

Lecture 2

14 Billion years of History: the Birth and Maturation of Galaxies

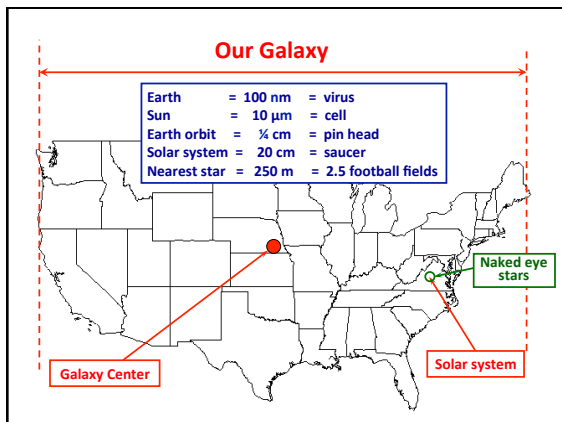
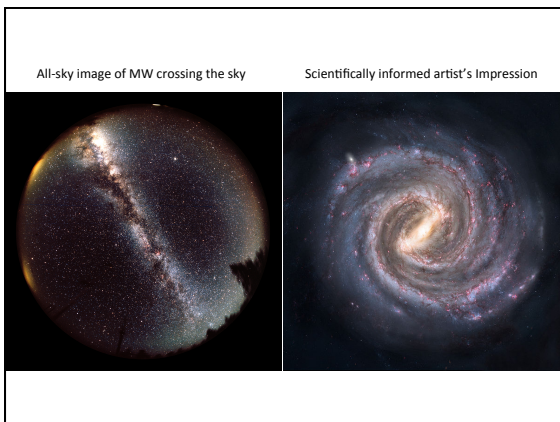
Our Four Lectures

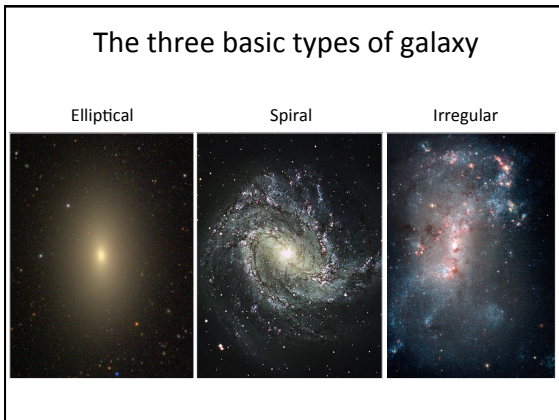
- 1) Evidence for the Big Bang:
Aim is to make a believer out of you.
- 2) The life-history of galaxies:
Wonderful systems, with a rich life-story
- 3) The first million years: the fireball era (seen as the CMB)
A spectacular period of light and semi-musical sound.
- 4) Inflation: the mechanism that
 - a) creates all the "stuff" in the Universe; out of nothing,
 - b) launches its expansion,
 - c) maybe makes many universes.

