Galactic Astronomy

Welcome !

- What is the course about
- Logistics
  - Textbook, web pages
  - Assignments, exams
  - Semester plan
- Discussion
  - Galaxies in the big pictures

- Goals
  - Have fun together, cover a lot of material, learn as much as possible about the newest/recent development
  - Come with your own requests if you have any, we'll find space in the program to discuss those

Textbooks

- General overview:
  - **Galactic Astronomy by Binney and Merrifield**
  - The Physics and Chemistry of the ISM by Tielens
  - Star Formation by Stahler
  - Galaxies in the Universe by Sparke and Gallagher
  - Galactic Dynamics (2nd Edition) by Binney and Tremaine

- Course web page
  - https://www.ces.clemson.edu/~majello/astr-8300/

- Office hours
  - Wednesday 2-3pm + by appointment (send an email)

Assignments and Grading

- Homework (30%):
  - Every two weeks, typically on Fridays
  - Collected at the start of a class the week after, don't be late

- Course Project (40%) :
  - A research paper/project on a chosen topic, to be presented also as a seminar at the end of the semester

- Mid-term exam (30%) :
  - Exam (sometime in Nov.) on the material covered on the course

- Class participation is encouraged, but not enforced
  - If you skip a class, get the notes from your colleagues or from myself

Also bear with me while I learn how to use: Blackboard, iROAR, Central…

Schedule

- Sept 2nd last date to drop a class without a W
- Nov 26th-28th: Thankgsgiving
- Midterm exam, likely towards end of November
- I might need to re-schedule a few lectures
  - What about Friday afternoons ? Any better time ? We can set up a doodle poll

What is a Galaxy ?

- Galaxies are gravitationally bound systems consisting of:
  - Stars, stellar remnants, gas, dust, CRs and dark matter

What are Galaxies made of ?

Sombrero Galaxy (M 104)

M81

What is a Galaxy ?

Topics we will cover

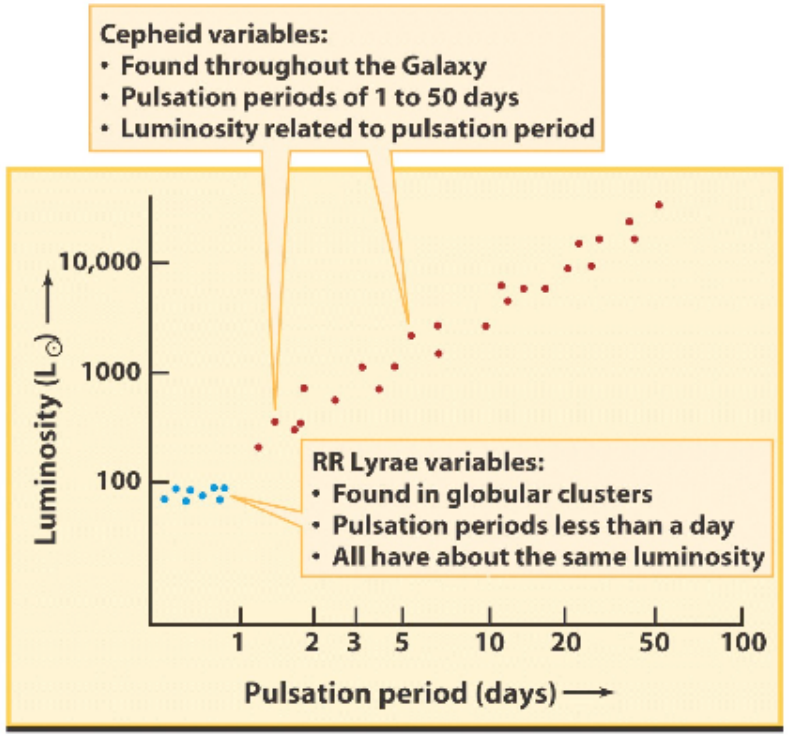
- Gas, Dust and CRs in Galaxies
- Star formation and stellar populations
- Milky Way as a detailed model of Galaxy
- Galactic dynamic – dark matter
- Galactic evolution/formation
- Active Galactic Nuclei – galactic centers

Research Topics

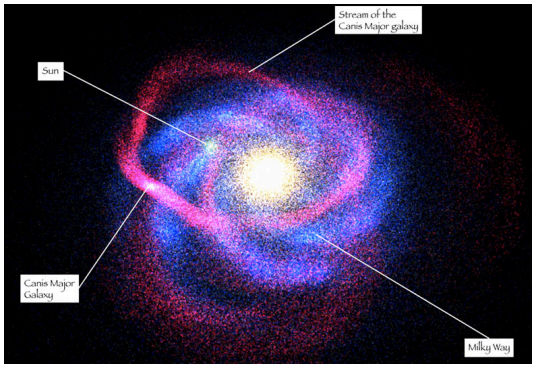
- Explain galaxy population over cosmic time
- How galaxies formed and evolved
- Co-evolution of Galaxies and their super massive black holes

Brief History

- Discovery of Nebulae in late 1700 (Messier)
- Debated whether they were Galactic or extragalactic
- Hubble resolved some external parts of galaxies into stars and identified Cepheids: the nebula was too far

