Observation of a Binary Black Hole just before its Merger

IGUCHI, Satoru (NAOJ)
OKUDA, Takeshi (Nagoya University)
SUDOU, Hiroshi (Gifu University)

In the galaxy formation process, galaxy clusters are believed to evolve into a giant elliptical galaxy through numerous galaxy mergers. Recent observational results show possible evidence that BBHs exist in the center of giant galaxies and may merge to form a supermassive black hole in the process of their evolution. Clarifying the BBH formation mechanism is essential for the study of galaxy mergers in galaxy formation, as well as for the understanding of the role of black hole mergers in the evolution of supermassive black holes and the detection of gravitational waves at the phase of BBH orbital decay.

We first detected a periodic flux variation on a cycle of 93 ± 1 days (Fig. 1) from the 3-mm monitoring observations of a giant elliptical galaxy 3C 66B[1], with which an orbital motion with a period of 1.05 ± 0.03 years had been observed[2]. The detected signal period is shorter than the orbital period; however it can be explained by the Doppler-shifted modulation associated with the orbital motion of a BBH. Assuming that the BBH has a circular orbit and that the jet axis is parallel to the binary angular momentum (Fig. 2), our observational results demonstrate the presence of a very close BBH that has a binary orbit with an orbital period of 1.05 ± 0.03 years, an orbital radius of $(3.9 \pm 1.0) \times 10^{-3}$ pc, an orbital separation of $(6.1^{+1.0}_{-0.9}) \times 10^{-3}$ pc, the larger black hole mass of $(1.2^{+0.5}_{-0.2}) \times 10^{9} M_{\odot}$, and the smaller black hole mass of $(7.0^{+4.7}_{-6.4}) \times 10^{8} M_{\odot}$. Since it is supposed that a black hole emits strong gravitational waves in the final stage of merger, the decay time of a BBH estimated from the gravitational radiation is $(5.1^{+60.5}_{-2.5}) \times 10^{2}$ years. The black hole merger is one of the most spectacular natural phenomena in the universe and our observational results show that the black hole collisions may have important implications for the formation of a supermassive black hole in the evolution process.

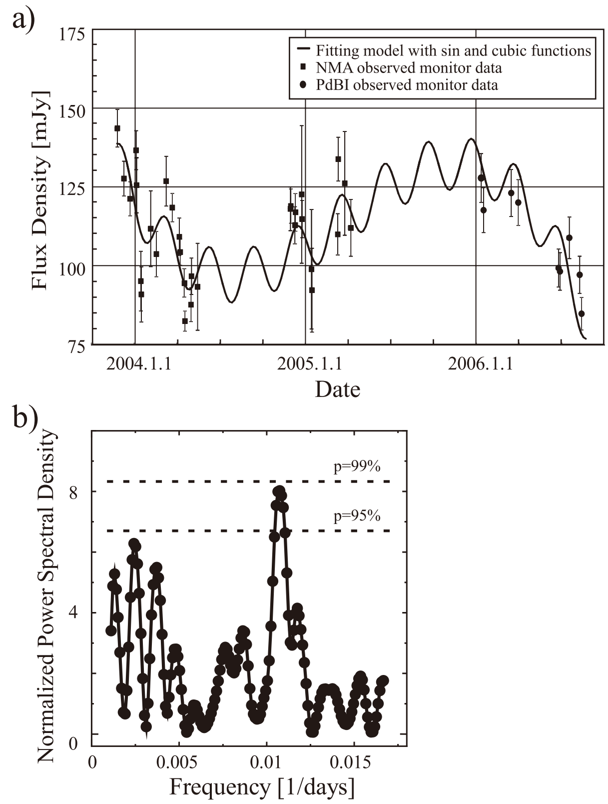

Figure 1: (a) Peak flux monitoring data of the core of 3C 66B at millimeter wavelength, observed with NMA (filled squares; 93.716 GHz) and PdBI (filled circles; 86.2 GHz). (b) Lomb- Scargle periodogram of the flux monitoring data above. The data shows the periodicity of 93 ± 1 days with a 98 % probability.

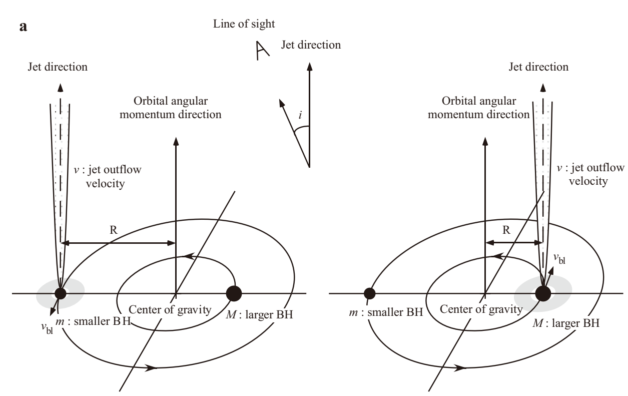

Figure 2: Two schematic geometries of a BBH. We assume that the BBH in 3C 66B has a circular orbit, that the jet is linked to the accretion disk around one of the two black holes, and that the jet axis is parallel to the total angular momentum of the binary. The observed jet is formed by either (a) the smaller massive black hole (with a mass of *m*) or by (b) the larger massive black hole (with a mass of *M*).

References

[1] Iguchi, S., Okuda, T., Sudou, H.: 2010, *ApJ*, **724**, 166.
[2] Sudou, H., Iguchi, S., Murata, Y., Taniguchi, Y.: 2003, *Science*, **300**, 1263.