Elements of Astrobiology
天體生物學的要素

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Objectives
目标

- Understand where the different elements of the periodic table arise.
- Understand the habitability conditions necessary for the development of life.
- Manage the minimum guidelines of life outside the earth.
- 理解元素周期表中不同元素从何而来
- 理解生命发展所必须的宜居条件
- 设法给出地球外生命指南

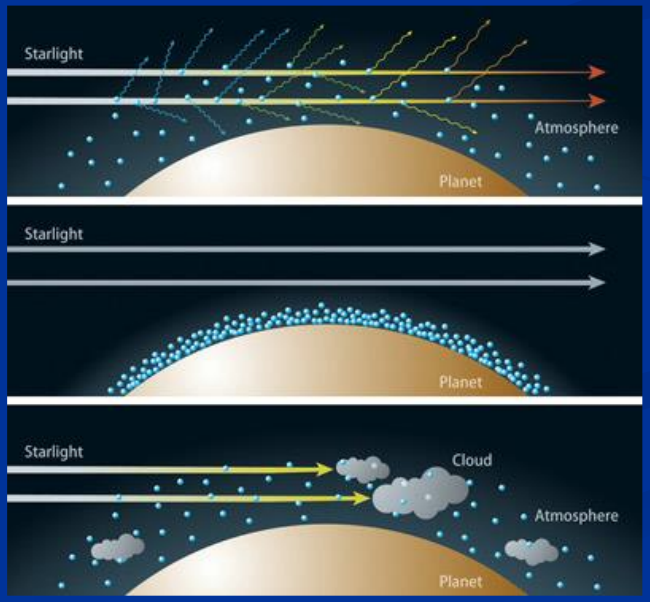
Formation of planetary systems
行星系统形成

During the formation of a star its planetary system is also constituted with the remains of material close to the star.

Spectroscopy is used to know the composition of the star and is also used to know the atmosphere of the exoplanets.

在一颗恒星形成过程中，靠近恒星的残余物质就构成了它的行星系统

光谱可以用来了解恒星的成分，也可以用来了解系外行星的大气



Activity 1: Formation of the planetary system from gas and dust
活动1:从气体和尘埃中形成行星系统

The group is divided into two: girls (gas) and boys (dust) e.g.
(If there is a substantial difference in the number of participants from one group and another, it is recommended that the group representing the gas be the largest, since, in a planetary system in formation, the mass of the gas is 100 times the mass of the dust).
将活动参与者分为两组：例如女孩子（代表气体）和男孩子（代表尘埃）
（如果参与活动的各组学生人数相差很大，建议人数最多的一组代表气体，因为在一个正在形成的行星系统中，气体的质量是尘埃质量的100倍）
As the participants listen to the story, they make a dynamic actions of what they hear, for example:
当活动参与者聆听讲述时，他们要按照所听到的内容做动态[illegible]，例如：

Activity 1: Formation of the planetary system from gas and dust 活动1:从气体和尘埃中形成行星系统

Text of the story: 故事文本：	Participants performance: 活动参与者的动作
There was once a cloud of a lot of gas and a little less dust. **曾经有一团大量气体和少量尘埃构成的云团**	All are mixed in a cloud. There are more participants representing gas. In the cloud, all participants hold hands randomly, forming as a network. **全部混杂在一处（云团）。多数参与者代表气体。在云团（人群）中，所有参与者随机手拉手，形成网络。**
Then the gas began to gather in the center of the cloud and around it the dust. **然后气体开始在云团中心聚集，尘埃在外围**	They begin to separate. Participants representing gas accumulate in the center and those representing dust hold hands around the centre. **参与者开始分离。代表气体的人聚集在中心，代表尘埃的人手拉手围绕着中心**

Activity 1: Formation of the planetary system from gas and dust 活动1:从气体和尘埃中形成行星系统

Text of the story:	Participants performance:
There was a lot of movement, gas particles attracted gas and dust particles attracted dust. **云团中有很多运动，气体粒子吸引气体，同样尘埃粒子吸引尘埃**	They begin to rotate, move, crash, vibrate, jump. Some shoot out as a result of so much movement and others "rescue", catch, hug those particles by identification (gas with gas and dust with dust). **参与者开始旋**转、运动、碰撞、震动、蹦跳。这么多运动使得有些人被弹出，而其他人要“**救援**”，捕获，按身份拥抱那些“粒子”（气体拥抱气体，尘埃拥抱尘埃）
In the center a dense opaque core formed surrounded by a disk of dust and gas. **在云团中心形成了一个致密不透明的核球，被一个由气体和尘埃构成的盘所围绕**	Those in the center (gas) accumulate and around them participants who represent dust in a kind of circle are taken by the hand. Clarification: not all gas is in the center, there is remote gas outside the circle. **代表气体的人在中心，代表**尘埃的人手拉手围成圆圈在中心外围。说明：不是全部气体都在尘埃圈之外还有气体

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Text of the story:	Participants performance:
This nucleus is the one that would finally give rise to the Sun or the parent star of an extrasolar system. 这个核球最终会形成太阳或一颗系外行星的母恒星	The Sun or the parent star begins to shine so that its rays must shoot outwards in all directions. Clarification: The moment the sun or the parent star begins to shine the "loose" gas begins to move away. 太阳或者母恒星开始发光，因此它的光芒必须从全方位射出 说明：当太阳或母恒星开始发光时，"松散"的气体开始向外移动
Some small planets were formed by the union of increasingly larger and larger dust grains, then rocks and so on until terrestrial planets are made. 越来越大的尘埃颗粒形成小的行星，然后岩石乃至类地行星也形成了	The participants representing the dust that forms the terrestrial planets begin to group together. Clarification: not all dust stays on terrestrial planets, there must be some dust in the farthest regions. 代表能够形成类地行星的尘埃开始聚集 说明：不是全部尘埃都要留下来形成类地行星，必须有一部分尘埃位于最远处

Activity 1: Formation of the planetary system from gas and dust 活动1:从气体和尘埃中形成行星系统

Text of the story:	Participants performance:
The giant planets formed away from the heat of the Sun or the central star where the gas could gather without hinderence. **巨行星在远离太阳或母恒星中心的地方形成，那里气体可以没有阻碍地聚集**	The rest, the giant planets, begin to come together: a lot of gas and some dust. Clarification: The decrease in temperature due to the greater distance from the Sun or the mother star was the cause of the main differences between the inner rocky planets and the outer giants. **其他人开始形成巨行星：很多气体和一些**尘埃 说明：远离太阳或母恒星导致的温度降低，**是造成内**侧岩质行星和外侧巨行星**差异的原因**

Activity 1: Formation of the planetary system from gas and dust 活动1:从气体和尘埃中形成行星系统

