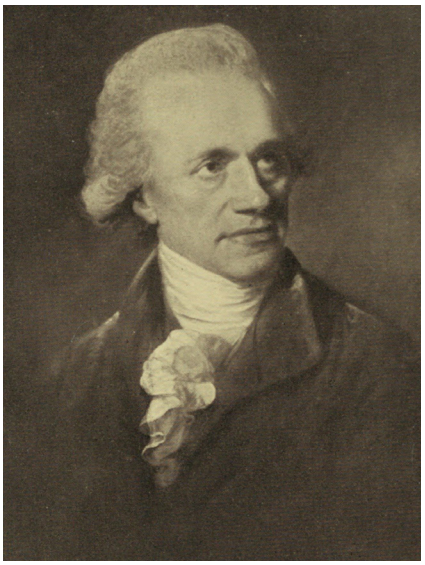
Leader Discussion Guide for *Cosmos: A SpaceTime Odyssey*

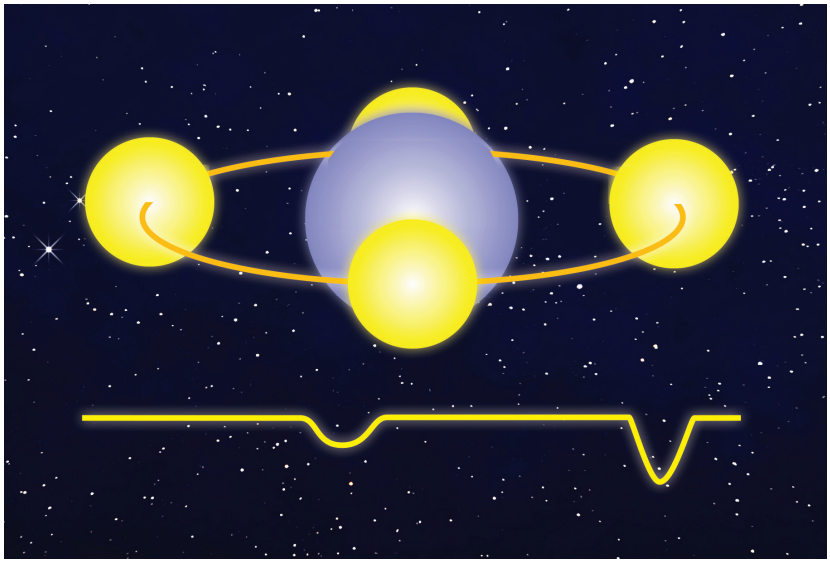
Episode 4: "A Sky Full of Ghosts"

The creators of *Cosmos: A SpaceTime Odyssey* state that their aim is to promote scientific literacy. Episode 4, "A Sky Full of Ghosts," discusses the speed of light, distant stars, and black holes. *Cosmos* host Neil deGrasse Tyson discusses the implications of the speed of light for space exploration and our earth-bound view of the stars. Unfortunately Tyson uses the topic as a platform to level a direct attack on all who accept the young age of the universe as presented in God's Word. His discussion of black holes crosses over from observable science that promotes scientific literacy to phantasmic speculations, finally suggesting that the mystery of how the big bang could ever have happened in the first place lurks beyond our reach in these hot gravitational light traps. In this discussion guide we focus on the observational science that relates to the speed of light and black holes.

1. **Who is the 18th century father of modern stellar astronomy? In addition to mapping much of the Milky Way, he was the first person to discover a planet since ancient times. (Do you know that planet's name?) He also catalogued hundreds of double stars and figured out how they moved. What do we call these double stars, and how do they move?**

   ANSWER: *Sir William Herschel* (1738–1822) was a devout Christian. As a scientist he believed that God had created an orderly universe and, along with his sister





Left: Sir William Herschel. Right: Here is a diagram of an eclipsing binary star (eclipsing binaries are a particular kind of binary stars). Seen through a modern telescope, the light—depicted in the graph below the image—will seem to "blink" periodically as each star eclipses the other. Dr. Danny Faulkner discusses binary stars and his research on them in his video *Things That Go Bump in the Night.*

