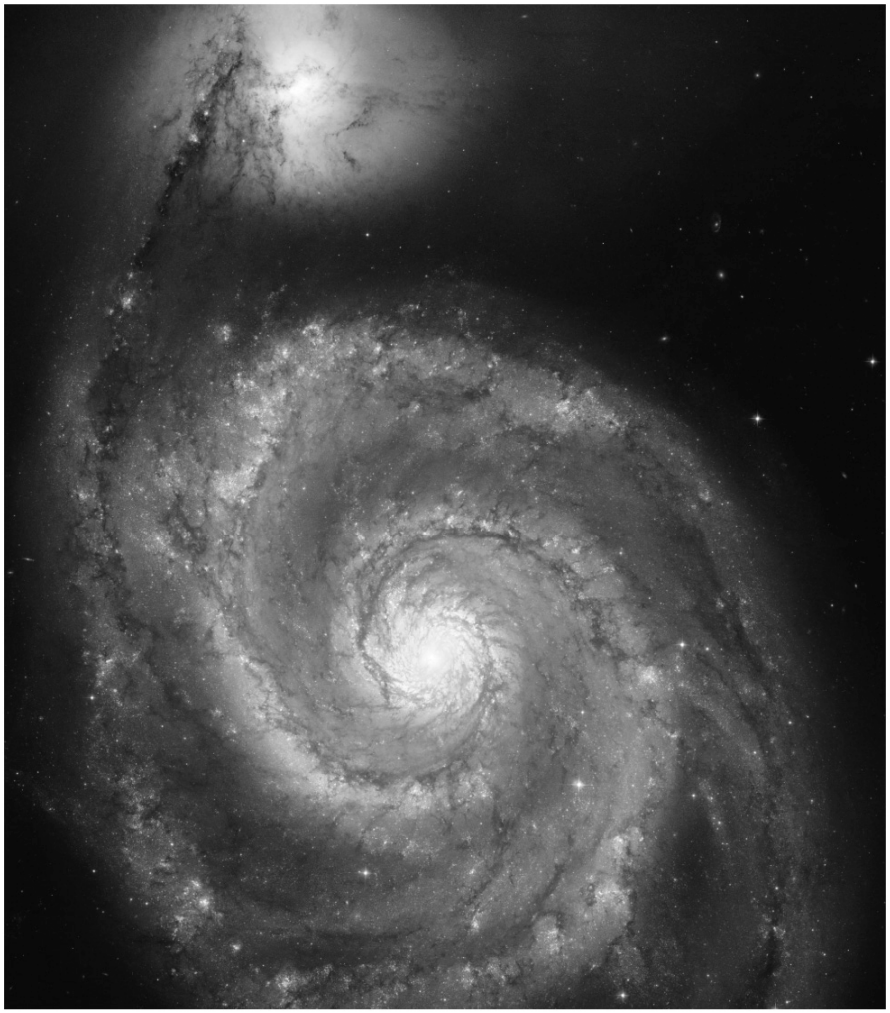
Chapter 15
Normal and Active Galaxies



Units of Chapter 15

Hubble's Galaxy Classification

The Distribution of Galaxies in Space

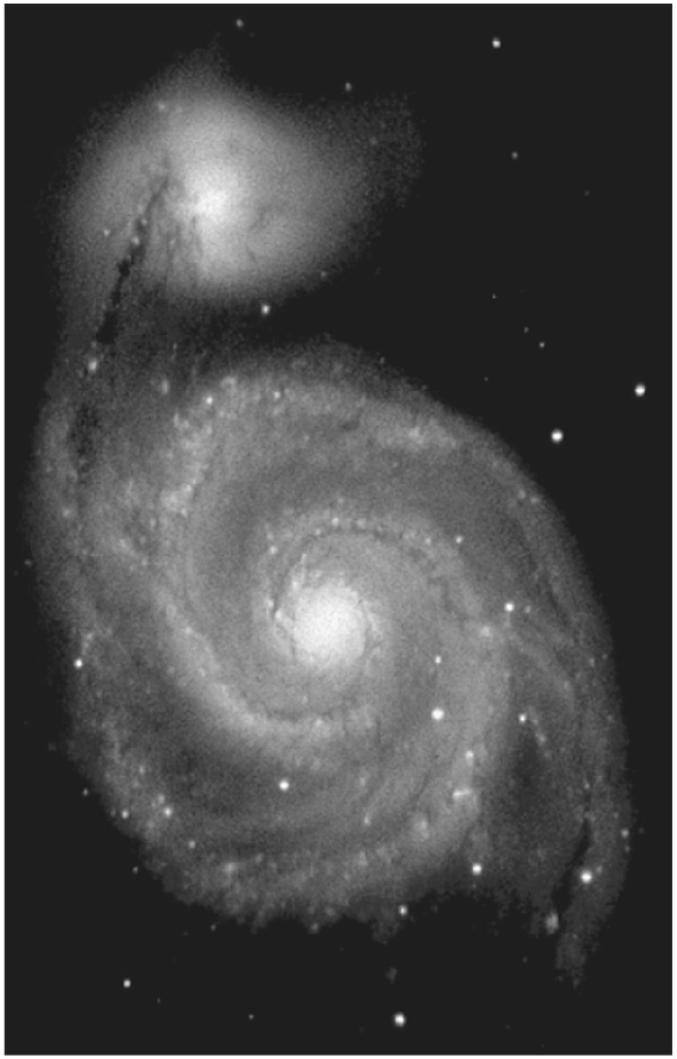
Hubble's Law

Active Galactic Nuclei

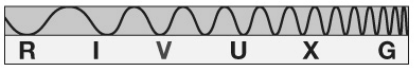
The Central Engine of an Active Galaxy

15.1 Hubble's Galaxy Classification

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



