# The Milky Way

- Scattering of light, or why is the sky blue?
- Milky Way in infrared, radio
- The 21 cm line of Hydrogen
- Spiral arms
- Density waves
- The center of the Milky Way

# Scattering of light

- Light is completely absorbed by very dense clouds of dust
- For less dense clouds, some light is transmitted
- Does the transmitted light have the same color as the scattered light?

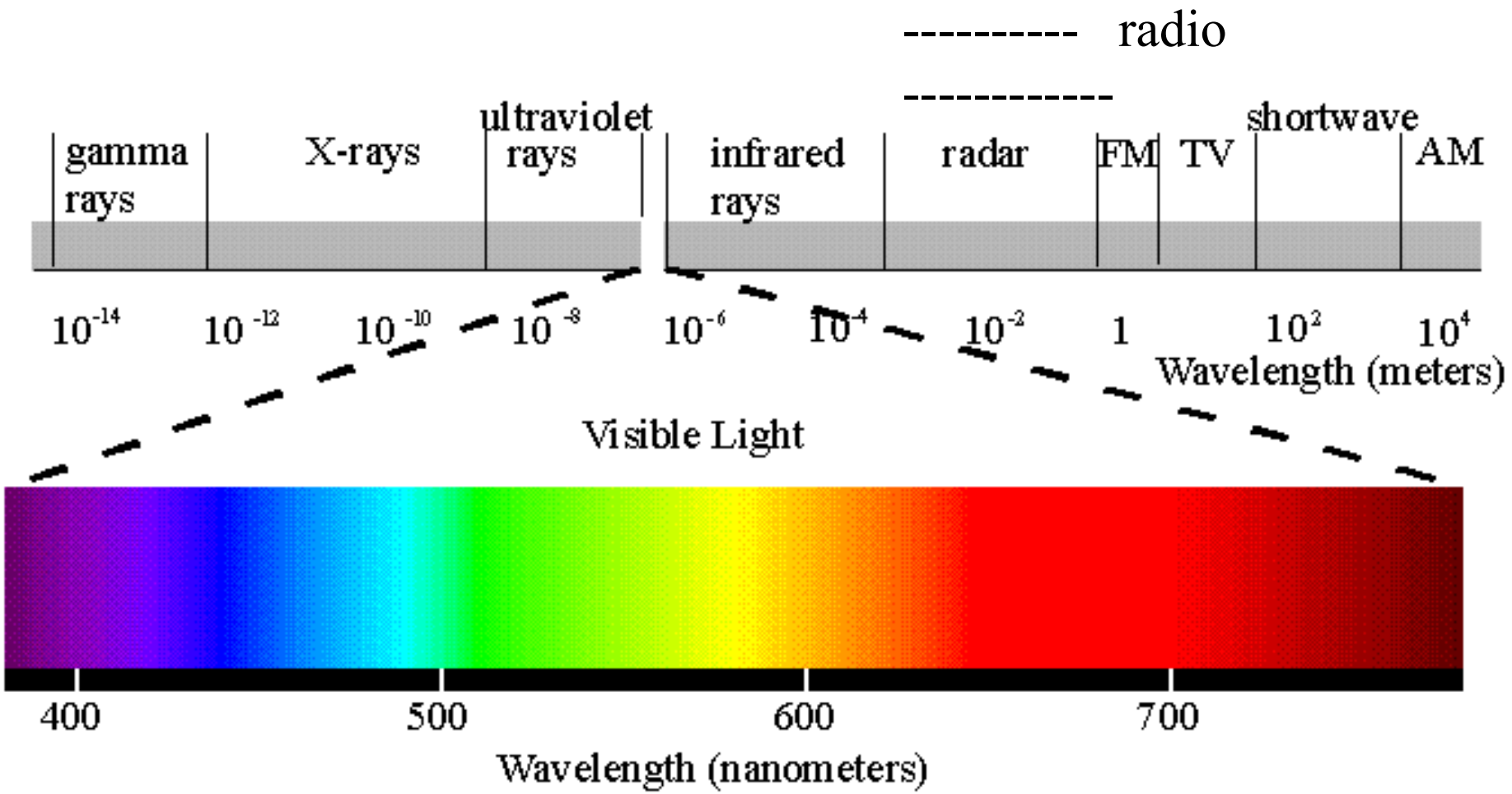
Do demo 6F40.10

# Scattering light

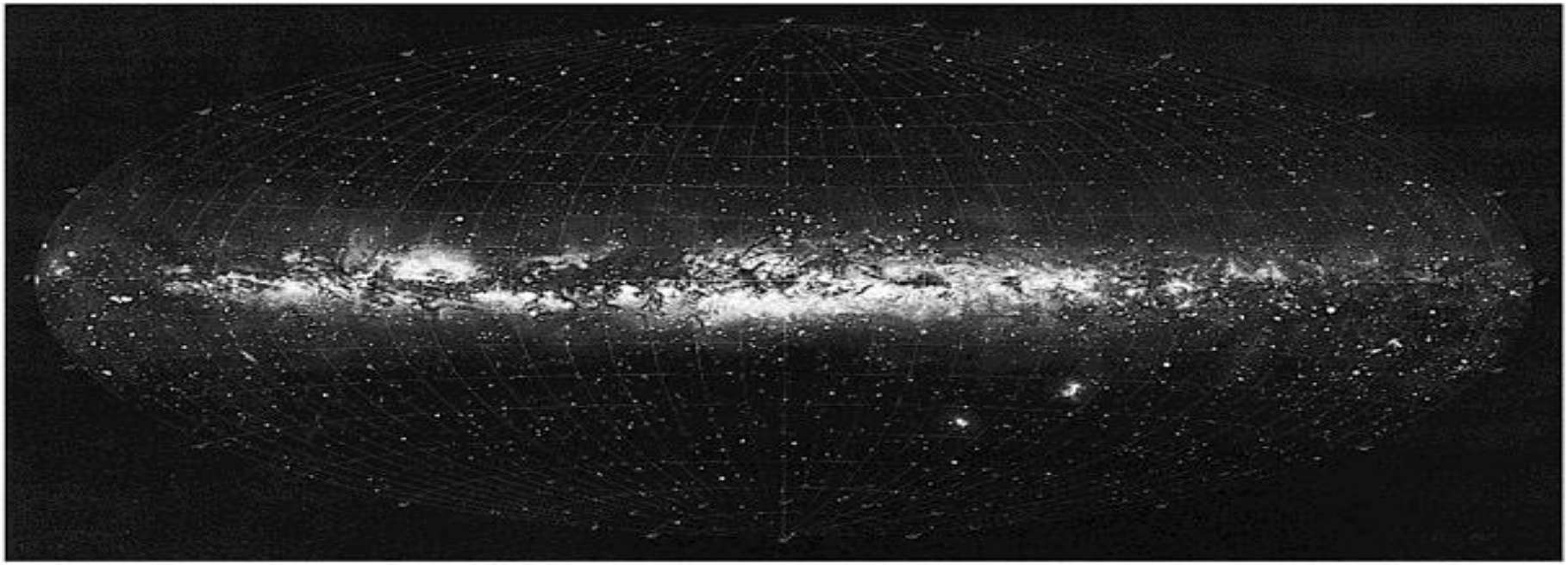
- Blue light is scattered more
- Red light is transmitted more

- This is why the sky is blue
- Stars seen through dust appear redder than they really are
- If we want to try to see through dust, what kind of light should we use?

