area of 1 cm^2 and were exposured to LEO for ten days.

C: Location of a limestone cliff in Beer, Devon, United Kingdom

D:Sample Location at the limestone

A and B: TEM images of the Cyanobacterium OU_20 that survived

exposure to low Earth orbit for ten days.



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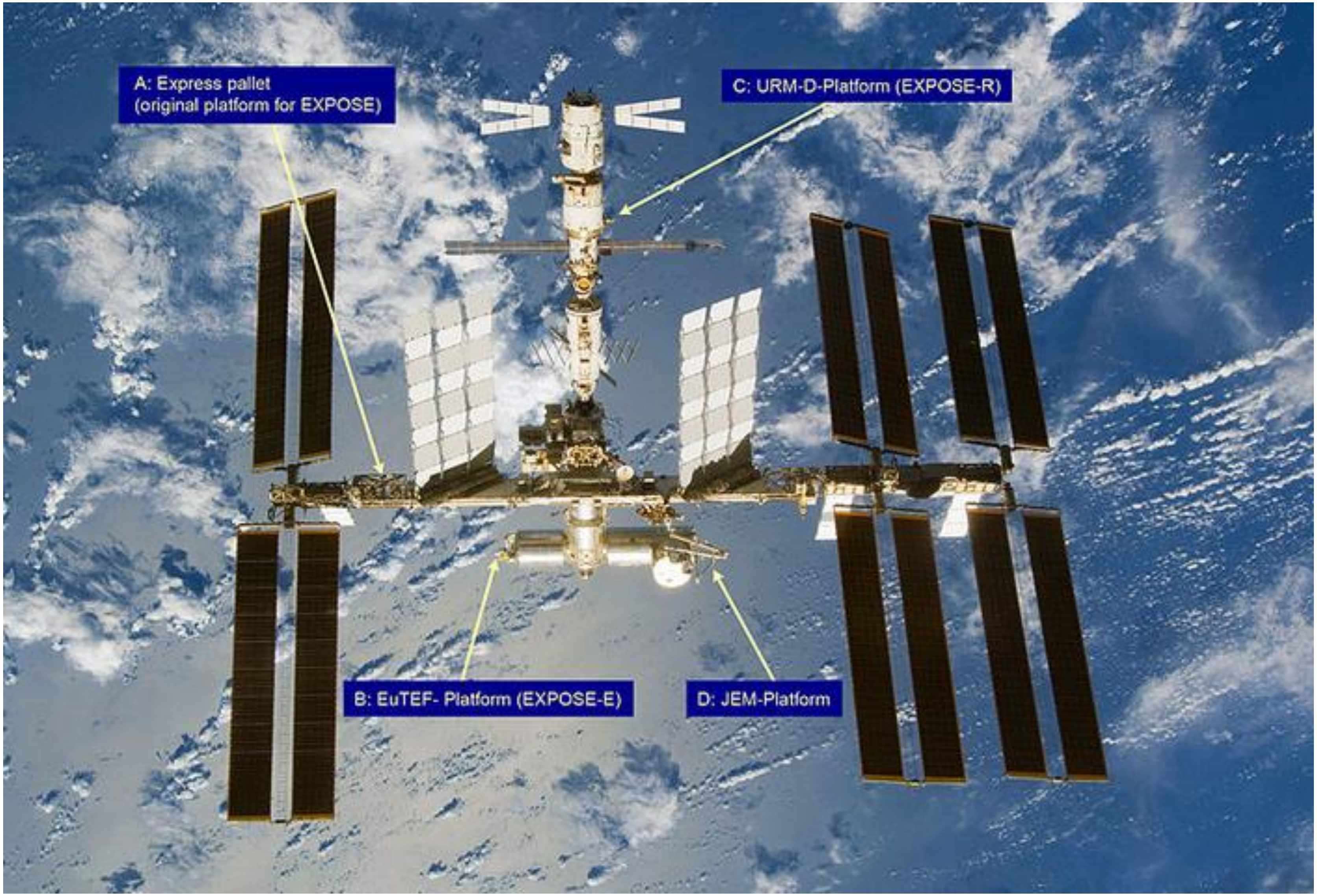
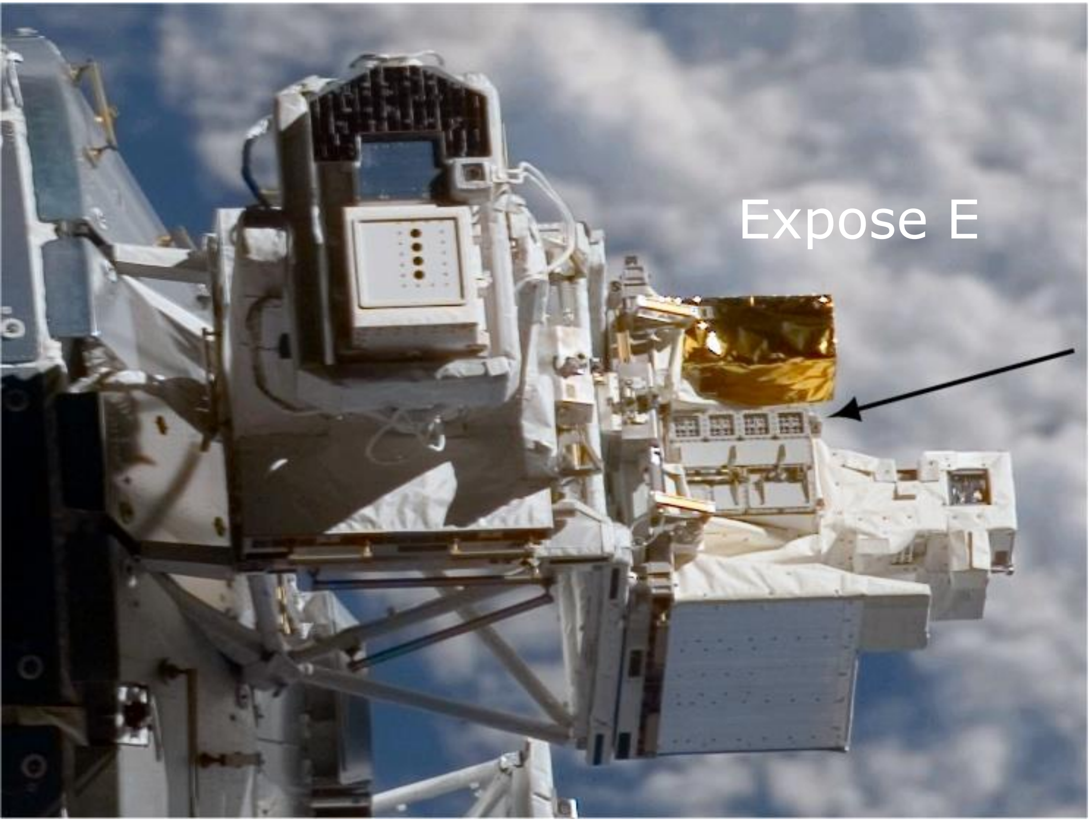
From :Karen Olsson-Francis
APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Apr. 2010, p. 2115–2121



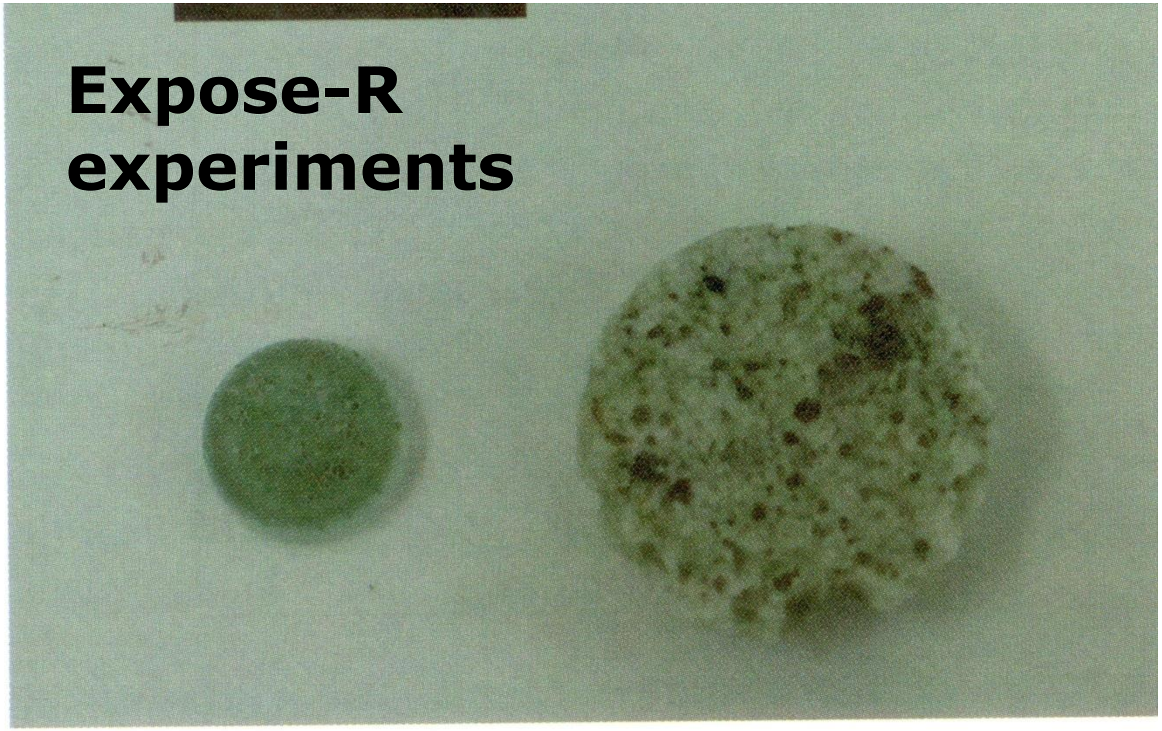
Expose-E From Feb. 15,2008 to Sep.2, 2009 for 548 days and Expose-R From Mar, 11,2009 to Jan.21,2011 for 682 days were executed at ISS expose platform.



