The End of Cosmology?
An accelerating universe wipes out traces of its own origins

By Lawrence M. Krauss and Robert J. Scherrer

Scientific American 27 Feb., 2008

http://www.sciam.com/article.cfm?id=the-end-of-cosmology&page=1

About one hundred years ago a Scientific American article about the history and large-scale structure of the universe would have been almost completely wrong. In 1908 scientists thought our galaxy constituted the entire universe.

They considered it an “island universe,” an isolated cluster of stars surrounded by an infinite void.

We now know that our galaxy is one of more than 400 billion galaxies in the observable universe.

Origin of the Universe

In the late 1920s, Edwin Hubble discovered that distant stars and galaxies are receding from earth in every direction and the velocities of recession increase in proportion to distance.

The implication is that the universe is expanding.

Expanding universe hypothesis

Deductions

Currently observed matter and energy were initially condensed in a very small and infinitely hot mass.

Huge explosion, now called the Big Bang, sent matter, energy, and space-time in all directions.

In 1908 the scientific consensus was that the universe was static and eternal.

* A decade ago astronomers made the revolutionary discovery that the expansion of the universe is speeding up. They are still working out its implications.

Big Bang leads to other deductions

Temperature of deep space should be several degrees above absolute zero.

In the mid-1960s astronomers at Bell Labs detected this radiation - *the cosmic microwave background*.

This has been confirmed by the Cosmic Microwave Background Explorer (COBE) satellite launched in 1991.

The Big Bang

One misconception about the Big Bang is that it provides a theory of cosmic origins.

The Big Bang is a theory that describes the evolution of the universe from a split second ***after time zero.***

It says nothing about what brought the universe into existence.

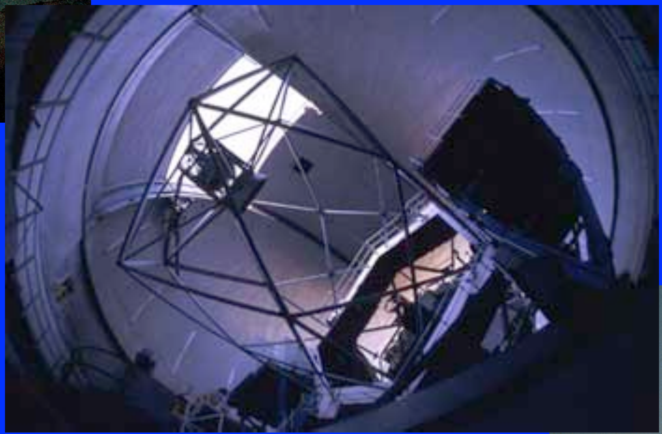
The data

What do we see and how do we see it?

Ground-based optical and infrared telescopes

8-10m class telescopes

VLT



Keck

Gemini

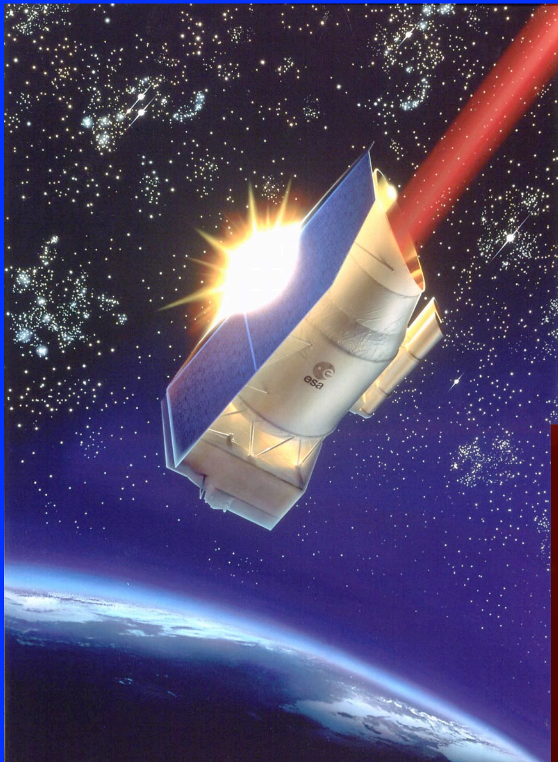
Ewine F. van Dishoeck, Leiden Observatory

Submillimeter telescopes

IRAM 30m

Pico Valeta, Spain

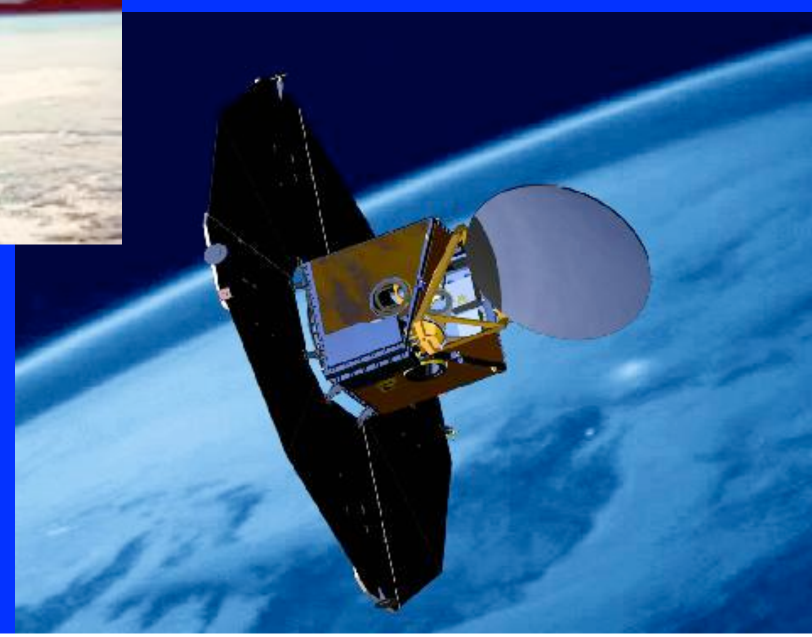
Space observatories



ISO

SWAS

ODIN



Large part of infrared and submm blocked by atmosphere (i.p. H_2O, O_2 and CO_2)

Herschel Space Observatory

Ewine F. van Dishoeck, Leiden Observatory

Orion nebula as seen by VLT

Nursery of thousands of new stars

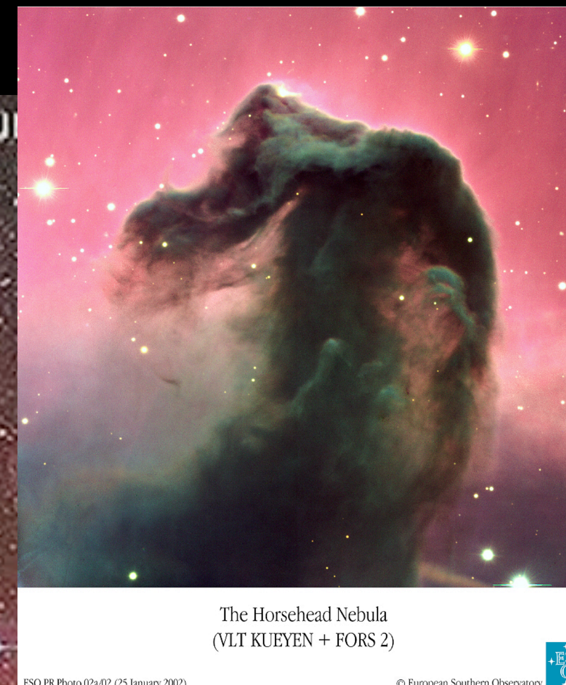
ESO-VLT
ISAAC image
McCaughrean et al. 2001

`The chaotic material of future Suns'
W.Herschel (1789)

Ewine F. van Dishoeck, Leiden Observatory

Star-forming regions:

NGC 2024 and Horsehead nebula in Orion



The Horsehead Nebula
(VLT KUEYEN + FORS 2)

Typical size clouds: ~few light yr
Typical mass cloud complexes: ~10^4 M_{Sun}

AAT

Ewine F. van Dishoeck, Leiden Observatory

S106 Star-forming region

Subaru-
Cisco

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Dark cloud B68

ESO-VLT
Alves et al. 2001

Dark clouds

99% gas (H_2) 1% dust by mass (~0.1 µm silicates + carbonaceous material)

Temperature: ~10 K

Density: ~10000 particles cm^{-3}

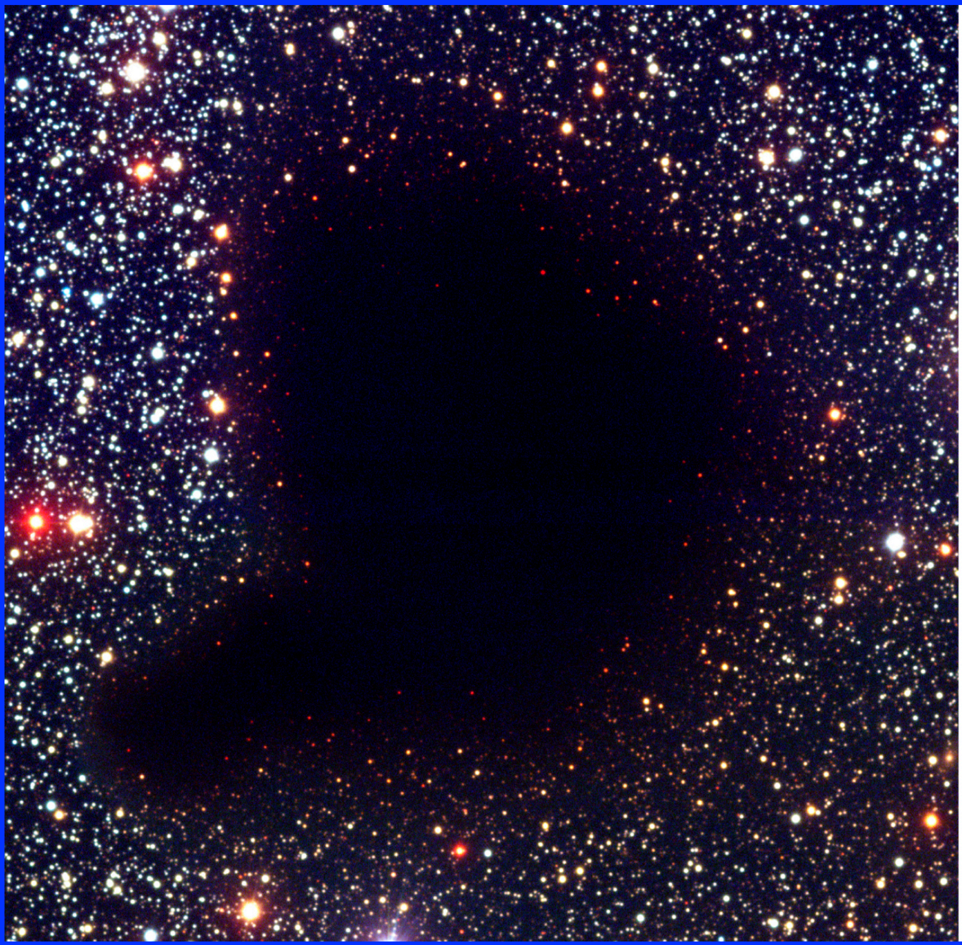
Line widths: 0.1 – few km/s

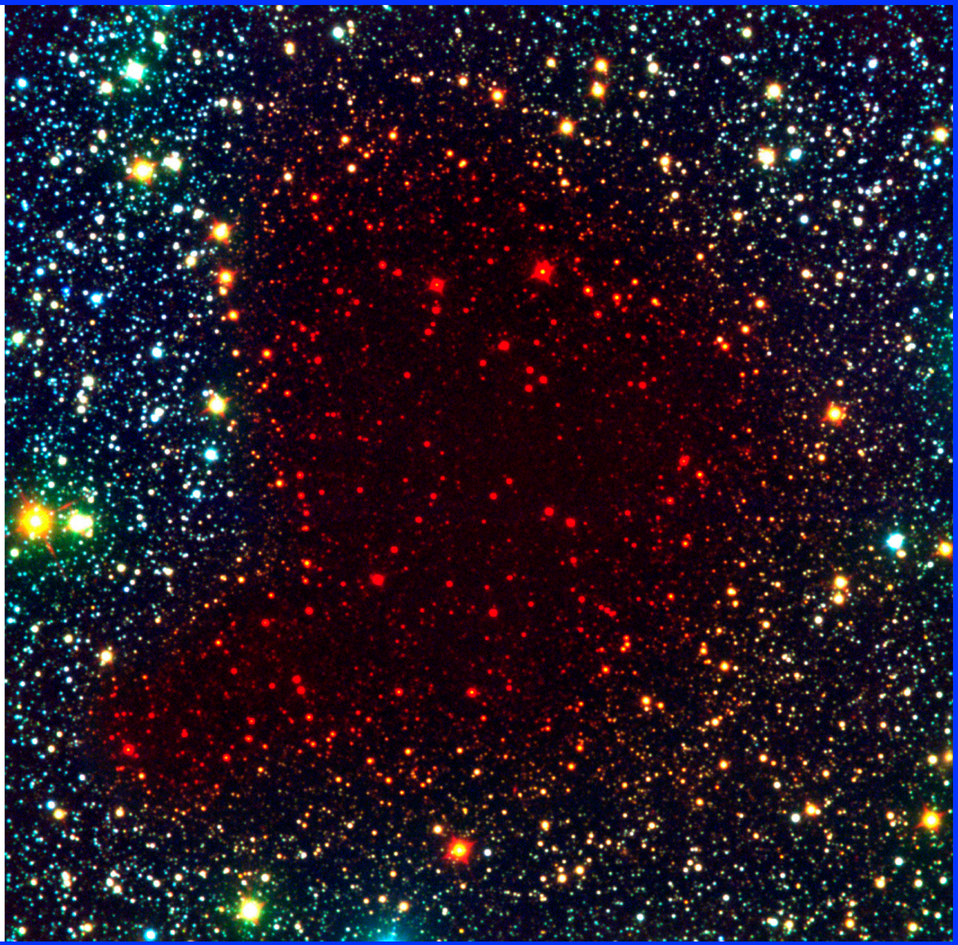
⟶ **Unique chemical and spectroscopy laboratory!**

Ewine F. van Dishoeck, Leiden Observatory

Observational techniques

Optical **Infrared**



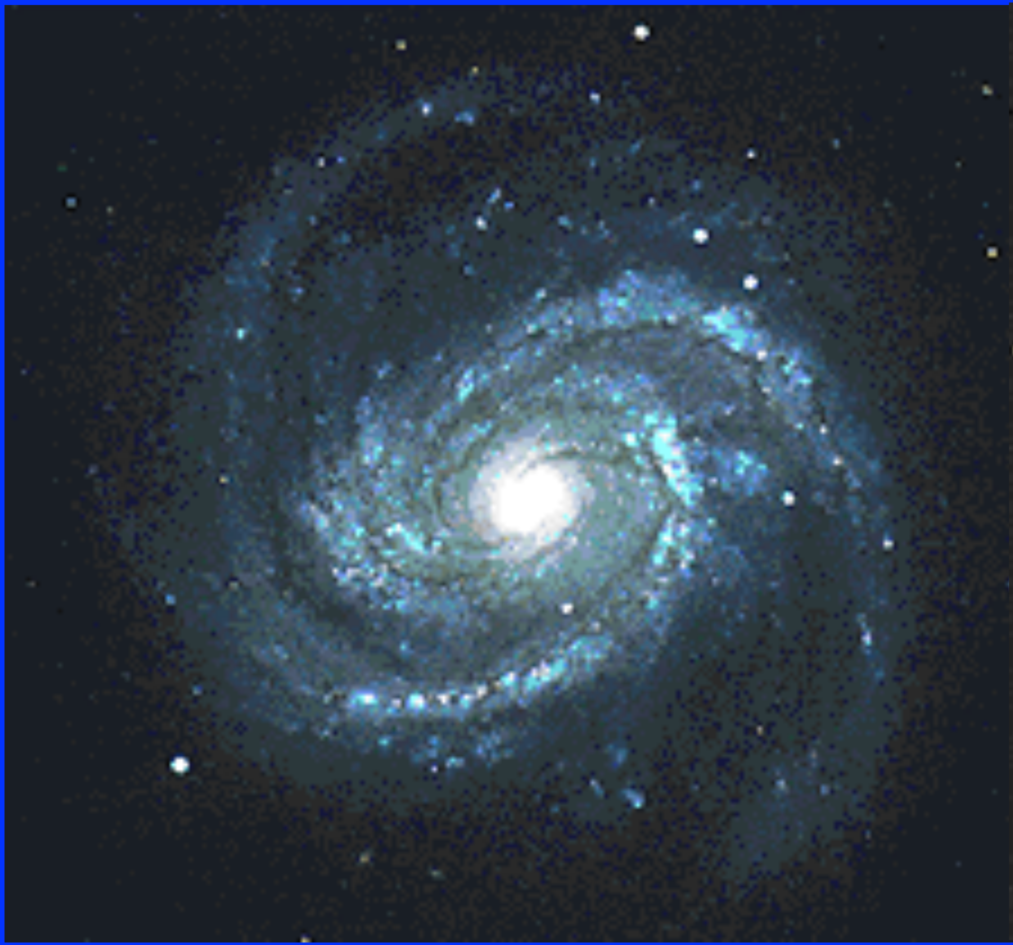
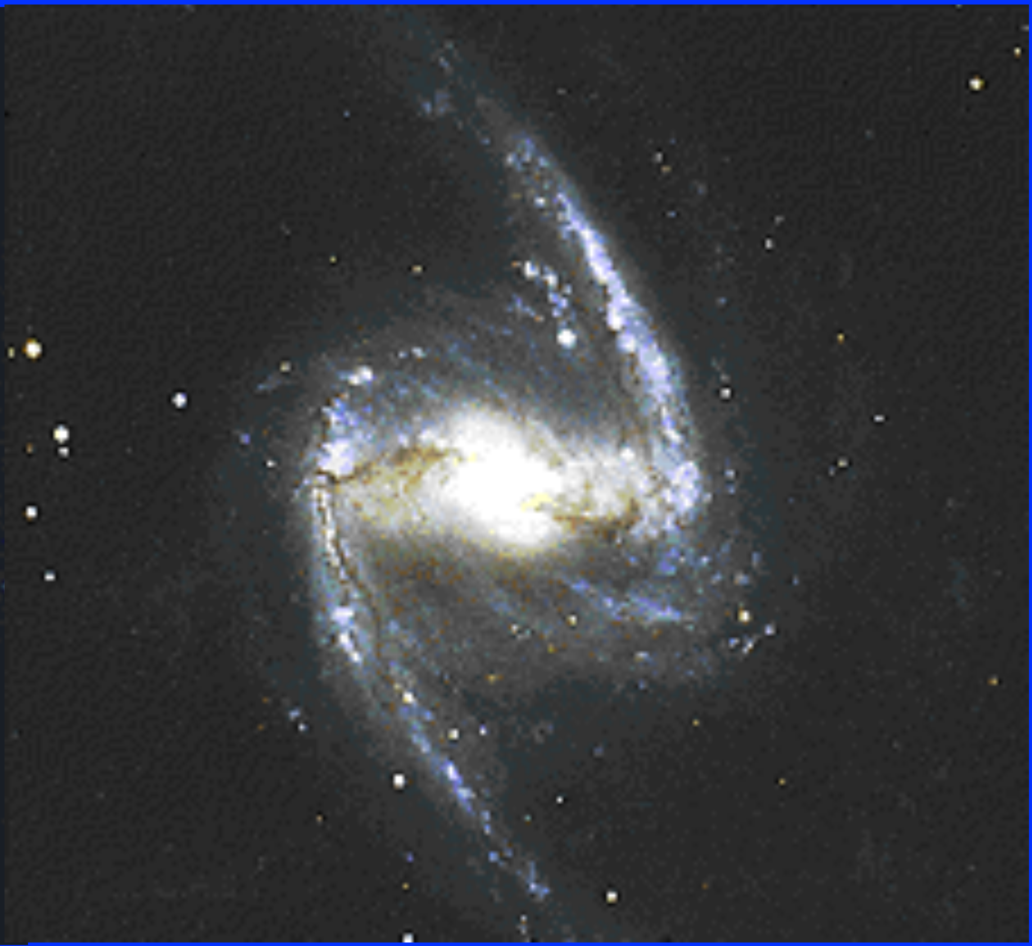


10-1000 mag extinction => long wavelengths (IR/mm)

(only low-density diffuse clouds with few mag extinction can be studied by optical spectroscopy)

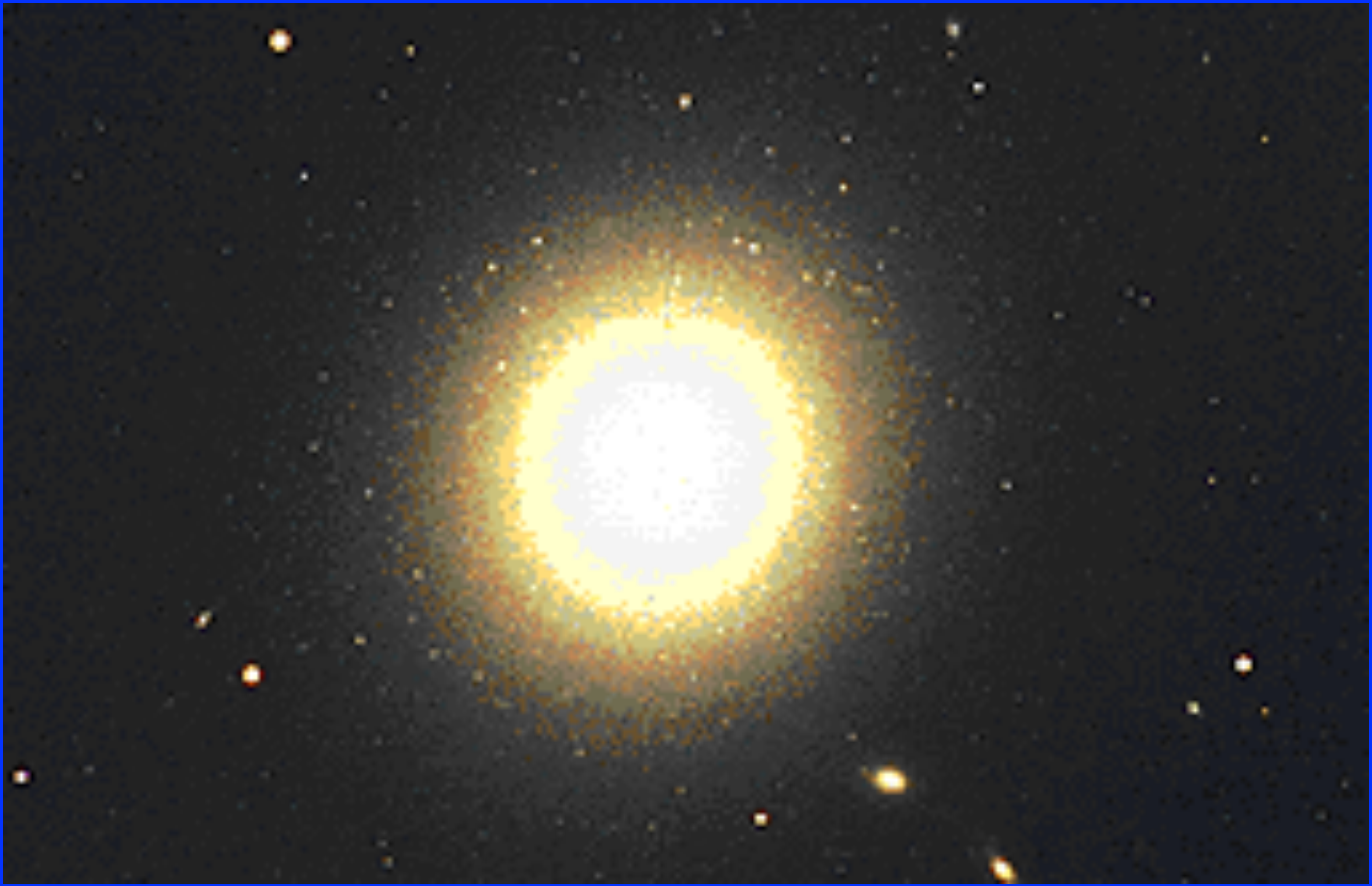
Alves et al. 2001

Spiral galaxies
M100 and NGC1365 (AAO)

