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at Ekudeni, South Africa

9th IVS General Meeting

Defining Sources Selection and Celestial Reference Frame Stability

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Historic on Celestial Reference Frame using VLBI

- **ICRF1** *[Ma et. al., 1998]* 608 sources, **212 defining sources** (DS)
  - → $Obs > 20 ; T_{obs} > 2\ yr ; \sigma_{\alpha \cos(\delta)}, \sigma_{\delta} < 1\ mas$
  - → subset of DS → applied rotation : $d\alpha \cos(\delta), d\delta < 0{,}5\ mas \vee 3\sigma$
  - → not an arc-sources (NL) and structure index 1 or 2
- **ICRF-Ext-1** **+59 sources**
- **ICRF-Ext-2** *[Fey et. al., 2004]* +109 sources, **207 defining sources**

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- **ICRF2** *[Fey et al. 2015, 2009]* 3414 sources, **295 defining sources**
  - → $N_{sess}>10 ; T_{obs}>2$
  - → scored by coordinates time series wrms and formal error on coordinates estimates
  - → homogeneous declination coverage
  - → not an arc-sources (NL) and structure index 1 or 2

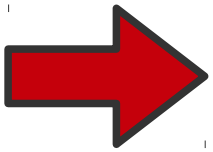
Why selecting defining sources ?

Purpose of a Celestial Reference System :

- Represent the Universe, hypothetically non-rotating

Purpose of a Celestial Reference Frame :

- Materialization of the Celestial Reference System



Need of Fixed direction of objects in the Universe from the Earth point of view.

But What do we really have ?

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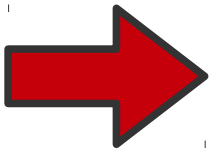

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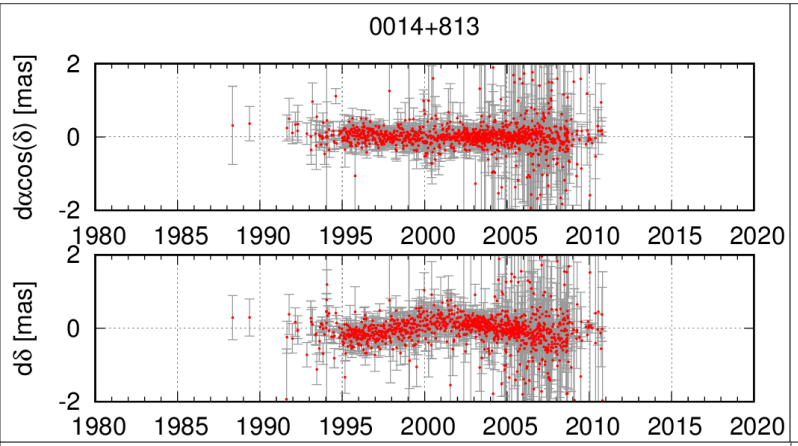
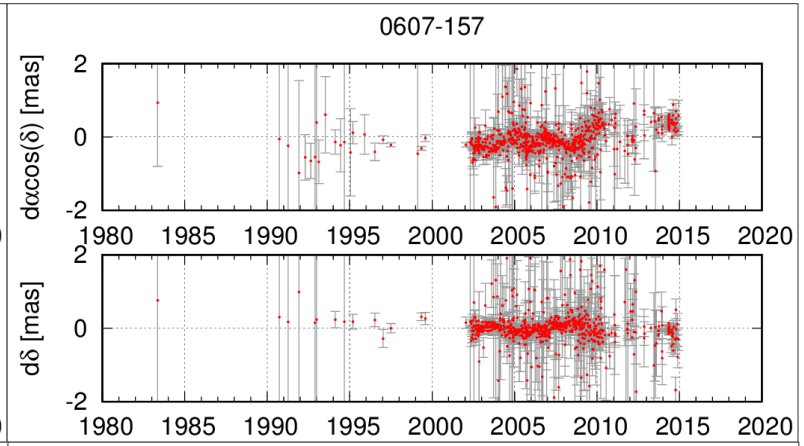
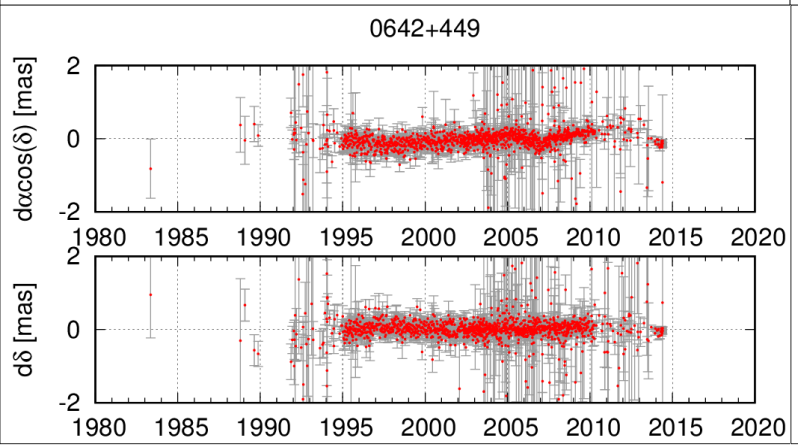
But What do we really have ?

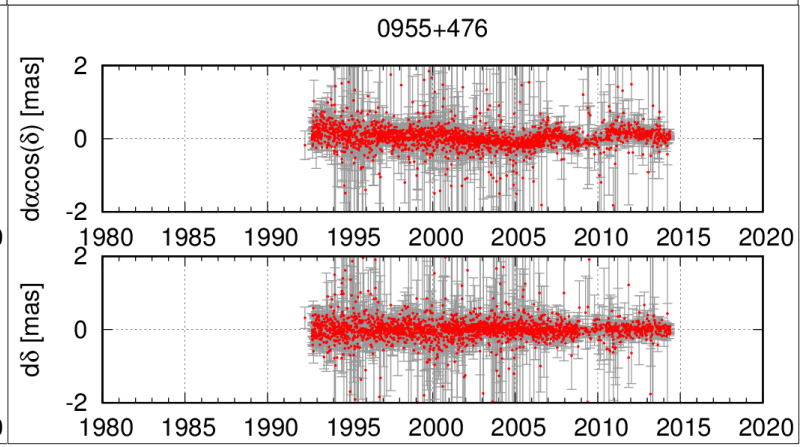
- **Extragalactic objects** with high power emission process : Active Galactic Nuclei (AGN)
- **Homogeneously scattered** on the celestial sphere
- **Inhomogeneously observed**
- **Animated** by several physical process

