Gaia compared to VLBI radio positions

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IAU 330, 24 April 2017

Affiliation & logo if relevant

Outline

- Gaia and ICRF2 sources
- Comparison to ICRF2 and limitations
- Alternatives to ICRF2 for comparisons
- Conclusions

ICRF Sources for Gaia - I

- ICRF2 is to date the best confirmed set of sources with accurate astrometry
  - one has sub-mas accuracy for the defining subset
- Sources are primarily QSOs observed in the radio domain with VLBI
- It is used for Gaia to align the optical solution to the ICRF frame
  - This is conventional and assumes that there is no systematic offset between the radio and optical positions
  - If untrue : a random shift will show up as an additional noise

ICRF Sources for Gaia - II

- Being very accurate the sources are also useful to check the quality of the Gaia result
  - way to strengthen or question the Gaia accuracy claims
- But this goes in both directions
  - ICRF community is as interested in the Gaia solution as we are in the ICRF positions !
  - DR1 Gaia frame is comparable in accuracy, but with a much larger number of sources

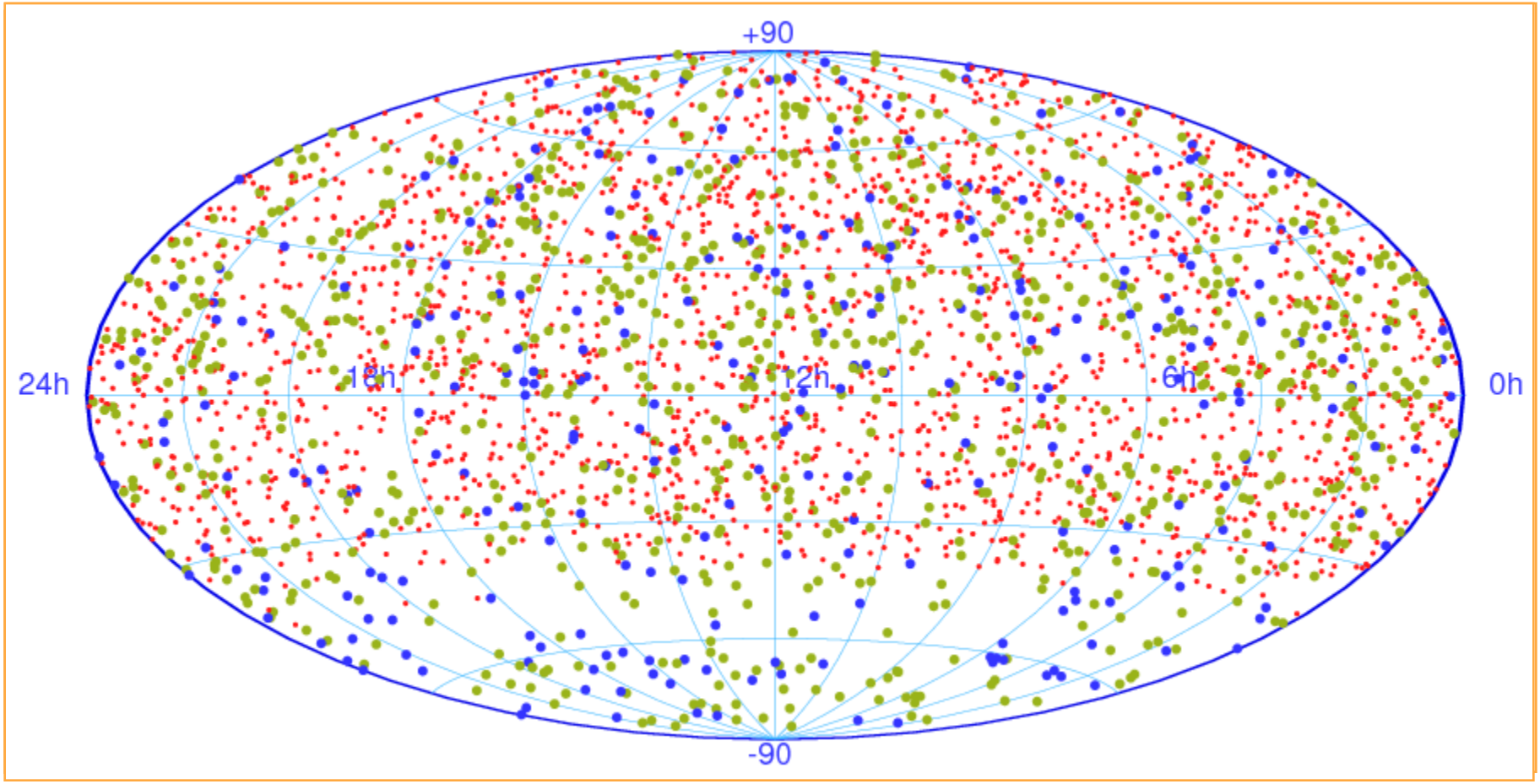
Limitations with ICRF sources for Gaia

- Limitation of ICRF2 for Gaia needs
  - Not many sources (3414 at most)
  - Faint in the optical domain
  - 65% with only one epoch
  - relatively poor accuracy for this subset (> few mas)
  - in many cases Gaia is better - it looked more as a check of ICRF2 vs Gaia
- For the DR1 this was relatively OK
  - but the comparison in Mignard et al. 2016, shows large residuals, clearly coming from ICRF2 and not representative of Gaia accuracy

ICRF-2 (2009) - 3414 sources

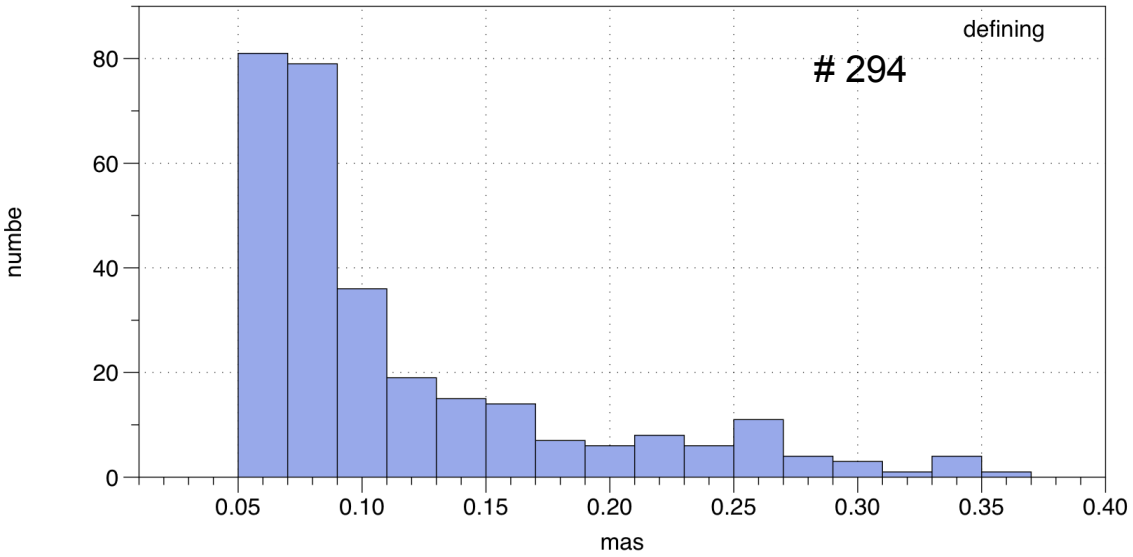
Gaia DPAC

σ~ 50 to 150 μas σ~ 0.2 to 2 mas σ~ 0.5 to 10 mas

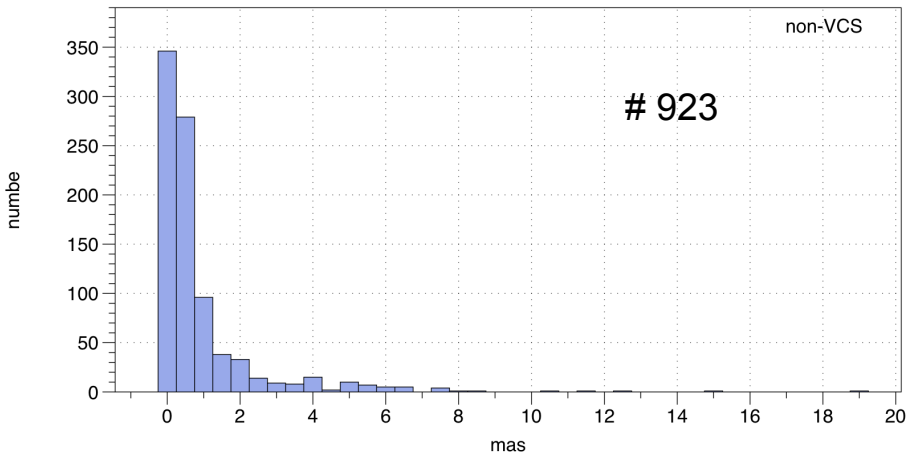


- defining (294)
- non VCS (923)
- VLBA Calib. (VCS) (2197)

