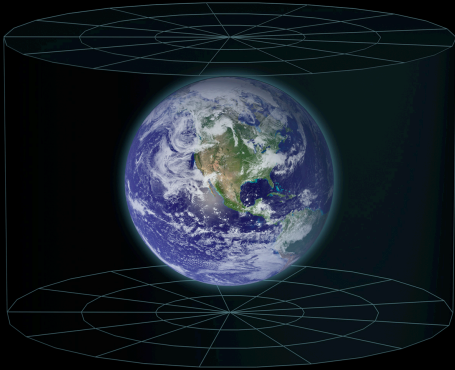
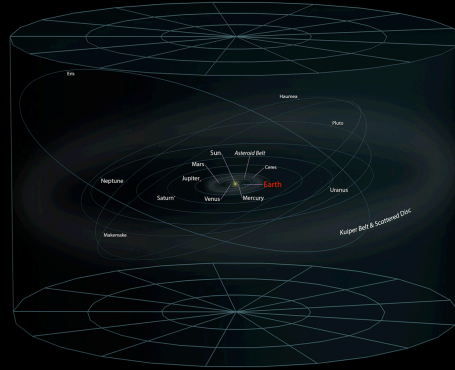


Evolution of the Universe

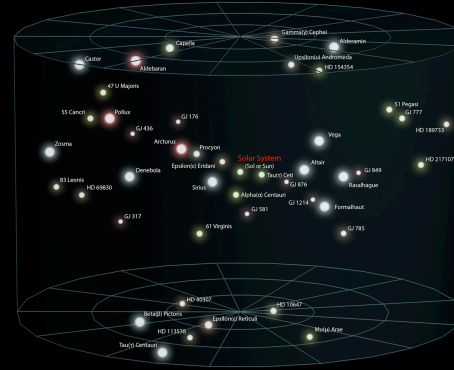
Earth



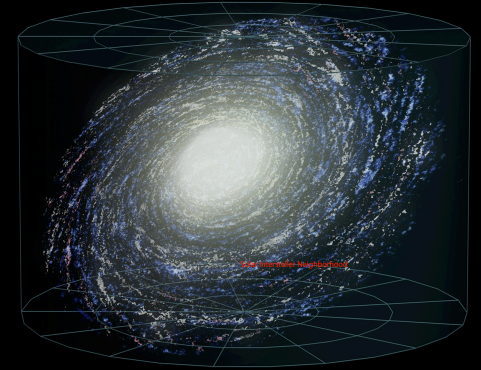
Solar System



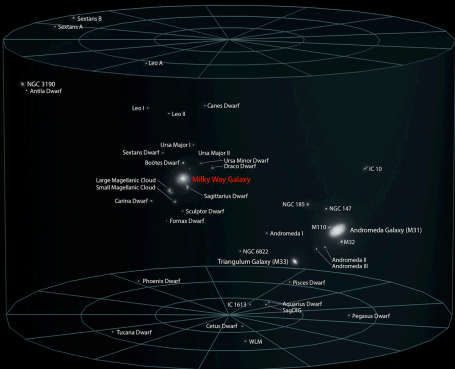
Solar Interstellar Neighborhood



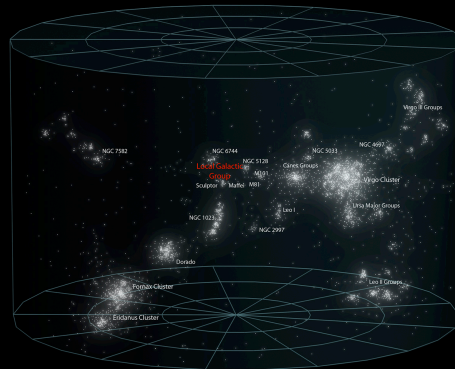
Milky Way Galaxy



