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Yin Zhu *

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A Conjecture on Another Supermassive Black Hole in the Bar of Our Milky Way

Yin Zhu

Agriculture and Rural Department of Hubei Province, Wuhan, China; waterzhu@163.com

Abstract: In the bar of our Milky Way, there should be another supermassive black hole B which is with the mass almost 10^{-2}~10^{-5} times the Sgr A* and with a distance almost 10,000 lightyears from the Sgr A*. The bar is formed by the stars that are orbiting around the two black holes Sgr A* and B. And, in the bar, a lots of stars orbit around B while another lots of stars around Sgr A*. The two orbits form the peanut shape with "x-shaped structure" in the bar, while the boxy core is formed with all of the three orbits. And, the orbits of the stars out of the bar could be repulsed to a distant place by the black hole B to form the galactic spiral arms. The ultrafast bar should indicate that the conjectured black hole has been observed.

Keywords: galactic bar; galactic spiral arms; Sgr A*; supermassive black hole; Newtonian theory of orbit

1. Introduction

The Milky Way is with a super gigantic scale which only can be observed with modern technology. Therefore, the outline of the galaxy only can be known in recent time and a long time has been spent in knowing the whole image of it. First, in 1958, it was observed by Oort et al. [1] that the hydrogen clouds are in pure circular rotation about the galactic center. Second, in 1976, it was observed by Georgelin & Georgelin [2] that the galaxy is with four spiral arms. Third, it was known a line about the galactic bar by Oort & Rougoor [3,4] in 1959 and in 1960; and the bar was further confirmed by de Vaucouleurs [5] in 1964; and, it was observed that there are two red clumps in the bar, and, the bar is with peanut shape and a boxy core or "x-shaped structure" [6–10]. Fourth, it was observed [11] that a supermassive black hole, the Sgr A*, is at the center of the galaxy. Firth, it is currently thought that the radius of the Milky Way is almost 10^5 lightyears, the thickness at the center of the galaxy is almost 10^4 lightyears; the mass of the Milky Way is almost $5.8 \times 10^{11}\ M_{sun}$. The observed image of the Milky Way is known as that in the Figure 1. The shape and structure of the Milky Way was generally known while the reason for the galactic bar and spiral arms is unknown [12].

Figure 1. The observed image of our Milky Way.

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On another line, for detecting gravitational waves, the supermassive black hole binaries was generally observed and studied. [13–23] It was presented that there is a pair of supermassive black holes with a separation less than 1 pc at the active galactic nuclei in a single galaxy or less than 30 kpc in an interacting system. And, it was reported that the binary supermassive black hole in one galaxy was discovered [24,25]. Therefore, it is certain that there can be two supermassive black holes in one single galaxy. (We think, only a little fraction of the supermassive black hole binaries can merge.) And, abundance of "x-shaped radio" galaxies were observed [14,15]. It was pointed out that the "x-shaped radio" may be a signposts of the supermassive black hole binaries [13].

In this work, from the peanut shape and the "x-shaped structure" or boxy core of the bar [6–10] and the studying about the supermassive black hole binaries [13–25], we present that there should be another supermassive black hole in the bar of our Milky Way. And, we try to understand the structure of the bar and the spiral arms of the Milky Way with the pair of supermassive black holes.

2. The Peanut Shape with the "x-Shaped Structure" or Boxy Core of the Bar: the Possible Another Supermassive Black Hole in the Bar of the Milky Way

2.1. The Possible Structure of the Bar of the Milky Way

As shown in Figure 2, if there should be two supermassive black holes Sgr A* and B, there should be a lots of stars orbiting around Sgr A* while another lots of stars around the B. The peanut shape with "x-shaped structure" or boxy core is formed by the two orbits. And, other a lots of stars orbit around both A* and B which formed the bar. The orbits around a pair of supermassive black holes is analogous to the orbits of the planets around the triple stars in [26]. And, from [26] we know, the black hole B should be orbiting around A*. The shape and structure of the bar cannot be changed by the orbit of B.

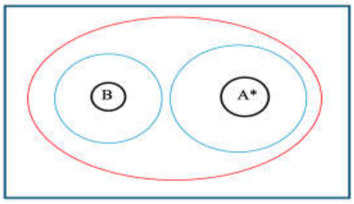

Figure 2. The bar with two black holes Sgr A* and B. The green circles are the orbits of stars around A* or B. The two obits appear a peanut. And, the "x-shaped structure" or a boxy core is between the two orbits. The orbits of the stars around both the two black holes is in red. The Figure 1 is inspired by the Figure 1 in [26].

The boxy core or "x-shaped structure". The boxy core in the bar was discussed [7–10,27–30]. But, as shown in Figure 2, a box could be formed from the three orbits in green and red. In the box, there is no other orbit. The observed image of the boxy core is determined with the direction of observation and the distance between the two black holes. Vertical to the line A*B, the observed image is a box; while along an angle from A*B, the two green orbits appear a "x-shaped structure", noting that the orbits of stars around one black hole forms a sphere. And, the box can be longer as the distance between two black holes is longer and the "x-shaped structure" disappears.

