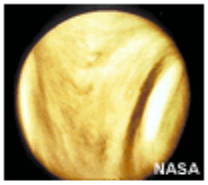
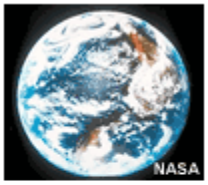
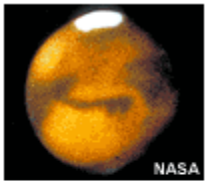
Johannes Kepler



Venus

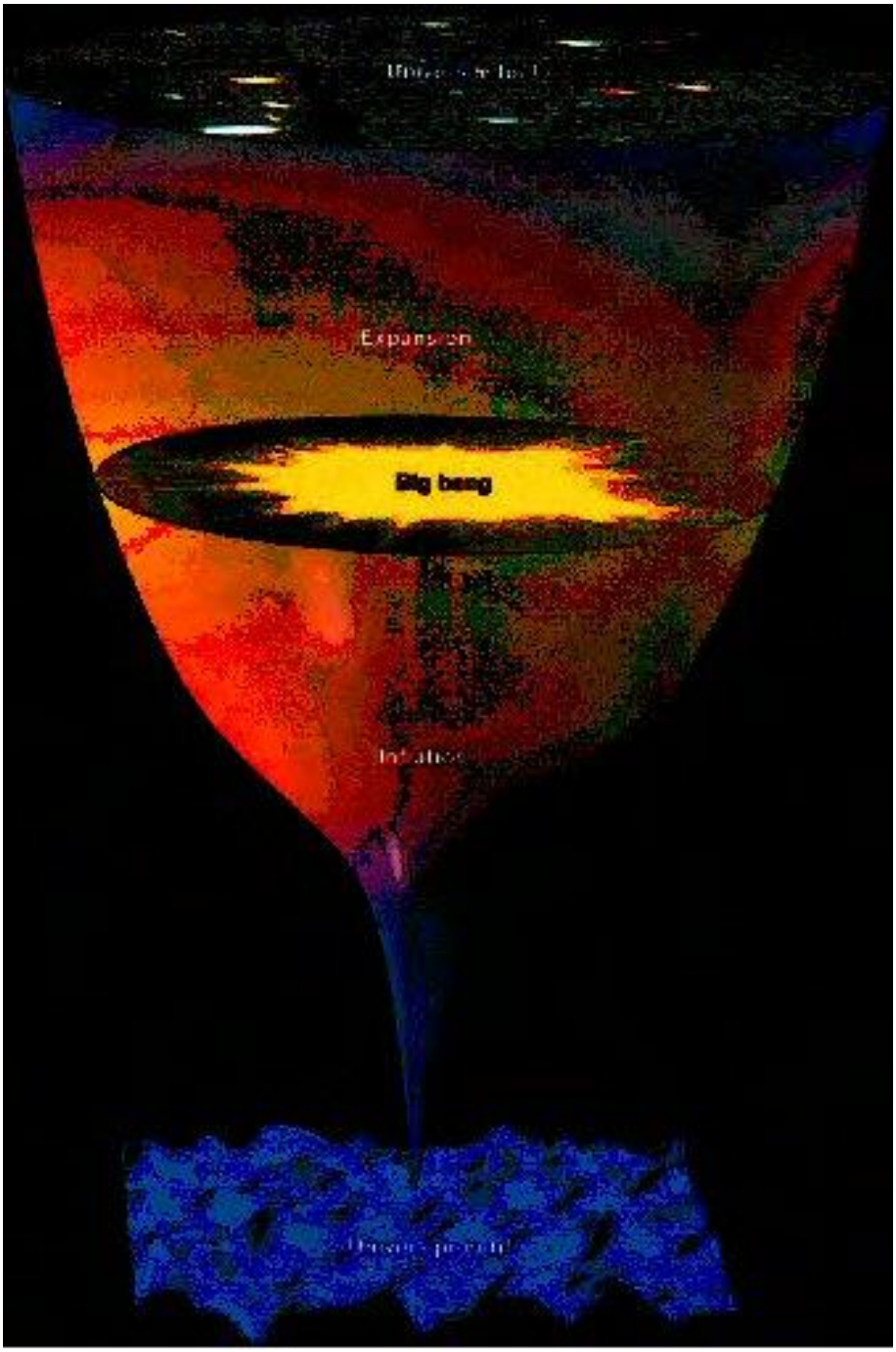


Earth

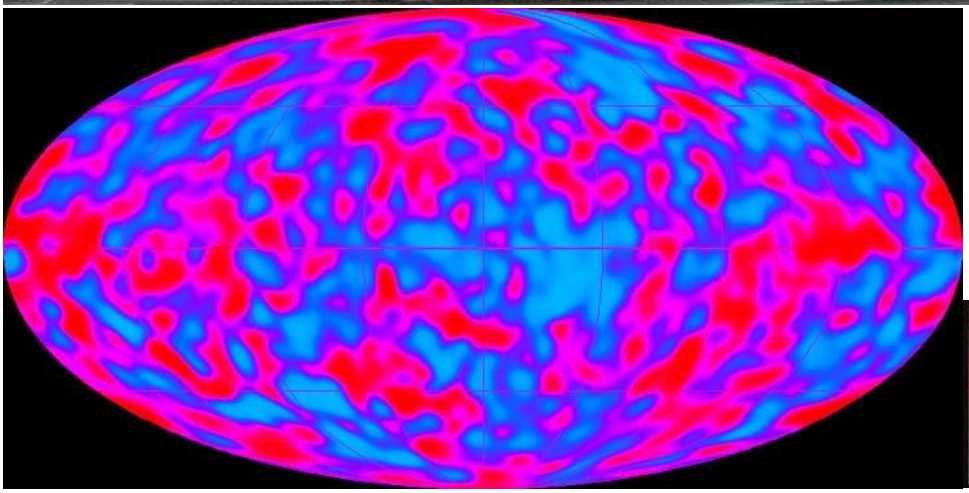


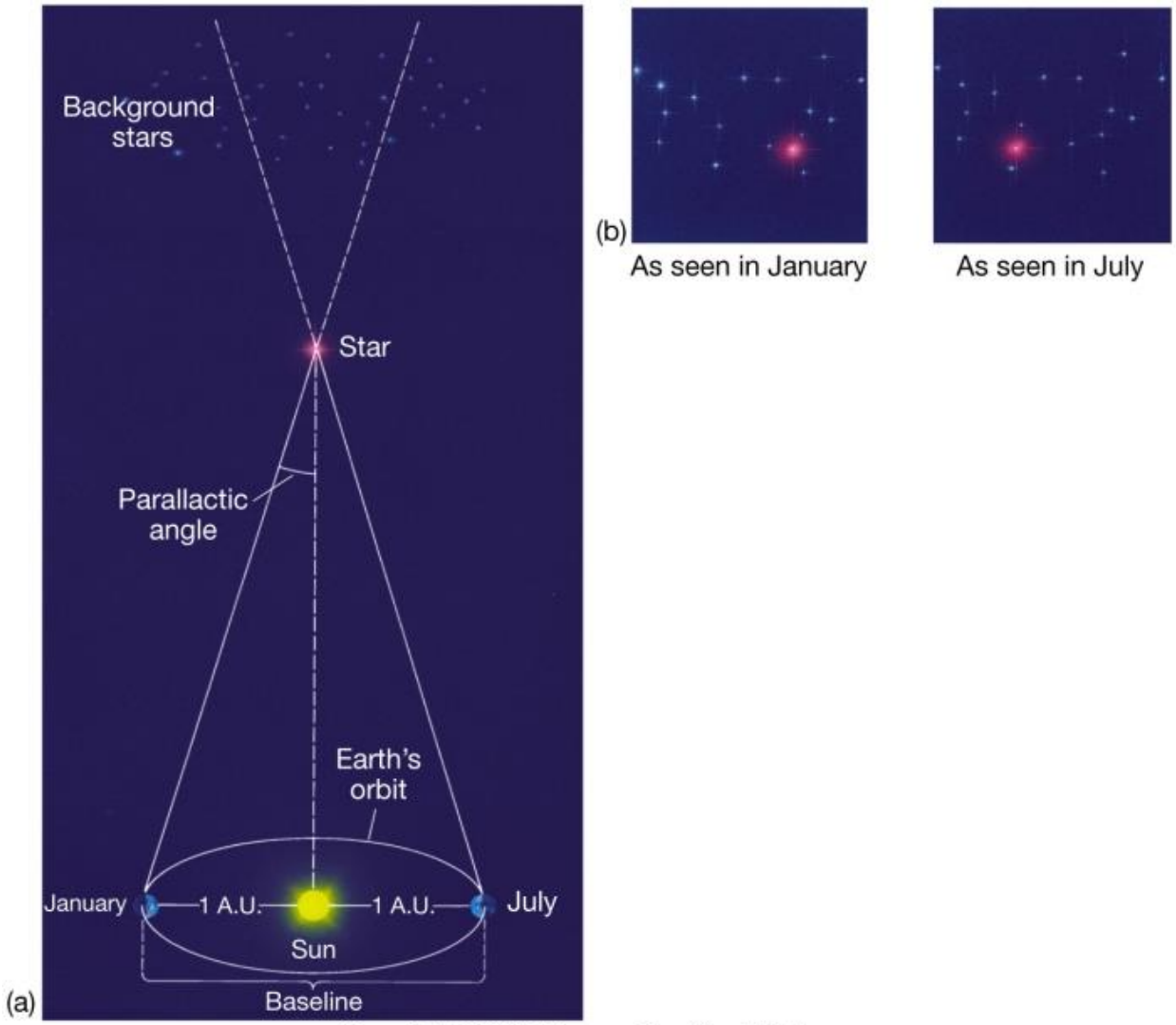
Mars

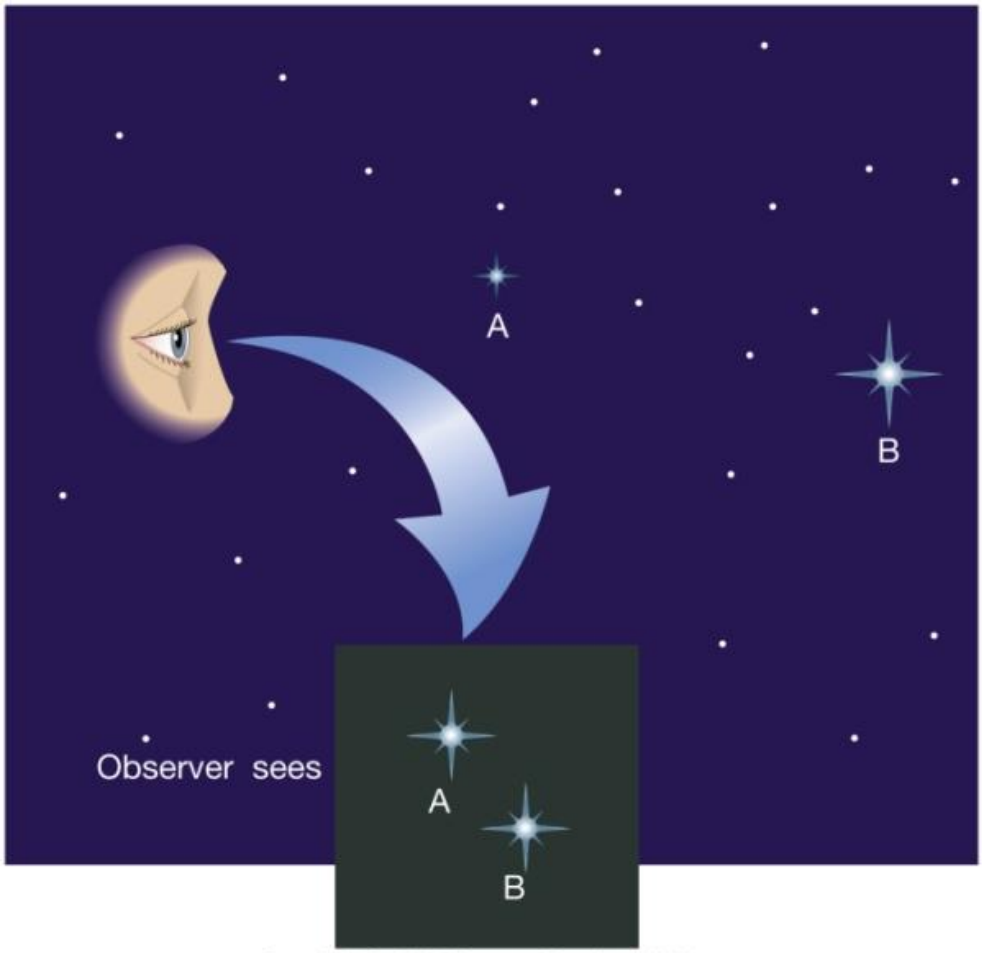
	Venus	Earth	Mars
Carbon Dioxide (CO_2)	96.5%	0.03%	95%
Nitrogen (N_2)	3.5%	78%	2.7%
Oxygen (O_2)	Trace	21%	0.13%
Argon (Ar)	0.007%	0.9%	1.6%
Methane (CH_4)	0	0.002%	0

