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Time stability of the K-band catalog sources

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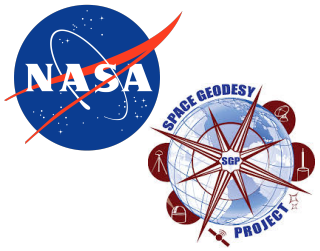
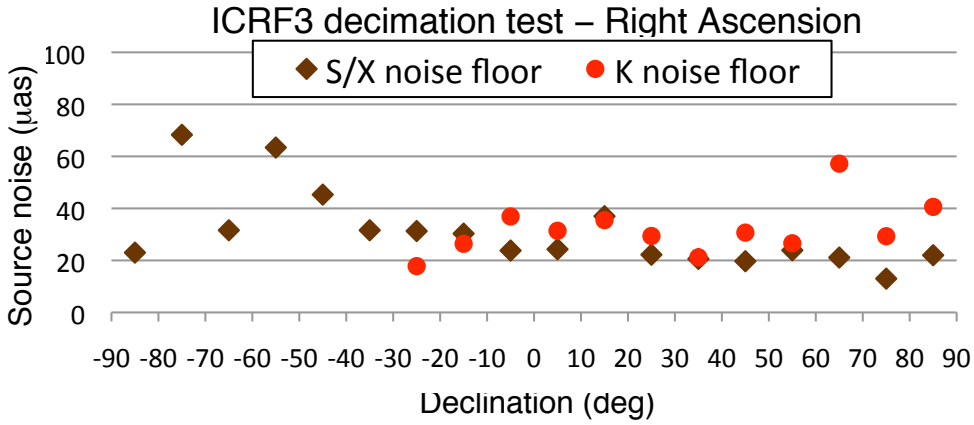


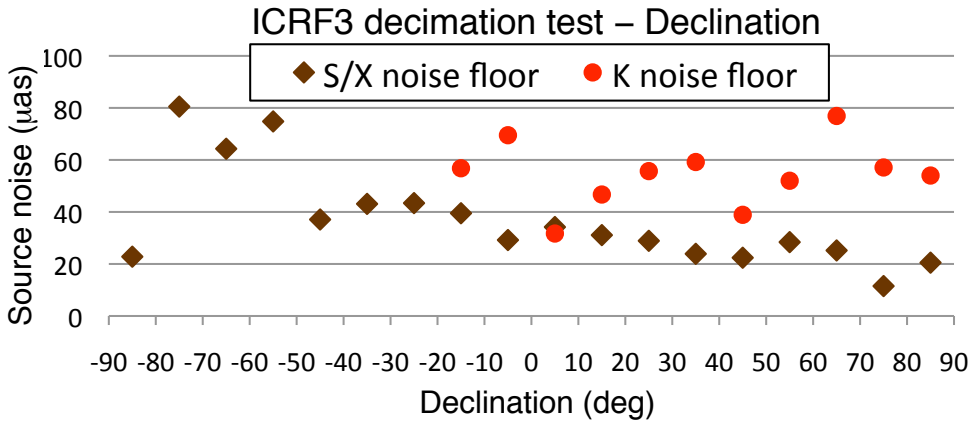
Outline

- K-band in ICRF3
- Brief review on how to use the Allan variance to determine noise floor of source time series
- Noise floor of the latest GSFC K-band time series solution and comparison with the latest GSFC S/X time series solution on 3 different sets

K-band

K-band in ICRF3





See **poster P306**: A. de Witt et al., "The K-band (24 GHz) Celestial Reference Frame".

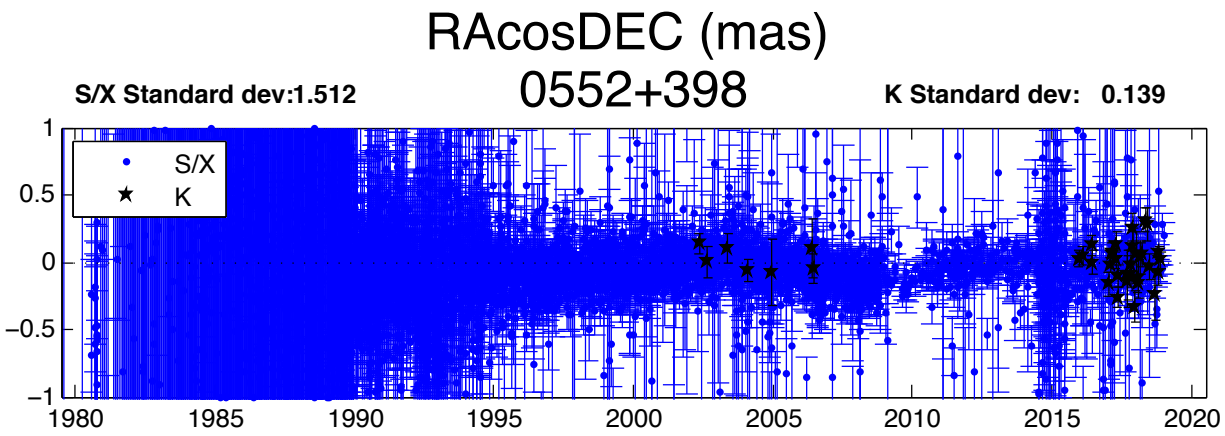
This paper: Study of the latest GSFC time series solutions for K and S/X.

