月亮「不」代表我的「星」

辜品高
師大地科系
中研院天文所

中秋節快樂

Thanks to the nice weather, I guess everyone saw the Moon on the Mid Autumn Festival. Perhaps you have heard from the News that the full Moon on the holiday was biggest compared with the Moon saw on the previous Mid Autumn Festivals in the last 9 years. This means that the full Moon was closer to us this time. You should not be surprised about this because I told you in class that the orbit of the Moon is not circular. In other words, the separation between the Earth and the Moon varies with time.

花間一壺酒，獨酌無相親。舉杯邀明月，對影成三人。
李白《月下獨酌》

牀前明月光，疑是地上霜。舉頭望明月，低頭思故鄉。
李白 《夜思》

戍鼓斷人行，秋邊一雁聲。露從今夜白，月是故鄉明。
杜甫 《月夜憶舍弟》

空山新雨後，天氣晚來秋。明月松間照，清泉石上流。
王維 《山居秋暝》

人有悲歡離合，月有陰晴圓缺，此事古難全。但願人長久，千里共嬋娟。
蘇軾 《水調歌頭》

都是月亮惹的禍，誰叫她靠地球這麼近，讓人類的心智為之瘋狂。
Shakespeare

月亮代表我的心 唱：鄧麗君 詞：孫儀 曲：湯尼

我相信月亮可以影響一個人的行為。 Carl Segan

Lunatic 瘋人

阿姆斯壯說錯了一個字 ？

http://times.hinet.net/news/20061001/internationality/9924c5e10647.htm

http://www.chron.com/disp/story.mpl/front/4225505.html

1969 7/20

"That's one small step for (a) man, one giant leap for mankind."

Figure 6-11
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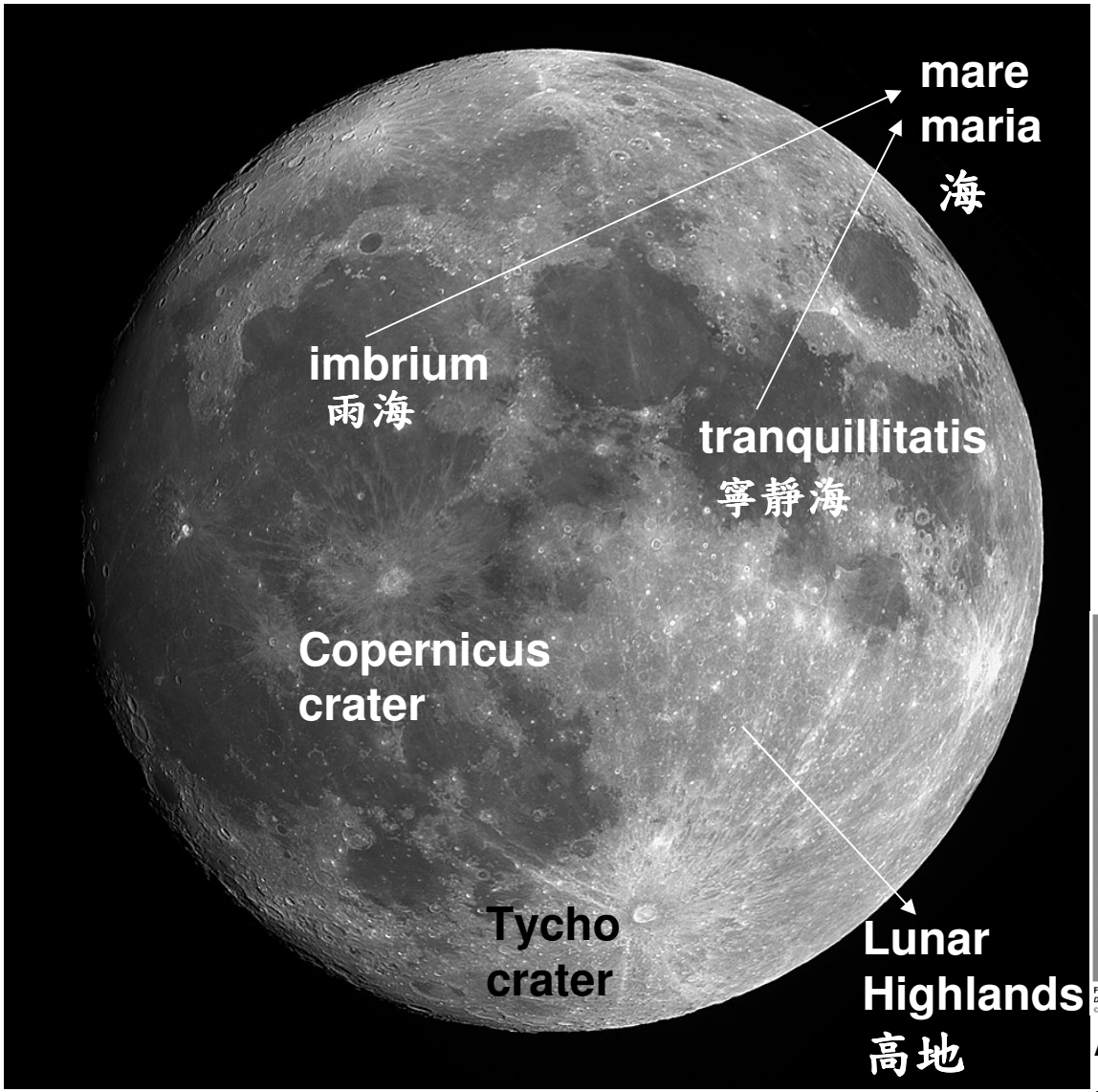
note

The albedo of the Moon is much smaller than that of the Earth (and other planets as you will learn later in this semester). It is because the Moon has little atmosphere.

Whether the atmospheric gas can be retained on a planet/satellite depends on two competing factors: one is the surface gravity described by the so-called escaped velocity, and the other is surface temperature. In the case of the Moon, the escape velocity is low due to its low surface gravity. A long time ago the atmospheric gas was heated by the Sun and moved faster its escape velocity. As a result, there is little atmosphere on the Moon.

Earth Side



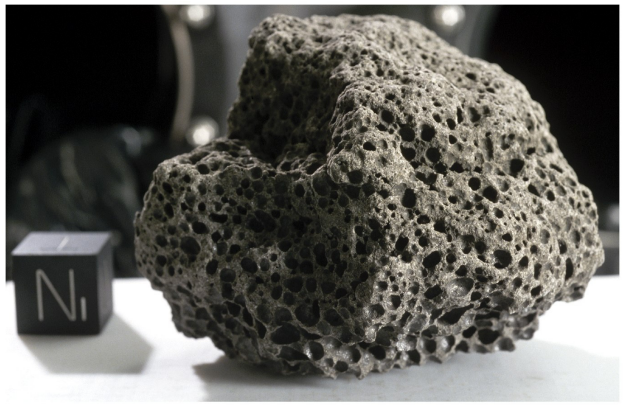


Figure 6-19
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Mare Basalt (玄武岩)
含鐵(iron)鎂(manganese)
It is lava, so it's heavy.

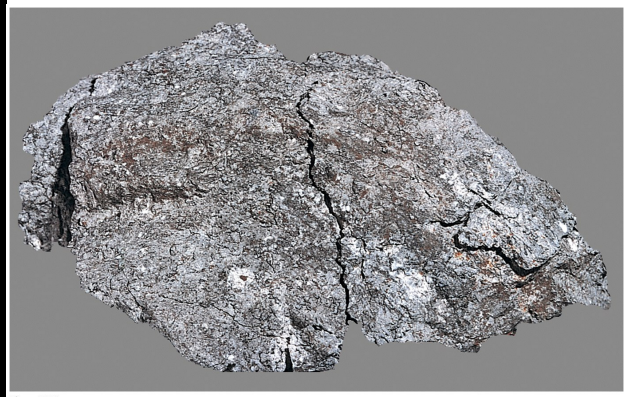

Figure 6-20
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Anorthosite(斜長石)
含鈣(calcium)鋁(aluminum)
It is light.

Mare Imbrium & the Surrounding Highlands

A mare is the low land caused by an asteroid/comet impact at a later time. During the impact, the underground lava emerged to the surface and cooled to form dark basalt rocks.