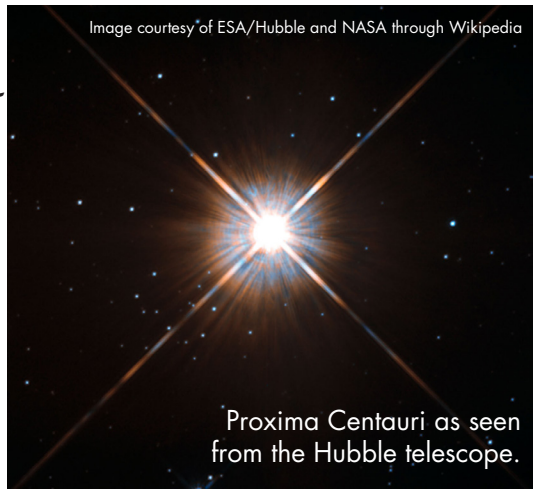
Caroline, he studied it systematically with his telescope. Herschel's numerous achievements include the discovery of the planet *Uranus* and 848 *binary stars.* Binary stars are not merely close together; they actually *revolve around each other*.

2. **How fast does light travel? Can anything travel faster than light?**

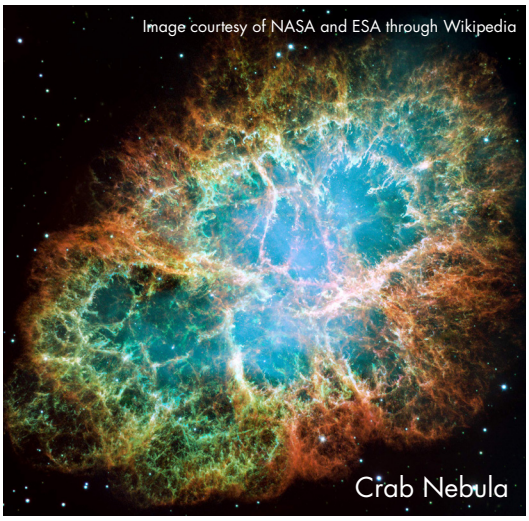
   ANSWER: The speed of light in a vacuum is 186,282 miles per second (299,792,458 meters per second), but 186,000 miles per second is a close enough answer for most people. No matter can travel faster than light.

3. **Because things in space are far apart, scientists find it most convenient to describe vast distances in terms of how many years we calculate light would take to travel that distance. Based on this, how far away are Proxima Centauri, the Pleiades Cluster, and the Crab Nebula? What is Proxima Centauri?**

   ANSWER: Proxima Centauri—the nearest star after our own sun—is four light years away. The Pleiades Cluster is about 400 light years away. The Crab Nebula is 6,500 light years away.



Proxima Centauri as seen from the Hubble telescope.



Please see the "Reaching Beyond" section below in order to address Tyson's claims that Bible-believing scientists are ignorant of the vast distances in space and the speed of light.

