Lookback Time in Our Everyday Lives: The Basics

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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 that 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 all of the time. 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" 1,235 kilometers per hour (343 meters per second, 767 miles per hour, 1,125 feet per second). 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), accurate to 1 meter per second.

Communicating with spacecraft

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.

Planet	**Distance**		**Planet**	**Distance**	
	AU	**Light time**		**AU**	**Light time**
Mercury	0.39	3.2 min	Venus	0.72	6.0 min
Earth	1.00	8.3 min	Mars	1.52	12.6 min
Jupiter	5.20	43.2 min	Saturn	9.54	79.2 min
Uranus	19.2	2.6 hr	Neptune	30.1	4.2 hr
Pluto	39.5	5.5 hr	Oort Cloud (comets)	2,000 to 50,000	280 days to 7000 days

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.

Therefore, when the Mars Rovers, Spirit and Opportunity, and the Mars Phoenix lander send pictures back to Earth, it can take from a little over 4 minutes (when Mars and Earth are on the same side of the Sun) up to more than 20 minutes (when Mars is on the other side of the Sun).

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.

Stellar distances and the 3D nature of the heavens

We use the Astronomical Unit as our unit of length for measuring distances in the Solar System. However, because stellar distances are so large, astronomers use another unit of length, the light-year (ly). The light-year is defined as the **distance** light travels in one year, 9.46 trillion kilometers (5.88 trillion miles or 63,241 AU). Next to the Sun, the closest star to the Earth is Proxima Centauri at 39.9 trillion kilometers (24.8 trillion miles, 267,000 AU, 4.22 ly). Therefore, it takes light 4.2 years to get to us. If something happened to Proxima Centauri, we would not know it for 4.2 years! For us in the northern hemisphere, the closest star that we can see in our sky is Sirius (the brightest star in the sky after the Sun) at 8.5 light-years (ly).

When we look at the star patterns in the sky that we call asterisms (the simple patterns like the Big Dipper and the Summer Triangle) and constellations (like Ursa Major, the Great Bear), what we are seeing is a group of bright stars that happen to be in the same direction as seen from our perspective on Earth. In actuality, the stars can be at vastly different distances. We have an activity called *3D Constellations* that demonstrates this for several constellations. We also have a related activity called *The Earth in Motion*.

Lucy, phone home

AM radio signals are refracted by the atmosphere and reflected by the ionosphere, so the first commercial radio signals that could be detected beyond the Earth's atmosphere were TV signals. Hence, science fiction movies and TV shows have used TV broadcasts as our first "contact" with beings from other worlds—they were "watching" us through our TV broadcasts. Two examples of this are the movie *Contact* where the first signals we receive from space are a rebroadcast of Hitler at the 1936 Summer Olympics in Germany while an episode of *Amazing Stories, Fine Tuning* has a boy tuning in on the broadcasts of aliens who are getting ready to visit Earth. They have created their own versions of *I Love Lucy,* the *George Burns and Gracie Allen Show,* and other early 50s sitcoms and now want to come to Earth to meet their favorite TV stars!

So how long would it really take for aliens in another star system to receive our TV shows? The real boom in TV occurred just about 60 years ago. So, civilizations as far away as 60 light-years are regularly getting our TV programs (not even in reruns yet), and civilizations within 30 light-years have been able to receive our broadcasts and send back hellos.

As of the writing of this activity (March 2013), there were 861 confirmed extrasolar planets (exoplanets) orbiting more than 677 stars (128 of these with multiple planets). Of these, more than 20 Earth-like exoplanets are within 50 light-years of Earth.

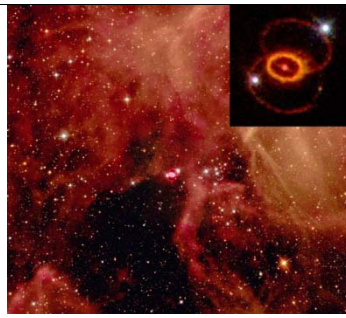
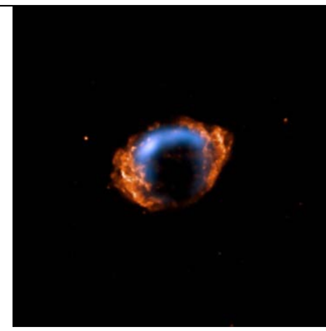
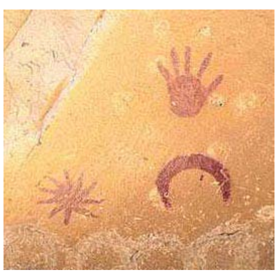
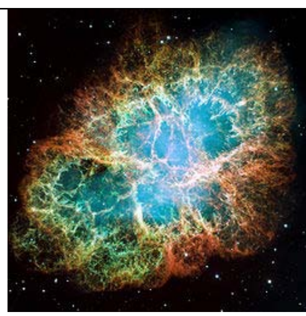
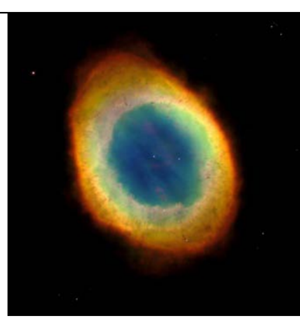
Astronomical events