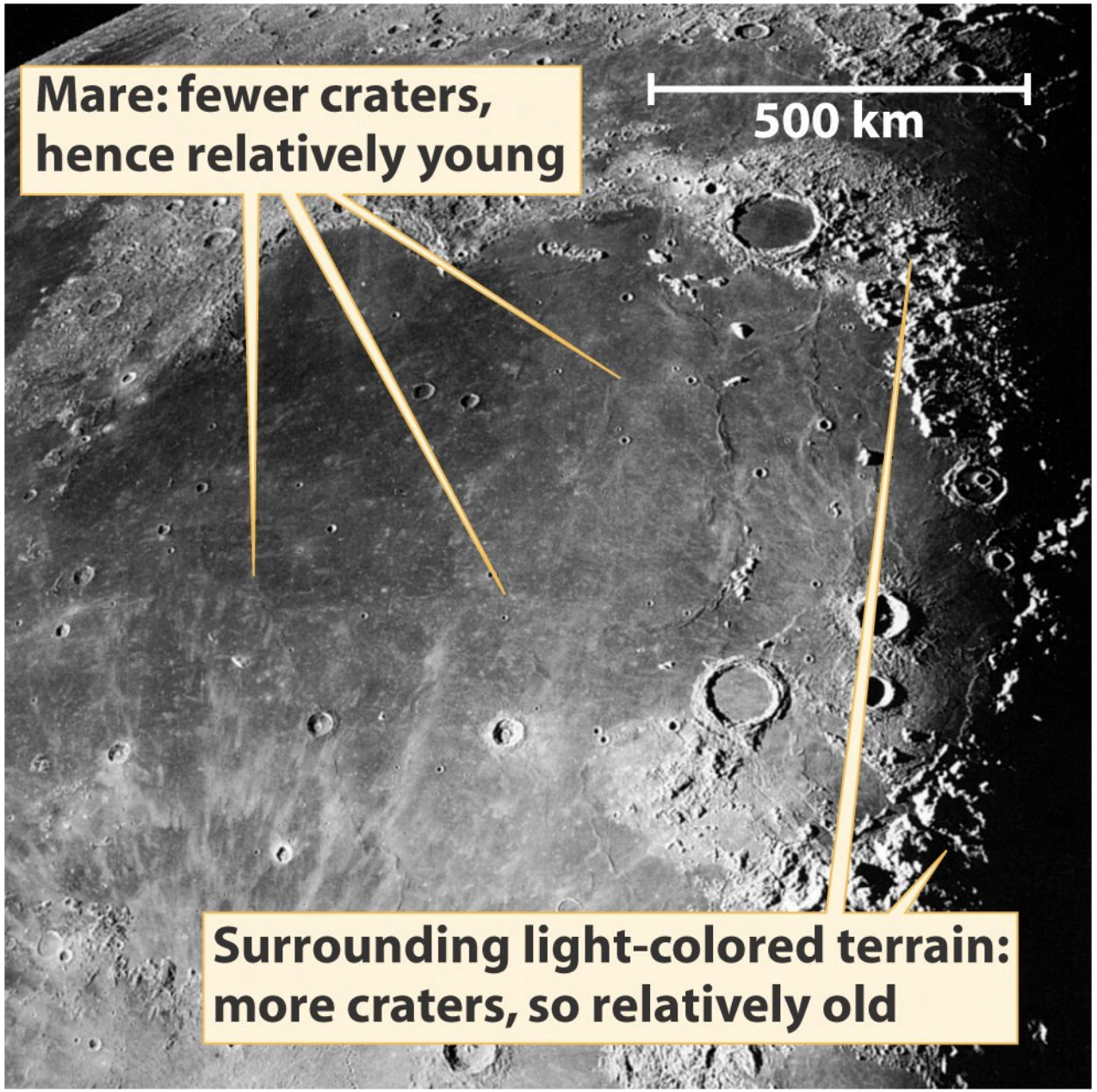

Figure 6-14
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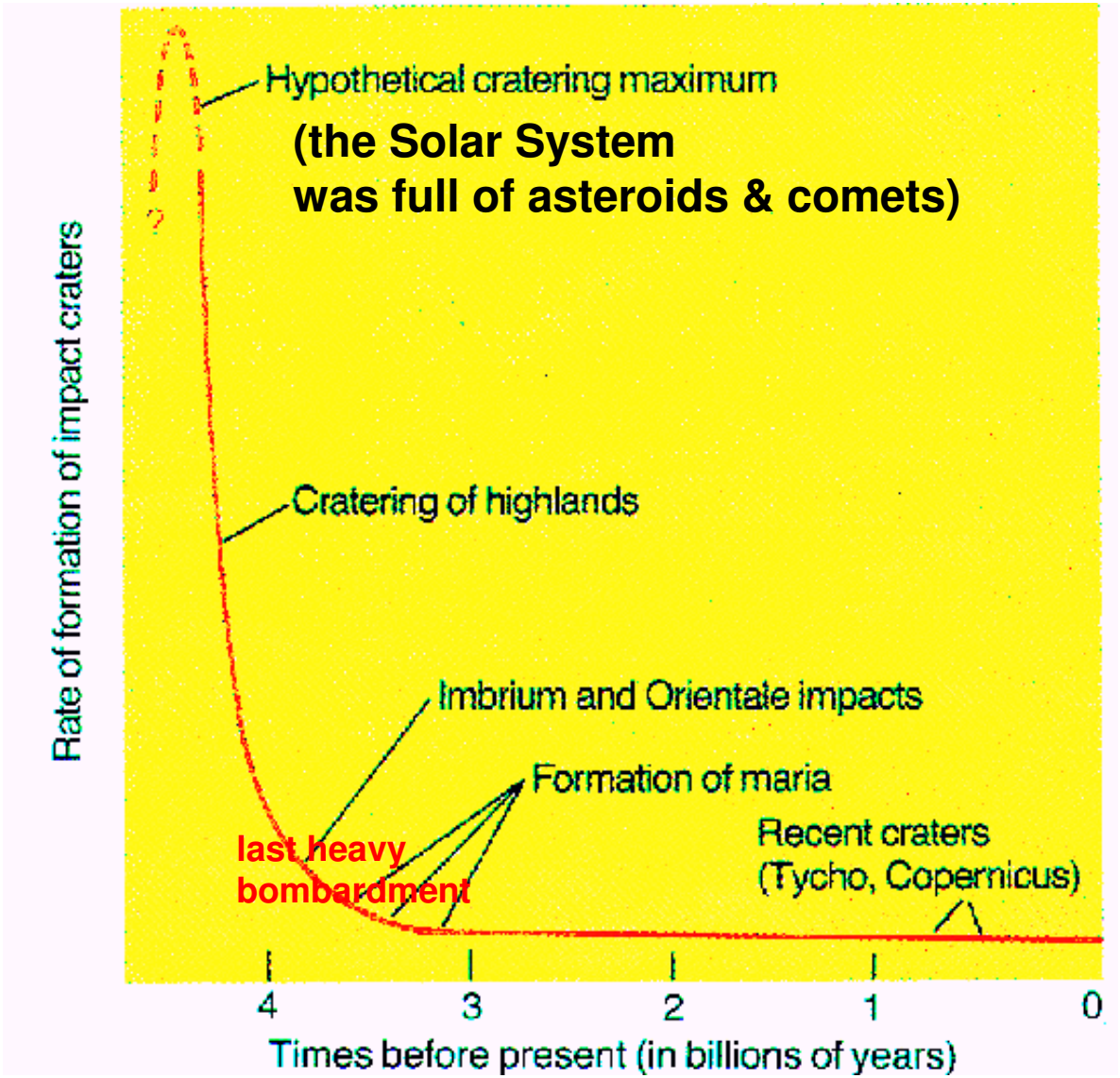
Rate of Crater Formation



The Moon now has little geological activity and weak magnet fields; ie lack of Internal heating.

Earth is alive, But Moon is almost dead!

Smaller objects cools faster because smaller volume to surface ratio.

last heavy bombardment?

note

The Moon has been losing internal heat more quickly than the Earth because its smaller size allows any internal heat to escape very quickly. This explains why the Moon has not been showing much of geological activities and preserves the surface features which are almost 4.6 billion years old.

There should be a small increase in the crater formation rate around 3.5-4 billion years ago on the plot of the previous slide (denoted by the phrase “last heavy bombardment” on the plot). Astronomers so far do not exactly know what caused the last heavy bombardment in the early history of the Solar System.

radioactive elements 放射性元素

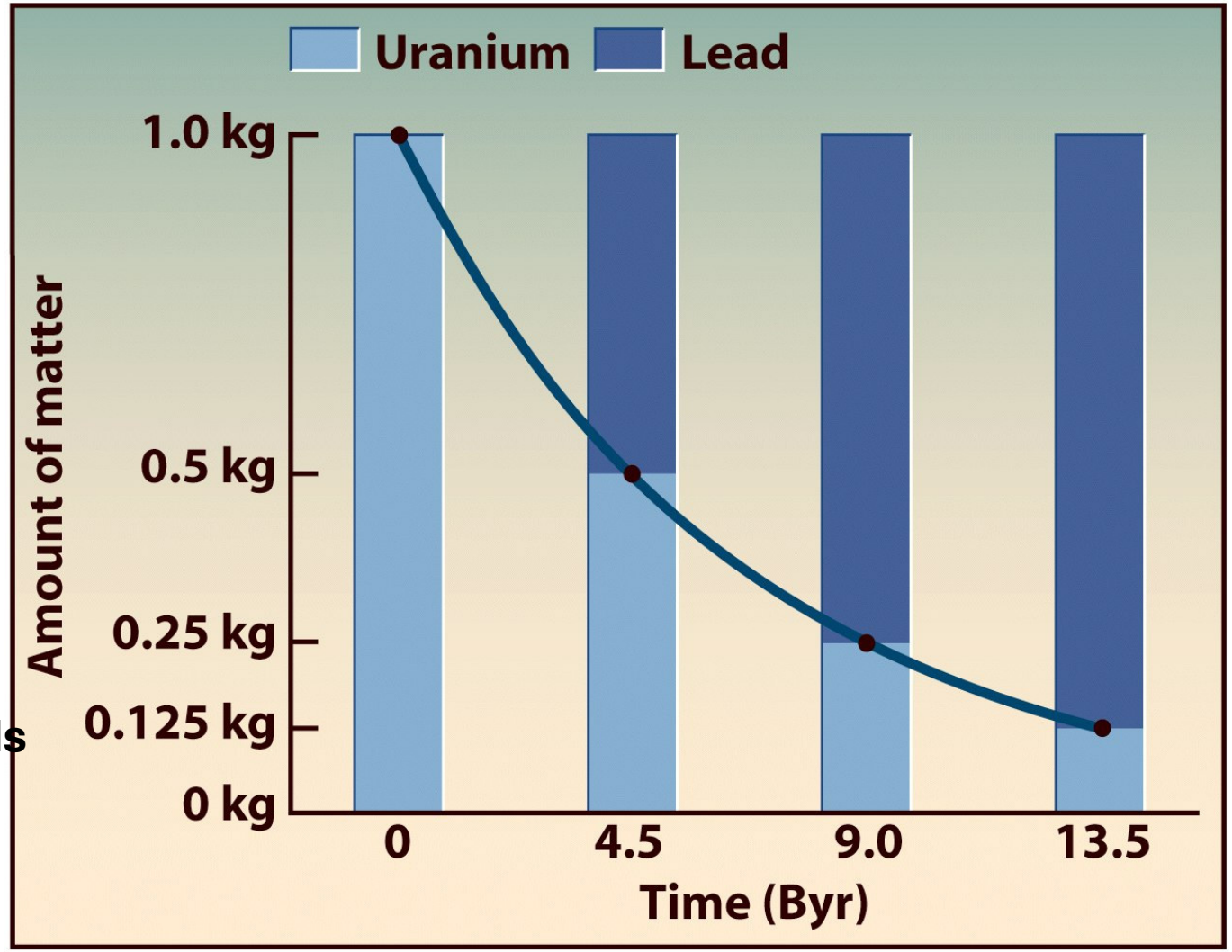
- some isotopes (同位素) of some elements are not stable and will transform to a stable daughter element by emitting fast-moving particles such as an alpha particle (nucleus of He) or an electron.
- This is a nuclear process and is described by statistics in terms of half-life $t_{1/2}$ 半衰期.
- fast-moving particles from radioactive elements provide heating. One of the main factors gives rise to differentiation of the interior of an asteroid, a satellite, and a planet. In an old planet like Earth, long-lived radioactive elements such as uranium 鈾238 ($t_{1/2}$=4.5Gyrs), thorium 釷232 ($t_{1/2}$=14Gyrs), and potassium 鉀40 ($t_{1/2}$=1.2Gyrs), are mostly responsible for the internal heating.
- can be used for dating a rock, but if the rock is re-melted, its radioactive clock is reset.

Radioactive dating: Clock within Atoms

利用放射性元素

Half life (半衰期)

Note that the oldest rock on earth is about 4.4 billion years old, which is younger than the rocks found in highlands of the Moon (4.6 billion years).



