Astro 301/ Fall 2005

(48310)

Introduction to Astronomy

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TAs: David Fisher, Donghui Jeong, and Miranda Nordhaus

Lecture 1: Th Sep 1

Astronomy

One of the greatest adventures of humankind : the quest for our origins and fate !

How did it start? where did we come from? Where are we going ?

Astronomy is one of the rare sciences that explore

à distance scales that range from the infinitesimal to the grandest

Atom's radius	5×10^{-11} m = 1.5 x 0.00000000001 m
Earth's radius	6.4×10^{6} m = 6.4 x 1000,000 m
Sun-Earth distance	1.5×10^{11} m = 1.5 x 100,000,000,000 m
Size of superclusters of galaxies	1.0×10^{23} m = 1.0 x 1,000,000,000,000……..000 m

à time scales that range from the earliest epochs to the present day

From $t = 10^{-43}$ seconds to 1.3×10^{17} s (13.7 billion years)

Astronomy

In this course we will address these issues

The present-day Universe from the infinitesimal to the grandest scales

How did the Universe begin in a Big Bang? What physical laws govern its evolution?

Over time, how did stars, planets, life, galaxies, and black holes form and evolve?

How did galaxies like our own Milky Way form?

What is the role of dark matter and dark energy?

What are predictions for the future of our Galaxy and of the Universe?

Can science solve the ultimate mystery of Nature?

Pick up for in-class discussion:

- Course Description
- Memo to Undergraduate Students regarding Astronomy Courses
  (applicable to ALL introductory astronomy courses)
- Course syllabus

Class website (has all critical info)

http://www.as.utexas.edu/~sj/a301-fa05

Math needed

Reviews appendix C.1, C.2, C.3, C.4, and C.5 of textbook before the next class.
Contact us asap if you need help

Tips for doing well in this class

- Attend the lectures

  à lectures cover material not in the book and you are responsible for knowing this material
  à Exams and homeworks follow the lecture material
  à Quizzes are based on the previous 1-2 lectures or on assigned reading
  à In-class activities (e.g, quizzes) make up 20% of the grade homework

- Get help early (office hours, help session for homework, exam reviews)

- Earn extra credit (EC) by getting certified to use the Painter Hall Telescope
  The EC can contribute up to 5% in one of your exams.

A guided overview of the course

The rest of this lecture gives an overview and selected excerpts from the course

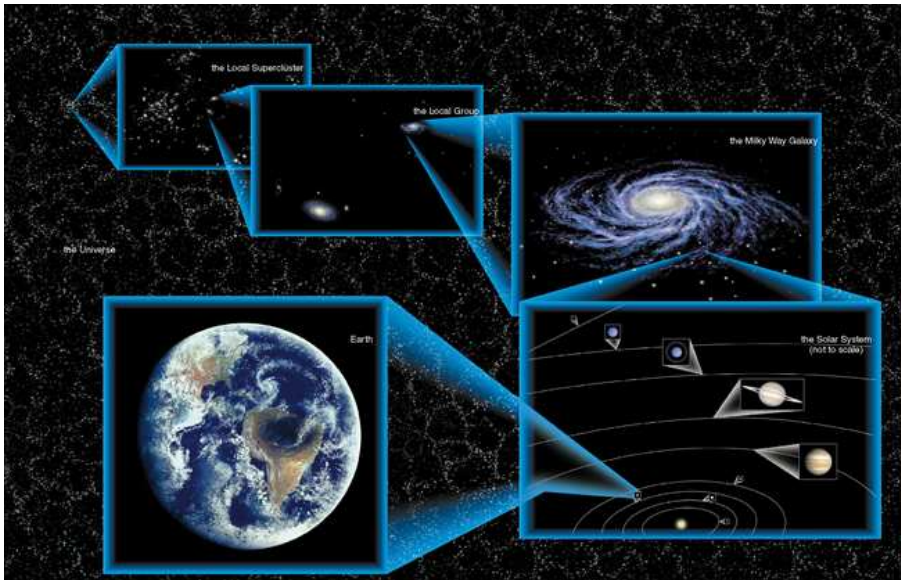
Do not worry if you do not get all the details, as we will return to each of these topic in details in the next lectures.