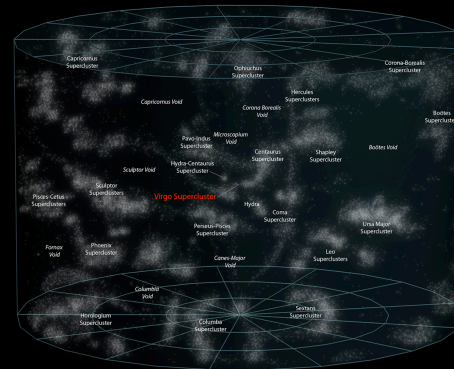
Local Galactic Group



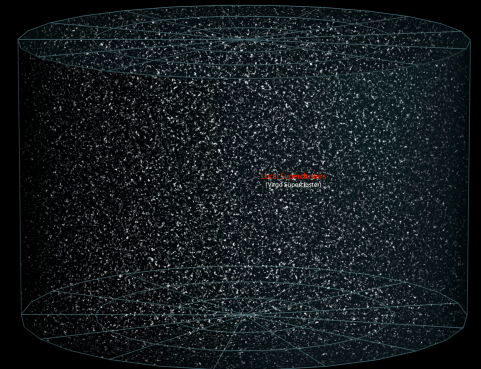
Virgo Supercluster



Local Superclusters



Observable Universe

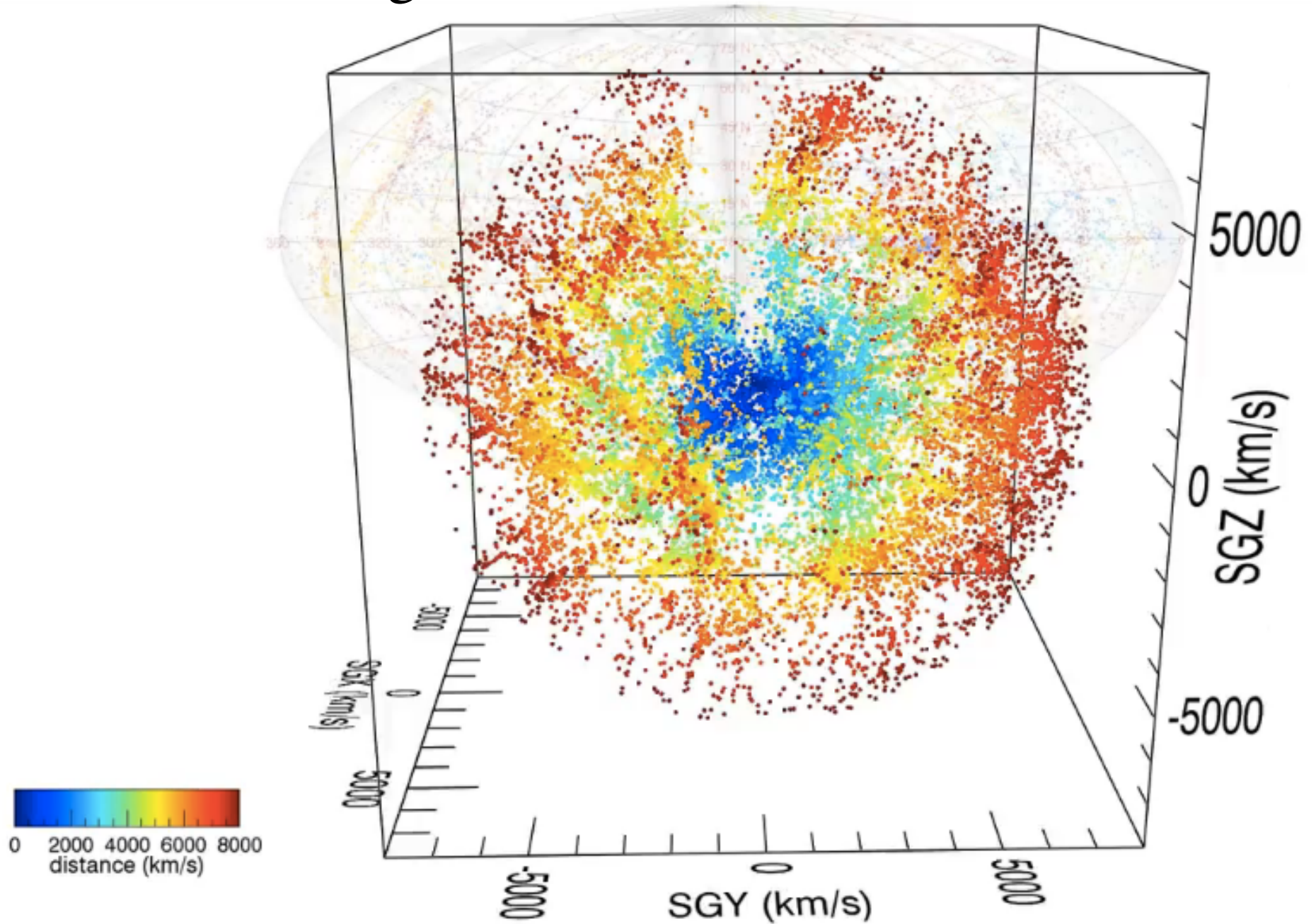


Definition : Redshift

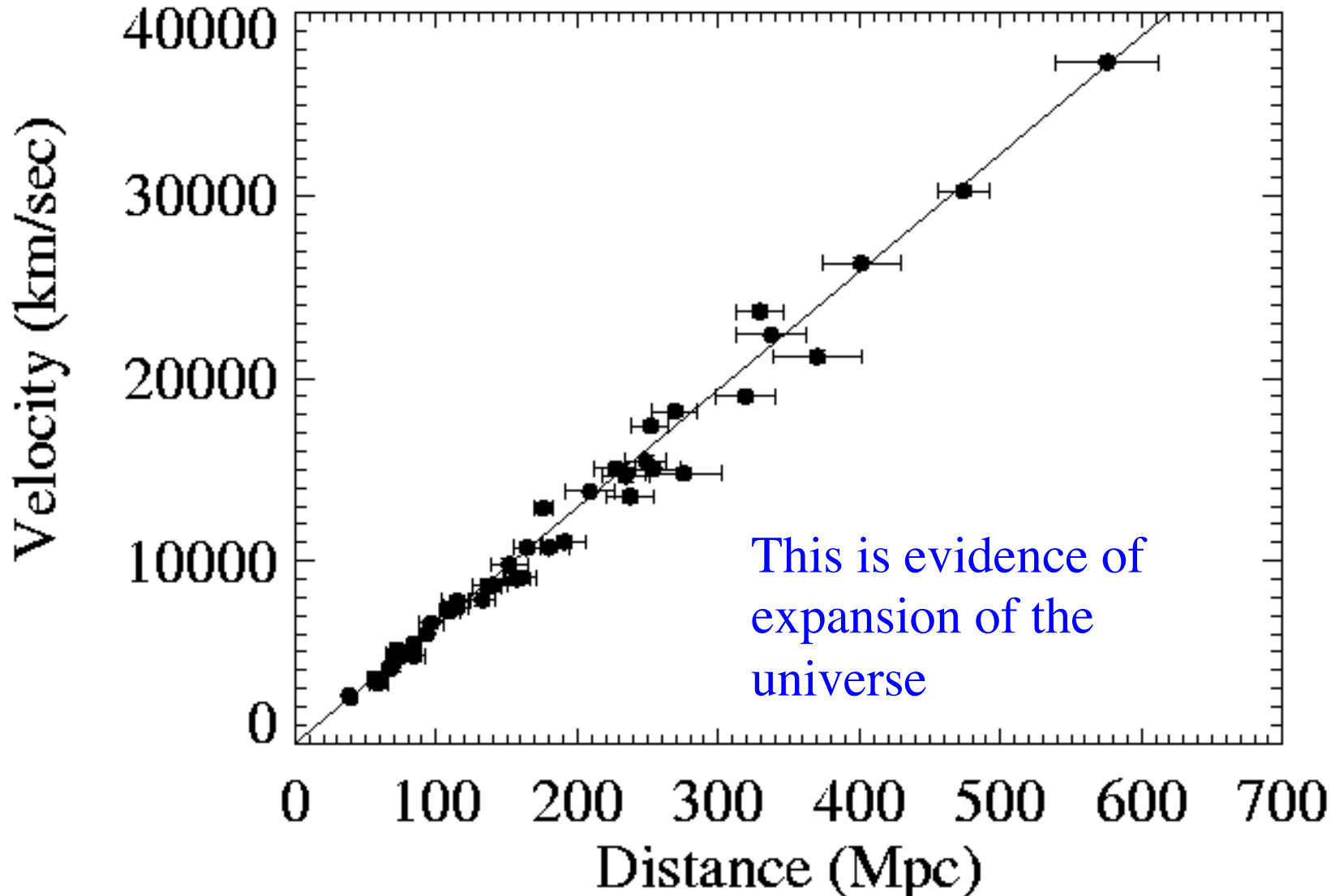
- The measure of the amount a spectral line is shifted in wavelength



