WHERE ARE WE GOING? I JUST FOLLOWED EVERYONE ELSE.

WE'RE HEADED TO PORTLAND, OR.

TO VISIT LIGO, LUCY SHOULD KNOW ALL ABOUT IT. IT'S BASED ON LASERS.

THEN TOMORROW WE'RE TAKING A FANCY BUS 4 HOURS TO HANFORD, WA.

COMIC BOOK CREATIVE TEAM:
REBECCA THOMPSON, PHD
SCOTT ARNOLD
ROEL TORRES
GUILHERME LINDEMENBERG MENDES

WHOA! TURBULENCE!
AFTER A 6 HOUR FLIGHT, THE TESLA JUNIOR HIGH SCIENCE CLASS GOT TO PORTLAND. THEY HAD SOME AMAZING MAPLE AND BACON FLAVORED DONUTS, ADVENTURES IN A LARGE BOOKSTORE, AND A NIGHT TELLING GHOST STORIES. RIGHT AND EARLY THE NEXT DAY THEY GOT ON A BUS TO HEAD TO HANFORD, WA.

UM, LEGOLAND?

THERE ARE NO LEGOS.

LIGO IS THE LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY.

THEN WHY ISN'T IT LIGOW?

THAT DOESN'T SOUND AS GOOD.

LIGO USES LASERS TO LOOK FOR GRAVITATIONAL WAVES.

GRAVITATIONAL WAVES ARE RIPPLES IN SPACE AND TIME CREATED BY ACCELERATING MASSES SUCH AS PAIRS OF BLACK HOLES.

WE ARE HERE! TWO LINES AND FORWARD MARCH!!
Wow, it looks like it takes all kinds of people to run this observatory.

This is a different way to think about gravity and black holes!

What’s with the big mirrors?

The mirrors are what respond to the gravitational waves. They are what the laser senses, so are crucial to the detector. The mirror coatings have to be specifically made to reduce noise or else the moving atoms in the coating make it impossible to detect gravitational wave signals.

Optics Olympiad winners from Hardy Middle School.

A Nobel Prize?!

You don’t see one of those on every field trip!

Gather up, everyone! Time for the tour!
Gravitational waves stretch and squish the very fabric of the universe. Imagine the Mona Lisa hanging on the wall...

As gravitational waves pass through her, she will be stretched along one direction and then the other.

Measuring how much she is stretched...

...or squished tells us about the gravitational wave.

Does LIGO have a copy of the Mona Lisa?

No, we measure gravitational waves by seeing how the distance traveled by the laser light in the detectors changes when gravitational waves pass by.
What we know of gravity is the result of warped space time caused by massive objects.

Picture sitting on a trampoline with a buddy. If one of you moves the other can feel it because the trampoline also vibrates. In space-time the vibrations are gravitational waves.

When really heavy things like black holes smash into each other they create large enough waves that LIGO can measure them.

LIGO measured gravitational waves for the first time on September 14th, 2015.
These are the tubes that make up the arms of the LIGO detector. They are welded in a spiral like a really, really long toilet paper roll.

Inside of the tubes needs to be a nearly perfect vacuum so the light from the laser won’t bounce off of air molecules. It takes 40 days to get the air out of both arms.

They have to be perfect cylinders or they will get crushed when the air goes away. There can’t be any leaks. The tubes are surrounded by concrete to protect them from the environment.

What would happen if a mouse got trapped in there while the air was being sucked out?

The vacuum would kill the mouse. Geeze...
The buildings you can see are the halfway point and in the far distance are the end stations.

Each arm is 2.5 miles long. If you ran up and back along each arm and then around the parking lot a few times that's as long as half a marathon.

The beams need to be long because the farther laser light travels the easier it is to see small changes in the distance travelled.

The interferometer splits the laser light and sends it down both arms of the detector. The laser light bounces off mirrors at the far ends of the arms and then returns to where it started.

If the arms are the same length then the light will return at the same time, but if the arms are a slightly different length then the two beams are slightly out of step.

Would you rather jog down one of the arms, or travel as a laser?

I'm thinking about going for a 5-mile jog.

But anything, really, will make the beam lengths different. We can notice the rumbling of the storms off the Aleutian Islands.

