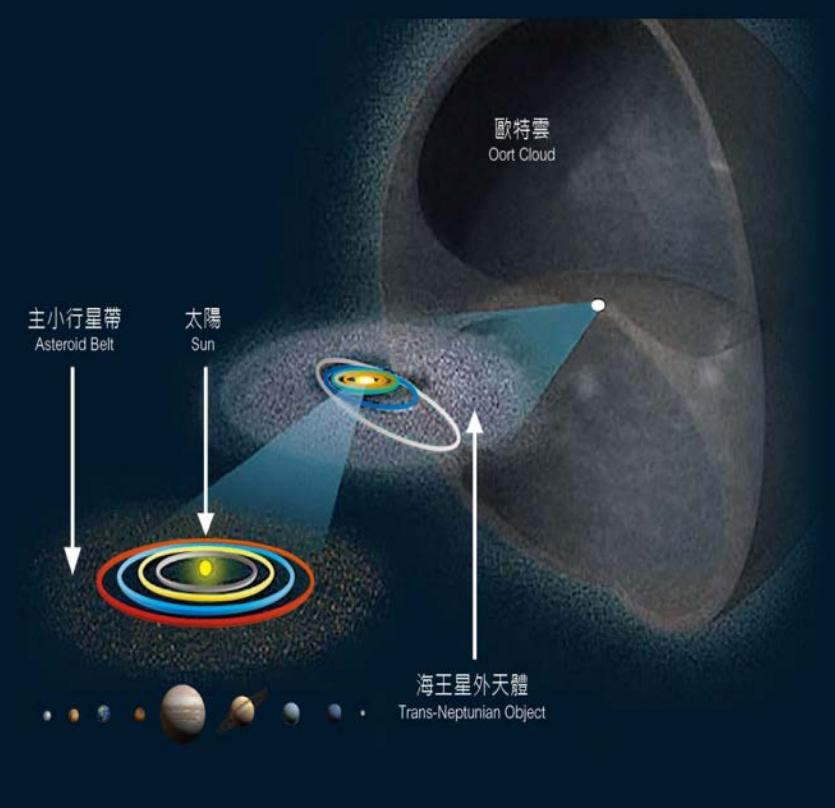
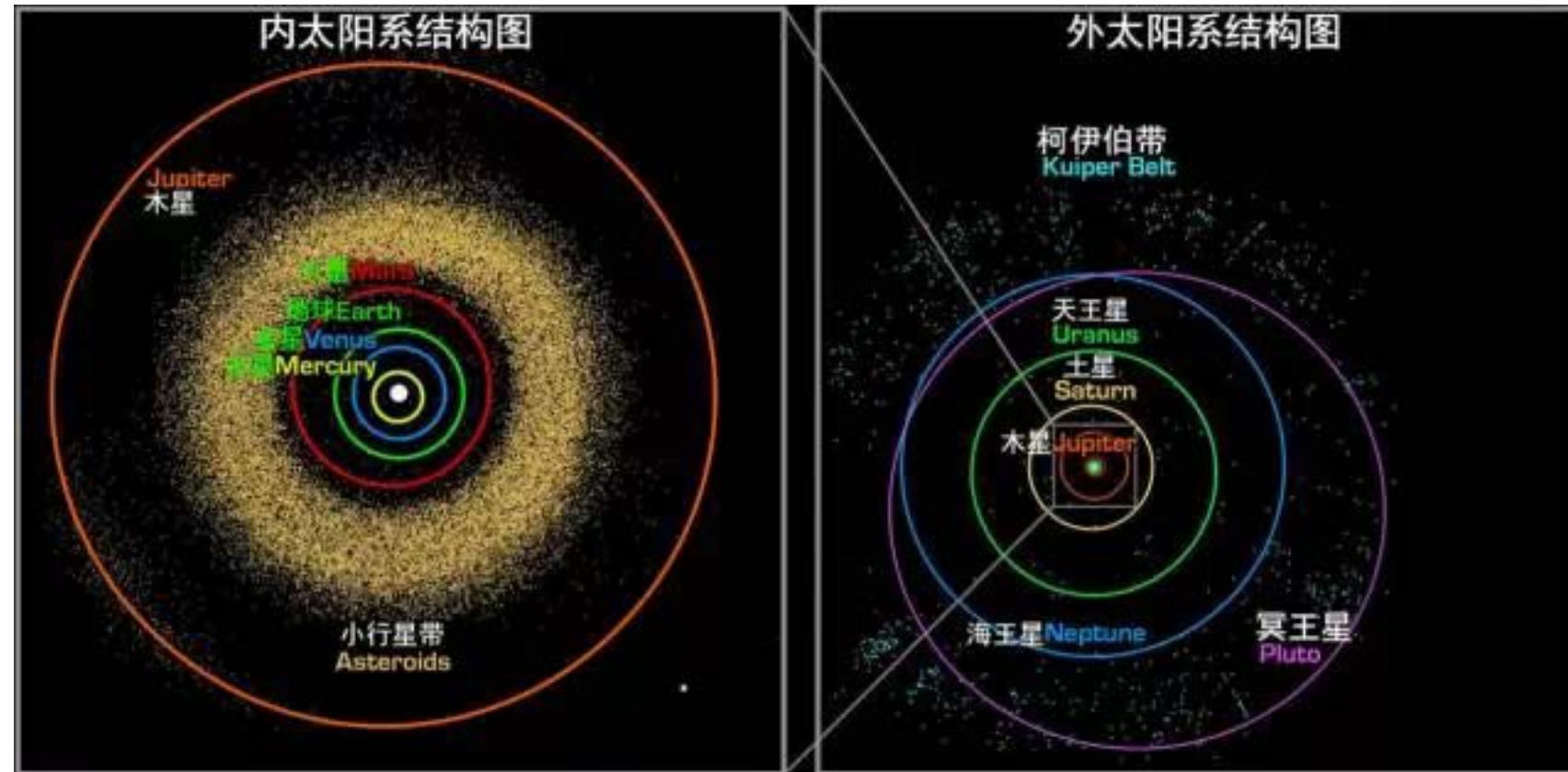


# Outer Solar System

# 太阳系结构

## 示意图

## 三维图



实际比例

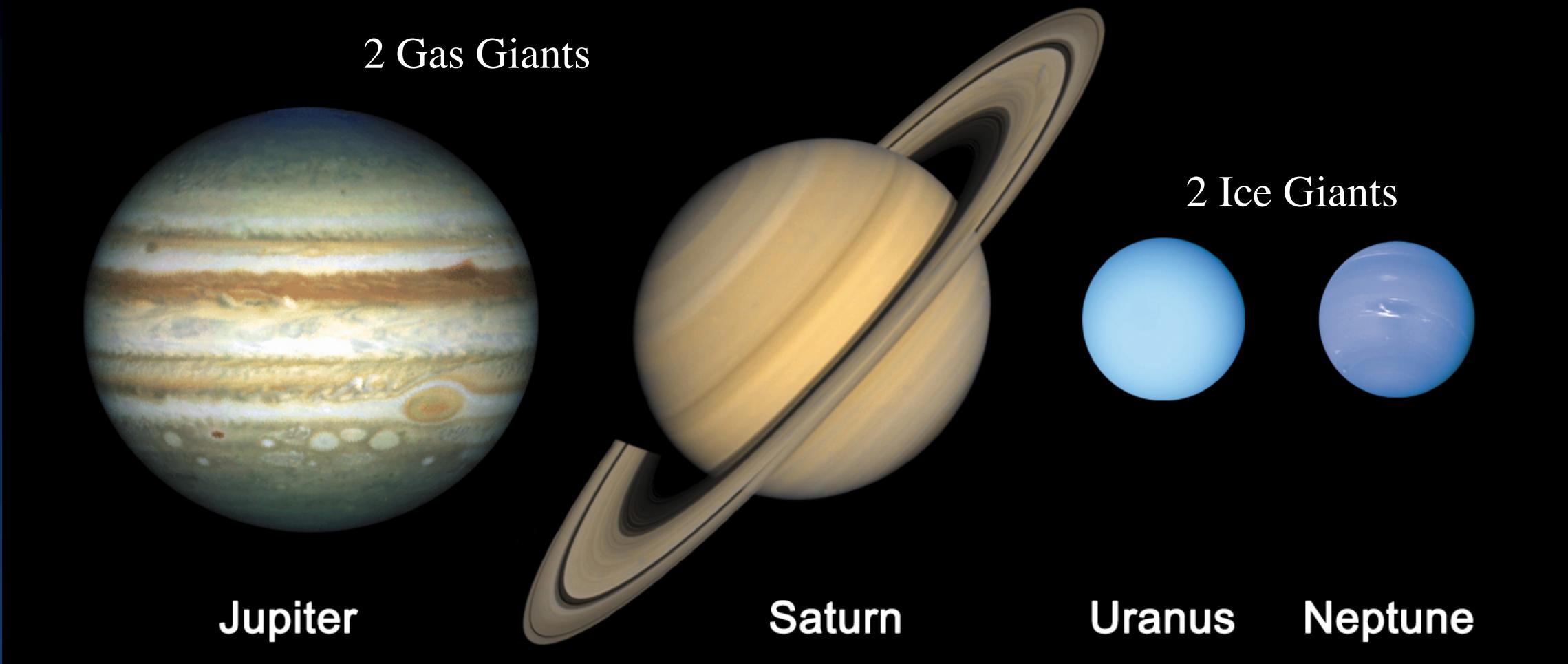


# 3. Outer Solar System

## 3.1 Outer Solar System Objects

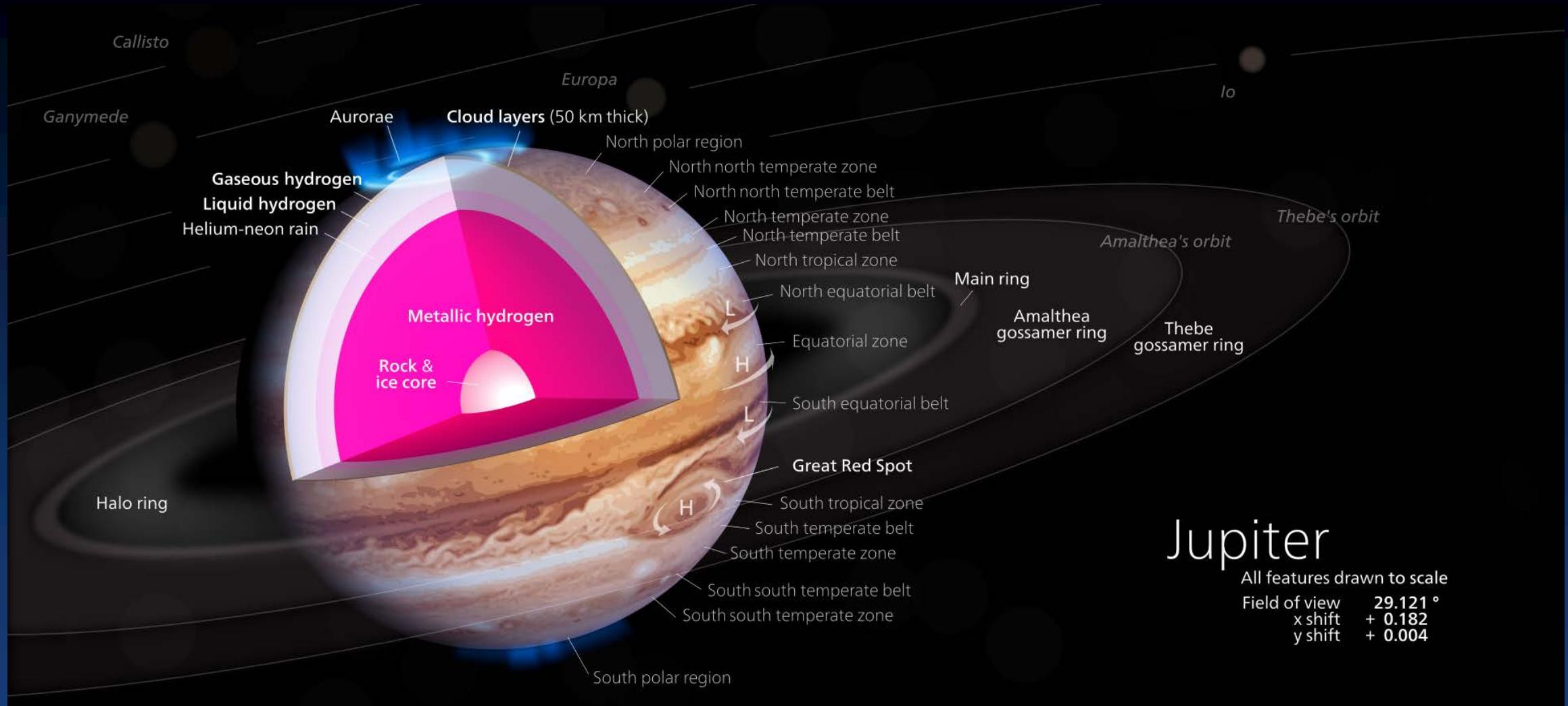
- Giant Planets
- Pluto
- Moons
- Asteroids and Comets

### 3.1 巨行星



- 直径是地球的 4–10 倍，总质量占行星质量的 99.7%
- 木星 (Jupiter, 罗马主神朱庇特) 是最大的行星
- 自转快, 公转慢
- 有许多 (>100) 卫星

# 木星



A diagram of [Jupiter](#) showing a model of the planet's interior, with a rocky [core](#) overlaid by a deep layer of liquid metallic hydrogen (shown as magenta) and an outer layer predominantly of [molecular hydrogen](#). Jupiter's true interior composition is uncertain. For instance, the core may have shrunk as convection currents of hot liquid metallic hydrogen mixed with the molten core and carried its contents to higher levels in the planetary interior. Furthermore, there is no clear physical boundary between the hydrogen layers—with increasing depth the gas increases smoothly in temperature and density, ultimately becoming liquid. Features are shown to scale except for the aurorae and the orbits of the [Galilean moons](#). By [KelvinSong](#)

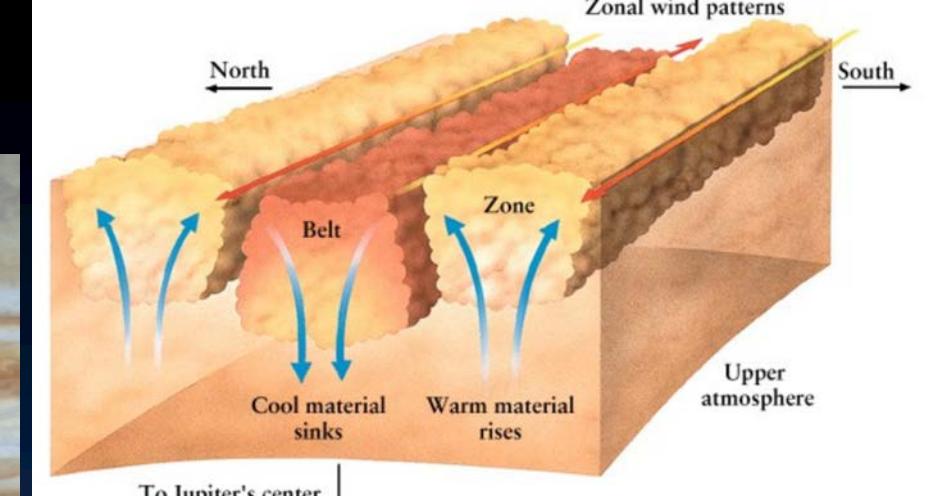


Photos of Jupiter  
or  
The Starry Night?