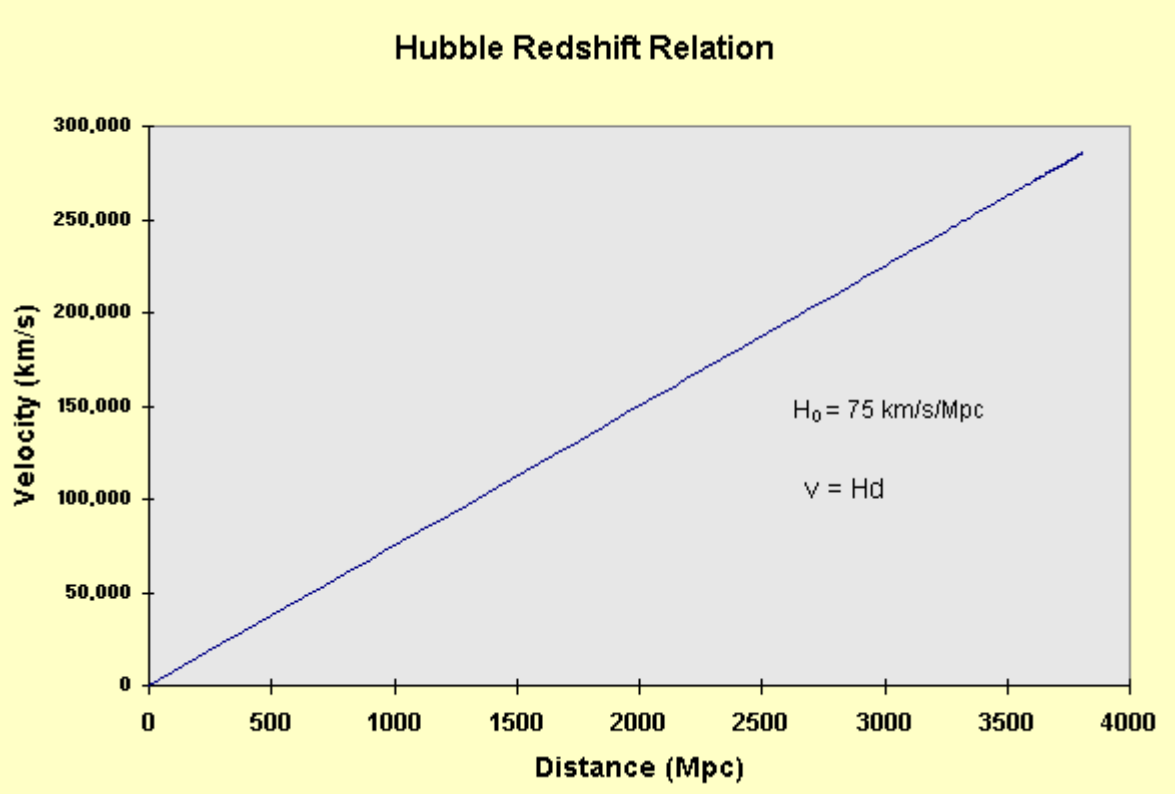

Expansion
Big bang

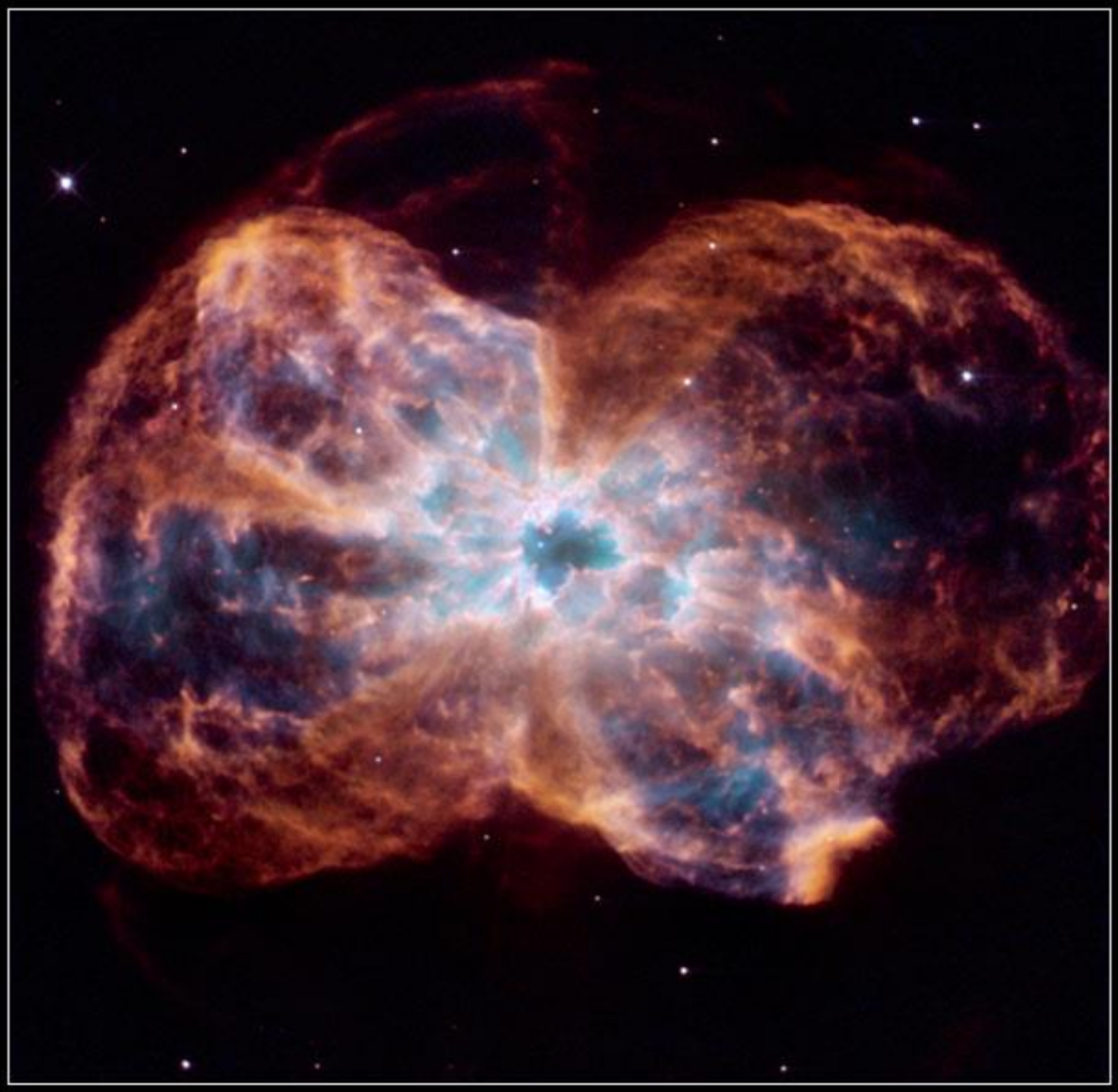

start calling pluto
an asteroid.....
and it starts acting
like one.
paid for by the friends of pluto
ahom.ru








Hubble Redshift Relation
300,000
250,000
200,000
150,000
100,000
50,000
0
Velocity (km/s)
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (Mpc)
H0 = 75 km/s/Mpc
V = Hd

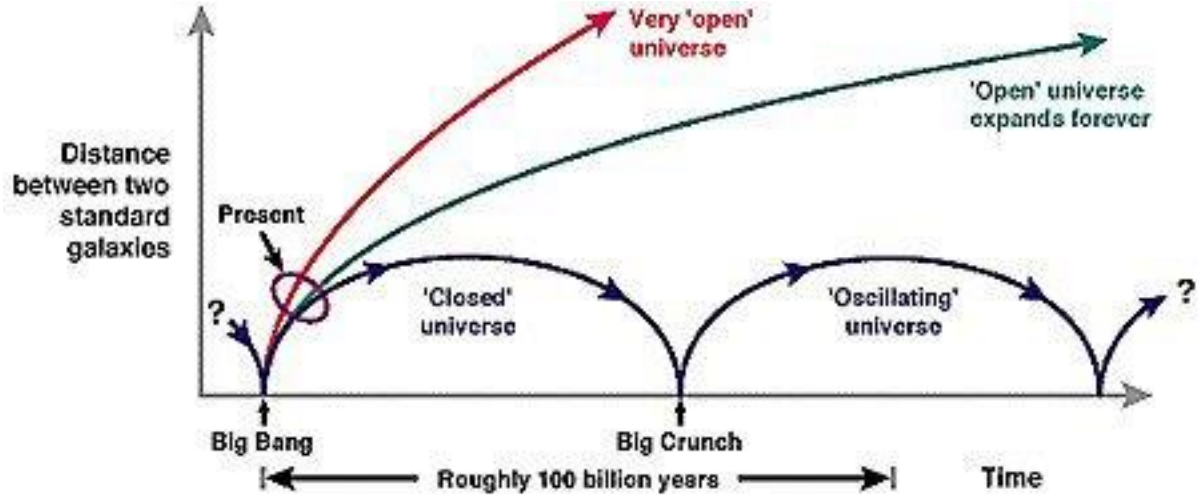


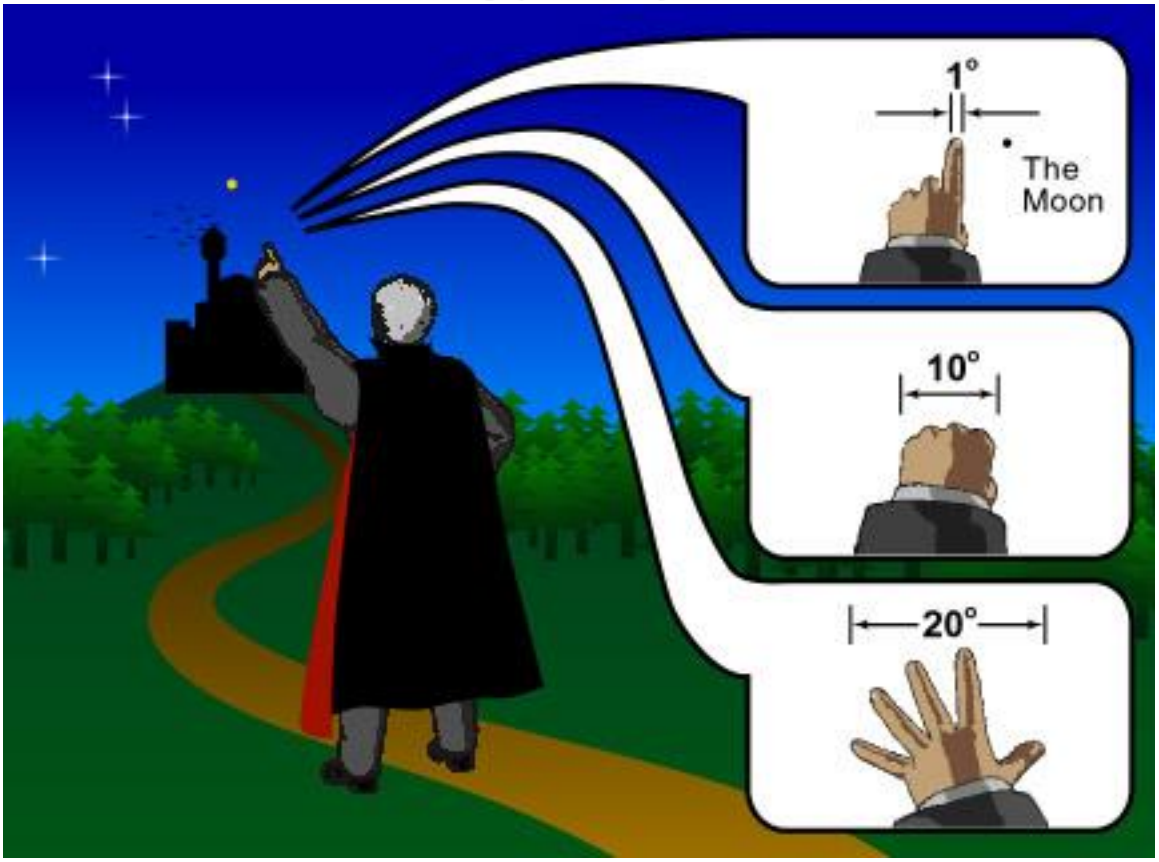
Planetary Nebula NGC 2440

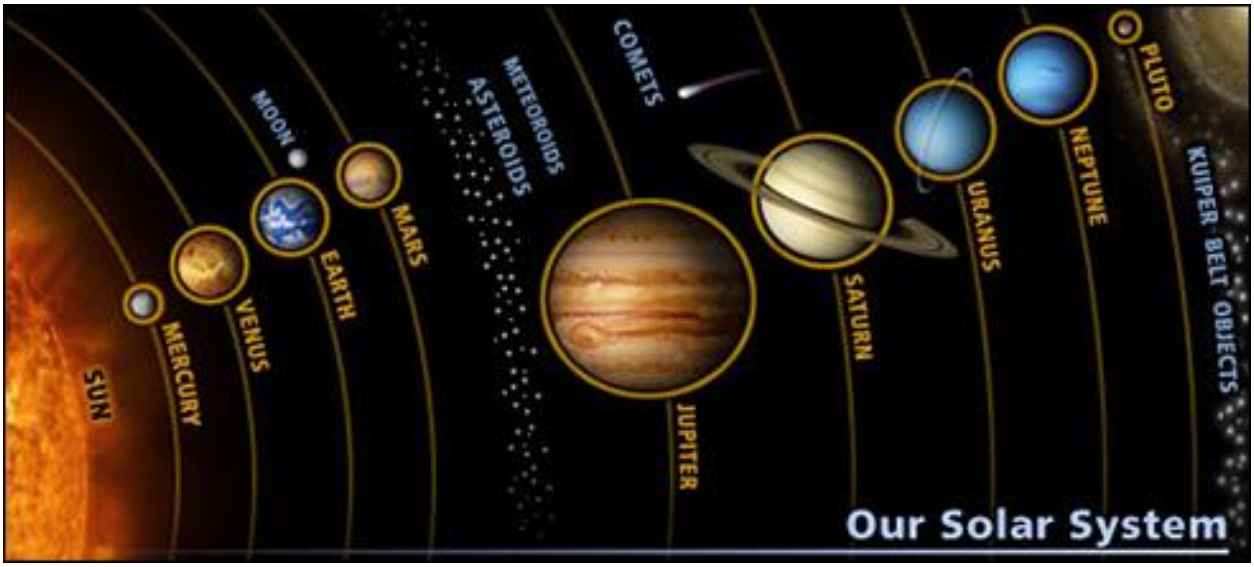
Hubble Space Telescope • WFPC2

NASA, ESA, and K. Noll (STScI)

