10th IVS General Meeting, Longyearbyen, Spitsbergen, Norway
3-8 June 2018

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Effect of VLBI Observation Network on Source Stability

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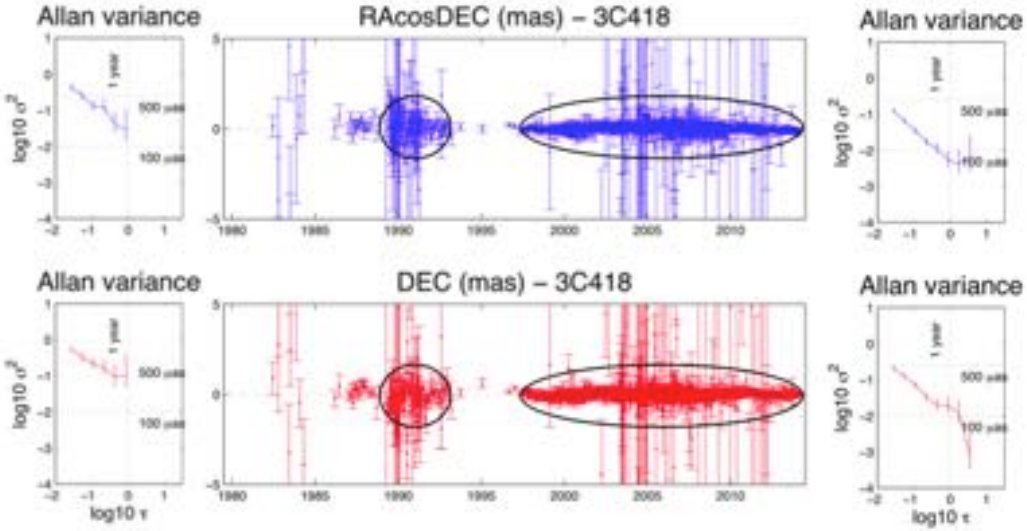
Context

1988 - 1993

RA noise:
Level at 1-year: 180 µas
Type: white to flicker

DEC noise:
Level at 1-year: 300 µas
Type: quasi flicker



1997 – 2005

RA noise:
Level at 1-year: 70 µas
Type: white

DEC noise:
Level at 1-year: 110 µas
Type: white

- Causes of non-stationarity in time series of source position.
  - One possibility is the improvement of the observations with time. The observations can change due to geometry or there can be improvements to the instrumentation or data processing.
  - A second possibility is that a source may be dynamic, changing with time. The problem we face is to investigate a source that might be changing, with an observing instrument or data that is changing with time, and whose sampling might be inhomogeneous.
- We can investigate the stability of a source by looking at the change in Allan variance for different time scales (see Gattano et al. – submitted to A&A).
- What is behind the non-stationarity?

Data studied in this work
Latest GSFC solution

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- Goddard VLBI time series.
- S/X solution generated on May 2, 2018.
- Databases from August 03, 1979 through March 26, 2018, for a total of 6182 sessions.
- Includes all of the VCS1-6, VCS-II, and UF001 A-T/UG002 A-C VLBA sessions.
- VLBI time series position for 4529 sources.
- There are significant discrepancies in number of observations per source:

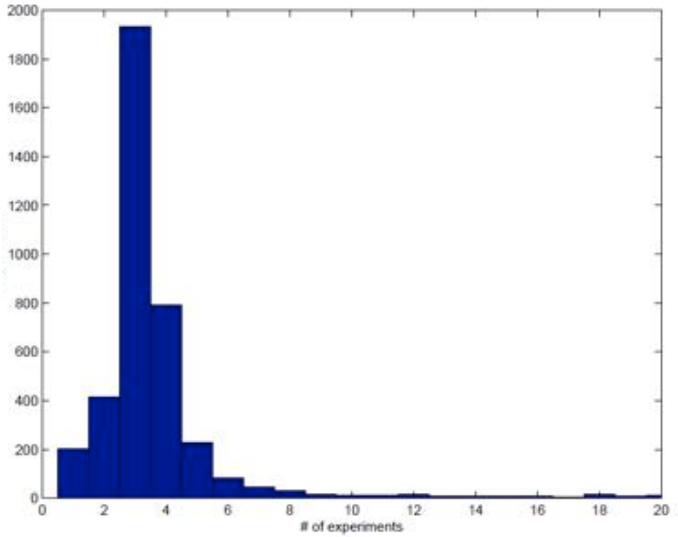
  222 sources observed successfully in only one experiment,
  3569 in 5 or less, 3747 in less than 10 experiments.

  ⇒ **Only 782 sources observed in 10 and more experiments.**

  OJ287 observed in 4361 experiments:
  April 1980 – March 2018.

  0552+398 observed in 4589 experiments:
  Aug 1979 – March 2018.

  3C418 observed in 1969 experiments.



3C418 on the period 2002.0-2018.3

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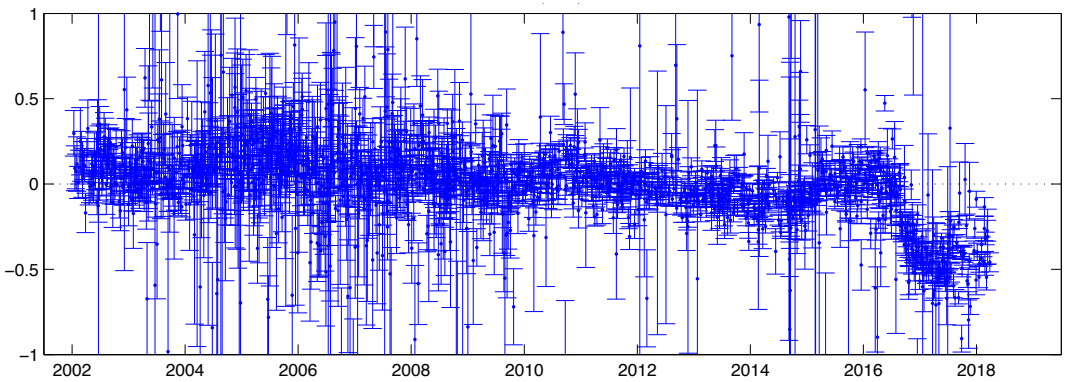
3C418 - RAcosDEC (mas)



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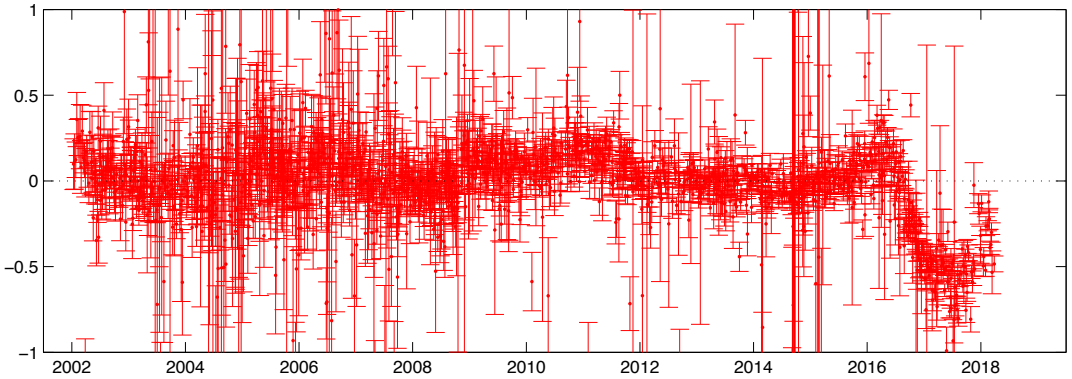
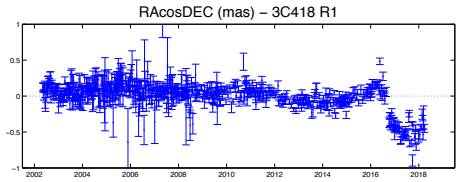
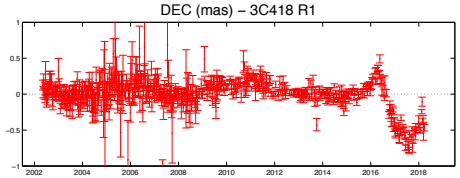


3C418 on the period 2002.0-2018.3





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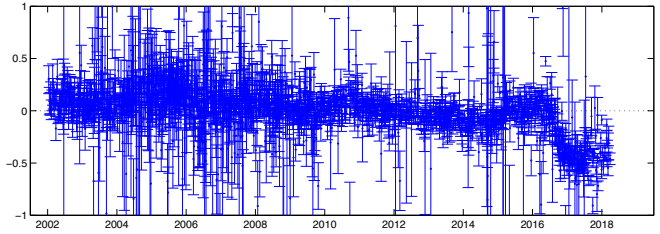

