# 太陽系有幾顆行星？
# (planet formation)


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# The Solar System

**Planets are almost on the same plane.**

**Planets orbit the Sun in the same direction.**

**The Sun is rotating in the same direction as the planets' orbital movement.**

**Planets form in a disk!**

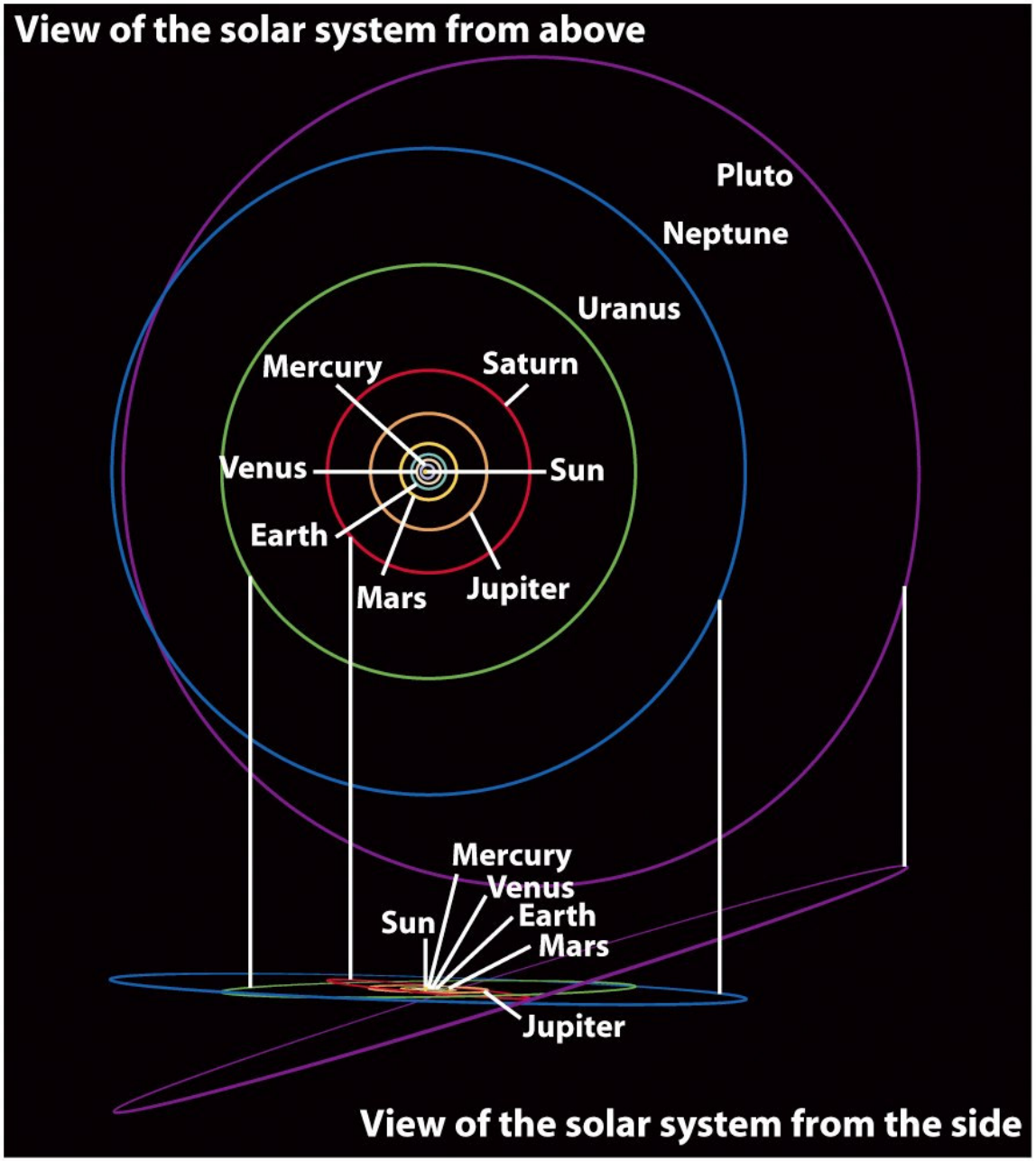


**Figure 5-7**
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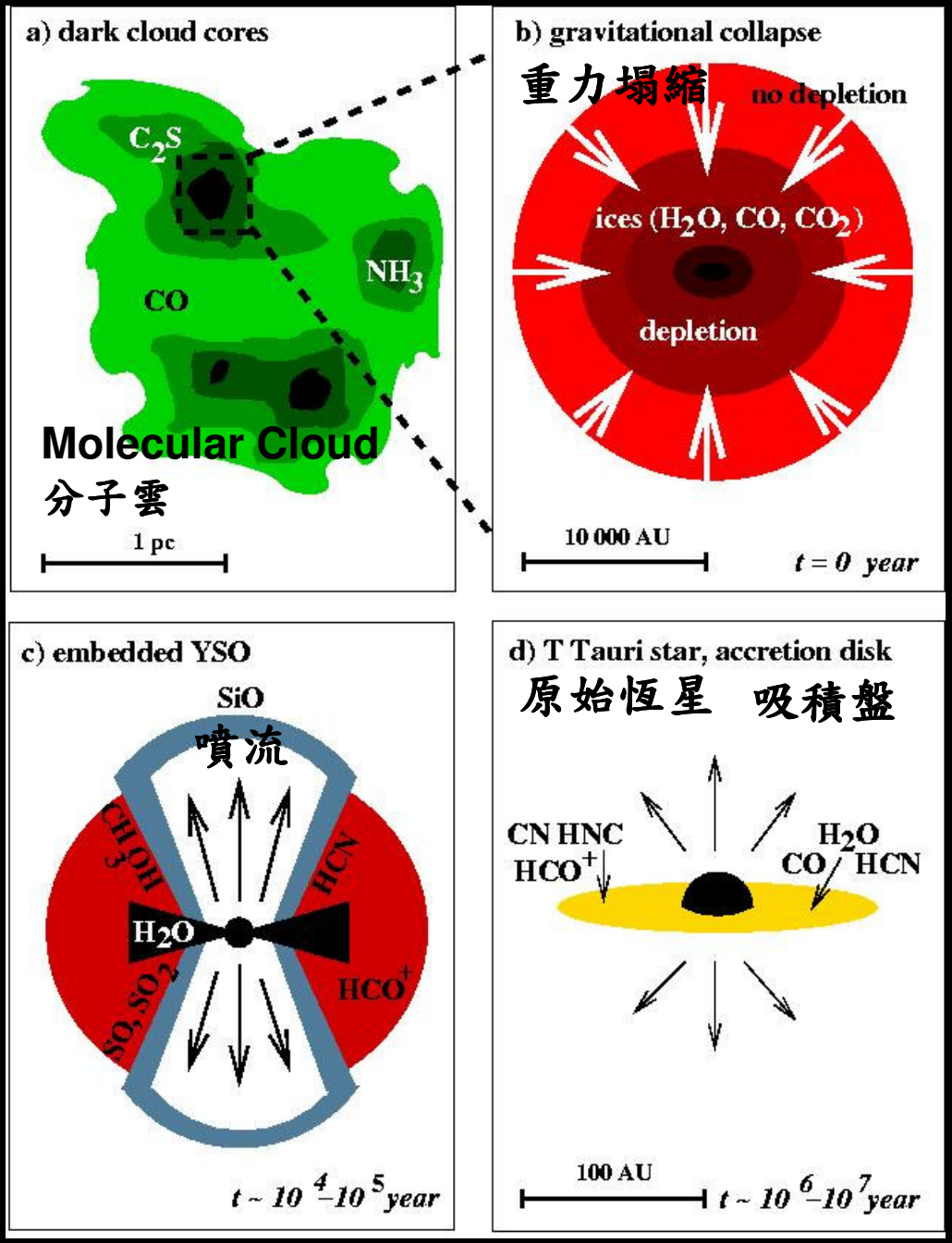
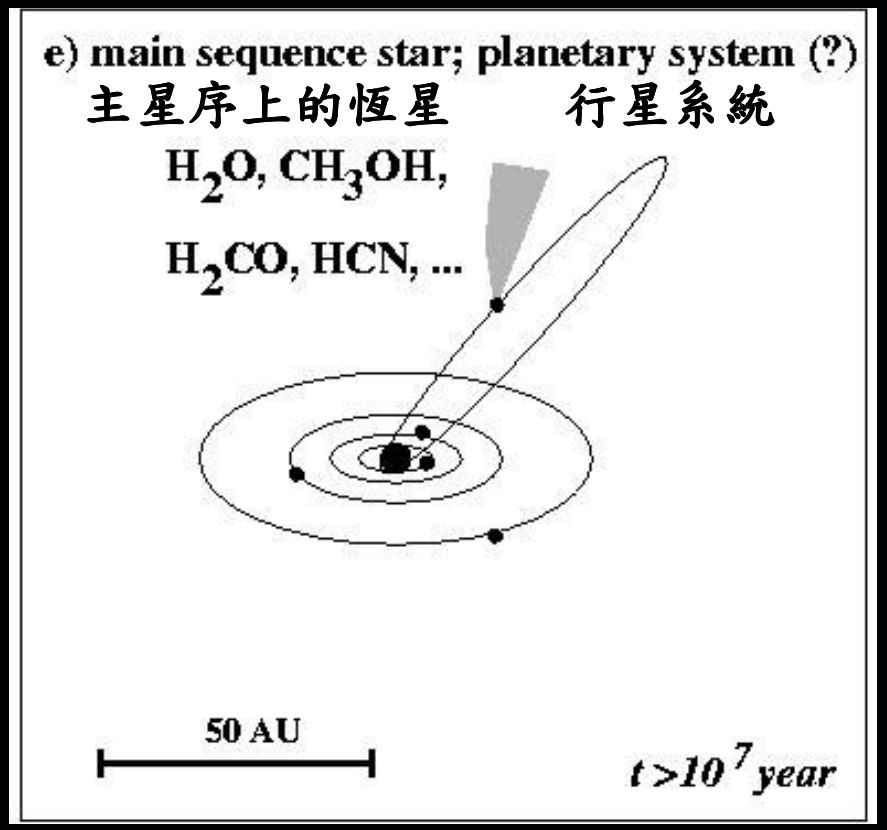
# Scenario of Star & Planet formation




A star is made of gas → star formation needs gas → a star forming region is full of dense gas and dust (原料).