Known galaxies within 8,000 km/s of us



Galaxies that are farther away from us are moving away from us faster



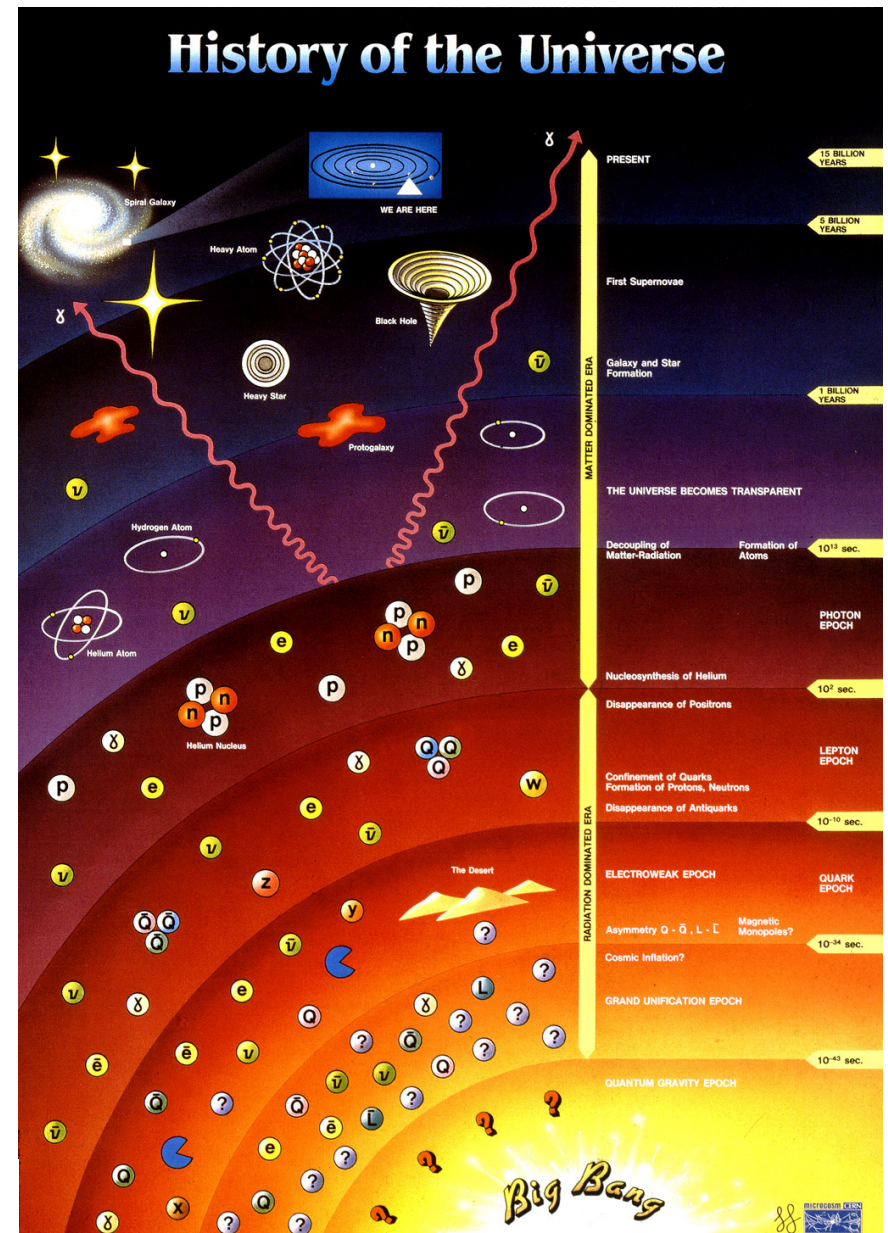
Status of the Big Bang

There is evidence for expansion, and the universe was hotter and denser in the distant past.

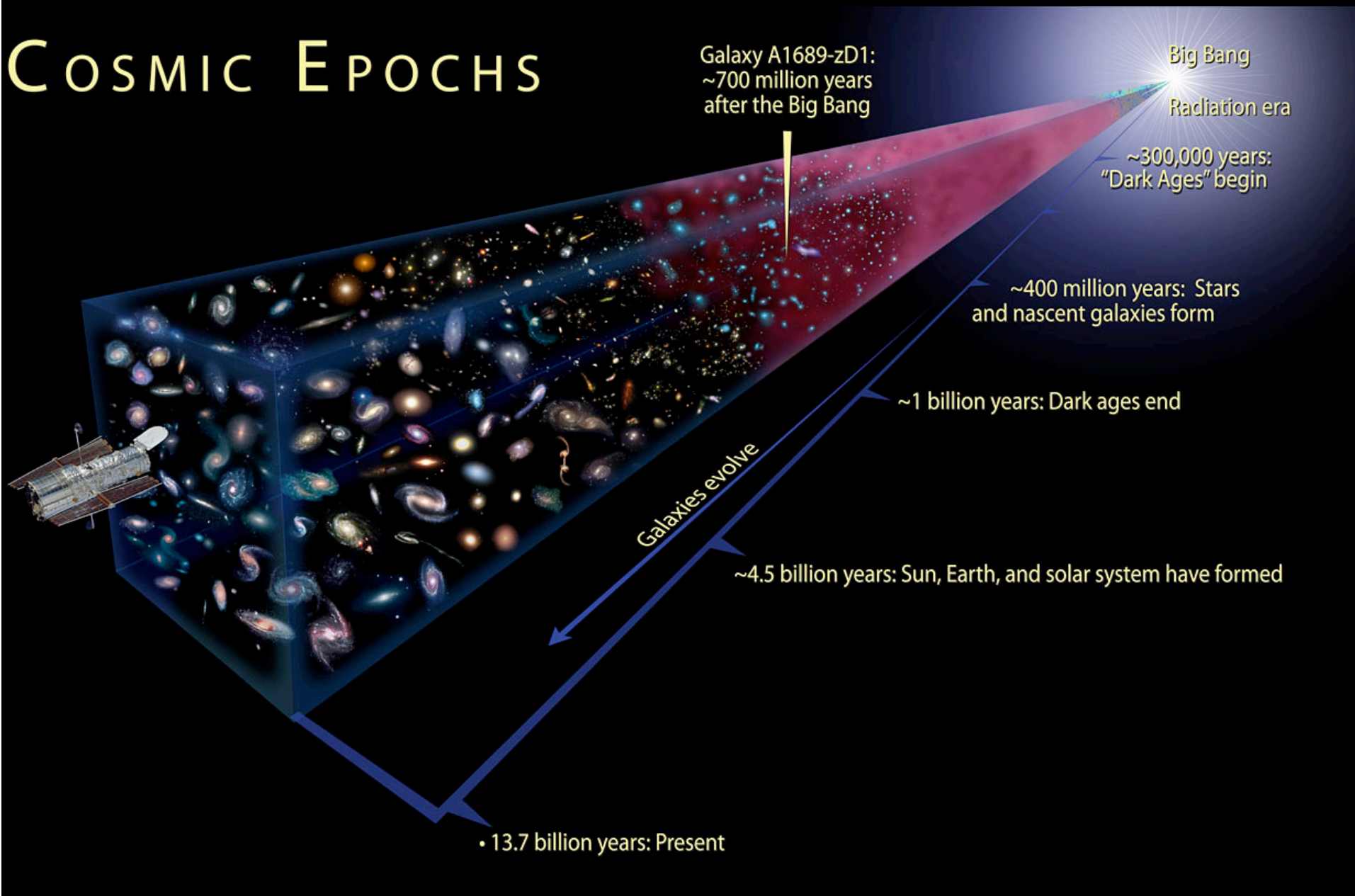
The microwave background and the helium abundance cannot easily be explained in any other way.

There are hundred of thousands of big bang photons in every breath you take: the big bang is all around us.

It is a theory, but a theory with a web of evidence to support it. The theory is mute about the cause of the cause.



COSMIC EPOCHS



Hubble Probes the Early Universe



1990

Ground-based observatories



1995

Hubble Deep Field



2004

Hubble Ultra Deep Field



2010

Hubble Ultra Deep Field-IR



FUTURE

James Webb Space Telescope



Redshift (z):