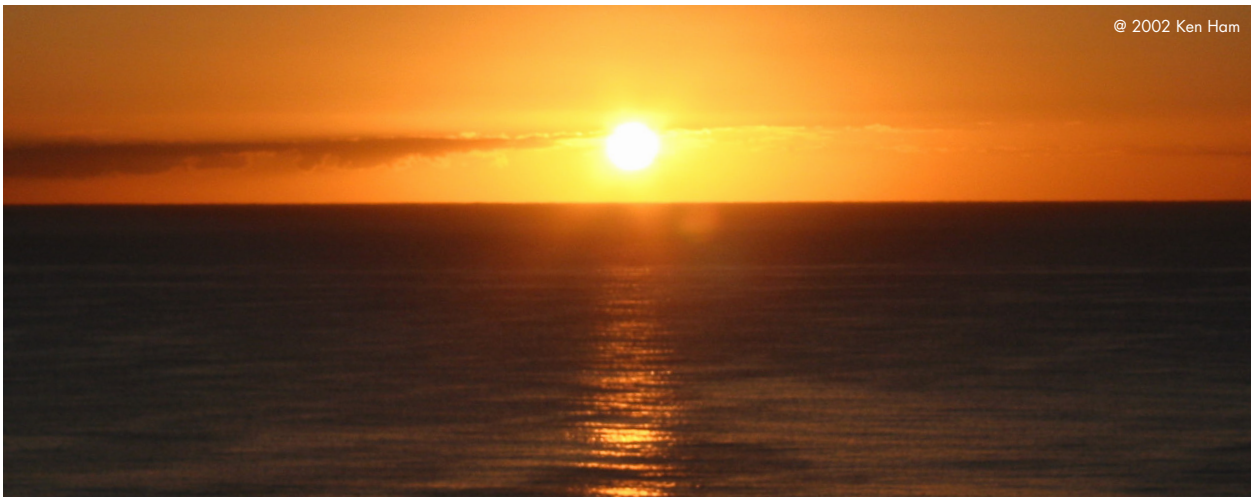
See the *Created Cosmos* video to gain an appreciation of the vast distances between objects in the universe God created: http://www.answersingenesis.org/store/sku/30-9-216

4. **If you were to see something happening on the sun's surface—though you must *never* look directly at the sun because doing so can permanently damage your eyes—how many minutes ago would that event have taken place? Some people say the telescope is a sort of time machine. Why? And why is this not a very accurate analogy?**

   ANSWER: Light carrying the image of an event on the sun's surface requires about eight minutes to reach earth. Calling the telescope a sort of "time machine" is just a way of saying that it takes a certain finite amount of time (like eight minutes) for light to travel to us. However, we not travel anywhere in time—the supposed telescopic look through time can only tell us about the past, not the future.

5. **What is really happening during our "sunrise"? What would be different about sunrise if earth had no atmosphere?**

   ANSWER: The earth is spinning on its axis as it revolves around the sun. The earth's rotation brings the sun into view for an earth-bound observer from the east about every 24 hours. *Sunrise* is the moment when the sun is visible over the eastern horizon. Because earth's atmosphere, like a lens, begins bending the sun's rays as soon as the rays hit it, the morning's first glimpse of the sun is the image of the sun projected above the horizon approximately two minutes before the



sun's position is directly over the horizon—the actual time varying according to atmospheric conditions. This process is called *atmospheric refraction.* If earth had no atmosphere, an earth-bound observer would not see the sun in the east until a couple of minutes later.

6. **How fast does the earth spin? Why don't you feel the earth spinning?**

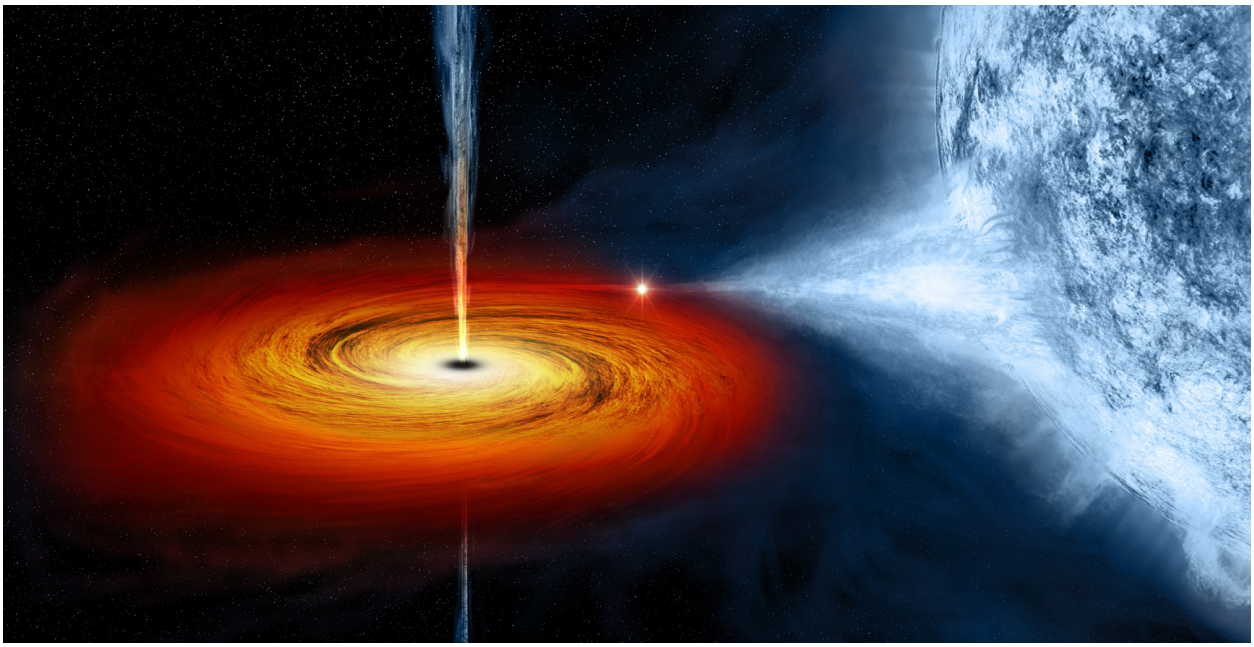
   ANSWER: Measured where the earth's circumference is greatest—at the equator—the earth spins at approximately 1,000 miles per hour (1,038 miles per hour or 1,670 kilometers per hour). You don't feel yourself or the earth spinning because you are spinning at the same speed.