The natural phototroph biofilm augmented with akinetes (dormant type) of *Anabaena cylindrica* and vegetative cells of *Nostoc commune* and *Chroococci diopsis,* was launched into low Earth orbit, and exposed to conditions in outer space for 548 days on the European Space Agency EXPOSE-E facility outside the International Space Station.

Results: **Only cells of *Chroococcidiopsis* were cultured from samples exposed to the unattenuated extraterrestrial ultraviolet (UV) spectrum (>110 nm or 200 nm)** , **on present Earth < 290nm UV can not reach on the surface of Earch, but not for early Earth** From Charles S Cockell et al The ISME Journal (2011) 5, 1671–1682

Expose-R experiments

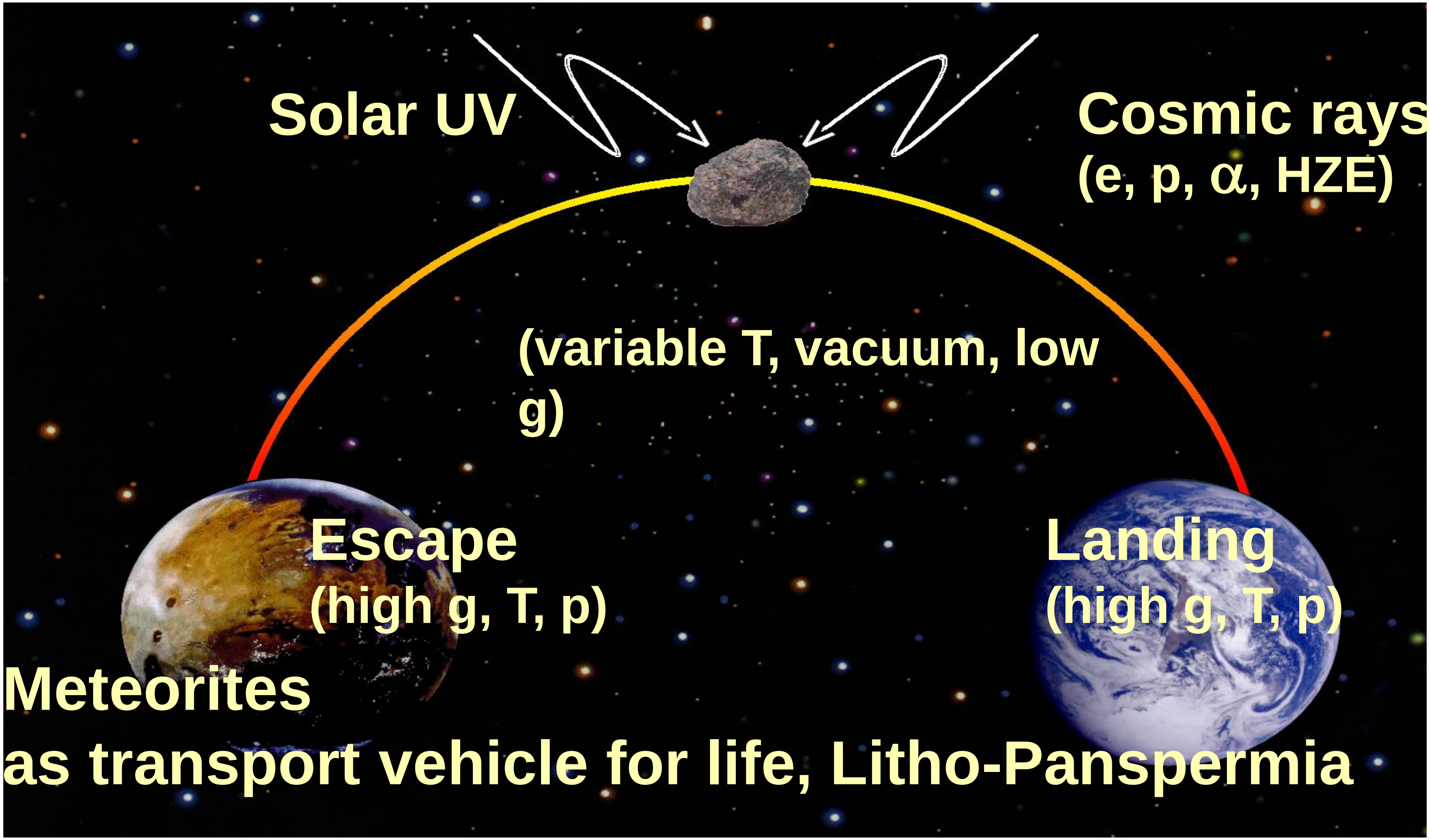


An aliquot of cells (chroococcidiopsis sp. CCME 029) were transferred onto the surface of 0.5cm diamter glass disc(left) and **1cm-diameter and 5mm thick disc of impact-shock gneiss (one kind of porous stone) (right).**

36 Inoculated glass discs and 12 rock discs were fixed into Expose-R facility, and exposed to LEO environment, Six rocks discs were exposed to 100% of UV radiation, and other 6 discs kept dark.

Result: Post flight check showed : **Organisms within impact-shocked gneiss exposed to the intense 100% UV radiation environment in LEO for 22 months were viable on their return to Earth.** Complete loss of viability for all of organisms on glass discs were found. (Casey C.B International Journal of Astrobiology 14(1): 115-122(2015)

Left: **Geologist Gordon Osinski standing near a large block of shocked gneiss**
Photo: G. Osinski, Canadian Space Agency
Location: Inside the Haughton impact structure, Devon Island, Canada
Right: **Example of shocked gneiss in the Impact Rock Kits**
Photo: F. Chuang, Planetary Science Institute
Location: Inside the Haughton impact structure, Devon Island, Canada



Cyanobactria is the possible life for Litho-Panspermia protedcted by porous rocks or by augumented biofilm, about landing we still need to consider.

Use of cyanobacteria for in-situ resource use in space applications Karen Olsson-Francis n, et al *Advances in Microbiology*, **2013, 3, 80-86**

Cyanobacteria, as Lithotrophic microorganisms may be used for in-situ resource exploiting in space applications. such as oxygen, fuel and biomass production, nutrient acquisition, extraction of elements and feedstock provisions.

Gloeocapsa strain OU_20, Leptolyngbya strain OU_13, Phormidium strain, Chroococcidiopsis 029; Arthrospira platensis; Synechococcus elongatus; and Anabaena cylindrica, were examined as potential organisms for space in-situ resource use**.**

Here Volcanic rocks, including basalt(low in SiO2) analogous to martianand lunar basalt, rhyolite(highinSiO2), and anorthosite analogous to lunar regolith were used as growth substrates for Cyanobactria.

We can observe that Elemental release from the volcanic rock the cyanobactria grow on , which was measured at the end of the experiment. A 10ml aliquot of culture sample was filtered through a 0.2 µm nylon syringe filter and acidified with concentrated HNO3 (final 5%acid). Here we cited the final element concentration after 45 days growth for Anabaena Cylindrica， and Phormidium Strain OU-10 with dd H_2O and Basalt as growth media.

	Ca (µM)	Cu (µM)	Fe (µM)	K (µM)	Li (µM)	Mg (µM)
Control No-biological	31.210	B.D	0.265	27.250	1.247	54.254
Anabaena Cylindrica	61.481	B.D	6.881	125.042	21.997	55.232
Phormidium Strain OU-10	42.477	5.126	5.498	56.167	11.025	55.264

Elemental release from the volcanic rock by Cyanobacteria, which value depend on different species and rocks. And for the non-nitrogen fixers the nitrogen compounds have to be added. Then mixed species of Cyanobacteria may be prefered.

