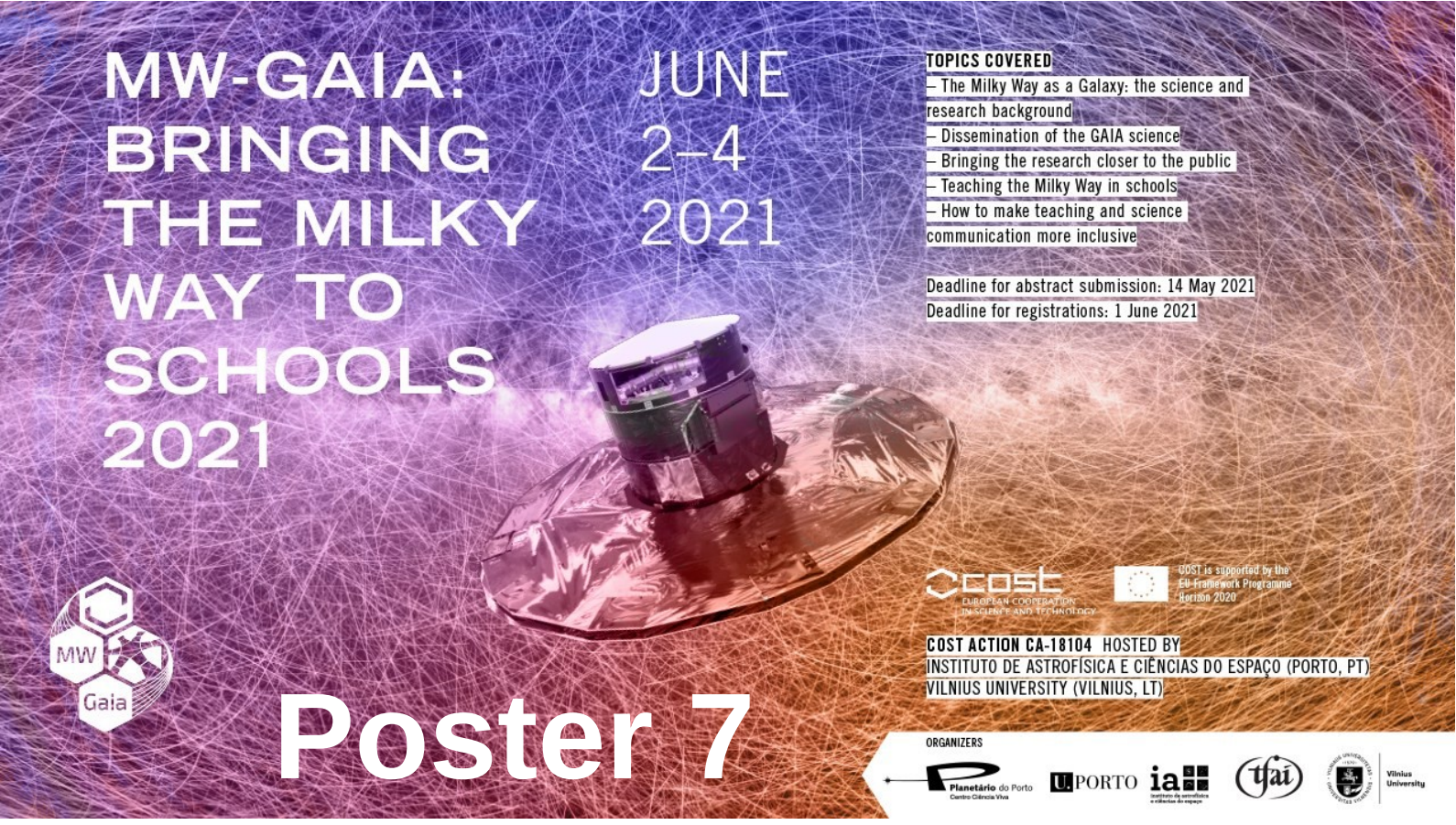

Jan Szauman-Szumski

Colegio Huerta de la Cruz, Algeciras, Spain

Habitable zone: could terrestrial life survive on the Moon?

