ASTR 1040: Stars & Galaxies

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Lecture 22 Thur 8 Nov 2018
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Tour of Galaxies

- Look at complex *effects of dust* in galaxies
- Examine how *21-cm radio emission* works: can map our galaxy (and its spiral structure)
- *Super-massive black hole* at center of MW
- Edwin Hubble using `Cepheid variables' showed *Andromeda* is a distinct *"island universe" – another Galaxy !*
- The rich range of galaxies: *spiral, barred spirals, ellipticals, and irregulars*
- Hubble's scheme to *classify galaxies*

Our Schedule

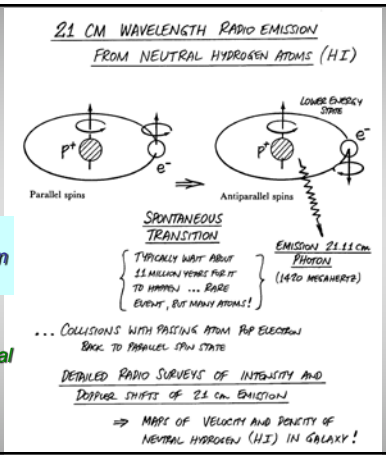
- *Homework #10* due today, new *HW #11*
- Read with care *20.2 `Measuring Cosmic Distances' and 20.3 `Hubble's Law'*
- Start reading *Chap 21 "Galaxy Evolution"*
- *Next class Tues Nov 13 meets in Fiske Planetarium*

REVISIT

21 cm emission (radio)

Sampling neutral hydrogen atoms (cold)

also how MRI does it in medical imaging!

