Planets and exoplanets
行星与系外行星

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Goals
目标

- Understand the meaning of the numerical values found in the data tables of the Solar System planets
- 理解太阳系行星数据表中各项数值的含义
- Understand the main characteristics of extra-solar planetary systems
- 理解太阳系外行星系统的主要性质

Solar system太阳系

We look for models that provide information,
not only arts and crafts.
我们从身边寻找一些模型来表现太阳系的信息，并不局限于艺术品。

According to the content

We want models with scientific content and those that display some concrete points

我们希望找到的模型既包含科学的内容，又能够非常具象

Activity 1: Distances from the Sun
活动1:太阳系的距离模型

Mercury 水星	57 900 000 km	⇨	6 cm	0.4 AU
Venus 金星	108 300 000 km	⇨	11 cm	0.7 AU
Earth 地球	149 700 000 km	⇨	15 cm	1.0 AU
Mars 火星	228 100 000 km	⇨	23 cm	1.5 AU
Jupiter 木星	778 700 000 km	⇨	78 cm	5.2 AU
Saturn 土星	1 430 100 000 km	⇨	143 cm	9.6 AU
Uranus 天王星	2 876 500 000 km	⇨	288 cm	19.2 AU
Neptune 海王星	4 506 600 000 km	⇨	450 cm	30.1 AU

Activity 2: Model of Diameters
活动2:直径模型

Sun	太阳	1 392 000 km	→	139.0 cm
Mercury	水星	4 878 km	→	0.5 cm
Venus	金星	12 180 km	→	1.2 cm
Earth	地球	12 756 km	→	1.3 cm
Mars	火星	6 760 km	→	0.7 cm
Jupiter	木星	142 800 km	→	14.3 cm
Saturn	土星	120 000 km	→	12.0 cm
Uranus	天王星	50 000 km	→	5.0 cm
Neptune	海王星	45 000 km	→	4.5 cm

Activity 2: Model of Diameters
活动2: 直径模型

T-shirt with the diameters of the planets to scale
按比例印有行星模型的T恤

Activity 3: Diameters and distances from the Sun

活动3:天文系的直径与距离

Sun	1 392 000 km		⇨	25.0 cm	
Mercury	4 878 km	57 900 000 km	⇨	0.1 cm	10 m
Venus	12 180 km	108 300 000 km	⇨	0.2 cm	19 m
Earth	12 756 km	149 700 000 km	⇨	0.2 cm	27 m
Mars	6 760 km	228 100 000 km	⇨	0.1 cm	41 m
Jupiter	142 800 km	778 700 000 km	⇨	2.5 cm	140 m
Saturn	120 000 km	1 430 100 000 km	⇨	2.0 cm	250 m
Uranus	50 000 km	2 876 500 000 km	⇨	1.0 cm	500 m
Neptune	45 000 km	4 506 600 000 km	⇨	1.0 cm	800 m

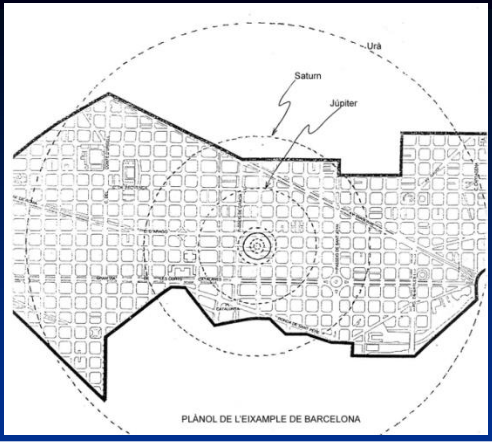
Usually a school yard only reaches out to Mars

通常利用学校的操场只能呈现太阳到火星

Activity 3: Diameters and distances from the Sun

活动3:天文系的直径与距离

Activity 4: Model in the city
活动4:城市中的模型
(Barcelona 巴塞罗那)



Sun	**Washing machine**	*Puerta Instituto*
Mercury	**Caviar egg**	*Puerta Hotel Diplomatic*
Venus	**Pea**	*Pasaje Méndez Vigo*
Earth	**Pea**	*Entre Méndez Vigo y Bruc*
Mars	**Pepper grain**	*Paseo de Gracia*
Jupiter	**Orange**	*Calle Balmes*
Saturn	**Tangerine**	*Pasaje Valeri Serra*
Uranus	**Chestnut**	*Calle Entenza*
Neptune	**Chestnut**	*Estación de Sans*

Model in the city of Metz (France)
法国梅茨的城市模型

Activity 5: Model of times
活动5:时间模型

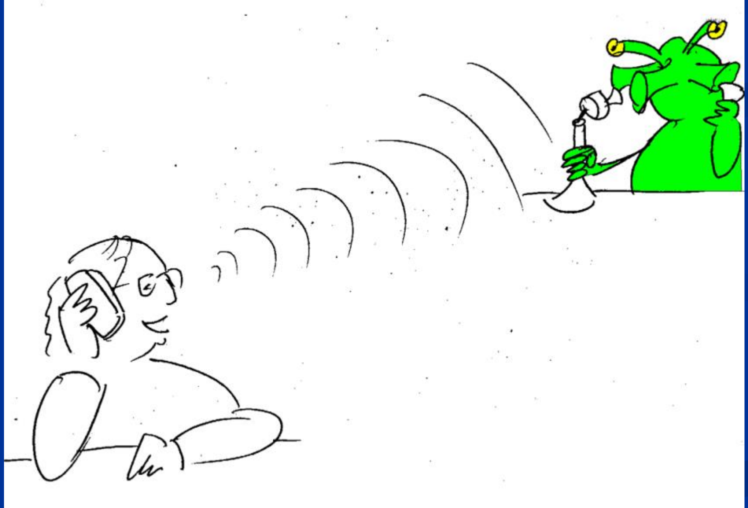
- c = 300 000 km/s

The time it takes light to go from Earth to Moon is:

t = distance EM / c = 384 000 km / 300 000 = 1.3 s

月球到地球的时间计算

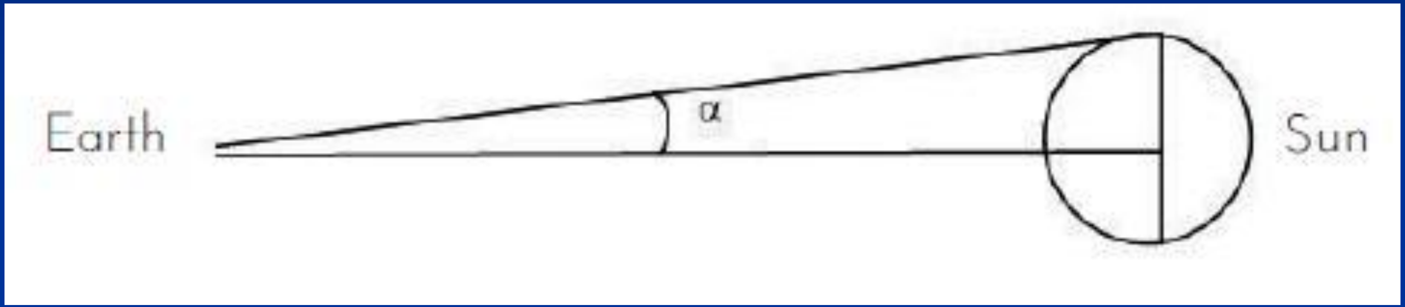
How would a conversation between planets by "video" be?
如果在行星间开"视频"会议会是怎样的情景呢？



Sunlight takes to get to ...
日光到达那里需要 ...