Does that mean this is the world's most sensitive weather detector?
THIS IS WHERE WE MONITOR ALL THE DATA TO SEE HOW THE LASERS ARE LINING UP. THE DATA LOOK REALLY NOISY BUT WE HAVE GREAT TOOLS TO SORT SIGNAL FROM NOISE. DURING AN OBSERVING RUN SOMEONE IS ON DUTY 24/7.

I CAN HANDLE BEING A SCIENTIST IF THERE ARE SNACKS.

K'ALL CAME AT THE RIGHT TIME. WHO KNOWS WHAT HAPPENS WHEN THE LARGEST STARS DIE??

IN A STAR, NUCLEI OF ELEMENTS ARE SLAMMED TOGETHER AND MAKE BIGGER ELEMENTS.

AT SOME POINT, THE STAR CAN'T MAKE ANYTHING ELSE AND IT COLLAPSES AND WHEN IT DOES IT MAKES A HUGE EXPLOSION WE CALL A SUPERNova.

AMAZINGLY, WE KNOW THAT A NEARBY STAR IS ABOUT TO GO SUPERNova!
NOW WHERE IS THE BATHROOM?

HMM. I THINK I TOOK A WRONG TURN.

WHOOPS!

LET ME TRY THE OTHER DIRECTION.
We just got an astronomer’s telegram. The star is about to go supernova.

This is the only chance this century to collect these data! We’re ready, let’s go!

The laser is off line! What’s going on?!

We don’t know! It was working fine today but it just went dead in the middle of an observing run!

We understand that the laser was working this morning. We tried turning it off and back on again, but it didn’t help.

I don’t like this lack of order! This doesn’t sound good...

We’re getting someone suited up to look at what happened.
WHERE'S KASE? WE NEED TO FIND HIM.

OKAY, EVERYONE OUT!

EVERYONE SEEMS PRETTY WORRIED THAT THE LASER WENT DOWN.

KASE IS MISSING AND THE LASER WON'T WORK. I DON'T THINK IT'S A COINCIDENCE. I BET YOU IT'S HIS FAULT.

THERE YOU ARE! WHERE HAVE YOU BEEN?

WHAT? I WAS JUST LOOKING FOR A BATHROOM. TOOK ME LONGER THAN I EXPECTED.

SURE, AND I'M GUESSING MAYBE YOU ALSO BROKE A LASER WHILE YOU WERE MISSING?

WAIT, THE LASER IS DOWN? I CAN TOTALLY FIX THAT!
OH NO! WE'RE NOT HOME, HOW ARE YOU GOING TO GET YOUR SPECTRA OUTFIT???

WE WERE GOING ON A FIELD TRIP TO A LASER LAB. OF COURSE I BROUGHT IT, AT THIS POINT I JUST ASSUME SOMETHING WILL GO WRONG.

YOU HAVE TO GO INTO THE LIGO INTERFEROMETER, SPLIT IN THE BEAM SPLITTER, BOUNCE BACK AND FORTH DOWN THE ARMS FOR A BIT, AND MEET BACK UP WITH YOURSELF.

YOU HAVE TO BE VERY POWERFUL. LIKE 200 WATTS WHICH IS ABOUT 50,000 TIMES MORE POWERFUL THAN WHEN YOU PLAY WITH YOUR CAT.

OK, I JUST HAVE TO WORK HARD AND BE MYSELF, WELL, MORE "MYSELF" THAN I'VE EVER BEEN I GUESS.

THIS IS BIG AND SCARY AND A WHOLE LOT IS RESTING ON ME, BUT BEING SCARED ISN'T GOING TO STOP ME. HERE GOES!

I WOULD HAVE PAID MORE attention if I'd known I was going to have a test on this.

YOU NEED TO BE EXACTLY 1044 NANO METERS, NO MESSING AROUND. YOU'LL BE INVISIBLE AT THAT WAVELENGTH, TOO. YOU'VE NEVER HAD TO BE THIS POWERFUL OR THIS EXACT.

THE SOLUTION MIGHT LOOK EASY, BUT THE POWER AND PRECISION ARE WHAT MAKES IT HARD. NEAR IMPOSSIBLE, SO SUIT UP AND GO GET 'EM, CHAMP!
I CAN MAKE YOUR EAR DRUM VIBRATE WITH MY SONICS MAN POWERS!

I NEED TO COMMUNICATE WITH SOMEONE IN THE CONTROL ROOM TO MAKE SURE I'M AT THE PROPER FREQUENCY AND GOING IN THE RIGHT DIRECTION.

