USNO Analysis Center for Source Structure Report

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Abstract

This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure for calendar year 2003. International Celestial Reference Frame (ICRF) sources were observed using the Very Long Baseline Array (VLBA) at 24 GHz and 43 GHz as part of a program to extend the ICRF to higher radio frequencies. Experiments BR079C and BL115A were calibrated and imaged. A program to measure apparent jet velocities from the motions of source components using 8.4 GHz VLBA images continued. A total of 60 sources have been analyzed to date. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Imaging of 69 southern hemisphere ICRF sources at 8.4 GHz was completed. Activities planned for the year 2004 include continued model fitting and imaging of ICRF sources at standard and higher frequencies as well as continued research into the effects of intrinsic source structure on astrometry.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of ICRF sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The web server for the Analysis Center is hosted by the USNO and can be accessed by pointing your browser to

`http://rorf.usno.navy.mil/ivs_saac/`

The primary service of the analysis center is the Radio Reference Frame Image Database (RRFID), a web accessible database of radio frequency images of most ICRF sources with declination greater than about −30 degrees. Source structure information is provided in the form of synthesis images and source models suitable for evaluating sources for astrometric and/or geodetic use and for long-term monitoring of sources. The RRFID contains 3060 Very Long Baseline Array (VLBA) images of 452 sources at radio frequencies of 2.3 GHz and 8.4 GHz. The RRFID can be accessed from the Analysis Center web page or directly at

`http://www.usno.navy.mil/RRFID/`

A recent addition to the RRFID are VLBA images of ICRF sources at radio frequencies of 24 GHz and 43 GHz. The RRFID contains 578 images of 230 sources at these frequencies.

2. Current Activities

2.1. VLBA High Frequency Imaging

VLBA observations to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) continued in 2003. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO) and Bordeaux

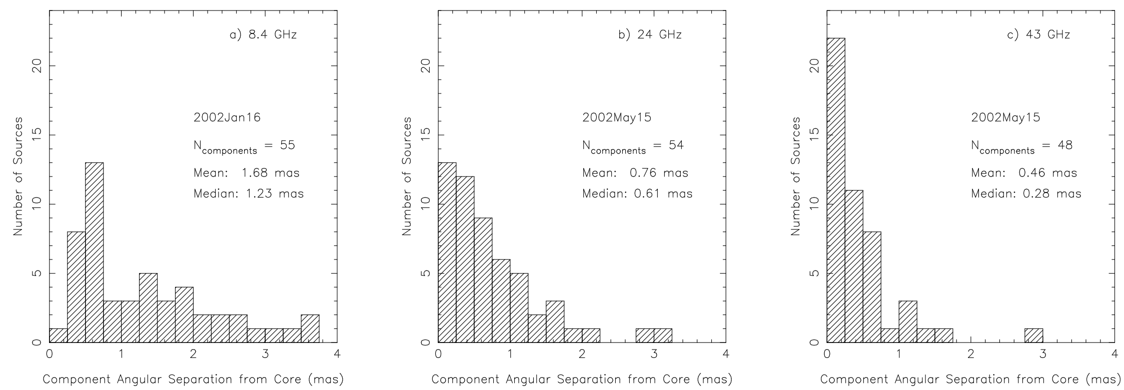

Figure 1. Distribution of Gaussian component angular separation from the assumed core component for the 28 common sources observed on 2002 Jan 16 and 2002 May 15 at a) 8.4 GHz, b) 24 GHz and c) 43 GHz. The core is defined as the model component fitted to the image having the smallest angular size.

Observatory. The long term goals of this program are to 1) develop higher frequency reference frames for improved deep space navigation, 2) extend the VLBA calibrator catalog at K/Q-band, 3) provide the benefit of the ICRF catalog to new applications at these higher frequencies, and 4) study source structure variation at K/Q-band in order to improve the astrometric accuracy. During the calender year 2003, two VLBA high frequency experiments (BR079C and BL115A) were calibrated and imaged.

