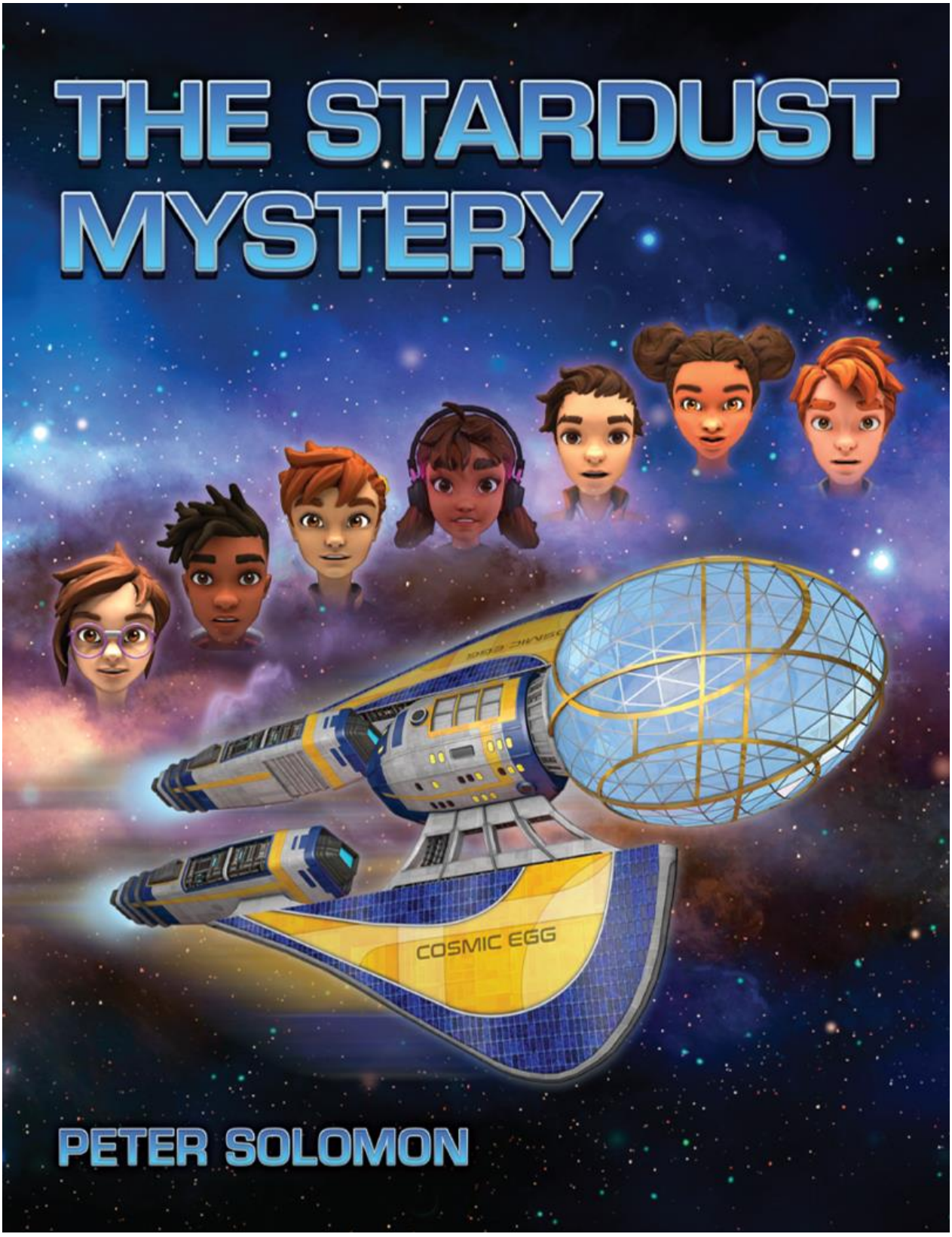
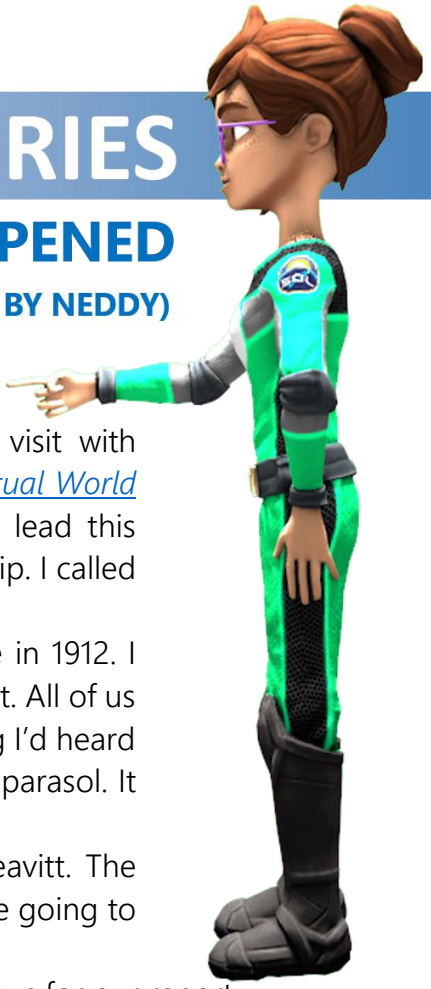


