The origin and evolution of the universe
宇宙的起源与演化

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The Universe is everything:
宇宙就是一切

Space 空间
Matter 物质
Energy 能量
The time 时间

It is in continuous evolution.
宇宙在不断演化

Each object in the universe changes, as well as our ideas on them.
宇宙中的每一个天体以及我们对它的想法都在改变

It’s been less than one century since we have enough observations to quantify the universe and try to do the science on that subject.

我们拥有足够的观测数据能够对宇宙本身的性质进行科学研究的历史还不足100年

The last few decades we have information about the universe and we can study it. Before there were only speculations.

今天我们在这里用智慧的力量想象宇宙的演化，直到若干年前我们还没有足够的信息能够研究宇宙，之前只能是凭空猜想

Our intuitive appreciation of the universe is not the standard model of the Big Bang.我们对宇宙的最初想象并非宇宙大爆炸标准模型。

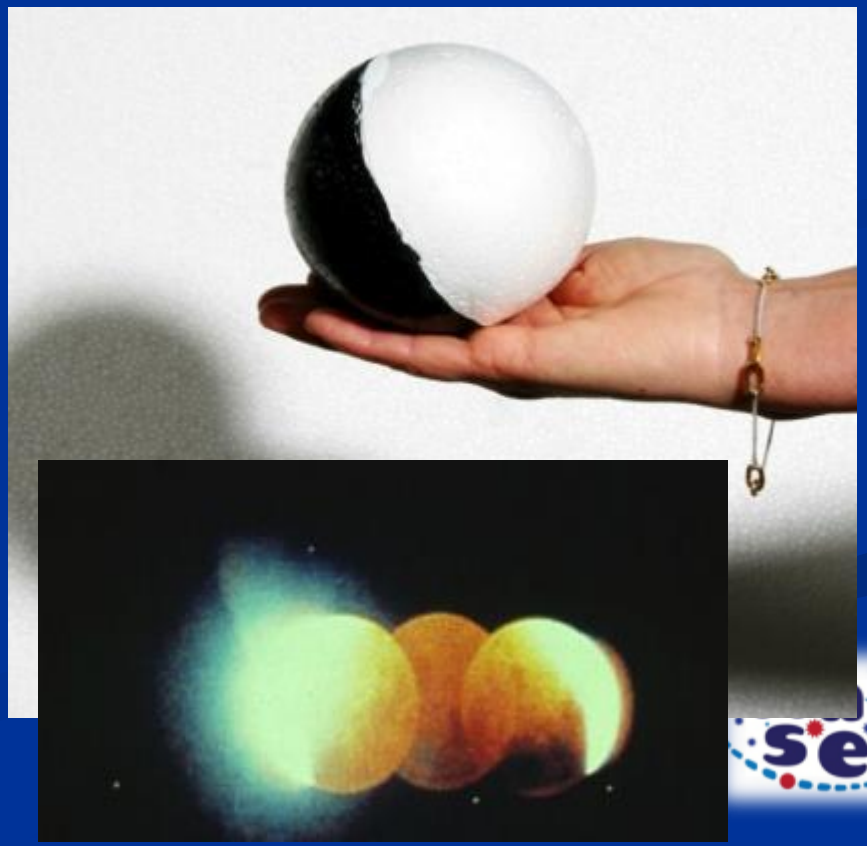
Historically, cultures attempt to explain the universe. For example, Babylonians thought that the Earth is flat, with certain elevations, and supported by elephants which, in turn, are placed on a tortoise surrounded by one snake. They were explaining the earthquakes with rearrangements of elephants.历史上，不同文化都试图解释宇宙。 例如，巴比伦人认为地球是平坦的，并具有一定的高度，由大象支撑着，而大象则站在被一条蛇垫起的乌龟上。 他们认为地震就是大象发生了运动所致。

Testing of the model:检验模型

The shadow of an elephant and a turtle, never looks like the shadow of the Earth on the Moon.
地球落在月球上的影子一点都不像大象或者乌龟。

Only one sphere always has a circular shadow. Demonstration a Moon Eclipse

只有球体的投影才可能永远是圆的。月食的展示



Advances in science科学的发展

- Reflecting直观反映
- Thinking about questions we have about the nature 思考自然中的问题
- Experimenting 试验
- Thinking about the results对结果进行思考
- Socializing the new knowledge through articles 从文章中获取新的知识
- When other thinkers comment favorably our ideas, the knowledge is consolidated. Also when we learn from our mistakes.

当其他研究人员认可我们的观点，表示这个知识是可信的。同时，我们也会吸取教训。

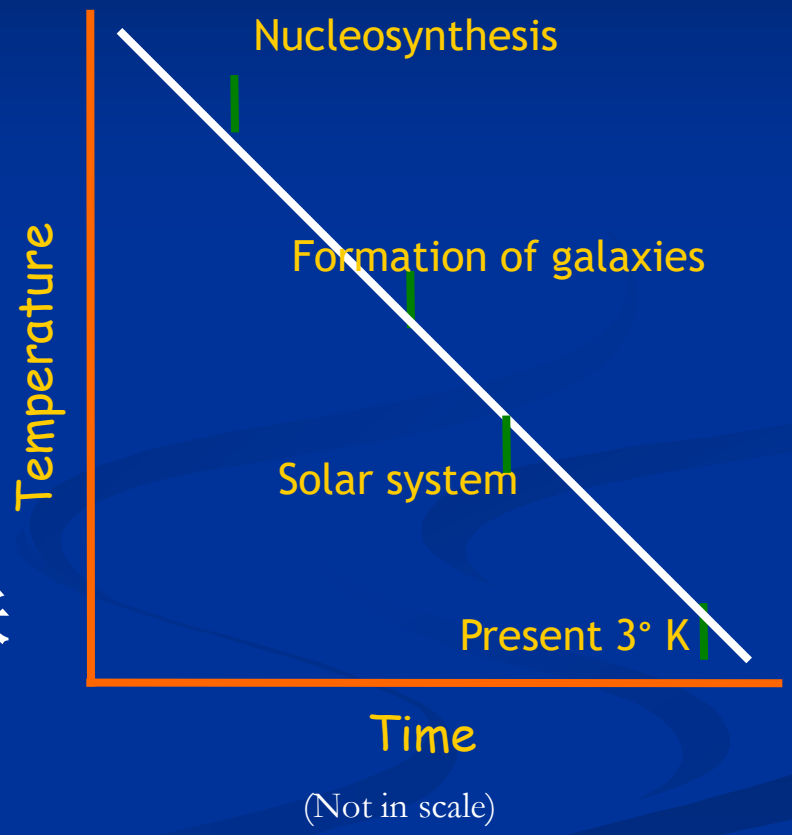
Standard model of the Big Bang
标准大爆炸宇宙模型

- This is the most simple one and explains the observations: 最简单的能够解释观测现象的模型：
  - Expansion膨胀
  - Cosmic background radiation宇宙背景辐射
  - Chemical abundances 化学元素丰度
  - Isotropy XXXXXX
- There are other models确有其他模型

- Science does not claim to have the truth – it is unattainable.
  科学并不追求终极真相。
  终极真相难以获得。

Expansion of the Universe
宇宙的膨胀

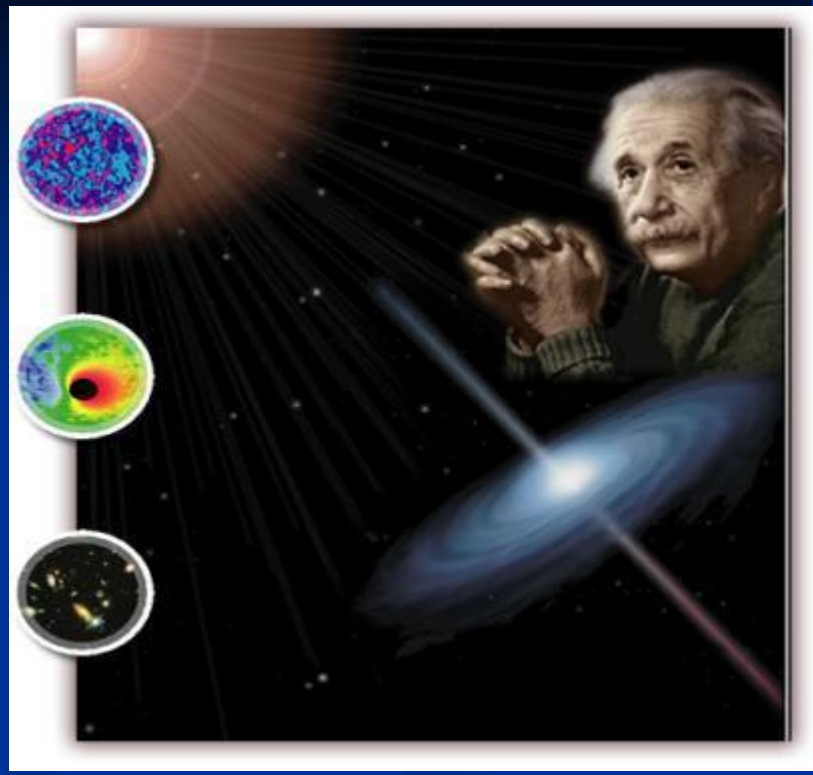
- The Universe was formed 14,000 million years ago.宇宙形成于140亿年前。
- Everything started when energy was released from the vacuum.一切的开始源自能量从真空中释放出来。
- This expanded and cooled in the process.在这在过程中发生了膨胀和冷却。
- As a result, this energy was transformed into matter .最终，这种能量转化为物质。



