Astro 301/ Fall 2006

(50405)

Introduction to Astronomy

http://www.as.utexas.edu/~sj/a301-fa06

Instructor: Professor Shardha Jogee

TAs: Irina Marinova + TBD

Lecture 1: Th Aug 31

Pick up handouts and flyers

1) Handout 1
   - Memo to Undergraduate Students regarding Astronomy Courses
   - Course Syllabus
   - Course calendar

2) Flyer for Astro 101L

Astronomy

The quest to understand the origin and future of the Universe using scientific methods

Explores size scales from the infinitesimal to the grandest
(10^{-10} m to 10^{23} m)

Explore time scales that range from the earliest epochs to the present day
t= 10^{-43} s to 1.3 x 10^{17} s

Some topics we will address

Constituents of the Universe: stars, galaxies, planets, dark matter dark energy.

What physical laws govern the evolution of the Universe from the Big Bang to now?

When and how did stars, planets, galaxies, and black holes form?

How do stars form, shine and die? Why are we ‘stardust?’

How did galaxies like our own Milky Way form? How will they evolve?

What is the role of dark matter and dark energy?

This is a science course :
WE WILL NOT BE DEALING WITH CONSTELLATIONS

Go to public viewing in RLM or Painter Hall for constellation/planet viewing

Outline

-- Course syllabus
  Course Pre-requisites
  Undergaduate Memo
  Textbook
  Help and Office Hours
  Grading policy
  Lecture attendance policy
  Extra Credit

-- Extra Labs

-- Extra Class Resources

-- Guided Tour of the Course

-- Math content of this course

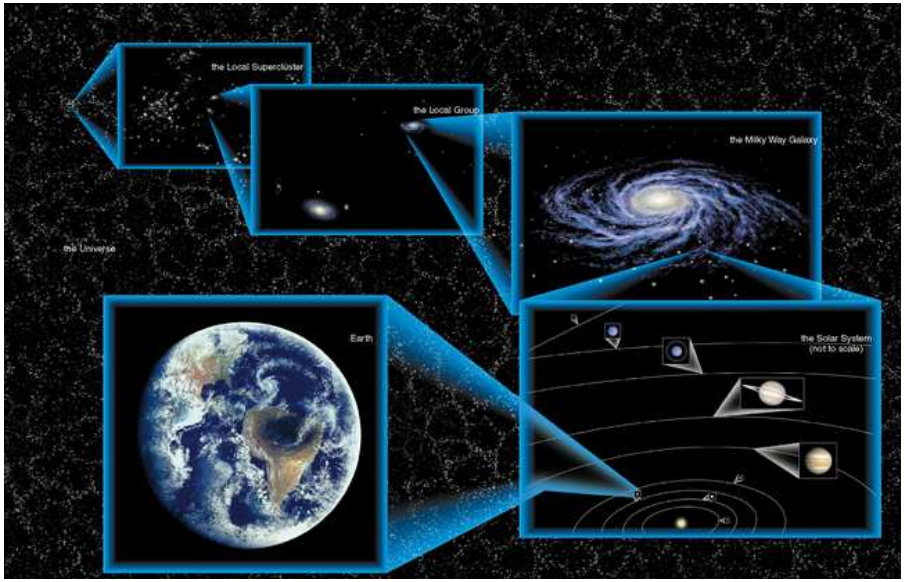
Earn extra credit (EC) by getting certified to use the Painter Hall 9-inchTelescope

Excerpts from the Course

Astronomy: From the Infinitesimal to the Grandest Scales

From the tiniest to the grandest scales

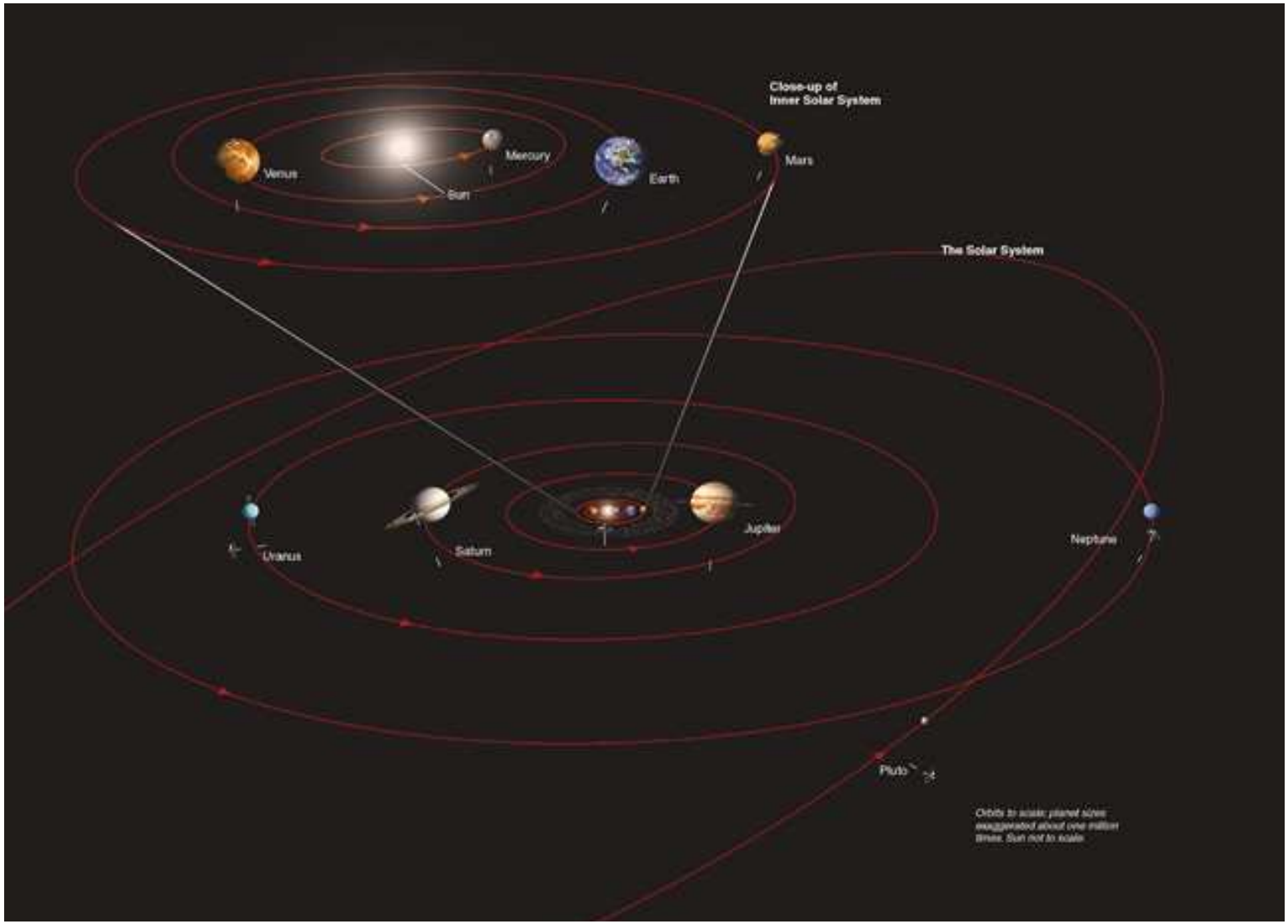
Radius of a hydrogen atom	5.0×10^{-11} m
Radius of Earth	6.4×10^{6} m
Sun-Earth distance	1.5×10^{11} m
Size of solar system from Sun to Pluto	39.5 Au = 3.95×10^{12} m
Distance travelled by light in 1 year	1 light year (ly) ~ 10^{16} m or ten thousand trillion m
Distance between stars	1 parsec (pc) =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



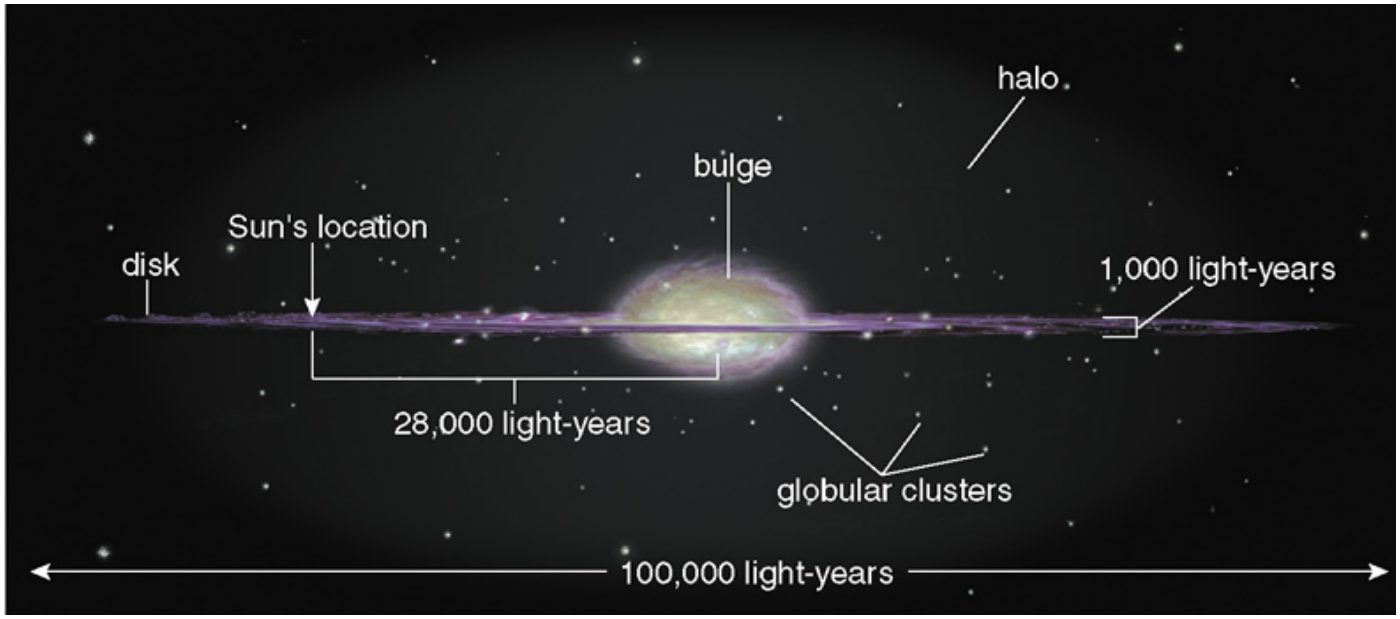
Our Solar System

Sun (star) + 9 planets M, V, E, Mars, J S N U (P=dwarf planet)

