TO STUDY THE PHENOMENA OF SAGITTARIUS A* SUPER MASSIVE BLACK HOLE THROUGH DIFFERENT OBSERVATORIES

1Ashish Lamichhane; 2Eak Raj Poudel

1DEPARTMENT OF PHYSICS, BIRENDRRA MULTIPLE CAMPUS, INSTITUTE OF SCIENCE AND TECHNOLOGY, TRIBHUVAN UNIVERSITY, NEPAL
2SUPERVISOR (LECTURER), DEPARTMENT OF PHYSICS, BIRENDRRA MULTIPLE CAMPUS, INSTITUTE OF SCIENCE AND TECHNOLOGY, TRIBHUVAN UNIVERSITY, NEPAL

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ABSTRACT:
In this research, we study the energy, flux values of Sagittarius A* black hole from various telescopes like Chandra Shekhar X-Ray, FERMI. It is found that from recent data from a similarly scattered screen is actually not directly in the galactic center. It is also found that variability appears to get stronger with frequency. This is compatible with plasma blobs streaming outward (in a jet or otherwise) and expanding adiabatically. The comparison of flux values and energy measured by different observatories are also observed and discussed.

Keywords: Supermassive black hole, Sagittarius A*, Hubble Space Telescope, Chandra Shekhar X-Ray Observatory, Energy Spectrum, Flux Values, EHT, FERMI, Spectral Energy Density.

1. INTRODUCTION

1.1 GENERAL CONSIDERATION
In this research, we study phenomenon of formation of black hole. The data are collected and discussed under the basis of energy value, energy flux and electric charge through different observatories like VERITAS, FERMI and EHT.

1.2 DISCOVERY OF BLACK HOLE
The scientist John Mitchell first put forward the Black hole theory in 1783, and the general theory of relativity by Albert Einstein subsequently developed it in 1915. According to their beliefs, massive objects may collide causing regions of space-time with extremely strong gravitational fields from which nothing could escape, not even light, under their own gravitational attraction.
In the Cygnus X-1 binary star system, a strong candidate for a black hole was identified in 1971. A huge star circling an undetectable companion was seen by astronomers. By measuring the velocity of the visible star, they got to the conclusion that the invisible Companion must be a black hole.
The first black hole to be discovered was Cygnus X-1, which is located within the Milky Way in the constellation of the swan Cygnus. The first gravitational wave discovery was made on February 11 by the Virgo collaboration and the LIGO Scientific Collaboration (LSC). By the end of 2018, 10 merging black holes had produced 11 gravitational wave instances, and the first direct photograph of a black hole and the surrounding space was released in April 2019. The Supermassive black hole at Meisser 87's galactic core was seen in 2017 using the Event Horizon Telescope. [1]
1.3 BLACK HOLE

A black hole is an area of space where gravity is so intense that nothing can escape its pulling power, not even light. It is created when a massive star collapse under its own gravity at the end of its life. The collapse cause the star to become extremely dense, with a tremendous amount of man concentrated in very small volume. Because of the degree to which the matter is crammed into a black hole's region, the gravitational pull there is incredibly strong. The area surrounding a black hole beyond which nothing can escape is known as the event horizon. Once an object has crossed the event horizon, it is said to be within a black hole because it cannot escape or be observed from the outside.

Astronomers have so far successfully distinguished between three different types of black holes: intermediate black holes, supermassive black holes, and stellar-black holes.

1.3.1 Stellar-mass black hole small but deadly

When a larger star breaks down, it keeps getting less and less massive until it forms a stellar black hole. Its unique attribute is that its mass is several times higher than our Sun’s, but it is compressed into a comparatively tiny volume. Though their precise mass range is not known, stellar-man black holes generally have masses between roughly 3 and 100 times that of the sun. X-ray emissions from hot stuff falling into stellar-man black holes or interactions with surrounding stars are two typical situations in which they are found. [2]

![Image of Cygnus X-1](https://www.esa.int/var/esa/storage/images/esa_multimedia/image_238924/medium/image_of_cygnus_x-1-esa-hubble_and-esa_information_centre-3.png)

**Figure 1:** Image of Cygnus X-1 [ESA/Hubble and ESA Information Centre] [3]

1.3.2 Intermediate-mass black holes

In 2014, in a spiral galaxy's arm researchers discovered what seemed to be an intermediate-man hole. As the name implies in terms of mass, intermediate black holes are those that are between stellar-sized and supermassive black holes. Although the exact mass range for intermediate black holes is still a matter of active study and discussion, they are typically thought to have masses ranging from thousands to tens of thousands, or perhaps tens of thousands of times that of the sun.