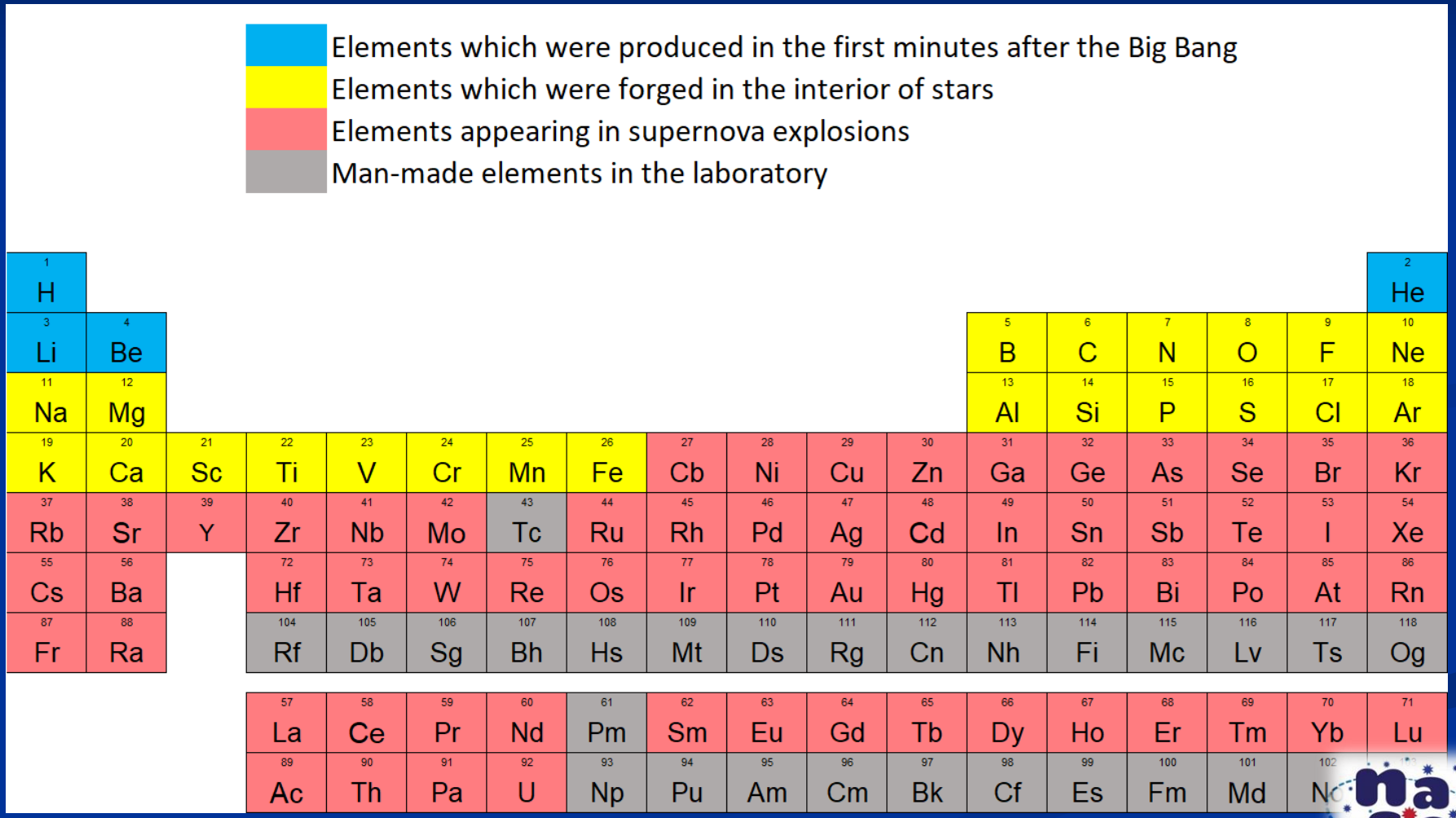
Activity 2: Emission spectrum
活动2：发射光谱

Spectroscopy allows us to know some information about the chemical composition of exoplanets and their atmospheres. We can visualize the spectrum of a light bulb with a DVD (we see the lines of the gases it contains inside)

光谱学使我们能够知道关于系外行星及其大气层的化学成分的一些信息。我们可以用DVD直观地看到一个灯泡的光谱（我们看到它内部所含气体的线条）

Chemical aspects of stellar evolution

恒星演化的化学



Activity 3: Periodic Table Classification
活动3:元素周期表分类

Place in each basket (blue, yellow and red) each object每个篮子（蓝色、黄色和红色）里放入以下每样物品

Ring: 戒指 Gold Au金	Drill bit coated with: 镀钛钻头Titanium Ti	Gas inside a child's balloon: Helium He 儿童气球内的气体：氦	Pan scourers:锅擦 Nickel Ni 镍
Mobile/button battery: 手机/纽扣电池 Lithium Li 锂	Car spark plugs: Platinum Pt汽车火花塞：铂	Electric copper wire: Copper Cu 电线：铜	Iodine solution: Iodine I碘溶液：碘
Water bottle H_2O: Hydrogen H 桶装水：氢	Old Cooking Pan: Aluminum Al旧煎锅：铝	Black Pencil Lead: Graphite C 黑铅笔：石墨，碳	Sulfur for agriculture: Sulfur S 农用硫
Can of soft drink: Aluminum Al 易拉罐铝	Wrist watch TitaniumTi 腕表 钛	Medal: Silver Ag 奖牌 银	Pipe: Lead Pb 水管 铅
Zinc pencil sharpener: 铅笔刀 锌 Zinc Zn	Rusty Old Nail: Iron Fe 生锈旧铁钉铁	Thermometer: Gallium Ga 温度计：镓	Matchbox: 火柴盒 Phosphorus P 磷

Elements generated in the first minutes after the Big Bang (blue)

Elements forged inside the stars (yellow)

Elements that appear in supernova explosions (red)

蓝色代表宇宙大爆炸最初几分钟形成的元素

黄色代表恒星内部形成的元素

红色代表超新星爆发形成的元素

Activity 3: Periodic Table Classification
活动3:元素周期表分类

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Mobile/button battery: 手机/纽扣电池Lithium Li 锂	Car spark plugs: Platinum Pt汽车火花塞：铂	Electric copper wire: Copper Cu 电线：铜	Iodine solution: Iodine I碘溶液：碘
Water bottle H_2O: Hydrogen H 桶装水：氢	Old Cooking Pan: Aluminum Al旧煎锅：铝	Black Pencil Lead: Graphite C 黑铅笔：石墨，碳	Sulfur for agriculture: Sulfur S 农用硫
Can of soft drink: Aluminum Al 易拉罐 铝	Wrist watch TitaniumTi 腕表 钛	Medal: Silver Ag 奖牌 银	Pipe: Lead Pb 水管 铅
Zinc pencil sharpener: 铅笔刀 锌 Zinc Zn	Rusty Old Nail: Iron Fe 生锈旧铁钉铁	Thermometer: Gallium Ga 温度计：镓	Matchbox: 火柴盒 Phosphorus P 磷

蓝色代表宇宙大爆炸最初几分钟形成的元素

黄色代表恒星内部形成的元素

红色代表超新星爆发形成的元素

Activity 4: Children of the stars
活动4:恒星的孩子

Composition of the human body:

Abundant elements: oxygen, carbon, hydrogen, calcium, phosphorus, potassium, sulfur, sodium, chlorine, iron and magnesium.

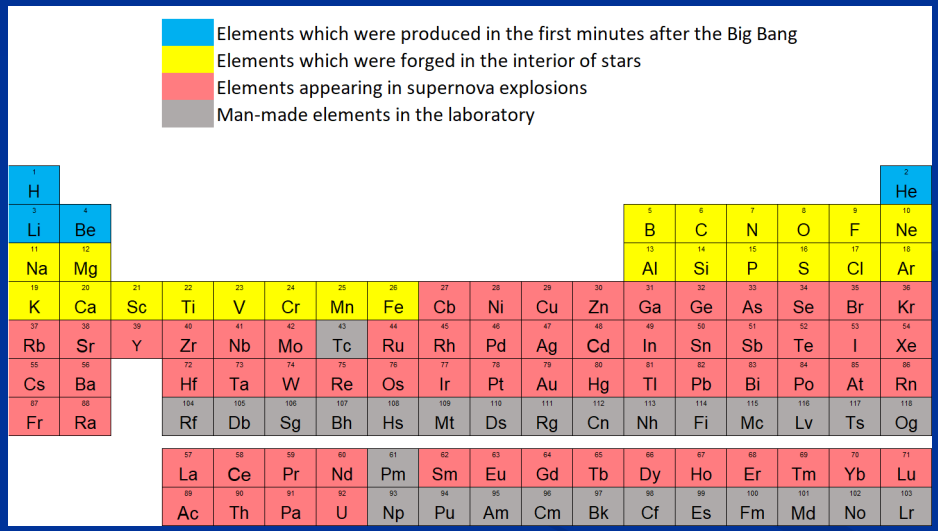
人体组成：丰富的元素：氧、碳、氢、钙、磷、钾、硫、钠、氯、铁和镁

Trace elements: fluorine, zinc, copper, silicon, vanadium, tin, manganese, iodine, nickel, molybdenum, chromium and cobalt

微量元素：氟、锌、铜、硅、钒、锡、锰、碘、镍、钼、铬、钴

Essential elements: lithium, cadmium, arsenic and tin.

必要元素：锂、镉、砷、、锡



All abundant elements (except H) have been produced within the stars.

所有的丰富元素（除了氢）都是在恒星内部产生的

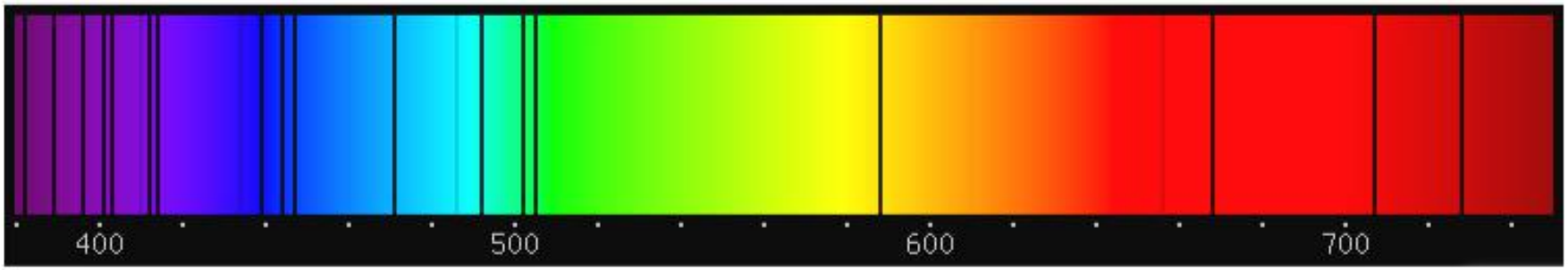
We are children of the stars !!!!我们都是恒星的孩子！

The Sun is not first generation
太阳不是第一代恒星

The first generation stars lived fast, died young and have not survived to this day. Only with Hydrogen, Helium and perhaps Lithium lines are visible.

