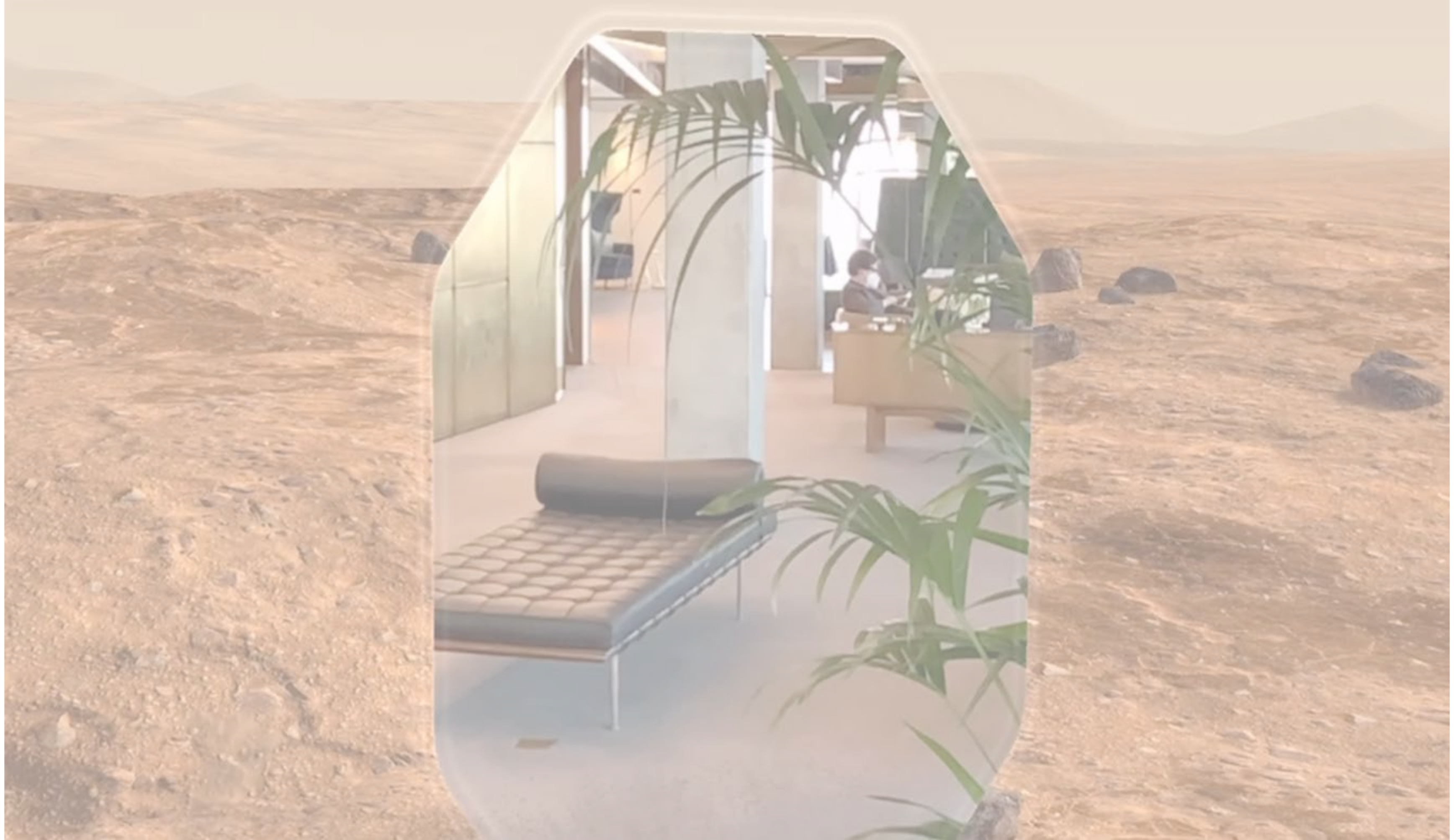
来自地球，去往火星

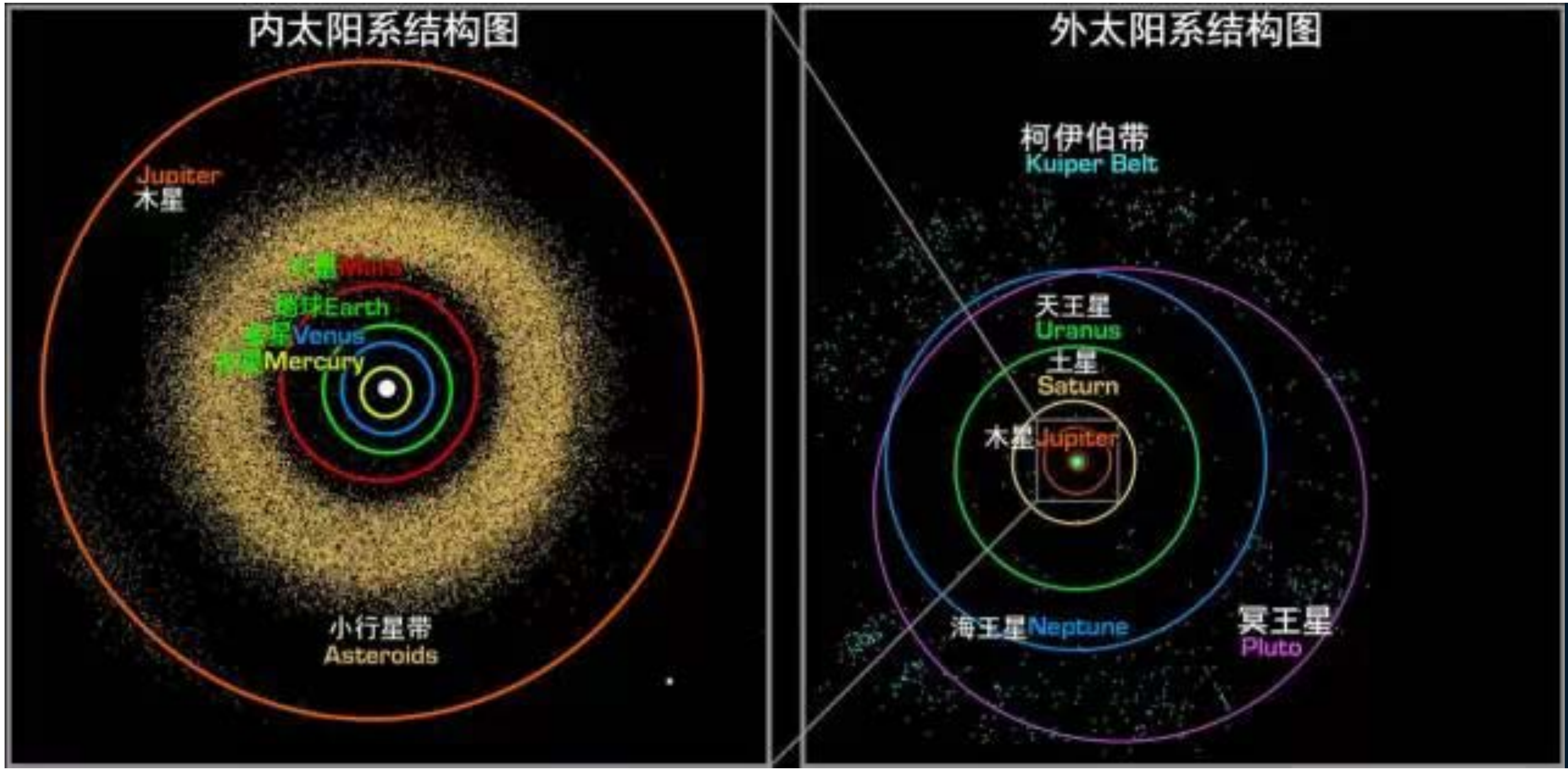
内太阳系类地行星简介

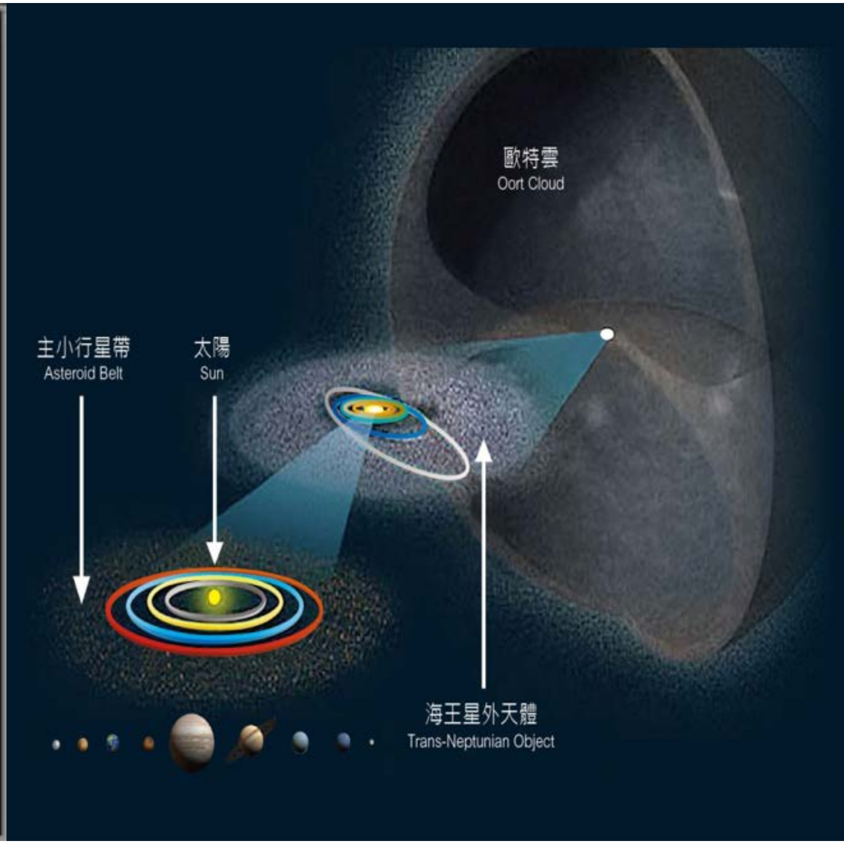


Review: 太阳系的结构

示意图

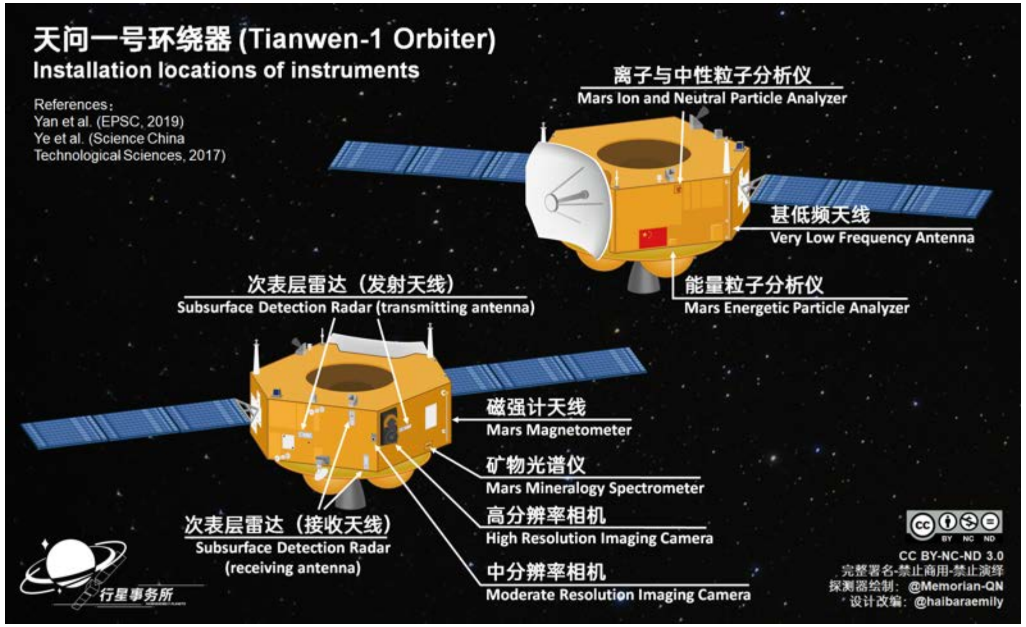
三维图

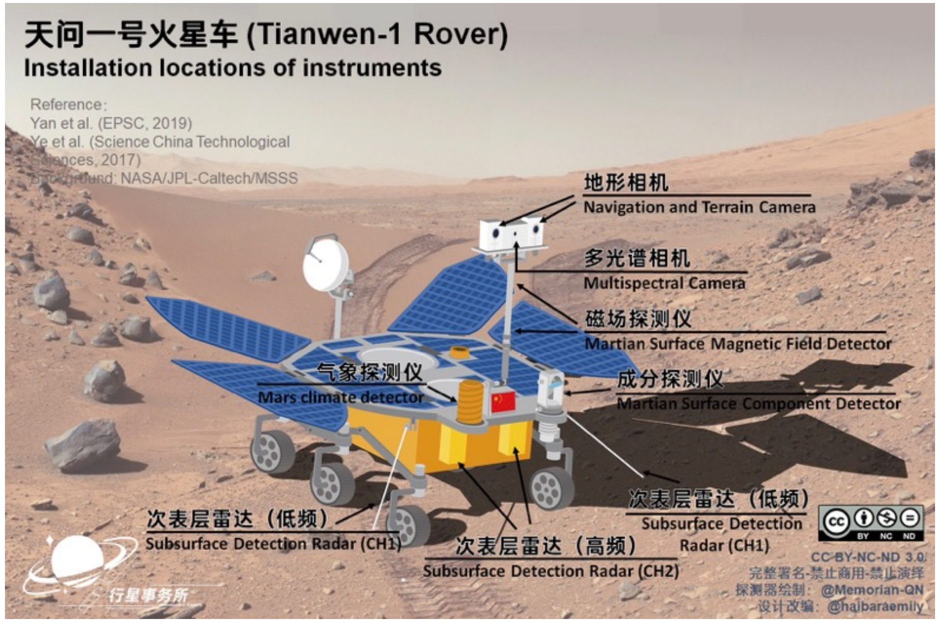


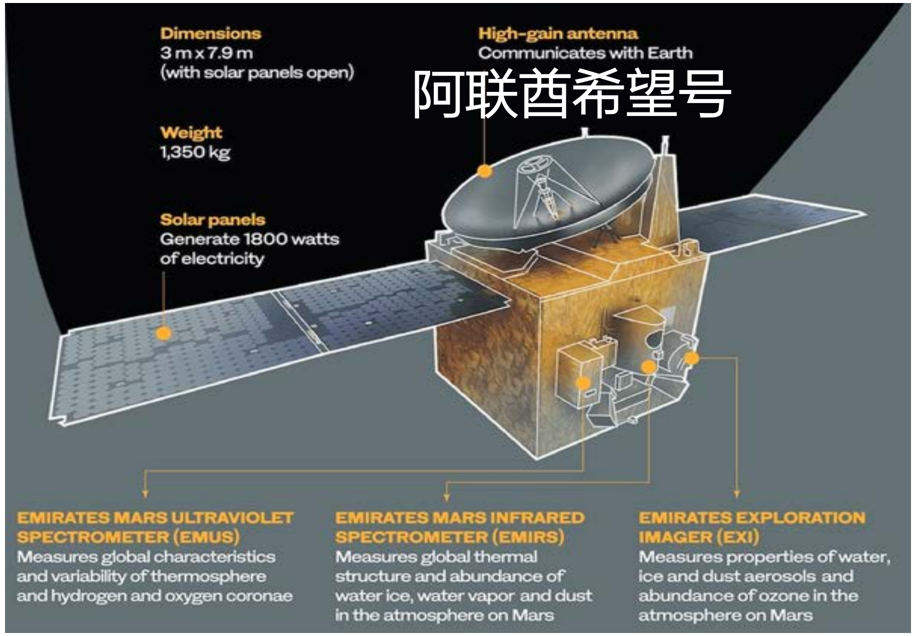


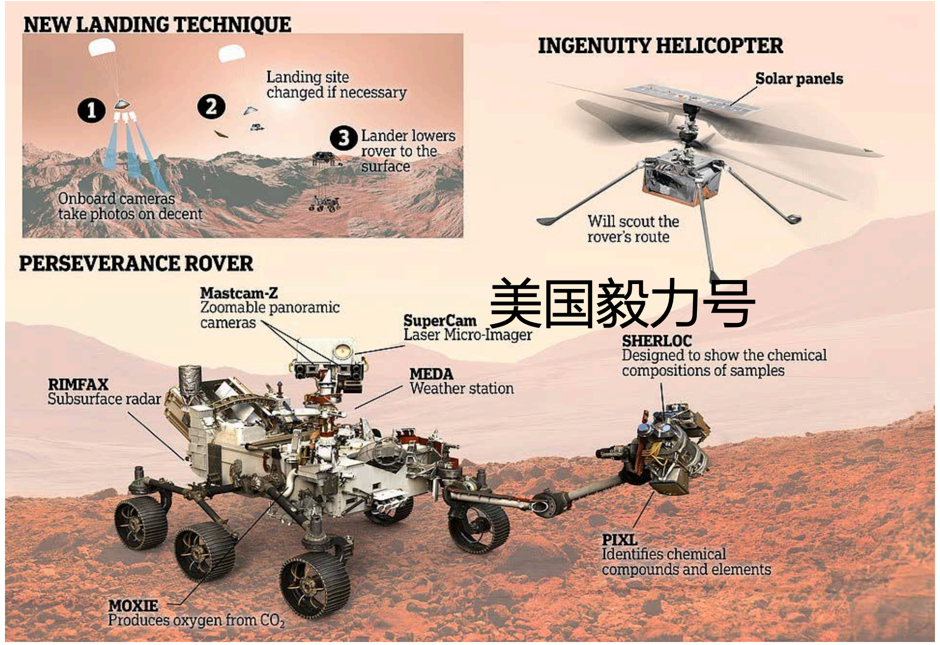
实际比例

Latest Missions to Mars (2020/7)