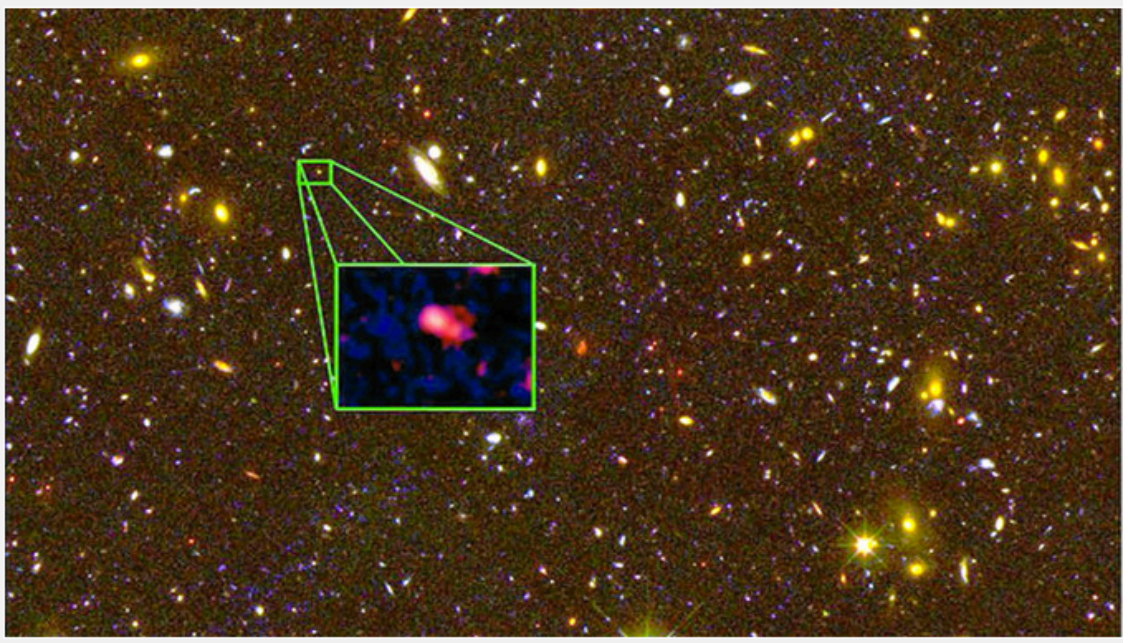


Quiz



- What's the closest galaxy?
- What's the 2nd closest galaxy ?
- What's the closest galaxy that is not a satellite of the MW ?
  - A satellite of Andromeda ☺
  - Andromeda is at 0.75 Mpc

- What's the furthest galaxy ?
  - Z8_GND_5296 (z=7.51)
  - 700Myr after BB
- Is this the furthest object ?
  - GRB 090423 (z~8.3)

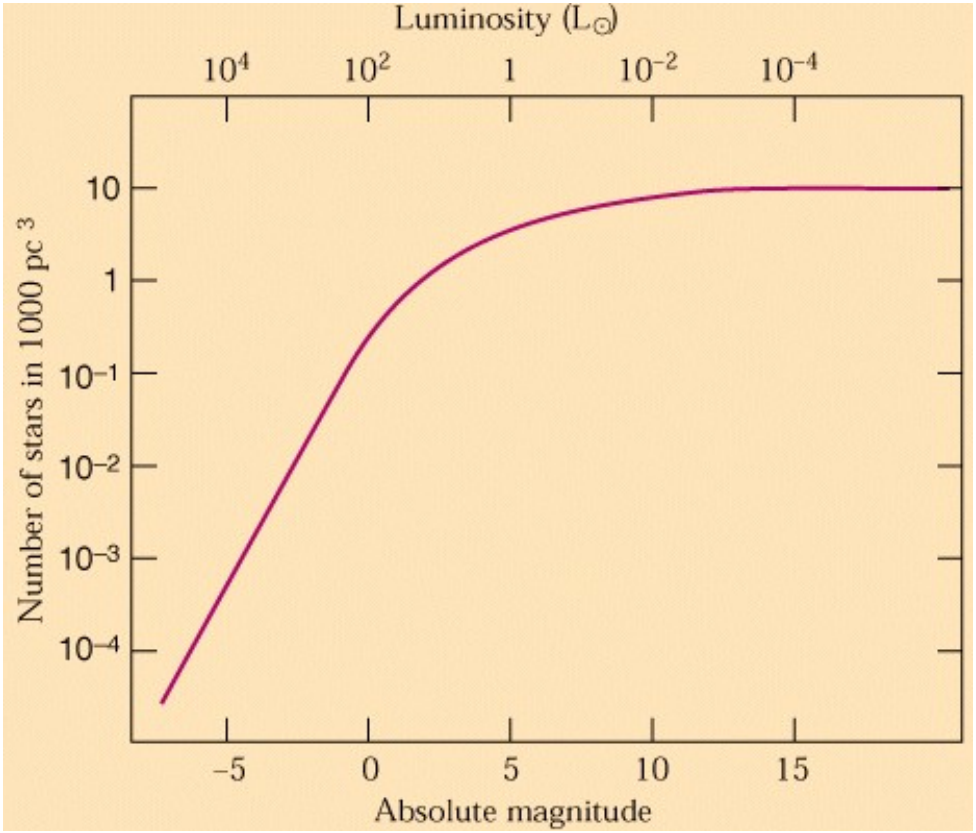


How many stars are in a Galaxy ?