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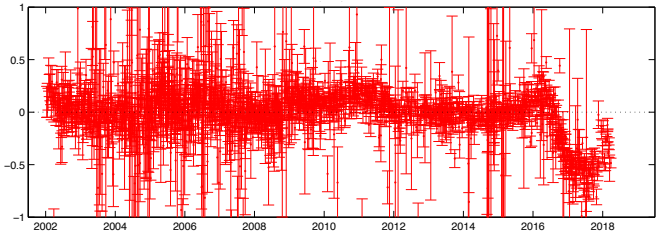
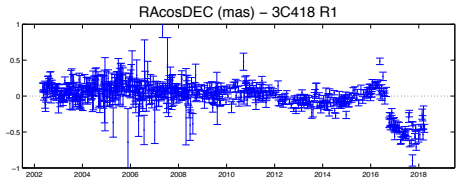
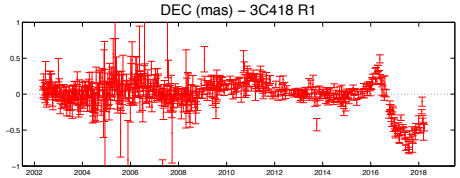


Type	#
All	1621
R1	592

3C418 on the period 2002.0-2018.3





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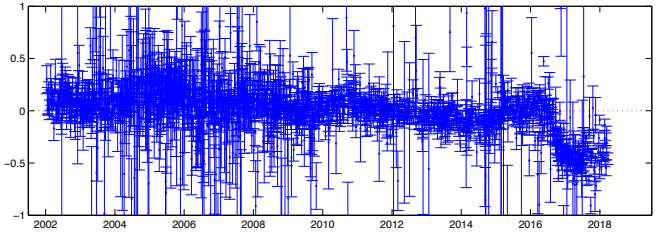

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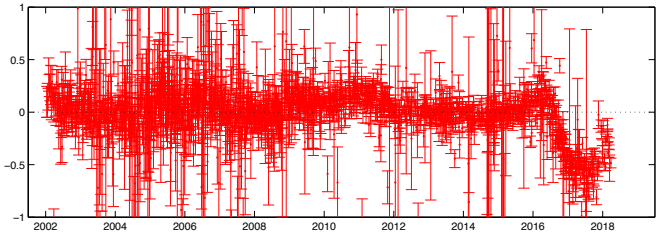
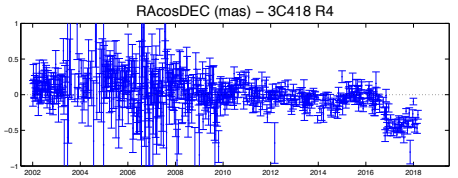
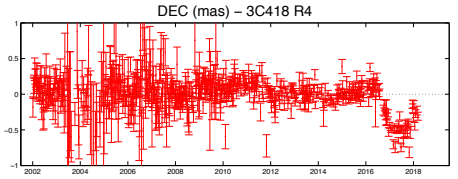
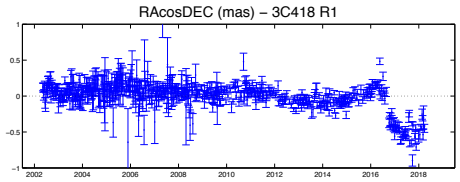


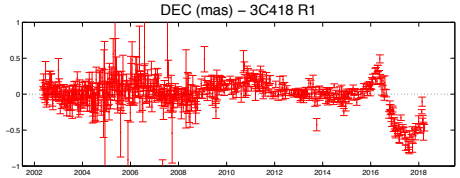


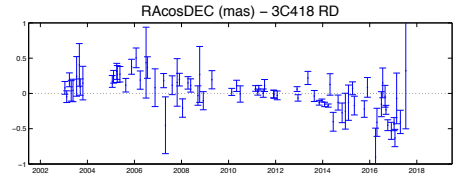


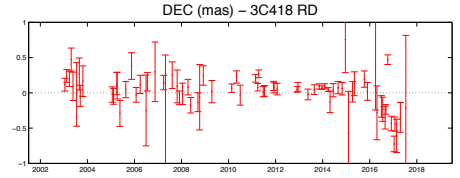
Type	#
All	1621
R1	592
R4	618

3C418 on the period 2002.0-2018.3









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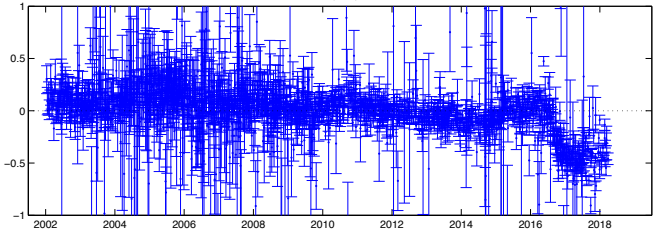

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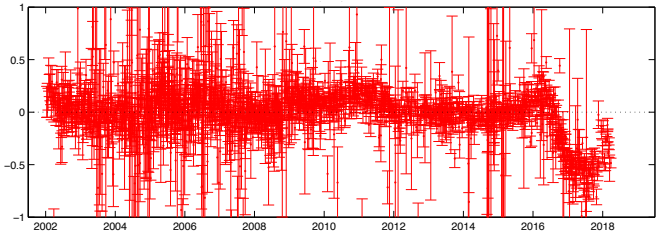
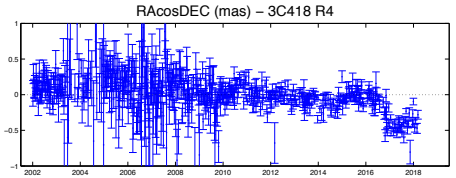
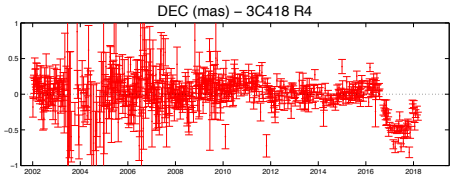
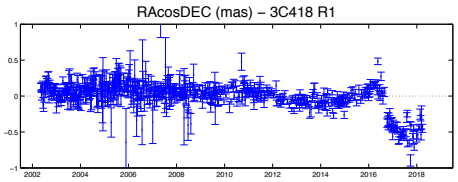


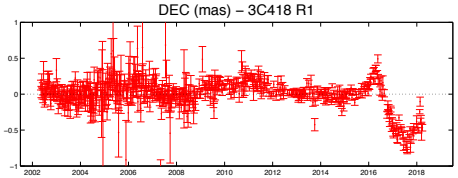


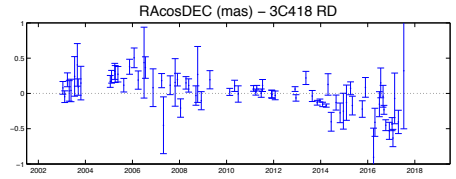


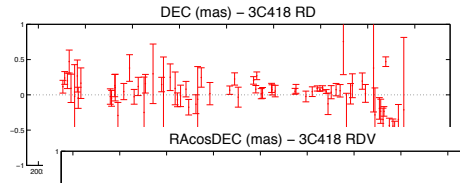
Type	#
All	1621
R1	592
R4	618
R&D	75

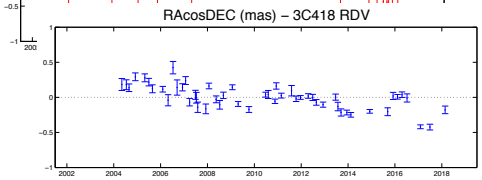
3C418 on the period 2002.0-2018.3

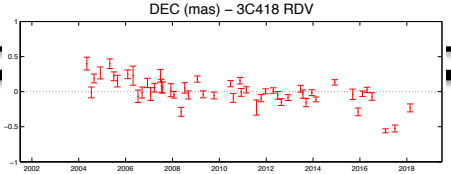


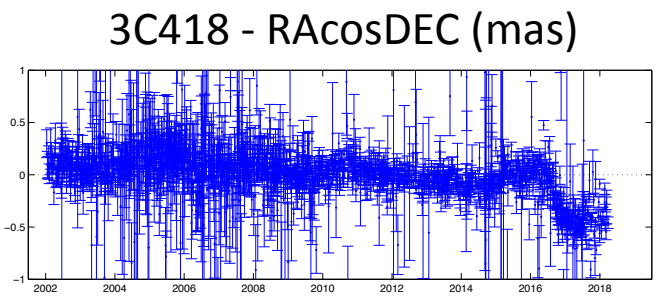


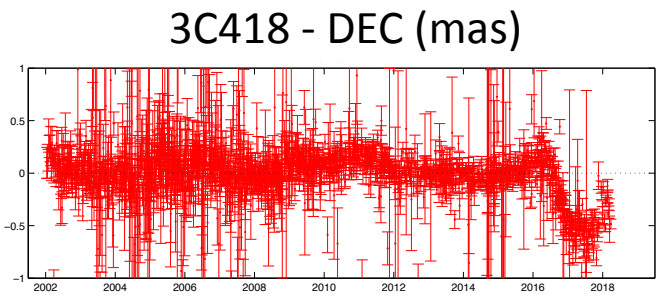


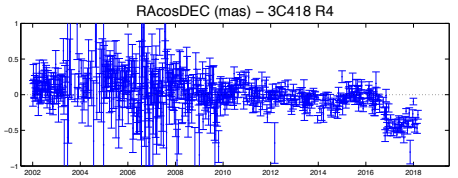


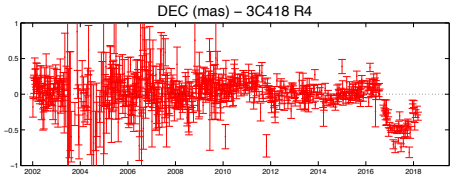












Type	#
All	1621
R1	592
R4	618
R&D	75
RDV	51

3C418 on the period 2002.0-2018.3

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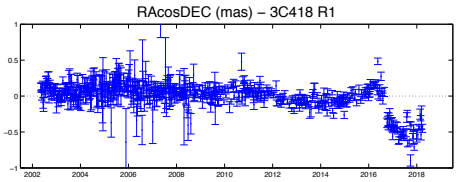
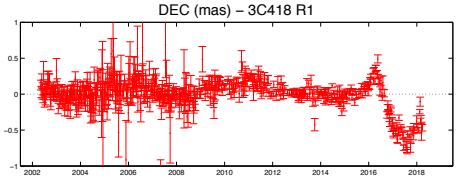
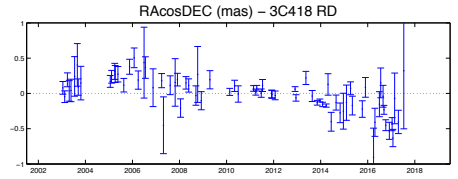
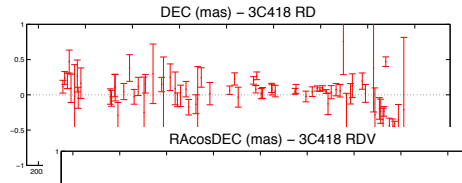
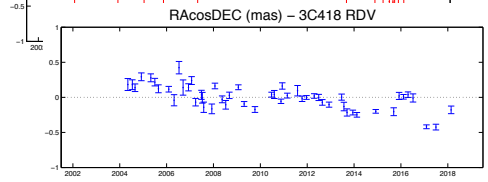
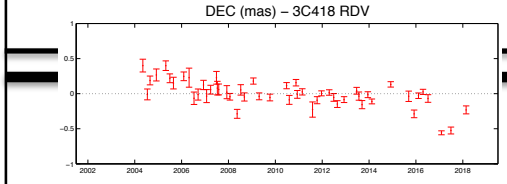




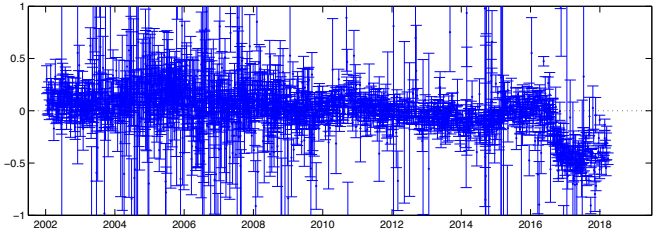








3C418 - RAcosDEC (mas)



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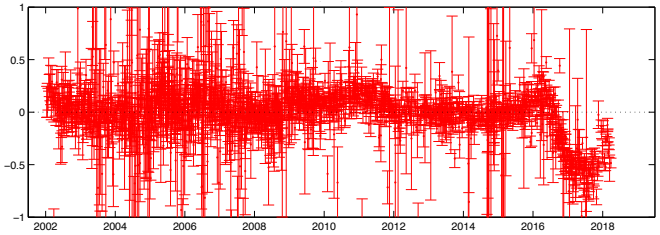
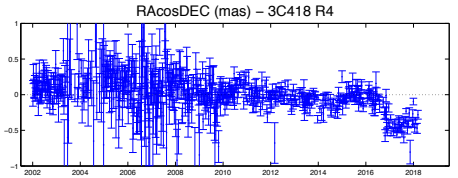
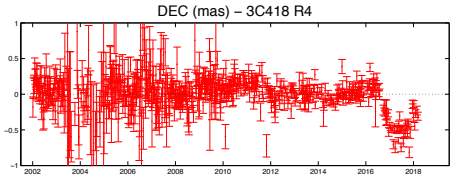
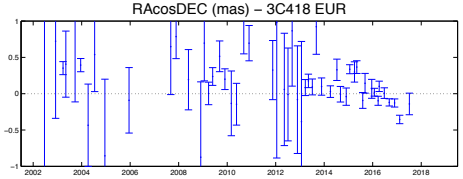
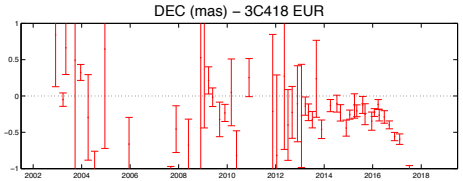




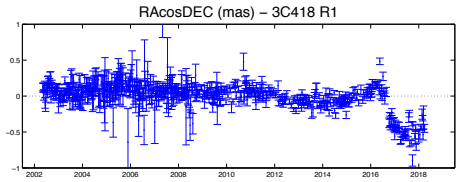


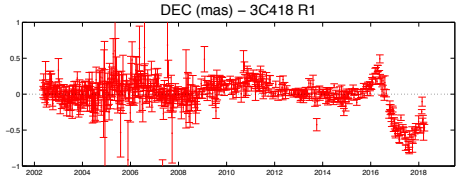


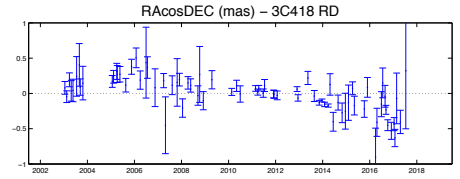


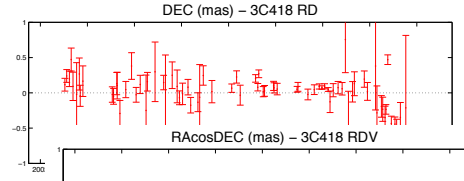
Type	#
All	1621
R1	592
R4	618
R&D	75
RDV	51
EURO	55

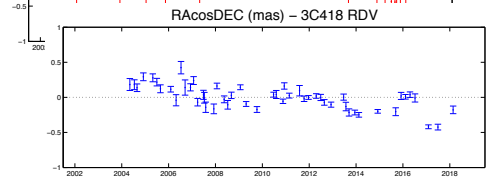
3C418 on the period 2002.0-2018.3

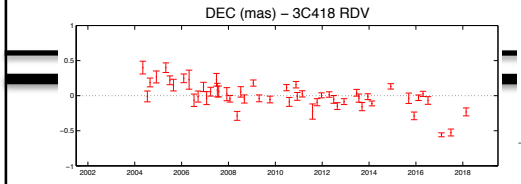












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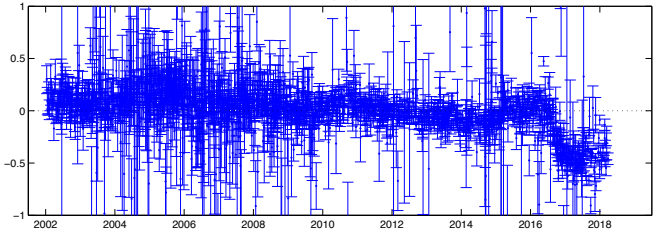

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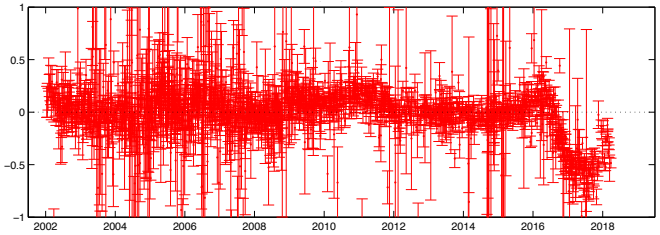

