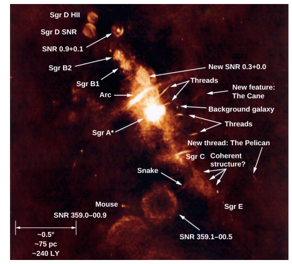
25.4 THE CENTER OF THE GALAXY

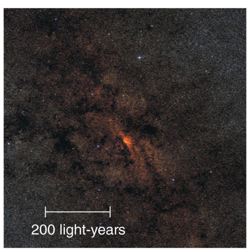
- **Galactic Center in X-Rays.** This artificial-color mosaic of 30 images taken with the Chandra X-ray satellite shows a region 400 × 900 light-years in extent and centered on Sagittarius A*, the bright white source in the center of the picture. The X-ray-emitting point sources are white dwarfs, neutron stars, and stellar black holes. The diffuse "haze" is emission from gas at a temperature of 10 million K. This hot gas is flowing away from the center out into the rest of the Galaxy. The colors indicate X-ray energy bands: red (low energy), green (medium energy), and blue (high energy). (credit: modification of work by NASA/CXC/ UMass/D. Wang et al.)

Figure 25.14



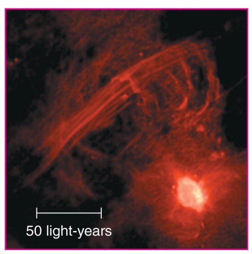
- **Radio Image of Galactic Center Region.** This radio map of the center of the Galaxy (at a wavelength of 90 centimeters) was constructed from data obtained with the Very Large Array (VLA) of radio telescopes in Socorro, New Mexico. Brighter regions are more intense in radio waves. The galactic center is inside the region labeled Sagittarius A. Sagittarius B1 and B2 are regions of active star formation. Many filaments or threadlike features are seen, as well as a number of shells (labeled SNR), which are supernova remnants. The scale bar at the bottom left is about 240 light-years long. Notice that radio astronomers also give fanciful animal names to some of the structures, much as visible-light nebulae are sometimes given the names of animals they resemble.

Infrared light from center



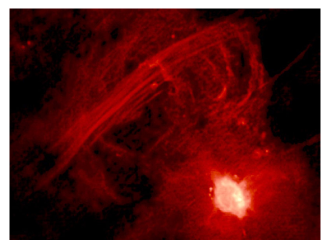
a This infrared image shows stars and gas clouds within 1000 light-years of the center of the Milky Way.

Radio emission from center



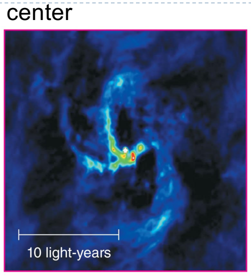
b This radio image shows vast threads of emission tracing magnetic field lines near the galactic center.

Figure 25.16



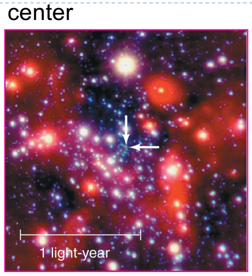
- **Sagittarius A.** This image, taken with the Very Large Array of radio telescopes, shows the radio emission from hot, ionized gas in the center of the Milky Way. The lines slanting across the top of the image are gas streamers. Sagittarius A* is the bright spot in the lower right. (credit: modification of work by Farhad Zadeh et al. (Northwestern), VLA, NRAO)

Swirling gas near center

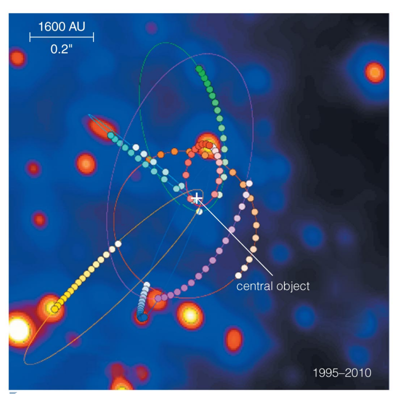


c This radio image zooms in on gas swirling around the radio source Sgr A* (marked by the white dot), suspected to contain a very massive black hole.

Orbiting stars near center



d This infrared image shows stars within about 1 light-year of Sgr A*. The two arrows point to the precise location of Sgr A*.



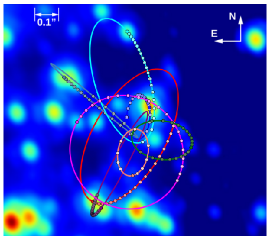
Stars appear to be orbiting something massive but invisible …

a black hole?