第一代恒星生命短暂，年轻时即告死亡，没有存续至今。

光谱中只能看到氢、氦也许还有锂的谱线。



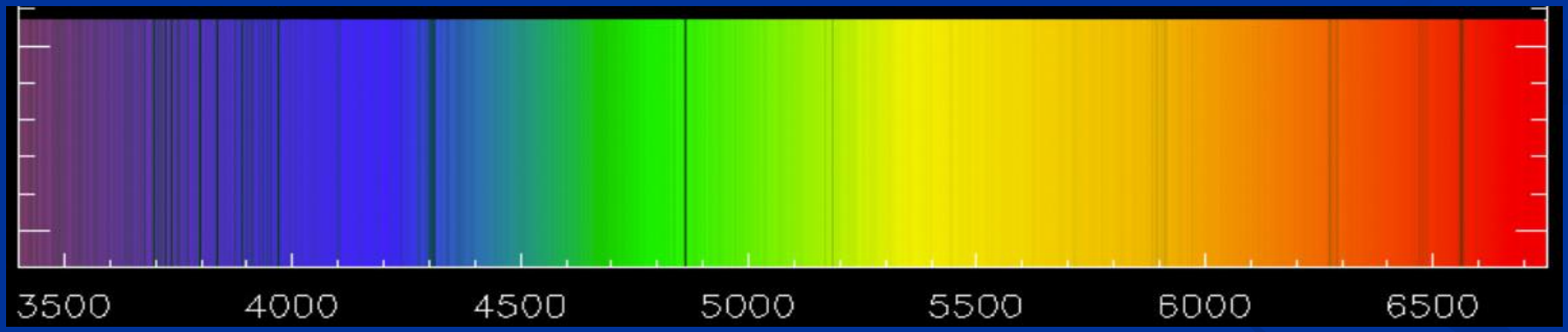
First Generation Spectrum (Artist's impression).

第一代恒星光谱（艺术家的想象图）

The Sun is not first generation
太阳不是第一代恒星

The stars with more elaborate elements means that their initial cloud started from the remains of a supernova explosion.

恒星如果拥有更丰富元素则意味着其诞生之处的原始星云来自超**新星爆**发遗迹。



Second Generation Spectrum.

SMSS J031300.36-670839.3 with Hydrogen and Carbon lines

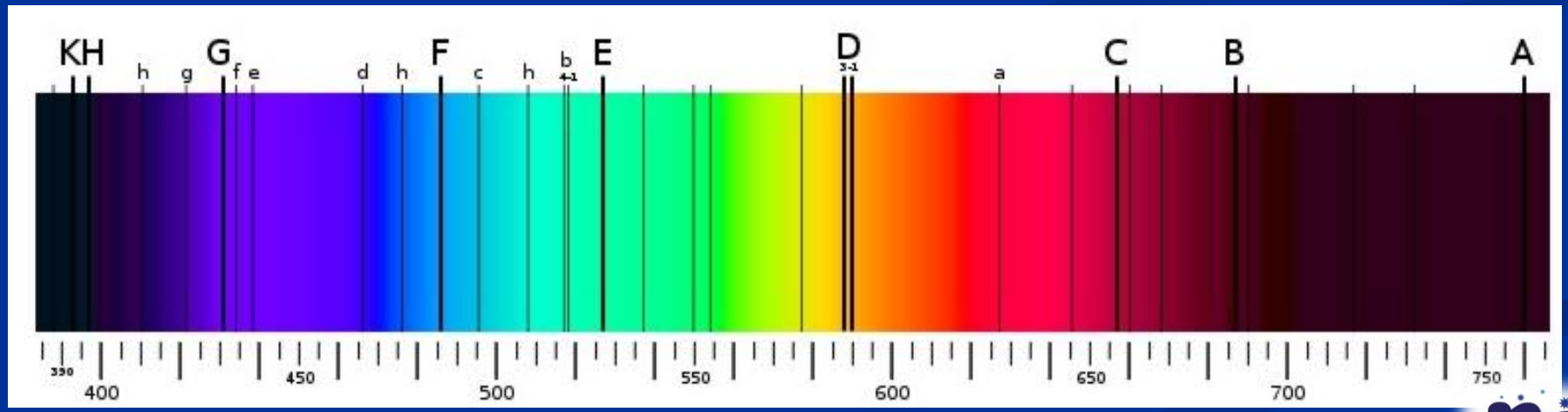
第二代恒星光谱

有氢线和碳线

The Sun is not first generation
太阳不是第一代恒星

In the solar system many elements that are arise after a supernova explosion are detected. Therefore the Sun was possibly formed from an initial cloud that corresponded to the remains of at least two supernova explosions, that is, it is a third-generation star.

在太阳系内探测到很多元素，它们都是在一次超新星爆发后产生的。因此，太阳很可能诞生于至少经历过两次超新星爆发遗迹的原始星云，也就是说，太阳是第三代恒星。



Spectrum of the Sun. With various spectral lines

太阳光谱。有多种元素的谱线。

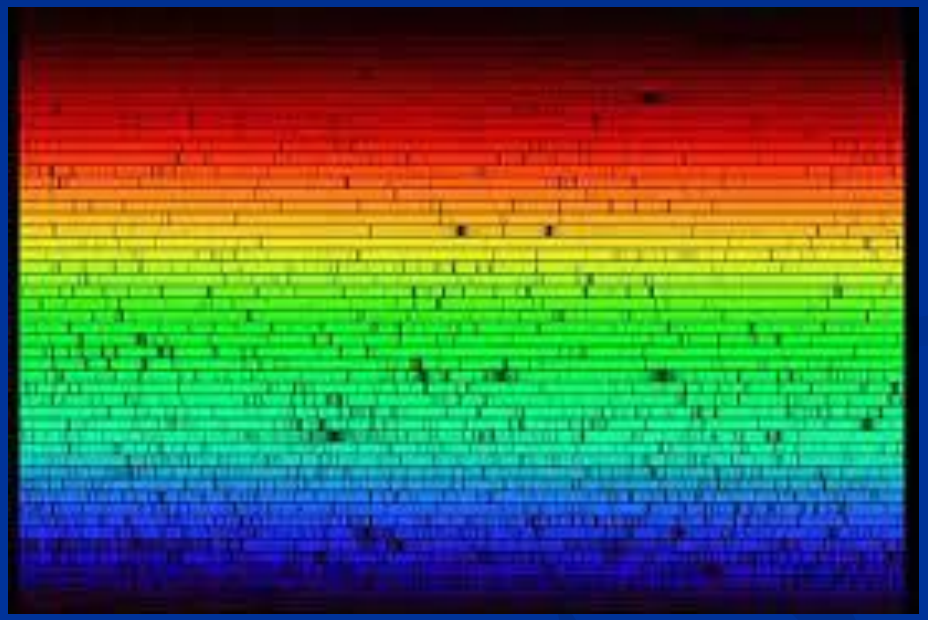
Activity 5: Fraunhofer lines of the Sun
活动5：太阳的弗劳恩霍夫线

The Sun's spectrum is continuous, with dark lines called Fraunhofer lines, which correspond to the chemical elements contained in its atmosphere.

They can be seen with the naked eye in the reflection of sunlight on a DVD. Many Fe lines are observed, the Mg triplet (in green), the Na doublet (in yellow)

