The Milky Way

https://apod.nasa.gov/apod/ap171125.html

Seen from the Earth

https://apod.nasa.gov/apod/ap180418.html

https://apod.nasa.gov/apod/ap171125.html
The Milky Way

Can you find familiar constellations?

https://apod.nasa.gov/apod/ap110405.html
The Milky Way in starlight

The whole sky seen from the Earth

https://apod.nasa.gov/apod/ap180427.html
The Milky Way in the infrared

The whole sky seen from the Earth

https://apod.nasa.gov/apod/ap080605.html
The Spindle Galaxy

edge-on spiral

https://apod.nasa.gov/apod/ap180725.html
The Whirlpool Galaxy (M51)

face-on spiral

https://apod.nasa.gov/apod/ap130224.html
The Whirlpool Galaxy (M51)

X-rays in purple (most BH/NS + giants)  
https://apod.nasa.gov/apod/ap140610.html
M81

about the same size as the Milky Way

https://apod.nasa.gov/apod/ap170917.html
NGC 4565

dust in the disk

https://apod.nasa.gov/apod/ap170524.html
Milky Way

artist’s conception!

https://apod.nasa.gov/apod/ap080606.html
NGC 1365

a barred spiral

https://apod.nasa.gov/apod/ap171012.html
Andromeda Galaxy

our nearest big neighbor

https://apod.nasa.gov/apod/ap161227.html
Andromeda Galaxy

taken with our telescope
Andromeda Galaxy

our nearest big neighbor

https://apod.nasa.gov/apod/ap161227.html
Globular clusters: key component

omega Cen

https://apod.nasa.gov/apod/ap170711.html
Globular clusters: key component

“main sequence turn-off” gives the age of the cluster

https://en.wikipedia.org/wiki/Globular_cluster
Globular clusters: key component

“main sequence turn-off” gives the age of the cluster

https://en.wikipedia.org/wiki/Globular_cluster
Main sequence turn-off for various clusters

https://www.e-education.psu.edu/astro801/content/l7_p6.html

“main sequence turn-off” gives the age of the cluster
M31, the Andromeda galaxy

Image credit & copyright: Jason Ware
The rotation speed of stars and gas in Andromeda, as a function of distance from the center

Positions of the rotational velocity measurements

The rotation speed is constant well beyond the visible edge of the galaxy!

This indicates a large amount of unseen mass, or dark matter

Image credit and copyright: V. Rubin and J. Dunlap, after M. Roberts
Rotation curves of other spiral galaxies, also showing the presence of dark matter.

**Figure 18.12.** Curves of rotational velocity at increasing distances from the centers of four spiral galaxies. The velocities remain roughly flat instead of becoming smaller with greater distances from the center, as would be expected if most of the mass were located in and near the central bulge. The expected decrease, labeled “Keplerian velocity,” is shown for NGC 7664. Contrast this with the observed velocity.
Stars and gas on the edges of spiral galaxies orbit much faster than they would if they only felt the gravity of the other stars in the galaxy.

There isn’t just more mass than the starlight we see can account for, but that mass is distributed differently than the stars.
Most of the mass in spiral galaxies is not stars (or gas, dust)

It is 80 to 90% dark matter

and that dark matter is much less centrally concentrated than the stars (and starlight) are
The most prominent single object in the Milky Way...is the Black Hole at the Galactic Center
Black Hole at the center of the Milky Way: X-ray flares

http://apod.nasa.gov/apod/ap121102.html
stars orbiting the Galactic center

http://www.astro.ucla.edu/~ghezgroup/gc/
8-year time-lapse

http://apod.nasa.gov/apod/ap001220.html
Wide-Field Radio Image of the Galactic Center

$\lambda = 90$ cm

(Kassim, LaRosa, Lazio, & Hyman 1999)