Preview

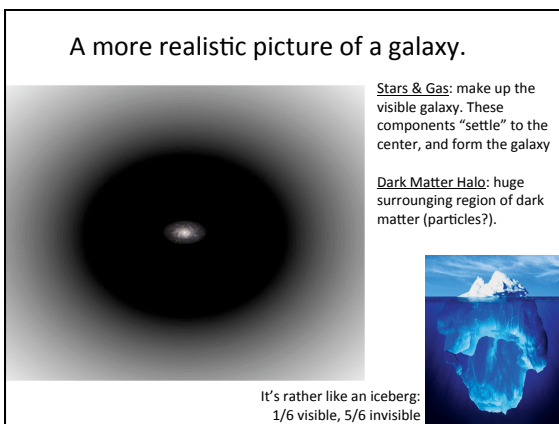
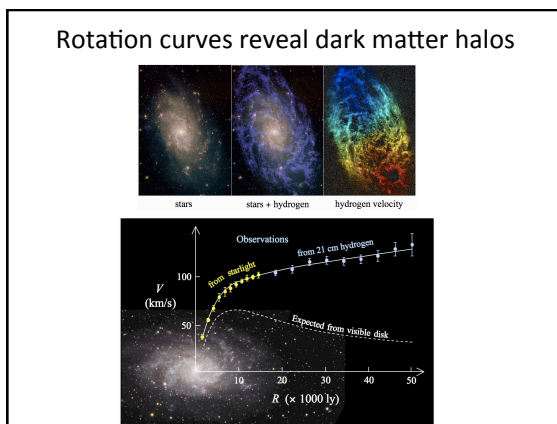
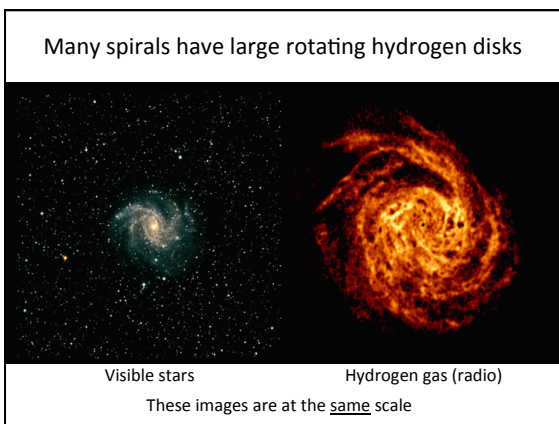
A number of related themes, building a fuller picture.

- 1) Nature & size of galaxies
- 2) Dark matter: a major cosmic constituent.
- 3) Galaxy collisions & star birth
- 4) Galaxy maps: the galaxy web
- 5) Infant galaxies – wild times.
- 6) History of star birth – an early baby-boom.
- 7) Growing black holes – galaxy sterilization
- 8) Galaxy masses – why the range of mass?





2: Invisible Components; Dark Matter Halos



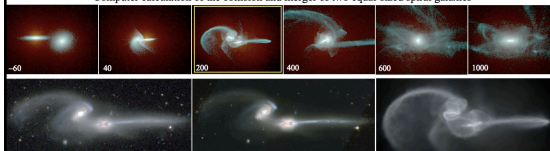
3: Galaxy Collisions; Triggering Star Birth

Galaxies can sometimes collide and merge



Complex patterns of galaxy collisions

Computer calculation of the collision and merger of two equal-sized spiral galaxies



The Mice: ground-based image

The Mice: Hubble Space Telescope

More sophisticated calculation

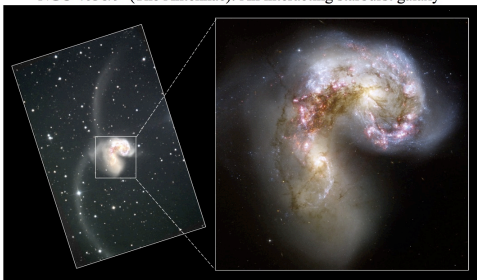
Simulation of the Mice collision
(Josh Barnes)



Galaxy collisions trigger star birth

Many of these colliding galaxies are "starburst" galaxies, meaning they have high rates of star formation (>100 stars/year)

