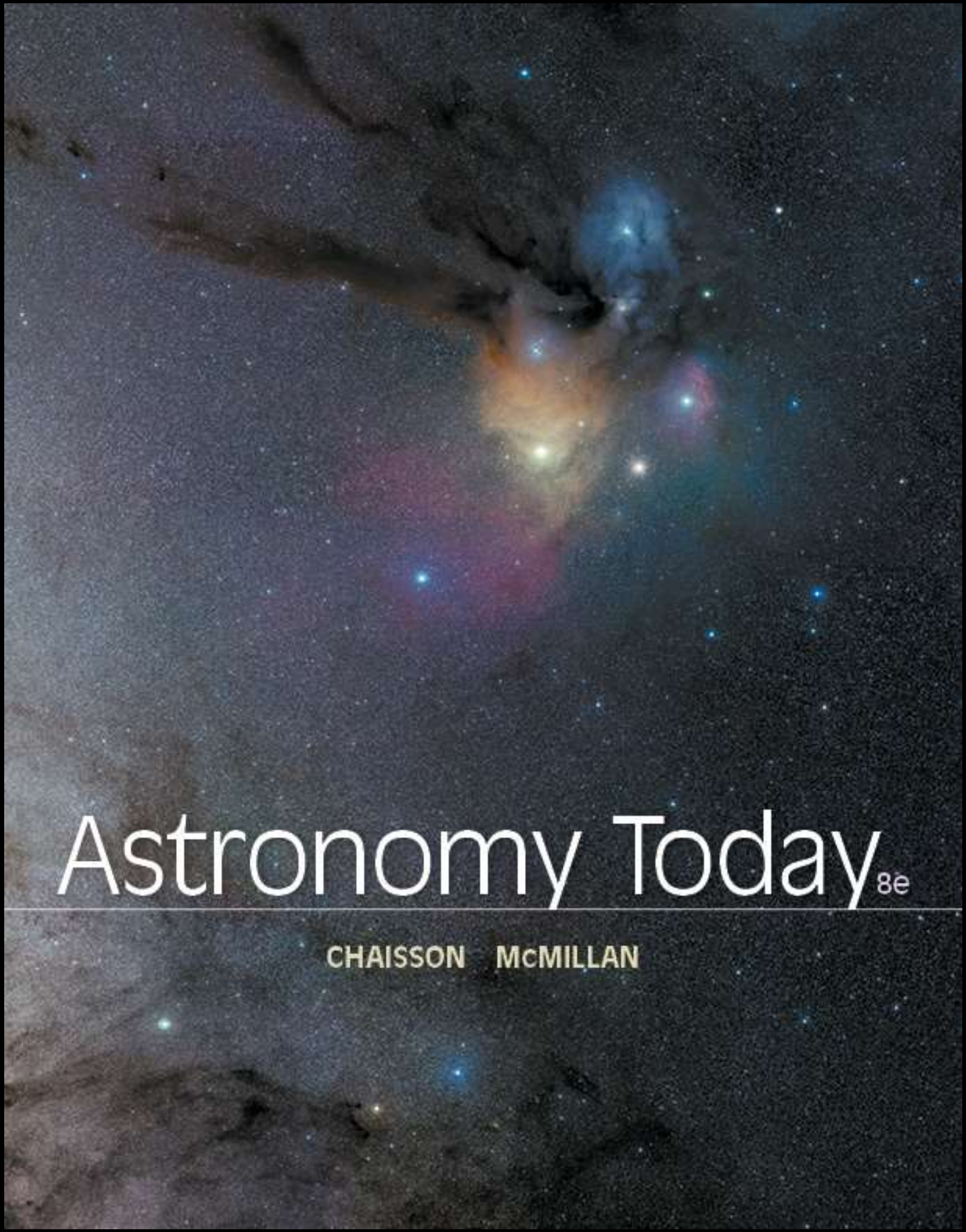


Lecture Outlines

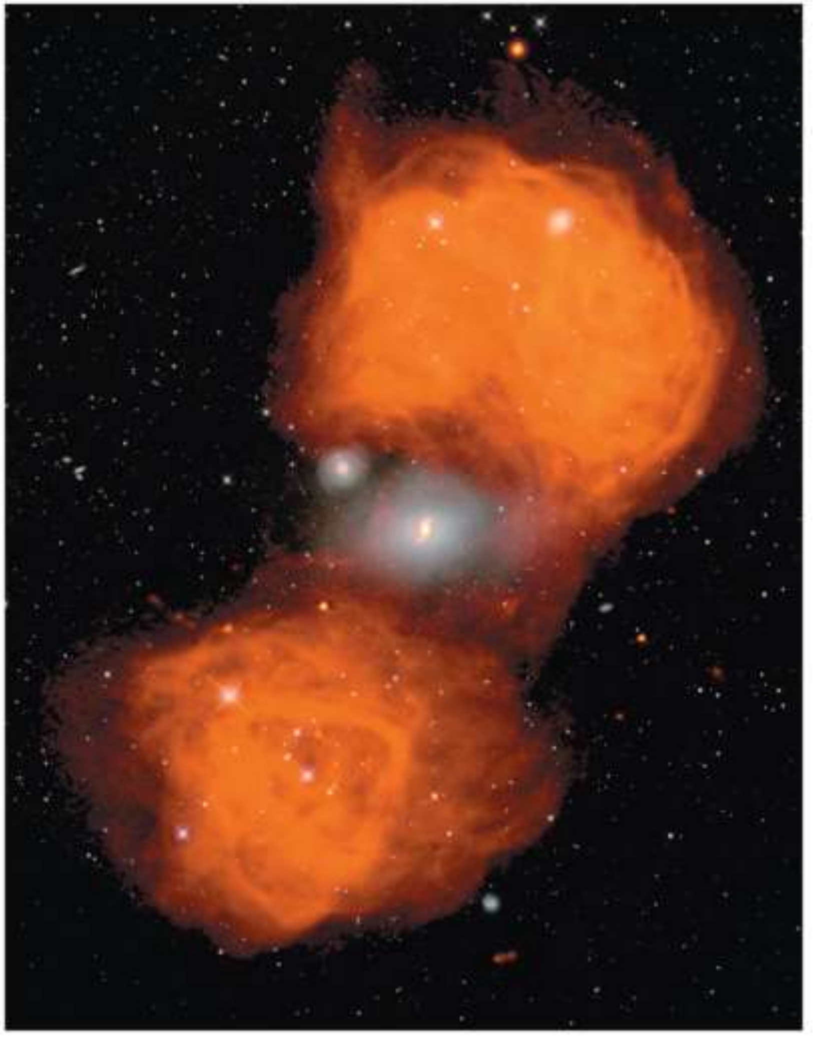
Chapter 24

Astronomy Today

8th Edition

Chaisson/McMillan

Chapter 24
Galaxies



Units of Chapter 24

24.1 Hubble's Galaxy Classification

24.2 The Distribution of Galaxies in Space

24.3 Hubble's Law

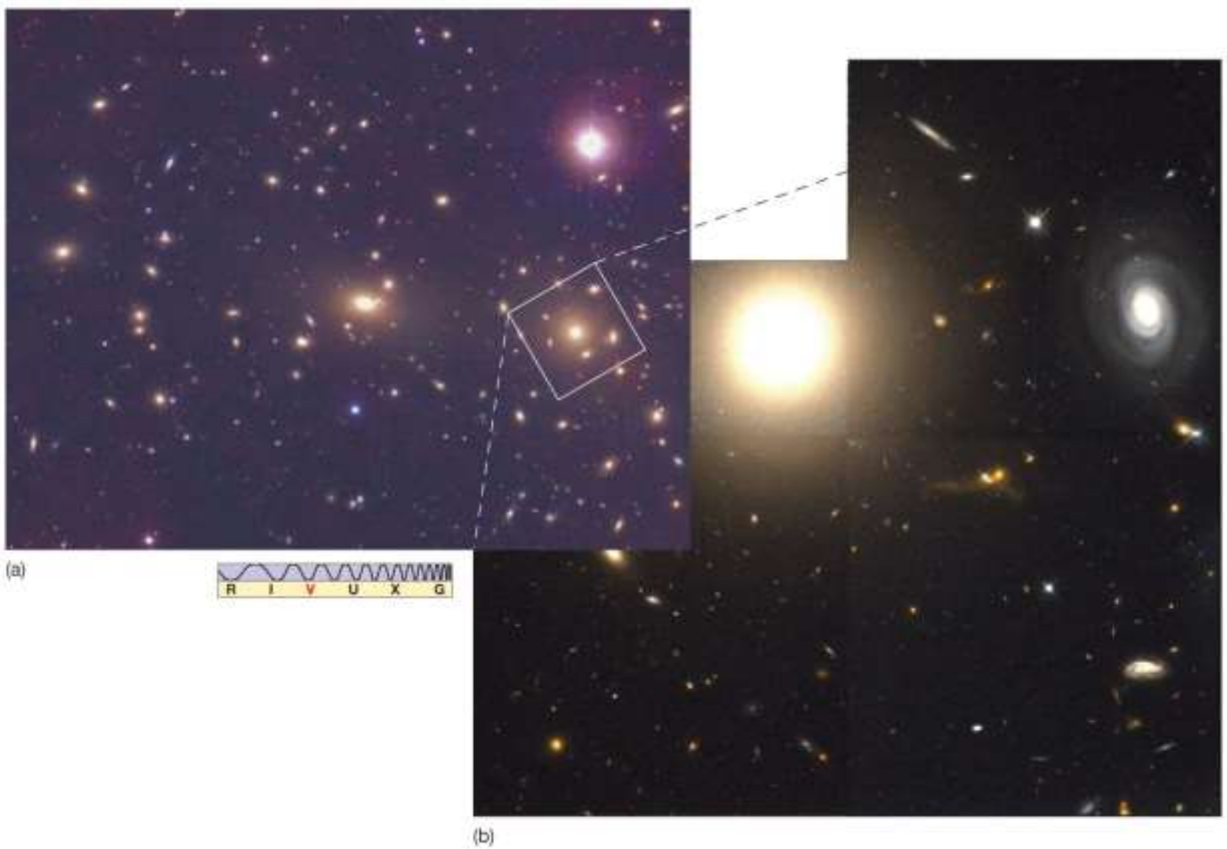
24.4 Active Galactic Nuclei

More Precisely 24-2 Relativistic Redshifts and Look-Back Time

24.5 The Central Engine of an Active Galaxy

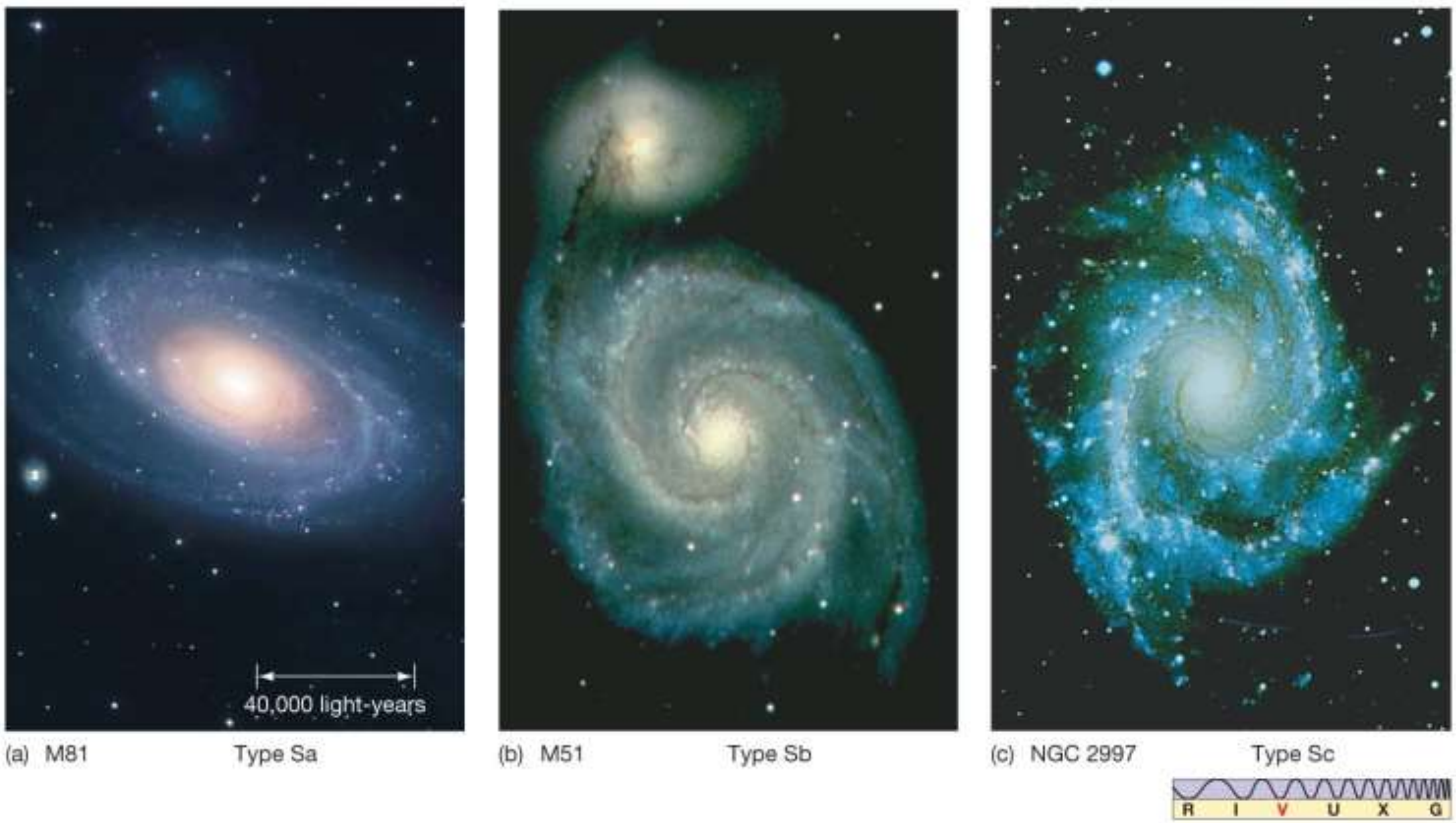
24.1 Hubble's Galaxy Classification

This pair of images shows the Coma cluster of galaxies. Almost every object visible is a galaxy.



24.1 Hubble's Galaxy Classification

Spiral galaxies are classified according to the size of their central bulge.



(a) M81 Type Sa (b) M51 Type Sb (c) NGC 2997 Type Sc

24.1 Hubble's Galaxy Classification

Type Sa has the largest central bulge, Type Sb is smaller, and Type Sc is the smallest.

Type Sa tends to have the most tightly bound spiral arms with Types Sb and Sc progressively less tight, although the correlation is not perfect.

