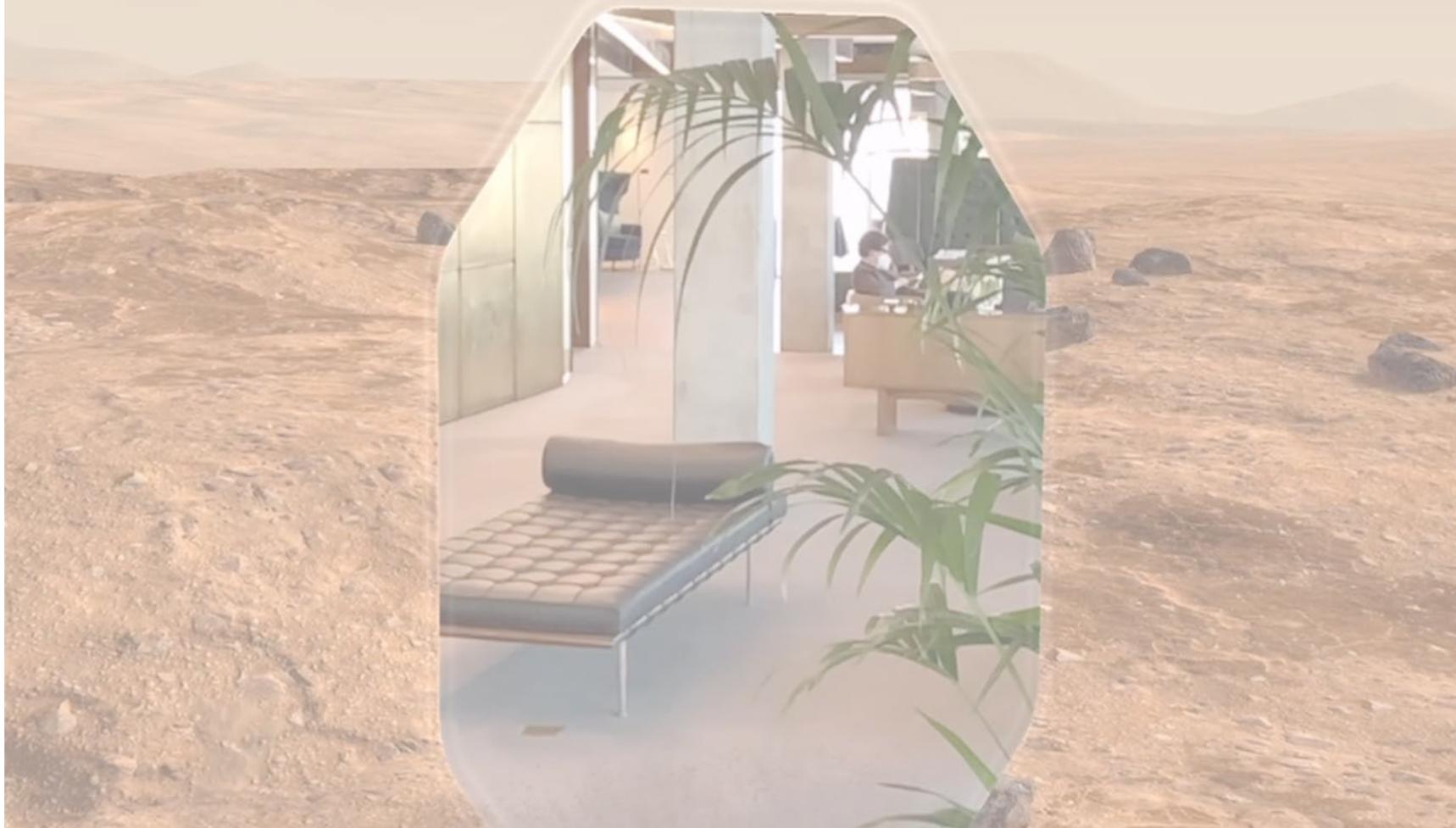


来自地球，去往火星

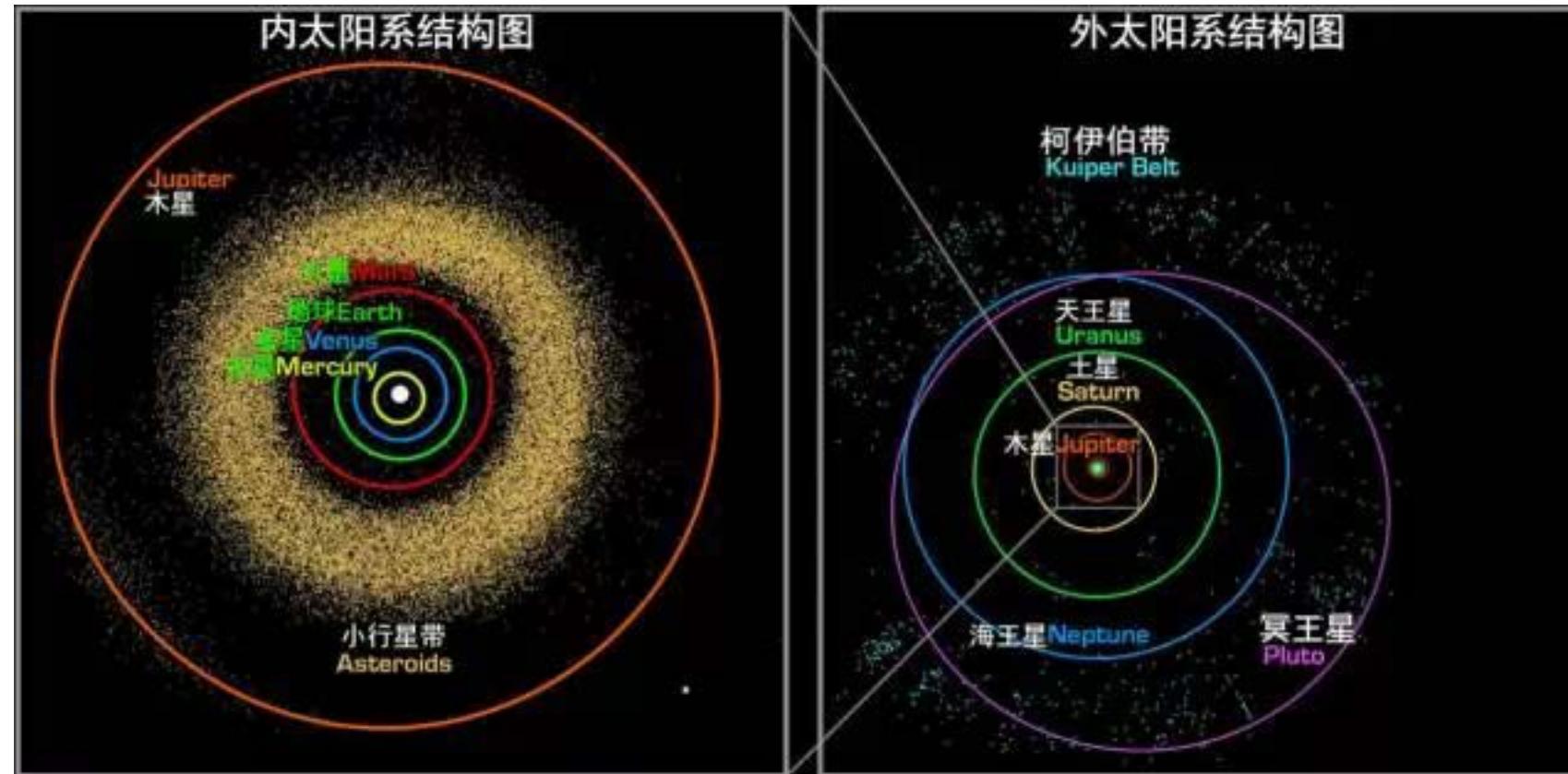
内太阳系类地行星简介



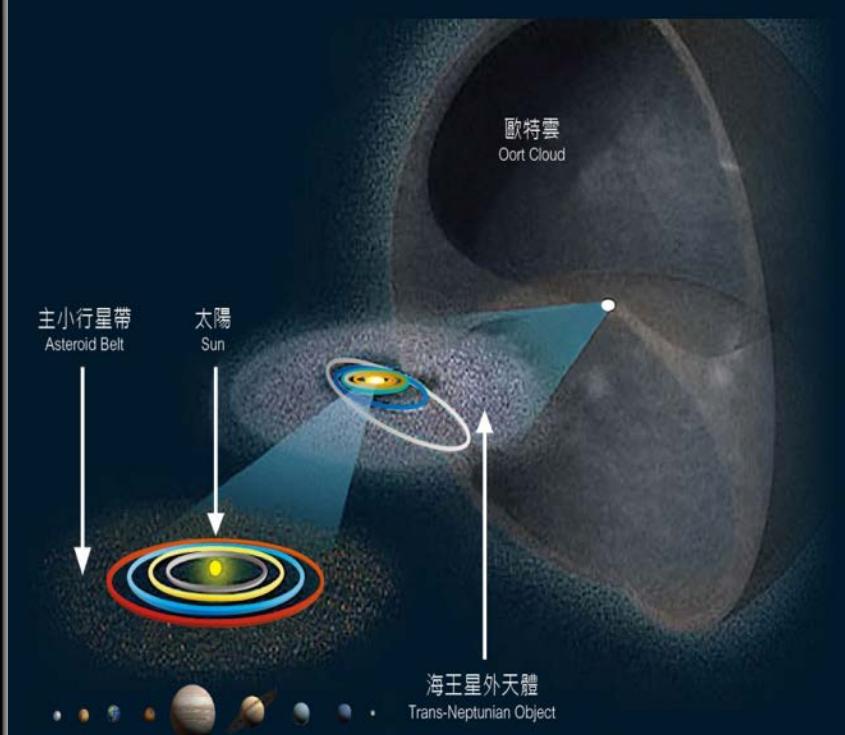
Review: 太阳系的结构

示意图

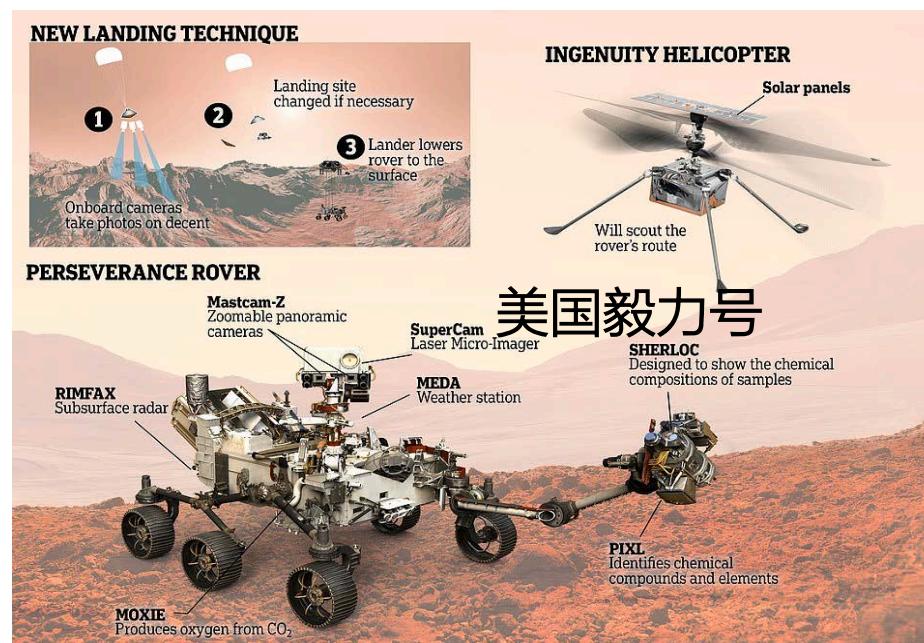
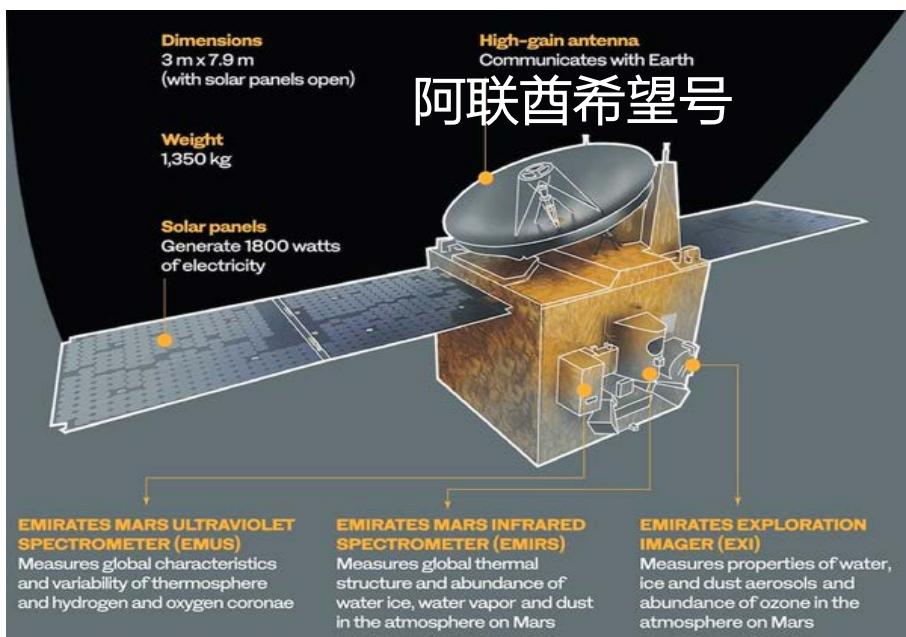
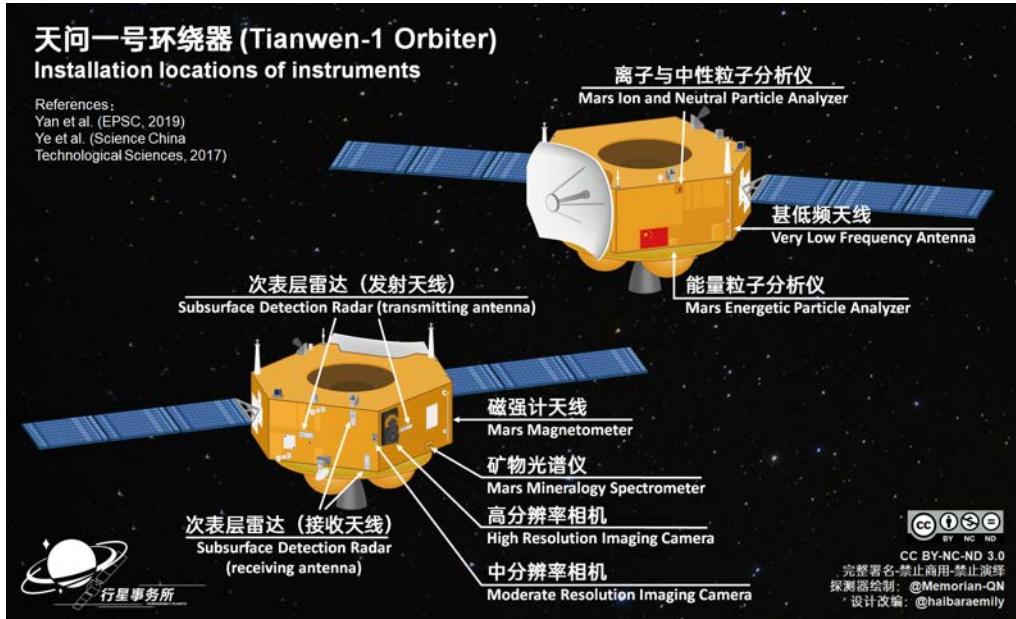
三维图



