History of the Universe

Where is the Sun located?

In the centre of the Milky way disc.

1 hand up

On the remote outskirt of the Milky way.

2 hands up

Half way out from the centre.

pray sign

We lie well above the Milky way disc.

stop sign

How dark is it in the interstellar space?

You can read the eyes of your companion.

1 hand up

You can barely make out the profile of his/her head.

2 hands up

You can read a newspaper.

pray sign

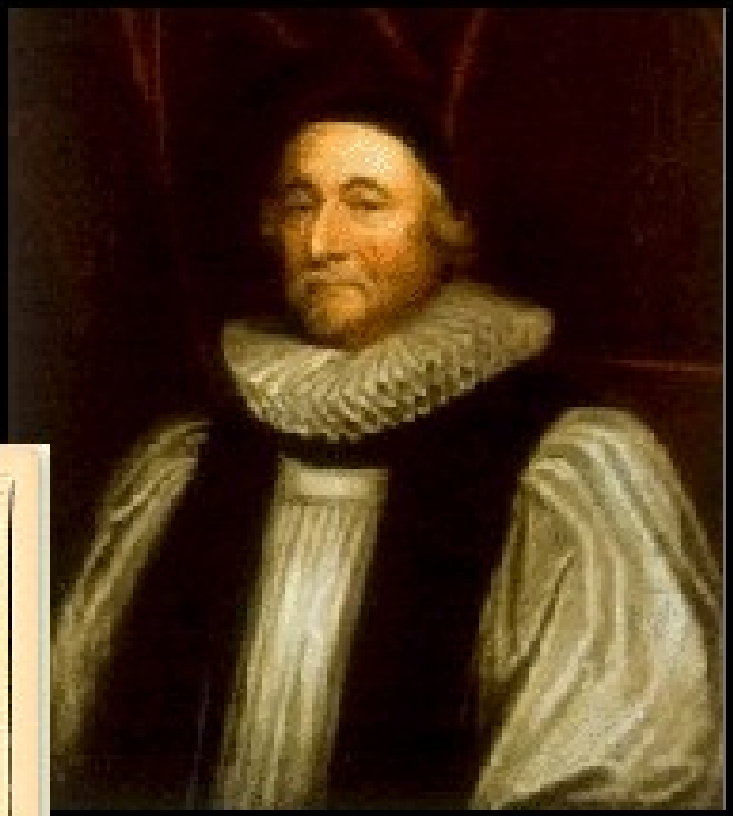
You cannot see each other at all.

stop sign

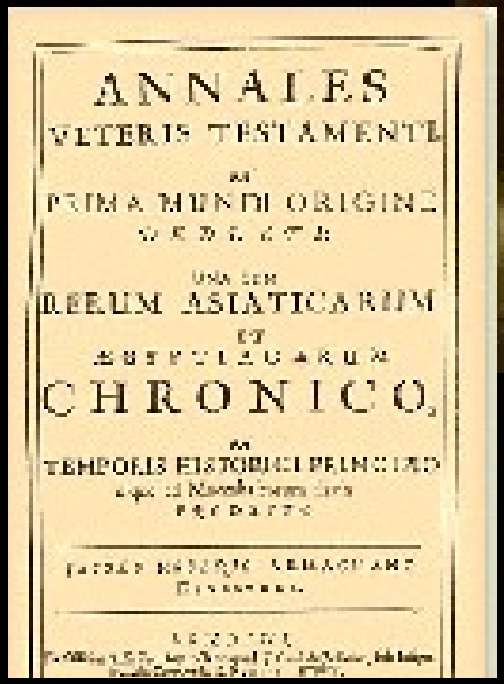
How old is the Earth?

1658: Bishop Ussher uses Biblical references to surmise that Earth/Universe was created on Sunday October 23, 4004 B.C.

1700-1900: growing conflict between literal interpretation of the Bible and evidence from geology and biology (evolution) for much longer timescales (*millions* of years)



James Ussher (1581-1656), Archbishop of Armagh, Primate of All Ireland, and Vice Chancellor of Trinity College, Dublin


ANNALES
VETERIS TESTAMENTI
A
PRIMA MUNDI ORIGINE
DEDUCTA
SIVE
REBUM ASIATICARUM
ET
ALIARUM
CHRONICON
A
TEMPORIS HISTORICI PRINCIPIO

Ussher's book (1658)

How old is the Earth?

1778: Comte de Buffon estimates the Earth needs 75,000 years to get cool enough.

1862/97: Lord Kelvin finds that 20 to 400 million years are needed for Earth to cool; similarly for the Sun.

1869: Huxley argues that geology/biology require Earth to be older.

1896: Becquerel discovers radioactivity
1903: Darwin/Joly argue this keeps Earth hot.
1907: Following a suggestion by Rutherford, Boltwood presents first radioactive dating.

Now: Earth is 4.55±0.02 billion years old.

How old is the Universe?

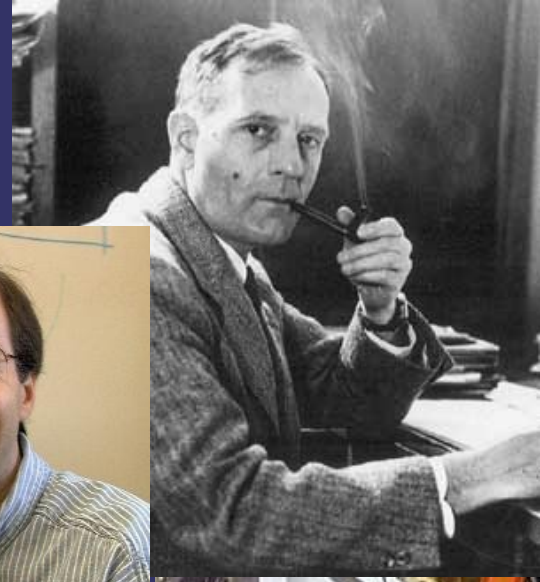
1929: Hubble discovers that the further away a galaxy is, the faster it receded from us. This implies the Universe is expanding.