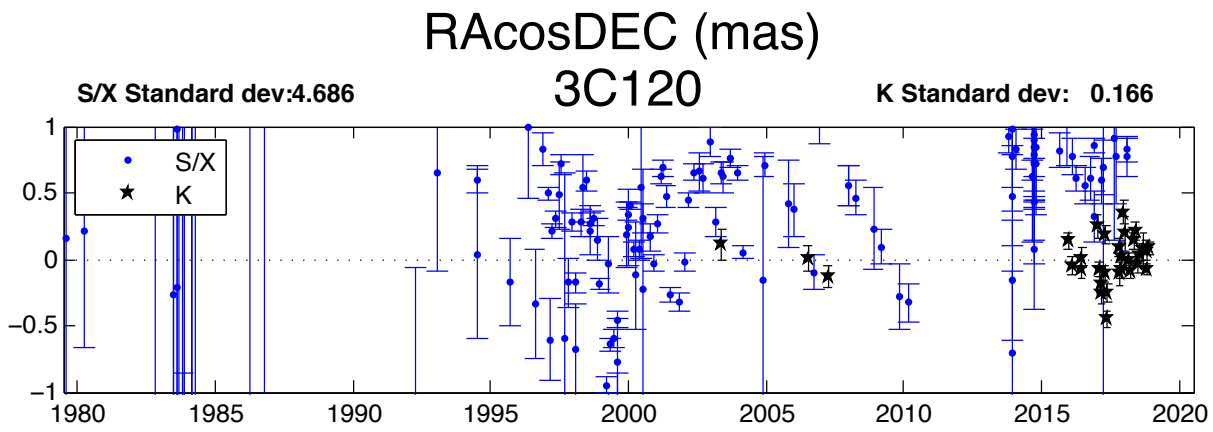
	K solution	S/X solution
Source #	906	4775
Session #	65	6271
Observation period	05/2002 – 11/2018	08/1979 – 01/2019
Source # (≥10 sessions)	354	788

310 common sources

K-band and S/X-band

Position time series examples





Different ways to look at these time series:

- Standard deviation => static quantity;
- Noise floor determined with the Allan variance => takes into account the time variable.

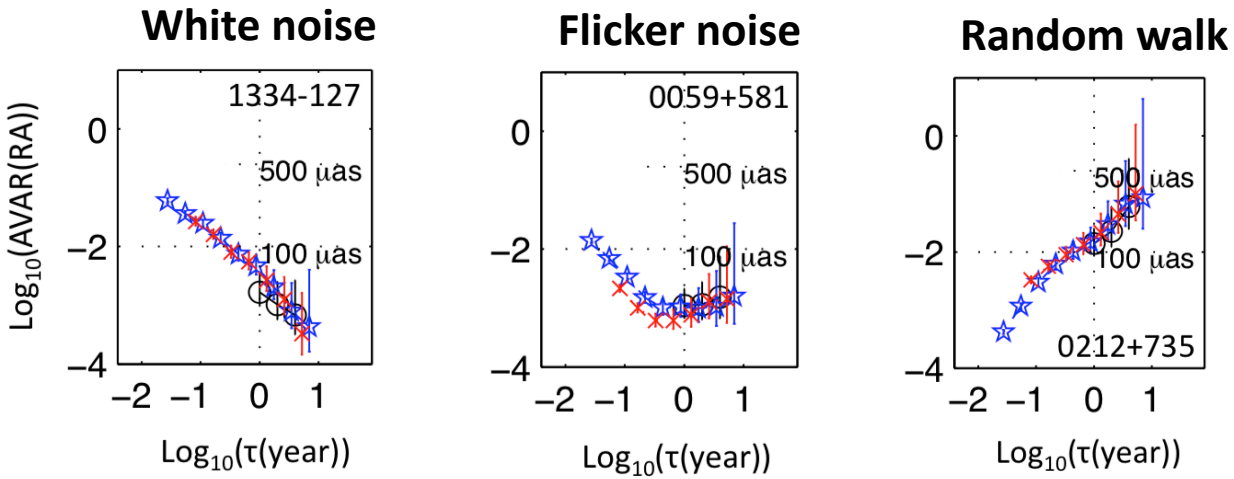
Using the Allan variance to determine noise floor (1/2)

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

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

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

-1	White noise
0	Flicker noise
+1	Random walk



Using the Allan variance to determine noise floor (2/2)

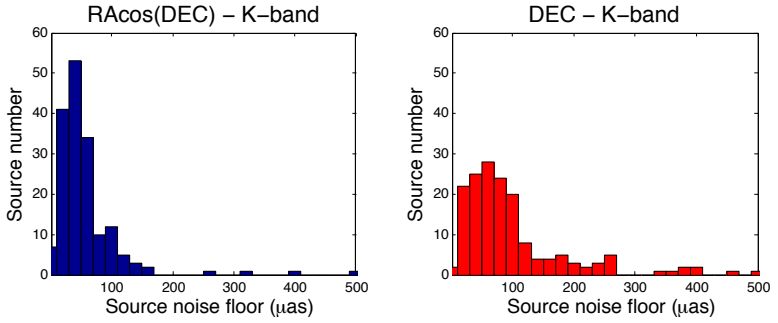
Real data: sources not observed regularly => difficulties in statistical determination due to gaps in between observations, number of observations,…

Preprocessing of the time series.