Time after the Big Bang

Present

1

6 billion years

4

1.5 billion years

5

6

7

800 million years

8

10

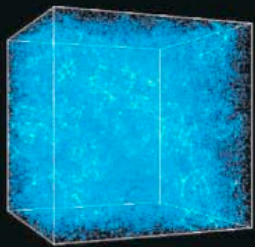
480 million years

>20

200 million years

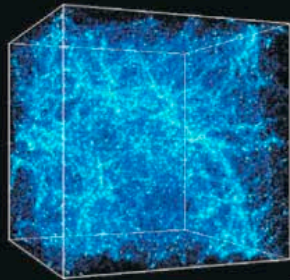
Growth of large scale structure

0.5 billion years



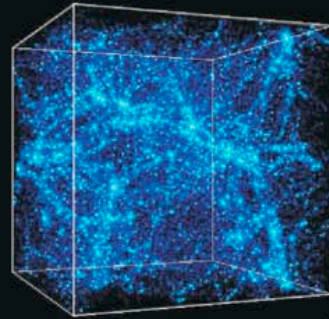
13 million light-years

2.2 billion years



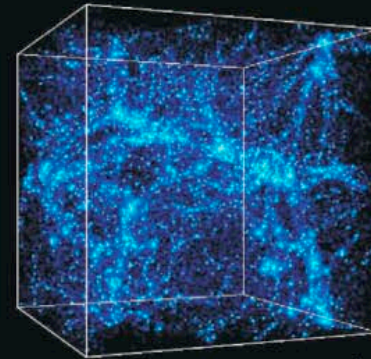
35 million light-years

5.9 billion years



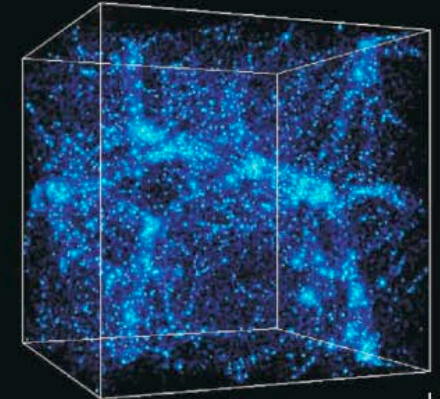
70 million light-years

8.6 billion years



93 million light-years

13.7 billion years



140 million light-years

As the universe expands over time, denser regions draw in more and more matter, creating a "lumpy" distribution.

Not to scale!

How do our lifetimes compare to the age of the Universe?

- The Cosmic Calendar: a scale on which we compress the history of the universe into 1 year.
- This is a time scale model where 13.7 billion years equals 1 year, i.e. 13,700,000,000:1.
- Our lives would scale similarly, so 80 years goes down by a factor of 13.7 billion too.
- In the scale model, a human life is about 2 tenths of a second!

JANUARY

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FEBRUARY

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				4	15	
				1	22	
				8		

MARCH

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23/30	24/31	25	26	27	28	29

APRIL

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27	28	29	30			

Jan 1st
midnight
Big Bang

JUNE

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JULY

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SEPTEMBER

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OCTOBER

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SEPTEMBER

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21	22	23	24	25	26	27
28	29	30	31			



JANUARY

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19	20	21	22	23	24	25
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FEBRUARY

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MARCH

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8

Jan 1st

12min. after midnight

Cosmic Microwave Background
(~300,000 yrs after Big Bang)

APRIL

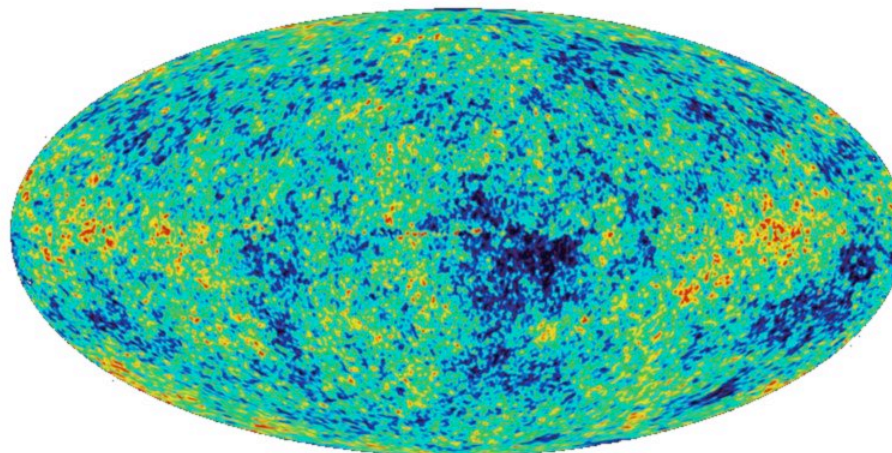
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JULY

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13	14	15	16	17
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OCTOBER

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				31



EMBER

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MBER

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JANUARY

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FEBRUARY

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MARCH

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9	10	11	12	13	14	15
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Jan 10st

1pm

Youngest galaxies observed to date
(~500 Myrs after Big Bang)

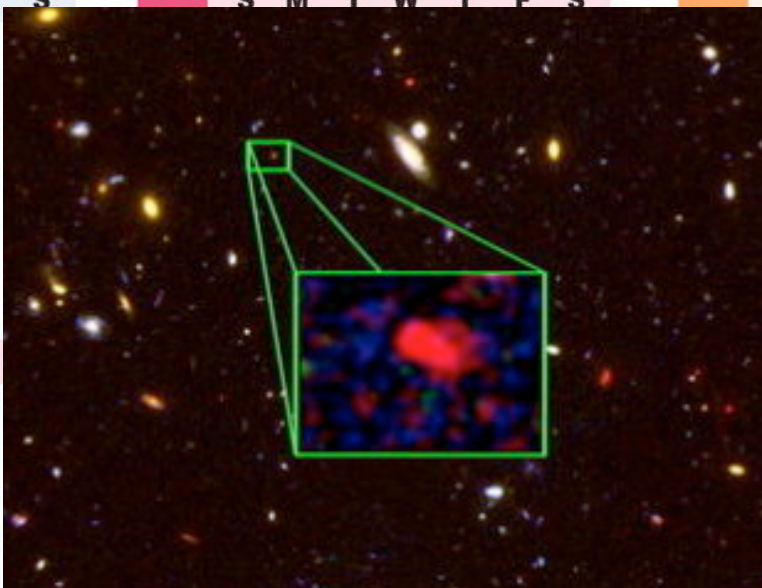
APRIL

S	M	T	W	T	F	S
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27	28	29	30	31		

JUNE

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SEPTEMBER



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OCTOBER

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DECEMBER

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JANUARY

S M T W T F S

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12 1
19 2
26 2

FEBRUARY

S M T W T F S

MARCH

S M T W T F S

Aug 31st

11am

Solar System and Earth Forms

(~9.1 Byrs after Big Bang)

(~4.6 Byrs ago)

JULY

S M T W T

1 2 3
6 7 8 9 10
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TEMBER

T W T F S

2 3 4 5 6
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OCTOBER

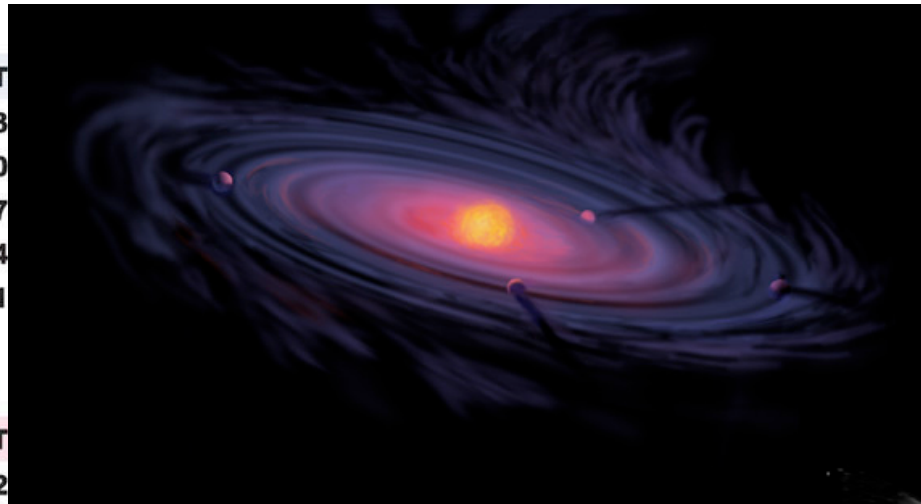
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26 27 28 29 30 31

EMBER

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21 22 23 24 25 26 27
28 29 30 31