1997/8: teams led by Perlmutter and Schmidt find that the expansion is accelerating.

2000: a team led by De Bernardis & Lange finds the Universe is not curved using Balloon measurements of the microwave background.

2001: a team led by Friedman makes the most precise measurement yet of the local expansion rate of the Universe.

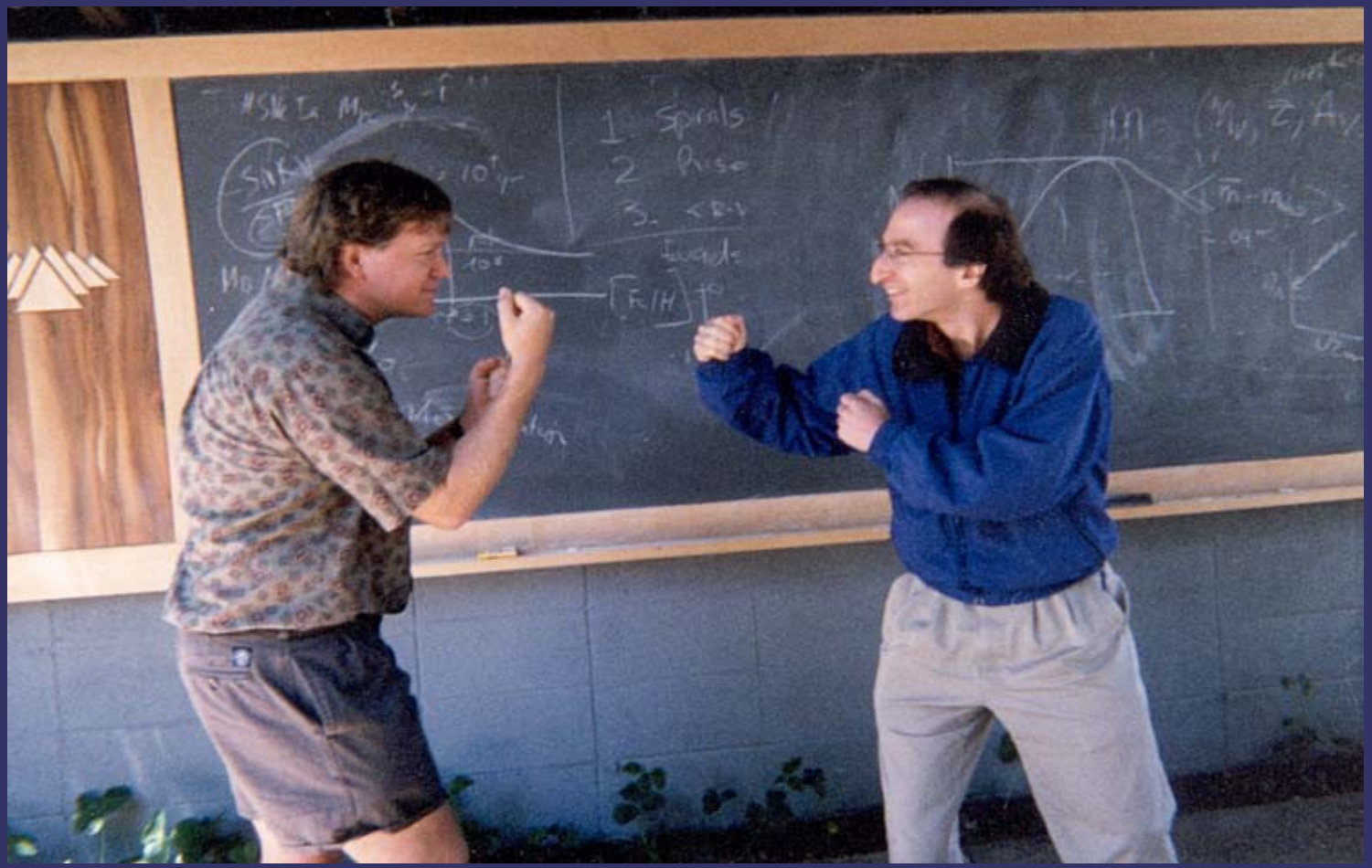
2003: a team led by Bennett uses the satellite WMAP to measure the microwave background, and finds the Universe is 13.7±0.2 billion years old.






The last two decades...

The universe is 13.7 billion years old
(accurate to a few percents)



Cosmic Calendar

If the entire age of the universe is just one year

-- one month will be just over a billion real years

- one day would be about 37 million real years

... everything for which 'we' are relevant occurs in the last minute...

THE HISTORY OF THE UNIVERSE IN 1 YEAR

January 1: The Big Bang

February: The Milky Way forms

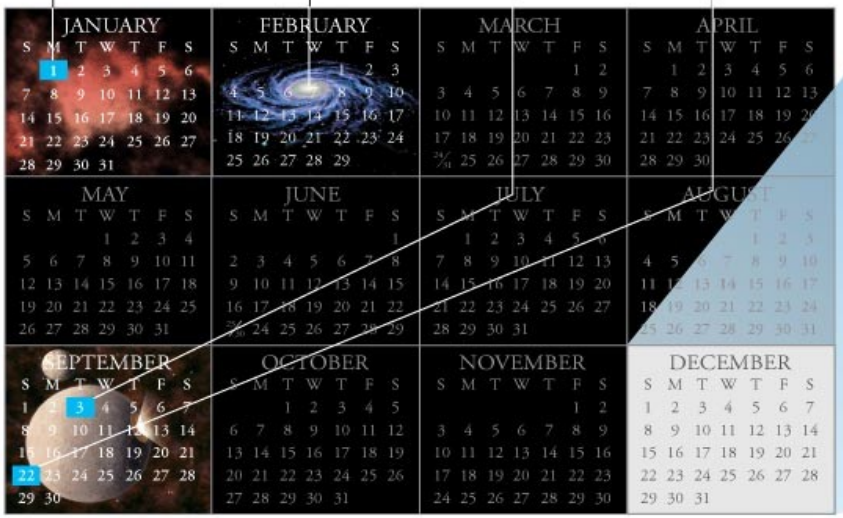
September 3: The Earth forms

September 22: Early life on earth

December 17: Cambrian explosion

December 26: Rise of the dinosaurs

December 30: Extinction of the dinosaurs



December 31:

9:00 pm: Early hominids evolve

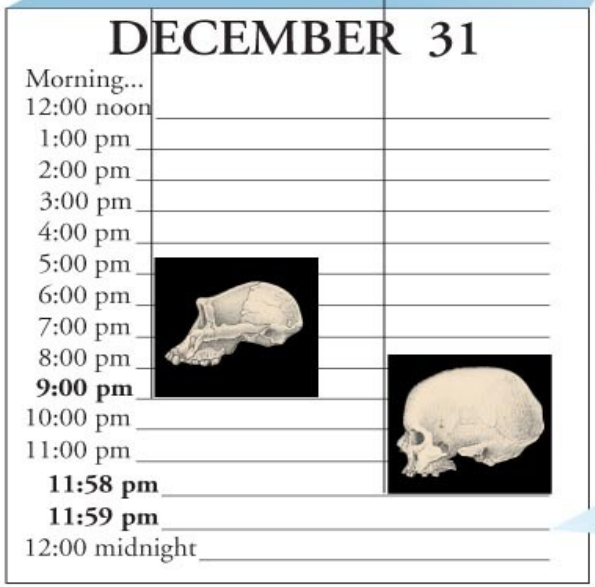
11:58 pm: Modern humans evolve

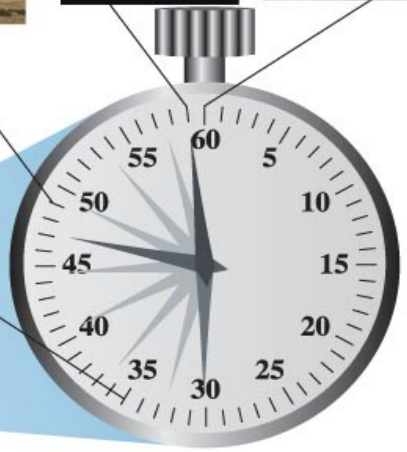
25 seconds ago: Agriculture arises

11 seconds ago: Pyramids built

1 second ago: Kepler and Galileo show that Earth orbits the Sun

Now

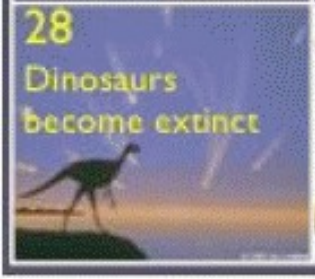
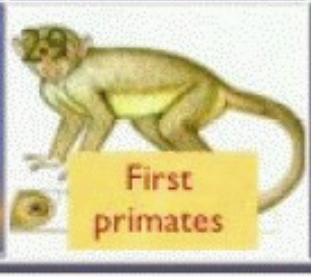




Cosmic Calendar (Carl Sagan)

January	February	March	April
1 *Big Bang*			
May	**June**	**July**	**August**
1 *Milky Way born*			
September	**October**	**November**	**December**
9 *Solar system born* 14 *Earth forms* 25 *First life on Earth?*	2 *Oldest rocks known* 9 *Oldest fossils (bacteria/blue-green algae)*	1 *Sex invented* 12 *Oldest fossil plant* 15 *Eukaryotes flourish*	*(zoomed in next slide)*

December (Note: dates depend on source!)

Sun	Mon	Tue	Wed	Thur	Fri	Sat
	1 Oxygen in atmosphere	2	3	4	5  Mars active	6
7	8	9	10	11	12	13
14	15	16  First worms	17  Cambrian explosion	18	19	20
21	22	23	24  Dinosaurs appear	25	26  First mammals	27
28  Dinosaurs become extinct	29  First primates		31 (Next slide)			

December 31

~13:30 Origin of Proconsul and Ramapithecus, probable ancestors of apes and men

~22:30 First humans

23:00 Widespread use of stone tools

23:46 Domestication of fire by Peking man

23:56 Beginning of most recent glacial period

23:58 Seafarers settle Australia

23:59 Extensive cave painting in Europe

23:59:20 Invention of agriculture (~10,000 years ago)

23:59:35 Neolithic civilization; first cities

23:59:50 First dynasties in Sumer, Ebla and Egypt; development of astronomy

23:59:51 Invention of the alphabet; Akkadian Empire

23:59:52 Hammurabic legal codes in Babylon; Middle Kingdom in Egypt

23:59:53 Bronze metallurgy; Mycenaean culture; Trojan War; Olmec culture; invention of the compass

23:59:54 Iron metallurgy; First Assyrian Empire; Kingdom of Israel; founding of Carthage by Phoenicia

23:59:55 Asokan India; Ch'in Dynasty China; Periclean Athens; birth of Buddha

23:59:56 Euclidean geometry; Archimedean physics; Ptolemaic astronomy; Roman Empire; birth of Christ

23:59:57 Zero and decimals invented in Indian arithmetic; Rome falls; Muslim conquests

23:59:58 Mayan civilization; Sung Dynasty China; Byzantine empire; Mongol invasion; Crusades

23:59:59 Renaissance in Europe; voyages of discovery from Europe and from Ming Dynasty China; emergence of the experimental method in science (~1400AD)

All recorded history can fit in 10 seconds.

December 31

Now: Widespread development of science and technology; emergence of global culture; acquisition of the means of self-destruction of the human species;

first steps in spacecraft planetary exploration and the search of extraterrestrial intelligence

Now: The first second of New Year's Day

The universe as we see it today...

