Great American Eclipse of 2017

UNIVERSITY OF NORTHERN COLORADO

Science With Solar Eclipses

In addition to being fascinating to observe, solar eclipses have also led to many notable scientific discoveries and advancements. Ancient cultures attempted to predict when eclipses would occur; how close they came on these predictions gave information about the accuracy of ancient models of how things moved in the sky. Perhaps the most famous scientific contribution of solar eclipses was providing the first test of Einstein's Theory of Relativity. Today NASA uses solar eclipses to study both the Sun and the Earth.

Testing Einstein

Albert Einstein's Theory of Relativity was a revolutionary break through in our understanding of the universe. When Relativity was first proposed in 1915, it did not gain immediate wide acceptance; while the math of the theory was elegant, scientists wanted observational evidence supporting the theory.

One prediction of the Theory of Relativity is that gravity is the warping of spacetime by a massive object. This warping of spacetime would cause light to bend if the light passes near a massive object. If one could measure how much light was bent by a massive object, then one could test this aspect of Relativity.

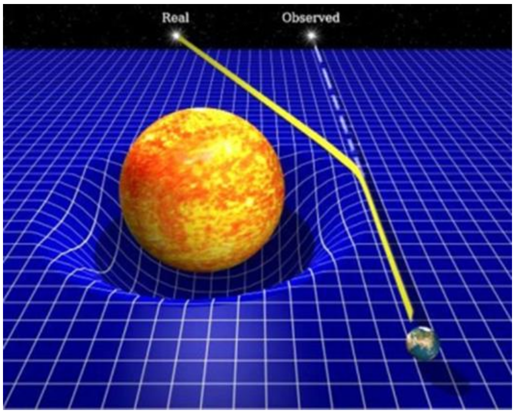

Fig. 1 According to relativity, mass/gravity causes spacetime to warp or curve. This curve in spacetime will cause the path of light rays to bend as they travel over the curve. Since our eyes always assume light travels in a straight line, this means that a distant star's apparent position in the sky would shift if its light was bent on the way to us.

The bending of light predicted by Relativity would be very small so scientists needed a very massive object, such as our Sun, to use for the test. If a distant star was positioned so that it was behind or near the Sun when viewed from Earth, its light should be bent. However when stars are near the Sun in the sky, they are up during daytime meaning we can't see stars in the sky, unless there is a total solar eclipse. In 1919 British astronomer Sir Arthur Eddington measured the positions of stars near the Sun during a total solar eclipse. His observations showed that the light from these stars was bent by the exact amount that Einstein's theory said it would be. Almost overnight Einstein was transformed into a celebrity.

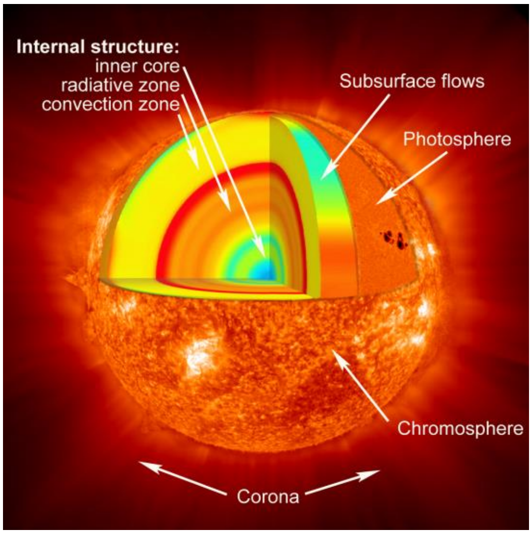

Fig. 2. Layers of the Sun.

Studying the Solar Corona

Almost all of the visible light we get from the Sun comes from the layer known as the photosphere; because of this the photosphere is often considered the surface of the Sun. There are layers below the photosphere (Figure 2) but we cannot see them as any light from these layers is blocked by the photosphere. There is also a layer above the photosphere known as the corona. The corona is a layer of very thin but extremely hot gas. The corona is actually over 100 times hotter than the photosphere but because the gas in it is so thin, it emits about a million times less light. This means that the light from the corona is easily drowned out by the light from the photosphere.

Studying the Solar Corona (continued)

The only way to observe and study the Sun's corona is if the light from the photosphere can be blocked. The corona is much larger than the photosphere so while the Moon will cover and block the photosphere during a total solar eclipse, it will not block the corona. During a total solar eclipse, the corona is visible as a hazy, whispy halo around the Moon and is visible to the naked eye as well as to telescopes. Astronomers have mechanical ways of blocking the photosphere of the Sun using small disks placed into a telescope but due to a property of light called diffraction, this results in the inner part of the corona appearing distorted. Thus, the best way to study the inner part of the Sun's corona is during a solar eclipse.