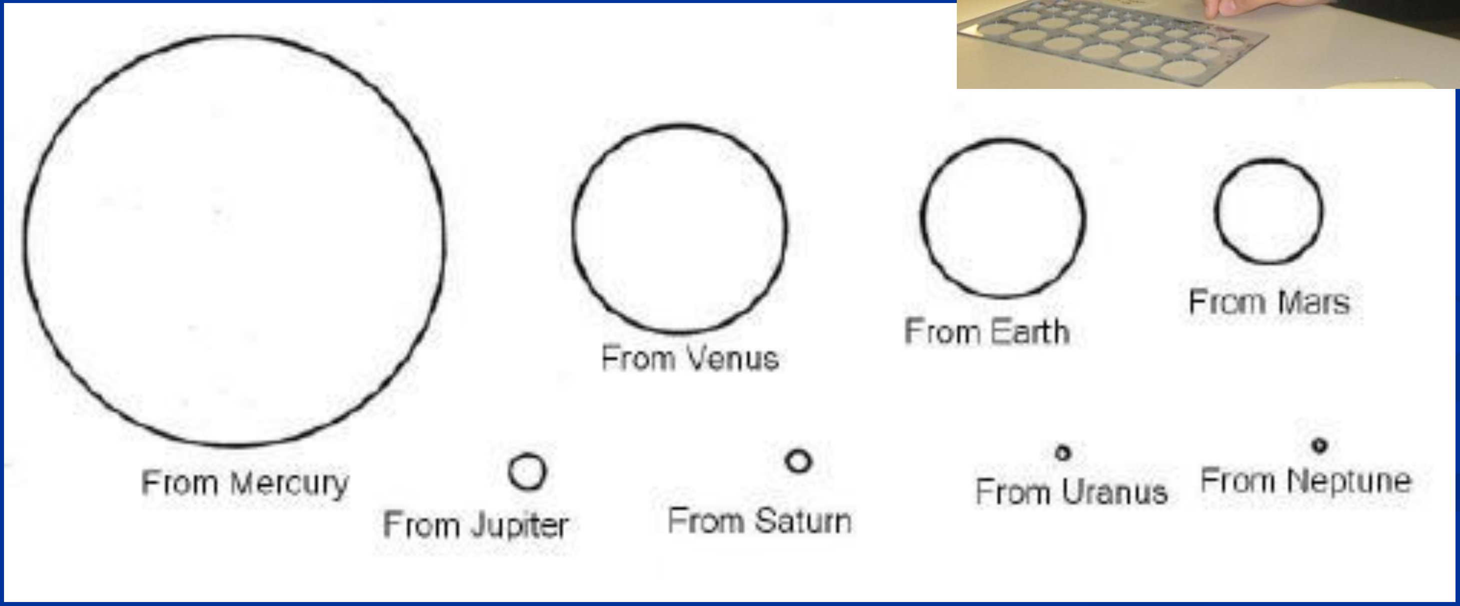
Mercury	57 900 000 km	⇨	3.3 minutes
Venus	108 300 000 km	⇨	6.0 minutes
Earth	149 700 000 km	⇨	8.3 minutes
Mars	228 100 000 km	⇨	12.7 minutes
Jupiter	778 700 000 km	⇨	43.2 minutes
Saturn	1 430 100 000 km	⇨	1.32 hours
Uranus	2 876 500 000 km	⇨	2.66 hours
Neptune	4 506 600 000 km	⇨	4.16 hours

Activity 6: The Sun as seen from the planets
活动6:其他行星上看到的太阳



- $\alpha = \tan \alpha$ = radius Sun / distance to Sun $= 700\,000/150\,000\,000 = 0.0045$ radian $= 0.255°$
- From the Earth, the Sun measures $2\alpha = 0.51°$
- 地球上看到的太阳的视直径

Activity 6: The Sun as seen from the planets
活动6:其他行星上看到的太阳



Activity 7: Model of densities
活动7:密度模型

Sun	1.41 g/cm^3		Sulfur 硫磺(1.1-2.2)
Mercury	5.41 g/cm^3		Pyrite黄铁矿 (5.2)
Venus	5.25 g/cm^3		Pyrite黄铁矿 (5.2)
Earth	5.52 g/cm^3		Pyrite黄铁矿 (5.2)
Mars	3.90 g/cm^3		Blende闪锌矿 (4.0)
Jupiter	1.33 g/cm^3		Sulfur硫磺(1.1-2.2)
Saturn	0.71 g/cm^3		Pine wood松木(0.55)
Uranus	1.30 g/cm^3		Sulfur硫磺(1.1-2.2)
Neptune	1.70 g/cm^3		Clay粘土 (1.8-2.5)

Activity 8: Flattening Model
活动8：椭率模型

- Cut cardboard strips of 35 x 1 cm.
- 剪一些 35 厘米长 1 厘米宽的纸条
- Attach them to a cylindrical stick 50 cm long and 1 cm in diameter. Leave the lower end loose so that it can move along the stick.
- 把纸条贴在一个长50cm直径1cm的圆柱体上，帖的时候要保证纸条下端可以整体沿圆柱移动。
- Rotate the stick in between your hands with quick rotations in one direction and the other. The centrifugal force deforms the cardboard bands as planets are deformed.
- 用双手搓圆柱体使它快速转动。离心力使纸条产生的形变就是行星上正在发生的现象。

Activity 8: Flattening Model
活动8:椭率模型

Planets	(equatorial radius-polar radius)/ equatorial radius (赤道半径-极半径)/赤道半径
Mercury	0.0
Venus	0.0
Earth	0.0034
Mars	0.005
Jupiter	0.064
Saturn	0.108
Uranus	0.03
Neptune	0.03

Activity 9: Orbital Periods model
活动9:公转周期模型

- Attach a weight (roll of tape) to one end of a rope and hold the rope opposite to it. Turn the rope over your head.
- 在绳子一端绑一个螺母，抓住绳子的另一侧，然后在头顶旋转绳子。
- As you release more rope, it takes longer to complete an orbital period.
- 当放开的绳子变长时，绕一圈所走过的路径就会变长。
- If you shorten the rope, it takes less time.
- 如果收紧绳子，速度就会变大。

Earth orbital data
地球轨道参数

The average orbital velocity $v = 2\pi R / T$
平均轨道速度

For the Earth 对于地球

$v = 2\pi \times 150 \times 10^6/365$

v = 2 582 100 km/day = 107 590 km/h = 29.9 km/s

(The average orbital speed of Sun around the galactic centre is 220 km/s or 800 000 km/h.)

（太阳绕银心运动的平均轨道速度是220 km/s 或 800 000 km

Orbital data
轨道参数

Planet 行星	Orbital period (days) 轨道周期	Distance from the Sun (km) 到太阳的距离	Orbital average speed (km/s) 轨道平均速度(km/s)	Orbital average speed (km/h) 轨道平均速度(km/h)
Mercury	87.97	57.9 x 10^6	47.90	172 440
Venus	224.70	108.3 x 10^6	35.02	126 072
Earth	365.26	149.7 x 10^6	29.78	107 208
Mars	686.97	228.1 x 10^6	24.08	86 688
Jupiter	4331.57	778.7 x 10^6	13.07	47 052
Saturn	10759.22	1 430.1 x 10^6	9.69	34 884
Uranus	30.799.10	2 876.5 x 10^6	6.81	24 876
Neptune	60190.00	4 506.6 x 10^6	5.43	19 558

Activity 10: Model of surface gravities
活动10:表面重力加速度模型

- Surface gravity, $F = G\,M\,m/d^2$, with $m = 1$, $d = R$. Thus $g = G\,M / R^2$, where $M = 4/3\,\pi\,R^3\,\rho$
- 表面重力$F = G\,M\,m/d^2$, 其中$m = 1$, $d = R$. 所以$g = G\,M / R^2$, 其中 $M = 4/3\,\pi\,R^3\,\rho$
- Replacing: 代入可得$g = 4/3\,\pi\,G\,R\,\rho$