For now just focus on the big picture and the central themes you will explore

Astronomy: From the Infinitesimal to the Grandest Scales

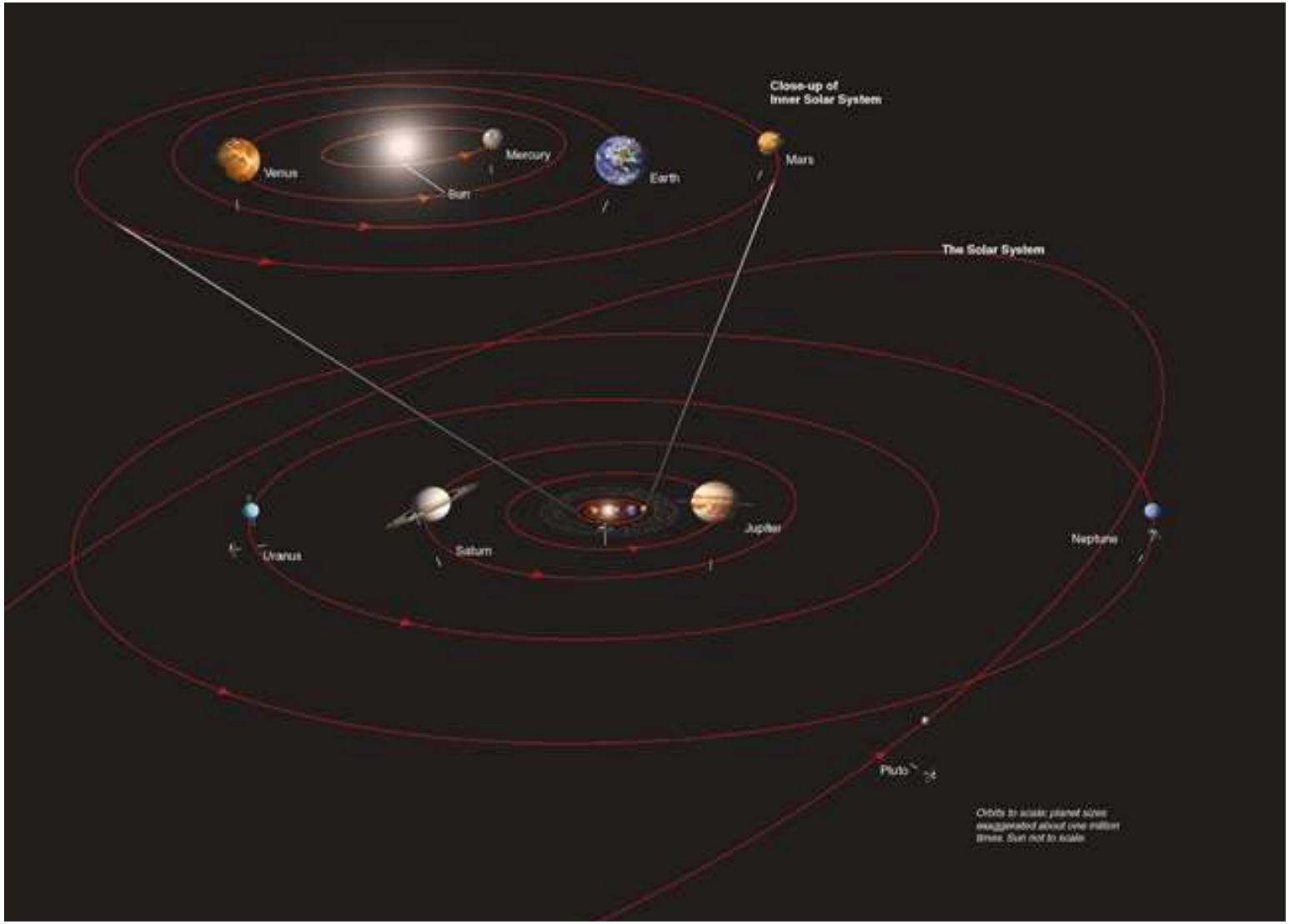
From the tiniest to the grandest scales

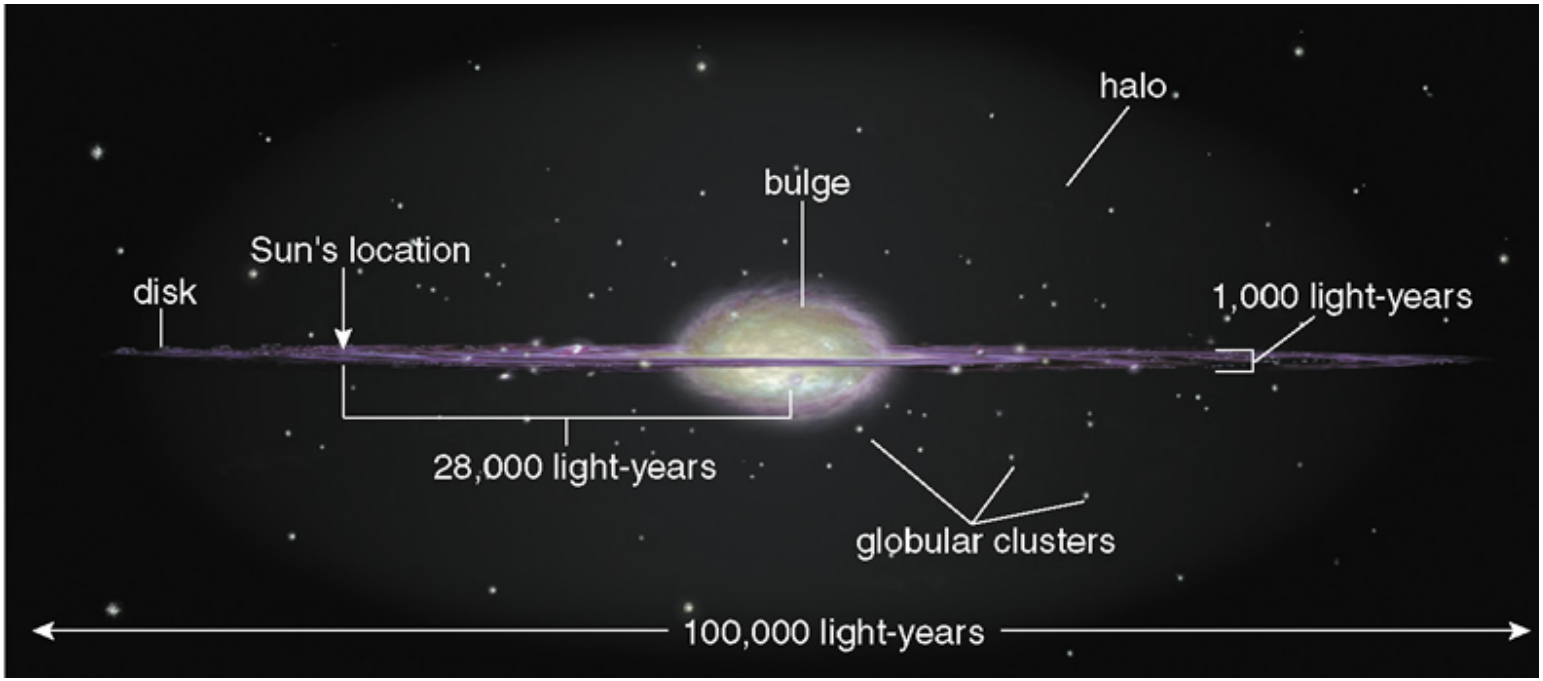
Radius of a hydrogen atom	5.0×10^{-11} m = 1.5 x 0.00000000001 m
Radius of Earth	6.4×10^{6} m = 6.4 x 1000,000 m
Sun-Earth distance	1.5×10^{11} m = 1.5 x 100,000,000,000 m = 1 AU
Size of solar system from Sun to Pluto	39.5 Au = 3.95×10^{12} m
Distance travelled by light in 1 year	1 light year (ly) ~ 10^{16} m or ten thousand trillion
Distance between stars	1 parsec (pc) = 3.2 light years
Sizes of galaxies	Tens of thousands of pc ~ 10^{20} m
Size of superclusters of galaxies	1×10^{23} m = 1.0 x 1,000,000,000,000……..000 m



Our Solar System

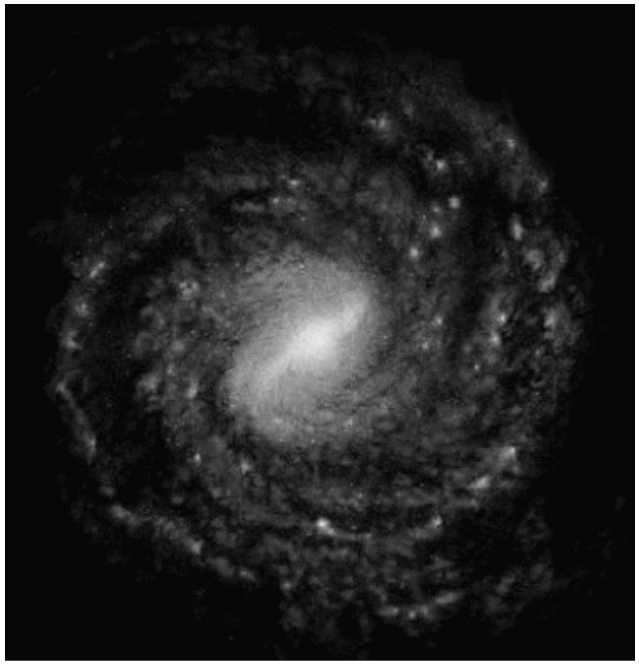
Distance between Earth and Sun = 1.5×10^{11} m = 1AU ; Pluto-Sun= 40 AU





Edge on view

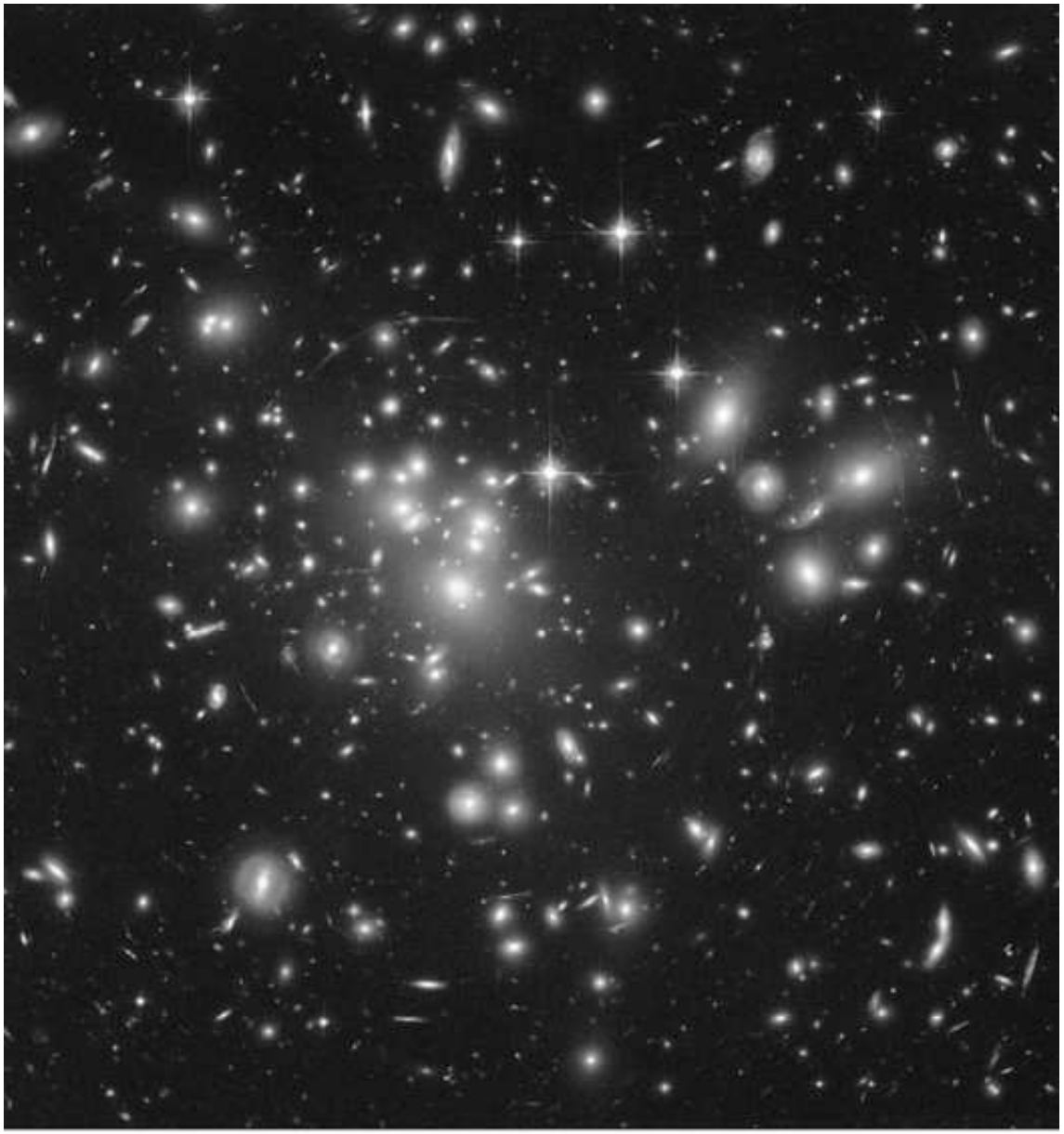
Face on view



Or Galaxy, the Milky Way is a barred spiral galaxy, 100,000 light years across, hosting our Sun and Solar system

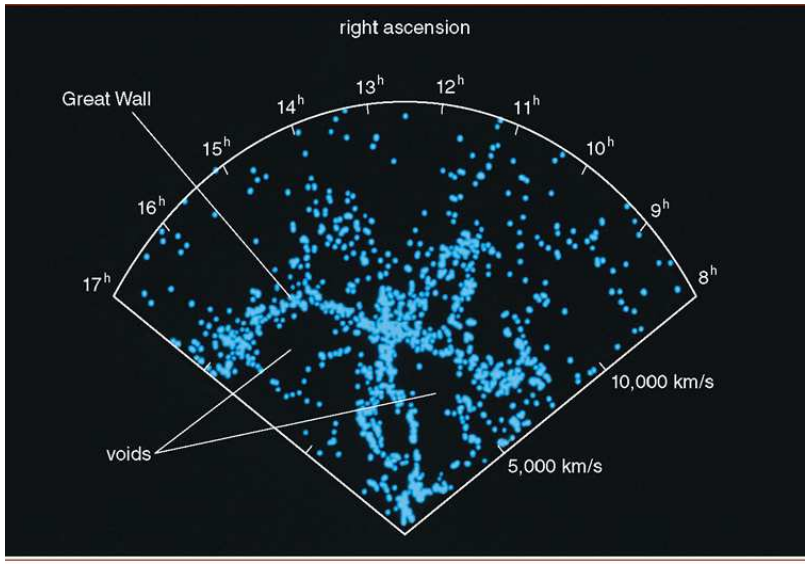
Groups/Clusters of galaxies = a set of galaxies bound by gravity.