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

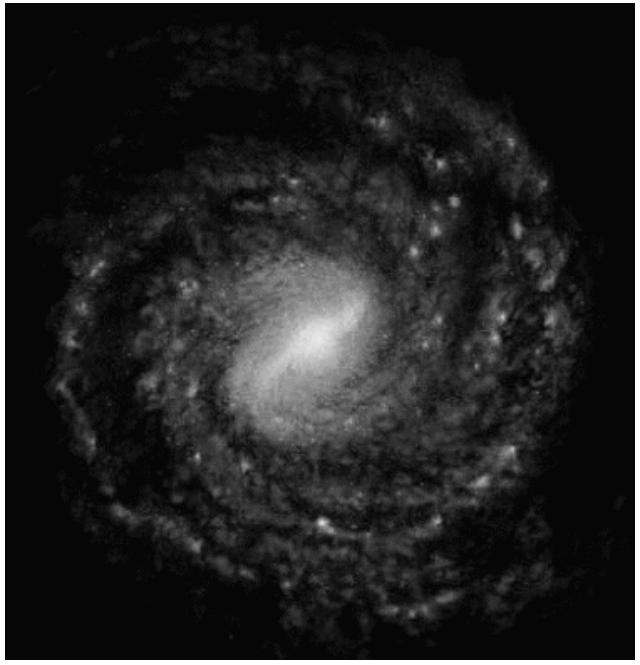


Galaxies are systems containing 10^8 to 10^{12} stars, plus gas, dust and dark matter



Edge on view

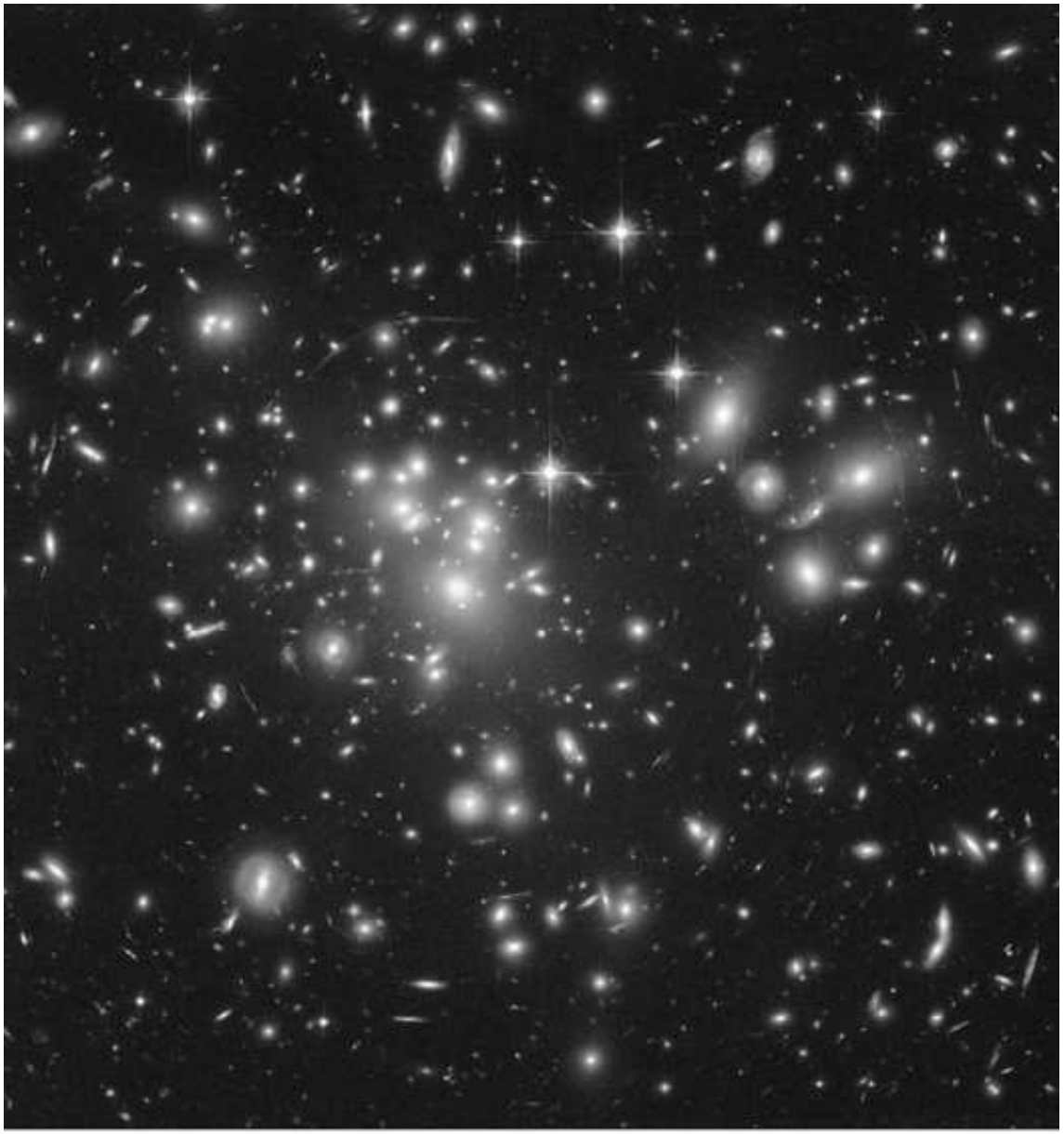
Face on view



Our Galaxy, the Milky Way is a barred spiral galaxy, 100,000 light years across, hosting our Sun and Solar system at 28,000 ly

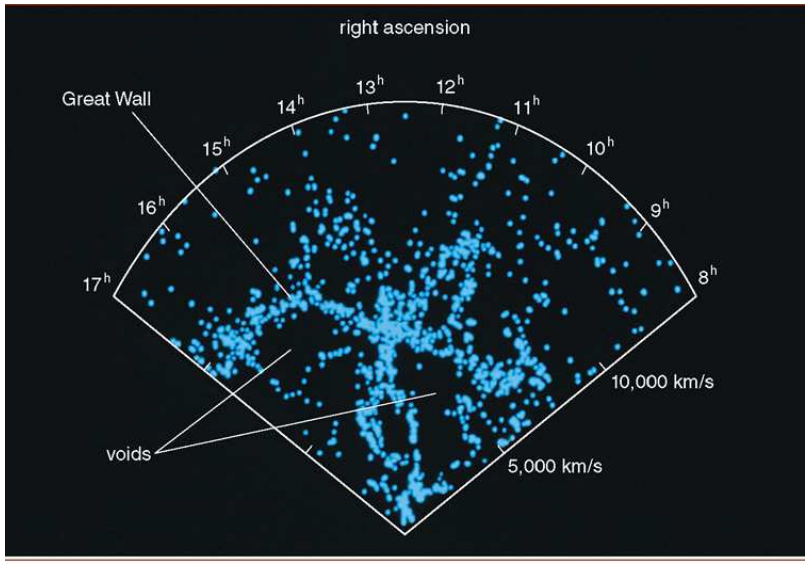
Groups/Clusters of galaxies = a set of galaxies bound by gravity.

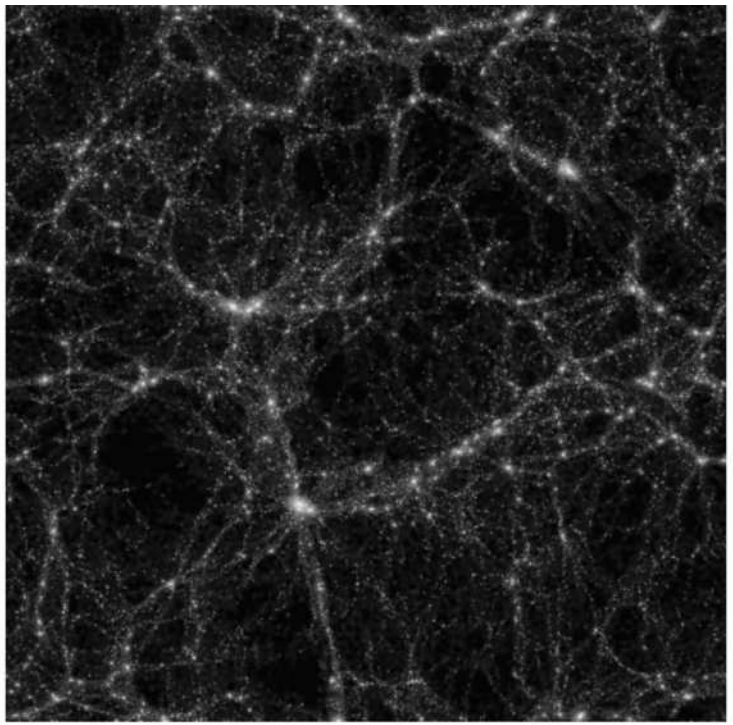
Virgo cluster = 64 x 10^6 lyr
Coma cluster = 3400 x 10^6 lyr
= 3.4 x 10^9 lyr
Abell clusters = several x 10^9 ly



