Astrobiology
Origin and Evolution of Life
天体生物学
生命起源与演化

Vassilissa Vinogradoff, Beatriz García, Rosa M. Ros

International Astronomical Union
CNRS, Aix-Marseille Université, PIIM laboratory, Marseille, France.
CONICET/Universidad Tecnológica Nacional, Mendoza, Argentina
Universidad Politécnica de Cataluña, Spain

天体生物学的定义
Definition of Astrobiology

天体生物学不是一门学科，而是一门围绕地球生命起源和演化及其可能存在于宇宙其他部分的问题的跨学科活动；它涵盖了所有感兴趣的领域，从天文学到生物学，包括地质学和化学，也包括科学的历史和哲学。

Astrobiology is not a discipline but an interdisciplinary activity around the question of the origin and evolution of life on Earth and its possible presence in other parts of the Universe; It covers all fields interested in this issue, from astronomy to biology, including geology and chemistry, but also history and philosophy of science.

病原学：外生学和天体生物学
Etimology: Exobiology and Astrobiology

随着太空竞赛和第一次月球和火星探测任务的进行，**生物**污染的风险出现了。

With space race and the first lunar and martian exploration missions, the risk of biological contamination appears.

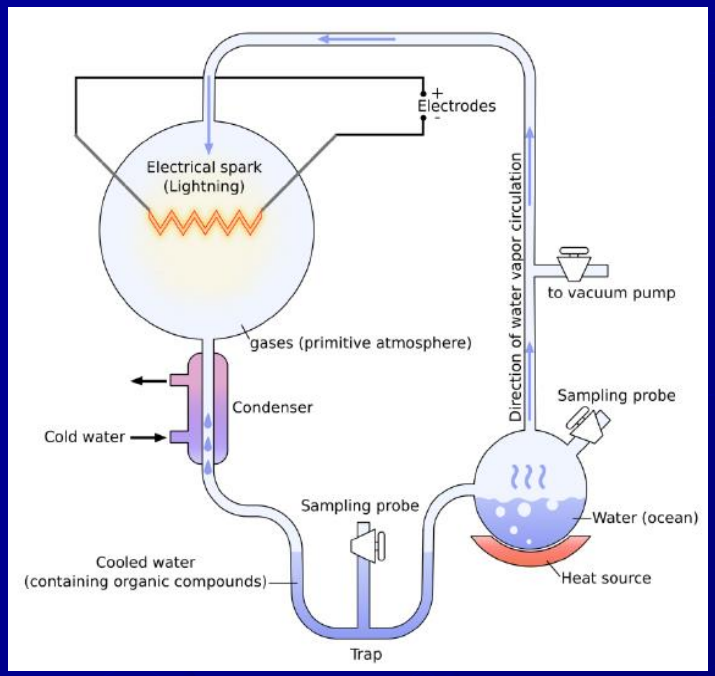
首先，**科学家**们认为
微生物不大可能经受住太空环境的考验。

今天，**我**们知道情况并非如此，**例如**，迟缓类动物能够抵抗极端条件，**包括太空中的极端条件**，这不是一个孤立的例子。

First, scientists assumed
that microbes were unlikely to withstand the conditions of space.
Today we know that this is not the case and, for example, tardigrades are capable of resisting extreme conditions, including those in space, and this is not an isolated case.

Water bear (tardigrade),
Hypsibius exemplaris
(Credit: B. Goldstein & V. Madden)

病原学：外生学和天体生物学
Etimology: Exobiology and Astrobiology



米勒 — 尤里实验方案。（来源：S.拉巴尔）
Scheme of the Miller-Urey experiment. (Credit: S. La Barre)

随着Miller-Urey的开拓性实验，实验室开始了第一个益生元分子合成的化学研究

With the Miller-Urey's pioneering experiment began the chemical studies for the synthesis of the first prebiotic molecules in the laboratory

通过太空探索寻找生命起源的一个新的关键学科出现：外生学，由Joshua Lederberg在1960年引入。

A new key discipline for the search for the origin of life through space exploration appears: Exobiology, term introduced by Joshua Lederberg in 1960.

“天体生物学”这个名词是2015年由IAU采用的。

The term “Astrobiology” was adopted in 2015 by the IAU.

天体生物学目标
Astrobiology Objectives

- 定义生命是什么。
- 确定生命的起源。
- 寻找它最古老的足迹。
- 了解它在地球上的演化机制。
- 在宇宙中寻找生命。

- Define what Life is.
- Determine the origin of life.
- Look for its oldest footprints.
- Understand its evolution mechanisms on Earth.
- Search for life in the universe.

天体生物学目标

Define Life

这个问题需要科学论证，
但这也是一个哲学问题。

This question requires scientific arguments,
but it is also a philosophical question.

生命是活的生物的特征，区别于后者是死的生物体或非活的生物，特别区别于

- **成长。**
- **代谢。**
- **对刺激有反应。**
- **适应。**
- **繁殖。**

Life is a characteristic of a living organism that distinguishes the latter from a dead organism or a non-living thing, as specifically distinguished by the capacity to

- **Grow.**
- **Metabolize.**
- **Respond to stimuli.**
- **Adapt.**
- **Reproduce.**

地球上生物的多样性
Diversity of Living Things on Earth

唯一已知的生命例子是陆地生命。

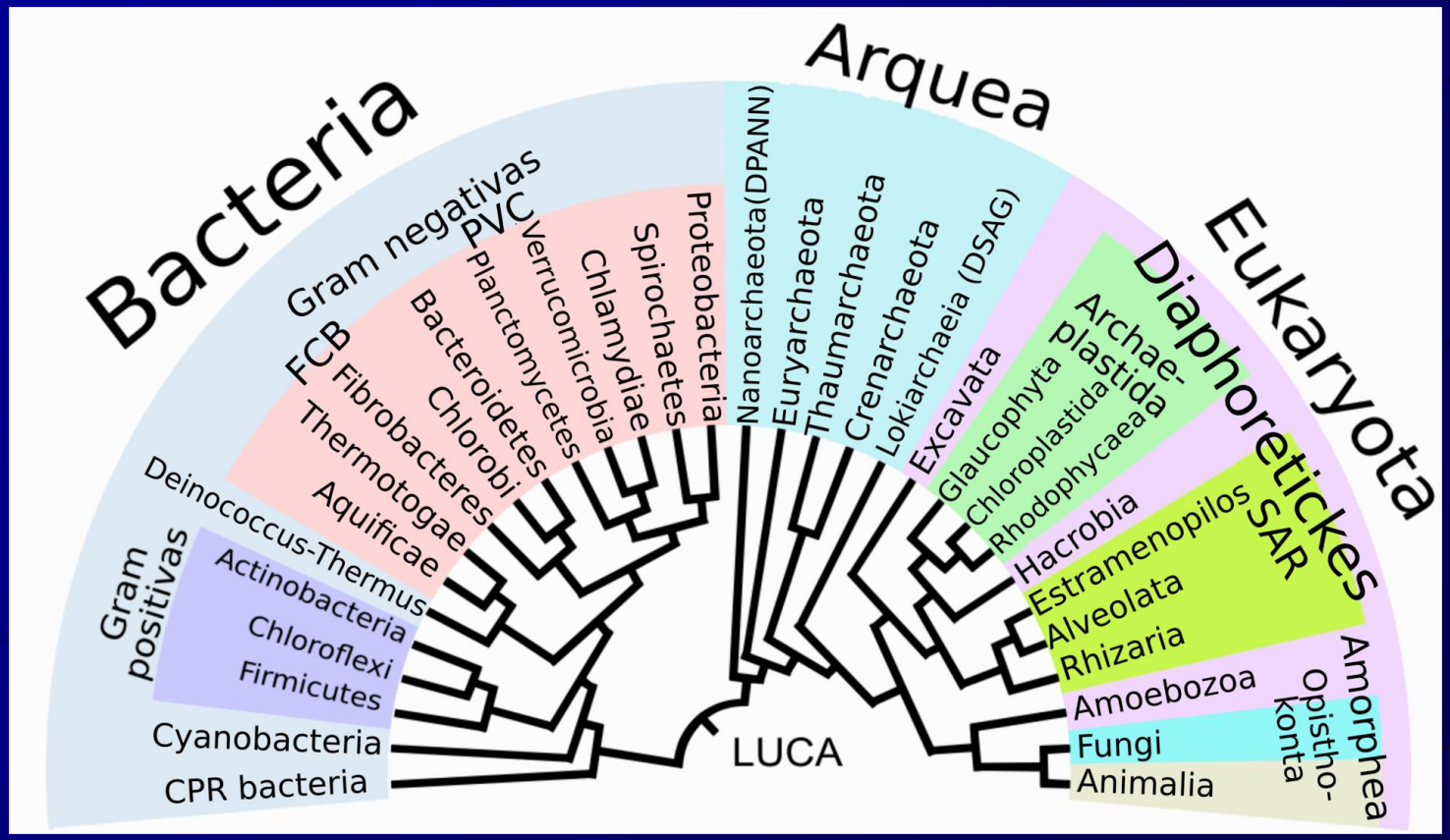
天体生物学将大部分精力集中在研究所有环境中的陆地生物，特别是最极端的环境，如水热温泉、盐湖或冰冻的地方。