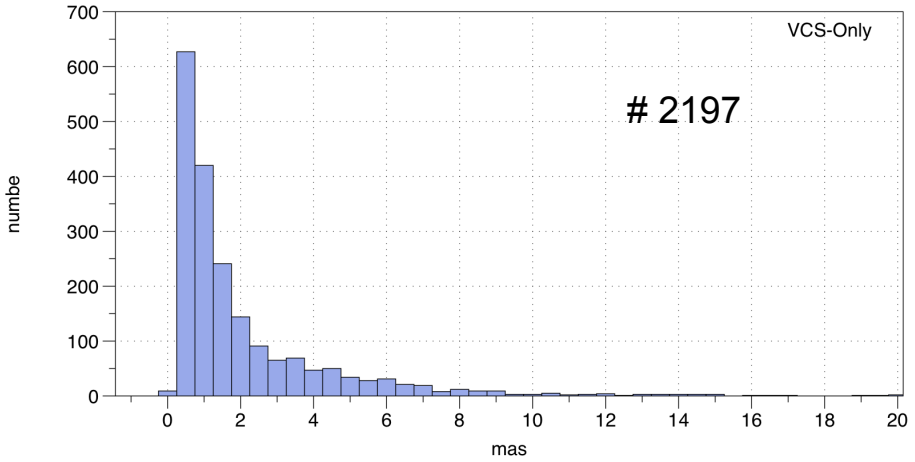
ICRF2 : Formal accuracy



9 % of ICRF2



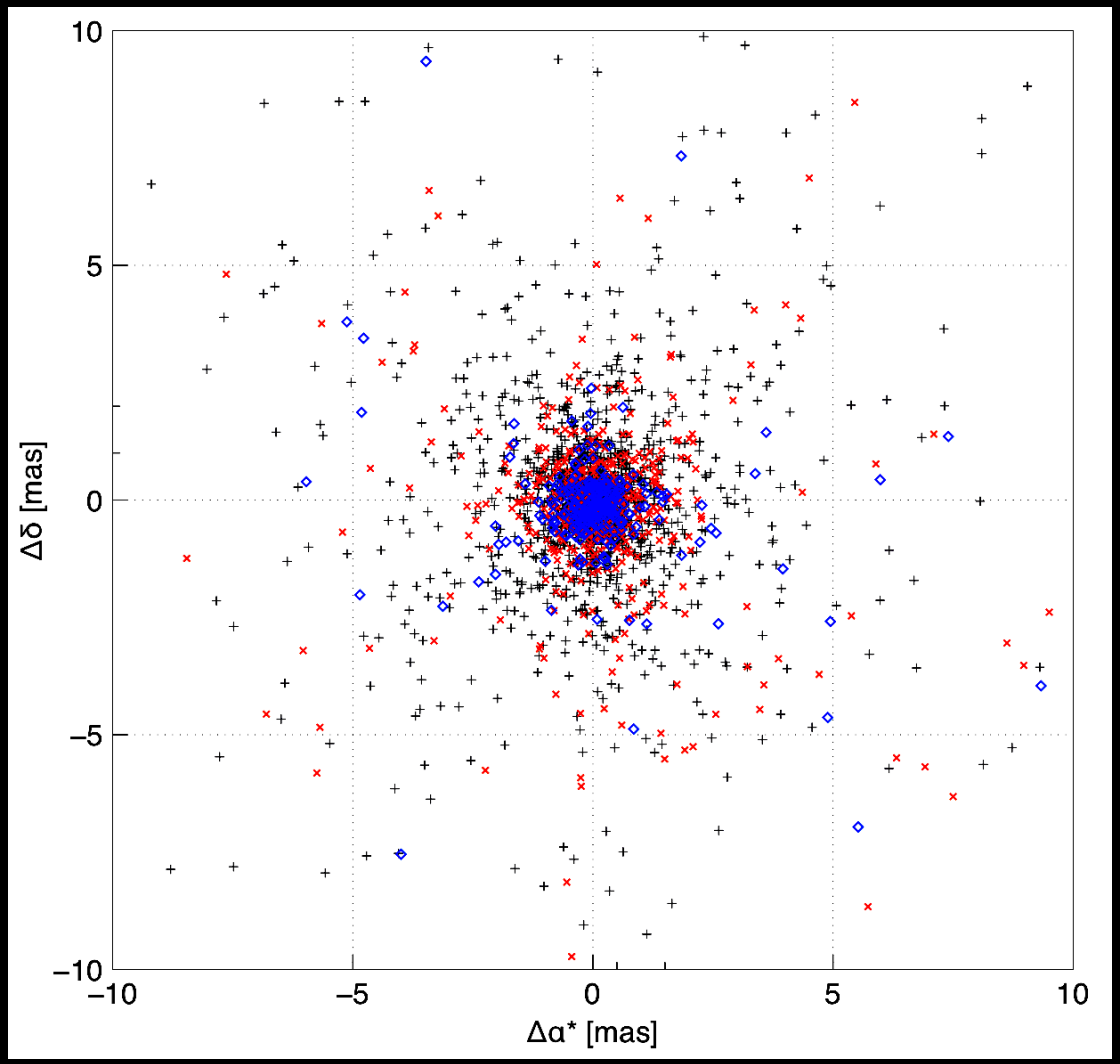
27 % of ICRF2



64 % of ICRF2

Reference Frame

- Comparison to radio (VLBI) positions of ICRF2

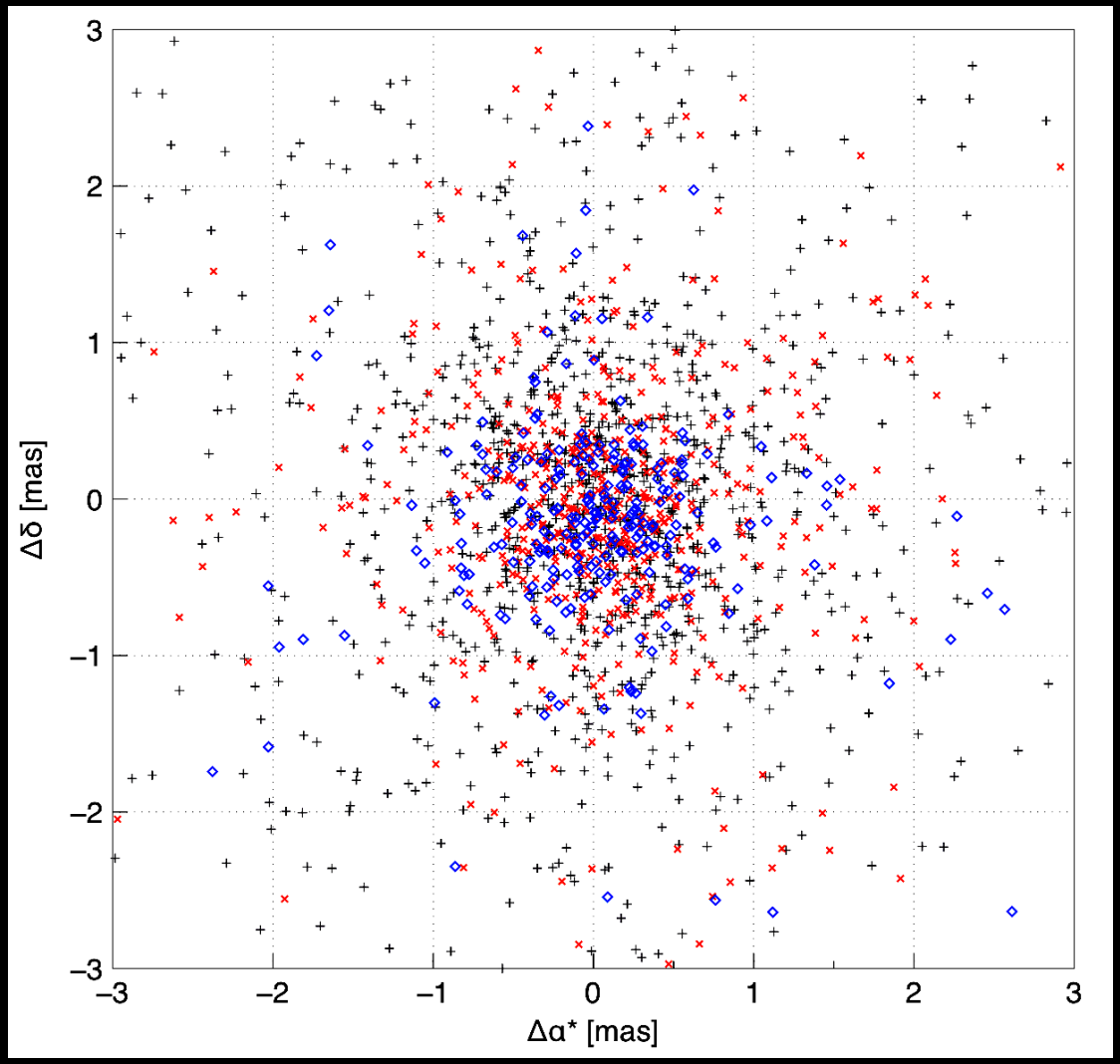


- central concentration of the defining sources
- large scatter of the VCS sources
- small bias in declination