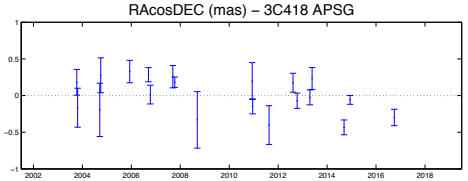

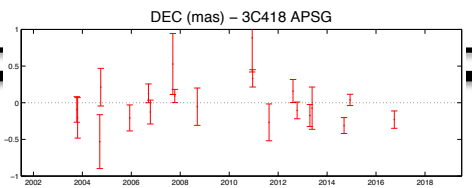

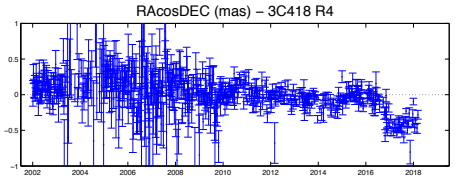

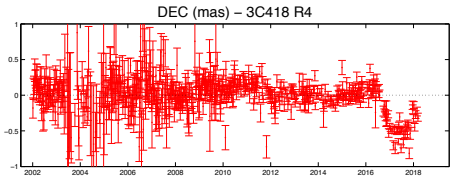

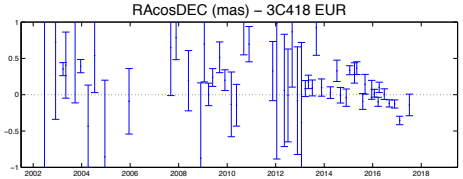

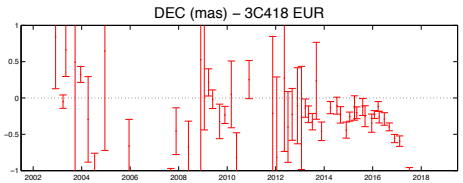

Type	#
All	1621
R1	592
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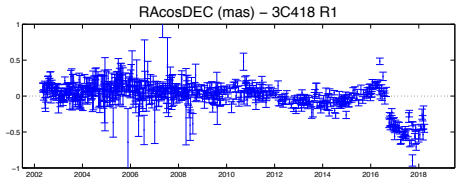
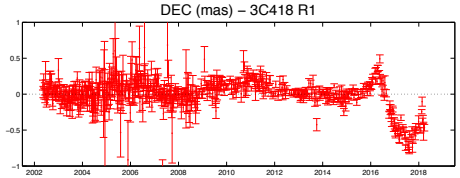
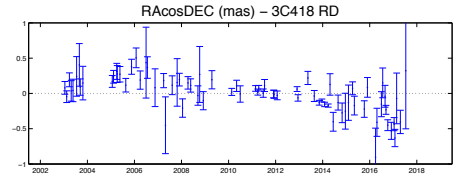
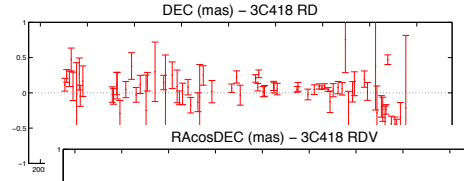
3C418 on the period 2002.0-2018.3

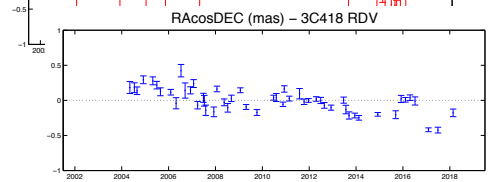
NVI, INC.

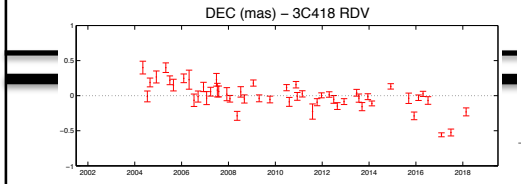




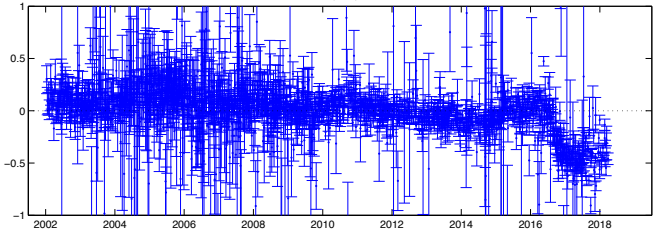




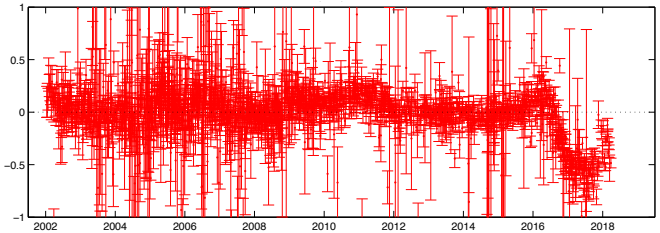


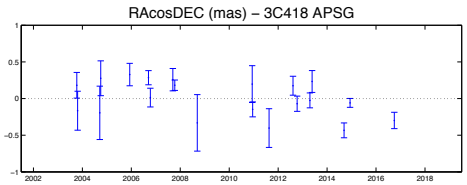


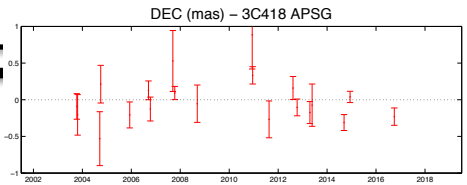
3C418 - RAcosDEC (mas)

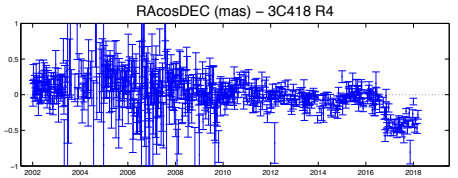


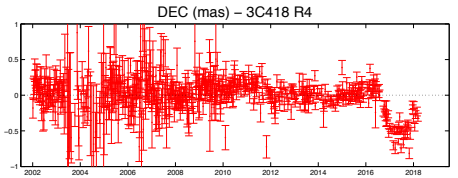
3C418 - DEC (mas)

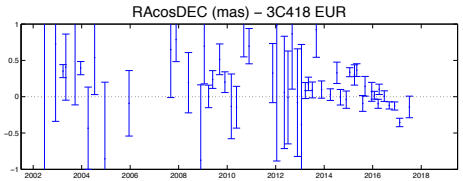


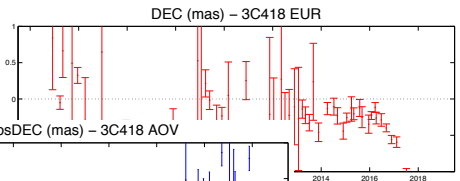


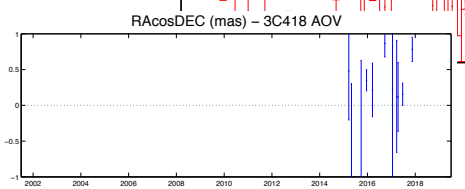


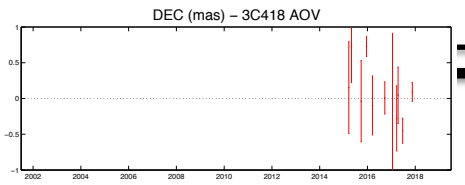












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All	1621
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R4	618
R&D	75
RDV	51
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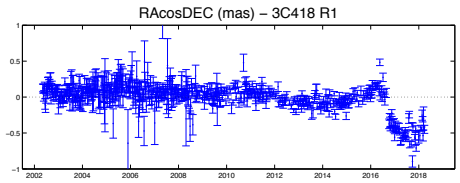
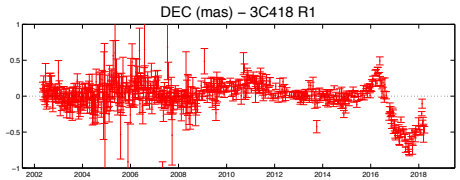
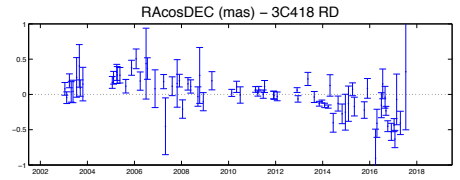
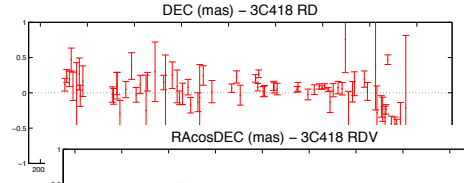
AOV	11

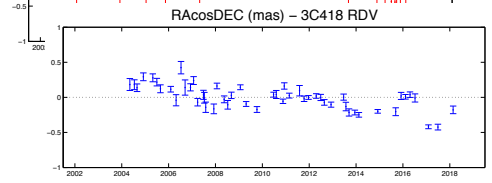
3C418 on the period 2002.0-2018.3

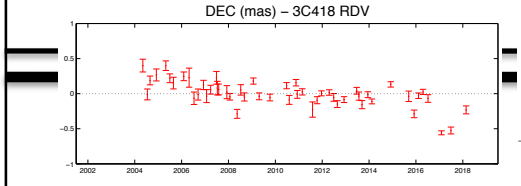




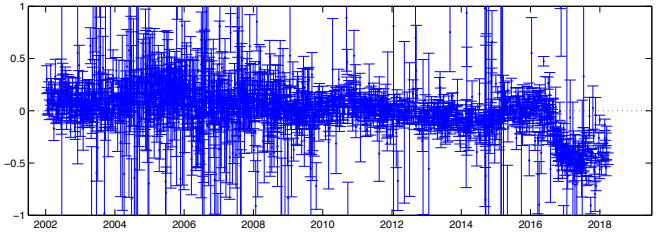




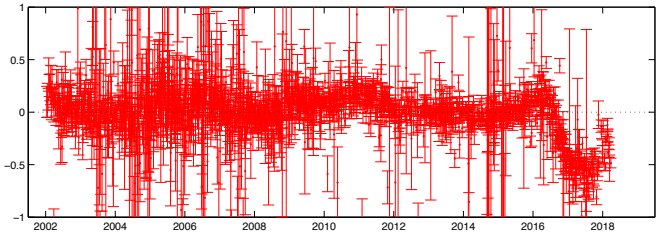


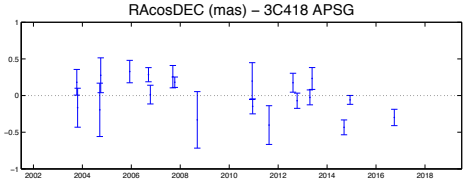


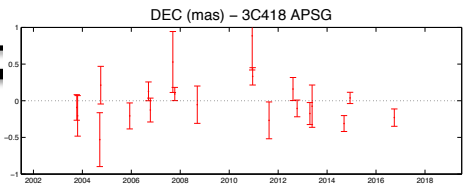
3C418 - RAcosDEC (mas)

