Stellar Parallax

The Method of Trigonometric Parallaxes

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'Stellar parallax' is the parallax effect caused by stellar distance, a significant and constructive perspective in astronomy. It is a method to calculate and measure the distance between a star and the earth. It needs to use astronomical measurement and trigonometric function to calculate in mathematics and obtain a scientific approximation.

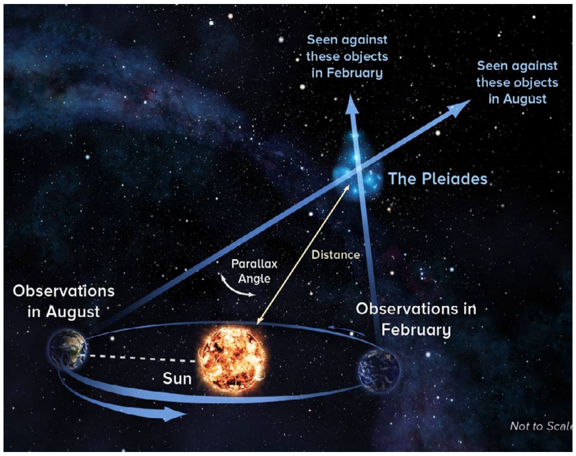
The theoretical basis of the stellar parallax is Euclid's Geometry. Its calculation process is complicated. It needs to be applied to astronomy and trigonometry in mathematics and relies on astronomical instruments. Although some minor errors and difficulties in the calculation process, Stellar parallax still significantly contributes to astronomy development. Mark Reid, an astronomer at Harvard Smithsonian University said, "Parallax is the best way to get the distance in astronomy," and he believed parallax as the "gold standard."

Origin and History

Stellar parallax is a very controversial topic in the history of astronomy, but it is also significant and constructive. It was born from human observations and comparisons of stars. Because astronomy is different from other sciences, it is entirely observational, requires tools and prolonged development.

In 189 BC, Greek astronomers Hipparchus used solar eclipses observed from two different locations to measure the moon's distance. This is the first known parallax measurement in history. In 1672, the Italian astronomer Giovanni Cassini and Jean Richer determined the distance between Mars and the Earth. In 1674, Robert Hooke searched for the annual motion of stars. Then Isaac Newton also tried to estimate the distance by comparing Sirius and the sun's brightness. In 1729, James Bradley first tried to measure stellar parallax, but he found it challenging to prove stars' motion with a telescope. Later, he discovered aberrations, the nutation of the earth's axis, and edited a catalog of 3,222 stars.

Stellar parallax did not officially appear until the beginning of the 19th century, but the astronomical telescopes at that time were still not sensitive enough to detect small parallax motions. In 1838, scientist Friedrich Bessel measured 61 Cygni at the Königsberg Observatory using Fraunhofer's heliograph. It is the first star to measure stellar parallax successfully, and this star is sometimes called Bessel's Star.



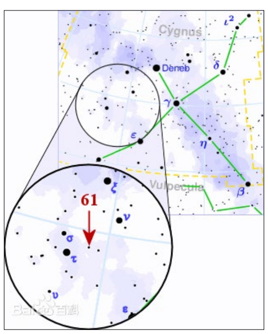
Schematic diagram of stellar parallax

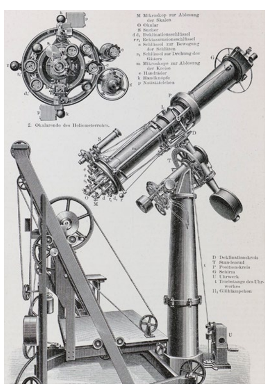
In 1896, a large altimeter was installed at the Kuffner Observatory. This makes their measurement and calculation in astronomy a big step forward. In 1910, people had already calculated 16 parallax distances to other stars. In 1989, the European Space Agency (ESA) launched the Hipparcos orbiting telescope. It accurately locates 100,000 stars, 200 times more accurate than before. The final catalog of Hipparcos is a high–precision catalog of more than 118,200 stars, released in 1997. In 2013, the ESA launched the GAIA Mission. It collects the distances and positions of more than 1 billion stars in the Milky Way.