STScI-PRC07-09

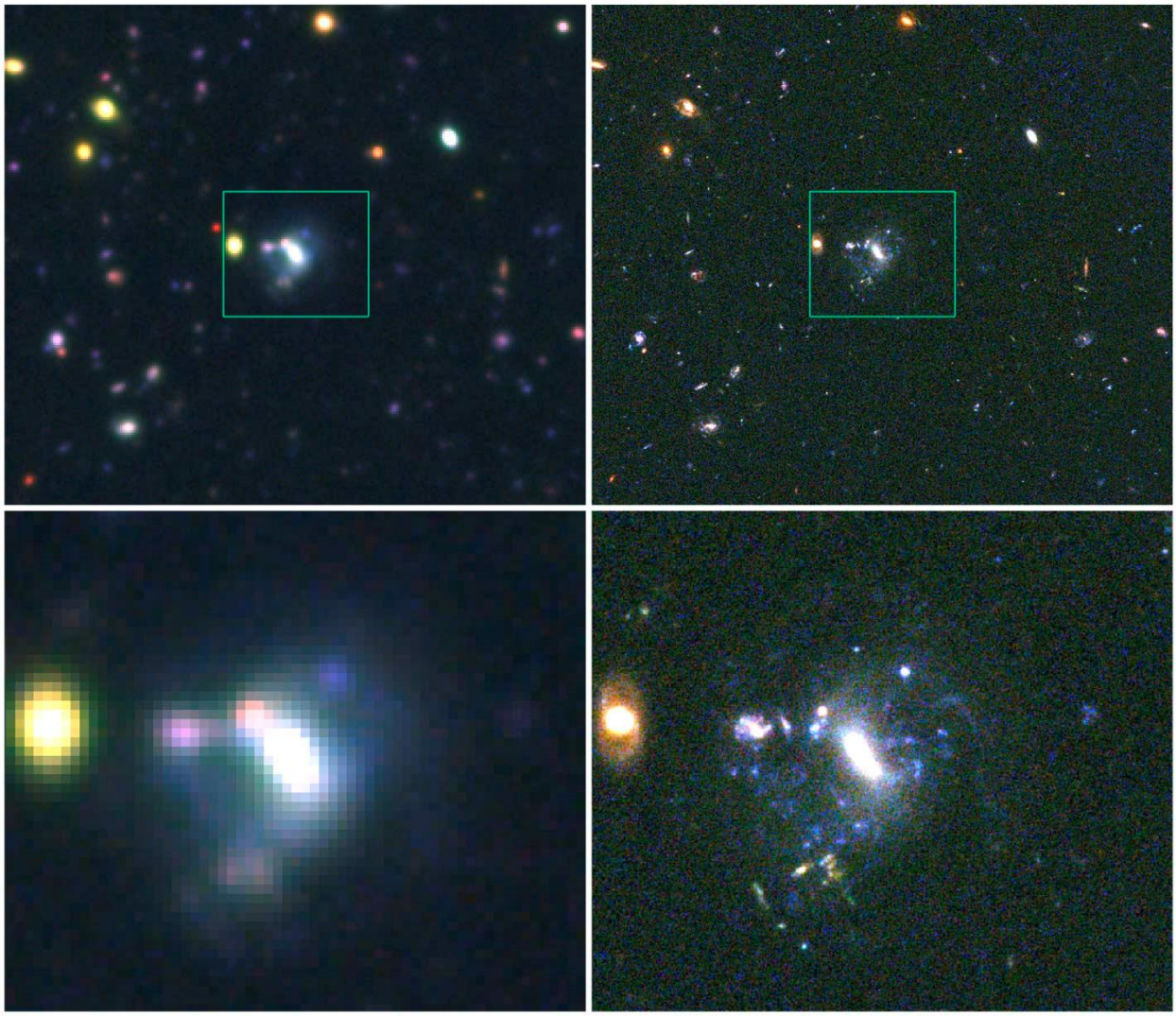

Very 'open' universe
'Open' universe expands forever
Distance between two standard galaxies
Present
?
'Closed' universe
'Oscillating' universe
?
Big Bang
Big Crunch
Roughly 100 billion years
Time

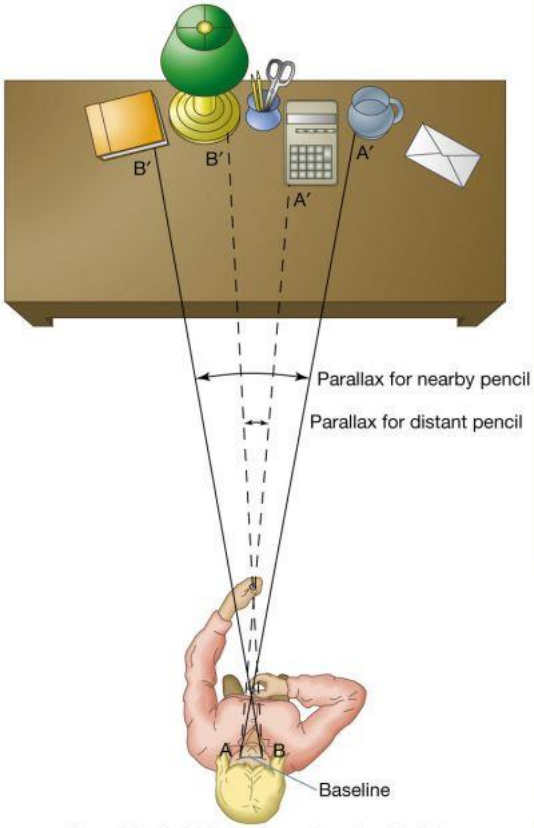

1°
The Moon
10°
20°

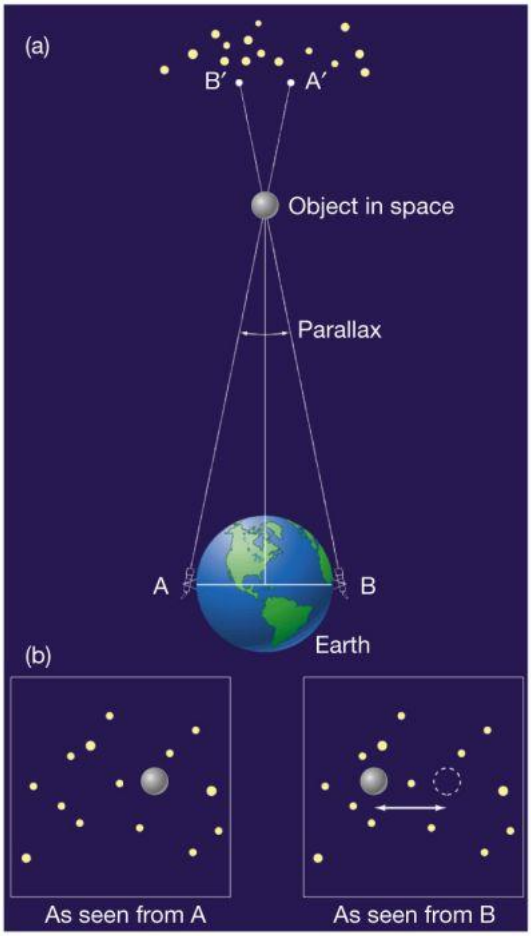


Ground: Subaru (8m)

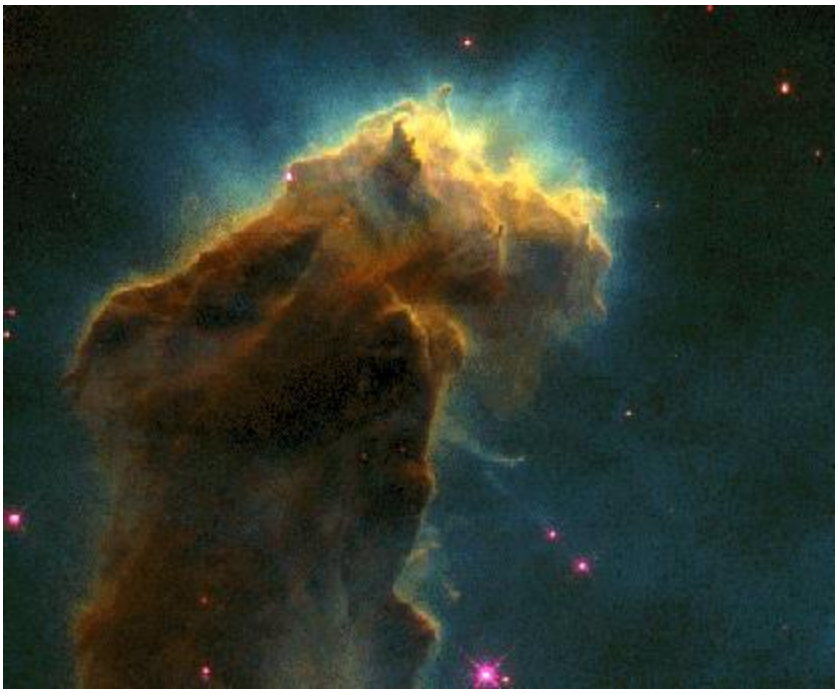
Space: *HST* (2.4m)