(b) M51 Type Sb



15.1 Hubble's Galaxy Classification

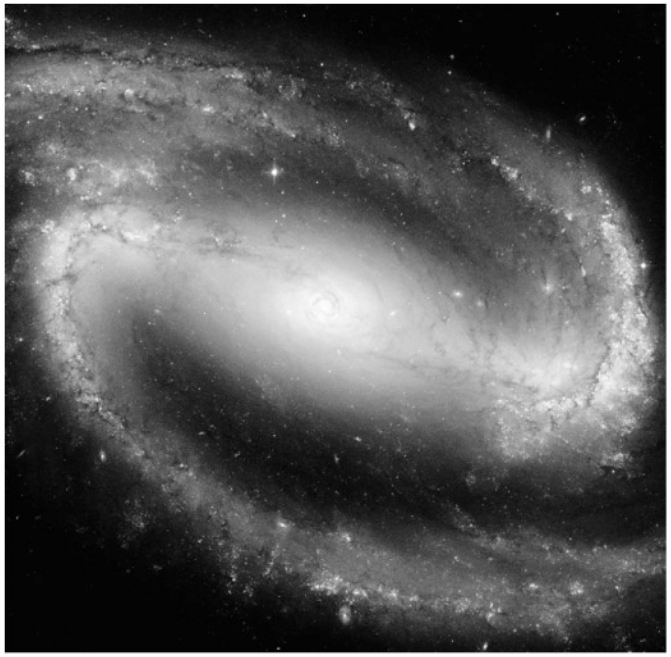
Type Sa has the largest central bulge, Type Sb is smaller, and Type Sc is the smallest.

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, spiral arms.

15.1 Hubble's Galaxy Classification

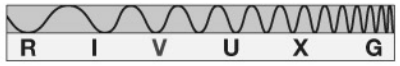
Similar to the spiral galaxies are the barred spirals:



(a) NGC 1300 Type SBa

(b) NGC 1365 Type SBb

(c) NGC 6872 Type SBc



15.1 Hubble's Galaxy Classification

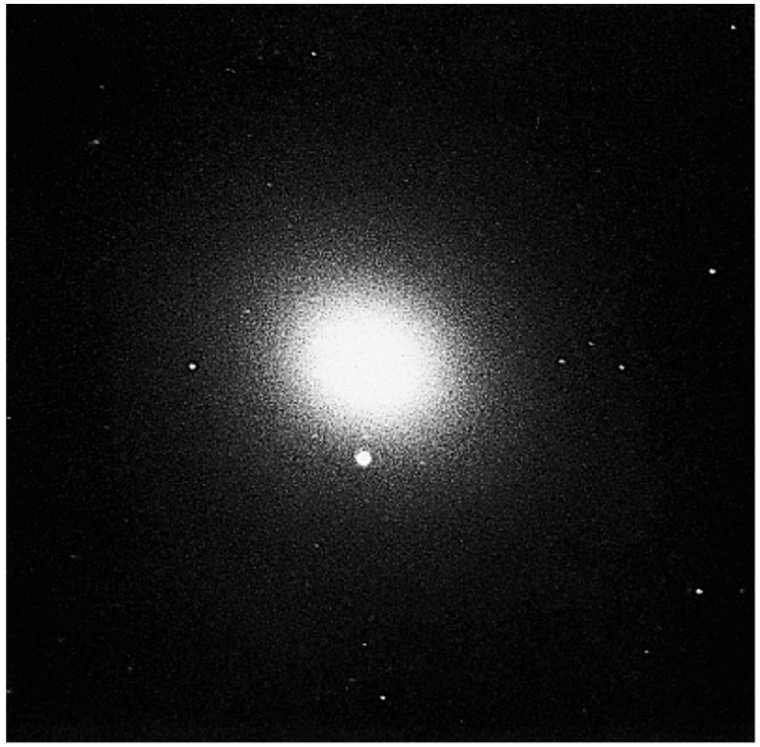
Elliptical galaxies have no spiral arms and no disk. They come in many sizes, from giant ellipticals of trillions of stars, down to dwarf ellipticals of less than a million stars.

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

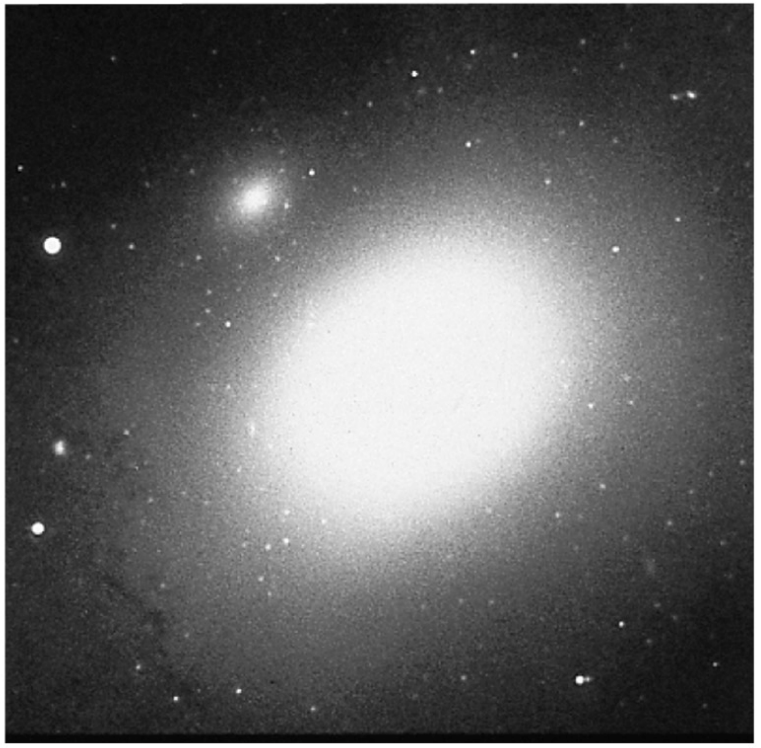
Many do, however, have large clouds of hot gas, extending far beyond the visible boundaries of the galaxy.

15.1 Hubble's Galaxy Classification

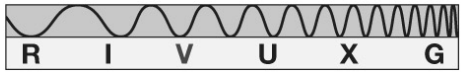
Ellipticals are classified according to their shape from E0 (almost spherical) to E7 (the most elongated).



