STEPS TOWARDS THE NEXT RADIO REALIZATION OF THE ICRS

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ABSTRACT. The VLBI data and analysis leading to the ICRF were completed in 1995. Since then there have been considerable refinements in both areas. A regular monitoring program has begun to increase the data set for identified stable and potentially stable sources. Several steps need to be taken in the next few years to generate the next radio realization of the ICRS. These include: a) enhancement of the data set for possible defining sources, b) comparison of source catalogues from VLBI analysis centers using a variety of approaches and software to identify systematic errors, c) time series analysis of past and as-available data to identify the set of defining sources for the next realization, d) discussion and decision on the final analysis configuration, particularly for the data to be included, troposphere modeling, treatment of unstable sources, and whether a combination of normal matrices of individual solutions is better than a single selected solution.

1. ENHANCEMENT OF THE DATA SET FOR POSSIBLE DEFINING SOURCES

A long-standing difficulty of the radio realization of the celestial reference system has been the paucity of VLBI (Very Long Baseline Interferometry) observations of astrometric sources, including the ICRF (International Celestial Reference Frame) defining sources. Figure 1 shows the distribution of observations for the ICRF defining sources and for the geodetic sources used in sessions to monitor Earth orientation parameters (EOP) and the terrestrial reference frame (TRF). The dearth of astrometric observations available in 1995 resulted in setting the criteria for ICRF defining sources at a low threshold in order to have a reasonable geometric distribution over the sky, especially in the southern hemisphere where observations were particularly scarce. Two recent developments should remedy or at least ameliorate this problem. The first is the systematic analysis of source position time series by Feissel-Vernier (2003). Her published results and subsequent analysis identified sources that are demonstrably or potentially stable in position, a prerequisite for an ICRF defining source. Her analysis showed that not all ICRF defining sources, which were selected using data from 1979-1995.6, are stable in the time interval 1990-2002 and that some ICRF defining sources have too few observations for useful time series analysis. See Figure 2. The second development is a systematic program of celestial reference frame (CRF) monitoring by the IVS (International VLBI Service for Geodesy and Astrometry) utilizing the on-going geodetic sessions. The goal is to observe each target source in at least one session every six months. The 307 target sources (see Figure 3) are drawn from

four categories: (1) stable sources identified in Feissel-Vernier (2003), (2) stable sources found in subsequent analysis of position time series where the CRF was set by the stable sources of category 1 (Feissel-Vernier, private communication), (3) potentially stable sources from sources with insufficient data for proper time series analysis, and (4) ICRF defining sources. The last category overlaps the first three. In Figure 3 "Other ICRF defining" includes both unstable and insufficiently observed ICRF defining sources. "Stable other" and "Potentially stable other" are candidates for new defining sources in the next radio realization. Stable sources, both ICRF defining and other, that are also geodetic sources are not included in the CRF monitoring list. Since the IVS EOP/TRF sessions use predominantly northern hemisphere networks, the IVS continues to devote its CRF sessions ($\sim$10 per year) to southern hemisphere sources. The southern hemisphere CRF networks are smaller than the EOP/TRF networks, so the number of observations per source per session is less for southern astrometric sources than for northern sources. Figure 4 shows the development of the CRF monitoring program, which began in February 2004. The "0 sessions" line goes to zero at the right, which indicates that all CRF monitoring sources will have been observed in one or more sessions in the previous 12 months by the end of 2004. Over the next few years the CRF monitoring program and the CRF sessions should provide sufficient data to select a new set of defining sources that is larger and better distributed than the current ICRF defining sources as well as augmenting the data set of the current ICRF defining sources.

2. COMPARISON OF SOURCE CATALOGUES

In 1995 there were only two VLBI analysis systems at three analysis centers used for the ICRF studies. Nonetheless, comparisons of software, models, and test results were important in deciding the actual uncertainty of the ICRF catalogue. At present there are ten analysis centers using six different software packages that have generated catalogues with all or a large part of the VLBI data set. See Table 1. This abundance of catalogues will permit a more robust analysis of differences for the next radio realization of the ICRS (International Celestial Reference System).