Unnumbered Figure pg 107
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Earth side & far side

月球被地球重力鎖住
→自轉週期
=公轉週期

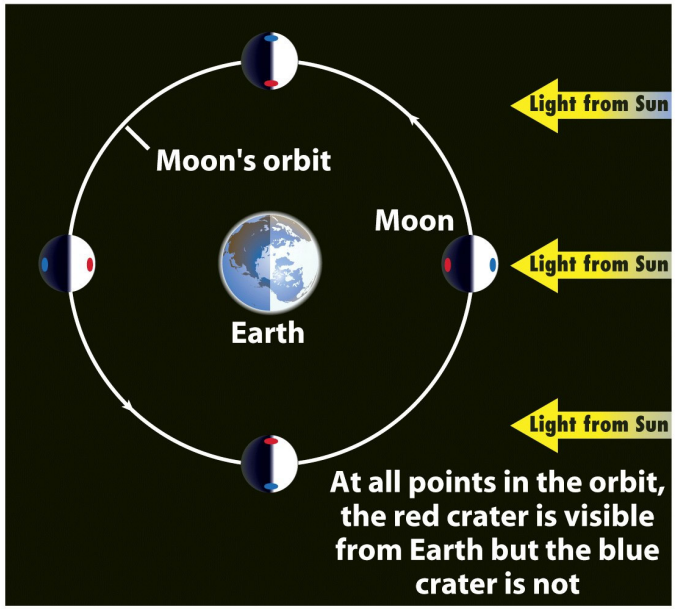

Figure 6-25
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2006/10/4

Figure 6-11 part 2
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Phases of the Moon (月的相)

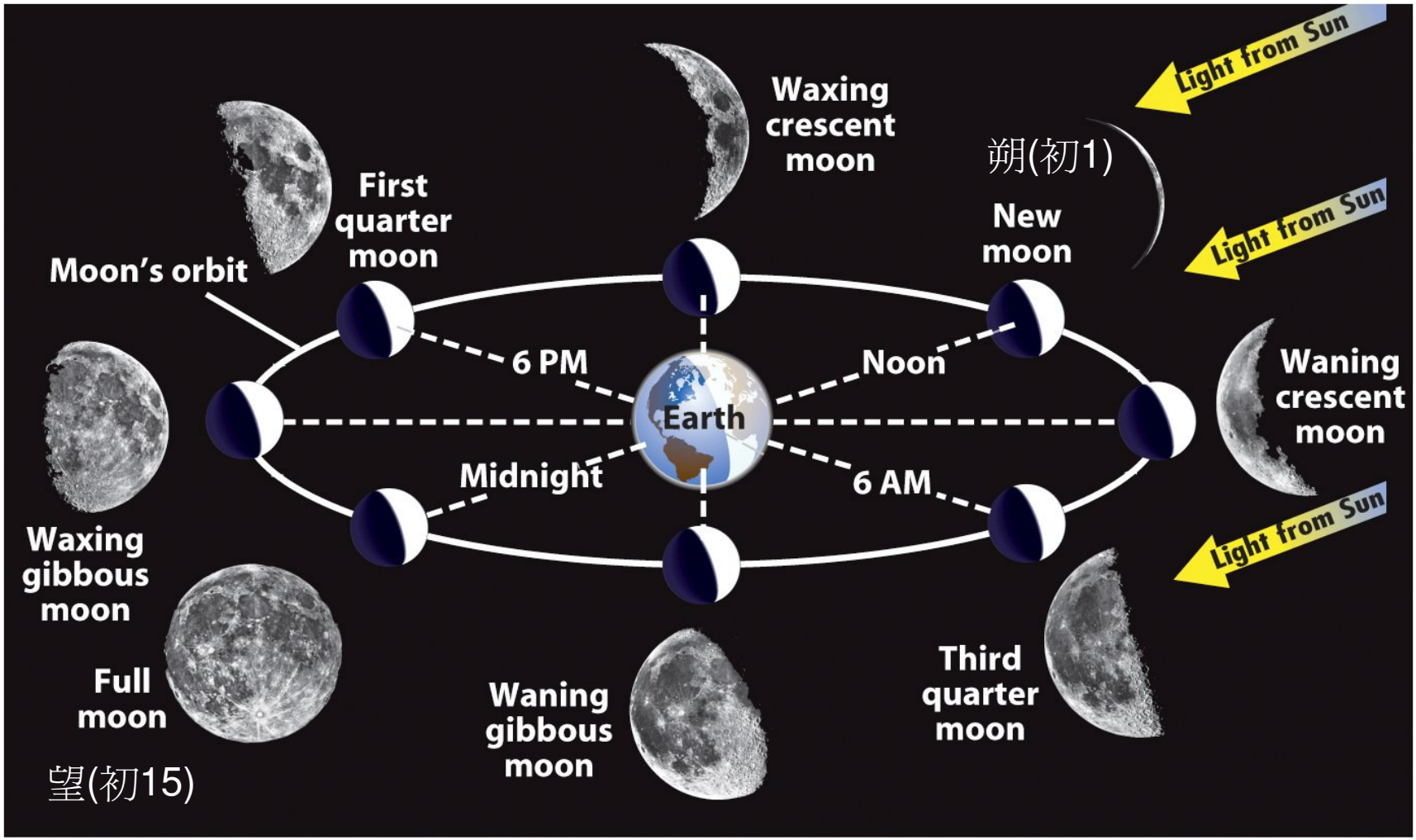

Figure 1-23
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Sidereal(27.3days) & Synodic Month(29.5days)

恒星的 會合的

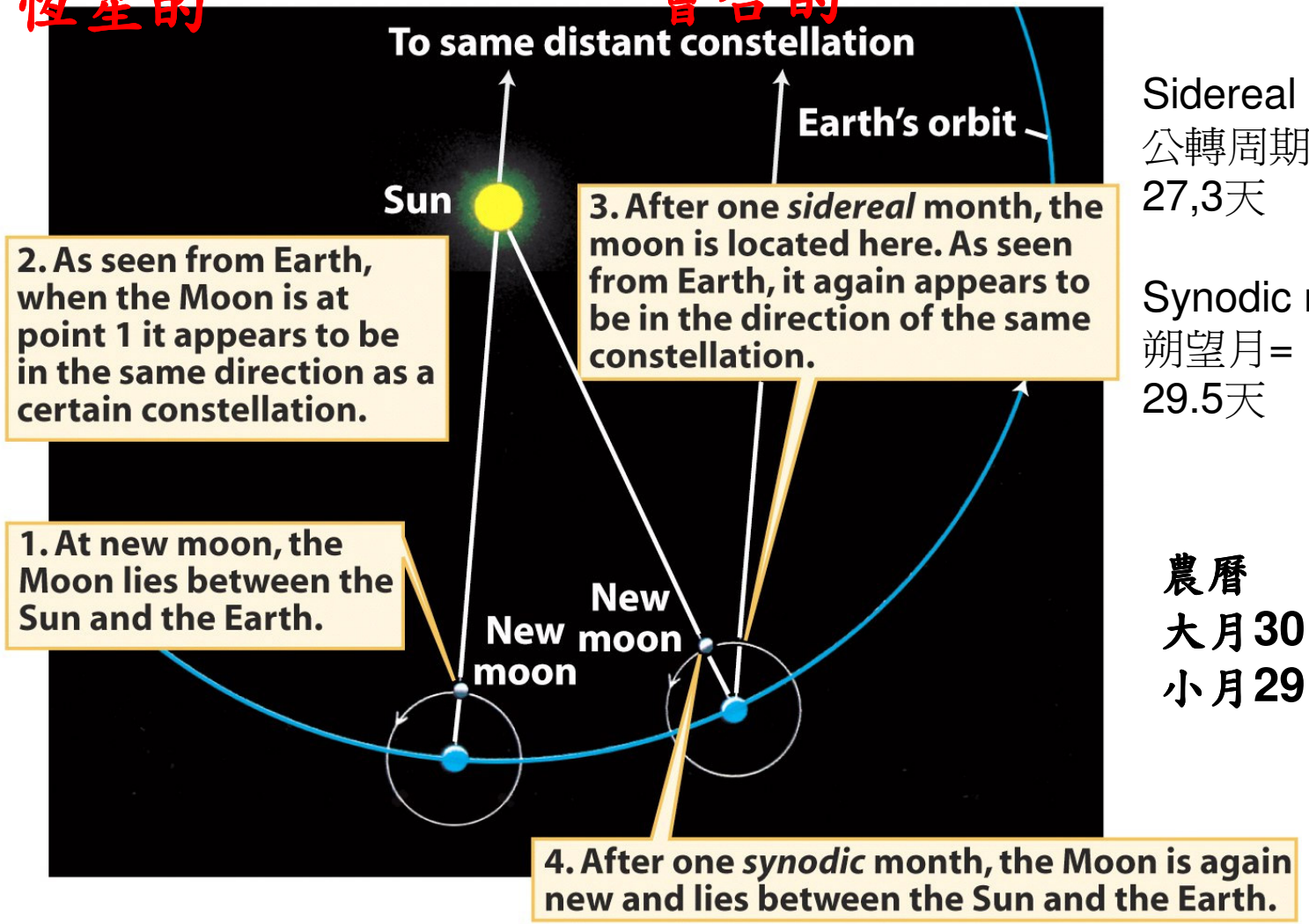

Figure 1-25
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Sidereal month:
公轉周期=
27,3天

Synodic month:
朔望月=
29.5天

農曆
大月30天
小月29天

Conditions for Eclipses

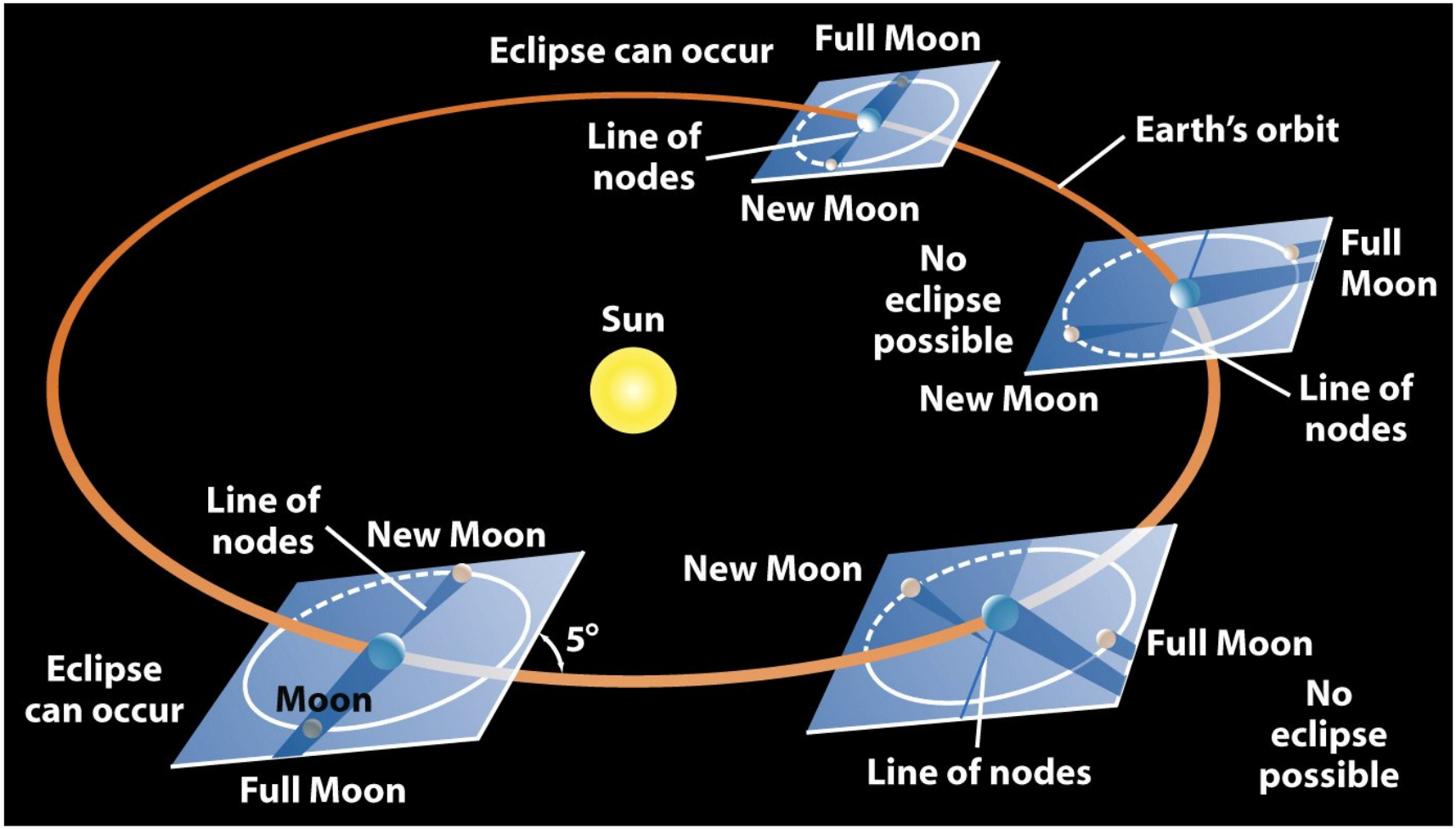

Figure 1-26
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Lunar Eclipse 月蝕