# Formation of the Solar System

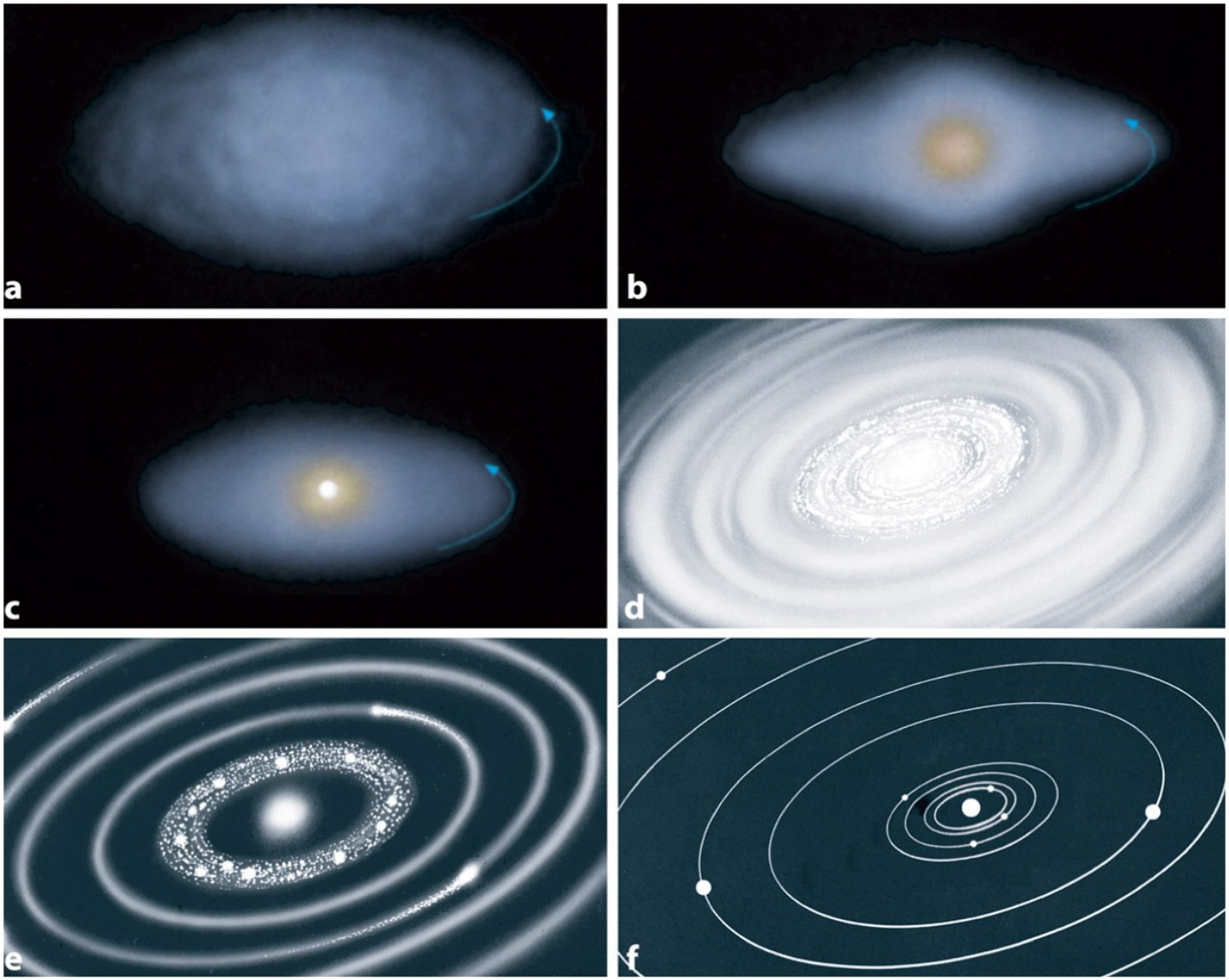



**Figure 5-3**
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# Formation of planetesimals

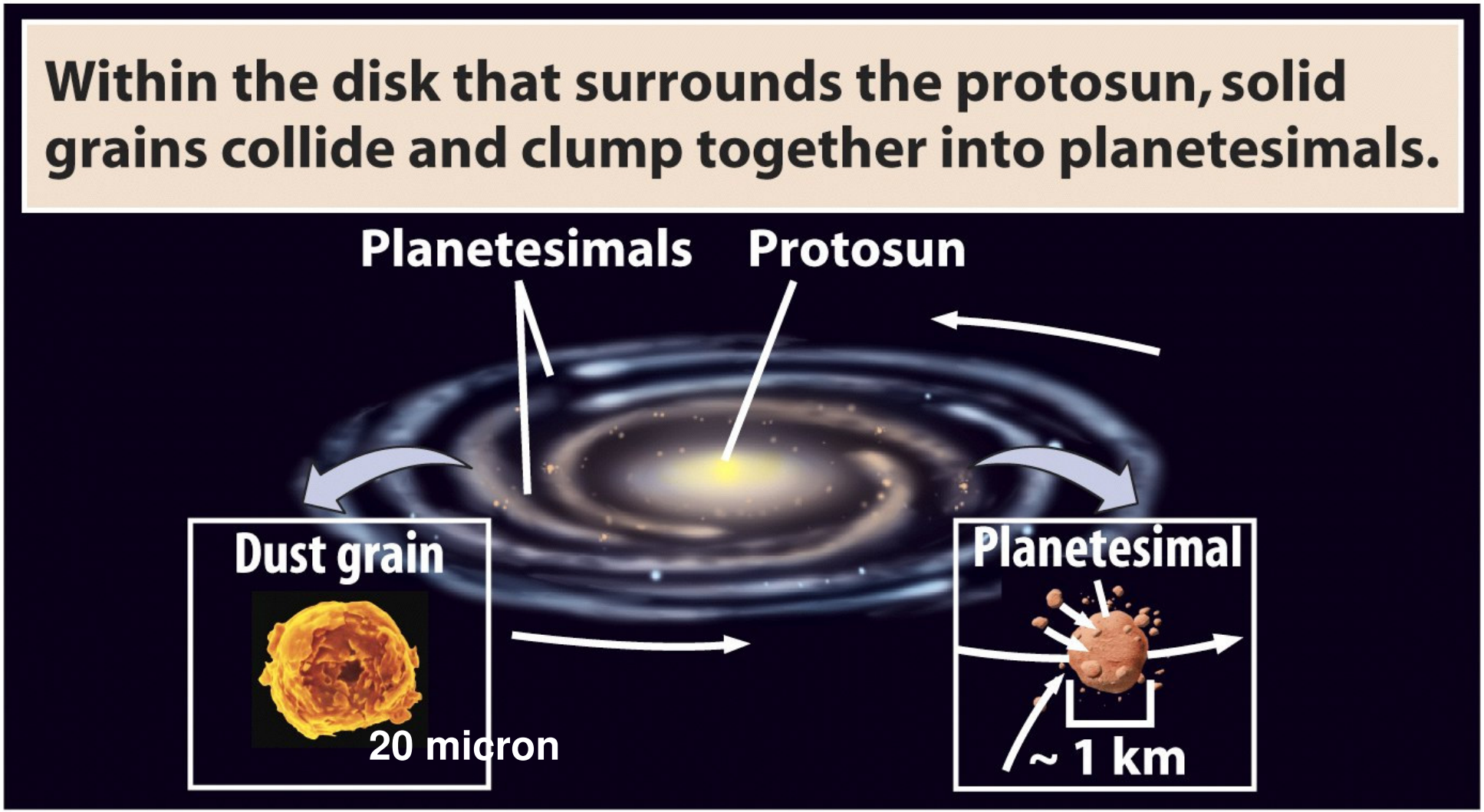


**Figure 5-5a**
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# Formation of planets

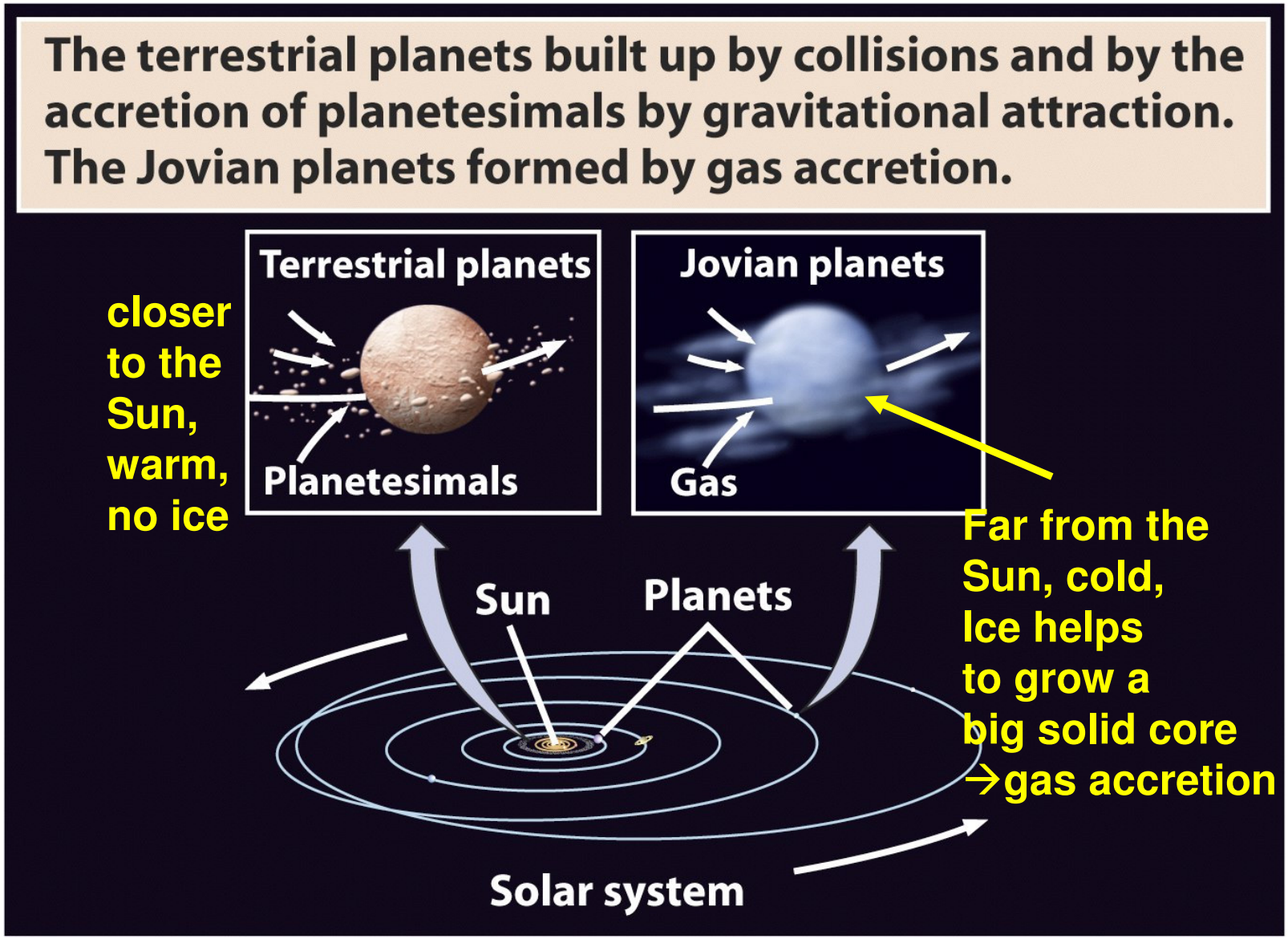


**Figure 5-5b**
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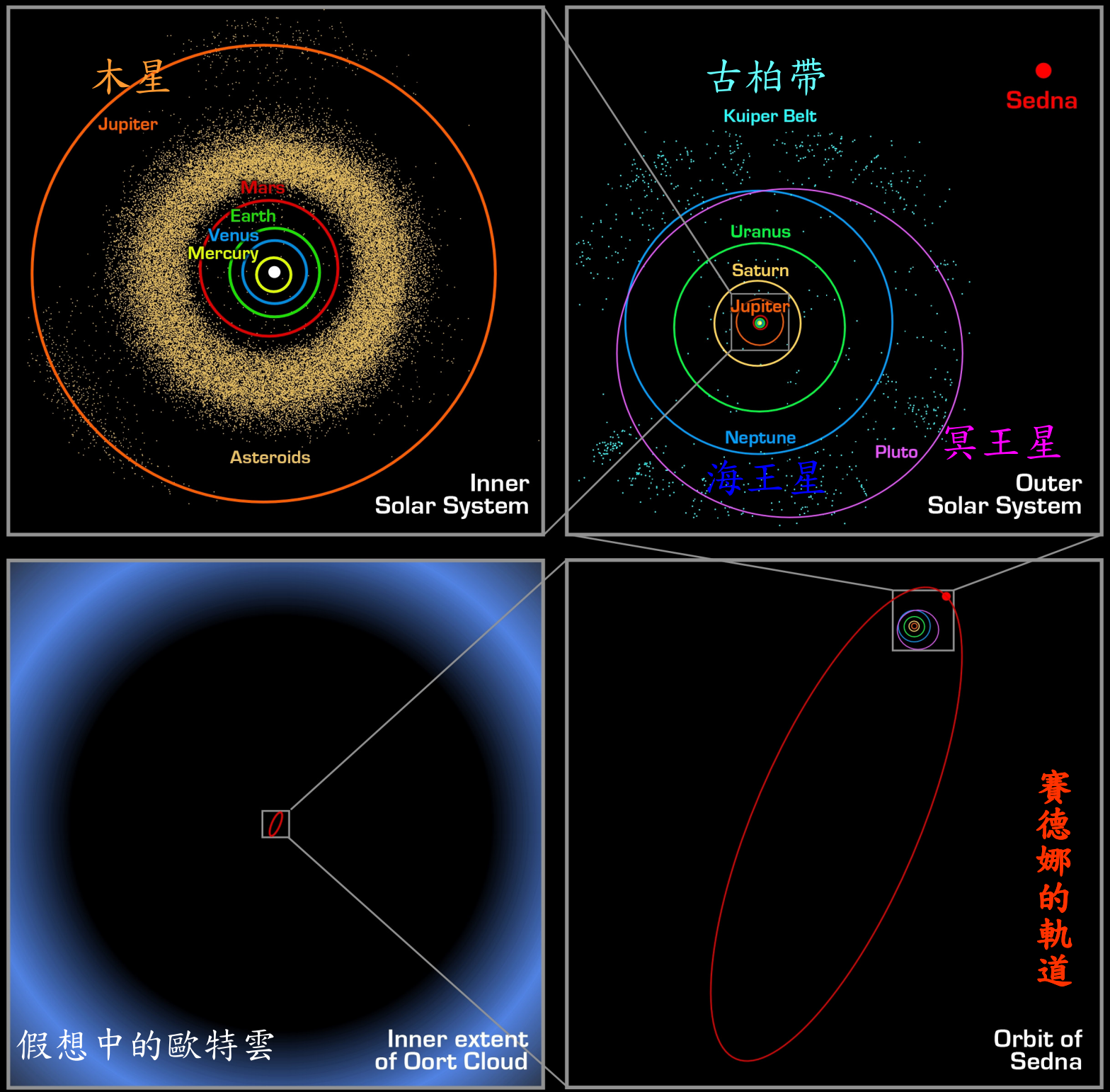


# 太陽系

## The Solar System

圖片來源:
http://www.gps.caltech.edu/~mbrown/

# Pluto: the 9th planet?

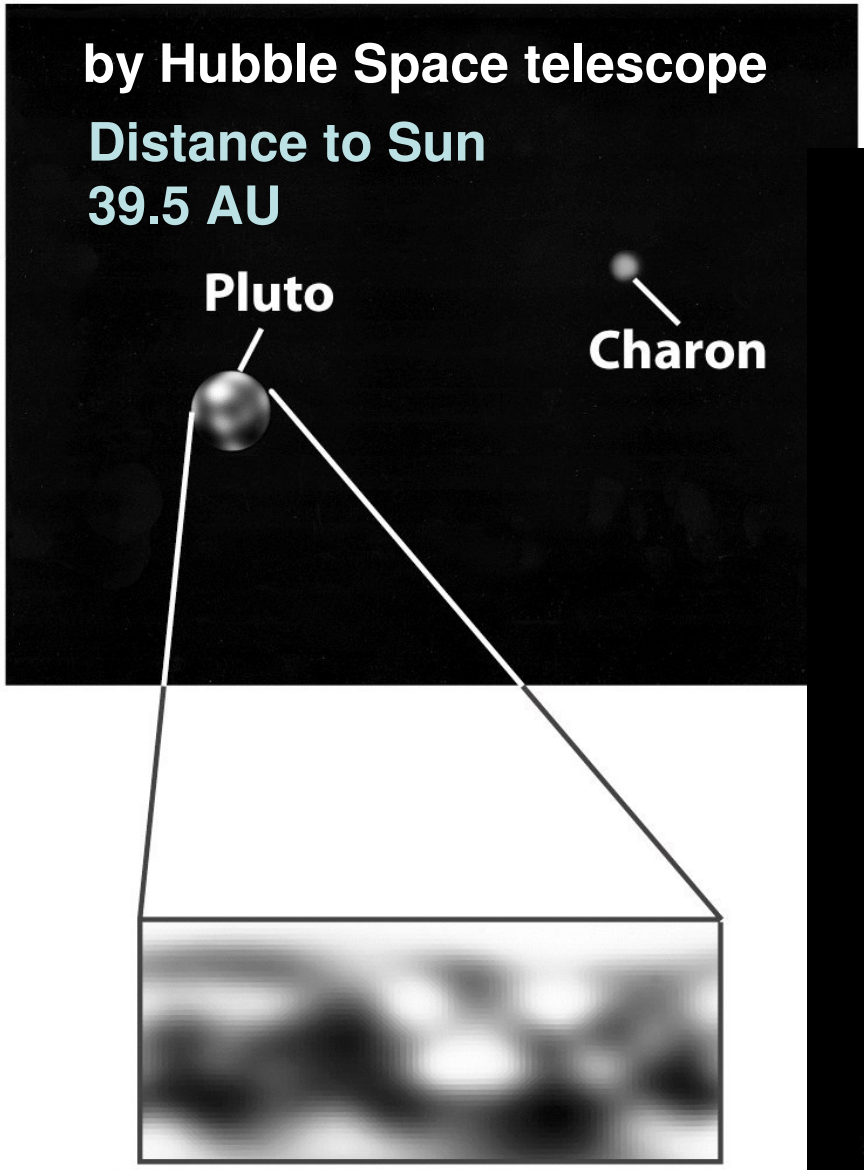


Figure 8-43
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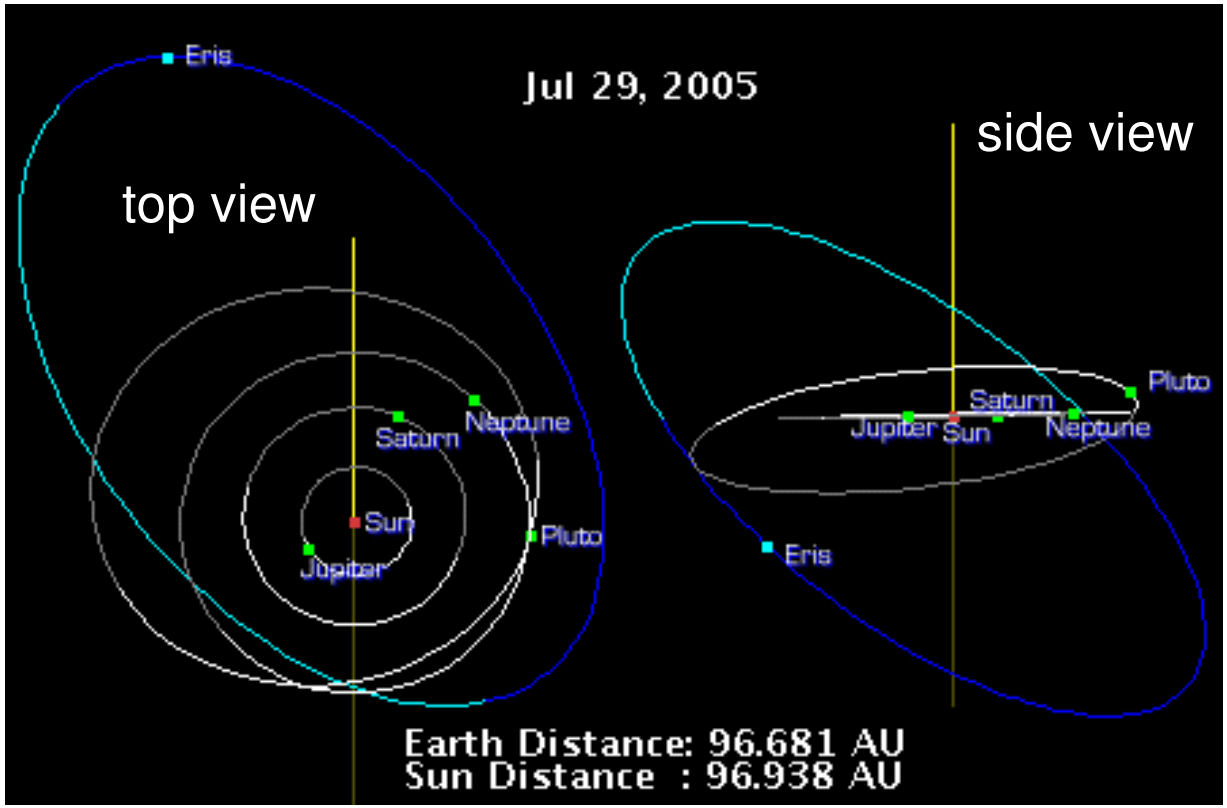
**1 AU (astronomical unit)**
**=earth-to-Sun distance**

# Orbit of Eris




http://bobthealien.co.uk/eris.htm

# New Planet Definition

http://www.iau2006.org/mirror/www.iau.org/iau0603/index.html

- **orbit a star (upper mass limit: brown dwarf 棕矮星, no nuclear fusion?)**
- **massive enough to keep a round shape (lower mass limit: about $5 \times 10^{23}$ g or 半徑>400 km ?)**
- **has cleared the neighborhood around its orbit.**