2 3 4 5 6 7 8
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JANUARY

FEBRUARY

MARCH

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12 1
19 2
26 2

Sep 27th

2am

APRIL

S
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13 1
20 2
27 2

**First fossil evidence for Life on Earth
(~10.1 Byrs after Big Bang)
(~3.6 Byrs ago)**

JULY

S M T
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20 21 22
27 28 29



OCTOBER

S M T
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SEPTEMBER

S M T W T F S
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DECEMBER

S M T W T F S
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JANUARY

FEBRUARY

MARCH

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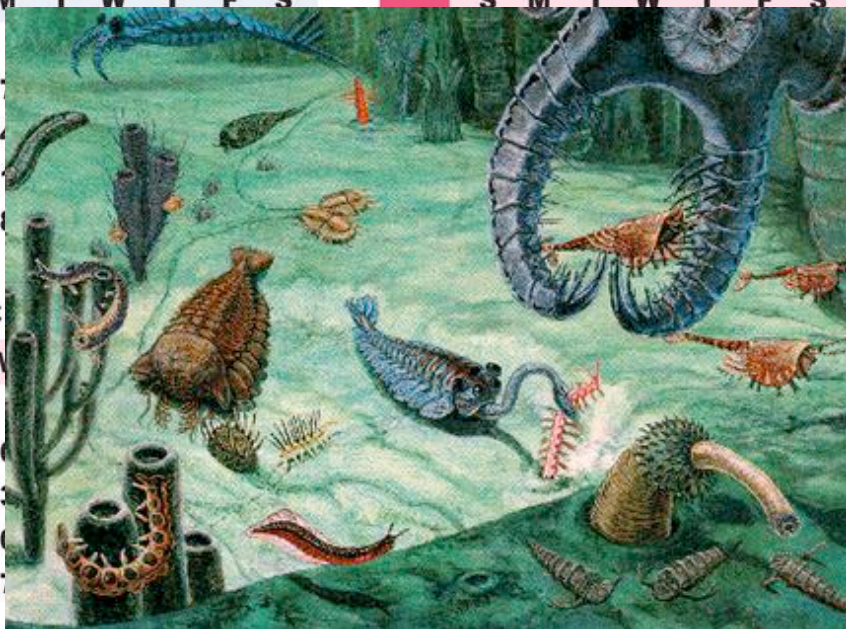
Dec 17th
Midnight

APRIL
S
6
13 1
20 2
27 2

**Cambrian Explosion – evidence for
complex multicellular life
(~13.2 Byrs after Big Bang)
(~550 Myrs ago)**

JULY

S M T W T F S
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13 1
20 2
27 2



OCTOBER
S M
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19 2
26 2

S M T W T F S
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7 8 9 10 11 12 13
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DECEMBER

S M T W T F S
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21 22 23 24 25 26 27
28 29 30 31

JANUARY

FEBRUARY

MARCH

Dec 30th

6:20am

Dinosaurs go extinct
(~65 Myrs ago)

S M

5

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SEPTEMBER

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DECEMBER

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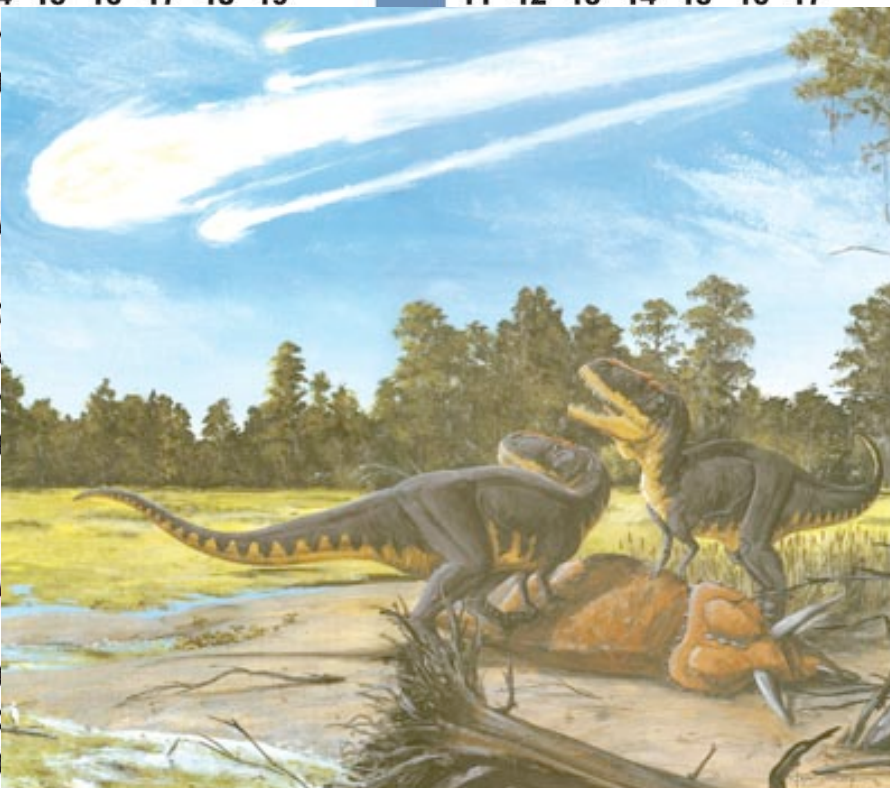
1 2 3 4 5 6

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14 15 16 17 18 19 20

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JANUARY

FEBRUARY

MARCH

Dec 31st

6pm

First Hominids
(~7-8 Myrs ago)

S M

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AUGUST

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NOVEMBER

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DECEMBER

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28 29 30 31



JANUARY

FEBRUARY

MARCH

S M
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12 1
19 2
26 2

Dec 31st
~10:30pm

First Stone Tools
(~2.5 Myrs ago)

APRIL

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25 26 27 28 29 30 31

15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30

JULY

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27 28

AUGUST

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SEPTEMBER

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OCTOBER

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NOVEMBER

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DECEMBER

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23/30



JANUARY

FEBRUARY

MARCH

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SEPTEMBER

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DECEMBER

S M T W T F S

1 2 3 4 5 6

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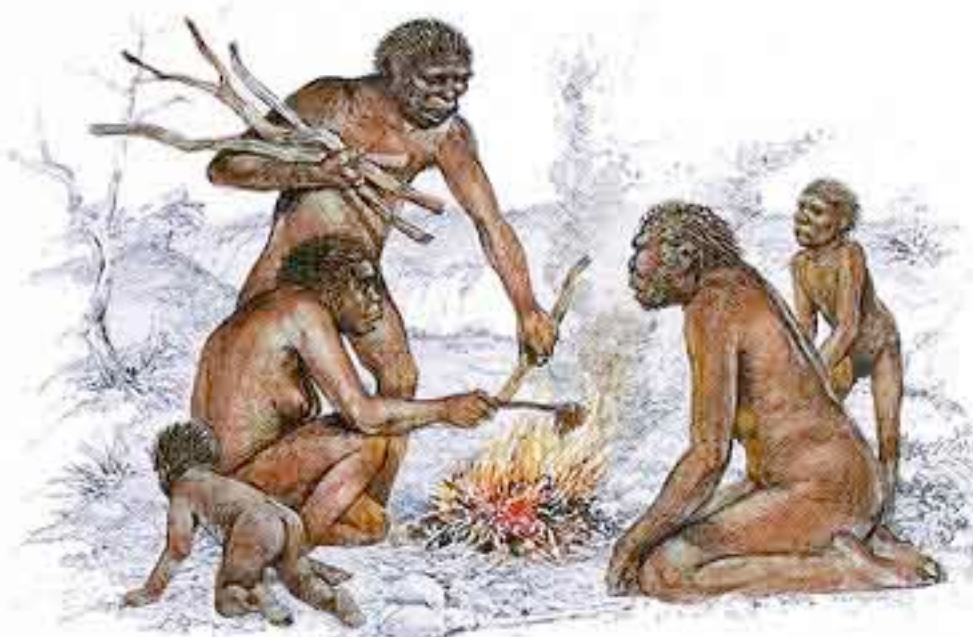
28 29 30 31