# Electromagnetic spectrum

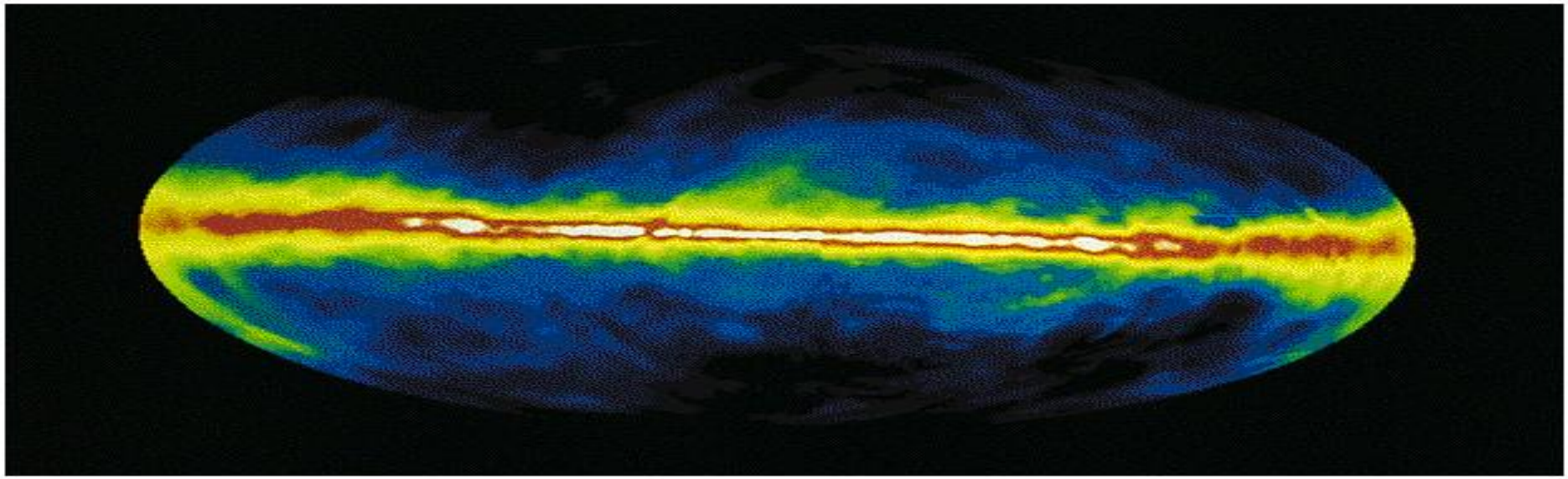


# Milky Way in optical light

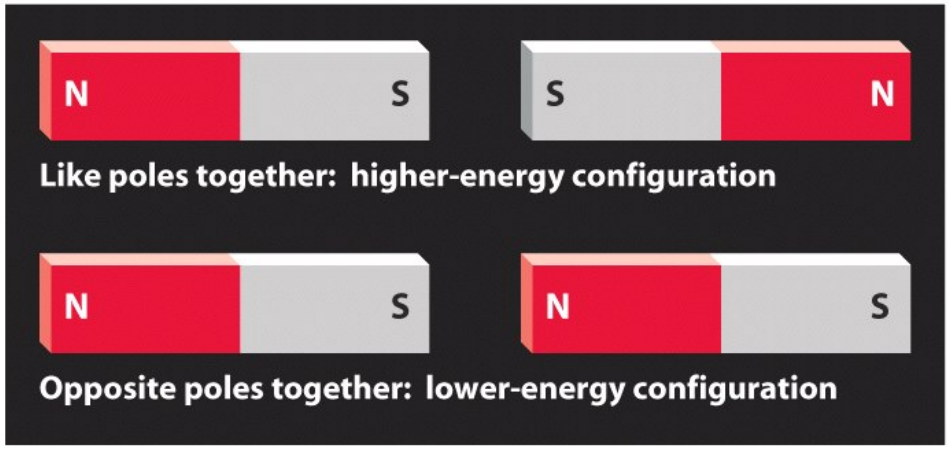


# Milky Way in infrared light

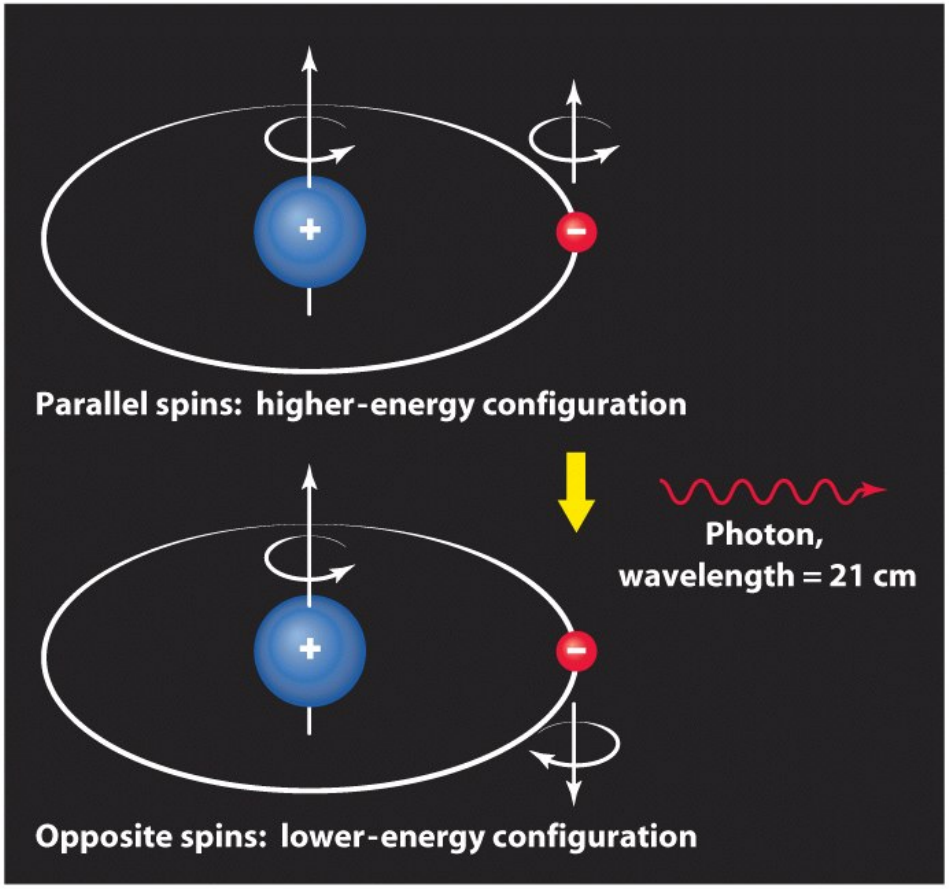
# Milky Way in radio waves



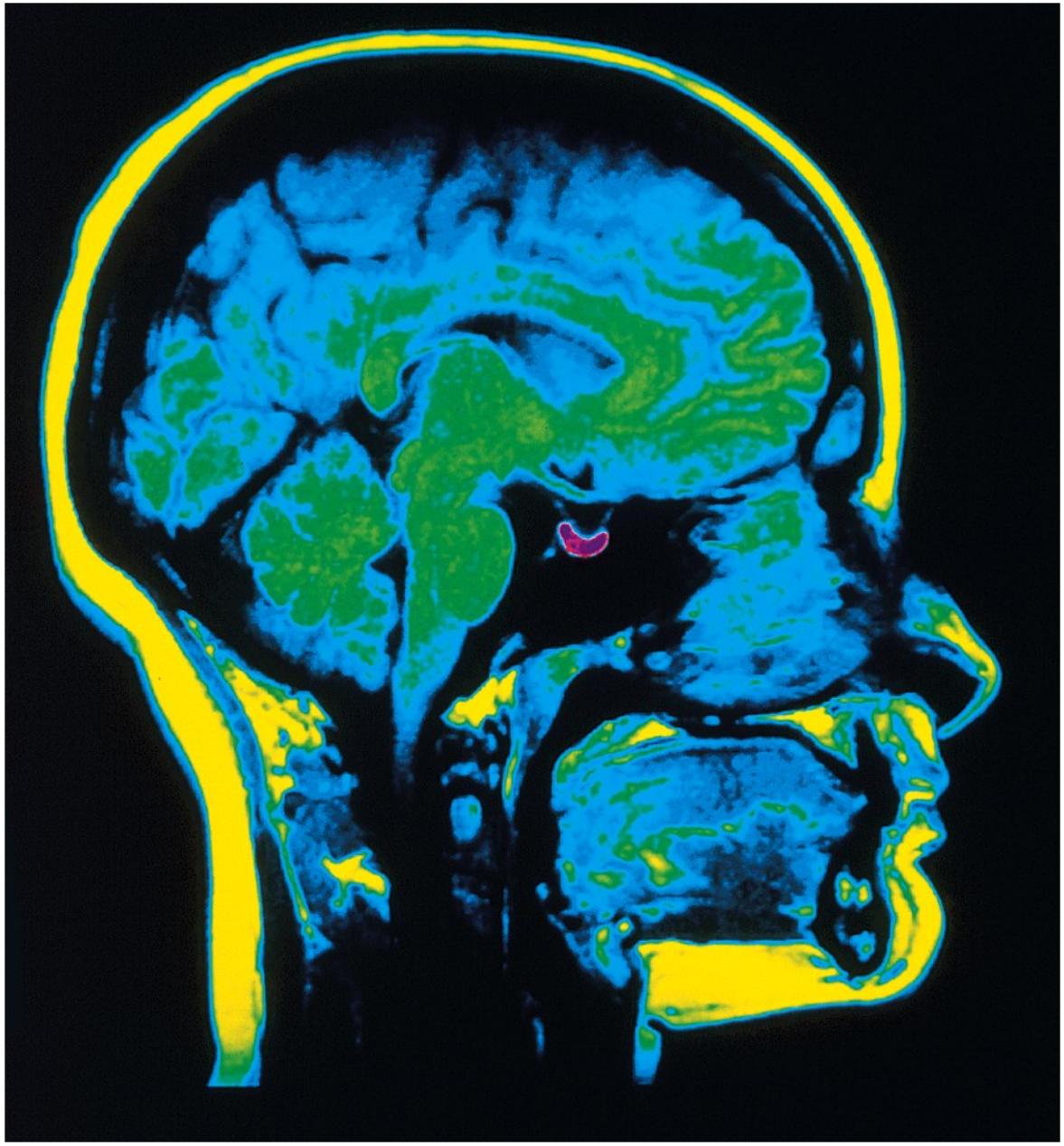
# Hydrogen emits 21 cm radio waves




(a) The magnetic energy of two bar magnets depends on their relative orientation




(b) The magnetic energy of a proton and electron depends on their relative spin orientation



Same effect in other atoms is used to do magnetic resonance imaging (MRI)

What effect do interstellar dust particles have on the appearance of a distant star?