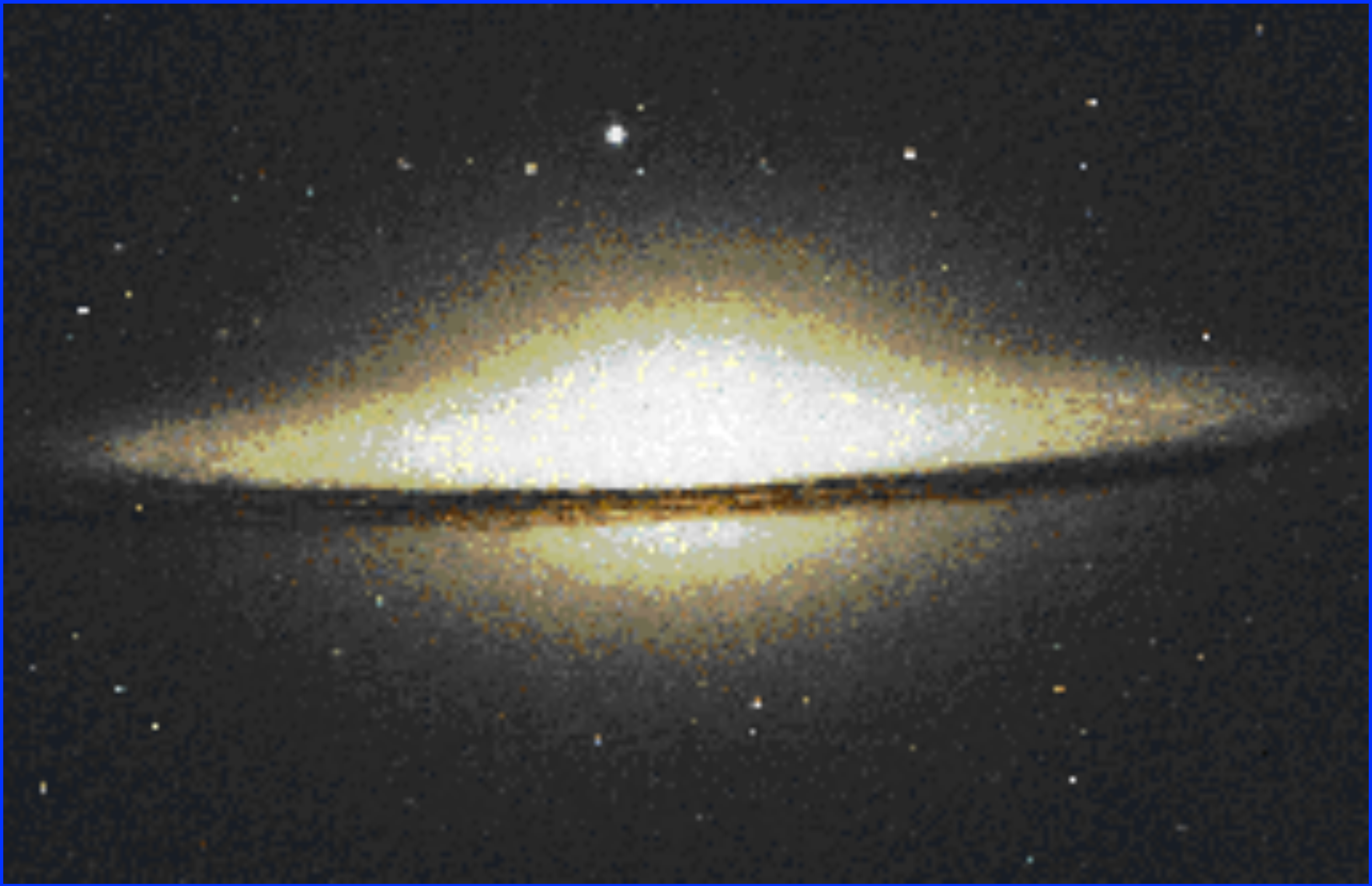
Anglo-Australian Observatory

The giant elliptical galaxy M87 (AAO)



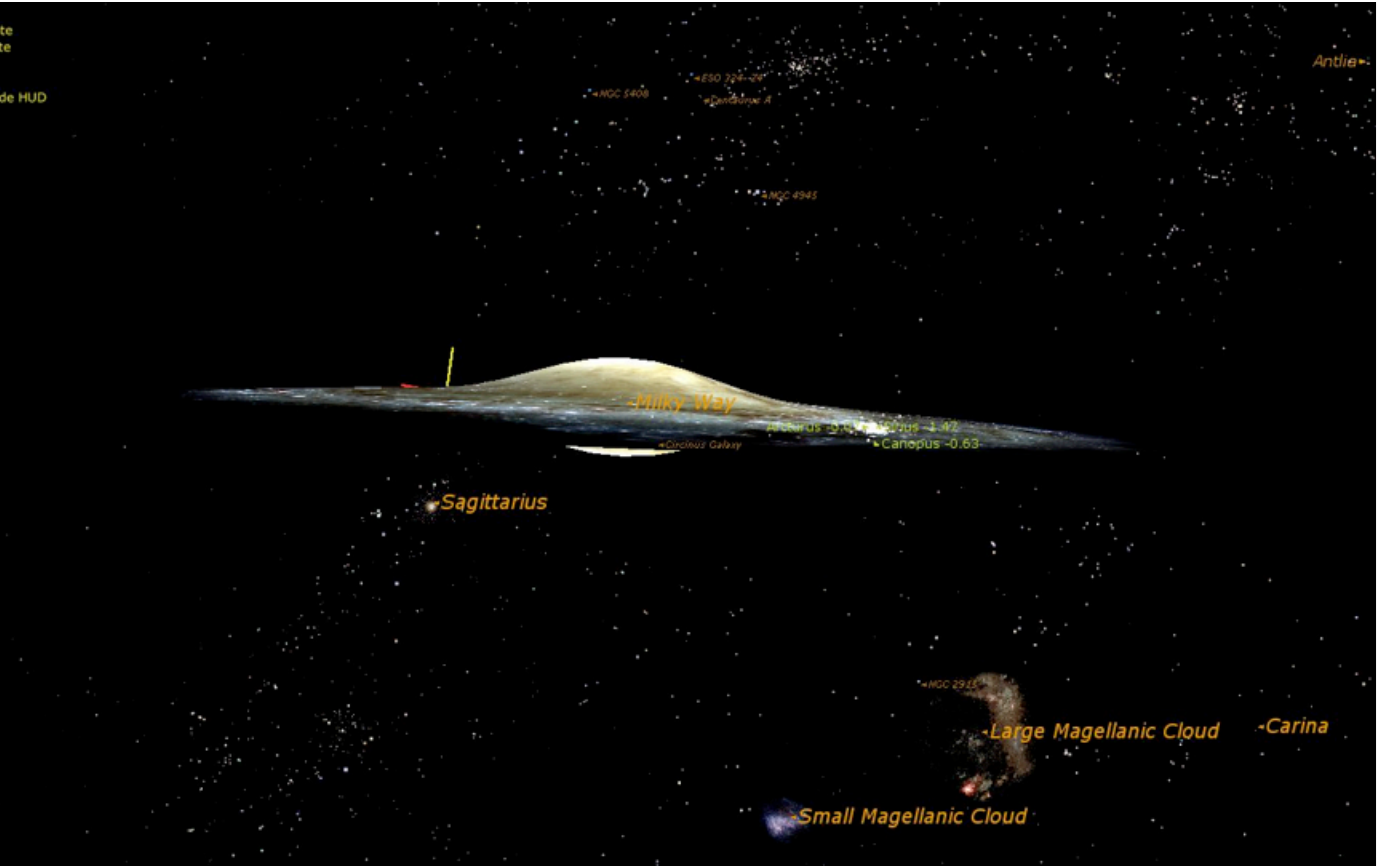
Anglo-Australian Observatory

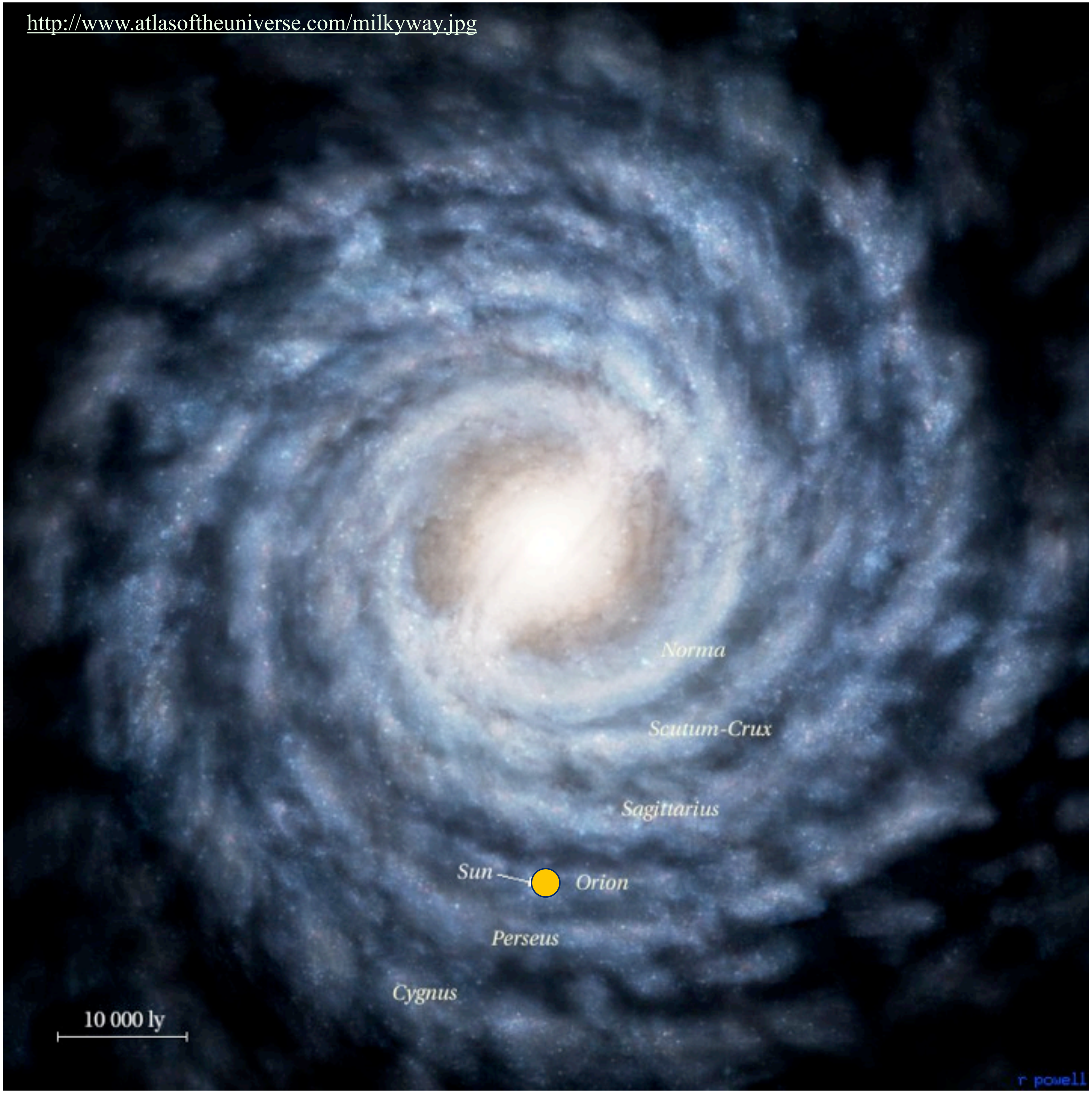
Sombrero galaxy NGC4549 (AAO)



Anglo-Australian Observatory

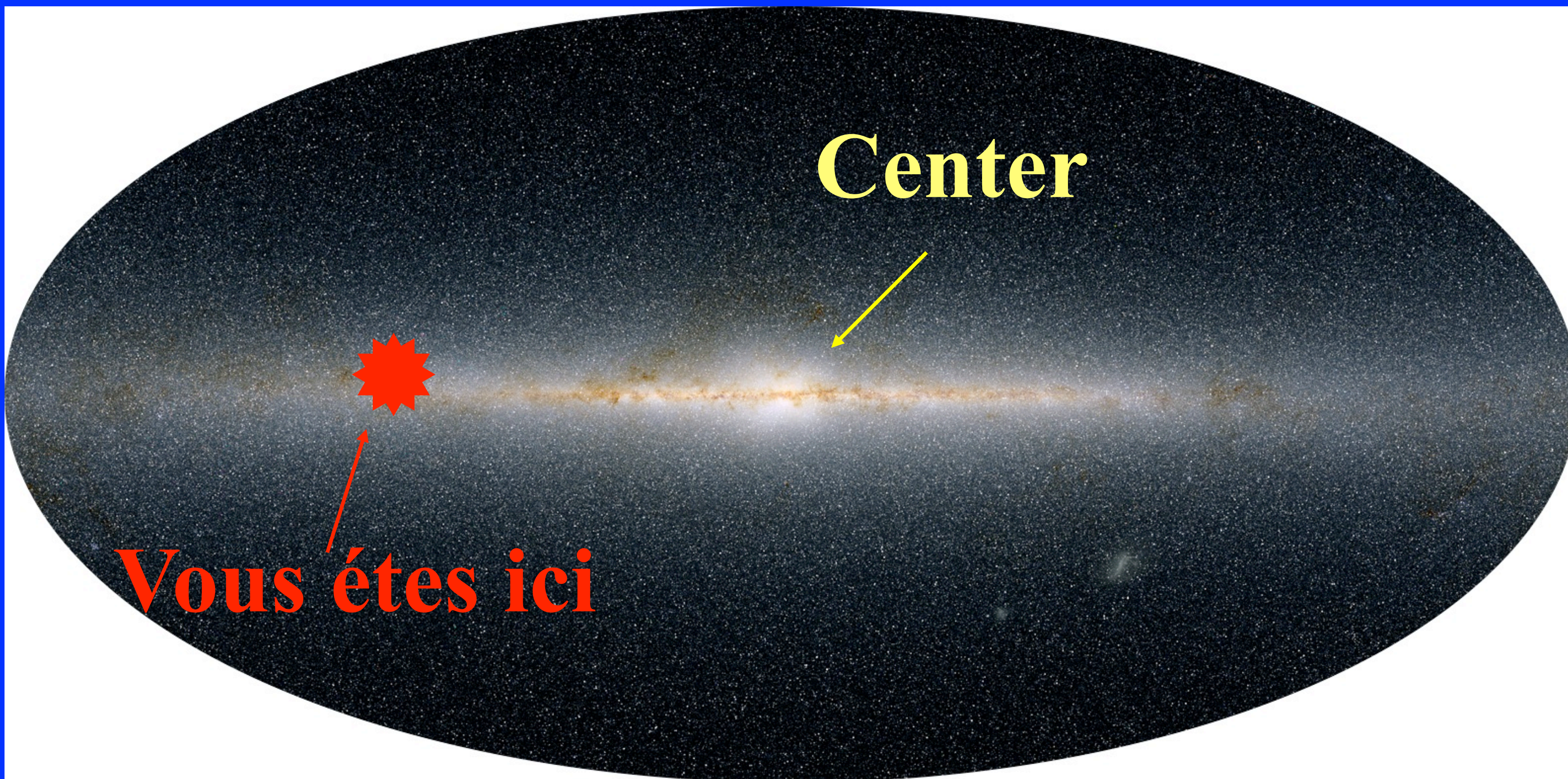
The Milky Way - home-sweet-home





http://www.atlasoftheuniverse.com/milkyway.jpg
Norma
Scutum-Crux
Sagittarius
Sun
Orion
Perseus
Cygnus
10 000 ly
r powell

Our Milky Way



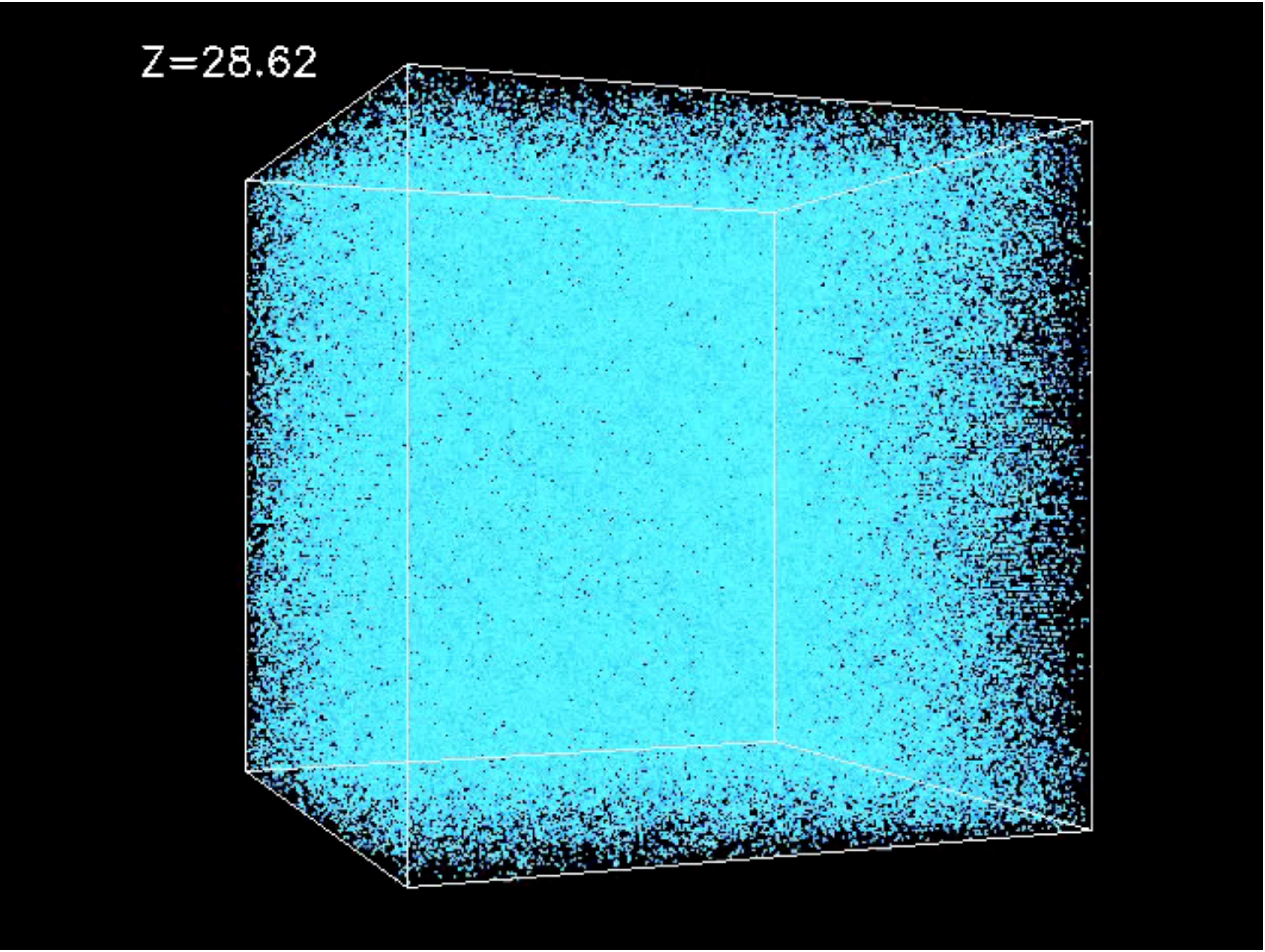
Solar Neighborhood
(<1500 lightyr from Sun)

2Mass/IPAC/NASA: J. Carpenter, T.H. Jarrett, R. Hurt

Formation of galaxies

As the universe expanded matter collected into clouds that began to condense and rotate, forming the forerunners of galaxies.