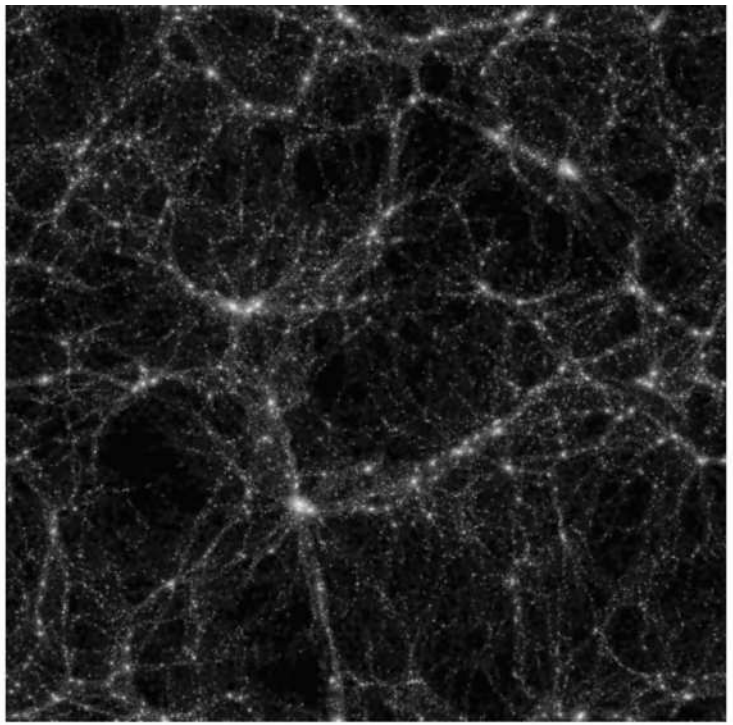
Virgo cluster = 64 x 10^6 lyr
Coma cluster = 3400 x 10^6 lyr
= 3.4 x 10^9 lyr
Abell clusters = several x 10^9 ly



Central Part of Abell
1689 Cluster of Galaxies

Region shown = 2 x 10^6 lyr





Large-scale structure: sheets, voids, filaments/walls

Superclusters = 10 million lyr = 10^{23} m or 10^{7} lyr
Fliaments = 10 x larger even….

From the tiniest to the grandest scales

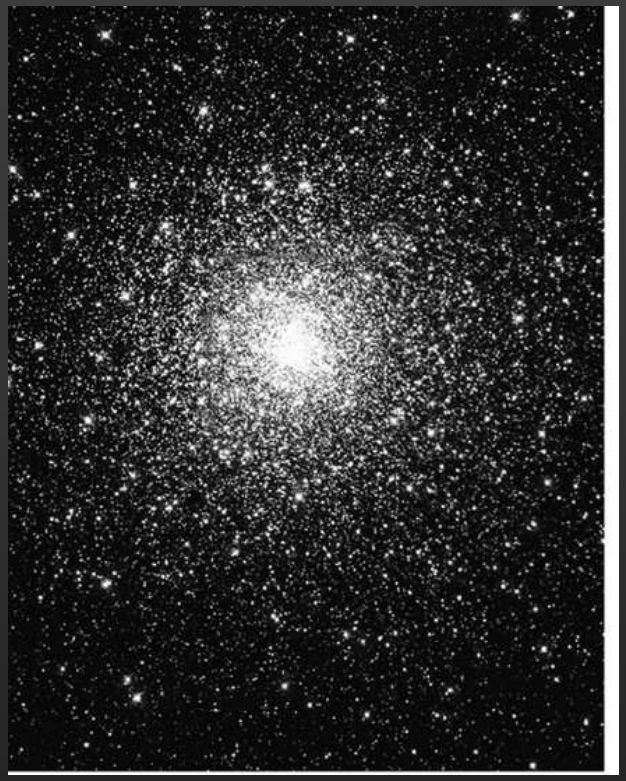
- In-class movie: Powers of ten

- In-class demo: Zooming 26 orders of magnitude

Age of human civilization : A mere blink of an eye in the cosmic timeline!

How do we estimate the age of Universe ?

Open Cluster Pleades

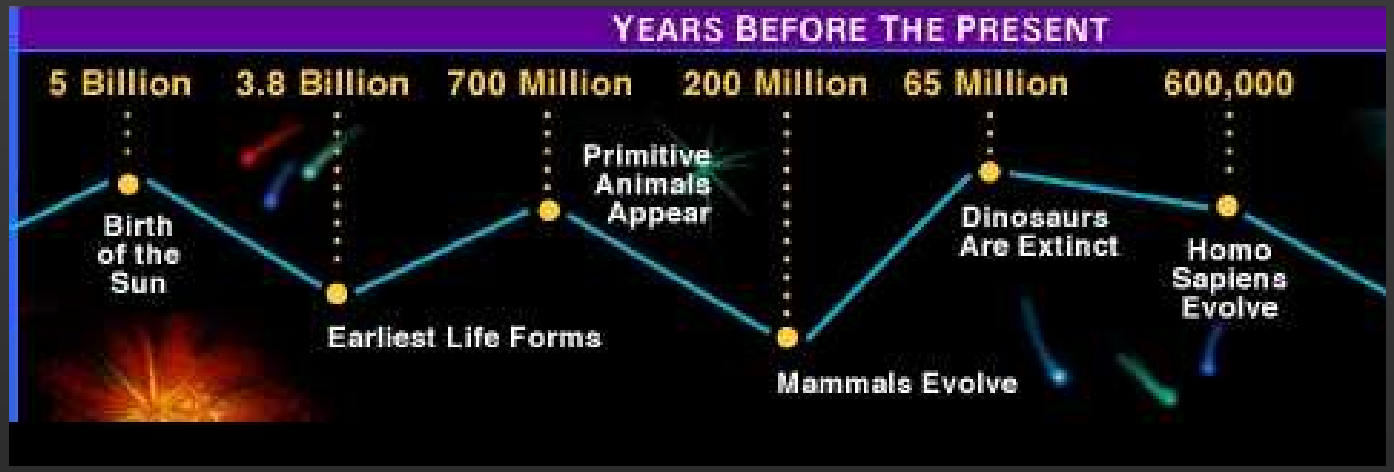


Globular cluster M80

On way is to observe stellar clusters called globular clusters and use the (color, brightness) information …….

Age of Universe today = 13.7 Billion years = 13.7 x 1000,000,000 years

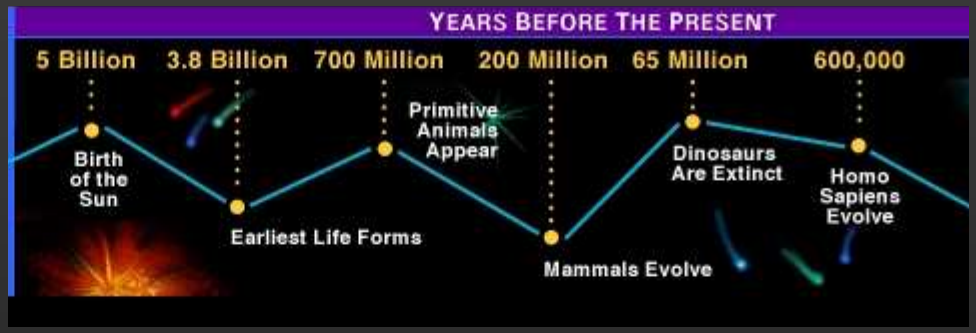
Humanoids appeared only 600,000 years ago

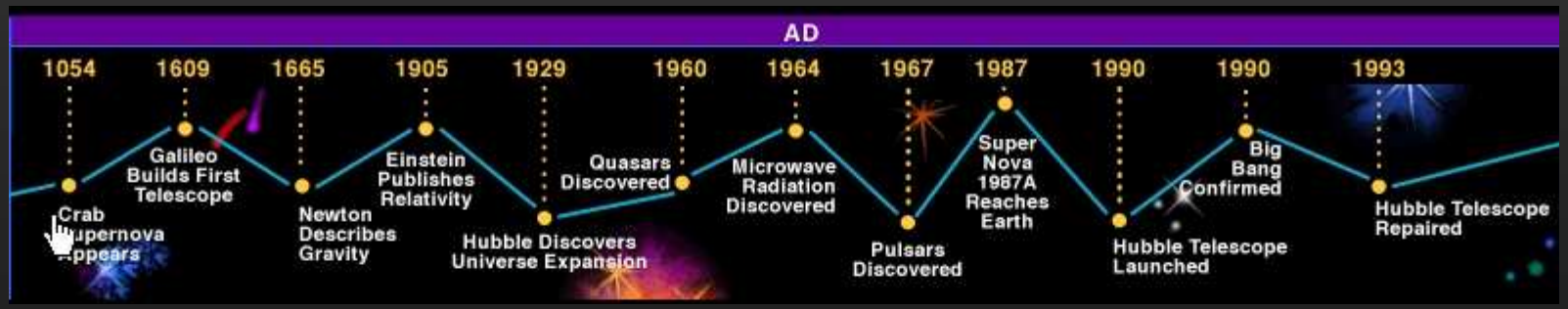


à If we make an analogy where the age of our Universe (13.7 billion years) is represented
by one year, from Jan 1 to Dec 31,
then humans appeared only in
last hour of Dec 31 …..a mere blink of an eye away.

The Last Century: A Privileged Era

Although we (humans) have been around for 'a mere blink of an eye' (600,000 years) , compared to the age of the Universe (13.7 billion years) , we have made tremendous progress in understanding our origin and evolution, especially in the last century