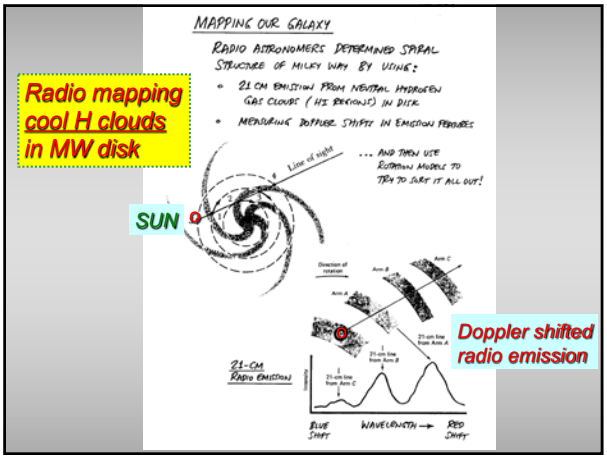


Green Bank 100 m Radio Telescope VA

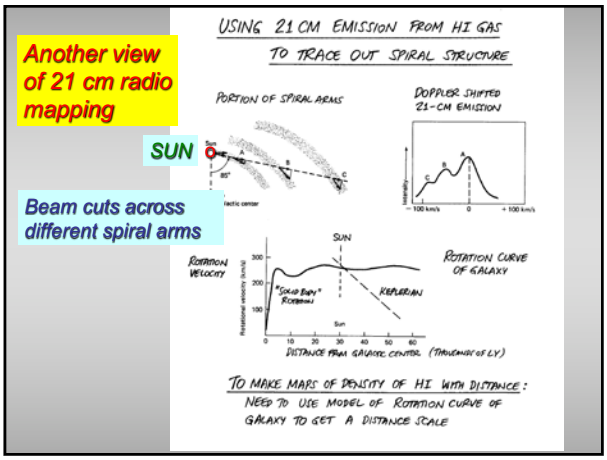
VLBA Radio Telescope Owens Valley CA

Very Large Array (VLA) Socorro NM

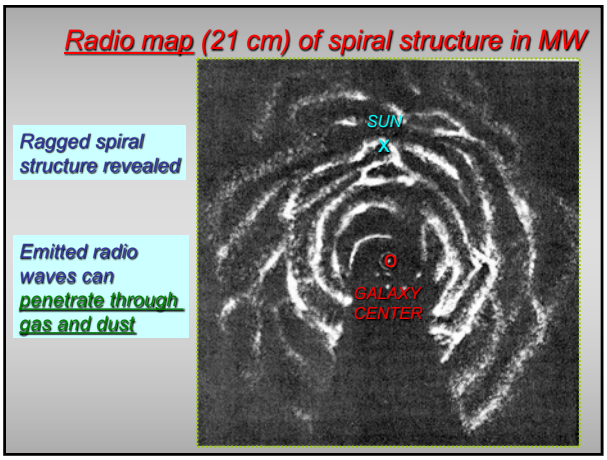
Radio mapping cool H clouds in MW disk



Another view of 21 cm radio mapping

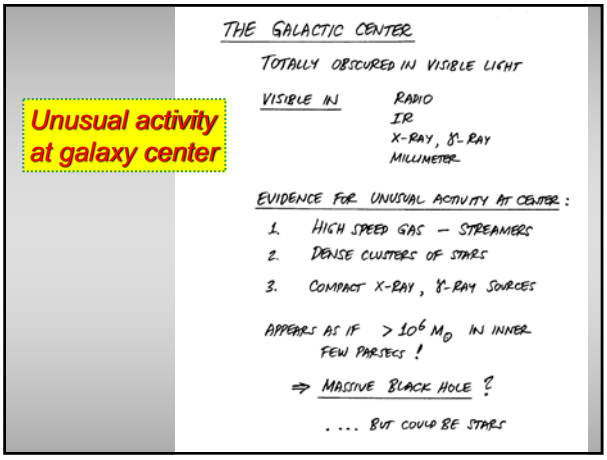


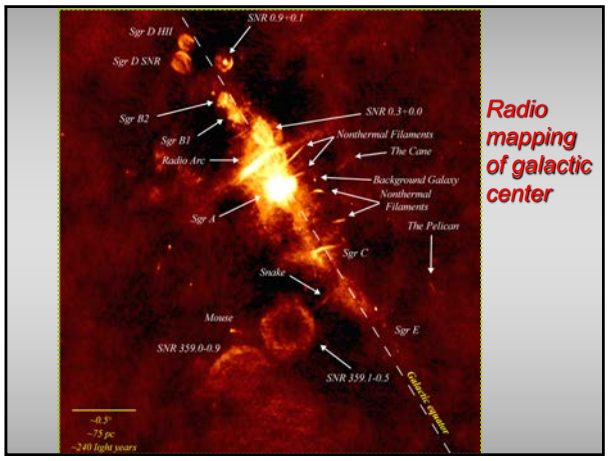
Radio map (21 cm) of spiral structure in MW



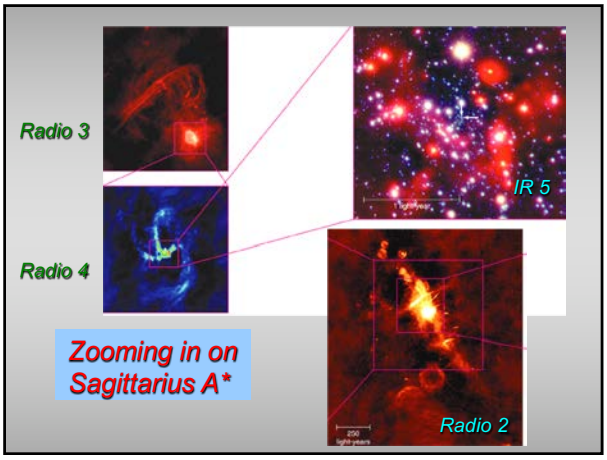
Galactic center in direction of Sagittarius: IR reveals a dense star cluster