The light-year

Distance light travels in 1 year

Speed of light: 300,000 km/s

Hence, 1 light-year is about 10 trillion km

(10,000,000,000,000 km)

Nearest star: 4.4 light-years

Nearest major Galaxy: 2.5 million light-years

Universe: 14 billion light-years

It takes time to get there…


The Large & Small Magellanic Clouds
our neighbouring 'island universe'
(160,000 & 200,000 lys)
© Anglo-Australian Observatory

Suppose an Andromedan observes the Milky way right now, could it see us?

2.5 million light-years

Yes, given a super-telescope

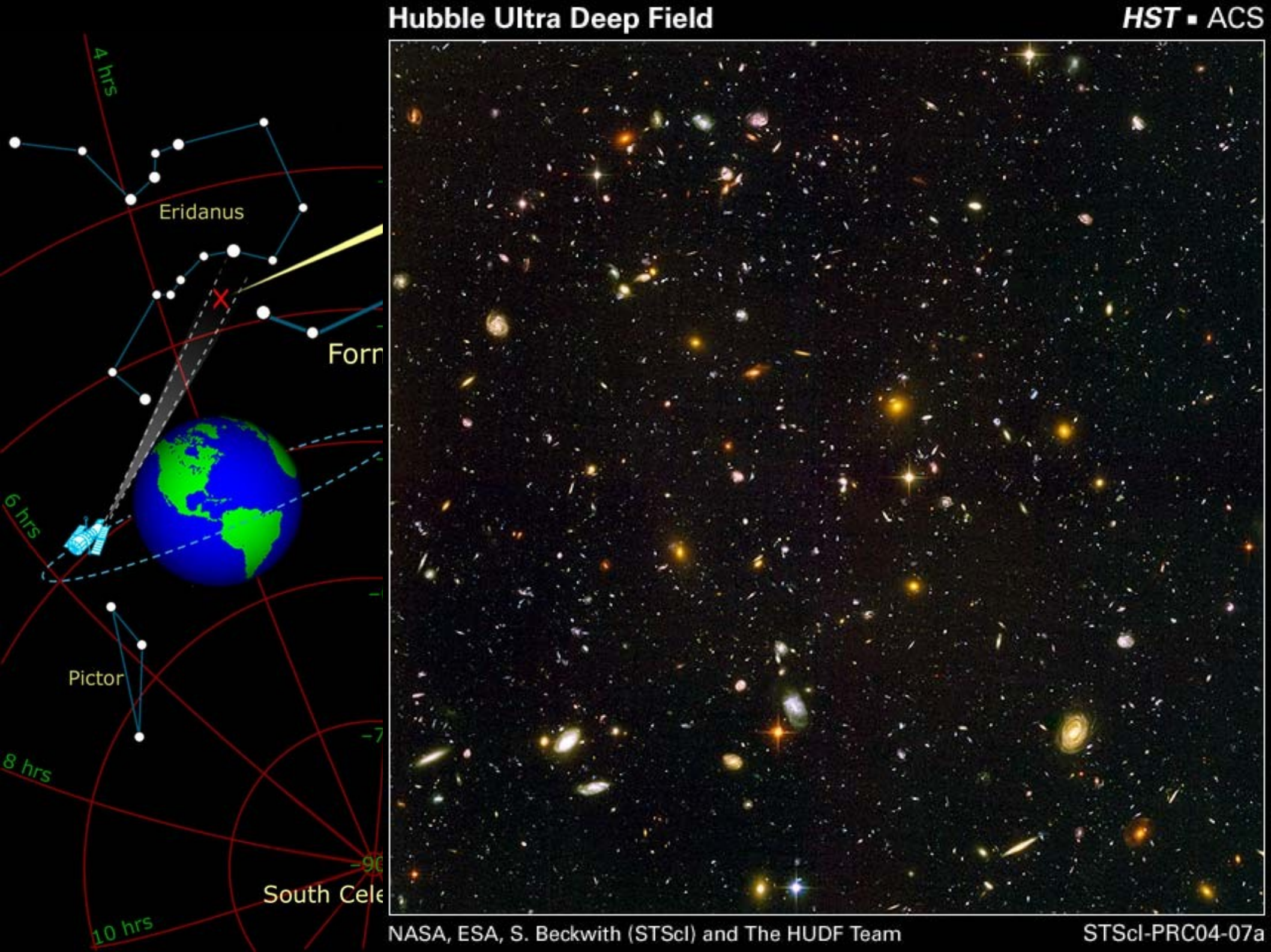
No. Only the most primitive of hominids existed

