

Our Universe Today



Bruno Leibundgut
European Southern Observatory (ESO)

Astronomen arbeiten im Dunklen, was sie ans Licht bringen, ist geeignet, unsere Vorstellungen von der Welt radikal zu verändern.

Astronomers work in the dark and what they bring to light can radically change our views of the world.

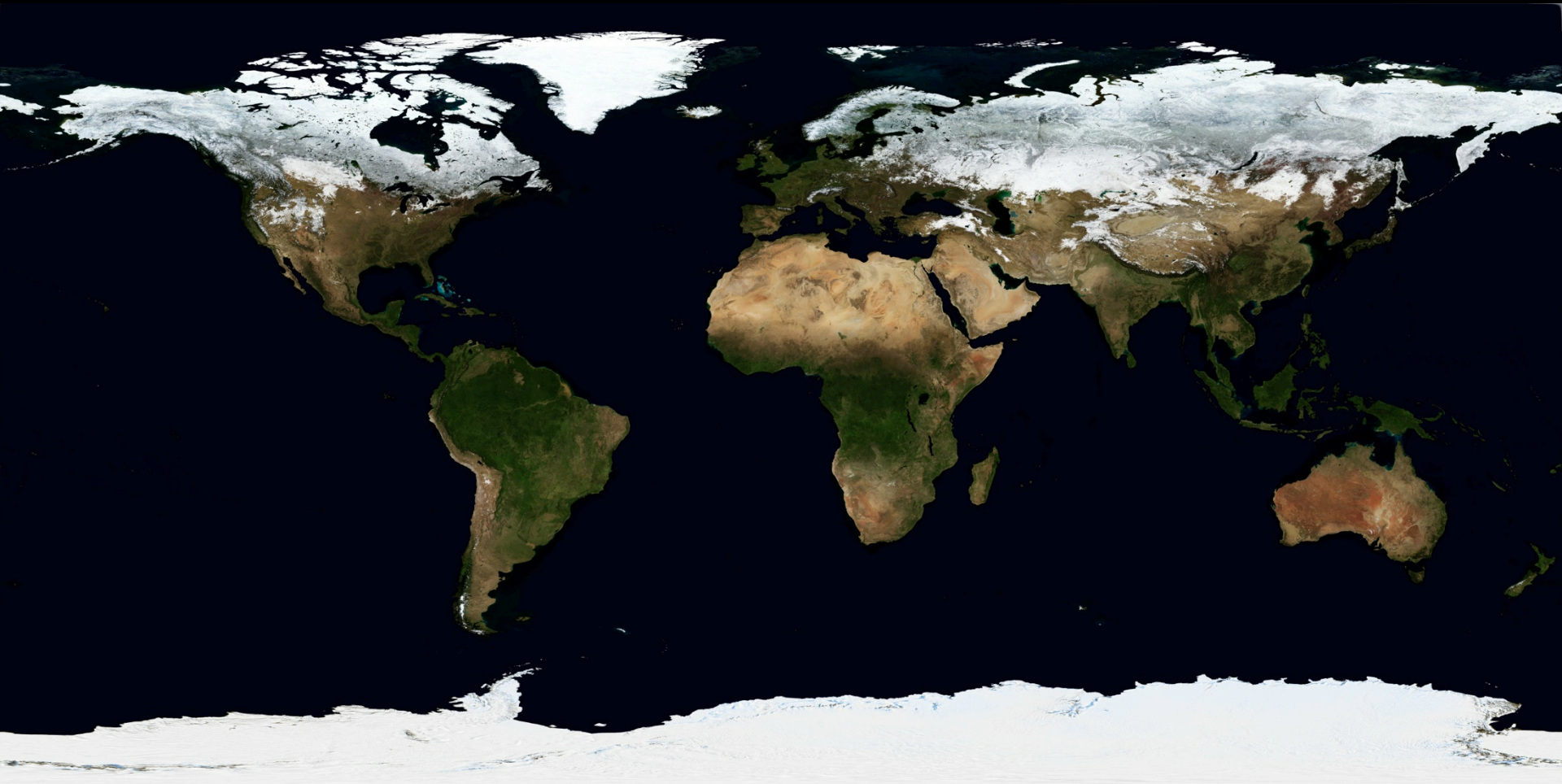


Einleitung zum Artikel über das ESO Headquarters Gebäude in Garching
in *Bauwelt*, Juli 1980

How do we see our world?