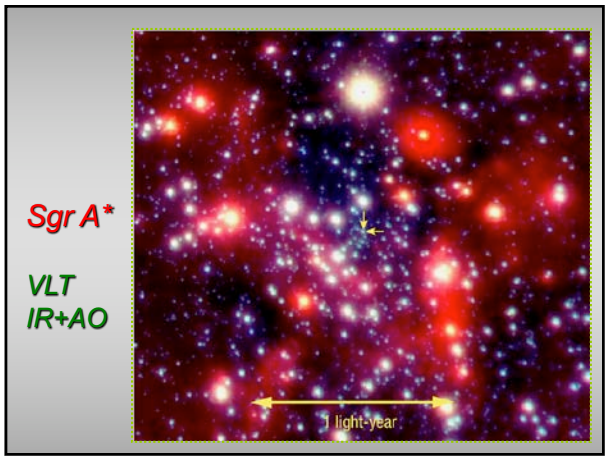
Unusual activity at galaxy center

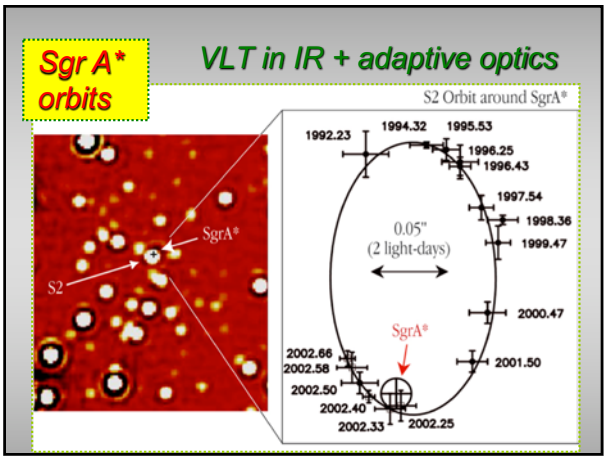


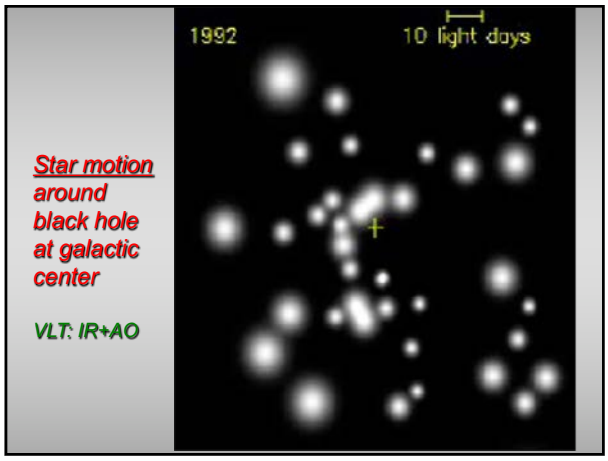


Radio mapping of galactic center



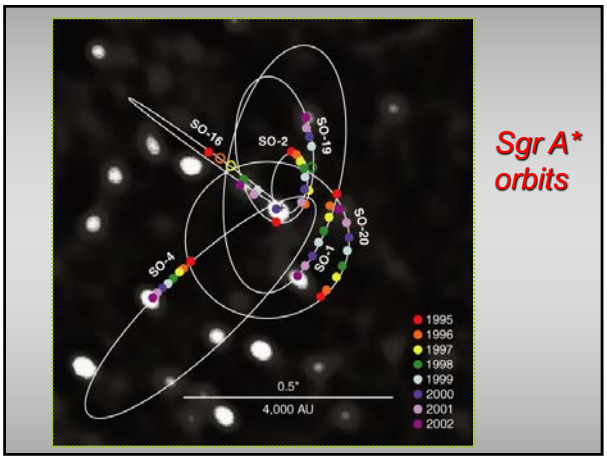




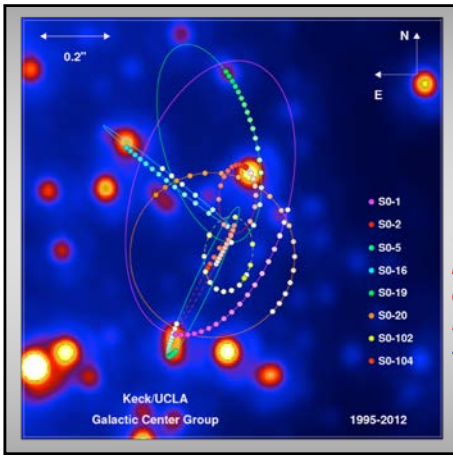


Star motion around black hole at galactic center

VLT: IR+AO

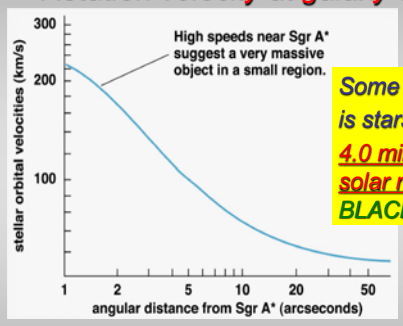


Sgr A* orbits



Orbits of stars indicate mass of ~4.2 million M_{sun} within 45 AU !

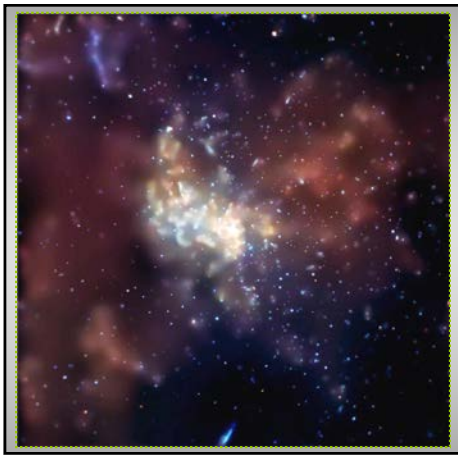
Rotation velocity at galaxy center



Some of central mass is stars, joined by 4.0 million (+/- 0.2) solar mass BLACK HOLE

But further 20% uncertainty from distance determination

Black hole still less than 1/1000 of MW mass



Sag A* in Chandra X-ray view

Exhibits outbursts, but starved of fuel ?

