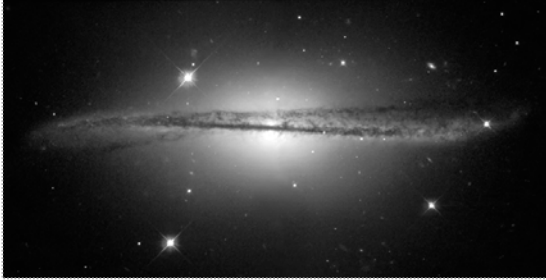


**ASTR 1120: Stars & Galaxies**



Prof. Juri Toomre TA: Ben Brown  
Lecture 31 Wed 30 Mar 05  
[zeus.colorado.edu/astr1120-toomre](http://zeus.colorado.edu/astr1120-toomre)

**Today's Topics**

- Today turn to *Galaxies in the Universe (Chap 20)* starting with Hubble's scheme to classify spiral galaxies, ellipticals, and irregulars
- Look at our *local group of galaxies* (Milky Way, Andromeda, Triangulum, LMC, SMC + dwarfs)
- Hubble used *Cepheid Variable stars* to show Andromeda is a galaxy of its own – major discovery !
- Re-read 20.2 *Galaxy Types*, and for Fri lecture 20.3 *Measuring Cosmic Distances*
- New *Homework Set 8 on Cosmic Distances and Hubble Law* still available; HW 7 returned graded + answer sheet

**Large-scale structure in Milky Way**

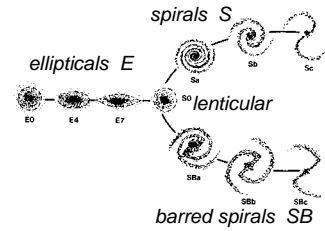
- We can observe the atomic hydrogen in interstellar gas in Milky Way with \_\_\_\_\_.
- A. space-based ultraviolet telescopes
- B. x-ray telescopes
- C. ground-based visible light telescopes
- D. 21 cm observations by radio telescopes

**D.**

**HUBBLE'S "TUNING FORK"**

Hubble's scheme to label galaxies

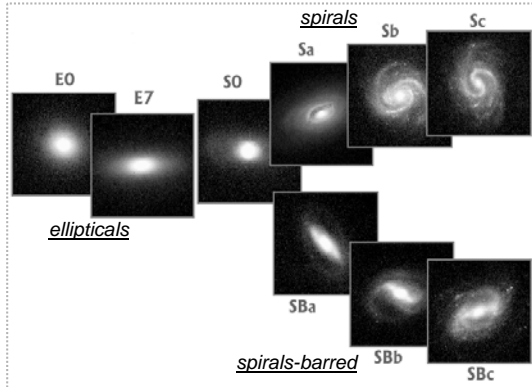
"MORPHOLOGICAL" CLASSIFICATION OF GALAXIES  
... BASED ON STRUCTURE (SHAPE)



+ some "irregulars"

**NOT AN EVOLUTIONARY SEQUENCE!**

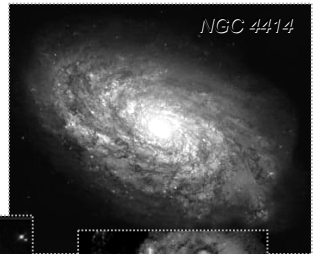
**"Tuning fork" shown with mugshots of galaxies**



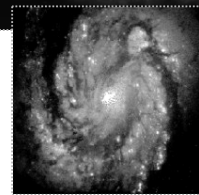
**Spirals**

~80% of galaxies

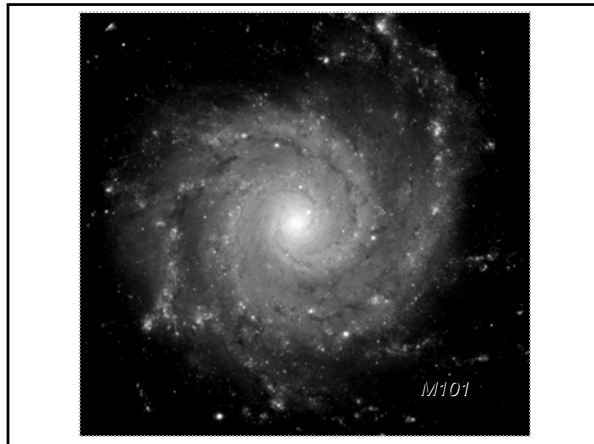
- Disks (with spiral arms) +
- Spheroids (bulges+halos)