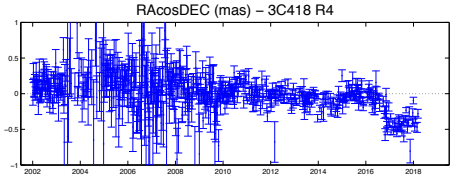


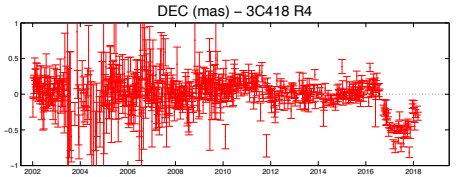
3C418 - DEC (mas)

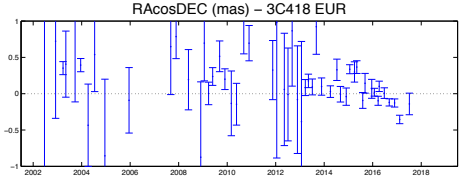


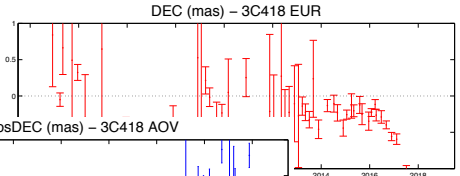


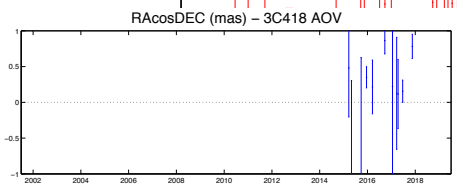


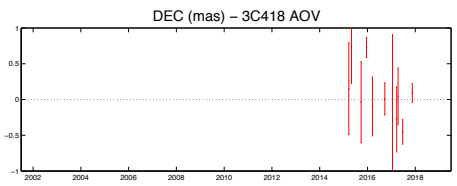






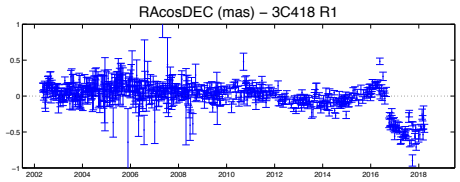


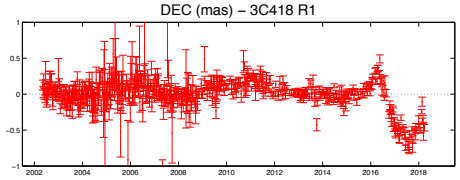


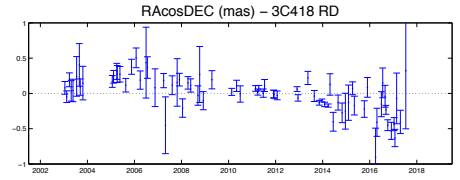


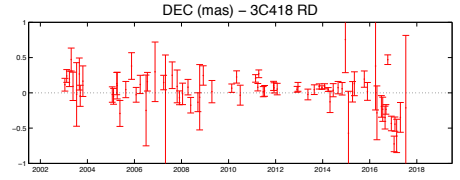
Type	#
All	1621
R1	592
R4	618
R&D	75
RDV	51
EURO	55
APSG	20
AOV	11
T2	63
AUST	5
AUA	2
AUG	2
Others	127

3C418 on the period 2002.0-2018.3

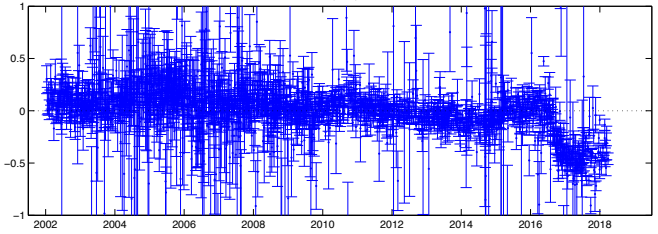








3C418 - RAcosDEC (mas)



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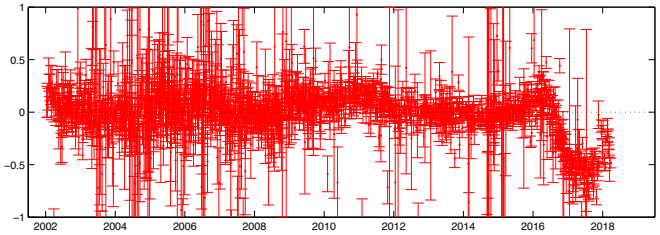

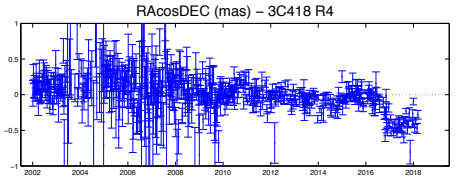

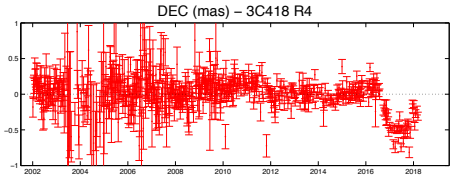

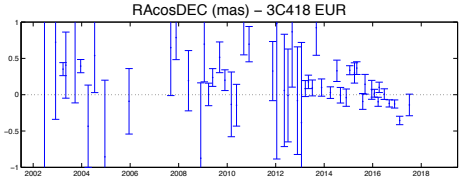

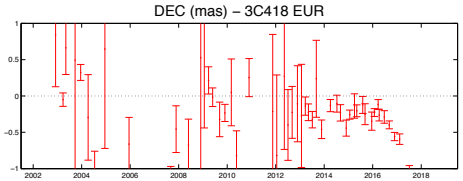

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AUG	2
Others	127

These sessions have different objectives, hence different observation networks, different scheduling software packages, different schedulers, different scheduling strategies, different technical settings (recording mode for example).

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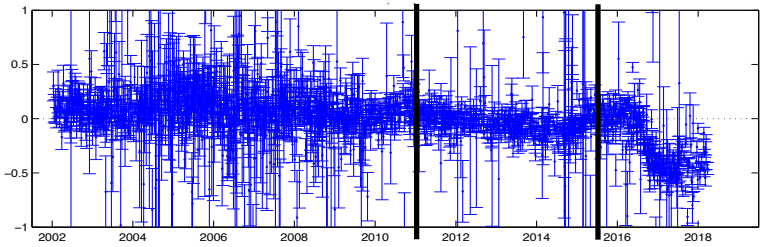
3C418 in R4 sessions

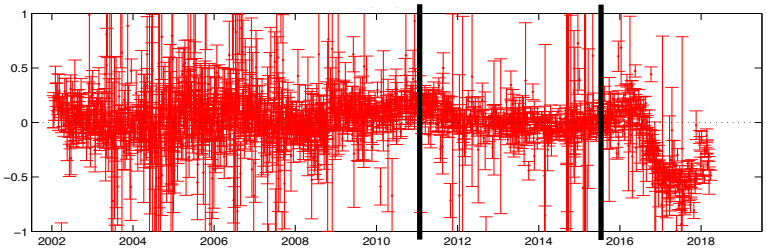
Position, number of observations and number of stations

NVI, INC.

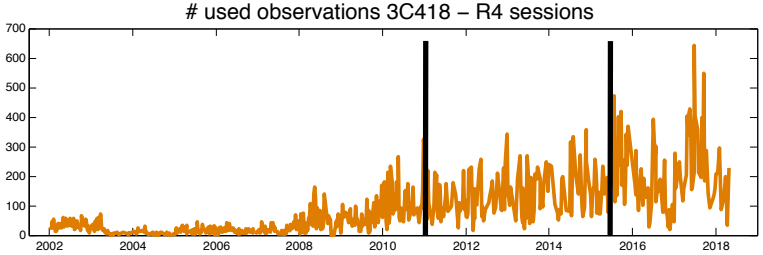
3C418 - RAcosDEC (mas)