Question: Why no powerful jet and accretion disk near MW's supermassive black hole?

- Modest emission in X-rays…though other signs of activity
- Answer: maybe it has eaten all it can – at least for now ?

Clicker – reading ahead

- What are the Magellanic Clouds? C.
- A. Two nebulae in disk of Milky Way visible only in southern hemisphere
- B. Clouds of dust and gas in many places throughout the Milky Way galaxy
- C. Two small galaxies that orbit Milky Way
- D. Star-forming clouds in constellation Orion

HOW DID IT ALL BEGIN?

Measuring galactic distances

Edwin Hubble made breakthrough using Cepheid variables to measure distance

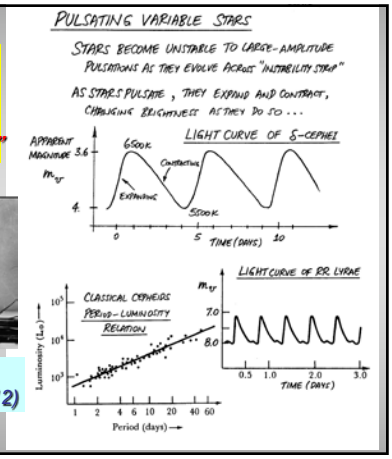
Found Andromeda far outside Milky Way

Huge step forward in thinking about universe

NGC 4414

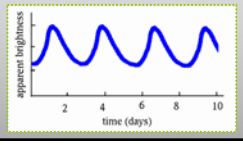
Cepheid variable stars as distance indicators: "standard candle"

