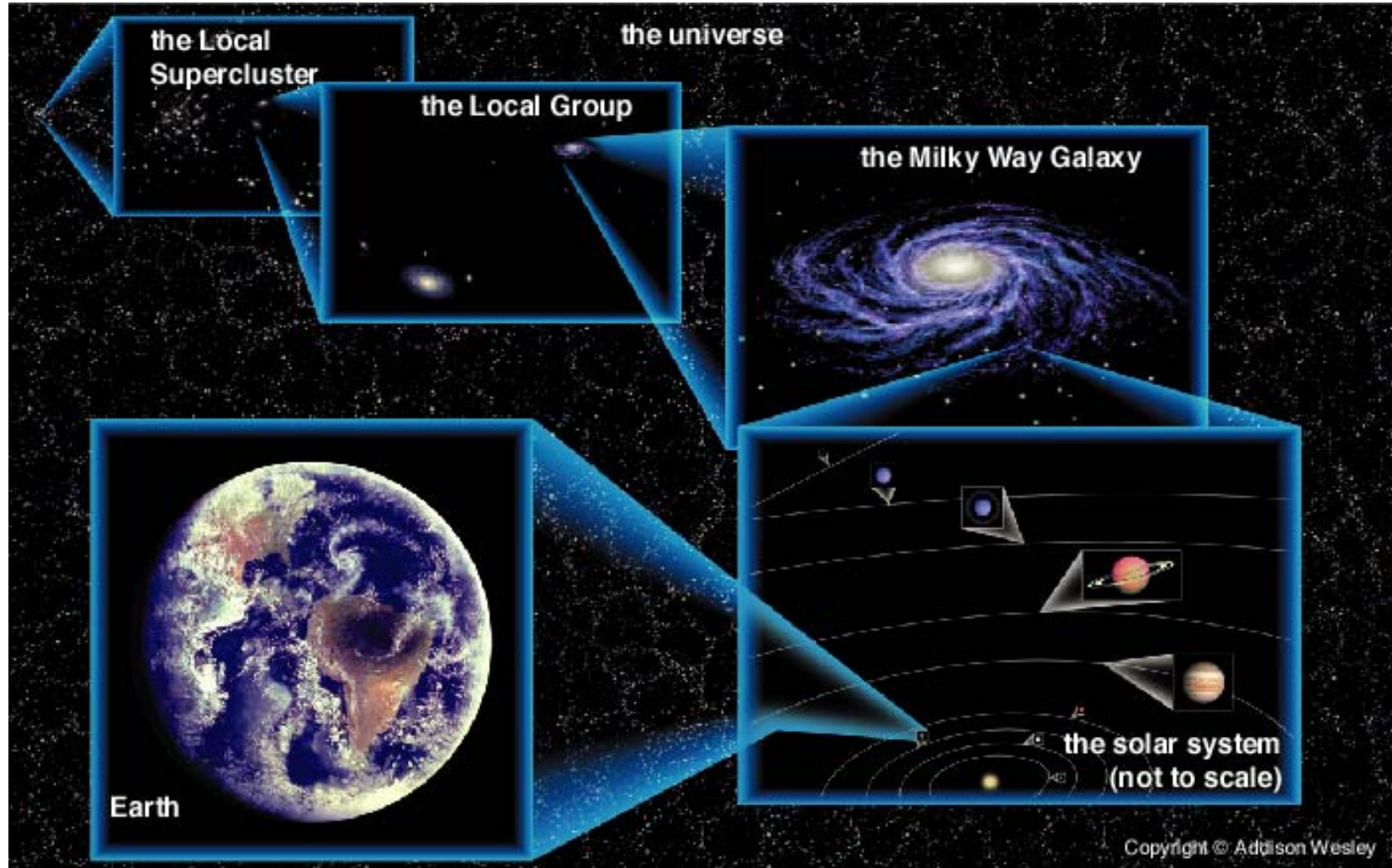


Where Are We In Space
and Time?

What is our physical place in the universe?



Scale Size

- Earth 6.4×10^3 km $\sim 10^4$ km
- Earth-Sun 1.5×10^8 km $\sim 10^8$ km
- Solar System 6×10^9 km $\sim 10^{10}$ km
- Alpha Centauri 4×10^{13} km $\sim 10^{13}$ km
- Milky Way $\sim 10^{18}$ km
- Local Group $\sim 3 \times 10^{19}$ km
- Local Super Cluster $\sim 10^{21}$ km

Comments

- With each box we are looking progressively further away
- With each box we are looking at less detail lower resolution
- With each box we are looking deeper back in time

Earth



- 4.5 Billion Years Old
- Radius 6,371 km
- Radius 0.0213 light seconds
- Earth-Sun 1.5×10^8 km \sim 8 light minutes

Distances in Terms of Light Speed

- It takes light about 8 minutes to travel from the Sun to the Earth. So the **distance** between the Sun and the Earth is approximately 8 **light minutes**.