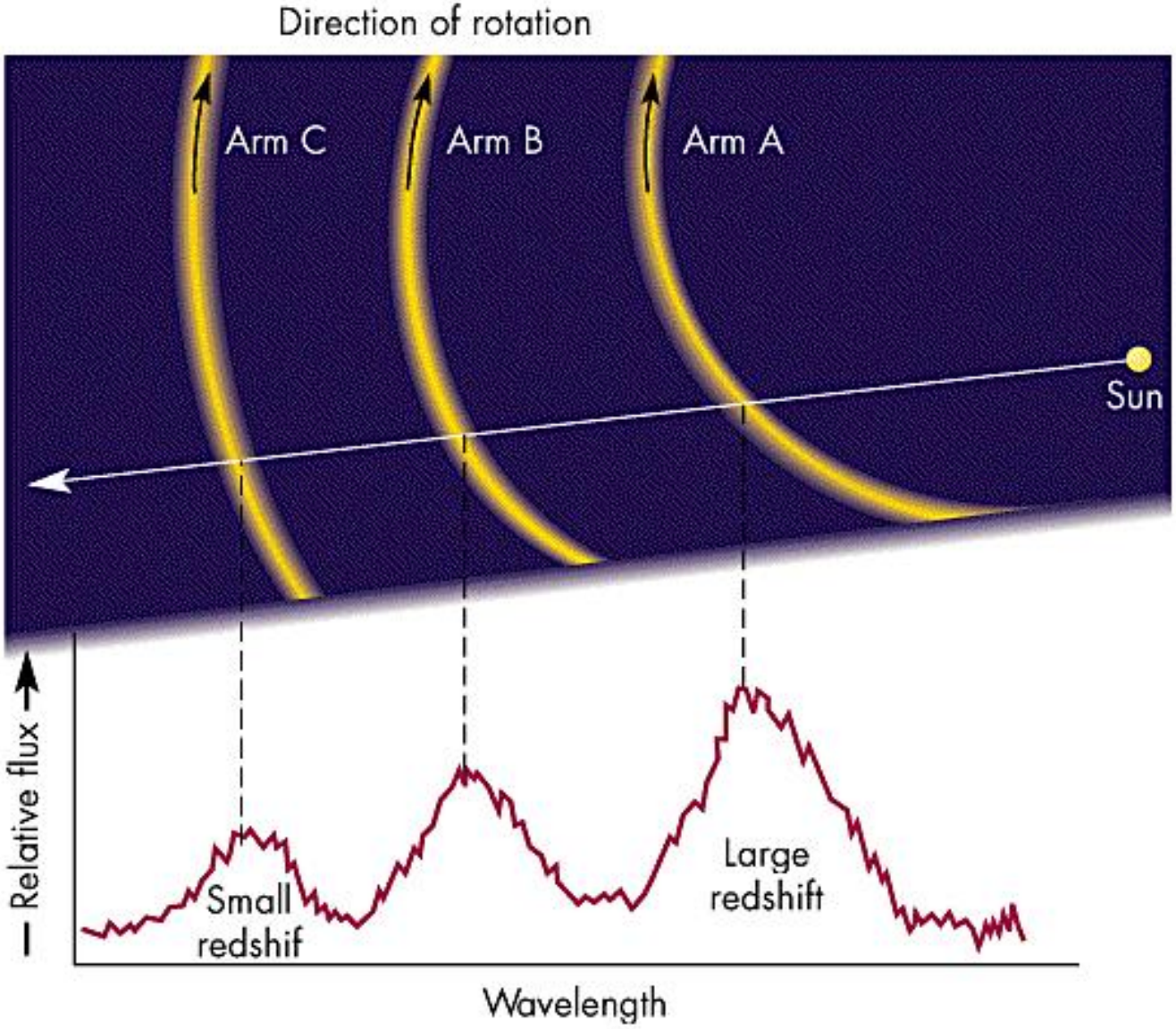
A) They make it look bluer and brighter
B) They make it look redder and brighter
C) They make it look bluer and dimmer
D) They make it look redder and dimmer

# Spiral arms

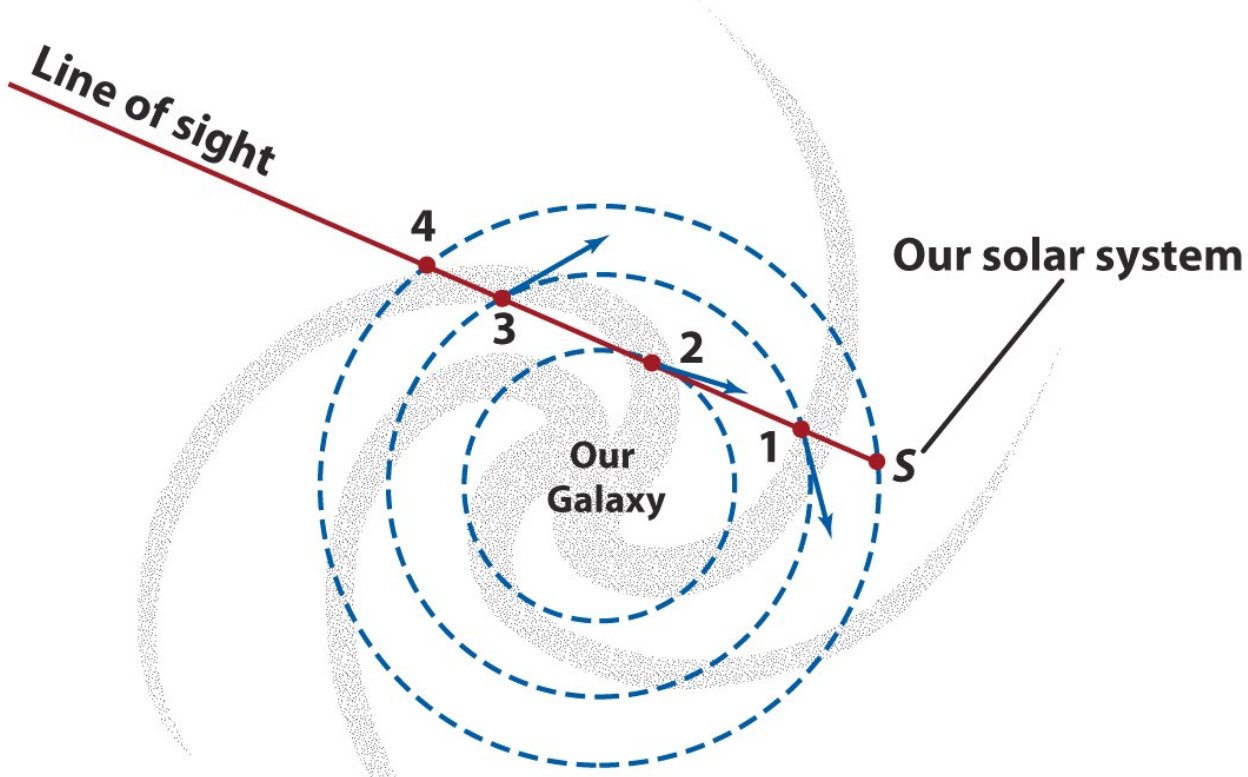
Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

ESO PR Photo 37d/98 (23 September 1998)

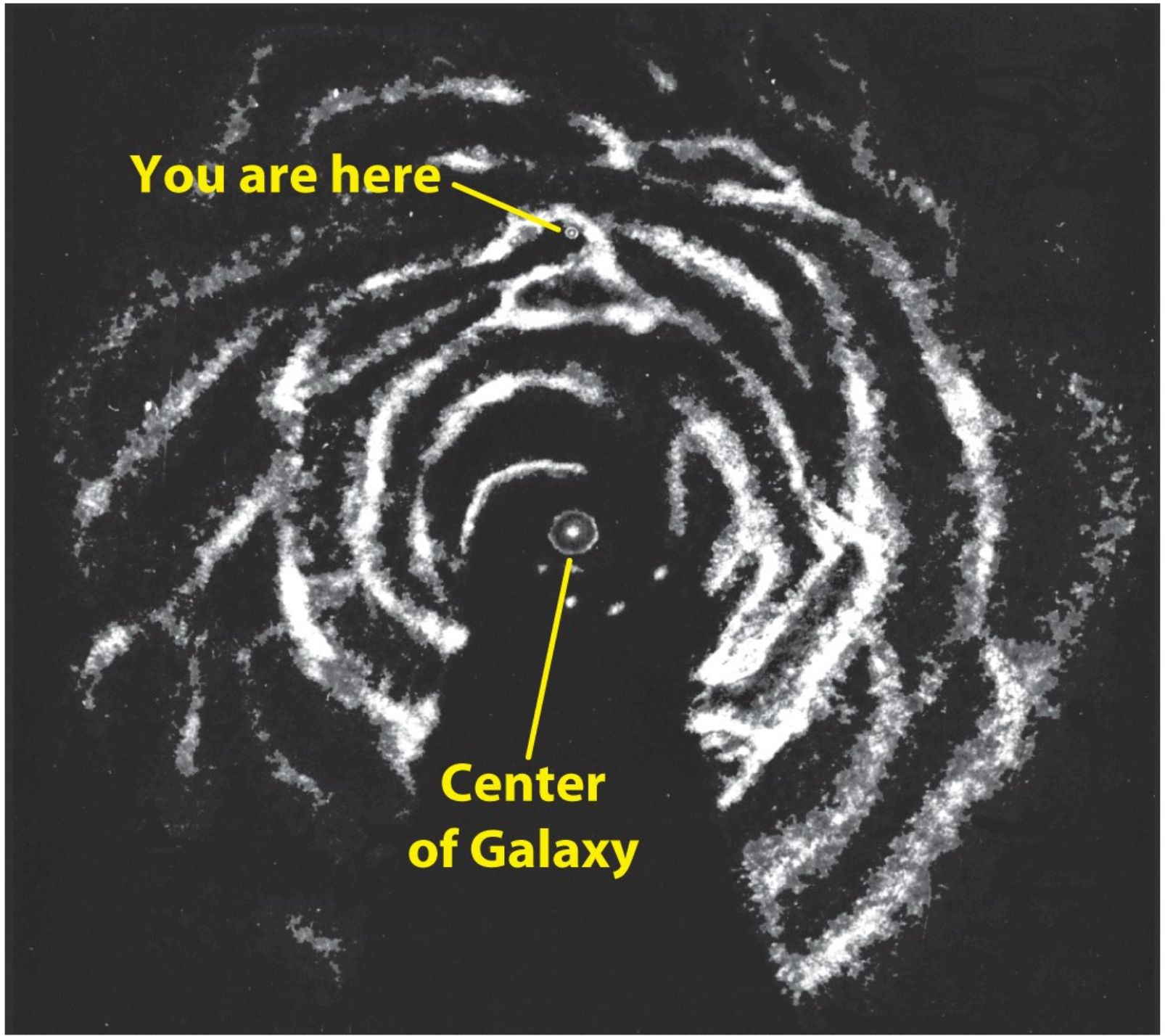
# Tracing spiral arms



# Spiral arms can be traced from the positions of clouds of atomic hydrogen



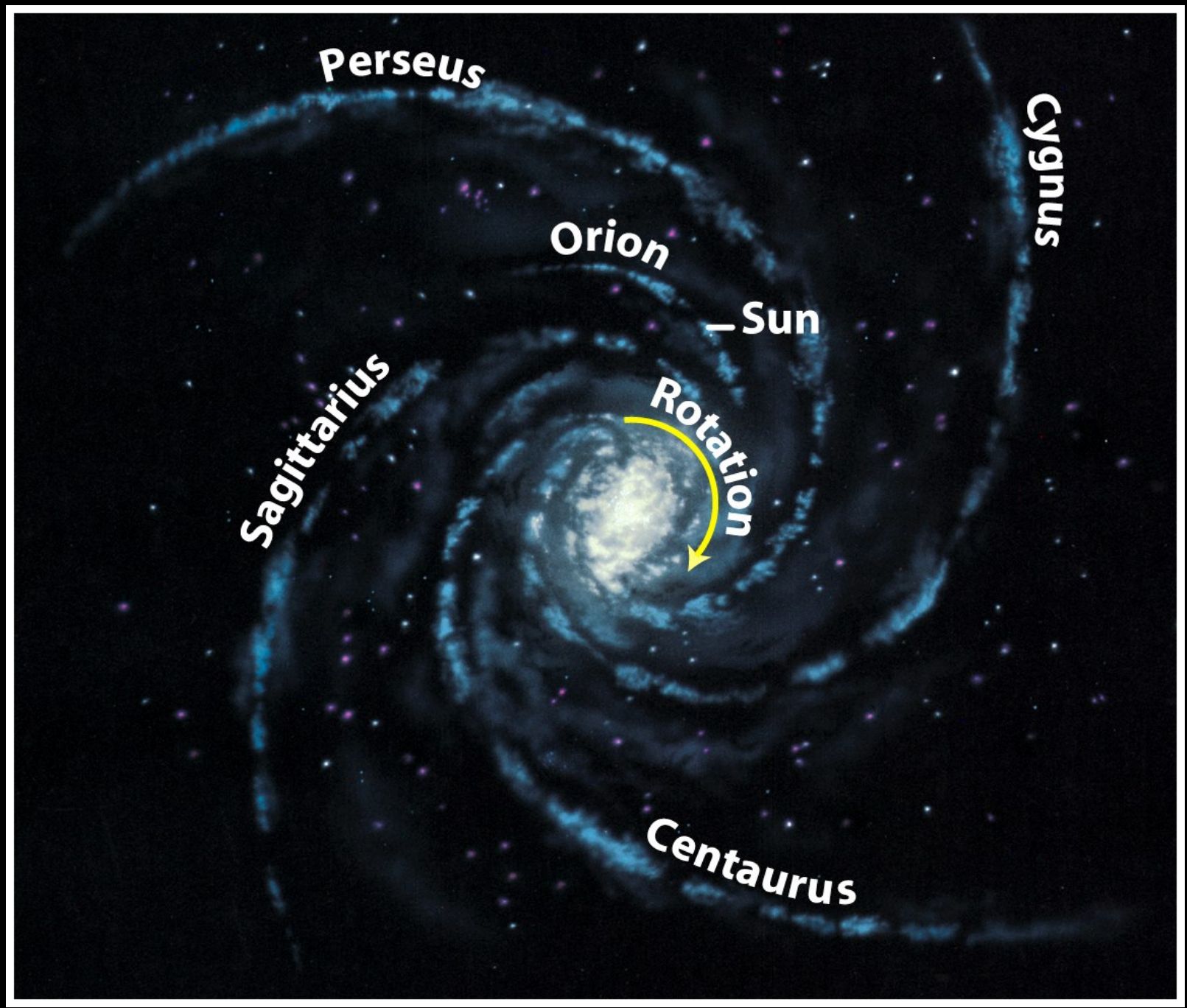

- Hydrogen clouds 1 and 3 are approaching us: They have a moderate blueshift.
- Hydrogen cloud 2 is approaching us at a faster speed: It has a larger blueshift.
- Hydrogen cloud 4 is neither approaching nor receding: It has no redshift or blueshift.


You are here
Center
of Galaxy

# Tracers of spiral arms

- Young stars and related objects also trace spiral arms

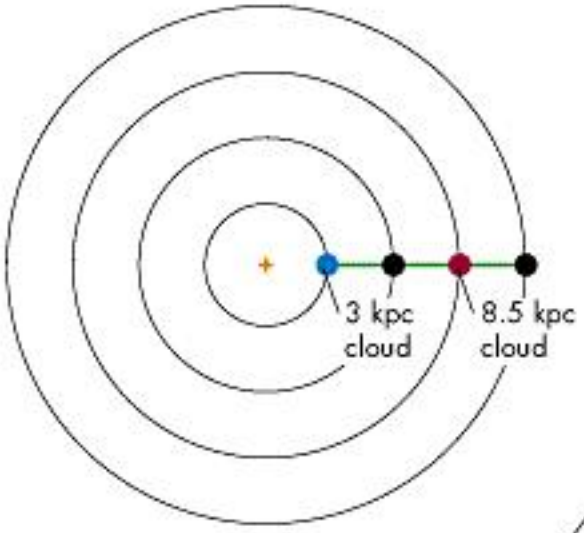
- Emission nebulae = H II regions
- Molecular clouds
- Clusters of young (O and B) stars


Perseus
Cygnus
Orion
Sun
Sagittarius
Rotation
Centaurus

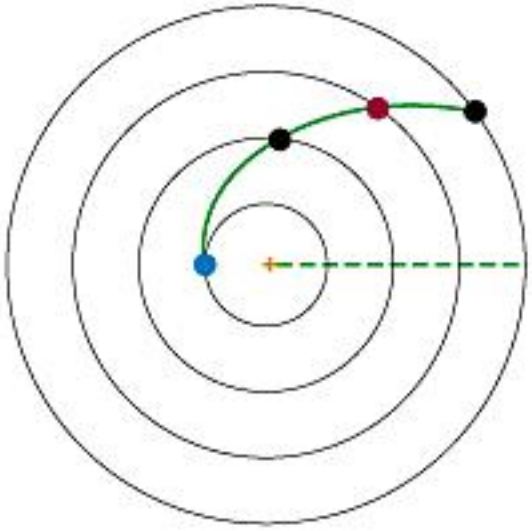
Which of the following objects are ***not*** found primarily in the spiral arms of the Galaxy?