(a) M49 Type E2



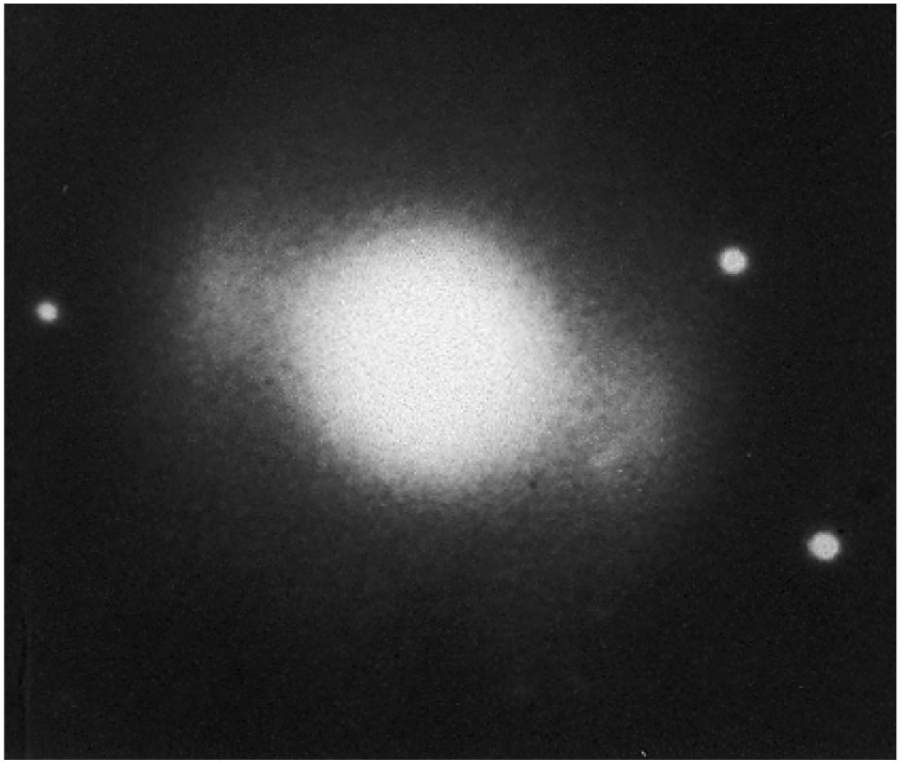
(b) M84 Type E3



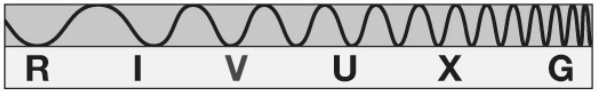
15.1 Hubble's Galaxy Classification

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



15.1 Hubble's Galaxy Classification

The irregular galaxies have a wide variety of shapes. Both these galaxies appear to be undergoing interactions with other galaxies.

(a) NGC 1427A--

(b) M82

15.1 Hubble's Galaxy Classification

A summary of galaxy properties by type:

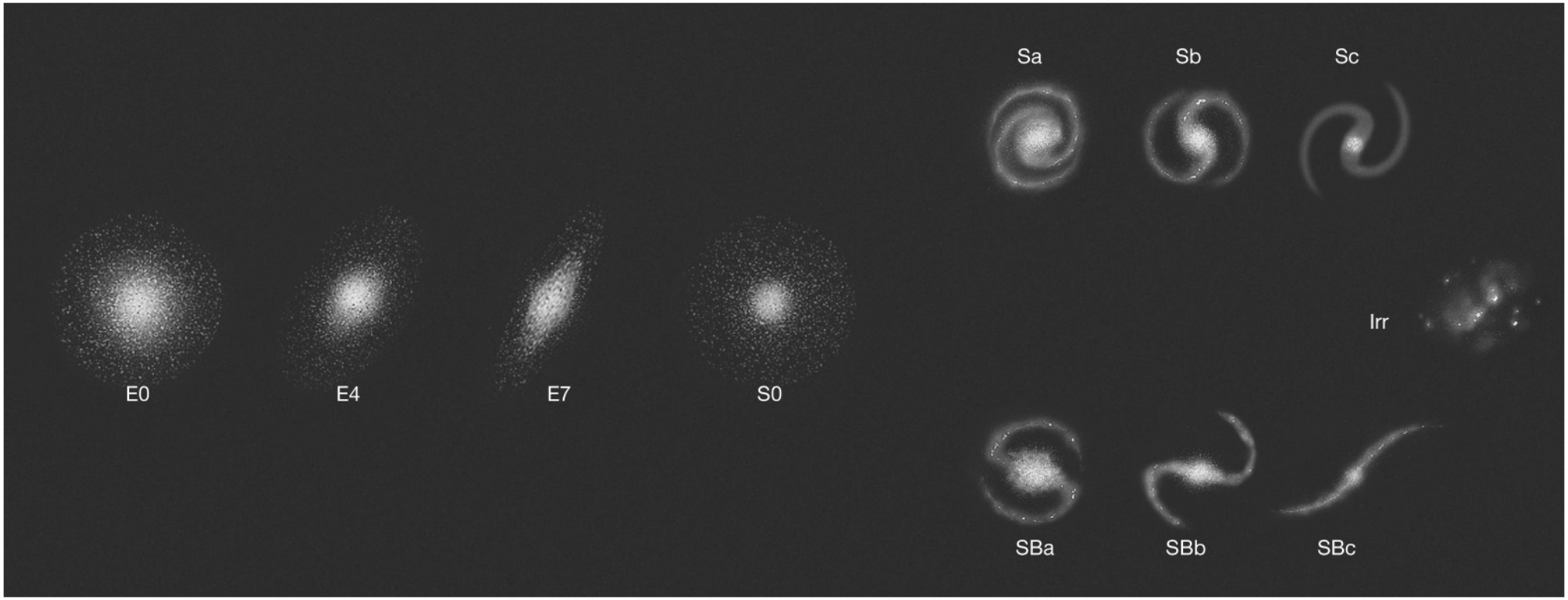
TABLE 15.1 Basic Galaxy Properties by Type