Physics studied in the Earth and applied to the rest of the universe is Astrophysics. 物理学是在地球上进行研究，将其应用于宇宙的其他地方就是天体物理学。

Albert Einstein discovered that the energy can be converted into the matter and vice versa. At the beginning of the universe, the vacuum energy converted to matter. 阿尔伯特爱因斯坦发现能量可以转化为物质，反之亦然。 在宇宙的最初就是真空能转化成了物质。

Inside the stars the energy turns into matter, that's why they shine.在恒星内部，能量转化为物质，这就是它们发光的原因。



Equivalence between matter and energy

$E = mc^2$

quarks , leptons

p^+ n e^-

At the beginning all matter was ionized
起初所有物质都是电离的

Later it recombined to form neutral atoms
后来结合成为中性原子

Atoms formed clouds, and inside, the first galaxies with the first stars.
原子形成分子云，其内部形成第一代恒星和第一代星系

Later, the rocky planets (such as Earth) were formed and the first life appeared.
再后来，形成了地球这样的岩质行星，生命出现

Chemical evolution 化学演化

Protons, neutrons and electrons formed in the first minute of the universe. They formed the simplest atoms, H and He.
第一分钟，质子、中子和电子形成。它们随后形成最简单的原子：氢和氦。

$E = mc^2$

H - Formed by a proton p^+

4 H - Turns to He + 2ν + $2e^+$ + 2γ

Chemical evolution化学演化

- The rest of the elements formed inside the stars through thermonuclear reactions.
其他元素在恒星内部通过热核反应形成
- The heaviest atoms, such as uranium, occurs when stars explode and eject particles that collide, forming new elements.
更重的原子如铀等，在恒星爆炸将气体抛出时通过碰撞形成
- Thousands of millions of years passed after the Big Bang, when elements other than hydrogen and helium were formed through stellar evolution.
在大爆炸后的千百万年，恒星内部才形成比氢和氦更重的元素

Physics and cosmology
物理学和宇宙学

We can explain the daily life matter with quarks, constituents of protons, neutrons, and leptons (one of the best-known is the electron) and their interactions, such as electromagnetism.我们可以用夸克、质子、中子和轻子（最著名的是电子）及其相互作用（如电磁学）来解释日常生活中的物质。

Family			Interaction
lepton	electron	neutrino	Electromagnetic force
quarks	up	down	Strong force
baryon	proton	neutron	Week force, strong force

This simplicity of the model helps to understand how was the early Universe, where energy was transforming into matter and matter into energy.这种简单的模型有助于我们理解早期宇宙是如何将能量转化为物质，将物质转化为能量的。

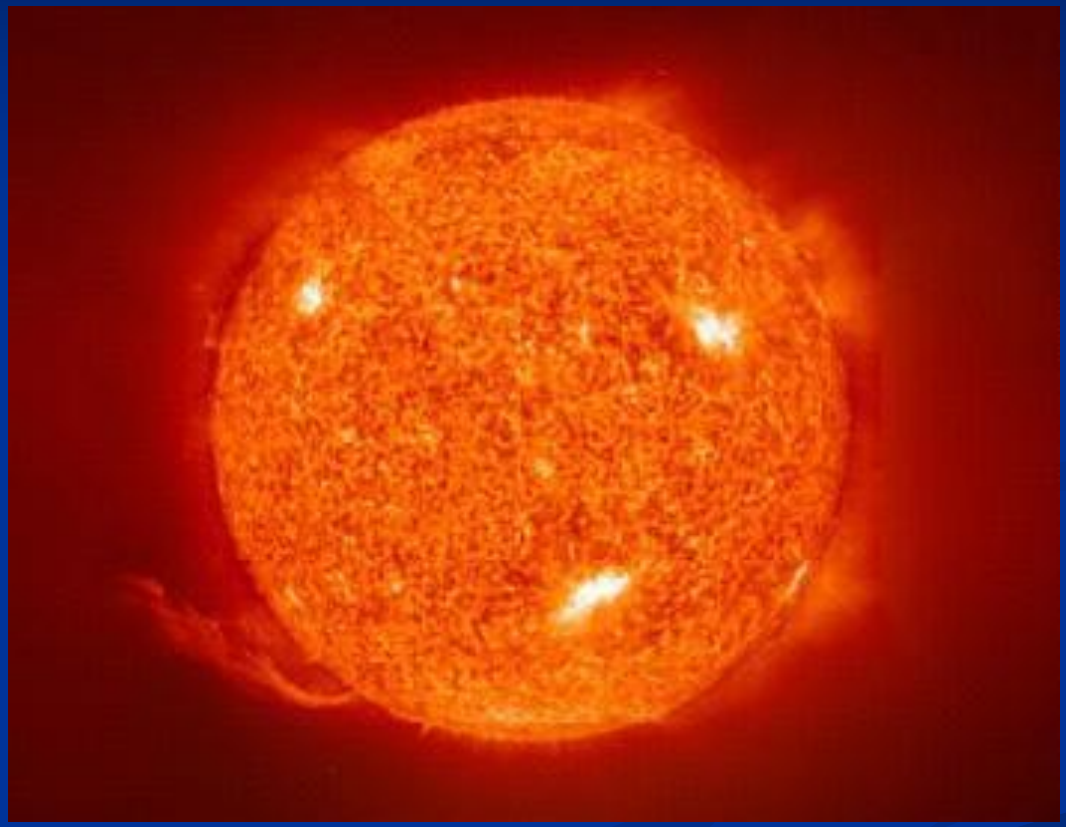
Through observations we learn about
通过观测理解宇宙

- The physical properties of the celestial objects 天体的物理特性
- Sizes and distances 尺寸和距离
- Times and ages 时间和年龄
- Expansion rate of the universe 宇宙的膨胀速率
- Temperature of the background radiation 背景辐射的温度
- Chemical composition 化学成分
- Structure of the Universe 宇宙的结构
- Why the night is dark 为什么夜晚是黑暗的
- The existence of dark matter and dark energy 暗物质和暗能量的存在

The Sun 太阳

The most studied objects are the brightest ones – easiest to do it.
研究得最多的、最亮的，也是最容易进行研究的天体。

The Sun and the rest of the stars are the most known objects.
太阳和其他恒星是人们最熟知的天体。



Extra solar planets 系外行星

In addition to stars, in the past few years a hundreds of planets have been discovered around other stars, not because they emit light, but because they disrupt the stellar orbits and light curves.

在过去的几年里，除了恒星之外，研究人员还在其他恒星周围发现了数百颗行星。并不是因为它们发光才会被发现，而是因为它们扰动了恒星轨道和光变曲线。

Life 生命

Another property of the Universe is life. We have not yet discovered the life outside the Earth.
宇宙的另一个特性就是生命的存在。 至今我们还没有发现地球以外的生命。

We believe that it requires water to flourish because it facilitates the exchange of substances and the formation of complex molecules.
我们有理由相信生命的繁荣需要水，因为它促进了物质的交换和复杂的分子形成。

Interstellar matter 际介质

The space between the stars is not empty, it is filled by interstellar matter. This is the material from which the new stars form.恒星之间的空间不是空的，被星际物质所填充着。这也是新生恒星形成的材料。

The stars are born inside the clouds of gas and dust. The clouds are compressed forming new stars. They spend the biggest part of their life transforming in their core hydrogen into helium and energy.
恒星诞生在气体和尘埃云中。 云团被压缩，形成新星。 它们一生中大部分的时间都在将核心的氢转化为氦和能量。

Then later forming carbon, nitrogen and oxygen - the elements that we are made of.
随后，还会形成碳、氮和氧——这也是组成我们的元素。

Life cycle of Sun-like star
类太阳恒星的一生

When stars exhaust their fuel, they eject into the surrounding space particles created inside of them. After each stellar generation, the interstellar medium -where new stars born – become more abundant with this elements. 当恒星耗尽燃料时，会向周围空间喷射内部形成的物质。所以每当恒星完成演化过程，它附近空间的星际介质元素将变得更加丰富。

Clusters 星团

Many stars are agglomerated in clusters containing between 100 and 1,000,000 stars