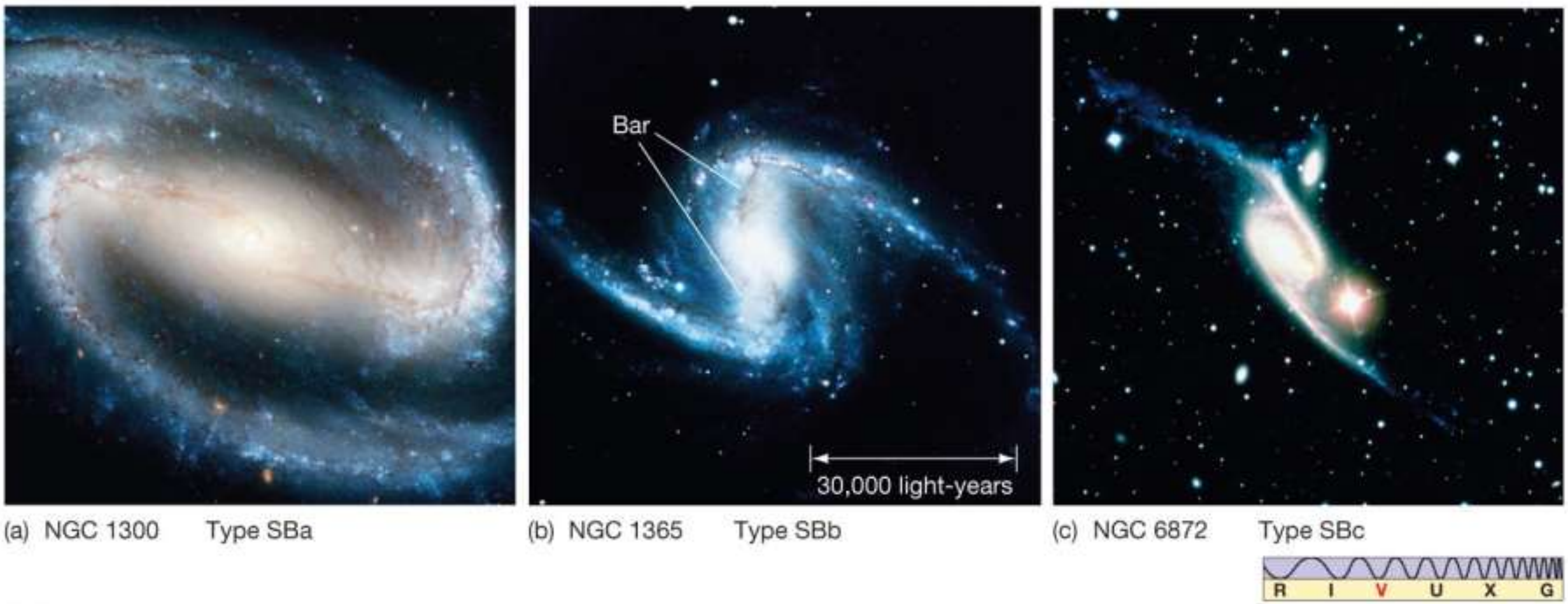
The components of spiral galaxies are the same as in our own galaxy: disk, core, halo, bulge, and spiral arms.

24.1 Hubble's Galaxy Classification

The Sombrero galaxy, with its large central bulge, is a type Sa. We cannot see the spiral arms, as they are edge-on.

24.1 Hubble's Galaxy Classification

Similar to the spiral galaxies are the barred spirals.



(a) NGC 1300 Type SBa (b) NGC 1365 Type SBb (c) NGC 6872 Type SBc

24.1 Hubble's Galaxy Classification

Elliptical galaxies have no spiral arms and no disk. They come in many sizes, from giant ellipticals of trillions of stars, down to dwarf ellipticals of less than a million stars.

Ellipticals also contain very little, if any, cool gas and dust, and they show no evidence of ongoing star formation.

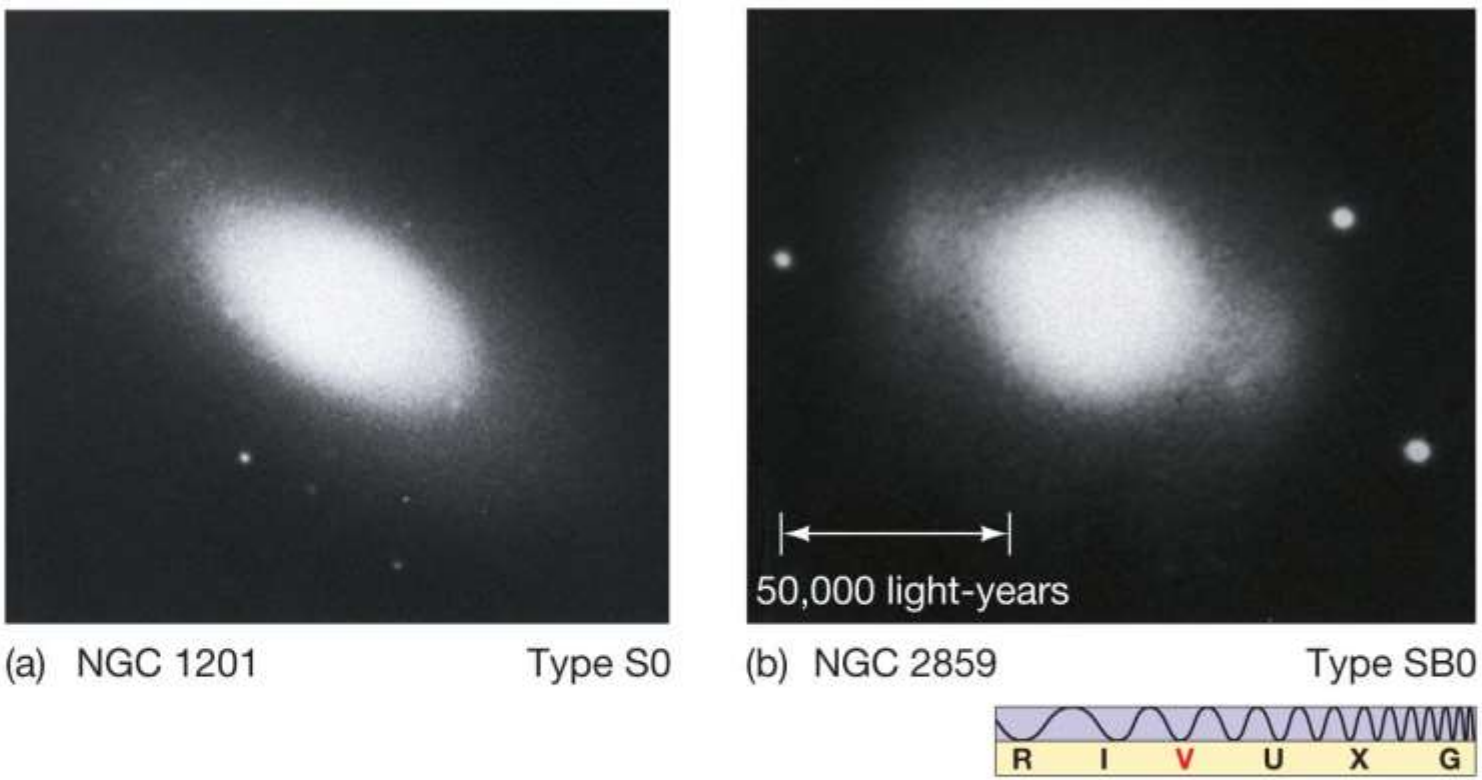
Many do, however, have large clouds of hot gas, extending far beyond the visible boundaries of the galaxy.

24.1 Hubble's Galaxy Classification

Ellipticals are classified according to their shape from E0 (almost spherical) to E7 (the most elongated).

24.1 Hubble's Galaxy Classification

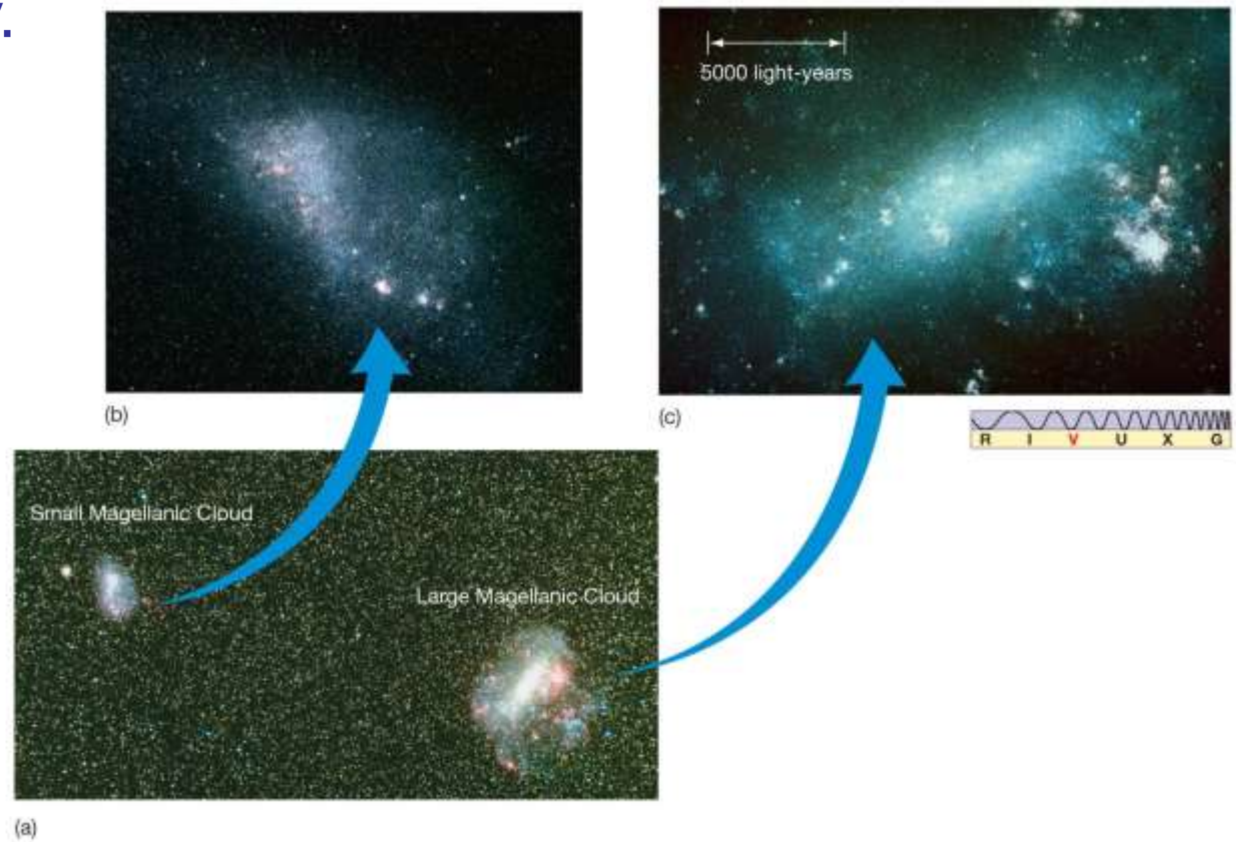
S0 (lenticular) and SB0 galaxies have a disk and bulge, but no spiral arms and no interstellar gas.



(a) NGC 1201 Type S0 (b) NGC 2859 Type SB0

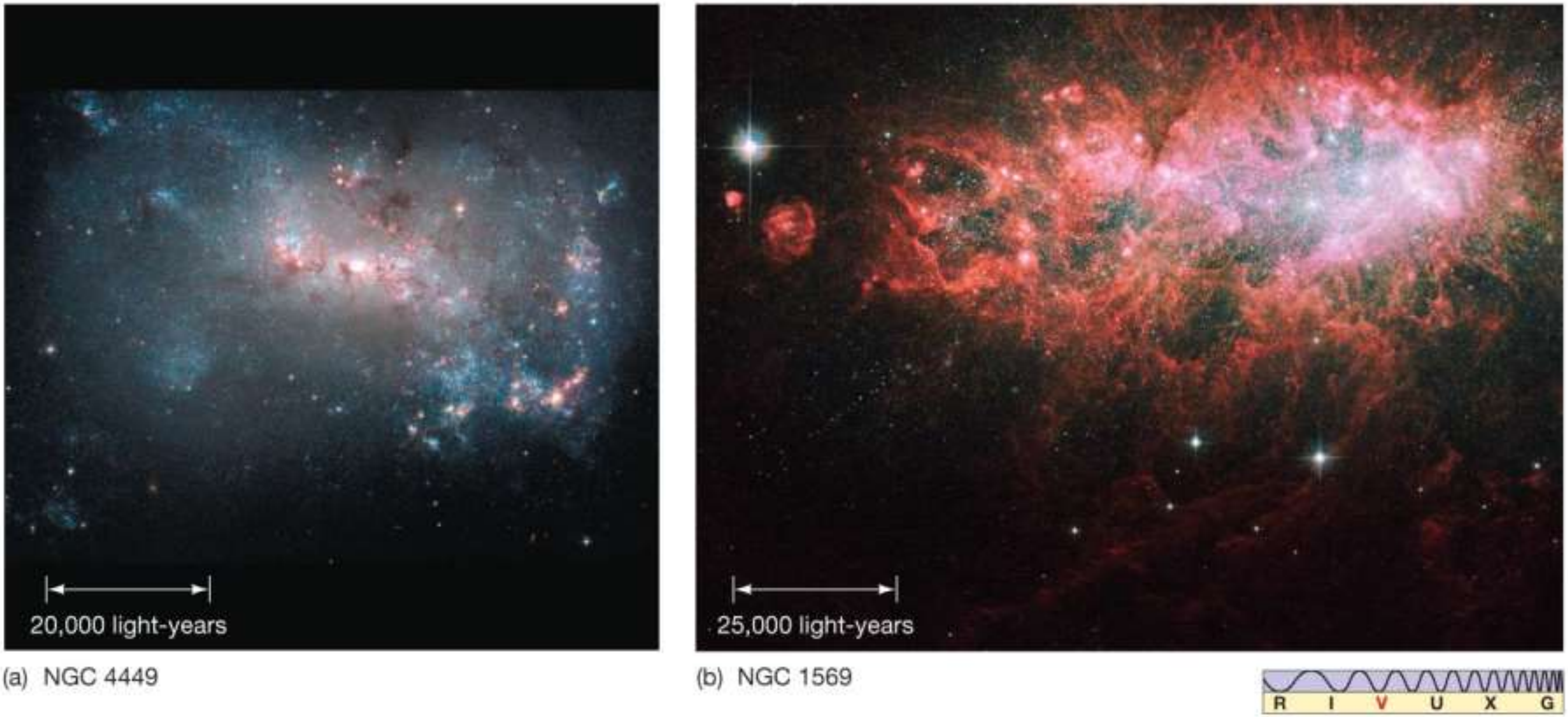
24.1 Hubble's Galaxy Classification

The irregular galaxies have a wide variety of shapes. The small and large Magellanic Clouds are close neighbors to our own Milky Way.