	SPIRAL/BARRED SPIRAL (S/SB)	ELLIPTICAL (E)[1]	IRREGULAR (Irr)
Shape and structural properties	Highly flattened disk of stars and gas, containing spiral arms and thickening to central bulge. SB galaxies have an elongated central "bar" of stars and gas.	No disk. Stars smoothly distributed through an ellipsoidal volume. No obvious substructure other than a dense central nucleus.	No obvious structure. Irr II galaxies often have "explosive" appearance.
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 very irregular orbits.

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

15.1 Hubble's Galaxy Classification

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



15.2 The Distribution of Galaxies in Space

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

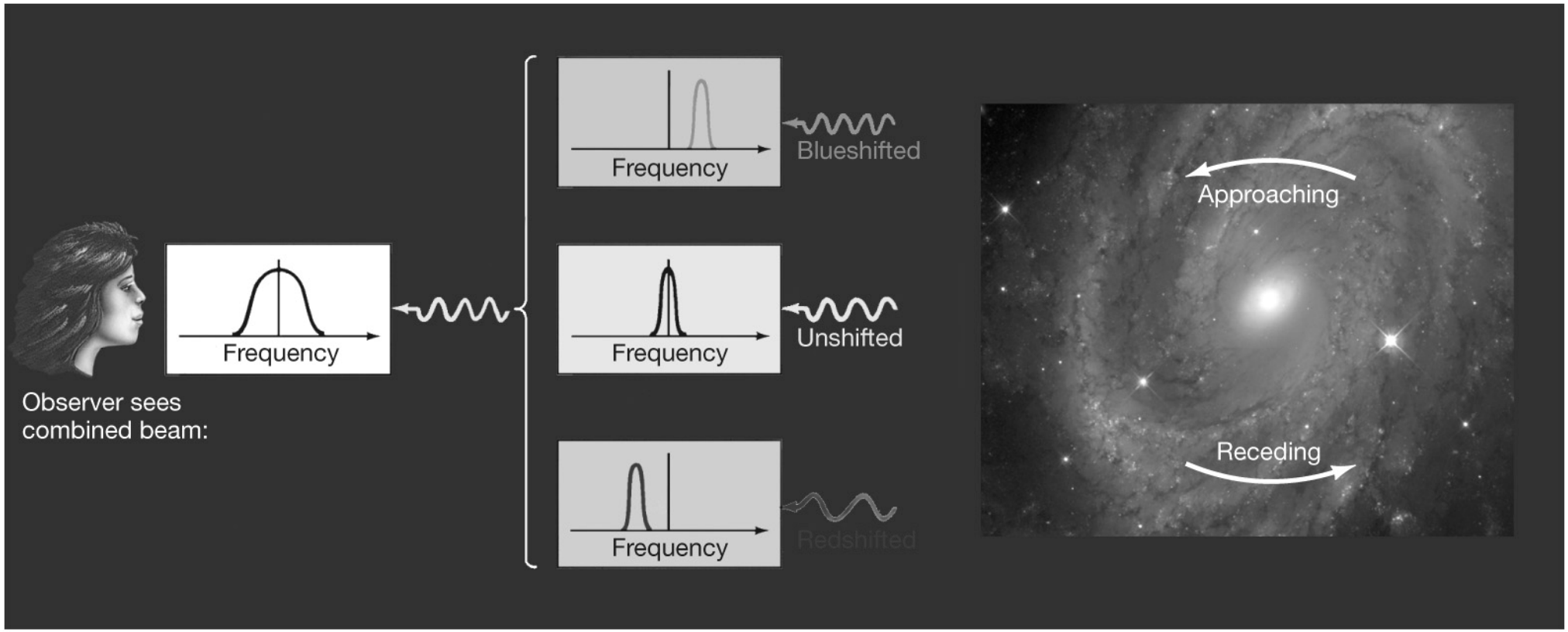
However, some galaxies have no Cepheids, and most are farther away then 25 Mpc. New distance measures are needed.