NEDDY'S STORIES

THE WOMAN WHO OPENED THE UNIVERSE (AS TOLD BY NEDDY)



We organized the tiny bit of information we got from our visit with Johannes Kepler in 1595, then decided to go back into the *Virtual World* right away and time-travel to see Henrietta Leavitt. I got to lead this expedition, even though Milo insisted on coming on our girls' trip. I called on Neddy, the *Virtual World* Guide to help us.

First, we chose fancy clothes that would be appropriate in 1912. I wore a long, white, lace dress with a black belt cinching my waist. All of us had on giant hats, but Milo's hat was smaller and like something I'd heard Grandpa call a "bowler hat." Awesomely, my outfit came with a parasol. It wasn't raining, so I just used it like a walking stick.

In the Gallery of Experts, we asked to see Henrietta Leavitt. The Neddy-Guide showed us her picture and indicated that we were going to Harvard University in Cambridge, Massachusetts, in 1912.

We took a screenshot of our arrival on the Harvard campus for our report.

"OK, now how do we find Henrietta?" I asked. We wandered around looking for a clue on how to find her.

"Hey, look at this!" Milo was thumbing through a Harvard Crimson newspaper, which we learned from the me-Guide, had been around since 1873.

I snatched the smallish paper out of his hands, which was impolite. But I was leading this sucker, so I got to snatch anything I wanted. It said that Henrietta Leavitt of the Harvard College Observatory was going to give a lecture that very day called "The Discovery of a Method to Measure the Distance to Stars."

"Wow," said VC, as she read the title over my shoulder.

"Oh, look!" I observed, "There's a lecture to follow by Edwin Hubble. Isn't he one of the people on the TSI list of important clues?"

"And the Hubble Telescope is named after him," I added. "His lecture is called 'Some Observations Based on the Leavitt Method.'"

"These things have got to be important to the stardust mystery," Lizzy jumped in.

"Aren't you glad you brought me along?" Milo asked annoyingly. But I high-fived him and everyone else. He did, after all, pick up the newspaper.

I asked a passing college student how to get to the Harvard College Observatory. He gave us directions.

On the way there, we couldn't cross the street because there was a parade of women going by.

"What is going on?" VC asked a man standing near us.

"Suffragette protest," he replied.

"What's a suffragette?" Milo asked.

"Why, they're radical women who are trying to get the right to vote!" he answered.

"The right to vote?" I wanted to know. "You mean like for the president of the United States?"

"And for senators and congressmen!" the man added. "Isn't that just ridiculous? Women are much too emotional and too uneducated to vote."

"Wow," I said, "I'm sure glad that I didn't live back then."

