- Temperature of a dust grain 10^{-4} and 1 pc from a 10^5 $L_\odot$

$$T = \left(\frac{L}{16\pi\sigma d^2}\right)^{\frac{1}{4}}$$

- At 10^{-4} pc

$$T = \left(\frac{10^5 \times 4 \times 10^{26}}{16\pi 5.8 \times 10^{-8}\left(10^{-4} \times 3.1 \times 10^{16}\right)^2}\right)^{\frac{1}{4}} = 1000\ \mathrm{K}$$

- At 1 pc

T=10 K

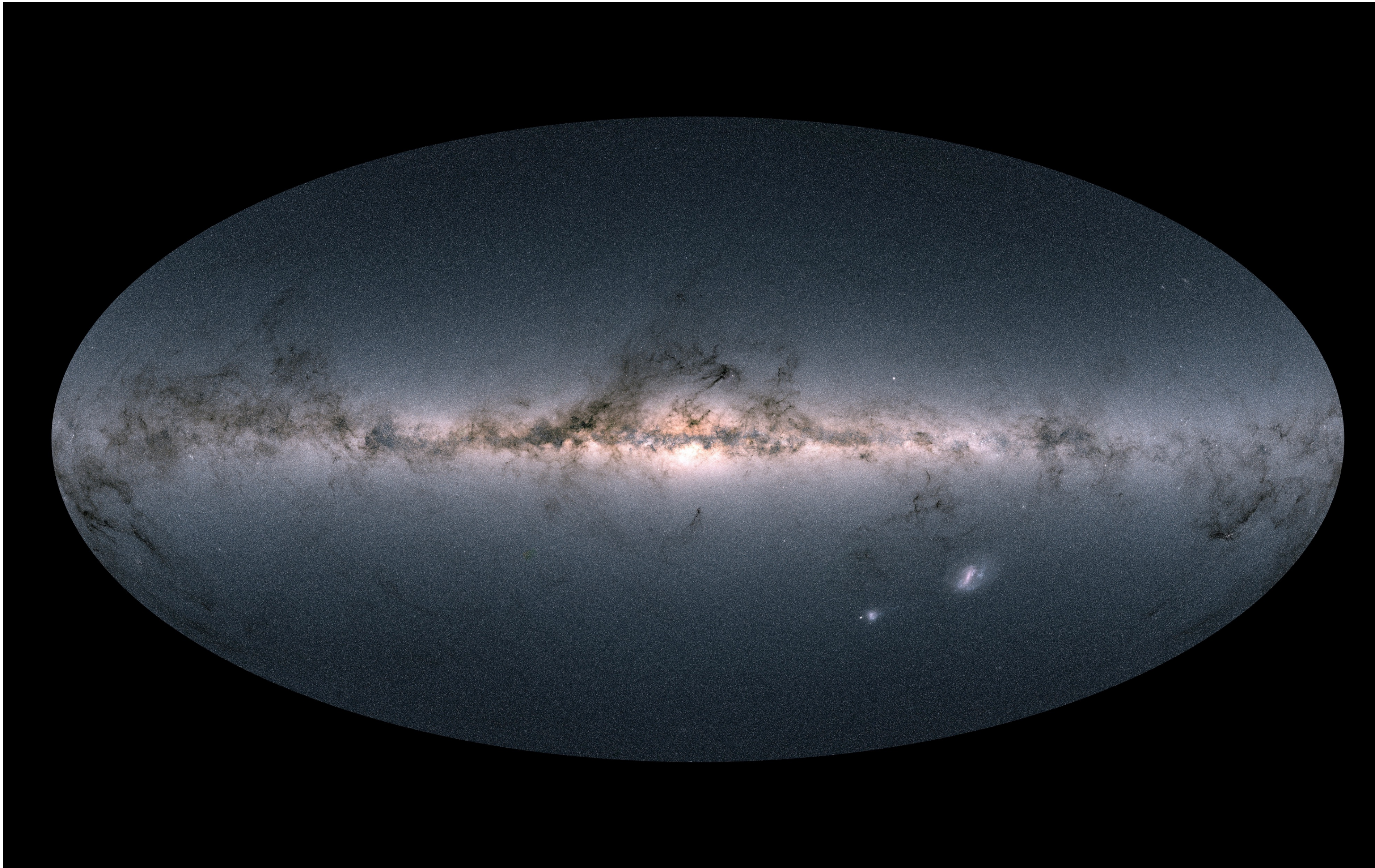
The Milky Way

- The Galactic Plane
- Spiral arms
- Galactic Halo

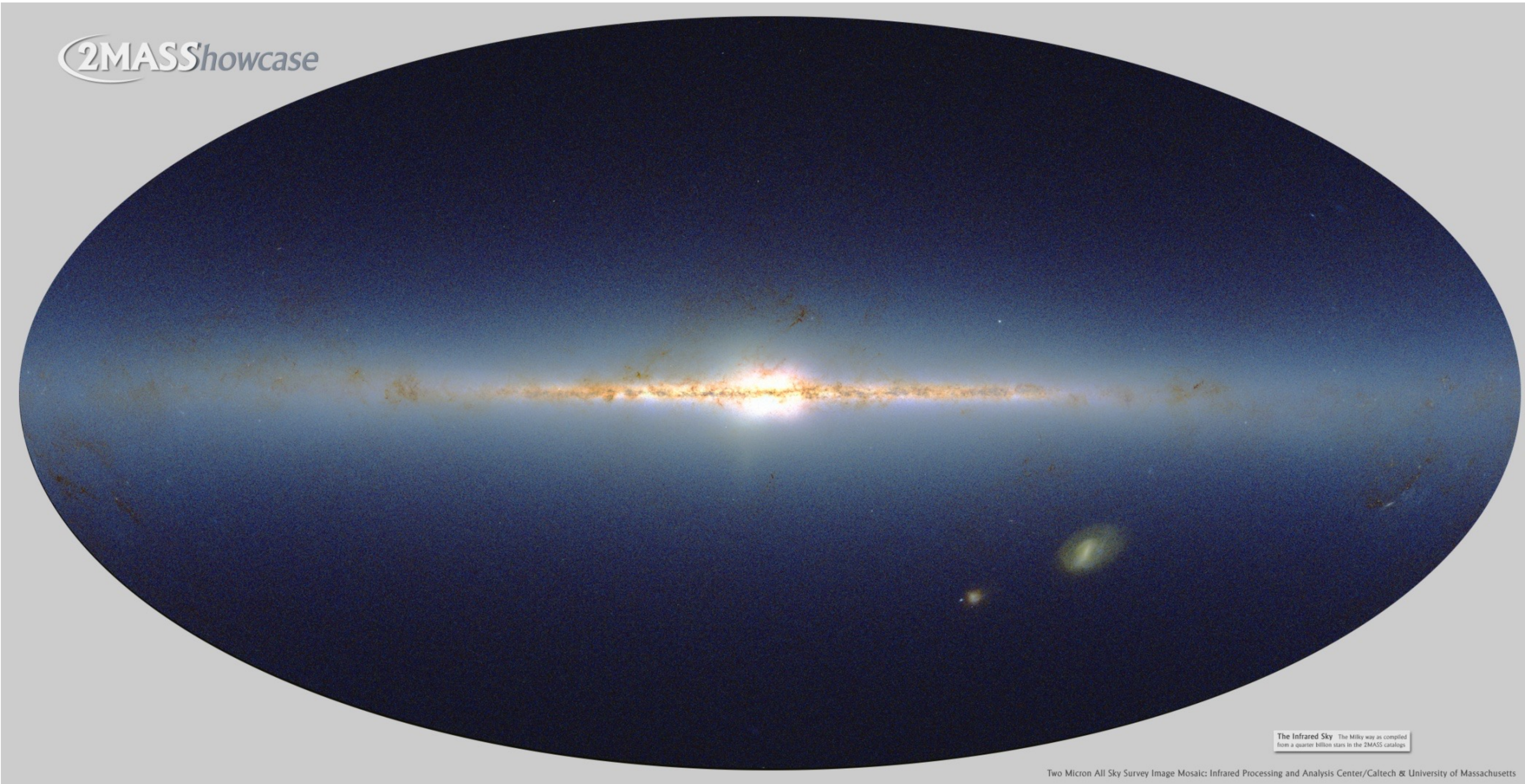
The Galactic Plane