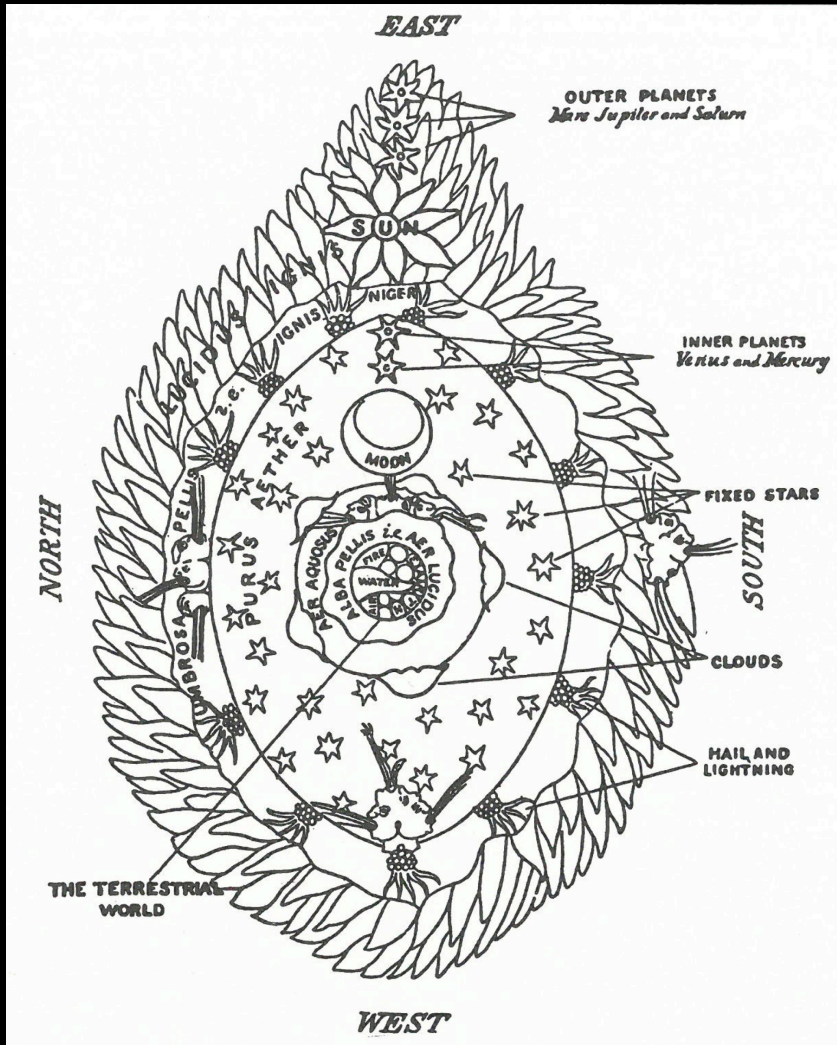
A changing world



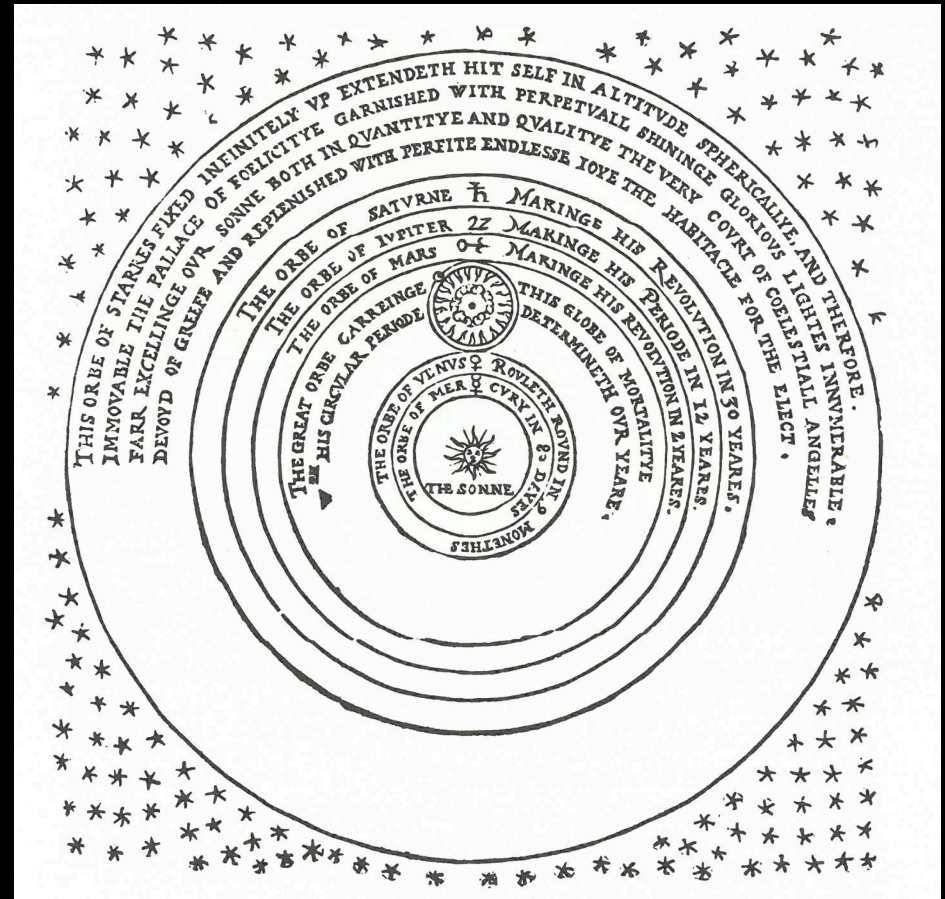
World Views



Past World Views

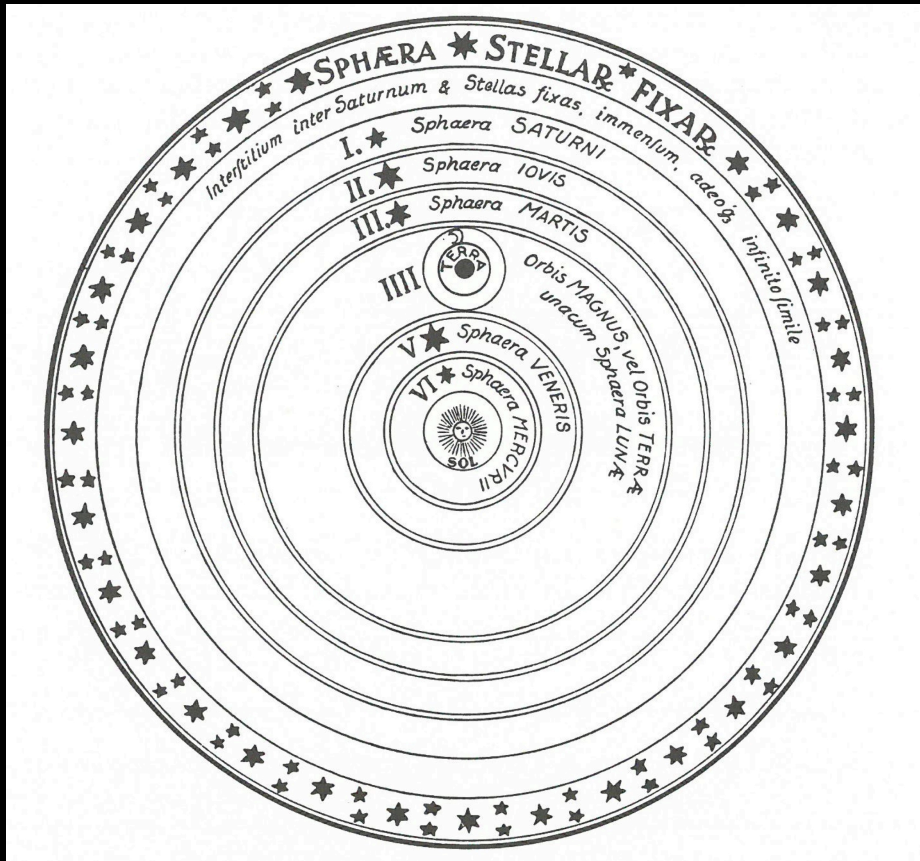


Hildegard von Bingen (1150)

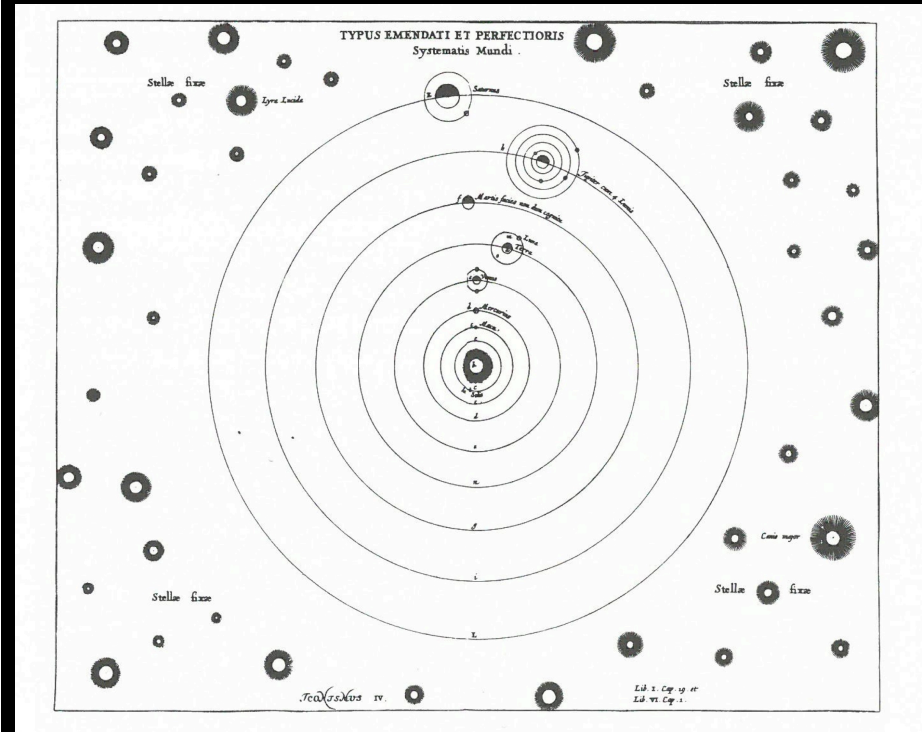


Thomas Digges (1576)

Past World Views

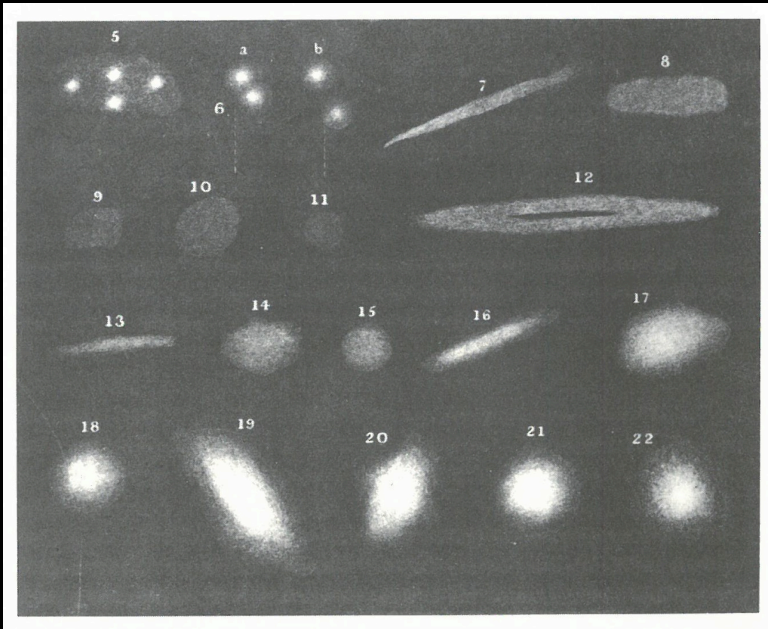
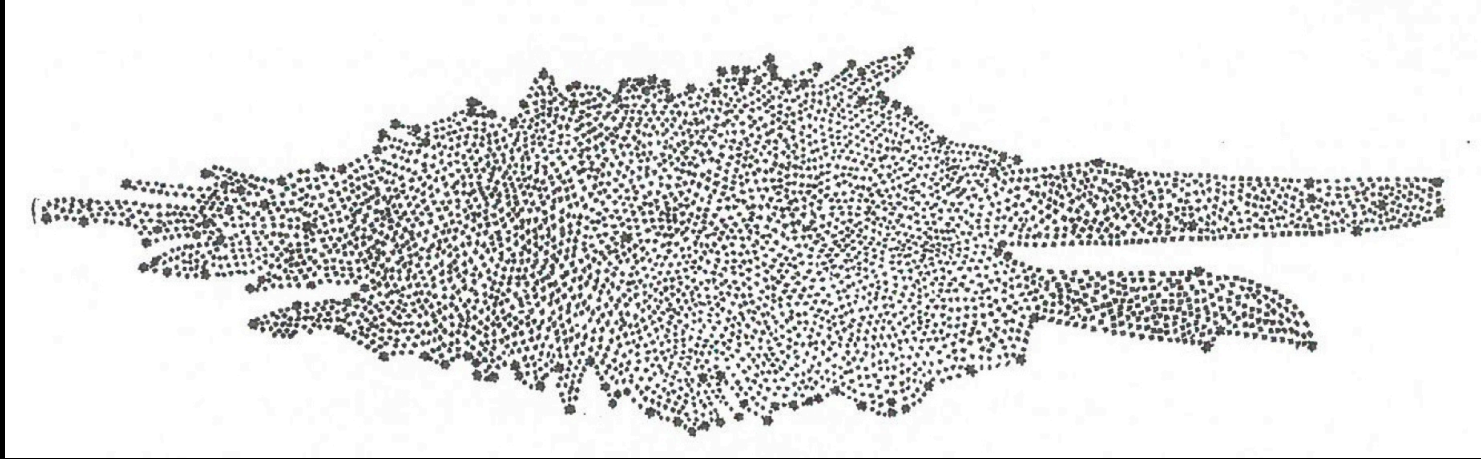