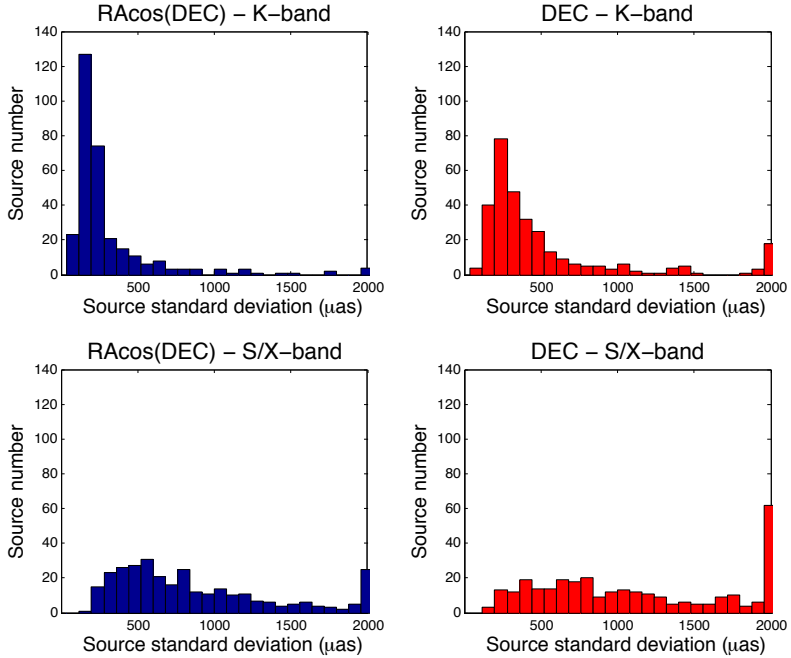
- **Step 1**: Keep sources with 10 or more observations.
- **Step 2**: Averaging (yearly and monthly) and interpolation. Threshold cut-off when interpolating.
- **Step 3**: Allan variance processing for each source, each coordinate, each averaged time series.
- **Step 4:** Noise floor determination for each source and each coordinate. We look at the noise type determined by the slope of the Allan variance curve:
  - White noise or flicker noise: the noise floor is the lowest Allan variance value.
  - Random walk: source rejected.

Comparison 1/3

310 common sources – Period 1979-now



Noise floor determined by the Allan variance



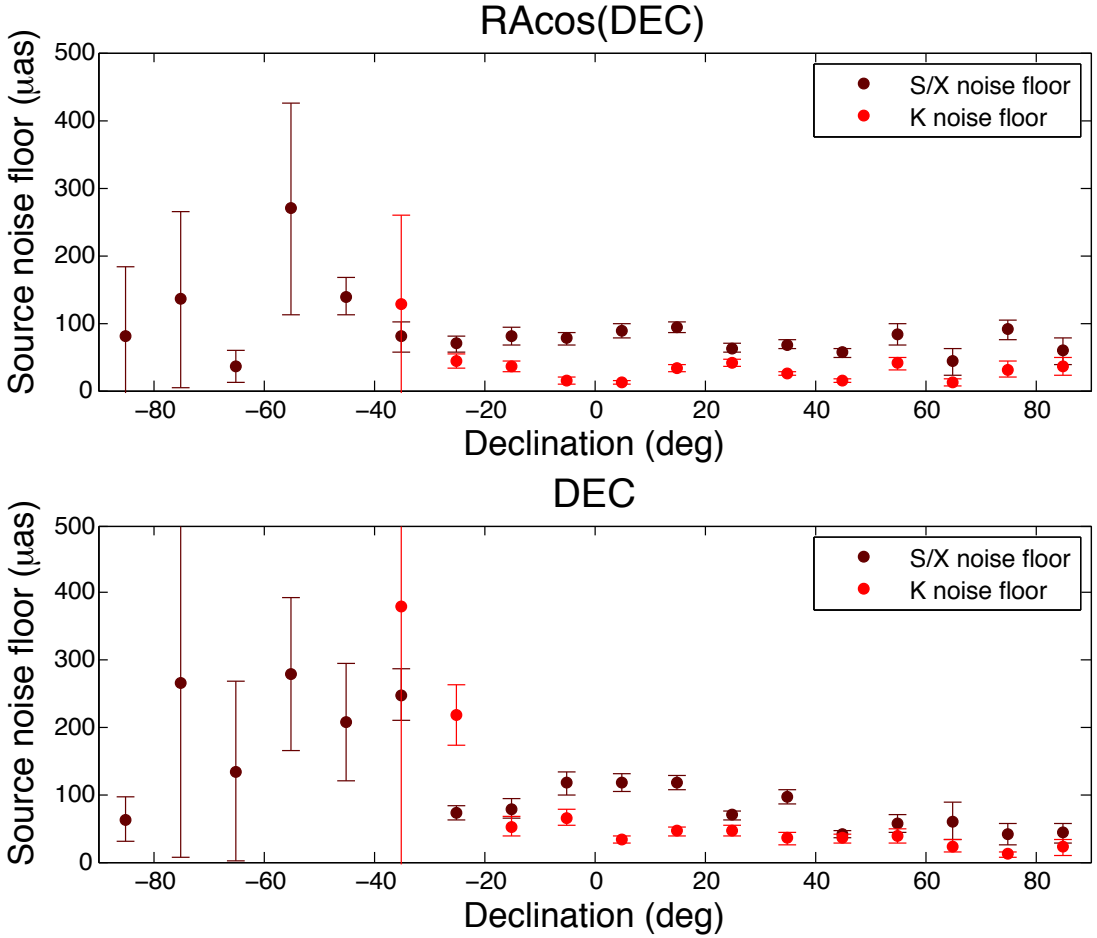
Standard deviation

The K noise floors tend to be smaller than the S/X noise floors.