这种环境可以成为类比地外位置的好环境。

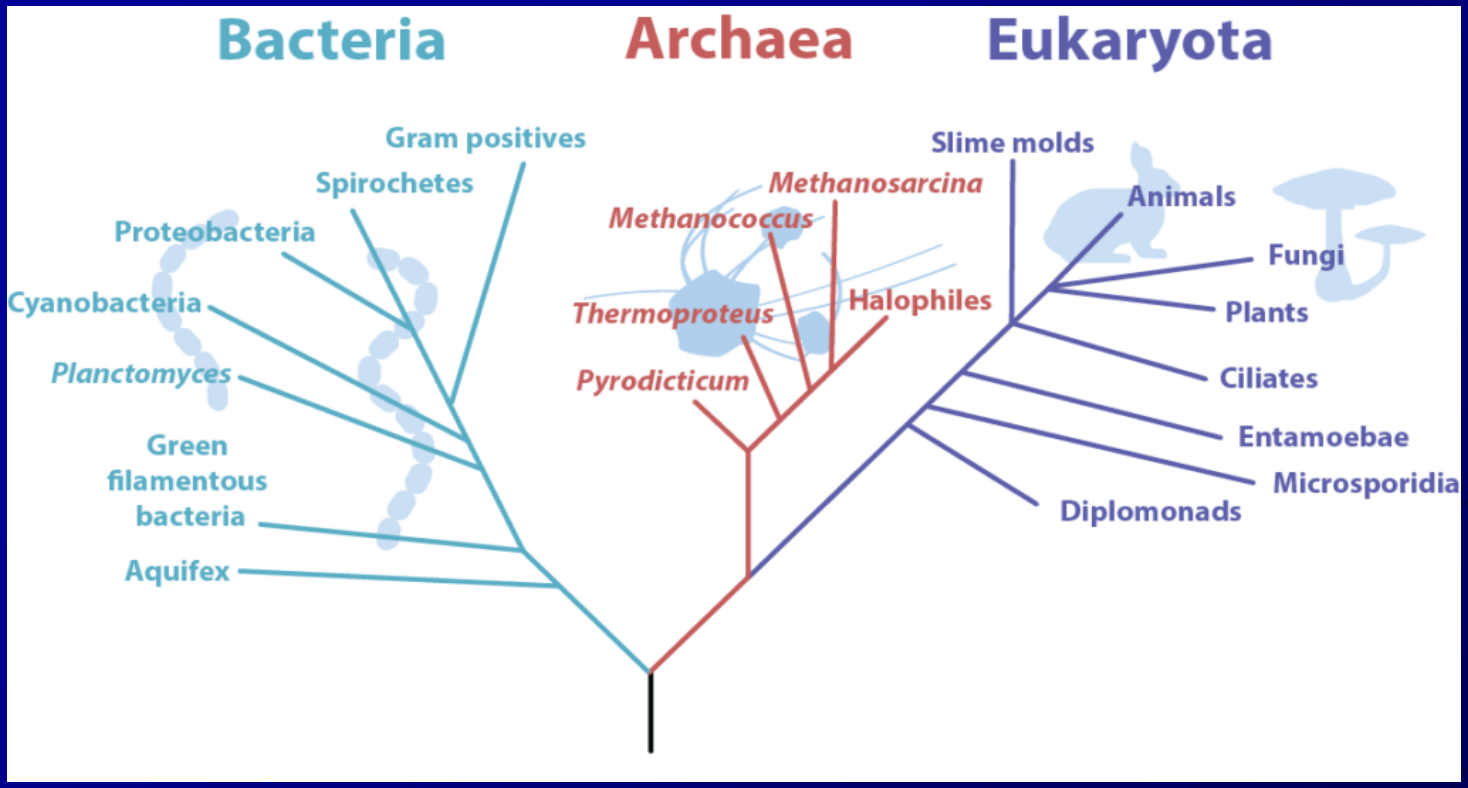
The only known example of life is terrestrial life.
Astrobiology concentrates much of its efforts on studying terrestrial life in all environments, especially in the most extreme ones, such as underwater hydrothermal springs, brine lakes or frozen places.
This type of environment can be a good analogue for extraterrestrial locations.

为了更好地了解生物体的极限和在极端环境中工作的机制，科学家试图确定生物体的系统发育和代谢多样性。

To better understand the limits of living organisms and the mechanisms at work in extreme environments, scientists seek to determine the phylogenetic and metabolic diversity of living organisms.



(Credit: Wikipedia)



(Credit: open.oregonstate.education)

生命树中特别感兴趣的分枝之一是古细菌（或古菌），由于它们的核糖体RNA序列而不同于原核细菌，并且特别适应极端环境(在压力、温度、盐度、营养物等)。

One of the branches of the tree of life that is of special interest are the archaebacteria (or archaea), different from prokaryotic bacteria due to their ribosomal RNA sequence and particularly adapted to extreme environments (in terms of pressure, temperature, salinit nutrients , etc).

寻找地球上最古老的生命痕迹：困难

Search for the oldest traces of life on Earth: Difficulties

1) 地球是一颗“有生命的”行星（构造，侵蚀），因此自45亿年前形成以来已经发生了巨大的演变。根据物种的谱系，第一个活的生物肯定是类似于细菌的单细胞生物。

2) 原始生物体必须是微观的。地球上最古老的生命痕迹可追溯到34.8亿年前，在澳大利亚被发现。

3) 难以解释和比较非生物系统，这可能形成类似生物特征或形态的指纹。

4) The Earth is a "living" planet (tectonics, erosion) and has therefore evolved greatly since its formation 4.5 billion years ago. Based on the genealogy of species, the first living organisms must have been single-celled beings similar to bacteria.