- In optical light the Milky Way delineates the plane of our Galaxy
- Dust lanes obscure much of the structure
- The true structure is only revealed in the near-IR where extinction is lower
- We are located about 8 kpc from the centre in a disc with a radius of about 20 kpc

The Milky Way over ALMA: Copyright: Babak Tafreshi btafreshi@twanight.org



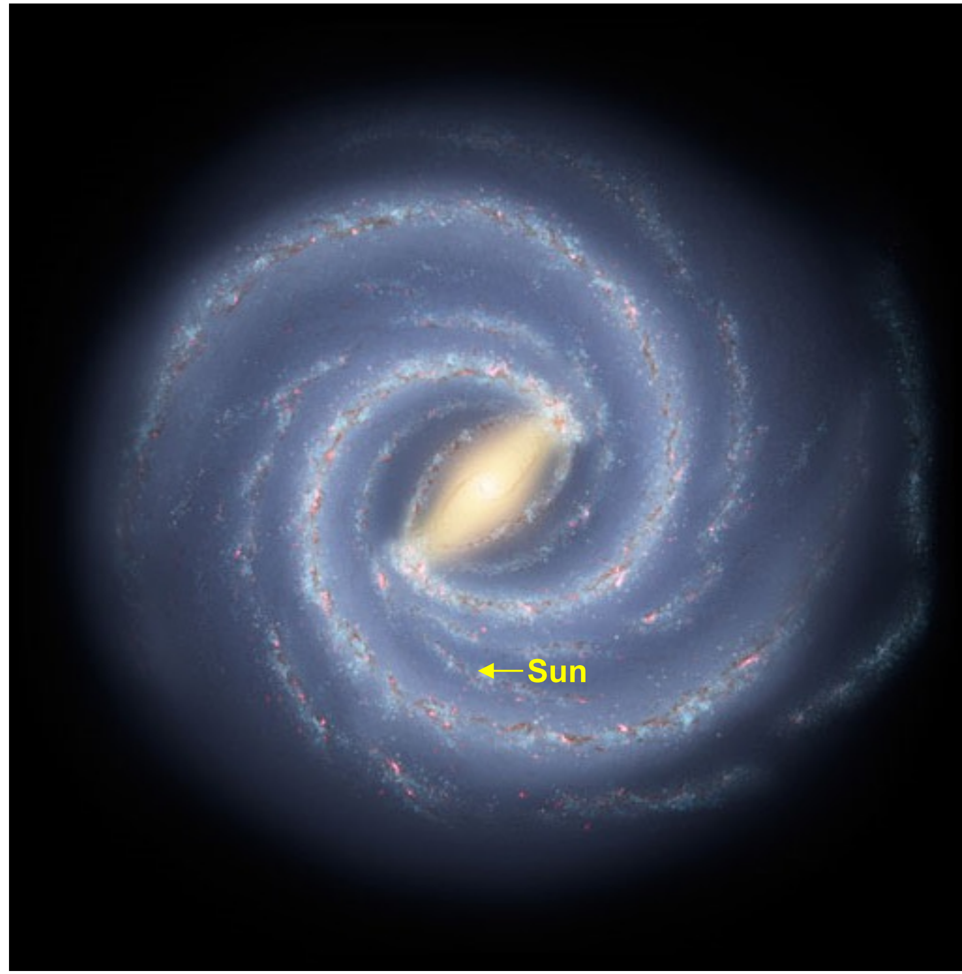
Near-infrared: 1-2 μm



Atlas Image obtained as part of the Two Micron All Sky Survey (2MASS), a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