**Pluto, Eris, and Ceres (穀神星) are now classified as "dwarf planets". They are the same as "planets" except that firstly they can't clear the neighborhood & secondly they are not satellites.**

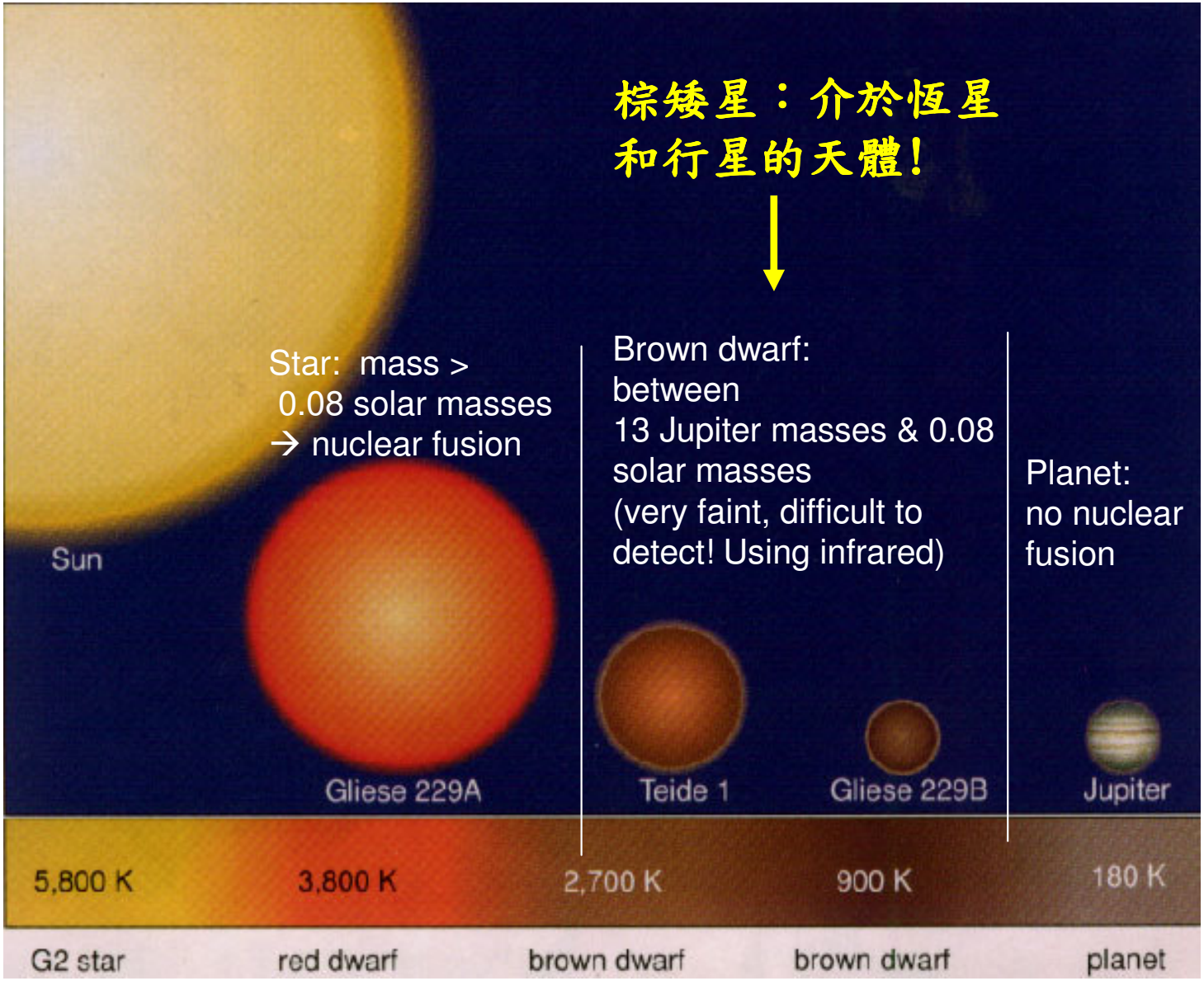
**Other Important Issues:**

- **thermal view: small planets may preserve the raw materials of planet formation**
- **formation view: Ceres & KBOs may fail to form an "original planet" in the past.**
- **twin view: what about if the planet mass is comparable to its satellite mass?**

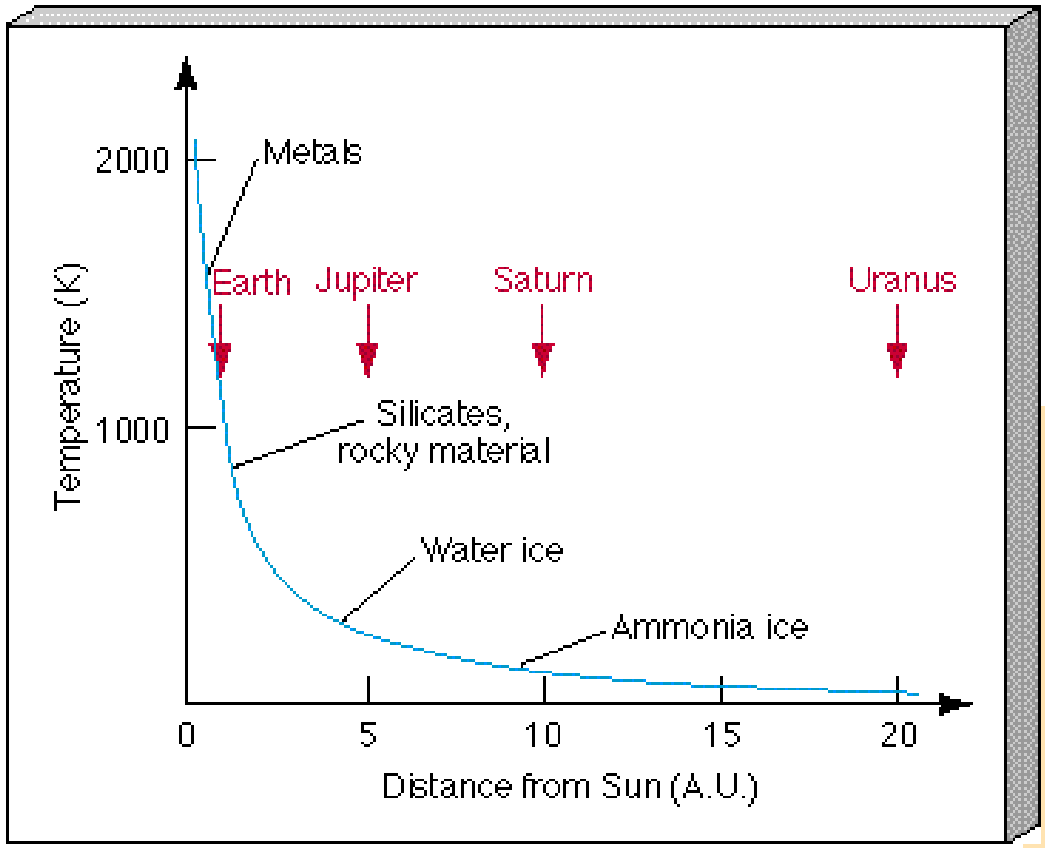
# note

**In the outskirt of the Solar System, Pluto is accompanied with a group of comet-like bodies at the similar orbital radii. This group is called the Kuiper Belt. The discovery of Eris and the continuous size distribution among largest Kuiper Belt objects suggest that we need to revise the definition of a “planet”. After the IAU (International Astronomical Union) general meeting held this August, astronomers have voted to re-define a “planet”. According to the new definition, now we have only 8 planets. Pluto and Eris are dwarf planets. The number of dwarf planets will increase.**