NGC 4038/9 (The Antennae): An interacting starburst galaxy

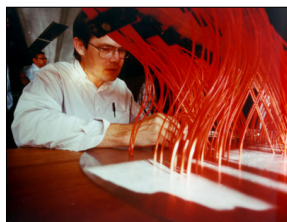


4: The Galaxy Distribution; Mapping the Universe

The Distribution of Galaxies: Redshift Surveys

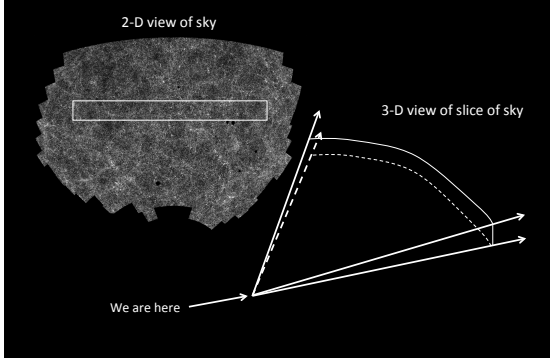


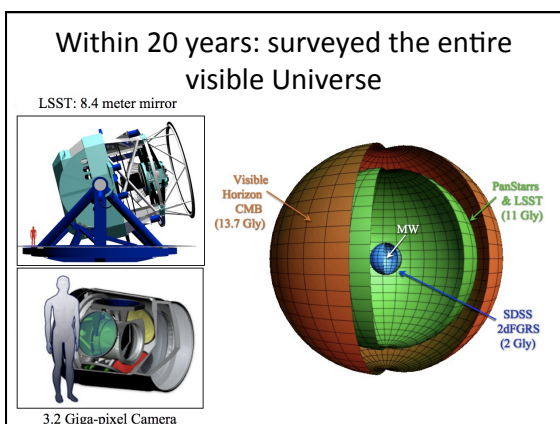
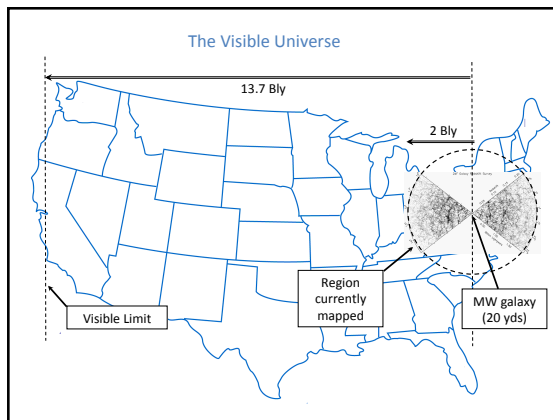
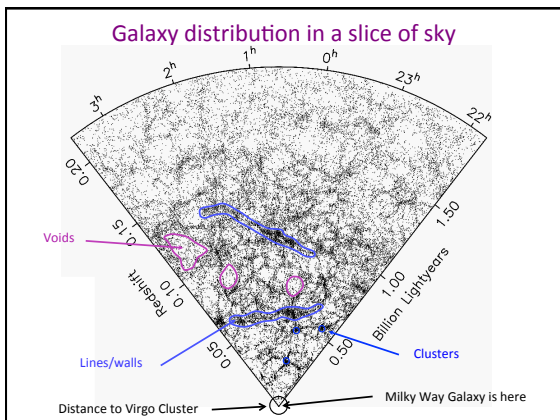
Sloan Digital Sky Survey
100 inch Telescope



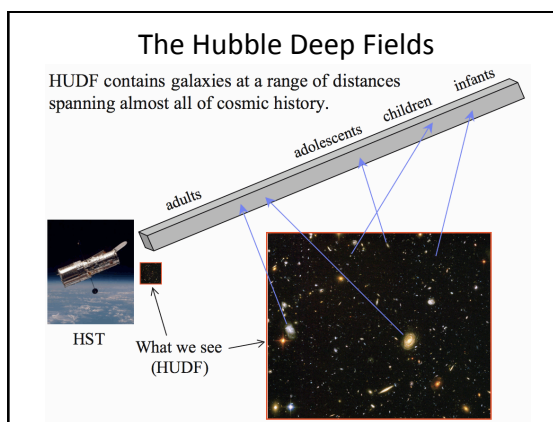
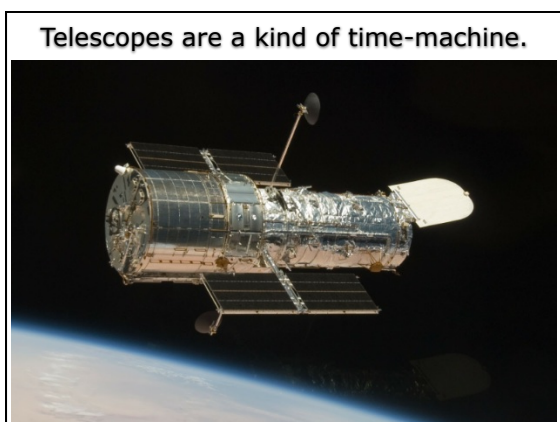
640 Fiber Spectrograph