The Bulge and Bar

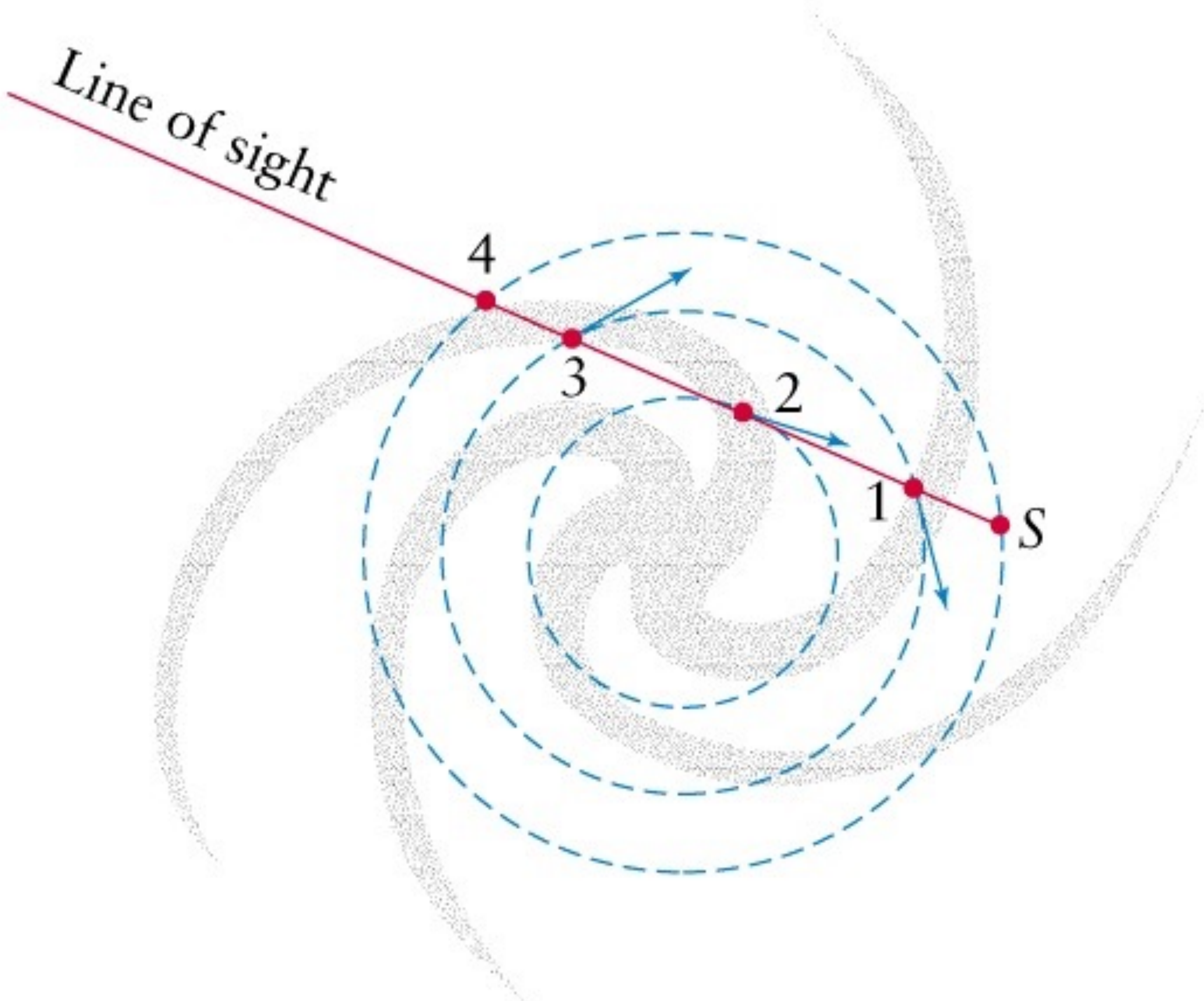
- Bulge is about 1 kpc in radius
- Bar is about 4 kpc in length



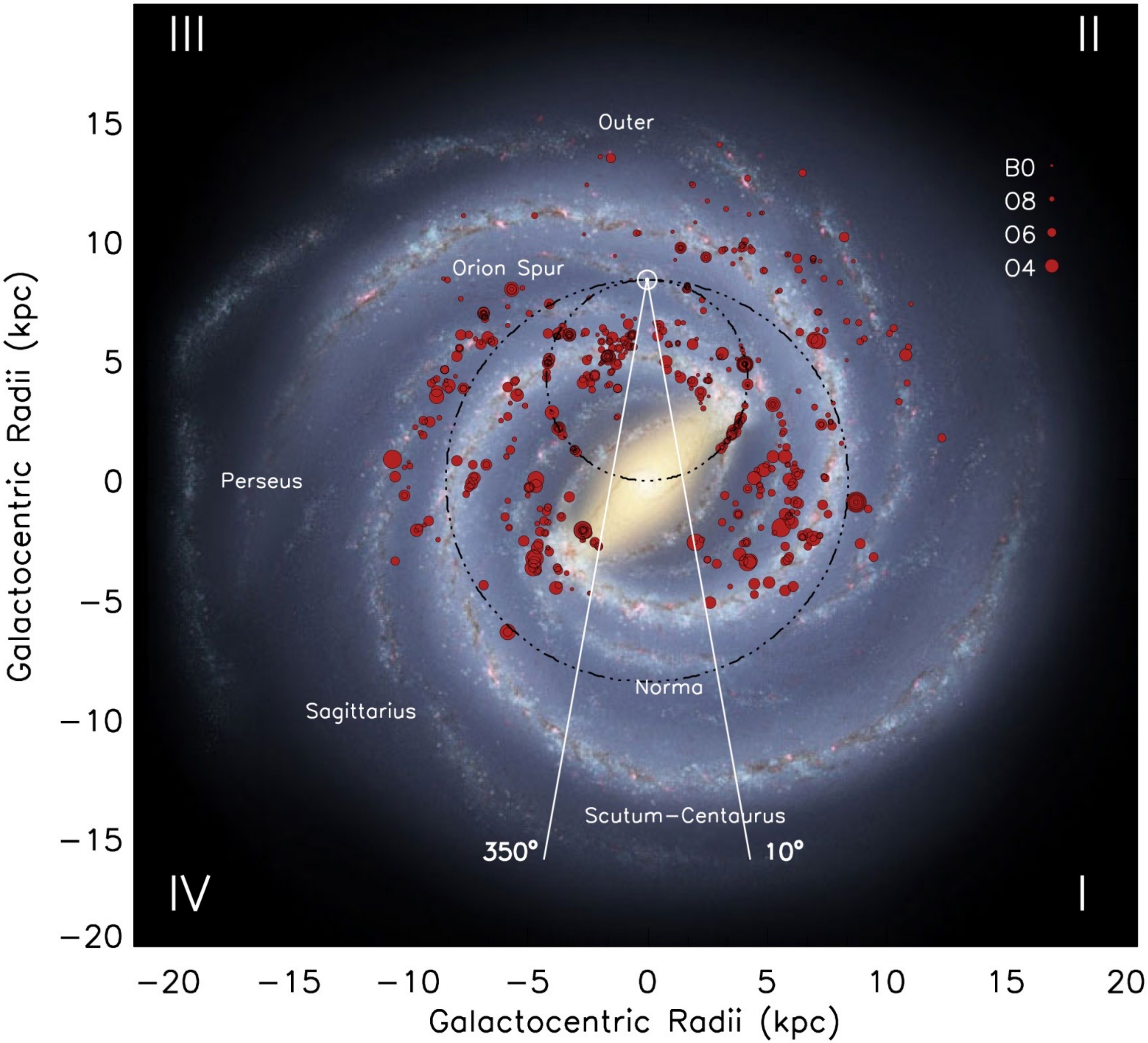
credit: NASA/JPL-Caltech

Spiral Arms

- The spiral arm structure is determined using tracers of massive star formation with known distances – usually via their Doppler shift and a rotation model
- H II regions and CO clouds are used
- Our galaxy has 4 star-forming gaseous arms and 2 stellar arms originating at each end of the bar



From Universe textbook



Distribution of massive star forming regions from the Red MSX Source Survey rms.leeds.ac.uk

Class Example

- What do you think the Hubble classification for our Galaxy is?