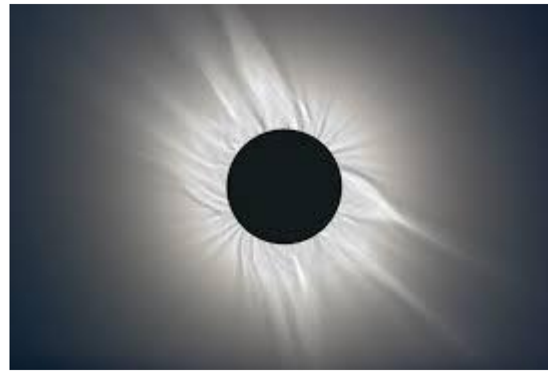

Fig. 3 The Sun's corona as seen during a total solar eclipse. The only way to see the corona is to be at a location having a total solar eclipse; the photosphere of the Sun is so bright that even if 99% of it is covered during a partial eclipse, it will still drown out the corona.

Studying the corona is important to not only our understanding of the Sun but also to modern life on Earth. Understanding the corona is important for understanding things such as the solar wind and coronal mass ejections, large amounts of charged particles that are blown outward from the Sun at high speeds. When these particles hit the Earth's atmosphere they can disrupt radio communications, knock out power grids, and damage satellites.

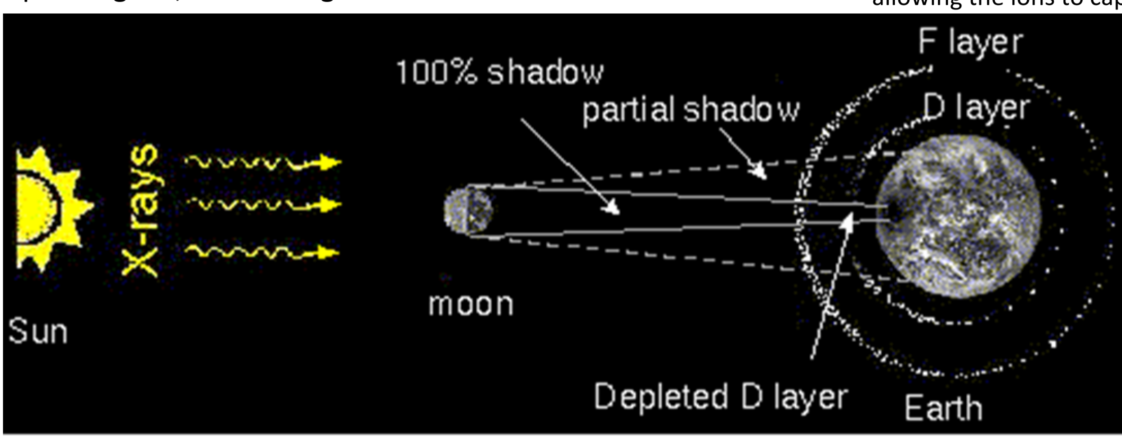

Fig. 4 Drawing of the ionosphere during a solar eclipse. The small dots in the rings around the Earth represent ions. There are less ions on the night side of the Earth due to the lack of sunlight allowing the ions to capture free electrons and become neutral atoms. A similar thing is occurring in the part of the atmosphere that is in 100% shadow (where the total solar eclipse is occurring).

Studying the Earth's Atmosphere

The ionosphere is part of Earth's upper atmosphere, located about 37-620 miles above the surface of the Earth. This layer derives its name from the fact that it is mostly made up of charged ions instead of neutral atoms. Being located high in the atmosphere, the ionosphere is exposed to much more light from the Sun than lower layers are. Some of this light will be absorbed by atoms in the ionosphere. If the light absorbed has enough energy, it will strip an electron off the atom, leaving a charge ion and a free floating electron. The ionosphere plays a role in radio communications because radio signals can be bounced off this layer, allowing them to travel much further around the Earth than if they just went in a straight line. This role in radio communication makes the ionosphere important to understand.

At night, when the ionosphere is no longer receiving sunlight, the ions recapture of the free electrons and become neutral atoms again. In the morning, as sunlight starts to hit that part of the atmosphere, electrons start to be stripped off again. During a total solar eclipse, a section of the atmosphere will have sunlight blocked, allowing scientists to study how fast ions recapture electrons and then how fast those electrons are stripped off again. This will provide important insight into the physics of the Earth's upper atmosphere.