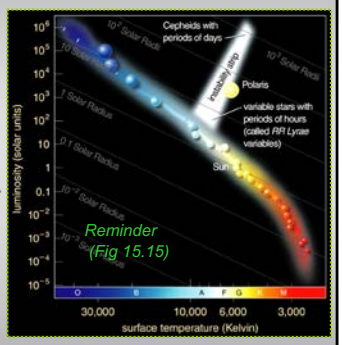
Vital discovery by Henrietta Leavitt (1912)



Cepheid stars in H-R diagram

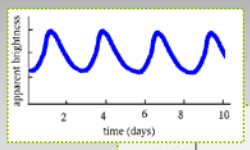
- "Instability strip" -- region in H-R diagram with large, bright stars
- Outer regions of star are unstable and tend to pulsate
- Star expands and contracts, getting brighter and fainter



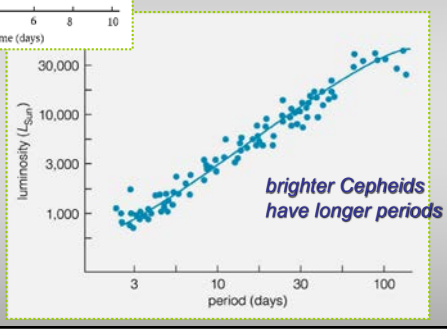


Reminder (Fig 15.15)

Cepheid variable stars



Period - Luminosity relation

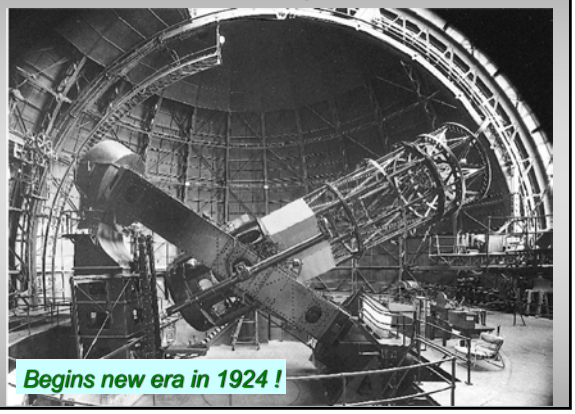


Andromeda found to be far outside Milky Way – another "island universe": galaxy!

- Edwin Hubble in 1924 identified Cepheids in Andromeda (M31) → showed they were far outside of Milky Way!
- Now known distance: 2.54 million ly (778 kp)
- His first big discovery (more to come) …

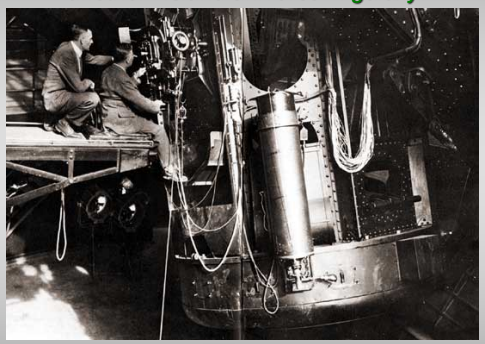
Hubble using new 100" Hooker telescope at Mt. Wilson (above LA)

100" Hooker telescope at Mt Wilson



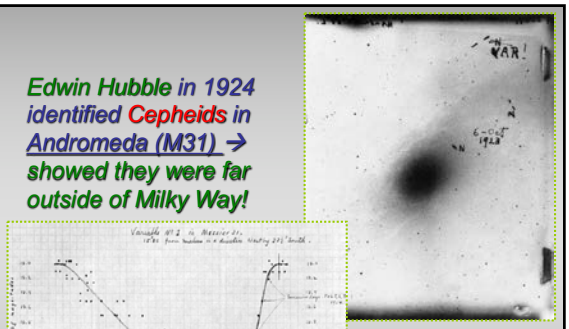
Begins new era in 1924 !