An accurate definition of the habitable zone is of great importance for the search of life in planets others than the Earth. The habitable zone is customarily defined as the range of orbits around a star within which a planetary surface can support liquid water given sufficient atmospheric pressure. Other requirements are that the greenhouse effect does not increase temperatures above a determined threshold, that volcanic activity does not drastically increase this greenhouse effect, that the planet owns a magnetic field strong enough for protection against highly-charged particles, or that the planetary albedo is not too high.

Just like the planetary systems, an habitable zone can be also defined for galaxies. The habitable zone of a galaxy is usually located from the centre of the galaxy within a radius ranging from 13,000 to about 33,000 light years, about a half of the galactic disk. Further away from this limit, the metallicity of the stars is too low to allow the formation of telluric planets like the Earth, and at distances closer to the galactic centre conditions for life are more hostile due to the higher exposition to more energetic and violent events like supernovas or black holes.

The Earth and our solar system are located at a radius of 27,000 light years from the centre of the Milky Way, within this habitable zone in the galaxy. But although on the Earth more than 8,7 millions of living species can be found, closer planets like Venus or Mars or our Moon are apparently inhabitable. From the physical and chemical properties of the Moon, which could be the most difficult to bear for terrestrial organisms? Furthermore, which of the 5 kingdoms of the natural world could tolerate better the harsh conditions of our satellite?

In 2019 the Chinese mission Chang’e 4 succeeded in the germination of Earth cotton seeds under the 1/6 gravity and long-term super cold environment on the far side of the Moon, while results of parallel experiments with potatoes, cress and breed silk worms may be published soon. From this starting point we wondered if these species were the best options to be the first lunar settlers, the “ambassadors” of planet Earth on another celestial body, so we set off “The Challenge of the five Kingdoms” a project for 10-11 year-old students which aims a comparison of the five Kingdoms of the natural world and asses their capacity to overcome variations in two physical properties: light and temperature. In doing so, we have tried to elucidate who could it be the super-organism with the best chances to survive on the Moon.

Our project studies the concept of the habitable zone and the characteristics of living organisms in accordance with the Primary school science curriculum. In the course of this research, students have analysed scientific papers, investigated about animals and plants development processes and performed scientific experiments with individuals from all the kingdoms in order to contrast their hypotheses.

This study is also a continuation of our astrobiology projects in which we work with students of different ages and their families.

Habitable zone: could terrestrial life survive on the Moon?

Colegio Huerta de la Cruz

Mª Pilar Orozco Sáenz-Javier Peralta Calvillo-Juan A. Prieto Sánchez

In 2019 Chinese scientists explained their aspiration to grow plants, such as potatoes and cress, and breed silk worms on the dark side of the Moon.

From this starting point we wondered if these species were the best options to be the first lunar settlers, the "ambassadors" of planet Earth on another celestial body, so we set off "The Challenge of the five Kingdoms".

Based on two physical properties, light and temperature, we compared the five kingdoms of the natural world in order to find the super-organism which could have the best chance to survive on the Moon.

Our project studies the concept the habitable zone and the characteristics of living organisms in accordance with the Primary school science curriculum. In the course of this research, students have analysed scientific papers, investigated about animals and plants development processes and performed scientific experiments with species from all the kingdoms in order to contrast their hypotheses.