1.3.3 Supermassive black holes

It’s possible that hundreds or thousands of tiny black holes merged to form supermassive black holes, but huge gas bubbles may also play a role for their fast mass deposition. Supermassive black holes can be inferred from figures of how they affect the dynamics of the stars and gas in the vicinity. Supermassive black holes are capable of producing strong jets of ejected materials into space.[4]
1.4 Sagittarius A* (Sgr A*):
These information shows the Milky Way galaxy's core, including the super-massive black hole Sagittarius A* (Sgr A*) at its center.

1. Location: Sagittarius A* is situated in the Constellation Sagittarius, specifically in the direction of the Sagittarius constellation's "A" radio source. About 26,000 light-years are thought to separate it from Earth.

2. Size and mass: Sagittarius A* is one of the closest known supermassive black hole, to earth while its physical size is relatively small (with an event horizon that is about 24 million kilometers in diameter), it contains an enormous amount of mass. Its mass is estimated to be approximately 4 million times that of our sun.

3. Observation: The existence of Sagittarius A* inferred from observations of stars of around on invisible object with extremely strong gravitational effect. Later, using radio, infrared and x-ray telescope, confirmed its presence and provided further insight into it properties.

4. Event Horizon Telescope (EHT): The first direct photograph of a black hole was published in 2019 by the worldwide Event Horizon telescope team. The supermassive black hole at the center of the M87 galaxy was visible in the photograph as a silhouette, which is significantly larger than "Sagittarius A". While Sagittarius A* was not directly imaged, the EHT project aims to gather more data to potentially image it in future. [6]
1.5 FORMATION OF BLACK HOLES

Astronomers claim that a star can extinguish its fire in one of only three ways, depending on its mass. A star with a mass smaller than the sun collides with another star until a very small object known as a "white dwarf" with a radius of only a few thousand kilometers is created. If the mass of a star is between one and four times that of the sun, it can become a "neutron star" with a radius of only a few kilometers; such a star is sometimes referred to as a "pulsar." The few stars that are four times as big as the sun are destined to disintegrate into their Schwarzschild radii and eventually become black holes. Thus, massive star collisions may create black holes.

The majority of astronomers think that enormous gas clouds that collapsed and broke up into individual stars are what created galaxies like the Milky Way. Now, the Center, or nucleus, is where the stars are most closely clustered together. It's possible that there was too much substance in the very center of the universe for a star to form normally, or that the stars that did form were so close to one another that they combined to form a black hole. Therefore, it is proposed that some galaxies may contain a truly big black hole that is equivalent to 100 million sun-like stars. [7]

2. LITERATURE REVIEW

2.1 History and development of black hole:
The history and development of our understanding of black hole is a fascinating journey that spans several centuries. Here a brief overview.

1. Early concepts (18-19th century): The concept of black holes began to emerge from studies of celestial mechanics and theory of gravitation. In the late 18th century, an English geologist and clergyman named John Michell proposed the idea of "dark stars" with gravitational forces so strong that not even light could travel through them. His work went largely unnoticed at the time.

2. Einstein's Theory of General relativity (1915). Albert Einstein’s theory of general relativity, published in 1915, revolutionized our understanding of gravity. According to this theory, massive object can warp the fabric of space time, creating gravitational fields. In 1916, Karl Schwarzschild, a German physicist, found a solution to Einstein's equation that described to non-rotating, spherically symmetric object with boundary called event horizon. Now known as black hole.

3. Oppenheimer- Synder Model (1939). In 1939, physicists J. Robert Oppenheimer and Hartland Synder published a groundbreaking paper that explored the gravitational collapse of massive star. They proposed a model in which star, after exhausting its nuclear fuel would undergo a catastrophic collapse under its own gravity, creating a black hole's event horizon around a singularity.

4. X-ray Discoveries (1960s): The first observation as evidence for existence of black holes came from X-ray astronomy. In the 1960s, astronomers discovered intense X-ray source in binary star systems, known as X-ray binaries. It was theorized that these X-ray's originated from accretion disks formed by matter falling into black holes or neutron stars.

