big astronomy

people ✦ places ✦ discoveries

Final Script as Recorded

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| 00:14 | As an astronomer, I always marvel at the night sky. |
| 00:20 | It's beautiful, of course, but light from the Universe also helps us unlock its secrets. |
| 00:29 | My name is Bárbara Rojas-Ayala, and I study stars. |
| 00:37 | We have learned that almost every star we see hosts one or more planets—and we are finding more planets all the time. |
| 00:50 | So for me, the night sky is filled not with distant, lonely stars—but with countless families of planets! |
| 01:01 | I want to share some of these families' stories with you—where they come from, how they take shape—but I also want to introduce you to where I come from—a place where astronomers study the sky, with the help of amazing technology and even more amazing people. |
| 01:33 | A place where people have experienced a strong connection to the night sky—for millennia. |
| 01:51 | I want to introduce you to astronomy in Chile. |

02:03 Chile lies on the west coast of South America. A long, narrow mountainous country. The Pacific Ocean lies to the west, the towering Andes Mountains to the east, and the Amazon rainforest to the north.

02:28 Chile is perhaps the best place in the world for observational astronomy, because of its special climate.

02:39 The Andes block rainclouds from the east, while currents in the Pacific Ocean bring cold waters north from the Antarctic. Along the Chilean coast, the air temperature drops, and as the cooled air sinks, it loses its moisture.

03:02 These factors combine to create stable, dry air over Chile's coastal mountains, with few clouds. Perfect conditions for astronomy!

03:16 Many major telescopes dot Chile's mountainous terrain… We will visit just three.

These observatories are looking at places in our solar system and beyond to help astronomers understand where planets like ours come from.

03:48 Standing on the side of this mountain, you can understand why it was named "Cerro Tololo," which in the Aymara language means "At the Edge of the Abyss."

Cerro Tololo Interamerican Observatory is home to dozens of telescopes.

04:06 Let's take a look at the largest—the Victor M. Blanco Telescope, with a primary mirror four meters in diameter.

04:23 Astronomers designed this telescope to observe the same kind of light our eyes can see—it's an *optical* telescope.

04:34 Light enters the large opening and bounces off the giant mirror—it's the first thing the light hits, so we call it the primary mirror. The bigger the mirror, the more light it can collect, so astronomers like to build large telescopes to gather as much light as possible!

The shape of the mirror focuses light on a giant lens—more than a meter across!

05:02 That lens is part of an amazing instrument called the Dark Energy Camera.

05:09 *The Dark Energy Camera has 62 science detectors—one of the biggest cameras in usage in the world right now.*

05:19 Marco Bonati is the first of several people we'll meet who keep these observatories running. As an electronics detector engineer, he is responsible for what happens inside the instrument.

05:33 *You need to be very careful that they are clean all the time because otherwise you have all sorts of stuff deposited in the surface and the surface is especially coated.*

*Basically, we want to avoid any dust particles. So in the clean room, we have a controlled environment. We can control the amount of dust inside by basically having filters and positive pressure that keeps the dust out.*

06:02 *All the light that the telescope gathers goes to a single point basically, and this point you put the detector. So the detector you put there depends on the science you want to do…*

06:16 Once the instrument is out of the clean room and mounted on the telescope, other team members help make the observations.

06:30 *Jackie Seron:*

*My name is Jacqueline Seron. I work at Cerro Tololo Interamerican Observatory. My position is night assistant.*

*This means taking care of the instrument and having the telescope ready, taking calibrations, making sure that everything is working fine. And during the night, operating the telescope, which means moving the telescope to the position the observer wants and making sure that everything is working correctly.*

07:11 *What I really like is to learn in general how the telescope works, how it takes data, and all these different systems that are interconnected and accomplish such a huge task—you know, all the engineering involved, it's amazing.*

07:38 Let's hear more from Kathy Vivas, a Venezuelan astronomer living in Chile…

07:45 *Kathy Vivas:*

*I am part of the support team of one instrument in the Blanco telescope, the Dark Energy Camera. Which is a wonderful instrument, it's a special to make surveys to cover large portions of the sky.*

08:00 *As part of the support team, we make sure that the camera is producing science-quality data that is really for astronomers from all around the world, to come and do*

