Escape Velocity

When you throw a ball in the air, it can’t help but come back down. The harder you throw, the higher it goes, yet it still comes back down. While the ball travels on its trajectory, it’s always conserving energy; the kinetic energy imparted by you on the ball is converted into potential energy as it rises. At the peak of its trajectory it has only potential energy, which it then converts back into kinetic energy as it falls. Throughout the trip, the ball always remains bound to the Earth, stuck in a “potential well” from the Earth’s gravity. That’s only because you didn’t launch the ball with enough kinetic energy to escape Earth’s gravitational potential. To do this, you would have to throw the ball above its escape velocity:

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

Where $G$ is Newton’s gravitation constant, and $M$ and $R$ are the mass and radius of the body you’re trying to escape. Plugging in Earth’s mass and radius we find that this is about 11 km/sec, or 25,000 MPH.
**What are black holes?**

Einstein told us that the speed of light $c$ is a cosmic speed limit; nothing can go faster than that. So what is a body whose escape velocity is equal to the speed of light? Plugging in $v_{\text{esc}} = c$ and doing a little algebra, we find its radius is

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

For a given mass, this is the radius from below which nothing can escape. Even light. If a body is so compact that its radius is below this radius, then its a black hole. To turn Earth into a black hole, it would need to be squeezed down to a radius smaller than 10 mm, e.g., smaller than a coffee bean. The Sun, smaller than 3 km.

**How Do We See Black Holes?**

We don’t. Since black holes are black, we must infer their properties from the radiation emitted by any surrounding matter there may be. If it’s in a binary system with a non-compact star, the gravitational pull of the black hole can sometimes rip matter from the surface of the star, which quickly settles down into an accretion disk about the black hole. As the matter spirals in towards the black hole it gets hotter and hotter, so hot that its thermal emission (the same kind that’s emitted from incandescent light bulbs) peaks in the x-ray part of the electromagnetic spectrum. Deemed x-ray binaries, by measuring the properties of this emission, along with the binary’s orbital parameters, we are able to estimate the black hole’s mass and rotation speed, but not very accurately. This is where LIGO comes in. LIGO will provide us with direct measurements of black hole properties, not relying on matter surrounding the black hole.