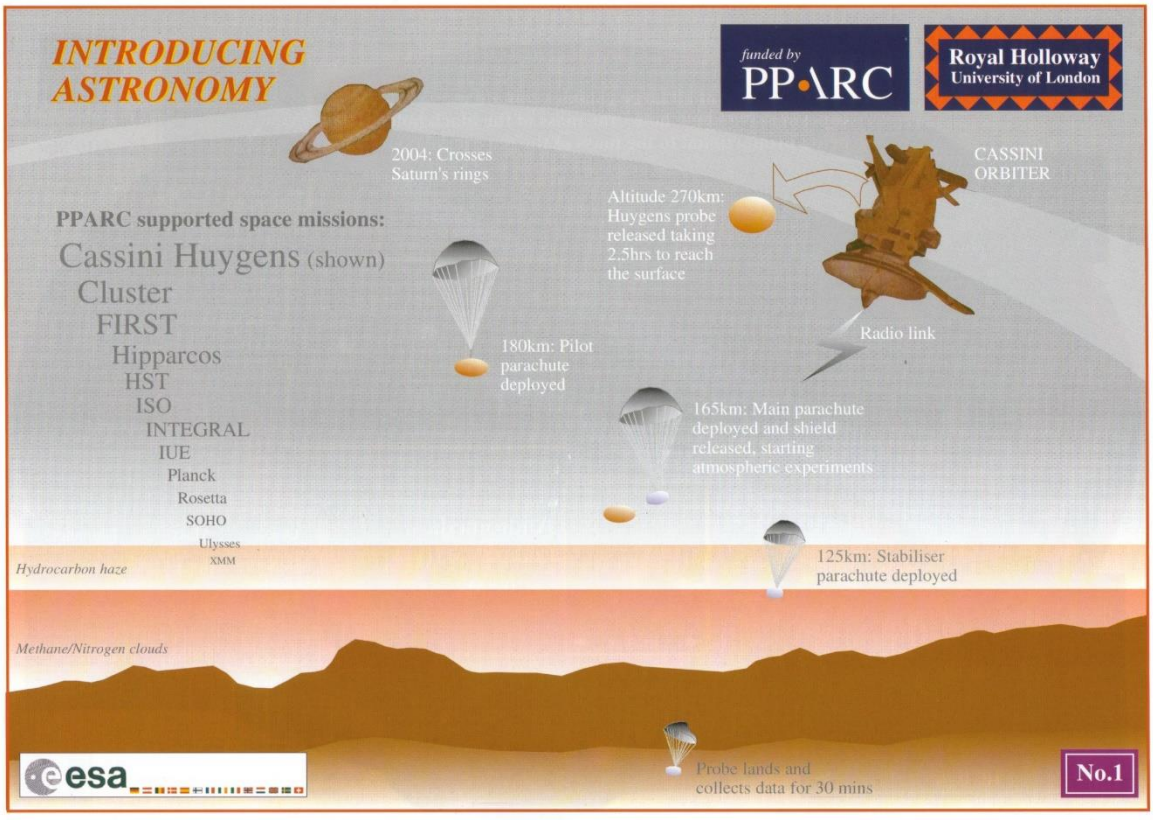


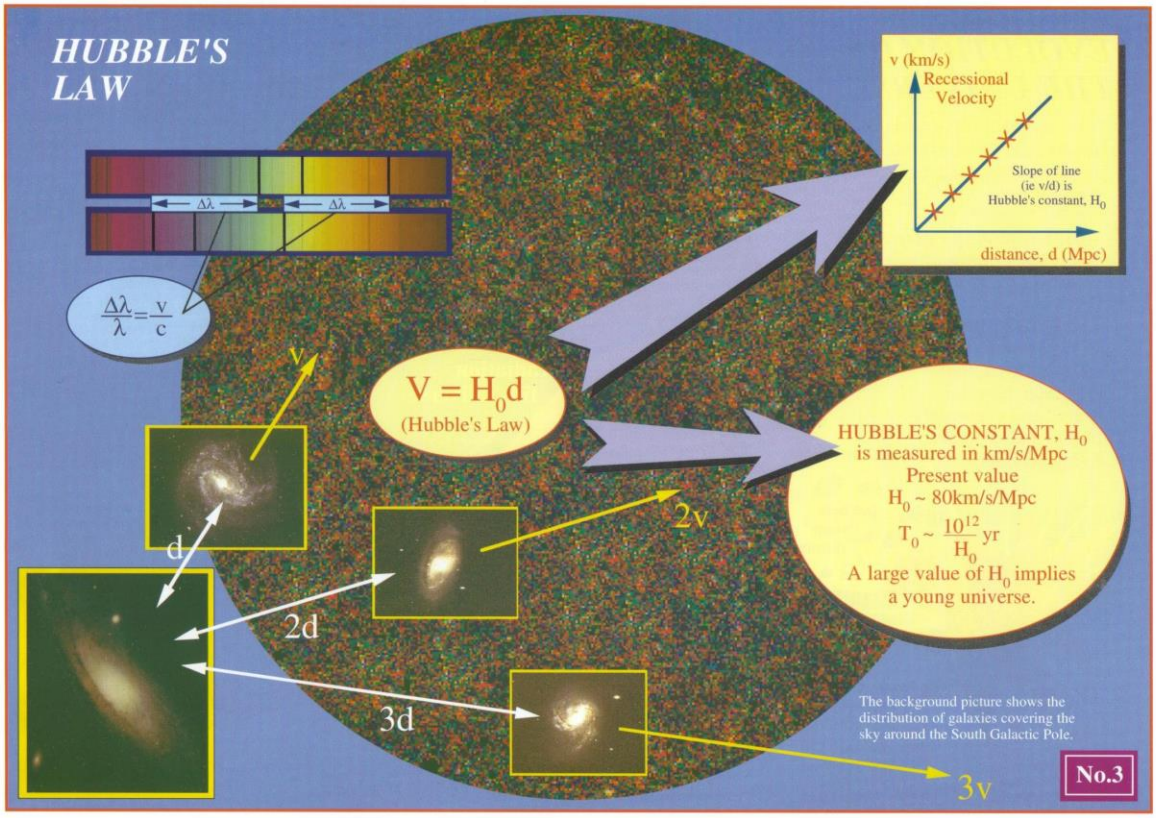


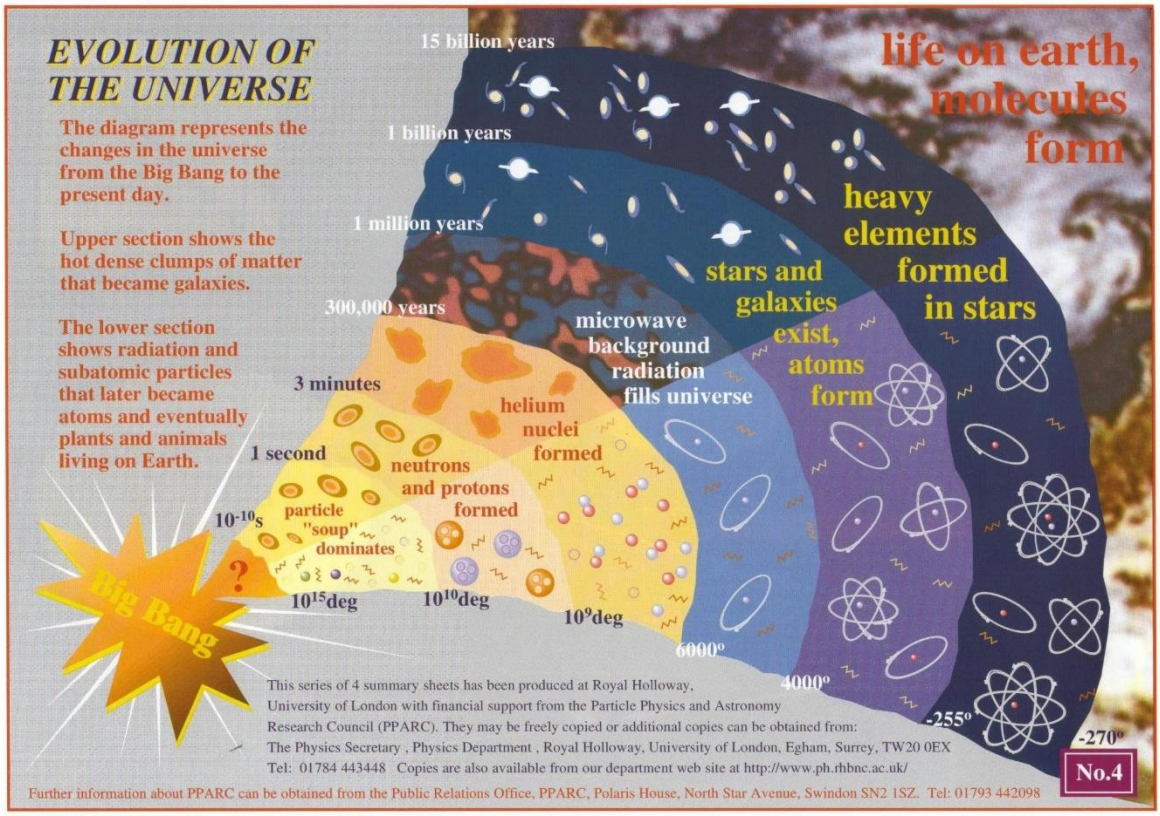


Trying to describe the size of the Big Bang




INTRODUCING ASTRONOMY
funded by PPARC
Royal Holloway University of London
2004: Crosses Saturn's rings
CASSINI ORBITER
Altitude 270km: Huygens probe released taking 2.5hrs to reach the surface
PPARC supported space missions:
Cassini Huygens (shown)
Cluster
FIRST
Hipparcos
HST
ISO
INTEGRAL
IUE
Planck
Rosetta
SOHO
Ulysses
XMM
180km: Pilot parachute deployed
Radio link
165km: Main parachute deployed and shield released, starting atmospheric experiments
Hydrocarbon haze
125km: Stabiliser parachute deployed
Methane/Nitrogen clouds
esa
Probe lands and collects data for 30 mins
No.1


HUBBLE'S LAW
v (km/s)
Recessional Velocity
Slope of line (ie v/d) is Hubble's constant, H_0
distance, d (Mpc)
$\Delta\lambda$
$\Delta\lambda$
$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
v
$V = H_0 d$
(Hubble's Law)
HUBBLE'S CONSTANT, H_0 is measured in km/s/Mpc
Present value
$H_0 \sim 80$km/s/Mpc
$T_0 \sim \frac{10^{12}}{H_0}$ yr
A large value of H_0 implies a young universe.
d
2v
2d
3d
3v
The background picture shows the distribution of galaxies covering the sky around the South Galactic Pole.
No.3


EVOLUTION OF THE UNIVERSE
The diagram represents the changes in the universe from the Big Bang to the present day.
Upper section shows the hot dense clumps of matter that became galaxies.
The lower section shows radiation and subatomic particles that later became atoms and eventually plants and animals living on Earth.
15 billion years
1 billion years
1 million years
300,000 years
3 minutes
1 second
10^{-10}s
Big Bang
?
particle "soup" dominates
neutrons and protons formed
helium nuclei formed
microwave background radiation fills universe
stars and galaxies exist, atoms form
heavy elements formed in stars
life on earth, molecules form
10^{15}deg
10^{10}deg
10^{9}deg
6000°
4000°
-255°
-270°
No.4
This series of 4 summary sheets has been produced at Royal Holloway, University of London with financial support from the Particle Physics and Astronomy Research Council (PPARC). They may be freely copied or additional copies can be obtained from:
The Physics Secretary , Physics Department , Royal Holloway, University of London, Egham, Surrey, TW20 0EX
Tel: 01784 443448 Copies are also available from our department web site at http://www.ph.rhbnc.ac.uk/
Further information about PPARC can be obtained from the Public Relations Office, PPARC, Polaris House, North Star Avenue, Swindon SN2 1SZ. Tel: 01793 442098