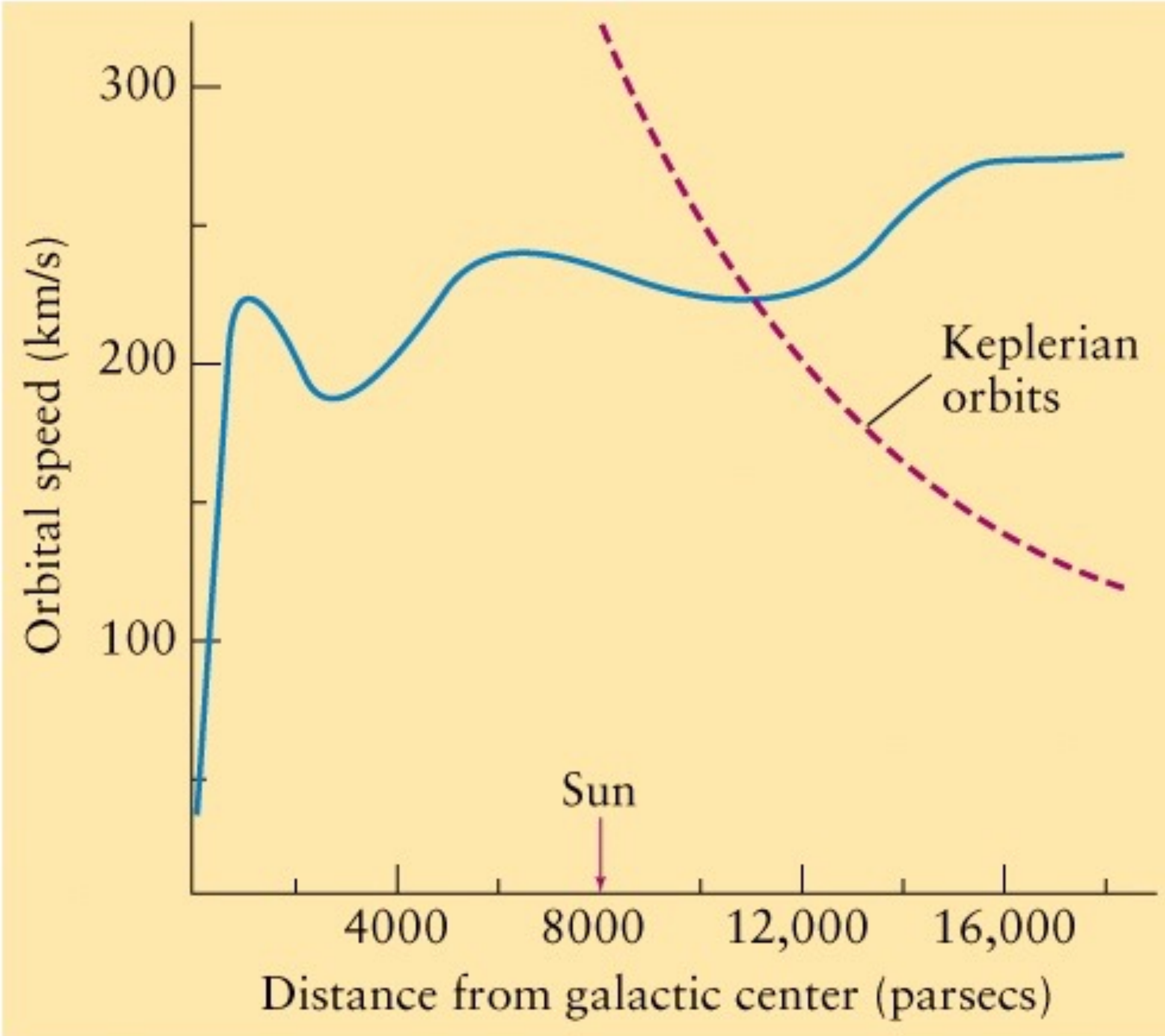
- Our Galaxy is thought to be a SBb or SBc

Rotation of the disc

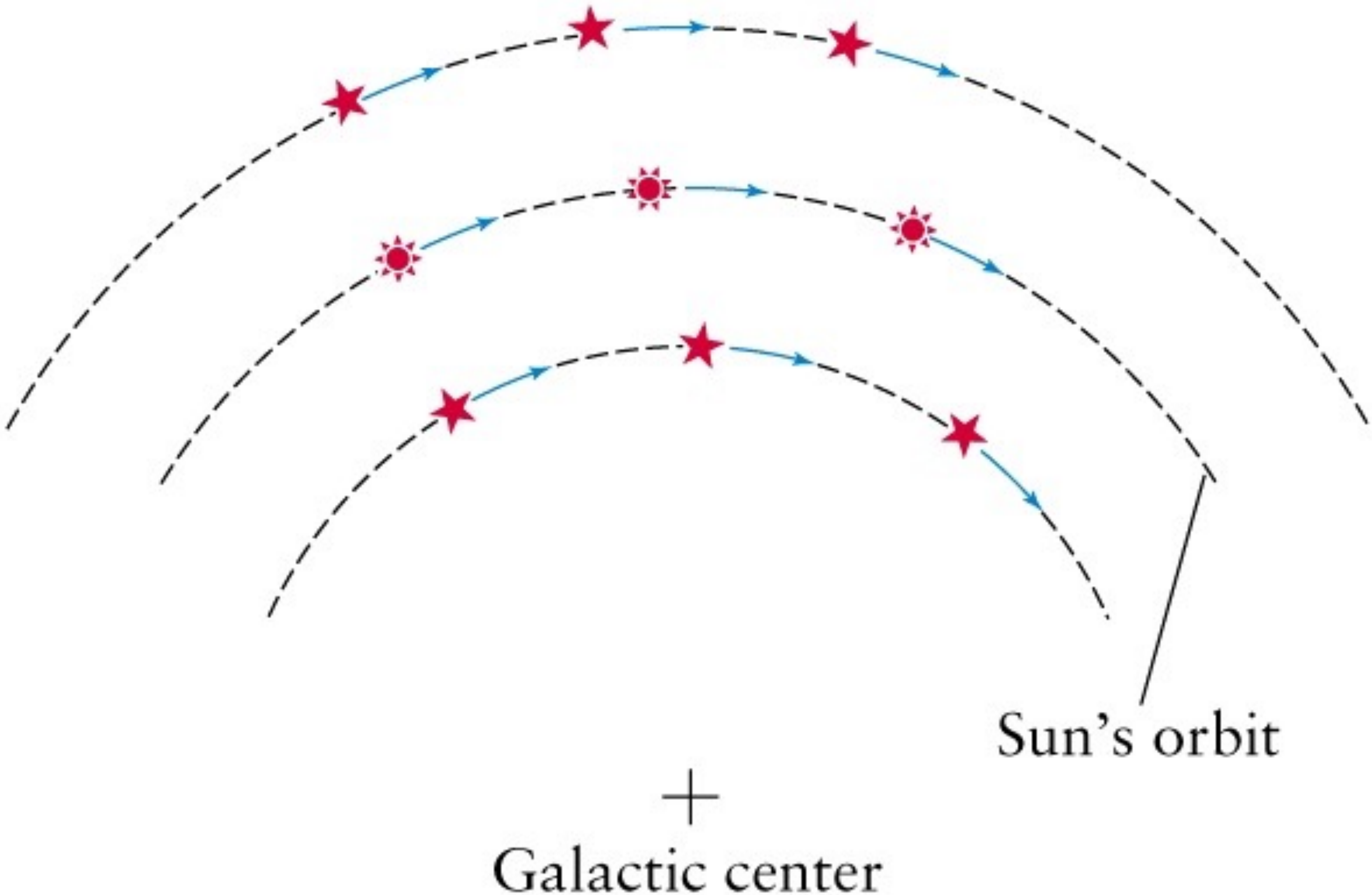
- The observed rotational velocity of the Galactic disc is approximately constant with radius