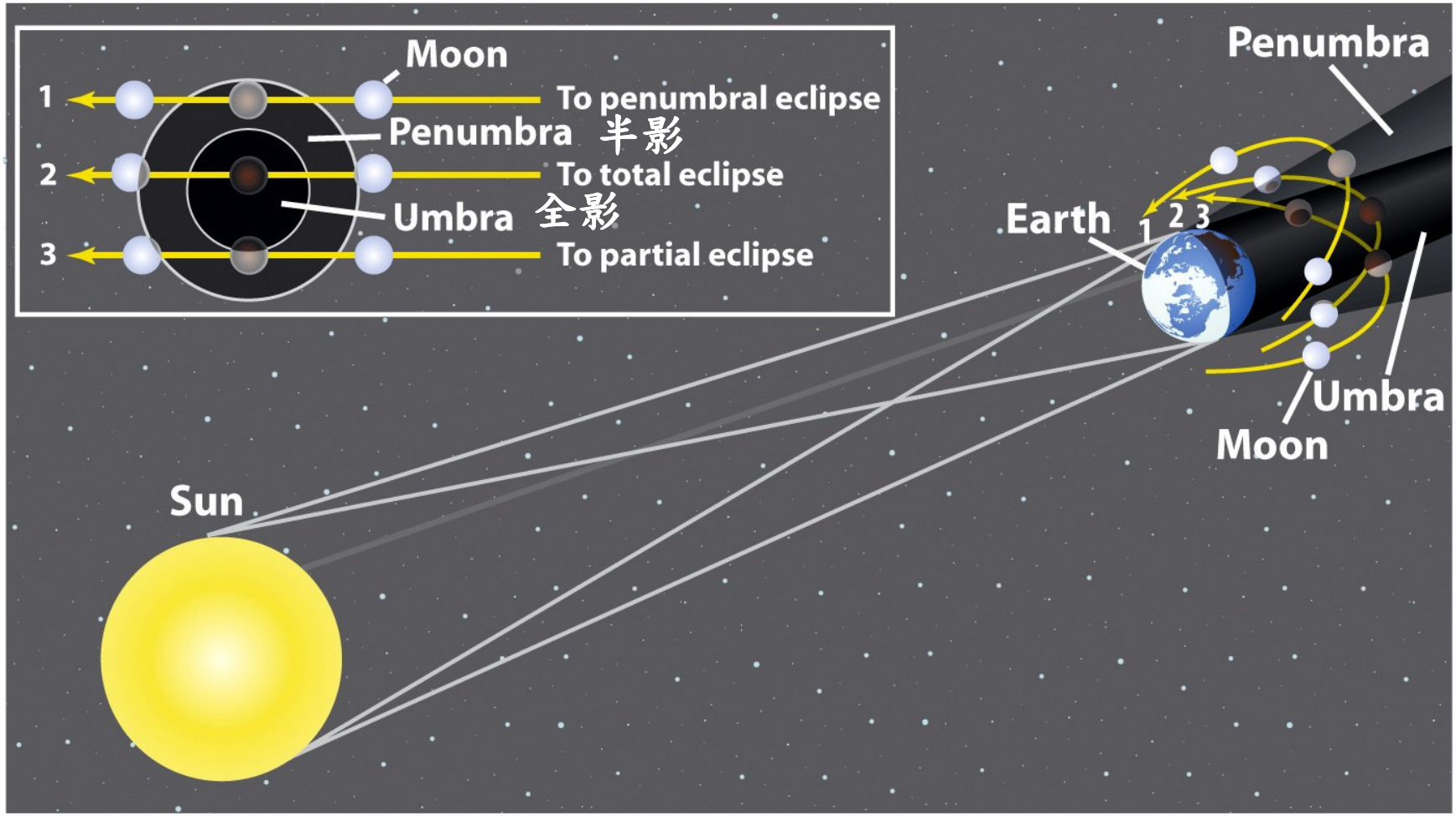

Figure 1-27
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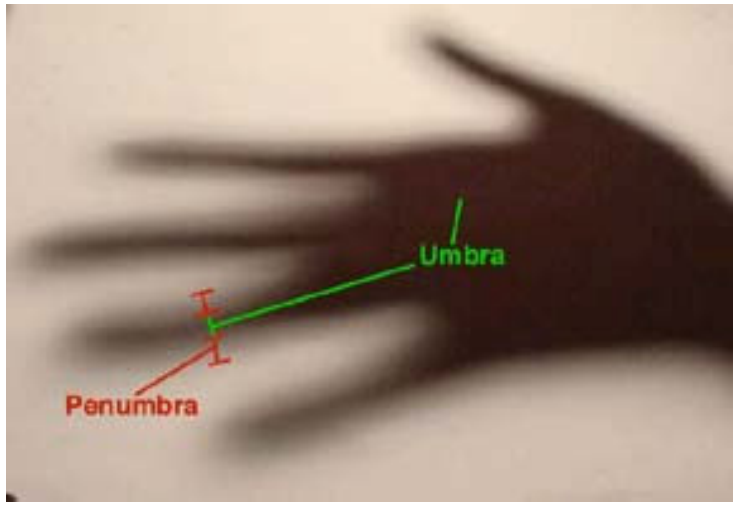
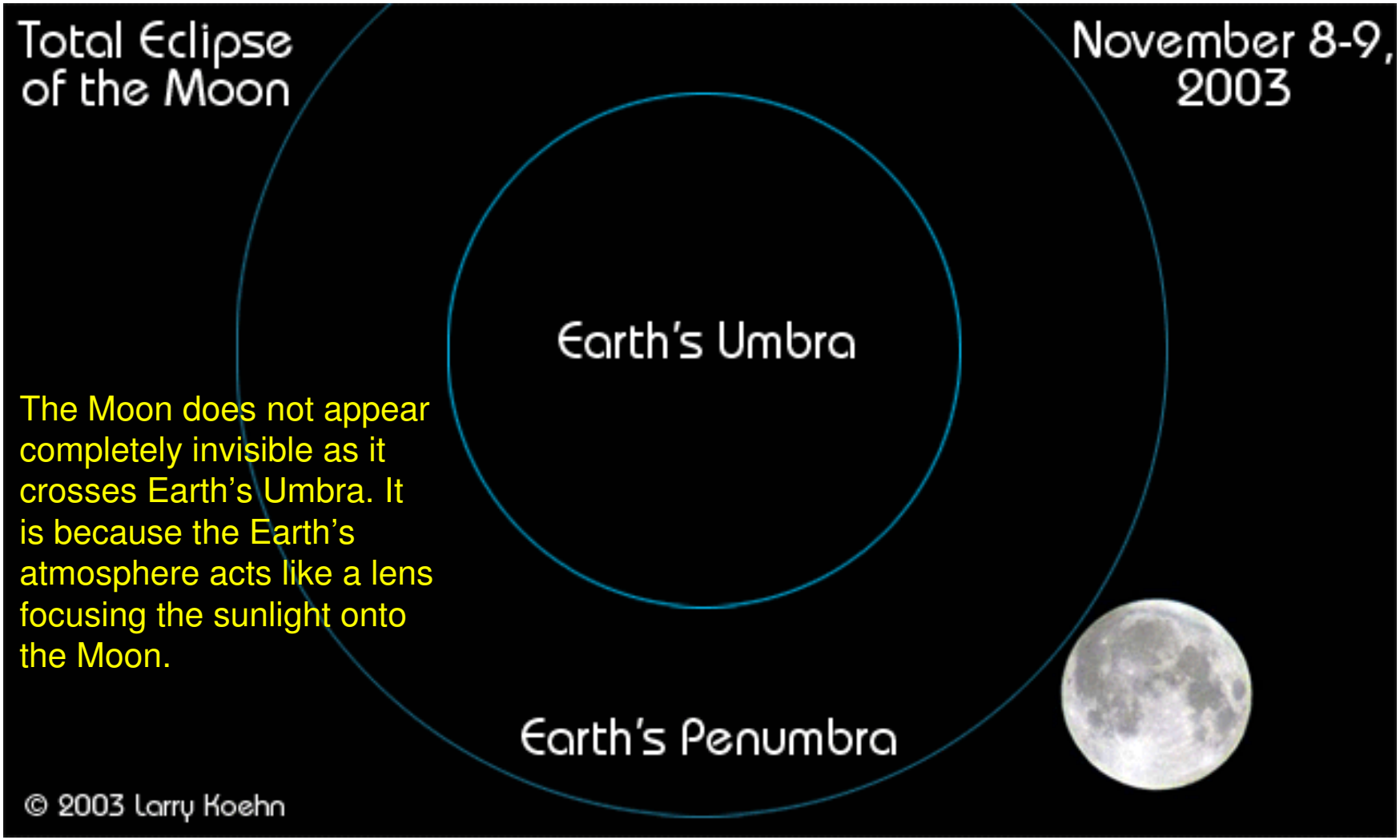
Umbra 全影& Penumbra半影



http://www.learner.org/channel/workshops/sheddinglight/highlights/highlights1.html

Lunar eclipse

http://antwrp.gsfc.nasa.gov/apod/ap031107.html



The Moon does not appear completely invisible as it crosses Earth's Umbra. It is because the Earth's atmosphere acts like a lens focusing the sunlight onto the Moon.

