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EP09｜莊子與愛因斯坦的淵源：淺談宇宙論

主持人｜張嘉泓

單曲長度｜00:27:54　發布時間｜2021-09-07

#張嘉泓 #物理好好玩 #海龜 #宇宙論 #逍遙遊 #菌菇 #銀河系 #宇宙背景輻射 #大霹靂

查看節目資訊

開始播放

張嘉泓

張嘉泓的專長是理論粒子物理，現任教於臺灣師範大學物理系。

追蹤 8　作品 1

追蹤

節目

物理好好玩【第一季】

★★★★★

5 (2)

同專輯的其他音檔

EP00｜科學太有趣，不能只有科學家知道

EP01｜這個方程式太美了，不可能會錯！

《莊子》的第一篇〈逍遙遊〉，是這樣開始的：「北冥有魚，其名為鯤，鯤之大，不知其幾千里也。」說的是一條大魚，大到無法言說。大就是〈逍遙遊〉的重點，在短短兩千字的文章中，出現了23次：大知、大樽、大樹、大若垂天之雲。莊子的意思是：胸懷能大，眼光能大，細微、短暫的現象，才不會拘泥你的心靈，人才能自由逍遙、遊於無窮。

在文章中，莊子順手提到了一個很特別的想法：當我們望向浩大的天空，天色蒼茫、整齊平靜無瑕，這是天空真實的樣貌嗎？現代的我們知道上空的風可是劇烈又多變，用莊子自己的語言，天空該是充滿塵埃、野馬似的生物之息。因此，蒼蒼天色，並不是真的因為天空沒有變化，其遠而無所至極也。實在太大，太遠到無法言說，以致看的人無法分辨而已。

愛因斯坦的宇宙論原則

https://www.mirrorvoice.com.tw/podcasts/78

能力

大學學習的重點是能力，不是知識

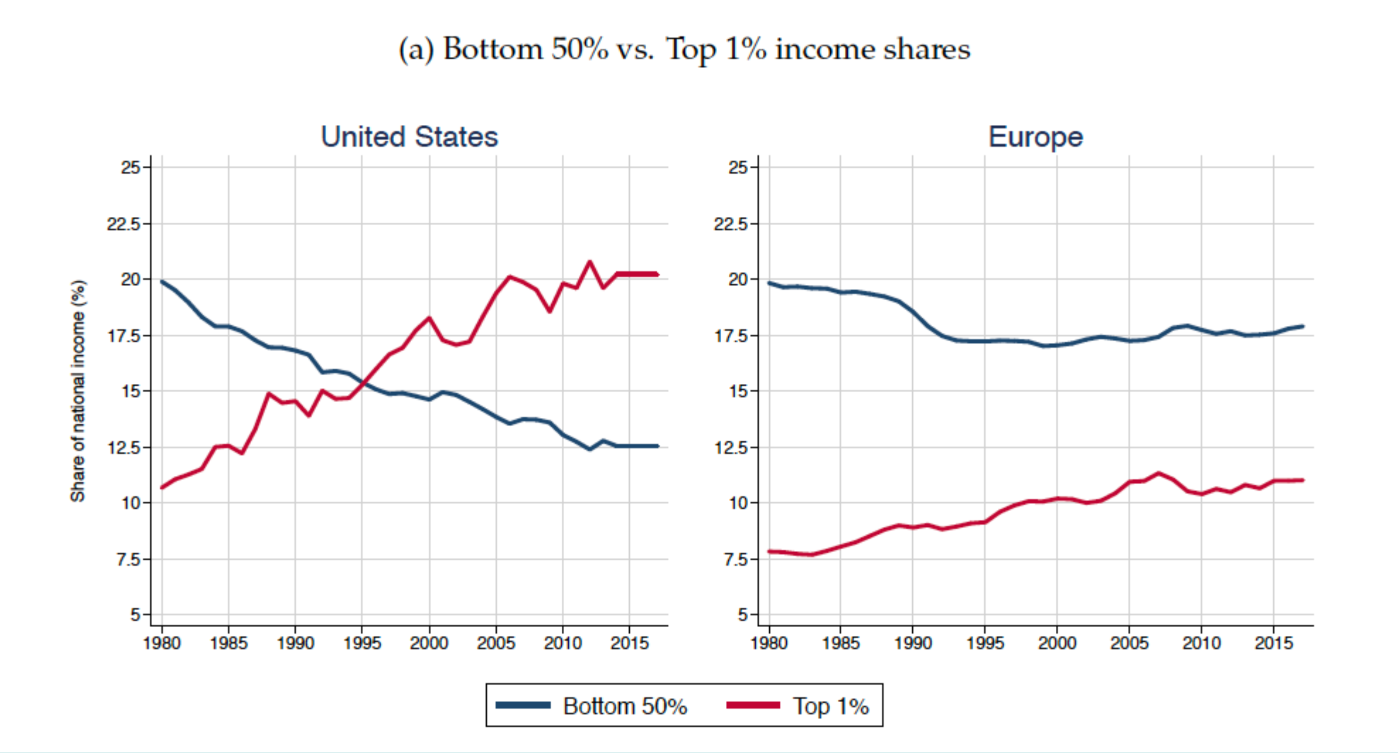
知識已經太過複雜，但容易取得，
而且許多人未來的發展還有各式的可能！

知識

但培養能力，必須透過知識的學習

只有透過知識的**學習、思考、討論、掙扎、挫折**，
才能培養思考與解決問題的能力！

思考力的重訓！



收入的分配是越來越不平均，報酬集中在頂端。

競爭是殘酷的！ 你競爭的利基是什麼？

如果你的志向就是尋找臉書上評分最高，IG上追隨者最多的，

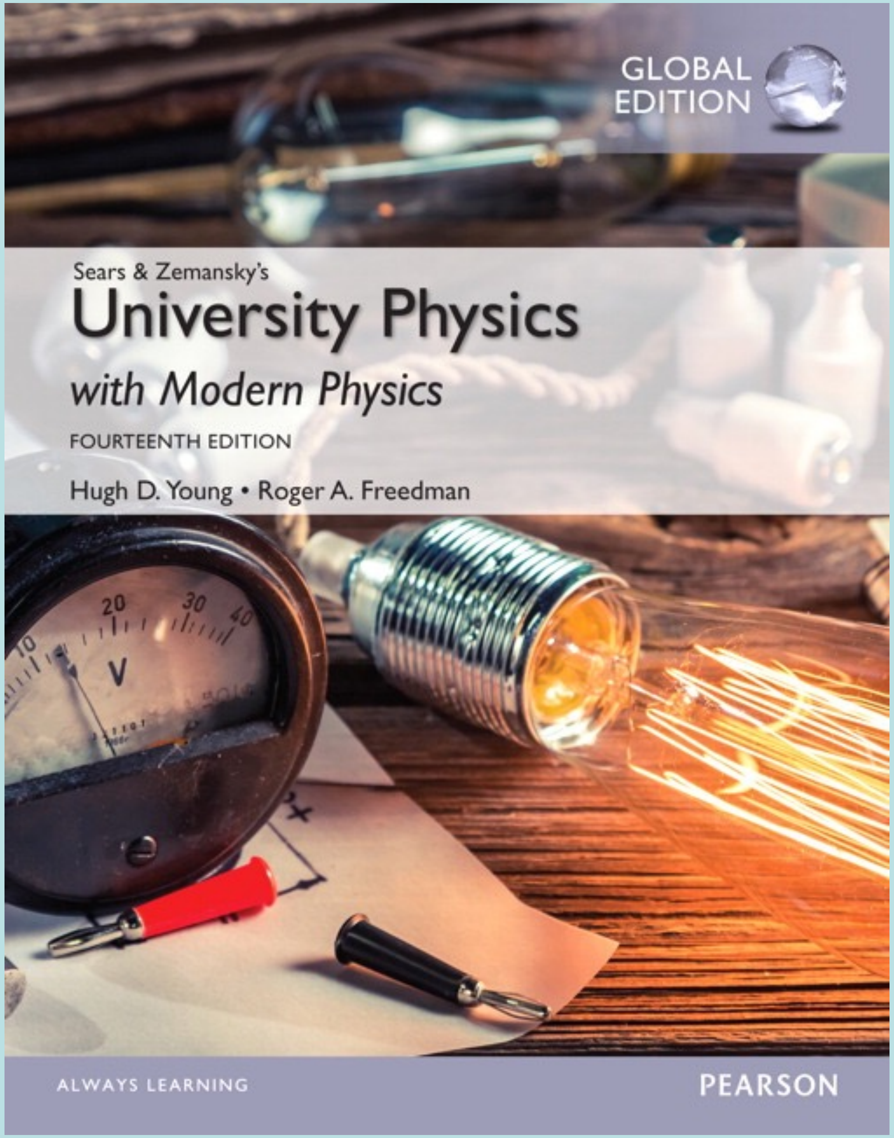
你註定就是與平均值對齊。

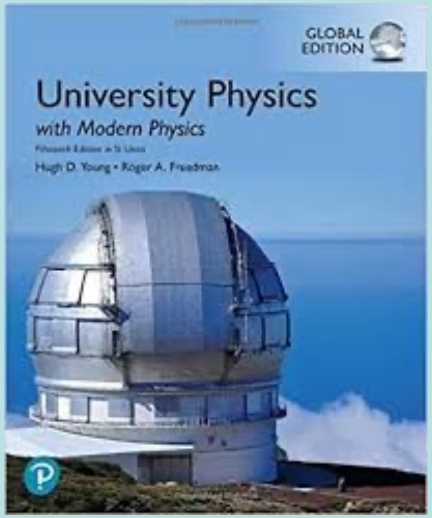
希望能在這個課程中，讓你感覺到物理思考的 **fun—樂趣**。

了解物理是一種有系統而且理性的思考方式
提供了我們面對自然世界，一個珍貴而不可或缺的觀點。

以這個觀點來了解自然，是充滿了 **fun** 樂趣。

而且非常有用！



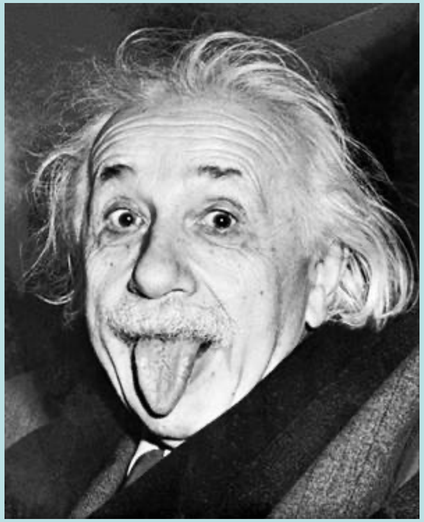


Sears and Zemansky's University Physics with Modern Physics 15/E
H. D. Young and R. A. Freedman

Grade:

一次期中考試（45%），一次期末考試（45%），習題（15%）

物理是什麼？



狹義相對論。原子能。

廣義相對論。黑洞。

Mechanics 力學 運動

微分

牛頓運動定律

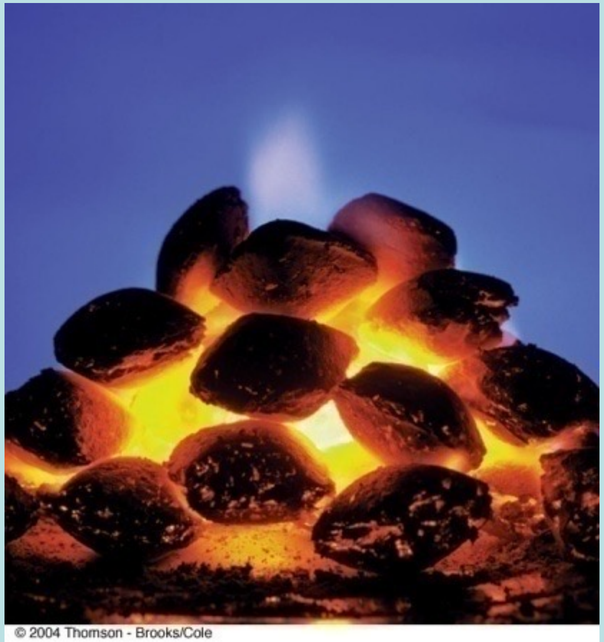
運動方程式（微分方程式）

簡諧運動：運動方程式之範例

能量守恆、積分

波動：波函數與波方程式

Thermal Physics 熱物理



固體與液體的熱物理　熱平衡

熱力學第一定律　熱作用就是熱量交換。

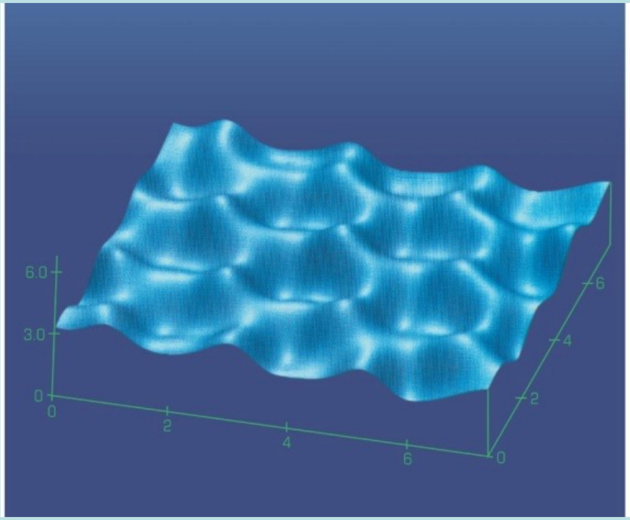
氣體的熱物理　熱量與功都是能量！

熱力學第二定律與熵　熱量與功是不一樣的！

氣體分子理論　原來熱學就是力學！

統計力學初步　微觀統計導致巨觀的熱現象

Quantum Physics 量子物理



光子

原子結構：光譜與波爾原子模型

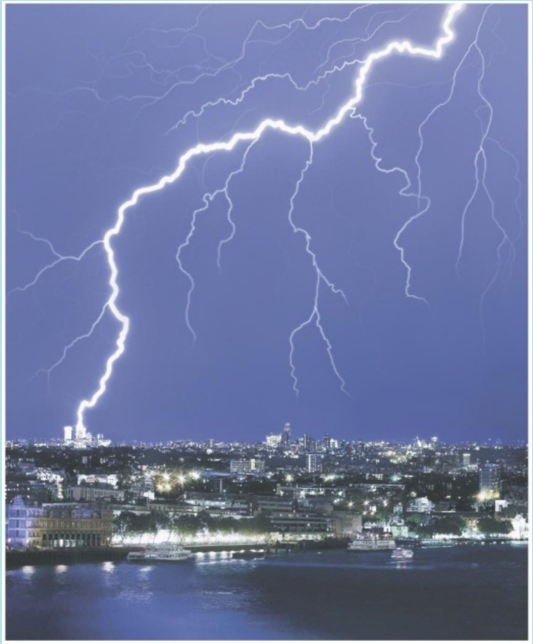
物質波

薛丁格波方程式

波與粒子的二重性　　　　　電子是波也是粒子。

原子結構

Electricity and Magnetism 電磁



靜電場

高斯定律

電位

靜磁場與安培定律

變化的電磁場：電磁感應

Maxwell Equations

電磁波

電磁場與電磁波

Modern Physics

Semiconductor?

Fundamental Particles?

Cosmology?

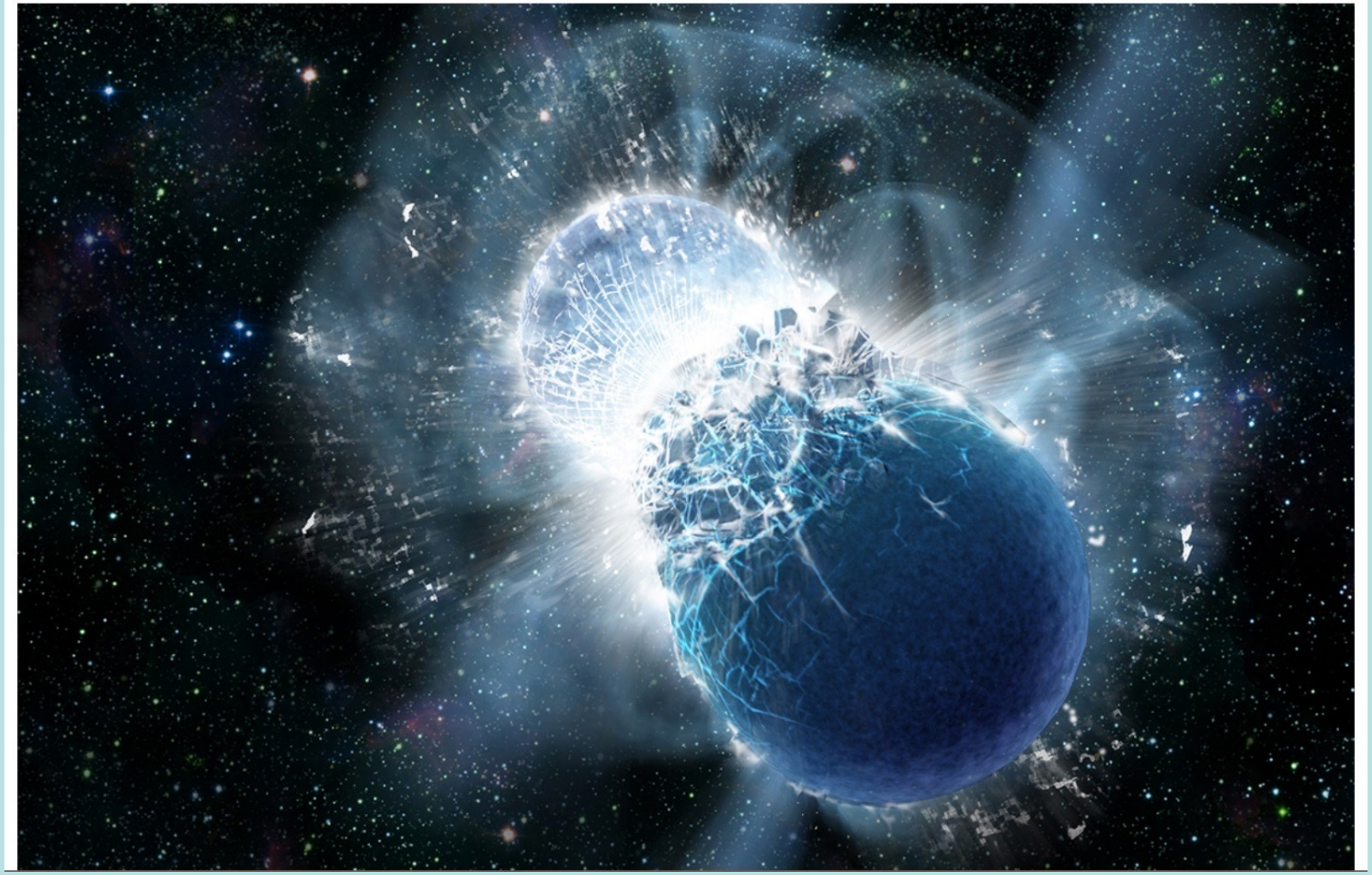
Laser and Modern Optics

It is an exciting time to be a scientist!

做科學很令人興奮!

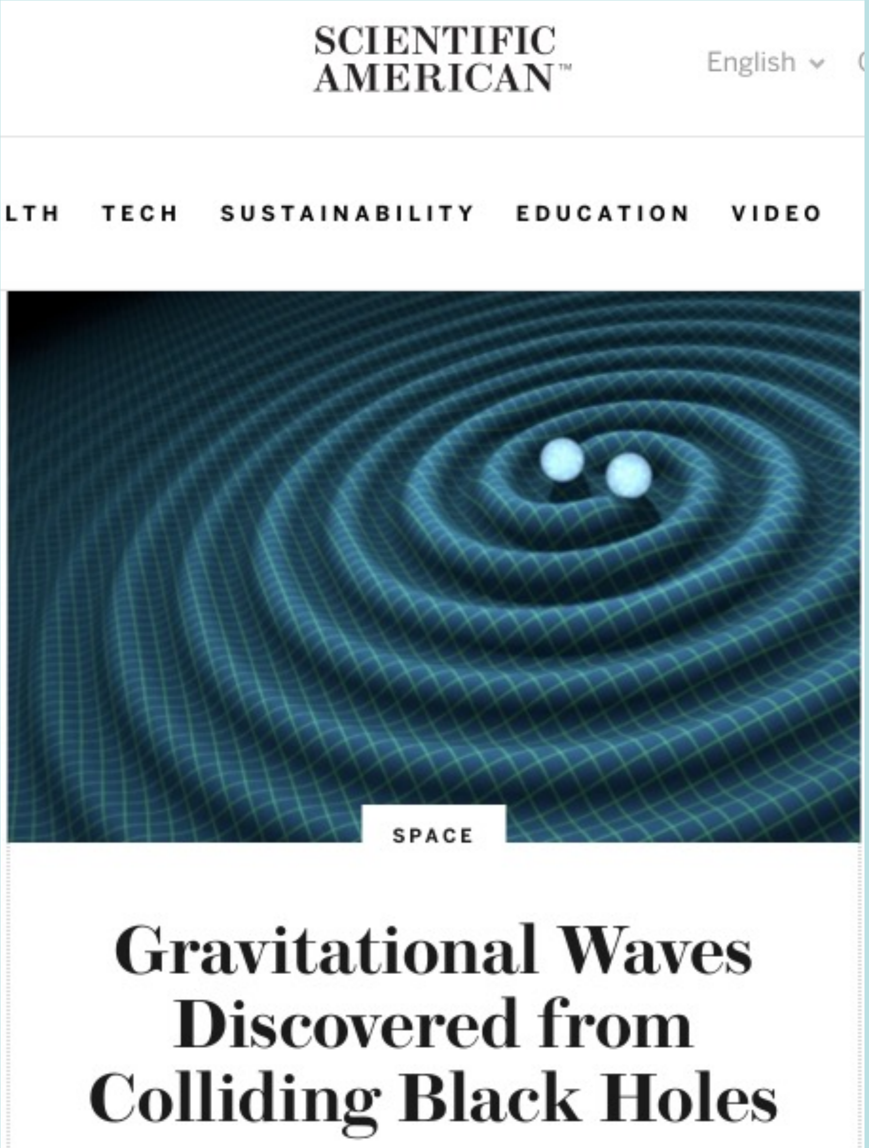
DAILY NEWS 23 August 2017, updated 23 August 2017

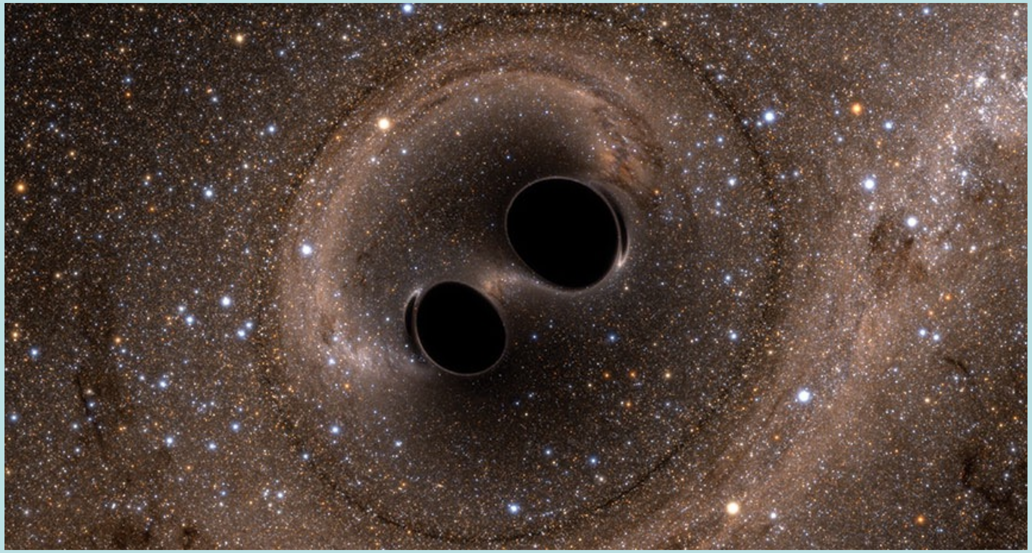
Exclusive: We may have detected a new kind of gravitational wave



