The Components of a Spiral Galaxy-a Bit of a Review

we have discussed this in the context of the MilkyWay

Disks:

Rotationally supported, lots of gas, dust, star formation occurs in disks, spiral arms

Origin in CDM models: disk galaxies form in halos with high angular momentum and quiet recent assembly history, ellipticals are the slowly-rotating remnants of repeated merging events. Disks, form out of gas that flows in with similar angular momentum to that of earlier-accreted material

Bulges:

- somewhat spheroidal featureless (no spiral arms,bars, rings etc) that stick out of the disk plane,
- mostly old stars (not much dust or star-forming regions),
- kinematically hot, i.e. dynamically supported by the velocity dispersion of their stars- but they do rotate more significantly than ellipticals

Origin

- thought to form via mergers (i.e. accretion of usually smaller external units)- disks reform later after merger by accretion of gas.

Halo

- Totally dominated by dark matter but does have gas (HI) ,some field stars and globular clusters

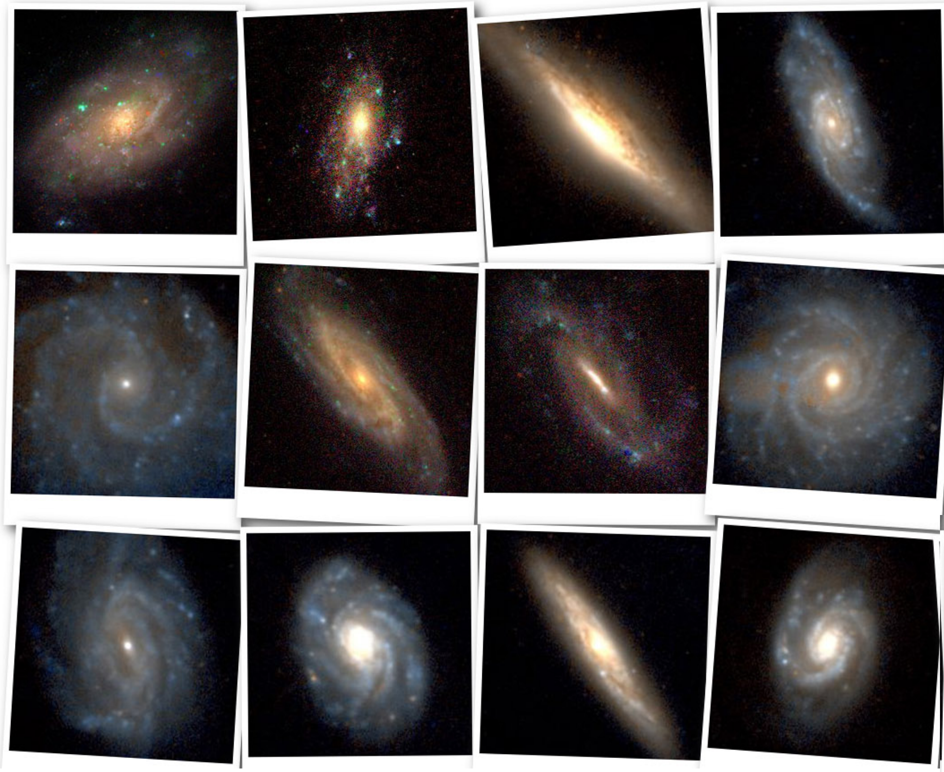
TABLE 23.1 Overall Properties of the Galactic Disk, Halo, and Bulge

GALACTIC DISK	GALACTIC HALO	GALACTIC BULGE
Highly flattened	Roughly spherical—mildly flattened	Somewhat flattened and elongated in the plane of the disk ("football shaped")
Contains both young and old stars	Contains old stars only	Contains both young and old stars; more old stars at greater distances from the center
Contains gas and dust	Contains no gas and dust	Contains gas and dust, especially in the inner regions
Site of ongoing star formation	No star formation during the last 10 billion years	Ongoing star formation in the inner regions
Gas and stars move in circular orbits in the Galactic plane	Stars have random orbits in three dimensions	Stars have largely random orbits but with some net rotation about the Galactic center
Spiral arms	No obvious substructure	Ring of gas and dust near center; Galactic nucleus

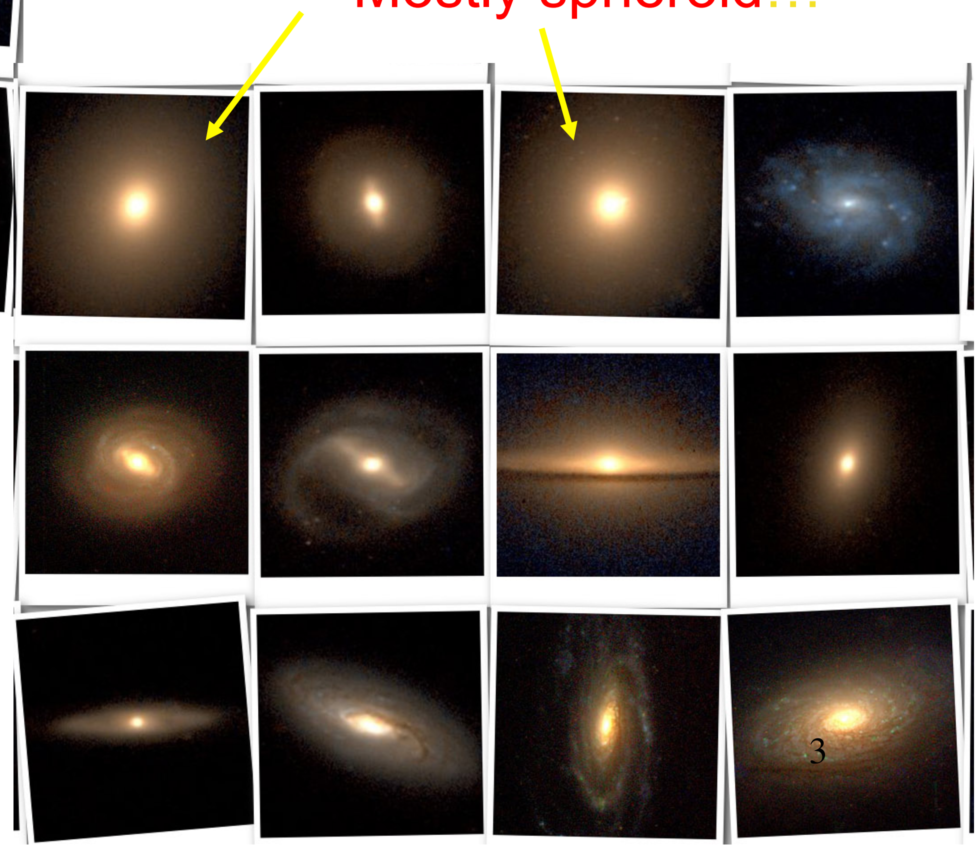
From Chaisson

A Bit of the Galaxy Zoo

Mostly disk…



Mostly spheroid…



- Disk-bulge separation is tricky and influenced by inclination angle and dust and wavelength observed (disks standout in the blue, bulges in the red)

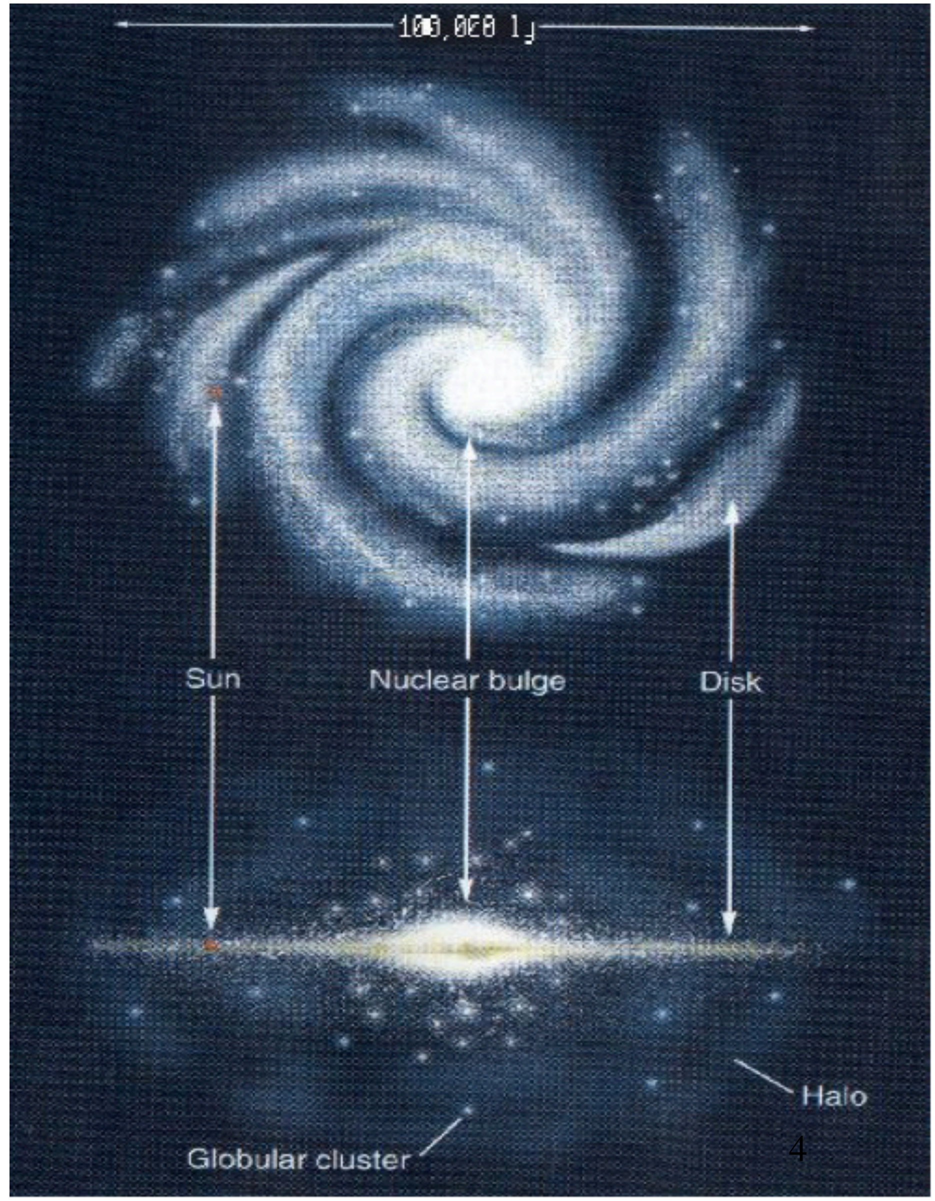
Spirals

- Composed of 3 components
  - disk
  - bulge
  - halo
- Bulge-oldish stars-tends to be metal poor
- Disk - young stars

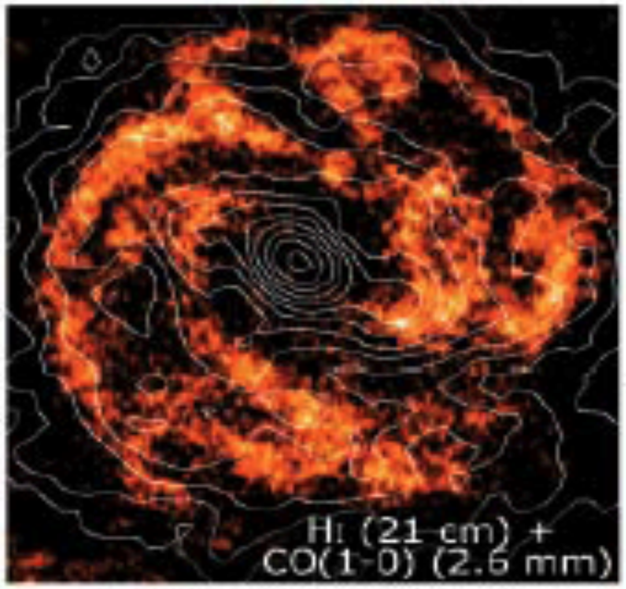
  The disk contains a large quantity of gas & dust, the bulge essential none

  Disks are cold (rotationally supported)