星团中有许多恒星聚集在一起，多至100到1, 000, 000颗

Jewel Box, open cluster

珠宝盒，疏散星团

Omega Centauri, globular cluster

半人马座欧米茄，球状星团

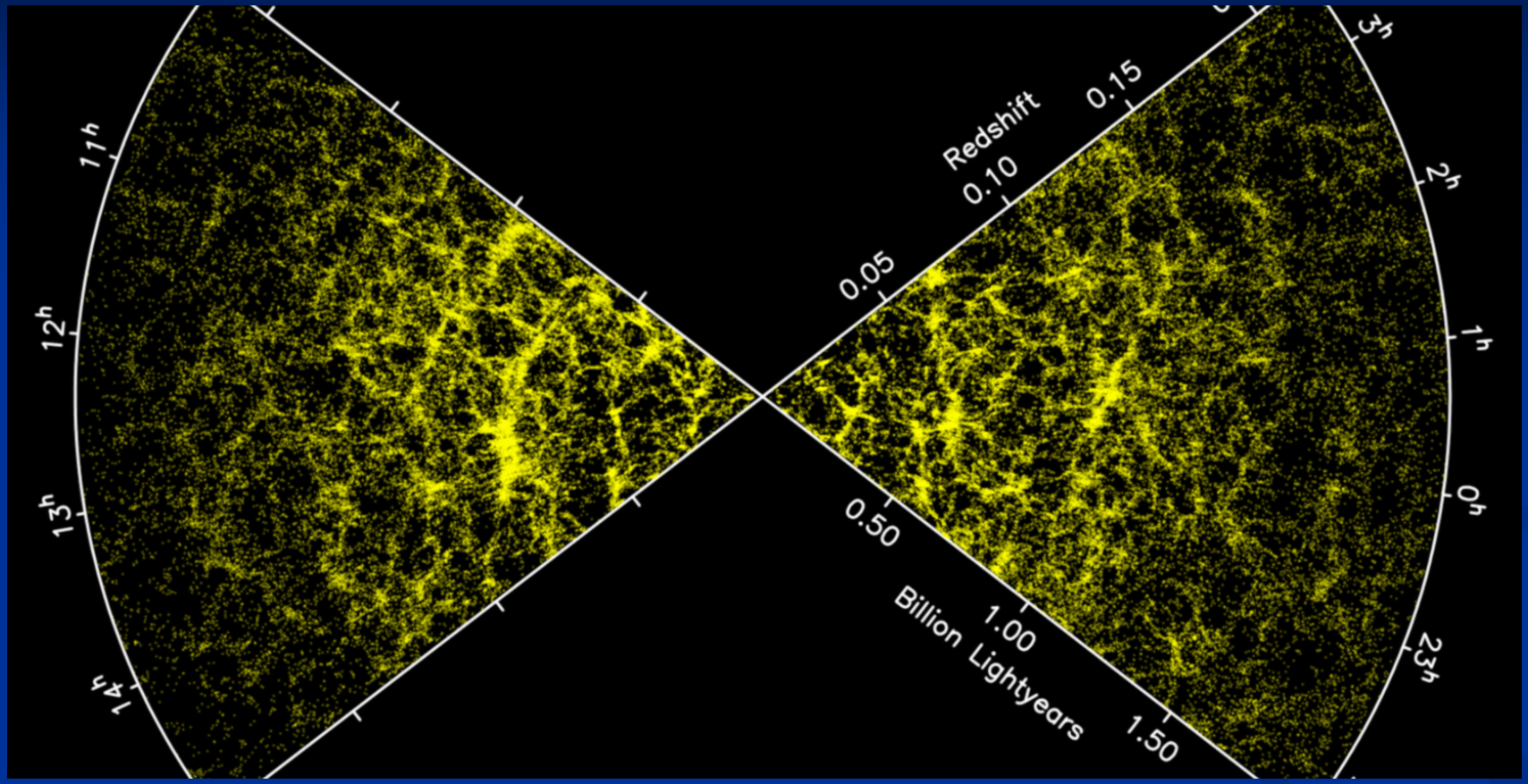
Galaxies 星系

Whirlpool Spiral Galaxy
Source: Hubble Space Telescope

Conglomerates by excellence are the galaxies, the spiral one like ours, have >100 billion stars, each one with its planets, satellites and comets, gas, dust and most of the so-called dark matter

更大的恒星集团是星系，像我们这样的旋涡星系里有超过1000亿颗恒星，每颗恒星都有属于自己的行星、卫星、彗星、气体、尘埃和大部分的暗物质

Filamentary universe 纤维宇宙



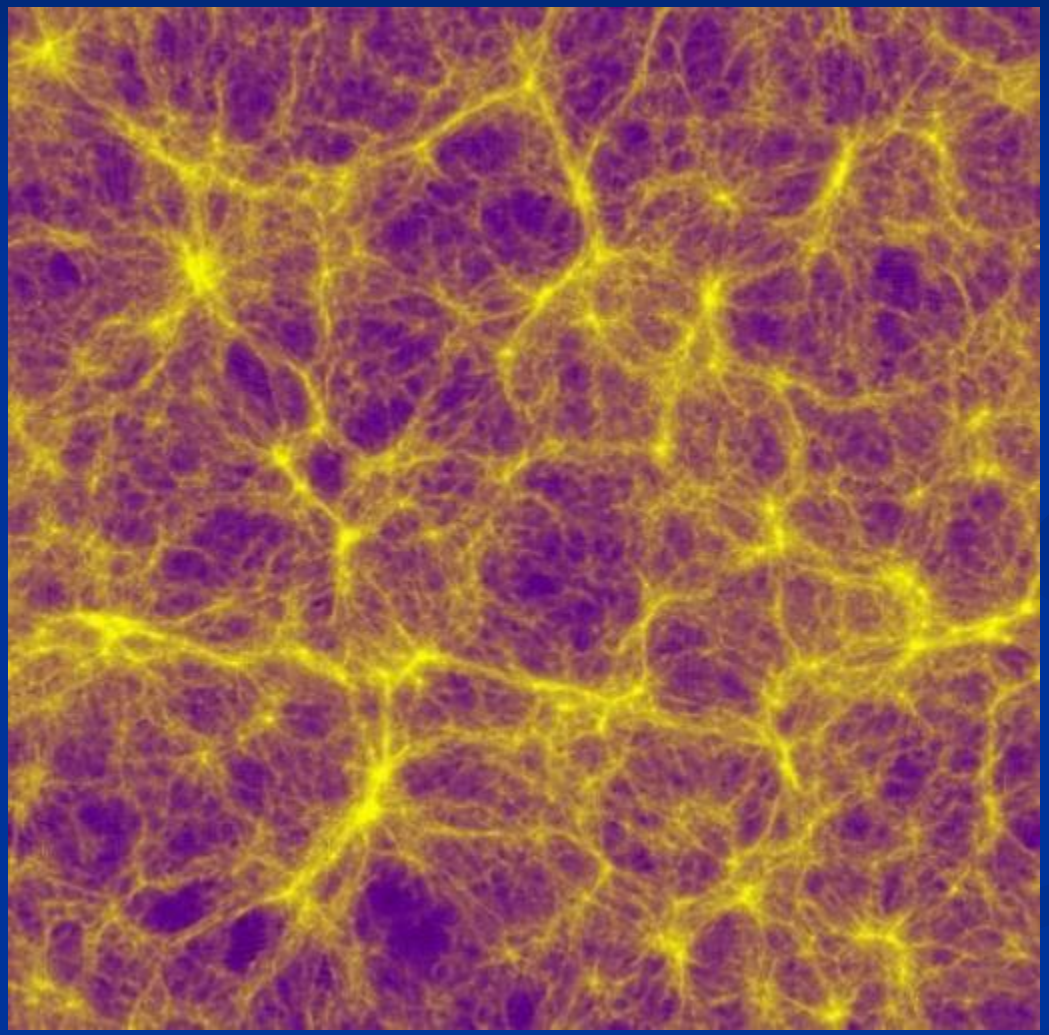
The groups of galaxies are arranged in what is called filamentary universe

星系群处于“纤维状宇宙”中

It‘s like the Universe is a bubble bath where the matter surrounds the space lacking with galaxies, and as the time passes the volume that luck with matter grows 宇宙就像浴池里的泡泡，物质周围是稀薄的空间，随着时间的流逝，物质分布稀疏的空间逐渐膨胀

As the Universe expands the space between clusters of galaxies increases and the universe dissolves more
随着宇宙膨胀，星系团间的距离不断增大，宇宙变得越来越稀疏

Model of the filamentary universe
纤维宇宙模型



Source: Millennium Project Max Planck Institute.

The clusters and superclusters of galaxies lie in the filaments, like on the surface of a bubble.
星团和超星系团处于纤维状结构上，就像泡沫表面一样。

The model is coincident with the observations
该模型与观察结果一致

Structure of the universe: synthesis

宇宙的结构：综合体

- The stars are in clusters.

恒星位于星团中。

- The stellar clusters are inside the galaxies.