7. **What is a black hole? Can we see them? Are black holes real?**

   ANSWER: A black hole is a small but massive, very dense, object possessing such great gravitational attraction that even light cannot escape from it. (Technically, we would say that a black hole's mass and gravity are so huge, that its escape velocity exceeds the speed of light, which is 186,000 miles per second.) Because light cannot escape from a black hole it is impossible to actually "see" one. Black holes are detected by observing the gravitational effects they exert on nearby objects in space.

8. **Where are black holes located?**

   ANSWER: *Stellar black holes* can be one member of a binary star system or they can be solitary. Though invisible, the great mass of a *stellar black hole* distorts the orbit of its companion star in a binary system, making it detectable. By applying the laws of motion to the observable motion, the mass of such a black hole can be calculated. We don't currently have a way to detect solitary stellar black holes.



Stellar black holes, like the one illustrated above, typically have a mass 3 to 20 times the mass of our sun. They are very dense, however, and due to their enormous gravitational pull even light cannot escape from them. Though therefore invisible, the stellar black hole in this artist's illustration is part of a binary star system. Material from the companion blue star is feeding the black hole. It glows as it is pulled into the black hole's accretion disc. Hot jets of high-energy particles shoot above and below the plane of the accretion disc.

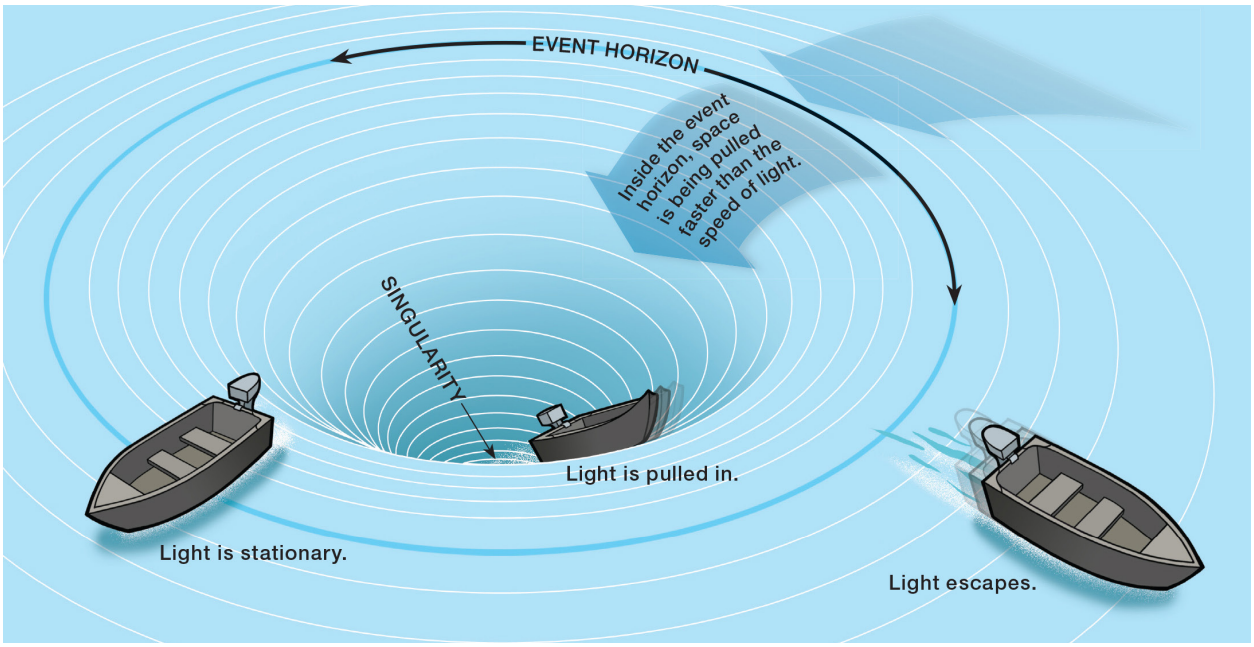
(This image from NASA/CXC/M. Weiss is used by Dr. Danny Faulkner as he discusses the interaction of black holes and their companion stars in his video presentation *Things That Go Bump in the Night*.)

Supermassive black holes are located at the centers of galaxies, including very bright distant galaxies called *quasars*.

9. What is an "accretion disc"? What is a black hole's "event horizon"? What are the "jets" shooting above and below the plane of a black hole?

ANSWER: As gases and objects fall toward a black hole, they pick up speed and spiral inward with increasing speed. This forms an "accretion disc" of fast-moving, hot gases around a black hole. As matter spirals faster into the black hole's gravity well, it approaches the speed of light. Compression of the fast-moving particles causes friction and generates great heat. Black holes emit electromagnetic radiation such as X-rays. The spinning of charged particles created a magnetic field. "Jets" of fast-moving high energy particles shoot out above and below the plane of the accretion disc. A black hole's "event horizon" is the boundary beyond which light and matter entering the black hole's gravity well passes the point of no return.

Gravity is so strong near a black hole that it pulls space and any nearby matter inward faster than light can travel away. There is a point at which light seems to "stop" because it is traveling outward at the same speed the space is being pulled inward. This is called the *event horizon*.

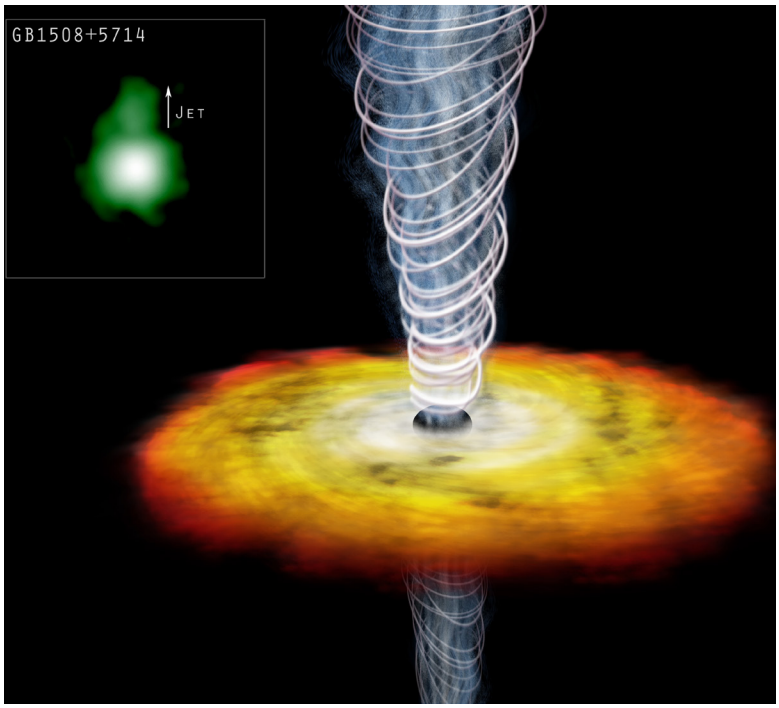


For further study:

http://www.answersingenesis.org/articles/am/v3/n1/black-holes-evidence

10. Do black holes go around space gobbling up things in their paths?

ANSWER: No. Black holes are compact massive dense objects in space. They have a great effect on anything that approaches them, such as the gases from a nearby star. In this way, material from a star in a binary star pair can feed a black hole.



The green image (inset) is the quasar GB1508+5714 as seen from the Chandra X-ray Observatory. Notice the bright accretion disc and the jets. A quasar is a massive, very distant galaxy emitting a great deal of energy. The artist's illustration shows the supermassive black hole at the quasar's center, its accretion disc, and jets of high-energy material. In his video *Things That Go Bump in the Night* Dr. Danny Faulkner uses this and many other illustrations to explain what black holes are.

(Image from NASA/CXC/A. Siemiginowska et al., and illustration from NASA/CSC/M. Weiss. This image is used in "Black Holes: The Evidence of Things Not Seen.")

This is the Sombrero Galaxy. It is located about 30 million light years from earth. The behavior of objects near its center is affected by the black hole believed to be at its center.

Black holes also have a great effect on the motion of objects close to them. Thus because of their great mass and gravitational pull, they deviate the movement of a companion star in a binary star pair and also the movements of objects orbiting near the center of a galaxy.

Reaching Beyond

11. What do black holes have to do with the evolutionary big bang model of the universe's origins?

ANSWER: Nothing. The evidence for the existence of black holes involves their indirectly observable effects on other observable objects. Their properties are explainable within the laws of physics. The big bang model of the universe's origins is a model wholly dependent on worldview-based assumptions. The big bang evolutionary model falls in the category of "historical science" because there is no way to observe that it ever happened in the first place. Additionally, the big bang model suffers from a number of problems.

For further study:

http://www.answersingenesis.org/articles/ud/ (Dr. Danny Faulkner's book *Universe By Design*)