Surface gravity行星表面重力

Planets	Equat. Radius	Density		Calc. Grav.	Real Gravity	
Mercury	2 439 km	5.4 g/cm^3	⇨	0.378	3.70 m/s^2	0.37
Venus	6 052 km	5.3 g/cm^3	⇨	0.894	8.87 m/s^2	0.86
Earth	6 378 km	5.5 g/cm^3	⇨	1.000	9.80 m/s^2	1.00
Mars	3 397 km	3.9 g/cm^3	⇨	0.379	3.71 m/s^2	0.38
Jupiter	71 492 km	1.3 g/cm^3	⇨	2.540	23.12 m/s^2	2.36
Saturn	60 268 km	0.7 g/cm^3	⇨	1.070	8.96 m/s^2	0.91
Uranus	25 559 km	1.2 g/cm^3	⇨	0.800	8.69 m/s^2	0.88
Neptune	25 269 km	1.7 g/cm^3	⇨	1.200	11.00 m/s^2	1.12
Moon			⇨		1.62 m/s^2	0.16

Activity 11: Model of "impact craters"
活动11:陨石坑模型

- Cover the floor with newspapers to prevent a mess
- 在地面上铺一些报纸
- In a shallow box, set a layer of 1 or 2 cm of flour with a strainer to make the surface very smooth在一个浅箱中用筛子铺一层1至2cm厚的面粉，使表面尽量平滑

- Sprinkle a layer of a few millimetres of cocoa powder over the flour with the strainer
- 用筛子在面粉上面铺一层几毫米厚的可可粉
- From about 2 m high, drop a tablespoon of cocoa powder to create marks like impact craters从2米高的地方，向下撒一大勺可可粉，就像发生了一次陨石撞击事件
- The used flour can be recycled for a new experiment
- 用过的面粉可以循环再利用做新的实验

Activity 12: Escape velocity
活动12:逃逸速度

- $E_{kin} = ½ mv^2$
- $E_{pot} = -GM_{Planet}m/R_{Planet}$
- $E_{mec} = E_{kin} + E_{pot} = 0$
- $g_{planet} = GM_{planet}/R^2_{planet}$

Then: $-GM_{planet}m/R_{Planet} + ½ mv^2 = 0$

$½ mv^2 = g_{planet}mR_{planet}$

the scape velocity results:

$v = (2gR)^{1/2}$

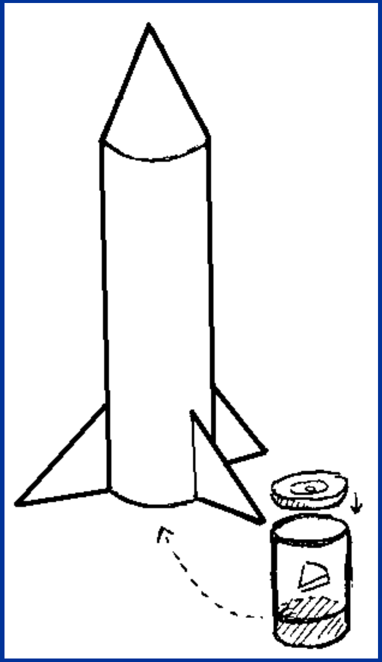
Activity 12: Escape velocity
活动12:逃逸速度

Planets	Equatorial Radius	Surface Gravity		Escape Velocity
Mercury	2 439 km	0.378		4.3 km/s
Venus	6 052 km	0.894		10.3 km/s
Earth	6 378 km	1.000		11.2 km/s
Mars	3 397 km	0.379		5.0 km/s
Jupiter	71 492 km	2.540		59.5 km/s
Saturn	60 268 km	1.070		35.6 km/s
Uranus	25 559 km	0.800		21.2 km/s
Neptune	25 269 km	1.200		23.6 km/

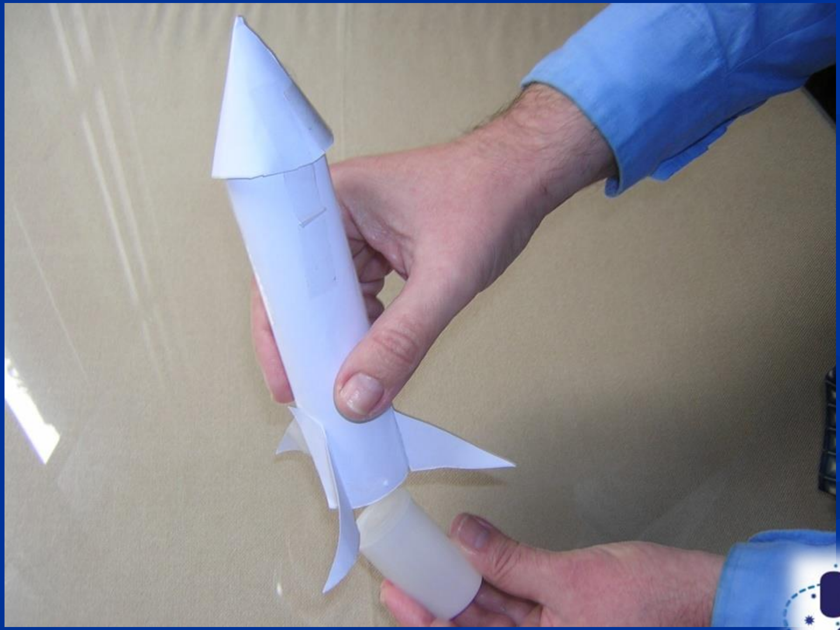
Rocket launch 火箭发射

- Cardboard 硬纸板
- Capsule film 胶卷盒
- ¼ Effervescent aspirin

  ¼ 泡腾片



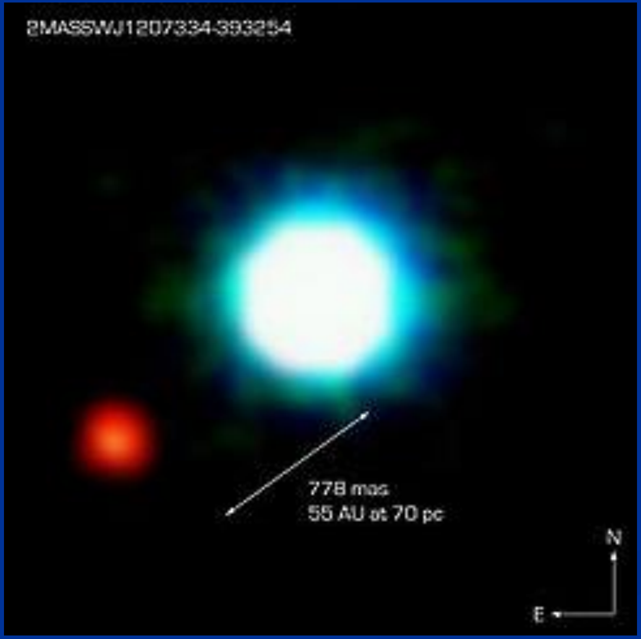


Extrasolar planetary systems
系外行星系统

In 1995 Michael Mayor and Didier Queloz announced the detection of an exoplanet orbiting 51 Pegasi

1995年， Michael Mayor和Didier Queloz宣布
发现了一颗绕飞马座51的系外行星。



2M1207b directly imaged (ESO)

The first image of an exoplanet

2003 March 16th

2013年3月16日拍摄的一颗系外行星的第一张照片

We depend on the technology
我们依赖技术

Galilei observed Saturn with his telescope in 1610 for the first time. He did not see a fine ring but interpreted it as a star with three bodies. You had to wait for Huygens (1659) with a better telescope to solve the ring. For this reason the painting of Rubens (1636-1638) symbolizes Saturn with three objects according to the discovery of Galilei.