Comparison 1/3

310 common sources – Period 1979-now

Noise floor comparison in 10° declination bands

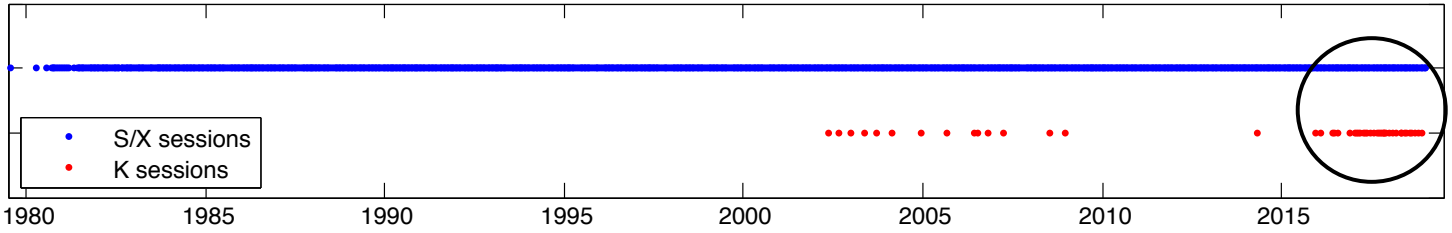


Comparison 2/3

87 common sources – Period 11/2016-11/2018

Focus on same period of observation:

November 2016 to November 2018.



	K solution	S/X solution
Source #	901	4728
Session #	44	391
Source # (≥10 sessions)	254	431

87 common sources

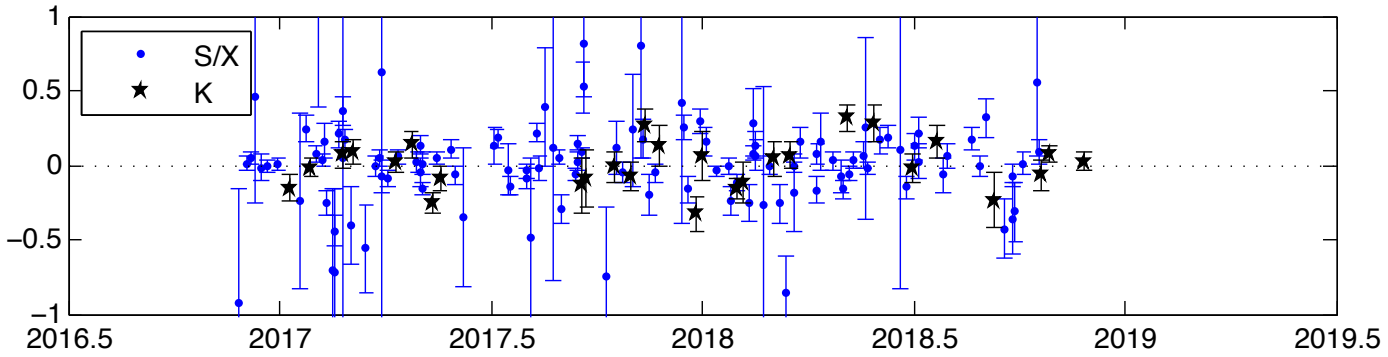
Comparison 2/3

87 common sources – Period 11/2016-11/2018

RAcosDEC (mas)

0552+398

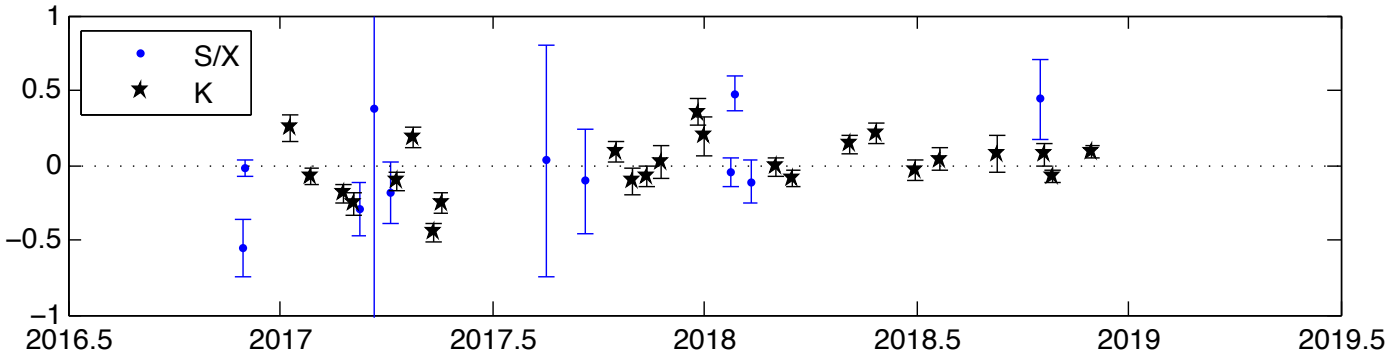
S/X Standard dev: 0.347 K Standard dev: 0.158