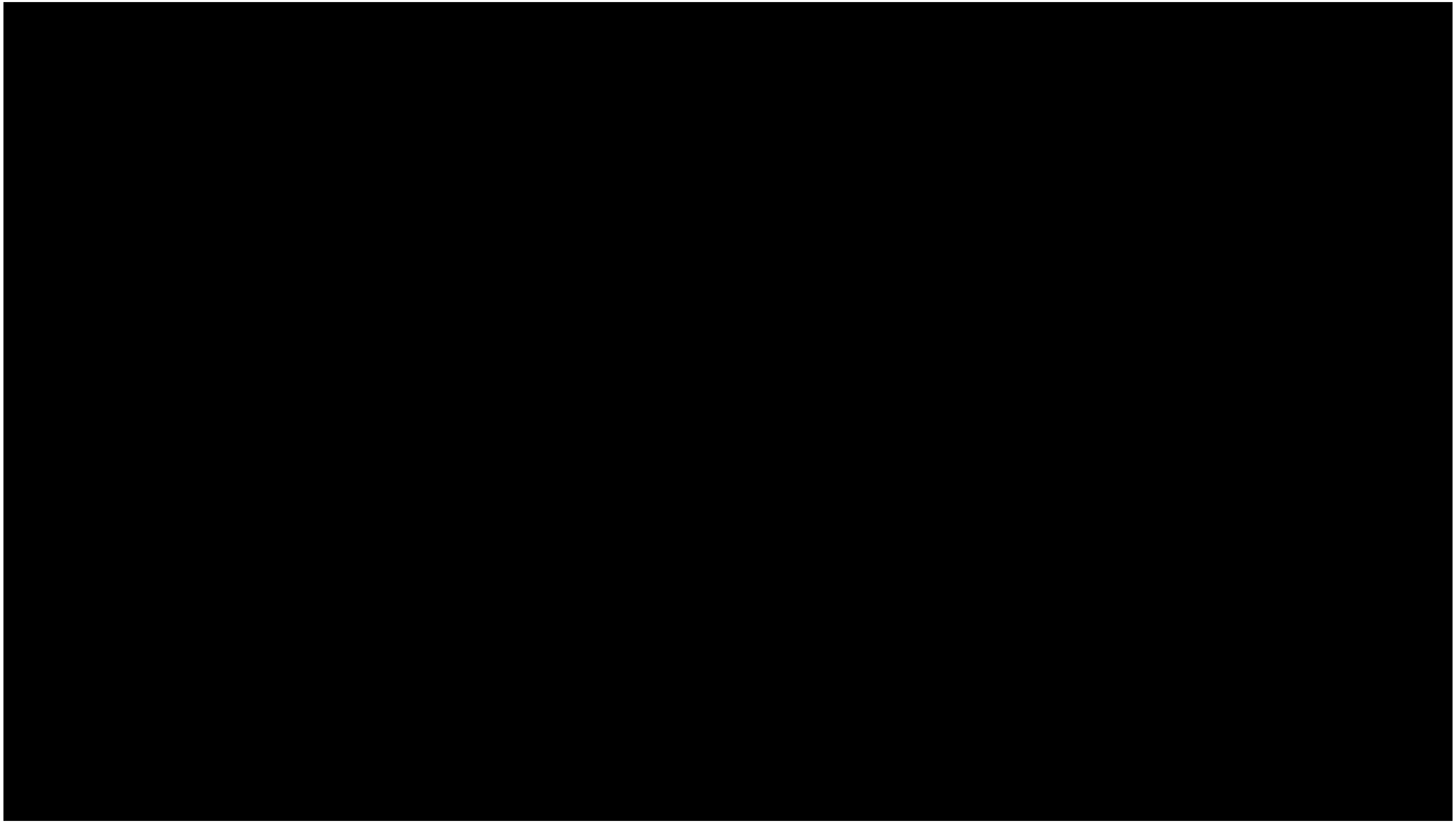




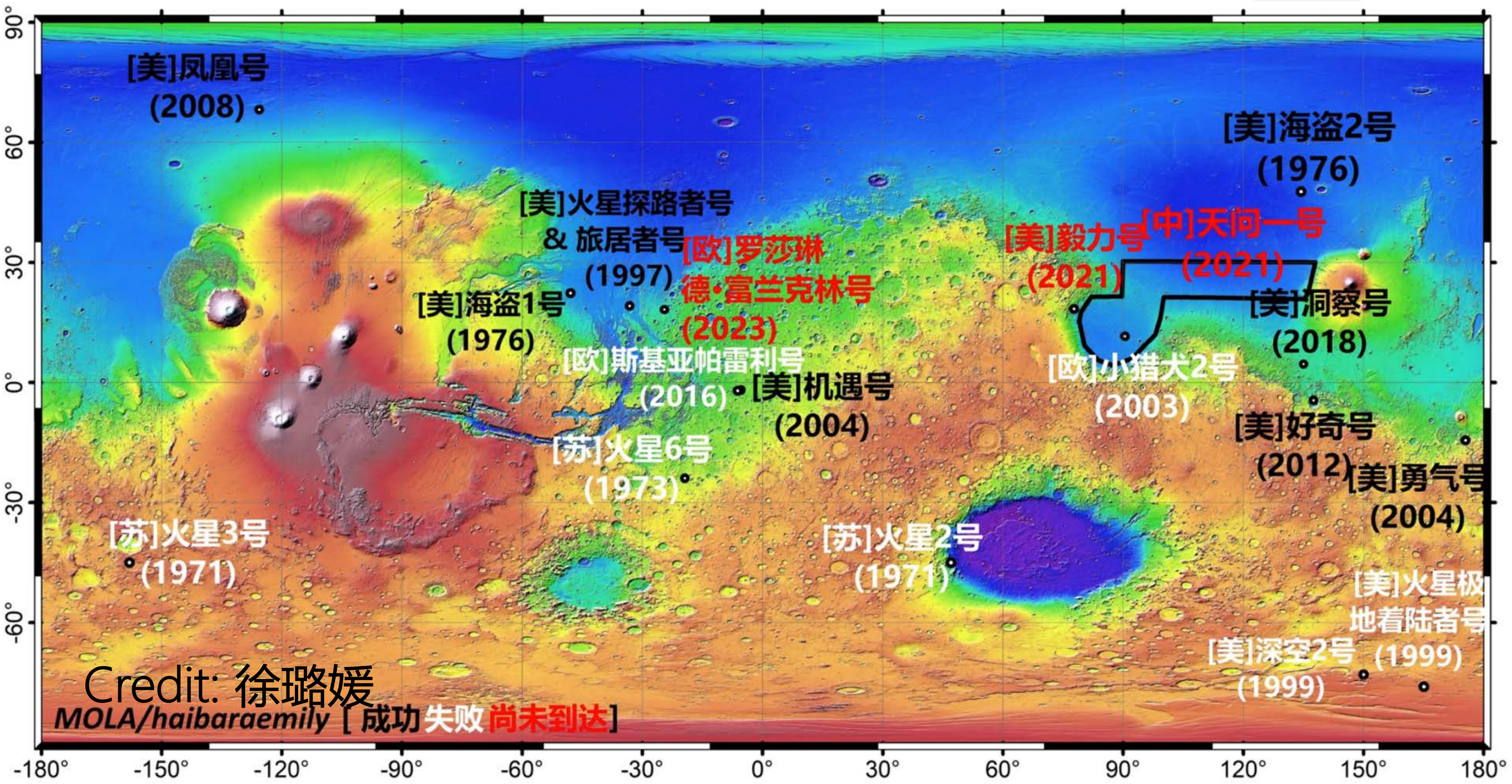




China’s Zhurong vs. NASA’s Perseverance: Rover Tech in Mars Space Race I WSJ

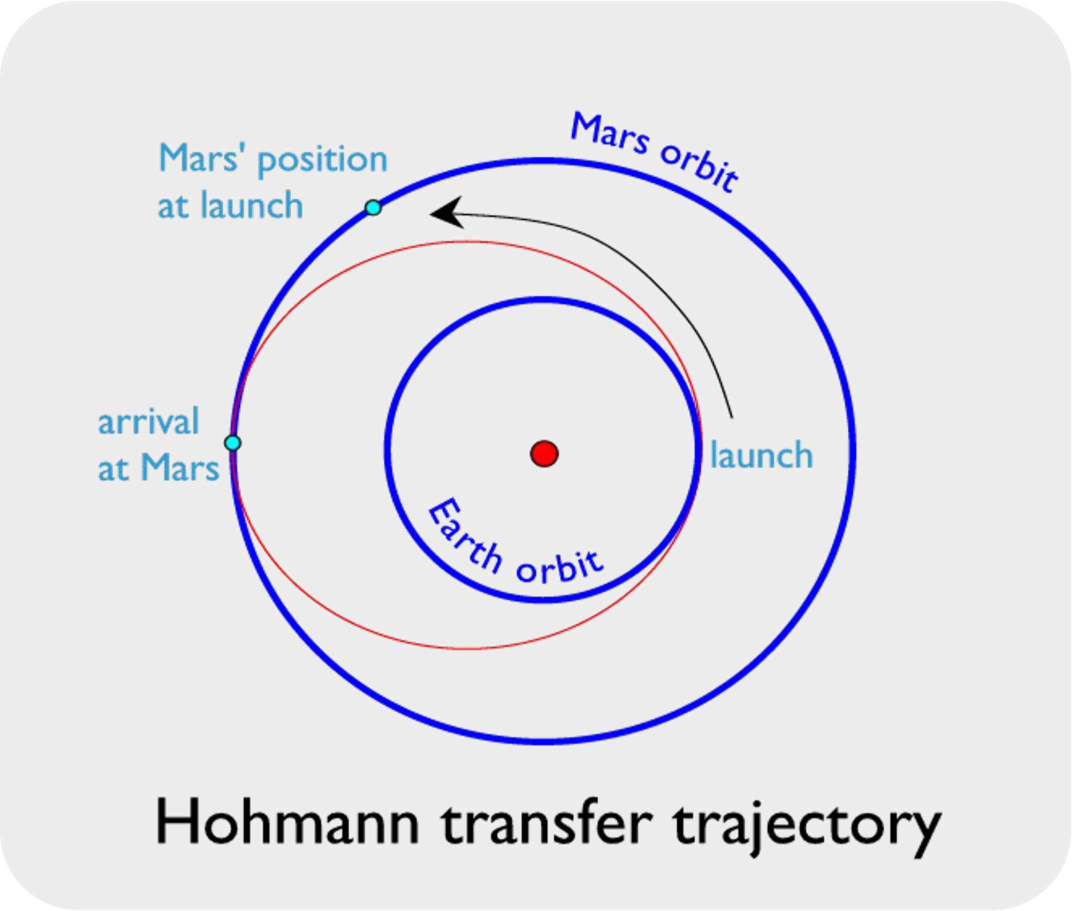


火星着陆点 (till early 2021)



- 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/spring
2014/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

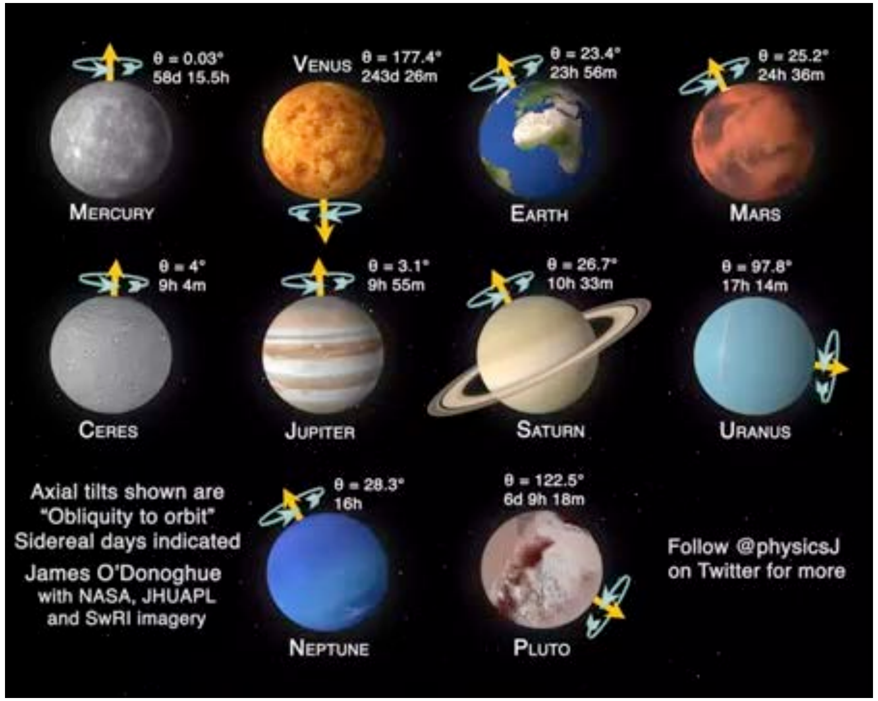
1.1

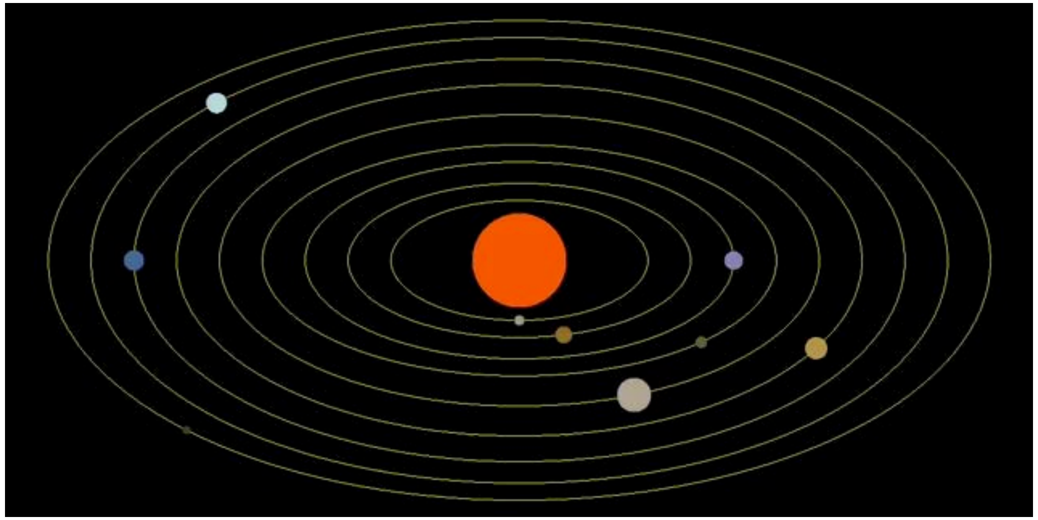
内太阳系介绍：

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

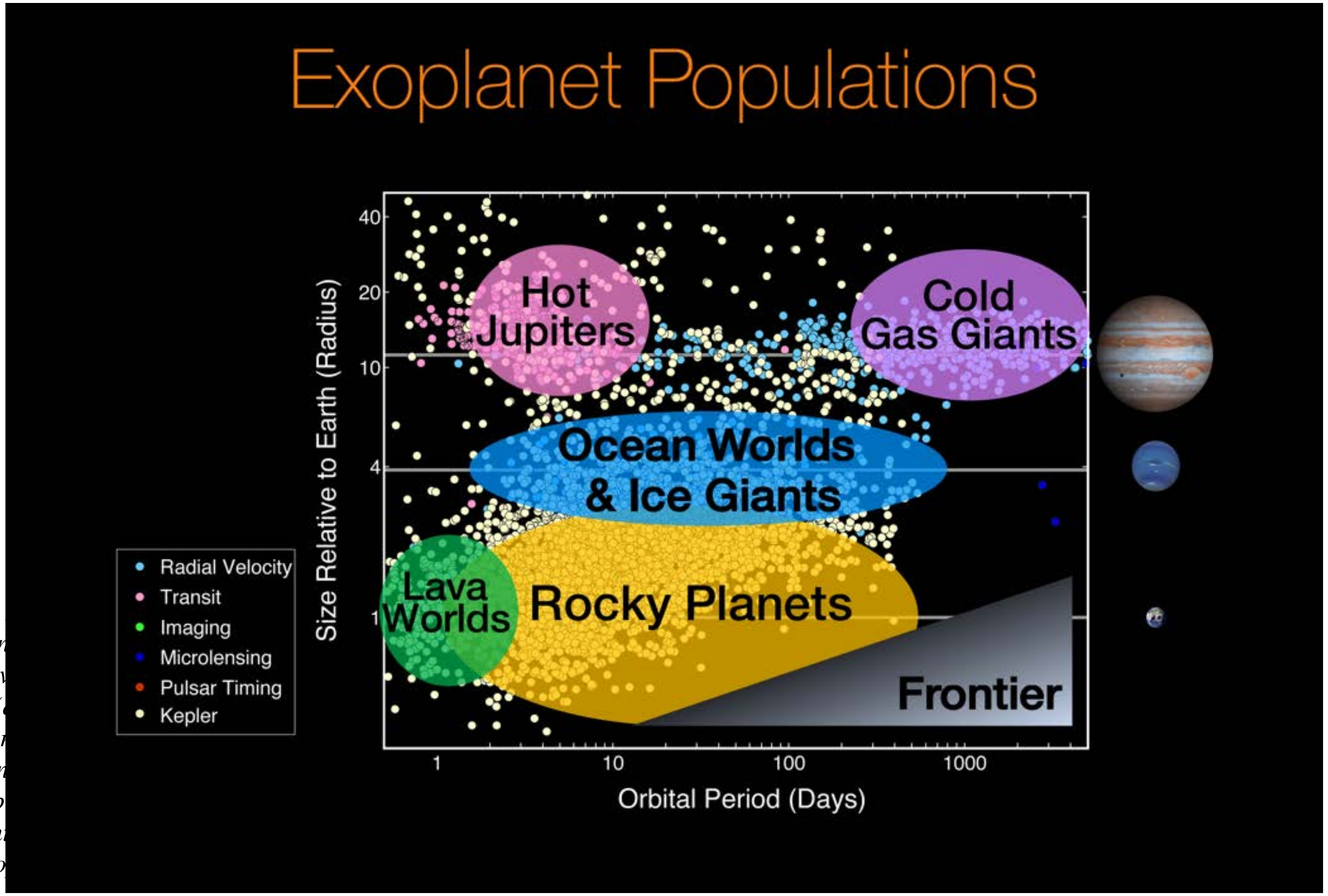
星體	平均密度	半長軸
<u>水星</u>	$5.4\ g\ cm^{-3}$	0.39 AU
<u>金星</u>	$5.2\ g\ cm^{-3}$	0.72 AU
<u>地球</u>	$5.5\ g\ cm^{-3}$	1.0 AU
<u>月球</u>	$3.3\ g\ cm^{-3}$	1.0 AU
<u>火星</u>	$3.9\ g\ cm^{-3}$	1.5 AU