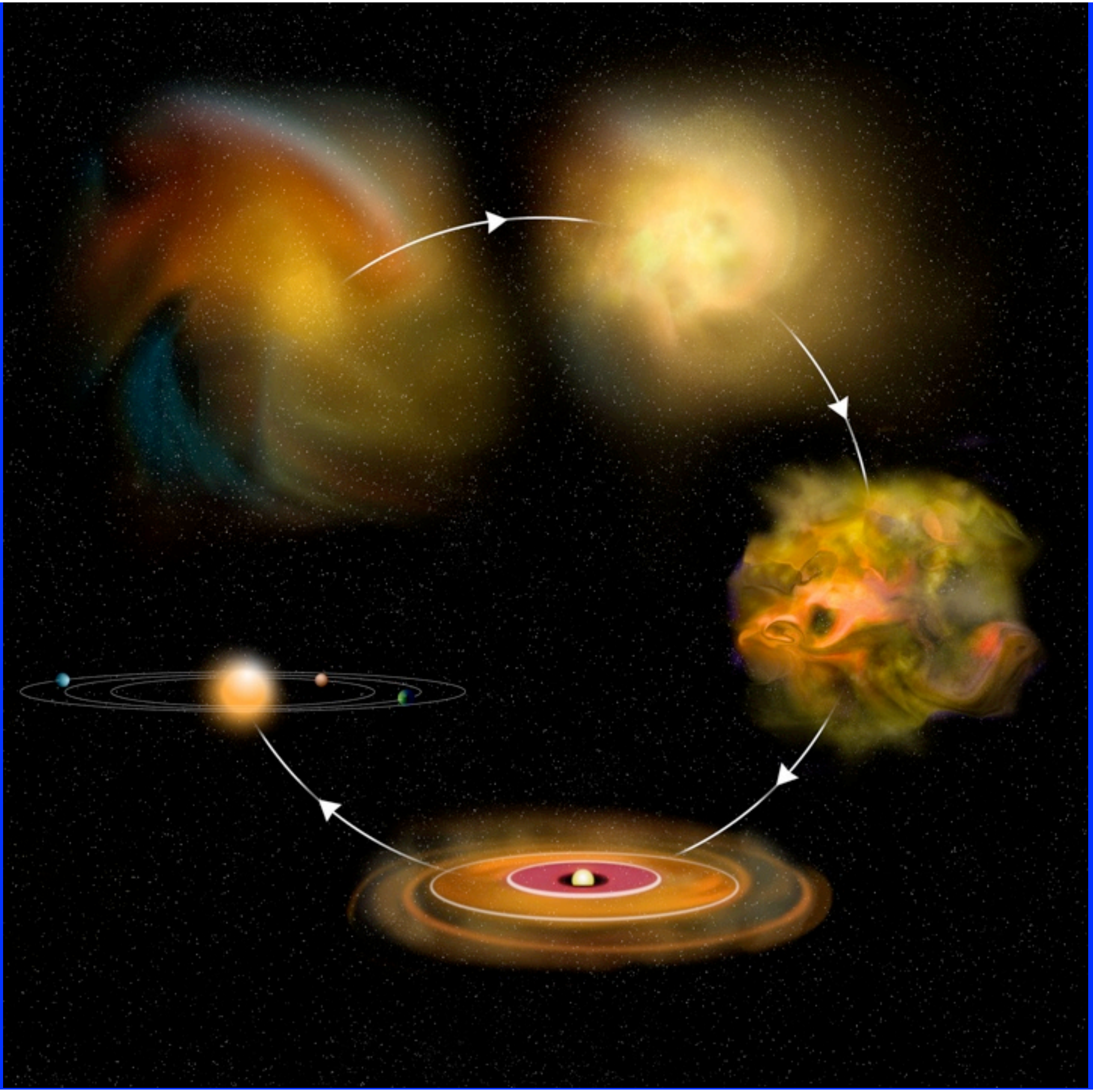
Within galaxies changes in pressure caused gas and dust to form distinct clouds. With sufficient mass and force, gravitational attraction caused the cloud to collapse.


Z=28.62

The birth of stars

If the mass of material in the cloud was sufficiently compressed, nuclear reactions began and a star was born.

In the case of our sun (and many other stars) the gas and dust within the disk collided and aggregated into small grains, the small grains into larger bodies called planetesimals (small planets)



The elements

Early giant stars, thousands of times the size of the sun, and supernova fused hydrogen and helium into all the other elements.

About 75% of ordinary matter is Hydrogen, 24% is Helium

Protoplanetary Disks

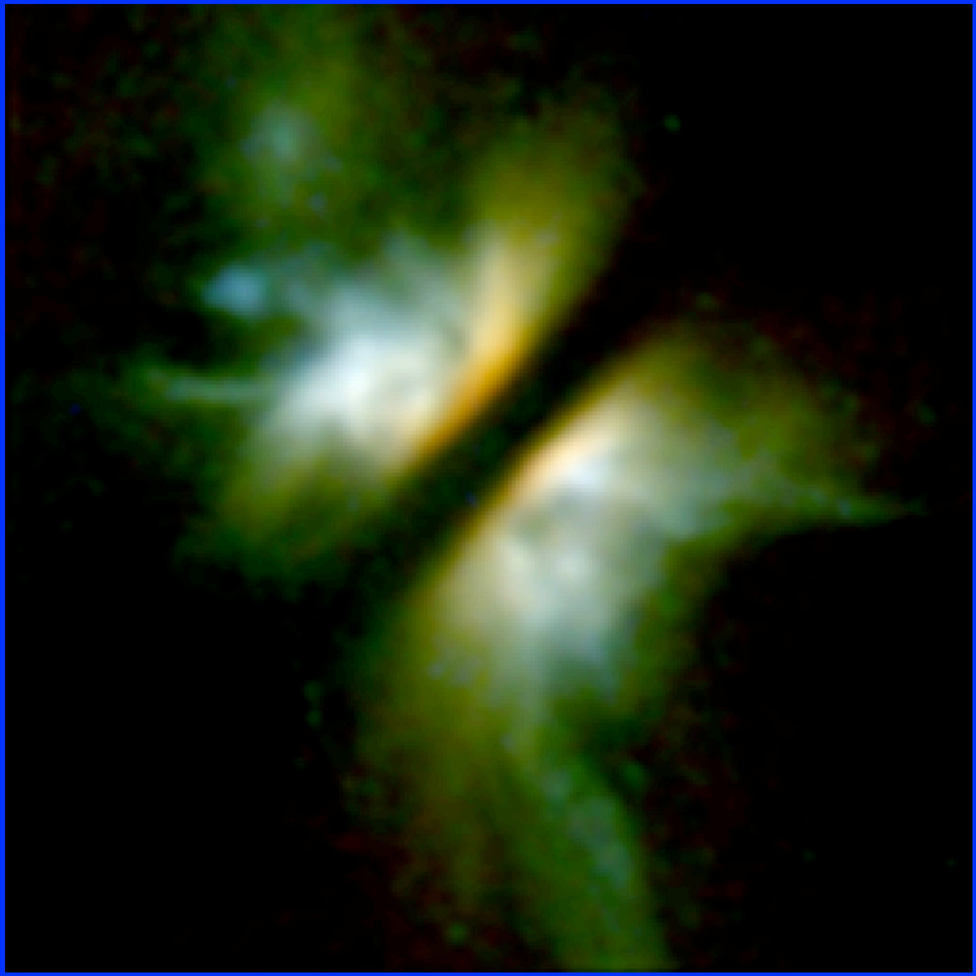
Most young stars are surrounded by disks

Sizes of disks comparable to that of our own solar system

Masses of disks usually enough to form solar system (~10^{-2} M_{sun}, ~10x mass of Jupiter), but significantly less than envelope

=> Disks are small (few arcsec) and lines are weak

Young edge-on disk in Taurus



IRAS04302+2247

HST-NICMOS

Padgett et al. 1999

Where are we in the space-time continuum?

Age of the universe

The age of the universe can be derived from the observed relationship between the velocities of galaxies and the distances separating them.

The velocities can be measured very accurately; the measurements of distances is more uncertain.

Age of the universe

Measurements of the Hubble expansion give estimates of the age of the universe between 7 billion and 20 billion years.

The most recent measurements are within the range 10 billion to 15 billion years

Age of the Milky Way galaxy

Determined two ways

Observed stages of evolution of different-sized stars in globular clusters

Abundances of several long-lived radioactive elements in the solar system

Age of the Milky Way galaxy from globular clusters

Globular clusters occur in a faint halo surrounding the center of the galaxy.

Each cluster has from a hundred thousand to a million stars.

The very low amounts of elements heavier than hydrogen and helium in these clusters indicate they were formed early in the history of the galaxy.

Age of the Milky Way galaxy from globular clusters

Estimates of the ages of the stars in the globular clusters fall within the range of 11 billion and 16 billion years

Radioactive decay

We have seen that elements occur in a number of isotopes.

These isotopes of an element differ in the number of neutrons in the nucleus and in the stability of the nucleus.

Over time, some elements literally "fall apart" into other elements

Radioactive decay

The time it takes for the element to fall apart is characteristic of the isotope in question. Each isotope has a different time.

Given any initial amount of element, the time it takes for half of the initial amount to be present is called the “half-life”

Electron capture

Protons and neutrons are roughly the same size. Protons have a positive charge and neutrons are neutral (no charge).

A proton can be transformed into a neutron if it captures an electron. The negative charge neutralizes the proton charge.

Similarly, a neutron can transform itself into a proton by expelling a unit of negative charge, i.e. an electron.

Decay of carbon 14

$$^{14}_{6}C \rightarrow \,^{0}_{-1}\beta + \,^{14}_{7}N$$

Beta rays are electrons.

In the unstable nucleus a neutron decays into a proton and an electron. The electron is ejected, leaving a nucleus with roughly the same mass and one more proton

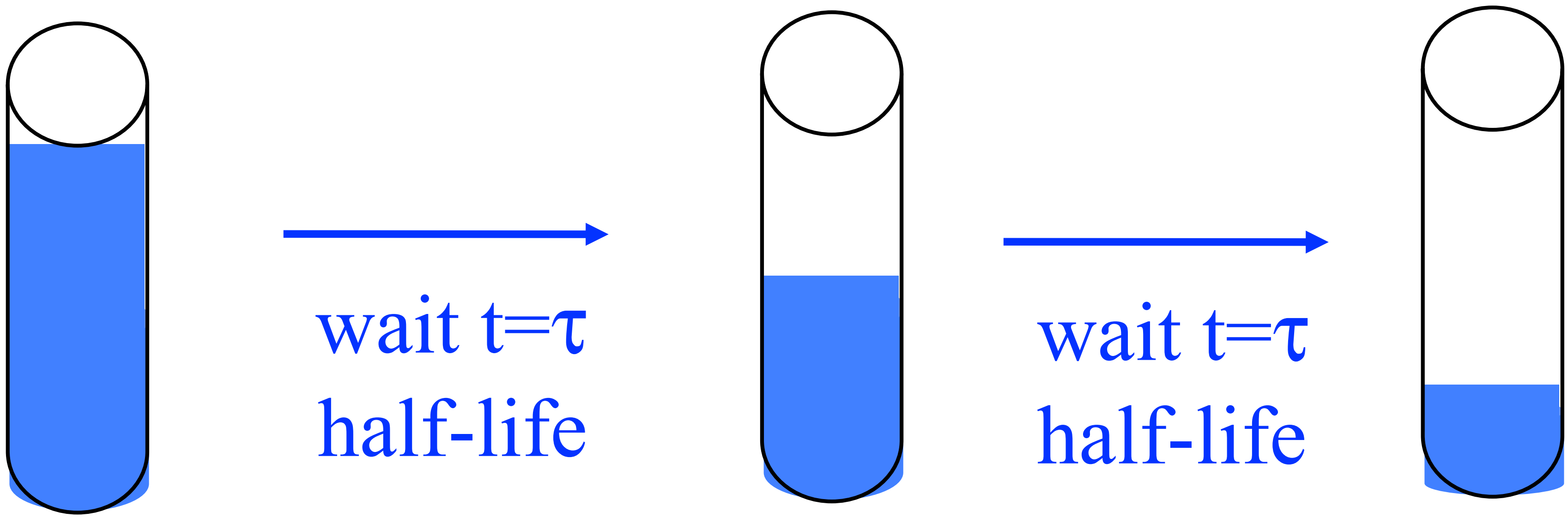
Radioactive decay

The decay follows what we call first-order kinetics and obeys the differential equation.

$$\frac{dN(t)}{dt} = -\lambda\, N(t)$$

1st order rate constant

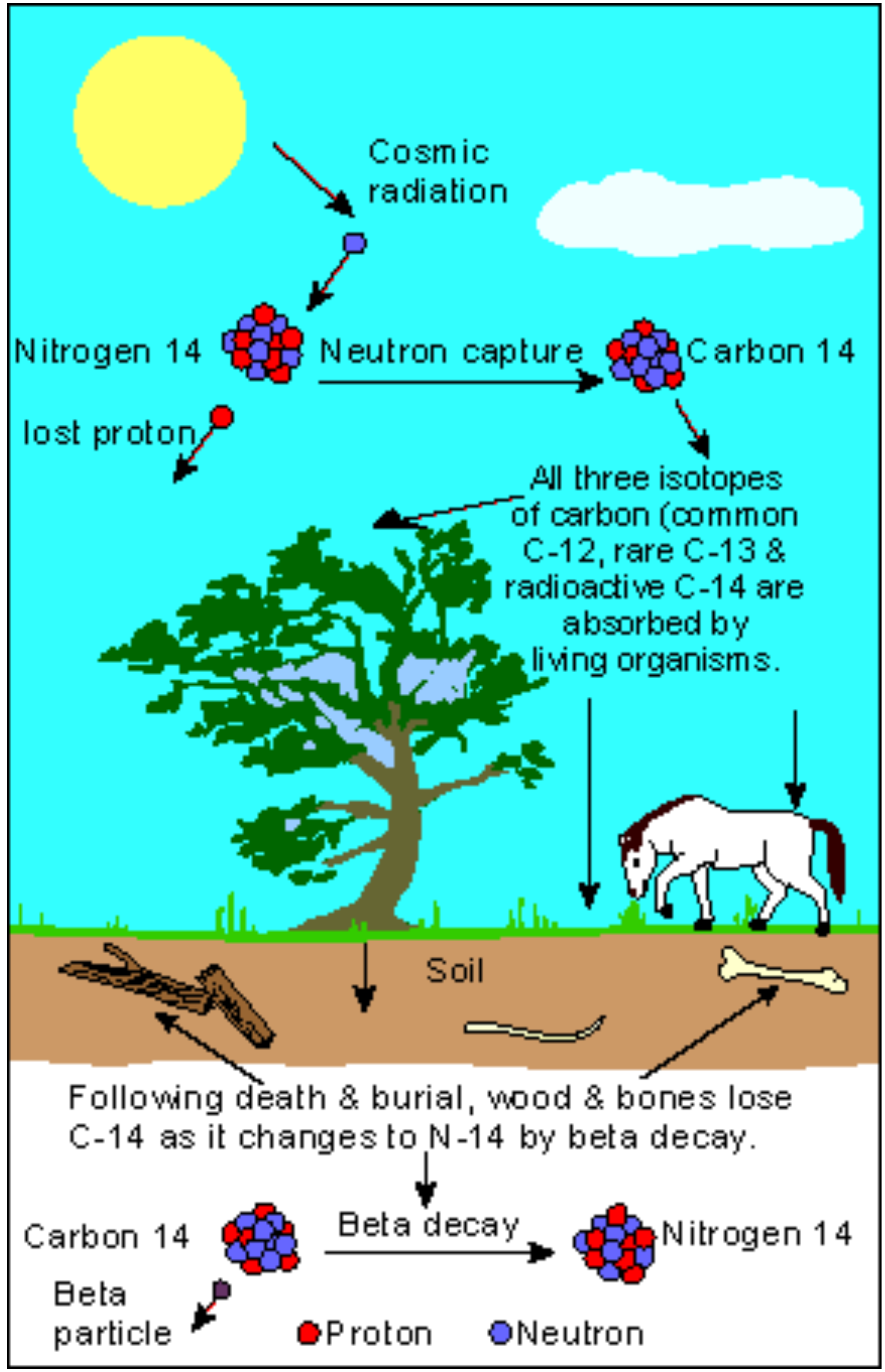
Decay process



Radioactive decay

When we know the ratio of isotopes for a stable and decaying isotope we can work backward to determine the age of an object.

Living things



Radioactive decay

For example, bones of animals.

Ratio of ^{14}C to ^{12}C known for living animal.

From bone, one can determine the current ^{14}C / ^{12}C ratio.

Radioactive decay

What has been happening is that ^{14}C has been decaying while ^{12}C is stable.

This allows us to find the ratio of the amount of $^{14}C_{present}$ to $^{14}C_{past}$

The radioactive decay eq. gives

$$\frac{^{14}C_{present}}{^{14}C_{past}} = e^{-\lambda t}$$

We know

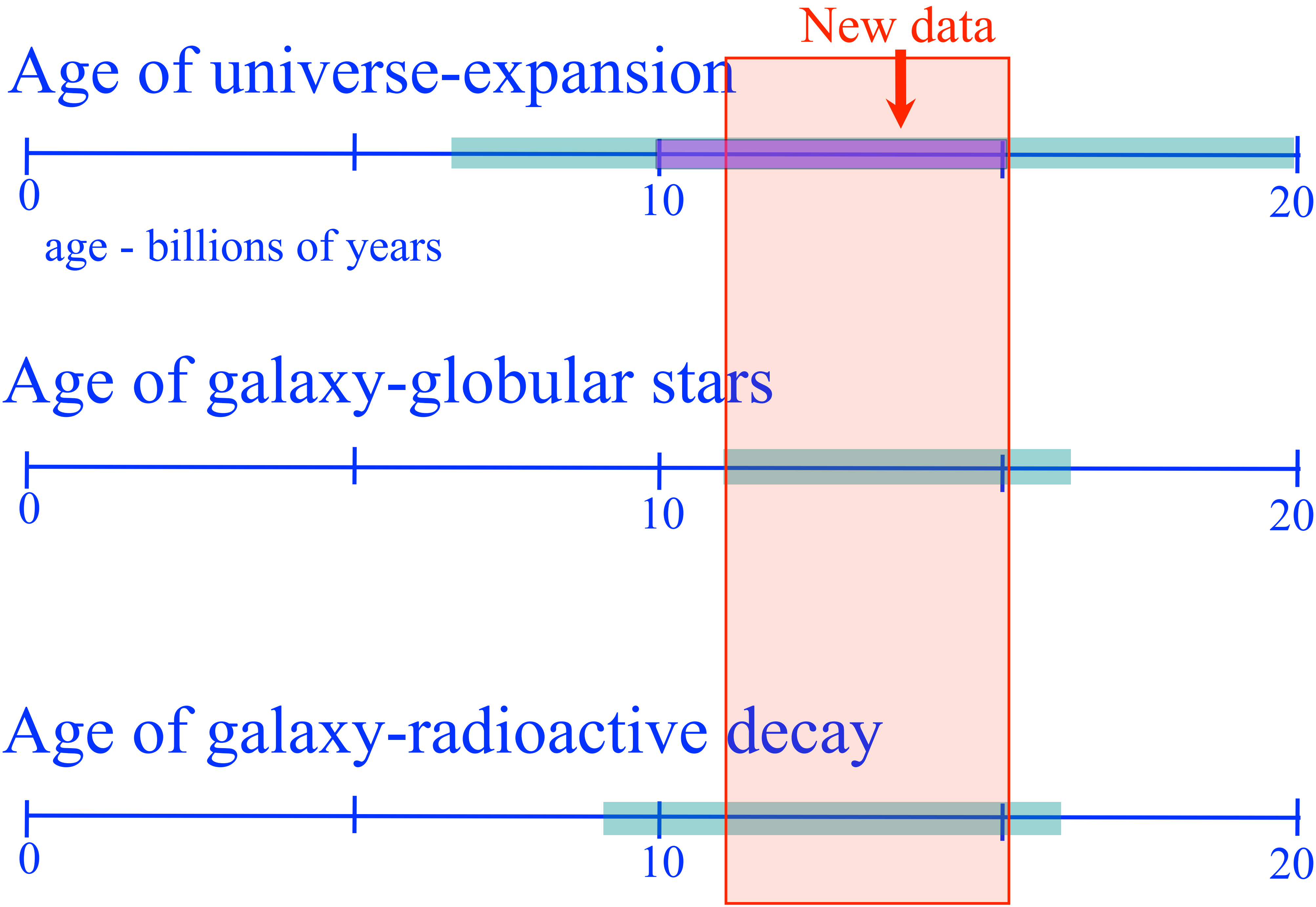
Solve for t

This tells us that the animal died t years ago

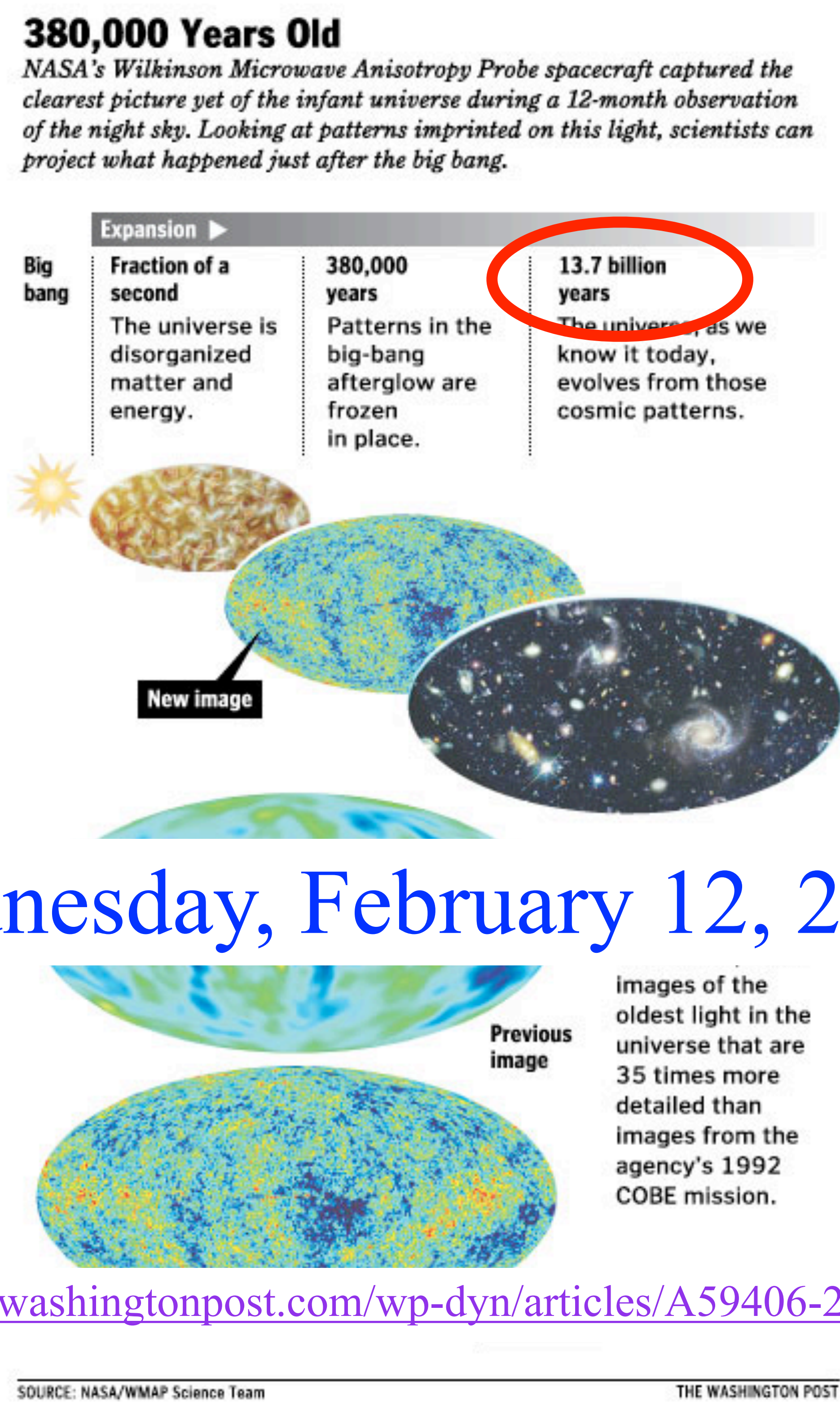
Age of the Milky Way galaxy From- Abundances of several long-lived radioactive elements in the solar system

