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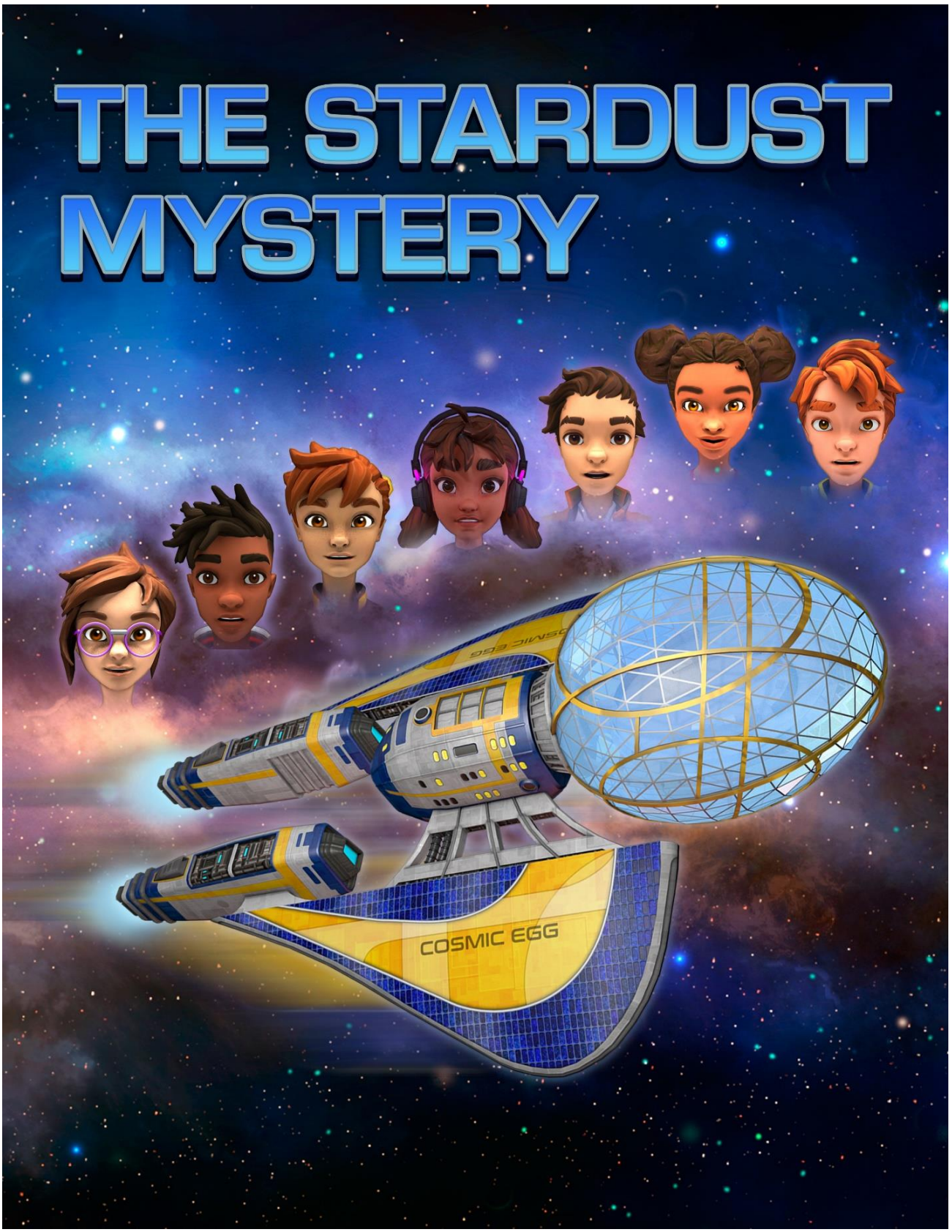

MILO'S STORIES

THE EXPANDING UNIVERSE

(AS TOLD BY MILO)

Oh man! I totally realized this morning when I checked the leaderboard that we're running out of time to solve this difficult mystery. Only two weeks left to the cut!

I know we've made good progress, but Svetlana and her siblings are still holding the lead. Don't get me wrong, I'm glad it's her. She's really fantastic. But I wish it were us. Anyway, the Cosmic Kids are now tied for second place. So hopefully by the end of the month we'll make the cut!

