A new method to detect/confirm weak structural changes with VLBI

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1. Introduction

VLBI provides the highest resolution among astronomical observing techniques. With Space-VLBI (HALCA), the resolution is further improved over that achievable with ground-based VLBI arrays alone. All these VLBI arrays provide limited $uv-$coverages when observing an astronomical radio source. This fact, together with the unavoidable site-dependent phase and amplitude errors, result in some non-uniqueness of the final images (see Wilkinson (1988) and references therein).

In a multi-epoch VLBI observation of a compact and time variable radio source, this kind of non-uniqueness, eg. on the morphology of the source structure, on the positions and on the scale-factors of the flux densities of the individual compact VLBI components, make the direct comparison of the final images from different epochs difficult or sometimes even meaningless. Here we discuss the reliable detection of weak structural changes, particular with regard to intra-day variable radio sources, which we recently observed with HALCA.

The closure quantities are usually free from the site-dependent errors. If we ignore the baseline-based errors, then we may focus on the closure quantities when searching for structural variations in the source. Detecting differences in the closure quantities of the data at different epochs, unambiguously will lead to the detection of structural variations.

2. Comparison of the closure quantities

In practice, it is easy to carry out the comparison of the closure quantities using a method which we call the cross-selfcalibration method. It works as follows:

Let us take a two-epoch observation for example. We have data of epoch-1 and epoch-2.

- First, process the data of epoch-1 and epoch-2, respectively. We get final images of epoch-1 and epoch-2. The residual maps of epoch-1 and epoch-2 should be free from mis-calibration and should look noise like.
- Second, take the final clean components of epoch-1 as input model, run self-calibration (amplitude and phase) on the data of epoch-2. Then take the final clean components of epoch-2 and work on the data of epoch-1 in a similar way.
- Third, inspect the residual maps obtained from the cross-selfcalibration in step 2. No structural variations are present in the source, if the residual maps are again noise like. Otherwise, the source structure must have varied. (see Jin et al. (2000)).

In this method, the clean components act as a carrier of the closure information. Normally, the clean components only carry the information of the structure of the source (the closure quantities) at the sampled $uv-$points, i.e., the $uv-$coverage of a VLBI experiment. If each telescope observes the source within the same GST range at every epoch, then we will get the same $uv-$coverages for every epoch. As we know, the earth does not rotate steadily. But the instability of the earth rotation will only cause small differences on the $uv-$coverages, and can be neglected when observing a compact radio source with an extent of several tens of milliarc-seconds. This will make better use of the above cross-selfcalibration method.

3. Simulated data

The data were generated by the AIPS task DTSIM. At a fixed offset position from the main source, a weak point source was added. The flux of the added point source equals to $3.0 \cdot [8.0 \cdot 10^{-5}]$, $5.0 \cdot [8.0 \cdot 10^{-5}]$, $9.0 \cdot [8.0 \cdot 10^{-5}]$ Jy, where the $[8.0 \cdot 10^{-5}]$ Jy is the RMS of the residual map near the added point source. The following images show the residual maps. The strength of the added point source increases from left to right. The upper row shows the 'normal' residual maps obtained from the data itself. The lower row shows the residual maps obtained with the cross self-calibration method: we took the final clean components of the original data set (where no point source was added) as input model, and then run self-calibration as described above. As one can see, the method allows to detect flux density variations at the level of 5*RMS.

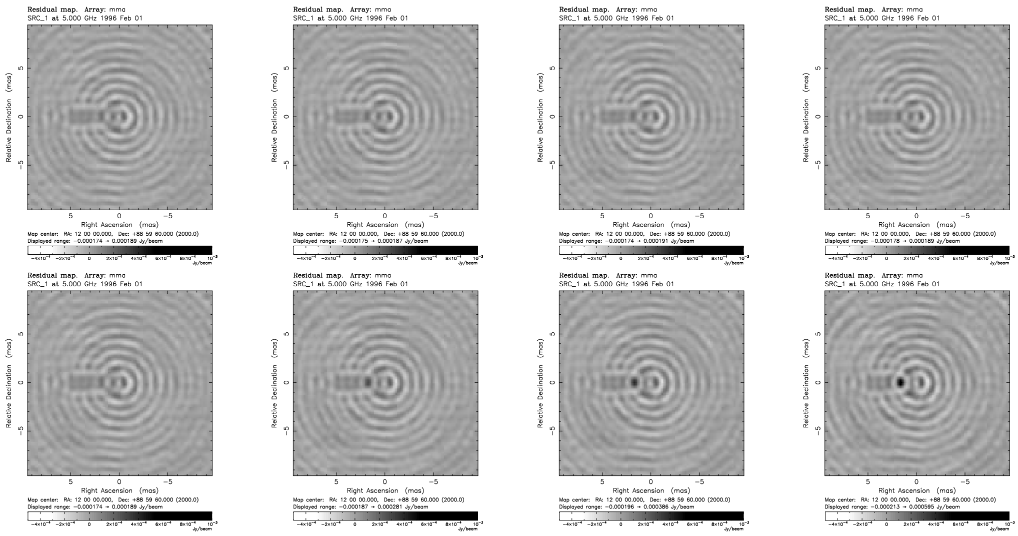

FIGURE 1. Strength of the added point source(from left to right): $0.0 \cdot [8.0 \cdot 10^{-5}]$, $3.0 \cdot [8.0 \cdot 10^{-5}]$, $5.0 \cdot [8.0 \cdot 10^{-5}]$, $9.0 \cdot [8.0 \cdot 10^{-5}]$ Jy.

4. Advantages and disadvantages of this method

The advantage of the method is the direct detection of even weak structural changes, since the method actually uses all the closure quantities of the data. The residual maps, in some sense, accumulate the differences of the two data sets. The method is particularly useful in the case, when the source structure is complicated and can not be described by a small number of (delta-) components.

The disadvantage of the method is that it does not give an accurate quantitative description of the structural changes, eg. the appearance of a new component, or the angular motion, etc. The method is sensitive to changes of the relative brightness of the individual structural components of the source, but it is not able to detect overall changes of the total flux density.

REFERENCES

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