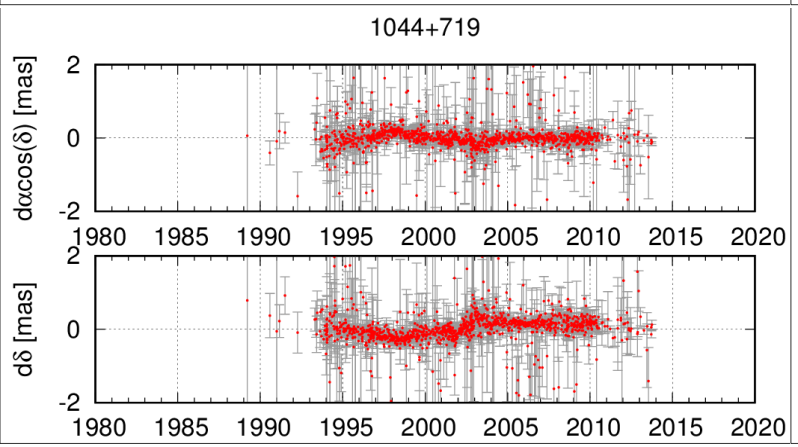
Examples of VLBI sources

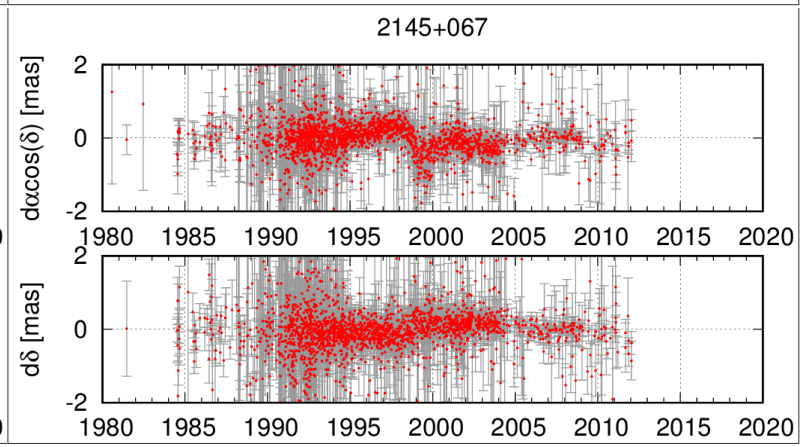






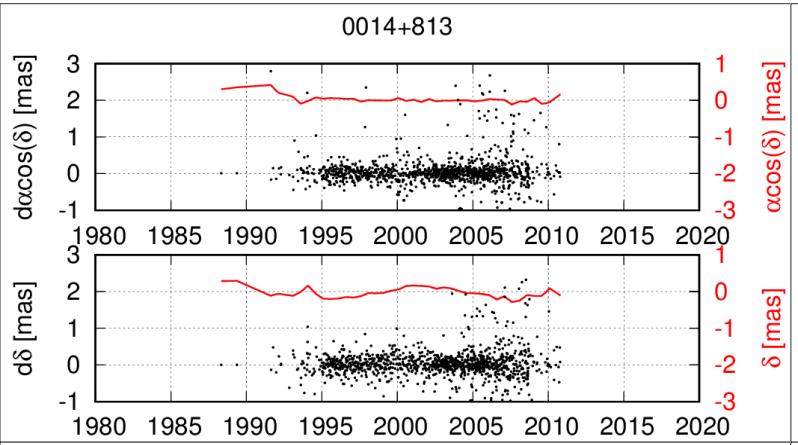


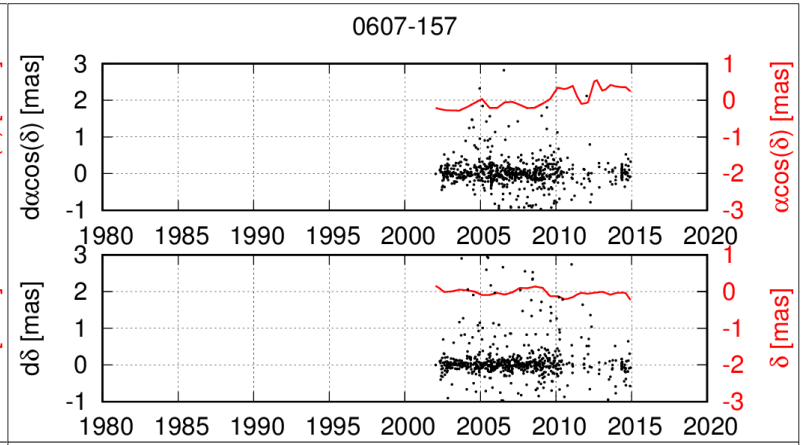


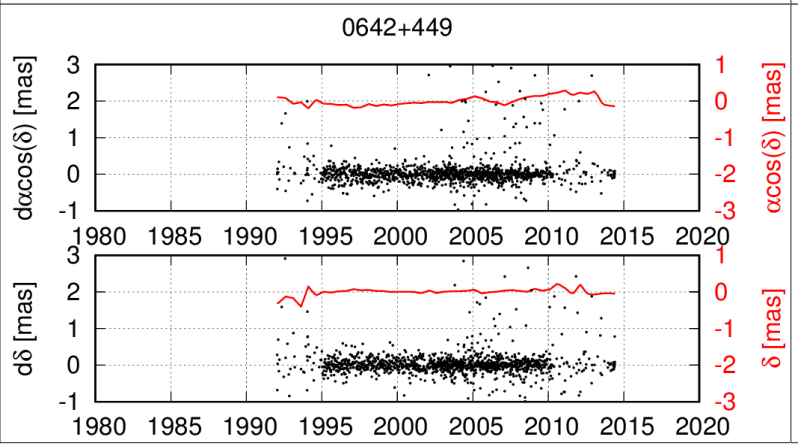


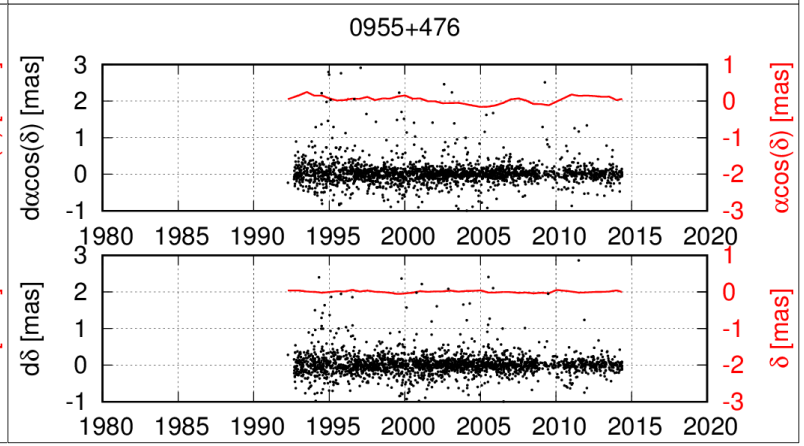
6 examples of sources with perceptible motion

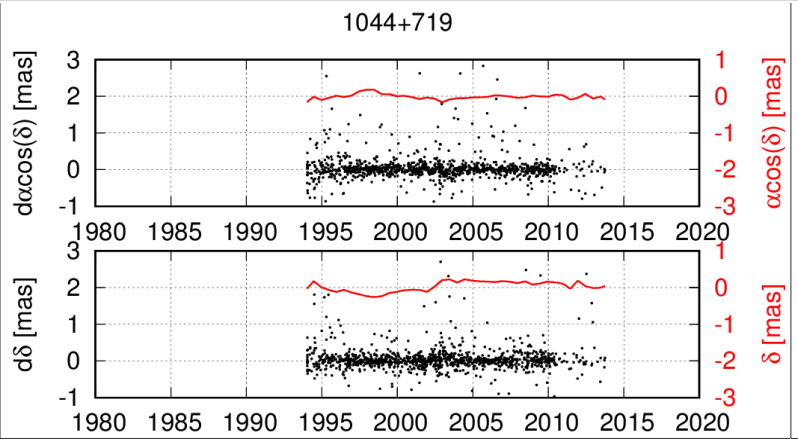
Decomposition of a source observed position

