GFZ Helmholtz-Zentrum POTSDAM

Radio source position offsets among various radio frames and Gaia

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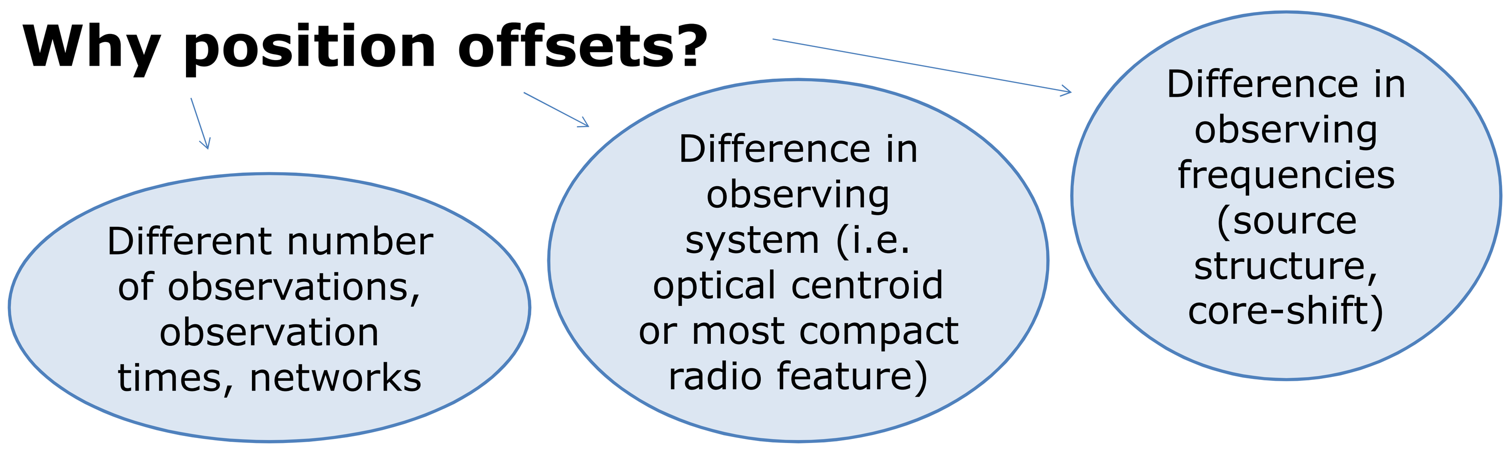
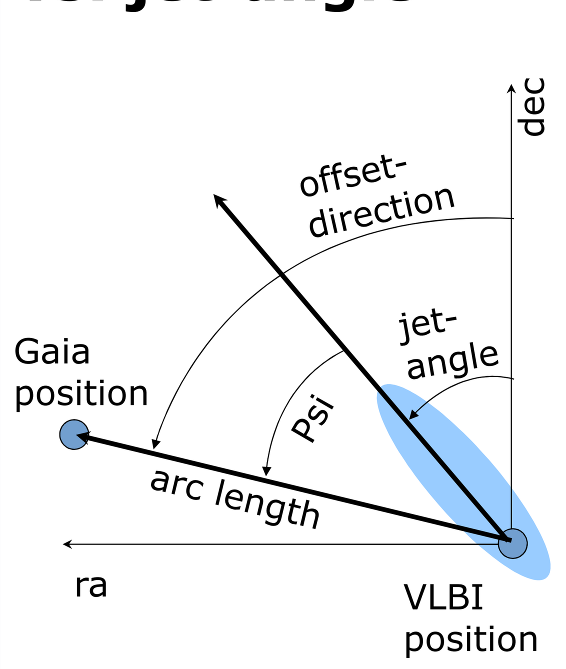
Why position offsets?



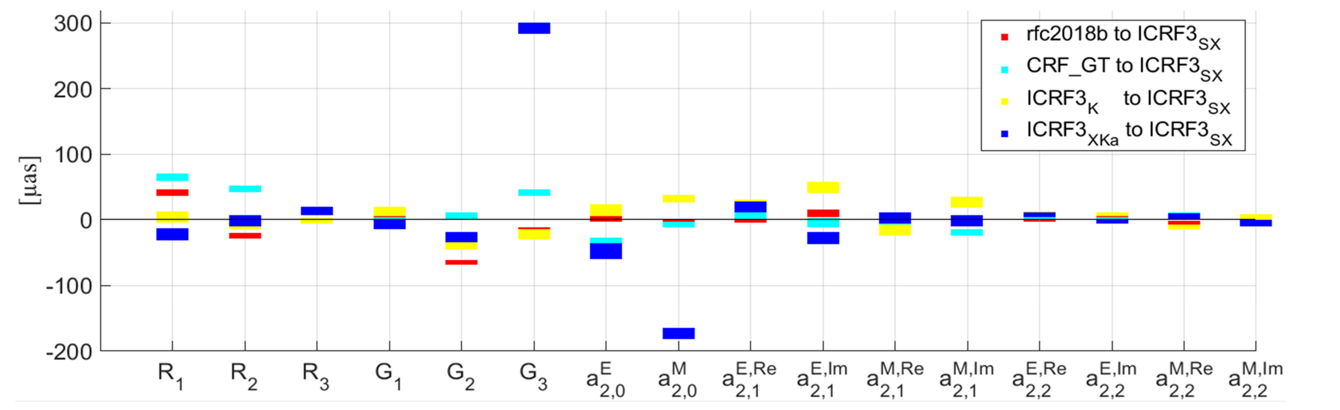
- Kovalev et al. (2017): comparison of position offset directions of their VLBI CRF and Gaia vs. jet angles they derived from radio source images
  → **favor of position offsets along the jet direction**
  → can be an indicator of optical source structure at [mas] scale.
- **We want to investigate whether or not this also holds for radio frames at other frequencies.**

Offset-direction vs. jet-angle



Radio frames at different frequencies

- ICRF3 (Charlot et al., in prep.) at three different frequencies: S/X, X/Ka, K
- rfc2018b (Petrov et al., 2018): mostly S/X
- CRF_GT: GFZ catalog in S/X at same time interval as the Gaia CRF based on the ICRF3-GFZ solution



Transformation parameters between various VLBI CRFs and ICRF3 in S/X using formulas from Titov et al. (2013). Outliers were rejected.

Selection of VLBI/Gaia matches

A: method Petrov et al. (2018)

	rfc2018b	ICRF3_SX	ICRF3_K	ICRF3_XKa	CRF_GT
Crossmatch 5 as/3 as radius	12048	4325	915	762	1942
PFA < 2*10^-4	9053	3373	700	604	1782
Bad sources¹	77	19	4	0	9
total	**8976**	**3354**	**696**	**604**	**1773**
Median offset [mas]	1.36	0.66	0.48	0.55	0.73
Maximum offset [mas]	583.18	288.04	43.03	42.80	310.58
Median semi-maj. error axis [mas]	V 0.65 G 0.35	0.20 0.29	0.14 0.24	0.11 0.24	0.28 0.28

B: method Lindegren et al. (2018)

	rfc2018b	ICRF3_SX	ICRF3_K	ICRF3_XKa	CRF_GT
Crossmatch 0.1 as radius	9014	3373	701	604	1781
No full 5 param. solution	1298	363	46	38	163
astrometric_matched_ observations <8	306	90	9	7	46
$\lvert(\overline{\omega}+0.029mas)/\sigma_{\overline{\omega}}\rvert < 5$	9+1298	1+363	0+46	0+38	1 + 163
$(\mu_{\alpha^*}/\sigma_{\mu\alpha^*})^2+(\mu_\delta/\sigma_{\mu\delta})^2 < 25$	47+1298	21+363	7+46	6+38	13 + 163
total	**7658**	**2983**	**647**	**558**	**1602**
Median offset [mas]	1.11	0.58	0.45	0.52	0 66
Maximum offset [mas]	99.89	87.39	33.15	13.76	86.76
Median semi-maj. error axis [mas]	V 0.63 G 0.29	0.19 0.26	0.14 0.23	0.11 0.23	0.28 0.26

C: combination of A and B

	rfc2018b	ICRF3_SX	ICRF3_K	ICRF3_XKa	CRF_GT
In A but not in B	1387	384	53	46	176
In B but not in A	69	13	4	0	5
A and B combined	**7589**	**2970**	**643**	**558**	**1597**
Median offset [mas]	1.11	0.58	0.45	0.52	0.66
Maximum offset [mas]	99.89	87.39	33.15	13.76	86.76
Median semi-maj. error axis [mas]	V 0.63 G 0.29	0.19 0.26	0.14 0.23	0.11 0.23	0.28 0.26