5. Black hole Thermodynamics (1970s-19903): In the 1970s, theoretical physicist Stephan Hawking made significant contributions to our understanding of block holes. He demonstrated how quantum processes near an event horizon cause black holes to generate thermal radiation now known as Hawking radiation. The discovery had profound implications for the thermodynamics of black hole and their eventual evaporation.

6. Direct observations and Imaging (the most (2010) : The first-ever direct image of a black hole was published in 2019 by the event horizon Telescope (EHT) collaboration, marking one of the most important turning points in the study of black holes. The supermassive black hole at the center of galaxy M87 was visible in the photograph. This breakthrough provided compelling visual evidence of existence of black hole, and matched theoretical predictions.[8]
2.2 List of known Black Holes, in brief:

### Stellar-Mass:

<table>
<thead>
<tr>
<th>Name</th>
<th>Constellation</th>
<th>Distance (Light years)</th>
<th>Mass (in solar Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cygnus X-1</td>
<td>Cygnus</td>
<td>7000</td>
<td>16</td>
</tr>
<tr>
<td>SS433</td>
<td>Aquila</td>
<td>16000</td>
<td>11</td>
</tr>
<tr>
<td>Nova Mon 1975</td>
<td>Monoceros</td>
<td>2700</td>
<td>11</td>
</tr>
<tr>
<td>Nova Persi 1992</td>
<td>Perseus</td>
<td>6500</td>
<td>5</td>
</tr>
<tr>
<td>IL Lupi</td>
<td>Lupus</td>
<td>13000</td>
<td>9</td>
</tr>
<tr>
<td>Novaoph 1997</td>
<td>Ophiuchus</td>
<td>33000</td>
<td>7</td>
</tr>
<tr>
<td>V4641 sgr</td>
<td>Sagittarius</td>
<td>32000</td>
<td>7</td>
</tr>
<tr>
<td>Nova Vul 1988</td>
<td>Vulpecula</td>
<td>6500</td>
<td>8</td>
</tr>
<tr>
<td>V404 Cygni</td>
<td>Cygnus</td>
<td>8000</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: Companion star and black hole masses are added to determine the mass. '16' stood for 16 times the mass of the sun.

### Galactic Mass:

<table>
<thead>
<tr>
<th>Name</th>
<th>Constellation</th>
<th>Distance (Light years)</th>
<th>Mass (in solar Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGC-205</td>
<td>Andromeda</td>
<td>23000000</td>
<td>90000</td>
</tr>
<tr>
<td>Messier-33</td>
<td>Triangulum</td>
<td>260000</td>
<td>50000</td>
</tr>
<tr>
<td>Sgr A</td>
<td>Sagittarius</td>
<td>27000</td>
<td>460000</td>
</tr>
<tr>
<td>Messier-31</td>
<td>Andromeda</td>
<td>23000000</td>
<td>45000000</td>
</tr>
<tr>
<td>NGC-1023</td>
<td>Cones Venatici</td>
<td>37000000</td>
<td>44000000</td>
</tr>
<tr>
<td>Messier-81</td>
<td>Ursa Major</td>
<td>13000000</td>
<td>68000000</td>
</tr>
<tr>
<td>NGC-3608</td>
<td>Leo</td>
<td>75000000</td>
<td>190000000</td>
</tr>
<tr>
<td>NGC-4261</td>
<td>Virgo</td>
<td>100000000</td>
<td>520000000</td>
</tr>
<tr>
<td>Messier</td>
<td>Virgo</td>
<td>520000000</td>
<td>3000000000</td>
</tr>
</tbody>
</table>

Note: Intermediate-May black holes are the name given to the first three. 'Supermassive' ore is the remaining ore.

2.3 History of Sagittarius A*

Among the founding radio astronomy pioneers, Karl Jansky, found a radio signal in the Milky Way’s core in April 1933, coming from a place near the Constellation of Sagittarius. Later, Sagittarius A* was the name given
to the radio source. Jack Piddington and Harry Minnett discovered a distinct and bright "Sagittarius Scorpious" radio source using the CSIRO radio telescope at Potts Hill reservoir in Sydney, Australia. The radio source was recognized in a letter to nature as probably the galactic center after additional observation with the 80-foot (24-meter) CSIRO radio telescope of Dover Heights. They did not, however, observe as far south as the Galactic Center, where we now know to be. [9]

Figure 4:- Area surrounding Sagittarius A* has been ringed in ALMA observations of molecular hydrogen-rich gas clouds.

