

1

In this chapter you will discover...

- the structure of our Milky Way Galaxy and Earth's location in it
- how galaxies are categorized by their shapes
- that galaxies are found in clusters that contain huge amounts of dark matter and why clusters of galaxies form in superclusters
- that the universe is expanding

2

Schematic Diagrams of the Milky Way

3

Our Galaxy

This wide-angle photograph spans half the Milky Way. The Northern Cross is at the left and the Southern Cross is at the right. The center of the Galaxy is in the constellation Sagittarius, in the middle of this photograph. The dark lines and blotches are caused by hundreds of interstellar clouds of gas and dust that obscure the light from background stars, rather than by a lack of stars.

4

Electron Spin and the Hydrogen Atom

Parallel spins: higher-energy configuration

Opposite spins: lower-energy configuration

Photon, wavelength = 21 cm

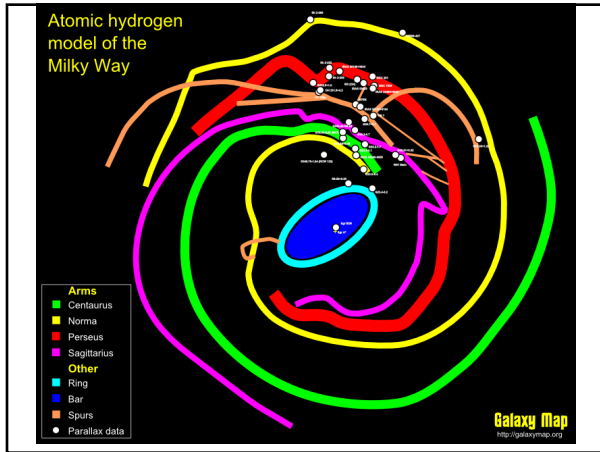
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Mapping the spiral structure of the Galaxy

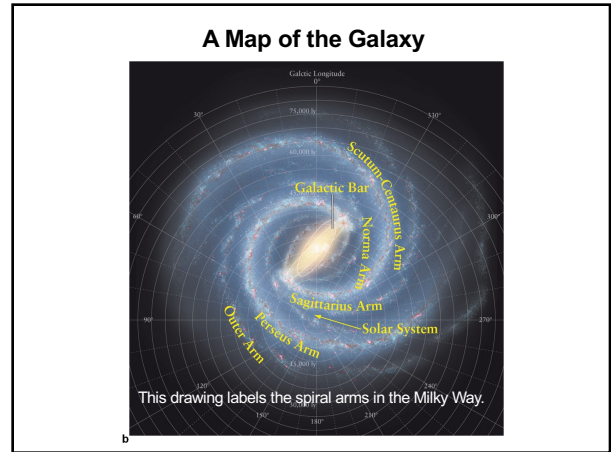
Four clouds all in the same direction. Use doppler shifts to distinguish one cloud from the other. Use the rotation curve to convert the doppler shifts of each cloud to distances from the center of the Galaxy. Do this for other directions to build up a map of the Galaxy strip by strip.