# Ultra-low mass stars & Brown dwarfs



# Condensation sequence (凝結序列)




**273K=0°C**

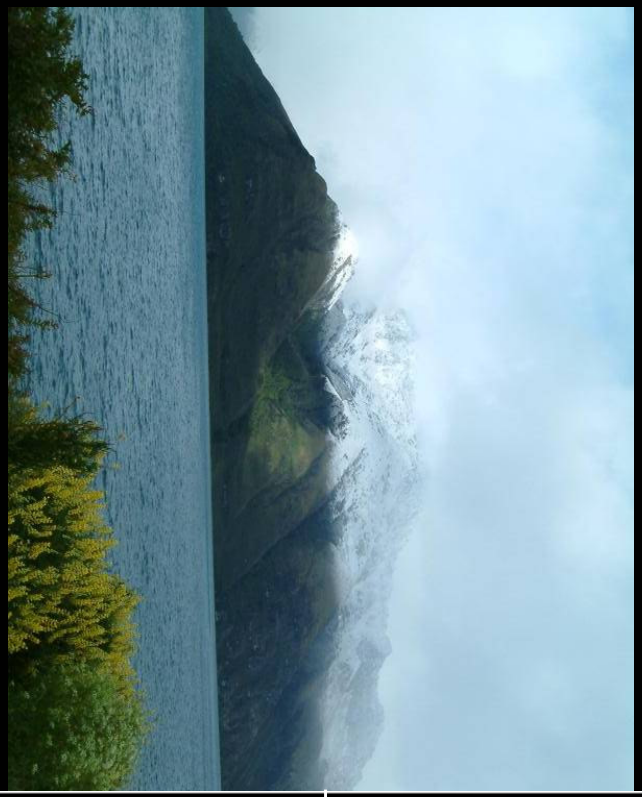
http://ircamera.as.arizona.edu/astr_250/Lectures/Lec_21sml.htm
http://inverse.astro.uwo.ca/ast21/slides20/slide2.html

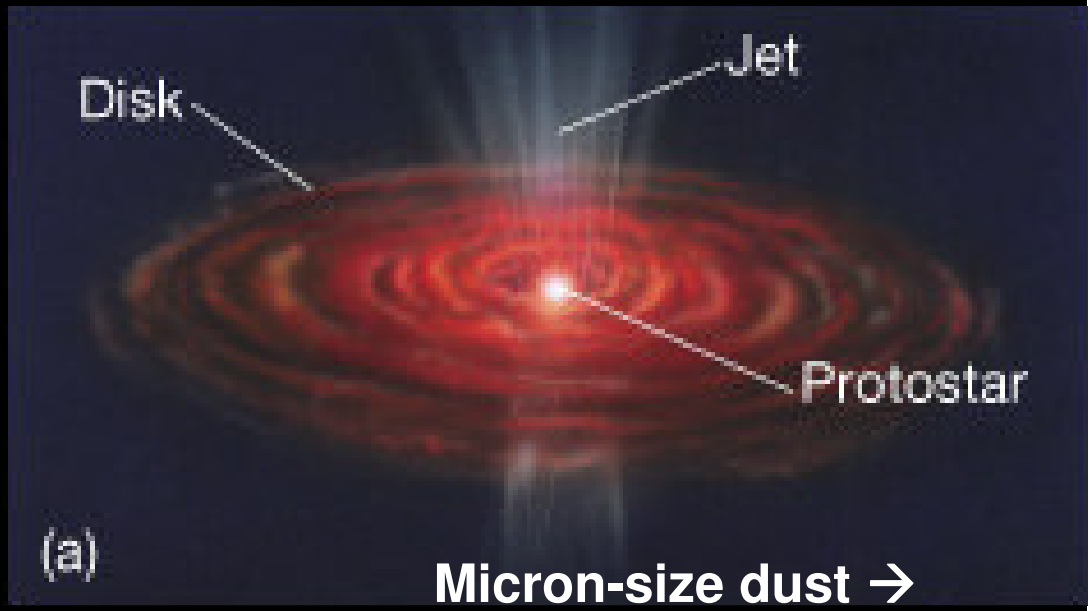
**Table 19-3** The Condensation Sequence

| Temperature (K) | Condensate | Planet (Estimated Temperature of Formation; K) |
|---|---|---|
| 1500 | Metal oxides | Mercury (1400) |
| 1300 | Metallic iron and nickel | |
| 1200 | Silicates | |
| 1000 | Feldspars | Venus (900) |
| 680 | Troilite (FeS) | Earth (600) |
| | | Mars (450) |
| 175 | $H_2O$ ice | Jovian (175) |
| 150 | Ammonia–water ice | |
| 120 | Methane–water ice | |
| 65 | Argon–neon ice | Pluto (65) |

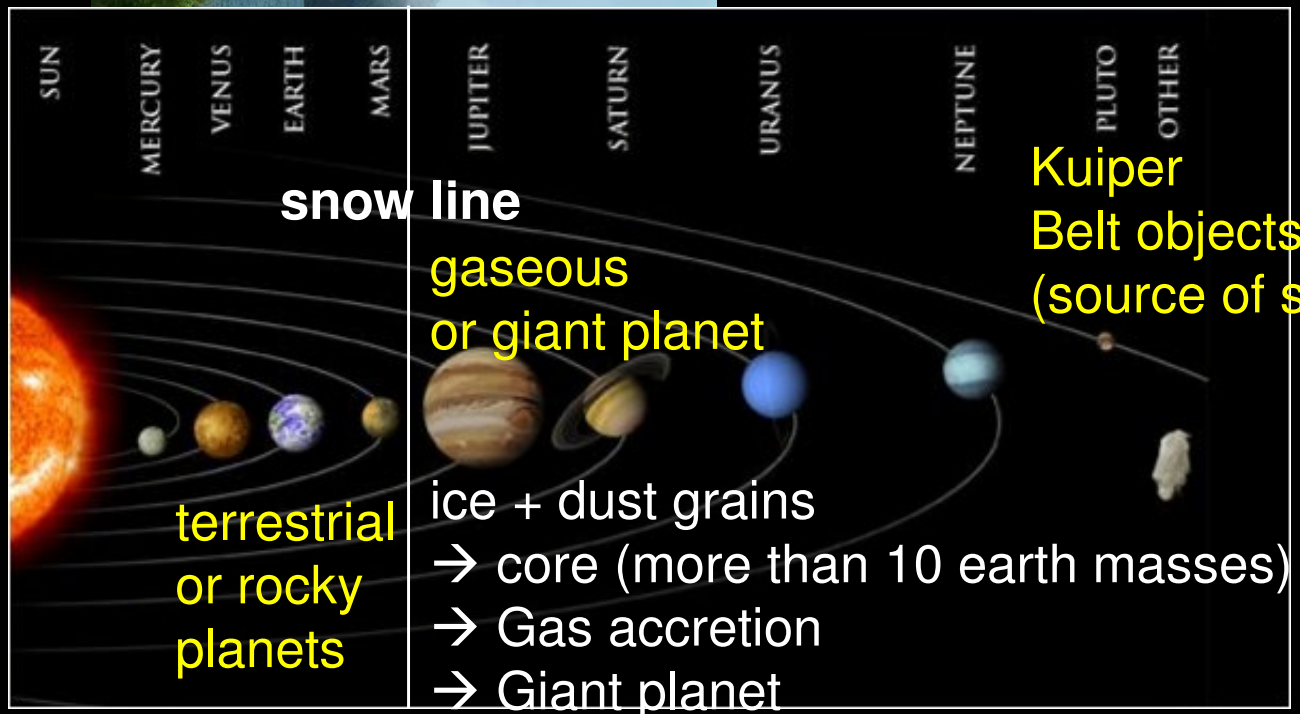
**Planets form in a proto-stellar disk around a protostar.**

# Snow Line on a proto-stellar disk






**Micron-size dust → planetesimals (comets or asteroids) → planets**




**snow line**

gaseous
or giant planet

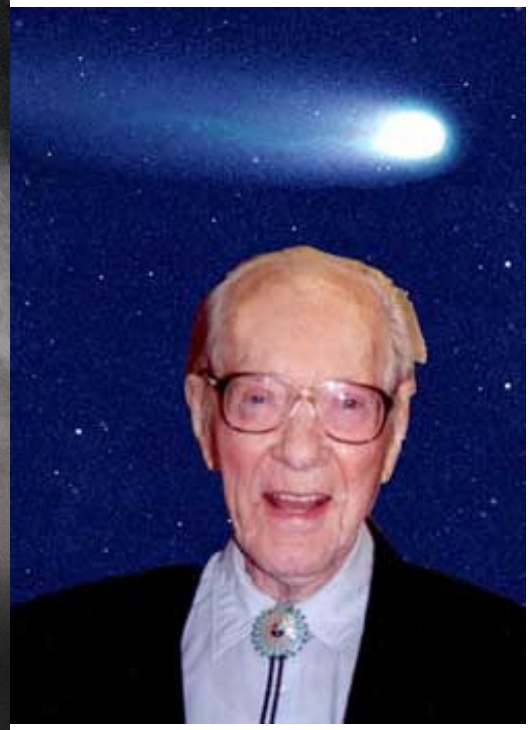
Kuiper
Belt objects
(source of short-period comets)

terrestrial
or rocky
planets

ice + dust grains
→ core (more than 10 earth masses)
→ Gas accretion
→ Giant planet