RAcosDEC (mas)

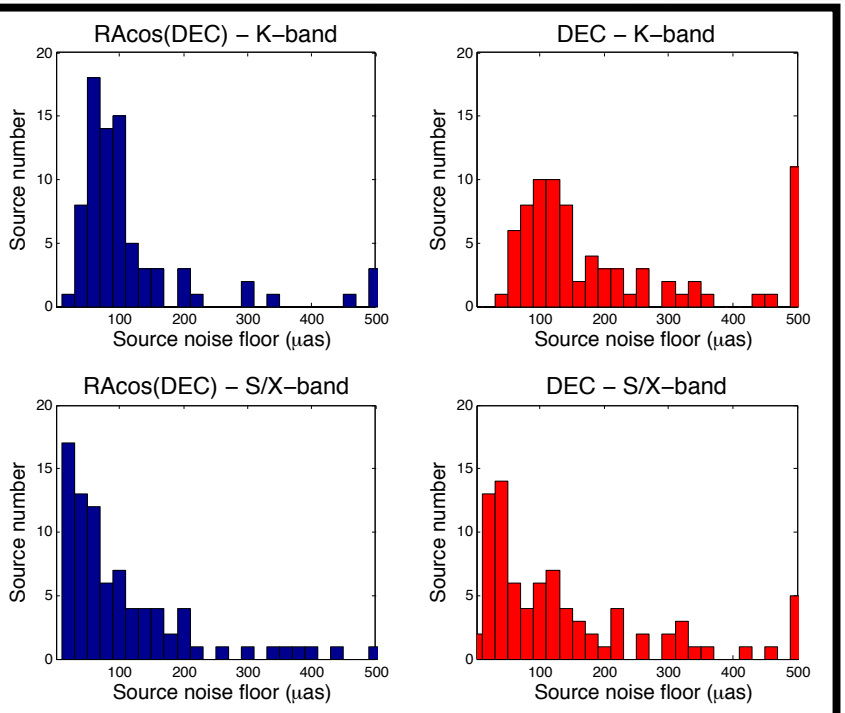
3C120

S/X Standard dev: 0.319 K Standard dev: 0.183

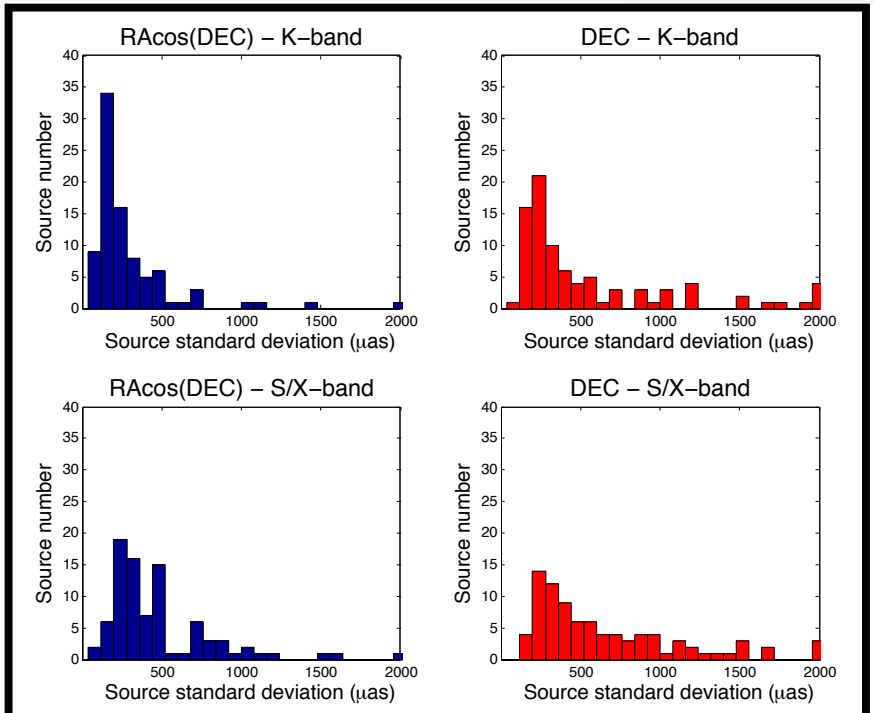


Comparison 2/3

87 common sources – Period 11/2016-11/2018



Noise floor determined by the Allan variance



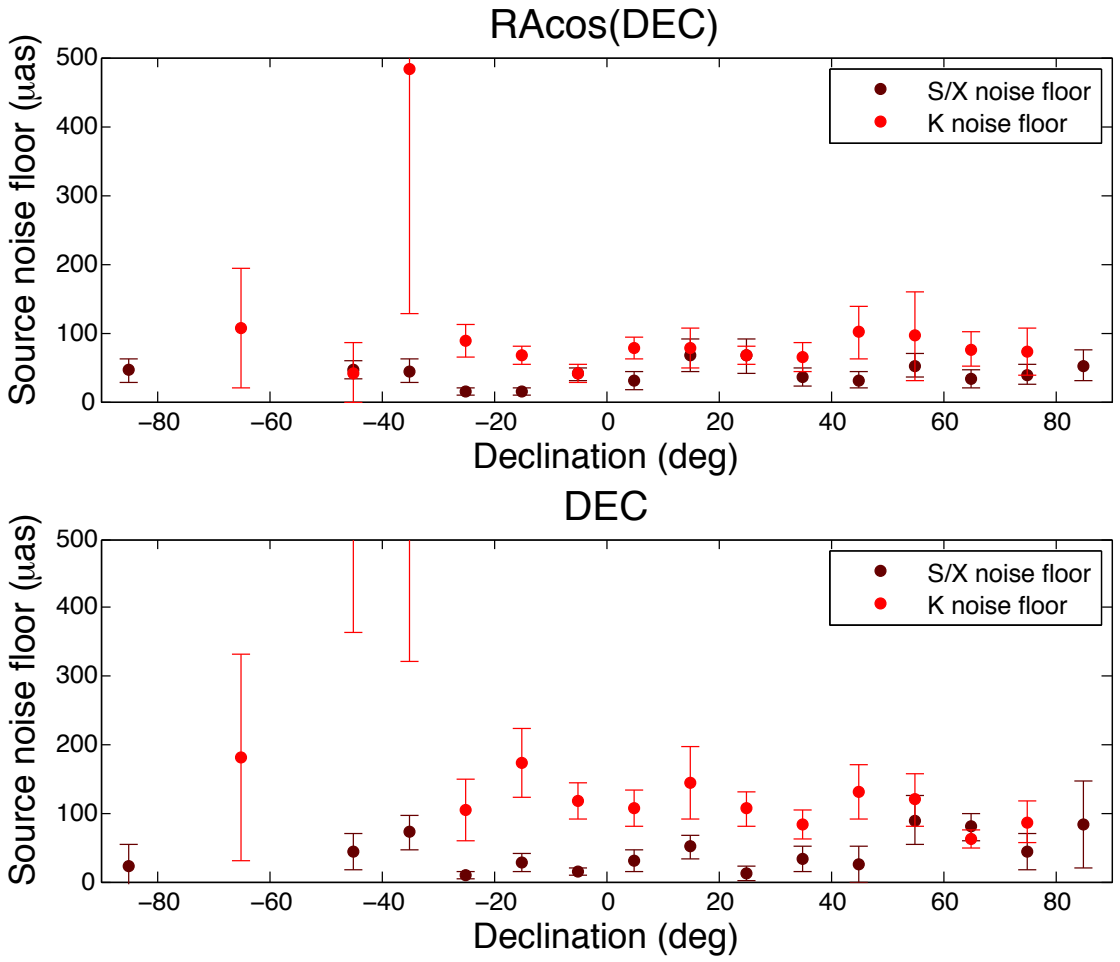
Standard deviation

The S/X noise floors tend to be smaller than the K noise floors.

Comparison 2/3

87 common sources – Period 11/2016-11/2018