No. It could see Earth, but no plant life had yet formed

No. The Sun & Earth did not yet exist

The Andromeda Galaxy

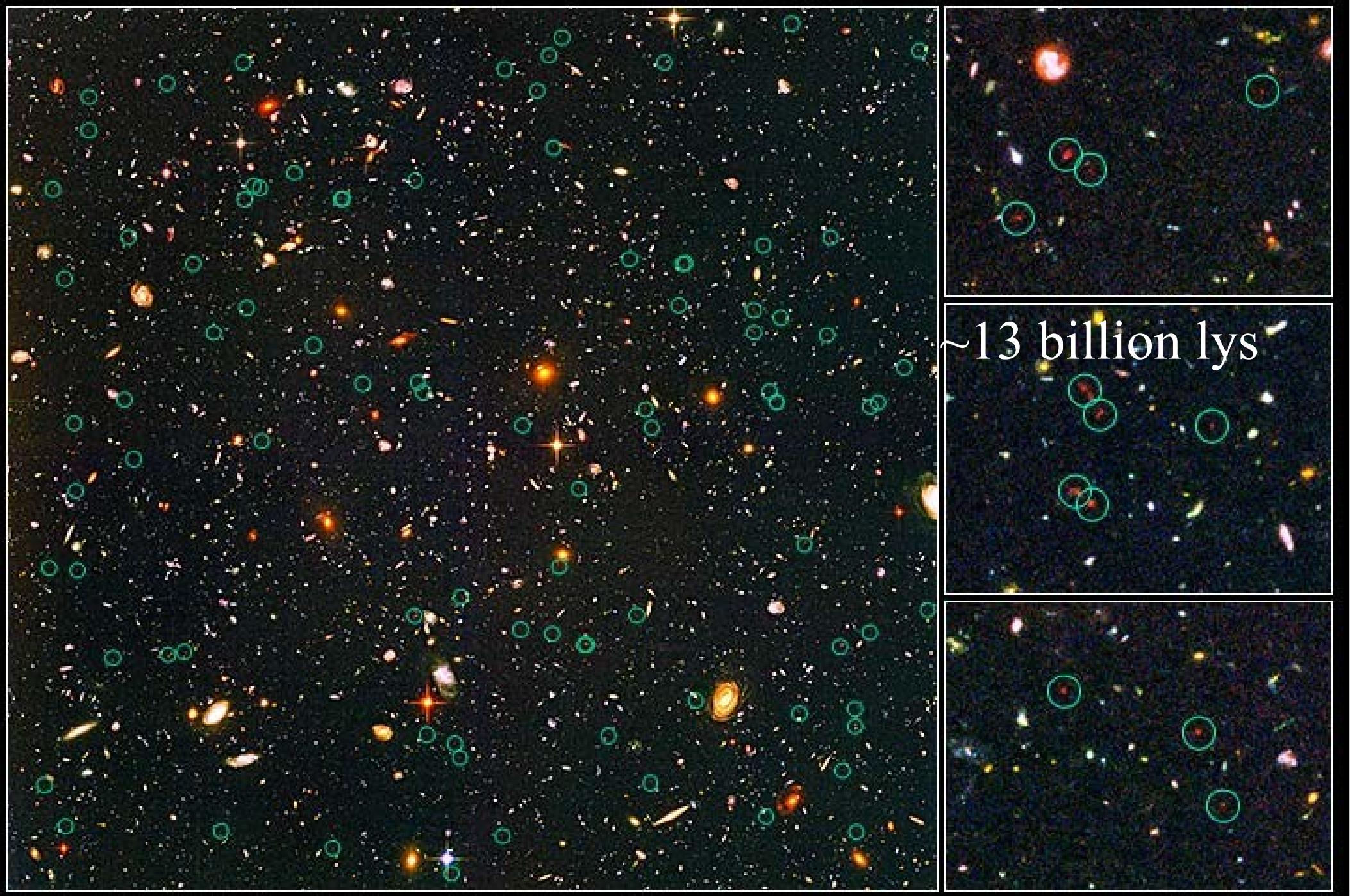

Core of the Virgo cluster
Virgo cluster of galaxies
~60 million ly

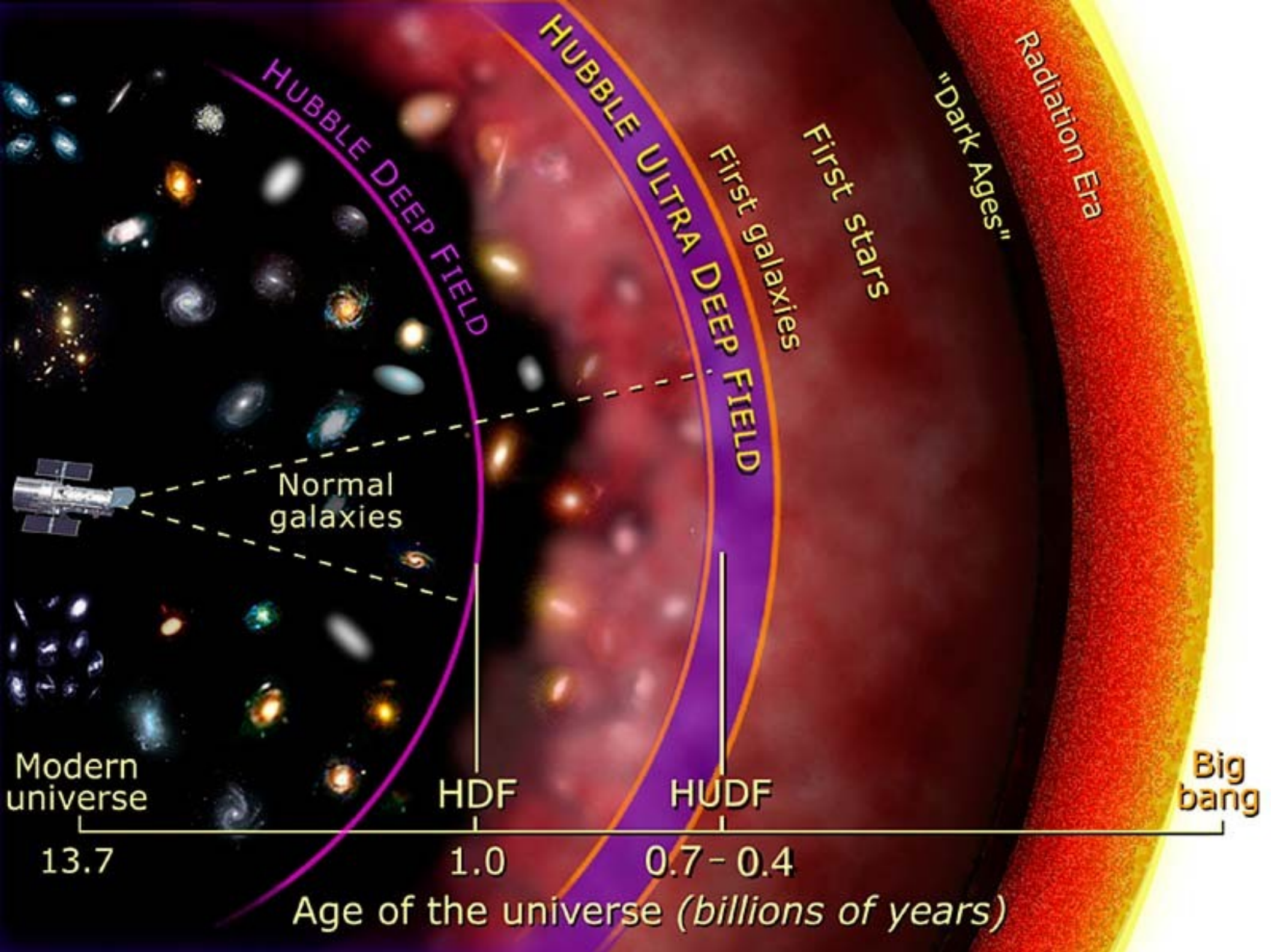

Hubble Ultra Deep Field
HST ▪ ACS
4 hrs
Eridanus
Forn
6 hrs
Pictor
8 hrs
South Cele
10 hrs
NASA, ESA, S. Beckwith (STScI) and The HUDF Team
STScI-PRC04-07a


Hubble Ultradeep Field


Hubble Ultradeep Field


Hubble Ultradeep Field


Distant Objects in the Hubble Ultra Deep Field
HST • ACS
~13 billion lys
NASA, ESA, R. Windhorst (Arizona State University)
and H. Yan (Spitzer Science Center, Caltech)
STScI-PRC04-28


HUBBLE DEEP FIELD
HUBBLE ULTRA DEEP FIELD
First galaxies
First stars
"Dark Ages"
Radiation Era
Normal galaxies
Modern universe
HDF
HUDF
Big bang
13.7
1.0
0.7 – 0.4
Age of the universe (billions of years)

Further away galaxies....

look younger because they were made later.

1 hand up

look redder because stars there are older.

2 hands up

can be formed at the same time as our galaxy.

pray sign

look younger because we can't see them very well.

stop sign

Another fundamental discovery:

Not only do further away galaxies look younger

they are also receding from us FASTER

Expansion of the universe...

Why are galaxies appearing to be moving away from us?