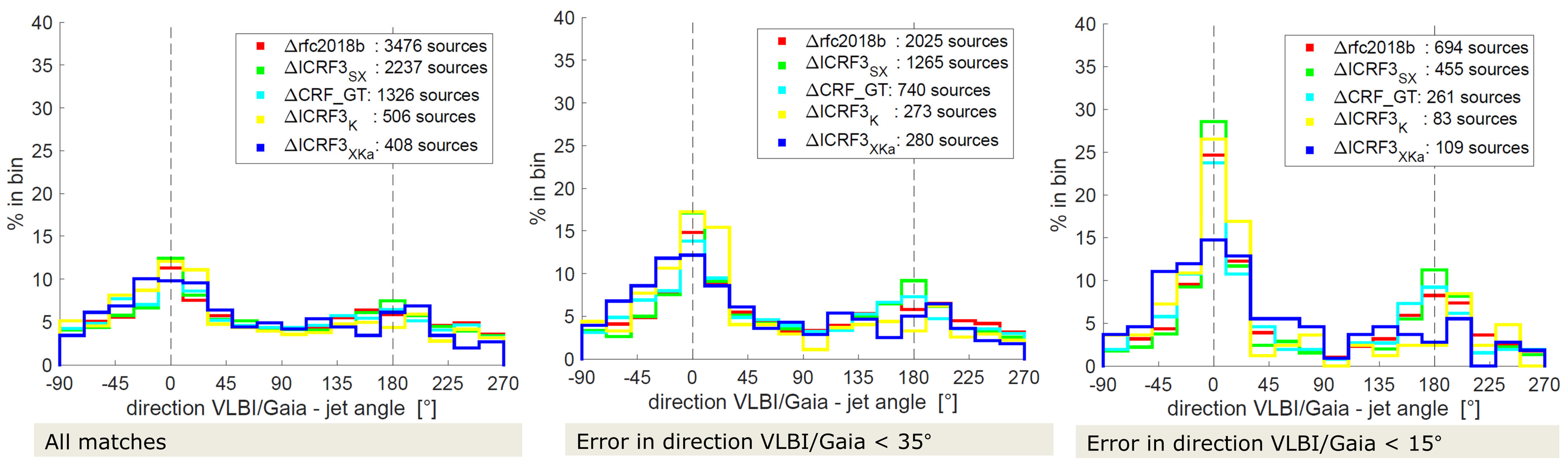
PFA… Probability of false association; $\overline{\omega}, \sigma_{\overline{\omega}}$ … parallax, $\mu_{\alpha^*}, \sigma_{\mu\alpha^*}; \mu_\delta, \sigma_{\mu\delta}$ … proper motion in right ascension*cos(declination) and declination

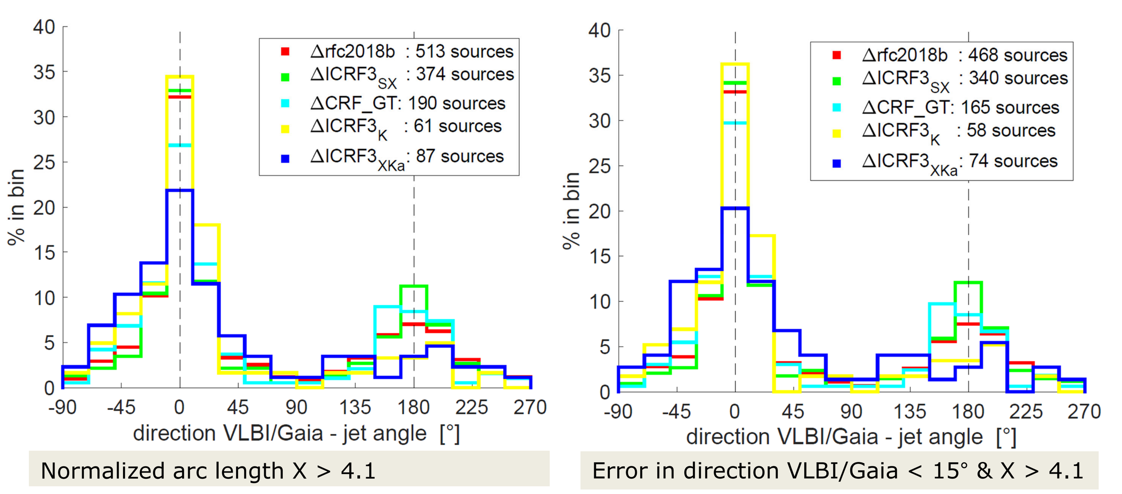
¹ Radio stars, supernova (remnants) and double or multiple galaxies as found in OCARS catalog (Malkin, 2018) and other meta data.