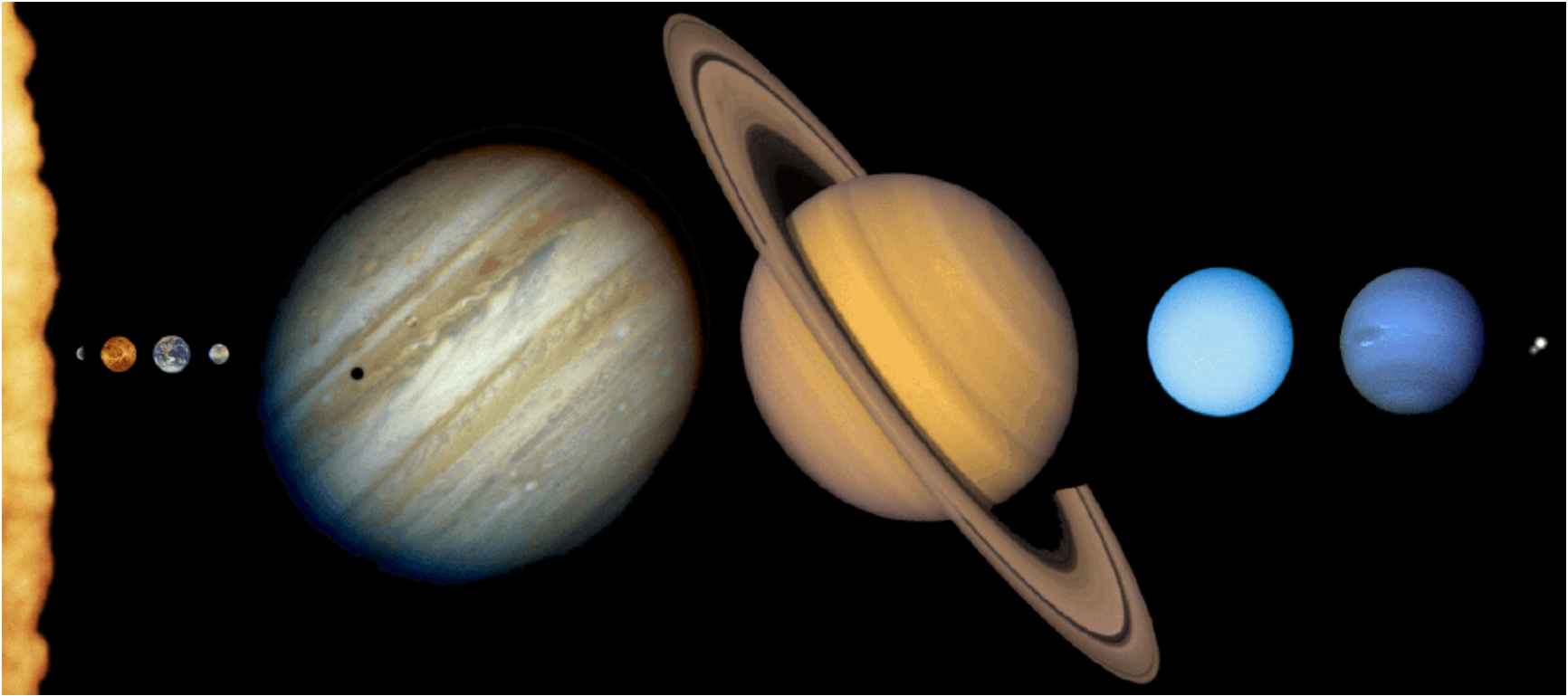
$$\text{Distance} = \text{Speed} \times \text{Time}$$
$$d = s \times t$$

$$s = 3 \times 10^5 \text{ km/s} \quad t = 8 \text{ min} (60 \text{ sec/min}) = 480 \text{ s}$$

$$d = 3 \times 10^5 \text{ km/s} \times 480 \text{ s} = 1.4 \times 10^8 \text{ km}$$

