The Explanation of The Moving Bright Areas In The First M87 Black Hole Images

Ting-Hang Pei

Abstract – After reading the papers about the first M87 event horizon telescope results, we find the moving bright areas in the observation images from Apr. 5 to Apr. 11 and the conclusion about that the south is brighter than the north is incorrect. We propose an explanation to initially explain the movement of the bright areas as the animation reveals.

Recently, the observation images of the M87 black hole have been revealed [1,2]. It is interesting that these pictures show a non-circularly symmetrical images which might indicates some special movements surrounding the black hole. We might ask how to explain such the non-circularly symmetrical images?

In the Ref. 1 and Ref. 2, it explains in detail why such observations at 230 GHz are presented. It is worthy to be references for understanding the black hole images [1,2], and the simulations of the nonradiation GRMHD model with Doppler beaming or relativistic beaming are used to explain why the south area is brighter than the north area on the photon ring.

After reading, we would like to propose other explanations about the observed images. According to the explanation of Doppler beaming, the bright and dark areas almost appear in the symmetrical position. However, the actual observation images from Apr. 5 to Apr. 11 [1,2] show the different positions of the bright and dark areas. We can see that the image on Apr. 5 is brightest in southwest by west and darkest in the northeast by east. On Apr. 6, there are two brighter areas, and the brightest one is in the southwest by west, and the brighter one in the south. In a meanwhile, the darkest area is in the northeast. On Apr. 10, the three brighter areas in order are in the southeast by south, southwest by west, and southeast by east. The three darker areas appear in the southwest, northeast, and northeast by north. On Apr. 11, two brighter areas are in the southeast and southwest by west, while the dark area move to the northeast. These bright and dark changes are presumed to be other factors that contribute to observations.

It is speculated that the brighter asymmetrical areas may be the large-mass star, white dwarf star, or neutron star. It seems to be at least one there, and the orbital radius is about few times the Schwarzschild radius. They also have much short revolution period. If the observation can be last for a long time, the gravity between them and the black hole should cause the black hole slight disturb, or these bright areas move around the center of mass in the black hole system. In Fig. 6 of Ref. 2, the animation clearly show the bright areas surround the black hole and sometimes there are several bright areas appear at the same time [2].

Above speculation has a similar example. In the binary 47 Tuc X9, a white dwarf star surrounds the black hole to form a binary system [3], in which the orbital velocity of the white dwarf star is about 1% the speed of light. Naturally, it induces the question whether it is possible for the M87 black hole to contain an illuminant like a star with high speed surrounding the black hole? If the illuminant moves at an orbital speed close to the speed of light, then the period around the black hole can be calculated. The photon ring has an average radius about 10 times the distance from Pluto to the Sun, while the distance from Pluto to the Sun is 39 AU and 1 AU is approximately 150 million kilometers. The average radius of the photon ring is estimated about 400 AU. The distance traveled one day by light is 172.8AU, so the high-speed illuminant only needs 14.55 days on the Earth around the M87 black hole. During the period from Apr. 5 to Apr. 11, this high-speed illuminant can travel approximately 150 degrees, or 5/12 circle. So it is reasonable to assume that there is at least one high-speed illuminant or illuminating group around the black hole, which may also explain the movement phenomenon of the bright areas. If the average radius is changed to 300 AU, closer to the observed image size, the period is about 10.91 days on the Earth. As long as the high-speed illuminant reaches 50% the speed of light, it can move about 100 degrees within six days.

The above-mentioned simulations using the nonradiation GRMHD model [2] can be highly consistent with Data on Apr. 6, and we guess the simulations using the observation values on Apr. 6 as the initial values. According to the simulation results in Fig. 6 [2], we can make sure the non-uniform distribution of mass and density on the accretion disk. Because the M87 black hole is 55 million light-years far away from the Earth, if the accretion disk has an uniform mass distribution and is symmetrical up and down, the images of the short-term observation should be unchanged. Furthermore, the rotation of the black hole during this period doesn’t change too much. Therefore, using the results of the simulations, the bright areas are evolving, and the mass and density distributions on the accretion disk is non-uniform. The arguments for the high-speed moving illuminants or illuminating groups on the orbit may be proved by this simulations.

In conclusion, the Doppler beaming is not an appropriate explanation to explain the observed images from Apr. 5 to Apr. 11 [1,2]. The animation in Fig. 6 [2] has clearly revealed the bright areas surrounding the black hole, not staying in the south area. Our explanation is reasonable and can provide the surrounding movements which might be observed in the future. Actually, the animation [2] also points out the similar movements of the bright areas. Furthermore, the Doppler beaming accompanying with the observed images from Apr. 5 to Apr. 11 would make the readers confused and result in an incorrect conclusion that the south is brighter than the north for a very long time. We have to point out this problem and give a more reasonable explanation.

References:

[1]. The Event Horizon Telescope Collaboration et al., "First M87 Event Horizon Telescope Results. I. The Shadow of The Supermassive Black Hole," The Astrophysical Journal Letters **875**:L1, (2019).

[2]. The Event Horizon Telescope Collaboration et al., "First M86 Event Horizon Telescope Results. V. Physical Origin of The Asymmetric Ring," The Astrophysical Journal Letters **875**:L5, (2019).

[3]. Arash Bahramian, Craig O. Heinke, Vlad Tudor, James C. A. Miller-Jones, Slavko Bogdanov, Thomas J. Maccarone, Christian Knigge, Gregory R. Sivakoff, Laura Chomiuk, Jay Strader, Javier A. Garcia, and Timothy Kallman, "The ultracompact nature of the black hole candidate X-ray binary 47 Tuc X9," *Monthly Notices of The Royal Astronomical Society* **467**, 2199 (2017).