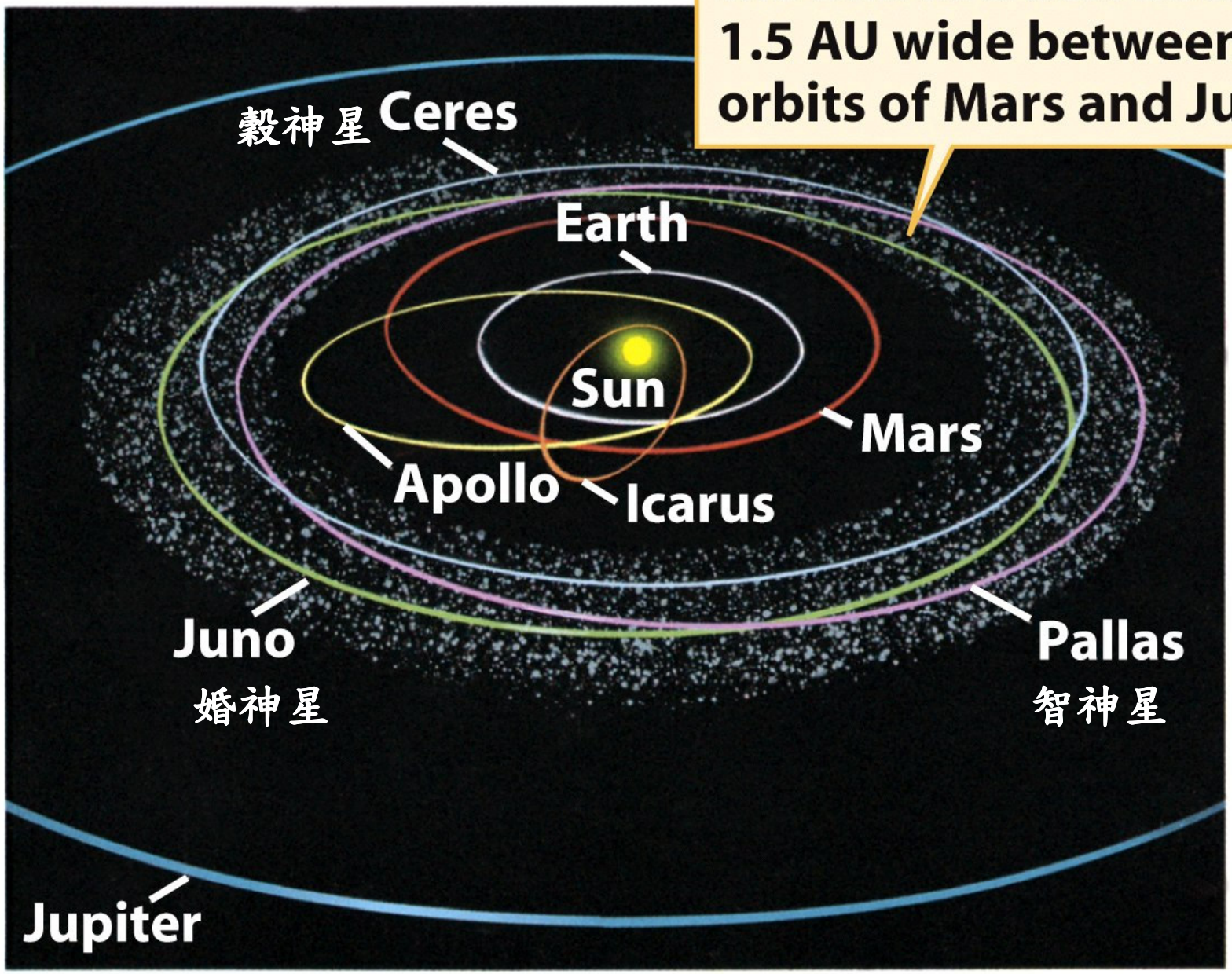
# Comet (彗星): dirty snowball


http://www.spitzer.caltech.edu/Media/releases/ssc2005-18/ssc2005-18b.shtm



**Fred Whipple proposed comets are dirty snowballs In 1950.**

# Asteroid: minor planet
# 小行星 (c.f. planetesimal)




2006/11/

Figure 9-2a
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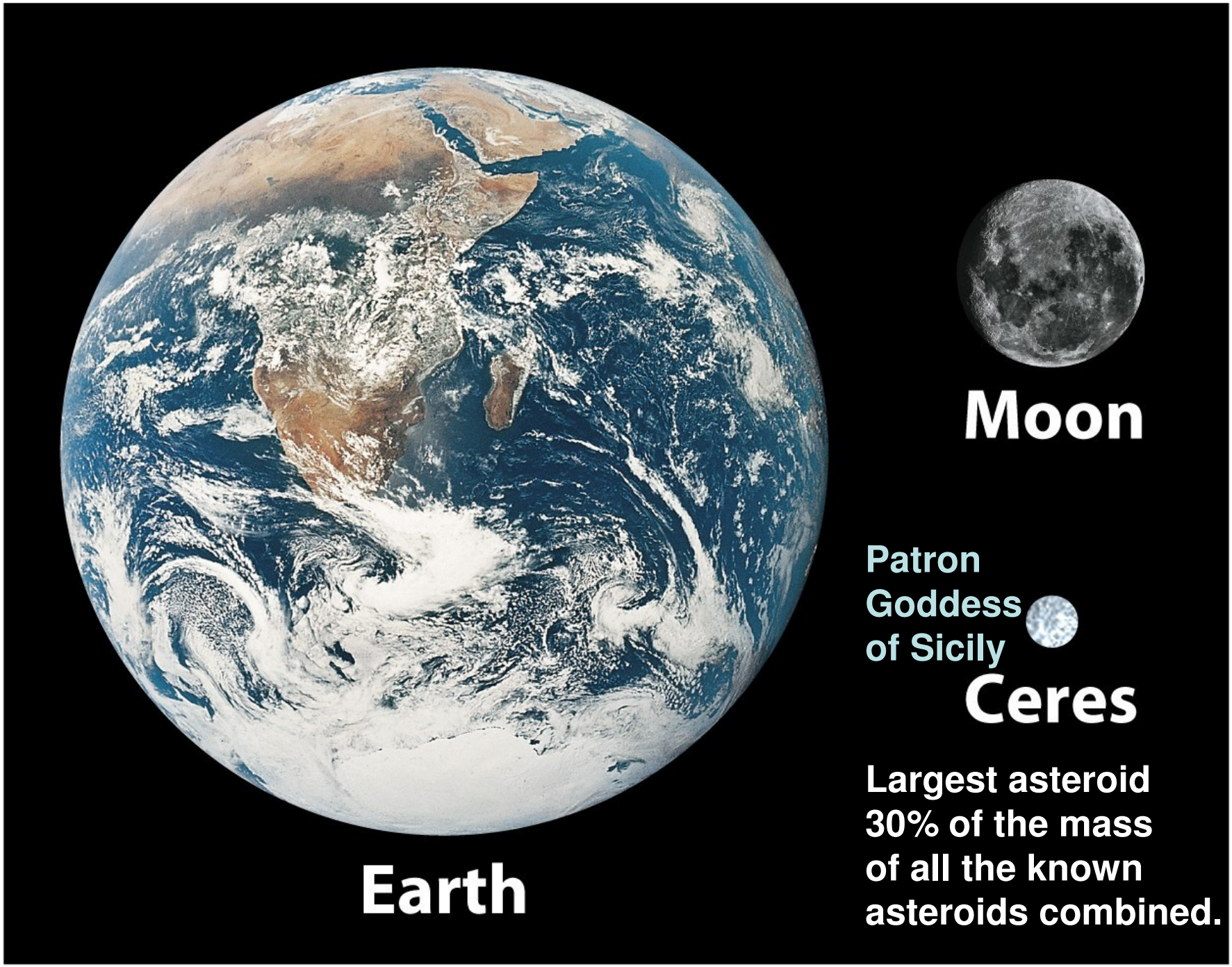


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**Figure 9-1**
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# An Asteroid has a “moon”

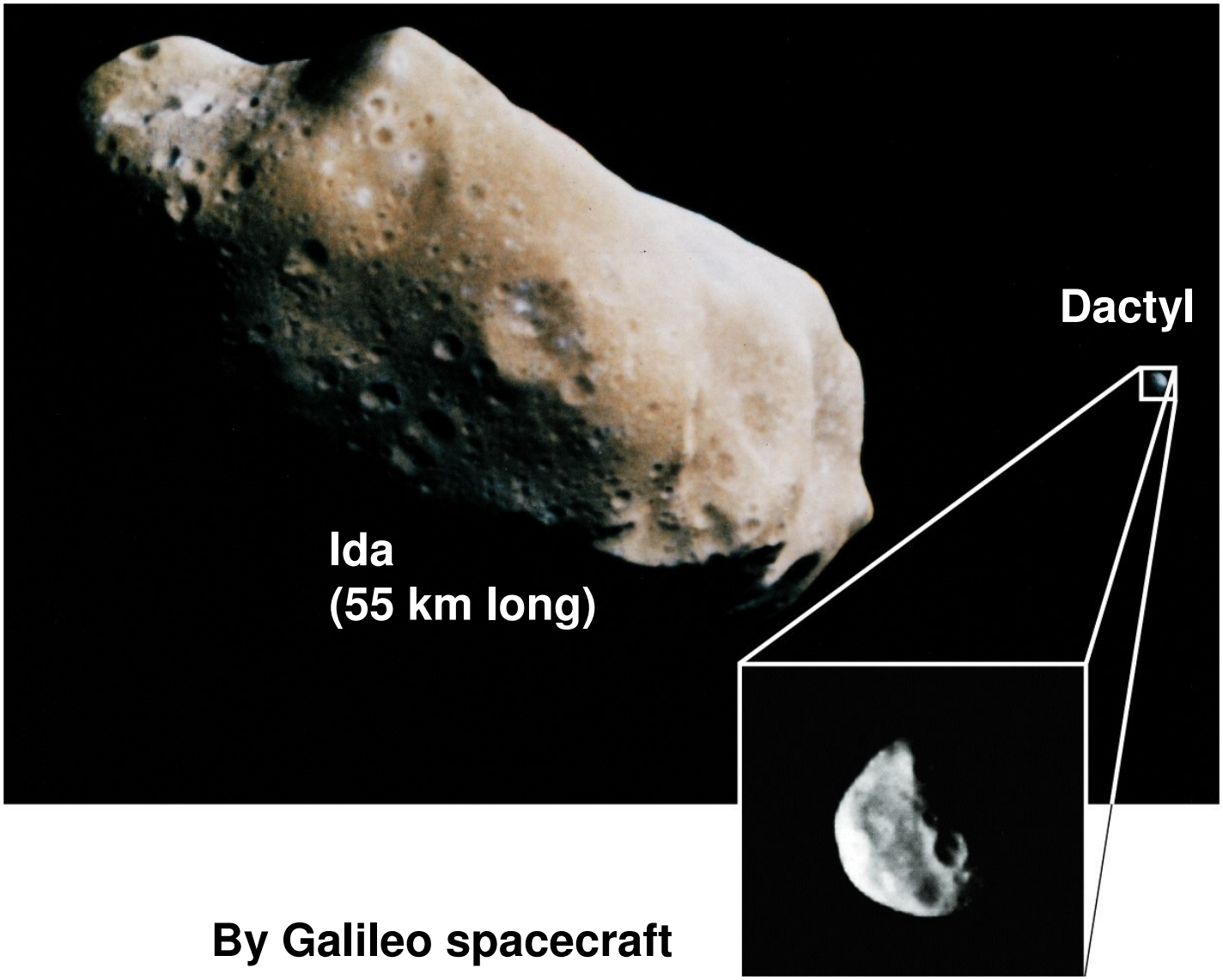


**Figure 9-5**
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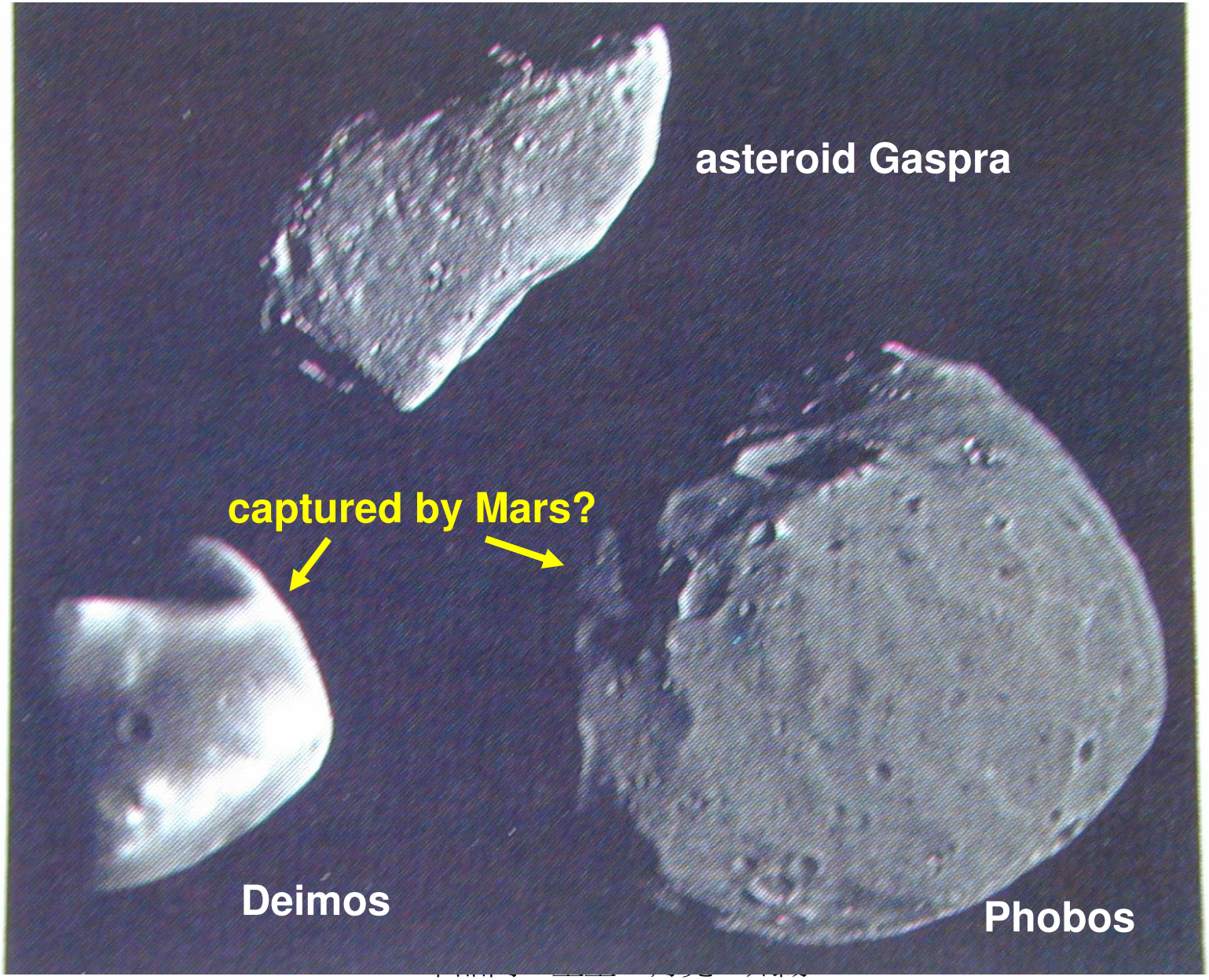
# Asteroid & Mars's Moons



# Name an asteroid

- Normally, the discoverer of an asteroid has the first right to name it after someone else, but recent automated telescopic surveys gave the IAU (International Astronomical Union) a surplus of asteroids with nothing but prosaic catalog designations. Anyone can petition the IAU to name an asteroid in someone's honor, but the process often takes years. Also, IAU's Committee for Small Body Nomenclature has specific rules for names, including a limit of 16 characters (including punctuation), a requirement that the name be pronounceable (in some language), and no names from pet animals allowed.
- For instance, 3 asteroids were named in Memory of September 11 terrorism victims: http://www.space.com/news/asteroid_setp11_011010.html

# Properties of belt asteroids

- Number: as of 2002, 52224 asteroids confirmed, more than 125000 awaiting confirmation.
- Average separation: 10 million km
- Composition & Albedo: S, C, M types
- Size: irregular shapes. 30 asteroids between 200-300 km in diameter. The number increases with decreasing size. Putting together → ½ the diameter of our Moon.
- A failed planet? (recall how a planet formed?)