Mignard, Klioner, Lindegren et al. 2016

Reference Frame

- Comparison to radio (VLBI) positions of ICRF2



- central concentration of the defining sources
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Mignard, Klioner, Lindegren et al. 2016

Alternatives to ICRF2

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A pathway to ICRF3 - I

- VLBI data are collected primarily for Earth rotation monitoring and geodetic purposes
  - Data is available and analysed by several groups
  - Astrometric solutions are produced
  - An ICRF3 will result from the combination

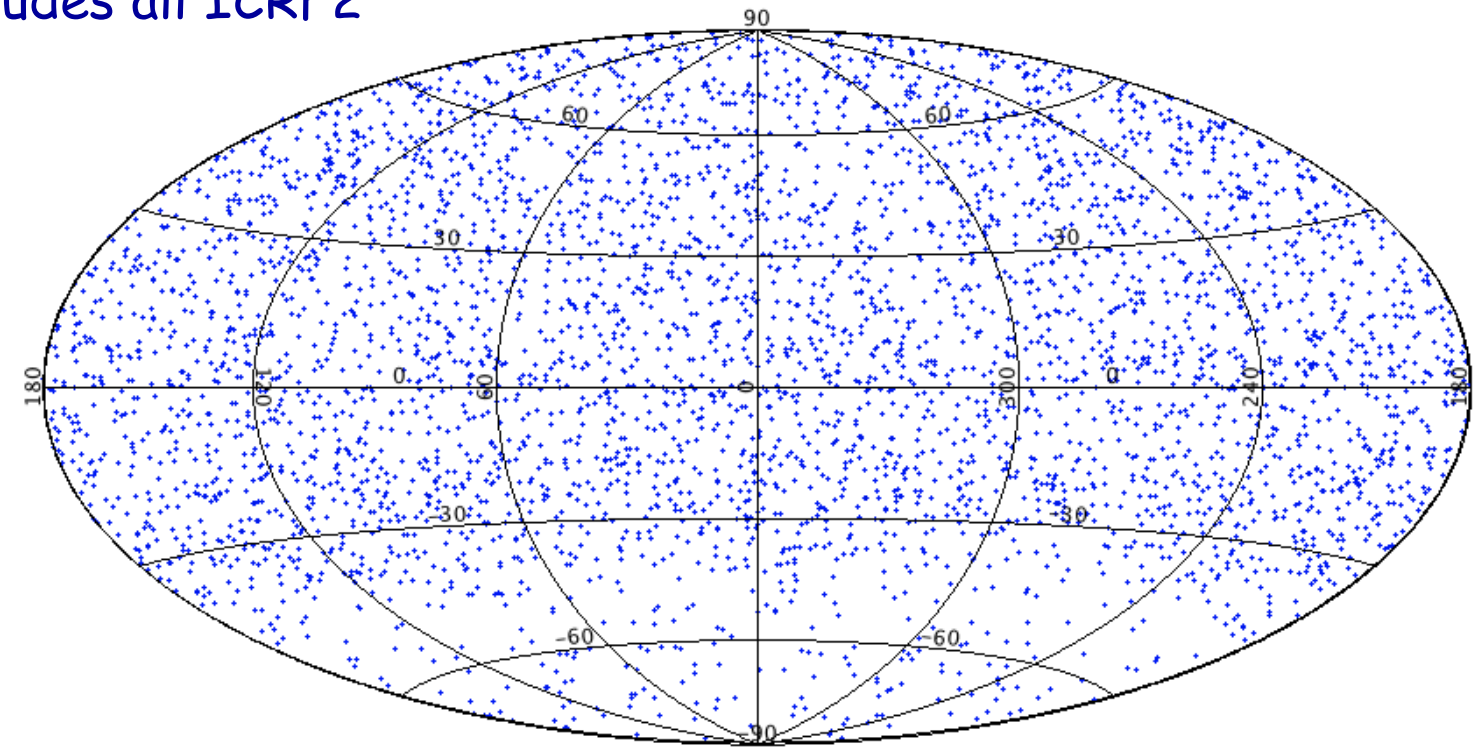
Already preliminary solutions better than ICRF2 available

A pathway to ICRF3 - II

- VLBI solution from GSF (NASA Godard) in X/S band
  - GSF2016a solution (Provided by ICRF3 Working Group)
- X/Ka band catalogue from Garcia-Miro & C. Jacobs
  - on-going work with a preliminary solution (Chris talk later this day)
- VLBI solution from Petrov et al.
  - RFC catalogue 2016c (Leonid talk in a few mn)
  - Comparison not shown in this talk

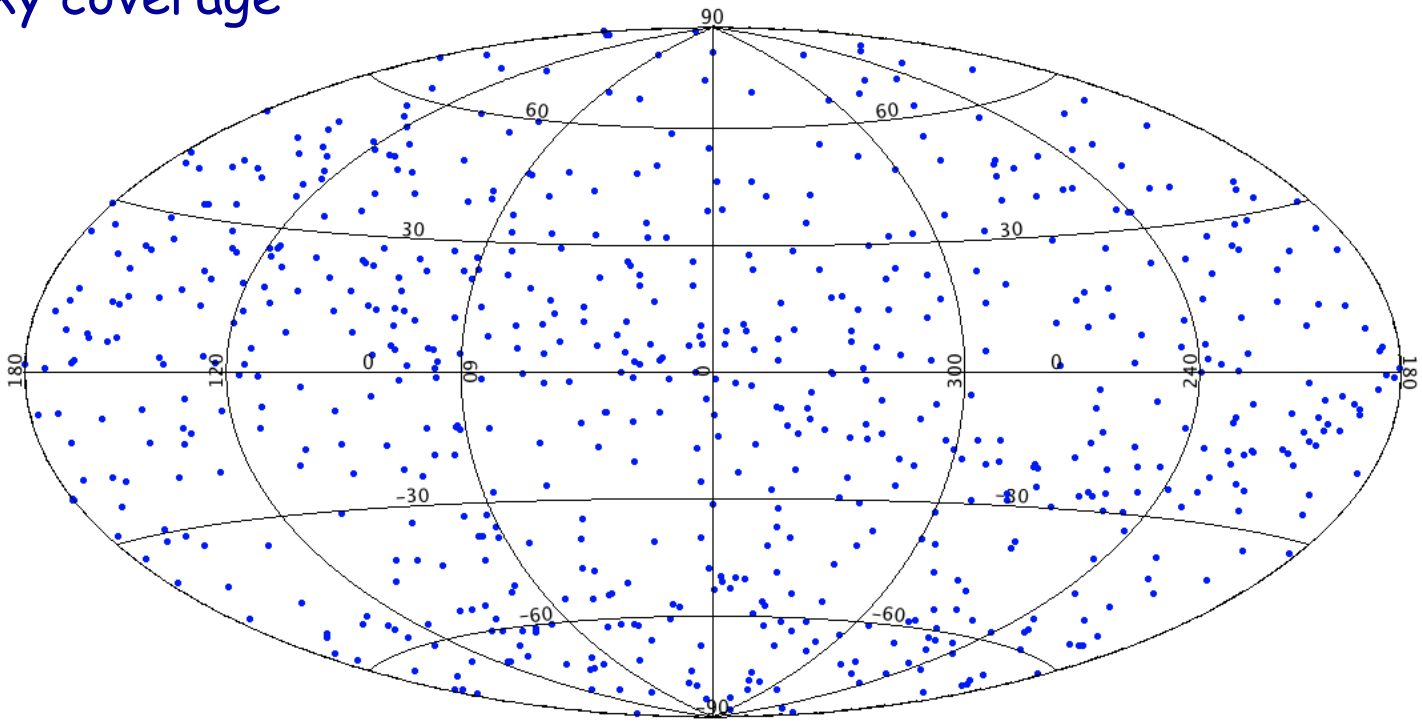
GSF2016a

- 4161 sources (ICRF2 = 3214)
- VLBI astrometry from 1979 to Sept 2016
- sub-mas accuracy
- includes all ICRF2



