Lesson: “What are the wandering stars?”

VIDEO TRANSCRIPT

EXPLORATION VIDEO 1

Hi, it's Doug! In this lesson, we're going to talk about planets. But before we do that, I just wanted to say two things about stars. Have you ever heard of a shooting star? If you have really dark skies and you happen to be looking in the right place at the right time, you might see one or two shooting stars every hour. If you watch carefully in this short video, you can see three of them. This was taken using a night vision camera if you're wondering why everything looks green. That's the horizon on the bottom, those are trees, and all those white dots are stars. All right, ready? See if you can find the shooting stars. OK, if you didn't see that, I'll play it again. Keep your eye directed to where the arrow is pointing. You'll see a bright one there at first, then there's a dim one off to the right, and then, finally, another bright one if you keep your eye directed over here toward the end. OK, ready? Shooting star isn't really a good name for these because they aren't stars at all. What they are, are actually tiny bits of rock falling from space. We call them meteors. They fall to Earth and burn up in our atmosphere along the way. Occasionally, one of them is large enough that it doesn't burn up all the way. And so if that happens, it lands on the ground, like this one did here. This rock came from outer space. So that's one kind of star I wanted to talk about. Now, there's another kind of star I want to talk about, and that's wandering stars. They're very slow, so they're nothing like shooting stars. They're called wandering stars because they're stars that aren't part of any constellation. They

move around; they're never in the same place from night to night. Like here. Say you go outside one summer night, but here next to the constellation Scorpius is a star that wasn't there before. And then you come out the next night, and watch what happens—it moves a little bit. And then the next night, it's moved more. And the next night. Within a few weeks, you come outside and you see that it's not in Scorpius at all anymore. But watch—now it's closer to the constellation Sagittarius, the teapot. And the other thing is, there are different wandering stars. Some are slower than others, like this one here is different. This one barely moves each night. Watch it here. The next night, and the next night. It's moving, but very slowly. It took a month just to go from here to here. So instead of getting from Scorpius to Sagittarius in a few weeks, like that other wandering star, it would take a whole year to do that. The ancient Greeks 2000 years ago were the first civilization to try to think scientifically about things. They were the first people to try to figure out why things are the way they are. And the wandering stars really baffled them. They wondered, why did wandering stars wander? Why don't they act like normal stars? They look like normal stars, except for the fact that they don't stay put in one constellation. And why do some of them move more quickly than others? Well, it turns out, to figure out the answer, you need a telescope. A telescope will lead you to their secret. The Greeks didn't have that. The telescope was invented in more modern times, over 1,000 years after the ancient Greeks. Here's one wandering star as it appears through a telescope. And here's another. And here's one of the other wandering stars through a telescope. Look familiar? Now, you've probably heard of a shooting star before, but if I had to guess, I would say you've never heard of the term wandering star before. But that's because I've been kind of sneaky. We don't call them by that name anymore. We use the name given to them by the ancient Greeks, who were kind of obsessed with trying to figure them out, and this was the name that they used. This word was their word meaning "wanderer." Those are Greek letters, so let me show you what this word

looks like using our alphabet. Planetes. Now do you know what I've been describing all this time? They're the planets! The planets are the wandering stars. So you probably thought I was giving you this little intro about stars, and nope, we're actually already talking about the planets. If you're surprised, good, because I want you to be surprised. Of course, planets are not stars at all, they're more like worlds. That's how you think of them. You hear planet and you think of these giant, colorful spheres. Or maybe it reminds you of a project where you made something like this. The reason I wanted to surprise you is to get your attention. To make you see that planets aren't just things in pretty pictures or Styrofoam you paint for a school project. Planets are worlds that you can see for yourself. They're actually visible to you in your sky, above your house, on any clear night. I want to change forever how you think about planets, so let's get started.

EXPLORATION VIDEO 2

So, let's consider again what you see in the sky and see if we can explain why the wandering stars—the planets—seem to do the weird things they do. To summarize the weird things they do: one, they don't stay put in one constellation, and two, some of them are faster, while others are slower. Both of these things are very nicely explained by a model—the model of the solar system. The idea here is that the Sun is at the center, and all the planets are going around it. That's why we call it the solar system. "Sol" in solar system is Latin for sun. It's helpful to think of each planet as something like a race car going around a giant racetrack, with the Sun being at the center of that racetrack. When you think of it that way, you can imagine why the wandering stars wander through the constellations. It's because they're planets in orbit of the Sun. Like race cars around a racetrack, they're moving. The stars in the constellations, on the other hand, it would seem are not moving. And the stars are so far away that they appear like a background.