- Take Andromeda:
  - L = 2.6e10 $L_\odot$
  - Average luminosity ?

- Most Stars are less luminous than our sun
  - Take L~0.1 $L_\odot$
  - We get 260billion stars

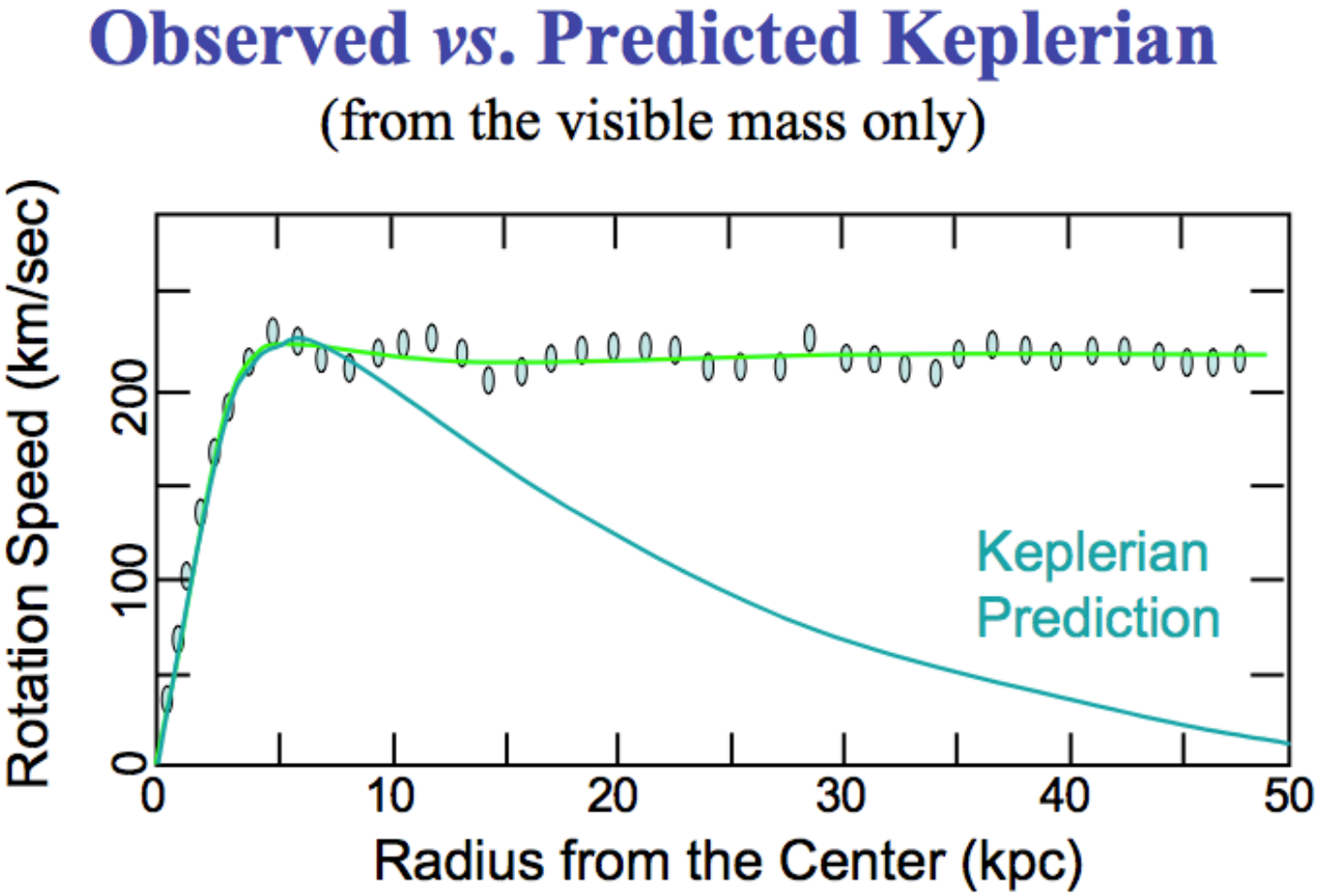
- Is there another way ?



Two bonus questions:

1. how long does it take for the sun to go around the Galaxy ?
2. Compare the sun power/mass w.r.t. the human body (1 W/kg)

Flat rotation curve



Galaxy Components by Mass

- Milky Way ~1-4 x 10^{12} $M_\odot$
  - Stars ~ 80 x 10^9 $M_\odot$ (60 are in the disk, 20 in the bulge, halos are a small %)
  - Gas ~5 x 10^9 $M_\odot$

- Age of the MW ?
  - 13.2 Gyr, measured from the abundance of long-lived radioactive elements in stars