The complicated orbits in the bar. Figure 2 shows, because of the two black holes, the orbits of the stars in the bar is very complicated. It is accordant with current observations. Now, in the bar, it was observed: 1) the circular velocity curve in the bar is very complicated [31–33], 2) the pure cylindrical rotation [34,35] and 3) the orbits in different components in the bar correspondent to different distinct orbital families [9,10]. Maybe, there is not a single circular velocity curve in the bar, just as the orbits of the planets around the triple stars in [26].

The possible two inner bars. From that the bar is with a thickness of almost 10,000 ly, it could be concluded that the orbits around A* or B form a sphere and around both A* and B form a spheroid, rather than a disk or a plane. It is analogous to the orbits of the moons around the Jupiter or to the orbits of the S-stars around the Sgr A* [36–41]. Therefore, the stars orbiting one of the black hole could

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form an inner bar in the primary bar, considering that one inner bar was observed in [42]. Under the condition of Figure 2, there should be two inner bars in the primary bar of our galaxy, which could be correspondent with the two red clumps [6–10]. Therefore, the orbits in the bar is very complicated. It is very difficult to observe the speed of the orbit around one of or both of the two black holes. And, the boxy core is factually a cylinder space. But, from [26] we know, the speed of the orbit of the black hole B around the Sgr A* could be observed. And, the mass of Sgr A* can be accurately and precisely known from this speed.

Strong and weak bar. It was observed that 44% of the spiral galaxies are with a bar which is with different strength. [43] Here, we present, the strength of a bar is determined with these factors: 1) the ratio of $\frac{M_B}{M_{A*}}$, where M_{A*} and M_B are the mass of the black hole A* and B, $0 < \frac{M_B}{M_{A*}} < 1$. As $\frac{M_B}{M_{A*}}$ is larger, the bar is stronger; as $\frac{M_B}{M_{A*}}$ is less, the bar is weaker; as $\frac{M_B}{M_{A*}}$ is very little, B shall become a satellite of A*, the bar is vanished. 2) The distance d between B and A*. As d is very large, no star can orbit both A* and B. Therefore, the necessary condition to form a bar is that the orbit of the stars is affected by both of the two black holes in the same way. 3) As d is very little, no star can orbit around B while many stars orbit around both A* and B. It is a strong bar.

Multi black holes in a bar. There should be more than two supermassive black holes in a bar and a lot of stars have orbits around all the black holes, just as the orbits of the planets around three stars in [26].

There were many observations and different discussions about the galactic bar [12,43–48]. However, we think, as 44% of the observed 4378 disc galaxies are with a bar [43], these bars should be formed by dynamics and kinematics, rather than by accidental event, such as a collision of two galaxies (galaxy-galaxy interaction or cluster-cluster interaction).

2.2. The Galactic Spiral Arms and Hill Sphere

The galactic spiral arms could be understood with the Hill sphere. For two celestial bodies, as the body with less mass is in the Hill radius of the larger one, it can have a stable orbit around the larger one. Or, the less one can move away from the larger one. Therefore, as two stars are orbiting around the Sgr A* with orbits ab and a'b' as shown in Figure 3, if the distance between ab and a'b' is less than the Hill radius of the two stars, the two orbits shall merge into one single orbit. Therefore, the condition for the two orbits ab and a'b' is that the distance between two orbits is larger than the Hill radius of the two stars.

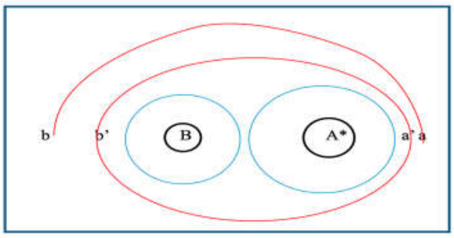

Figure 3. The galactic spiral arm produced by the orbit perturbation. The orbit ab is being perturbed by the star orbiting around both the black holes A* and B. From Hill sphere $r = d\sqrt{m/3M}$, we know, for a same star, the Hill radius of this star at point b' is larger than that at a' for that $d_{b'} = b'A^* > a'A^* = d_{a'}$, where point a' and b' are at the orbit around both the two black holes. It results in that the distance bb' > a'a.

From $r = d\sqrt{m/3M}$ we know, for one same stars, the Hill radius of a star is determined with the distance d between the star and the center mass which the star is orbiting around. In the Figure 3, because the distance d for the star at point b is larger than that at a, the Hill radius of the same star at point b is larger than that at point a. As the Hill radius of the star at point b is $r = d\sqrt{m/3M} = bb'$, then, only the orbit with the distance L ≥ bb' can be remained. It makes the spiral arm produced.

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There were different understandings about the reason for the galactic spiral arms [12,43–48]. Here, we presented that the reason need be accordant with celestial dynamics or kinematics. As the reason is not accordant with dynamics or kinematics, the orbit should be broken off.

