

# IAU Working Group on Multi-waveband ICRF

## Annual Report 2021-2022

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### 1. Formation of the working group

A new Division A working group entitled “Multi-waveband ICRF” has been established in 2021. This working group takes over two former working groups: (i) the working group on the “Third Realization of the International Celestial Reference Frame (ICRF3)”, terminated in 2018 with the realization and adoption of the ICRF3 (IAU Resolution B2, 2018), and (ii) the working group entitled “Multi-waveband realizations of the International Celestial Reference System (ICRS)”, terminated in 2021 after the adoption of the Gaia-CRF3 as the optical realization of the ICRS (IAU Resolution B3, 2021).

The objective of the new working group is to work toward the realization of a fully integrated multi-waveband celestial reference frame, incorporating positions in both radio and optical bands and ensuring their consistency over the various bands. Membership was established by assembling the expertise considered necessary to reach this objective, covering a wide-range of topics, from VLBI and Gaia to reference frames and active galactic nuclei. The working group comprises 18 members<sup>1</sup> coming from 14 institutions in 10 different countries. An overview of the work to be performed is given below.

### 2. Description of activities

The end goal of the working group will be to produce the next generation VLBI frames at the S/X, K, and X/Ka bands, or at any other radio band that may emerge in the coming years, to match these with the optical realization from the Gaia space mission, and to place all such positions on a common grid guaranteeing consistency of the source positions over the different bands comprised in the frame. Before this can be accomplished, a number of questions relating to the construction of such a multi-waveband frame are to be addressed. In particular, specific attention should be given to the following issues:

#### - Sky distribution

Having a uniform distribution of sources over the celestial sphere and a uniform distribution of coordinate uncertainties is essential to limit deformations of the individual frames produced in each waveband and to properly align these on a common grid. While such properties are largely verified for the Gaia optical frame, that is less true in the radio band with ICRF3 showing a deficiency of sources in the south and asymmetries in the coordinate uncertainties. Correcting this non-uniformity goes through increasing VLBI observing in the southern hemisphere.

#### - Galactic acceleration

The acceleration of the solar system in its motion around the Galactic center, with an amplitude of about 5  $\mu\text{as/yr}$ , is now seen from the VLBI and Gaia measurements and has been integrated into the realization of ICRF3 and Gaia-CRF3, albeit with a slightly different amplitude value. As data accumulates, present estimates of this amplitude will further improve and the data will also determine precisely the direction of the acceleration vector. In order to ensure consistency, it is mandatory that Galactic acceleration is modeled identically in the radio and optical bands, adopting the most accurate vector determination (whether from Gaia or VLBI) for this purpose.

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<sup>1</sup> The members are: Sonia Anton, Felicitas Arias, Patrick Charlot (Chair), Alet de Witt, Bryan Dorland, David Gordon, Robert Heinkelmann, Christopher Jacobs, Sergei Klioner, Hana Krásná, Sébastien Lambert, Lennart Lindegren, Valeri Makarov, Zinovy Malkin, François Mignard, Elena Skurikhina, Jean Souchay, and Oleg Titov.

- **Alignment of frames**

There is not a single way to align reference frames produced independently at different bands or with different techniques. Whether only rotations or both rotations and deformations should be considered in the alignment process, whether individual source positions should be given equal weights or weighted separately, whether all sources or only a subset of them (e.g. the so-called defining sources in the successive ICRF realizations) should be considered, is a matter of debate. In this respect, the working group should establish a common practice, to be applied for generating the proposed multi-waveband realization and any other future realizations.

- **Wavelength- and time-dependent source positions**

The process to align reference frames at different bands may be further affected by wavelength-dependent source positions. Comparing radio and optical positions shows that these do not coincide for a significant portion of the sources. Even within the three radio bands, positions are found to differ for a fraction of the sources. Additionally, positions may show instabilities with time, as revealed by VLBI time series, and this may also be the case on the optical side when position time series are released by Gaia. In this context, the working group should propose a scheme to deal with this frequency dependence and time variability of the source positions in the alignment process.

### **3. Terminology**

Besides constructing the frame, the working group will also work towards defining a proper terminology for referring to the individual (per wavelength) components of the multi-waveband frame. For historical reasons, the ICRF terminology, though not attached specifically to the radio band, has been associated with the VLBI realizations, simply because there was no other technique with similar capabilities until the advent of Gaia. Whether keeping this terminology, incorporating the Gaia optical realizations, or whether a new one should be defined, is a matter of debate and agreement within the community.

### **4. Timeline**

The projected timeline for the work anticipates that the issues relating to the construction of the frame (as described above) would be addressed by the end of this triennium (2024), while the foreseen multi-waveband celestial reference frame would be generated in the period from 2024 onwards,