A) white dwarf stars
B) HII regions
C) supernovas
D) O and B stars

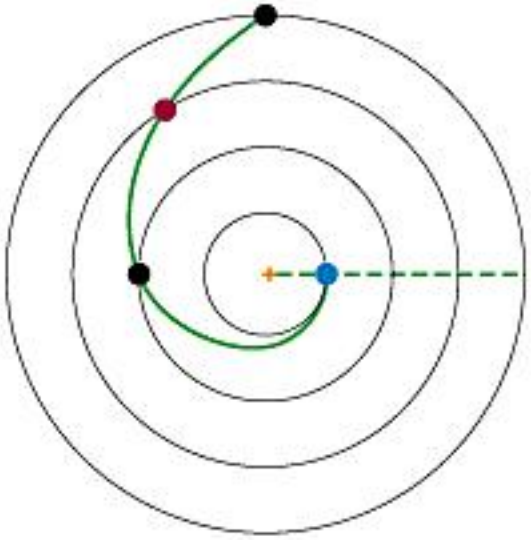
# So what causes spiral arms?



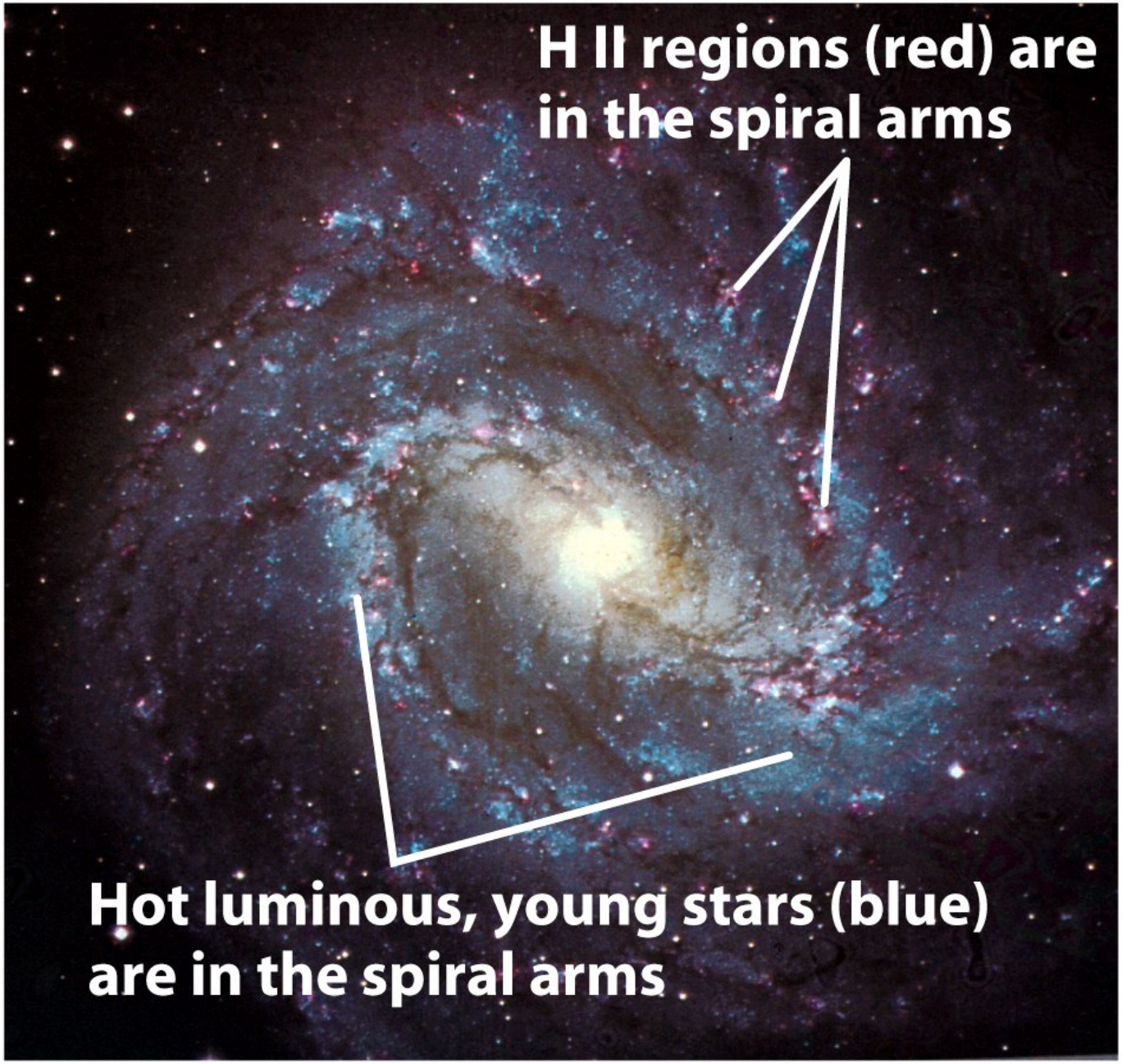

**A** A string of gas clouds lines up radially



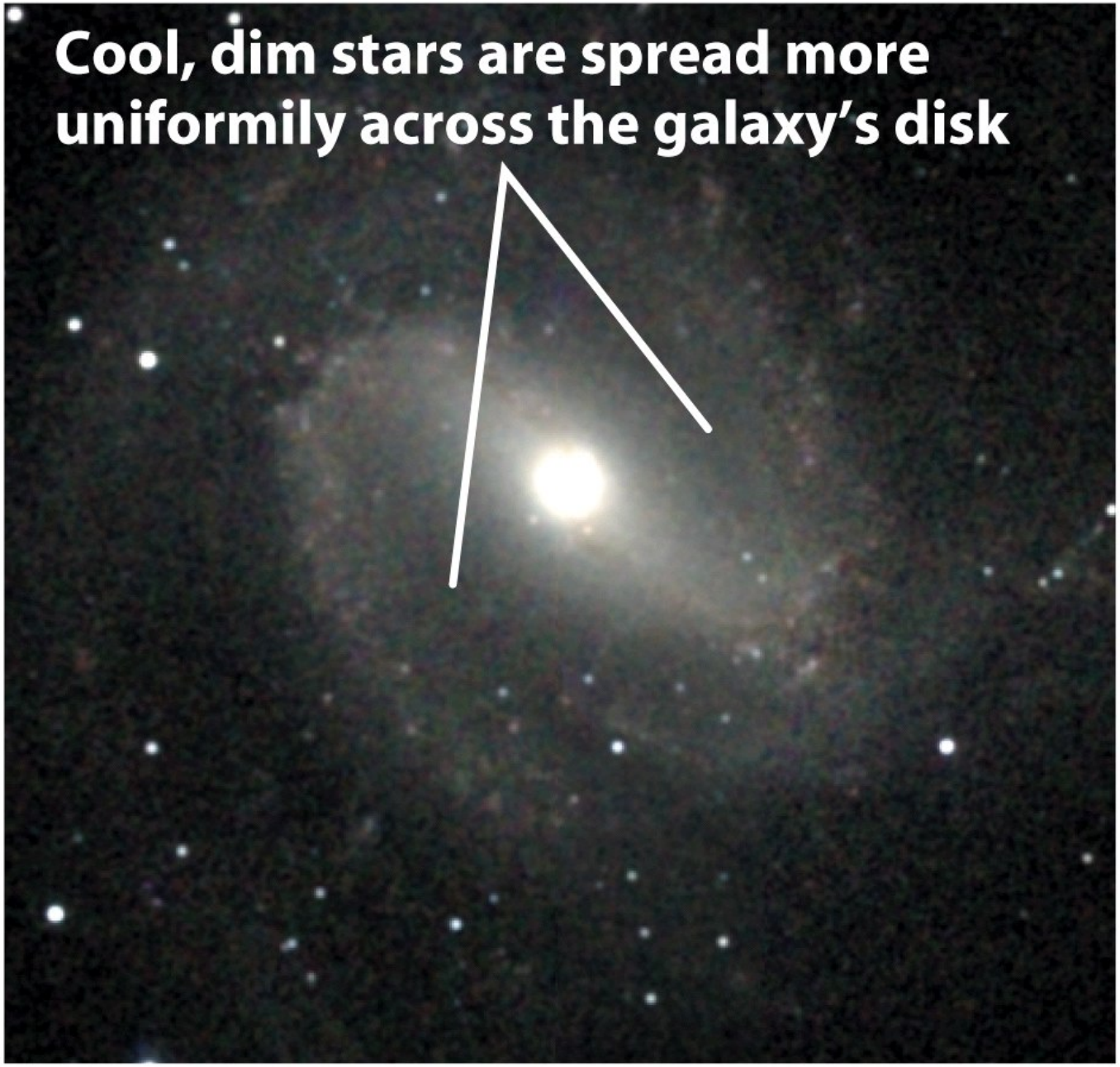
**B** The 3 kpc cloud completes half of a revolution in the time the 8.5 kpc cloud completes $\frac{1}{6}$ of a revolution



**C** The 3 kpc cloud will pass the 8.5 kpc cloud in little more than one orbit

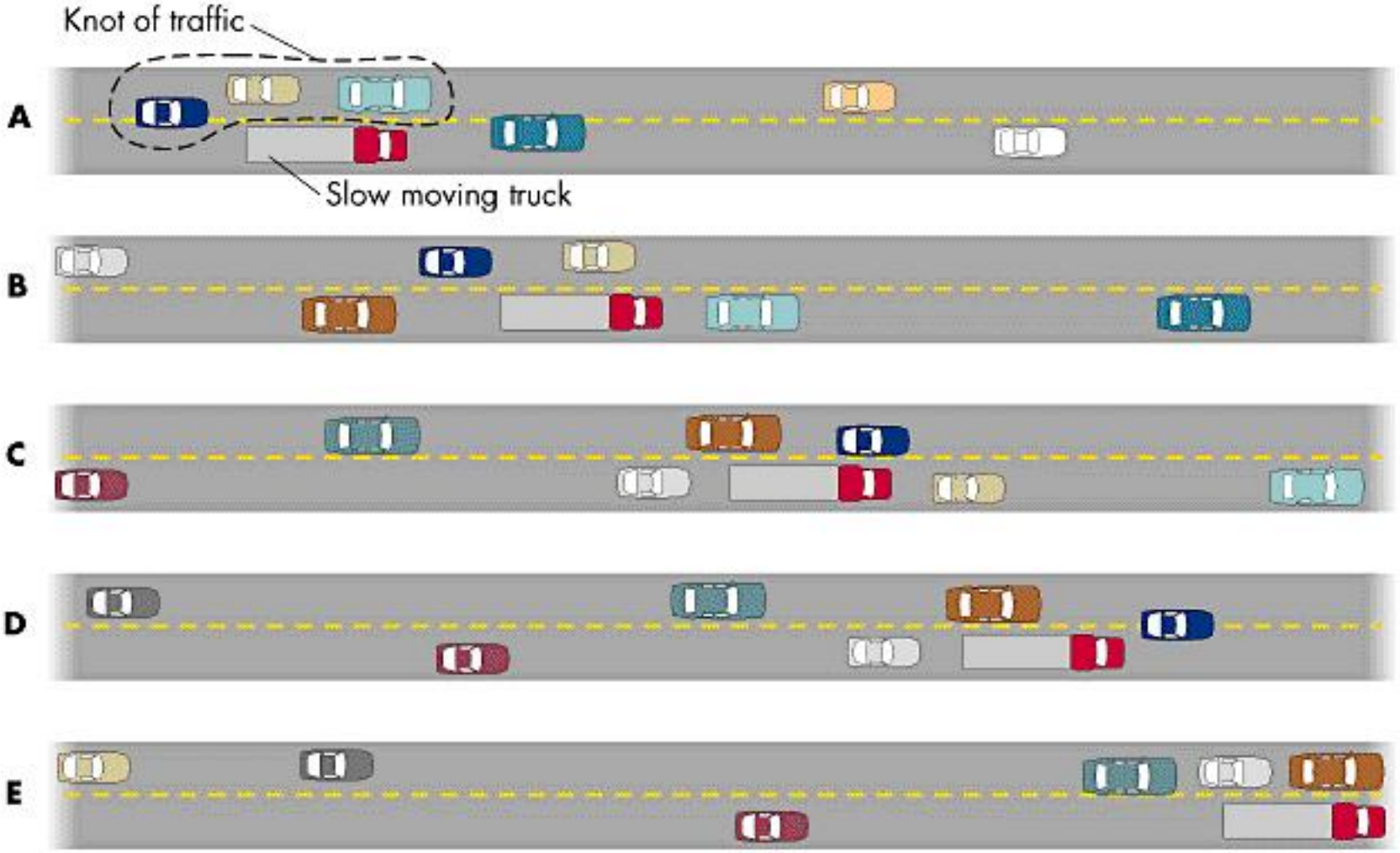



Visible-light view of M83




Near-infrared view of M83

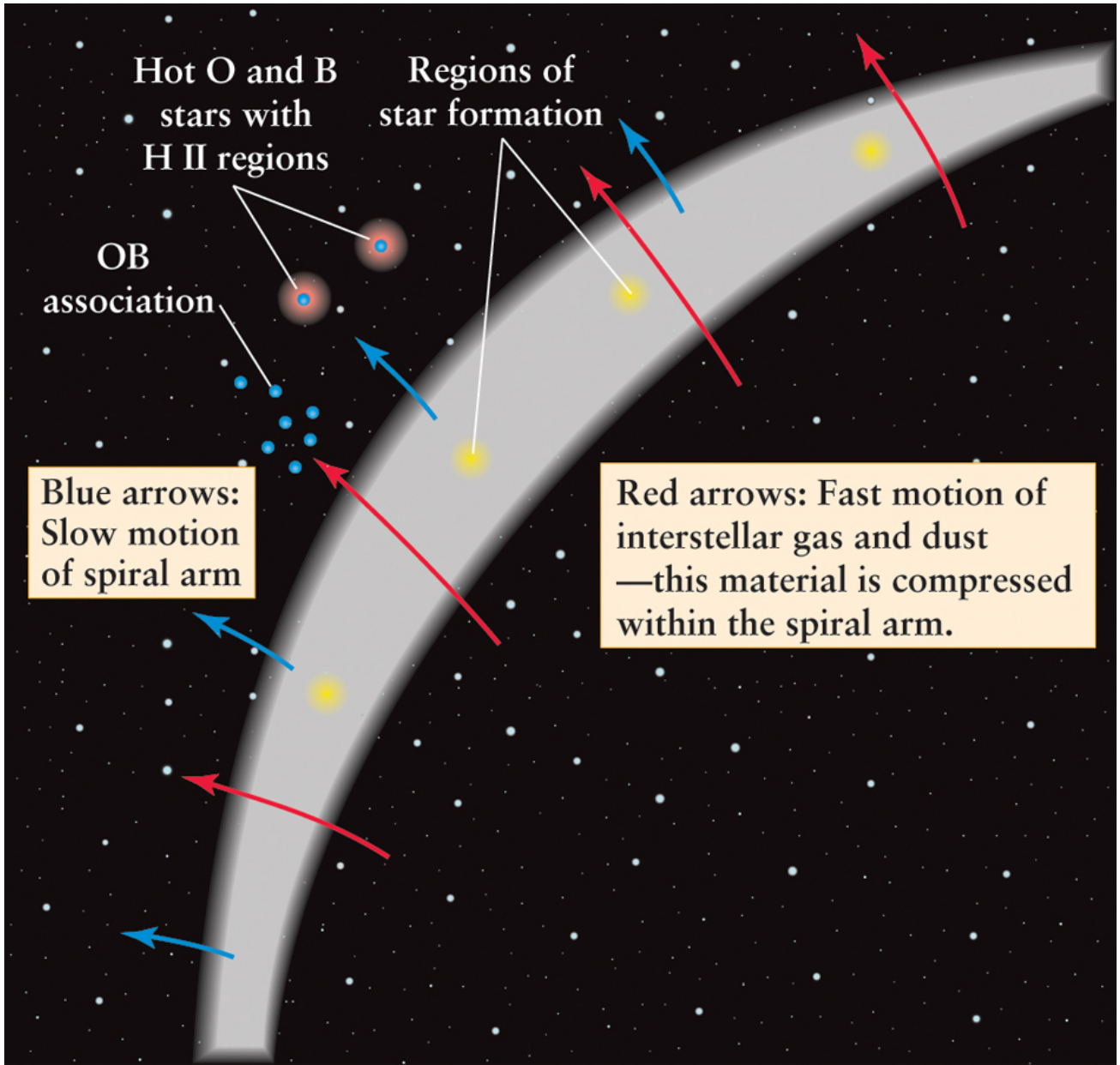
# Density waves



# Spiral arms are patterns

- According to the density-wave theory, spiral arms are waves of high density that sweep around the Galaxy
- The gravitational field of the density wave causes stars and gas to slow down near the arm
- This compresses the interstellar clouds, triggering the formation of stars.
- New stars appear on the “downstream” side of the densest part of the spiral arms.
- The entire arm pattern rotates around the Milky Way once every 500 million years.