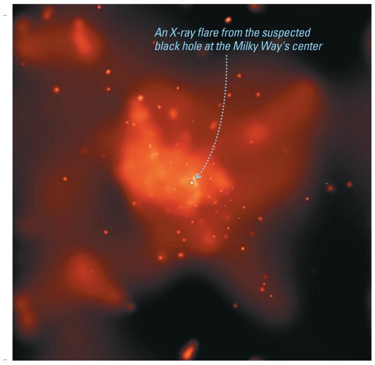
Orbits of stars indicate a mass of about 4 million M_{sun}.

Figure 25.17

openstax



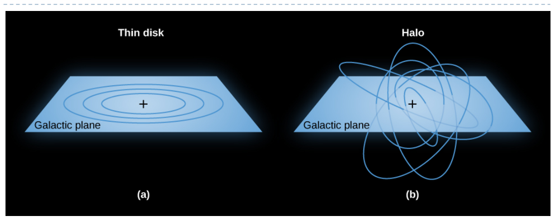
- **Near-Infrared View of the Galactic Center.** This image shows the inner 1 arcsecond, or 0.13 light-year, at the center of the Galaxy, as observed with the giant Keck Telescope. Tracks of the orbiting stars measured from 1995 to 2014 have been added to this "snapshot." The stars are moving around the center very fast, and their tracks are all consistent with a single massive "gravitator" that resides in the very center of this image. (credit: modification of work by Andrea Ghez, UCLA Galactic Center Group, W.M. Keck Observatory Laser Team)



X-ray flares from galactic center suggest that tidal forces of suspected black hole occasionally tear apart chunks of matter about to fall in.

25.5 STELLAR POPULATIONS IN THE GALAXY

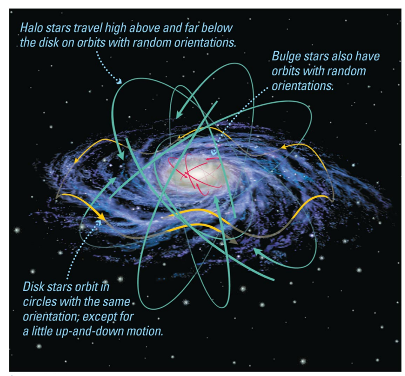
openstax



- **How Objects Orbit the Galaxy.**

(a) In this image, you see stars in the thin disk of our Galaxy in nearly circular orbits.

(b) In this image, you see the motion of stars in the Galaxy's halo in randomly oriented and elliptical orbits.



Stars in the disk all orbit in the same direction with a little up-and-down motion.

Orbits of stars in the bulge and halo have random orientations.

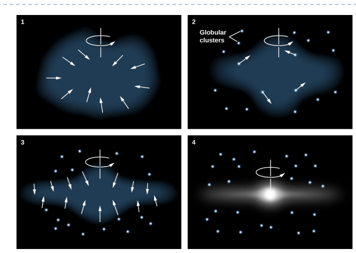
Figure 25.20

openstax

- **Andromeda Galaxy (M31).** This neighboring spiral looks similar to our own Galaxy in that it is a disk galaxy with a central bulge. Note the bulge of older, yellowish stars in the center, the bluer and younger stars in the outer regions, and the dust in the disk that blocks some of the light from the bulge. (credit: Adam Evans)

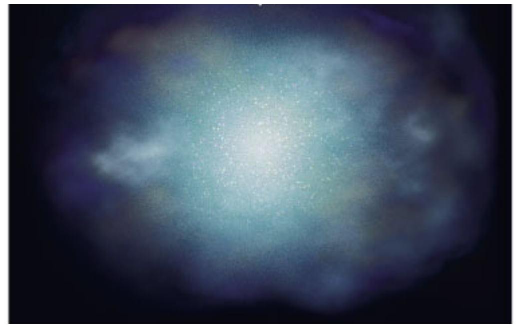
25.6 THE FORMATION OF THE GALAXY

openstax



- **Monolithic Collapse Model for the Formation of the Galaxy.** According to this model, the Milky Way Galaxy initially formed from a rotating cloud of gas that collapsed due to gravity. Halo stars and globular clusters either formed prior to the collapse or were formed elsewhere. Stars in the disk formed later, when the gas from which they were made was already "contaminated" with heavy elements produced in earlier generations of stars.

Our galaxy probably formed from a giant gas cloud.