24.1 Hubble's Galaxy Classification

Here are several other irregular galaxies: AM 0644-741 and its neighbors on the left, and NGC 1569 on the right.



(a) NGC 4449 (b) NGC 1569

24.1 Hubble's Galaxy Classification

A summary of galaxy properties by type

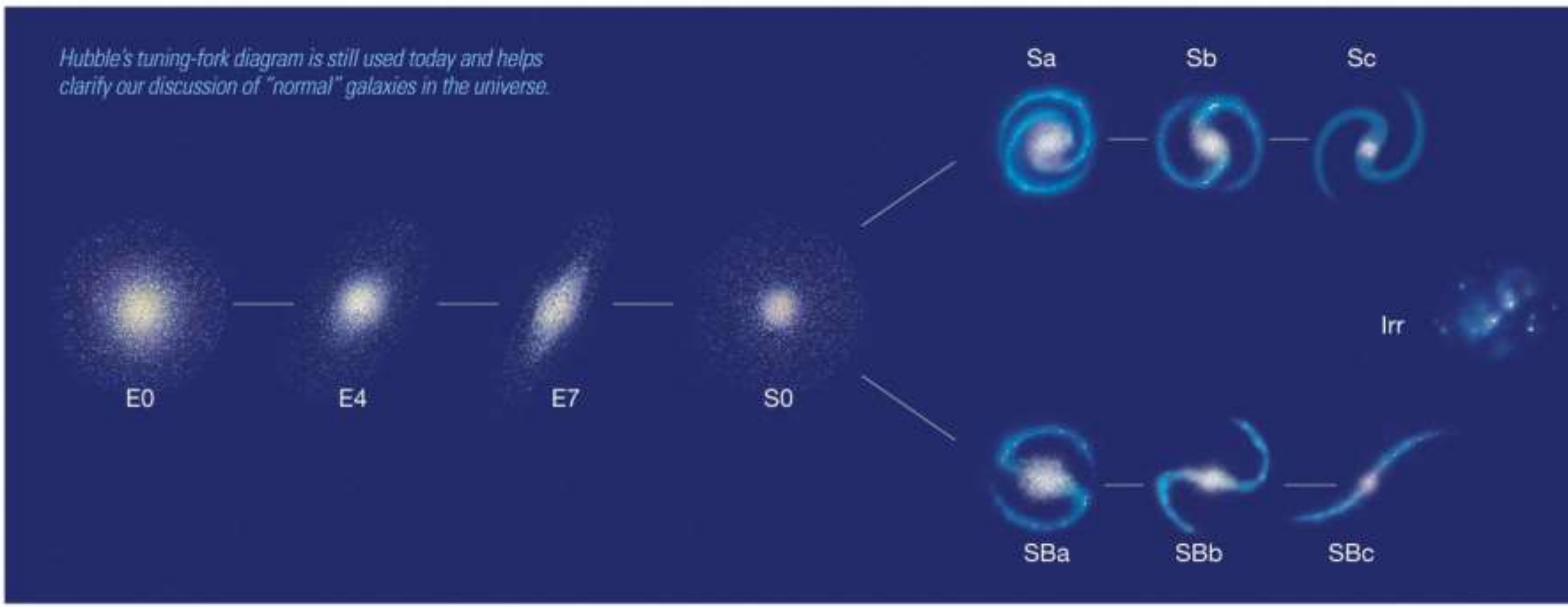
TABLE 24.1 Galaxy Properties by Type

	Spiral/Barred Spiral (S/SB)	Elliptical* (E)	Irregular (Irr)
Shape and structural properties	Highly flattened disk of stars and gas, containing spiral arms and thickening central bulge. Sa and SBa galaxies have the largest bulges, the least obvious spiral structure, and roughly spherical stellar halos. SB galaxies have an elongated central "bar" of stars and gas.	No disk. Stars smoothly distributed through an ellipsoidal volume ranging from nearly spherical (E0) to very flattened (E7) in shape. No obvious substructure other than a dense central nucleus.	No obvious structure. Irr II galaxies often have "explosive" appearances.
Stellar content	Disks contain both young and old stars; halos consist of old stars only.	Contain old stars only.	Contain both young and old stars.
Gas and dust	Disks contain substantial amounts of gas and dust; halos contain little of either.	Contain hot X-ray–emitting gas, little or no cool gas and dust.	Very abundant in gas and dust.
Star formation	Ongoing star formation in spiral arms.	No significant star formation during the last 10 billion years.	Vigorous ongoing star formation.
Stellar motion	Gas and stars in disk move in circular orbits around the galactic center; halo stars have random orbits in three dimensions.	Stars have random orbits in three dimensions	Stars and gas have highly irregular orbits.

** As noted in the text, some giant ellipticals appear to be the result of collisions between gas-rich galaxies and are exceptions to many of the statements listed here.*

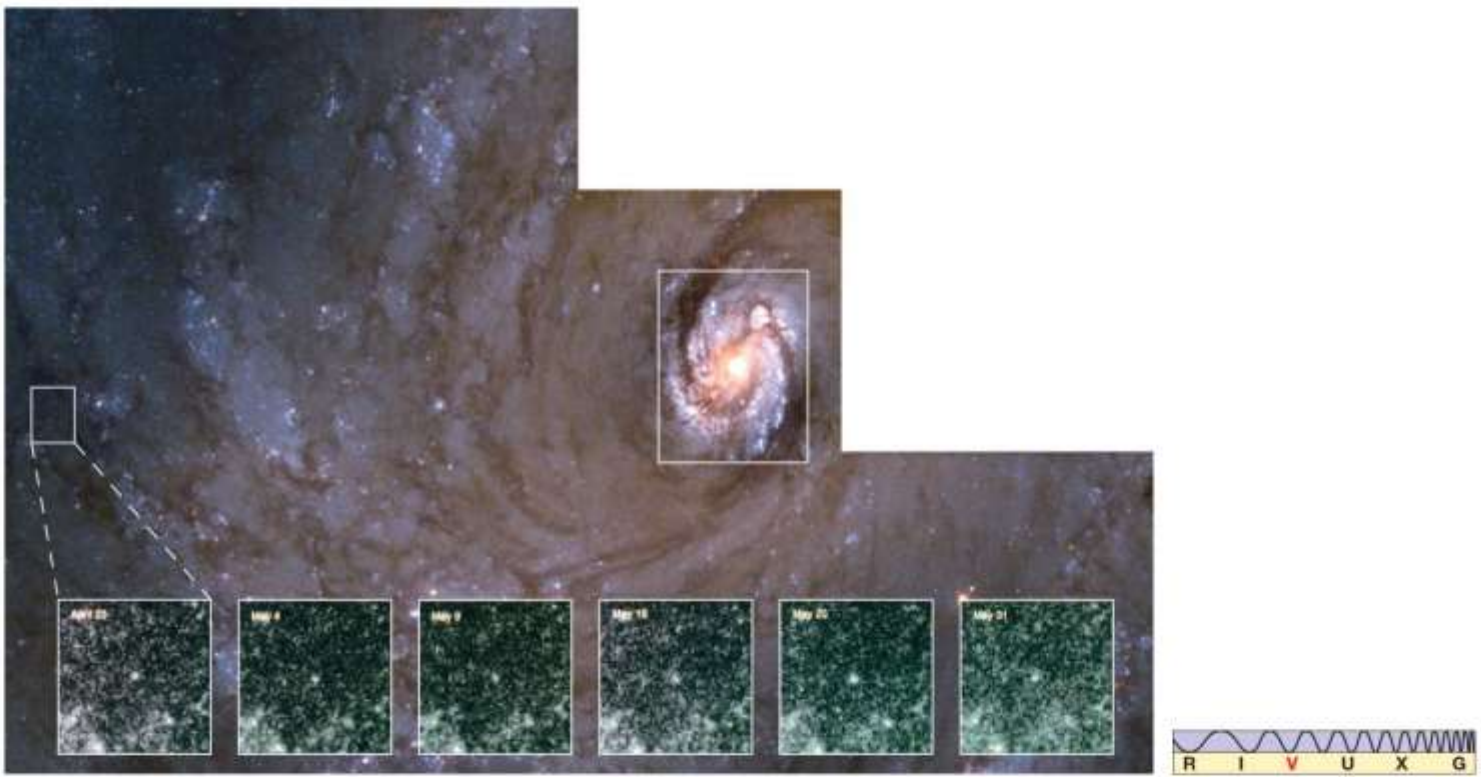
24.1 Hubble's Galaxy Classification

Hubble's "tuning fork" is a convenient way to remember the galaxy classifications, although it has no deeper meaning.



24.2 The Distribution of Galaxies in Space

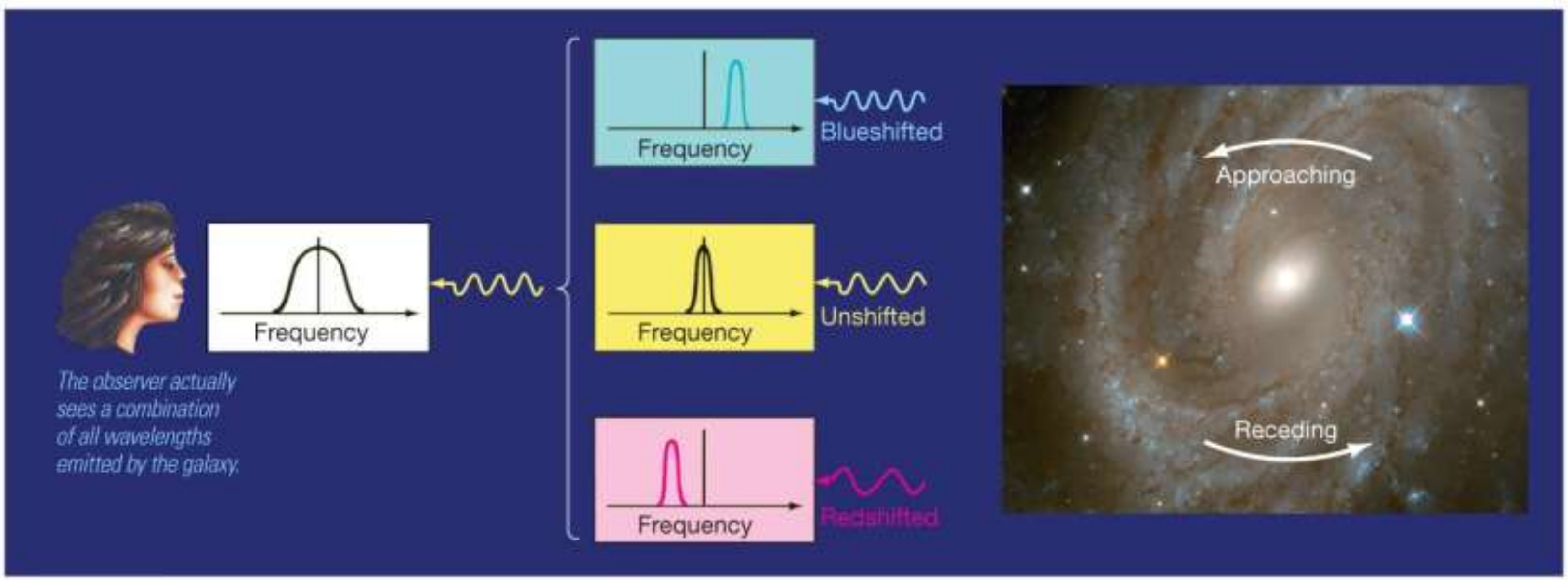
Cepheid variables allow measurement of galaxies to about 25 Mpc away.



24.2 The Distribution of Galaxies in Space

However, some galaxies have no Cepheids, and most are farther away than 25 Mpc. New distance measures are needed.

- Tully-Fisher relation correlates a galaxy's rotation speed (which can be measured using the Doppler effect) to its luminosity.

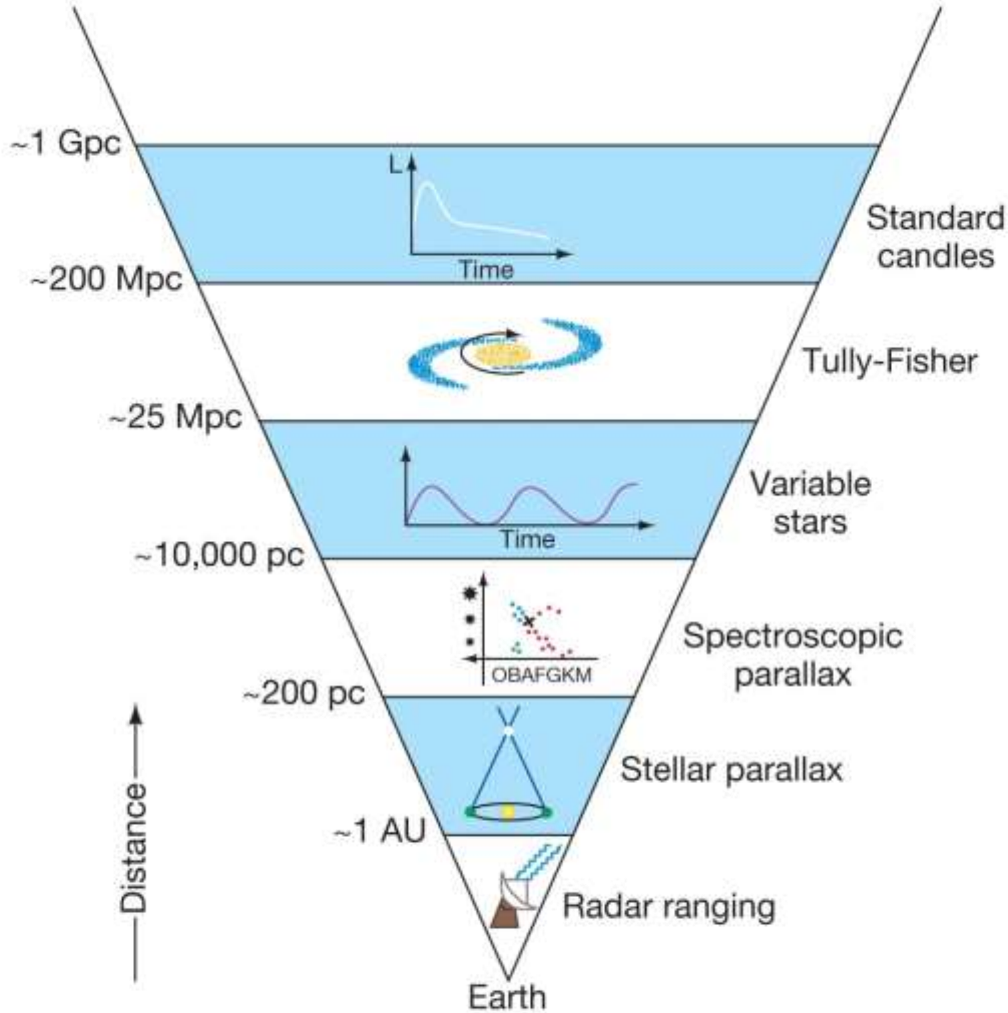


24.2 The Distribution of Galaxies in Space

Type I supernovae all have about the same luminosity, as the process by which they happen doesn't allow for much variation. They can be used as "standard candles"—objects whose absolute magnitude is known, and which can therefore be used to determine distance using their apparent magnitude.

