THE STAR

THE NEWSLETTER OF THE
MOUNT CUBA ASTRONOMICAL GROUP
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<u>MISSION STATEMENT:</u>

The Mission of the Mt. Cuba Astronomy Group is to increase knowledge and expand awareness of the science of astronomy and related topics and technologies.

<u>ASTRONOMICAL TERMS AND NAMES:</u>

When reading the articles in the STAR, you will come across various terms and names of objects you may not be familiar with. Therefore, in each edition of the STAR, we will review terms as well as objects related to Astronomy and related technologies. These topics are presented on a level that the general public can appreciated.

Cepheids - a variable star having a regular cycle of brightness with a frequency related to its luminosity, so allowing estimation of its distance from the earth.

gamma-ray burst - flashes of gamma rays associated with extremely energetic explosions that have been observed in distant galaxies. They are the brightest electromagnetic events known to occur in the universe. Bursts can last from ten milliseconds to several hours. The initial burst is usually followed by a longer-lived "afterglow" emitted at longer wavelengths (X-ray, ultraviolet, optical, infrared, microwave and radio).

gravitational wave - Gravitational waves are 'ripples' in the fabric of space-time caused by some of the most violent and energetic processes in the Universe.

Astronomically Far Away: How to Measure the Universe

Credit:

Paul Sutter is an astrophysicist at The Ohio State University and the chief scientist at COSI Science Center. Sutter is also host of the podcasts Ask a Spaceman and RealSpace, and the YouTube series Space In Your Face. Sutter contributed this article to Space.com's Expert Voices: Op-Ed & Insights.

Things in space are, appropriately enough, astronomically far away. The distance to the sun and other planets in the solar system is easy enough to calculate, especially because we can toss probes about here and there, and presumably, the probes will know how far they've traveled when they land.

But how can astronomers make the great leaps to measure the distances to the far-flung stars? How can we claim with any certainty the breadth and depth of the Milky Way? And what ruler spans the farthest reaches of the universe, separated from us by seemingly unfathomable oceans of darkness?

It starts with triangles

I want you to perform a science experiment. Come on, this will be fun. Start by shoving your nose right into the screen. That's it, right here. Close one eye. Now switch to the other. Continue alternating. If anybody gives you distraught glances, smile calmly, and with your sagest voice, tell them, "This is for science."

As you alternate eyes, the words on this screen should leap left and right, covering huge apparent distances. Now, back up to normal reading distance. Continue switching eyes. The words still shift, but not nearly as much as when we were a little more intimate.

Congratulations! You've discovered parallax. It's part of the reason it's useful to have two eyes: With binocular vision, your brain can judge distances without needing to evolve a ruler coming out of your forearm

It's easy enough to calculate the distance: The span between your eyes forms the base of a long, skinny triangle. The amount of swing a distant object appears to travel as you switch eyes gives you one of the angles in the triangle. With a little bit of high-school geometry, you can know the distance to your desired target.

OK, great, but that's not exactly useful for stars, which are vastly farther away than this screen. But that's fine; we can still play the same game — we just need a different set of cameras. How about, say, Earth in the summer and Earth in the winter?

That's a pretty big triangle. Because we know the distance from the Earth to the sun, we know how wide our binoculars are. And by carefully measuring the teensy-tiny wiggle in a star's position between the seasons, we can compute the distance.

Well, to a point. I mean, most stars are so fantastically far away that we could never hope to measure their parallax, no matter how sophisticated — or big — our triangle gets.

Even better than triangles

To carry us even farther into the reaches of the cosmos, we need to switch to a different measurement method. This new method is again based on a very simple concept: brightness. If I know exactly how bright something is, then by measuring how bright something looks, I can figure out how far away it is. Farther things look dimmer. Super simple. We just need to know exactly how bright stuff in space is.

Fortunately, nature gives us a few of these "standard candles." One is a kind of star called a Cepheid , which periodically goes from dumb and dim to hot and bright in the matter of weeks or even days. That itself isn't all that special — stars do, after all, change brightness all the time — but what's peculiar about Cepheids is that the time between episodes is proportional to their true brightness. The brighter a Cepheid is in real life (as in, up-close-in-your-stellar-face real life), the longer it takes to cycle back and forth.