以天文為例：

2015 發現由黑洞撞擊產生的重力波





First Images of a Black Hole from the Event Horizon Telescope

13

By Susanna Kohler on 10 April 2019 FEATURES

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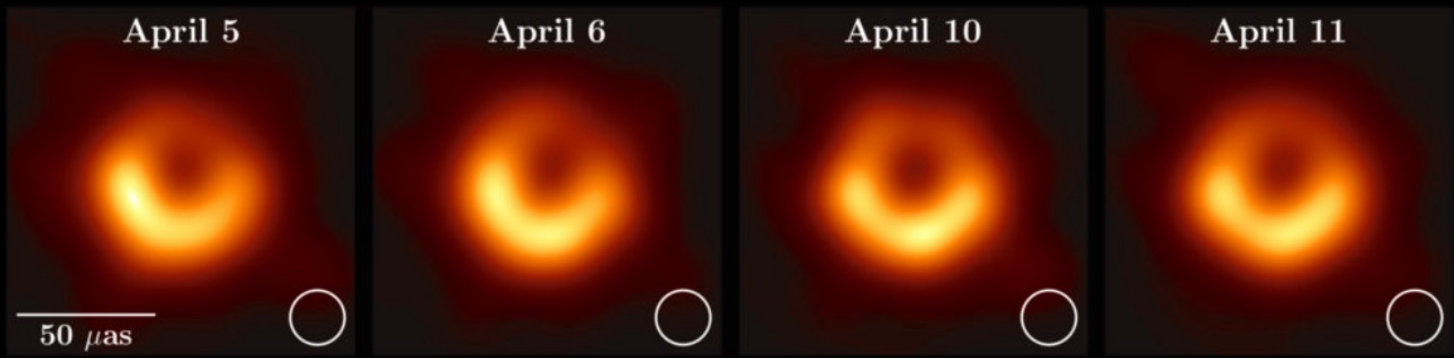
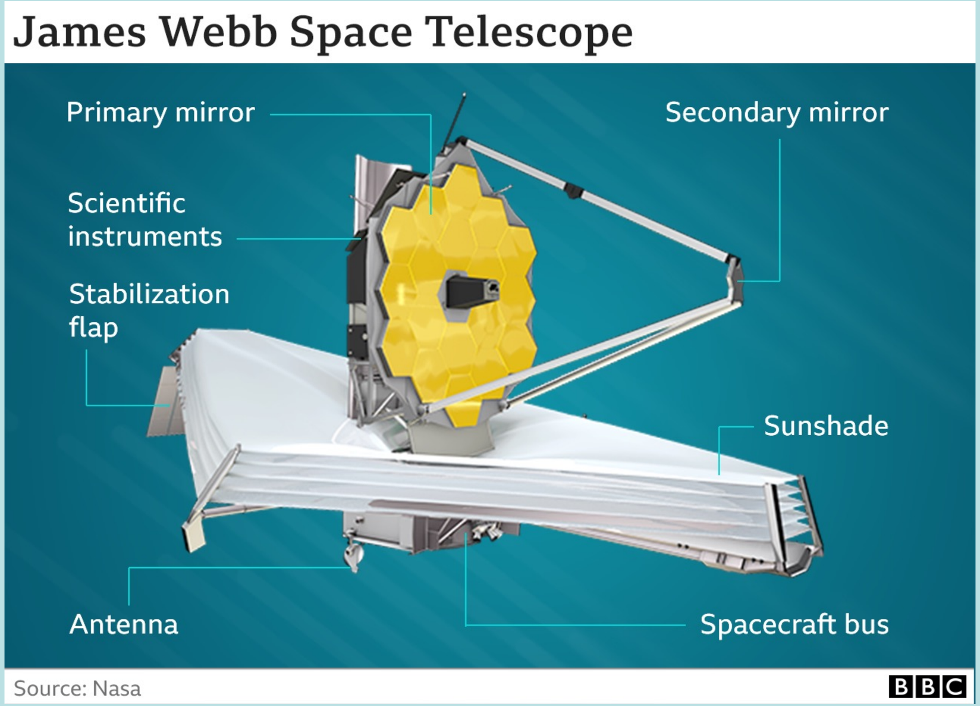


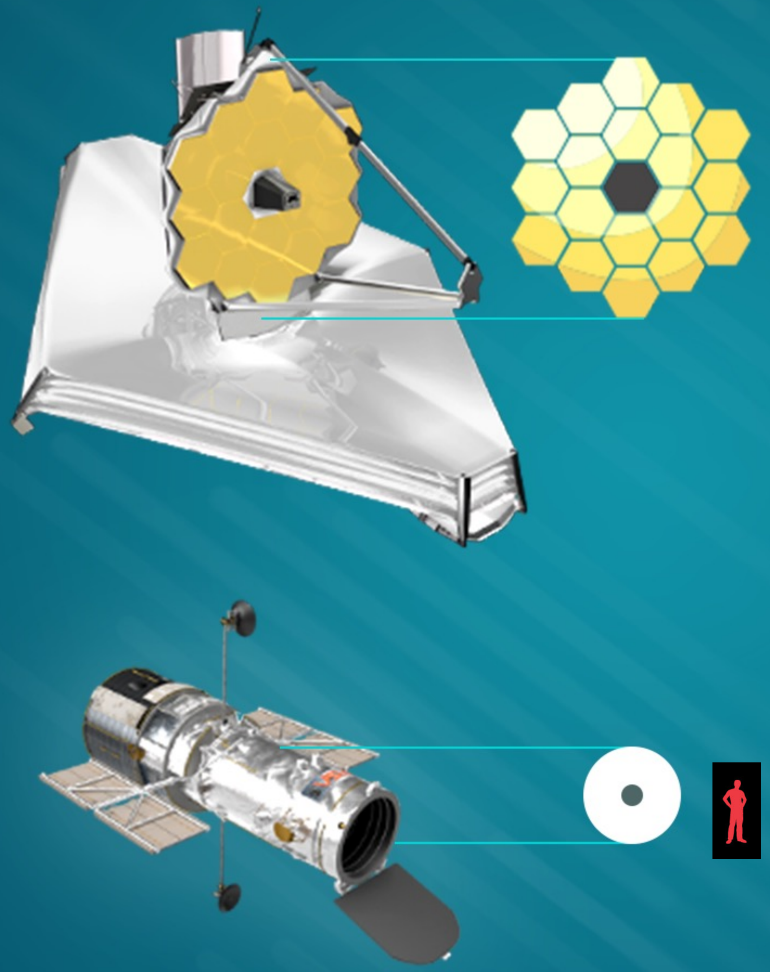
Observations from the Event Horizon Telescope of the supermassive black hole at the center of the elliptical galaxy M87, for four different days. [EHT Collaboration et al 2019]

Webb Space Telescope 韋伯太空望遠鏡

一百億美金，費時三十年籌備



James Webb and Hubble compared



JAMES WEBB

Launch 2021
Lifetime . . . . .10 years
Mirror size 6.5m
Mass . . . . 6,200 kg
Operating
temperature . . .-230C

HUBBLE

Launch 1990
Lifetime . . . . .31 years
Mirror size 2.4m
Mass 12,200kg
Operating
temperature 20C

Source: Nasa

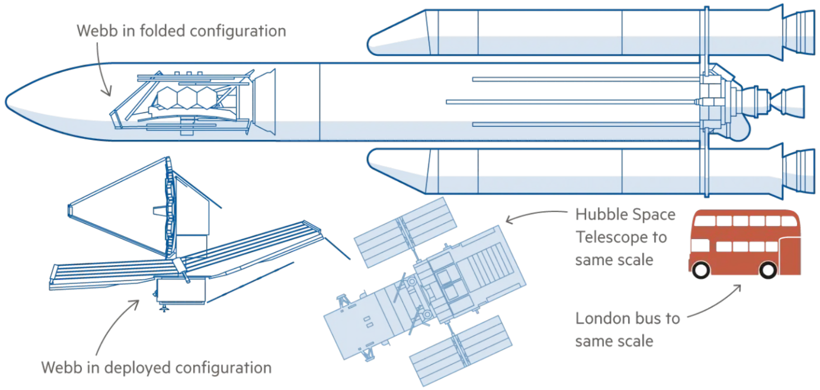
BBC

The James Webb Space Telescope

An international collaboration between US, European and Canadian space agencies. It will observe extremely distant objects at infrared wavelengths

Size

To achieve its goals, it has to be large but must fit in the fairing of an Ariane 5 rocket. So it is designed to fold, deploying over the month-long journey to orbit



The telescope

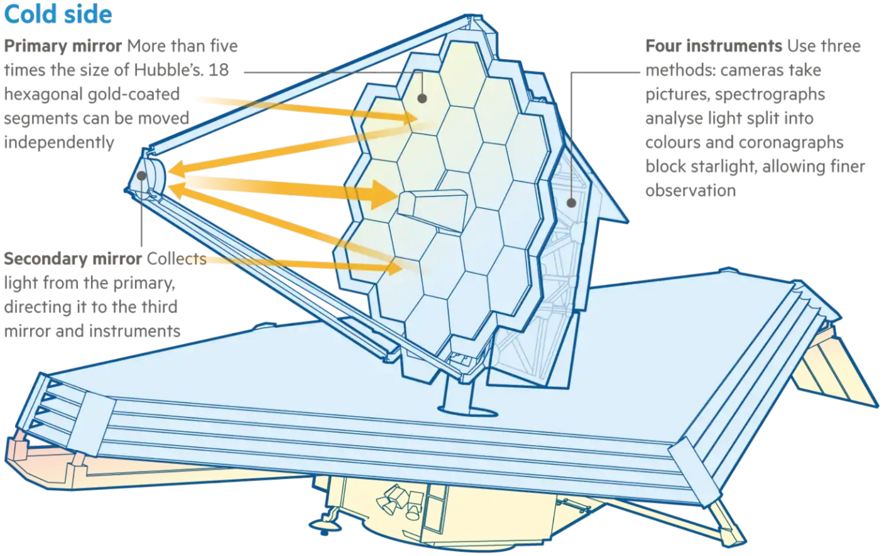
Webb has a hot (85C) and a cold (minus 233C) side

Cold side

Primary mirror More than five times the size of Hubble's. 18 hexagonal gold-coated segments can be moved independently

Four instruments Use three methods: cameras take pictures, spectrographs analyse light split into colours and coronagraphs block starlight, allowing finer observation

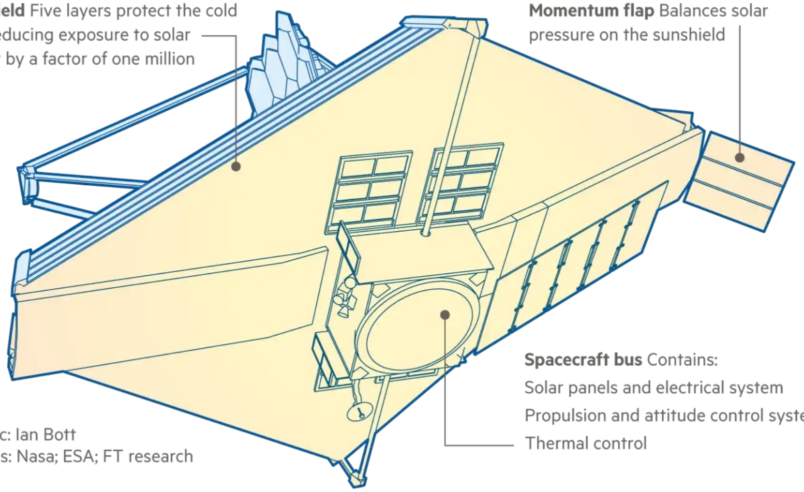
Secondary mirror Collects light from the primary, directing it to the third mirror and instruments



Hot side

Sunshield Five layers protect the cold side, reducing exposure to solar energy by a factor of one million

Momentum flap Balances solar pressure on the sunshield



Spacecraft bus Contains:

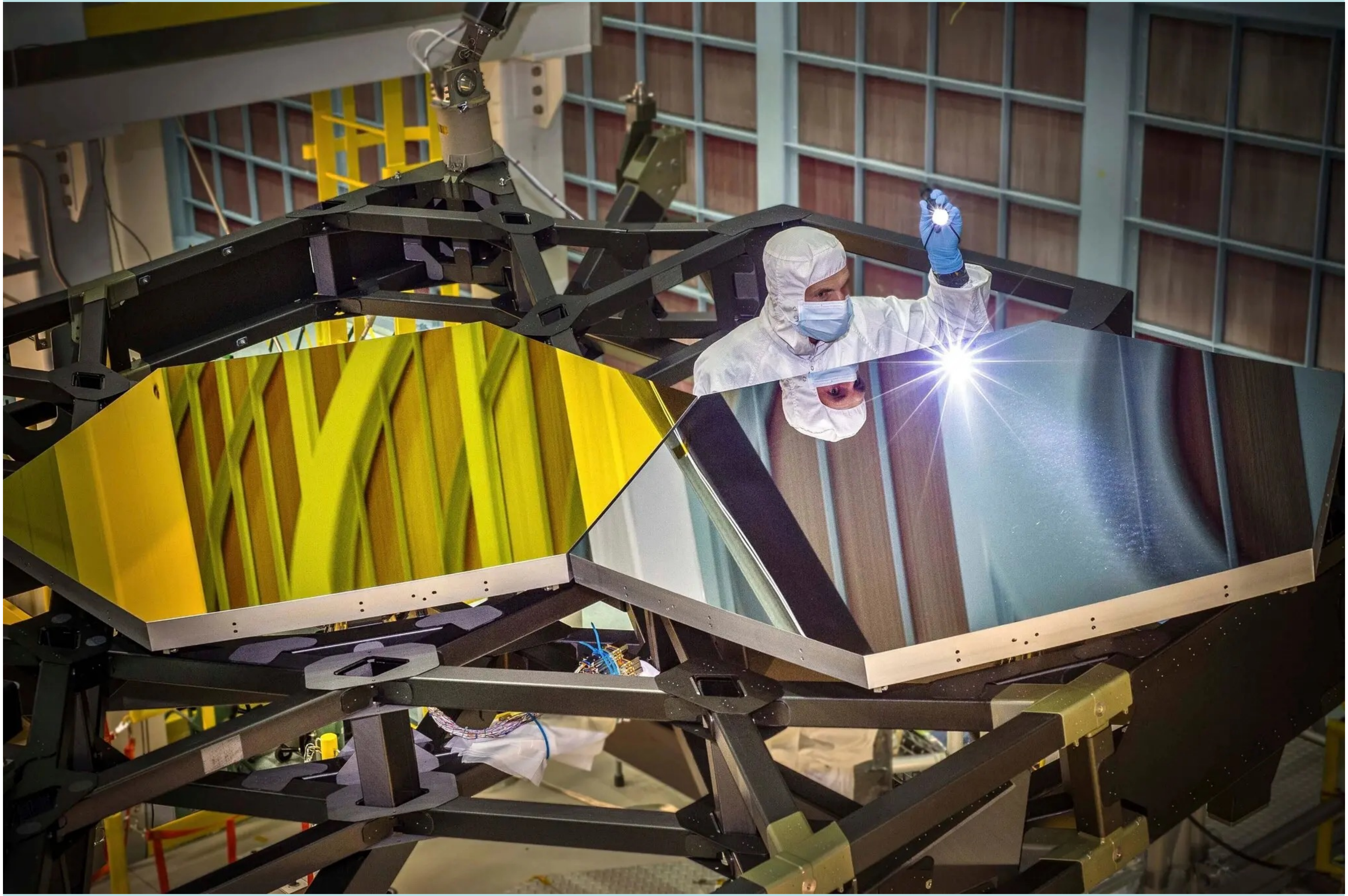
Solar panels and electrical system

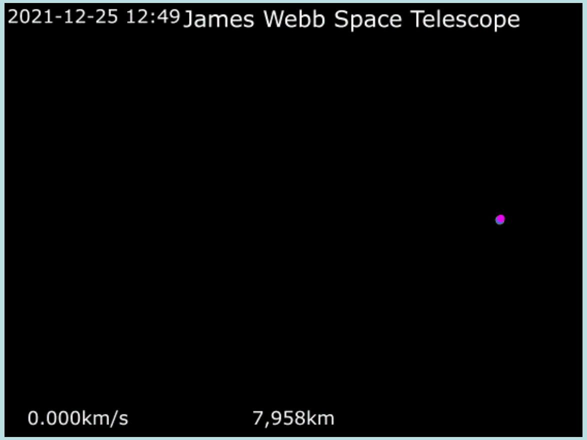
Propulsion and attitude control system

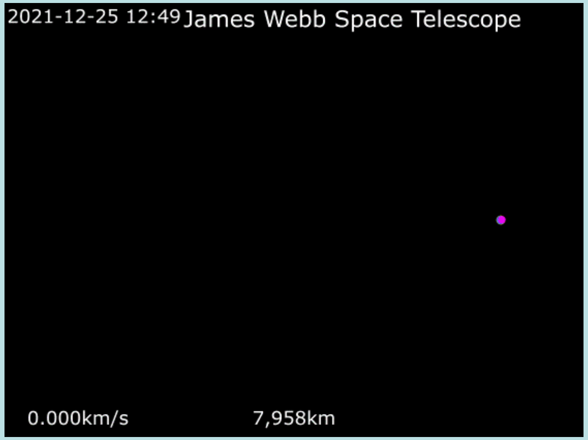
Thermal control

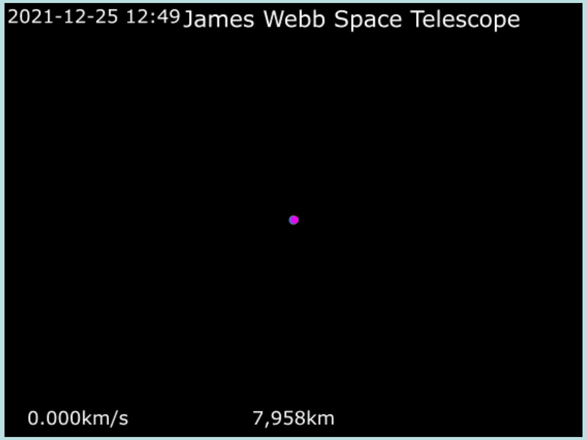
Graphic: Ian Bott

Sources: Nasa; ESA; FT research

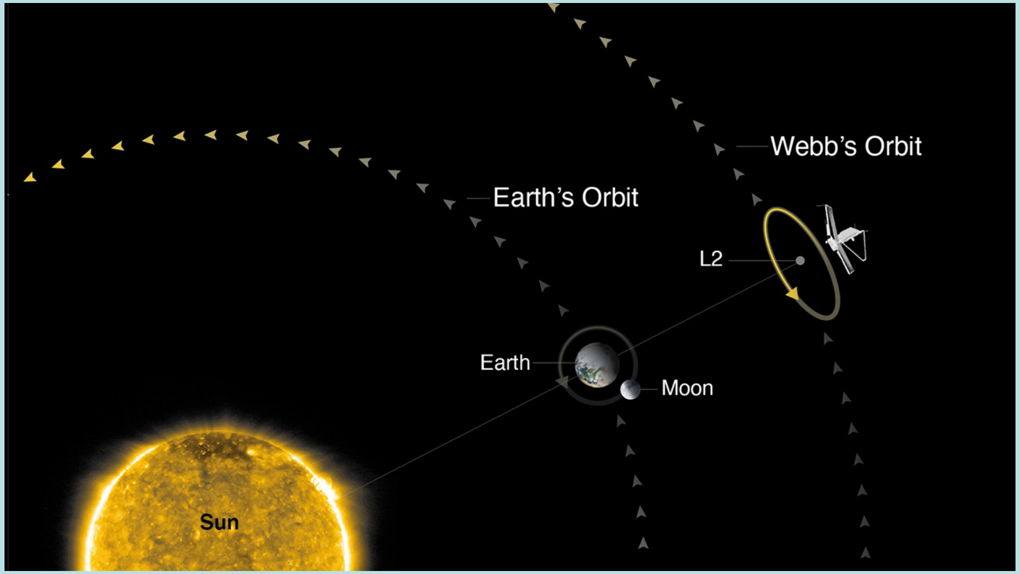




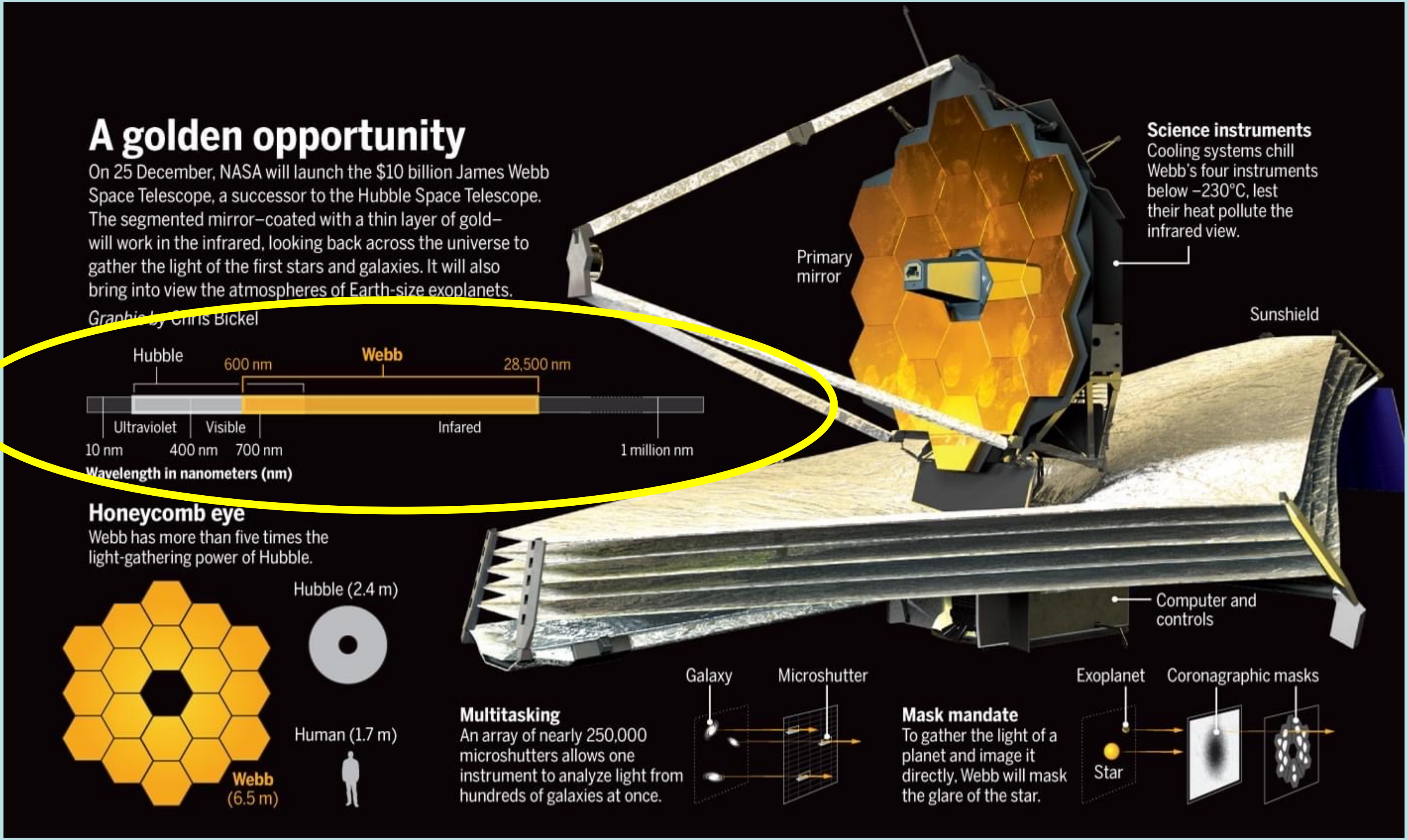




Top view　　Side view　　Side view from the Sun

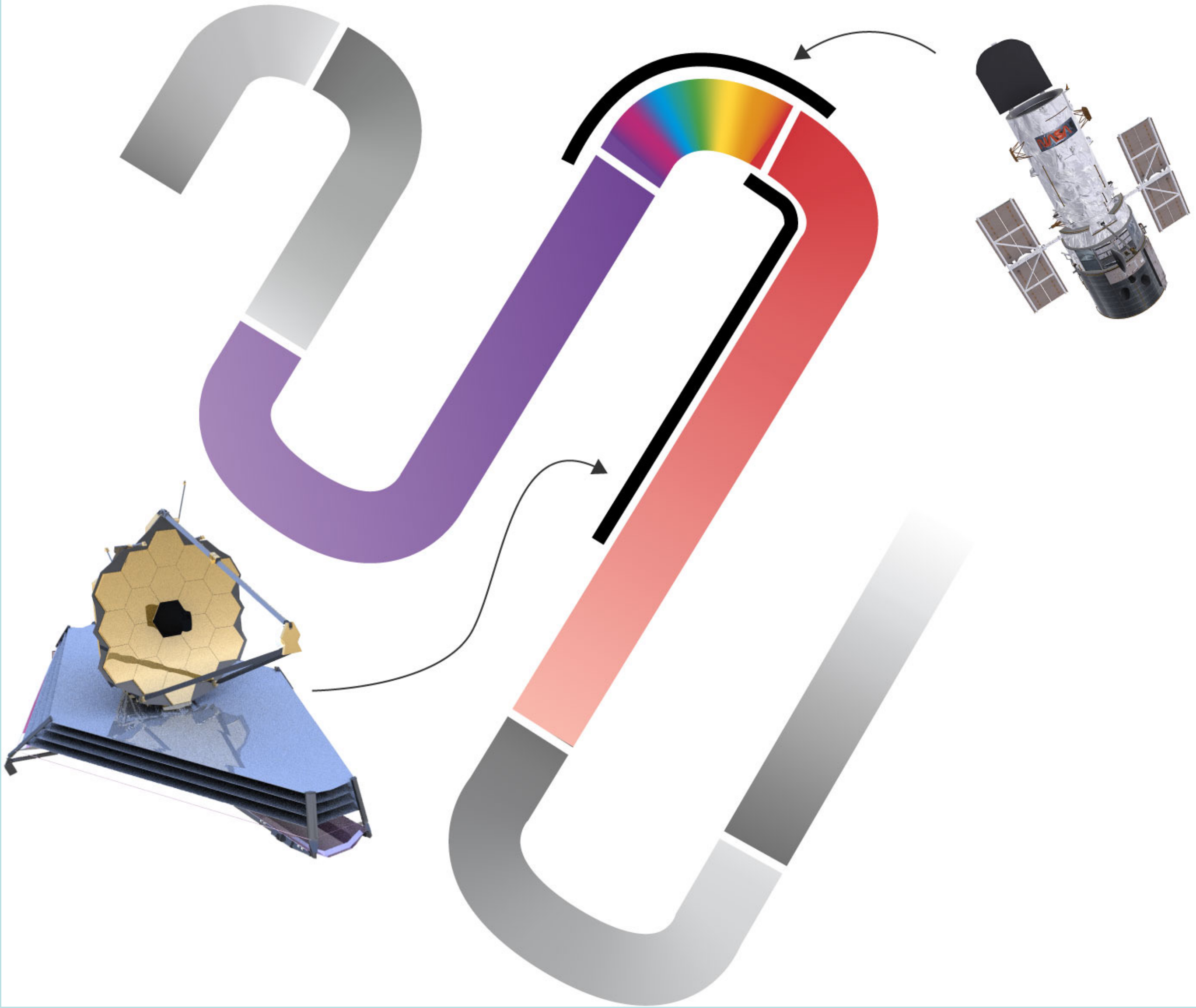


韋伯望遠鏡繞L2點旋轉：地球與太陽重力合力恰等於向心力，同時隨著地球一起繞日。



A golden opportunity
On 25 December, NASA will launch the $10 billion James Webb Space Telescope, a successor to the Hubble Space Telescope. The segmented mirror–coated with a thin layer of gold–will work in the infrared, looking back across the universe to gather the light of the first stars and galaxies. It will also bring into view the atmospheres of Earth-size exoplanets.
Graphic by Chris Bickel
Hubble
600 nm
Webb
28,500 nm
Ultraviolet
Visible
Infared
10 nm
400 nm
700 nm
1 million nm
Wavelength in nanometers (nm)
Honeycomb eye
Webb has more than five times the light-gathering power of Hubble.
Hubble (2.4 m)
Human (1.7 m)
Webb (6.5 m)
Primary mirror
Science instruments
Cooling systems chill Webb's four instruments below −230°C, lest their heat pollute the infrared view.
Sunshield
Computer and controls
Galaxy
Microshutter
Multitasking
An array of nearly 250,000 microshutters allows one instrument to analyze light from hundreds of galaxies at once.
Exoplanet
Coronagraphic masks
Star
Mask mandate
To gather the light of a planet and image it directly, Webb will mask the glare of the star.

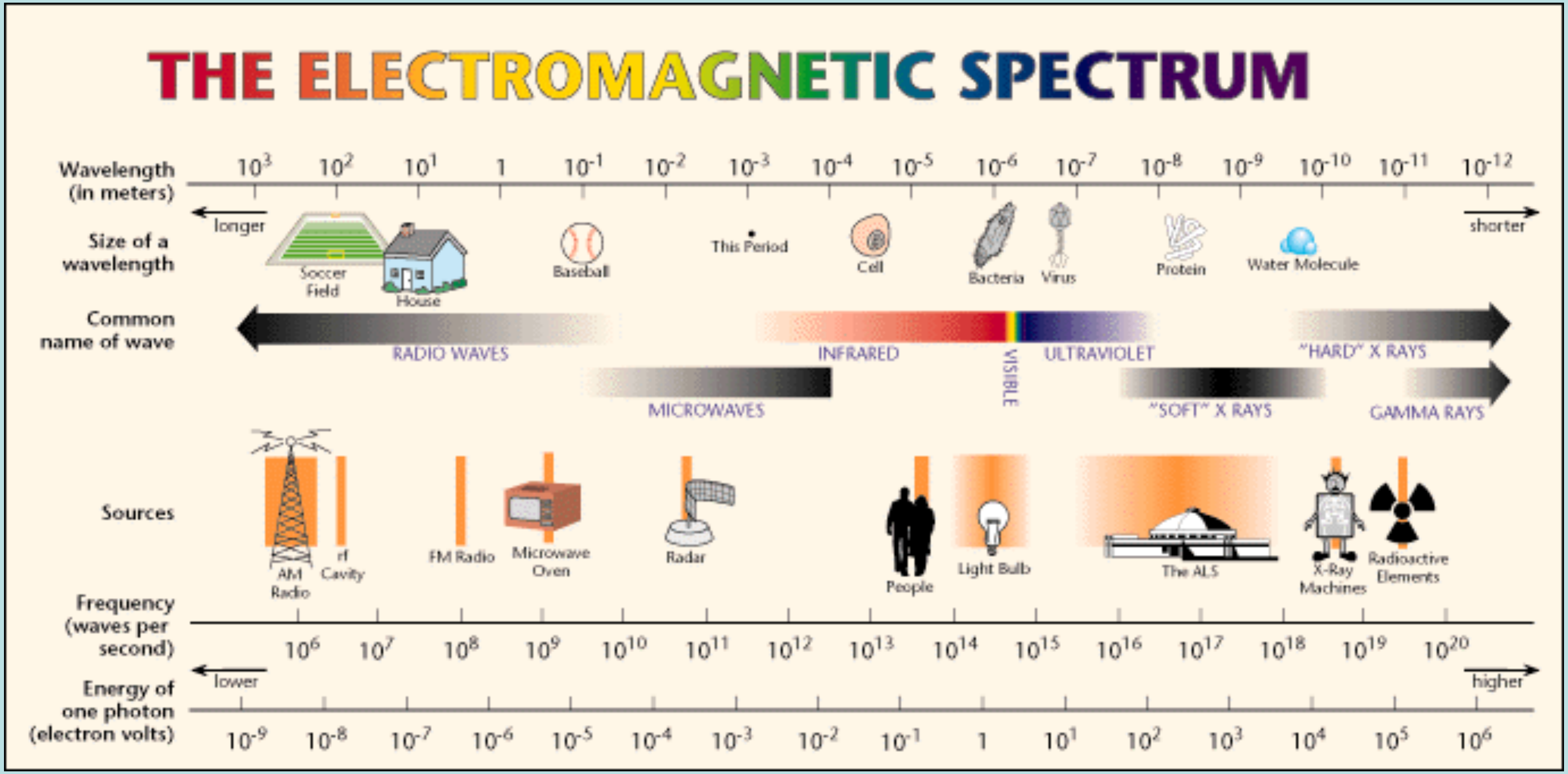
韋伯是一個紅外線望遠鏡！不像哈伯是可見光望遠鏡。
與其說是望遠鏡，不如說是接收電磁波的天線！



ALMA, the Atacama Large Millimeter Array

電磁波（微波）偵測天線陣列

馬克斯威爾的彩虹：依照頻率即波長排列的電磁波。



First Images of a Black Hole from the Event Horizon Telescope

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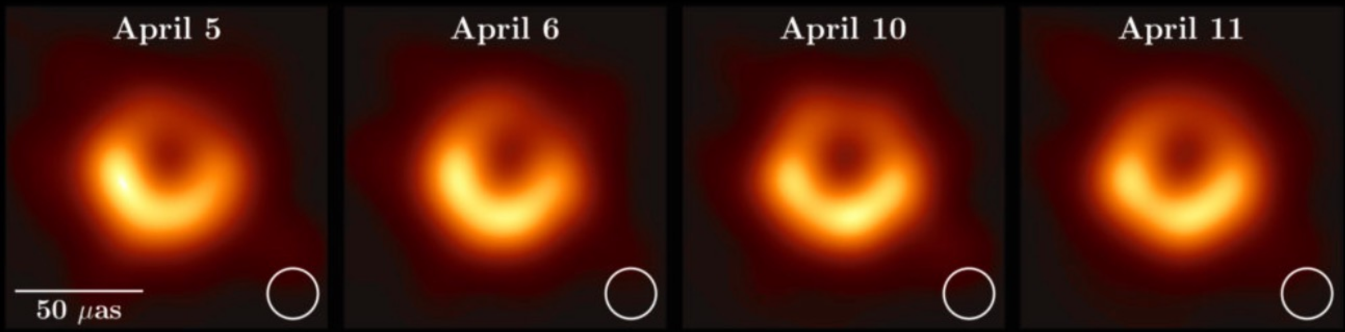
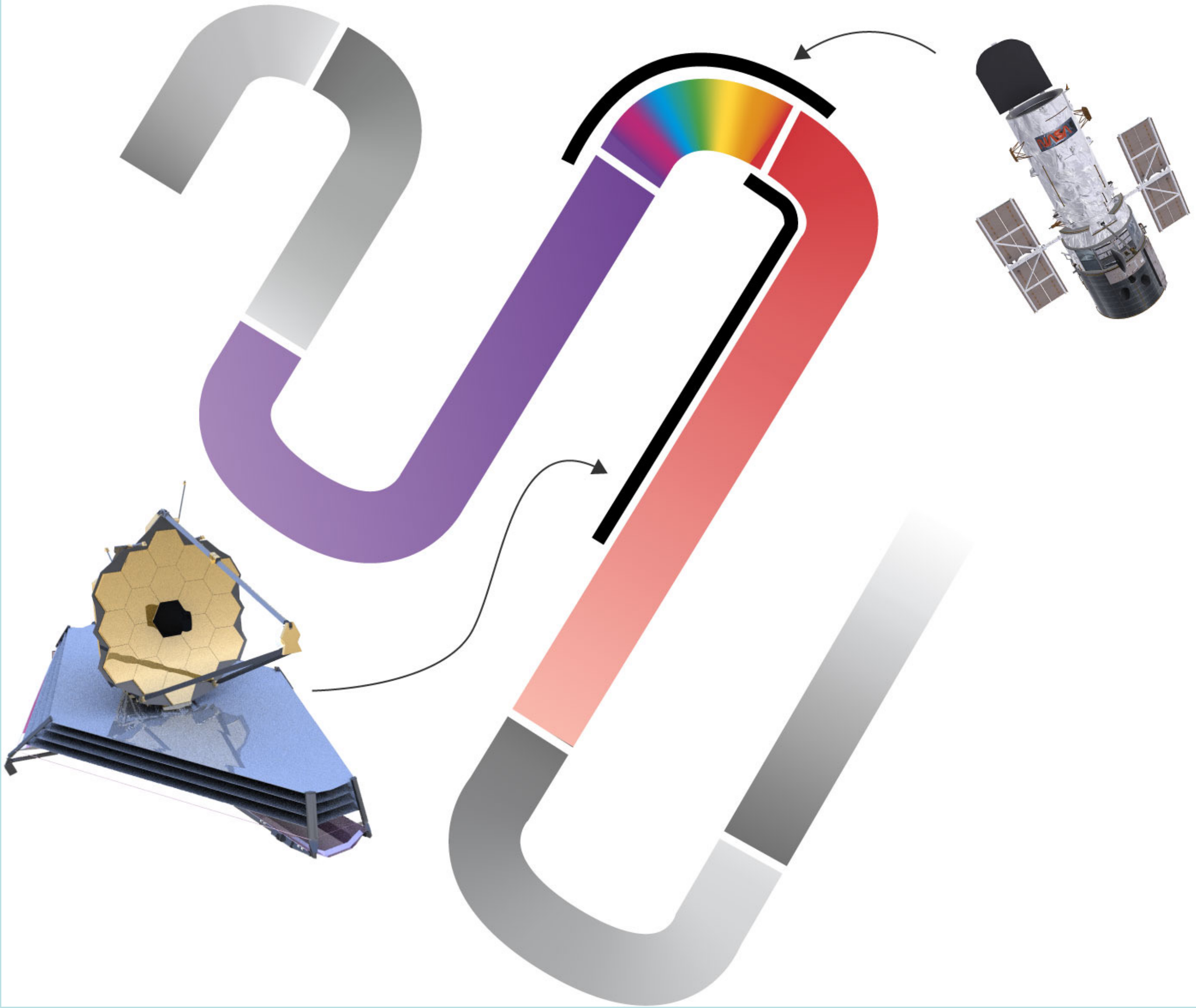


Observations from the Event Horizon Telescope of the supermassive black hole at the center of the elliptical galaxy M87, for four different days. [EHT Collaboration et al 2019]

這張黑洞照片是微波，不是可見光。

哈伯望遠鏡是可見光望遠鏡

韋伯是一個紅外線望遠鏡！不像哈伯是可見光望遠鏡。
與其說是望遠鏡，不如說是接收電磁波的天線！



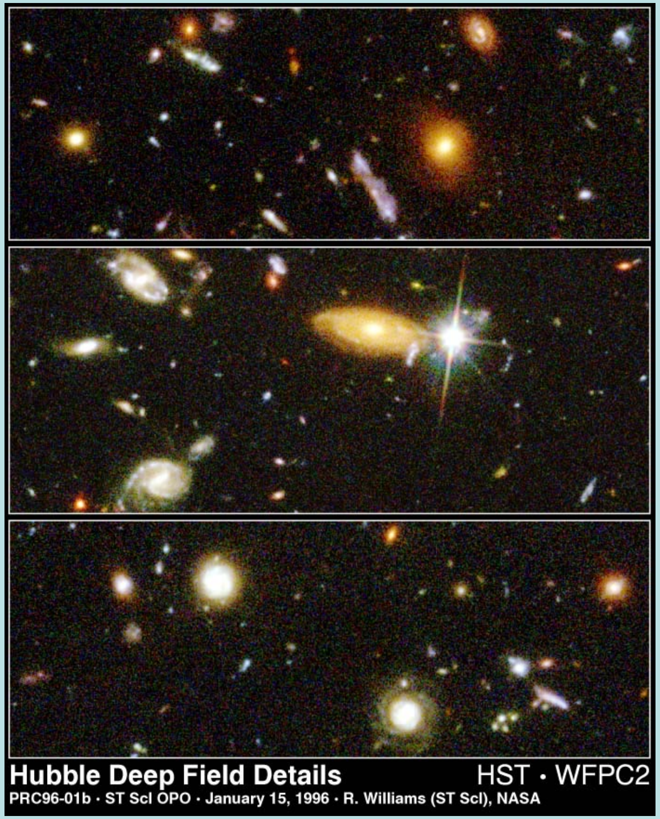
紅外線望遠鏡最大的好處是：

可見光會被塵埃遮蔽

紅外線可以透過塵埃

紅外線望遠鏡更大的好處是：可以看到非常古老的星系：

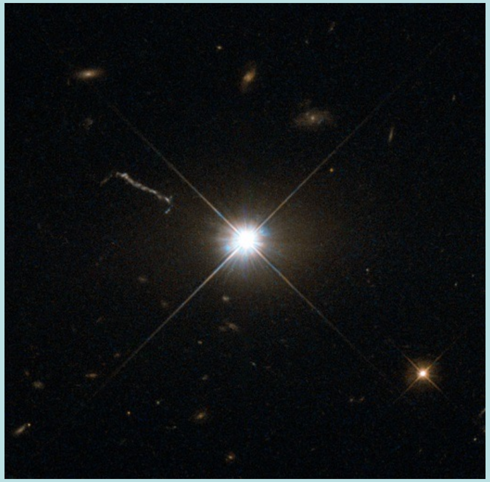
越遠的星系，時間越古老，當然光越弱，所以要用深空觀測：

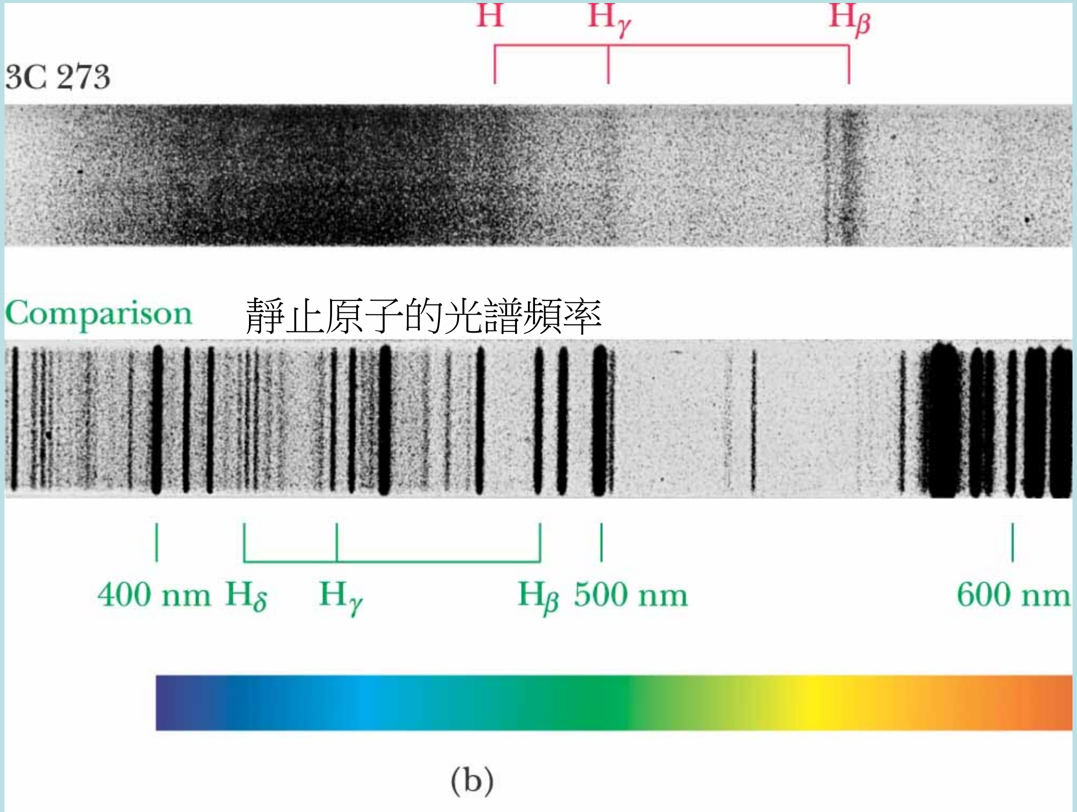


Hubble Deep Field

而且越遠的星系，紅移越厲害。

Hubble發現遠處星光的紅移現象redshift：星光的光譜頻率低於靜止原子的光譜頻率！



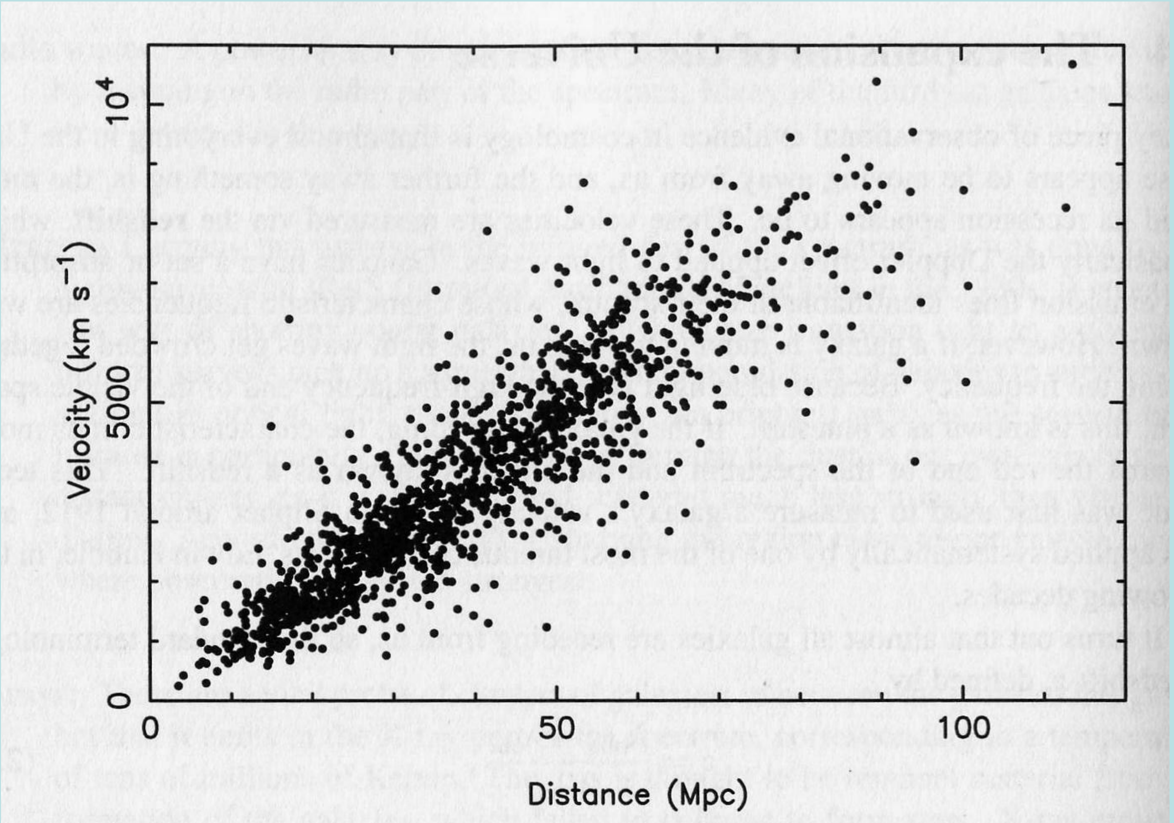


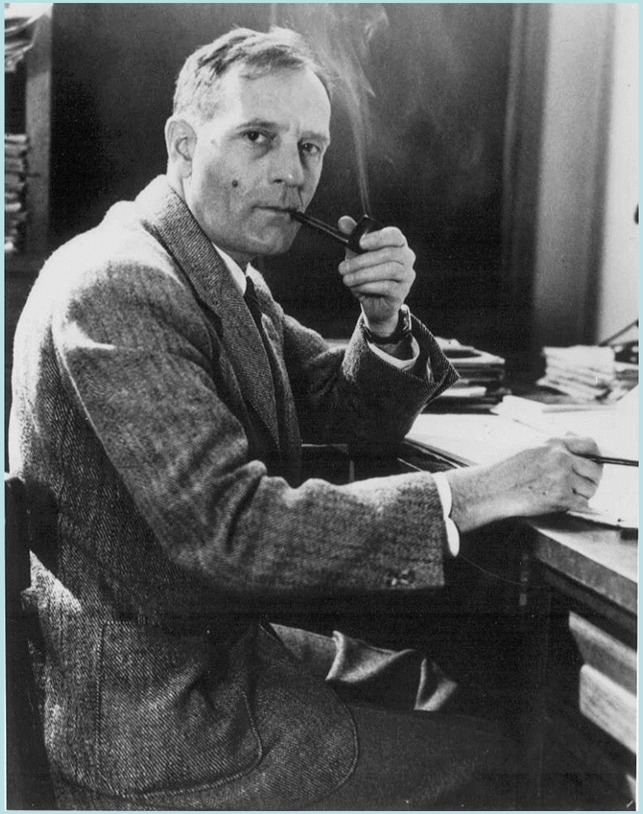
Vesto Slipher
1875-1969

3C 273 is a quasar located in the constellation Virgo. It was the first quasar ever to be identified. It is the optically brightest quasar in our sky and one of the closest with a redshift, *z*, of 0.158.