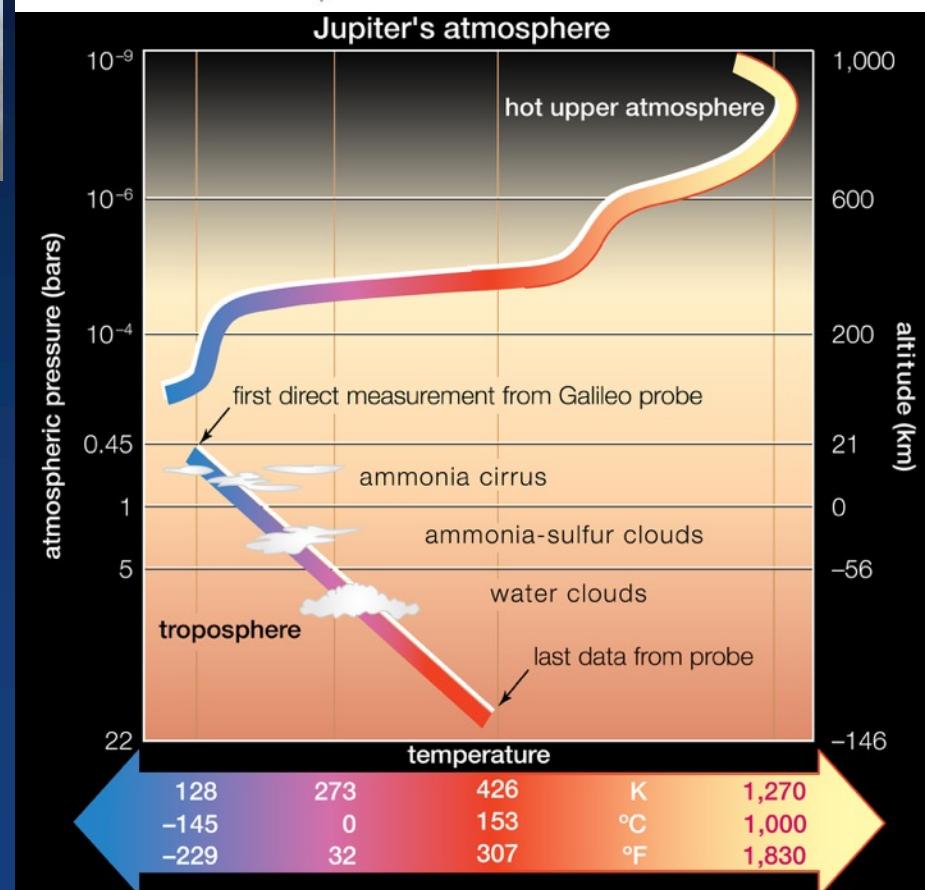
# What if you fell into Jupiter



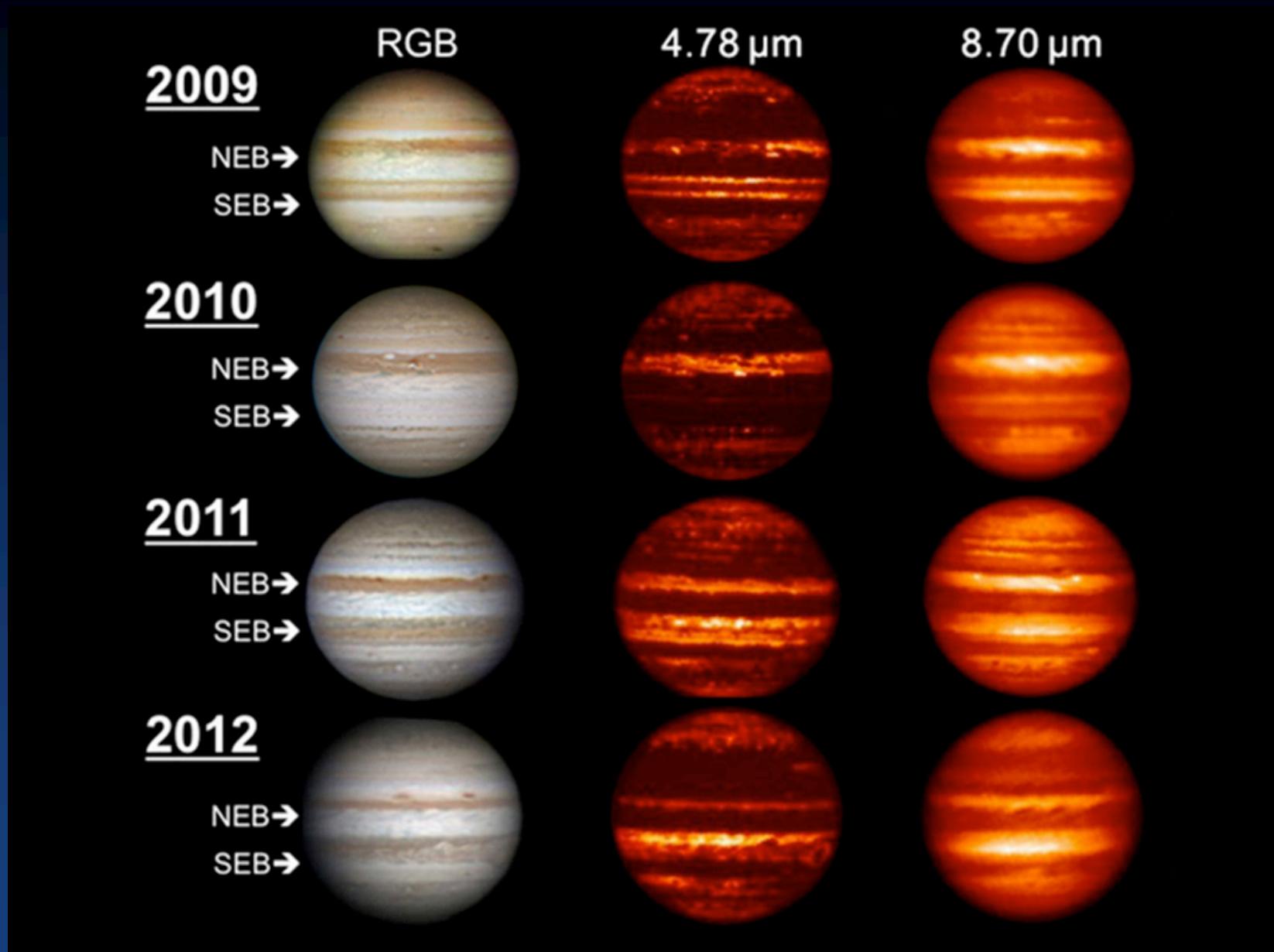
### 3.1.2 大气和雾霾



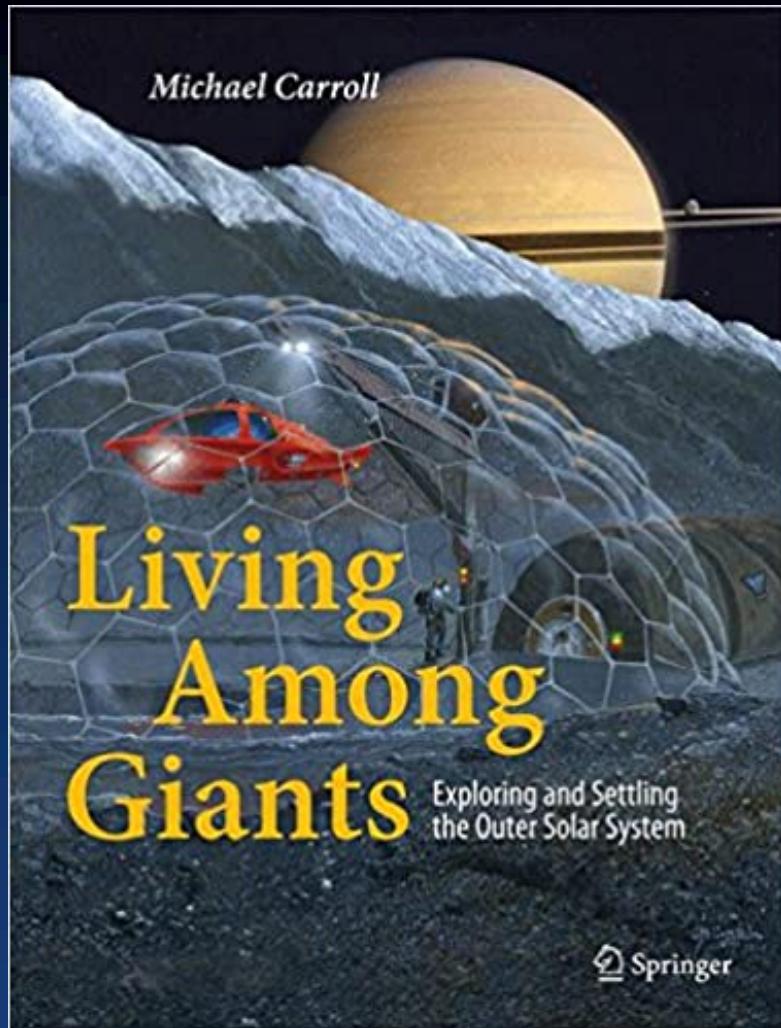
- Darker belt: phosphorus (磷) compounds ionized by radiation and lightning in the fast-moving winds
- Whiter zones: surface ammonia (氨) gas crystallizing
- Temperature upper inversion: absorption of solar energy at these altitudes by gases and aerosol particles (similar to Earth's ozone)
- <https://www.teachastronomy.com/textbook/The-Giant-Planets-and-Their-Moons/Clouds-and-Weather-on-Gas-Giant-Planets/>
- <https://cosmicpursuits.com/2126/guide-to-observing-planet-jupiter/>



# 变化的大气环流



# Extreme Weathers



- “木星大气主要由氢和氮组成，与甲烷等化学物质混合成一种极度的混沌态弥散在大气中，棕褐色和灰色映衬着木星和土星的大气。闪电穿透厚厚的云层，一次放电的能量足够一座小城市使用数周。木星巨大的红斑是个超级气旋，足以吞下三个地球。”
- 而土星在北极上空存在一个六角形的巨型云团，以北极点为中心，横跨北半球，并随着土星自传而旋转。
- 天王星和海王星大气结构则不同于木星和土星，属于冰巨星。天王星是太阳系内温度最低的行星，大气中的甲烷吸收了红色光谱，使得天王星和海王星呈现出蓝色。由于天王星是远日行星，观测效果偏向绿色，加上淡黄色的环，使得天王星越加神秘。
- 科学家认为海王星上的甲烷雨会迅速凝结，并膨胀成一个皮球大小。海王星的天空中没有云，因为甲烷雨在大气中消失得太快了。”

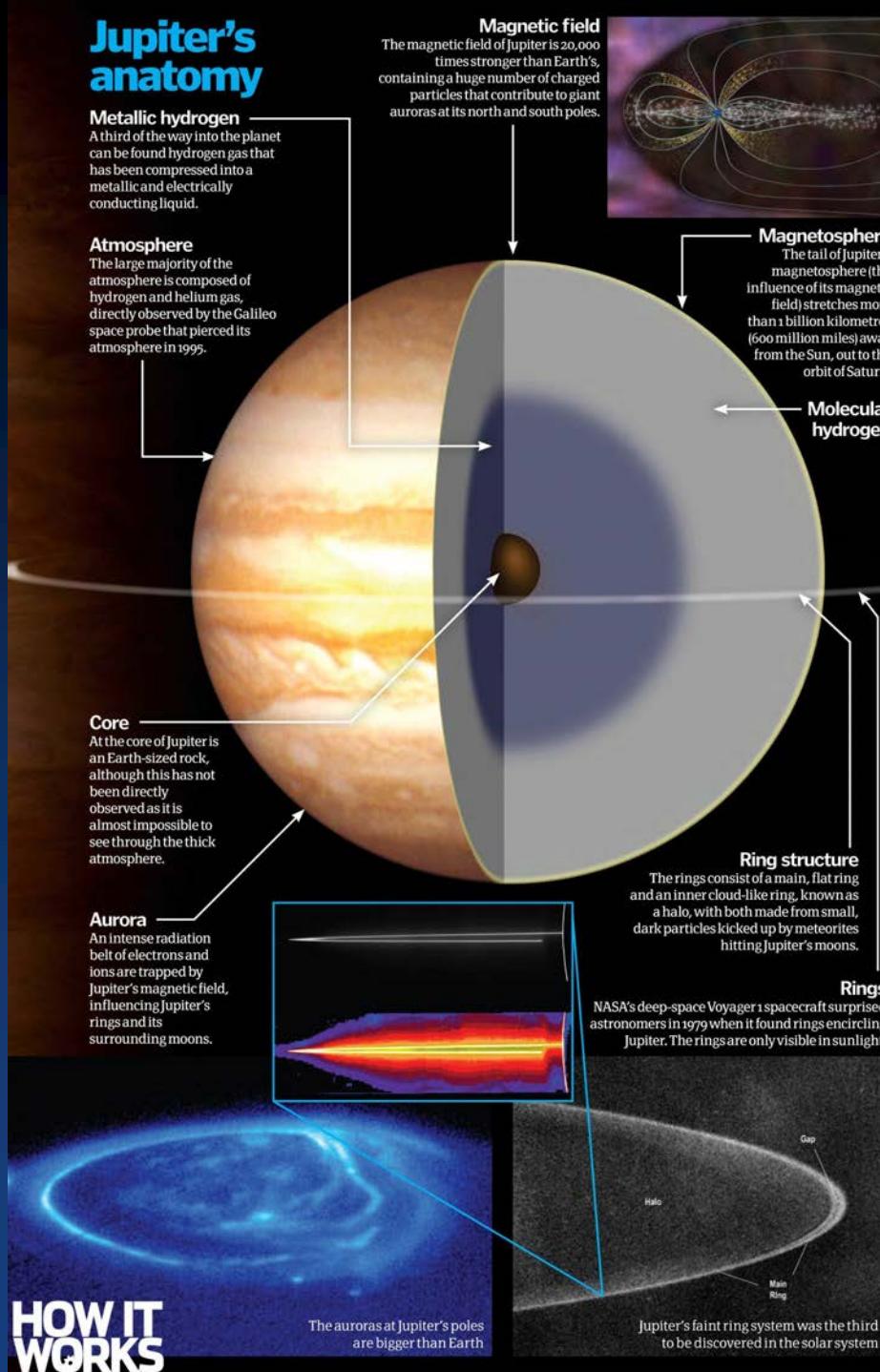
*From: <http://www.uux.cn/viewnews-27614.html>*

