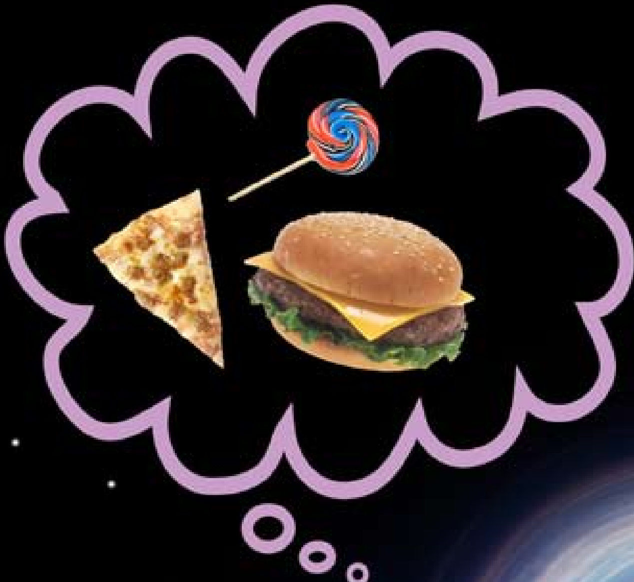
What Do Black Holes Eat For Dinner?

And other silly, *yet totally smart*, questions about space



Dr. Grant Tremblay & Katie Coppens

For my daughter Adelaide,

who taught me where the stars live.

- G. T.

For my dad,

who taught me no question is too silly.

- K.C.

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What Do Black Holes Eat For Dinner?

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The most important thing to understand about space is how absolutely enormous it is. When you look at our Universe, there is endless possibility. It is the willingness to be curious and ask questions that has propelled humans' scientific understanding forward. And it is *your* willingness to ask questions that will propel *your* scientific understanding forward.

Seriously? I can ask anything?

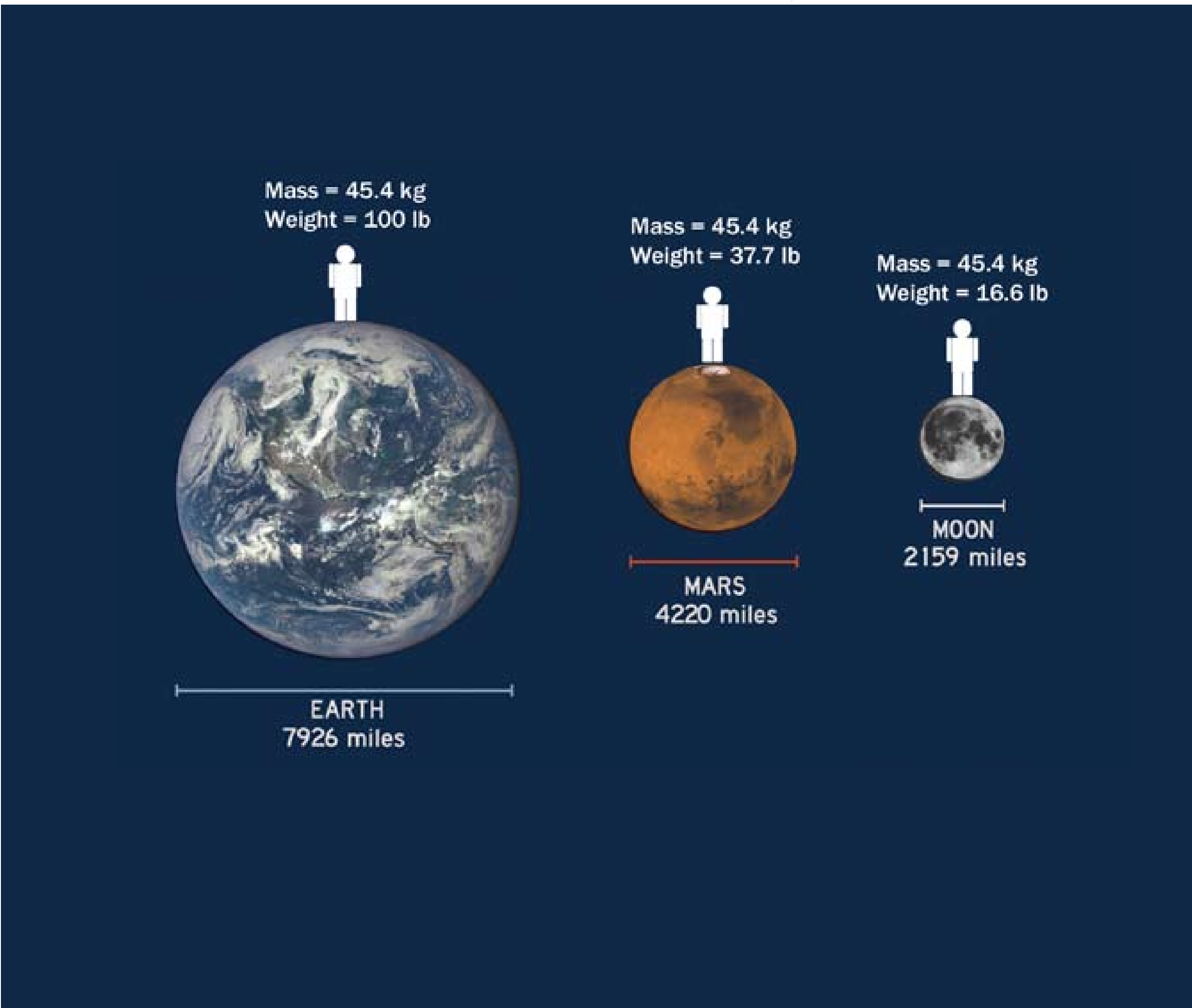
Anything. My guess is that your questions will lead to answers that surprise you, possibly even shock you, and definitely open up your thinking to more and more questions. I can't promise all of the answers to your questions are known, but I will answer them with the most accurate thinking that we have at the time that this book is published.