星团位于星系中。

- The galaxies form clusters, made of few galaxies or thousands of them.

星系组成星系团。星系团中有几个或数千个星系。

- The biggest structures in the universe are filaments, formed by clusters and super clusters of galaxies.

宇宙中最大的结构是纤维状结构，由星系团和超星系团组成。

Sizes in the Cosmos 宇宙的尺度

We can estimate the size of one meter, similar to the size of a child, and also a unit thousand times greater, one kilometer…
我们可以估计一米或者一个孩子的大小，也可以放大一千多倍，估计一千米的大小

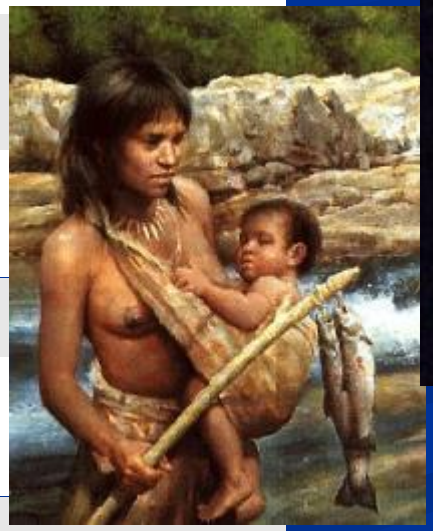
… distance thousand times greater, thousand kilometers, can be crossed by plane in couple of hours.
再放大一千倍，对于一千千米而言，我们坐飞机可以在几个小时内到达

To get to the Moon we need three days and to cover the distance between the Sun and Jupiter several years.
我们需要三天时间到达月球，而从太阳到木星却需要几年。

The distance to nearby stars is thousand times higher
到附近恒星的距离更是要再远一千倍

Time in the Cosmos in years
宇宙的时间（年）

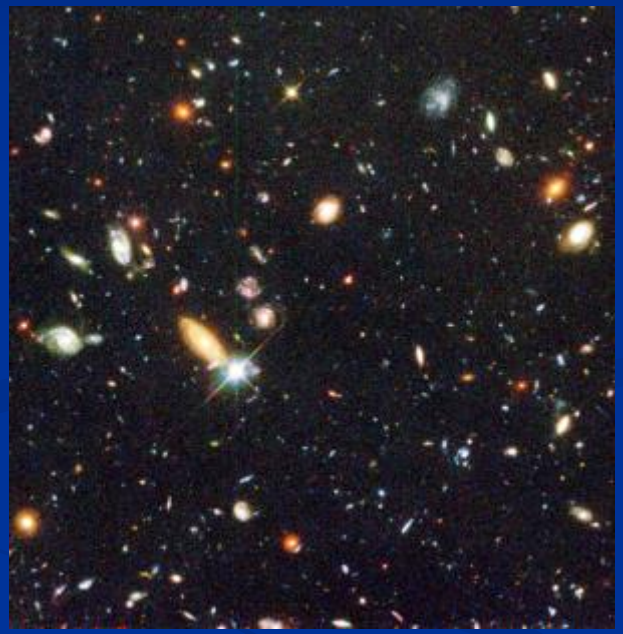
Big bang	14 000 000 000
Galaxy formation	13 000 000 000
Solar System formation	4 600 000 000
Appearance of life on Earth	3 800 000 000
Appearance of complex life	500 000 000
Appearance of dinosaurs	350 000 000
The Cretaceous extincion	65 000 000
Appearance of the modern man	120 000



The appearance of the man is very recent

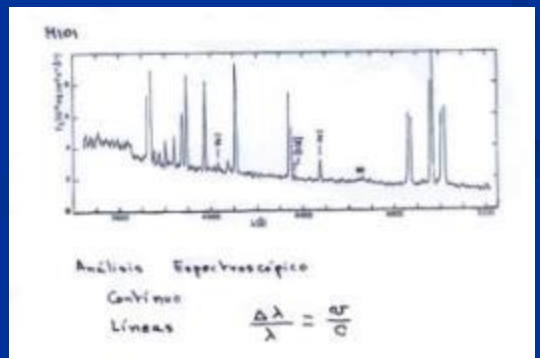
Observing the universo 观测宇宙

You can take an image to determine the position or the appearance of a star, or the amount light emitted.
可以通过拍摄图像来确定恒星的位置、外观或辐射出的光量。



The spectra can determine the speed of the stars. This is what is known as the Doppler effect of light. 通过光谱可以确定恒星的速度——光的多普勒效应。

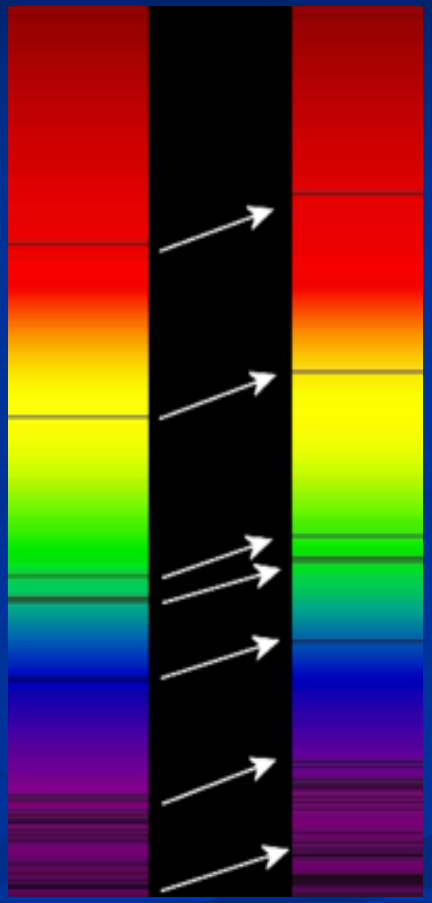
Analyzing the radiation that stars and galaxies emit, reflect or absorb, we learn about their nature. (Doppler effect)
通过分析恒星和星系的发射、反射或吸收的辐射，我们可以了解它们的本质。
（多普勒效应）



Pillars of the Standard Model
标准模型的基石

Expansion of the universe
宇宙的扩张

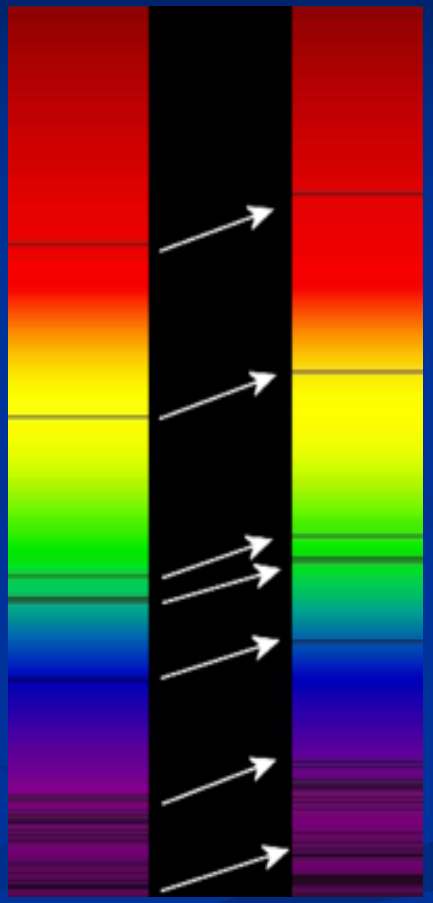
Doppler shift to red demonstrates the expansion (If the stars are close to the observer the light is bluer and farther they are it is redder).
The groups of galaxies are moving away from each other and if they are further, they are moving away at faster rate
多普勒红移表明宇宙膨胀（如果恒星向着观察者运动，为蓝色；向着远处运动，则为红色）。目前，星系群正相互远离。它们距离越远，远离的速度也相应越快。



Pillars of the Standard Model
标准模型的基石

Chemical abundances in the universe
宇宙中的化学丰度

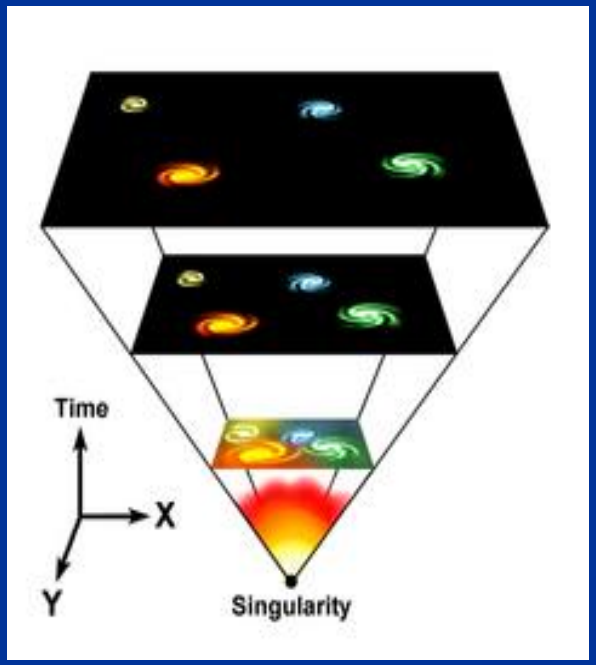
In the first minutes of the Cosmos, only H and He were formed; the expansion stopped the production: the radiation lost the energy and it was not possible any more to transform into protons and neutrons. C, N and O were created inside the stars and were mixed with the interstellar medium when the stars died.
在宇宙诞生后的第一分钟，只有氢和氦形成；随后，膨胀影响了进一步形成：当缺少辐射的能量时，质子和中子的形成也停止了。碳、氮和氧在恒星内部形成，并在恒星死亡时与星际介质相融合。



Cosmic Expansion 宇宙膨胀

The space expand, and also the photons of radiation are stretched. What in the past were tiny wavelength gamma rays, today we observe them as radio waves.

