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EARTH-SPACE VLBI OF THE QUASAR PAIR 1038+52A,B

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ABSTRACT

We present recent results from 1.6 GHz space-ground VLBI observations of the quasar pair 1038+52A and B, using the HALCA orbiting antenna, and a ground array consisting of the VLBA and the DSN antennas at Robledo and Goldstone. The two sources are separated by only 33 arcsec on the sky, and could thus be observed simultaneously with all VLBI elements. Separate correlations were made with the VLBA correlator for the two quasars, which allows us to image both sources separately, and also provides a unique opportunity to investigate both phase-referencing and relative astrometry on Earth-Space baselines.

INTRODUCTION

The quasar pair 1038+52A,B (Owen *et al.*, 1978) consists of two flat-spectrum radio sources with redshifts 0.678 and 2.296 (Owen *et al.*, 1980), separated on the sky by only 33 arcsec. Because of their close angular proximity, perturbing contributions to the VLBI visibility phase from the troposphere, ionosphere and errors in geometry are largely the same for both sources when observed simultaneously, and their visibility phase difference can be used to measure their astrometric separation (Marcaide and Shapiro, 1983). Using this property, VLBI observations of 1038+52A,B result in map pairs whose precise separation is known. This has been exploited in multi-epoch observations to study internal source motions with respect to an external reference (Marcaide *et al.*, 1994; Rioja *et al.*, 1997; Rioja and Porcas, 1998) and in multi-frequency observations to study the frequency dependence of the structures of both quasars using unambiguous map registrations (Marcaide and Shapiro, 1984; Porcas and Rioja, 1997).

One of the main limitations in such source-pair studies is the problem of defining reference points within each source structure, since this must be done in maps with finite beamwidths, which in turn are frequency-dependent. In 1038+52A, for example, this may hamper attempts to correctly interpret and quantify the well known frequency-dependent shift in the peak emission in the jet. VSOP observations of this pair can provide low-frequency images of both sources at a resolution matched to higher frequency observations from ground arrays, and thus overcome these interpretation difficulties.

OBSERVATIONS and ANALYSIS

Observations of 1038+52A,B were made at 1.6 GHz on 24 November 1997, using HALCA together with the VLBA and the DSN 70m antennas at Robledo and Goldstone and using tracking stations at Tidbinbilla, Robledo and Green Bank to receive the HALCA signal. Both A and B quasars were within all antenna beams simultaneously. Correlation of the 2 x 16 MHz bandwidth, 2-bit sampled signals was done at the VLBA correlator, with a frequency resolution of 0.125 MHz and time sampling of 2s on HALCA baselines and 4s on all others. Two correlation passes were necessary, one at each of the two quasar positions, resulting in two separate visibility functions.

We analysed the data using the NRAO AIPS package. Quasar A was "detected" using the FRING program on HALCA baselines during all tracking station passes. We performed a straightforward analysis, calibrating the visibility amplitudes using the radiometry data provided for all antennas, and applying the fringe-fit residuals before averaging together all frequencies within each IF channel, and in time for 30s. Figure 1 shows the amplitude of the visibility function versus (u,v) distance. Hybrid mapping was performed using a number of cycles of the tasks IMAGR and CALIB. A map of quasar A made with uniform weighting is shown in Figure 2. We have used a circular CLEAN restoring beam of 1 mas FWHM throughout.

Quasar B is well detected on ground baselines but no fringes could be detected on baselines to HALCA. Although errors in HALCA's position are much larger than those of terrestrial antennas, due to orbit uncertainties, the small source separation of this pair does allow the use of phase referencing techniques, and the transfer of instrumental residuals determined on quasar A to calibrate quasar B. We have done this in two ways. First, we used the phases, delays and rates determined for A using FRING, and applied these to the B data set before averaging and imaging with IMAGR. A map of 1038+52B made this way, using uniform weighting, is shown in Figure 3. In a second analysis we used the method of "hybrid double mapping" ("HDM"; Porcas and Rioja, 1996) in which the sum of the visibility functions is mapped to form a compound image containing both source structures. A position offset of 15 mas in declination was applied to the B data before adding to the A data. The fringe-fit residuals determined on A were then applied to the composite visibility, and a number of hybrid mapping iterations were performed. (As both individual visibility functions are corrupted by the same phase errors, the composite function also shares these errors, which can be separated out in the usual way). An HDM image after 5 iterations is shown in Figure 4a. We experimented with a number of different weighting schemes to try and assess the contribution of the HALCA data to our maps. An extreme test is the HDM image made using HALCA baselines alone, shown in Figure 4b. Finally, we made measurements of the positions of the traditional source reference features in these maps (brightness peak in quasar A; central peak in quasar B) using task MAXFIT.