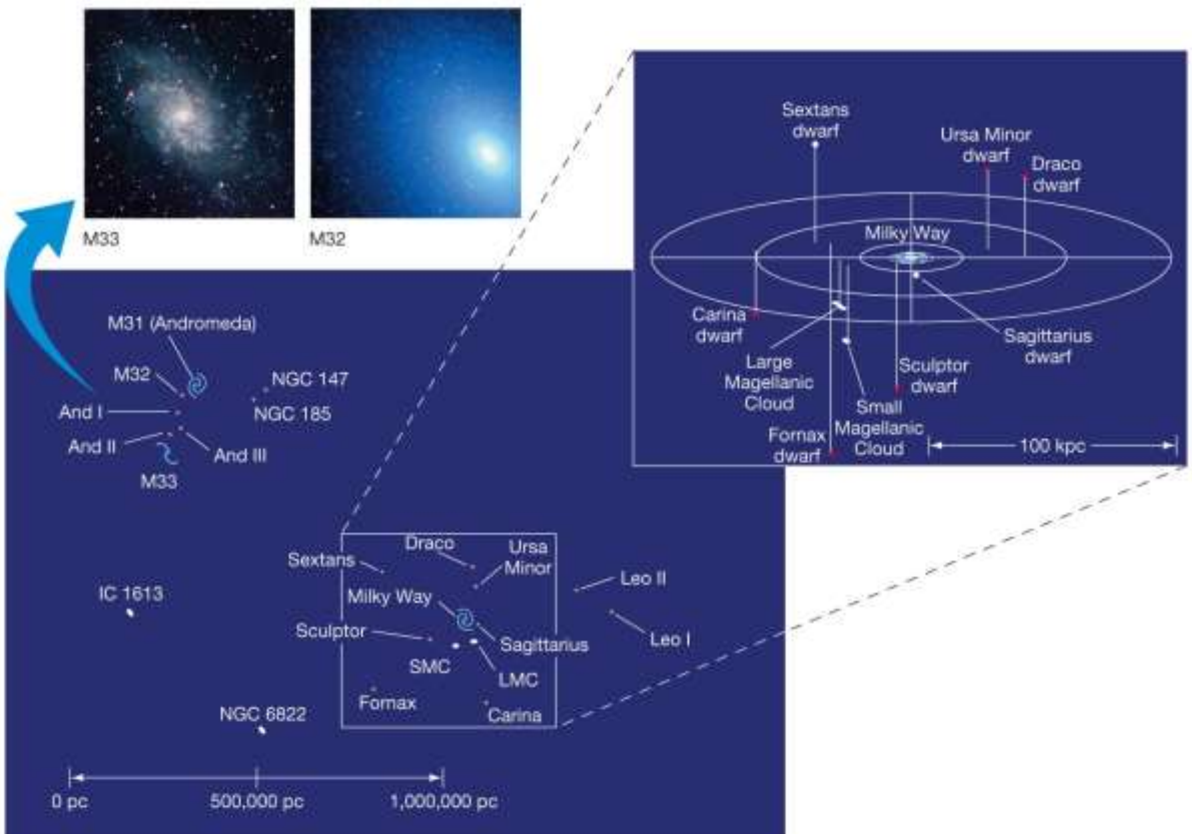
24.2 The Distribution of Galaxies in Space

With these additions, the cosmic distance ladder has been extended to about 1 Gpc



24.2 The Distribution of Galaxies in Space

This is the Local Group of galaxies, about 45 galaxies within about 1 Mpc of the Milky Way



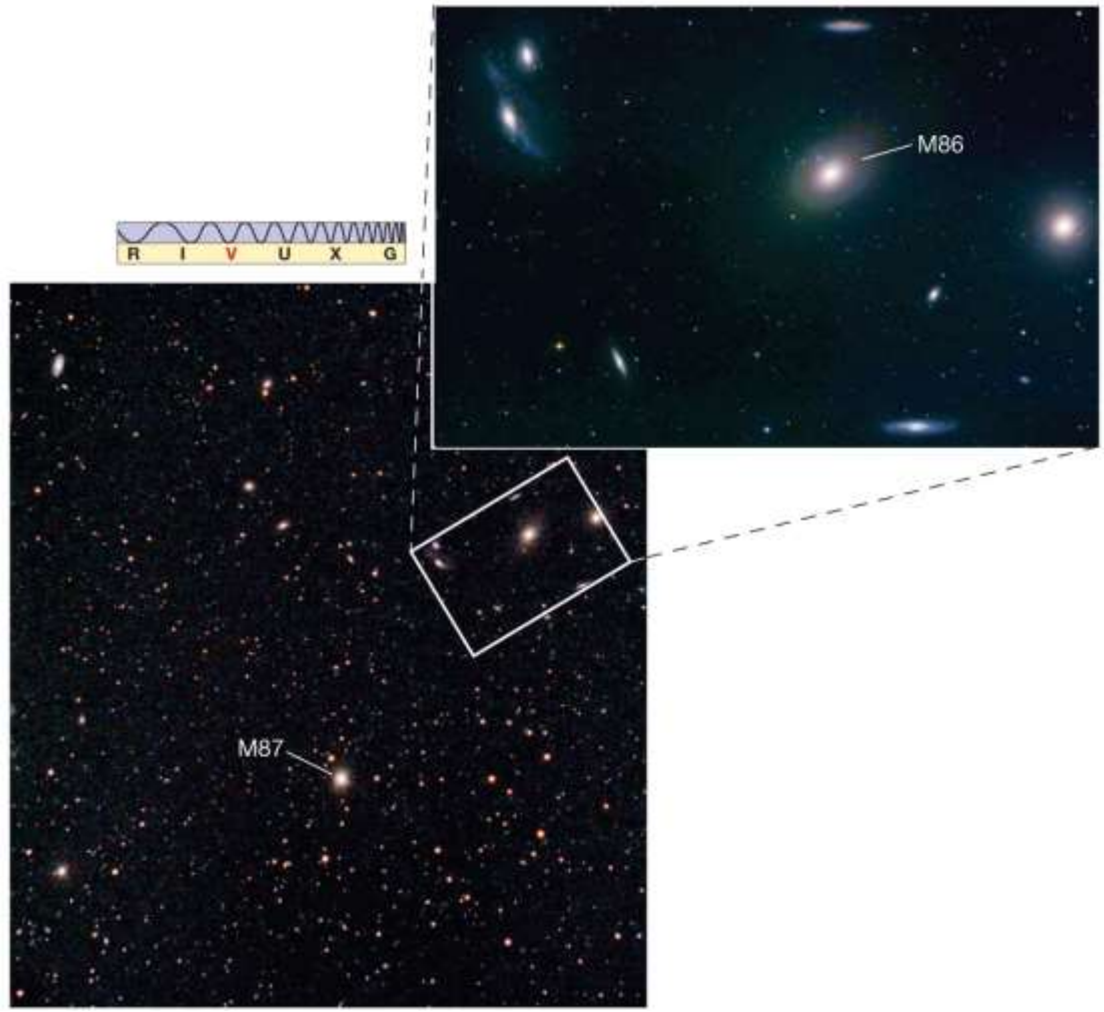
24.2 The Distribution of Galaxies in Space

There are three spirals in this group—the Milky Way, Andromeda, and M33. These and their satellites—about 45 galaxies in all—form the Local Group.

Such a group of galaxies, held together by its own gravity, is called a galaxy cluster.

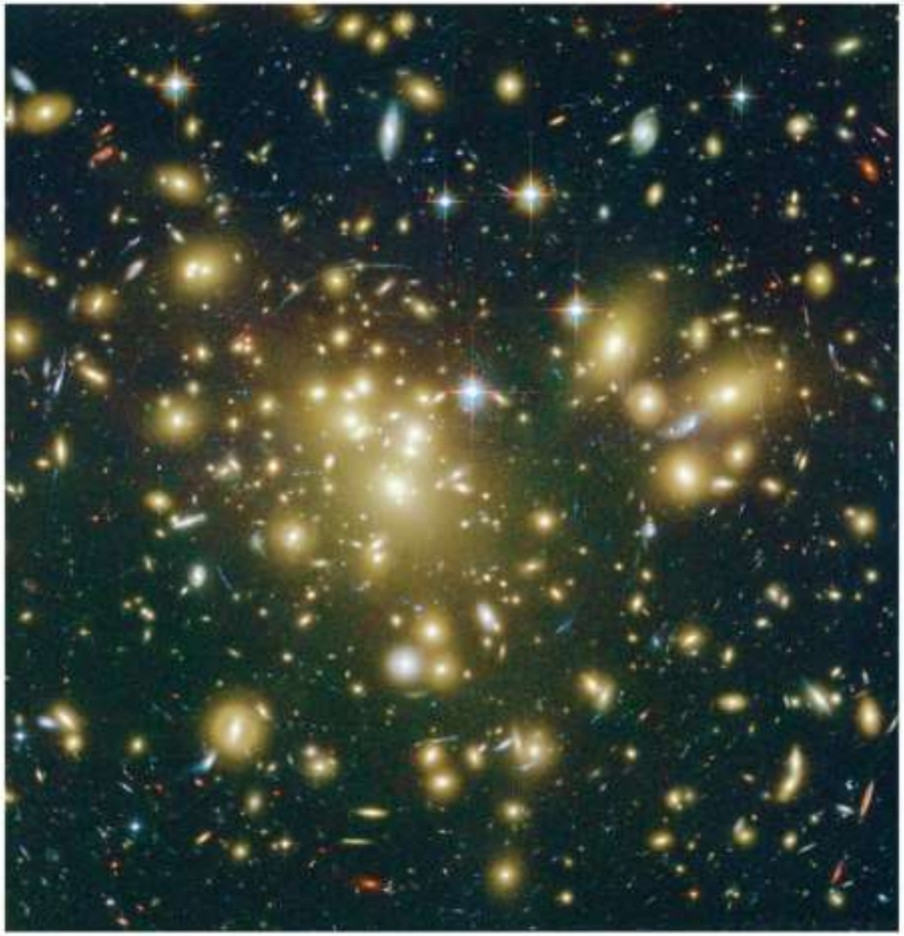
24.2 The Distribution of Galaxies in Space

A nearby galaxy cluster is the Virgo Cluster; it is much larger than the Local Group, containing about 3500 galaxies.



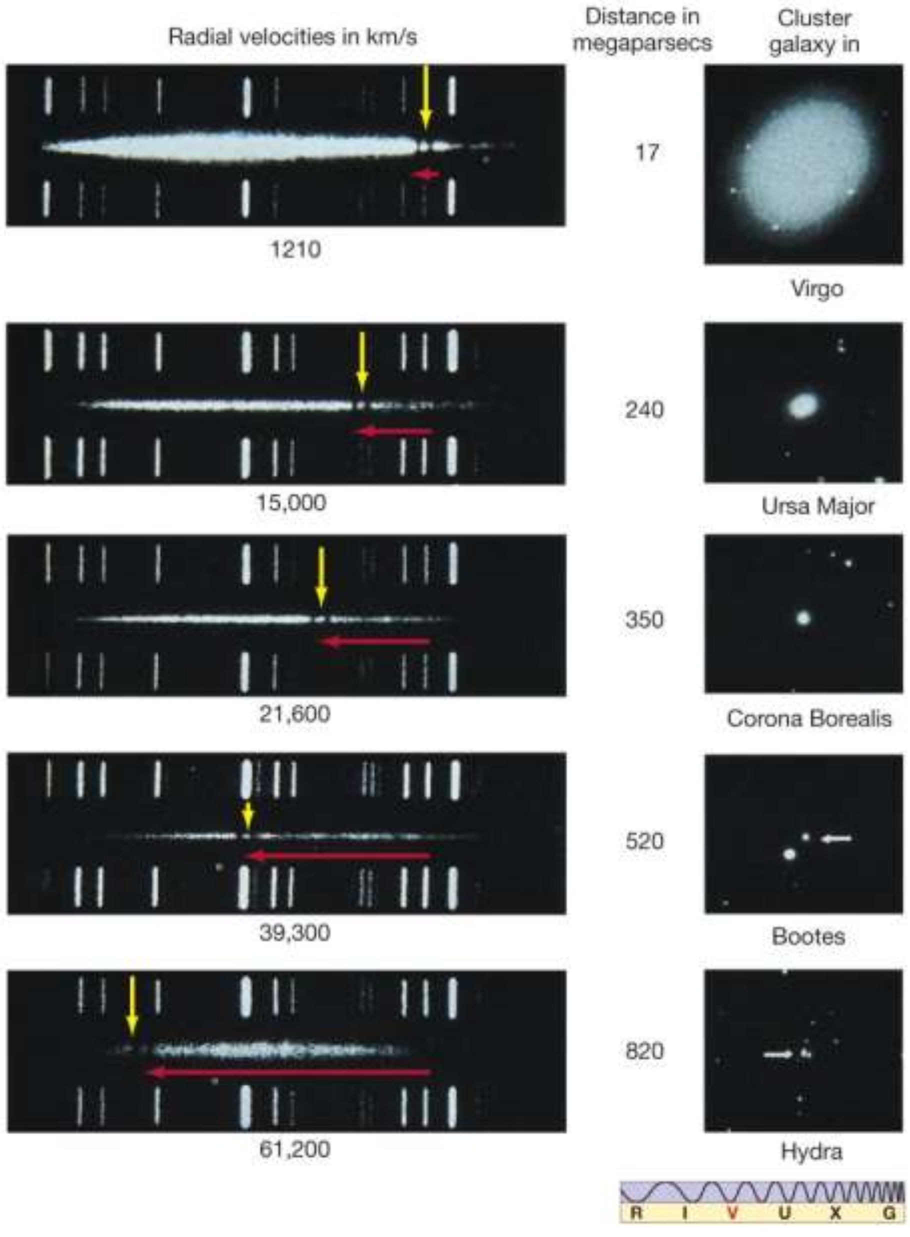
24.2 The Distribution of Galaxies in Space

This image shows the Abell 1689 cluster of galaxies, a very large cluster almost 1 billion parsecs away.