Solar Eclipse 日蝕

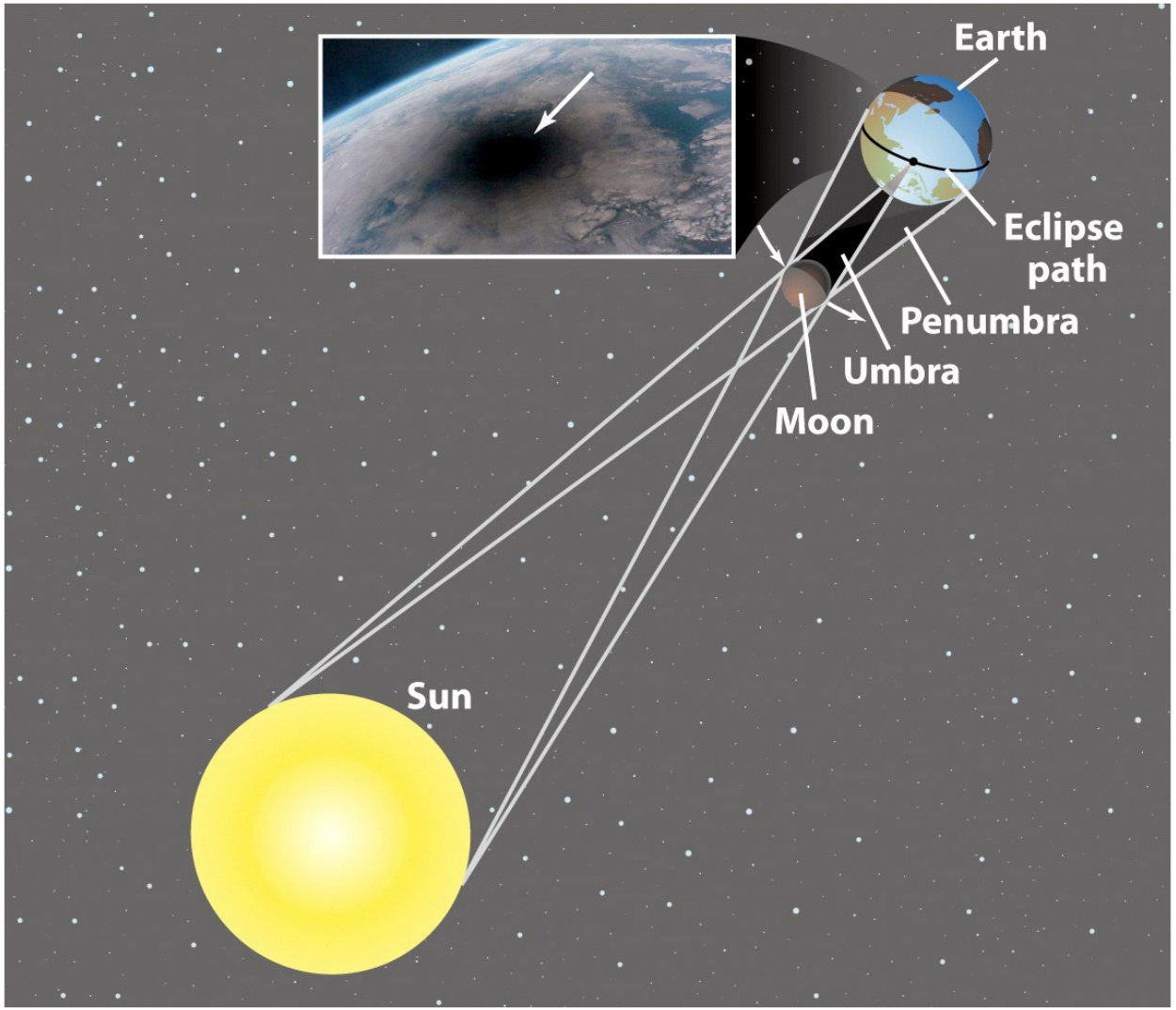


Figure 1-30
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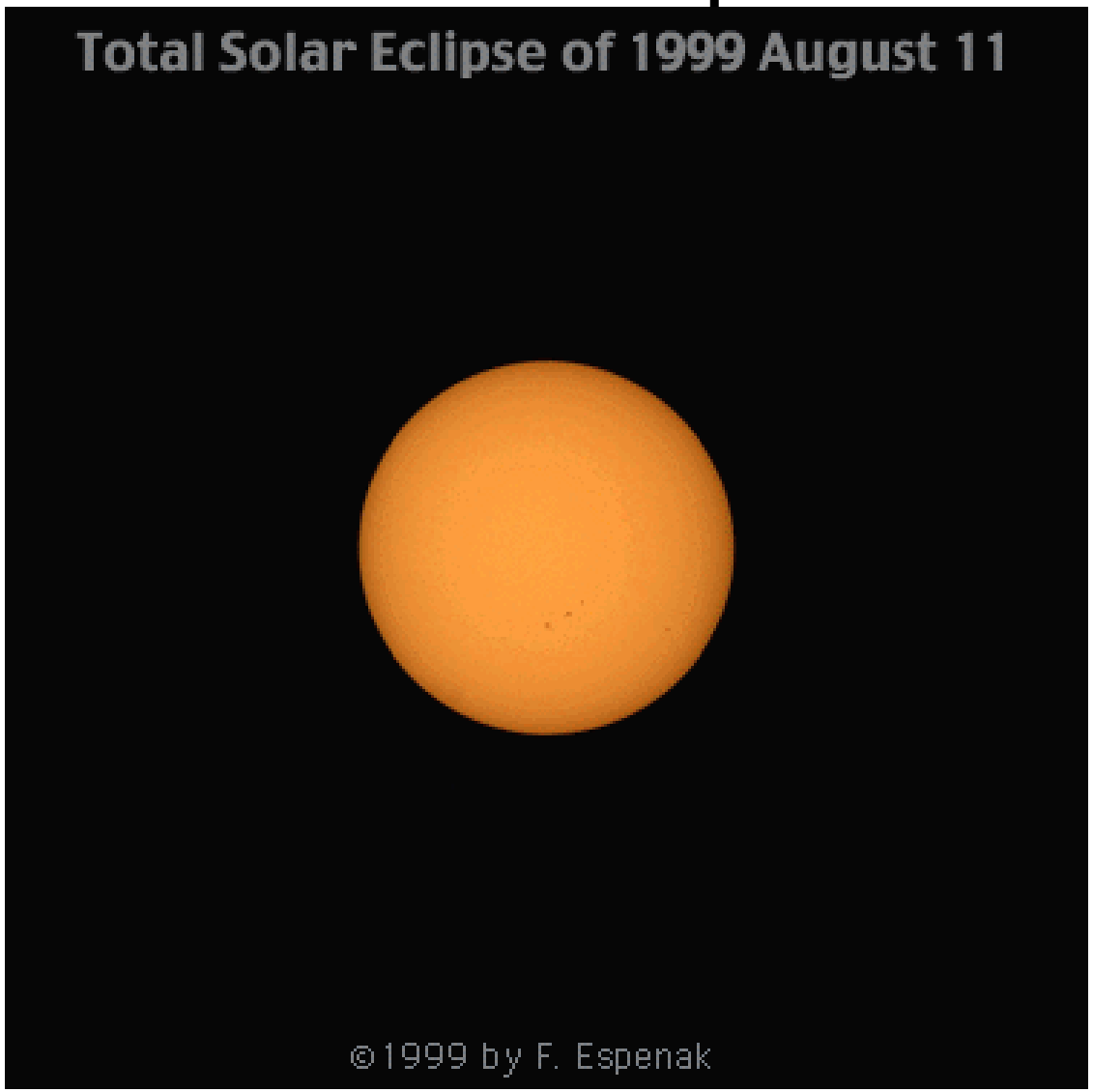
Solar eclipse

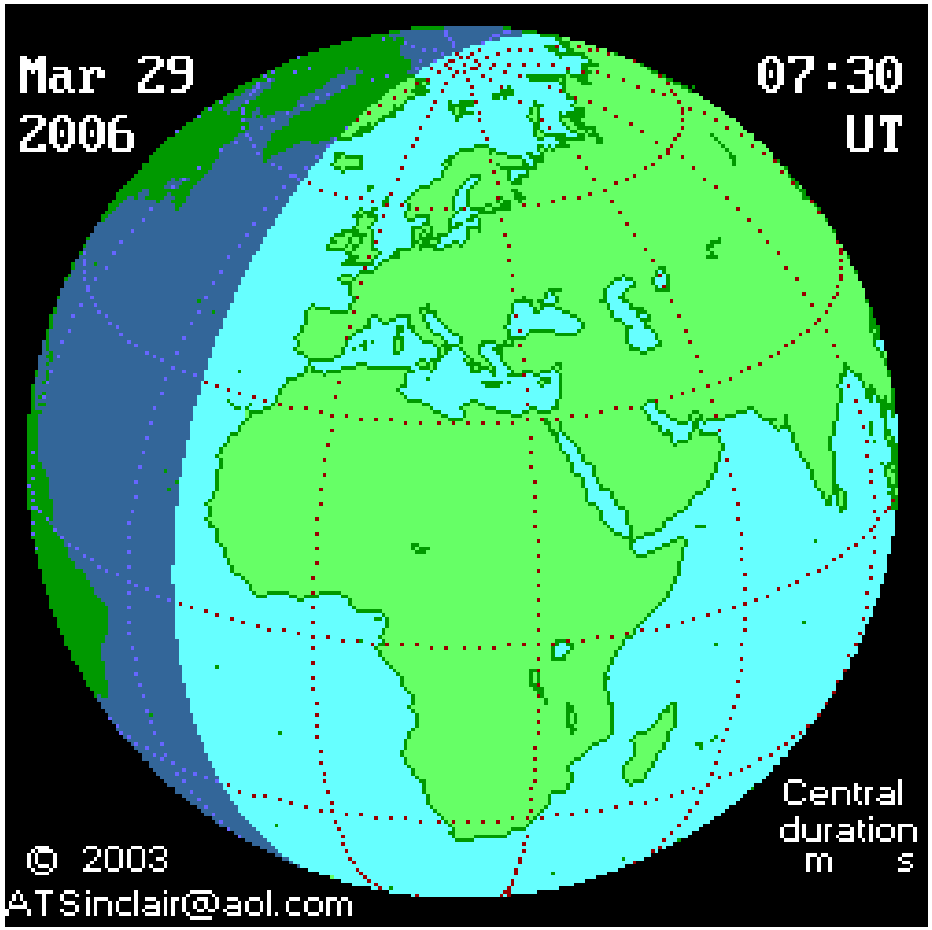


Pay attention to solar corona (日冕) when the sun is totally blocked by the Moon.

