Science Forward--Astronomy

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Summer Ash: When you look up at the night sky, what do you see? For as long as humans have been around, we've been looking up at that sky and wondering," What are those points of light in the darkness? What can we learn from them? Is there life out there?" For thousands of years the night sky has inspired dreamers and poets, sailors and shepherds. But what kinds of questions have scientists been asking about the universe beyond our planet?

In this video we'll talk to some of my colleagues about the tools astronomers use to observe and analyze those lights in the sky and what they can tell us about our place in the universe. We'll even talk about that burning question, "Are we alone?"

Summer Ash: Telescopes are often the first things that come to mind when people think about how astronomers study the universe. They've been around for well over 400 years.

Irving Robbins: Galileo. Famous, right? Why? First of all, spectacle makers. Lenses were one of the first systems that people worked with. In Holland somehow they came out with spectacles. I'm wearing one, you're wearing one, very nice, helpful for vision.

Somebody in Holland had the brilliant idea of taking...now some people are nearsighted, some people are farsighted. He took the two different types of lenses, put it together, and he made a telescope. Galileo found out about it. That practically opened our field of astronomy because he built the telescope. Actually, he originally built it to stop the pirates from invading Venice.

Summer Ash: The telescopes we're most familiar with are optical telescopes. They collect visible light, the kind of light our eyes can see. But the universe emits all kinds of light in what we call the electromagnetic spectrum.

Light travels through the universe as a wave, which means we can characterize different kinds of light based on their wavelength. You could think of this as measuring the distance between two corresponding points on a waveform. Visible light has a wavelength on the order of nanometers, which is 10 to the minus 9 meters. But the entire electromagnetic spectrum spans over 15 orders of magnitude.

Why do we care about wavelength? We can use wavelength to figure out the energy of the processes that are generating the light, so we can use light as a proxy for those processes. For example, infrared light is important to Emily Rice at the College of Staten Island, who studies brown dwarfs.

For people that don't know, can you actually define what a brown dwarf is?

Emily Rice: A brown dwarf is an object that forms like a star does. It forms from a collapsing cloud of gas and dust. It spins, it condenses, it becomes round. But then it doesn't ever have enough mass to fuse hydrogen and helium in its core. But these brown dwarfs, they seem like stars at first when they're first formed. But then they cool and fade with time.

Summer Ash: How do we actually see brown dwarfs if they're not shining like stars?

Emily Rice: Brown dwarfs, they do shine like stars a little bit. They don't produce their own energy, so they don't shine very brightly in visible light. But because they're cooler, they actually shine more brightly at longer wavelengths of light. They shine pretty brightly in the infrared, and that's how they were actually discovered. They were postulated to exist about 50 years ago, but they weren't actually discovered until about 1995.

The cool thing about the brown dwarfs is that they don't ever die. A star like the sun will die after about 10 billion years of a total lifetime. Brown dwarfs actually will never really burn through their fuel.

There's a lot of them, they're really small, and they live forever. Sometimes I think of brown dwarfs as like the cockroaches of the universe. Then I think about it too much and I think, "No, I don't want to call my research objects cockroaches." [laughs]

Summer Ash: Astronomers are also looking for and finding another kind of object. One we can't often see directly. Exoplanets are planets that orbit around stars other than our own.

Caleb Scharf: The methods we use to detect planets around other stars are interesting, because the typical earth-like planet around a star like the sun is a billion times fainter than the star. Our telescopes simply aren't up to the job of separating out the light of the planet and the light of the star.

Summer Ash: Usually we can't see these planets any more than we could see a firefly next to a searchlight. But astronomers do have techniques for finding them.

Caleb Scharf: To find exoplanets we have to resort to a number of so-called indirect detection methods.

Emily Rice: The indirect ways of detecting planets, one of them is called the radio velocity method or the wobble method. What you're measuring in that case is the motion of the star towards or away from you.

SummerAsh : We can detect this motion because of something called the Doppler Effect, which causes the wavelengths of light from a source moving towards us to be compressed, or blueshifted, and the wavelengths of light from a source moving away from us to be stretched, or redshifted.

Emily Rice: The same way the pitch of an ambulance, for example, of its siren gets shifted if that ambulance is driving towards or away from you. You hear it as a higher pitch if it's driving towards you, and then you hear it as a lower pitch if it's driving away from you.