Australia	Geoscience Australia
China	Shanghai Astronomical Observatory (SHAO)
Germany	Bundesamt für Kartographie und Geodäsie (BKG)
	Deutsches Geodätisches Forschungsinstitut (DGFI)
Italy	Matera Space Geodesy Center (ASI/CGS)
Russia	Institute of Applied Astronomy (IAA)
Ukraine	Main Astronomical Observatory (MAO)
USA	Goddard Space Flight Center (GSFC)
	Jet Propulsion Laboratory (JPL)
	U.S. Naval Observatory (USNO)

Table 1: VLBI catalogues

3. ANALYSIS OF POSITION TIME SERIES

Systematic time series analysis is an essential tool in selecting the next set of defining sources, which all should possess exemplary position stability. The time series can also show the changes in position related to evolution of source structure. While sources with detectable structure are generally undesirable as defining sources, some sources with unchanging structure may be useful if time series analysis confirms position stability. The comparison of time series from different analyses (varying software, analysis configuration, etc.) will contribute to the identification and

quantification of systematic analysis errors. Likewise the consistency of position rates derived from time series with apparent motion parameters estimated globally will provide an indication of the reliability of the solutions.

4. ANALYSIS CONFIGURATION FOR THE NEXT ICRS REALIZATION

The 1995 ICRF analysis was the state of the art at that time. The analyses for ICRF-Ext.1 and ICRF-Ext.2 (Fey et al. 2004) used all the same data as the ICRF (Ma et al. 1998) augmented by subsequent observations and also used essentially the same analysis configuration. In particular, the defining sources were used at their published ICRF positions. Some small systematic errors are known to be present in the ICRF and its extensions. No substantial changes were made in the modeling or data although significant improvement is now possible. There is evidence that data before 1990 is inferior in quality (Gontier et al. 2001). Improvements in modeling the troposphere and station motions should now permit the simultaneous estimation of CRF, TRF and EOP without degrading the CRF results. A better and larger set of defining sources will significantly decrease the uncertainties of the CRF axes. It should be possible to accommodate source position instabilities more smoothly than by treating unstable sources as arc parameters, perhaps through apparent motion parameters or linear position changes over shorter time intervals. An issue that probably can only be resolved by empirical testing is whether a new ICRS realization should be determined by a single, finely tuned, well understood solution or by a combination, perhaps even including non-VLBI data to ensure consistency of TRF, CRF and EOP.

5. CONCLUSIONS

Substantial progress has been made in CRF and VLBI analysis since 1995. The recent initiation of a systematic CRF monitoring program by the IVS will provide much better data in the next few years. A concerted effort must be made to coordinate the generation and comparison of source catalogues and to decide the analysis configuration of the next radio realization of the ICRS. For this work it may be useful to have some formal organization that would also prepare the astronomical community to accept a new realization.

6. REFERENCES

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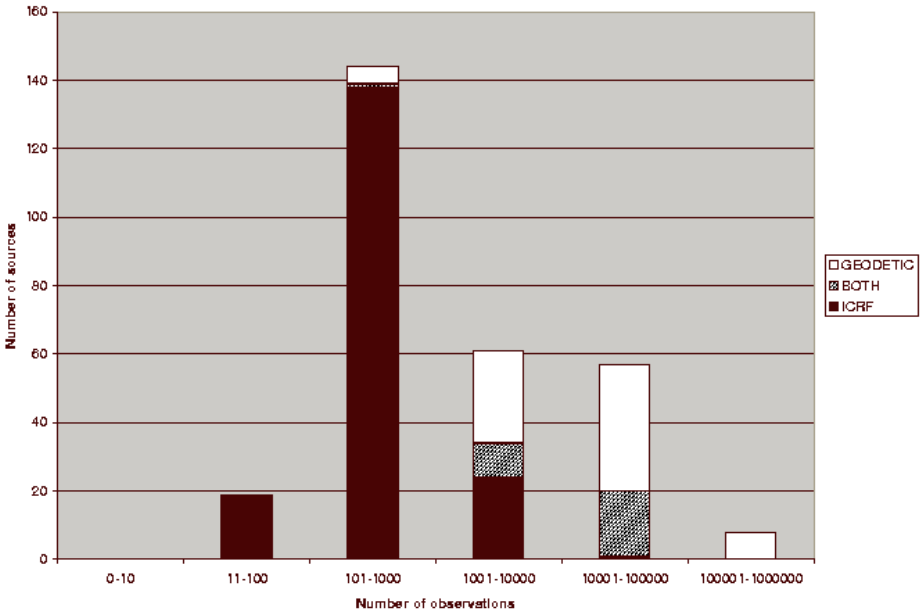