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| | *their science projects with the telescope and that they can achieve their science goals with this instrument.* |
| 08:27 | The Dark Energy Camera was designed to peer into the farthest reaches of the Universe. But because it can observe a large portion of the sky, it also helps us search for objects much closer to home. |
| 08:49 | Leaving Earth behind, we see the orbits of planets around the Sun…<br>Mercury, Venus, Earth, and Mars.<br>Jupiter, Saturn, Uranus, and Neptune.<br>But our solar system includes many other objects—not just planets! |
| 09:16 | Astronomers have used the Dark Energy Camera to find numerous small, icy bodies in the outer reaches of the Solar System. We have tracked thousands of these objects, which reside far away from the Sun, past the most distant planet, Neptune.<br>They make up what's called the Kuiper Belt. |
| 09:44 | Billions of years ago, everything we see here likely revolved in the same plane. But the massive planets' gravity tugged the lightweight Kuiper Belt Objects into different orbits. They now travel far above and below the plane of the planets' orbits. |
| 10:05 | Each tiny icy world we discover helps us answer questions about the history of our solar system. What did it look like billions of years ago, when the planets were taking shape?<br>We can't go back in time, but we can observe other planetary systems in the process of forming. |
| 10:30 | This work requires our most powerful telescopes, so let's return to Chile.<br>We are heading to a mountain called Cerro Pachón, only about 20 kilometers from Cerro Tololo. |
| 10:59 | Here we find the Gemini South Observatory, which began viewing the sky in 2002. |
| 11:09 | Inside the dome, we can see the giant telescope, with a mirror more than eight meters across—more than twice the diameter of the Blanco Telescope! |
| 11:20 | This giant mirror must remain highly reflective, which means it needs cleaning every week.<br>Such a big job requires a lot of teamwork. |

11:35 *Vanessa Montes:*

*My name is Vanessa Montes. I'm an electronics engineer.*

*We have different disciplines like optics, mechanics, electrical, software also. I think that's very unique to observatories and astronomy in general.*

*We all work very well. It's a lot of team effort. And a lot of collaboration between everyone. And I think that's very positive. The more you can encourage people to participate more creatively in the different projects that we do, it's a more collaborative work environment.*

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12:06 Cooperation on Gemini extends around the globe. Astronomers rarely travel to Chile to use the telescope; instead, they telecommute.

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12:17 Here in the Gemini Base Facility in the coastal town of La Serena, nearly 100 kilometers from Cerro Pachón, technicians can operate a special instrument that looks at young planetary systems, called the Gemini Planet Imager, or "Gee-Pie."

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12:39 Almost 10,000 kilometers away, at Stanford University in California, observers see the same displays—and guide the work with GPI.

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12:50 Astronomers need somebody they can trust on the other end of the line, and that's where Alysha Shugart, Science Operations Specialist, comes in.

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13:02 *Alysha Shugart:*

*We operate the telescope at night. We take the data for the astronomers who have all contributed proposals for science and when we shift between night and day schedules, we take turns. We rotate to day schedules where we do data quality analysis and daily instrument health inspections.*

*I really enjoy observing. I think about it as if these photons that literally… are billions of years old arriving and I'm seeing them for the first time.*

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13:25 Not all photons are *billions* of years old. Many were created more recently, closer to home. Light detected by GPI reveals what happens when planets form around nearby stars…

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13:43 We can imagine traveling to one such place, so far away that its light takes more than sixty years to reach us.

This star is more massive and much brighter than the Sun. The star and its planetary system are less than 30 million years old, mere infants compared to our own, middle-aged solar system. Dust and debris form a disk around the star.

Some tiny objects in this disk will end up like our Kuiper Belt—icy bodies at the edge of the system.

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14:25 GPI allows us to peer into the center of the disk. Astronomers then use computers and the laws of physics to simulate what might be happening.

We have discovered one giant planet—more than a dozen times more massive than Jupiter—whose gravity has sculpted the dusty disk into a warped spiral.

Could something similar have happened in our solar system billions of years ago?

15:05 For the next part of the story, we must now travel much farther north in Chile, to the Atacama Desert, one of the driest places on Earth.

15:25 Home to a collection of 66 radio antennas, the Atacama Large Millimeter/submillimeter Array, or ALMA.

15:39 The skies of the Atacama Desert are famously clear, and people have observed the sky from here for millennia.