Central Part of Abell
1689 Cluster of Galaxies

Region shown = 2 x 10^6 lyr





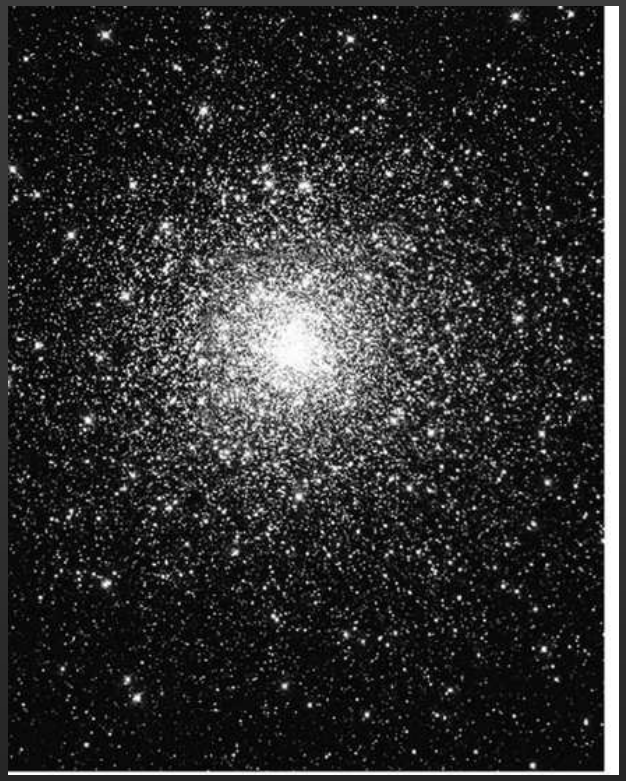
Large-scale structure: sheets, voids, filaments/walls

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

Astronomy :a young science in a very old Universe

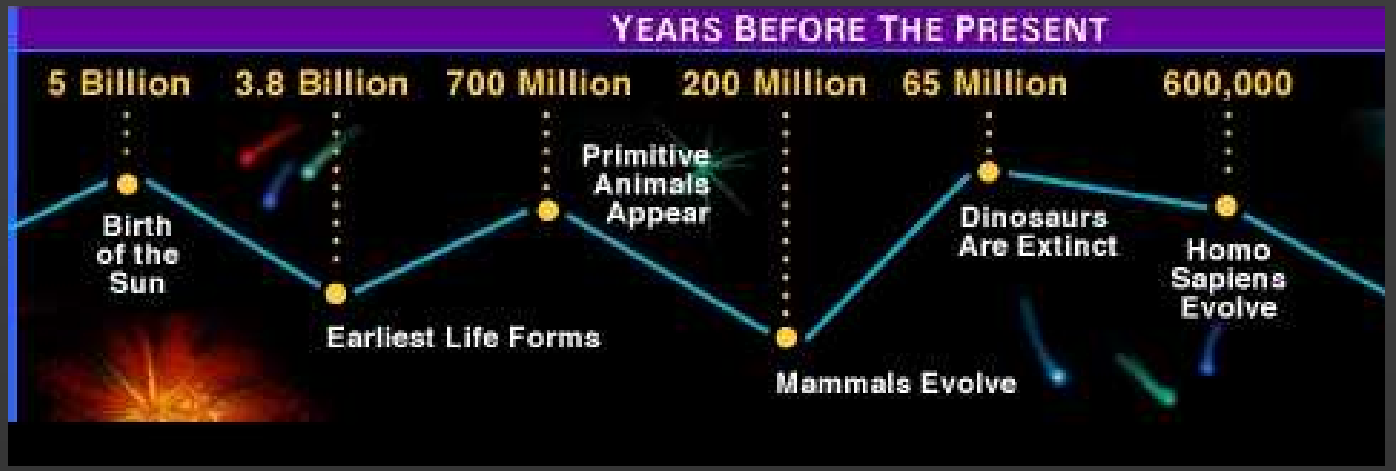
What is age of the Universe? How do we estimate this?

Open Cluster Pleades



Globular cluster M80

Observe old stellar clusters called globular clusters and apply theory of stellar evolution to infer age of oldest stars à lower limit on age of Universe!



Universe came into existence 13.7 billion years ago

Humanoids appeared only 600,000 years ago

If we represent the age of our Universe by one year, from Jan 1 to Dec 31

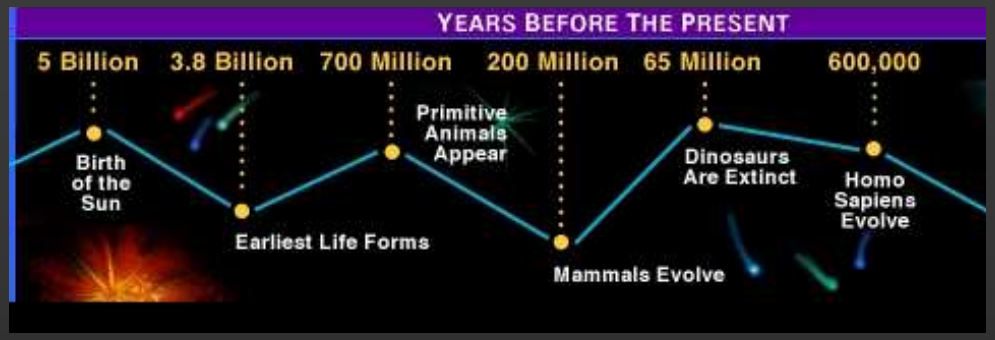
- à The Big Bang happened on Jan 1 at 00:00 hr
- à Today is Dec 31 at midnight
- à then humans appeared …. only at 11:37 pm on Dec 31

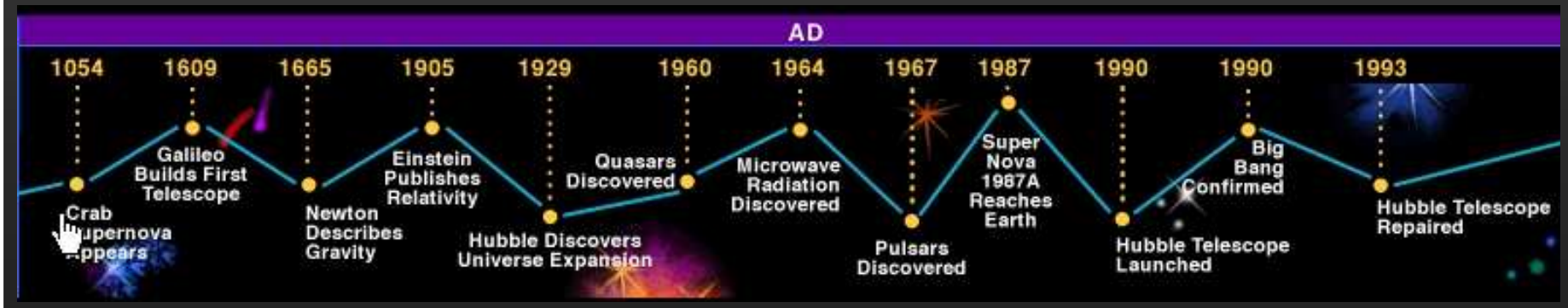
On a cosmic timeline, our civilization has been around for

a mere blink of an eye

The Last Century: A Privileged Era

The last century : tremendous progress in astronomy and astrophysics
à mapping the origin and evolution of the Universe



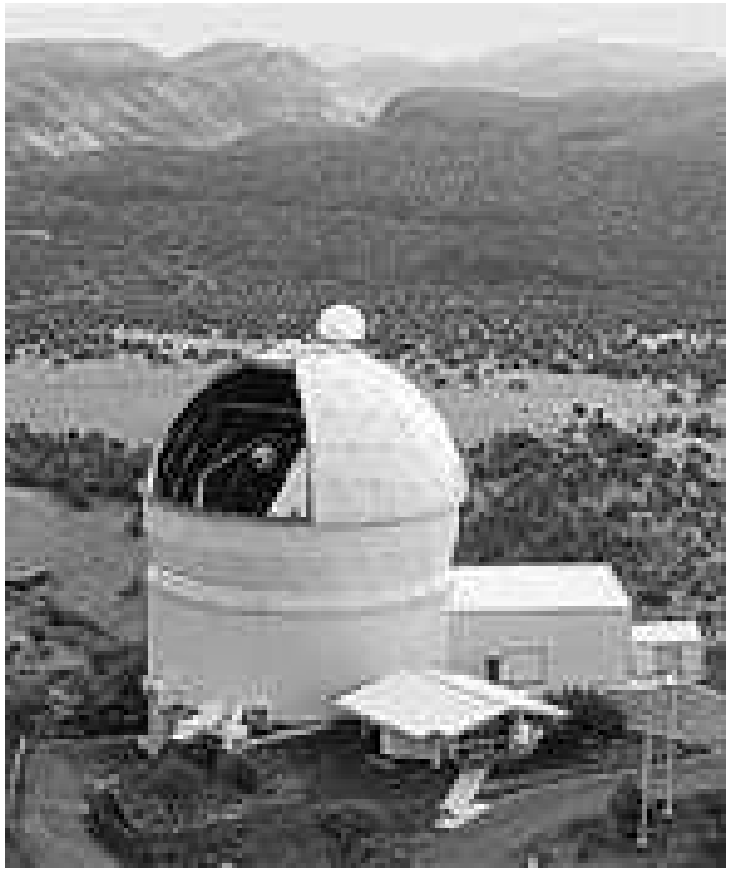


Einstein's theory of relativity, dark matter and dark energy discovered;
COBE, Hubble and other NASA Great Observatories launched,
Cutting edge galaxy surveys to look back in time at the first galaxies

Telescopes: Portals of Discovery

Largest Ground-Based Optical and Infrared Telescopes

10-m SALT telescope in South Africa
UT is a partner in the SALT consortium.
Inaugurated in 2005