這是單一星體。第一個發現的Quasar。

Edwin Hubble 1889-1953



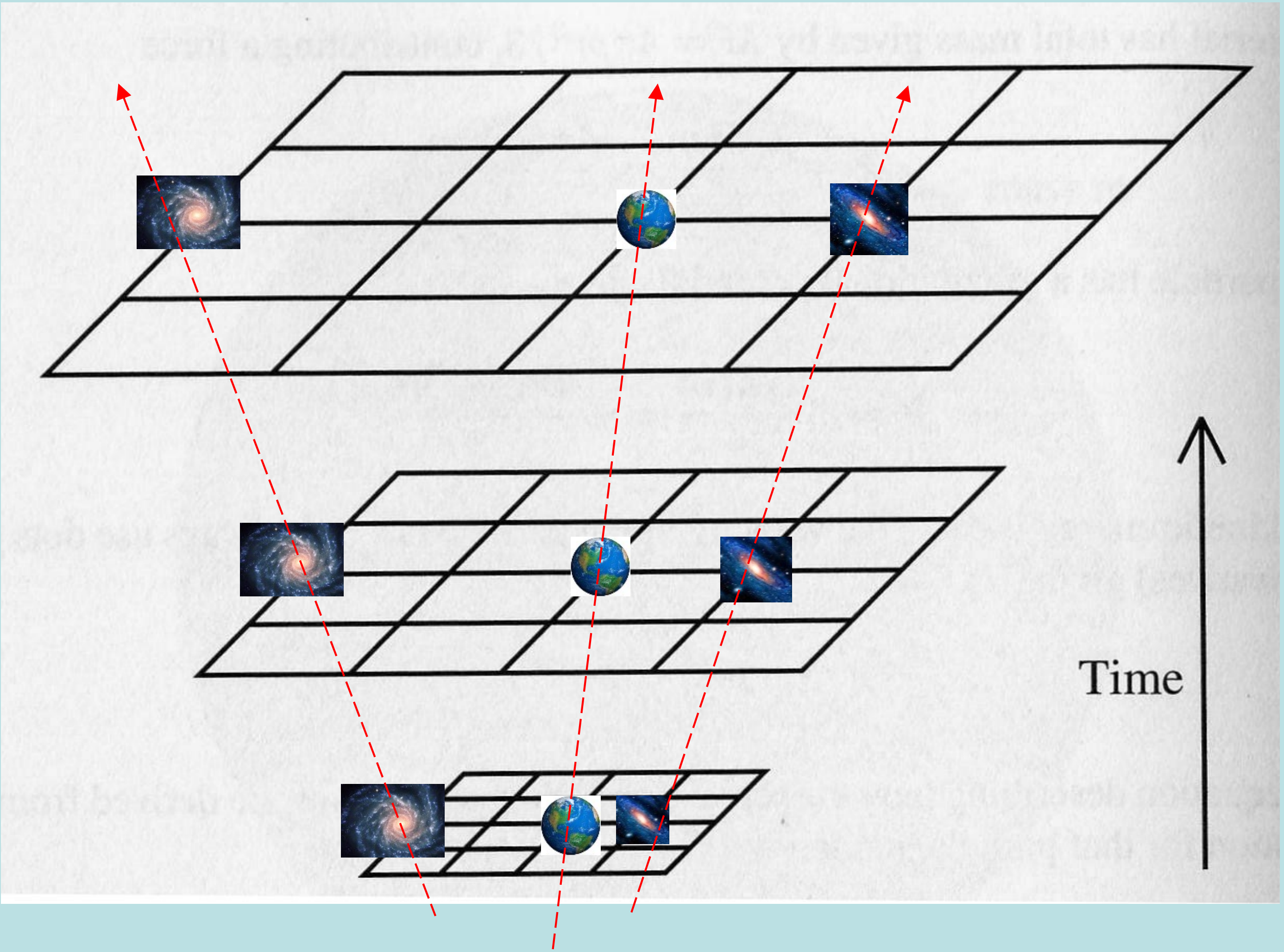


最近的數據，距離已經延伸至億光年。

Hubble發現銀河離開我們的速率，與該銀河與地球的距離成正比！

$v = Hd$ Hubble's Law

而且越遠的星系，紅移越厲害

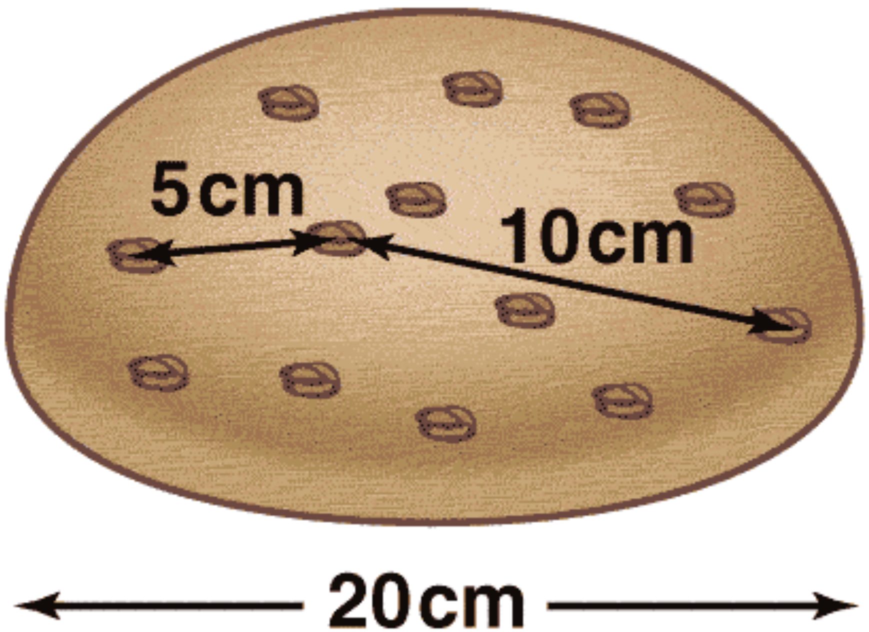


另一個可能是，宇宙是均勻在擴張之中！

想像宇宙的空間中有一測量距離的方格！銀河相對於方格是靜止的。

但宇宙的方格整個在擴張！方格間距隨著時間而越來越大！

那麼越遠的銀河，自然遠離我們的速率越快！ $v = H \cdot d$

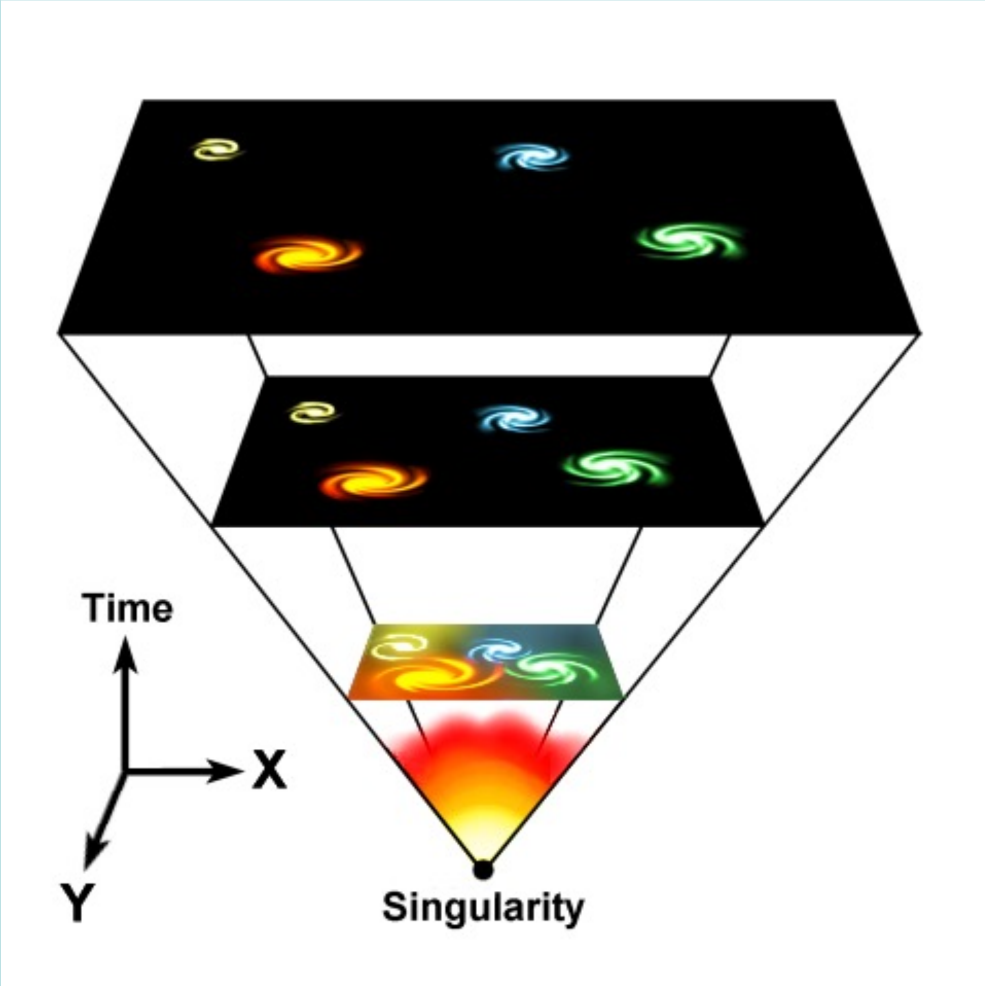


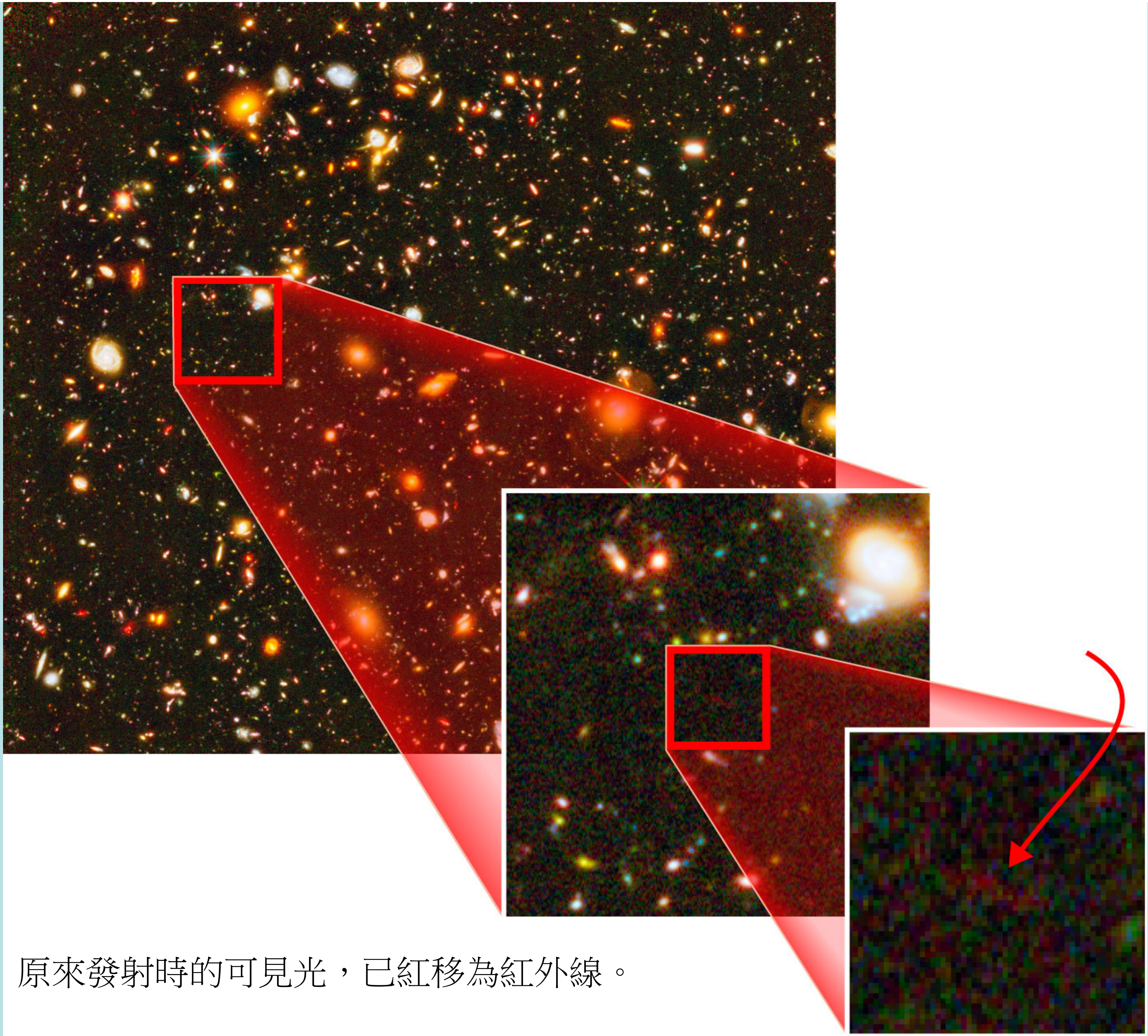
MAP990404

宇宙真得像果凍…….或氣球

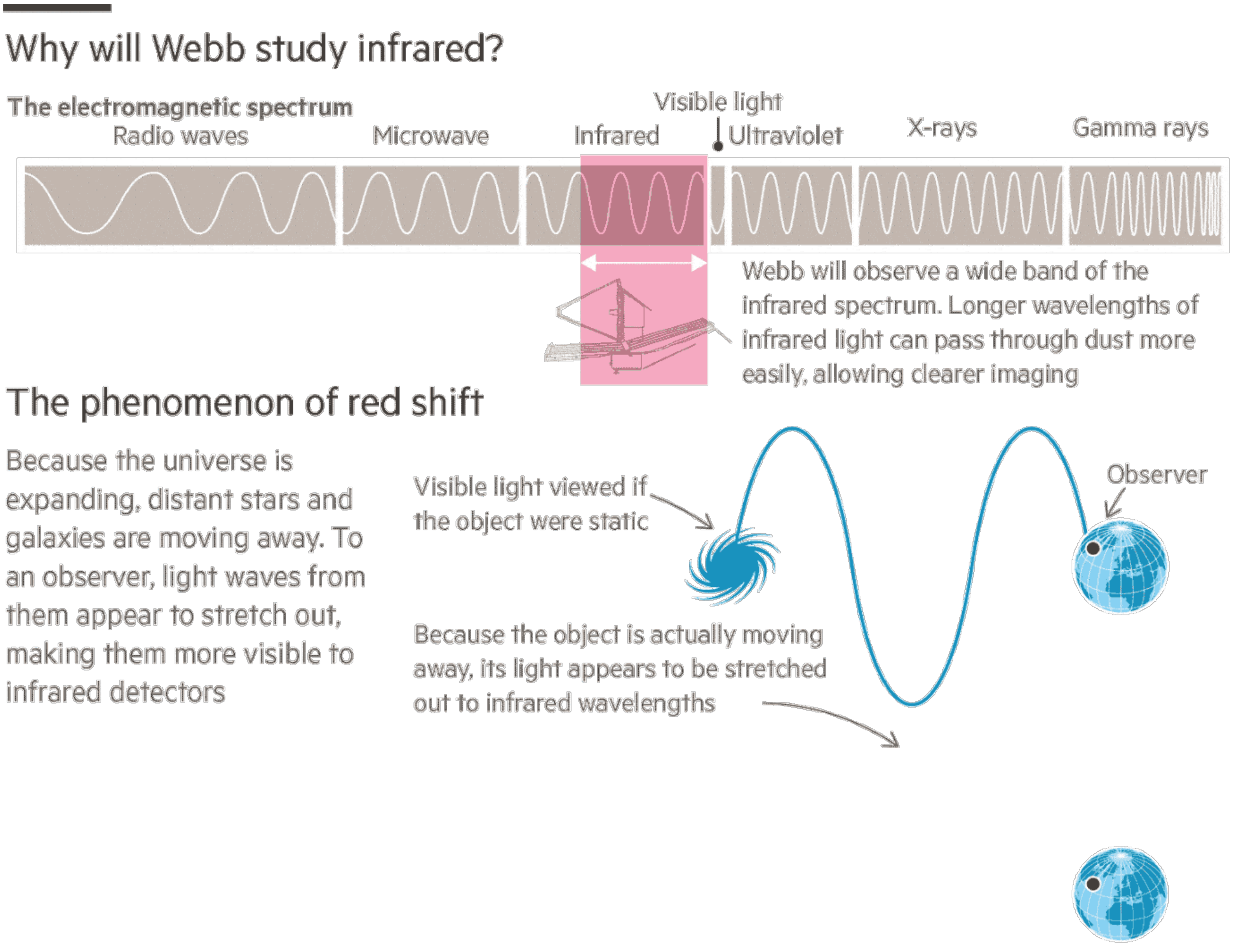
宇宙正在擴張之中

往過去看，宇宙自然就是越來越限縮，因此一定是越來越熱！



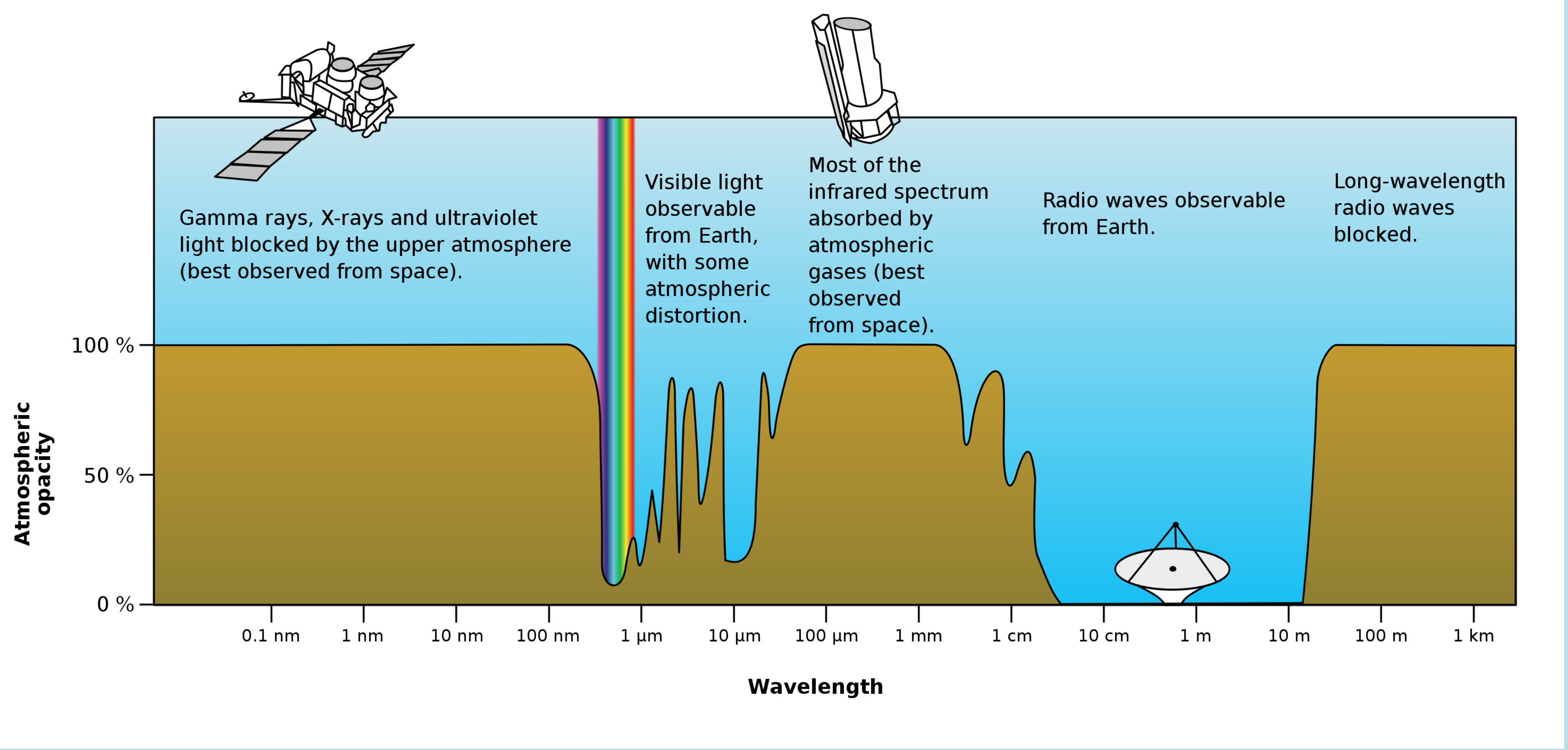


原來發射時的可見光，已紅移為紅外線。



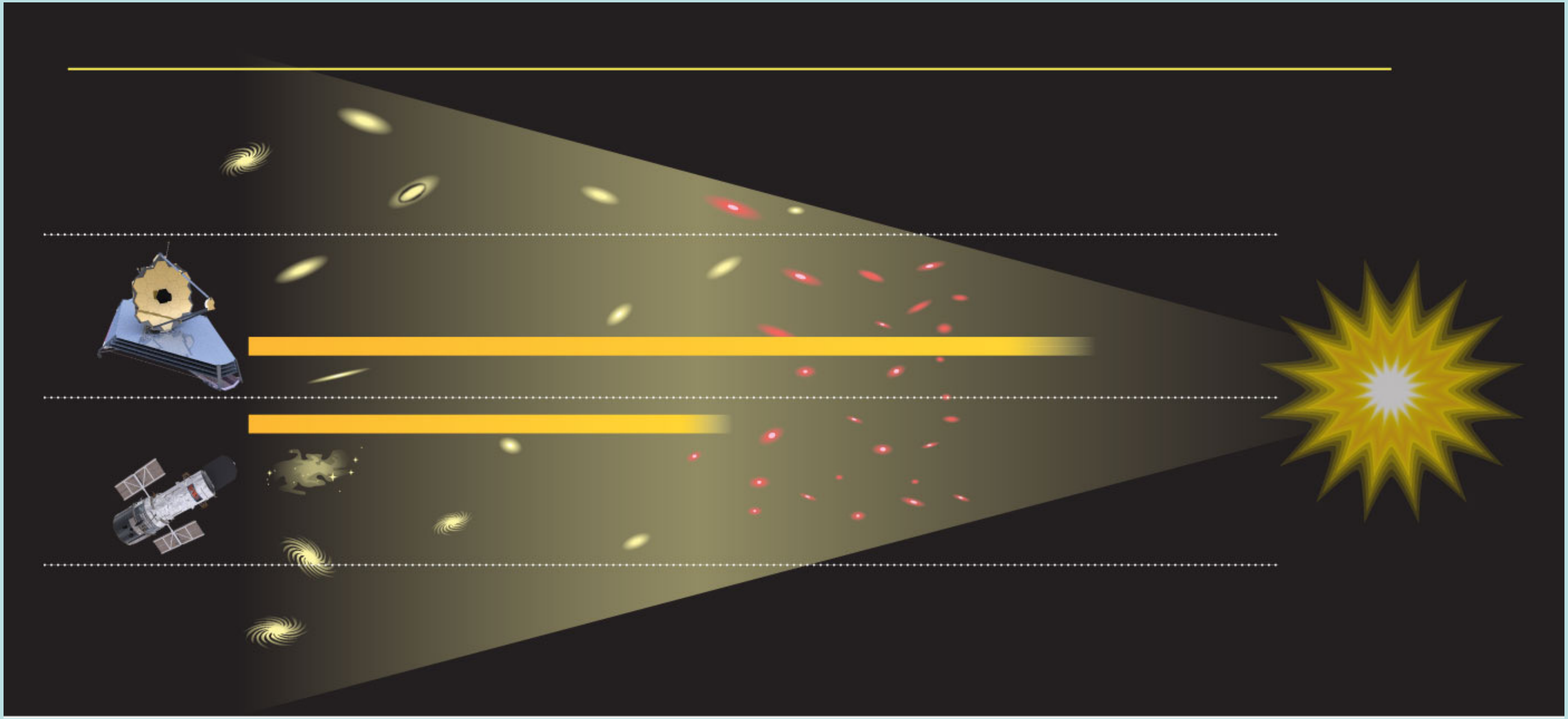
Graphic: Ian Bott
Sources: Nasa; ESA; FT research

