



### **Black holes**

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# Black Hole at the center of the Galaxy





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- Imagine compressing all of the mass of the Sun into a sphere about four miles in diameter.
- If you could do that, what would it be like?
- The gravity at the surface would be so strong that nothing could escape, not even light.
- Once that happened, gravity is also so strong that no force can keep the star from collapsing completely under its own weight.
- It becomes a point (!), containing all of its original mass.





- Will black holes suck up everything in the Universe? No.
- Their strong gravity is only strong very close to the black hole.
- The *event horizon* marks the ghostly reminder of the surface of the star that just barely can't let light escape from it. Further away from the star, gravity falls off, getting weaker just as it would for matter in a more ordinary form.
- If the Sun suddenly became a black hole, its gravity at Earth's distance would be the same, and we'd orbit like before. (Of course, we'd miss the light!)





- Black holes consist of matter in one of its most extreme forms ever imagined. So dense, that it almost isn't matter. All that is left of its character is its mass. Otherwise, "A black hole has no hair."
- Another way of looking at a black hole is that it consists of pure gravity, or in Einstein's terms, it consists of pure "space-time curvature".





A view of the space-time in the vicinity of a black hole.

In the region where the escape velocity exceeds *c*, the geometry of the curved spacetime becomes extreme.





#### The sad fate of matter that forms a black hole



No force can hold up the matter that forms a black hole. All of the matter inside collapses down to a point.







- The idea of black holes is pretty exotic.
- We'd like to know if black holes actually exist. If they do, what are their properties? How massive? How many?At first, it seems unlikely that we could ever know. After all, if even light can't escape from a black hole, how could be observe it?
- Nevertheless, evidence is accumulating that black holes do exist.
- Now, I'll explain a new way of looking for black holes that will let us get "up close and personal" with them.



## Black hole vibrations create space-time ripples



- If a black hole is disturbed, distorted, or newly-created, it will vibrate.
- A vibrating black hole launches ripples in space-time, also known as *gravitational waves*.
- If two pre-existing black holes collide, they will form a new larger (but momentarily distorted) black hole.
- This happens often, from black holes in binary pairs, two black holes orbiting each other.
- Gravitational waves are made by the orbiting black holes. This carries away energy, causing them to spiral towards each other, eventually colliding and forming a single more massive black hole.



### A simulation of two black holes colliding





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