It is noted that, in the solar system, although the distance between the orbits of two neighboring planets is affected by the Hill sphere, the factual distance is much larger than the Hill radius of the planets. And, the factual distance of the neighboring orbits can be described with the Titius-Bode law. So, it could be concluded that the distance between two neighboring arms in a galaxy is much larger than that obtained from the Hill sphere.

2.3. The Mass and Position of the Black Hole B

From [26] we know, the black hole B is orbiting around Sgr A*. The Hill radius of B is $r = d\sqrt{m_B/3M_{SgrA*}}$. It is known that the length of the bar of our Milky Way is almost 20,000 lightyears and the largest thickness is almost 10,000 lightyears. It is noted that the thickness is determined with the orbits around both the black holes Sgr A* and B. Therefore, the radius of the orbits of the stars around the Sgr A* or B is a ratio, k, to the thickness. In Figure 3, it could be known that the distance between Sgr A* and a′ is almost 5,000 lightyears. For the same reason, the distance between B and b′ can be approximately known. Here, for convenience, for the possible maximum mass of B, assuming Bb′=2,500 ly, then, the distance between B and Sgr A* should be almost d~20,000 − 5,000 − 2,500 =12,500 ly. Assuming k=0.6, the radius of the orbits of the stars around the black hole B should be 2500k=1500 ly, it could be concluded that $m_B \sim \frac{1}{30} M_{SgrA*}$. While, for the possible minimum mass of B, assuming Bb′=250ly, it could be concluded that $m_B \sim \frac{1}{72{,}000} M_{SgrA*}$. From these assumptions, according to Figure 1 and the observation about the distance between two red clumps [6], it could be concluded that the distance between the two black holes is almost 10,000 ly and the mass of B should be in the range of 10^{-2}~$10^{-5} M_{SgrA*}$. This is only a concluding based on the assumed condition. To accurately know the mass and position of B, the radius of the orbits around B or Sgr A* need be accurately measured. Of course, the position and mass of black hole B could be directly measured with the orbits of the stars around B if the B had been observed.

3. Discussions

3.1. The Conjectured Supermassive Black Hole May Have Been Observed Through the Rotation of the Bar

The rotation speed of the bar and the position of the conjectured supermassive black hole. The shape of the bar is stable. It makes the rotation of the bar around the Sgr A* as one single body; the bar can be treated as a rigid body. As shown in Figure 4, the black hole B is orbiting around the Sgr A*; which makes the bar rotated around the Sgr A*. This may be the reason that the shape of the bar is stable. In this case, the rotation speed of the bar around the Sgr A* should be determined with the speed of the black hole B orbiting around the Sgr A*: $v_{bar} = \sqrt{M_{SgrA*}/R_{AB}}$, and the angular speed of the bar rotating around the Sgr A* is $\Omega_{bar} = v_{bar}/R_{AB}$, where M_{SgrA*} is the mass of the Sgr A*, R_{AB} is the distance between Sgr A* and B. (The Poisson equation shall be discussed in Sec. 3.5.) It is clear, the angular speed Ω_{bar} can be exactly expressed with the straight line AB rotating around the Sgr A*. Therefore, the position of B could be accurately observed from $v_{bar} = \sqrt{M_{SgrA*}/R_{AB}}$.

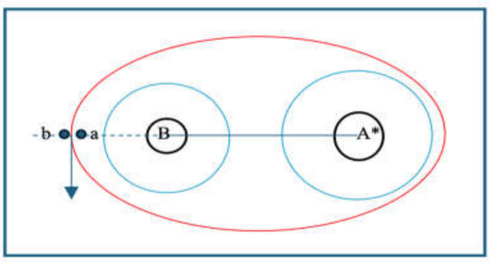

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Figure 4. The rotation speed of the bar and the speeds of the stars in the bar and in the disc. A* and B are the black holes. The bar is in the red ellipse. The stars a and b are on the straight line A*b; and, a are in the bar while b are in the disc; and, the distance between a and b is very little. The black hole B is orbiting around the Sgr A* which makes the bar as a rigid body moved along the arrow with the speed v_{bar}. In the bar, the stars a are moved with the speed v_a while in the disc, the stars b are orbiting around the Sgr A* with the speed v_{disc} along the arrow.

The mass of the Sgr A*. The mass of the Sgr A* can be measured from $v_{bar} = \sqrt{M_{SgrA*}/R_{AB}}$. Now, the mass of the Sgr A* is measured with the orbit of the S-stars around the Sgr A*. Here, a possible new way should be known to measure the mass of the Sgr A*.

It was presented that the mass of the Sgr A* should be $\sim 1 \times 10^{11} M_{Sun}$ [49]. In this case, the rotation speed of the bar, $v_{bar} = \sqrt{M_{SgrA*}/R_{AB}}$, could be larger than 100 times that as the mass of the Sgr A* is only $4.3 \times 10^6 M_{Sun}$. However, so large a difference could be easily measured. And, it is clear that the observed bar pattern speed [50–53] cannot be produced from so little a mass that is only $4.3 \times 10^6 M_{Sun}$, instead, a mass of $\sim 1 \times 10^{11} M_{Sun}$ is needed.