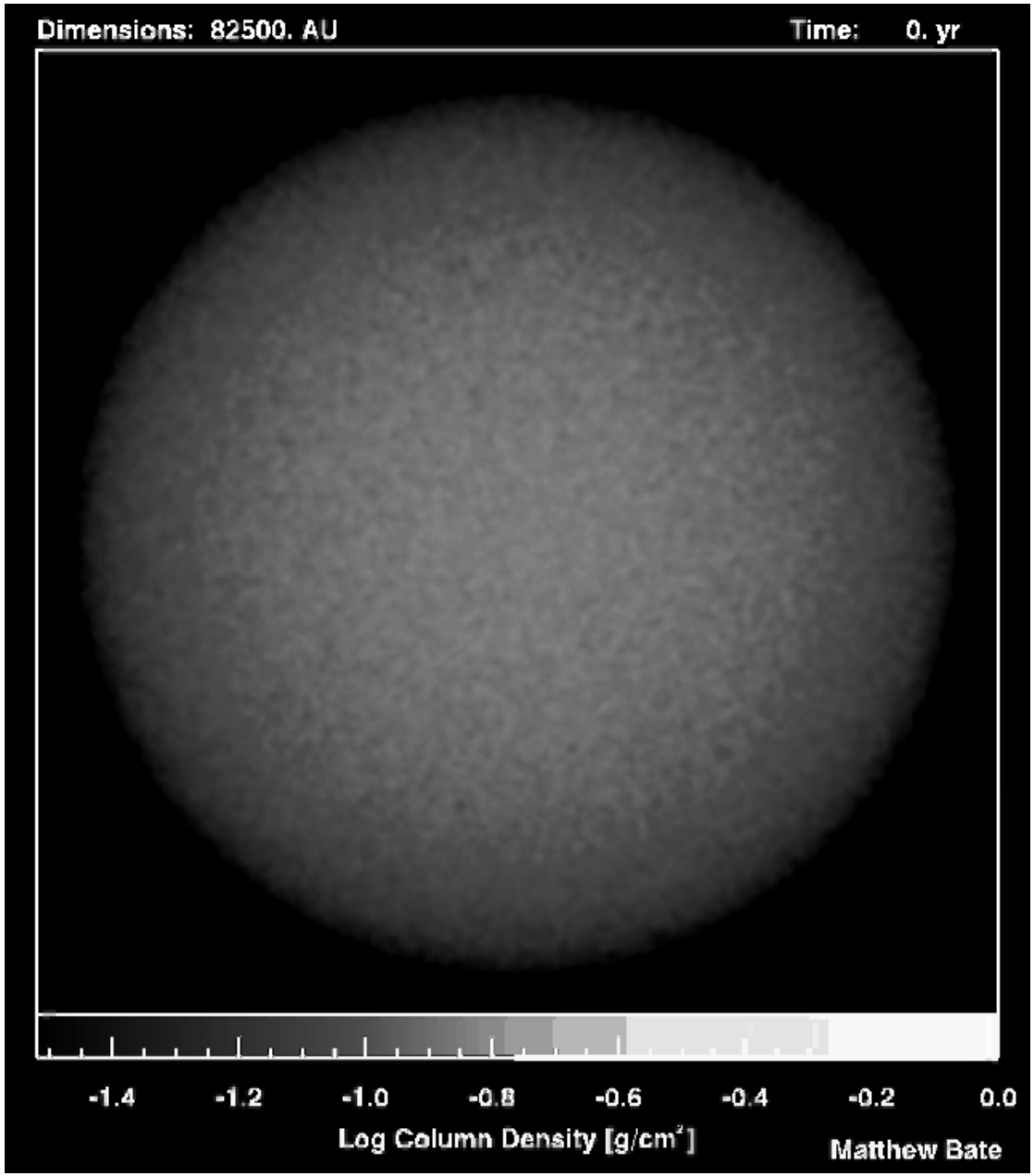




Einstein's theory of relativity, dark matter and dark energy discovered; COBE, Hubble and other NASA Great Observatories launched …

How do stars and planets form?

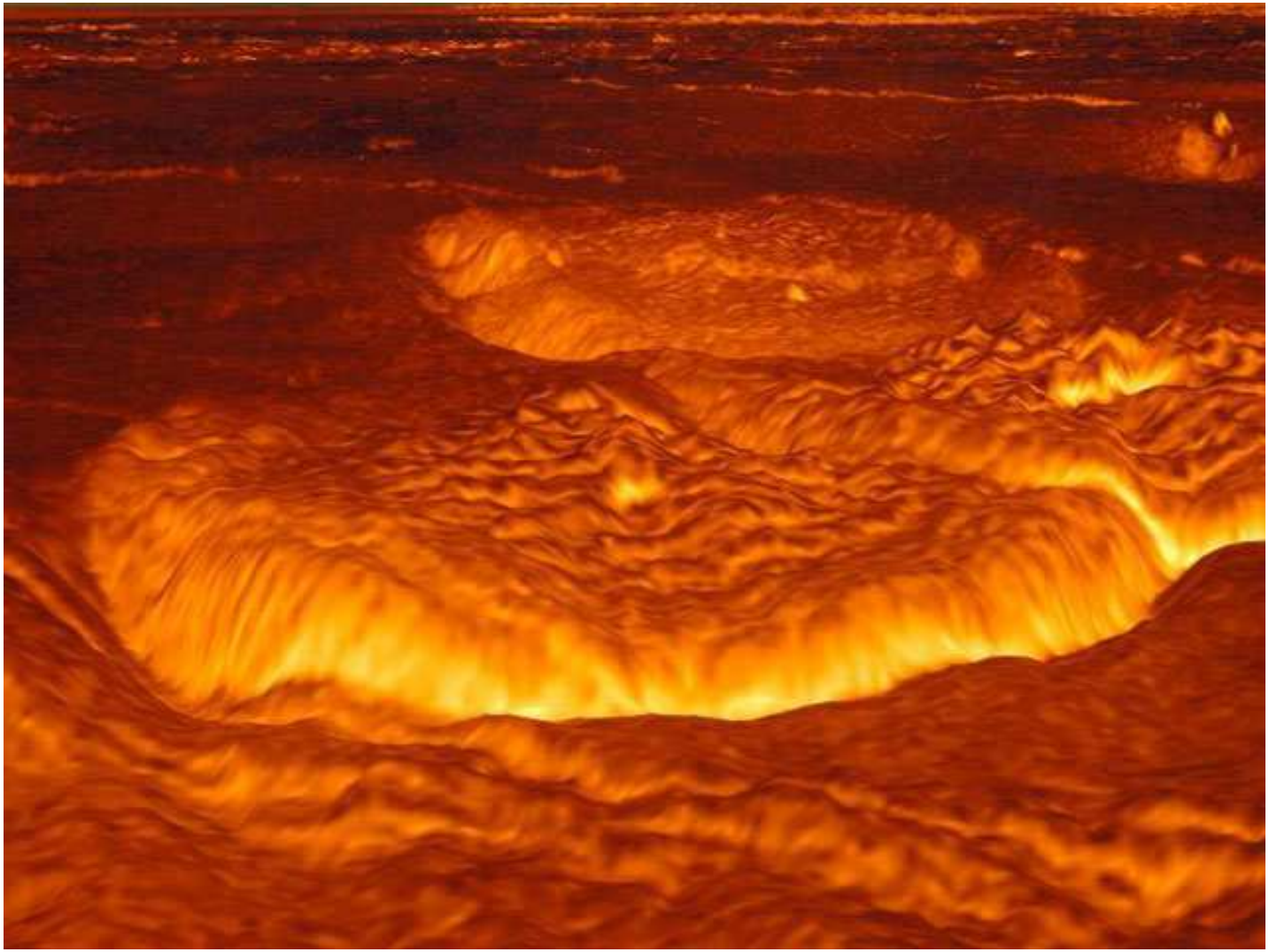
Collapse of a cloud to form a Sun-like star and its planetary system



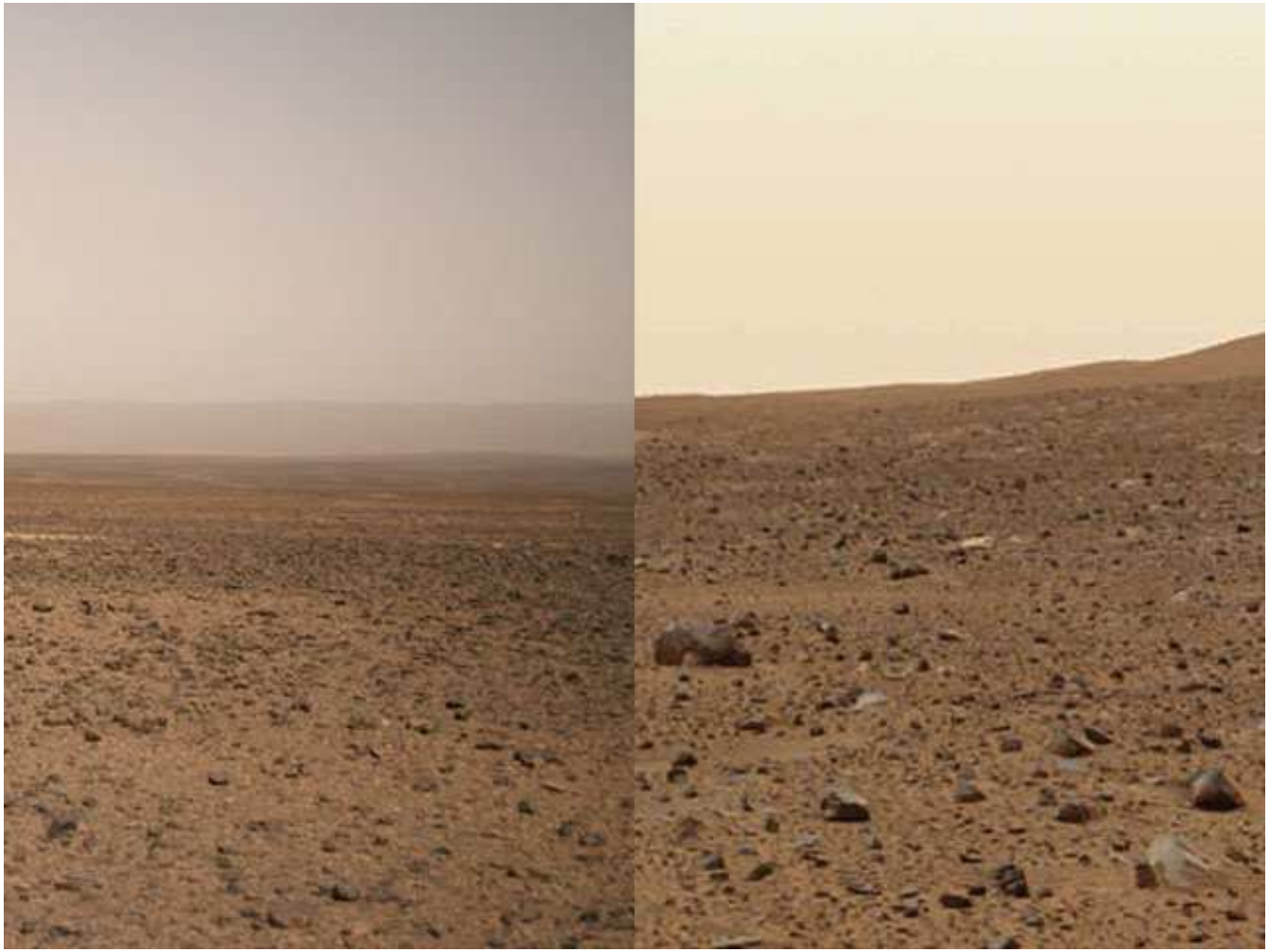
The simluation shows the collapse and fragmentation of a molecular cloud with a mass 50 times that of our Sun. The cloud iniitially has a diameter of 1.2 light-years (9.5 million million km) and a temperature of 10 K.