See also Mathematical Insight 1.1 in Bennett

Solar System



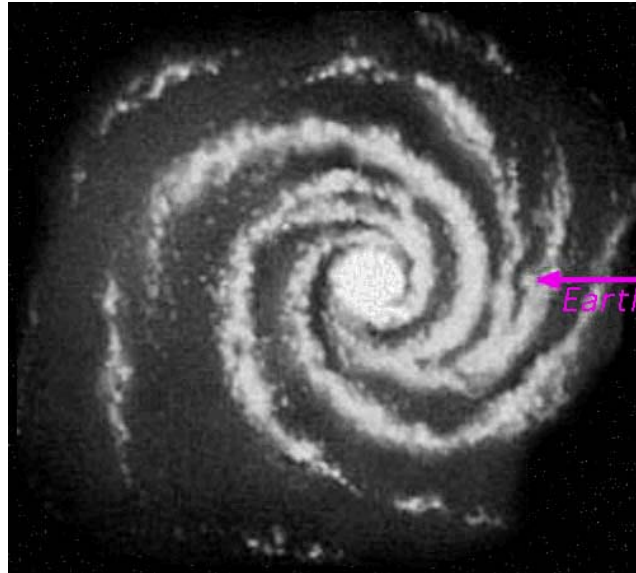
- 4.55 Billion Years old
- Radius 6×10^{12} meters (Pluto's Orbit)
- Radius 20,000 light seconds (333 light min)

Alpha Centauri



- Comprised of 3 Stars
- Nearest Star System
- 4.4 lyr from the Sun
- 4th Brightest “Star” in the Sky
- Observable in the Sourthern Sky

Milky Way Galaxy



Artist's Conception of the Milky Way Galaxy

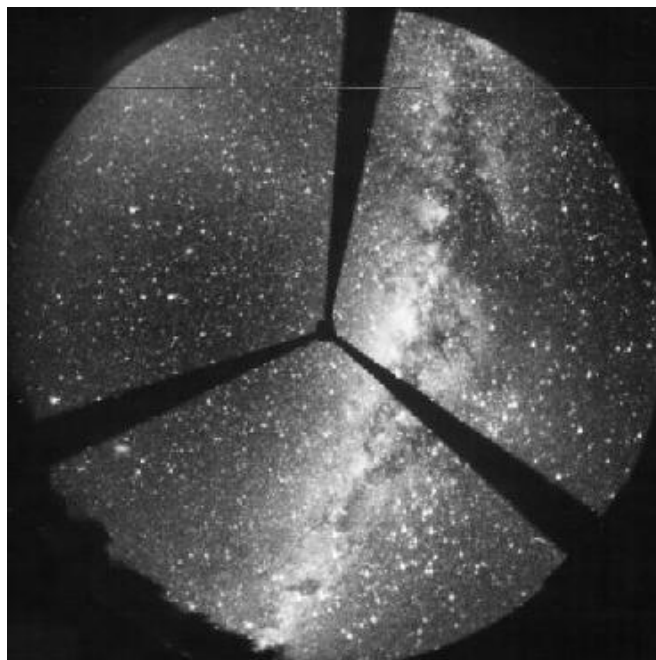
The Milky Way Galaxy is fairly large containing over 100 billion stars

The Milky Way Galaxy is approximately 100,000 lyrs in diameter
($\sim 10^{18}$ km)

The Sun is an average star residing in the Milky Way Galaxy on a spiral arm approximately 2/3 of the way from the center to the outer edge

Our Solar System orbits the center of the Galaxy with a period of about 250 million years