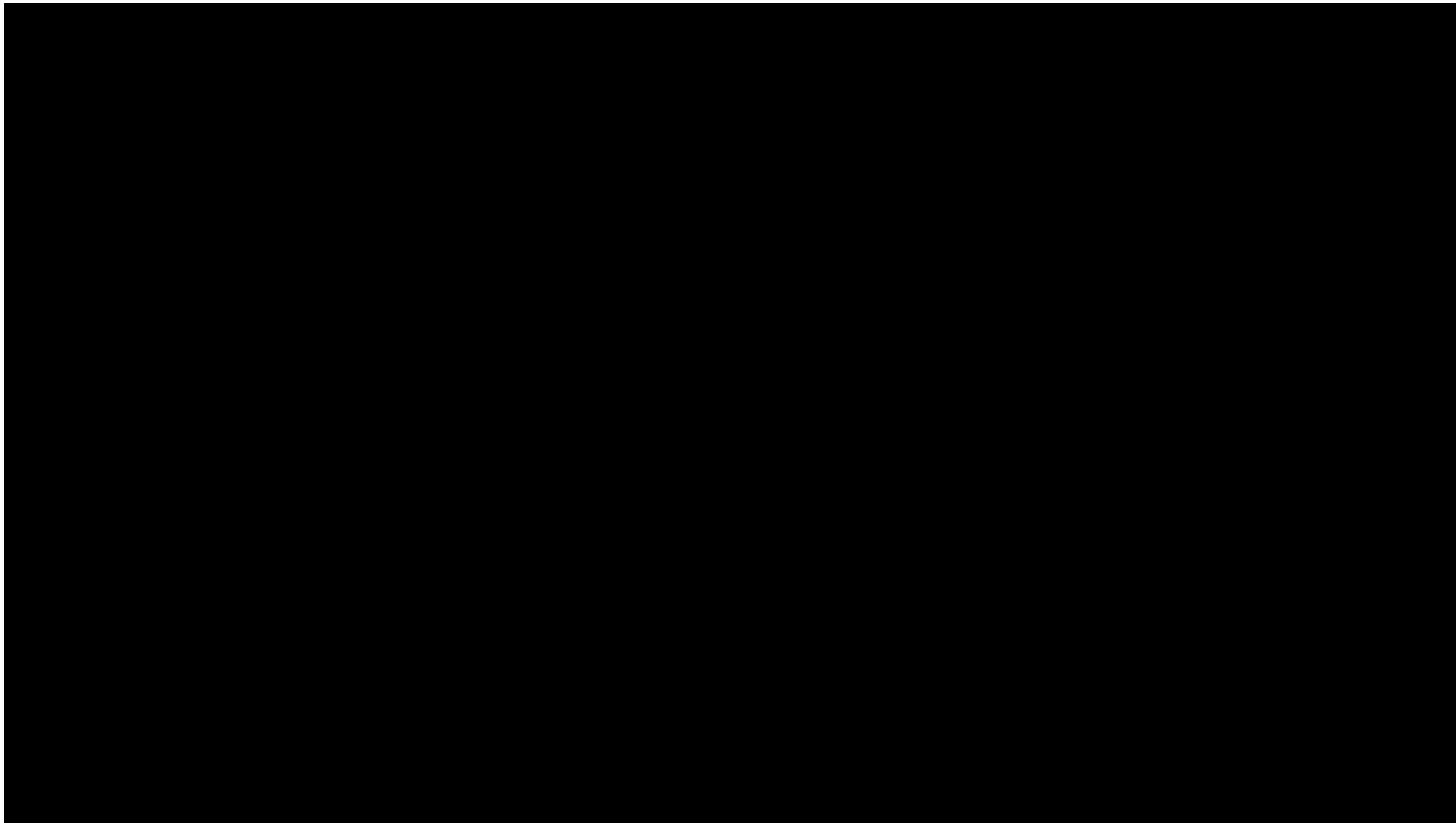
实际比例



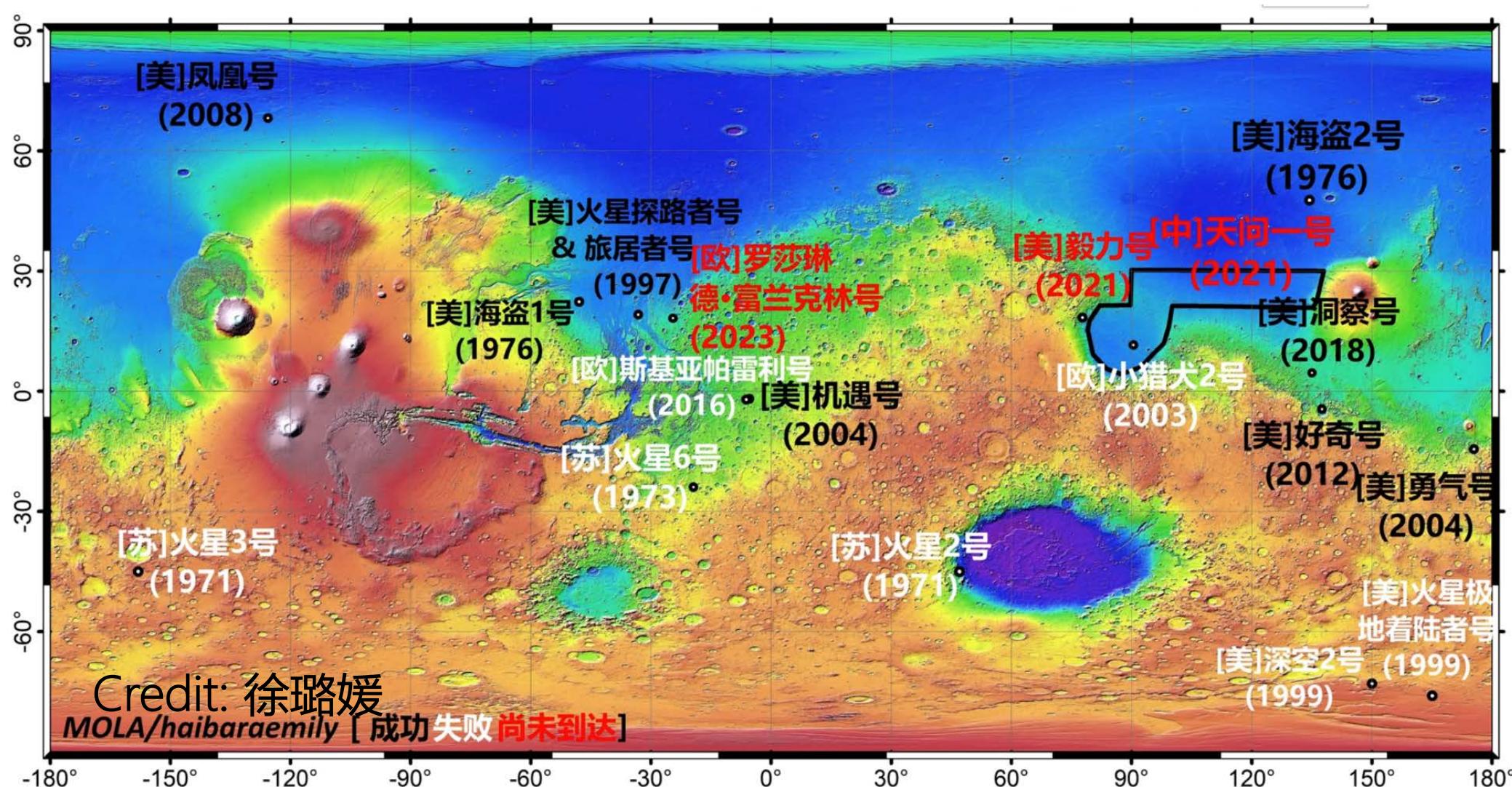
Latest Missions to Mars (2020/7)



China's Zhurong vs. NASA's Perseverance: Rover Tech in Mars Space Race | WSJ

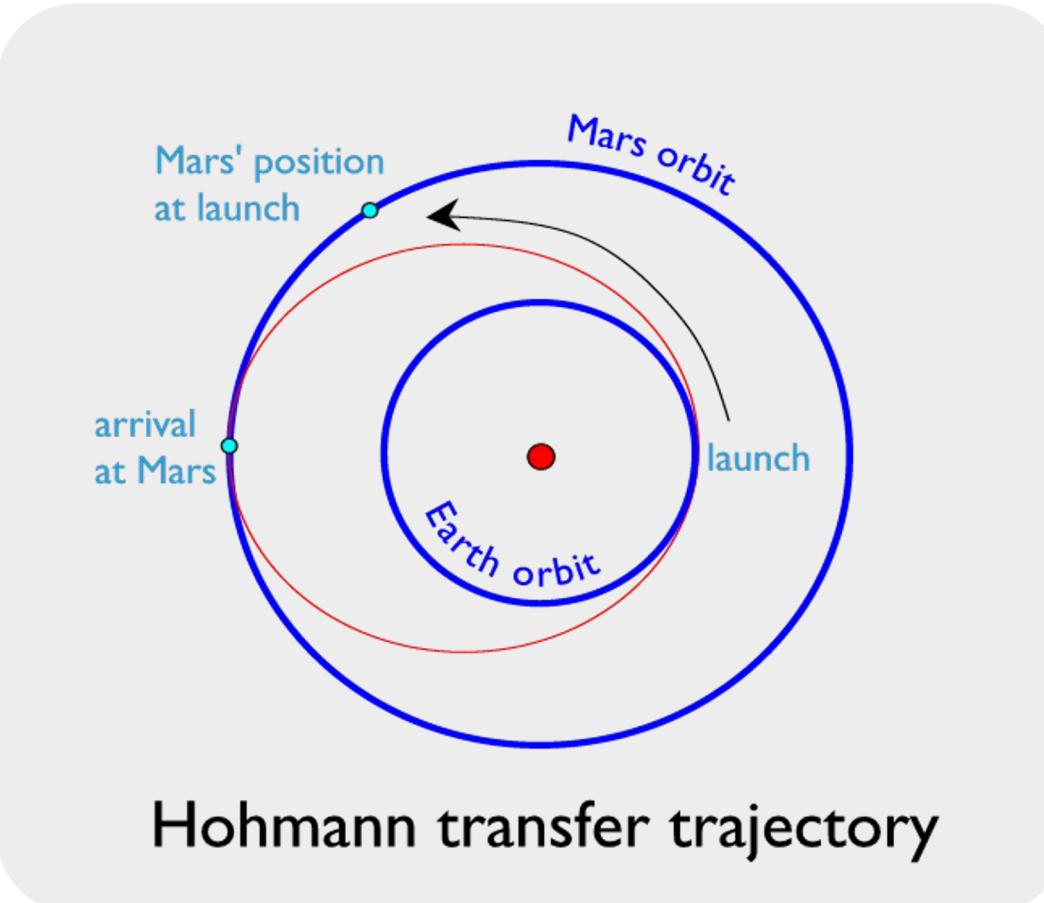


火星着陆点 (till early 2021)



- Check interactive map:
https://en.wikipedia.org/wiki/Template:Features_and_artificial_objects_on_Marsv

Way to Mars



Retrieved from
http://www.lpl.arizona.edu/undergrad/classes/spring2014/Hubbard_206/Lectures1/Jan21.htm

Questions of Today: Why Mars?

- Why do space agencies explore Mars?
- And why SpaceX wants to colonize Mars?
- What will you do if you are going to Mars?
- How could it be possible?

第二讲

来自地球，去往火星

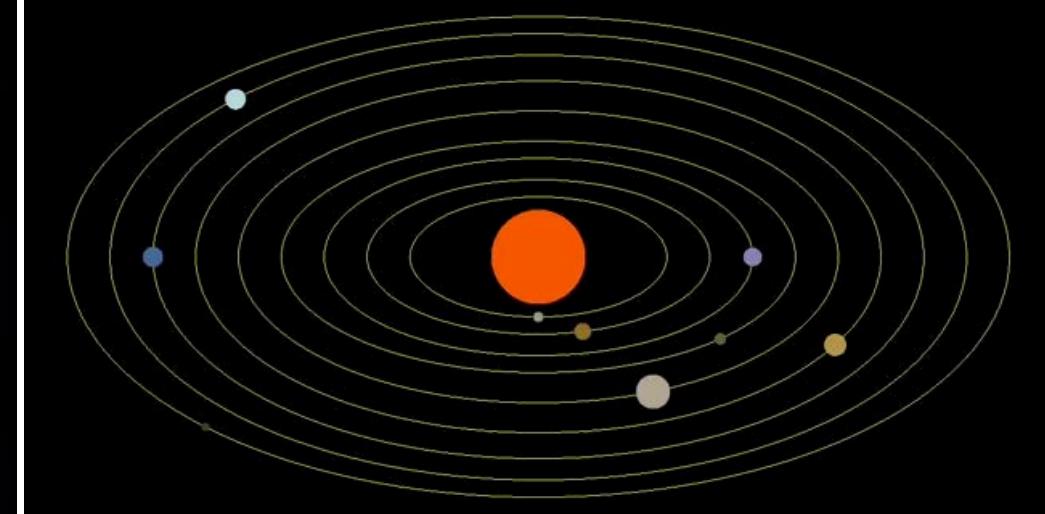
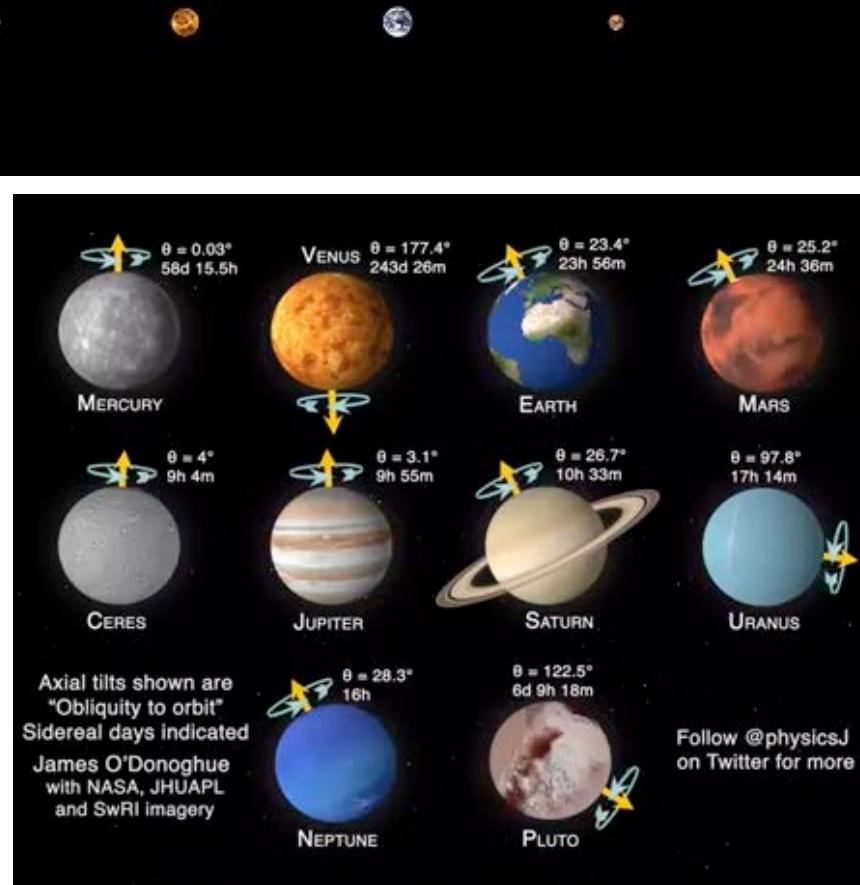
1.1