# Star Formation in the Density-Wave Model



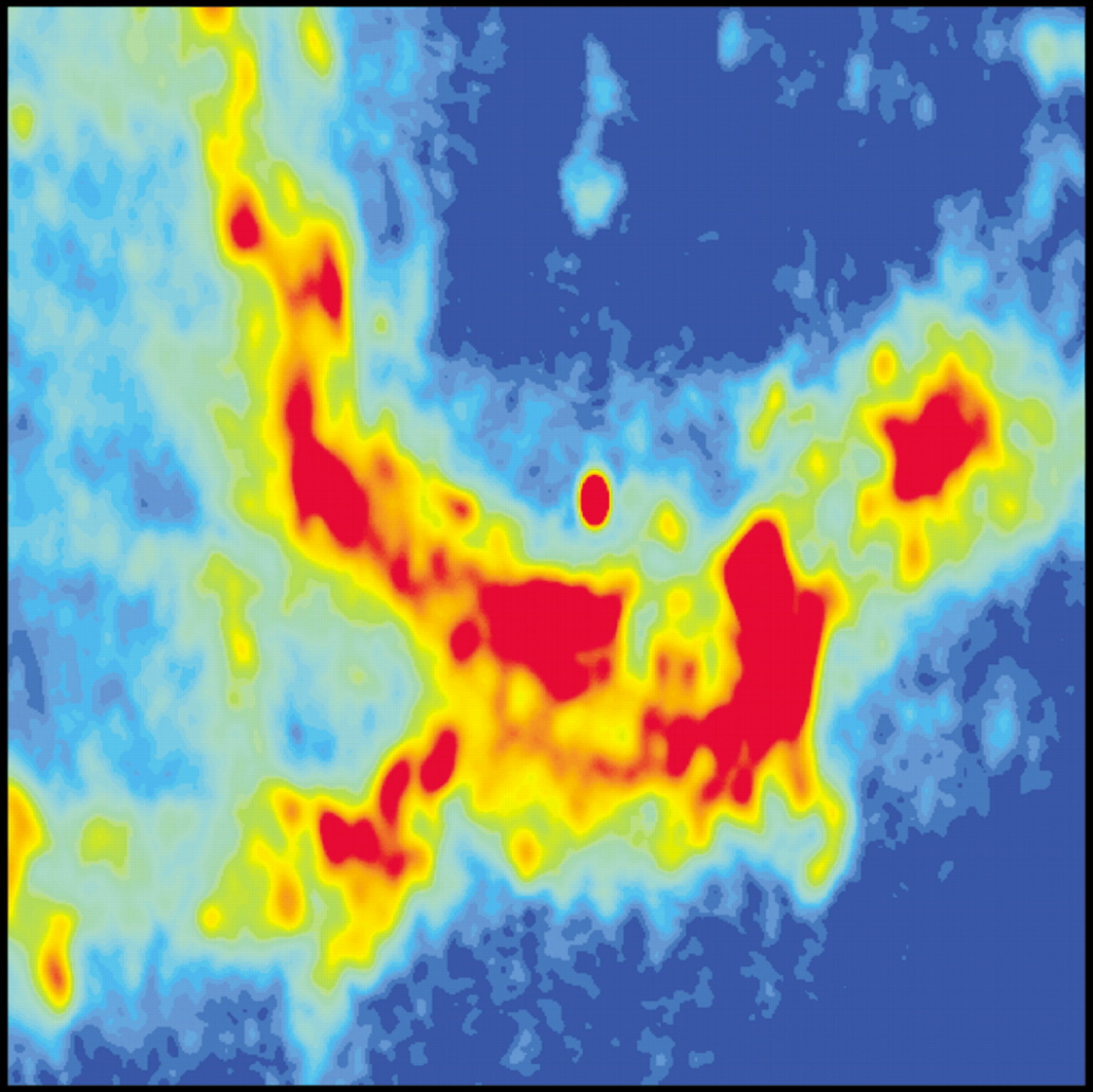
# Which is true of spiral arms?

A) Once a star enters a spiral arm it remains there

B) Spiral arms are spun off the core of the galaxy

C) Spiral arms contain a very high density of less than one solar mass stars

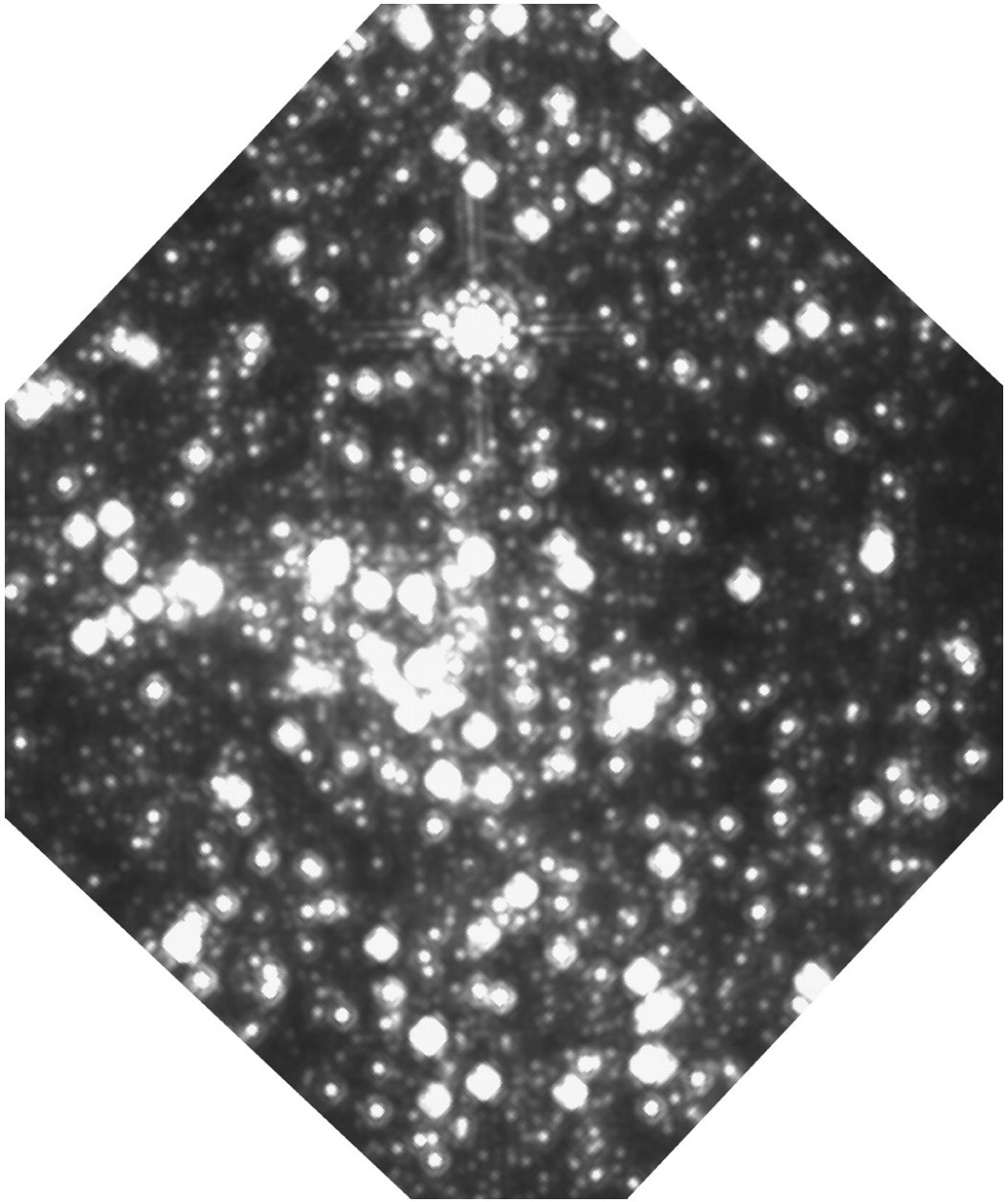
D) Stars preferentially form in spiral arms