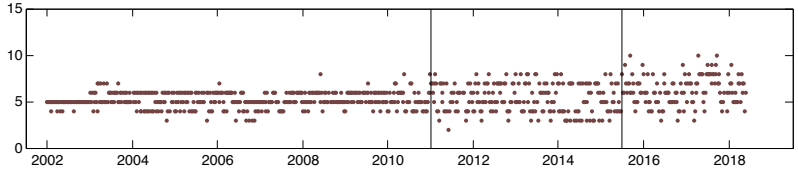
3C418 - DEC (mas)



used observations 3C418 – R4 sessions

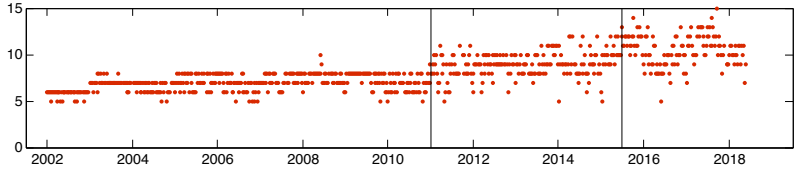


Stations in the North – R4



Stations in the South – R4

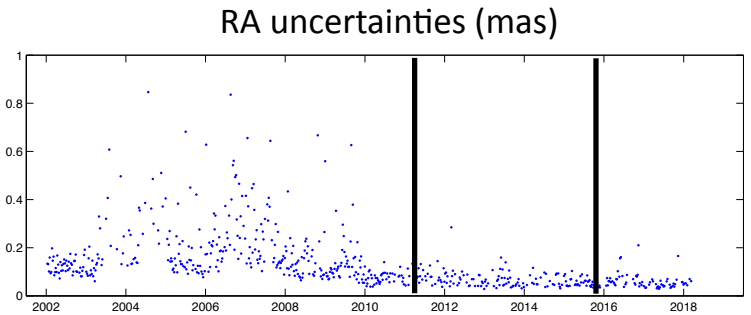
Total # of stations – R4

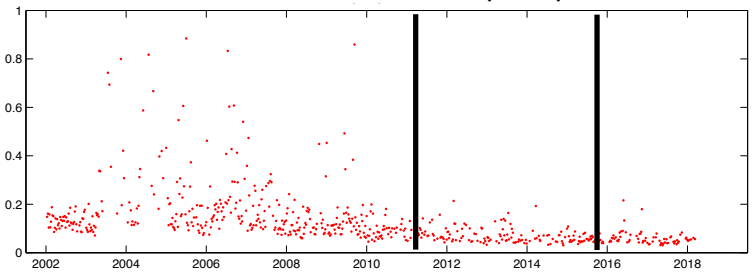


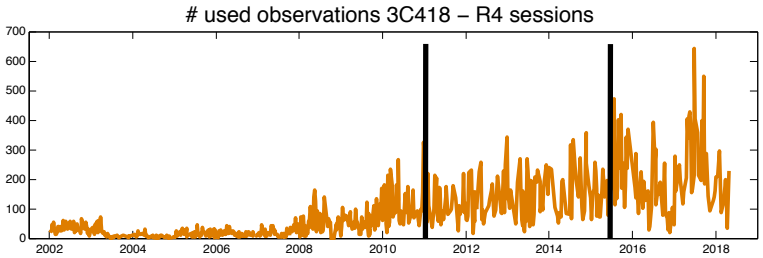
	Total # of stations		Stations in the north		Stations in the south	
	Aver.	Std	Aver.	Std	Aver.	Std
2002-2011	7.0	0.8	5.2	0.7	1.7	0.4
2011-2015.5	8.9	1.7	5.4	2.3	3.4	2.2
2015.5-2018.3	10.5	2.5	6.2	2.5	4.3	1.8

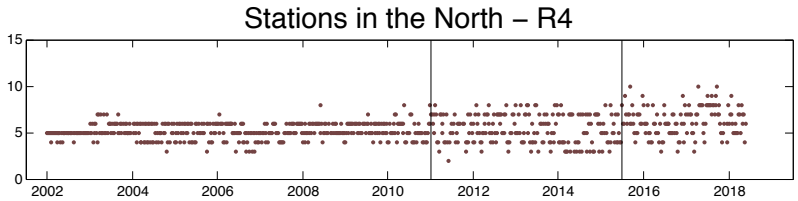
3C418 in R4 sessions

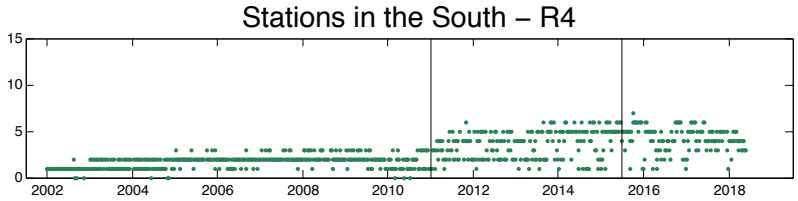
Position uncertainties, number of observations and number of stations

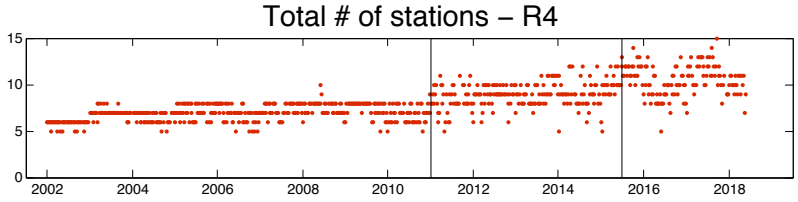












As expected the position uncertainties are correlated with the number of observations of the source during the session.
Does the change in number of observations and their distribution affect the statistical characterization of the source?
See C. Thomas et al. poster on complete study of R1 and R4 sessions.

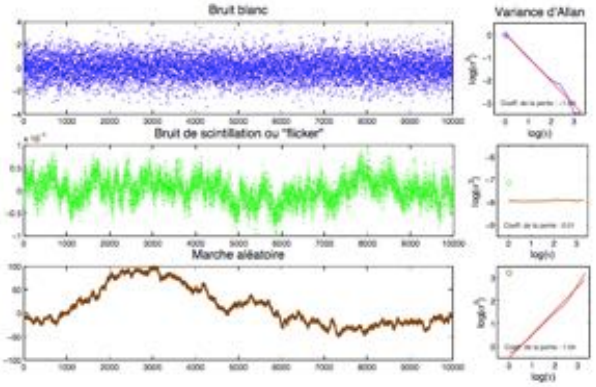
Tool to determine the type and level of noise: The Allan variance

NVI, INC.

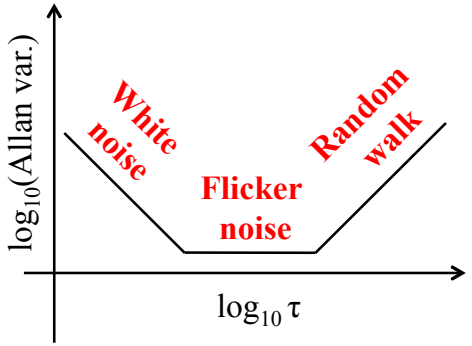
- The Allan variance is a statistical tool that gives the level and the type of noise of time series.
- If $(x_i)_{i=1,n}$ are the measurements and τ the sampling time, the

Allan variance is: $\sigma^2(\tau) = \frac{1}{2}\left\langle \left(\overline{x_{i+1}} - \overline{x_i}\right)^2 \right\rangle$

- The type of noise is determined by the slope of the curve $\log_{10}\left(\sigma^2(\tau)\right) = f\left(\log_{10}(\tau)\right)$



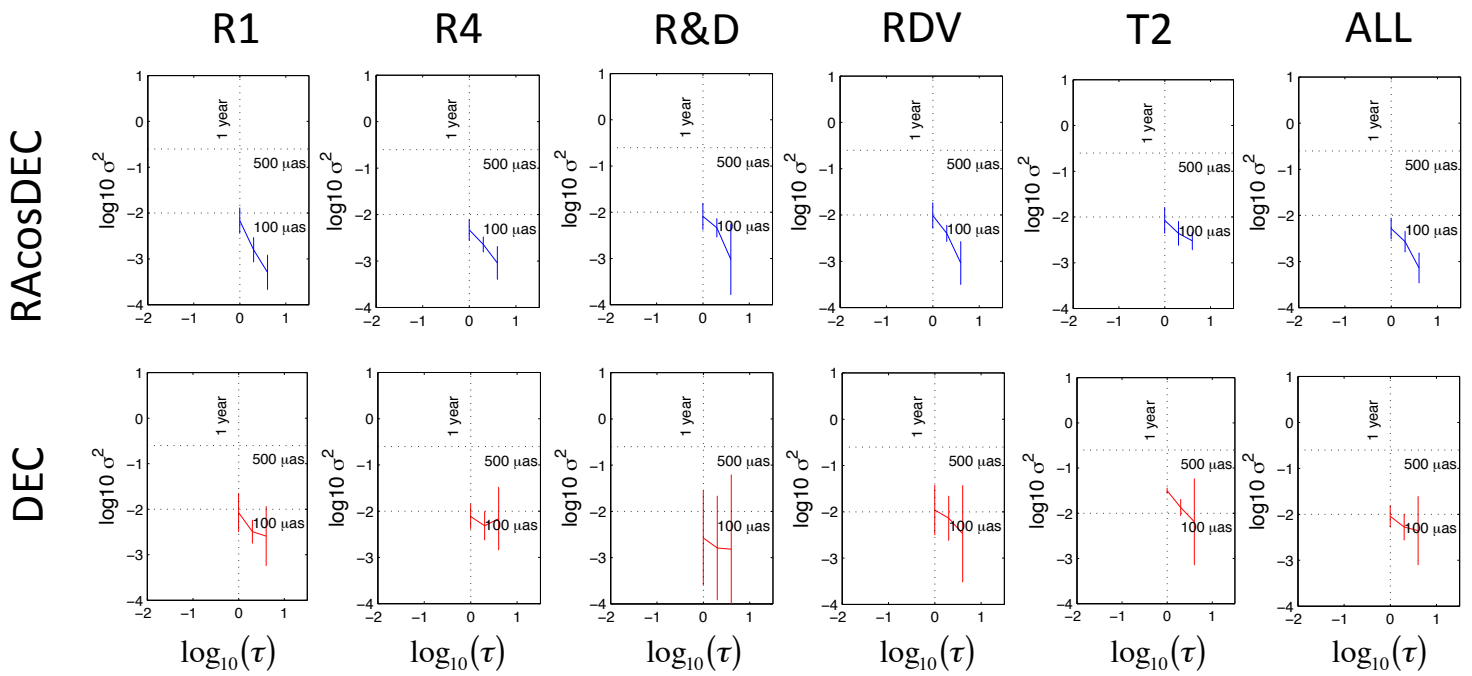
-1	White noise
0	Flicker noise
+1	Random walk



- Cons: it has to be applied to regularly spaced time series.