Milky Way Galaxy

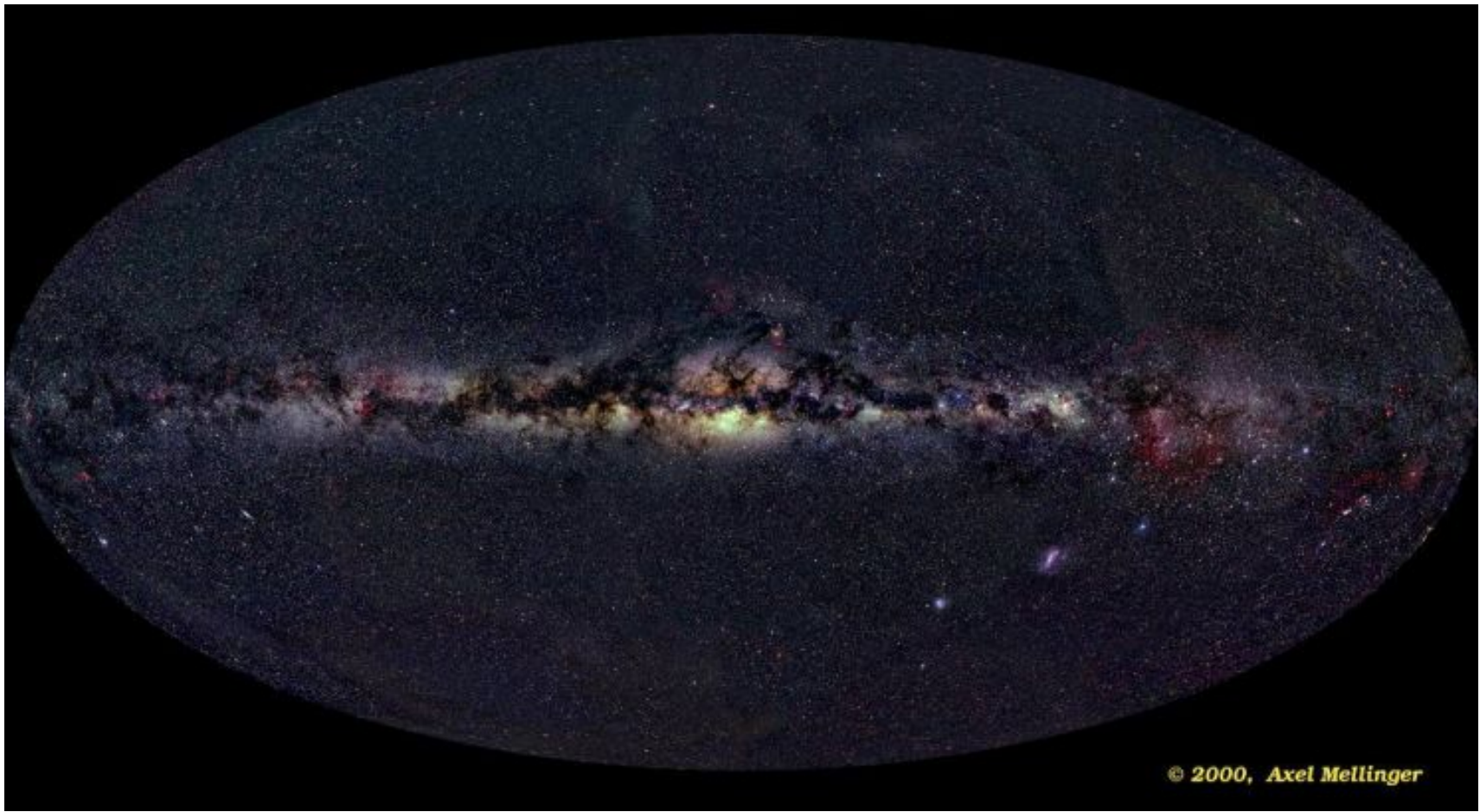


Local Sky Observation of the Milky Way

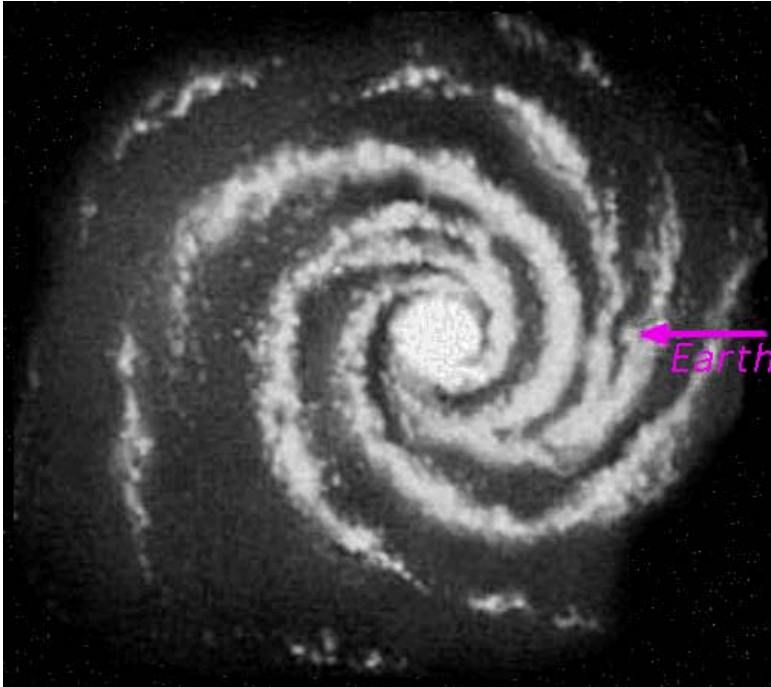


Milky Way in the Near Infrared For the Entire Sky

Composite Sky Image



Local Group



Milky Way Galaxy



Andromeda Galaxy

The local group is a group of over 30 objects. The Milky Way is the second largest in the group next to the Andromeda Galaxy which is 2.4 to 2.9 million lyr from Earth.