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

• Type I supernovae all have about the same luminosity, as the process by which they happen doesn't allow for much variation.

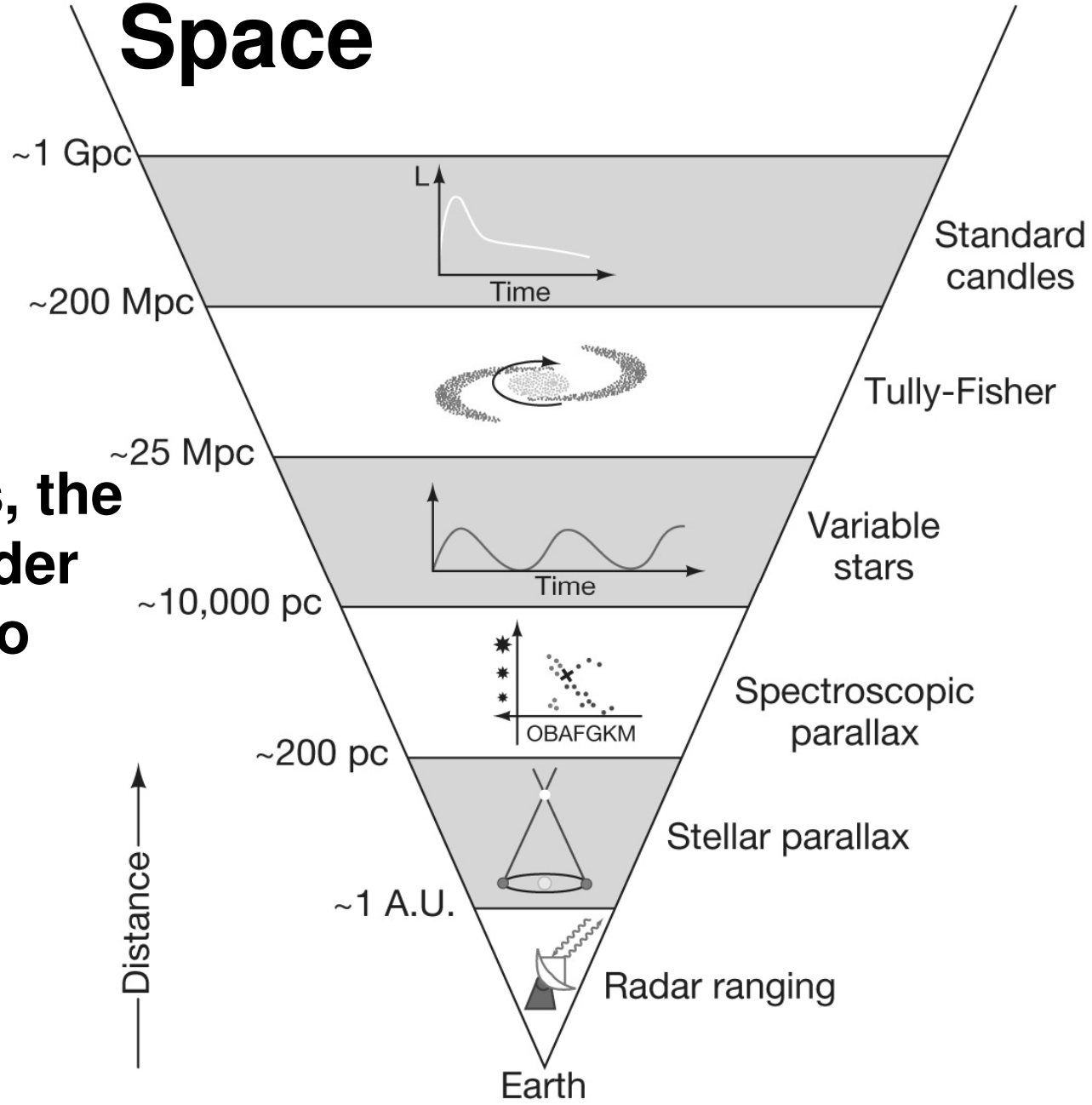
15.2 The Distribution of Galaxies in Space