David Barrera is president of the indigenous community of San Pedro de Atacama.

15:59 *David Barrera:*

*I feel that the cosmos walks with me. It walks with you, with human beings, it's part of our life.*

16:15 *We human beings are nothing compared to what the great cosmos is, that's why we're part of the cosmos. We walk together.*

16:29 *We make up a single unit. That's the marvel of human understanding.*

16:39 *ALMA has been a respectful neighbor because it has asked: "What is the ancient wisdom of the native people in regards to the cosmos?" And ALMA's invitation to the indigenous community is in some way to unite scientific knowledge with indigenous knowledge.*

17:12 Astronomers have come to this unique spot on Earth, to build an array of telescope antennas that benefit from the clear, dry skies 5,000 meters above sea level.

17:30 These giant antennas work together, like a single, enormous eye observing the sky in unprecedented detail.

And they can work both night *and* day.

17:46 Each dish weighs about 100 tons! And they need to move from place to place, both to make different kinds of observations and to receive maintenance when needed.

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| 18:03 | Alfredo Elgueta is one of only four people trusted to operate the transporters that move the telescopes. |
| 18:12 | *Alfredo Elgueta:*<br>*The transporter has just one basic work that it's designed to do and it's move this big radio telescope from one point to another.* |
| 18:24 | *When you're doing the maneuver of trying to load the antenna or unload the antenna you have to do it with the remote.* |
| 18:34 | *But when you're doing the translation from one point to another, you have to do it from the cabin.* |
| 18:41 | *Every time that an antenna needs a big fixing or anything we try to bring it down. But it takes a lot of coordination to do that.* |
| 18:53 | *It takes around five hours, driving like five kilometers per hour.* |
| 19:05 | Once the antennas are in their correct locations, they collect a huge amount of data. And they work as a network: data from each antenna is compared to data from every other one.<br>Celia Verdugo, an astronomer and data analyst, collects and studies these observations for astronomers from Chile and other parts of the world. |
| 19:33 | *Celia Verdugo:*<br>*The kind of light we are collecting from the sky is a light is emitted in the radio wave shape, you see. We are looking at the parts of the universe with the lowest temperature and because of that low temperature they emit their energy through radio waves.* |
| 19:52 | *We collect that signal and from that, we can get either spectral information—which means either the emission or absorption lines in the spectra of the object we are observing—or we can also get images of source we are observing.* |
| 20:02 | *We are taking data for projects that are really breaking the limits of what we know. Going beyond the limit of our knowledge. That is really fascinating.* |

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| 20:16 | One of the ways ALMA has revolutionized our view of the Universe is by giving us a close-up look at young planetary systems.<br>Here we are seeing not just the leftovers of planet formation, but the actual disk of material from which planets take shape. |
| 20:40 | This is ALMA's image of PDS 70, a very young star, less than 10 million years old.<br>Its debris disk looks more like a ring of dust surrounding the star, with a large gap where at least one Jupiter-sized planet is forming. That planet has a small disk of its own, where moons could be forming around it. |
| 21:10 | Here, we are seeing the results of a computer simulation, which we can compare with data from ALMA and other telescopes to help astronomers understand how planets grow.<br>Perhaps our solar system looked like this billions of years ago, a family of planets taking shape… |
| 21:40 | Pioneering work in astronomy requires investing in the next generation of telescopes. |
| 21:48 | When completed, this telescope will observe the entire visible sky every few nights. It will generate 20 terabytes of data each night—twice as much as the Hubble Space Telescope generates in a whole year!<br>All the data will be made freely available to the world, enabling anybody to make the next great discovery. |
| 22:20 | The future of astronomy lies in all our hands.<br>That's why I enjoy meeting with students of all ages. I hope some of them will grow up to work with me at one of Chile's great observatories—or elsewhere in the world.<br>All of us you met today come from different backgrounds with many different talents and skills to contribute. |
| 22:56 | We invite everybody to look, to learn, and to enjoy astronomy.<br>We hope to share the wonder of the sky—and the excitement of discovery—with the whole world. |
| 23:35 | If you'd like to meet more amazing people and hear more stories about big astronomy in Chile, visit BigAstronomy.org, where you will find live conversations with observatory staff, exclusive behind the scenes content, and educational activities. |