PRELIMINARY RESULTS and CONCLUSIONS

Although further analysis of this valuable data set is continuing, a number of results can be noted already. As expected, quasar A shows a compact "core" component at 1.6 GHz, as at other frequencies, at the base of its mas jet, giving rise to $\sim 250 - 350$ mJy of correlated flux density on HALCA baselines. Quasar B exhibits all 3 components which are seen in ground-only 2.3 GHz images, including the central "reference" component. However, all these components are heavily resolved on HALCA baselines; our map using HALCA baselines alone shows a faint response of only ~ 10 mJy at the position of the reference component. Whilst this response confirms that we have successfully phase-referenced the B quasar data on HALCA baselines using the A quasar residuals, it underscores the need to consider a possible frequency-dependent position for this traditional marker,

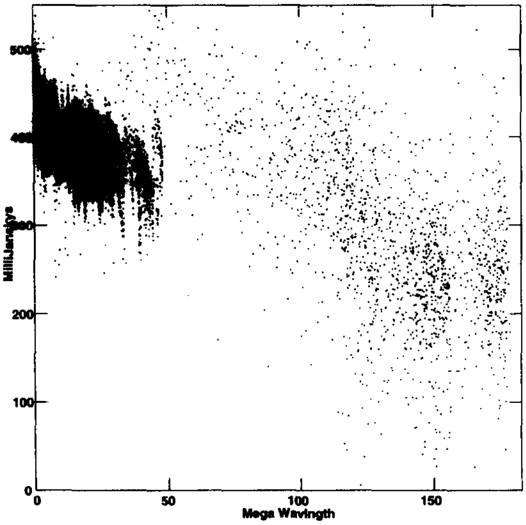

Fig. 1. *Amplitude of 1038+52A visibility function vs u,v distance.*

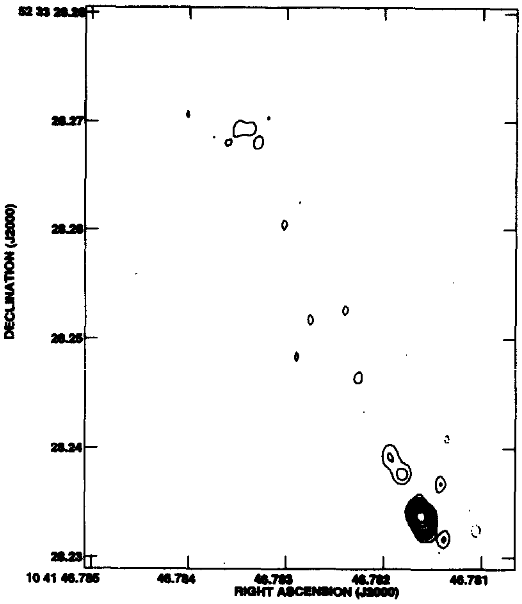

Fig. 2. *Hybrid map of 1038+52A using HALCA+GRT data. Uniform weighting, circular restoring beam 1 mas; tick interval 10 mas, peak 280 mJy/beam, lowest contour 2.5 mJy/beam.*

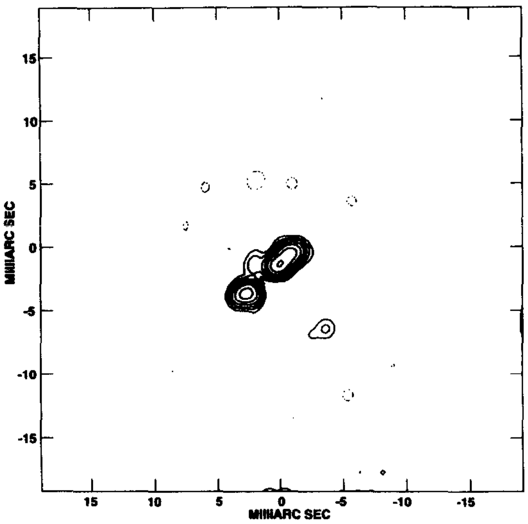

Fig. 3. *Phase-referenced map of 1038+52B using HALCA+GRT data. Uniform weighting, beam 1 mas; tick interval 5 mas, peak 34 mJy/beam, lowest contour 0.5 mJy/beam.*