The rotation of a galaxy results in Doppler broadening of its spectral lines:

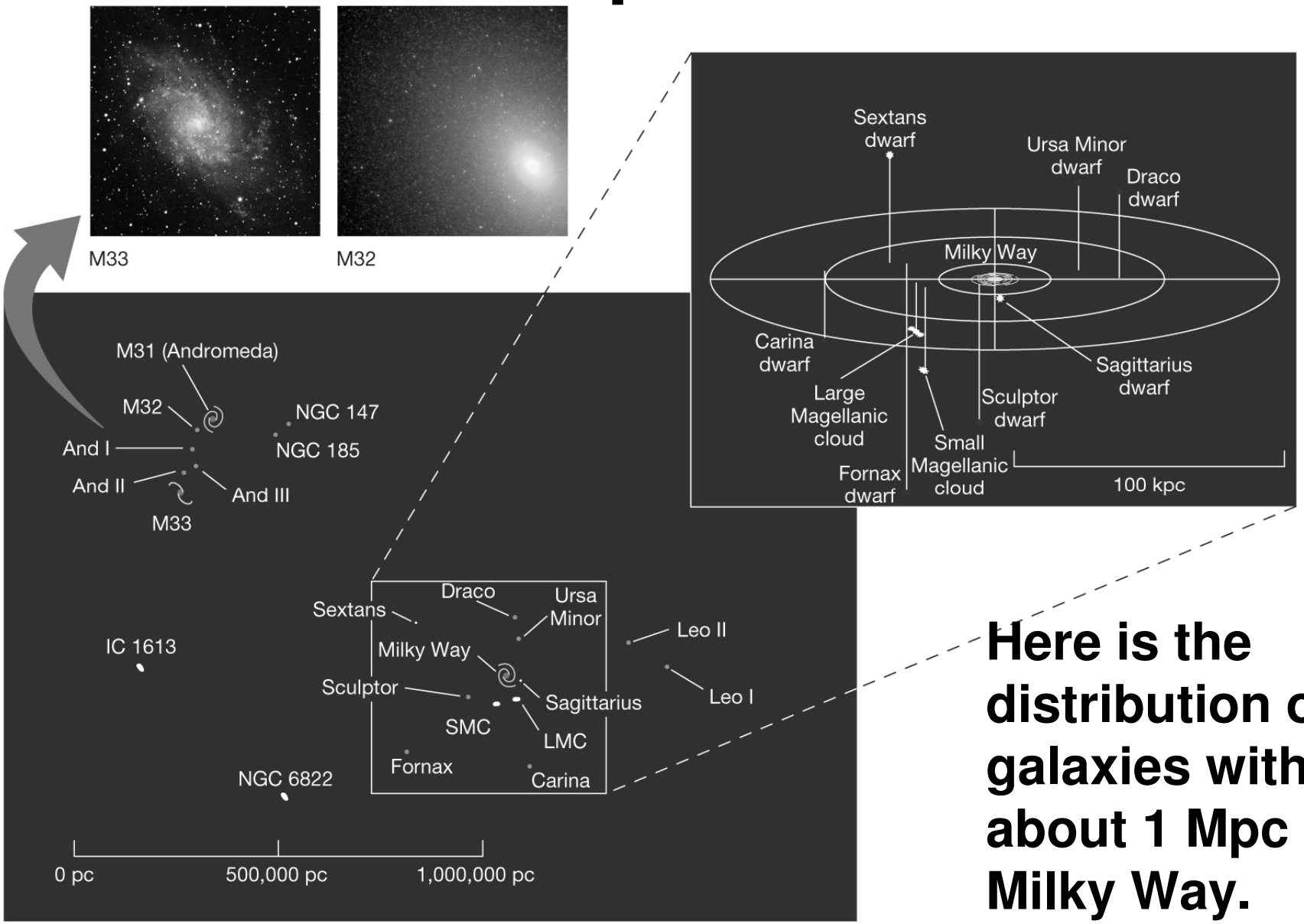


15.2 The Distribution of Galaxies in Space

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



15.2 The Distribution of Galaxies in Space