STANDARD CANDLES

Cepheid variable

Pulse ∝ size

Pulse rate

↳ size of star

Look at size it appears on earth

↓

Determine distance

Type 1 supernova

mass ≃ 1.4 Sun

↓

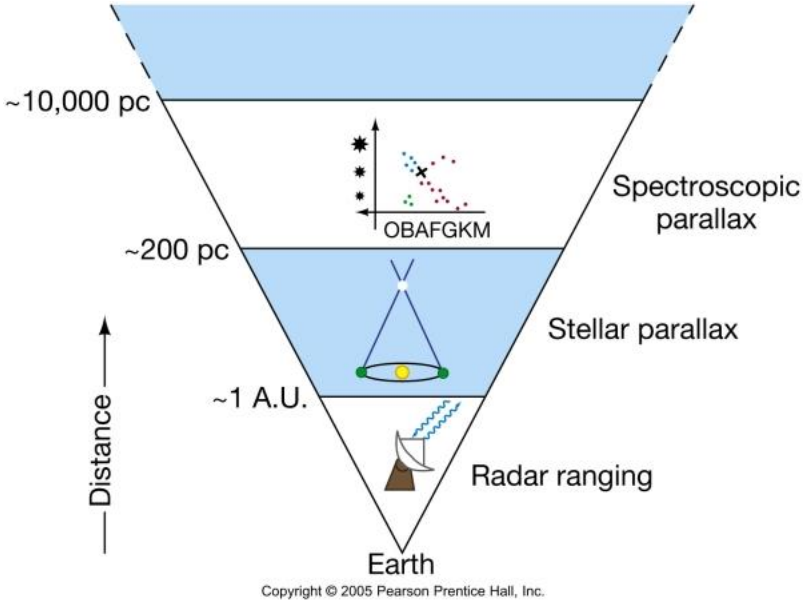
explodes

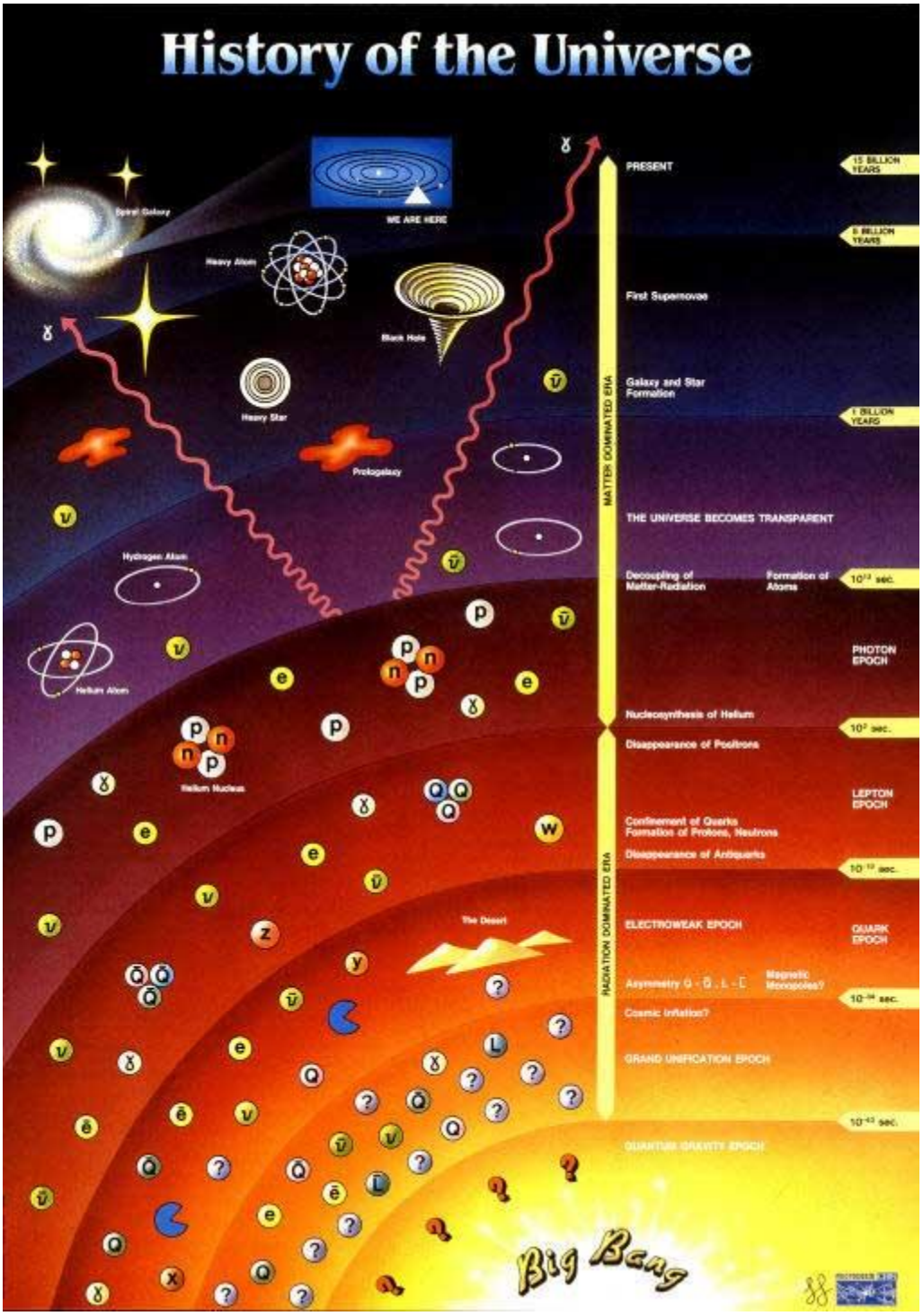
constant flash intensity

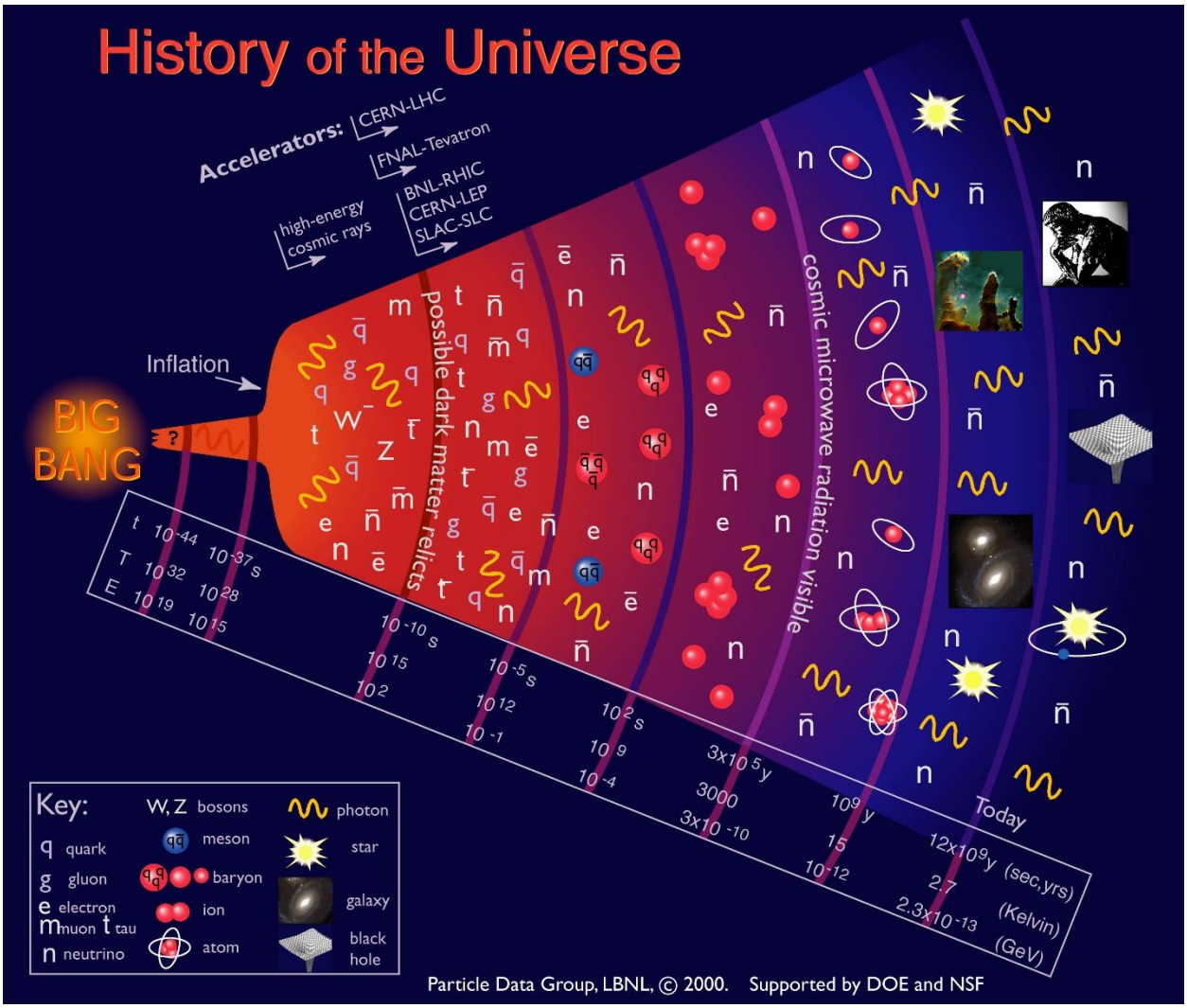
↓

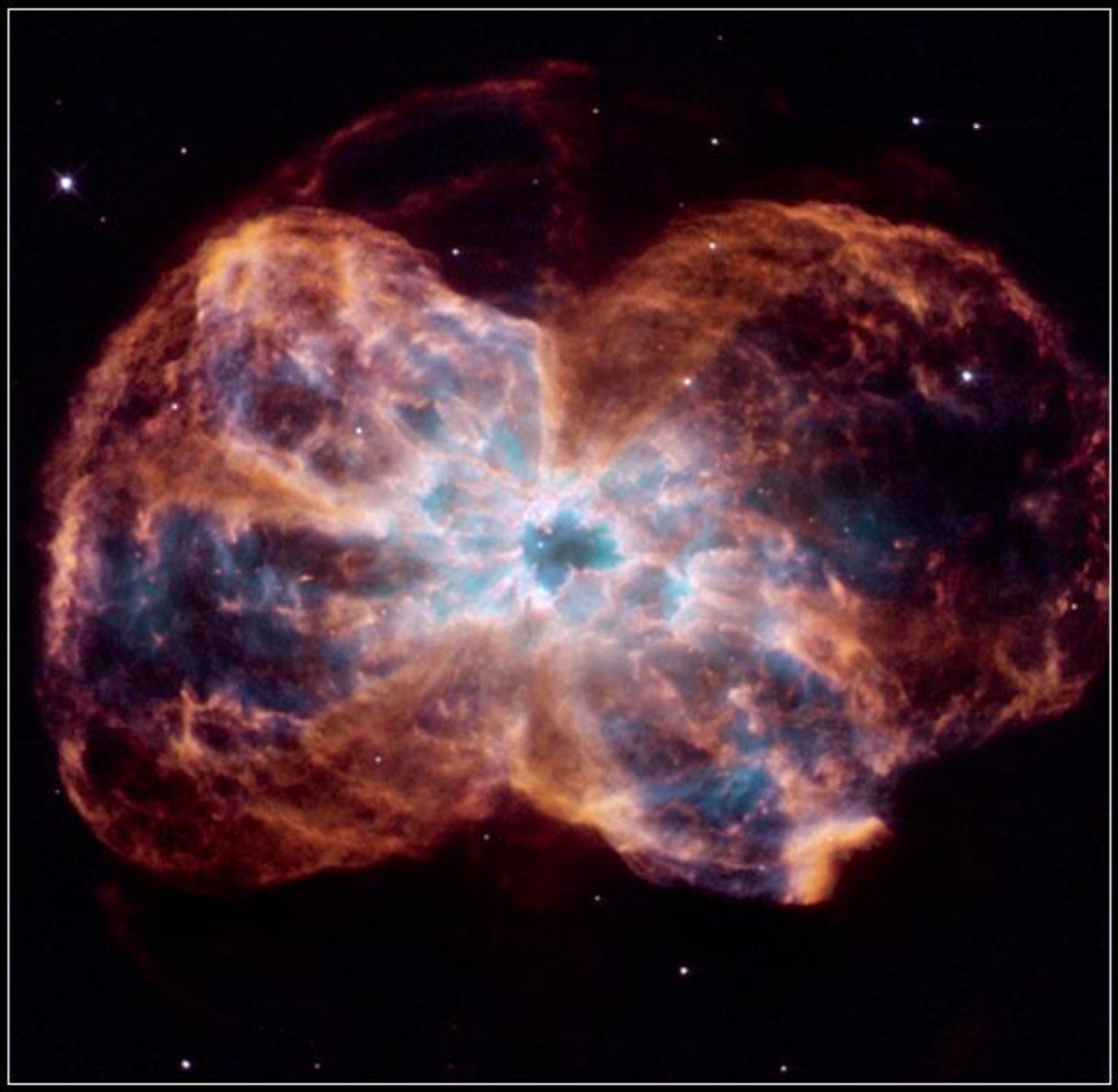
Determine distance

Closer objects → Parallax




History of the Universe
Spiral Galaxy
WE ARE HERE
Heavy Atom
Black Hole
Heavy Star
Protogalaxy
Hydrogen Atom
Helium Atom
Helium Nucleus
The Desert
PRESENT
15 BILLION YEARS
8 BILLION YEARS
First Supernovae
Galaxy and Star Formation
1 BILLION YEARS
THE UNIVERSE BECOMES TRANSPARENT
Decoupling of Matter-Radiation
Formation of Atoms
10^{13} sec.
PHOTON EPOCH
Nucleosynthesis of Helium
10^{2} sec.
Disappearance of Positrons
LEPTON EPOCH
Confinement of Quarks
Formation of Protons, Neutrons
Disappearance of Antiquarks
10^{-12} sec.
ELECTROWEAK EPOCH
QUARK EPOCH
Asymmetry Q - Q̄ , L - L̄
Magnetic Monopoles?
10^{-36} sec.
Cosmic Inflation?
GRAND UNIFICATION EPOCH
10^{-43} sec.
QUANTUM GRAVITY EPOCH
MATTER DOMINATED ERA
RADIATION DOMINATED ERA
Big Bang


History of the Universe
Accelerators:
CERN-LHC
FNAL-Tevatron
BNL-RHIC
CERN-LEP
SLAC-SLC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
Today
Key:
q quark
g gluon
e electron
m muon
t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

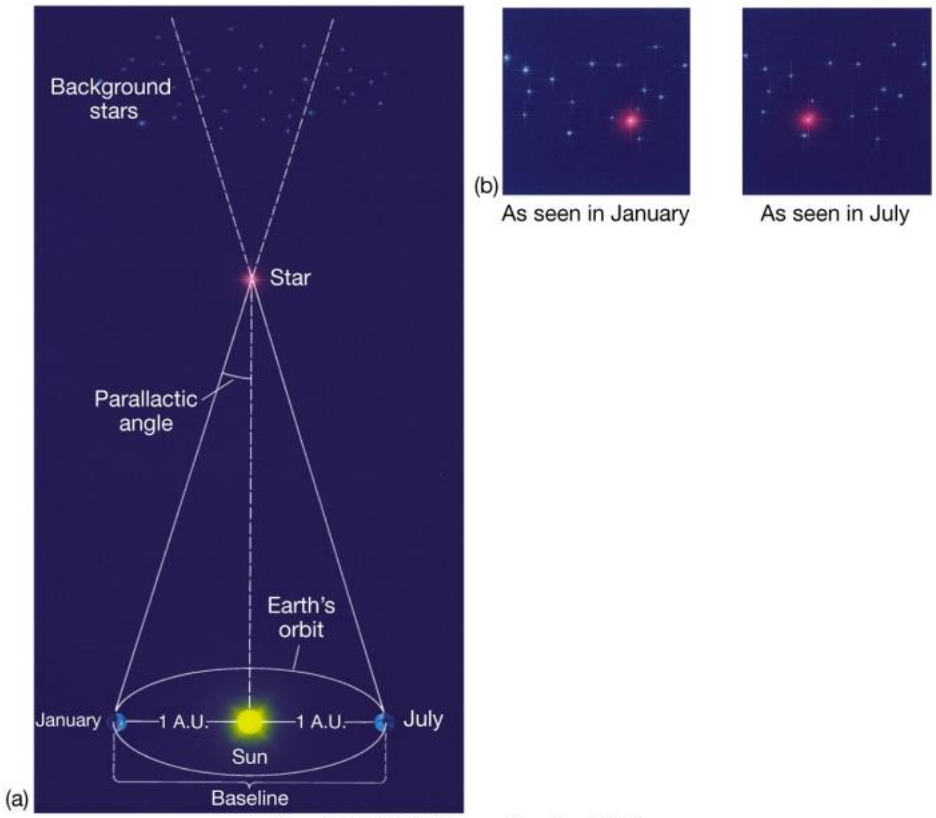


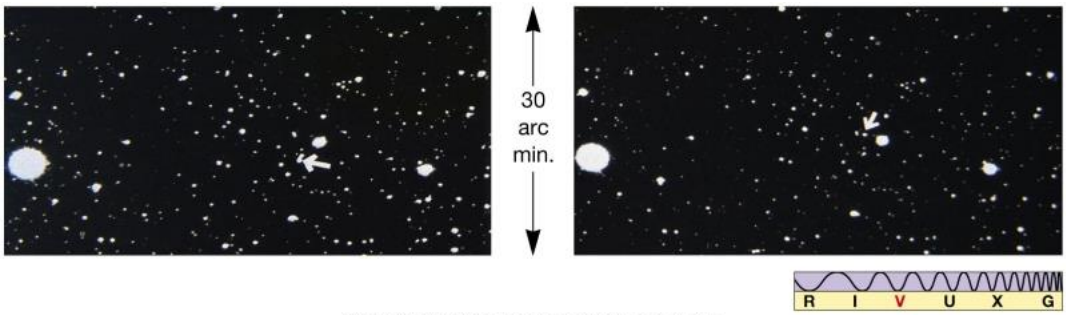
Planetary Nebula NGC 2440

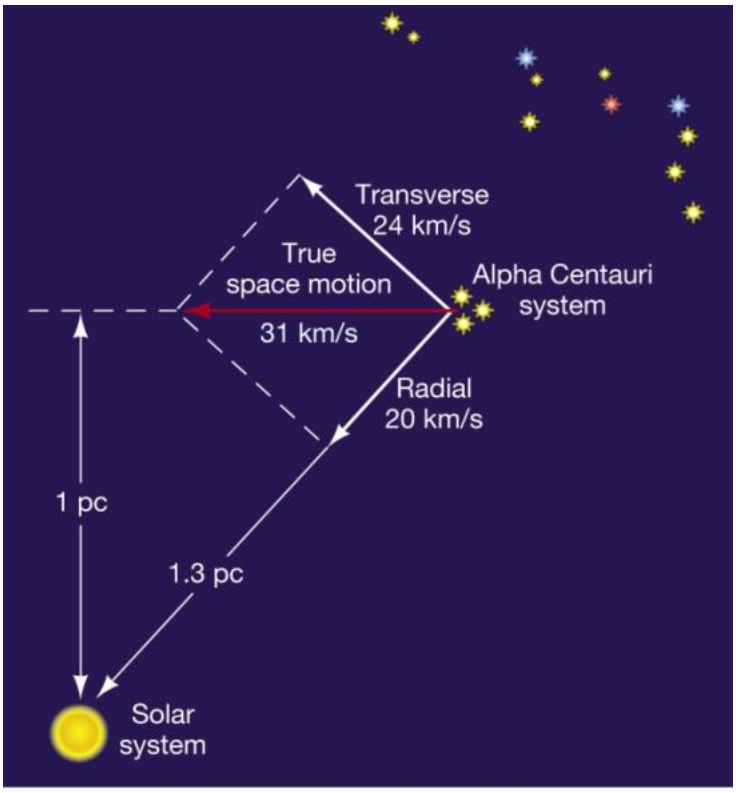
Hubble Space Telescope • WFPC2

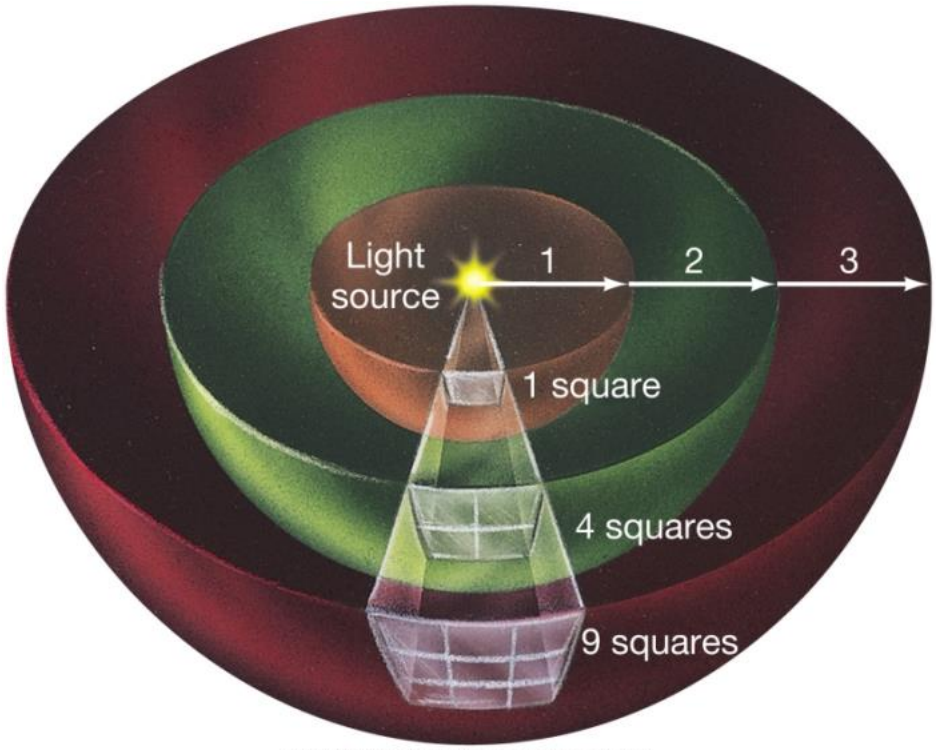
NASA, ESA, and K. Noll (STScI)