Novas and supernovas are astronomical events that have been recorded down through history. The remnants of some of these are now seen as glowing nebulae. Below is a list of some of these events, when they were seen on Earth, and when they actually occurred (taking into account the light time to get from there to here). The misconception of when these events occurred came up recently when a spacecraft discovered the remnants of a supernova that occurred near the center of our galaxy. Most of the news releases stated that the event occurred only about 140 years ago. In reality, it could have been seen here on Earth 140 years ago, but it actually occurred about 26,000±1,400 years ago, the distance to the center of our galaxy. Please note that, in the table below, my math is not that bad. Distances to nebulae are only approximations. They are usually determined by estimating the speed at which they are expanding and their true sizes. Therefore, the distances to these nebulae are sometimes uncertain by hundreds or even thousands of light-years (ly).

Lookback time

What does this mean? When we "see" an event, such as a supernova explosion, we are actually seeing something that happened thousands of years ago. The event is now thousands of years old. One way of viewing these events is to say which event occurred first. There were three supernovas seen by observers on Earth in a period of about 100 years: Tycho in 1572, Kepler in 1604, and Flamsteed in 1680. Even though these astronomers saw these supernovas over a period of 100 years, these supernovas actually occurred over a period of about 7,000 years with the supernova that Kepler saw being the first event. For stars that have "lifetimes" of billions of years, a few thousand years has little meaning. However, if we now think about nearby and distant galaxies, we can view lookback in a different way. Let us assume that the Milky Way Galaxy, our galaxy, and the Andromeda Galaxy, our nearest neighbor at a distance of 2.5 million light-years, are the same age. Since it takes light 2.5 million years to get here, we are seeing the Andromeda Galaxy when it was 2.5 million years younger. When NIRCam (Near Infrared Camera) and JWST (James Webb Telescope) look back at distant galaxies that are, say, 13 billion light-years away, we are seeing them as they looked 13 billion years ago when they were much younger and perhaps we will be seeing them as they first formed into the galaxies we see today.

Year	**Supernova Name/Observed**	**Remnant Name (Nebula)**	**Distance (ly)** Uncertainty may be 20% or more	**How Long Ago It Happened (Years)**
1987	SN 1987A Discovered (independently): Chile, New Zealand, Zimbabwe; naked eye object	SNR 1987A	~168,000	~168,000
~1868	No record	G1.9+3.9	~26,000	~26,000
1054	SN 1054 Recorded in: China, Japan, North America (Anasazi;Chaco Canyon)	Crab Nebula	~6,500	~7,500
~400	No record	Ring Nebula	~2,300	~4,000

Supernova Remnant	Image, visible	Image, other
SNR 1987A	 HST (Insert)	
G1.9+3.9		 Chandra (X-ray)
Crab Nebula 	 HST	 Spitzer
Ring Nebula	 HST	 Spitzer

Earth-Planet Times (When Planets Closest to Earth)

Planet	Distance From Earth AU	Light time	Planet	Distance From Earth AU	Light time
Mercury	0.61	5.1 min	Venus	0.28	2.3 min
Earth	1.00	0.0 min	Mars	0.52	4.3 min
Jupiter	4.20	34.9 min	Saturn	8.54	70.9 min
Uranus	18.2	2.5 hr	Neptune	29.1	4.0 hr
Pluto	38.5	5.3 hr	Oort Cloud (comets)	2,000 to 50,000	280 days to 7000 days

Earth-Planet Times (Today)

Planet	Distance From Earth AU	Light time	Planet	Distance From Earth AU	Light time
Mercury	1.30	0.8 min	Venus	1.68	14.0 min
Earth	0.00	0.0 min	Mars	0.93	7.7 min
Jupiter	5.25	42.7 min	Saturn	9.79	81.4 min
Uranus	19.9	2.8 hr	Neptune	30.3	4.2 hr
Pluto	32.7	4.5 hr	Oort Cloud (comets)	2,000 to 50,000	280 days to 7000 days

Other Distances/Times

Distance/Light-times

1 kilometer	0.000005 light-seconds	Nearest Star	4.3 light-years
Center of Galaxy	25, 000 light-years	Andromeda Galaxy	2.5 million light-years

Other Distances/Times (Scale Model 5 km/hour = 460 times speed of light = warp factor 6.2)

Distance/Light-times

Pluto	35 seconds	Nearest Star	3.4 days
Center of Galaxy	54 years	Andromeda Galaxy	5,500 years