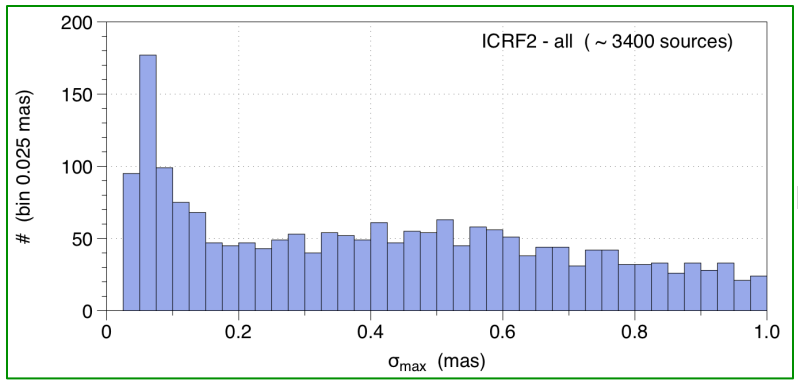
X/Ka catalogue

- 673 sources (ICRF2 = 3214)
- VLBI astrometry in X/Ka band
- 0.2 mas accuracy
- full sky coverage

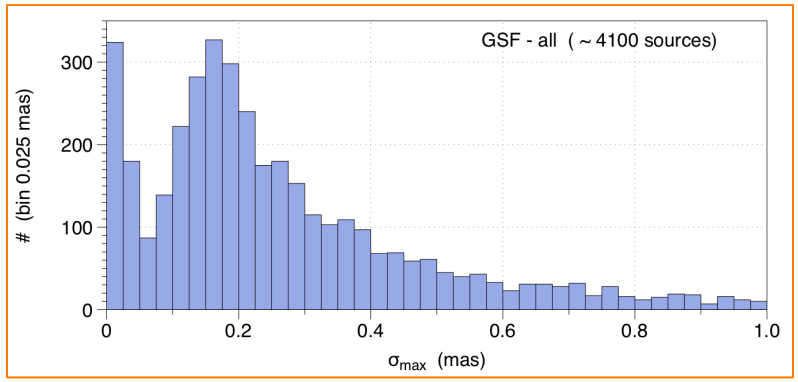


Formal accuracy - I

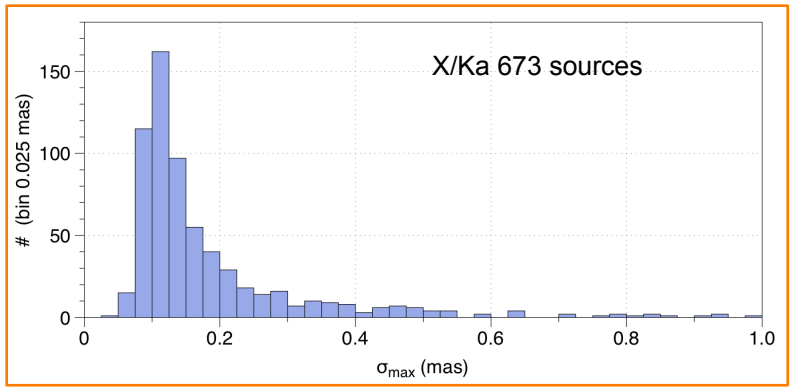
- Illustration with ICRF2, GSF, X/Ka
- Plots from the quoted accuracy
  - σ_{max} computed with error ellipse
- zoom to σ < 1 mas



ICRF2



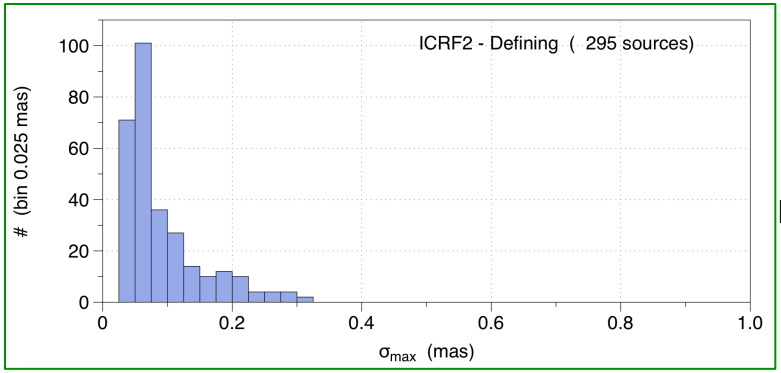
GSF



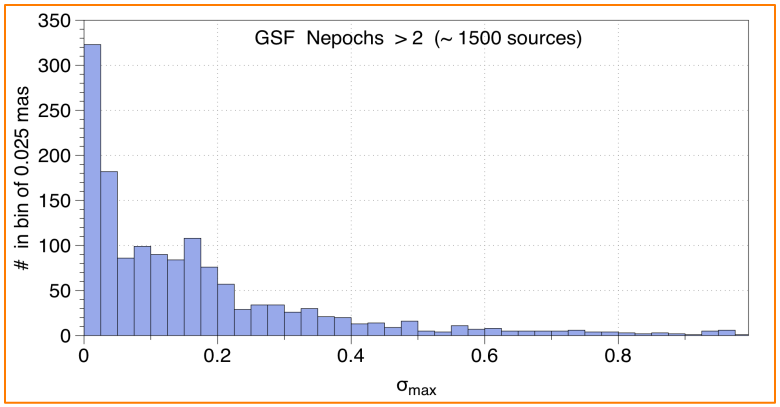
X/Ka

Formal accuracy - II

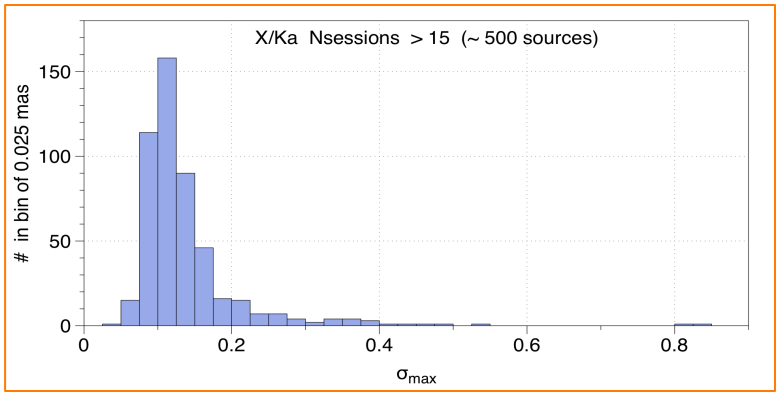
- Illustration with ICRF2, GSF, X/Ka
- Plots from the quoted accuracy
  - σ_{max} computed with error ellipse
- Well observed subset



ICRF2



GSF



X/Ka

Comparison to Gaia DR1

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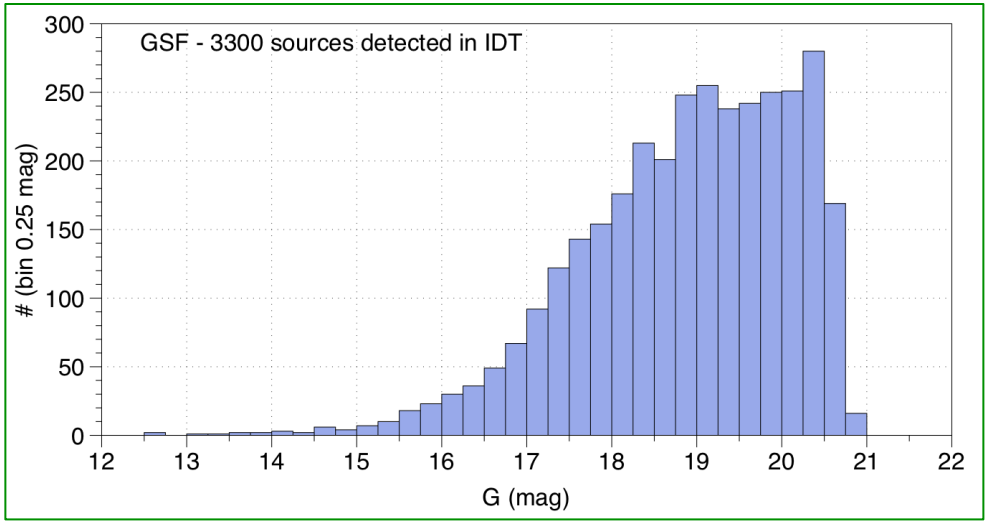
Analyses of differences to DR1