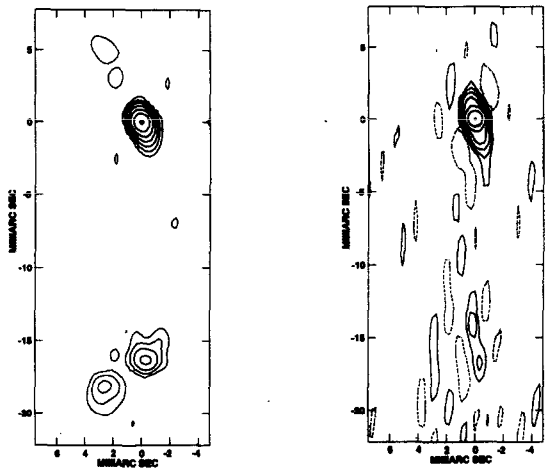

Fig. 4. *HDM images of 1038+52 (A+B). Beam 1 mas, tick interval 5 mas, B offset -15 mas in declination, lowest contour 4 mJy/beam.* a) *HALCA+GRT data, uniform weighted; peak 280 mJy/beam;* b) *HALCA baselines only, peak 267 mJy/beam*

usually considered compact and achromatic (Porcas and Rioja, 1997).

Assuming that the peak of the B reference component is indeed frequency-independent, the peak in the "core" of A is displaced from its position at 8.4 GHz (measured in 1981.2) by 0.21 mas in RA and 1.31 mas in declination. Allowing for the known outward motion of the reference component of 0.014 mas/yr (Rioja and Porcas, 1998) these become 0.397 and 1.169 mas, respectively, or 1.235 mas in PA 19^0, along the A jet axis. As we have pointed out earlier, it is unclear whether this shift of peak with wavelength should be considered a true "*core* shift" or the merging of distinct subcomponents with decreasing turnover frequencies; the SW extension of the 1.6 GHz peak is in the direction of, and (if real) could comprise emission from, the position of the *core* and *knot* components seen at 8.4 and 15 GHz (Porcas and Rioja, 1997). Further analysis of these 1.6 GHz observations, and planned higher resolution VSOP observations at 5 GHz, should shed more light on this issue.

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REFERENCES

Marcaide J.M., and Shapiro I.I., *Astron. J.,* **88**, 1133 (1983).

Marcaide J.M., and Shapiro I.I., *Astrophys. J.,* **276**, 56 (1984).

Marcaide J.M., Elósegui P., and Shapiro I.I., *Astron. J.,* **108**, 368 (1994).

Owen F.N., Porcas R.W., and Neff S.G., *Astron. J.,* **83**, 1009 (1978).

Owen F.N., Wills B.J., and Wills D., *Astrophys. J.,* **235**, L57 (1980).

Porcas R.W., and Rioja M.J., *Proc. of the 11th Working Meeting on European VLBI for Geodesy and Astrometry*, edited by G. Elgered, pp. 209-218, Chalmers University of Technology, Goteborg, Sweden (1996).

Porcas R.W., and Rioja M.J., *Proc. of the 12th Working Meeting on European VLBI for Geodesy and Astrometry*, edited by B. Pettersen, pp. 133-143, Statenskartverk Geodesidivisjonen, Honefoss, Norway (1997).

Rioja M.J., Marcaîde J.M., Elósegui P., and Shapiro I.I., *Astron. Astrophys.,* **325**, 383 (1997).

Rioja M.J., and Porcas R.W., IAU Colloquium 164: Radio Emission from Galactic and Extragalactic Compact Sources, **144**, edited by J.A. Zensus, G.B. Taylor, and J.M. Wrobel, pp 95-96, *Astronomical Society of the Pacific Conference Series,* (1998).