# Composition of asteroids

**Consist primarily of rock & metal.**

**Compared with comets which are composed of rock and Ices (dirty snowball).**

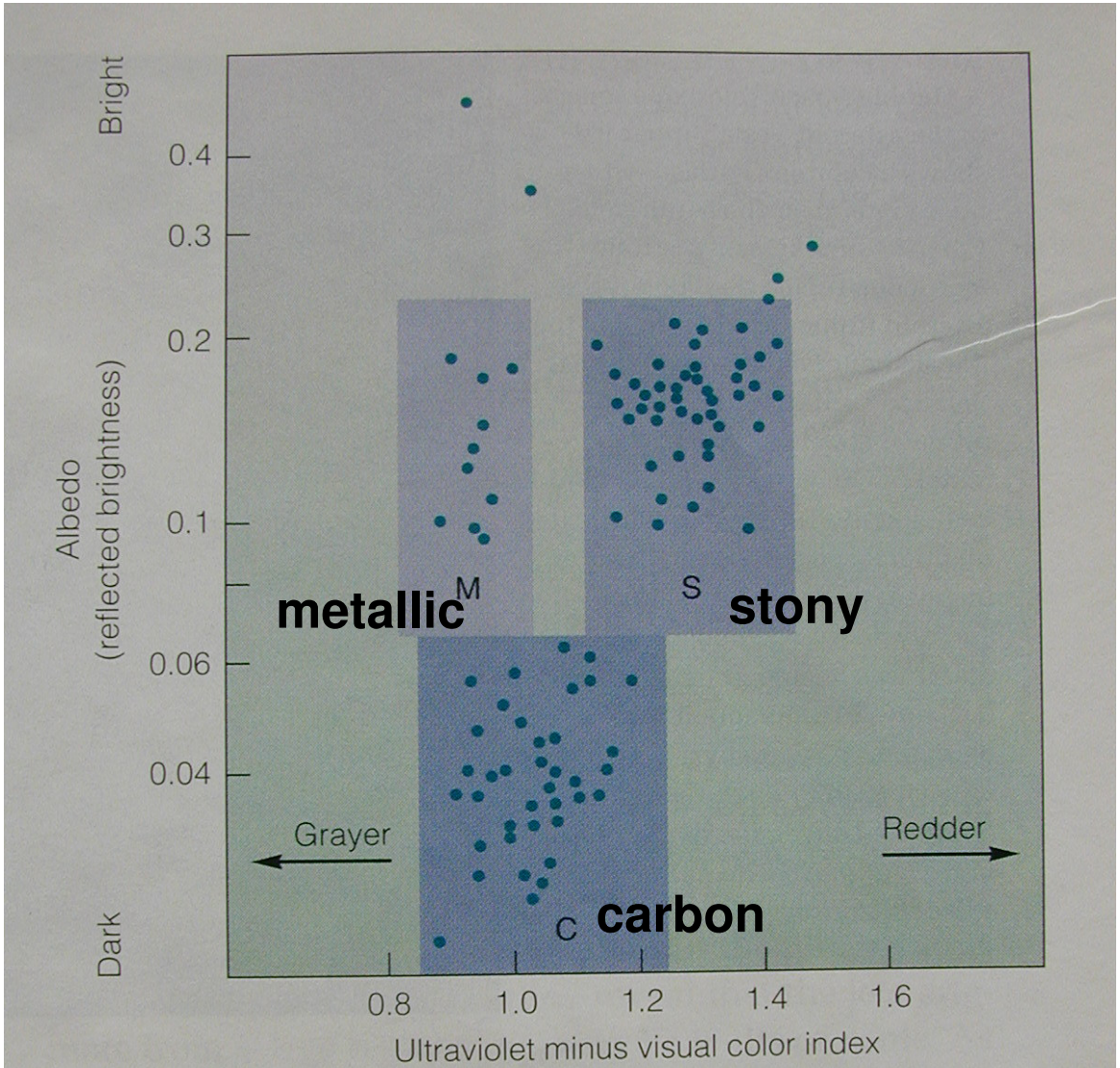



**FIGURE 9-6**
The three principal types of asteroids. In a diagram of albedo versus color (ultraviolet minus visual), the most reflective asteroids lie near the top, and the reddest at the right. The S types, which are believed to resemble chondrites, are clearly redder than the M types, which seem to be metallic. The darkest asteroids, the C types, are believed to be similar to carbonaceous chondrites. *(Diagram adapted from a figure by B. Zellner)*

# Trojan (特洛伊) asteroids

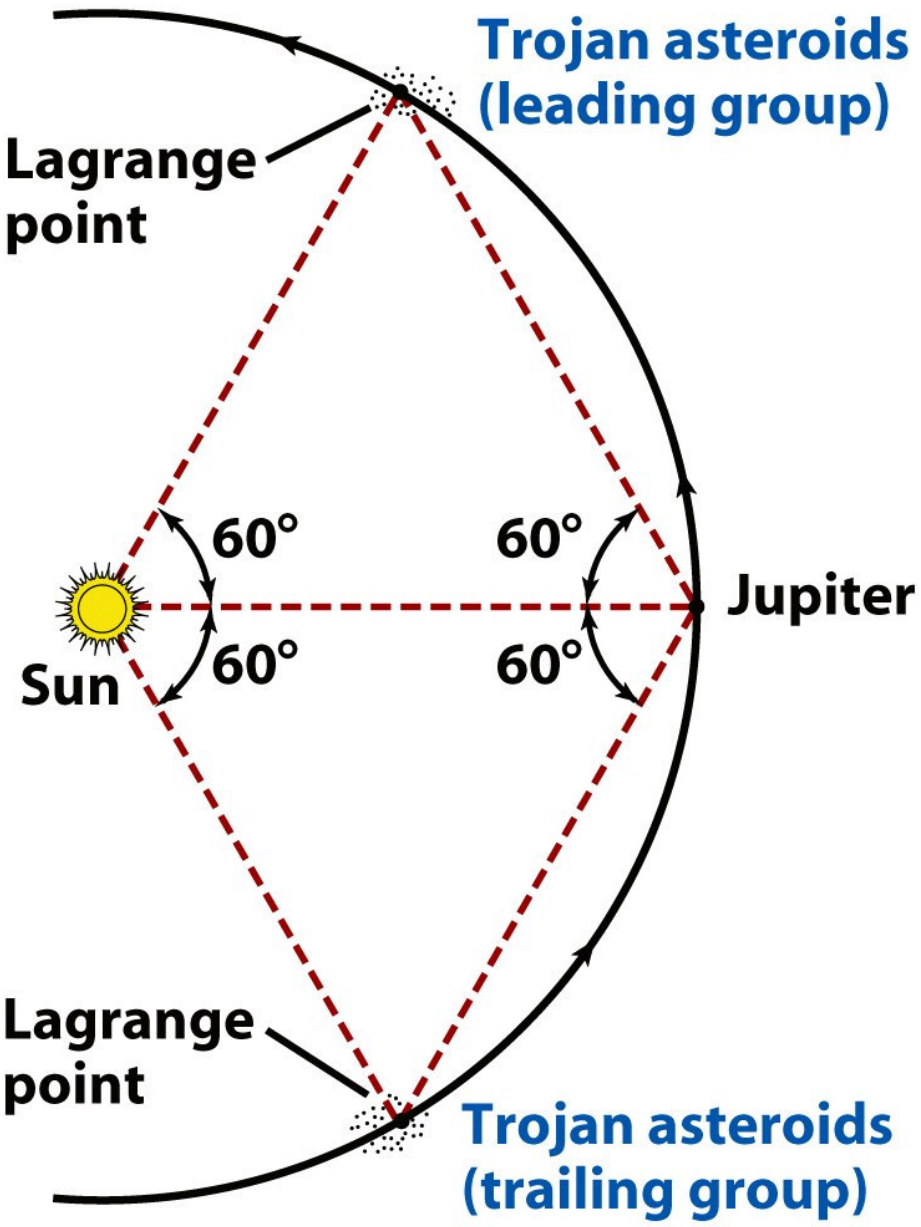



**Figure 9-6**
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# Landing on an asteroid

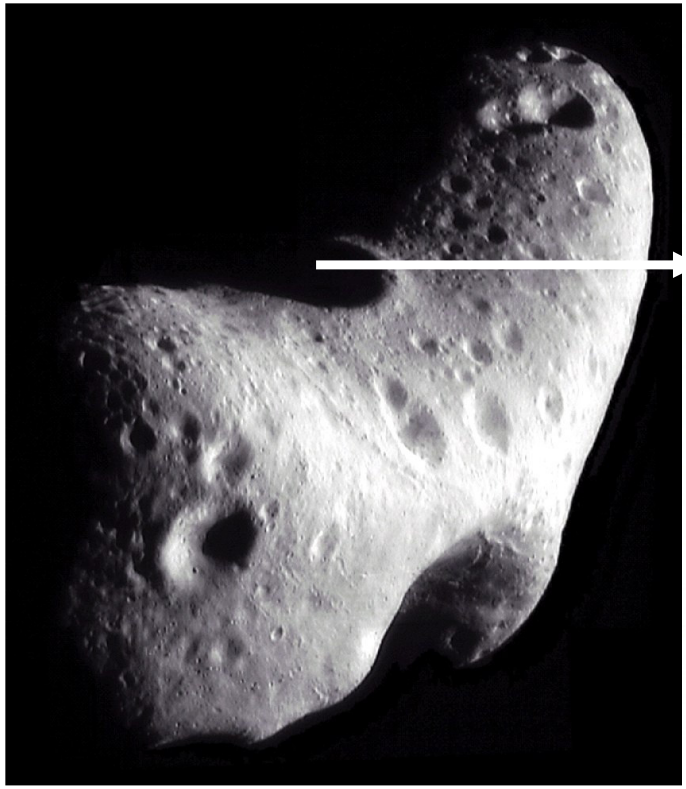

Figure 9-9a
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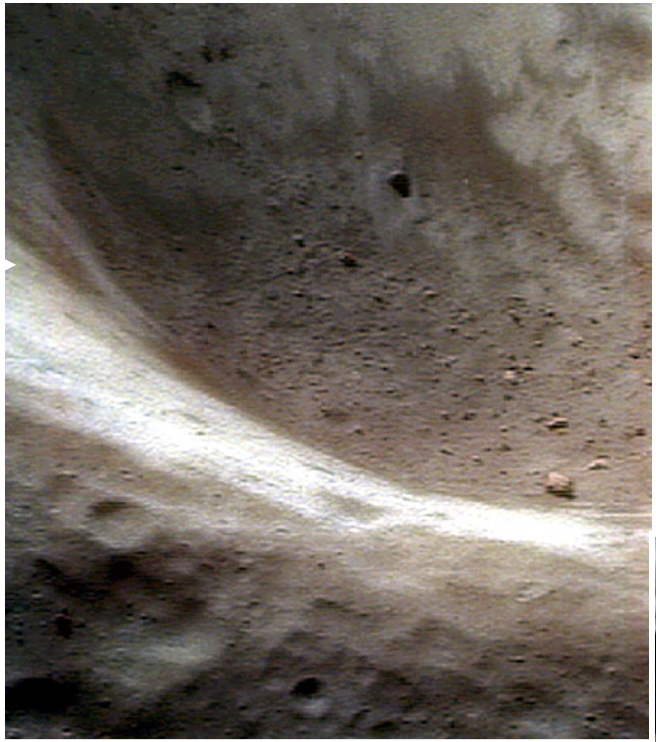

Figure 9-9b
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**Eros(愛神): 33x13x13km**
**5.24 hours/rotation**

**Near Earth Asteroid Rendezvous Shoemaker (NEAR)**

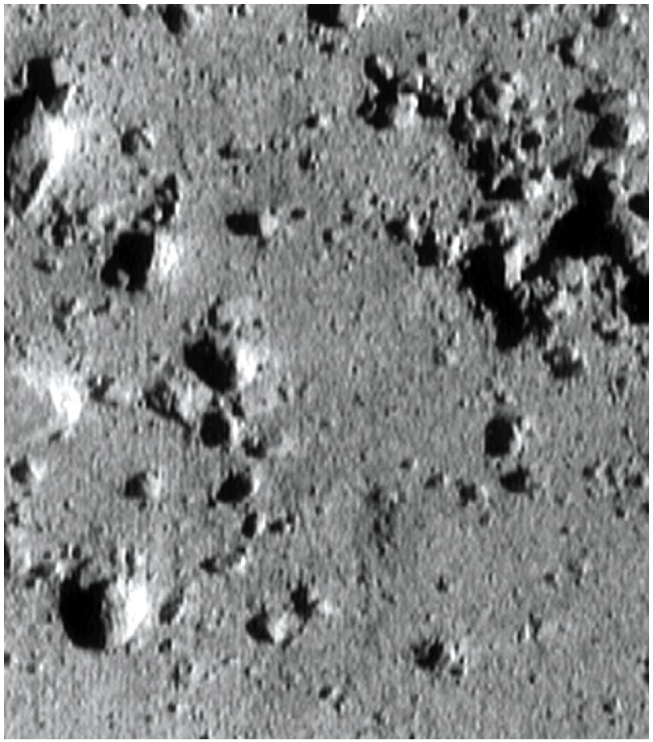

Figure 9-9c
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# Close encounter

**Asteroid 1994 XM1 was less than ½ the distance from the Earth to the Moon!**

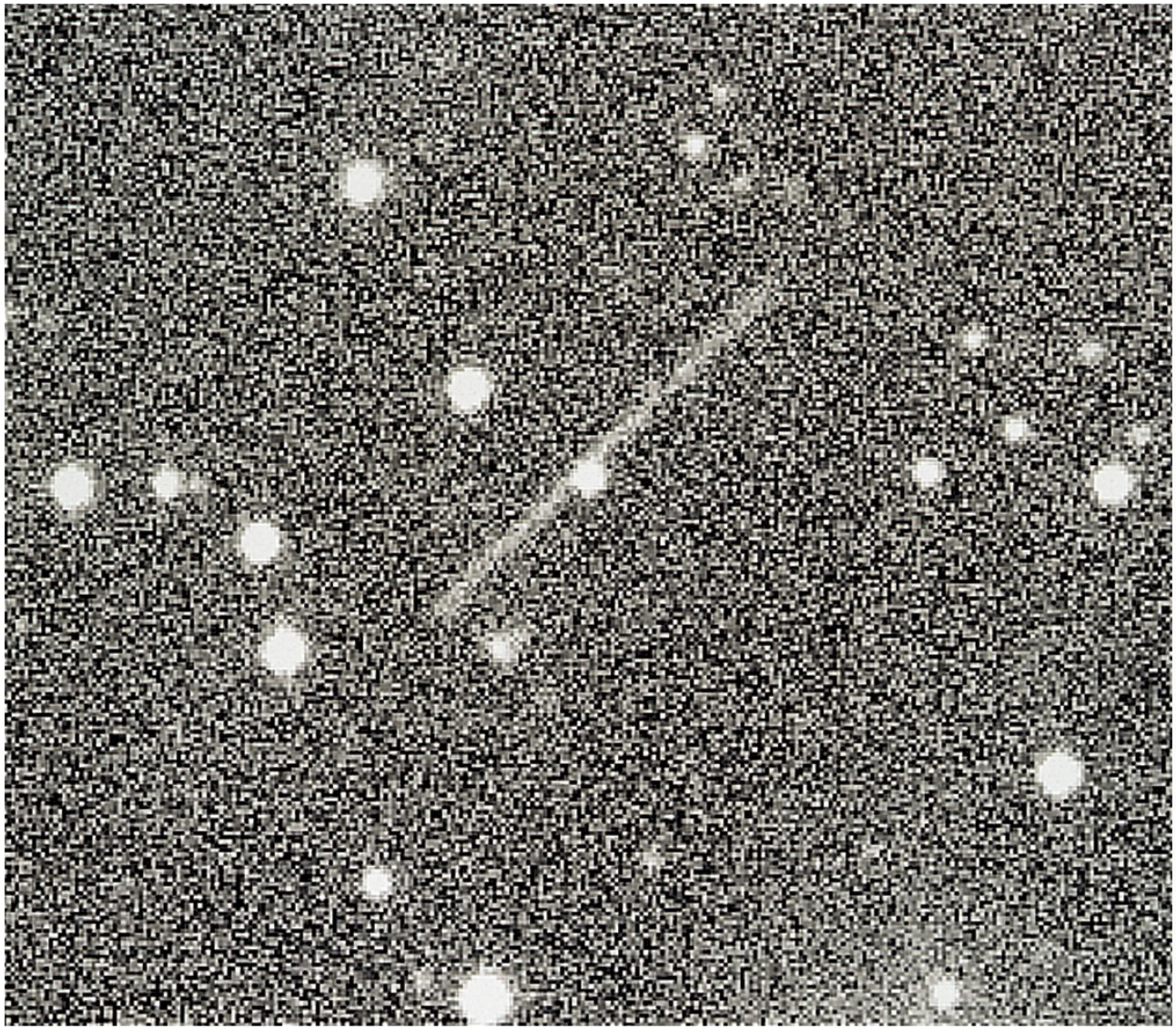

**Figure 9-7**
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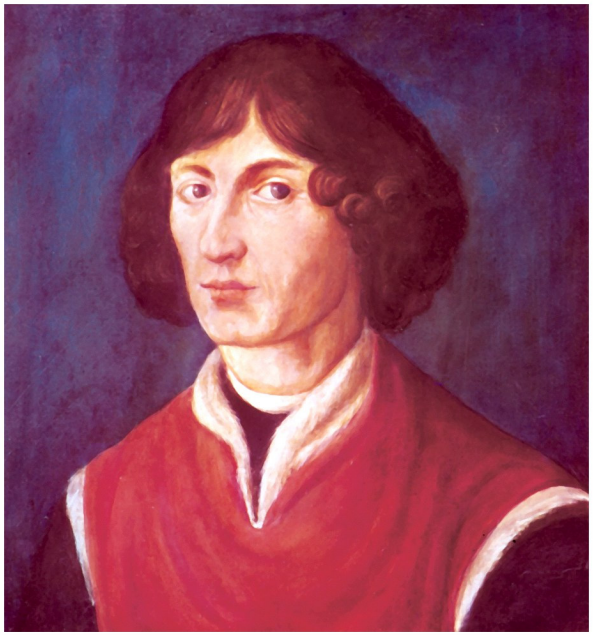
# Near-earth objects (NEOs)

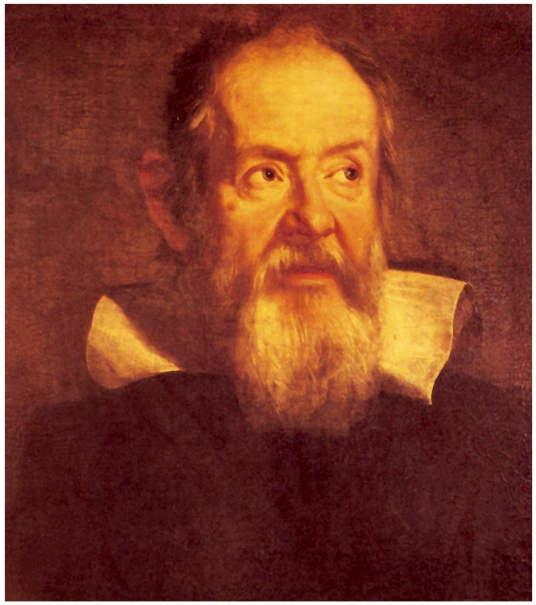
http://neo.jpl.nasa.gov/

| Group | Description | Definition |
|---|---|---|
| NECs | **Near-Earth Comets** | *q*<1.3 AU, *P*<200 years |
| NEAs | **Near-Earth Asteroids** | *q*<1.3 AU |
| Atens | Earth-crossing NEAs with semi-major axes smaller than Earth's (named after asteroid 2062 Aten). | *a*<1.0 AU, *Q*>0.983 AU |
| Apollos | Earth-crossing NEAs with semi-major axes larger than Earth's (named after asteroid 1862 Apollo). | *a*>1.0 AU, *q*<1.017 AU |
| Amors | Earth-approaching NEAs with orbits exterior to Earth's but interior to Mars' (named after asteroid 1221 Amor). | *a*>1.0 AU, 1.017<*q*<1.3 AU |
| PHAs **There are currently known 730 PHAs.** | **Potentially Hazardous Asteriods: NEAs whose Minimum Orbit Intersection Distance (MOID) with the Earth is 0.05 AU (about 20 times the distance between Earth & Moon) or less and whose** absolute magnitude (H) is 22.0 or brighter. | *MOID*<=0.05 |

# Astronomers (A.D.1500-1700)



**Copernicus (1473-1543) Heliocentric theory**



Unnumbered Figure pg 43c
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**Galileo (1564-1642) First use a telescope to watch the sky**

Unnumbered Figure pg 43b
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**Tycho (1546-1601) Half helio + Half geo & Kepler (1571-1630) 3 laws**

Unnumbered Figure pg 43d
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**Newton (1642-1727) Law of universal gravitation**

# Ellipse

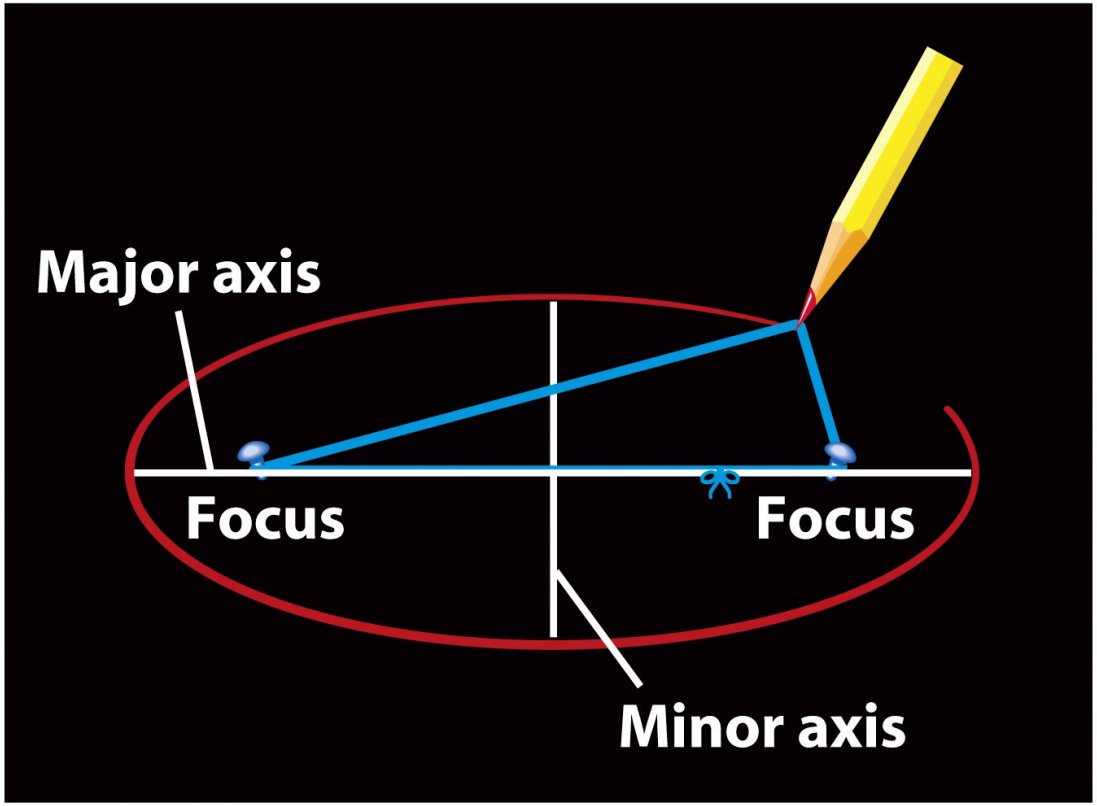


Figure 2-8a
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**e 是 eccentricity 離(偏)心率**