The abundances are set by their rates of production and distribution through exploding supernovas

According to these calculations the age of our galaxy is between 9 billion and 16 billion years



New data
Age of universe-expansion
0
10
20
age - billions of years
Age of galaxy-globular stars
0
10
20
Age of galaxy-radioactive decay
0
10
20

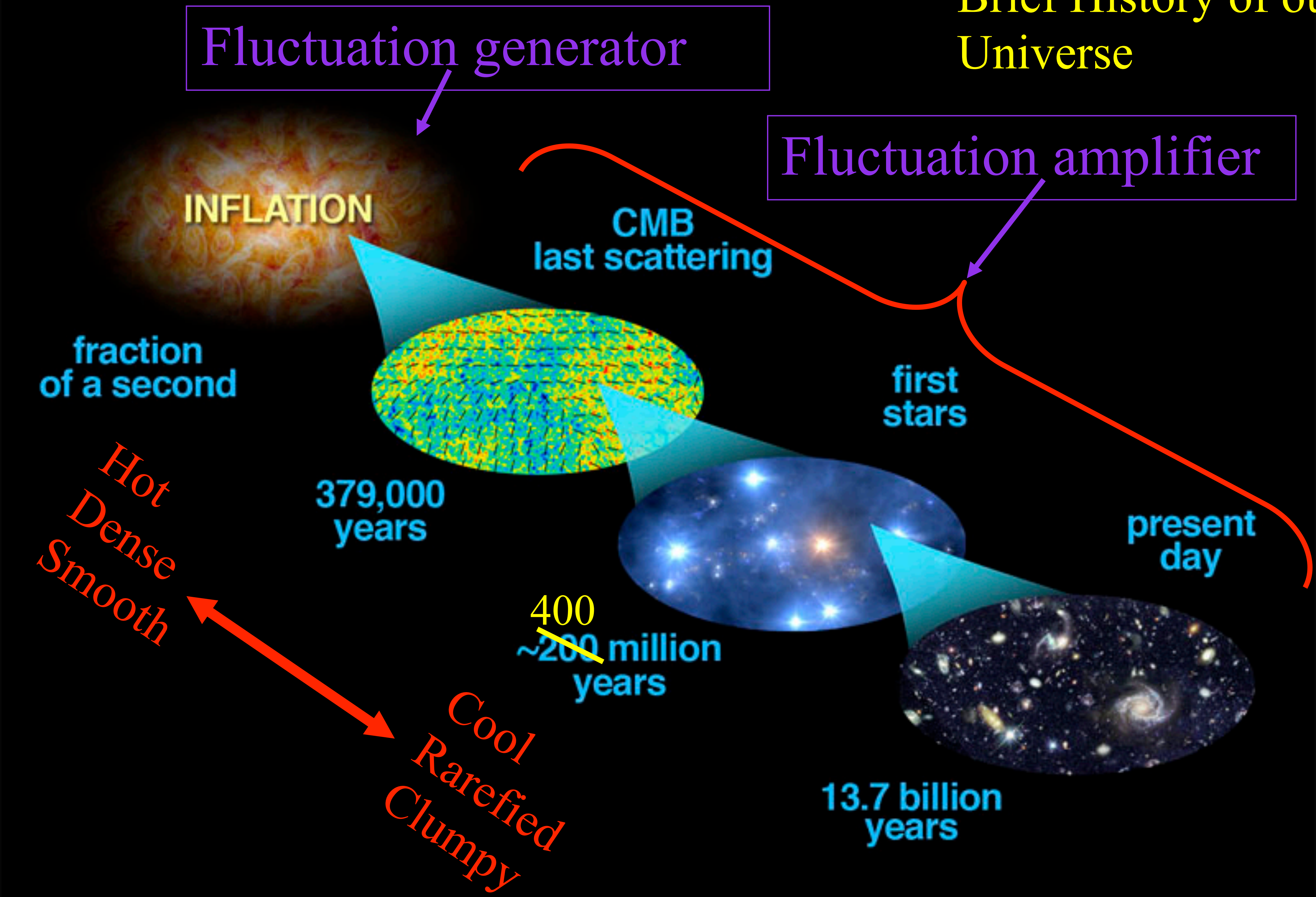


Wednesday, February 12, 2003

<http://www.washingtonpost.com/wp-dyn/articles/A59406-2003Feb11.html>

The sky as a time machine

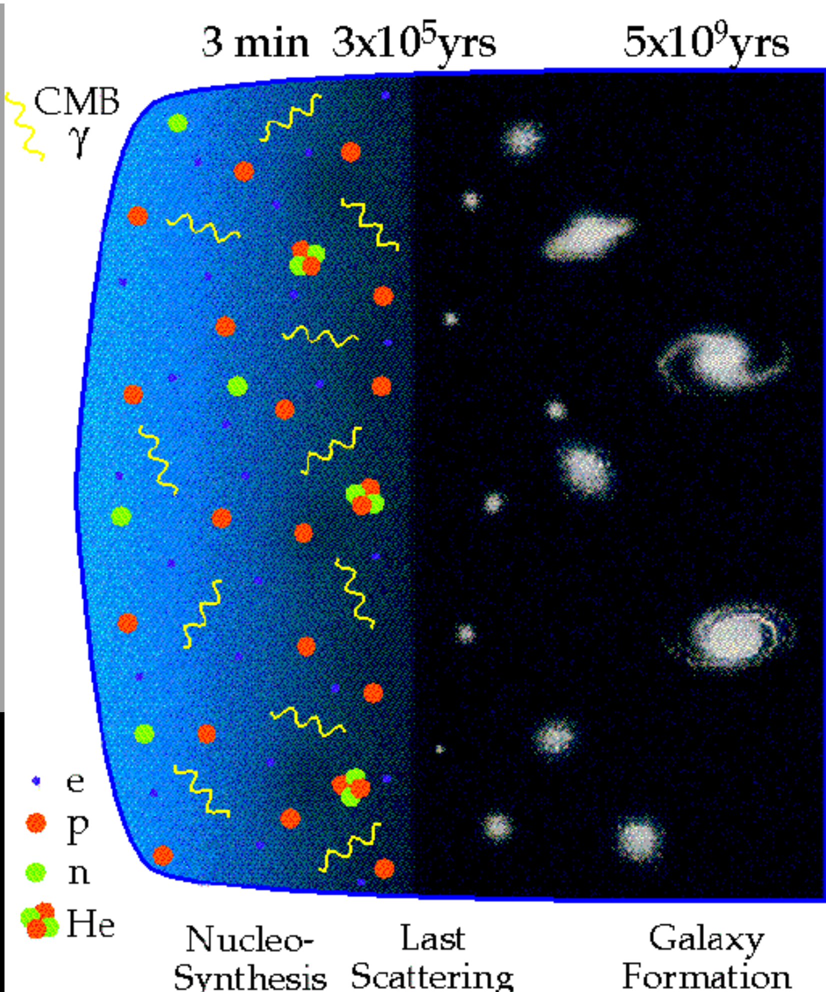
Brief History of ou
Universe



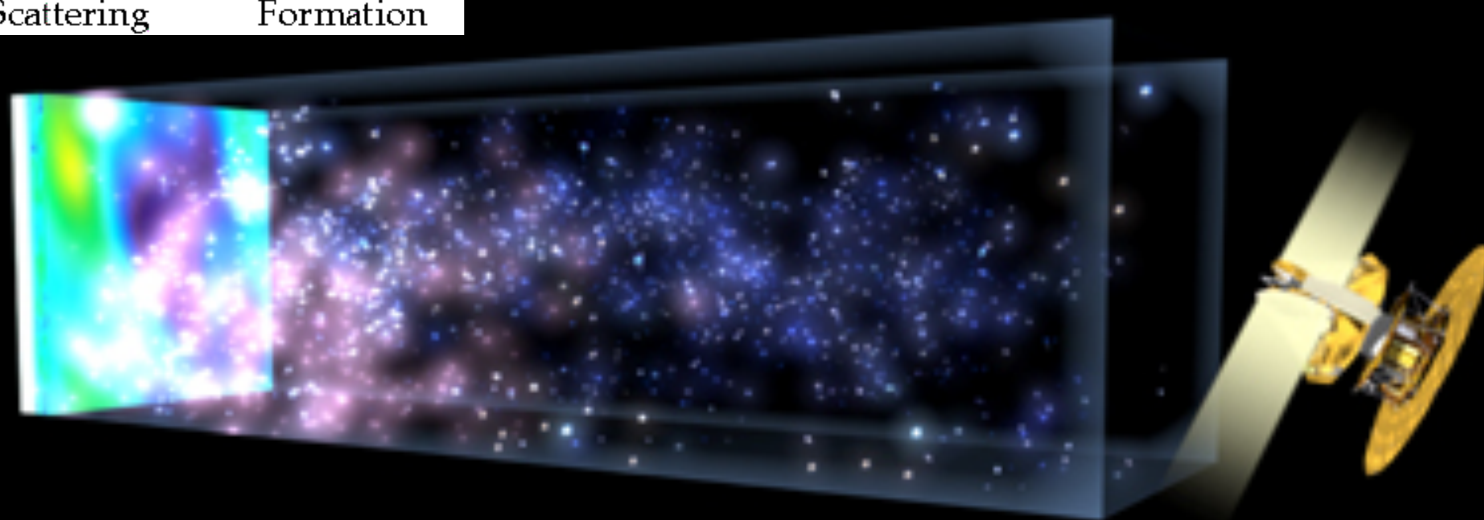
(Graphics from Gary Hinshaw/WMAP team)

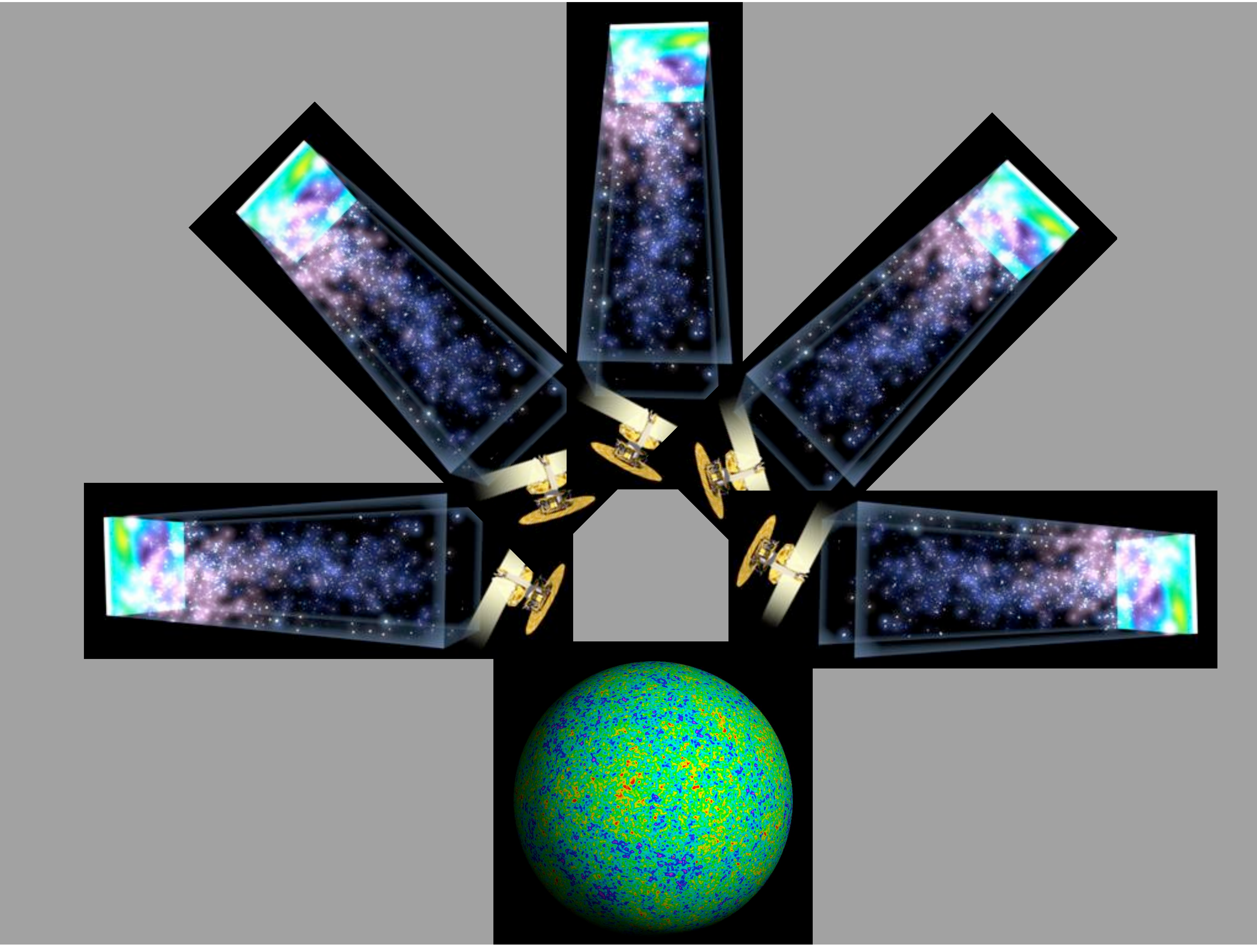
very brief history

(Figure from Wayne Hu)



(Figure from WMAP team)





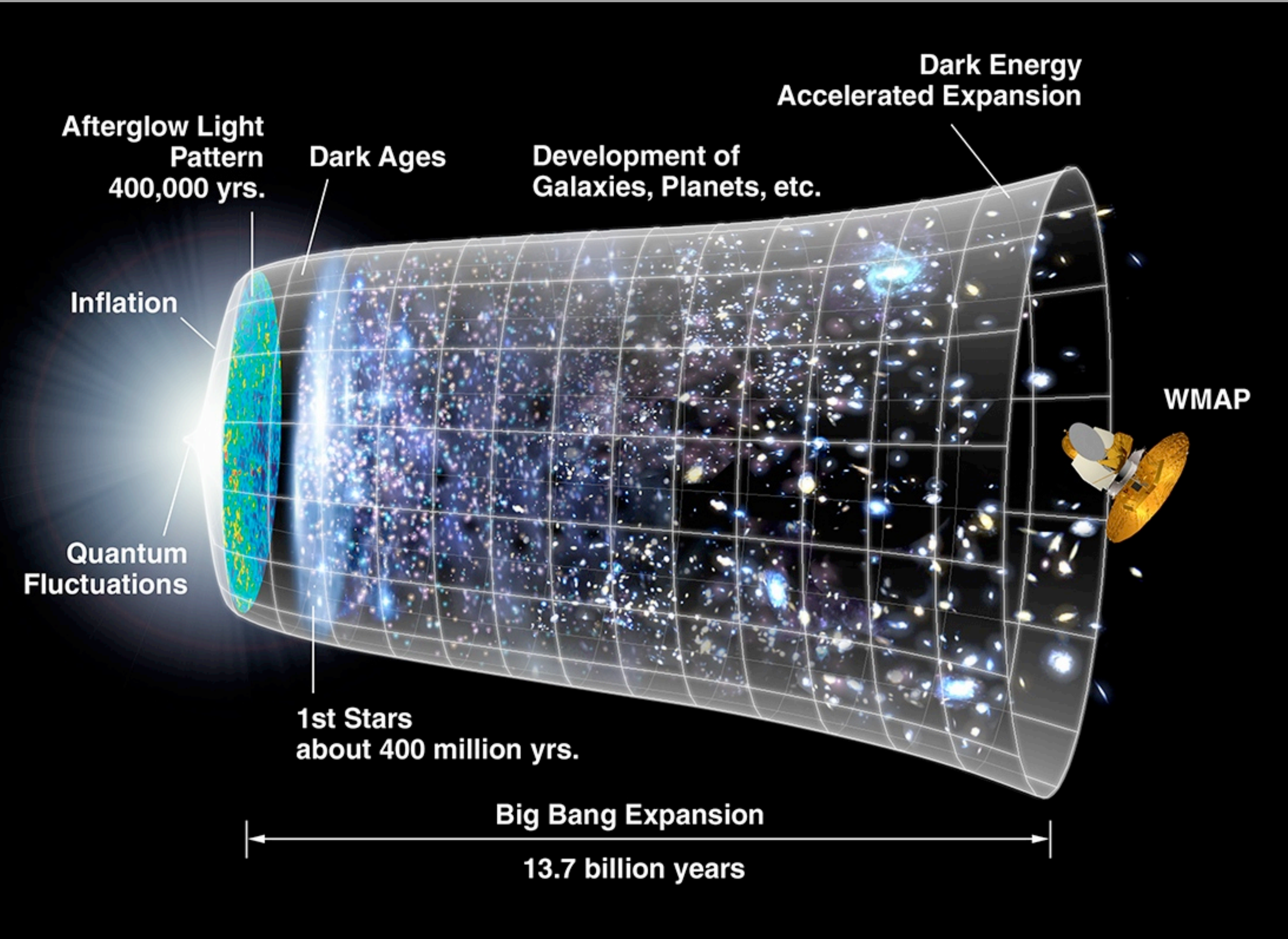
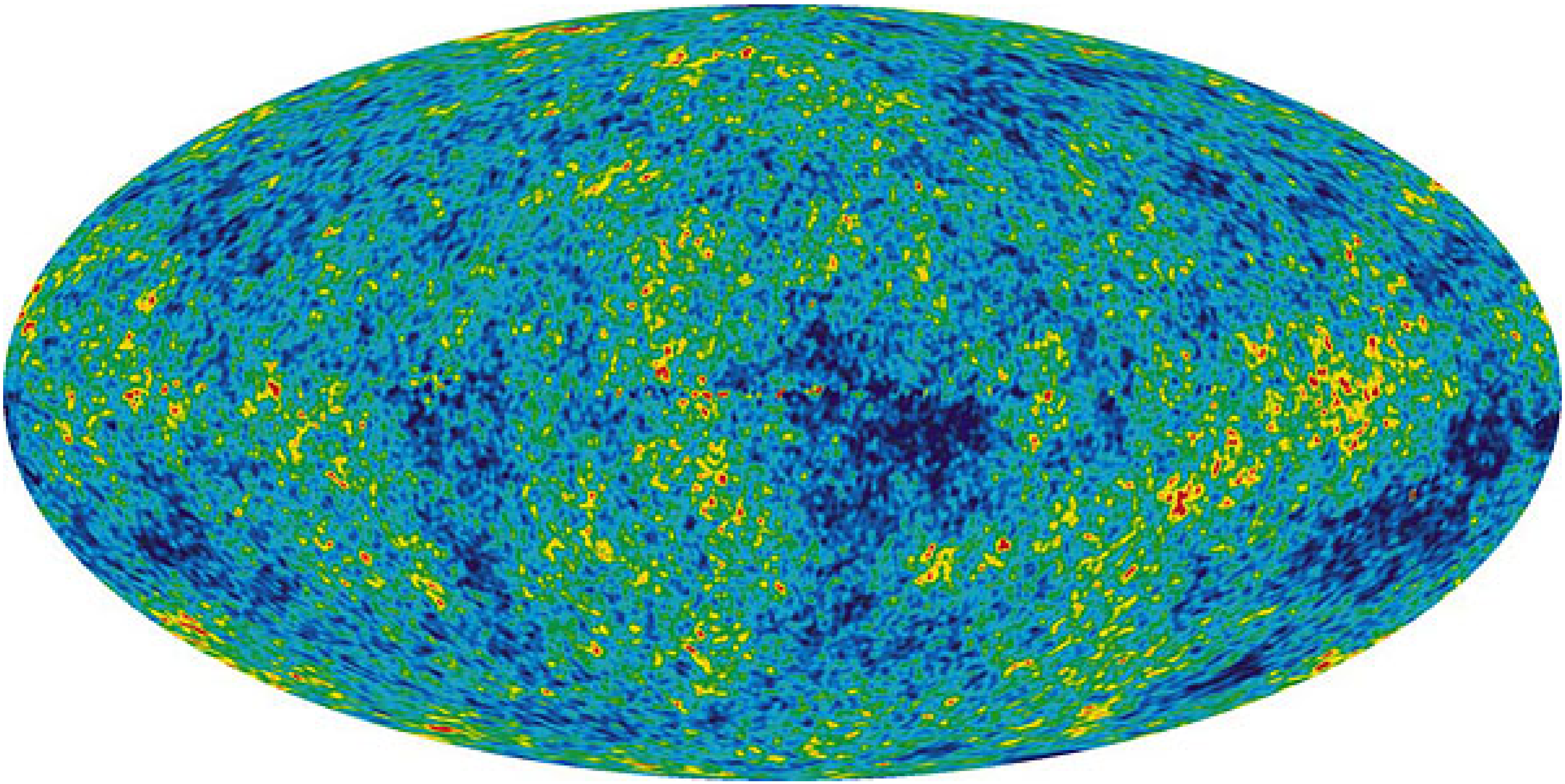