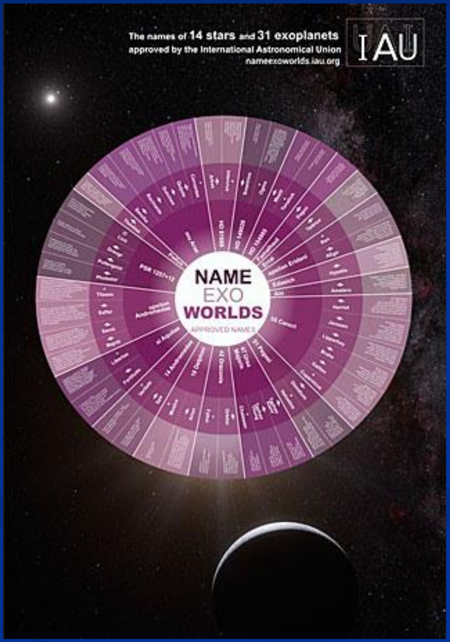
1610年伽利略第一次用他的望远镜观测土星时，并没有看到土星环，而是认为看到一颗由三部分组成的恒星。要分辨出土星环，你必须等到1659年惠更斯用更强大的望远镜观测才行。正因如此，在鲁本斯的画作（1636-1638）中，根据伽利略的发现，土星被象征性地描绘为三部分。

Names for exoplanets系外行星的命名

A letter is added after the name of the central star starting with "b" for the first planet found in the system (e.g.

51 Pegasi b).

行星系统中的第一颗行星的命名方法是在母星的名称后面加一个字母“b”（例如飞马座51b）



The next planets are named following the alphabet: c, d, e, f, etc.

(51 Pegasi c, 51 Pegasi d, 51 Pegasi e or 51 Pegasi f).

接下来的行星依次加上 c、d、e、f 等字母。

（飞马座51c，飞马座51d，飞马座51e，或飞马座51f）

Methods used to detect exoplanets
探测系外行星的方法

Many methods are used, e.g. :
测量方法有很多种，例如：

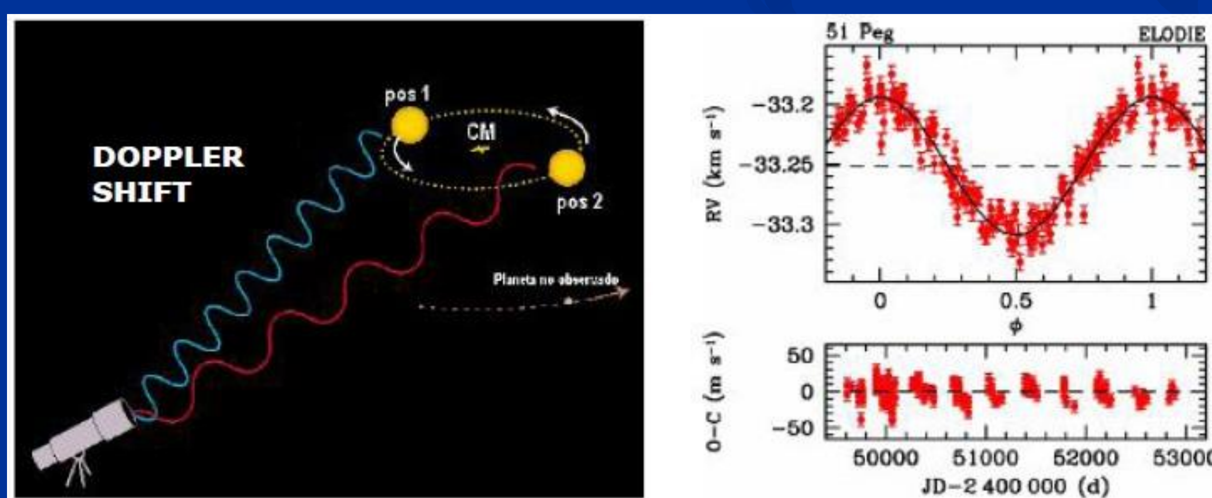
- Radial velocity or Doppler effect
  径向速度与多普勒效应
- Transit Method
  中天法
- Microlensing
  微引力透镜
- Others
  其他

Detection Method: Radial Velocity
探测方法:视向速度

The variation of the radial velocity of the star when orbiting the barycenter of the planet and star system is measured using the Doppler Effect. It was with this method that the first exoplanet 51 Pegasus b was detected.

利用多普勒效应可以测量恒星围绕恒星-行星系统的质心运动时视向速度的变化

系外行星飞马座51b就是利用这种方法探测到的



Activity 13: Doppler Effect活动13：多普勒效应

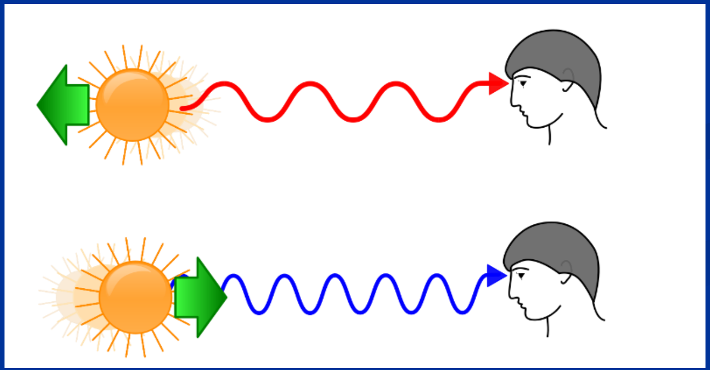
The Doppler effect is the change of the wavelength of light when the source is in motion.
多普勒效应是指当光源移动时光的波长会发生变化

When the source approaches the wavelength is shortened and the observed light shifting to the blue part of the visible spectrum.

当光源靠近时，波长变短，观测到的光向可见光谱的蓝端移动

When it moves away, the wavelength increases and the observed light shifting to the red part of the visible spectrum.