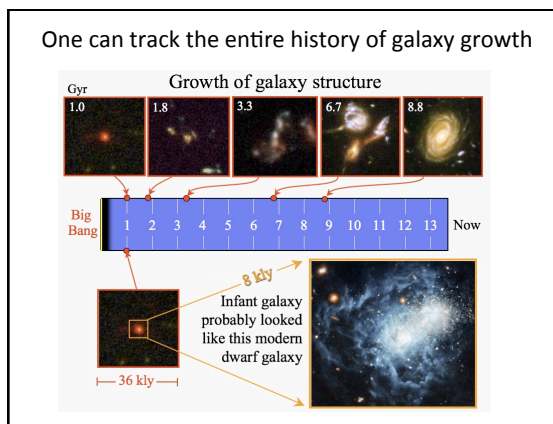
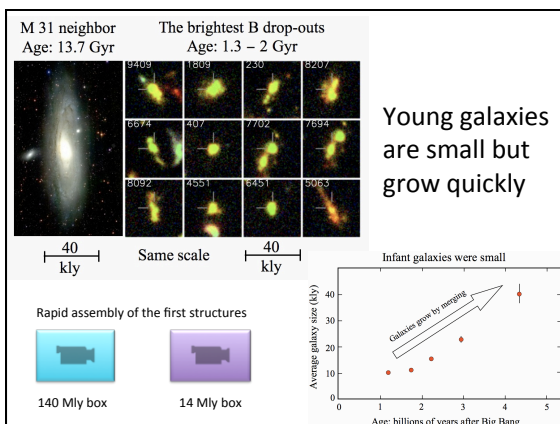
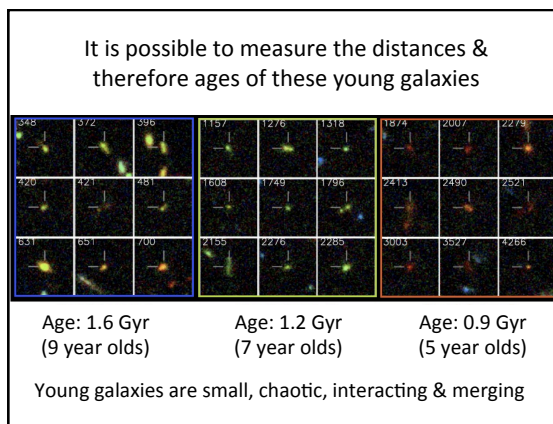
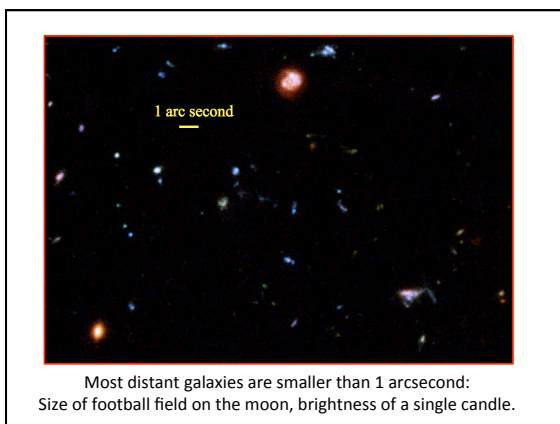
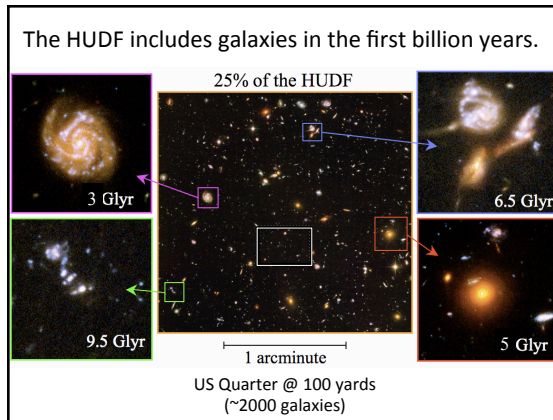
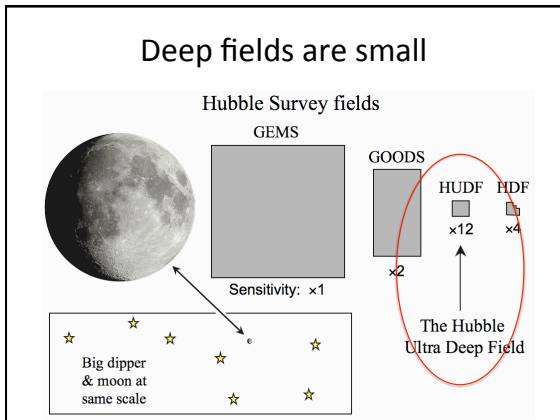
A Slice of Sky, Viewed in 3-D