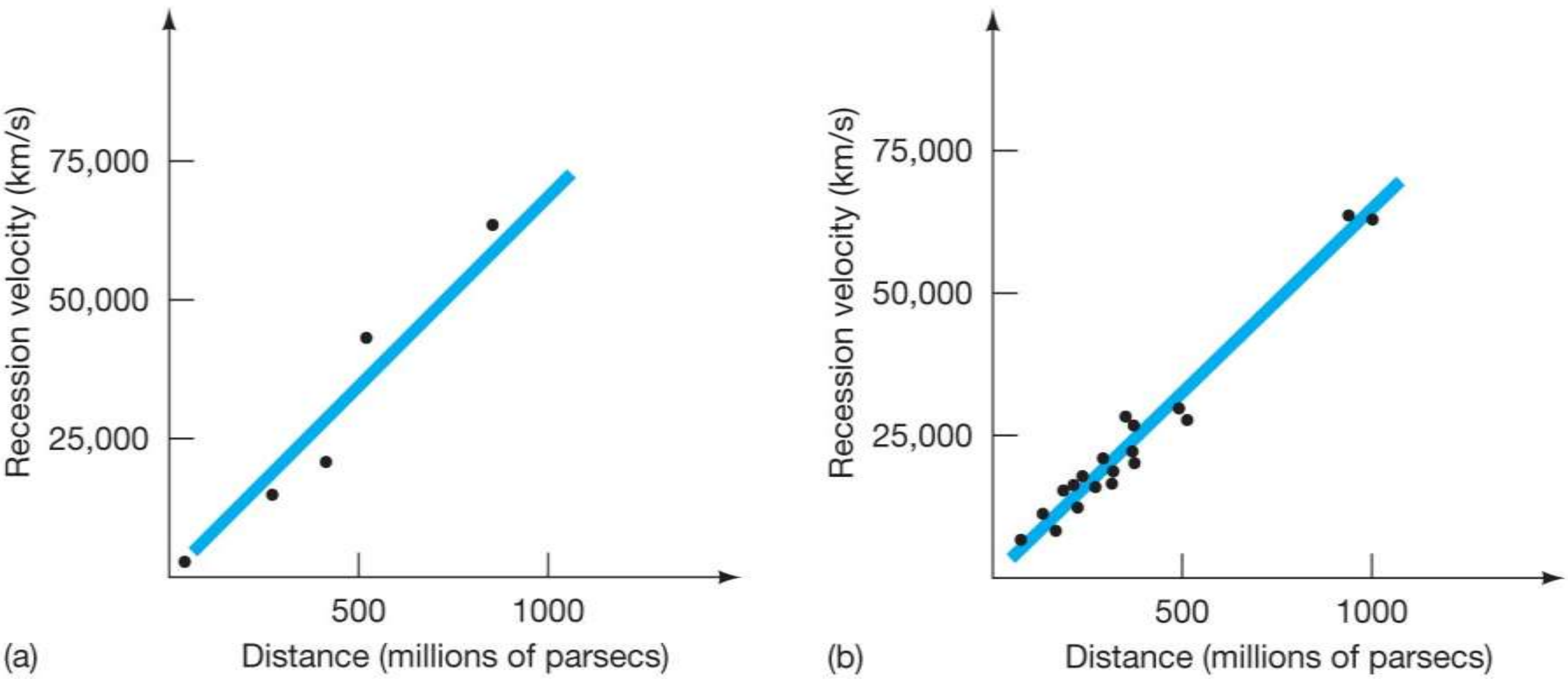
24.3 Hubble's Law

Universal recession: all galaxies (with a couple of nearby exceptions) seem to be moving away from us, with the redshift of their motion correlated with their distance.



24.3 Hubble's Law

These plots show the relation between distance and recessional velocity for the five galaxies in the previous figure, and then for a larger sample.



24.3 Hubble's Law

The relationship (slope of the line) is characterized by Hubble's constant H_0:

$$\text{recessional velocity} = H_0 \times \text{distance}$$

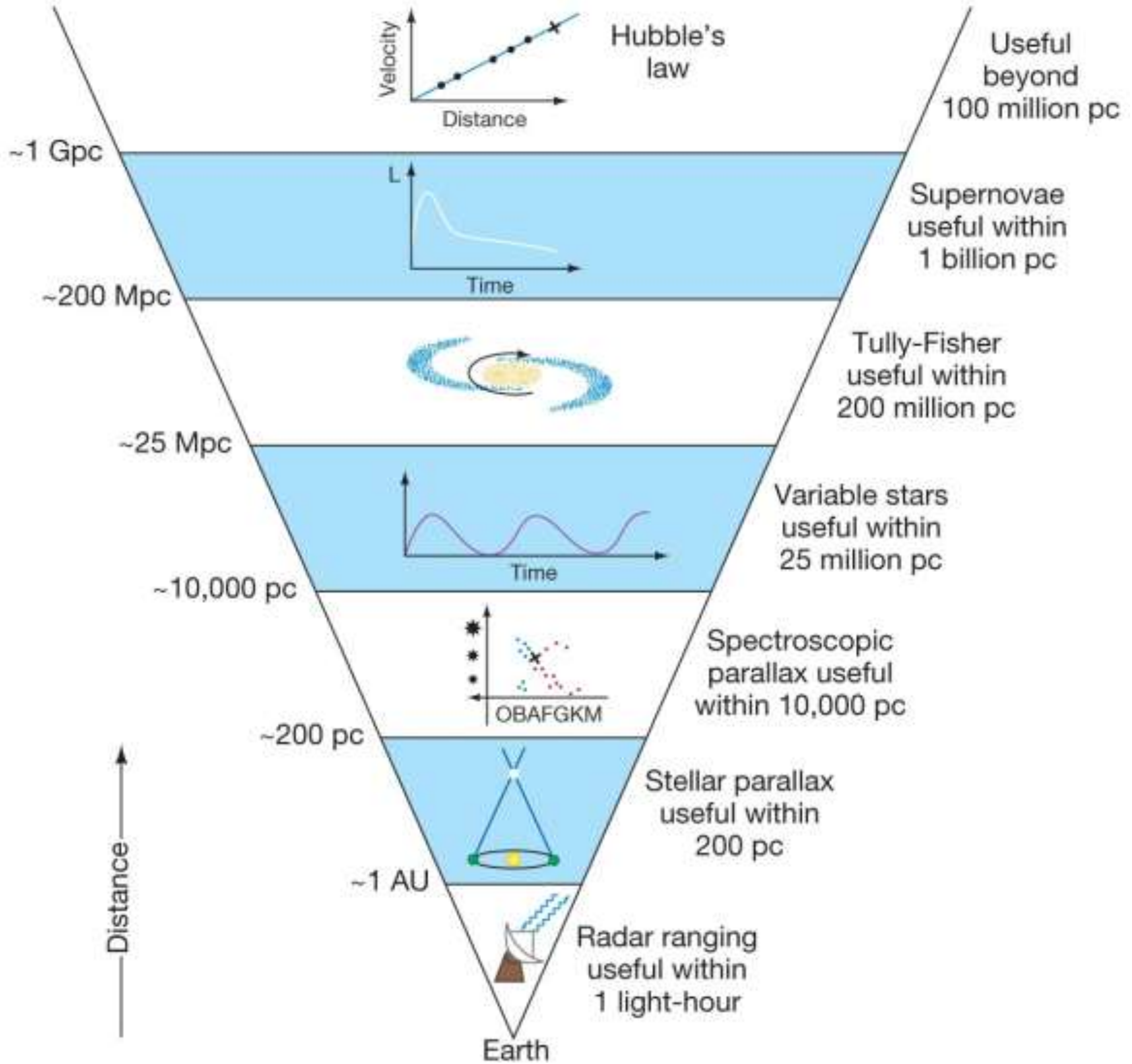
The currently accepted value for Hubble's constant is

$$H_0 = 70 \text{ km/s/Mpc}$$

Measuring distances using Hubble's law actually works better on farther away objects; random motions are overwhelmed by the recessional velocity.

24.3 Hubble's Law

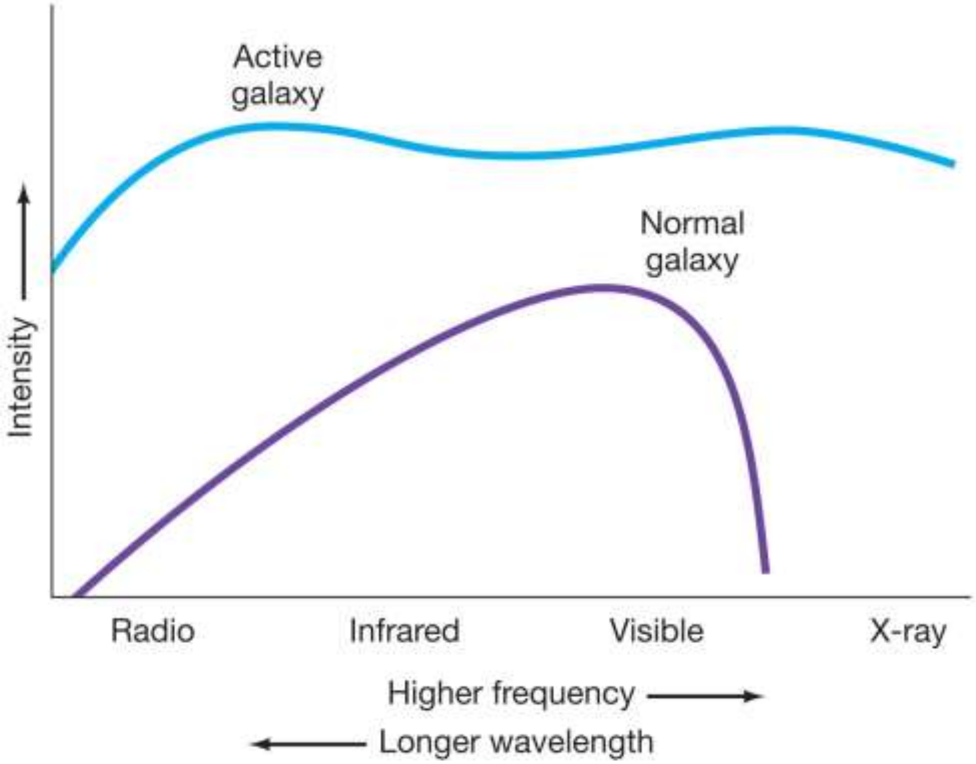
This puts the final step on our distance ladder



24.4 Active Galactic Nuclei

About 20–25% of galaxies don't fit well into the Hubble scheme—they are far too luminous.

Such galaxies are called active galaxies. They differ from normal galaxies in both the luminosity and type of radiation they emit.



24.4 Active Galactic Nuclei

The radiation from these galaxies is called nonstellar radiation.

Many luminous galaxies are experiencing an outburst of star formation, probably due to interactions with a neighbor. These galaxies are called starburst galaxies, and we will discuss them later.

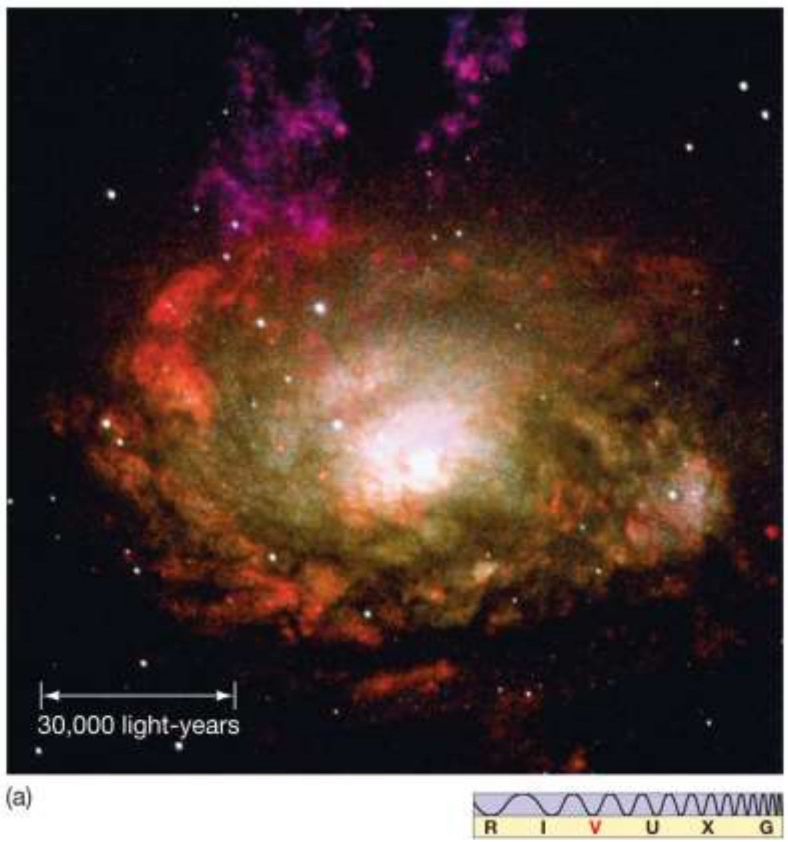
The galaxies we will discuss now are those whose activity is due to events occurring in and around the galactic center.

24.4 Active Galactic Nuclei

This active galaxy has star-formation rings surrounding a very luminous core.

24.4 Active Galactic Nuclei

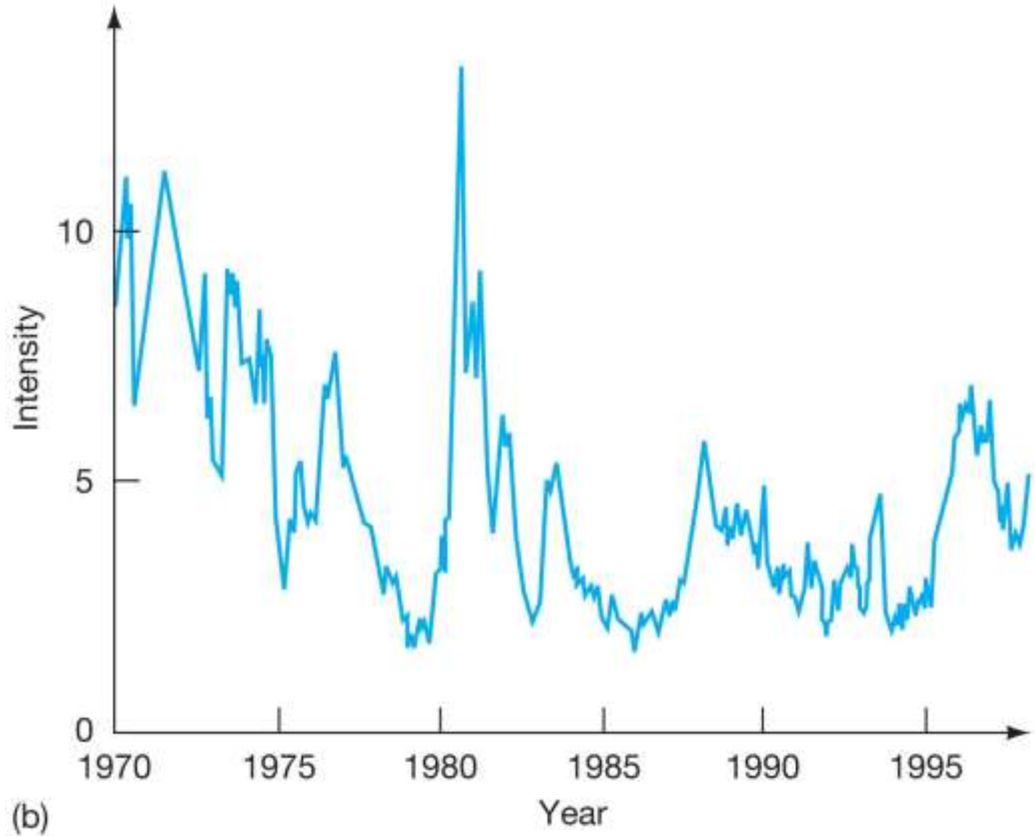
Active galaxies are classified into three types: Seyfert galaxies, radio galaxies, and quasars. Seyfert galaxies resemble normal spiral galaxies, but their cores are thousands of times more luminous.