# Radio image, central 3 ly

Center is the red ellipse at the center

Called Sgr A*



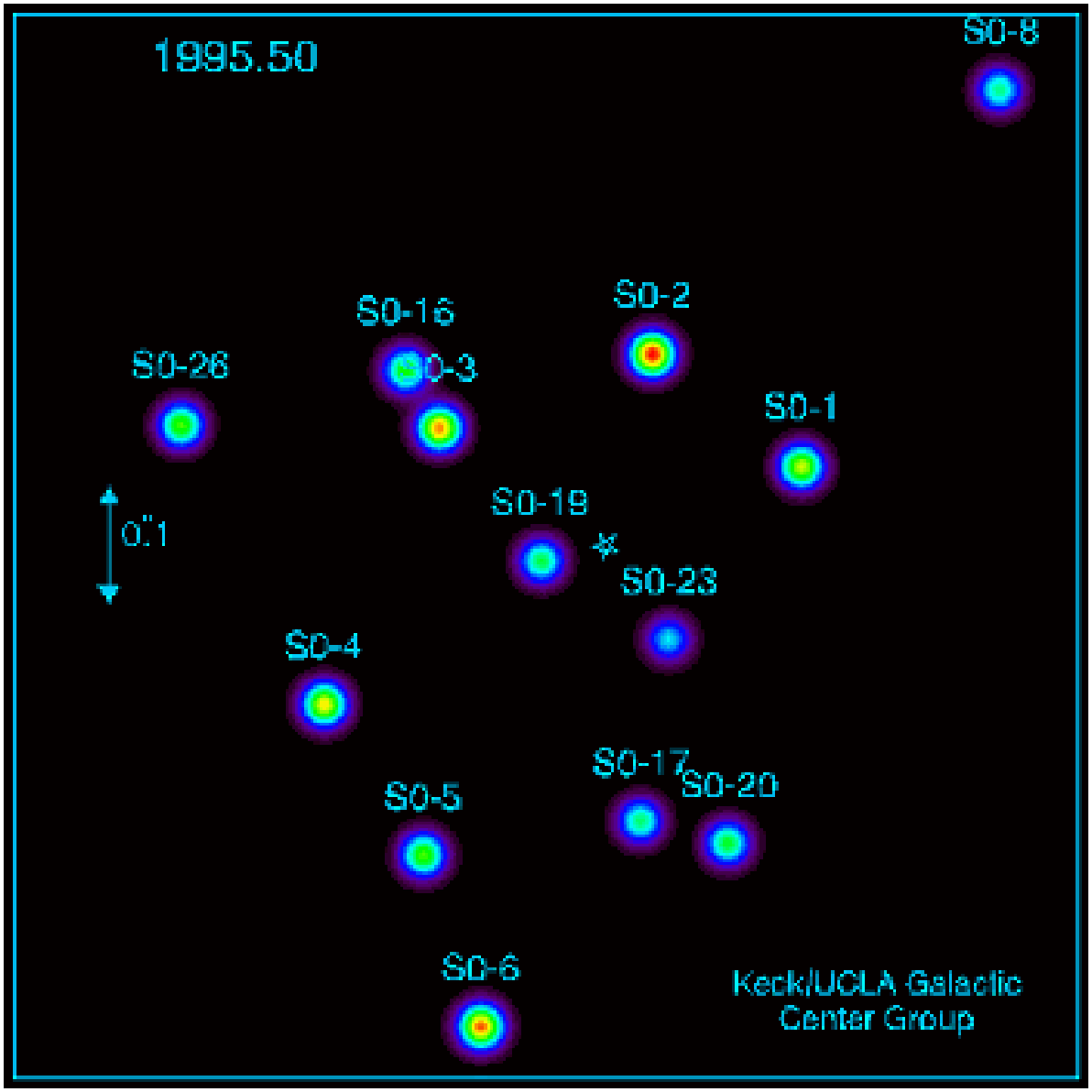
# Infrared image, central 3 ly

Sgr A* does not appear.

There are about 1,000,000 stars in the area covered by this image.

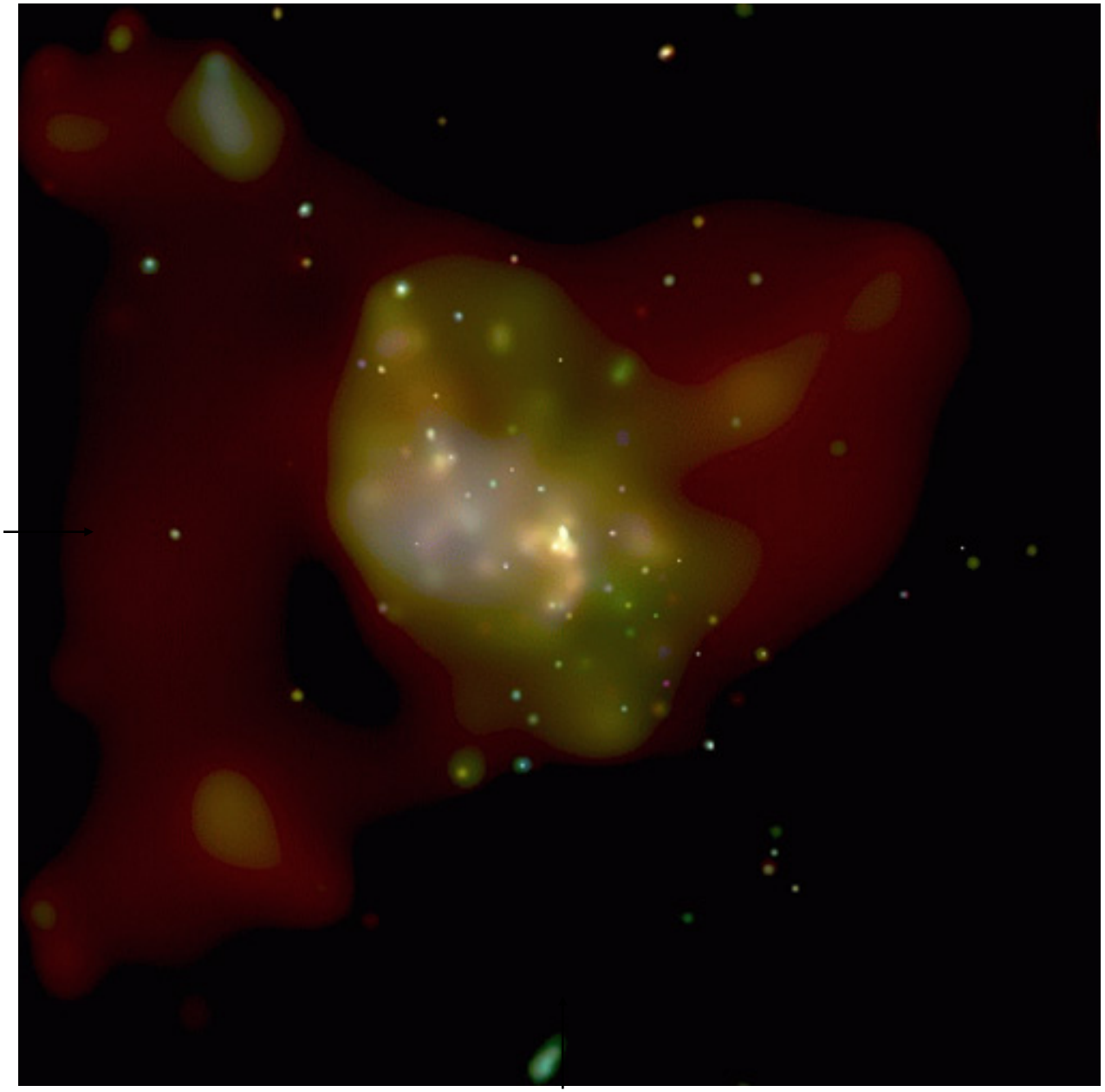
Stars are only 1000 AU apart.

# Stellar Orbits in the Galactic Center



# Mass of Sgr A* can be measured using stellar orbits

- Fastest moving star moves at 2% of the speed of light, 5000 km/s
- Mass is about 3 million solar masses
- Emits radio and X-rays
- Almost certainly a black hole



X-ray image, central 3 ly

Sgr A* is the bright object in the center of the image.

Makes flares in X-rays.

Movie.

# Spiral arm structure is best found by mapping the locations of

A) Globular clusters
B) Young, massive stars
C) RR Lyra variable stars
D) Solar mass and lighter stars

# How do we know that the Milky Way has a spiral structure?

A) By observing the gravitational influence of the arms on nearby galaxies

B) By plotting the distances and directions of objects known to be in spiral arms

C) By observing the changing conditions as the Sun enters and leaves a spiral arm

D) By viewing the Milky Way from a point well above its plane

# Review Questions

- Why do stars behind dust clouds appear red?
- Why is the sky blue?
- Why are wavelengths of light outside the visible useful in studying the Milky Way?
- How is the 21 cm line of Hydrogen produced?
- Describe the spiral arms of the Milky Way and what causes them.
- What lies at the center of the Milky Way?