The rotation speed of the bar in Figure 4 can be expressed as $v_i = \Omega_{bar} r_i$, where i is the point on the straight line A*a; then, the speeds v_i are on a straight line. While, according to the Poisson equation, the rotation speed is $v'_i = \sqrt{M(r_i)/r_i}$ which is a part of the galactic rotation curve; it is emphasized that, in this case, the shape of the bar is unstable for that the angular speed based on $v'_i = \sqrt{M(r_i)/r_i}$ relative to different r_i are different.

Ultrafast bar and the conjectured black hole. In Figure 4, the orbital speed of the stars b in the disc near the bar is $v_{disc} = \sqrt{M_{SgrA*}/(R_{AB} + r)}$, the angular speed is $\Omega_{disc} = v_{disc}/(R_{AB} + r)$, where r is the distance between B and b. Therefore, there is a difference between the angular speed of the bar rotating and that of the stars b orbiting around the Sgr A*

$$\Omega_{bar} - \Omega_{disc} = \sqrt{\frac{M_{SgrA*}}{R_{AB}^3}} - \sqrt{\frac{M_{SgrA*}}{(R_{AB}+r)^3}} \quad (1)$$

Correspondently, there is a difference between the rotation speed of the bar at the radius of $(R_{AB} + r)$ and that of the star b

$$v_{bar} - v_{disc} = \sqrt{\frac{M_{SgrA*}(R_{AB}+r)^2}{R_{AB}^3}} - \sqrt{\frac{M_{SgrA*}}{R_{AB}+r}} \quad (2)$$

A difference between the rotation speed of the bar and that of the stars near the end of the bar can be obtained from bar pattern speed. It is very important that the ultrafast bar was observed [50–53]; which means that the rotation speed of the bar is larger than that of the stars near the end of the bar. From Equation (2), it could be concluded that the conjectured supermassive black hole should have been observed by the ultrafast bar [50–53].

We noted that the ultrafast bar is being argued [54]. But, we know, the argument is based on the current galactic rotation curve which was contradicted with recent observations; and as it is noted that the fastest stars is near the Sgr A*, it shall be easy to know that the ultrafast bar is general [49].

The speed difference between the stars in and out the bar. Under the condition of Figure 4, the speed of the stars a in the bar is determined with two parts: the velocity of the B orbiting around the Sgr A* and that of the stars a orbiting around both Sgr A* and B, and $v_{in} = \sqrt{M_{SgrA*}/R_{AB}} + \sqrt{M_{SgrA*}/(R_{AB} + r)}$. While the orbital speed of the stars b out the bar only is $v_{out} = v_{disc} = \sqrt{M_{SgrA*}/(R_{AB} + r)}$. It is clear,

$$v_{in} - v_{out} = \sqrt{M_{SgrA*}/R_{AB}} \ (3) \quad (3)$$

can be one strong evidence for the black hole B.

The orbits of the stars in the bar are in a spheroid, rather than in a plane. For example, some of the orbits are vertical to others. So, the direction of the orbital speeds $v_a = \sqrt{M_{SgrA*}/(R_{AB} + r)}$ of the stars a in the bar are different from each other. It results in that the speeds v_a of the stars with a small

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distance between them can be with a large speed difference. So, it need be noted that, only under the condition that the orbital plane of the stars a and b are in a same plane, there are $v_a = v_{disc}$ and $v_{in} - v_{out} = \sqrt{M_{SgrA*}/R_{AB}}$.

3.2. The Complicated Orbits in the Bar: The Strong Evidence for the Conjectured Supermassive Black Hole

It is generally agreed that the boxy core of the bar was observed while it is argued whether there is the "x-shaped structure" [7,27–29], even the two red clumps [29]; while several observations [6,8–10,27,28] think they were observed. However, it is clear, the boxy core certainly showed that the Srg A* is not at the center of the bar, under the condition that the boxy core is the core of the bar [6–10,27–29]. Therefore, as shown in Figure 2, there are two stellar clumps positioned in the different side of the boxy core, no matter what are the kinds of the stars that form the stellar clumps. So, the two red clumps [6–10,27–29] is fundamental to the structure of the bar. The "x-shaped structure" or boxy core is only formed by the orbits in the two red (stellar) clumps (or possible inner bars). And, if the Sgr A* is in one side of the boxy core, systematically, there should be another correspondent black hole in the opposite side.

As the orbits in the red clumps is noted, it shall be clearly known that the boxy core or two red clumps [6–10] shows the very complicated orbits in the bar. It is emphasized that the complicated orbits in the bar [9,10,31–35] could be the strong evidences for the possible two supermassive black holes with the two inner bars. If there should be only one black hole, the orbits in the bar should be much simpler. Now, besides the assumption of two black holes with two inner bars, the complicated orbits in the bar cannot be explained with other condition.

Now, the position of the Sgr A* in the galaxy [11] and the orbits of the S-stars around it were observed [36–41]. Here, it is emphasized that, from the orbits around the Sgr A*, the structure of the bar can be certainly known. The orbits in the bar were observed from different aspects [9,10,27–35,48]. However, all of the orbits in the bar have not been completely known. And, it is too early to have a conclusion about the structure of the bar before the orbits in the bar have been completely known. To observe the orbits that is different from the orbits around the Sgr A*, such as the pure cylindrical rotation [6,34,35] and the orbits in different components in the bar correspondent to different orbital families [9,10], is important to know whether there is another supermassive black hole. If the numbers of the orbits that are not around the Sgr A* is a large ratio to that around Sgr A*, it could be concluded that there is another black hole with a very large mass.

On another hand, the possible another black hole can be certainly observed from the orbits around it. It is clear that the stars in the different sides of the boxy core cannot have the same orbits around the Sgr A*. Thus, it is a problem that what is the center mass that the stars in opposite side of the boxy core orbit around? So, the boxy core strongly implies that another supermassive black hole is needed for the orbits of the stars (red clumps) in opposite side. It means that a pair of supermassive black holes is needed to make the stars in both of the sides of the boxy core can have stable orbits.

It is very important, as we select these observations: two red clumps [6], "x-shaped structure" [6–10], boxy core [7–10,27–29] and inner bar [42], we can arrive at Figure 2. And, if Figure 2 should be valid, the orbits around the Sgr A* in the inner bar can appear as pure cylindrical rotation [34,35]. So, our conclusion that there should be two supermassive black holes in the bar is supported by observations.

3.3. The Supermassive Black Holes Binaries in a Galaxy

Currently, only the supermassive black hole binaries that should merge was focused on, the orbits about the pair of black holes are varying [13–23]. While, in our work, it is assumed that the orbits in a galaxy are stable. We think, in a galaxy, only a little fraction of the black hole binaries can merge. Therefore, the numbers of the existent pair of black holes is much larger than the observed merged ones and cannot be estimated with the merged ones.

Although there was the idea that there is a second supermassive black hole with mass above 100,000 times the mass of the Sun and farther than about 200 times the distance between the Sun and the Earth, it was ruled out by replacing an intermediate black hole [55–57]. The idea is for detecting the gravitational waves and the distance between two black holes is small. While, our work is to understand the structure of the bar and the dynamics for the spiral arms of the galaxy and the distance between two black holes is large. It is important, our conclusion is based on the observations in [6–10,27–35,42,50–53].

3.4. The Sgr A Is the Critical Coordinate to the Observations About the Structure and Orbits of the Milky Way*

We found, the Sgr A* is the critical coordinate to the observations about the structure and orbits of the Milky Way. But, as some of these observations were obtained, the Sgr A* had not been confirmed. Therefore, in these observations, the Sgr A* cannot be considered. It resulted in that some of the understandings about these observations are incomplete or unclear. For example, in the galactic rotation curve, the Sgr A* has to be considered. As soon as the Sgr A* is considered, it shall be know that nearer the Sgr A*, larger the orbital speed, and the current galactic rotation curve should have been revised [49]. While, in some of the observations obtained after the Sgr A* had been confirmed, the Sgr A* was considered [6,8,28–41]. We think, as the positions of all the observations relative to the Sgr A* are known, a clear outline about the structure of the bar and the orbits in the whole Milky Way shall be arrived at.

Therefore, we think, from the observed data, the mass and position of the possible black hole could be known. This work should be suitable to artificial intelligence. In fact, artificial intelligence is needed for astronomy for the two reasons: 1) very long time (more than 10 years) continuous observation, 2) very tremendous observed data

3.5. The Newtonian Theory of Orbit Perturbation and the Galactic Dynamics

In Newtonian theory of gravity, an orbit only is determined with a center mass although other masses are always perturbing on it [58,59]. For example, although the calculated force of the Sun on the Moon is almost 2.2 times that of the Earth, the Earth is the center mass for the orbit of the Moon which results in that the orbit of the Moon around the Earth cannot be broken off by the Sun [59]. In the Milky Way, the Sgr A* is the only center mass. The orbits in the galaxy are only determined with the mass of the Sgr A* while the other masses only can perturb the orbits. So, here, only the action of the Sgr A* on the orbits in the galaxy is considered, while the action of other masses is omitted.

