Frequency-dependent core shift in ultracompact quasars

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Introduction

We present results of a pilot project to measure apparent frequency-dependent core shift effect in ultracompact quasars by the phase referencing method. A new method has been developed for measuring the core shift based on observations of close triplets of radio sources using relative astrometry. We found significant effect in 9 out of 24 targets. Mean values of the core shift for frequencies 1.7, 2.3, and 5.0 GHz relative to the highest frequency of 8.4 GHz are 1.8, 1.2, and 0.2 mas, respectively. This work is accepted for publication in Astronomy Reports journal. Full text available on arXiv: https://arxiv.org/abs/1809.10011

Method

It is not possible to separate the frequency-dependent core shift effect of the phase calibrator and target sources without using some additional information. Previous studies show that the VLBI core usually shifts along the relativistic jet of the source with frequency (Pushkarev et al., 2012). This makes it possible to measure the core shifts independently for each source in a triplet. We used the following model for our calculations:

\[ \mathbf{X}_{\text{core},i}^{j} = (\mathbf{S}_{\text{apex}} - \mathbf{S}_{\text{ph.c.}}) + \Delta \mathbf{S}_{\text{core},i}^{j} \cdot \mathbf{d}_{i} \]

where \( i \in \{1, 2, 3\} \) — source number in the triplet, \( j \in \{L, S, C, X\} \) — frequency band, \( \mathbf{X}_{\text{core}} \) — core position on the map, \( \mathbf{S}_{\text{apex}} \) — coordinates of the jet base (apex), \( \mathbf{S}_{\text{ph.c.}} \) — coordinates of the phase center used in data correlation, \( \mathbf{S}_{\text{center}} \) — coordinates of the map center after fringe fitting, \( \mathbf{d} \) — unit vector of jet direction, \( \Delta \mathbf{S}_{\text{core}} \) — core shift we are seeking.

Results of the Astrometric Core-shift measurements

The plots below show a measured frequency dependence of the VLBI core position relative to the X band. Filled circles represent the results obtained using \textit{a priori} information of the jet directions while the hollow ones the results obtained without jet directions assumption. The curve and shaded region correspond to the dependence \( \Delta \mathbf{S}_{\text{core}} = a + b/f \) with the 68\% confidence interval.

Conclusions

We have developed an approach to measuring the frequency-dependent core shift effect of each source in a group of closely spaced quasars, which are related by a single phase solution derived from VLBI relative astrometry. We demonstrate that this method is capable of reaching the stated goal for ultracompact sources.

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