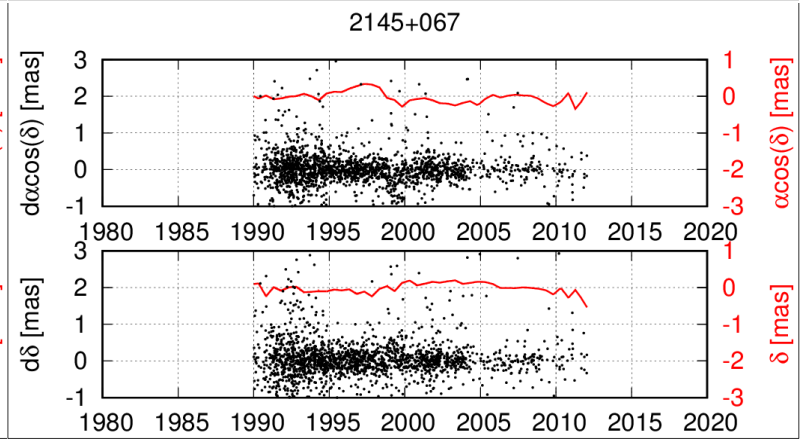












High Frequency Noise :

Thermal noise (instrumental) + Atmosphere effects + Source structure effects = Observing System noise

Low Frequency Noise or **Long-Term Tendency :**

Intrensic AGN motion [random walk] or [scintillation noise]

Characterization of sources

cf. poster « Source Characterization by the Allan Variance » *[Gattano, C., Lambert, S.]*

- **Sources « Allan 0 [AV0] »**
  - **White Noise behaviour**
    the allan variance decrease linearly with time-scale in a log-log scale

- **Sources « Allan 1 [AV1] »**
  - **Mixed white and colored noise with a with noise behaviour at long time-scale**
    the allan variance decrease, increase, decrease, … , decrease

- **Sources « Allan 2 [AV2] »**
  - **Mixed white and colored noise with a colored noise behaviour at long time-scale**
    the allan variance decrease, increase, …, increase

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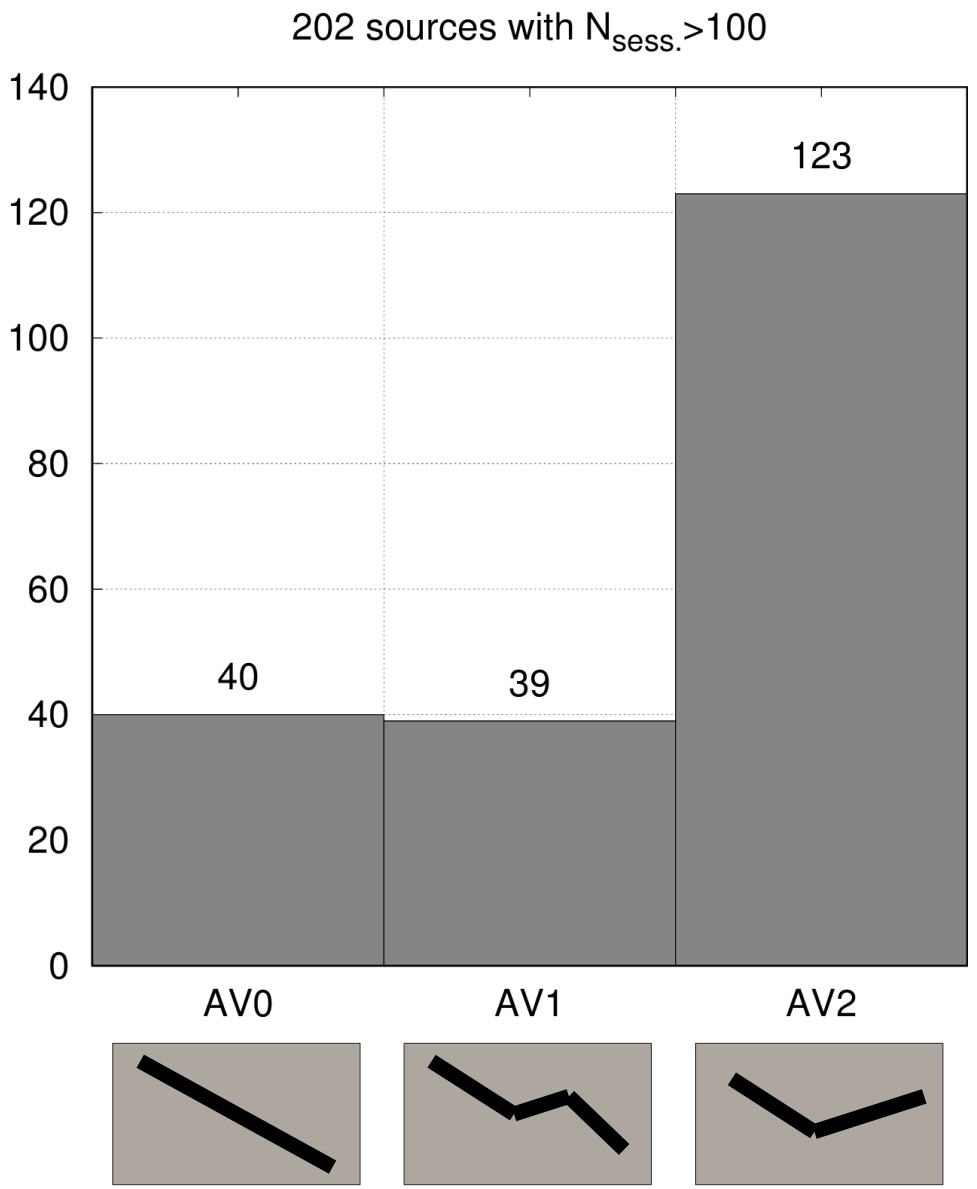
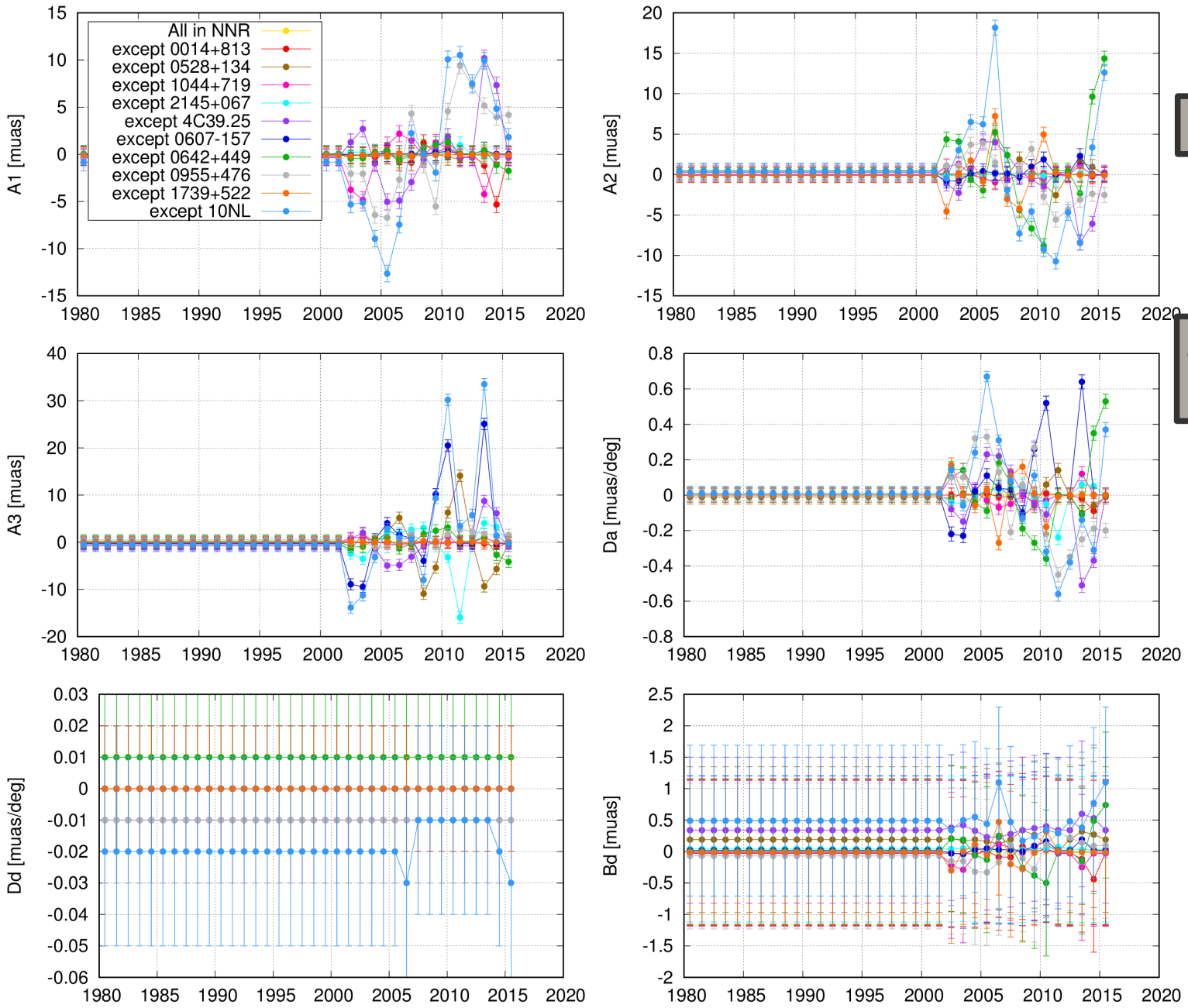