It is noted that, before the Sgr A* had been confirmed, the Poisson equation was used to calculate the orbits in the galaxy. However, this is inapt and unwarranted for that the Sgr A* is the center mass that the whole galaxy is rotating around, it cannot be omitted. Although now the Poisson equation is still prevailing in studying the orbits in the galaxy, it is contradicted with observation. First, as the Poisson equation is applied to the obit of the Moon, the calculated orbit of the Moon around the Earth should be broken off by the sum of the masses of the Sun and Earth, which was studied in detailed in [59]. Second, it was observed that there are the fast-moving stars around an intermediate-mass black hole in ω Centauri [60]. The Poisson equation is invalid to understand the fast-moving stars. Third, it is observed that the orbits in the bar are very complicated [6–10,27–29] which is clearly contradicted with the Poisson equation. Therefore, we emphasize, not only in the solar system, but also in a galaxy, the orbits only can be understood with Newtonian theory of orbit perturbation. [58,59] While the Poisson equation is invalid in the solar system, we have not had evidence for that it is valid in a galaxy. So, after the Sgr A* has been discovered, the invalidity of the Poisson equation is clarified. And, theoretically, the Poisson equation is simply questioned. According to the Poisson equation, an orbit is determined with $F = GM(r)/r^2$, where $M(r)$ is the sum of the masses enclosed in the sphere with the radius of r. It means that, 1) the masses in the sphere have a same force on the orbit; 2) the mass out of the sphere has no force on the orbit. But, first, a force is with a direction. The force of the mass at different point is with different direction, which results in different action on the orbit. Second, the mass out of the sphere certainly has a force on the orbit. This is the initial knowledge of mechanics. It is very strange that the Poisson equation, which violated the initial knowledge, can be prevailing.

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So, it is emphasized that a center mass in a galaxy is needed to make the orbit stable. Therefore, at the center of a stelar cluster, there should be a center mass, such as a black hole. And, it could be concluded, at the center of each one of the two red clumps [6], there should be a black hole, respectively.

For the pair of black holes, only the black hole with the larger mass is the center mass. The black hole with the less mass is orbiting around the larger one, just analogous to the orbits in [26]. If the two black holes were orbiting around the center of the mass of them as usually thought, it should result in that, relative to the stars orbiting around them, the distribution and the center of the mass of the two black holes are varying. It should further result in that the orbits of the stars around the two black holes is unstable [59]. As soon as a real orbit is considered, this conclusion should be clear. Therefore, only the larger one is the center black hole. Any other celestial bodies, including other supermassive black holes, are orbiting around the center black hole. And, the circular velocity curve of the Milky Way only can be determined with the mass of the center black hole while other masses only can perturb it [59].

It was presented that the mass of Sgr A* may be ~1×10^{11} M_{Sun} [49]. If the mass of B is larger than that of Sgr A* which is with the mass of ~4.3×10^{6} M_{Sun} as current thought [11], from the Hill sphere, it could be concluded that B is the center black hole with the mass of ~1×10^{11} M_{Sun}. And, the distance between the two black holes is ~10,000 ly.

In the stellar system, the stability of the orbit can be described with the Hill sphere, such as the orbits in the stars system in [26]. The orbit in the Hill radius is stable. We clearly know, the orbit in a galaxy is stable. For example, the condition for the galaxy rotation curve and the recent observation about circular velocity curve of the Milky Way are based on the condition that the orbits in a galaxy are stable and obey the Newtonian theory of orbit [31–33]. Therefore, the Hill sphere is valid to describe the stability of the orbit in a galaxy. While, the Hill sphere is little used to study the orbit in a galaxy, although no evidence shows that the Hill sphere is invalid in a galaxy. In this work, the Hill sphere is directly used to understand the orbits of stars around the supermassive black hole and to predict the possible supermassive black hole. It should be a necessary way to make galactic dynamics more completed.

4. Conclusion

The conjectured supermassive black hole may have been observed through the ultrafast bar [50–53].

The two red (stellar) clumps [6–10,27–29] should be strong evidence for a pair of supermassive black holes. And, it is an important line to detect the possible black hole: at the center of one of the stellar clumps, there should be a supermassive black hole; and, there should be the orbits around the black hole.

The peanut shape with the "x-shaped structure" or boxy core of the bar very strongly implies that there should be a pair of supermassive black holes in the bar of our Milky Way. The complicated orbits in the bar [9,10,31–35] should be strong evidence for the implication.

If there should be a pair of supermassive black holes in the bar, the origin and orbital motion of the bar and the arms, even the structure and motion of the whole galaxy, can be well understood. Therefore, to test the possible another supermassive black hole is significant to well understand the whole Milky Way.

References

1. Oort J. H., Kerr F. J. & Westerhout G., 1958, The galactic system as a spiral nebula (Council Note), MNRAS, 118, 379
2. Georgelin Y. M. & Georgelin Y. P., 1976, The spiral structure of our Galaxy determined from H II regions, A&A, 49, 57
3. Oort J. H., & Rougoor G. W., 1959, The interstellar gas in the central part of the galaxy, AJ, 64, 130
4. Rougoor G. W. & Oort J. H., 1960, Distribution and Motion of Interstellar Hydrogen in the Galactic System with Particular Reference to the Region Within 3 Kiloparsecs of the Center, Proceedings of the National Academy of Science, 46, 1

