High-sensitivity 3 mm VLBI Observations of M87: Imaging the Jet Base Near the Supermassive Black Hole

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Understanding the formation, collimation and propagation of relativistic jets in active galactic nuclei (AGN) is a longstanding concern in high-energy astrophysics. Recent theoretical progress based on general relativistic magneto-hydrodynamical simulations has begun to reveal the detailed physics of jet formation regions within 10–100 Schwarzschild radii (R_S) from the central black hole. It is therefore important to present detailed observations that can directly image the relevant scales.

The radio galaxy M87 at the center of the Virgo cluster shows one of the nearest (16.7 Mpc) AGN jets. Due to the proximity and the large mass of the central black hole, the jet formation region has been imaged on a scale of 100 R_S with cm-VLBI. More recently, an extremely compact structure below 6 R_S has been resolved with the global mm-VLBI array project at 1.3 mm (Event Horizon Telescope; EHT). However, the EHT is still technically challenging to synthesize interferometric images due to the severe atmospheric disturbance and the limited number of available stations. Consequently, there still remains a large gap in our current understanding of this jet between the cm-VLBI and the EHT. In this context, an important bridge to connect this gap is observational study at a wavelength of 3 mm.

In 2014 February we conducted high-sensitivity 3 mm VLBA observations of M87 in concert with the Green Bank Telescope (GBT) [1]. The results are shown in Figure 1. Thanks to the large collecting area of the GBT, we obtained images of the M87 jet at a unprecedented quality, where the image dynamic range improved by a factor of greater than 10 from previous VLBA-only images. We found a complicated evolution of the jet forming between 10 and 100 R_S from the black hole.

Moreover, we detected significant polarized emission from the jet base near the black hole, where a highly polarized (up to 20 %) feature was seen, suggesting the presence of a well-ordered magnetic field at this scale. This may be in agreement with the magnetically-driven jet scenario. A further increase in the array sensitivity is necessary. The upcoming incorporation of the phased-ALMA to the existing mm/submm VLBI network will allow us to image the jet launching structure and associated magnetic-field structure in much more detail.

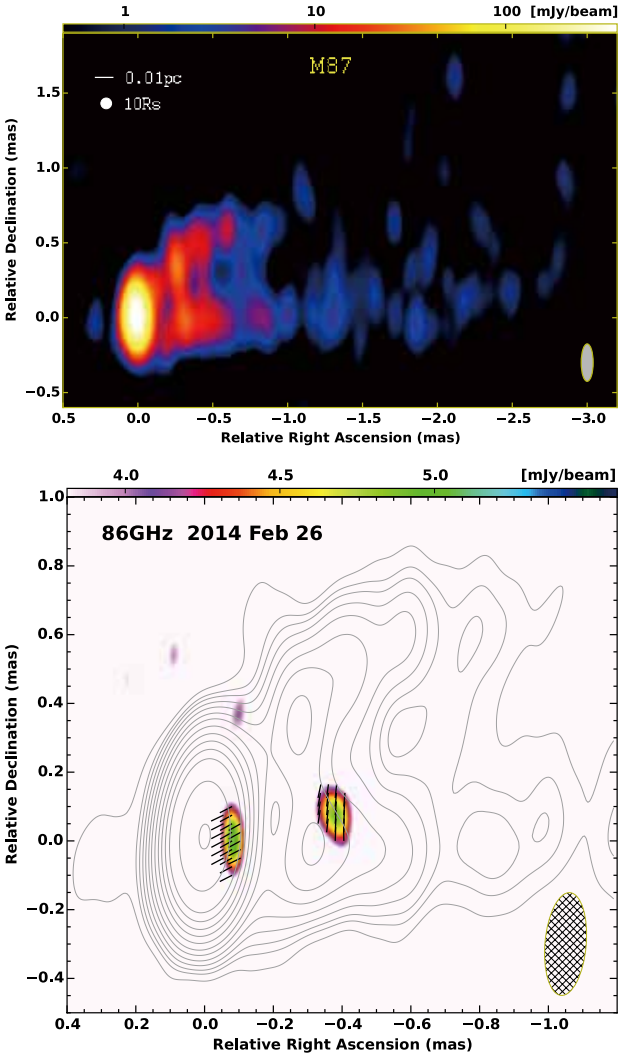

Figure 1: VLBA+GBT 3 mm images of the M87 jet [1]. The top panel shows the observed total intensity image, while the bottom panel (colored) indicates the observed polarization emission (the contours describe the total intensity). At the bottom-right corner of each panel the beam size is shown by the filled ellipse.

Reference

[1] Hada, K., et al.: 2016, *ApJ*, **817**, 131.