"And I'm sure glad that the rest of the men didn't all think like him," Lizzy added, "because in eight years, in 1920 when the Nineteenth Amendment to the Constitution was approved, women did get the right to vote."

"Did they get to stop wearing those uncomfortable dresses?" I asked.

"Hey, what is that thing on the other side of the street?" Milo suddenly changed the subject. We all looked. It definitely looked like the flea from Lizzy's trip into the dog's hair. We made our way through the marching suffragettes and across the street, but by the time we got to where the flea had been, it was gone.

"That's weird," Milo said.

"And really freaky," I agreed.

"Wait!" Lizzy called. "It's . . ." then her voice trailed off. While the others walked ahead, I stayed back with her.

"What did you see?" I asked.

"That woman again."

We looked around, but she was as gone as Fleazilla.

We walked to the Observatory and arrived just in time to see a bunch of people, mostly ladies, having their picture taken in front of the building. One of them was Henrietta Leavitt. We recognized her from the picture the me-Guide showed us.

After the photograph was taken, we followed the group inside.

"Hi." I greeted, running up beside Henrietta Leavitt, "my name is Neddy, and this is Milo, Lizzy, and VC."

"Hello," replied Henrietta, "I am pleased to meet you Neddy, Milo, Lizzy, and VC."

"We are working on a science project, and we heard that you made a fantastic discovery. Could you tell us about it?" Lizzy asked.

"I am so happy that you girls . . . and boy," she added looking at Milo, "are interested in science," she said. "I can tell you about my work, and about measuring the distance to stars. What would you like to know?"

"What did you discover," I asked, "and why is it important?"

"Good questions," said Henrietta. "Let's take a walk up to one of the telescopes. It's easier if I show you what I did."

We followed Henrietta up to the top floor of the building, to the biggest telescope.

"This is where we take the star photographs," she explained. "At the Harvard College Observatory, we look at stars and take their photographs using a telescope. The telescope makes things much bigger and sharper than what we can see with the naked eye. We ladies

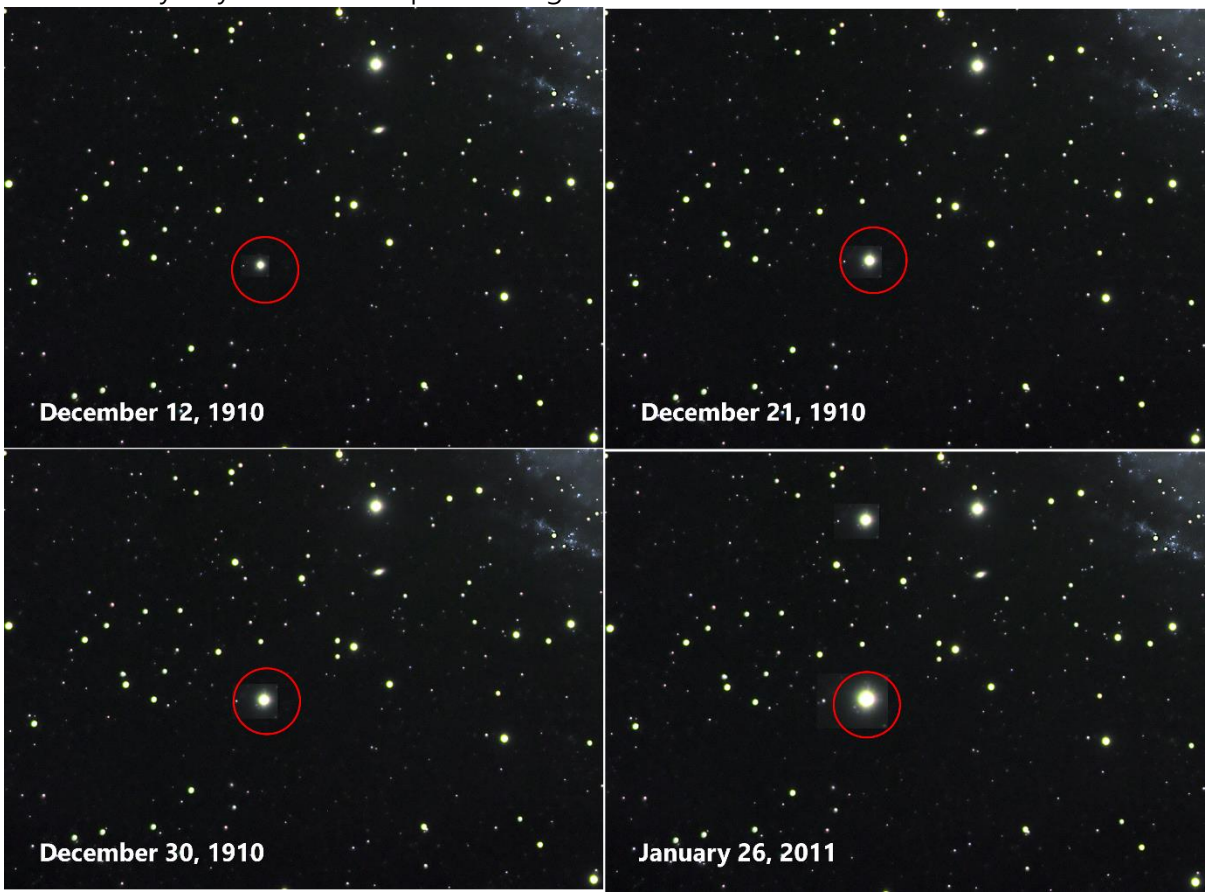
are called the 'computers.' What we do is identify each star and compute how bright it is in the photograph and write all the data in a big logbook."