The cloud collapses to form stars. Surrounding some of these stars are swirling discs of gas which may go on later to form planetary systems like our own Solar System.

Condition for life on a planet



à Computer reconstruction of the surface of Venus was created from Magellan spacecraft data
à Venus' surface is so hot and hostile that no surface probe has lasted more than a few minutes.

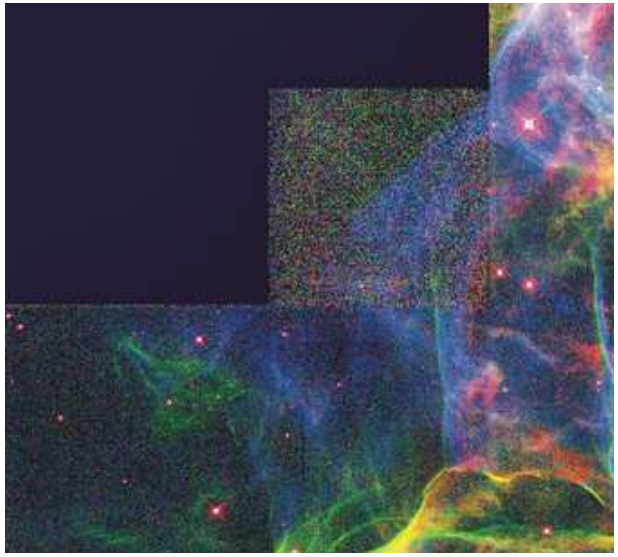


- à One image is taken by robot Spirit rover currently on Mars. (Twin Rovers landed on Mars in Jan 2004 as part of NASA's Mars Exploration Rover mission.)
- à Other image taken by a human across the desert south of Morocco on Earth

Why is it said that humans are “stardust” ?

Supernova remnant: Expanding hot clouds of gas produced when a high-mass star undergoes a supernova explosion at the end of its life. The gas is enriched with heavy elements like C , O, S.

- Cygnus loop SN remnant; 130 ly; optical
- HST/optical : Visibe Ionized O, Atomic H, ionized S



Crab Nebula; VLT/ Optical

First observed in 1054

Present-Day Galaxies: Diversity and Multiplicity

Galaxies

What is a galaxy ?

Collection of few times (10^8 to 10^{12}) stars orbiting a common center and bound by gravity. Made of gas, stars, dust, dark matter.

They come in many shapes and sizes

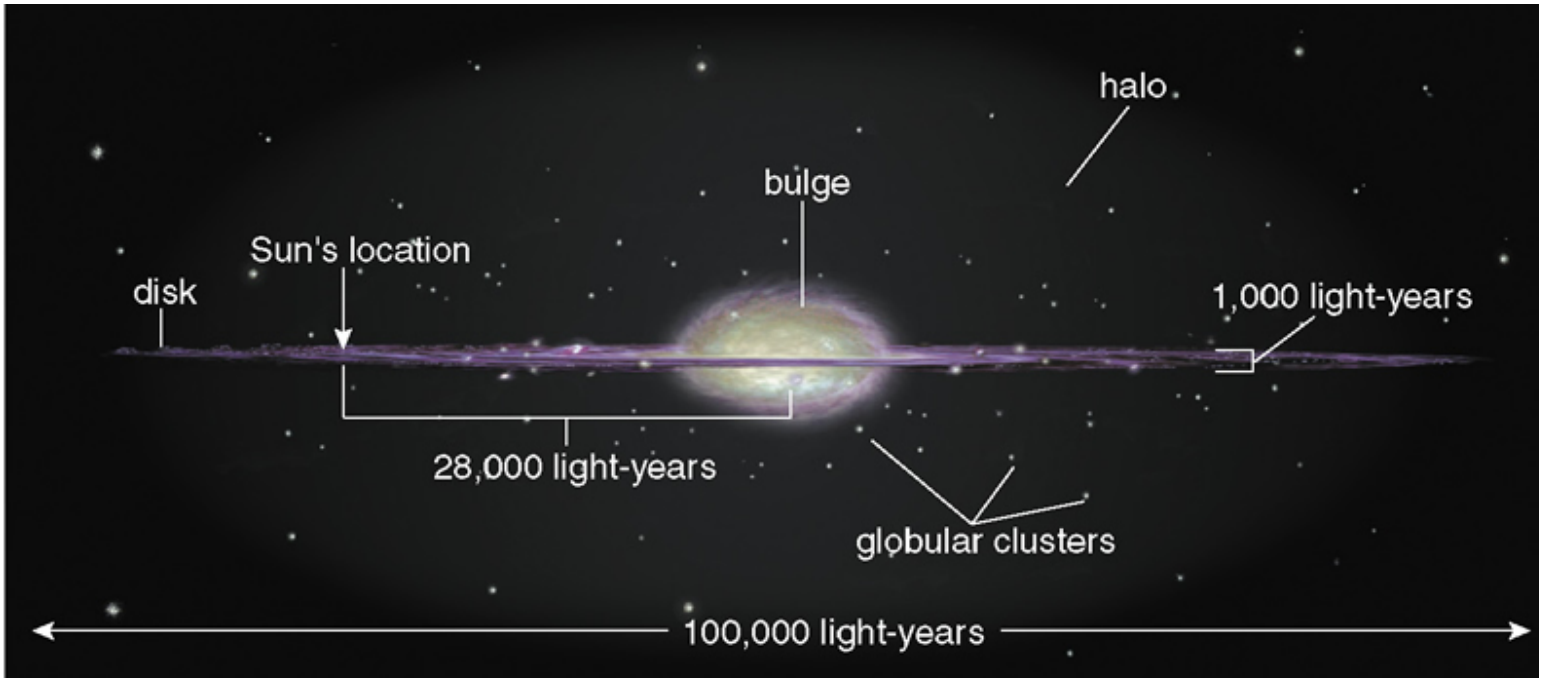
Spiral Galaxies

They have a disk component and contain up to 10^{12} stars

Have lots of gas, dust, ongoing star formation .

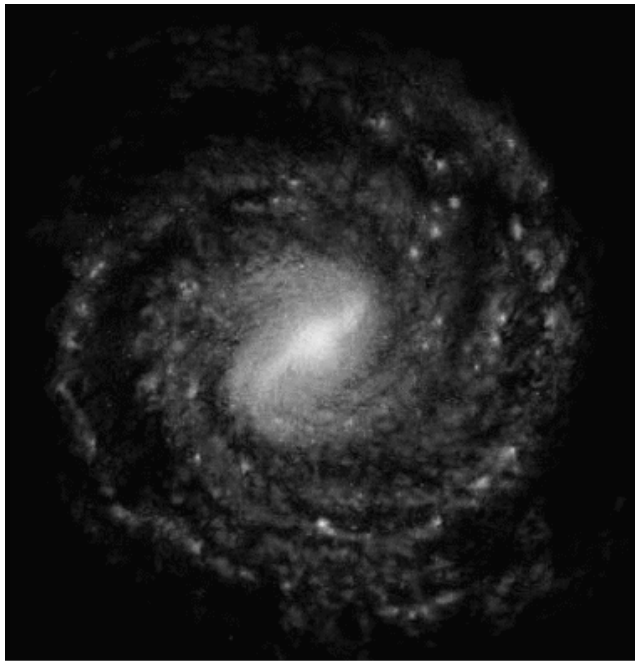
Unbarred spiral (SAab) NGC 4622

Strongly Barred spiral (SBbc) NGC 1300



Edge on view

Face on view



Our Galaxy, the Milky Way is a barred spiral galaxy, 100,000 light years across, hosting our Sun and Solar system

Elliptical Galaxies

Spheroidal systems (shaped like a water melon) and have no extended disks
Have a smooth appearance.
Are mostly made of old stars, have little gas, dust, and recent star formation

Giant elliptical M87

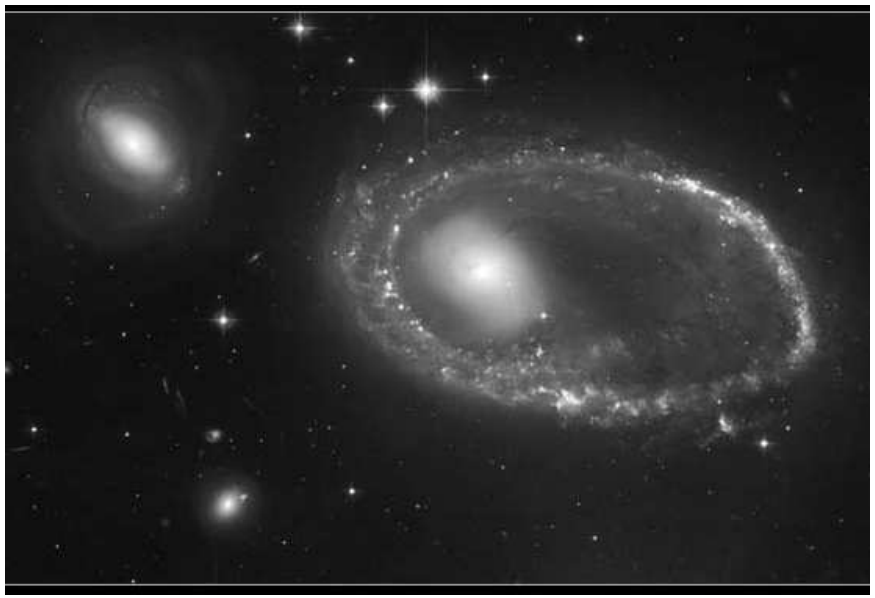
Galaxy Collisions: Cosmic Fireworks And New Personalities

Interactions between galaxies can induce dramatic changes in morphology.