Gaussian component models fitted to selected images show that the sources are generally more compact as one goes from the ICRF frequency of 8.4 GHz to 24 GHz. This result, shown in Figure 1, suggests that reference frames defined at higher radio frequencies will be less susceptible to the effects of intrinsic structure than the ICRF.

The distribution of “Structure Index” calculated from the first epoch of K/Q-band images (Charlot 2002, private communication) is shown in Figure 2. Also shown are values for the 28 sources observed in RDV31 at X-band which overlap with these sources. Note the shift toward lower values as the frequency of observation increases.

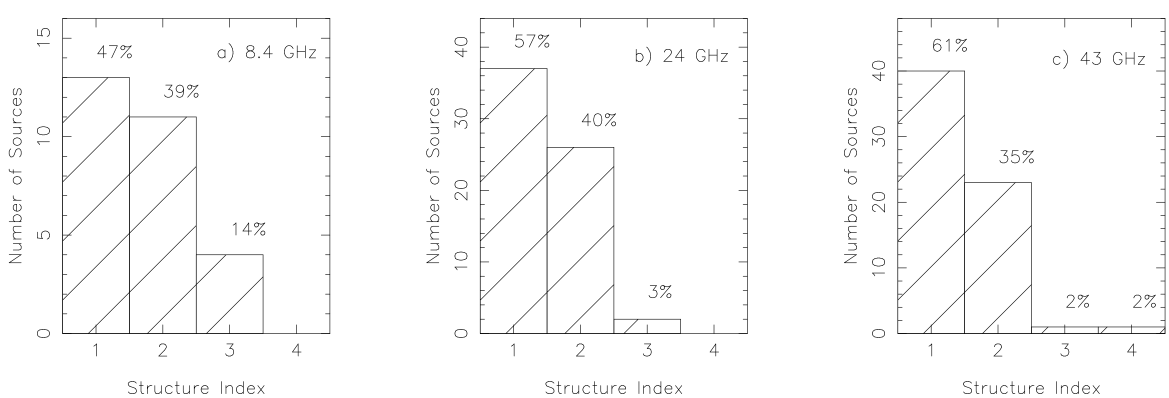

Figure 2. Distribution of “Structure Index” for sources at a) 8.4 GHz, b) 24 GHz, and c) 43 GHz. A total of 65 sources were observed at 24 and 43 GHz on 2002 May 15 (BR079A). Also shown are the values for the 28 overlap sources observed at 8.4 GHz on 2002 Jan 16 (RDV31).

The BL115A experiment was conducted as a 24 GHz survey in order to obtain a better idea of the number of ICRF sources detectable at this frequency. Of the 249 sources observed, there were sufficient data to image a total of 184 sources. As an estimate of the compactness of the sources a core fraction, defined as the ratio of core flux density to total flux density, was calculated. Core flux density is defined as the CLEAN-ed flux density in an image contained within one synthesized beam. The total flux density is defined as the total CLEAN-ed flux density (i.e., the sum of all CLEAN model components). The distribution of source core fraction versus source total flux density is shown in Figure 3. As can be seen in this figure, the weaker sources appear to be more compact (but this may just be a selection effect).