Figure from WMAP team

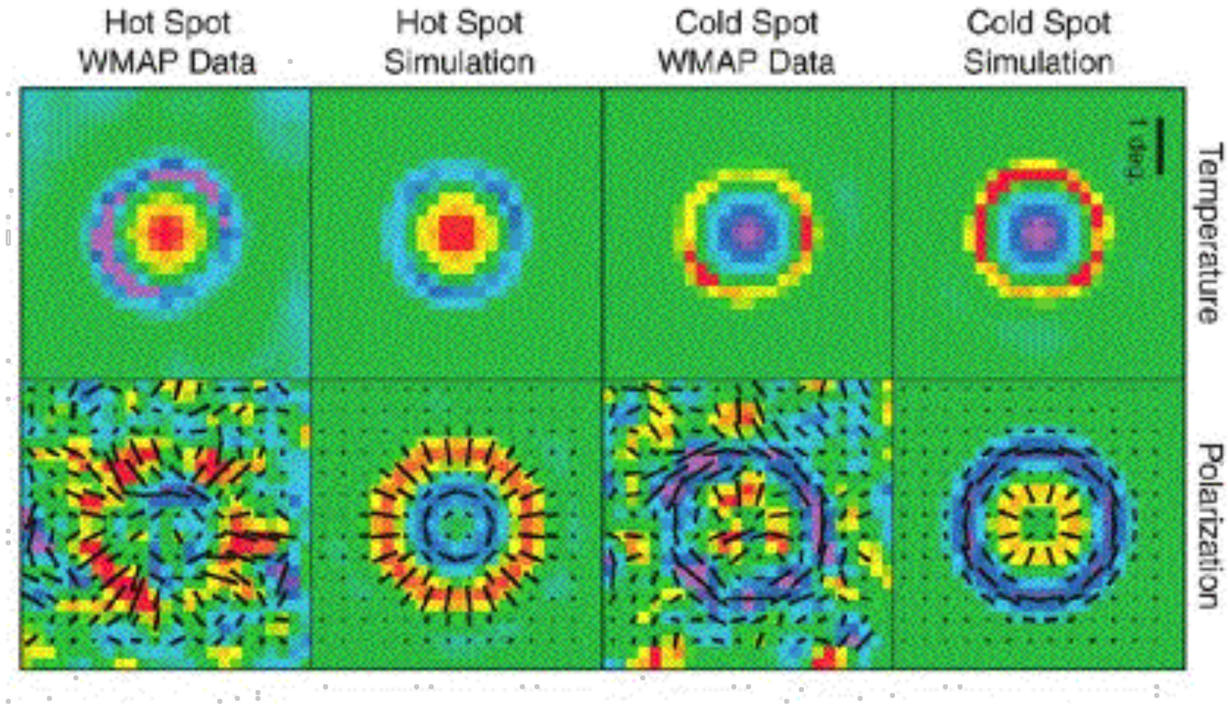


Results 2008

The universe is 13.73 billion years old, give or take 120 million years

http://www.nytimes.com/2008/03/09/science/space/09cosmos.html?_r=1&oref=slogin

Universe 20 Million Years Older Than Thought



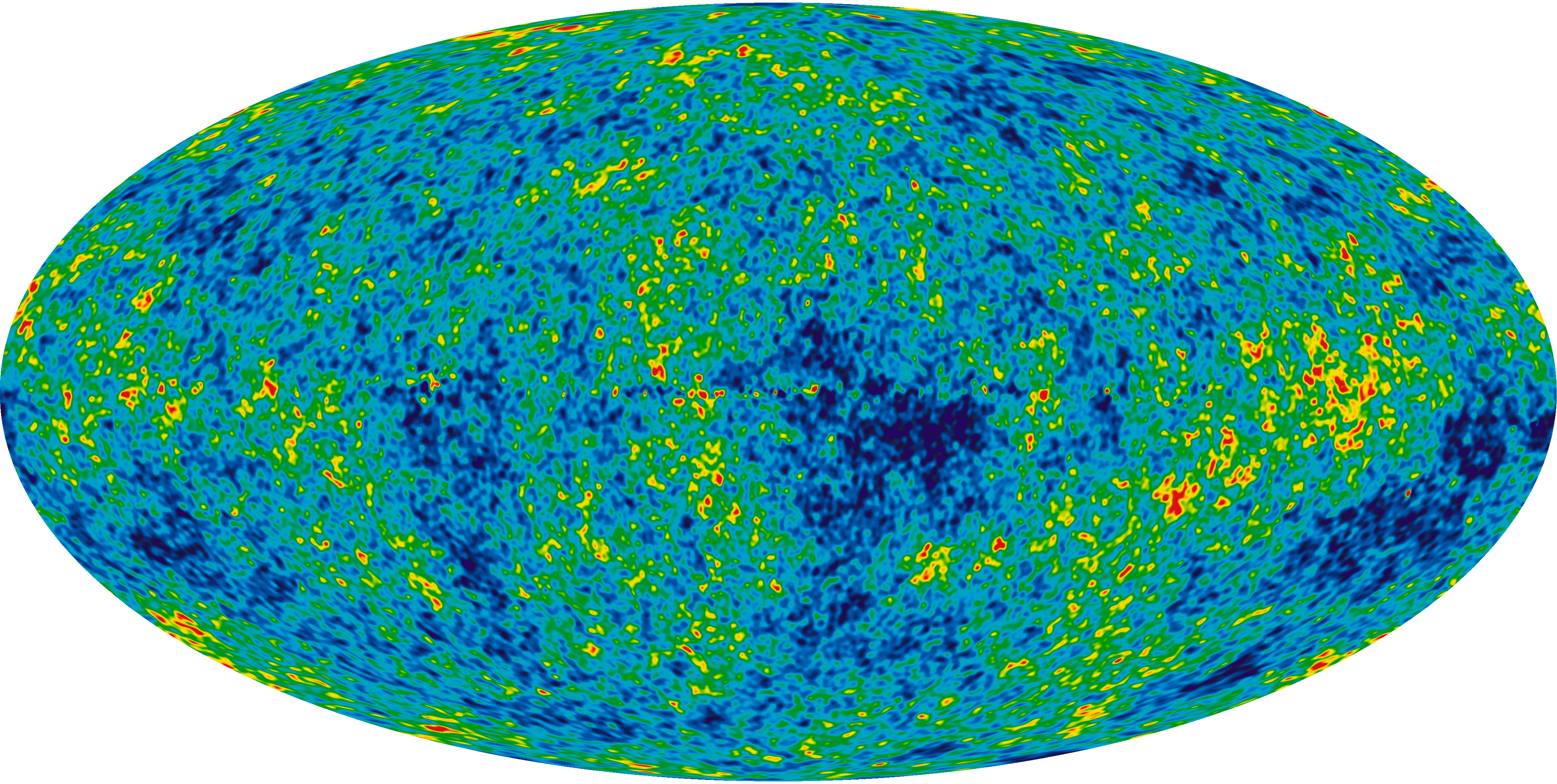
A diagram shows the WMAP satellite's observations of the universe's temperature.

Rachel Kaufman for National Geographic News Published February 9, 2010

If you want to celebrate the universe's birthday, you might need to add a few more candles to the cake.

That's because our universe is about 20 million years older than thought, according to the most accurate measurement yet made of the universe's age.

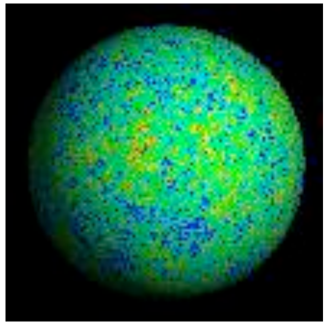
13.75 billion years old



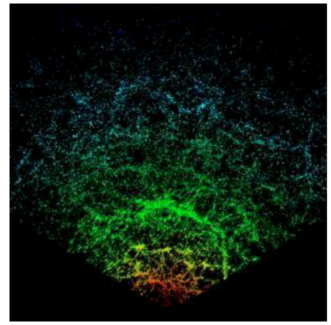
Results 2013

The universe is 13.772 ± 0.059 Gyr (billion years) old

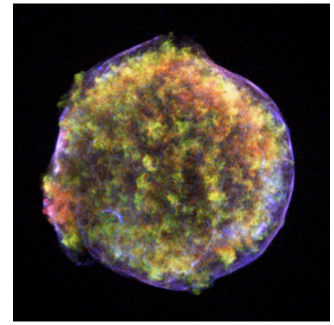
https://map.gsfc.nasa.gov



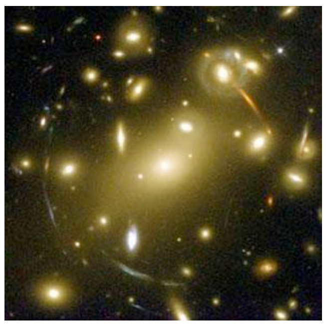
Microwave background



Galaxy surveys

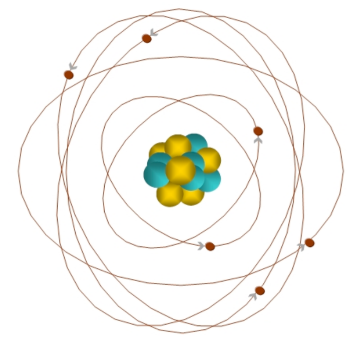


Supernovae Ia



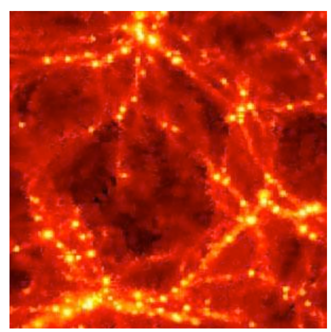
Gravitational lensing

THE COSMIC SMÖRGÅSBORD

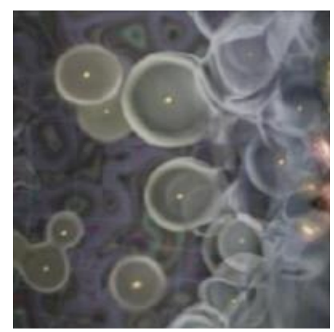


Big Bang nucleosynthesis

Galaxy clusters

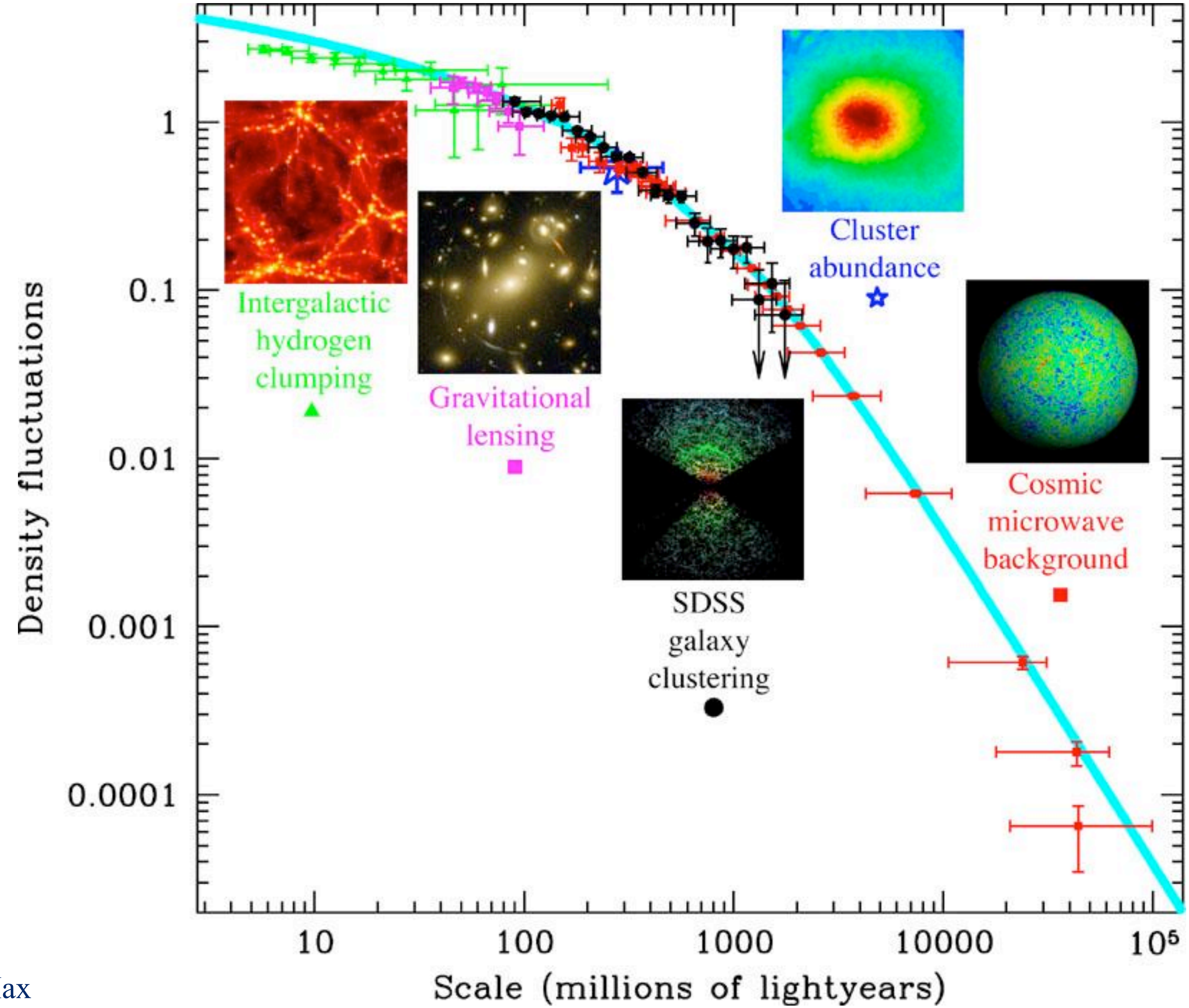


Lyman α forest



Neutral hydrogen tomography

Courtesy of Max Tegmark, MIT



Courtesy of Max Tegmark, MIT

Closer to home

Our solar system and earth.

Age of Earth

Dr. John Lightfoot, a 17th century Anglican clergyman estimated that creation occurred during 4004 BCE.

Bishop James Ussher made the same estimate a decade later, and got almost all the credit.

Other uses for radioactive decay

Radioactive elements occurring in rocks and minerals also provide a means of estimating the age of the solar system and earth.

Several elements with half-lives between 700 million and 100 billion years can be used to date objects.

Age of the objects in the solar system

Meteorites and fragments of asteroids formed between 4.53 billion and 4.58 billion years ago.

Lunar samples –formation of the moon between 4.4 and 4.5 billions years ago.

Oldest rocks on earth (northwest Canada) 3.96 billion years ago.

Zircon crystals (western Australia) 4.3 billion years ago.

Age of the objects in the solar system

The best estimates of earth's age are obtained by calculating the time required for the development of the observed lead isotopes in earth's oldest lead ores – yields 4.54 billion years

Age of Earth

Dr. John Lightfoot, a 17th century Anglican clergyman estimated that creation occurred during 4004 BCE.

Wrong by about

4.54 billion years!!!

the credit.

Life in the Universe

Is Earth special?

Are the molecules that lead to life special to our planet?

Organic molecules (C, O, H, P …)

Vitalism

Some chemists theorized that the synthesis of organic compounds required some sort of vital force found only in living organisms.

Organic compounds from inorganic sources

In 1828 Friedrich Wöhler synthesized *urea* in his laboratory. He said of the process

"I can no longer, as it were, hold back my chemical urine; and I have to let out that I can make urea without needing a kidney, whether of man or dog, the ammonium salt of cyanic acid is urea."

Comet Hale-Bopp

Chemical composition comets comparable with interstellar ices

Ehrenfreund et al. 1997
Irvine et al. 2000
Bockelee-Morvan et al. 2000

Ewine F. van Dishoeck, Leiden Observatory

Inventory of molecules

More than 120 different molecules found

Ordinary molecules

NH_3, H_2O, H_2CO, CH_3CH_2OH, ….

More than 120 interstellar molecules

(table needs updating)

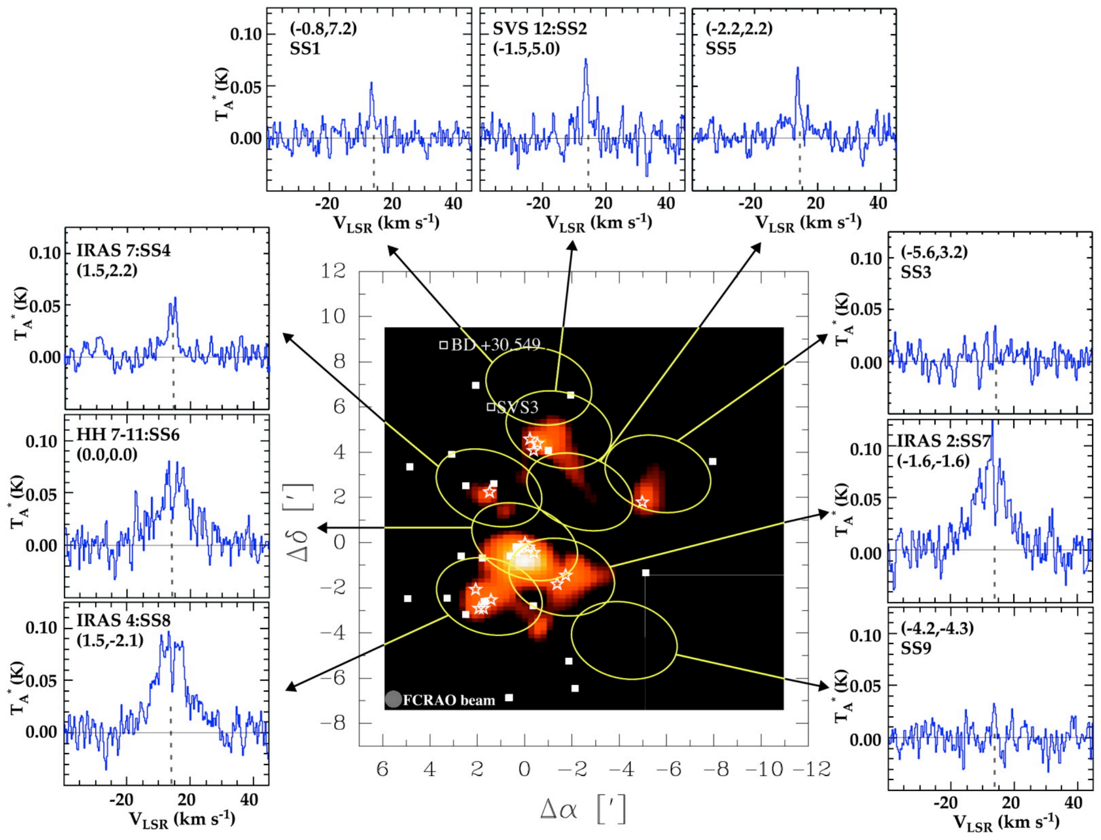
Number of Atoms										
2	3	4	5	6	7	8	9	10	11	13
H_2	C_3	c-C_3H	C_5	C_5H	C_6H	CH_3C_3N	CH_3C_4H	CH_3C_5N?	HC_9N	$HC_{11}N$
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	$HCOOCH_3$	CH_3CH_2CN	$(CH_3)_2CO$		
AlCl	C_2O	C_3N	C_4Si	C_2H_4	CH_3C_2H	CH_3COOH?	$(CH_3)_2O$	NH_2CH_2COOH?		
C_2	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH			
CH	CH_2	C_3S	c-C_3H_2	CH_3NC	$HCOCH_3$	H_2C_6	HC_7N			
CH^+	HCN	C_2H_2	CH_2CN	CH_3OH	NH_2CH_3		C_8H			
CN	HCO	CH_2D^+?	CH_4	CH_3SH	c-C_2H_4O					
CO	HCO^+	HCCN	HC_3N	HC_3NH^+						
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO						
CP	HOC^+	HNCO	HCOOH	NH_2CHO						
CSi	H_2O	HNCS	H_2CHN	C_5N						
HCl	H_2S	$HOCO^+$	H_2C_2O							
KCl	HNC	H_2CO	H_2NCN							
NH	HNO	H_2CN	HNC_3							
NO	MgCN	H_2CS	SiH_4							
NS	MgNC	H_3O^+	H_2COH^+							
NaCl	N_2H^+	NH_3								
OH	N_2O	SiC_3								
PN	NaCN									
SO	OCS									
SO^+	SO_2									
SiN	c-SiC_2									
SiO	CO_2									
SiS	NH_2									
CS	H_3^+									
HF										