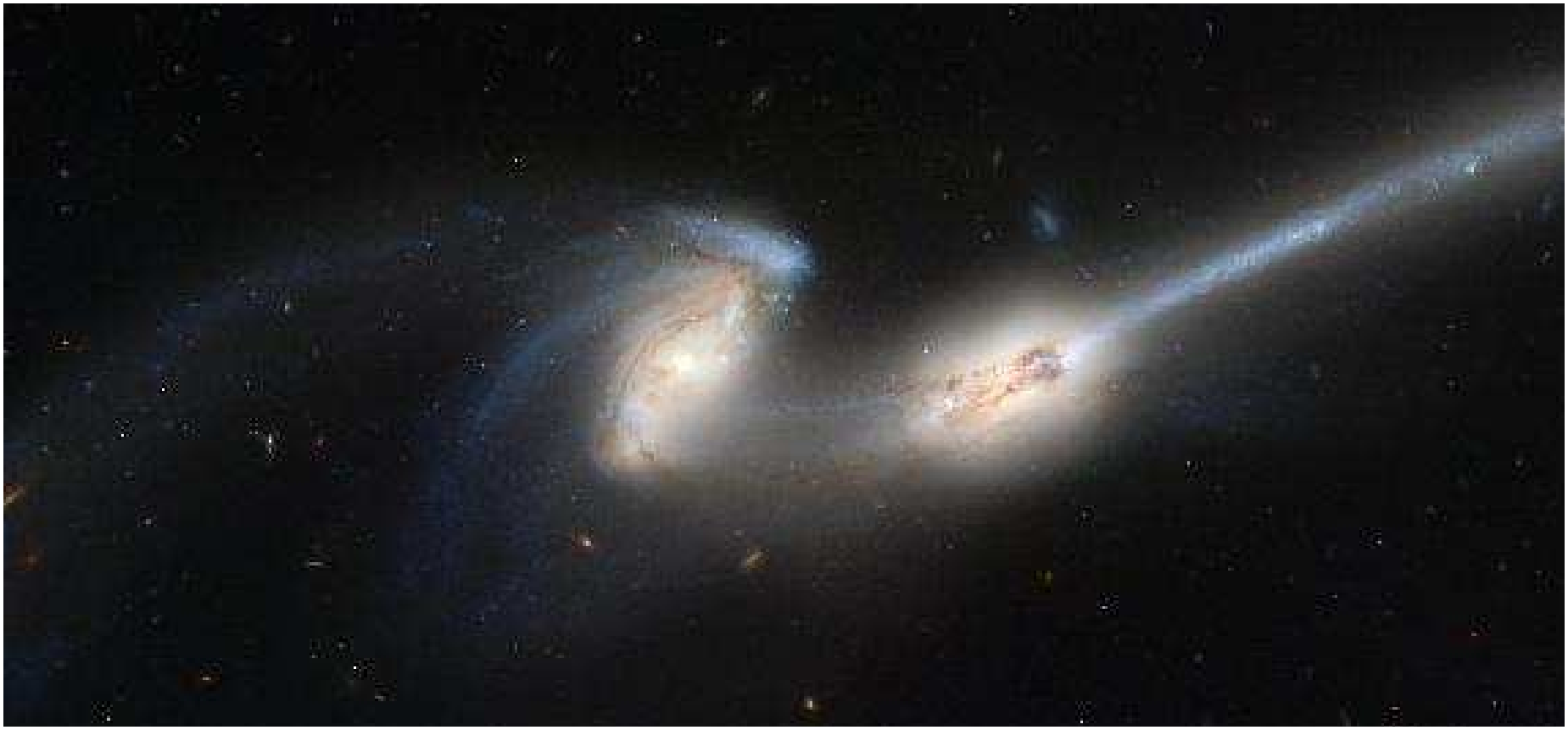
Polar ring galaxy
NGC 4650

Cartwheel galaxy
Head-on collision

Ring galaxy AM 0644-741 50,000 ly across



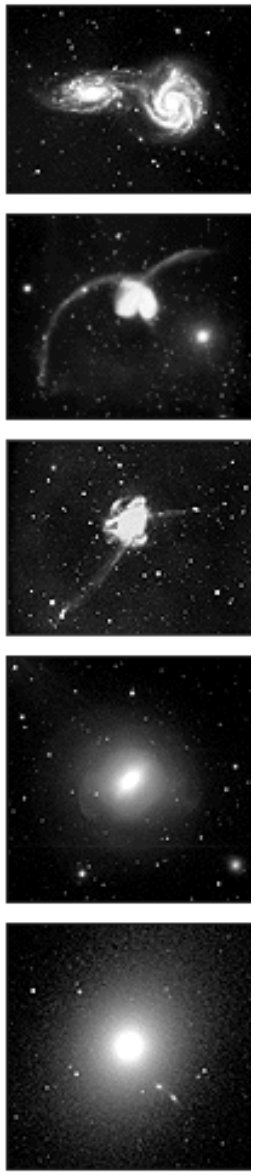
Interacting galaxies in the local Universe



Collision of 2 spiral galaxies, 100,000 light years apart

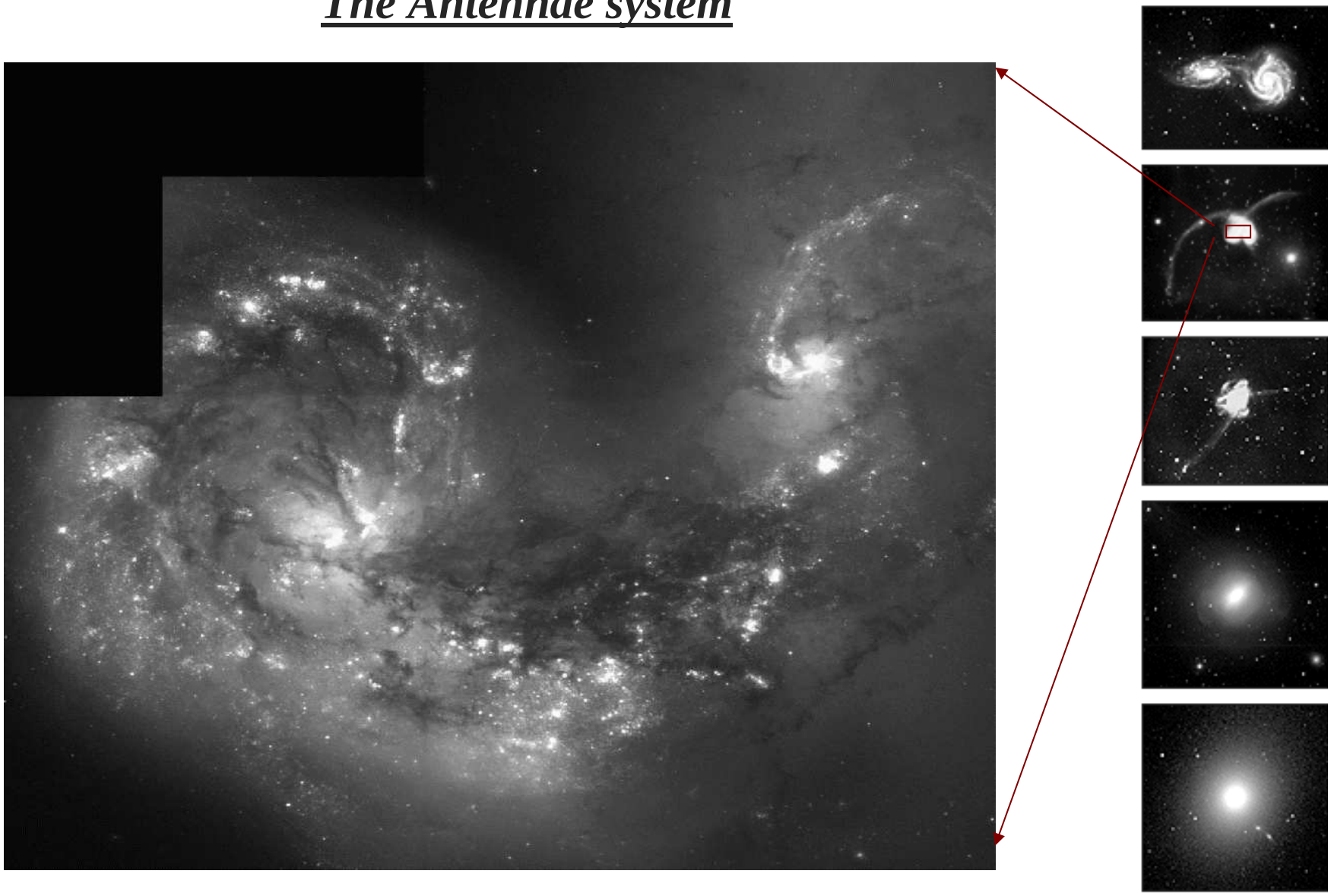
NGC 4736 / The Mice (Credit: NASA & ACS Science team)

Simulation of Major Mergers



Merger of 2 spirals can produce a dramaticallly different system-à What?

The Antennae system



The HST image shows a mess of gas and dust BETWEEN the two disk galaxies that collided

Is our own Galaxy interacting?

Has it eaten up some of its neighbors already?

