In this class we will cover Normal Galaxies:

- Types of galaxies
- Spiral arms and star formation
- Rotation curves and dark matter
Types of Galaxies

Spiral Galaxy

Elliptical Galaxy

M31

M87
Properties of spirals and ellipticals

See Kutner Table 17.1

<table>
<thead>
<tr>
<th>Property</th>
<th>Spirals</th>
<th>Ellipticals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Yes</td>
<td>Some</td>
</tr>
<tr>
<td>Dust</td>
<td>Yes</td>
<td>Some</td>
</tr>
<tr>
<td>Young stars</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Shape</td>
<td>Flat</td>
<td>Round</td>
</tr>
<tr>
<td>Stellar motions</td>
<td>Circular rotation</td>
<td>Random</td>
</tr>
<tr>
<td>Color</td>
<td>“Blue”</td>
<td>“Red”</td>
</tr>
<tr>
<td>Mass range</td>
<td>$10^7$ to $10^{11} M_☉$</td>
<td>$10^6$ to $10^{12} M_☉$</td>
</tr>
</tbody>
</table>
Luminosity functions

Galaxy brightness falls off from the center according to empirical “laws” for the luminosity per unit area.

Elliptical galaxies

\[ L(r) = L_0e^{-(r/r_0)^{1/4}} \quad \text{“de Vaucouleurs’s Law”} \]

Typically \( L_0 \approx 2 \times 10^5 \frac{L_\odot}{pc^2} \) with large spread in \( r_0 \)

Spiral galaxies (disk)

\[ L(r) = L_0e^{-r/D} \quad \text{Typically} \quad D \approx 5 \text{ kpc} \]
Views and Classes of Spiral Galaxies

Edge-on View

Barred Spiral

© Malin/IAC/RGO

© Anglo-Australian Observatory
The Hubble “Tuning Fork”

Despite the suggestion, this is not an evolutionary path!

See Kutner Fig. 17.1
Other types of galaxies

Colliding galaxies

Irregular galaxy

Dwarf galaxy
Images of M31

Visible

Ultraviolet

Infrared

21 cm
Star Formation in Spiral Arms

M81 in Visible Light

From UV to IR...

“Blue Stars are hot, therefore massive, therefore young stars”
Spiral arms are not from “windup”

We know the speed (≈220 km/sec) of stars in the disk. So...

Start 50 Million Years 100 Million Years 500 Million Years

But today, 15,000 Million Years later, we see...

There must be some other mechanism for forming spirals!
Present Understanding: Density Waves

Cars can move quickly on a highway, but they will slow up if they encounter a region of high density, before moving on:

The same thing can happen to galactic gas, dust, and stars:

- density wave
- only the long-lived stars make it out.
- incoming clouds and stars
- compression!
- density wave (enhanced gravity)
- stars form
Rotation Curves and Dark Matter

Just as with the Milky Way, galaxies in general show “flat” rotation curves. This is evidence for “dark matter”.

See also Kutner Fig. 17.21