5. de Vaucouleurs G., 1964, in IAU Symposium, Vol. 20, The Galaxy and the Magellanic Clouds, ed. F. J. Kerr, 195
6. McWilliam A. & Zoccali M., 2010, Two Red Clumps and the X-shaped Milky Way Bulge, ApJ, 724, 149
7. Li Z.-Y. & Shen J., 2015, Mapping the Three-Dimensional "X-Shaped Structure" in Models of the Galactic Bulg, ApJL, 815, L20
8. Wegg C. & Gerhard O., 2013, Mapping the three-dimensional density of the Galactic bulge with VVV red clump stars, *Monthly Notices of the Royal Astronomical Society*, 435(3), 01, 1874–1887
9. Mattia M. C., Gerhard O., Portail M., Vasiliev E., Clarke J., 2022, The stellar mass distribution of the Milky Way's bar: an analytical model, *Monthly Notices of the Royal Astronomical Society: Letters*, 514, L1–L5
10. Skokos Ch., Patsis P. A., Athanassoula E., 2002, Orbital dynamics of three-dimensional bars—I. The backbone of three-dimensional bars. A fiducial case, *Monthly Notices of the Royal Astronomical Society*, 333, 847
11. Genzel R., Eisenhauer F. and Gillessen S., 2010, The Galactic Center Massive Black Hole and Nuclear Star Cluster, Reviews of Modern Physics, 82.4, 3121-3195
12. Shen J. and Zheng X., 2020, The bar and spiral arms in the Milky Way: structure and kinematics, RAA, 20, 159
13. Merritt D. & Ekers R. D., 2002, Tracing Black Hole Mergers Through Radio Lobe Morphology, Science, 297, 1310
14. Roberts D. H., et al., 2015, The Abundance of X-Shaped Radio Sources: Implications for the Gravitational Wave Background, ApJ 810, L6
15. Roberts D. H., et al. 2015. The Abundance of X-Shaped Radio Sources I. VLA Survey of 52 Sources With Off-Axis Distortions. ApJS 220, 7
16. Bansal K., et al., 2017, Constraining the Orbit of the Supermassive Black Hole Binary 0402+379, ApJ 843 14
17. Wang J. and Li Y., 2020, Observational signatures of close binaries of supermassive black holes in active galactic nuclei, Res. Astron. Astrophys. 20 160
18. Komossa S., et al., 2021, Supermassive Binary Black Holes and the Case of OJ 287, arXiv:2104.12901
19. O'Neill S., et al., 2022, The Unanticipated Phenomenology of the Blazar PKS 2131–021: A Unique Supermassive Black Hole Binary Candidate, ApJL 926 L35
20. Gómez J. L., Traianou E., et al., 2022, Probing the innermost regions of AGN jets and their magnetic fields with Radio Astron. V. Space and ground millimeter-VLBI imaging of OJ 287, APJ 924, 122
21. Jiang W., et al. ,2023, Observational Evidence of a Centi-parsec Supermassive Black Hole Binary Existing in the Nearby Galaxy M81, ApJ 959 11
22. Magallanes-Guijón G. & Mendoza S., 2024, A Supermassive Binary Black Hole Candidate in Mrk 501, Galaxies, 2, 30
23. Foord A., Cappelluti N., Liu T. Volonteri M. et al. 2024, Tracking Supermassive Black Hole Mergers from kpc to sub-pc Scales with AXIS, Universe 10(6), 237
24. Goulding A. D., *et al.*, 2019, Discovery of a Close-separation Binary Quasar at the Heart of a $z \sim 0.2$ Merging Galaxy and Its Implications for Low-frequency Gravitational Waves, *ApJL* **879** L21
25. Valtonen M. J., Zola S., Gopakumar A., Lähteenmäki A.,et al, **Refining the OJ 287 2022 impact flare arrival epoch**, *Monthly Notices of the Royal Astronomical Society*, 2023; 521 (4): 6143
26. Busetti F., Beust H. and Harley C., 2018, Stability of planets in triple star systems, A&A619, A91
27. Lee Y., *et al.*, 2018, Assembling the Milky Way Bulge from Globular Clusters: Evidence from the Double Red Clump, *ApJL* **862** L8
28. Iwanek P., *et al.* 2023, A Three-dimensional Map of the Milky Way Using 66,000 Mira Variable Stars, *ApJS* **264** 20
29. López-Corredoira M., 2017, Absence of an X-shaped Structure in the Milky Way Bulge Using Mira Variable Stars, *ApJ* **836** 218
30. Nataf D., *et al.*, 2010, The Split Red Clumps of the Galactic Bulge From OGLE-III, *ApJL* **721** L28
31. Zhou Y., et al., The Circular Velocity Curve of the Milky Way from 5–25 kpc Using Luminous Red Giant Branch Stars, ApJ, 946, 73 (2023)
32. Jiao Y., Hammer F., Wang H., Wang J., et al., 2023, Detection of the Keplerian decline in the Milky Way rotation curve, A&A678, A208
33. Eilers A., Hogg D. W., Rix H. and Ness M. K., 2019, The Circular Velocity Curve of the Milky Way from 5 to 25 kpc, ApJ, 871 120
34. Howard D.*et al* 2008, The Bulge Radial Velocity Assay (BRAVA). I. Sample Selection and a Rotation Curve, *ApJ* **688** 1060
35. Kunder A. *et al.*, 2012, The bulge radial velocity assay (BRAVA). II. Complete sample and data release, *AJ* 143 57
36. Peißker F., Eckart A. and Parsa M. 2020, S62 on a 9.9 yr Orbit around SgrA*, ApJ, 889, 61
37. Peißker F., Eckart A., Zajaček M. and Britzen S., 2022, Observation of S4716- A star with a 4 year orbit around Sgr A*, ApJ, 933, 49