内太阳系介绍：

1. 位置和轨道特征
2. 类地行星和岩石
3. 地貌特征
4. 结构和演化
5. 磁场
6. 大气层

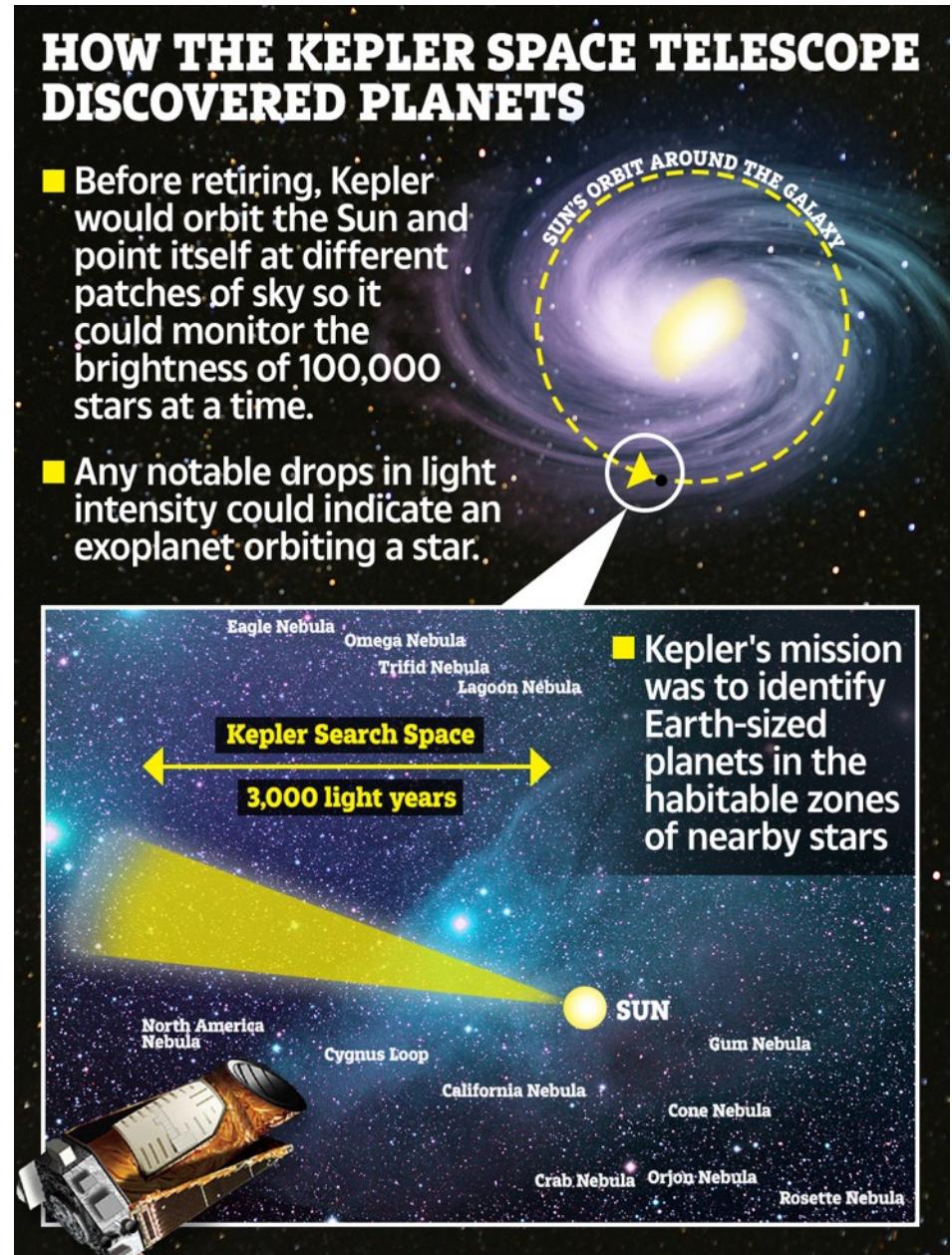
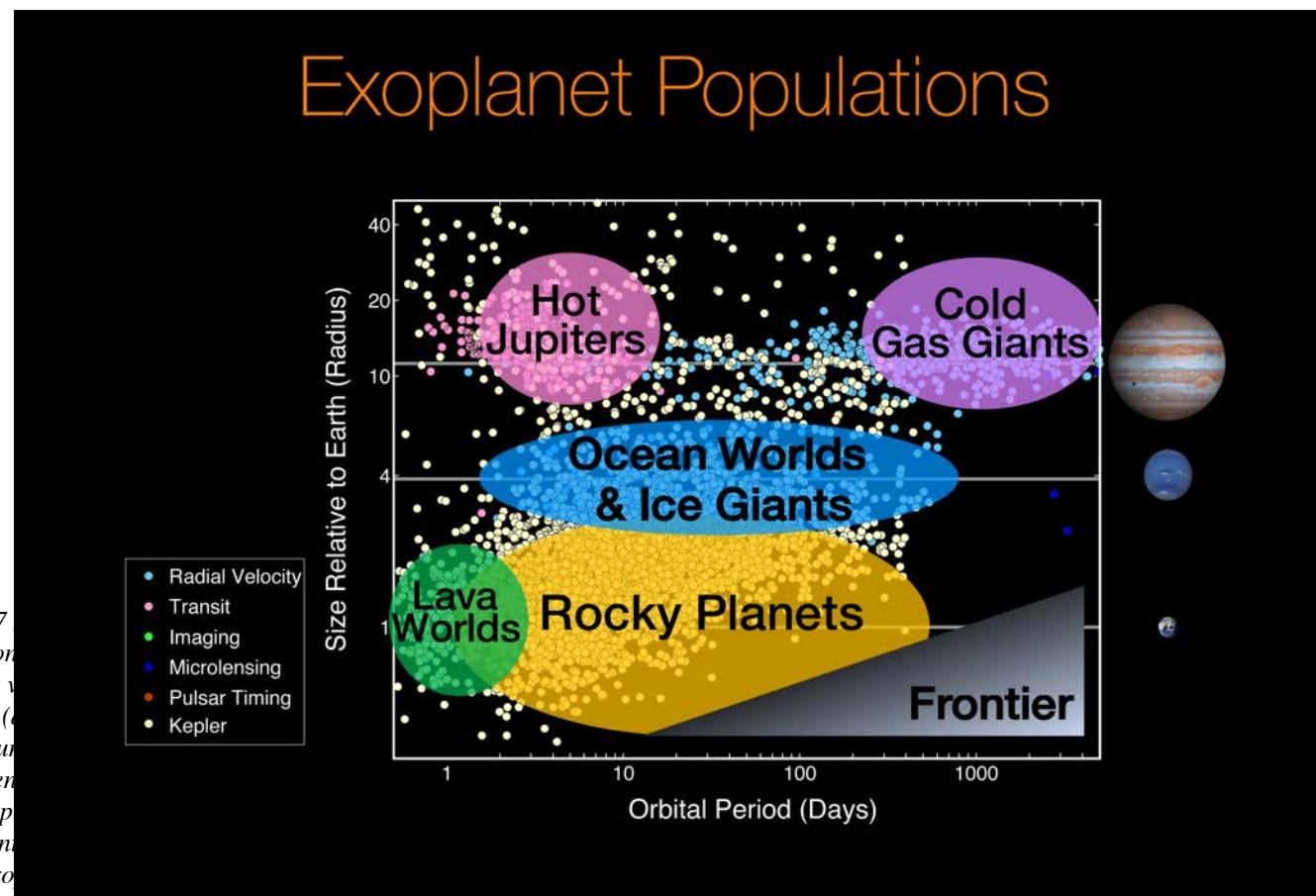
1.自转和轨道

星體	平均密度	半長軸
水星	5.4 g cm^{-3}	0.39 AU
金星	5.2 g cm^{-3}	0.72 AU
地球	5.5 g cm^{-3}	1.0 AU
月球	3.3 g cm^{-3}	1.0 AU
火星	3.9 g cm^{-3}	1.5 AU



2. 类地行星

- 類地行星（英語：terrestrial planet），又稱地球型行星（telluric planet）或岩石行星（rocky planet）都是指以硅酸鹽岩石為主要成分的行星。
- 地球所在的太陽系有四顆類地行星：水星、金星、地球和月球(卫星)。



Carbon versus Silicon



dry ice

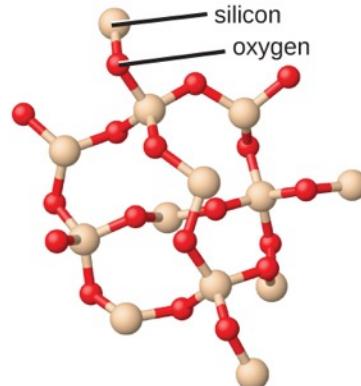


quartz



CO_2
(a)

- 离散分子



SiO_2
(b)

- 无限网络

Why Silicon in computer chips?

Silicon is a semiconductor which can be altered to be either a conductor or insulator. Also it is used to make microprocessors in computer chips.



- Computer chips & Silicon Valley
- Sci-Fi: Silicon-based Life?

Rocks of Fire

Igneous (from Latin *ignis*, "fire") rocks form when magma coming from the rocky mantle (underneath the crust) rises, cools, and solidifies. When magma comes to the surface as lava and solidifies relatively quickly, it creates extrusive rocks, such as basalt or rhyolite. On the other hand, when magma seeps into caves or between rock layers and slowly solidifies, intrusive igneous rocks, such as gabbro and granite, are formed. These rocks usually have thicker grains and are less dense than the extrusive ones. They are arranged in structures called dikes, sills, and batholiths beneath the surface. Igneous rocks make up most of the Earth's crust.

A Complex Process

The Earth's crust is 44 miles (70 km) deep at most. Farther down, rocks are molten or semimolten, forming magma that rises through the crust and opens paths through cracks, cavities, or volcanoes. Magma can solidify when it is moving or still or when underground or expelled to the surface. All these characteristics together with different mineral compositions create a wide variety of igneous rocks.

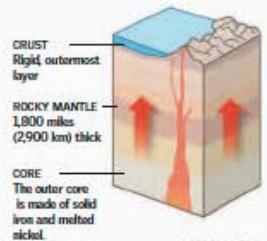
BENEATH THE SURFACE PLUTONIC ROCKS

Most magma is underground in the form of plutons, which undergo a solidification process. This forms intrusive (or plutonic) rocks. When magma intrudes into vertical fissures, the resulting rock formations are called dikes; those between sedimentary layers are sills; and batholiths are masses hundreds of miles long. In general, intrusive rocks crystallize slowly, and their minerals form thick grains. But the solidification process will determine the structure; the rock will be different depending on whether solidification is slow (over millions of years) or fast and whether it loses or gains materials along the way.



DIKES
The structure of the rock depends on its formation process. Thus, a rock resulting from magma intrusion into a dike will have a structure and coloring different from the rock around it because of having crystallized faster.

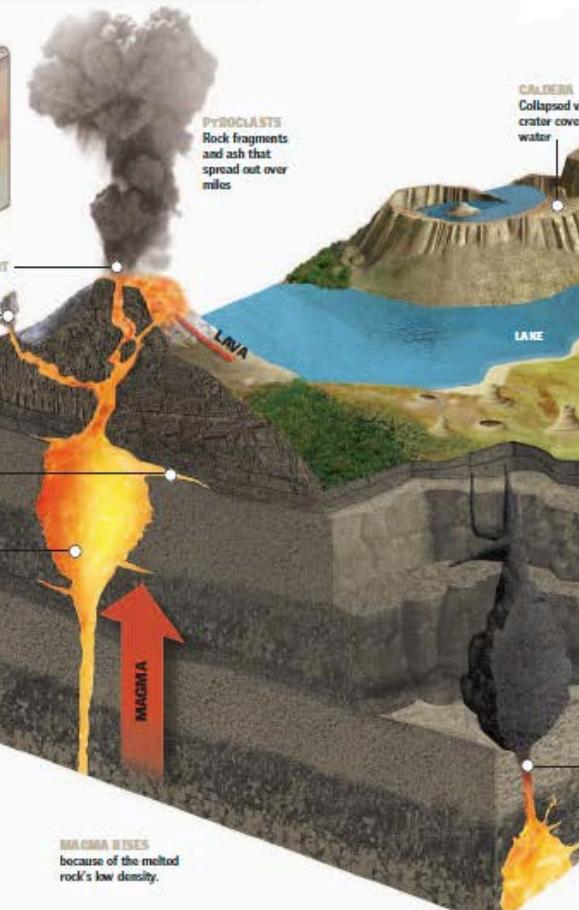
70% SILICA CONTENT



2,200° F
(1,200° C)
THE TEMPERATURE OF
LAVA IN THE CRUST

SILLS
occupy the spaces between overlying layers of rocks.

MAGMA CHANNEL
receives magma material from the mantle.



MAGMA RISES
because of the melted rock's low density.

ON THE SURFACE VOLCANIC ROCK

Volcanic, or extrusive, rocks are those that reach the surface as lava because of volcanic activity. They solidify relatively quickly on the surface. Some, like the obsidians, solidify too quickly to crystallize. This class of rock is distinguished by its viscosity, caused by the low silica content and dissolved gas at the moment of eruption, which give these rocks a particular texture. Highly liquid lava, such as basalt, usually covers large surfaces because it solidifies on the outside while still remaining fluid underground.

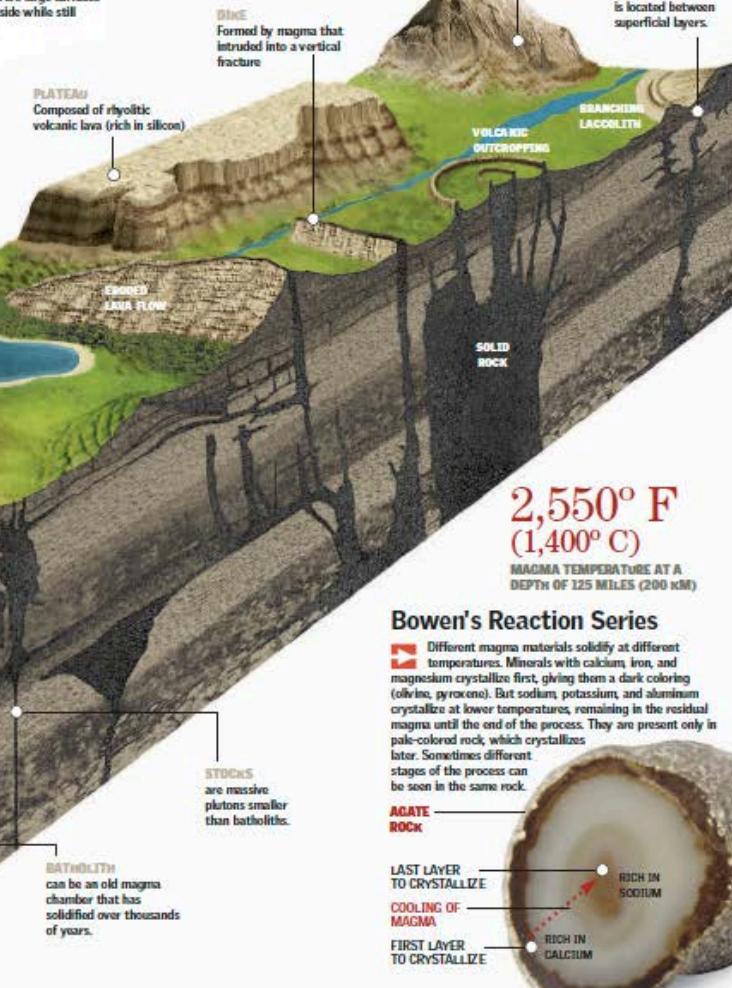


BASALT ROCK
originates from highly liquid fluid magma that cools quickly.

50% SILICA CONTENT
According to the type of lava

ASH CONE
Composed of pyroclasts of the volcano itself

LACCOLITH
is located between superficial layers.

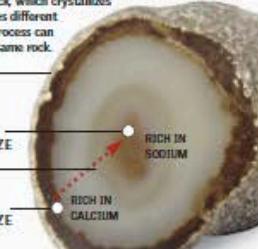


2,550° F
(1,400° C)
MAGMA TEMPERATURE AT A
DEPTH OF 125 MILES (200 KM)

Bowen's Reaction Series

Different magma materials solidify at different temperatures. Minerals with calcium, iron, and magnesium crystallize first, giving them a dark coloring (olivine, pyroxene). But sodium, potassium, and aluminum crystallize at lower temperatures, remaining in the residual magma until the end of the process. They are present only in pale-colored rock, which crystallizes later. Sometimes different stages of the process can be seen in the same rock.

ACATE
ROCK



岩石和矿物的用途

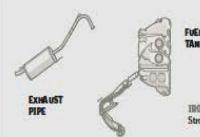
Britannica Illustrated Science Library – Rocks and Minerals

In Daily Life

It is impossible to conceive of modern life without the constant use of objects and materials made of rocks and minerals, metallic or nonmetallic. To illustrate this, it is enough simply to consider the elements that make up a car, trace them back to their origins, and consider the processes that shaped them. In some cases, the texture and characteristics of each material can be easily seen. Other materials, especially nonmetals such as coal and sulfur, are less noticeable, but they are a part of the production process as well. This process tends to emphasize and improve the physical, chemical, and electric characteristics of each material.

Hydrocarbons, the Source of Energy

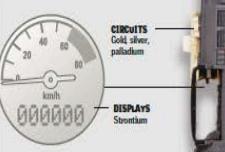
The combustion of petroleum derivatives provides energy for propulsion. The combustion pathway begins with the storage of gas in the tank and ends with the oxidation of words gases through the exhaust pipe. There a catalyst with thousands of cells filters the most toxic gases: carbon monoxide and nitrogen oxide.



Electric Properties: Conductors, Insulators, and Semiconductors

Metals, which tend to lose electrons, are the sole of electric cables and circuits. Nonmetals (and their polymeric derivatives) hinder the flow of electrons and are used as insulators. Other minerals, such as silicon, have a unique property: electronic components are manufactured by adding impurities to modify their properties.

In smaller contact areas, more expensive metals are used (the heat conductor). Chips and other electronic components contain silicon. Phosphorescent displays have strontium paint.



Metals

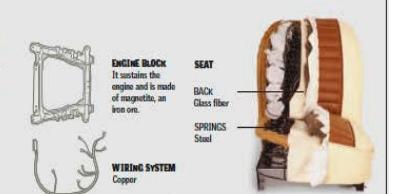
The body of a car is made of iron (present in both steel and magnetite), aluminum, magnesium, and manganin. Other metals are used to produce parts that are resistant to temperature, corrosion, or wear. Gold, silver, and palladium are used in specific fields. Cobalt and platinum are used in very specific parts, and other metals are used in smaller amounts in lubricants, fluids, or paints.

20%

MORE ALUMINUM IS REQUIRED BY VOLUME FOR THE SAME WEIGHT OF STEEL.

SPRINGS Copper

WIRING SYSTEM



Nonmetals

Silicon and its derivatives (silicones, silica, and silicates such as asbestos) are component materials in car manufacturing. They appear in crystallized form, such as quartz, and in metasilicified—or glass—form. Other nonmetals aid in the strengthening of metals—for example, carbon is the production of steel and sulfur in the vulcanization of rubber.

WHEELS Titanium is often used in alloys and in the car's finish.

MIRRORS Glass and head

STEERING WHEEL Silicon coating

ENGINE JOINTS Asbestos

SPARK PLUGS Porcelain (kaolin)

TIRES Vulcanized steel mesh

Black Gold

Because of its economic importance as a source of energy, petroleum, or oil, is called black gold. Searching for it requires large amounts of money and years of investigation and exploration, all with no guarantees. Once discovered, petroleum extraction entails the use of expensive machinery, which includes everything from oil pumps to refineries that convert oil into many derivative products. The oil trade is one of the most lucrative businesses worldwide, and a change in its price can affect national economies and put whole countries on guard. Petroleum is a nonrenewable source of energy.