Noise floor comparison in 10° declination bands



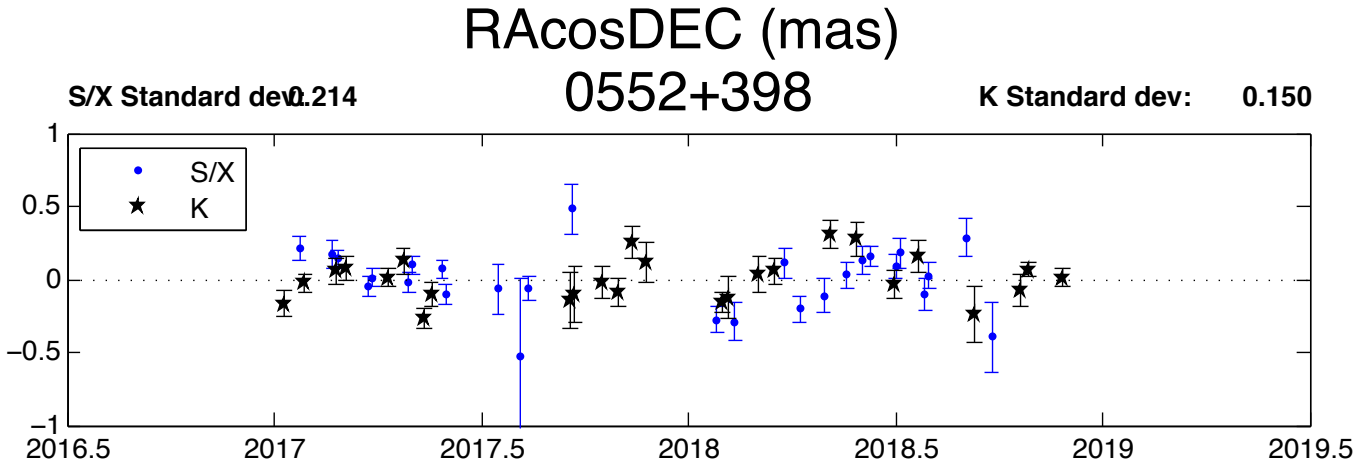
Comparison 3/3

31 common sources - VLBA sessions

- **UD sessions**: 24-hour VLBA sessions at **K-band**.
- **UF001 and UG002 sessions**: 24-hour VLBA sessions at **S/X band**. Goals: improving the precision of ICRF3, ICRF3 maintenance, and future updates of the ICRF at radio frequencies. Approximately 3300 of the weakest ICRF3 sources will be re-observed during these sessions.