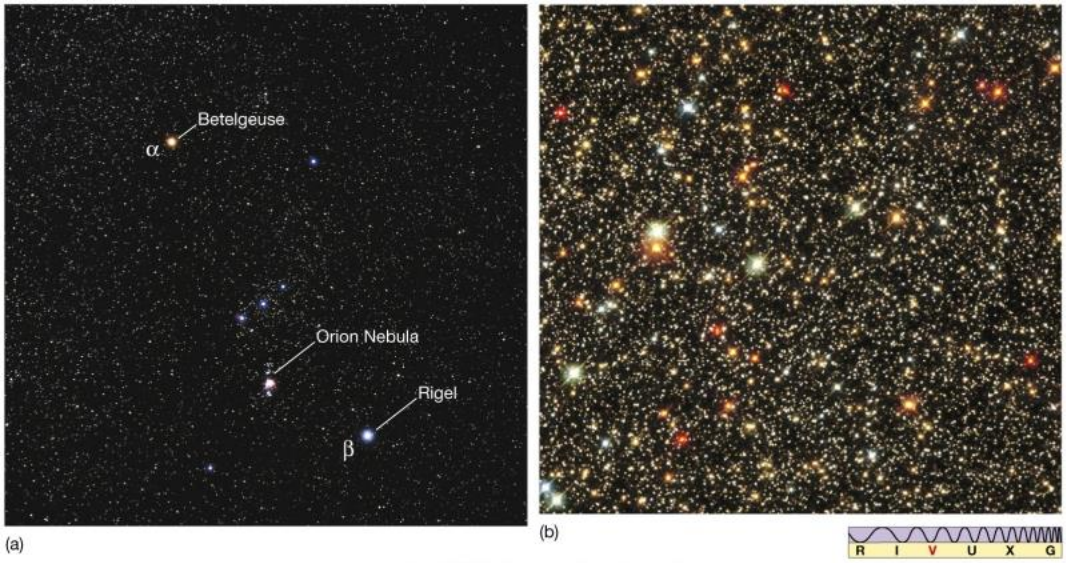
STScI-PRC07-09

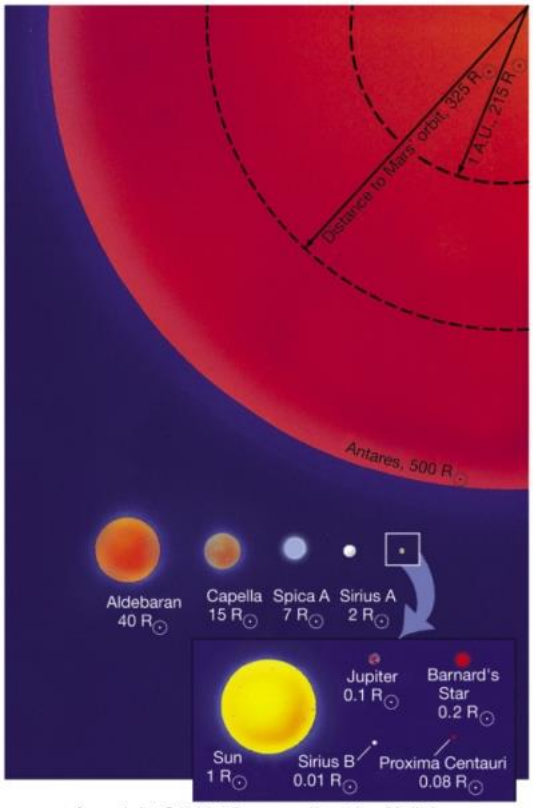


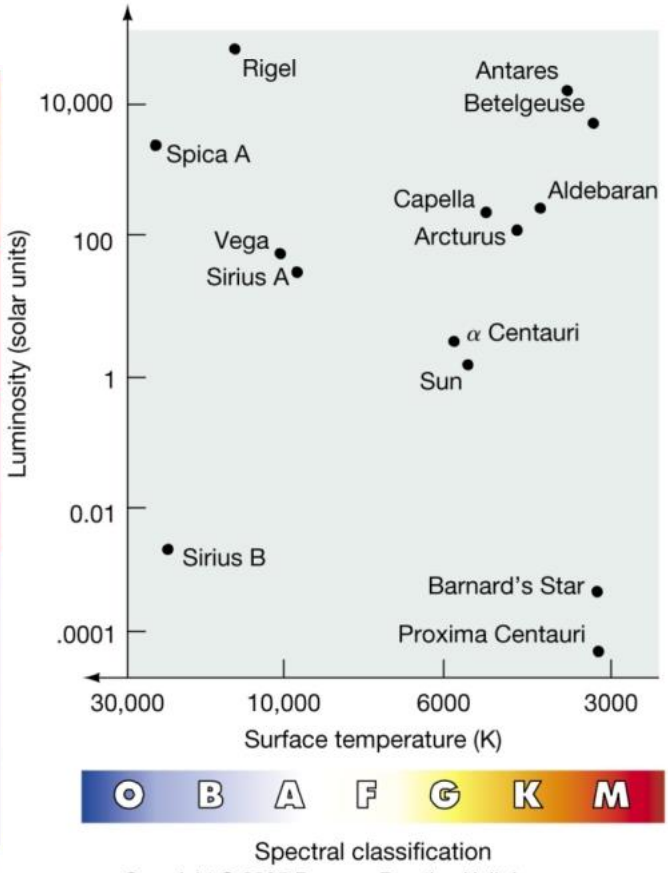


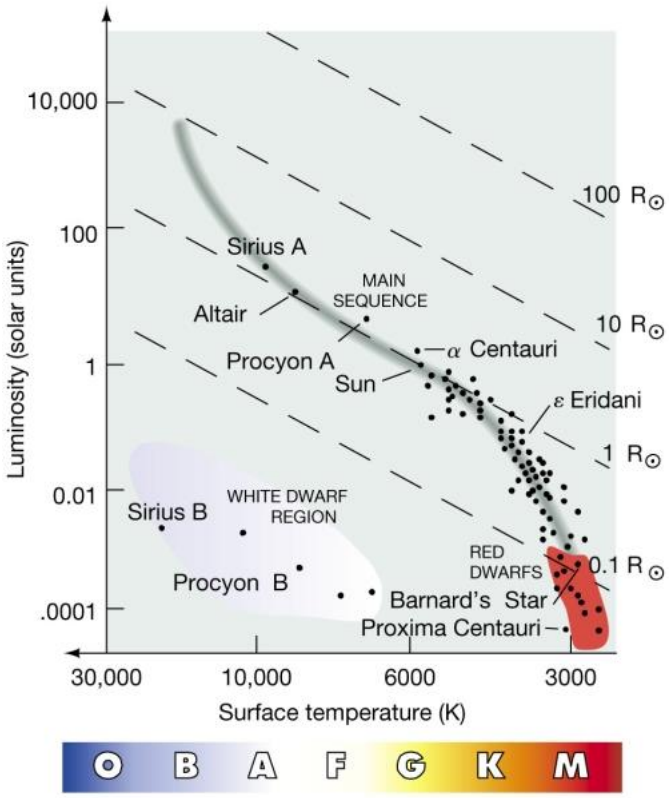


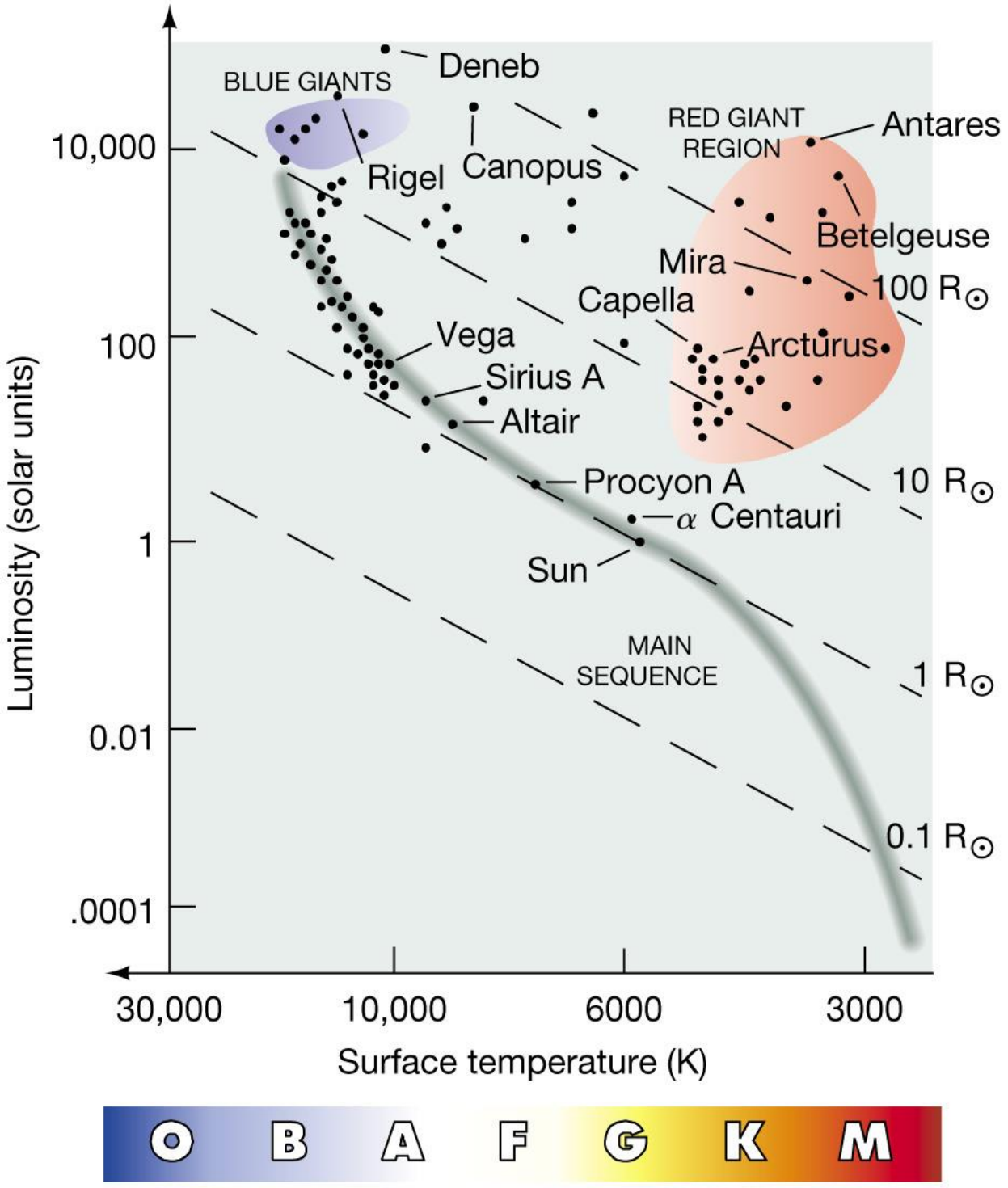


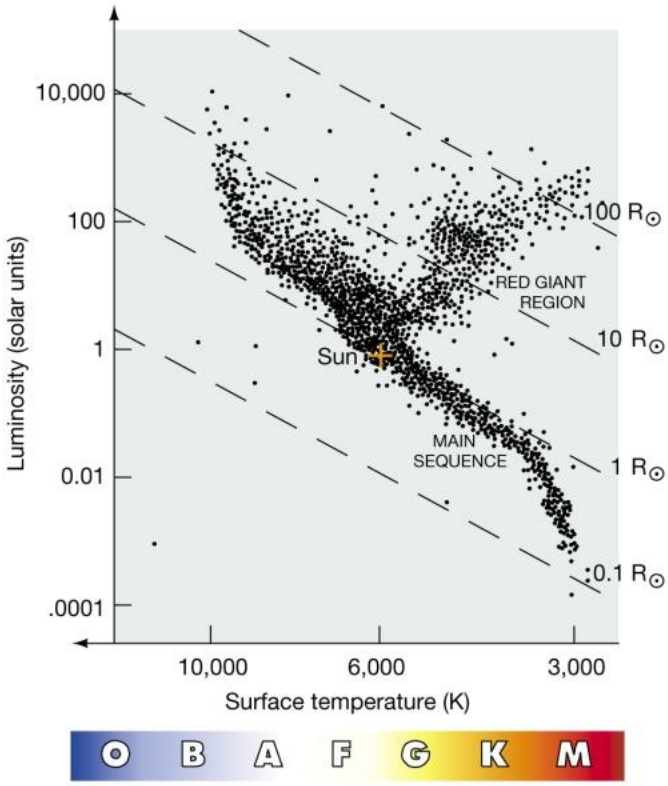


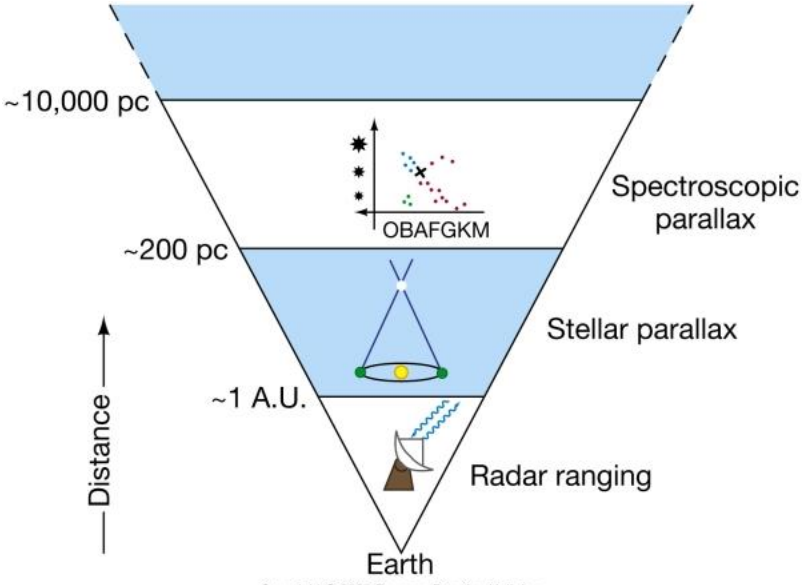


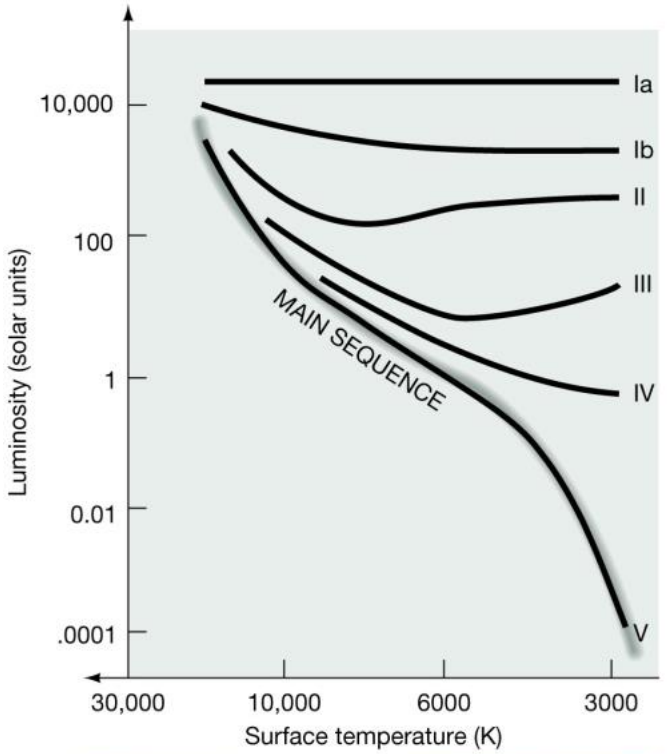


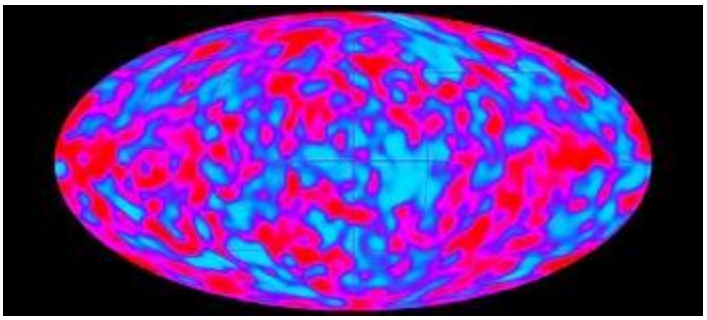


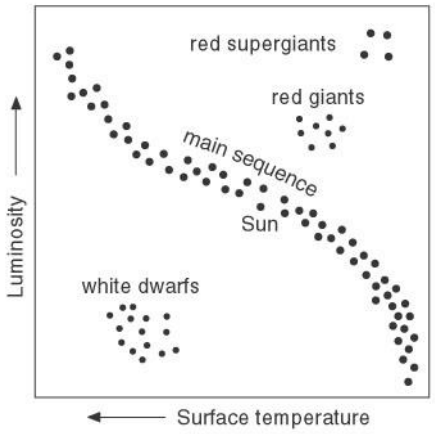




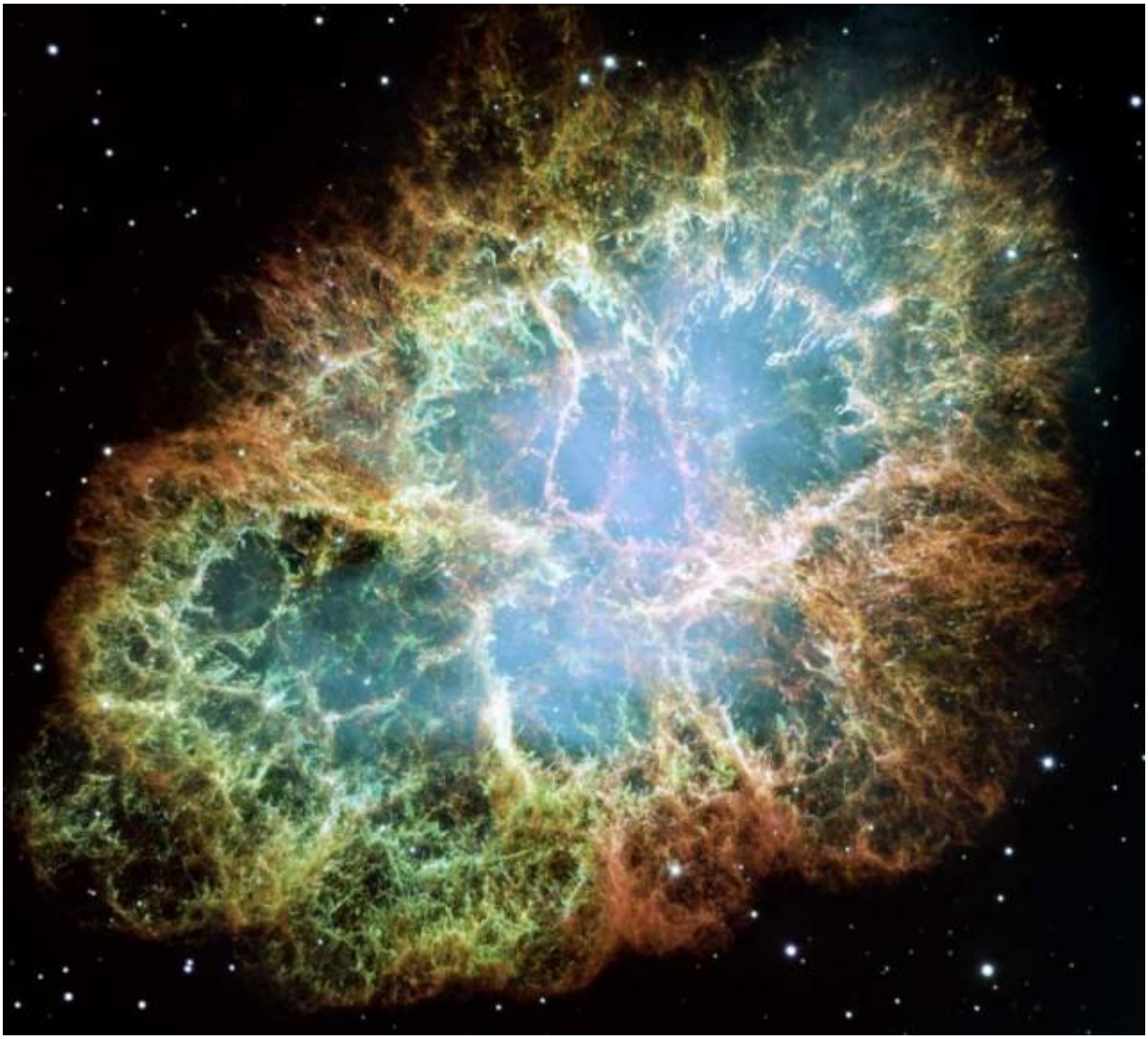


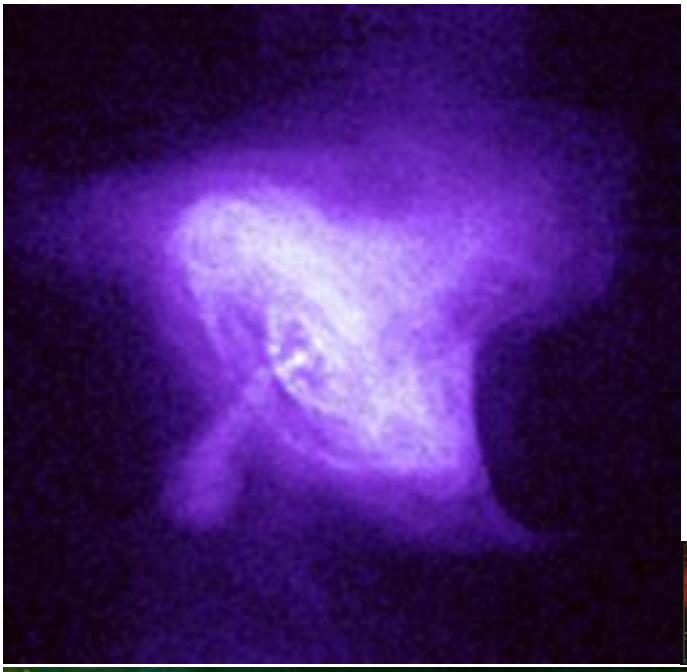






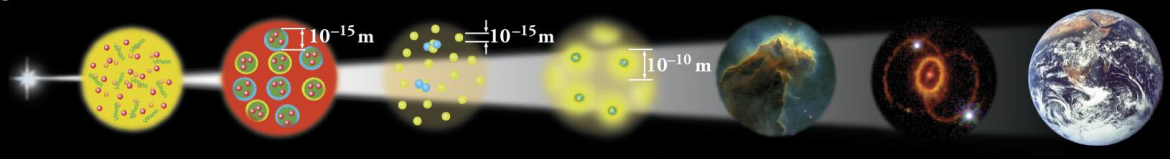

CASSINI SPACECRAFT
4m High-Gain Antenna
Low-Gain Antenna (1 of 2)
11m Magnetometer Boom
Radar Bay
Fields and Paticles Pallet
Radio/Plasma Wave Subsystem Antenna (1 of 3)
Huygens Titan Probe
Remote Sensing Pallet
Radioisotope Thermoelectric Generator (1 of 3)
445 N Engine (1 of 2)