空间膨胀后，辐射光子也被拉伸。在过去的宇宙中是伽马射线辐射，到了今天我们观测到的却是射电波。



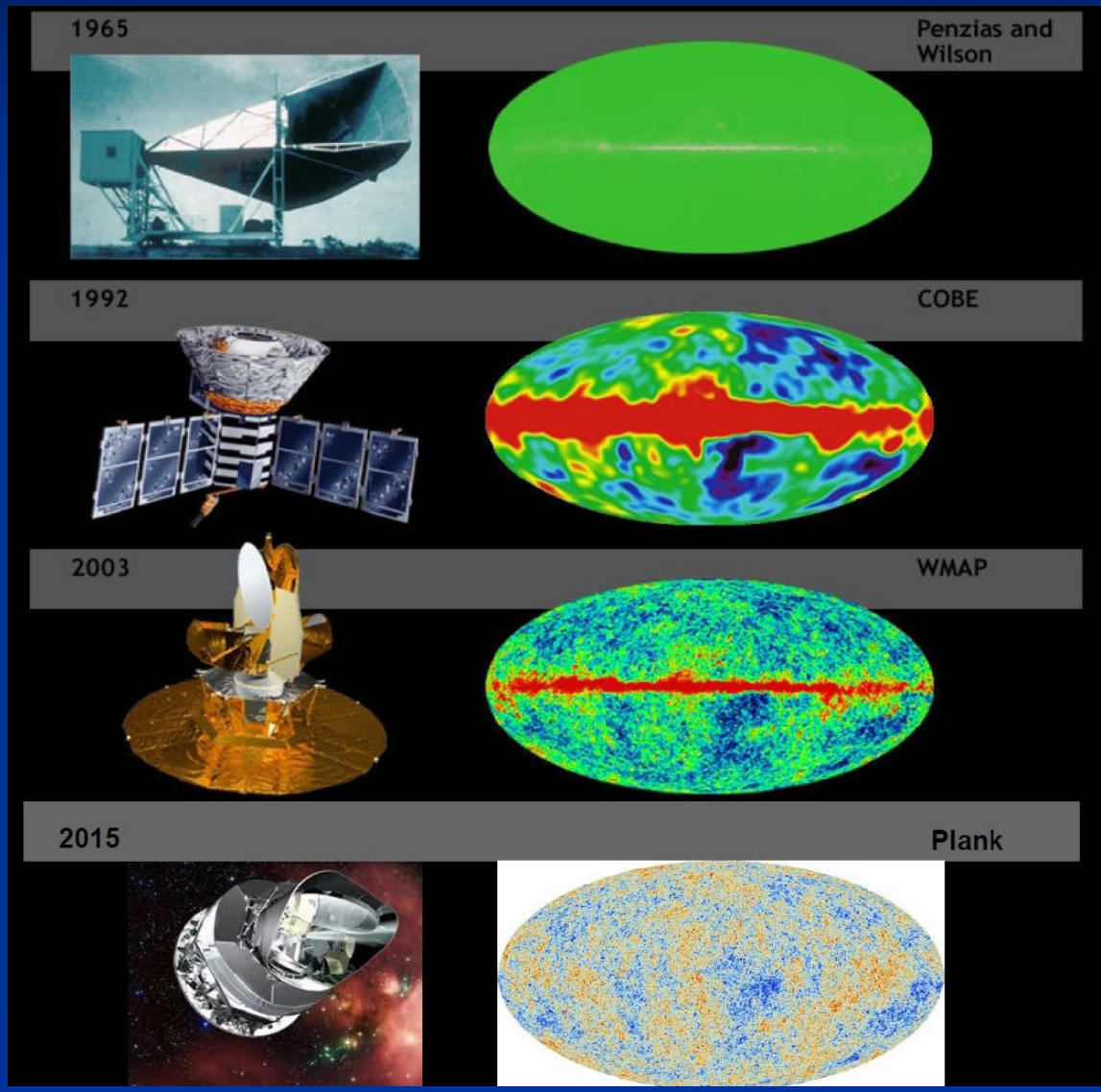
Measuring the cosmic expansion, we can calculate the age of the Universe, 14 billion years. This estimation is higher than the age measured for oldest stars

通过测量宇宙膨胀，我们可以计算出宇宙的年龄是140亿年。 这个估计值要高于最老恒星的年龄

Cosmic Microwave Background (CMB) Radiation
宇宙微波背景辐射

The COBE, WMAP and PLANCK missions made a map of the sky of CMB radiation, every time with more detailes, detecting small fluctuations: imprints of lumps of matter from which galaxies began to form .

COBE，WMAP和PLANCK任务给出了全天的微波背景辐射分布。而且不断给出越来越多的细节，以及检测到的小波动——包括星系开始形成的物质块的印记



Is there the edge of the universe?
宇宙有限吗？

A necessary condition for the stability of the universe is that it is in continuous expansion. Otherwise, it would stop to exist as we see it now. The expansion of the universe is one of the pillars of the standard model of the Big Bang

宇宙稳定的一个必要条件是它在不断膨胀。 否则，它将无法维持现在我们看见的模样。 宇宙的膨胀是宇宙大爆炸标准模型理论的支柱之一

but… there is no centre of the expansion

但是，膨胀并没有中心点

Does Gravity dominates the universe?
重力是否支配着宇宙？

The Universe contains mass,so it has a huge gravitational force. Gravity attracts.
宇宙有质量，所以有着巨大的引力。引力吸引。

The expansion of the big bang compensates the gravity
大爆炸的膨胀抗衡着重力

The universe is accelerating and the source of energy responsible for that acceleration is unknown.
宇宙正在加速，但导致这种加速的能量来源仍是未知的。

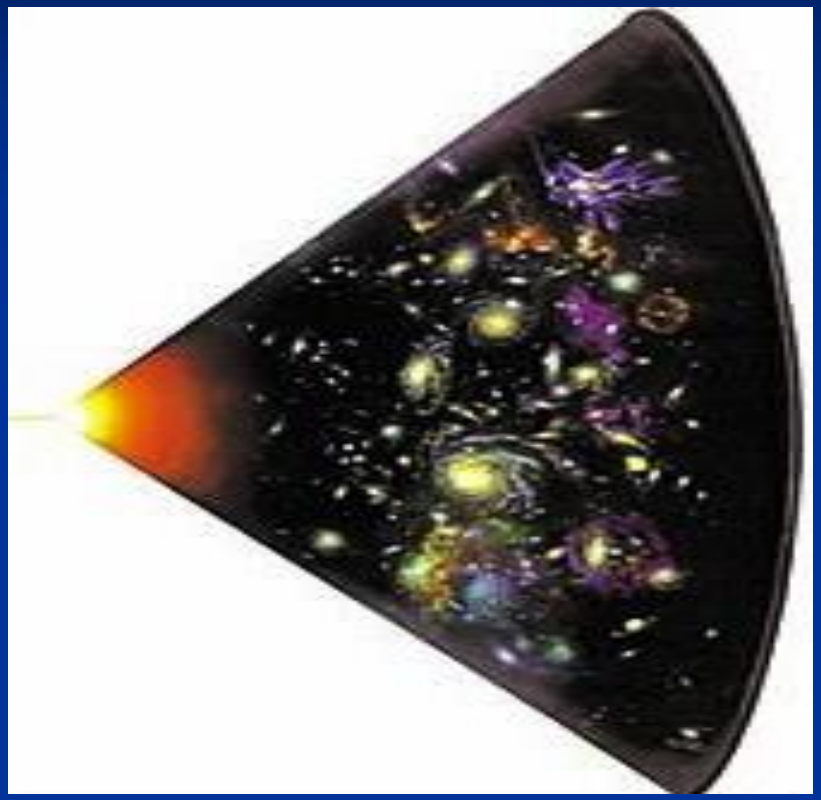
When observing distant galaxies, we look how they were in the past. Nearby galaxies are different from the distant galaxies

在观测遥远的星系时，我们看见的是它们过去的样子。附近的星系与遥远的星系样貌不同。

Nearby Spiral Galaxy

Distant galaxies are small and amorphous

Evolution 演化



There is a limit beyond which we do not have information about the Cosmos.
对于实际可以观测的宇宙范围，我们存在一个限制。
We cannot observe the stars whose light takes more than fourteen billion years to reach us.
我们无法观察到光线需要超过140亿年才能到达我们的恒星。

If our universe was small we would only have information about a small section, and if it was infinite this would be tiny
如果我们的宇宙不大，那么我们只能得到关于一小部分的宇宙的信息。而如果它是无限的，那么这部分将更加微小。

The INVISIBLE part of the universe, 95% dark matter and dark energy, is detected due to its action on VISIBLE objects.

通过对可见物体的作用，我们间接检测到宇宙的不可见部分——95%暗物质和暗能量。

We don't know the type of material that it is made off

我们并不知道它的物质构成

Sea surface
洋面

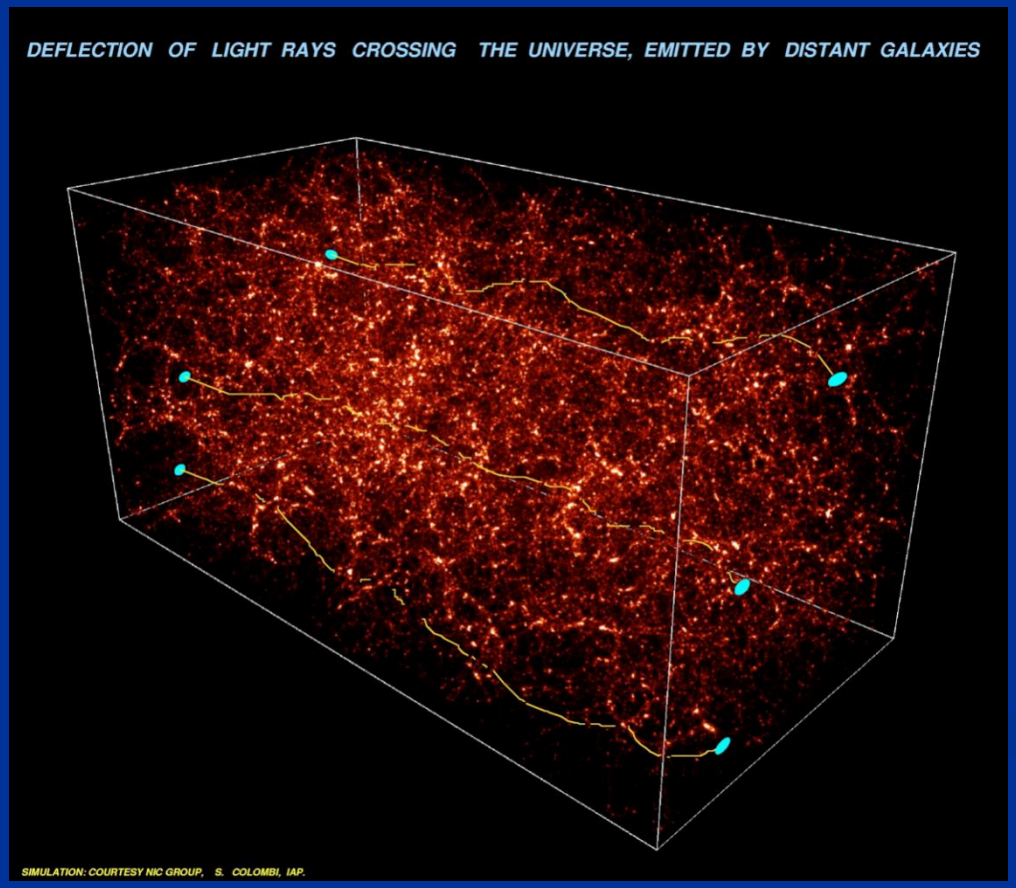
It's like we are marine biologists, but we can only see the surface of the sea
如果我们是海洋生物学家，那就好像我们只能看到海面

Bottom of the sea
洋底

If we look from closer, we could discover a great diversity
如果我们可以接近，将能发现更多

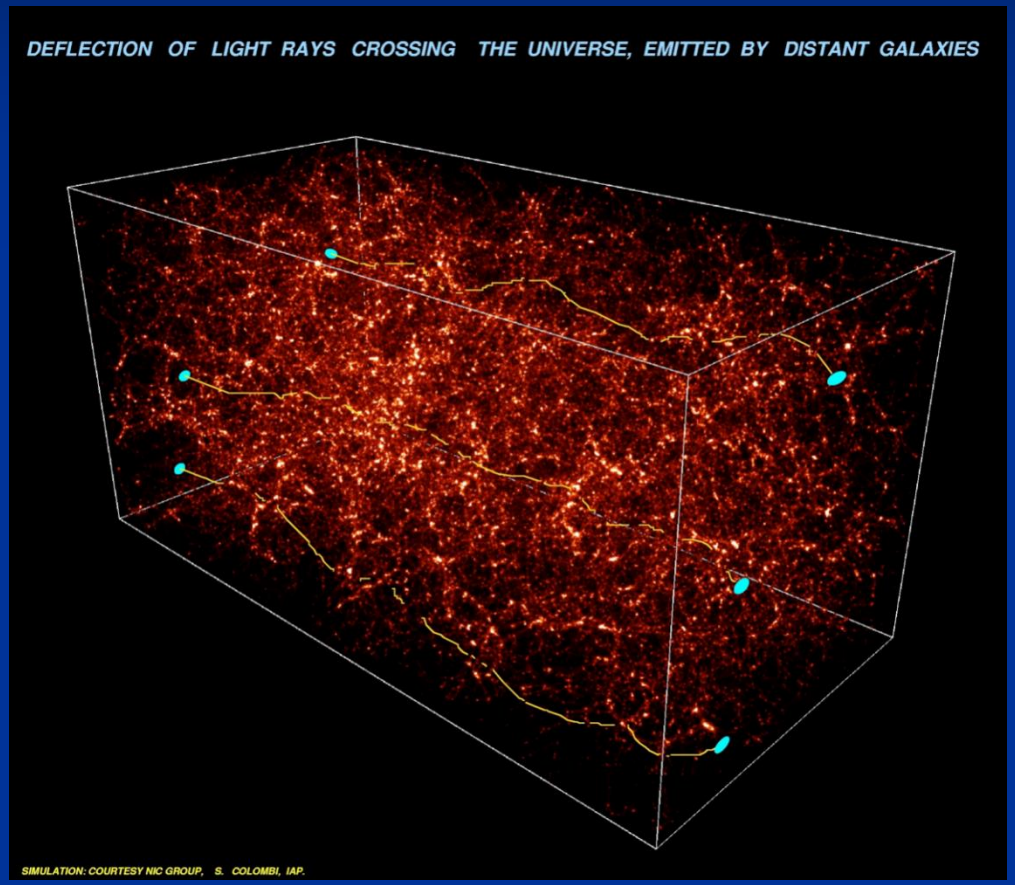
The dark matter 暗物质

We know that for every detected astronomical object there are thousand more which we have no information, only the mass containing. We do not know its shape and distribution



我们已经知道，相对于每个被探测到的天体，还有上千倍的天体没有被发现，我们只能通过它们的质量间接知道它们的存在。我们并不知道它的形状和分布。

The dark matter 暗物质



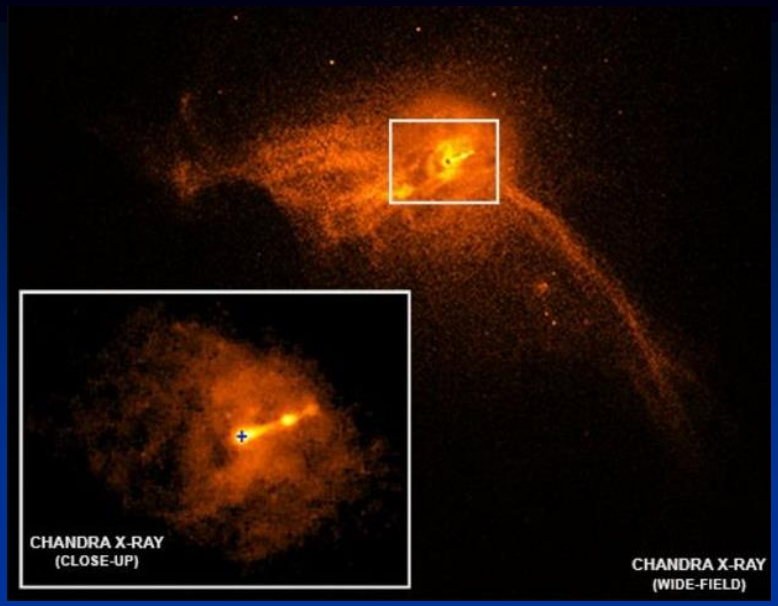
It is thought that dark matter is distributed filamentary. The blue shapes are distant galaxies. The yellow lines are the paths of light emitted by galaxies.
Without dark matter they would be straight.