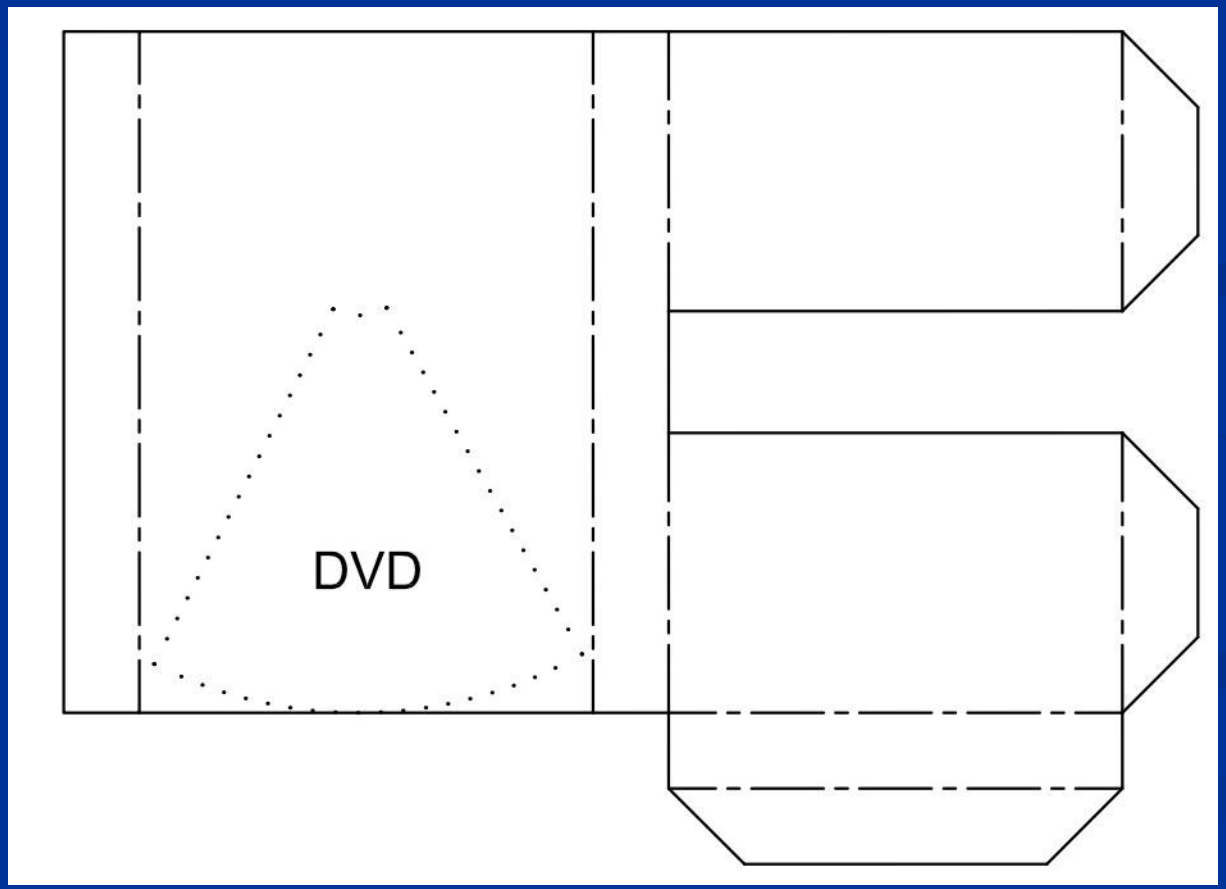
太阳的光谱是连续的，有被称为弗劳恩霍夫线的暗线，对应于其大气中包含的化学元素。

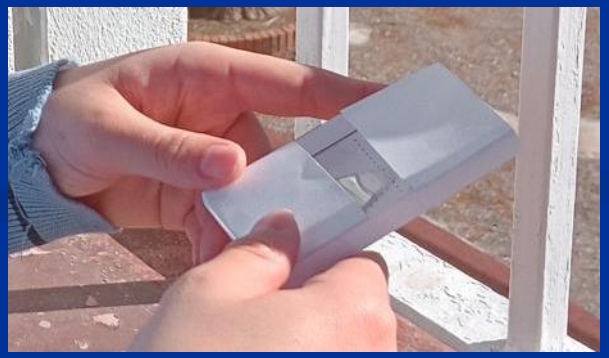
它们可以用肉眼在DVD上的阳光反射中看到。可以观察到许多铁线、镁三线（绿色）、钠双线（黄色）。

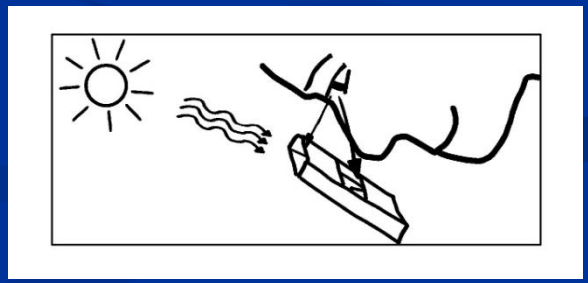


Activity 5: Fraunhofer lines of the Sun
活动5：太阳的弗劳恩霍夫线

Cut out the template, glue 1/8 of the DVD and assemble the box with the DVD inside, folding along the dotted lines. 剪下模板，粘上 DVD 的 1/8，然后将装有 DVD 的盒子组装起来，沿虚线折叠。







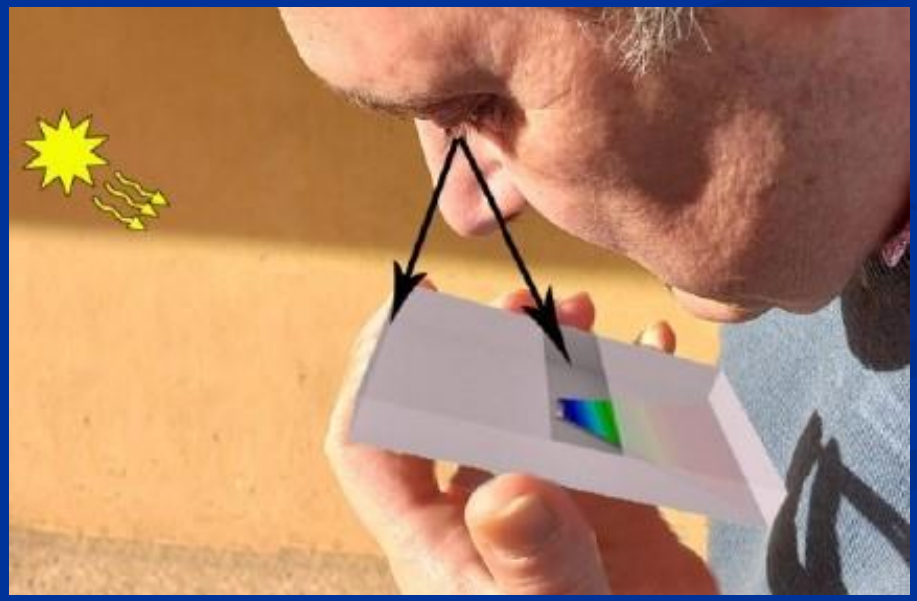
Activity 5: Fraunhofer lines of the Sun
活动5：太阳的弗劳恩霍夫线

Go outside on a sunny day and face the Sun.

Place the box in front of your face, with the top edge at eye level, as seen in the photo. Looking at the DVD inside, move slowly until you see the bright, multicolored radial reflection of the Sun on the DVD.

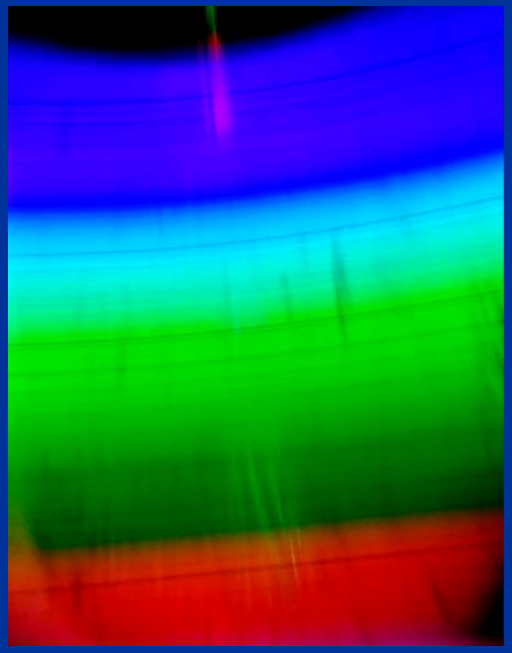
在阳光明媚的日子出去面对太阳。

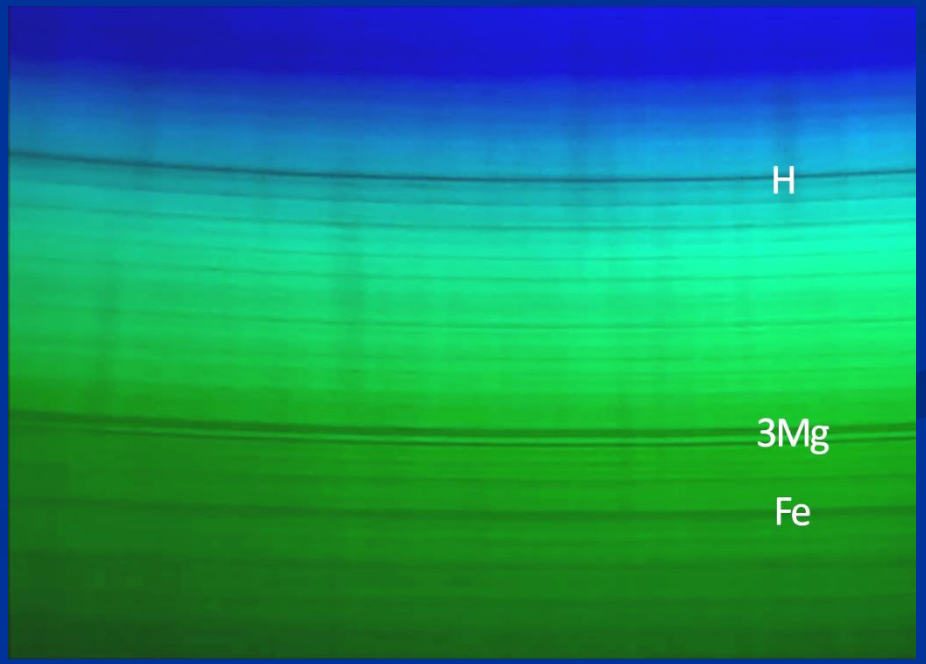
将盒子放在您的面前，顶部边缘与眼睛齐平，如图所示。看着里面的 DVD，慢慢移动，直到您在 DVD 上看到太阳明亮的、五彩的径向反射。



Activity 5: Fraunhofer lines of the Sun
活动5：太阳的弗劳恩霍夫线

Bring your face closer to the box, always looking at the reflection, which will appear wider. When your eye is almost touching the window, you will see thin, sharp black lines in the color area. They are the spectral lines of the chemical elements that are in the Sun.
将你的脸靠近盒子，始终看着反射，它会显得更宽。 当您的眼睛几乎接触到窗户时，您会在颜色区域看到细而尖锐的黑色线条。 它们是太阳中化学元素的谱线。





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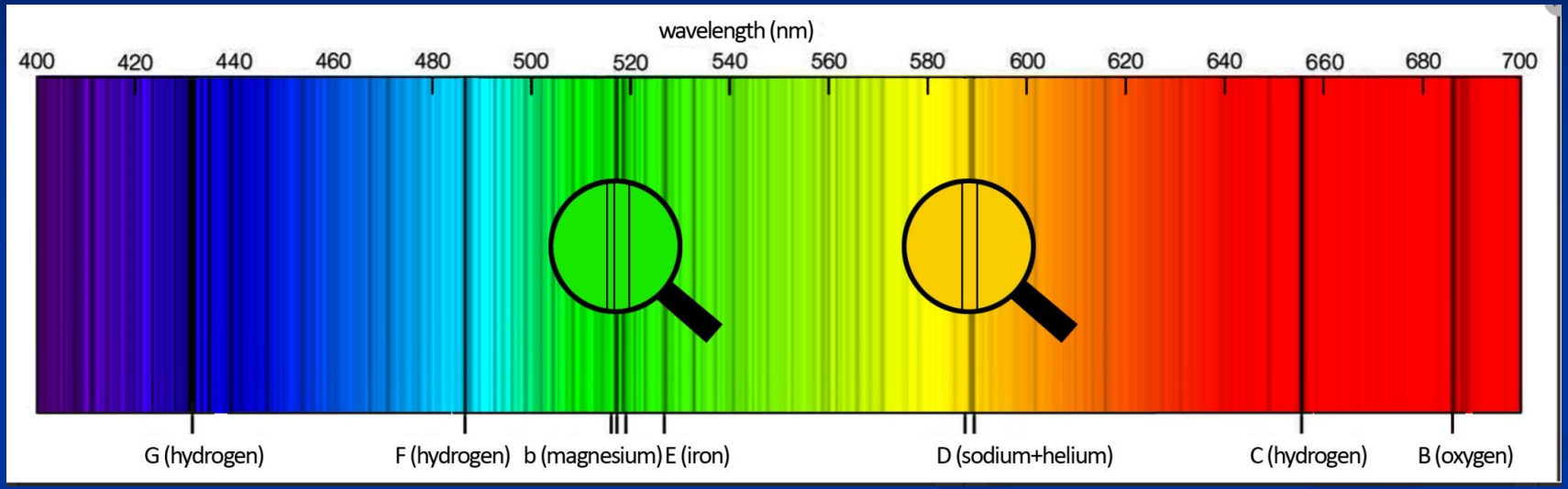


Many lines are seen, some more intense than others. The main one seen in the blue comes from Hydrogen, in the green you can see three very close stripes very well, which is the triplet of Magnesium, and another separate one that comes from Iron. In the yellow part you can see a double stripe, which is from Helium and Sodium. In the red part you can see an intense, Hydrogen.

可以看到许多线条，其中一些线条比其他线条更强烈。 蓝色中看到的主要条纹来自氢，在绿色中你可以很好地看到三个非常接近的条纹，这是镁的三重态，另一个单独的条纹来自铁。 在黄色部分你可以看到双条纹，它来自氦和钠。 在红色部分，您可以看到强烈的氢。

Zone of Habitability
宜居带

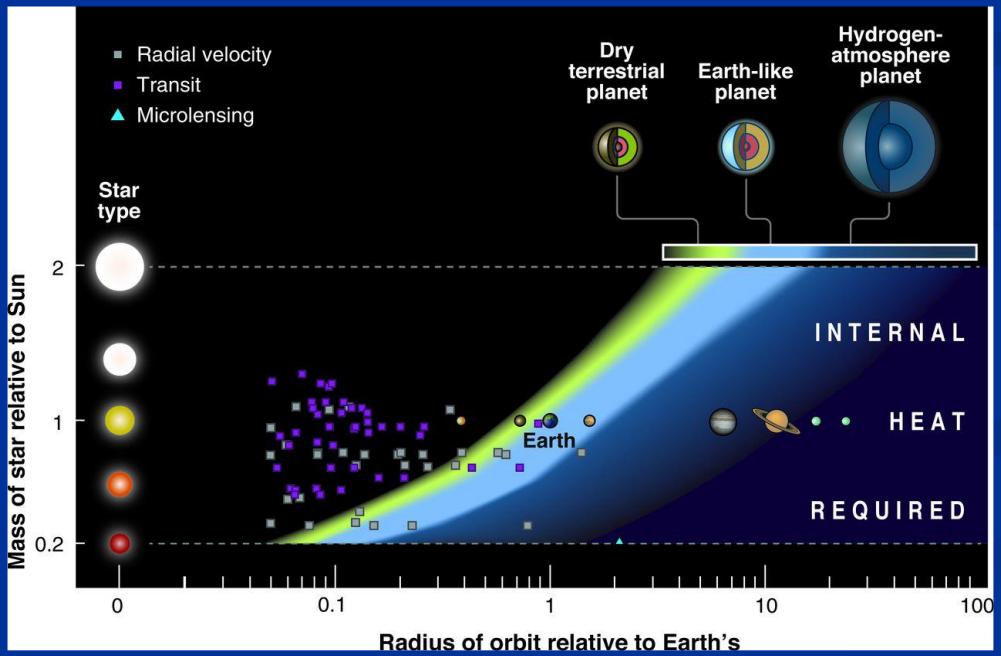
Zone of habitability is the region around a star in which the flow of radiation onto the surface of a rocky planet would allow the presence of liquid water.
carbon-based life is assumed the presence of liquid water)
宜居带是恒星周围的特殊区域，该处获得的辐射能量能够允许岩质行星表面能够存在液态水。

It usually occurs in bodies of mass between **0.5 and 10 Me** and an atmospheric pressure greater than 6.1 mbar, corresponding to the triple point of water at a temperature of 273.16 K (when water coexists in the form of ice, liquid and steam).
通常行星的质量介于0.5**个到**10**个地球**质量之间，大气压强大于6.1mbar，对应的水的三相点为273.16K（即水以冰、液态水和蒸气的混合状态存在）

Zone of Habitability
宜居带

The zone of habitability **depends on the mass of the star**. If the mass is greater then its temperature and brightness increase and consequently the zone of habitability is increasingly distant.

宜居带与恒星质量有关。如果恒星质量较大，那么它的温度和光度都大，因此宜居带距离母恒星的距离就更远。

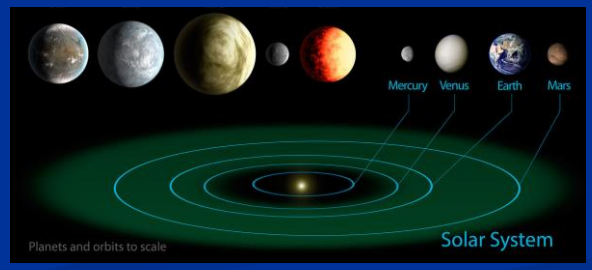


Other conditions for Habitability
宜居的其他条件

The **orbital distance** of the planet that places it in the zone of habitable is a necessary condition, but not enough for a planet to embrace life.

Example: Venus and Mars.

行星的轨道距离使其位于宜居带内是必要的条件，但还不足以让一颗行星孕育生命。例如金星和火星。



The **mass of the planet must be large enough** so that its gravity is able to retain the atmosphere.

It is the main reason why Mars is not habitable at present, since it lost most of its atmosphere and all surface water, which it had in its first billion years.

行星的质量必须足够大，其引力能够束缚大气。这也是今天的火星**不再宜居的主要原因，因为**火星丧失了绝大部分空气和全部的表面**水，而在其形成的最初几十**亿年里，火星是拥有大气和表面水的。

Activity 6: Liquid water on Mars?

活动6：火星上的液态水？

On Mars the atmospheric pressure is weak (0.7% of the Earth's one). Despite this low pressure, the water form clouds at the planet's poles. But why Mars has no liquid water on its surface?

火星上的大气压力十分微弱（只有地球的0.7%）虽然大气压力如此低，但在火星的两极，水仍以云的形式存在。可是为什么在火星表面没有液态水存在呢？

We put inside the syringe hot water close to boiling

我们把接近沸腾的热水注入注射器

If we pull the plunger the inside pressure lowers and the water begins to boil, becomes steam and gradually disappears. To simulate the Martian pressure we should have a very long syringe and to pull the plunger up to 9 m.