Spiral structure of Galaxy

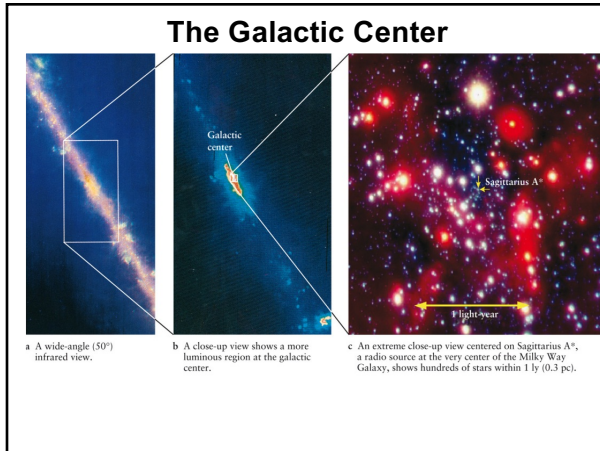
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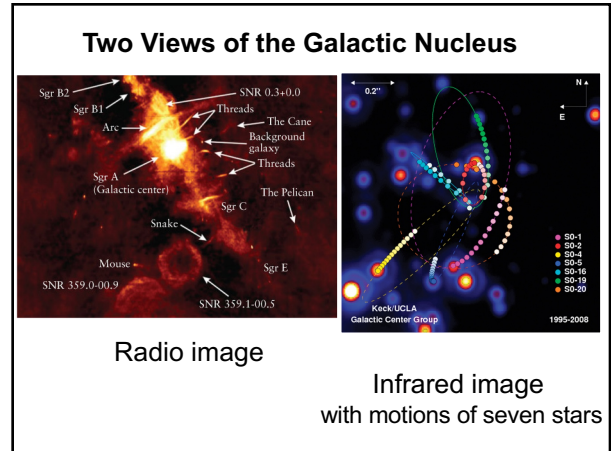
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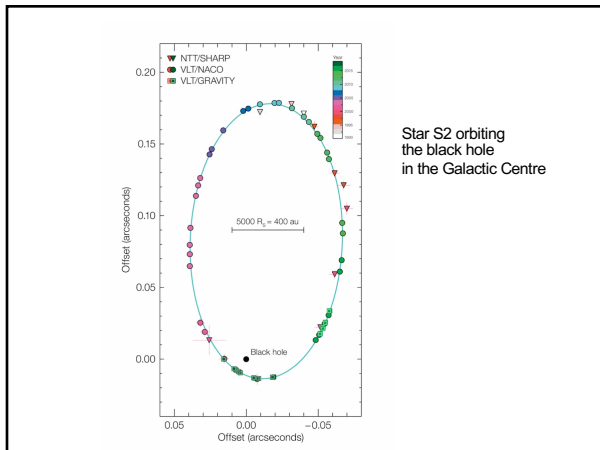
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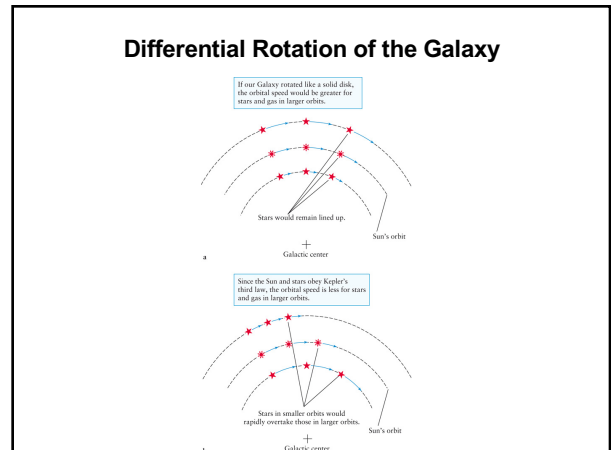
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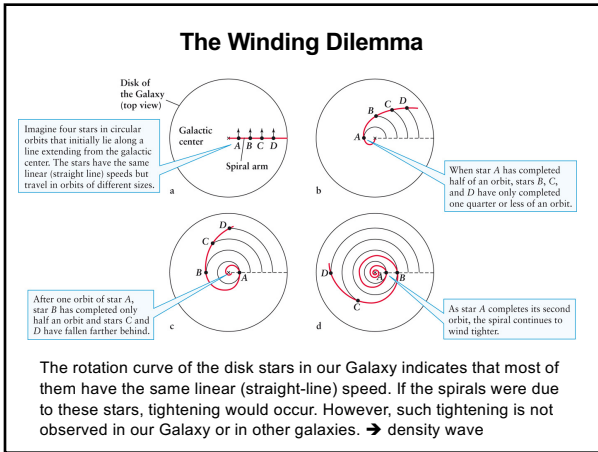
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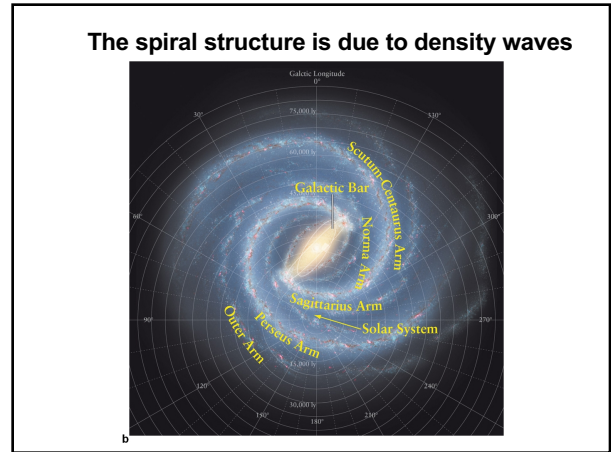
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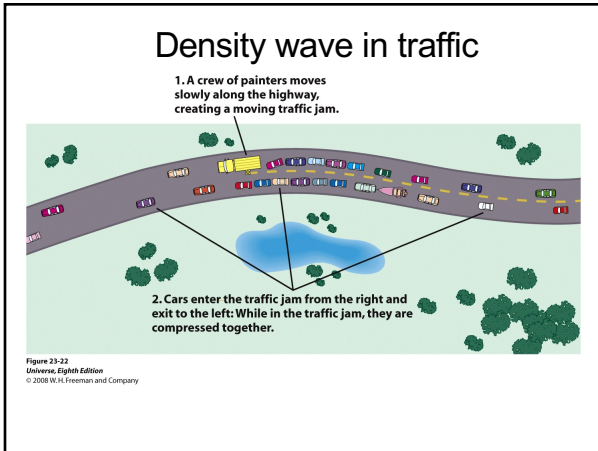
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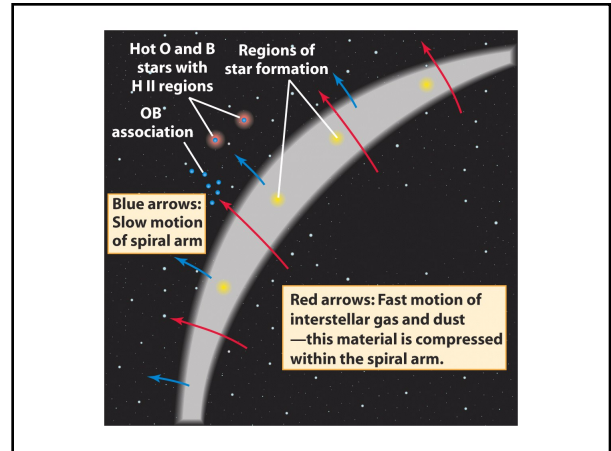
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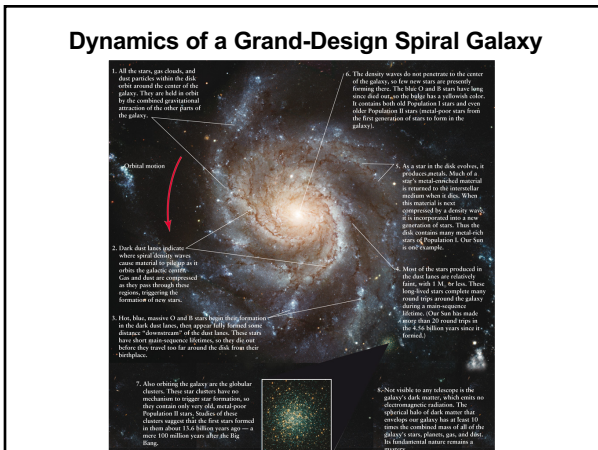