Astronomers identified Sagittarius A* on February 13 and 15, 1974. Later studies, however, showed that Sagittarius A* truly is made up of many overlapping sub-components. The National Radio Astronomy Observatory's base interferometer is used by Bruce Balick and Robert Brown. Since an asterisk indicates an excited state of an atom, Brown's study from 1982 gave the object the name Sagittarius A* owing to the excitation of the radio emission. Since the 1980s, it has been obvious that Sagittarius A*'s main component is almost definitely a black hole. Charles H. Townes, a Nobel winner, and Reinhard Genzel, a future Nobel laureate, headed a Berkeley team that undertook research in 1994 that showed Sagittarius A*'s mass was heavily concentrated and on the order of 3 million solar Mass.

Over the course of 10 years, a global team led by Reinhard Genzel observed the passage of star S2 near Sagittarius A*. The Max Planck Institute for Extraterrestrial Physics released a report on October 16, 2002 released a study detailing their findings. Since 52 and other pertinent stars traveled so swiftly relative to nearby, slower-moving stars, it was possible to crop them out of pictures:
Figure 5: Supermassive black hole at the Milky Way's center is passed by dust cloud 62.

In the far future, it's possible that Sagittarius A* will combine with another supermassive black hole. Galaxies are hypothesized to collide and spiral together as their center black holes, causing such mergers. Despite the overwhelming evidence that Sagittarius A* is a supermassive black hole, numerous competing theories have been put forth. These include the potential existence of an item other than a black hole that is huge and compact or a group of smaller black holes. Magnetic fields, gas, and gravity interact intricately during the accretion process around Sagittarius A*. Scientists may learn more about how matter behaves in severe situations and put their knowledge of basic physics to the test by studying this process. The Event Horizon Telescope and other joint projects with advanced telescope technology continue to open up new possibilities for investigating Sagittarius A* black hole in more detail. Future observations might provide further more information regarding its behavior and nature.

Figure 6: A 2013 observation of an abnormally brilliant x-ray Wave from Sgr A*.
A record-breaking X-ray outburst from Sagittarius A* was observed on January 5, 2015, according to NASA. It was 400 times brighter than typical. According to astronomers, the unexpected occurrence may have been brought on by an asteroid fragment shattering as it fell into a black hole or by the entangled magnetic field lines in plasma that was pouring towards Sagittarius A*.

Keck Observatory measurements show that Sagittarius A* unexpectedly brightened in May 2019 and became 75 times brighter than typical. This implies that there’s a chance the supermassive black hole and something else collided.[10]

Figure 7:- Supernova remnants discharge material that can form planets.

3. CHANDRA SHEKHAR X-RAY OBSERVATORY AND SAGITTARIUS A* BLACK HOLE

3.1 Introduction
On July 23, 1999, NASA launched the Advanced X-ray Astrophysics Facility (ARAF), originally known as the Chandra X-ray Observatory (CXO), outside the space shuttle Columbia during STS-93. Due to the great angular resolution of its mirror, Chandra is 100 times more sensitive to X-ray than any other X-ray telescope. A 64-hour orbiting Earth satellite named Chandra is still on a mission as of 2023[11]

3.2 History of Chandra Shekhar X-ray observatory
The Chandra X-ray observatory, then known as AXAF, was suggested to NASA by Riccardo Giacconi and Harvey Tanan Baum in 1976. Preliminary work at the Chandra X-ray center in the Center for Astrophysics/Howard and Smithsonian’s Marshall Year Space Flight Center began the next year. In contrast, in 1978 NASA launched Einstein (HEA 0-2) into orbit, the first imaging x-ray telescope. The AXAF project was still being worked on throughout the 1980s and 1990s. As part of a NASA contest that attracted more than 6000 entries from all around the globe in 1998, the spacecraft was rebuilt in 1992 to cut costs and given the new name Chandra. [12]

Although Chandra was originally assigned a life expectancy of 54 years, NASA extended its life to 10 years on September 4, 2001 based on its exceptional findings [13]. However, Chandra might physically live much longer. The observatory may operate for at least 15 years, according to a 2004 analysis conducted at the Chandra X-897 center [14]. It is still operational as of 2022 and the Chandra X-ray Center has scheduled further observations [15]

The international X-ray observatory, a project that ESA, NASA, and JAXA were collaboratively developing, was first suggested to be the next major X-ray observatory [16]. Later, ESP revived the project under the name Advanced Telescope for High Energy Astrophysics (ATHENA), with a midday target of 2028. [17]

Due to a gyroscope malfunction, Chandra commenced safe mode operations on October 10, 2011. According to NASA, all scientific equipment is safe [18] [19]. Soon after it was discovered that one of the gyros had a 3 Second data mistake, arrangements were made to resume Chandra in full function. The faulty gyroscope was put in reserve and is otherwise in good condition.
Instruments
1) (HRC) High resolution camera
2) ACIS, or Advanced CCD Imaging Spectrometer
3) HETRS, or high energy transmission grating spectrometer
4) LEGTS, which stands for Low Energy Transmission Crating Spectrometer.

3.3 Examples discoveries by Chandra Shekhar X-ray Observatory:
The study of x-ray astronomy has substantially progressed thanks to the data that Chandra acquired. Here are some examples of findings that were confirmed by Chandra’s observations.
1) Cassiopeia A’s first light photograph let scientists to see for the first time the compact object in the remnant’s center, which is probably a black hole or neutron star.
2) A further supernova remnant in the crab nebula, Chandra discovered jets that older telescopes could only partially identify as well as a never-before-seen ring surrounding the core pulsar.
3) Chandra discovered a lot more cold gas spiraling into the Andromeda galaxy’s center than was anticipated.
4) When galaxy clusters merge in Abell 2142, pressure fronts were for the first time detected in great detail.
5) SNA 1987A was the first supernova to have its shock wave captured in an x-ray picture.
6) In a picture of Perseus A, Chandra made it possible to glimpse a little galaxy’s shadow for the first time or the fact that layer one is engulfing it.
7) In galaxy M82, a brand-new class of black hole known as a mid-mass entity was found believed to be the missing piece connecting stellar-sized and supermassive black holes.
8) Chandra proposed that the previously identified pulsars RXJ1856.5-3754 and 3C58 may really be quark stars, which are far denser things. These conclusions are still debatable.
9) In the Perseus cluster in 2003, supermassive black hole’s environment was found to produce sound waves from violent activity.
10) Two stars that resemble the sun were discovered to be in orbit around a brown dwarf named TWA 5B.
11) By monitoring super cluster collisions, Chandra in 2006 discovered compelling evidence that dark matter exists.
12) The poles, not the auroral ring, are the source of Jupiter’s x-rays [20]
13) A significant hot gas halo was discovered around the Milky Way [21].
14) PSRB 1509’s image titled “The Hand of God”

3.4 Mission Overview
A telescope specifically created to detect x-ray emission from extremely hot parts of the cosmos, such as materials around black holes, clusters of galaxies, and destroyed stars, is NASA’s Chandra X-ray observatory because the atmosphere of Earth absorbs x-rays. Chandra must or somewhat above it, reaching a height of 86,500 miles (189,000 km) in space. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, is home to the Chandra x-ray center and it manages the satellite, analyses the data, and sends it to researchers all around the world for examination.

3.5 Size and structure of Sagittarius A*:
**Size:** It’s interesting to note that recent data from a similarly dispersed pulsar close to Sagittarius A* indicate that this dispersion screen is not truly located in the galactic center. The law that governs the observed size of Sagittarius A* states that the scattered-broadened angular size is

\[ \varphi_{\text{scatt}} = (1.36 \pm 0.02) \text{mass} \times \left( \frac{\Lambda}{\text{cm}} \right)^2 \]  \( \text{(1)} \)

At 43 and 22 GHz, however, Bower et al. found that the observed sizes really deviate from the behavior when employing a closing amplitude technique in a little way. Closure amplitudes are produced to eliminate telescope-based gain error by integrating the complex amplitudes in the correlated data (visibilities) obtained from sets of four separate telescopes. Then, as a reliable source size indication, the closure amplitude is employed. According to Bower et al., the intrinsic size contribution, which was seen to decrease in frequency, was what produced the departures from the scattering equation. The size is actually about 4Rs at 230 Hz, as demonstrated by measurements taken at higher frequencies by Shen et al. and Doeleman et al., which supported this tendency. Using the data’s natural size and fitting all the information one finds. [22]

\[ \varphi_{\text{sgr A*}} = (0.52 \pm 0.03) \text{mass} \times \left( \frac{\Lambda}{\text{cm}} \right)^{1.3\pm0.1} \]  \( \text{(2)} \)
Structure of Sagittarius A*

Since black holes are regions of extreme gravitational distortion, their internal structure is not well understood. However, based on theoretical models, Sagittarius A* is believed to have following components.