$$v \approx \text{constant} \approx 220\ \text{km s}^{-1}$$

- This requires differential rotation: stars closer to the centre of the galaxy orbit in a shorter time (period P α r) and overtake us, whilst we overtake stars further out



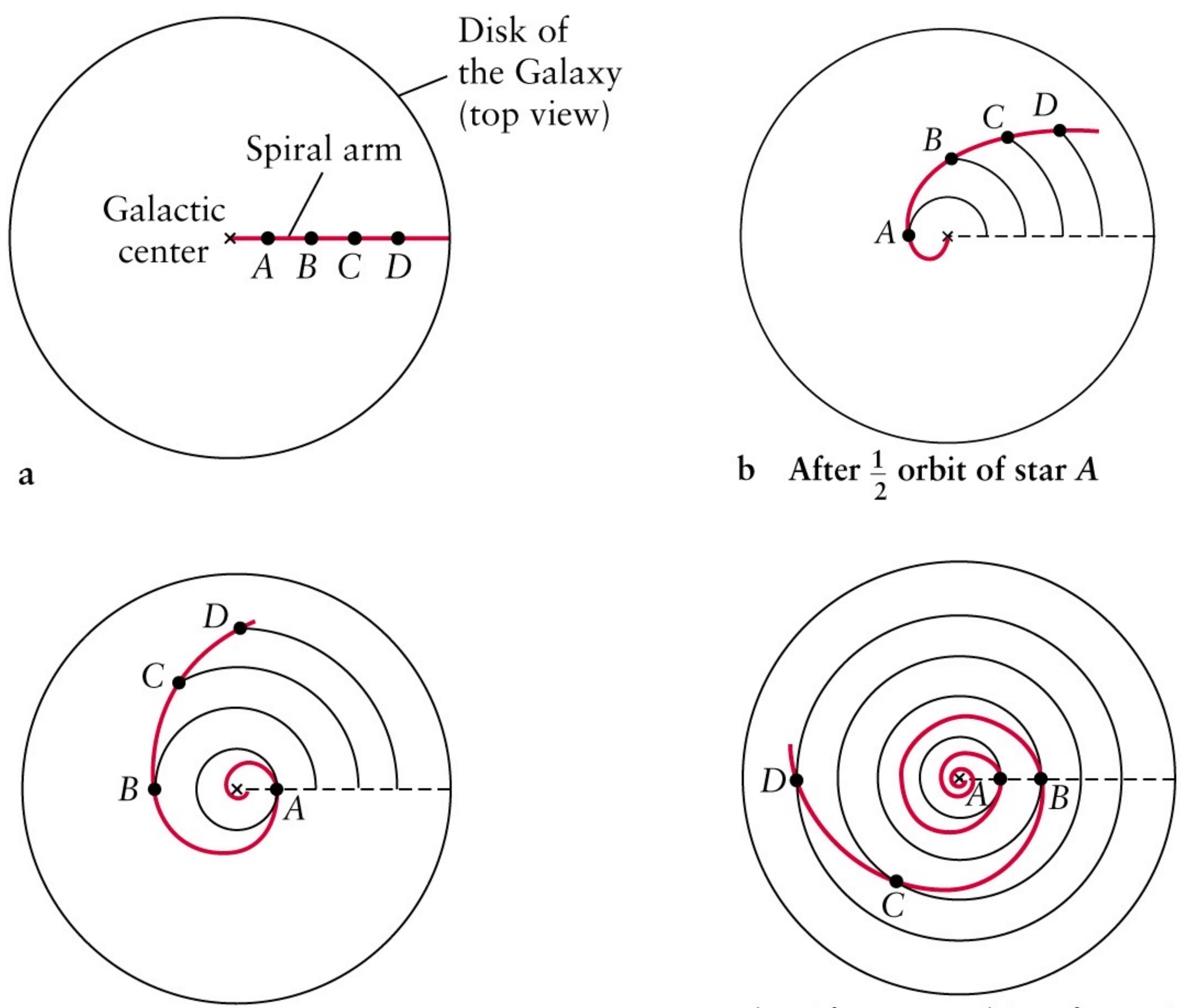
From Universe textbook



From Universe textbook

The Wind-up Problem

- If the spiral arms were a fixed pattern in the stars and gas the differential rotation would cause them to 'wind-up' in a few revolutions



a

b After $\frac{1}{2}$ orbit of star A

c After one orbit of star A

d After two orbits of star A

From Universe textbook

Class Example

- How long does it take the Sun (8 kpc from the centre) to orbit the Galaxy and how many orbits has it completed?

$$P = \frac{2\pi R}{v}$$

$$= \frac{2\pi\left(8\times10^{3}\times3.1\times10^{16}\right)}{220\times10^{3}}$$