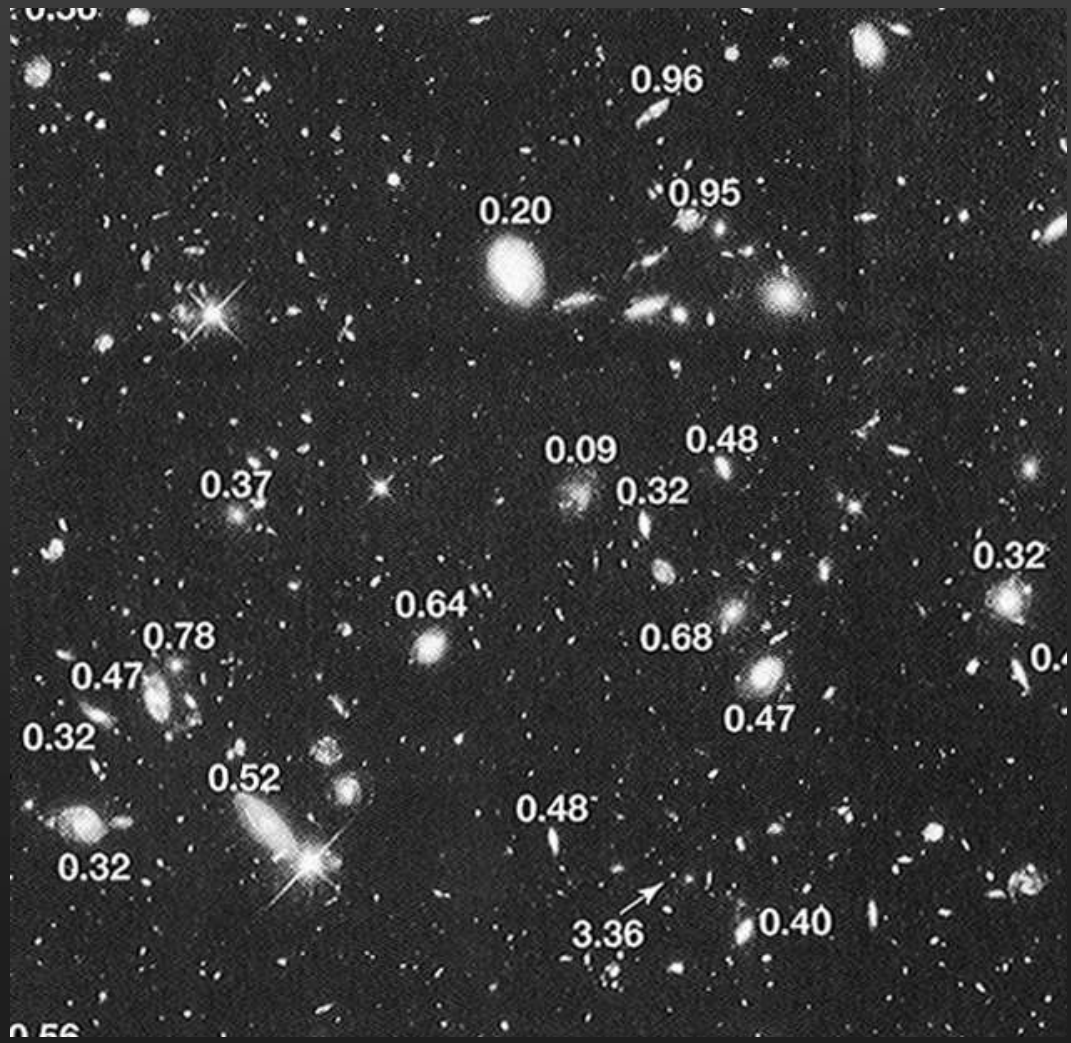
Is it on a collision course in the future?

What is its predicted fate?

Looking Back in Time to Probe the Young Universe

How do astronomers look back in time?

Images of distant galaxies allows us to look back in time

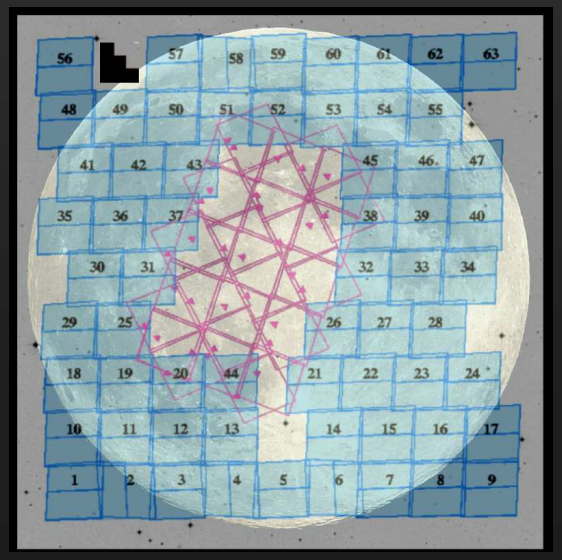


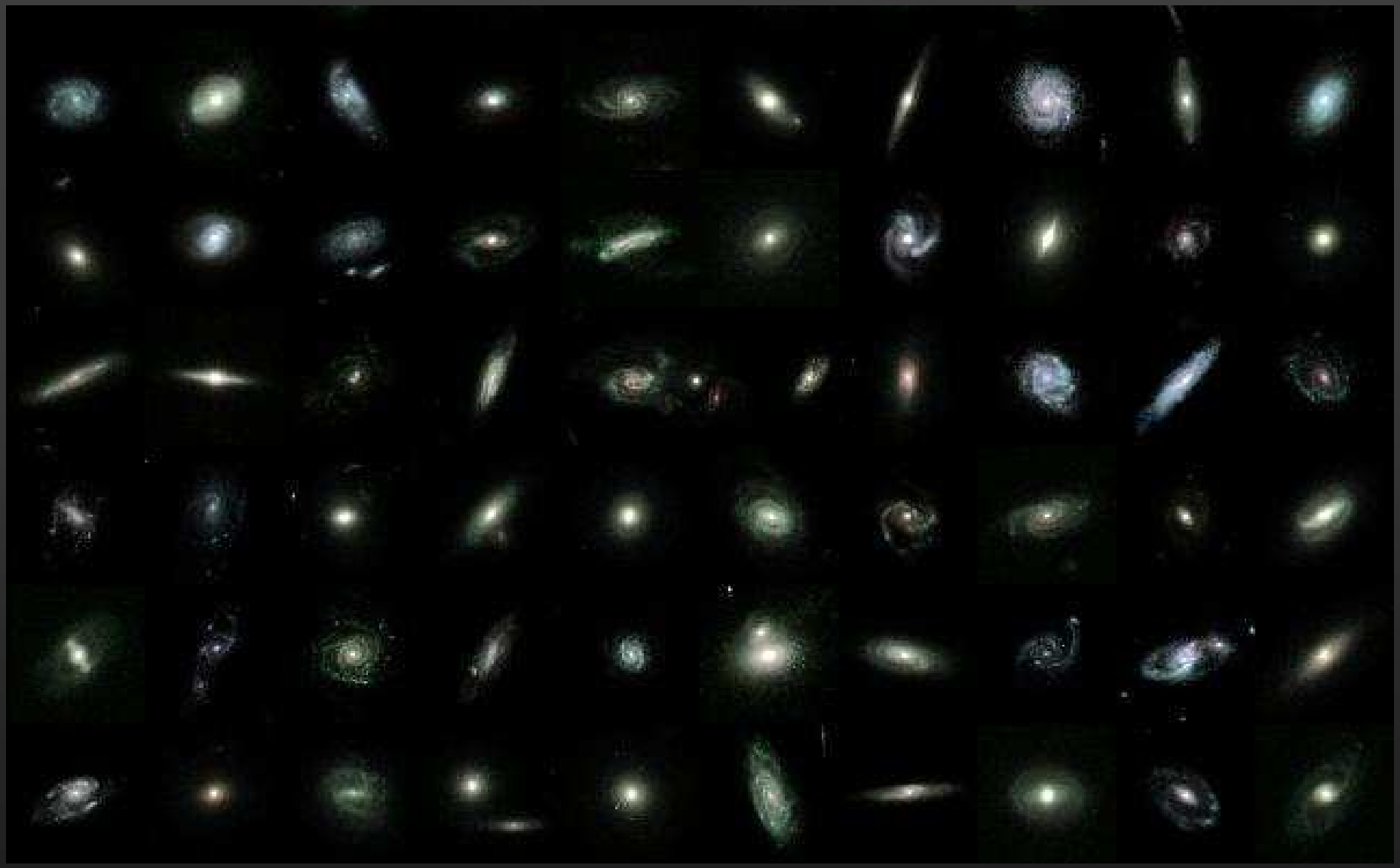
Looking back in time 9 billion years with the GEMS Survey

We conducted the GEMS survey in 2004 using Hubble Space Telescope

- à GEMS is the largest-area survey ever done in 2 filters with Hubble Space Telescope
- à GEMS survey images are deep enough to allowsus to look back in time about 9 billion years, out to epochs when the Universe was only a third of its present age !!!

30’