5) Primitive organisms had to be microscopic. The oldest proven traces of life on Earth date back 3.48 billion years and were discovered in Australia.

6) Difficulty in interpretation and comparison with abiotic systems, which could have formed fingerprints similar to biological signatures or morphologies.

益生元化学与从无生命向有生命过渡

Prebiotic chemistry and the transition from non-living to living

今天，在地球上所有现存的物种中，有由C,H.N和O组成的基本块

Today, in all living species on Earth, among all the existing diversity, there are elementary blocks made of C, H, N and O

这些区段包括蛋白质（复制的基础）、DNA（脱氧核糖核酸）（携带遗传信息）和两亲物（构成细胞壁进行细胞分离）。

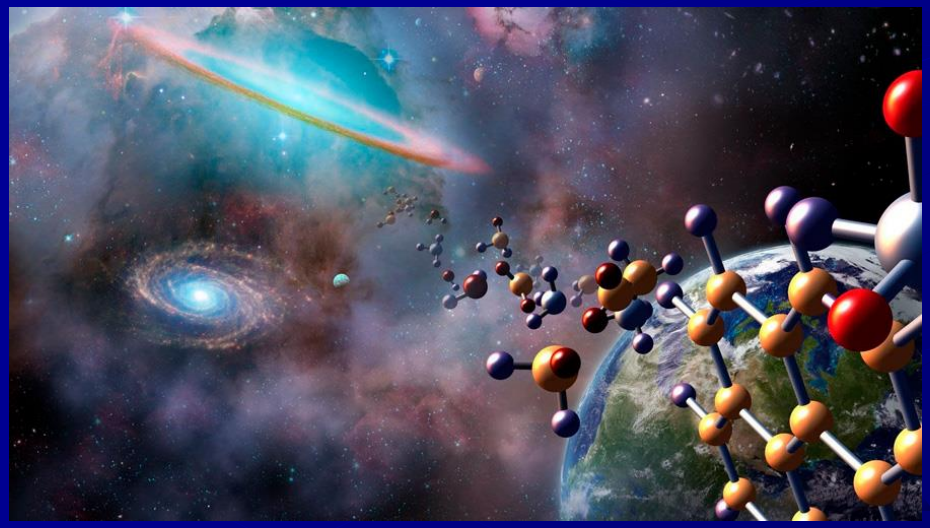
These blocks are proteins, the basis of replication, DNA (deoxyribonucleic acid), which carries genetic information, and amphiphiles, which constitute cell walls for compartmentalization.

因此，地球上每个生物都有五种类型的分子（有时称为生命砖）、氨基酸、含氮碱、糖、磷、脂类（或脂肪酸）。

The elemental bricks that every living species on Earth has are, therefore, five types of molecules (sometimes called the bricks of life), amino acids, nitrogenous sugars, phosphorus, lipids (or fatty acids).

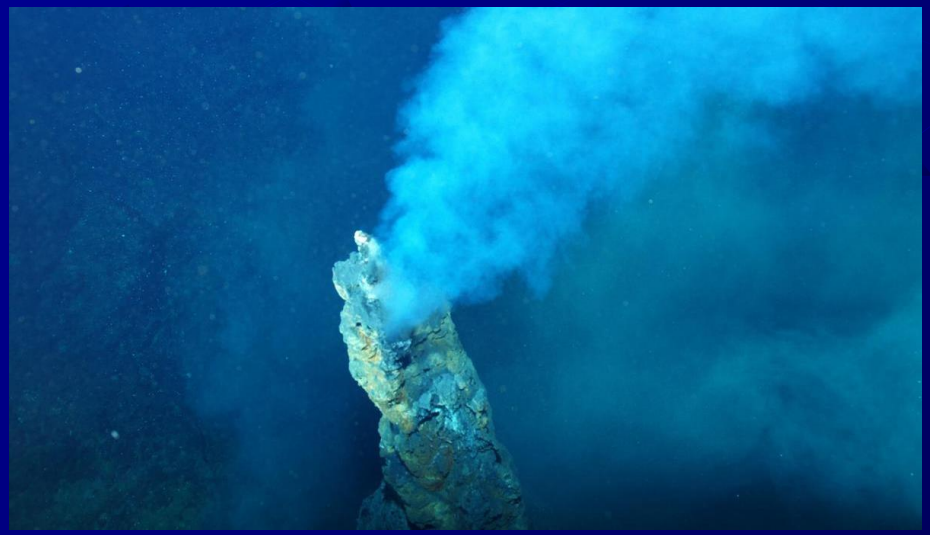
益生元化学与从无生命向有生命过渡

Prebiotic chemistry and the transition from non-living to living



这些要素对陆地生命至关重要，对其起源的研究使我们能够对生命起源本身给予更多的限制。

These elements are essential for terrestrial life and the study of their origin allows us to give more limitations to the origin of life itself.



这些分子在地球的大气层中，也有可能在热液喷口中形成。

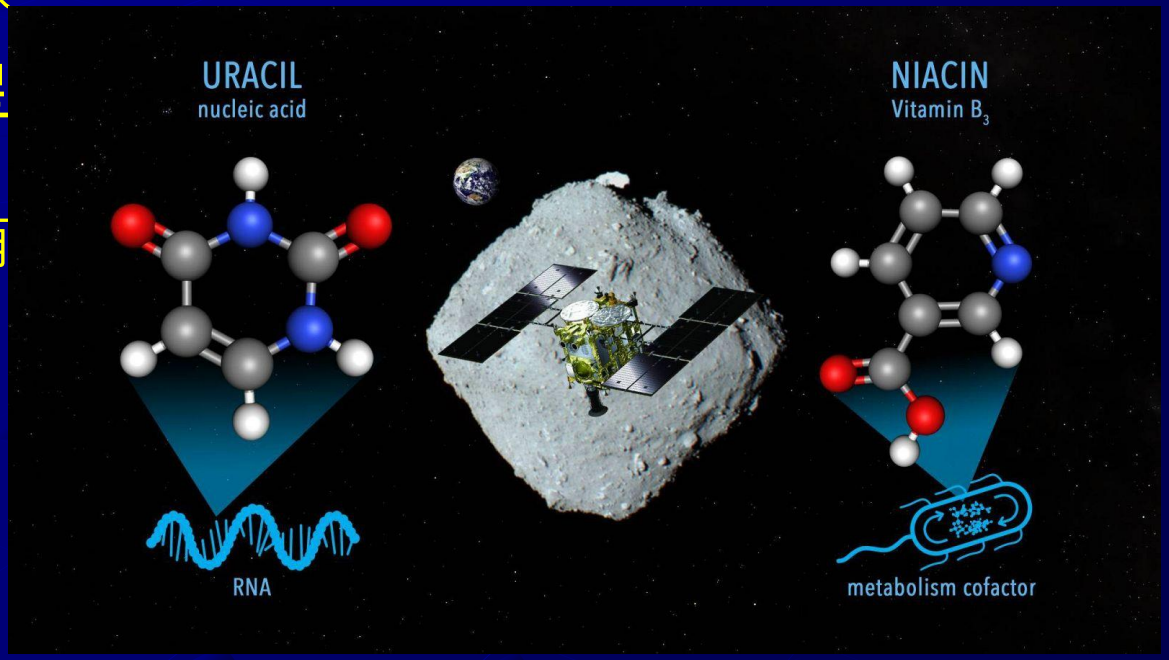
Abiotically, these molecules could have formed in the Earth's atmosphere, also in hydrothermal vents.

