

Characterizing the *Gaia* Bright Reference Frame

GaiaNIR meeting

Eero Vaher

Lund Observatory

19.07.2023

Introduction

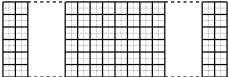
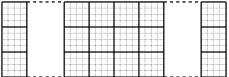
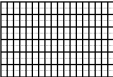


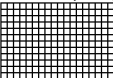
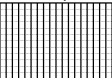

Gaia Bright Reference Frame

Combining astrometry from different catalogs can provide precise proper motion estimates, but accuracy might be affected by systematics.

- What is the *Gaia* Bright Reference Frame?
- How to quantify *Gaia*-BRF bias?
- What does the data say?

What is *Gaia*-BRF?

Window classes

Strip	$G < 13$	$13 < G < 16$	$16 < G$
SM	WC0: 40×6 (2×2) PSF 	WC1: 20×3 (4×4) PSF 	
AF1	WC0: 18×6 (1×2) PSF 	WC1: 12×1 (1×12) LSF 	WC2: 6×1 (1×12) LSF 
AF2-9	WC0: 18×12 (1×1) PSF 	WC1: 18×1 (1×12) LSF 	WC2: 12×1 (1×12) LSF 

The limited telemetry budget necessitates the introduction of window classes (Rowell et al., 2020).

What is *Gaia*-BRF?

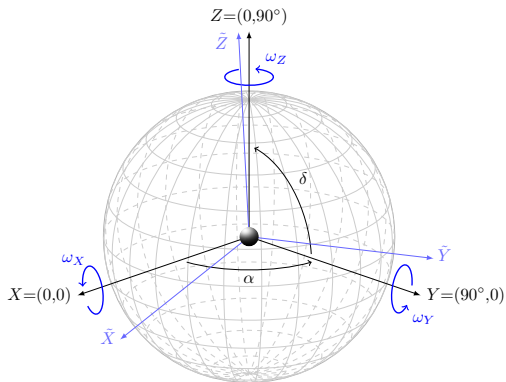
Gaia-CRF

Gaia DR3 astrometry is given in *Gaia*-CRF3. Quasars can be used both to ensure that *Gaia*-CRF3 is not rotating and to align it with the ICRF3 radio catalog (Gaia Collaboration et al., 2022).

Quasars are not bright enough for *Gaia*-BRF.

What is *Gaia*-BRF?

Frame rotation



An arbitrary frame rotation can be expressed as 3 rotations around 3 orthogonal axes (figure from Cantat-Gaudin & Brandt, 2021).

How to quantify *Gaia*-BRF bias?

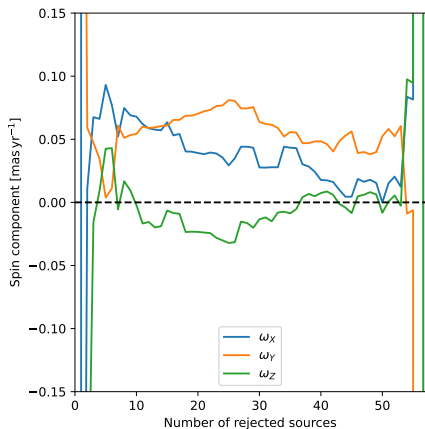
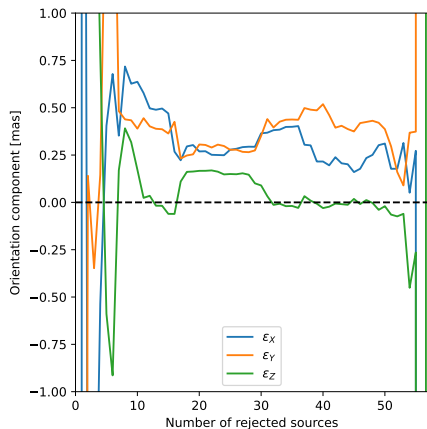
Comparison with VLBI

Lindegren (2020) compares *Gaia* DR2 astrometry with Very Long Baseline Interferometry (VLBI) observations of optically bright sources.

Number of available sources is low, number of suitable sources even lower.

How to quantify *Gaia*-BRF bias?

Orientation and spin

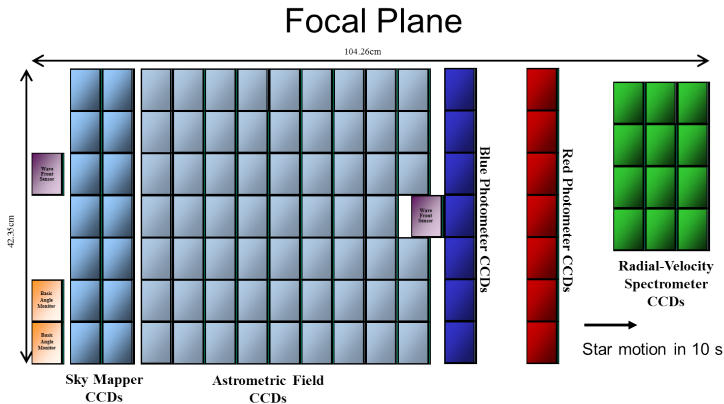


VLBI data by Minghui Xu and Susanne Lunz.

7/18

How to quantify *Gaia*-BRF bias?

Gaia focal plane



Lindegren et al. (2012).

How to quantify *Gaia*-BRF bias?

Spin bias

Cantat-Gaudin & Brandt (2021) compare proper motions of bright and faint stars in

- binary systems
- open clusters

How to quantify *Gaia*-BRF bias?

Binaries

Suppose a binary that contains two Sun-like stars at 500 pc with separation 10 000 au.

Corresponding angular separation is $20''$, which *Gaia* can resolve.

For face-on circular orbits orbital velocity is 200 m s^{-1} .

Corresponding proper motion is $\sim 100 \mu\text{as yr}^{-1}$.

How to quantify *Gaia*-BRF bias?

Open clusters

For a cluster at a distance of 400 pc a velocity dispersion of 1 km s^{-1} , means relative proper motions of $\sim 500 \mu\text{as yr}^{-1}$.

How to quantify *Gaia*-BRF bias?

Averaging

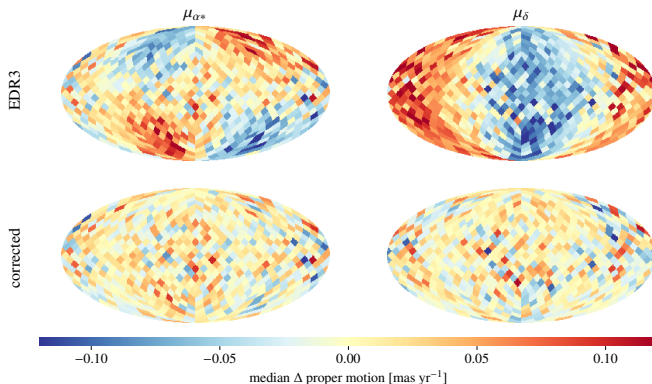
In both cases the orbital motion of the stars is very significant.

And in both cases it can be averaged away if the sample size is large enough.

Cantat-Gaudin & Brandt (2021) use about 55 000 binaries and 358 000 cluster stars of which 37 000 are bright.

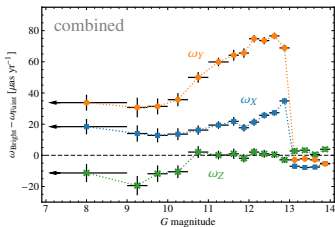
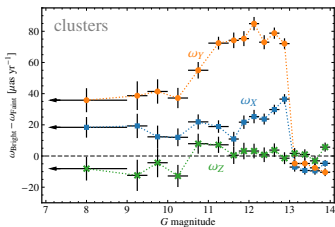
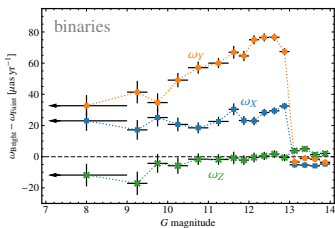
How to quantify *Gaia*-BRF bias?

Frame spin estimate



Proper motion bias in corrected and uncorrected data for $11 < G < 13$ (figure from Cantat-Gaudin & Brandt, 2021).

13/18



Frame rotation components
from Cantat-Gaudin
& Brandt (2021).

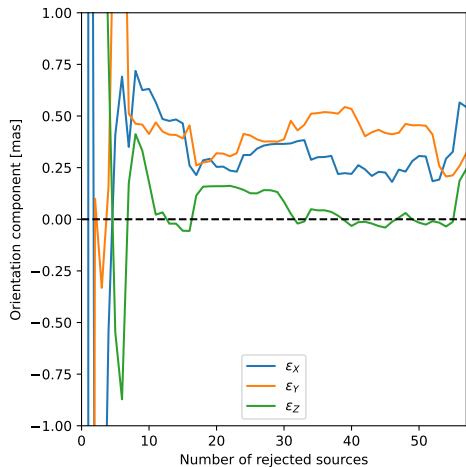
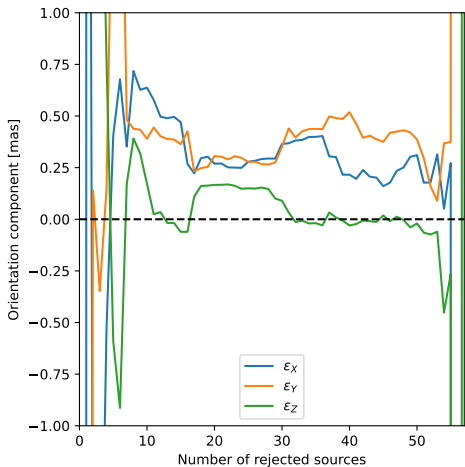
How to quantify *Gaia*-BRF bias?

Combining the methods

Can the *Gaia*-BRF orientation estimate be improved by including the frame spin from Cantat-Gaudin & Brandt (2021) in the comparison with optically bright VLBI sources?

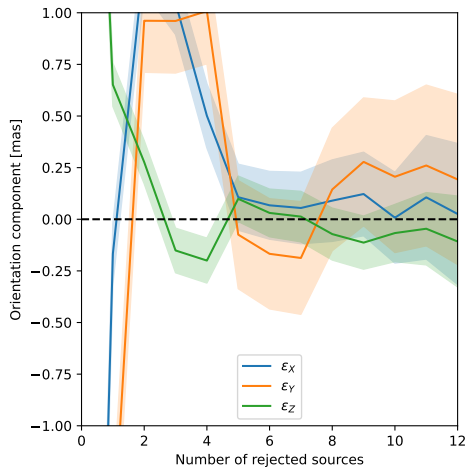
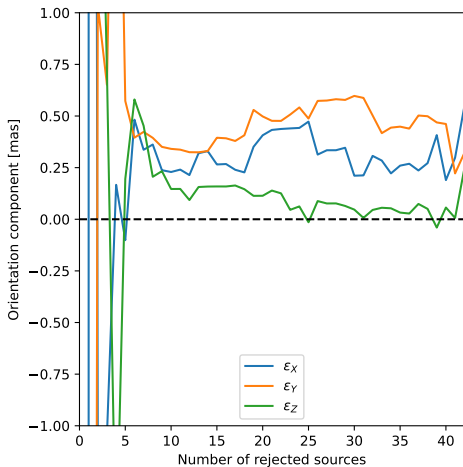
How to quantify *Gaia*-BRF bias?

With and without spin data



How to quantify *Gaia*-BRF bias?

Binning



Summary

On the faint end *Gaia* astrometry can be verified using quasars, but the bright reference frame might be different.

Gaia-BRF rotation can be quantified by comparing *Gaia* and VLBI astrometry, but number of suitable bright sources is still low.

Including frame spin data might allow binning VLBI sources by optical magnitude.

Bright sources might have position offsets of ~ 0.5 mas.