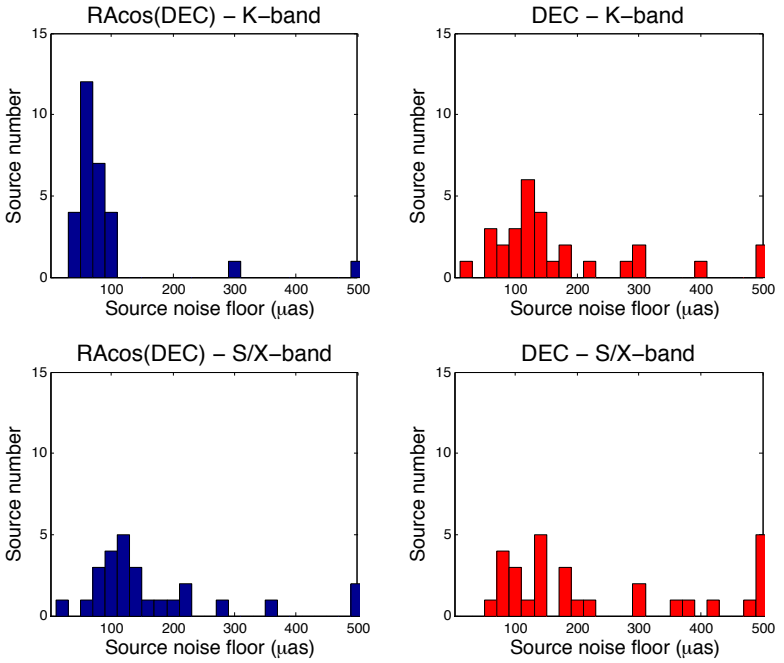
	K solution	S/X solution
Source #	819	4145
Session #	27	40
Source # (≥10 sessions)	149	132