益生元化学与从无生命向有生命过渡

Prebiotic chemistry and the transition from non-living to living

另一种假设认为这些分子可能是由来自小行星和彗星的天体（陨石）带来的：陨石被证明有非常丰富的有机物质。

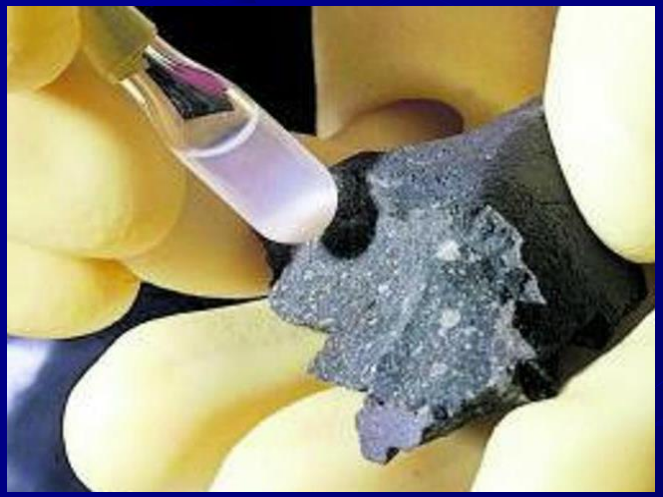
Another hypothesis proposes that these molecules could have been brought by celestial objects (meteorites), coming from asteroids and comets: meteorites have proven to have great organic richness.



Representation of the asteroid Ryugu
(Credit: NASA Goddard/JAXA/Dan Gallagher

益生元化学与从无生命向有生命过渡

Prebiotic chemistry and the transition from non-living to living



当陨石坠落到地球时，可能运送了在45亿年前分化的表面发现的部分水和亲铁元素。

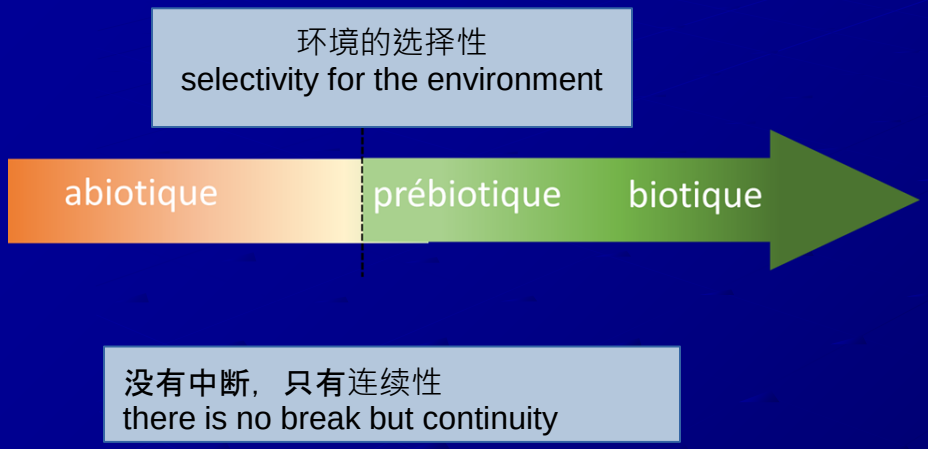
When falling to Earth, the meteorites could have transported part of the water and siderophile elements found on their surface after differentiation 4.5 billion years ago.

这些天体还没有发现生命形式，但它们包含数千个分子，这些分子的多样性和多样性，与非生物合成所必需的那些。

No life form has yet been found in these objects, but they contain thousands of molecules as diverse and varied as those necessary in abiotic synthesis.

益生元化学与从无生命向有生命过渡

Prebiotic chemistry and the transition from non-living to living



非生物系统和生物系统之间没有严格的分离，而是通过前生物化学的连续性。

There would not be a strict separation between an abiotic and a biotic system, but rather a continuity, passing through said prebiotic chemistry.

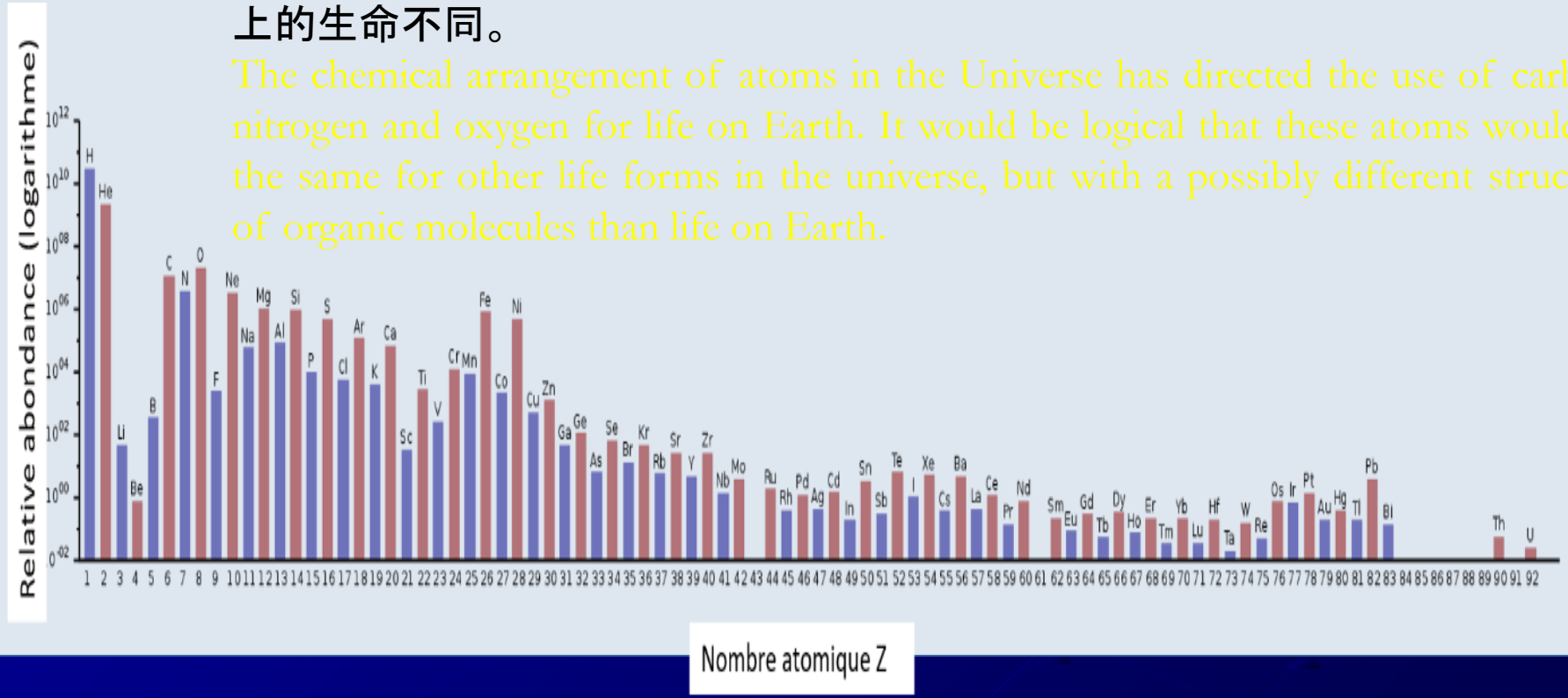
生命在地球上的起源方式和地点仍然是最复杂的生物学问题，可能的化学途径是如此之多，以至于不清楚有一天会找到答。

How and where life arose on Earth remains the most complex exobiological question and the possible chemical pathways are so numerous that it is not obvious that the answer will one day be found.