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Animal kingdom

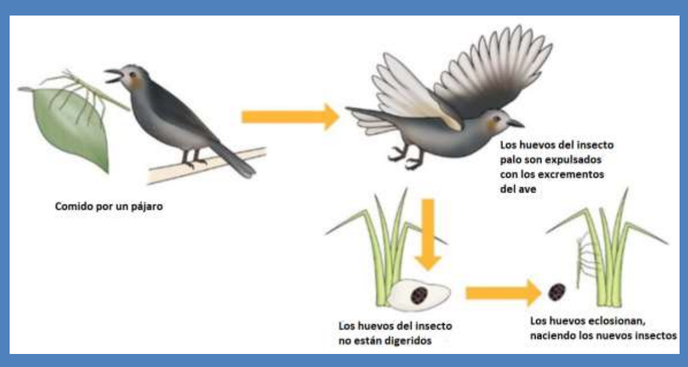


Table. *Experiments with silkworm eggs*

Temperature	Light	Nº Exp.
Intenso Cold (24h A -28ºc)	Absolute Darkness	1
	Day/Night Alternation	2
Low Temperature (North Facing Place)	Absolute Darkness	3
	Day/Night Alternation	4
Environmental Temperature	Absolute Darkness	5
	Day/Night Alternation	6 Control

Table. *Results experiments with silkworm eggs*

Nº Experiment	1	2	3	4	5	6
Viability Eggs	No	Only 1	Most	All	Most	All
Caterpillar size	---	Abnormal	Normal	Normal	Normal	Normal

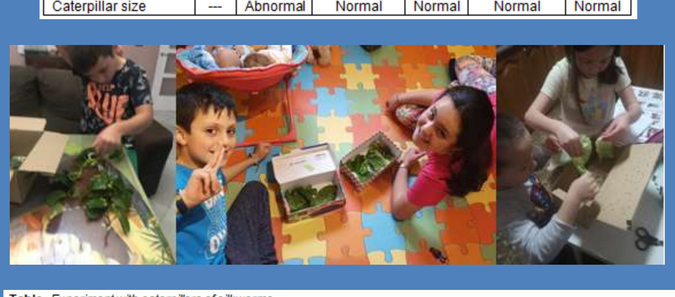


Table . *Experiment with caterpillers of silkworms*

Light	Diet	Grothw	Chrysalis formation
Absolute Darkness	Mulberry	Normal	Normal
	Mulberry/Lettuce Alternation	Less	Littel Densa
Day/Night Alternation	Morera	Normal	Normal
	Mulberry/Lettuce Alternation	Less	Littel Densa

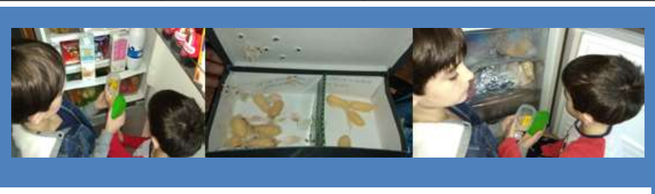


Table. *Experiment with silkworms chrysalis*

Temperature	Cold (24h a -28ºC)	Low Temperature	Environmental Temperature (Control)
Hatching	No	No	All

Fungi Kingdom

Table . *Results of exposure to different temperatures and light of the Fungi Kingdom*

	Mass 1	Mass 2	Mass 3	Mass 4	Mass 5
	Direct exposure to the sun	Ambient temperatura but in the shade	Ambient temperatura but in the dark	Moderate cold (4 º C) for 24h	Intense cold (-22 º C) for 24h
1º day	Very Active	Active	Active	No Active	No Active
				Ambient Temperature	Ambient Temperature
2º day	----	----	----	Active	Active

General objectives

- Study the general characteristics of the five realms of terrestrial nature.
- Understand what habitability zone means.
- Study how living things appeared on Earth.
- Recognize the physical conditions that affect life.
- Continue working in the field of astrobiology from the primary curriculum based on the scientific method.
- Encourage families to carry out home experiences in an orderly and rigorous way.
- Revalue the family-school binomial through interinstitutional participation in the project

Protoctist Kingdom

Table. *Results of the experiment with algae*

	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5
	Direct exposure to the sun	Ambient temperatura but in the shade	Ambient temperatura but in the dark	Moderate cold (4 º C) for 24h	Intense cold (-22 º C) for 24h
1ºweek	Green tone	Brown tone	Brown tone	Brown tone	Brown tone
2º week	More volumen. They float	Brown tone. They don't grow	Precipitation	Green tone. Best look	Green/Brown tone Best look
3º week	Brown/Green tone.. Too much volume. They float	Brown tone. They don't grow	They don't survive	Best look	Best look
Photos					

General Conclusions

Once we have studied all the kingdoms of nature, it is difficult for us to come to a conclusion. The variety of life on Earth makes potential candidates multiply. The table lists the overall results of our experiences.