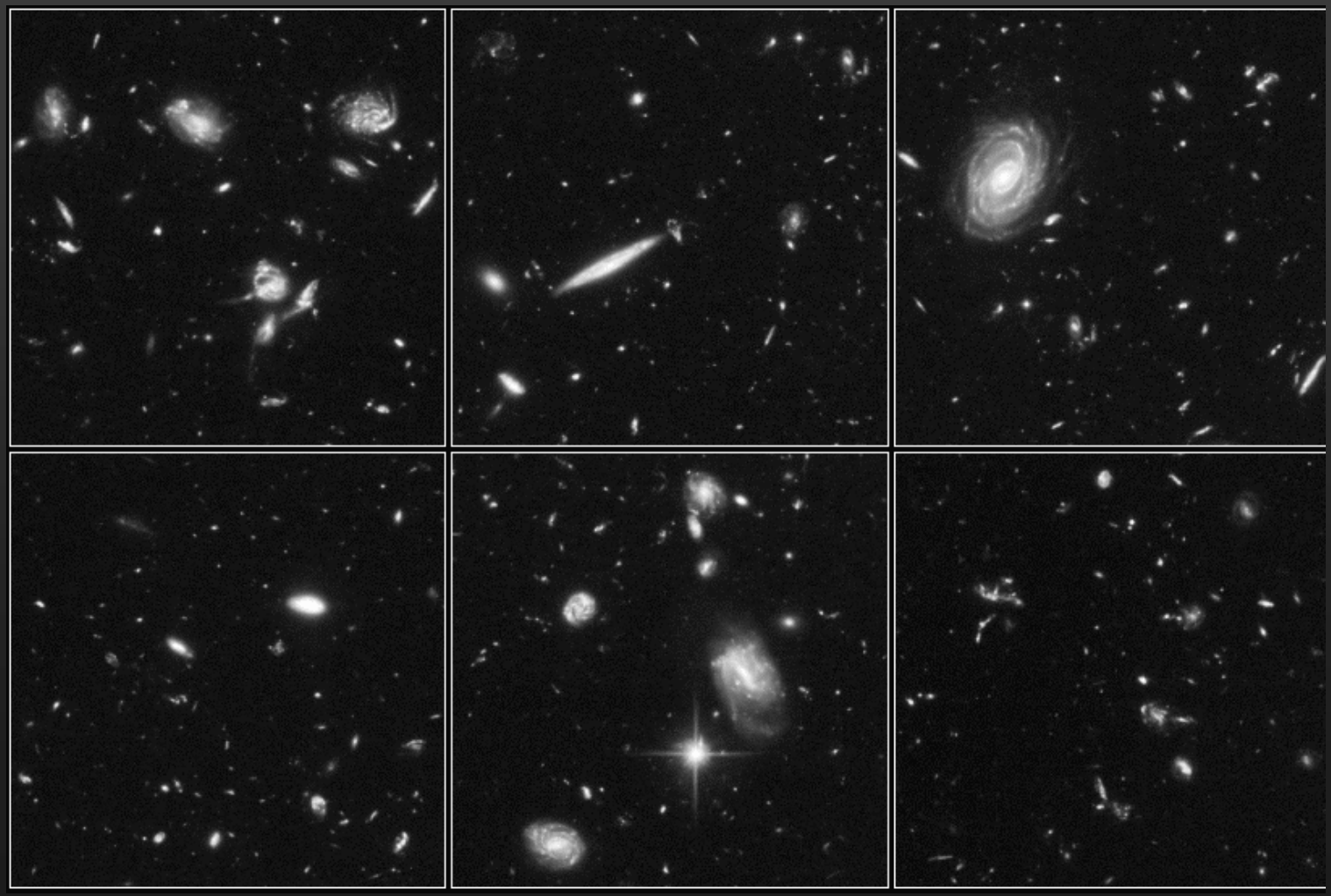


Diversity of galaxies 9 Gyr ago, when Universe was only 30% of its present age!

The family album of how galaxies looked like in their youth ('thirties')

Looking back in time 12 billions years with the HUDF Survey

The Hubble Ultra Deep Field (HUDF) is ***the deepest visible-light image of the Universe.*** it consists of a million second s exposure taken by the HUDF team with the Hubble Telescope in 2004. Allows us to look back about 12 Gyr in time…..



From 10^{-43} s to the first 3 minutes

The Beginning of Time - From 10^{-43} s to to the First Second

0 | 10^{-43} s | 10^{-38} s | 10^{-10} s | 10^{-3} s | 1 s → Time

$t < 10^{-43}$s
Planck era

10^{-43}-10^{-38} s
GUT era

10^{-38} - 10^{-10} s
Electroweak era

10^{-35}-10^{-32}
Inflation

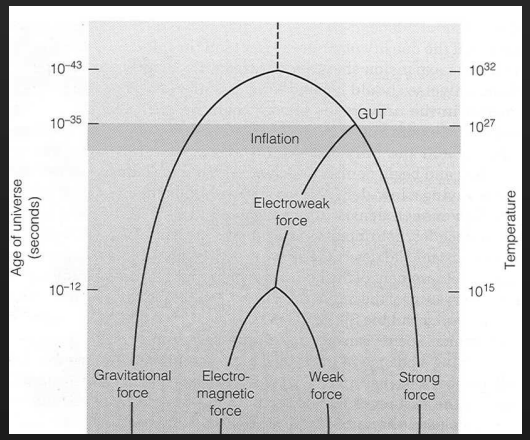
10^{-10}s - 1 s
Matter-antimatter pairs form from radiation and a net excess matter particles (n p e) emerge

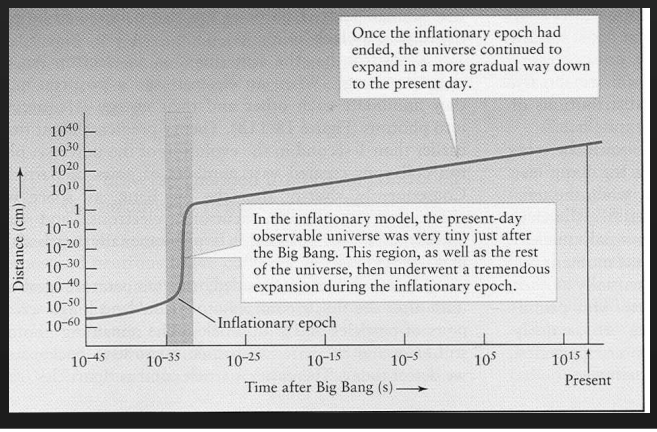
In GUT era, gravity freezes out while the strong and electroweak forces remain unified as a GUT force

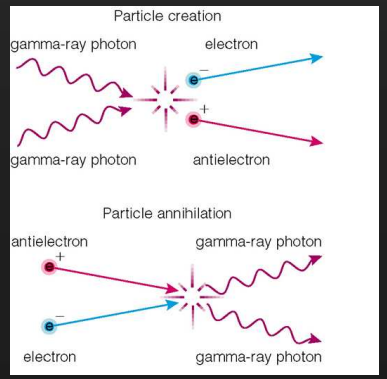
In the electroweak era, the strong force freezes out from electroweak forces. Inflation blows up the size of the Universe by a factor of 10^{25}

n, p freeze out at t~ 10^{-6} s when T drops below 10^{13} K

e- freeze out at t ~1 second when T drops below 10^{9} K

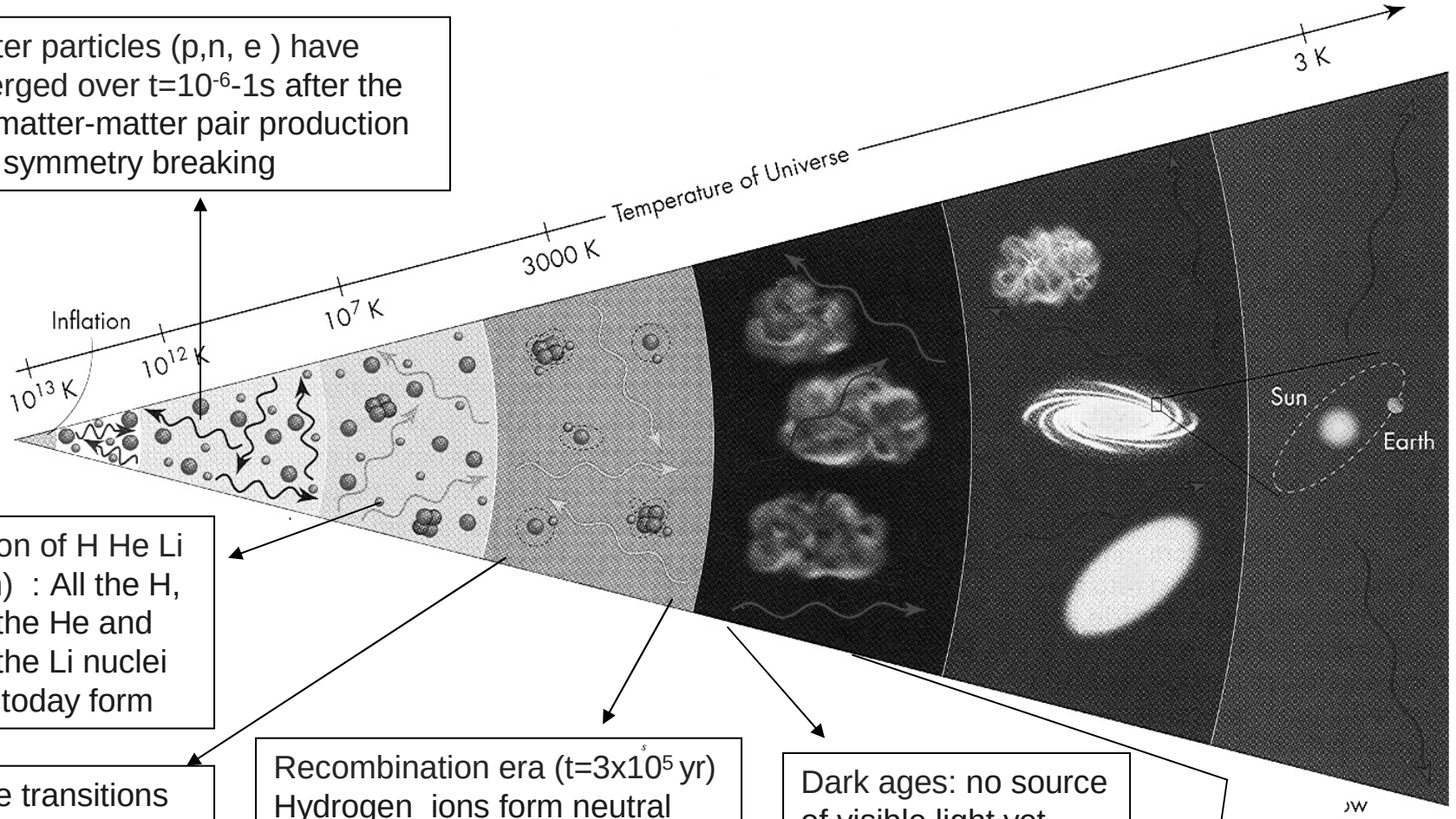






Overview: From the first second to the first billion years

Matter particles (p,n, e) have emerged over t=10^{-6}-1s after the antimatter-matter pair production and symmetry breaking



Formation of H He Li (t=3 min) : All the H, 90% of the He and 10% of the Li nuclei present today form

Universe transitions from radiation-dominated to matter-dominated (t=3x10^4 yr)

Recombination era (t=3x10^5 yr) Hydrogen ions form neutral atoms, and Universe changes from opaque to transparent. The photons released are the oldest ones we see and get redshifted to form the CMB at mm wavelengths and T=2.7 K

Dark ages: no source of visible light yet.

First luminous objects form: stars at t=1-2 x10^8 yr), then proto-galaxies (t=3-7x10^8yr) These end the dark ages and their UV light also reionized neutral H back to protons and electrons (reionizaion era) .