如果向外拉动活塞，内部压力降低，水就会开始沸腾形成水蒸气并逐渐消失。为了模拟火星大气压力我们需要一支非常长的注射器，把活塞拉至9米长。

Activity 7: Greenhouse effect
活动7：温室效应

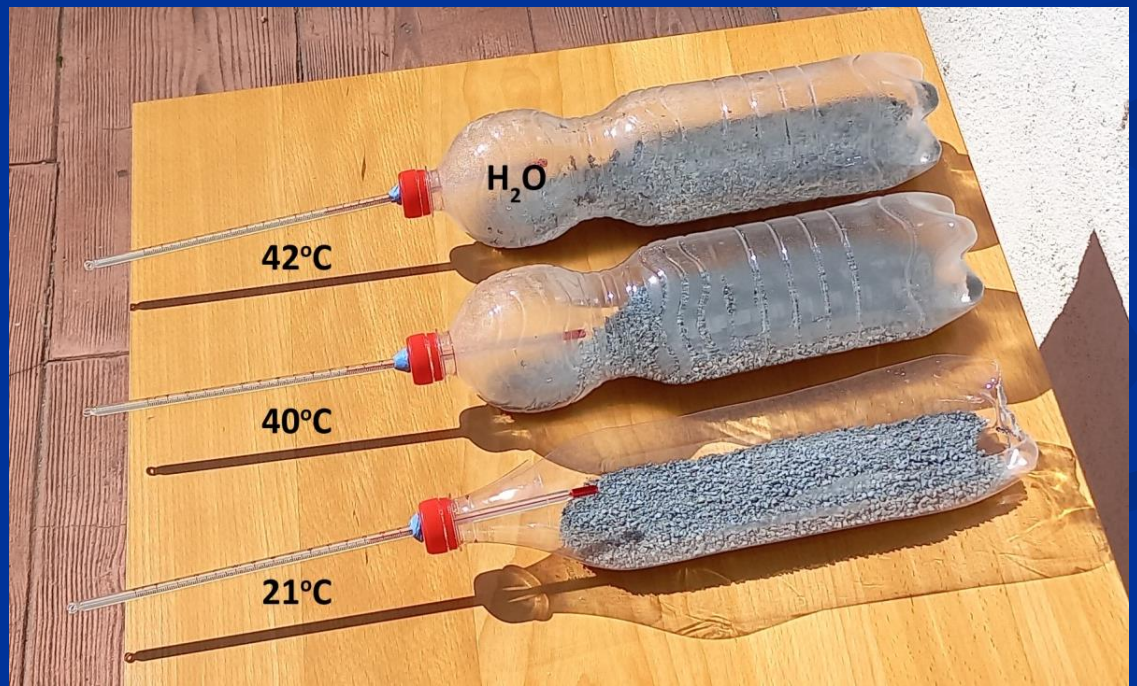
We put dark earth inside 2 empty plastic bottles, and in a third cut lengthwise in half. We inserted a thermometer into the stopper of each bottle. The cut bottle simulates the planet without clouds, the first whole bottle simulates the planet with clouds, and in the last one, we put a few drops of water inside it, to simulate an atmosphere with water vapor.

我们在两个空塑料瓶中放入黑土，在第三个纵向切成两半的瓶子中放入黑土。我们在每个瓶子的塞子上都插入了一个温度计。切开的瓶子模拟没有云的星球，第一个完整的瓶子模拟有云的星球，在最后一个瓶子里，我们放了几滴水，以模拟有水蒸气的大气。

Activity 7: Greenhouse effect
活动7：温室效应

We put the bottles in the sun and measure the temperature inside every 5 minutes. We write down the measurements to determine how the greenhouse effect influences.

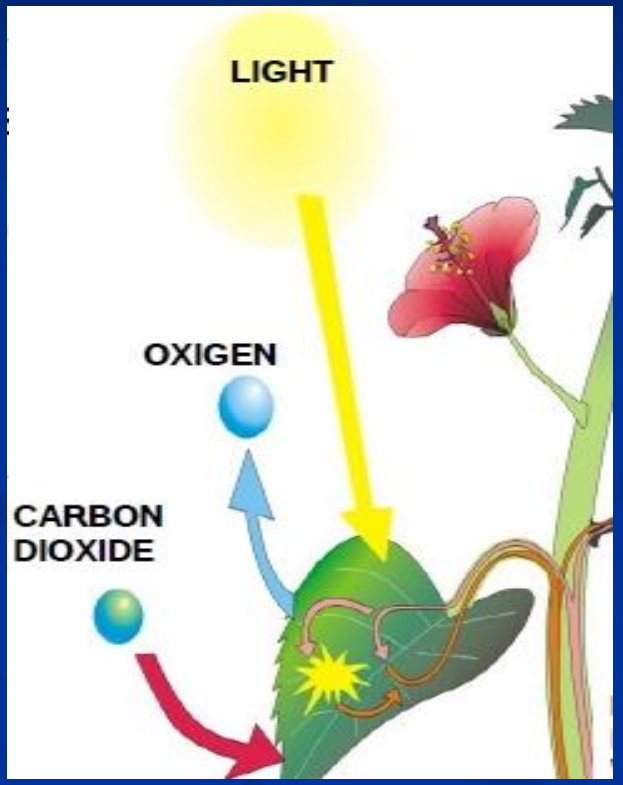
我们把瓶子放在太阳下，每5分钟测量一次里面的温度。
我们写下测量结果，以确定温室效应是如何影响的。



Photosynthesis: Oxygen production
光合作用：产生氧气

Photosynthesis is the process by which plants and some bacteria use sunlight **to produce glucose, carbohydrates and oxygen** from carbon dioxide and water.

光合作用是植物和一些细菌利用太阳光从二氧化碳和水中产生葡萄糖、碳水化合物和氧气的过程。

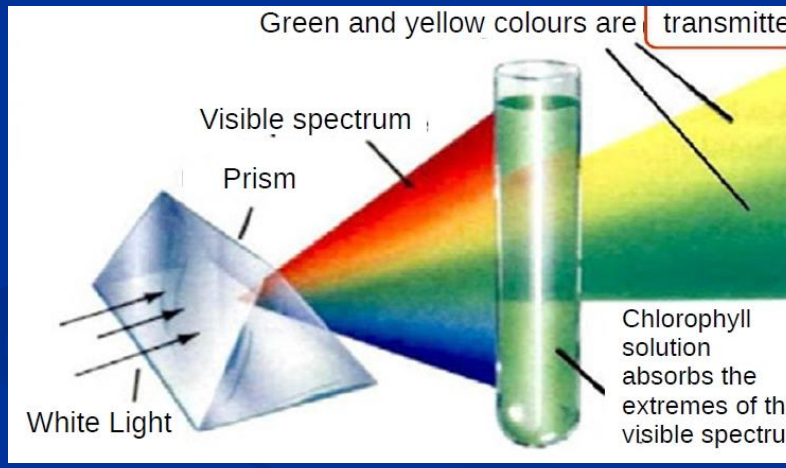


Molecules called photosynthetic pigments convert light energy into chemical energy.

分子层面称为光合作用的色素将光能转化为化学能。

Photosynthesis: why the leaves are green?
光合作用：为什么叶子是绿色的？

The light that is absorbed can be used by the plant in different chemical reactions, while the reflected wavelengths of the light determine the color of the pigment that will appear to the eye.
植物吸收利用光来完成不同的化学反应，而反射的光波长决定了人看到的色素颜色。



One of the groups of photosynthetic pigments are chlorophylls that typically have two types of absorption in the visible spectrum, one in the blue region (400-500 nm), and another in the red zone (600-700 nm).
其中一组光合作用色素是叶绿素，在可见光谱波段有两种吸收线，一种是蓝色（400-500nm），另一种是红色（600-700nm）

However they reflect the middle part of the spectrum, which corresponds to the green color (500-600 nm).
然而它们反射的是二者的中间波长，对应的是绿色（500-600nm）

Photosynthesis: Oxygen production
光合作用：产生氧气

The pigments are illuminated and transfer their electrons that are excited by the light. Water is a donor of electrons that jump from one molecule to another and **the end result is the production of oxygen when the water molecules break down.** This is the luminous phase of photosynthesis.

色素被照亮，将被光激发的电子转移出去。水是电子的贡献者，电子从一个分子跳跃到另一个分子，其最终结**果是当水分子被分解，就**产生了氧气。这是光合作用光**明的一面。**

In the dark phase carbohydrates or sugars are produced. Light is not necessary for that part.

而光合作用暗黑的一面则产生碳水化合物和糖。这部分**不需要太阳光。**

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

Use two transparent glass jars and place blue and red cellophane paper at the end of the jar.

找两个透明的玻璃罐，分别把蓝色和红色的玻璃纸放在罐底

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

With the help of a punch, cut discs of uniform sheets (spinach or chard avoiding veins). Put 10 discs in each jar.
用打孔器在菜叶上均匀打孔（菠菜或者甜菜叶，避开叶脉部分）。每个玻璃罐里放10片菜叶。

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

Prepare a solution of sodium bicarbonate of 2 g / 1 litre of water. Place 20 ml of it in each bottle.

Impregnate the leaf discs with the bicarbonate solution. Place the discs in a 10 ml disposable syringe and draw in the bicarbonate solution until the discs are suspended.

准备用1升水和2g碳酸氢钠配制的溶液。每瓶里注入20ml的溶液。用碳酸氢钠溶液浸泡叶片。将叶片放入10ml的一次性注射

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

Remove as much as possible the air that has entered, leaving only discs suspended in bicarbonate.

Seal the end of the syringe with a finger and suck tightly, trying to make the vacuum, so in the internal spaces of the plant tissue air is replaced by bicarbonate solution that will be an available carbon source, close to the photosynthetic structures of the leaf.