Solar corona is the outermost part of Sun's atmosphere

Solar eclipse

http://www.flycapers.com/tours/voyages/2006/2006Eclipse/eclipse.html



Crater 隕石洞 formation

投石入水

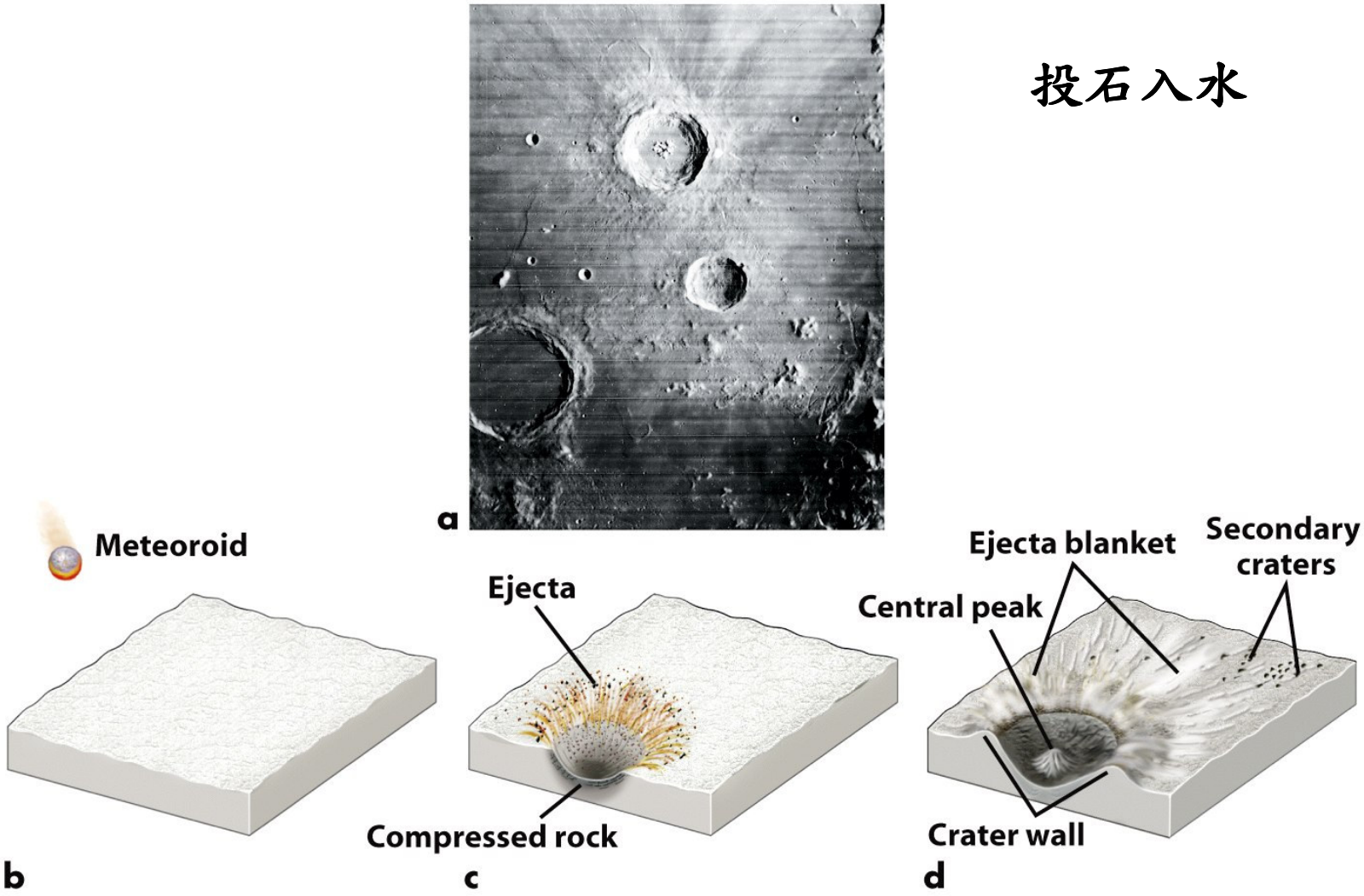


Figure 6-12
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Some Craters on Earth

- **Arizona: 五萬年前, 200m**
- **Gulf of Mexico: 6500萬年前, 10km**
- **Siberia: 1908 A.D., no crater?? (exploding before hitting the ground), 70m**
- **台東縣嘉明湖? 1-2萬年前, 10-20m**
- **澎湖群島? 2000萬年前, 500m**


Arizona


Siberia

台東縣嘉明湖?(未證實)

海拔3310公尺的嘉明湖，位於台東縣海端鄉，長約120公尺，寬約80公尺，湖底有一個凹洞，因其湖面形狀為規則橢圓，湖邊佈滿大大小小有稜有角的碎石，與一般不規則形狀及湖邊有風化土發育的高山湖泊不相同，經中央地質調查所採樣調查發現，某些碎片表面有高溫熔化痕跡，石頭內之石英顆粒有極端碎裂現象，及氧化鐵、銅、氧化鎳等金屬含量與附近當地岩石不同，且附近地區無火山活動或冰川/冰雪移動侵蝕的痕跡，故推測嘉明湖之形成以損石撞擊的可能性最大。

http://itrifamily.itri.org.tw/trip/92/trip921115-1.html

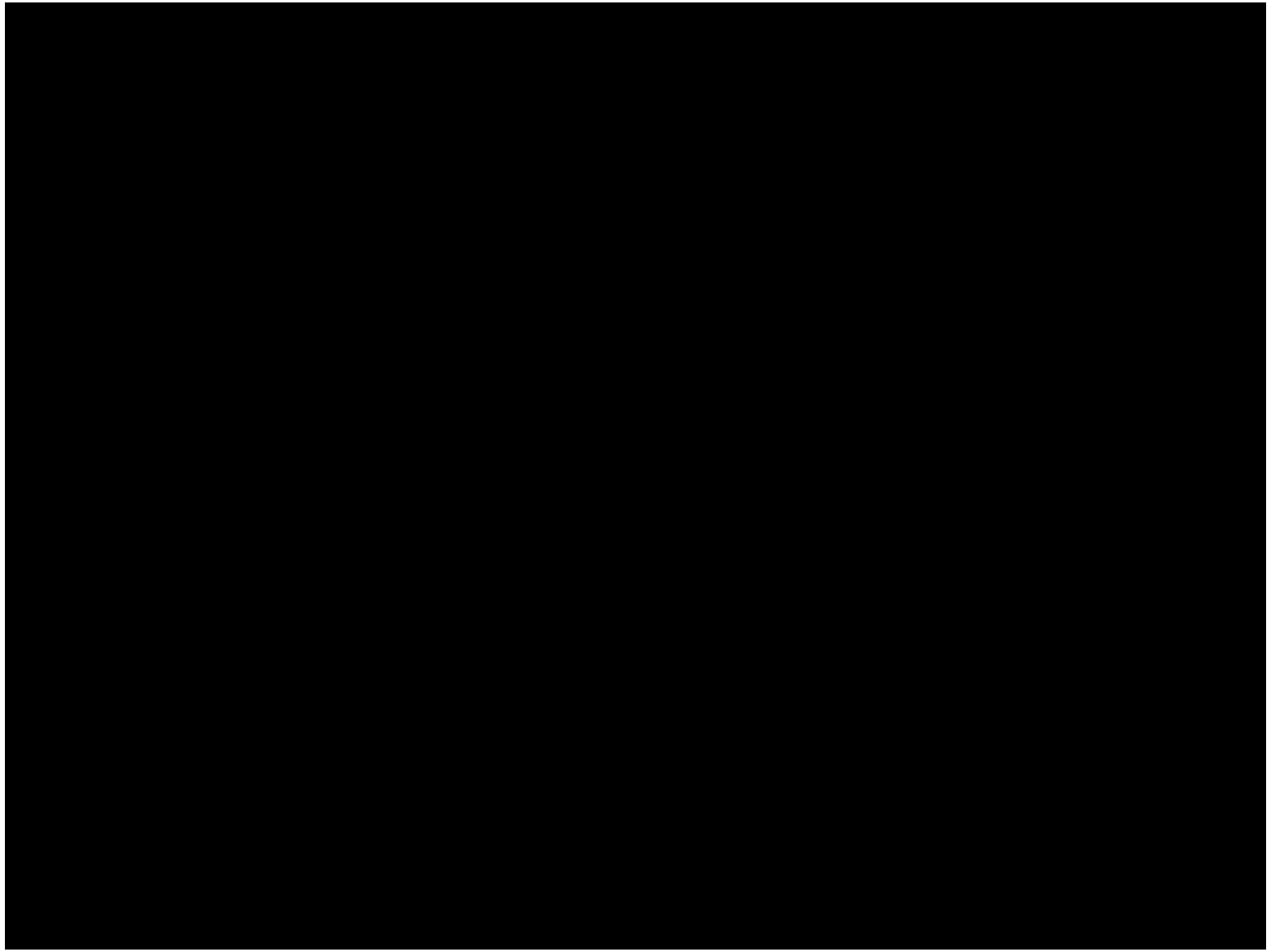
Origin of the Moon

月亮「不」代表我的「星」：月球和地球有些不同

- **Its density is smaller than the Earth**
- **lack of volatiles 揮發性物質 (element or compounds with low melting/boiling temperatures & water)**
- **same oxygen isotope ratios**
- **too big to be captured**

→ collision+ejection model

Moon Formation



Tidal force (潮汐力)

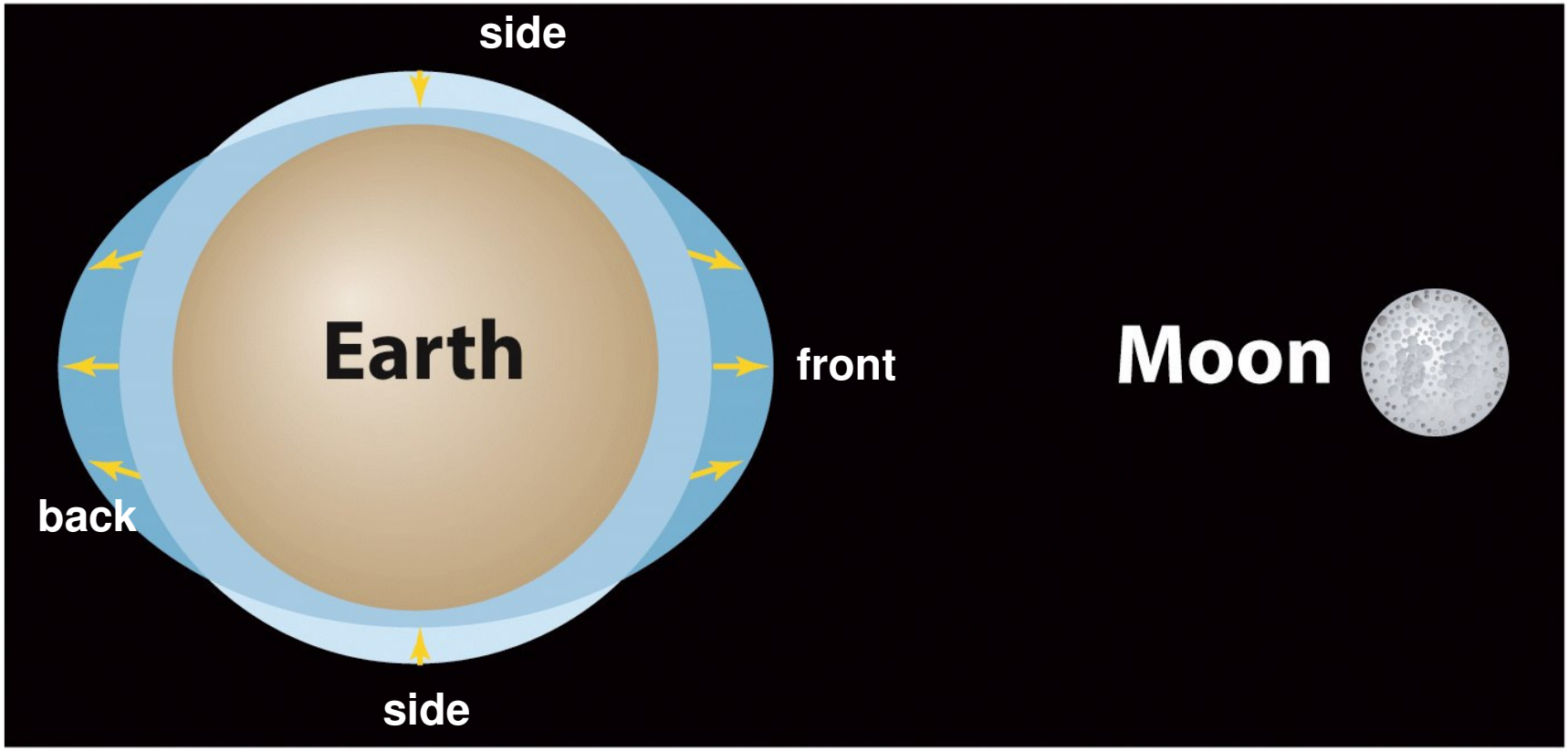


Figure 6-26b
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潮汐力是重力不同所造成的拉扯力(前後)和壓縮力(兩側)
地球自轉 → 一天有兩次高潮兩次低潮

