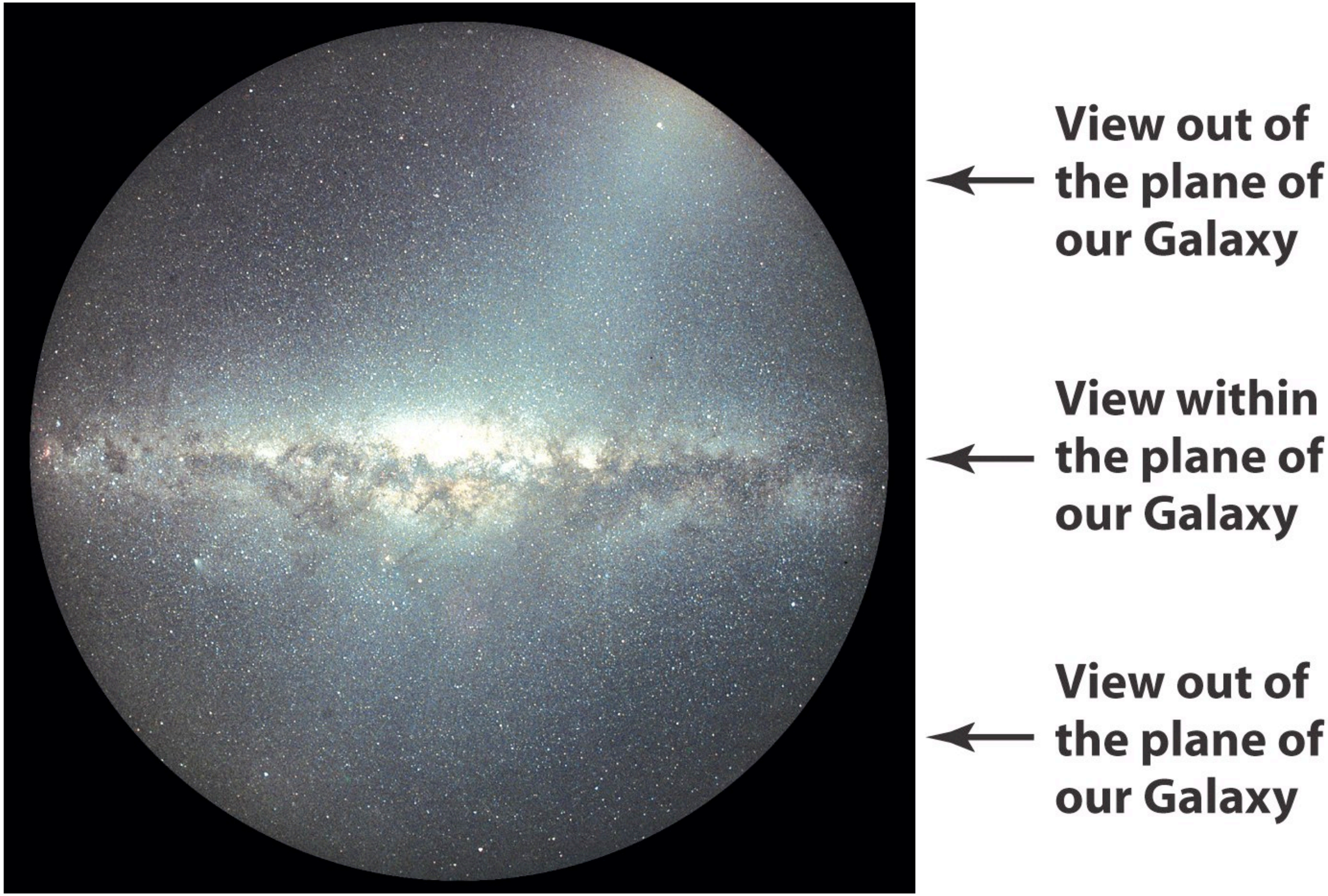
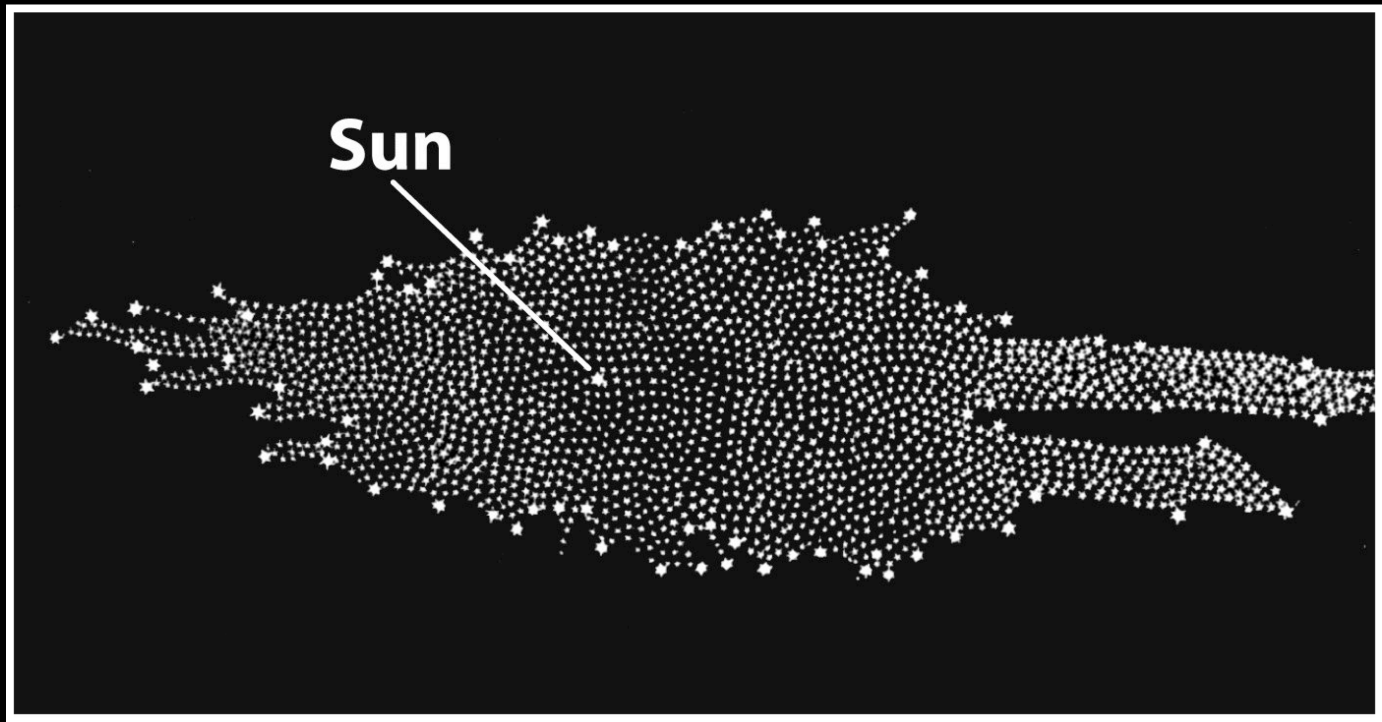
Our Galaxy

Chapter Twenty-Five



Interstellar dust obscures our view at visible wavelengths along lines of sight that lie in the plane of the galactic disk

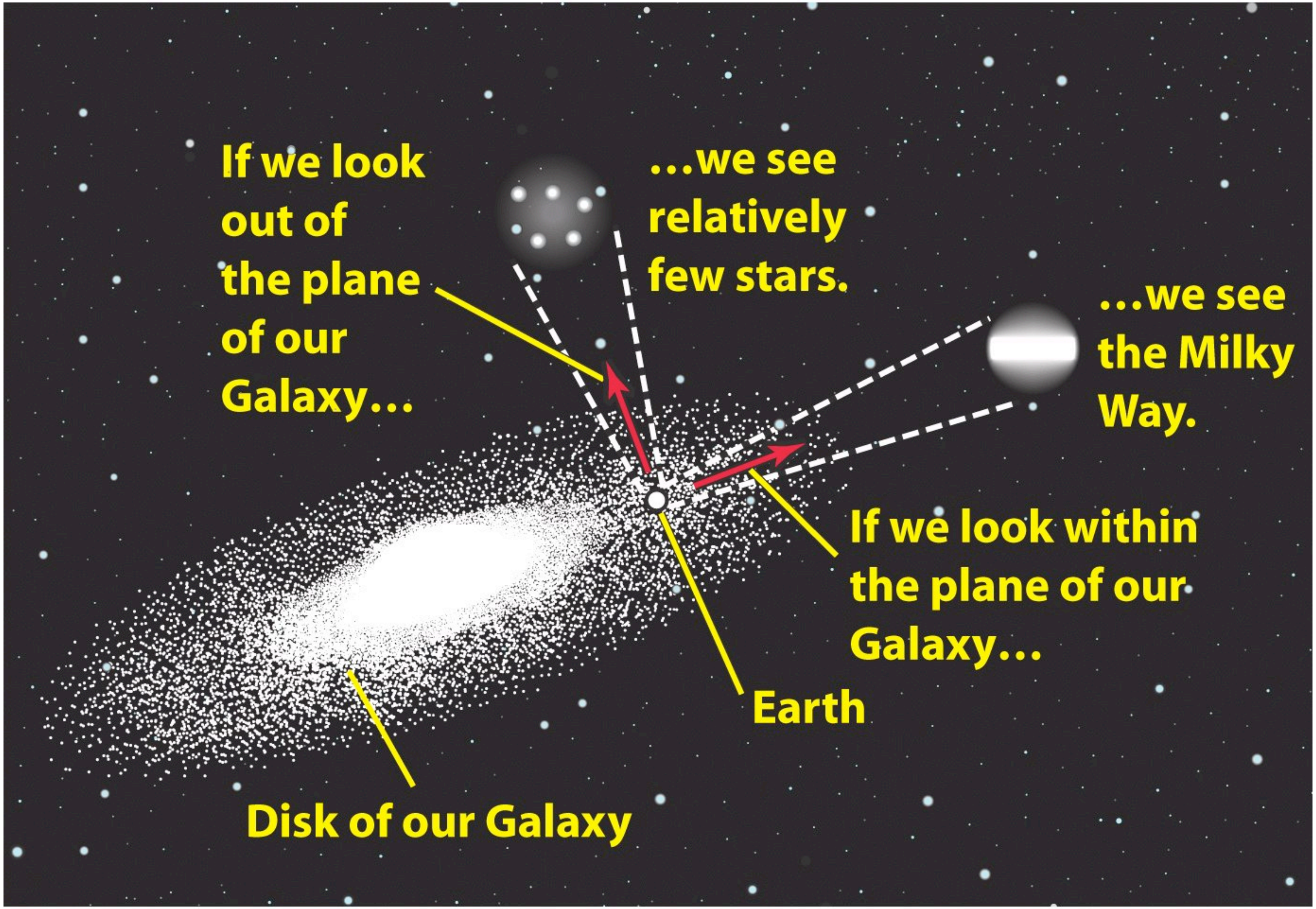
As a result, the Sun's location in the Galaxy was unknown for many years

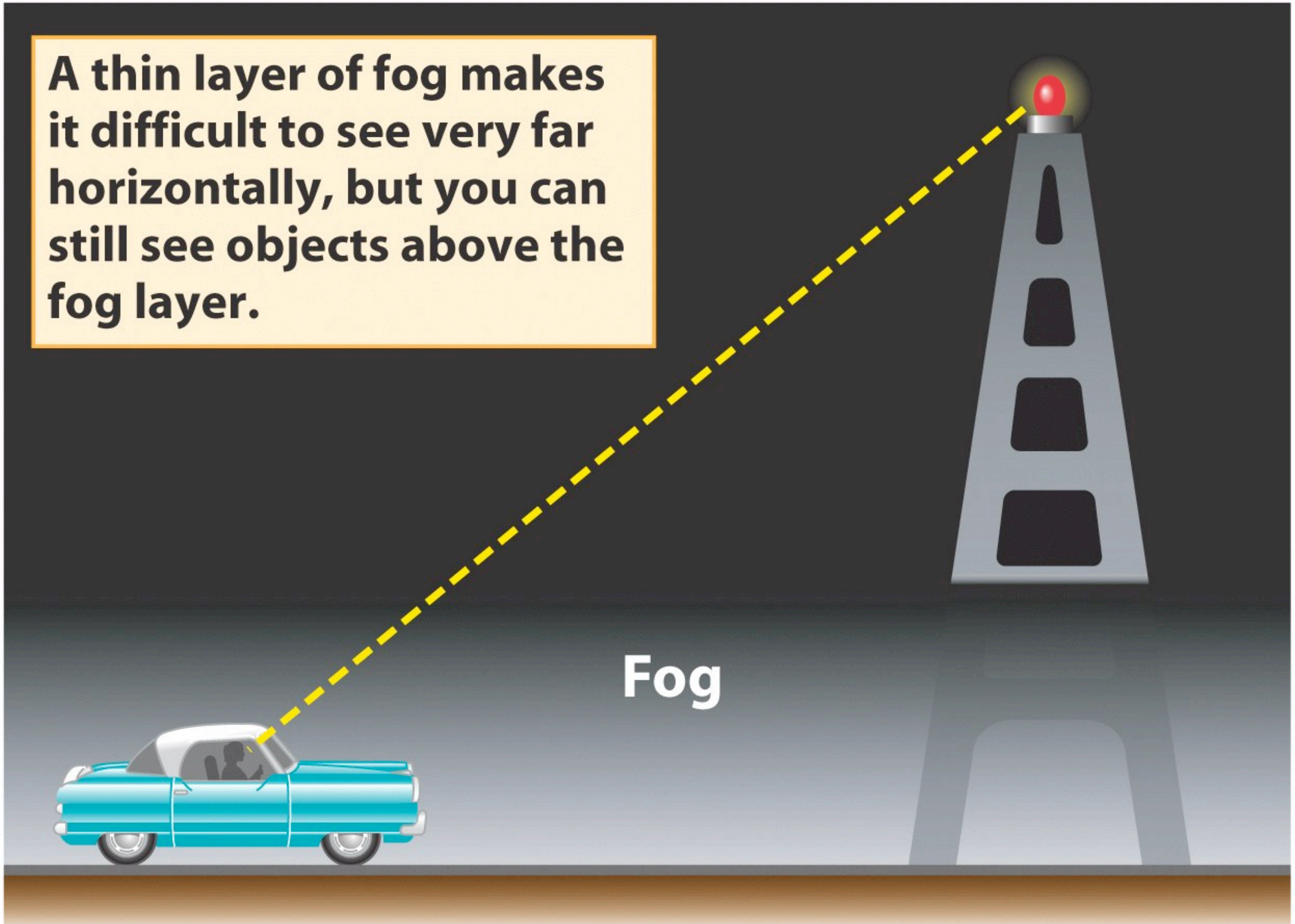


Herschel found same density of stars all along the Milky Way (therefore
He concluded that Earth was at the center of the galaxy)