Table. *General results*

Reaction		Bacteria	Algaes	Yeast	Moss	Legumes	Worms
Light		Doesn't affect	Affect	Doesn't affect	Affect	Affect	Doesn't affect
Temp.	heat	Favors	Favors	Favors	Favors	Favors	Favors
	soft	Doesn't affect	Doesn't affect	Doesn't affect	Doesn't affect	Doesn't affect	Doesn't affect
	Cold	Survive	Survive	Survive		Germinated die Seeds surviven	Adults die Eggs surviven
Food		Doesn't affect	Doesn't affect	Doesn't affect	Doesn't affect	Doesn't affect	Affect

On the one hand, we would have to choose the least complex kingdom, the bacteria. But on the other hand, it would be more appropriate to lead a small ecosystem made up of representatives of each of these kingdoms, hence they could complement and help each other not only survive, but grow and reproduce. A colonizing ecosystem like those organisms that appeared on Earth and were evolving, photosynthetic and decomposing first and then animals and organism consumers.

Plantae Kingdom

Briophytes: Mosses

Table. *Results of moss exposure to different temperatures and light.*

	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5
	Direct exposure to the sun	Ambient temperatura but in the shade	Ambient temperatura but in the dark	Moderate cold (4 º C) for 24h	Intense cold (-22 º C) for 24h
1º Week	Green colour	Green colour	Green colour	Green colour	Green colour
2º Week	Green colour	Dark Green colour	Dark Green colour	Green colour	Green colour
3º Week	Green colour	Dark Green colour	Dark Green colour	Green colour	Green colour

Vascular plants: Legumes

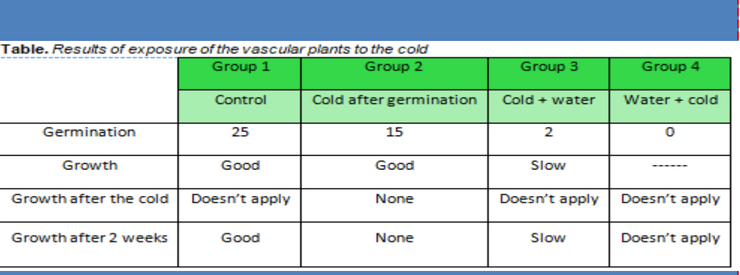
Table. *Results of exposure of the vascular plants to the cold*

	Group 1	Group 2	Group 3	Group 4
	Control	Cold after germination	Cold + water	Water + cold
Germination	25	15	2	0
Growth	Good	Good	Slow	------
Growth after the cold	Doesn't apply	None	Doesn't apply	Doesn't apply
Growth after 2 weeks	Good	None	Slow	Doesn't apply

Monera Kingdom

Table. *Conditions of the experiment with the morera kingdom*

	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5
	Direct exposure to the sun	Ambient temperatura but in the shade	Ambient temperatura but in the dark	Moderate cold (4 º C) for 24h	Intense cold (-22 º C) for 24h
Day 1	Half curdled	A curdled milk ring is observed	A curdled milk ring is observed	Liquid	Solid
Day 2	Curdled	Half curdled	Half curdled	A curdled milk ring is observed	Liquid A curdled milk ring
Day 3	Curdled	Curdled	Curdled	Half curdled	Half curdled
Day 4	Curdled	Curdled	Curdled	Curdled	Curdled



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