The reason we came up with this model was because it neatly explains everything we see in our sky. If the planets are moving, like race cars around a racetrack, then we would expect that if they appear as little dots of light in our sky, they wouldn't stay put in one place. Remember, they're moving, so they would appear to do things like this. If the planets are moving like race cars around a racetrack, then we might also expect that some of them move faster than others. So, if you watch here in this video again, you can see how the inner planets, where the arrow is pointing, move a lot more quickly than the outer planets. It turns out that the closer a planet is to the Sun, the faster it moves. So the model of the solar system, or what we can think of as the racetrack concept, makes a lot of sense. When we look in our sky, we see here two wandering stars, Mars and Saturn. And Mars is a little bit closer to the Sun, so Mars is going to appear to move faster through our sky each night than Saturn does. And when we watch and look, that's exactly what we see. Just like this. Most of the ancient Greeks never in a million years would have imagined that the Earth was itself one of the wandering stars. That would mean that it was moving, like a race car, around the Sun, and it sure doesn't feel like the Earth is moving. How is it possible that we're moving and yet it doesn't feel like we're moving? Well, that is a completely different topic, which we're not going to talk about, and that topic is the start of a whole new science called physics. You should study it one day if you're curious.

EXPLORATION VIDEO 3

Who figured out that the wandering stars weren't actually stars, but were whole entire worlds? None other than this man, Galileo. Four-hundred years ago, he created one of the first telescopes. Here is one of Galileo's actual telescopes he made. And he was the very first human being to point one up at the night sky. When he pointed his telescope up at a star, it wasn't anything too different. Here on the left is the view of a star if you were looking through a

telescope like Galileo's. You notice how a star doesn't look that different in a telescope because stars aren't magnified much by telescopes, it turns out, because they're so far away. But when he pointed his telescope at a wandering star, he was amazed by what he saw. Like Venus, just looking at it in the night sky, you see a bright white star. But in a telescope, Galileo observed a disk shape. And that disk shape changed. Weeks later, he could see it like this, as a crescent. Venus has phases, a result of the fact that we're seeing it as it's going around the Sun. This wasn't a star or a point of light, it was clearly an entire world. Take this wandering star, for example. Through his telescope, this one appeared fuzzy, almost as if it were three planets instead of one. Here's how Galileo drew it in his journal. Was it three planets? What was it exactly? He couldn't really tell. But as telescopes got bigger and better, we figured it out. Those two things off on either side of the planet, they are rings. This is the planet Saturn. This is how it appears in a telescope that's somewhat larger and better than Galileo's. A couple of hundred years after Galileo, one person had made a telescope nearly 4 feet across and 40 feet long. It required a wooden frame larger than a house just to hold it. With these bigger, better telescopes that people were making, we started discovering more surprises. The greatest surprise of all was the discovery of entirely new planets. There are only five planets you can see in our night sky with your bare eyes: Mercury, Venus, Mars, Jupiter, and Saturn. So, for thousands of years, these were the only wandering stars anyone knew about. But, using these more powerful telescopes, a new planet was discovered, the planet Uranus—a small, blue disk. And within a few decades, the planet Neptune was discovered, too. Because they were so far away and so dim, these two new planets didn't look like much, just pale blue dots, but they were clearly planets and not stars. They had an obvious disk shape, and they don't stay put in one constellation. They wander or move just as you'd expect of a planet orbiting the Sun.

