Progress Towards ICRF4 at X/S and K Bands

David Gordon[1], Alet de Witt[2], Christopher S. Jacobs[3]

Abstract In the nearly six years since ICRF3, considerable progress has been made with the X/S and K band source catalogs. The X/S dataset has increased by ∼40%, the number of sources has increased by ∼25%, and the source precision has improved by ∼25%. At K band, the amount of data has increased more than fivefold, the number of sources has increased by ∼60%, and the source precision has improved by ∼40%. Work will continue over the next three years towards generating ICRF4 catalogs at X/S and K bands for presentation and approval at the XXXIII IAU General Assembly (August 2027).

Keywords ICRF, radio astrometry, VLBI

1 Introduction

The third realization of the International Celestial Reference Frame (ICRF3) was generated by an International Astronomical Union (IAU) working group and adopted by the IAU membership in 2018, becoming official on January 1, 2019. ICRF3 has VLBI source catalogs at X/S (8.4/2.3 GHz), K (24 GHz), and Ka/X (34/8 GHz) bands. A follow-on IAU working group, known as the 'Multi-waveband International Celestial Reference Frame (optical+VLBI) Working Group' is now working to generate ICRF4 catalogs in the radio at X/S, K, and Ka/X bands and in the optical Gaia band in time for the XXXIII IAU General Assembly (August 2027). Here we summarize the current progress on expanding and improving the ICRF at X/S and K bands using data from the VLBA and other networks and from IVS sessions.

2 Progress at X/S Band

In addition to hundreds of 24-hour IVS sessions in the nearly six years since ICRF3, there have also been approximately monthly VLBA X/S astrometry sessions, run under USNO's VLBA time allocation. Subsequently, the X/S dataset has grown ∼40%, from ∼13.2 to ∼18.4 million observations, and the number of sources in the catalog has grown by about ∼25%, from 4,536 to 5,707 sources. Precision for the original ICRF3-S/X sources has improved by ∼25%, from median RA/Dec uncertainties of 127/218 to 107/189 μas (microarcseconds). Most of the additional 1,172 sources have come from VLBA astrometry and RV sessions, while ∼120 have come from IVS AOV and AUA sessions. Around 500 of the additional sources are within 7° of the ecliptic, a result of efforts to densify the ecliptic region for future spacecraft navigation usage. Figure 1 shows the distribution of the current 5,707 sources, while Figure 2 shows the 1,172 additional sources that have been added since ICRF3. Imaging of all X/S sources observed in the VLBA astrometry sessions is also being done at USNO and stored in the FRIDA image database, at https://crf.usno.navy.mil/FRIDA (see [1]).

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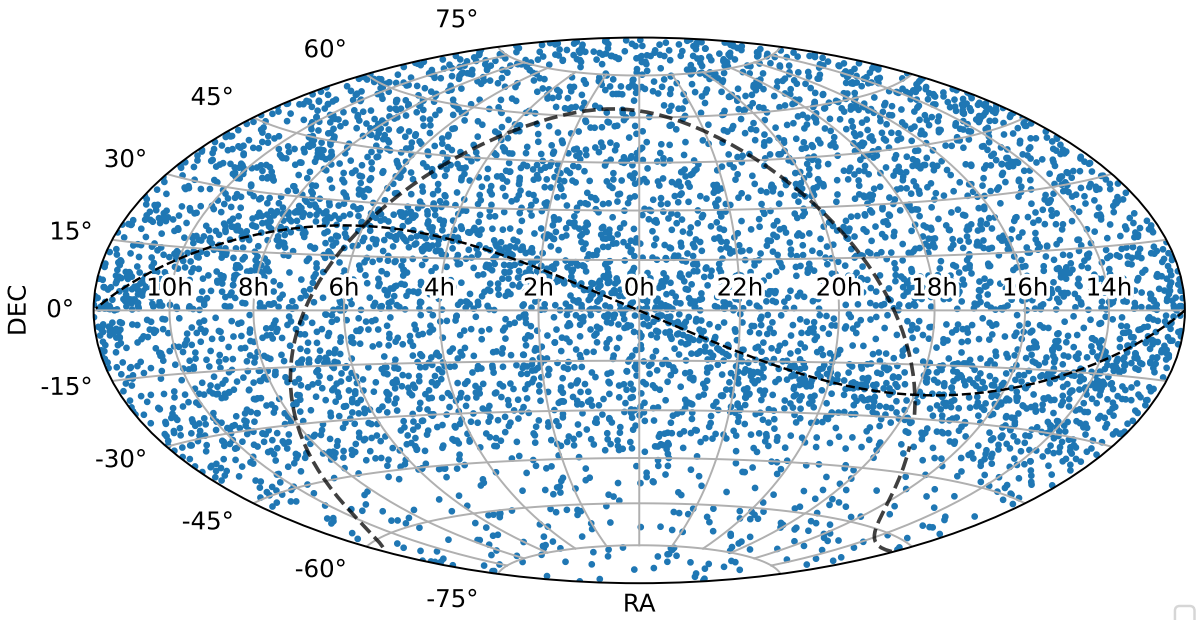