Johannes Kepler (1596)



Otto von Guericke (1672)

Past World Views

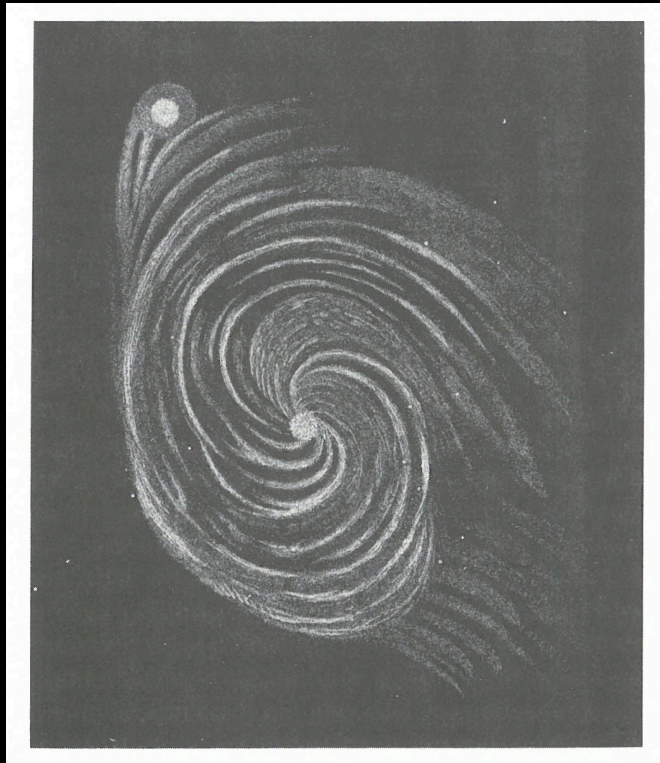


William und Caroline Herschel
(late 18th century)

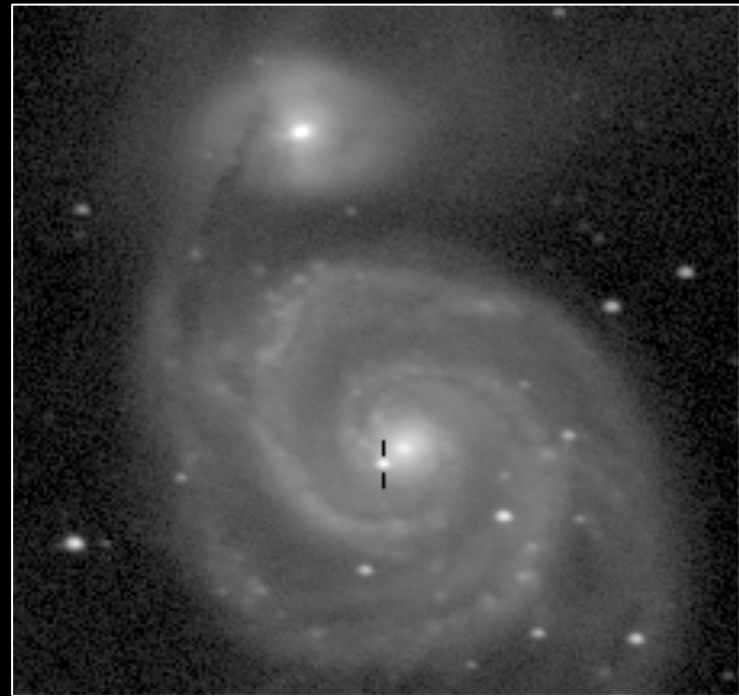


Past World Views

Messier 51



William Parson (1845)



Modern Image (1991)



Hubble Space Telescope
Ultradeep Field

The Earth at night



Our place in the universe



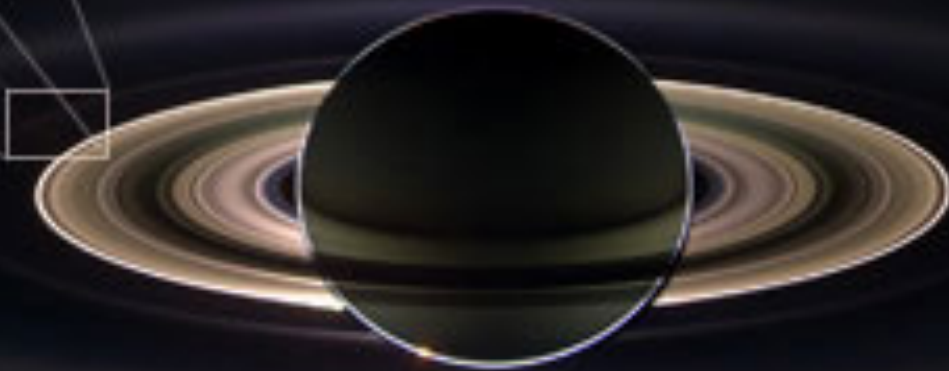
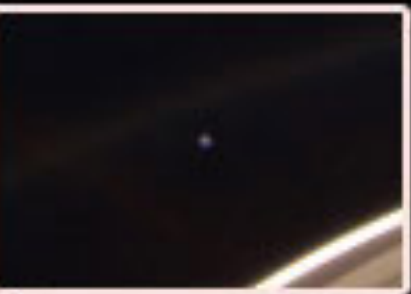
Our Home