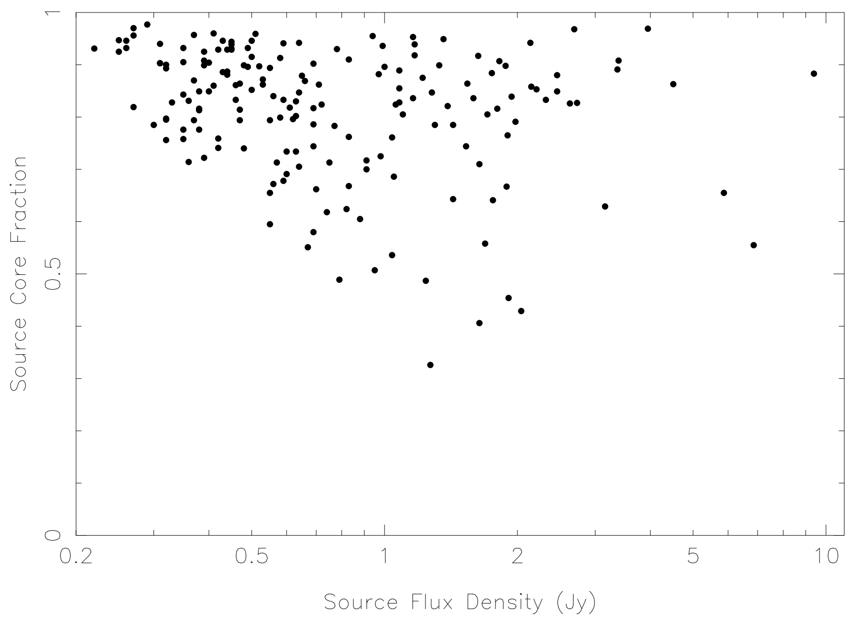

Figure 3. The distribution of source core fraction (ratio of core flux density to total flux density) versus source total flux density. Core flux density is defined as the CLEAN-ed flux density in an image contained within one synthesized beam. The total flux density is defined as the total CLEAN-ed flux density (i.e., the sum of all CLEAN model components).

2.2. Motions of Source Components

VLBA observations for maintenance of the celestial and terrestrial reference frames have been carried out since about 1994. Since 1997, these VLBA RDV observations have been part of a joint program between the USNO, Goddard Space Flight Center (GSFC) and the NRAO. Images produced from VLBA RDV observations are made available through the RRFID.

A joint program between Whitier College and the USNO to measure apparent jet velocities from the motions of source components using RRFID data at 8.4 GHz was initiated by Piner et al (2002, AAS, 200, 4501). To date, a total of 60 sources have been analyzed (Piner et al. 2003, AAS, 203, 9207). Results show that the distribution of apparent component speeds peaks at low values (near 1c, where c is the speed of light) but extends to values as high as 30c. The average apparent speed for all components is 4.8c.

2.3. ICRF Maintenance in the Southern Hemisphere

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a continuing VLBI research program in Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the Southern Hemisphere. Plans include strengthening the ICRF in the Southern Hemisphere by a) increasing the reference source density with additional S/X-band bandwidth-synthesis astrometric VLBI observations, and b) VLBI imaging at 8.4 GHz of ICRF sources south of $\delta = -20°$.

VLBI images for a total of 69 Southern Hemisphere ICRF sources were made at a frequency of 8.4 GHz using the Australian Long Baseline Array (Ojha, et al. 2004, in preparation). The images were used to calculate a core fraction, i.e., the ratio of core flux density to total flux density, for all observed sources. The resulting distribution, with a mean value of 0.83, suggests that most sources are relatively compact. However, just over half the observed sources show significant extended emission in the form of multiple compact components. These sources are probably poorly suited for high accuracy reference frame use unless intrinsic structure can be taken into account. Many of the observed sources have never been previously imaged at milliarcsecond resolution.

3. Staff

The staff of the Analysis Center is drawn from individuals who work at the USNO. The staff and their responsibilities are:

Name	Responsibilities
Alan L. Fey	Primary scientific contact, Web and data base design and content, Webmaster, Web server administration, VLBA data analysis (imaging), structure analysis
David A. Boboltz	VLBA data analysis (imaging), structure analysis
Ralph A. Gaume	Liaison to the ICRF Product Center of the IERS
Kerry A. Kingham	Web and data base design and content, Webmaster, Web server administration, geodetic data analysis (imaging), Mark 4 interface to imaging software, structure analysis

4. Future Activities

The Analysis Center currently has a program of active research investigating the effects of intrinsic source structure on astrometric position determination. Results of this program are published in the scientific literature.

The following activities for 2004 are planned:

- Continue imaging and analysis of VLBA 2.3/8.4 GHz experiments
- Continue imaging and analysis of VLBA 24/43 GHz experiments
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners