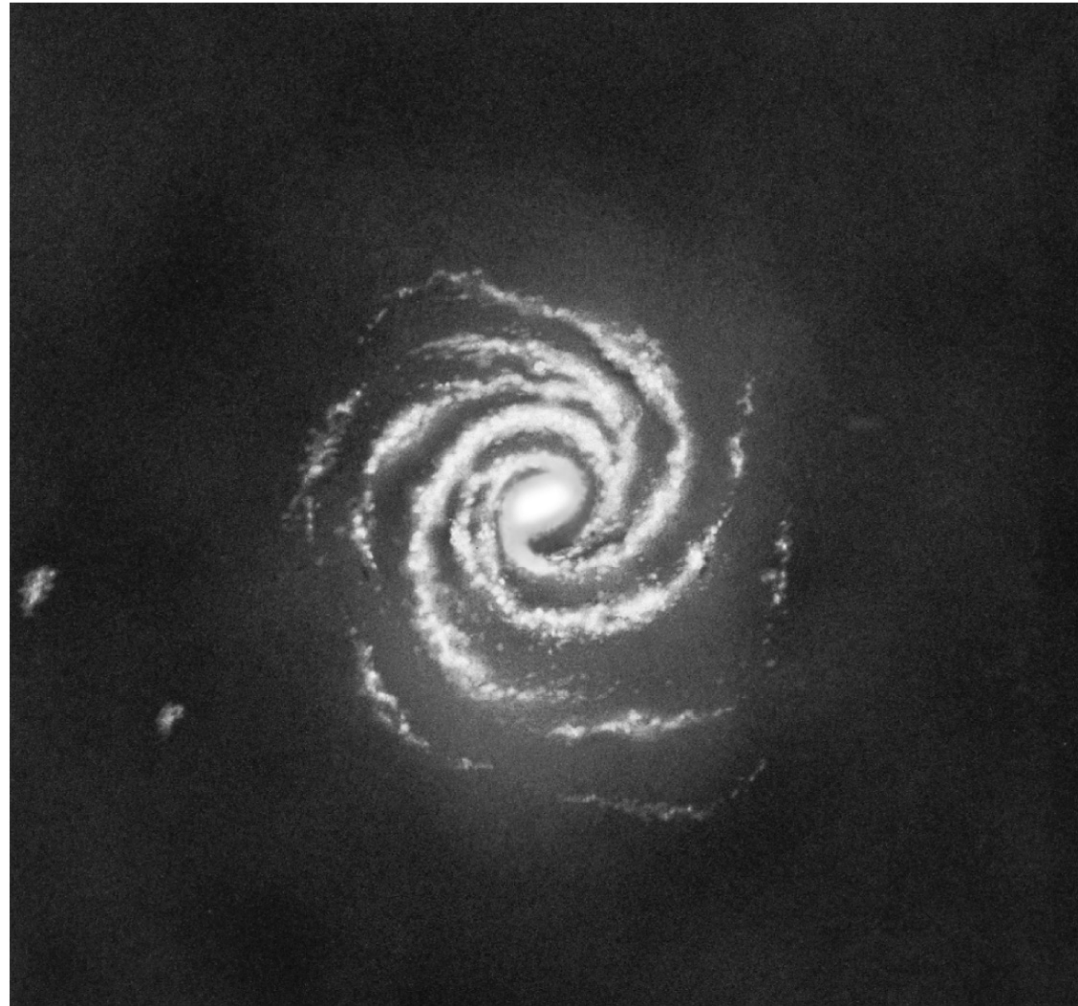


14.5 Galactic Spiral Arms

Measurement of the position and motion of gas clouds shows that the Milky Way has a spiral form:

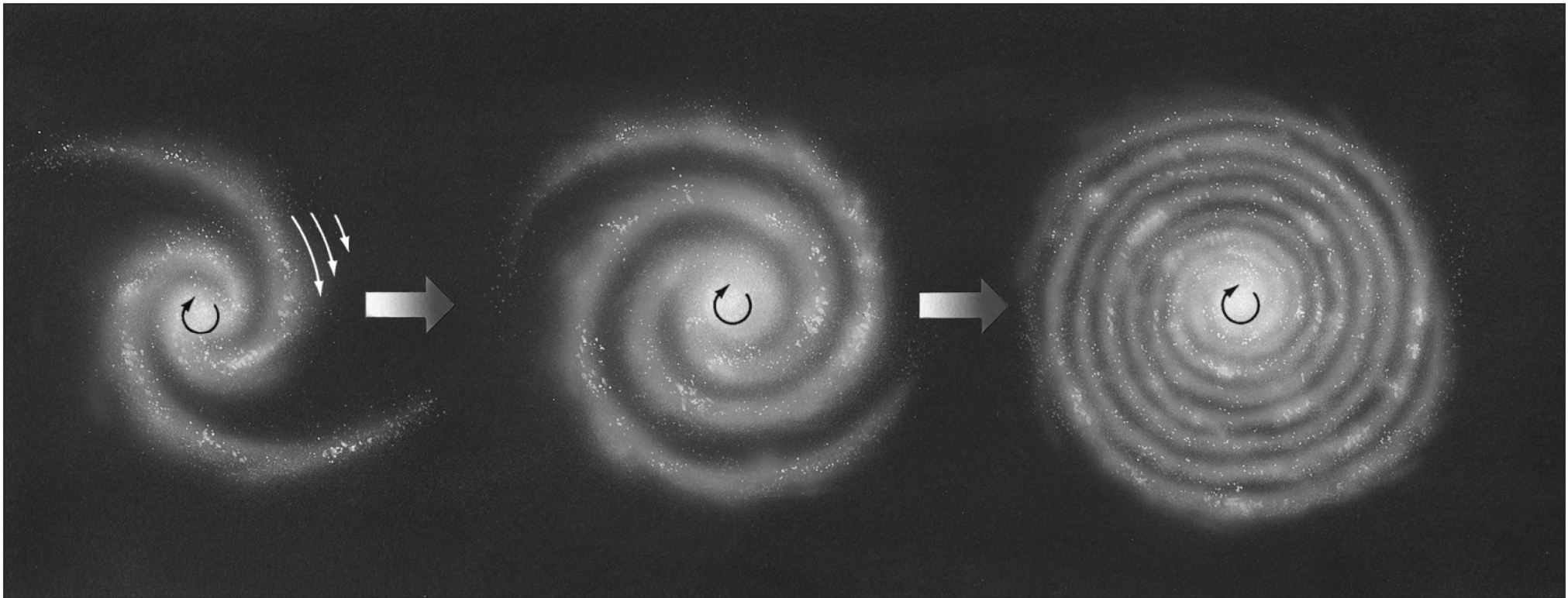


30 kpc

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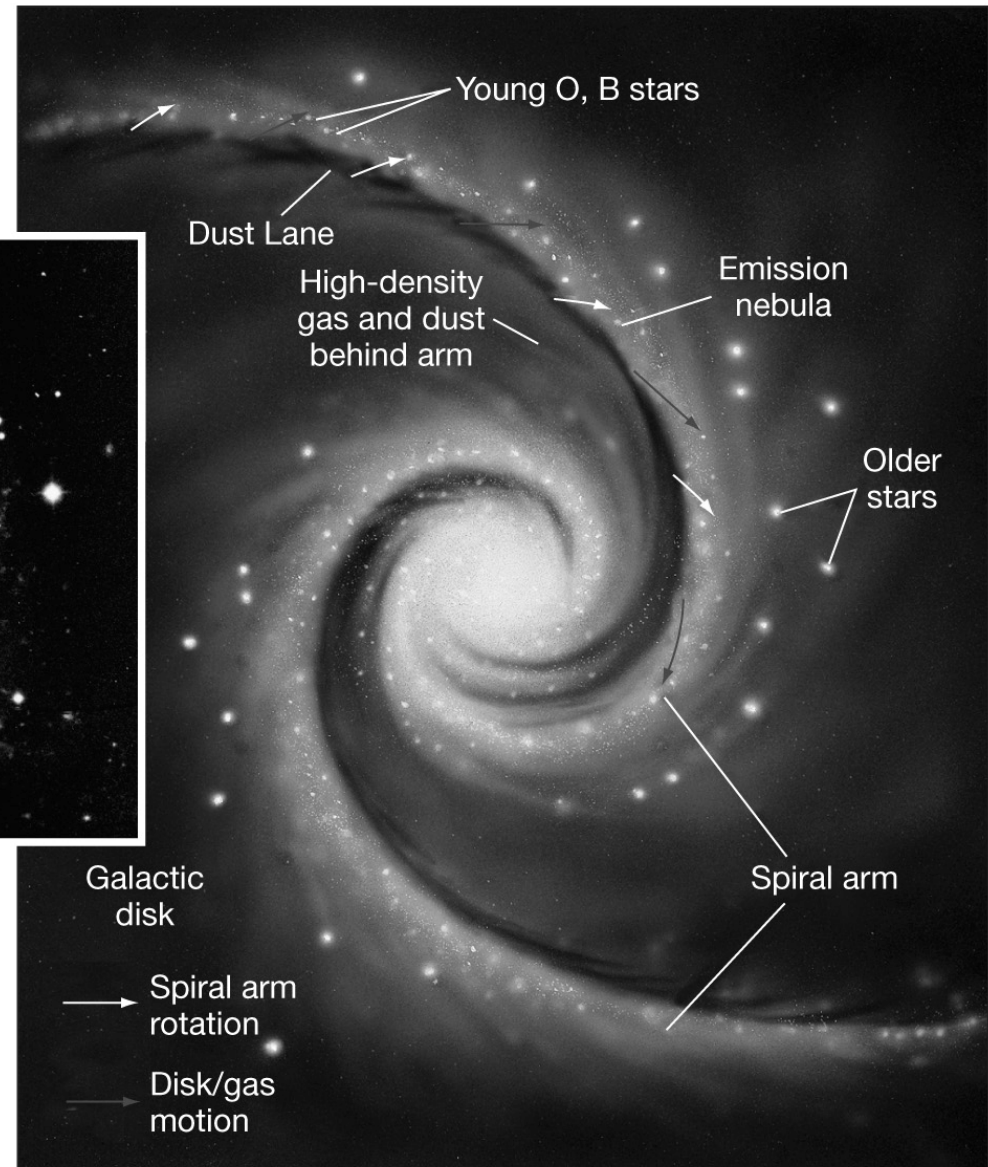
14.5 Galactic Spiral Arms