Ellipse

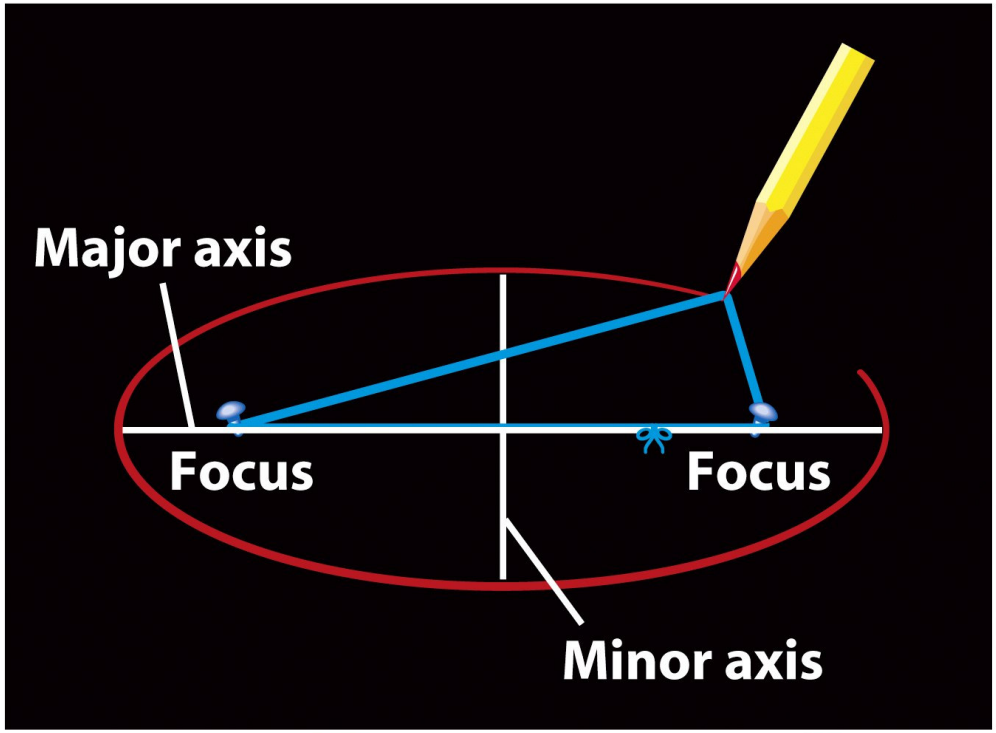

Figure 2-8a
Discovering the U
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e 是 eccentricity 離(偏)心率

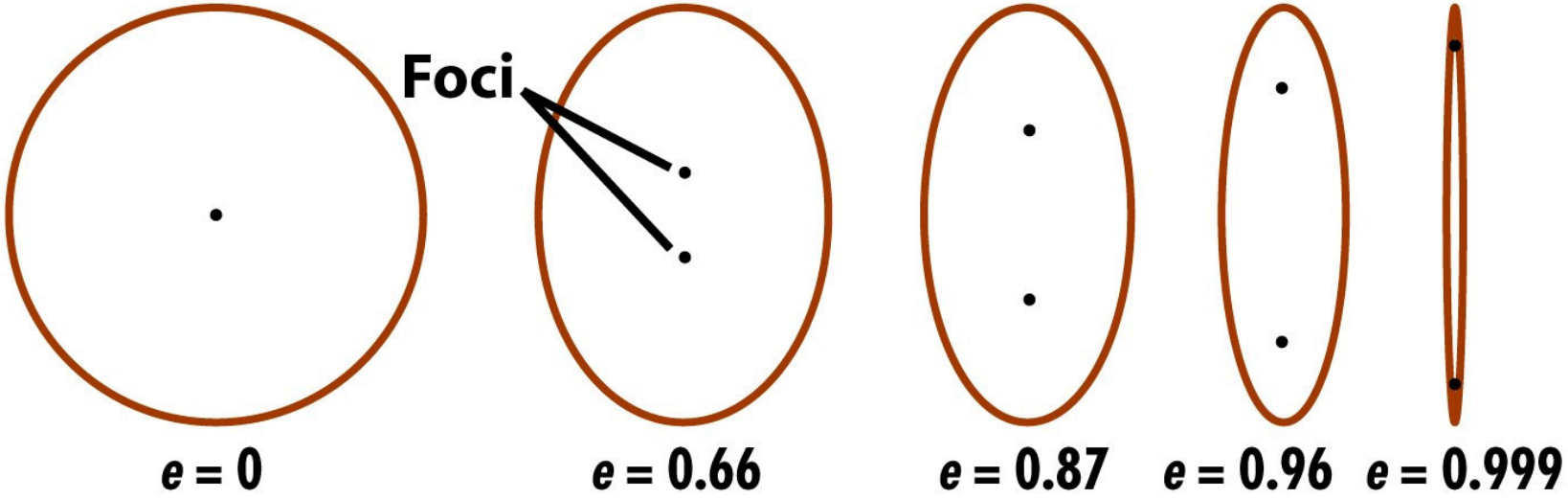

Figure 2-8b
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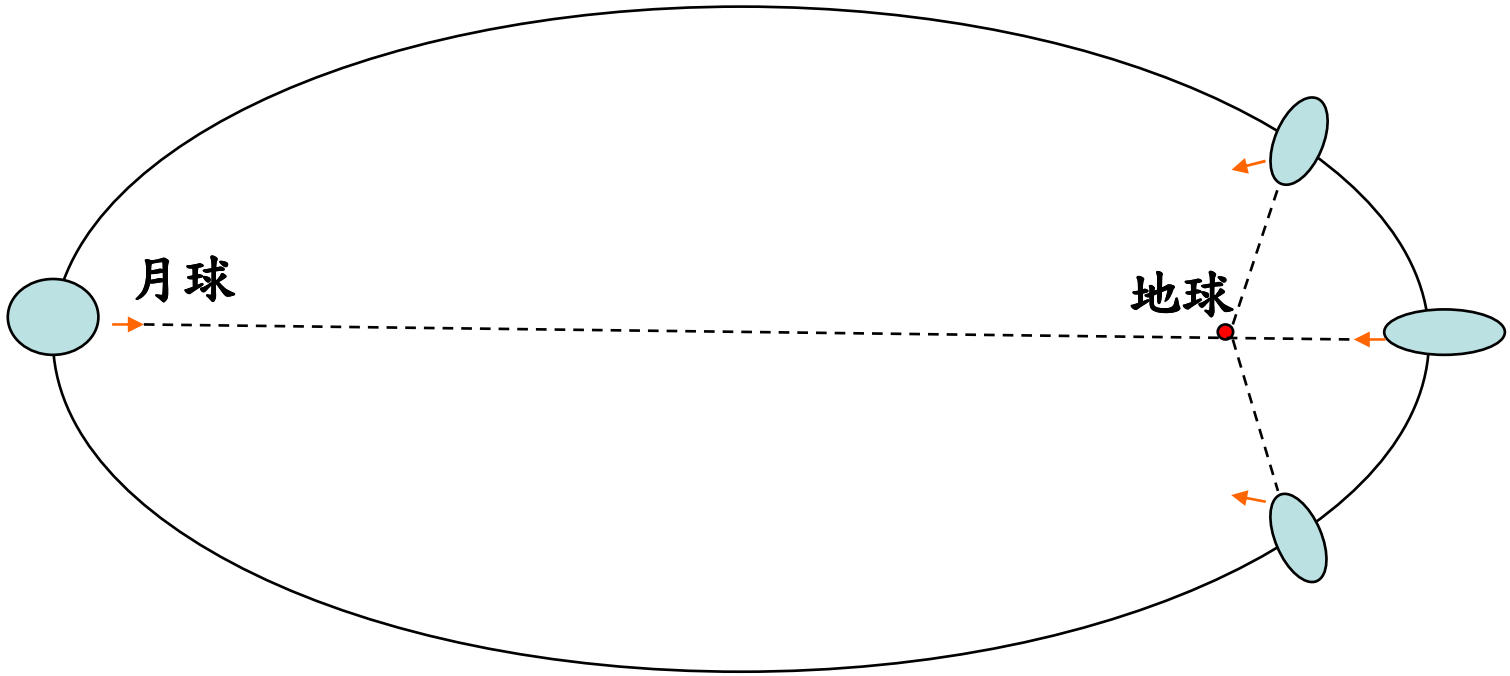
Moonquake 月震