26 27 28 29 30 31

23/30 24 25 26 27 28 29

Dec 31st
~11:40pm

First use of fire by humans
(~500,000 yrs ago)



JANUARY

FEBRUARY

MARCH

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12 1
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Dec 31st
~11:59:00pm

AP

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Oldest known cave paintings
(~35,000 yrs ago)

13 14 15 16 17 18 19
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27 28 29 30

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18 19 20 21 22 23 24
25 26 27 28 29 30 31

15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30

SEPTEMBER

S M T W T F S
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DECEMBER

S M T W T F S
1 2 3 4 5 6
7 8 9 10 11 12 13
14 15 16 17 18 19 20
21 22 23 24 25 26 27
28 29 30 31



JANUARY

FEBRUARY

MARCH

Dec 31st
~11:59:32pm

Agriculture and Farming
(~12,000 yrs ago)

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26 2

APRIL

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JUNE

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SEPTEMBER

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21 22 23 24 25 26 27
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OCTOBER

S M T W T F S
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NOVEMBER

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DECEMBER

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28 29 30 31

JANUARY

FEBRUARY

MARCH

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SEPTEMBER

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DECEMBER

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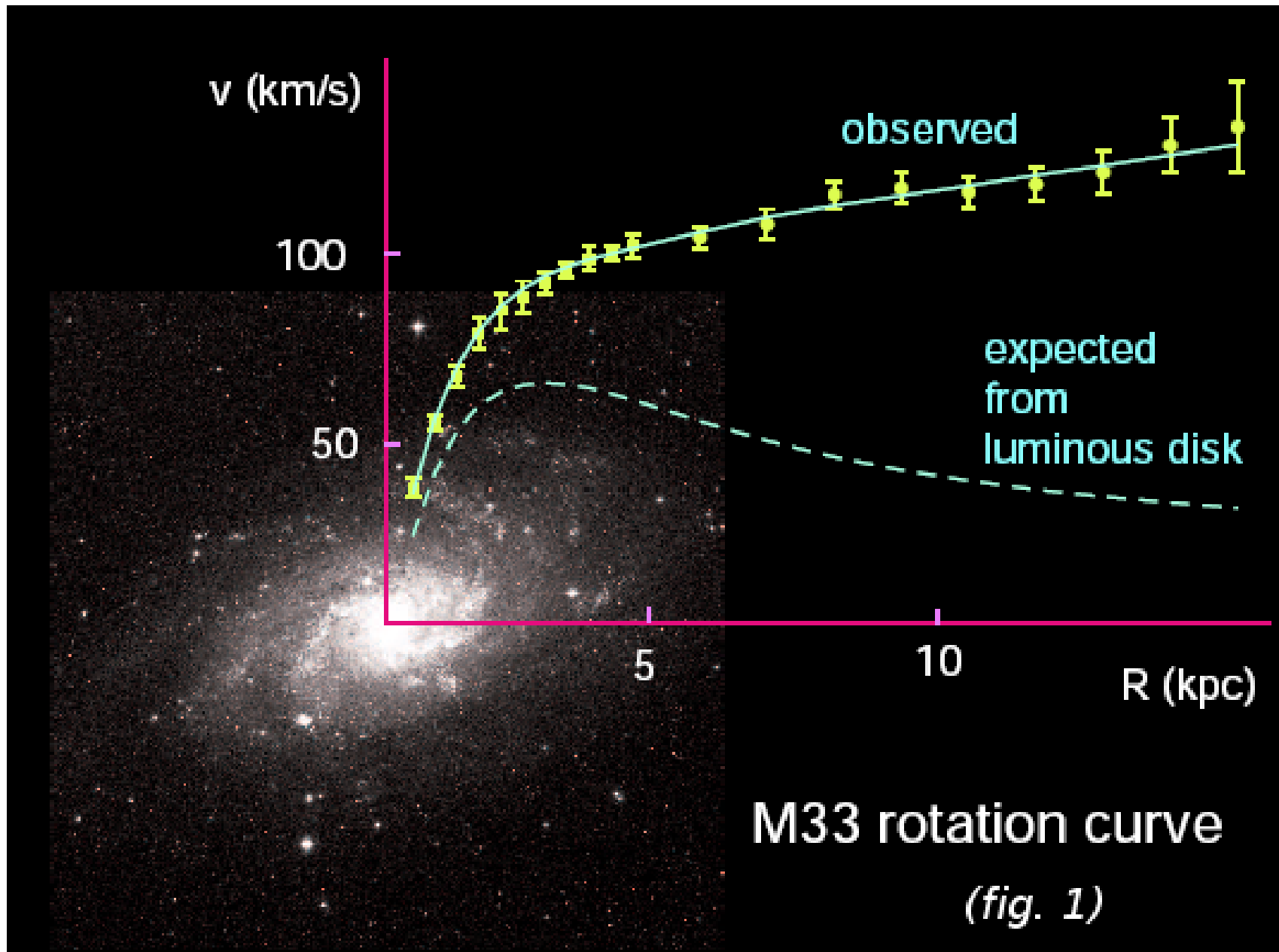
28 29 30 31