Let's see where your questions take us!

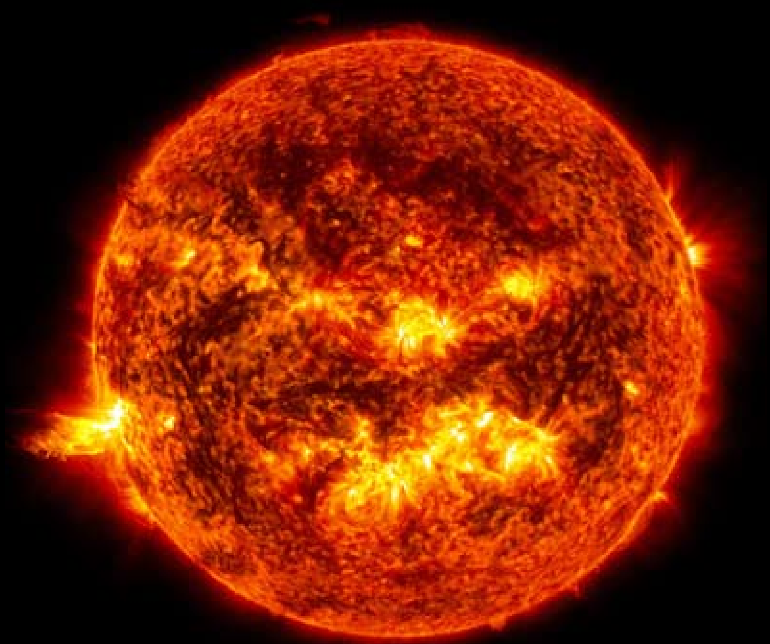
> Okay, here I go. What do black holes eat for dinner?

Great question. I like the way your mind thinks! But, to answer your question, we first have to understand a bit about black holes. You know your parents' vacuum cleaner? That big scary loud thing that roams the house devouring *everything* in its path? Well, that's *not* what a black hole is like. You may have been told that black holes suck in anything that dares to come near them, but it's just not true. Black holes don't "suck." They're nothing more than a mass. A very large mass, mind you, but just a mass nonetheless.

Well, you may be asking yourself, what is a mass? "Mass" is, basically, a measure of how much "stuff" is in something. As you grow bigger, your mass will increase. A big boulder has more mass than a small pebble. You might have guessed that mass sounds like the same thing as *weight*. Mass is a measure of the amount of material within an object, and weight is a measure of the force that gravity exerts on that object. This is why, if you went into deep space, your *weight* would effectively go to zero, but your mass would remain the same.