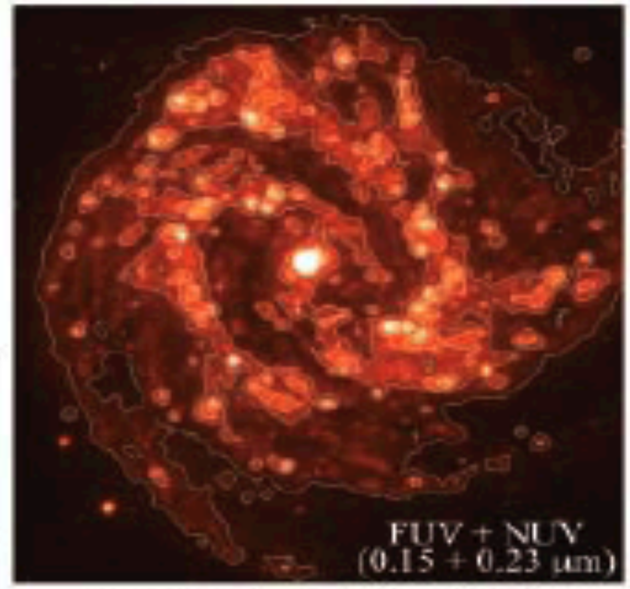
  Bulges are 'hot' supported by random motions
- The rotation curves of spiral galaxies rise like a solid body in the central regions, then flattens out (i.e., v(r) = constant). This flattening is due to the presence of a **dark matter halo**.



M 83: from Gas to Stars

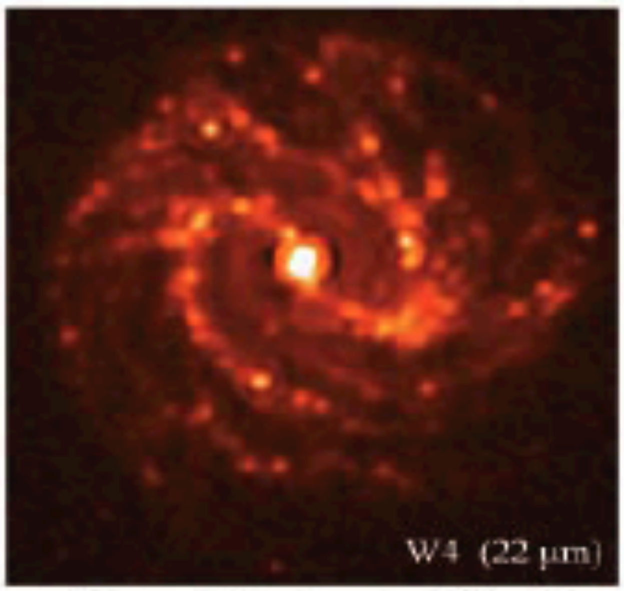


Neutral gas is the *reservoir*, molecular gas fuels the star formation



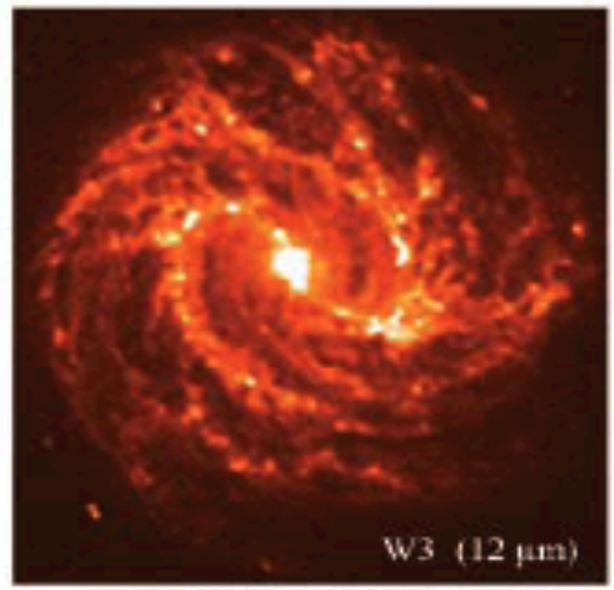
Young hot stars represent the current epoch of star formation