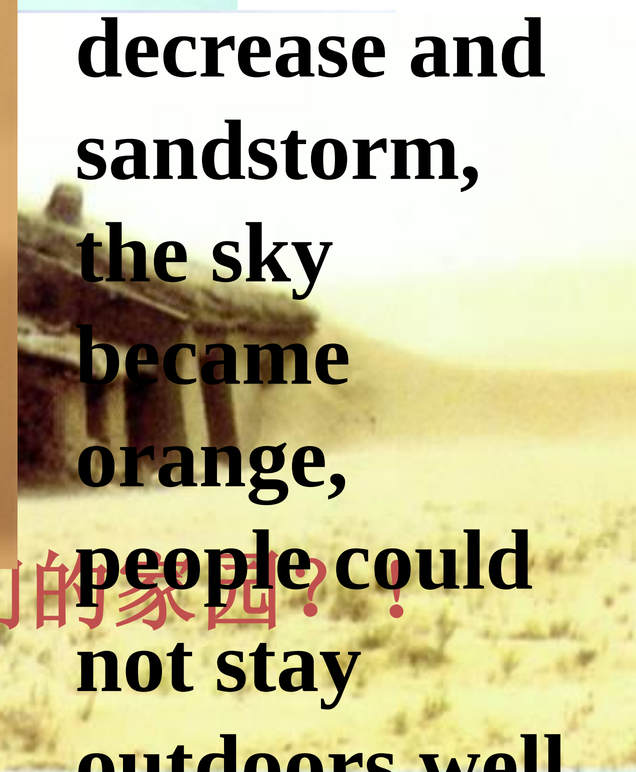
	Mn (µM)	Na (µM)	Ni (µM)	Sr (µM)	Zn (µM)	SiO_4 (µM)
Control No-biological	B.D	0.148	B.D	0.032	0.410	75.062
Anabaena Cylindrica	B.D	0.492	0.115	0.642	1.369	125.351
Phormidium Strain OU-10	0.625	0.214	B.D	0.140	1.115	121.323

Cited from Karen Olsson-Francis n, et al ***Advances in Microbiology*, 2013, 3, 80-86**

United Nations Convention to Combat Desertification

- **Desertification is one of the major environmental problems facing humankind;**
- **China is one of the countries most affected by desertification in the world, is a party to the United Nations Convention to Combat Desertification;**
- **In the country's 1.73 million km^2 of desertified land, 530,000 km^2 could be managed, but will take about 300 years, according to estimates.**
- **Desertification control needs to increase investment, and also calls for supports of the Innovation and Technology.**

Sandstorm



Strong wind caused temperature decrease and sandstorm, the sky became orange, people could not stay outdoors well.

我们的家园？！

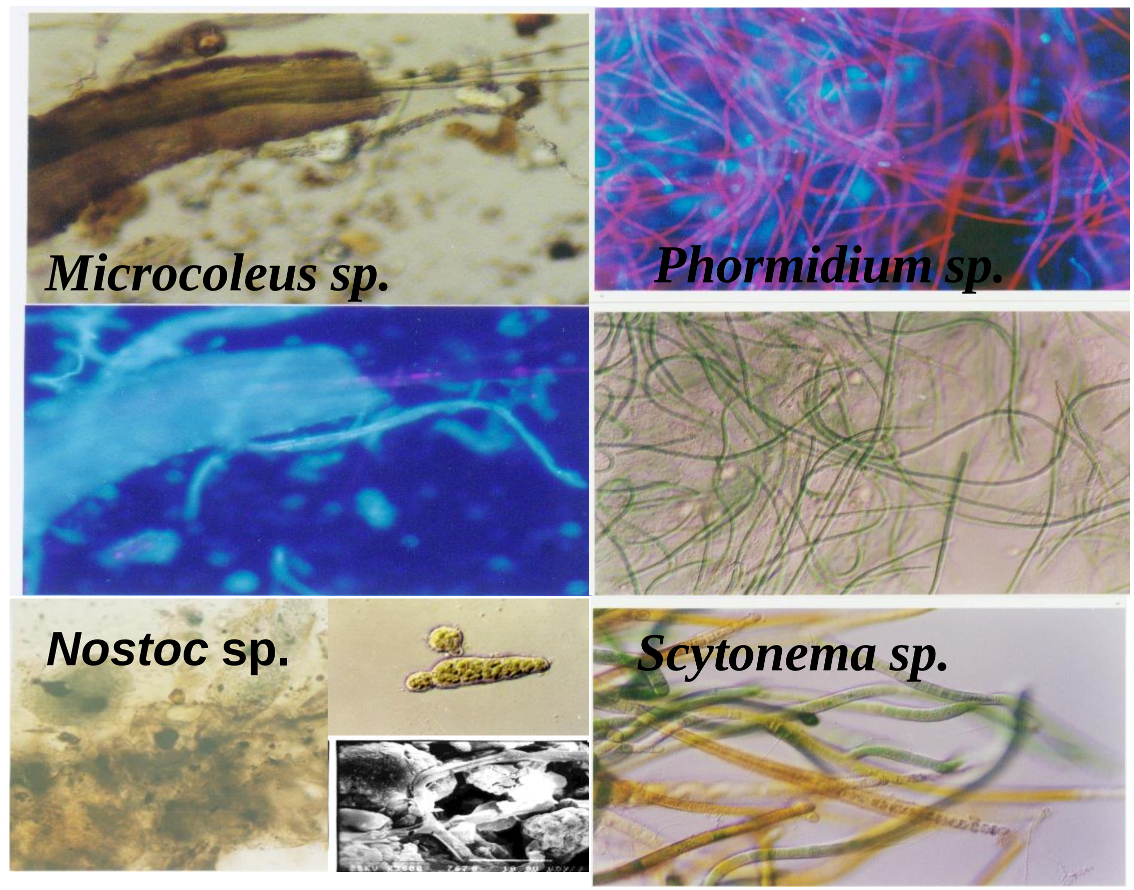
Biological Soil Crust formation can prevent desertification for covering sands.
The vertical distribution of cyanobacteria and microalgae in the **biological soil crusts** was distinctly laminated Liu From Liu Y.**ASTROBIOLOGY Volume 8, Number 1, 2008**

This ia a Biological Soil Crust formed on the surface of the desert.

Main Cyanobacteria in Biological Soil Crust (BSC)

The authors' team isolated desert cyanobacterial strains from the Biological Soil Crust (BSC), *e.g.*,for using to form BSC.

Cyanobacteria
Aphanocapsa **sp.**
O.tenuis **Ag.**
Phormidium africanum **Lemm.**
P. jadinianum **Gom.**
P. jenkelianum **Schmid.**
P. tenue **(Men.) Gom.**
Phormidium **sp.**
L. dendrobia var. skujaii **Skuja**
L.martensiana **Men.**
L. semiplena **(C.Ag.) I. Ag.**
Schizothrix arenaria **(Berk.) Gom.**
Schizothrix fragilis **(Kutz.) Gom.**
S. friesii **(Ag.) Gom.**
S. mascarenica **Gom.**
Schizothrix **sp.**
M. vaginatus **(Vauch.) Gom.**
Calthrix **sp.**



Principles of man-made algal crusts

1. Photosynthetic cyanobacteria as pioneer in colonization of the sandy land
2. Cementation and sand fixation by man-made blue algal (another name of Cyanobatria) crust
3. Soil formation by biological process
4. Systematic Ecological Environment transformation