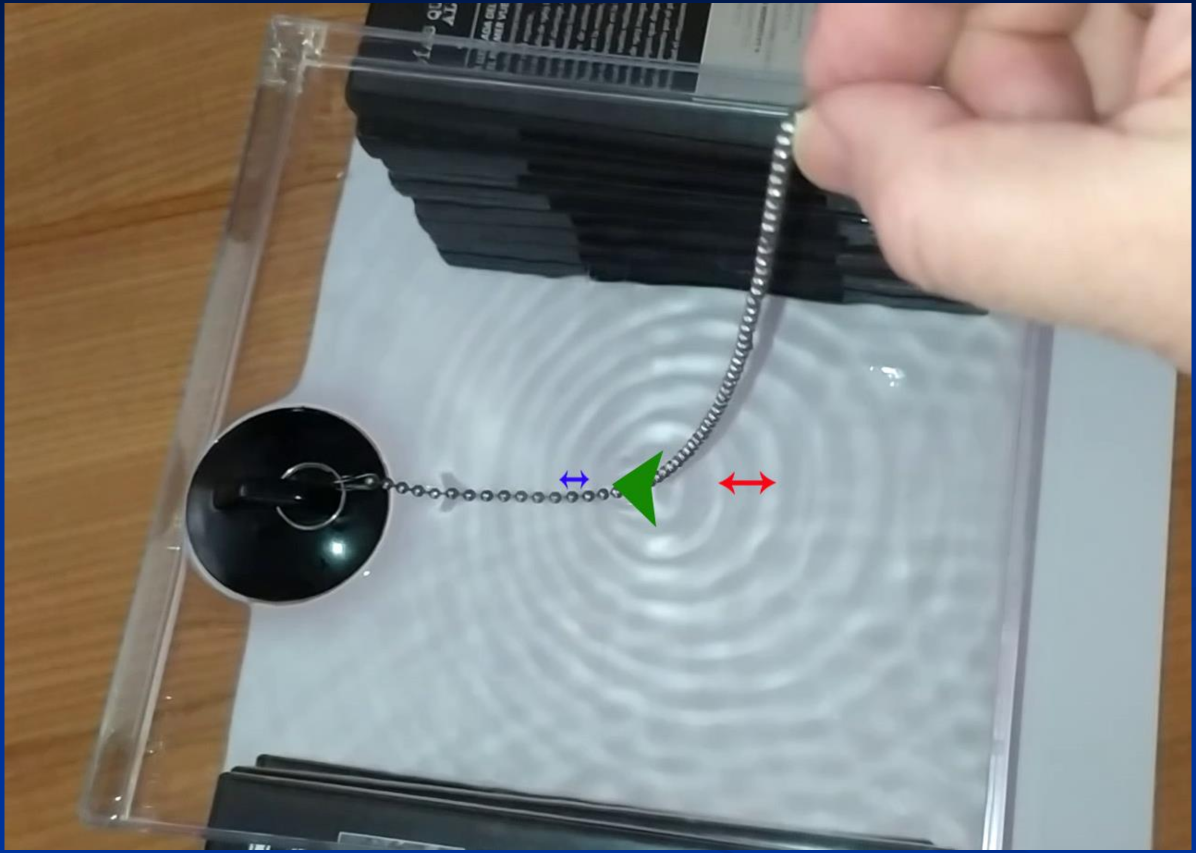
当光源远离时，波长变长，观测到的光向可见光谱的红端移动

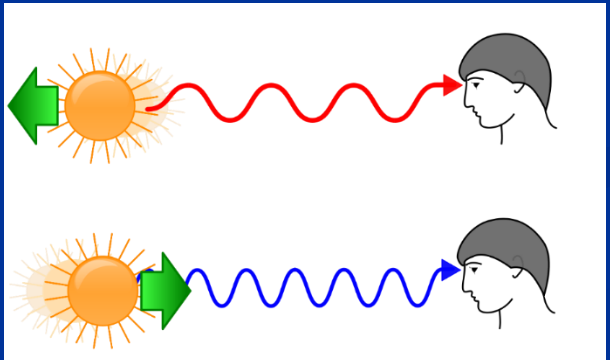


Activity 13: Doppler Effect活动13：多普勒效应

It has been reproduced with a bucket of water, a cap with chain and the mobile phone’s flash.

用一个充满水的水桶（水槽），一个有链子的盖子和手机的手电筒就可以重现多普勒效应



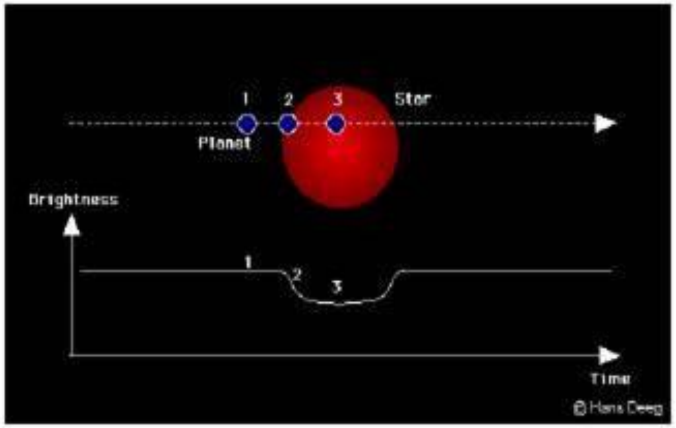


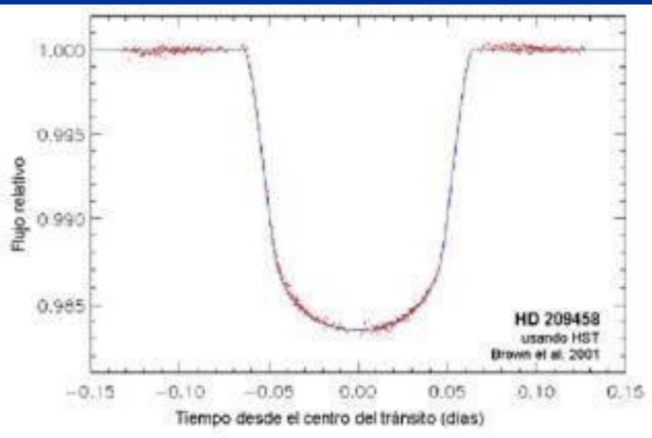
Detection Method: Transits
探测方法：掩星法

During the transit of an exoplanet, the brightness of the star undergoes a small decrease.

For solar-type stars and Jupiter-sized planets, the brightness decrease is approximately 1%, in the case of Earth-sized planets the decrease is around 0.03%.

当一颗系外行星遮掩住其母恒星（掩星）时，母恒星的光度会略微下降。以一颗类太阳恒星被一颗类木星行星遮掩为例，母恒星的光度大约下降1%；若发生掩星的是一颗类地行星，则母恒星的光度大约下降0.03%





Activity 14: Transit simulation
活动14：掩星模拟

Using two balls: one large for the star and one small for the exoplanet orbiting the star.

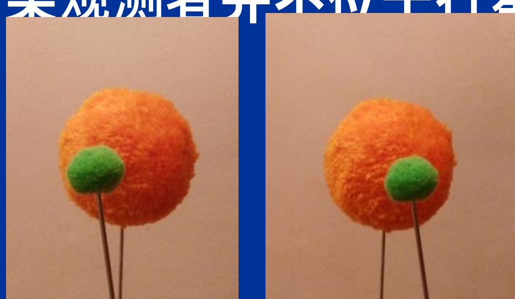
With the observer in the same plane of the orbit and observing from that place, you will see the exoplanet passing in front of the star and the brightness of the star decreasing.

But if the observer is not in the same plane of orbit, no change in the brightness curve will be observed.

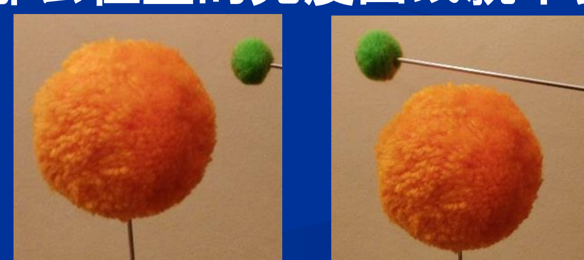
材料：两个球，大球代表恒星，小球代表围绕恒星运动的系外行星

当观测者位于行星轨道面，则可以看到行星在恒星前面经过，恒星的光度会下降；

但如果观测者并不位于行星轨道面，那么恒星的光度曲线就不会发生任何变化



Observer in the plane of the orbit
观测者位于轨道面

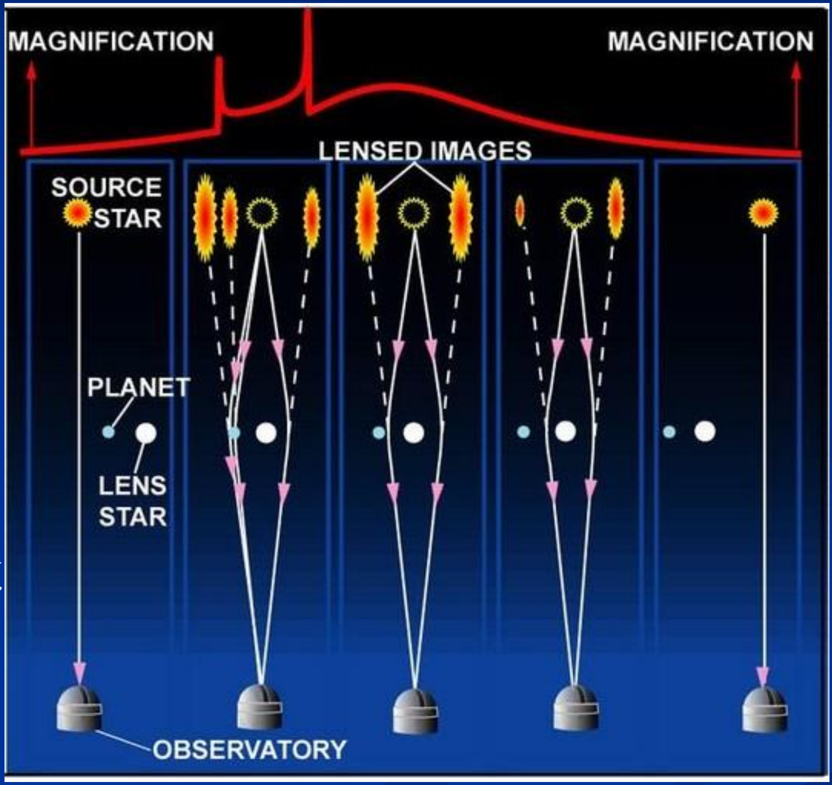


Observer out of the plane of orbit
观测者在轨道面之外

Detection Method: Micro Lensing
探测方法：微引力透镜

There is an enlargement or distortion that highlights the star-exoplanet system, due to the alignment of the system with a star or object that makes the gravitational lens.