Abundances vary from 10^{-4} to 10^{-11} w.r.t. H_2

Ewine F. van Dishoeck, Leiden Observatory

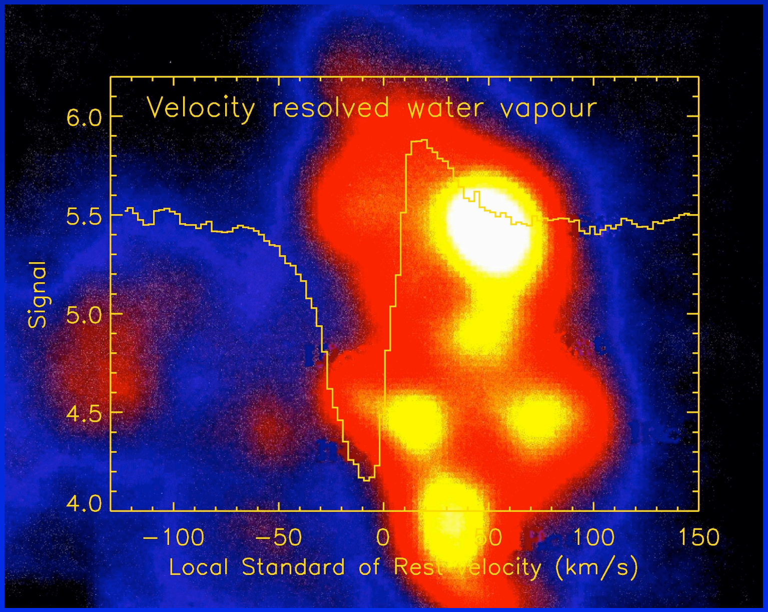
Water everywhere

H_2O in NGC 1333



SWAS 557 GHz Bergin et al. 2003

H_2O in Orion



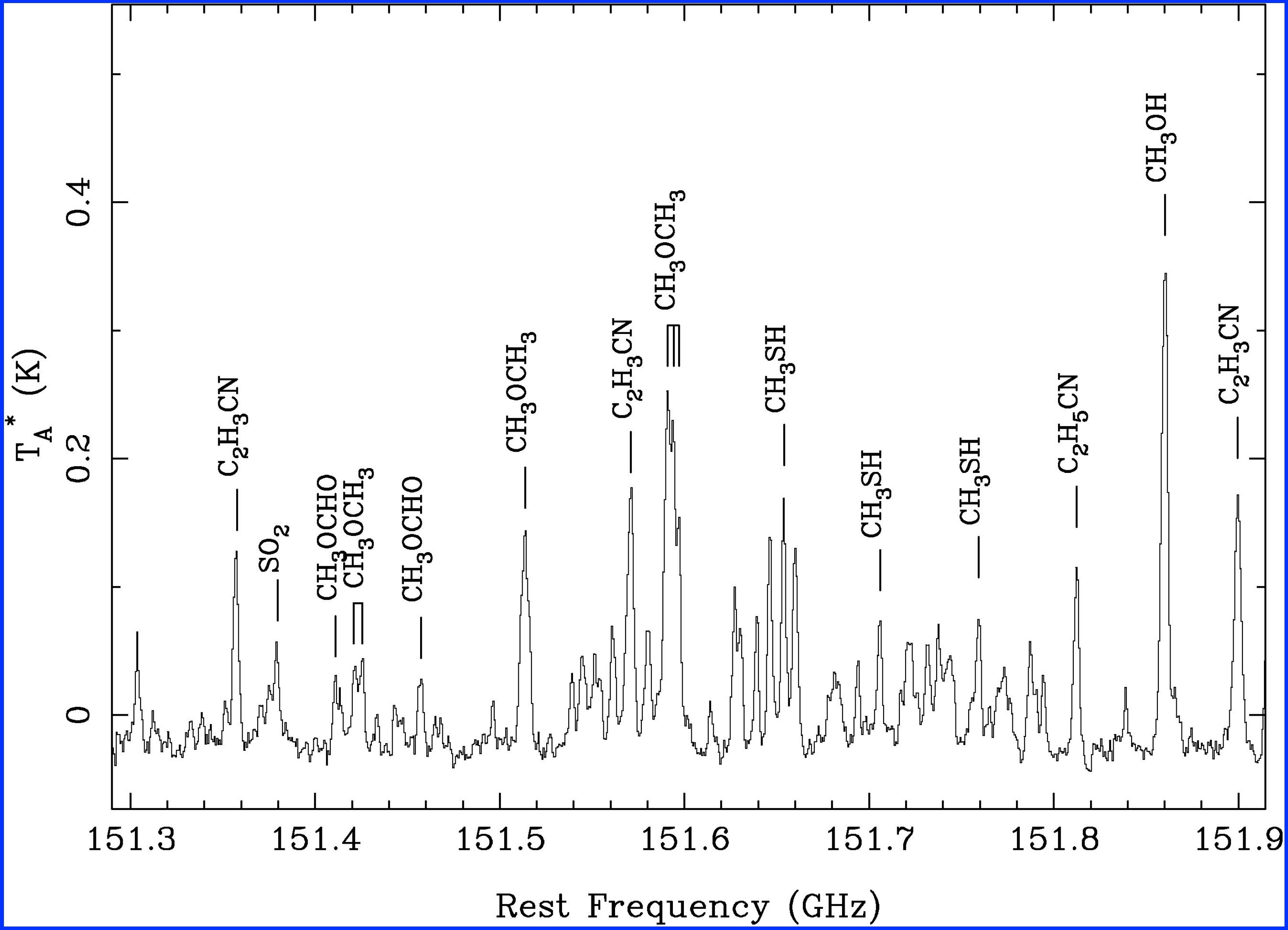
ISO-SWS 41 μm Wright et al. 2001

H_2O abundance high (~10^{-4}) in warm regions; low (<10^{-8}) in cold regions

Ewine F. van Dishoeck, Leiden Observatory

Hot core spectrum

Associated with the earliest stages of massive young stars



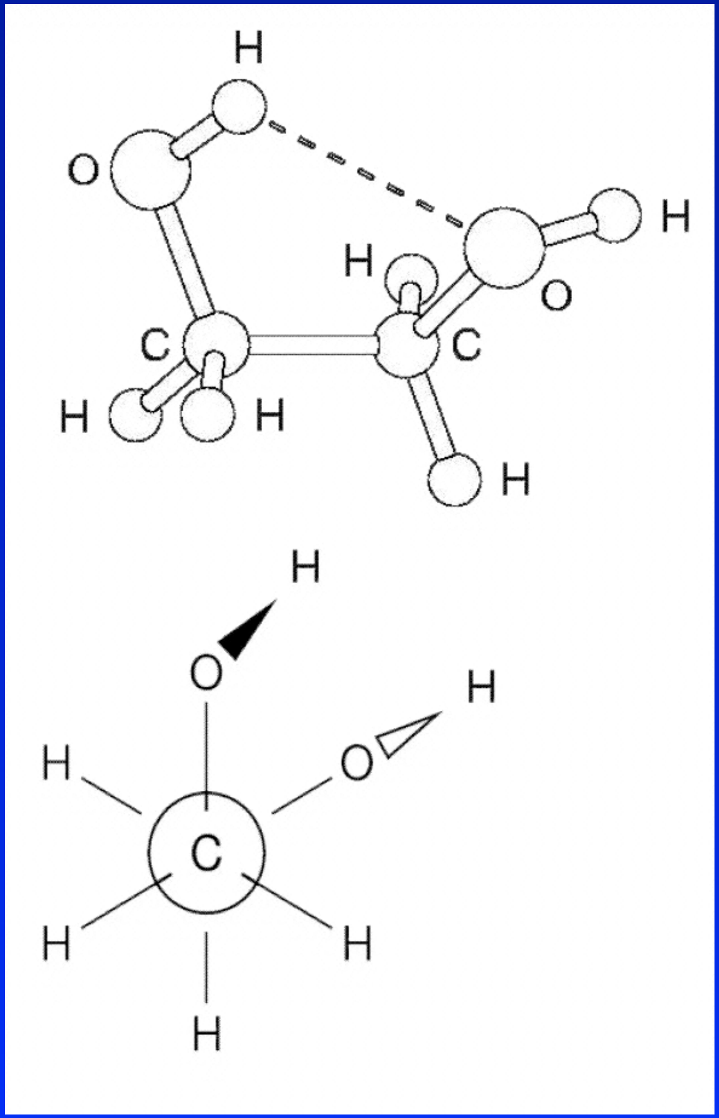
G327.1
SEST

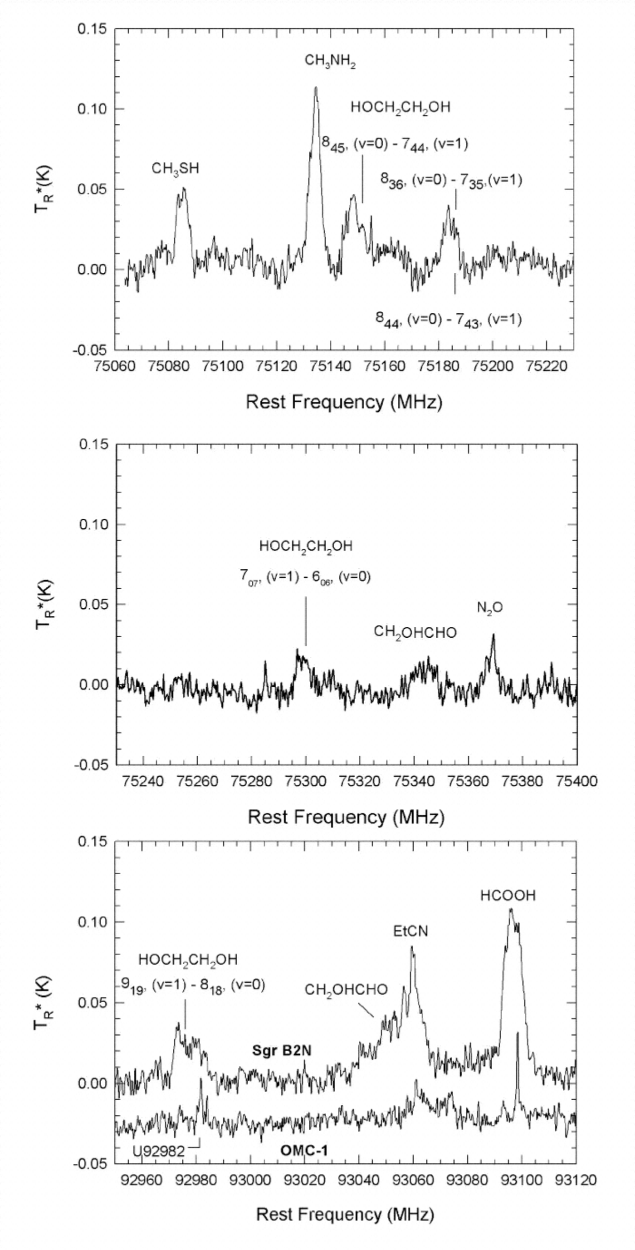
- Many complex organic molecules

- Spectra confusion limited

Gibb et al. 2001

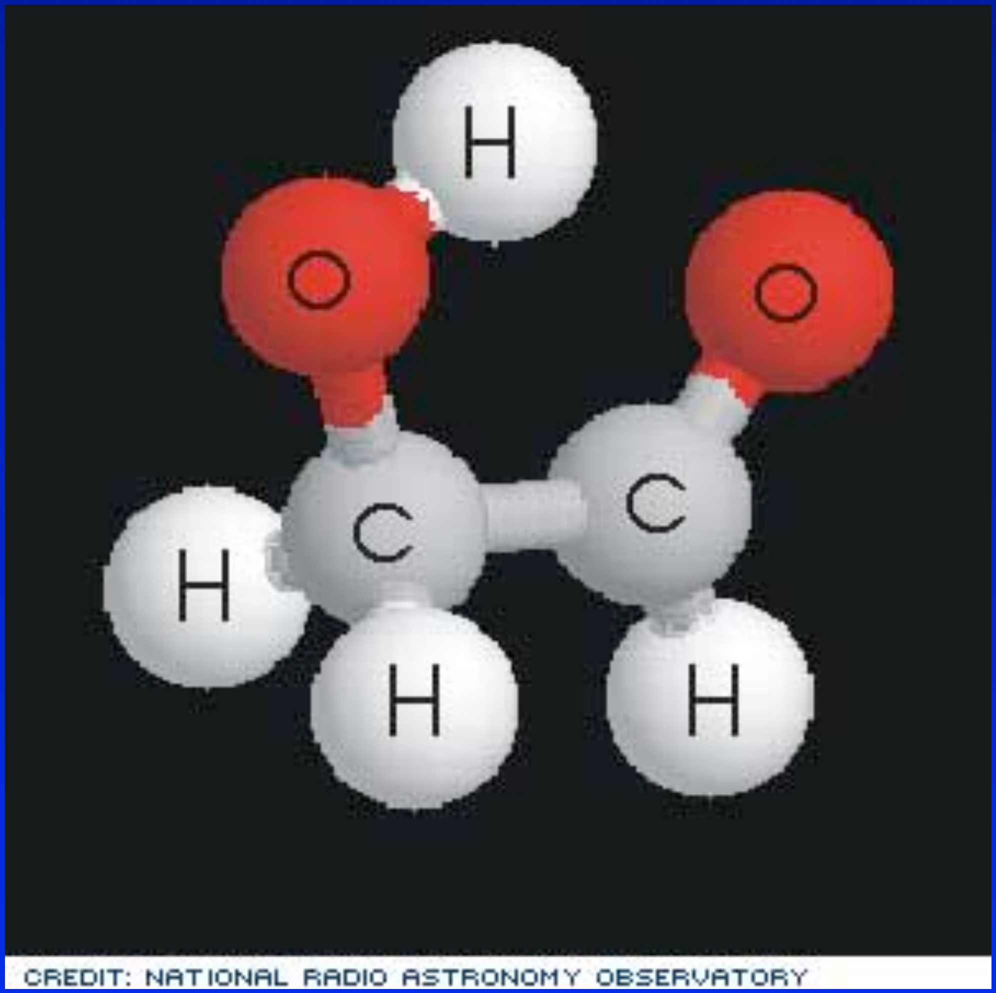
Interstellar antifreeze





Turner et al. 2003

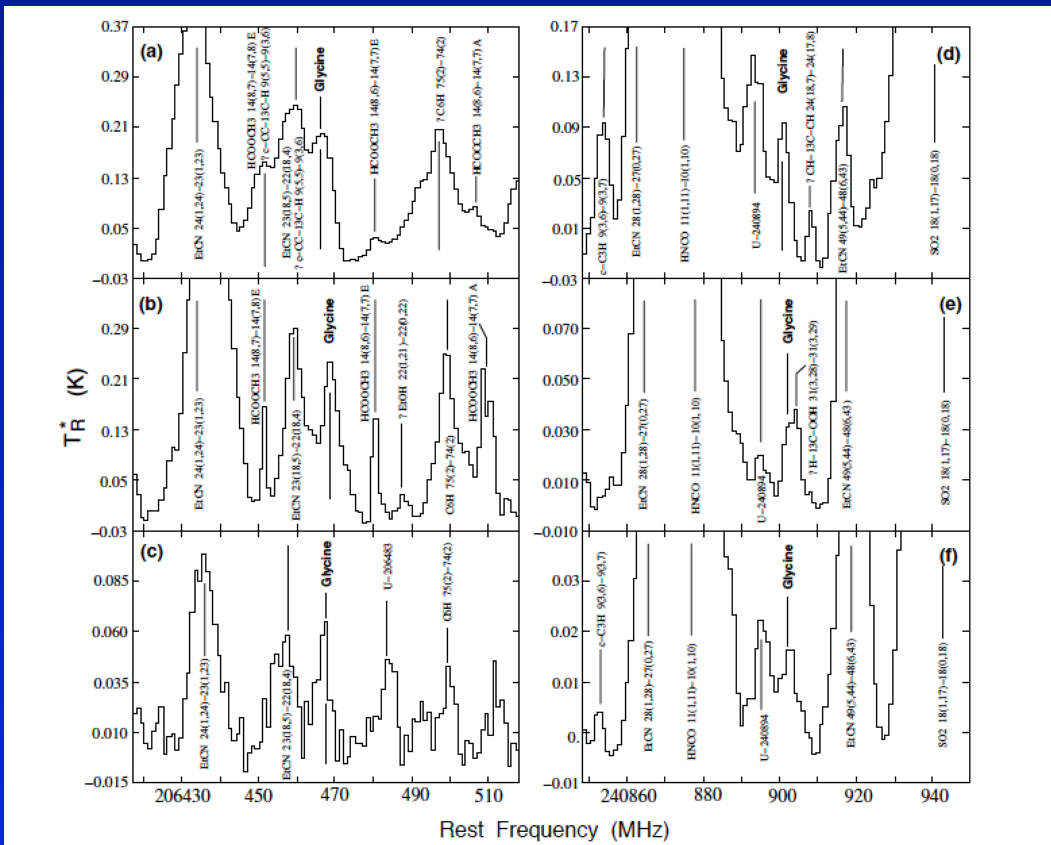
First interstellar sugar

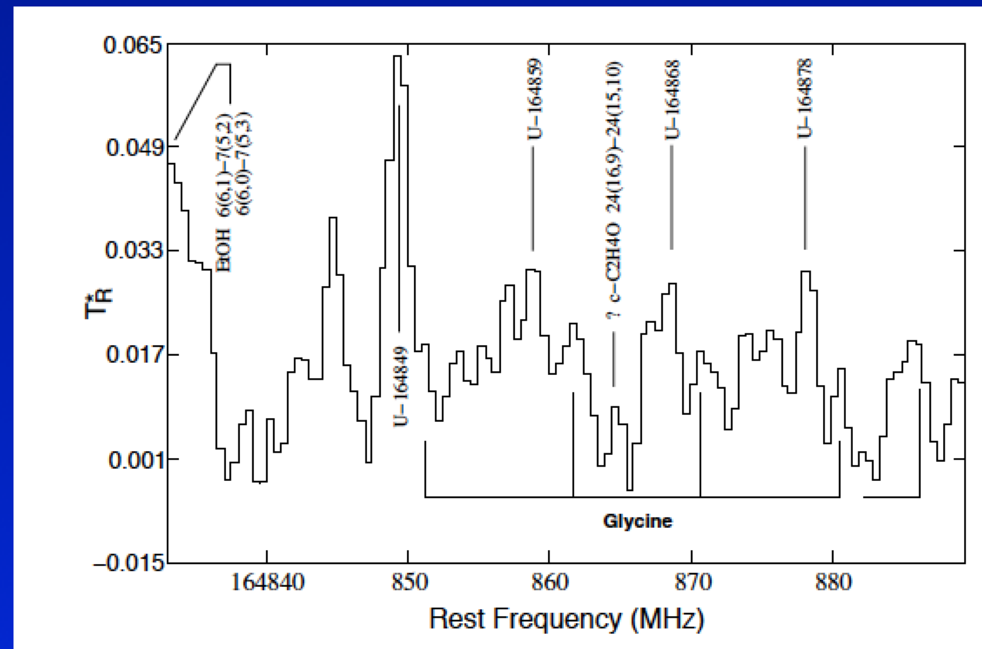


Different abundances of isomers:

Methyl formate >> Acetic acid >> Sugar

Interstellar amino acids





(Glycine spectrum in Orion)

(a) Sgr B2(N-LMH)
(b) (b) Orion KL
(c) W51

Yi-Jehng Kuan, Steven B. Charnley, Hui-Chun Huang, Wei-Ling Tseng, and Zbigniew Kisiel, Interstellar Glycine, The Astrophysical Journal, **593**, 848 (2003)

Origins of life on Earth

There is evidence that bacteria-like organisms lived on earth 3.5 billion years ago. These were very simple organisms.

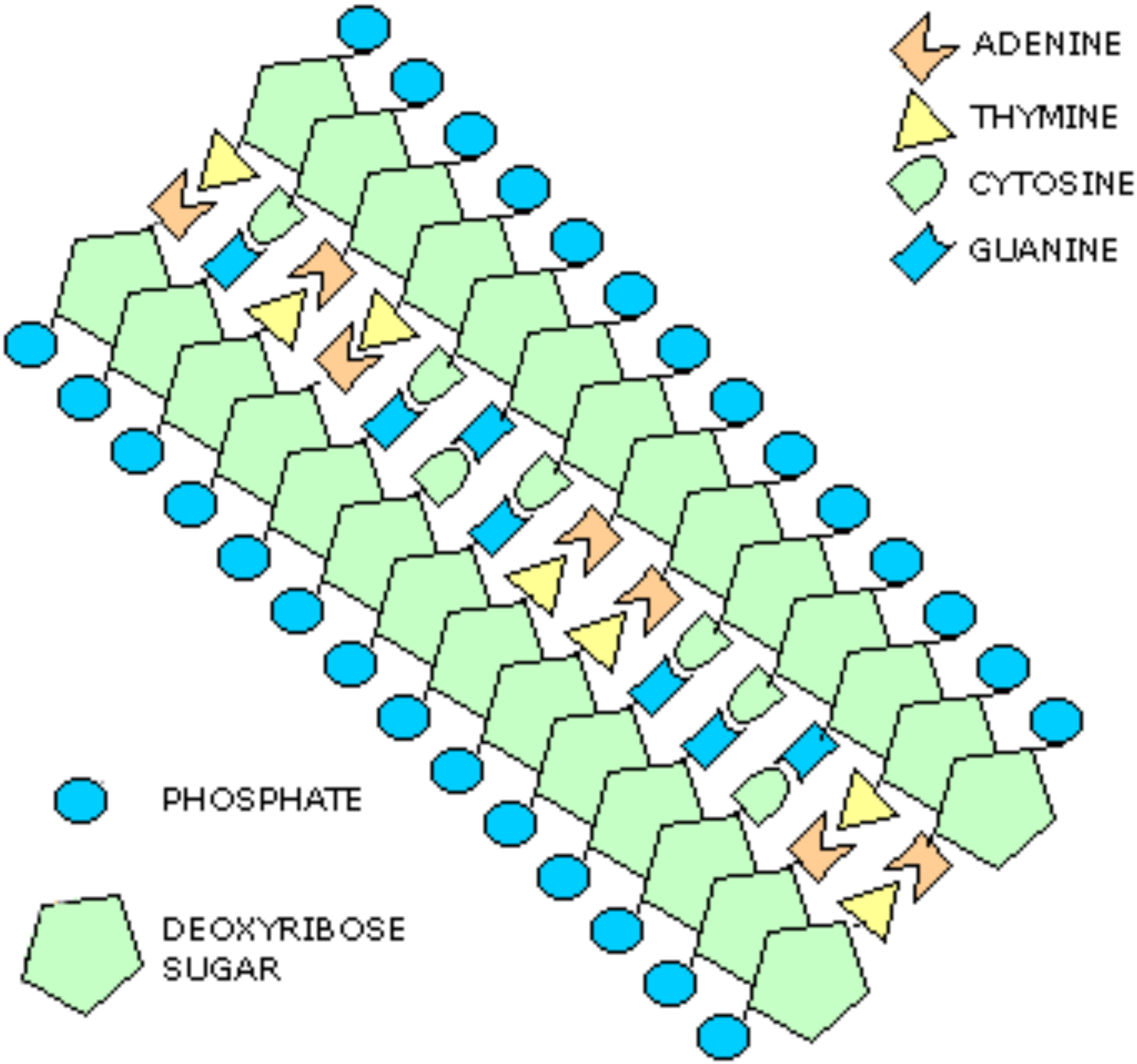
Today, living organisms store and transmit hereditary information using two kinds of molecules: RNA and DNA

RNA and DNA

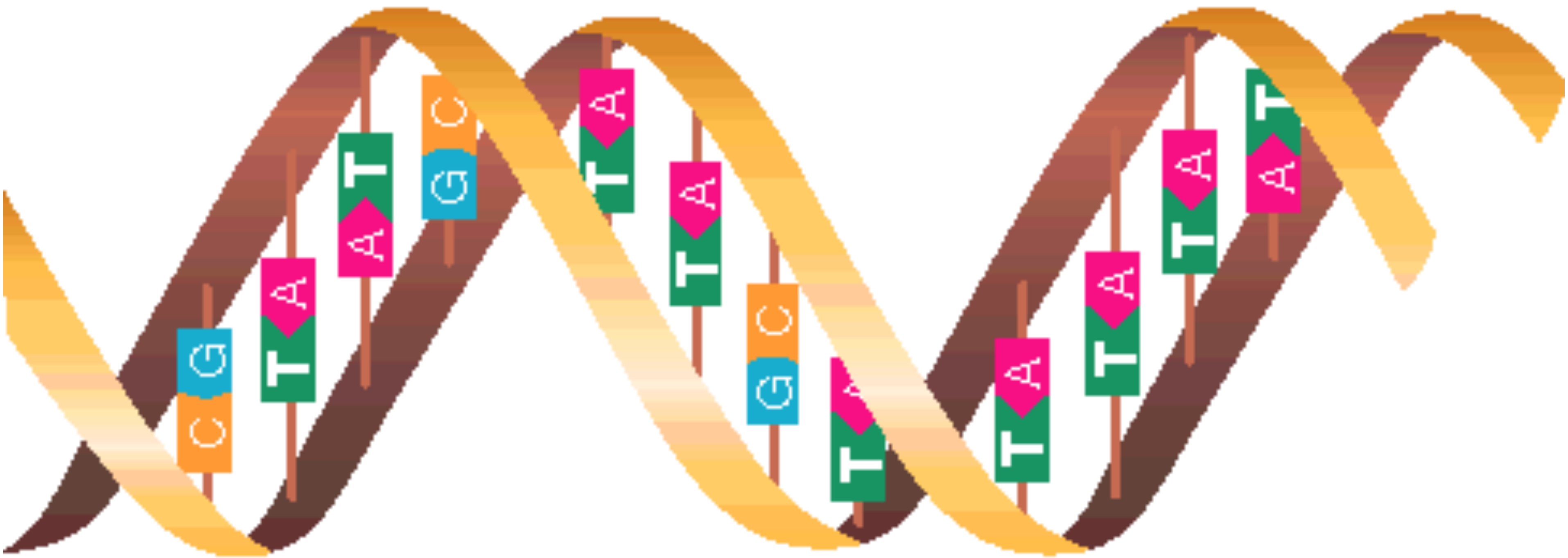
Each are composed of sub-units called nucleotides.