"That's funny," Lizzy said. "Where we live, a computer is an electronic device, not a person."

Henrietta continued. "One problem that astronomers have is that if we see a very bright star, we don't know if it is bright because it is a very big star, or it is bright because it is a smaller star that is much closer to Earth. So, astronomers don't know how big the universe is. They don't know which stars are close, and which are far away."

"OK," VC responded, "I understand that. How did you fix the problem?"

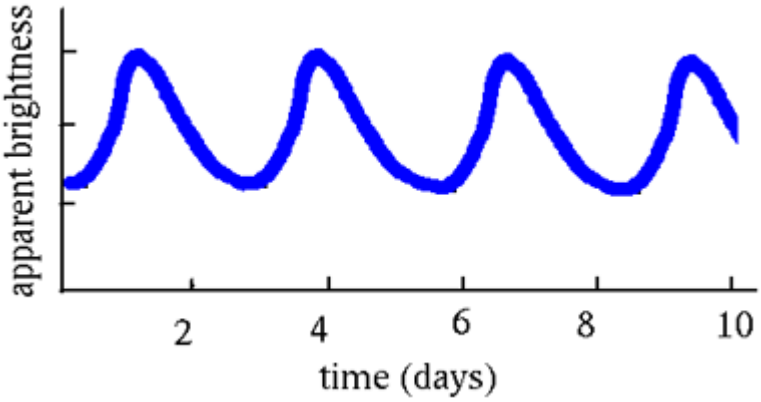
Ms. Leavitt pulled out some photos and said, "Here are some pictures that we took between December 17, 1910, and January 26, 1911. You see the star in the center with the red circle around it. Look what happens to it during that time. In the early photos on the top, the star is much dimmer than in the later photos on the bottom, where it appears to get much brighter. We called stars that did that variable stars. I would measure how bright the star was every day and make a plot of brightness over time."



She continued, "Here is one of those plots for a star that changed from dim to bright over just two days. What I discovered from making these plots for lots of these variable stars in a cluster was that the brightest stars took the longest time to go from dim to bright and back to dim."

"Oh!" chimed in Lizzy, "So the speed of change—or how fast the star went from dim to bright—was a clue as to how big the star was!"

