The K-band (24 GHz) 2019a Celestial Reference Frame

Can it be more accurate than SX (8 GHz)?

Abstract: A K-band (24 GHz) celestial reference frame of 918 sources covering the full sky has been constructed using 0.68 million measurements from 69 observing sessions from the VLBA and HartRAO-Hobart. Observations at K-band are motivated by their access to more compact source morphology and reduced core shift relative to observations at the historically standard S/X-band (2.3/3.4 GHz). The factor of three increase in interferometer resolution at K-band should resolve out structure which is a concern for AGN centroid stability. K median precision is comparable to S/X precision (for common sources) thereby raising the question of which frame is more accurate. The accuracy of the K CRF is quantified by comparison of 85 sources in common with the current (2019 Jan) S/X-band producing wRMS agreement of 78 µas in α cos(δ) and 133 µas in δ. There is evidence for systematic errors below the 60 µas level. The success of Gaia optical astrometry contributes to work the radio and optical frames. K-band data and Gaia Data Release 2 give a frame tie precision of ~15 µas (1σ, per 3-D rotation component). If K-band precision can be pushed below ~20-30 µas, the K frame has potential to produce a tie to Gaia that is superior to S/X due to reduced astrophysical systematics at K relative to S/X. The K-band 2019a frame is an incremental update to the ICRF-3 K-band component thereby answering the IAU’s call for maintenance of the ICRF-3.

Executive Summary: Celestial angular coordinates (α, δ) are derived from VLBI measurements at 24 GHz (1.2 cm) of Active Galactic Nuclei. Agreement of S/X is at approximately the 100 µas level. K-band has reduced astrophysical systematics vs. S/X.

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II. Accuracy: K vs. S/X

Comparison of K-band to the current (190121) S/X, after removing 97 outliers > 5σ, leaves 783 sources in common. The wRMS agreement is 78/133 µas in α cos(δ) and δ respectively. We tested for spatially correlated differences by estimating vector spherical harmonics (Mignard & Kilozer, 2012) to defer and order 2; Z-dipole was 58 µas, all other terms were < 28 µas.

III. Gaia Optical-Radio Frame Tie and Accuracy Verification

Background: Launched in Dec. 2013, ESA’s Gaia mission measures positions, proper motions and parallaxes of 1.7 billion objects down to 21st magnitude—as well as photometric and radial velocity measurements. Gaia’s observations will include more than 500,000 AGN of which ~20,000 will be optically bright (V < 18 mag).

Comparison: The Gaia celestial frame is independent from K-band in three key respects: optical vs. radio, space vs. ground, pixel centroiding vs. interferometry. As a result Gaia provides the most independent check of K-band accuracy available today. With Gaia Data Release 2 (Mignard, 2018), 569 sources are detected in both the optical and K-band radio—after removing 11% of the sources as outliers > 5σ; Rotational alignment is made with ~15 µas precision (1σ, per 3-D component). Scatter is ~220 µas wRMS. Vector Spherical Harmonics differ between terms out to degree and order 2 reveal a Z-dipole of 56 µas with all other terms < 35 µas, indicating excellent global agreement.

V. Conclusions: The K-band CRF has 918 sources covering the full sky and is making rapid improvements in the precision. The K-band CRF now has comparable precision to the current S/X frame in RA. Spherical harmonic differences vs. S/X are < 58 µas and vs. Gaia < 56 µas. Improving accuracy will depend on controlling systematics from ionosphere and adding North-South baseline geometry.

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