9.2-m Hobby Eberly Telescope of
Mc Donald Observatory/ UT Austin

Largest Ground-Based Optical and Infrared Telescopes

Concrete base, 40 ft diameter, that supports the 9.2m Hobby Eberly Telescope

Next Generation Largest Ground-Based Telescopes

Giant Magellan Telescope GMT

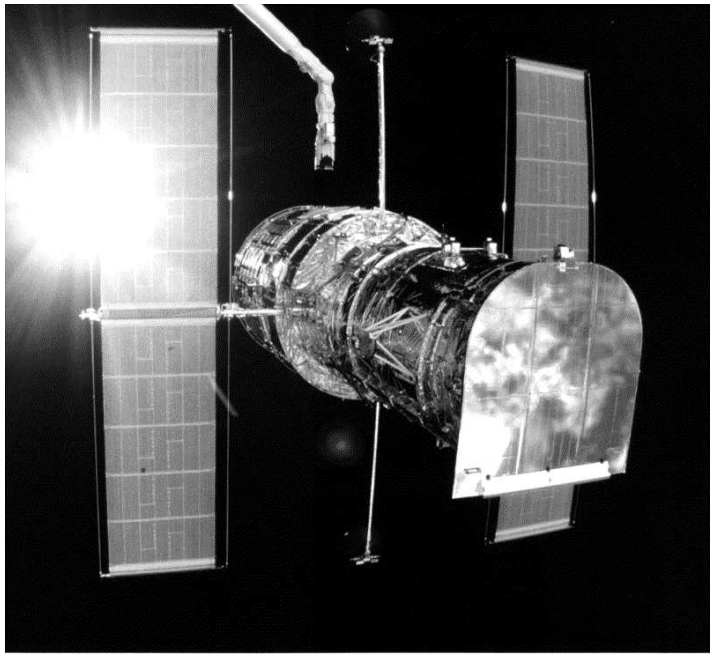
- 7 mirrors of size 8.4 m
(equiv to aperture of diameter 22 m)
- Location = Northern Chile
- First light in 2016

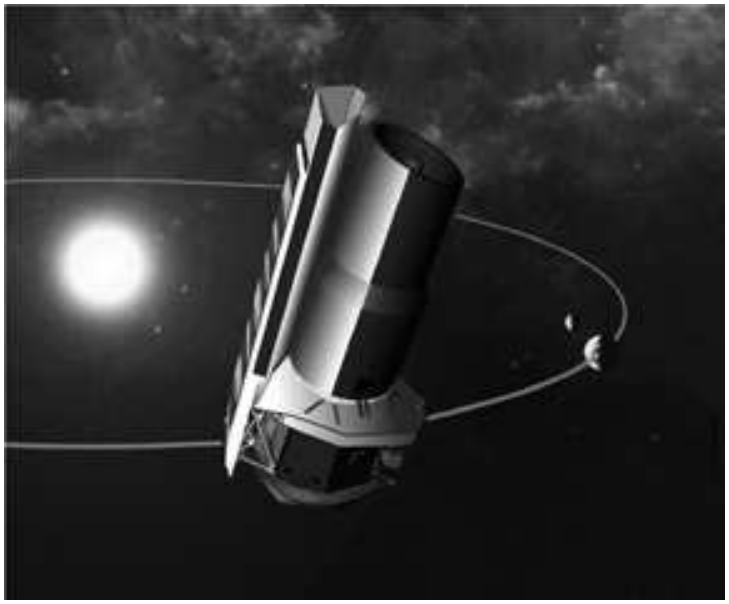
GMT partners include
- Arizona
- **UT Austin**
- Carnegie Observatories
- Harvard
- MIT
- Michigan

Casting of first mirror completed 27 Oct 2005!

NASA's Great Observatories

Hubble Space Telescope
(2.5 m; 1990)
Takes UV, optical and
near-infrared images
that are 10 times sharper
than from the ground



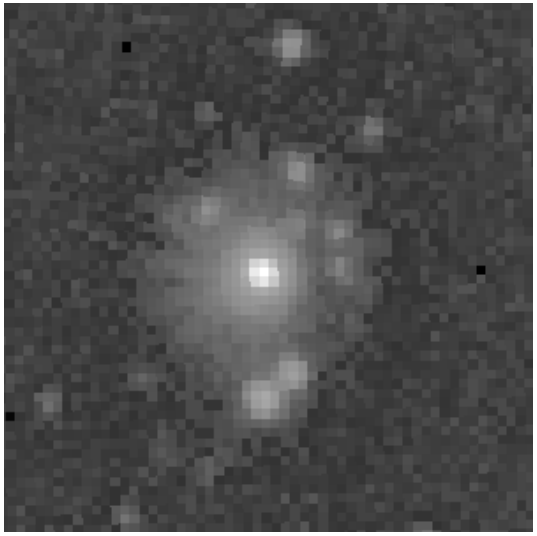


Chandra X-ray Observatory (CXO; 1999)
Largest satellite launched by Columbia

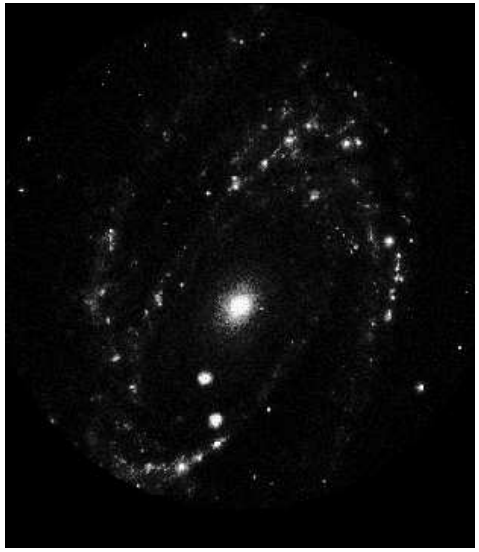
Spitzer Infrared
Space Telescope
(0.85m; 2003)

Largest infrared
satellite launched
into space

Multi-Wavelength view of M81



X-ray/ROSAT

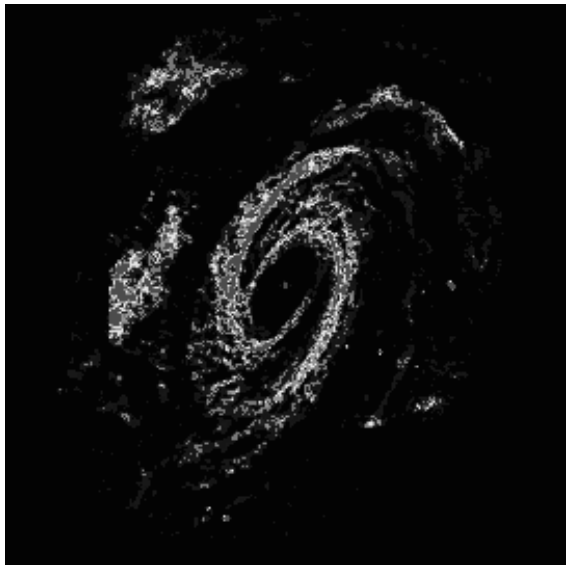


Ultraviolet/ASTR0-1

Visible light

Near infrared/Spitzer

Far-infrared/Spitzer

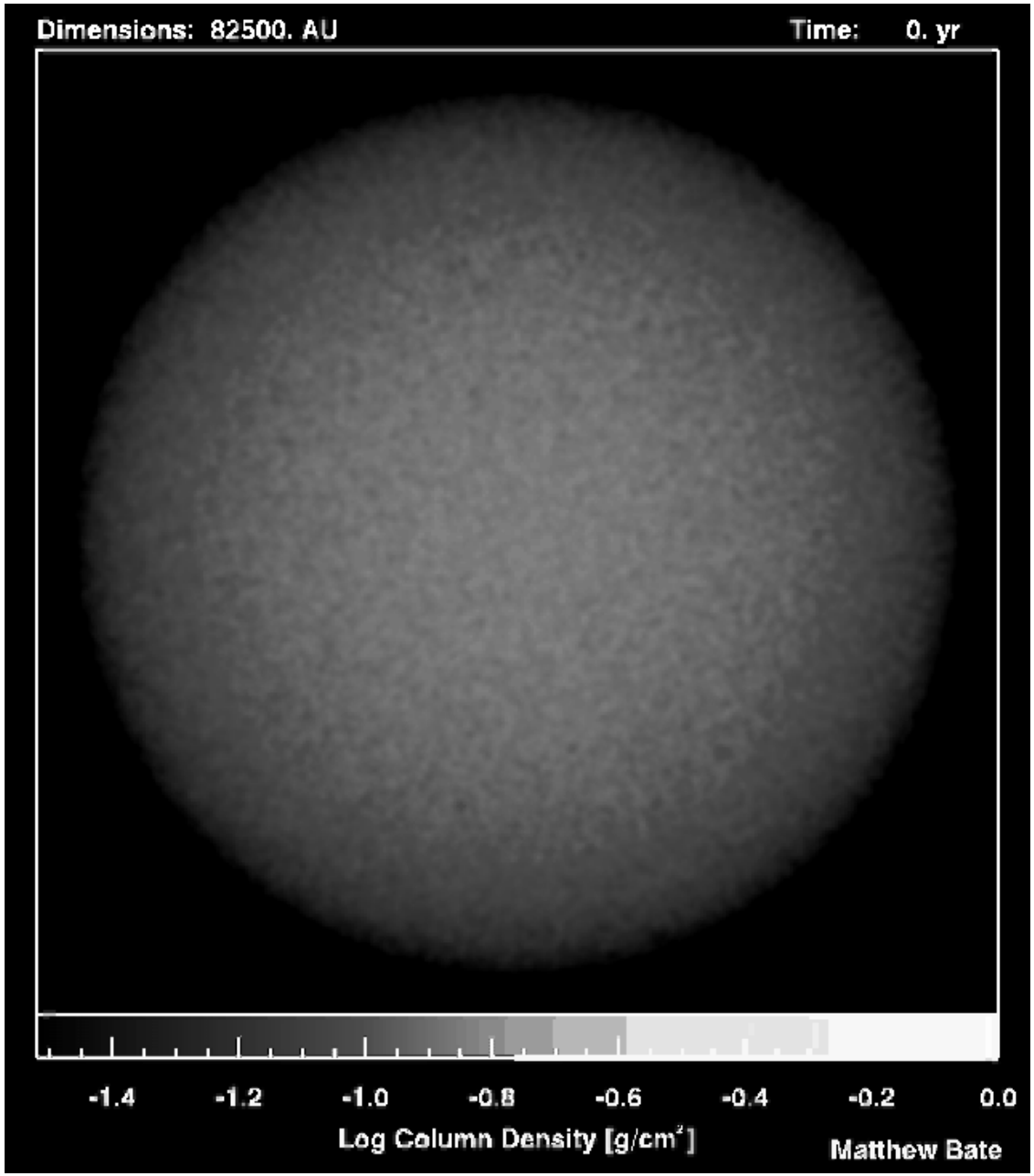


Radio 21cm/VLA

Penetrating the Dust …with Spitzer Infrared Images

Birth and Death of Stars

Formation a Sun-like star and its planetary system



Start with a **gas cloud** whose
- mass ~ 50 times that of our Sun.
- diameter~1.2 light years (~10^{16}m)
- temperature ~ 10 K.