现在一般认为，暗物质的分布呈纤维状。 图中蓝色的标示出遥远的星系。 黄线对应的是星系发出的光的路径。 如果没有暗物质存在的话，光路将会是直的。

The stars move around the galactic center because its mass attracts them. Clusters of galaxies remain bounded due to the gravitational force.由于银心物质的引力作用，恒星围绕其运动。星系团也因为引力作用而保持形状。

The dark matter is not visible , but can be detected through the gravity 暗物质不可见，但可以通过重力检测到。

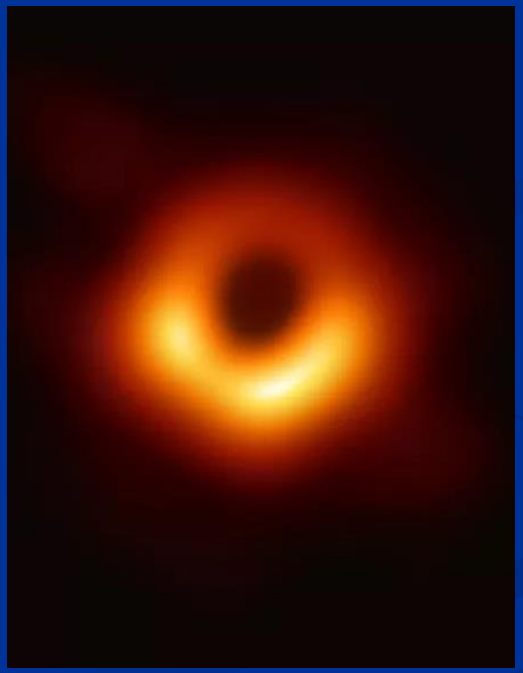
There are objects that move around others that we can not see. For example, there are stars and groups of stars that move around the black holes in the center of the galaxies有些天体围绕着我们看不见的物质在运动。例如，有一些恒星和恒星群绕着星系中心的黑洞运动。



A consortium of more than 200 scientists and 60 institutions in 18 countries of 6 continents are part of the Event Horizon Telescope: 8 radio telescopes on all the Planet六大洲18个国家的200多名科学家和60个机构组成了事件视界望远镜：地球上的8个射电望远镜构成

Center of M87, distant 53.5 million l.y. from the Sun . M87中心，距离太阳5350万光年.

(credit: NASA/CXC/Villanova Uni./J. Neilsen)



The first image ever taken of a supermasive black hole, was presented at a press conference on April 10th 2019 2019年4月10日的新闻发布会，首次展示了拍摄到的超大质量黑洞

"Shadow" and the event horizon of the supermasive black hole in the center of M87, 6.5 billion times more massive than our Sun

(credit: Event Horizon Telescope)

图中是M87中心的黑洞"阴影"和视界，这个黑洞的质量是太阳的65亿倍

Evolution of the universe
宇宙的演化

In the long timescales, the universe will continue to expand. The velocity of the expansion increases with time, it is accelerated. The energy responsible for this acceleration is still unknown. We call it dark energy.

在较长的时间尺度下，宇宙将继续扩张。膨胀速度随时间增加，不断加速。造成这种加速的能量至今仍然未知。我们称之为暗能量。

Evolution of the universe
宇宙的演化

After ~trillions of years all interstellar matter will be consumed and stellar formation will stop.
大约数万亿年后，所有的星际物质都将被消耗，恒星形成将停止。

The protons will disintegrate, and the black holes will evaporate.
质子将解体，黑洞将蒸发。

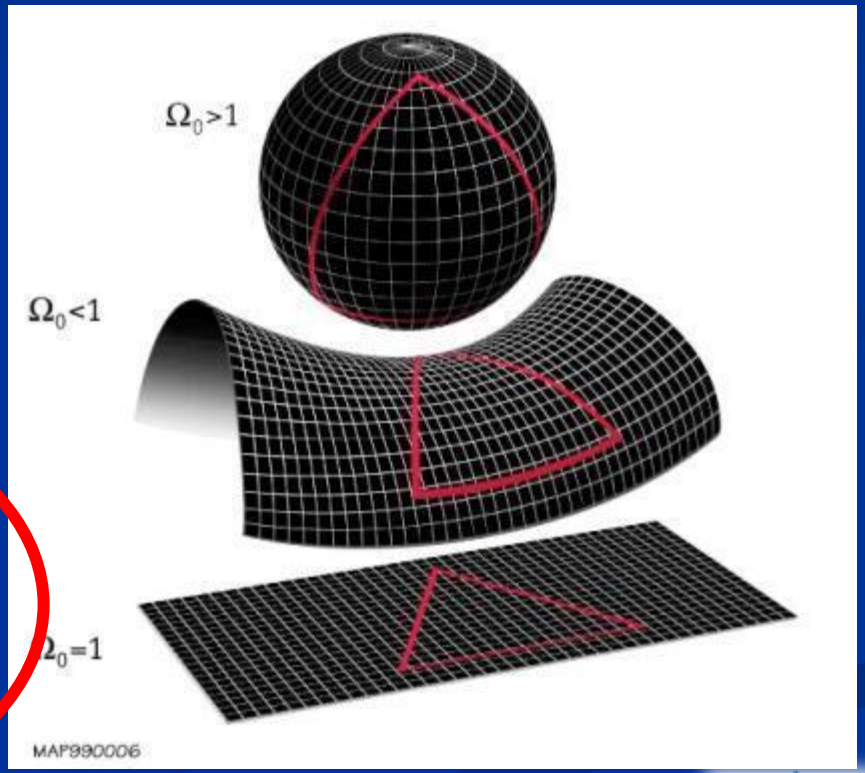
The universe will be immense, populated with exotic matter and low-energy radio waves.
宇宙将变得巨大，充满了异常物质和低能射电辐射。

Geometry of the universe depending on the Cosmological constant
宇宙的几何形状取决于宇宙常数

闭宇宙Close → Ω>1

开宇宙Open → Ω<1

平坦宇宙Flat→ Ω=1
(predicted by inflationary theory and coincident with observations)



Evolution depends of the content of the universe
宇宙的演化取决于其中的物质

Cosmological constant

$\Omega_{total}=1.0$

Heavy elements

0.03%

Neutrinos

Neutrinos:

0.47%

Stars

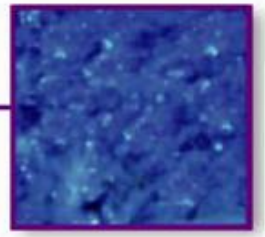
Stars:

0.5%

Free H and He

& He:

4%



Dark matter

Dark Matter:

25%

Dark Energy:

70%

A Successful Model: The Big Bang
(predictions-verifications)
一个成功的模型：大爆炸（预测-验证）

- **Expansion: 膨胀：**
  verified at the beginning of 20th century by E. Hubble.由哈勃在20世纪初验证。

- **Background Cosmic Radiation:宇宙背景辐射：**
  discovered in 20th c. by A. Penzias and R. Wilson.在20世纪由彭齐亚斯和威尔逊发现。

- **Abundance of the Chemical elements:化学元素丰度：**
  demonstrated in 20th c. 在20世纪被揭示。