1. Singularity:
   At the core of Sagittarius A*, there is a gravitational singularity which is an infinitely dense and infinitely small point. It is surrounded by event horizon, beyond which singularity's gravitational effects become significant.

2. Accretion Disk:
   Surrounding the event horizon, there is an accretion disk composed of gas, dust, and other stellar debris. This disk is formed as matter from surrounding stars and interstellar medium is drawn into gravitational pull of black hole. The accretion disk emits various forms of radiation, including X-rays.

3. Jets and outflows:
   Some supermassive black holes, including Sagittarius A*, are known to generate powerful jets of high-energy particles and electromagnetic radiation. These jets are thought to originate from the vicinity of black hole's event horizon and can extend for thousands of light years. [22]

3.6 Radio Variability of Sagittarius A*:

The radio emission itself has a 2.5% rms variance throughout the radio spectrum. At wavelengths of 13.6, 3.1, 3 and 0.7 cm, respectively, there are 17% and 21%. As a result, variability appears to get stronger with frequency. This is compatible with plasma blobs streaming outward (in a jet or otherwise) and expanding adiabatically. The rms variance is significantly bigger at the highest frequencies, and there are outbursts that are many factors above the quiescent level.

Here are some key aspects of radio variability of Sagittarius A*.

   1. Flux Density Variations:
      The flux density, which measures the amount of radio emission received from Sagittarius A*, shows significant variations over different time scales. These variations can occur on time scales ranging from minutes to hours, days, and even longer. The radio emission from Sagittarius A* can increase or decrease in intensity, sometimes by several orders of magnitude.

   2. Flares:
      Occasionally, Sagittarius A* experiences dramatic increases in radio emission known as flares. These flares can be short-lived, lasting only a few minutes to hours, or they can persist for days. Flares are often associated with rapid changes in brightness and spectral properties of emitted radio waves.

   3. Quiescent state:
      In addition to variability and flares, Sagittarius A* also spends significant periods in a relatively quiescent state. During these quiescent periods, the radio emission from the black holes remains relatively stable at lower level.

4. Correlations with other wavelengths:
   Astronomers have observed the correlation between radio variability of Sagittarius A* and emissions at other wavelengths, such as X-rays and infrared. These correlations suggest that processes responsible for radio variability may be linked to phenomena occurring closer to black hole, such as accretion disk or relativistic jets.

4. MATERIALS AND METHODOLOGY

4.1 INTRODUCTION:

Since black holes are very far away from us, we cannot see it through our naked eyes. So, we need help from some instruments to observe and store the data. There are several telescopes and observations that have been used to study black holes across various wave lengths of electromagnetic spectrums. Here are some notable telescopes and observatories.

   1. Event Horizon Telescopes (EHT)
   2. Hubble Space Telescopes
   3. Fermi Gamma ray Space Telescope
   4. Neil Gehrel's swift observatory
   5. LASER Interferometer Gravitational wave observatory (LIGO)
1) EVENT HORIZON TELESCOPE:

A collection of observatories known as the event horizon telescope cooperation (EHT) has come together to photograph the radiation surrounding supermassive black holes. The EHT array is made up of telescopes in France, Spain, Greenland, Chile, Mexico, the South Poles, the United States (Arizona and Hawaii), and Chile. Both theoretical investigations and simulation studies are included in the EHT project. The Event Horizon Telescope Collaboration (EHTC) and joint ALMA observatory (JAO) have announced that the VLBI 1 millimeter observations made by the Event Horizon telescope in April 2017 will be made available to the public. The main goal of the observations is to capture high-resolution images of the supermassive black holes M87 and Sagittarius A at event horizon scales as well as the AGNs OJ 287, 3C 279, Centaurus A, and NGC 1052 at event horizon sizes. In a series of six scientific papers, the EHT collaboration published the first image of the black hole in the center of galaxy Messier 87 on April 10, 2019. This observation was taken by the array at 1.3 mm wavelength, with a potential resolution of 25 micro arc seconds. A polarized-based picture of a black hole that was initially exhibited by the group in March 2021 may assist to more clearly identify the dynamics that give origin to quasars. Sagittarius A*, the supermassive black hole at the center of the Milky Way, was captured in its first image, was released by scientists on May 12, 2022.

