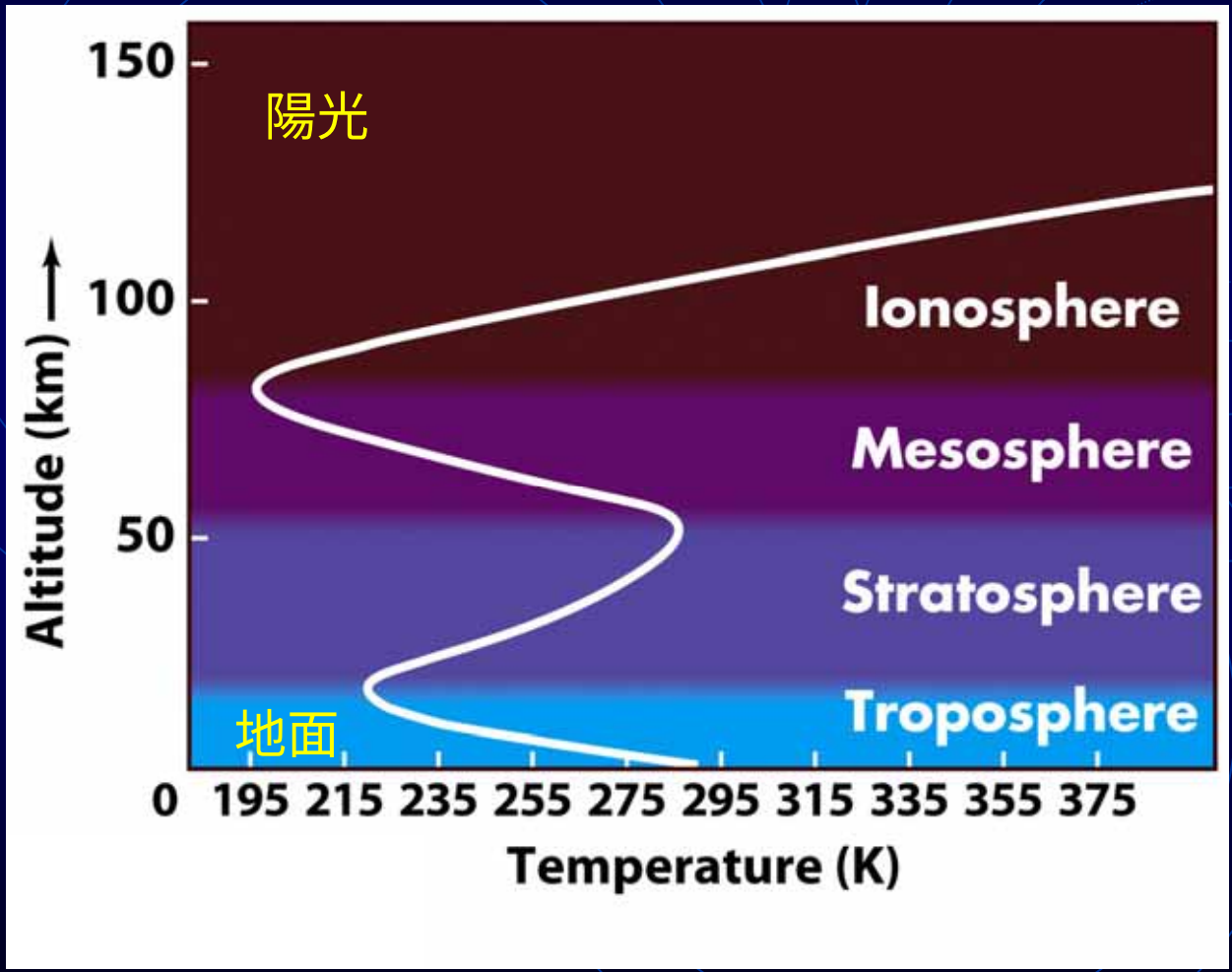
地球 (Earth)

- 水的世界，孕育生命
- 活躍的地表（火山，地震等）
- 磁場與大氣層（80%氮 nitrogen, 20%氧 oxygen）的保護
- 我們的近鄰： 永遠同一面的月球；潮汐
  如果沒有月球會如何？

[Pressure] ＝ [Force] / [Area]

大氣壓力
＝大氣的重量



海拔（公里）

電離層

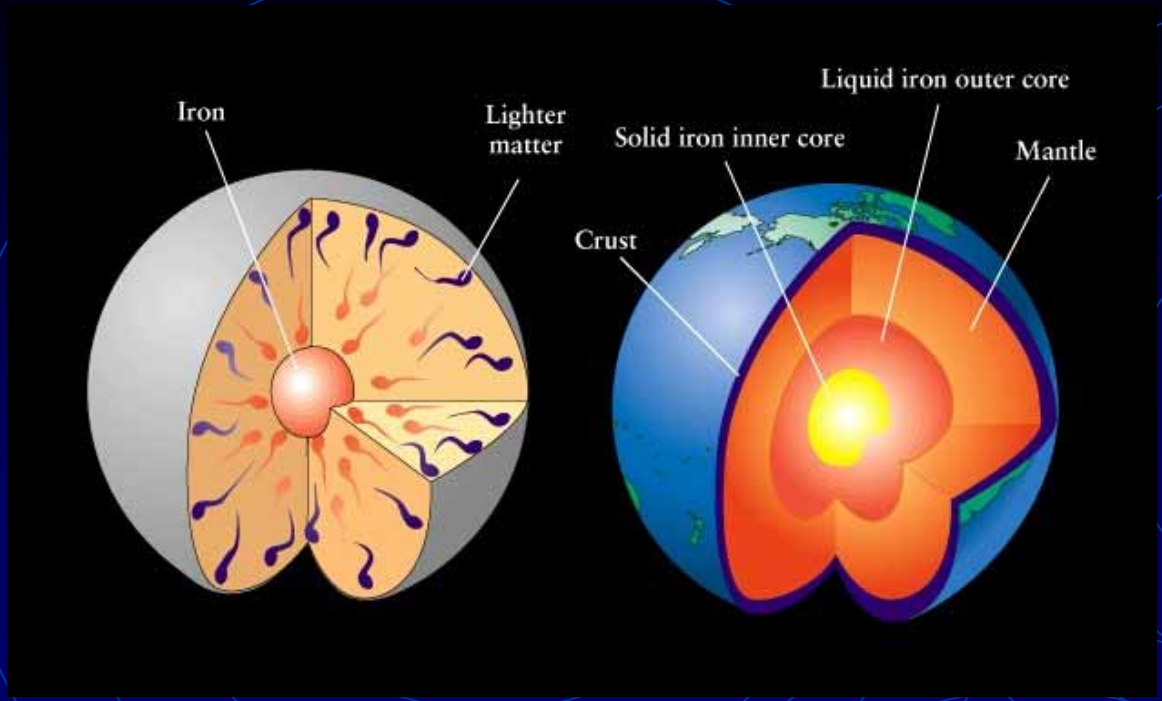
中氣層

同溫層

對流層

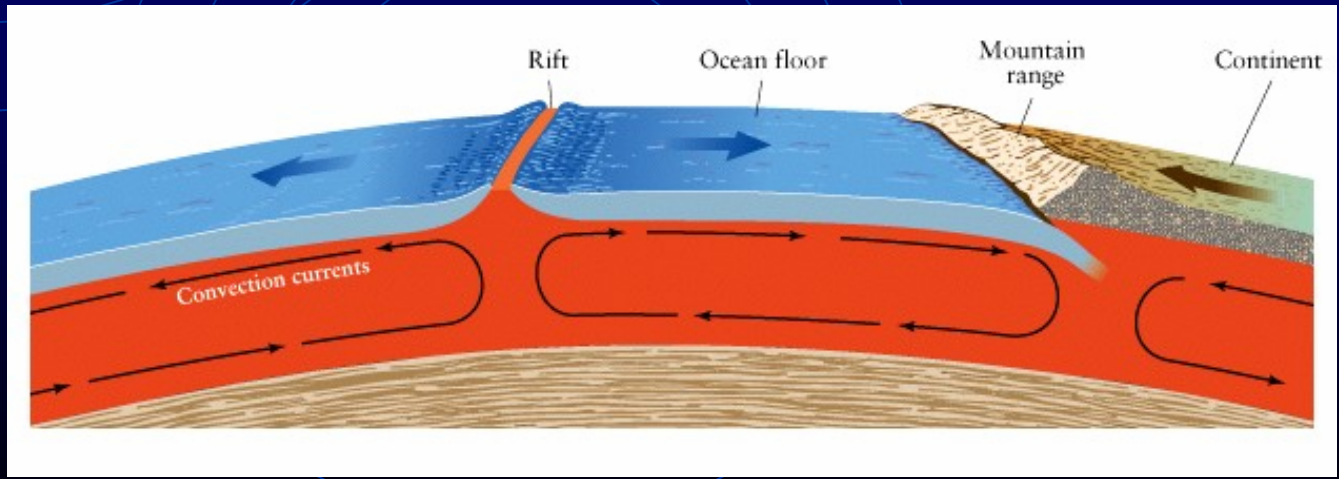
11-50 km
臭氧層
（保護層）

溫度 (K) = 攝氏 ＋ 273



地球中央有個鐵鎳核心 (core)，外面包覆著岩石地函 (mantle)

地球內部對流造成**板塊運動 (plate tectonics)**



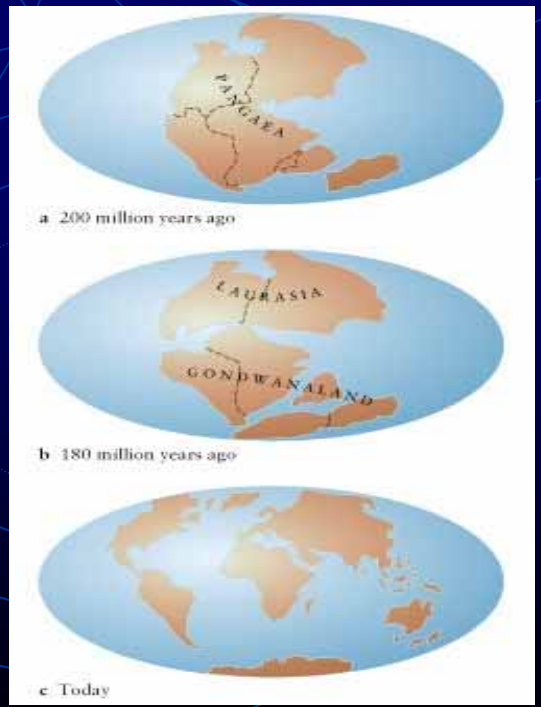
中洋脊

大西洋當中的海底山脈 (the Mid-Atlantic Ridge)，乃是地球內部岩漿冒出而成

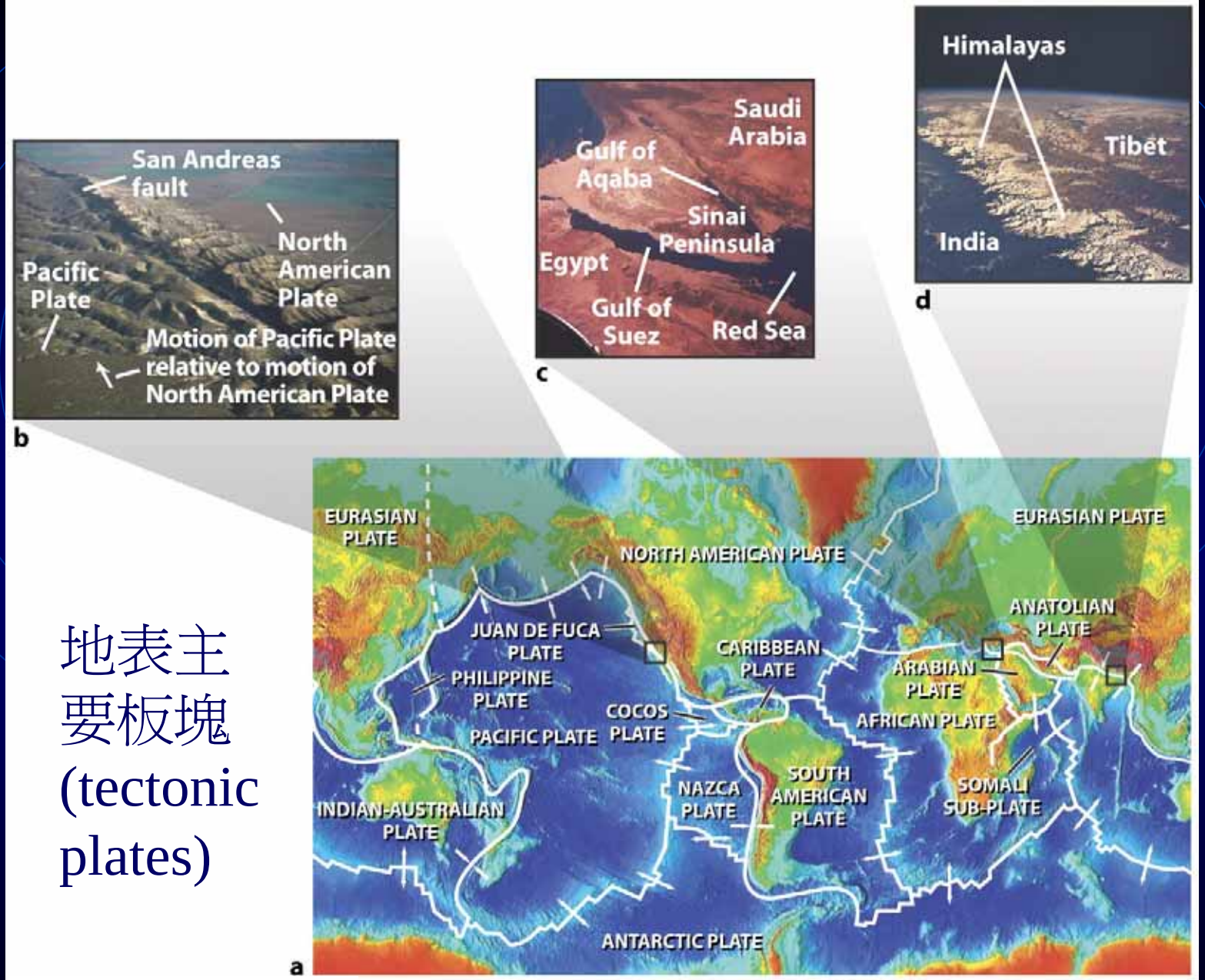
大陸邊緣吻合

➔以前是連在一起的

Alfred Wegener：
大陸飄移學說
(continental drift)

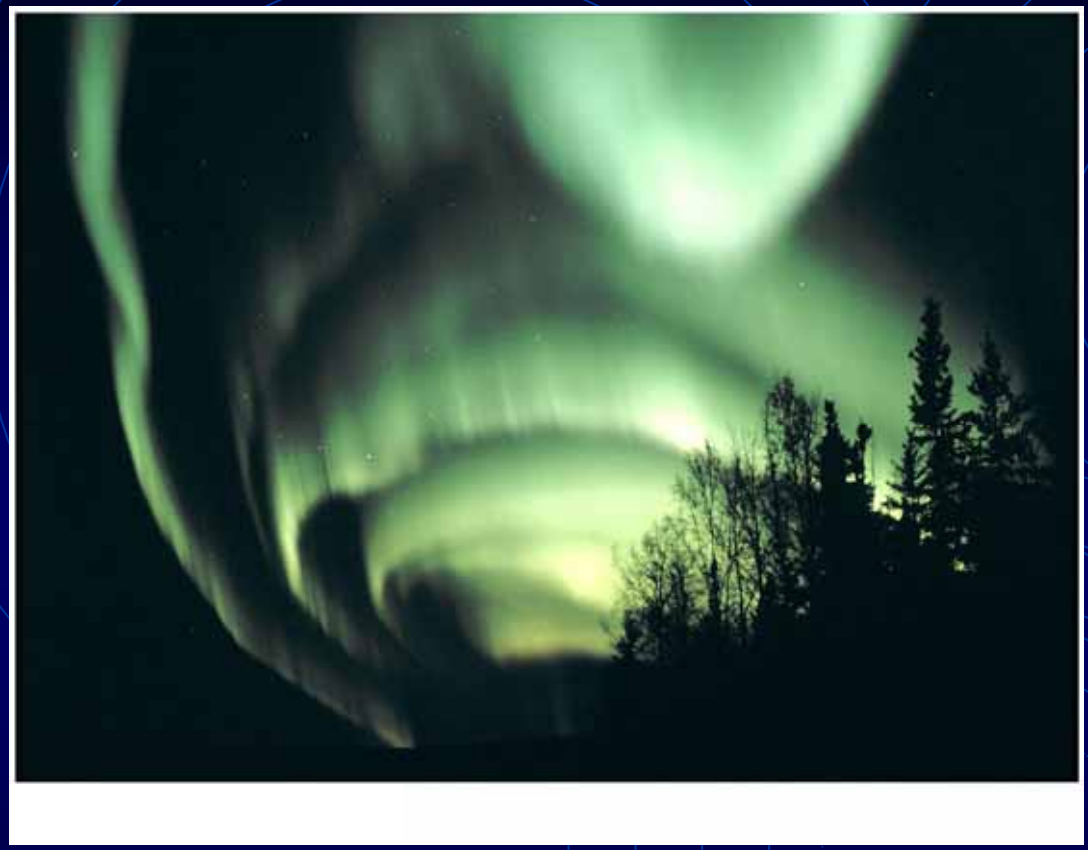


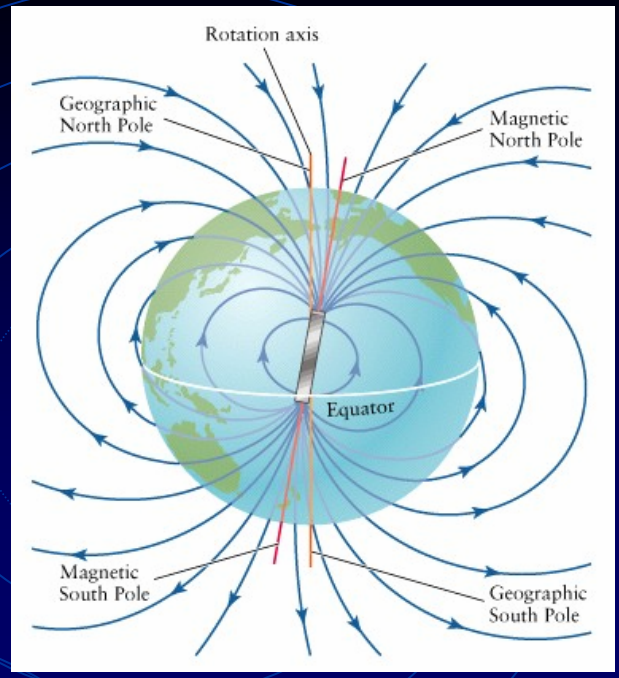
Pangaea
盤古大地

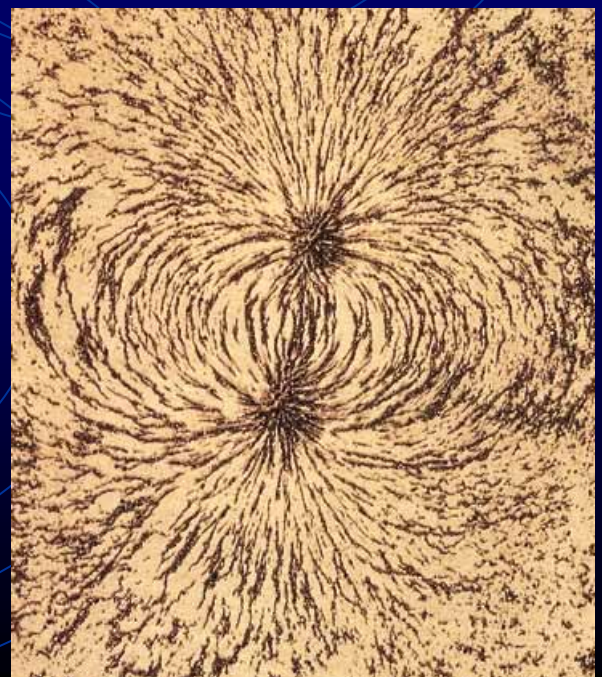


地表主要板塊 (tectonic plates)

極光 (aurora)

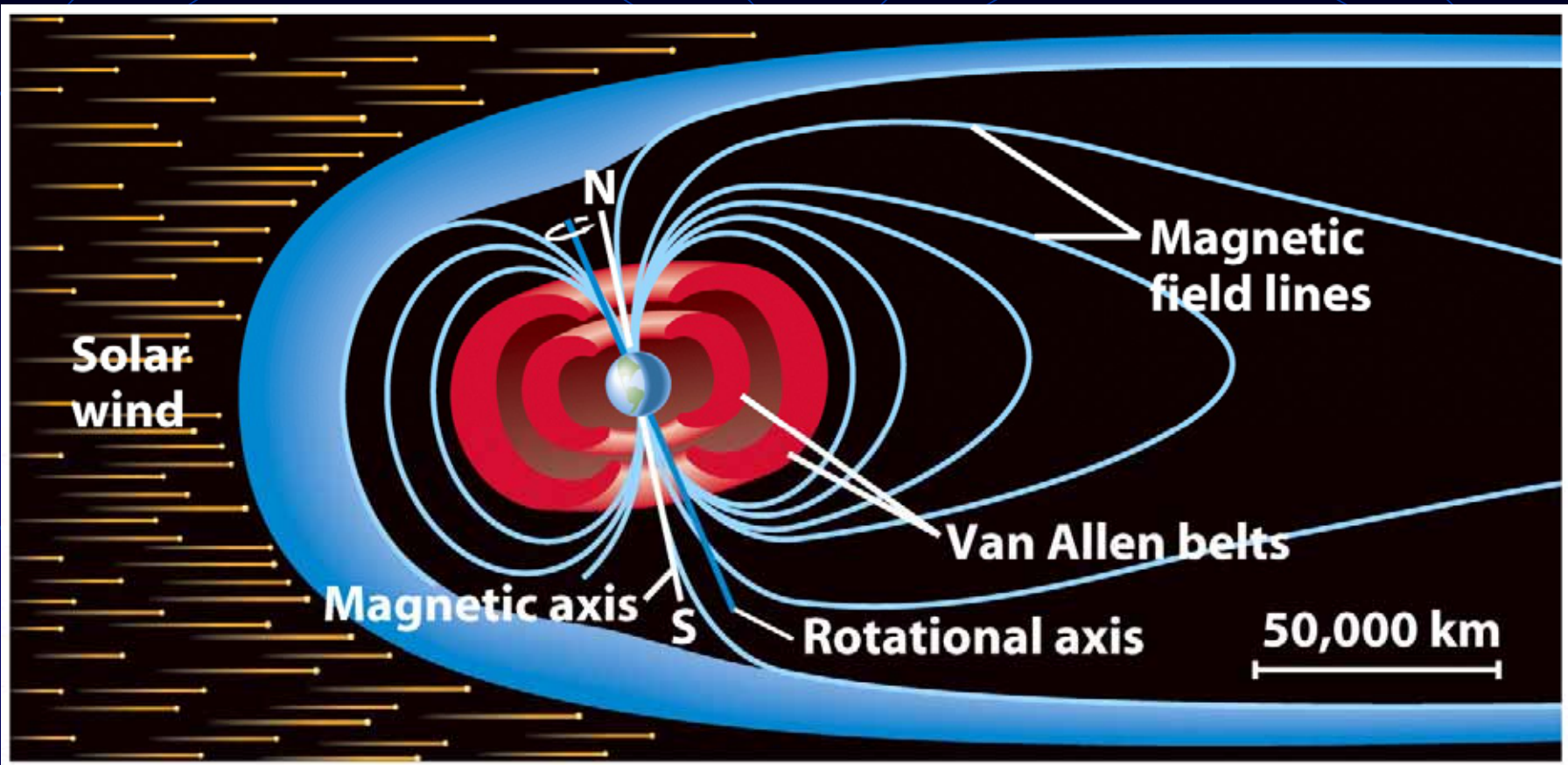






地球本身有磁場，保護地表與生物免於受太空帶電粒子（宇宙射線）的侵襲

Magnetosphere （磁層）



Van Allen radiation belts: 地球周圍兩個泳圈狀區域，乃太陽風帶電粒子集中之處

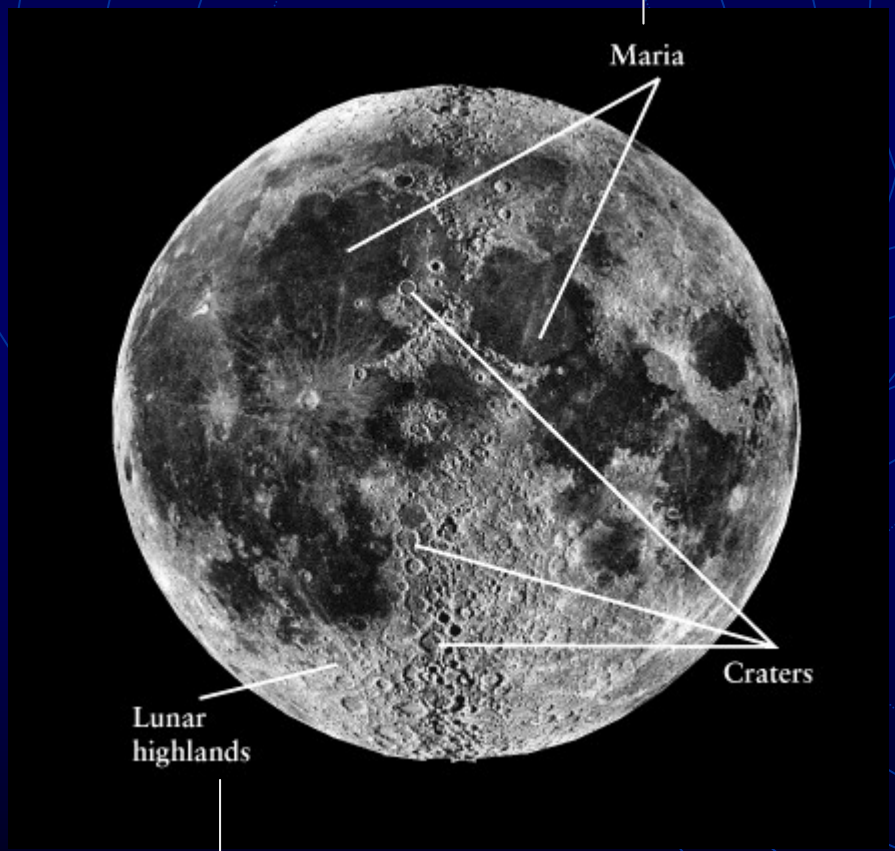
登入 Blackboard 網路教學平台的方式

學生登入方式: **bb.ncu.edu.tw**
使用者名稱：學號　　密碼：學號
登入後即可更改密碼

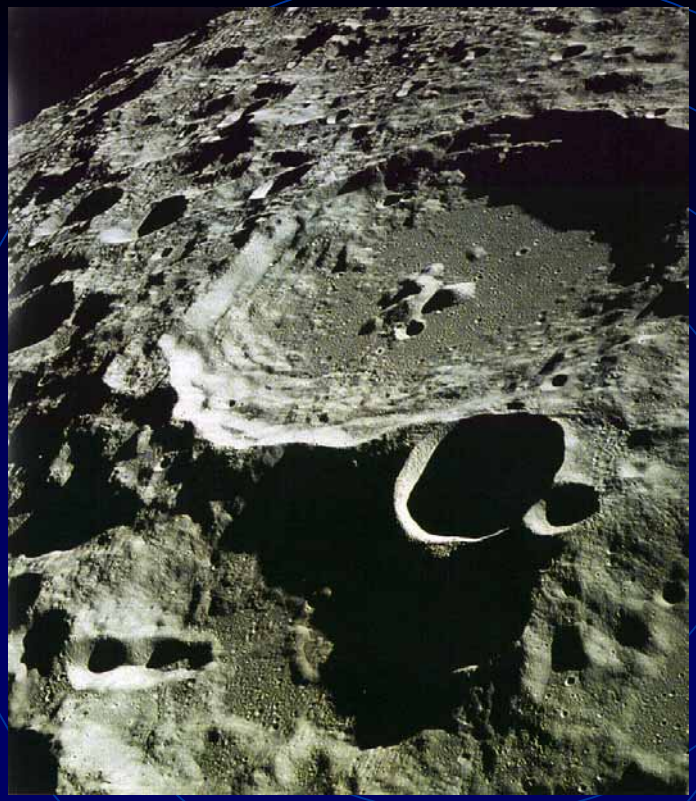
新的上課投影片將放在 BB 上

月球 (Moon)

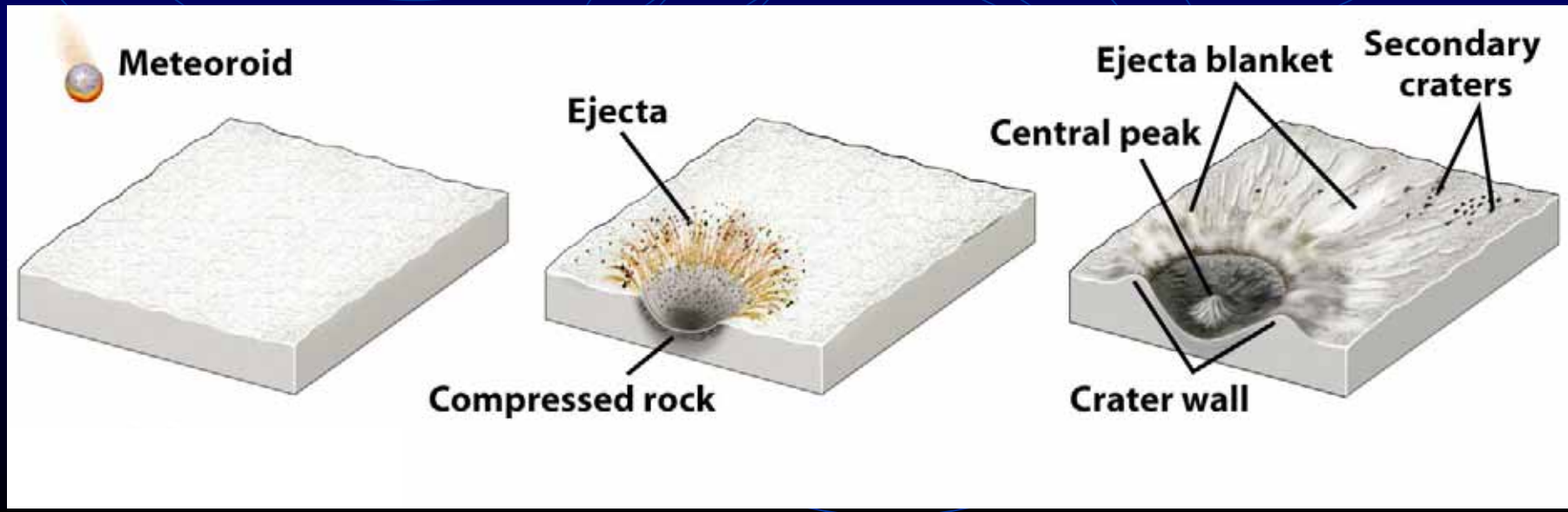
「月海」(mare) ＝顏色灰暗；低窪地區



highland 高地，佔月面 83% 面積



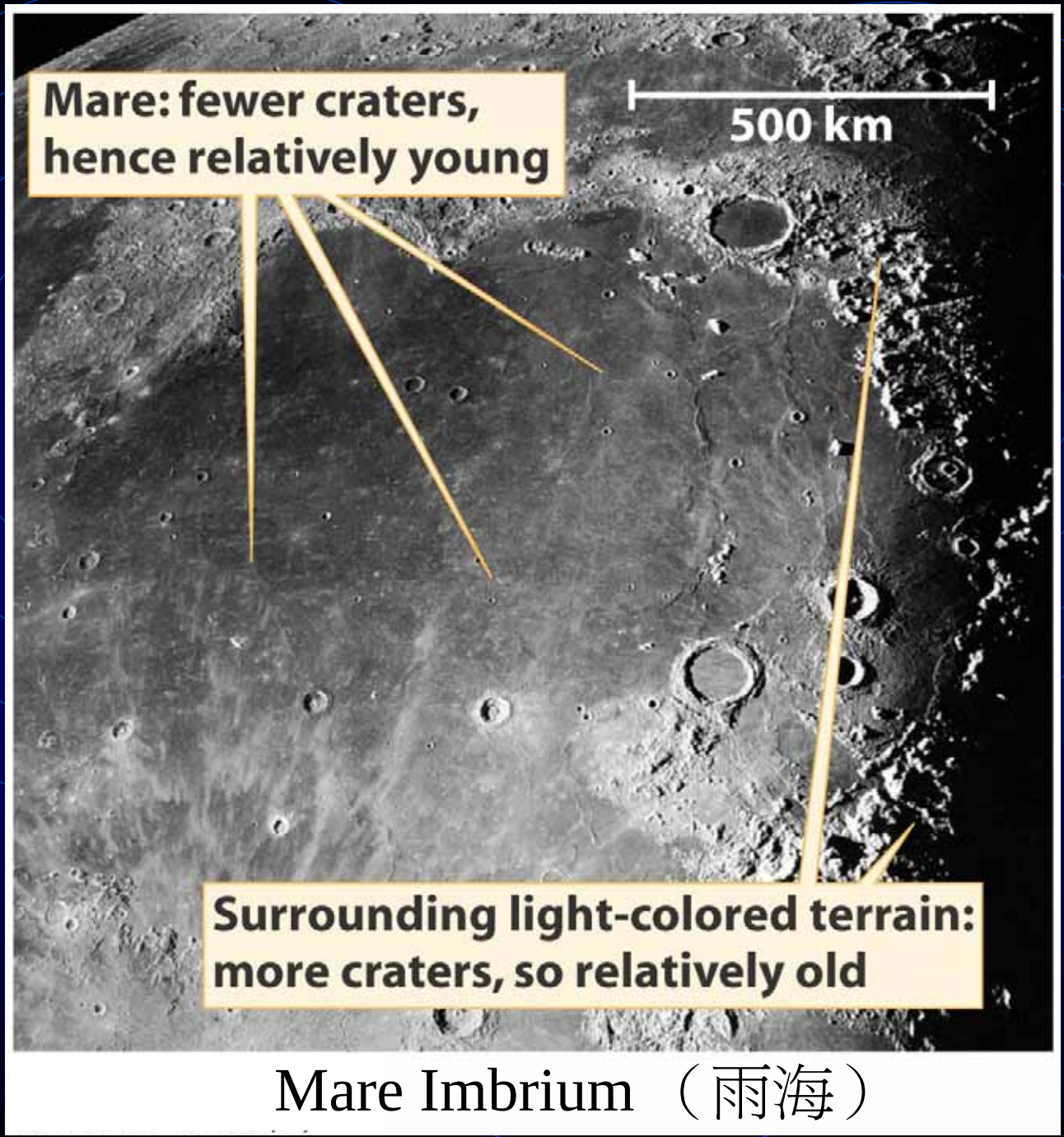
從地球使用望遠鏡可以看到超過 3 萬個隕石坑，一般大型隕石坑以天文學家、物理學家、數學加、哲學家命名，例如凱卜勒、哥白尼、畢達哥拉斯 (Pythagoras)、柏拉圖 (Plato)、亞里斯多德 (Aristotle)



Microscopic Lunar Crater < 1 mm

月海 (mare; 複數爲 maria)

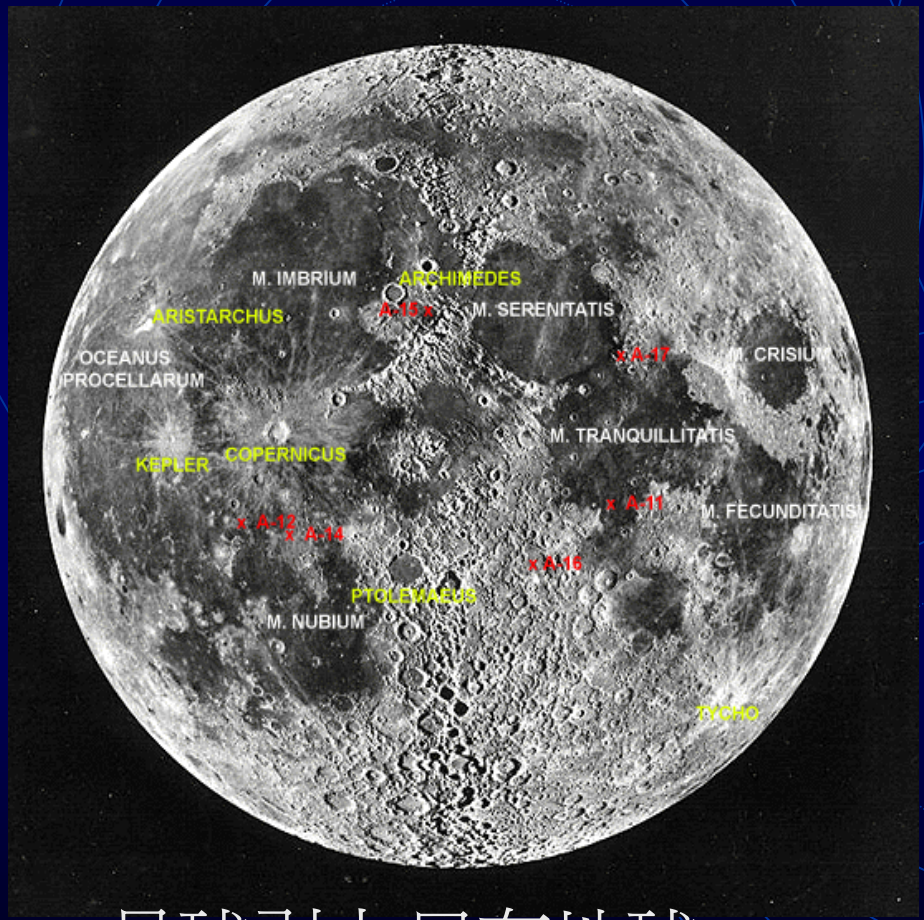
- 拉丁文「海」之意。十七世紀觀察月球者以爲是「海」
- 現在我們知道這些並非水，而是月面岩漿往低窪地區流動構成的盆地區域
- 有名的月海：
  Mare Imbrium (Sea of Showers 雨海）最大的月海,直徑 1100 km
  Mare Tranquillitatis (Sea of Tranquillity 寧靜海)
  Mare Nebium (Sea of Clouds 雲海）
  Mare Nectaris (Sea of Nectar 酒海）
  Mare Serenitatis (Sea of Serenity 澄海)



