Galaxies

- Star systems like our Milky Way
- Contain a few thousand to tens of billions of stars,
  as well as varying amounts of gas and dust
- Large variety of shapes and sizes

Even seemingly empty regions of the sky contain thousands of very faint, very distant galaxies

Large variety of galaxy morphologies:
- Spirals
- Ellipticals
- Irregular (some, interacting)

Galaxy Classification

Elliptical Galaxies
- E0 = Spherical
- E7 = Highly elliptical

Spiral Galaxies
- Small nucleus; loosely wound arms
- Large nucleus; tightly wound arms

Edwin Hubble's Classification Scheme

Spirals
- Seyfert
- E0
- E1
- E2
- E3
- E4
- E5
- E6
- E7
- S0
- Sa
- Sb
- Sc
- Sd
- Sc

Ellipticals
- E0
- E1
- E2
- E3
- E4
- E5
- E6
- E7
Galaxies with disk and bulge, but no dust are termed S0.

Barred Spirals

Some spirals show a pronounced bar structure in the center.

They are termed barred spirals:

Sequence:
S0, Sd, Sc, analogous to regular spirals.

Irregular Galaxies

Often: result of galaxy collisions / mergers
Often: Very active star formation (“Starburst galaxies”) Somewhat: Small (“Dwarf galaxies”) satellites of larger galaxies (e.g., Magellanic Clouds)

Large Magellanic Cloud

NGC 4038/4039

The Cocoon Galaxy
Structure of Spiral Arms

- density wave model
  - arms are higher density regions
  - rotate at velocities lower than gas and stars
  - like traffic slow-down
    - moving 60 mph
    - encounter a few cars moving 40 mph
    - slow down to 40 mph, pass, and then resume 60 mph
- Density waves produced by perturbation - interaction?
- Spiral structure is stable

Formation of Spiral Arms

Formation of Spiral Arms?
Properties of Elliptical Galaxies

- oblate spheroid
  - oblate, prolate (symmetric egg), triaxial?
- Smooth distribution of light
  - \( \log I(r) \sim r^{-1/4} \)
- ellipticity = \( 10(a - b)/1 \)
  - \( a \) = semi-major axis
  - \( b \) = semi-minor axis
- stars follow random orbits
- Formed from merger of two spirals

Formation of Elliptical Galaxy

Galaxy Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Elliptical</th>
<th>S0</th>
<th>Spiral</th>
<th>Irregular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (M_\odot)</td>
<td>( 10^9 - 10^{12} )</td>
<td>( 10^9 - 10^{12} )</td>
<td>( 10^8 - 10^{12} )</td>
<td>( 10^7 - 10^8 )</td>
</tr>
<tr>
<td>Diam (kpc)</td>
<td>1-200</td>
<td>5-50</td>
<td>5-50</td>
<td>1-10</td>
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<tr>
<td>Lumin. (L_\odot)</td>
<td>( 10^7 - 10^{11} )</td>
<td>( 10^9 - 10^{10} )</td>
<td>( 10^8 - 10^{10} )</td>
<td>( 10^7 - 10^9 )</td>
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<tr>
<td>Stars</td>
<td>K-M</td>
<td>G-M</td>
<td>O-M</td>
<td>O-M</td>
</tr>
<tr>
<td>Population</td>
<td>II</td>
<td>II</td>
<td>I &amp; II</td>
<td>mainly I</td>
</tr>
<tr>
<td>Gas (% mass)</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>&gt;20</td>
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<tr>
<td>Dust</td>
<td>very little</td>
<td>very little</td>
<td>much</td>
<td>much</td>
</tr>
<tr>
<td>Disk/Bulge</td>
<td>all bulge</td>
<td>bulge &gt; disk</td>
<td>disk &gt; bulge</td>
<td>all disk?</td>
</tr>
<tr>
<td>Location</td>
<td>rich cluster</td>
<td>clusters &amp; groups</td>
<td>field &amp; group</td>
<td>field</td>
</tr>
</tbody>
</table>
Clusters

- Morphology variations
  - clusters ~55% E/S0s
  - field ~20% E/S0s
- Two observables
  - Morphology
  - Star formation