Their name doesn't mean anything special. As usual in astronomy, they're named after the constellation where they were first discovered — in this case, Cepheus. And the connection between their true brightness and the time between episodes was discovered about 100 years ago using the ever-reliable parallax method on a few nearby stars. That means we can measure a Cepheid star's cycle (which is super easy, at least when it comes to astronomy) and immediately know its true brightness (which is super hard, at least until we can build probes that go there and just look). And we can compare the true brightness to how bright it looks, do a little math, take a little nap and tell the world how far away that Cepheid is, reaching even beyond the limited parallax method.

By the way, this is how Edwin Hubble convinced everyone that we should change the name from the Andromeda nebula to the Andromeda galaxy, because the Cepheids there were just a bit too far away to be inside the Milky Way, thereby radically expanding our conception of the true size of the universe.

Knowing what we don't know

Also, we're not exactly sure how Cepheids … you know, work. The best we can figure is that it has something to do with the layers of gas surrounding the star. The gas may be (somewhat) cool, hugging close to the star and blanketing the light from our eager telescopes. But the star's intense radiation puffs the gas out farther away from the star, thinning it enough to let the starlight pass through. After a while, the gas layer gets tired of that game, cools off and settles back closer to the star. Unsure of where exactly to live, it cycles back and forth, sometimes days at a time, for centuries.

That's only our best guess; we actually have only a vague understanding of what powers the variability of Cepheids. But get this: It doesn't matter. I'll say it again, with emphasis: It doesn't matter. When it comes to using Cepheids as a distance-measurement device, what matters most is there's some way to measure the true brightness. The fact that a relationship exists between a Cepheid's period and brightness is all we need. (Well, yeah, if you're an astrophysicist interested in explaining all the goings-on up in space, then it's important. But if you just need a reliable distance estimator, then not so much.)

Cepheids give us rulers to some pretty far-out places — even those beyond our own galaxy. But at even greater distances, their usefulness peters out. If you can't see an individual star anymore, then it's no use to try to measure its periodicity. You need to use something brighter, something more intense, something … super. A supernova, for example.

Bright enough, common enough and reliable enough to use as a standard candle, supernovae (and, specifically, ones known as Type Ia) are so supremely bright that they allow us to measure some truly awe-inspiring distances, over halfway to the edge of the observable universe.

Not bad for a little trigonometry.

NASA has detected a burst of light that might be linked to one of the most monumental space discoveries ever made.

In September, physicists made a monumental discovery that opened up a new window to the universe.

Using equipment called the Laser Interferometer Gravitational-Wave Observatory (LIGO), the researchers detected ripples in the fabric of space-time called gravitational waves, something Einstein's general theory of relativity predicted a century ago.

These gravitational waves should allow scientists to directly study some of the most violent processes out there and probe general relativity by observing how gravity behaves in extreme conditions.

But on that same day — less than half a second after LIGO made its monumental discovery — the Fermi Telescope, a space observatory orbiting the earth, picked up a brief, faint signal from the same region of space. The chances of that being coincidental hover around 0.2%. And if it wasn't a coincidence, it could open the door to a whole new world of physics.

A flash of gamma rays

On September 14, Fermi observed what's known as a gamma-ray burst, a flash of the most energetic type of light in the electromagnetic spectrum, radiating from the same neighborhood as the black-hole merger.

According to what we know about black holes, this shouldn't have happened: Light shouldn't be able to escape from two betrothed black holes since any gas surrounding them would be swallowed up by one before it merged.

But in order to produce a gamma-ray burst, there must have been some gas left over.

"Gamma-rays arising from a black hole merger would be a landmark finding because black holes are expected to merge 'cleanly', without producing any sort of light,"

To figure out what this gamma-ray burst means, then, physicists will need to observe more of them. And, like this one, the bursts will have to be linked with gravitational waves from black-hole mergers.

How to spot a gravitational wave

LIGO is just one key way scientists hope to hunt for gravitational waves. It currently consists of two detectors, one in Louisiana and the other in Washington. The detectors use a laser beam, split between a pair identical arms that form an L-shape, to detect almost imperceptible differences in length caused by a gravitational wave passing through and warping the fabric of space-time where the detector sits.

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What are Gravitational Waves?