Figure 1: Distribution of Observations of ICRF Defining vs. Geodetic Sources, 1979-2003

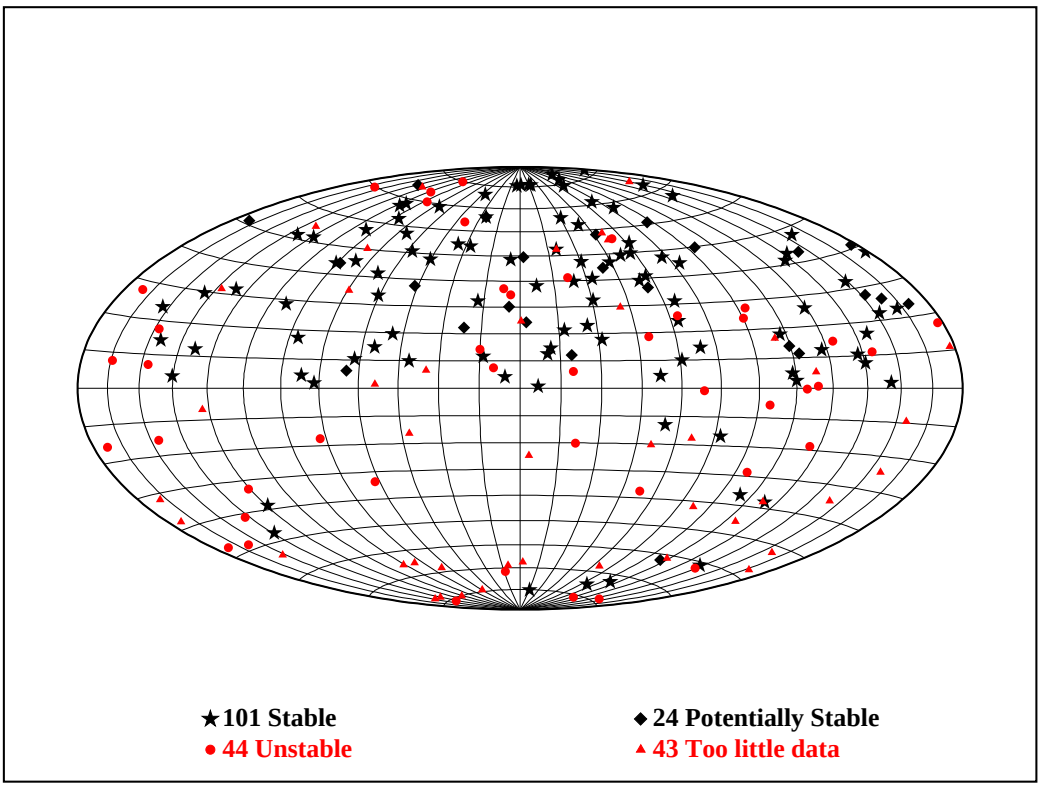

Figure 2: ICRF Defining Sources