Cyanobacteria produce Biomass and Organic Matter to colonize the desert

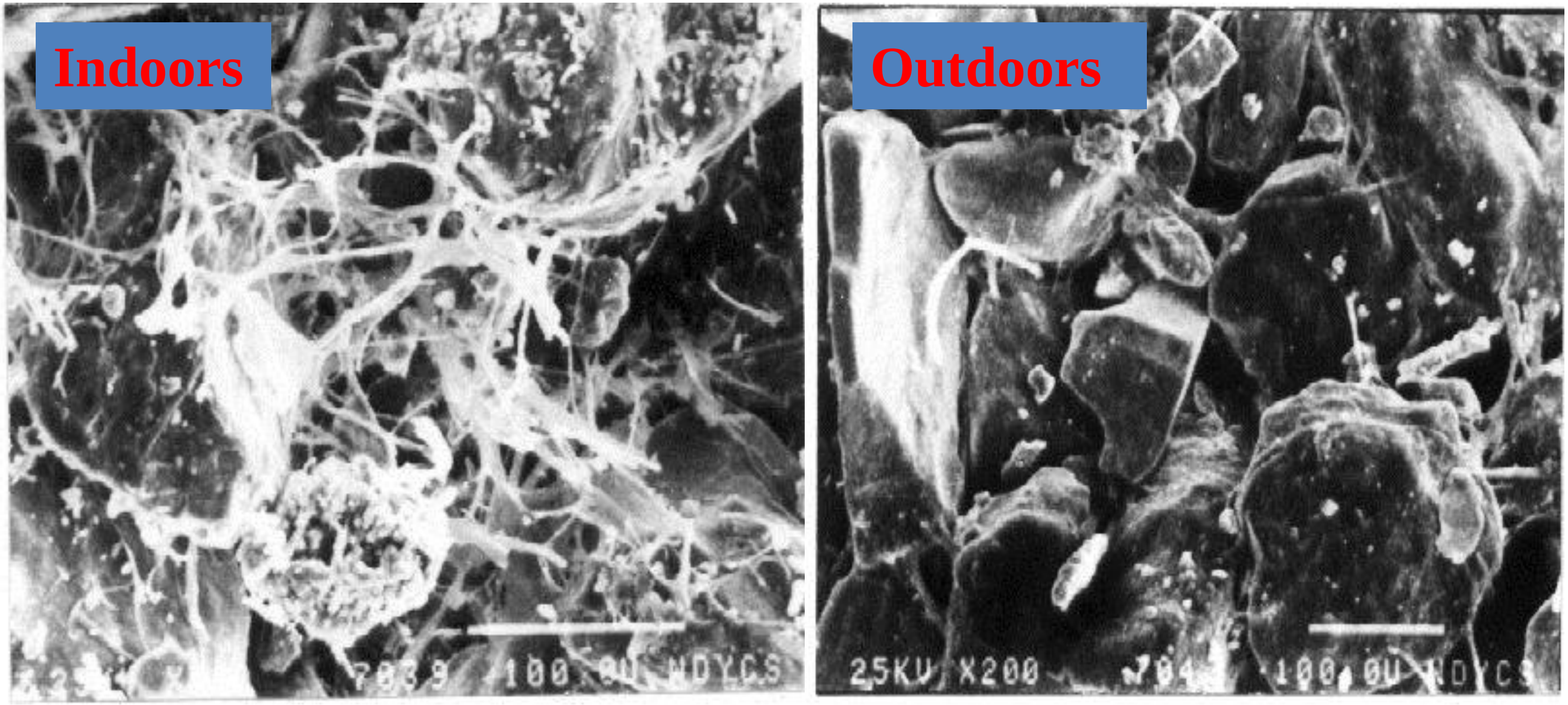
EPS from the pioneer cyanobacteria make great contribution in colonization

Crusts	pH	Biomass (mg g^{-1})	Organic matter (mg g^{-1})[a]	Amorphous oxides			
				$CaCO_3$(mg g^{-1})[b]	Fe_2O_3(μg g^{-1})	Al_2O_3(μg g^{-1})	SiO_2(mg g^{-1})
ST1	8.33±0.04	10.56±1.34	13.76±0.87	49.96±0.12	0.040±0.008	3.55±0.01	0.15±0.01
ST2	7.96±0.00	7.19±0.08	10.26±0.56	45.78±0.94	0.035±0.000	3.12±0.06	0.14±0.01
ST3	7.97±0.01	8.88±0.10	11.45±0.82	43.64±0.84	0.040±0.001	3.08±0.08	0.15±0.00
ST4	7.99±0.02	2.06±0.06	8.68±0.10	35.36±0.09	0.030±0.001	3.25±0.00	0.14±0.00
FC	8.10±0.03	3.82±0.68	5.19±0.31	32.75±0.11	0.030±0.006	2.47±0.01	0.16±0.00
IC	7.89±0.01	3.34±0.31	3.57±0.44	32.35±0.07	0.026±0.007	3.03±0.01	0.16±0.01

Samples are taken with same culture time and protocol on sands.
There is a significant correlation between a and b. If the content of $CaCO_{3}$ is high, the organic matter is high too.

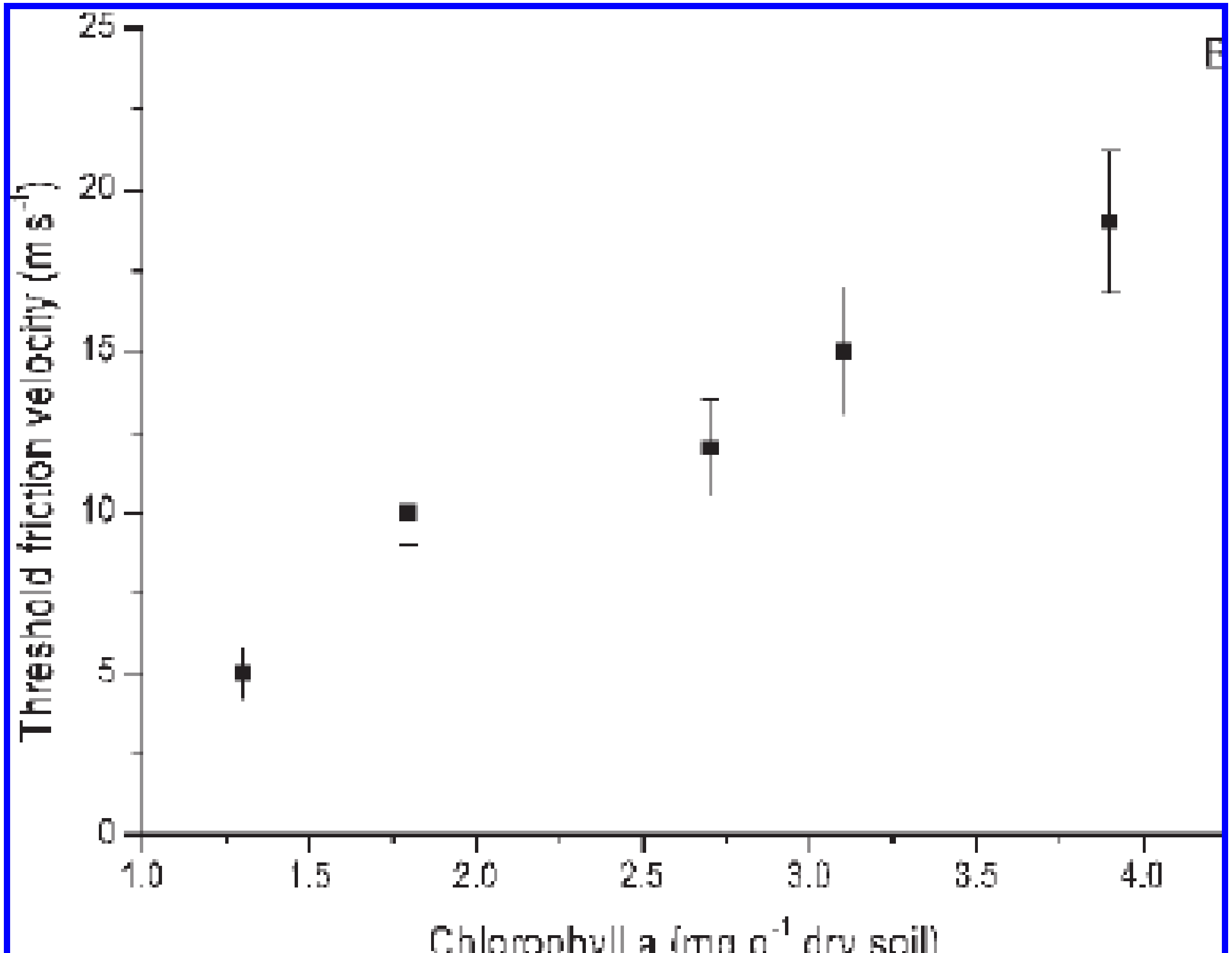
Cyanobacteria produce EPS/OM to colonize the desert

EPS from the pioneer cyanobacteria make great contribution in colonization



Produce **Extracellular Polysaccharides, OM Organic Matter**
And filaments for sticking the sand granula can be obsevered.