How Petroleum Is Obtained

1. SEARCH

Indirect methods are used to detect the presence of hydrocarbons. However, the information obtained is not conclusive.

2. EXPLORATION

Once a deposit is detected, a soil is drilled to verify that there is petroleum with economic potential.



1 DRILLING A borehole is made in the rock strata to extract oil.

2 INJECTION OF MUD WATER The injection of mud water pushes up the petroleum and makes it flow faster.

3 CIRCULATION Flow sheet flows through the pipe and exits through the drill bit.

4 SHELL MUD Once oil is detected, the drilling proceeds more slowly, and valves are closed to prevent the oil from flowing back under high pressure.

5 AS THE MUD RISES, IT CARRIES THE OIL AND ROCKS WHICH STRATA HAVE BEEN PERFORATED.

3. EXTRACTION

If the well is productive, the drilling towers are removed and extraction systems are installed.

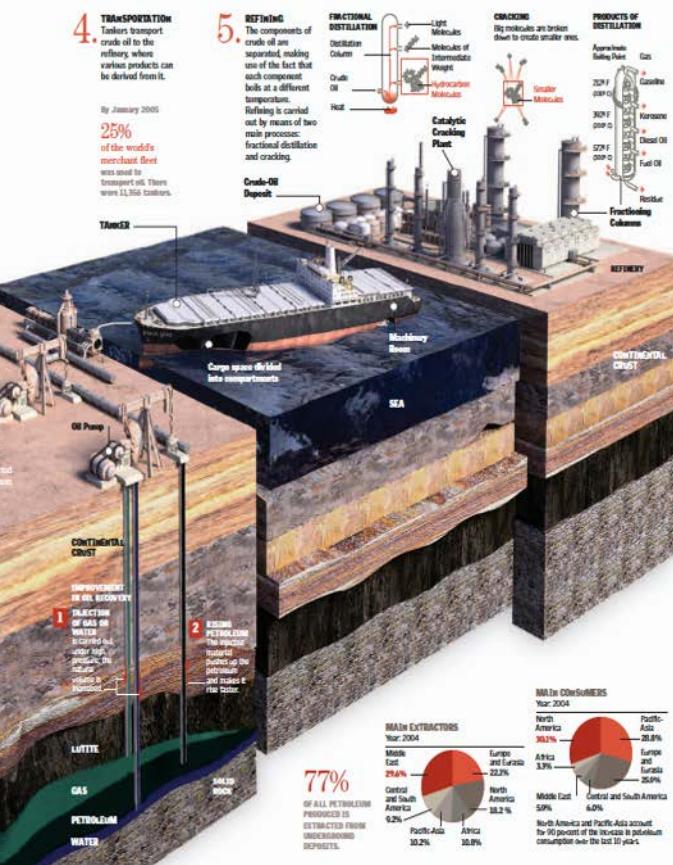
4. TRANSPORTATION

If the well is productive, crude oil to the refinery, where various products can be derived from it.

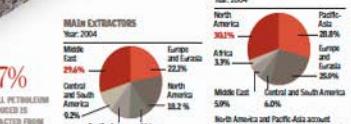
5. REFINING

The components of crude oil are separated, making use of the fact that each component boils at a different temperature.

Refining is carried out by means of two main processes: fractional distillation and cracking.



MAIN EXTRACTORS Year 2004



77%

OF ALL PETROLEUM PRODUCED IS EXTRACTED FROM UNDERGROUND DEPOSITS.

Middle East
30.1%
Europe and Eurasia
29.4%
North America
18.3%
Central and South America
8.2%
Africa
10.2%
Pacific Asia
10.8%

North America is the top annual producer for 90 percent of the increase in petroleum consumption over the last 10 years.

3. 地貌

Mercury
diameter = 4880 km



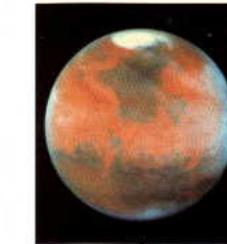
Venus
diameter = 12,100 km



Earth
diameter = 12,800 km

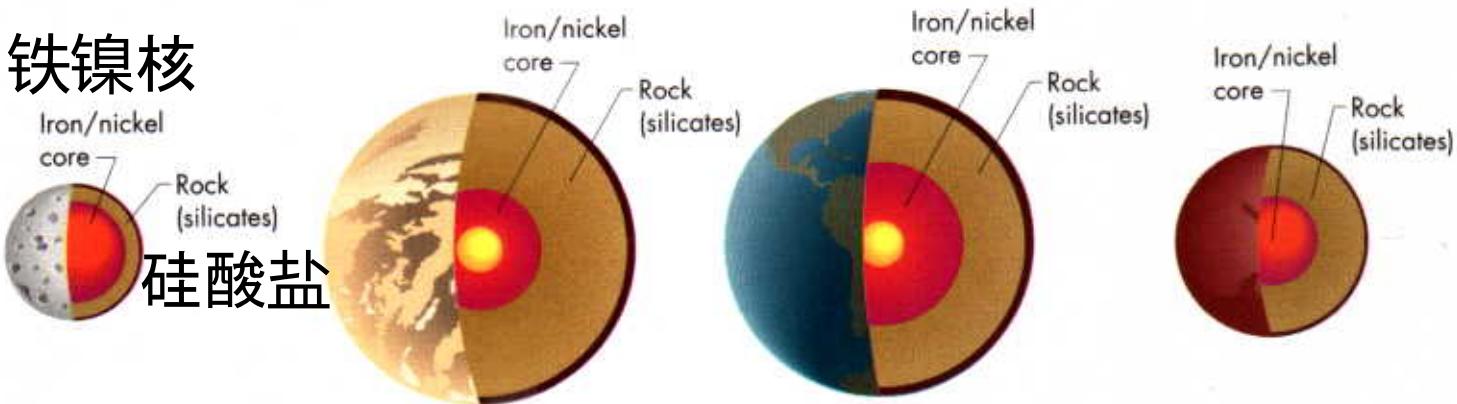


Mars
diameter = 6,800 km

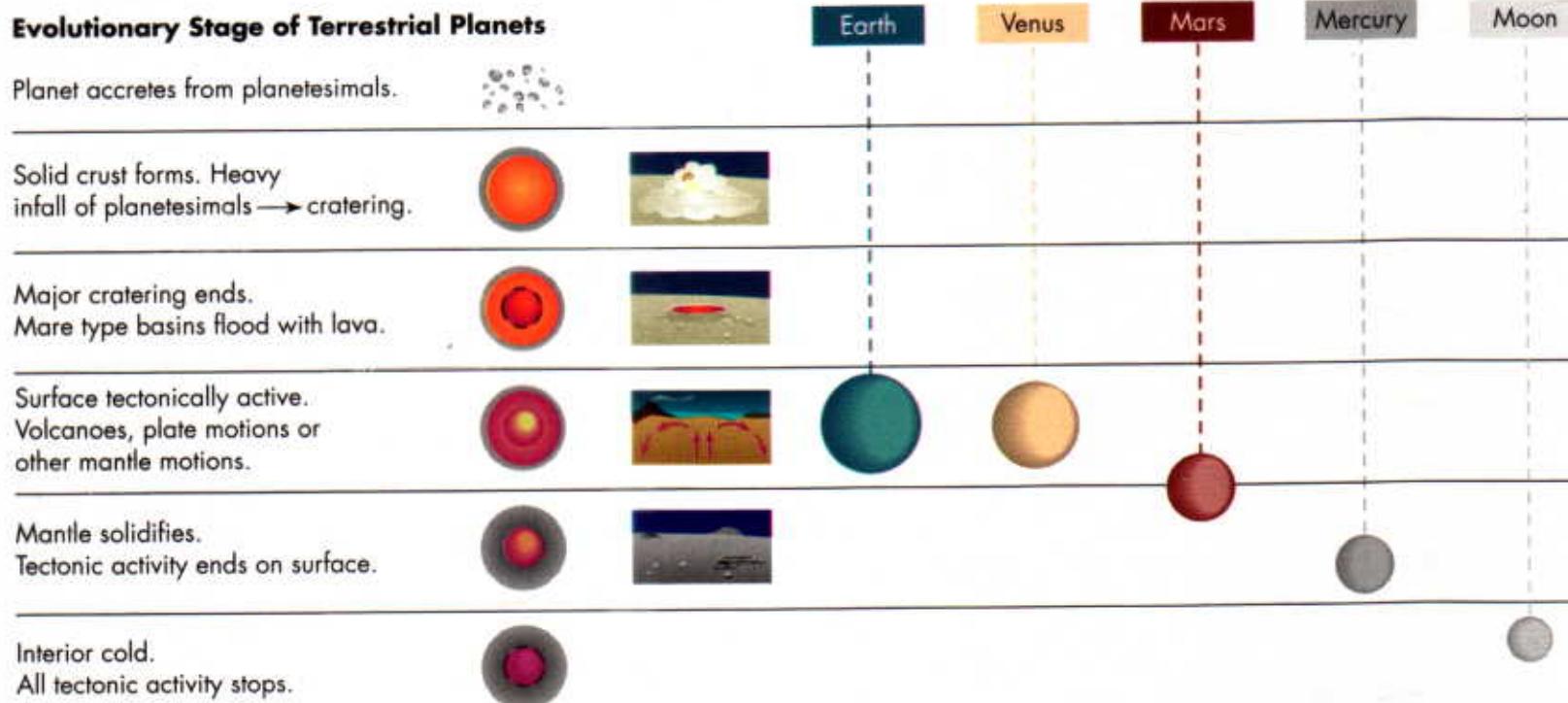


4. 类地行星的内部结构和演化

铁镍核

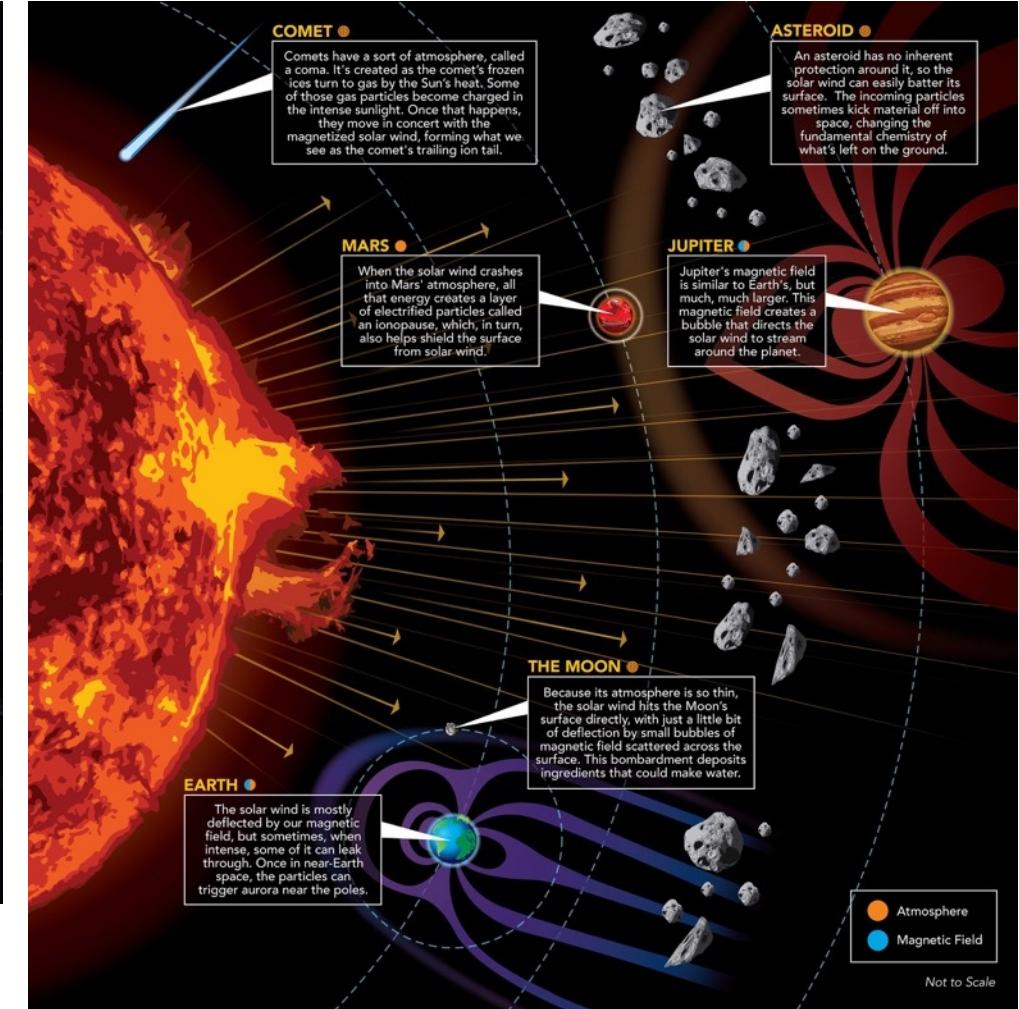
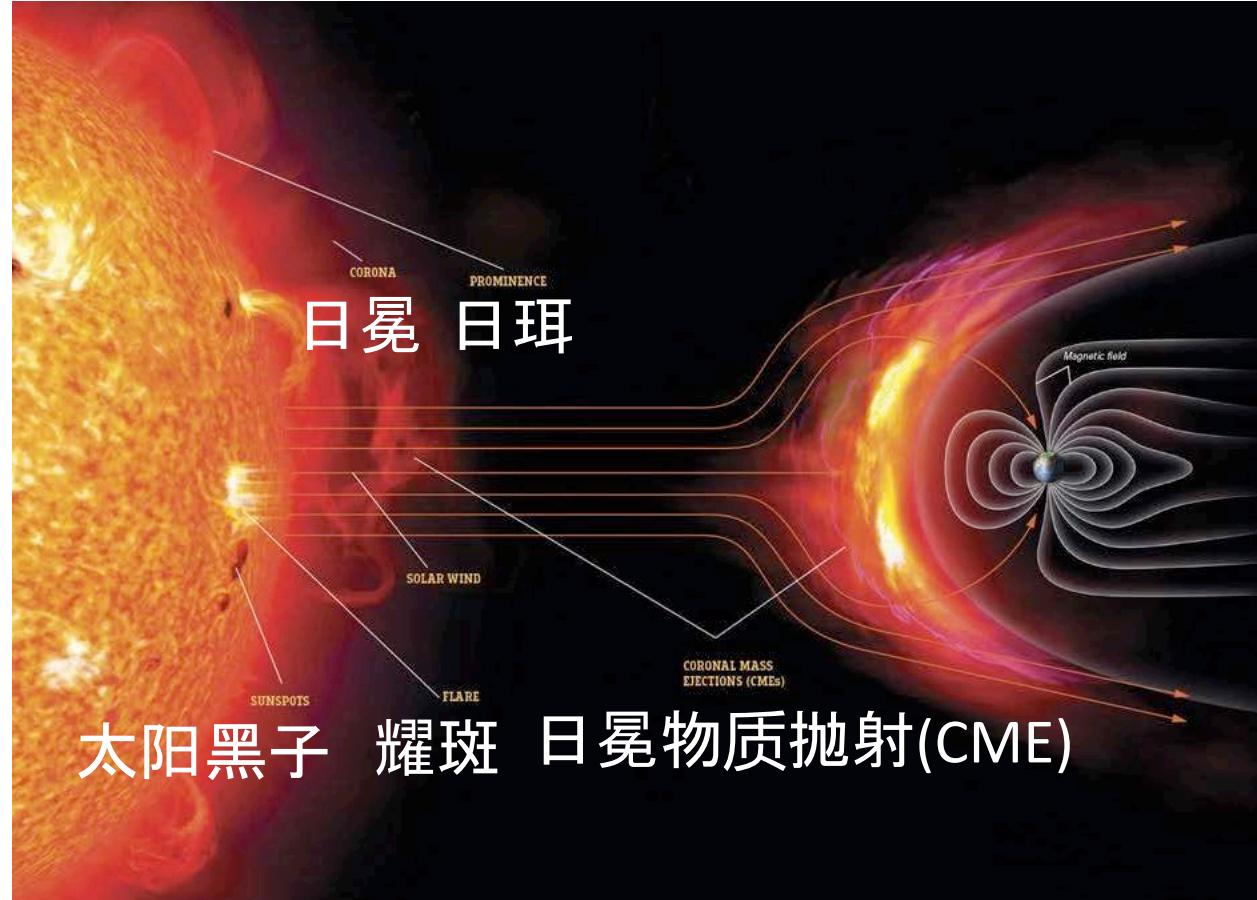


硅酸盐

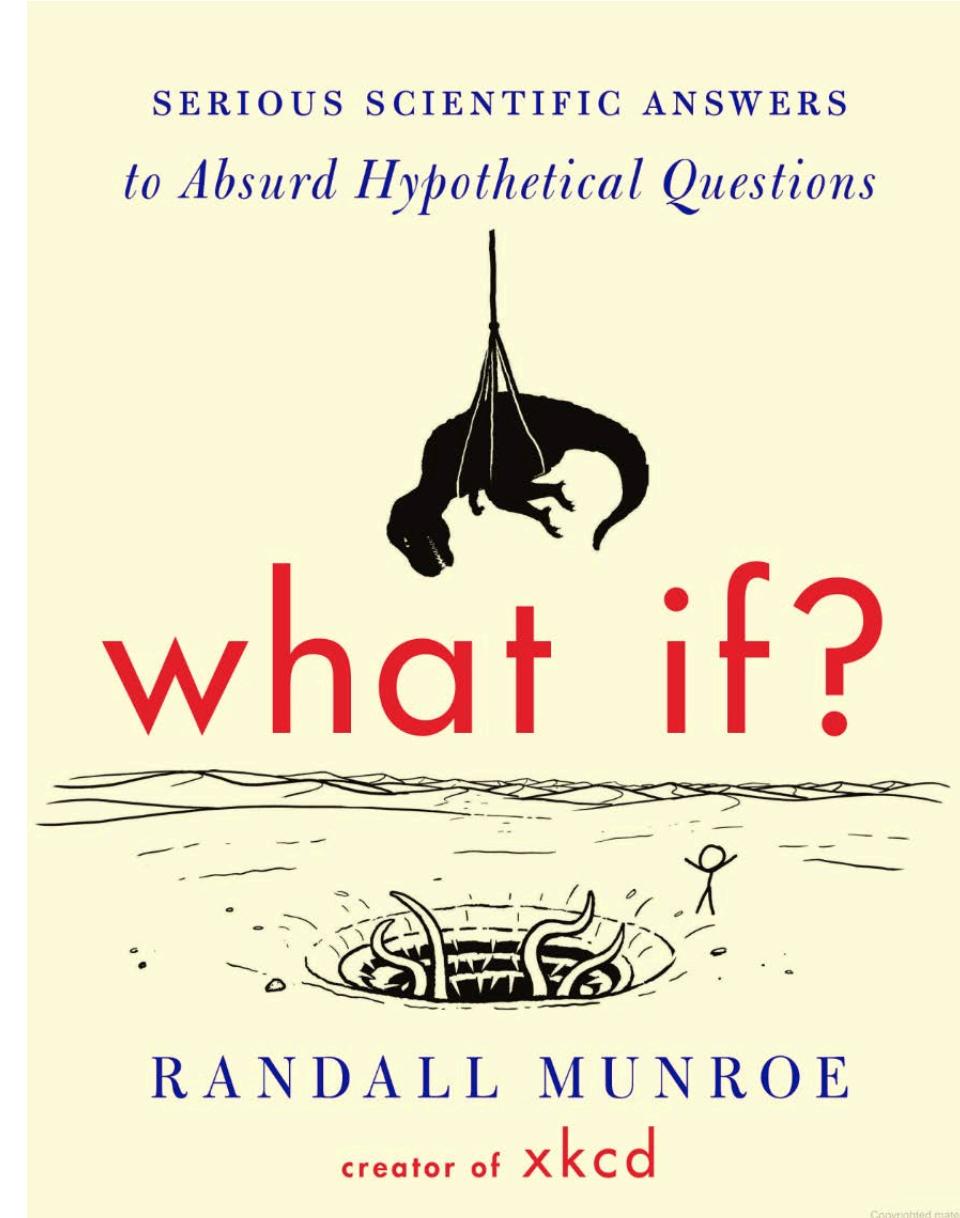


5. Magnetic field, Dynamo, and Magnetic Shield

- <https://www.britannica.com/science/dynamo-theory>
- Mercury's field is weak because it rotates so slowly.
- Venus doesn't have an appreciable field because there appears to be little convection in its molten interior.
- Mars doesn't have an appreciable field – although it did in the past – because its interior has solidified.



Question: What If Earth loses its magnetic field?



6. Atmospheres of terrestrial planets

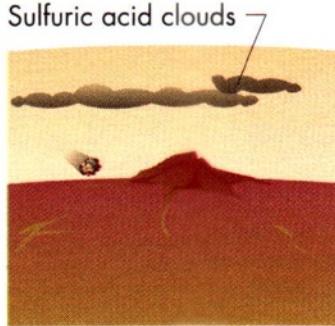
Mercury



$T_{\text{surface}} \approx 623\text{K}$ (day)
(approx. 660°F)
 $\approx 100\text{K}$ (night)
(approx. -279°F)

Venus

硫酸云
Sulfuric acid clouds



$\text{CO}_2 \approx 96\%$ $\text{N}_2 \approx 3.5\%$
 $T_{\text{surface}} \approx 750\text{K}$
(approx. 900°F)

Earth

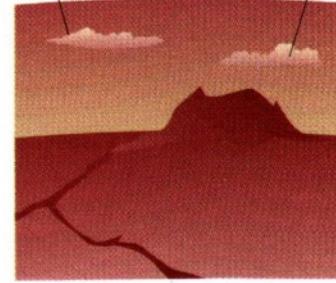
H_2O clouds



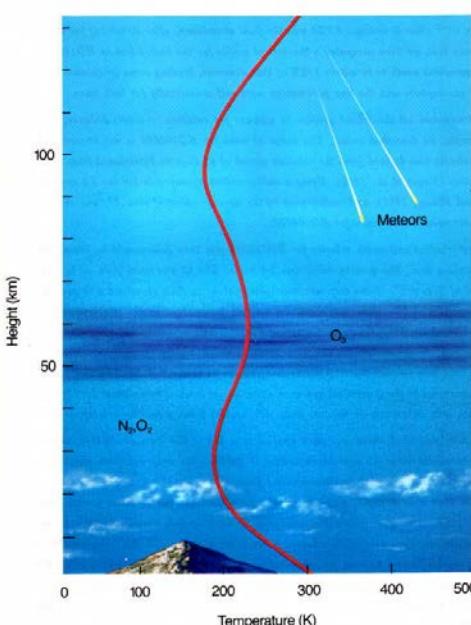
$\text{N}_2 \approx 78\%$ $\text{O}_2 \approx 21\%$
 $T_{\text{surface}} \approx 300\text{K}$
(approx. 70°F)

Mars

Frozen CO_2 clouds
Frozen H_2O clouds



$\text{CO}_2 \approx 95\%$ $\text{N}_2 \approx 2.7\%$
 $T_{\text{surface}} \approx 218\text{K}$
(approx. -67°F)



电离层(磁层)

中间层

臭氧层

平流层

对流层

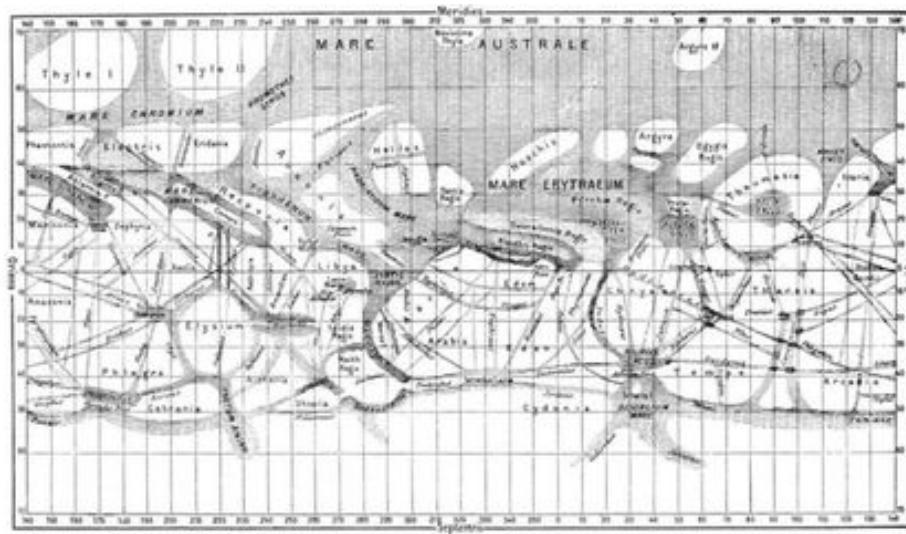
World	Composition of Atmosphere	Surface Pressure*	Average Surface Temperature	Winds, Weather Patterns	Clouds, Hazes
Mercury	helium, sodium, oxygen	10^{-14} bar	day: 425°C (797°F); night: -175°C (-283°F)	none: too little atmosphere	none
Venus	96% carbon dioxide (CO_2) 3.5% nitrogen (N_2)	90 bars	470°C (878°F)	slow winds, no violent storms, acid rain	sulfuric acid clouds
Earth	77% nitrogen (N_2) 21% oxygen (O_2) 1% argon H_2O (variable)	1 bar	15°C (59°F)	winds, hurricanes, rain, snow	H_2O clouds, pollution
Moon	helium, sodium, argon	10^{-14} bar	day: 125°C (257°F); night: -175°C (-283°F)	none: too little atmosphere	none
Mars	95% carbon dioxide (CO_2) 2.7% nitrogen (N_2) 1.6% argon	0.007 bar	-50°C (-58°F)	winds, dust storms	H_2O and CO_2 clouds, dust

* 1 bar = the pressure at sea level on Earth.

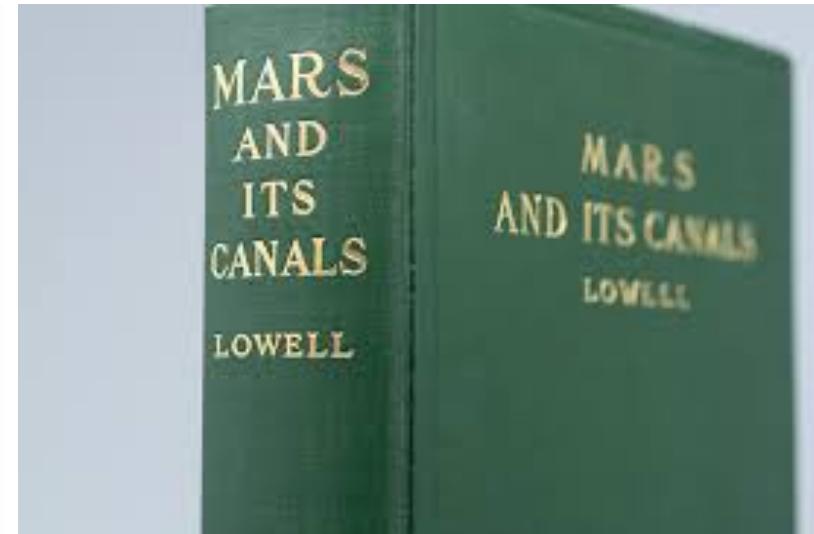
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火星之旅

Giovanni Schiaparelli 乔范尼·弗夏帕雷利 (1835–1910)

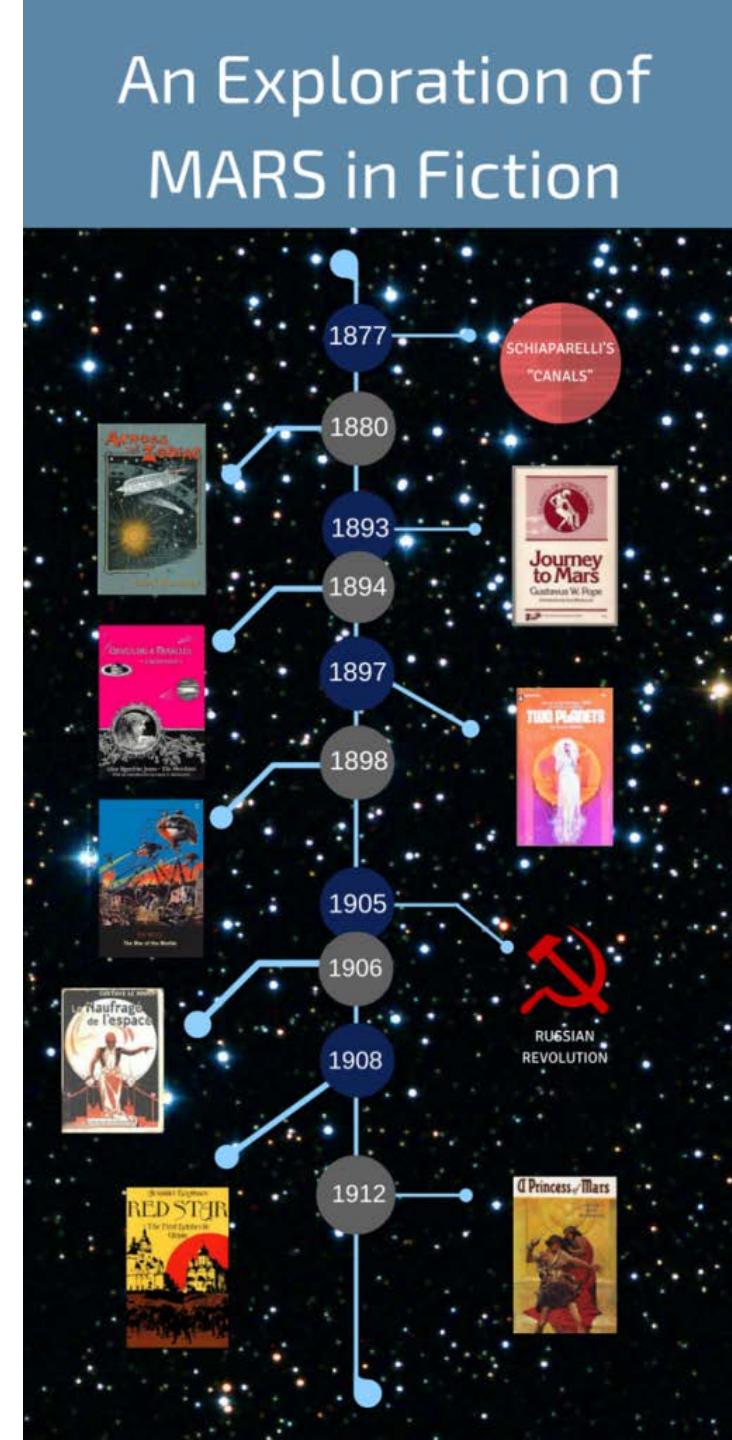


SCHIAPARELLI'S CANALS WENT VIRAL BECAUSE OF A MISTRANSLATION. INSTEAD OF ITS LITERAL MEANING OF MARKS OR GROOVES, "CANALI" IN ENGLISH BECAME "CANALS," SUGGESTIVE OF WATER, LIFE, AND INTELLIGENT INTERVENTION IN THE MARTIAN LANDSCAPE.

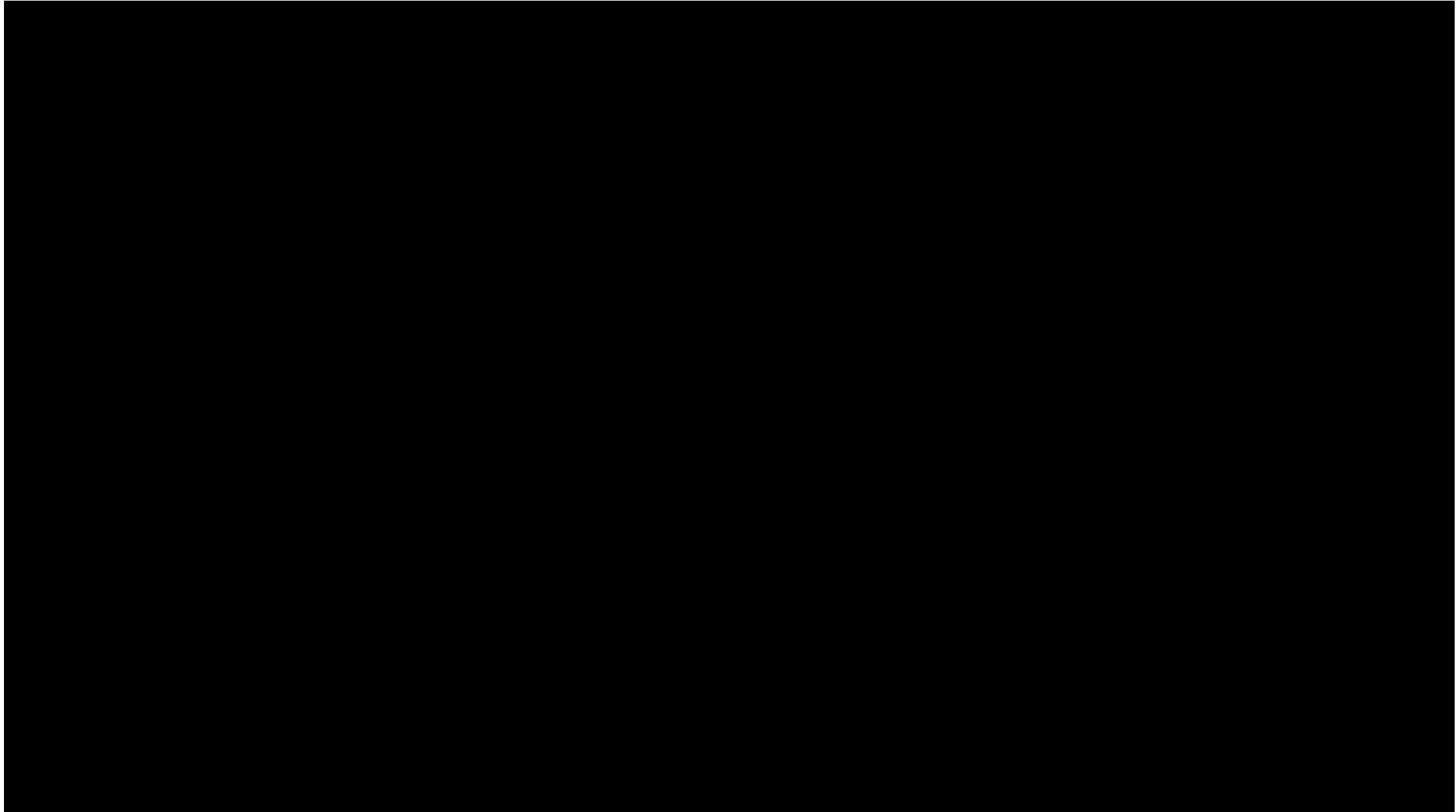


AN 1898 ARTICLE IN THE ATLANTIC MONTHLY NOTED THAT MARS MIGHT BE IN "AN ADVANCED STAGE OF EVOLUTION" COMPARED TO EARTH, AT LATER STAGE IN ITS LIFESPAN.