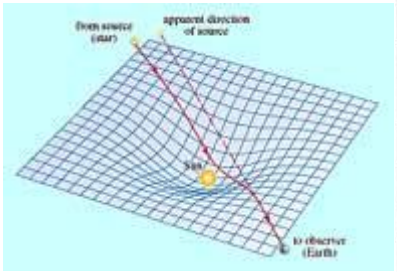


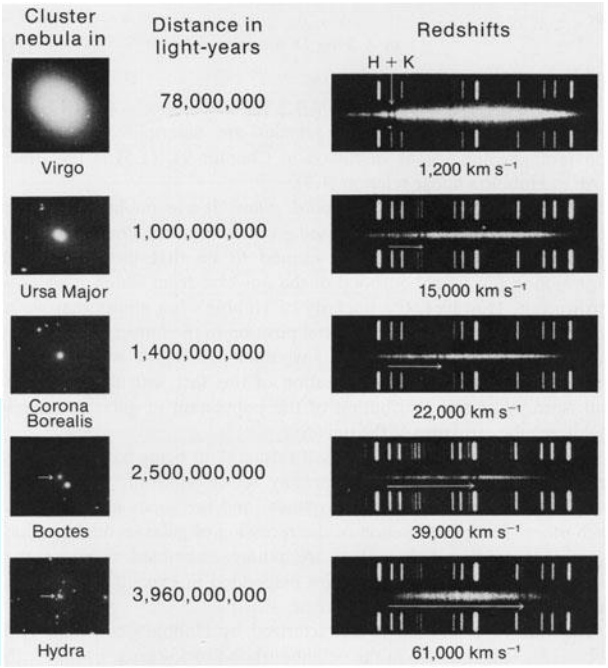
Expansion of the Universe

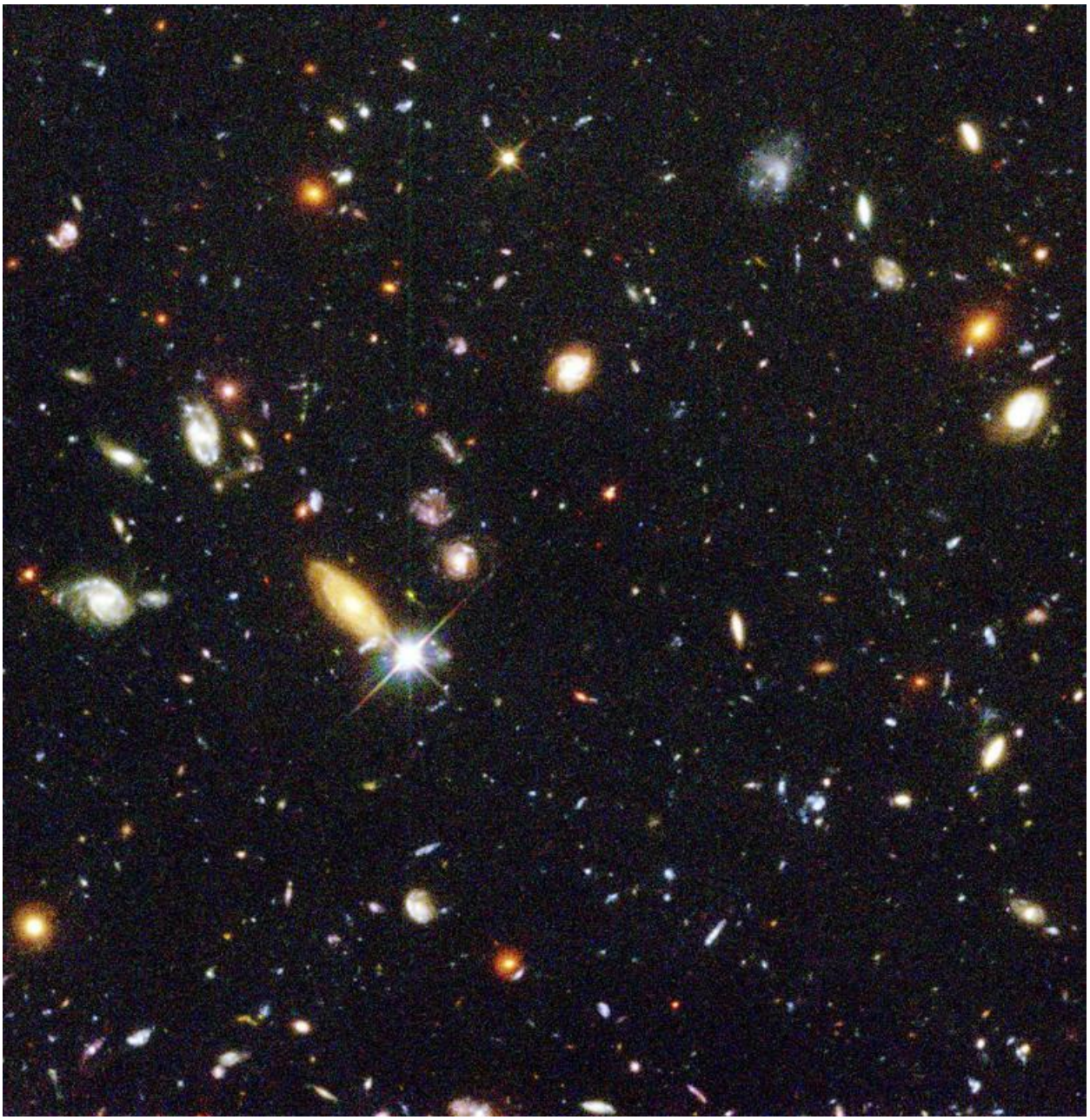
After the Big Bang, the universe expanded and cooled. At about 10^{-6} second, the universe consisted of a soup of quarks, gluons, electrons, and neutrinos. When the temperature of the Universe, $T_{universe}$, cooled to about 10^{12} K, this soup coalesced into protons, neutrons, and electrons. As time progressed, some of the protons and neutrons formed deuterium, helium, and lithium nuclei. Still later, electrons combined with protons and these low-mass nuclei to form neutral atoms. Due to gravity, clouds of atoms contracted into stars, where hydrogen and helium fused into more massive chemical elements. Exploding stars (supernovae) form the most massive elements and disperse them into space. Our earth was formed from supernova debris.