We all got together at the G-parents' for a meeting and to use the *Beamer*. We were going to visit Edwin Hubble. He's the guy that the giant space telescope is named for—launched into low Earth orbit by NASA in 1990. He's also the guy that Henrietta Leavitt suggested we talk to.

I was gonna plan the visit, but Lizzy interrupted because she had gone back to Harvard to find out more about Henrietta Leavitt and because she's annoying.

"Based on my follow-up visit to Harvard in 1930," she said, "I found out that Leavitt's discovery led to some great things! Like Edwin Hubble used her method to discover lots of new galaxies." She yammered on, saying that our Milky Way is only a small part of the universe. "Hubble also used Leavitt's discovery to show that all the stars are moving *away* from Earth and from each other, and the further away they are, the faster they are moving!"

That sounded very awesome.

"That means that the universe is expanding!" shouted VC.

"And Georges Lemaître, who is also on our list, actually predicted an expanding universe two years earlier than Hubble, based on solving Einstein's General Relativity equations!" Neddy added.

Lizzy, who had her hands on her hips and looking super annoyed, waiting for everyone to stop talking over her. But Neddy continued, "Professor Lemaître also suggested that the expansion all started with something called the *Cosmic Egg*, which is now called the *Big Bang*."

Then Lizzy started getting madder and louder. She stared right at me and hollered, "Here is an example of how you men don't give us women any credit. Ten 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.

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Before using the *Beamer*, we talked about the questions we needed to ask Hubble.

Then we each logged on, chose our avatars, and asked VC the Guide (because it was VC's turn to lead the visit, and we almost never used VC the Guide) to see Edwin Hubble. VC the Guide showed us a picture of this old guy with a pipe in his mouth and informed us that we were going to the Palomar Observatory in California in the year 1950. After a minute or so, we found ourselves outside a large, domed white building, which I guessed was the observatory.

"What the. . ." said Lizzy. "I think I discovered another bug in the *Beamer* software. Look how I am dressed." We looked at her. She was in her martial arts uniform, but we had all seen her put on her *Beamer* crew outfit.

"Wait!" Neddy cried out. "Weren't you wearing that outfit when you first saw the flea in the dog's hair?"

"Yes!" Lizzy agreed. "Do you think my outfit, the flea in the dog hair, and the flea at Harvard and now here are connected?"

"And what about the dancing Kepler?" I added.

"Is there a glitch in the *Beamer* software?" asked Lizzy.

No one had an answer.

Well, we were here now, so we followed a path toward the observatory where we found Professor Hubble.

"Hi, Professor Hubble!" I called, as we walked over to him. I introduced us. "Can we ask you some questions about your work?"

"Sure," he answered. "What do you want to know?"

"We spoke to Henrietta Leavitt," started Lizzy, "and she said that you were doing some amazing work based on her method of measuring the distance to stars."

"Hey, are you kids trying to pull a fast one on me?" demanded Hubble. "Henrietta Leavitt died over twenty-five years ago. You kids are way too young to have talked to her."

"What she meant to say," Neddy corrected, "was that she *imagined* talking to her."

"Yes," Lizzy nodded and flashed the smile with the dimple. "I really just *read* about it."

"Oh, OK, let's start again," said Hubble. "What would you kids like to know?"

"Well," I asked, "what did you discover using her star distance measuring technique?"

"I discovered two things," he said as he held up his fingers to count. "One, there were many more galaxies out there besides the Milky Way. We had previously thought that was the only cluster of stars in the universe. And two," he put up his second finger, "the universe is expanding. All the stars and galaxies appear to be moving away from us and from each other. The further away they are, the faster they are moving."

"Were these two discoveries important?" I asked.

"Oh, yes," Hubble replied. "I can tell you a story about my work and Albert Einstein. When Albert heard about my work on the expanding universe, he said that he had made the 'biggest blunder of his life.'"

"Can you tell us about the blunder?" I asked.

"Yes," he said. "Einstein's *General Theory of Relativity* predicted that the universe was expanding. But at the time, everyone believed it was static, that it wasn't expanding or contracting. So, Einstein added a fudge factor, the *Cosmological Constant*, to make the theory predict a static universe. When he heard about my measurements showing the universe was expanding, he said adding the *Cosmological Constant* was the biggest blunder of his life.

"Wow," said Lizzy, "that is quite a story. "Then she added, "I have one last question. Do you know anything about stardust?"

"No," said Hubble.

We asked whether he knew how atoms like carbon were formed and he told us that it was formed by nuclear fusion. He also said we should talk to a professor named Fred Hoyle. "He has been working on how atoms form in stars," he said.

Just as we were leaving, something terrible happened. We heard heavy footsteps, like from the dinosaurs in the *Jurassic Park* movie and in our MissionKT adventure, and some crunching

sounds. We looked back toward the observatory where the sound was coming from to see what was going on.

I think Lizzy knew what it was even before she saw it. It was the giant flea that has been stalking her during our *Beamer* visits. It seems to be a bug in the software.

The weirdest thing about the giant flea is that it actually looks kind of cute. Its face almost look like a mouse face with little beady black eyes and teeth that stick out where a mouse's whiskers would be.

Lizzy's mouth opened when she saw the flea, but no sound came out.

"Lizzy?" VC said in her soothing voice.

"Breathe, cousin," I added.

"YOU GUYS!" said Lizzy, regaining her voice big time. "IT'S THE FLEA THAT CHASED ME THROUGH THE DOG'S HAIR!"

"The *Beamer* software really does have bugs, real ones!" Neddy said,

Lizzy started running. VC and I did too, while Neddy just stood there a puddle of socially stunted confusion.

But luckily for Neddy, the flea didn't want her. It didn't want VC or me either. It wanted Lizzy!

VC and I slowed down and watched as Lizzy ran around the observatory, trying to outrun Fleazilla. She kept looking for ways to lose it, but every time she changed directions, it did too. The prehistoric-looking animal was gaining on her. She put forth a burst of speed and ran as hard as she could.

"Help!" she cried, staring at first me, then VC.

But it was no use. The flea caught her, picked her up in its claws and bit off her head.

No one spoke for a minute then I groaned, "Oh man, that was gross."

We logged off without saying goodbye to Hubble.

"I am so never leaving Grandma's house!" cried Lizzy.

"I know it sucks to be killed," I said, "but I mean, dude, it's just *virtual*."

Lizzy turned to me and walked eight steps in about three strides and said right in my face, "You have no idea how bad it sucks to be killed, Milo! But you're about to . . ."

VC grabbed Lizzy's arm and pulled her back. "Get over here, tiger," she said. "Let's take it down a notch."

Everyone calmed down, and we finally started talking about our next mission.

What was Hubble's most important discovery?

GRANDPA'S GLOSSARY

General Theory of Relativity: General relativity is the geometrical theory of gravitation published by Albert Einstein in 1915. When Einstein became aware that feeling weightless in the absence of gravity, or in free fall acceleration because of it, were equivalent and something extremely fundamental, he called it the "happiest thought of my life." This observation guided him in the development of the theory in which gravity is a geometric property of space. In Einstein's theory, mass tells space how to curve, and the curvature of space tells mass how to move. The General Theory of relativity has important predictions. Georges Lemaître's solution of Einstein's equations for an expanding universe led to his Big Bang theory. The bending of light by gravity can lead to the phenomenon of gravitational lensing, in which multiple images of the same distant astronomical object are visible in the sky. The attraction of light by mass leads to the prediction of black holes, whose mass is so large that no light can escape. The theory predicts that cosmic events can produce gravitational wave distortions of space itself that travel at the speed of light. The first observation of gravitational waves was made by LIGO in 2015. The theory predicts the Twin Paradox described in chapter 18. The predictions of general relativity have been confirmed in all observations and experiments to date.

Cosmological Constant: The solutions to Einstein's General Relativity equations predicted that the universe would be expanding or contracting. Think of a ball that you throw up in the air. It could be going up or it could be going down, but it can't stay still. But at the time Einstein was working on his theory, everyone believed that the universe was static (or still). So, Einstein added a term to his equations called the Cosmological Constant. It was an anti-gravity term to "hold back gravity" and achieve a static universe. But Edwin Hubble's measurements showed that the universe was expanding, so then the Cosmological Constant could be removed. But wait a minute, cosmologists have discovered that there is something called dark energy that is acting like antigravity material in accelerating the expansion of the universe. So now the Cosmological Constant is back in the equations of General Relativity.

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