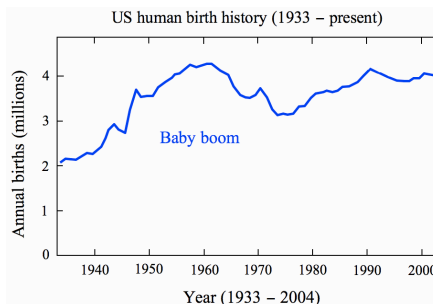
5: Galaxy Evolution; Young Galaxies



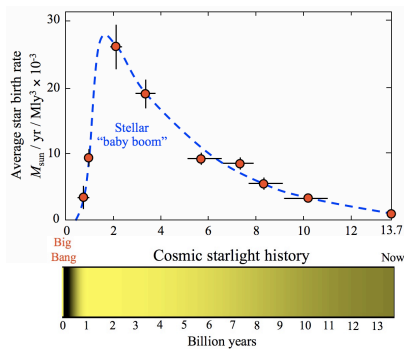


6: Star Birth History

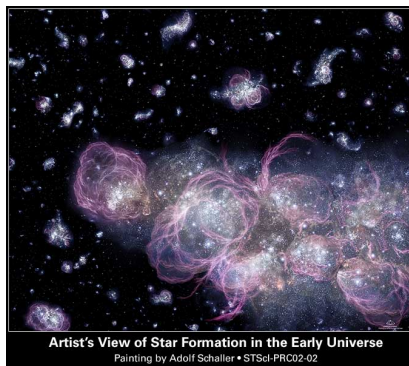
Analog: human birth history



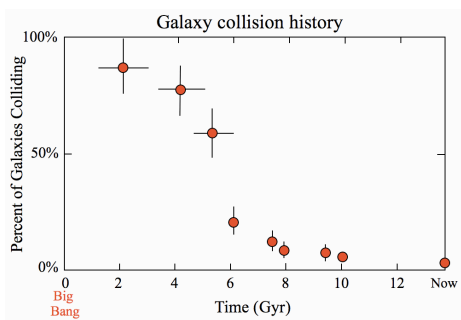
Cosmic star birth history



The young Universe was spectacular



One reason for decline in star birth



7: Central Black Holes

Black holes in galaxy nuclei

No gas falling into the BH: not visible

Gas falling into the BH, making energy: light and jets

Accreting black hole

Active Galaxies: Feeding Nuclear Black holes

Quasars (☛) and Radio Galaxies (☞)

Feeding (and growing) black holes was common in the past, and is rare today.

10,000 Quasars

Billions of light years

We are here

Quasar number evolution

Relative Number

Time (Gyr)

Big Bang

Now

Black hole at the center of the Milky Way galaxy

Milky Way

Sagittarius (scorpius)

Galactic Center

Intra-red

1 degree 430 lyr

5 arcsec 0.6 lyr

Star orbit

S14

S2

Star A

1 arcsec 45 1-dy

Star orbits around the black hole

Feedback can clear out a galaxy's gas which prevents further star formation

Supernova blowout in M82

Black Hole blowout

Summary

Galaxies are the primary units of structure we find in the Universe. They are huge compared to stars and solar systems.

They come in a range of sizes and shapes: spirals, ellipticals, irregulars. Each is embedded within a large halo of dark matter.

Galaxies fill the visible Universe in a web-like pattern of filaments, voids, and clusters – as revealed by recent large redshift surveys.

Deep surveys of small regions (e.g. the HUDF) allow us to study the life history of galaxies:

- they are initially small, but quickly grow by collisions and mergers
- this growth also involves the birth of stars
- this also includes the feeding of massive black holes

The mass distribution of galaxies comes from the mass distribution of dark matter halos, with several suppression mechanisms that prevent the formation of stars.

8: Galaxies Large and Small; The Galaxy Mass Function

Explaining the galaxy mass function

Human mass function

Explaining the galaxy mass function

Dark halo mass function

Explaining the galaxy mass function

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