A notable scientific achievement, the M87 black hole’s successful imaging shed light on the characteristics of black holes. The EHT is still monitoring other black holes, most notably the Sagittarius A* (Sgr A*) black hole at the center of our own Milky Way galaxy. [23][24]

![Figure 10: The Global mm-VLBI Array (GMVA) and the Event Horizon Telescope (EHT) participant telescope locations are shown in this infographic.](image)

2) HUBBLE SPACE TELESCOPES:

The primary wavelengths that the Hubble Space Telescope uses are optical and near-infrared. It takes pictures of the celestial objects at high detail, giving us amazing vistas of galaxies, stars, nebulae, and other cosmic phenomena. The Hubble is situated above the distortion caused by the earth’s atmosphere, in contrast to ground-based telescopes, allowing astronomers to observe celestial objects in amazing detail. There have been several groundbreaking discoveries made by the Hubble space telescope. It has contributed to our knowledge of dark matter and dark energy and helped quantify the pace of the universe's expansion. We now know more about the early cosmos because to the Hubble Deep field photos, which were taken by a telescope and showed hundreds of galaxies in a small area of the sky. The space telescope science institute (STSci), which also manages the data processing selects Hubble's targets and the Goddard Space Flight Center (GSFC), which manages the spacecraft.[25]
3) Fermi Gamma Rays Telescope (FERMI):
The Gamma-ray Large Area Space Telescope (GLAST), also known as the Fermi Gamma-ray Space Telescope (FGST, sometimes known as FGRST), is an observatory in low earth orbit that is used to conduct gamma ray astronomy investigations. It has helped us comprehend the high energy processes of active galaxies with supermassive black holes by detecting Gamma ray emissions from these galaxies. With the help of Fermi, researchers can investigate a wide range of issues, including the origin of cosmic rays and crushed stellar remnants like pulsars, as well as stellar explosions known as gamma ray bursts, galaxies driven by supermassive black holes, and searches for signs of novel physics.[26]
4) Neil Gehrel’s Swift Observatory:
Interferometric Laser LIGO stands for Gravitational-Wave Observatory. Space-time ripples known as gravitational waves created by the acceleration of enormous objects, are the focus of this vast physics experiment and observatory. The National Science Foundation (NSF) of the United States provided funding for the original LIGO observatories, which were designed, constructed, and are currently run by Caltech and MIT. These observatories employ mirrors with a four-kilometer separation that are only capable of reflecting light with a proton’s charge diameter or less[27]

![Image of Neil Gehrel’s Swift Observatory](image1)

**Figure 13:**- Neil Gehrel’s Swift Observatory

### 4.2 METHODS

For the measurement of energy flux and energy spectrum of Sagittarius A* black hole, we have collected the data from various sources like research papers, books and with the help of internet. These data are shown in table below.

**TABLE 1**

**4.2.1 DATA OF FLUX VALUES IN SGR A* BLACK HOLE TAKEN FROM FERMI TELESCOPE BETWEEN 0.1 AND 100 KeV.**

<table>
<thead>
<tr>
<th>S.N</th>
<th>Energy Range (KeV)</th>
<th>Flux ($10^{-12}$erg cm$^{-2}$s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2-0.4</td>
<td>4.6</td>
</tr>
<tr>
<td>2</td>
<td>0.4-1.3</td>
<td>3.9</td>
</tr>
<tr>
<td>3</td>
<td>1.3-2.8</td>
<td>2.1</td>
</tr>
<tr>
<td>4</td>
<td>2.8-10</td>
<td>2.9</td>
</tr>
<tr>
<td>5</td>
<td>10-100</td>
<td>1.7</td>
</tr>
</tbody>
</table>

TABLE 1. Flux value of Sgr A* black hole measured with Fermi measured in spring 1992.
TABLE 2
4.2.2 DATA OF ENERGY SPECTRUM OF SGR A* BLACK HOLE MEASURED WITH CHANDRA SHEKHAR OBSERVATORY.