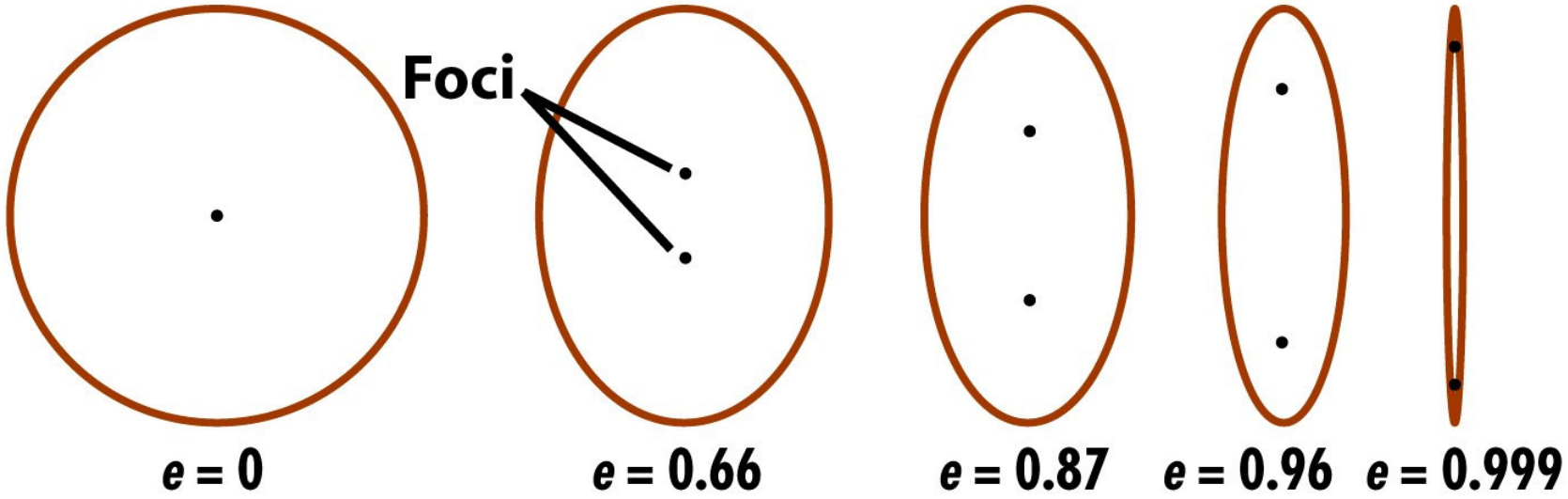


**Figure 2-8b**
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# Kepler's 3 Laws

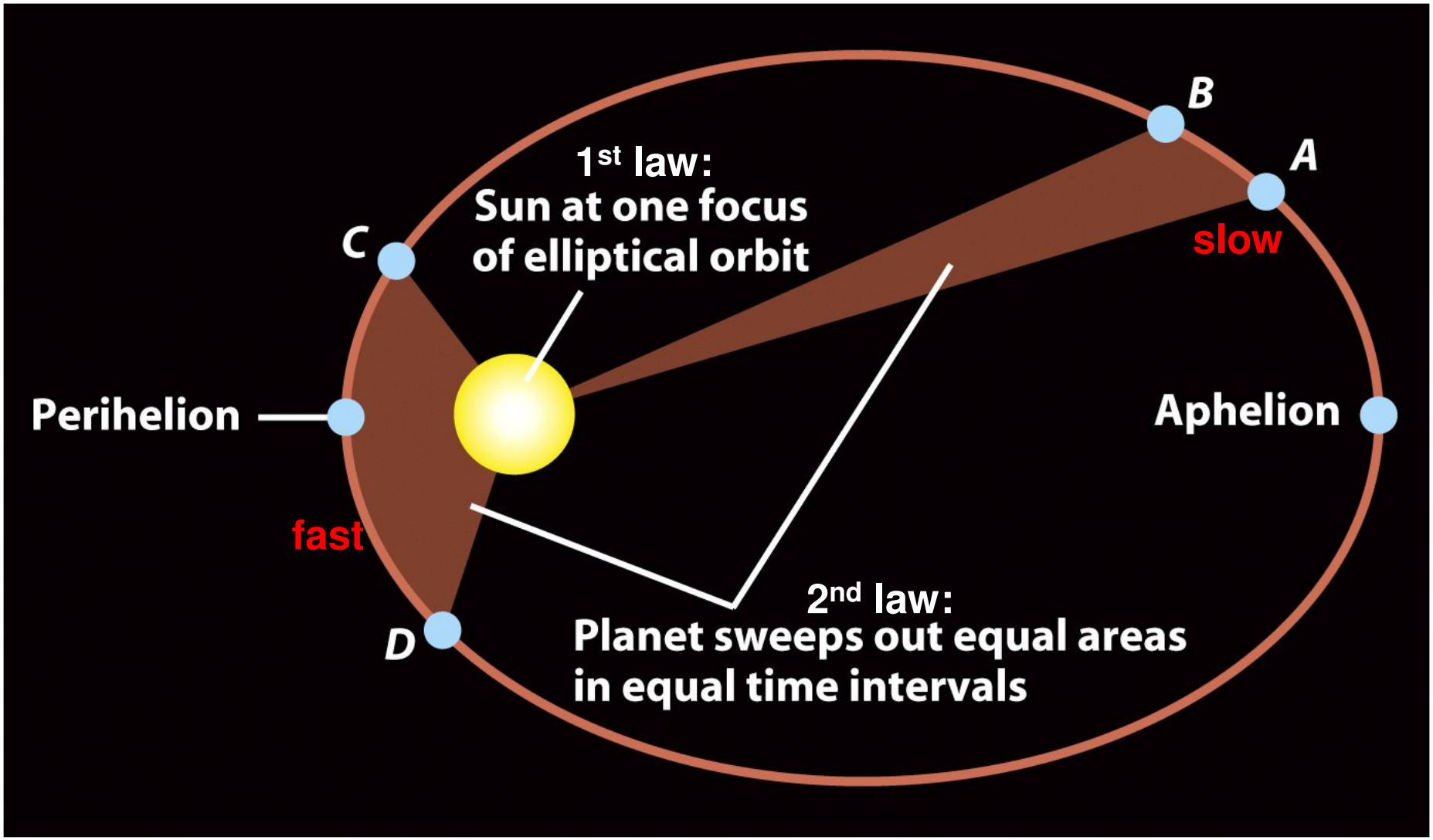


Figure 2-9
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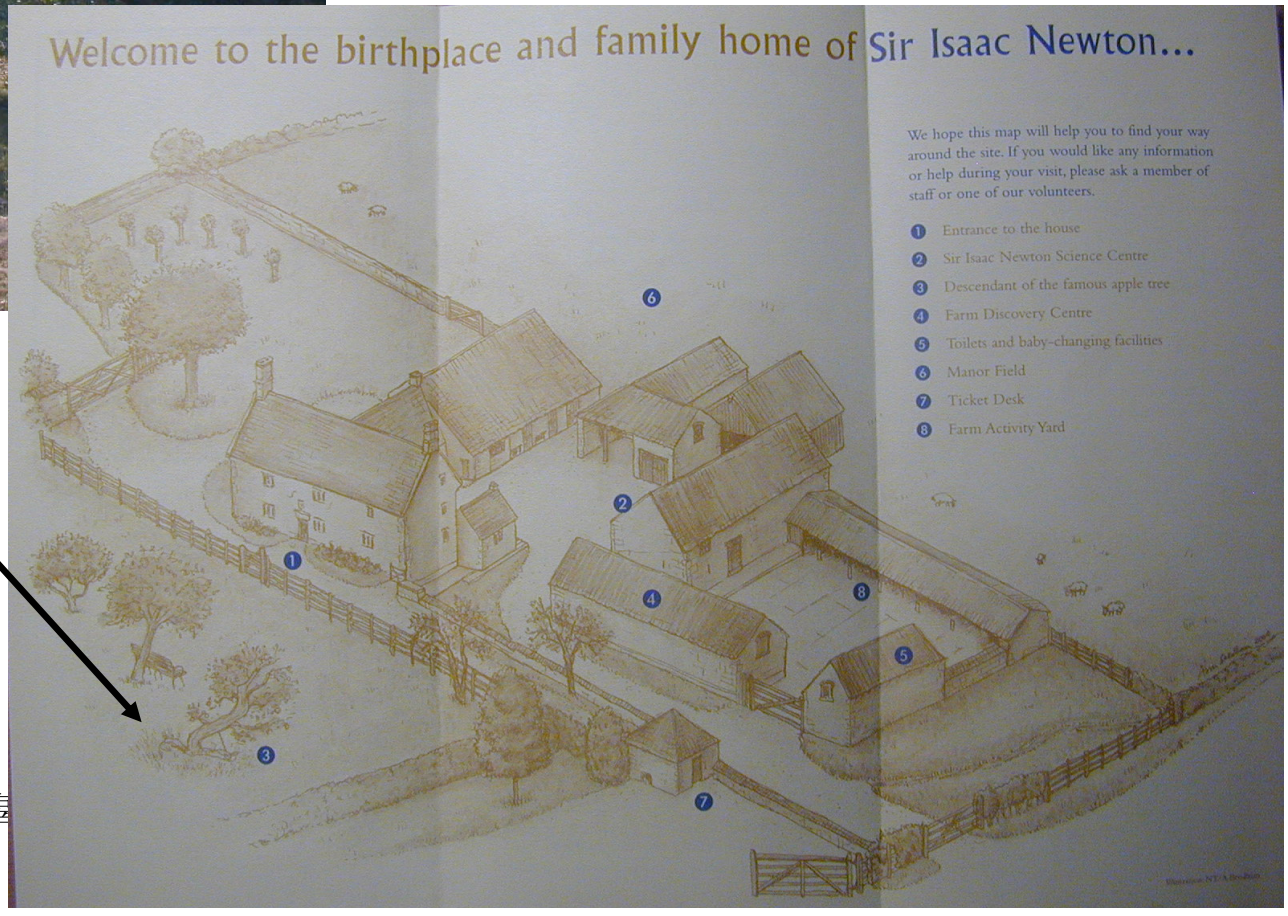
**3rd law: period$^2$=distance$^3$ the closer, the faster!**

**(Newton: the smaller the distance, the stronger the gravitational force)**

# Newton & Gravitation

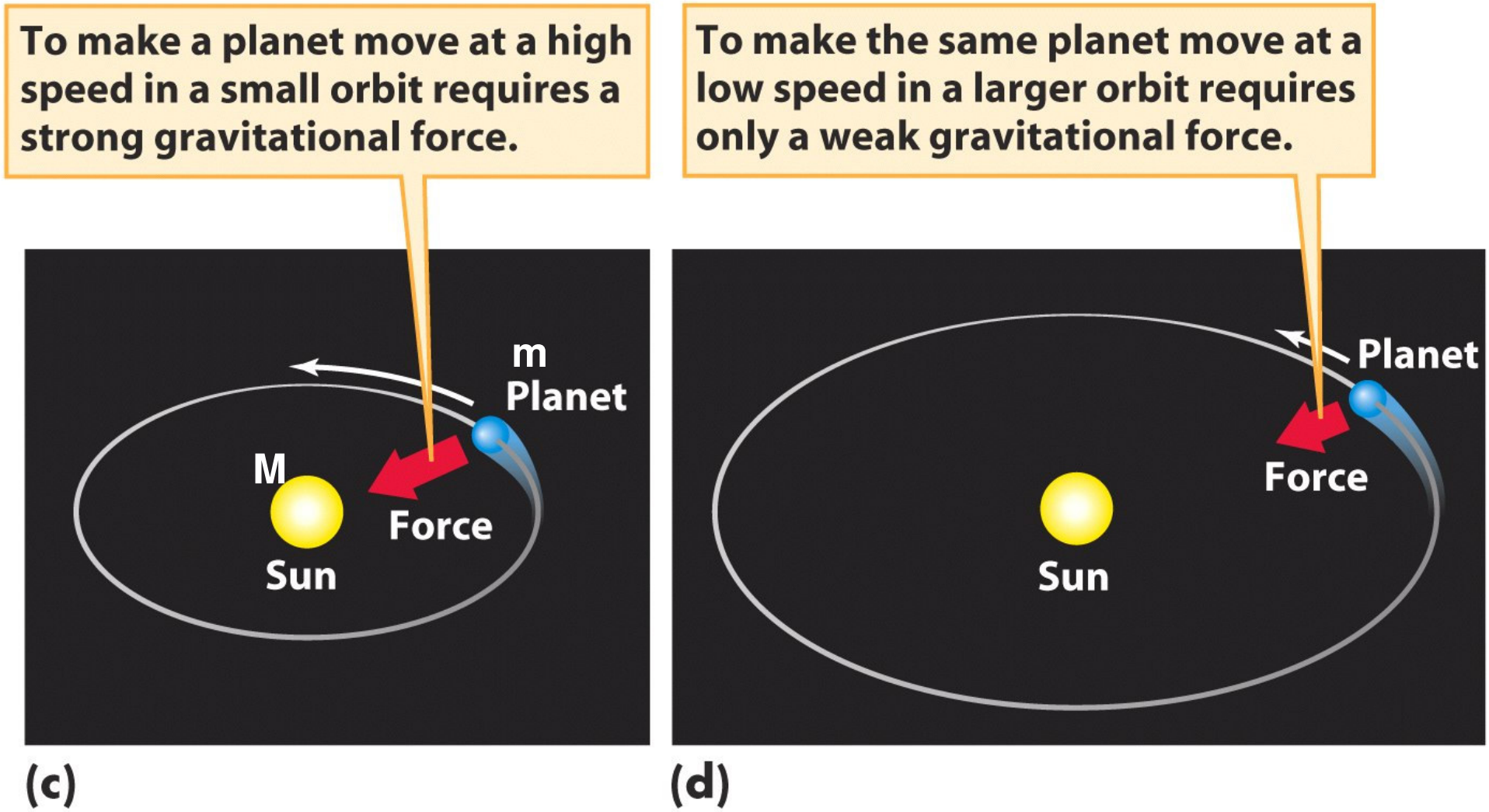
**Woolsthorpe**



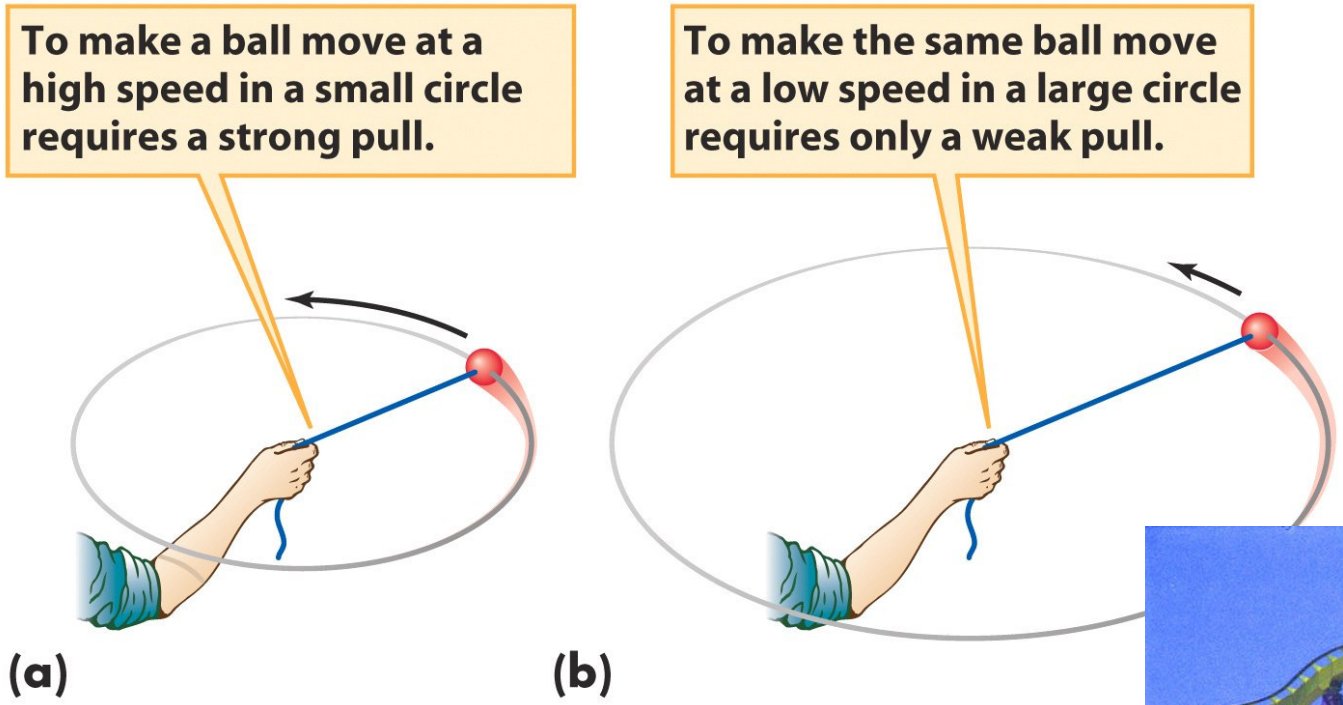
# Newton's law of gravitation

$$F_{gravity} \propto \frac{Mm}{r^2}$$ → **Kepler's laws**

**怎麼不會相撞？Ans:離心力**



# Centrifugal force (離心力)




# summary

- 為什麼行星都朝同一個方向以及大略同一個平面做公轉？
- 太陽系除了行星外還有什麼物質?
- 行星形成是由小而大逐漸組合成，還是由大而小破裂成？
- 為什麼說小行星帶可能是早期一羣無法形成行星的小天體?
- 什麼是太陽系的雪線？它對行星的形成和組成有何影響？
- 什麼是特洛伊(Trojan)小行星?
- 什麼是near earth objects?人類有注意它們的行蹤嗎(怕怕)?
- 小行星(asteroid)和慧星(comet)的組成有何不同?
- 為什麼慧星的尾巴與太陽的位置相反?
- 為什麼說古柏帶(Kuiper Belt)是短週期慧星的來緣?
- 為什麼天文學家臆測有歐特雲(Oort Cloud)的存在?
- Eris是第十顆行星嗎?
- 為什麼大型的天體(行星或矮行星)是球形的？
- 有介在恆星和行星之間的天體嗎？
- 什麼是台美掩星計畫?
- 什麼造成流星雨?
- 什麼是牛頓的重力理論？
- 為什麼越接近太陽，行星公轉得越快？