尽量排空筒内的空气，只保留悬浮在碳酸氢钠溶液中的叶片

用手指紧紧地封住注射器底部，尽量保持真空，使得植物组织的内部空间充满碳酸氢钠溶液，提供碳的来源，与叶片的光合作用结构相近。

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

Place the leaf discs in each jar. Cover each of the jars with red and blue cellophane paper.
每个玻璃罐里都放入叶片。分别用红色和蓝色的玻璃纸盖住玻璃罐。

Place an individual light bulb (not less than 70W) over each jar (with the paper covering it). Both lights at the same distance.
每个玻璃罐（用玻璃纸盖住）上方相同距离处都放置一个灯泡（不超过70W）。
Better LED because others emit energy as heat.
最好是LED灯泡，因为其他类型的灯泡会以热能的形式辐射能量。

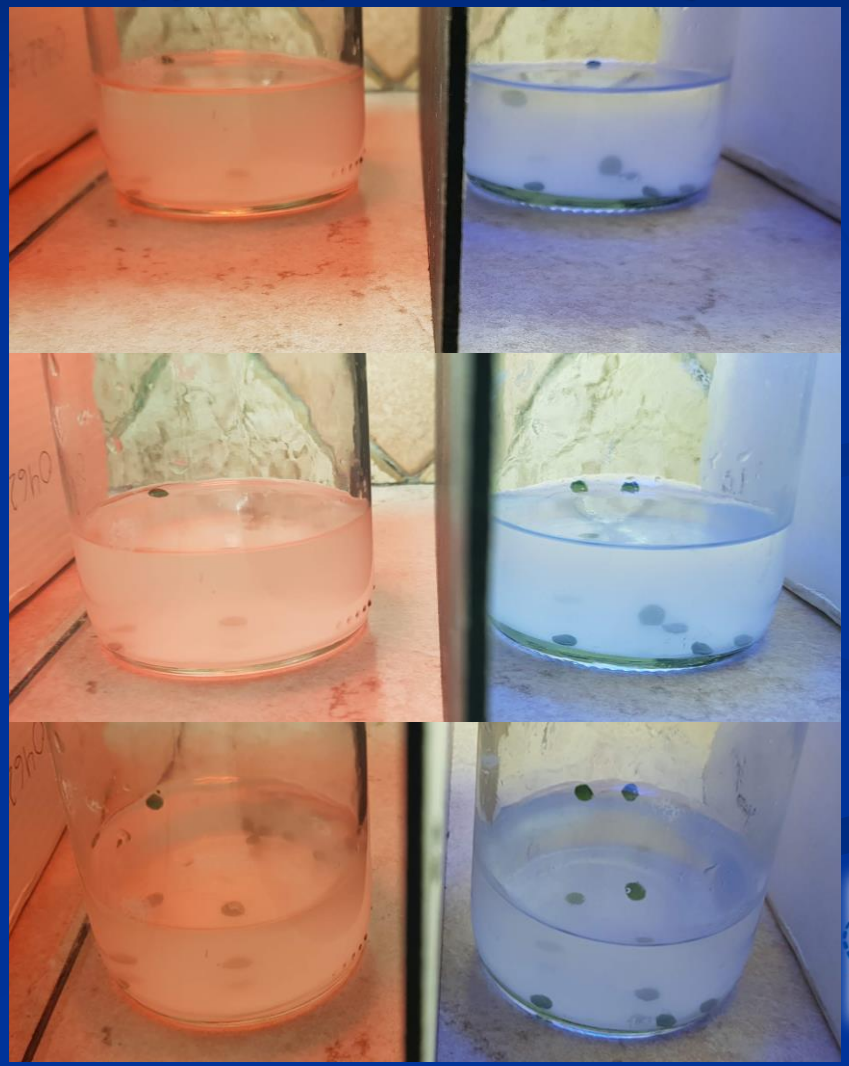
Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

When turning on the light and start recording the time for the discs to float.
当点亮灯泡时，开始记录叶片漂浮的时间

It is an indirect measure of the rate of photosynthesis.
这是个间接测量光合作用速度的办法。

Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

Wait about 5 minutes and the discs begin to rise (depending on the powers of the lights and their distance).
等待大约5分钟，叶片开始上升（与光的强度和距离有关）



Activity 8: Oxygen production by photosynthesis
活动8：光合作用产生氧气

The discs begin to float as they release oxygen in the form of bubbles, which help in floating.
随着氧气以气泡的形式不断产生，叶片开始上浮

Times are different, depending on the color of light: it is faster for blue light (it is the high energy component of electromagnetic radiation, it is the most efficient in the process)
光的颜色不同，叶片上浮的时间也不同：蓝光更快一些（蓝光是电磁辐射中能量较高的部分，是光合作用过程中最有效的）

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Yeasts (fungi) transform sugar (glucose) into ethyl alcohol or ethanol and carbon dioxide.

酵母（真菌）将糖（葡萄糖）转化为乙醇或酒精以及二氧化碳。

Fermentation is a low energy efficiency process, while breathing is much more cost-effective and more recent from an evolutionary point of view.

发酵是一种低能效过程，从演化的角度看，呼吸则是更高效更近代的过程。

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

If the presence of carbon dioxide is observed we will know that there has been fermentation and therefore the possibility of life has been tested.
如果观察到二氧化碳的存在，我们就知道曾有发酵过程，因此就有可能探测到生命。

In all cases of our experiment we start from a crop in which water is present.
我们全部的试验都从一粒含水的农作物开始。

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

We will use:
我们将用到：

1 tablespoon of yeast (to make bread). It is a live microorganism easy to get,

1 glass of warm water (just over half a glass between 22º and 27º C),

1 tablespoon of sugar that microorganisms can consume.

一勺酵母（用来做面包的），它是容易获得的活体微生物

一杯温水（22度到27度，半杯）

一勺糖，供微生物消耗

The same procedure in the control experiment and the other experiments developed under extreme conditions.

在控制实验和极端条件实验中采用完全相同的过程

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Control experiment:
控制实验：

In a glass, dissolve the yeast and the sugar in warm water. The mixture obtained is quickly placed in an airtight plastic bag, removing all the air inside and closing it.

在玻璃杯中用温水溶解酵母和糖。将混合液体迅速装入密封塑料袋中，排出全部空气并密封。

It is important not to leave any air inside the bag.

特别重要的是必须将塑料袋中的空气全部排出。

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

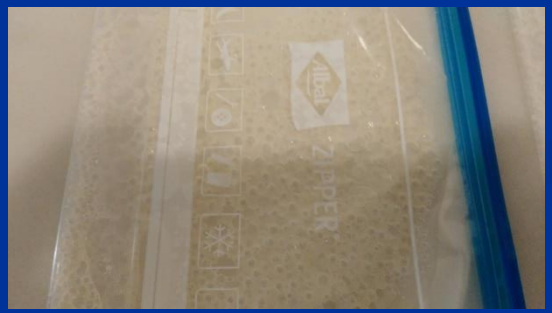
Control experiment控制实验

After 15-20 minutes you see the carbon dioxide bubbles in the swollen bag

The presence of carbon dioxide bubbles shows that microorganisms are alive.

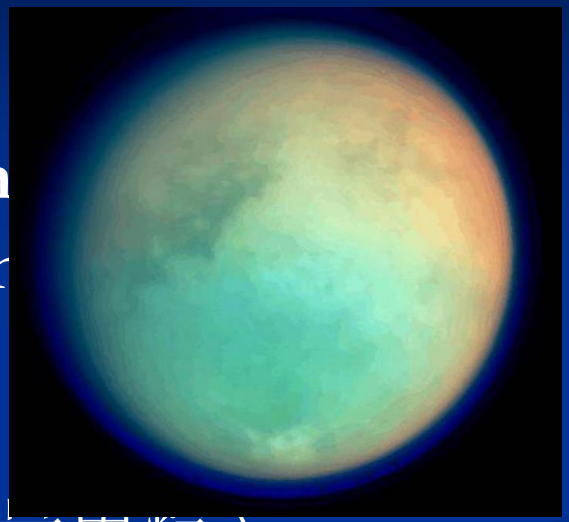
15到20分钟后你能够看到膨胀的塑料袋中出现二氧化碳气泡。

这些二氧化碳气泡的出现说明微生物是活着的。



Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Procedure on an "alkaline planet"
(e.g. Neptune or Titan both with ammon
Repeat the experiment with sodium bicarbon
ammonia
在一颗"碱性行星"上的实验过程：
（例如海王星或者土卫六，二者都有大量甲烷）
用碳酸氢钠或甲烷重复实验过程
Ph alkaline scales: Ph碱性指标
Sodium Bicarbonate or Baking soda: Ph 8.4
碳酸氢钠或者烘培苏打：ph值8.4
Homemade Ammonia: Ph 11
自制甲烷：ph值11



Titan土卫六, Credit NASA

If there are bubbles there is life
如果有气泡出现，就说明有生命存在

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Procedure on a "saline planet"
eg Mars or Ganymede).
在一颗"含盐行星"上的实验过程
（例如火星或木卫三）

Repeat the experiment dissolving sodium chloride (common salt) in the water.

用溶解的氯化钠（普通食盐）重复实验

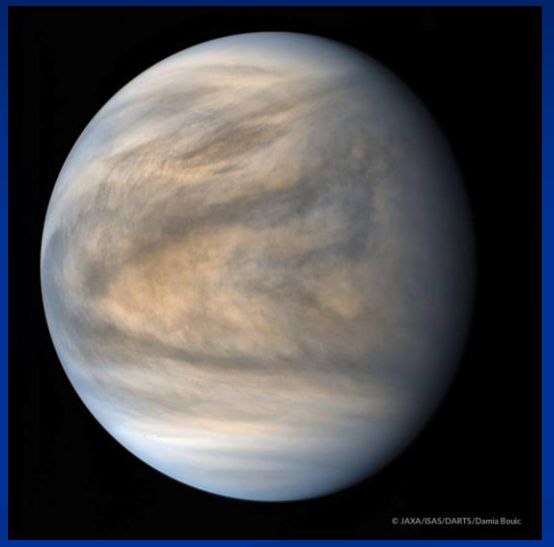
Ganimede木卫三, Credit NASA

If there are bubbles there is life
如果有气泡出现，说明有生命存在

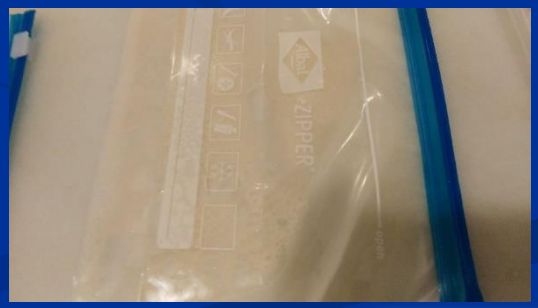
Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Procedure on an "acid planet" (eg Venus that has sulfuric rainfall):
在一颗"酸性行星"上的实验过程（例如有酸雨的金星）