越遠的星系，紅移越大，紅外線看更清楚。

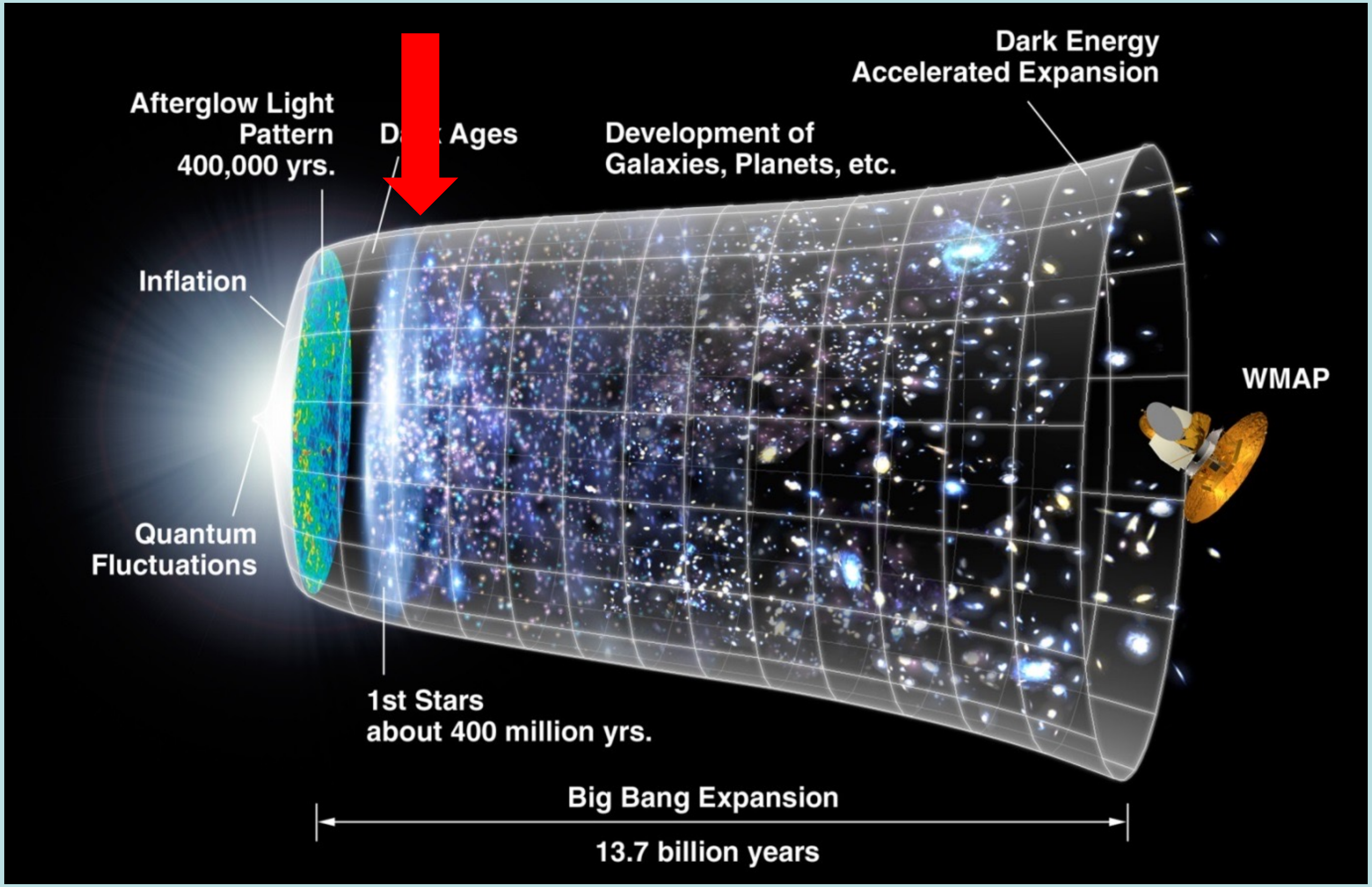


但紅外線會被地球大氣層吸收。

因此得到更高的太空觀察。

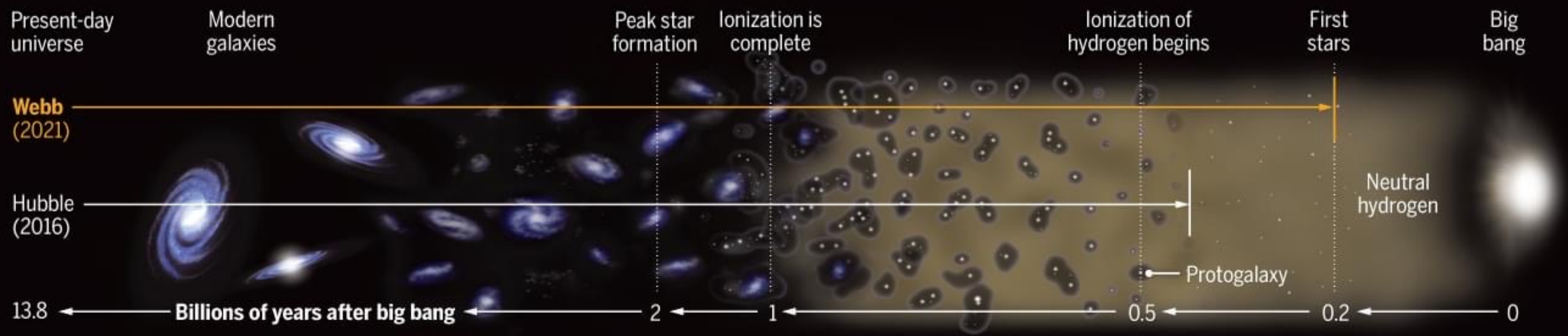


韋伯望遠鏡是一個紅外線望遠鏡，可以看得更遠，也就是更早。


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Da k Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Peering into the past

Webb will reach farther out in space and further back in time than Hubble or ground-based telescopes. It could show how galaxies evolved from ungainly clumps to the elegant spirals and ellipses seen today. It should also reveal whether starlight was sufficient to ionize the hydrogen gas that filled the universe, or whether black holes assisted.

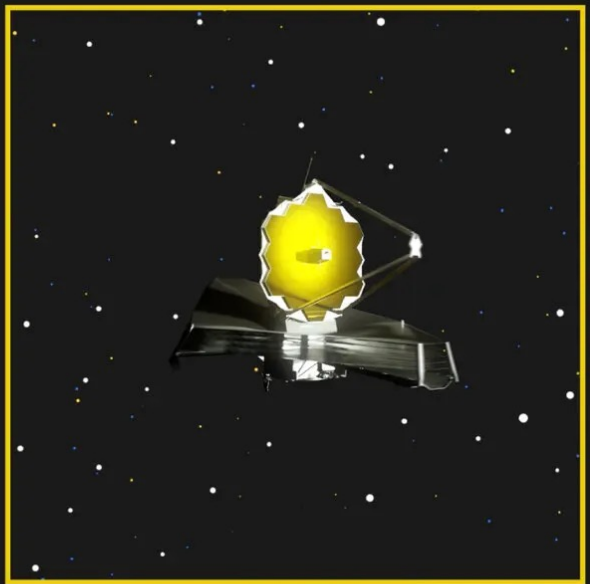


DATA: RYAN MACDONALD/CORNELL UNIVERSITY; NASA

大約是星球生成的時代

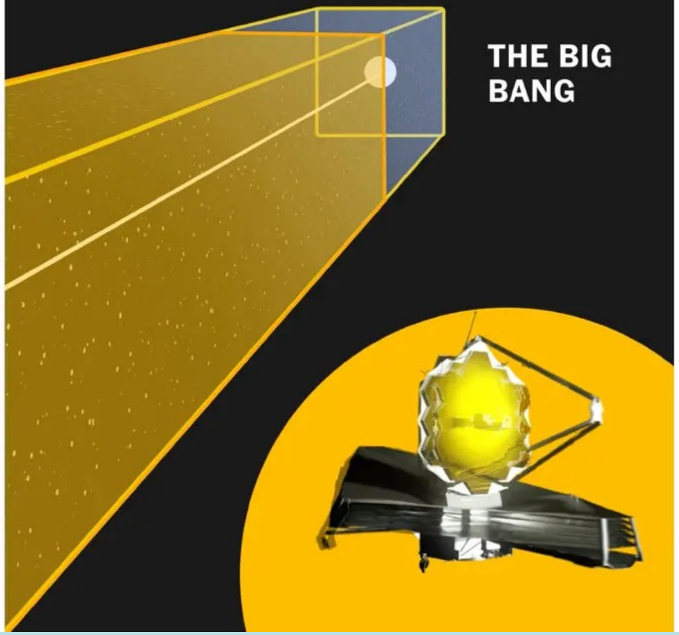
What Will the James Webb Space Telescope See?

After 30 years in development, the largest space telescope in history is scheduled to launch on Dec. 24. It will peer 13 billion years into the past to observe the universe in its infancy.



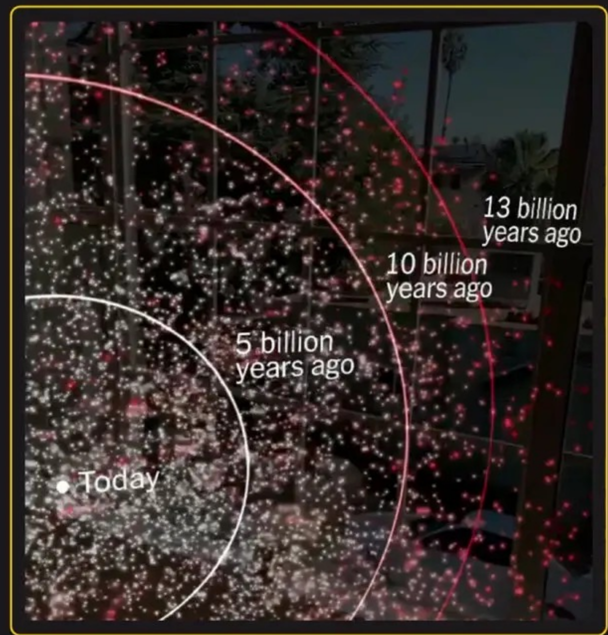
Webb takes us even closer to the beginning.

With a 22-foot mirror and the ability to see invisible infrared light, Webb will reveal the universe when it was just 250 million years old.



We created a 3-D map of the observable universe to show you where Webb will be looking for some of its first missions.

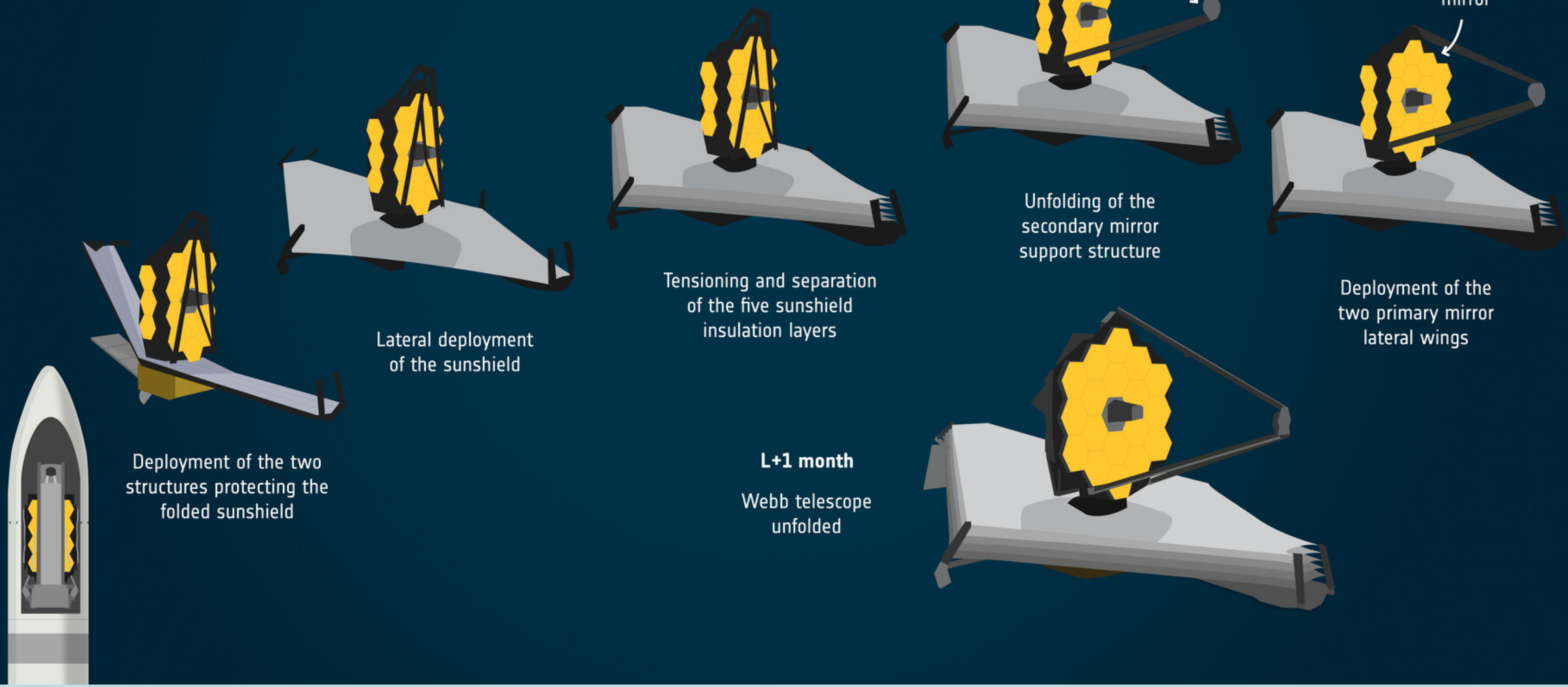
Tap the link to see it in your space with AR.