EXPLORATION VIDEO 4

We continue to keep building bigger telescopes, but there's a limit to how much we can learn by just looking at a place from the Earth. If we want to learn more, we have to get off the Earth. We have to travel to the planets. When your grandparents were children, such an idea was still science fiction. People wrote books and articles about the idea of one day going to the planets, but there wasn't any way for it to happen. Back then, this is the most anyone had seen of a planet like Mars. This was as good as we had for understanding a planet—a photo through a telescope. But by the time your parents were children, we had rockets and computers. It was now possible to launch an unmanned spacecraft and send it all the way to a planet to take photos from up close. The first spacecraft to visit another planet and get close-up photos was this, the Mariner spacecraft sent to Mars. Now, keep in mind that this would have been the best picture we had of Mars when your grandparents were children. Imagine how excited the world was when we started to get planet photos like this. People were blown away. We've now sent spacecraft to every planet in our solar system, and so we have close-up photos for each one of them. For most of the planets, we've only sent spacecraft to fly up close, take photos, and perform scientific measurements. It's a whole other engineering challenge to actually land on a planet. But it's been done, starting with Mars. Here's the lander that was designed, which first had to be tested in the desert. That's as close to a Martian environment as we can get here on Earth. And here's our first view from Mars. Mars' red color is because the rocks and soil are red. This turns out to be rust. The whole surface of the planet is very rusty. Notice the color of the Martian sky. This photo was taken when the Sun was high at noon. The sky is a butterscotch yellow color, so, unlike Earth's blue skies. We even have a little robot car driving around on it right now. Here's a photo that was taken recently by one of these robotic landers on the surface.

Do you recognize that little star there in the sky? I can't blame you if you don't. You might not even be able to see it, but there's a speck of light there, and that's us. That's the Earth. Being that the Earth is the third planet from the Sun, it makes sense that we explored Mars first because it's the fourth planet from the Sun. So Mars is closer to us than most other planets. But the planets aren't evenly spaced apart. Venus, the second planet from the Sun, is even closer to us. It's also almost the same size as Earth. That means it's an Earth-sized planet that's a little bit closer to the Sun than we are. Naturally, that made people wonder—was the entire planet Venus maybe warm and tropical? Could this become the greatest vacation destination ever? Does it even have air? That would definitely make a vacation less enjoyable if there were no air. Even before we could send a spacecraft, we knew that Venus at least had an atmosphere. On very rare occasions, from Earth, Venus appears to go in front of the Sun. Remember, it's the second planet from the Sun, so from our orbit, it's possible for Venus to look like it's going in front of the Sun. We can actually watch this happen. So watch right here, and then in a telescope—you see, with the sunlight behind it, we see this very thin layer around Venus. Do you see that? That's proof that Venus has an atmosphere. So it has some kind of air. It's closer to the Sun. What's it going to be like? Here's Venus from up close, as seen from a spacecraft we sent to it. By sending a spacecraft to fly close to Venus and take photos, we discovered that Venus is covered in clouds all the time. The clouds are so thick and they never break. You can't see the surface of Venus, which means that if you were on the surface, you can't ever see the Sun. It's always completely cloudy. The Soviet Union created this probe to be landed on Venus. Here it is before being sent. It contained cameras as well as thermometers that would record the temperature and send the information back to Earth. What the probe found was that far from making Venus shady and cool, the clouds trap in the heat. These thick clouds, combined with the fact that Venus is closer to the Sun, make Venus hot—very hot. Venus became the second

planet that human beings sent a robotic lander to the surface of, and the surface temperature was measured to be 900 degrees Fahrenheit. Go look at your oven. You'll notice it only goes to 500 degrees. Nine-hundred isn't even a setting on your oven. That's how hot Venus is. Here is one of the only photos we have from the surface of Venus, and we only have a few because each time a lander has been sent, the longest it lasts is two hours, and then the thing melts. So those are the only two planets we've actually landed something on—Mars and Venus. Well, next up is Mercury. From Earth, here's the best we can see of the planet Mercury through a telescope. And when we send a spacecraft to it, it looks like this. This is the view from up close. We still don't know a lot about Mercury. It's the closest planet to the Sun, and the smallest planet. But one thing we were surprised by is how much it reminds us of another, more familiar object. Do you see any resemblance to something you know? Mercury looks a lot like our Moon. Both are covered in craters, and neither has an atmosphere. In fact, in this side-by-side photo, you almost can't even tell them apart. Being so close to the Sun, we think that Mercury probably reaches temperatures of 700 degrees in the daytime. But without any atmosphere, on the nighttime side, all the heat is lost to outer space, and so the temperature dips down to minus 300 degrees Fahrenheit. This makes Mercury the most extreme planet in terms of temperature differences. That would be a serious problem for us to deal with if we were to ever land there.

EXPLORATION VIDEO 5

The next planet we got up-close photos of is Jupiter, the largest of the planets and the fifth planet from the Sun. Here's what we see of Jupiter from a telescope on Earth. Through a telescope, you notice two brownish-orange bands or stripes across the face of Jupiter. Are you ready for the up-close view when we sent a camera to Jupiter? Here it is. It's beautiful. We've sent a few spacecraft close, and the thing that's impressive every time is how colorful Jupiter is.

These are all clouds. When you're looking at Jupiter, you're looking at the tops of clouds. In this time-lapse video taken by one of the spacecraft we sent, you can actually see the clouds swirling over the course of one Jupiter day. Clouds on Earth are made of water, and they tend to look white. Jupiter has some white clouds, but it also has brown clouds, tan clouds, pink clouds, orange clouds, and no one really knows why they're those colors. One of these colorful clouds deserves special mention, this one the arrow is pointing to—the Great Red Spot. I'm not making that name up. That's what scientists call it. Almost 200 years ago, scientists were able to see the Great Red Spot through their telescopes. So we know that it's been around for at least that long. When we watch this carefully, we realize that it's not just some cloud, but a storm—a hurricane. Watch the time-lapse video again, but this time pay attention to the Great Red Spot. Notice how it's swirling, just like a hurricane on Earth does. It's crazy to think this is a hurricane that's been raging for at least 200 years and doesn't seem to be stopping anytime soon. But that's not even the craziest thing about the Great Red Spot. This storm is over twice the size of the Earth. That gives you a sense of how massive the planet Jupiter is. Let's see up-close photos of the next planet up. Now, long before sending a spacecraft, everyone knew that being up close to Saturn would lead to some of the most amazing scientific photos ever taken. And Saturn has not disappointed us. So that you get a full sense of how awesome Saturn looks from up close, first look at this picture and remember what it looks like through a medium-sized telescope on Earth. And recall that for your grandparents when they were kids, this is how Saturn would have often been depicted in diagrams or books. And ready? Now you see what Saturn actually looks like. This is a true color photo. If you flew to Saturn, this is what you'd see. Special measurements by spacecraft made us believe the rings are mostly made of dust and water ice. So in other words, we think the rings are many trillions of clumps of dirty ice all spread out—basically dusty snowballs. And the rings—here's a close-up video—they orbit Saturn too.

We can see that in the video here. The rings are all moving at thousands of miles an hour. We haven't been able to get super close-up photos of Saturn's rings yet, allowing us to actually see the ice clumps and be certain if our theory is true. But if the theory is true, it would be risky to bring a spacecraft too close to the rings, for fear of it bumping into one of these ice balls at fast speed and getting damaged. What about landing a probe on Jupiter or Saturn? Why not land something on them? Well all four of the outer planets—Jupiter, Saturn, Uranus, and Neptune—we're pretty sure we can't ever land on because there's no surface. There's nothing to land on. We believe all of these planets are almost entirely clouds or gas. These two planets are the least known of all the eight planets. We've only sent a single spacecraft that flew by Uranus in 1986 and reached Neptune three years later in 1989. Uranus and Neptune are so far away. Remember, they weren't even discovered until telescopes had been invented and improved. We knew that they were blue and likely made of gas. And by the mid-1900s, the very best telescopes we had allowed us to even see an occasional cloud or two. But that's about all. So we were excited to see what they looked like up close in detail. The Voyager 2 spacecraft sent back the first-ever close-up image of Uranus in 1986. Are you ready? Weirdly, Uranus still just looked like a blue disk. It's kind of pretty, actually. But when we use special filters to look at Uranus, suddenly, details of its clouds could be seen. What's very unusual about Uranus is the tilt of its spin or rotation—its axis. Uranus spins or rotates around itself, just like the Earth and other planets do. But Uranus does this on its side. Its north pole doesn't point anywhere near Polaris or up above the solar system. Instead, it points off sideways to the solar system. All the other planets' poles point up and down—but not Uranus. This makes scientists wonder if at some point in its history, maybe something slammed into Uranus and knocked it over on its side like this. Neptune, the farthest planet from the Sun, was for this reason also the last to have a spacecraft sent to it. It takes almost 10 years for any spacecraft to get to Neptune. Neptune's

color appears to be much deeper blue than Uranus. And, unlike Uranus, when we sent a spacecraft to get close-up photos, we saw lots of cloud features, including this: a dark blue-colored hurricane we discovered. This was creatively named by scientists the Great Dark Spot. So we've flown robotic cameras past all the planets and put landers on two of them—Mars and Venus—which are the planets scientists now know the most about. We've even remote control landed something on one of Saturn's moons, 10 times farther away from the Sun than we are, the farthest away we've ever landed something on. No human being has ever been to another planet yet, but this will happen within your lifetime. There are people right now working on sending the first colony to Mars. One of the companies considered most likely to succeed is SpaceX, headed by this man: Elon Musk. The first trip is scheduled for about 11 years from now. Maybe someone you know will be on that flight. Our knowledge of the planets is only just beginning. We have so much to learn. But as Mars soon becomes our second home, it will be the planet we become total experts on next.