Crossmatch was done with Gaia DR2 (Gaia Collab., 2018).
→ **C used in further analysis**

Favor of offset-direction in jet direction from images

Percentage of celestial objects in bins according to the angle Psi between the jet-angle and the offset-direction to the Gaia object. Only for matches with images available plus further selection criteria in grey boxes.

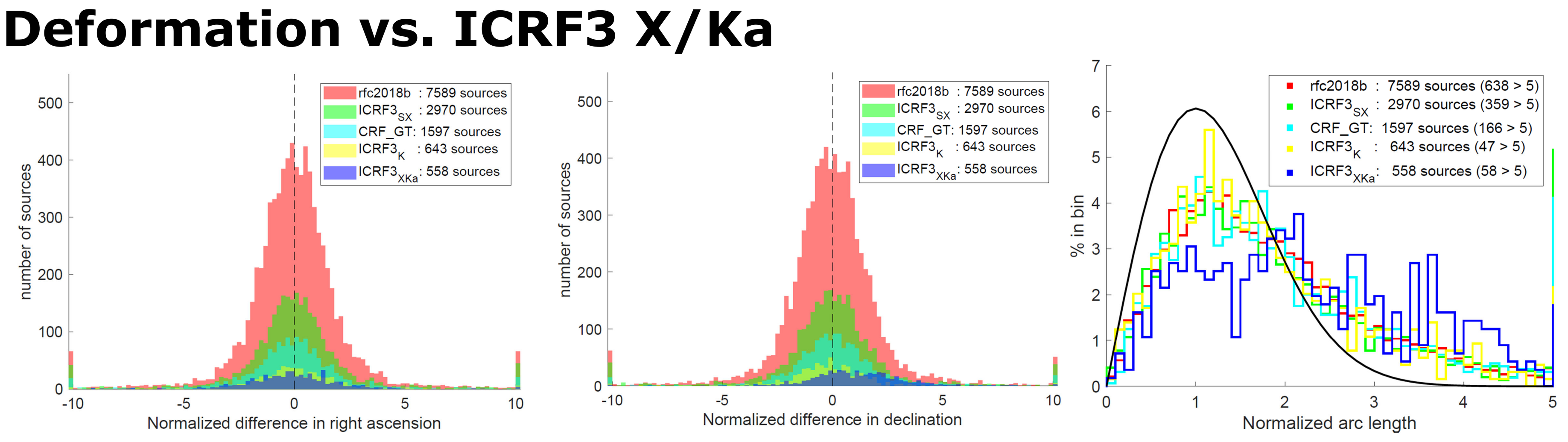


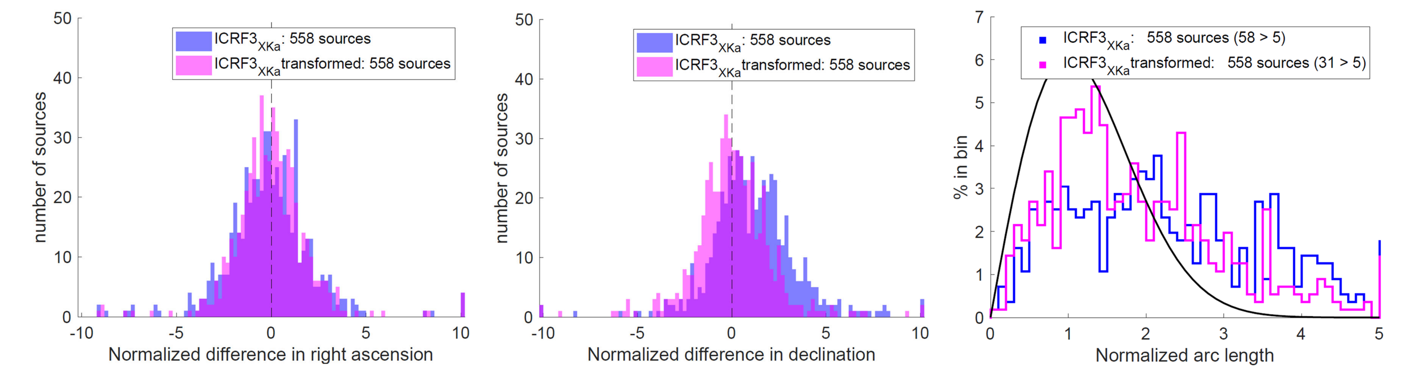


The angles Psi between the jet-angles and the offset-directions to the Gaia objects show the same pattern for all frames except X/Ka.