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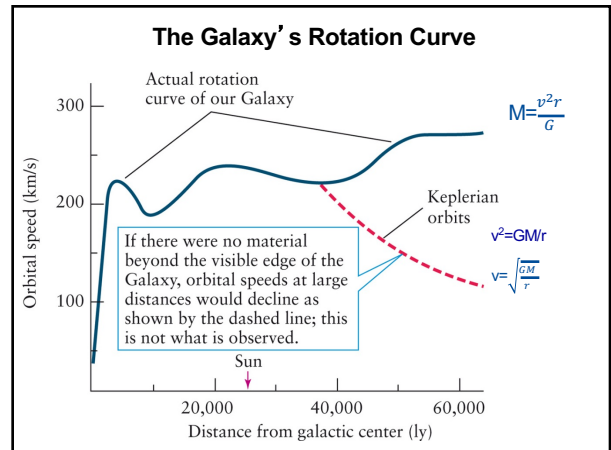
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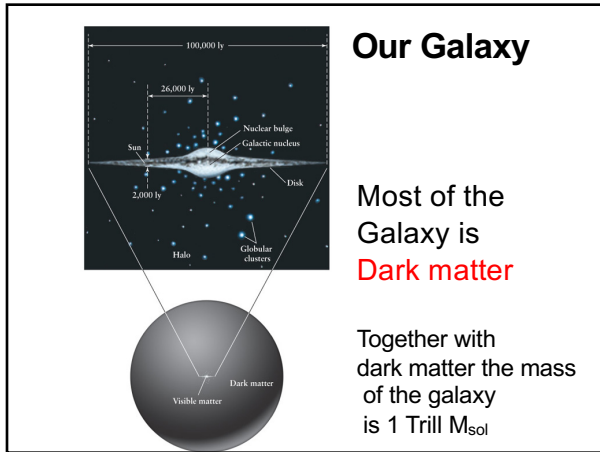
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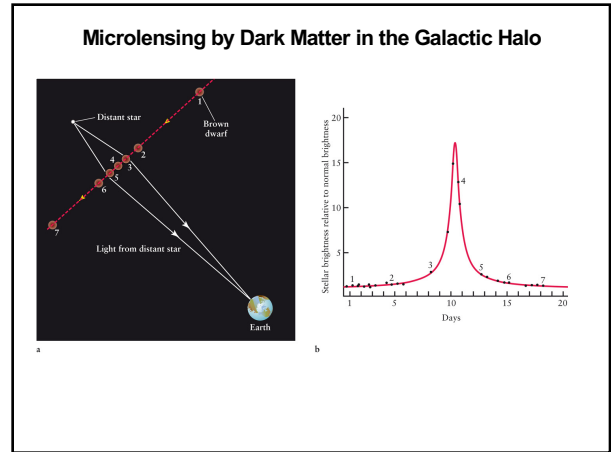
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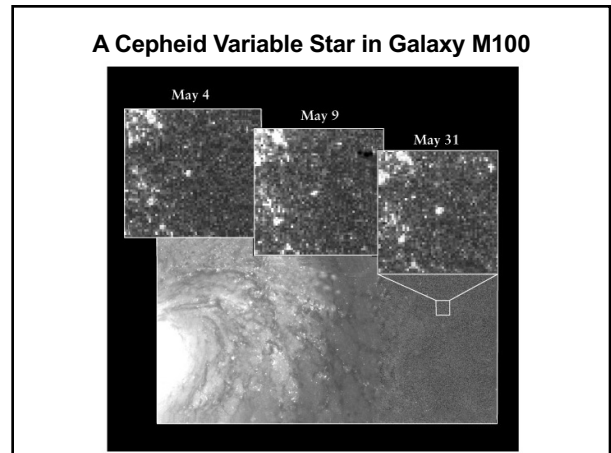
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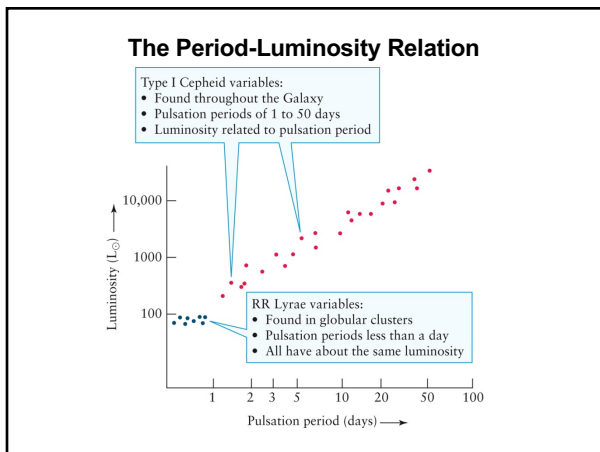
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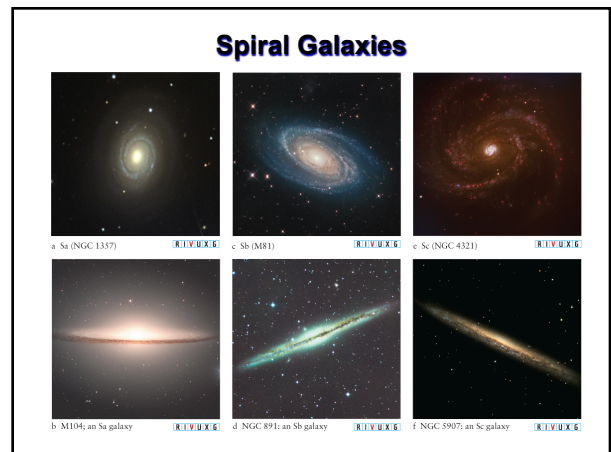
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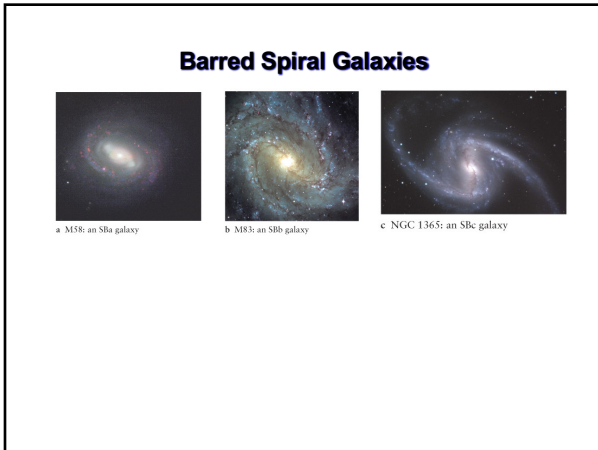
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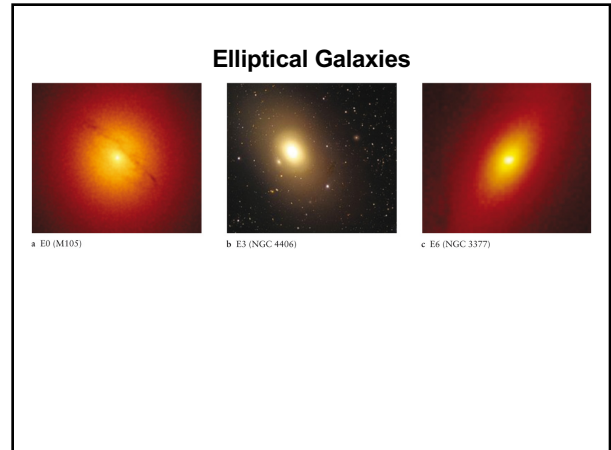
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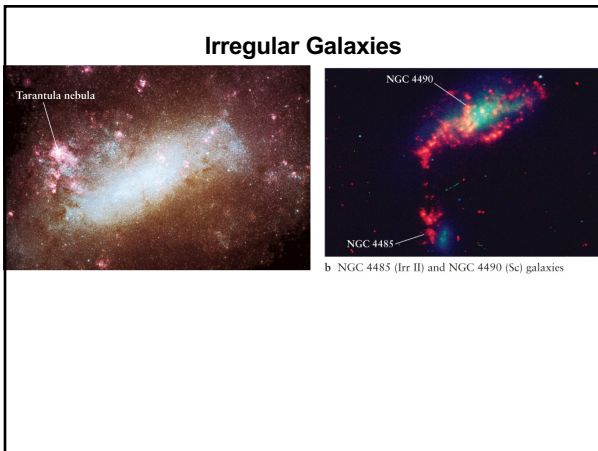