Anyway, to give you a sense of the size of the mass of a black hole, let's compare it to something we can picture, the nearest star to us — the Sun. If you were to replace the Sun with a black hole of equal mass, *nothing would change* with the orbit of the planets around it, including Earth. They would all keep on moving in exactly the same way they did when the Sun was there.



The Sun is 864,000 miles in diameter and has a surface temperature of 10,000 degrees Fahrenheit.
Credit: NASA

Of course, I don't want you wishing we were orbiting a black hole right now. First of all, if you were, you wouldn't be reading this. You see, black holes don't emit light like stars do. Our Sun is a star. Without the Sun's light and energy fueling all life on Earth, species couldn't survive, and without light Earth would literally and figuratively look very different.

Speaking of the way things look, let's picture a black hole. Do you literally picture a dark, black hole? Well, instead picture *blindingly* bright, white light. I know I just said black holes don't emit light. You'd only see this blindingly bright, white light in *the fraction of a second* before you were *vaporized*. That's right, if you were actually close to a massive black hole that was "accreting" (gobbling up gas), you wouldn't see a dark void of nothingness, but rather the incredibly intense radiation field given off by that infalling gas in its death spiral toward the "event horizon," which you can think of as a black hole's edge. As the gas falls inward, it collapses into a spinning vortex that, due to friction, superheats to millions of degrees. Gas that hot is also incredibly, blindingly bright, giving off a radiation field that would *fry* you very, very quickly.

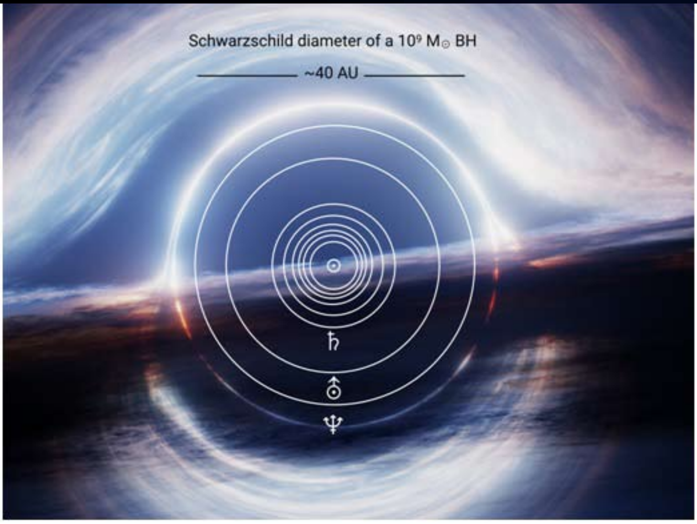
If the black hole at the center of our galaxy were a bit more massive and consuming more gas than it is currently (that is, if it turned into a *quasar*), then there would be *no life on Earth!* Yes, the radiation would be so intense that, even though the black hole at the center of our galaxy is 26,000 light years (or 153 *peta*miles … that's 152,844,000,000,000,000 *miles*) away, the radiation it would put out would be capable of killing everything on … uhhh … this series of questions is getting pretty grim. Again, you *really* don't need to worry about this. It's not gonna happen.

What is a quasar?

A "quasar" is a supermassive black hole that is eating a LOT for dinner! In consuming this all-you-can-eat buffet, the area surrounding the black hole becomes so bright that it outshines the ENTIRE GALAXY that it resides within. We call such an object a quasar.

Now, how large do you imagine a black hole to be? The size of a house? A planet? An entire solar system? Yes, yes, and yes. Black holes can grow to be larger than 10 billion times the size of our Sun. Imagine that! But black holes don't have to be massive. A black hole can have the mass of, say, a *mouse!*

Wait, a *mouse*?!



A black hole is — you guessed it — very black, and therefore impossible to see directly. BUT, you CAN see the incredibly bright light emitted by matter that falls into the black hole, and you can even see the warping of space itself by the immense gravity of the black hole. In other words, you can see the effects that the black hole has on its surroundings, even if you can't see the black hole itself. The above artists' rendering is an example of what a supermassive black hole might actually look like if you could ever approach one (trust us, you wouldn't want to).
Credit: N. Maisuradze & G. Tremblay

Credit: N. Maisuradze & G. Tremblay

You see, a black hole isn't called a black hole because of its size (although *it certainly can be enormous!*), but because it is extremely, extremely *dense*. "Density" is a measure of how much mass is contained within a certain "volume," or region of space. Something with higher density has more mass crammed into the same volume of space. There is much more mass in one cubic inch of rock, for example, than in one cubic inch of air. Imagine, say, the pillow on your bed. It's really easy to lift, right? Now imagine that your pillow were the same size, but made of solid rock. You probably wouldn't be able to lift it. This is because, being made of rock, there would be far more mass crammed into the same volume, relative to your actual pillow, which is stuffed with feathers or cotton.