Dec 31st
~11:59:59pm

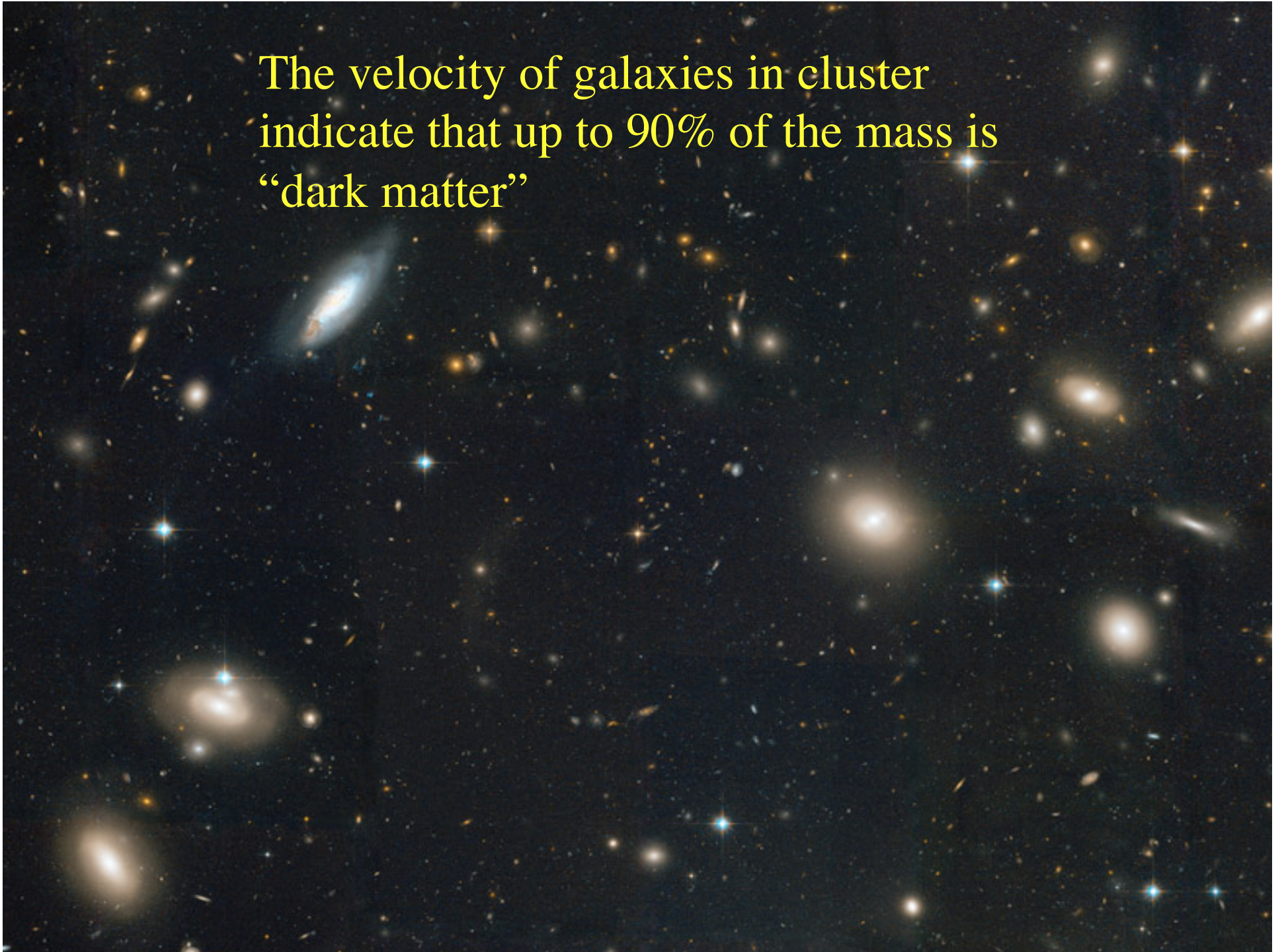
Galileo 1st telescope observations
(~500 yrs ago)



Galaxy Rotation Curves – Evidence for Dark Matter

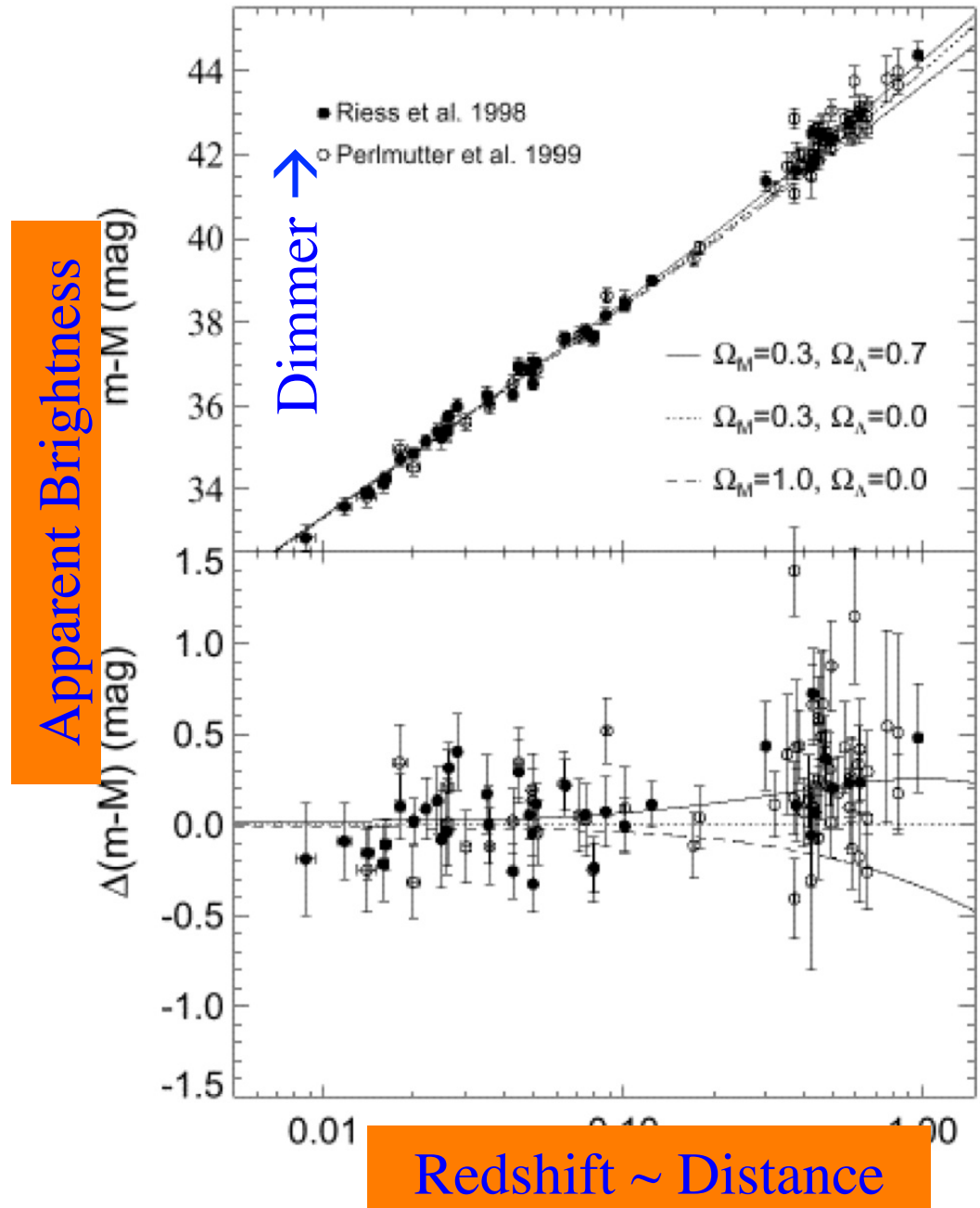


The velocity of galaxies in cluster
indicate that up to 90% of the mass is
“dark matter”



Expansion is Accelerating!

