Meteors: Crash Course Astronomy #23

Crash Course: Astronomy
https://youtube.com/watch?v=TuDfZ2Md5x8
https://nerdfighteria.info/v/TuDfZ2Md5x8

I love astronomy. You may have noticed. But there's one really frustrating aspect of it: Everything we study is really far away. Nearly everything we understand about the universe comes from light emitted or reflected by objects. I'd be nice if we could get actual samples from it. Physical specimens we could examine in the lab.

Well, sometimes the universe can be accommodating and allows us to hold it in our hands. Cambot, can we get this up on still store?

(Intro)

If you go outside on a clear, dark, moonless night, and you really should, chances are pretty good that within a few minutes, you'll see a shooting star. It'll zip across the sky, a fiery dot leaving a long glowing trail behind it. They're one of the most exciting and fun things you'll see when you look up, and they always get a gasp and a squeal of delight from someone who's stargazing. What you're actually seeing is a tiny bit of interplanetary debris: rock, ice, or metal ramming through the Earth's atmosphere, heated to incandescence. Most are faint, but some can be astonishingly bright. I saw one once that left an afterimage on my eye. Obviously shooting stars aren't really stars, so what do we call them?

Sometimes it seems like astronomers use different names for objects to keep things as confusing as possible, but really we do that to separate out different things. In this case, the actual bit of solid stuff coming from space is called a meteoroid. The phenomenon of the meteoroid getting hot and blazing across the sky is called a meteor, and finally, if it hits the ground, we call it a meteorite. I think the second best way to tick off an astronomer is to mix up meteor and meteorite. Sometimes astronomers can be pretty pedantic about such things. Oh, the best way to tick off an astronomer? Ask 'em, "Hey, what's your sign?"

Amazingly, a typical meteor that you'll see is due to a meteoroid that's tiny, probably smaller than a grain of sand. How can that be? It's because they're hauling mass. You heard me. The meteoroid is orbiting the Sun, probably at speeds of a few dozen kilometers per second. As it approaches the Earth, our planet's gravity accelerates it an additional 11 kilometers per second, Earth's escape velocity. And when it enters our atmosphere, it's moving incredibly fast, up to 70 kilometers per second or more. The energy of motion is called kinetic energy. If you wanna get something moving, you have to give it energy, and if you want it to stop, you have to take that energy away. This kinetic energy depends on the mass of the object and how fast it's moving. In fact, it depends on the square of the velocity, double its speed, and it'll have four times the kinetic energy. Meteoroids may usually be small, but they're screaming fast and have a huge amount of kinetic energy. As they hit our atmosphere, they slow from their ridiculous orbital speed to nearly a standstill, and all that energy has to go somewhere. It gets converted into light and heat, and that's what we see as a meteor.

A big misconception about meteors is that they got hot due to friction with air. Actually, a far bigger contributor to their heat is compression. One of the most basic laws of physics is that when you compress a gas, it heats up, and a meteoroid coming in at hypersonic speeds compresses the air in front of it a lot, heating it hugely. The gas can reach temperatures of thousands of degrees Celsius for a few seconds. The air radiates away this heat, in turn heating up the meteoroid. The material on the surface vaporizes and blows away, a process called ablation. That ablated material leaves a glowing trail behind the meteor, which we call a train. Sometimes it can glow for several minutes, getting twisted up in high altitude winds, leaving behind an eerie ghost-like persistent train. This all happens high above your head, about 90 to a hundred kilometers above the ground.

Typically, from any one location, you can see a few meteors per hour. It may not seem like much, but when you add them up all over the planet, you find the Earth is getting pelted to the tune of about a hundred tons of material a day. But again, most of these meteoroids are teeny tiny. Those random meteors are called sporadic meteors. They tend to be rocky in composition and generally come from asteroids. If two asteroids smack into each other, the collision can eject little bits of material that then orbit the sun on their own. If their orbit crosses the Earth, then you have a potential meteor. It may take a few million years, but at some point the Earth and the meteorite are at the same place at the same time, and boom.

But sometimes, meteoroids travel in packs. When that happens, we can get meteor showers, many dozens or even hundreds of meteors per hour. With one exception: those don't come from asteroids. They come from comets. When a comet orbits the sun, the ice on it turns to gas, dislodging dust and gravel mixed in. This material leaves the comet and tends to stay more or less in the same orbit as the comet itself. Over time, that material gets scattered all along the orbit, creating a puffy ribbon of tiny pieces of space debris around the sun. When the Earth plows through that cloud of debris, we get a meteor shower.

From our viewpoint on Earth, we see meteors shooting across the sky, apparently radiating away from a single point. That's a perspective effect. It's like driving through a tunnel and seeing the tiles on the wall and ceiling flying past you, all apparently coming from a point ahead of you. The point on the sky where the meteors come from is called the radiant, and the shower is named after the constellation the radiant's in.