Evolved star population constitutes the *Stellar Backbone*



Very small dust grains efficiently reprocess energy from star formation

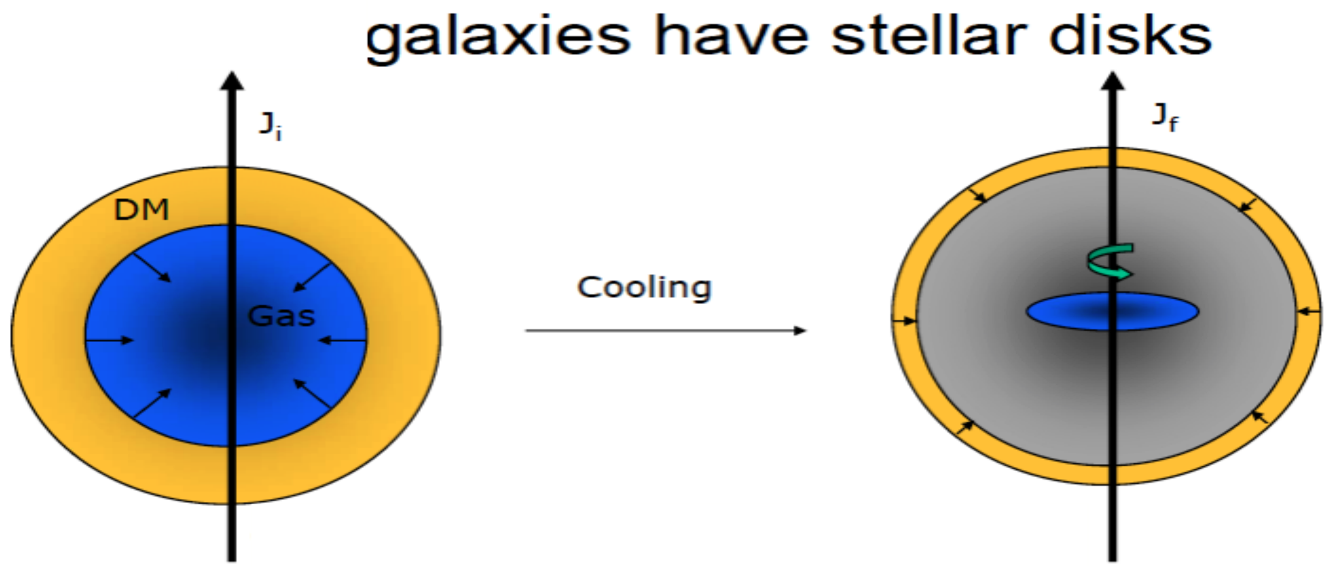
Spiral galaxies are panchromatic objects- different physical process are best shown in different wavebands



Excited PAH molecules due to *ISM heating* by hot stars

Simple Model of Why Galaxies Have Disks

- A circular orbit has the lowest energy for an initial angular momentum J- thus since angular momentum is conserved, if the in falling gas loses energy (cools) will tend to form a disk
- If stars form from dense gas they will also be in a disk.