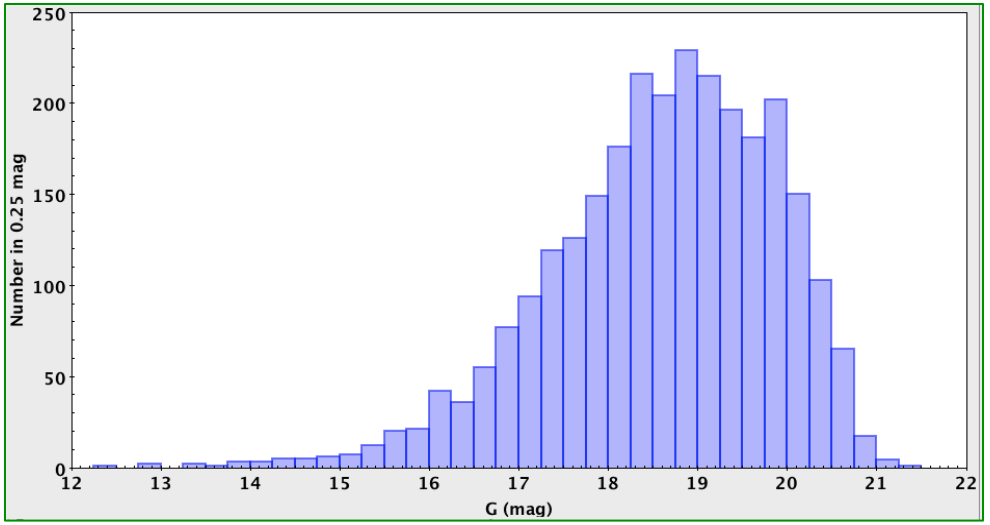
- Same analysis as in Mignard et al. paper
  - Selection of the 2191 good matches from the QSO Aux solution
  - Differences with the reference positions
    - ICRF2
    - GSF2016a
    - X/Ka
  - Statistical analysis
  - Outliers

GSF sources in Gaia data

- GSF in Gaia data
  - 3300 detected out of 4200



- GSF in DR1 solution
  - 2700 solved out of 4200

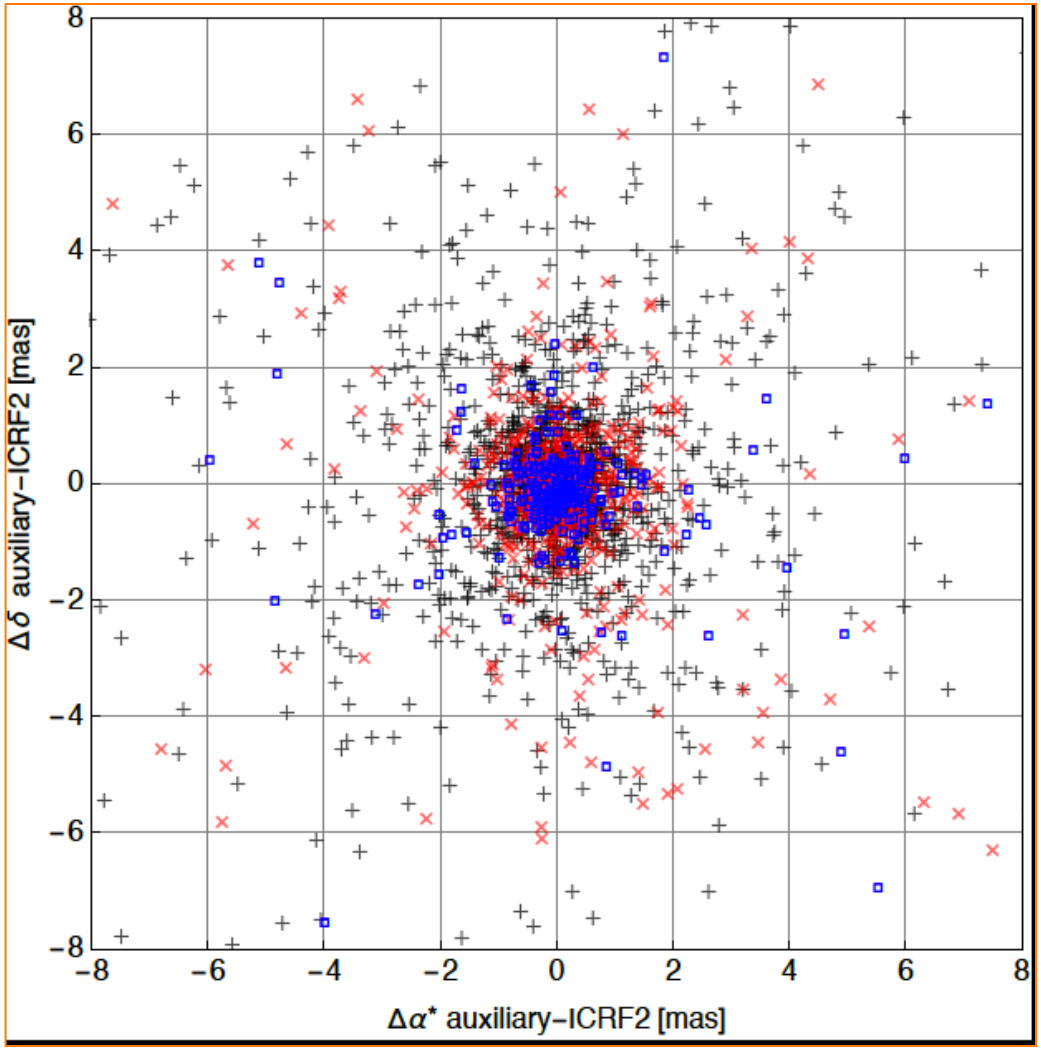


All the 2191 sources

- Distribution $\Delta\alpha*$, $\Delta\delta$ in [-8, +8] mas

DR1 - ICRF2

DR1 - GSF



Def.

non VCS

VCS

All the 2191 sources

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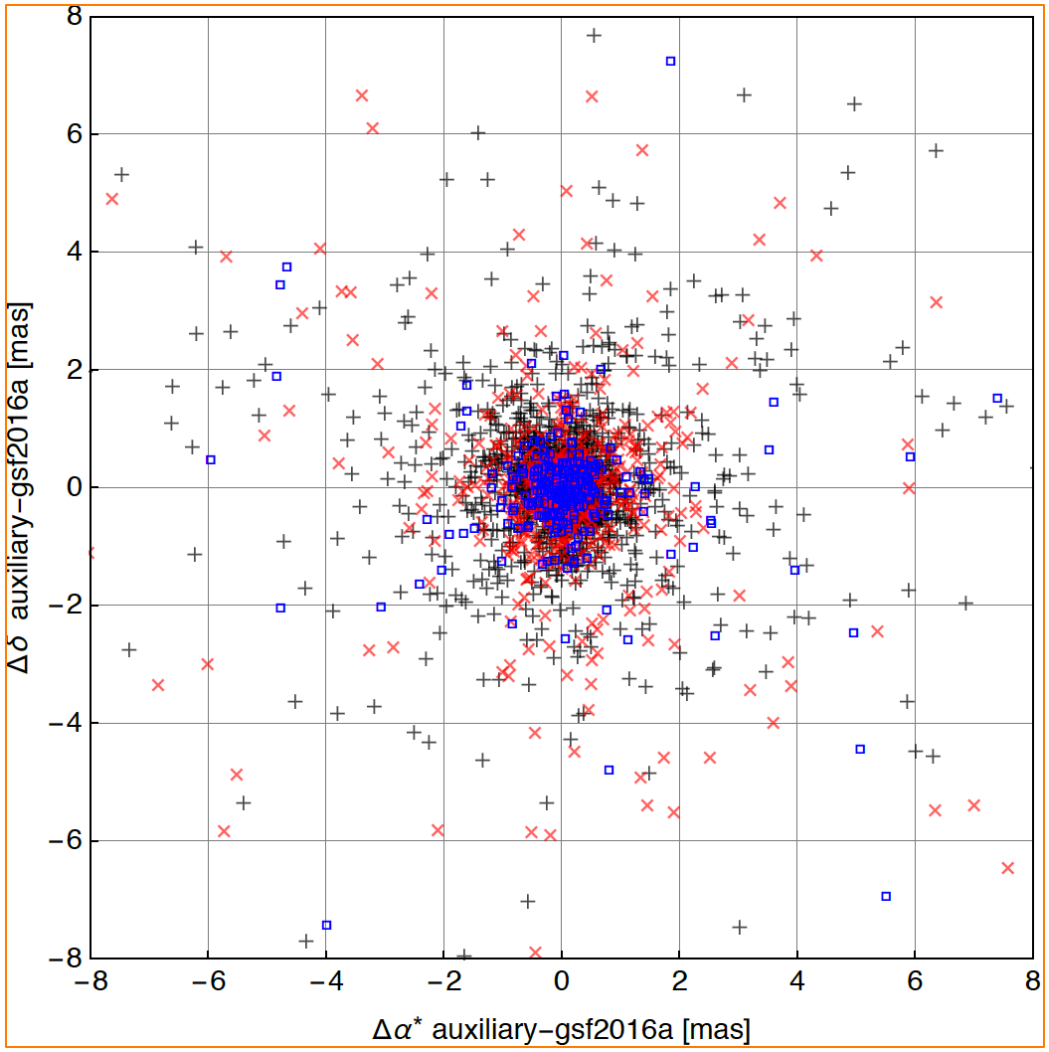
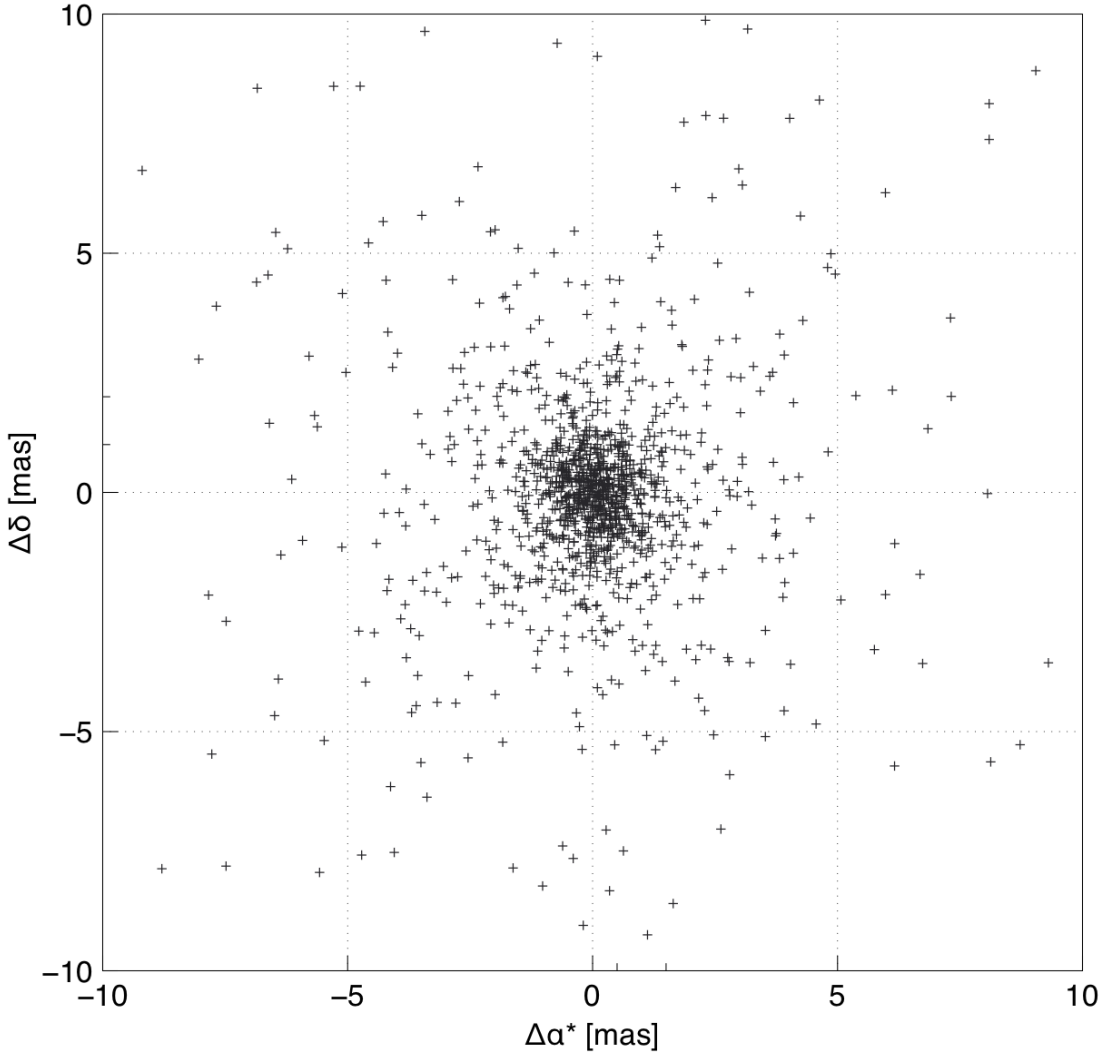