Fig. 1 Distribution of the 5,707 X/S sources in the 2024Jan19 solution.

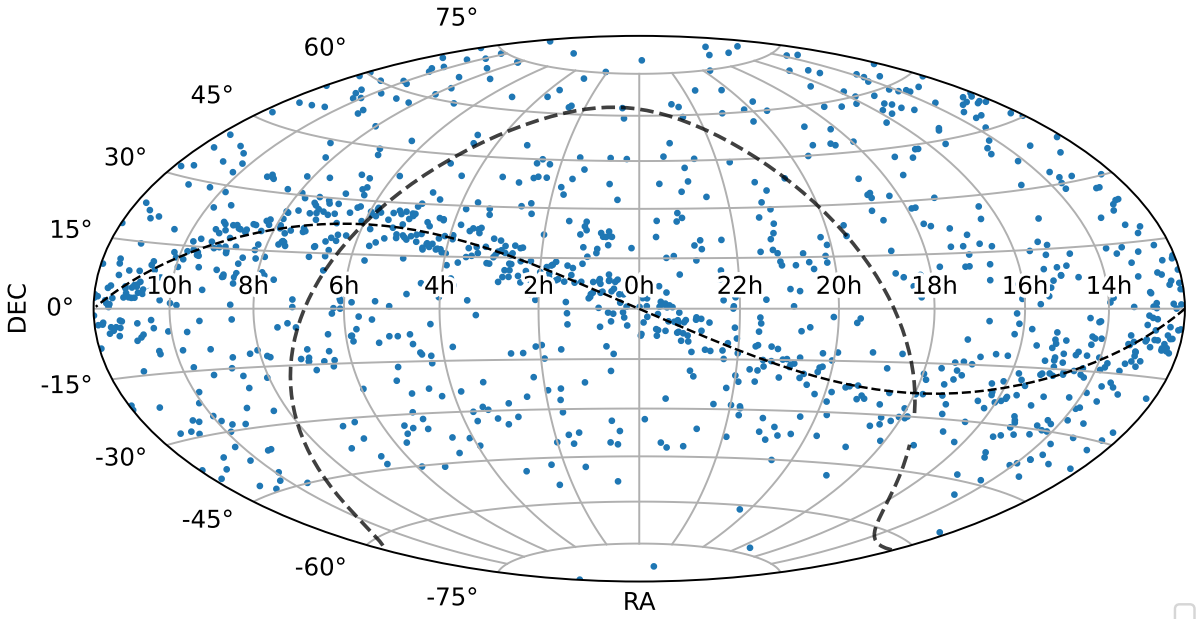

Fig. 2 Distribution of the 1,172 additional X/S sources since ICRF3.