(a)

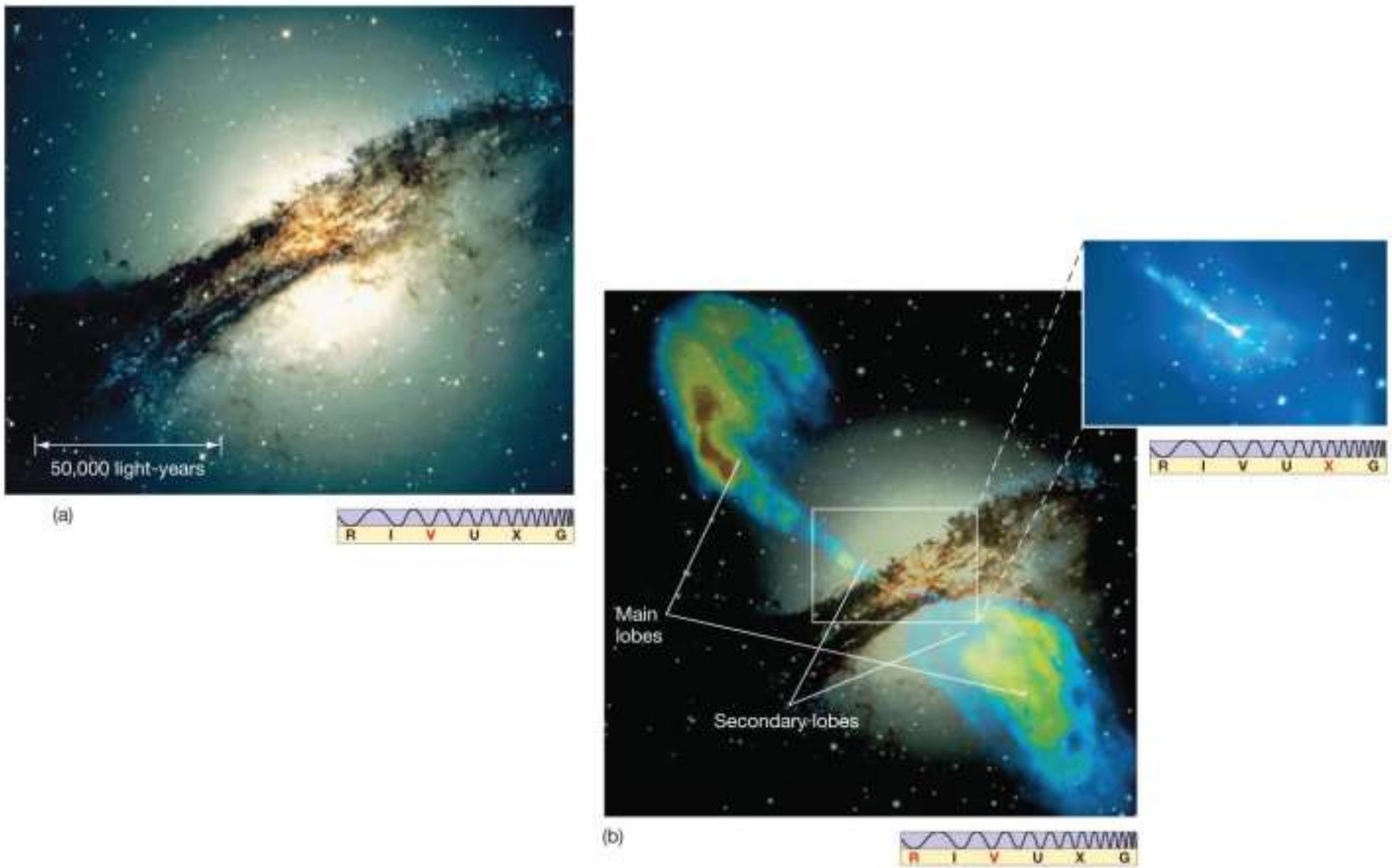
24.4 Active Galactic Nuclei

The rapid variations in the luminosity of Seyfert galaxies indicate that the core must be extremely compact



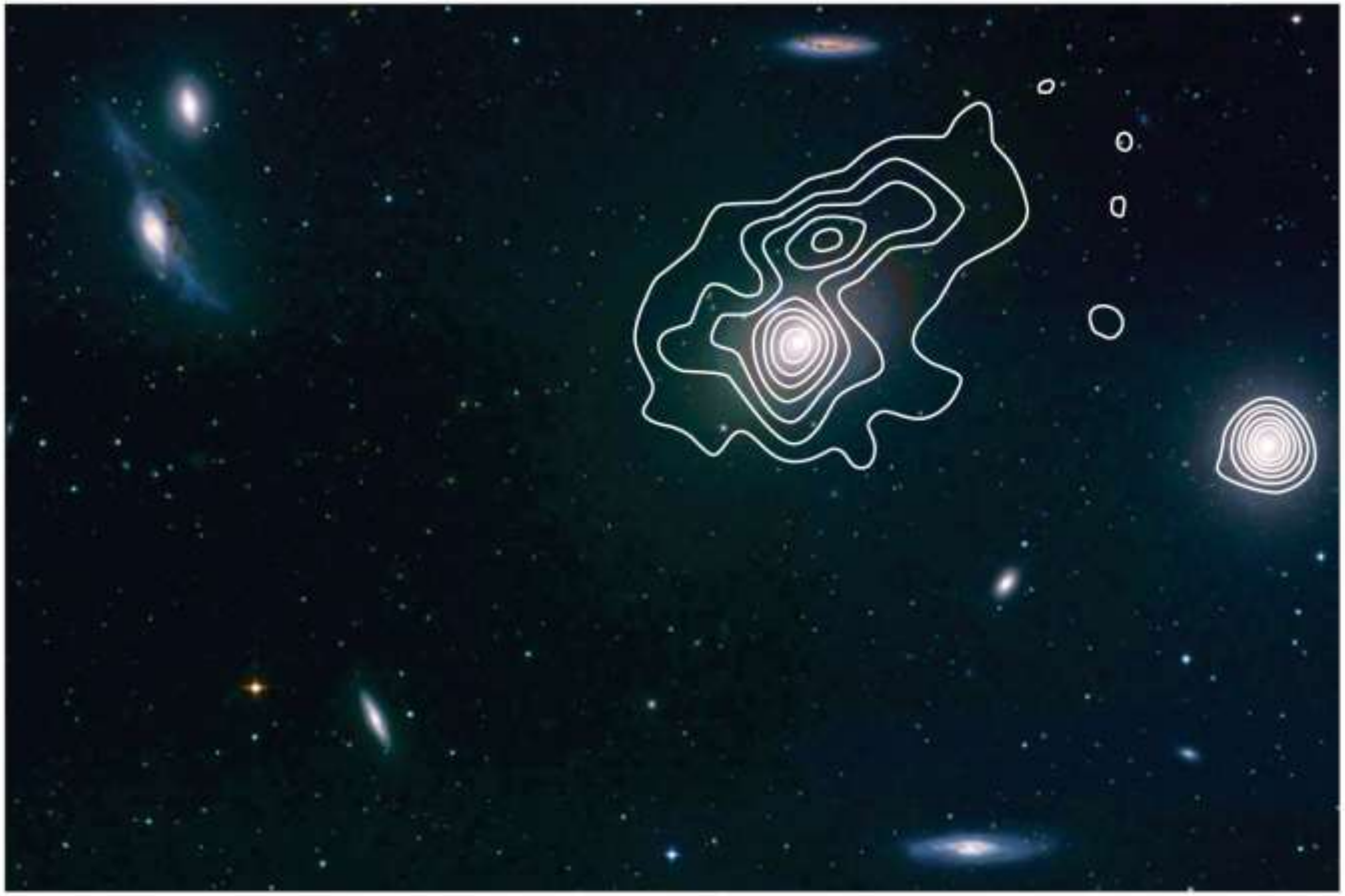
24.4 Active Galactic Nuclei

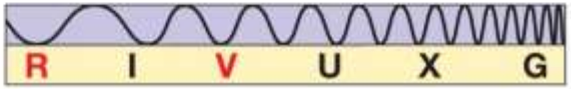
Radio galaxies emit very strongly in the radio portion of the spectrum. They may have enormous lobes, invisible to optical telescopes, perpendicular to the plane of the galaxy.



24.4 Active Galactic Nuclei

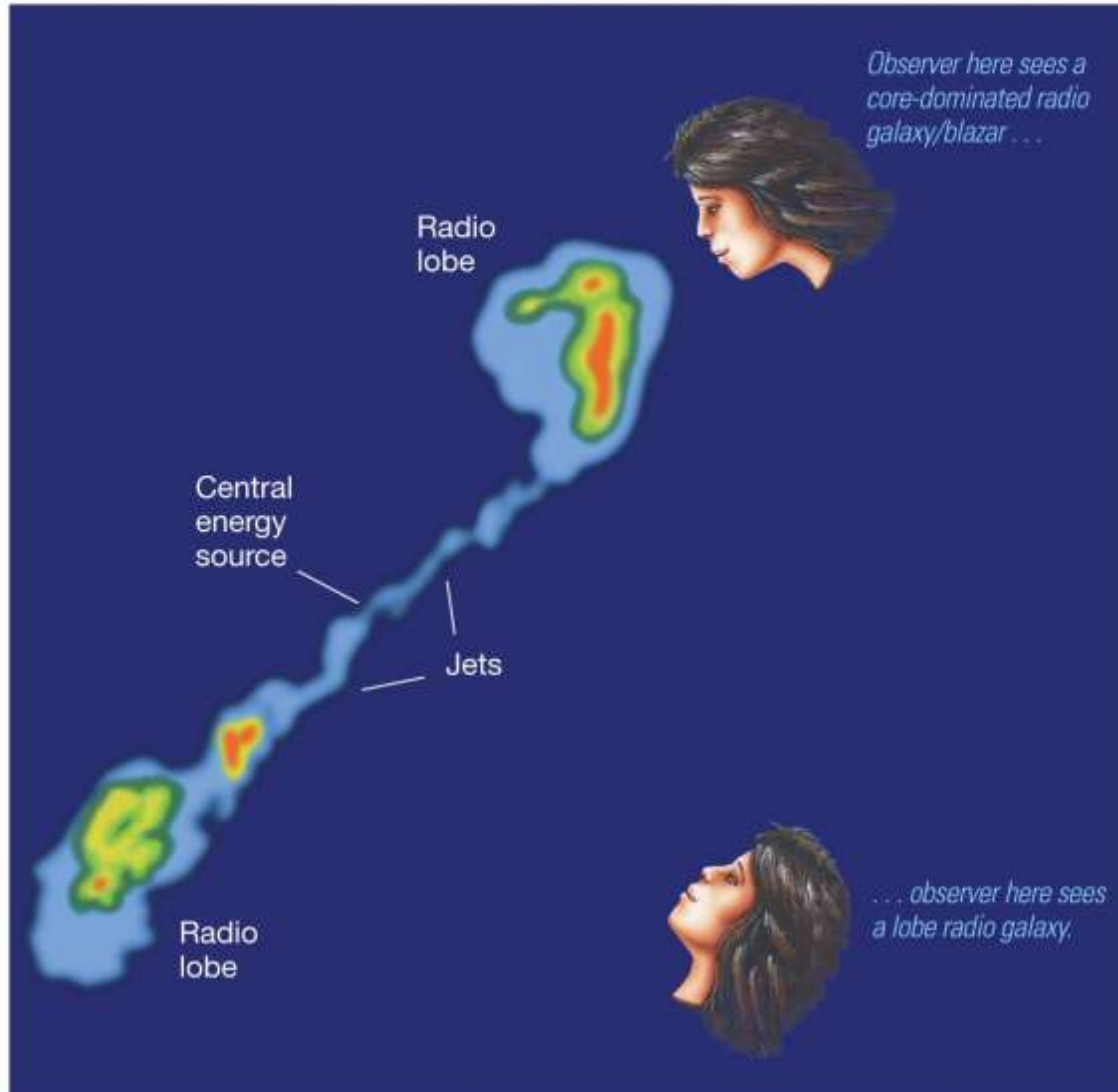
Radio galaxies may also be core dominated.





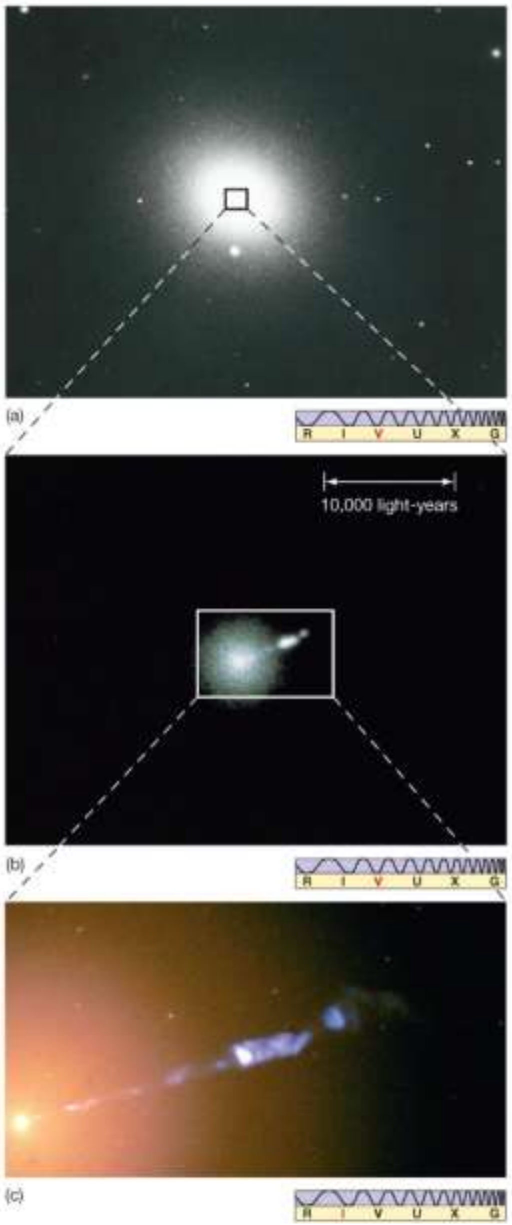
24.4 Active Galactic Nuclei

Core-dominated and radio-lobe galaxies are probably the same phenomenon viewed from different angles.