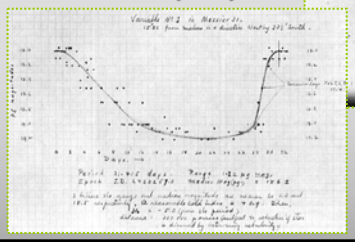
Andromeda found to be far outside Milky Way – another "island universe": galaxy!

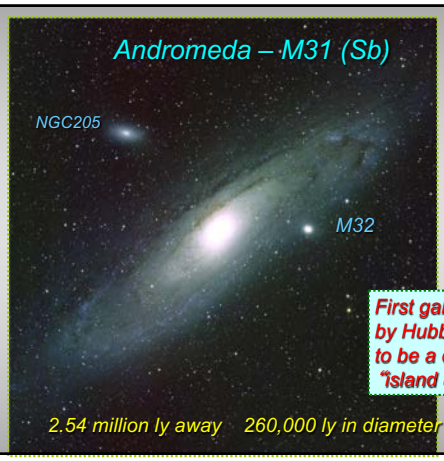


Hubble (and Jeans) at new 100" Hooker telescope on Mt. Wilson

Edwin Hubble in 1924 identified Cepheids in Andromeda (M31) → showed they were far outside of Milky Way!







First galaxy shown by Hubble (1924) to be a distinct "island universe"

2.54 million ly away 260,000 ly in diameter

LATEST IR IMAGING

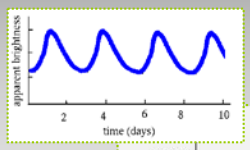
M31 from WISE + M32 (below) + M110 (NGC 205)

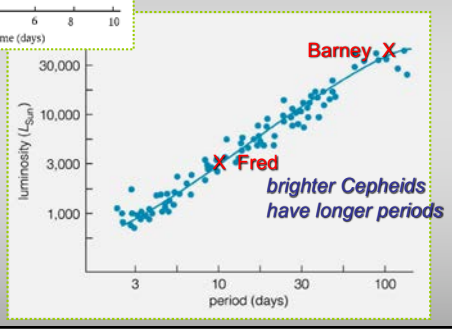
Clicker Question

Two Cepheid stars, Fred and Barney, have the same apparent brightness. Fred has a period of 10 days, and Barney of 100 days. Which is closer?

A. Fred
B. Barney
C. They are both the same distance
D. Not enough information to tell

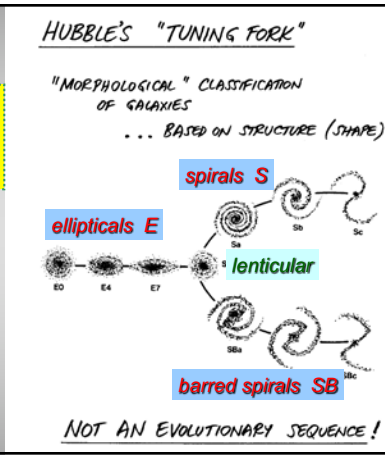
Cepheid variable stars





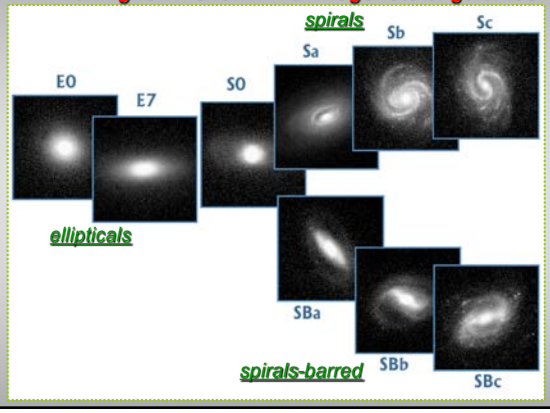
Period - Luminosity relation

Hubble's scheme to label galaxies



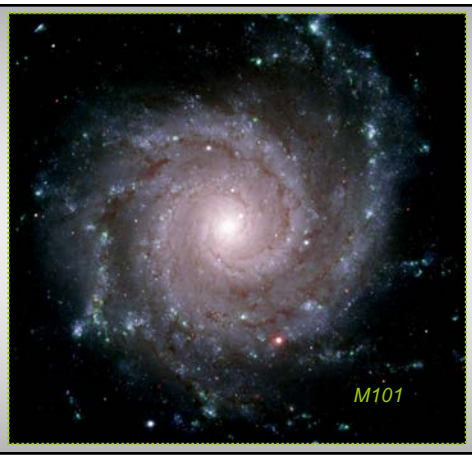
+ some "irregulars"