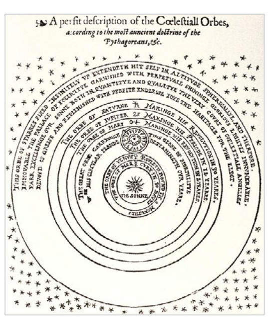
In the 21st century, the measurement of stellar parallax can reach the scale of the Milky Way. Moreover, we have already known a lot of knowledge and formulas. In the future, with the development of science and technology, astronomical instruments and tools will become more developed, so the approximate value of the measurement will become more and more accurate so that the calculation result of stellar parallax will become more and more accurate and the calculation range will become wider and wider.

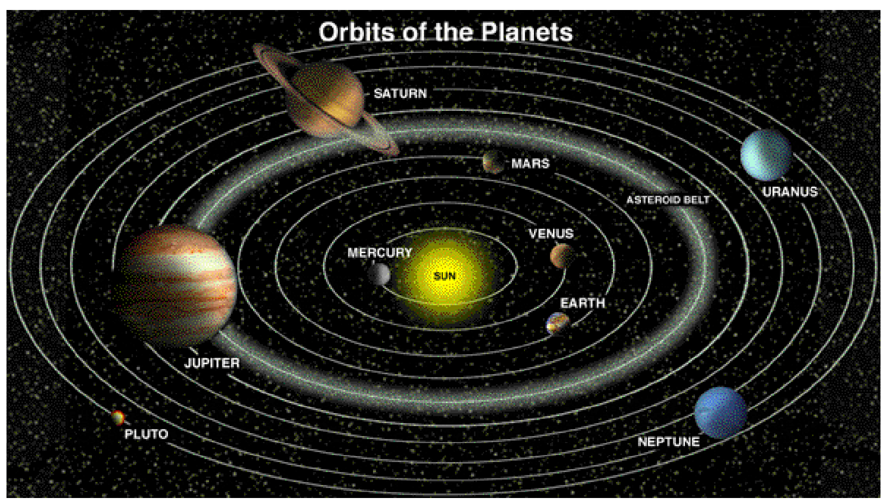
Copernicanism and Stellar Parallax

In the history of astronomy, parallax is also inseparable from the theory, and people even never stopped discussing the topic of stellar parallax, especially for the famous “heliocentric theory” and “geocentric theory.” In the 16th century, Copernicus’s “heliocentric theory” was born. The “heliocentric theory” proposed by Copernicus described that the sun is the center of the universe, not the earth. Therefore it is a severe and practical challenge to the “geocentric theory” at that time. Nevertheless, it effectively broke the “geocentric theory” that religions had long dominated and realized a fundamental change in astronomy.









**Overview of the position of Cygnus 61 in space*

**Diagram and sketch of a heliometer from the 1911 Encyclopædia Britannica*

**Copernicanism, schematic diagram of the heliocentric theory*

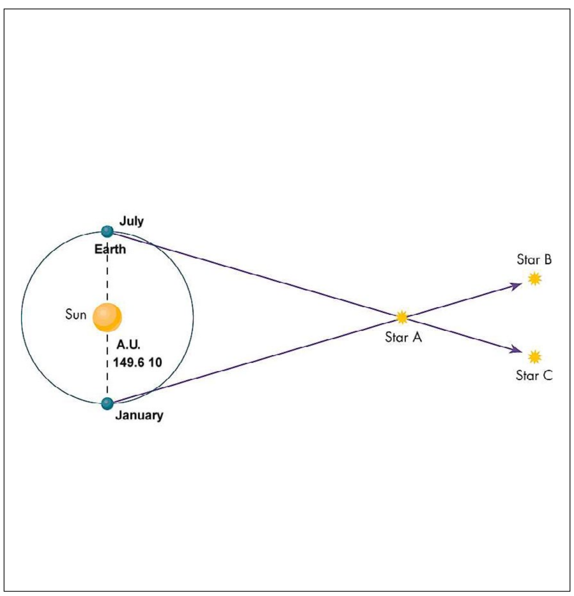
**Copernicanism, schematic diagram of the heliocentric universe*