This pillow and rock have about the same volume, but very different densities. Just think, when someone says their pillow is as hard as a rock, it actually could be that hard if the pillow had enough density.

Trust me, I promise there's a point to all of this.

Earth, thankfully, is not a black hole. But we could theoretically *make it* a black hole by squeezing it down to the size of a pea. All that cramming would make Earth super, super dense. Imagine cramming the entire mass of Earth, all *6,000,000,000,000,000,000,000,000 kilograms* of it, into the size of a green pea. If we did that, the "escape velocity" from this now-smaller Earth would increase. Escape velocity is the speed an object must attain in order to completely escape the gravitational pull of another object. The escape velocity from, say, a cereal bowl, or your body, is extremely low.

Before we crushed Earth down to the size of a pea, the escape velocity of Earth was about 7 miles per second, or about 25,000 miles per hour. That's how fast a rocket has to get going to escape Earth's gravity and head off, say, to Mars.

But *after* we cram its mass into the volume of a pea, the escape velocity from the surface of this… ahem, pea-sized world… *would be greater than the speed of light!*

Imagine Earth's mass crammed into the volume of a pea?

We're almost certain that the speed of light is the fastest possible velocity attainable by any matter in the Universe. This is because *accelerating* (speeding up) any object with any nonzero mass to the speed of light would require an infinite amount of energy. Did I lose you? Sorry. To put it simply, if some piece of mass has an escape velocity greater than the speed of light, *nothing can ever escape its gravitational pull,* not even light itself!

When this condition is met, the incredibly massive, incredibly dense object, like our pea-sized Earth, is shrouded in a purely mathematical boundary we call the "event horizon." Crossing this boundary means you would become

What's an event horizon?

An event horizon is the zone around a black hole in which light can no longer be given off.

causally disconnected from the rest of spacetime. So, there's that to think about. Let's be glad we're not on a compressed pea-sized Earth.

What's causally disconnected?

Causally disconnected means you are no longer part of the observable universe. Yep.

Wait, thinking about peas reminds me of something: what was your original question?

Um, my question was what do black holes eat for dinner?

Why, *everything!* Yep, all of that lead-up to that one answer — *everything!* Black holes may not roam like a vacuum, but they do shred stars apart and consume them whole. Giant clouds of gas fall toward black holes. As they get close, they pancake into a spinning vortex of superheated plasma that eventually falls into the event

What is plasma?

Plasma is the fourth state of matter (after liquid, solid, and gas). Plasma is an ionized gas. Typically electrons are in the nucleus, but the electrons in plasma move around more freely. It's like in an incredibly hot SOUP of electrons, protons, and neutrons. In a way, black holes eat really hot soup for dinner.

horizon. Now, do black holes eat pizza? Chicken nuggets? Peas (very funny...)? That has never been observed, but the answer cannot be a no. You see, if, say, Earth were to ever fall into the event horizon of a black hole*, its dinner would be pretty much like yours — chicken nuggets, with a side of PLANET.

*Again, *please* don't worry. This won't actually happen.

> Um...I saw that little asterisk that said "*Don't worry, this won't actually happen." How do I know that Earth won't be "eaten" by a black hole?