NGC 4414



M100 center



Barred spiral galaxies

- Spiral arms emerge from central bar

NGC 1365

NGC 1300

HST: Center of barred spiral NGC 1365

WFPC2

NICMOS

IR view

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)

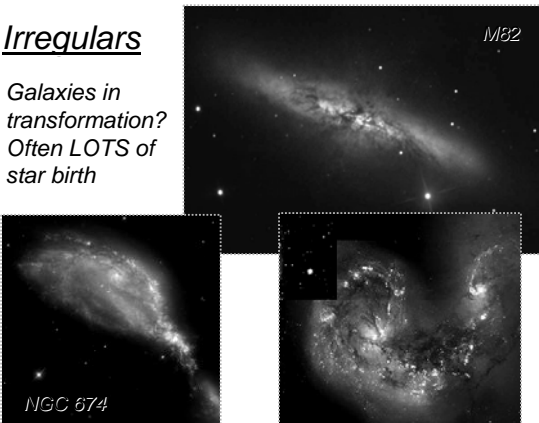
Dwarf ellipticals

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

NGC 205 2MASS

**Irregulars**

- Galaxies in transformation? Often LOTS of star birth

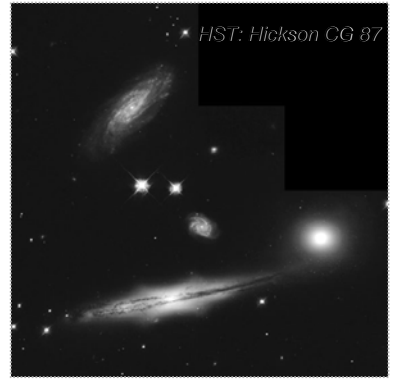


M82

NGC 674

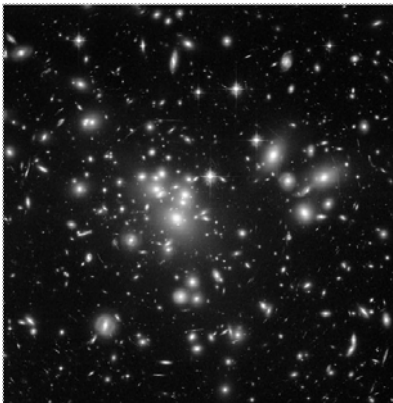
**Where do spirals and ellipticals live?**

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



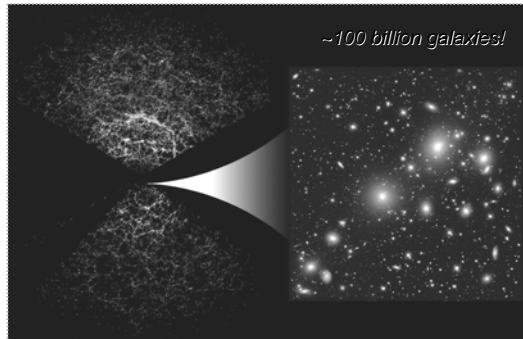
HST: Hickson CG 87

- Ellipticals** - most often in dense clusters of galaxies (involve 100's to 1000's)



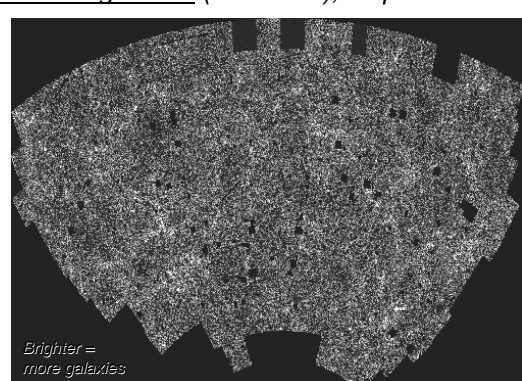
HST: Abell 1689

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



~100 billion galaxies!