Apollo 8



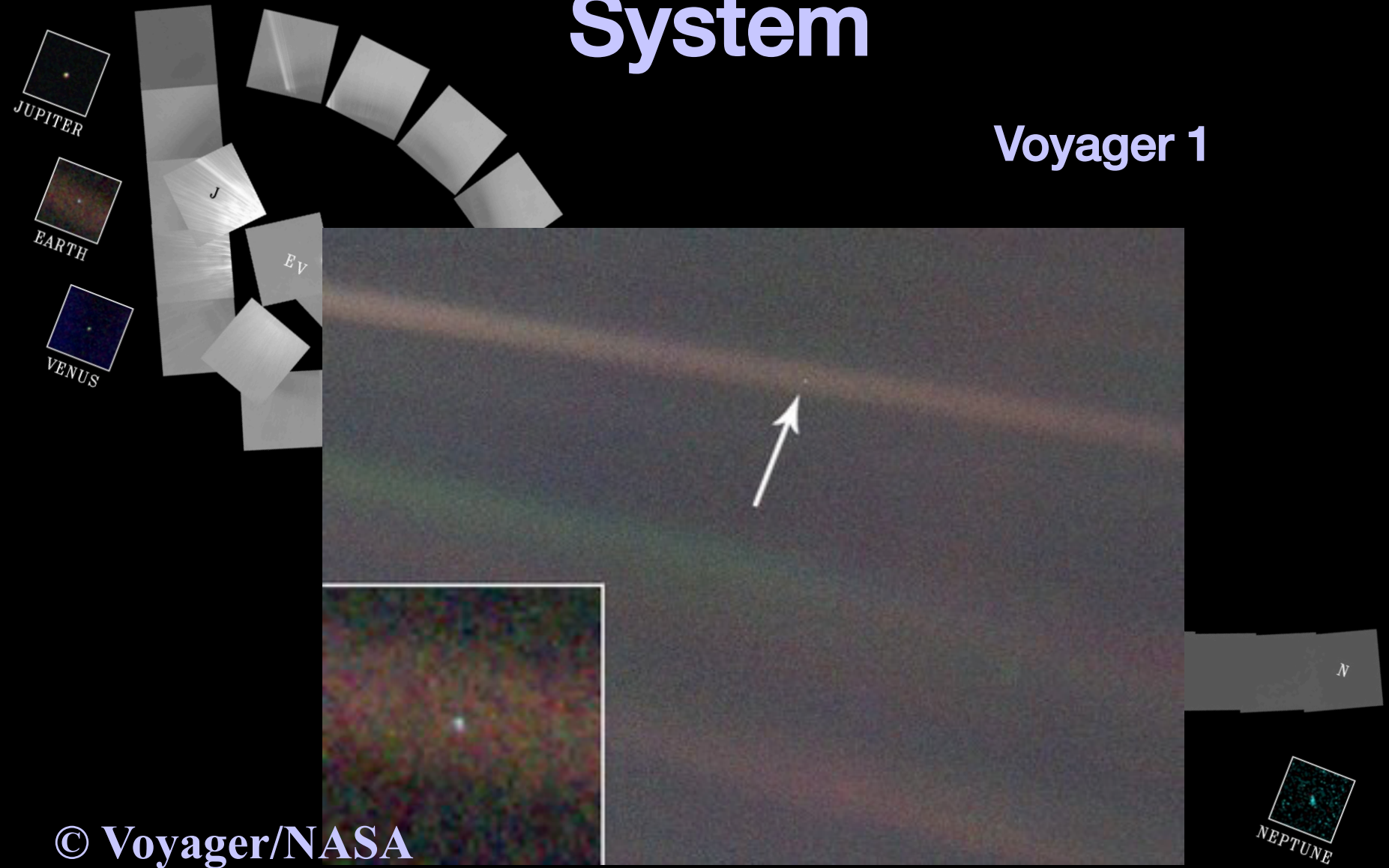
Our Home



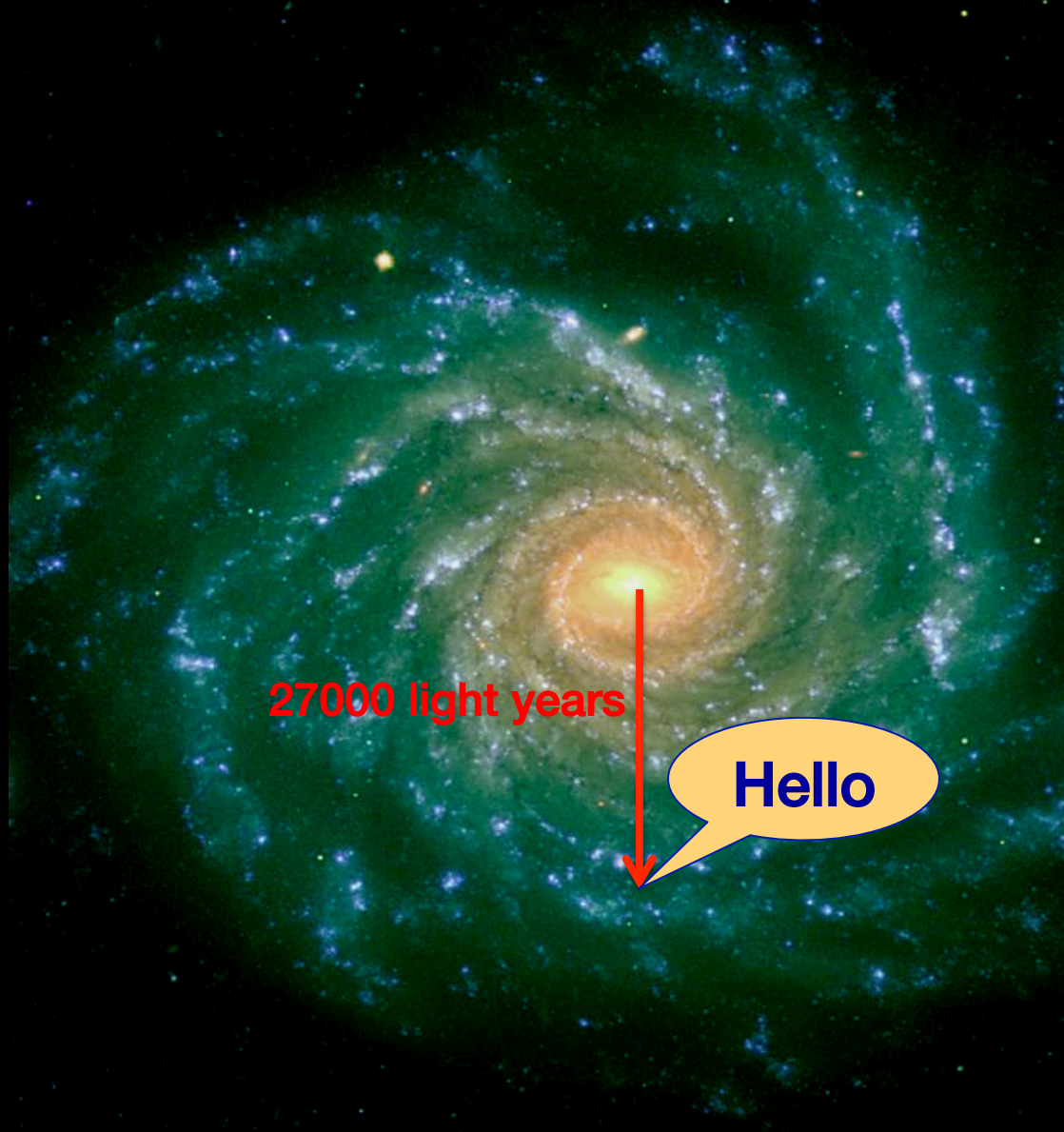


Family Portrait of the Solar System

Voyager 1



Our place in the Milky Way



27000 light years

Hello

1. January:
Big Bang

The Milky Way
forms

Sun and planets
form

Oldest
known life

First multi-cellular
organisms

January

February

March

April

May

June

July

August

September

October

November

December

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

Cambrian
Explosion

16

17

Emergence
of first
vertebrates

18

Early land
plants

19

20

First four-limbed
animals

21

Variety of
insects begin
to flourish

22

23

24

First
dinosaurs
appear

25

First
mammalian
ancestors
appear

26

27

First known
birds

28

29

Dinosaurs
wiped out
by asteroid
of comet

30

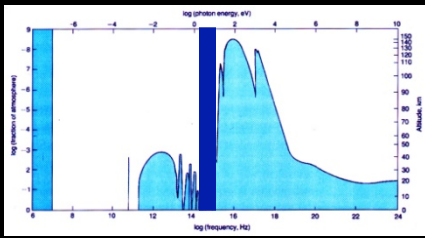
31

23:54 Modern humans (homo sapiens) appear
23:59:45 Invention of writing
23:59:50 Pyramids built in Egypt
23:59:59 Galileo observes the sky with a telescope

Earth's atmosphere

Shield and Window to the Universe





„visible“

[New Years Day](#) [The Big Bang](#) [Baby](#) [May](#) [June](#) [July](#) [August](#) [September](#) [October](#) [November](#)