Galaxies

Ellipticals

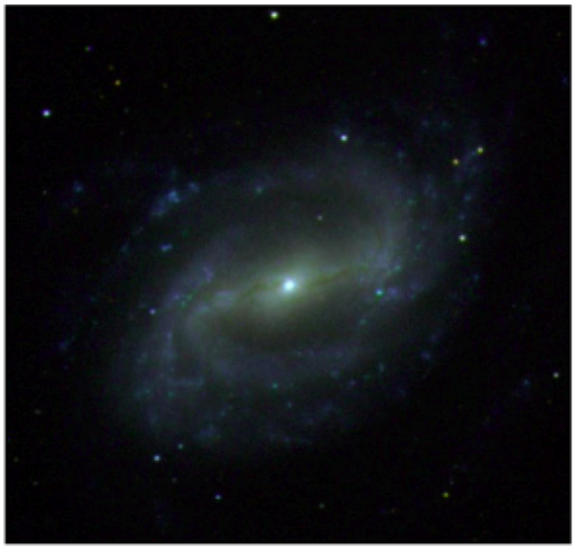
$M_{halo} > 10^{11} M_\odot$

V~350km/s

Highly Clustered

Old stars

little star formation now



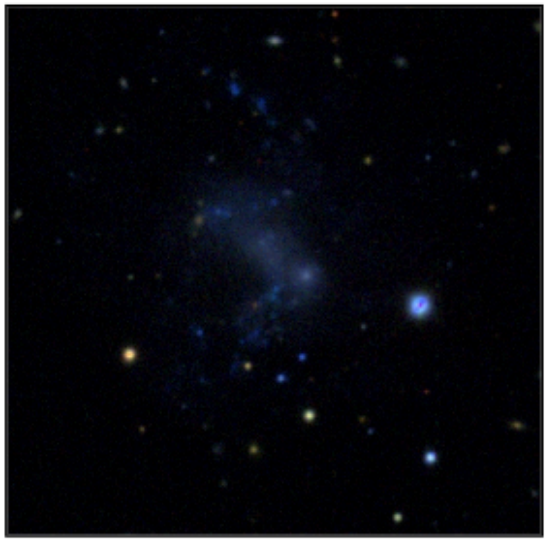
Spirals

$M_{halo} > 10^{10} M_\odot$

V~200km/s

wide range of stellar ages

star forming



Dwarfs

$M_{halo} > 10^{8} M_\odot$

V~30km/s

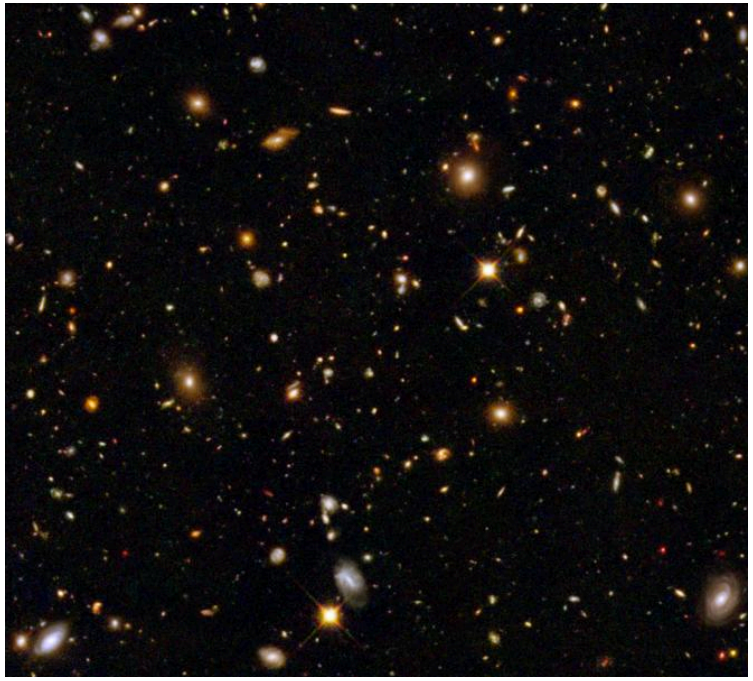
Weakly Clustered

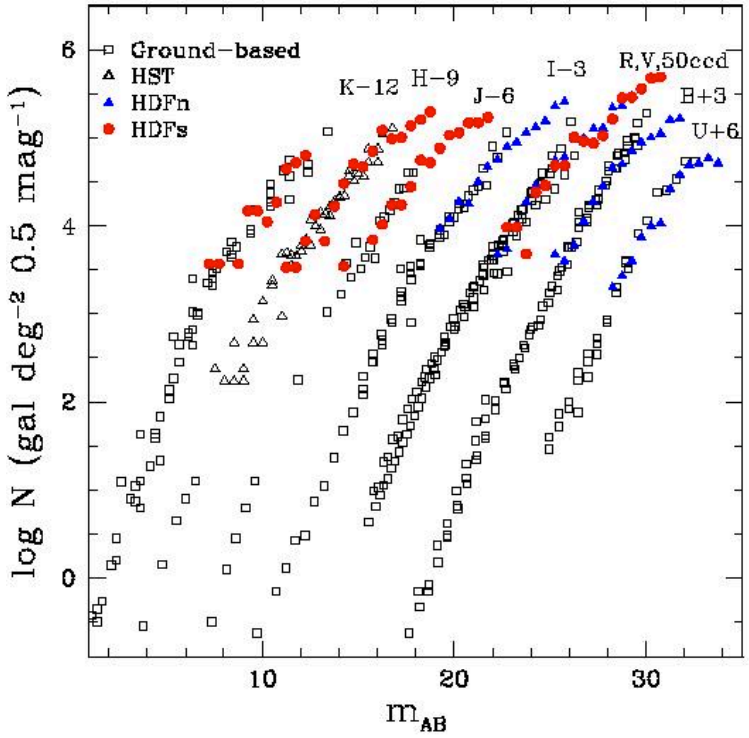
Young stars

Numerous

How many galaxies are there ?