- In [1907, Is Mars Habitable? by A.R. Wallace](#) directly critiqued Lowell's book, "furnishing a quite natural explanation of features of the planet which have been termed 'non-natural' by Mr. Lowell," as Wallace writes in the introduction.
- Despite the debunking, by [1938, Orson Welles](#) took Mars fever and amplified it with the radio drama *War of the Worlds*, which riffed on the possibilities of the canals.
- In popular films (especially as depicted on their attendant posters), Mars then became a dry, red, craggy landscape populated only by malevolent aliens bent on fighting humans. The composite image seems far from what Lowell would have imagined as the watery, productive, developed society of the planet.
- The various misinterpretations and curveballs of Mars's gradual discovery came to a more certain conclusion with [NASA Viking program in the 1970s](#). We could finally see what its surface actually held. [The truth was closer to the movies—desiccated, cratered, not a river or canal in sight.](#)



Past Missions to Mars



Ongoing Missions (as of 2019)

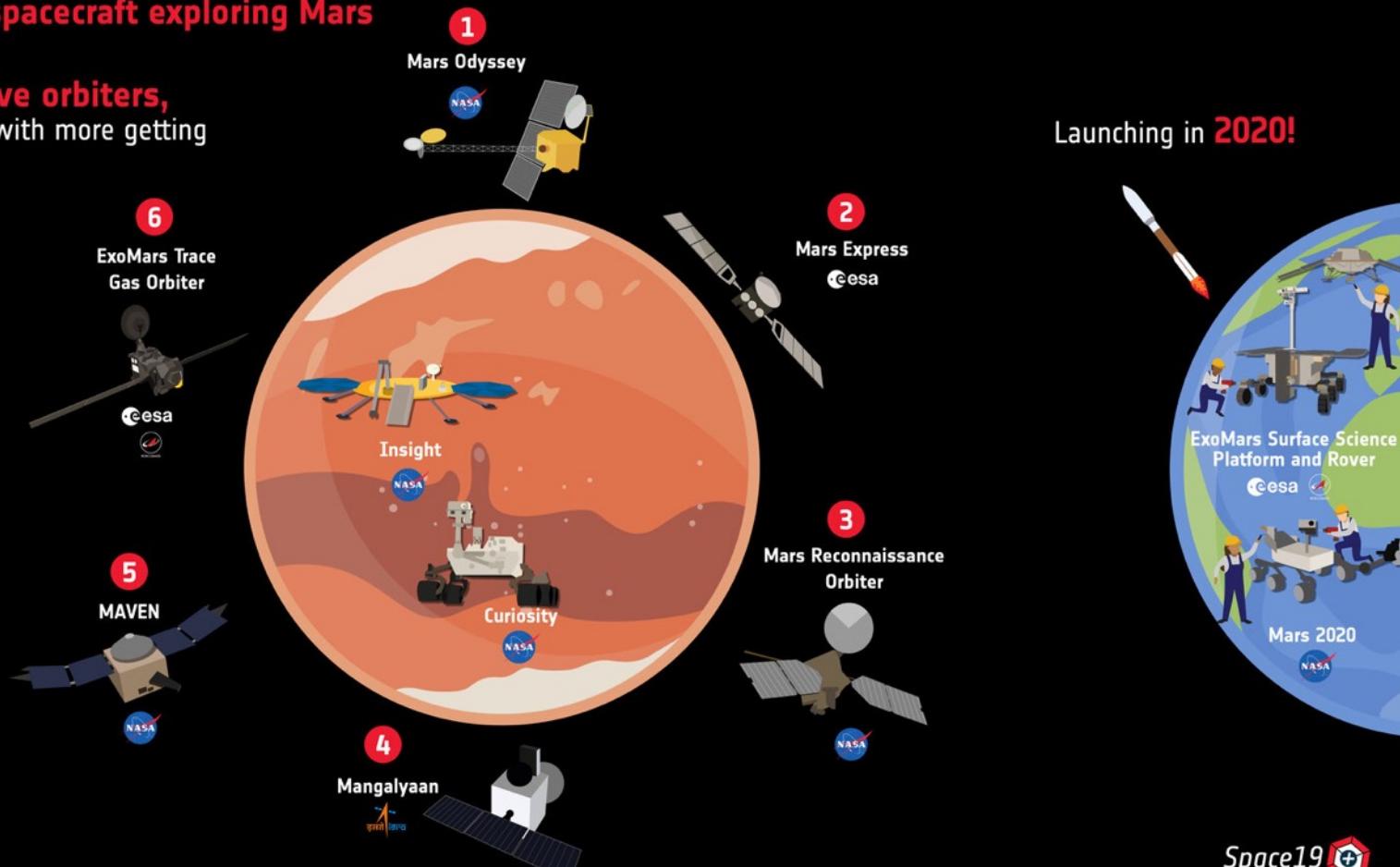


→ TEN THINGS YOU DID NOT KNOW ABOUT MARS

1. There are currently eight spacecraft exploring Mars

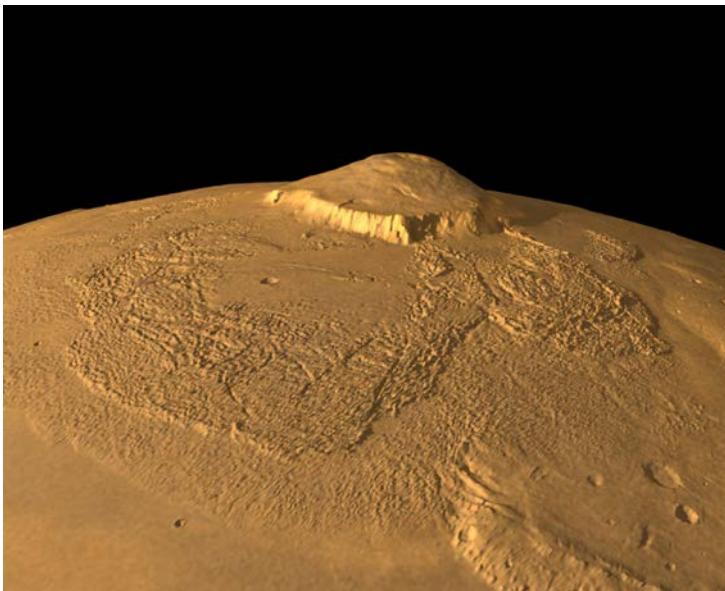
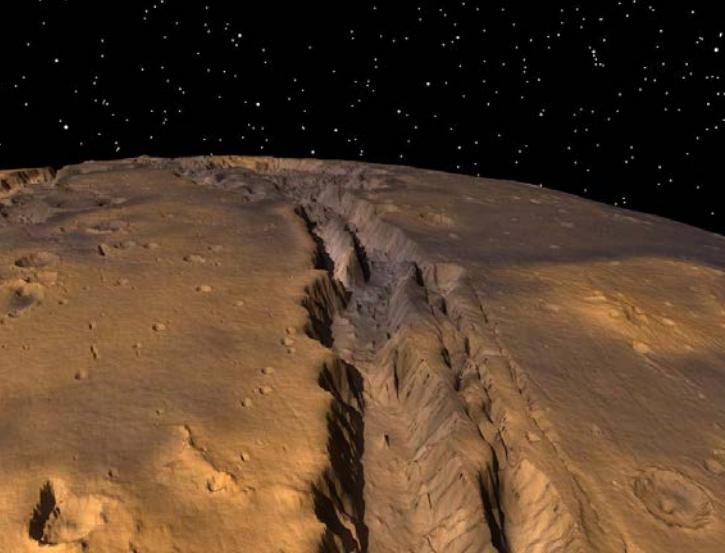
As of 2019, Mars hosts **six active orbiters**, **one lander** and **one rover**... with more getting ready to join the fleet

ESA and international partners are preparing for a **Mars sample return mission**. Like the return of Moon rocks to Earth, bringing Mars rocks back will be a defining moment in space exploration and in the understanding of our Solar System



火星地貌

	Mars	Earth
Atmosphere (composition)	Carbon dioxide (95.32%) Nitrogen (2.7%) Argon (1.6%) Oxygen (0.13%) Water vapor (0.03%) Nitric oxide (0.01%)	Nitrogen (77%) Oxygen (21%) Argon (1%) Carbon dioxide (0.038%)
Atmosphere (pressure)	7.5 millibars (average)	1,013 millibars (at sea level)
Deepest Canyon	Valles Marineris 7 km (4.35 miles) deep 4,000 km (2,485 miles) wide	Grand Canyon 1.8 km (1.1 miles) deep 400 km (248.5 miles) long
Distance from Sun (average)	227,936,637 kilometers (142,633,260 miles)	149,597,891 kilometers (92,955,820 miles)
Equatorial Radius	3,397 kilometers (2,111 miles)	6,378 kilometers (3,963 miles)
Gravity	0.375 that of Earth	2.66 times that of Mars
Largest Volcano	Olympus Mons 26 kilometers (16 miles) high 602 kilometers (374 miles) in diameter	Mauna Loa (Hawaii) 6.3 miles high 121 kilometers (75 miles) in diameter
Length of Day (time required to make a full rotation on its axis)	24 hours, 37 minutes	Just slightly under 24 hours
Length of Year (time required to make a complete orbit of the Sun)	687 Earth days	365 days
Polar Caps	Covered with a mixture of carbon dioxide ice and water ice	Permanently covered with water ice
Surface Temperature (average)	-81 degrees F (-63 degrees C)	57 degrees F (14 degrees C)
Tilt of Axis	25 degrees	23.45 degrees
# of Satellites	2 (Phobos and Deimos)	1 (Moon)

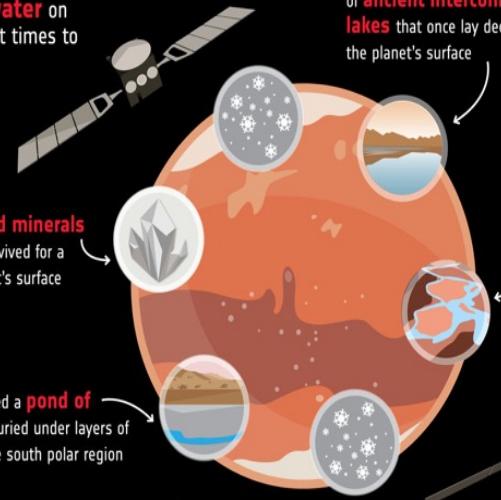


火星地表水

→ TEN THINGS YOU DID NOT KNOW ABOUT MARS

6. There is buried liquid water on Mars

Mars Express has found much **evidence of water** on Mars from ancient times to present day



Geological evidence of a system of **ancient interconnected lakes** that once lay deep beneath the planet's surface



esa

River networks show vast volumes of water once flowed across the surface

Understanding critical resources like water is essential to understand the potential for life on other worlds – and for future robotic and human exploration

Discovery of **hydrated minerals** shows liquid water survived for a long time on the planet's surface

Radar data revealed a **pond of liquid water** buried under layers of ice and dust in the south polar region

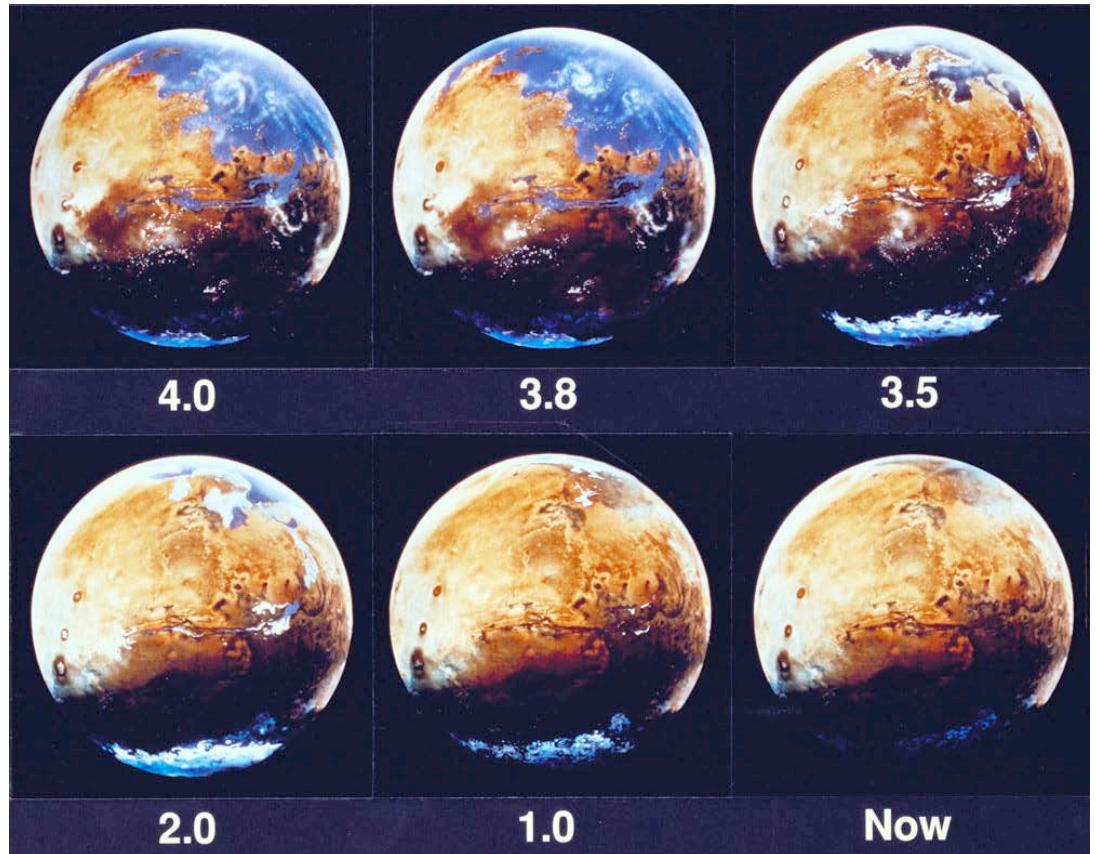
Water-ice is present at the planet's poles

#Space19plus #ExploreFarther

The ExoMars Trace Gas Orbiter is producing the best map of **shallow sub-surface water-ice** and **water-rich minerals** on Mars

Space19

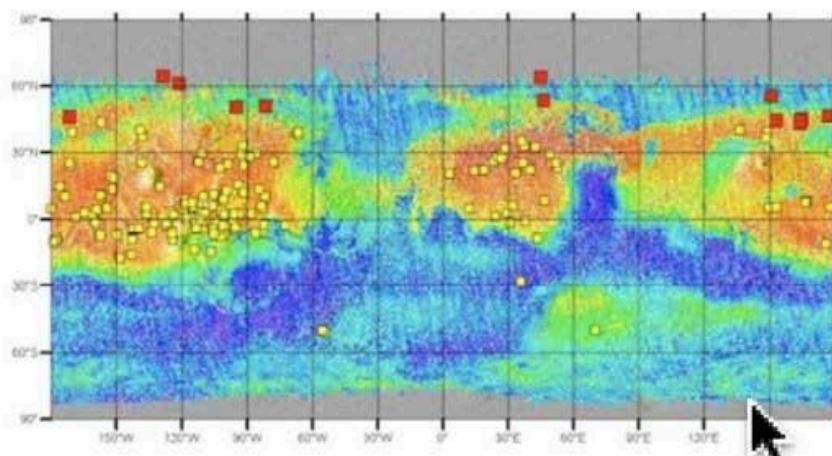
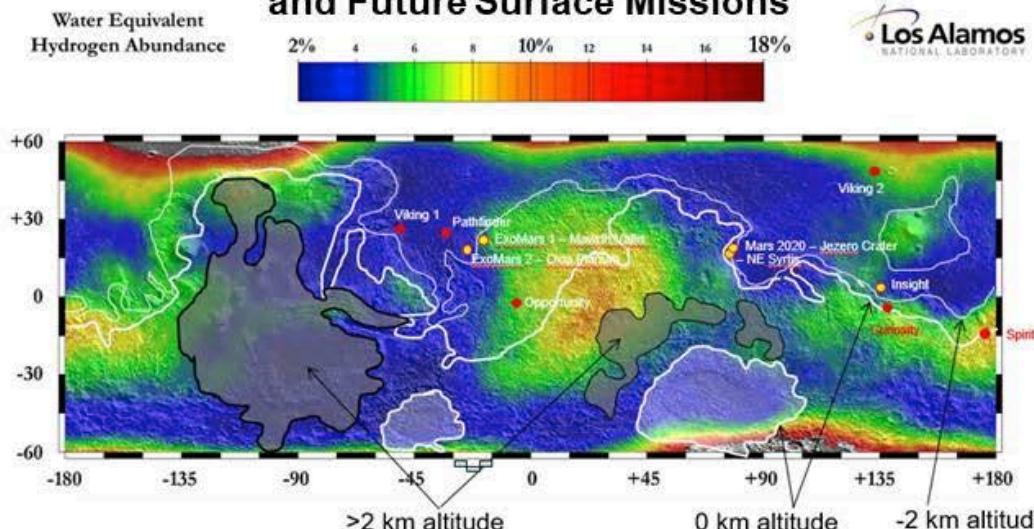
History of water on Mars? (Ga)