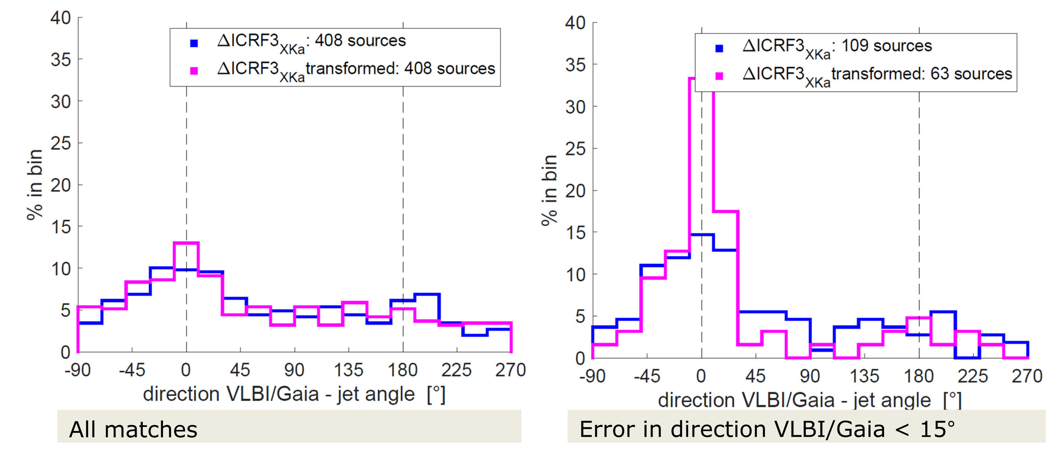
For angle error calculations the formula from Petrov et al. (2018) was used. Normalized arc length X as the arc lengths normalized by their errors according to Mignard et al. (2016). Radio sources with X > ~4.1 are considered as outliers.
rfc2018b recently got an update (rfc2019a) wich has data comparable to ICRF3 and thus better accuracies.

Deformation vs. ICRF3 X/Ka



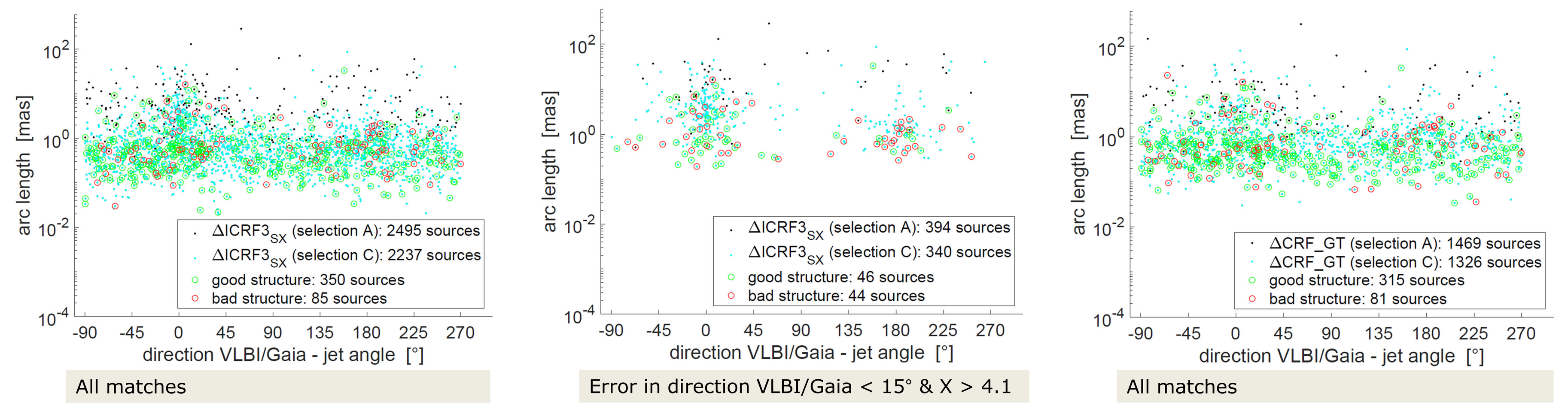


The black line shows the ideal distribution of the normalized arc lengths X.



