A Brief Study Of Galactic Center- The Super Massive Black Hole Sgr A* And Star S0-2

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Abstract

About 8kpc away from our planet earth lays the nearest supermassive black hole (SMBH) Sagittarius A* (Sgr A*) at the center of the Milky Way galaxy. Since 1995, scientists at UCLA have been gathering data of astronomical objects with the use of astrophotography near the center of the Milky Way. Studies have lasted over the past 3 decades in pursue to estimate the location and property of the SMBH through astrophotography and model constructions in computing. During this period, there has been many improvements in methods and technologies, which provided more precision for further studies by reducing systematic errors during the research process and was able to correct errors occurred in the previous data. Amongst all the technological advances, one of the most effective improvement was the displacement of speckle imaging with adaptive optics (AO).

Introduction

Perhaps the first idea of Black hole, was proposed by an English man in the 18th century, John Michell. in 1783 he proposed came up with a concept for a type of star with extraordinary density which the escape velocity would achieve the speed of light, therefore light shall not escape from such mass of a star. Michell called these astronomical objects "dark stars" and believed that they can not be observed directly by astronomical instruments while very likely existing within many parts of the universe. Such theory demonstrates a lot in common with the general concept of black hole we adapted to this date.

The fascination of the possible existence of black hole have became one of the top interest for scientists in pursue of learning more about the universe.

In the later half of the 20th century, the possibility of one of such "exotic" astronomical object was believed to be found within the our very own Milky way Galaxy. In mid February (Feb.13th-Feb 15th) 1974, astrophysicists Robert Brown and Bruce Balick discovered a significant compact radio source at the nucleus of the Milky Way galaxy (the inner 2-3 pc at the center of the galaxy) which was later named by Brown Sagittarius A*. Many studies suggested that the character of Sgr A* as astronomical object is most likely to be in the form of a supermassive black hole.

Image and data from the Chandra X-ray Observatory shows the X-ray emission near the region of Galactic Center indicates an absolute substantial energy level around Sgr A*, unlike any other region nearby, it also shows that the star cluster at Sgr A* have extreme heated temperature and great quantity of radioactivity at alpha particle emission, which are evidences for the abnormal phenomenon of the activities of the star cluster near the Sgr A* region.

The attempt observations of Sgr A* under different wavelengths from several observatories around the globe have not yet provide an image of Sgr A* in clarity that shows its characteristics, therefore are not able to prove the property of Sgr A* as a SMBH yet directly through astrophotography.

The Implementation of Astrophotography

Over the past decade, there had been projects that tried to capture the image of black hole, it had not been an easy task for many research teams. However one was able to provide an image through observations and imaging techniques, of another supermassive black hole in a distant galaxy. On April 10th 2019, the Event Horizon Telescope (EHT) project provided the world the first image of a black hole. The astronomic object source of the image was a SMBH at the center of the Messier 87 galaxy which has approximately 6.5 billion times of mass of that of the Sun, and a distant of 55 million light-years from Earth. The picture of the M87 SMBH was completed through a method of imaging. First data were gathered from multiple telescopes across earth that observe the same and specific area in the sky, which creates a great baseline to work as an enormous telescope in order to observe stars in the extremely far distance. Than the data were transferred for imaging, the imaging process uses data received back from the source (which were the fragment of its whole) with algorithms in computing to construct the model of the SMBH in its most probable form, eventually created the image of the SMBH that has been released, which was technically the estimation of the physical property of the SMBH being constructed into to the most possible model for demonstration. Such method of imaging has been used often in the field of astrophysics.

0.1 Speckle Holography

During the early researches on Sgr A* from the UCLA Galactic Center Group since 1995, Speckle imaging was mainly used for the visual data of the astronomical objects. Speckle imaging uses large apertures with a narrow depth of field and have short exposure (fast shutter speed), but this allows more light to pass through the lenses with focus on a specific area and often results in the blend of many light sources in the images, the light sources from the images tense to appear stronger than that of the actual physical property they have, therefore this requires a method of calibration. One of the method that has been commonly used in Speckle imaging to resolve for calibration is the Shift and Add (SAA) method. First, the telescopes provide large amount of data-photographs taken of a common region at different dates. Then the images are stack together by a brightest point, this is relatively easy is astronomy as the images can be using a common astronomical object (star) as reference. The images are filtered with the same frame of reference, therefore reducing the false information given by the flux differentiation in each image, averaging out the most likely position for each astronomical object and their properties base on that of the reference star.

0.2 Adaptive Optics

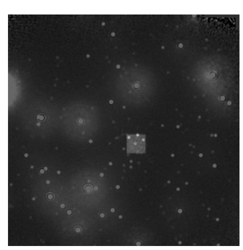
Researches have been conducted at ground-base observatories with very large telescopes to make observations in distance far into the universe. Among the large telescope observatories, the Keck II telescope was the first to be equipped with the "Adaptive Optics" system, which advanced its ability to provide high accuracy data for its objects. There has been a limitation for all ground-base telescopes in observing the universe that is-atmospheric turbulence, which affects all telescopes built on surface of the Earth. Although over the years as researchers tried to construct these ground-base telescopes at high altitude sites with less turbulence around the globe, turbulence always occur under the Earth's atmosphere, therefore losing critical advantage to the space telescopes. But with the implementation of the AO, ground-base telescopes were able to correct the data under turbulence caused by motions of the air, with the help of computing to control special deformable mirrors to adjust angles according to the live-time distortion in the air, providing observers with corrected data for objects observed under differentiated turbulence. The AO system proved very effective in collecting correct data for observations. However, it often requires a bight astronomical object as a resource of reference in determining the positions and properties of the objects observed within a specific region. At times, a source of reference could be unavailable to a certain region in the sky, therefore causing a problem to collect the correct information on all of the objects within the region. But a method was developed that work along side the AO to resolve such problem, the invention of the Laser Guide Star Adaptive Optics system (LGS-AO). The LGS-AO was able to sent out laser beams that excite a layer within the mesosphere with abundance of sodium atoms, in doing so the lights were able to create an "artificial star" which could be used in observations as the bright source (star), that provides the necessary reference for gaining accurate information about the astronomical objects within an area that was previously ineligible in such observation.

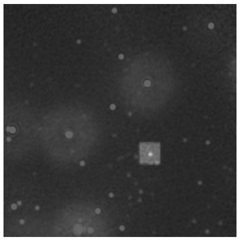
Estimated location of Sgr A* through S-02

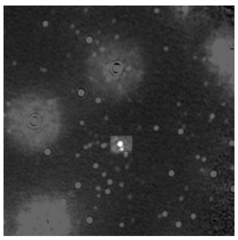
As mention earlier, we are currently unable to observe Sgr A* the SMBH directly through astrophotography, but there has been an efficient method to estimate the location of Sgr A* over the past years, astronomers used the stars orbited around Sgr A* to make prediction about its position and property, one of the most valid reference star is S-02, a giant astronomical object with the size approximately 15 times more massive and mass of 4 millions times than that of the Sun. It is among the few stars that came closest to the center of the Milky Way Galaxy (near Sgr A*). Astronomers discovered the significant phenomena of the orbit of S-02 around Sgr A*. The study of S0-2's orbit confirmed Einstein's theory of general relativity and observed the gravitational redshift of the source, which strongly suggests the presence of a SMBH at the location of Sgr A* as the movement of stars and the behavior of lights in the region match perfectly with the predictions from the theory of general relativity.