Impact of a non linear sources on a CRF



Referent solution :
Defining sources set

$202\ sources\ with\ N_{sess} > 100$

Test solution :
Defining sources set

$202\ sources\ with\ N_{sess} > 100$
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Figure.
Yearly rotation of all set of sources between referent and test solution

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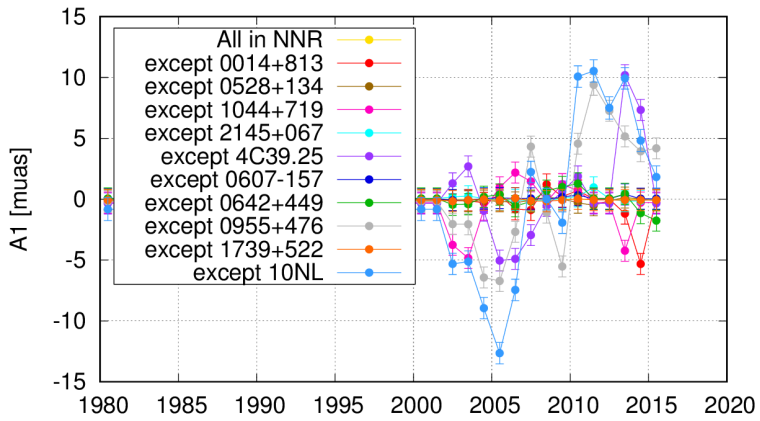