However In A Hierarchical Universe Things are More Complex

- Formation of a spiral galaxy

The Big Picture- Two Populations

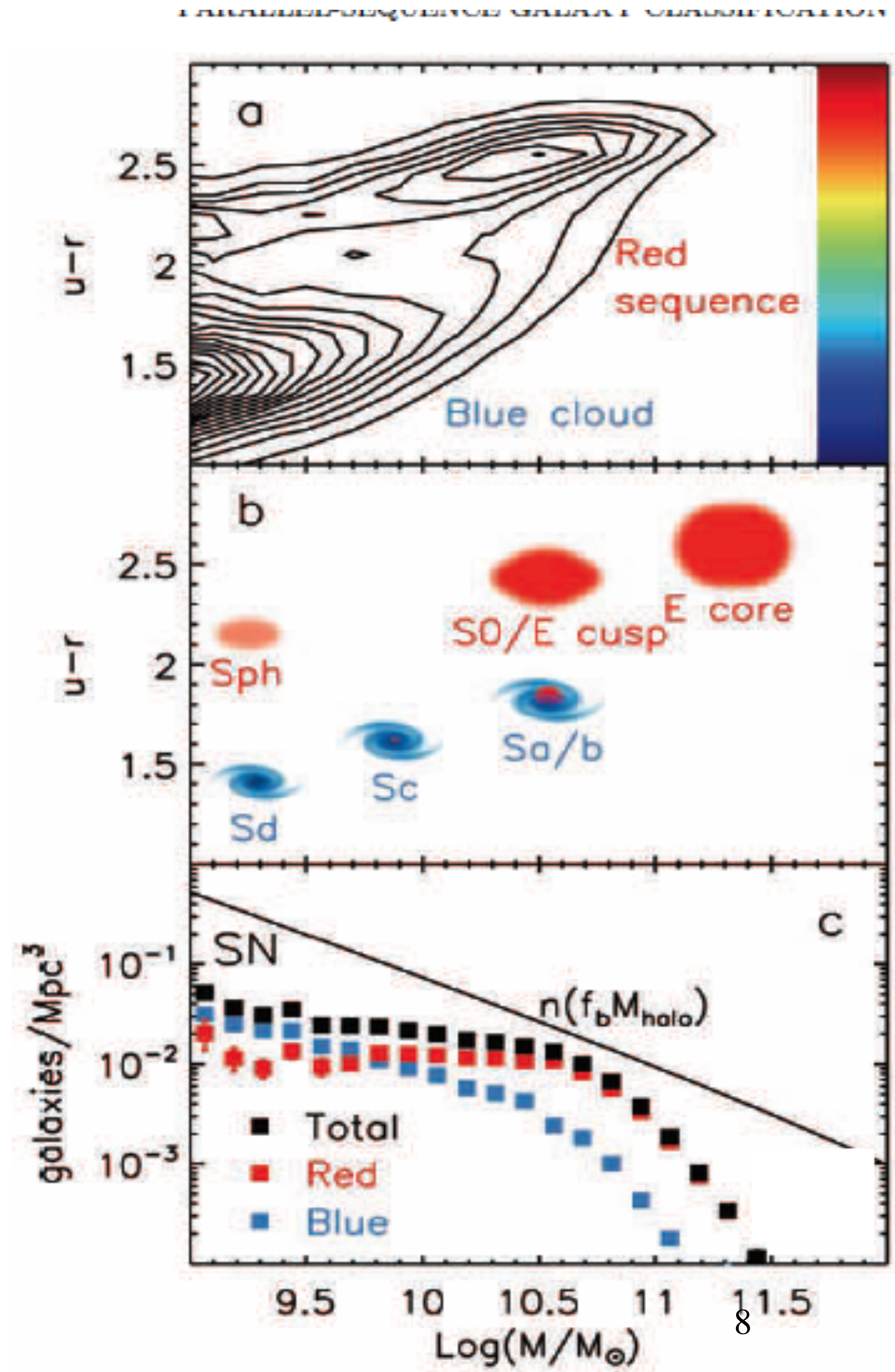
- top panel color distribution vs mass of a large sample of local galaxies from the SDSS

  Middle panel is the morphologies that dominate at each mass

  bottom panel shows the galaxy **mass function** divided by color- the **spirals are mostly blue** (some S0s are red) (Cattaneo et al 2009)-

  spirals tend to be less massive than ellipticals

  the black solid line is the prediction from cold dark matter theory of the number density of halos vs mass- <u>notice does not agree with the galaxy mass distribution</u>



Summary of Tuesdays-Lecture Spirals

- Components of Spirals
    - bulge
    - disk
    - halo
  - each has a different stellar population, gas content.
- Connection between color, mass, morphology for galaxies as a whole- patterns on the color, mass, morphology.

Top Level Summary-Spirals

- Galaxies have a wide variety of morphologies, from spheroids , disks with and without bars and irregular galaxies.
- Their physical properties (e.g. gas content, average stellar age, the rate of current star formation, mass etc) correlate with morphology.
- disks are predominantly rotationally flattened structures
- spheroids have shapes largely supported by velocity dispersion.

- Conventional theoretical 'wisdom' : disks form at the center of dark matter halos as a consequence of angular momentum conservation during the dissipational collapse of gas (Fall & Efstathiou 1980) , spheroids result predominantly from merger events
- Thus morphology is a transient feature of the hierarchical formation of a galaxy:
  - a disk galaxy may be transformed into a spheroidal one after a major merger, but could then re-form a disk through further gas accretion only to be later disrupted again by another merger