到处寻找生命
Search for life everywhere

宇宙中原子的化学排列指导了地球生命使用碳、**氮和氧。合乎**逻辑的是，这**些原子**对于宇宙中的其他生命形式是相同的，**但有机分子的**结构可能与地球**上的生命不同。**

The chemical arrangement of atoms in the Universe has directed the use of carbon, nitrogen and oxygen for life on Earth. It would be logical that these atoms would be the same for other life forms in the universe, but with a possibly different structure of organic molecules than life on Earth.

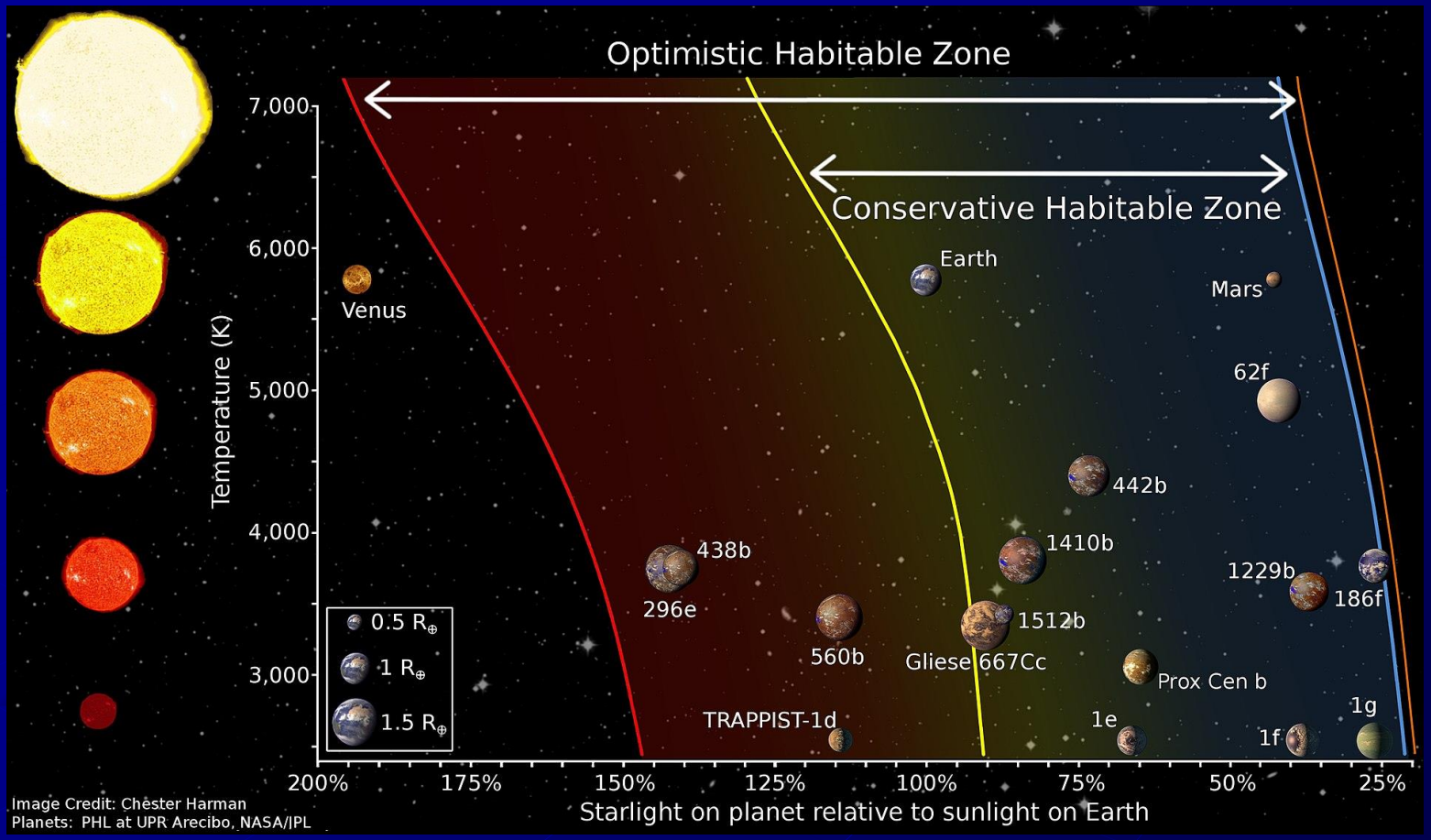


在其他地方寻找生命你必须知道要找的是什么，**天体生物学的基**础之一，**也是它的弱点，是在生物学上**寻找与我们的相似的生命。

To look for life in other places you have to know what to look for and one of the bases of Astrobiology, but also its weakness, is the search for life biologically similar to ours.

到处寻找生命

Search for life everywhere



适居性的概念是一个争论的主题，它的定义与允许唯一的（陆地）生命出现和演化的条件相关。B组

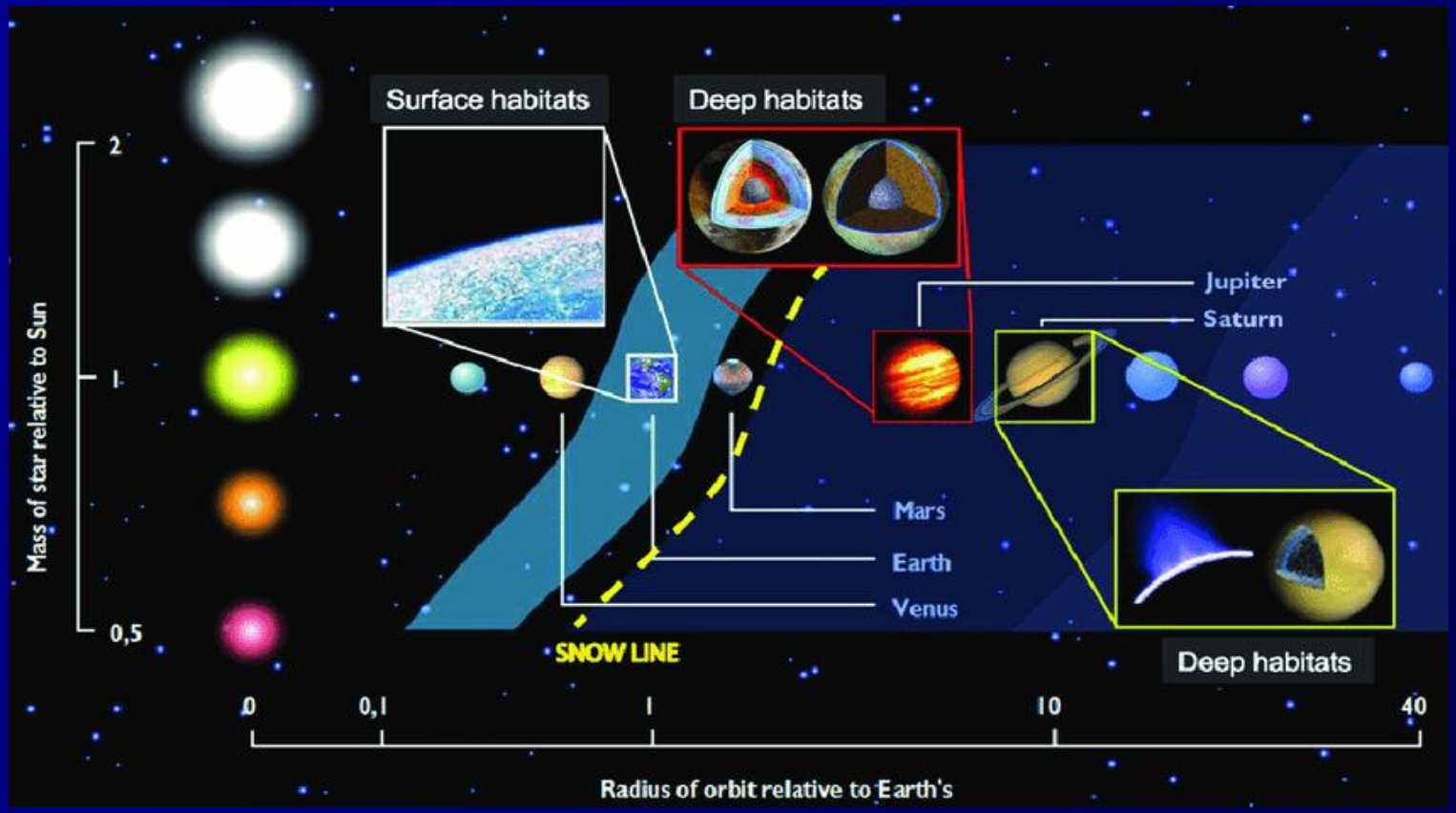
The notion of habitability is a debated topic , its definition is linked to the cond that allowed the emergence and evolution of the only (terrestrial) life we know.