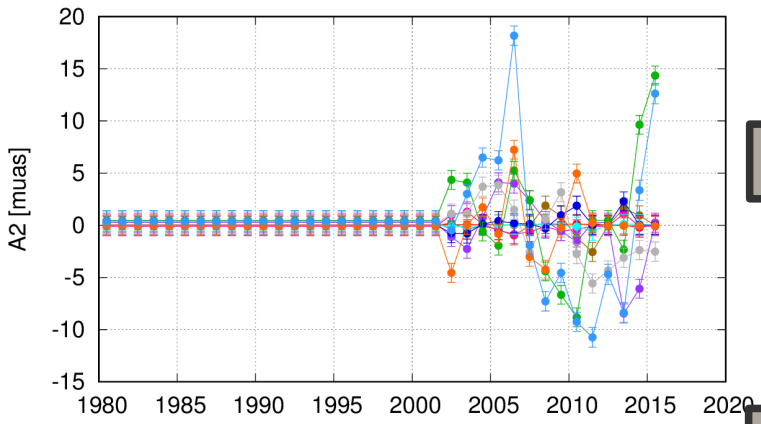

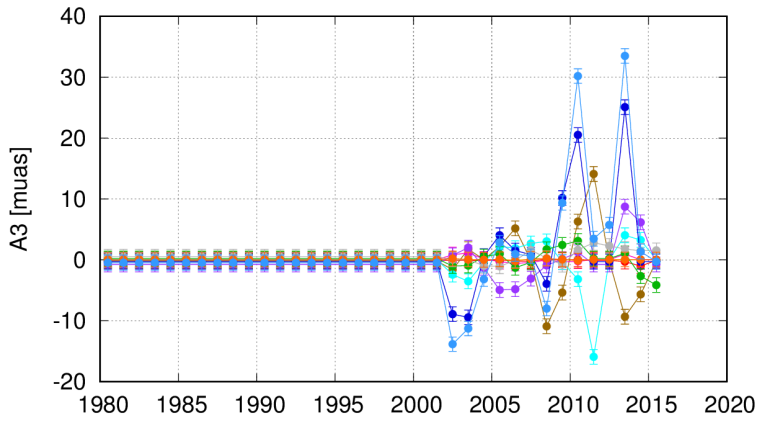

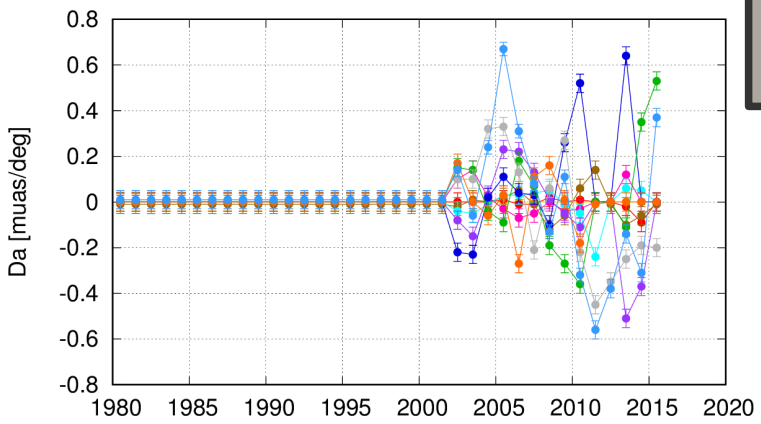

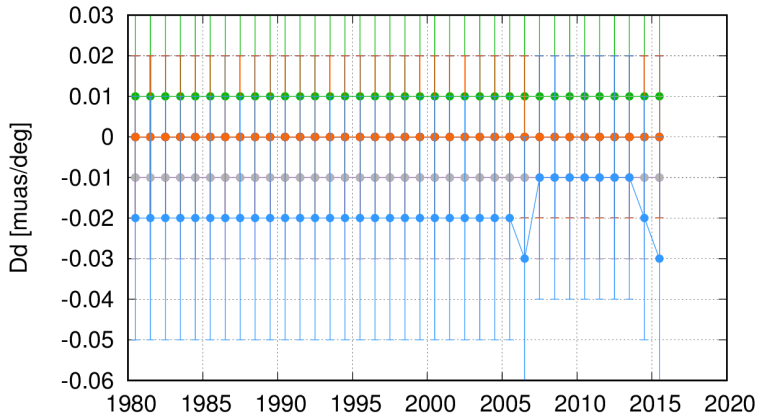

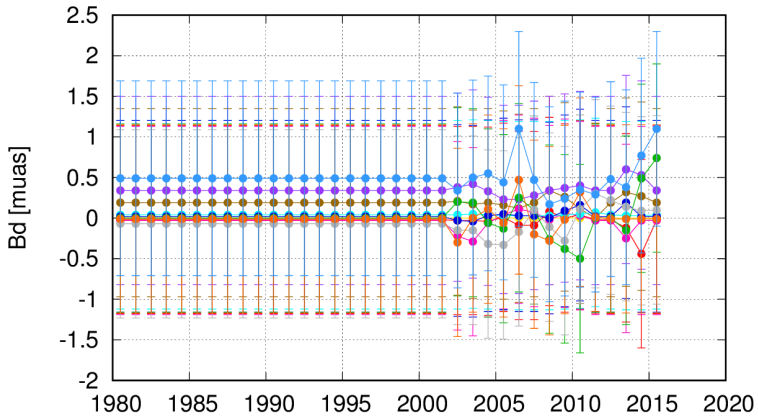

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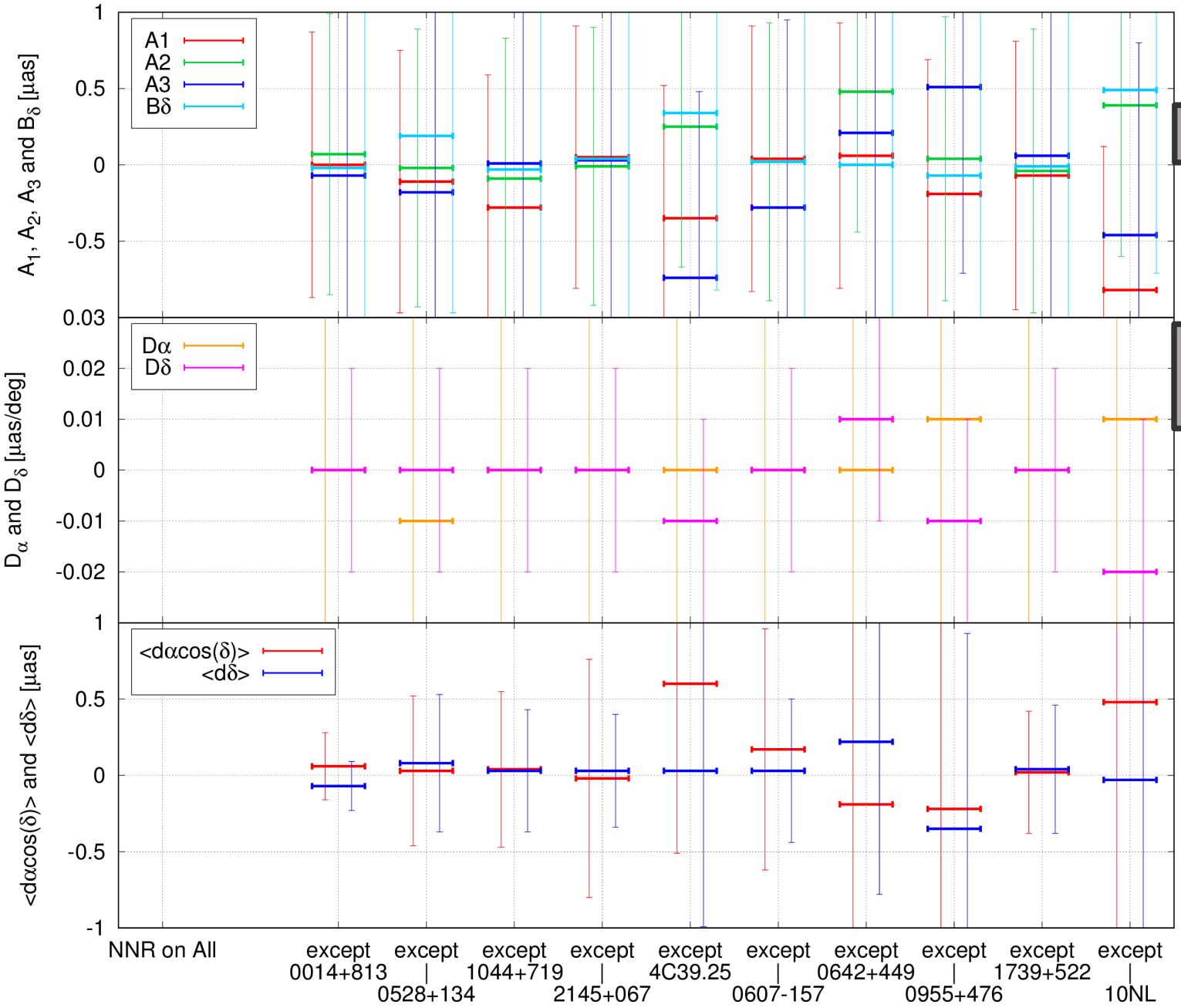
1-10 muas effect

cumulative effect

Figure.
Yearly rotation of all set of sources between referent and test solution

What happened for astrometry if we select a bad source ?



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Under muas effect

Additive effect

Figure.
Rotation, deformation, bias of common defining sources frame between referent and test solution

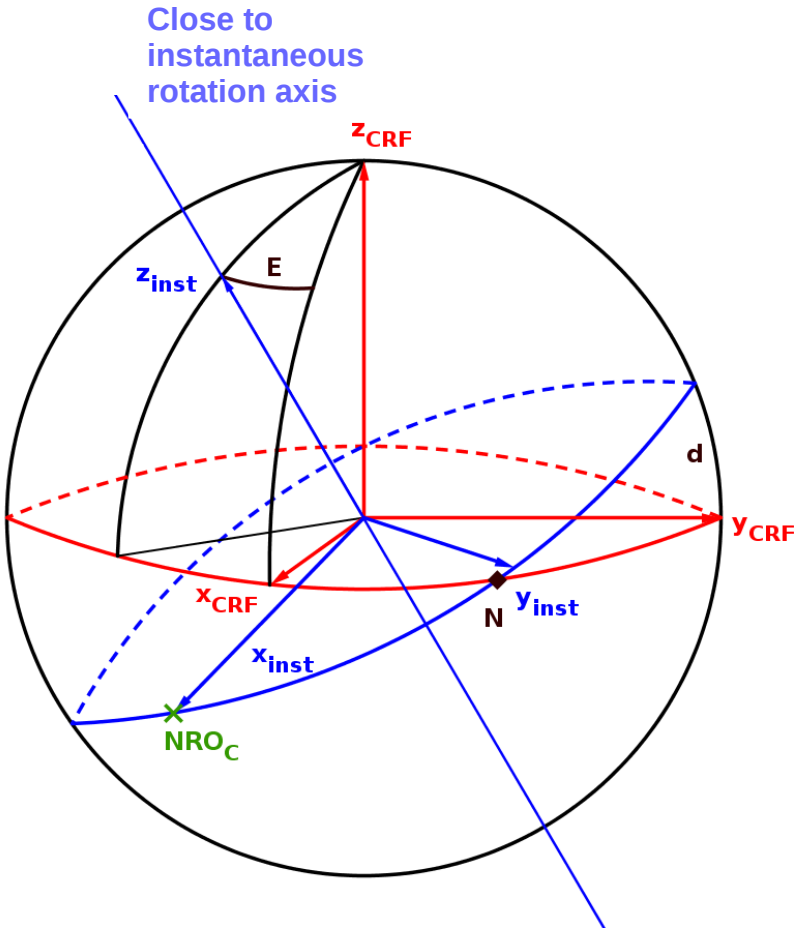
The Precession-Nutation

[CRF] = PN . A . PM [TRF]

Where **PN**, **A** and **PM** are rotation matrix products.

PN allows to change :

- From the immediate frame of the date *(having as pole the Earth rotation pole and possessing a non-rotating origin according to the celestial sphere)*
- To the celestial reference frame



⇒ **Precession-nutation**

- Parameters : **X** and **Y** compared to IAU2000A/2006 precession-nutation model : **dX** and **dY**

[Mathews et. al., 2002 ; Capitaine et. al. 2006]

What happened for geodesy if we select a bad source ?

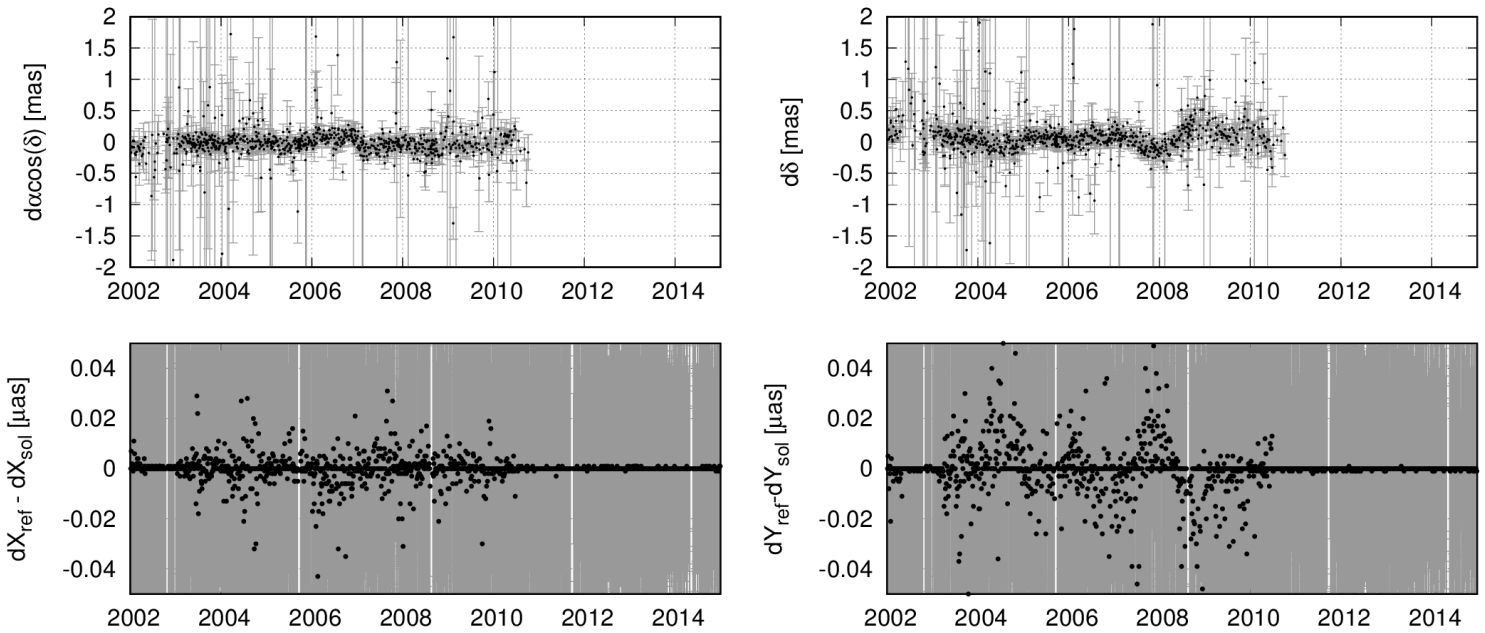
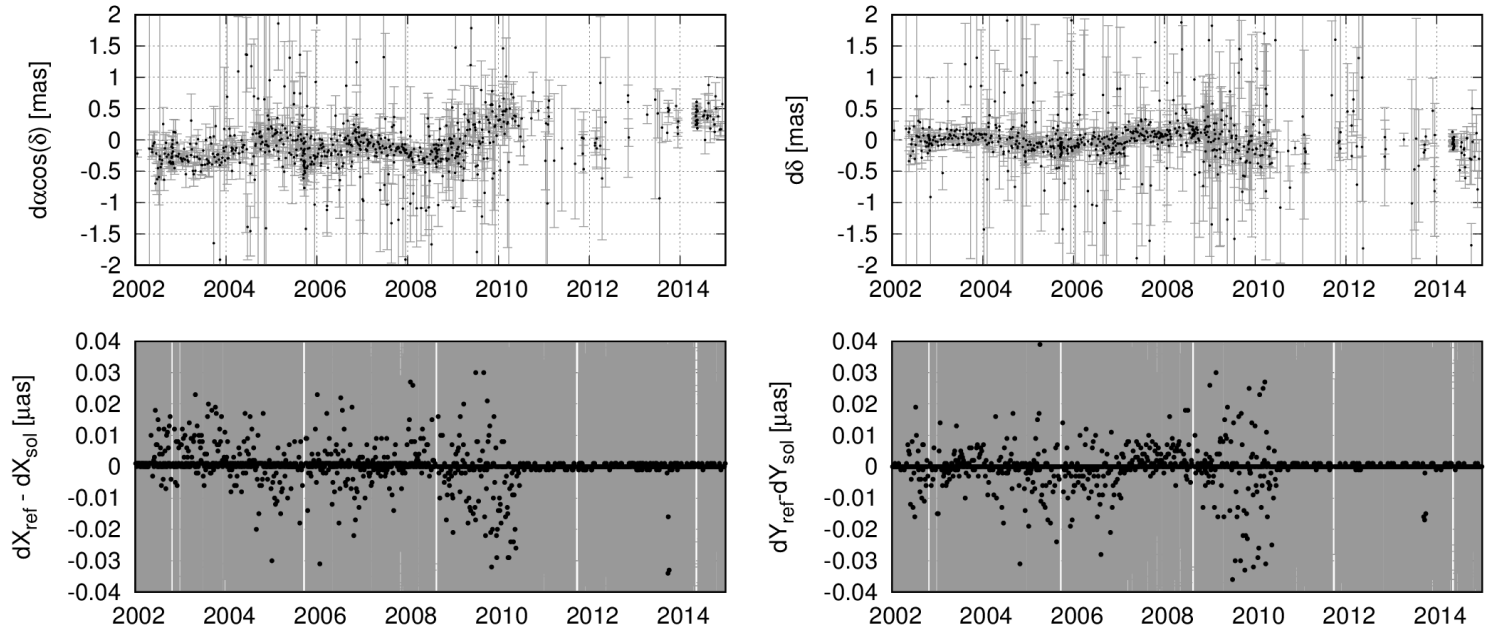


Figure.
Difference on nutation offset between the referent solution and the test solution.
The graph is compared to the coordinates time series of the non linear source differenciating the two solutions



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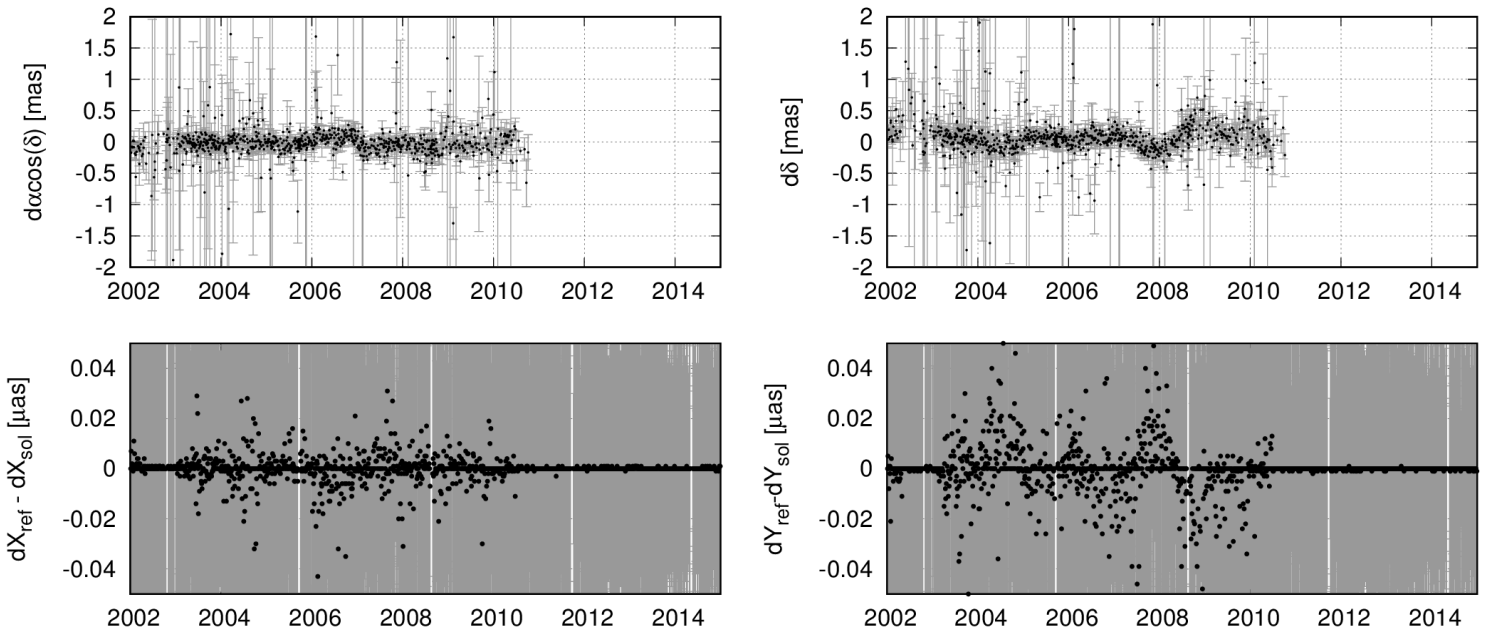

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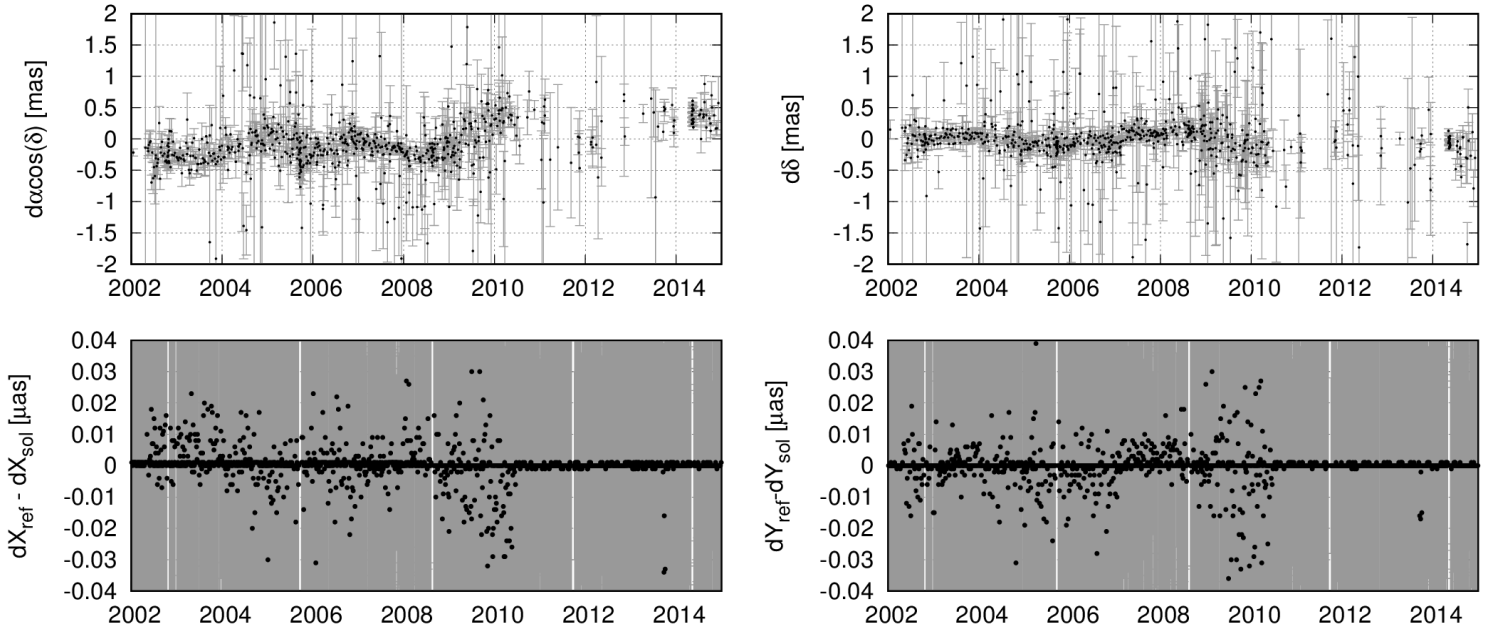
➡ Contamination of the precession-nutation parameters by the motion of the source **at the level of tenth of muas**



Use of the Allan Variance Characterization on Selection Process

Test several subsets on R1-R4 sessions (2002-today)

	Defining sources (Glo+NNR)	Standard Sources (Glo)	Non linear Sources (Loc)
Reference	ICRF2 DS	ICRF2 Std	ICRF2 NL
Test-no_threshold_1	AV0	AV1	AV2
Test-no_threshold_2	AV0 + AV1	-	AV2
Test-no_threshold_3	AV0	-	AV1 + AV2
Test_with_threshold_1	AV0(-) + AV1(-) + AV2(-)	-	AV0(+) + AV1(+) + AV2(+)
Test_with_threshold_2	AV0(-) + AV1(-) + AV2(-)	AV0(+)	AV1(+) + AV2(+)
Test_with_threshold_3	AV0(-) + AV1(-) + AV2(-)	AV0(+) + AV1(+)	AV2(+)
Test_with_threshold_4	AV0(-) + AV1(-)	AV2(-)	AV0(+) + AV1(+) + AV2(+)

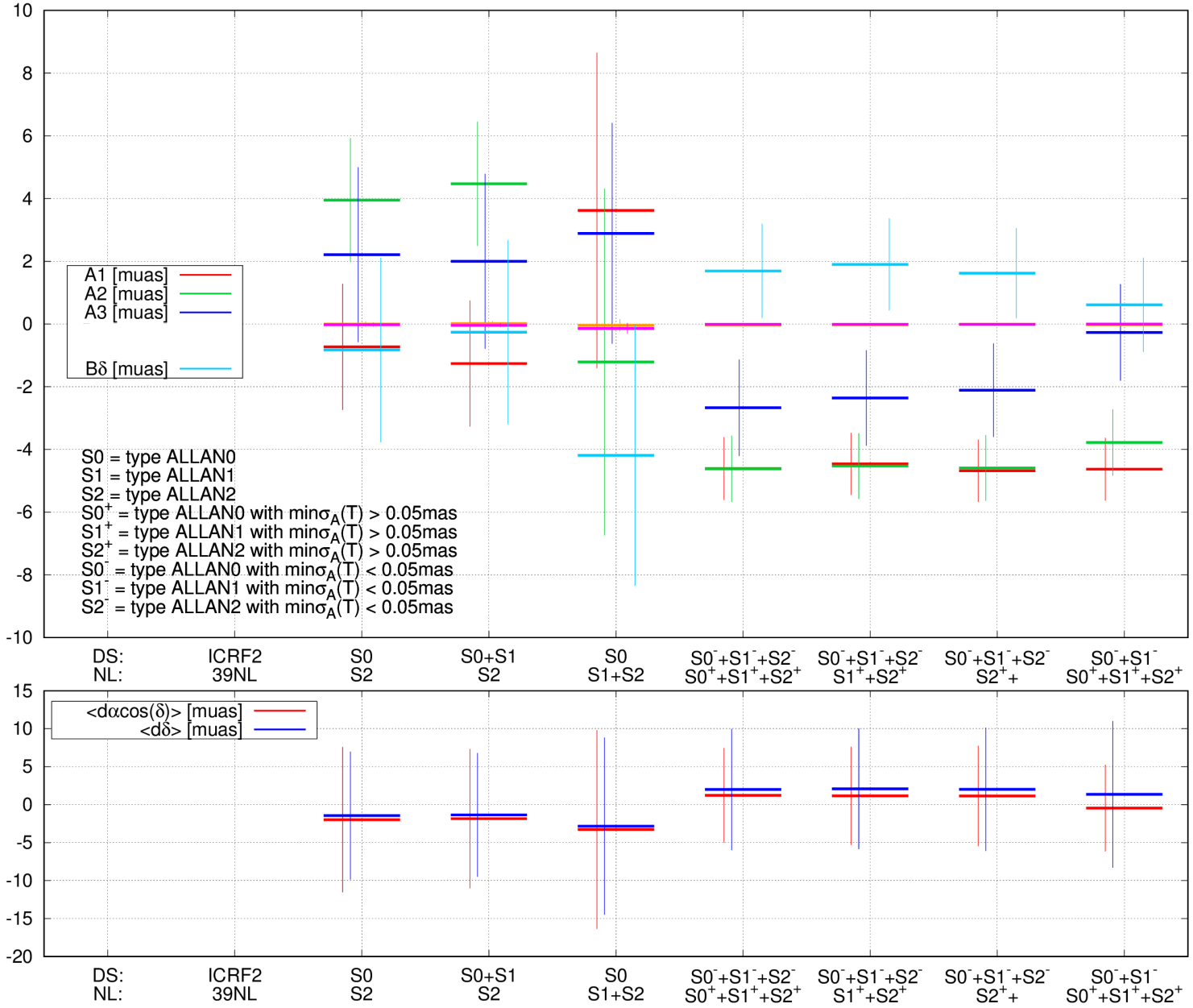
Threshold :

$$AVx(+.) \Rightarrow \sqrt{\left(min\left(AV_{\alpha.\cos(\delta)}\right)+min\left(AV_{\delta}\right)\right)} > 0{,}05\,mas$$

(x = 0,1,2)

$$AVx(-.) \Rightarrow \sqrt{\left(min\left(AV_{\alpha.\cos(\delta)}\right)+min\left(AV_{\delta}\right)\right)} < 0{,}05\,mas$$

Rotation between the CRF



We are dealing with

muas rotation

between the

solution

Impact on Precession-nutation estimates

Defining sources (Glo+NNR)	Standard Sources (Glo)	Non linear Sources (Loc)	σ(res.dX) [mas]	σ(res.dY) [mas]
ICRF2 DS	ICRF2 Std	ICRF2 NL	0,390	0,787
AV0	AV1	AV2	0,299	0,839
AV0 + AV1	-	AV2	0,297	0,840
AV0	-	AV1 + AV2	0,254	0,753
AV0(-) + AV1(-) + AV2(-)	-	AV0(+) + AV1(+) + AV2(+)	0,428	0,799
AV0(-) + AV1(-) + AV2(-)	AV0(+)	AV1(+) + AV2(+)	0,412	0,804
AV0(-) + AV1(-) + AV2(-)	AV0(+) + AV1(+)	AV2(+)	0,405	0,809
AV0(-) + AV1(-)	AV2(-)	AV0(+) + AV1(+) + AV2(+)	0,429	0,800

Impact on Precession-nutation estimates

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AV0(-) + AV1(-)	AV2(-)	AV0(+) + AV1(+) + AV2(+)	0,429	0,800

Best configuration according to the precession-nutation residuals after adjustment of the 42 nutations *[Mathews et. al. 2002]* with the annual retrograde nutation variable and adjustment of the Free Core Nutation

Conclusion

- Allan Variance can **classify sources with respect** to the noise, i.e. **internal motion**, of the sources.
- **Too few sources have a well-suited behaviour**.
- **We can't select the perfect CRF** where a sufficent number of defining do not show an internal motion at the current level of accuracy and on all the observation time span.
- **Residuals on precession-nutation** can be a way to compare CRFs and select the best one
  (commonly used tool : statistical rotation of a subset of the CRF and time-rotation of the CRF using the coordinates time series)

Future Works

- We have to test our new classification on the ICRF2 data set to directly compare the two selection algorithm of defining sources.

- Limited by the number of good sources, we can think about using **finite-time defining sources**, or **local defining sources**, i.e. such a source will constrain the orientation of the CRF on a finite time range.

- Allan variance can **provide a time range** for each source where they will have the white noise behaviour that we search.