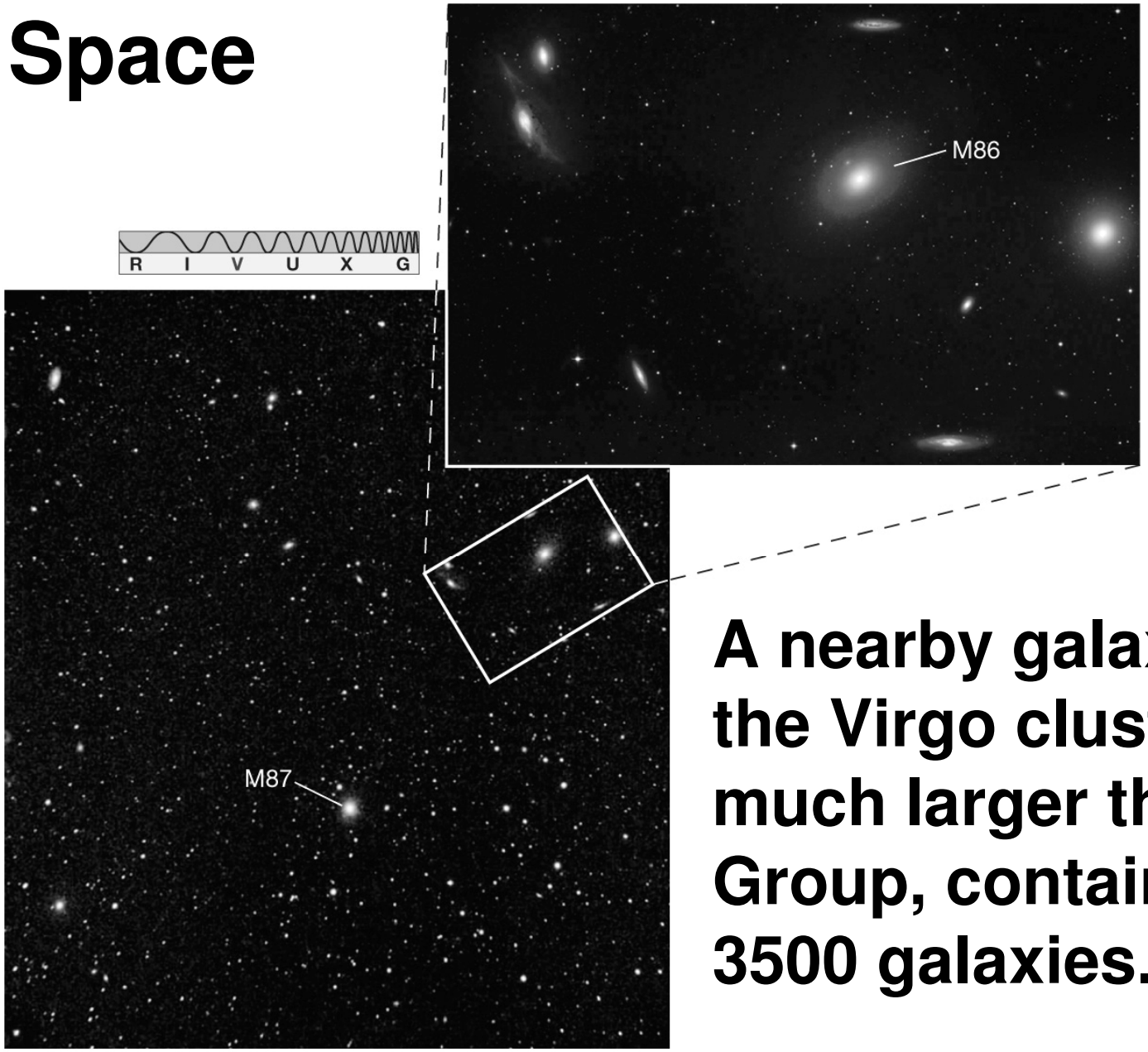
Here is the distribution of galaxies within about 1 Mpc of the Milky Way.

15.2 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.

15.2 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.