Follow-up of 3C48 position change at 0.06 arcsec

1 Introduction

Analysis of a routine IVS VLBI experiment R4844 observed on 2018.05.31 showed position of 3C48 shifted at -57.70 mas ± 0.50 mas in declination and 1.54 mas ± 0.42 mas in right ascension with respect to its previous position determined over the period of 1990–2017. Last time when 3C48 was observed with VLBI and had normal positions was on 2017.06.26, IVS experiment R1798. Source position jitter at a level of 0.1–1.0 mas is not unusual, but a shift at $0.06''$ is extraordinary. Data analysis procedure was carefully checked to rule out hardware/software/correlator problems. When position of 3C48 is estimated, all 10 points lay within a scatter of other points, i.e. within 0.05–0.2 ns. Lifting position estimation, makes them to become outliers at a 3–6 ns level. This is not consistent with hardware failures.

A quick literature search revealed (An et al. 2010) that 3C48 had three components at X-band, A, B, and B2 (See Figure 1); component A being 55.2 mas south of the component B. An et al. (2010) have demonstrated that A is the core. In 2004.06.05, components A and B at 8.3 GHz were equally compact, $\theta_{\max}$ 1.18 and 1.34 mas respectively, but component A (the core) was weaker than component B: 18.1 mJy versus 55.8 mJy.

Figure 1: VLBA 3C48 image on 2004.06.05 epoch from An et al. (2010)

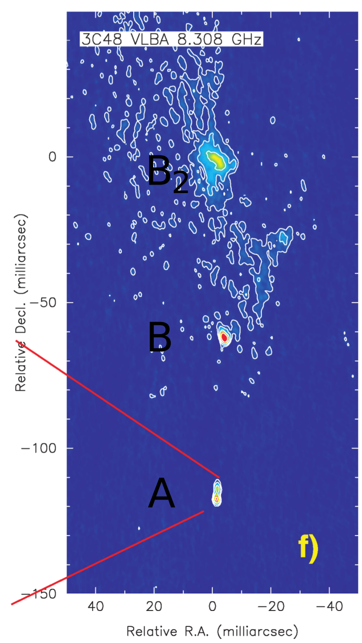

Table 1 shows estimates of 3C48 positions. We see that X-band position differs from S-band position by 51.5 mas. The X-band position is within of 0.7 mas of Gaia positions. The most plausible explanation is that prior 2018 B-component dominated, and fringe fitting process picked B-component. We suggest that in 2018 a flare in the core happened, and component A became brighter than B and X-band, but remained relatively weak at S-band. The fringe fitting process picked component A at X-band and component B at S-band.

Experiment r4844 was processed by the USNO, and unfortunately neither visibility, nor calibration information is available.

A rough estimate of flux density (SNR 9.4 reached over 390 s integration time at baseline HART15M/WETZELL) is 100–200 mJy at both X and S-band.

Table 1: Estimates of 3C48 positions

			RA J2000.0	$\sigma(\alpha)$ mas	DEC J2000.0	$\sigma(\delta)$ mas
3C48	J0137+3309	VLBI prior 2018 X/S	01 37 41.299543	0.34	+33 09 35.13377	0.44
3C48	J0137+3309	VLBI on 2018.05.31 X/S	01 37 41.299646	0.42	+33 09 35.07607	0.50
3C48	J0137+3309	VLBI on 2018.05.31 S	01 37 41.299644	1.57	+33 09 35.13236	3.40
3C48	J0137+3309	VLBI on 2018.05.31 X	01 37 41.299644	0.39	+33 09 35.08074	0.44
3C48	J0137+3309	Gaia DR2	01 37 41.299625	0.05	+33 09 35.07998	0.05

2 Why new observation is needed

We ask for 3 hours of VLBA time and propose to observe 3C48 in order to get a new image, determine its absolute and differential positions, spectral energy distribution of components, and core-shifts of components A, B, and B_2. Flares at AGNs are common, but we argue 3C48 is a special case and deserves dedicated observations.

First, a flare that shifts position estimate at a mind-blowing 58 mas is extraordinary. We cannot sweep such a case under the carpet. This event will go to textbooks. The source was observed since 1990.01.29 and astrometric positions was related to the component B for at least 28 years. It may happen that the component A will become dimmer very soon and then future astrometric observations will again provide positions of component B that is 55.2 mas away if proper data reduction for source structure is not made.