So we have the Perseid meteor shower, the Leonids, the Camelopardalids, or the Camelopardalids, and since the Earth hits a specific comet stream around the same time every year, the showers are annual. The Perseids are in August and the Leonids in November. Watching a meteor shower is easy. Just go outside and look up. Generally, they're better after local midnight. The Earth plows into the meteoroids, so facing the direction of Earth's orbital motion means more meteors, just like you get more raindrops on the front windshield of your car than on the back when you're driving through a storm. After local midnight, you're on the part of the Earth facing into the orbit, so you see more meteors. By the way, if you happen to be on the International Space Station, you have to look down to see a meteor. In 2011, astronaut Ron Garan photographed a Perseid burning up below him, but don't worry, the odds of the Space Station getting hit are extremely low. Space is big.

Oh, and that one exception that I mentioned before? That's the annual Geminid shower, which occurs in December. That comes from the asteroid 3200 phaethon, which is on an orbit that takes it very close to the Sun. It's possible it gets so hot that the rock vaporizes, making it act like a comet.

The vast majority of meteorites are small and tend to burn up in our atmosphere, but they can be bigger. A bolide or fireball is an extremely bright meteor, and those can be about the size of a grapefruit. Those happen pretty often somewhere over the Earth. I've seen a few myself. Very rarely, an incoming meteoroid will survive all the way to the ground and become a meteorite. Sometimes, the immense pressure of ramming Earth's air causes the incoming meteoroid to crumble or even explode, raining down dozens or hundreds of smaller pieces. Typically, they slow rapidly after their blaze of glory and simply fall the rest of the way to the ground. The air up there is cold, and their interiors are cold from being in space so long. So despite what you might think, meteorites don't cause fires when they hit the ground. In fact, they can be quite chilly.

Meteorites are classified into three broad categories: stony, which are mostly rock, iron, which are mostly metal, and stony iron, which are a mixture of the two. The majority of meteorites we find are stony. The stony meteorites are themselves subdivided into two kinds: chondrites and achondrites.

Chondrites contain chondrules, small grains of minerals. These are very primitive and are thought to have condensed out of the original disk of material that formed in the solar system. Their ages can be found by looking at ratios of elements in them formed from radioactive decay. The oldest known meteorite formed 4.568 billion years ago: before the Earth itself formed.

Achondrites don't have chondrules in them. Most likely they came from a bigger asteroid, one that was once molten all the way through, mixing the minerals. A big collision disrupted the parent body, creating the achondritic meteorites. Iron meteorites most likely come from the center of a large asteroid, one big enough that metals fell to the center via gravity. Again, a big impact blew the asteroid up, scattering its material around the asteroid belt, and with some on orbits that eventually intersected Earth's.

Stony irons are the rarest. Some have green or orange crystals of a mineral called olivine embedded in a web of metal. Called pallasites, they might be the most beautiful of all meteorites. I actually collect meteorites. It's fun but can be a somewhat pricey hobby. If you're interested, make sure you get them from a licensed dealer, we have links to some in the doobly-doo.

Of course, on occasion, the meteorite coming in can be a tad bigger, and when that happens, well, all hell can break loose. On February 15th, 2013, residents of the Russian city of Chelyabinsk got a rude awakening. At 9:20 AM local time, a rock about 19 meters across came in at a low angle. It got nearly as bright as the sun as it slammed into the atmosphere, and the pressure of its passage broke it up into several chunks, which broke up again. In a moment's time, the sudden energy released was equivalent to the detonation of a half million tons of TNT, as much as a small atomic bomb.

While no one was killed, over 1,000 people were injured by flying glass, shattered by the explosion. No doubt they were at their windows, gawking at the huge vapor trail in the sky when the shock wave hit. There was no warning for this event. The asteroid was essentially too small to detect while it was out in space. Well, for now at least.

Telescopes are coming online soon that should be able to find smaller asteroids, and give us some warning. Astronomers are more worried about ones roughly 100 meters across or bigger. These can do serious damage on a city-wide scale, or larger, but at the moment aren't easy to spot much in advance. And what to we do if we do see one headed our way?

As of right now, there's not much we can do. Studies have been done to determine the best course of action, maybe lobbing a nuke at it or simply ramming it with a space probe to change the orbit and make sure it misses Earth. These ideas look good on paper, but they haven't been tested yet, we're still a few years from that. The good news is that objects that size hitting the Earth are rare, maybe once every century or three, but if we do nothing, it will happen eventually. As science fiction writer Larry Niven points out, "Dinosaurs went extinct because they didn't have a space program," hopefully, we're smarter than they were.

Today you learned that meteors are small bits of interplanetary debris sloughed off by asteroids and comets. When the Earth plows through the stream emitted by a comet, we get a meteor shower. Meteors burn up about 100 kilometers above the Earth, but some survive to hit the ground. Most of these meteorites are rocky, some are metallic, and a few are a mix of the two. Very big meteorites can be a very big problem, but there are plans in the works to prevent us from going the way of the dinosaurs.

Crash Course Astronomy-- hey, Crash Course, meteors, cool. Crash Course Astronomy is produced in association with PBS Digital Studios. Head over to their channel for even more awesome videos. This episode was written by me, Phil Plait. The script was edited by Blake de Pastino, and our consultant was Dr. Michelle Thaller. It was directed by Nicholas Jenkins, the script supervisor and editor is Nicole Sweeney, and sound designer is Michael Aranda, and the graphics team is Thought Cafe.