3 Progress at K Band

The K band reference frame has also been significantly expanded and improved since ICRF3. The latest K band catalog now has 1315 sources, or ∼60% more than ICRF3-K. And the amount of data has grown more than fivefold, from ∼0.5 million to ∼2.6 million observations. Precision for the 824 ICRF3-K sources has improved by ∼40%, with median RA/Dec uncertainties decreasing from 73/134 to 52/91 μas. ICRF3-K used only data from the VLBA and the HARTRAO–HOBART26 baseline. But since ICRF3,

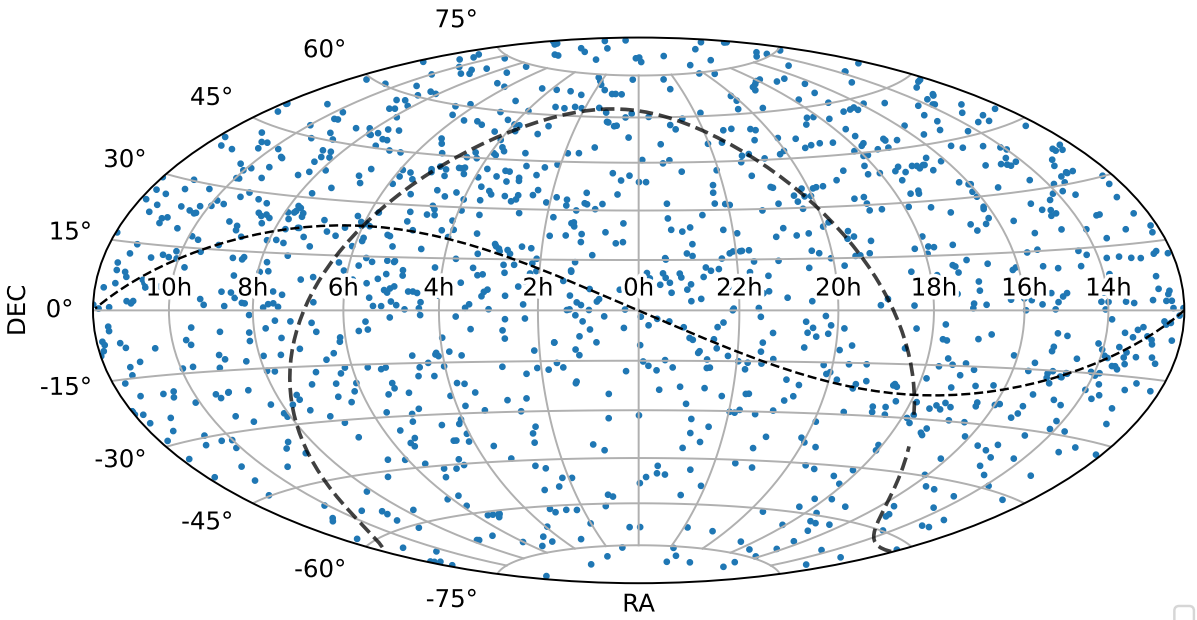

Fig. 3 Distribution of the 1,315 K band sources in the 2024Feb11 solution.