到处寻找生命

Search for life everywhere

适居带延伸到地下环境是太阳系这些环境中生命可能性的一个研究例子。

The extension of the habitable zone to underground environments is an example of research into the possibility of life in these environments of the solar system.



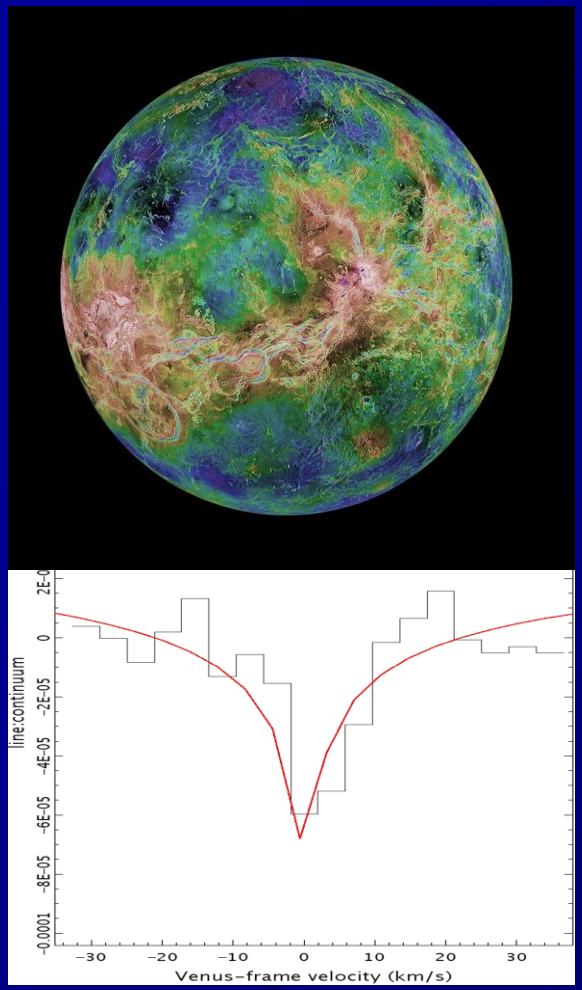
太阳系中的天体及其天体生物学兴趣
Bodies in the Solar System and their astrobiological interest

天体生物学研究则关注在这些被定义为适居的环境中（地球之外）可能出现的生命

Astrobiology studies are then interested in the possible emergence of life in these environments, beyond Earth, which have been defined as habitable

太阳系中的行星及其天体生物学兴趣：金星

Planets in the Solar System and their astrobiological interest: VENUS



我们的“姐妹星球”有相对复杂的有机化学，硫和磷分子存在于由96%以上的二氧化碳组成的极稠密大气中。

它并不在太阳系的适居带中发现，并且缺乏一个关键成分：其表面的水。

Our "sister planet" has relatively complex organic chemistry, with sulfur and phosphorus molecules in an extremely dense atmosphere composed of more than 96% CO_2.

It is not found in the habitable zone of the solar system and it lacks an essential component: water on its surface.

Deuterated water (HDO) (Credit: Greaves, J.S., Richards, A.M.S., Bains, W. et al.)

太阳系中的行星及其天体生物学兴趣：金星

Planets in the Solar System and their astrobiological interest: VENUS

金星在形成之后曾受益于地球等外来物质，金星表面可能有液态水，45亿年前有一段时间的大气层富含水。

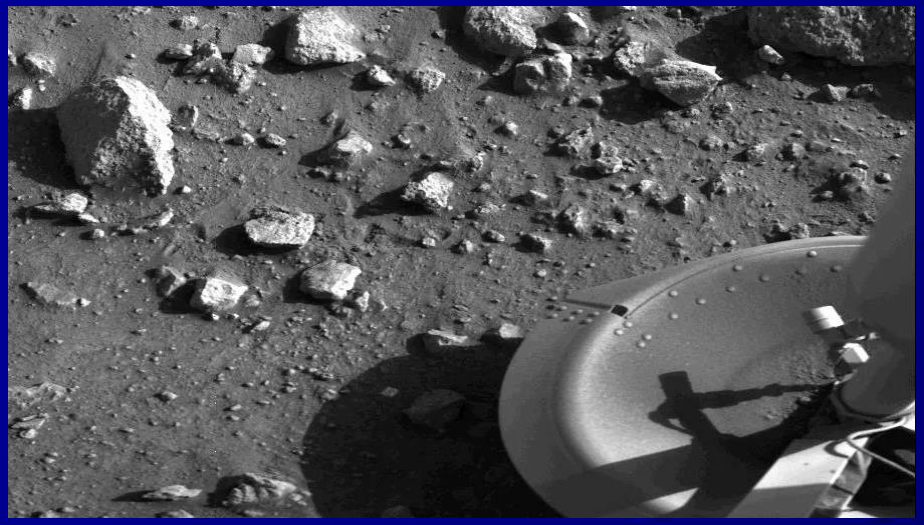
目前它的表面只有活火山，温度约为460°C。

如果生命在最有利的时间发展，有人建议它以微生物的形式生存在其云层中，温度~75°C

Venus benefited from exogenous inputs like Earth after its formation, it may have had liquid water on its surface and a water-rich atmosphere 4.5 billion years ago and for some time.
Currently its surface is only active volcanism with temperatures of around 460°C.
If life developed at the most favorable time, it is proposed that it survived in the form of microorganisms in the clouds of its atmosphere, with a temperature of ~75°C