Credit: NASA / Michael Carroll; data source: C. McKay (NASA Ames)

火星气候：寻找水和生命

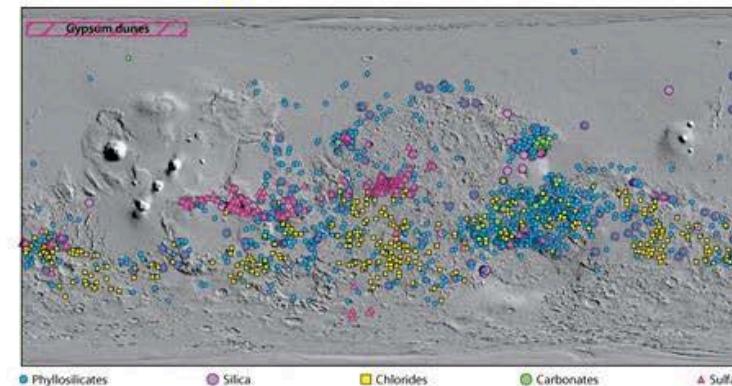
Water Abundance and Altitude with Past, Present, and Future Surface Missions



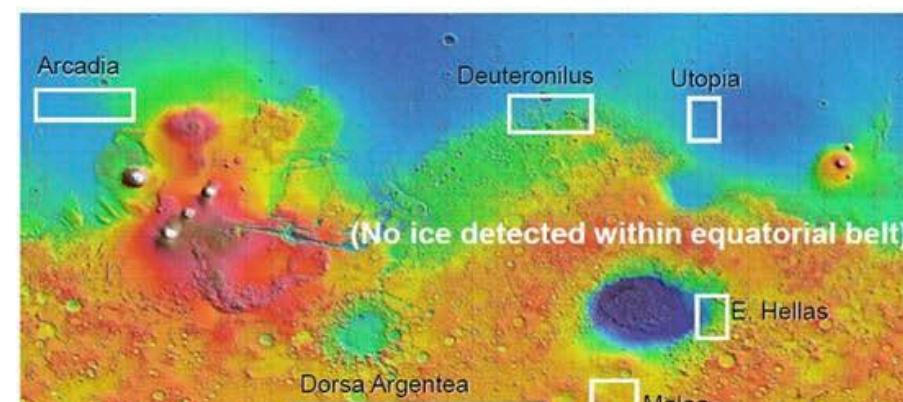
New Craters Confirm Shallow, Nearly Pure Ice

- Newly formed craters exposing water ice (red) are a subset of all new craters (yellow). Background color is TES dust index.
- (Adapted from Byrne et al. (2011) Science)

Map of aqueous mineral detections

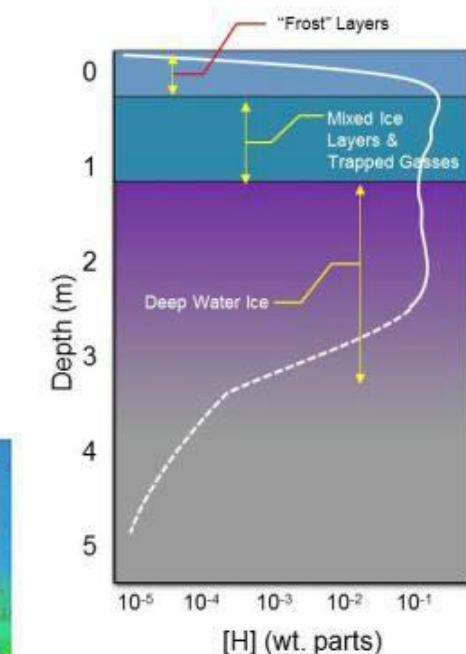


- Minerals formed in liquid water environments
- Phyllosilicates, sulfates, carbonates contain enhanced water content, to ~8%
- Exposed in areas without mid-latitude mantle



Summary map outlining areas of subsurface ice detections based on data from the MARSIS and SHARAD instruments. Source: Special Regions SAG2, Rummel & Beatty et al., 2014.

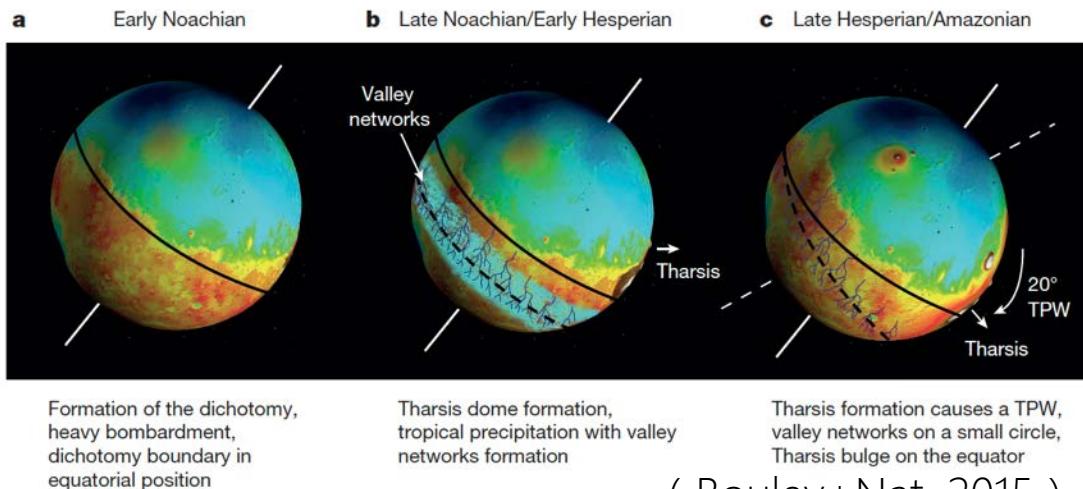
Radar Detection of Non-Polar Ice



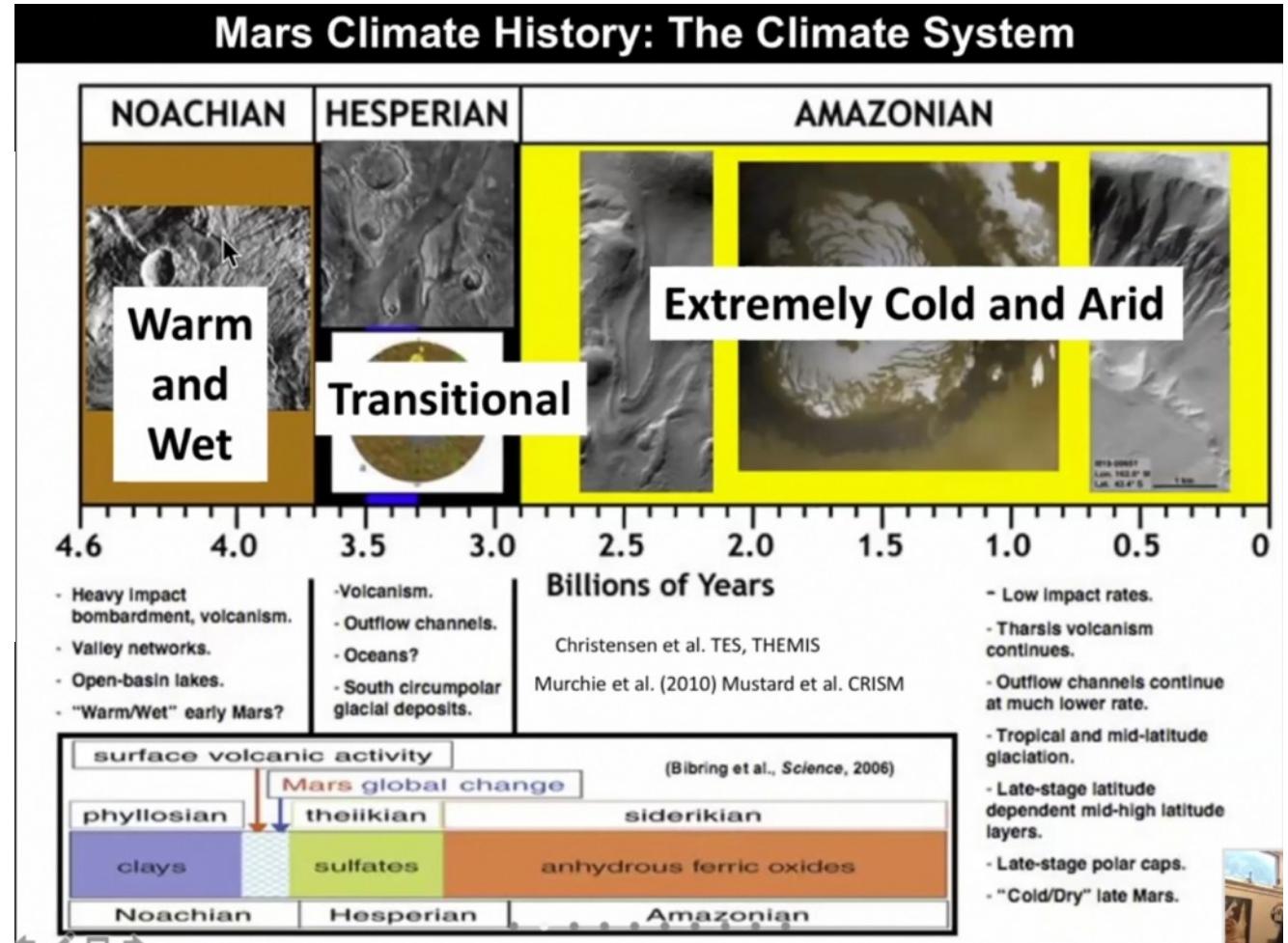
Credit: Gerald Sanders

早期火星气候

Tharsis → 极移TPW

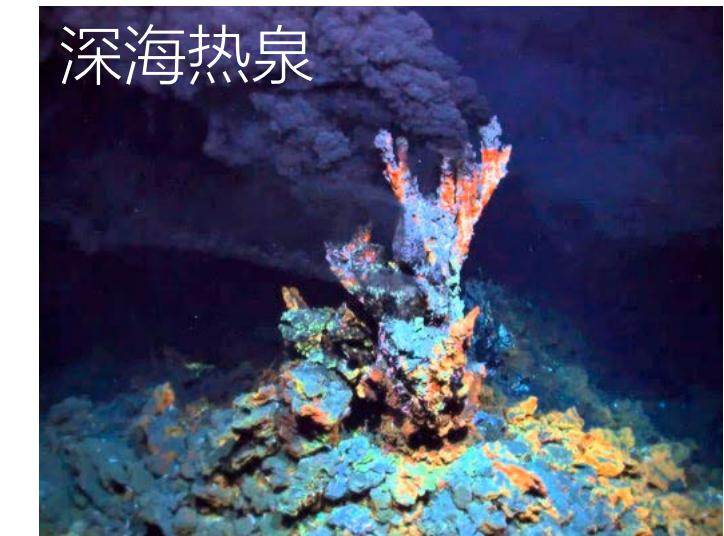
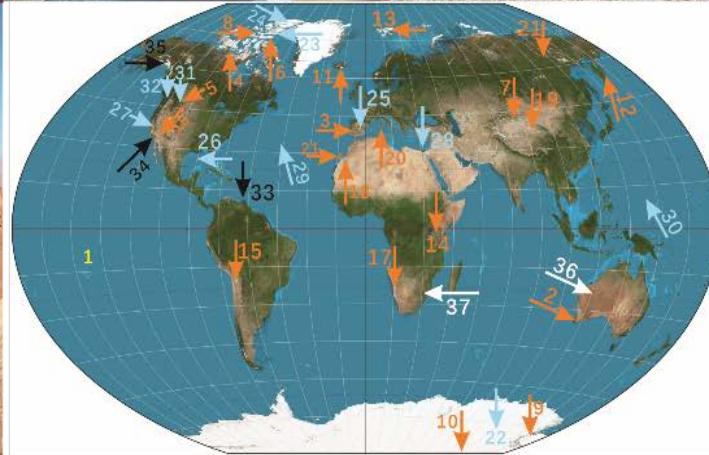


(Bouley+Nat, 2015)



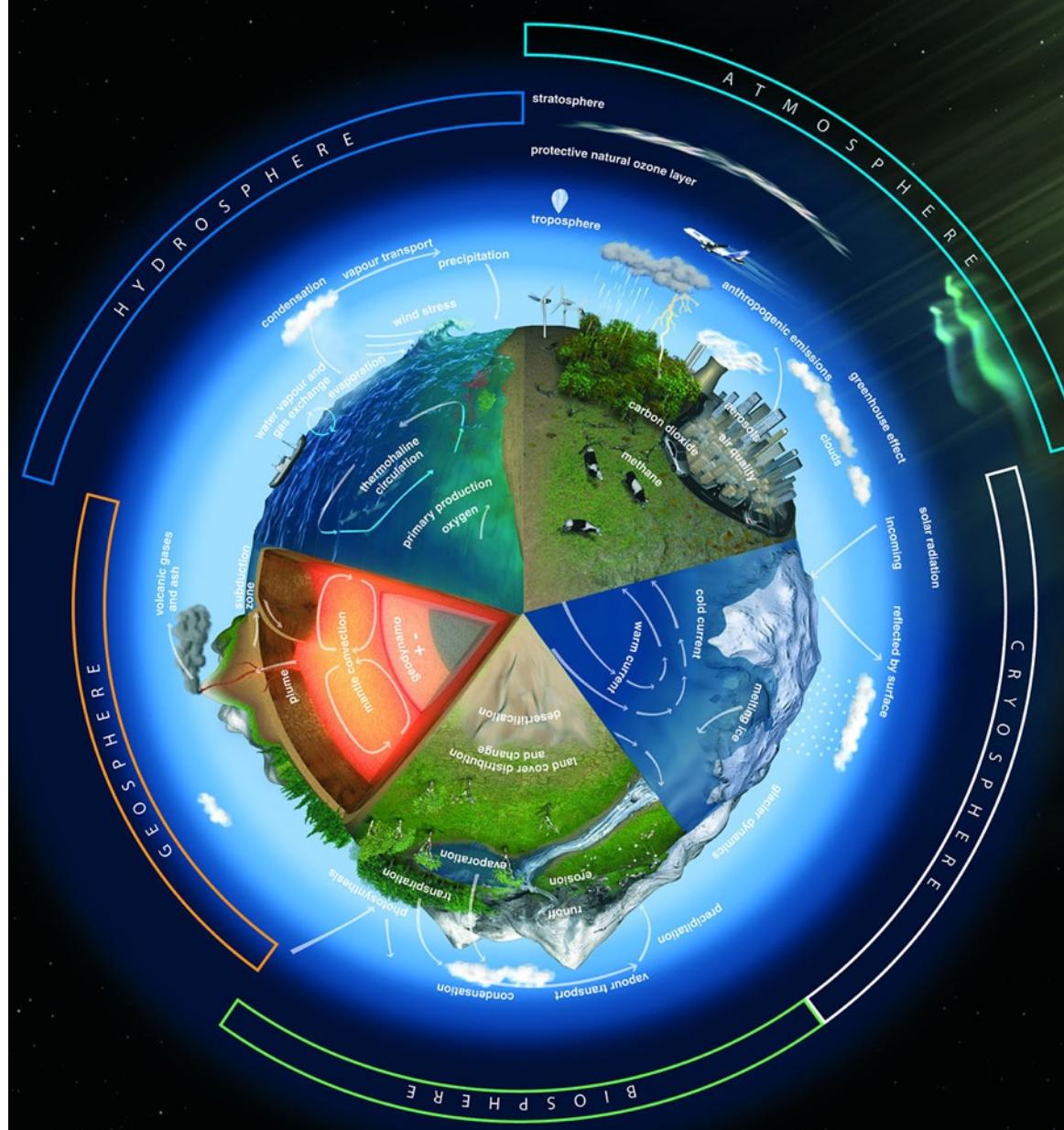
- 气候受到轨道和自转 (TPW) 的控制
- 早期火星是 warm&wet 还是 cold&dry ?