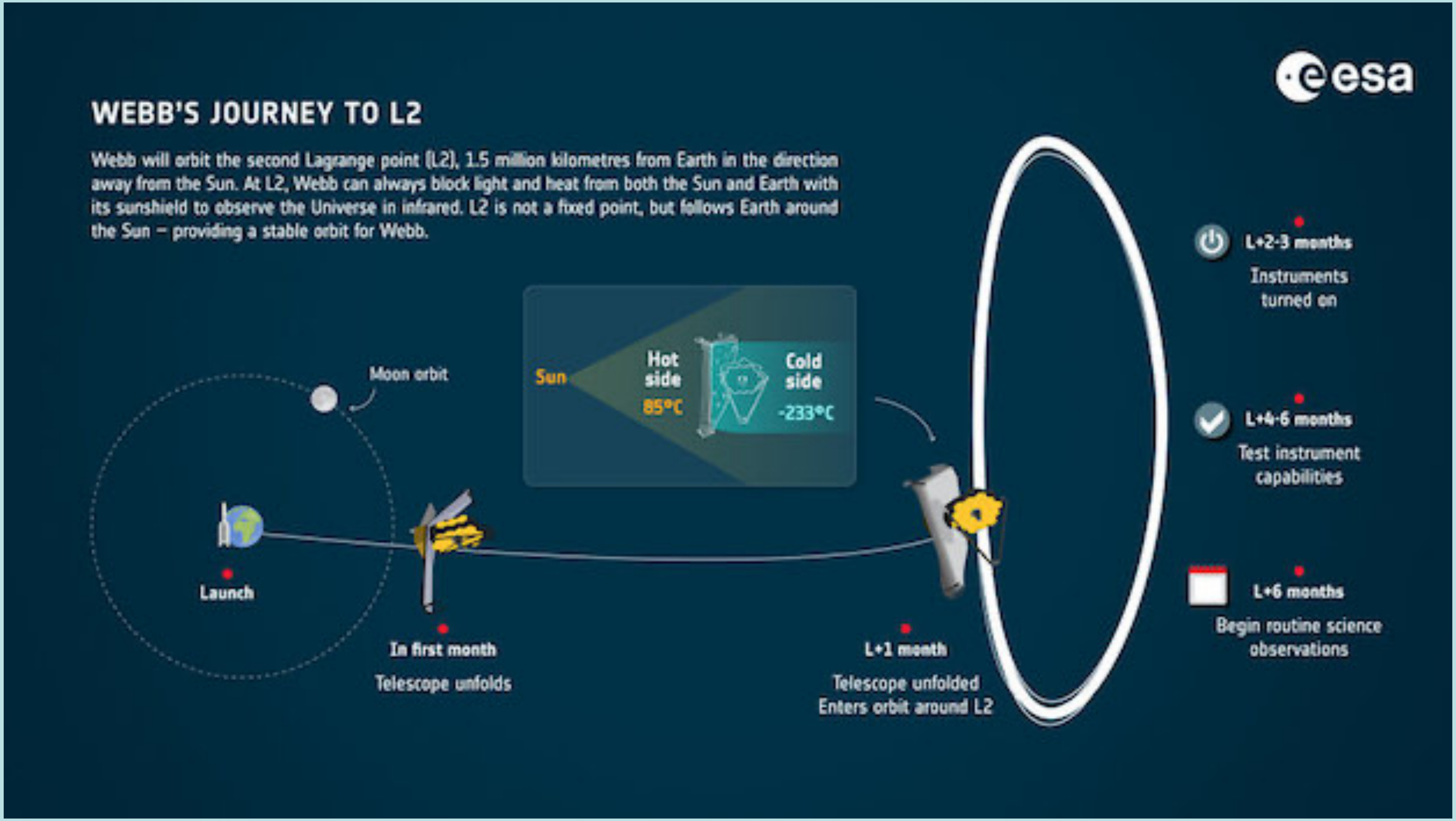


2021耶誕節

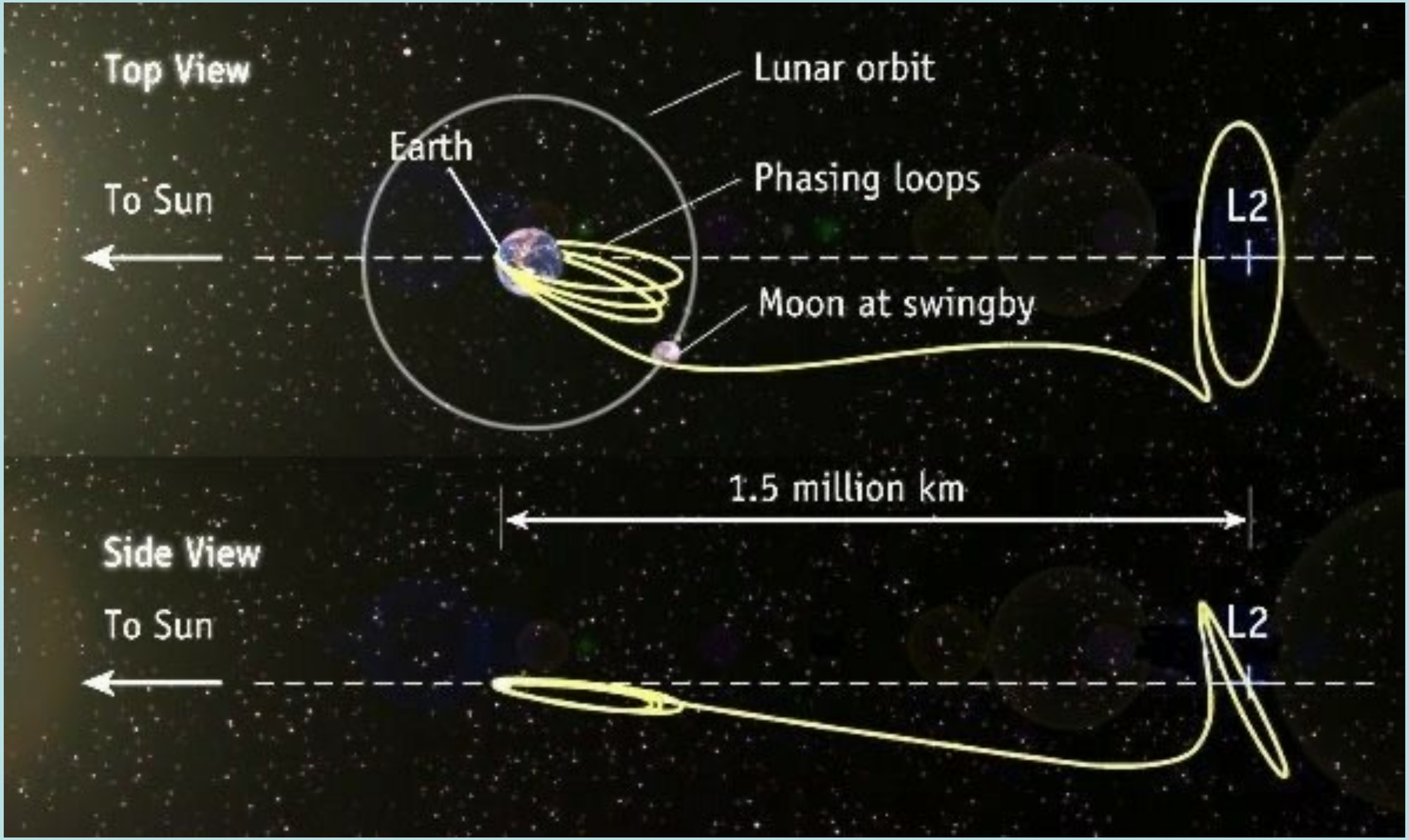
WEBB UNFOLDING SEQUENCE

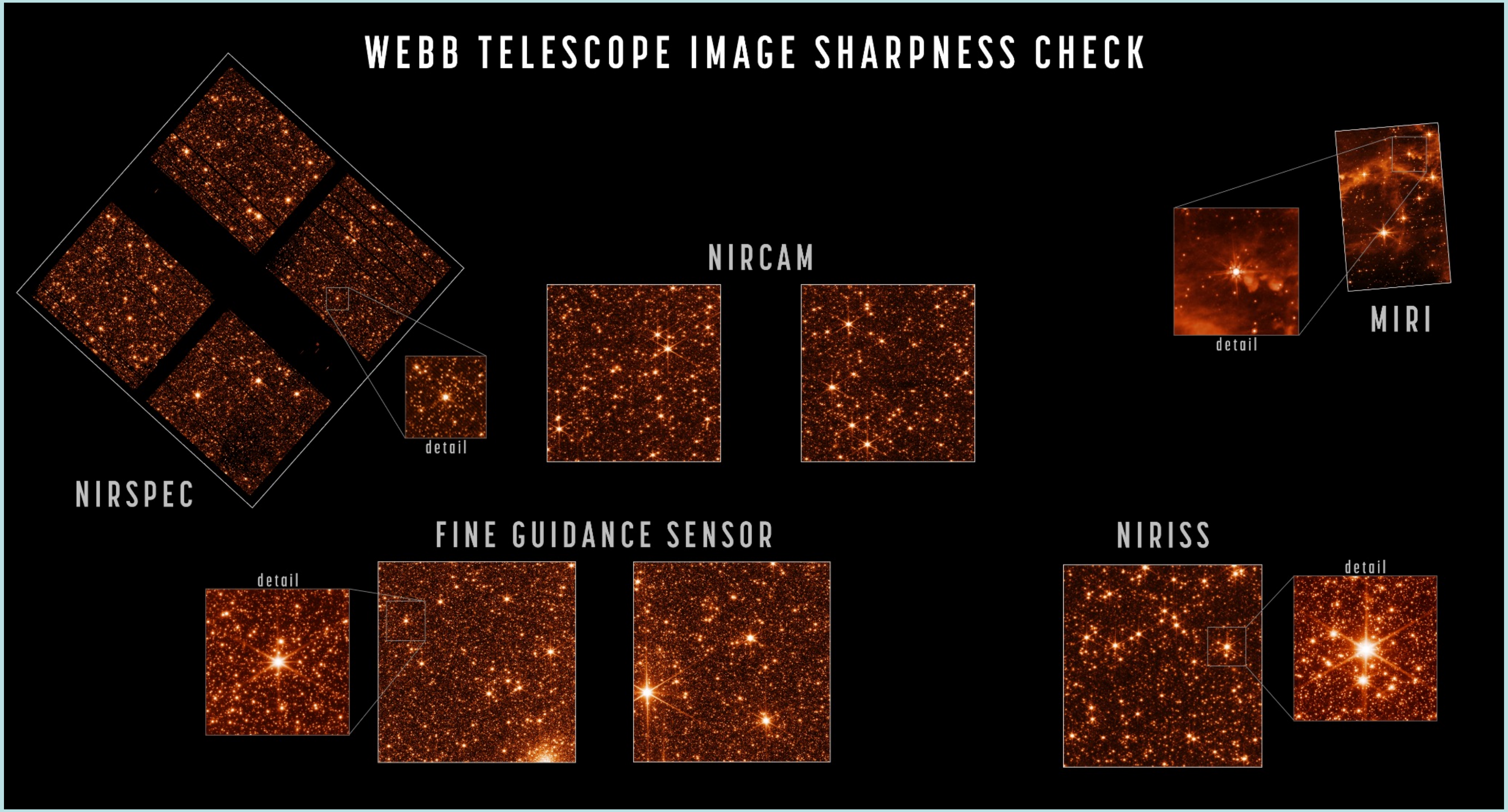
Webb is so big that it has to fold origami-style to fit in the Ariane 5 rocket and it will unfold like a ‘transformer’ in space. This graphic shows a few key steps of the unfolding sequence, which is a complex process that Webb will go through in its month-long journey to L2.





WEBB'S JOURNEY TO L2
Webb will orbit the second Lagrange point (L2), 1.5 million kilometres from Earth in the direction away from the Sun. At L2, Webb can always block light and heat from both the Sun and Earth with its sunshield to observe the Universe in infrared. L2 is not a fixed point, but follows Earth around the Sun – providing a stable orbit for Webb.
Moon orbit
Sun
Hot side
85°C
Cold side
-233°C
Launch
In first month
Telescope unfolds
L+1 month
Telescope unfolded
Enters orbit around L2
L+2-3 months
Instruments turned on
L+4-6 months
Test instrument capabilities
L+6 months
Begin routine science observations


Top View
Lunar orbit
Earth
To Sun
Phasing loops
L2
Moon at swingby
1.5 million km
Side View
To Sun
L2


WEBB TELESCOPE IMAGE SHARPNESS CHECK
NIRSPEC
detail
NIRCAM
MIRI
detail
FINE GUIDANCE SENSOR
detail
NIRISS
detail

人類探索宇宙新突破！韋伯望遠鏡「首高解析彩色圖」曝

2022-07-12 08:19 聯合報／ 編譯張君堯／即時報導

＋ 太空

眾所期盼的詹姆斯韋伯太空 [illegible] 第一張全彩色照片已經發布，而它「並沒有讓人們失望」，詹姆斯韋伯拍攝的更多照片將於12日由美國NASA向全球發布。


THE WHITE HOUSE
WASHINGTON
NASA
JAMES WEBB
SPACE TELESCOPE

第一張韋伯深空區照片，包含上千個星系，每個星系又有上億顆恆星，是宇宙至今最深、最清晰的紅外線影像。照片前景中，大部分星系是屬於星系團SMACS 0723，距離我們大約50億光年。而更顯眼、正要緊的是許多後方更加極度遙遠的星系，它們發出的光先經過SMACS 0723才到地球。被SMACS 0723極大的重力影響，光是彎著走的，所以它們影像好像經過了透鏡，被扭曲、放大成奇怪的形狀，有的看似毛筆隨意的一筆，有的像一段圓弧，有的甚至像是被壓扁了的麵疙瘩。這是典型的重力透鏡效應，

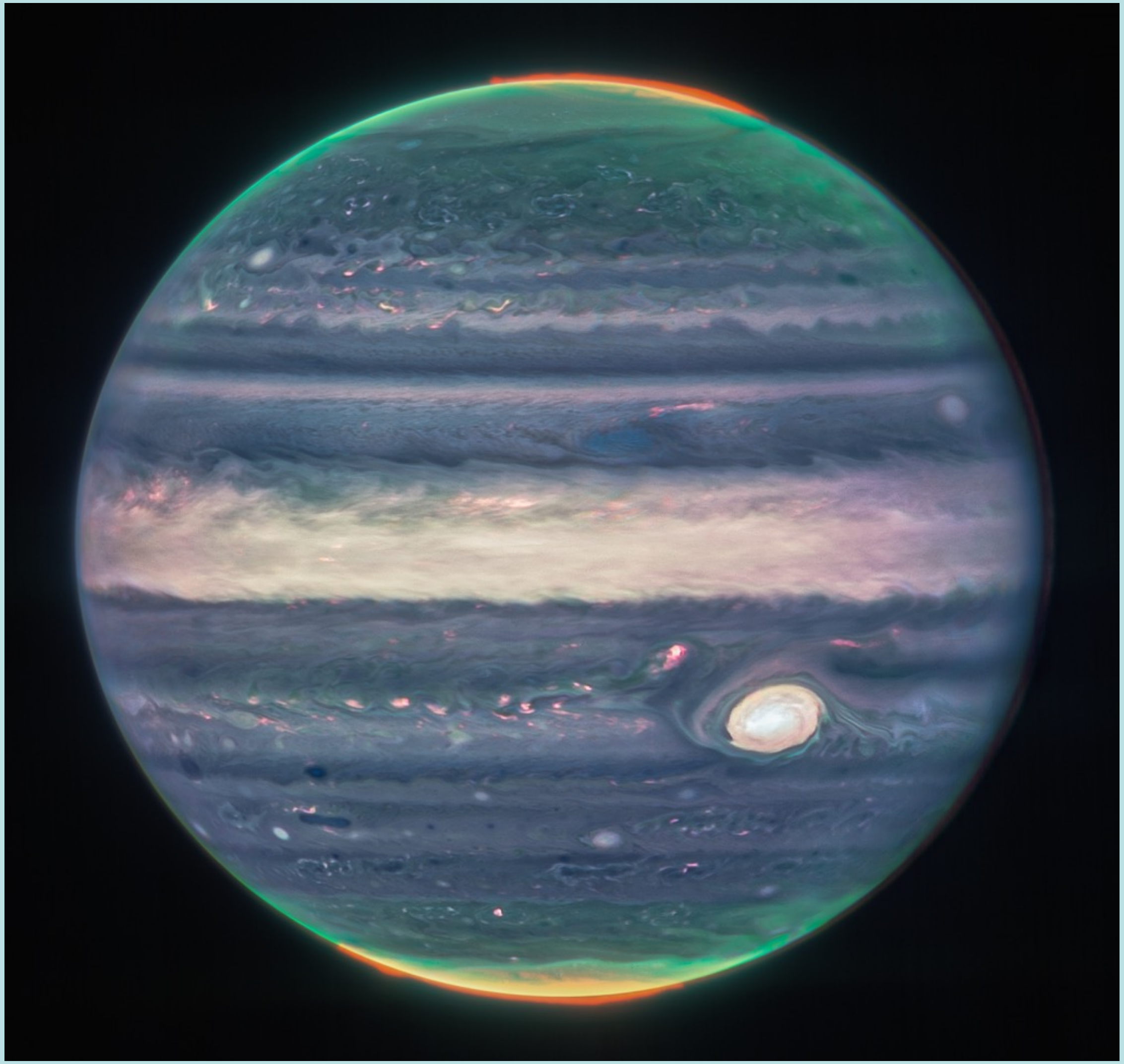
這是典型的重力透鏡效應，韋伯望遠鏡使他們細微結構清晰可見。因為距離極遠，這些光多半來自宇宙誕生初期，所以韋伯不只是一個望遠鏡，還是一個時間機器呢，對這些光仔細研究，將讓我們可以看透整個宇宙的歷史。

第三張照片 南環星雲NGC 3132，距離2,500光年，星雲的中央有一頻死的恆星，正釋放出大量的塵埃與氣體，韋伯望遠鏡將能更細緻的解析氣體的成分與分佈。

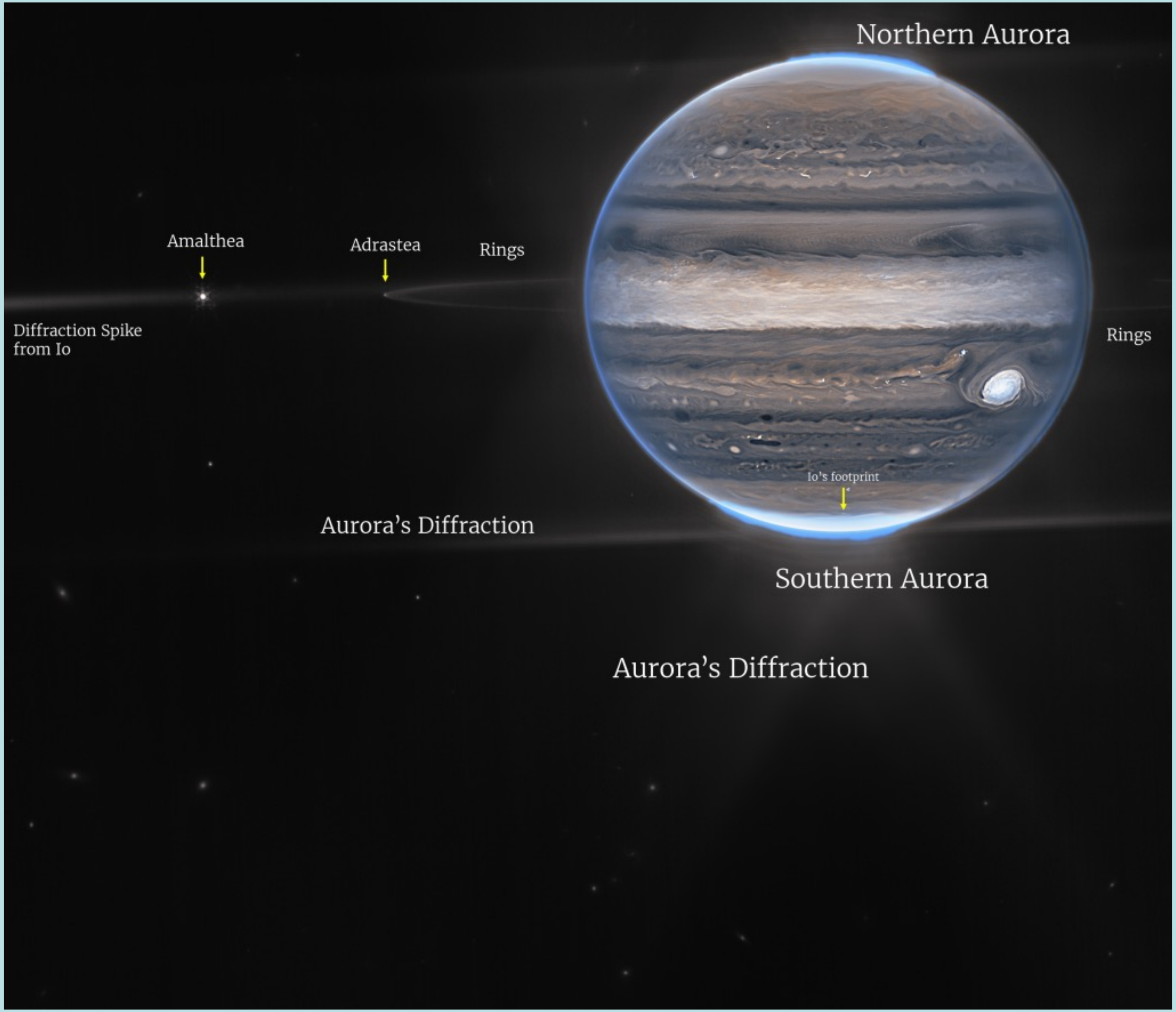
第四張照片 史蒂芬五重奏，五個相互吸引的星系，顯示在早期宇宙，星系彼此的作用、碰撞引發星系的演化。韋伯望遠鏡可以解析在星系交會處，出現激烈的恆星生成，以及大量氣體噴發。這張照片是由將近一千張影像拼接而成，是韋伯至今最大的照片。範圍達到滿月半徑的五分之一。

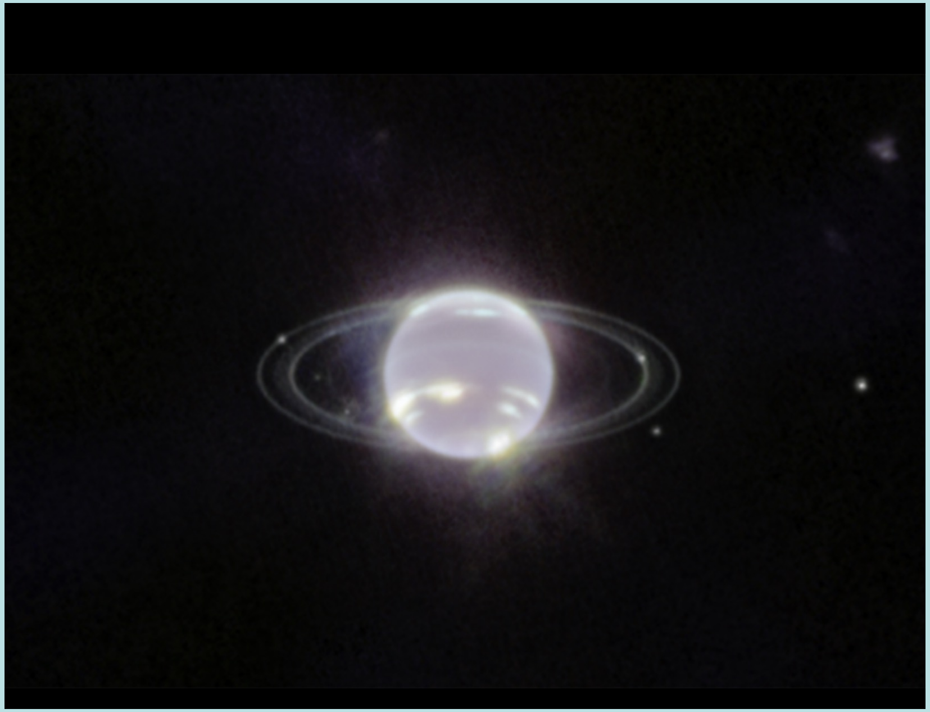
第五張照片 ：NGC 3324內的船底座星雲，這是大量年輕恆星的誕生地。星雲的邊緣看來如同懸崖，這是由上方圖片外，極重極熱的新生成恆星，所發出的強烈紫外線與星際風，所推擠造成。


Hubble
Webb

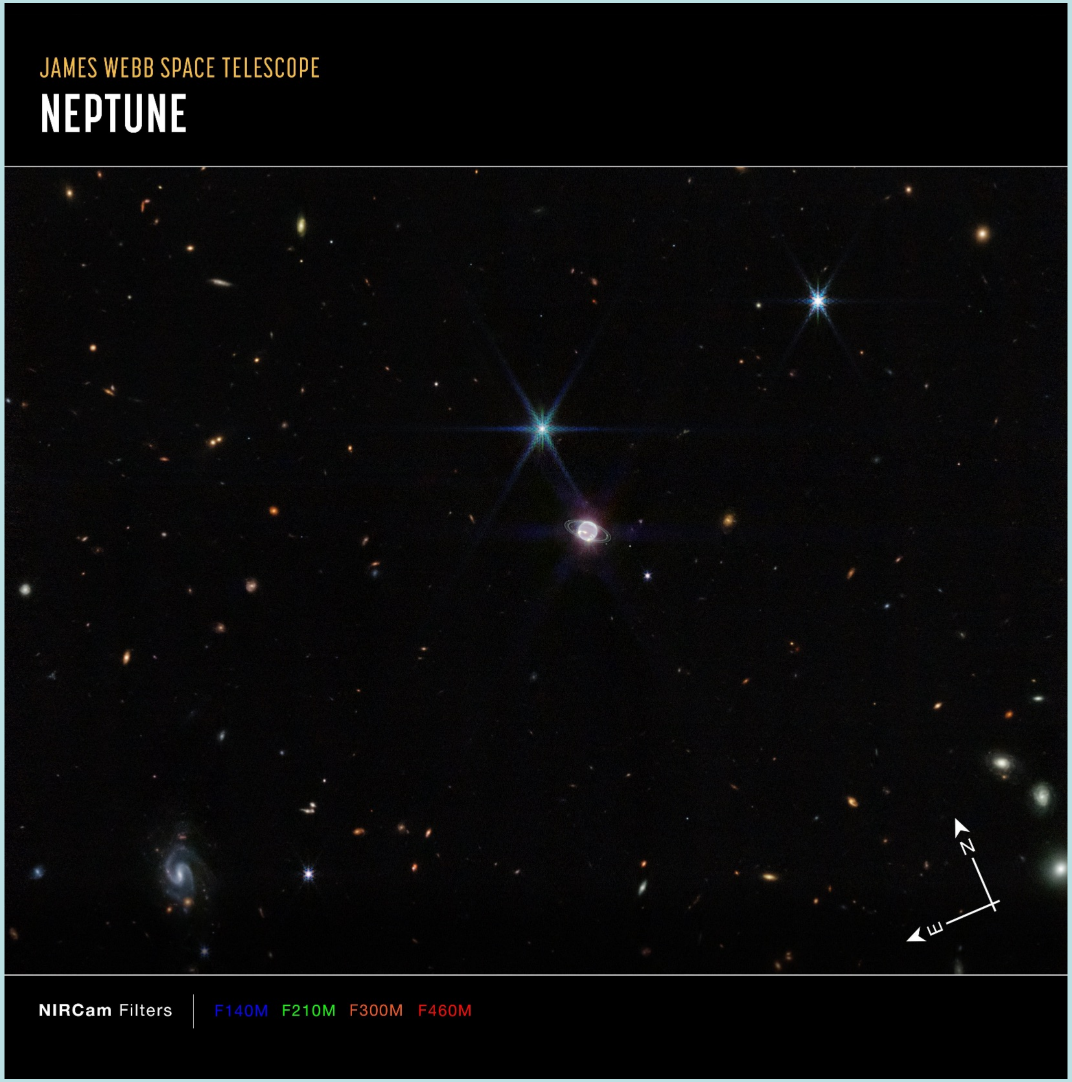


Webb NIRCam composite image of Jupiter from three filters – F360M (red), F212N (yellow-green), and F150W2 (cyan) – and alignment due to the planet's rotation. Credit: NASA


Northern Aurora
Amalthea
Adrastea
Rings
Diffraction Spike
from Io
Rings
Io's footprint
Aurora's Diffraction
Southern Aurora
Aurora's Diffraction

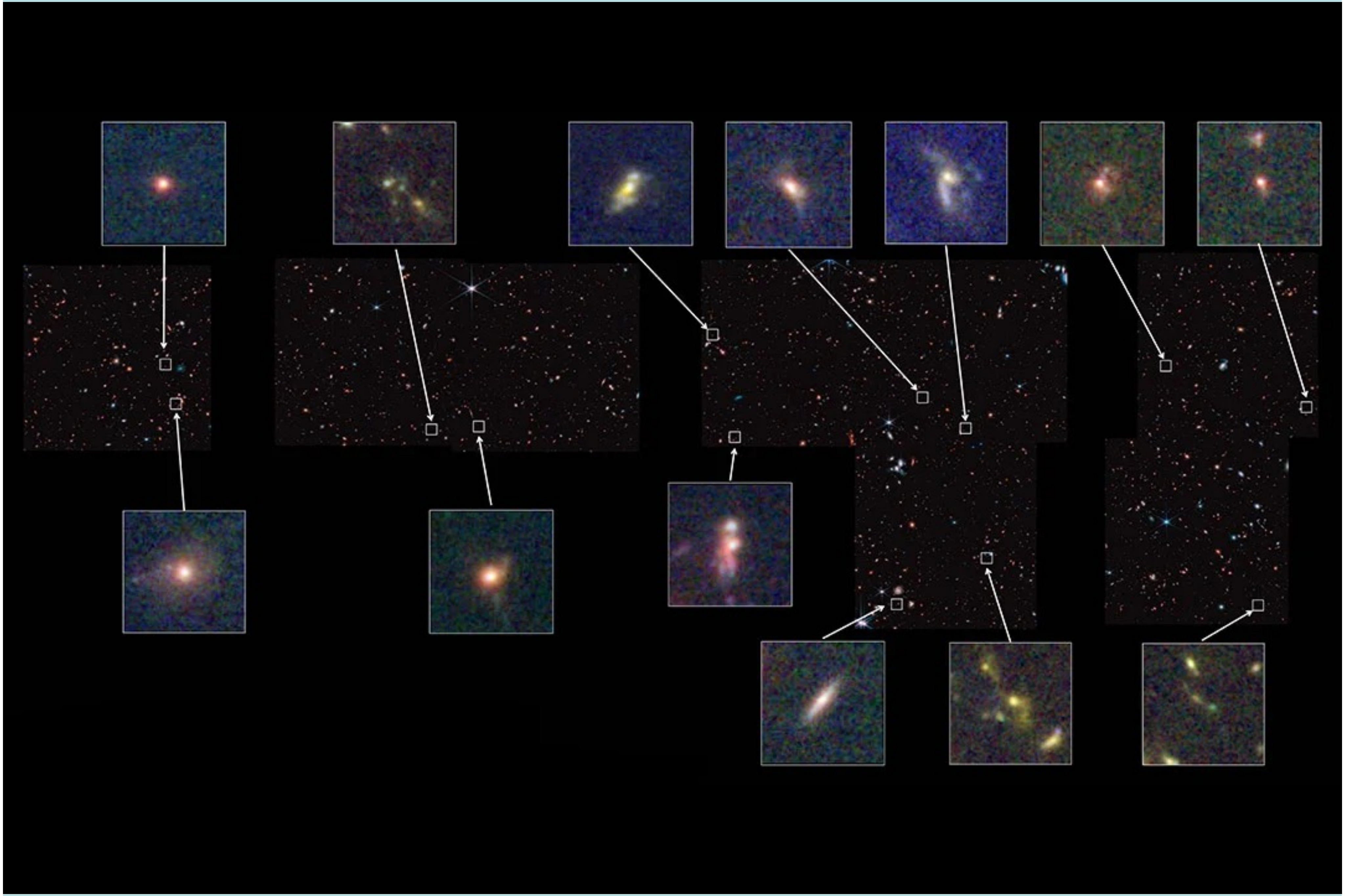


Neptune


JAMES WEBB SPACE TELESCOPE
NEPTUNE
N
E
NIRCam Filters
F140M F210M F300M F460M

週年紀念照

The first anniversary image from NASA's James Webb Space Telescope displays star birth like it's never been seen before, full of detailed, impressionistic texture. The subject is the Rho Ophiuchi cloud complex, the closest star-forming region to Earth. It is a relatively small, quiet stellar nursery, but you'd never know it from Webb's chaotic close-up. Jets bursting from young stars crisscross the image, impacting the surrounding interstellar gas and lighting up molecular hydrogen, shown in red. Some stars display the telltale shadow of a circumstellar disk, the makings of future planetary systems.