$$= 7\times10^{15}\ \text{s} = \ 240\ \text{million years}$$

- The Sun has made about 20 rotations of the Galaxy

Density Waves

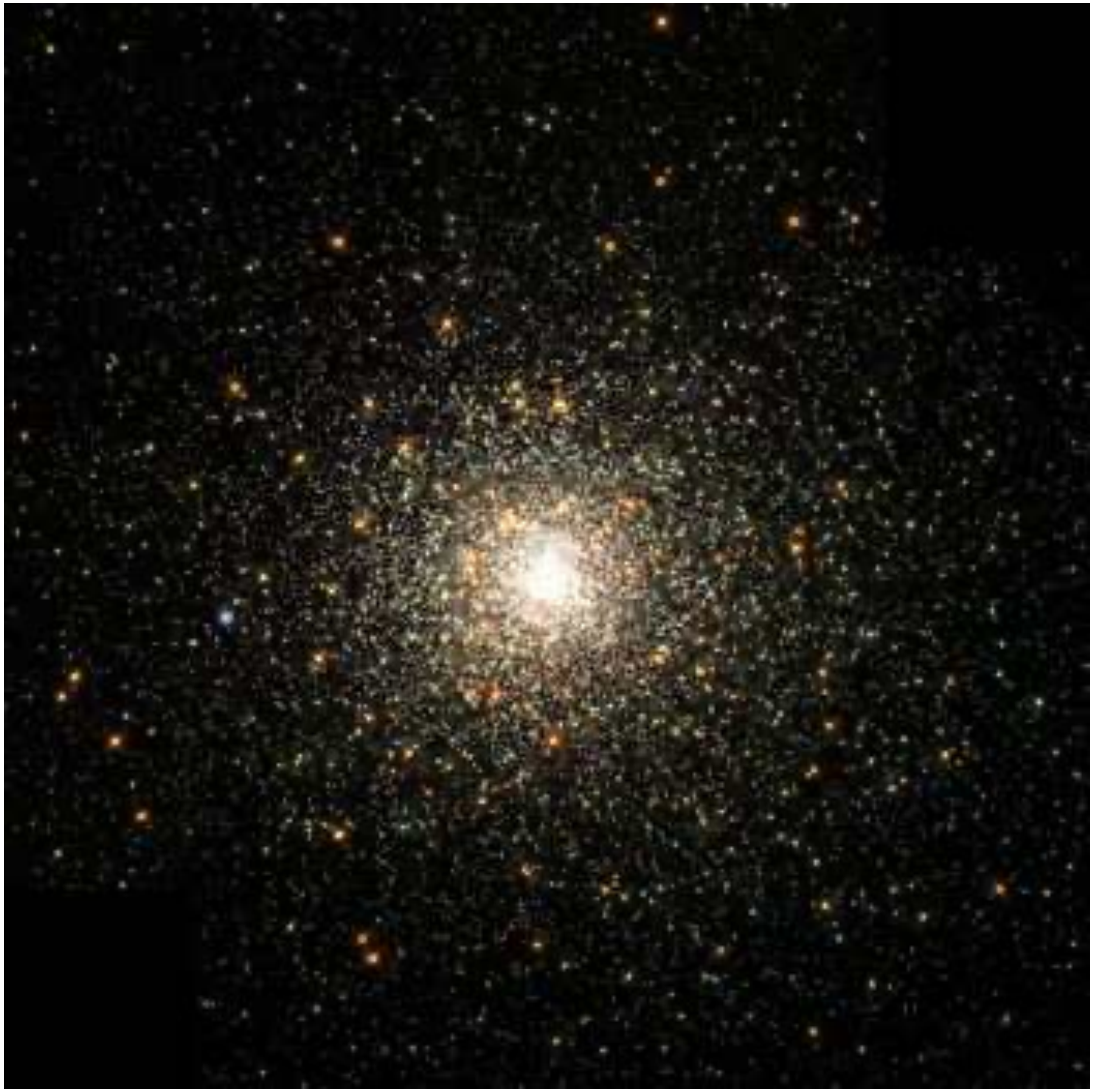
- The current model for spiral arms is that they are a density wave pattern that rotates at a slower speed than the galaxy
- Stars and gas pass in and out of the arm
- As gas gets compressed in the arm molecular clouds form with subsequent star formation
- Spiral arms usually trail the rotation

- Dust lane where material enters spiral arm, then H II regions, then blue stars

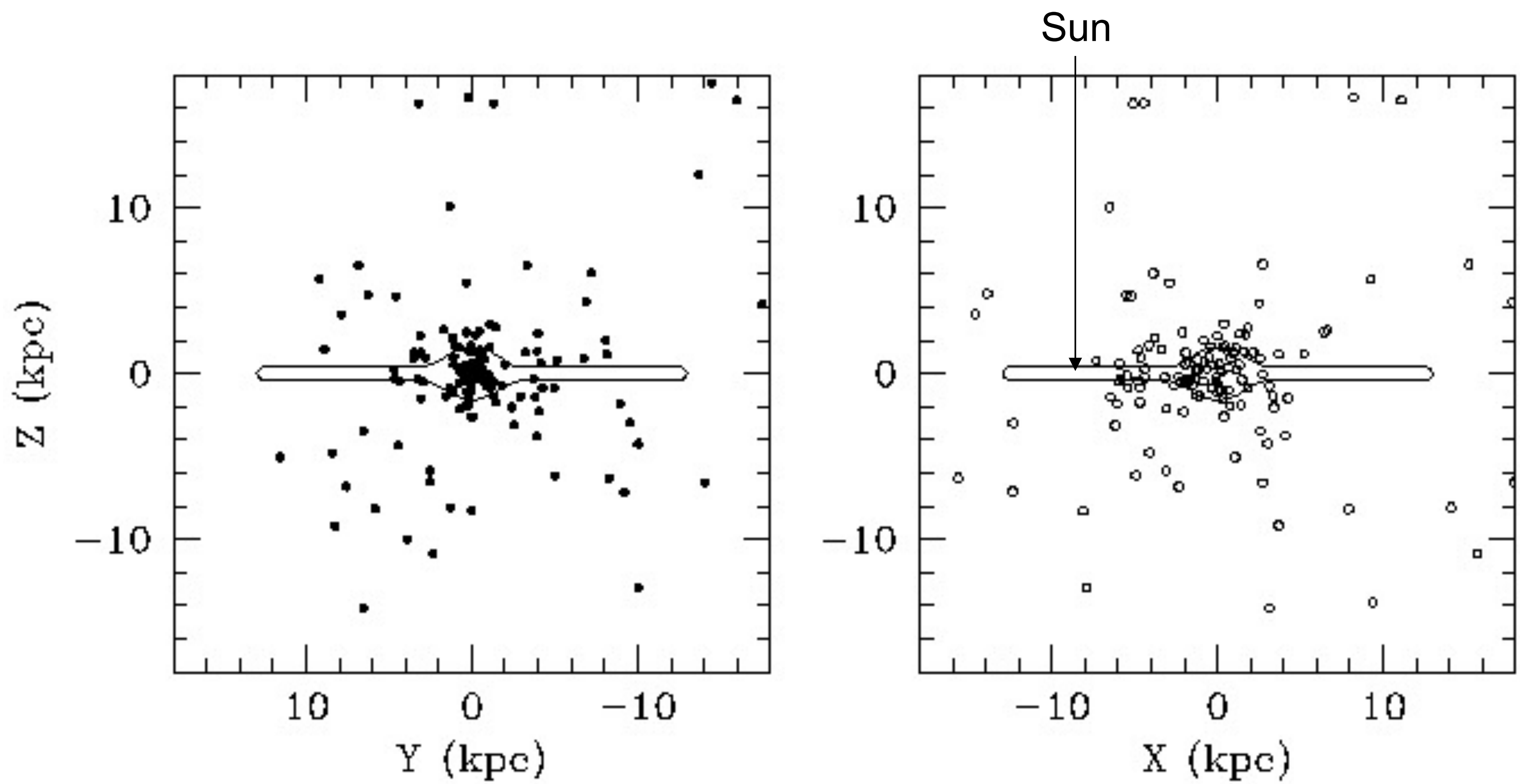
Credit: NASA and The Hubble Heritage Team (STScI/AURA)