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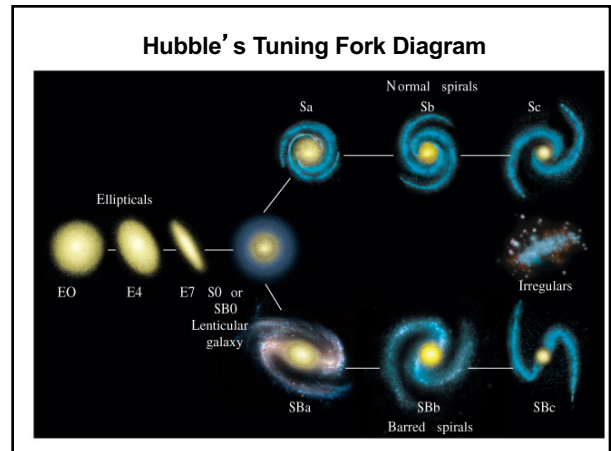
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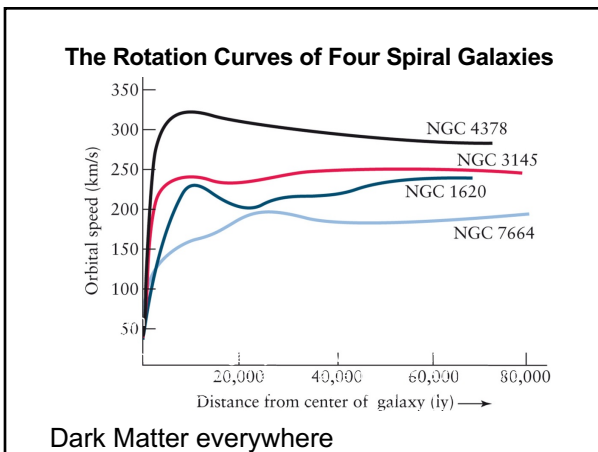
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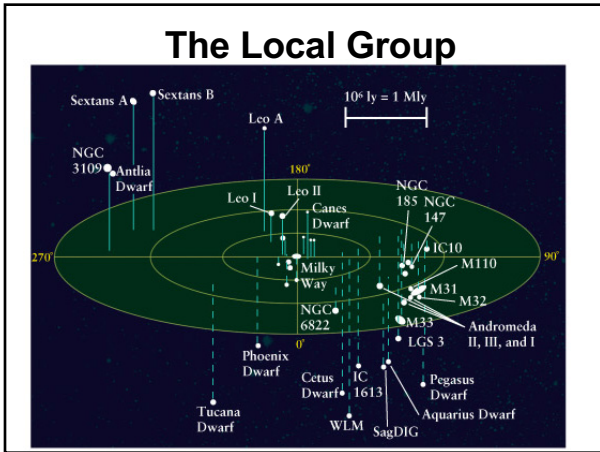
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TABLE 12-1 Some Properties of Galaxies			
	Spiral (S) and barred spiral (SB) galaxies	Elliptical galaxies (E)	Irregular galaxies (Irr)
Mass (M_{\odot})	10^7 to 4×10^{11}	10^7 to 10^{11}	10^6 to 3×10^{11}
Luminosity (L_{\odot})	10^6 to 2×10^{10}	3×10^6 to 10^{10}	10^7 to 10^9
Diameter (ly)	1.6×10^4 to 8×10^5	3×10^4 to 6.5×10^5	3×10^4 to 3×10^6
Stellar populations	Disk: young Population I central bulge; halo: Population II and old Population I	Population II and old Population I	Mostly Population I
Percentage of observed galaxies	77%	*20%	3%