 doi:10.20944/preprints202406.1730.v4

38. Peißker F., Eckart A., Zajaček M., Britzen S., Ali B. and Parsa M. 2020, S62 and S4711: Indications of a Population of Faint Fast-moving Stars inside the S2 Orbit—S4711 on a 7.6yr Orbit around Sgr A*, ApJ, 899, 50
39. Peißker F., Eckart A. and Ali B. 2021, Observation of the Apoapsis of S62 in 2019 with NIRC2 and SINFONI, APJ, 918, 25
40. GRAVITY Collaboration, et al., 2022, Deep images of the Galactic center with GRAVITY, A&A 657, A82
41. GRAVITY Collaboration, et al., 2022, Mass distribution in the Galactic Center based on interferometric astrometry of multiple stellar orbits, A&A 657, L12
42. Nishiyama S., et al. 2005, A Distinct Structure inside the Galactic Bar, ApJ, 621, L105
43. Yu S. and Ho L. C. 2020, The Statistical Properties of Spiral Arms in Nearby Disk Galaxies, ApJ, 900, 150
44. Mondal D., Chattopadhyay T., 2021, Role of galactic bars in the formation of spiral arms: a study through orbital and escape dynamics—I. Celest Mech Dyn Astr 133, 43
45. Lindblad P. A. B. & Kristen H., 1996, Hydrodynamical simulations of the barred spiral galaxy NGC 1300. Dynamical interpretation of observations, Astronomy and Astrophysics, 313, 733-749
46. Yoon Y. & Lee M. I., et al., 2019, Observational evidence for bar formation in disk galaxies via cluster–cluster interaction, Nat Astron 3, 844–850
47. Costantin L., Pérez-González, P.G., Guo, Y. *et al., 2023,* A Milky Way-like barred spiral galaxy at a redshift of 3, *Nature* 623, 499–501
48. Hey D. R., *et al.,* 2023, The Far Side of the Galactic Bar/Bulge Revealed through Semi-regular Variables, *AJ* **166** 249
49. Zhu Y., 2024, The Mass of the Center of the Milky Way Revalued from the Fastest Orbits around the Center and the Circular Velocity Curve of the Milky Way, doi: 10.20944/preprints202402.1765.v3
50. Aguerri J. A. L., Méndez-Abreu J., Falcón-Barroso J., Amorin A., et al., 2015, Bar pattern speeds in CALIFA galaxies I. Fast bars across the Hubble sequence, A&A,576, A102
51. Cuomo V., Aguerri J. A. L., Corsini E. M., Debattista V. P., et al., 2019, Bar pattern speeds in CALIFA galaxies II. The case of weakly barred galaxies, A&A 632, A51
52. Guo R., Mao S., Athanassoula E., Li H., et al., 2019, SDSS-IV MaNGA: pattern speeds of barred galaxies, MNRAS, 482, 1733
53. Roshan M., Banik I., Ghafourian N., Thies I., et al., 2021, Barred spiral galaxies in modified gravity theories, MNRAS **503,** 2833–2860
54. Garma-Oehmichen L., Hernández-Toledo H., Aquino-Ortíz E., Martinez-Medina L., et al., 2022, SDSS IV MaNGA: bar pattern speed in Milky Way analogue galaxies, *Monthly Notices of the Royal Astronomical Society*, 517(4), 5660–5677
55. Naoz S., *et al.,* 2017, The Eccentric Kozai–Lidov Mechanism for Outer Test Particle, *AJ* **154** 18
56. Naoz S., *et al.,* 2020, A Hidden Friend for the Galactic Center Black Hole Sgr A*, *ApJL* **888** L8
57. Will C. M., et al., 2023, Constraining a companion of the galactic center black hole Sgr A*, *ApJ* **959** 58
58. Gutzwiller M. C., 1998, Moon-Earth-Sun: The oldest three-body problem. Review of Modern Physics, 70(2), 589-639
59. Zhu Y., 2021, Interaction of Gravitational Field and Orbit in Sun-planet-moon system, doi: 10.20944/preprints202105.0203.v1
60. Häberle M., Neumayer, N., Seth A., *et al., 2024,* Fast-moving stars around an intermediate-mass black hole in ω Centauri, *Nature* **631**, 285–288