The Galactic Halo

- The plane of our galaxy is surrounded by a more spherical halo of objects
- Consists of globular clusters and halo stars
- Total radius of the halo is ~ 100 kpc

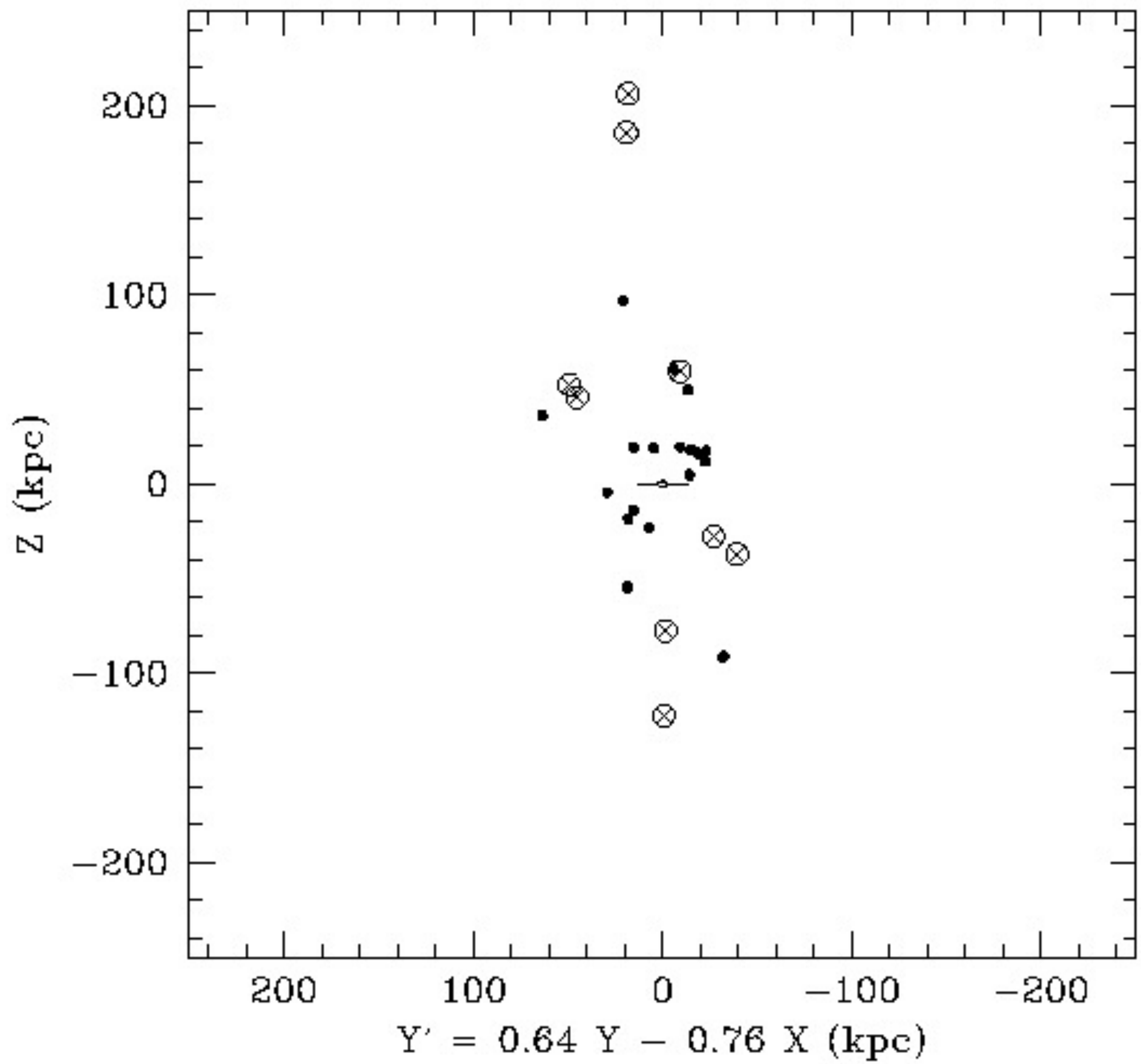


Globular Cluster M80: NASA HST



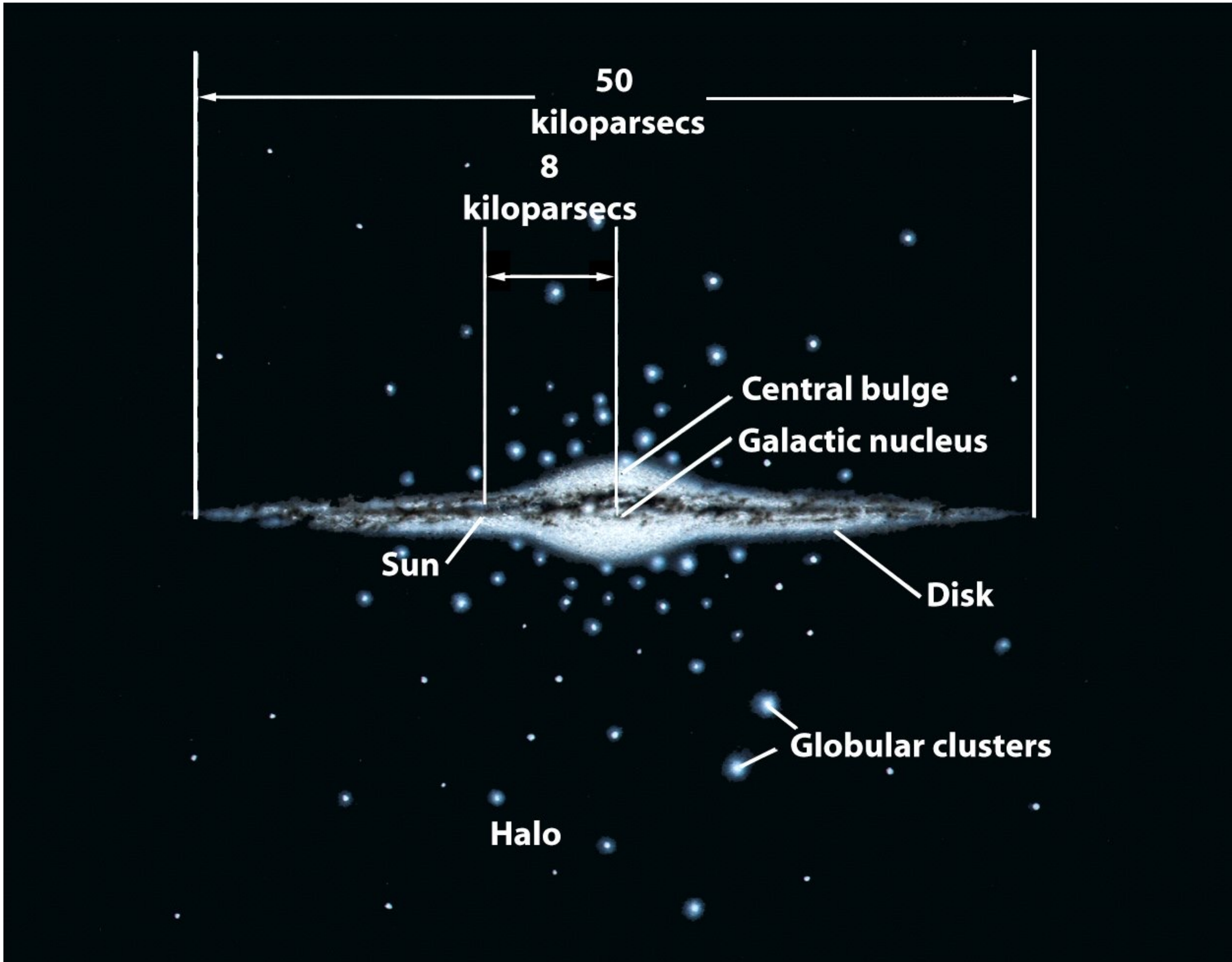
Distribution of nearby globular clusters in the plane of the Galaxy

