On the other hand, if the curvature of space was zero or negative, the universe would be *open*. It could just go on forever. An open universe could be *infinite*, but not necessarily according to recent research.

Today the evidence is very strong that the universe on a large scale is very close to being flat. Indeed, it is so close to being flat that we can't tell if it might be very slightly positive or very slightly negative.

Black Holes

According to Einstein's theory, space-time is curved near massive bodies. We might think of space as being like a thin rubber sheet: if a heavy weight is hung from it, it curves as shown in Fig. 33–18. The weight corresponds to a huge mass that causes space (space itself!) to curve. Thus, in Einstein's theory† we do not speak of the "force" of gravity acting on bodies. Instead we say that bodies and light rays move as they do because space-time is curved. A body at rest or moving slowly near the great mass of Fig. 33–18 would follow a geodesic (the equivalent of a straight line in plane geometry) toward that body.

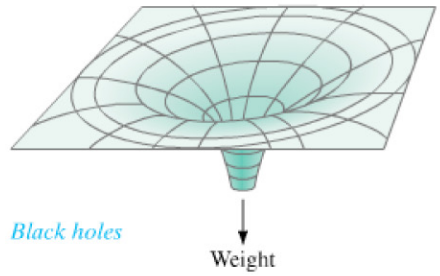

FIGURE 33–18 Rubber-sheet analogy for space-time curved by matter.

Black holes

The extreme curvature of space-time shown in Fig. 33–18 could be produced by a **black hole**. A black hole, as we saw in the Section 33–2, is so dense that even light cannot escape from it. To become a black hole, a body of mass M must undergo **gravitational collapse**, contracting by gravitational self-attraction to within a radius called the **Schwarzschild radius**:

$$R = \frac{2GM}{c^2},$$

where G is the gravitational constant and c the speed of light.

Event horizon

The Schwarzschild radius also represents the event horizon of a black hole. By **event horizon** we mean the surface beyond which no signals can ever reach us, and thus inform us of events that happen. As a star collapses toward a black hole, the light it emits is pulled harder and harder by gravity, but we can still see it. Once the matter passes within the event horizon the emitted light cannot escape, but is pulled back in by gravity.

All we can know about a black hole is its mass, its angular momentum (there could be rotating black holes), and its electric charge. No other information, no details of its structure or the kind of matter it was formed of, can be known because no information can escape.

How might we observe black holes? We cannot see them because no light can escape from them. They would be black objects against a black sky. But they do exert a gravitational force on nearby bodies. The black hole believed to be at the center of our Galaxy was discovered by examining the motion of matter in its vicinity. Another technique is to examine stars which appear to be rotating as if they were members of a *binary system* (two stars rotating about their common center of mass), although the companion is invisible. If the unseen star is a black hole, it might be expected to pull off gaseous material from its visible companion (as in Fig. 33–10). As this matter approached the black hole, it would be highly accelerated and should emit X-rays of a characteristic type before plunging inside the event horizon. Such X-rays, plus a sufficiently high mass estimate from the rotational motion, can provide evidence for a black hole. One of the many candidates for a black hole is in the binary-star system Cygnus X-1.

† Alexander Pope (1688–1744) wrote an epitaph for Newton:

> "Nature, and Nature's laws lay hid in night:
> God said, *Let Newton be!* and all was light."

Sir John Squire (1884–1958), perhaps uncomfortable with Einstein's profound thoughts, added:

> "It did not last: the Devil howling '*Ho!*
> *Let Einstein be!*' restored the status quo."