Local Group



Large Magellanic Cloud

Scale Model of Solar System and Beyond

- Scale: $R_{\text{sun}} = 6.96 \times 10^5 \text{ km} = 10 \text{ cm} = R_{\text{soccer ball}}$
- Using this scale, we can calculate (see below) the size of the planets and distances between the planets in the scale model.

$$\frac{R_{\text{ModJup}}}{R_{\text{ActJup}}} = \frac{R_{\text{ModSun}}}{R_{\text{ActSun}}}$$

$$R_{\text{ModJup}} = \frac{R_{\text{ModSun}}}{R_{\text{ActSun}}} R_{\text{ActJup}} = \frac{10 \text{ cm}}{6.96 \times 10^5 \text{ km}} 6.99 \times 10^4 \text{ km} = 1 \text{ cm}$$

Results of calculations based on the scale above are presented in the following table. [See also Mathematical Insight 1.2 in Bennett](#)

Scale Model of Solar System and Beyond

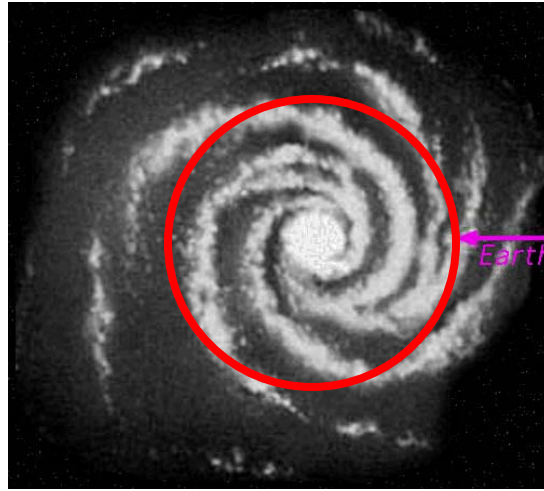
	Actual Radius Km	Scale Radius (cm)	Actual Distance to Sun (km)	Scale Distance to Sun (m)
Sun	6.96E+05	10		
Mercury	2.43E+03	3.49E-02	5.79E+07	8.32E+00
Venus	6.06E+03	8.71E-02	1.08E+08	1.55E+01
Earth	6.37E+03	9.15E-02	1.50E+08	2.16E+01
Mars	3.37E+03	4.84E-02	2.28E+08	3.28E+01
Jupiter	6.99E+04	1.00E+00	7.78E+08	1.12E+02
Saturn	5.85E+04	8.41E-01	1.43E+09	2.05E+02
Uranus	2.33E+04	3.35E-01	2.87E+09	4.12E+02
Neptune	2.21E+04	3.18E-01	4.50E+09	6.47E+02
Pluto	1.50E+03	2.16E-02	5.91E+09	8.49E+02
Alph Centauri			4.00E+13	5.75E+06
Milky Way	1.00E+18	1.44E+13	3.00E+17	4.31E+10

Perspective

- In a scale model where the Sun is the size of a soccer ball, Jupiter is the size of grape located one football field away.
- In a scale model where the Sun is the size of a soccer ball, Earth is twenty steps away and the size of the tip of a pen.
- In a scale model where the Sun is the size of a soccer ball, Pluto is smaller than the tip of a pen and about one half a mile away.
- In a scale model where the Sun is the size of a soccer ball located in Oneonta, Alpha Centauri is located somewhere on the west coast of the United States
- In a scale model where the Sun is the size of a soccer ball, the center of the Milky Way is located on Venus.

How fast are they moving?

- We rotate about the Earth's axis (1670 km/hr at the equator)
- The Earth revolves around the Sun (100,000 km/hr)
- The Sun revolves around the center of the Milky Way (1,000,000 km/hr)



- Distance = $2\pi R = 2 \pi 3 \times 10^{17} \text{ km} = 1.9 \times 10^{18} \text{ km}$
- Time = $2 \times 10^8 \text{ years} = 1.8 \times 10^{12} \text{ hours}$
- Speed = Distance / Time
- Speed = $1.9 \times 10^{18} \text{ km} / 1.8 \times 10^{12} \text{ hours} = 1.1 \times 10^6 \text{ km/hr}$
- See also Mathematical Insight 1.4 in Bennett

How Do the Galaxies Move?

- Edwin Hubble Circa 1920
 - Galaxies generally moving away from us
 - More distant galaxies are moving away faster

We can “trace” the expansion back to estimate the age of the universe at ~14 billion years