http://www.answersingenesis.org/articles/am/v3/n1/black-holes-evidence

http://www.answersingenesis.org/articles/ud/problems-with-big-bang

http://www.answersingenesis.org/store/sku/90-2-161

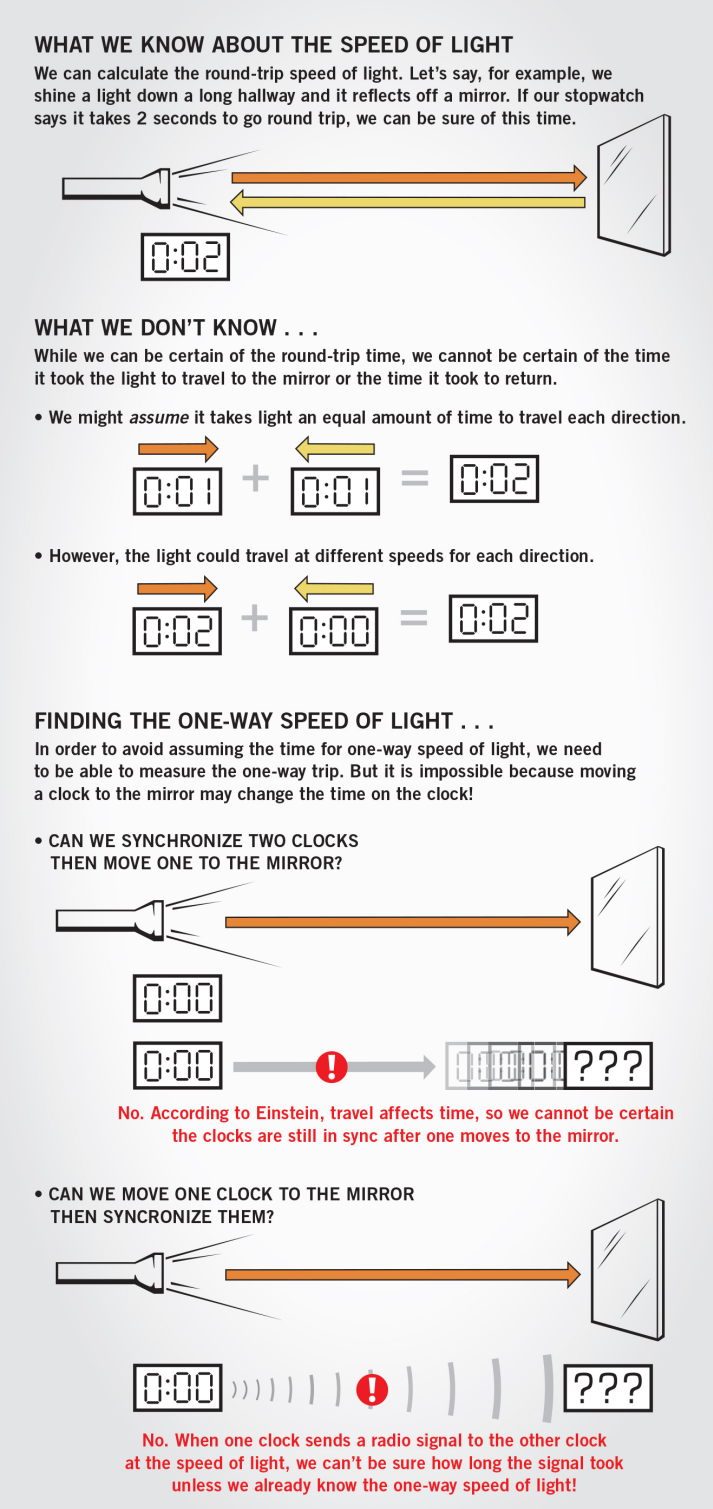
12. What famous physicist is credited with explaining how time, space, light, motion, and gravity are related to each other? Because of this relationship, he noted that it is impossible to measure the speed of light in the same way we measure speeds and distances closer to home. Explain this limitation.

ANSWER: Albert Einstein (1879–1955) described the relationships of time, space, light, motion, and gravity. As a consequence, he noted that it is impossible to directly measure the *one-way* speed of light.

We can determine the average speed of our one-way trips accurately enough for ordinary purposes. For instance, to calculate the average speed we used during a trip to the grocery store, we simply need to know the distance to the store, the time our watch tells us we left home, and the time we arrived at the store.

But because travel affects time, we cannot depend on clocks to truly remain synchronized and to give us accurate information when trying to measure the speed of light. Therefore, like Tolkien's

One of the models by which biblical creation scientists explain the light time travel (distant starlight) problem depends on the limitations Einstein noted in our ability to measure the speed of light. You can read more about this in "Distant Starlight: The Anisotropic Synchrony Convention": http://www.answersingenesis.org/articles/am/v6/n1/distant-starlight



The Hobbit, the way physicists measure light involves letting the light go "there and back again." Physicists measure the *round-trip speed of light* and *assume* that it is the same in both directions. This "time convention" helps us make sense of our world.

Leaders, while this concept is not presented in the *Cosmos* program, it should help more advanced students understand that the simplistic version of the "light time travel" problem used by Tyson to mock Bible-believers is not as simple as meets the eye. Students need to understand that God created the sun, moon, and stars for a purpose—to declare His glory and to mark our times and seasons. These heavenly bodies, to fulfill these purposes, must have been visible to Adam the day God made him. Biblical creation astronomers do have scientifically sound, biblically consistent models to address the light time travel issue. We can present these concepts without resorting to explanations that violate the laws of physics or wrongly paint God as somehow deceptive.

For further study:

http://www.answersingenesis.org/articles/arj/v6/n1/light-travel-time-problem

http://www.answersingenesis.org/articles/am/v6/n1/distant-starlight