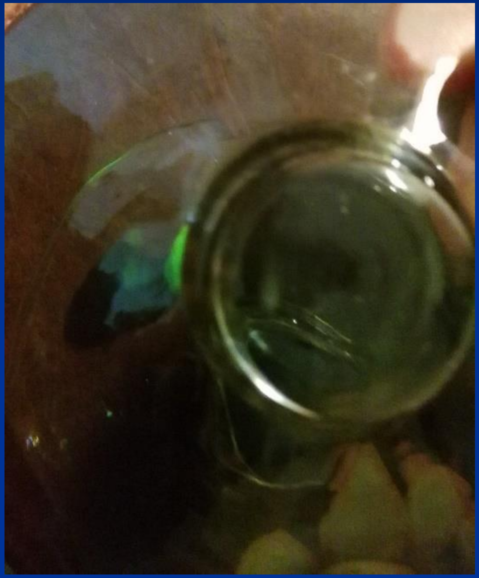
如果系外行星系统恰好位于观测者和更遥远的背景恒星之间，能够形成引力透镜，那么通过观测背景恒星的光变曲线的变化（放大或扭曲）就可以发现系外行星的存在



There must be complete visual alignment between the three bodies (earth, object-lens and star-exoplanet).

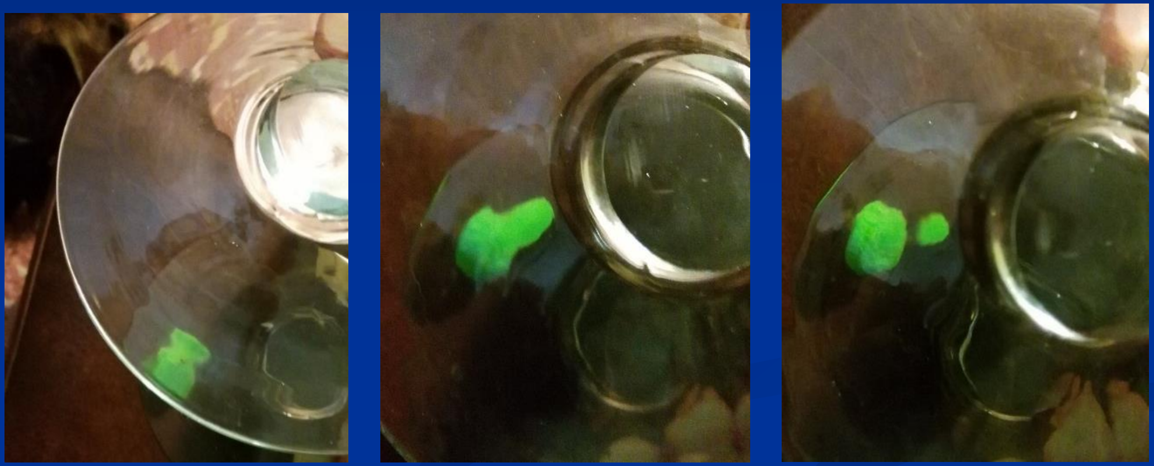
地球、系外行星系统、遥远背景恒星三者在视线方向必须严格排列成一条直线

Activity 15: Simulation of microlenses
活动15：微引力透镜模拟



With only one wine glass foot, nothing is seen.

只通过一只高脚杯底看，没有任何发现



With a pair of wine glass feet

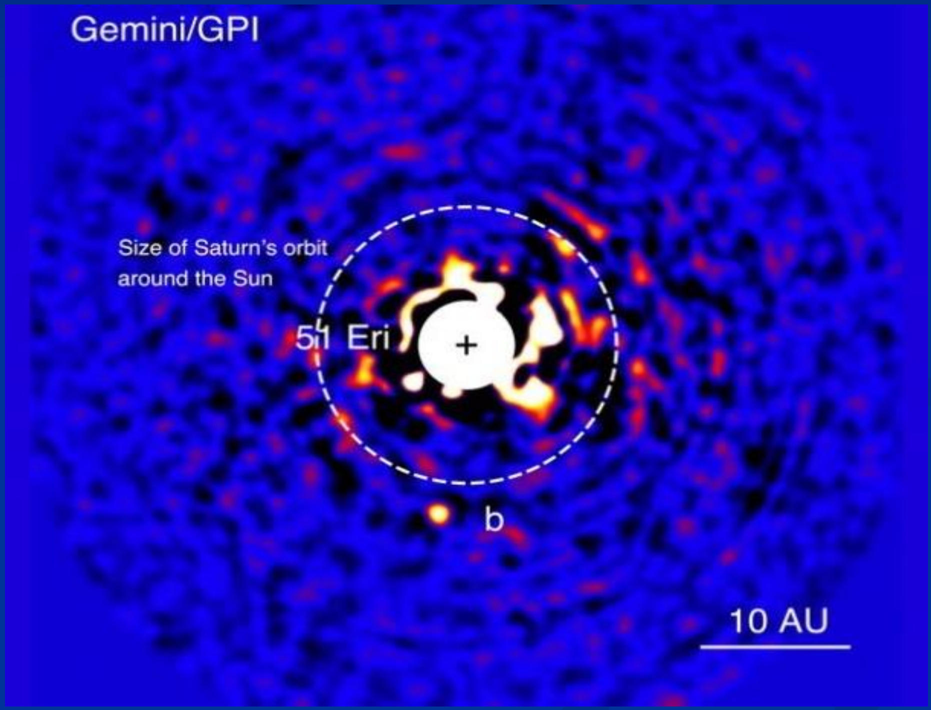
Then we pass one over the other and a point emerges and then even two.

通过一对高脚杯底观察，一个透过一个，我们就能看到一个点，甚至是两个

Detection Method: Direct
探测方法：直接成像

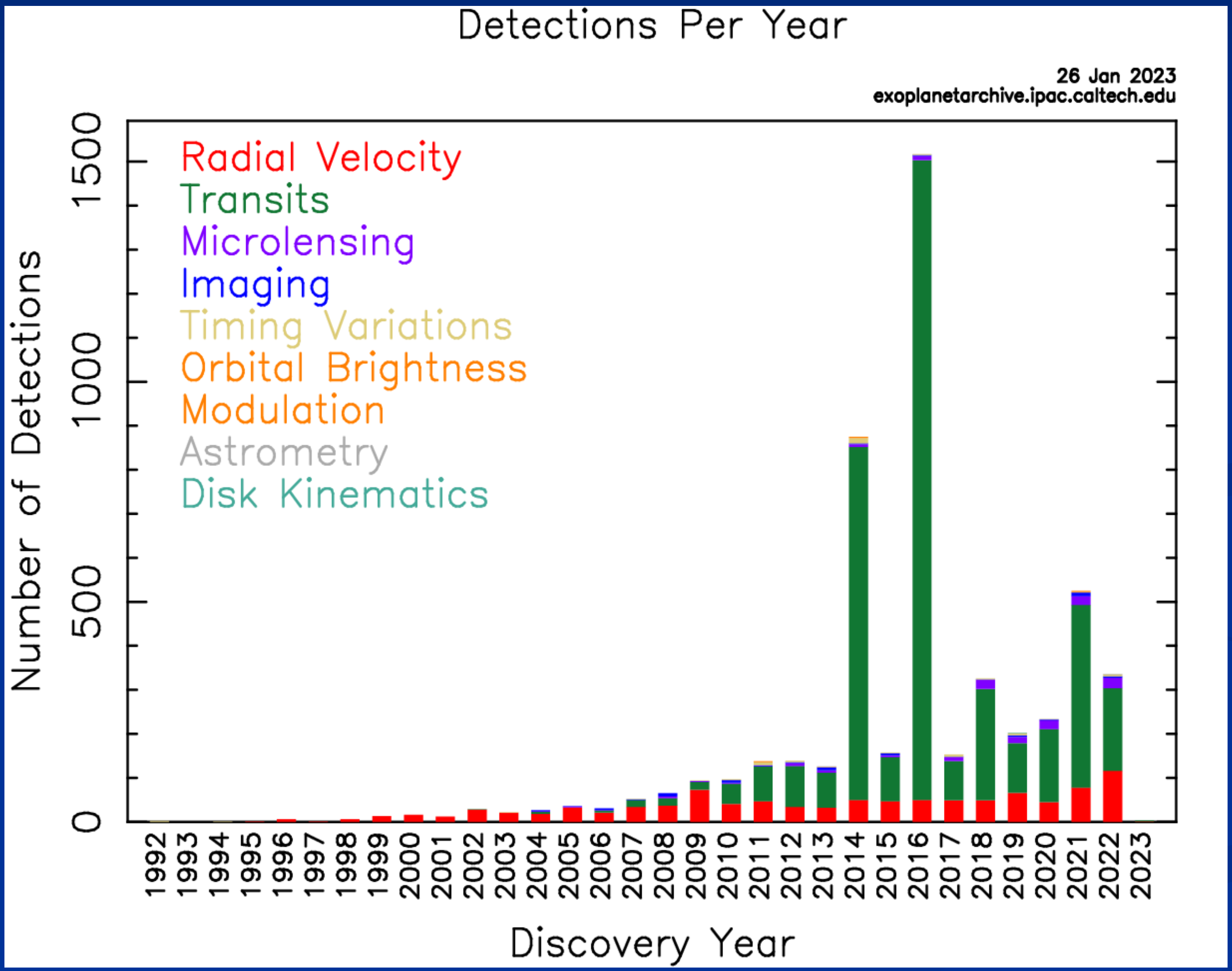
The image of the star is studied to determine the exoplanets around it.