JWST's First Glimpses of Early Galaxies Could Break Cosmology

The James Webb Space Telescope's first images of the distant universe shocked astronomers. Is the discovery of unimaginably distant galaxies a mirage or a revolution?

By Jonathan O'Callaghan on September 14, 2022

Astronomers Grapple with JWST's Discovery of Early Galaxies

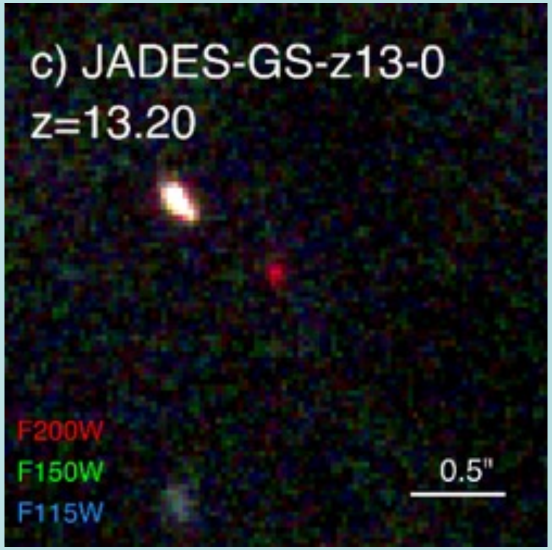
Researchers are convinced the James Webb Space Telescope has glimpsed an unexpected population of galaxies in the early universe. Now they're trying to decide what this means for our understanding of the cosmos

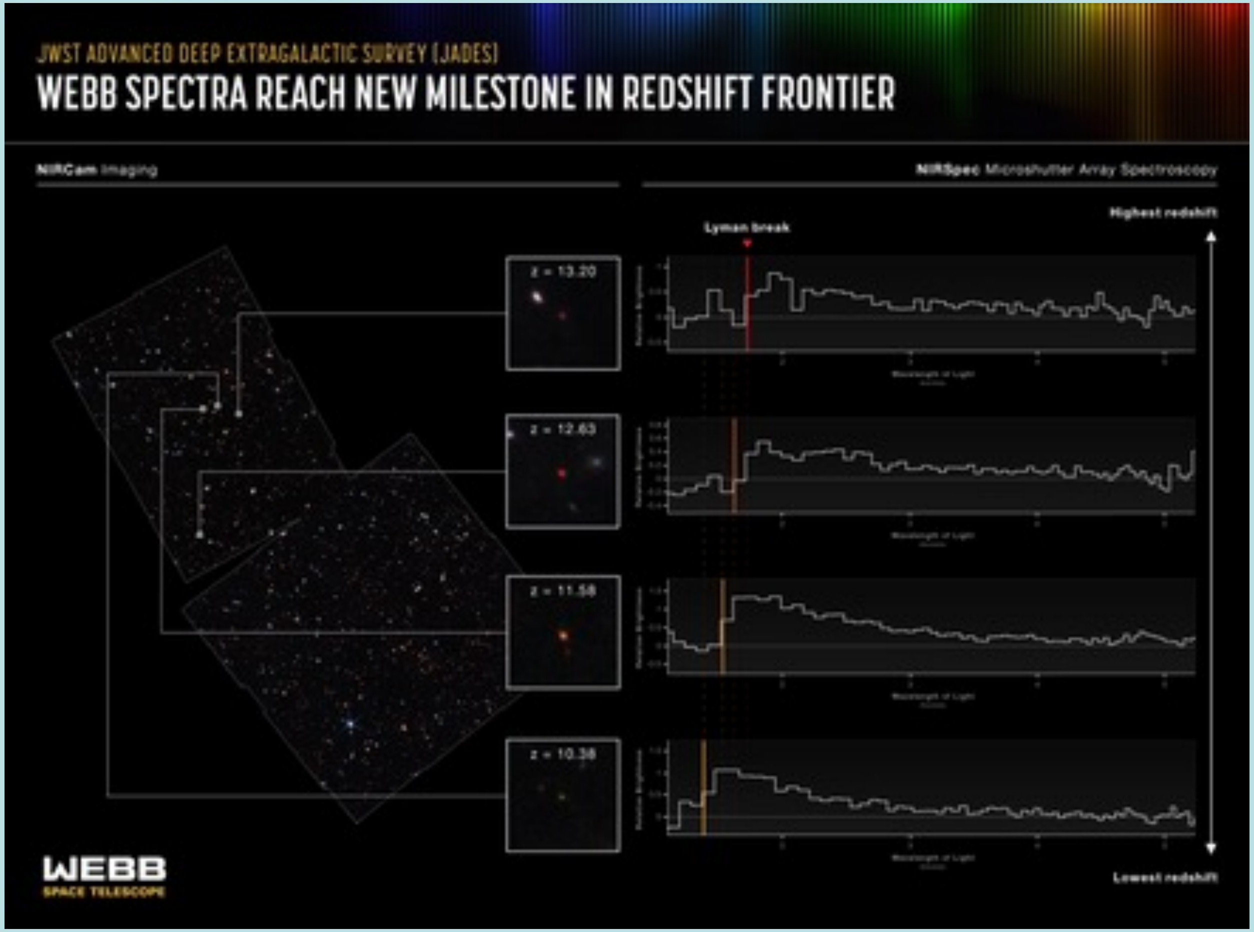
By Jonathan O'Callaghan on December 6, 2022 أعرض هذا باللغة العربية

JWST's Newfound Galaxies Are the Oldest Ever Seen

We now know that the first galaxies in our universe formed shockingly fast, thanks to the latest results from the James Webb Space Telescope

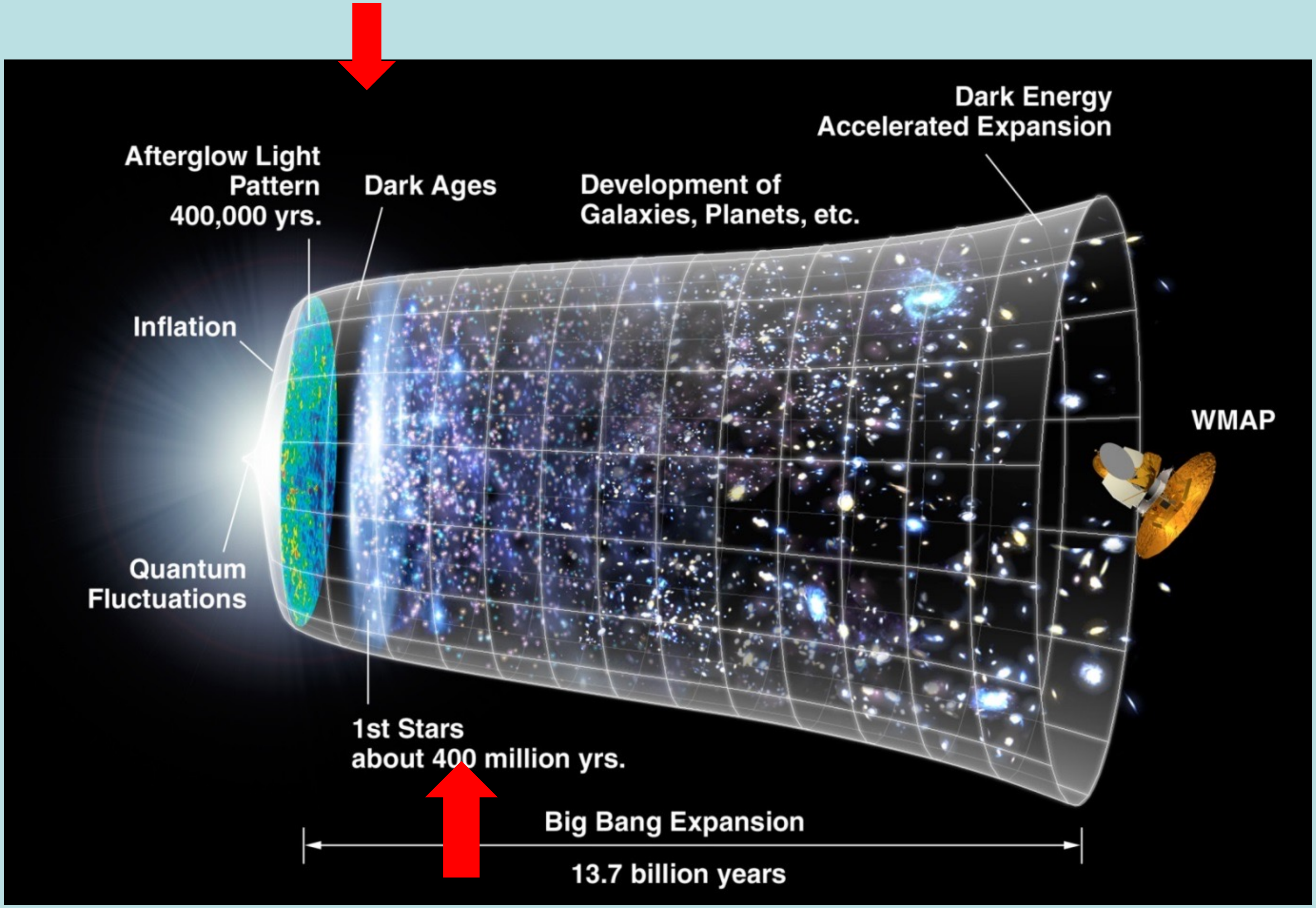
By Jonathan O'Callaghan on April 13, 2023





Of the four, the most distant is one with the somewhat unwieldy name JADES-GS-z13-0. It has a redshift value of 13.2, meaning we are seeing the galaxy as it appeared just 320 million years after the big bang. That high redshift makes JADES-GS-z13-0 the most distant currently known in the universe

JADES-GS-z13-0



我們竟然在宇宙論預測第一個恆星生成的霹靂後4億年之前的3億年找到星系。

JWST's First Glimpses of Early Galaxies Could Break Cosmology

3 Years of Science: 10 Cosmic Surprises from NASA's Webb Telescope

Since July 2022, NASA's James Webb Space Telescope has been unwaveringly focused on our universe. With its unprecedented power to detect and analyze otherwise invisible infrared light, Webb is making observations that were once impossible, changing our view of the cosmos from the most distant galaxies to our own solar system.

Webb was built with the promise of revolutionizing astronomy, of rewriting the textbooks. And by any measure, it has more than lived up to the hype — exceeding expectations to a degree that scientists had not dared imagine. Since science operations began, Webb has completed more than 860 scientific programs, with one-quarter of its time dedicated to imaging and three-quarters to spectroscopy. In just three years, it has collected nearly 550 terabytes of data, yielding more than 1,600 research papers, with intriguing results too numerous to list and a host of new questions to answer.

Here are just a few noteworthy examples.

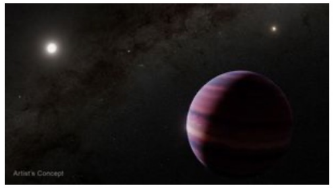
1. The universe evolved significantly faster than we previously thought.

The JADES Deep Field uses observations taken by NASA's James Webb Space Telescope (JWST) as part of the JADES (JWST Advanced Deep Extragalactic Survey) program. A team of astronomers studying JADES data identified about 80 objects that changed in brightness over time. Most of these objects, known as transients, are the result of exploding stars or supernovae. Prior to this survey, only a handful of supernovae had been found above a redshift of 2, which corresponds to when the universe was only 3.3 billion years old — just 25% of its current age. The JADES sample contains many supernovae that exploded even further in the past, when the universe was less than 2 billion years old. It includes the farthest one ever spectroscopically confirmed, at a redshift of 3.6. Its progenitor star exploded when the universe was only 1.8 billion years old.
NASA, ESA, CSA, STScI, JADES Collaboration

Webb Narrows Atmospheric Possibilities for Earth-sized Exoplanet TRAPPIST-1 d

The exoplanet TRAPPIST-1 d intrigues astronomers looking for possibly habitable worlds beyond our solar system because it is similar in size to Earth, rocky, and resides in an area around its star where liquid water on its surface is theoretically...

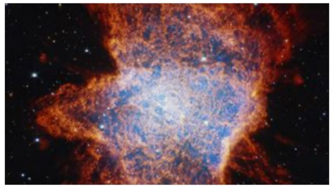
ARTICLE



NASA's Webb Finds New Evidence for Planet Around Closest Solar Twin

Astronomers using NASA's James Webb Space Telescope have found strong evidence of a giant planet orbiting a star in the stellar system closest to our own Sun. At just 4 light-years away from Earth, the Alpha Centauri triple star system...

ARTICLE



NASA's Webb Traces Details of Complex Planetary Nebula

Since their discovery in the late 1700s, astronomers have learned that planetary nebulae, or the expanding shell of glowing gas expelled by a low-intermediate mass star late in its life, can come in all shapes and sizes. Most planetary nebula...

ARTICLE

NASA's Webb Scratches Beyond Surface of Cat's Paw for 3rd Anniversary

It's the cat's meow! To celebrate its third year of revealing stunning scenes of the cosmos in infrared light, NASA's James Webb Space Telescope has "clawed" back the thick, dusty layers of a section within the Cat's Paw Nebula (NGC...

ARTICLE

Downloads

NASA's James Webb Space Telescope's near-infrared view of the Cat's Paw Nebula reveals mini "toe beans." Massive young stars are carving the gas and dust while their bright starlight is producing a bright nebulous glow. Eventually this turbulent region will quench star formation.
NASA, ESA, CSA, STScI.

氣候變遷

SOCIAL AND ECONOMIC IMPACT
OF CLIMATE CHANGE

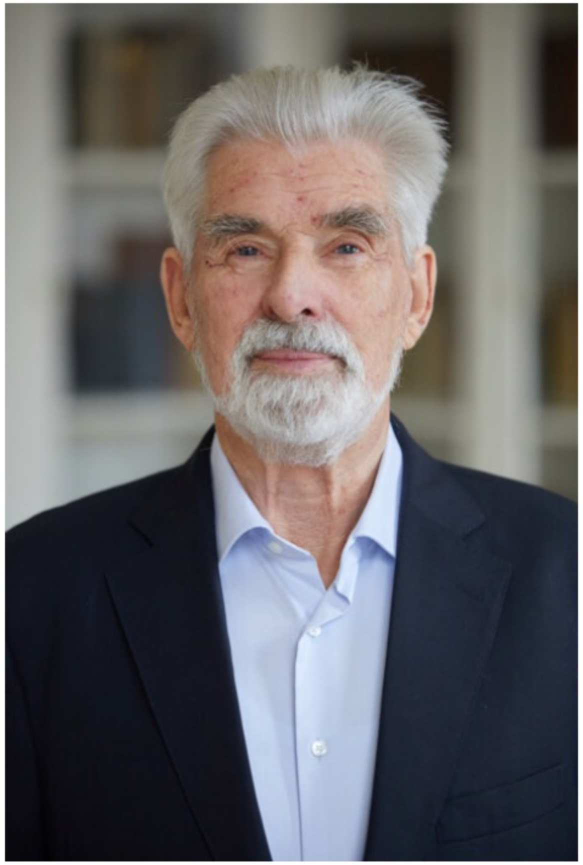
- The cost of **adapting coastal areas** to rising sea levels
- Loss of the **capacity to work** due to heat
- More wars to gain **access to limited resources**
- **Fresh water will be in short supply** in some areas
- Relocation of **whole towns**
- Shrinking **productivity of harvests**
- Prices of **basic foodstuffs and consumer goods** will rise
- **Extreme meteorological phenomena** will cause widespread poverty
- Diseases will spread due to **higher temperatures**

The Nobel Prize in Physics 2021

© Nobel Prize Outreach. Photo: Risdon Photography

Syukuro Manabe

Prize share: 1/4



© Nobel Prize Outreach. Photo: Bernhard Ludewig

Klaus Hasselmann

Prize share: 1/4

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Giorgio Parisi

Prize share: 1/2

Screenshot

"for groundbreaking contributions to our understanding of complex physical systems"

with one half jointly to

Syukuro Manabe
Princeton University, USA

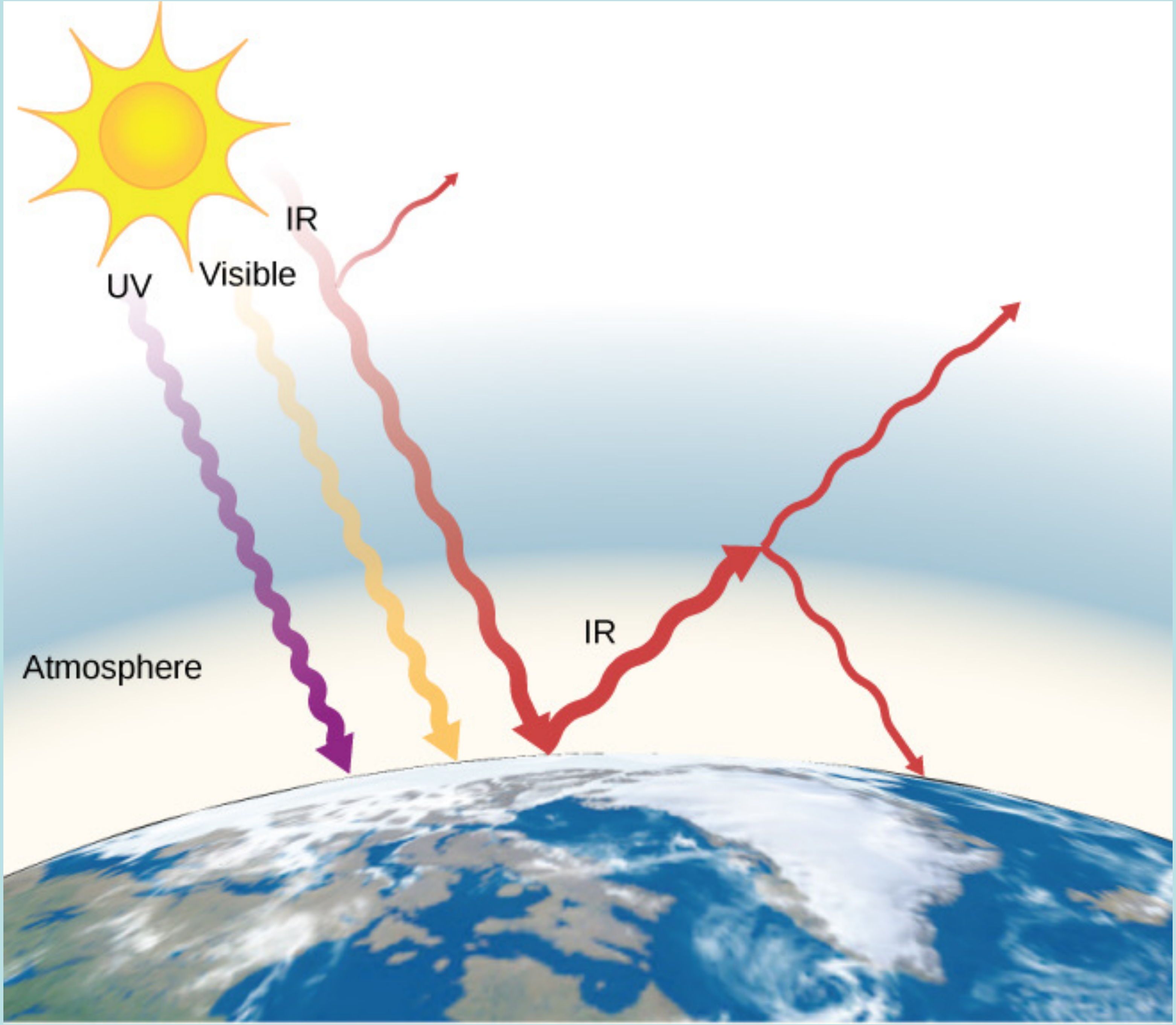
Klaus Hasselmann
Max Planck Institute for Meteorology, Hamburg, Germany

"for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

and the other half to

Giorgio Parisi
Sapienza University of Rome, Italy

"for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales"