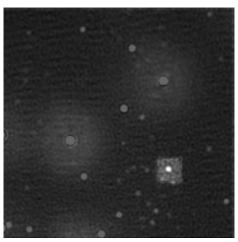
Position Chart	
Dates	Coordinates
1995 Jun	(513.2,366.9)
1996 Jun	(513.2,365.7)
1997 May	(511.9,363.2)
1998 Apr	(513.2,359.6)
1999 May	(511.9,354.8)
2000 Oct	(510.7,351.1)
2001 May	(508.3,346.3)
2002 May	(610.9,453.8)
2003 Apr	(499.9,353.6)
2004 Apr	(498.7,354.8)
2005 Apr	(498.7,355.9)

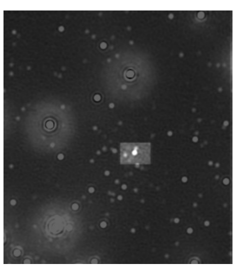
The chart and graphs shows the CCD value and images of the coordinates of star S0-2 that is used to predict the approximate location of Sgr A*


1995


1996


1997


1998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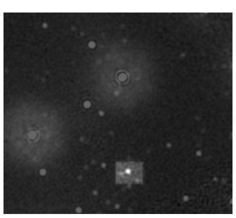
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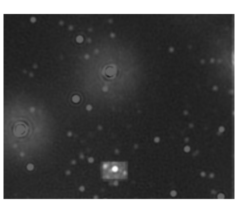
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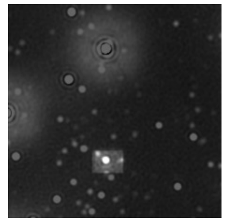
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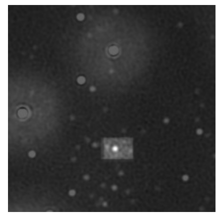
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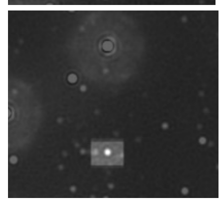
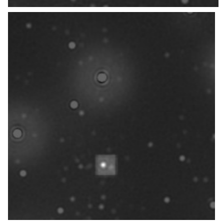

2004


2005

Conclusion

The 20th century has been a climax for scientific studies that gave birth to the many theories and mechanics the science community use and cherish today. Technological developments boosted internationally after the World Wars. The reason for which astronomy was able to advance was because of the development and implementation of new methods and mechanics that provided the access for further observations of the universe beyond our reach in history. It is with deep honor and gratitude as a student and a lover of science to appreciate the works of numerous scientists and thinkers that came before us and laid down the paths to theories and experiments of subjects that we still follow by today, in fact all of the previous hardships and achievements of our scientist predecessors, has constructed the foundation for the modern field of science, they are the reason that allowed the rapid development of science in the human world that has come to this far as today, which greatly influence the daily lives of us individuals, as well as determining the fate of humanity and the path we are about to take as a universal civilization. As a quote from the great scientist Sir Isaac Newton once proposed:"If I have seen further than others, it is by standing upon the shoulders of giants." We too have owe our all of our accomplishments to our mentors from the past, in the field of science especially subject as complex as astronomy, the entry for the most basics would demand much from the development in others to support it such as theories in mathematics and physics. And in the future ahead, we would strive to becoming the giants ourselves fully equipped with the ideas and knowledge that we human have accumulated throughout the course of time, in able to pass them on to the next generation of greatness yet to come. The wisdom of the logical mind, and the strong curiosity from the depth of our heart have given birth to the field of science in human society and continuing to build upon these knowledge and discover those of the universes of unknown, this passion for science, perhaps in some aspects shows the most valuable of us human being, and will always be our reason to move forward, towards a greater goal, a better world, and finally, the pursuit of truth.

Reflection

Throughout the course of study and research experiences with Ms.Chen, I have gained so much of the basic understanding of Astronomy and the universe beyond our world. We were able to explore space, the properties of different astronomical objects, mathematics models and statistics, ground-base and space telescopes, it was quite an adventure around many astronomical entities within the observable universe, and developments in theories and facilities for astronomy by our scientist on Earth. This research study was definitely a rewarding experience that broadened my horizon, also as a great introduction to the subject of astronomy and the universe we live in.