possibility #1:

Milky way is at the center of the universe,
except for us, everyone else is going somewhere.

possibility #2:

The space itself is expanding. So it appears they
are leaving us. It looks the same to an Andromedean.

How to figure out?

does 1 make sense?
does 2 make sense?

Is the Milky Way Galaxy at the center of THE universe?

1) Yes. We are at a special place because every other galaxy is receding away from us.

2) Yes. We are more evolved than other galaxies, some of which are just forming.

3) Yes. We are surrounded by the cosmic microwave background.

4) No. We are not a big galaxy so we can not be at the center.

5) none of the above argument is correct.

No. Nobody is special.
There is no 'center of THE universe'.

Residents in every galaxy has the same view...
The other galaxies 'look' younger to us because
their earlier images have just reached us now.

Looking out to space = Looking back in time

The universe was smaller yesterday
than it is today.

At some point in the past, the universe
is just a point.


Big Bang Theory
Surely you are joking.
God

The Ancient Root of Astronomy

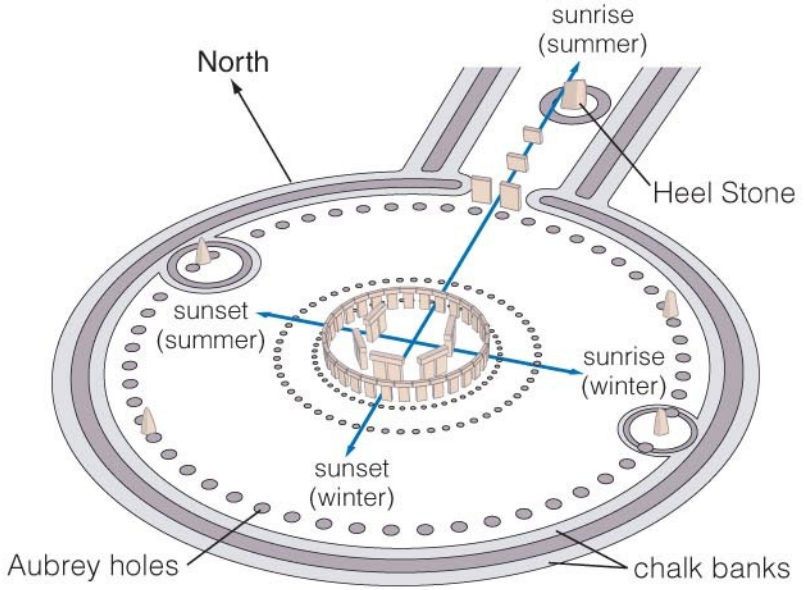
Before the invention of clocks, a prime purpose of astronomy is to tell time.

Why is it useful to tell time?

How to tell time of the day:

How to tell time of the year:

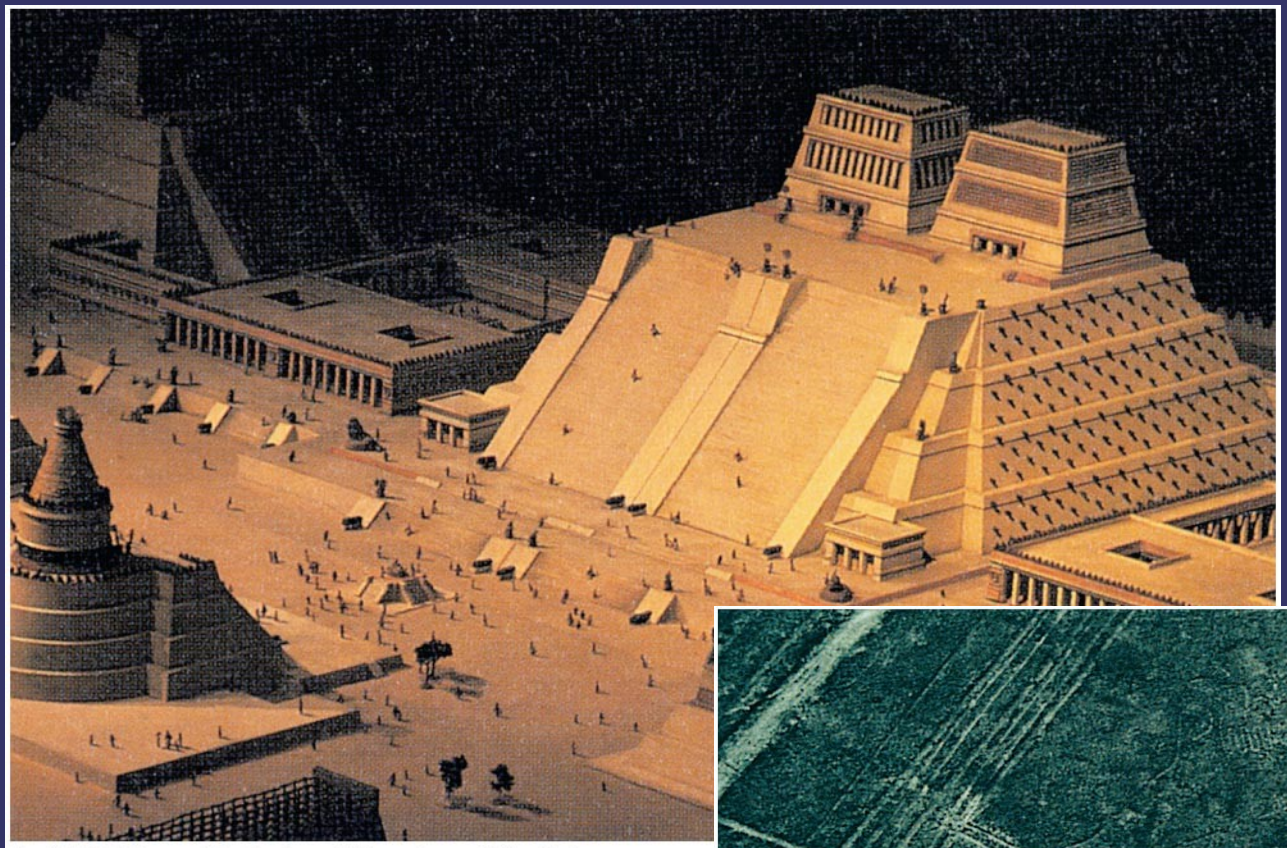
a The remains of Stonehenge today.



b This sketch shows how archaeologists believe Stonehenge looked upon its completion in about 1550 B.C. Several astronomical alignments are shown as they appear from the center. For example, the Sun rises directly over the Heel Stone on the summer solstice.

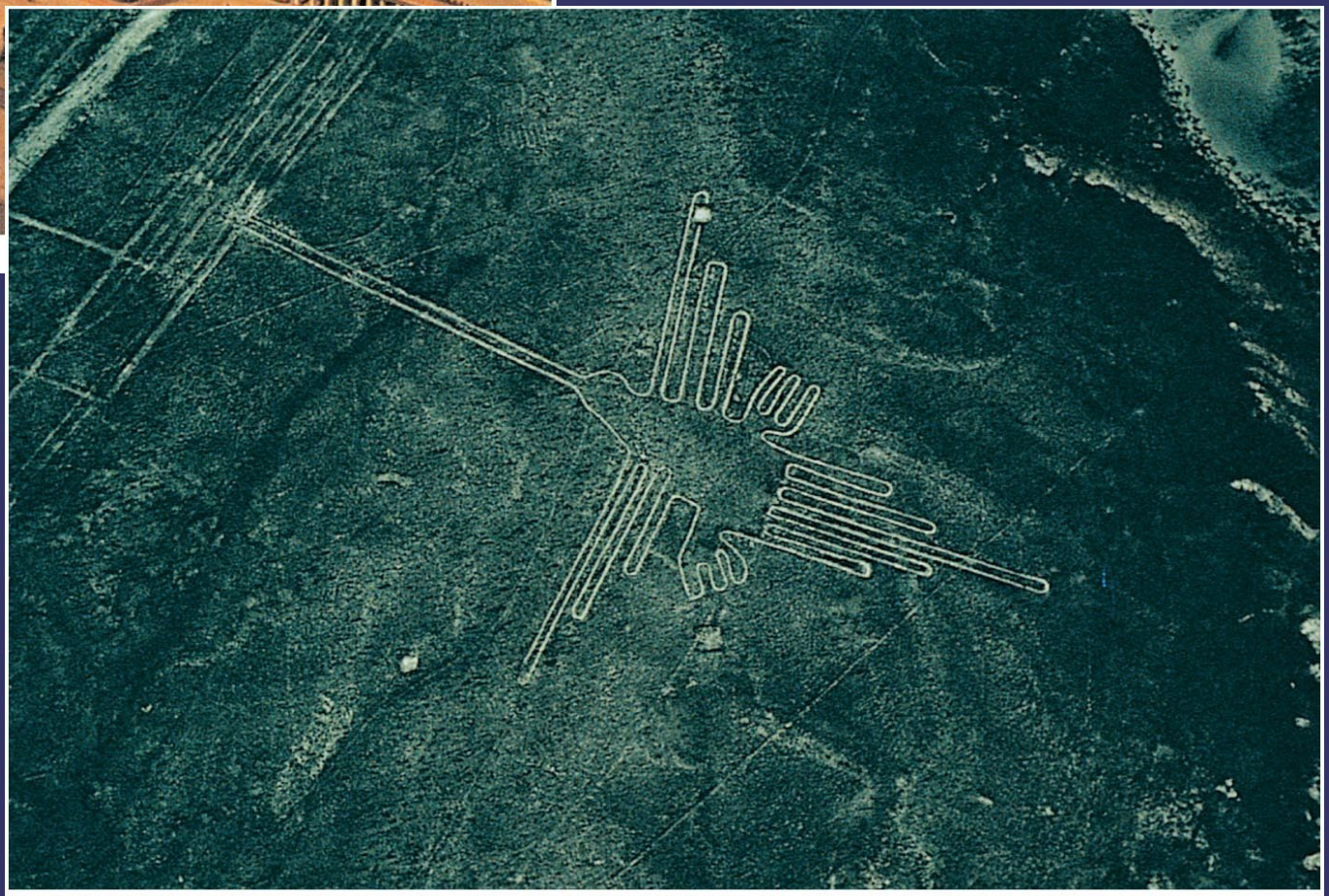
a A single dagger of sunlight pierces the center of the carved spiral only at noon on the summer solstice.

b Fajada butte in Chaco Canyon, New Mexico, where the Sun Dagger is located on a vertical cliff near the top.