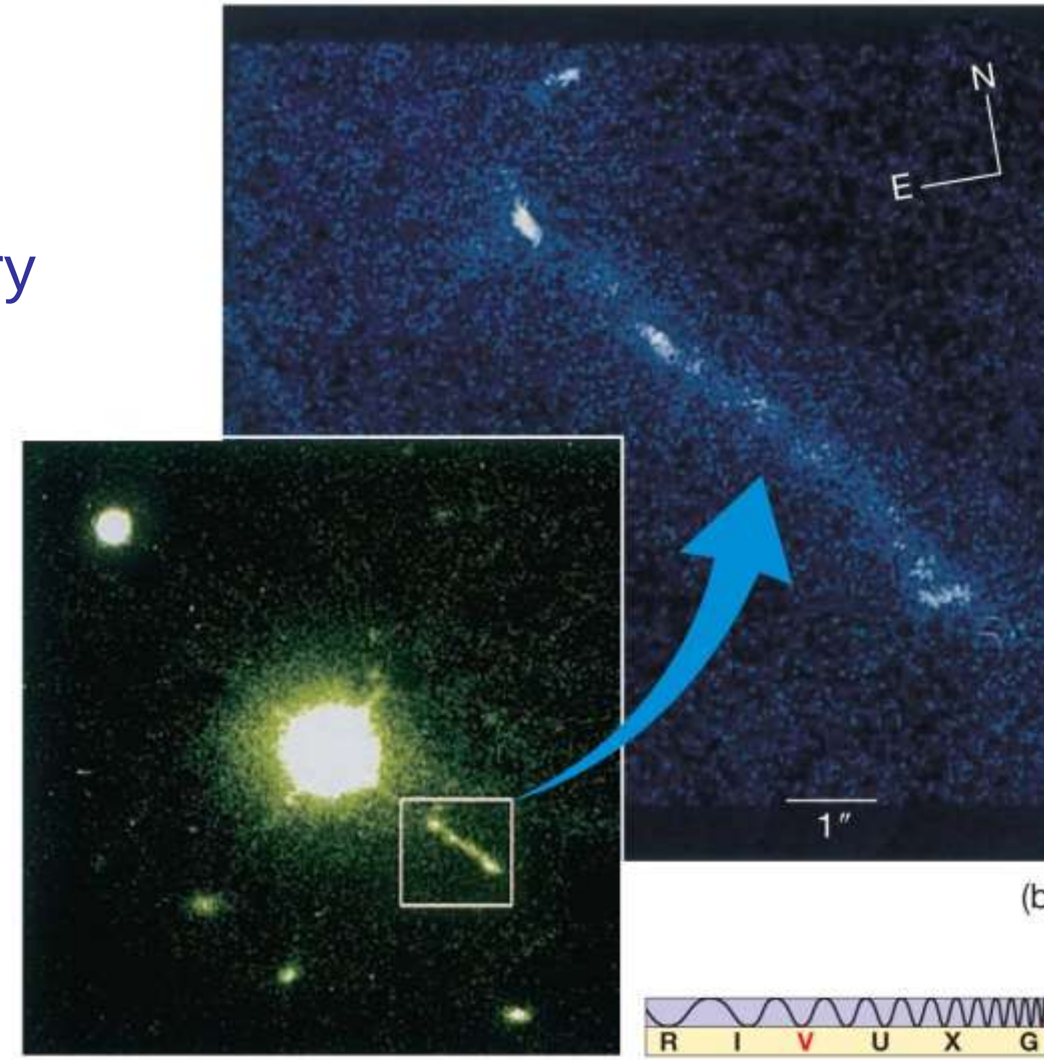
24.4 Active Galactic Nuclei

Many active galaxies have jets, and most show signs of interactions with other galaxies.



24.4 Active Galactic Nuclei

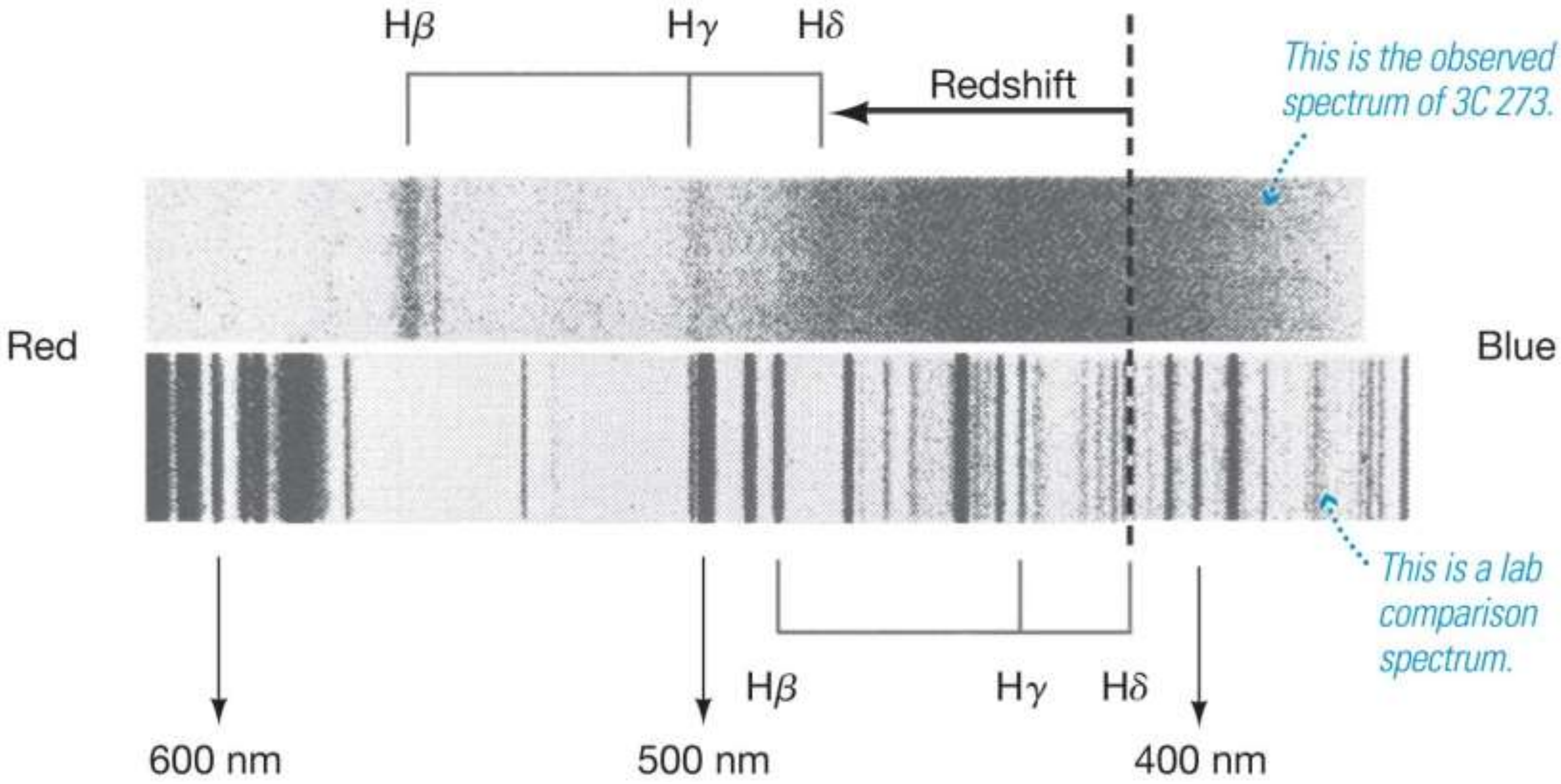
Quasars—quasi-stellar objects—are starlike in appearance, but have very unusual spectral lines.



(a) (b)

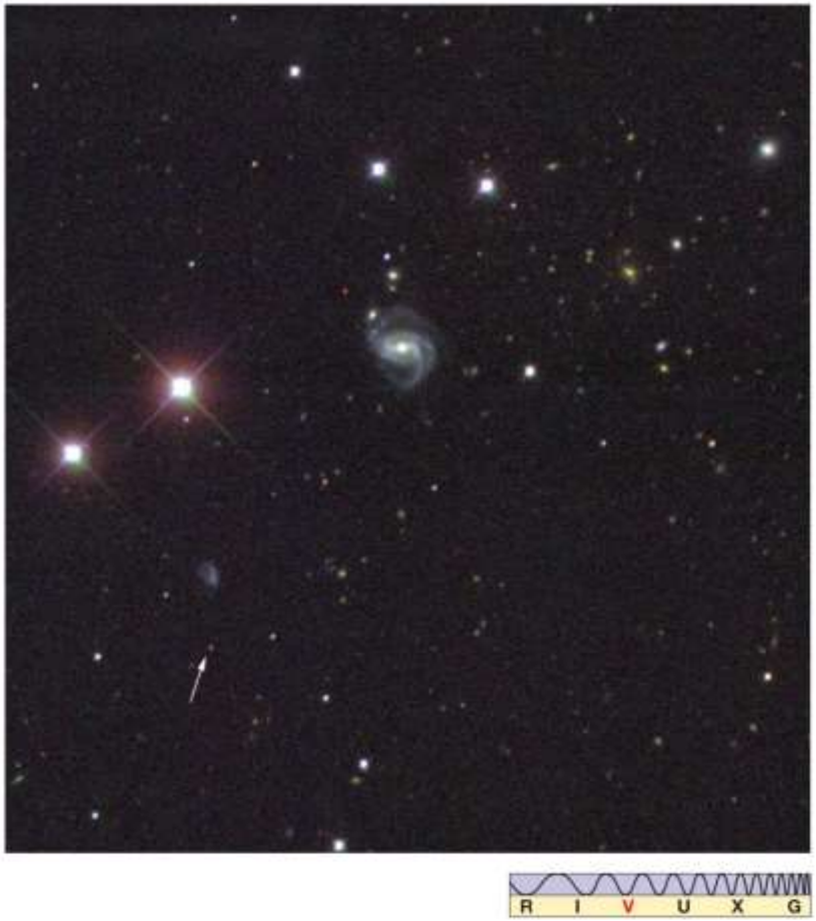
24.4 Active Galactic Nuclei

Eventually it was realized that quasar spectra were normal, but enormously redshifted.



24.4 Active Galactic Nuclei

Solving the spectral problem introduces a new problem—quasars must be among the most luminous objects in the galaxy, to be visible over such enormous distances.



More Precisely 24-1: Relativistic Redshifts and Look-Back Time

The redshift of a beam of light is its fractional increase in wavelength. Redshifts are measured directly; distances are calculated from them using Hubble's constant, which is uncertain. Astronomers therefore prefer to quote redshifts rather than distances.

The look-back time is the time when light was emitted from a distant object; for very distant objects it is less than the redshift would indicate, as the object has receded in the meantime.

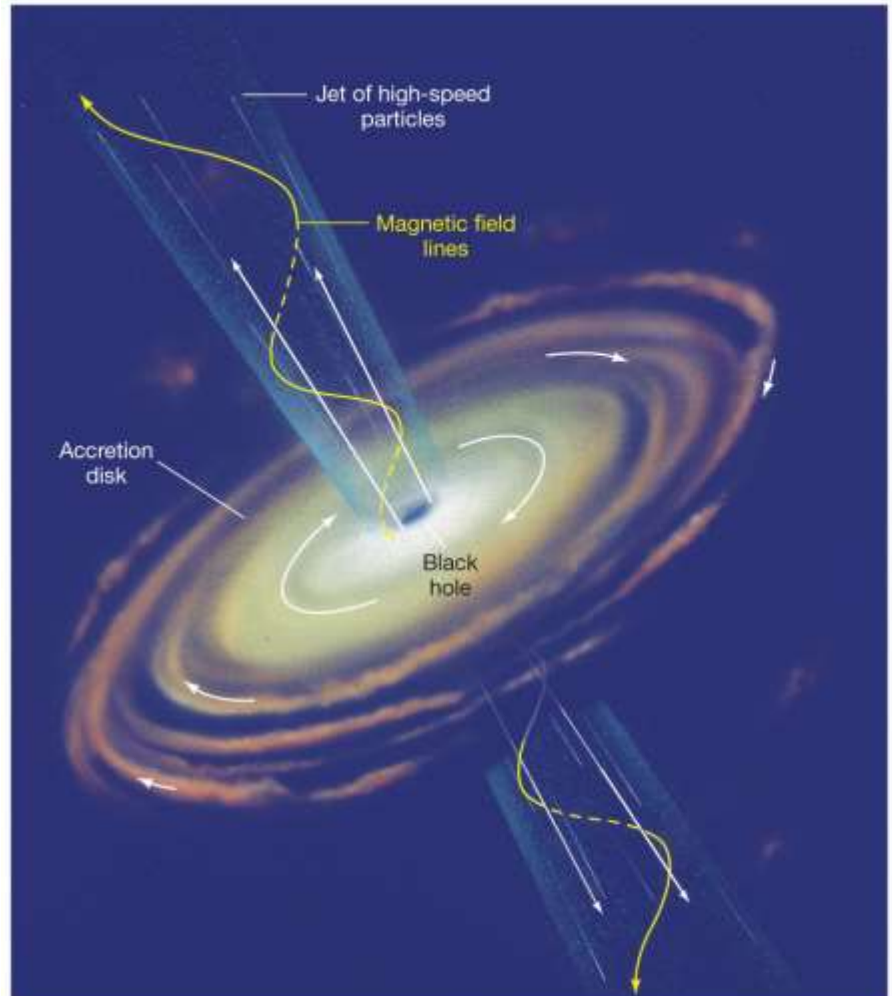
24.5 The Central Engine of an Active Galaxy

Active galactic nuclei have some or all of the following properties:

- high luminosity
- nonstellar energy emission
- variable energy output, indicating small nucleus
- jets and other signs of explosive activity
- broad emission lines, indicating rapid rotation

24.5 The Central Engine of an Active Galaxy

This is the leading theory for the energy source in an active galactic nucleus: a black hole, surrounded by an accretion disk. The strong magnetic field lines around the black hole channel particles into jets perpendicular to the magnetic axis.