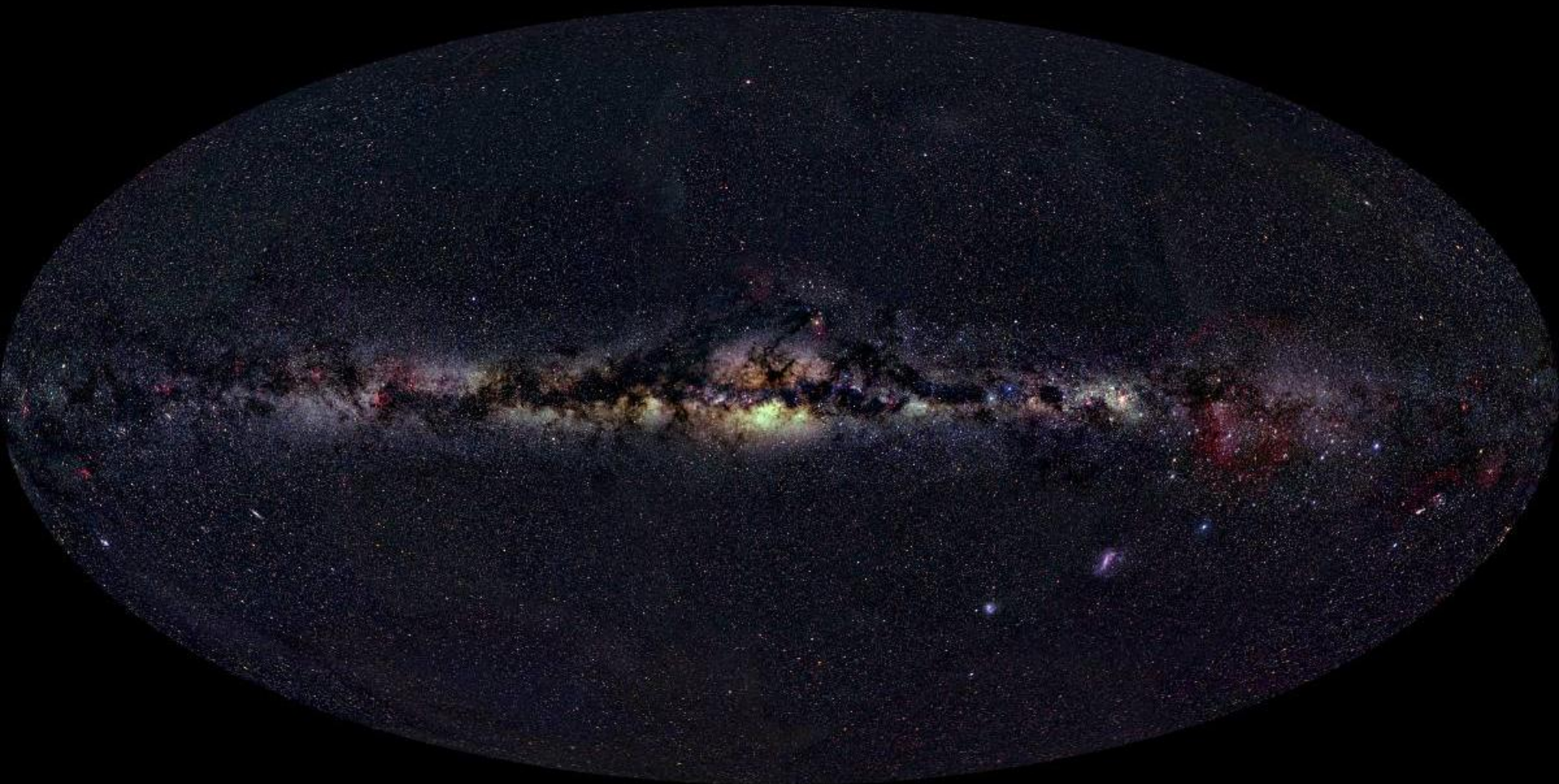
[Sun on planets](#) [Golden Gate](#) [Life Cycle](#) [cuckoo](#) [First multi-cellular organism](#)

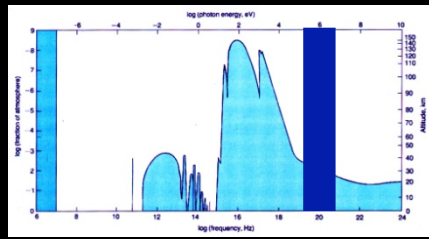
January February **April** May June July August September October November

December

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
Cambrrian explosion (burst of new life forms)	Emergence of first vertebrates	Early land plants	First four-limbed animals	First three-limbed animals	Variety of insects begin to flourish	
22	23	24	25	26	27	28
First dinosaurs appear	First dinosaurs appear	First dinosaurs appear	First dinosaurs appear	First dinosaurs appear	First dinosaurs appear	First dinosaurs appear
29	30	31				

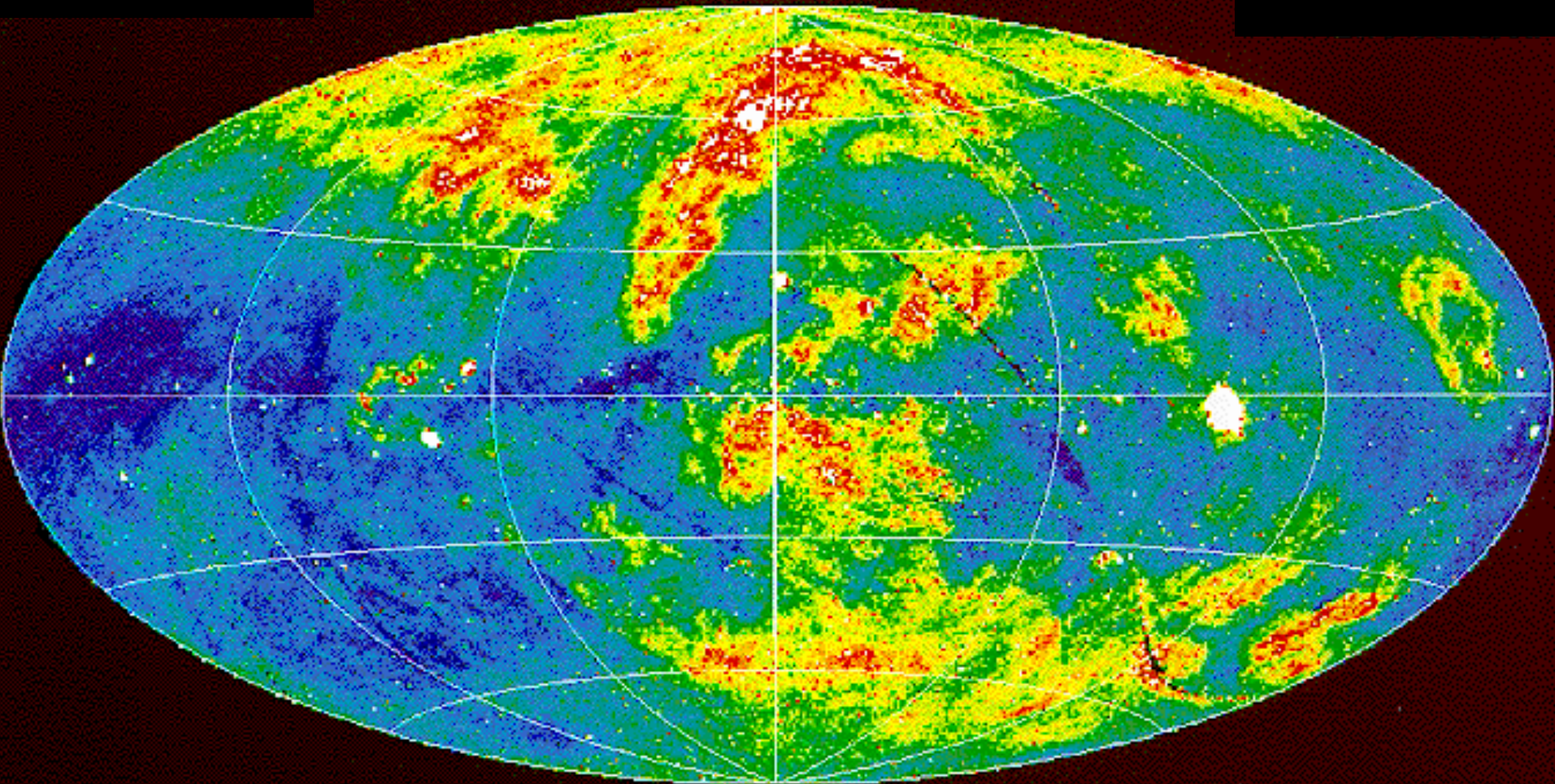
23:54 Anatomically modern humans appear
 23:59:45 Invention of writing
 23:59:50 Pyramids built in Egypt
 23:59:59 Voyage of Christopher Columbus

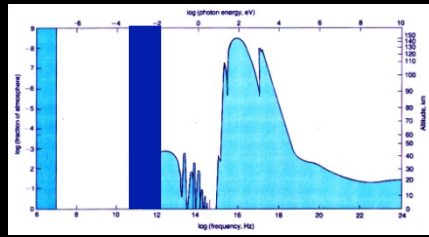




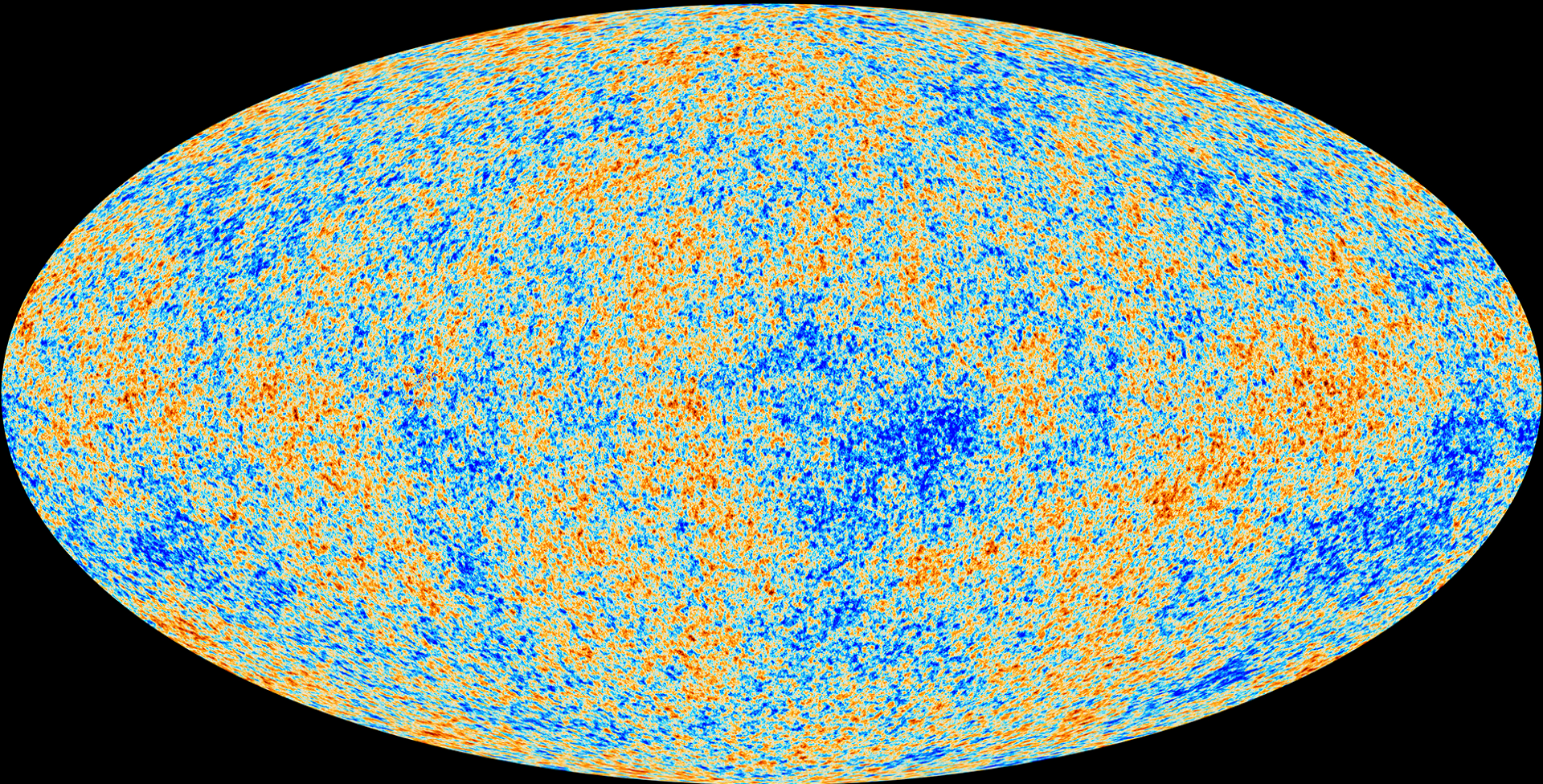
„invisible“

January	February	March	April	May	June	July	August	September	October	November
December										
1	2	3	4	5	6	7				
8	9	10	11	12	13	14				
15	16	17	18	19	20	21				
Cambrrian explosion (burst of new life forms)		Emergence of first vertebrates	First land plants	First four-limbed animals		Variety of insects begin to flourish				
22	23	24	25	26	27	28				
	First dinosaurs appear	First amphibians appear	First reptiles appear	First mammals appear	First birds appear					
29	30	31								
Dinosaurs wiped out by asteroid or comet		23:54 Anatomically modern humans appear		23:59:45 Invention of writing		23:59:50 Pyramids built in Egypt		23:59:59 Voyage of Christopher Columbus		





„invisible“





The dark side of the universe

What is the universe made of?

How do we understand the universe?

What are Dark Matter and Dark Energy?

The „invisible” Universe

- Large parts of the Universe are dark
- „Dark“ (non-luminous matter) is everywhere
 - e.g. planets, molecules, dust, cool gas
- Measurements through indirect methods
 - ➔ Gravitation!
 - ➔ Model for the evolution of the Universe
 - ➔ Einstein’s Theory of Relativity

Basics of Cosmology

(our world view)

Theory of Gravity

Einstein's Theory of General Relativity

Isotropy

There are no preferred directions in the Universe

Homogeneity

**No special region in the Universe
(e.g. no centre)**

Anthropic Principle

The Universe created us

Gravitation!

Of the four fundamental forces (Gravitation, Electromagnetism, Weak and Strong Forces) **only gravitation determines the evolution of the universe.**





WALL TO WALL
ALL BENEFIT
FOR WORLD
CUP
LHO M... 2003

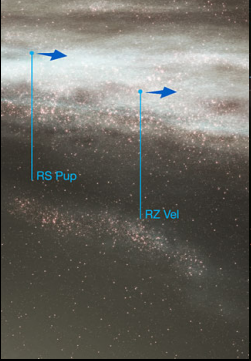
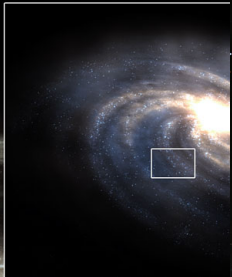
$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G}{c^4} T_{\mu\nu}$
A. EINSTEIN

AMSTERDAM
VOLK

ERWIN S. ALBA


What is in the Universe?

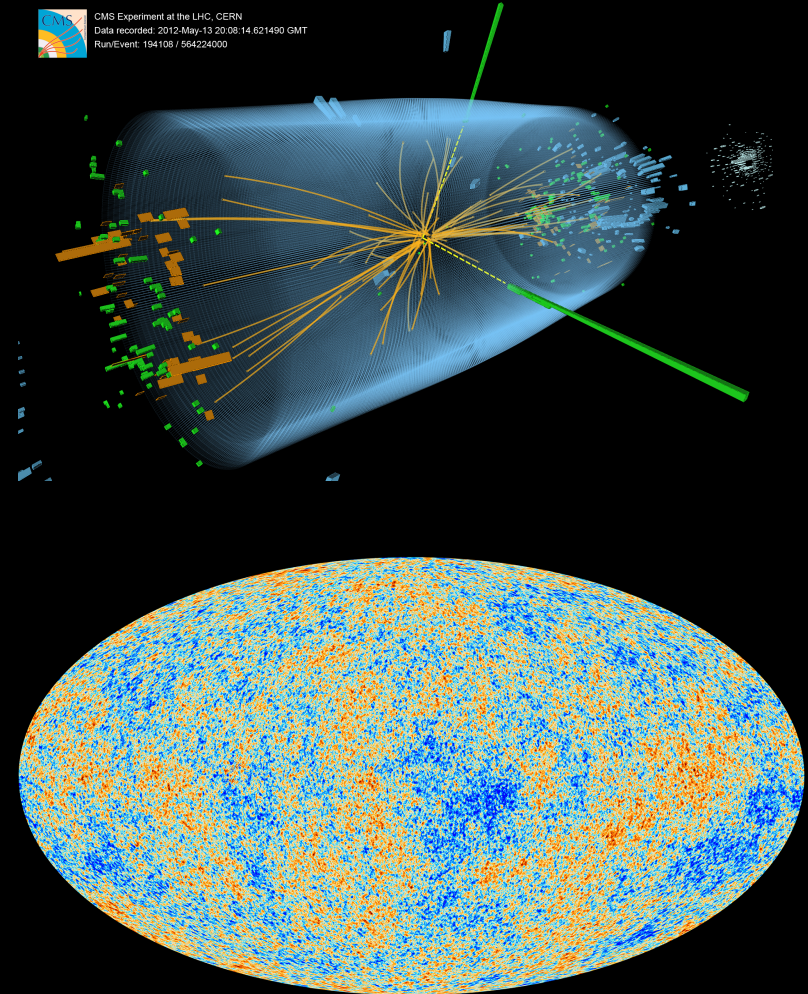
- We are!



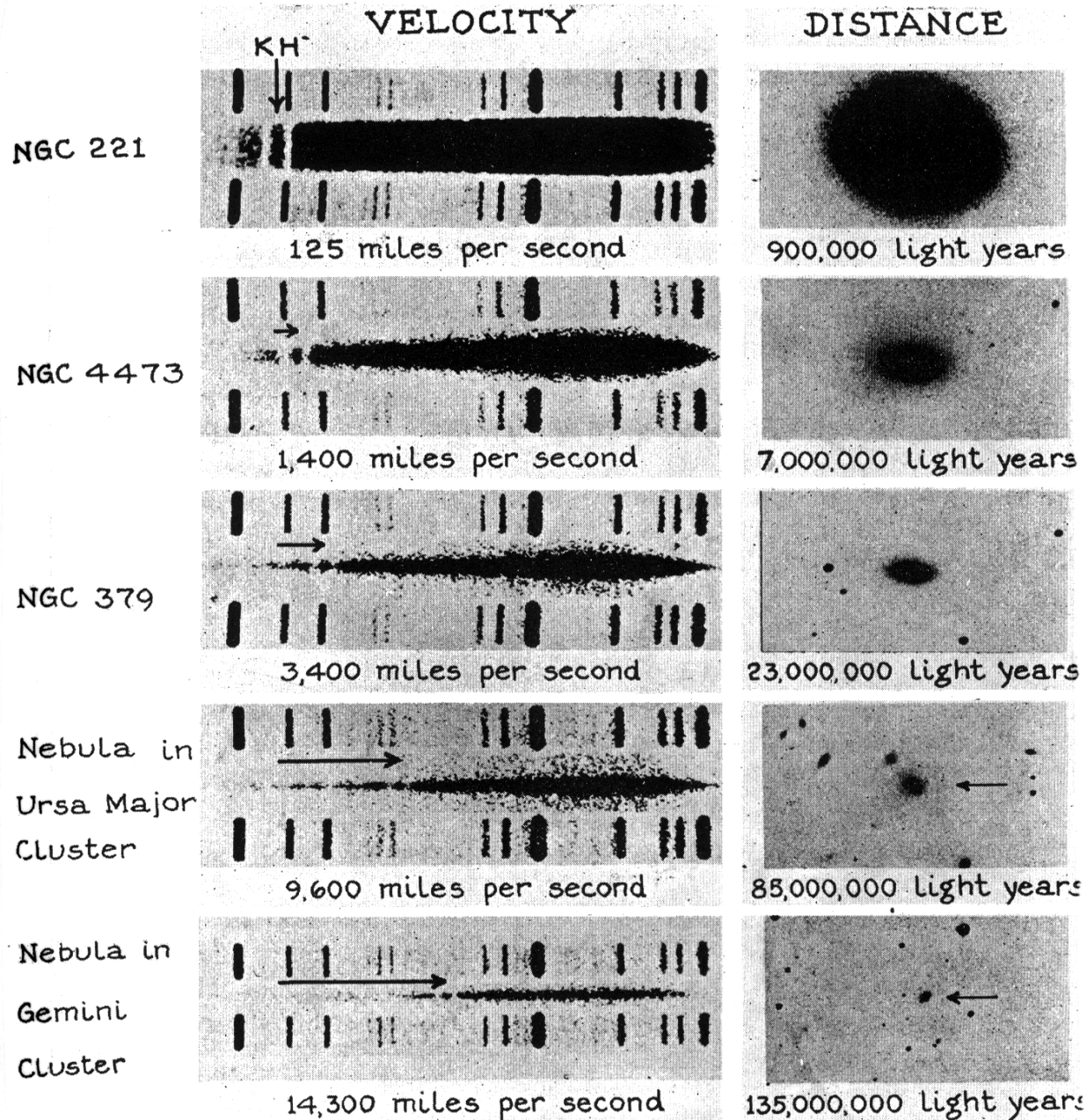
What is in the Universe?

- What else?
 - **Elementary particles**
 - Neutrinos
 - Higgs particle
 - yet unknown particles
 - **Other forms of energy**
 - radiation
 - ?????

 CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 56422400



THE VELOCITY-DISTANCE RELATION FOR EXTRA-GALACTIC NEBULAE



Hubble

Supernova!



The supernova of 1054



Cosmology with Supernovae

It is very difficult to measure distances in the universe. Supernovae are an essential tool to determine the expansion rate and its history.

Type Ia Supernovae are excellent distance indicators

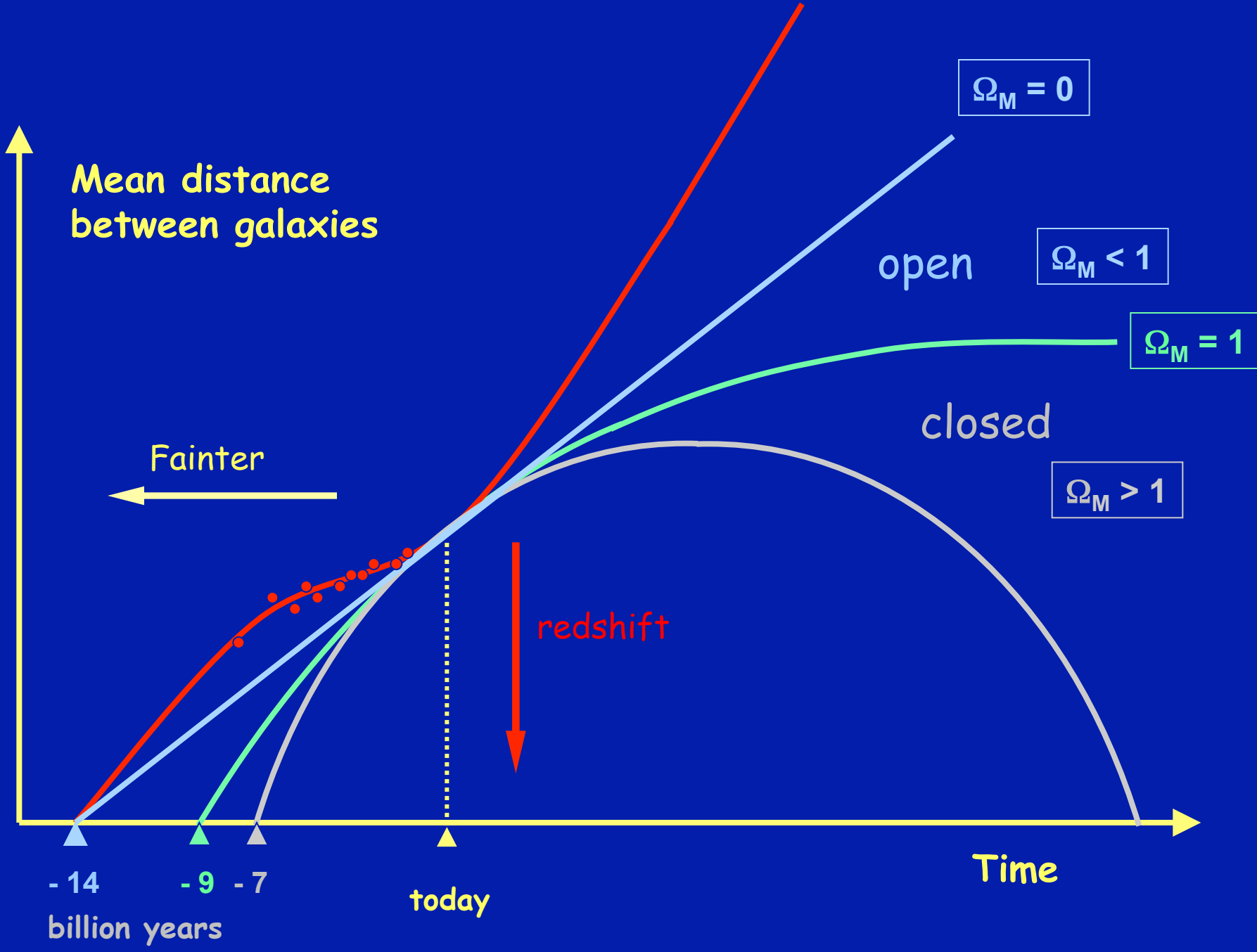
Distance measurement with a constant light source



1000w



1000w



Physics Nobelprize 2011



Saul Perlmutter



Brian Schmidt



Adam Riess

"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"

You need to dress up for this



December 2011

The High-z Supernova Search Team December 2011



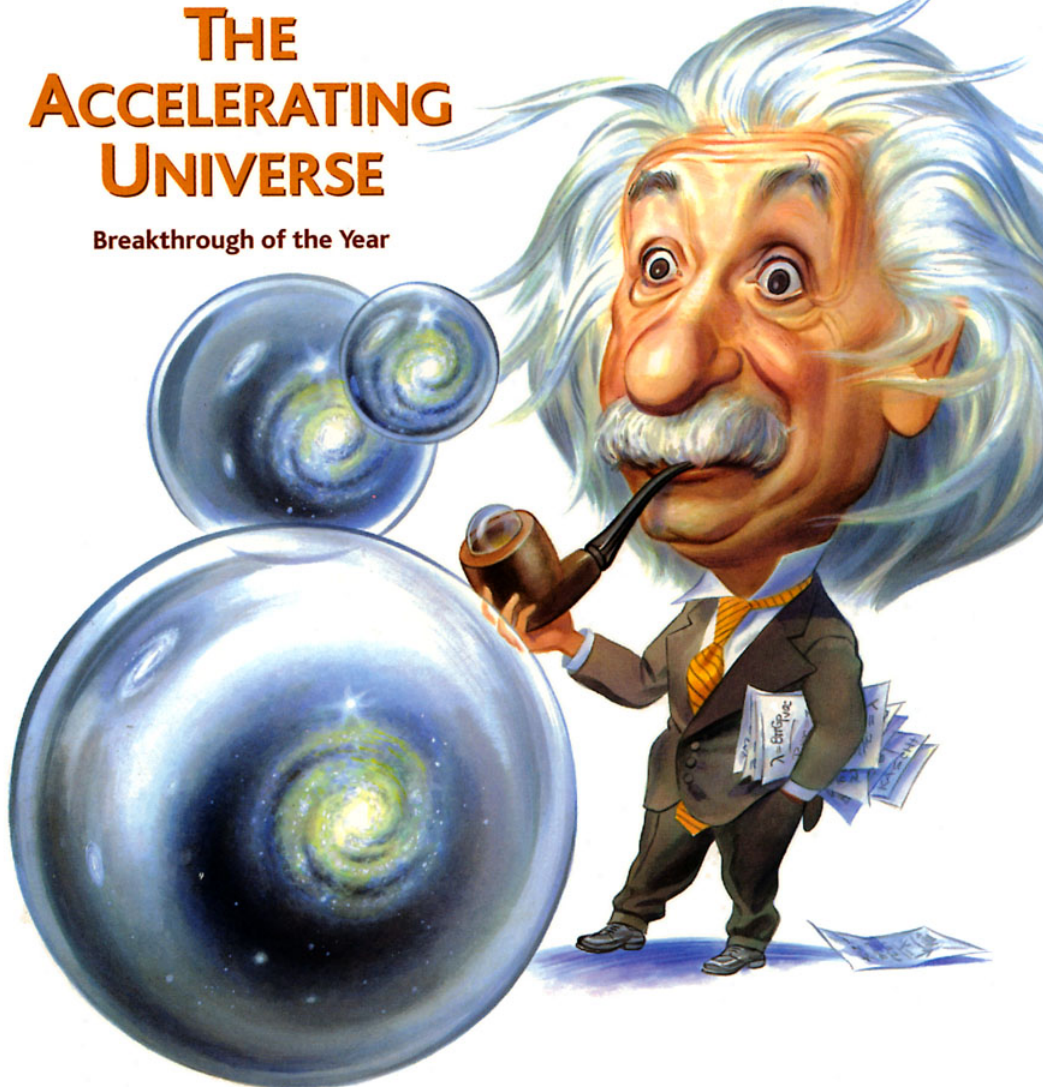
18 December 1998

Science

Vol. 282 No. 5397
Pages 2141-2336 \$7

THE ACCELERATING UNIVERSE

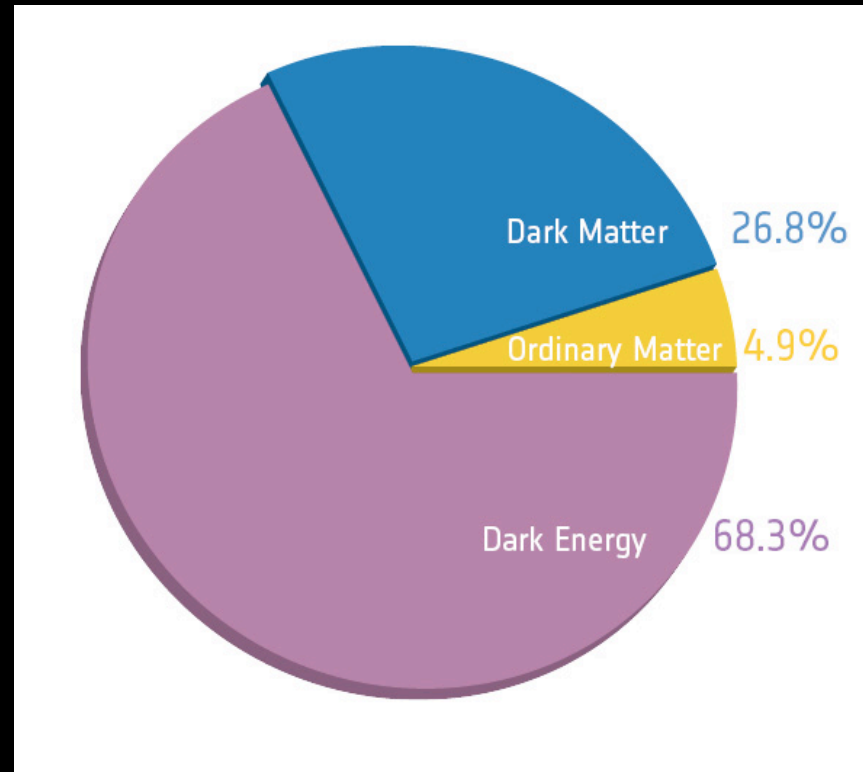
Breakthrough of the Year



AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Contents of the universe

Dark Matter and Dark Energy are the dominant energy components in the universe.



What does this mean?

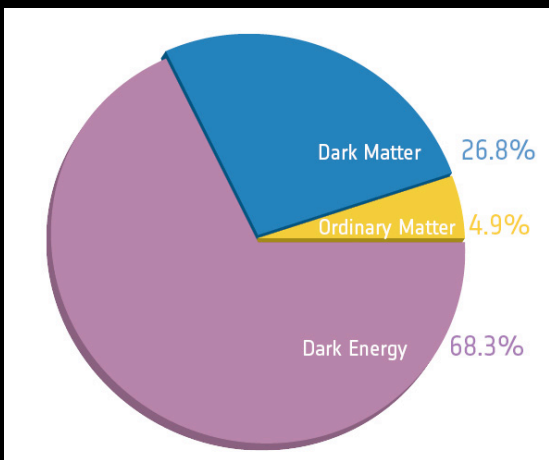
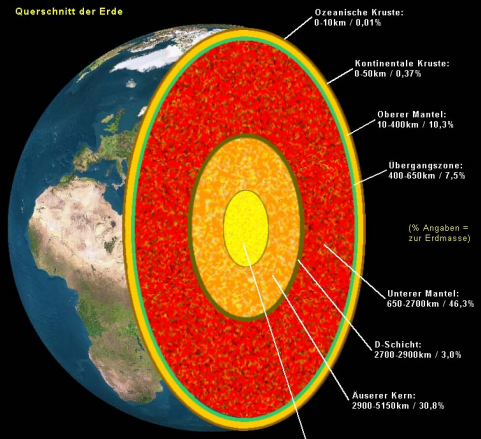
The universe is essentially

empty

The universe expands forever

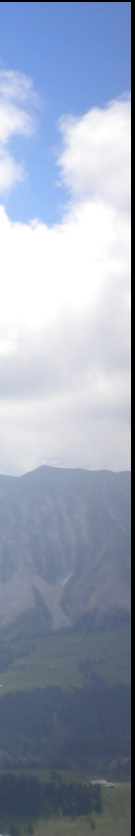
No convincing physical interpretation of
the cosmological constant or the
vacuum energy (**Dark Energy**)

Only 4% of the universe are of the same
matter as we are (and that we know)



Our universe

Our world



The true age of discovery in astronomy is only just starting.

F. Zwicky