太阳系中的行星及其天体生物学兴趣：火星

Planets in the Solar System and their astrobiological interest: MARS



这颗行星经常被认为是太阳系中拥有或仍然拥有生命条件的最佳地点。

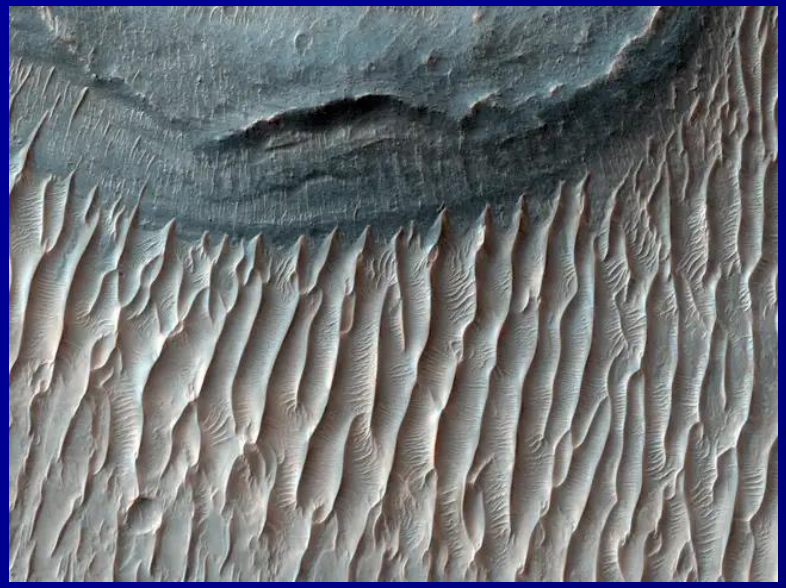
This planet has often been proposed as the best place in the solar system to have had, or still have, conditions for life.

在70年代海盗任务筹备期间，已经考虑过微生物生命的存在：登陆者配备了可以进行实验的仪器，这些实验旨在突出火星生命，检测光合生物活性或为火星细菌提供营养物质，但反应是负面的。

The existence of microbial life was already considered in the 70s during the preparation of the Viking mission: the landers were equipped with instruments capable of carrying out experiments aimed at highlighting Martian life, detecting photosynthetic biological activity or providing nutrients to Martian bacteria, with negative responses.

太阳系中的行星及其天体生物学兴趣：火星

Planets in the Solar System and their astrobiological interest: MARS



Credit: Curiosity, NASA/JPL)

维京人确认了火星过去存在液态水，观测了水道、干河和树突状山谷。

The Vikings confirmed the presence of liquid water in the past of Mars, observing channels, dry rivers and dendritic valleys.

水可能在其表面停留了至少10亿年，并且仍然存在于目前覆盖其表面的矿物中。

The water could have remained on its surface for at least a billion years and is still present in the minerals that currently cover the surface .

在极冠有水冰，怀疑火星地壳有大量的水

At the poles there is water ice in the polar caps and it is suspected that water is present in greater quantities in the Martian crust

太阳系中的行星及其天体生物学兴趣：火星

Planets in the Solar System and their astrobiological interest: MARS

火星上的生命可能与地球上的生命同时发展，并可能在地底下持续存在。

在火星上发现生命将为我们星球上生命的出现提供许多答案。

如果生命在火星上存在，甚至是以微生物的形式存在，并且因为火星不再具有地质活性，那么就有可能在火星表面以痕迹化石的形式发现生命，甚至希望生命存在并存留在地下。

Life could have developed on Mars at the same time as on Earth and perhaps persisted underground.

Finding life on Mars would provide many answers about the emergence of life on our planet.

If life existed on Mars, even in the form of microorganisms, and since the planet is no longer geologically active, it should be possible to discover it in the form of trace fossils on the surface or even hope that it exists and has survived underground.

太阳系中的天体及其天体生物学兴趣：卫星

Bodies in the Solar System and their astrobiological interest: SATELLITES

近几十年来，其他有兴趣的天体生物体被发现超越了小行星的屏障：巨型气态行星的卫星。

巨行星对天体生物学的兴趣有限，因为它们没有表面，因此没有岩石。

它们的卫星对于了解太阳系的起源和演化也很重要。

In recent decades, other habitable bodies of astrobiological interest have been discovered beyond the asteroid barrier: the satellites of giant gaseous planets.
Giant planets are of limited interest to astrobiology because they have no surfaces and therefore no rocks.
Their satellites are also important for understanding the origin and evolution of the Solar System.

太阳系卫星及其天体生物学兴趣

Satellites in the Solar System and their astrobiological interest

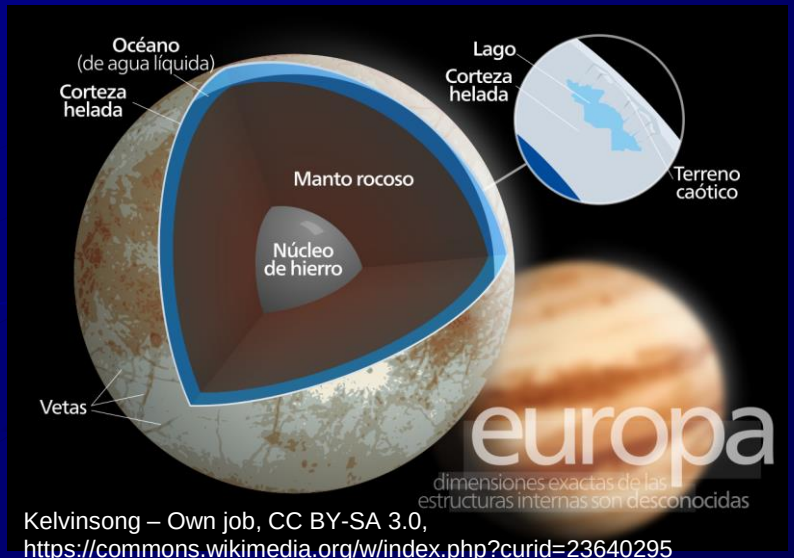
木星周围：木卫三、卡利斯托和欧罗巴。
土星：土卫二和土卫六。
由于卡西尼 — 惠更斯探测器(1997-2017)造访了这些世界15年，土星的冰卫星惊讶于它们的多样性和它们所含的液态水的丰度。

Around Jupiter: Ganymede, Callisto and Europa.
Around Saturn: Enceladus and Titan.
Revealed thanks to the Cassini-Huygens probe (1997-2017), which visited these worlds for 15 years, the icy satellites of Saturn surprise with their diversity and the abundance of liquid water they contain.

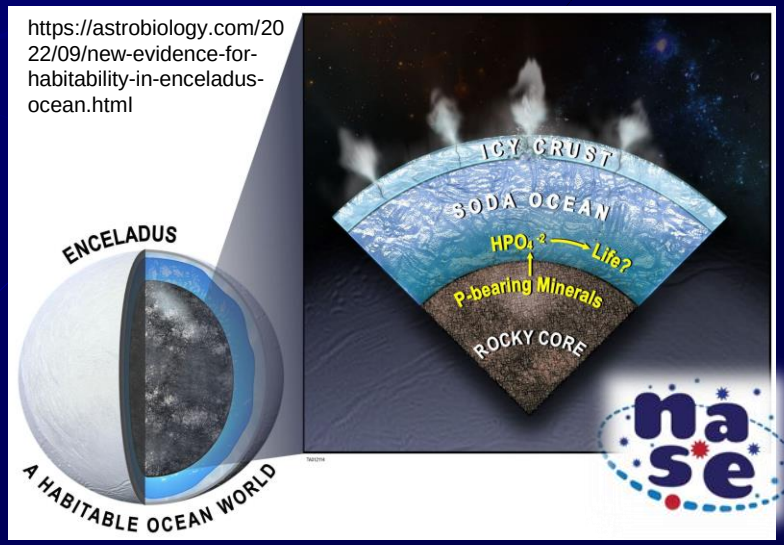
太阳系卫星及其天体生物学兴趣
Satellites in the Solar System and their astrobiological interest

欧罗巴将包含比地球大10倍的海洋，而比我们的行星小3倍。
土卫二在2014年在其表面发现水间歇泉，延伸至其表面以上100公。
这个观测显示冰盖下有一片海。

Europa would contain an ocean ten times larger than Earth's, while being three times smaller than our planet.
Enceladus In 2014 water geysers on its surface, which extend up to 100 km above its surface, were discovered.
This observation has revealed the presence of an ocean under the ice sheet.



Kelvinsong – Own job, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=23640295



太阳系卫星及其天体生物学兴趣：TITAN

Satellites in the Solar System and their astrobiological interest: TITAN

土星最大的卫星“土卫六”在大气层中形成大量的有机物质。

在1980年和1981年，旅行者1号和2号探测器发现了主要由氮气和甲烷组成的极其稠密的大气。

泰坦大气中的化学被证明是极其复杂的，导致有机气溶胶形成并沉积在表面。

Saturn's largest satellite, Titan, presents a large amount of organic matter that forms in its atmosphere.

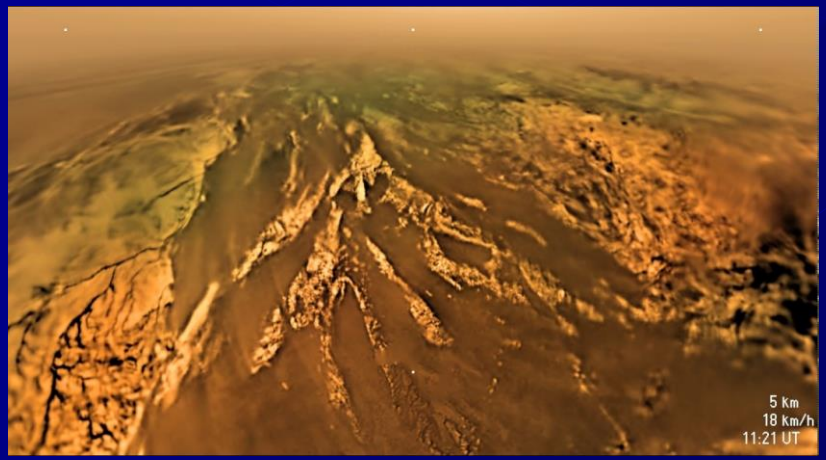
In 1980 and 1981, the Voyager 1 and 2 probes revealed an extremely dense atmosphere composed primarily of nitrogen and methane.

The chemistry in Titan's atmosphere has proven to be extremely complex, resulting in the formation of organic aerosols that settle on the surface.

卡西尼 — 惠更斯任务(1997-2017)证实了土卫六大气层复杂的有机化学。

The Cassini-Huygens mission (1997-2017) confirmed complex organic chemistry in the atmosphere of Titan.

Cassini/Huygens Mission (Credit: NASA)



Titan (Credit: Cassini/Huygens, NASA)

在覆盖有有机颗粒、沙丘和碳氢化合物湖泊的表面获得了令人印象深刻的图像。

天体物理模型认为泰坦可能在其表面下藏有大量的液态水，并提供了出现丰富生命前化学物质和生命形式的所有必要成分。

Impressive images were obtained of the surface covered with organic grains, dunes and hydrocarbon lakes.

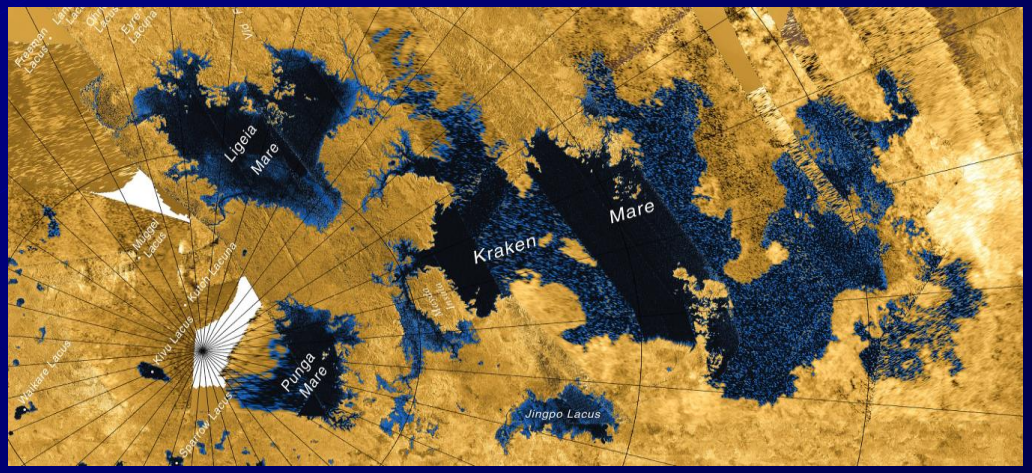
Astrophysical models have proposed that Titan may harbor an ocean of liquid water beneath its surface and presents all the necessary ingredients for the emergence of rich prebiotic chemistry and a possible form of life.

演化地球化学模型显示，从泰坦形成后的第一百万年，这个地下海洋与大气接触，产生了第一个复杂分子。

与地球类似，预计在这个土卫六海洋中会出现热液喷口，这些喷口是有机分子的能量来源，也是生物前系统的潜在环境。

Evolutionary geochemical models suggest that from the first million years after the formation of Titan, this underground ocean was in contact with the atmosphere, in which the first complex molecules would have been produced.

By analogy with Earth, the presence of hydrothermal vents is expected in this Titan ocean, which constitute a source of energy for organic molecules and a potential environment for prebiotic systems.



太阳系之外
Beyond the Solar System

5500颗系外行星（截至2024年）已经被发现并证实在我们的银河系中。它帮助我们了解太阳系的形成，这可能是独一无二的。
目前天体生物学领域的知识和进步使得我们很难假设一个有人居住的行星以及银河系内外已证明存在的生命。

生命的发展似乎有越来越多的潜在场所，但是生命的实际发展呢？

5500 exoplanets (up to now 2024) have being discovered and confirmed in our galaxy. It helps us to understand the formation of our Solar System and that islikely unique.
With the current state of knowledge and advances in the field of Astrobiology, it is very difficult to hypothesize an inhabited planet and the proven presence of life in our galaxy or beyond.
There seem to be more and more potential sites for the development of life, but about the actual development of life?

结论
Conclusions

天体生物学试图确定生命是否可能存在于宇宙的其他部分，如果可以，以什么形式存在，试图回答一个存在性问题：我们是否独自在宇宙中？

几十年来，了解地球上生命的外观对于确定它是巧合还是特定条件和环境中的可再现现象至关重要。

Astrobiology attempts to determine whether life could exist in other parts of the universe and, if so, in what form, to try to answer an existential question: are we alone in the universe?

For several decades, understanding the appearance of life on Earth has been crucial to determine whether it is a coincidence or a reproducible phenomenon under specific conditions and environments.

结论
Conclusions

这种理解对于得出关于宇宙中其他地方的生命可能性的结论是必要的。

尽管作出了积极努力，但尚未得出任何此类结论。

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This understanding is necessary to draw conclusions about the possibility of life elsewhere in the universe.

Despite active efforts, no such conclusions have yet been reached.

谢谢你的关注！

Thank you for
your attention!