Harris, W. E. "Globular Clusters", 1999, Cambridge University Press



Distribution of globular clusters that are distant from the Galaxy

Harris, W. E. "Globular Clusters", 1999, Cambridge University Press



From Universe textbook

Formation of the Galaxy

- Spherical halo formed first out of metal-poor material
  - One initial burst of star formation and none since
- Disc formed later
  - Continuous star formation leading to metal-rich population
- Bulge also has some metal-rich stars as a result of mergers with small galaxies

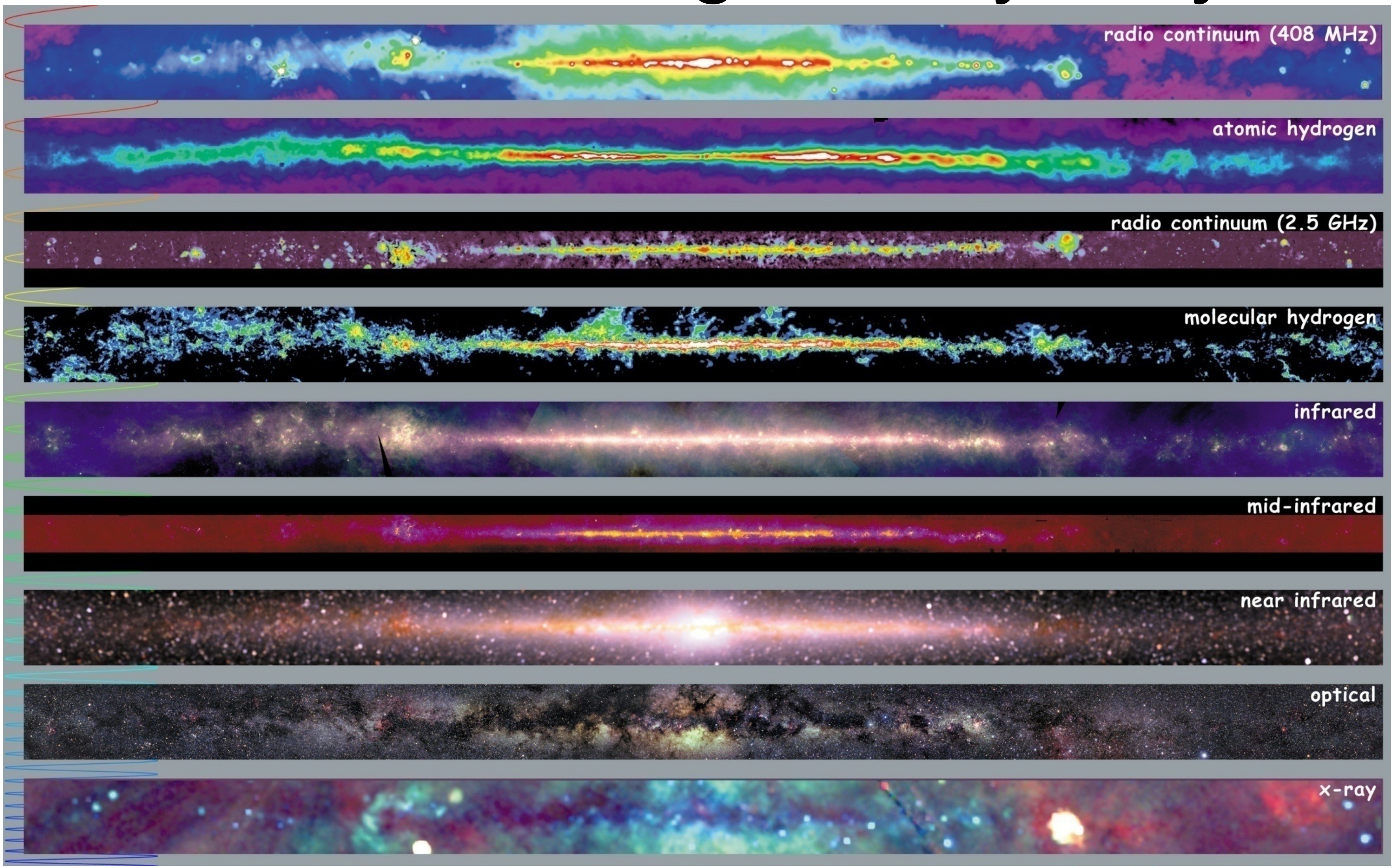
Summary

- Our Galaxy is a SBb or c
- The disc is surrounded by a spherical galactic halo
- The galactic halo is made up of Population II objects and was formed at an earlier stage than the disc

Class Example

- Inspect the Multi-Wavelength Milky Way images and explain why the galaxy looks like it does at each waveband. What is the main component dominating the emission at each waveband, e.g. stars, gas or dust? Why is it distributed as it is? What correlations and anti-correlations exist and why?

Multi-wavelength Milky Way



mwmw.gsfc.nasa.gov