Summer Ash: When we observe the light from a star very closely, we look to see if the frequency of light coming from that star changes over time.

Emily Rice: Basically, you put back together that the star is moving cyclically towards and away from you. What you're actually seeing is the towards and away from you component of the circular motion of the star. You might think, "Well, why is that star moving in a circle?" The reason that the star is moving in a circle is actually because there's a planet orbiting it. That's the first technique, the radio velocity technique, or I call it the wobble technique.

Then there's another one that's called the transit technique, and sometimes I call it the wink technique, and I could try to wink on camera, but I'm not going to be very good at it. The wink technique is, you're looking at the star. If you happen to have a planetary system that's lined up directly edge-on with the star, as the planet passes in front of the star, the brightness of the star is going to dip a tiny a little bit. A tiny, tiny, tiny little bit.

Summer Ash: Both of these techniques allow us to infer the presence of a planet and get a rough idea of its properties. But if we can use both techniques at the same time, we can learn even more.

Emily Rice: If you get really lucky and you can use both techniques for one star, then you can get the mass, and you can get the radius of the planet. Then you can get the density of the planet, and then you can maybe infer something about the bulk composition of the planet.

Then you can figure out if it's a rocky planet or if it's an iron planet or if it's a gaseous planet or if it's a water planet. But again, you're only figuring out the average density of the whole planet, and there's a lot of uncertainty in that.

Summer Ash: We know that there are other planets out there, and we even know a little bit about them. But there's still that pressing question, "Could any of them have life?"

Caleb Scharf: Why are we looking for life in the universe? Why do we care? It's a good question. Obviously on the one hand it's a deeply, almost emotional question. Are we alone? Is there anybody else out there?

But I think scientifically, certainly for me, one of the motivations is that to understand ourselves, to understand the origin of life here on earth and what has happened here over the last 4 billion years, we may need another example. We need another sample set.

Like any experiment, if you just do it once, it's very hard to figure out the fundamentals. You need more experiments. That's part of the motivation. For me to find life in the universe also means to find out what happened here on earth, and that's really interesting.

Summer Ash: What type of life are we looking for?

Caleb Scharf: The type of life that we're looking for in the universe on the one hand is the sort of life that we understand, which is the life here on earth. But we have to be aware that that may be a very biased template. We don't know the type of life here on earth, the type of biochemistry, the type of evolutionary history that we've had here on earth is going to be typical anywhere.

It's an open question, and so we have to be very careful to, on the one hand, look for things that we know, but we capable of spotting stuff that we really don't understand.

Summer Ash: How are you going about looking for life?

Caleb Scharf: The way that we're going about looking for life in the universe at the moment is very much focused on finding planets that resemble the earth in some way.

The idea of an Earth-like planet is much more complicated, because it's asking questions about whether or not there's an ocean on this planet, whether there's an atmosphere with clouds and oxygen and water vapor in it. Whether the surface temperature is nice. Whether there is the right sort of chemistry for organisms. Whether there are things like fluffy bunnies running around [laughs] on the planet.

Earth-like is a tricky term to use. It's not a particularly scientific term, because of all these complicated factors that go into it. I personally prefer other terms. I like Earth analog, and I also like to point out that when we say "Earth-like" we're really thinking about the earth today. Actually, what we're interested in is Earth at any point in its history, or other planets that resemble the earth at any point in its history.

Summer Ash: When astronomers ask questions about what we see in the night sky, we're really asking some of the biggest questions about our universe and how it all works. Not just out there, but everywhere.

Emily Rice: The most interesting thing about astronomy is that we can know anything about it all. For hundreds of years, we just made up stories about the night sky, like it was our religion, it was our mythology, and things like that.

But now in the last several hundred years, we've actually figured out the science behind the universe, and actually the physics and the chemistry. Everything that we can test here on earth is the same, it's the same laws that govern the entire universe.

We can drop a ball here and demonstrate gravity, and then we can use that same gravity to explain how galaxies form. Or we can look at a rainbow on earth. Then we can use basically a measurement of a similar rainbow from an object that's hundreds or thousands of light-years away to figure out that object's physical properties.

It's the same physics, the same chemistry behind everything, and it's real, it's testable, and it's knowable. Thinking about that just constantly blows my mind.

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