Lookback Time in Our Everyday Lives:
Introductory Activity
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One of the activities that we have done as part of the GSUSA Astronomy Camps is *Lookback Time*. The farther away we look out into the Universe, the farther back in time we see. Why is this? Do we ever experience this effect in our everyday lives?

Lookback all comes down to the speed of light, 299,792 kilometers per second (186,282 miles per second or 670,615,000 miles per hour). If you could travel at the speed of light, you could circle the Earth 7.5 times in one second (though light travels in a straight line)!

In a way, we see and hear lookback time frequently. When we are watching fireworks, we see the magnificent display before we hear the loud bang that it makes. When there is a thunderstorm, we see the lightning and then, a few seconds later, we hear the thunder. That is because sound travels at "only" 1,236 kilometers per hour (343 meters per second, 767 miles per hour, 1,125 feet per second [at sea level in dry air]). So, if a lightning strike is a mile away, we see it almost the instant it happened (0.000005 seconds later), but do not hear it for more than four seconds.

As a side note, when we talk about "the speed of light," we are talking about how fast all electromagnetic radiation travels; light and radio waves are both part of the electromagnetic spectrum.

Background: the speed of light

The concept of light having a finite speed dates back to about the time of Aristotle. However, it was not until the early part of the 1600s that Galileo and others proposed experiments to determine its speed. Some of these experiments were tried, but they failed to determine a speed of light since the distances used were too small (a few miles). It was not until 1676 that an actual measurement of the speed of light was made. Giovanni Cassini and his staff had been making observations of the moons of Jupiter. They used these observations to determine the orbital period of Io (Jupiter's inner moon) by observing Io as it came out of Jupiter's shadow—a lunar eclipse. However, as the Earth in its orbit moved away from Jupiter in its orbit, Io's emergence from the shadow occurred later and later than he had predicted.

Ultimately, it took Earth-based and laboratory-based measurements to determine the now-accepted value of 299,792.458 kilometers per second in a vacuum (and about 0.03% slower in the Earth's atmosphere), exactly.

Activity: Communicating with spacecraft

In this activity, we will use a model of the Solar System to model the time it takes to send a signal back to Earth and thus the concept of lookback.

When astronauts went to the Moon, they were about 384,400 kilometers (239,000 miles) away. Therefore, when Neil Armstrong spoke his famous words, "The Eagle has landed," and later "One small step…," it took 1.3 seconds for those words to get from the Moon to the Earth. We can calculate light time in three ways: how long it takes light from the Sun to get to a planet, how long it takes light (or a signal) to get from a planet to the Earth (at its closest distance to Earth), or how long it takes a signal to get from the planet to the Earth as they both orbit the Sun.

At the moment, there are spacecraft in orbit around Mercury, Venus, the Moon, Mars, the asteroid 4 Vesta, and Saturn. There are also spacecraft orbiting the Sun and in orbits around the Sun that will eventually take them to Jupiter and Pluto, as well as spacecraft that are well beyond Pluto.

Part 1:

In the table below are listed the planets, the asteroid Vesta, Pluto (representing the Kuiper belt), and the Oort cloud (the source of long-period comets). It should be noted, that while we have now seen more than 100 Kuiper belt objects, we have only observed one or two objects that are thought to come from the inner part of the Oort cloud. To save time, we will do this as a group.

Planet	Distance (from Sun)		Distance From Earth (closest)		Distance From Earth (today)	
	AU	Light time	AU	Light time	AU	Light time
Mercury	0.39					
Venus	0.72					
Earth	1.00	8.3 min	0.00	0.0 min	0.00	0.0 min
Mars	1.52					
Vesta	2.36	19.6 min	1.36	11.3 min	3.47	28.9 min
Jupiter	5.20					
Saturn	9.54					
Uranus	19.2				21.0	
Neptune	30.1				30.5	
Pluto	39.5				31.9	
Oort cloud	50,000					

Above is a table of the mean distances of the planets from the Sun in Astronomical Units (1 AU = the mean distance of the Earth from the Sun, 149.6 million kilometers) and in light time from the planet to the Sun and from the planet to the Earth. You have been given the distances to Vesta, Uranus, Neptune, and Pluto as these are not on the orrery model.

So, when the Dawn spacecraft takes a picture of the asteroid Vesta, which is now on the far side of the Sun, it is actually telling us what it saw nearly a half hour ago. When the New Horizons spacecraft reaches Pluto, it will fly through Pluto's shadow about one hour after its closest approach to Pluto. If the spacecraft were to immediately send images back to Earth, where will the spacecraft be (it will be traveling past Pluto at 14 km/s)?

Voyager 1 is now over 100 AU from the Earth; so when it sends back its information to us, by the time the signal gets to us, it is telling us what was observed about 14 hours earlier.

Part 2:

Finally, pace yourself and walk from Jupiter (at 5.2 AU) to the Sun. How long did it take? How many times the speed of light were you going in this model (compared to Jupiter's light time). How long do you think it would take you to walk (in this model) to the nearest star (not the Sun), Proxima Centauri, which is 4.3 light-years away? (A light-years is equal to 63,241 AU.) If someone on a planet around Proxima Centauri e-mailed you and invited you to a party, how long would it be before the email arrived?