恒星的图像可以用来研究判断是否有行星围绕其运动



Due to the amount of light emitted by the star, it is not easy to carry out.

由于恒星光度太强，这种办法实施起来并不容易



已知的2023颗系外行星，不同符号代表不同的探测方法

2023 known exoplanets according to the different detection methods

Models for Exoplanetary Systems
系外行星系统模型

Currently, about 4,000 planetary systems have been discovered, more than 5,300 exoplanets, and observations of about 10,000 exoplanet candidates have been made.

目前已发现约4000个行星系统，5300多颗系外行星，已观测约10000颗系外行星候选者。

Jet Propulsion Laboratory (NASA; http://planetquest.jpl.nasa.gov/)

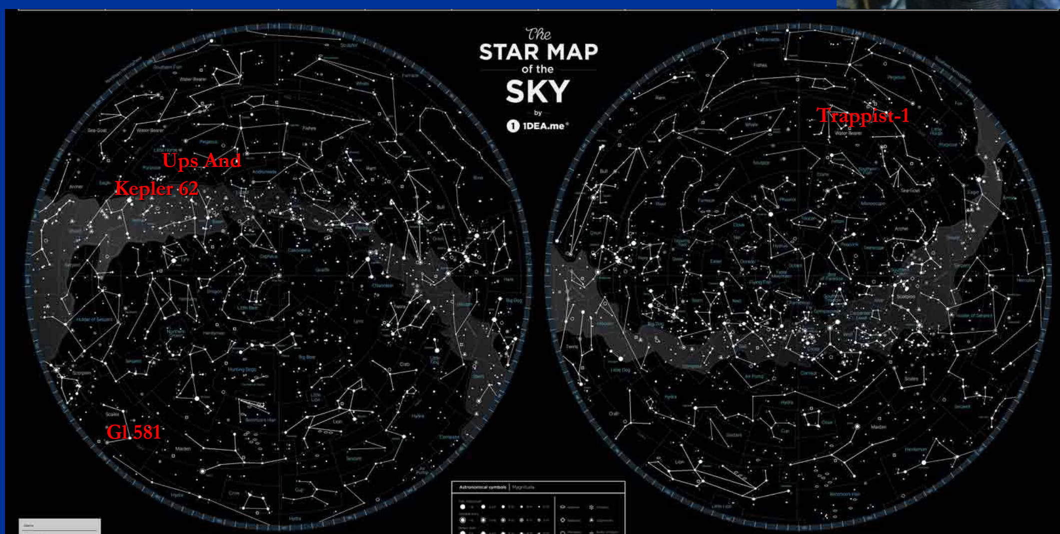
The masses of the discovered exoplanets are often compared to the mass of Jupiter (1.90 x 10^{27} kg) or similar to Earth (5.97 x 10^{24} kg)

通常将系外行星的质量与木星(1.90 x 10^{27} kg)或地球(5.97 x 10^{24} kg)进行比较。

- technical limitations
- 技术限制

Activity 16: Scale models of exoplanetary systems

活动16：系外行星系统比例模型



Distance 1 AU = 1 m
Diameter 10000 km = 0.5 cm

Activity 16: Build Solar System:
活动16：建造太阳系

Solar System 太阳系	Distance 距离 AU	Diameter直径 km	Model Distance 模型距离	Model Diameter模型直径
Mercury水星	0.39	4 879	40 cm	0.2 cm
Venus金星	0.72	12 104	70 cm	0.6 cm
Earth地球	1	12 756	1m	0.6 cm
Mars火星	1.52	6 794	1.5 m	0.3 cm
Jupiter木星	5.2	142 984	5 m	7 cm
Saturn土星	9.55	120 536	10 m	6 cm
Uranus天王星	19.22	51 118	19 m	2.5 cm
Neptun海王星	30.11	49 528	30 m	2.5 cm

Host Star Sun G2V, Diameter of the Sun in the model is 35 cm

母恒星太阳，类型G2V，模型中太阳的直径为35cm

Distance 1 AU = 1 m   Diameter 10000 km = 0.5 cm

Activity 16: Build 1st exoplanetary system:
活动16:建造第一个系外行星系统

Upsilon Andromedae Titawin （仙女座υ）	Discovery year发现年代（年）	Distance 距离AU	Diameter 直径km	Model Distance 模型距离	Model Diameter 模型直径
Ups And b/Saffar仙女座Ub	1996	0.059	108 000	6 cm	5.5 cm
Ups And c/Samh仙女座Uc	1999	0.830	200 000	83 cm	10 cm
Ups And d/Majriti仙女座Ud	1999	2.510	188 000	2.5 m	9 cm
Ups And e/Titawin e 仙女座Ue	2010	5.240	140 000	5.2 m	7 cm

Host Star Ups And F8V is at 44 l.y. in And.,
Diameter 1.28 of the Sun in the model is 45 cm
母恒星仙女座U，类型F8V，距离44光年，直径为1.28个太阳模型，为45cm

Distance 1 AU = 1 m Diameter 10000 km = 0.5 cm

Activity 16: Build "terrestrial" planets
活动16:建造"类地"行星

Gliese 581 格蕾丝 581	Discovery year发现年代	Distance AU距离	Diameter km直径	Model Distance 模型距离	Model Diameter 模型直径
Gl.581 e	2009	0.030	15 200	3 cm	0.8 cm
Gl.581 b	2005	0.041	32 000	4 cm	1.6 cm
Gl.581 c	2007	0.073	22 000	7 cm	1.1 cm

Host star Gliese 581 M2,5V is 20,5 l.y. in Libra, Diameter 0.29 of the Sun in the model is 10 cm
母恒星格蕾丝581，类型M2,5V，位于天琴座，距离20.5光年，直径为0.29个太阳直径，模型直径10cm

Distance 1 AU = 1 m Diameter 10000 km = 0.5 cm

Activity 16: Build "habitable terrestrial"planets
活动13:建立“宜居类地”行星

Kepler 62 开普勒62	Discovery year发现年代	Distance AU距离	Diameter km直径	Model Distance 模型距离	Model Diameter 模型直径
Kepler-62 b	2013	0.056	33 600	5.6 cm	1.7 cm
Kepler-62 c	2013	0.093	13 600	9 cm	0.7 cm
Kepler-62 d	2013	0.120	48 000	12 cm	2.4 cm
Kepler-62 e	2013	0.427	40 000	43 cm	2 cm
Kepler-62 f	2013	0.718	36 000	72 cm	1.8 cm

Host star Kepler 62 K2V is at 1200 l.y. in Lyr,.