"Yes!" agreed Henrietta. "It seemed that big stars took a month, while small stars took only two days. If that was always true, we had a way to determine how big a variable star was. We just measure the time it takes to go from bright to dim, and that would tell us whether a star was big or small. And for the first time since people started studying stars, we would know how big the variable star is. My observation then allows us to use its peak brightness to tell us how far away it is. I think that will be very important for astronomy."



"Yes," Milo said. "It has been very important."

"What do you mean?" Henrietta asked, looking confused.

Milo started to answer, but Lizzy cut him off. "Thank you," said Lizzy. "You made it very easy to understand."

"Can you help answer a question about our science project?" asked VC. "We think that our bodies are made of stardust, and we think that the stardust is atoms. Could atoms be made by stars?"

"I don't know," replied Henrietta. "That's an interesting idea, but I don't have an answer. Maybe there will be some new discoveries now that we can measure the distance to the stars. I know that Dr. Edwin Hubble has been using my method, and he is going to talk later today about his observations that all the stars are moving away from Earth."

Henrietta also told us about a Belgian physicist named Georges Lemaître that was also interested in her hypothesis. "He has written me to ask about my discovery," she added. "By the way, Professor Lemaître is a Catholic priest. Isn't that interesting?"

Milo whispered to me, "I think he is the guy that invented the *Big Bang* theory."

"I have another question," added Neddy. "Do you think that you will win a Nobel Prize for your discovery?"

"Oh my, no," replied Henrietta. "Thank you, but that will never happen. Only one woman, Marie Curie, has ever won a Nobel Prize in Physics, and I don't think that my work is that important."

Finally, VC asked, "Why are the computers all women?"

"That is easy," said Henrietta. "We work for much less money than men, and we do a better job. I only get paid twenty-five cents an hour."

"How much do men get?" Milo asked.

"Oh, I think it is at least thirty to fifty cents an hour," replied Henrietta.

I had one last question, "Are you computer ladies respected for your work?"

"Oh my," replied Henrietta, "that is kind of a touchy subject. I will let you be the judge. We work for Professor Edward Pickering and everyone calls us Pickering's Girls or Pickering's Harem. Do you think that sounds respectful?"

"What's a Harem?" I asked.

"It's a group of women kinda all married to one man," answered Lizzy.

"Gross," Neddy said. And Henrietta and the rest of us agreed.

With that, we thanked Henrietta Leavitt, then we sat in on some of her lecture, but then we all got kind of squirmy and decided to log off of the *Virtual World*.

Later we agreed we'd have to visit Edwin Hubble and Georges Lemaître.

"Now, about Henrietta Leavitt," said Lizzy. "She's my new hero."

For our contest report, we wrote about how Henrietta's discoveries allowed astronomers to calculate how far away stars are from Earth. It was something that they could never do before she came along. Before then, everyone believed that stars were just part of the Milky Way galaxy. Her discovery allowed astronomers to see and show that the universe is a whole lot bigger than that.

I also did some research I added. "The stars she studied became knowns as Cepheid variable stars, So her discovery allowed astronomers to tell whether a star's brightness was from being big or from being close to Earth. And that was fantastic because her method opened up a whole new universe to study."

Lizzy was really curious about whether Henrietta ever got any credit for the important work she'd done. So, after the meeting, she logged on to the *Virtual World* for Harvard University in 1930. She asked around about Ms. Leavitt and didn't like what she found out. Not one bit. Henrietta had been almost completely erased from her own discovery.

When we were together for our next team meeting, Lizzy told us what she had found out. She stared right at Milo and hollered, "Here is an example of how you men don't give us women any credit. Twelve years after her discovery, the men of science finally realized what a great discovery Henrietta had made and were considering giving her the 1924 Nobel Prize in Physics. But they found out that she had died three years earlier. Men! Here's a woman who did such great work that they were going to award her a Nobel Prize, and they didn't know that she had already died!"

"Men can be so inconsiderate," said VC. Which sounded pretty funny coming from a twelve-year-old.