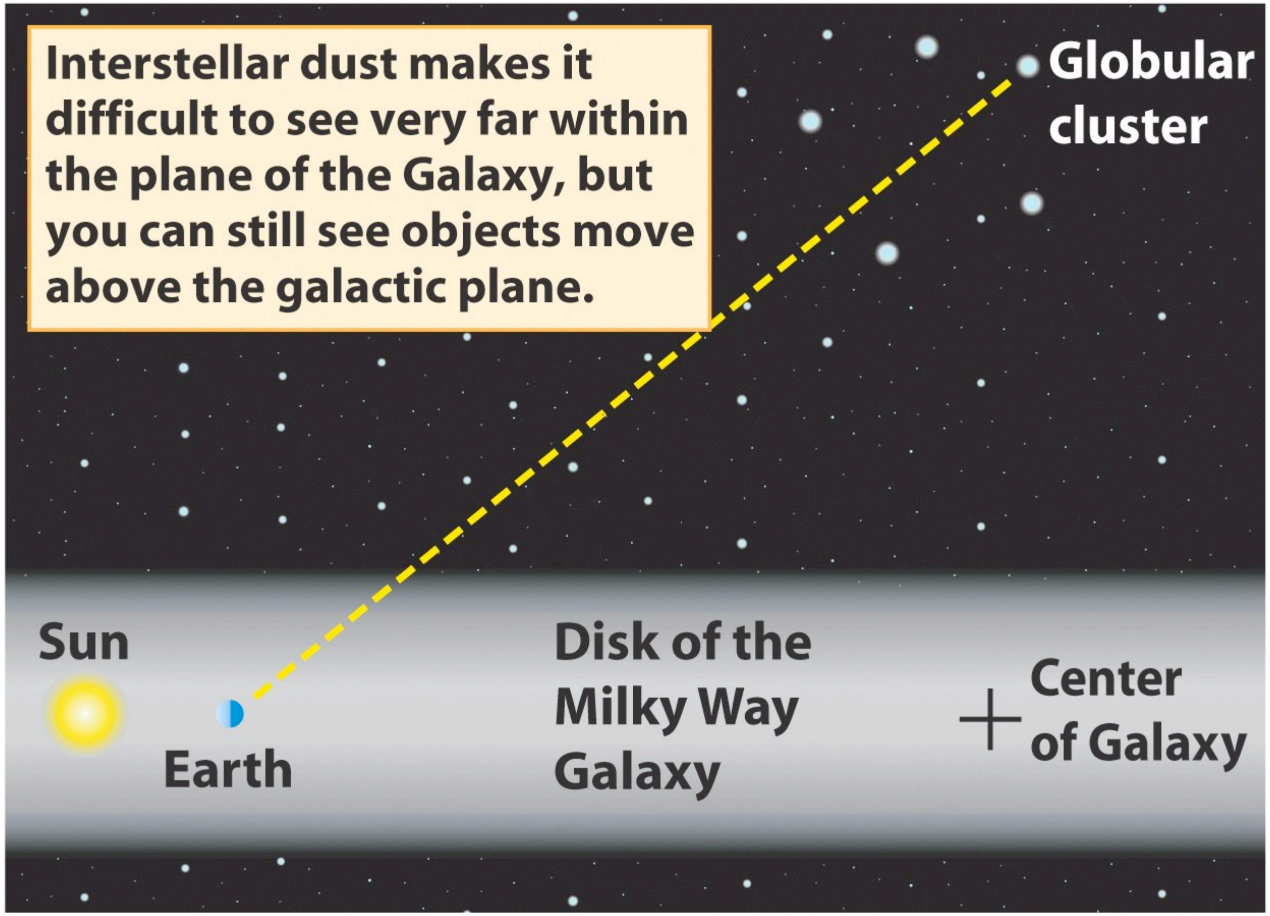
Kapyten came to essentially same conclusion

This dilemma was resolved by observing parts of the Galaxy outside the disk





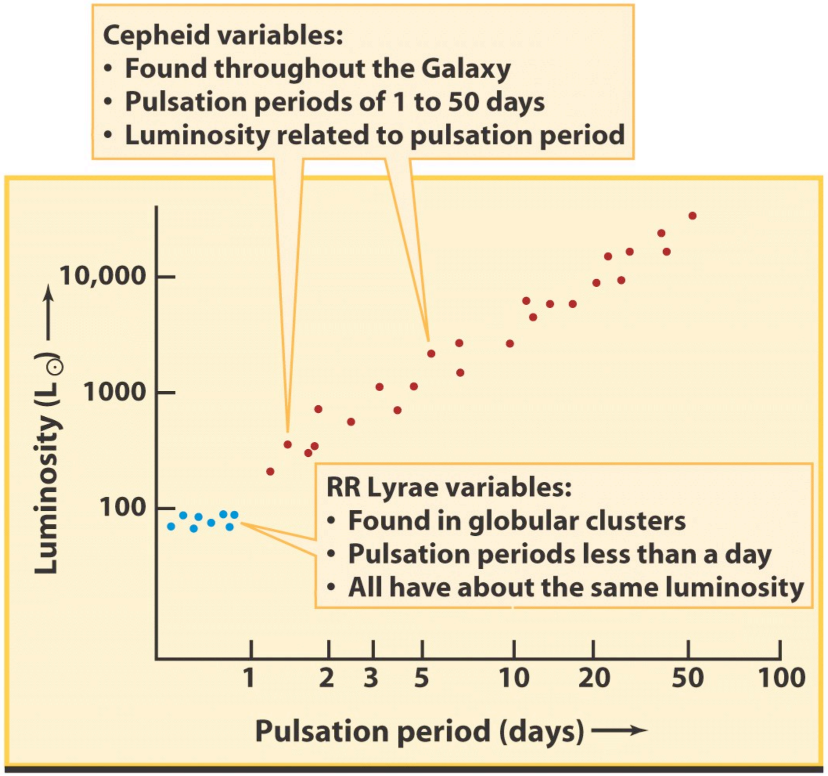
Determining your position in the fog



Determining your position in the Galaxy

Globular clusters are a spherical distribution of roughly 10^6 stars packed
In a small volume;

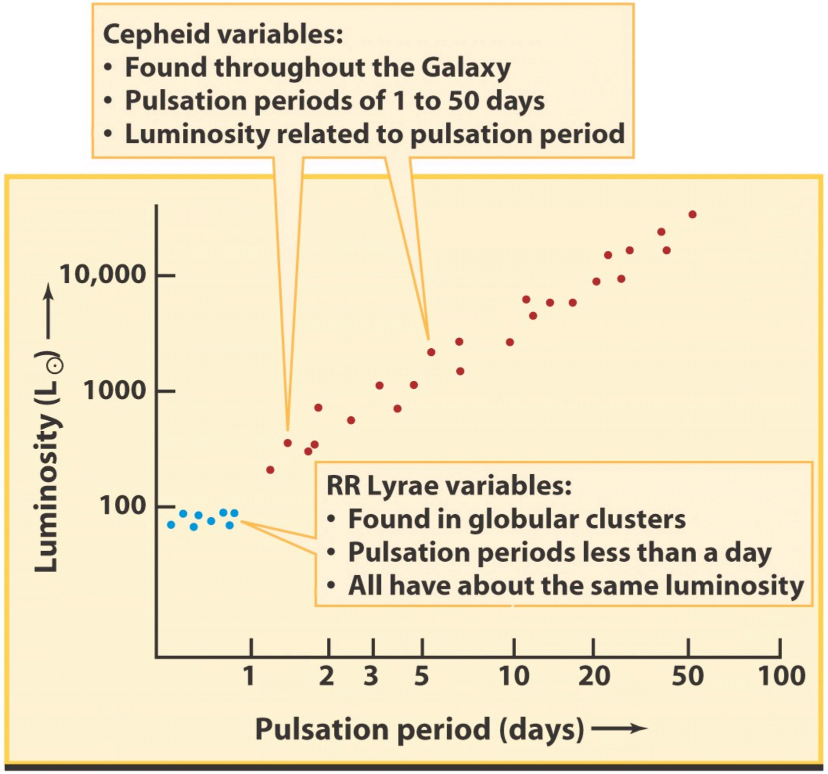
Determining the distance and direction of the globular clusters gave us the Sun's location

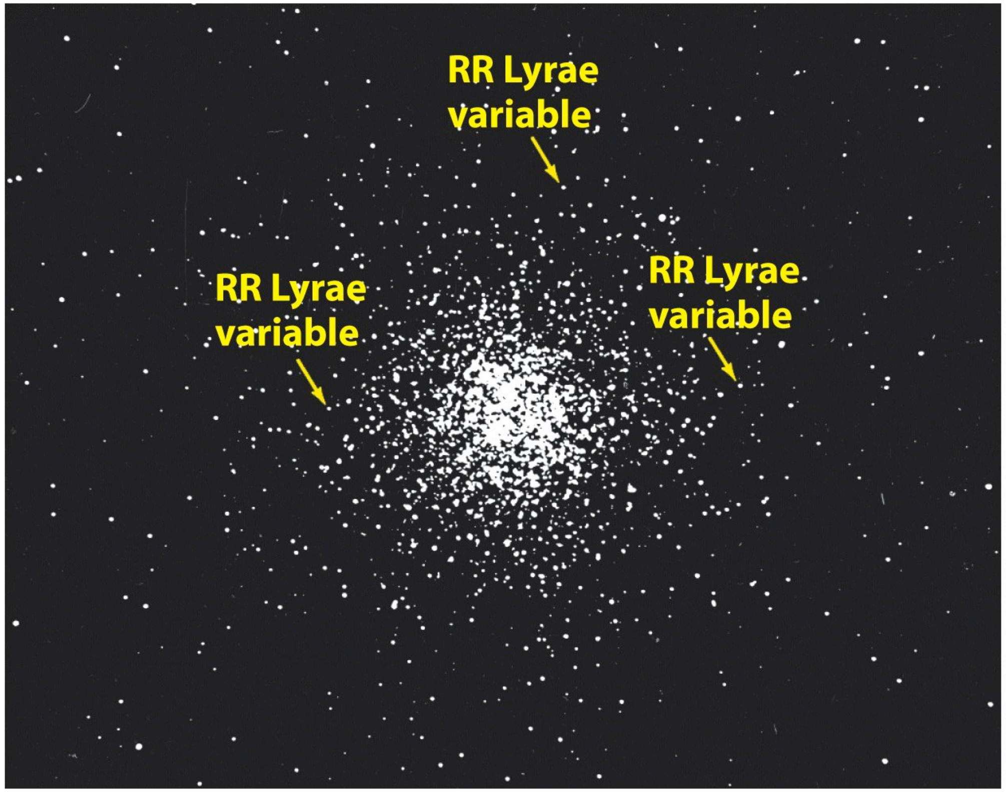


In 1912 H. Leavitt reported the discovery
Of the period-luminosity relationship
For Cepheid. By measuring the
Period you can find their luminosity
And find their distance (in order to obtain
the observed *brightness*.

Then Shapley discover the relationship
Between period and luminosity for
RR Lyrae (The importance of RR Lyrae
Is that they are commonly found in
globular clusters)

Determining the distance and direction of the globular clusters gave us the Sun's location



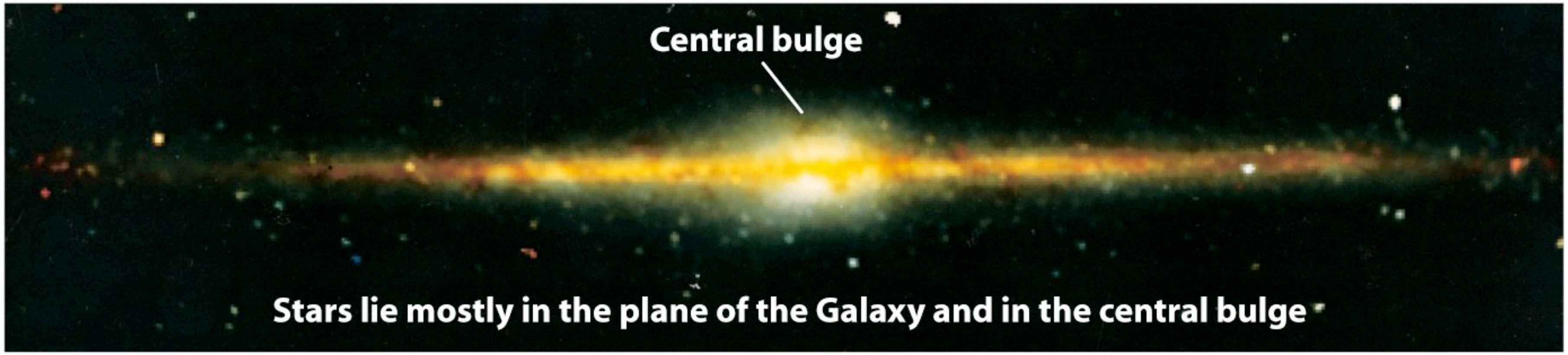


Our Sun lies within the galactic disk, some 8000 pc (26,000 ly) from the center of the Galaxy