IR
UV
Visible
IR
Atmosphere

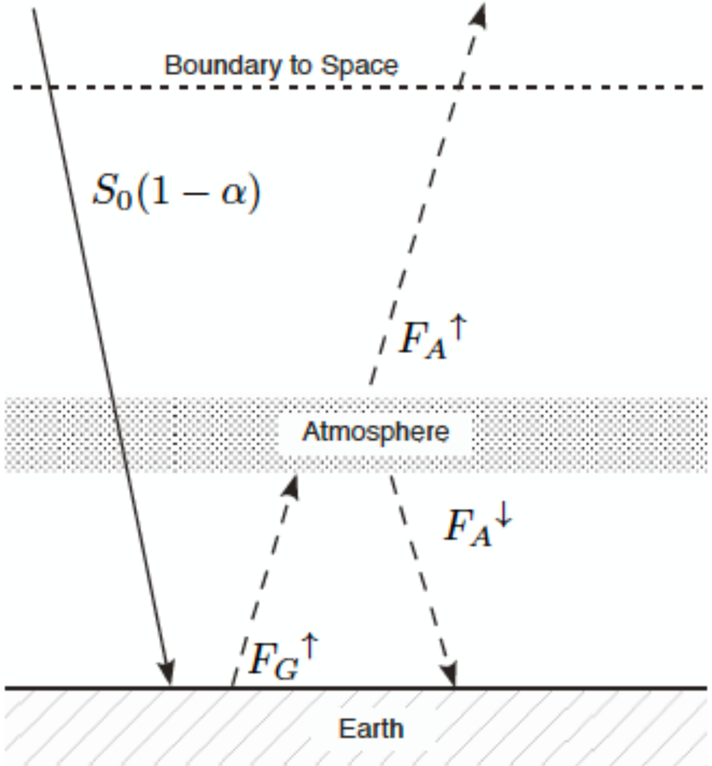
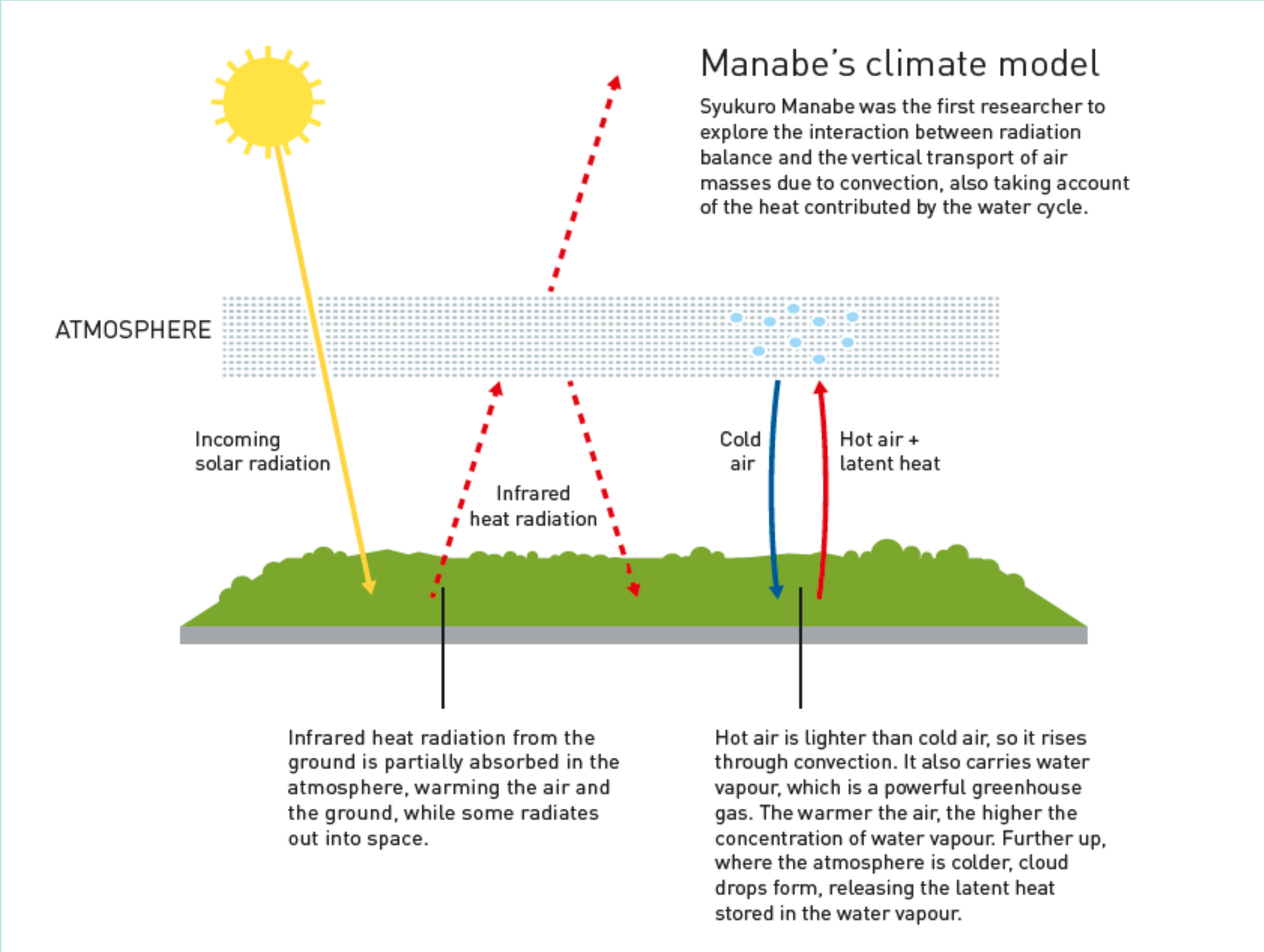


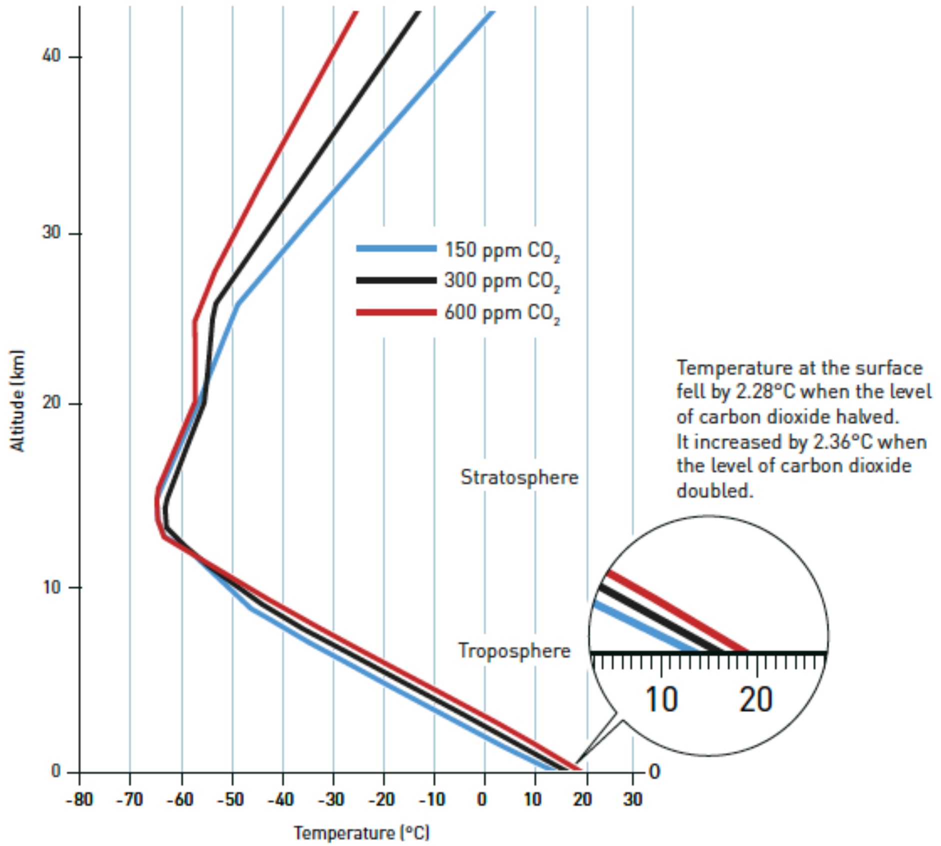
FIG. 5. Approximately as envisioned by Svante Arrhenius in 1896 [6], a "one-layer atmosphere" over Earth that absorbs and emits the outgoing infrared radiation from the surface $F_G{}^{\uparrow}$. We assume the outgoing atmospheric infrared emission is the same as the incoming, and that the atmosphere is isothermal, so that $F_A{}^{\downarrow} = F_A{}^{\uparrow} \equiv F_A$. Modified from [5].



真鍋先生的模型將溫度隨高度的變化考慮進去，以數值模擬大氣的流動與熱導：

Carbon dioxide heats the atmosphere

Increased levels of carbon dioxide lead to higher temperatures in the lower atmosphere, while the upper atmosphere gets colder. Manabe thus confirmed that the variation in temperature is due to increased levels of carbon dioxide; if it was caused by increased solar radiation, the entire atmosphere should have warmed up.



Source: Manabe and Wetherald (1967) Thermal equilibrium of the atmosphere with a given distribution of relative humidity, *Journal of the atmospheric sciences*, Vol. 24, Nr 3, May.

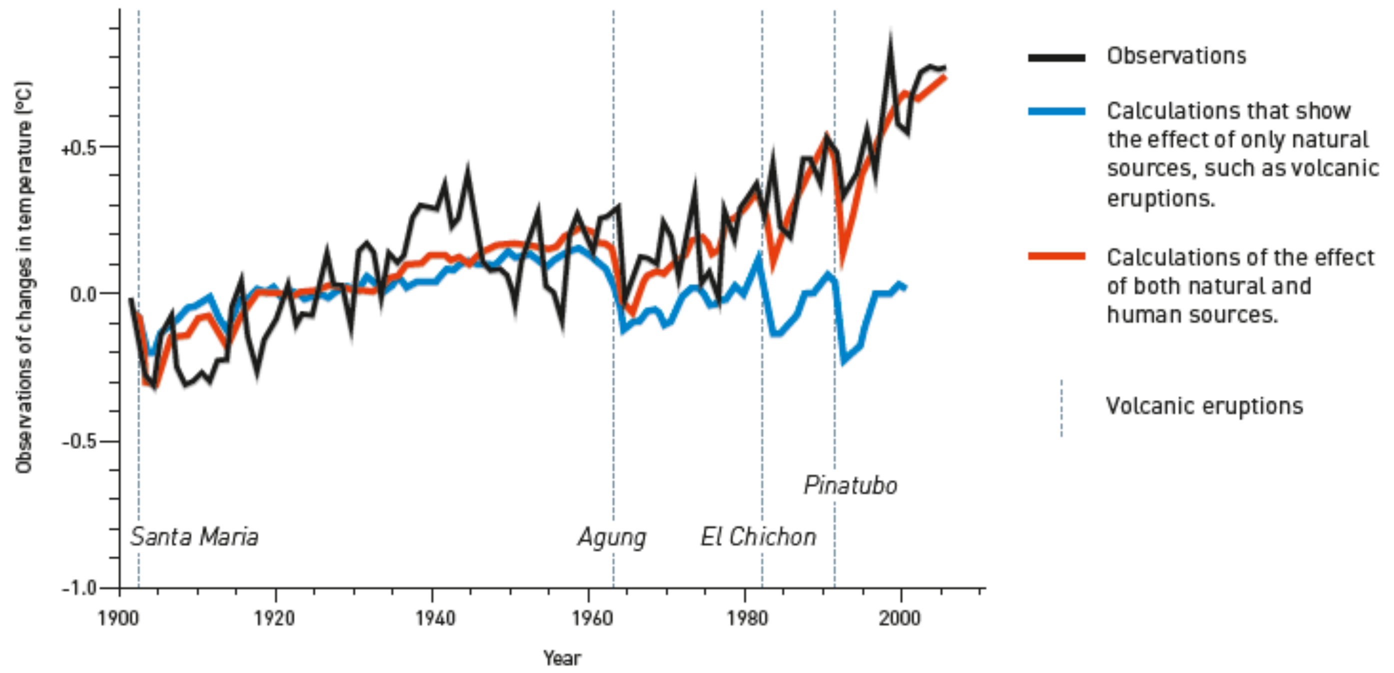
模擬不同的溫室氣體濃度下，不同高度的大氣溫度。

溫室氣體濃度增加一倍，地表溫度增加約2°C。

高層溫度反而降低。這是因地球反射的熱被溫室氣體束縛在低層。

Identifying fingerprints in the climate

Klaus Hasselmann developed methods for distinguishing between natural and human causes (fingerprints) of atmospheric heating. Comparison between changes in the mean temperature in relation to the average for 1901–1950 (°C).



Source: Hegerl and Zweirs (2011) Use of models in detection & attribution of climate change, *WIREs Climate Change*.

模擬有溫室氣體(紅)與無溫室氣體(藍)時，地表溫度的歷史變化。

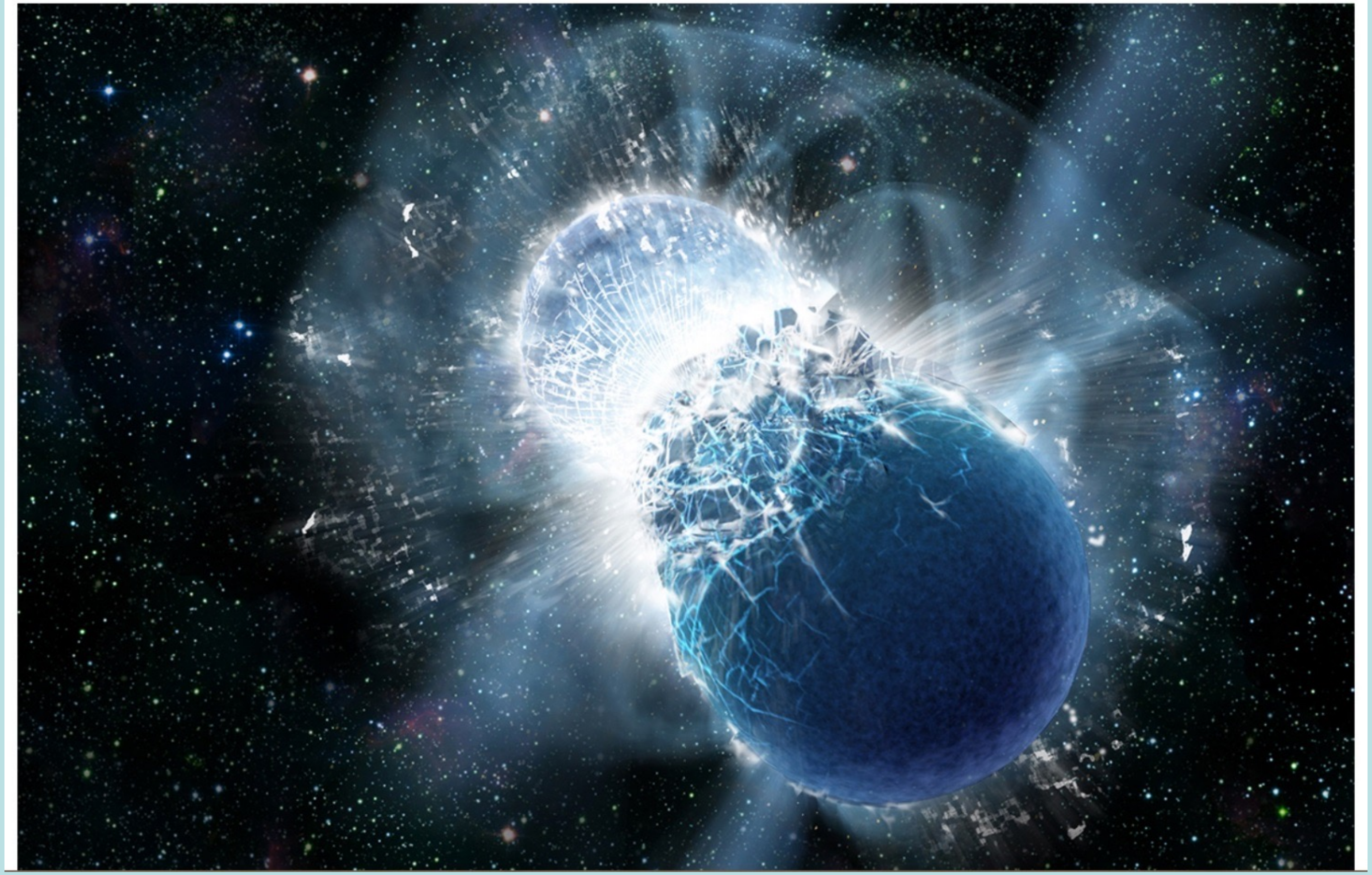
與實際觀測比對，如此才能在科學上以數值確立溫室氣體對氣候變遷的影響。

It is an exciting time to be a scientist!

做科學很令人興奮!

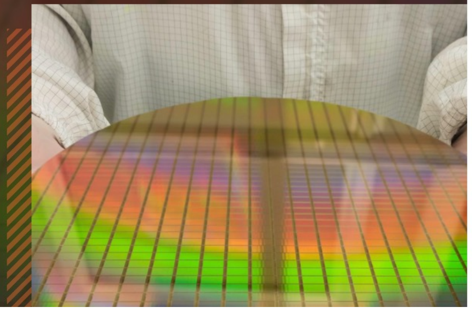
DAILY NEWS 23 August 2017, updated 23 August 2017

Exclusive: We may have detected a new kind of gravitational wave



科學家還有其他職涯的可能：加強數理與英文能力

鏡好聽 MIRROR VOICE　發現　節目　有聲書　課程　節目主持人/有聲書主播　訂閱說明　APP下載　登入 / 註冊



節目　知識好好玩

EP08｜台灣這美麗的矽島——聊一聊半導體物理

主持人｜張嘉泓

單曲長度｜00:25:46　發布時間｜2021-08-03

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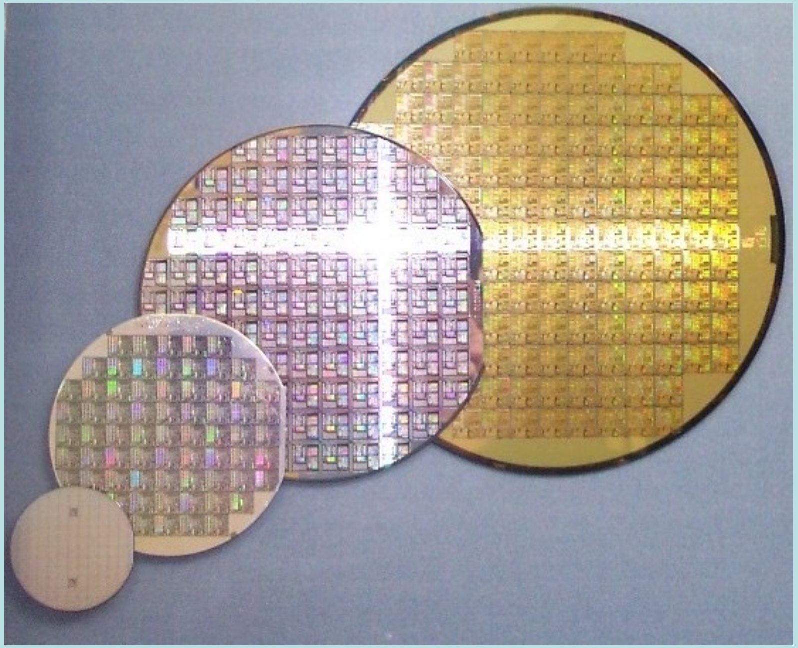
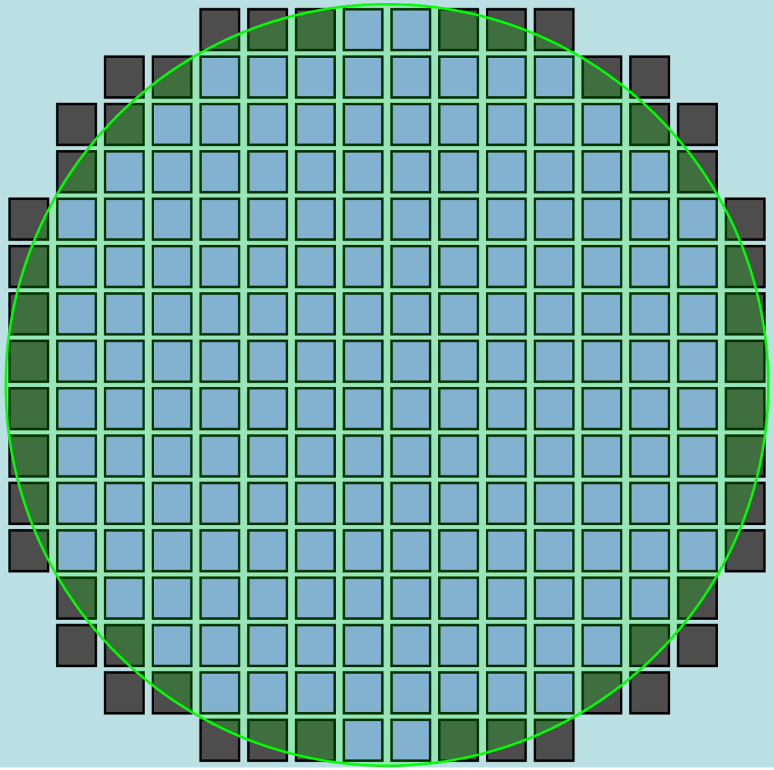
以上所描述的電晶體配置有一個很長的名字：金屬氧化物半導體、場效型電晶體 MOSFET，比起傳統的雙極型電晶體，場效電晶體更適合於平面的半導體大量製造，而且體積可以極度縮小。如上所述，場效電晶體的主體是由p型與n型半導體分布組成，這個分布可以規劃在二維平面上，於是由電晶體所組成的電路就可以在一片平板上展開。製作時會以矽為晶片基板，第一步先全部摻雜為p型半導體。接著先設計好藍圖，在平面上安排出n型半導體的位置。第三步，在基板上塗一層感光的光阻劑，然後將設計畫在一片光罩上，當光罩放置於基板上時，光罩的圖案會遮蓋規劃為p型半導體的區域。接著以紫外線曝照，消除掉光罩圖案未遮蓋處的光阻劑，於是規劃為n型半導體區域的基板就曝露在外。最後，將此曝露的部分滲進適當雜質，就得到所設計的n型半導體分布，而光阻劑覆蓋的部分則維持原來的p型。利用這樣的製程就可以在晶片上建構出你所設計的分布，其他如絕緣層、導電線路與電極也可以用類似的方式往上堆疊建構。

上一段描述是不是讓你感覺很枯燥、很機械化？那就對了，一個接著一個的步驟，有條不紊，如此，就可以大量機械化生產。而且平面化的設計，可以將電路非常節省空間地集中在一塊小晶片上，這就稱為積體電路。它的最大好處在於，只要你的藍圖光罩夠精細，電晶體的大小幾乎可以無限地縮小。如此我們才能把驚人的計算能力，置於一個日常生活能夠輕鬆攜帶的裝置。積體電路在1960年代出現，大概從



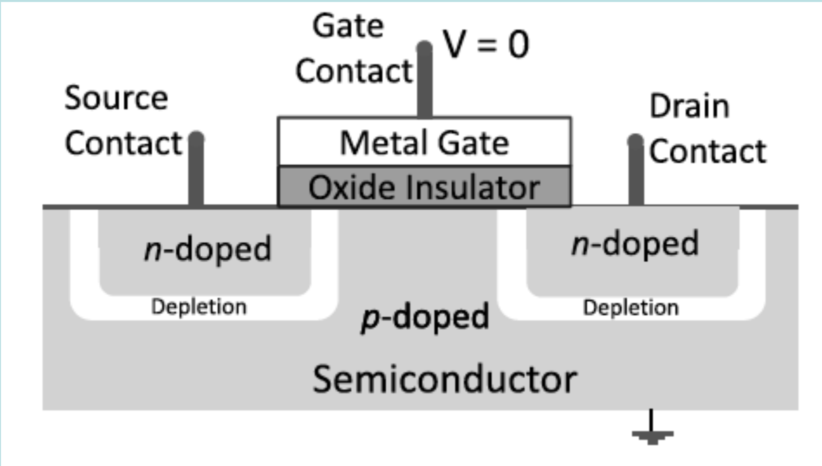


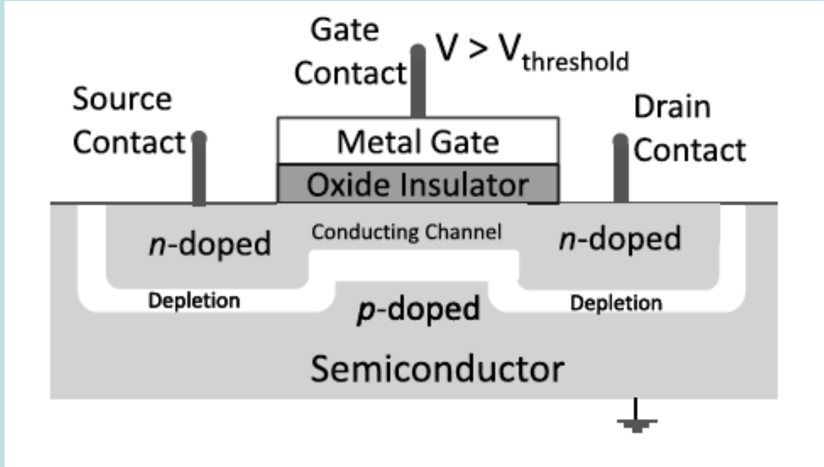

tsmc


RELIEF WRENCH
LOCATED BEHIND
THIS PANEL

EUV stands for extreme ultraviolet light, which produces the circuitry.

V_G





如此以閘電壓V_G做為條件，來控制電壓V_S是否能產生I_S。

如果電壓V_G很小而且有訊號，電壓V_S很大，所產生的大I_S就會攜帶訊號。

V_G