- **Large Scale Structure:大尺度结构：**
- discovered at the end of 20th c.在20世纪末被发现。

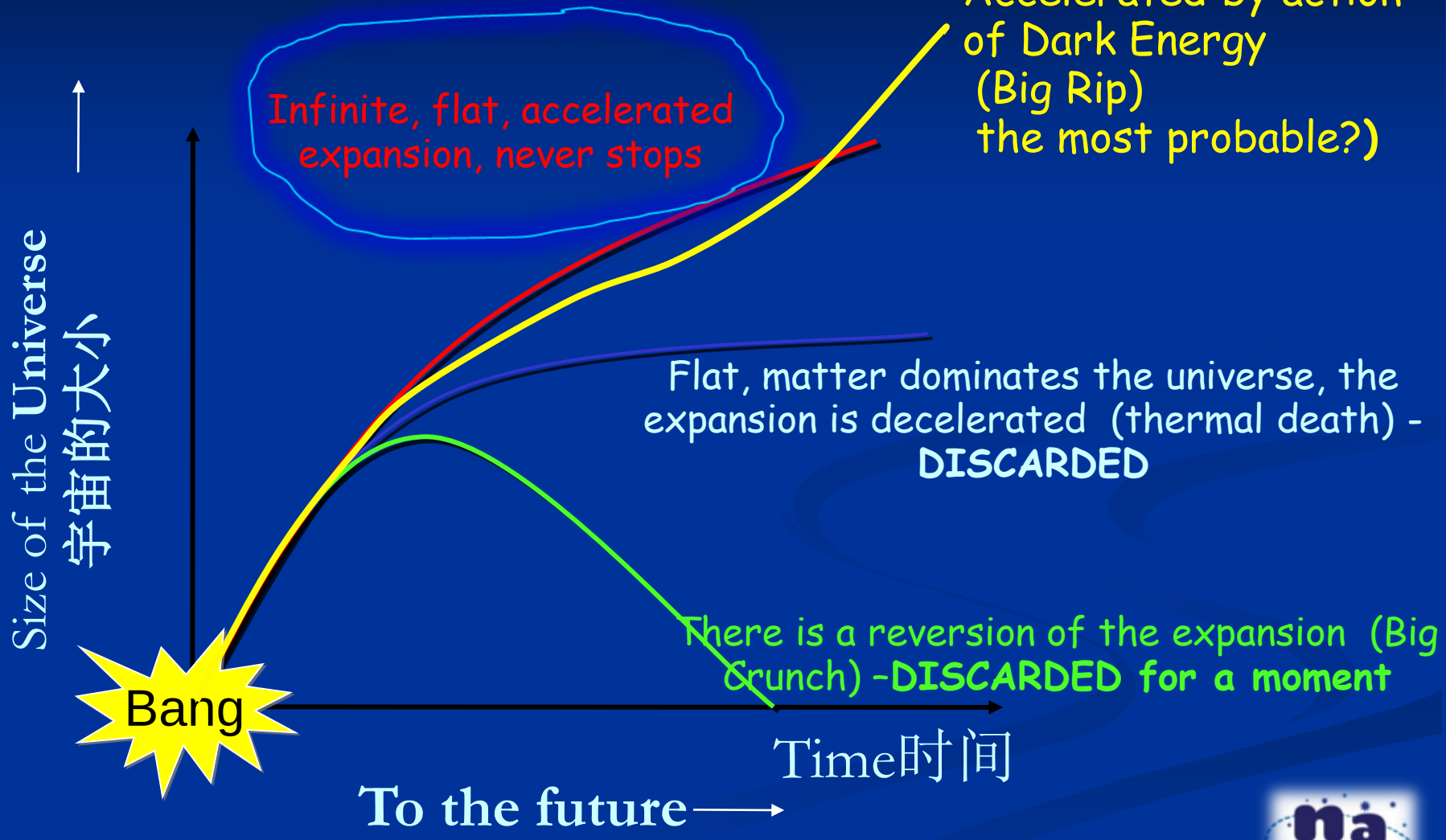
Final Destiny of the universe (possible scenarios)
宇宙可能的最终命运

- Big Crunch (reversion of expansion)
大挤压（膨胀的逆转）
- Flat, thermal death (the expansion stops)
平坦，热死亡（停止膨胀）
- **Infinite, flat, in permanent expansion (this is the scenario now accepted)**
无限，扁平，永久扩张（目前普遍接受的一种）
- Big Rip (accelerated expansion)
大撕裂（加速膨胀）

The Future depends on the content of the universe, on the critical density and on the existence of dark energy.

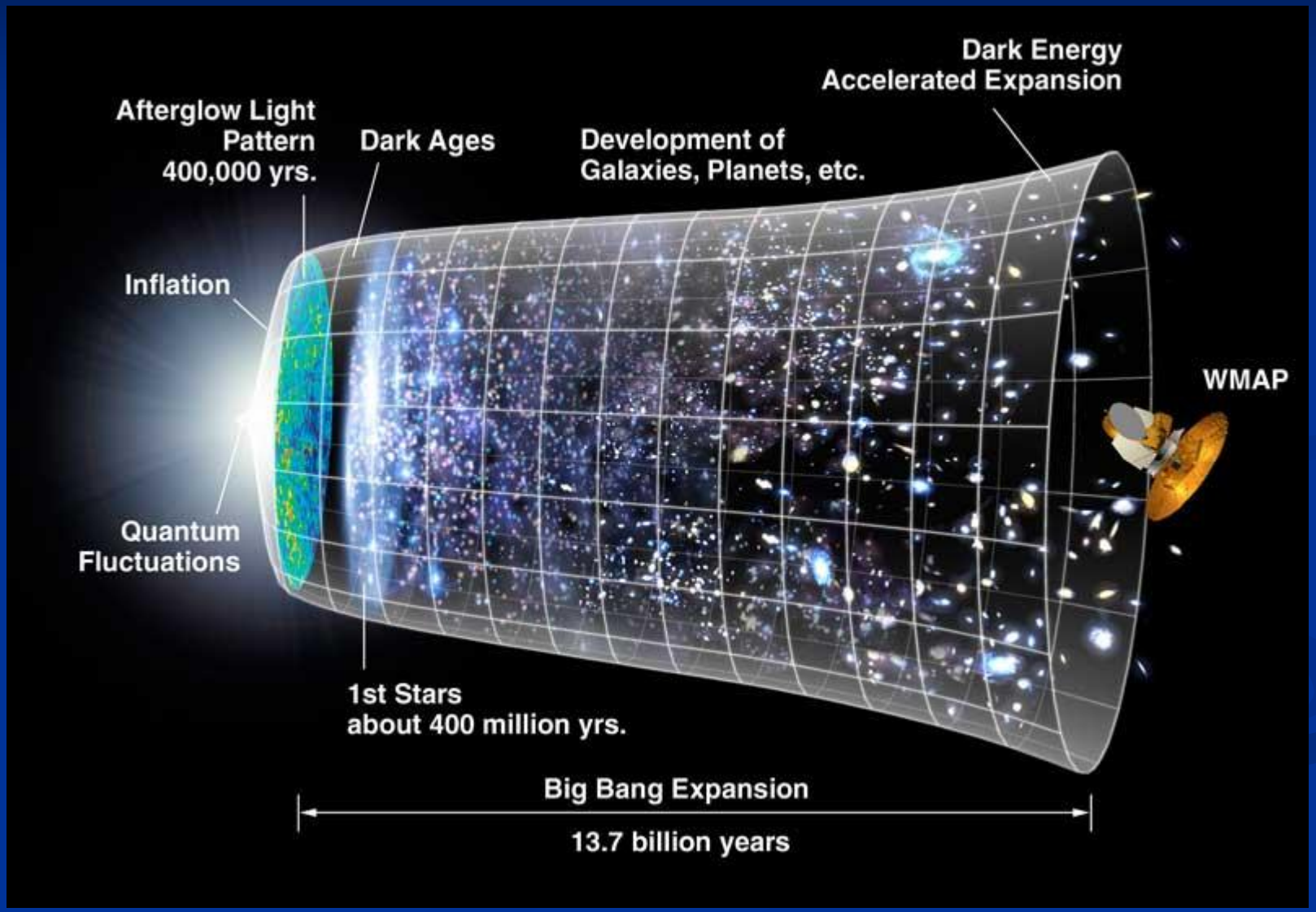
宇宙的未来取决于其中的物质，取决于临界密度，取决于暗能量的存在情况。

Shape and Destiny of the Universe
宇宙的形状和命运



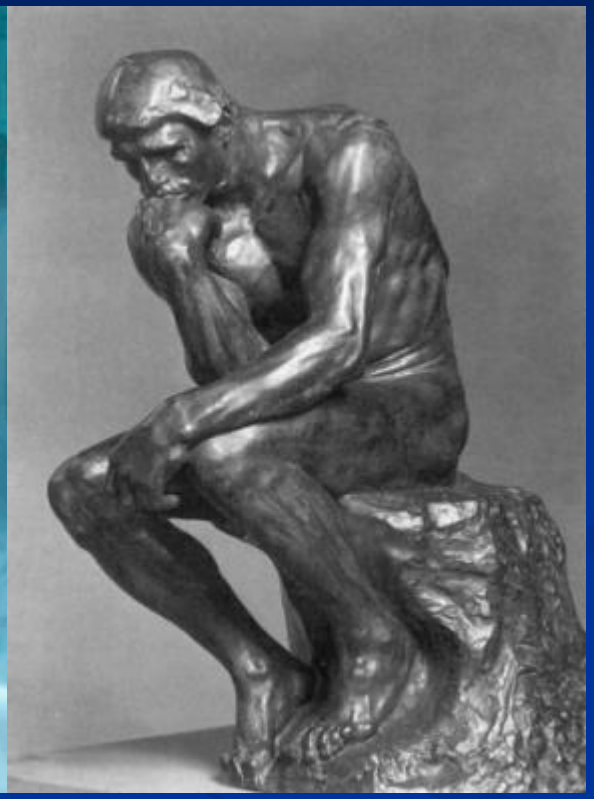
Credit: Daniel Thomas - Mapping the sky

History of the universe
宇宙的历史



Epilog结语

We live in an extraordinary epoch in which we can think about the universe using the physical laws.
我们生活在一个非凡的时代，我们可以用物理定律来思考宇宙。



It is possible that with time our ideas change, but that's how is science. 随着时间的推移，我们的想法有可能会发生变化，但这就是科学。

Many thanks
for your attention!
谢谢！