"Tuning fork" shown with mugshots of galaxies



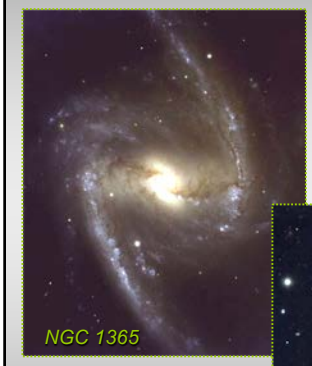
Spirals
~80% of galaxies

- Disks (with spiral arms) +
- Spheroids (bulges+halos)

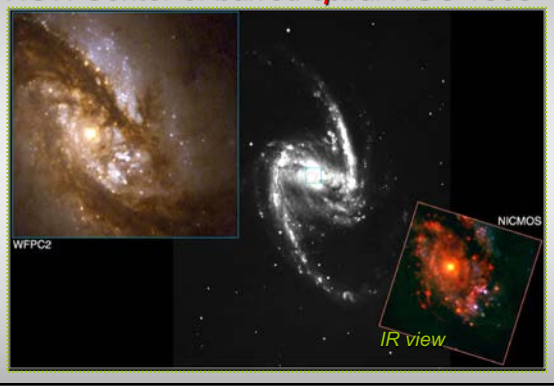


Barred spiral galaxies

- Spiral arms emerge from central bar

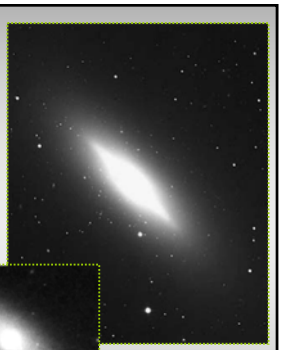


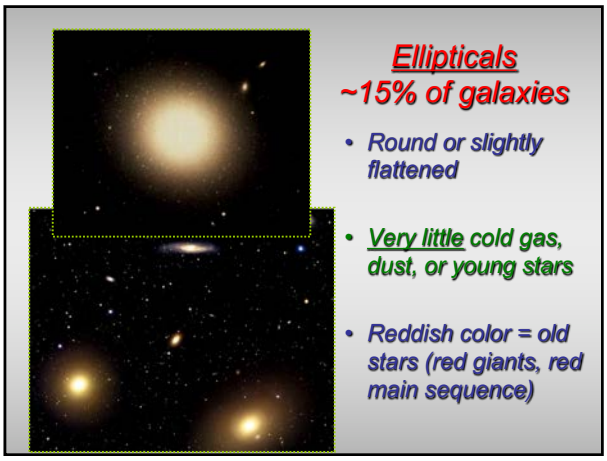
HST: Center of barred spiral NGC 1365



Lenticulars (lens-shaped)

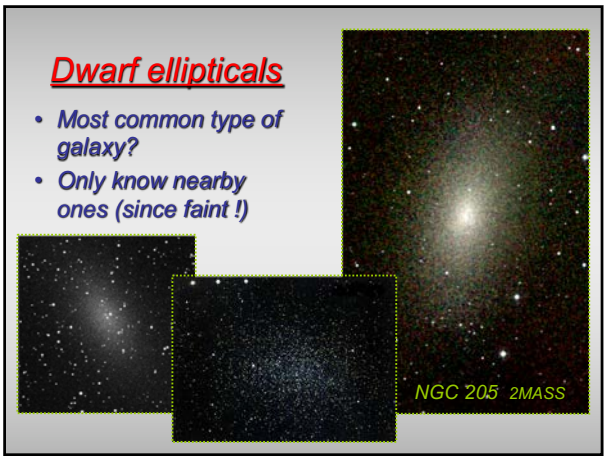
- Disks, but less gas and star formation
- Note lack of dust & pink nebulae