Level and type of noise of 3C418

2002.0-2018.3 – Yearly averaged series

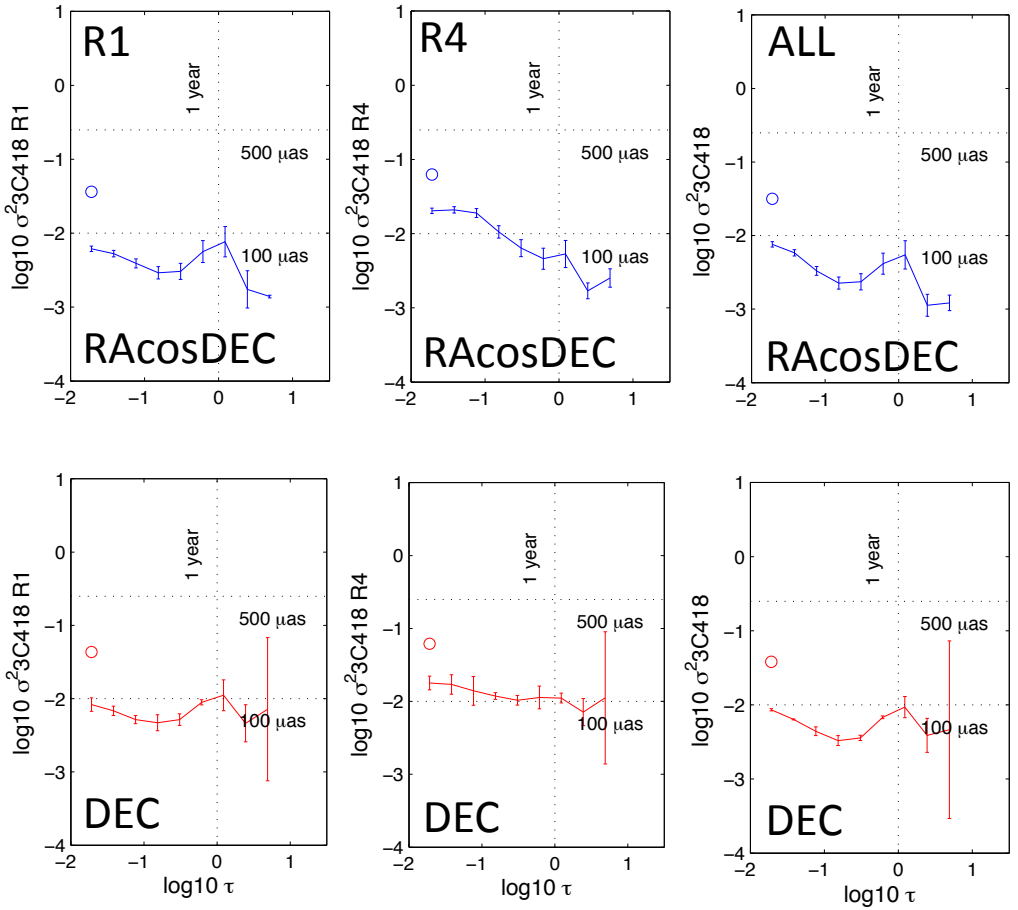


The Allan variance plots for R1, R4, R&D, RDV, and T2 sessions are comparable to the Allan variance plots of the total time series.

Level and type of noise of 3C418

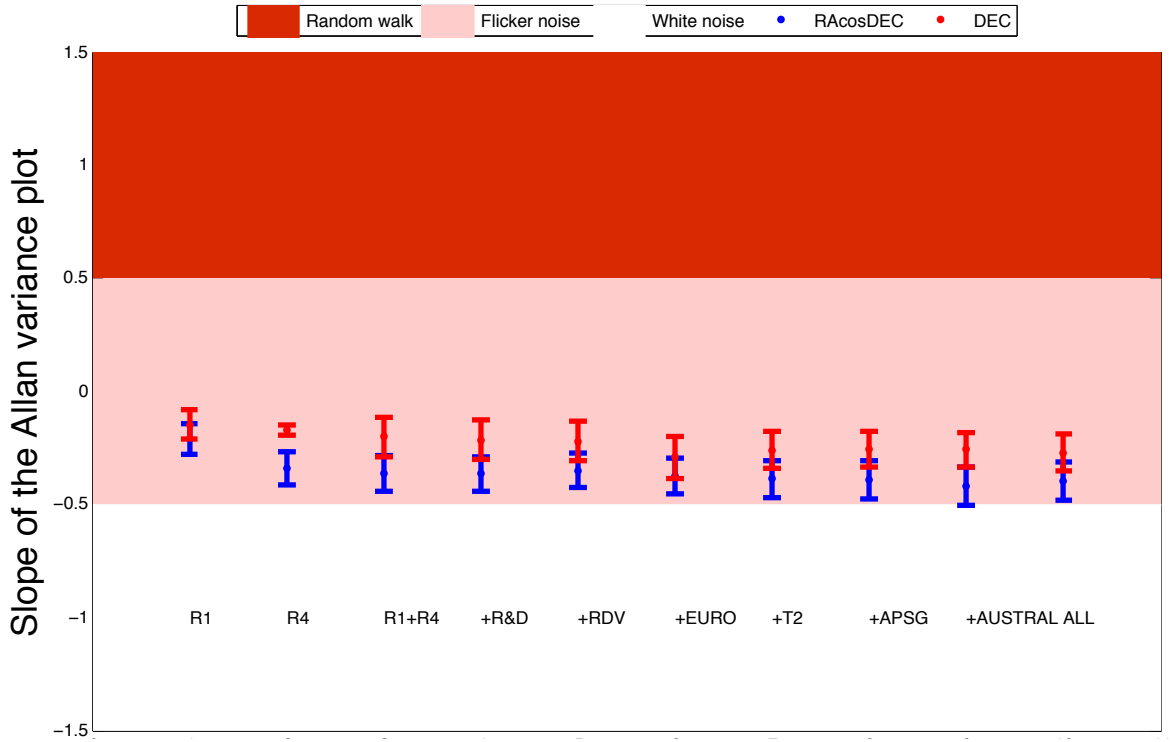
2002.0-2018.3 – Cumulative weekly averaged series

R1 and R4 session Allan variance plots show a slightly different slope. This may be due to the fact that the R4 session series are noisier.



Level and type of noise of 3C418

2002.0-2018.3 – Cumulative weekly averaged series



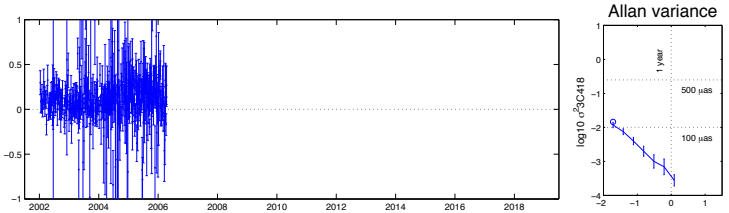
The type of noise is comparable for all successive cumulated series and the total series.

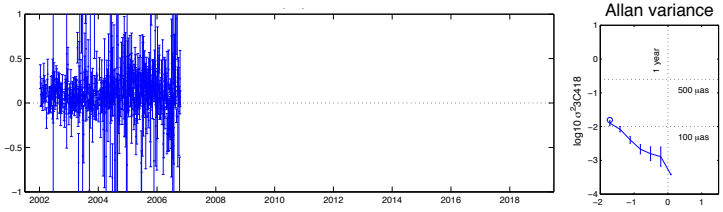
Level and type of noise of 3C418

2002.0-2018.3 – Temporal study

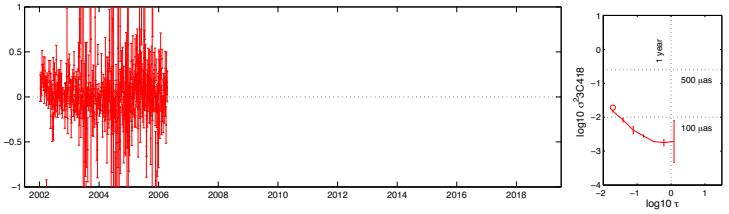
Temporal study: analysis of the time series of the source for different periods of time, 2002.0-2006.3 as the initial time period to study, adding six months of data at a time until the series are reconstructed. All sessions are considered.

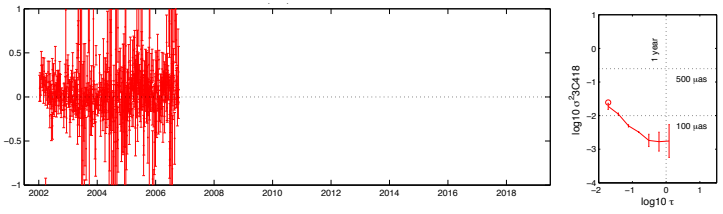
RAcosDEC





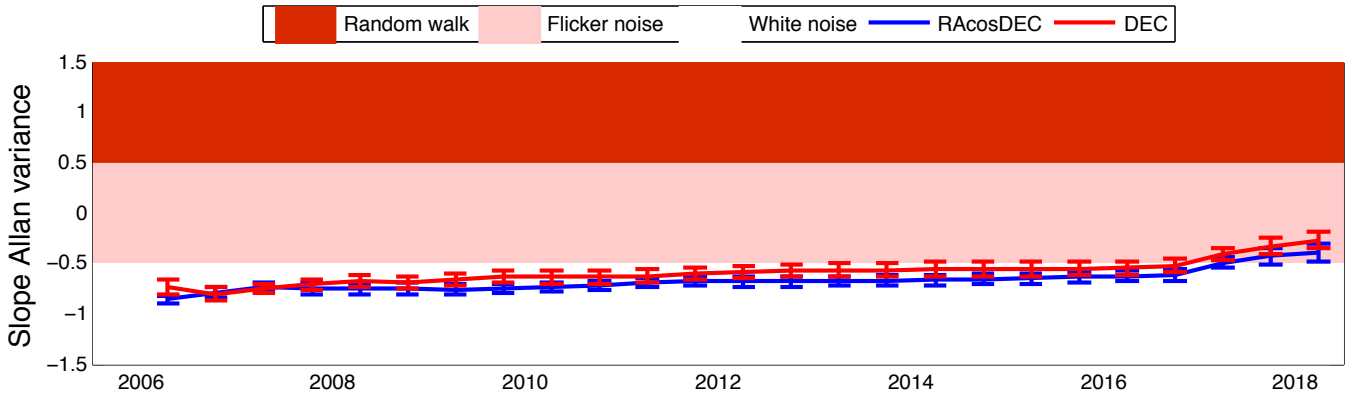
DEC

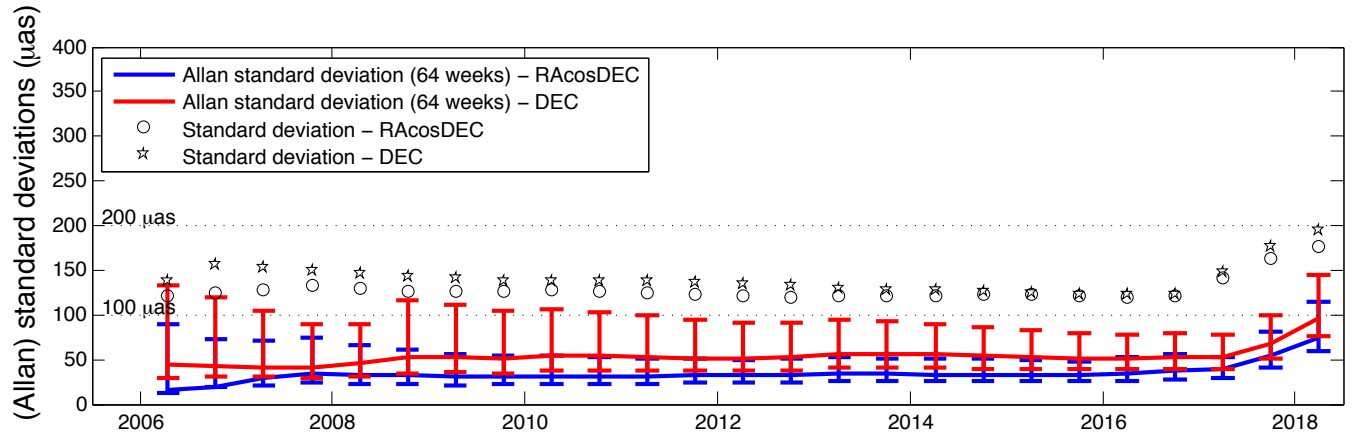




Level and type of noise of 3C418

2002.0-2018.3 – Temporal study





Conclusion and future work

Does the network impact the stationarity of the source position time series?

- The type of sessions does not impact directly the statistical characterization of the time series.
- The number of observations impacts the uncertainties of the source position.

What impacts the stationarity of the source position time series?

- The source evolves with time, unpredictably.

APPLICATIONS.

- 3C418 is a source in a sked catalog called the source.cat.geodetic.good. As of June 5, 2018, this catalog has 301 sources that are used as a basis for scheduling geodetic sessions. They were chosen because they were strong and compact. This study shows that it is time to revise this set of sources.
- It is necessary to observe regularly every source:
  - A source considered compact or "stable" at a date may not be as compact or "stable" twenty years later and vice versa. MORE OBSERVATIONS.
  - To be able to significantly study the statistical characterization of a source, we need a significant number of points. MORE OBSERVATIONS.

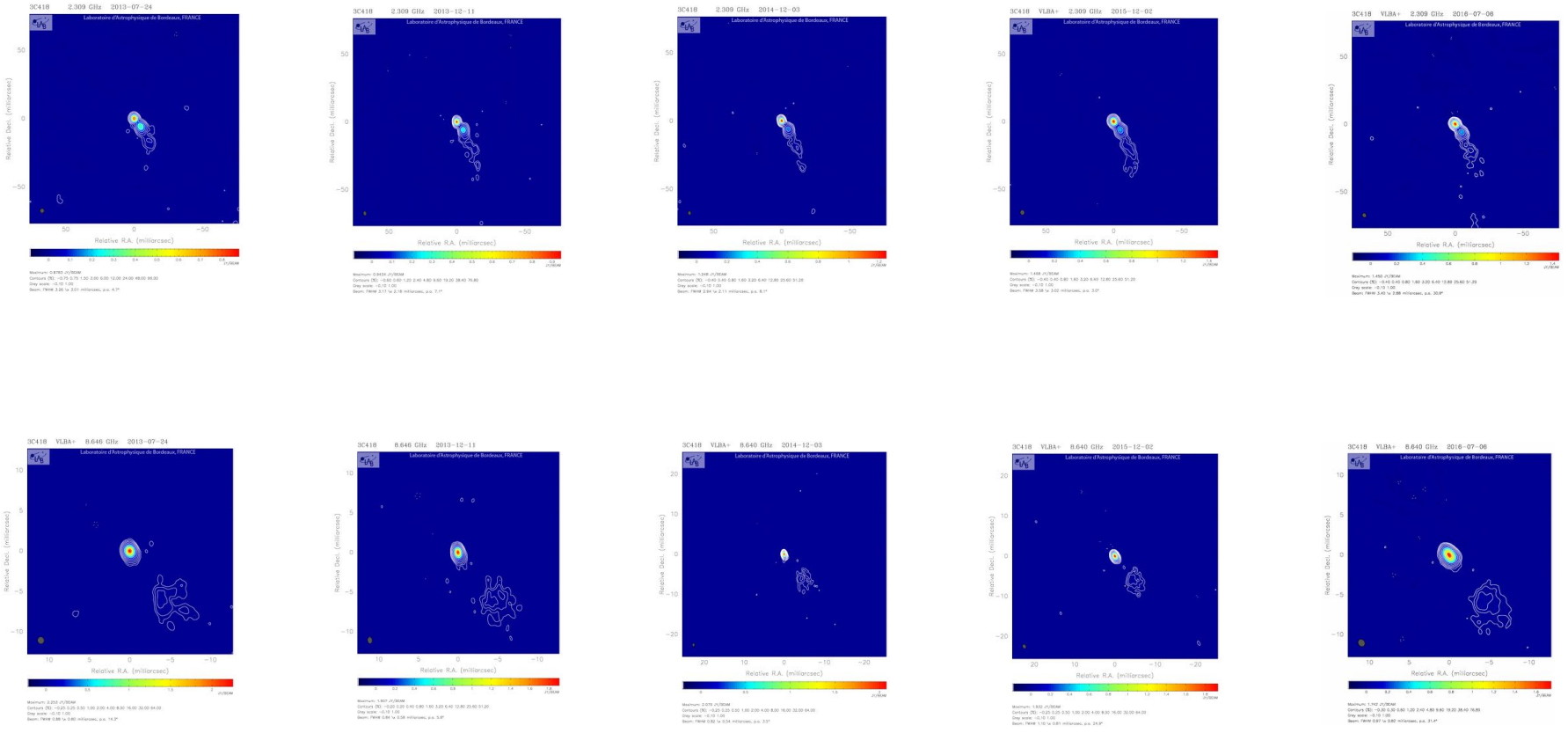
⇒ REGULAR MONITORING OF SOURCE POSITION.

FUTURE.

- It will be interesting to look at the time series of these sources for other bands (K-band?).

Level and type of noise of 3C418

Structure



The Bordeaux VLBI Image Database: : http://www.astrophy.u-bordeaux.fr/BVID/