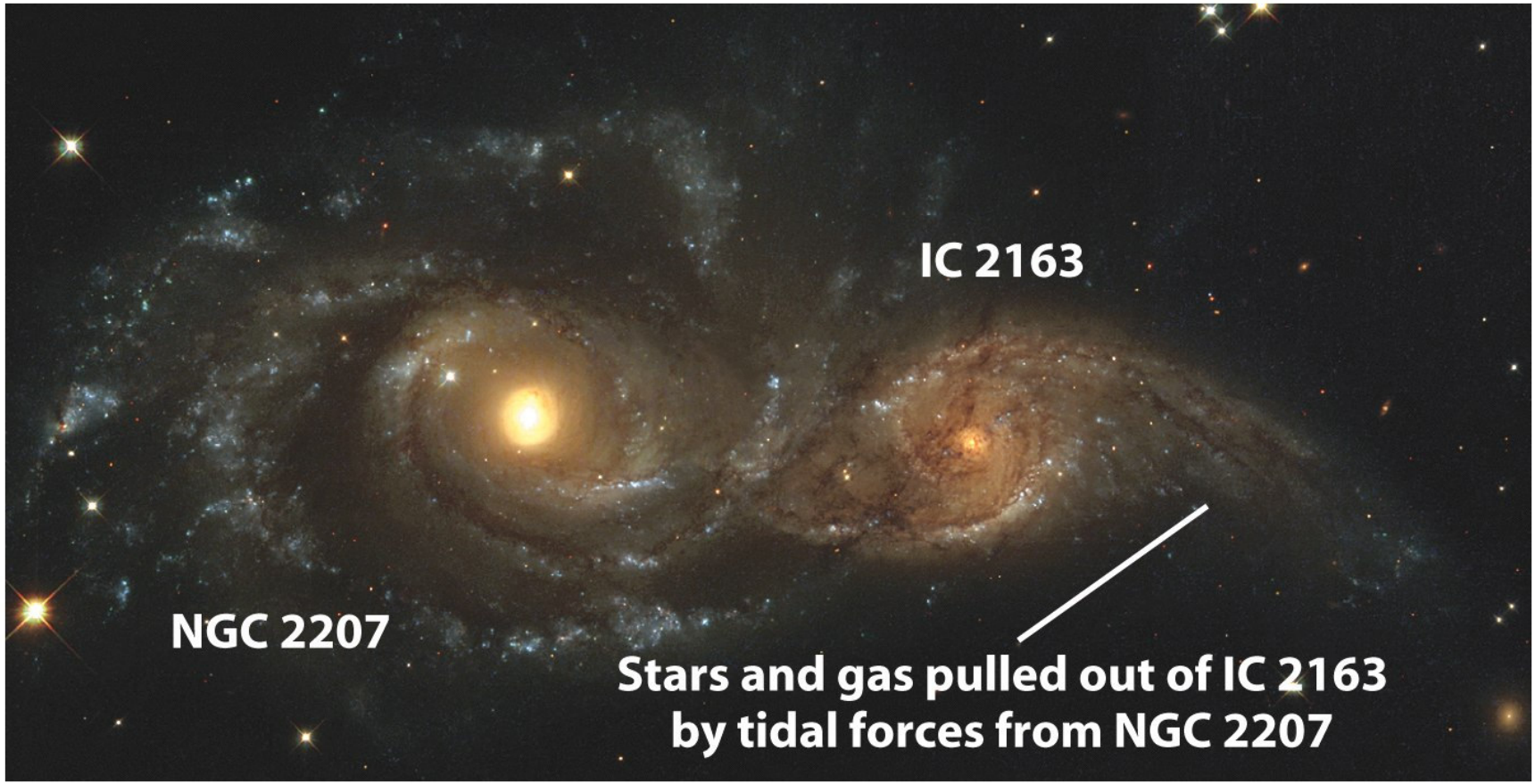
The Earth lies at one of the focus of the elliptical orbit of the Moon.

elliptical orbit (eccentricity =0.055 >0) →
separation varies → distortion → internal heating → moonquake

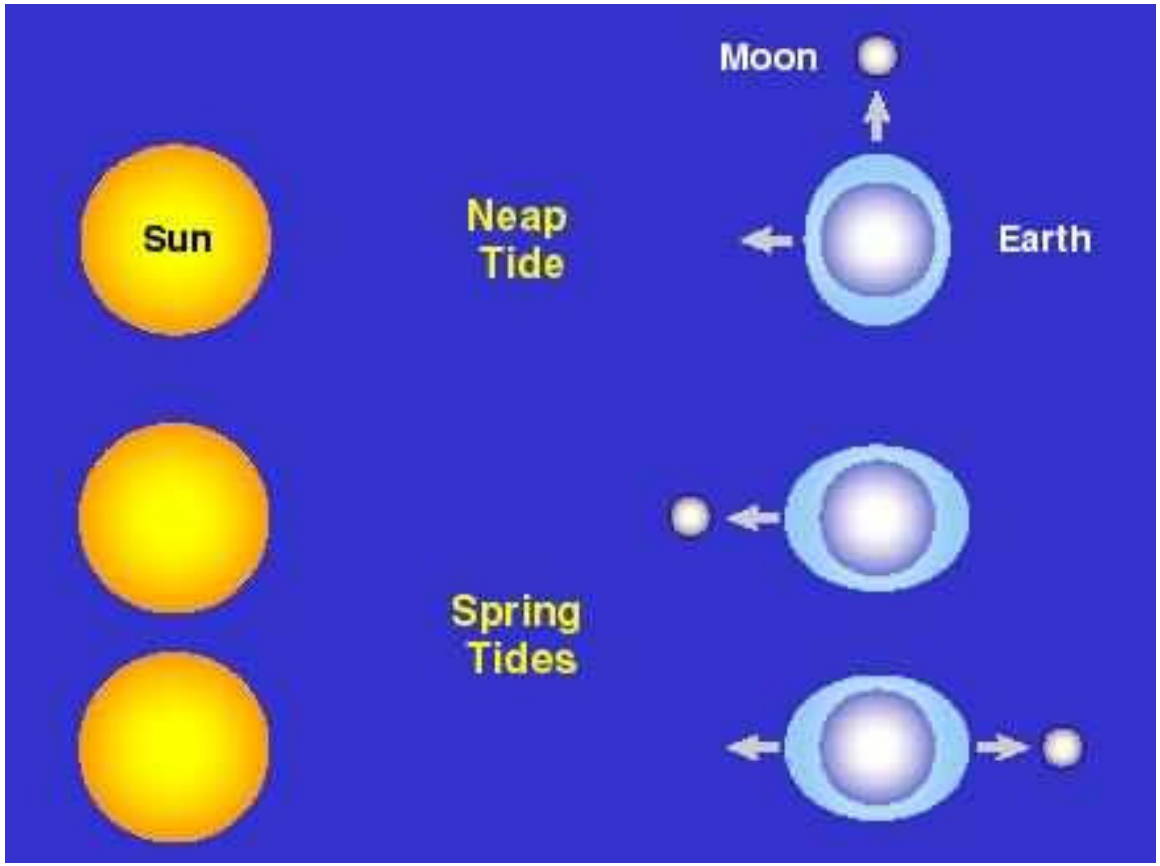


The elliptical shape of the orbit shown here is exaggerated for a better viewing effect.

Galactic tide 星系間的潮汐作用



Spring (大潮) & (小潮) Neap Tides



http://www.courseworld.com/ocean/tides.html

Outcome of tidal interactions

- **You can regard tidal interactions as a friction force (such as the friction between ocean water and sea floor) that slows things down (remark: not exactly, but this explanation is easier for beginners)**
- **The Moon is already tidally locked by Earth: we can only see one side of the Moon now.**
- **However, the Earth is not yet tidally locked by the Moon; i.e. an observer on the Moon can see different parts of the Earth at different times (not just one face all the time). As a result, the rotation of the Earth is being slowed down by the tides excided by the Moon. This means that the days are getting longer and longer. Meanwhile, the Moon is slowly moving away from us! (does it sound terrible to you that gravity in this case actually pushes two things apart?)**

Lunar Ranging

Figure 6-28
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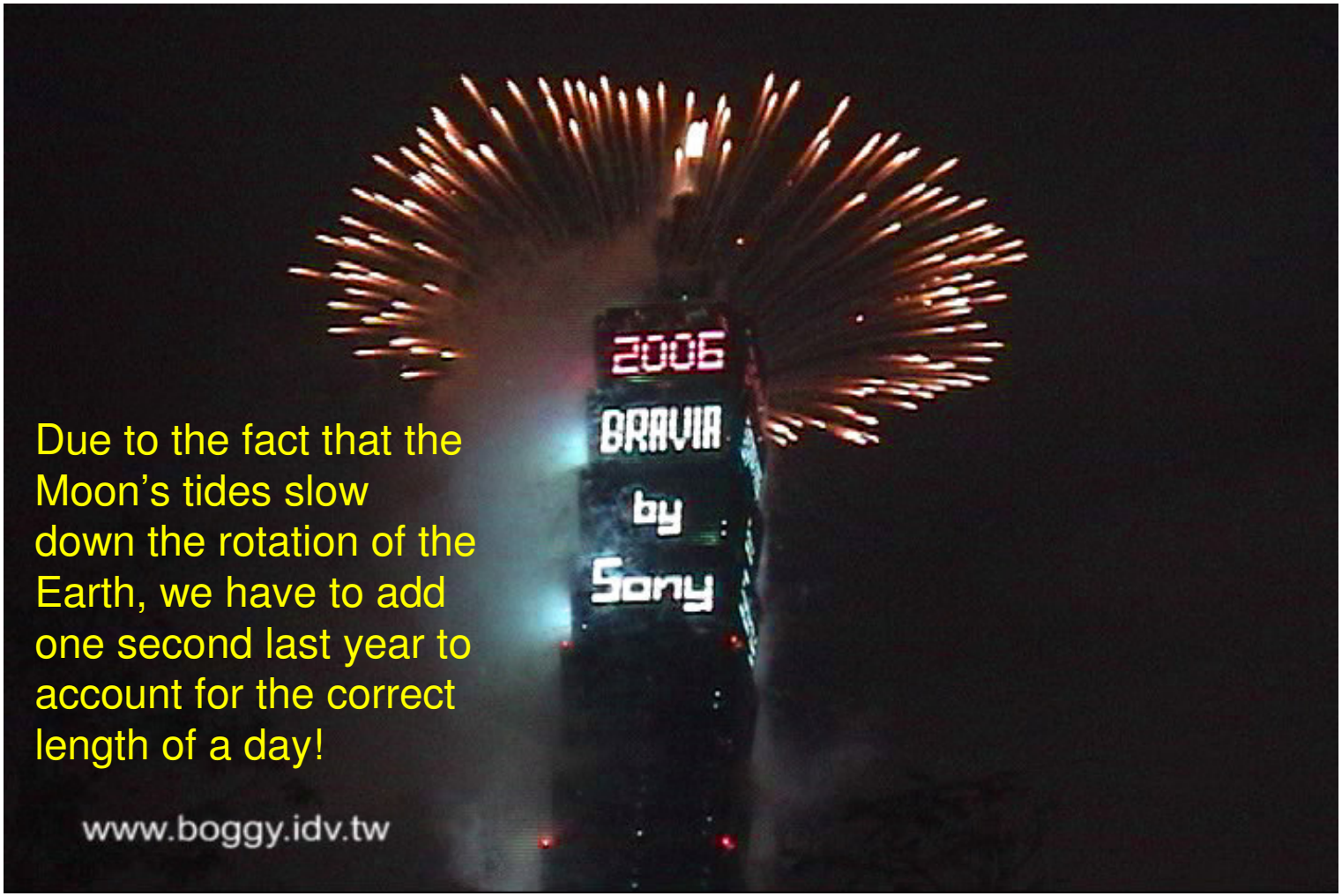
2006 countdown: 閏秒？



summary

- 為什麼月球會發光？怎麼會有圓缺？
- 為什麼月球沒有大氣？
- 為什麼月球的反光率很低？
- 為什麼地球的隕石坑比月球上的少？
- 如何推測岩石的年齡？
- 為什麼隕石坑數量隨時間遞減？
- 為什麼月球上黑暗(海)的區域比明亮(高地)的區域稍為年輕？
- 為什麼地球上最老的岩石比月球上最老的岩石年輕？
- 為什麼月蝕發生於望，而日蝕卻發生於朔？
- 為什麼有時候影子的邊緣呈現半明半暗的模糊狀(penumbra)？
- 為什麼潮汐力是一種在前後方向的扯力？人類身體為何感受不到？
- 滿潮(spring tide)都在什麼時候發生？
- 月球不是已死了嗎，怎麼月球上也會有「地震」呢？
- 為什麼月球總以同一面朝著地球？
- 為什麼月球正離地球遠去？為什麼地球一天的時間增長？
- 為什麼月球的密度比地球低？