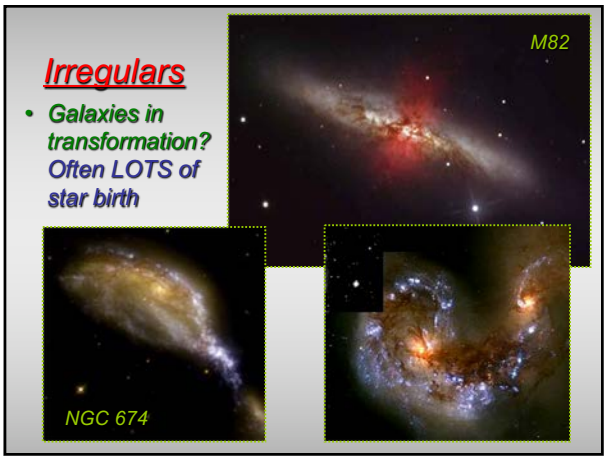
Ellipticals ~15% of galaxies

- Round or slightly flattened
- Very little cold gas, dust, or young stars
- Reddish color = old stars (red giants, red main sequence)



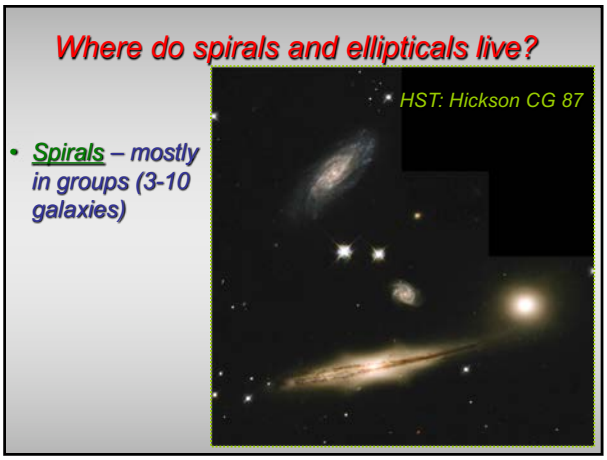
Dwarf ellipticals

- Most common type of galaxy?
- Only know nearby ones (since faint !)



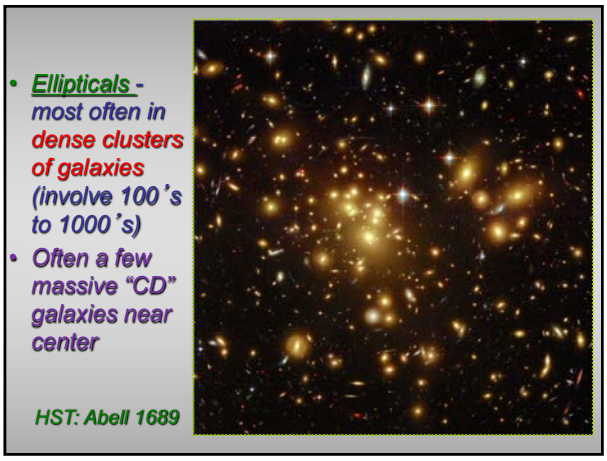
Irregulars

- Galaxies in transformation? Often LOTS of star birth



Where do spirals and ellipticals live?

- Spirals – mostly in groups (3-10 galaxies)



- Ellipticals - most often in dense clusters of galaxies (involve 100's to 1000's)
- Often a few massive "CD" galaxies near center

The Big Picture: Universe is filled with network of galaxies in groups and clusters