PART 3 Galaxies

Gas, Stars and stellar motion in the “Milky Way”
The Interstellar Medium

- Space is far from empty!
  - Clouds of cold gas
  - Clouds of dust
- In a galaxy, gravity pulls the dust into a disk along and within the galactic plane
- This dust can obscure visible light from stars and appear to be vast tracts of empty space
- Fortunately, it doesn’t hide all wavelengths of light!
Emission Nebulae

- We frequently see nebulae (clouds of interstellar gas and dust) glowing faintly with a red or pink color.
- Ultraviolet radiation from nearby hot stars heats the nebula, causing it to emit photons.
- This is an emission nebula!
Reflection Nebulae

• When the cloud of gas and dust is simply illuminated by nearby stars, the light reflects, creating a reflection nebula
• Typically glows blue
Dark Nebulae

- Nebulae that are not illuminated or heated by nearby stars are opaque – they block most of the visible light passing through it.
- This is a dark nebula
Interstellar Reddening

• As starlight passes through a dust cloud, the dust particles scatter blue photons, allowing red photons to pass through easily.
• The star appears red (*reddening*) – it looks older and dimmer (*extinction*) than it really is.
If one region of the sky shows nearby stars but no distant stars or galaxies, our view is probably blocked by

    a) nothing, but directed toward a particularly empty region of space.
    b) an emission nebula of ionized gas.
    c) an interstellar gas and dust cloud.
    d) a concentration of dark matter.
The Milky Way does not rotate like a solid disk!
- Inner parts rotate about the center faster than outer parts
- Similar to the way planets rotate around the Sun
- This is called differential rotation.

A plot of rotation speed vs. distance is called a rotation curve.

A star is held in orbit around the galactic center by gravitational forces of all matter inside its orbit!
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Calculating the Mass of the Galaxy

The rotational velocity of the Sun around the center of the galaxy can be used to estimate the galaxy’s mass.

The combined gravitational effect of all mass within the Sun’s orbit is equivalent to one large lump of mass at the center of the galaxy.

Newton’s Law of Gravitation shows that the mass of all matter within the Sun’s orbit is $9 \times 10^{10}$ solar masses!

We can estimate the mass of the entire galaxy by measuring the orbital velocity of small satellite galaxies in orbit around the Milky Way ($2 \times 10^{12}$ solar masses).
Dark Matter!

- What is it!
- How do we know?
- What does it do?
- How does it affect the formation of galaxies and the Universe?
If there was no dark Matter in the Milky Way the velocity of the sun around the Galactic Center would be
  a) greater
  b) smaller
  c) the same
  d) impossible to say
The Galactic Center and Edge

- Despite the appearance of being closely spaced, stars in the Milky Way are very far apart
  - At the Sun’s distance from the center, stellar density is around 1 star per 10 cubic parsecs
- Density is much higher at the core
  - Exceeds 100,000 stars per cubic parsec!
- X-ray and gamma ray telescopes reveal a supermassive black hole at the Milky Way’s core
  - Called Sag A*
  - 5 million solar masses!