Mare Imbrium（雨海）

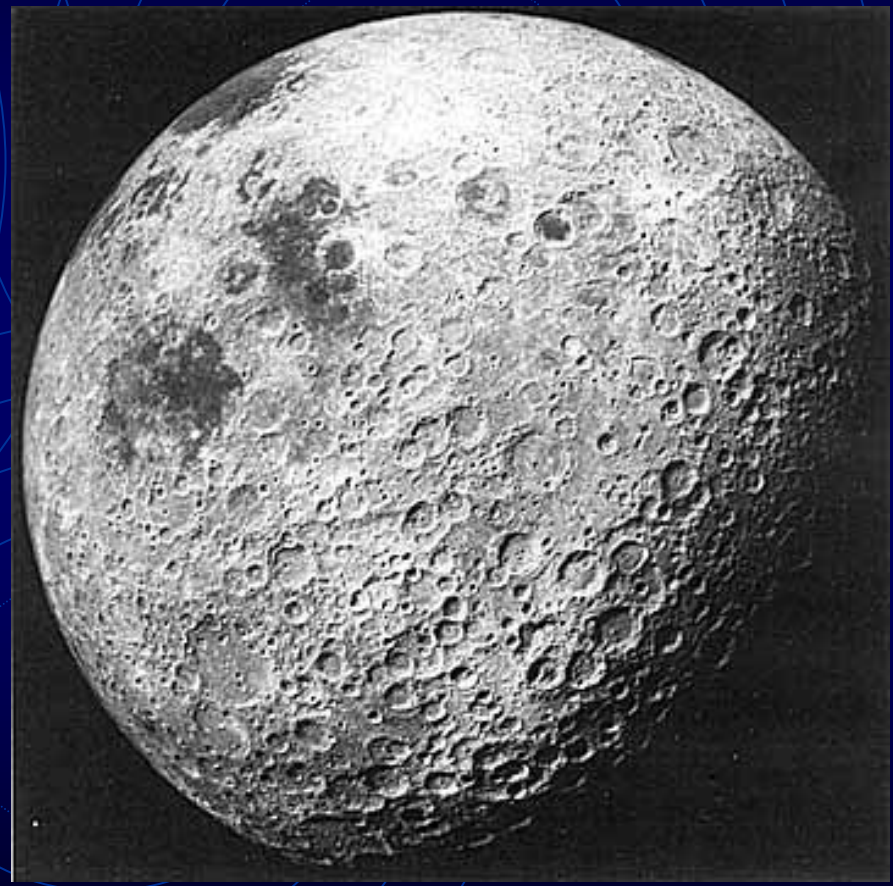
月球永遠以同一面對著地球

我們看到的月球表面

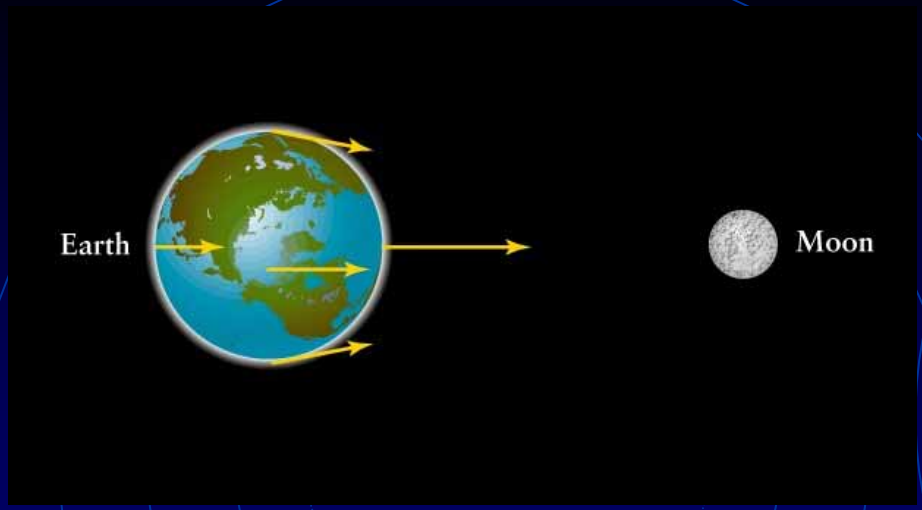


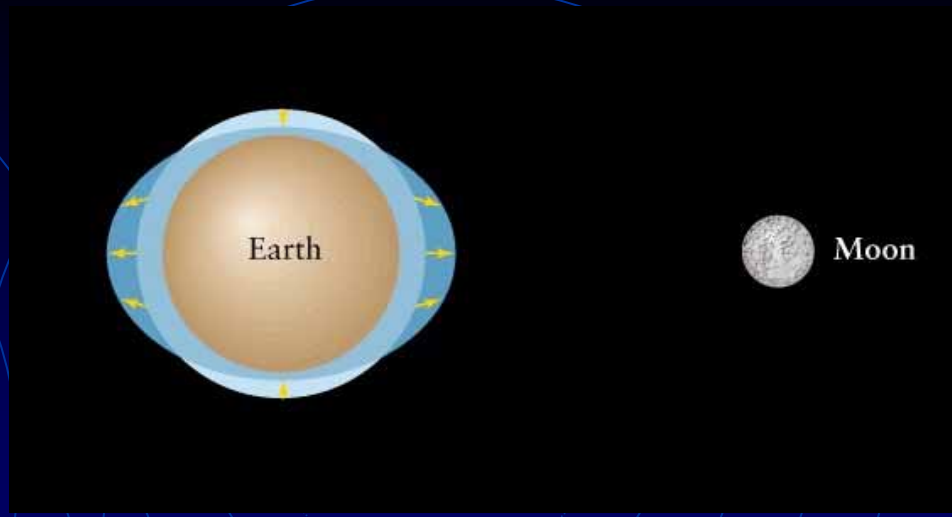
月球引力只有地球1/6，無法抓住大氣層

月球背面 (farside)



灰暗（低窪）區域比較少
→ 高地居多





潮汐來自月球與太陽的**萬有引力差**

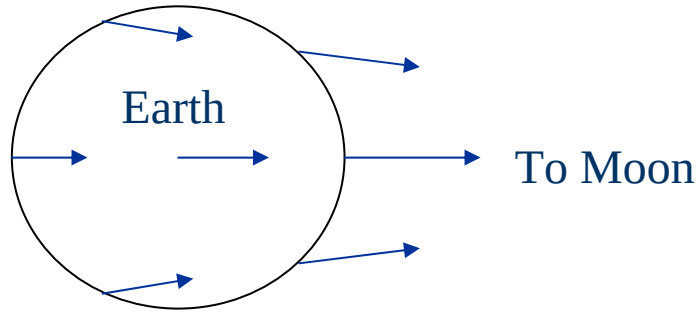
月球雖然小，但是距離地球近，影響較大

滿月、新月 → 大潮

上弦、下弦 → 小潮

Tidal Force　潮汐力 = 萬有引力差

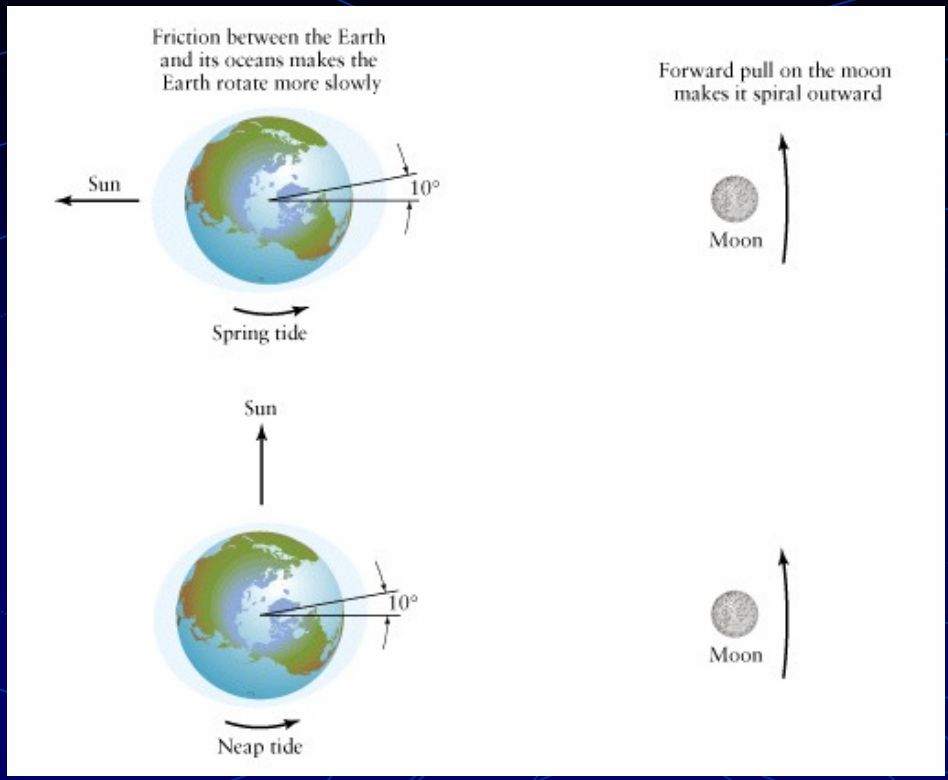
$$dF/dR = -2GM_{\text{moon}}/R^3$$



dF is the differential gravitational force directed along R, and dR is the diameter of a single solid body or the separation between two bodies being acted upon by the tidal forces.

驗證：

The tidal force of the Sun relative to that of the Moon is $\approx 5/11$.



地球的海洋突起指向月球「前方」
（因爲地球自轉比月球公轉快）
→ (1) 地球自轉越來越慢（每世紀千分之一秒，
地球剛誕生時可能每6小時轉一圈），
(2) 月球越來越遠（每年3.8公分）

近來對月球的探測的重點之一，在於月球是否有水...

水不但可以提供生活所需，分解後也可以提供氫（燃料）及氧（生命所需）

Fission Theory --- Moon pulled out from a rapidly rotating proto-Earth. Moon is receding from us.
But lunar samples showed no water in the rocks

Capture Theory --- Moon formed elsewhere, but drawn into orbit about the Earth
But the Moon and Earth's surface have similar geochemistries

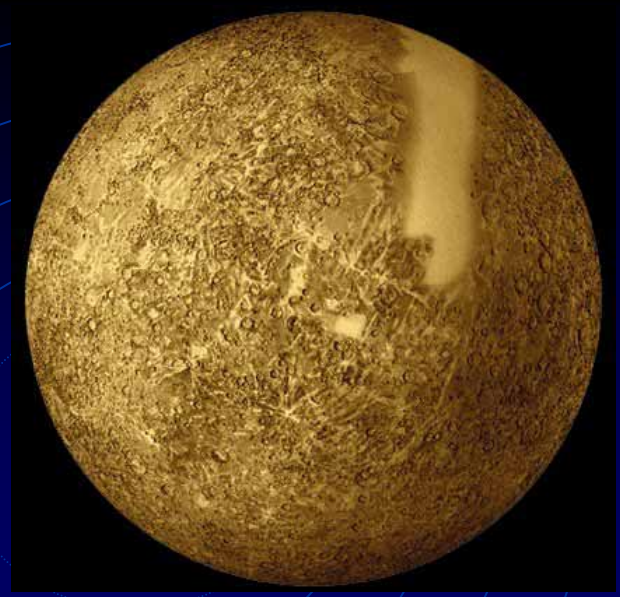
Cocreation Theory --- Moon and Earth formed near each other at the same time
But the Moon has less of the denser elements (e.g., iron) compared to the Earth

Giant Impact Theory --- young Earth struck at an angle by a Mars-sized asteroid.
Earth's surface layer → orbit → Moon

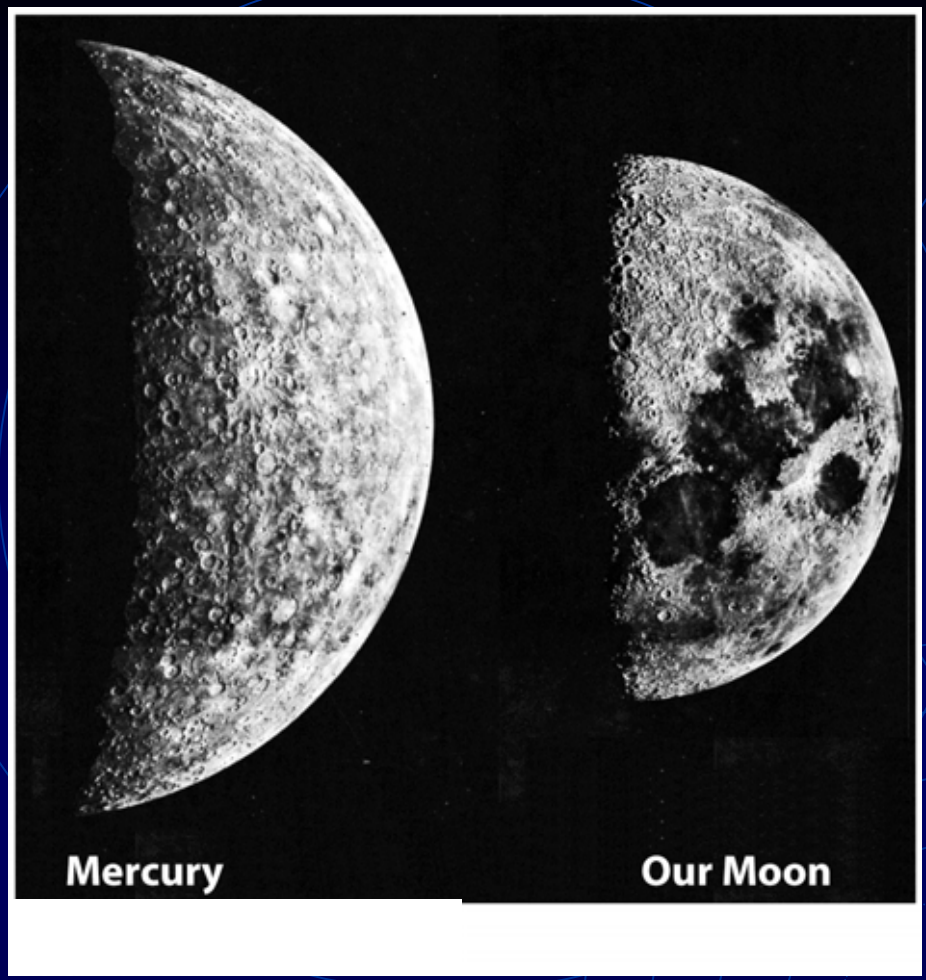
WHAT IF the Moon Didn’t Exist?

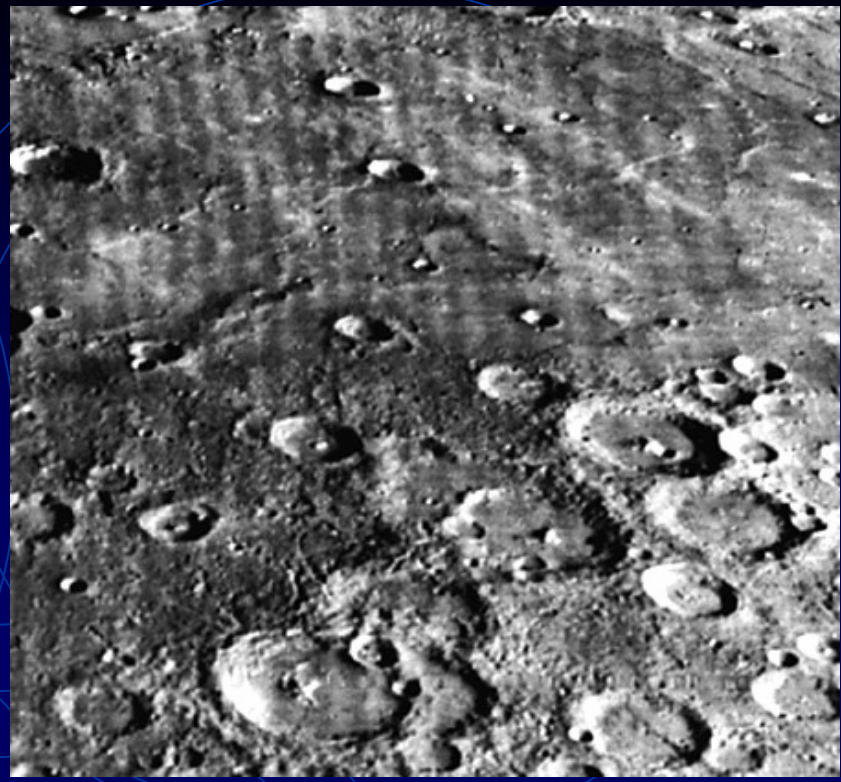
- Delayed Origins 生命可能不會這麼快誕生
- Harsh Conditions 地球環境可能更惡劣
- Rush Hours 一天6小時
- Tumbling Earth 自轉軸指向不穩定

水星 (Mercury)



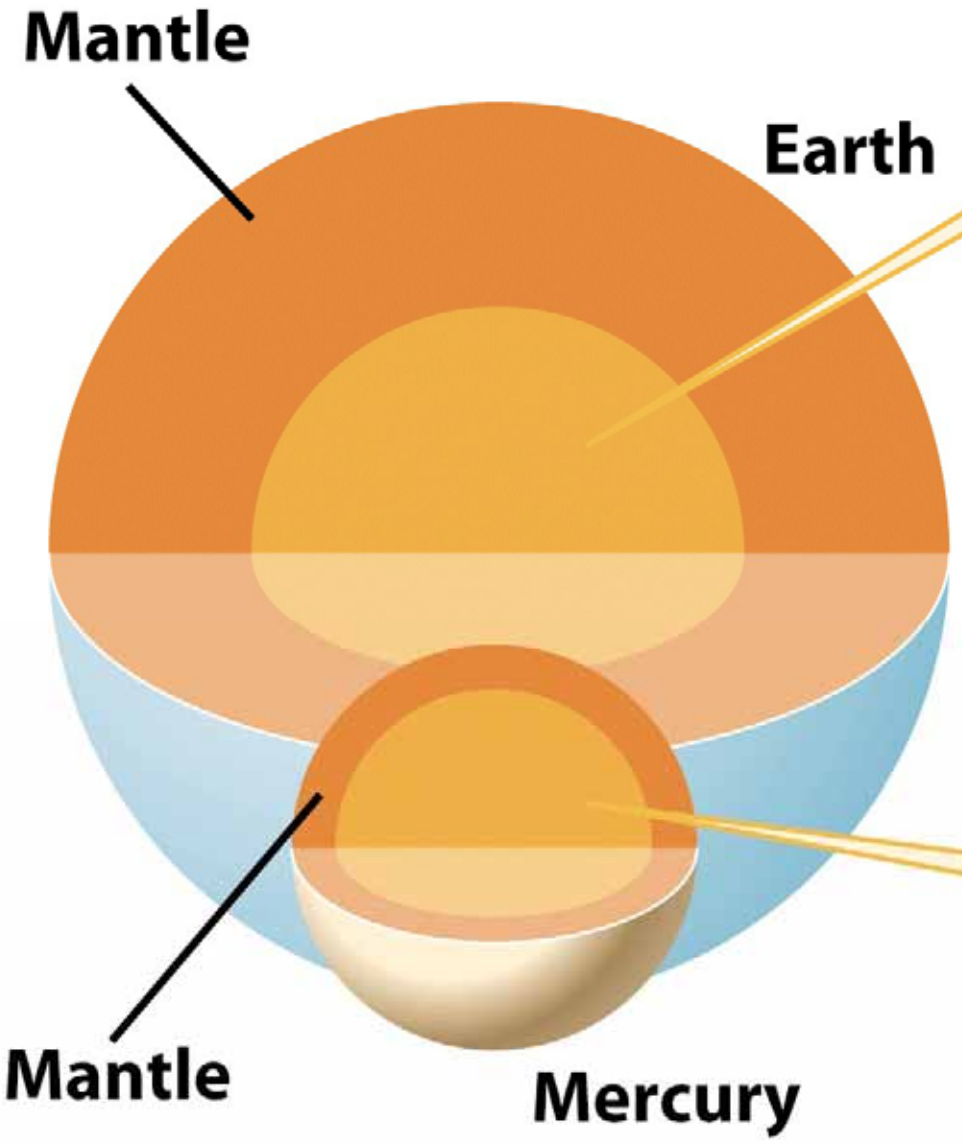
- 隕石坑多（與月球很相像）
- 離太陽最近的行星
- 幾乎沒有大氣層 為什麼？少數氣體來自岩石擠壓及太陽風（主要是氫與氦）
- 日、夜溫差大（太陽系中最大者）
  正午 700K，夜晚 100K
- 太陽潮汐力（公轉兩次，自轉三次，也就是水星的一天相當於兩年）





1974 by *Mariner*

水星的兩極有些隕石坑沒有日照，似乎有冰。是彗星撞擊所致，還是來自水星內部的氣體造成的？

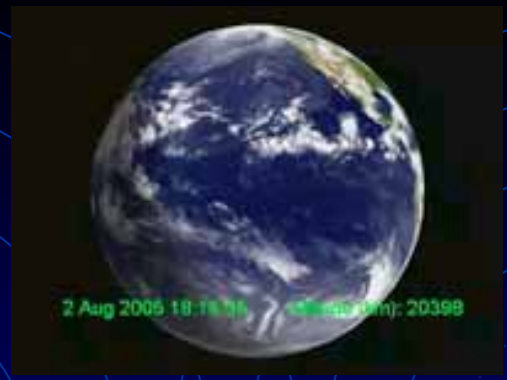


Earth's iron core is 55% of the diameter of the entire planet, or 17% of its volume…

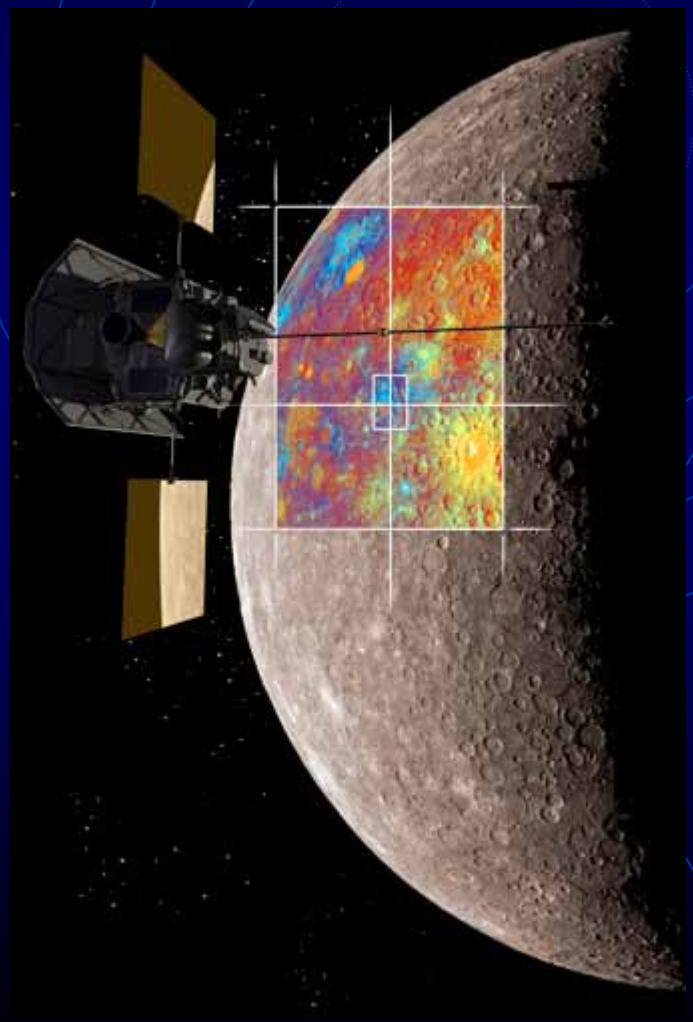
水星是太陽系中鐵含量最豐富的行星

…whereas Mercury's iron core is about 75% of the planet's diameter, or 42% of its volume

Messenger 任務



2005 Earth flyby

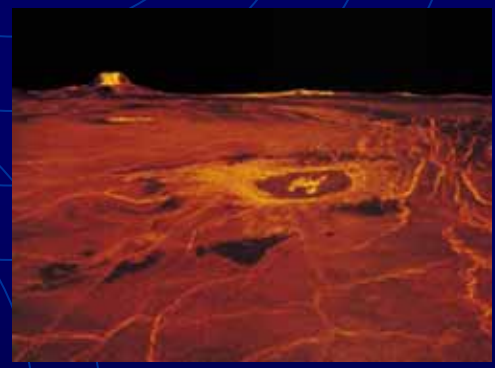


MESSENGER launched from Cape Canaveral Air Force Station, Fla., on August 3, 2004. It returned to Earth for a gravity boost on August 2, 2005, then it will fly past Venus twice, in October 2006 and June 2007. The spacecraft uses the tug of Venus' gravity to resize and rotate its trajectory closer to Mercury's orbit.

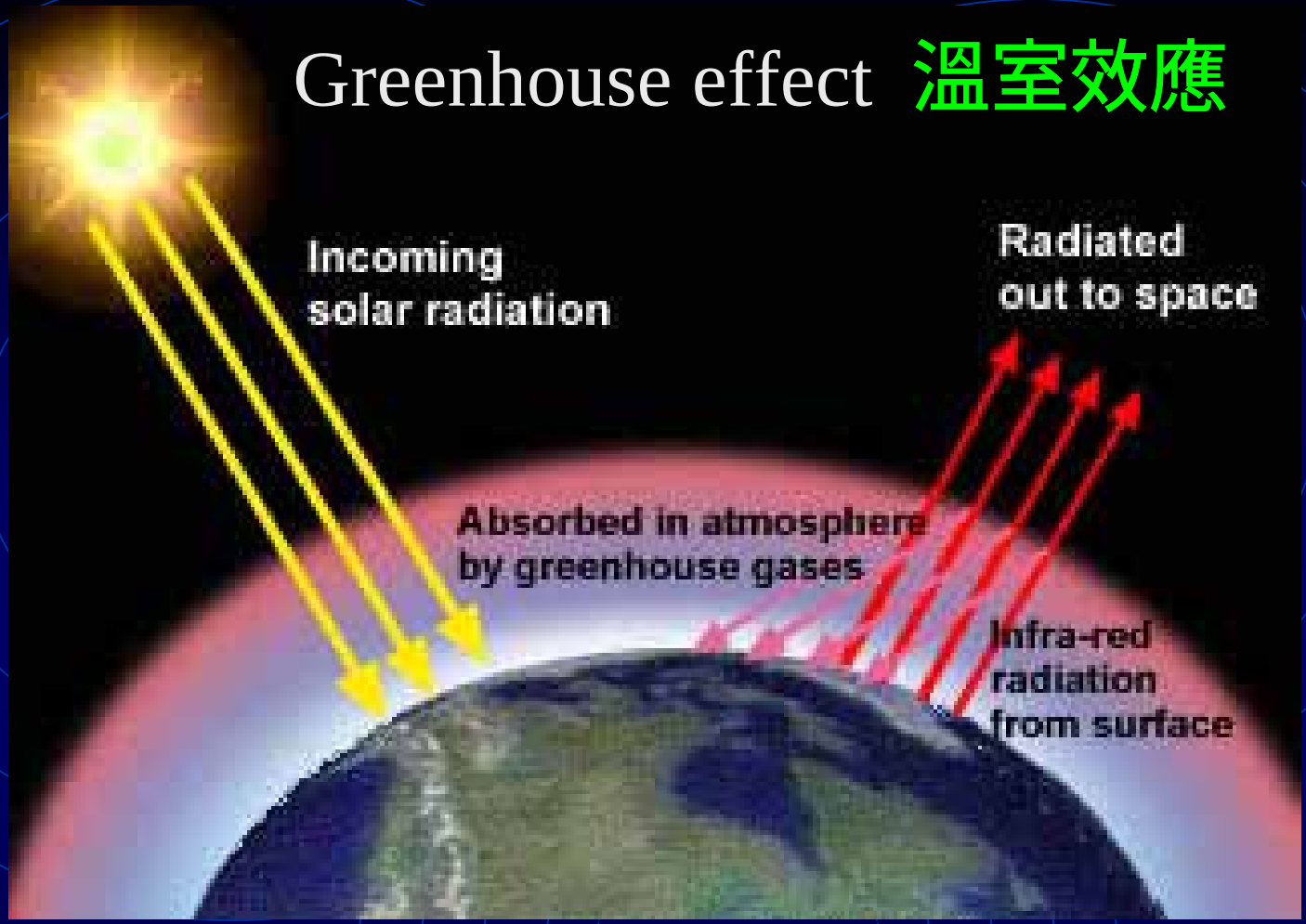
Three Mercury flybys, each followed about two months later by a course correction maneuver, put MESSENGER in position to enter Mercury orbit in March 2011. During the flybys – set for January 2008, October 2008 and September 2009 – MESSENGER will map nearly the entire planet in color, image most of the areas unseen by Mariner 10, and measure the composition of the surface, atmosphere and magnetosphere. It will be the first new data from Mercury in more than 30 years – and invaluable for planning MESSENGER's yearlong orbital mission.

http://messenger.jhuapl.edu/

金星 (Venus)

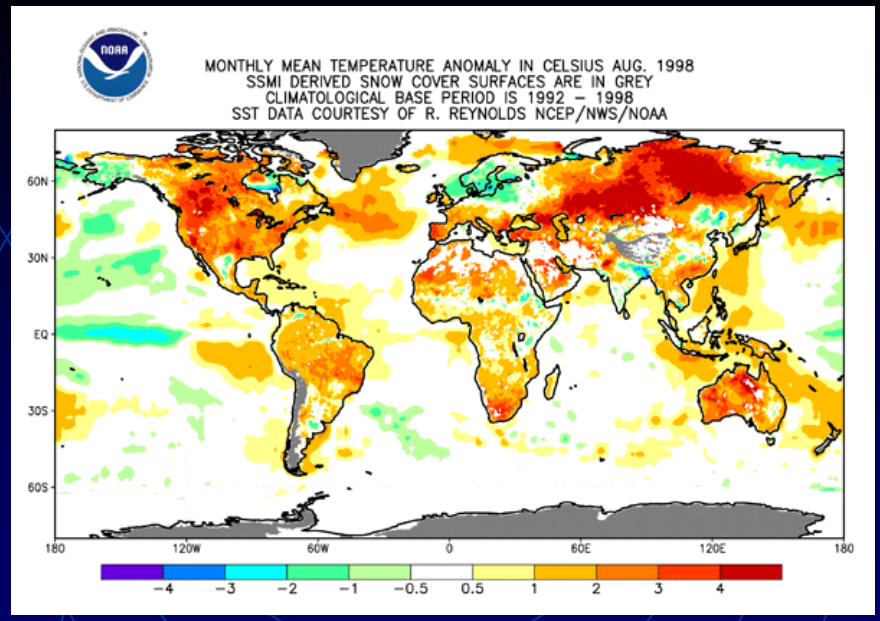


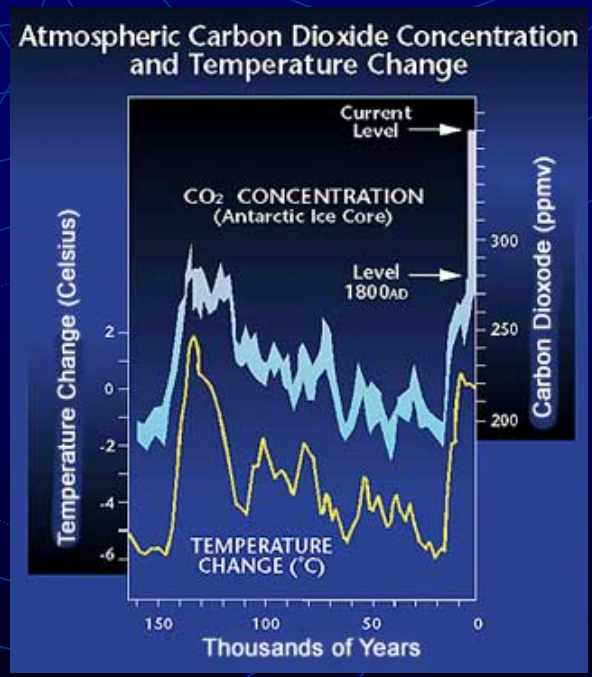
- 凌晨，黃昏地平面上；耀眼
- 離地球最近的行星
- 沒有磁場
- 大小與地球相當
- 自轉方向與其他行星相反
- 厚重的大氣
  → 嚴重的「**溫室效應**」**(Greenhouse effect)**
  → 表面溫度極高（太陽系中最熱的行星）
- 麥哲倫號發現曾經有火山（岩漿）活動



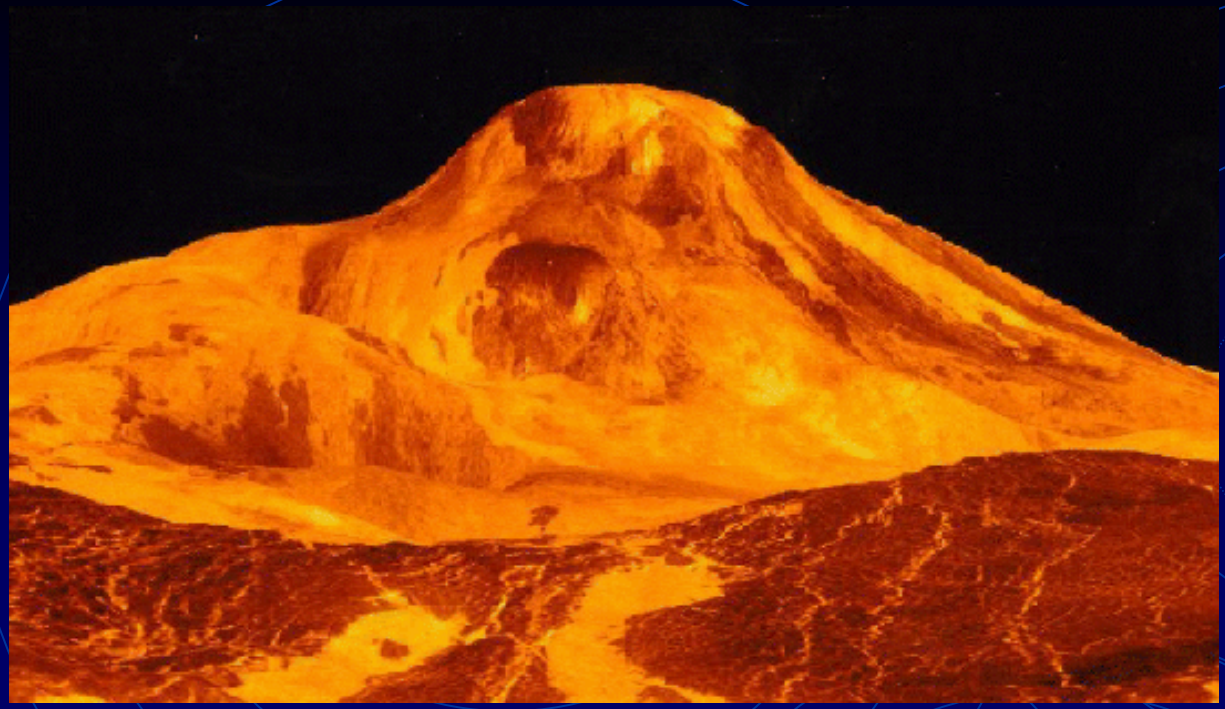
陽光（主要是可見光與紫外線）照射，地表受熱後輻射紅外線與微波，這些長波輻射容易被大氣分子吸收

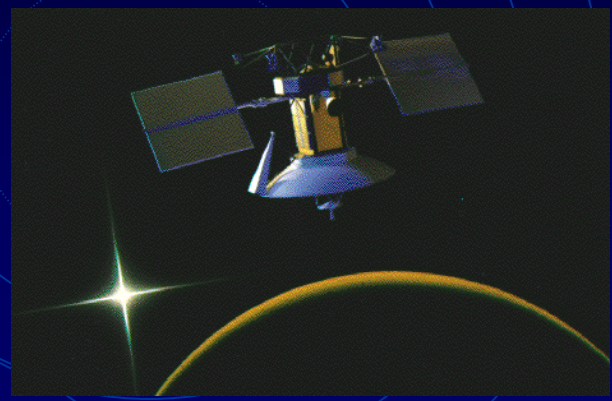
- 因爲有溫室效應地球才有生命誕生
- 如果沒有 greenhouse effect，地球的平均溫度會低攝氏30度，也就不是現在的攝氏15度，而在冰點以下
- 但要是人類製造太多「溫室氣體」，使溫室效應惡化，便有全球暖化、氣候失調的危機