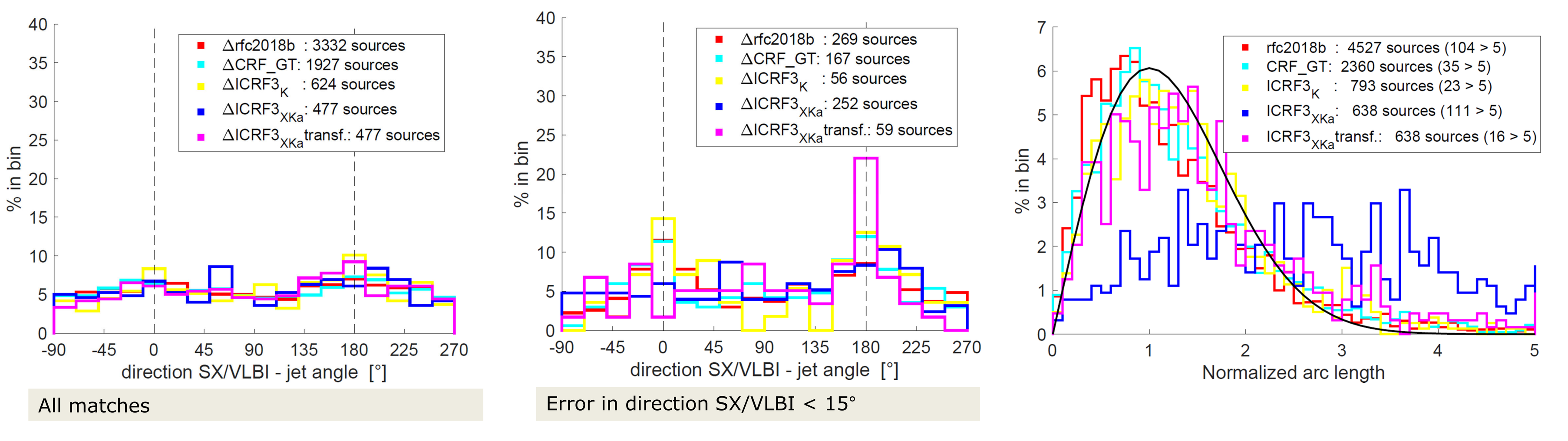
Results for X/Ka frame deviate from expected results + it shows large transformation parameters compared to the S/X frame.
→ after transformation the biases vanish.

Angle difference vs. arc length and source structure



… good sources, bad sources according to Xu et al. (subm.): influence of source structure on closures → see poster P315

Radio to radio position offsets in jet direction?



Angle Psi between the jet-angle and the offset-direction of radio source positions in ICRF3 S/X and various radio frames.

Conclusions and outlook

- Narrowing the time interval of the VLBI reference frame to the one of Gaia DR2 did not change the overall results.
- Influence of the transformation of the X/Ka frame on the results was shown
- Source structure categorization from radio frequency does not show clear pattern regarding angle difference or arc length
- Radio position offsets show fewer favor in jet direction
- Results coincide with Petrov et al. (2018) and Plavin et al. (2018)
- Future investigations:
  - include redshift information, parallaxes, types of radio sources, spectral information
  - include other resources of offset measurements
  - transformation: radio source selection, time variability
  - compare VLBI proper motions and parallaxes with Gaia ones

References and acknowledgements

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Many thanks to L. Petrov, Y. Kovalev and A. Plavin for providing the data on jet angles. This project is supported by the DFG grant (HE5937/2-2). The attendance to this conference was enabled by the International Association of Geodesy (IAG) in form of the IAG International Travel Award. This work has made use of the data from the European Space Agency (ESA) mission Gaia processed by the Gaia Data Processing and Analysis Consortium. Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.