(low density=red, high density=yellow

The cloud collapses under its own gravity, and fragments to form **dense gas clumps and eventually stars.**

Swirling discs of gas around the newly born stars may later form **planetary systems like our own Solar System.**

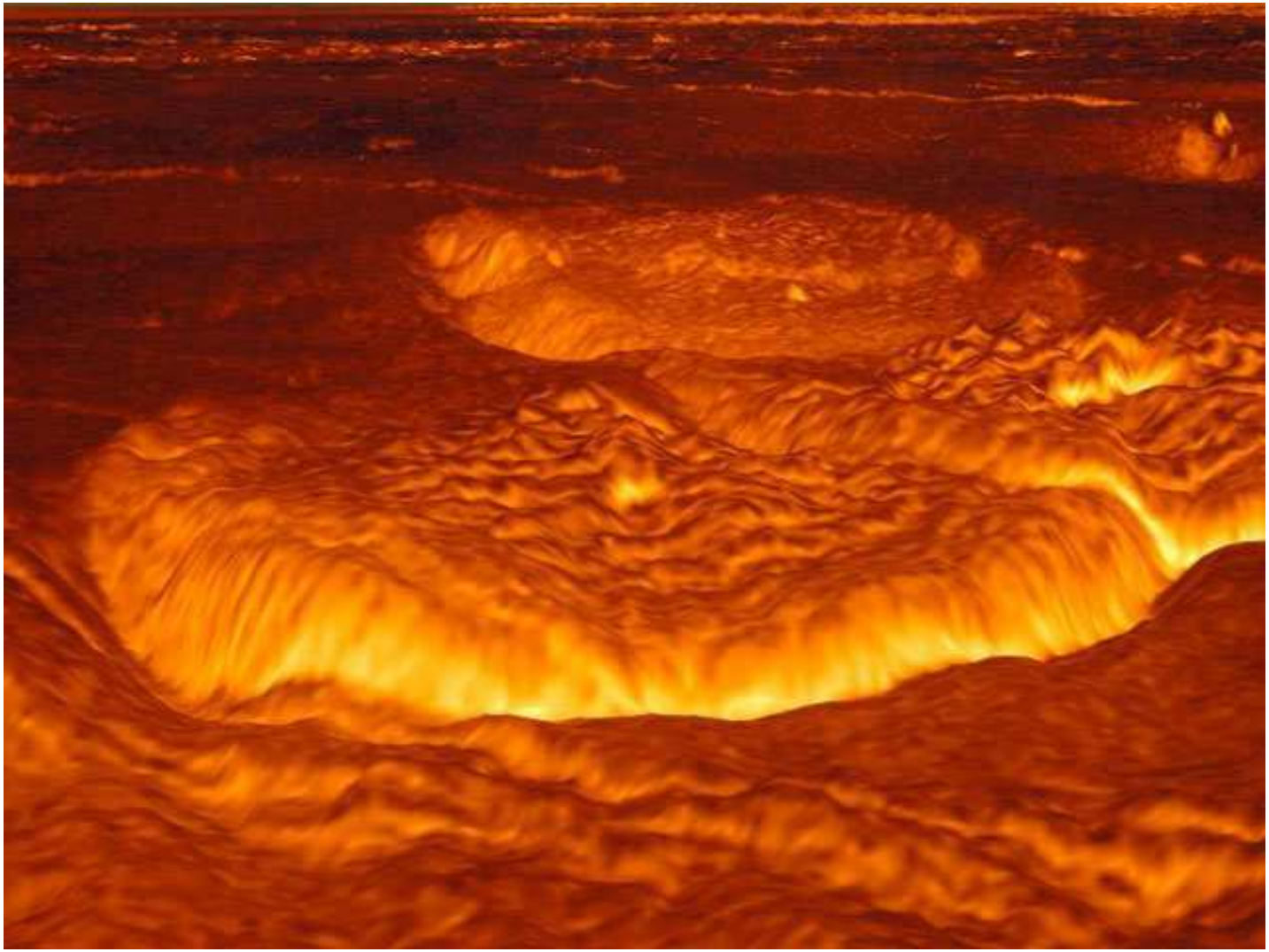
Death of a massive star … and why we are stardust

When a massive stars (with mass > 8 x mass of Sun) die,

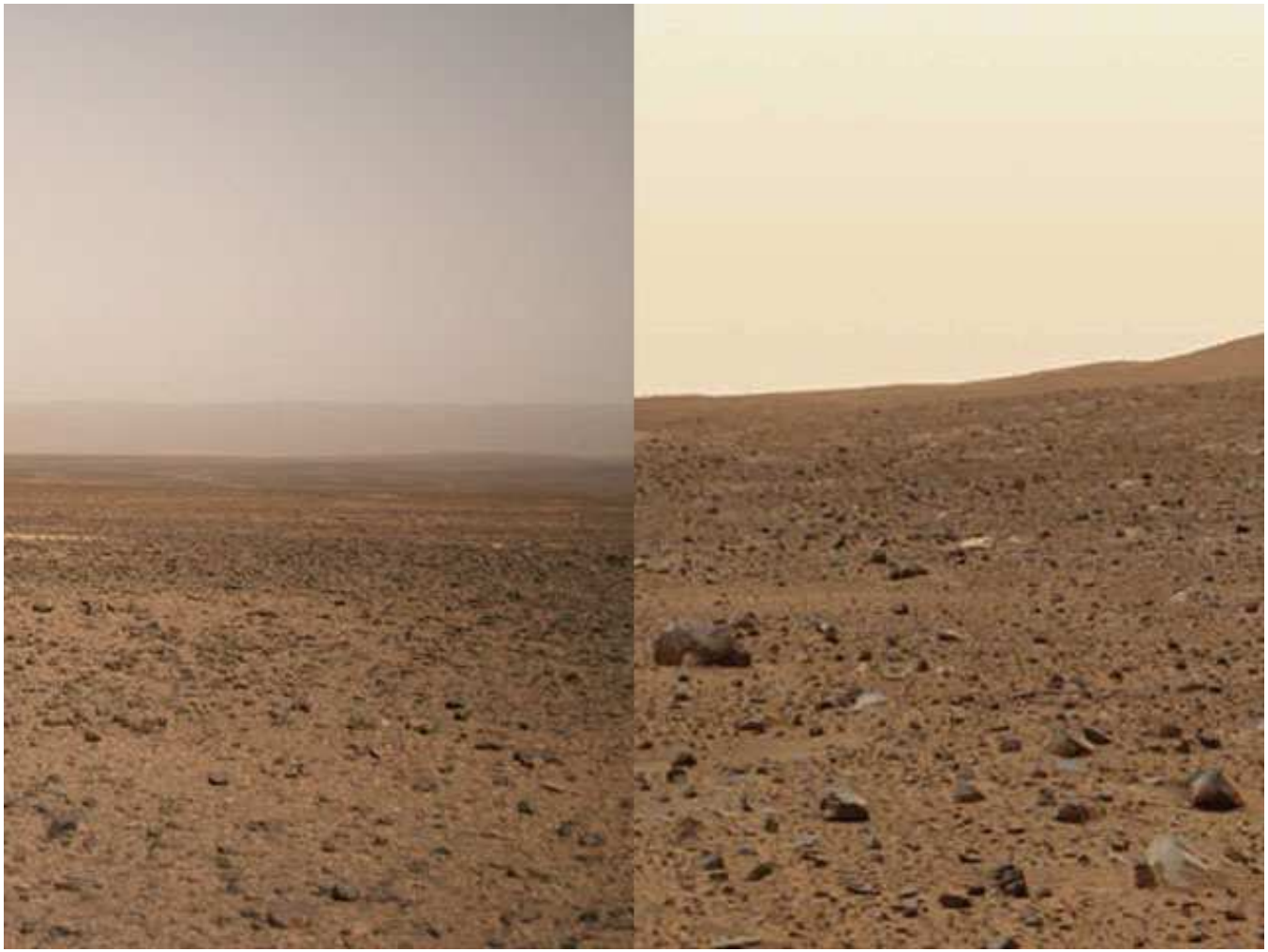
- its core collapses into a black hole or neutron star
- a supernova explosion ejects its envelope of hot gas to form a supernova remnant

The gas is enriched with C ,O, N, S -- elements essential for life ---produced by nuclear fusion in the massive star. This gas can later cool and collpase into stars +planets with C N O S that may be able to sustain life

Optical image of a supernova remnant called Crab Nebula;



- Computer reconstruction of the surface of Venus was created from Magellan spacecraft data
- 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

Galaxy Collisions: Cosmic Fireworks And New Personalities

Galaxies

Galaxies are made of gas, stars, dust, dark matter.They contain a few times (10^8 to 10^{12}) stars that orbit a common center and are bound by gravity.

Different types of galaxies (shapes, sizes, some harbor active black holes)

Spiral galaxy NGC 1300

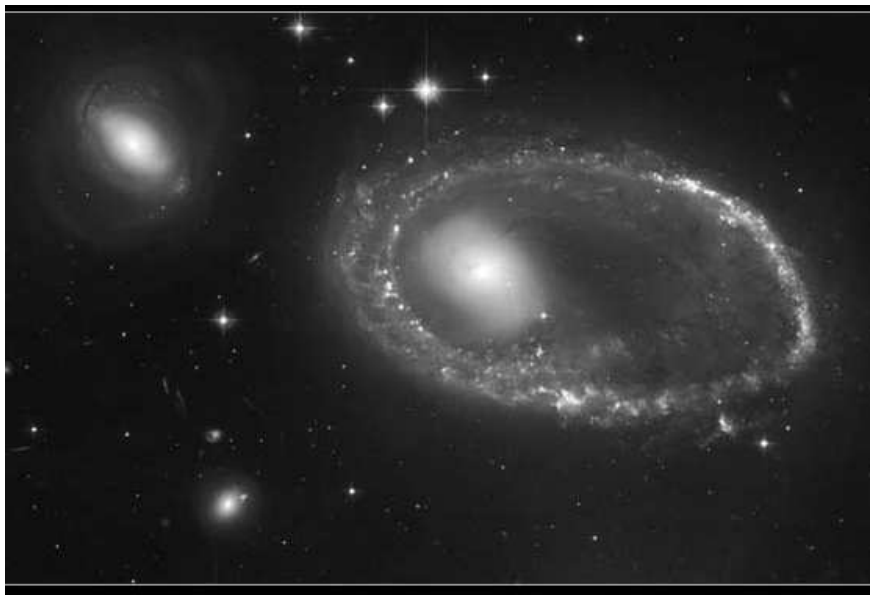
Elliptical galaxy M87

Interactions between galaxies can induce dramatic changes in morphology.

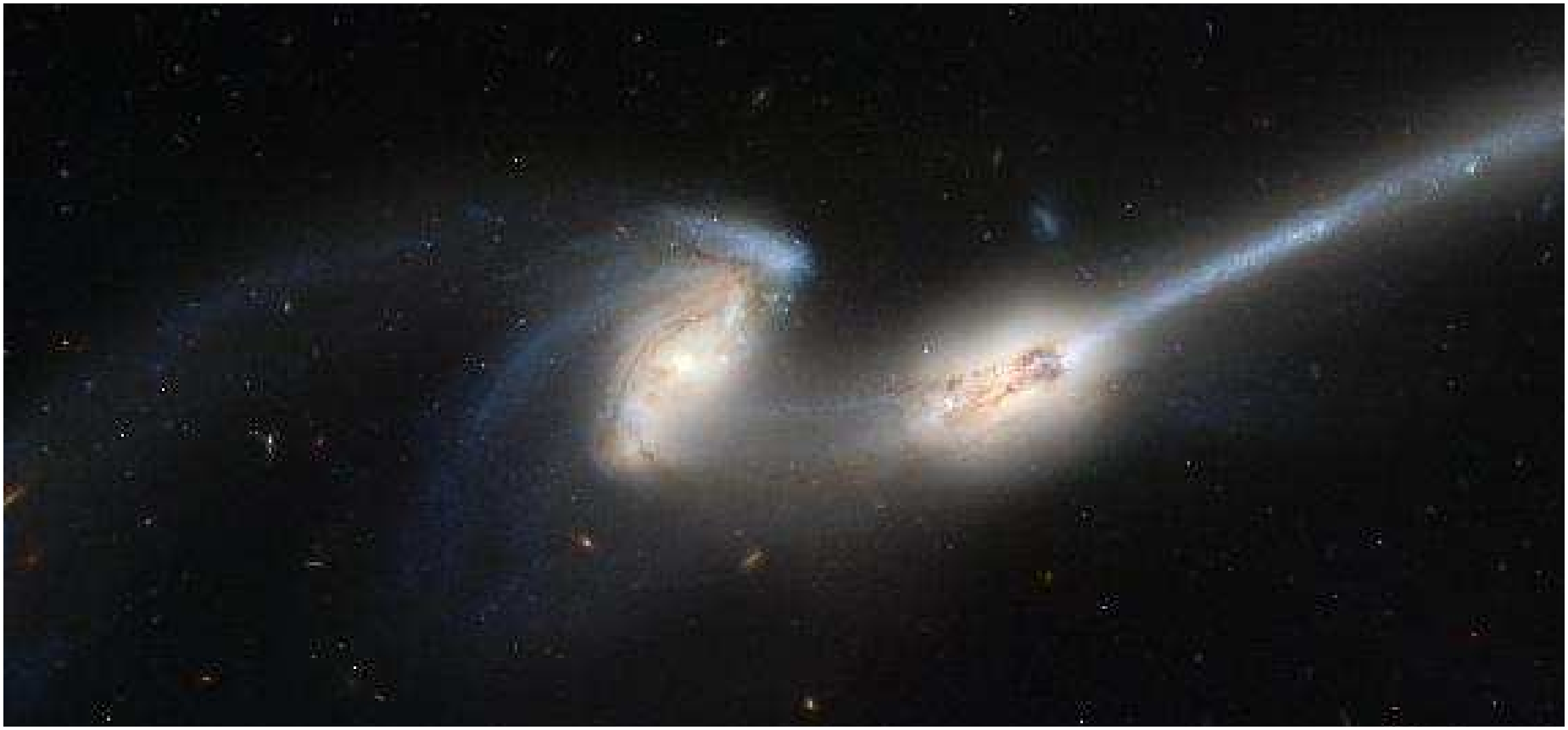
Polar ring galaxy
NGC 4650

Cartwheel galaxy
Head-on collision

Ring galaxy AM 0644-741 50,000 ly across



Interacting galaxies in the local Universe



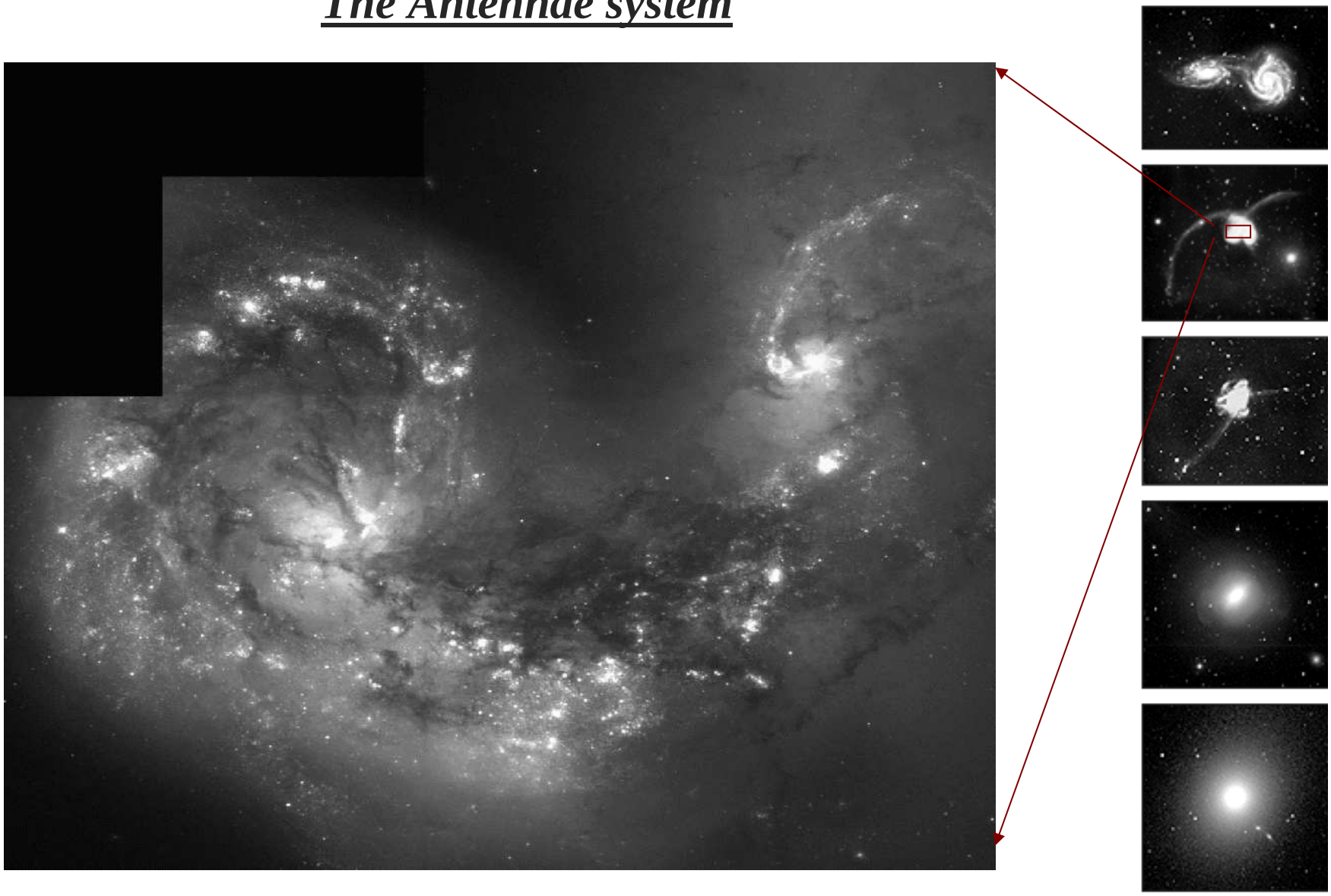
Collision of 2 spiral galaxies, 100,000 light years apart

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

Merger of 2 spiral galaxies

Merger of 2 spiral galaxies 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?

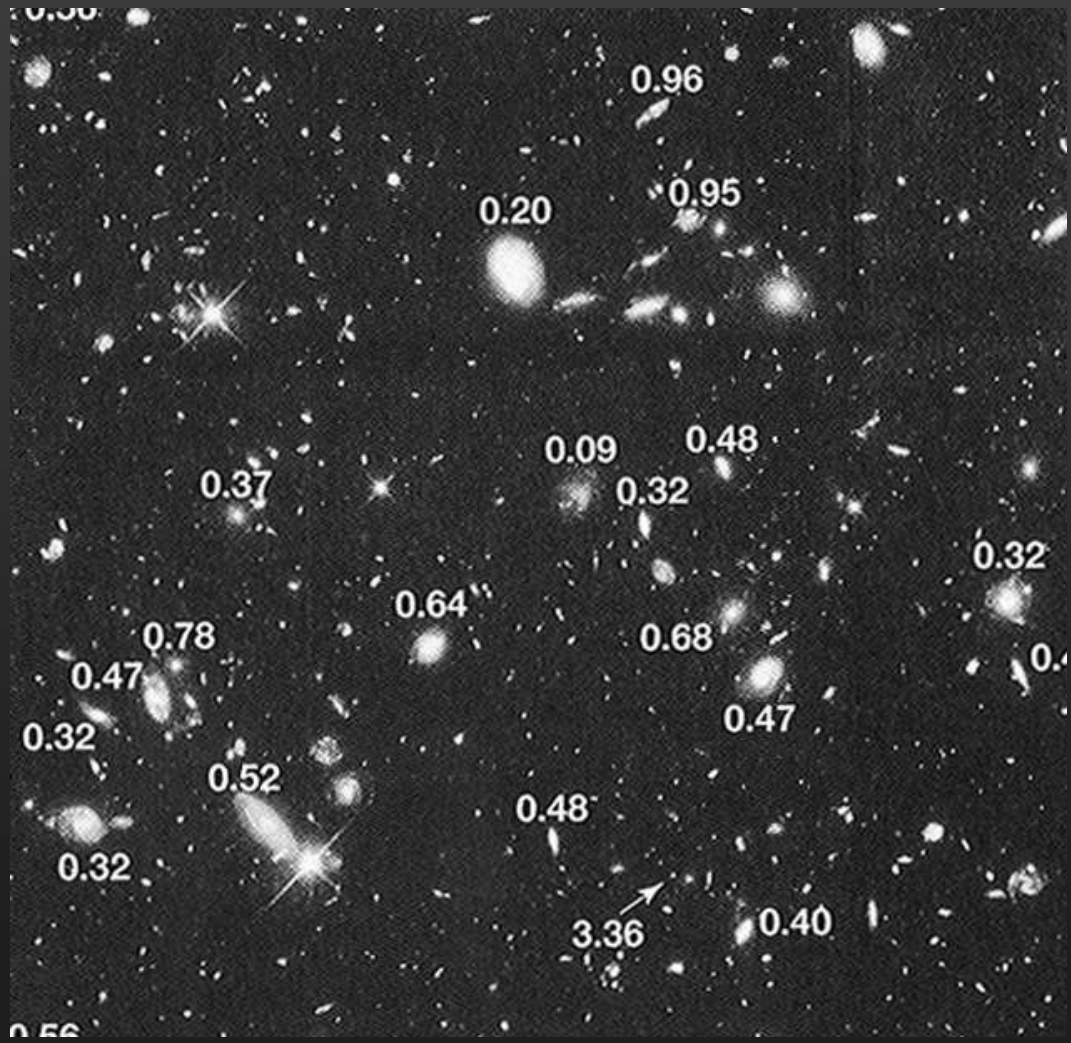
Is it on a collision course in the future?

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

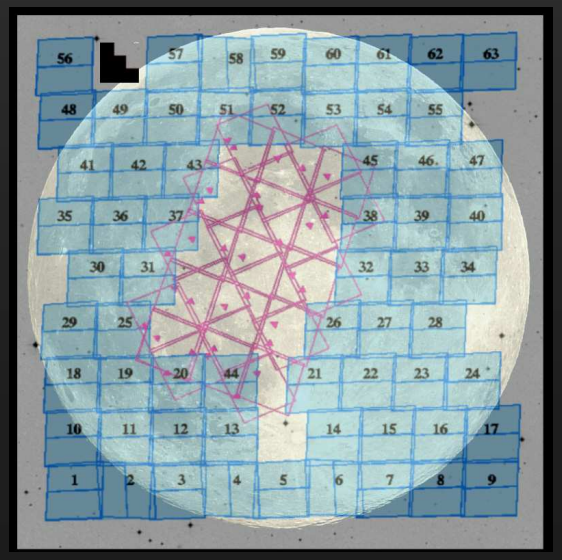


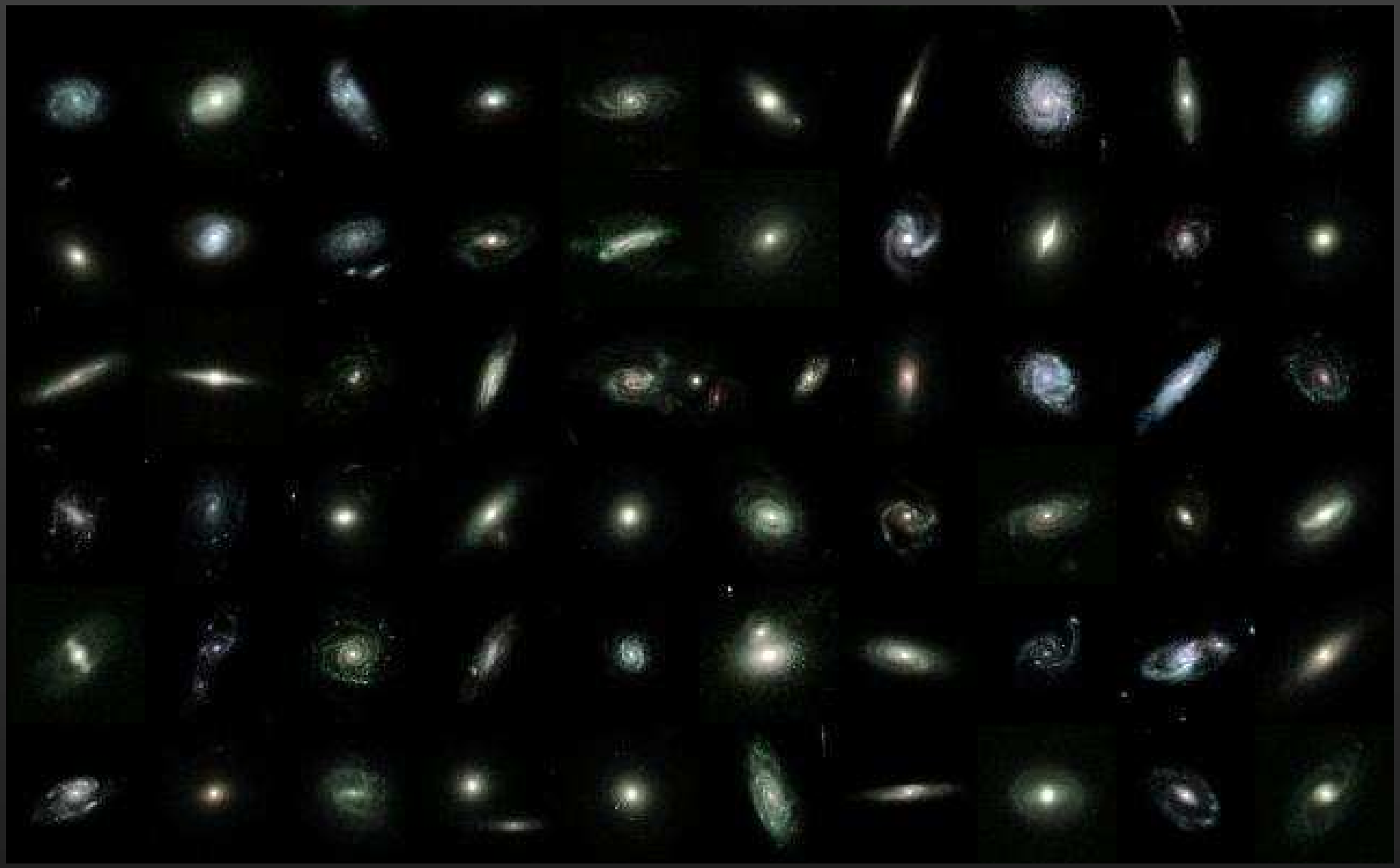
Looking back in time 9 billion years with the GEMS Survey

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’



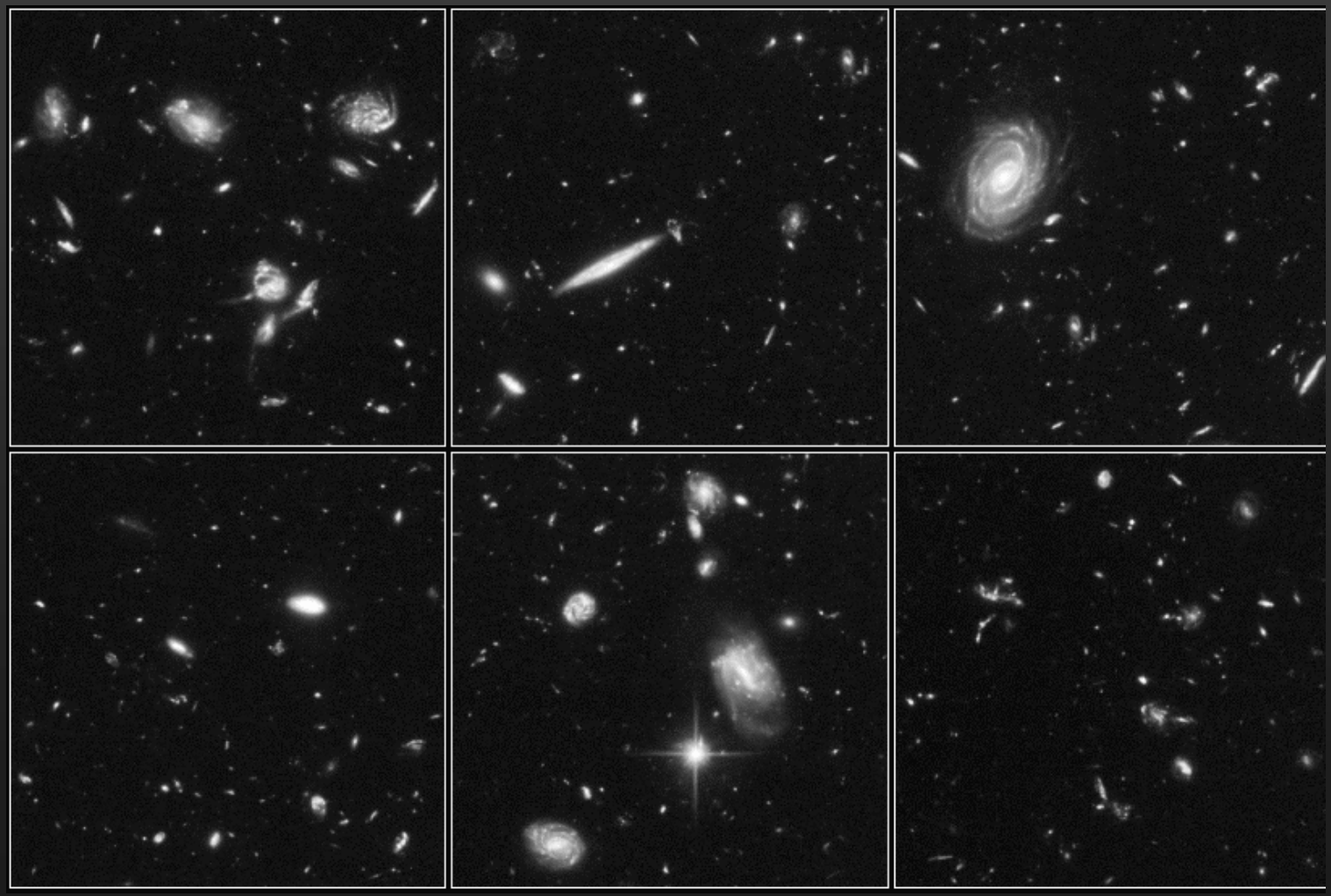


Diversity of galaxies 9 Gyr ago, when Universe was only 30% of its present age!

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

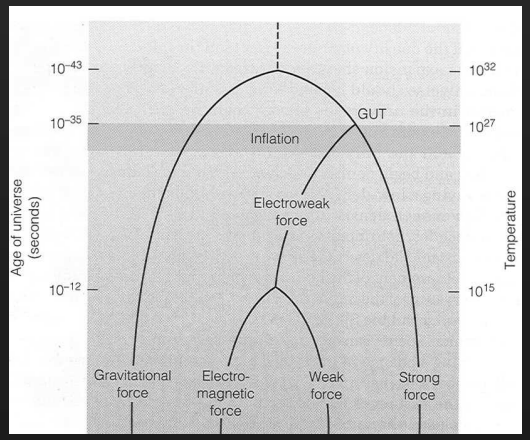
10^{-10}s - 1 s
Matter-antimatter pairs form from radiation and a net excess matter particles (n p e) emerge

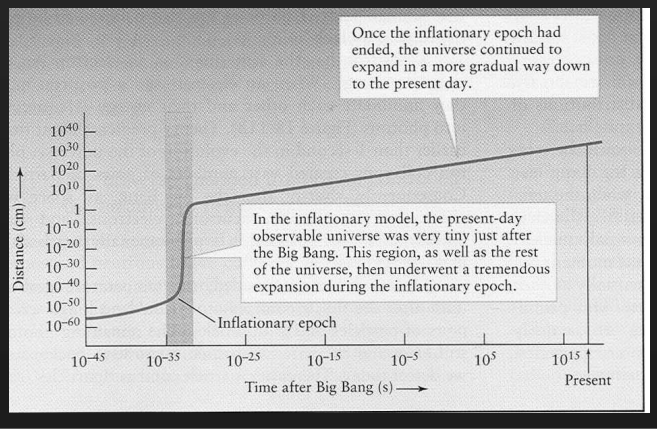
In GUT era, gravity freezes out while the strong and electroweak forces remain unified as a GUT force

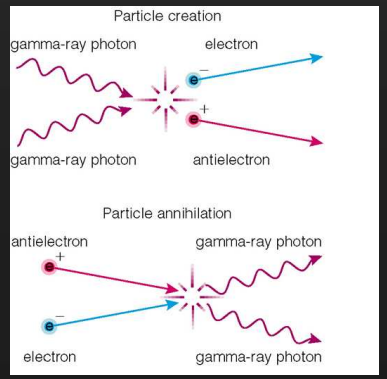
In the electroweak era, the strong force freezes out from electroweak forces. Inflation blows up the size of the Universe by a factor of 10^{25}

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

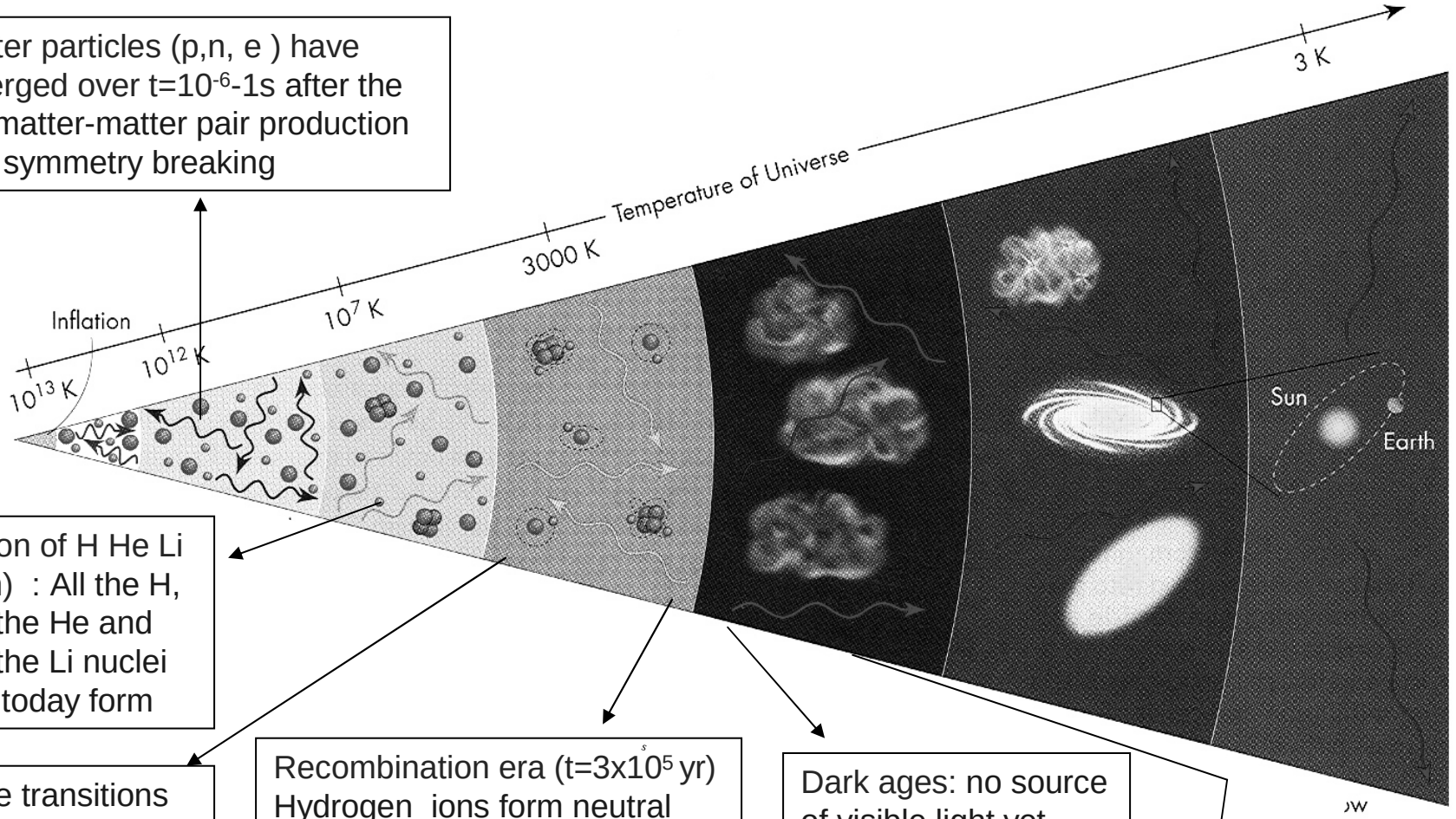






Overview: From the first second to the first billion years

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) .

Use of Math in this course

Math content of this course

This is a science course : we will use formulae and simple algebra
Consult 3 documents are posted on class website

--> A primer of basic mathematical skills (also in Appendix C of your book).
Make sure you go through **all the worked examples** before Lecture 3.
Quiz will include examples from it

à A list of typical formulae used in this class

à A study aid on how to apply formulae and laws
USE THIS EVEN IF YOUR MATH SKILLS ARE OKAY.