Cyanobacterial BSCs promote the soil surface stable

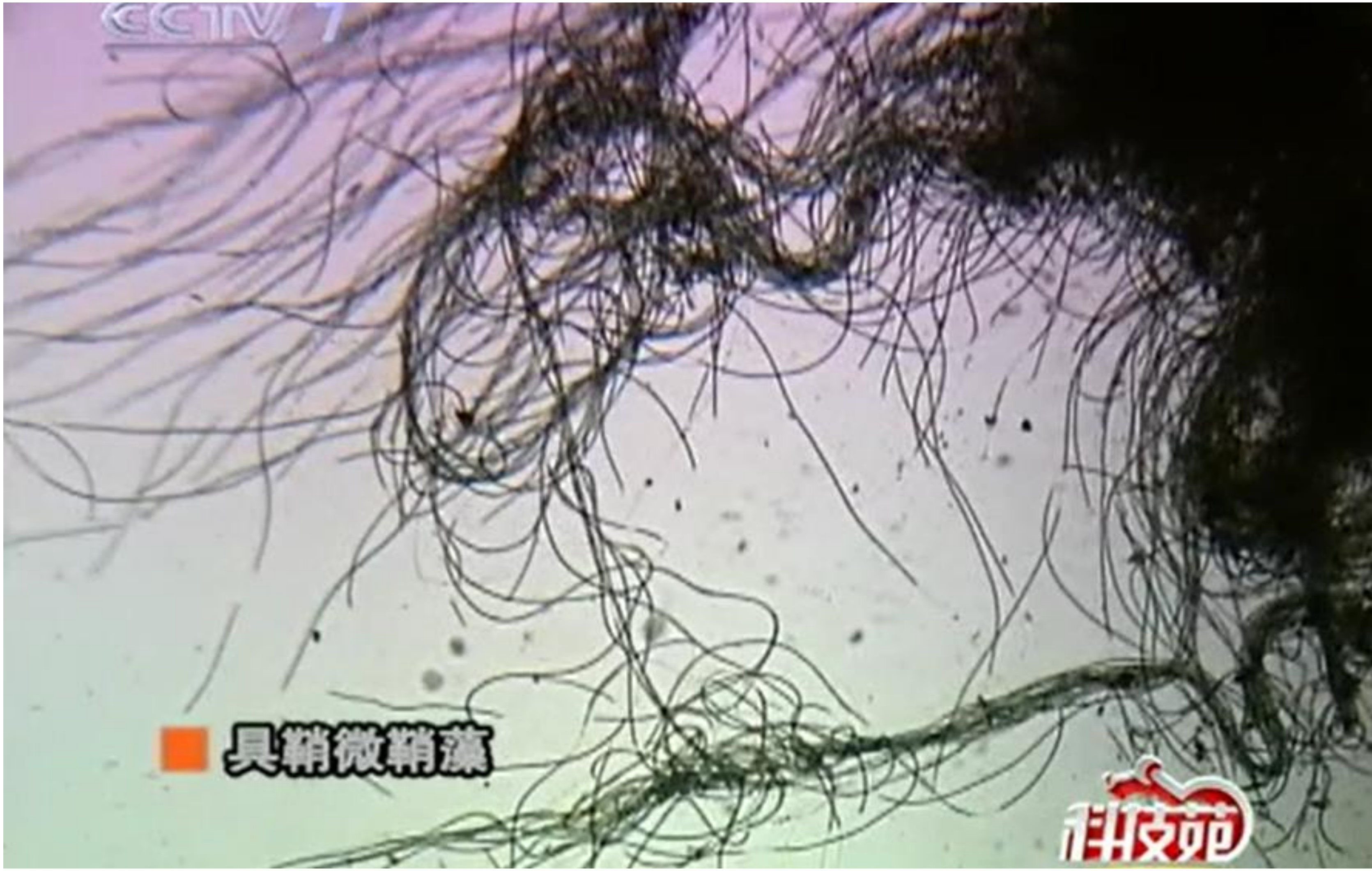


The wind velocity for sand holding versus Chorophyll content (as index of Biomass of Cyanobactria),
The artfical BSC were tested in the wind turnel.

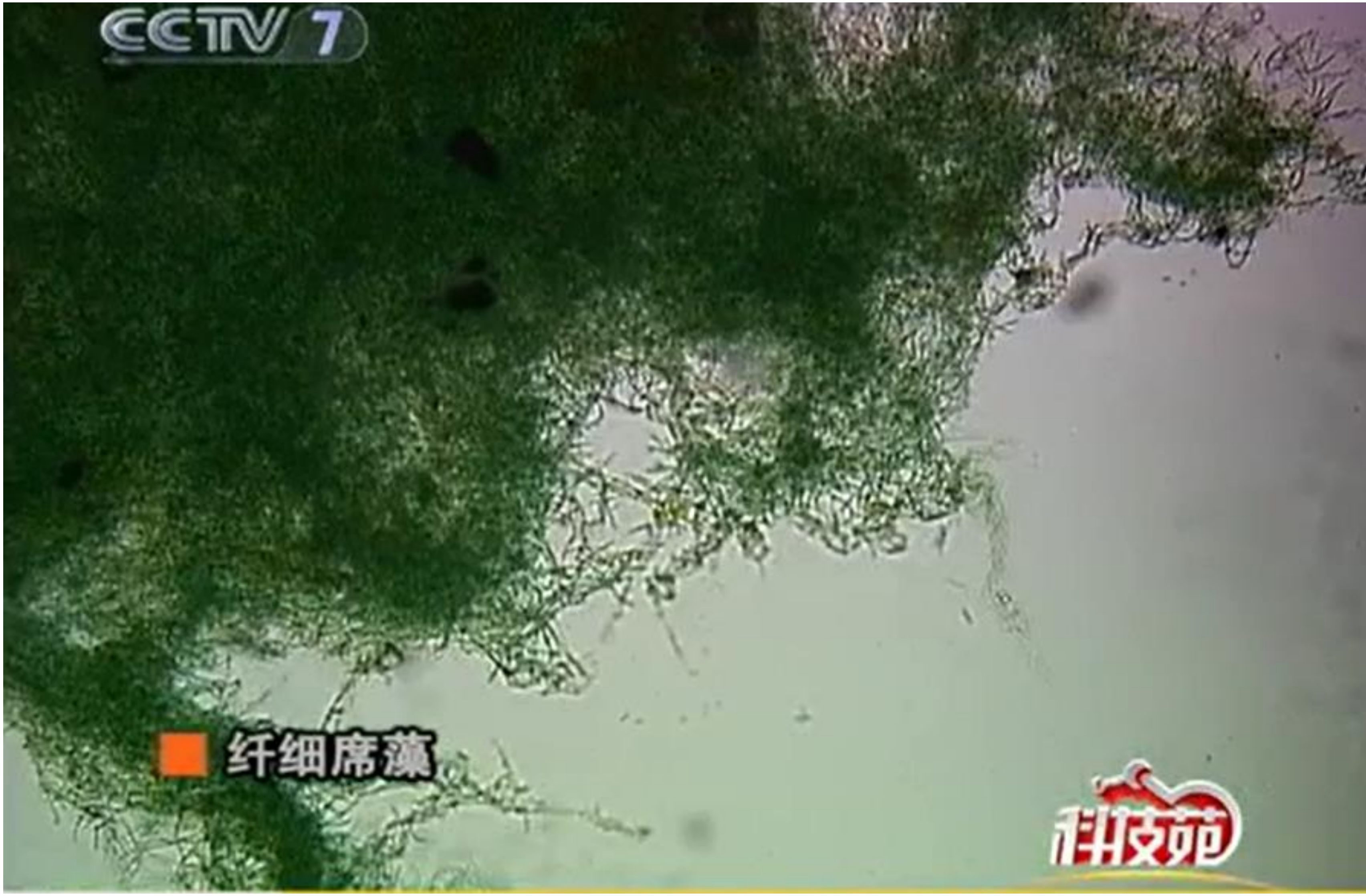
Components of Extracellular Polysaccharides of crust-forming cyanobacteria for diiferent Cyanobaxtria

s	*M. vaginatus*	*S. javianicum*	*P. tenue*	*D. olivaceus*	*Nostoc* sp.
Arabinose	9.4	9.6	43.9	13.1	n.d.
Rhamnose	5.5	7.4	10.4	7.0	3.5
2-O-methyl rhamnose	2.5	6.0	n.d.	n.d.	n.d.
Fucose	4.4	tr	2.3	1.4	n.d.
Xylose	8.5	6.0	4.7	12.4	20.9
Mannose	21.2	22.9	2.9	5.9	1.6
Galactose	18.3	23.4	1.3	28.8	21.54
Glucose	20.1	24.8	32.5	27.6	44.0
2-O-methyl glucose	n.d.	n.d.	n.d.	3.9	8.6
Galacturonic acid	4.6	tr	tr	tr	n.d.
Glucuronic acid	3.4	tr	n.d	tr	n.d.
N-acetyl glucosamine	2.1	tr	1.3	n.d.	n.d.
Total carbohydrate (%)	27.6	16.6	36.1	16.2	40.5
Total protein (%)	50.3	50.2	21.9	14.2	7.5