Additional Ref: *The Science of Extreme Weather:*

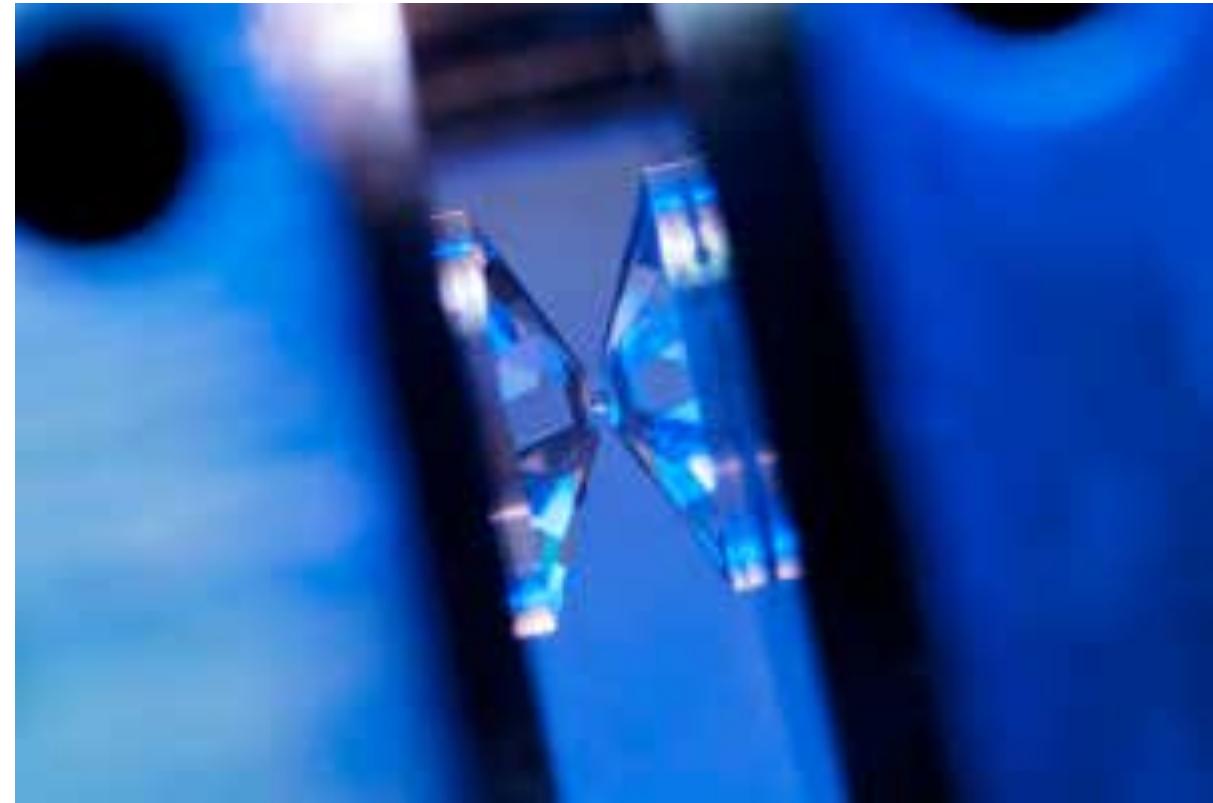
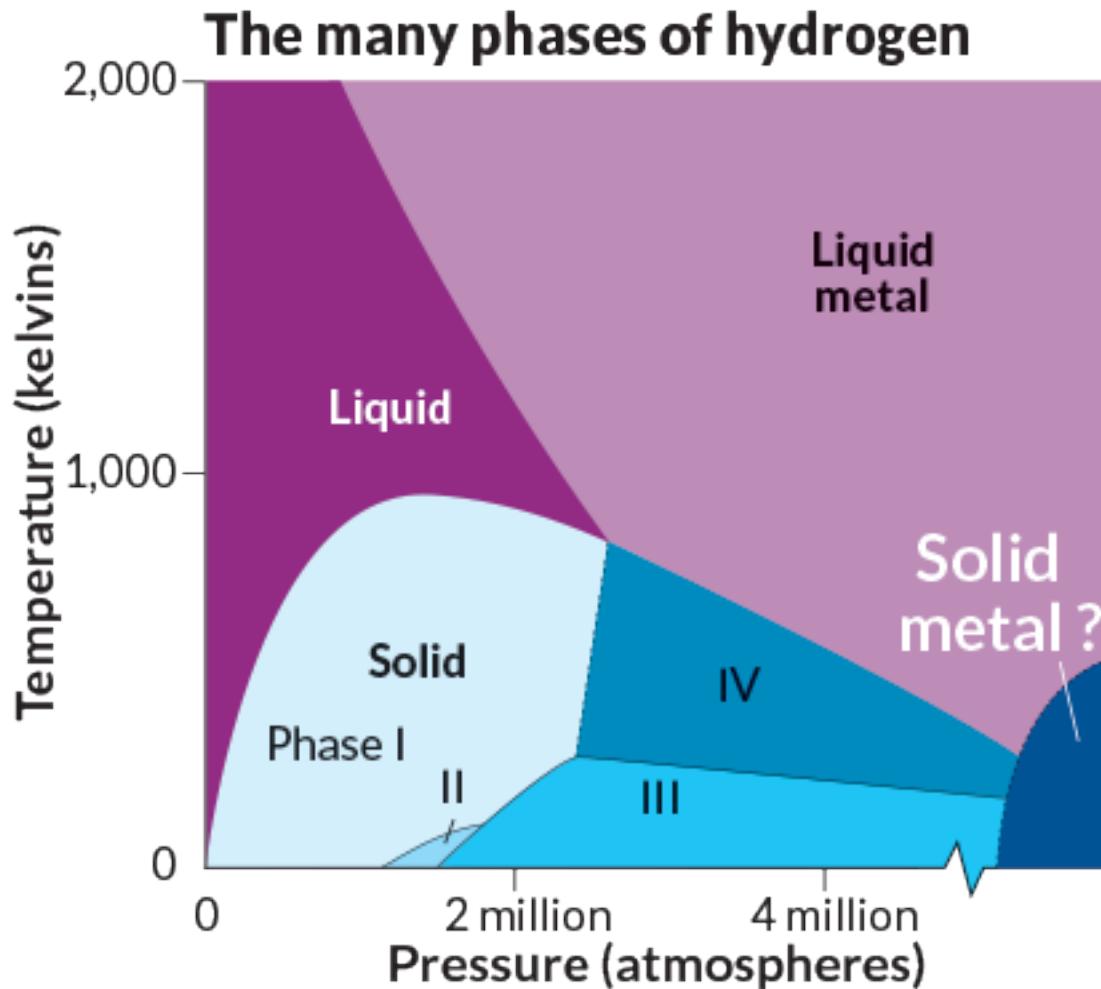
<https://www.thegreatcourses.com/courses/the-science-of-extreme-weather.html>

### 3.1.3 Magnetic Field of Jovian Planets

- Metallic hydrogen: At high pressure, hydrogen become ionized. Free electrons make the gas electrically conductive.



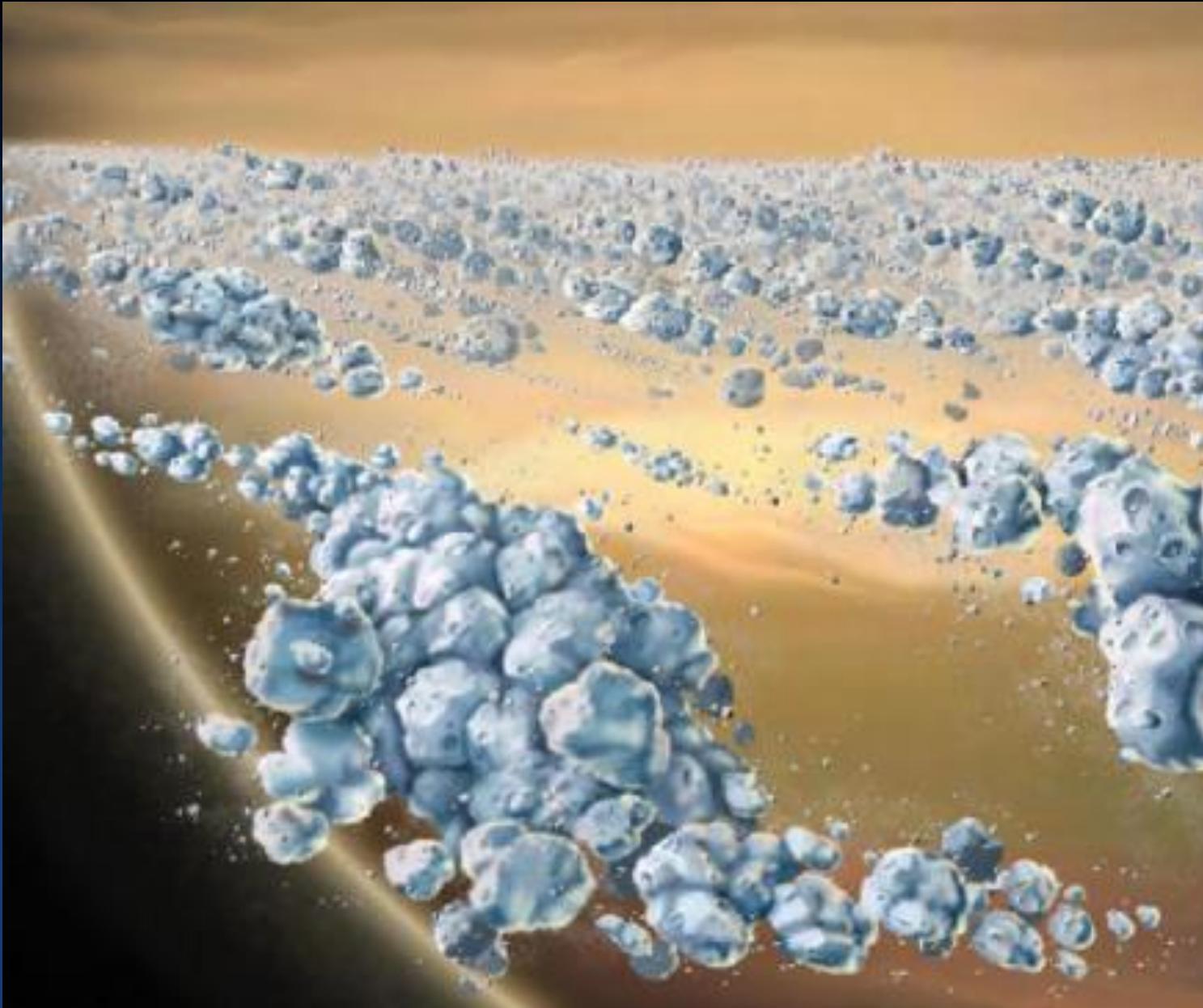
# Metallic Hydrogen: Best Rocket Fuel?



