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The Impact of Minimal Ground Antenna Coverage on the VSOP Survey

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Abstract

The VSOP survey consists of 5 GHz space-VLBI observations of over two hundred active galactic nuclei using the HALCA satellite and various telescopes located around the world. Generally only a few ground telescopes participate in any given observation, which results in poor coverage of the (u, v) plane. By making comparisons with datasets using a full array of ground antennas, we find that the VSOP survey data can be used to obtain reliable brightness temperature measurements of strong components in AGN jets. The images, however, are of low dynamic range, and are not well-suited for detailed statistical studies of jet morphology.

1 Introduction

One of the key projects of the VLBI Space Observatory Programme (VSOP) is a survey of several hundred active galactic nuclei at 5 GHz (Fomalont et al. these Proceedings). The individual observations for the survey are carried out with a minimal number (i.e., less than four) ground telescopes, plus the spacecraft, which results in poor quality images and a sparse sampling of the (u, v) plane. In this paper we examine what source information is lost when one goes from a ground array of ten telescopes used in a typical general observing time (GOT) experiment, to just three telescopes for a survey experiment. Such a study is necessary to determine what properties of AGNs can be reliably measured by the survey program, and to identify possible biases that may affect the results.

2 Method

In order to minimize observing time requirements, some data for the VSOP survey are "extracted" from GOT observations by keeping data from only three ground antennas and one spacecraft orbit. We have performed these data extractions on nineteen survey sources that are also members of our Pearson-Readhead GOT survey (Preston et al. these Proceedings). The extractions were made following the fringe-fitting and amplitude calibration stage, giving us a "full" and "extracted" dataset for each source. We reduced these datasets independently using the Caltech Difmap package, and compared the resulting images and model fits. It is important to note that most of the observations in the VSOP survey are of weaker objects than those in our sample, and are generally of poorer data quality. Our results should therefore be interpreted as a "best-case" scenario for the amount of information that can be reliably drawn from survey data.

3 Imaging

There are three main aspects of VLBI images that are highly sensitive to the loss of ground antennas. These are: i) on-source errors, caused by holes in the (u, v) plane, ii) a loss of dynamic range, due to increased image noise, and iii) a lack of sensitivity to diffuse, extended emission, due to the loss of short baselines.

The issue of on-source errors is especially complicated for space-VLBI images, since the (u, v)-coverages are generally elongated in one direction, and contain significant holes at spacings slightly larger than an earth diameter. These tend to create large side-lobes and sinusoidal ripples in space-VLBI images that can mimic oscillations in brightness along the jet. A full quantitative description of the effects of (u, v)-holes on the true dynamic range of an image (i.e., peak flux / maximum flux error) has yet to be formulated. It is possible to obtain an upper limit on this quantity, however, by taking the ratio of peak flux in a map to the off-source rms noise level.

In the top panel of Fig. 1 we show the percentage difference in peak/rms noise level between the full and survey images for nineteen AGNs in the Pearson-Readhead sample. Given that the system equivalent flux density of HALCA at 5 GHz is roughly 50 times that of a typical VLBA antenna, the drop from 10 to 3 ground antennas implies a theoretical rms thermal noise roughly twice that of an image made with the full dataset. This prediction is verified in Fig. 1.

Another consequence of limited ground antenna coverage is the potential lack of short baselines, which are sensitive to extended structure in the source. In the bottom panel of Fig. 1 we plot the percentage dif-

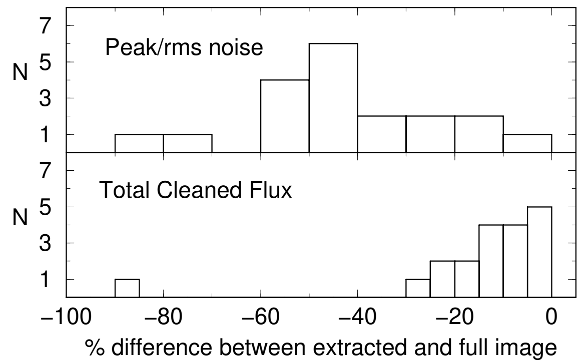

Figure 1: *Top*: Distribution of percentage difference in image dynamic range between full and extracted datasets of Pearson-Readhead AGNs. *Bottom*: Same as top panel, for total cleaned flux density.

ferences in total cleaned flux density for the two types of image. In the majority of cases, over $\sim 85\%$ of the parsec-scale emission is recovered in the survey image. One notable exception is 3C 84, a nearby radio galaxy with a large amount of extended emission on milliarcsecond scales. The fact that the survey and full dataset images recover similar amounts of flux is likely due to the nature of our sample, which was selected on the basis of sufficient flux (> 0.4 Jy) on baselines > 6000 km. As such, it is heavily biased towards objects that have bright cores and little extended structure. The VSOP survey should contain a similar bias, as most of its members are also flat-spectrum, core-dominated AGNs.

4 Model Fitting

We used the model fitting routine in Difmap to fit Gaussian components to the bright core features in our survey and full datasets. The survey data gave reliable core fluxes (top panel of Fig. 2), but less reliable sizes (middle panel). In two cases, the core components dropped below the noise level in the survey images, and could not be model fit. In terms of brightness temperature, which is proportional to core flux divided by component area, the survey data reproduced the values from the full datasets to within approximately a factor of two (bottom panel).

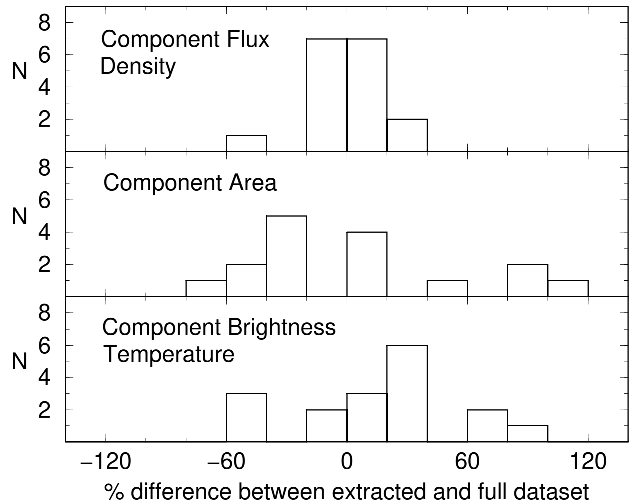

Figure 2: *Top*: Distribution of percentage difference in fitted core component flux density between full and extracted datasets of Pearson-Readhead AGNs. *Middle*: Same as top panel, for component area. *Bottom*: Percentage difference distribution for brightness temperature.

5 Conclusions

Our comparison experiments have shown that the images from the VSOP survey are likely to have very poor dynamic range due to minimal ground antenna coverage and large (u, v) holes. As such, they are not well-suited for statistical studies of jet morphology, with perhaps the exception of crude estimates of jet position angle on parsec scales. The absence of short-baselines should not have a large impact on the survey results, as most of the sources are intrinsically core-dominated. However, the total cleaned flux density (and in turn, the measured flux on shortest baselines) are subject to strong biases, depending on the properties of each individual source. Our model fitting tests have shown that reliable brightness temperatures can be obtained with the survey data, although in some cases the identification of the true core component may be difficult due to the high thermal noise level in the image.

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