Can you think of anyone in science that has shown us anything as big as Henrietta Leavitt?

GRANDPA'S GLOSSARY

Virtual World: Virtual worlds, also known as virtual environments, use computer technology to create a simulated world that a user can explore and interact with, while creating a feeling as if he or she were in that world. The representation of the user in that world is called an avatar. The user can even wear goggles to make it appear that he or she is surrounded by the 3-D virtual world. That is called virtual reality.

Cepheid Variable Stars: Cepheid variable stars are special stars whose appearance cycles from large and bright to smaller and dimmer. Henrietta Leavitt had a hunch that the time period it took to go from bright to dim might depend on the size of the star. To test her idea, she reasoned that stars in the Small Magellanic Cloud (a distant star cluster) would be about the same distance away from Earth, so their brightness would indicate their size. She found twenty-five variable stars in the cluster and determined that the period varied with the size or average brightness. Bigger, brighter stars took longer to change than smaller, dimmer stars. Knowing how the time for the brightness to change varied with a star's size allowed astronomers, for the first time, to determine the size of any Cepheid variable star in the universe. By knowing the size, the astronomers could use the peak brightness to determine the distance from Earth.

The Big Bang: The planet Earth that we live on is sometimes called a Goldilocks planet. It is not too hot. It is not too cold. It is just right as a home to support the lives of beings such as our own species and millions of others. And our species has been constantly fascinated with the questions of where we live and how we got here.

More than two thousand years ago, humans looked at all the things in the sky and decided that the universe consisted of the Earth at the center with the sun, moon, and stars all revolving around the Earth. In the fifteenth and sixteenth centuries, Copernicus and then Kepler and Galileo said that the universe has the sun as the center, and everything revolves around the sun. Then, in the nineteenth century the picture changed to the sun and planets revolving around the center of the Milky Way galaxy. In the early twentieth century, the work of Henrietta Leavitt and Edwin Hubble showed that the Milky Way galaxy was only a small part of the universe, which has billions more galaxies like the Milky Way. What's more, Hubble's measurements and the predictions of Alexander Friedmann and Georges Lemaître showed that the universe is expanding, with the most distant stars moving away from us the fastest.

Based on the expansion of the universe, Lemaître made a bold prediction. He reasoned that if you follow the universe back in time, it gets smaller. The further back in time you look, the smaller it has to be. So, if the evolution of the universe were a movie showing its expansion, and you played it backwards it would be contracting. The contraction of the

universe would put the universe in one tiny, super dense point about 14 billion years ago. Lemaître pictured the expansion of the universe from that point as the hatching of "the Cosmic Egg exploding at the moment of the creation". Other scientists call this the Big Bang theory. Lemaître gave lectures explaining his theory, including at Princeton University, where Albert Einstein was in attendance. It was reported that Einstein said, "This is the most beautiful and satisfactory explanation of creation to which I have ever listened."

How do we know that the Big Bang theory is correct? Well, scientists can calculate what occurred as the universe expanded from that first point. They can make predictions about the concentrations of elements in the universe and about the leftover radiation from the earliest times, which can still be seen as the cosmic microwave background. They can predict the size of stars, galaxies and galaxy clusters, and the rate of the universe's expansion. Compared with these observations, the Big Bang theory is very accurate.

When we look at all the things that have to be just right for the universe to evolve as it has, and for us to be here on our Goldilocks planet, it seems that we live in a Goldilocks universe too. But we understand our Goldilocks planet as being the one that is just right in the millions of other planets that aren't just right. Living things may be on the ones that are just right, but not on the others that aren't. So, is our Goldilocks universe just the one that is right out of the millions of other universes that aren't just right? Are there millions of other universes out there that aren't just right? So, just like we found the Earth, and then the sun, and then the Milky Way galaxy were only a small part of the universe, maybe the universe that evolved from our Big Bang is only a small part of the multiverse. . . or was there a creator?

THE STARDUST MYSTERY PROJECT

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THE RACE TO THE BIG BANG: Coming in May 2021

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