ACTIVITY VIDEO 1

In this activity, you're going to take the students outside and help them understand the relative distance between the planets by marking them out in chalk on the ground. In addition to conveying a sense of distance, it also reinforces the order of the planets, and it's a fun challenge you can pose to the kids. This video's going to walk you, the teacher, through the prep you need to do in advance and explain how to guide your students. This video is not intended for your students to watch. Here are the supplies you need: a 12-inch ruler, sidewalk chalk—ideally several different colors, colors that are gonna match up with the planets—40 feet of string, a permanent black marker, a toilet paper tube, scissors, and your reference sheet with the scale of the solar system. First, take your toilet paper tube and cut a small slit on one side. Then

repeat on the other side, like this. It should look like this when you're done, so go ahead and do this now. When you're done with this step, press the arrow on the right.

ACTIVITY VIDEO 2

Now set this aside and take your string and ruler and measure out two feet of string by wrapping it to one end of the ruler and back. And with your marker, put a clear black mark to indicate two feet of distance. Be sure to color the front and the back of the string, so go ahead and do this first one. When you're done with this step, press the arrow on the right.

ACTIVITY VIDEO 3

Your string should now look like this. You're going to lay the string on the ground outside, so you want your students to easily spot the markings. Each of these markings is going to be one astronomical unit. An astronomical unit, or AU, is the distance from the Sun to the Earth. This is the unit of measurement that scientists use within our solar system rather than miles, which are too small, and rather than light years, which scientists use within our galaxy and are too big. So now do a second marking, two feet from the first. Just wrap your string to the end of your ruler and back again, and color the front and back. When you're done with this step, press the arrow on the right.

ACTIVITY VIDEO 4

Now that you've done two markings, you need 28 more. You want 30 markings total, but you're going to end up with a huge tangled mess of string, so start winding your marked string onto your toilet paper tube. Stick one end of the string in like this, and then start winding it up. Go ahead and do 28 more markings and wind up as you go. I suggest keeping tick marks on a

sheet of paper so you don't lose count. Trust me on this—I had to unwind my string twice to recount where I was at. Go ahead and complete all 30 markings. When you're done with this step, press the arrow on the right.

ACTIVITY VIDEO 5

When you've done 30 markings, cut your string. If you aren't certain you did 30, you may want to do a couple more now, because you can always trim off the extra string when you take it outside. And after you cut your string, tuck the loose end into the other slit, like this. Now you're prepared to do the activity with your kids. What you're going to do with them is take everyone outside and unroll your string on the ground. Be sure you have your box of chalk and your reference sheet with you. Decide who's going to draw each planet on the ground and let them get creative with it. At the very end of the string, have someone draw the Sun very large. It's hard to make it too big. The Earth should be drawn at the first black mark on the string. Earth is at one astronomical unit. Mercury is about a third of an astronomical unit from the Sun, and Venus is about 2/3 of an astronomical unit from the Sun. So between the Earth and the Sun, you can just evenly divide Venus and Mercury. Mars is in between the first and second black mark. It's at 1 1/2 AU. Then draw Jupiter out at 5 AU and Saturn at 10 AU, Uranus at 20 AU, and Neptune at the end at 30 AU. After you've completed them all, it should look something like this. Now tell the kids that you're going to call out a planet and they have to run to it as fast as they can and stand on it. It's surprising how much fun kids have with this. And what they don't realize is that you're helping them learn the order of the planets without it feeling like a boring exercise in memorization. As you play the game, you'll watch the kids respond faster and faster. And it's fun to go at first maybe a little bit in order with the planets and then switch it up and randomly call them out. So they get all the way to Neptune and then yell out Venus and they

have to run all the way back. There'll be a lot of laughs—enjoy! And when you're all done, wind up the string for next year. This is going to save you lots of time each year.