与地球极端环境的对比研究

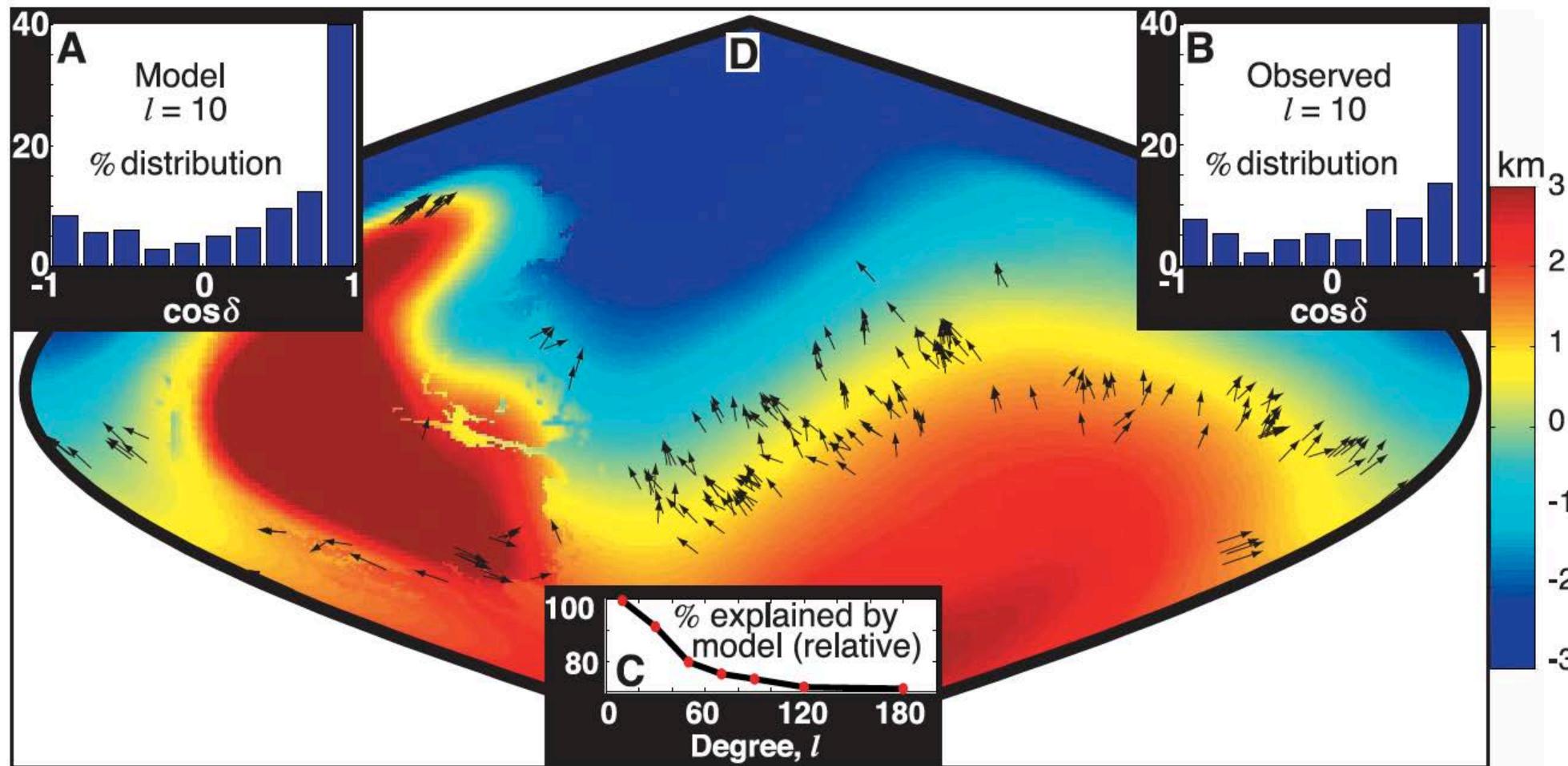


Credit: 黄婷

早期火星：岩石圈 - 水圈 (-生物圈) 协同演化



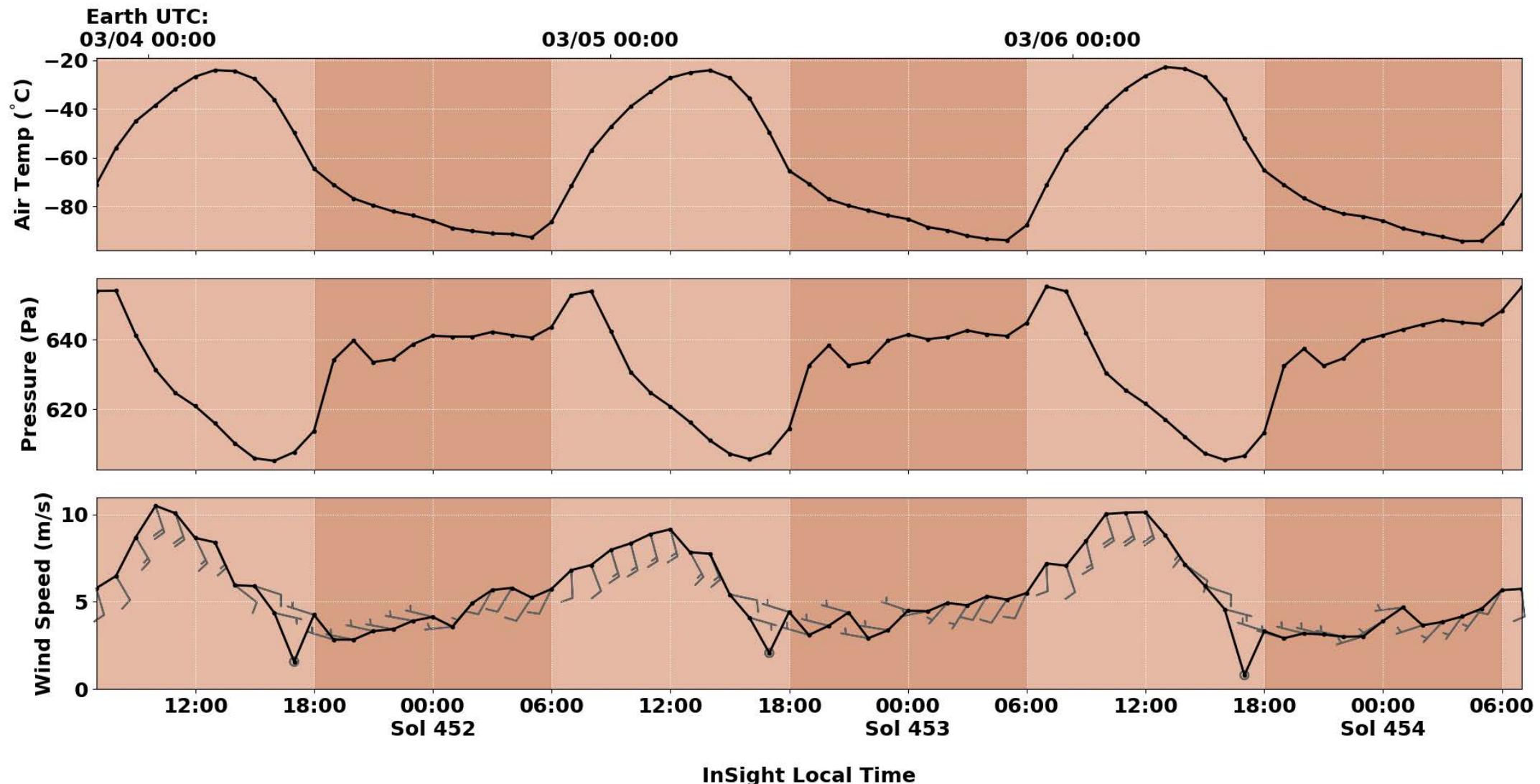
例子: Tharsis → 气候和地形 → 河谷分布→ 微生物?



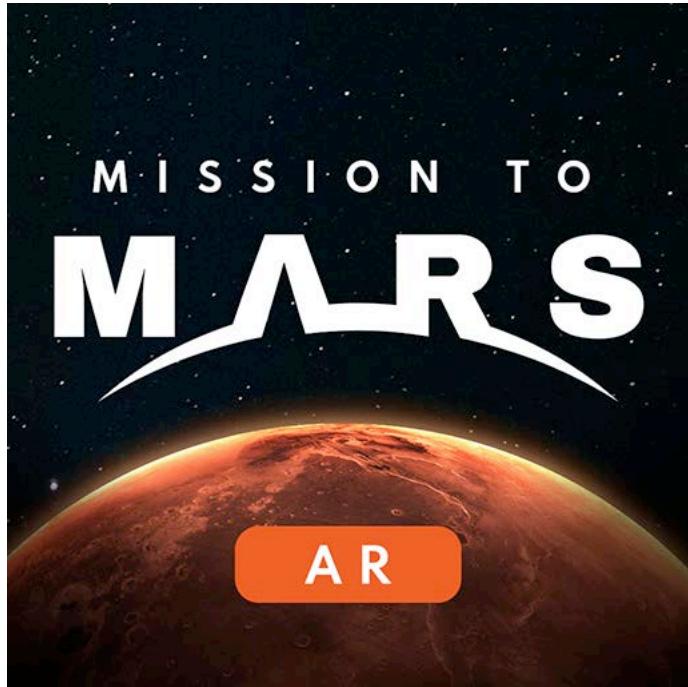
(Phillips et al., Science, 2001)

Mars Weather Report

Mars InSight Weather Report



Let's explore Mars together
Using Mission to Mars AR



Science or Fiction?

幻: 想象力

科: 真实性

可能世界的想象

技术现状

未来世界的预期

观测事实

人文元素/文学性

科学定理



Example 1: How Scientifically Accurate is the film Martian? Chemically, Geologically, Meteorologically

- 火星日 (Sol)
- 种土豆：火星的大气中95%是二氧化碳，高浓度的二氧化碳将有利于土豆的生长，其收成将是正常地球环境下的两到四倍。
- Johnson Space Center & Jet Propulsion Lab
- 巨大的暴风雨：火星确实有风。但它的大气层仅是地球密度的1%，这意味着它永远不会像故事中的那样巨大。
- 火星辐射：太阳高能粒子和银河系宇宙射线；仅单程180天的旅行将使他们受到核电厂工人每年允许使用剂量15倍的宇宙辐射。沃特尼 (Watney) 在火星上停留的时间超过500 sol (或火星日，仅比我们的一天长39分钟)，更不用说乘母舰来回飞行了。可以采取各种方式免受辐射：人造磁场或铝或水甚至食物的绝缘层，甚至将食物和堆积在墙体中的人类粪便提供必要的保护。但是 Martian 从来没有提到这些事情。
- 救援：In order for Watney to be rescued, the rest of the crew must cancel its homecoming and, the moment their spacecraft reaches Earth, simply whip around it and head back to Mars. It has regularly been used in interplanetary explorations.

References: Andy Weir - The Martian: How Science Drove the Plot :

<https://www.nasa.gov/ames/ocs/2015-summer-series/andy-weir>

<https://time.com/4055413/martian-movie-review-science-accuracy-matt-damon/>

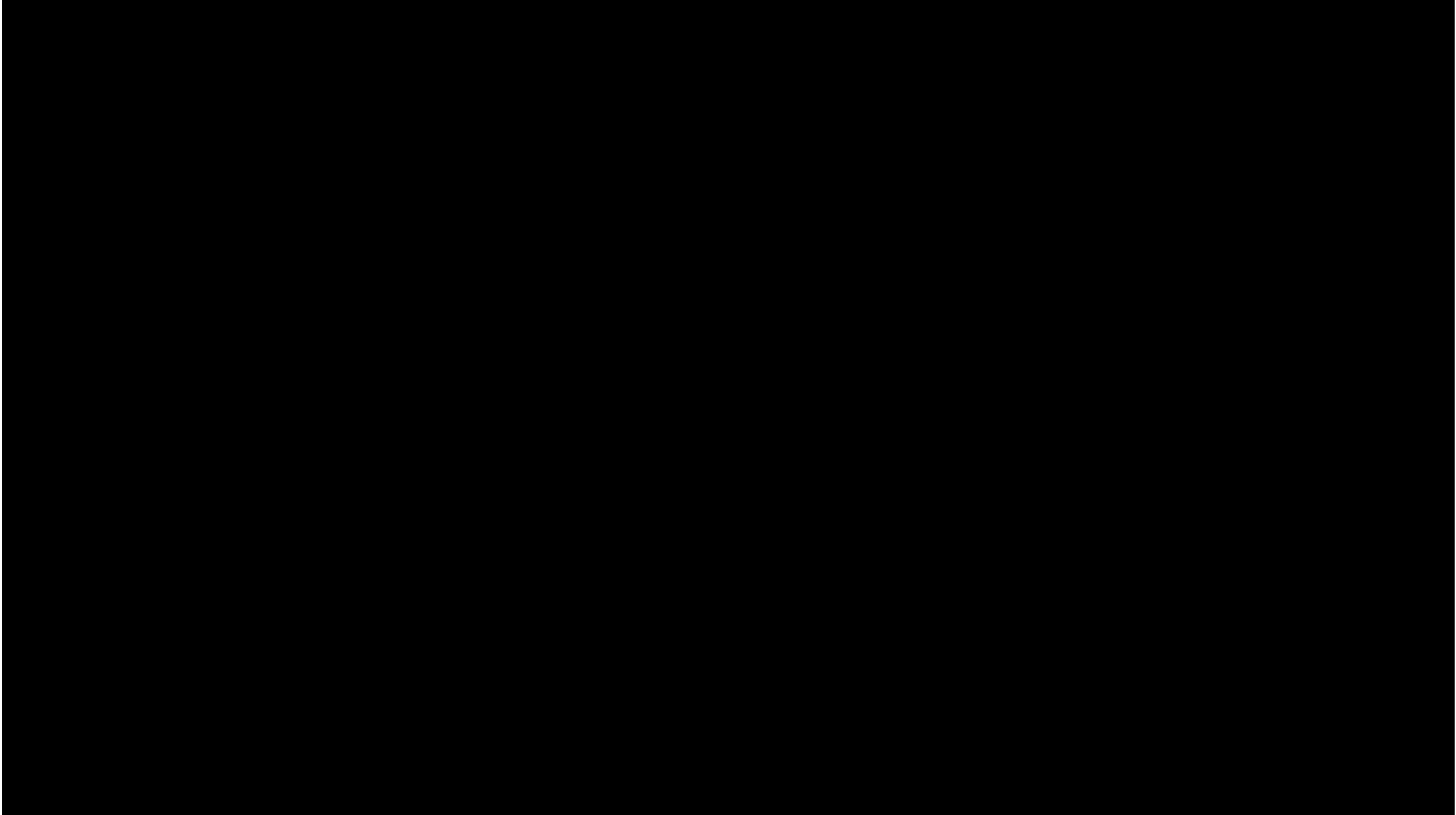
Example: 如何殖民火星？

<https://zh.wikipedia.org/wiki/%E7%81%AB%E6%98%9F%E5%9C%B0%E7%90%83%E5%8C%96>

火星的地球化可以有以下幾個方法：

1. 在大气中增加适合适量的气体（包括温室氣體和适合生物生存的氣體），增加地表溫度與氣壓，主要是為了液態水，其次是植物、動物。
 2. 在太空中架設巨大反射（或折射）鏡群，增加照射到火星表面的太陽光強度。
 3. 大量融解地下凍土層，再把水引到地表。雖然一開始會結冰，但隨著工程進行，冰層進而融化形成水圈。
 4. 在冰上（包括兩極）培植深色藻類或散佈煤灰等深色物質增加吸熱进而加速融化。
 5. 散布固沙菌類、植物，防止沙暴的發生，進而生成土壤，擴大居住地。
 6. 建立行星推進器（引擎），改變火星運行軌道。
 7. 在進行融化地下層時，雖然上層凍土的重量會把下面融解的液態水擠到地表，但是地層會下陷，而且結成的冰會增加地表的反照率，加上昇華至大氣的水，都會改變氣候，因此這些因素都要考慮進去。
- 另外，來自太空的輻射，雖然可以用太空的反射鏡處理，但是這些鏡子是非常脆弱的。不過隨著大氣逐漸增厚，問題就小多了。最根本的辦法就是到地核去啟動火星的磁場，抵抗太陽風和宇宙射線。但是這需要大量的能量，需要的技術還得再加強，且地磁的成因仍未完全了解。
 - 改造火星一般估計要花非常長的時間，例如千年。不過在動工之前，人類應完整而仔細的審視這星球的一切，並且設立保護區與開發限制。因為只要一開工，保存久遠的地質資料和景觀可能因為加速侵蝕而遭破壞，例如位於極冠中的沉積資料可能會消失。

SpaceX's Plan



Group Discussion 10 Min + 10 Min



- Will you accept it if offered by SpaceX a ticket to Mars?
- What will you pack with you?
- What need to be prepared before colonizing Mars? Flying to Mars?
- How will you make a living on Mars?