- Typically, surveys find
  - 50 gal/arcmin^2 @ m~25
  - 175 gal/arcmin^2 @ m~29

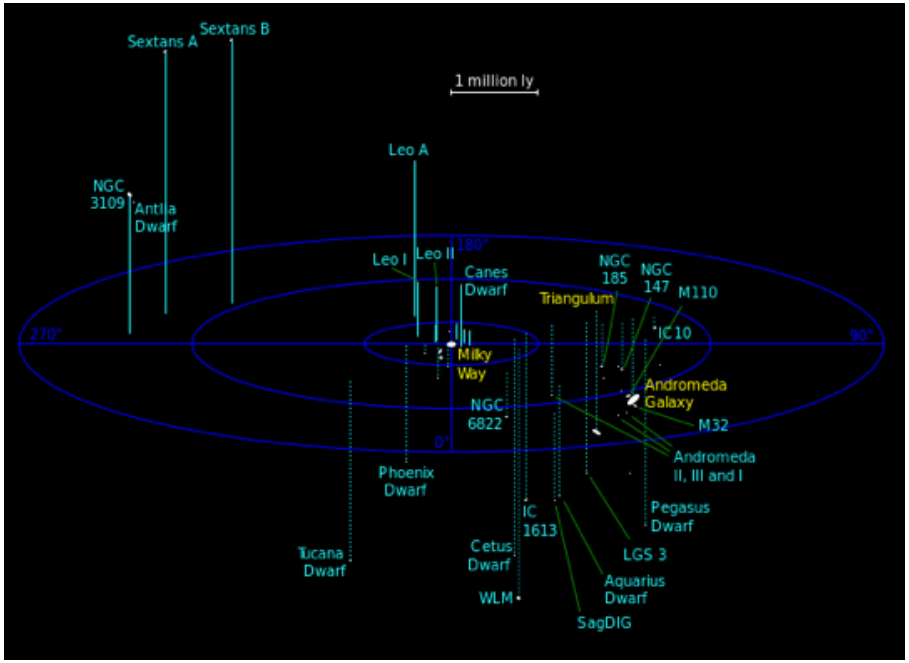


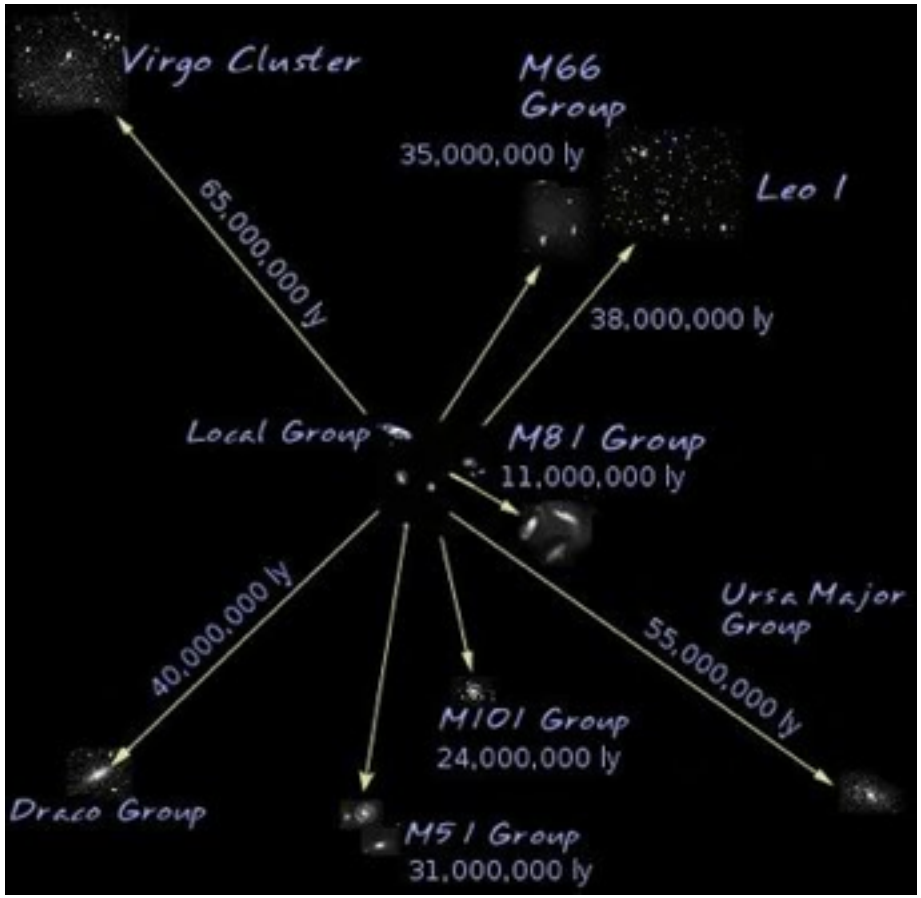


> 25 billion galaxies, in reality
is more like ~100 billion

Do Galaxies live Alone ?