S. Javanicum filamentous Cyanobactria

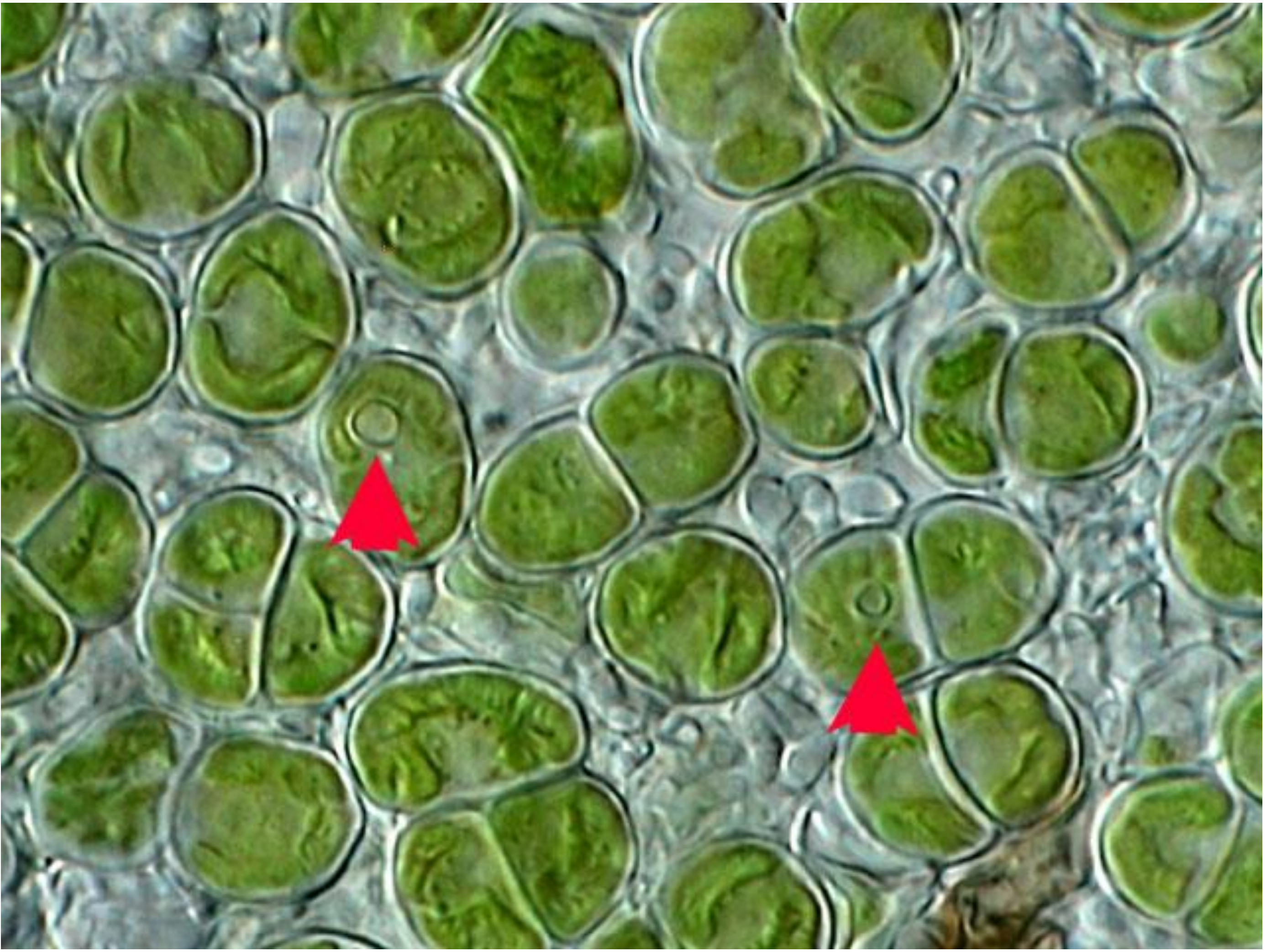


Microcoleus vaginatus **filamentous Cyanobactria**



Phormidium tenue **filamentous Cyanobactria**

Nostoc commune var. *sphaeroides*, *Cyanobactria*, *which can fix nitrogen*



Desmococcus olivaceus, secreting **Polysaccharide,** a genus of green algae

- Strains isolation and purification
- Cell culture (Microcoleus, Scytonema javanicum, Nostop sp., and Desmococcus olivaceus(one kind of green alage)

- Cell culture

- **Mass culture**

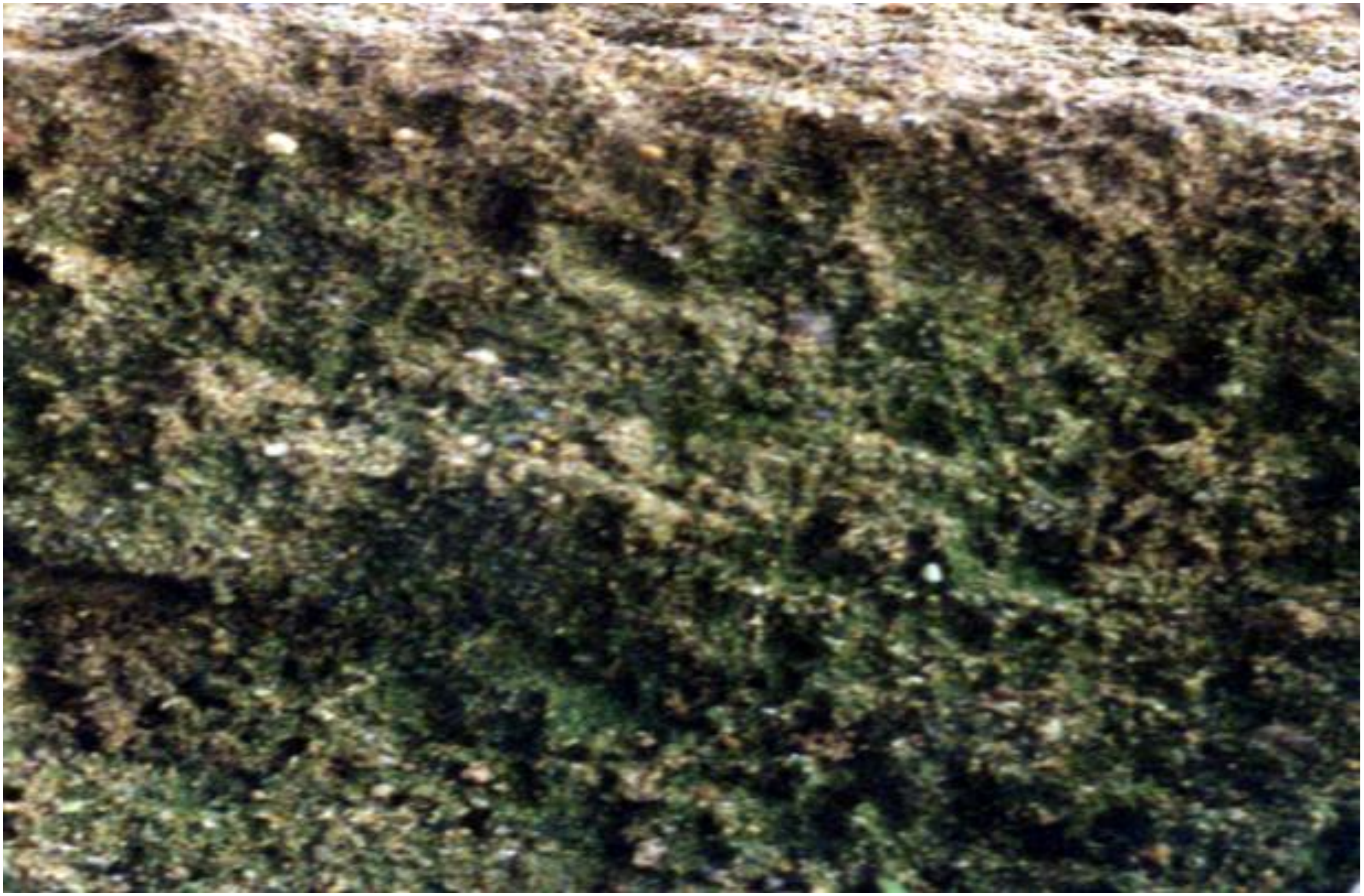
Inoculation, spraying the cultures onto surface of sandy soil of desert

Inoculation, spraying the cultures onto surface of sandy soil of desert (from Chinese Television Station)

Biological Surface Crust forms and Vegetation recovery (from Chinese Television Station)

Before treatment

Before treatment



After Treatment

After Treatment

After treatment .

An area of 38 km^2 in Inner Mongolia, China had been turned moving sandy land into grassland with man-induced BSCs and vegetation recovery

Cyanobacteria are important elements for space living environment establishment, Closed Ecological Life Support System (CELSS), And Eco-agricultrure as primary producers.

Especially one kind of Cyanobacteria, Nostoc sphaerodies Kuetzing, which was named Ge-Xian-Mi, related with a alchemist phsician in China, whose name was Ge-hong (284-364AD), is edible for human, in China Nostoc sphaerodies Kuetzing is edible for about near 1800 years.

Possible to transform extraterrestrial planet for residence?