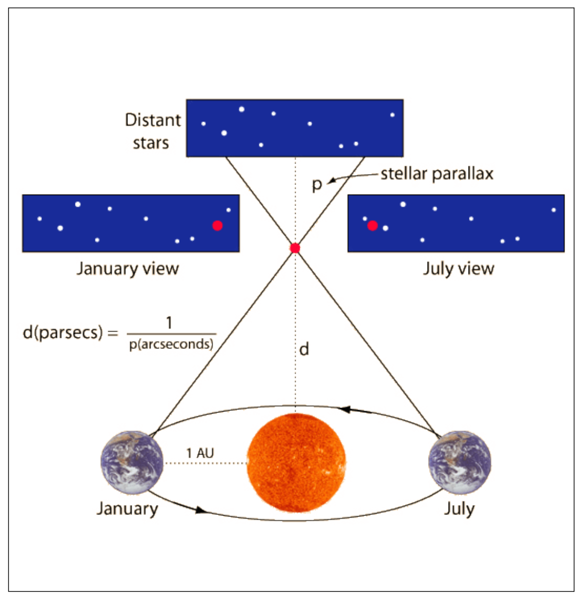
Scientists at that time believed that, according to Copernicus and Galileo’s “heliocentric theory,” then there should be a parallax effect observed by people. Still, no one was able to prove this at that time. Not only that, but the theoretical basis of stellar parallax is Euclidean geometry, and the stars we want to measure are far. Hence, the angle formed is also minimal, so the survey and calculation of this kind of stellar parallax are challenging to achieve. So at that time, it was impossible to get testimony to Copernicus’s “heliocentric theory” from this method.

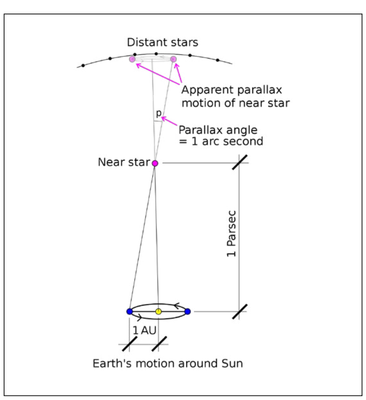
It was not until 1838 that German scientist Friedrich Bessel finally observed stellar parallax. In 1729, James Bradley discovered the one-year movement of stars. This also provides much help for the Copernicus's "heliocentric theory" and the study of stars. However, no matter how many arguments are for or against this hypothesis, it is enough to prove that it is difficult to recognize the theory. Today, the difficulty remains the same as four centuries ago. Therefore, stellar parallax is related to many other theoretical sciences in the history of astronomy. It provides observational theories, methods, speculation, and debate and has made remarkable achievements in astronomy development.

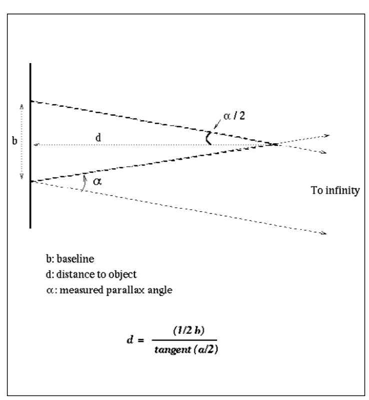
The method of Stellar Parallax

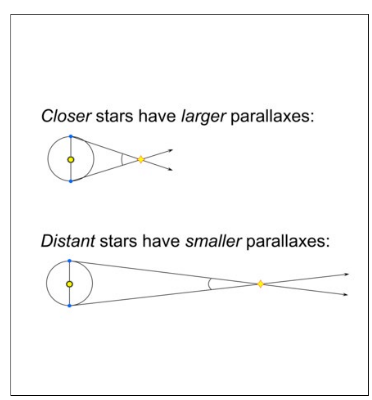
Stellar parallax is the classical way to measure distances to the nearby stars that show the apparent shift of stars due to Earth's movement around the sun. Although the night sky stars seem like one tiny dot, those stars' actual size could be larger than the size of the sun. In this case, how can you measure the distance? To know this distance, astronomers use the primary method of Stellar Parallax, which means that stars would move slightly into their position against comparison to its background as the Earth orbits the sun in one-year intervals. Once astronomers measure a star's position, they can calculate the apparent change by measuring its position six months later. In this situation, the star's apparent movement is called stellar parallax. Then, the distance "d" is measured in parsecs, the parallax angle "p" is measured, and the distance can be calculated.