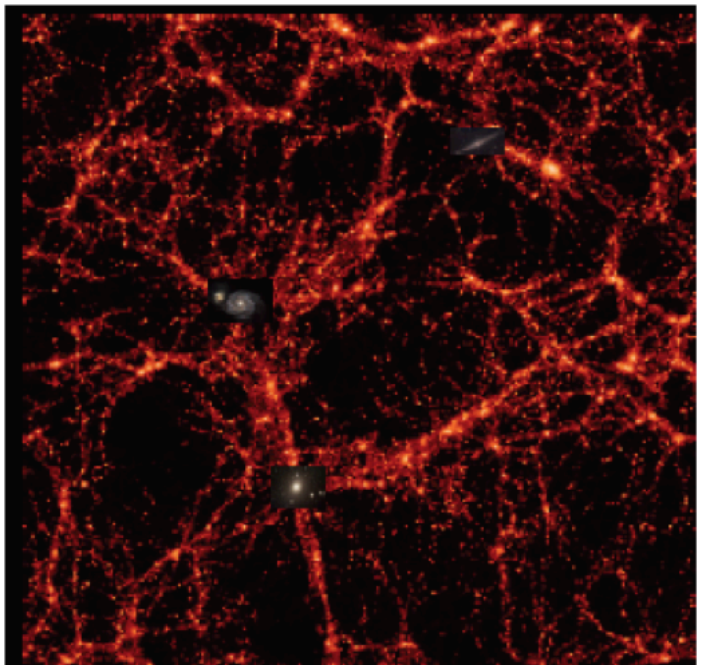
- The Universe is highly clustered at present age



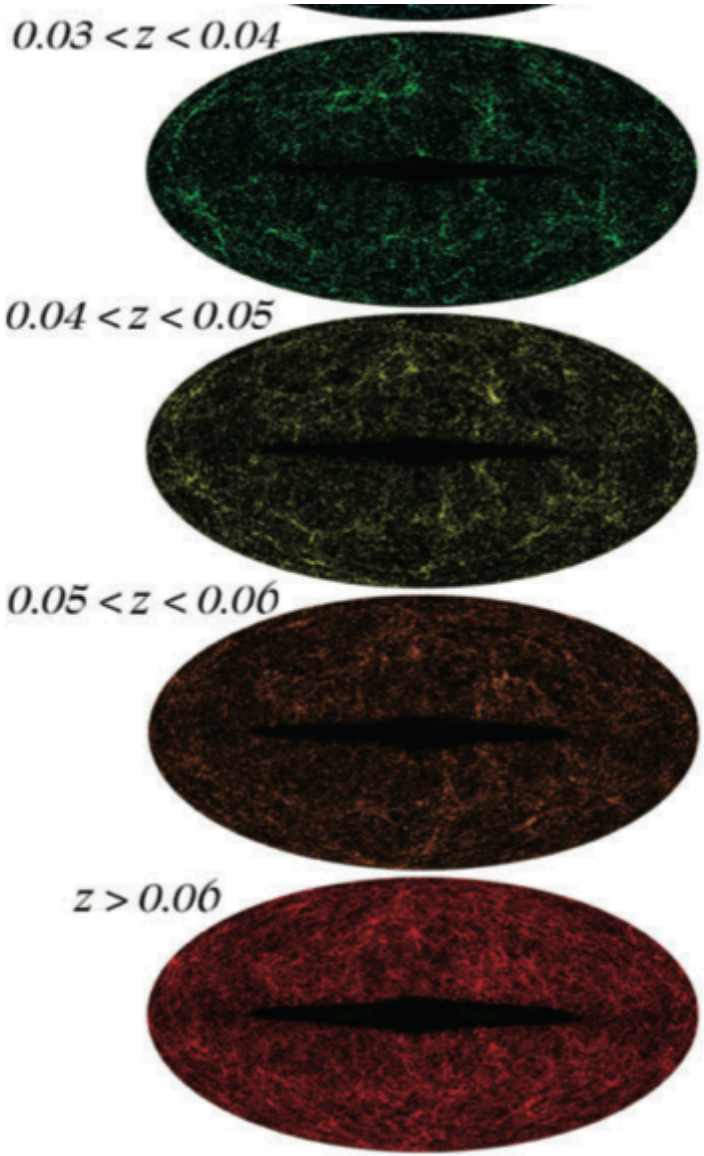


The Cosmic Web

- The cosmic web has a structure at all scale, but becomes homogeneous for R>300 Mpc