We would like to recruit graduate students and visiting scholars to attend our projects related with Astrobiology and Life Support System, Eco-agriculture and to Combat Desertification; for **international collaboration with space emerging countries.**

I am told that a third of Africa is under threat of desertification, if this work can help for anti-desertification, we will do our effort to do it.

The region（Africa） is also challenged by serious environmental threats, including desertification,deforestation and climate change.Africa has thus been a priority area for the activities of the United Nations, and the Plan of Implementation of the World Summit on Sustainable Development refers to Africa’s sustainable development as a cross-cutting issue.

Access to natural resources is worsening in the region, owing to the continuing crise in demand for natural resources, a rapidly growing population, processes of deforestation and desertification, the impact of climate change and resource mismanagement.

Cited from “**Space benefits for Africa: contribution of the United Nations system**” United Nations A/AC.105/941

IAA STUDY GROUP
"HUMAN SPACE TECHNOLOGY PILOT PROJECTS WITH DEVELOPING COUNTRIES"

- **Leadeship**: Co-Chairs; G.Reibaldi (Italy), F.Zhuang (China), Secretary: Dr.Nair Unnikrishnan (India)
- **Members:** 32 from 12 countries: India, China, Austria, Germany, Singapore, Japan, Malaysia, Italy, Russia, Thailand, Korea, Pakistan, Ecuador
- **Goals:** Define Emerging Spacefaring Countries Challenges and Opportunities and foster their involvement in HSF technologies (e.i. Life Science and Education)
- Identify available Infrastructures, Ground and
- In-orbit, for implementing projects Confirm need of

Call for Proposal for Pilot Project

Pilot Projects selection, definition, implementation

Decision Road map in cooperation with UNOOSA

Status: Preliminary Content List defined

History of RCSSTEAP

Beihang International Space Education Center
(2004)

Ministry of Education approved the establishment of graduate international program for space technology applications in Beihang University in 2006

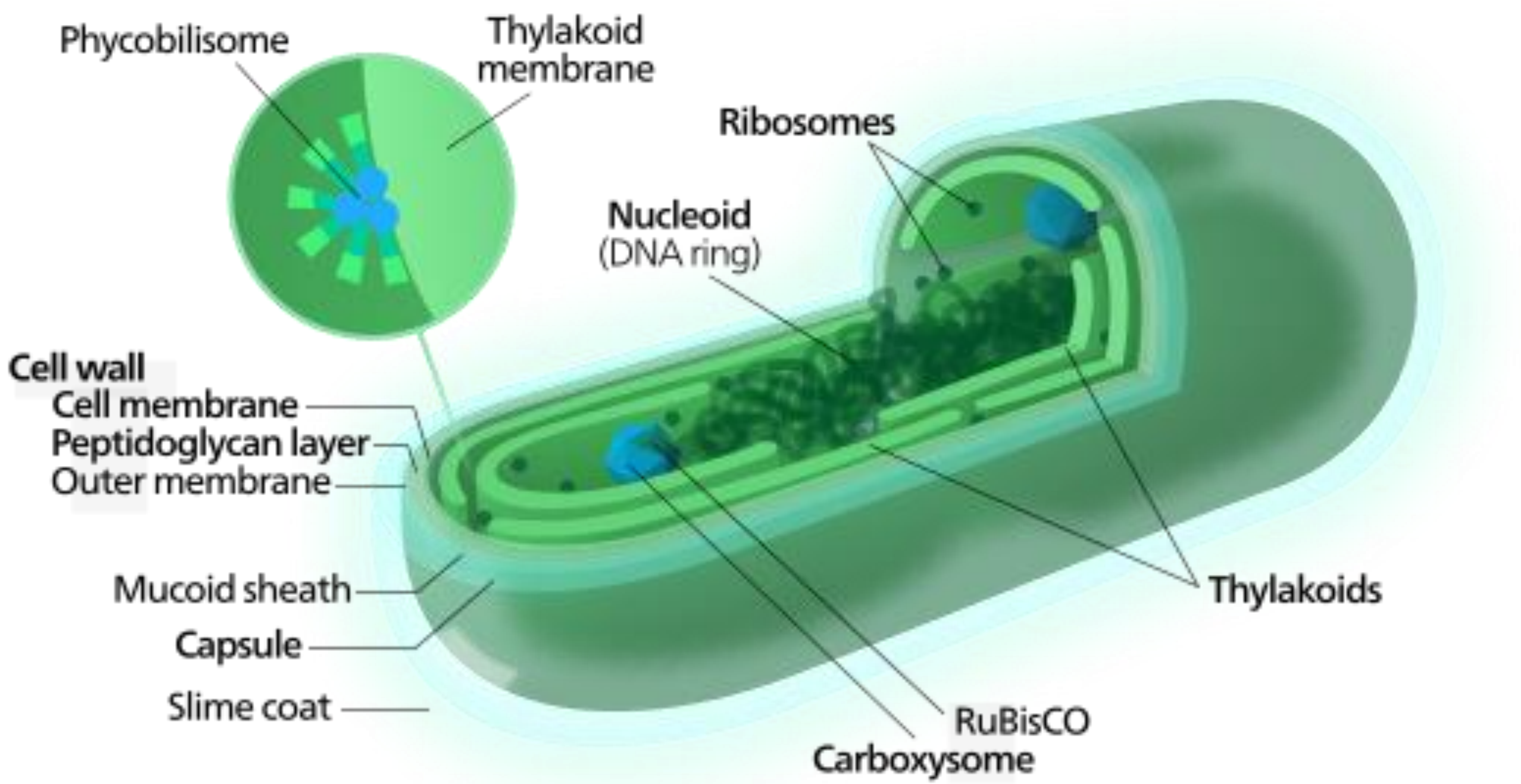
China Satellite Navigation System Management Office
Beidou International Exchange and Training Centre
(2012)

Asia-Pacific Space Cooperation Organization Education and Training Center in China
(2013)

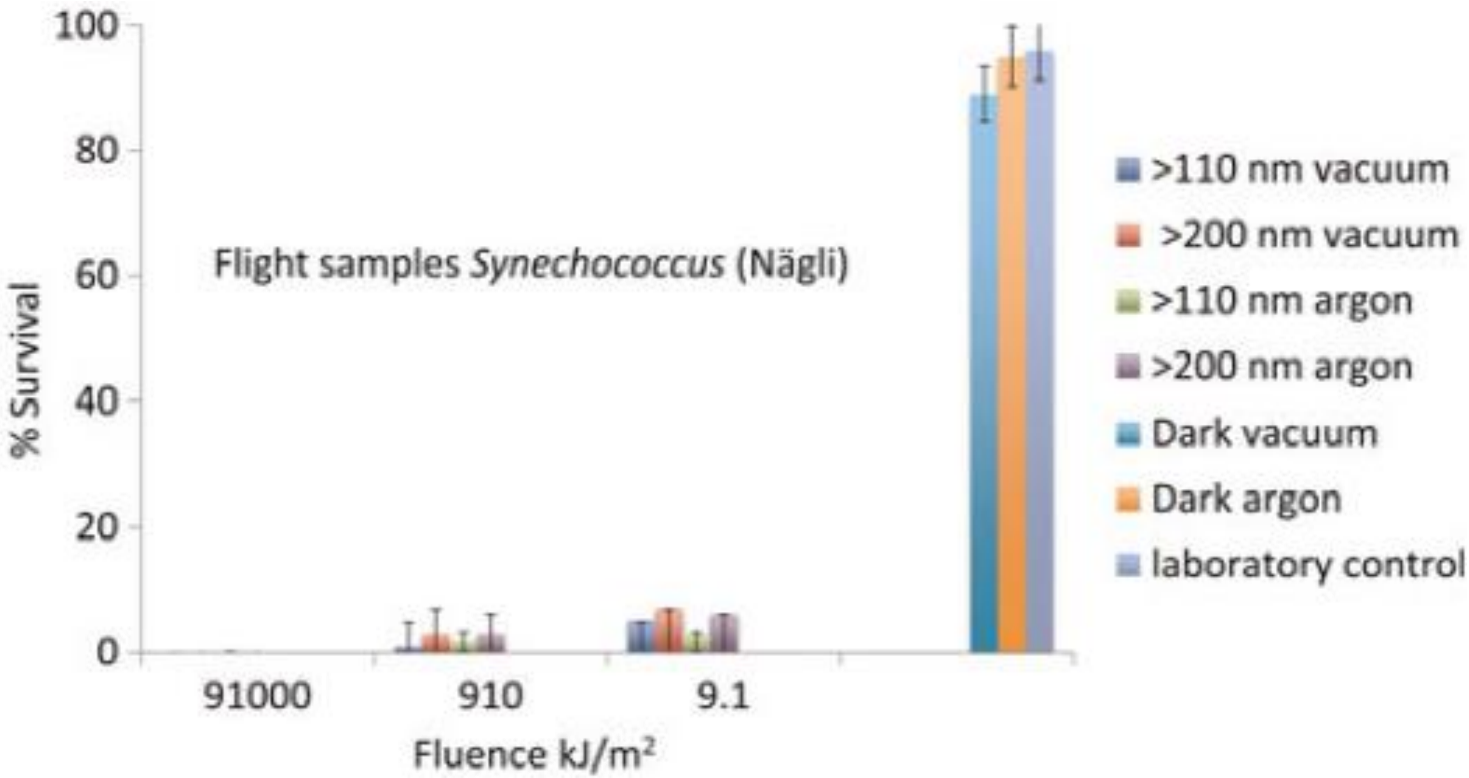
The Regional Centre for Space Science and Technology Education in Asia and the Pacific (China) (Affiliated to the United Nations) (2014)


Thank you for
your attention!