Second, 3C48 is used as a primary VLA flux calibrator. If our hypothesis about the flare will be confirmed, the source might be demoted from the status of a primary calibrator. Anyway, changes in flux density or a primary calibrators seems to be a matter of primary importance.

Third, 3C48 was well studied in the past. The source was observed with VLBA in 1996.01.20 and 2004.06.25 and with EVN on 2005.06.07. These observations revealed superluminal motion of A1 component and tentatively motion of B2 component with $\beta = 1.4 \pm 0.3$ c. A new epoch after 13 years is promising to improve our understanding of its kinematics.

Table 3 in An et al. (2010) shows that the ratios of peak flux density of components B to component A at X-band and L-band were very close in 2004: 3.1 versus 3.2. It follows from R4844 data that this ratio is more than 1 at S-band and less than 1 at X-band. **This prompts us to suggest we observe the flare in progress: its X-band flux density rose in 2018.05.31, but S-band flux density has not yet.** Since we do not know how long 3C48 will be in the elevated state since May 2018, we request prompt observations to catch the flare. We would like to measure the core-shift since there were indications (Plavin et al. 2017) that during strong flaring activity the equipartition state is violated and **the core-shift is changed**. Observations of the flare in progress provides us a good opportunity to test it. We also preparing a RadioAstron proposal for measuring its brightness temperature.

Fourth, 3C48 is optically bright (G=15.83 mag) and its Gaia positions are determined with high accuracy. Therefore, Gaia position time series scheduled for release in 2022 will have very high accuracy. We expect to significant Gaia position wander caused by this flare predicted by Petrov & Kovalev (2017b). It was shown in that paper that correlation of VLBI/Gaia position differnec evolution with light curves provides important information about miliarcsecond optical structure and allows to pinpoint the region whether the flare took place. Preliminary results of comparison of proper motion of VLBI/Gaia matching quasars from Gaia DR2 present an indirect evidence of the predicted jitter in Gaia AGN positions: the distribution of directions of proper motions in optical range with respect to the jet direction has strong peaks at directions along the jet or at 180° with respect to the jet direction (Petrov et al. (2018) in preparation).

The IVS has included 3C48 in the monitoring list. Thus, we will have its radio position evolution.

3 Proposed observations

We propose multi-frequency observations of 3C48 and two phase calibrators at 1.6 GHz, 2.3/8.7 GHz, 4.2/5.9 GHz, and 24.3 GHz with four VLBA receivers in order to determine their core-shifts and spectral energy distribution of the components.We will spread intermediate frequencies over 480 MHz bandwidth for observations at 4.2, 5.7, and 8.7 GHz in order to determine group delays with high accuracy. We will observe the calibrators in the sequence C1-T-C1-T-C2-T-C2, integrating each calibrator for 40 s and integrating the target for 100 s. It will take 36 minute to observe the sequence with four receivers. We are going to observe each multi-frequency block three times. That will results in integrating the target for 20 minutes at each frequency band. We are going to observe with 2.3/8.7 GHz a 20 minute geodetic block between the multifrequency blocks, as well as before and after them. The observations will be analyzed in three modes: a) absolute astrometry using ionosphere-free group delays of the off-beam calibrators at 2.3/8.7 GHz, 4.2/5.9 GHz, and the geodetic blocks, b) differential astrometry, and c) core-shift analysis using jet features. The objective of the first mode of analysis is to analyze the impact source structure on absolute positions of the target. In the second mode of analysis we will determine positional offsets for every pair of calibrators at each frequency band from the differential astrometry analysis. Assuming the core-shift of every off-beam calibrator is aligned along a straight line, we will be able to separate variables and determine the core-shift independent positions and the parameters of the core-shift dependence on frequency for every object. In addition, for control, in the third mode of analysis we will determine the core-shift using the jet feature method as it was done by Sokolovsky at el. (2011).

We waive proprietary period and ask to make the correlator output public available immediately after correlation.

References

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Petrov, L., Kovalev, Y.Y., 2017, MNRAS, 471, 3775.
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