The spiral arms cannot rotate along with the galaxy; they would “curl up”:



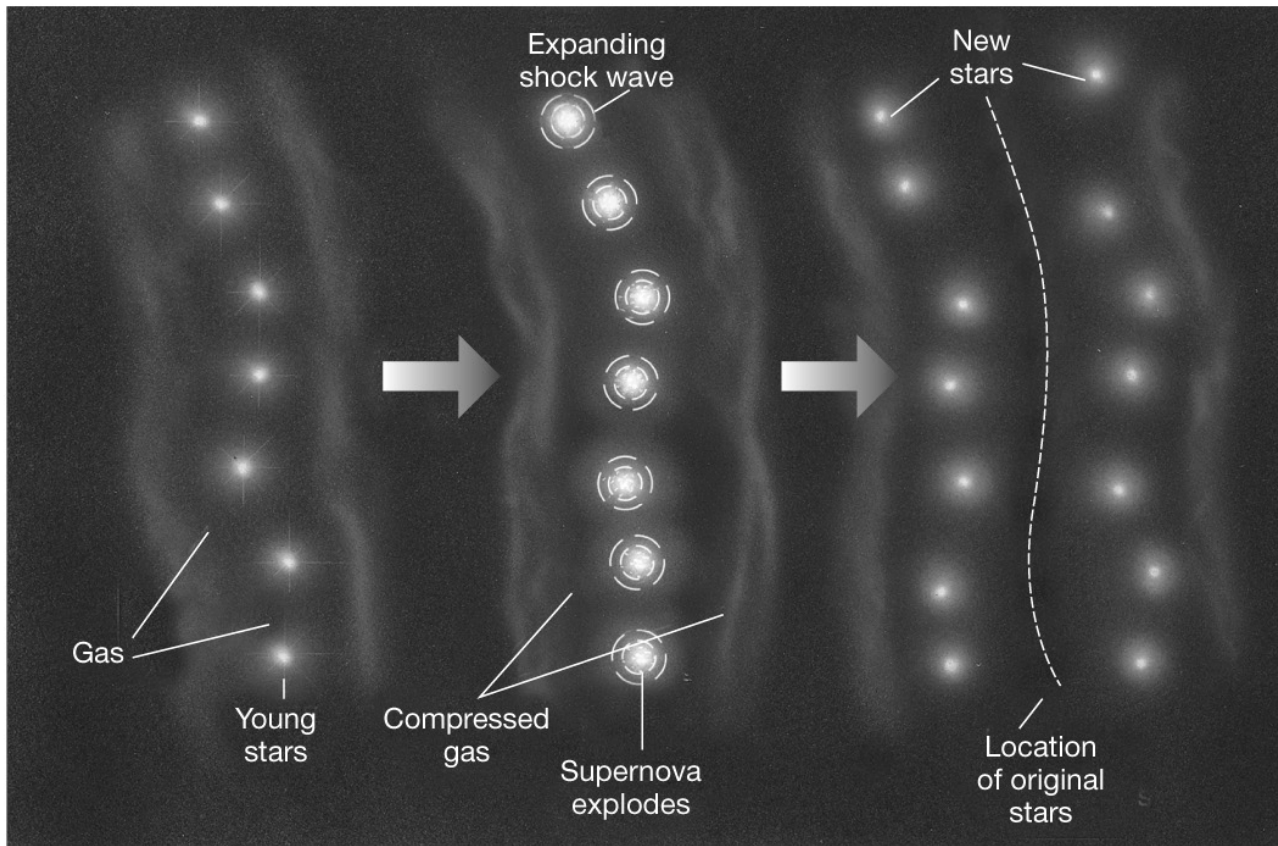
14.5 Galactic Spiral Arms

Rather, they appear to be density waves, with stars moving in and out of them much as cars move in and out of a traffic jam:



14.5 Galactic Spiral Arms

As clouds of gas and dust move through the spiral arms, the increased density triggers star formation. This may contribute to propagation of the arms. The origin of the spiral arms is not yet understood.



(a)

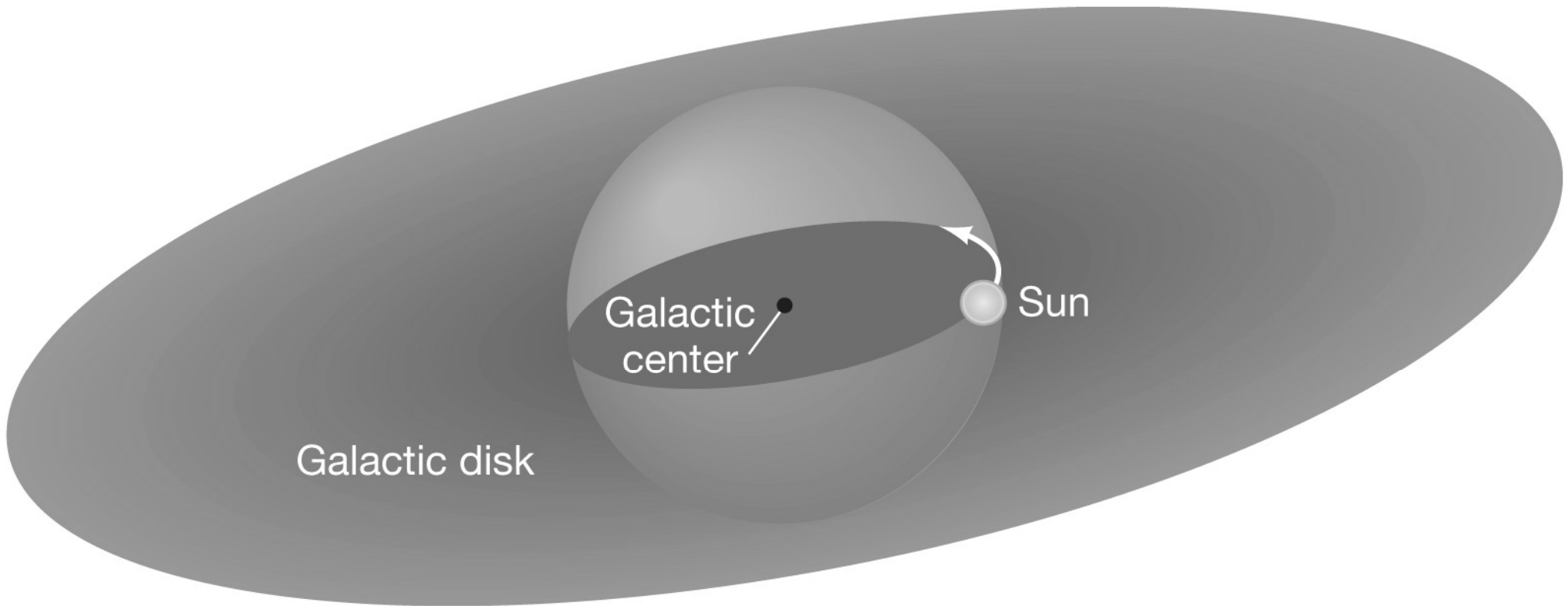


(b)



14.6 The Mass of the Milky Way Galaxy

The orbital speed of an object only depends on the amount of mass between it and the galactic center:

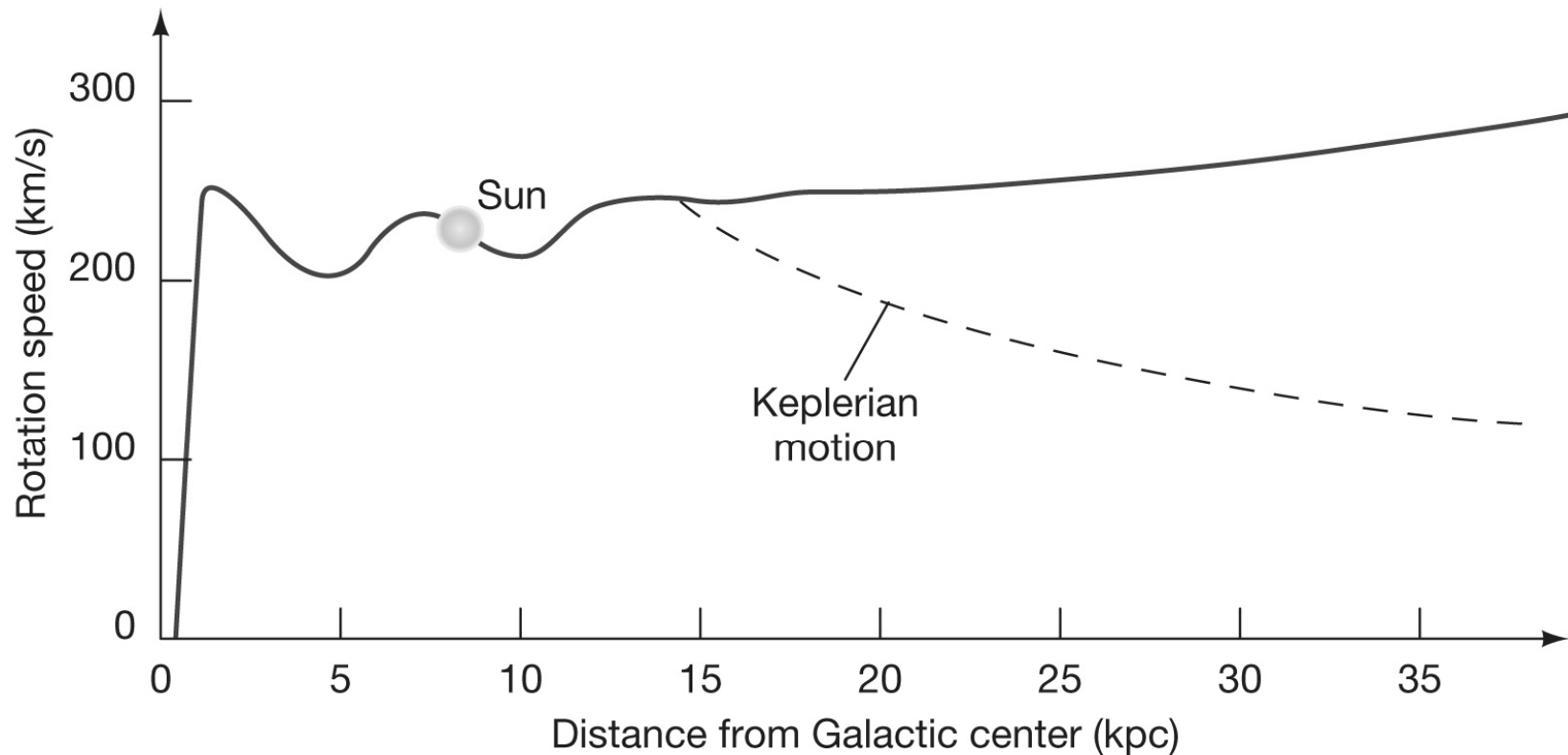


(a)

14.6 The Mass of the Milky Way Galaxy

Once all the galaxy is within an orbit, the velocity should diminish with distance, as the dashed curve shows.

It doesn't; more than twice the mass of the galaxy would have to be outside the visible part to reproduce the observed curve.



(b)

14.6 The Mass of the Milky Way Galaxy

What could this “dark matter” be? It is dark at all wavelengths, not just the visible.

- **Stellar-mass black holes?**

Probably no way enough could have been created

- **Brown dwarfs, faint white dwarfs, and red dwarfs?**

Currently the best star-like option

- **Weird subatomic particles?**

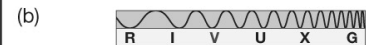
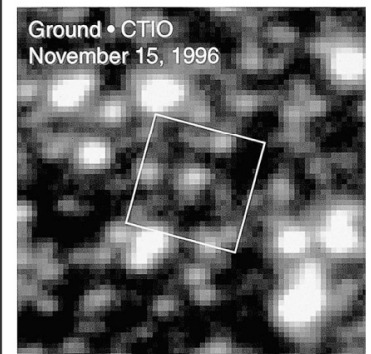
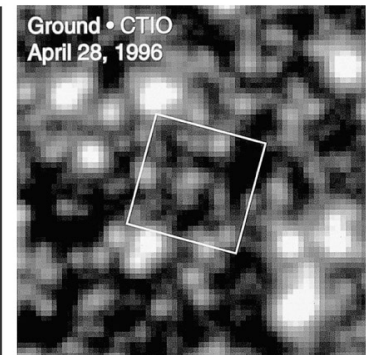
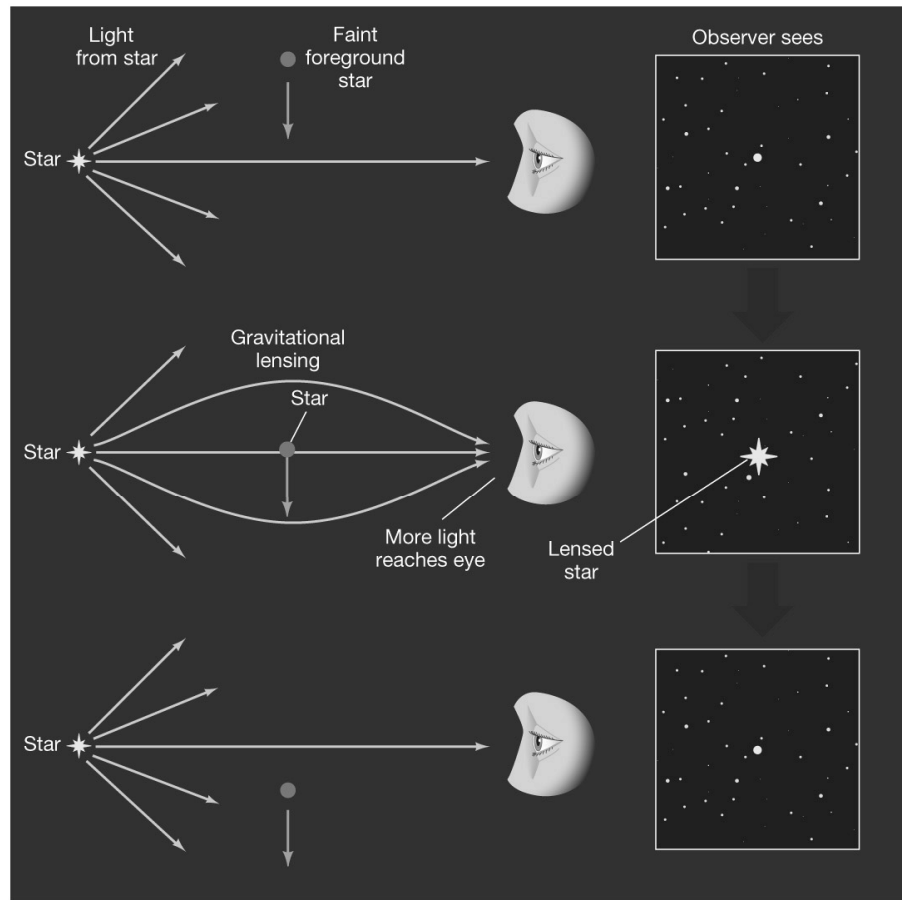
Could be, although no evidence so far

14.6 The Mass of the Milky Way Galaxy

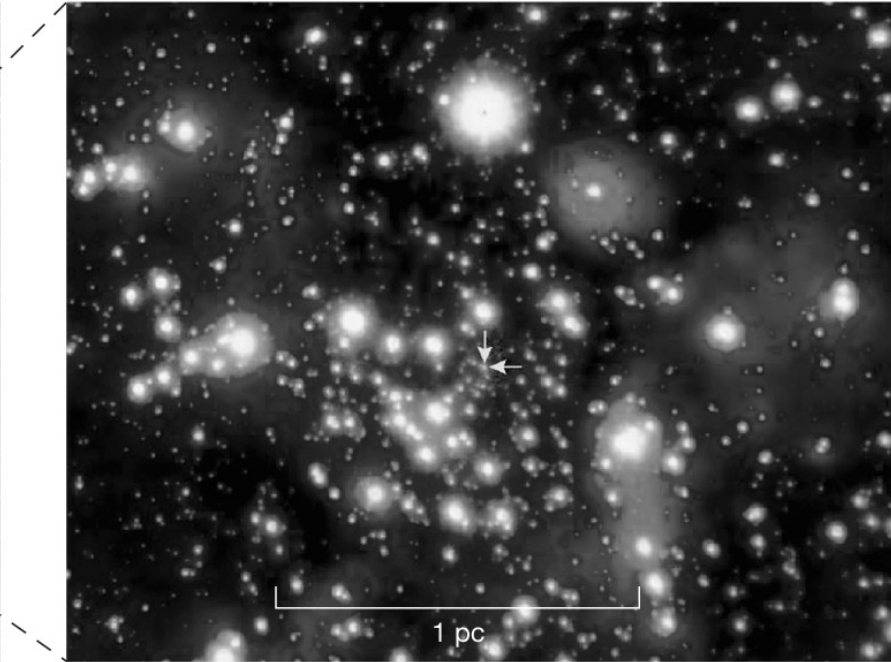
The bending of spacetime can allow a large mass to act as a gravitational lens:

Observation of such events suggests that low-mass white dwarfs could account for about half of the mass needed.

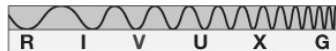
The rest is still a mystery.



14.7 The Galactic Center

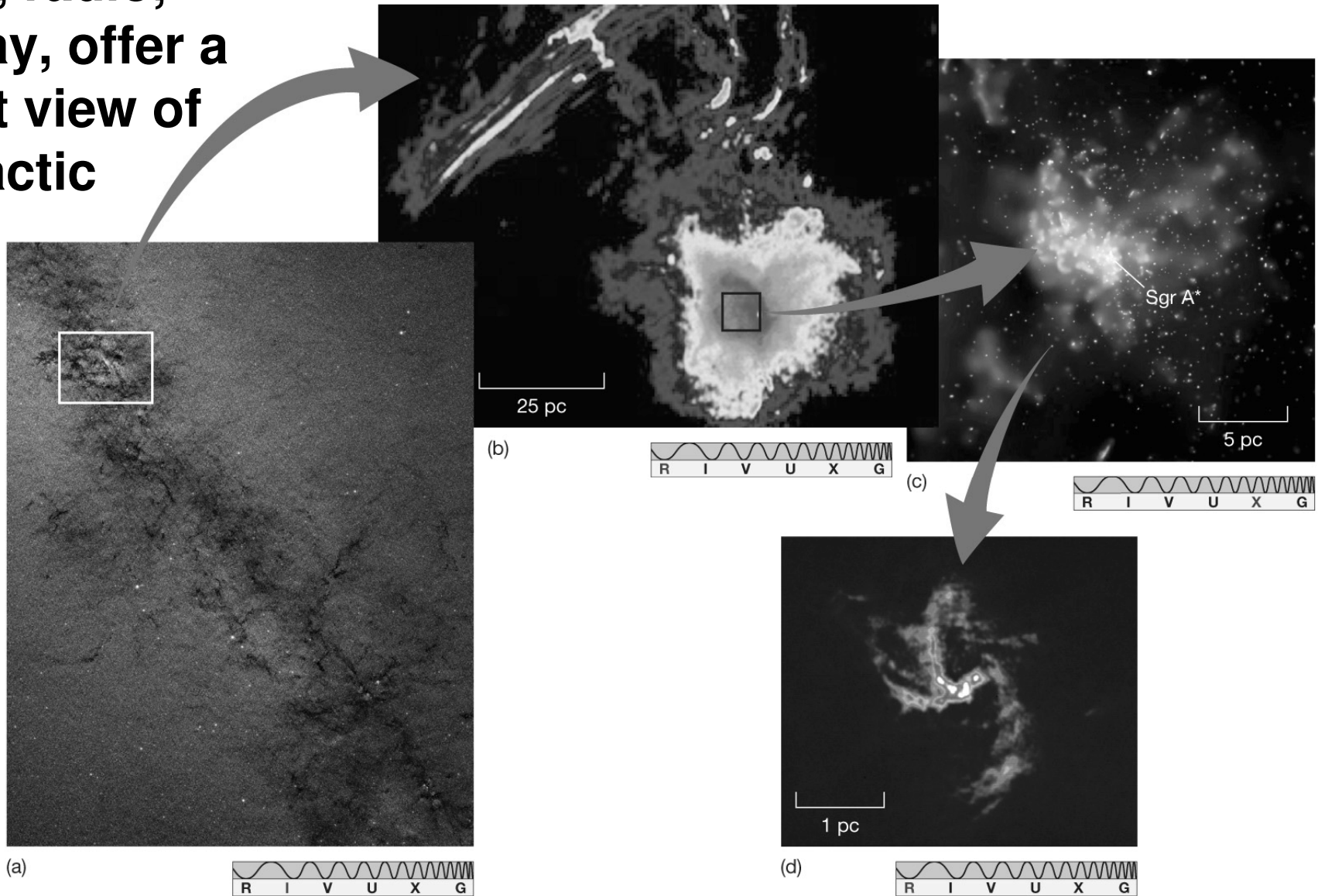


This is a view towards the galactic center, in visible light. The two arrows in the inset indicate the location of the center; it is entirely obscured by dust.



14.7 The Galactic Center

These images, in infrared, radio, and X-ray, offer a different view of the Galactic center.



14.7 The Galactic Center

The galactic center appears to have a stellar density a million times higher than near Earth;
a ring of molecular gas 400 pc across;
strong magnetic fields;
a rotating ring or disk of matter a few parsecs across; and
a strong X-ray source at the center

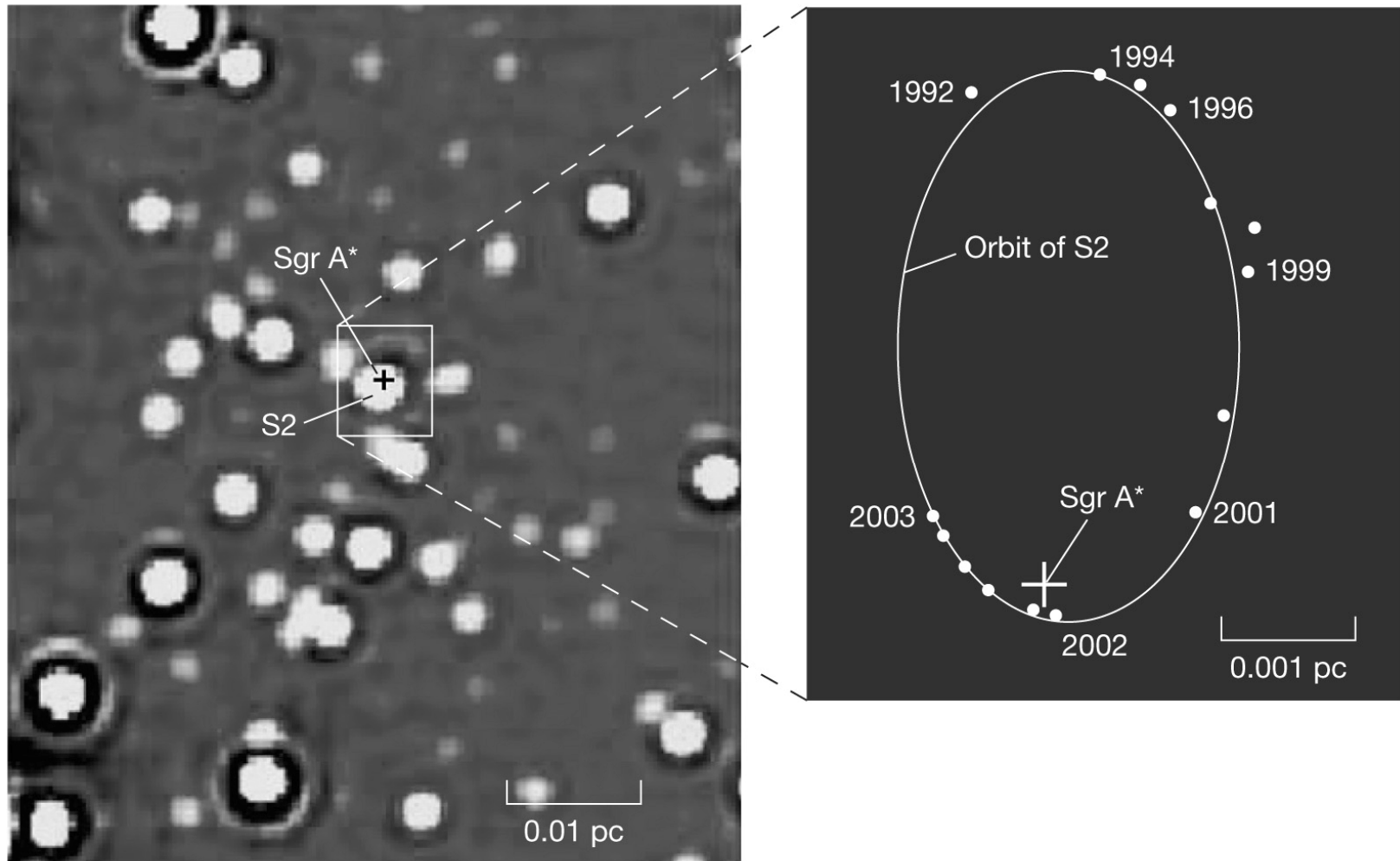
14.7 The Galactic Center

Apparently, there is an enormous black hole at the center of the galaxy, which is the source of these phenomena.

An accretion disk surrounding the black hole emits enormous amounts of radiation.

14.7 The Galactic Center

These objects are very close to the galactic center. The orbit on the right is the best fit; it assumes a central black hole of 3.7 million solar masses.



Summary of Chapter 23

- **Galaxy is stellar and interstellar matter bound by its own gravity**
- **Our galaxy is spiral**
- **Variable stars can be used for distance measurement, through period-luminosity relationship**
- **True extent of Galaxy can be mapped out using globular clusters**
- **Star formation occurs in disk, but not in halo or bulge**

Summary of Chapter 23, cont.

- **Spiral arms may be density waves**
- **Galactic rotation curve shows large amounts of undetectable mass at large radii; called dark matter**
- **Activity near galactic center suggests presence of a 2-3 million solar-mass black hole**