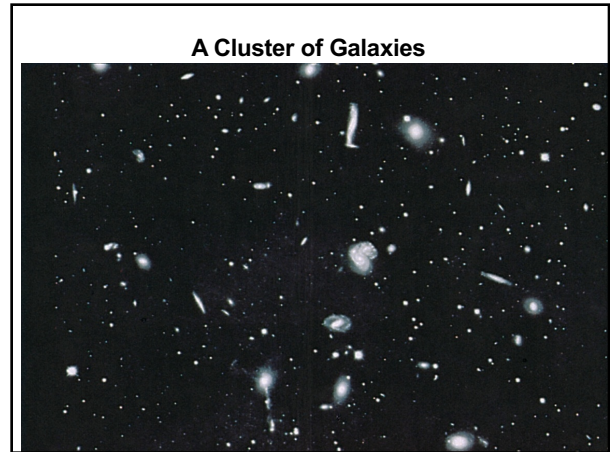
*This percentage does not include dwarf elliptical galaxies that are as yet too dim and distant to detect. Hence, the actual percentage of galaxies that are ellipticals is likely to be higher than shown here.

Population I: metal-rich stars
Population II: metal-poor stars

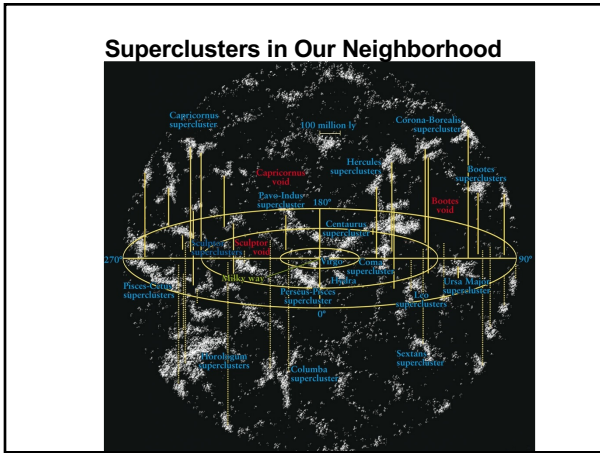
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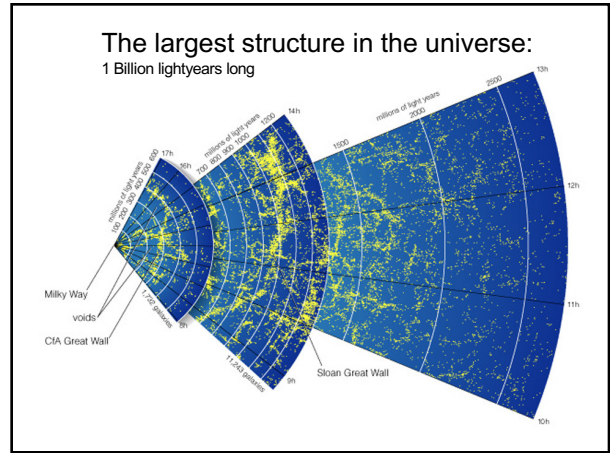
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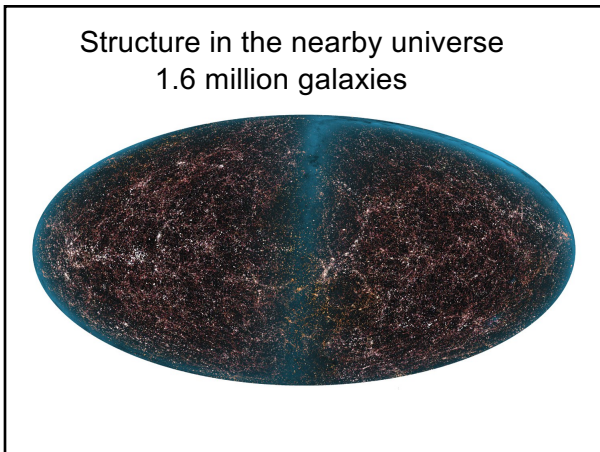
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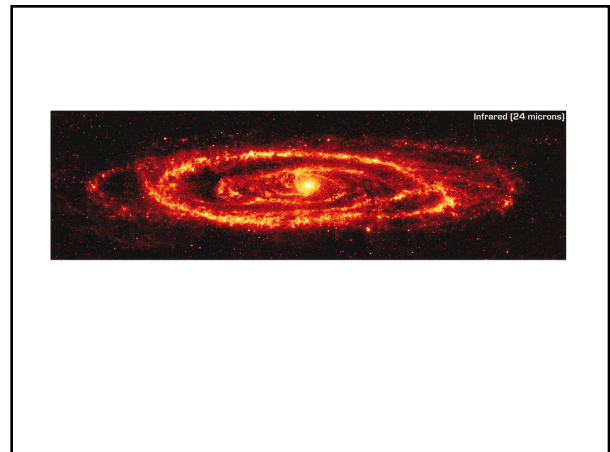