Diamond anvils can achieve pressures higher than those at Earth's core. Max Alexander/Science Photo Library

Read more: <https://www.newscientist.com/article/mg24532630-800-metallic-hydrogen-would-be-the-ultimate-fuel-if-we-can-make-it/#ixzz6GMeyleEs>

### 3.1.4 Rings of Saturn



**Artist's Idealized Impression of the Rings of Saturn as Seen from the Inside.** Note that the rings are mostly made of pieces of water ice of different sizes. At the end of its mission, the Cassini spacecraft is planning to cut through one of the gaps in Saturn's rings, but it won't get this close. (credit: modification of work by NASA/JPL/University of Colorado)

# Moons and rings of Saturn into music

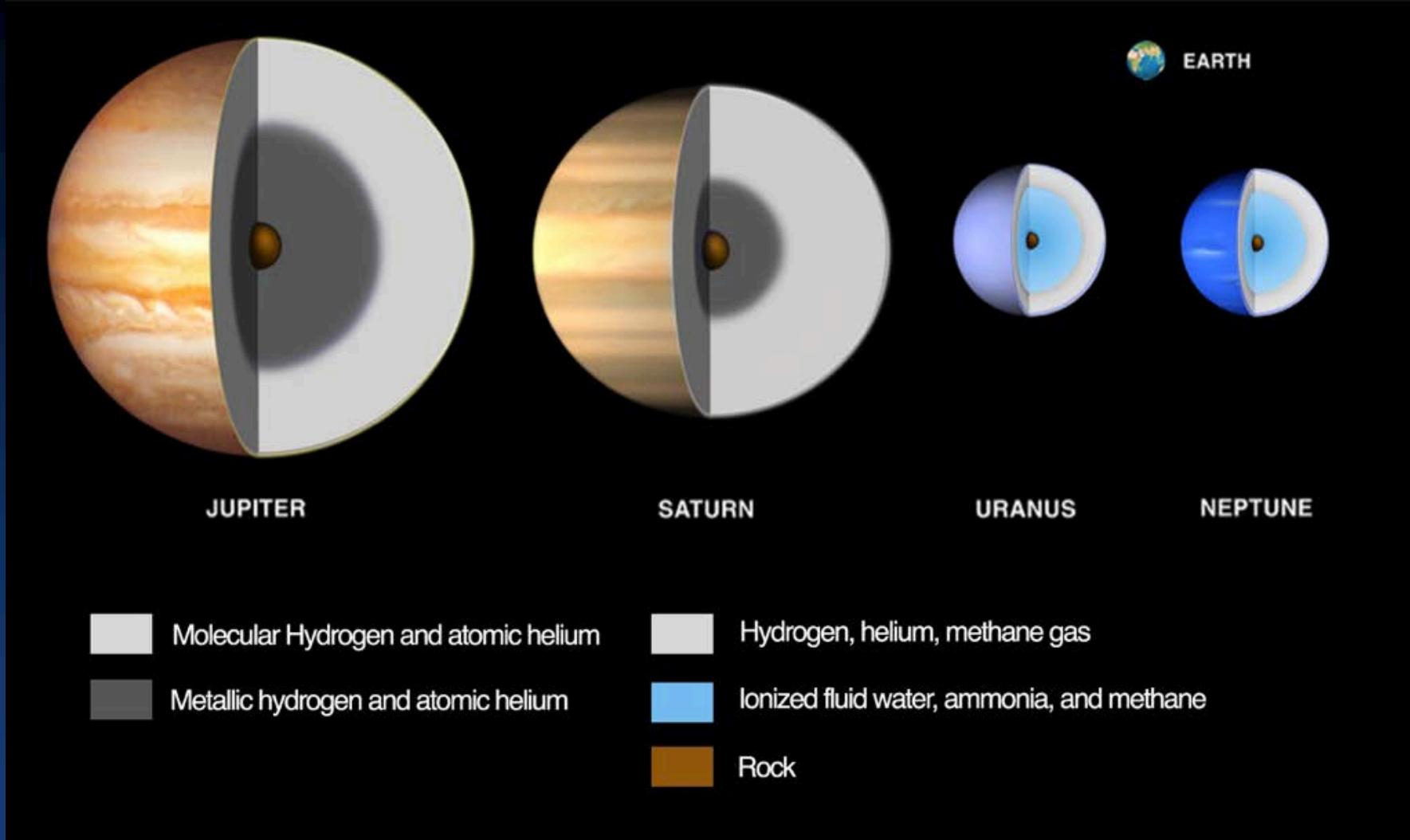


- <https://www.youtube.com/watch?v=UGnuDE7sINI&feature=youtu.be>
- Increased the natural orbital frequencies of Saturn's six large inner moons by 27 octaves (八度音阶) to arrive at musical notes. "What you hear are the actual frequencies of the moons, shifted into the human hearing range" says Russo. The team then used a state of the art numerical simulation of the moon system developed by Tamayo to play the resulting notes every time a moon completes an orbit.

# Orbital Resonance

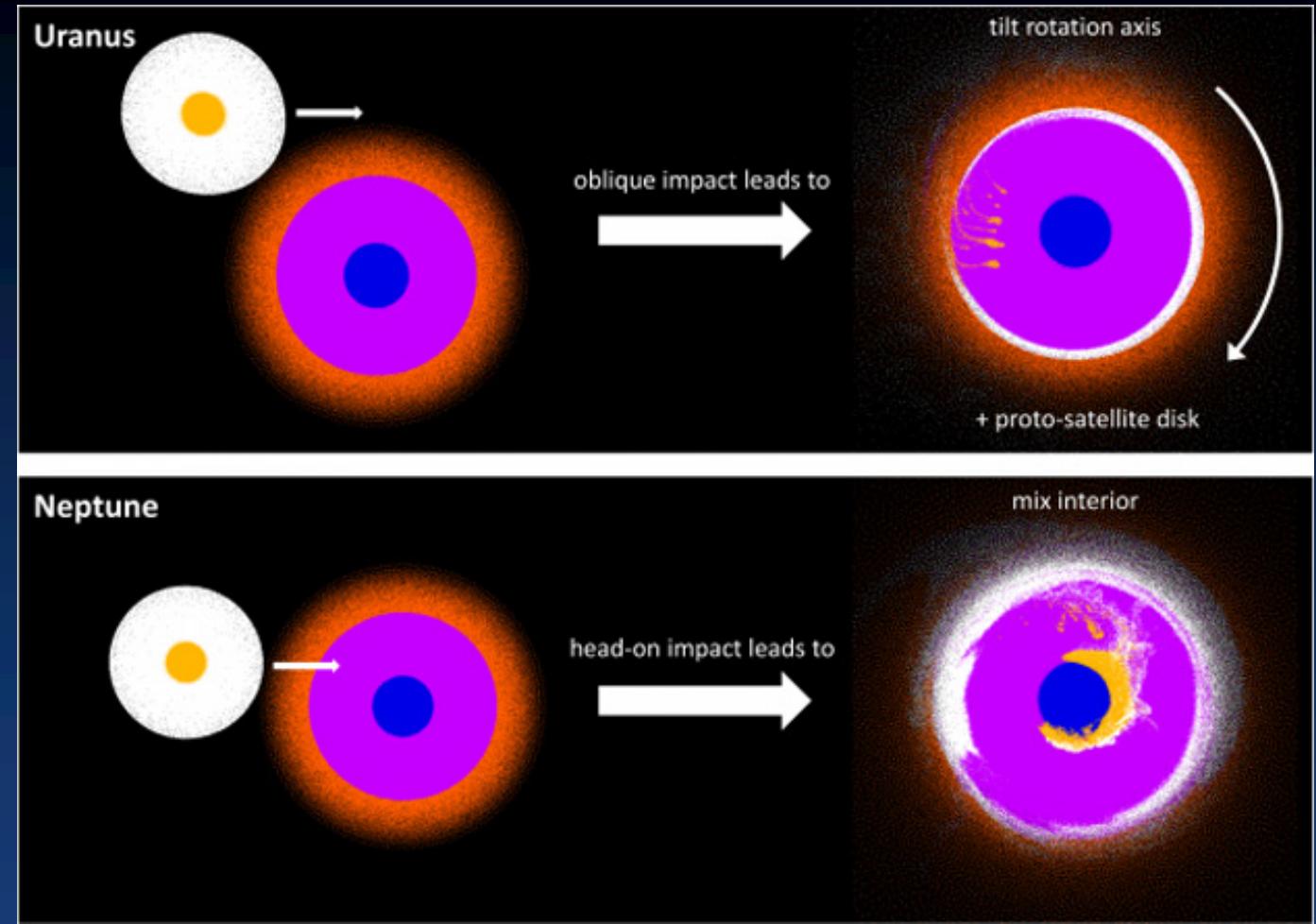
- Elliptical orbits
- Tidal Force -> orbital drift

### 3.1.5 Ice Giants: 天王星和海王星



- Mantle: water,  $\text{NH}_3$ ,  $\text{CH}_4$  ices

# Uranus & Neptune

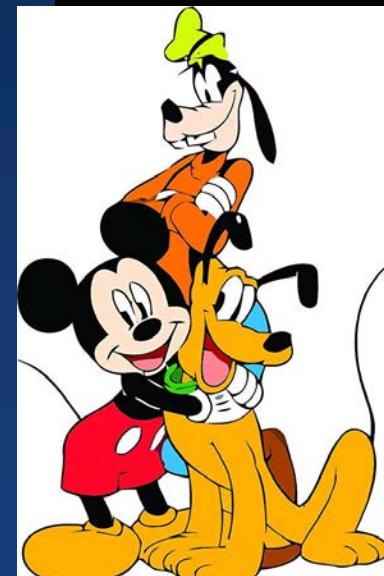


- <http://spaceref.com/uranus/why-uranus-and-neptune-are-different.html>

### 3.1.6 The Story Behind Pluto Now Becoming a Dwarf

- **April 6, 1929: Search for Planet X Begins** (Percival Lowell)
- **February 18, 1930: Pluto Discovered** (Clyde Tombaugh)
- **June 22, 1978: Charon Discovered**
- **February 7, 1979: Pluto Crosses Neptune's Orbit**
- **January 19, 2006: New Horizons Launched**
- **August 24, 2006: Pluto Demoted to Dwarf Planet**
- **July 14, 2015: New Horizons Flies by Pluto**

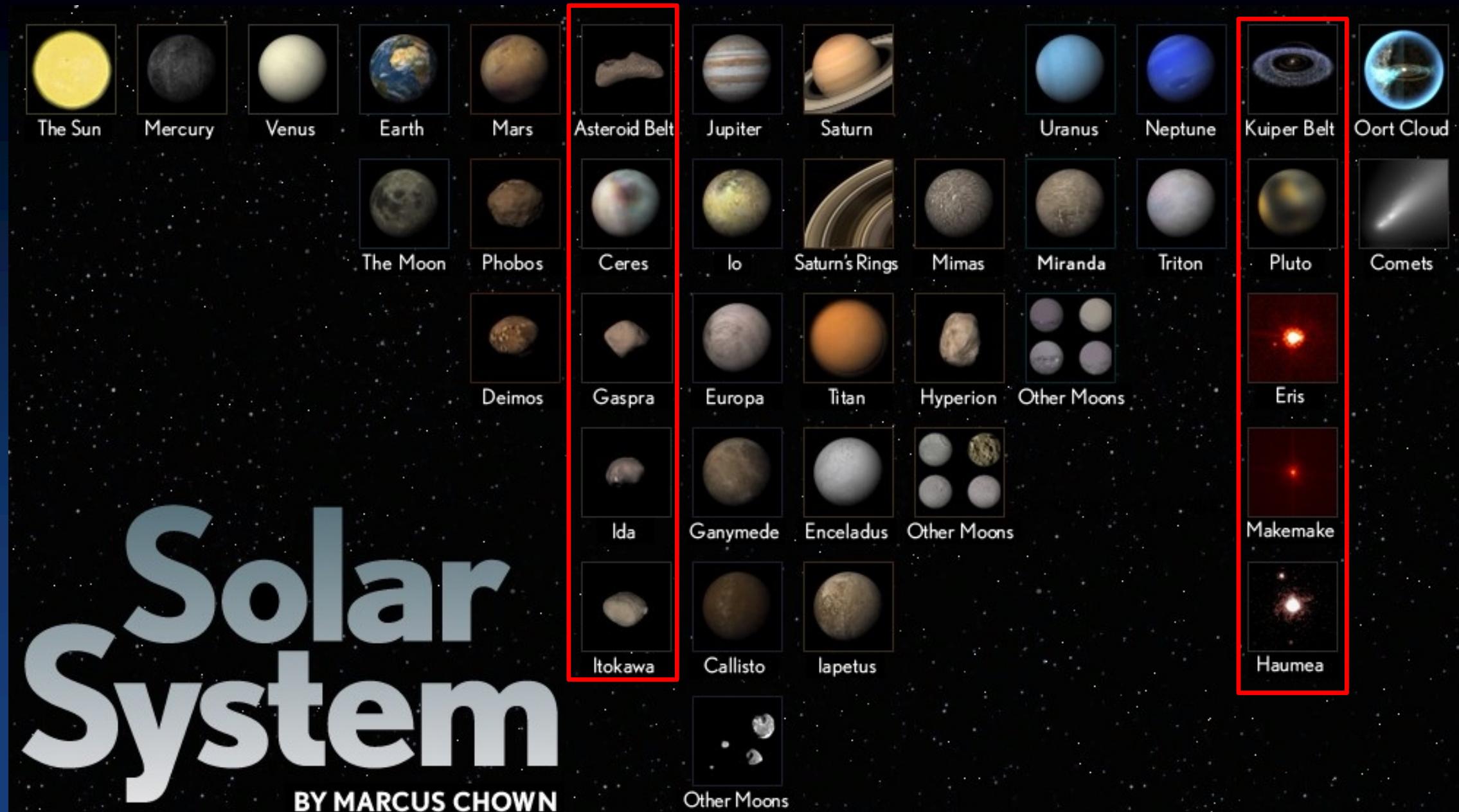
Double Planet: Pluto & Charon



<https://www.britannica.com/list/10-important-dates-in-pluto-history>

# Discussions - What's Your Opinion?

### 3.1.7 Planets' Moon, Dwarf Planets, Asteroids, Comets



# Dwarf Planets, Comets, and Asteroids

**SPACE.COM**

[www.SPACE.com](http://www.SPACE.com)

## Dwarf Planets in the Solar System

In 2006, the organization responsible for classifying celestial bodies, the International Astronomical Union (IAU) decided that a new class of objects was needed. Pluto, considered a planet since its discovery in 1930, was reclassified into the new “dwarf planet” category. To date, five dwarf planets have been found, although some astronomers expect there may be as many as 50 in the solar system.