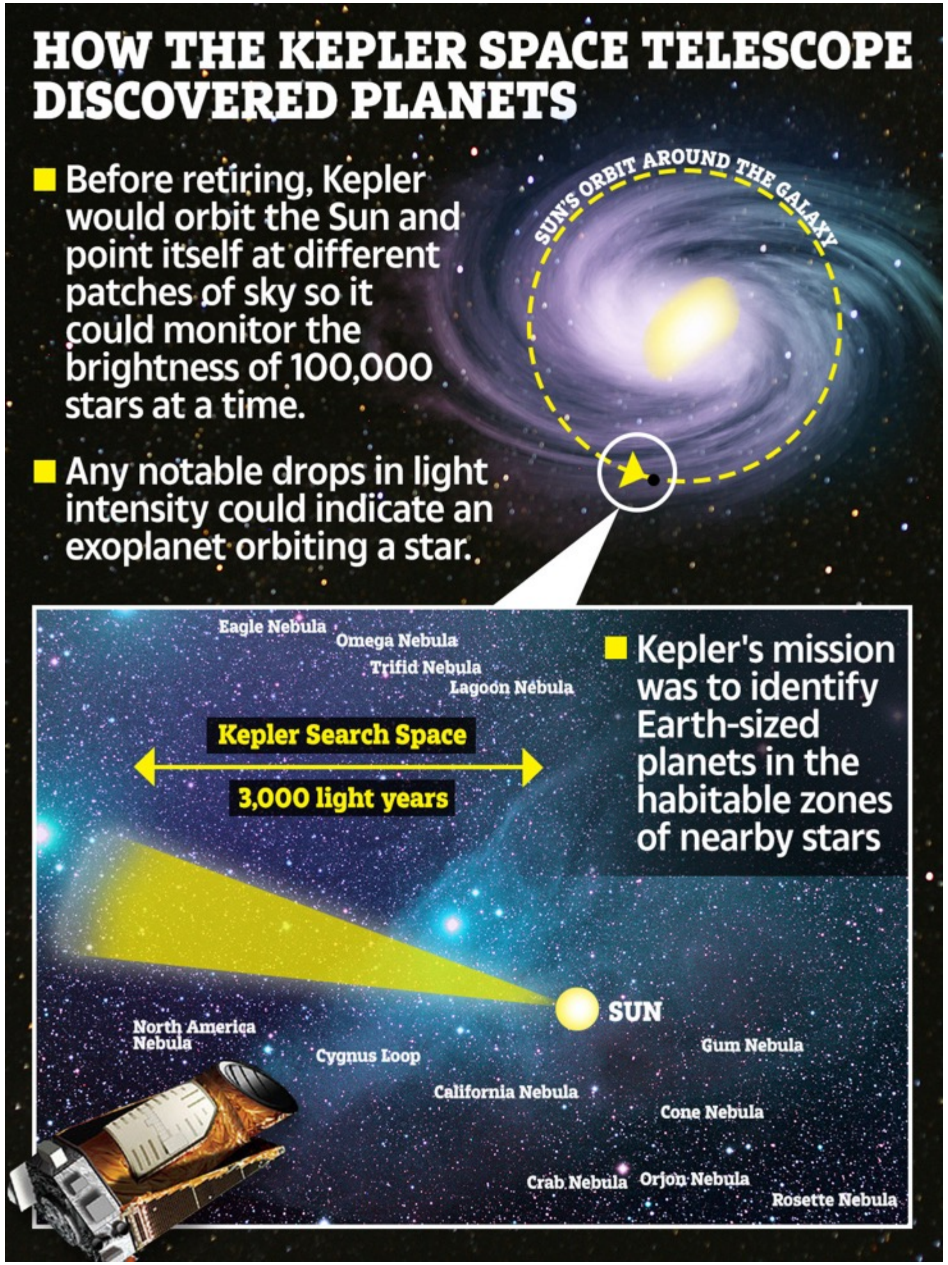


2. 类地行星

- 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)。



June 16, 2017
The population
surveys using
microlensing (
Jupiter, Neptu
denote differen
(blue), rocky p
exoplanet fron
quantity of exo



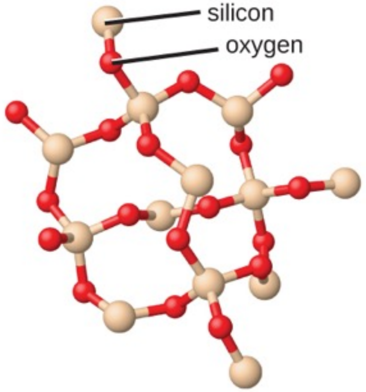
Carbon versus Silicon

dry ice

quartz

CO_2

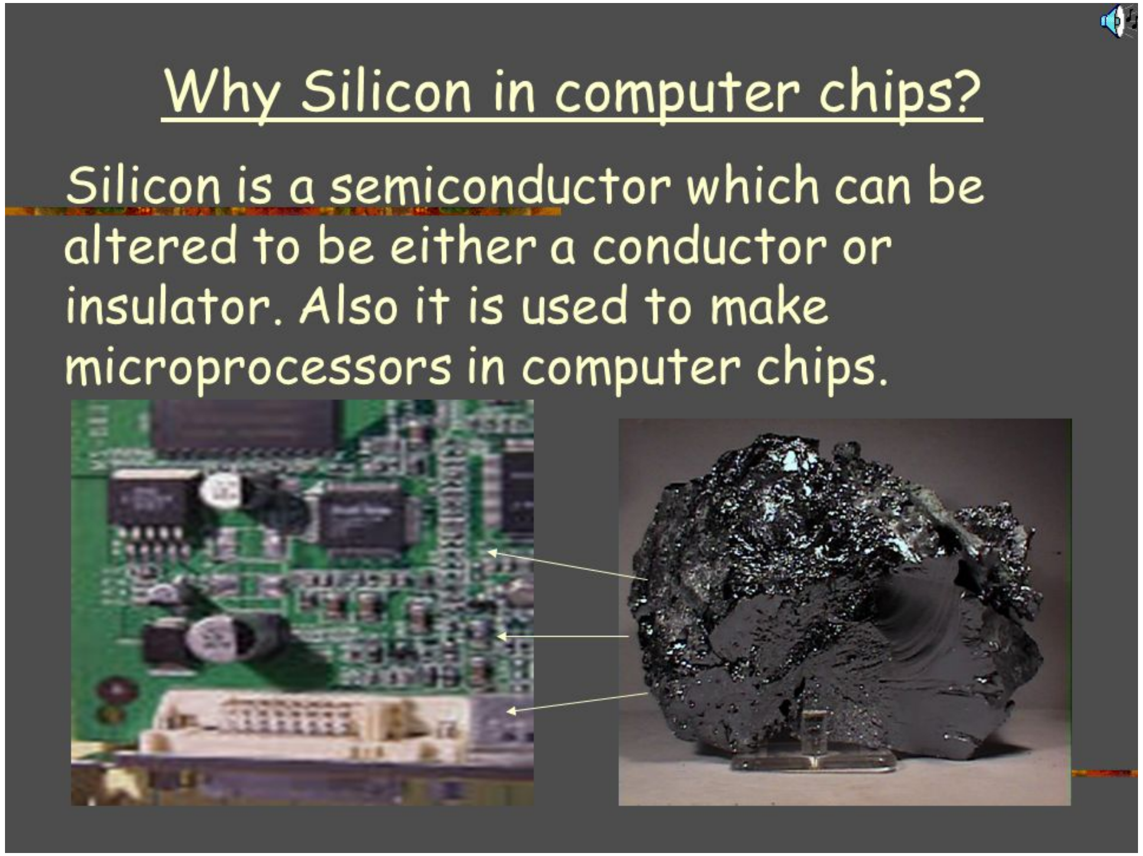
(a)



SiO_2

(b)

- 离散分子
- 无限网络

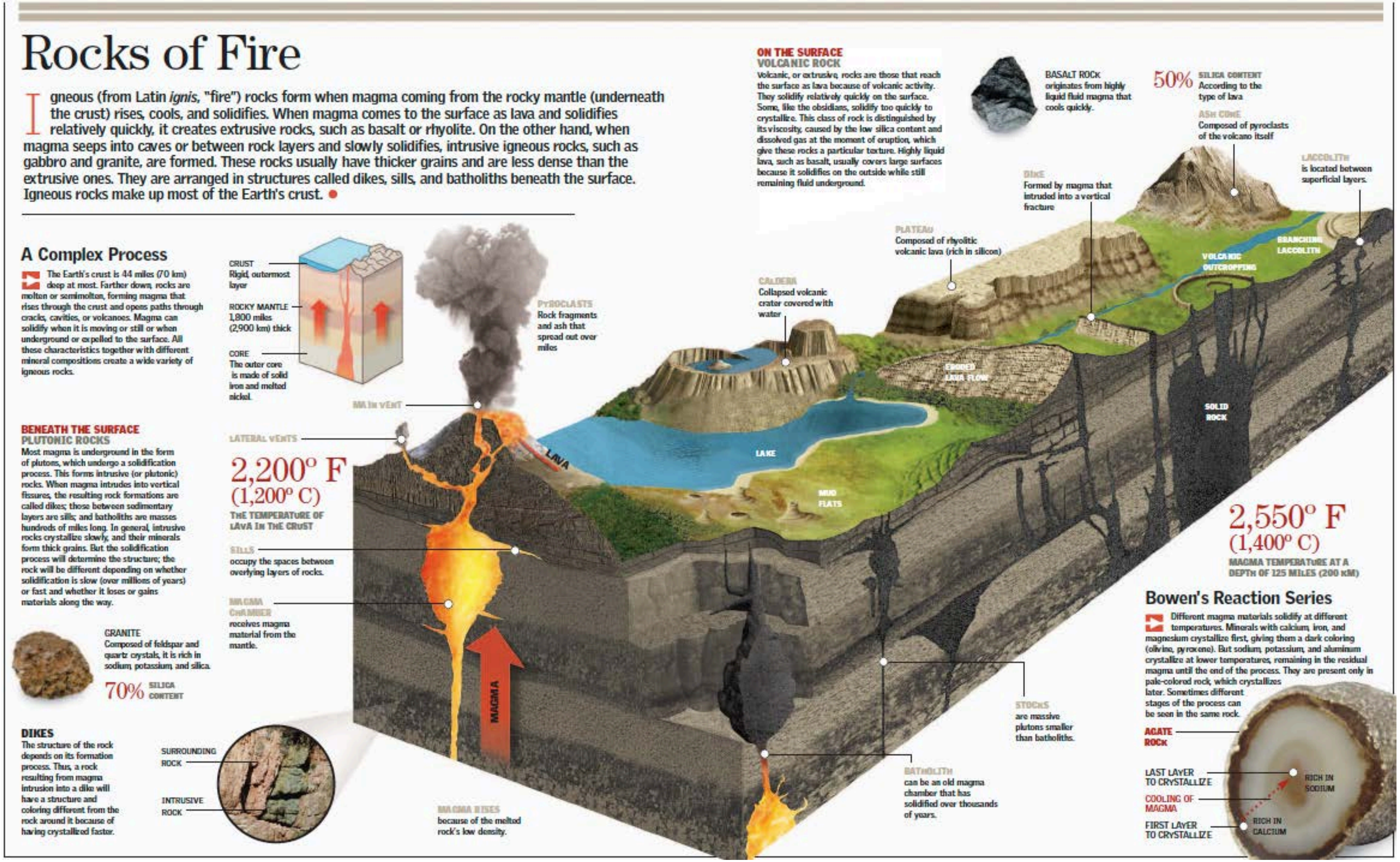


- Computer chips & Silicon Valley
- Sci-Fi: Silicon-based Life?

Credits: Erica Gerdes; Didier Descouens; https://opentextbc.ca/chemistry/chapter/18-3-structure-and-general-properties-of-the-metalloids/

岩石

From Britannica Illustrated Science Library – Rocks and Minerals



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.

CRUST
Rigid, outermost layer

ROCKY MANTLE
1,800 miles (2,900 km) thick

CORE
The outer core is made of solid iron and melted nickel.

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.

GRANITE
Composed of feldspar and quartz crystals, it is rich in sodium, potassium, and silica.

70% SILICA CONTENT

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.

SURROUNDING ROCK

INTRUSIVE ROCK

MAIN VENT

LATERAL VENTS

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

SILLS
occupy the spaces between overlying layers of rocks.

MAGMA CHAMBER
receives magma material from the mantle.

MAGMA

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

PYROCLASTS
Rock fragments and ash that spread out over miles

LAVA

LAKE

MUD FLATS

CALDERA
Collapsed volcanic crater covered with water

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.

DIKE
Formed by magma that intruded into a vertical fracture

PLATEAU
Composed of rhyolitic volcanic lava (rich in silicon)

ERODED LAVA FLOW

VOLCANIC OUTCROPPING

BRANCHING LACCOLITH

SOLID ROCK

STOCKS
are massive plutons smaller than batholiths.

BATHOLITH
can be an old magma chamber that has solidified over thousands of years.

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.