Gravitational waves are 'ripples' in the fabric of space-time caused by some of the most violent and energetic processes in the Universe. Albert Einstein predicted the existence of gravitational waves in 1916 in his general theory of relativity. Einstein's mathematics showed that massive accelerating objects (such as neutron stars or black holes orbiting each other) would disrupt space-time in such a way that 'waves' of distorted space would radiate from the source (like the movement of waves away from a stone thrown into a pond). Furthermore, these ripples would travel at the speed of light through the Universe, carrying with them information about their cataclysmic origins, as well as invaluable clues to the nature of gravity itself.

The strongest gravitational waves are produced by catastrophic events such as colliding black holes, the collapse of stellar cores (supernovae), coalescing neutron stars or white dwarf stars, the slightly wobbly rotation of neutron stars that are not perfect spheres, and Though gravitational waves were predicted to exist in 1916, actual *proof* of their existence wouldn't arrive until 1974, 20 years after Einstein's death. In that year, two astronomers working at the Arecibo Radio Observatory in Puerto Rico discovered a binary pulsar--two extremely dense and heavy stars in orbit around each other. This was exactly the type of system that, according to general relativity, should radiate gravitational waves. Knowing that this discovery could be used to test Einstein's audacious prediction, astronomers began measuring how the period of the stars' orbits changed over time. After eight years of observations, it was determined that the stars were getting closer to each other at *precisely* the rate predicted by general relativity. This system has now been monitored for over 40 years and the observed the remnants of gravitational radiation created by the birth of the Universe itself. changes in the orbit agree *so well* with general relativity, there is no doubt that it is emitting gravitational waves.

Since then, many astronomers have studied the timing of pulsar radio emissions and found similar effects, further confirming the existence of gravitational waves. But these confirmations had always come indirectly or mathematically and not through actual 'physical' contact.

That was the case up until September 14, 2015, when LIGO, for the first time, physically sensed distortions in space-time itself caused by passing gravitational waves generated by two colliding black holes nearly 1.3 billion light years away! LIGO and its discovery will go down in history as one of the greatest human scientific achievements.

Lucky for us here on Earth, while the origins of gravitational waves can be extremely violent, by the time the waves reach the Earth they are millions of times smaller and less disruptive. In fact, by the time gravitational waves from the first detection reached LIGO, the amount of space-time wobbling they generated was thousands of times *smaller than the nucleus of an atom*! Such inconceivably small measurements are what LIGO was designed to make. To find out how LIGO can achieve this task, visit LIGO's Interferometer.

Public Nights and Family Nights at MCAO

Friday, June 03, 2016	8:30 PM	Greg Weaver	**FAMILY NIGHT**
Monday, June 13, 2016	8:30 PM	Greg Weaver	**FAMILY NIGHT**
Monday, June 27, 2016	8:00 PM	Greg Lee	"Moonstruck"
Monday, July 11, 2016	8:00 PM	Stan Owocki	"Ask An Astrophysicist About Absolutely Anything Astrophysical"
Monday, July 25, 2016	8:00 PM	Amy Hornberger	"What's It Like to Be an Astronaut"
Monday, August 8, 2016	8:30 PM	Greg Weaver	**FAMILY NIGHT**
Monday, August 22, 2016	8:00 PM	Judi Provencal	Topic Pending
Friday, September 9, 2016	8:30 PM	Greg Weaver	**FAMILY NIGHT**
Monday, September 12, 2016	8:00 PM	Carolyn Stankiewicz	"Astronomy and Astrology-Similar and Different.
Monday, September 26, 2016	8:00 PM	Billie Westergard	"Stellar Evolution of the Smallest Stars"
Monday, October 10, 2016	8:00 PM	Scott Jackson	Topic Pending
Monday, October 24, 2016	8:00 PM	Bill Hanagan	Choosing Your First Telescope
Monday, November 7, 2016	8:00 PM	Shelia Vincent	Tales of the Night Sky
Monday, November 21, 2016	8:00 PM	Budd Howard	Topic Pending
Monday, December 12, 2016	8:00 PM	Scott Jackson	Christmas Star

Family Nights are scheduled from late spring to early fall on Friday nights at 8:30PM. These programs are opportunities for families with younger children to see and learn about astronomy by looking at and enjoying the sky and its wonders. It is meant to teach young children from ages 6-12 about astronomy in simple terms they can really understand. Reservations are required and admission fees are $3 for adults and $2 for children.