Sequences of nucleotides of different lengths are known as genes.

Proteins, RNA, and DNA can be produced in the lab under conditions mimicking early Earth.



http://www.biology-online.org/1/5_DNA.htm



http://www.schoolscience.co.uk/content/4/biology/abpi/genome/genome3.html

FIRST EVER GENE THERAPY

from The San Francisco Chronicle April 28, 2004

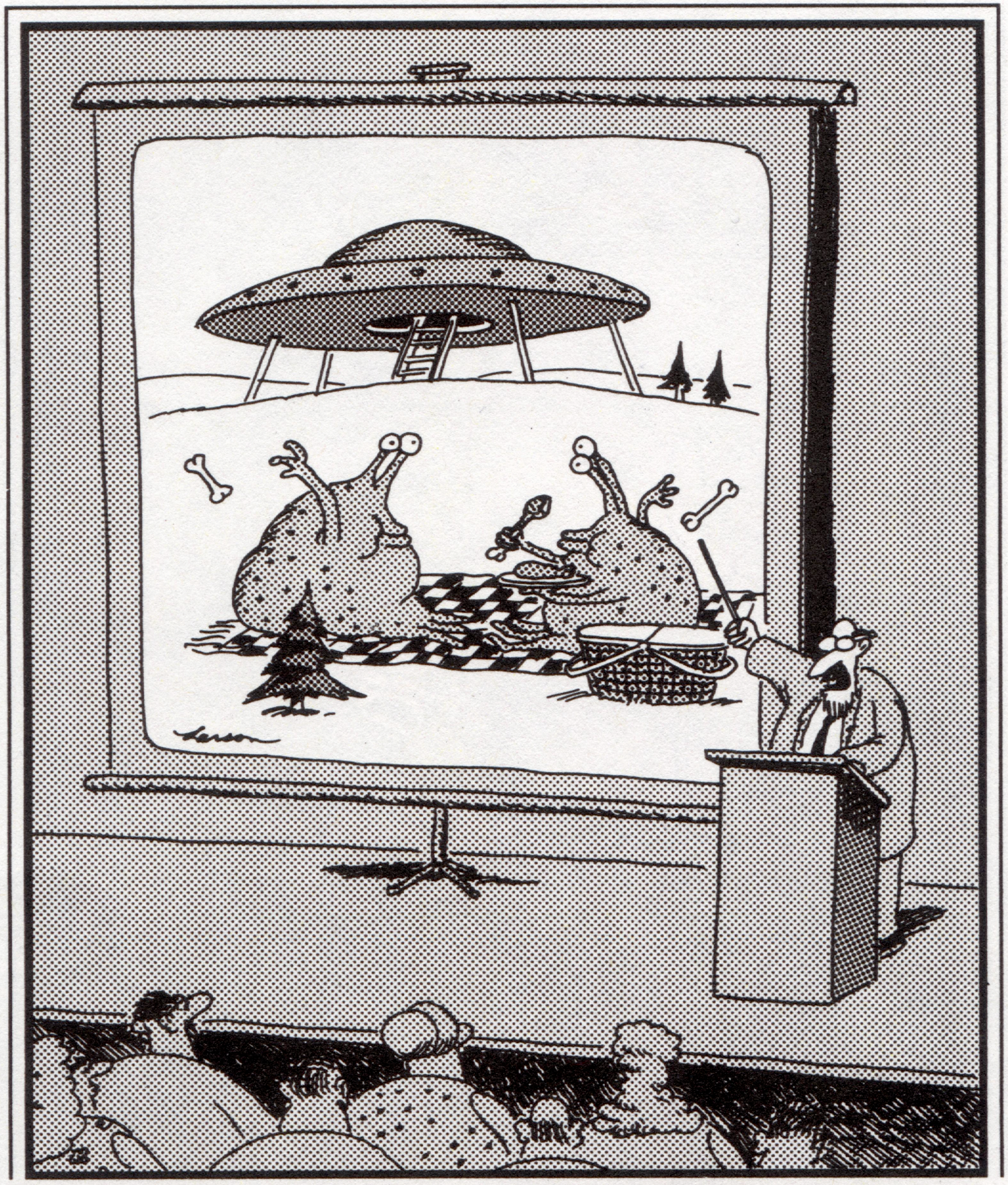
Despite some early disasters, a novel gene-therapy treatment for Alzheimer's disease has produced encouraging results in the first half-dozen patients, scientists reported Tuesday.
After years of animal studies, researchers led by Dr. Mark Tuszynski, a neuroscientist and neurologist at UC San Diego, began the first human safety trial of the new approach in April 2001.
Tuszynski summarized the results during the annual meeting of the American Academy of Neurology, which is under way this week in San Francisco.

The study has drawn attention as the first attempt to use gene therapy to treat an incurable neurodegenerative disorder. Alzheimer's disease currently affects about 4 million people in the United States, and that number is growing as the population ages.

http://snipurl.com/60eq

“For those who are studying the origin of life, the question is no longer whether life could have originated by chemical processes involving nonbiological components. The question instead has become which of the many pathways might have been followed to produce the first cell.”

The National Academy of Science



Professor Ferrington and his controversial theory that dinosaurs were actually the discarded "chicken" bones of giant, alien picnickers.

Biological Evolution

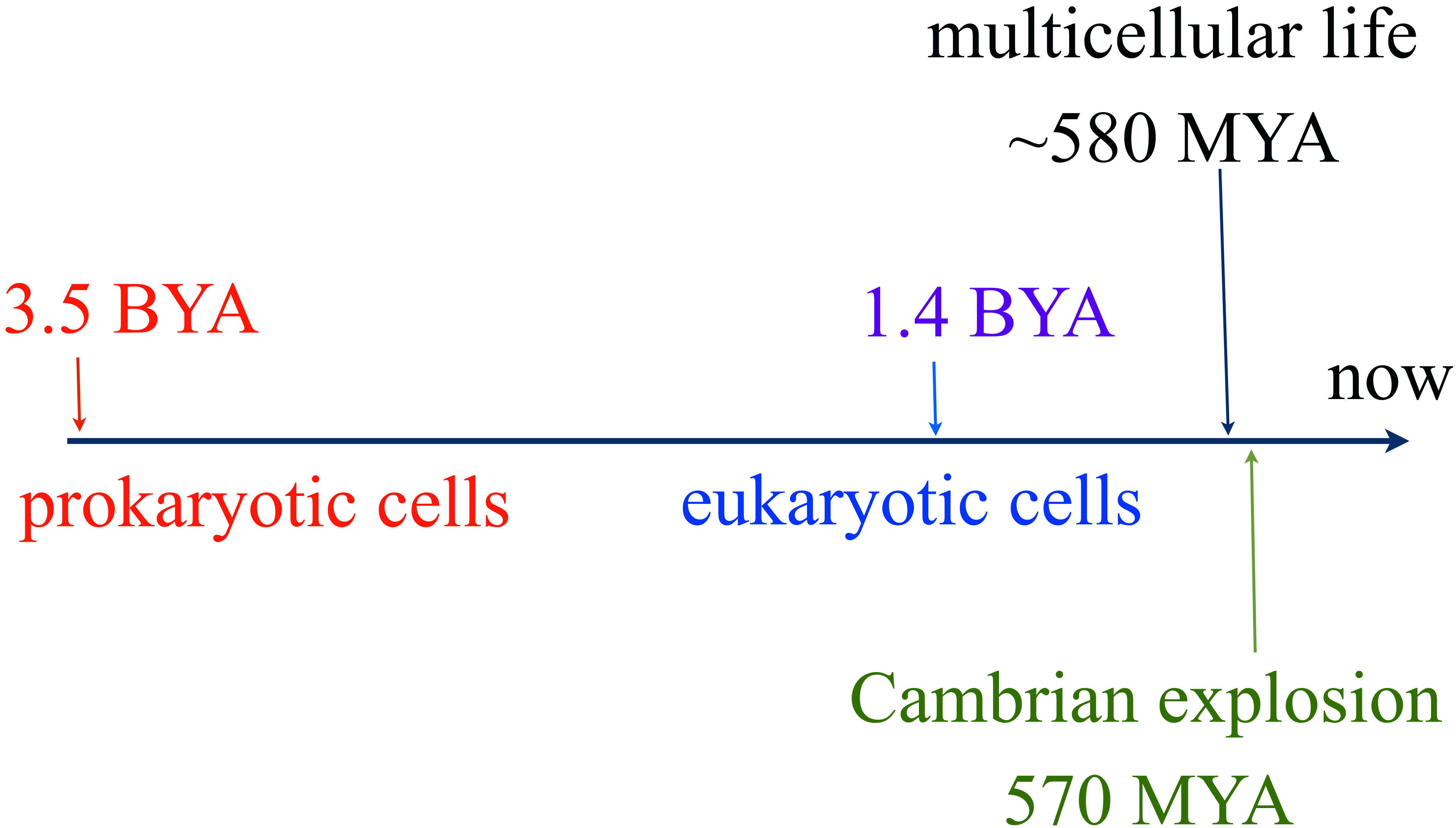
3.5 billion
years ago
First life

?

Present

How did we get here?

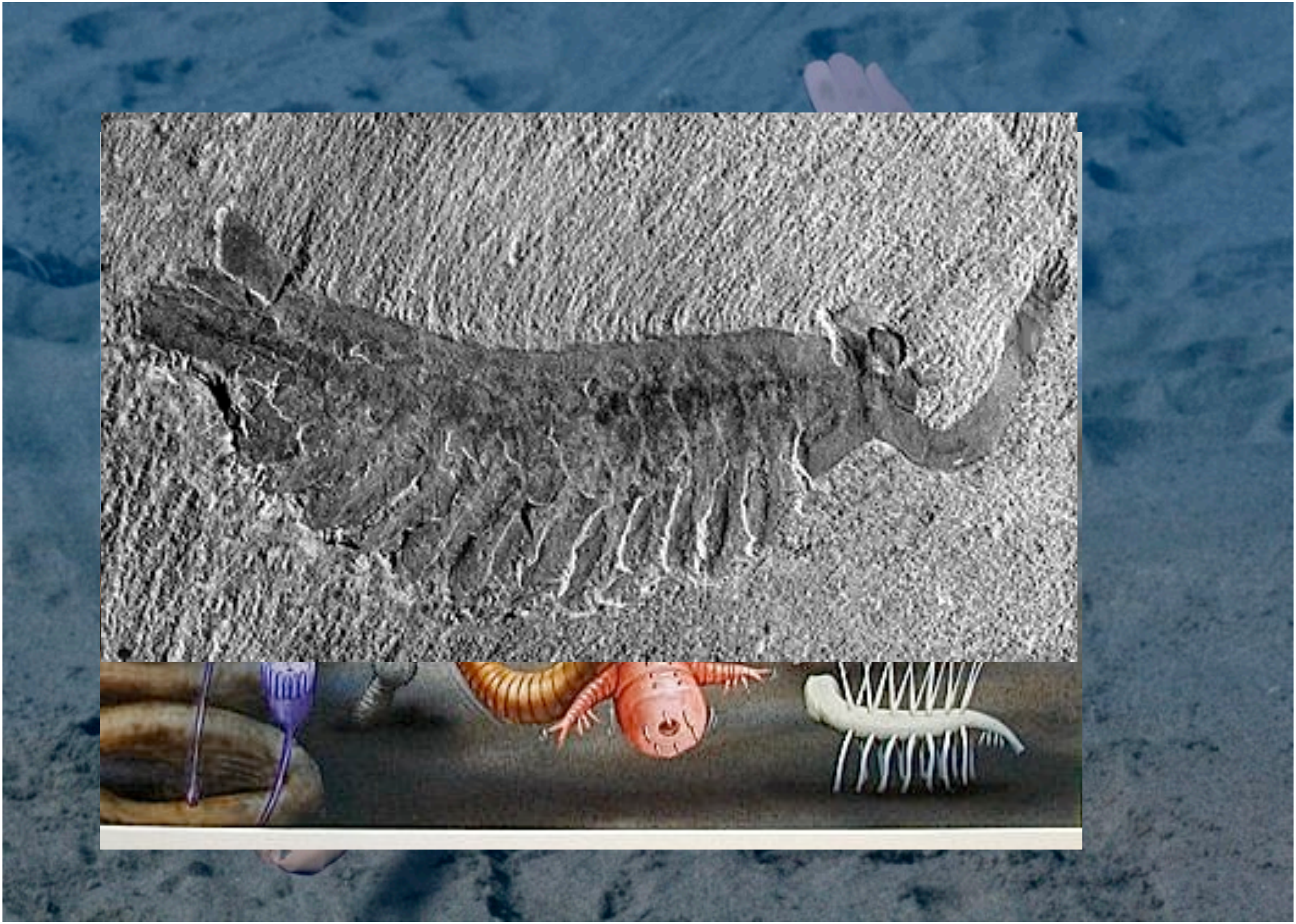
time line



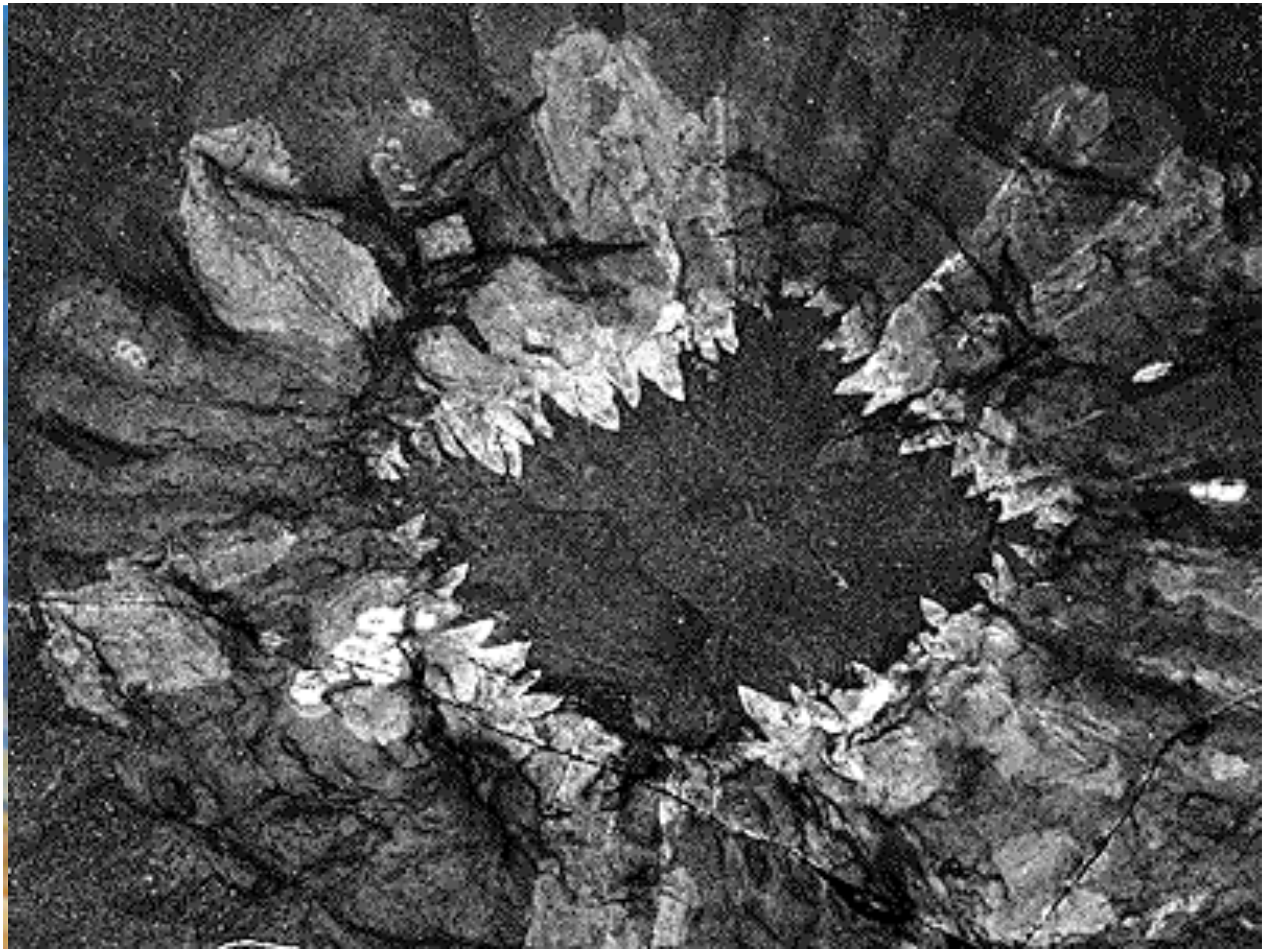
multicellular life
~580 MYA
3.5 BYA
1.4 BYA
now
prokaryotic cells
eukaryotic cells
Cambrian explosion
570 MYA

The Burgess Shale Site 510 Million Years Ago

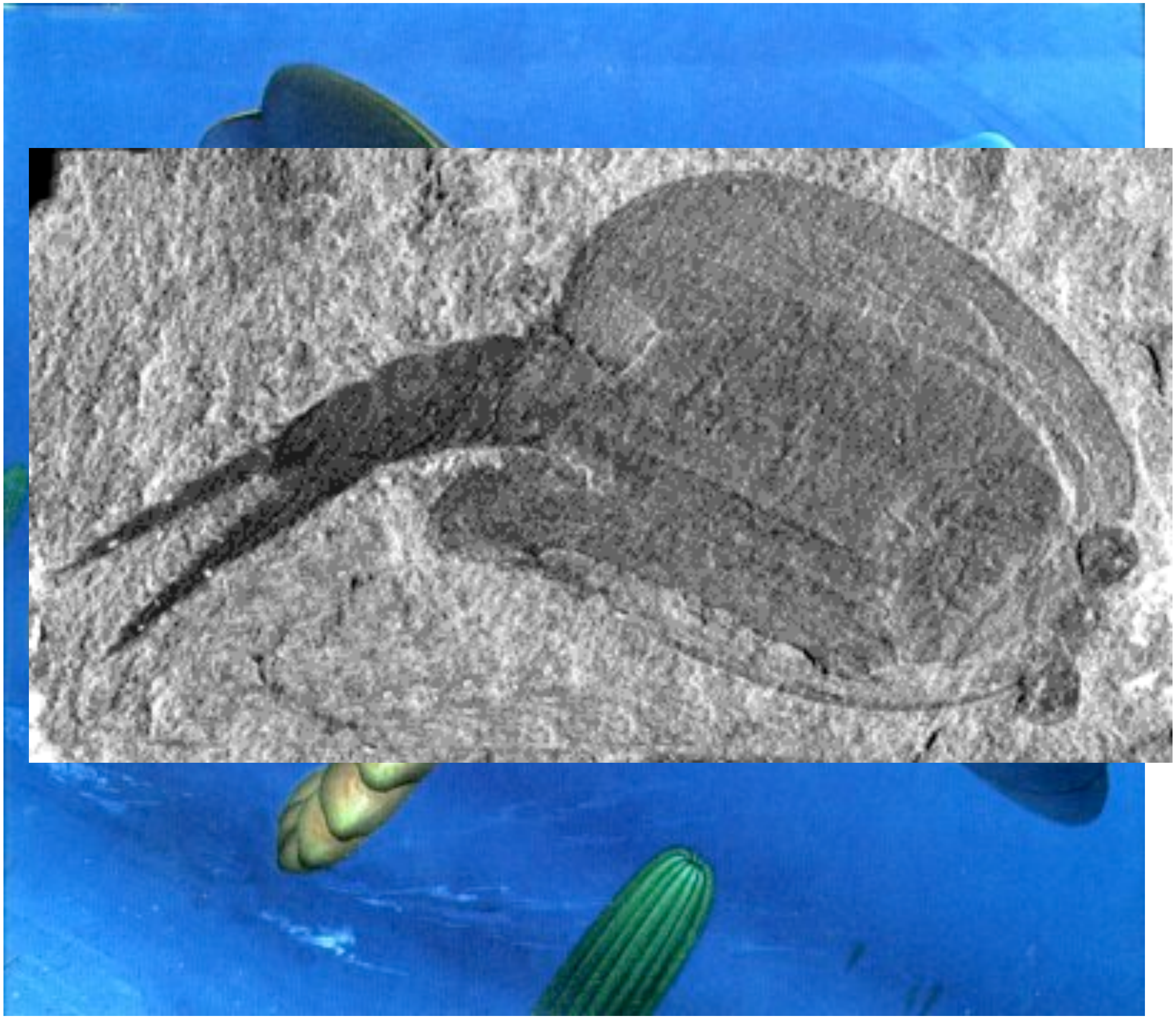
Hallucigenia sparsa (an onychophoran)