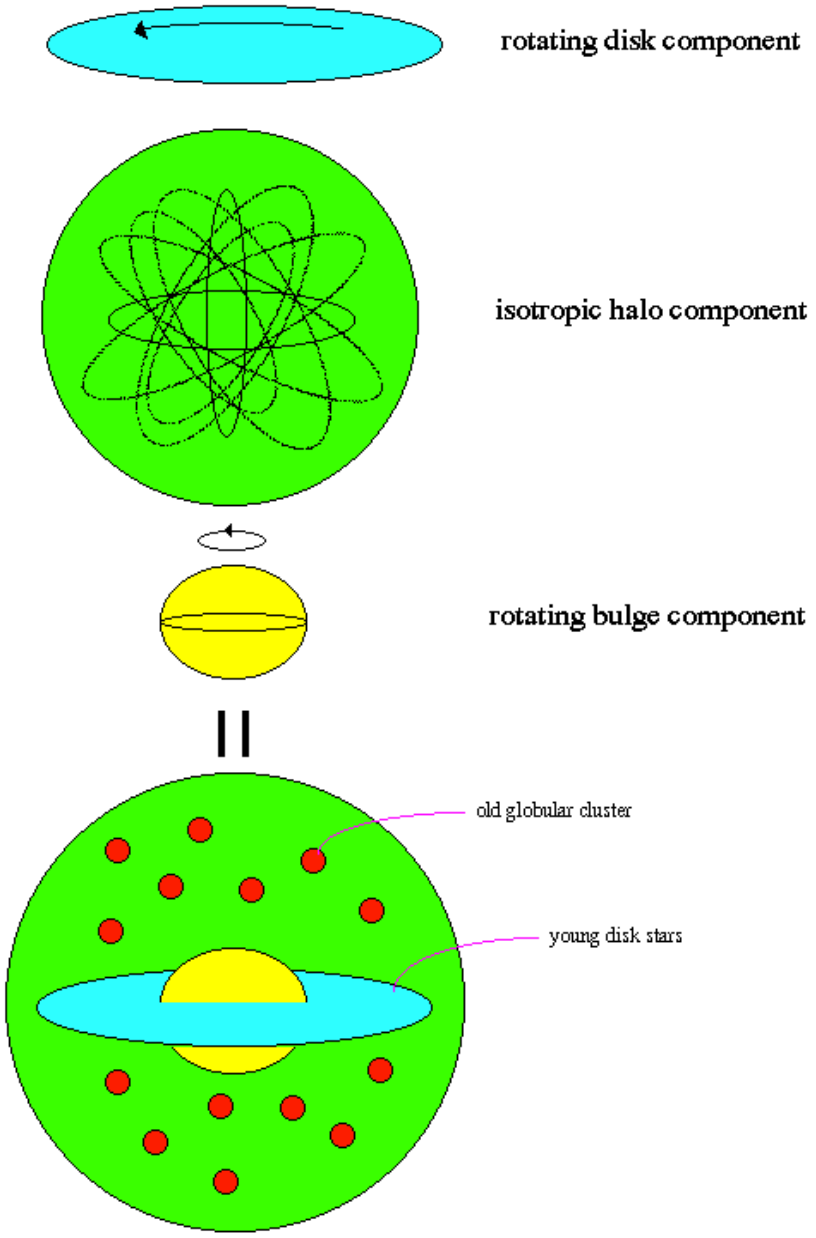


2MASS Galaxy Catalog

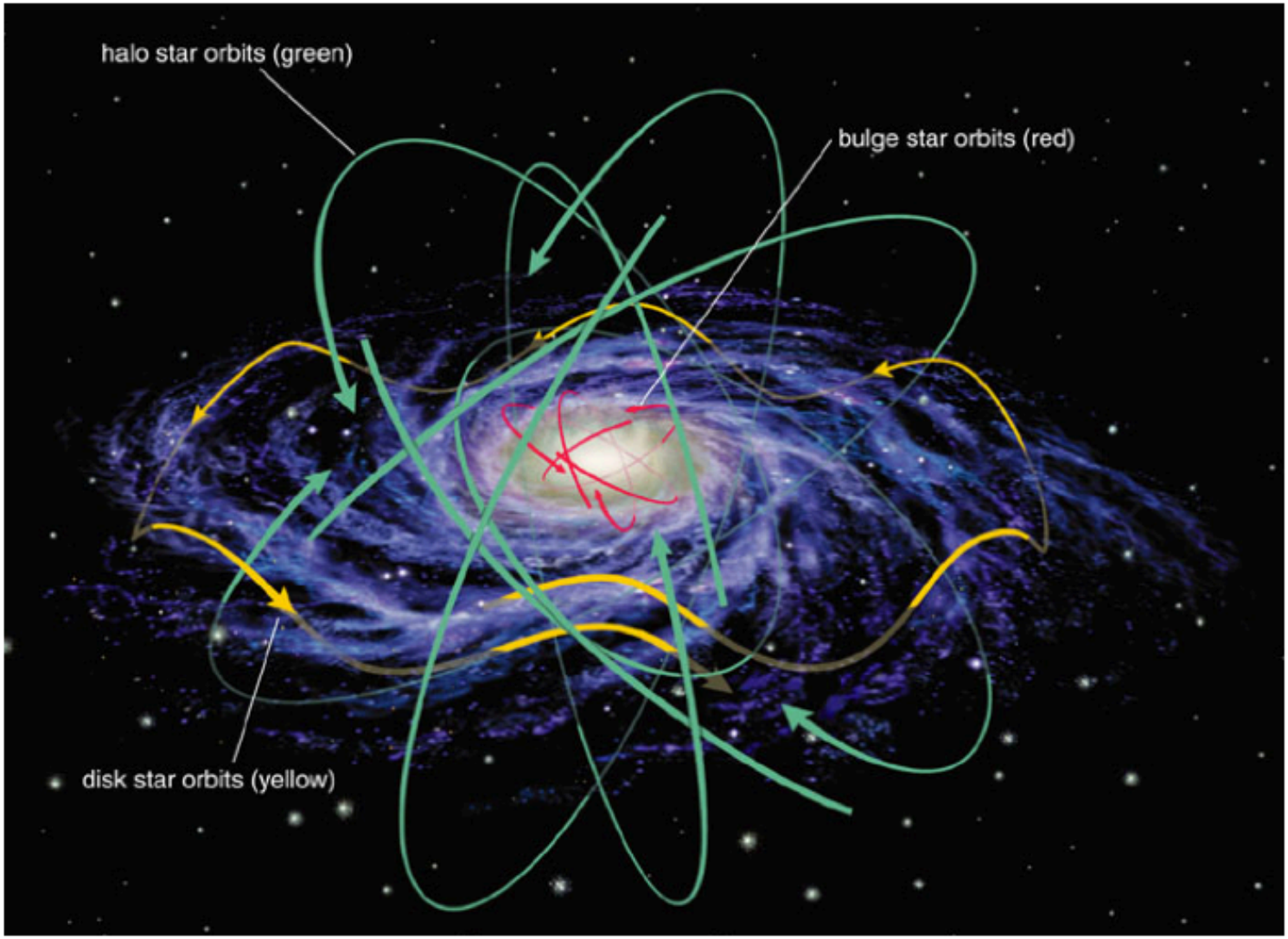


Schematic View of the Galaxy

- 3 stellar populations
  - Corresponding to 3 dynamical components of our Galaxy
  - Disk, halo, bulge
- The 3 components have different kinematic properties, but also different stellar pop.
  - Disk contains most of the gas-> young and old stars
  - Bulge is dominated by old stars and has a violent core
  - The halo contains old stars and globular cluster
- Chemically they are also different
  - Bulge and disk stars are metal rich
  - Halo stars are metal poor



Stellar Orbits



The Concept of Stellar Populations

- Originally discovered by Baade, who came up with 2 populations:

  Pop. I: young stars in the (thin) disk, open clusters

  Pop. II: old stars in the bulge, halo, and globular clusters

  – Today, we distinguish between the old, metal-rich stars in the bulge, and old, metal-poor stars in the halo