**Pattern of galaxies** (3 million+), 15° portion of sky



Brighter = more galaxies

**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

**OUR "LOCAL GROUP" OF GALAXIES**

... IN OUR NEAR NEIGHBORHOOD

Legend  
 ① Spiral  
 ② Irregular  
 • Dwarf  
 • Irregular

**OUR "local group" of galaxies**

**3 spirals:**  
 Andromeda (M31)  
 Milky Way  
 Triangulum (M33)

**2 irregulars:**  
 LMC  
 SMC  
 16+ dwarfs

**LARGEST: 3 SPIRAL GALAXIES**

ANDROMEDA	M31	Sb	2/3 M <sub>gal</sub>
OUR GALAXY (MILKYWAY)		Sb	1 "
TRIANGULUM	M33	Sc	1/5 "

**2 IRREGULAR GALAXIES**

LARGE MAGELLANIC CLOUD (LMC)			1/6 "
SMALL " (SMC)			1/30 "

**10 DWARF ELLIPTICAL GALAXIES**  
**2 DWARF IRREGULAR GALAXIES**  
**4 SMALL ELLIPSOIDS** ~ 21 GALAXIES

**Biggest is Andromeda (Sb - M33)**

- Andromeda is ~3 million light years away (or ~30 MW diameters), has ~1.5 mass of MW
- We see her as she was 3 million years ago, not as she is today! – this is lookback time
- Oops! she may crash into MW in about 2 billion years

**Triangulum (M33)**

- 1/5 mass of MW, spiral classified as Sc
- Several bright (pink) star forming regions

**Large & Small Magellanic Clouds**

**LMC has 30 Doradus, home of SN 1987A**

**SN 1987a – before and after**

More on SN in planetarium show next Wed 6 Apr

## Measuring galactic distances

Tough challenge!

Edwin Hubble made breakthrough using Cepheid variables

Found Andromeda far outside Milky Way

Huge step forward in thinking about universe

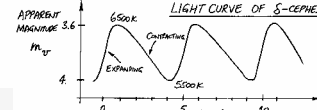


NGC 4414

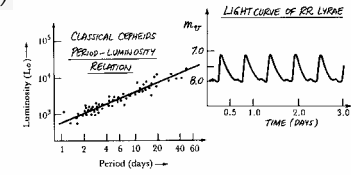
Cepheid variable stars as distance indicators: "standard candle"

### PULSATING VARIABLE STARS

STARS BECOME UNSTABLE TO LARGE-AMPLITUDE PULSATIONS AS THEY EVOLVE ACROSS "INSTABILITY STRIP"  
AS STARS PULSATE, THEY EXPAND AND CONTRACT, CHANGING BRIGHTNESS AS THEY DO ...

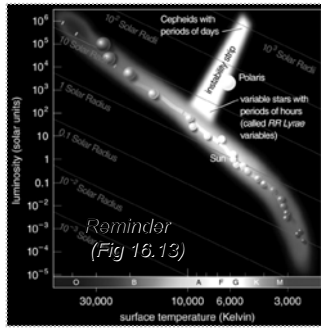
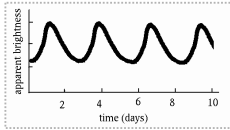


Vital discovery by Henrietta Leavitt (1912)

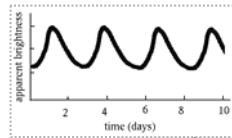


## Cepheid stars in H-R diagram

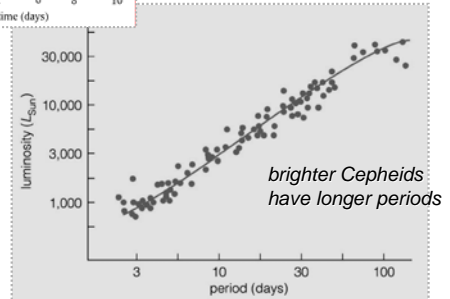
- "Instability strip" -- region in H-R diagram with large, bright stars
- Outer regions of star are unstable and tend to pulsate
- Star expands and contracts, getting brighter and fainter



## Cepheid variable stars



Period - Luminosity relation



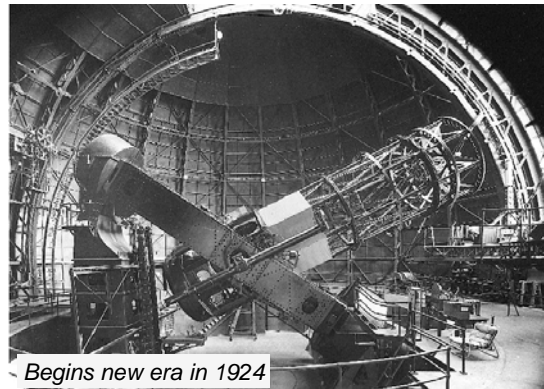
Andromeda found to be far outside Milky Way – another "island universe" : galaxy!

- Edwin Hubble in 1924 identified Cepheids in Andromeda (M33) → showed they were far outside of Milky Way!
- 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