Repeat dissolving vinegar or lemon juice in the cultivation water.
用醋或柠檬汁的培养液重复实验过程
Ph Acid scales: Ph酸性指标
Vinegar: Ph 2.9 醋： Ph值2.9
Lemon juice: Ph 2.3 柠檬汁： Ph值2.3



Venus金星, Credit NASA



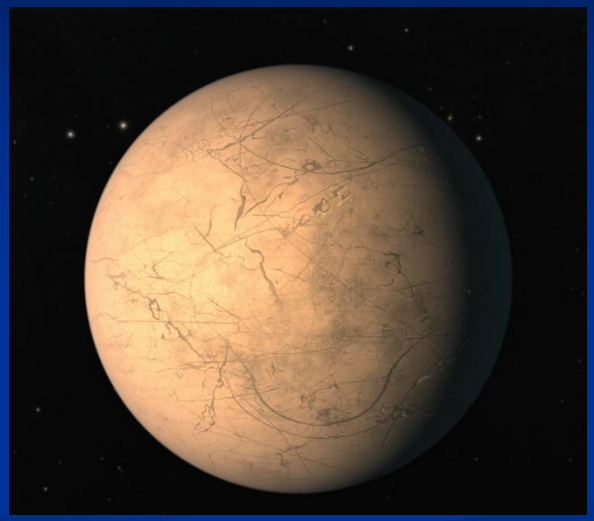
If there are bubbles there is life
如果有气泡出现，说明有生命存在

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Procedure on an "icy planet" (eg Europa or Trapist-1 h)
在一颗"冰冻行星"上的实验过程（例如木卫二或Trapist-1h）

Place the bag in a container full of ice or use a freezer

把酵母糖溶液装入冰袋或者用电冰箱冰冻



Trappist 1h Artist's impression
艺术家想象图

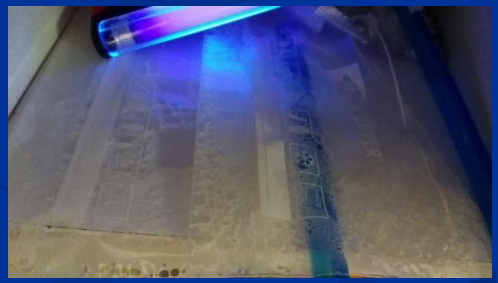
If there are no bubbles there is no life
如果没有气泡，就没有生命

Activity 9: Life in extreme conditions
活动9：极端条件下的生命

Procedure on a “planet with UV” (eg Mars)
在一颗“有紫外辐射的行星”上实验（例如火星）

Marte火星, Credit iStock

Perform experiment but with the bag under UV light
其他实验材料和条件都相同，只是将密封袋放在紫外光灯下照射



If there are no bubbles there is no life
如果没有气泡，就没有生命

Activity 10: Looking for a second Earth
活动10：寻找另一个地球

Earth is the only known planet with life. Let's look for an exoplanet with similar conditions. But what parameters are important?

地球是已知唯一拥有生命的行星。让我们来寻找一颗有相同条件的系外行星。但哪些参数是重要的呢？

- Radius and Mass 半径和质量
- Habitable zone 宜居带
- Host star 母恒星

Radius and Mass (exoplanet)
半径和质量（系外行星）

The radius and mass of the planet must be considered to assess an adequate density.
要确定行星的密度，必须知道其半径和质量。

Using the Kepler Mission criteria: 采用开普勒任务的标准

- Earth-sized planets must have a radius of less than 2 Earth radii. R<2Re
  地球大小的行星其半径必须小于两倍地球半径 R<2Re
- 10 Earth masses are considered an upper limit for super-terrestrial planets M<10Me
  超级类地行星的质量上限为10倍地球质量

Habitability Zone

The main sequence stars have a direct correlation between brightness and temperature. The hotter the surface temperature is, the brighter the star is and the further away is the habitable zone.

主序恒星的光度和温度之间有直接的相关关系。表面温度越高的恒星，光度也越大，其宜居带距离母恒星也越远。

Spectral Type 光谱型	Temperature K 温度（K）	Habitability Zone AU 宜居带距离（AU）
O6V	41 000	450-900
B5V	15 400	20-40
A5V	8 200	2.6-5.2
F5V	6 400	1.3-2.5
G5V	5 800	0.7-1.4
K5V	4 400	0.3-0.5
M5V	3 200	0.07-0.15

Host Star Mass
母恒星质量

The evolution and life of a star depends on its mass. The energy that a star can obtain from hydrogen fusion is proportional to its mass. And **the main sequence time is obtained by dividing this energy by the luminosity of the star.** Using the Sun as a reference, the life of a star in the main sequence is

恒星的一生和演化过程依赖于其质量。恒星能够从氢聚变反应获得的能量与其质量成比例。该能量除以恒星的光度，就得到恒星处于主序阶段的时间。以太阳为参考，一颗恒星处于主序阶段的时间为：

$$t*/ts = (M*/Ms)/(L*/Ls)$$

Host Star Mass
母恒星质量

For the main sequence, the luminosity is proportional to the mass according to $L \alpha M^{3.5}$

对于主序星，光度与质量的比例关系为

$t*/ts= (M*/Ms)/(M*^{3.5}/Ms^{3.5})=(M*/Ms)^{-2.5}$

$$t*/ts=(Ms/M*)^{2.5}$$

As **the life of the Sun tS=10^{10} years**, the lifespan of a star is:

太阳的寿命为10^{10}年，则该恒星的寿命为：

$$t*\sim 10^{10}\cdot(Ms/M*)^{2.5} \text{ years}$$

Host Star Mass
母恒星质量

Let's calculate the upper limit for the mass of the star so that **the residence time in the main sequence is at least 3×10^9 years to give time for life to evolve.**

我们来计算一下恒星的质量上限，以保证恒星在主序阶段至少还有3×10^9 年的时间允许生命演化

$$M^* = (10^{-10} \times t)^{-0.4} M_s$$

$$M^* = (10^{-10} \times 3\,000\,000\,000)^{-0.4} M_s$$

$$\mathbf{M^* =< 1.6\ M_s}$$

Looking for a second Earth 寻找另一个地球

Exoplanet Name 系外行星	Mass质量（地球质量）in masses of Earth	Radius半径（地球半径）in Earth radii	Distance to star与母恒星的距离（AU）in AU	Star Mass母恒星质量（太阳质量）in masses of the Sun	Star Spectral Type/surface temperature光谱型/表面温度
Beta Pic b	4100	18.5	11.8	1.73	A6V
HD 209458 b	219.00	15.10	0.05	1.10	G0V
HR8799 b	2226	14.20	68.0	1.56	A5V
Kepler-452 b	unknown未知	1.59	1.05	1.04	G2V
Kepler-78 b	1.69	1.20	0.01	0.81	G
Luyten b	2.19	unknown未知	0.09	0.29	M3.5V
Tau Cet c	3.11	unknown未知	0.20	0.78	G8.5V
TOI 163 b	387	16.34	0.06	1.43	F
Trappist-1 b	0.86	1.09	0.01	0.08	M8
TW Hya d (yet unconfirmed)	4	unknown未知	24	0.7	K8V
HD 10613 b	12.60	2.39	0.09	1.07	F5V
Kepler-138c	1.97	1.20	0.09	0.57	M1V
Kepler-62f	2.80	1.41	0.72	0.69	K2V
Proxima Centauri b	1.30	1.10	0.05	0.12	M5V
HD 10613 b	12.60	2.39	0.09	1.07	F5V

Looking for a second Earth 寻找另一个地球

Exoplanet Name 系外行星	Mass质量（地球质量）in masses of Earth	Radius半径（地球半径）in Earth radii	Distance to star与母恒星的距离（AU）in AU	Star Mass母恒星质量（太阳质量）in masses of the Sun	Star Spectral Type/surface temperature光谱型/表面温度
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Kepler-452 b	**unknown未知**	**1.59**	**1.05**	**1.04**	**G2V**
Kepler-78 b	1.69	1.20	~~0.01~~	0.81	G
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HD 10613 b	~~12.60~~	~~2.39~~	~~0.09~~	1.07	F5V
Kepler-138c	**1.97**	**1.20**	**0.09**	**0.57**	**M1V**
Kepler-62f	2.80	1.41	~~0.72~~	0.69	K2V
Proxima Centauri b	1.30	1.10	~~0.05~~	0.12	M5V
HD 10613 b	~~12.60~~	~~2.39~~	~~0.09~~	1.07	F5V

Conclusions
结论

- Know the concept of habitability zone.
- Introduce the concepts of astrobiology.
- Show how it is possible to generate oxygen and obtain carbon dioxide.
- How to locate a second Earth.
- 了解宜居带的概念
- 介绍天文生物学概念
- 演示如何吸收二氧化碳产生氧气
- 了解如何寻找另一个地球

Thank you very much
for your attention!
谢谢！