Activity Report for NAOJ Visiting Joint Research in FY(2019)

Date: 2020/06/01

Applicant (Host Researcher)	Name	Kazuhiro Hada
	Affiliation/ Title	Mizusawa VLBI Observatory / Assistant professor
Research Title	Probing the deep inside of AGN jets and magnetic fields with high-resolution VLBI	
Work location	Mizusawa	
Visiting Joint Researcher	Name	Wara Chamani
	Affiliation/ Title	Aalto University / Mestähovi Radio Observatory. 4th year PhD student

1. Summary of research

Formation of powerful relativistic jets in Active Galactic Nuclei (AGN) is a longstanding question in high-energy astrophysics. According to leading theoretical models of jet production, the black hole (BH) spin and magnetic flux in the jet launching regions are suggested to be the two key parameters for producing a powerful jet. In particular, recent state-of-the-art general relativistic MHD simulations have revealed that the magnetic flux may be more relevant than the BH spin (Tchekhovskoy et al. 2011). Therefore, to test this paradigm, it is important to constrain the magnetic flux directly from high-resolution observations.

In this joint research program, we investigate the innermost regions of several key AGN jets using the data from the East Asian VLBI Network (EAVN) and the Very Long Baseline Array (VLBA). Recently, an innovative method has been established to robustly derive the magnetic flux at the jet formation scales (Zamaninasab, Clausen-Brown, Savolainen et al. 2014, Nature) based on multi-frequency VLBI data. This method makes use of an accurate measurement of "core-shift", which is a frequency-dependent position shift of the synchrotron photosphere (optical depth = 1 surface) at the jet base (Hada et al. 2011, Nature).

We apply this method for a variety of targets having different jet power. This includes famous jets M87/3C84/3C273 obtained by EAVN (PI: Hada) and lower power sources (IIIZw2, PG2209+184, PG1309+355, E1821+643) obtained by VLBA (PI: Chamani/Savolainen). We will investigate the magnitude of core-shift as a function of jet power by combining the results from EAVN/VLBA. Ultimately, by comparing the derived magnetic flux with a theoretical prediction, we will test the validity of the current leading scenario.

2. Research achievements *Please fill out the attachment if you have made presentations at academic conferences or if your research has been published in academic journals

Our original plan during Ms. Chamani's 3-month stay in Mizusawa was to work on her VLBA data (IIIZc2, PG2209+184, PG1309+355, E1821+643) for the first 2months and later our my EAVN data on higher power targets (M87, 3C273, 3C84). However, due to the growing outbreak of covid19 from February, our joint program was unfortunately shortened to 1.5months and we only processed the VLBA dataset on IIIZw2, for which the BH spin parameter was estimated by Ms. Chamani's previous X-ray work and thus considered as a high-priority source.

The VLBA data on IIIZw2 consisted of a large number of subdata (four frequency bands (5, 8, 15 and 22GHz) and four sources (1 target and 3 phase-referencing calibrators)), so we spent most of the time for the careful analysis of these data. First, before we made detailed phase-referencing analysis, we performed the normal data reduction and imaging for individual sources to check the overall morphology of each source. Thanks to the excellent signal-to-noise ratios of the data, we produced high-quality images for each source. An important finding by our careful imaging was that some of the calibrators have significantly complicated strcutures, which was not expected before. Such deep images on calibrtors was very useful to achieve better astrometric accuracy of the core-shift measuremnt of IIIZw2 by phase-referencing. After we completed the initial calibration, we then moved to the phase-referencing analysis. We performed this analysis by checking every step of calibration very carefully. After several cycles of trial and error of data analysis, we could finally obtain the first set of phase-referenced images. Overall quality of the phase-referenced maps was quite good and we detected a hint of core-shift of IIIZw2 in these preliminary results.

Nevertheless, we found that the phase-referenced maps obtained here still contain some residual phase components from the troposphere and ionosphere, which limit the accucary of our core-shift meansurement. Then, after Ms. Chamani was back in Finland, we are still keepng in touch with each other and further refining the calibration. As of May 2020, Ms. Chamani has significantly improved phase-referencing images by further calibrating both troposphere and ionospjhere. Very soon we will be able to measure the core-shift of this target very accurately and accordingly the strength of B-field at the jet base.

Besides the data analysis described, we also attended an international AGN jet conference held at Tohuku University during January 20-23 ("Active Galactic Nucleus Jets in Event Horizon Telescope Era"). Ms Chamani had an oral talk reporting the X-ray and VLBI observations of IIIZw2. The talk was very successful with many interests and questions from the audience. It was very a good opportunity for her to interact with many experts and other young students. .

3. Any comments on this program【From the applicant】

I thank the NAOJ Reserach Coodination Commettee for offering this excellent opportunity. The covid-19 pandemic was very unfortunate, but our intensive joint work over the 1.5 months through this program was very fruitful and productive.

4. Any comments on this program【From the visiting joint researcher】

My visit to Mizusawa Observatory has been one of my best experiencies doing researcher abroad. Despite of the tight schedule of Dr. Hada, we have managed to work together in a relaxed way. This lead to a productive outcome as the obtaining of the preliminary images of my phase referencing data. Unfortunately, I had to leave Japan earlier than planned to prevent complications of my stay due to the outbreak of the coronavirus in Japan. However, I look forward to visit the observatory again in the near or distant future to work in further AGN jets science projects.

Name/Affiliation	Wara Chamani / Aalto University / Mestahovi Radio Observatory
Period of stay	2020/01/06 ～ 2020/02/27 (53)days
Period of stay	YYYY/MM/DD ～ YYYY/MM/DD ( )days
Total	( ) days

(Notes)
・If additional space is required to complete any item within this form, please edit the size of the blank spaces as needed.
・For item 5, please include all period(s) of stay(s) of the joint researcher, adding extra lines as necessary. If you have invited more than one joint researcher, please copy and create a table for each invited person.
・If you have any concerns or difficulties with publicizing the items of this report, please identify the relevant items and the reasons for each.

(Request)
After a year following the completion of the joint research period, we will send you a request to submit a list of papers and other results that have been produced by this research collaboration. We appreciate your cooperation.