WE'VE TALKED TO YOU IN LASER ROOM BEFORE, THIS SHOULD WORK.

IS KAS REALLY OUR BEST CONTACT FOR BRAINY STUFF?

DON'T WORRY -- I'LL TELL KAS WHAT TO SAY. I'LL HANDLE THAT PART.

THE GRAPHICS IN THE CONTROL ROOM WILL INDICATE IF YOU'RE FIXING THINGS.

I'M SCARED TO TRY THIS, BUT THERE'S NO MORE TIME FOR STALLING.

YOU CAN BE BRAVE AND SCARED AT THE SAME TIME. BEING BRAVE MEANS DOING SOMETHING EVEN IF YOU'RE SCARED.
Hurry up, Lucy. The laser is still down.

I guess they need everyone to be clean in here.

There aren’t any windows for entry.

I’ll apologize later, but for right now, I need to create a hole so I can get in there.

I don’t know what part of the beam path was messed up, but I’ll start from the beginning and go from there.
HEADING DOWN THESE TUBES IN LASER FORM IS EXCITING!

THE BEAM SPLITTER!

IM SPLITTING UP!

OH, LOOK, THERE I AM. HELLO, ME!

HI, ME!

END OF THE ROAD, BOUNCING BACK TO THE STARTING POINT.

I'M COMBINING BACK TOGETHER, THEY MUST NOT BE GETTING A SIGNAL.

LET ME TRY AGAIN.
This vacuum is amazing. I've never had such a clear path!

I'm back to the beam splitter but where's the other me?

You're going great, you just need to adjust your wavelength a little bit.

I've got to get this right. The supernova signal is about to arrive and we don't want to miss it!

I can feel myself building up power!
The detector is coming back online.

It looks like it is just fixing itself?!

Spectra, it’s working!

I can’t keep this up forever. I need a break.

Oh no! What happened to the laser?

I told you lasers can’t fix themselves!

Good thing I developed my stamina with all my swim training!

Let’s give this one more try!
IT WORKED! I’VE NEVER FELT SO POWERFUL OR SO PRECISE!

WOW! THIS IS THE FIRST TIME WE’VE EVER OBSERVED GRavitATIONAL WAVES FROM A SUPERNOVA!

YEAH! ALL RIGHT!

THE LASER CAME BACK ONLINE JUST IN TIME!

LET’S CHECK WITH THE NEUTRINO DETECTORS TO SEE IF THEY CAUGHT IT!

THERE IS SO MUCH GREAT SCIENCE FROM THIS ONE EVENT, THESE DATA WILL KEEP US BUSY FOR YEARS!

KURODA, TAKIWAKI, KOTAKE (2016)
CAN WE TRUST OUR DATA? HAVE WE HEARD FROM LIVINGSTON?

YEY! VIRGO AND KAGRA ALSO DETECTED IT! IT'S REAL!

WELCOME BACK, LUCK!

NICE JOB! YOU REALLY SAVED THE DAY!

WHAT ARE YOU KIDS DOING HERE? YOUR BUS LEFT A LONG TIME AGO!

THIS IS OUR SUPERHERO FRIEND, SPECTRA. I GUESS PEOPLE HAVEN'T HEARD ABOUT HER OUTSIDE OF INDIANA.

I CAN TURN INTO A LASER. I RAN DOWN THE ARMS AND BOUNCED AROUND. I WANTED TO TRY AND HELP TO MAKE SURE YOUR EXPERIMENT WAS A SUCCESS.

SHE USUALLY SAVES LIVES AND TOWNS, BUT THIS IS THE FIRST TIME SHE SAVED A SCIENCE EXPERIMENT.
Hi, I’m Mike Landry, Head of the Lab. Would you like to work with us? We have a sweet retirement package.

Hi, I’m Mike Landry, Head of the Lab. Would you like to work with us? We have a sweet retirement package.

Thank you, but I have to decline. I’m still in school. It’s too early to think about retirement.

I don’t want to spend my days in an interferometer. I would rather build better lasers.

I understand. Well, when you’re ready, you’re welcome back here any time.

Here, take an official Ligo coffee mug.

I don’t drink coffee yet, but my parents will love it! Thank you!

Uh, our bus left a long time ago. Could someone give us a ride back to Portland?

It’s four hours away and our plane leaves tomorrow -- we want to get back in time for donuts!

END
Keep up with the latest in the world of physics and the original laser superhero

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