Observations at nonvisible wavelengths reveal the shape of the Galaxy

IRAS

(a) Infrared emission from dust at wavelengths of 25, 60, and 100 μm

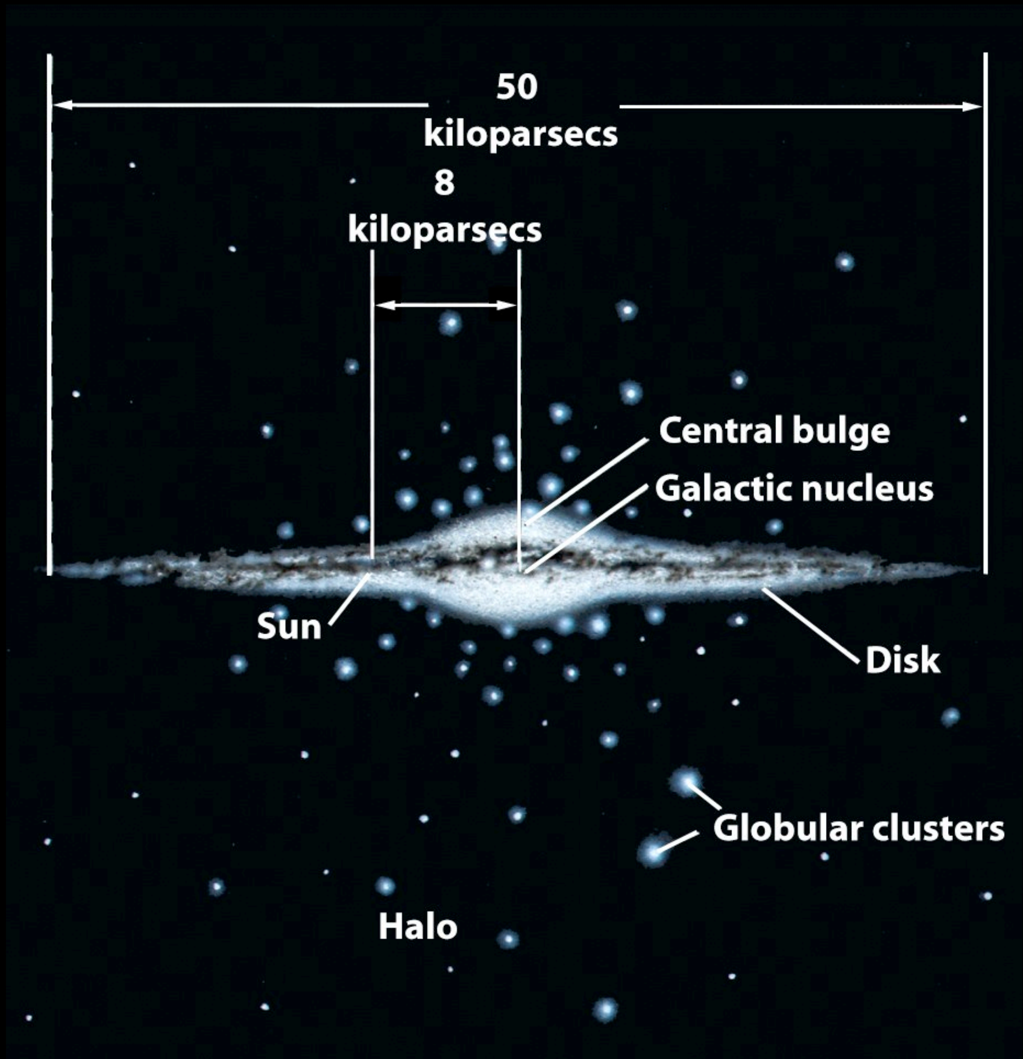


(b) Infrared emission from dust at wavelengths of 1.2, 2.2, and 3.4 μm

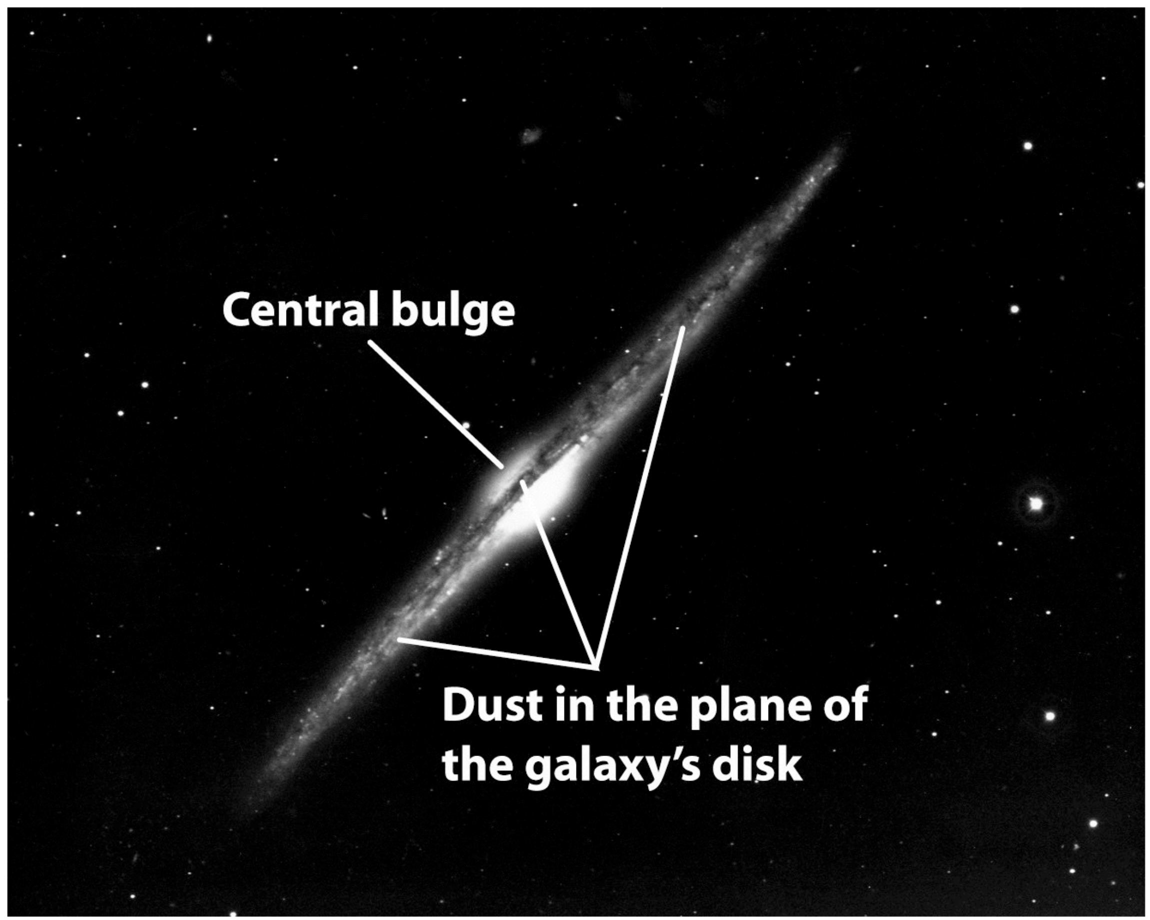
COBE

Far infra-red (30-100micro m) : dust radiated more strongly than stars

There are about 200 billion (2×10^{11}) stars in the Galaxy



- Our Galaxy has a disk about 50 kpc (160,000 ly) in diameter and about 600 pc (2000 ly) thick, with a high concentration of interstellar dust and gas in the disk
- The Sun orbits around the center of the Galaxy at a speed of about 790,000 km/h
- It takes about 220 million years to complete one orbit

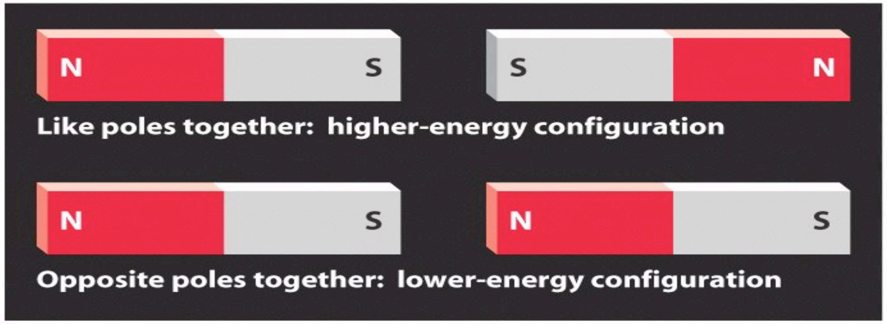


Globular clusters & isolated stars in the halo:
old metal-poor Pop II stars

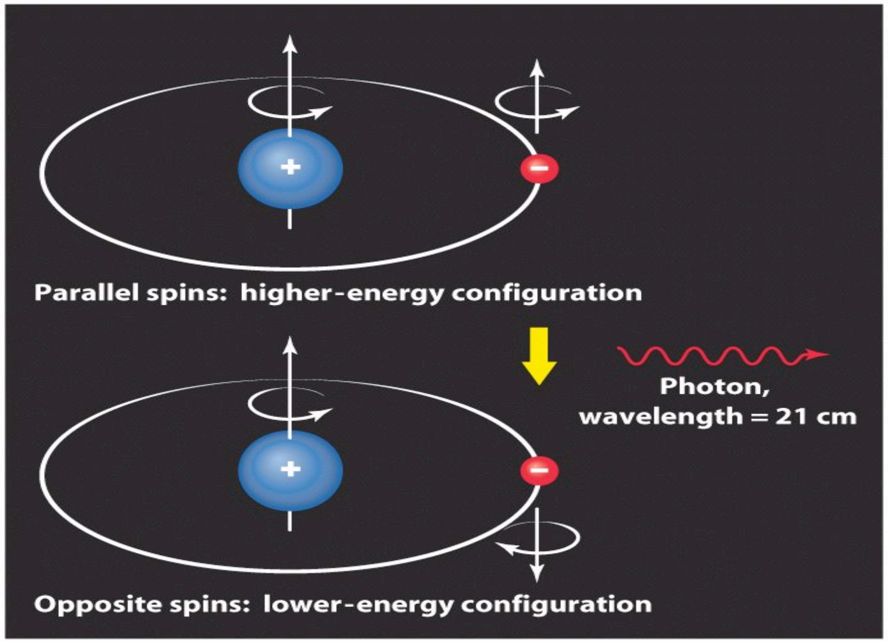
Stars in the disk: mostly young metal-rich Pop I stars
(the disk apprea bluish because of hot O and B stars)

- The galactic center is surrounded by a large distribution of stars called the central bulge
- This bulge is not perfectly symmetrical, but may have a bar or peanut shape
- The disk of the Galaxy is surrounded by a spherical distribution of globular clusters and old stars, called the galactic halo

The spin-flip transition in hydrogen emits 21-cm radio waves



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

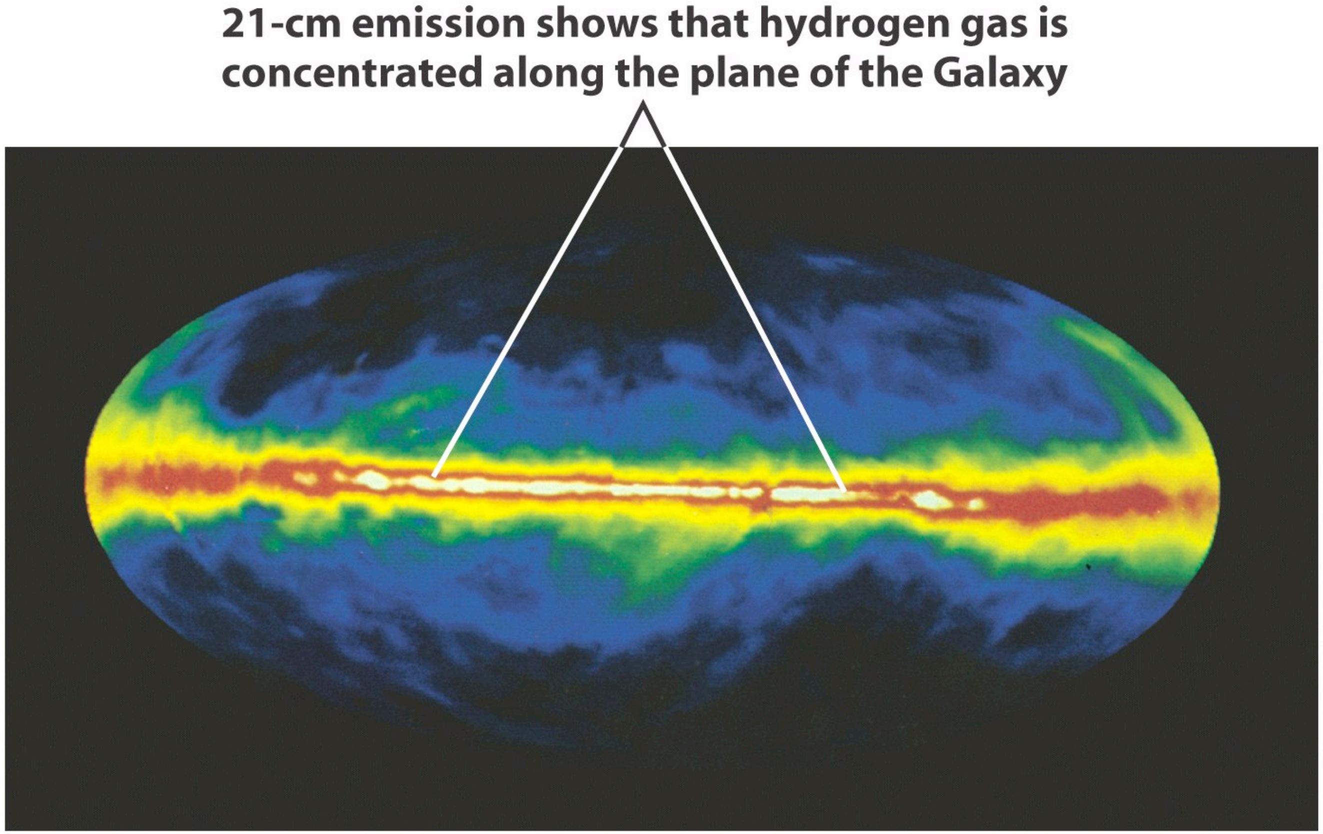


(b) The magnetic energy of a proton and electron depends on their relative spin orientation

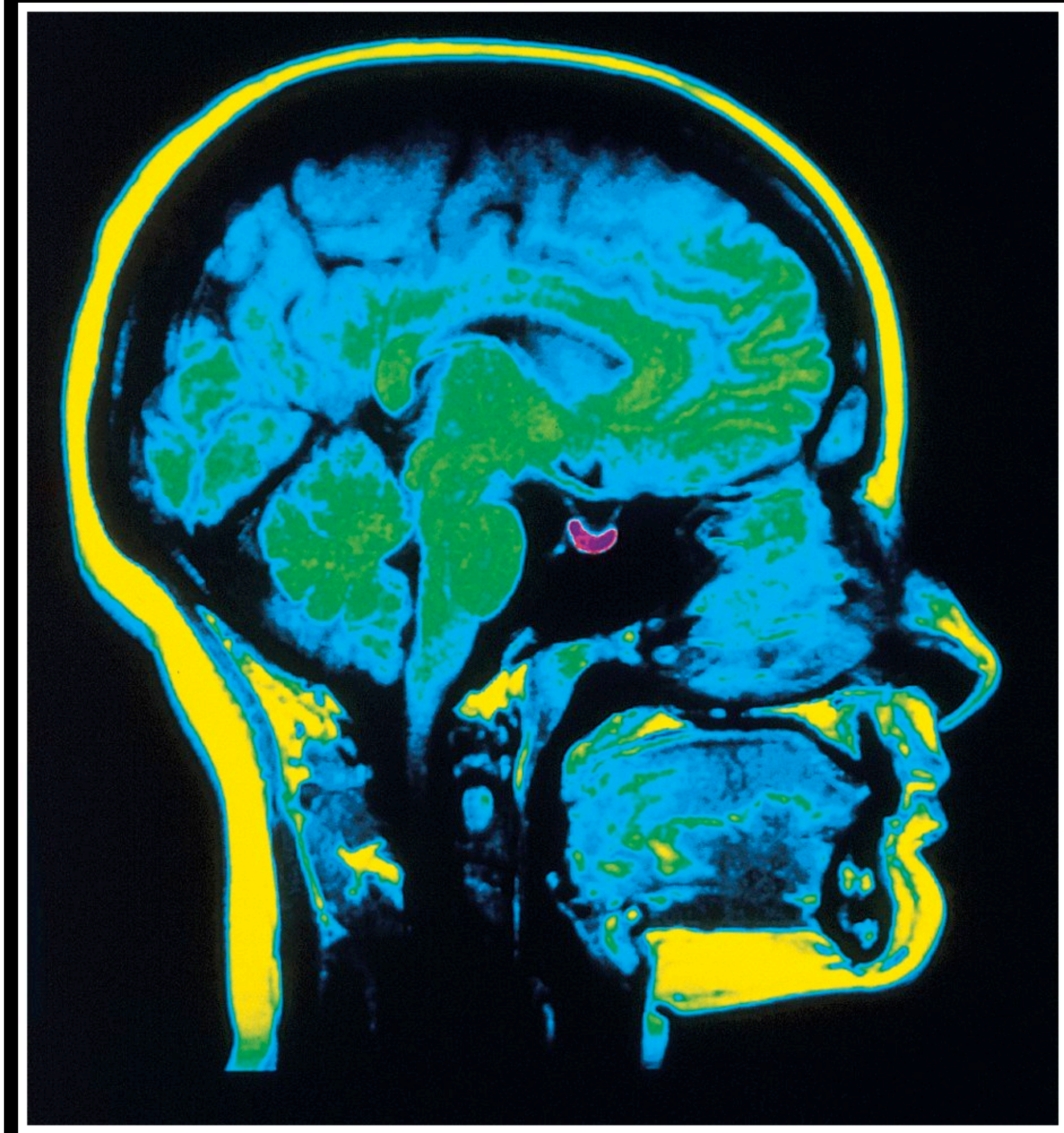
H is the most abundant element in the universe. What makes it possible to map
The dsitirbution of hydrogen in our Galaxy is that even *cold* hydrogen clouds emit
Radio waves.

(very small energy between the transition between configurations

These emissions easily penetrate the intervening interstellar dust

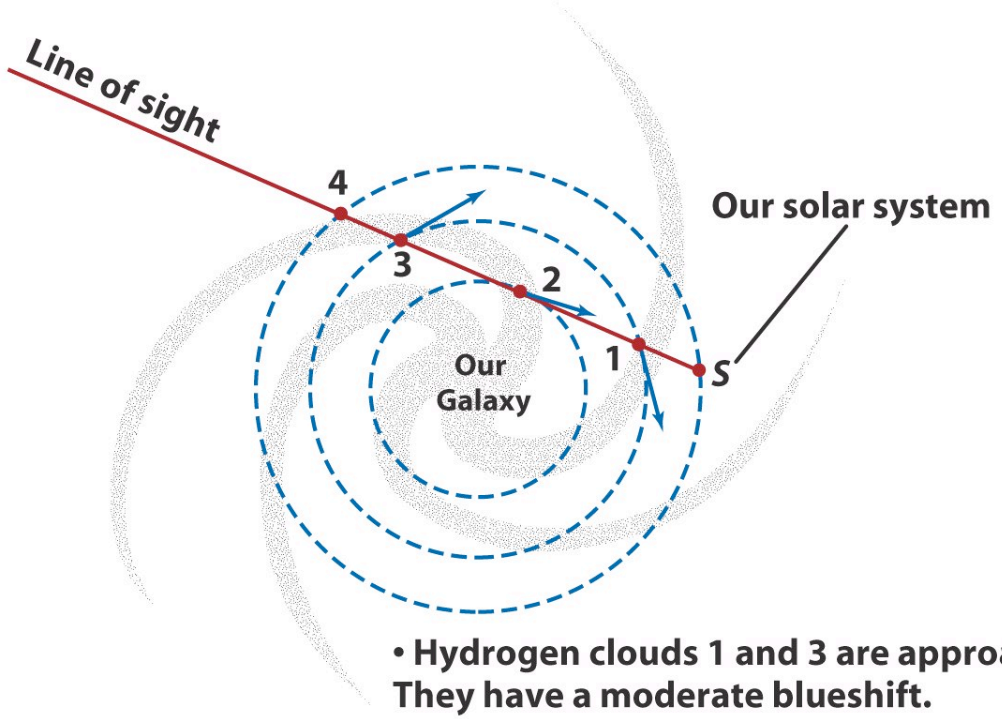


1951 Ewen and Purcell were the first to succeed in detecting this faint emission
From hydrogen between the stars



- This is the same physical principle behind magnetic resonance imaging (MRI), an important diagnostic tool of modern medicine

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.

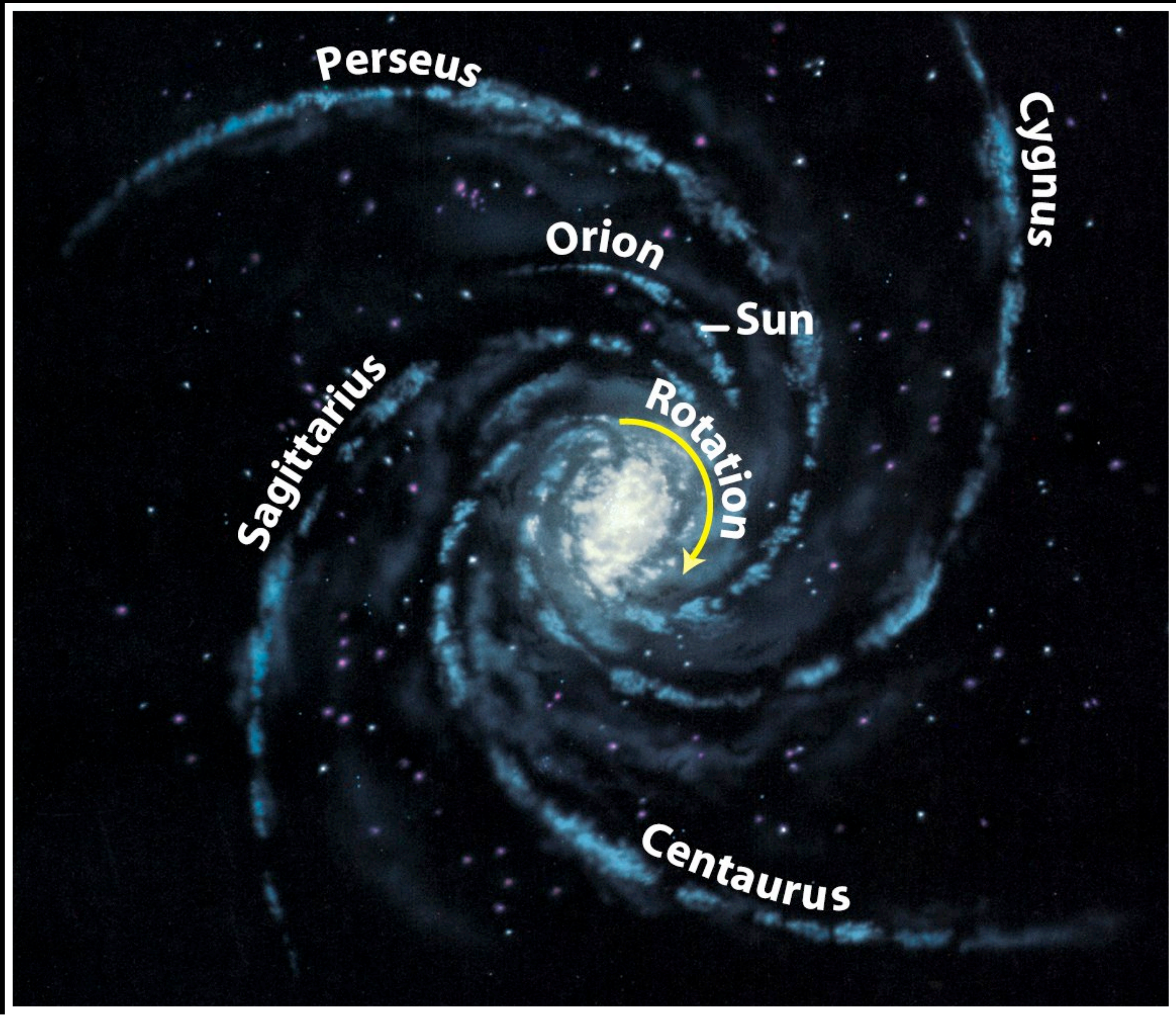
• Hydrogen cloud 2 is approaching us at a faster speed: It has a larger blueshift.

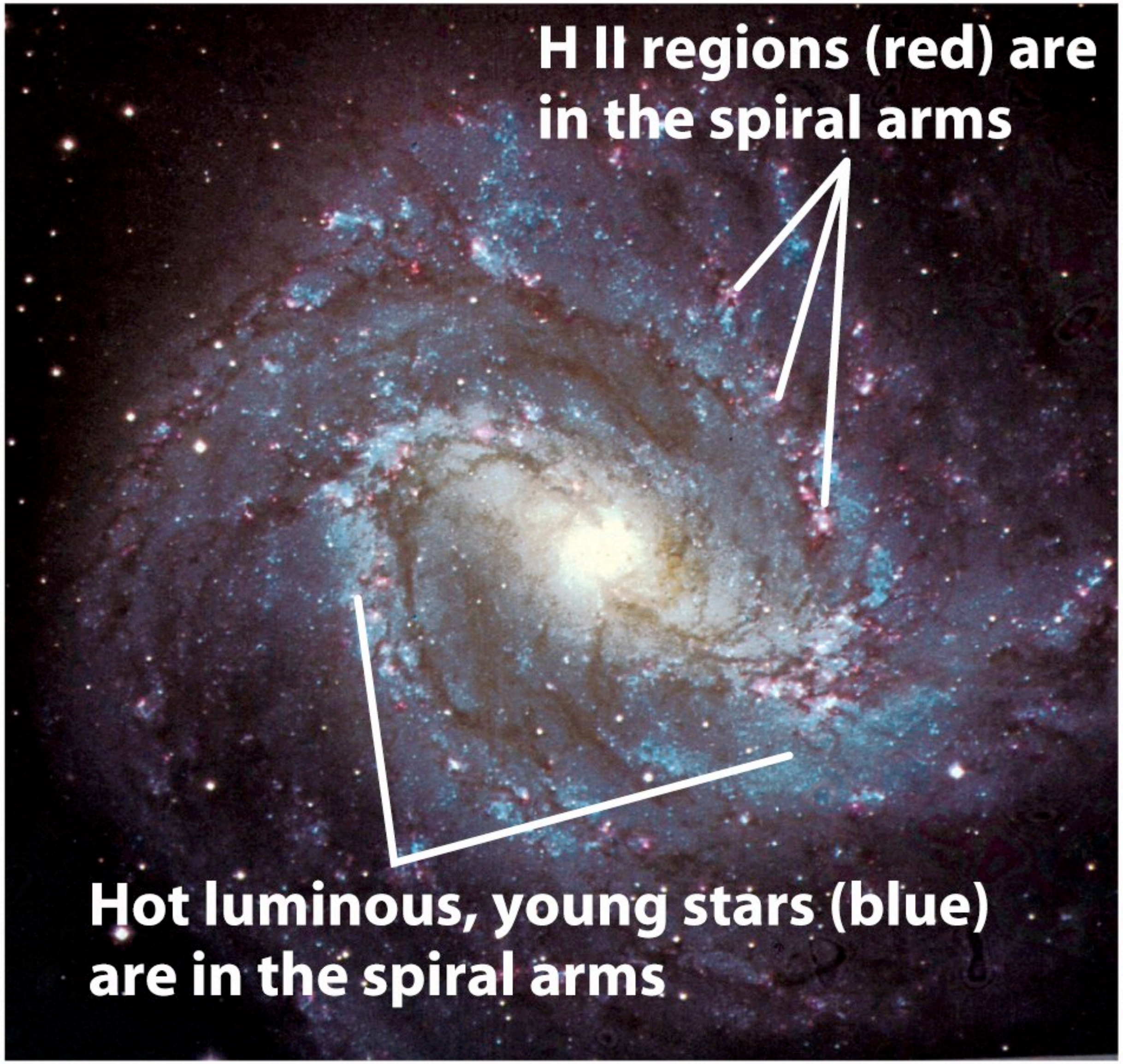
• Hydrogen cloud 4 is neither approaching nor receding: It has no redshift or blueshift.

Remember: doppler shift reveals only motion *along* the line of sight

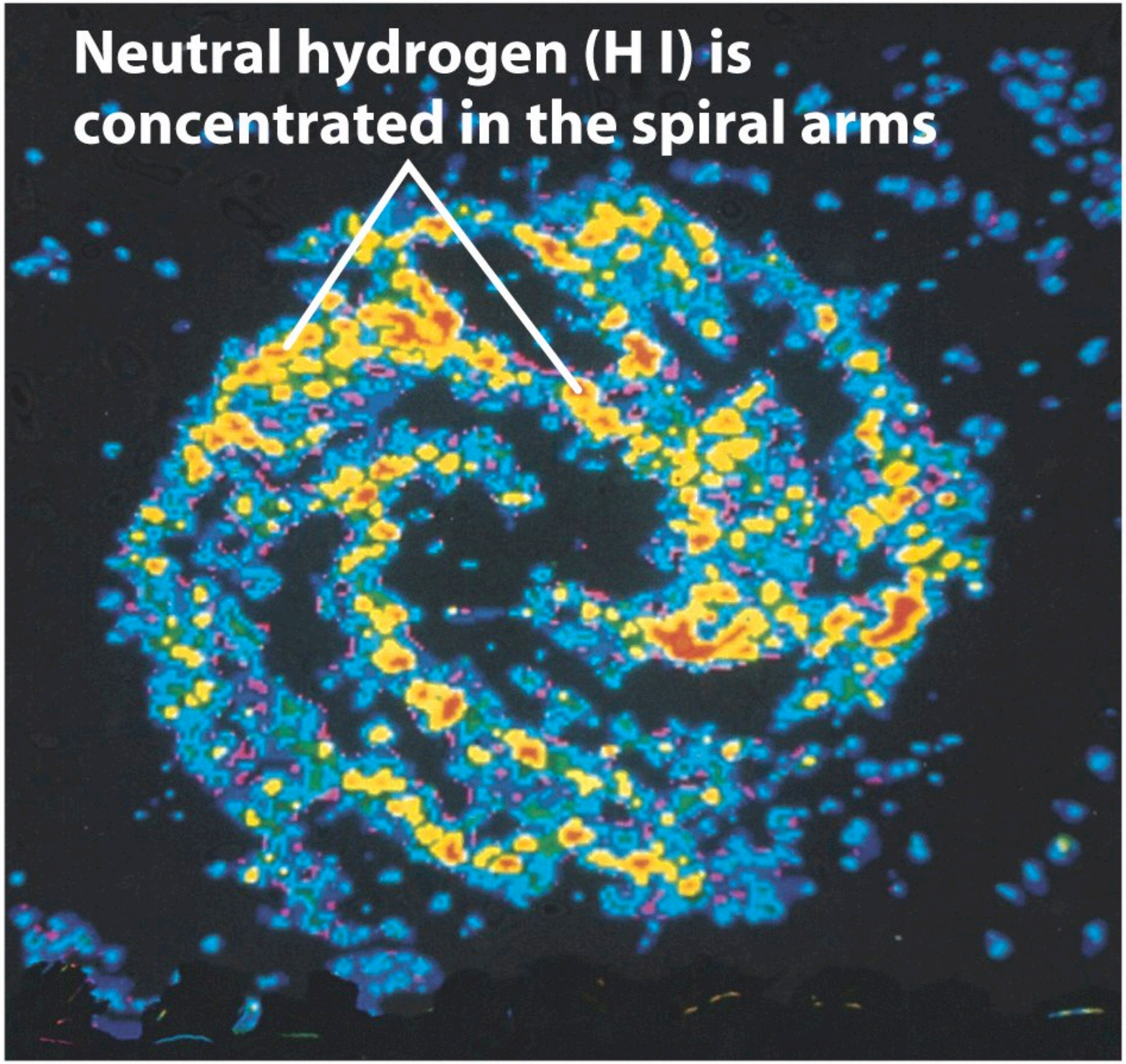

You are here
Center
of Galaxy

OB associations, H II regions, and molecular clouds in the galactic disk outline huge spiral arms

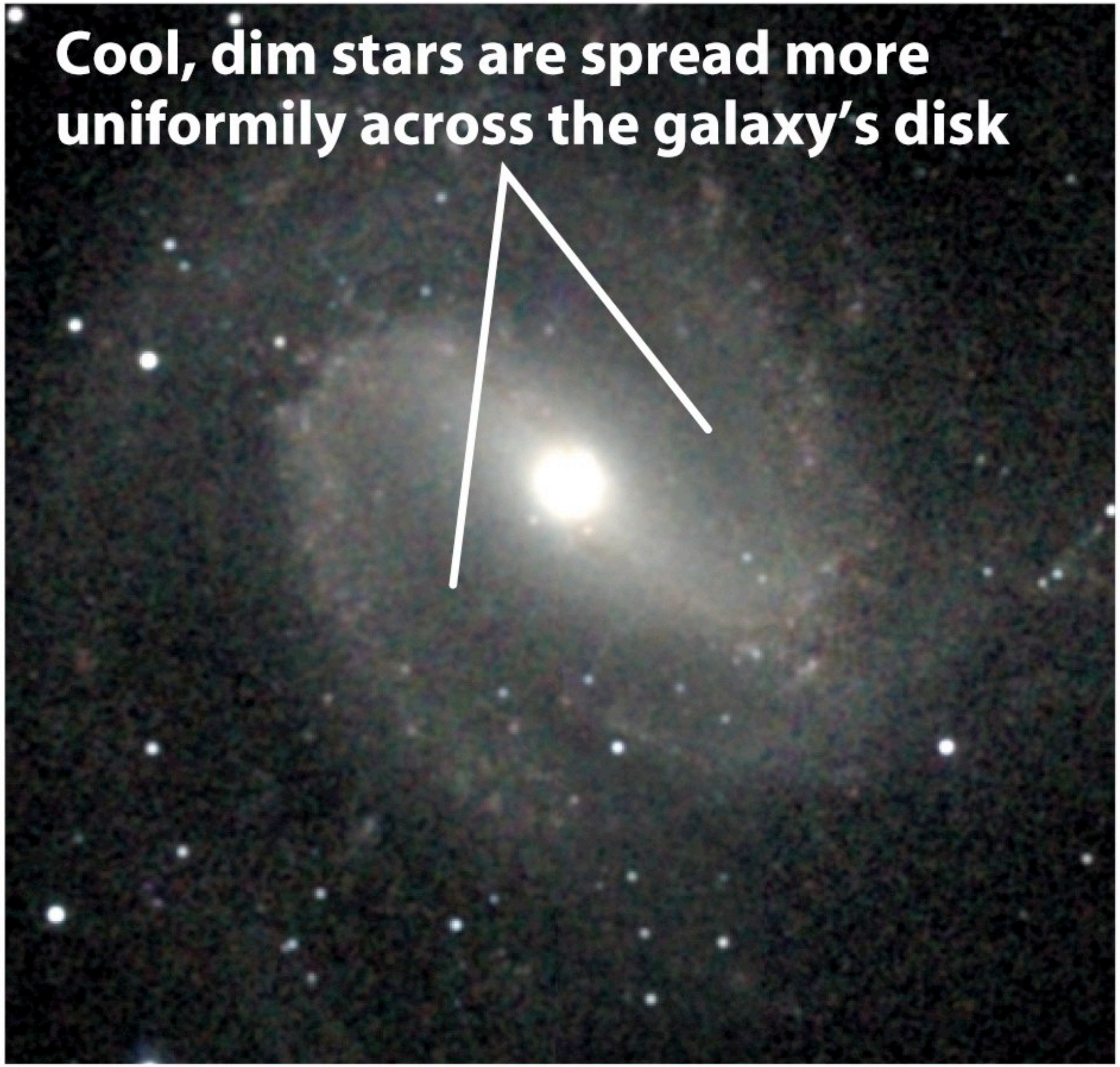




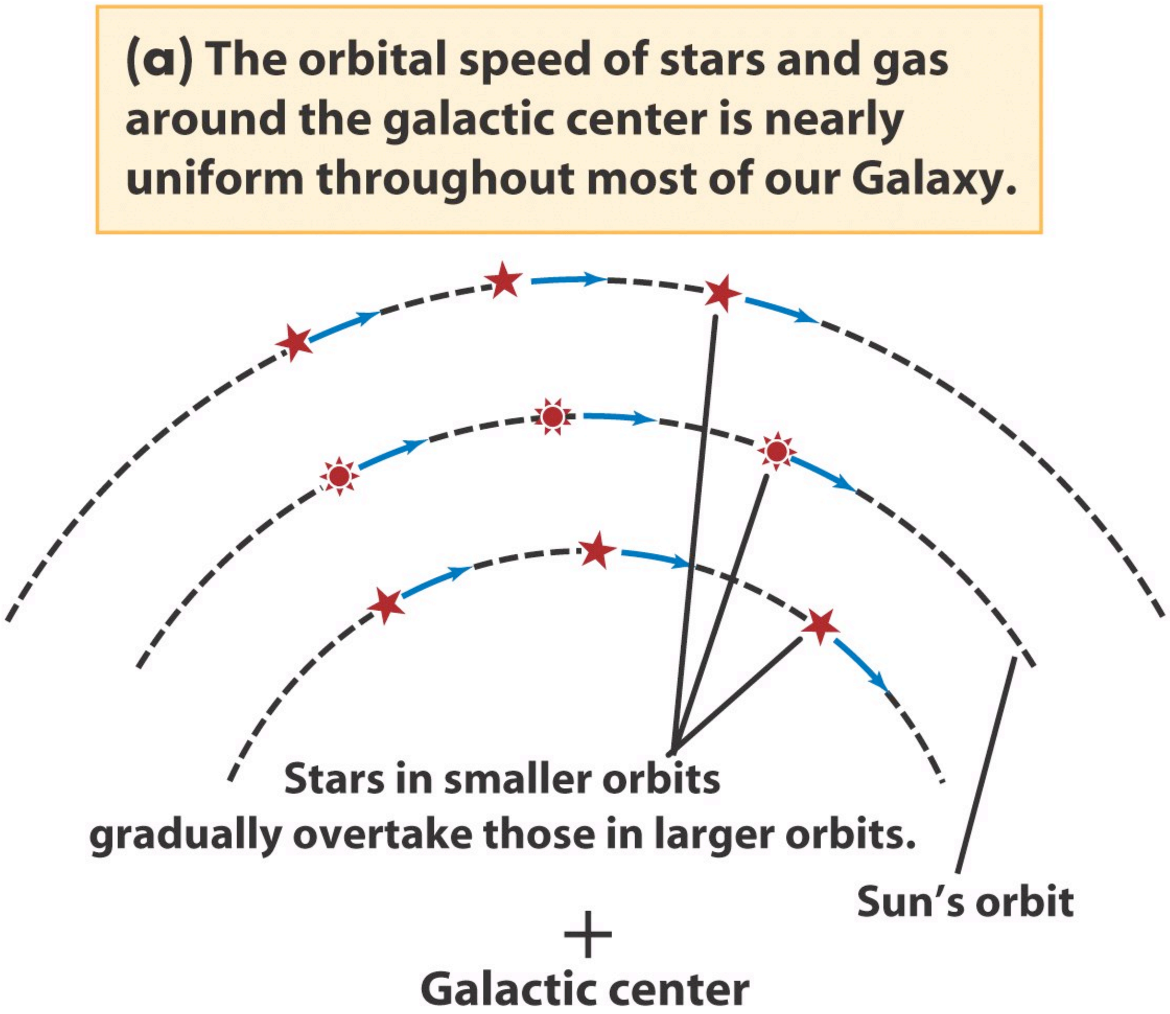
Visible-light view of M83



21-cm radio view of M83

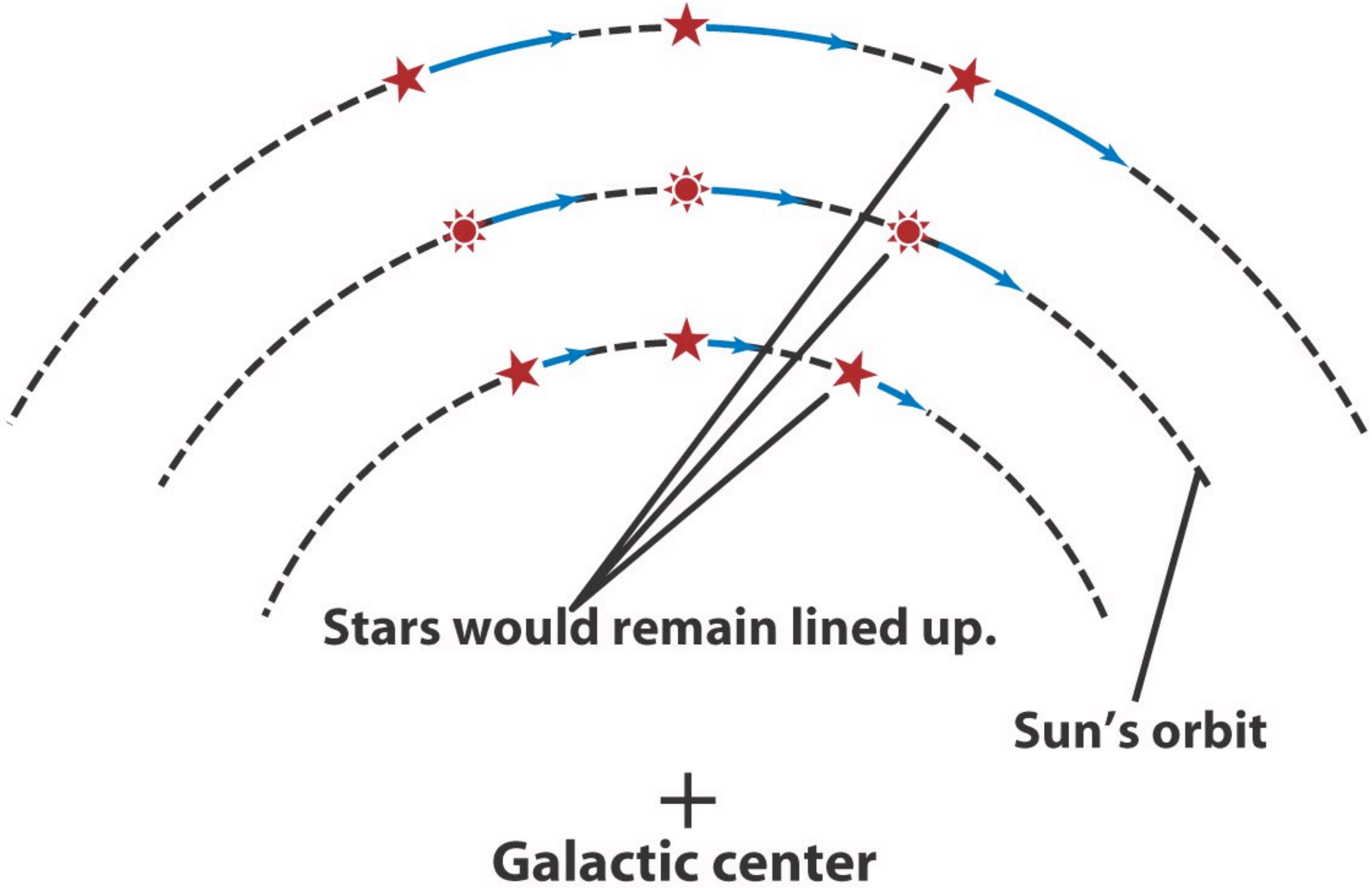


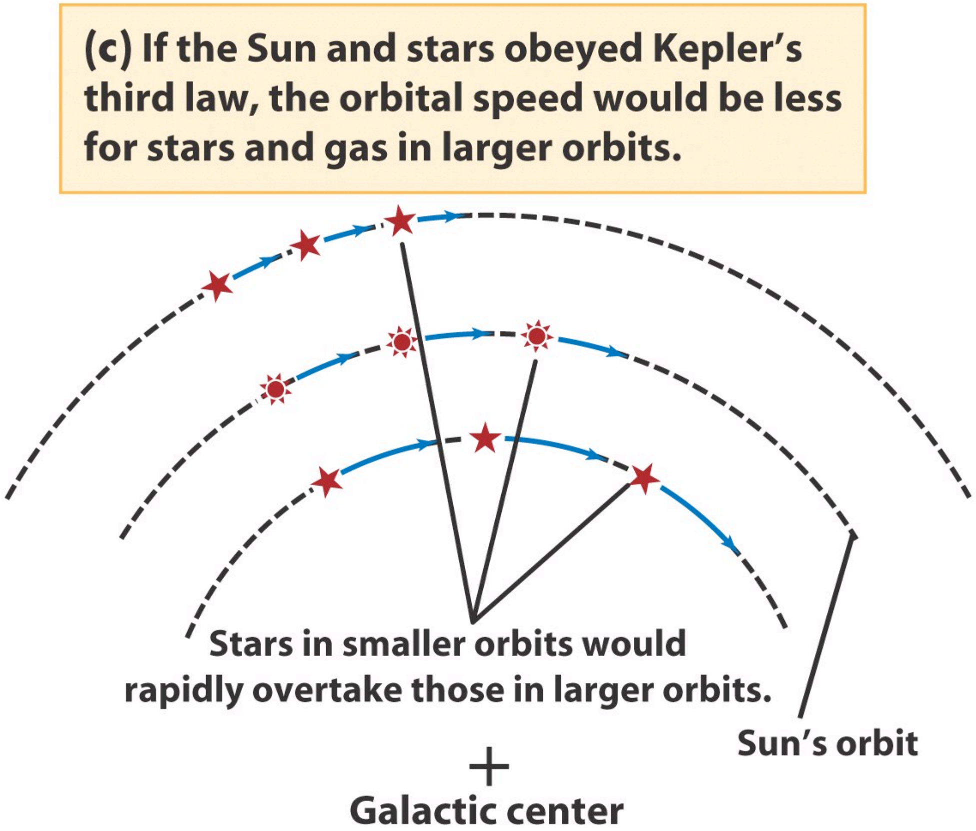
Near-infrared view of M83



Radio observation of 21 cm indicated that the star and gas all orbit in the same
Direction around the galactic center and that the orbital speed is
Fairly uniform throughout much of the Galaxy's disk

(b) If our Galaxy rotated like a solid disk, the orbital speed would be greater for stars and gas in larger orbits.