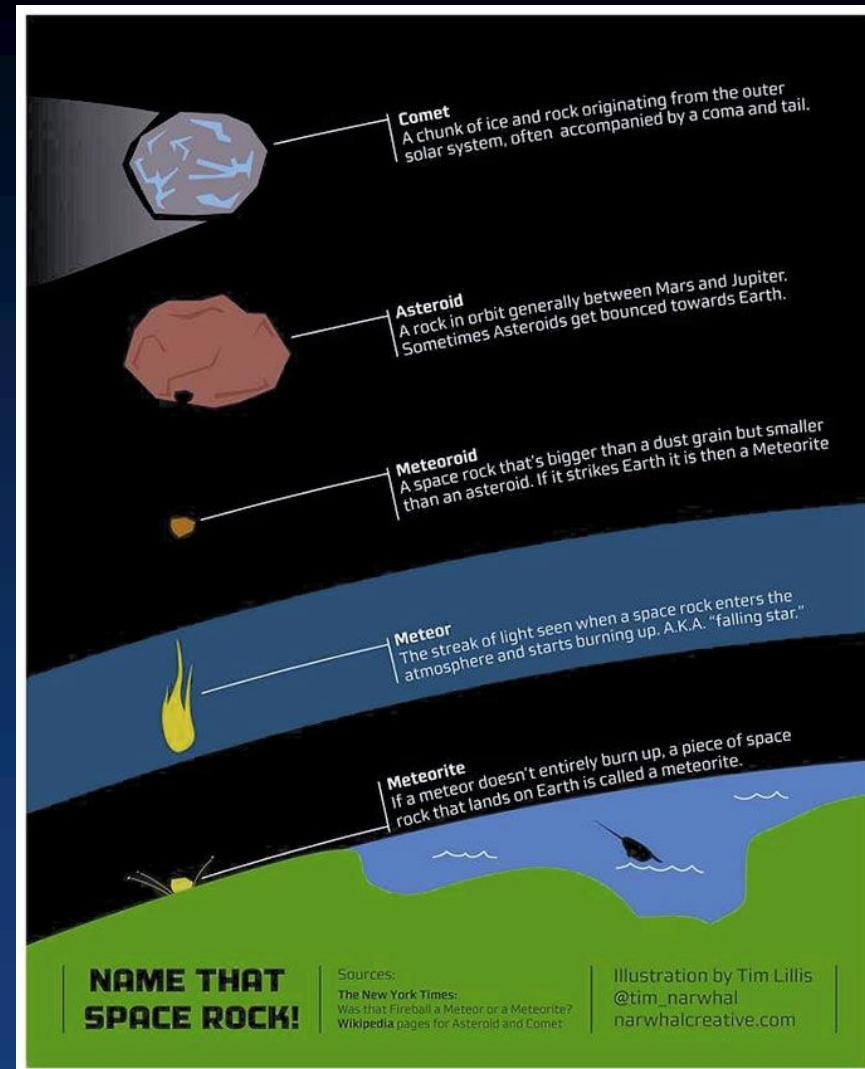
Earth's moon to scale

ERIS PLUTO HAUMEA MAKEMAKE CERES

Year of discovery	2003	1930	2003	2005	1801
Diameter (mean)	1,445 miles 2,326 km	1,430 miles 2,302 km	892.3 miles 1,436 km	882 miles 1,420 km	591.8 miles 952.4 km
Orbital period (Earth years)	561.4	247.9	281.9	305.34	4.6
Distance from sun (times Earth's distance)	68	39.5	43.1	45.3	2.8
Orbital inclination (degrees)	46.9	17.14	28.2	29	10.59
Rotation period	25.9 hours	6.39 Earth days	3.9 hours	22.5 hours	9.1 hours
Moons	1	5	2	0	0

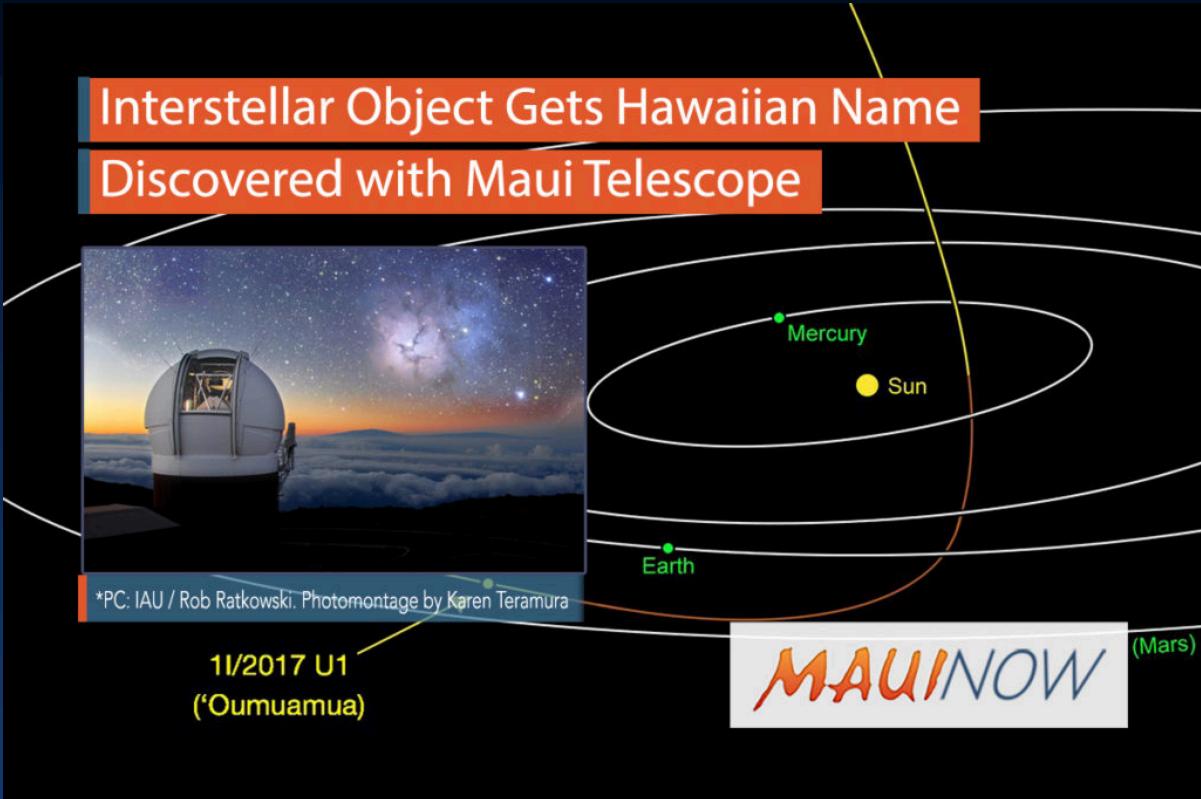
SOURCE: NASA

KARL TATE / © SPACE.com



- Periodic comets originate in the Kuiper belt
- Nonperiodic comets come from the Oort cloud

# The first confirmed interstellar object to visit solar system 'Oumuamua 奥陌陌 (2017/10/28)



Artist's impression of 'Oumuamua

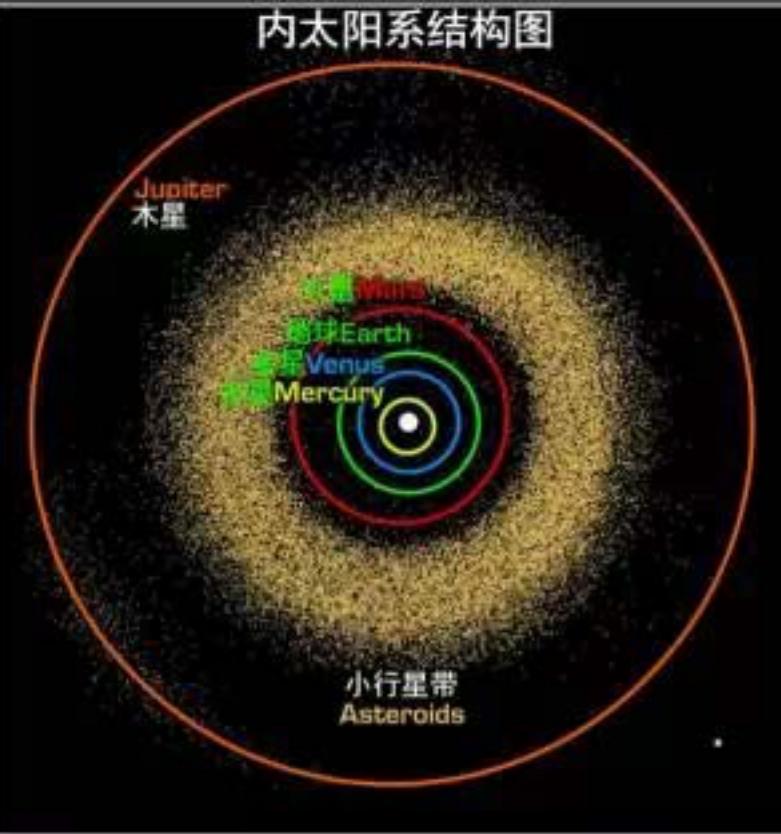
- It was briefly classified as an asteroid until new measurements found it was accelerating slightly, a sign it behaves more like a comet.

# Summary: 太阳系结构

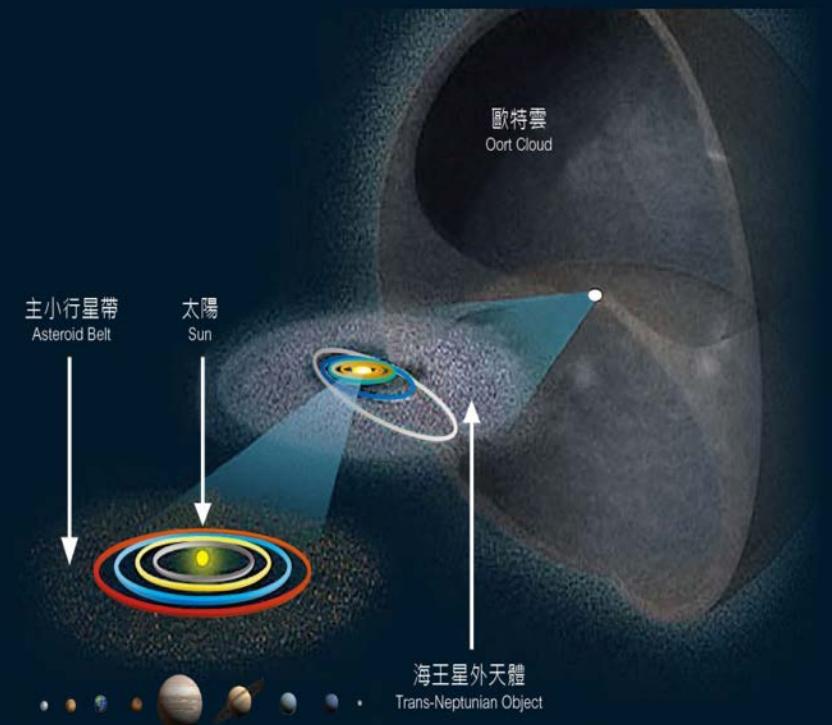
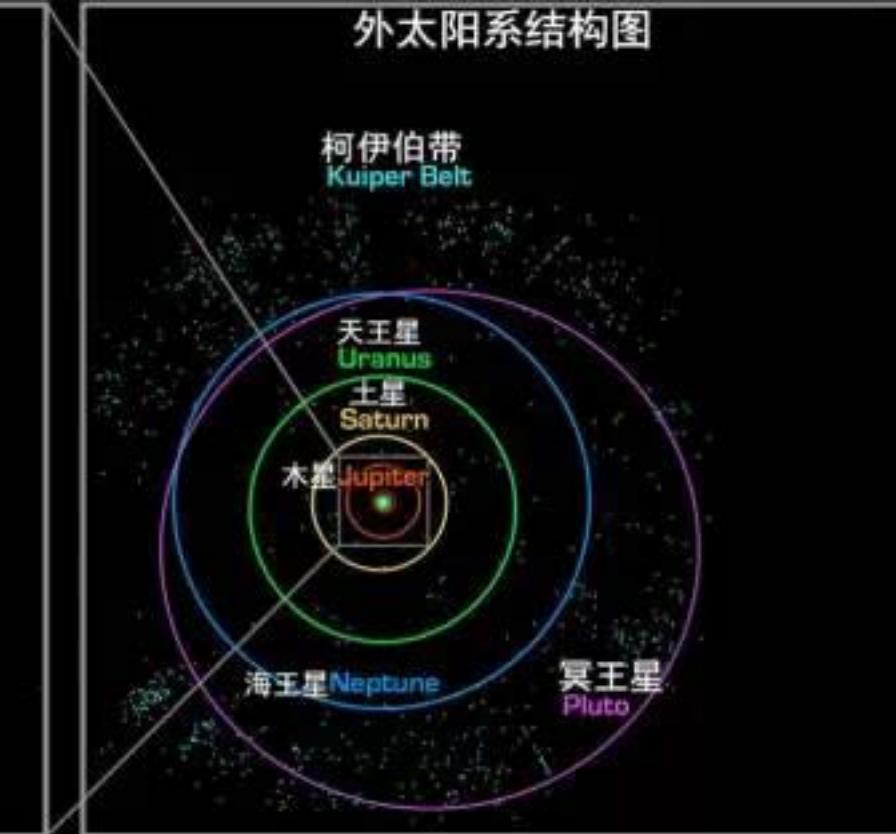
示意图

三维图

内太阳系结构图



外太阳系结构图



实际比例



## 3.2 Formation and Evolution of the Solar System

- Nebula Hypothesis
- Planet Migration Hypothesis: NICE Model
- Moon Formation Hypothesis

# Hypothesis, Data, Theory, and Fact (Law)

## 2 Formation hypothesis

- 2.1 Alternative theories
  - 2.1.1 Tidal theory
  - 2.1.2 The Chamberlin-Moulton model
  - 2.1.3 Lyttleton's scenario
  - 2.1.4 Band-structure model
  - 2.1.5 Interstellar cloud theory
  - 2.1.6 Hoyle's hypothesis
  - 2.1.7 Kuiper's theory
  - 2.1.8 Whipple's theory
  - 2.1.9 Urey's model
  - 2.1.10 Protoplanet theory
  - 2.1.11 Cameron's hypothesis
  - 2.1.12 Capture theory
  - 2.1.13 Solar fission
  - 2.1.14 Herndon's model

## 2.1.15 Classification of the theories

## 2.2 Reemergence of the nebular hypothesis

## 2.3 Outstanding issues

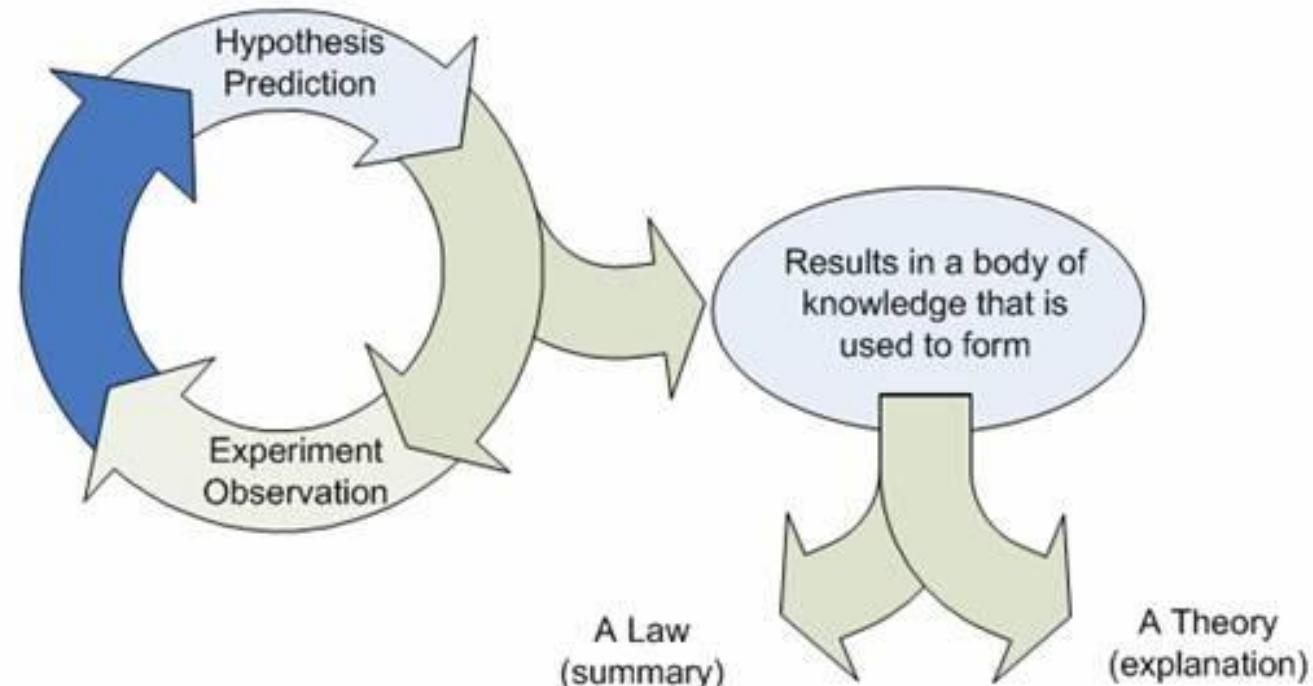
## 3 Solar evolution hypotheses

- 3.1 Kelvin-Helmholtz contraction
- 3.2 Red giants
- 3.3 White dwarfs
- 3.4 Planetary nebulae

## 4 Lunar origins hypotheses

- 4.1 Apollo missions
- 4.2 Giant impact hypothesis
- 4.3 Outstanding issues
- 4.4 Other natural satellites

## Scientific Method



## 3.2.1 Nebula hypothesis 星云假说 (~1800): Emanuel Swedenborg, Immanuel Kant, Pierre Simon Laplace



- Tidal locking
- Nebula hypothesis
- Coriolis force
- Physical Geography
- Star and Galaxy
- Philosophy: Perception, Understanding, Morality, Freedom, Political, Aesthetic, Anthropology
- Analysis, probability, and astronomical stability
- Tidal dynamics
- On the figure of the Earth  
Planetary and lunar inequalities
- Black holes
- Analytic theory of probabilities
- Laplace transforms
- Political philosophy

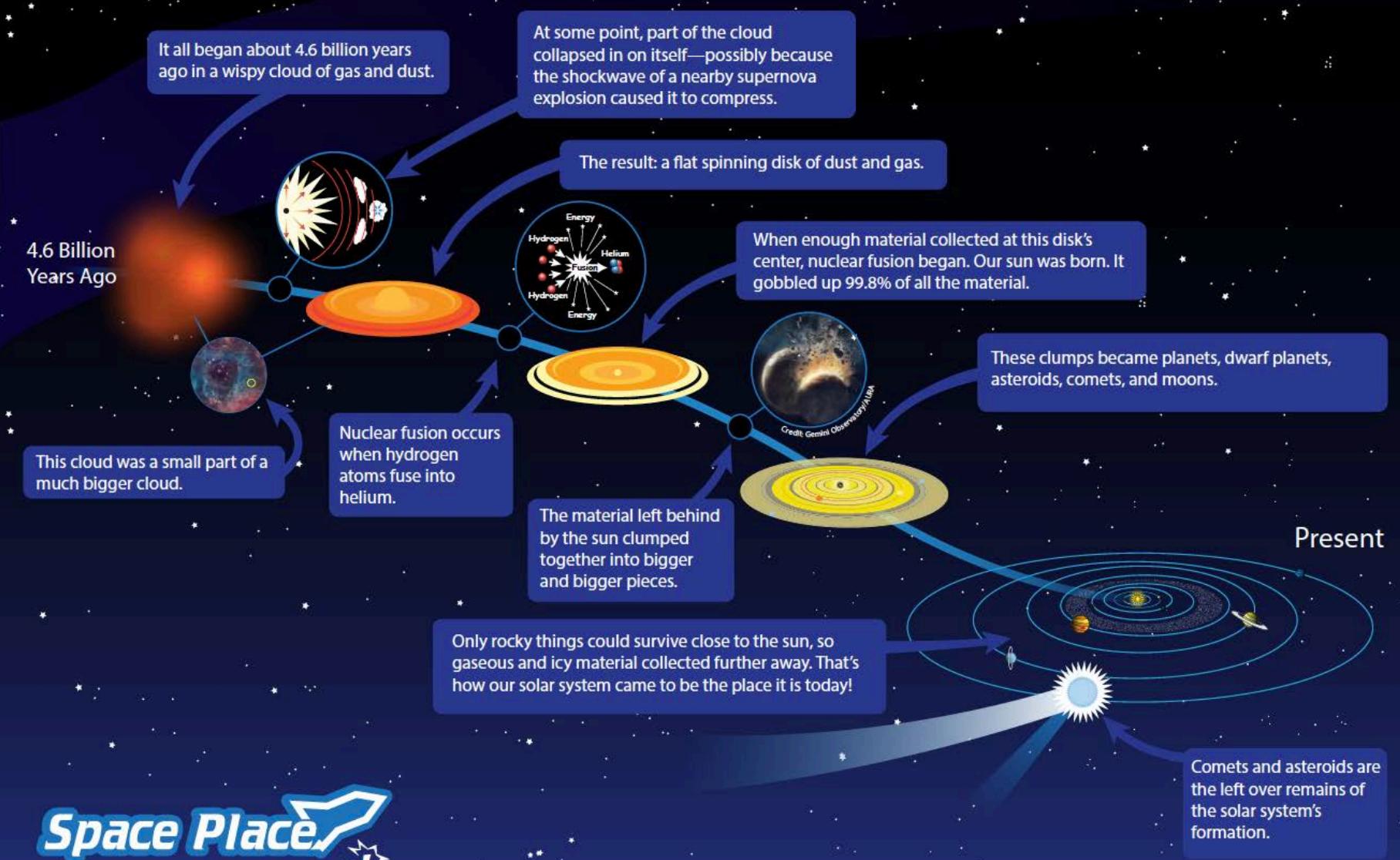
Reference: Wikipedia

# Solar System Formation and Evolution



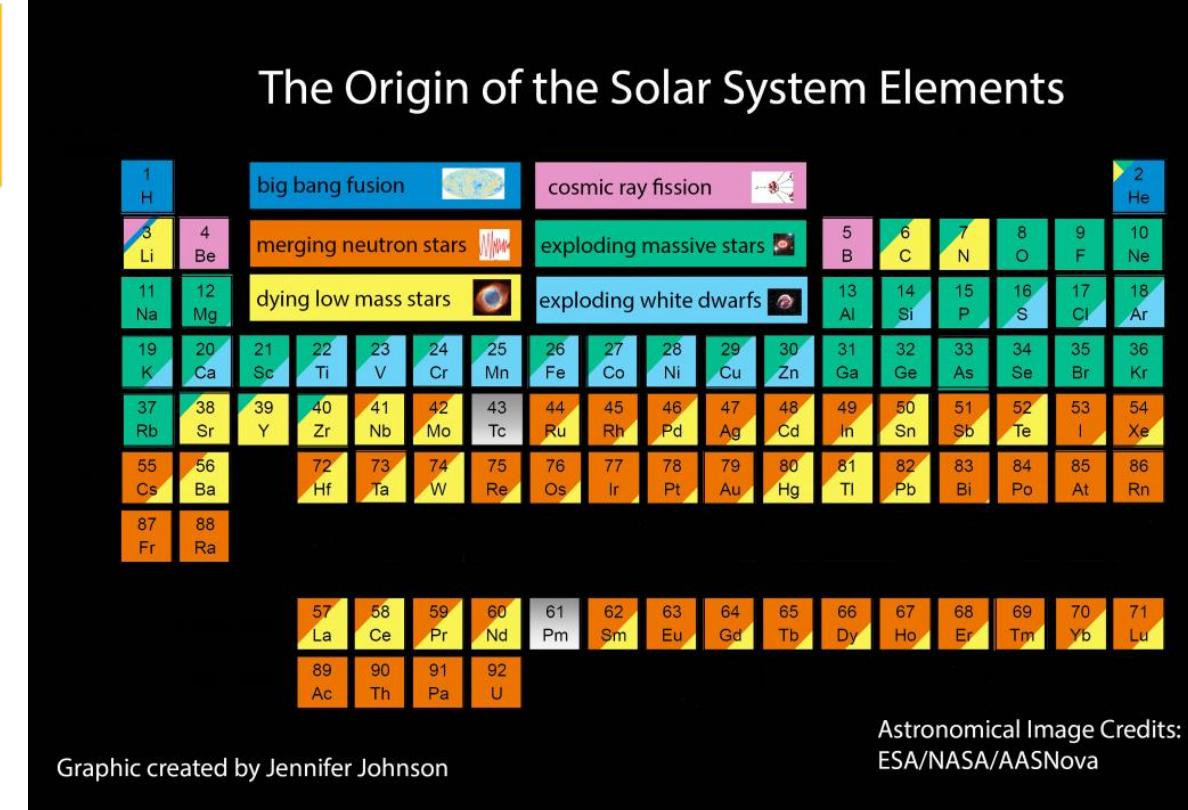
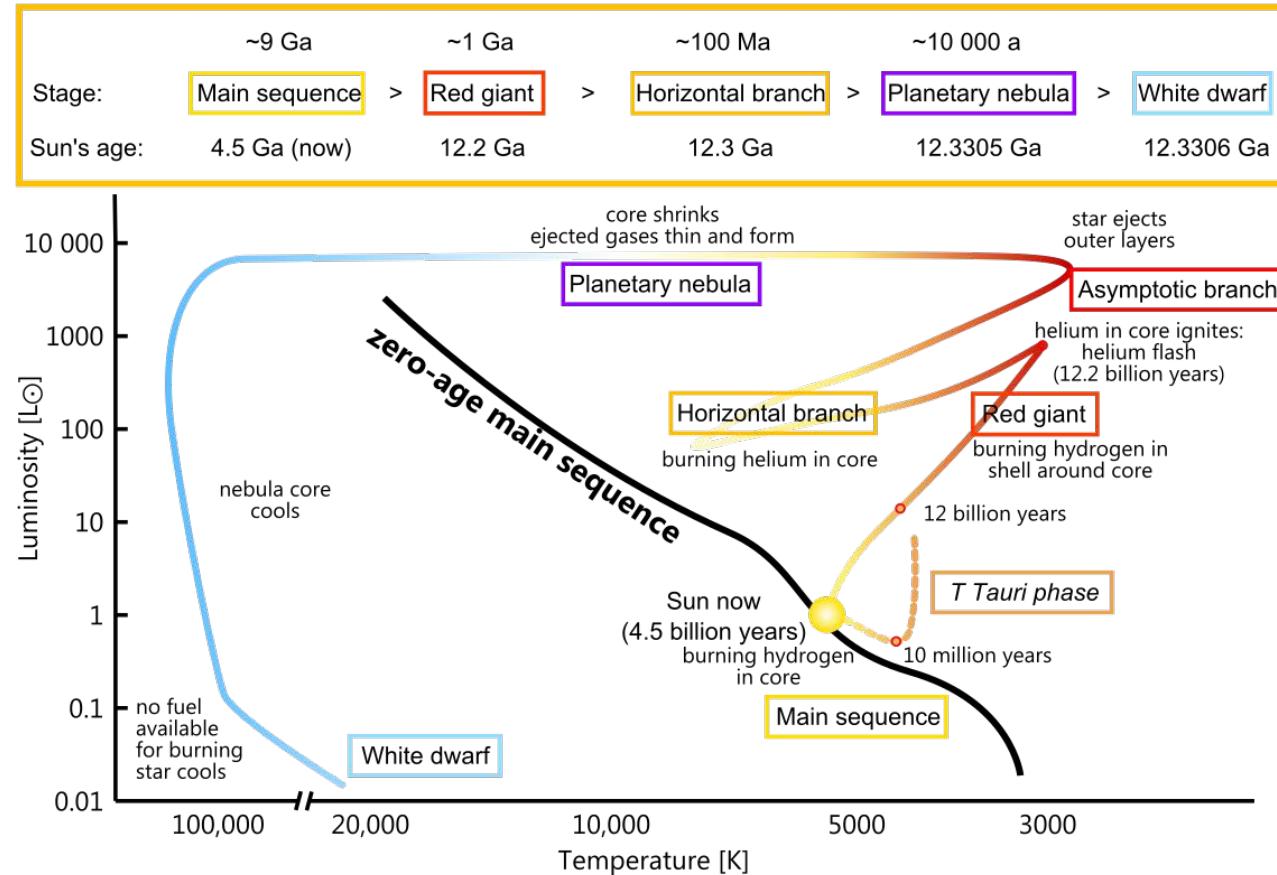
# How did our solar system come to be?