AGATE ROCK

LAST LAYER TO CRYSTALLIZE

RICH IN SODIUM

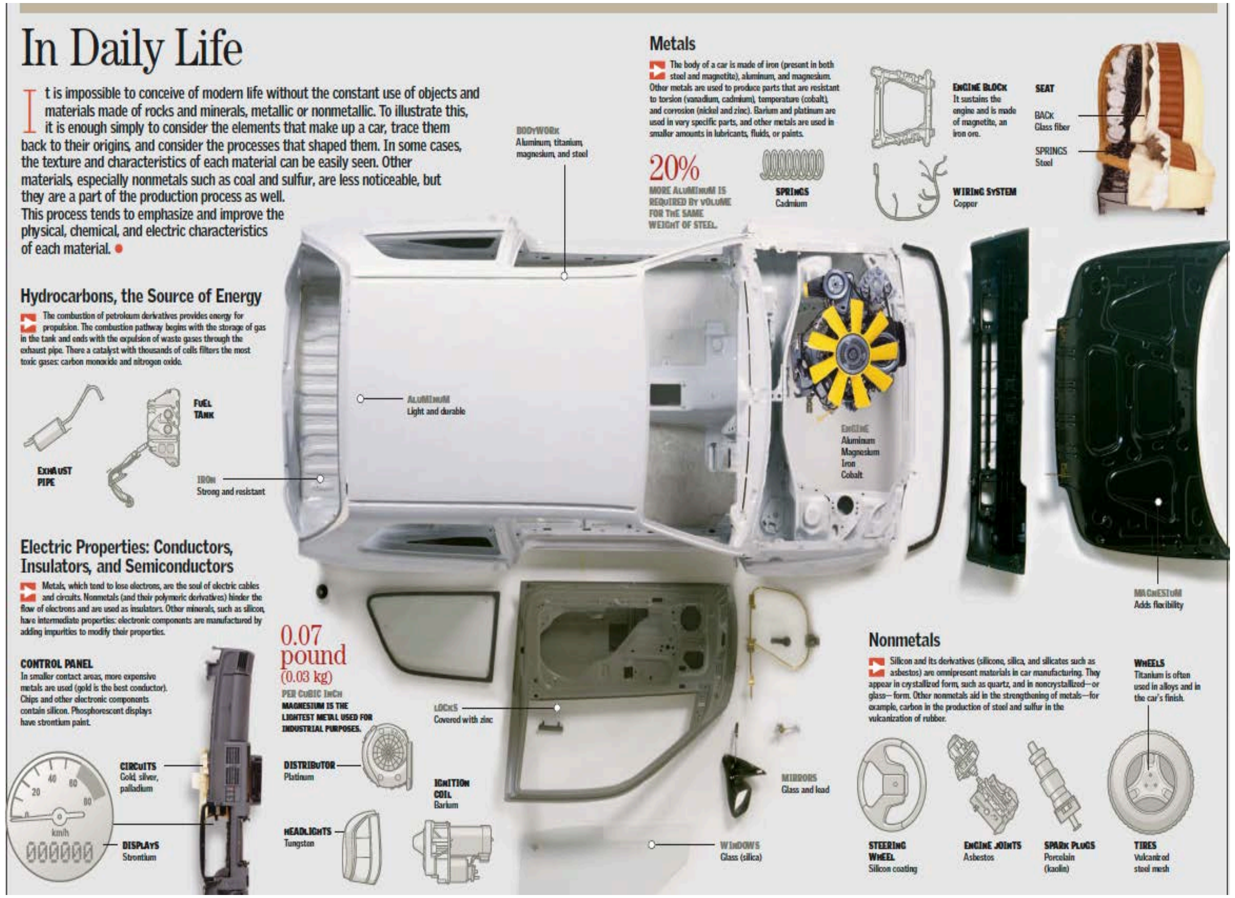
COOLING OF MAGMA

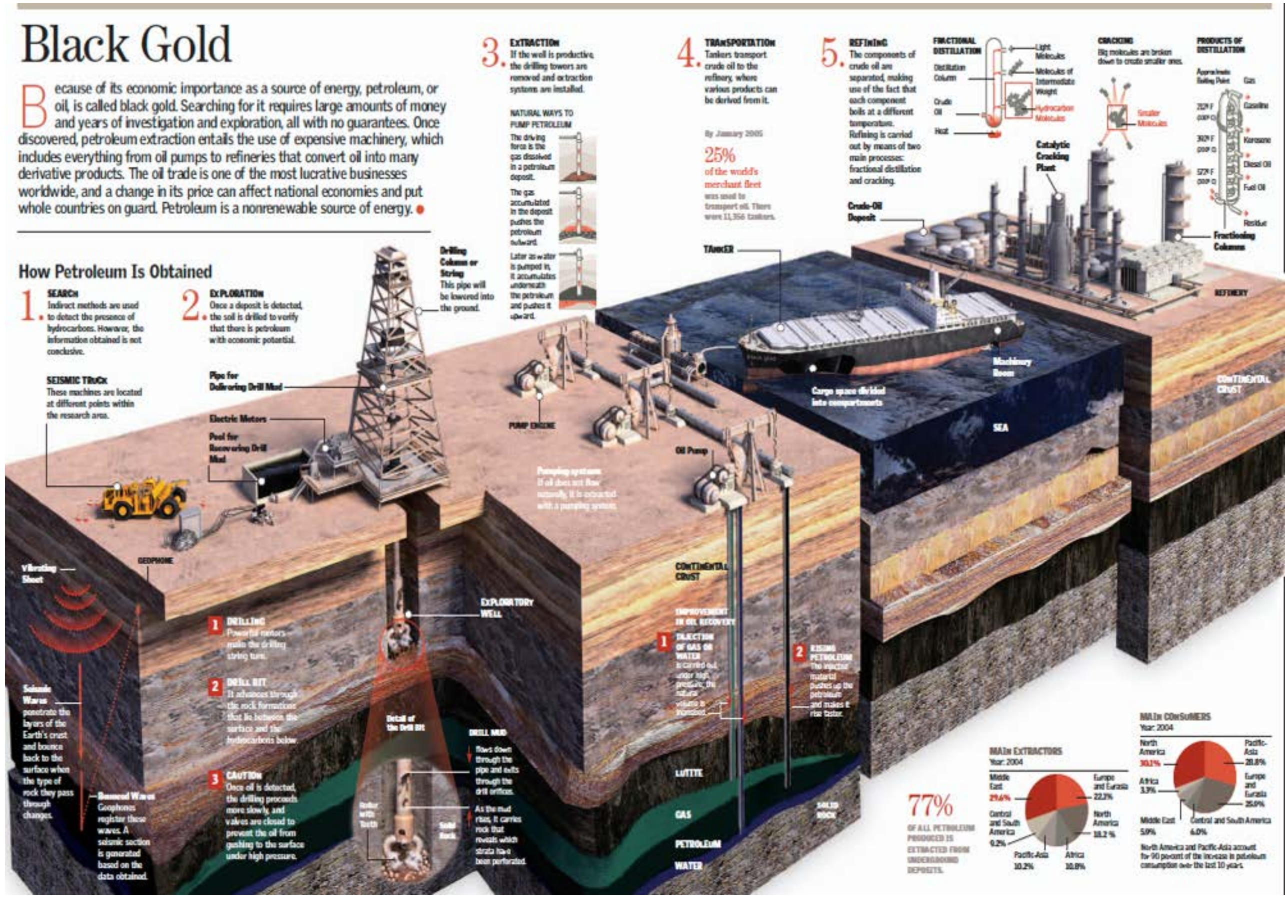
FIRST LAYER TO CRYSTALLIZE

RICH IN CALCIUM

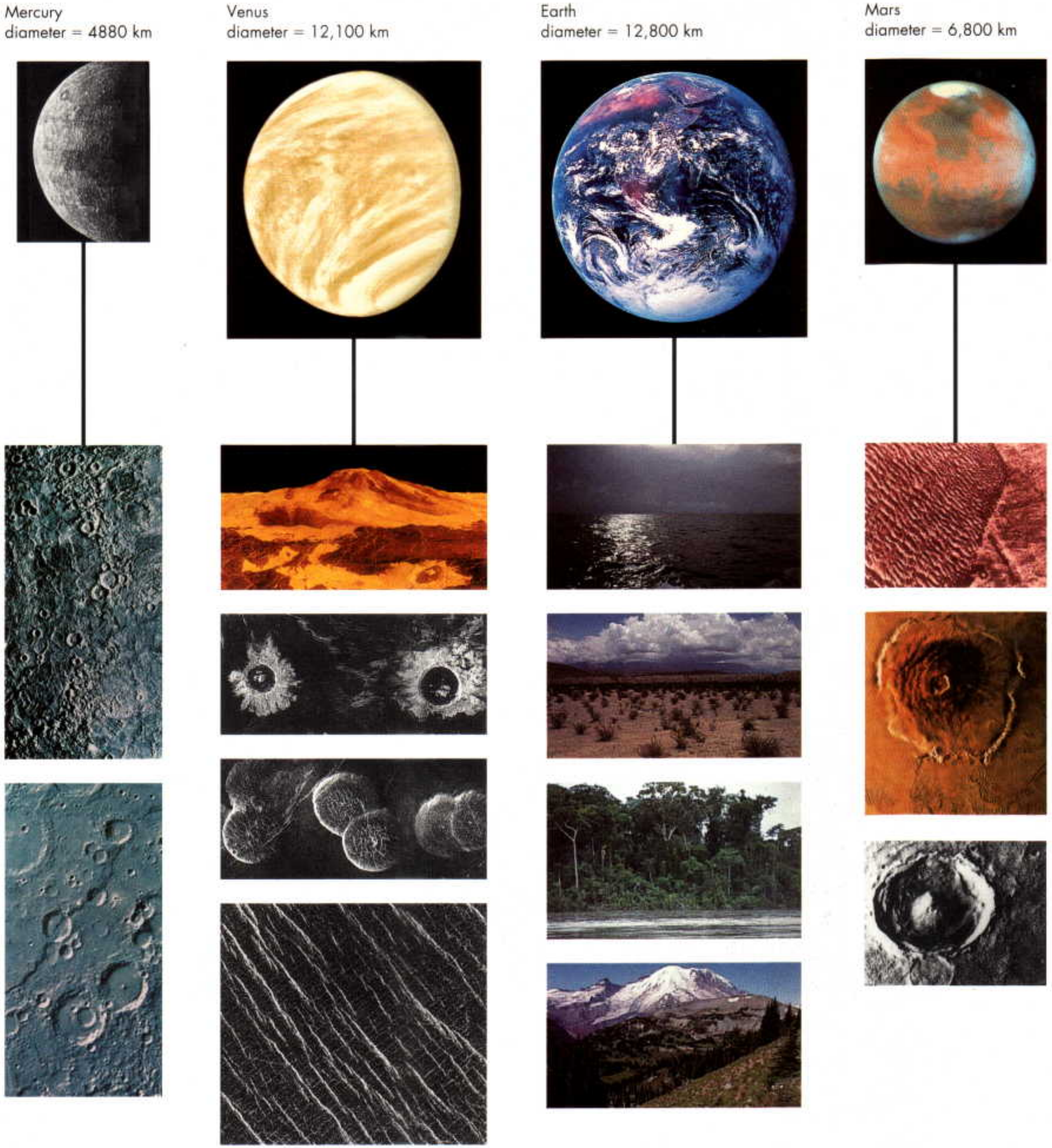
岩石和矿物的用途

Britannica Illustrated Science Library – Rocks and Minerals

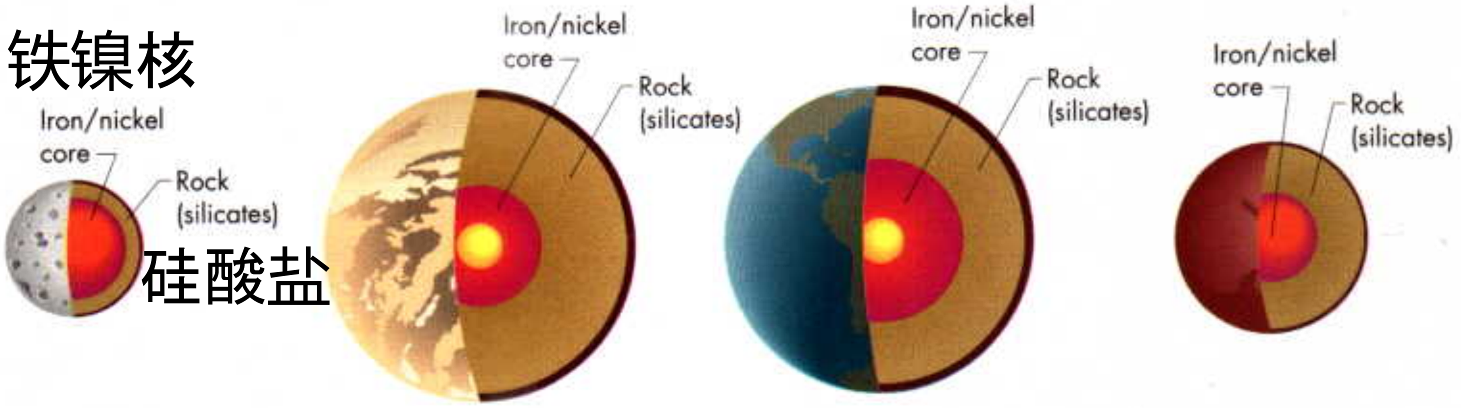


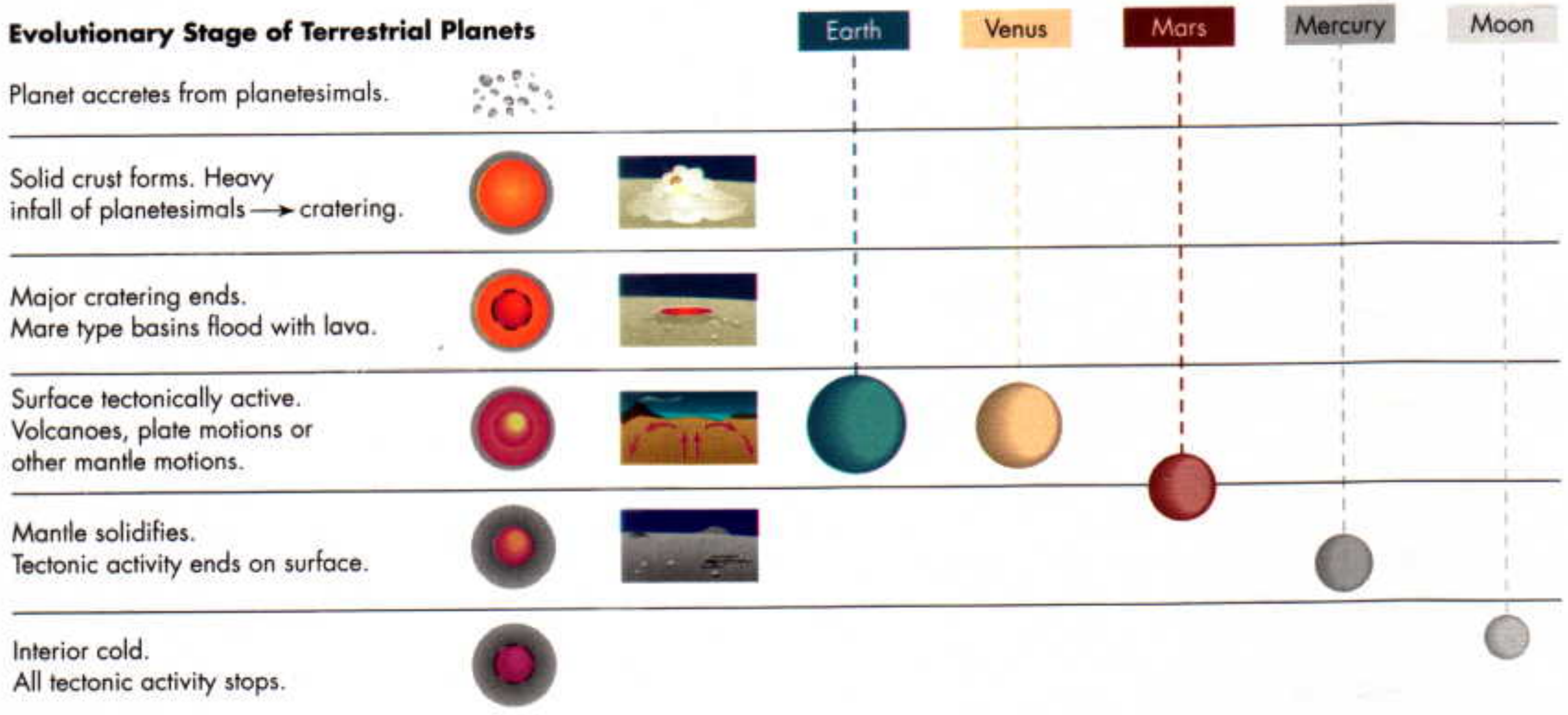


3. 地貌


Mercury
diameter = 4880 km
Venus
diameter = 12,100 km
Earth
diameter = 12,800 km
Mars
diameter = 6,800 km