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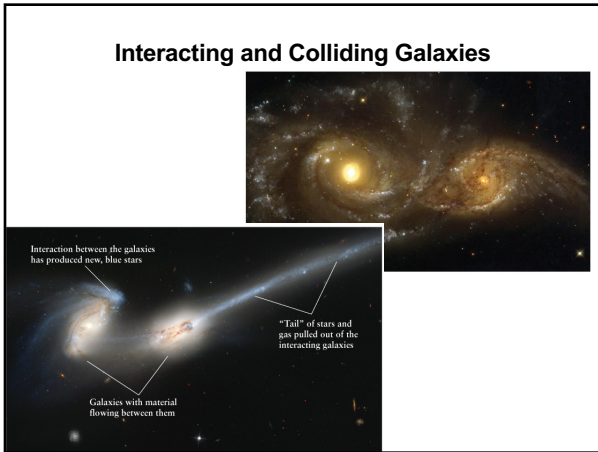
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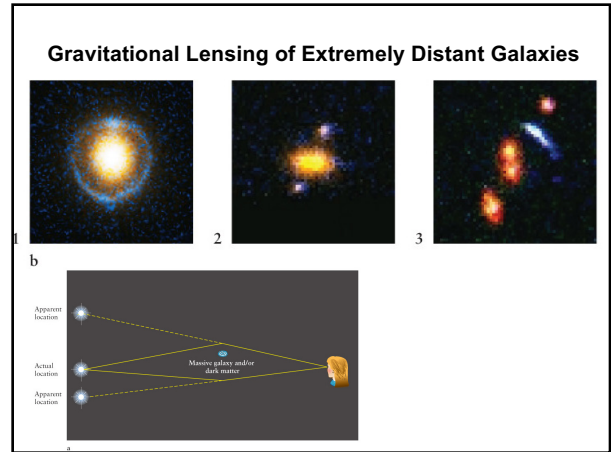
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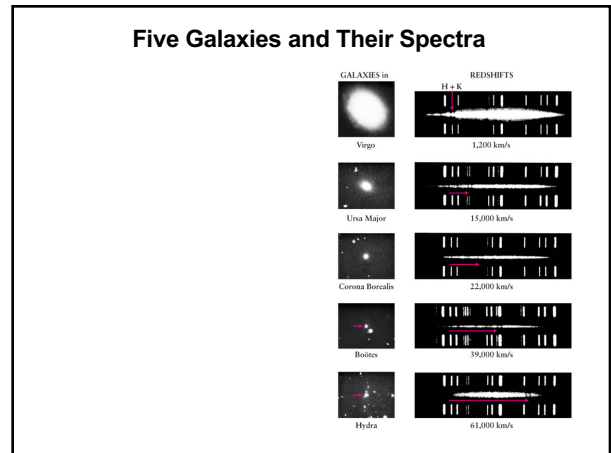
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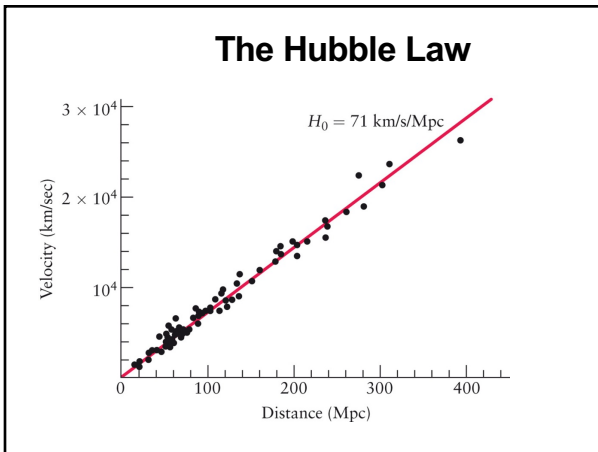
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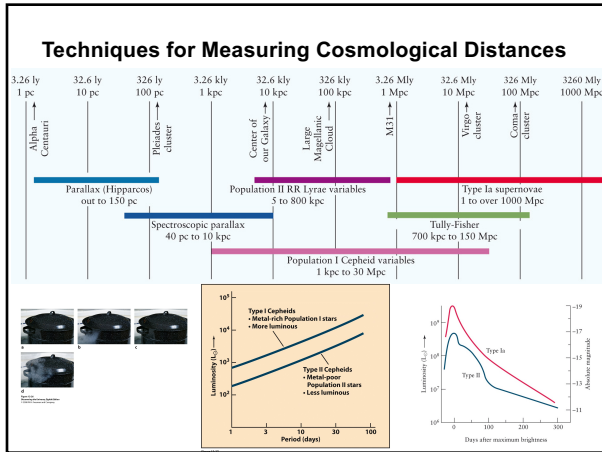
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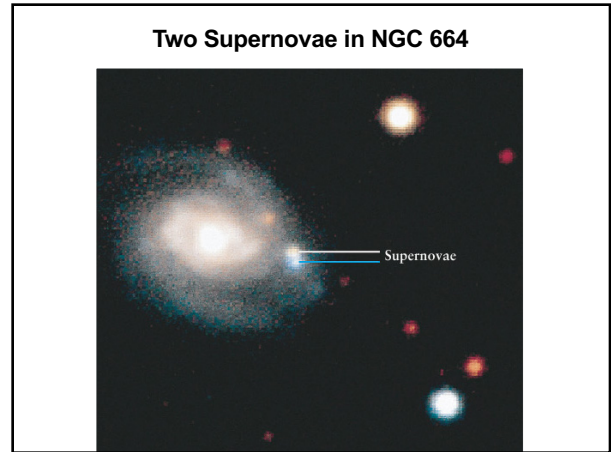
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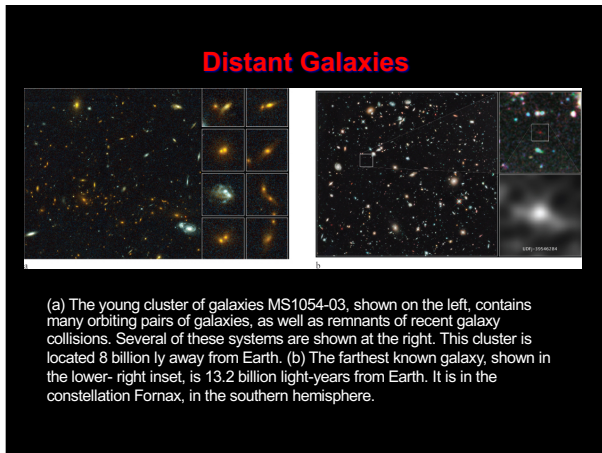
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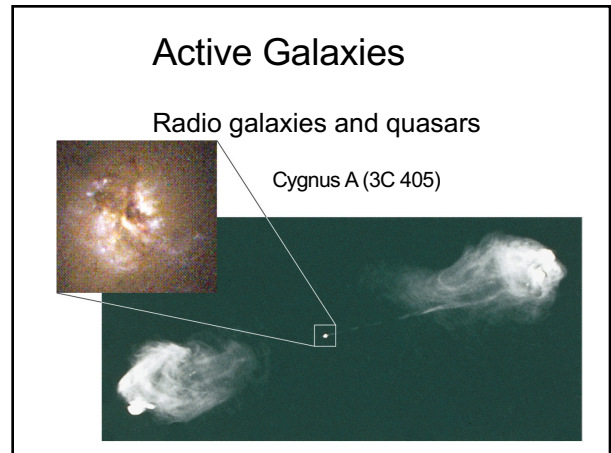