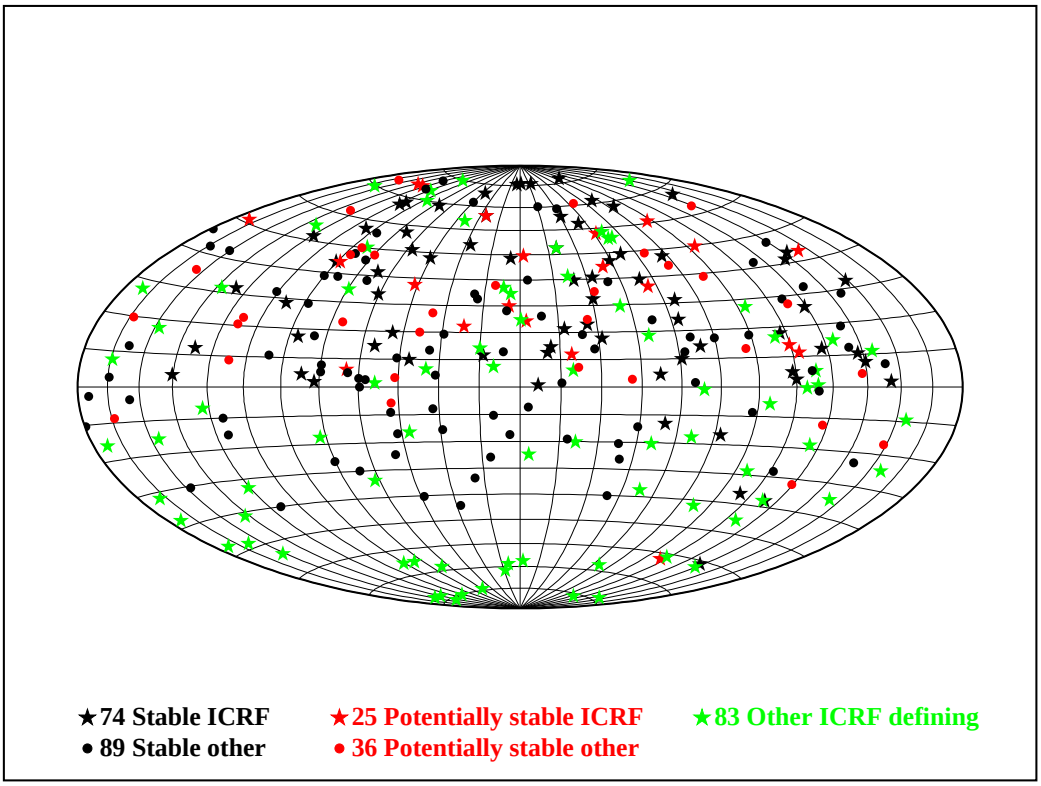

Figure 3: CRF Monitoring Sources

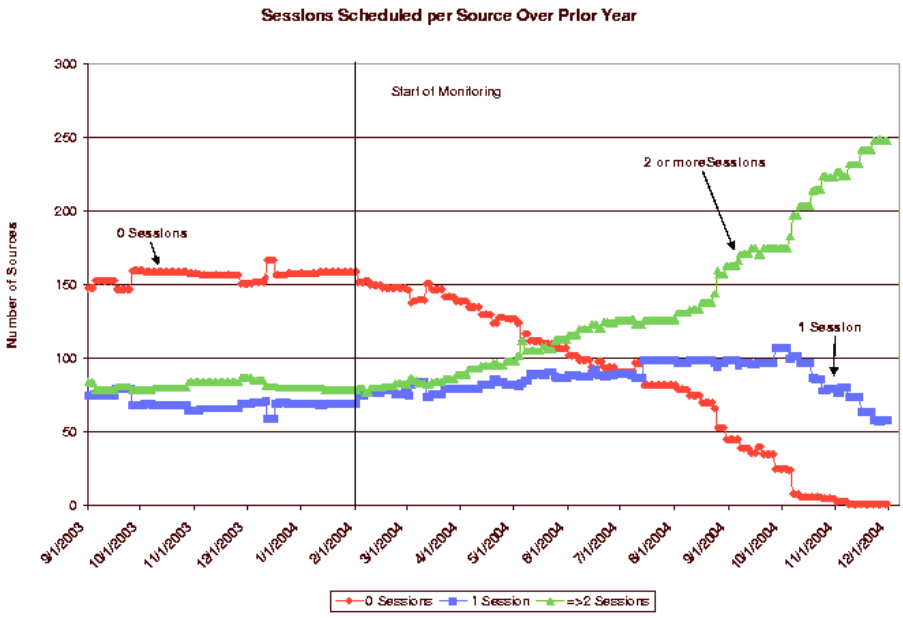

Figure 4: Sessions Scheduled per Source over Prior Year