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Selection of sources to construct a more uniform reference frame

— *The preliminary results*

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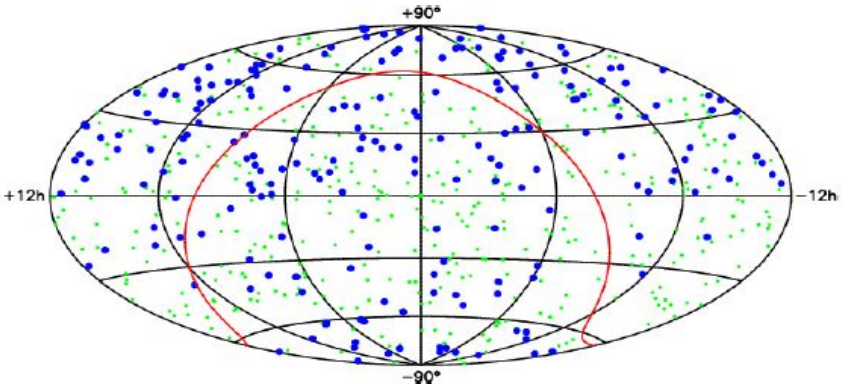
Outline

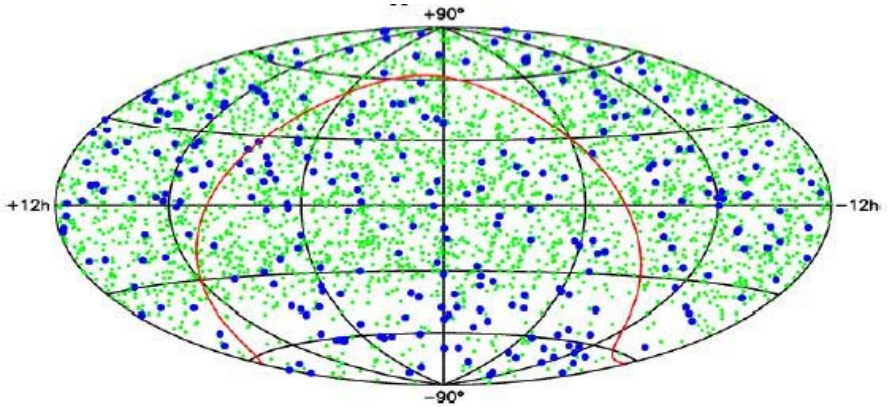
- The homogeneity of the source distribution
- Data and analysis strategy
- Selection of the radio sources

The ICRF realized by the radio sources

- ICRF1: January 1998
- ICRF2: January 2010 *as fundamental reference fames*



ICRF1



ICRF2

The ICRF2 has achieved:

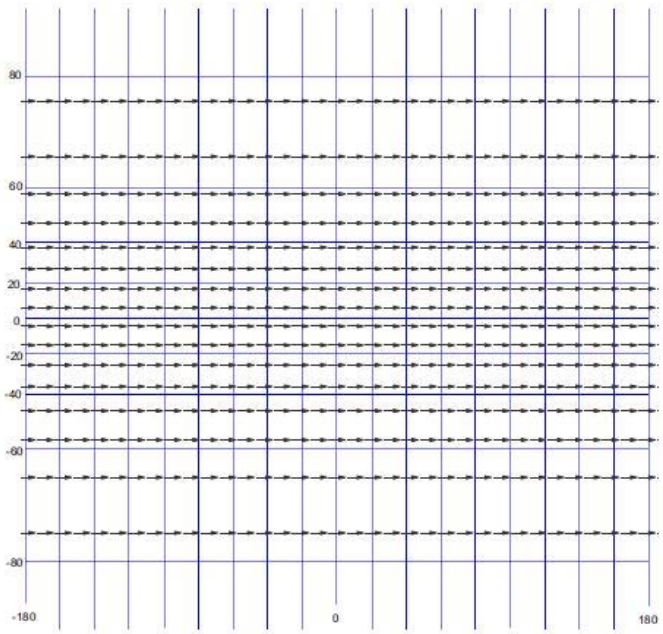
- More uniform distribution of the defining sources.
- Improving the source position uncertainty (from 250 μas to 40 μas for noise floor).
- Elimination of large systematic error at the level of 0.2 mas.

The ICRF3

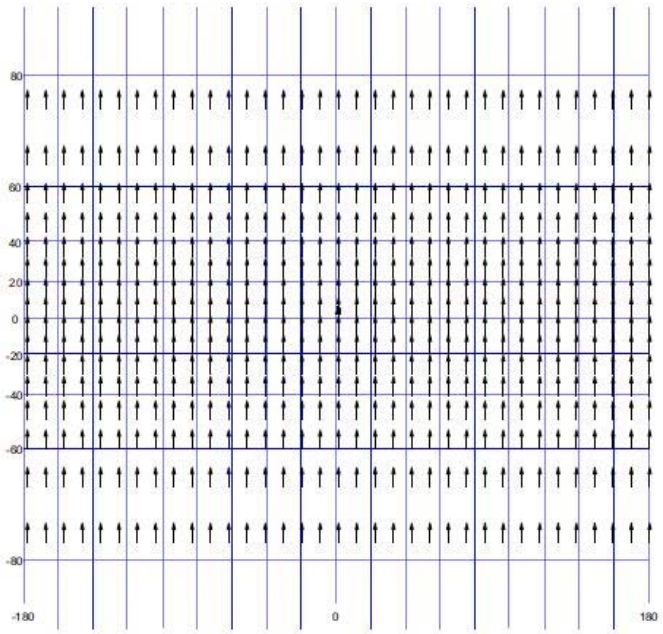
- The inertial ICRF3
  - No global rotation
  - No acceleration
  - VLBI realized a quasi-inertial frame with origin at the Solar system barycenter (SSB)
- The path to the future
  - Higher frequency
  - More south hemisphere sources for uniform special coverage
  - Higher and more uniform accuracy for all sources
  - Competitive accuracy with Gaia
  - Prepare for optical-radio frame link
- Adopt in the IAU GA 2018?

cf: Jacobs 2013, Journées 2013 presentation, Paris

Description of the homogeneity of source distribution



(a) Rotation



(b) Glide

$$\boldsymbol{V}^R = \boldsymbol{R} \times \boldsymbol{u}$$

$$\boldsymbol{V}^G = \boldsymbol{u} \times (\boldsymbol{G} \times \boldsymbol{u}) = \boldsymbol{G} - (\boldsymbol{G} \cdot \boldsymbol{u})\,\boldsymbol{u}$$

Topologically orthogonal to each other.

cf: Mignard & Klioner (2012) A&A

Source distribution

- Calculate glide proper motion
  - Is there global rotation hidden in the glide (dipole) pattern
  - If the distribution is uniform

Glide

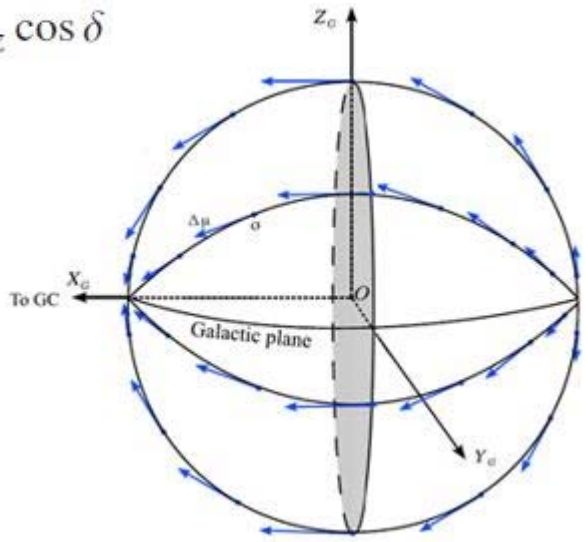
$$\Delta\mu_\alpha \cos\delta = -d_1 \sin\alpha + d_2 \cos\alpha,$$
$$\Delta\mu_\delta = -d_1 \cos\alpha \sin\delta - d_2 \sin\alpha \sin\delta + d_3 \cos\delta,$$

- Fit the proper motion field to global rotation equations

Rotation

$$\Delta\mu_\alpha \cos\delta = -\omega_x \cos\alpha \sin\delta - \omega_y \sin\alpha \sin\delta + \omega_z \cos\delta$$
$$\Delta\mu_\delta = +\omega_x \sin\alpha - \omega_y \cos\alpha,$$

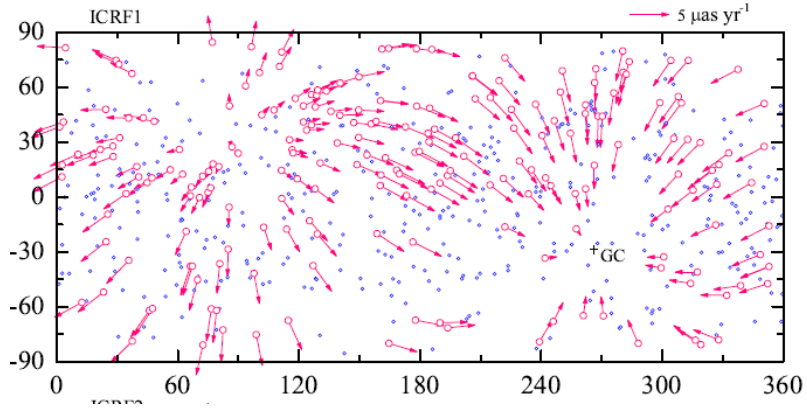
- Example for the ICRF source distribution

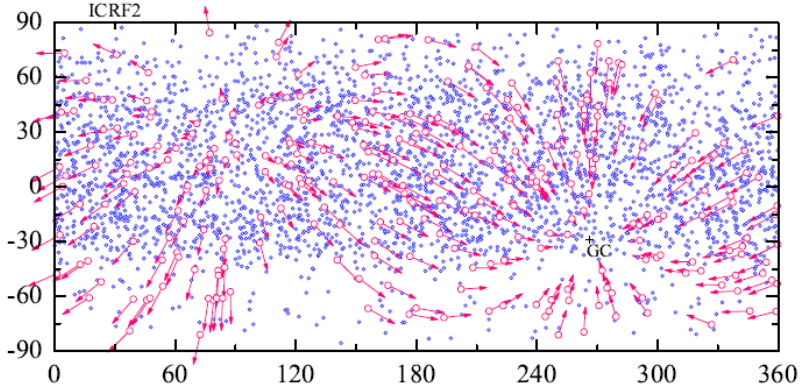


cf: Liu, Capitaine, Malkin et al. (2012) A&A

Source distribution

- Galactic aberration – Glide apparent proper motion





The magnitude of the dipole $A = \dfrac{\omega_0 V_0}{c} \simeq 5\,\mu\text{as yr}^{-1}$

- Results of the Global rotation fitted to the theoretical proper motions

Catalog	No.	ω_{X_G}	ω_{Y_G}	ω_{Z_G}	ω_{tot}	θ
ICRF1 def	212	+0.03 ± 0.08	+0.73 ± 0.08	−0.82 ± 0.09	1.09 ± 0.14	−48°.3
ICRF1	608	−0.01 ± 0.05	+0.15 ± 0.05	−0.18 ± 0.05	0.23 ± 0.09	−50°.2
ICRF2 def	295	−0.01 ± 0.07	+0.26 ± 0.07	+0.15 ± 0.07	0.30 ± 0.12	+30°.0
ICRF2	3414	−0.00 ± 0.02	+0.51 ± 0.02	−0.74 ± 0.02	0.90 ± 0.03	−55°.4
uniform	2500	+0.00 ± 0.02	+0.00 ± 0.02	+0.00 ± 0.02	0.00 ± 0.03	− − −

With uniform distribution, the global rotation should be zero.

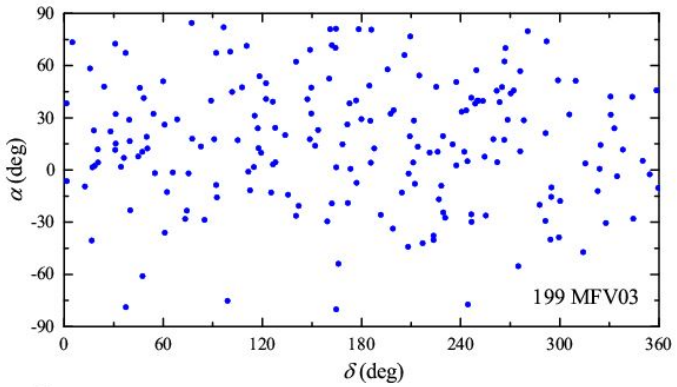
Source distribution index

- The amplitude of global rotation fitted from glide proper motion can be used to characterize uniformity of source distribution on the sky

- Several choices
  - 295 ICRF2 defining sources (Fey et al. 2009)
  - 199 MFV03 selected sources (Feissel-Vernier 2003)
  - 247 MFV06 selected sources (Feissel-Vernier et al. 2006)
  - 269 LG09 selected sources (Lambert & Gontier 2009)

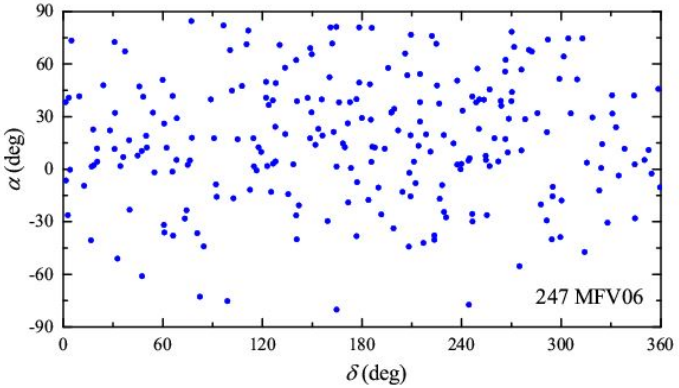
- Dipole
  - Coordinates of the apex: $(\alpha = 0,\ \ \delta = 0)$
  - Amplitude: $A = 5\ \mu as\ yr^{-1}$

Source distribution index



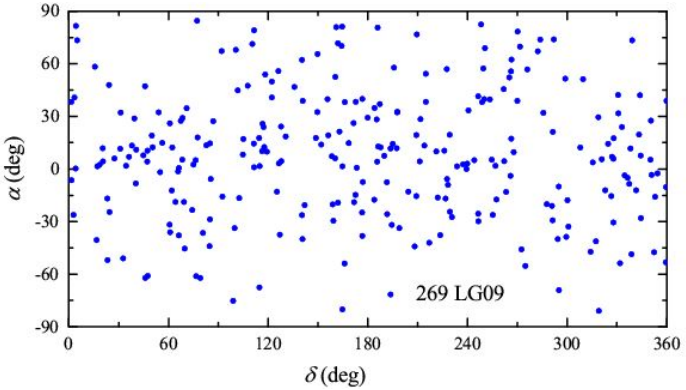
199 MFV03 sources

ω = 1.792 $\mu as\ yr^{-1}$



247 MFV06 sources

ω = 1.842 $\mu as\ yr^{-1}$



269 LG09 sources

ω = 0.886 $\mu as\ yr^{-1}$

295 ICRF2 defining:

ω = 0.154 $\mu as\ yr^{-1}$

212 ICRF1 defining:

ω = 0.989 $\mu as\ yr^{-1}$

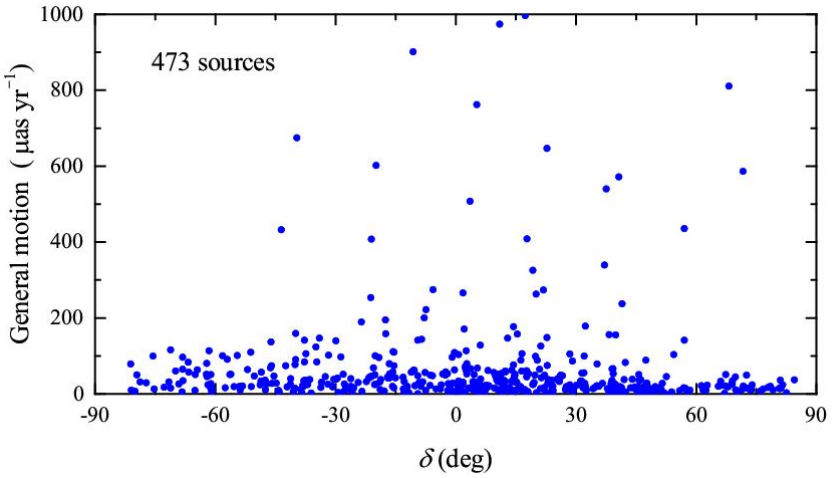
The data for radio sources

- Coordinate series from 1979-2015 (IVS analysis center at Paris)
- For non-defining sources, only sources with 50 more sessions are selected
- Only post 1990 data are used
- Various parameters are estimated for each source
  - LSQ derived motion (proper motion)
  - RMS, WRMS
  - Slope for Yearly mean coordinates (with more than 3 observation)
  - Allan variance for Yearly mean coordinates

- 473 sources including
  - 295 defining sources
  - 178 non-defining sources with more than 50 sessions
- Northern hemisphere: 280 sources
- Southern hemisphere: 193 sources

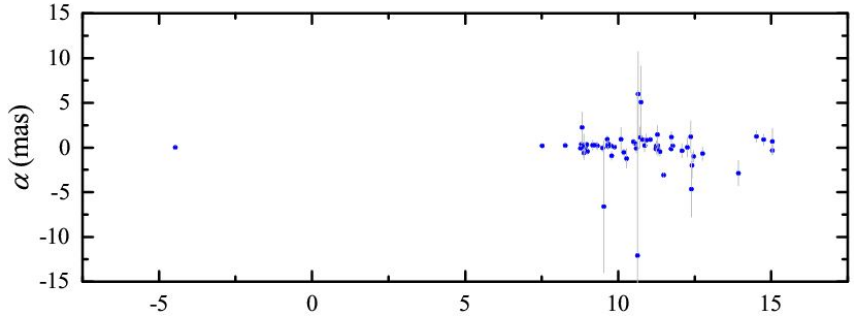
Slope of coordinates

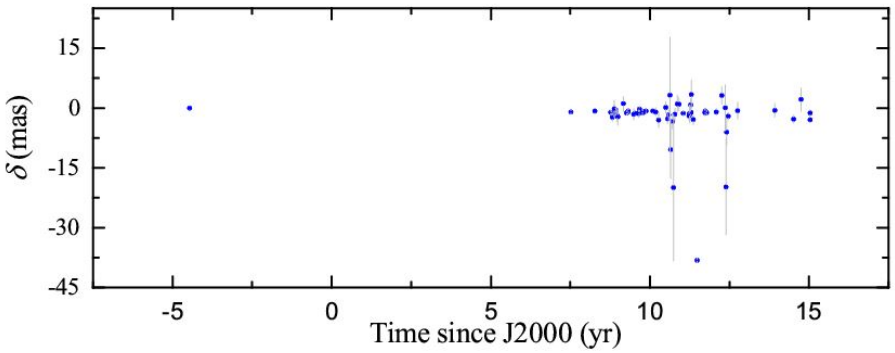
- Parameters are not strictly correlated
- The slope of α and δ are derived from weighted squares fit
- Some large motion are found for defining sources, e.g.



Defining source 1456+044

1456+044: Z = 0.391547



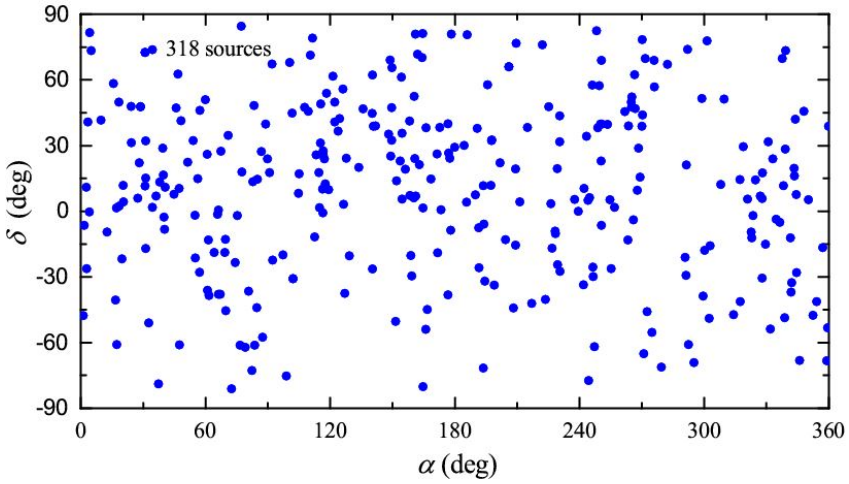


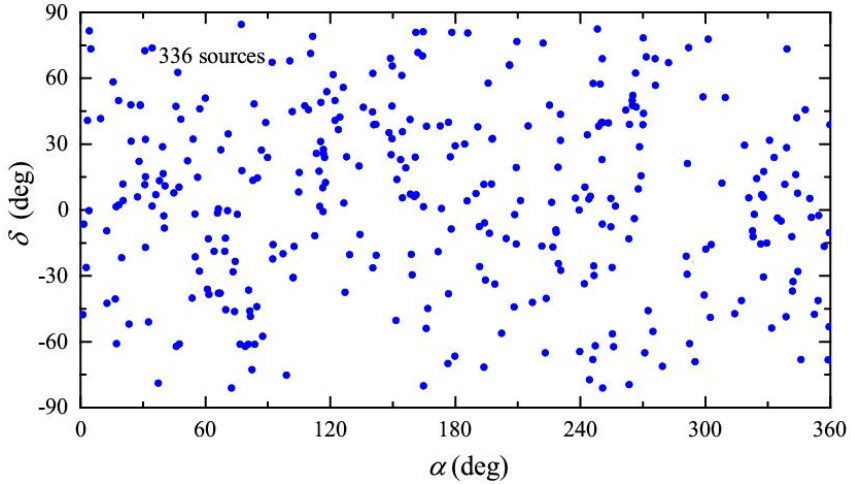
Selection of sources based on "proper motion"

- Select sources with motion $\mu < 50\ \mu as\ yr^{-1}$
  - 318 sources with mean declination = $10.54°$

- For more homogeneous distribution we change the restrictions
  - Northern hemisphere: $\mu < 40\ \mu as\ yr^{-1}$
  - Southern hemisphere: $\mu < 60\ \mu as\ yr^{-1}$
  - 336 sources with mean declination = $5.12°$

More uniform set

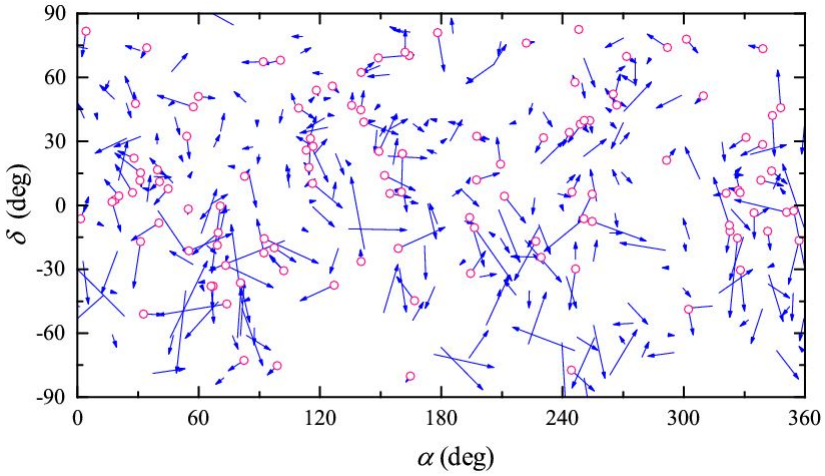




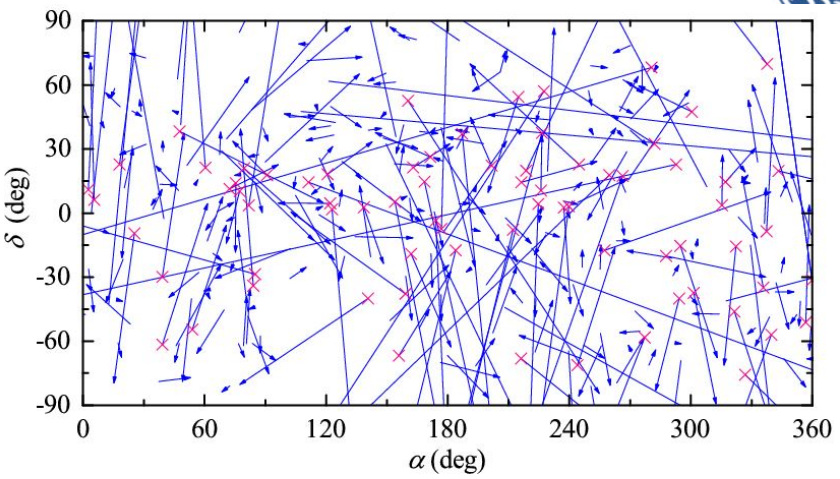
$\omega = 1.169\ \mu as\ yr^{-1}$

$\omega = 0.668\ \mu as\ yr^{-1}$

New list vs ICRF2 defining sources



336 new sources



295 ICRF2 sources (more uniform set)

- Fit the apparent motion of sources to global and glide simultaneously

sources	r_1	r_2	r_3	r	g_1	g_2	g_3	g
295 ICRF2	1.95	-17.1	1.12	17.2	-2.58	-2.45	-2.90	4.59
318 set	-0.17	-0.15	0.59	0.63	-0.02	-2.31	-4.06	4.68
336 set	-0.42	-0.25	0.85	0.98	-0.18	-2.89	-4.42	5.28

$unit$: $\mu as\ yr^{-1}$

Summary

- Possible way to evaluate the homogeneity of sky distribution
- Balance between homogeneity and stability
- More parameters to be tested to find a best criterion

Thank you for attention!

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