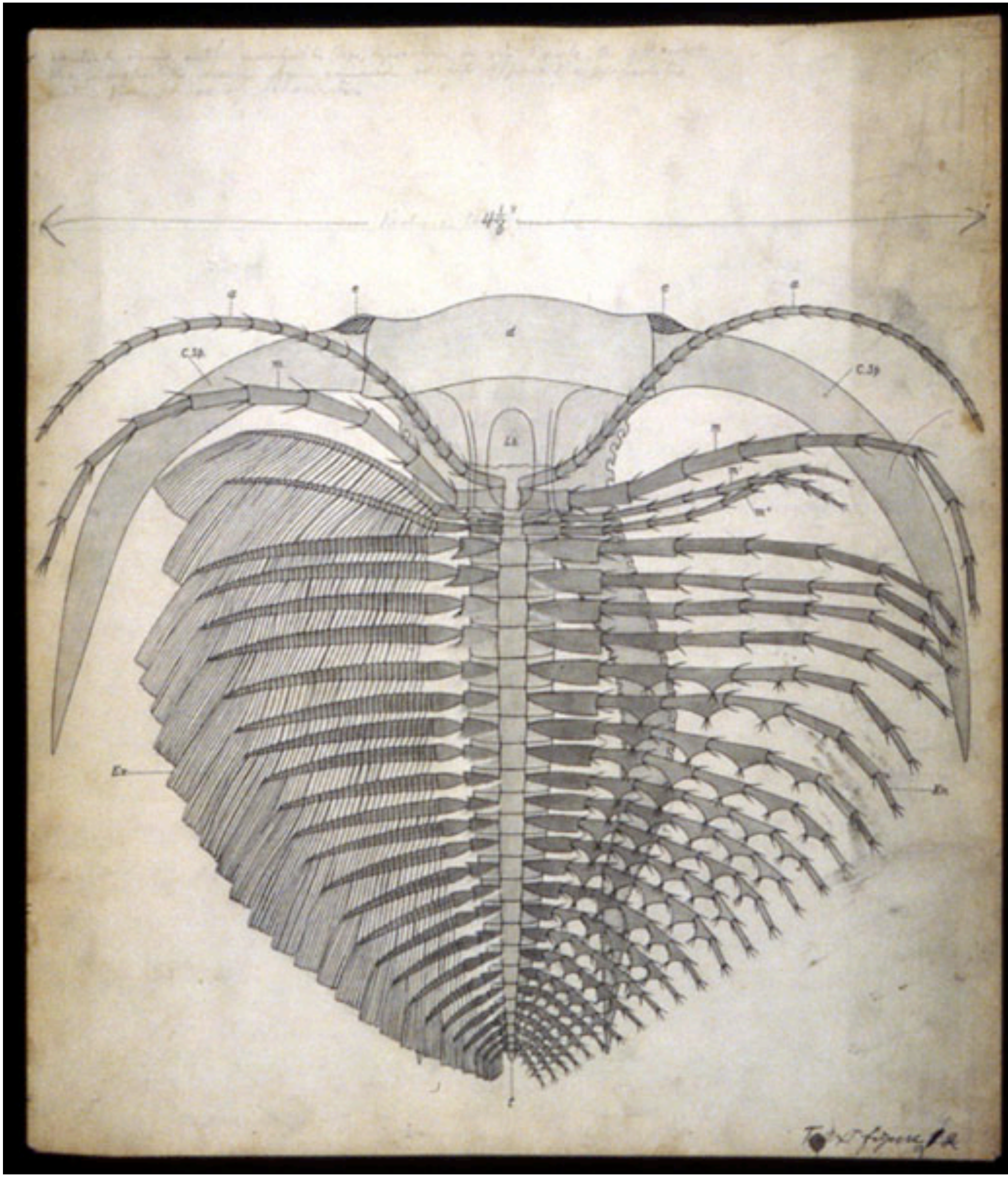
***Opabinia regalis* (unknown affinity)**



Anomalocaris canadensis (proto-arthropod)



***Perspicaris* (an arthropod)**


a
e
d
C.3p
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Ex
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t

Classification example: humans

Kingdom	Animal
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	Homo
Species	H. sapiens

Trinomial name: Homo sapiens sapiens

Natural selection – Darwin was not the first

The idea that similar species go back to a common ancestor came from ancient Greek philosophers.

Darwin backed it up with observations made at the Galapagos Islands.

Darwin's original hypothesis has undergone extensive modifications but the central concept stands firm.

Darwin - *The Origin of Species*

1. All organisms tend to produce more offspring than can possibly survive.

2. Offspring vary among themselves, and are not carbon copies of an immutable type.

3. At least some of this variation is passed down by inheritance to future generations.

4. if many offspring must die, and individuals in all species vary among themselves, then on average survivors will tend to be those individuals who adapt to changing local environments.

Genetic variations

Genetic variations result from changes, or mutations, in the nucleotide sequence of DNA.

Genetic mutations arise by chance.

Organism may or may not be better equipped for survival.

The concept is based on population dynamics not individual dynamics.

Species

There are a number of operational definitions of species.

A species is where the individuals can only mate with members of the same species

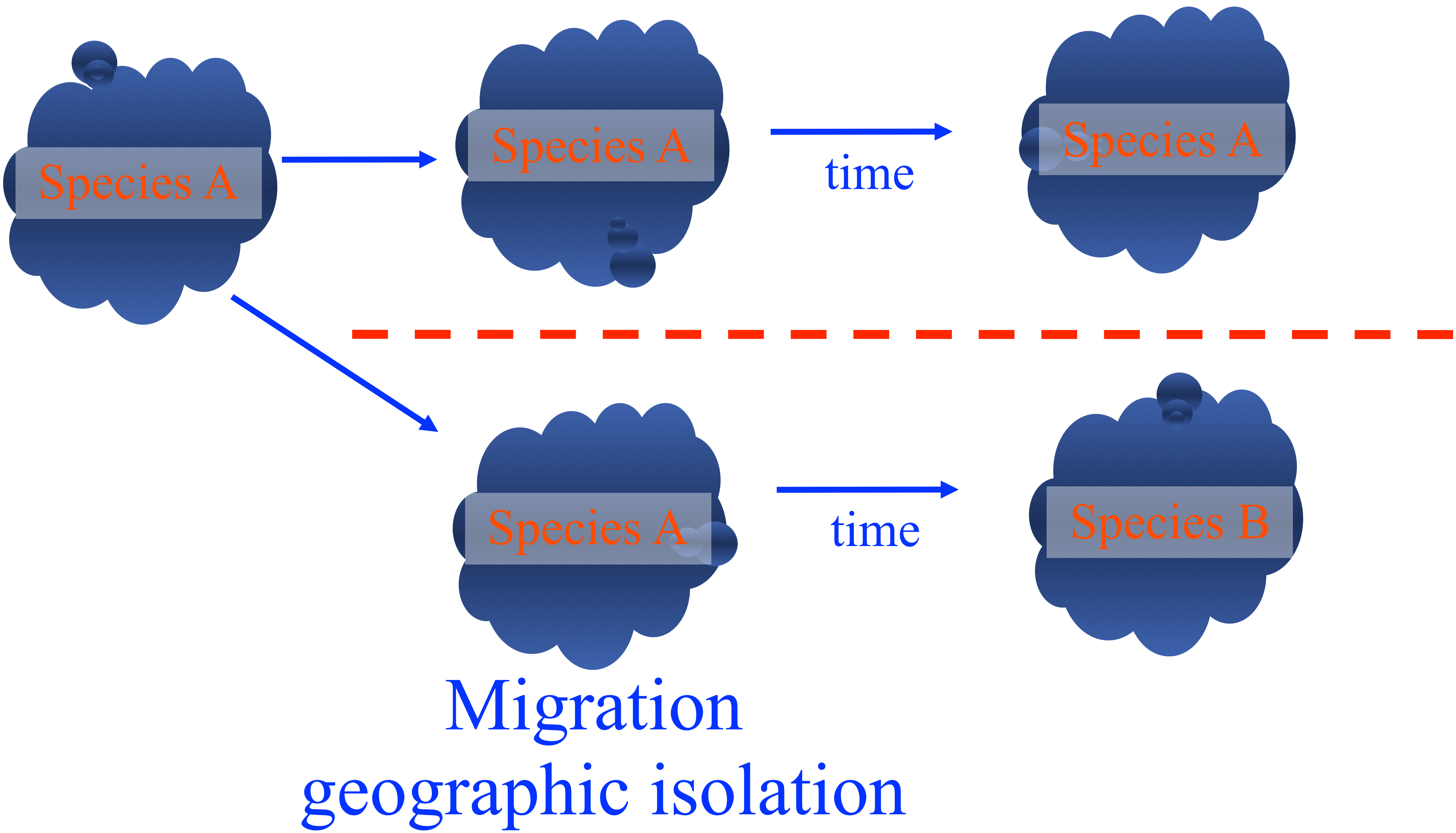
A new species is one in which the individuals cannot mate and produce viable descendants with individuals of the preexisting species

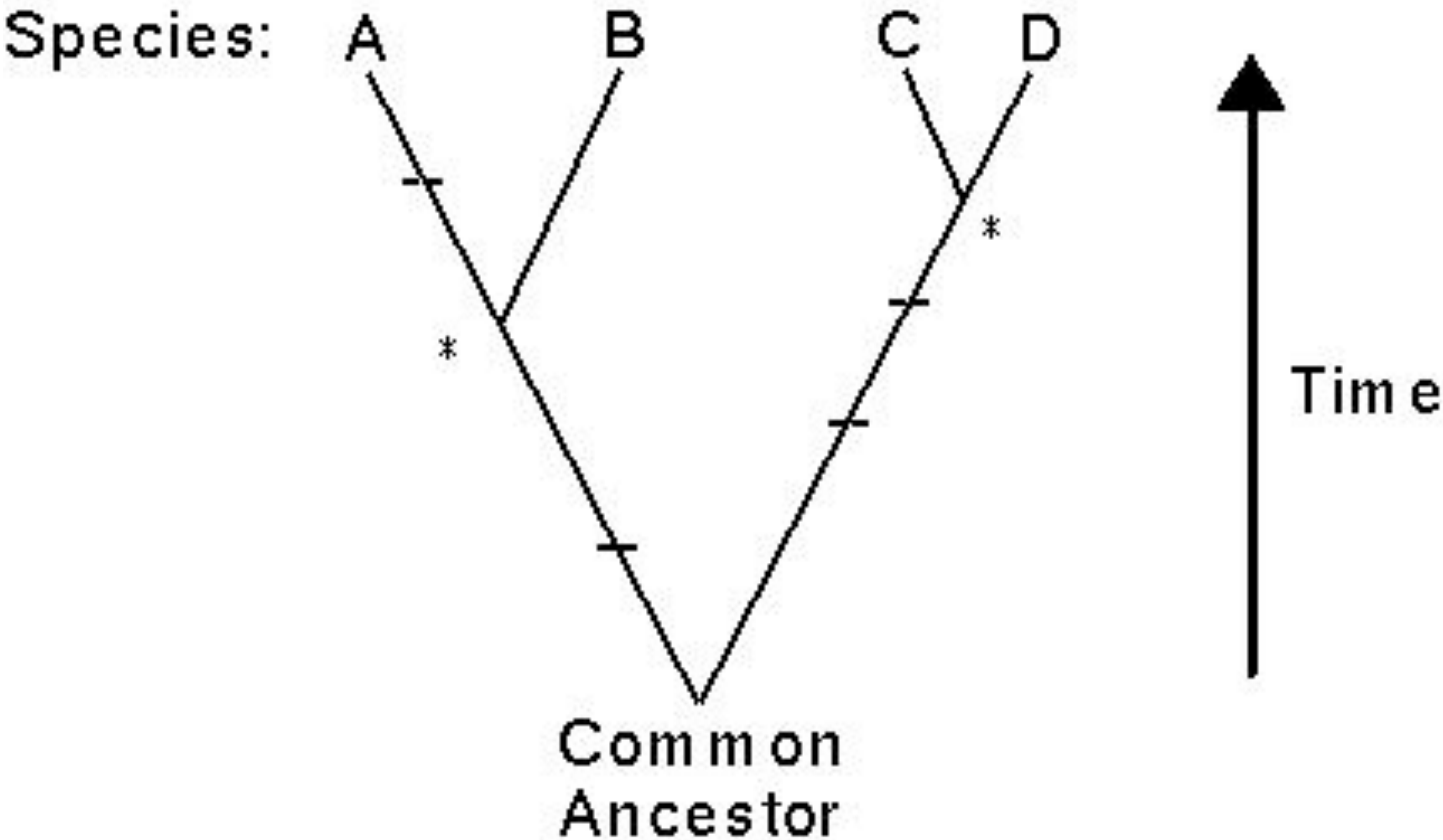
Species

Lions and tigers can mate in zoos to produce (sterile) “ligers” or “tigrons”

Horses and donkeys can mate to produce (sterile) mules

Generating new species





(* = Speciation event. -- = Mutation)

Why do we think this is true?

Fossil record

Biogeography

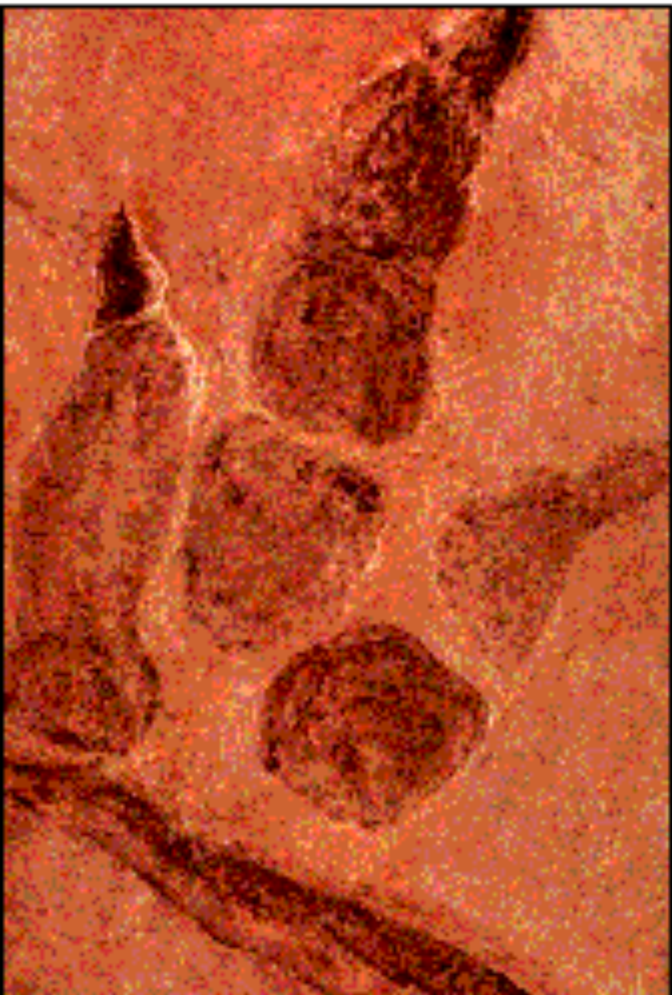
Embryology

Common Structures

Molecular Biology

fossil record

Dinosaur footprint



Devonian tree fern

Trilobite fossil

Bat fossil

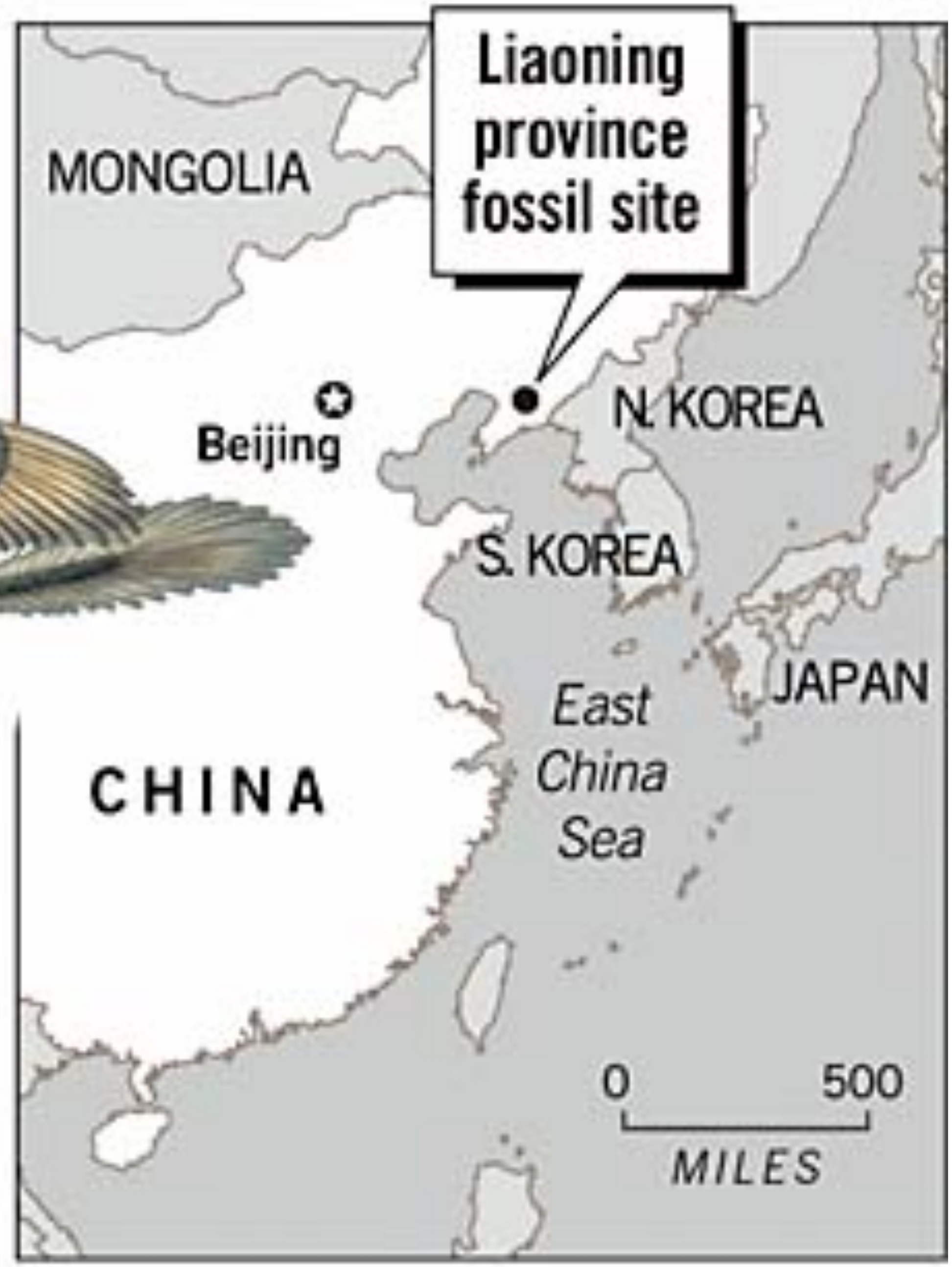
archaeopteryx

Four-winged dinosaur

Six fossils of a 128-million-year-old dinosaur were found in China.

Microraptor gui

- About 30 inches long from head to tail.
- Had claws on the leading edges of all four wings, a long feathery tail and unusually bowed limbs.
- Lived in trees and probably used its four wings to glide down to capture prey.



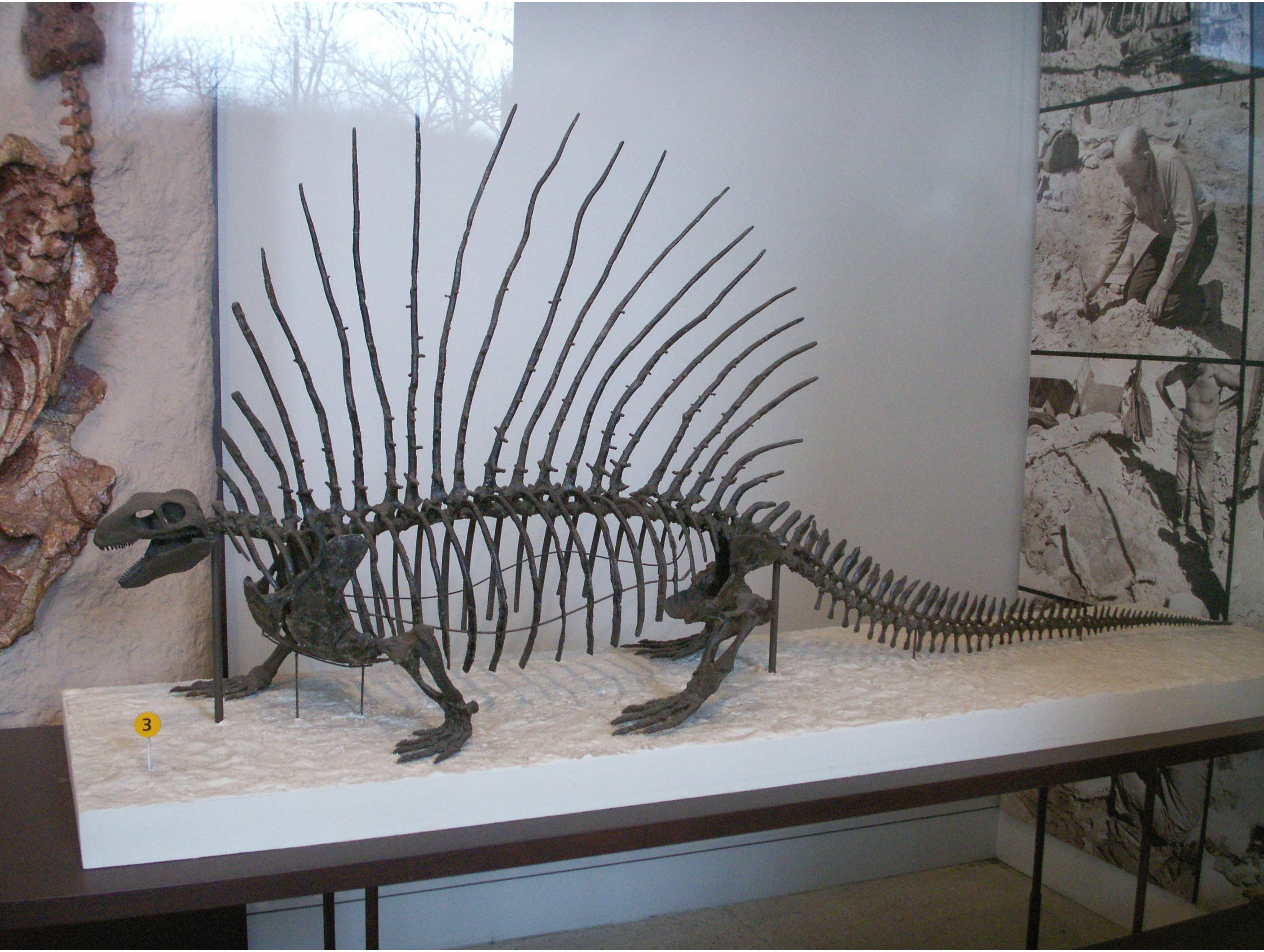
23 Jan 2003

Sources: Nature; ESRI

Associated Press Graphic


Did Stegosaurus Have 2 Brains
Were Stegosaurus's front legs sprawled out or not when it walked?


Neopterygians
Semionotids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