VCS only sources

- Distribution $\Delta\alpha*$, $\Delta\delta$ in [-10, +10] mas

DR1 - ICRF2

DR1 - GSF



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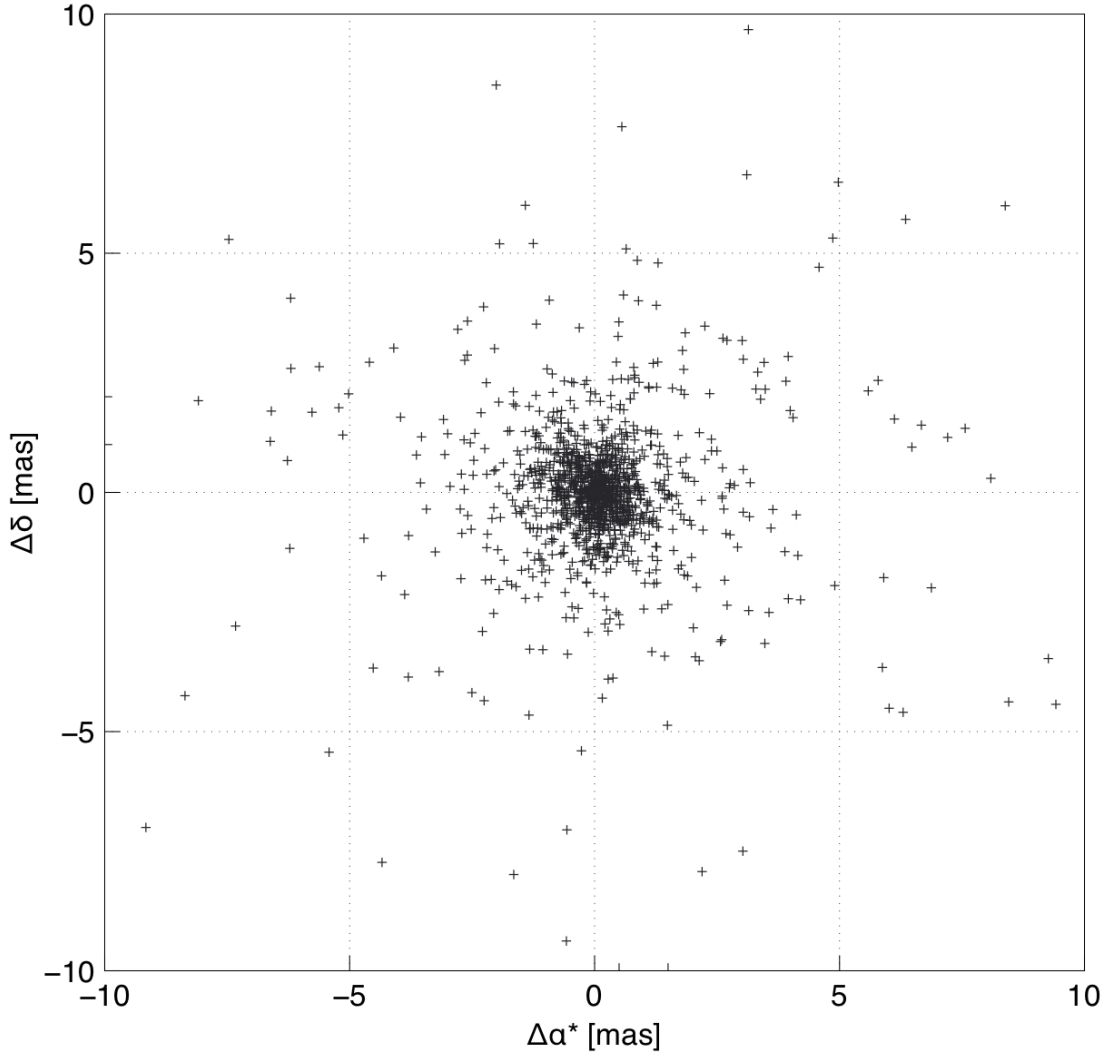
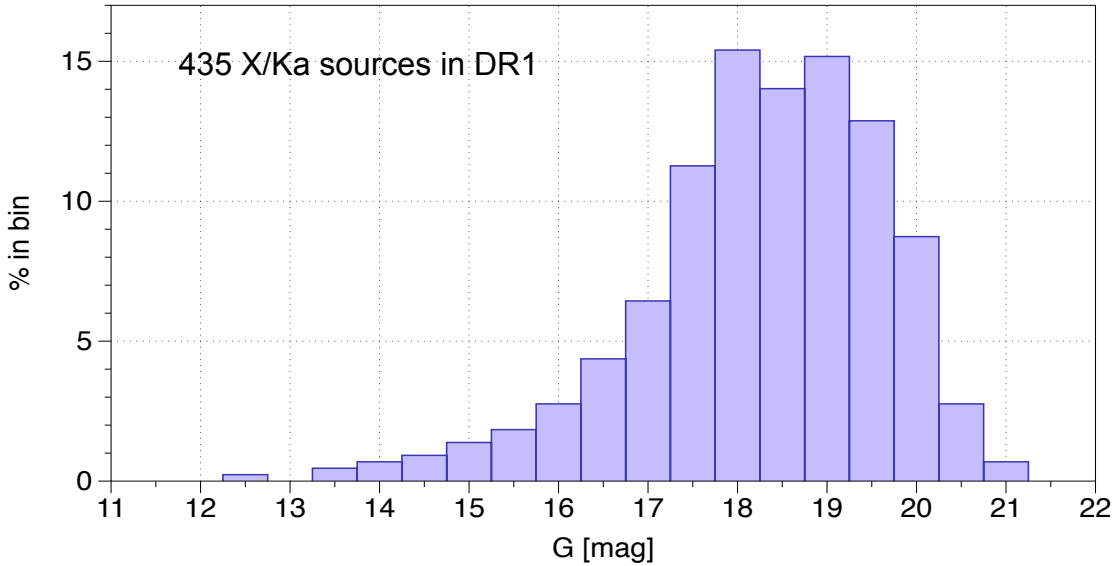
DR1 - ICRF2