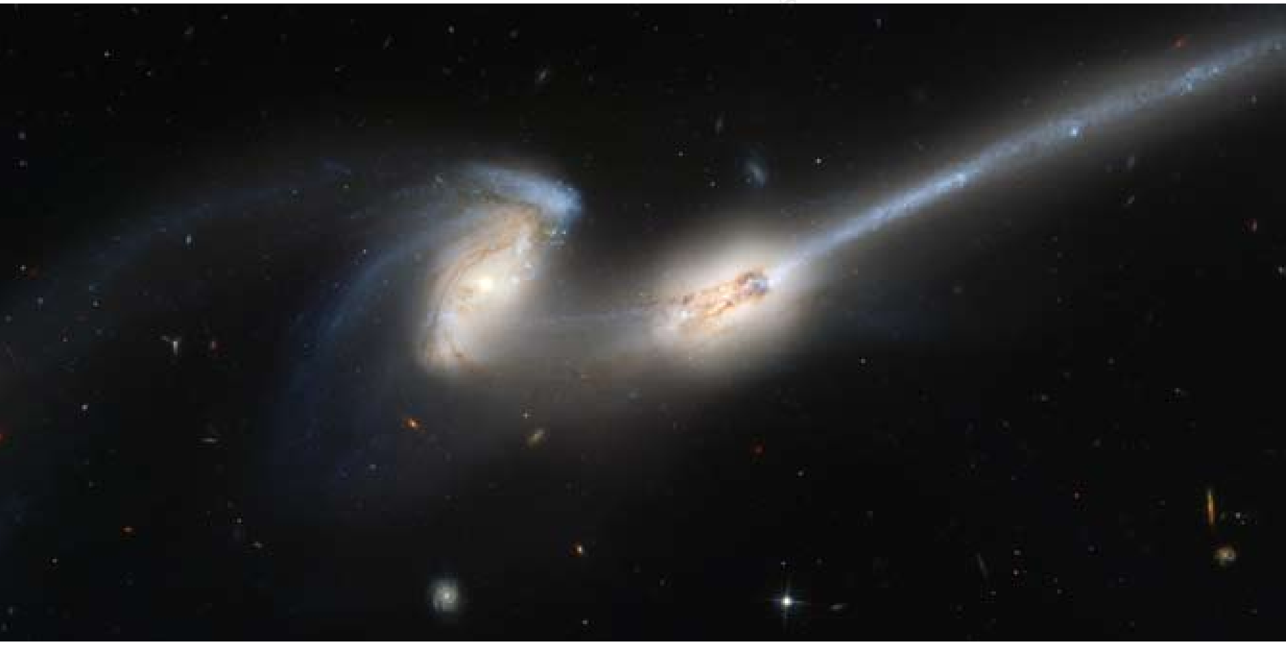
I can't say this enough... The thing to remember is that space is really, *really,* ***really*** big. Impossibly, indescribably enormous. The chances of us ever coming even *close* to a black hole that could cause us any harm is just ridiculously, ridiculously low. I feel 100% confident that you can take black holes off of your worry list.

Okay, so I get that I shouldn't worry about Earth being "eaten" by a black hole. How about this? Can galaxies crash into each other?

This also does not belong on your list of things to worry about (I'm assuming you have a list of things you worry about based on your last two questions.) Just so you know, astrophobia is a real thing — it's a fear of everything involving space, like stars, aliens, etc. If you do have astrophobia, this probably isn't the best book for you.

It's totally normal to have *some* fears in life (like for some it's public speaking or heights), but I hope I can ease your space fears by reminding you again how absolutely enormous all of space is and how really, really small Earth is compared to it. To give a sense, Earth is one tiny little planet amongst over a hundred billion stars and planets in our one galaxy. Remember I told you that the Universe is crazy, super, enormously large. Our galaxy, the Milky Way, is just one of two trillion galaxies (yep, one of 2,000,000,000,000 galaxies).

Having said that, here I go… galaxies collide with one another *all the time*. This happened more frequently in the past, serving as a major driver of the growth of galaxies through cosmic time. Among the most energetic events in the Universe, these so-called "galaxy mergers" occur when two galaxies slowly wander too closely to one another. Their mutual gravity takes over, pulling them even closer together, until they finally collide.



A Hubble Space Telescope image of the "Mice" Galaxies. Also known as NGC 4676, these are two galaxies that have passed close to one another and are in the process of "merging", or crashing into one another. Credit: NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA

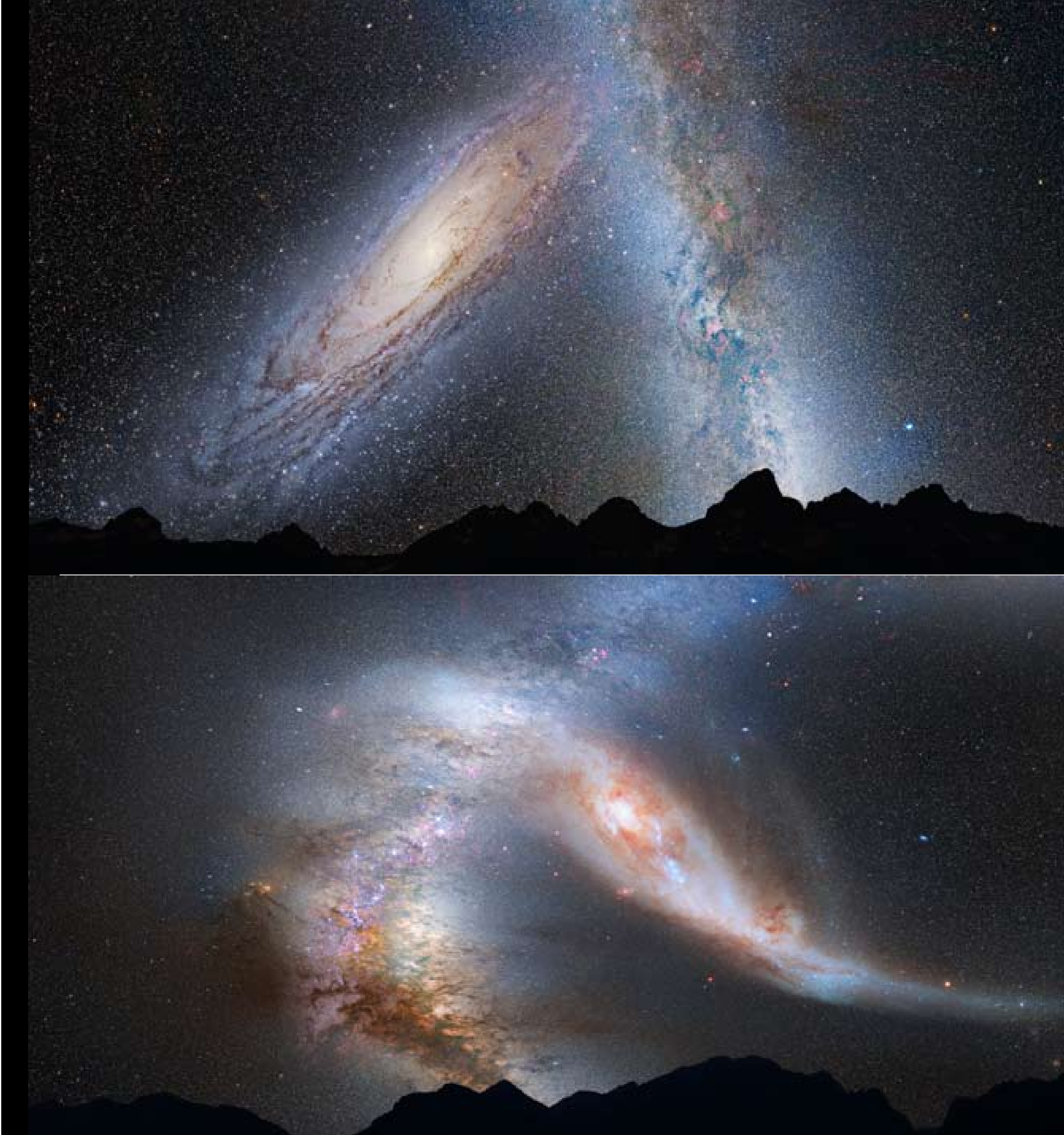
But here's the crazy thing: the galaxies pass through each other almost like ghosts! Cool, huh? Remember how we said there are *hundreds of billions of stars* in each and every galaxy? So how can it be that galaxies with hundreds of billions of stars, just "pass through one another" without any major collision of stars?

It's because galaxies are HUGE. Even if filled with 200 billion stars, the *volume density* of those stars is very low, simply because the volumes those galaxies occupy are so enormous. In simple words, even though there are a lot of stars, they are very, very, very far apart. To give an example of this in our home galaxy, the Milky Way, the so-called stellar density is about one solar mass per ten cubic light years. To help you picture this, even with over 200,000,000,000 stars, galaxies are mostly just empty space. As galaxies crash into each other, the stars that make up those galaxies will quietly pass one another, like ships in the night. They just won't collide, because even with four hundred billion stars flying around, there is so much empty space between then, that the chances of collision are still incredibly low.