The farther a planet is from the Sun the less gravitational force it experiences
And the slower the speed it needs to have to remain in orbit. The fact that the speed does *not* decrease with increasing distance demonstrate that there in no such *single* Massive object

The rotation of our Galaxy reveals the presence of dark matter

From studies of the rotation of the Galaxy, astronomers estimate that the total mass of the Galaxy is about 10^{12} $M_\odot$

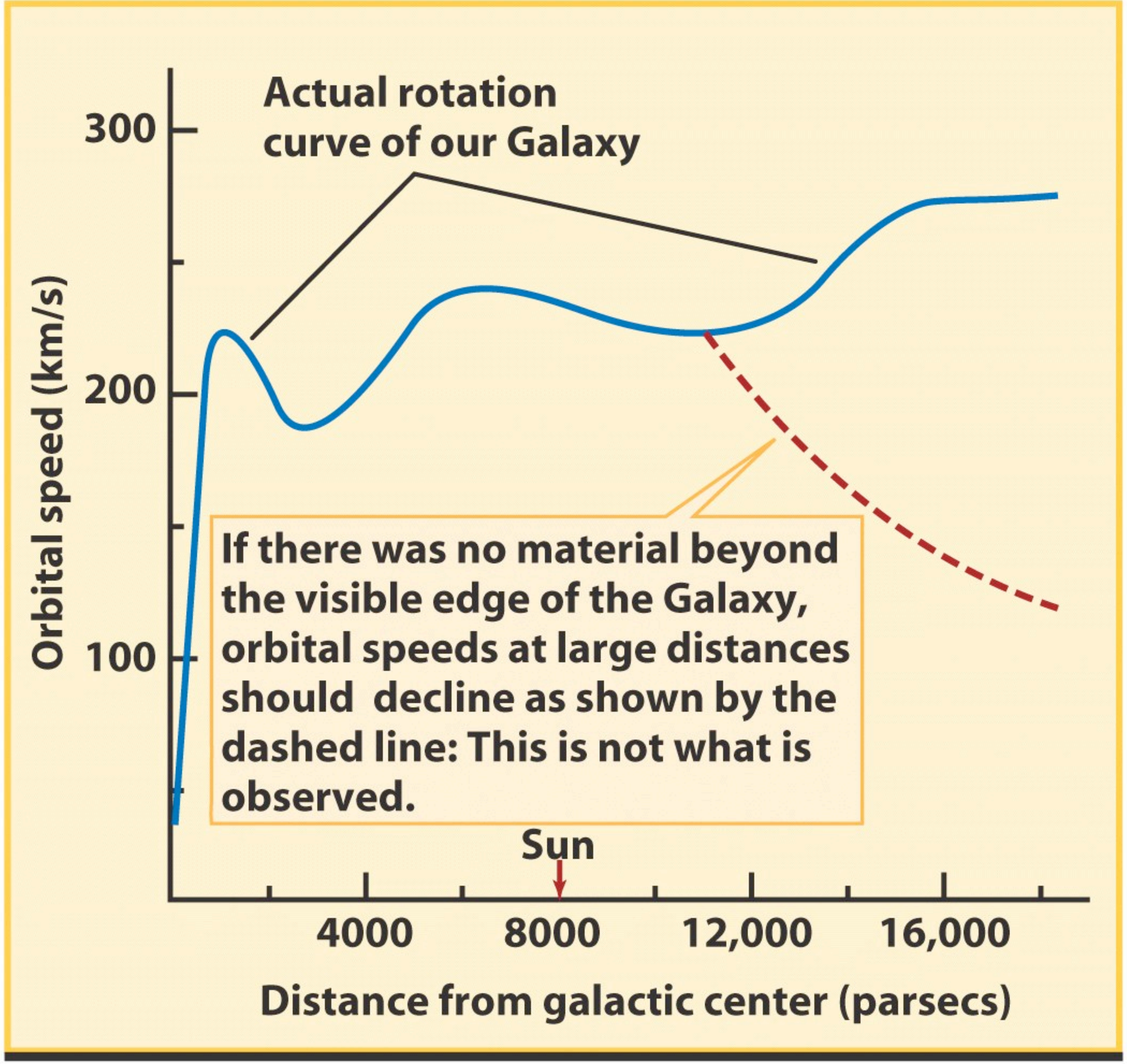
$$M = \frac{rv^2}{G}$$

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

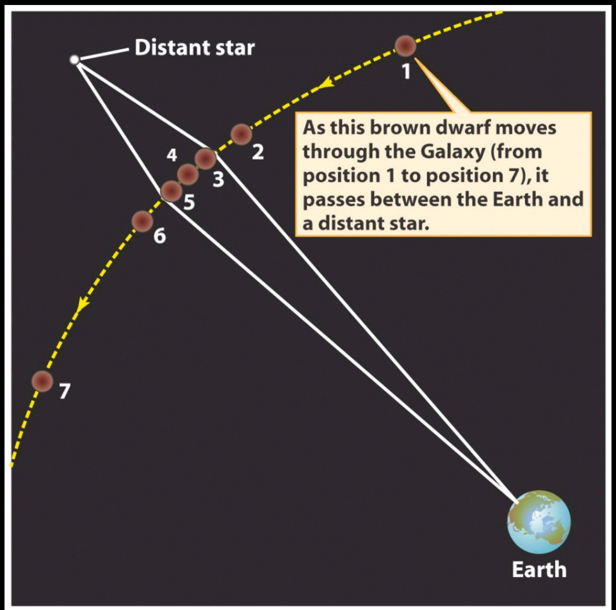
P = orbital period of the Sun

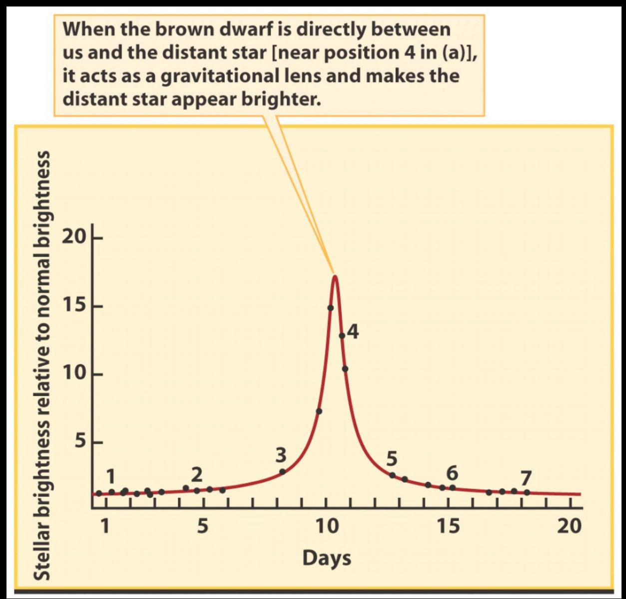
r = distance from the Sun to the galactic center

v = orbital speed of the Sun


Actual rotation
curve of our Galaxy
300
200
100
Orbital speed (km/s)
If there was no material beyond the visible edge of the Galaxy, orbital speeds at large distances should decline as shown by the dashed line: This is not what is observed.
Sun
4000
8000
12,000
16,000
Distance from galactic center (parsecs)

Only about 10% of this mass is in the form of visible stars, gas, and dust

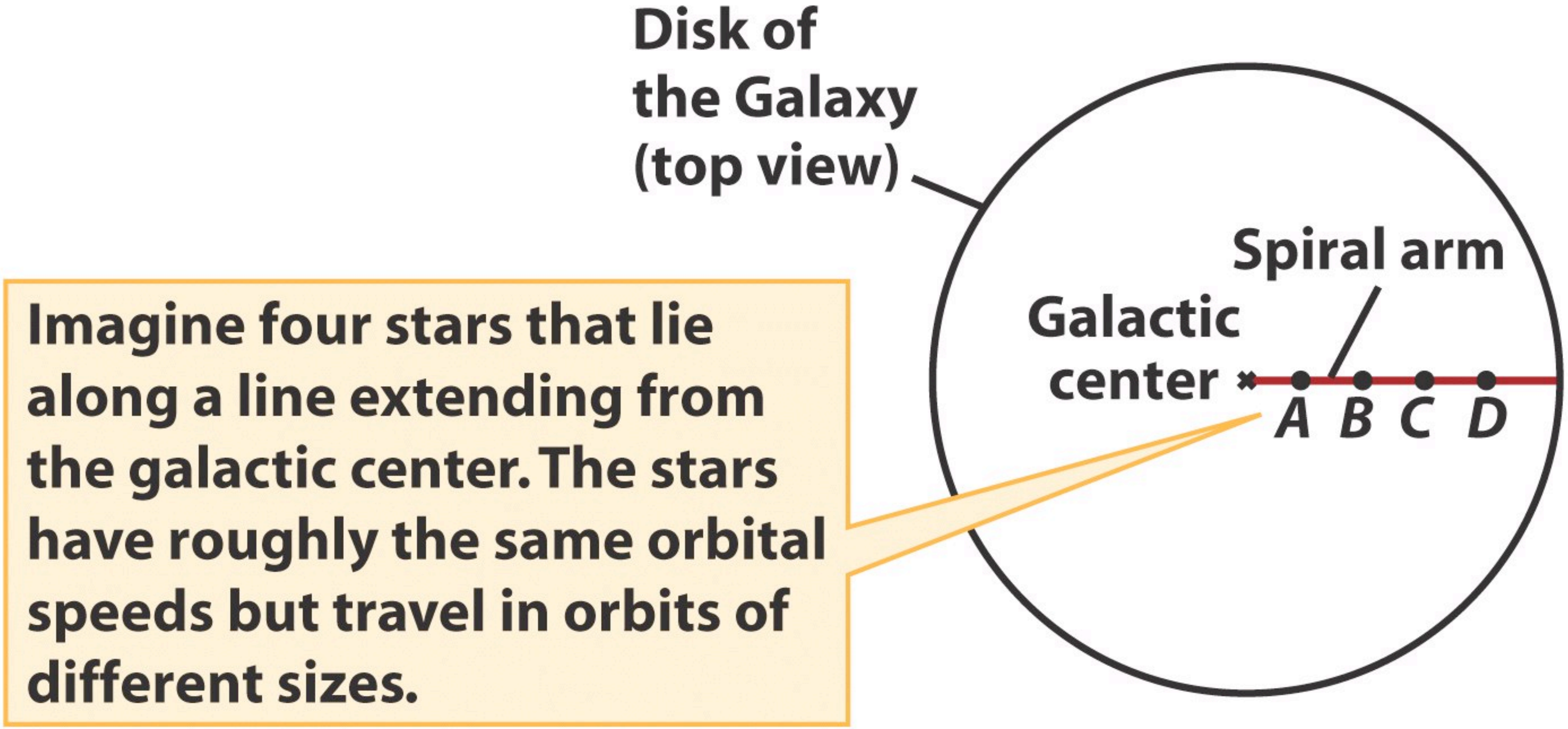


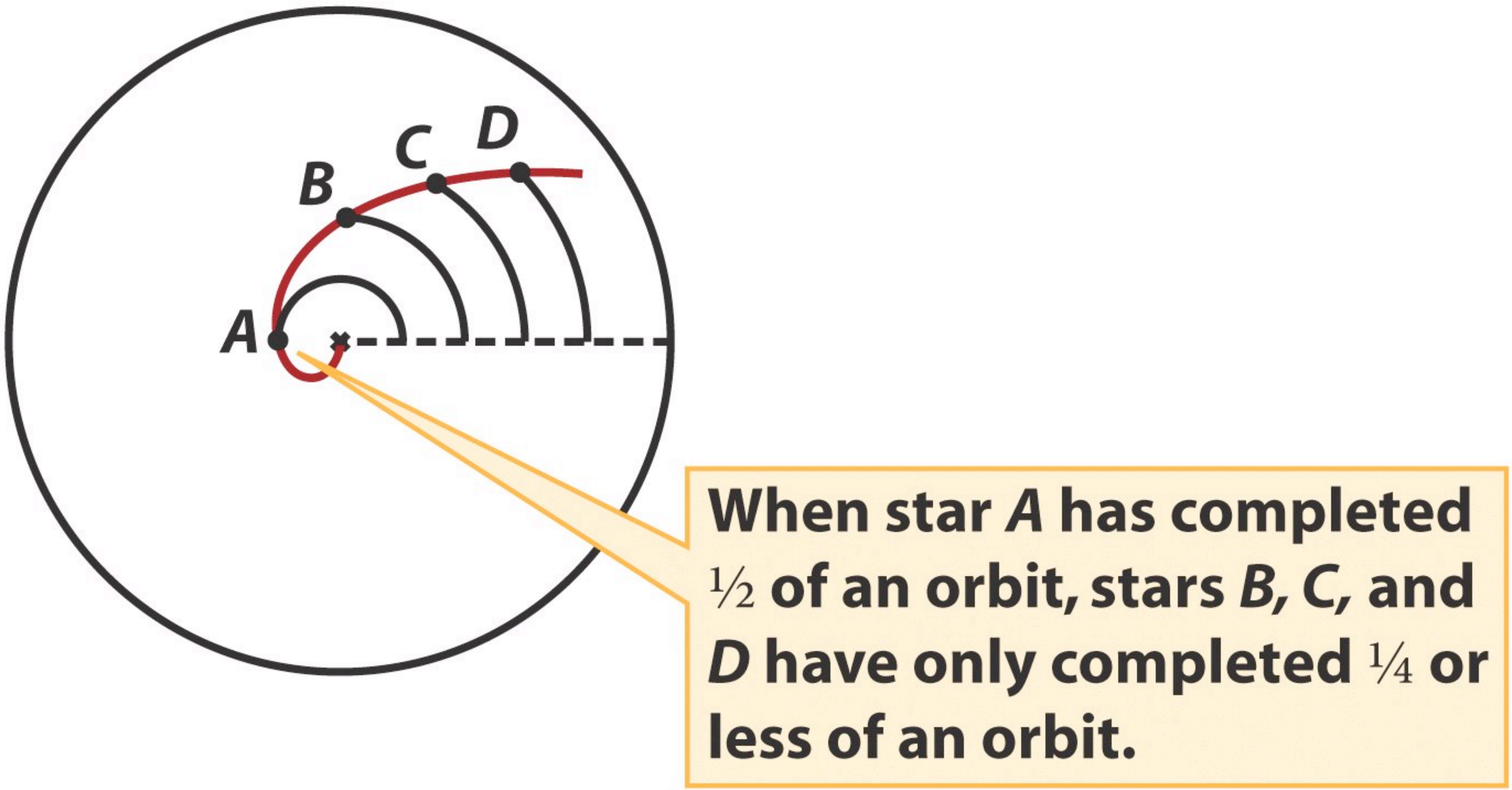


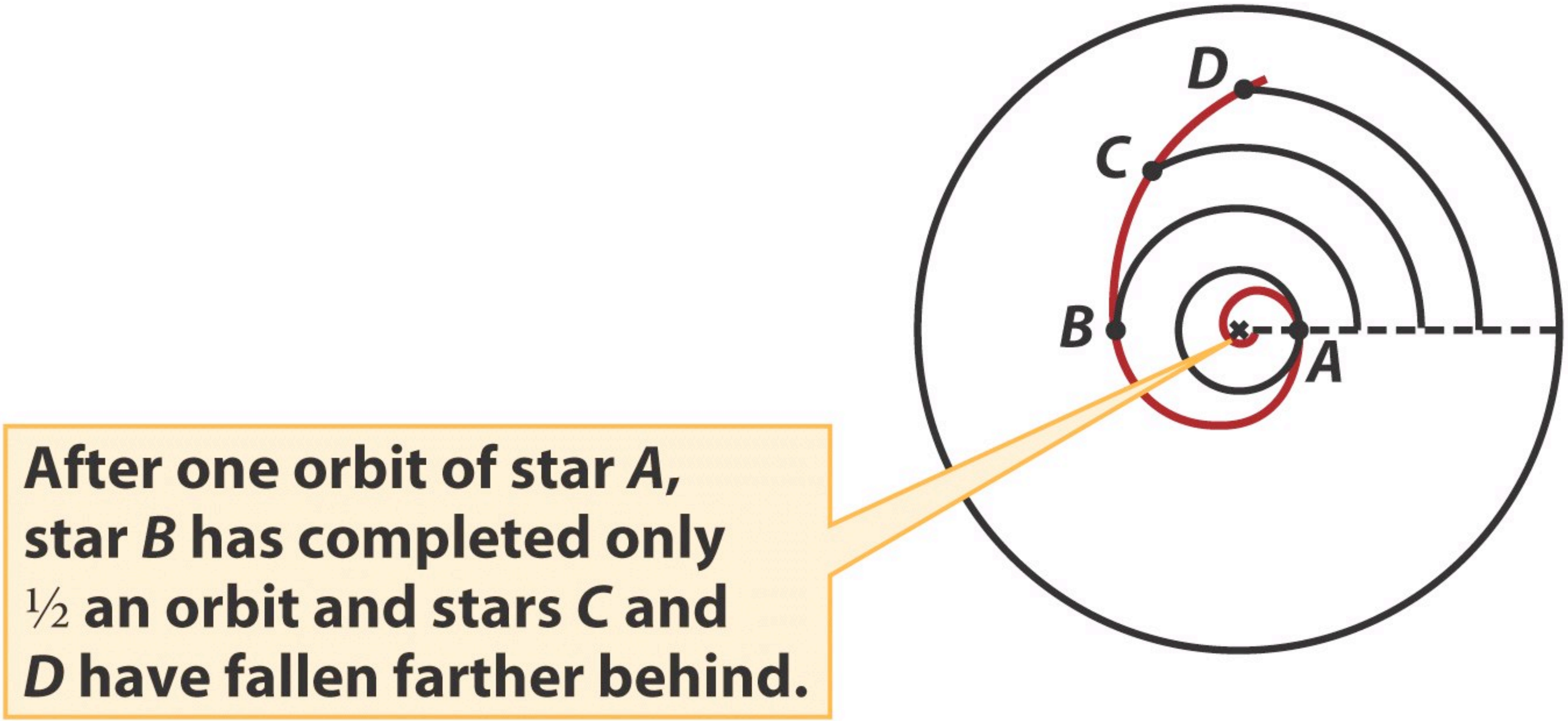
- The remaining 90% is in some nonvisible form, called dark matter, that extends beyond the edge of the luminous material in the Galaxy
- Our Galaxy’s dark matter may be a combination of MACHOs (dim, star-sized objects), massive neutrinos, and WIMPs (relatively massive subatomic particles)