Diameter 0.64 of the Sun in the model is 22 cm

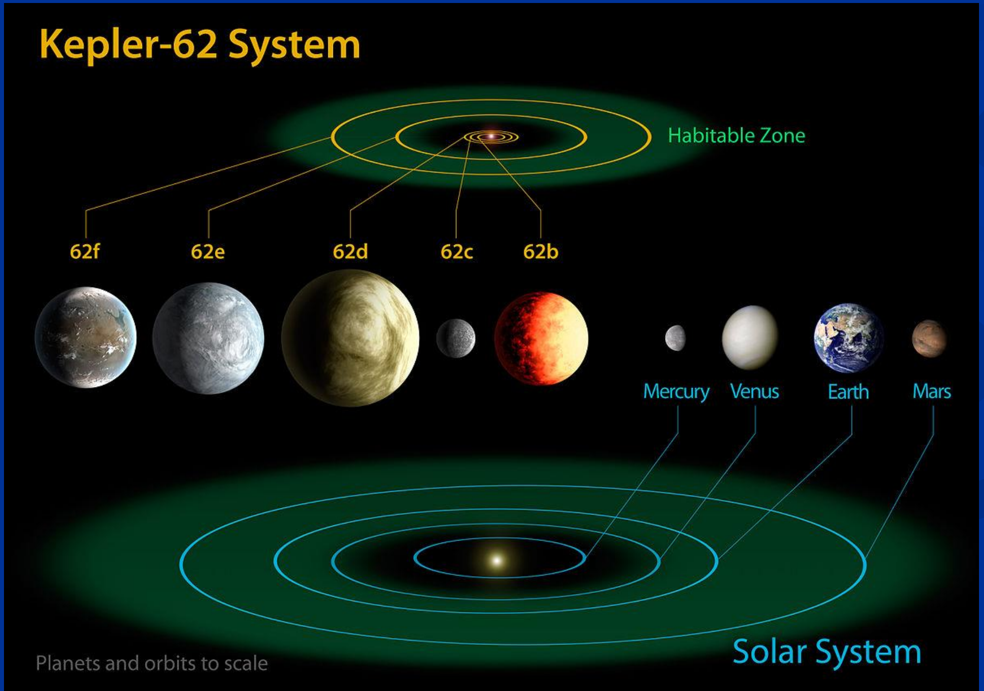
母恒星开普勒62，类型K2V，位于天琴座，距离1200光年，
直径为0.64个太阳直径，模型直径22cm

Distance 1 AU = 1 m   Diameter 10000 km = 0.5 cm

Possible habitability of exoplanets
系外行星可能的宜居性

In the habitable zone of Kepler-62: the two exoplanets could have liquid water on their surfaces. For Kepler-62e, which is near the interior of the habitable zone, this would require coverage of reflective clouds that reduces the radiation that heats the surface. Kepler-62f, on the other hand, is in the outer zone of the habitable zone

在开普勒62的宜居带内：有两颗系外行星表面可能拥有液态水。对于开普勒62e来说，由于其靠近宜居带内侧，就需要拥有反射云团覆盖来减少行星表面接受到的辐射热能。另一方面，开普勒62f则位于宜居带的外侧。



Activity 16: Build "habitable terrestrial"planets
建造"宜居类地"行星

Trappist-1 特拉皮斯特-1	Discovery year发现年代	Distance AU 距离	Diameter km直径	Model Distance 模型距离	Model Diameter 模型直径
Trappist-1 b	2016	**0.012**	**28 400**	**1.2 cm**	**1.4 cm**
Trappist-1 c	2016	**0.016**	**28 000**	**1.6 cm**	**1.4 cm**
Trappist-1 d	2016	**0.022**	**20 000**	**2.2 cm**	**1.0 cm**
Trappist-1 e	2017	**0.030**	**23 200**	**3.0 cm**	**1.2 cm**
Trappist-1 f	2017	**0.039**	**26 800**	**3.9 cm**	**1.3 cm**
Trappist-1 g	2017	**0.047**	**29 200**	**4.7 cm**	**1.5 cm**
Trappist-1 h	2017	**0.062**	**19 600**	**6.2 cm**	**1.0 cm**

Host star Trappist 1 M8V is at 40 l.y. in Acuarius,
Diameter 0.1 of the Sun in the model is 4 cm

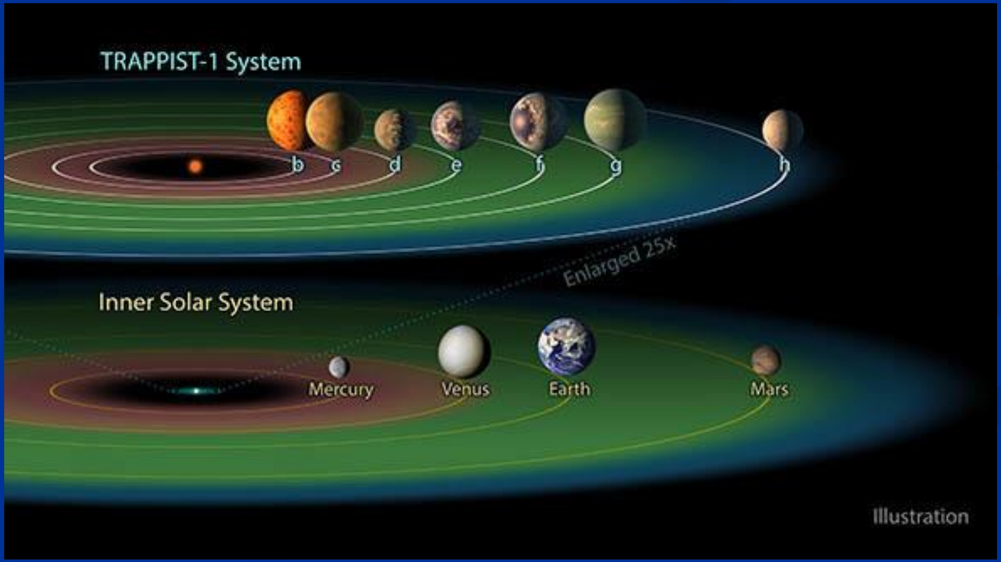
母恒星特拉皮斯特1，类型M8V，位于宝瓶座，距离40光年
直径为0.1个太阳直径，模型直径4cm

Distance 1 AU = 1 m Diameter 10000 km = 0.5 cm

Possible habitability of exoplanets
系外行星可能的宜居性

In the Trappist-1 system are rocky and could have large amounts of water on their surface, either liquid, in the form of steam, or as an ice crust. In the habitable zone of Trappist 1 is Trappist-1e which appears to have a dense nucleus, comparable to Earth which seems to indicate that of all the planets in this system, this is the most Earth-like and is likely to have a protective magnetosphere.

在特拉皮斯特-1系统中有岩质行星，可能拥有大量水，无论是以液态还是气态或冰壳的形式存在。在系统的宜居带内，行星特拉皮斯特-1e似乎拥有致密的核，与地球相比，这一点说明在这个系统的所有行星当中，1e是与地球最相似的行星，很可能有保护性的磁层。



Conclusions
总结

- Knowledge is more "concrete" of planets
- 更加“具体的”了解行星的有关知识
- Relationships establish "parameters" that allow a better understanding of dimensions
- 通过建立各项“参数”的概念更好的理解尺度
- The solar system "is empty«
- 太阳系是非常“空旷的”
- Introduction of exoplanets
- 了解系外行星

Thank you for your attention!

谢谢！