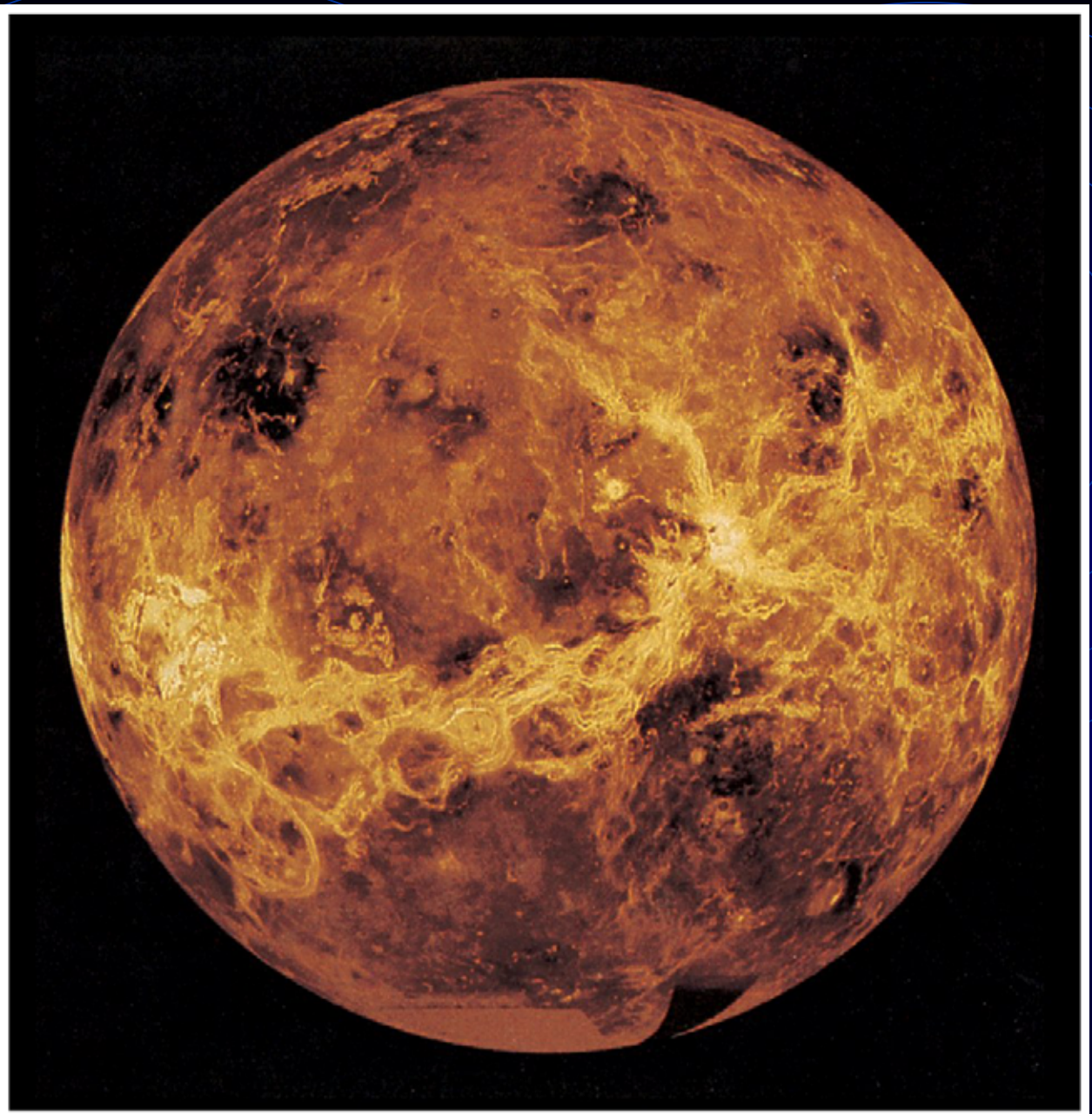


http://www.tufts.edu/tie/tci/ClimateChange.html

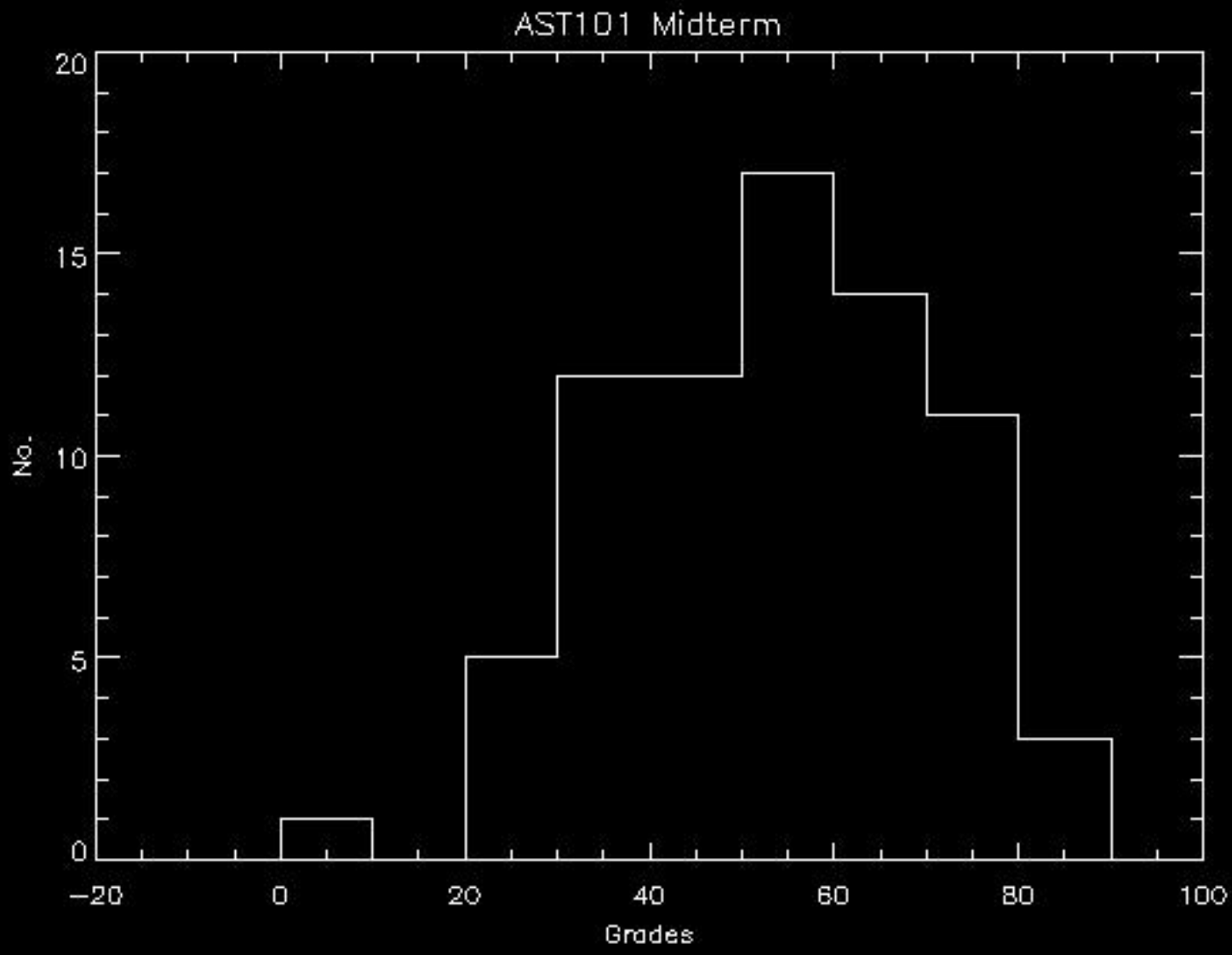




Volcano (Maat Mons 8 km tall) on Venus by the *Magellan* radar, with the coloring based on the Soviet *Venera 13* lander (1982). *Astronomy Picture of the Day*, 28 September 1995



A global view of Venus by *Magellan*


AST101 Midterm
20
15
10
5
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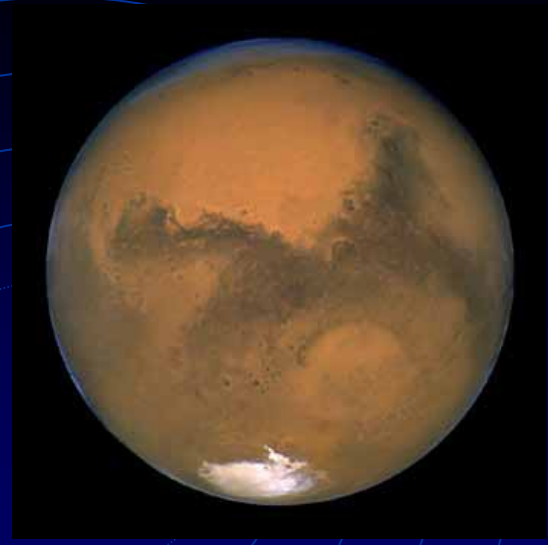
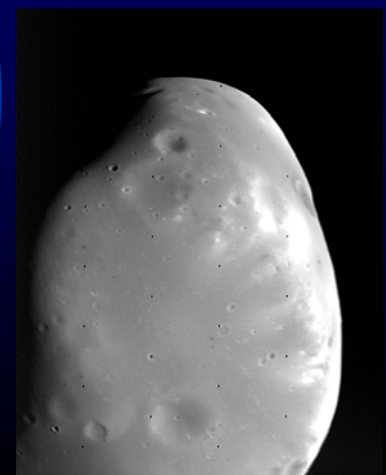
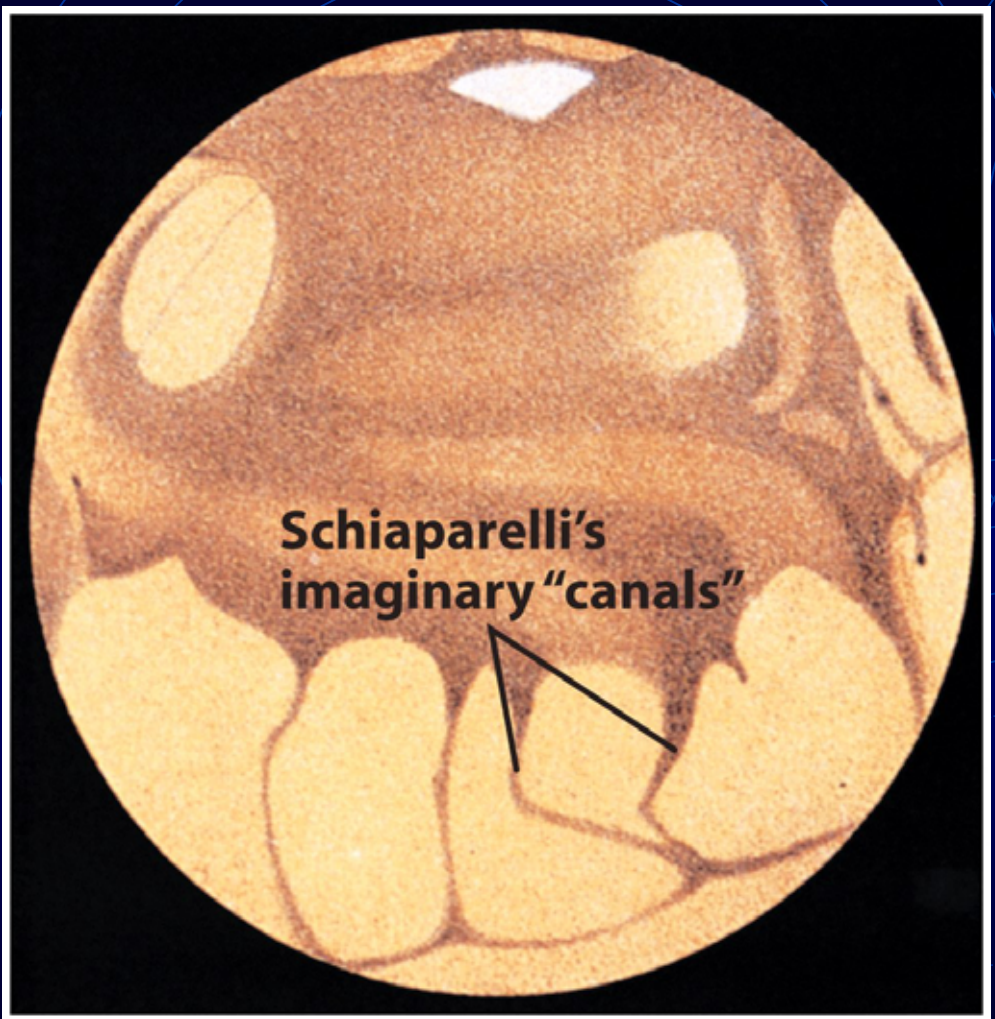
No.
−20
0
20
40
60
80
100
Grades

火星 (Mars)

- 土壤及大氣中的氧化鐵（鐵鏽）➔ 紅色外觀
- 自轉軸傾斜二十四度，有季節變化，兩極有冰（極帽）
- 火星人（運河）？
- 二顆小衛星（小於10公里），Phobos (‘fear’) 及 Deimos (‘panic’) 皆爲不規則形狀，爲攫獲之小行星

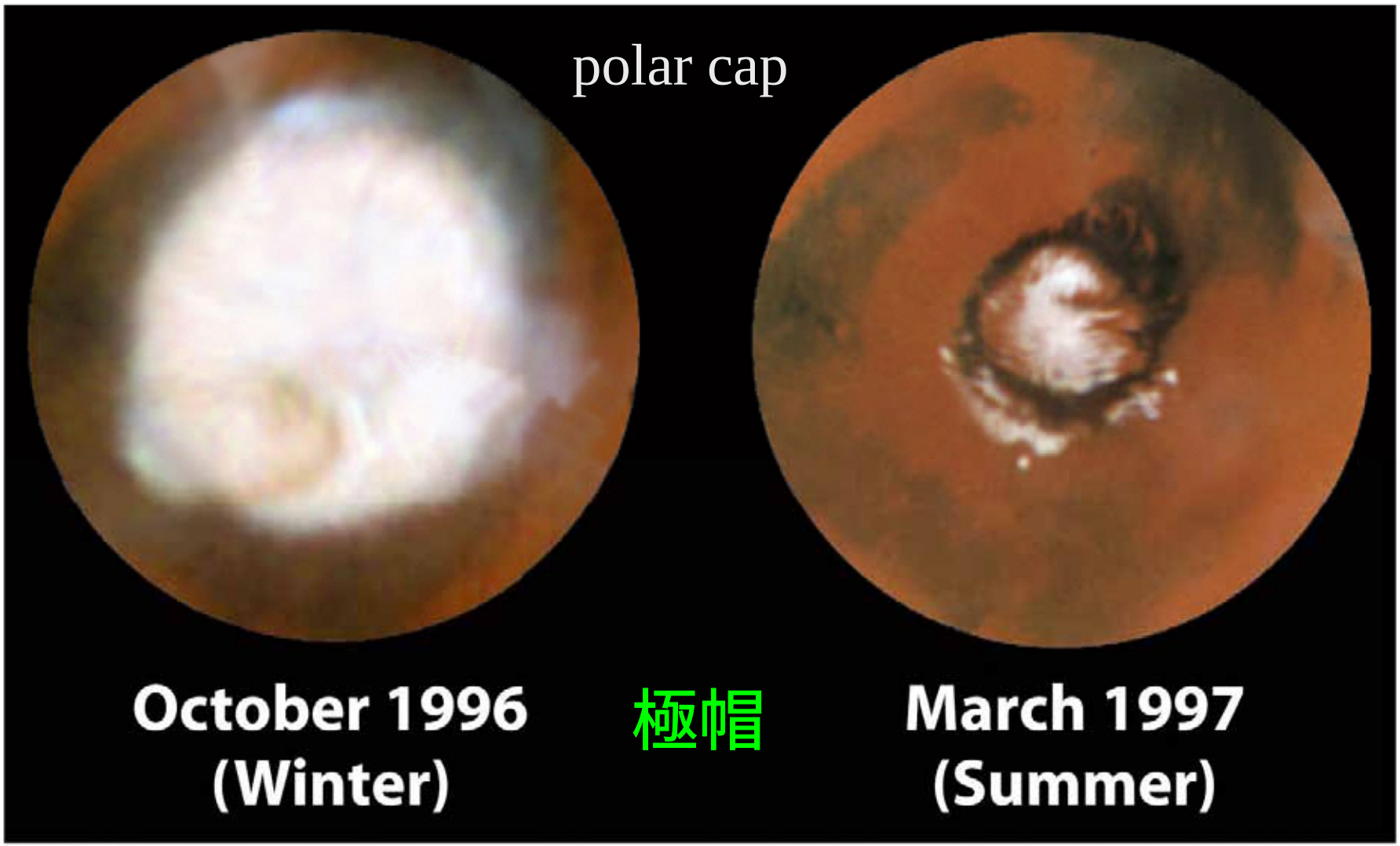






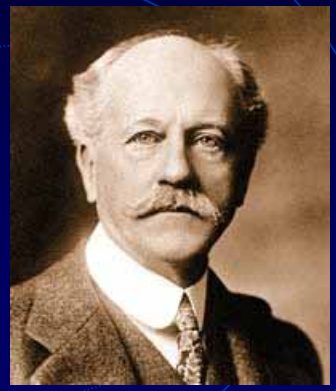
火星運河？

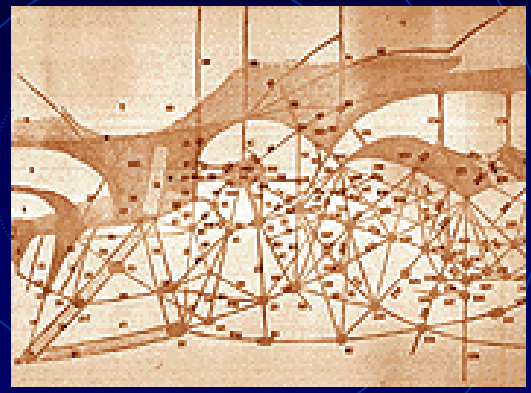
1877年，義大利天文學家史基帕洛里 (Schiaparalli) 在良好觀測條件下注意到火星表面有條狀結構，乃記載 canali，義文「條狀結構」之意，相當於英文 channel，但譯成英文時卻被譯爲較不常用的 canal。這下「火星人」正式走入「地球人」的歷史！因爲 channel 形容自然界的東西，而 canal 則是人工運河！由於史基帕洛里是受人尊崇的科學家，因此他發現的「火星運河」甚受矚目，在全球報紙刊載，終而引發火星人風潮。



火星的季節變化

洛吾爾（Lowell) 自設天文台觀測火星，發現條狀結構顏色、大小隨季節而變，因爲科學研究顯示火星的萬有引力不足以抓住厚重的大氣層，因此表面不會有大量液態水，理當有全球「灌溉系統」

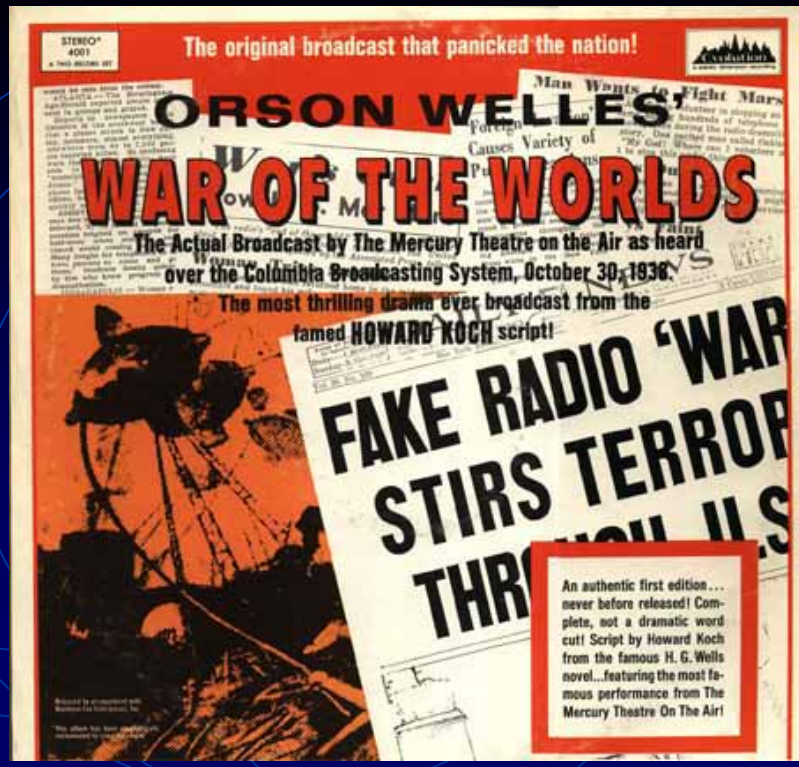




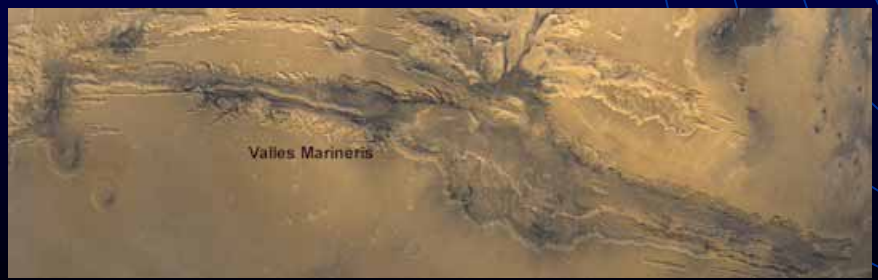
1898年威爾斯 (H. G. Wells) 的科幻著作 “*War of the Worlds*”，以及1912年美國小說家巴洛斯 (Edgar Rice Burroughs）融入洛吾爾想法，寫成系列科幻小說 “*Under the Moons of Mars*”，描寫主角 John Carter 前往火星（當地人稱火星爲 *Barsoom*）的冒險故事（「泰山」也是他寫的）。故事中的綠色火星人擁有高度智慧、呼吸氧氣、居住在乾燥的海床（科學事實）、飲用的水則來自洛吾爾所描述的火星表面運河系統（根據科學研究的結果），居住在環境惡劣的火星人很自然想要侵略地球奪取資源

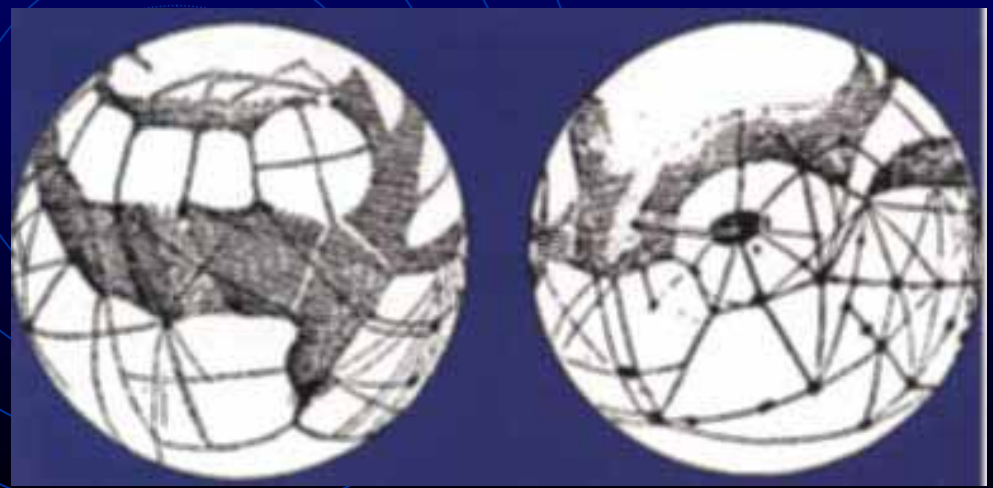
羅馬神話裡火星 Mars 原就是戰神，這樣的劇情構成引人入勝又具說服力的作品要件

- 火星人傳說在1938年10月30日當年「萬聖節」達到高峰
- 當夜由威勒斯 (Orson Welles, 1915-1985) 在紐約市現場播出改編自威爾斯的「星際大戰」“***The War of the Worlds***”的廣播劇，故事是火星人登陸美國紐澤西州
- 由於劇情逼真，造成紐約與紐澤西地區民眾恐慌，競相出走

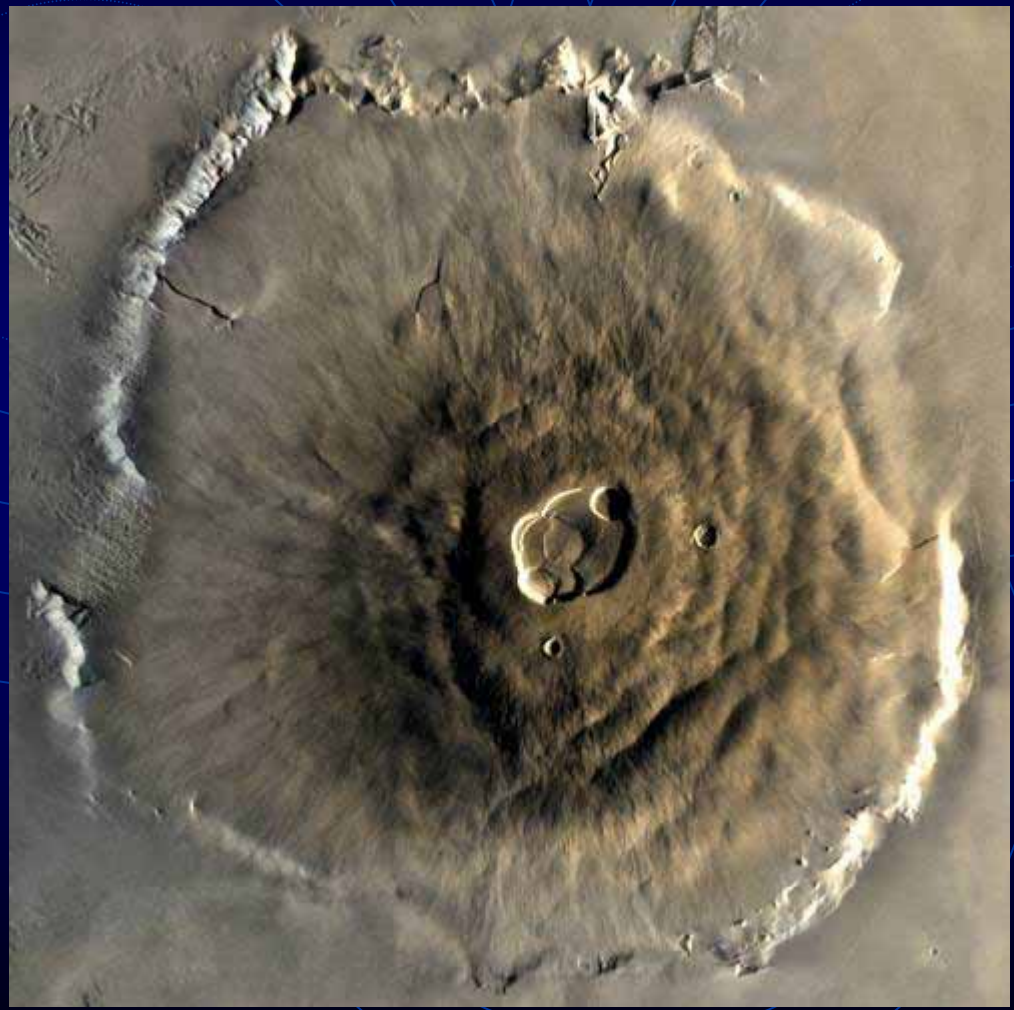


- 1965 年「水手四號」(Mariner 4) 照片傳回，之後還有系列 Mariner 任務，都未看到火星人
- 1976 兩架 Viking Orbiters：找微生物，也找大型生物；相機拍了一年
  → 都未看到運河，或是所宣稱的綠色農作物
- 可能的解釋是**人類視覺易把點連成線，以及在明亮紅色旁邊的灰色區域會產生呈現藍綠色的錯覺**





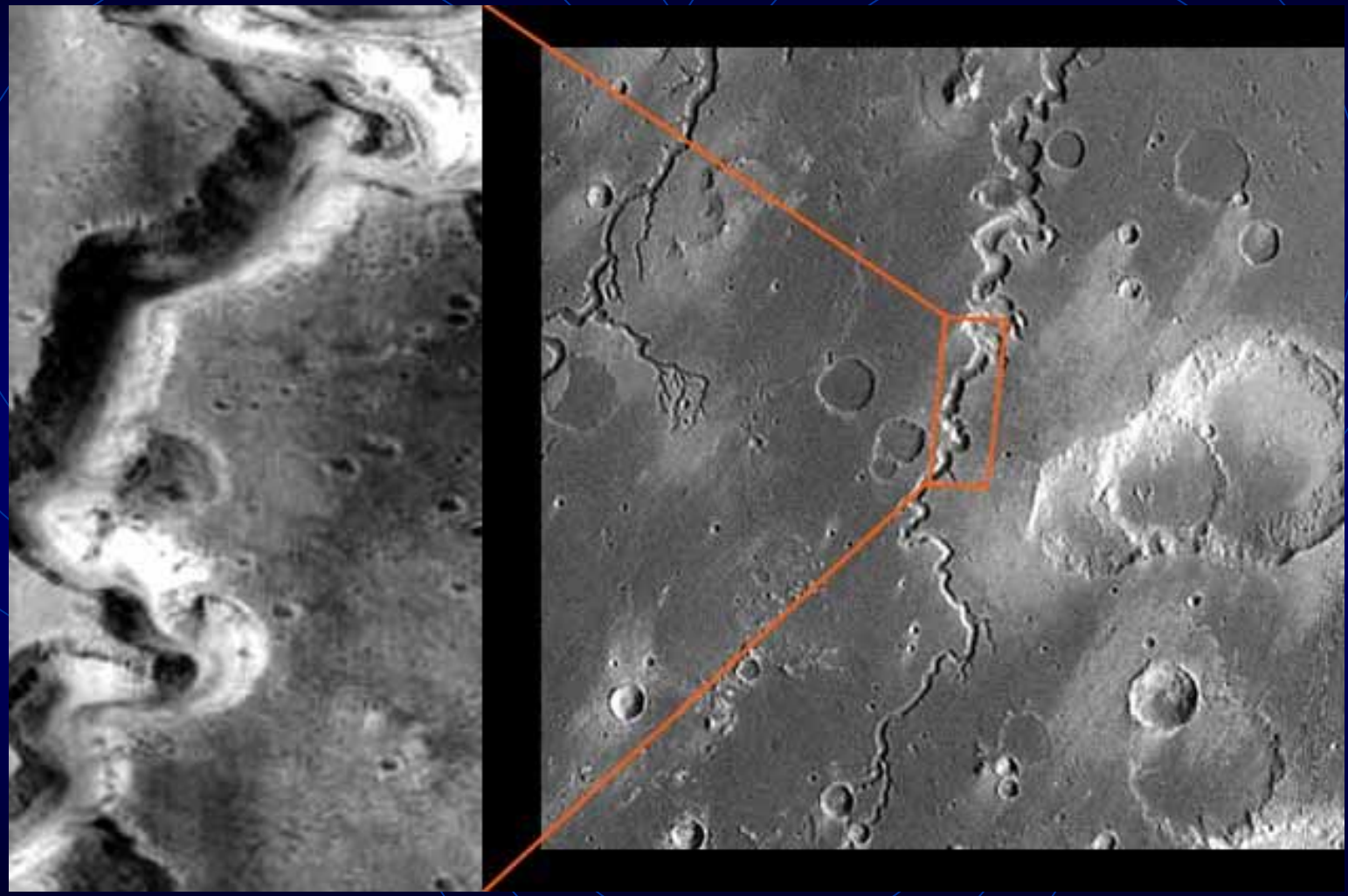
火星表面的奧林帕斯（火）山 (Olympus Mons) 達24公里高



caldera
（火山）

Q：地球也有火山活動，爲什麼地表最高的山脈只有8公里高？

火星表面早年有大量流水



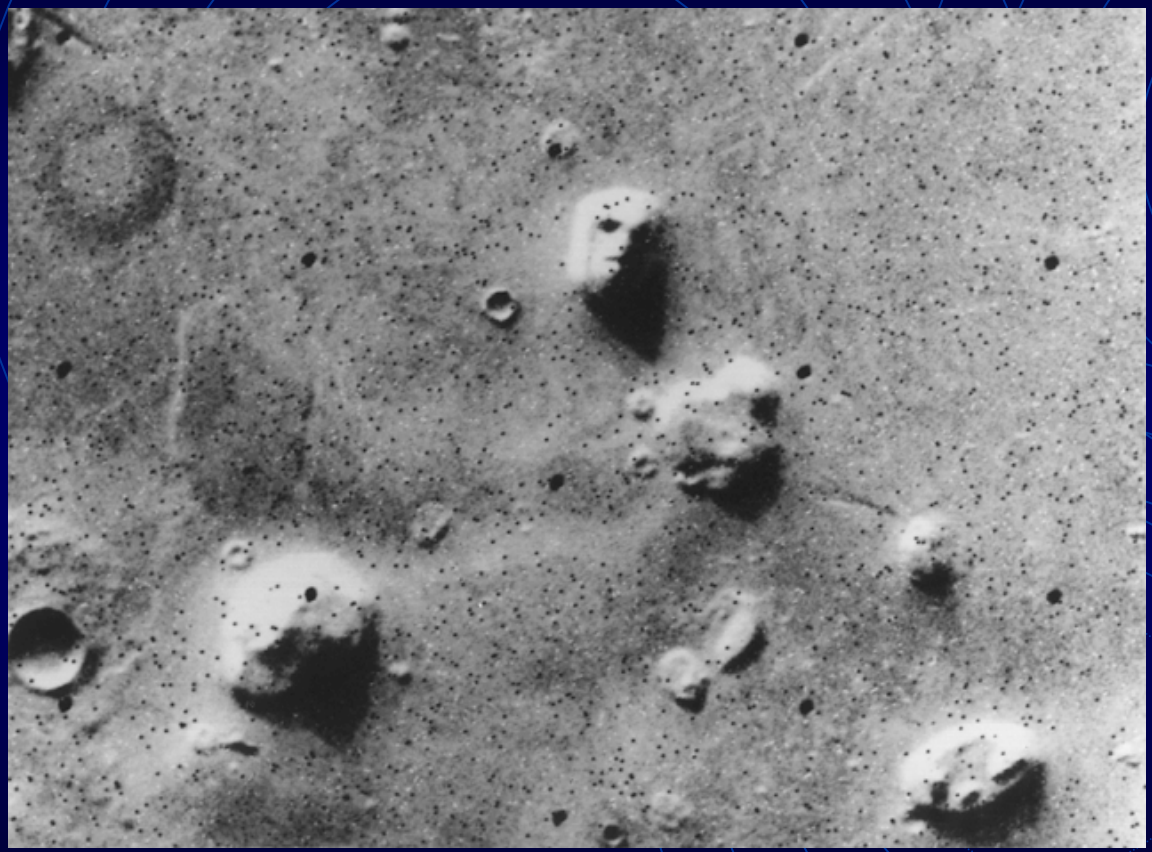
What happened to Mars?

火星的天空

「鏽色」的天空

從 *Pathfinder* lander
看 Sojourner

火星上的「人面石」？



Scientists view haunting pictures sent from the dying planet

Stone face on Mars beams TV warning to Earth

By RAGAN DUNN

A gigantic stone face on the surface of Mars houses a TV transmitter that has been signaling Earth for at least 500,000 years.

That's the claim of UFO-wise astronomer Liadin Paesche, who says the ancient but ongoing Martian signal presents a grim warning to the people of Earth.

"The programming is a chilling look at a civilization in total decline," the expert told reporters in Zurich. "It shows thousands and thousands of wretched souls dying in the streets. It is nothing short of a doomsday warning — recorded and beamed to a neighboring planet. We must take heed."

The suggestion is that the planet had been stricken with a deadly plague. These people are thin and bloated and very sick.

"At the very least they are dying of hunger and thirst. It is a horrifying thing to see," Dr. Paesche claims to be one of 50 scientists worldwide who have seen the mind-boggling Martian television transmissions.

He says that Soviet and American scientists have been monitoring the fuzzy black-and-white signals for more than two years, but have less than 90 seconds worth of clear, undistorted pictures on videotape.

"The signal is weak but constant, which is a miracle because the transmitter is at least half a million years old," he said.

"It is housed within the great stone face photographed by America's Viking probe in 1976.

"And it proves that the face is not a trick of nature or light, as some have said, but genuinely the work of a lost race which once dominated the planet.

"The face itself is clearly that of a humanoid, with eyes, nose, mouth and chin," Dr. Paesche continued.

"The mile-long monument also appears to be wearing a helmet. Many of the humanoids in the videotape are wearing helmets, too."

American and Soviet space officials would neither confirm nor deny Dr. Paesche's report.

Privately, however, they acknowledged that Dr. Paesche has worked closely with both Dr. Lars-Tyar Carlsson, the noted Swedish astronomer who also claims to have knowledge of the Martian TV signal.

And he flatly stated that the Russians' unmanned space probe, launched last month, is specially equipped to receive and record the Martian transmissions at their source for rebroadcast back to a scientific team on Earth.

"Contrary to what the public has been led to believe, that is the probe's prime reason for being," he said. "The lost Martian civilization will remain a mystery until we receive its message clearly.

"Let us all hope that we can learn from what we hear and see."

Face-shaped Mars rock is a puzzler

WASHINGTON — (AP) — Unusual formations on the surface of Mars, including a mile-long face shaped like a human face, may have been carved by a lost civilization — or maybe not, four scientists said.

NEWSPAPERS throughout the world have carried stories of the mysterious monument.

Doomsday images are 500,000 years old!

Yuppies spark bourbon boom

Fashion-conscious professionals are tired of wine coolers and Corona beer, according to a new survey that found young professionals are drinking bourbon these days.

The study found that Jim Beam is now the favorite beverage among yuppies.

CREEPS KICK BLIND DAD TO DEATH

By DICK DONOVAN

Soft-spoken 38-year-old father of two Ernie King was beaten and kicked to death by four cowardly brutes who didn't give a tinker's damn that their helpless victim was deaf and blind.

King was hitchhiking to his home in Santa Cruz, Calif., after his studies at San Jose State University when the savage thugs attacked him.

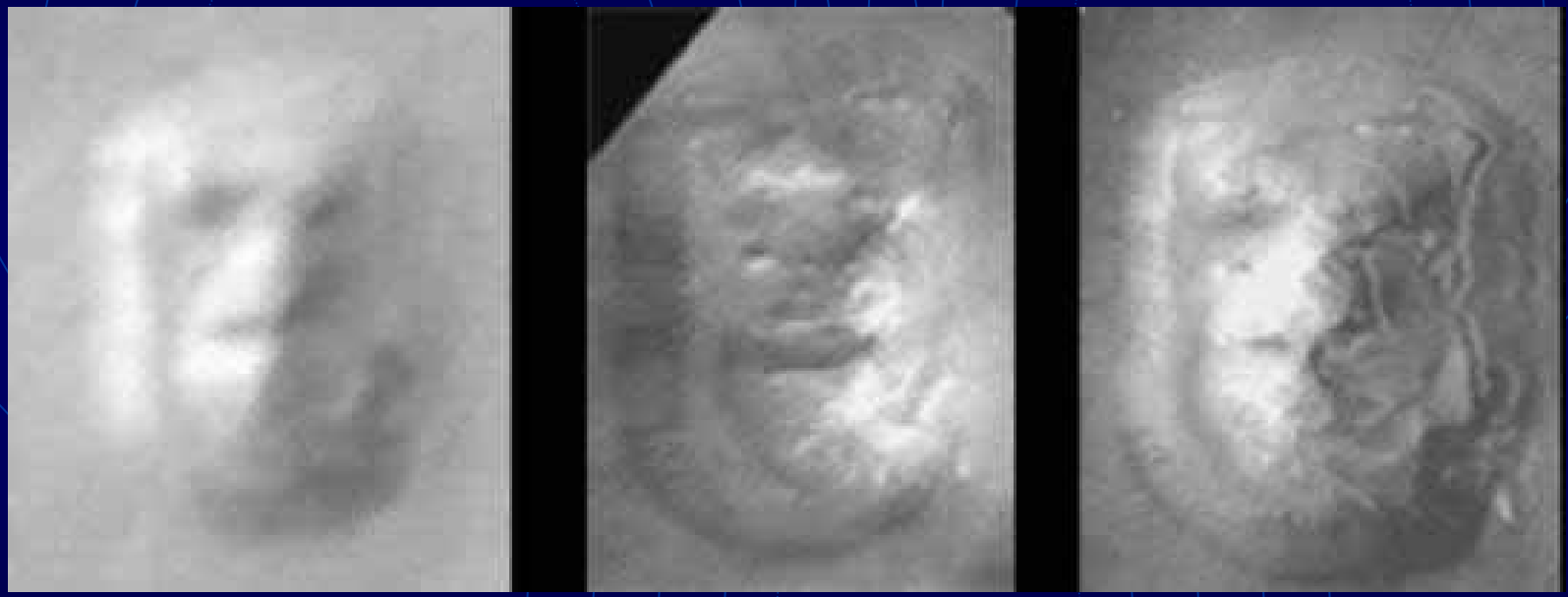
King, who suffered multiple skull fractures, was pronounced dead on arrival at Santa Cruz Memorial Hospital.