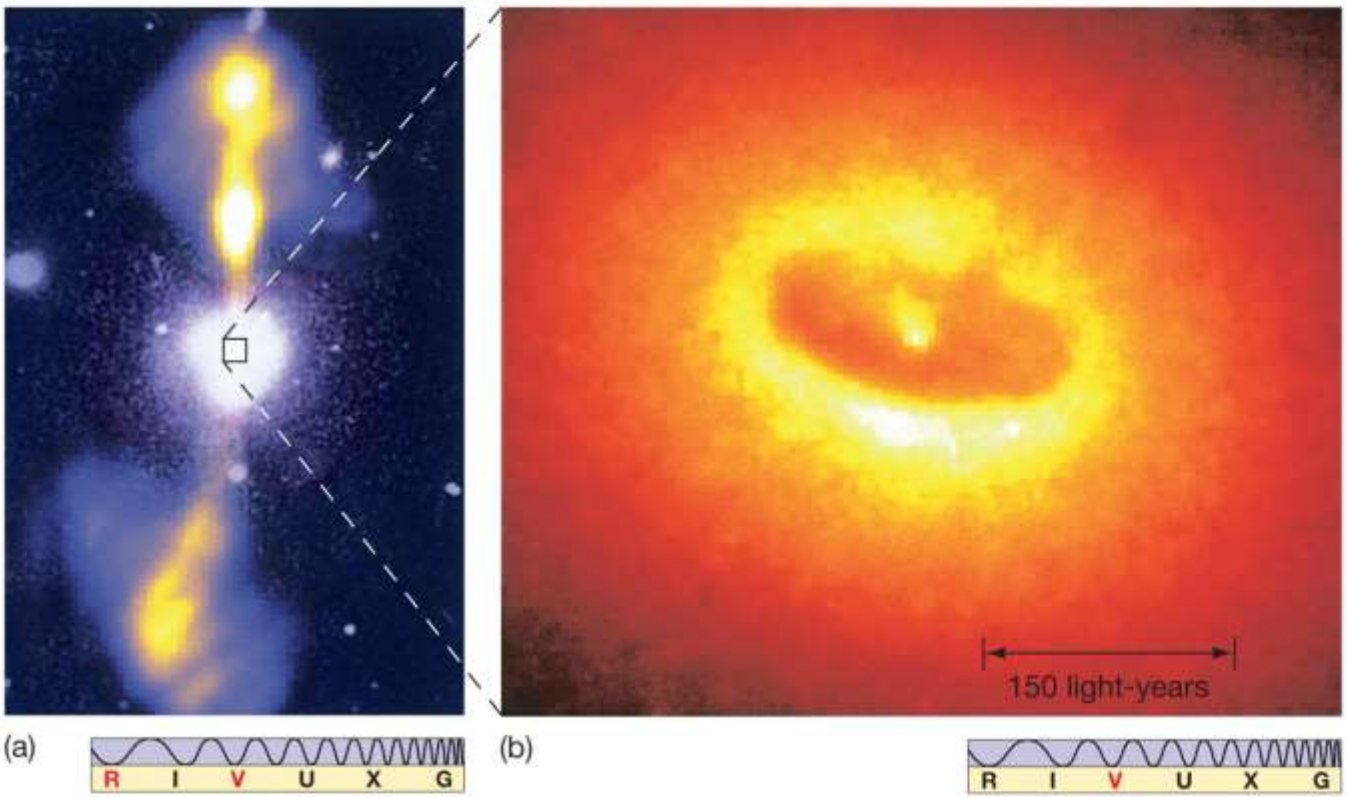
24.5 The Central Engine of an Active Galaxy

In an active galaxy, the central black hole may be billions of solar masses.

The accretion disk is whole clouds of interstellar gas and dust; they may radiate away as much as 10–20% of their mass before disappearing.

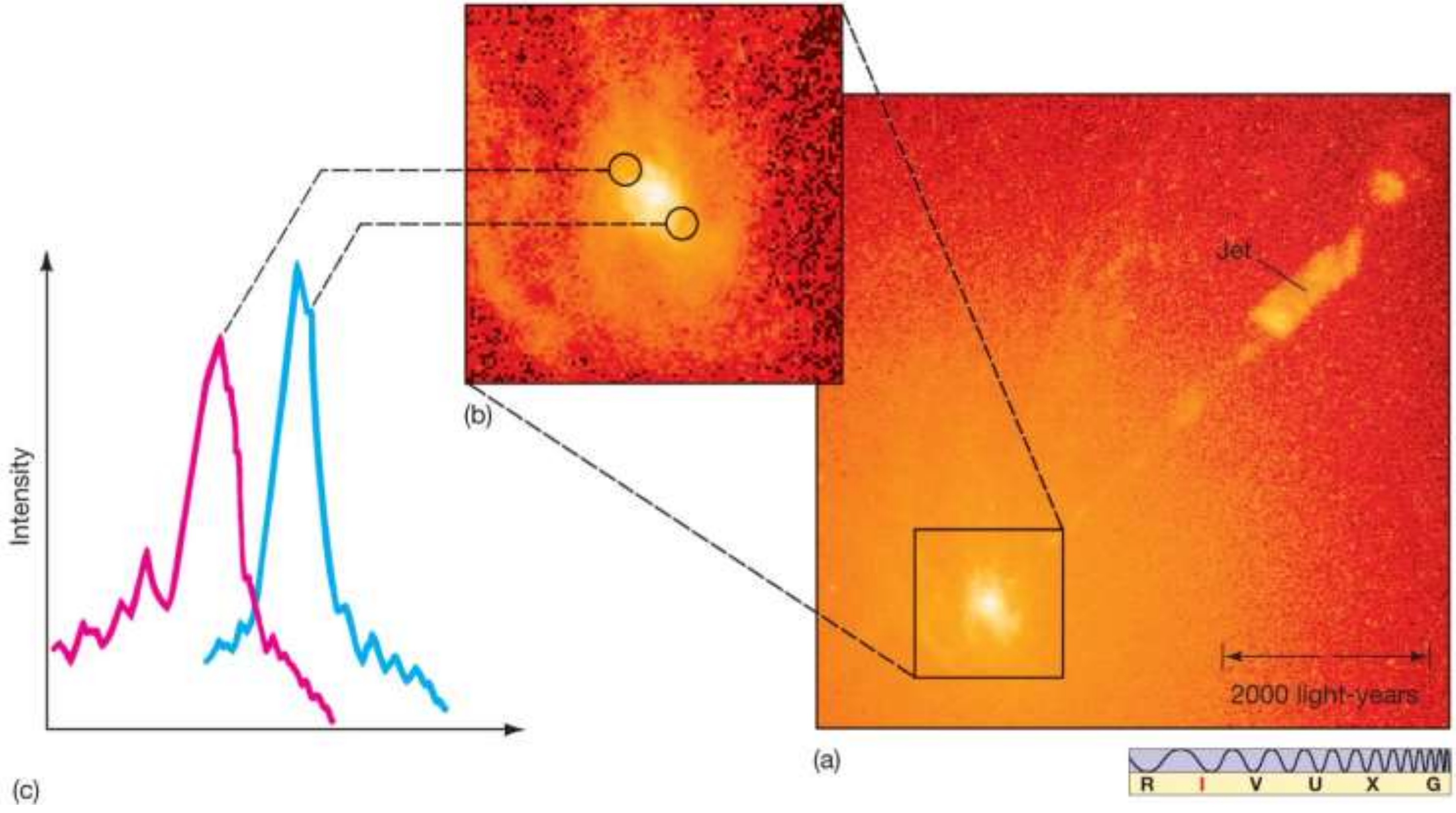
24.5 The Central Engine of an Active Galaxy

This pair of images shows evidence for a black hole at the center of NGC 4261.



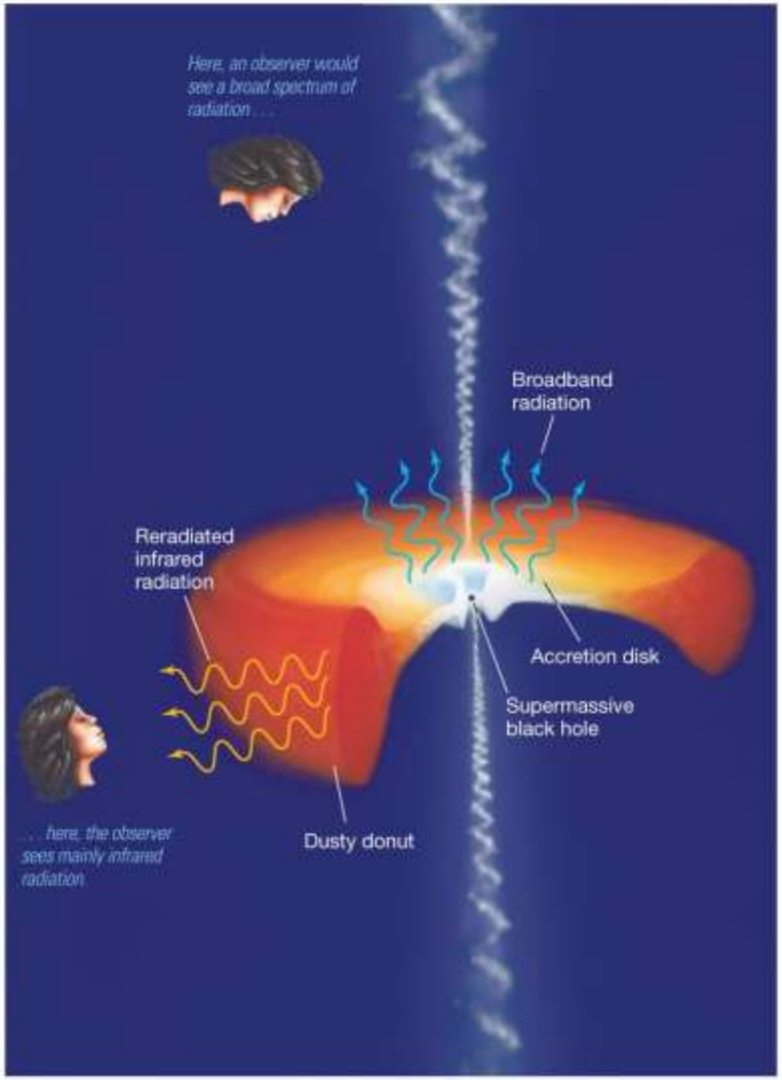
24.5 The Central Engine of an Active Galaxy

The central portion of M87 shows rapid motion and jets characteristic of material surrounding a black hole.



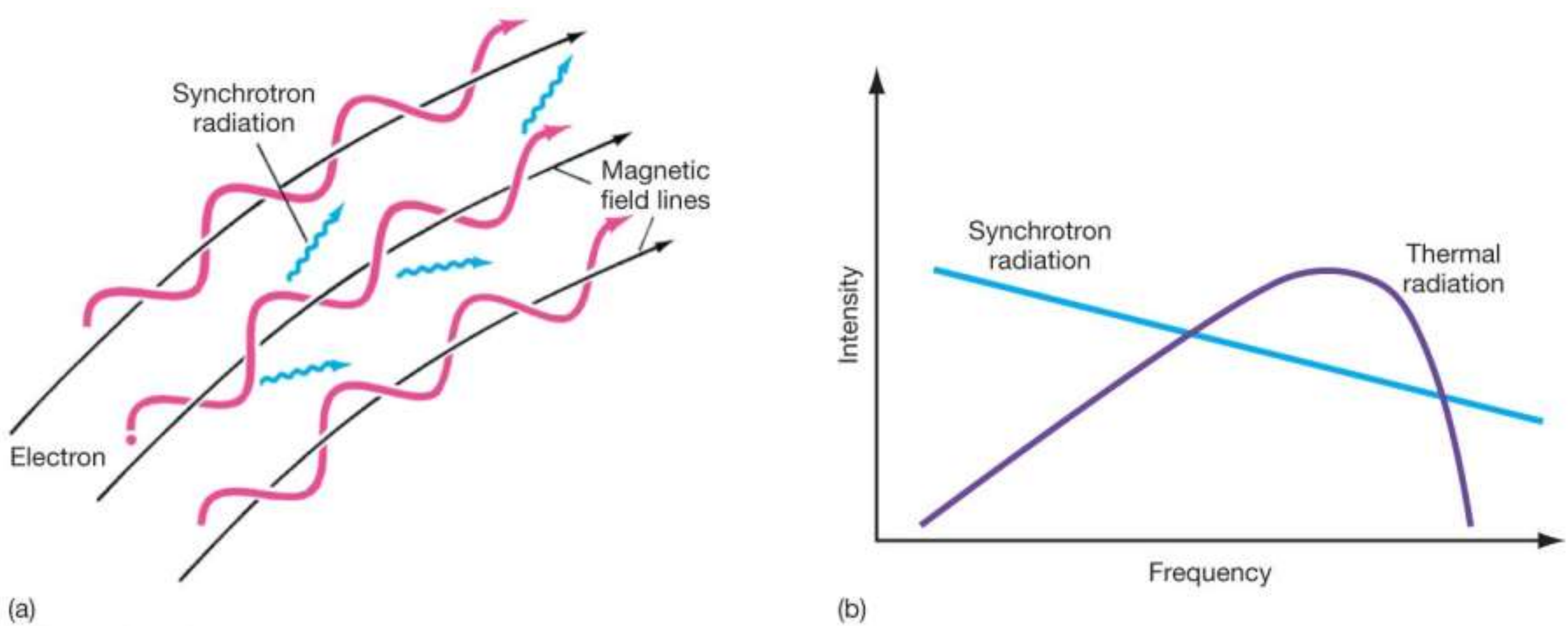
24.5 The Central Engine of an Active Galaxy

One might expect the radiation to be mostly X and gamma-rays, but apparently it is often “reprocessed” in the dense clouds around the black hole and reemitted at longer wavelengths.



24.5 The Central Engine of an Active Galaxy

Particles will emit synchrotron radiation as they spiral along the magnetic field lines; this radiation is decidedly nonstellar.



Summary of Chapter 24

- Hubble classification organizes galaxies according to shape
- Galaxy types: spiral, barred spiral, elliptical, irregular
- Objects of relatively uniform luminosities are called "standard candles"; examples include RR Lyrae stars and Type I supernovae
- The Milky Way lies within a small cluster of galaxies called the Local Group.
- Other galaxy clusters may contain thousands of galaxies

Summary of Chapter 24 (cont.)

- Hubble's Law: Galaxies recede from us faster the farther away they are
- Active galaxies are far more luminous than normal galaxies, and their radiation is nonstellar
- Seyfert galaxies, radio galaxies, and quasars all have very small cores; many emit high-speed jets
- Active galaxies are thought to contain supermassive black holes in their centers; infalling matter converts to energy, powering the galaxy