<table>
<thead>
<tr>
<th>S.N</th>
<th>Energy Spectrum (eV)</th>
<th>Spectral Energy Density per unit frequency ((10^{-12} J/Hz))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$-5.1$</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>$-6$</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>$-3.4$</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>$-1.5$</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>$-4.5$</td>
<td>0.1</td>
</tr>
<tr>
<td>6</td>
<td>$-2.5$</td>
<td>0.2</td>
</tr>
</tbody>
</table>

TABLE 2. Energy spectrum of Sgr A* black hole measured with Chandra Shekhar X-ray Observatory measured in 2007.

5. RESULT AND DISCUSSION

5.1 GENERAL CONSIDERATION
The conclusions of our research are covered in this chapter and are outlined below. The data of flux values and differential flux of Sgr A* black hole measured with different telescope is studied.

5.2 RESULT
5.2.1

Histogram diagram of Stellar-Mass of different black holes from table 2.2
5.2.2

Histogram diagram of Galactic mass of different black holes from table 2.2

5.3 Graph 1

Flux value of Sgr A* black hole measured with FERMI.

Figure 5.3: Graph of flux value Vs energy range measured with FERMI.
To compare the flux values with respect to energy range measured by FERMI, we can consider different energy range and flux value of Sgr A*. However, the flux value will depend on specific source being observed, its distance from earth, and energy range being considered.

Let's say we divide the energy range into several intervals, such as 0.2 to 0.4 Gev, 1.3 to 2.8 Gev, 2.8 to 10 Gev and 10 to 100 Gev. For each energy bin, the Fermi telescope would measure the flux of gamma rays within that energy range. Here we consider, in the graph that the curve is peak at 0.2 to 0.4 energy range i.e. 3.9 energy flux and then again decreases at 1.3 to 2.8 energy range i.e. 2.1 energy flux. The curve then increase from 2.8 to 10 energy range i.e. 2.9 flux and suddenly the curve again decreases sharply at 10 to 100 Gev i.e. 1.7 energy flux.

In general, the flux values obtained by FERMI will likely show variations across energy ranges. Gamma-ray sources can exhibit different spectral shapes, and their flux may decrease or increase as energy of gamma rays changes. In this way, we can plot the graph of energy ranges and energy flux of Sagittarius A* black hole.

5.4 Graph 2

![Graph of energy spectrum of Sgr A* black hole](image)

**Figure 5.4:** Graph of energy spectrum measured with Chandra Shekhar X-ray Observatory.

The energy spectrum of an astronomical object, such as black hole refers to the distribution of energy emitted or absorbed by object at different frequencies of electromagnetic radiation whereas the spectral energy density is a representation of energy emitted by an astronomical object across the entire electromagnetic spectrum, from radio-waves to gamma rays. It is a plot of object's luminosity (or flux) at each wavelength, showing the overall picture of its emission characteristics.

The above graph is of Table 2. The above shows the relation between energy spectrum and spectral energy density per frequency of Sgr A* black hole measured with Chandra Shekhar X-ray observatory. As we see that, the graph is eventually decrease at -5.1 ev to -6.1 ev i.e. 2*10^-12 and 4*10^-12 spectral energy density and again increases rapidly from -3.4 to -1.5 and again decreases at -4.7 and then slightly increases at -2.5 ev.
5.5 COMPARISON OF FLUX VALUE AND ENERGY SPECTRUM OF SAGITTARIUS A* BLACKHOLE MEASURED WITH DIFFERENT OBSERVATORY.

6. CONCLUSION

1. We show the relation between flux value and energy range of Sagittarius black hole A* measured with FERMI between 0.1 to 100 GeV and we found out that as flux value decreases then tends to increases rapidly.

2. We show the relation between energy spectrum and spectral energy density of Sgr A* measured with Chandra Shekhar observatory and we found out that the curve is increases rapidly then slightly decreases and again eventually increases.

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LIST OF ACRONYMS AND ABBREVIATIONS

- **EHT**: Event Horizon Telescopes
- **VLBI**: Very Long Baseline Interferometry
- **JWST**: James Webb Space Telescope
- **AGN**: Active Galactic Nucleus
- **GRMHD**: General Relativistic Magnetohydrodynamics
- **LSO**: Last Stable Orbit
- **AGM**: Accreting Gas Model
- **GRB**: Gamma Ray Burst
- **HEALPix**: Hierarchical Equal Area Isolatitude Pixelization
- **SINFONI**: Spectrograph for integral field observations in the Near-infrared
- **CMB**: Cosmic Microwave Background

REFERENCES


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