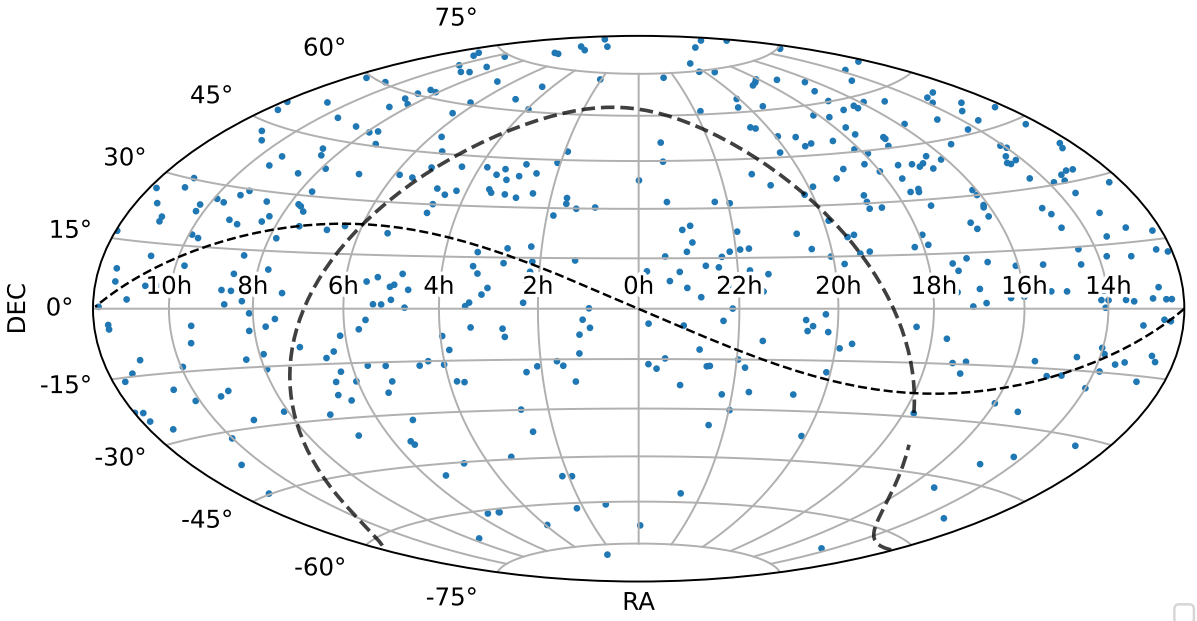

Fig. 4 Distribution of the 491 additional K band sources since ICRF3-K.

the K band has been augmented with much more data from those networks, as well as with several sessions on the HARTRAO–YEBES40M baseline and the Korean VLBI Network (KVN) with HARTRAO, YEBES40M, HOBART26, MOPRA, and/or SEJONG participating in some of the KVN sessions. Figure 3 shows the distribution of the 1,315 sources in the current K band catalog, and Figure 4 shows the additional 491 sources added since ICRF3-K. Imaging of K band sources from the VLBA sessions is being done at the South African Radio Astronomy Observatory ([2]).

One issue with the K band frame is that the VLBA and the non-VLBA networks are disjointed, i.e., not directly inter-connected at K band. Fortunately though, all sessions from the non-VLBA networks contain HARTRAO, and there is a strong tie between the VLBA and HARTRAO at X/S band from the RDV and RV sessions. Therefore, we use those X/S site positions and velocities to tie together the K band networks, and we get fairly good links from the VLBA through HARTRAO to HOBART26, YEBES40M, SEJONG, and the KVN stations. However, the possibility of rotations and/or distortions in the frame still exists, and we have found that MOPRA, in Australia, does not fit well in the solutions and distorts the celestial reference frame in the far South. Therefore we are excluding MOPRA data from the analysis for the time being. However, ten EVN global K band astrometry sessions (Patrick Charlot is the PI), including European, KVN, African, Australian, and VLBA stations, will be run over the next three years, and these global sessions should allow establishing of the direct links between the various networks at K band that are needed to tie the networks together and prevent any such rotations or distortions.

4 Goals Approaching ICRF4

Over the next three years, efforts will be made to address several issues. At X/S bands we will try to re-observe on the VLBA all sources north of -45° that have been observed in fewer than five sessions, to improve the overall precision of the catalog. Efforts will also be made to improve the IVS southern hemisphere observations by including VGOS stations in mixed mode in CRDS sessions. At K band we will try to re-observe all sources south of -45°, provided that additional southern hemisphere sessions can be made. And the upcoming EVN global astrometry sessions will be analyzed and used to interconnect the various networks and improve the K band CRF.

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