A teenage witness described the four killers as "mountain men types."

WEEKLY WORLD NEWS

1976年「海盜號」(Viking) 拍攝到的火星地景。匪夷所思吧？

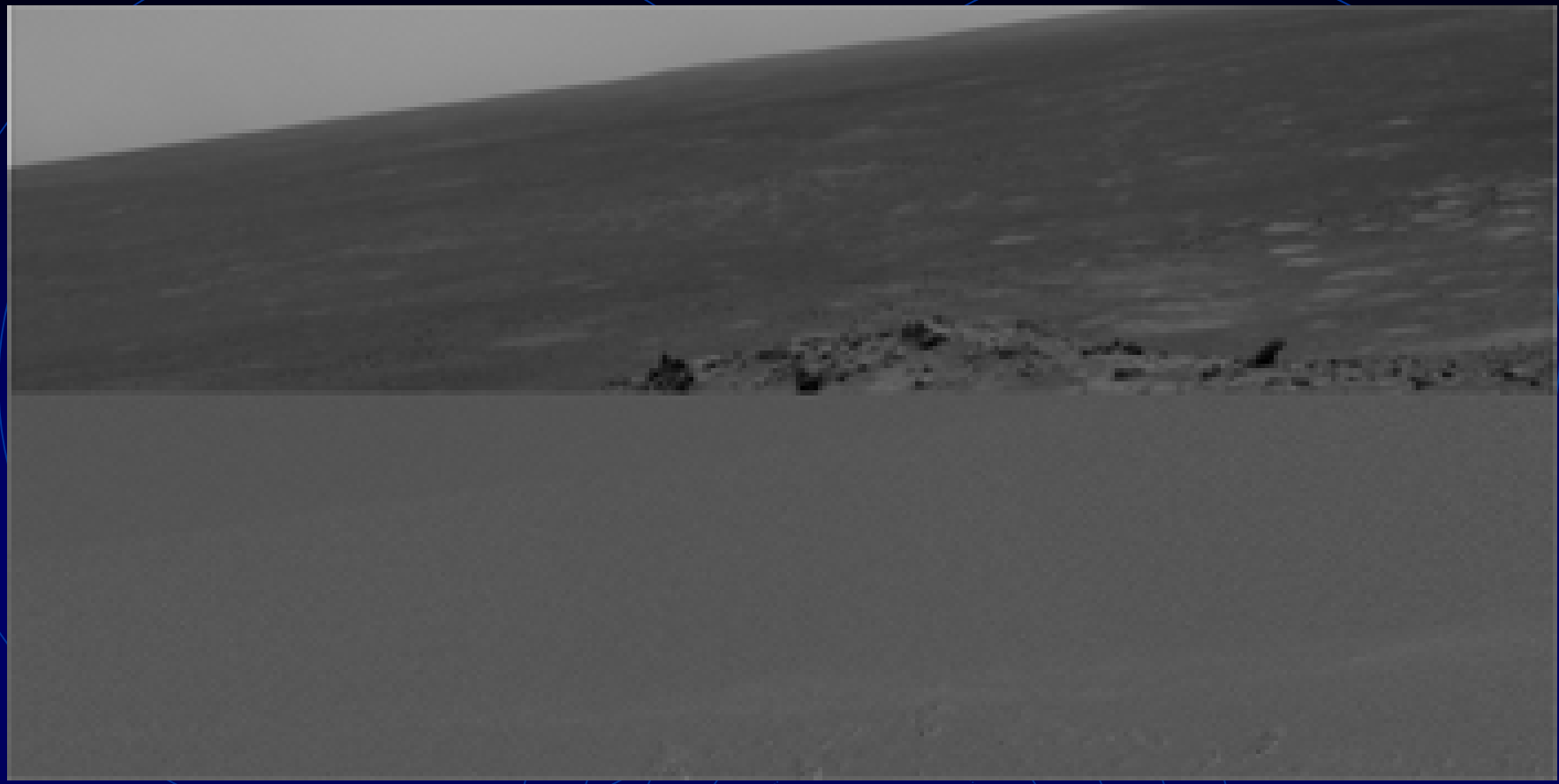
火星的「人面石」 (Face on Mars)



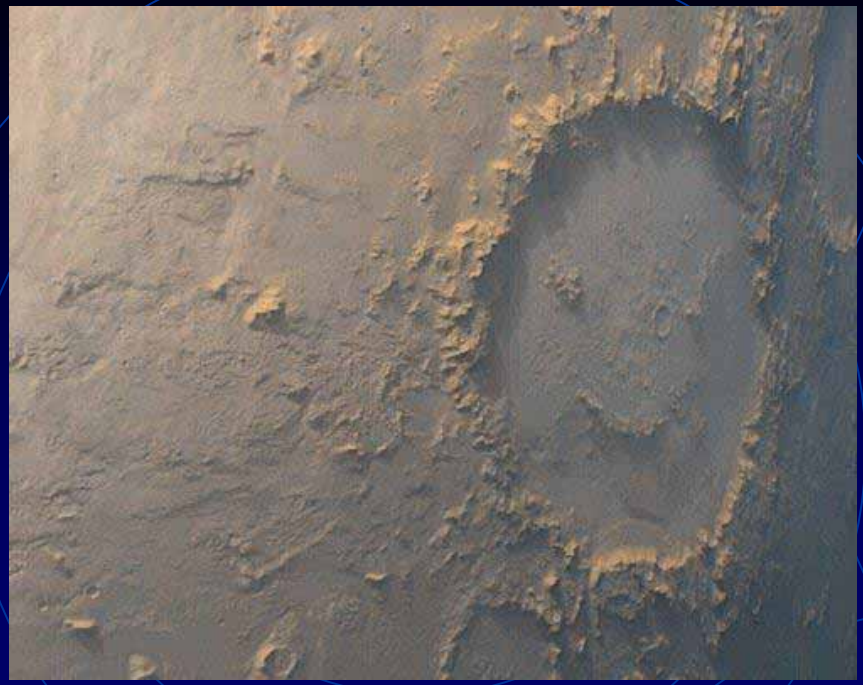
1976 Viking　　1998 MOC　　2001 MOC

陰影？山丘？
火星人？

1998 by Mars Orbiter
20幾 年之後，天氣侵蝕的後果



靈異塵暴？ Mars Exploration Rover Spirit 號 2005年4月15日在 Gusev 隕石坑所拍攝



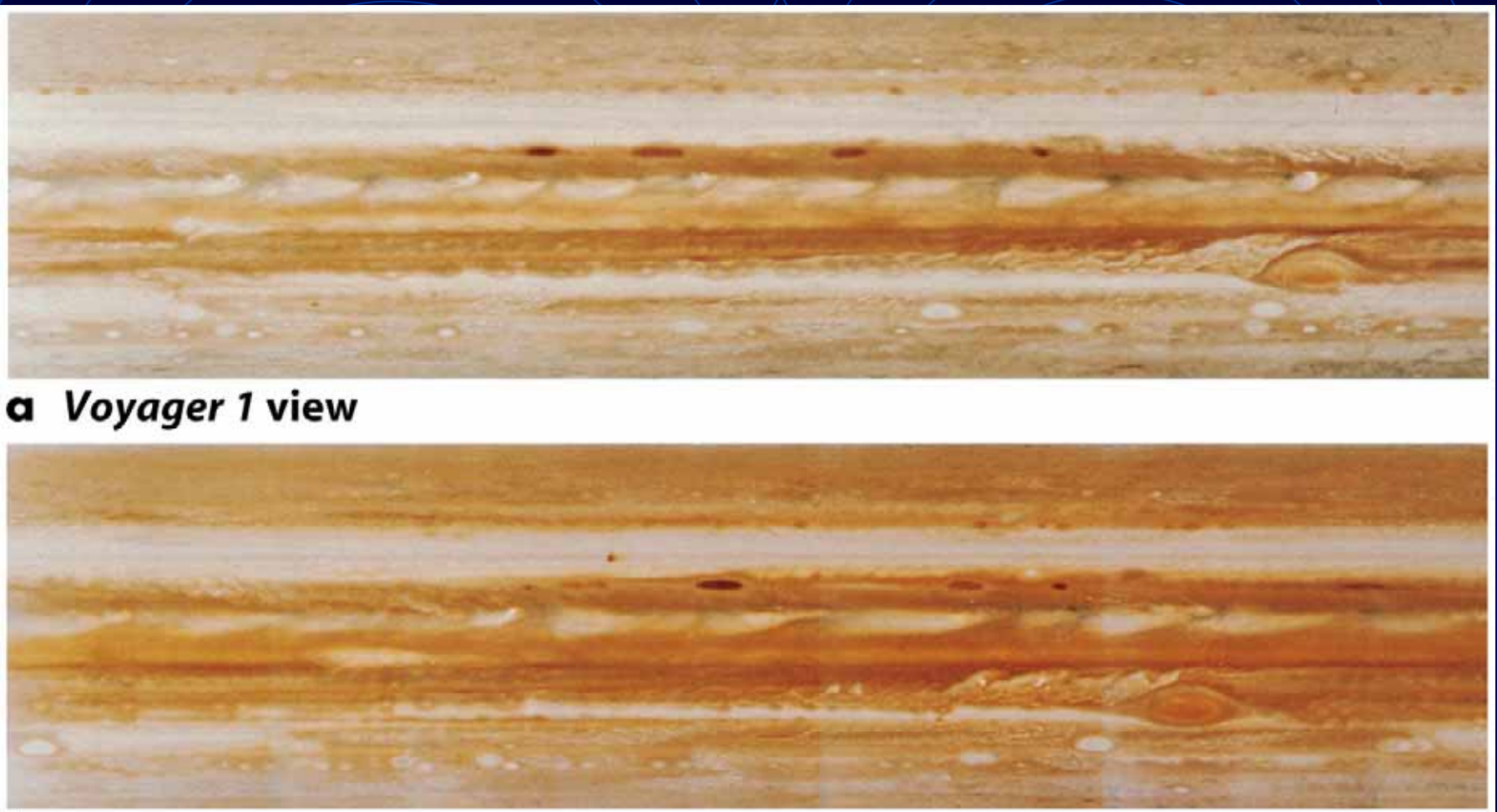
不是火星人特愛「面子」
而是我們看得太清楚了

木星 (Jupiter)

- 太陽系最大行星（71%行星物質；太陽的千分之一）
- 彩色雲帶
- **大紅斑 (Great Red Spot)**
  乃表面風暴，至少已 300 年；較周遭冷、高；逆時鐘旋轉；約地球兩倍大小
- 大氣：氫，氦　內部：高壓；液態氫
- 自轉快，呈扁球狀
- 放出熱量爲吸自太陽的兩倍：目前仍在收縮
- 有不明顯的環

木星的大氣 —— 帶狀結構

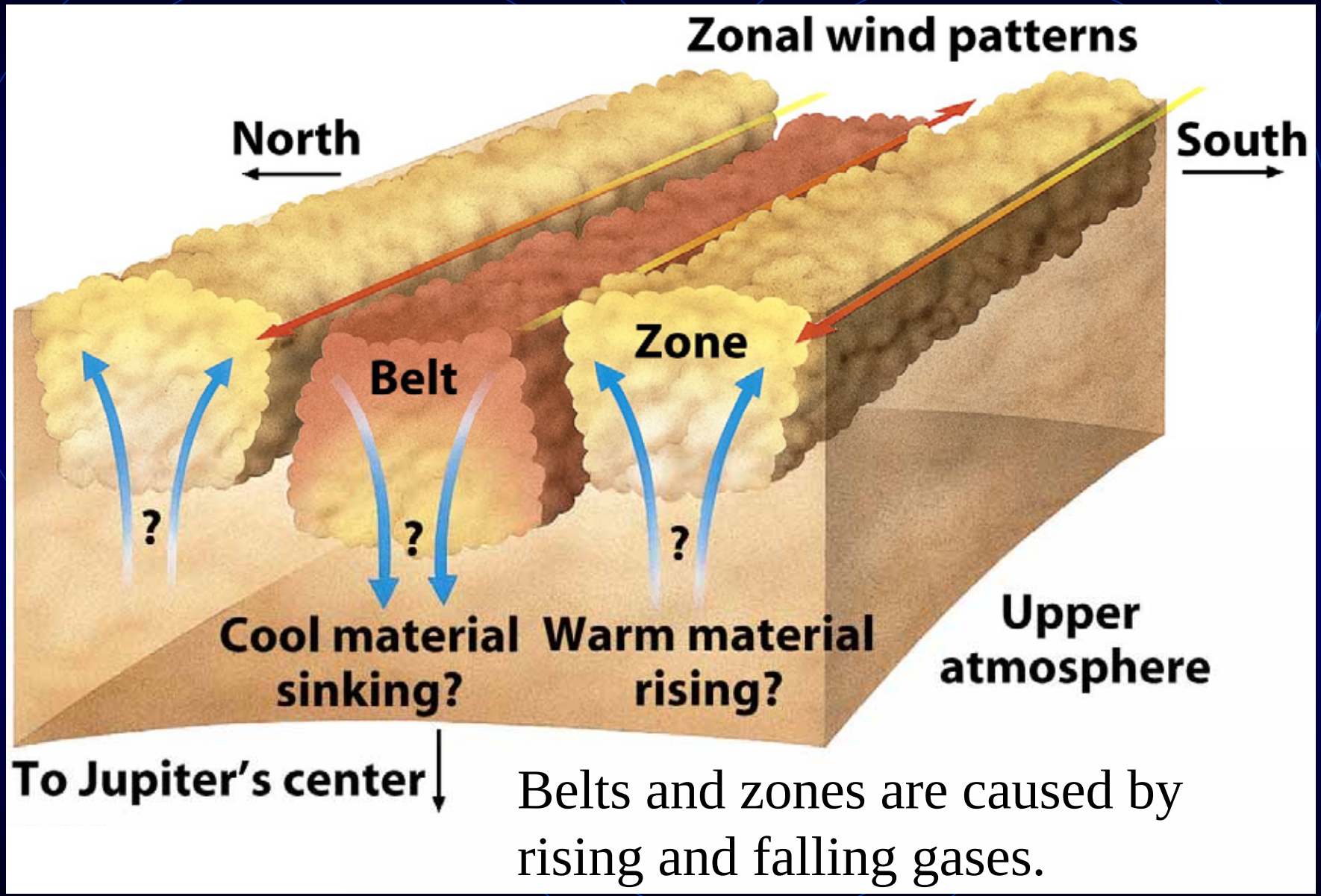
淡色 → zones
深色 → belts



a *Voyager 1* view

b *Voyager 2* view

狂風、快速自轉、內熱、複雜成分



Belts and zones are caused by rising and falling gases.

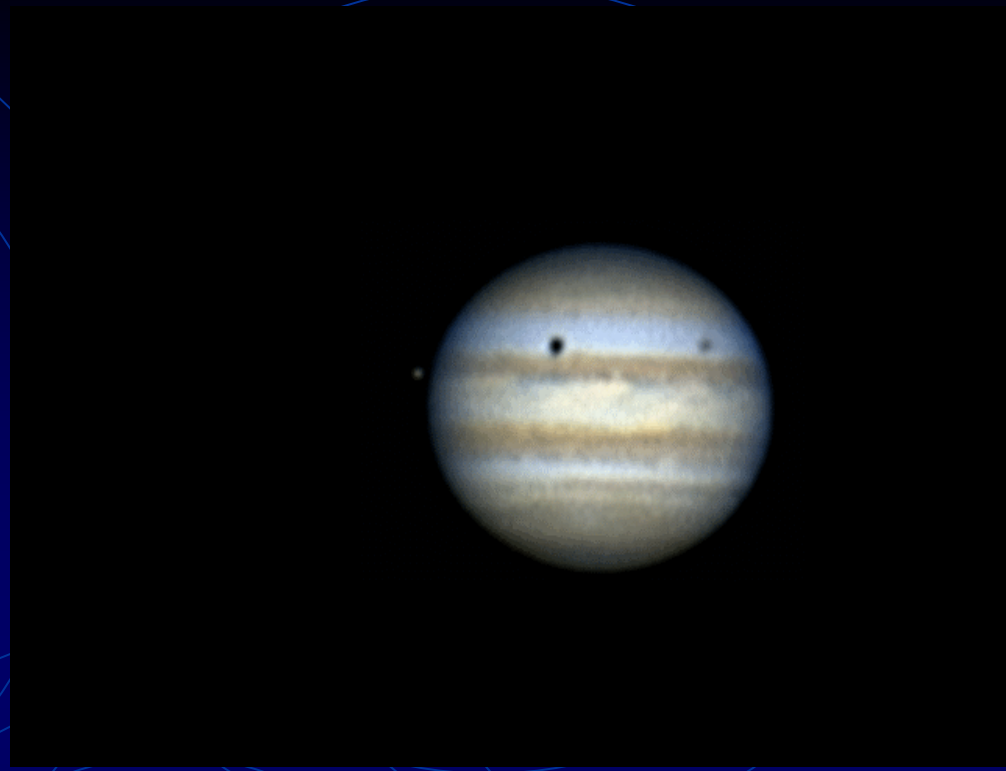
加利略發現的木星四顆衛星：

Io（木衛一）

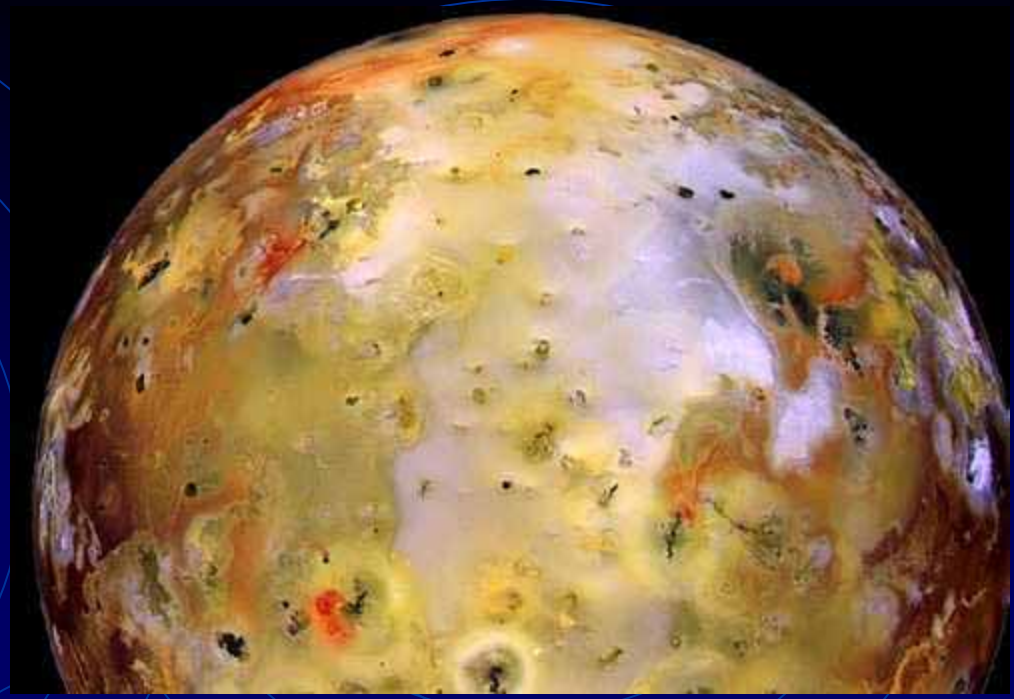
Europa（木衛二）

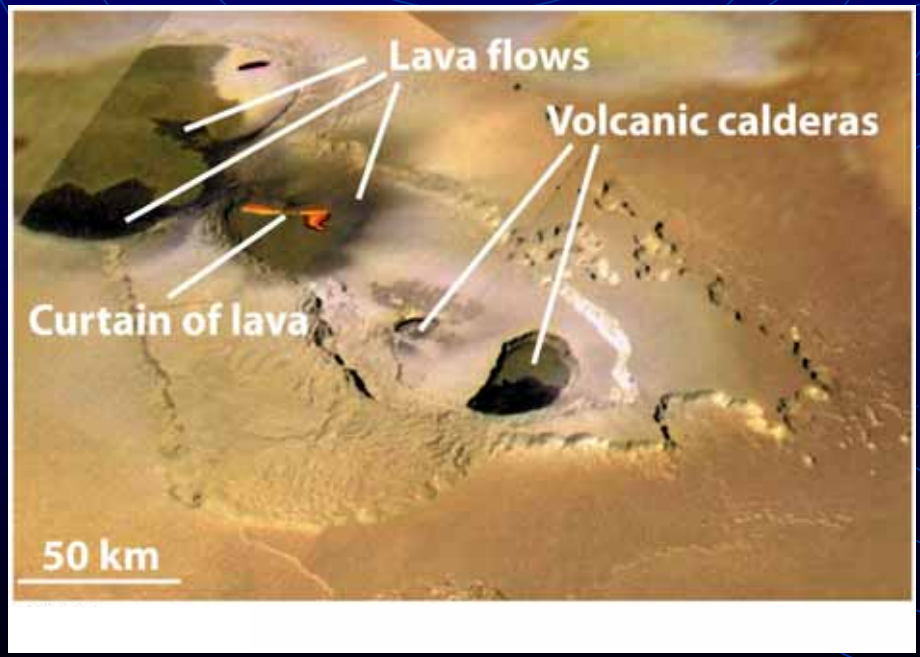
Ganymede（木衛三）

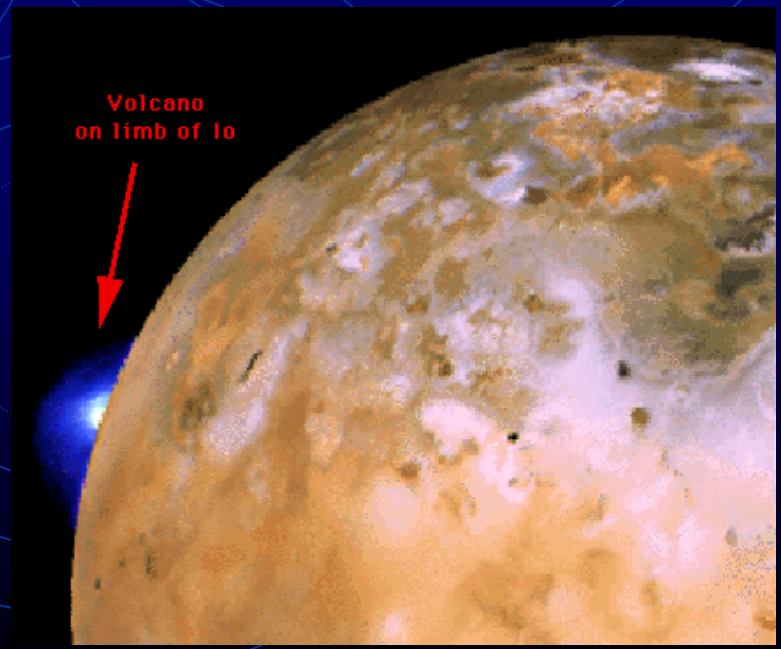
Callisto（木衛四）



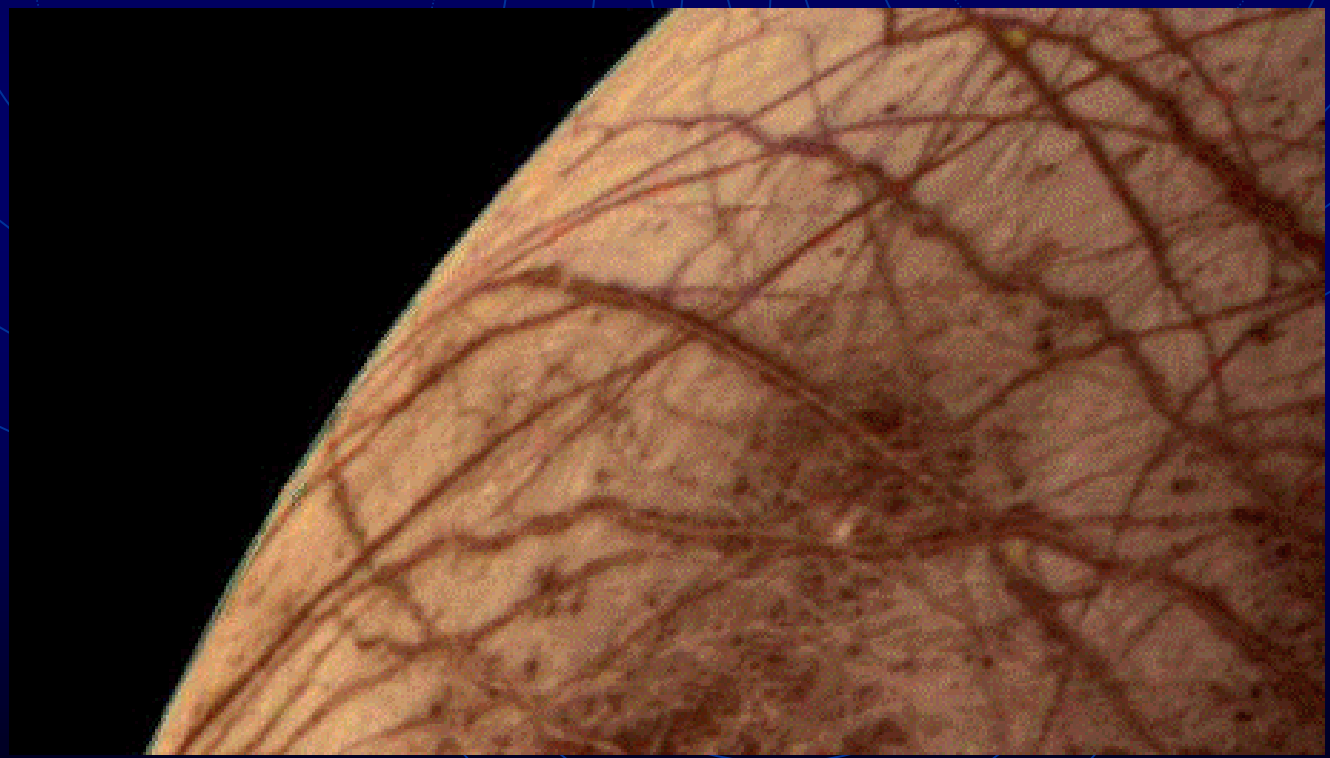
木星的衛星埃歐 (Io) 表面有火山活動，噴發大量硫化物



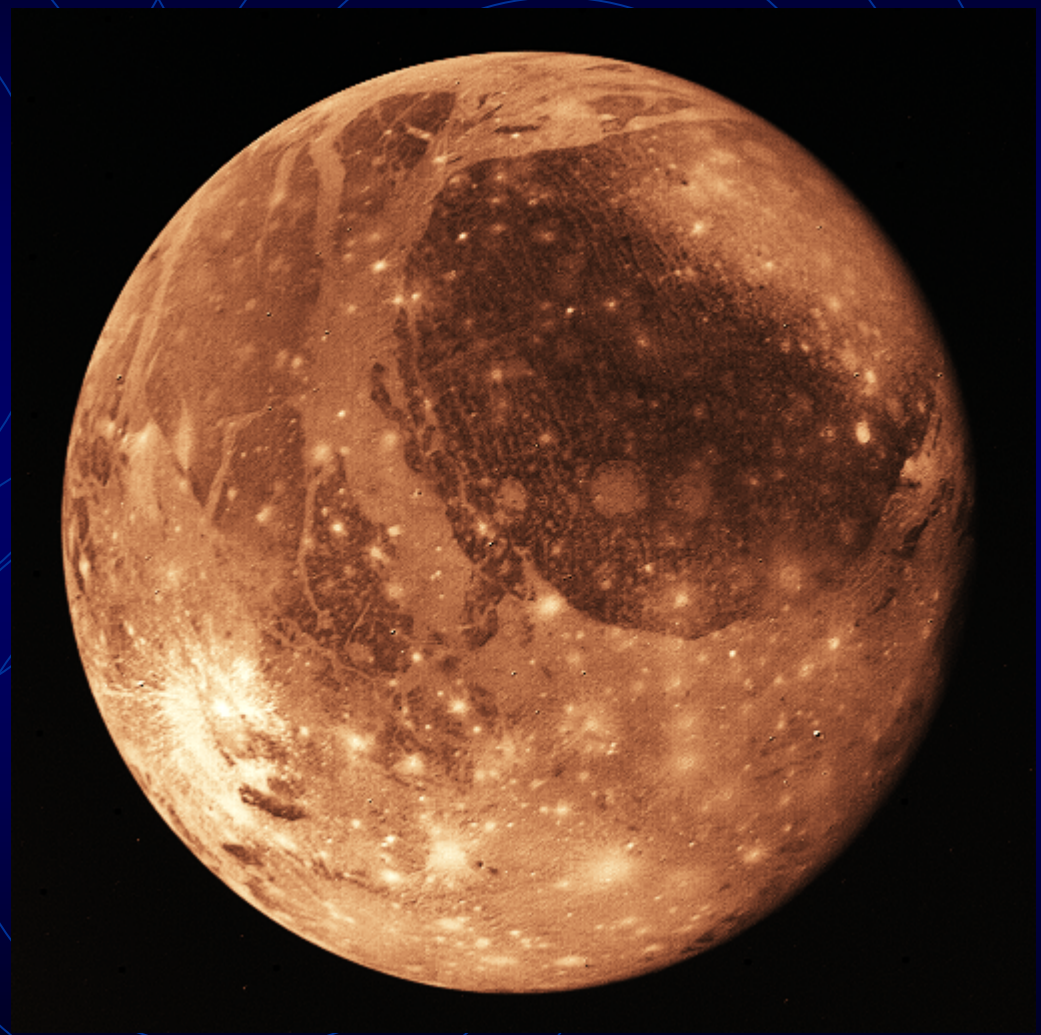


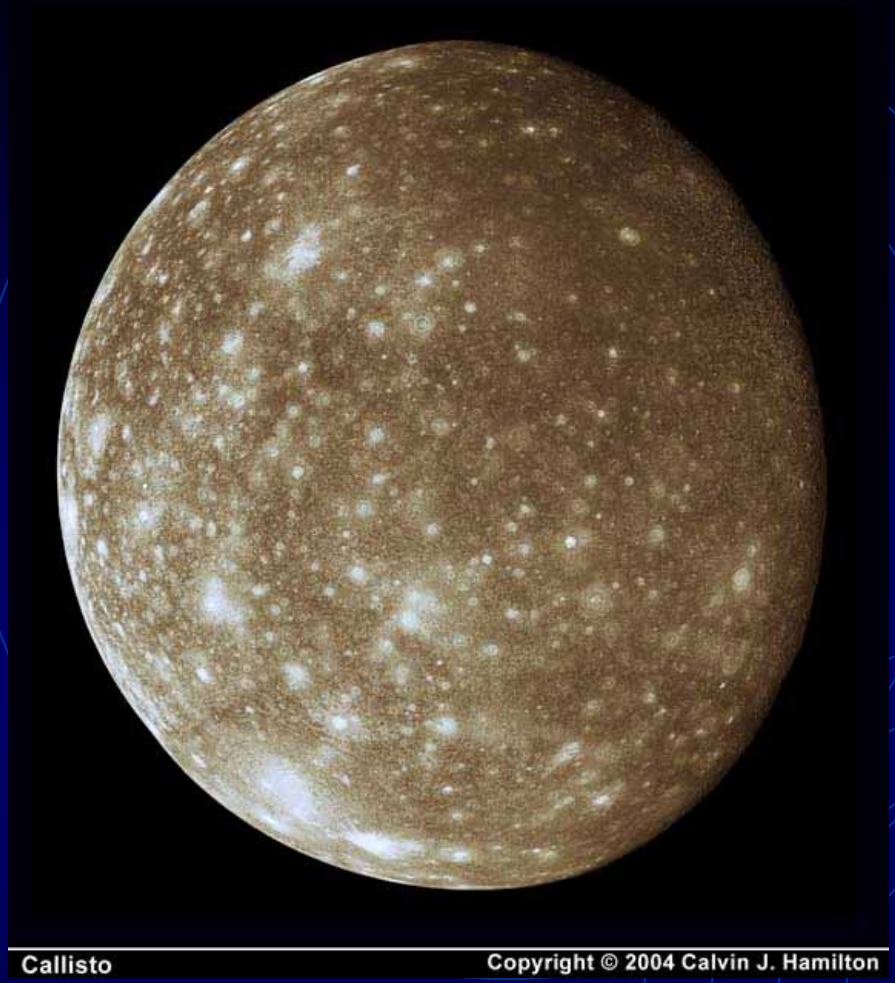


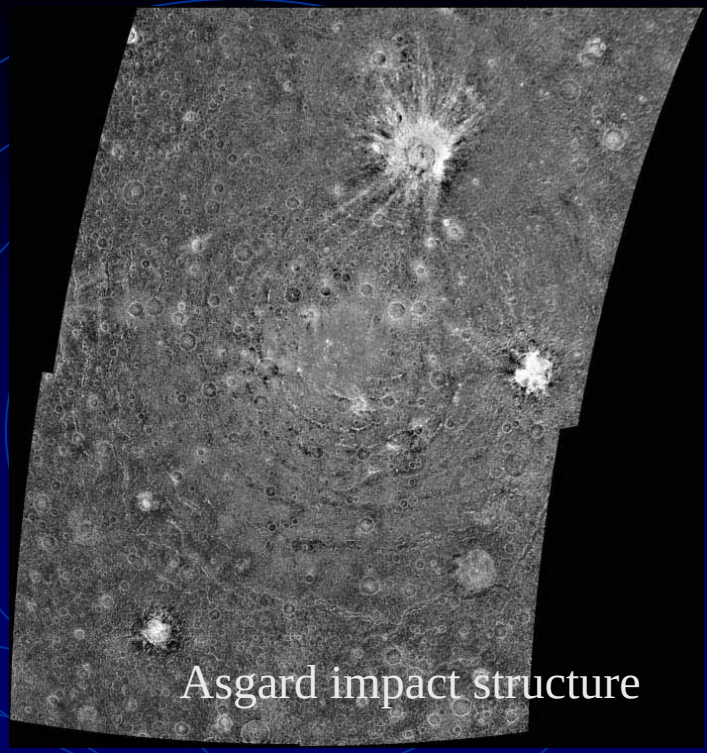
木星的衛星歐羅巴 (Europa) 表面有彩色裂痕，表層之下有水，甚至可能有海洋



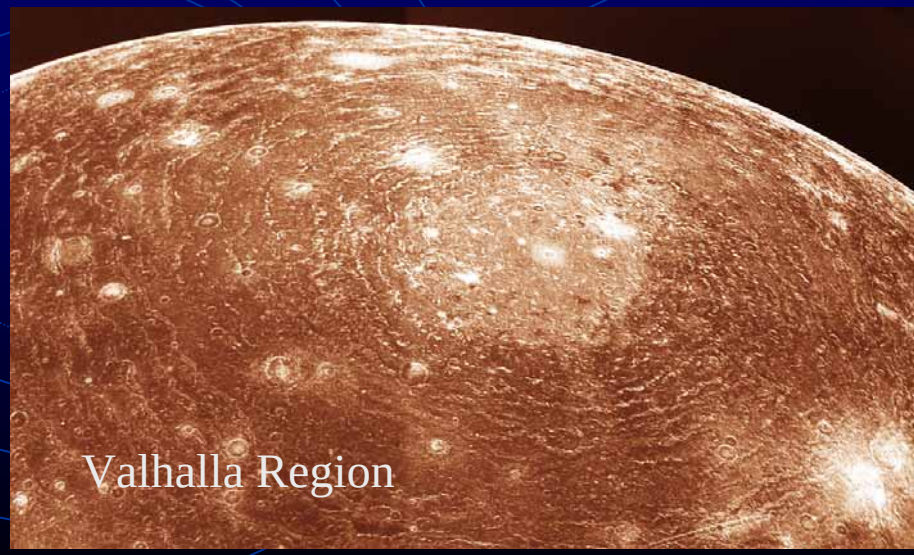
甘尼米德 (Ganymede) 直徑達5262公里，是太陽系當中最大的衛星。甘尼米德有複雜的地質活動（例如高山、窪地、隕石坑、岩漿流）。表面的暗黑區域有大量隕石坑，表示地質年齡比較老。



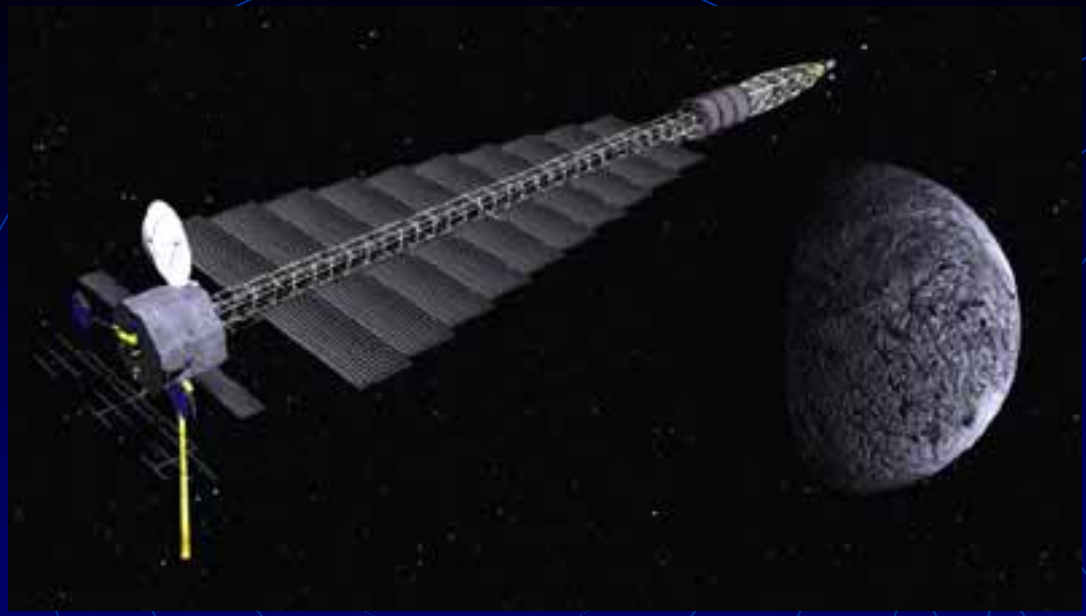




隕石坑周圍的同心環結構



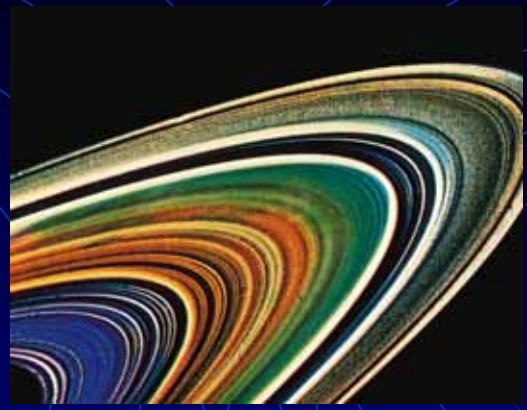
卡利斯多 (Callisto) 大小與水星相當，是太陽系當中隕石坑最多的衛星



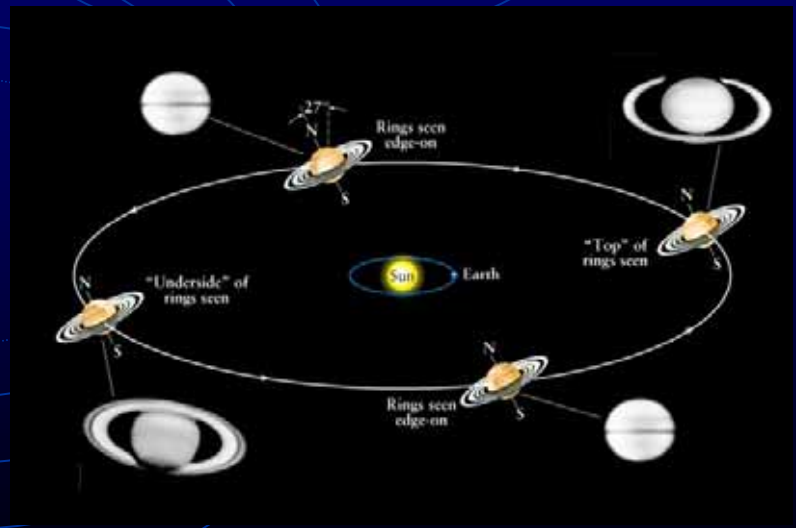
NASA 規劃 2011 年以後發射 Jupiter Icy Moons Orbiter

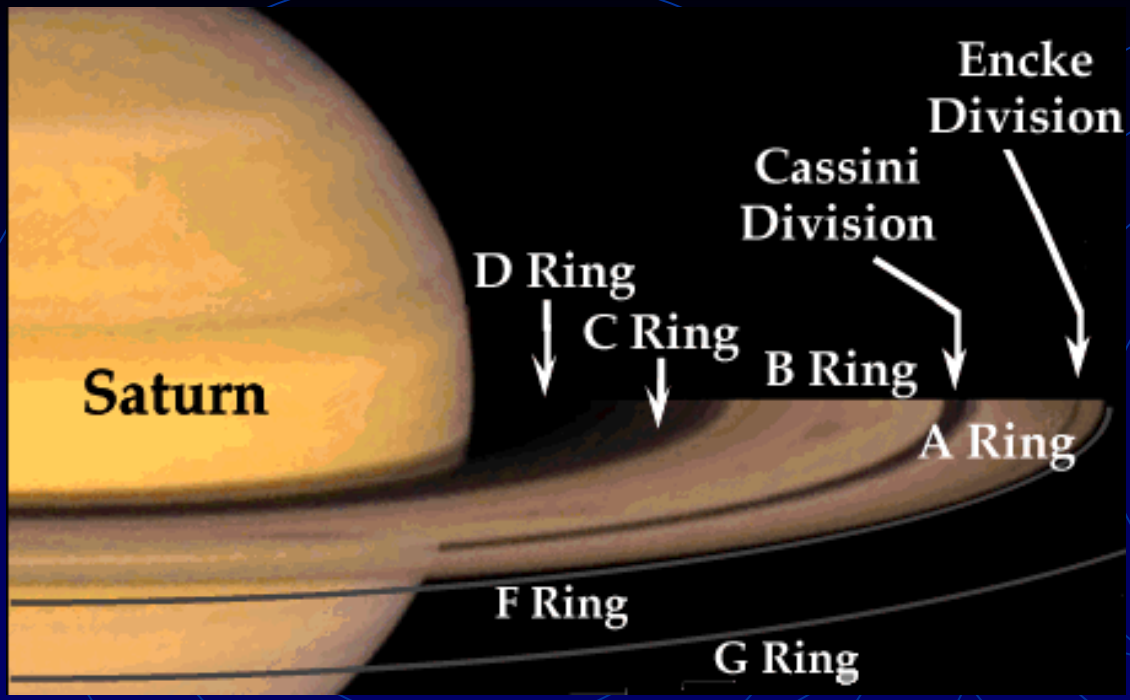
利用 cryobot/hydrobot 穿越 Europa 的冰層後，會看到這樣的光景嗎？

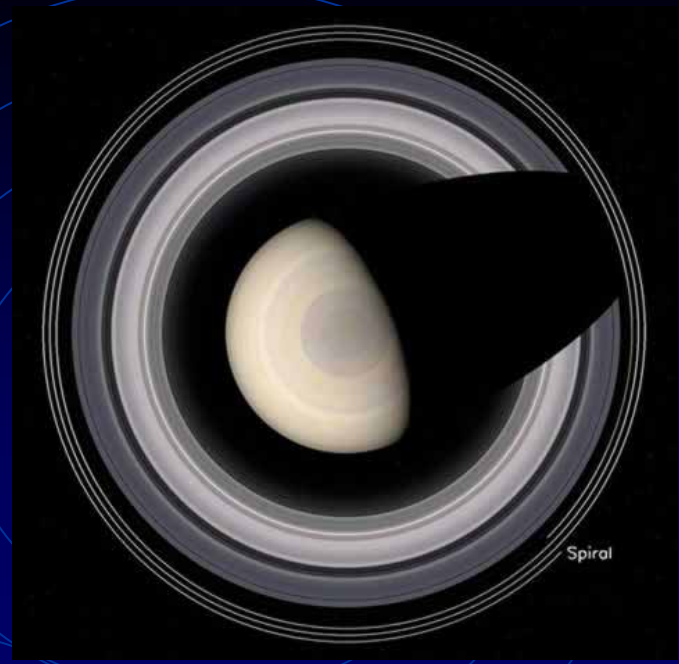
土星 (Saturn)



- 美麗炫目的光環，從地球觀看角度（時間）不同，光環呈現不同景觀
- 光環由無數小環組成，環寬而薄，成分爲碎冰（水、阿摩尼亞、甲烷）
- 也有彩色雲帶



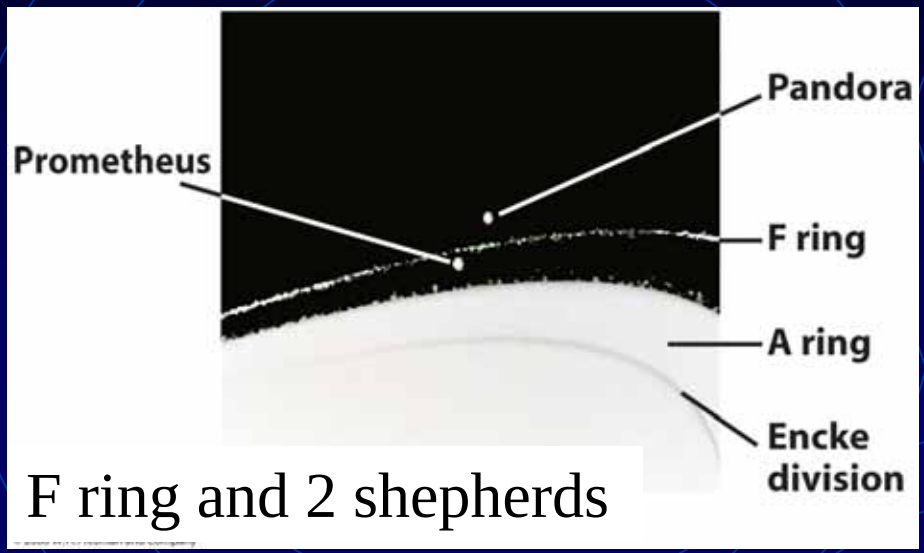




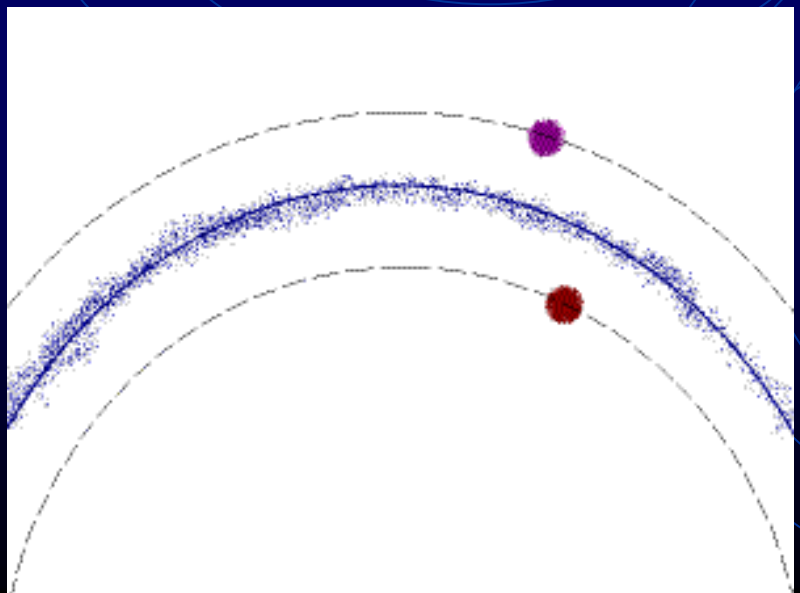
Moonlets Perturb Saturn's F Ring,

Cassini (2006)

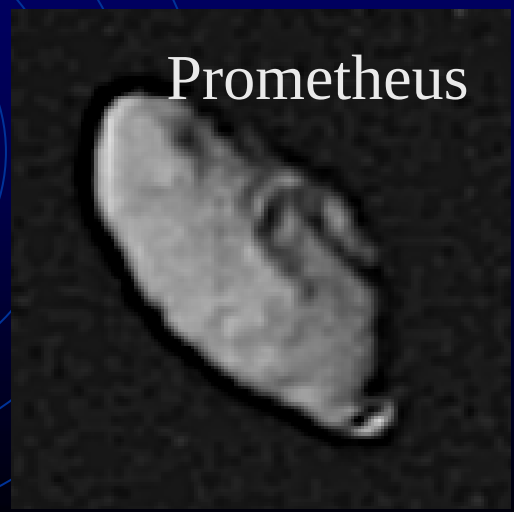
Rings and Shepherd Moons



F ring and 2 shepherds



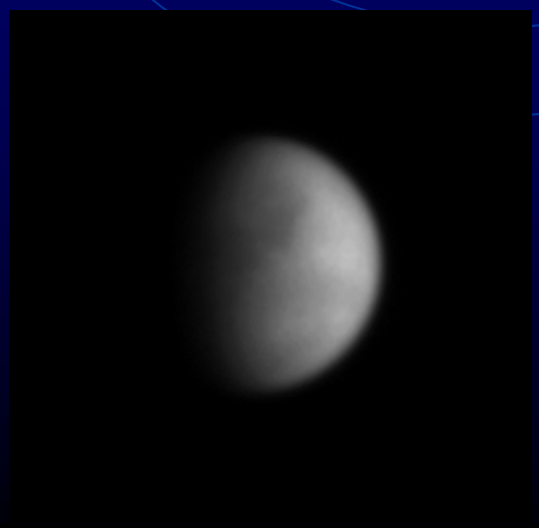
Each moon
~ 50 km

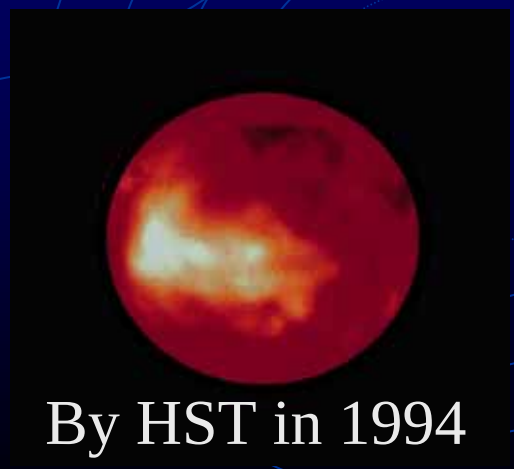


泰坦 (Titan) —— 土星的衛星

1655 年由 Christiaan Huygens 發現

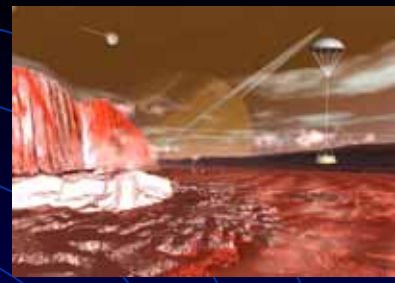
擁有厚重的大氣層，充滿氮氣（90%）、甲烷，以及其他碳氫化合物



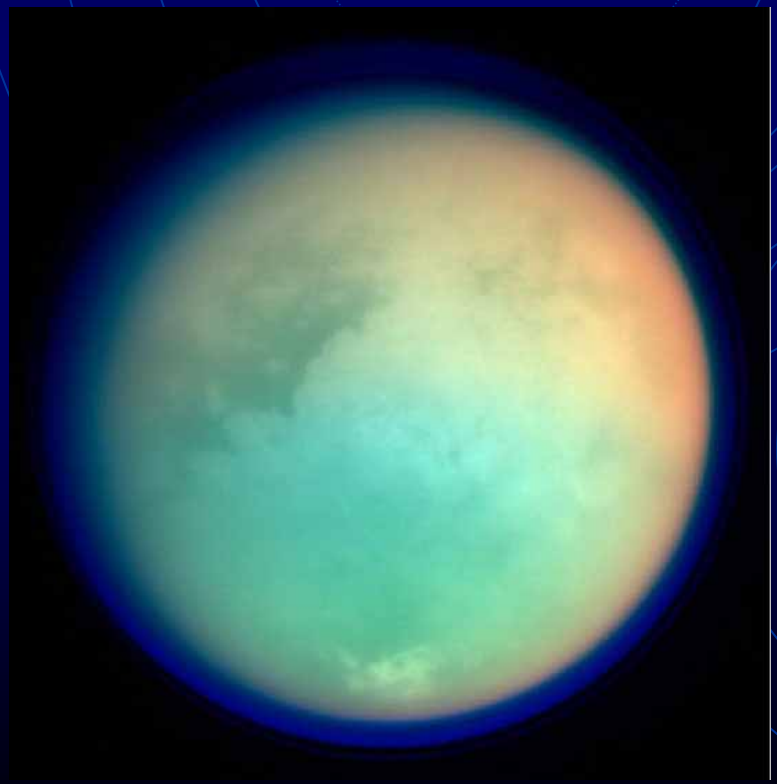


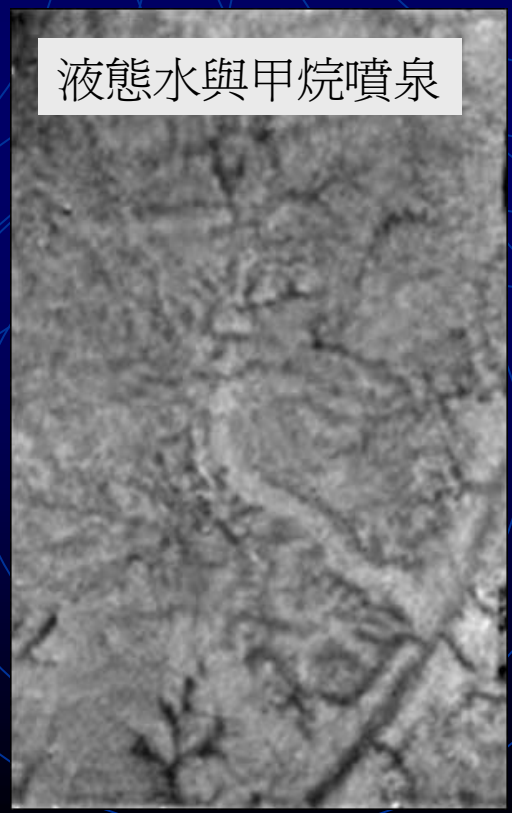
By HST in 1994

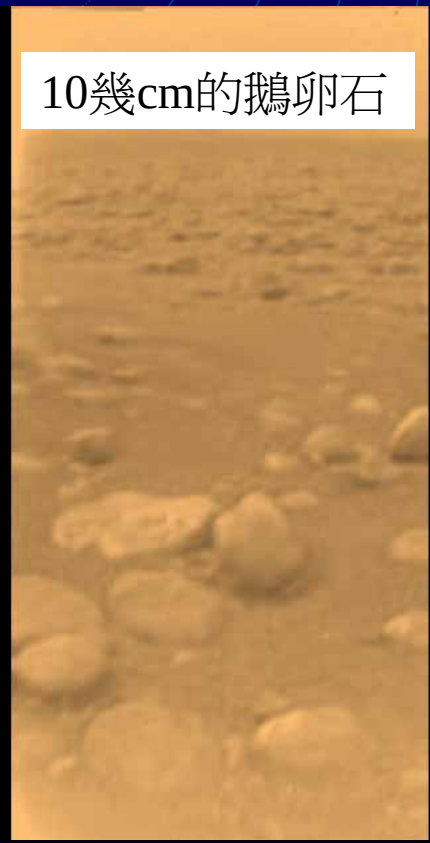
By Voyager 2



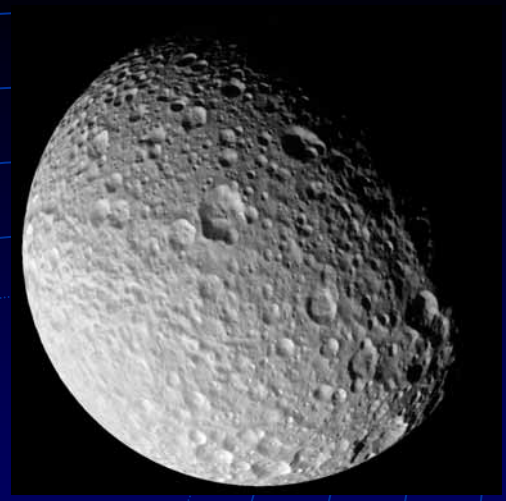
卡西尼任務：1997 年發射，2005年抵達土星，釋放登陸艇到「泰坦」衛星

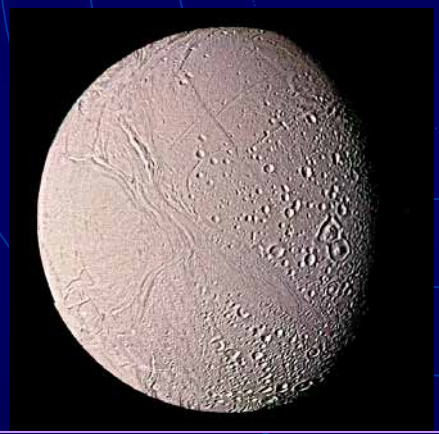




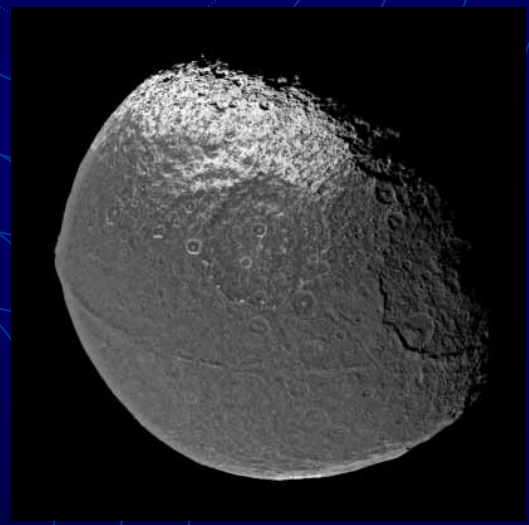


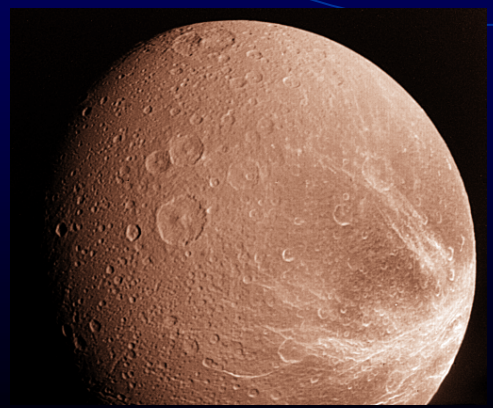
Mimas (D=392 km)





Enceladus
(D=500 km)



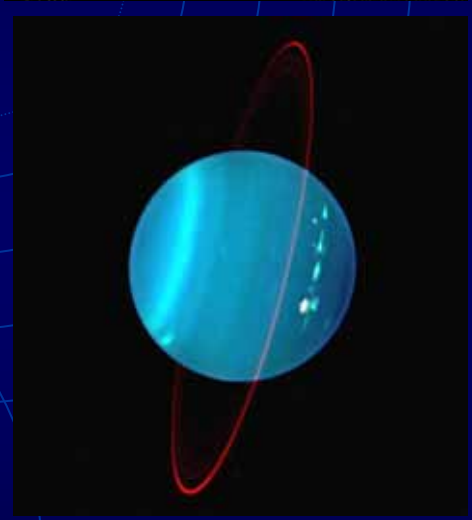


Dione
(D=1120 km)

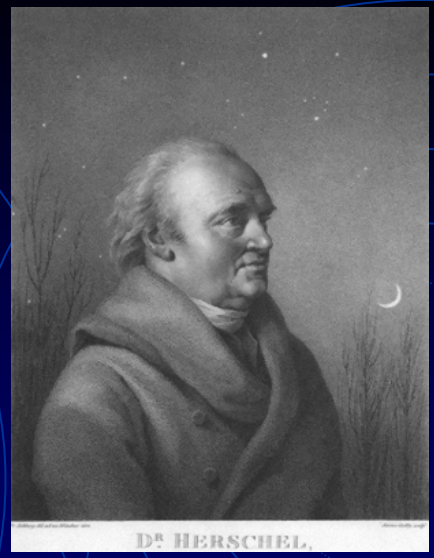
Iapetus
(D=1460 km)

天王星 (Uranus)

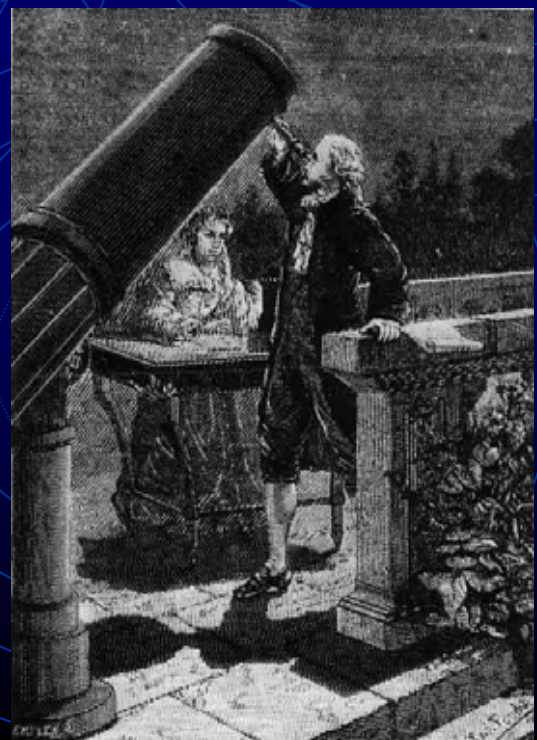
- 1781年由William Herschel 以自製的望遠鏡（6.2吋）發現
- 自轉軸在公轉面上。原因未知，或許因爲行星成形後經歷大撞擊造成
- 有環
- 看起來無彩色雲帶。

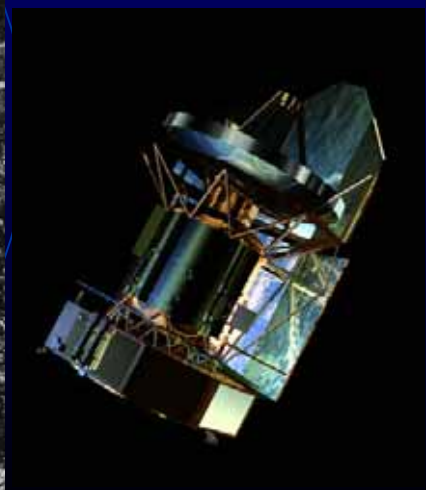


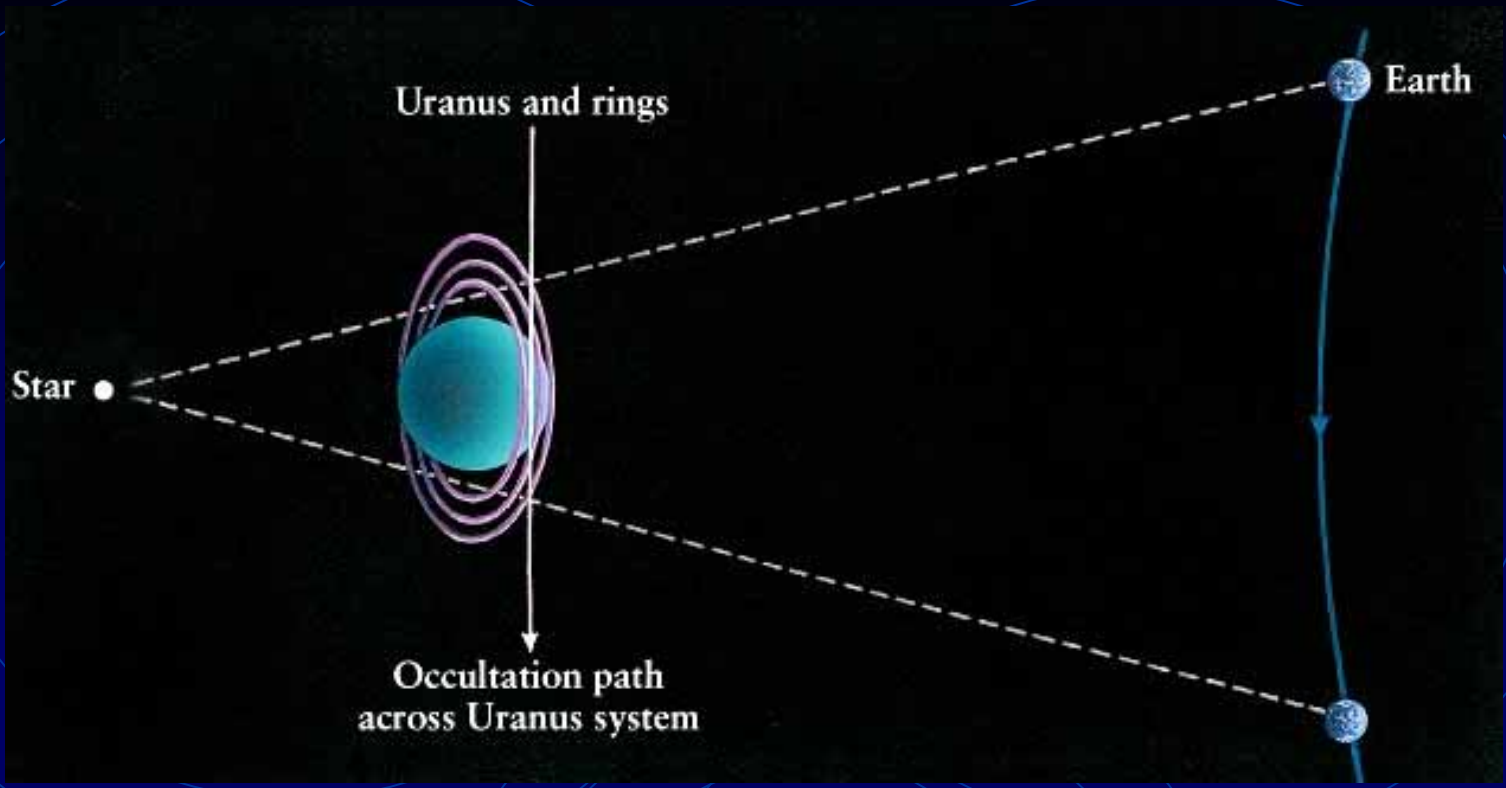
- William Herschel Musician, optician and astronomer; found Uranus
- Caroline Herschel, sister of William, became one of the pioneering woman astronomers in history; found 2500 nebulae and 8 comets before she died at an age of 97



http://www.agnesscott.edu/Lriddle/women/herschel.htm







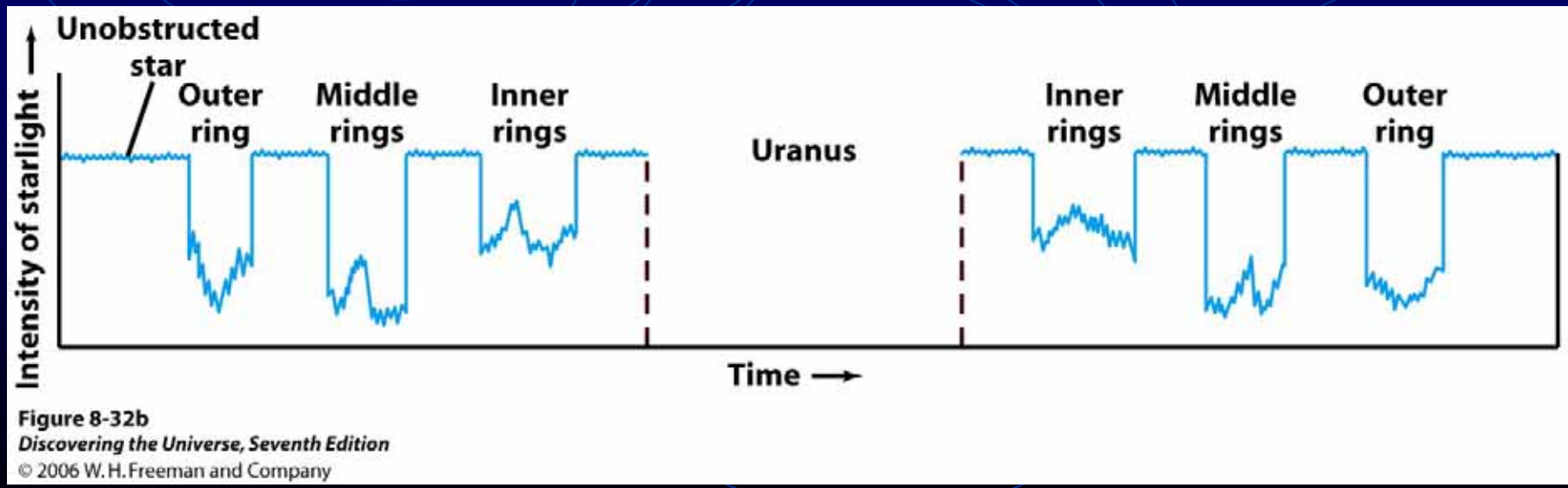


Figure 8-32b
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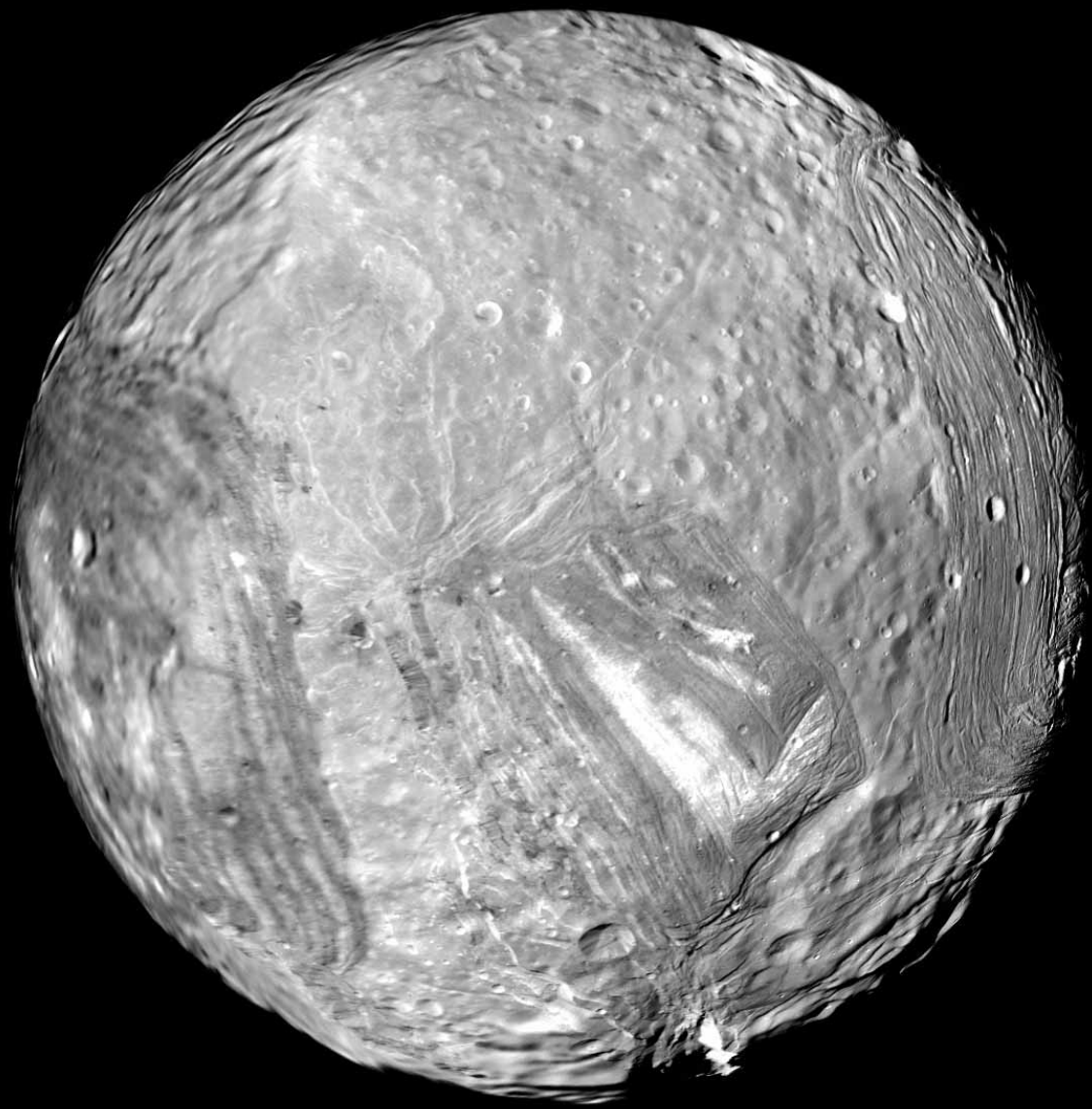
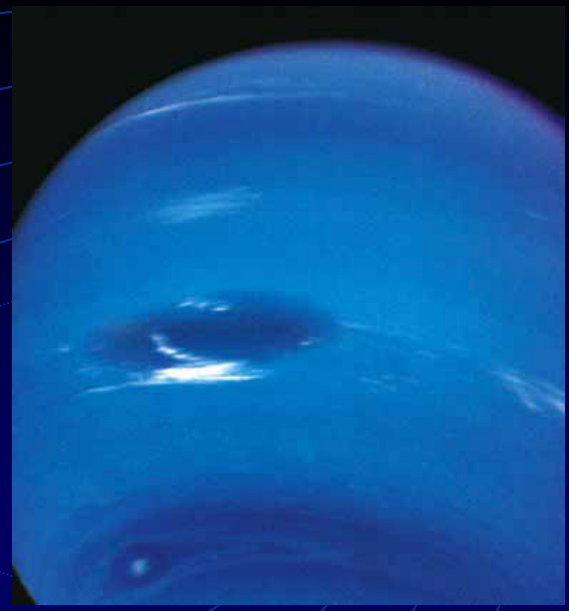
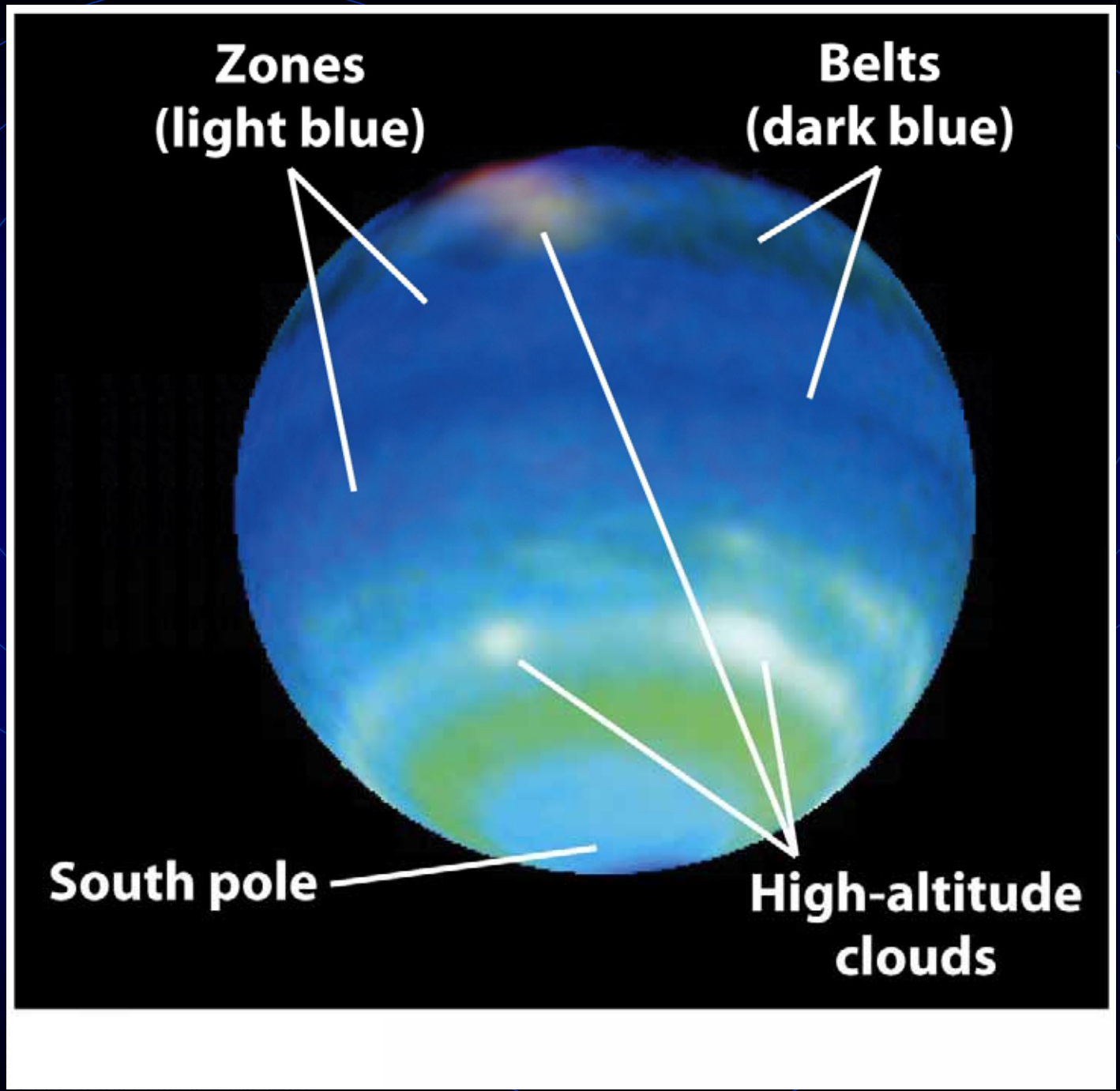
Miranda --- Uranus's moon



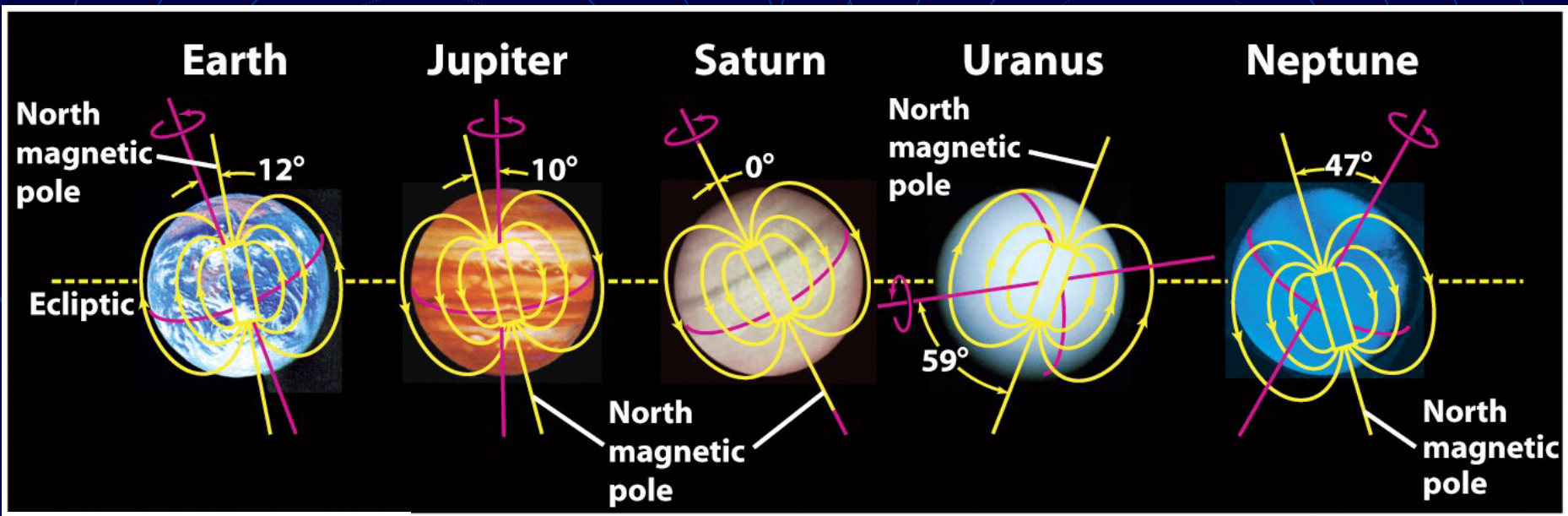
海王星 (Neptune)



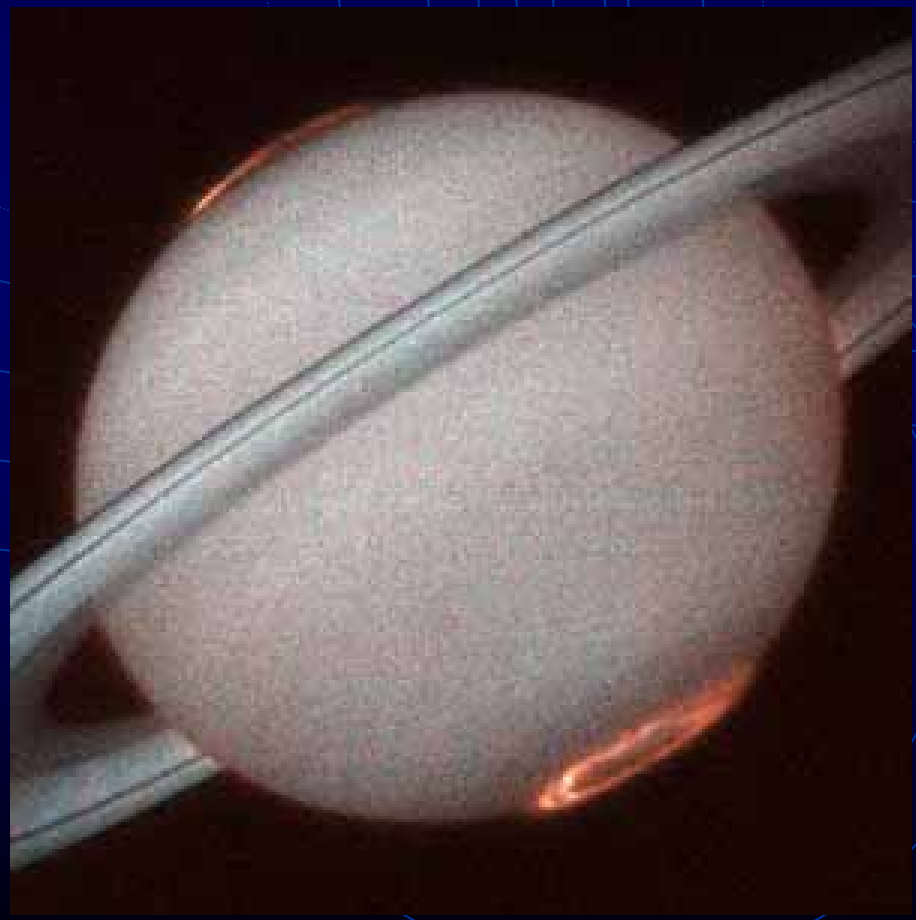
- 1846年法國 Leverrier 由天王星不規則的軌道推算出海王星位置，由 Galle 尋獲
- 之前於1845年由英國 Adams 已有類似預測，但是…
- 天王星的發現爲牛頓力學的一大勝利
- 大暗斑。
- 有環（石塊而非冰塊）


Zones
(light blue)
Belts
(dark blue)
South pole
High-altitude
clouds

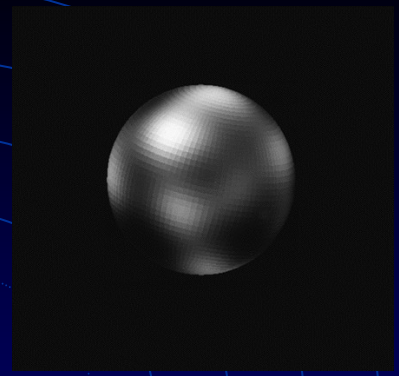
行星的磁場


Earth
Jupiter
Saturn
Uranus
Neptune
North magnetic pole
12°
Ecliptic
10°
0°
North magnetic pole
North magnetic pole
59°
47°
North magnetic pole

Saturn, Rings and Aurora

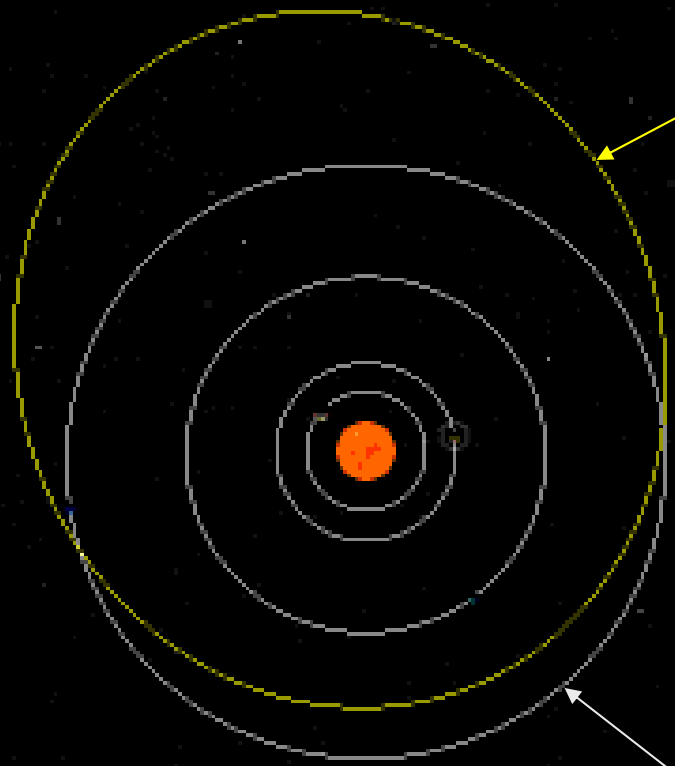


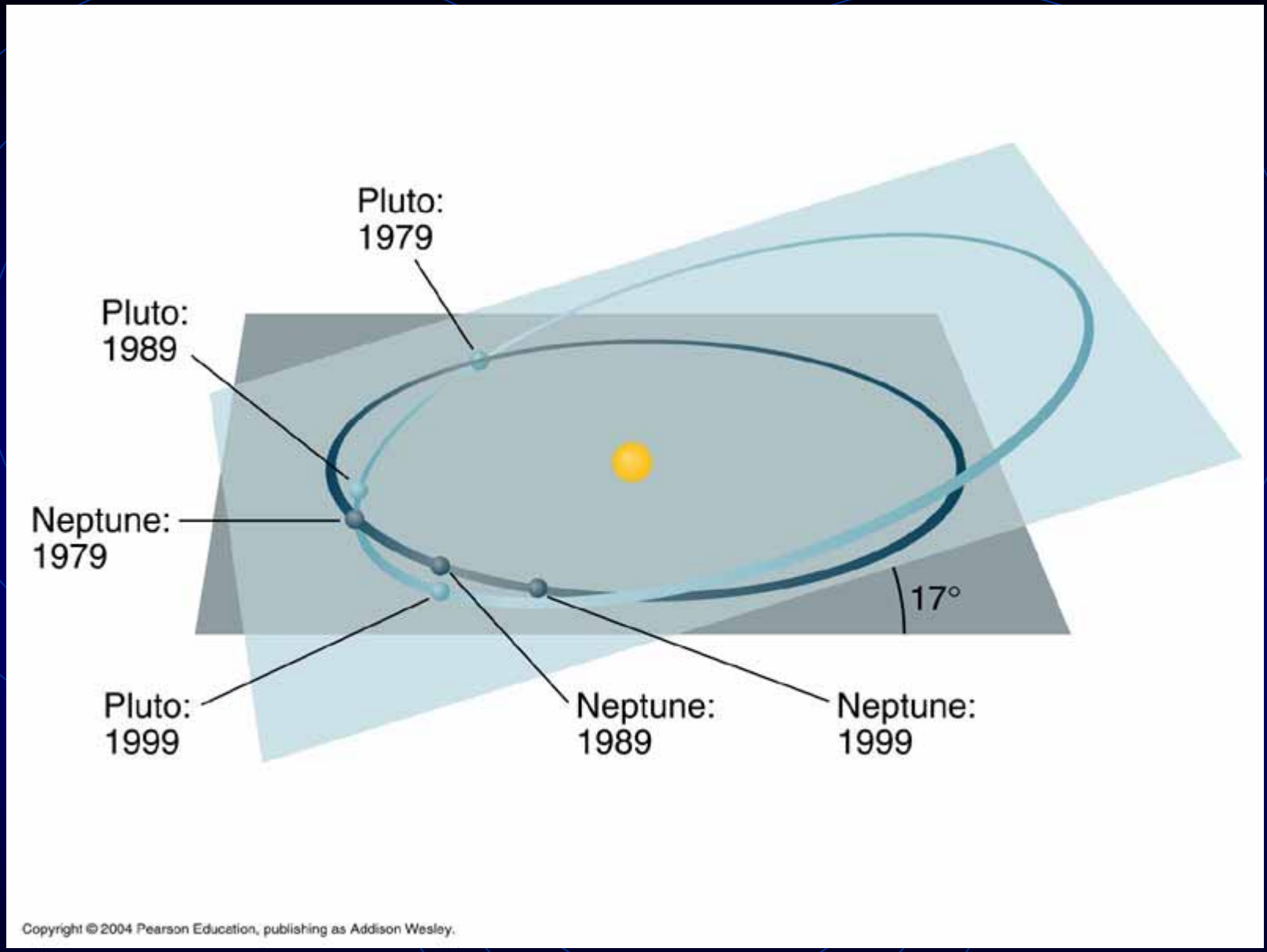
冥王星 (Pluto)



- 1930年Tombaugh 繼續 P. Lowell 未完志業，在 Lowell 天文台以海王軌道擾動尋找未知行星。乃幸運發現，因爲 Lowell 預測未知行星應有7倍地球質 量，但 Pluto 實際上只有0.002倍！根本不足以造成擾動
- 離心率大 → 橢圓軌道，有時（例如 1979 至 1999 年間）比海王星更接近太陽
- 公轉面與太陽系平面成17度
- 稀薄大氣，表面（！）爲氮化物與甲烷冰層

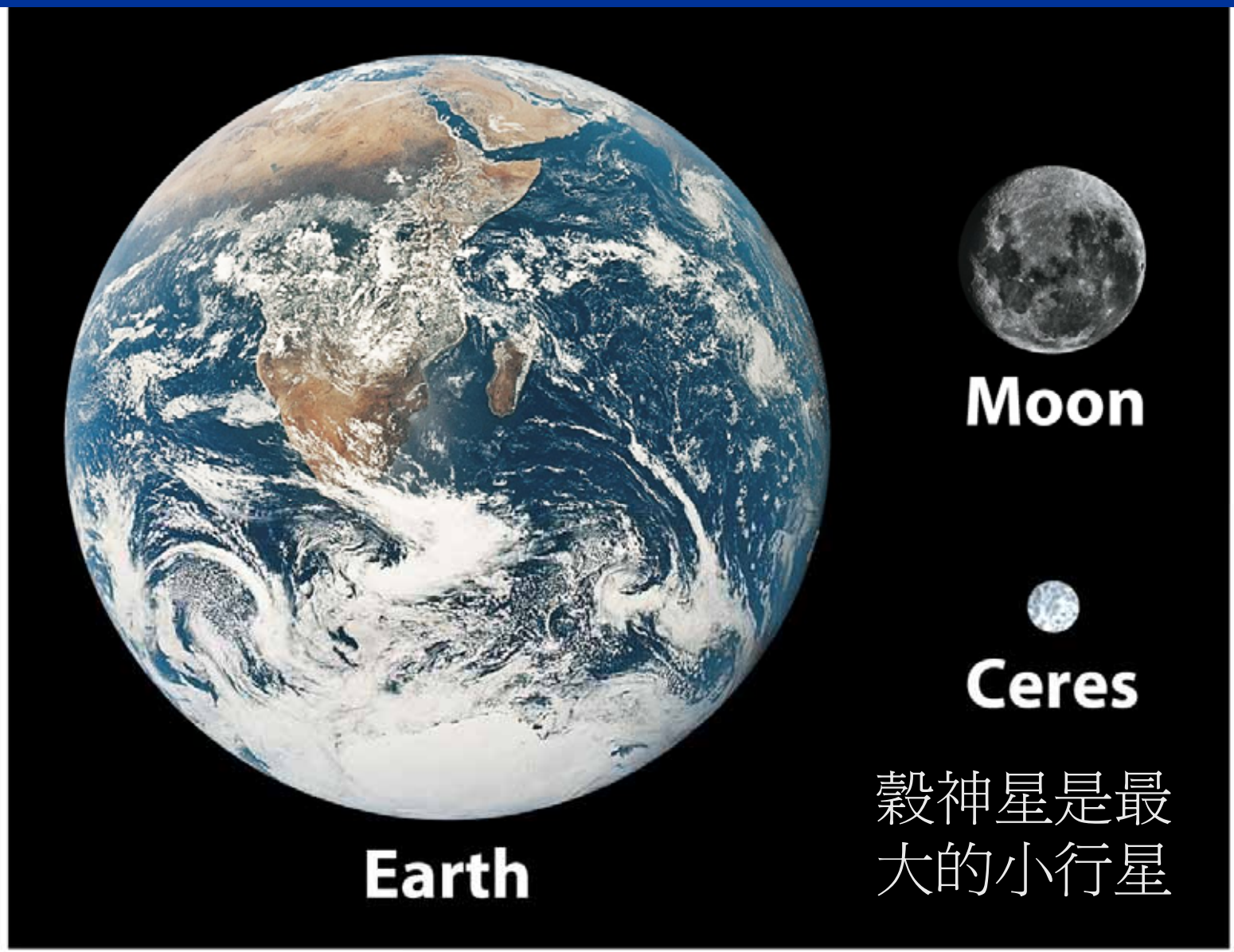
→ 行星中的異數

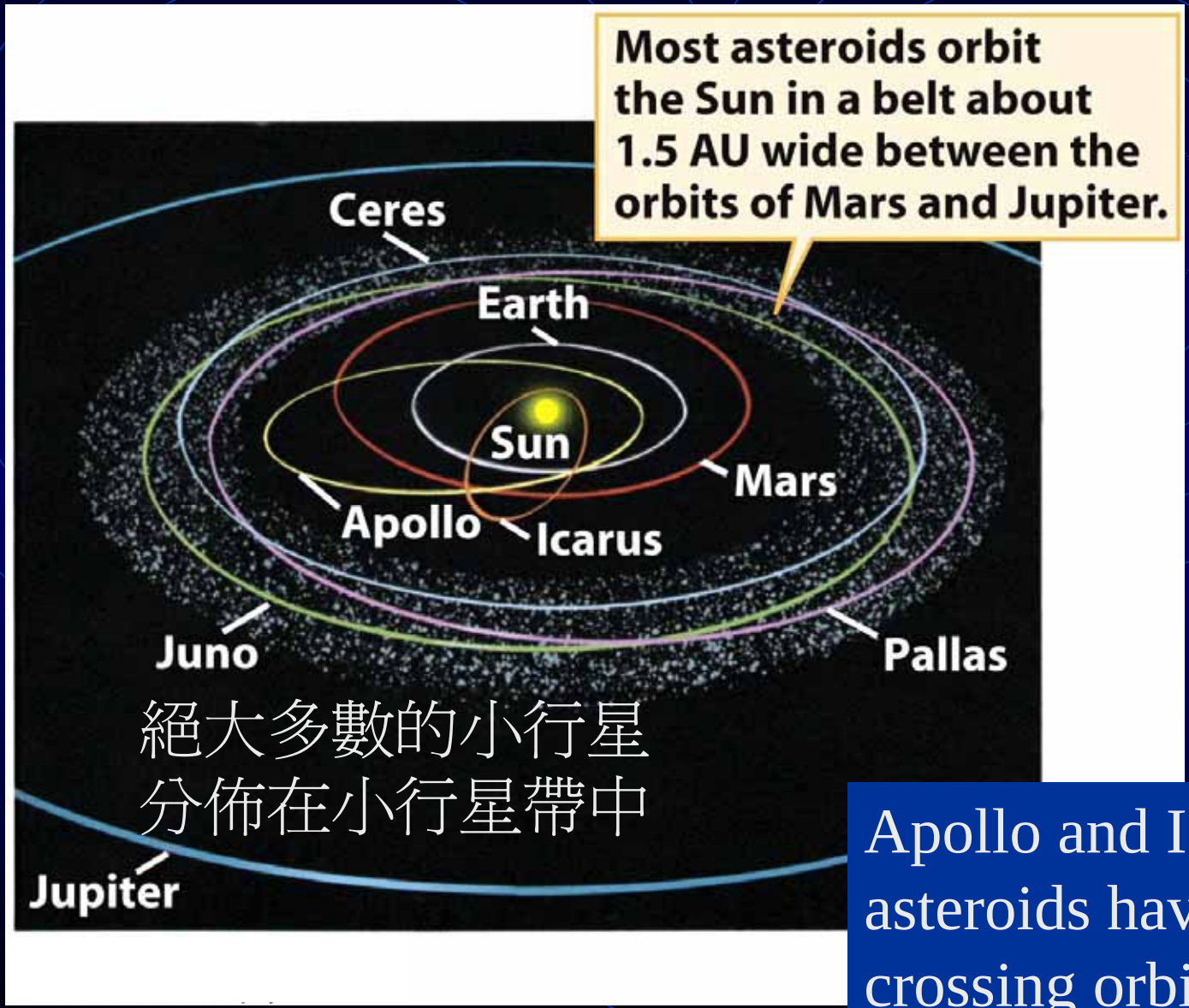

冥王星軌道
海王星軌道



http://www.physast.uga.edu/~jss/1010/ch13/13-14.jpg

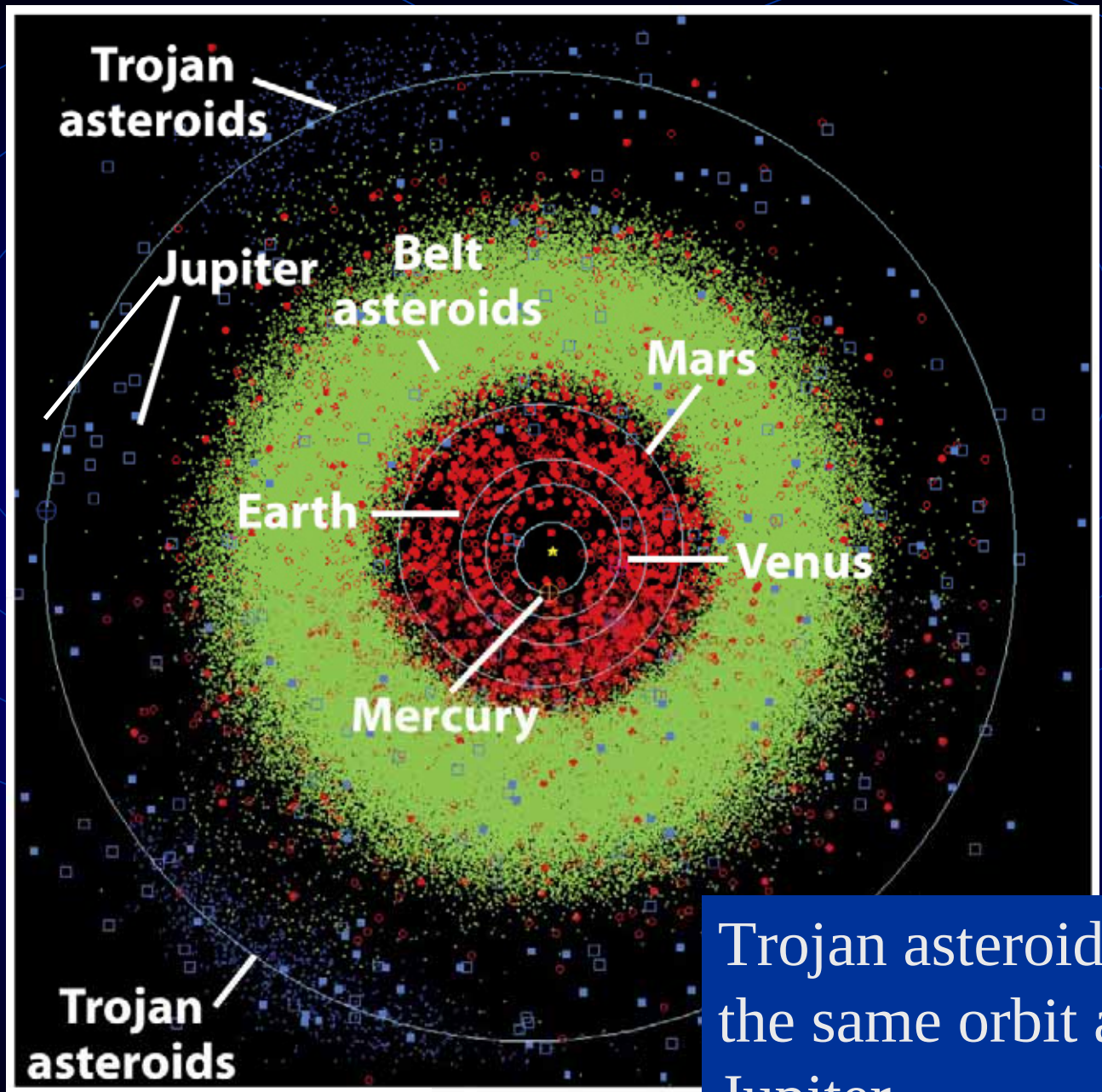
小行星 (asteroid; minor planets)





絕大多數的小行星
分佈在小行星帶中

Apollo and Icarus asteroids have Earth-crossing orbits.



Trojan asteroids have the same orbit as Jupiter.

Stable Lagrange points (leading and trailing)

Some ~1700 Jupiter Trojans have been catalogued.

Neptune is known to have at least one Trojan asteroid.

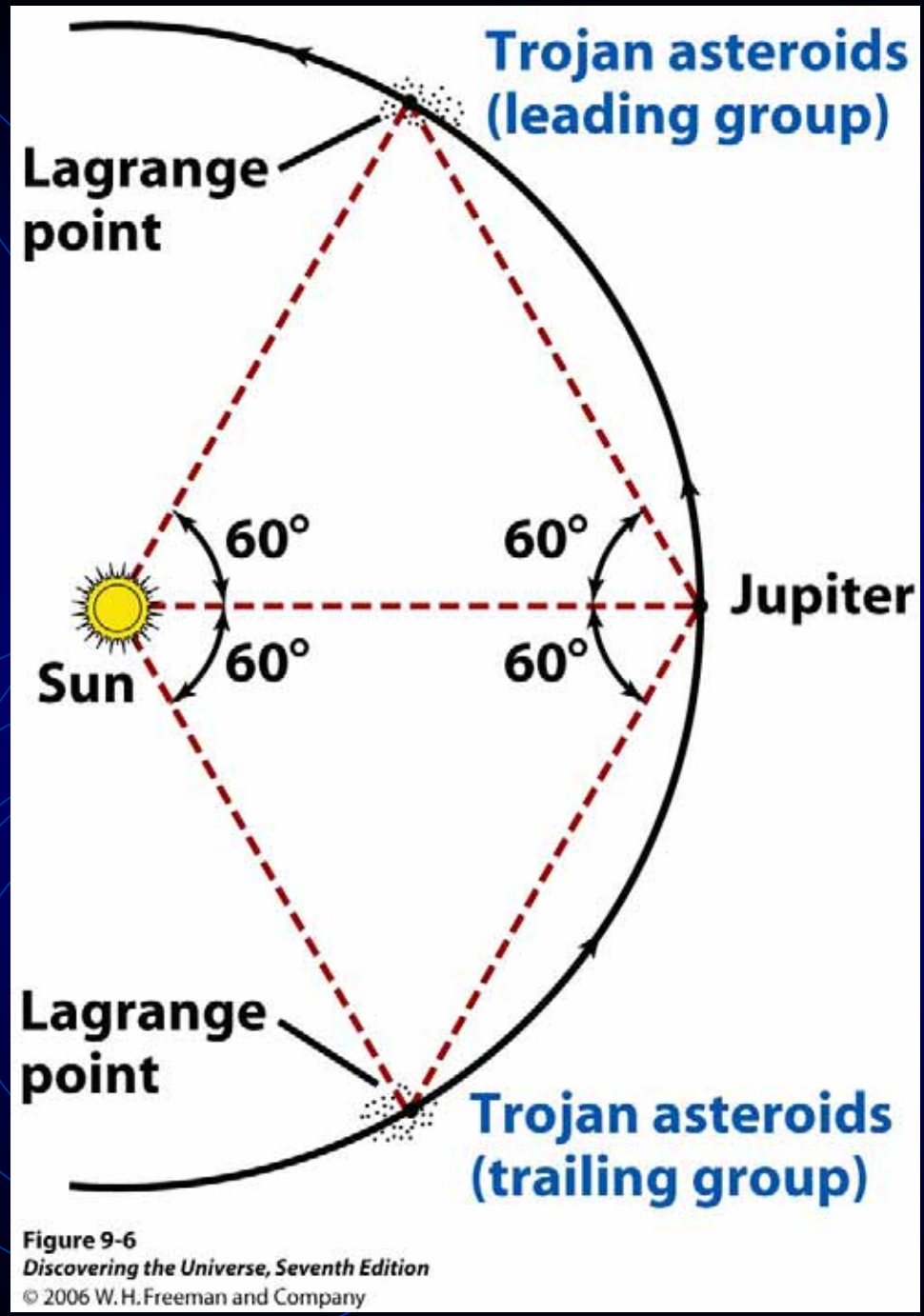
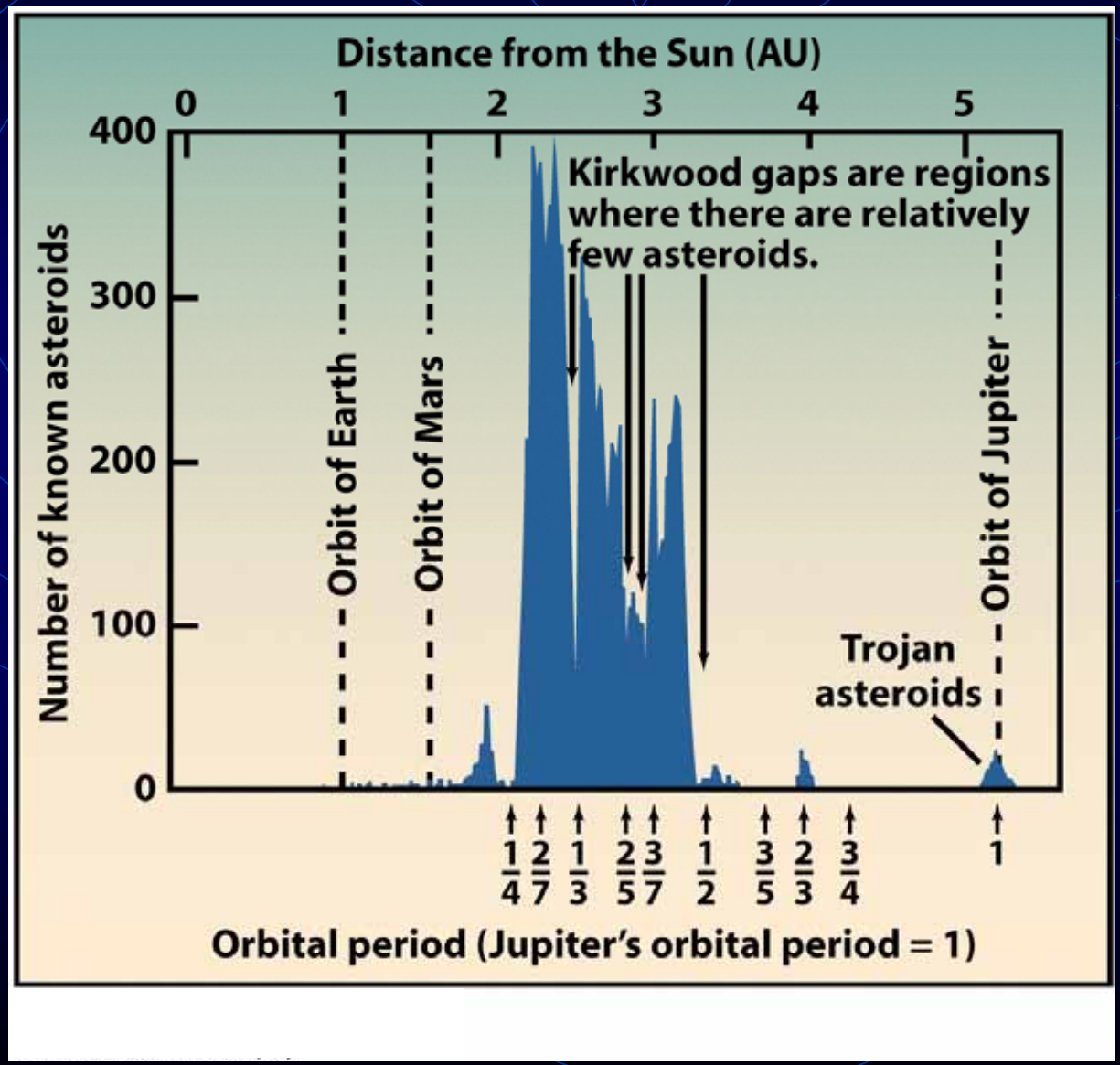
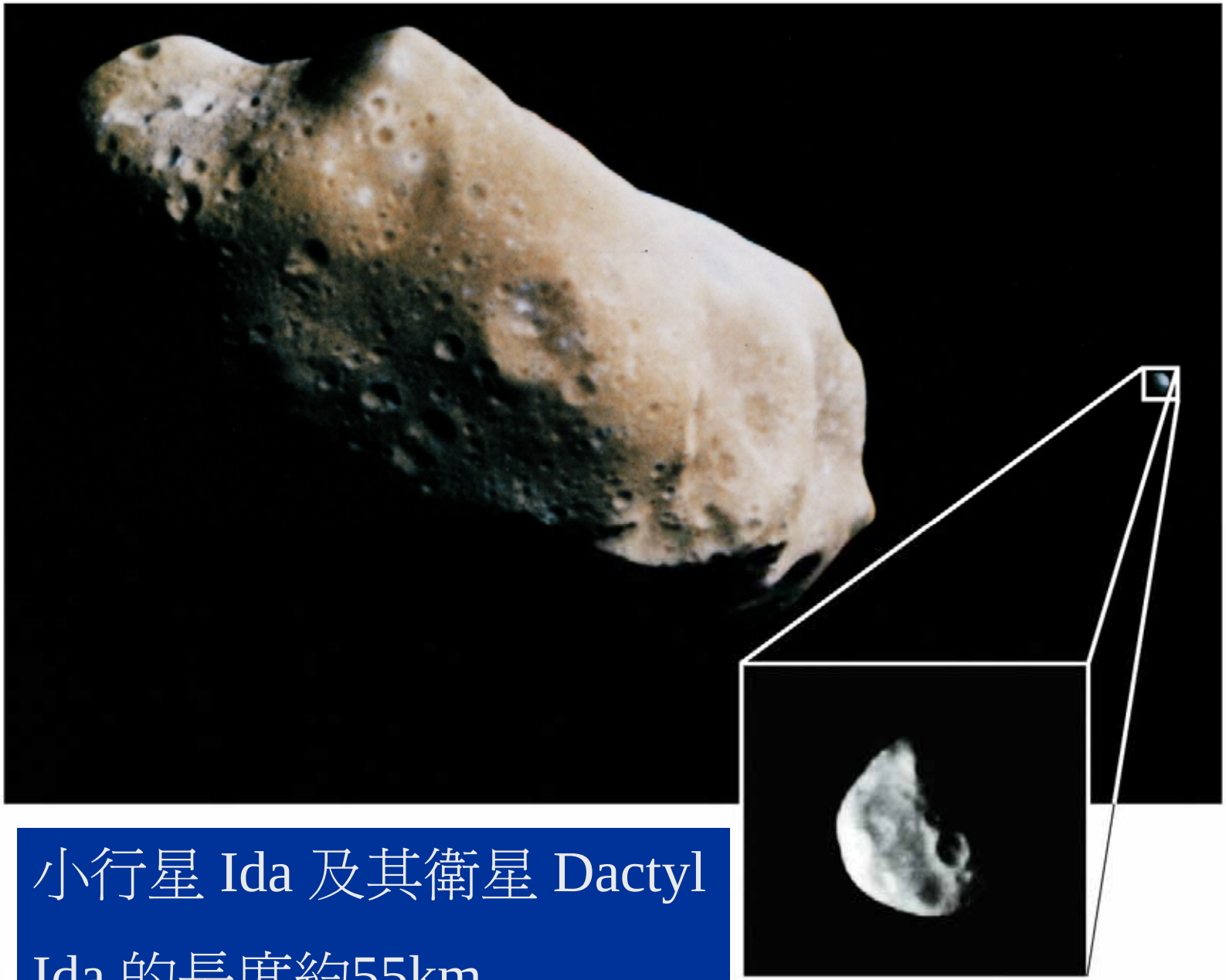


Figure 9-6
Discovering the Universe, Seventh Edition

Kirkwood gap --- simple fractions of Jupiter's orbital periods → harmonics/resonance

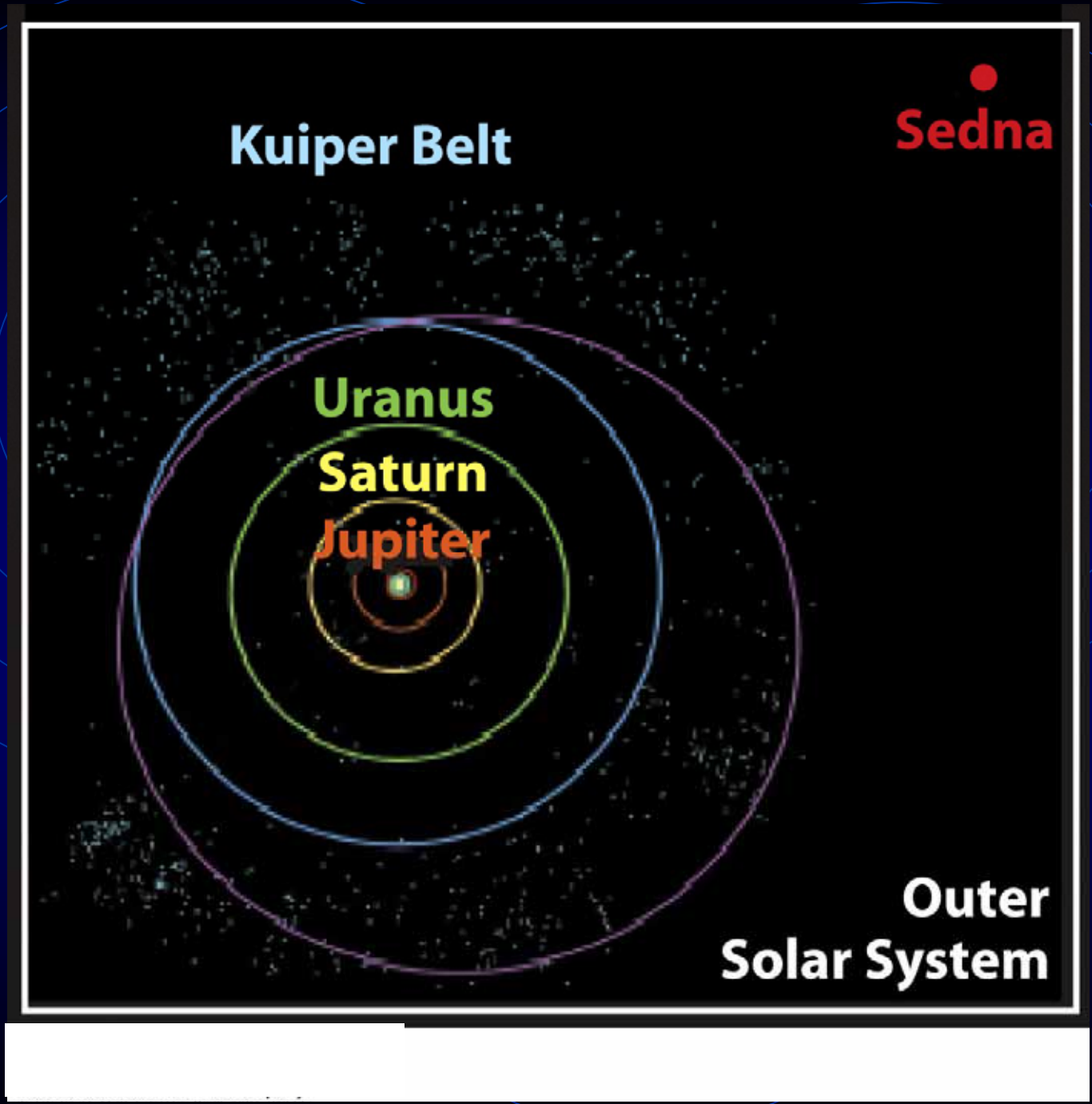


同樣的共振現象見於 Mimas 造成土星光環中的 Cassini division



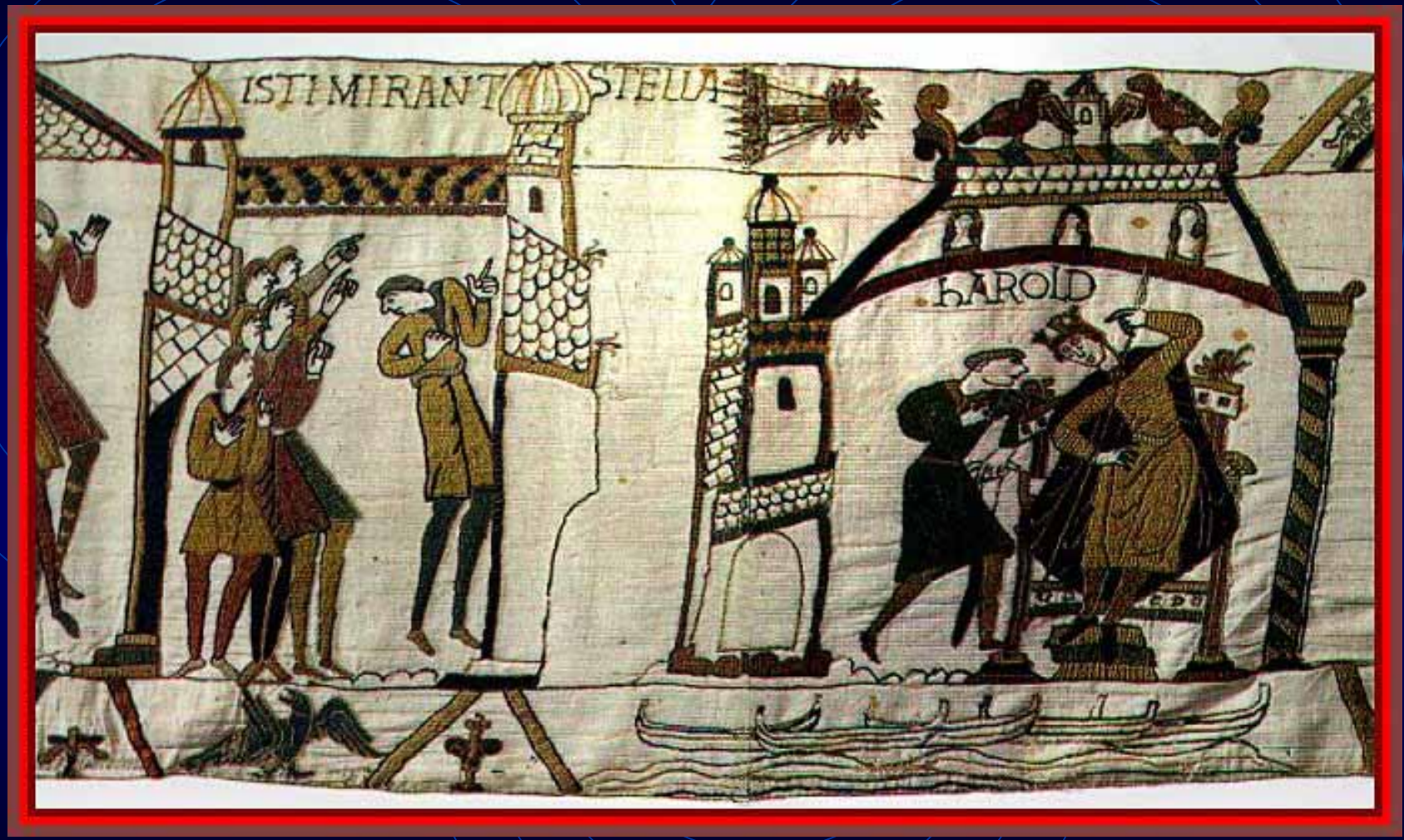
小行星 Ida 及其衛星 Dactyl

Ida 的長度約55km

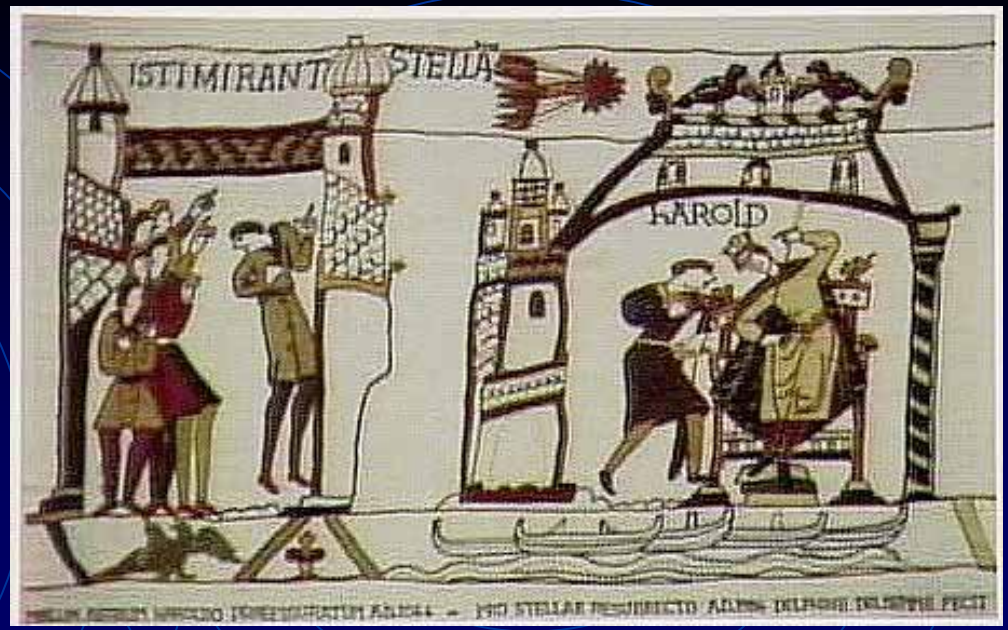

Kuiper Belt
Sedna
Uranus
Saturn
Jupiter
Outer
Solar System

Sedna --- artist’s view

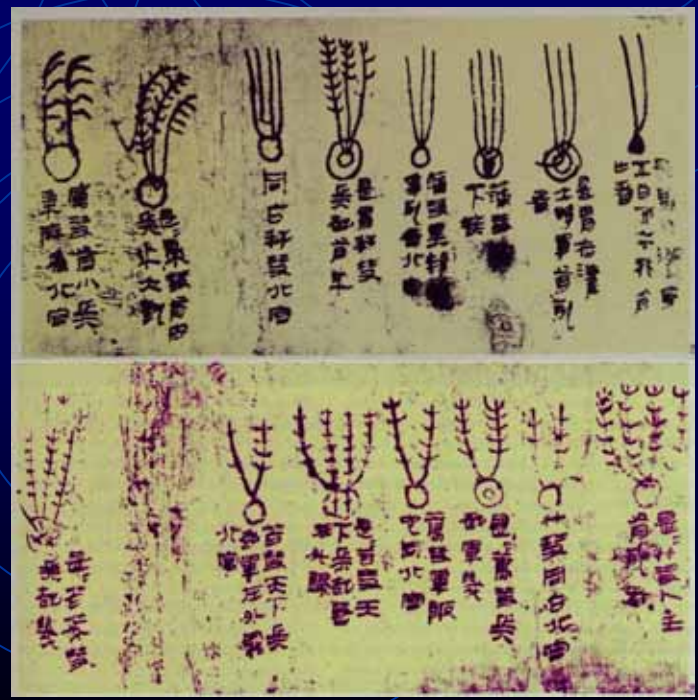
彗星 (comet)



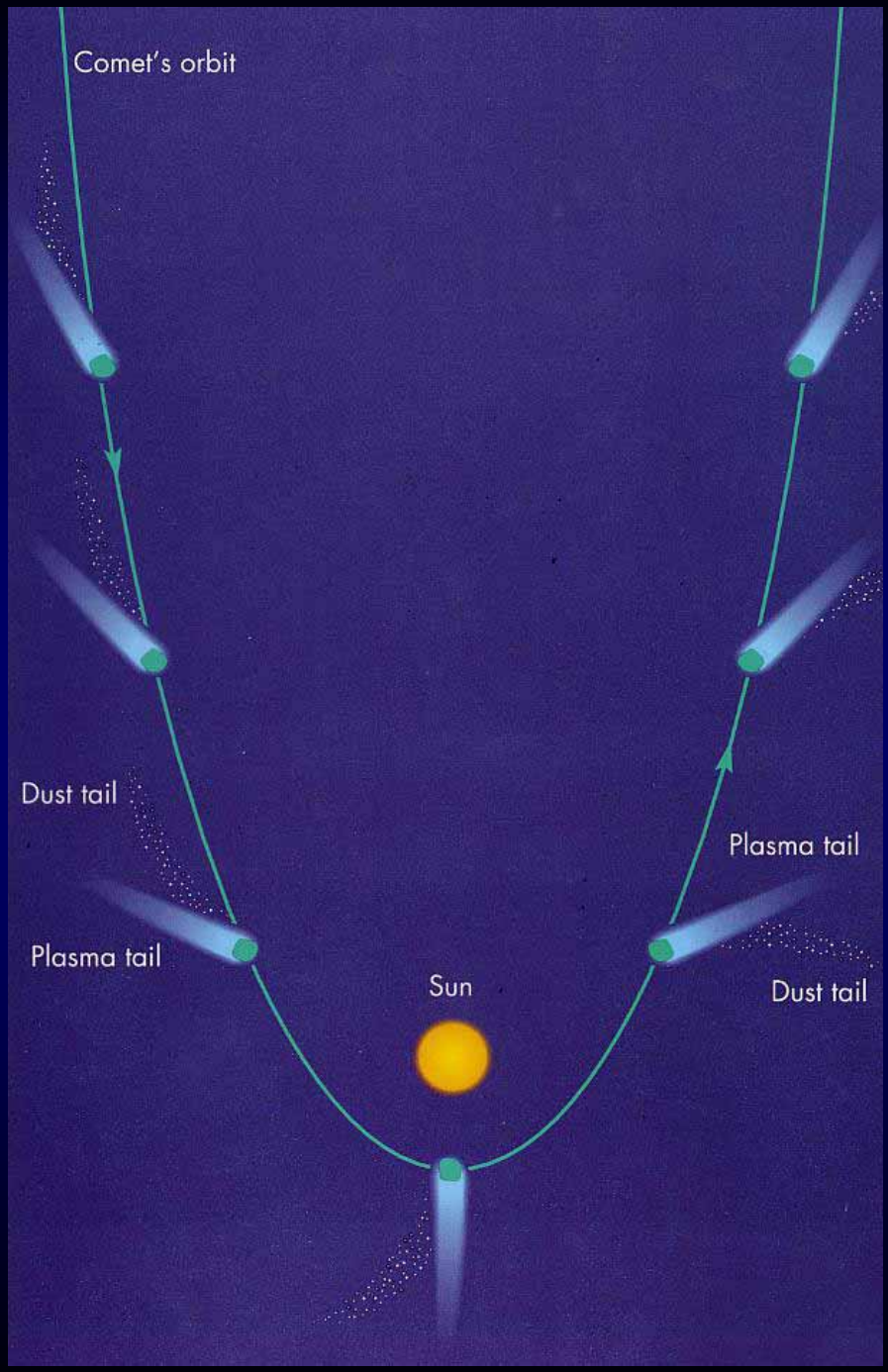
Halley’s comet, first seen on the 24 April 1066, was considered a bad omen by the Saxons.



Thomas Nast, cartoon - "The Comet of Chinese Labor" (1870)



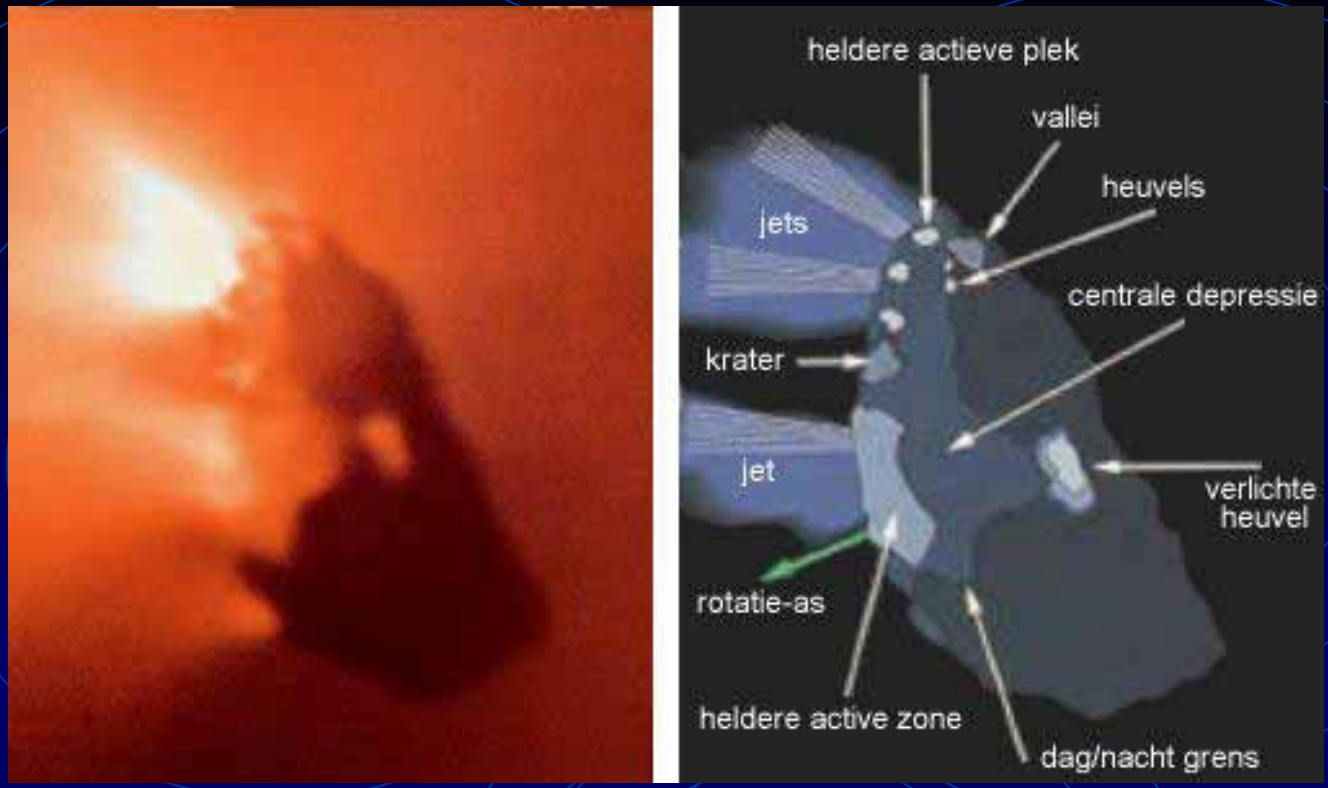
長沙馬王堆出土西漢帛畫中的彗星圖



彗尾指向太陽的反方向

爲什麼？

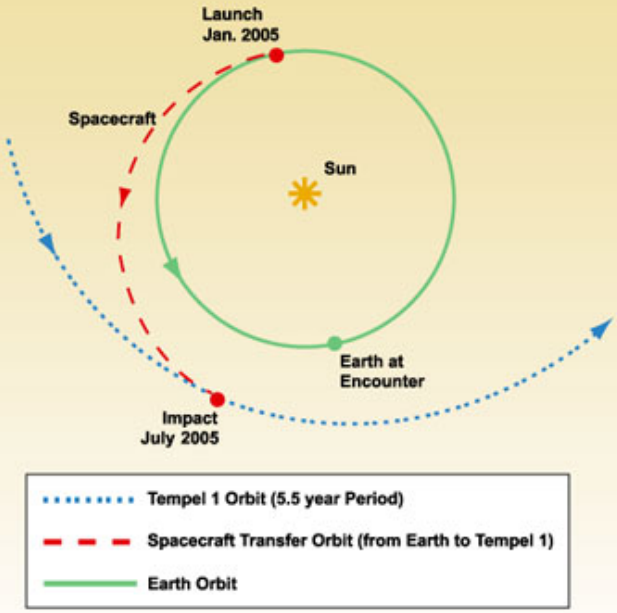
冰體受熱 → 蒸發、昇華 → 彗星（現象）



哈雷彗星每76年繞行太陽一圈。這張照片是1986年哈雷彗星接近太陽時，太空船前往近距離拍攝，可看到形狀不規則的彗核正噴發氣體。

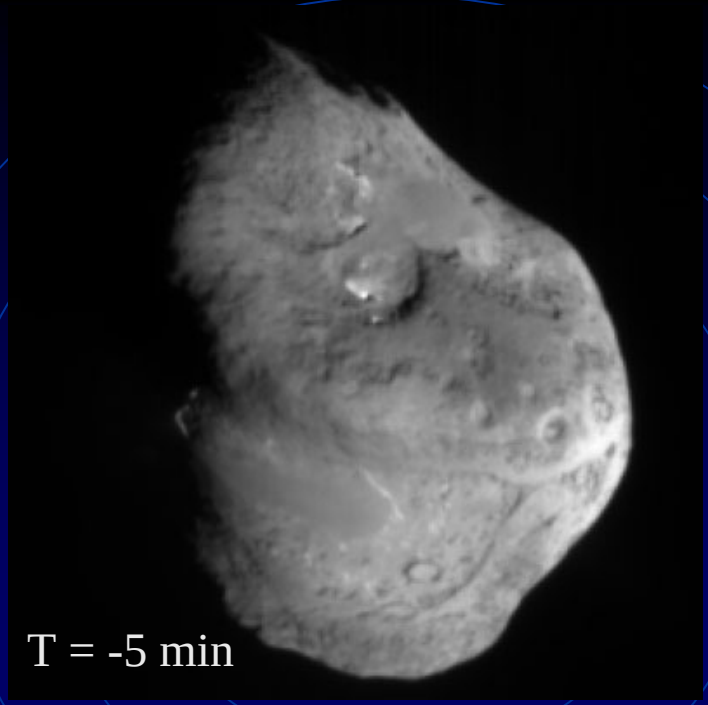
http://nssdc.gsfc.nasa.gov/image/planetary/comet/giotto_halley.jpg

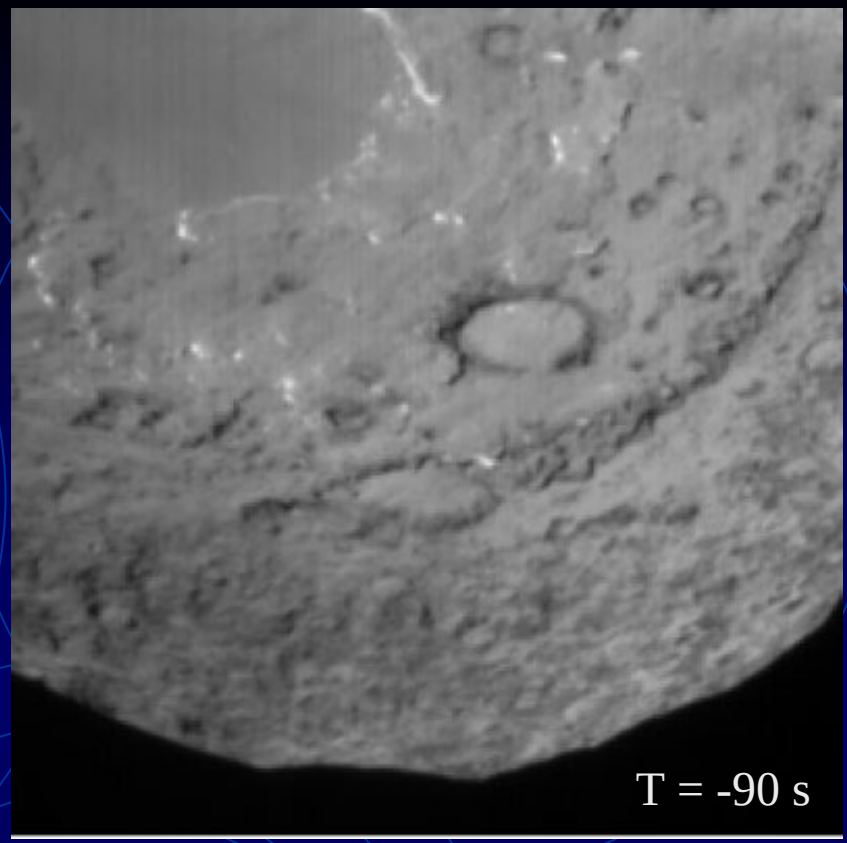
2005年1月發射

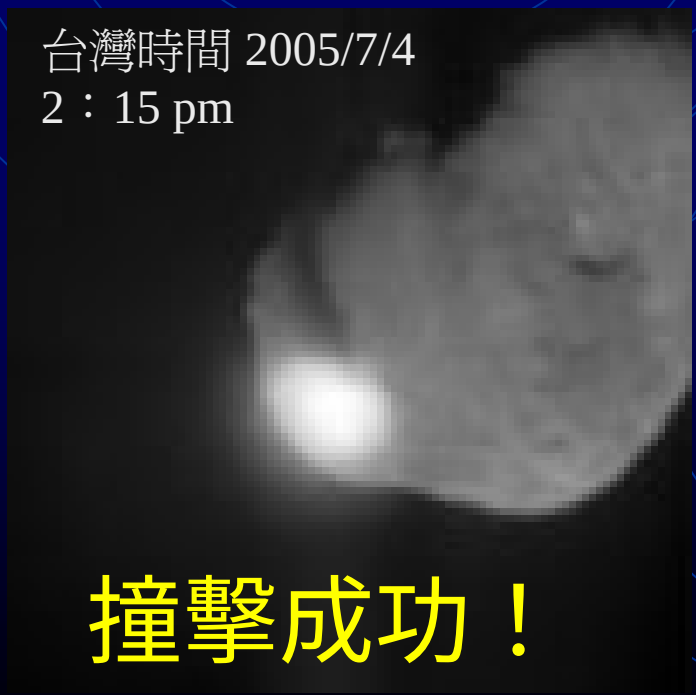


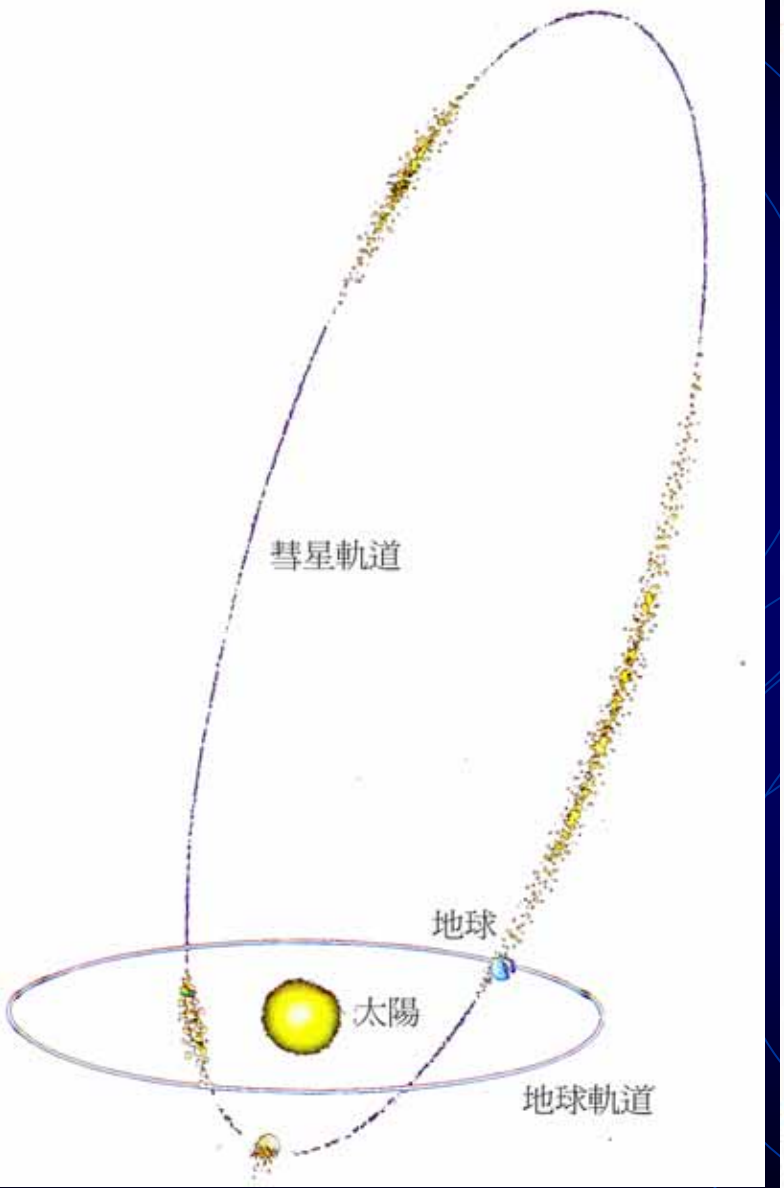
7月4日抵達譚普一號 (Temple 1) 彗星，釋放370公斤子船「撞擊號」 (impactor) 自行導引以時速36000公里撞向彗星。預期產生大小、深度達十幾公尺到幾十公尺的坑洞，藉此研究彗星表面塵埃、氣體噴出，以及內部結構。

母船「飛掠號」 (flyby spacecraft) 撞擊後改變軌道，以500公里近距離觀察撞擊結果，並將結果傳回地面 NASA Deep Space Network


T = -5 min


T = -90 s


台灣時間 2005/7/4
2：15 pm
撞擊成功！

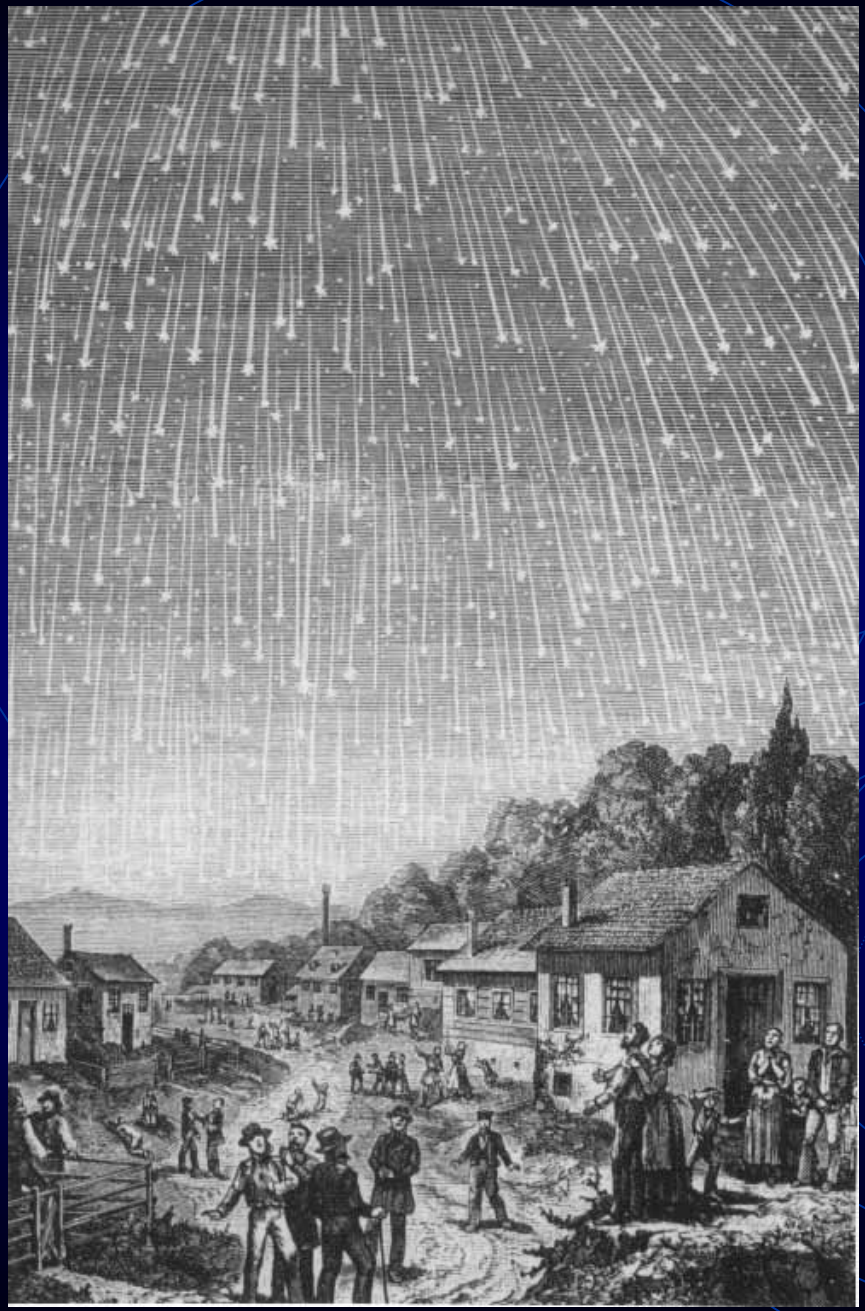


PROMINENT YEARLY METEOR SHOWERS

Shower	Date of maximum intensity	Typical hourly rate	Constellation
Quadrantids	January 3	40	Boötes
Lyrids	April 22	15	Lyra
Eta Aquarids	May 4	20	Aquarius
Delta Aquarids	July 30	20	Aquarius
Perseids	August 12	80	Perseus
Orionids	October 21	20	Orion
Taurids	November 4	15	Taurus
Leonids	November 16	15	Leo Major
Geminids	December 13	50	Gemini
Ursids	December 22	15	Ursa Minor

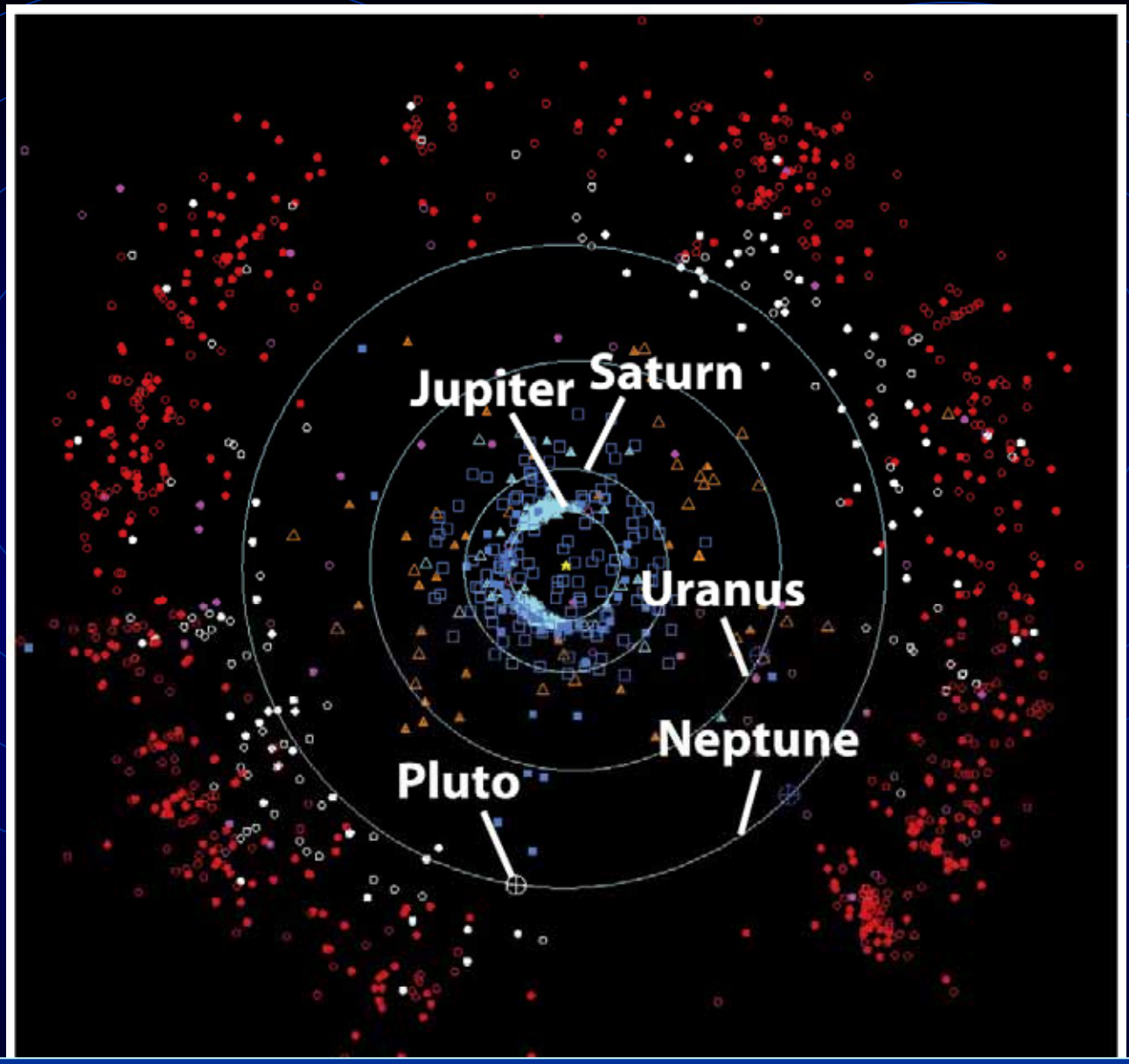
Figure 9-27
Discovering the Universe, Seventh Edition

有名的流星雨



Leonids in 1833?