DR1 - GSF

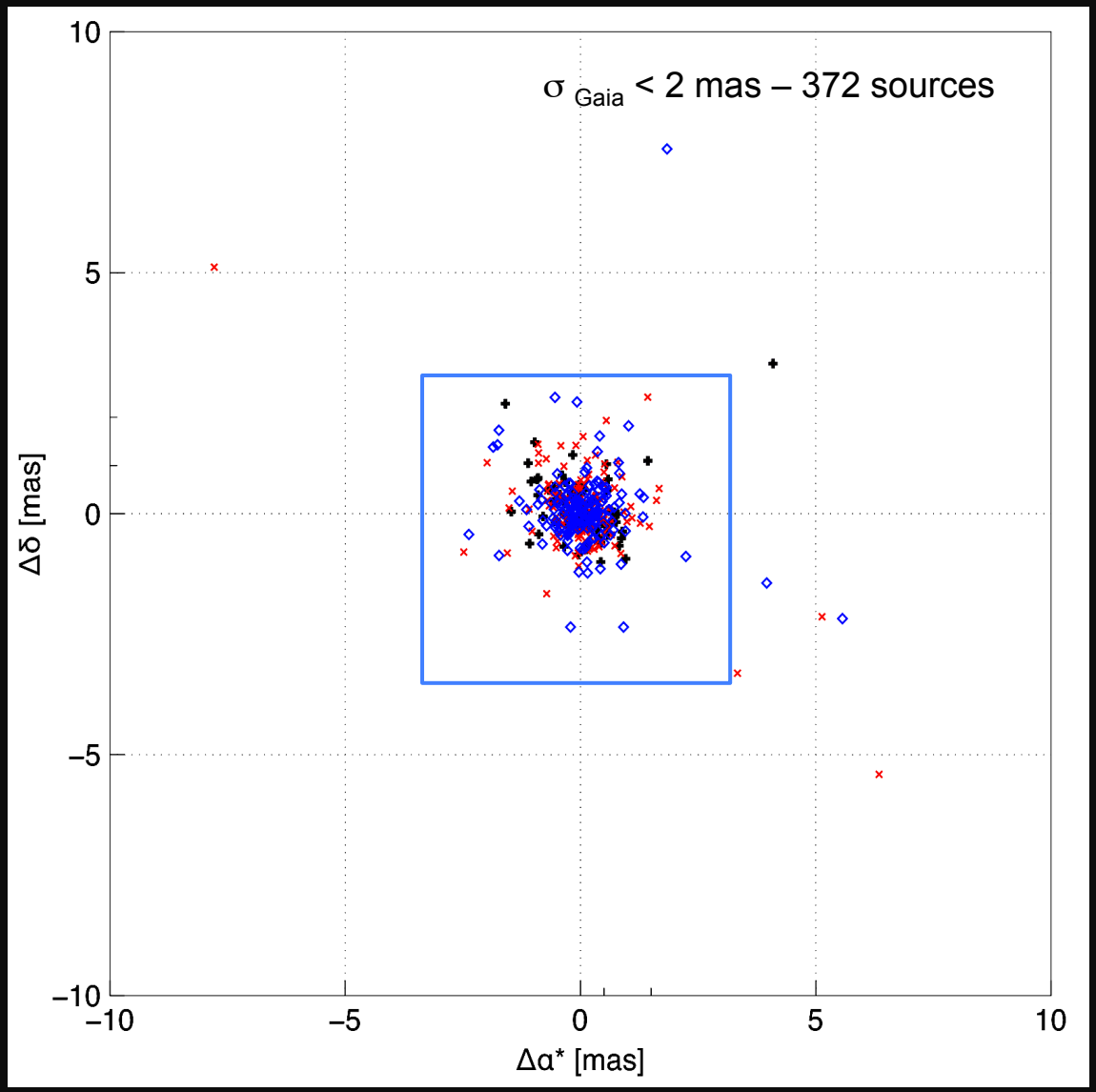


Comparison to X/Ka catalogue

- VLBI Observations on X/Ka band (higher frequencies than S/X)
- Data set independent of ICRF2 or GSF
- First solution by C. Garcia-Miro, C. Jacobs et al. 2015
  - 673 sources in the catalogue with σ ~ 0.1 – 0.2 mas
  - 435 found in the Gaia QSO good solutions
- Nominally better than Gaia DR1

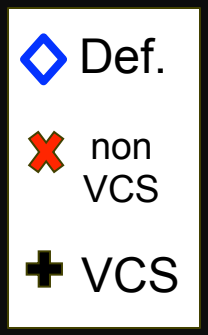


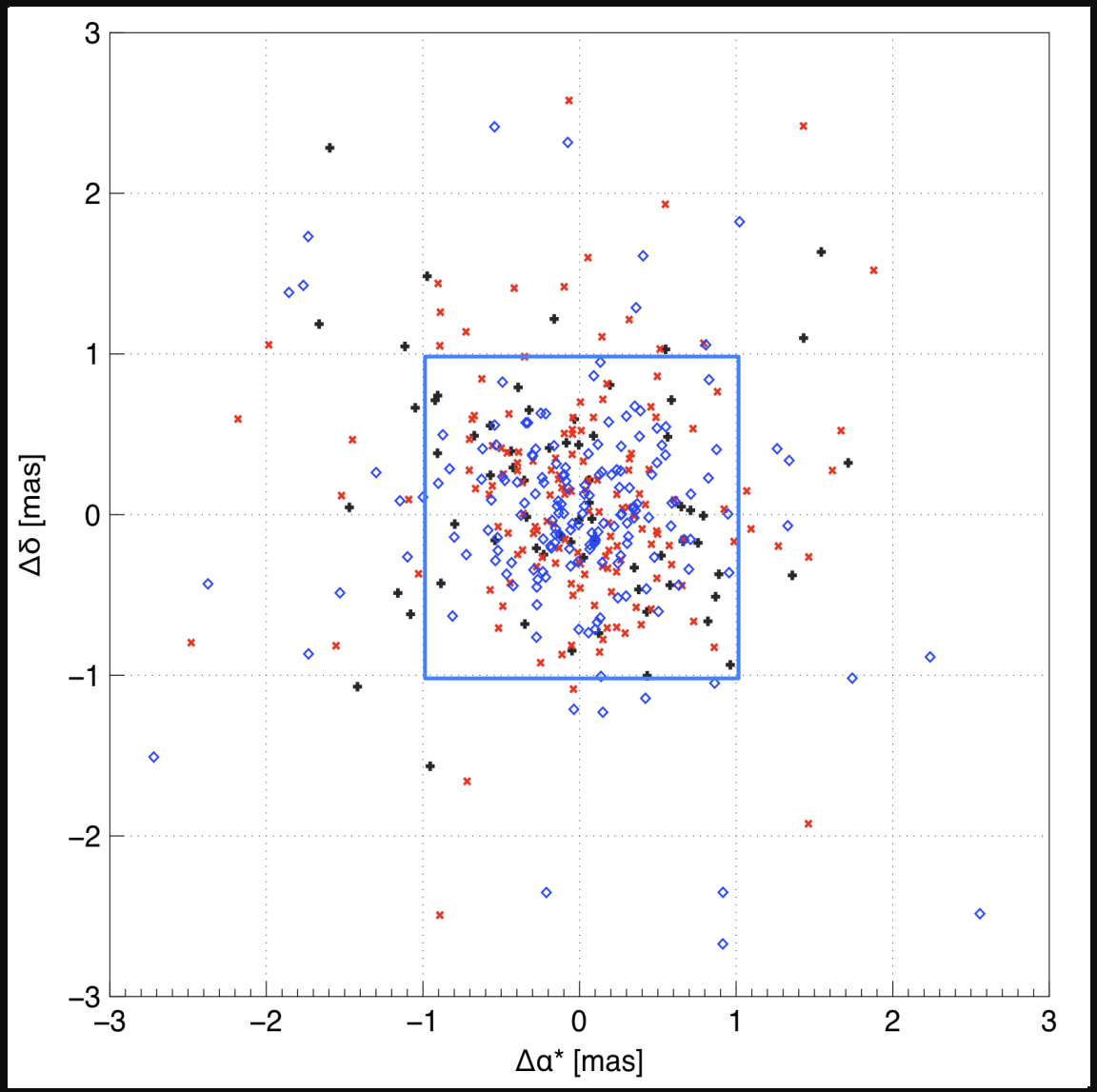
Comparison Gaia – X/Ka



- no distinctive feature with ICRF categories
- remaining scatter shared between Gaia and X/Ka
- no bias in declination or RA
- Gaia formal uncertainties realistic