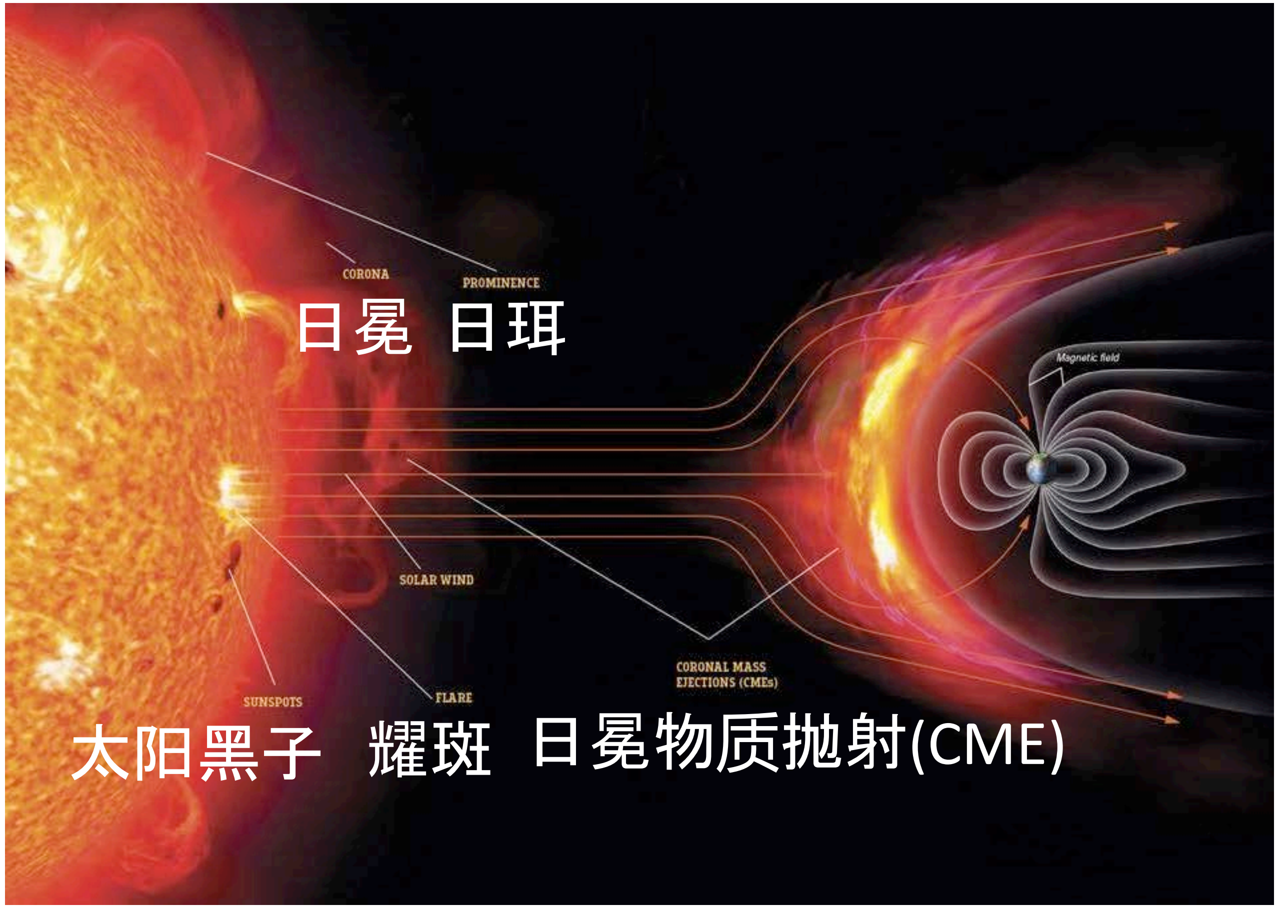
4. 类地行星的内部结构和演化

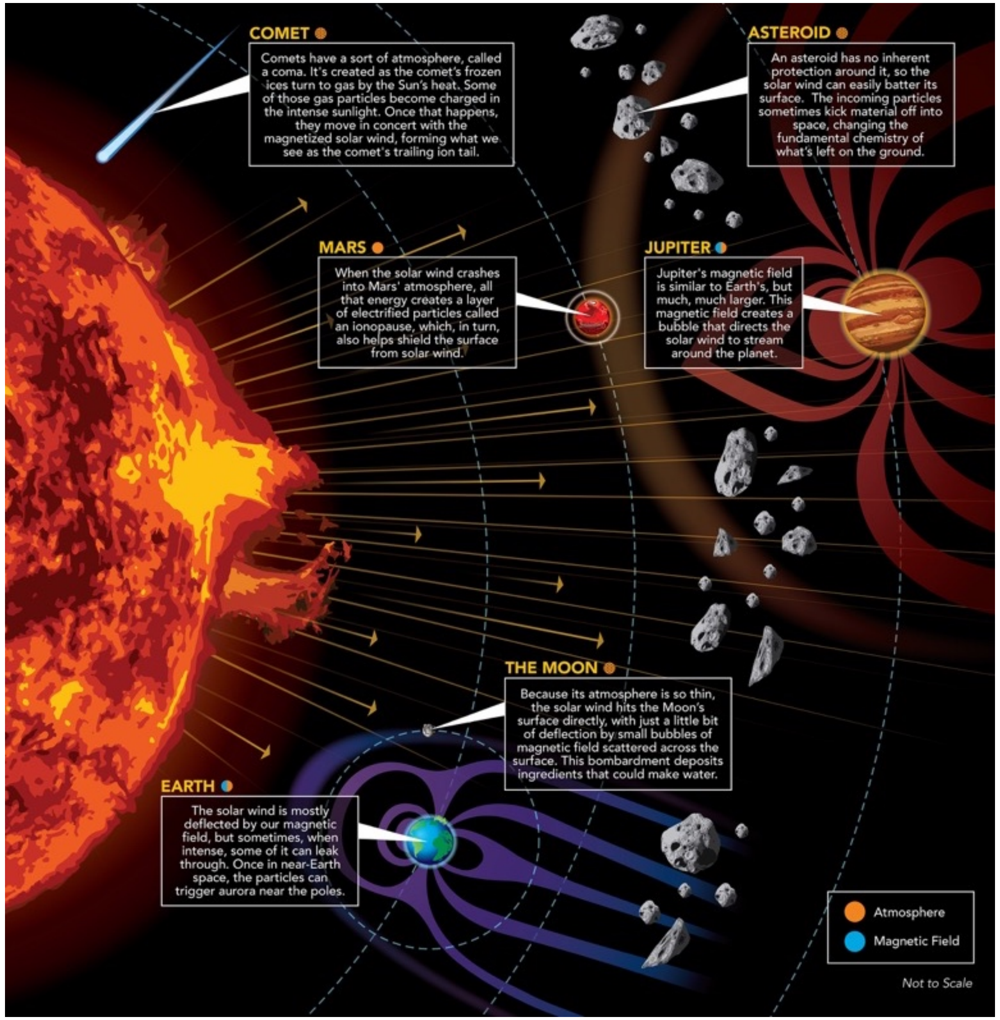




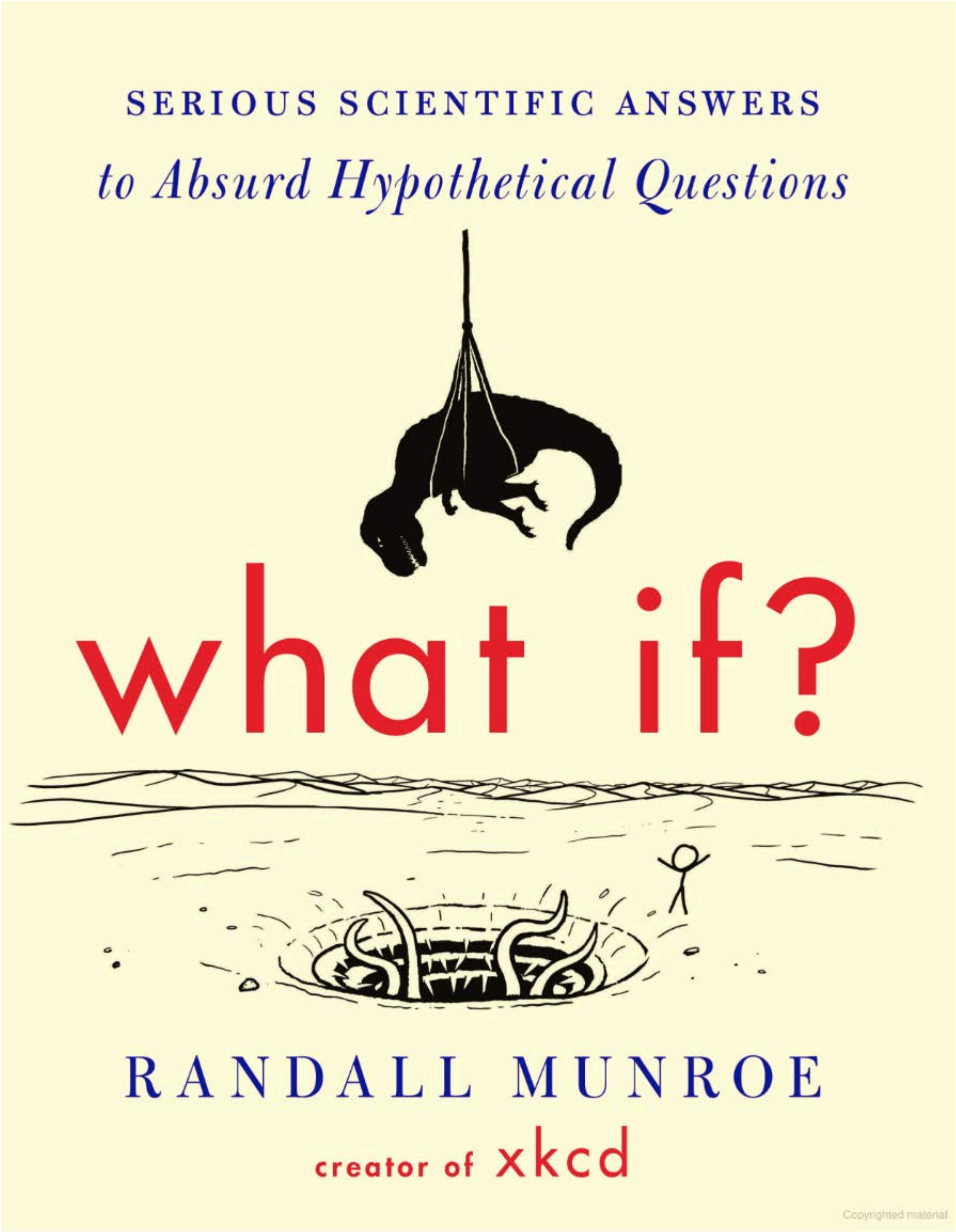
5. Magnetic field, Dynamo, and Magnetic Shield

- 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.

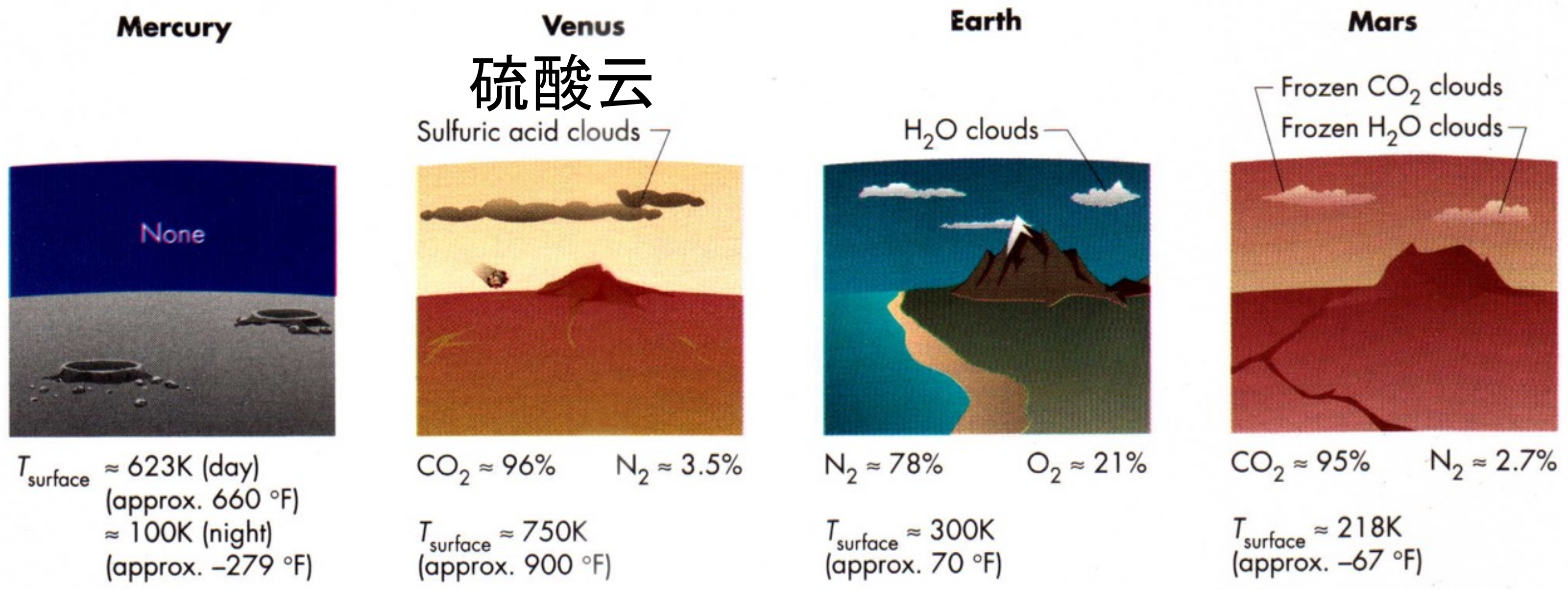


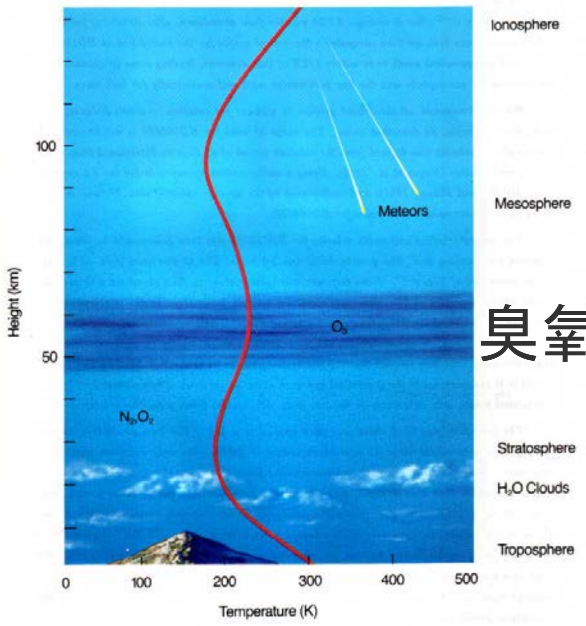


Question: What If Earth loses its magnetic field?



6. Atmospheres of terrestrial planets





电离层(磁层)

中间层

臭氧层

平流层

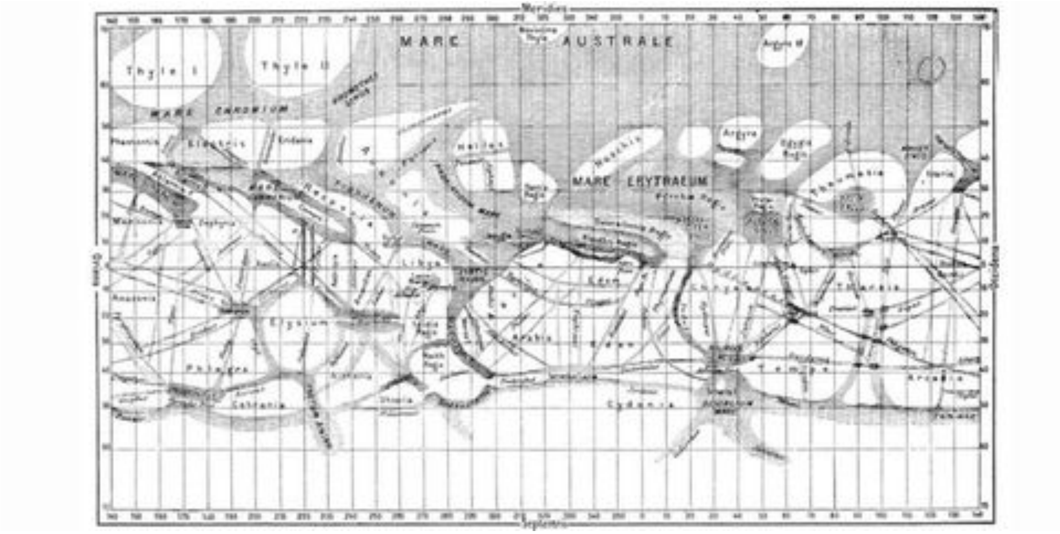
对流层

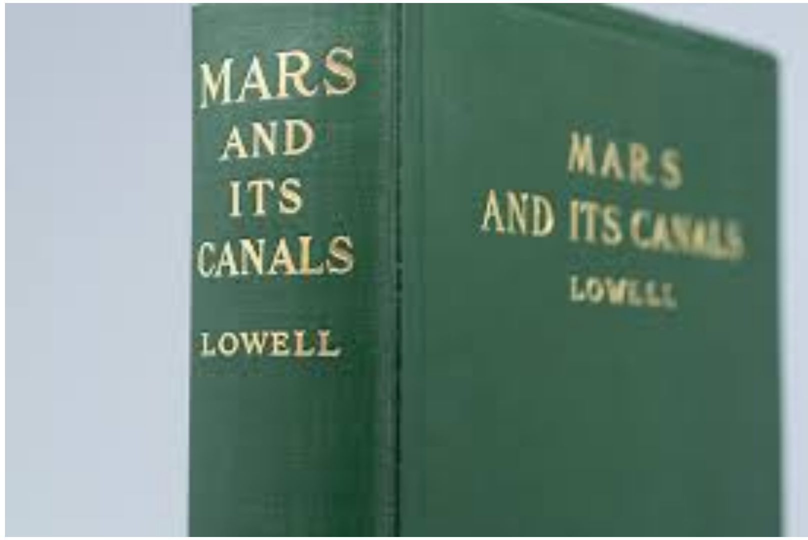
World	Composition of Atmosphere	Surface Pressure*	Average Surface Temperature	Winds, Weather Patterns	Clouds, Hazes
Mercury	helium, sodium, oxygen	10^{-14} bar	day: 425°C (797°F); night: −175°C (−283°F)	none: too little atmosphere	none
Venus	96% carbon dioxide (CO_2) 3.5% nitrogen (N_2)	90 bars	470°C (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.

火星之旅

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



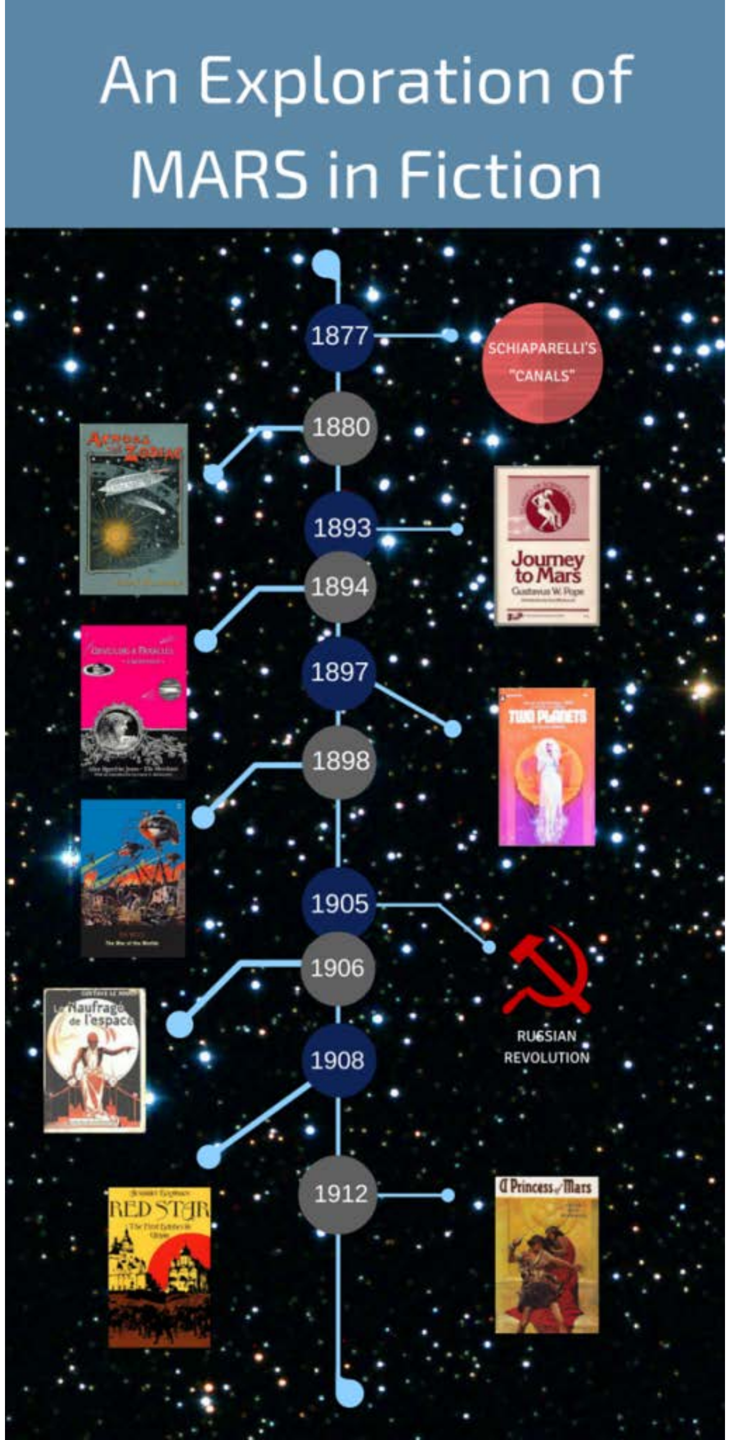


SCHIAPARELLI'S CANALS WENT VIRAL BECAUSE OF A MISTRANSLATION. INSTEAD OF ITS LITERAL MEANING OF MARKS OR GROOVES, "CANALI" IN ENGLISH BECAME "CANALS," SUGGESTIVE OF WATER, LIFE, AND INTELLIGENT INTERVENTION IN THE MARTIAN LANDSCAPE.

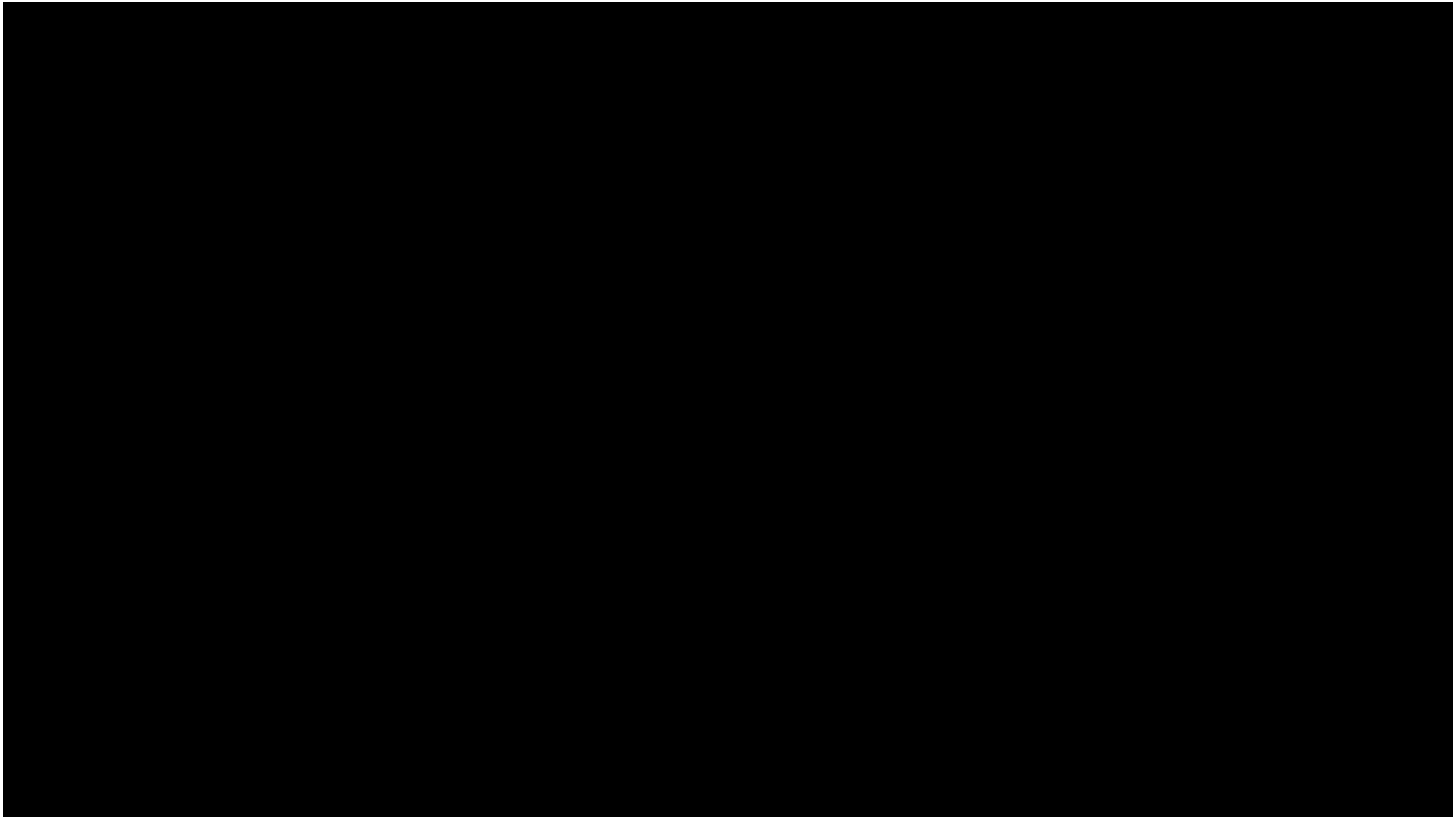
AN 1898 ARTICLE IN THE ATLANTIC MONTHLY NOTED THAT MARS MIGHT BE IN "AN ADVANCED STAGE OF EVOLUTION" COMPARED TO EARTH, AT LATER STAGE IN ITS LIFESPAN.

Ref: https://www.popularmechanics.com/space/moon-mars/a17529/a-short-history-of-martian-canals-and-mars-fever/; https://www.space.com/1583-mars-history-false-impressions.html

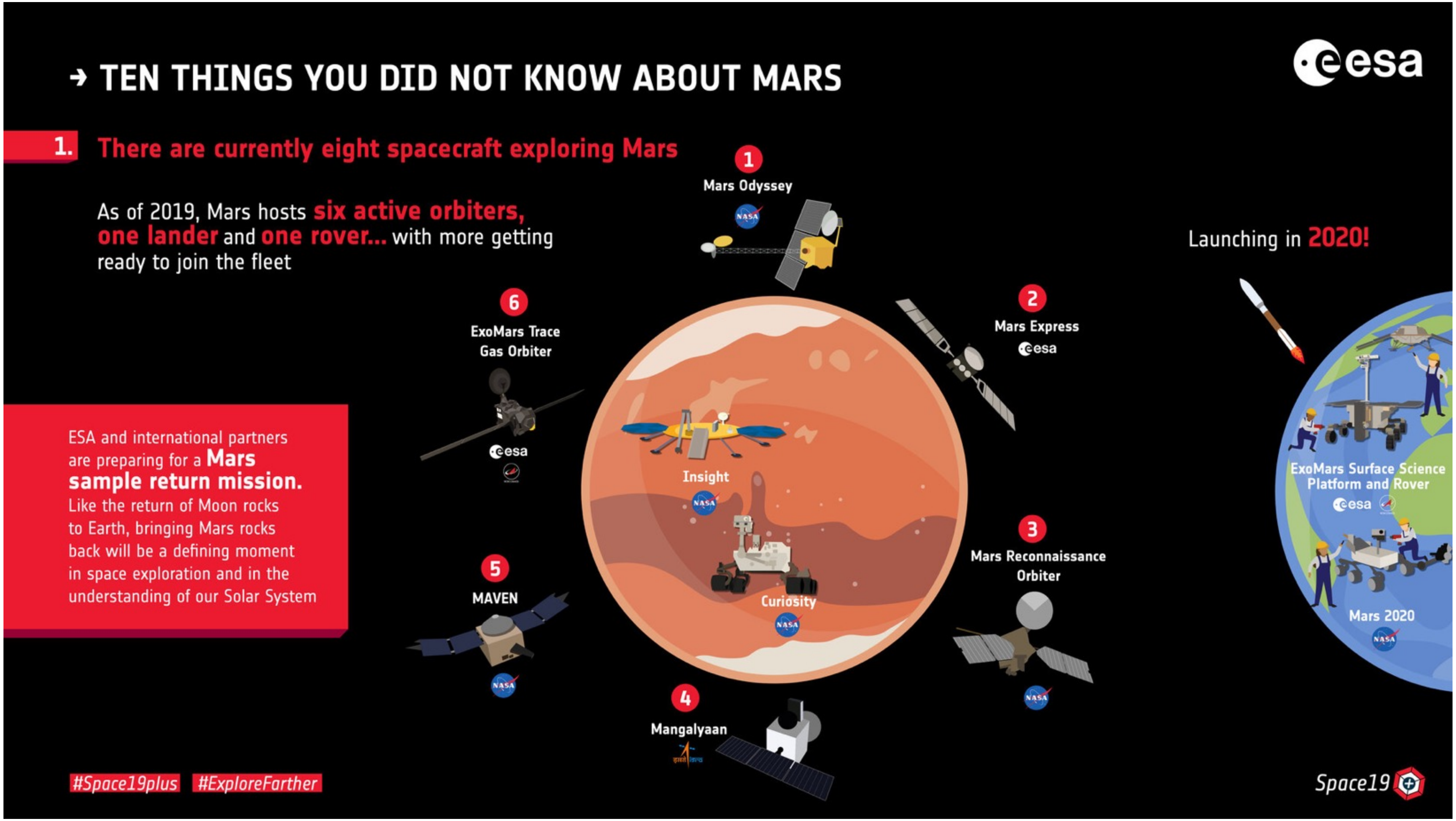
- In 1907, Is Mars Habitable? by A.R. Wallace directly critiqued Lowell's book, "furnishing a quite natural explanation of features of the planet which have been termed 'non-natural' by Mr. Lowell," as Wallace writes in the introduction.
- Despite the debunking, by 1938, Orson Welles took Mars fever 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

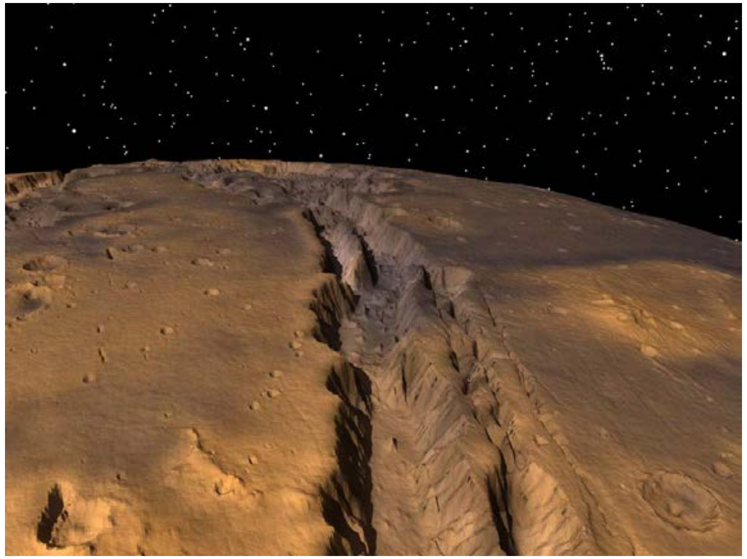


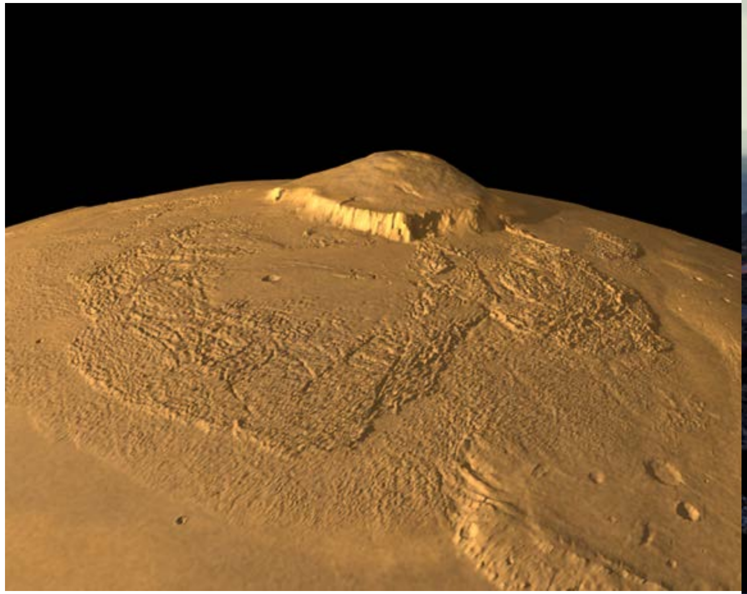
Ongoing Missions (as of 2019)



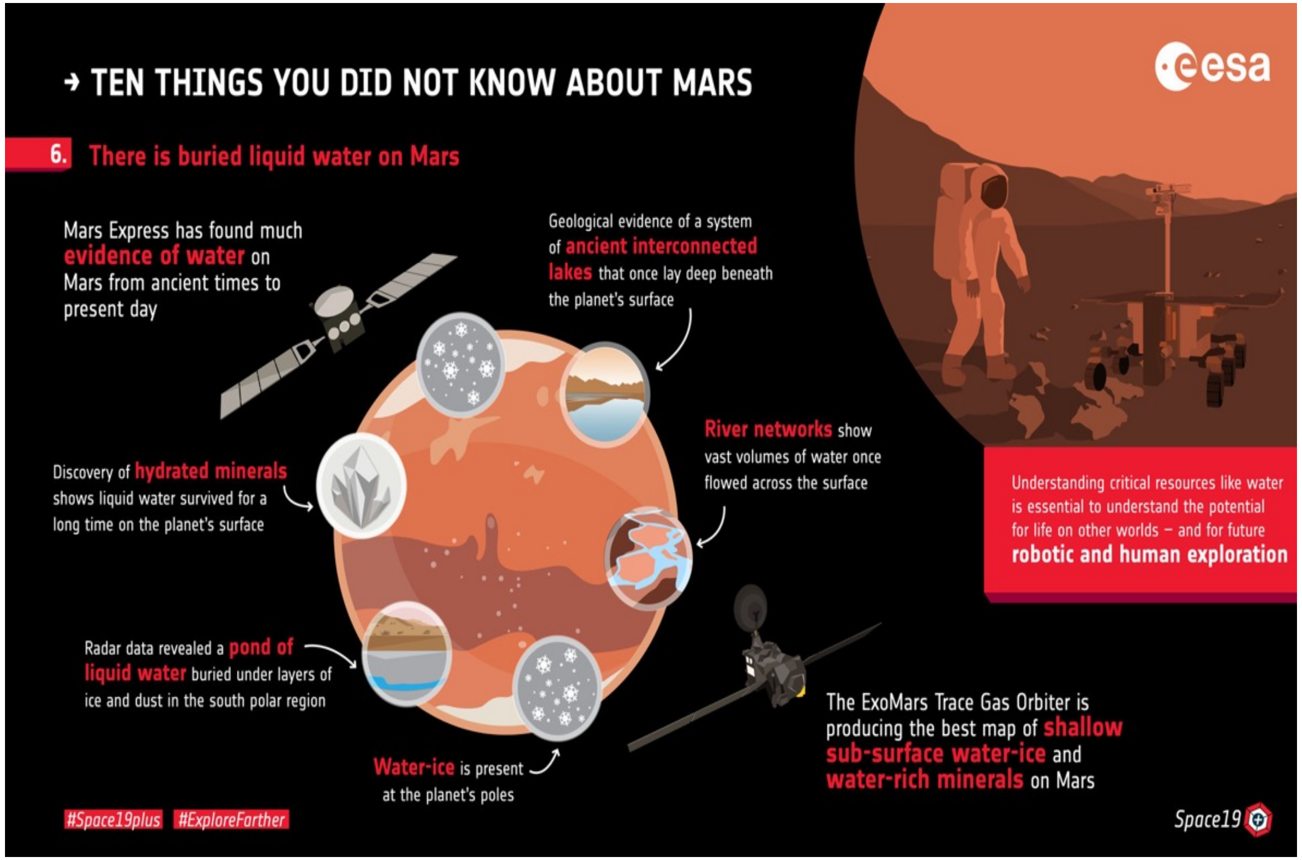
火星地貌

	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)

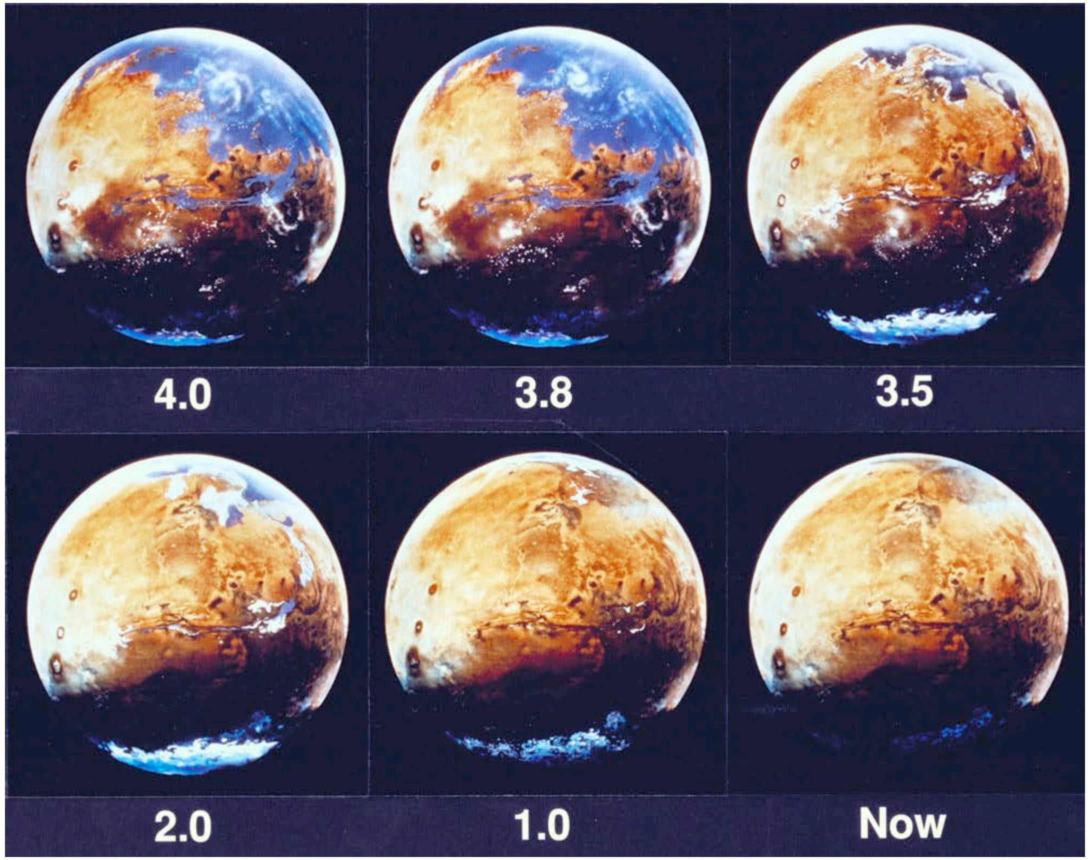




火星地表水



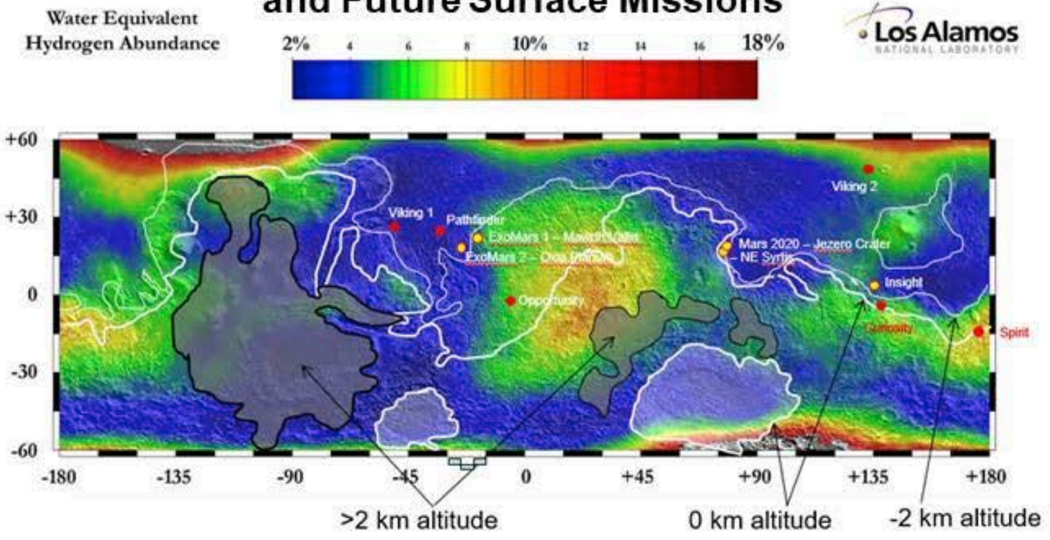
History of water on Mars? (Ga)



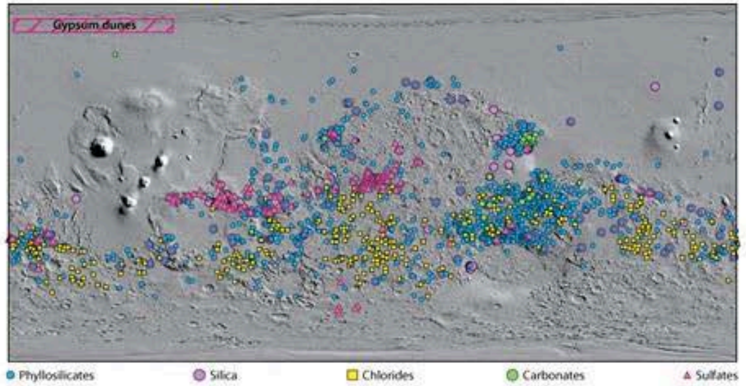
Credit: *NASA / Michael Carroll; data source: C. McKay (NASA Ames)*

火星气候：寻找水和生命

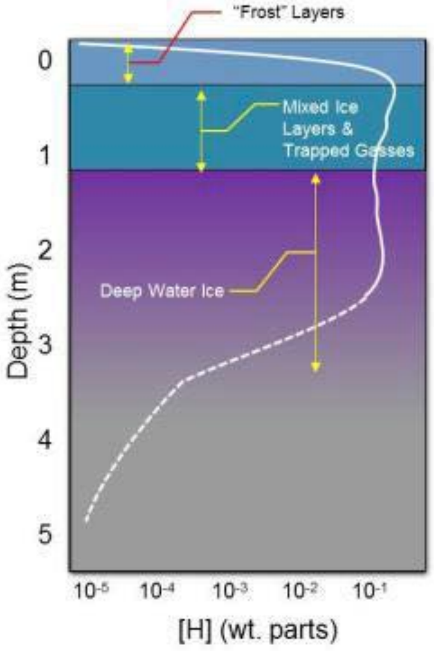
Water Abundance and Altitude with Past, Present, and Future Surface Missions

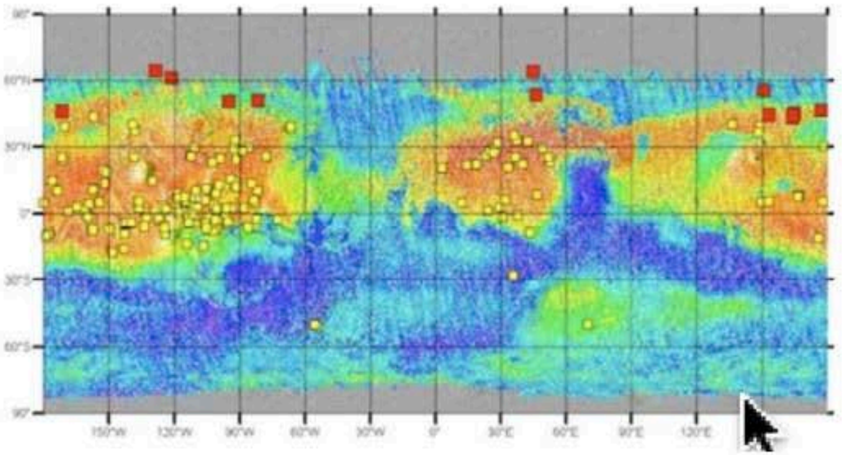


Map of aqueous mineral detections



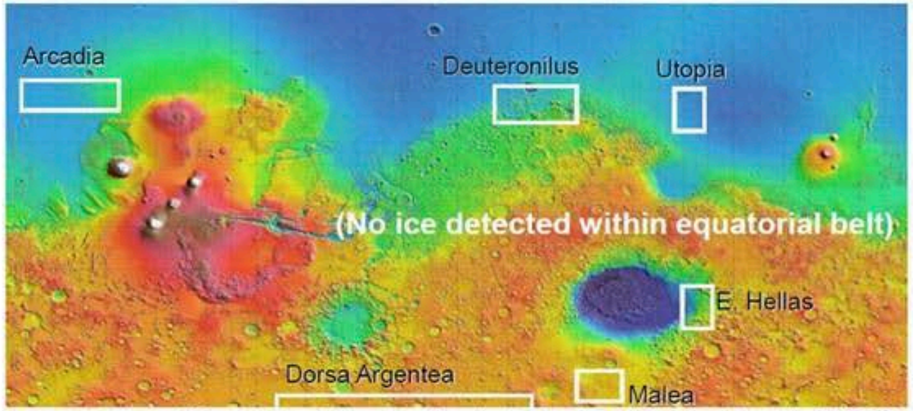
- Minerals formed in liquid water environments
- Phyllosilicates, sulfates, carbonates contain enhanced water content, to ~8%
- Exposed in areas without mid-latitude mantle





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)



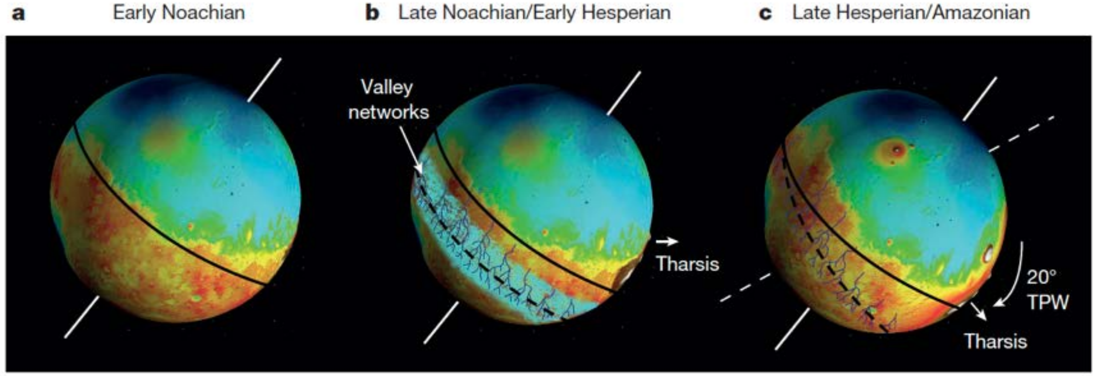
Summary map outlining areas of subsurface ice detections based on data from the MARSIS and SHARAD instruments. *Source: Special Regions SAG2, Rummel & Beaty et al., 2014.*

Radar Detection of Non-Polar Ice

Credit: Gerald Sanders

早期火星气候

Tharsis → 极移TPW

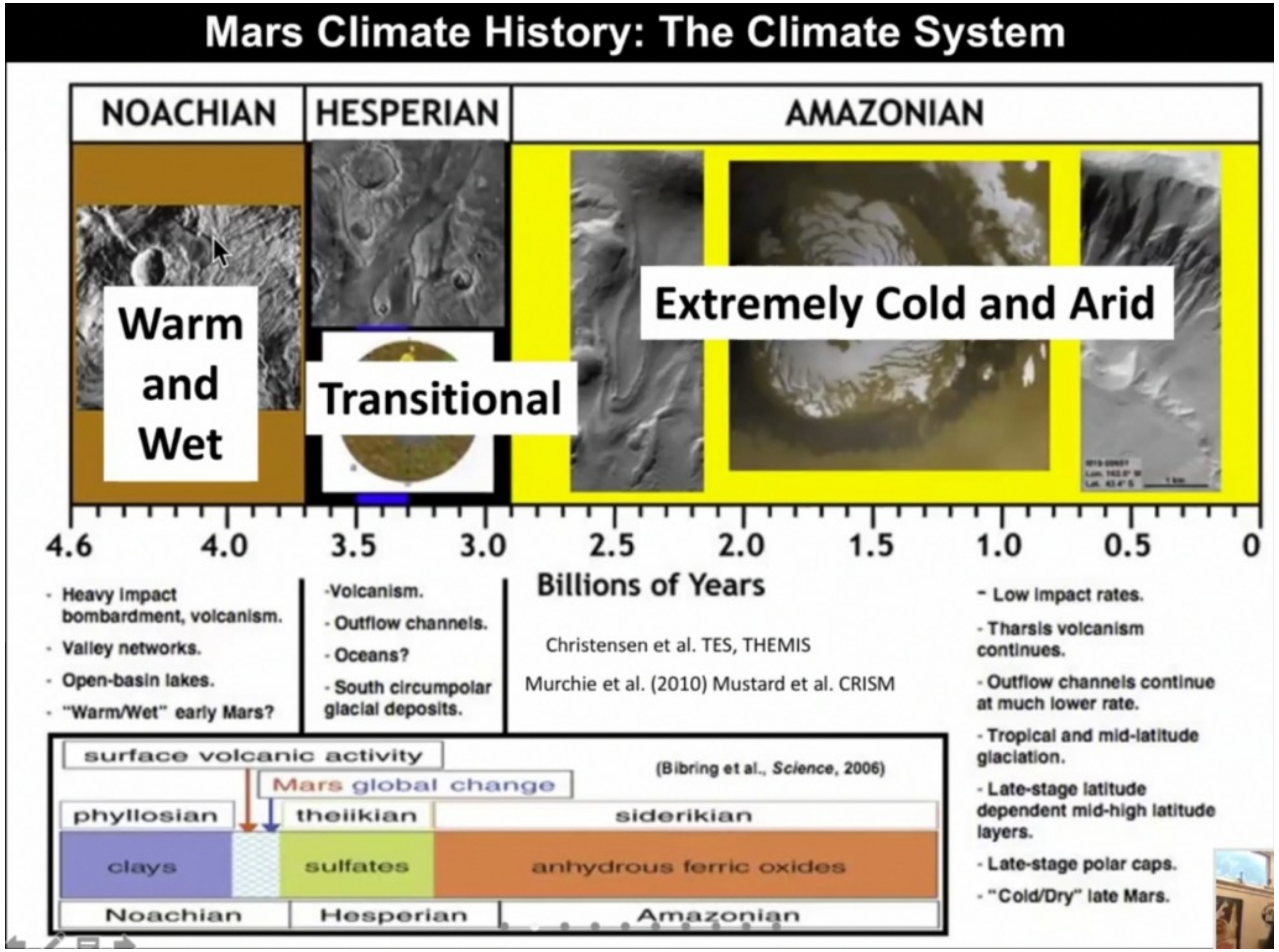


Formation of the dichotomy, heavy bombardment, dichotomy boundary in equatorial position

Tharsis dome formation, tropical precipitation with valley networks formation

Tharsis formation causes a TPW, valley networks on a small circle, Tharsis bulge on the equator

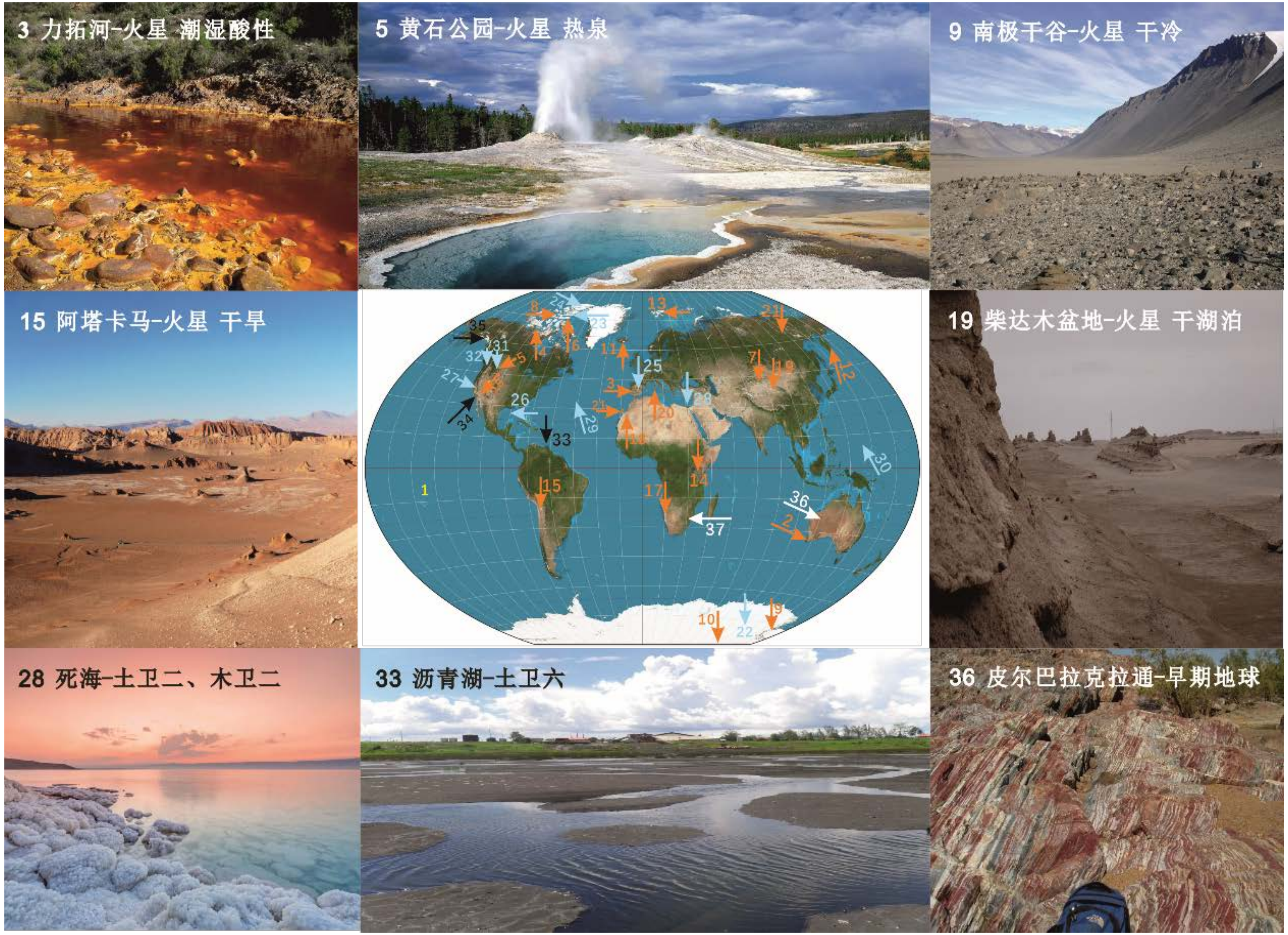
（Bouley+Nat, 2015）

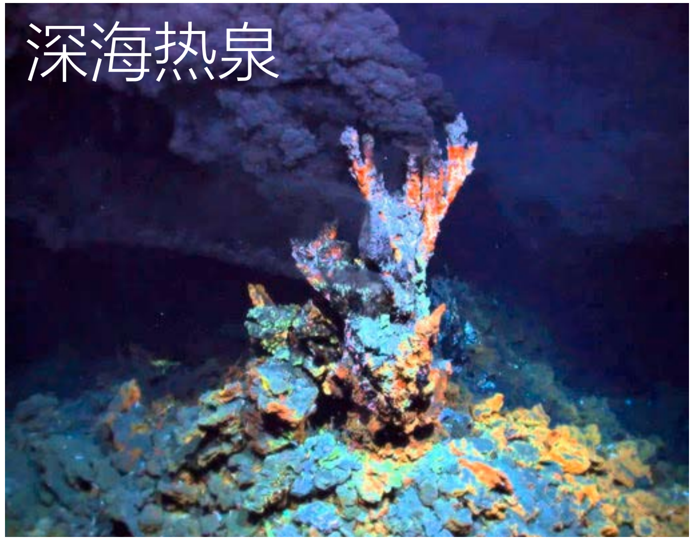


Credit: Jim Head

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

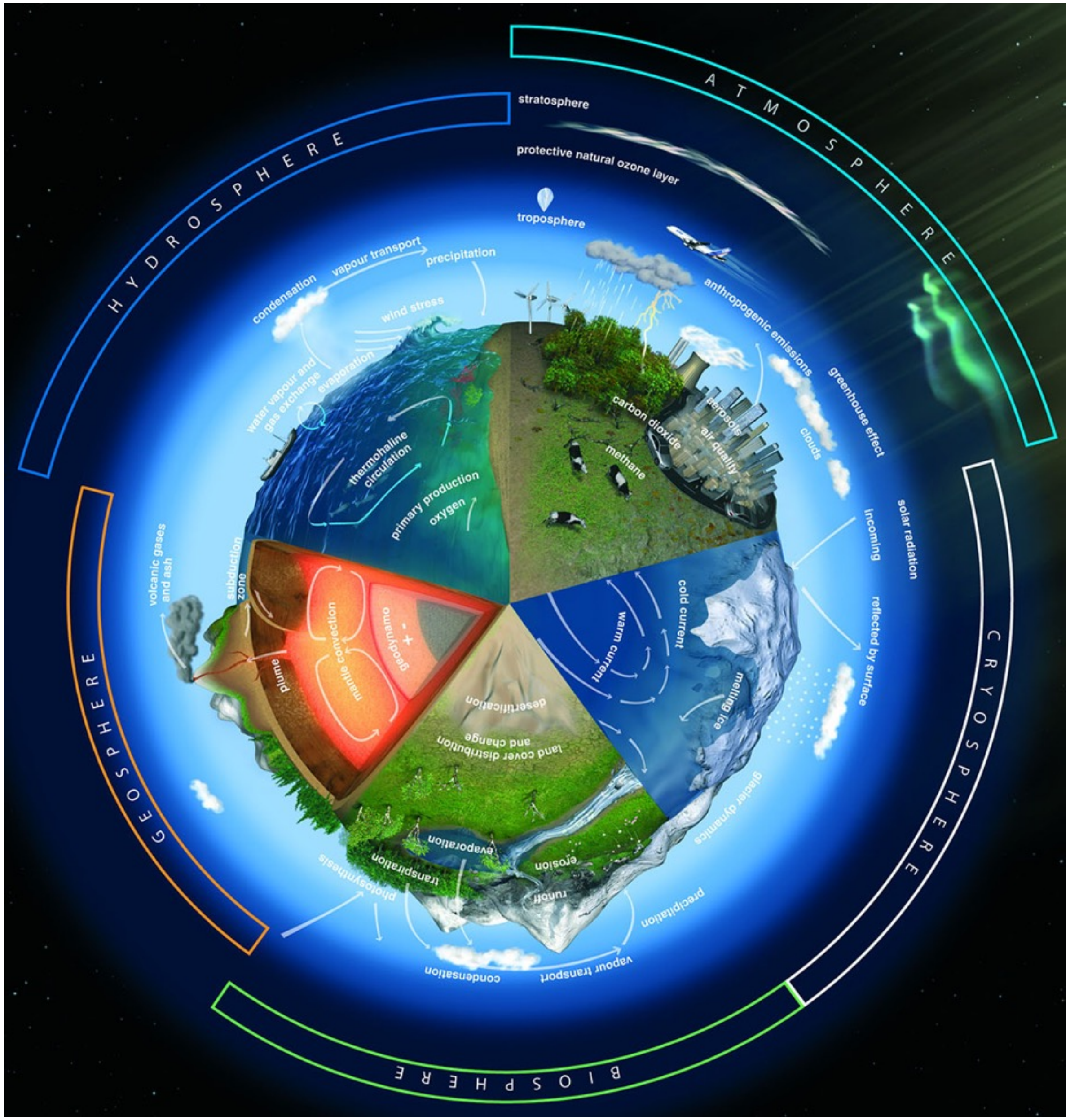
与地球极端环境的对比研究





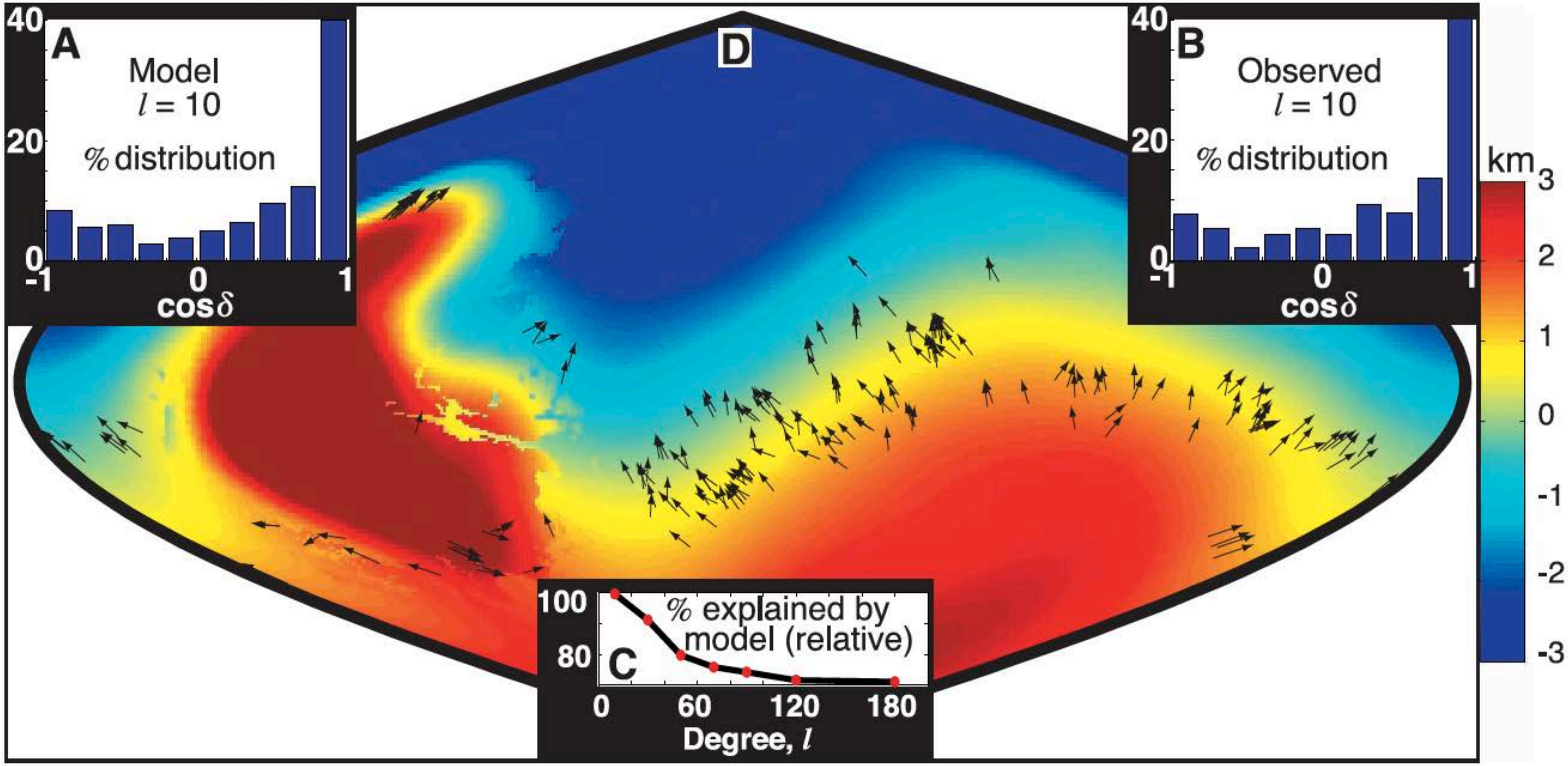
Credit: 黄婷

早期火星：岩石圈 - 水圈 (-生物圈) 协同演化



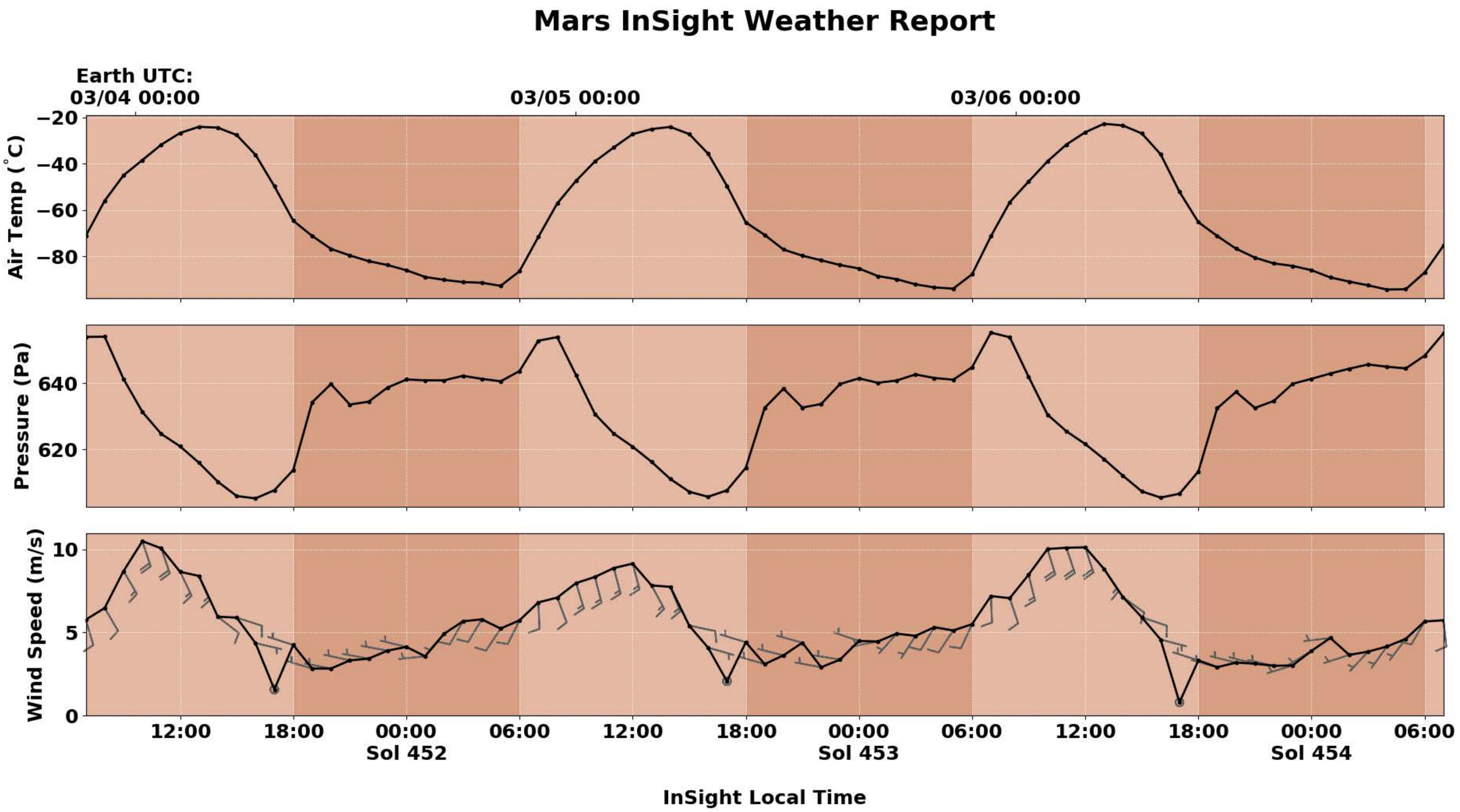
ESA 2014: About Future Missions

例子: Tharsis → 气候和地形 → 河谷分布→ 微生物？



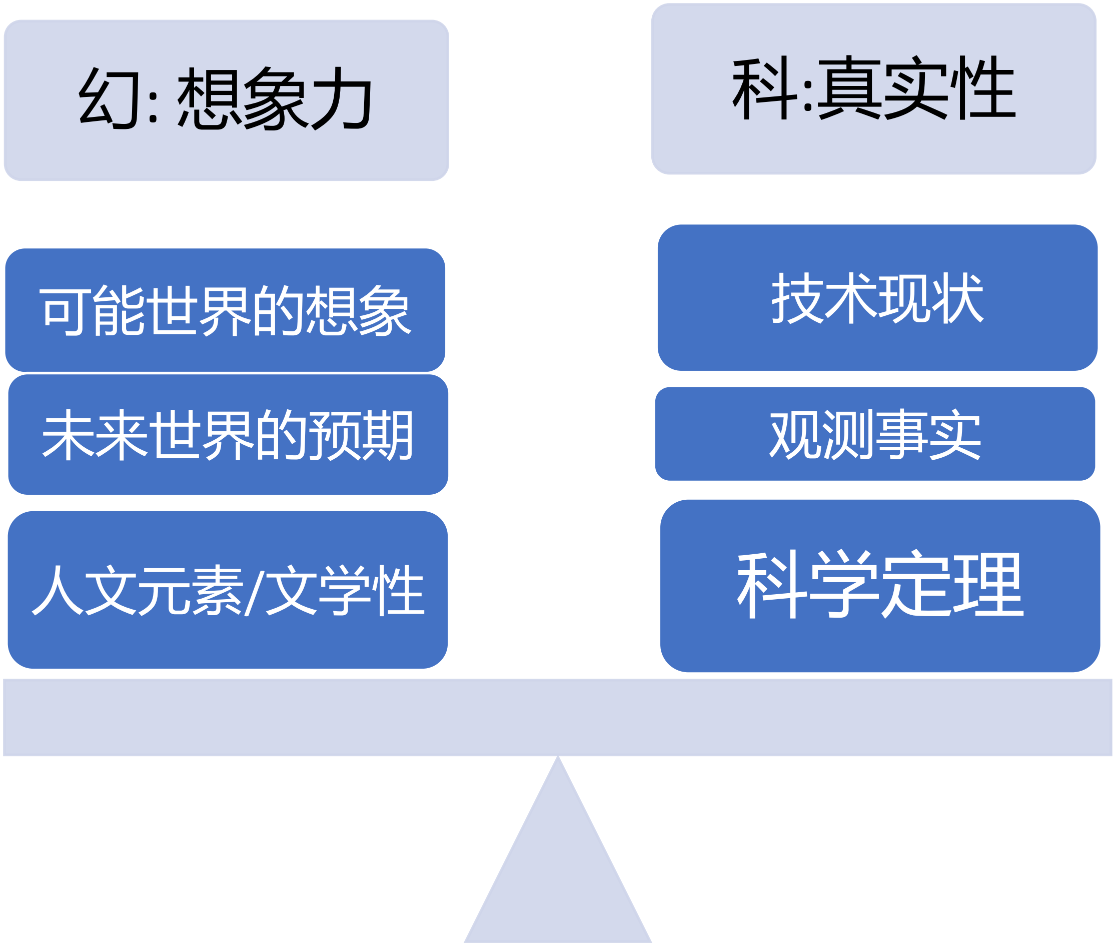
(Phillips et al., Science, 2001)

Mars Weather Report



Let's explore Mars together
Using Mission to Mars AR

Science or Fiction?



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？

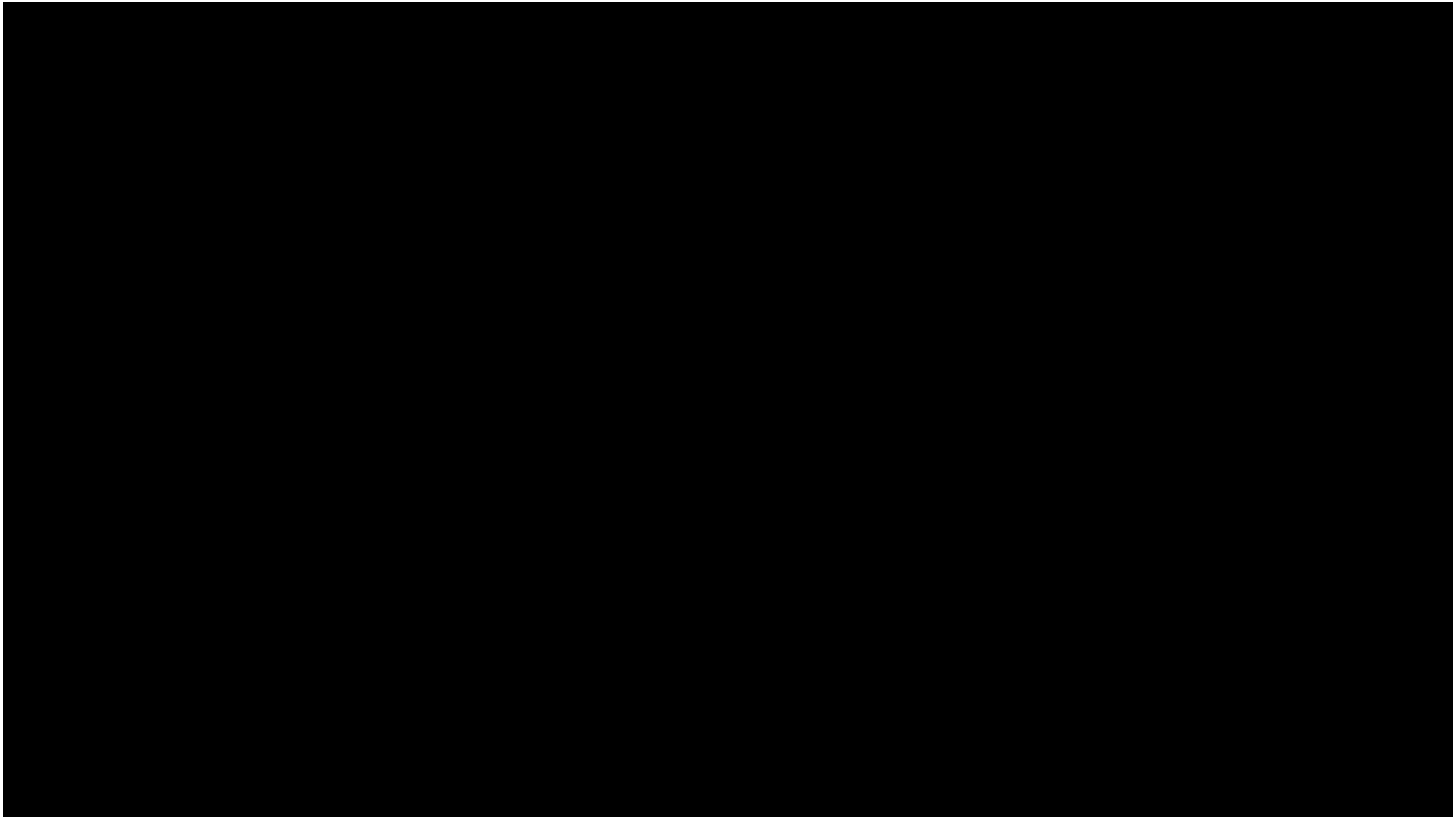
https://zh.wikipedia.org/wiki/%E7%81%AB%E6%98%9F%E5%9C%B0%E7%90%83%E5%8C%96

火星的地球化可以有以下幾個方法：

1. 在大气中增加適合适量的气体（包括溫室氣體和適合生物生存的氣體），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?