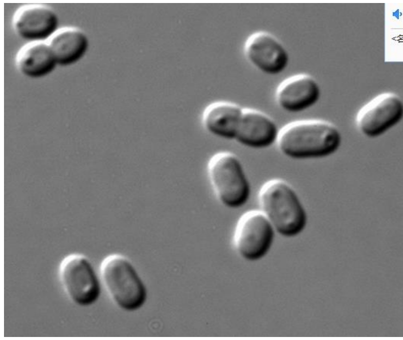
Early lives reform Earth for advanced life to apperar



cyanobacteria



R.L.Mancinell International Journal of Astrobilogy, 14(1): 123-128 (2015)

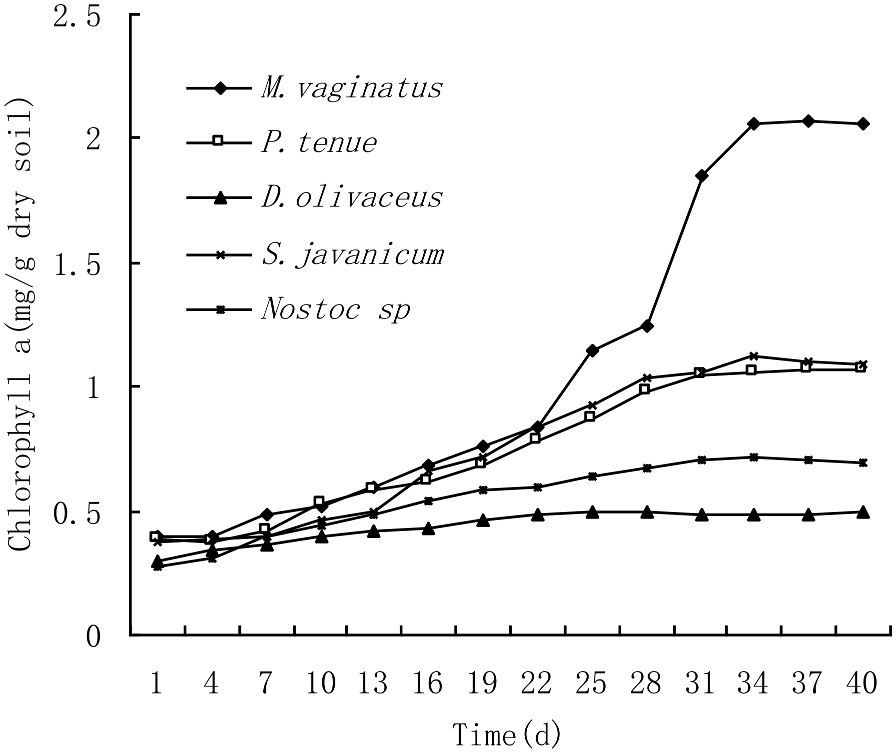


Survival experiments on Expose-R for Synechocous (Naegeli)(a halophilic caynobacterium), a monolayer of this cayanobactria is exposed to space enviroments for dark vacuum, Dark argon and 100%, 1% and 0.01% of ultraviolet. No survive was detected using cell growth for full UV radiation. But the dark group have a high percentage survive for nearly two years exposure.

Cyanobacterial adaptation abilities to the desert environment

on cellular, physiological, biochemical and ecological levels

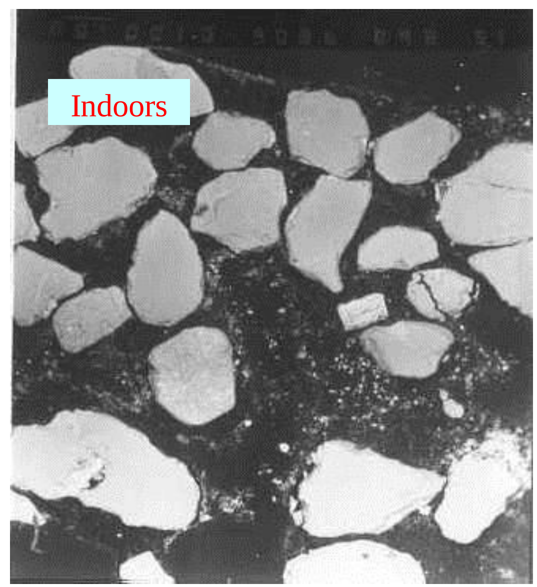
- **high irradiation**
- **extreme drought**
- **severe temperature changes**
- **poor nutrition**
- **Chlorophyll content as the index of growth rate**

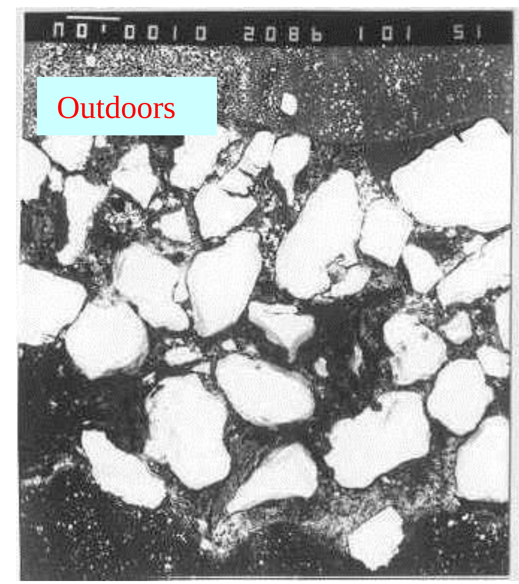


Growth rate of desert cyanobacterial strains

Man-induced BSCs with cyanobacteria obviously changed the structure and strength of surface soil

- ✷Making surface soil consisting of **EPS (Extracellular Polysaccharides , OM (organic matters),IM(inorganic Matters)**
- ✷Cyanobacteria producing OM 1.4 times of its biomass, then the strength enhanced 2.5 times
- ✷Full BSC (EPS+OM+IM) enhanced the strength 2~6 times again.





Experimental results of man-induced BSCs with cyanobacteria

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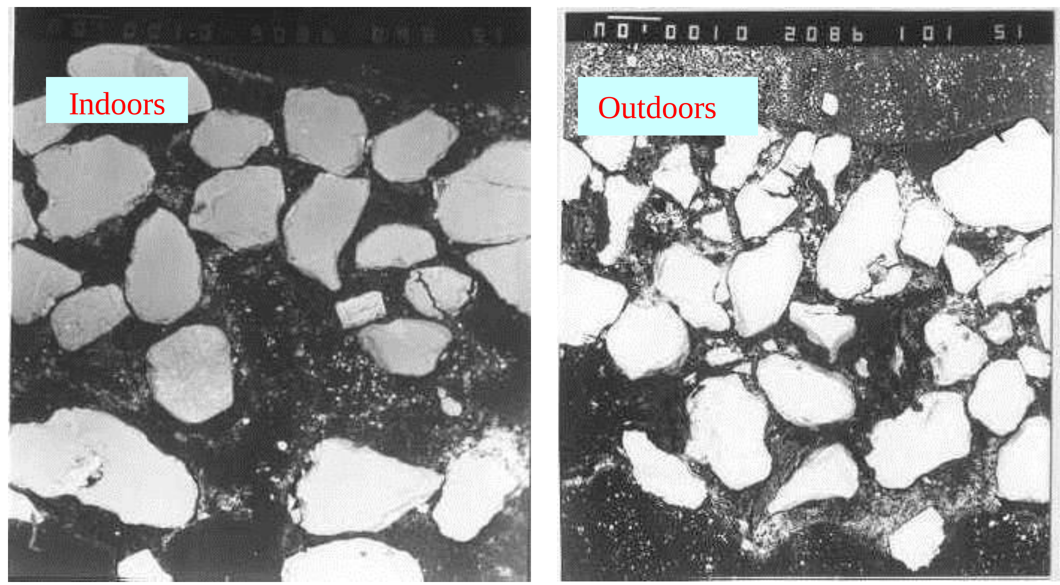

Experimental results of man-induced BSCs with cyanobacteria


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