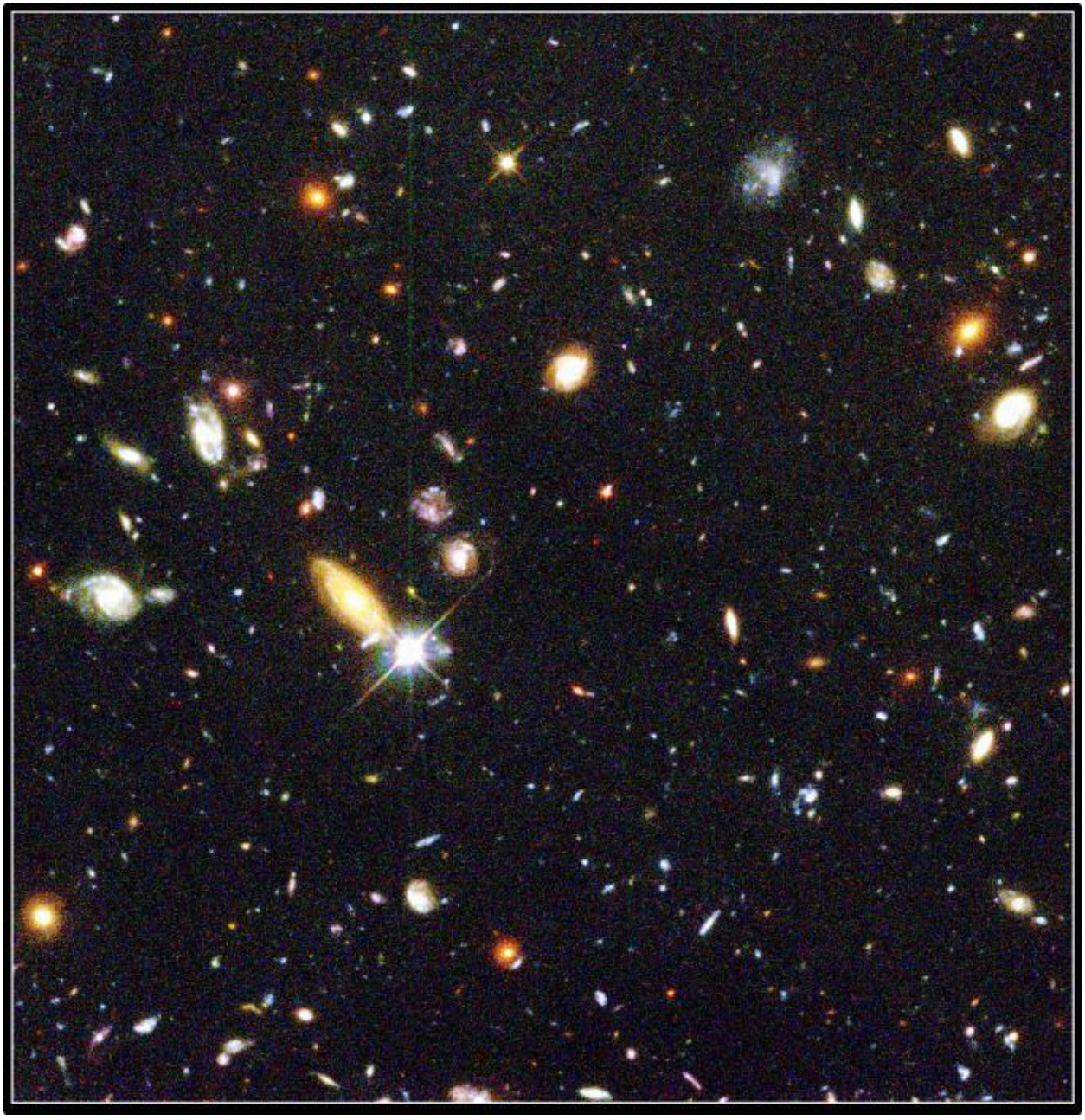


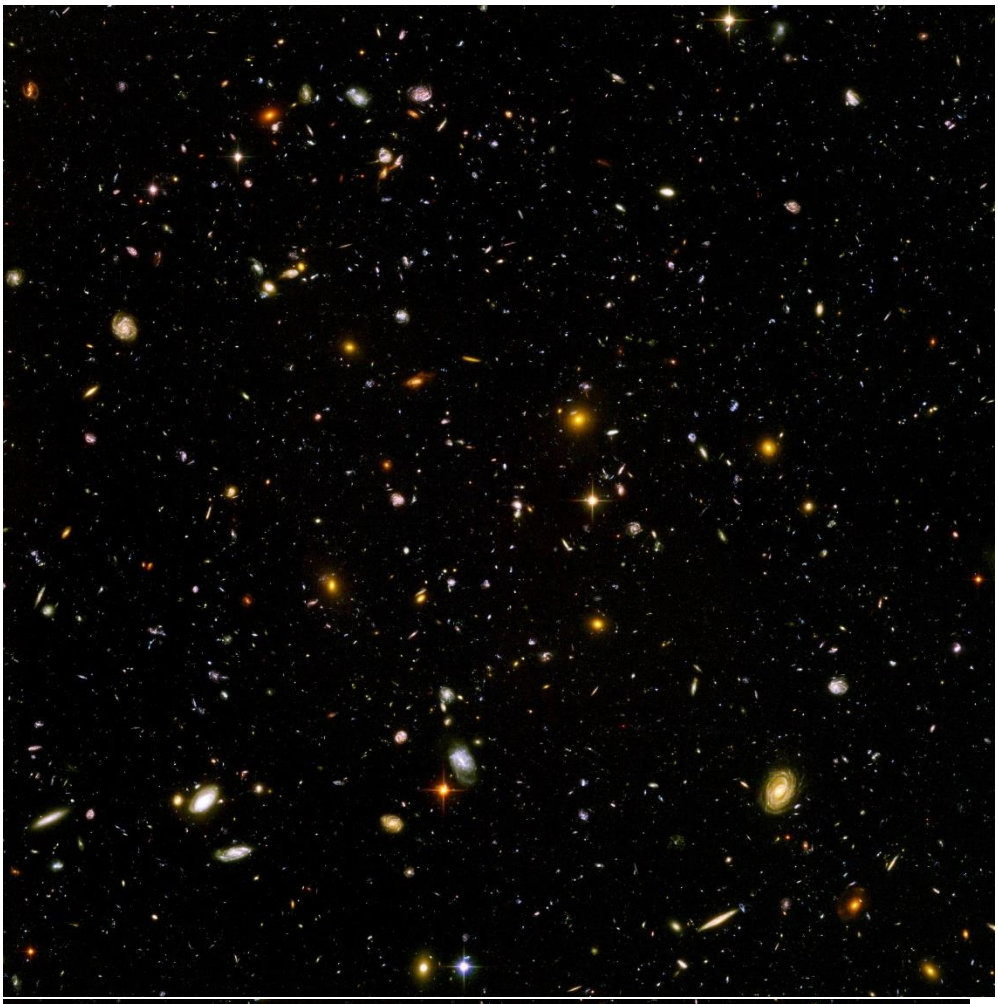
	Big Bang	quark-gluon plasma	proton & neutron formation	formation of low-mass nuclei	formation of neutral atoms	star formation	dispersion of massive elements	today
$T_{universe}$		$>10^{12}$ K	10^{12} K	10^{9} K	4,000 K	50 K–3 K	<50 K–3 K	3 K
time		10^{-6} s	10^{-4} s	3 min	400,000 yr	3×10^{8} yr	$>3 \times 10^{8}$ yr	14×10^{9} yr

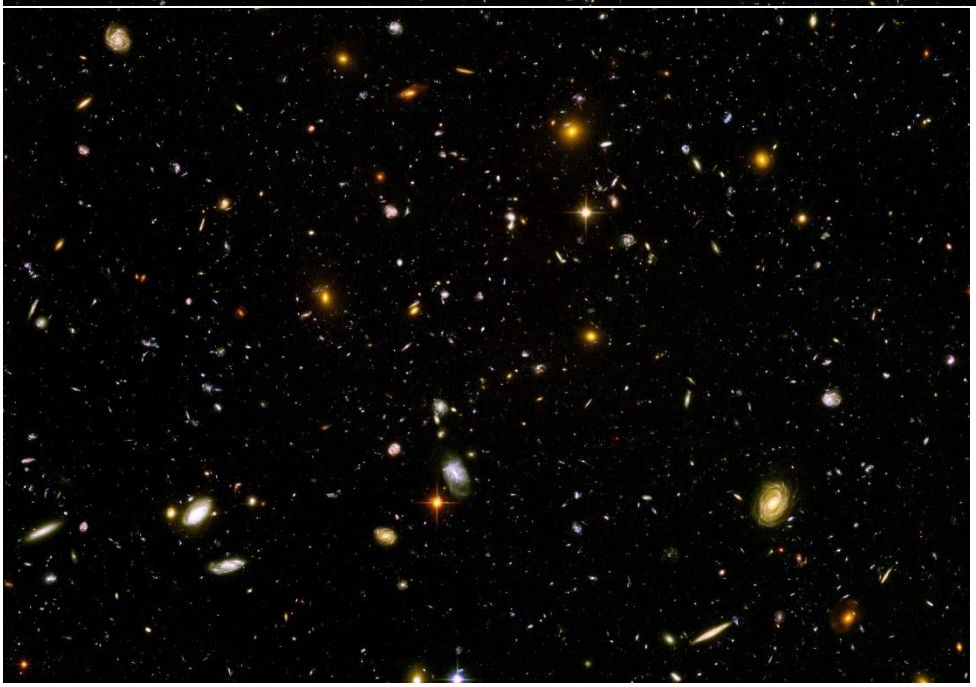


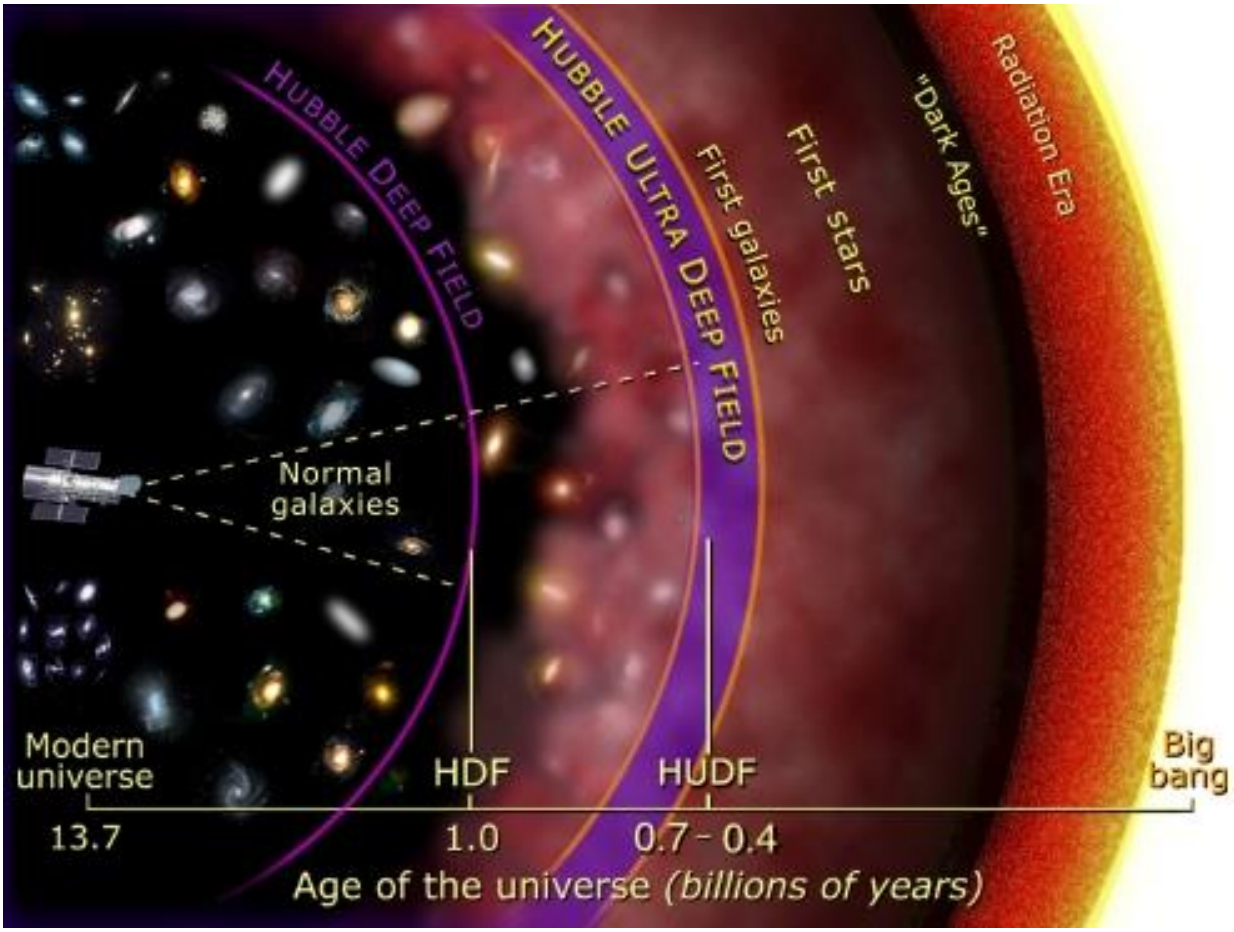











Hubble Deep Field
Hubble Ultra Deep Field
First galaxies
First stars
"Dark Ages"
Radiation Era
Normal galaxies
Modern universe
HDF
HUDF
Big bang
13.7
1.0
0.7 - 0.4
Age of the universe (billions of years)


Nice store. How do you keep the floors so clean?
Oh, we hired this dude named Kepler, he's really good. Hard worker. Doesn't mind the monotony. Sweeps out the same area every night.