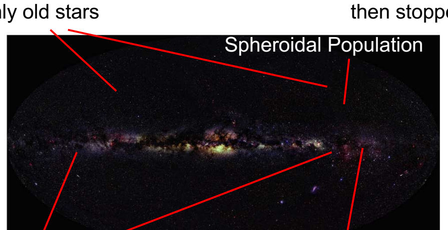
Halo stars formed first as gravity caused the cloud to contract.

The remaining gas settled into a spinning disk.

Stars continuously form in the disk as the galaxy grows older.

Halo Stars:
- 0.02–0.2% heavy elements (O, Fe, …), only old stars

Halo stars formed first, then stopped.

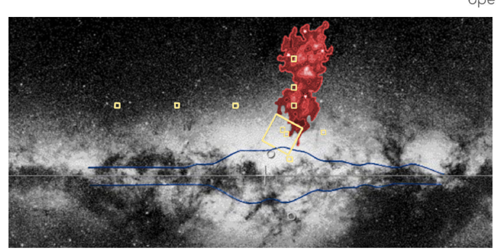


Disk Stars:
- 2% heavy elements, stars of all ages

Disk Population:
- Disk stars formed later, and kept forming.

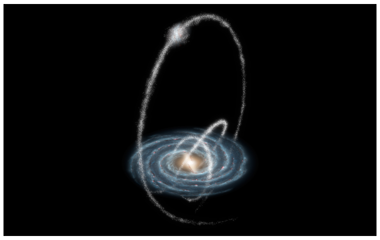
Figure 25.22

openstax



Sagittarius Dwarf. In 1994, British astronomers discovered a galaxy in the constellation of Sagittarius, located only about 50,000 light-years from the center of the Milky Way and falling into our Galaxy. This image covers a region approximately 70 × 50° and combines a black-and-white view of the disk of our Galaxy with a red contour map showing the brightness of the dwarf galaxy. The dwarf galaxy lies on the other side of the galactic center from us. The white stars in the red region mark the locations of several globular clusters contained within the Sagittarius dwarf galaxy. The cross marks the galactic center. The horizontal line corresponds to the galactic plane. The blue outline on either side of the galactic plane corresponds to the infrared image in Figure 25.7. The boxes mark regions where detailed studies of individual stars led to the discovery of this galaxy. (credit: modification of work by R. Ibata (UBC), R. Wyse (JHU), R. Sword (IoA))

Figure 25.23

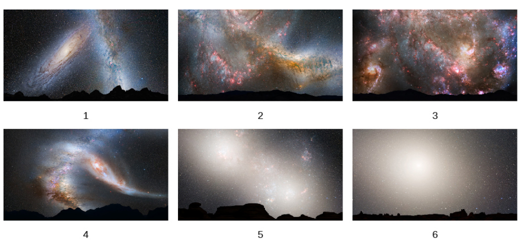


- **Streams in the Galactic Halo.** When a small galaxy is swallowed by the Milky Way, its member stars are stripped away and form streams of stars in the galactic halo. This image is based on calculations of what some of these tidal streams might look like if the Milky Way swallowed 50 dwarf galaxies over the past 10 billion years. (credit: modification of work by NASA/JPL-Caltech/R. Hurt (SSC/Caltech))

Figure 25.24

- **Globular Cluster M54.** This beautiful Hubble Space Telescope image shows the globular cluster that is now believed to be the nucleus of the Sagittarius Dwarf Galaxy. (credit: ESA/Hubble & NASA)

Figure 25.25



- **Collision of the Milky Way with Andromeda.** In about 3 billion years, the Milky Way Galaxy and Andromeda Galaxy will begin a long process of colliding, separating, and then coming back together to form an elliptical galaxy. The whole interaction will take 3 to 4 billion years. These images show the following sequence: (1) In 3.75 billion years, Andromeda has approached the Milky Way. (2) New star formation fills the sky 3.85 billion years from now. (3) Star formation continues at 3.9 billion years. (4) The galaxy shapes change as they interact, with Andromeda being stretched and our Galaxy becoming warped, about 4 billion years from now. (5) In 5.1 billion years, the cores of the two galaxies are bright lobes. (6) In 7 billion years, the merged galaxies form a huge elliptical galaxy whose brightness fills the night sky. This artist's illustrations show events from a vantage point 25,000 light-years from the center of the Milky Way. However, we should mention that the Sun may not be at that distance throughout the sequence of events, as the collision readjusts the orbits of many stars within each galaxy. (credit: NASA; ESA; Z. Levay, R. van der Marel, STScI; T. Hallas, and A. Mellinger)

Links

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