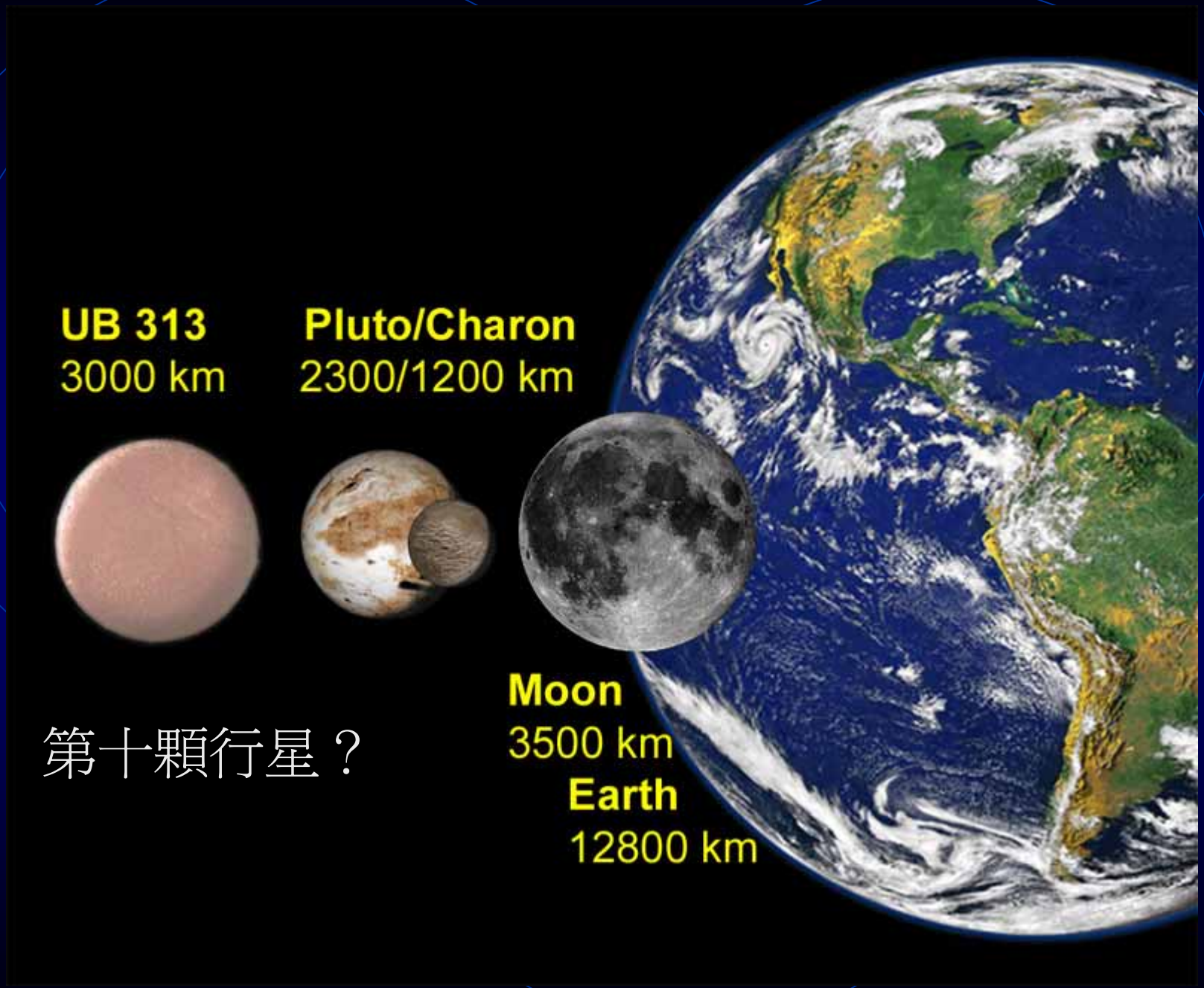
http://star.arm.ac.uk/leonid/Meteor-Shower.jpg

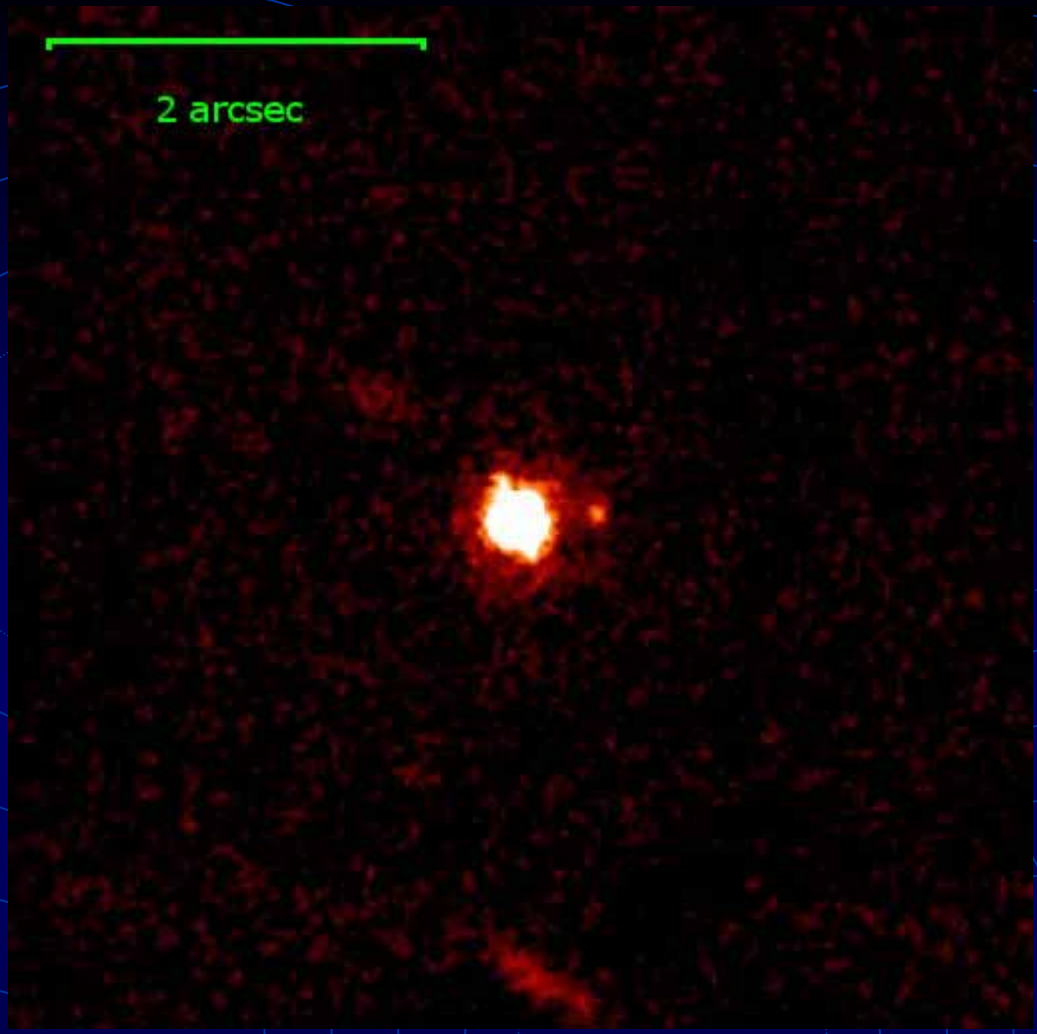


古柏帶 **(Kuiper belt)** 是製造行星剩下的小天體　　目前已經知道超過**2000**個


Sedna
800-1100 miles
in diameter
Quaoar
(800 miles)
Pluto
(1400 miles)
Moon
(2100 miles)
Earth
(8000 miles)

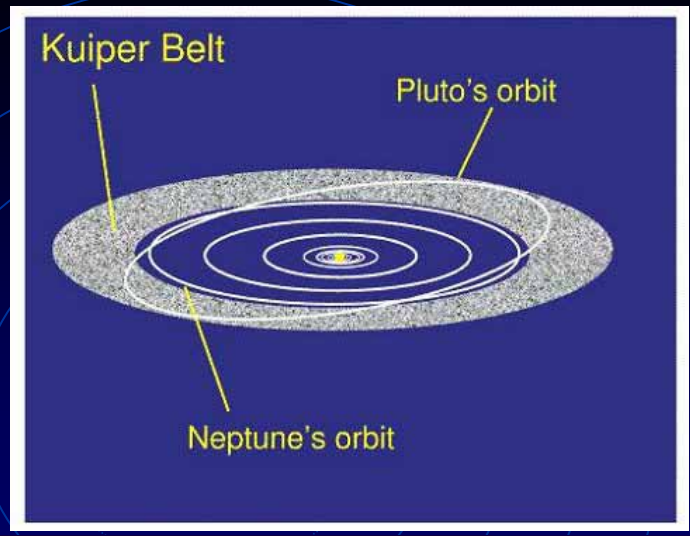
古柏帶中的小型天體

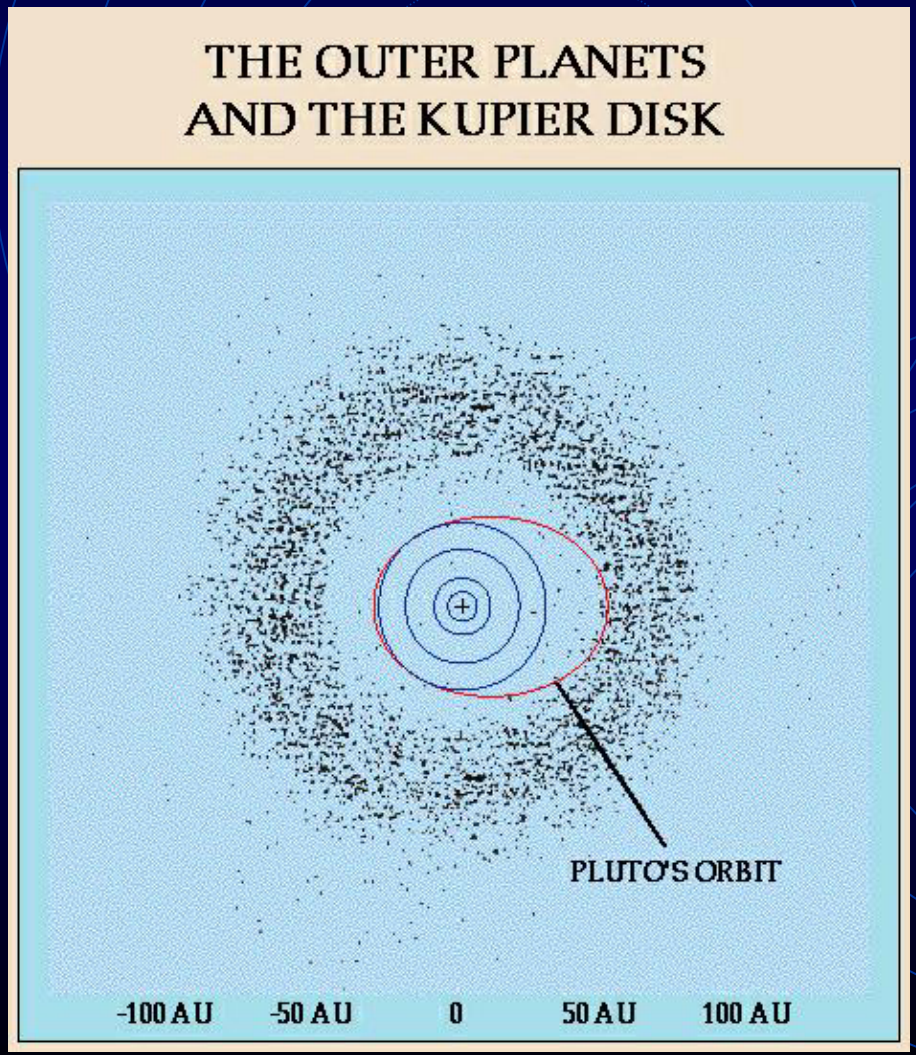

UB 313
3000 km
Pluto/Charon
2300/1200 km
Moon
3500 km
Earth
12800 km
第十顆行星？

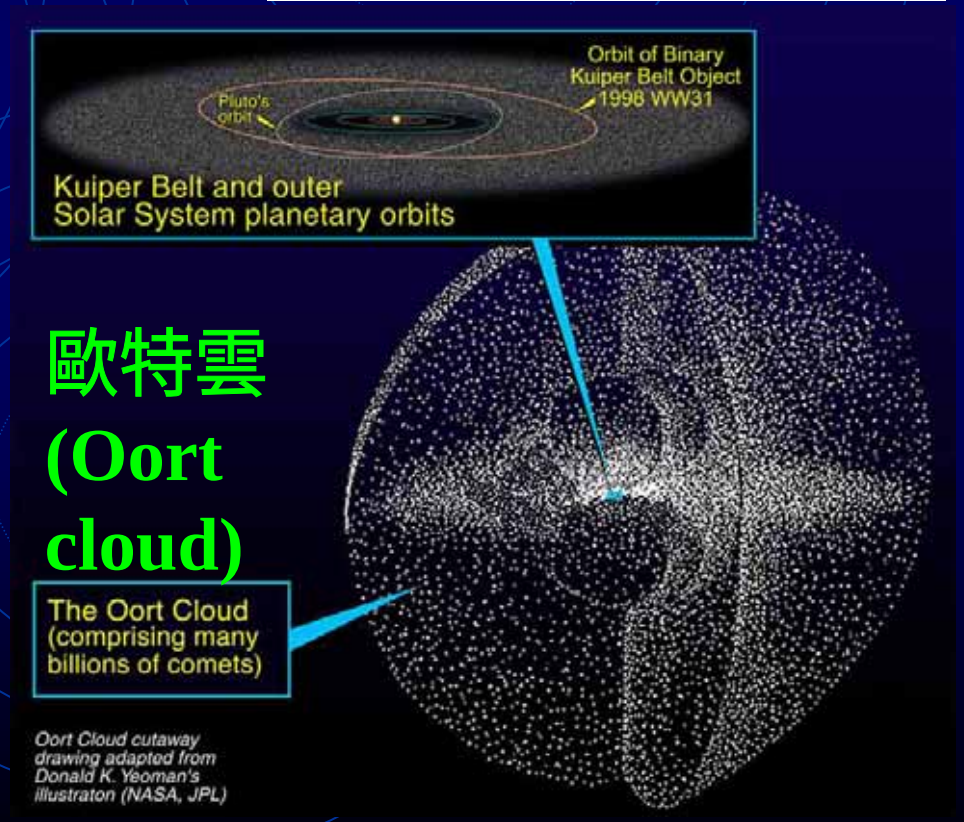


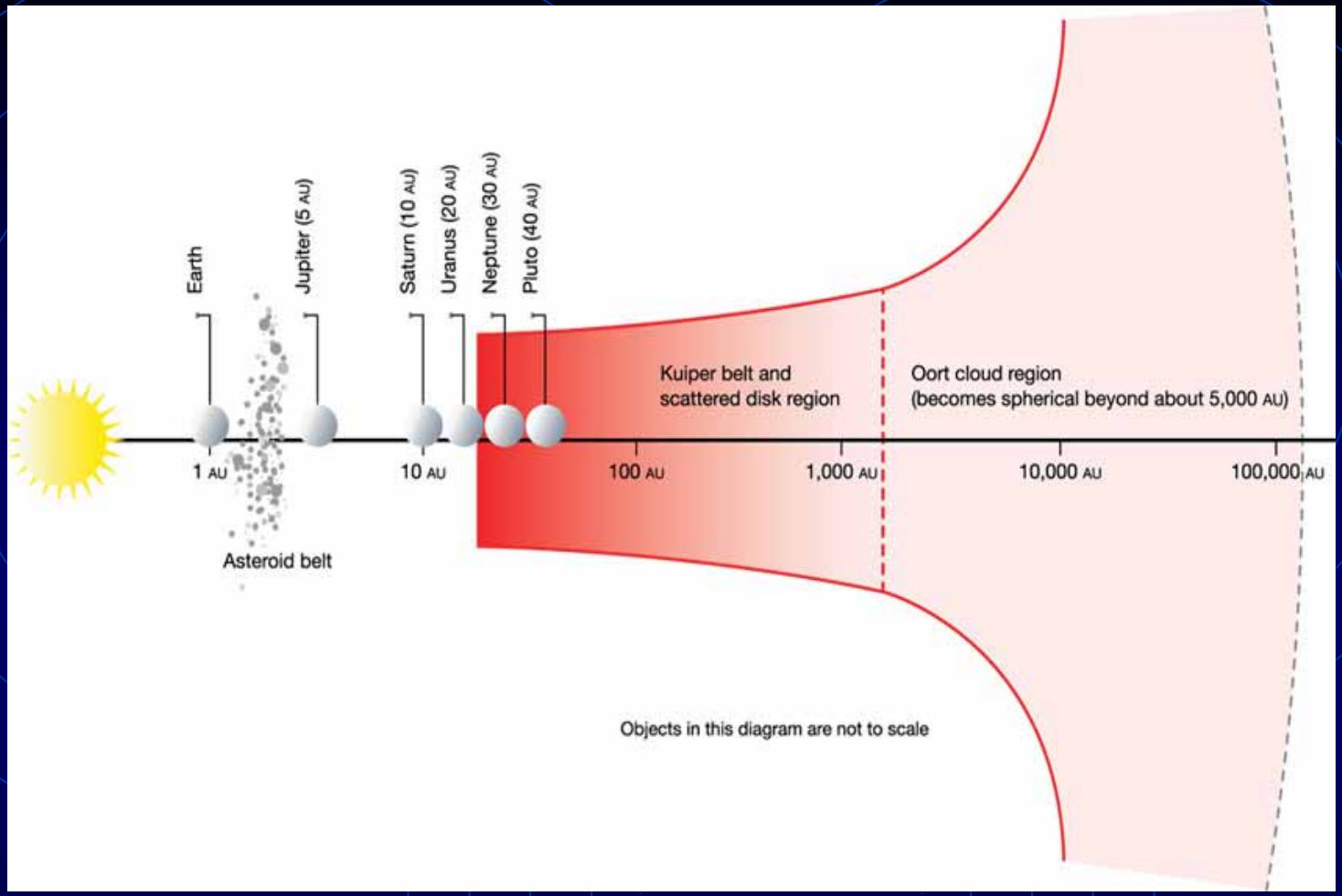
Keck Telescope image of **Eris** (2003 UB313, dwarf planet 矮行星) and its moon Dysnomia. The pair had been tentatively nicknamed "Xena and Gabrielle" at the time the picture was taken.

The surplus material and plantesimals become the Kuiper disk or Kuiper belt .



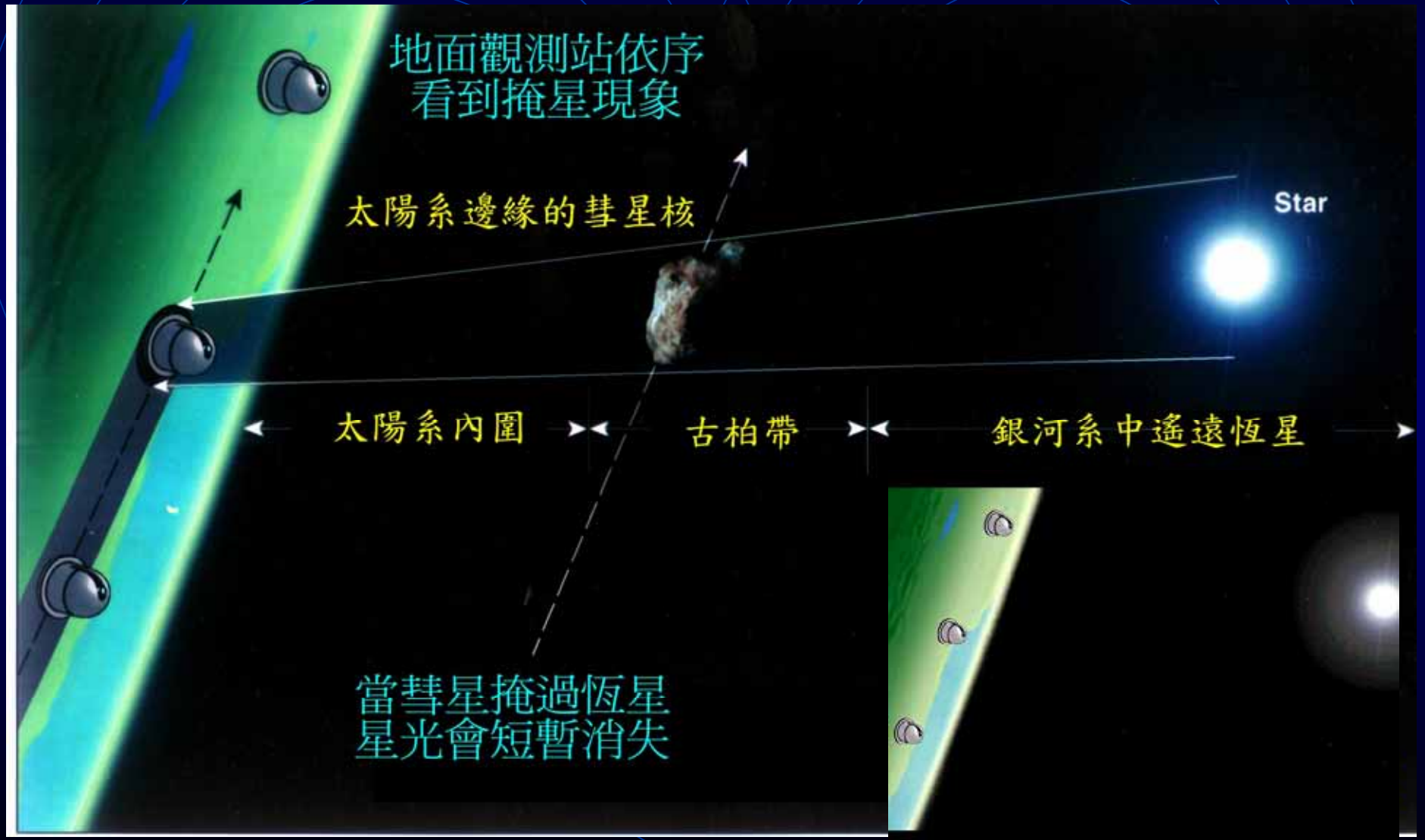


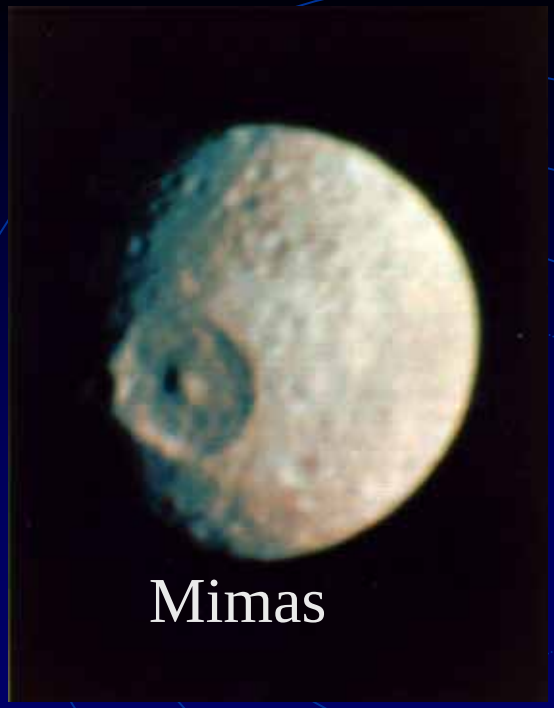




The Kuiper belt is the remnant planetary disk extending beyond Naptune to perhaps > 1,000 AU.

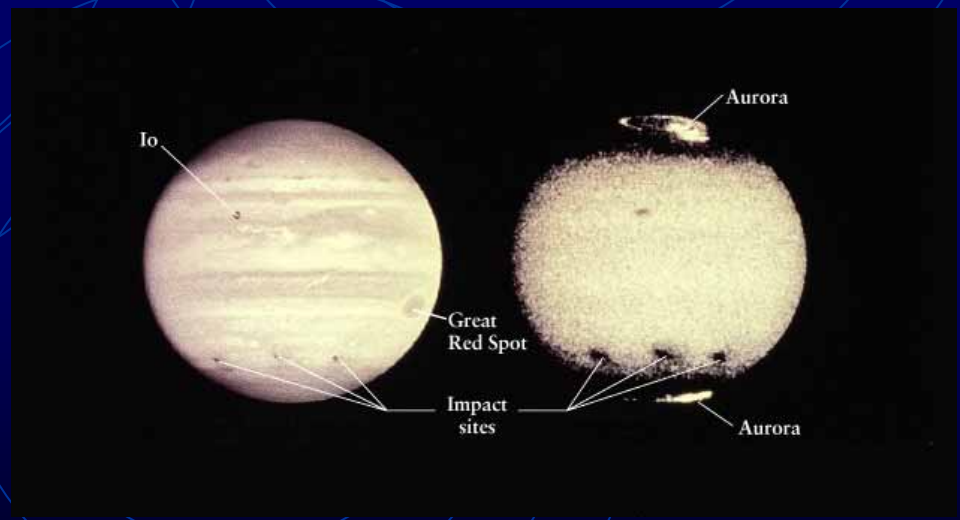
中美掩星計畫 (TAOS)


地面觀測站依序
看到掩星現象
太陽系邊緣的彗星核
Star
太陽系內圍
古柏帶
銀河系中遙遠恆星
當彗星掩過恆星
星光會短暫消失



Mimas

月球表面
有大量撞
擊的痕跡



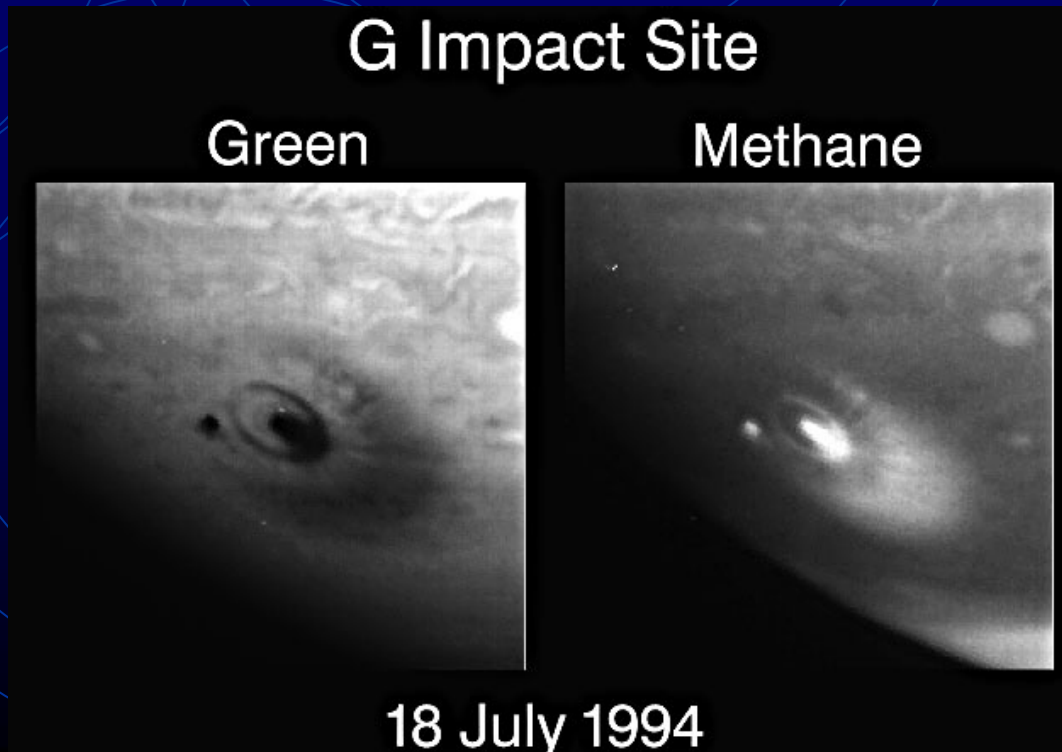
Gaspa 小行星表面
也有很多撞擊證據

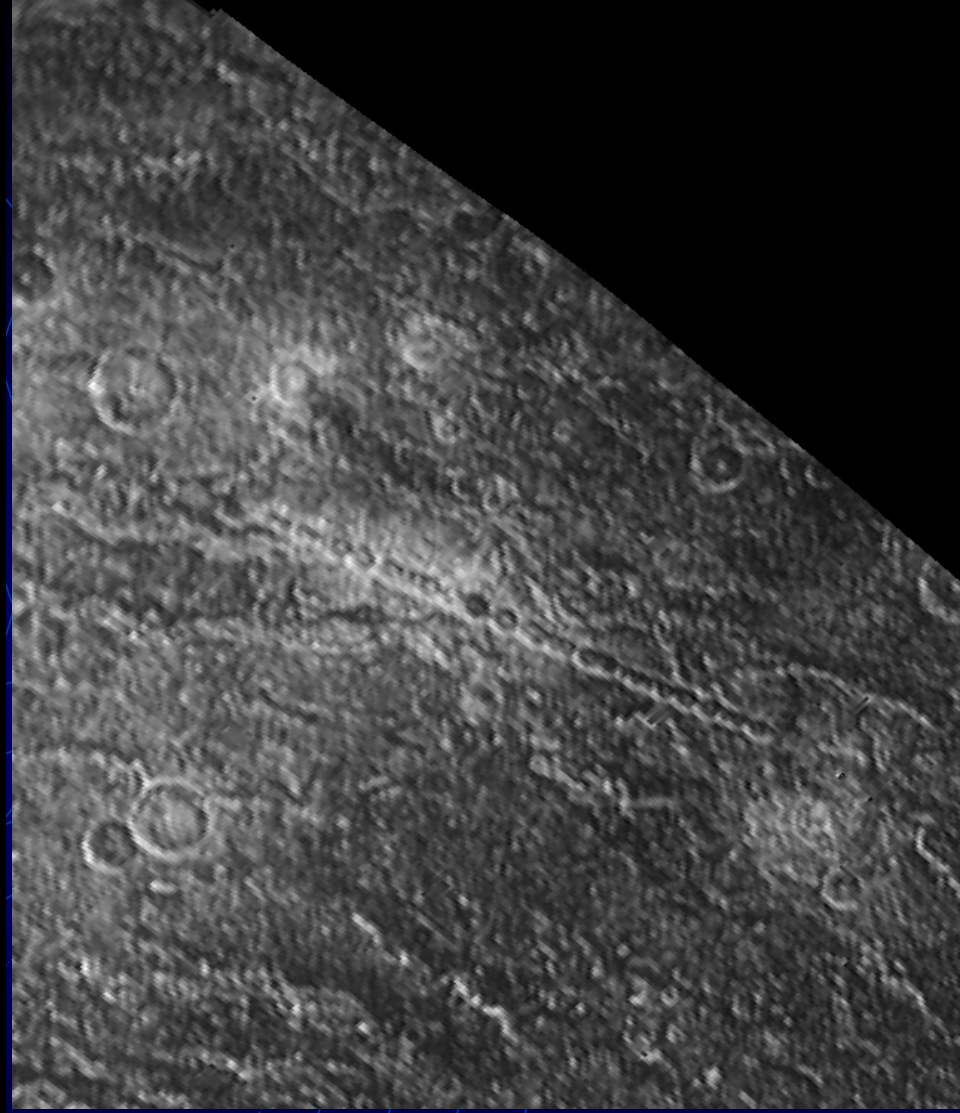
木星也曾被撞
得鼻青臉腫

Shoemaker-Levy9 彗星分裂成21碎塊

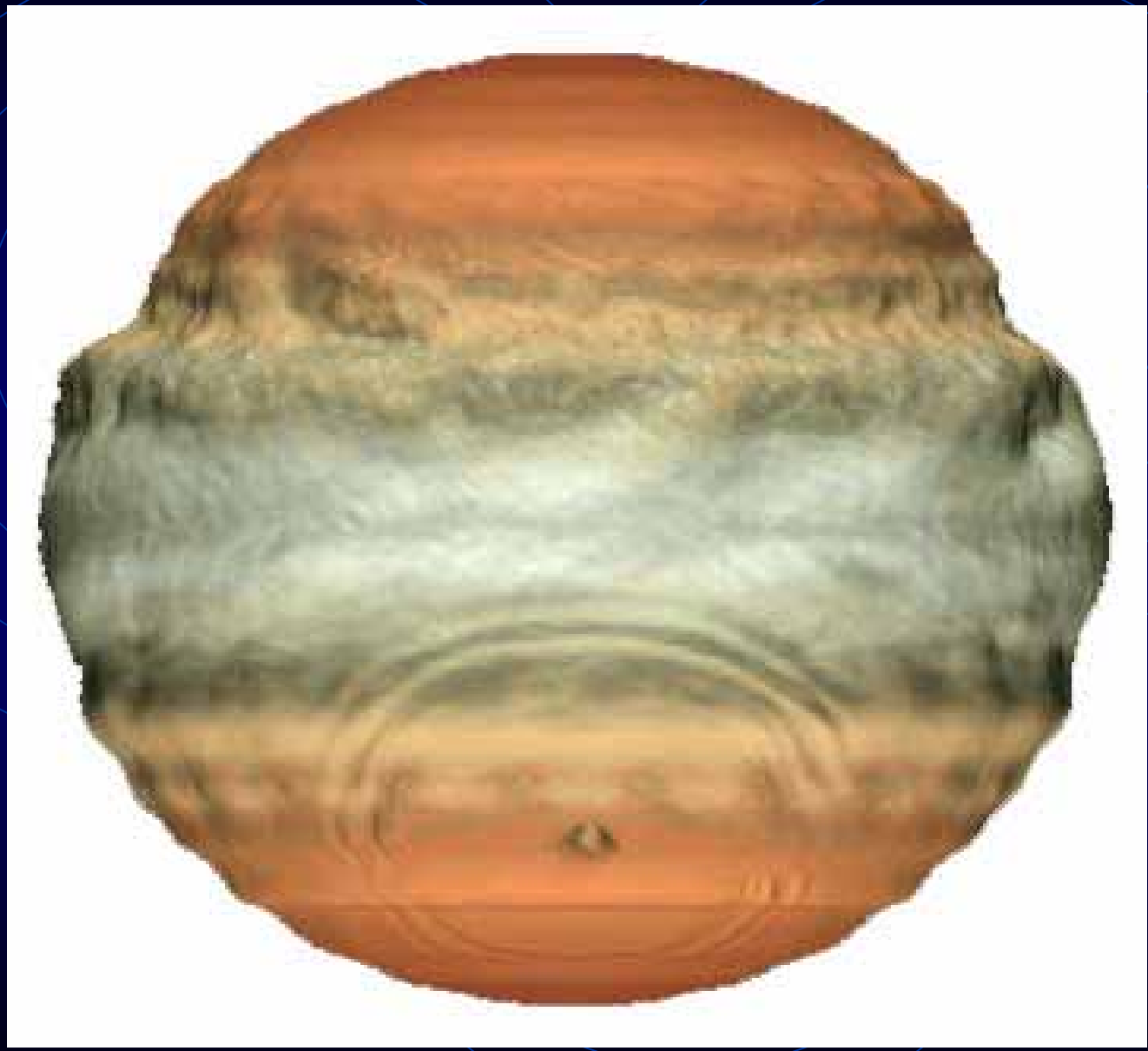
彗星為什麼會分裂呢？

那一年夏天 (1994)
彗星撞木星





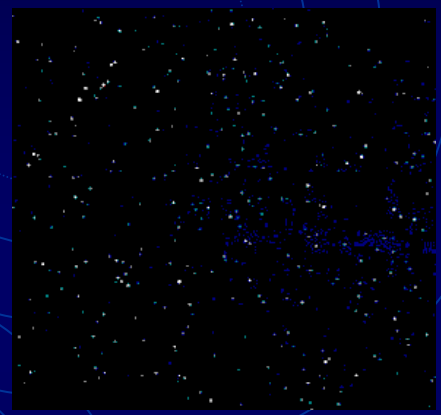
木星的衛星 Callisto 表面的串狀隕石坑




Earth 100 minutes after a G-Sized impact
G impact scar reprojected onto Earth, to scale

如沙粒般的碎渣掉入地球大氣 → 流星

- 地球撞向彗星留在軌道上的殘渣 → 流星雨
- 大一點的如小石，燃燒剩餘部分落到地面 → 隕石
- 再大一點的呢？

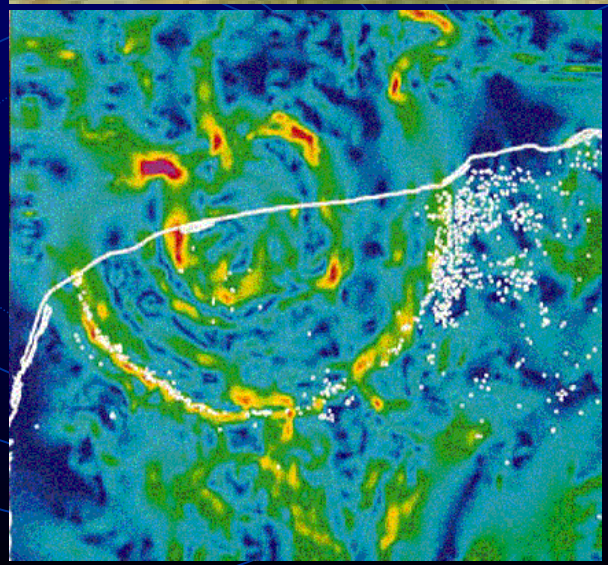


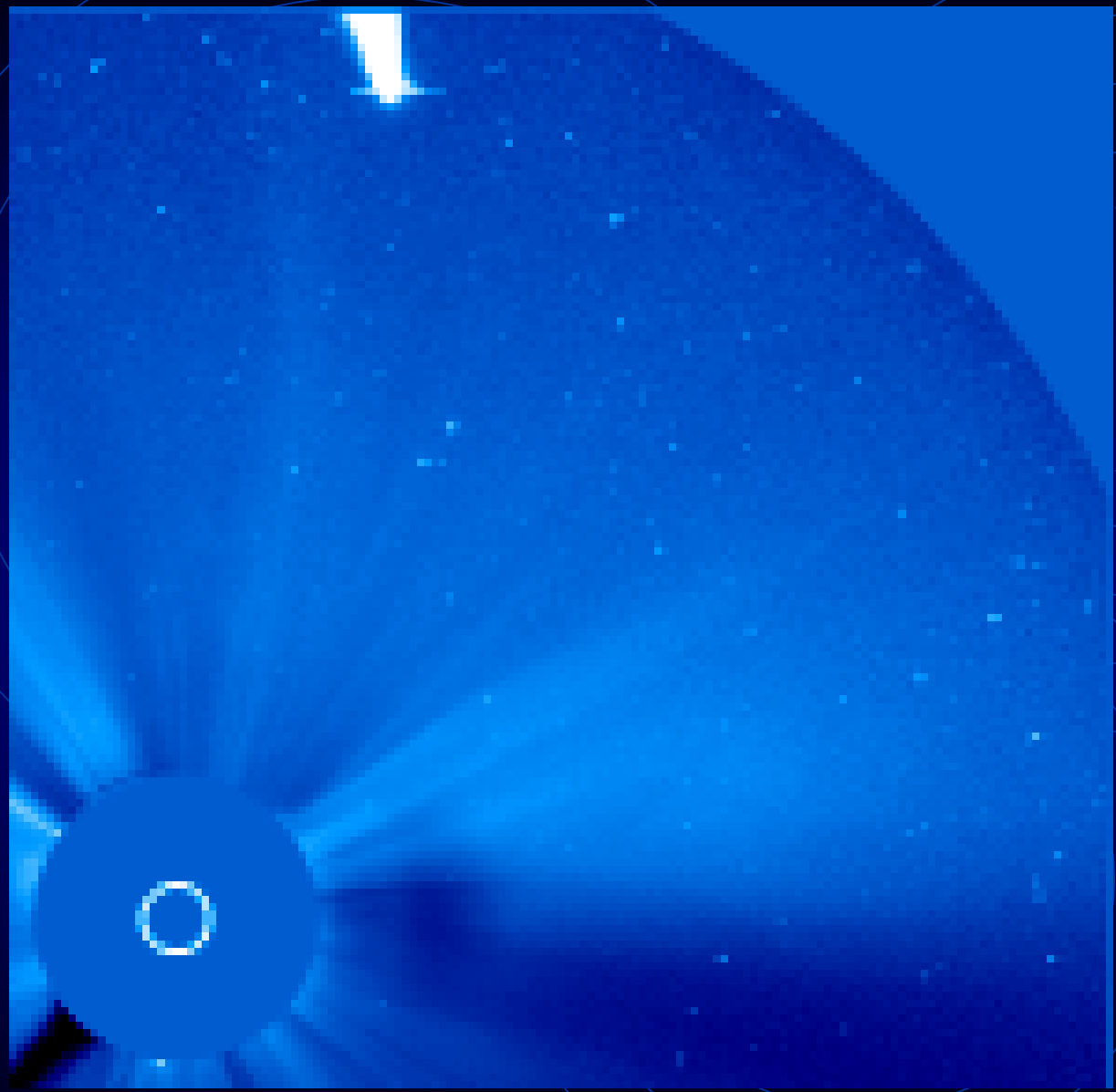
Barringer Meteor Crater, Arizona, USA

1927 年所攝 「通古斯加地方」(Tunguska) 離爆炸點約20公里的森林

恐龍怎麼滅種的？

6500萬年前的撞擊！





彗星撞太陽