But, I'm sure you're thinking, "I read that the odds are incredibly low, not impossible." You're a smart one, and yes, a collision *could* occur. What would happen during the collision is a complete reshaping of both galaxies by *gravity*. Even though those stars won't actually collide with one another, they will gently tug at the orbits of all their stellar neighbors as the galaxies merge, slowly and completely reshaping both galaxies participating in the crash. This process can take far more than a billion years, so the reshaping is a slow, even elegant process that turns disk-like galaxies first into beautiful irregular patterns, like those merging galaxies shown on the next page, and finally changes them into spherical stellar systems in which the orbits of stars is more like a swarm of bees than a record player.

A Hubble Space Telescope image of the Antennae Galaxies, also known as NGC 4038 and NGC 4039. These two galaxies have been crashing into one another for the past six hundred million years, resulting in this beautiful cosmic trainwreck. Credit: NASA/ESA/STScI

I need to prepare you, especially if you *actually* do have astrophobia, with the news that our galaxy, the Milky Way, will actually collide with the nearby Andromeda galaxy in about 3 billion years. (Please don't have things on your worry list that are going to happen in billions of years.) More than a billion years after the collision begins, Earth's night sky (sorry, I have to say it… that's assuming Earth, and/or humans, are still here around 3 billion years from now) will look VERY different from the calm scene you can see tonight. Andromeda will fill almost the entire sky, and in over a billion years it will reshape into a beautiful "S" shape. The Milky Way will be stretched and tugged at in a similar way, and, over the course of a little more than a billion years, it will transform from a beautiful spiral into an even more beautiful irregular galaxy. It will probably look something like this:

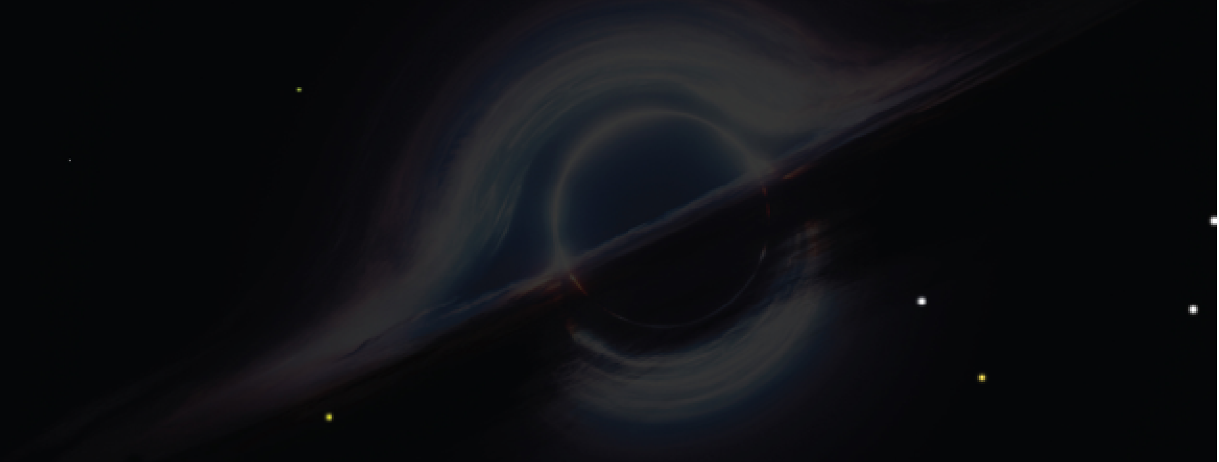


An artist's illustration of what the night sky on Earth might look like in about 3.5 billion years, after the Milky Way begins to merge with the Andromeda Galaxy. The shape of our galaxy will be altered forever, but actual collisions between stars will be very rare. The merger will therefore be a long, almost "gentle" process of reshaping our galaxy from a spinning disk of stars into a more spherical shape. Credit: NASA, ESA, Z. Levay and R. van der Marel (STScI), T. Hallas, and A. Mellinger

What Do Black Holes Eat For Dinner?

Fascinating astronomy facts delivered in a lighthearted, illustrated, Q&A format

Space facts from an astrophysicist, brought down to earth by a middle school teacher—these are answers to kids' real, wacky, smart questions. Light, space, stars, galaxies, planets and more, all explained with accuracy and humor, and accompanied by images from across the Universe.



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