**The method of Trigonometric Parallaxes.*

**With the side view, the method of Trigonometric Parallaxes.*

**Measuring stellar distances by parallax.*

**Measure the distance to the stars.*

*P*arallax decreases with Distance.*

In the picture above, the star's placement in January's view is located differently in these observations than in June, when the Earth is on the other side of its orbit. The red dots represent nearby stars from the Earth against the background, and the nearby star appears to sweep through half of this angle, is the Parallax, p. The parallax angle can be decreased when the distance to a star increases. While the Earth revolves around the Sun, the nearby star appears shifted despite not moving location due to the distance between stars and the Earth. Therefore, Parallax is an angle that varies depending on where you observe.

The Principle of Stellar Parallax

Once we know the stellar Parallax, we can easily measure the star's distance by using trigonometry. The object's movement appears different from its background by looking at something from two different vantage points. It means that the objects close to us are relatively shifted from those far away. Stellar Parallax is the basis for the parsec, an astronomical unit (AU) abbreviated with "pc." The parsec is the distance from the Sun to an astronomical object with a parallax angle of one arcsecond.

There are limitations of distance measurement using stellar Parallax from the ground. They can only be detected stars up to 50 parsecs away because the largest measured parallaxes are tiny that is less than an arcsecond. If a star's distance takes away more than that, its parallax angle p is too small to measure that its slight angle is less precise than the distance measurement. Therefore, people use this method only for measuring starts within 20 pc. Furthermore, the accuracy of the distance Stellar parallax from the Earth is reduced by the effect of the Earth's atmosphere. These days, people use photography and digital imaging techniques to measure parallaxes.

**The Hipparcos satellite, ESTEC, February 1988*

Technology and Application

The technical principle of stellar parallax is the parallax. The application range of parallax is extensive. In astronomy, stellar parallax greatly helps people observe and measure unknown stars. In the same way, it assisted the development of astronomic tools, forming a complementary situation. In 1989, ESA launched the Hipparcos satellite, which allowed people to obtain distances of about 1 billion stars and helped people finish the 3D universe maps. Therefore, more and more images of stars in the universe can be observed by people, which is very useful to the development and research of astronomy.

In addition, the application of parallax is also a critical issue to the 3D image display. This means capturing a 2D object by using two slightly different angles. This technology is widely used in movie screenings in modern society. Therefore, the contribution of parallax is not only aimed at astronomy but also natural sciences, physics, and even humanistic philosophy.

Conclusion

Stellar parallax is a method of calculating and measuring the distance between a star and the earth. It is a controversial topic in the history of astronomy, but it is still very constructive. Its calculation process is complicated, needs to be applied to astronomy and trigonometry, and also relies on astronomical instruments. Although very difficult, it is still a critical and creative view of astronomy, which promotes the development of astronomy and mathematics. The history and source of stellar parallax are very long and ancient. It was first born from people's observation and comparison of stars in the night sky. Then, because of people's curiosity and thirst for knowledge, they continue to develop observations and hypotheses, and they continue to overturn and debate. The most typical example is the stellar parallax view of Copernicus's "heliocentric theory". This makes it more sophisticated and valuable.

In addition, it also promoted the development of astronomical measuring instruments, such as the astronomical telescopes and altimeters. The current measurement of stellar parallax can reach the scale of the Milky Way. Therefore, its existence is of great significance to natural sciences, mathematics, and even history and humanistic philosophy. In the future, more and more science and technology will help us invent more and more high–tech astronomical instruments, and we will also find more scientific, accurate measurement and calculation methods to measure the distance of stars. With the development of human astronomy, we will discover and record more and more star distances. Therefore, the sidereal time difference is a significant and meaningful discovery.

**The 3D synthetic observation map of the Milky Way*

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Thank You!