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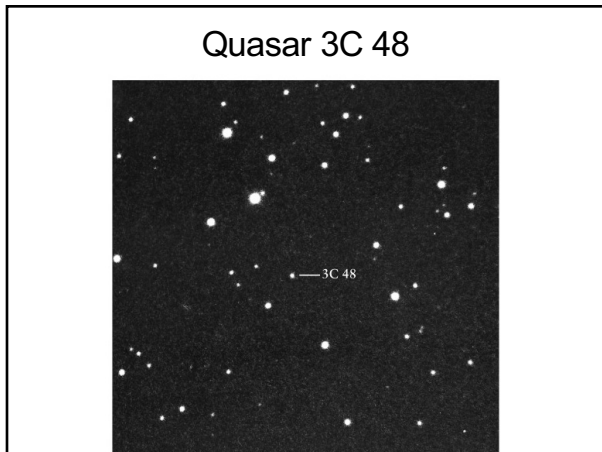
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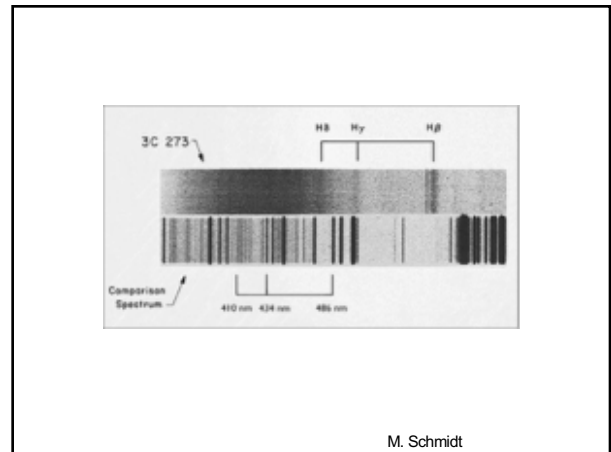
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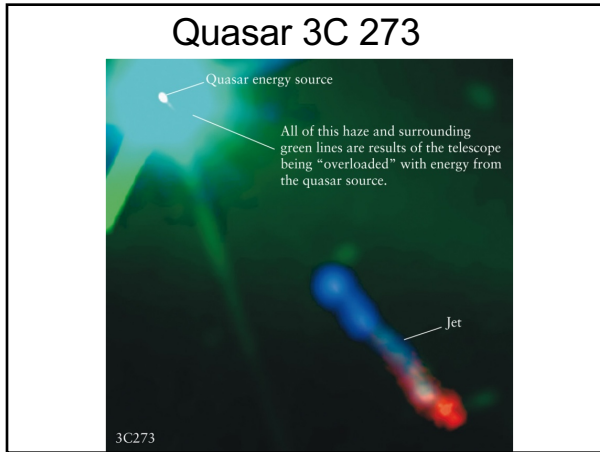
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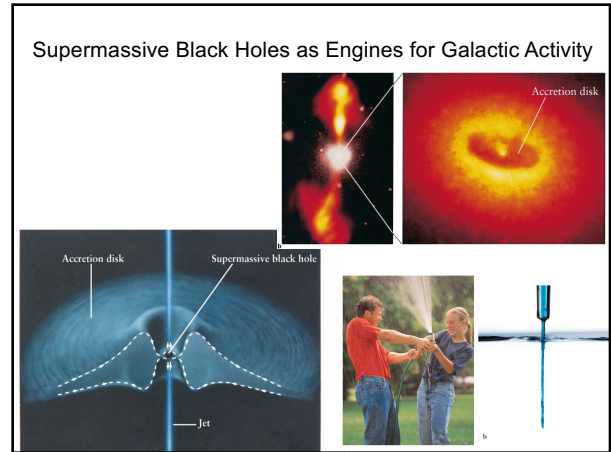
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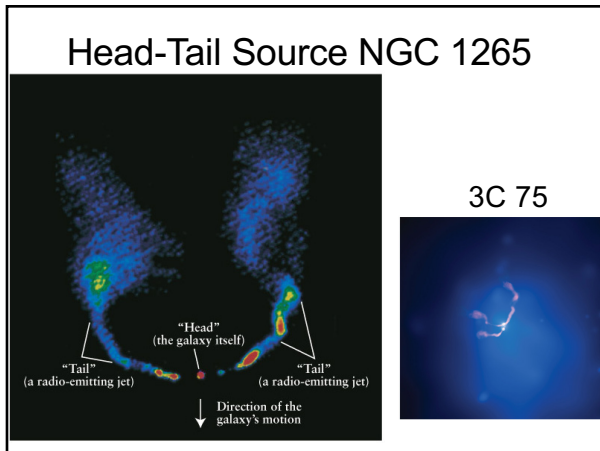
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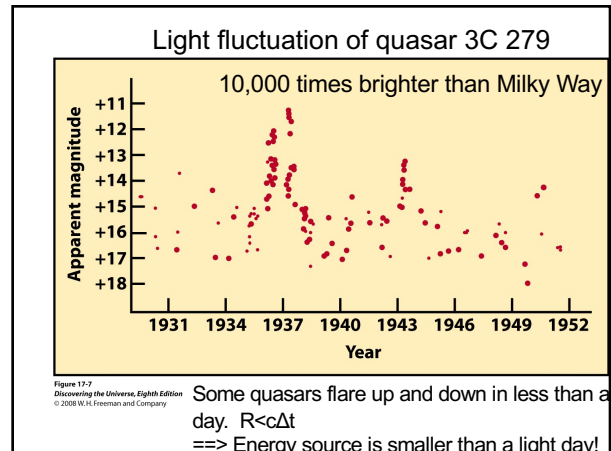
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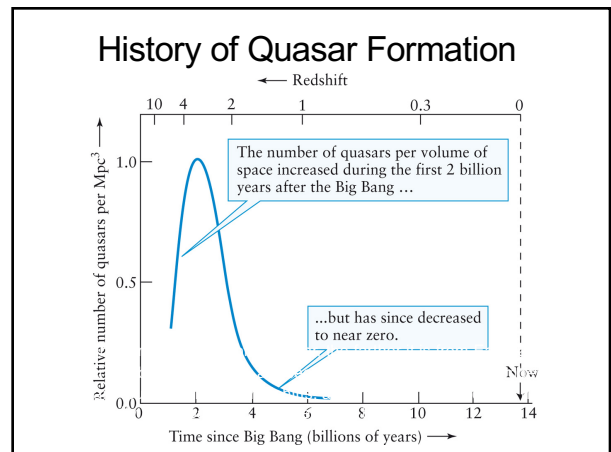