Comparison Gaia – X/Ka





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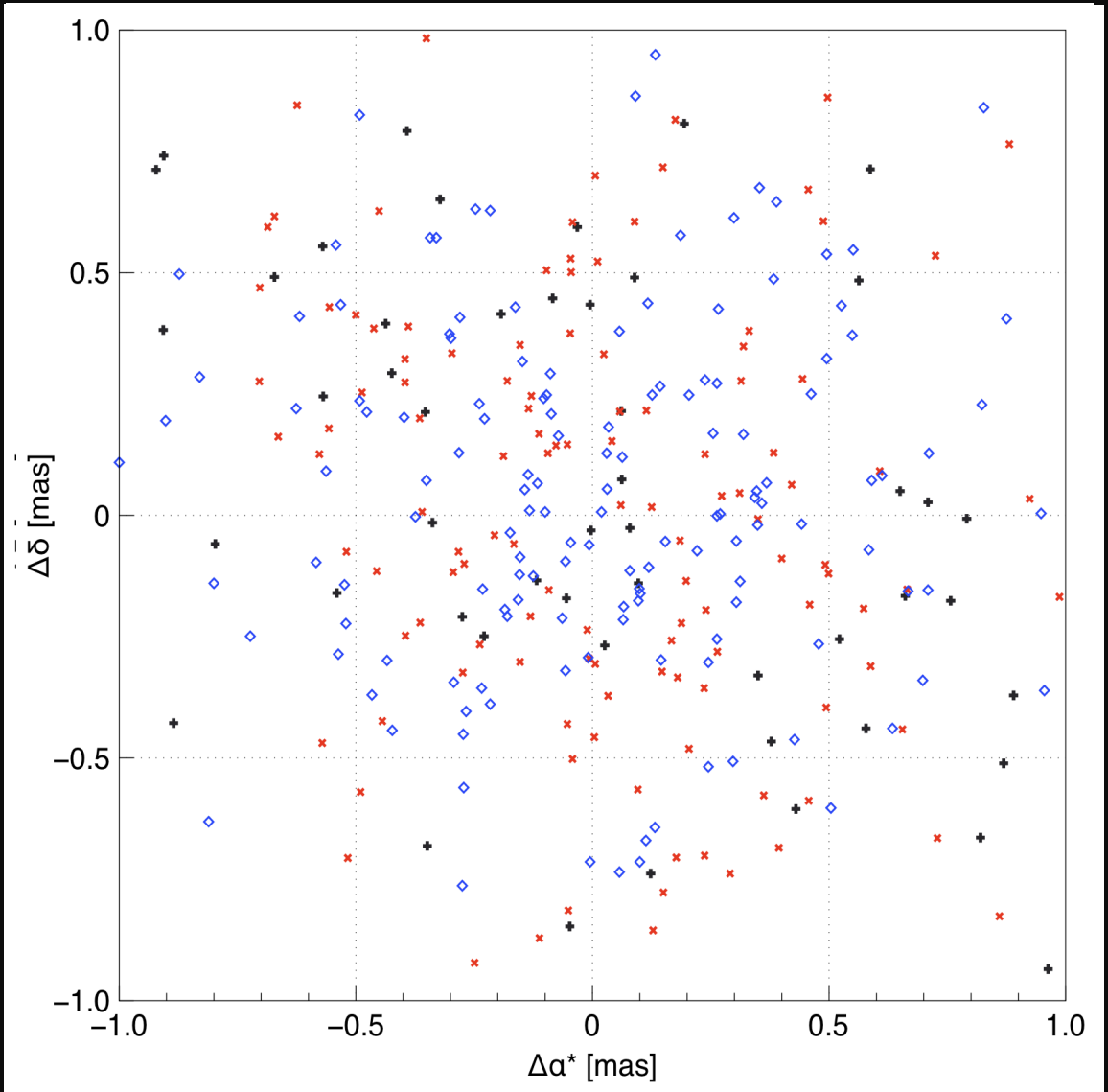
Comparison Gaia – X/Ka

Def.
non VCS
VCS



- no distinctive feature with ICRF categories
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- no bias in declination or RA
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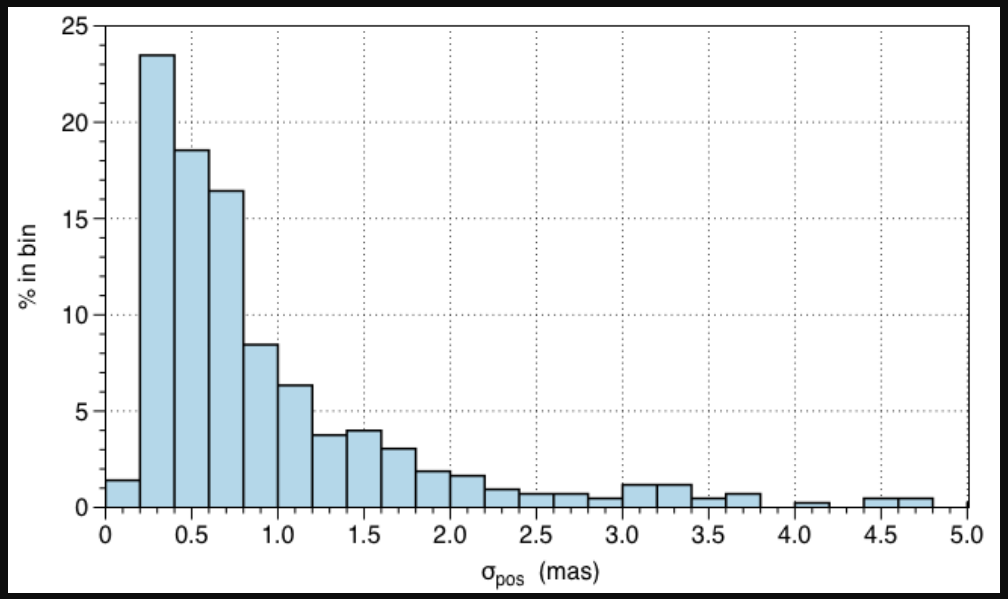
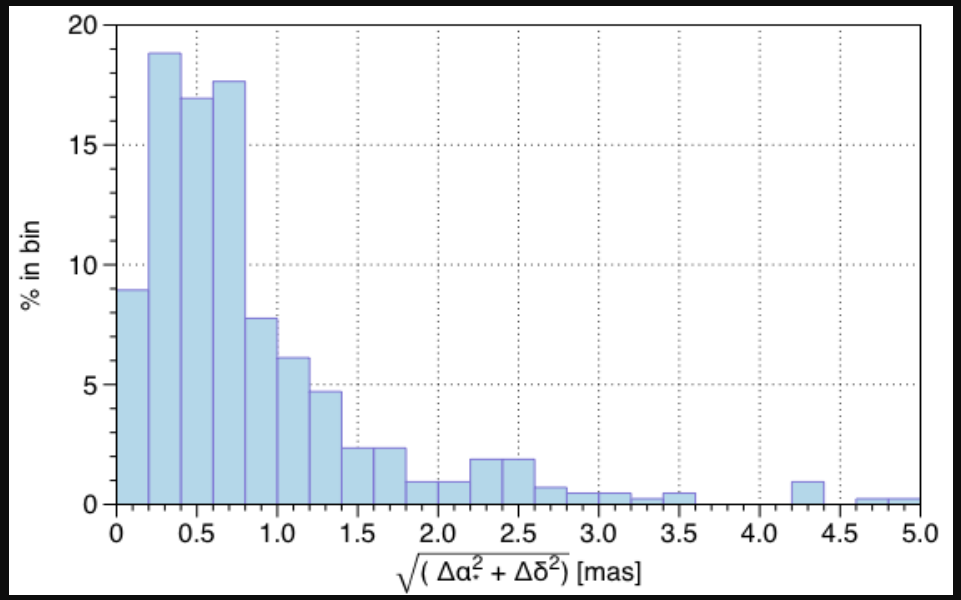
Gaia: realistic uncertainties



- Quoted uncertainties (max axis of error ellipse)

- Distances Gaia- X/Ka



Conclusion

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Conclusions

- The new analyses with GSF2016, X/Ka confirm the quality of the Gaia-DR1
  - the large residuals seen with ICRF2 are down with the improved VLBI solutions
  - Gaia DR1 quoted uncertainties look realistic at faint end
  - Gaia optical frame in the DR1 already better than ICRF2
  - No trace of clear radio-optical offset
- ICRF2 is no longer the best reference catalogue
  - this is acknowledged by the relevant IAU WG
- By the time of the Gaia-DR2, ICRF3 not yet published
  - but near final prototype could be made available in 2017
    - Otherwise alignment could be done with GSF2016a