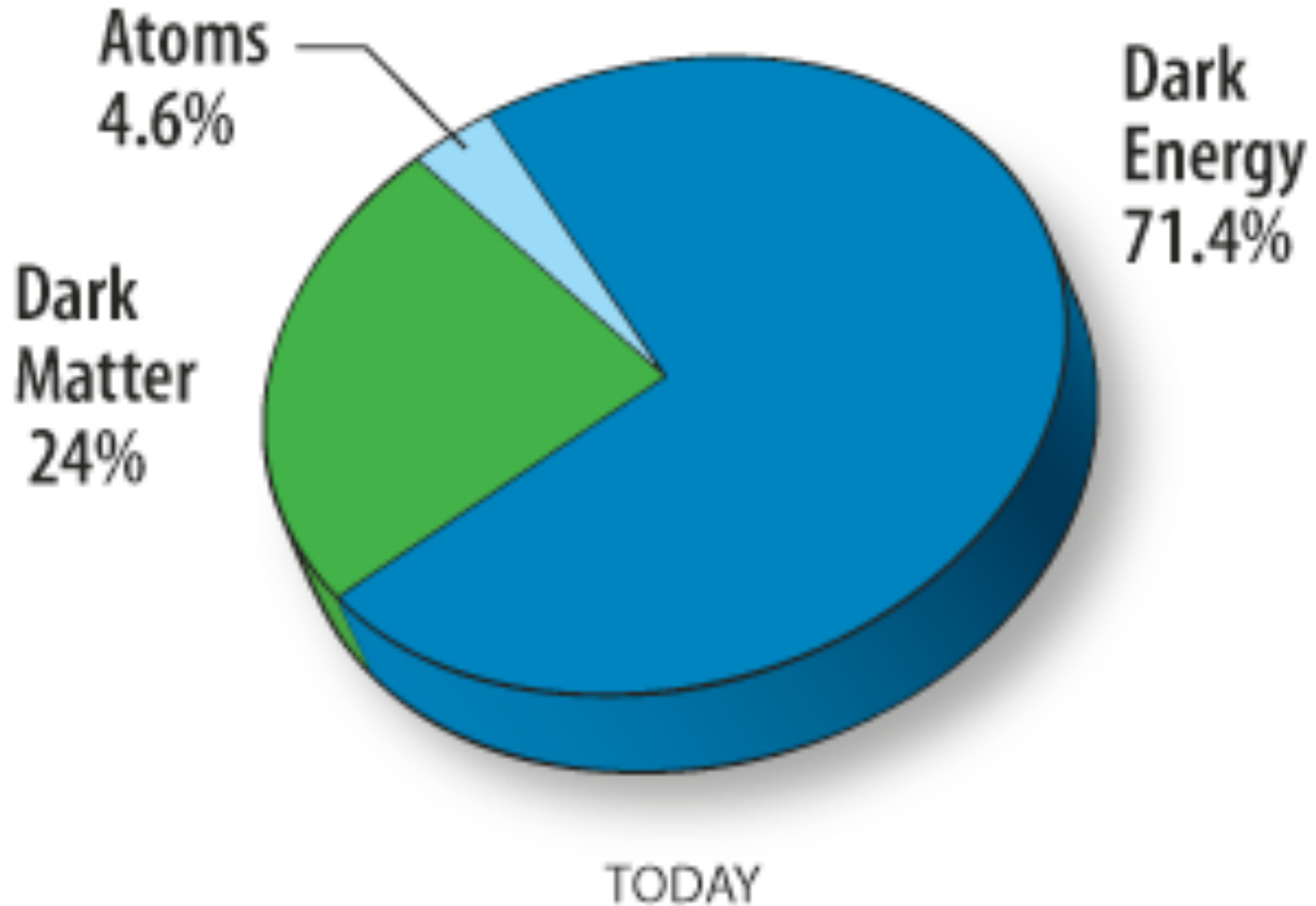
- The plots on the right were the data from supernovae that showed that the expansion of the universe is not constant but has changed value over time.
- More distant supernovae are dimmer than expected
- Something (“Dark Energy”) is causing the expansion to accelerate. We don’t know what Dark Energy is – only that it appears to counteract gravity



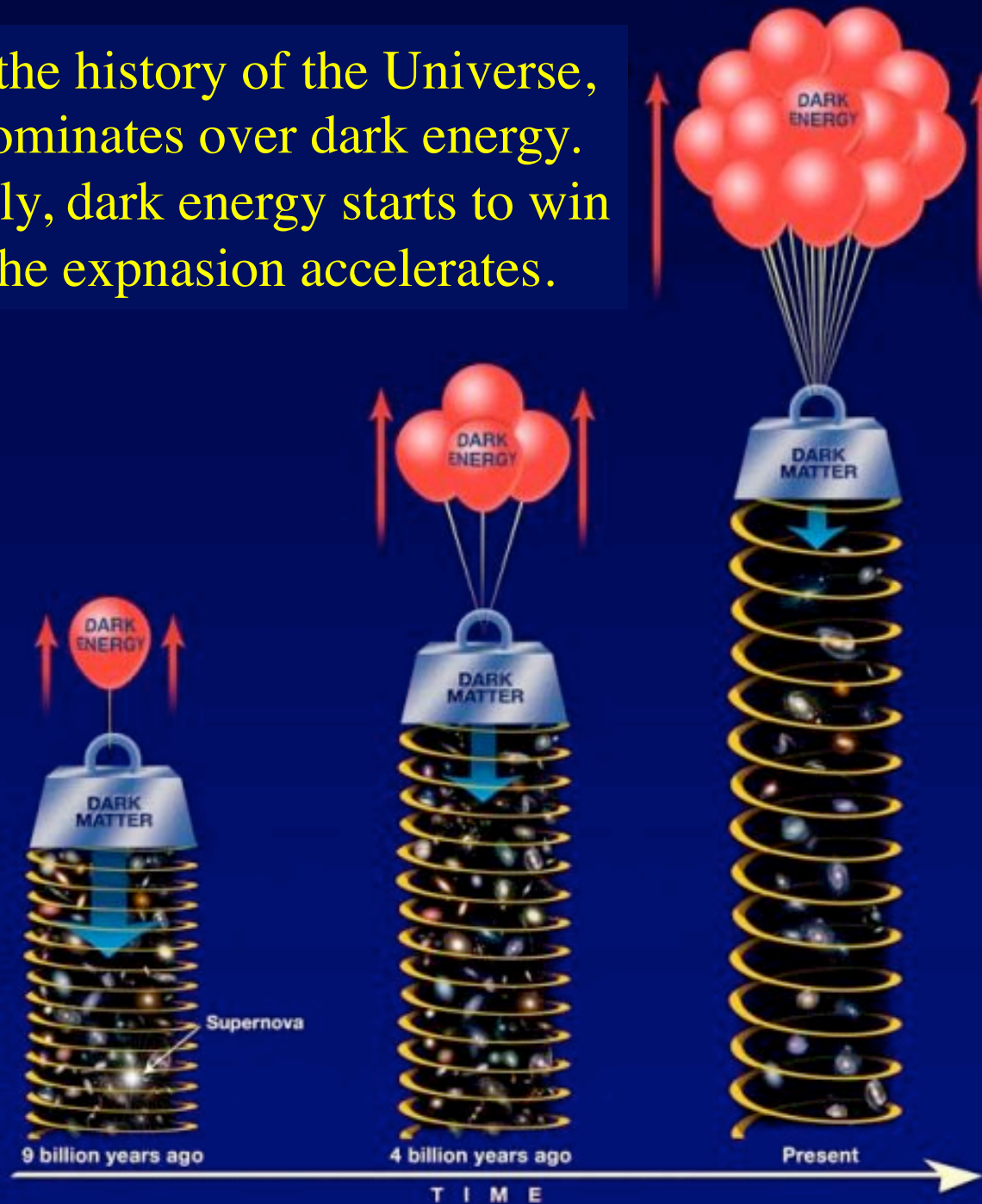
Brian Schmidt (Arizona Alumnus '89)
wins Nobel Prize for discovery of
acceleration of Universe



What is the Universe made of ?



Early in the history of the Universe, matter dominates over dark energy. Eventually, dark energy starts to win out and the expansion accelerates.



The Raw Material for Astrobiology

- **Space:** the potential habitable worlds around ten thousand billion billion stars; ours is just one.
- **Time:** a cosmic history of nearly 14 billion years; life took less than 1 billion years to start here.

“If they not be inhabited, what a waste of space.”

Thomas Carlyle, Scottish Essayist (1795-1881)