National Aeronautics and  
Space Administration

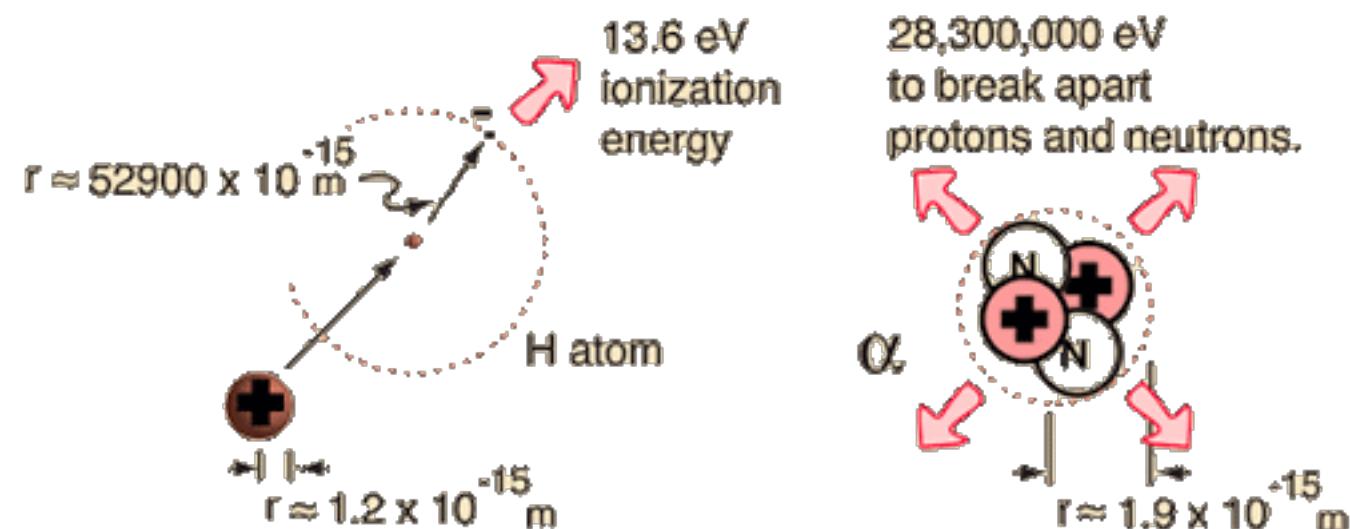
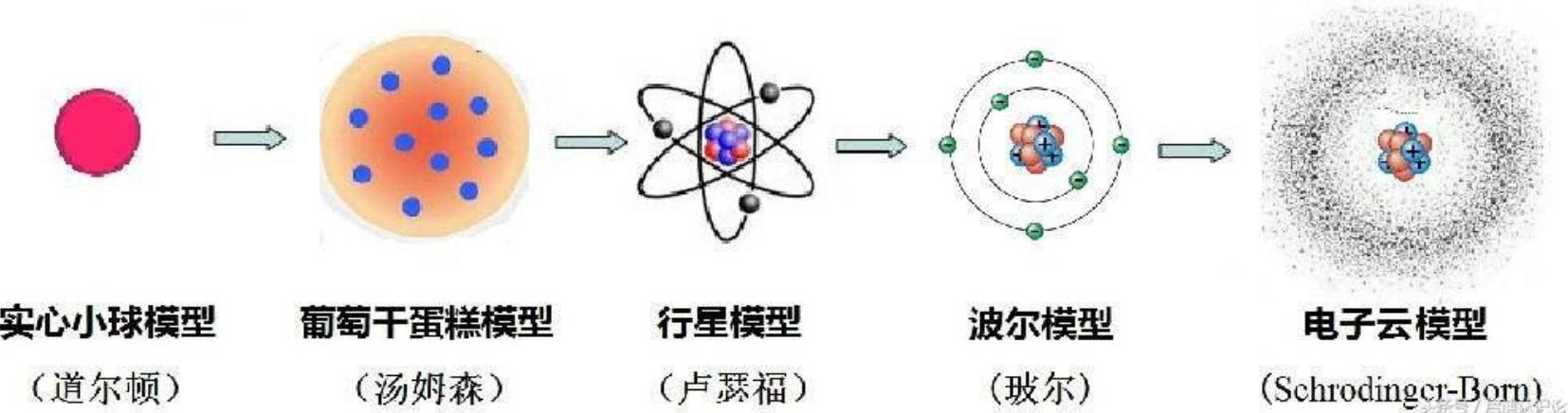


**Space Place**  
in a Snap!

# 太阳的演化



# 原子结构

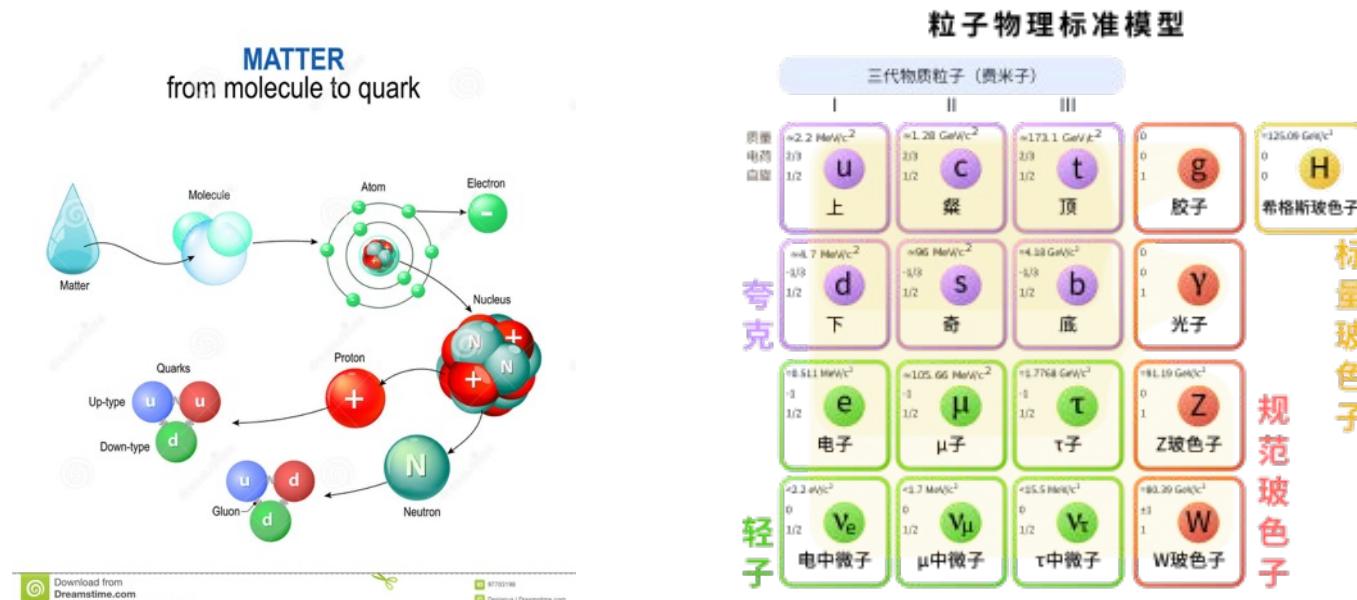


Comparison of atomic and nuclear scales and binding energy

# 强相互作用力和粒子物理标准模型

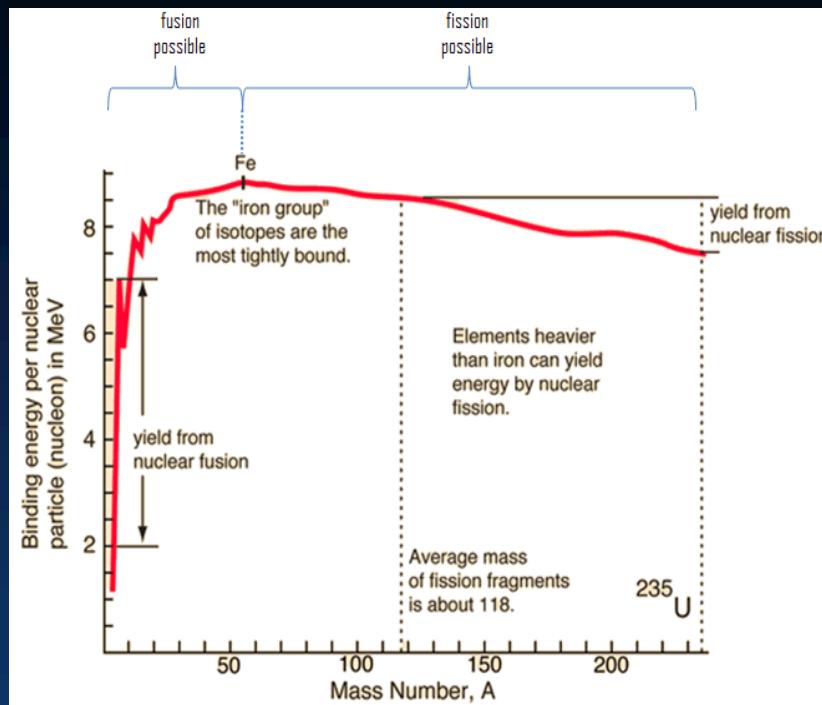
- 1954年，杨振宁和罗伯特·米尔斯提出了非阿贝尔规范群理论（杨-米尔斯理论）。
- 1961年，谢尔登·格拉肖将弱力和电磁力统一起来考虑
- 1967年，史蒂文·温伯格和阿卜杜勒·萨拉姆将电弱统一理论建立在了杨-米尔斯场论的基础之上，将希格斯机制引入格拉肖的弱电理论，从而得到了一个完美而自洽的理论，形成我们现在看到它的形式。
- 1973年发现由Z玻色子引起的弱中性流之后，电弱理论被广泛的接受。由此贡献，萨拉姆和温伯格获得1979年的诺贝尔奖。
- W和Z玻色子在1981年被实验所发现，而他们的质量已经被当时所逐步建立的标准模型预言了。
- 至于强相互作用的理论，大多在1973-74年做出进步：那会儿正是有关实验得出成果的时候。强子所带的分数电荷也是那时候验证的。