Templo Mayor, Aztec

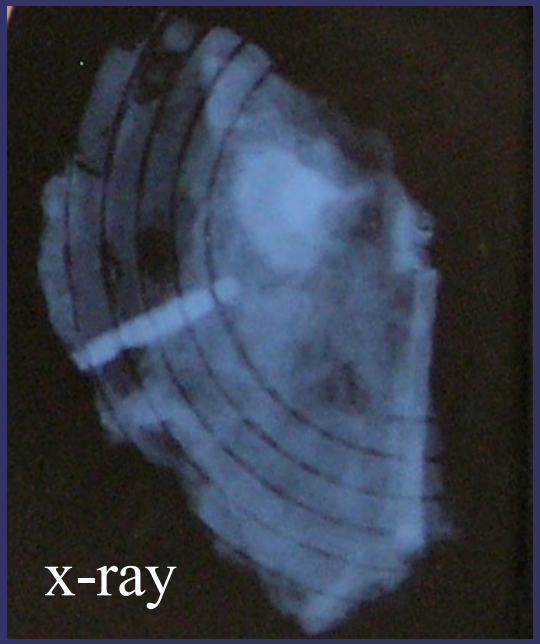
Nazca Desert, Peru



The Antikythera Mechanism (~150 BC)
~80 rusted metal pieces discovered in Roman shipwreck (1901)

The Antikythera Mechanism (cont'd)

2006: X-ray image confirmed its purpose as an analog computer for positions of Sun,Moon and planets



~37 gears, predict lunar and solar eclipses, planetary positions on the sky, even account for the slightly non-circular orbit of the Moon)

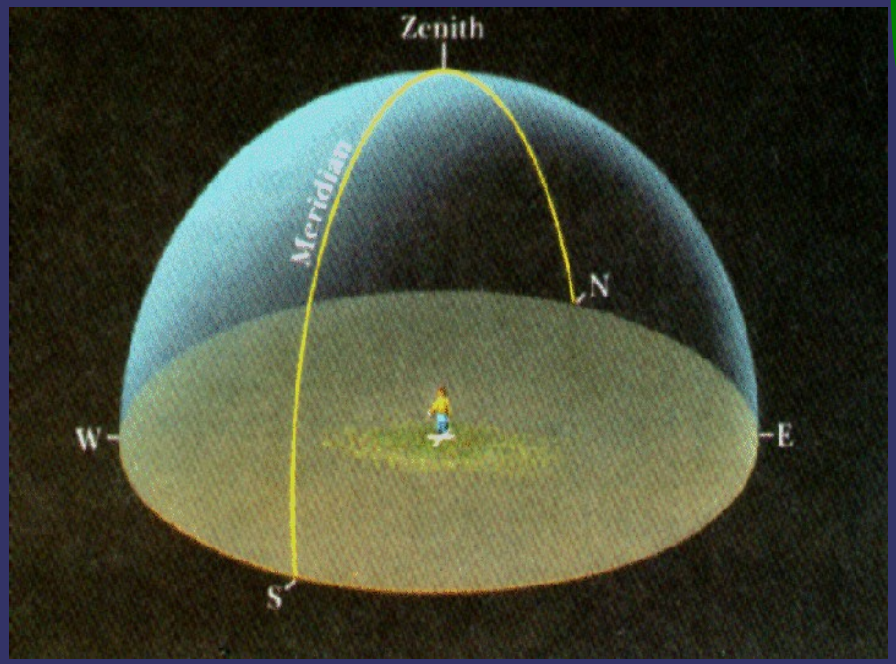
"Technically more complex than any other known device by at least a millenium afterwards"

--- Lost knowledge? Smarter ancients?

Vestiges of ancient astronomy in everyday life

1) days of the week

2) AM/PM, hour



3) alignment of city grids

Table 3.1 The Seven Days of the Week and the Astronomical Objects They Honor

The correspondence between objects and days is easy to see in French and Spanish. In English, the correspondence becomes clear when we look at the names of the objects used by the Teutonic tribes who lived in the region of modern-day Germany.

Object	*Teutonic Name*	*English*	*French*	*Spanish*
Sun	Sun	Sunday	dimanche	domingo
Moon	Moon	Monday	lundi	lunes
Mars	Tiw	Tuesday	mardi	martes
Mercury	Woden	Wednesday	mercredi	miércoles
Jupiter	Thor	Thursday	jeudi	jueves
Venus	Fria	Friday	vendredi	viernes
Saturn	Saturn	Saturday	samedi	sábado

4) Lunar calendar: using lunar phases as a clock

many religious/cultural holidays
follow the lunar phases
Passover, Easter, Ramadan, Chinese New Year...

Easter: Jesus Christ's resurrection
Apr. 7th, 2007
Mar. 23th, 2008
Apr. 12th 2009...

1 solar calendar year = 365 days
= 12.37 lunar months
(Moon goes from new to new, ~29.5 days)

We are stardust

We are made of atoms

Atoms are made in stars

Only the first (and simplest) atoms are created during the Big Bang

More complex atoms are all created in stars

When the star dies, atoms are expelled into space ..... to form new stars and planets and people