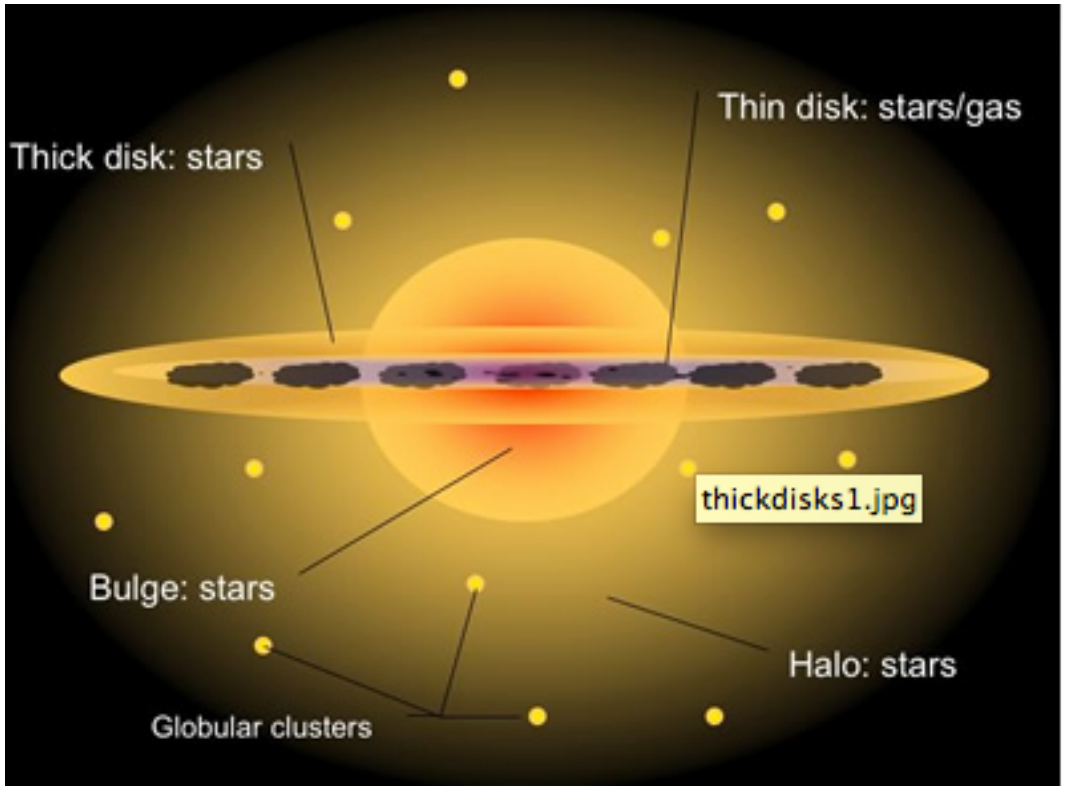
  – Not clear whether the Pop. I is homogeneous: young thin disk, vs. intermediate-age thick disk

- A good modern definition of stellar populations:

  Stellar sub-systems within the Galaxy, distinguished by density distributions, kinematics, chemical abundances, and presumably formation histories.

Thick Disk

- Debated for some time, not all galaxies can have it. The MW has one
- The thin disk has a vertical scale height of ~300 pc
- The thick disk has a vertical scale height of ~1kpc



End of Lecture

- Get together with your neighbor and discuss what we covered today then let's discuss together
- Brief History of Galaxies
- What Galaxies are made of
  - Stars, ISM, CRs, DM
- Galactic components
  - Disk, halo, bulge: different kinematics and different stellar populations

- Cosmic Web and local group

Next: ISM and the role of dust