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TABLE 12-2 Galaxy and Quasar Luminosities

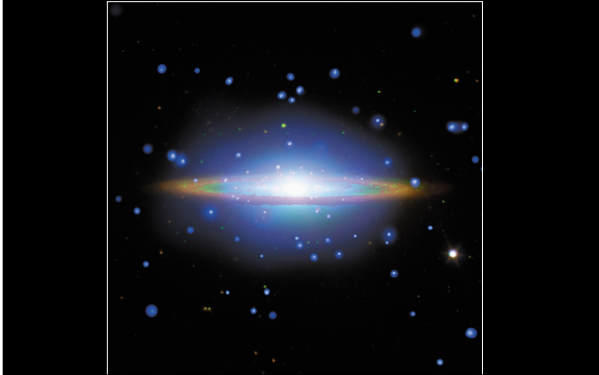
Object	Luminosity (watts)
Sun	4×10^{26}
Milky Way Galaxy	10^{37}
Seyfert galaxies	$10^{36} - 10^{38}$
Radio galaxies	$10^{36} - 10^{38}$
Quasars	$10^{38} - 10^{42}$

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Sombrero Galaxy (M104)



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Hawking radiation

Black holes evaporate

The process happens because black holes can convert their mass into energy through virtual particle production in the vicinity of the event horizon.

Virtual particle pairs ($e^+ e^-$ or photon photon) appear and disappear within 10^{-21} s.

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Tidal forces could pull them apart where one Particle disappears beyond the event horizon and the other particle becomes real.

The particles that leave the vicinity of the black hole are called Hawking radiation.

The result is that black holes loose mass and evaporate.

The timescale of evaporation is for

$$M_{\text{BH}}=5M_{\text{sol}} \rightarrow 10^{62} \text{ yr}$$

$$M_{\text{BH}}=10^{10}\text{kg} \rightarrow 15 \text{ Bill yr}$$

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