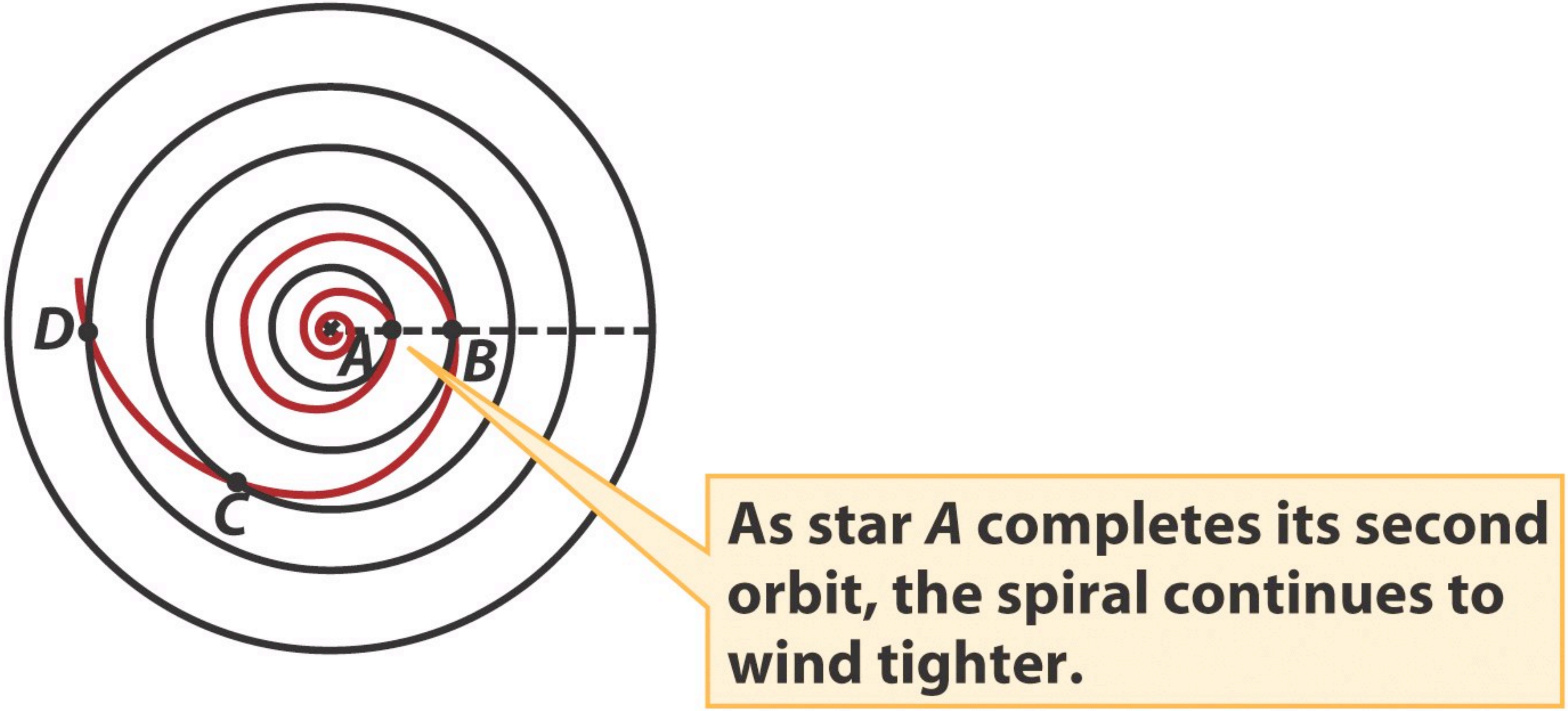
Dark Matter and Vera Rubin

In 1965, Rubin became the first woman permitted to observe at the Palomar Observatory.When George Gamow invited Rubin to visit him at the Applied Physics Laboratory, they had to talk in the lobby of the Laboratory because women were not allowed in to the offices.


Disk of the Galaxy (top view)
Spiral arm
Galactic center
A B C D
Imagine four stars that lie along a line extending from the galactic center. The stars have roughly the same orbital speeds but travel in orbits of different sizes.


A
B
C
D
When star *A* has completed ½ of an orbit, stars *B*, *C*, and *D* have only completed ¼ or less of an orbit.


D
C
B
A
After one orbit of star A, star B has completed only ½ an orbit and stars C and D have fallen farther behind.

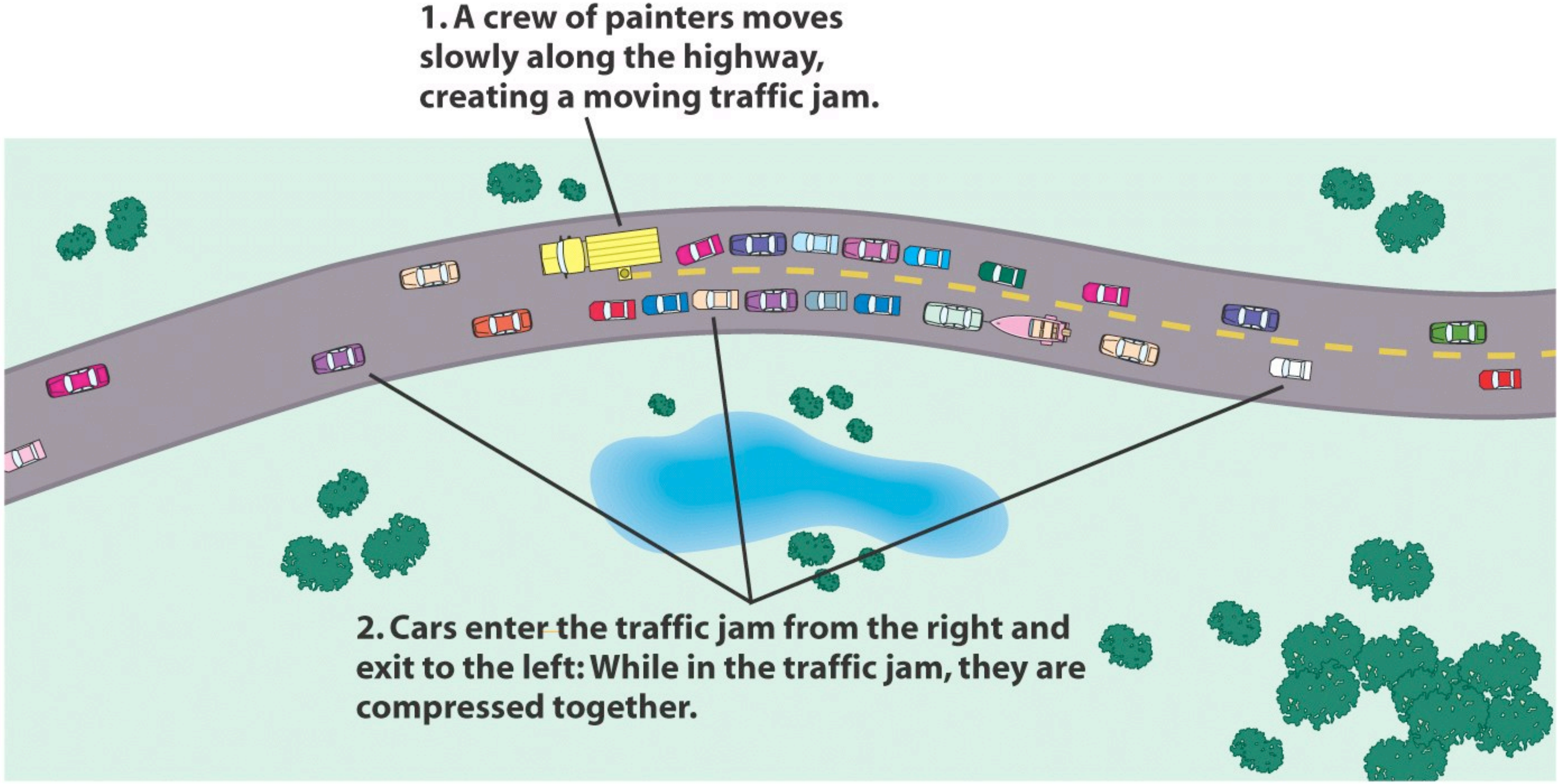


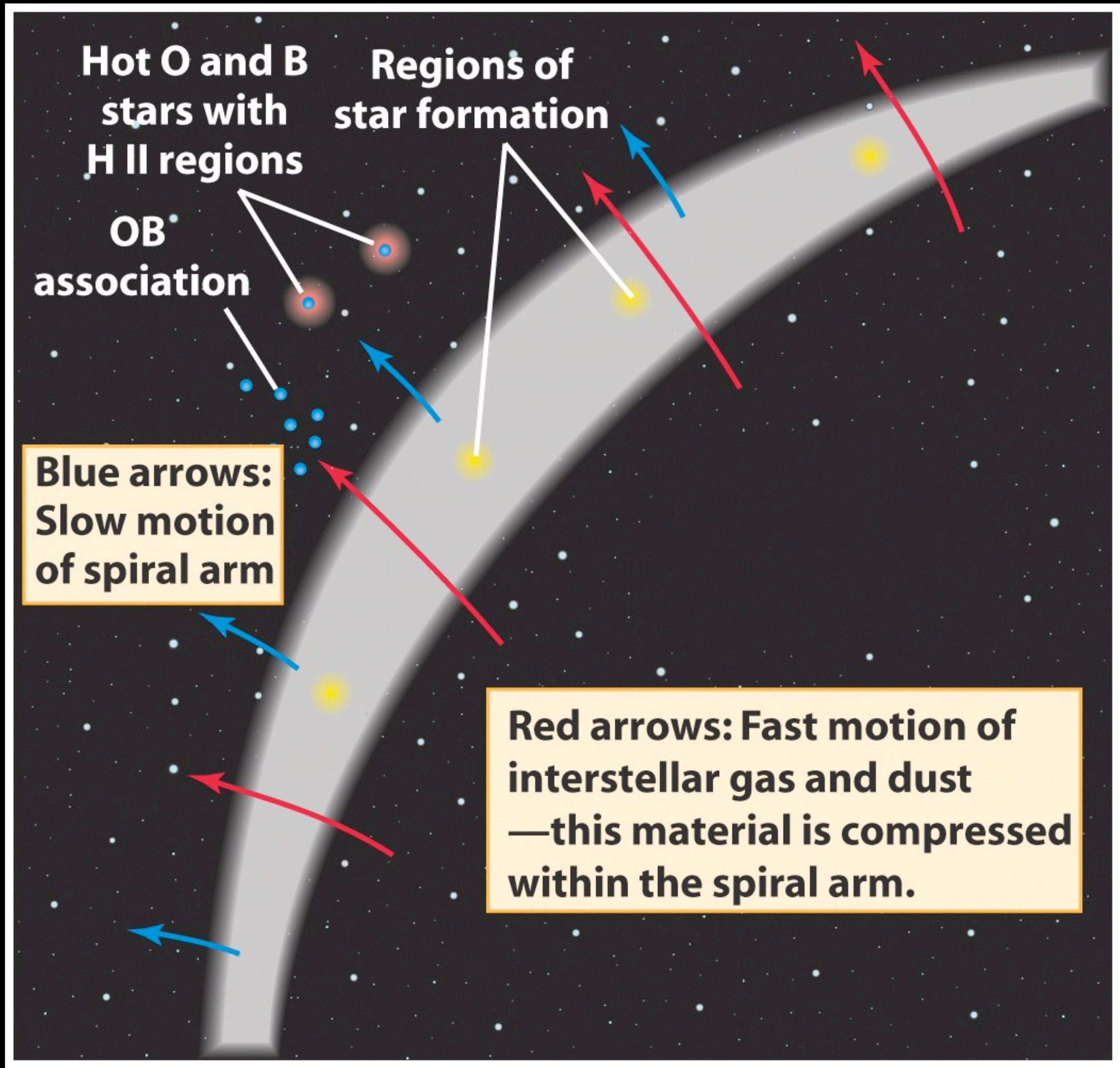
This suggest that the MW spiral arms ought to have disappeared by now
This is the **winding dilemma**

Spiral arms are caused by density waves that sweep around the Galaxy

Grand-design spiral galaxy

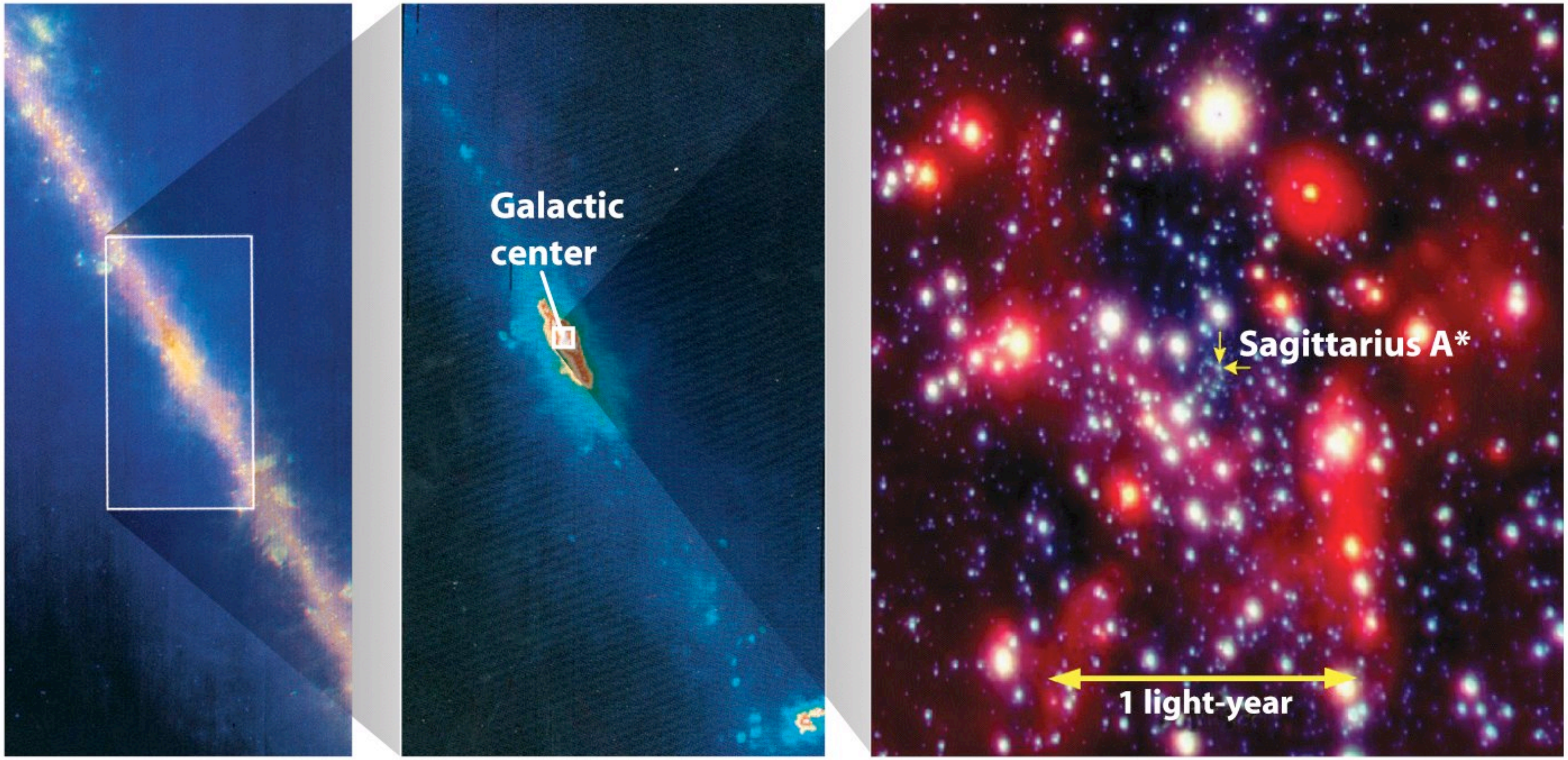
- There are two leading theories of spiral structure in galaxies
- According to the density-wave theory, spiral arms are created by density waves that sweep around the Galaxy (first suggested by Bertil Lindblad (1940) and then enhanced in 60’ by Lin & Shu.
- The gravitational field of this spiral pattern compresses the interstellar clouds through which it passes, thereby triggering the formation of the OB associations and H II regions that illuminate the spiral arms


1. A crew of painters moves slowly along the highway, creating a moving traffic jam.
2. Cars enter the traffic jam from the right and exit to the left: While in the traffic jam, they are compressed together.


Hot O and B stars with H II regions
Regions of star formation
OB association
Blue arrows: Slow motion of spiral arm
Red arrows: Fast motion of interstellar gas and dust —this material is compressed within the spiral arm.

- According to the theory of self-propagating star formation, spiral arms are caused by the birth of stars over an extended region in a galaxy
- Differential rotation of the galaxy stretches the star forming region into an elongated arch of stars and nebulae.

Flocculent spiral galaxy

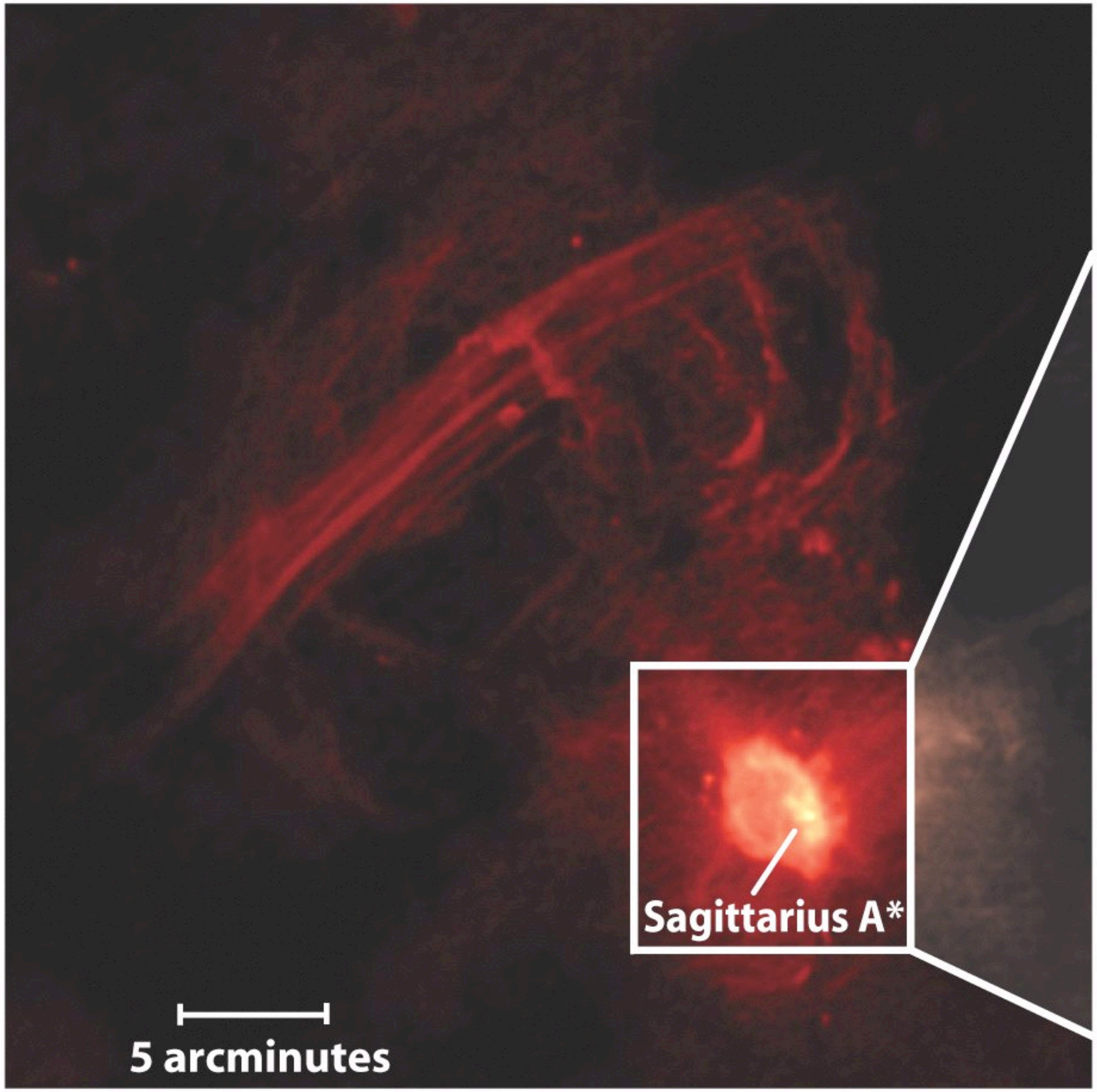


(a) A wide-angle (50°) infrared view

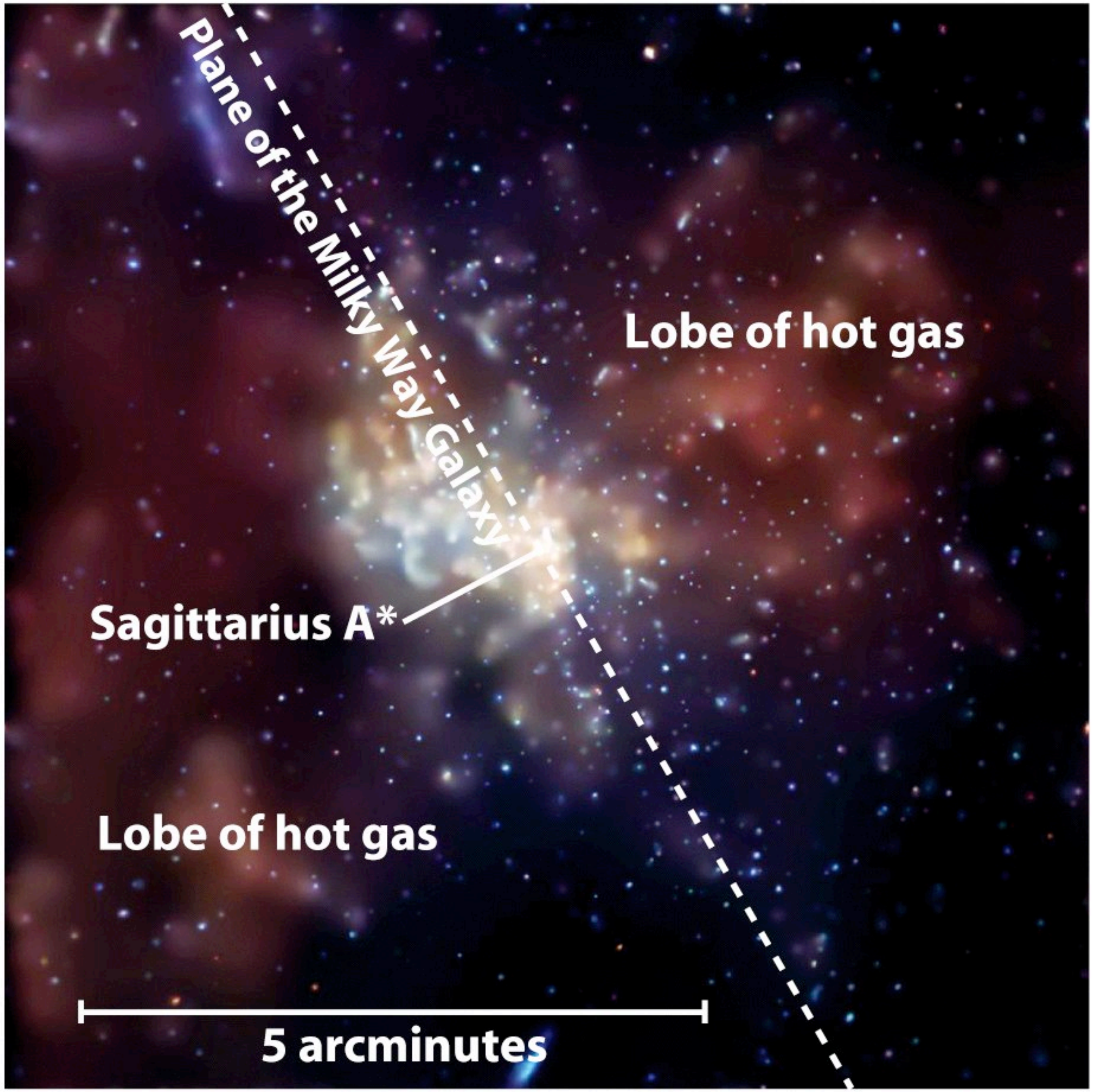
(b) A close-up view shows a more luminous region at the galactic center

(c) An extreme close-up view centered on Sagittarius A*, a radio source at the very center of the Milky Way Galaxy, shows hundreds of stars within 1 ly (0.3 pc)

The innermost part of the Galaxy, or galactic nucleus, has been studied through its radio, infrared, and X-ray emissions (which are able to pass through interstellar dust)

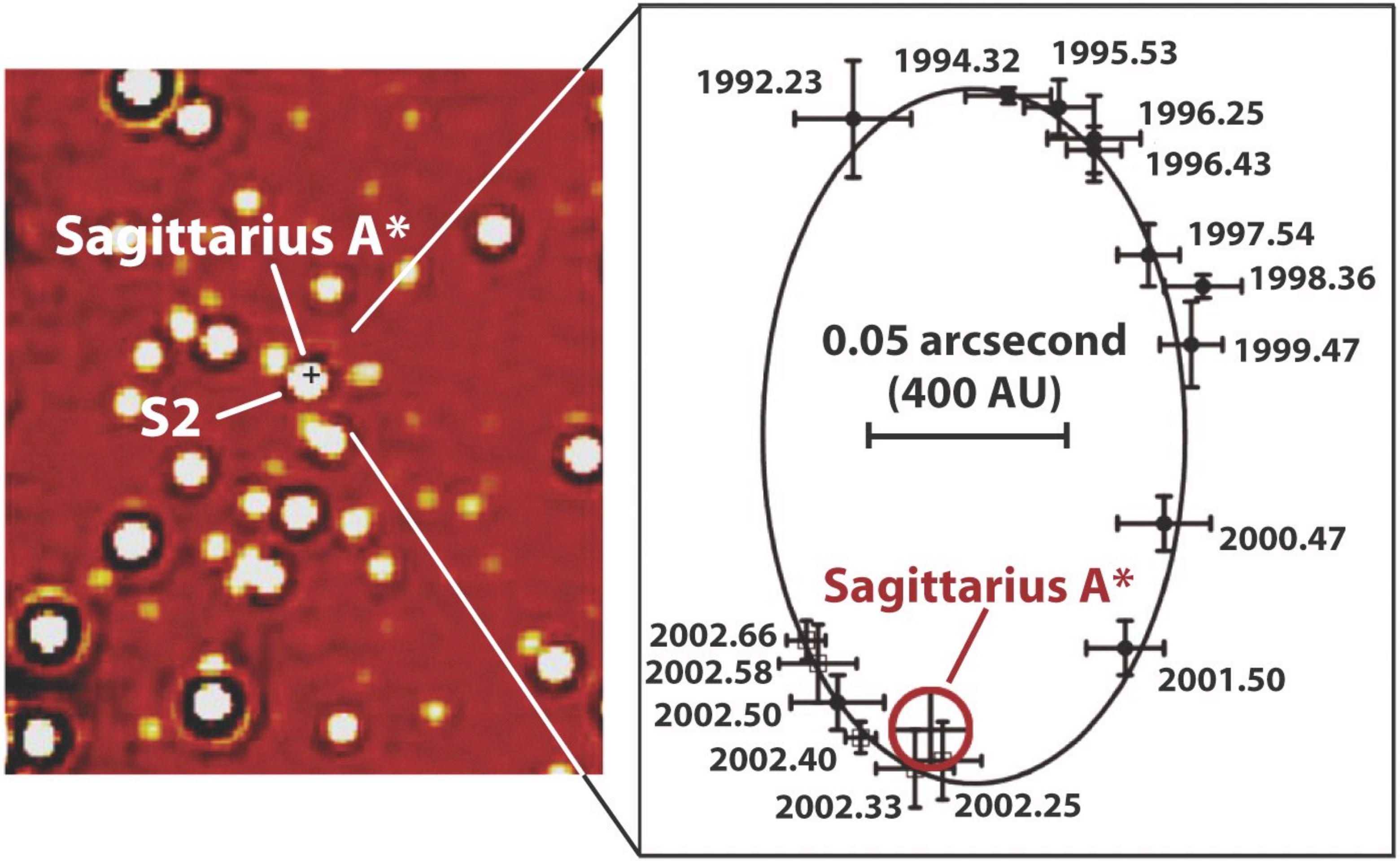


A radio view of the galactic center



An X-ray view of the galactic center

A strong radio source called Sagittarius A* is located at the galactic center



This marks the position of a supermassive black hole with a mass of about $3.7 \times 10^6\ M_\odot$