From: <https://zh.wikipedia.org/wiki/%E6%A0%87%E5%87%86%E6%A8%A1%E5%9E%8B>

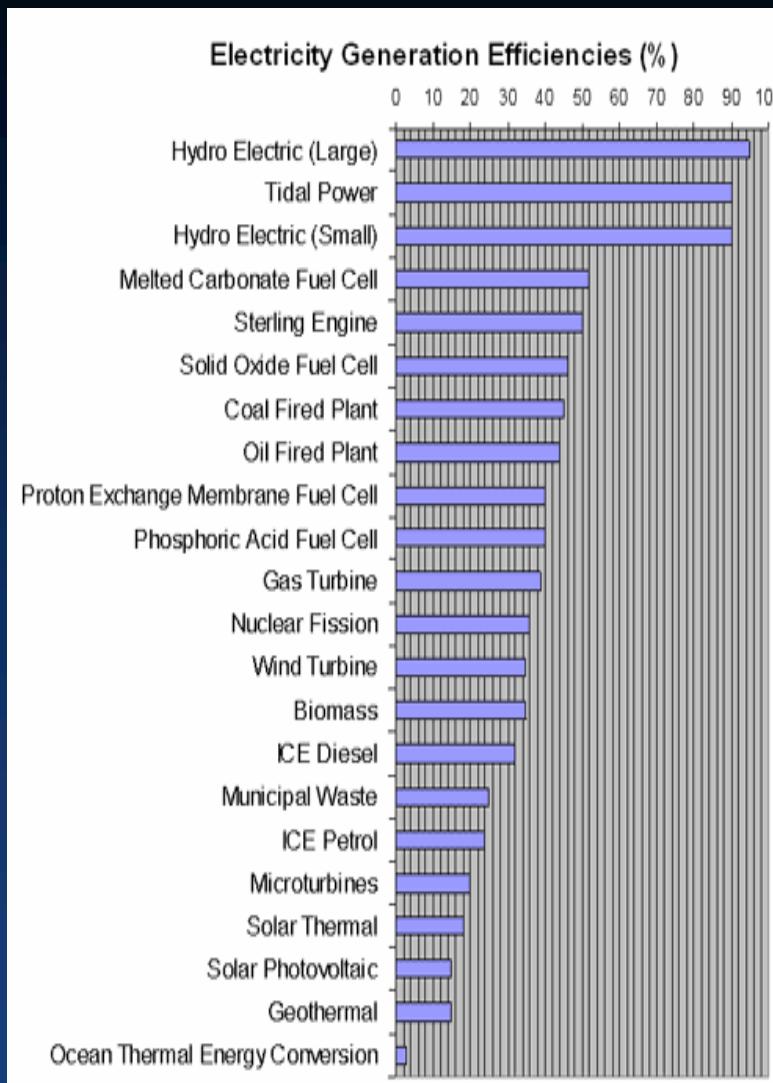


# Nuclear Energy

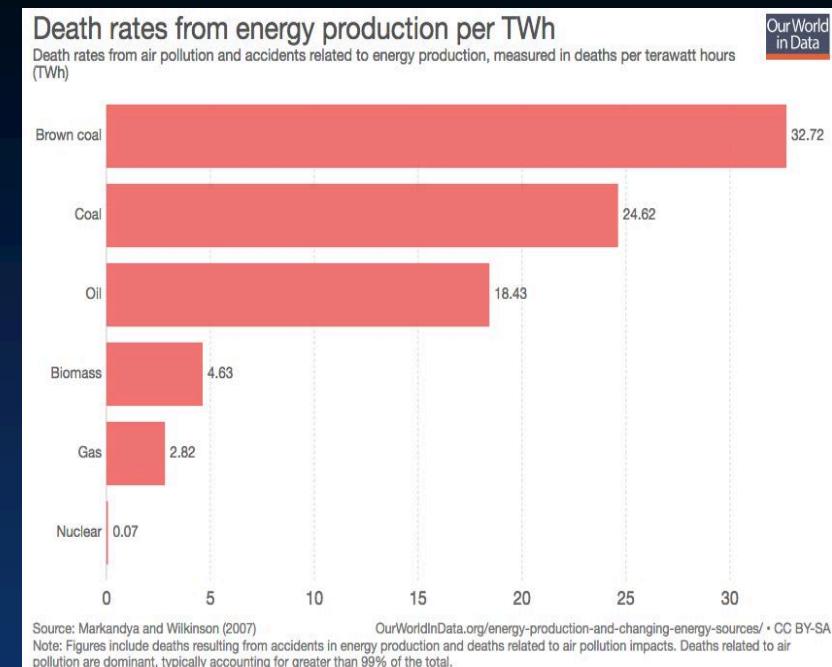
## 核聚变/裂变原理



## 产能率



## 核聚变安全性

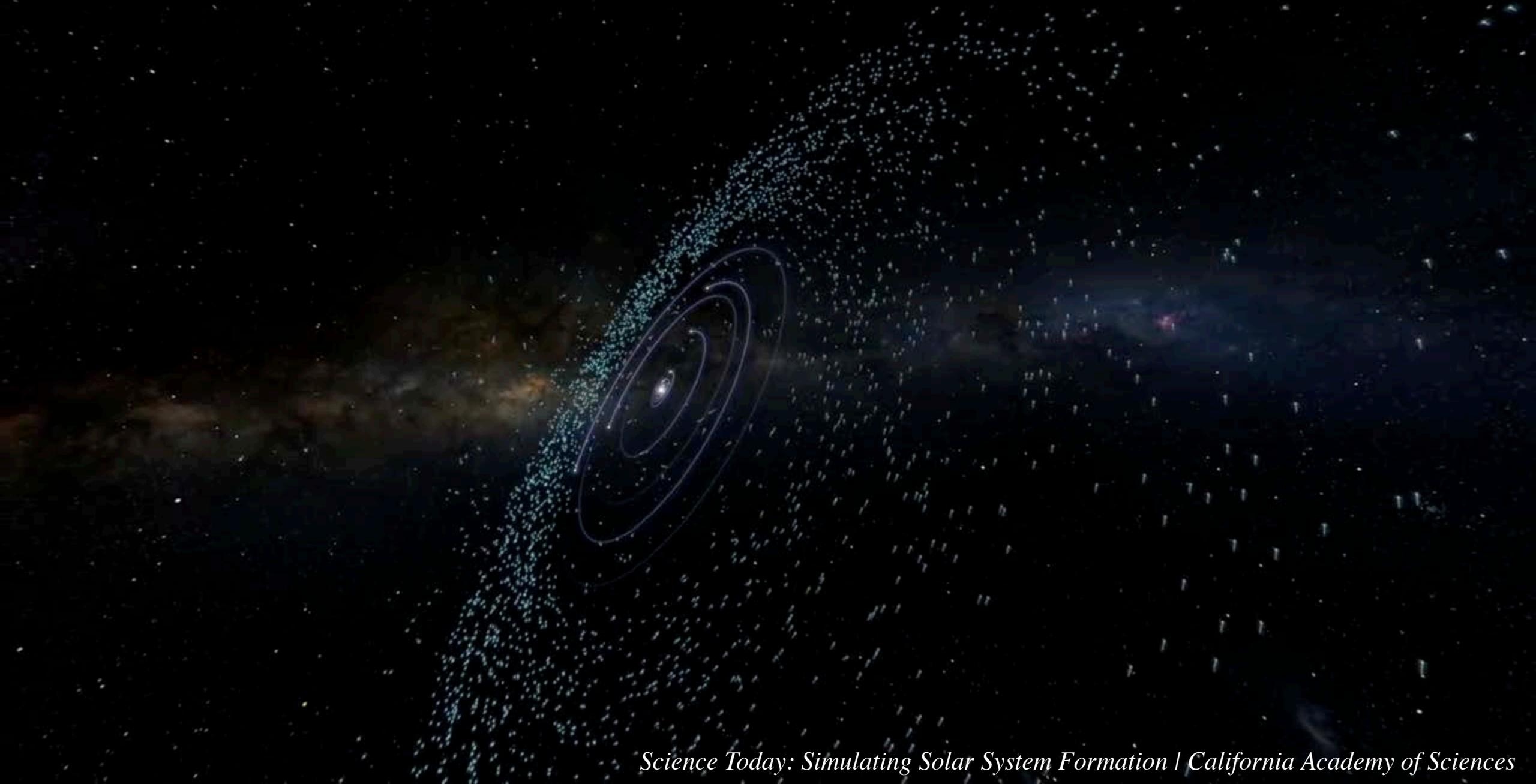


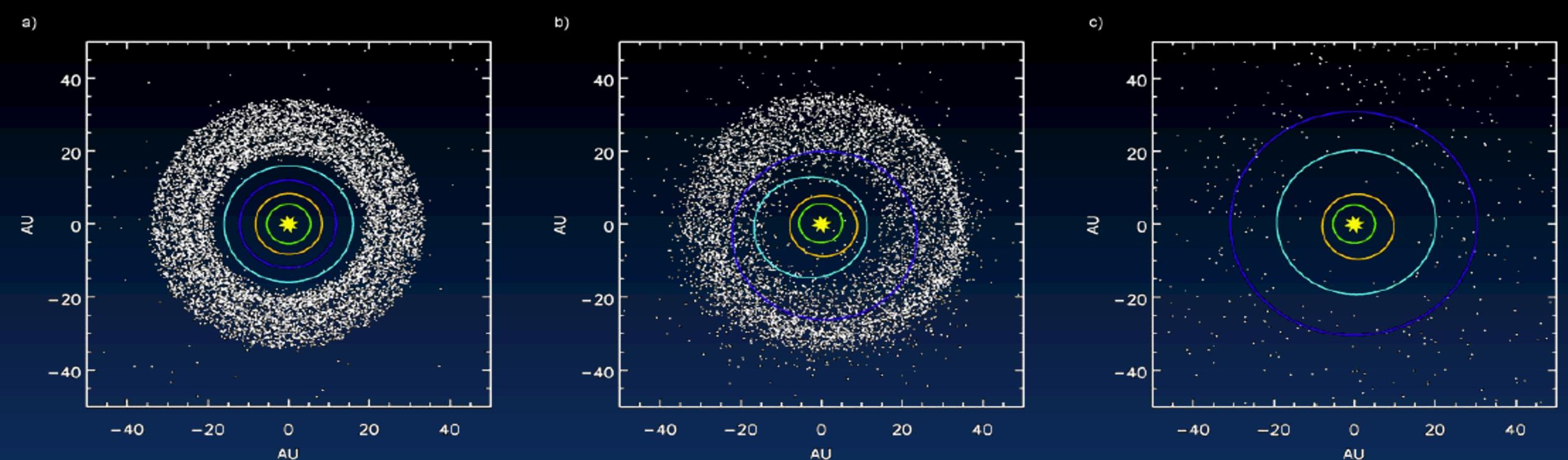
The concept of this so-called "TerraPower reactor" is that you, in the same reactor, you both burn and breed. So, instead of making plutonium and then extracting it, we take uranium - the 99.3 percent that you normally don't do anything with - we convert that, and we burn it.

— Bill Gates —

AZ QUOTES

### 3.2.2 行星轨道演化、月球大灾变原因：Nice Model (2005)





# The '*Nice*' Model

Planet migration in a planetesimal disk

The *Nice* model

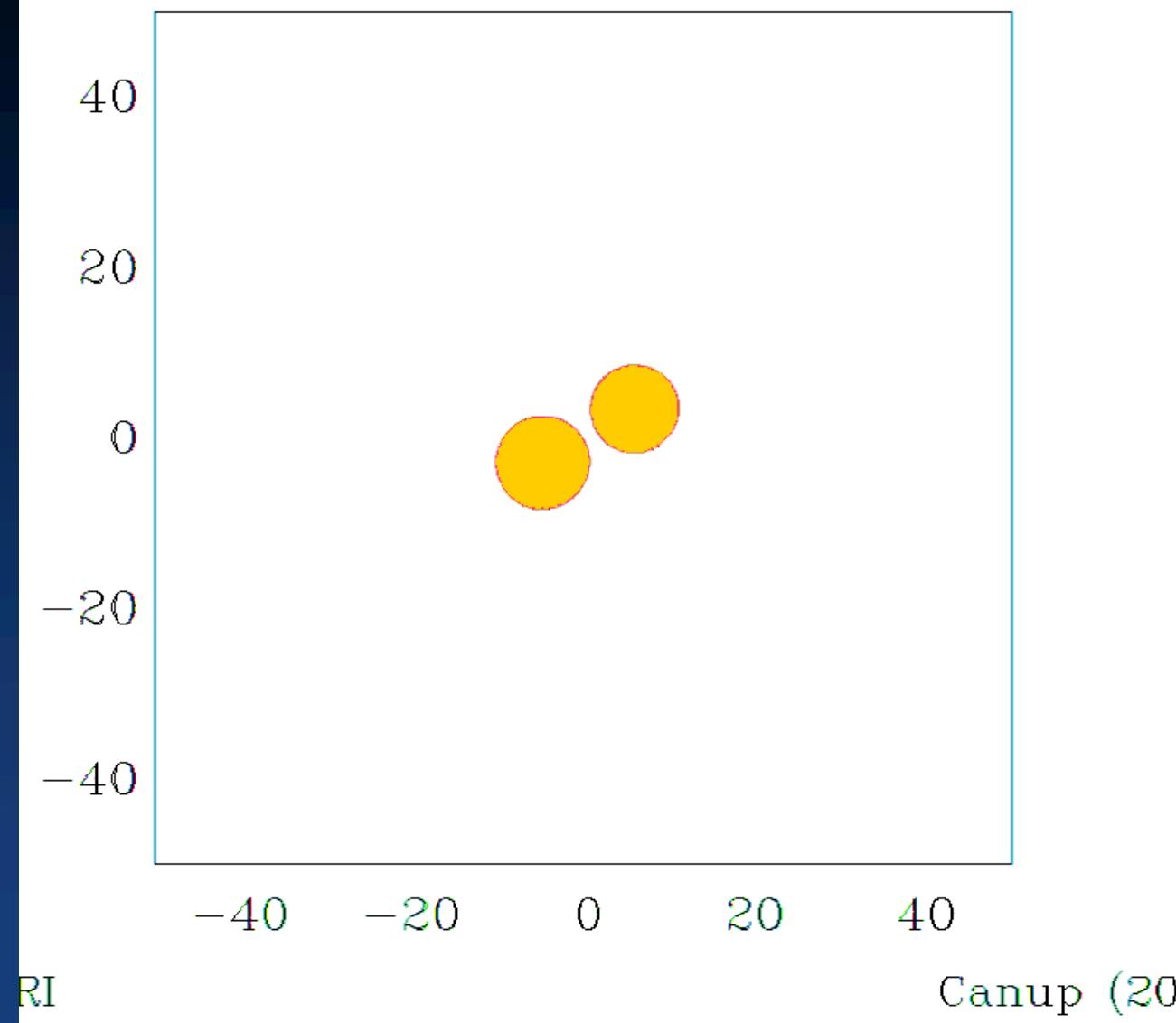
Consequences of the *Nice* Model: Epoch of Late Heavy Bombardment, Kuiper belt and asteroid belt distribution, Trojan asteroid distribution

### 3.2.3 月球的起源：大碰撞 (Giant Impact)

Artist' s View



数值模拟

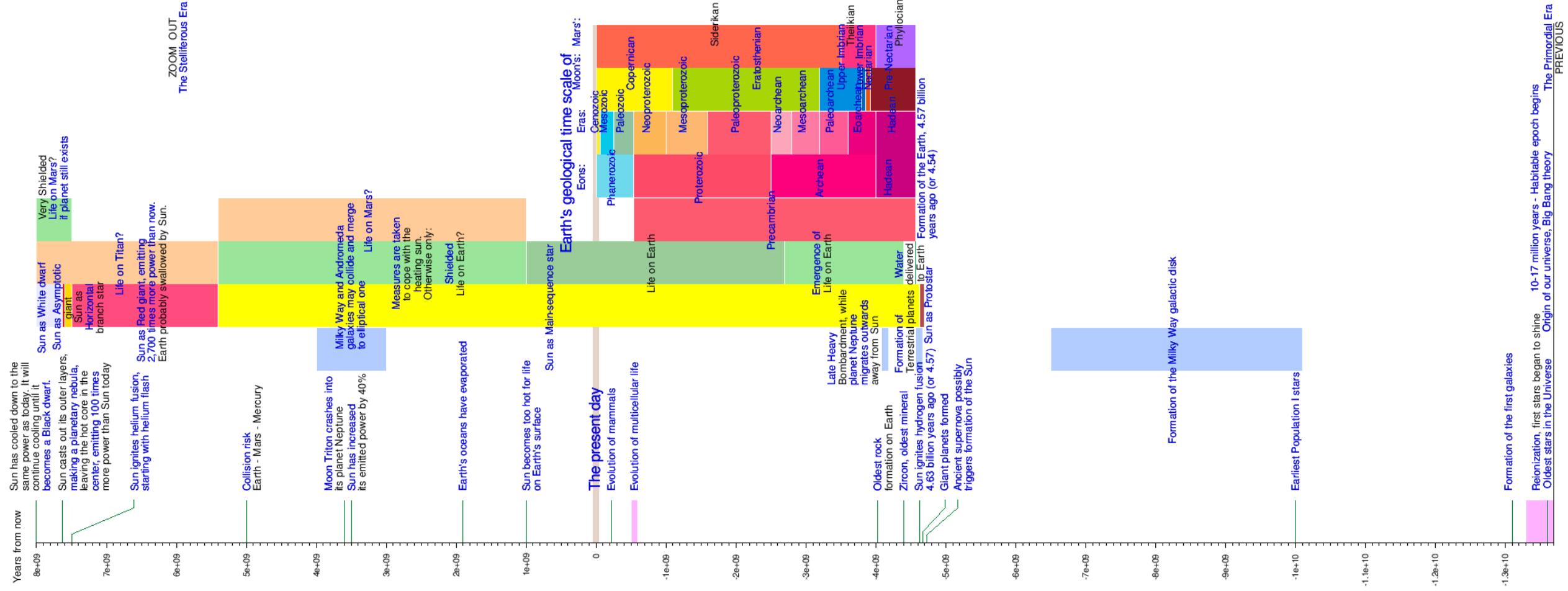


# 3. Outer Solar System

## 3.3 Impact Cratering

See the outer ppt.

# Events in Solar System Evolution



• [https://en.wikipedia.org/wiki/Graphical\\_timeline\\_of\\_the\\_universe](https://en.wikipedia.org/wiki/Graphical_timeline_of_the_universe)