31 common sources

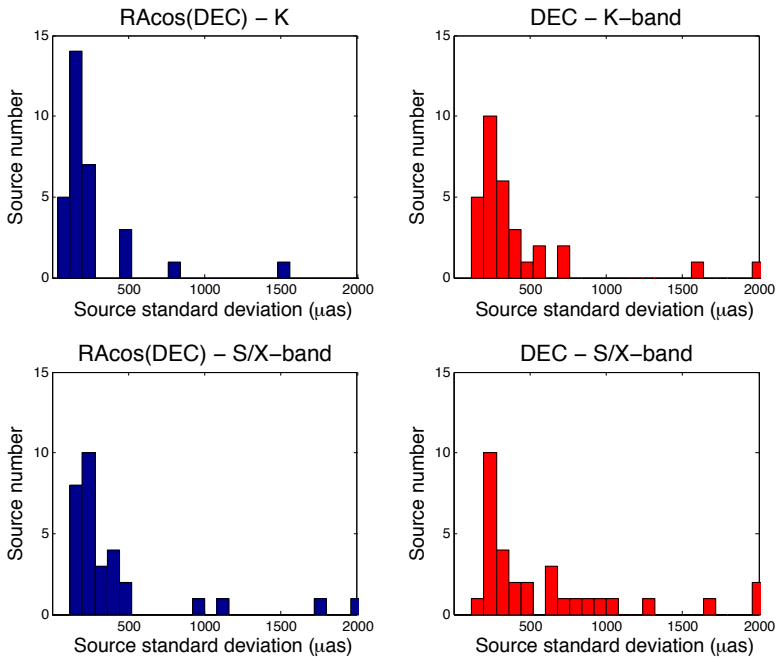


Comparison 3/3

31 common sources - VLBA sessions



Noise floor determined by the Allan variance



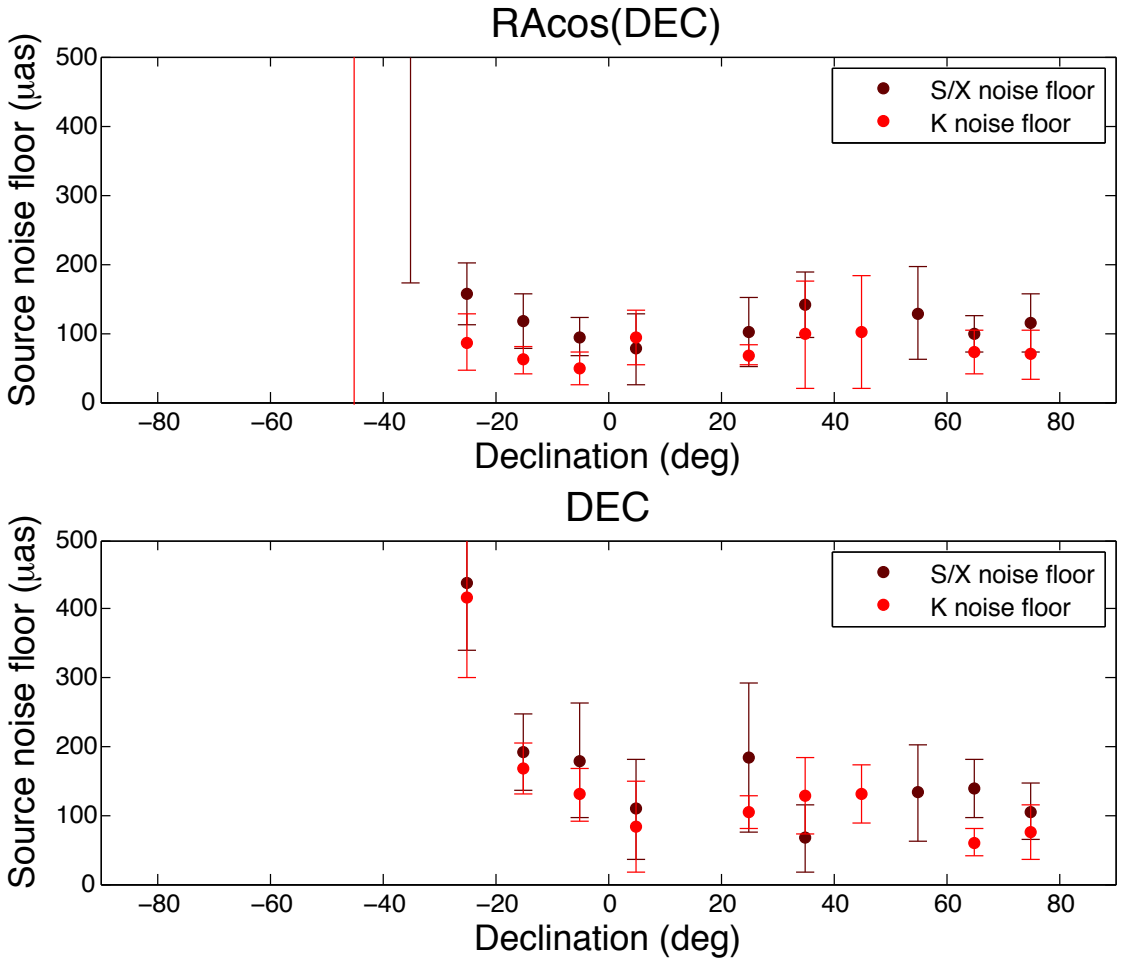
Standard deviation

The K noise floors and the S/X noise floors seem to be equivalent.

Comparison 3/3

31 common sources - VLBA sessions

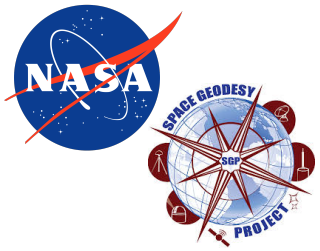
Noise floor comparison in 10^o declination bands



Conclusions

- K-band time stability
  - The K-band observations have reached a level of stability equivalent to the level of current S/X observations.
  - The strength of the S/X data set is in its broad diversity of baselines and sessions.
  - We need to continue monitoring the K-band observations and comparing the stability of the frame realized by the K-band observations with the S/X frame.

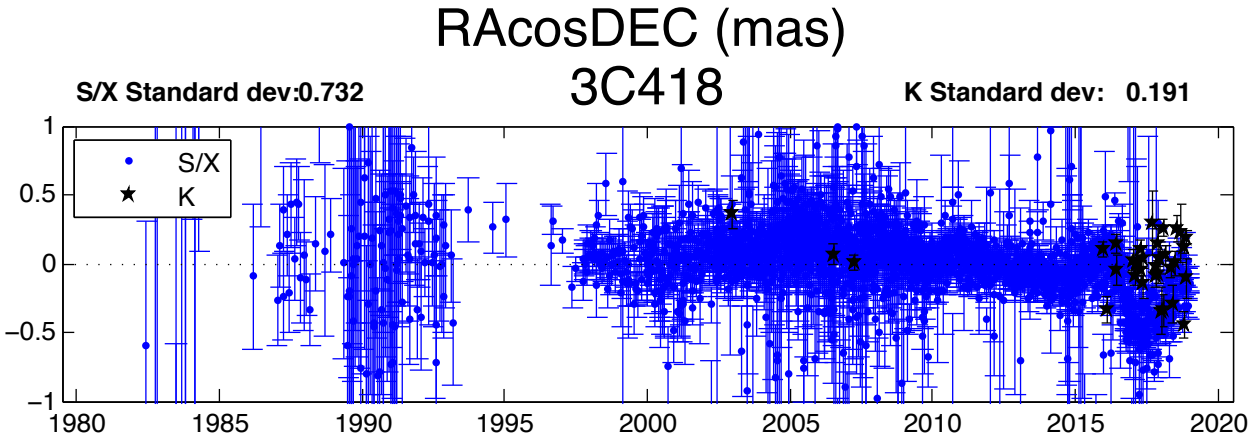
- Thanks to the VLBA, K-band observations have increased greatly in the past two years, prompting many studies. At the 2019 EVGA:
  - Benedikt Soja: “Ionospheric calibration for K-band celestial reference frames”.
  - Hana Krásná: “Earth orientation parameters estimated from K-band VLBA measurements”.
  - Aletha de Witt: “The K-band (24 GHz) Celestial Reference Frame”.

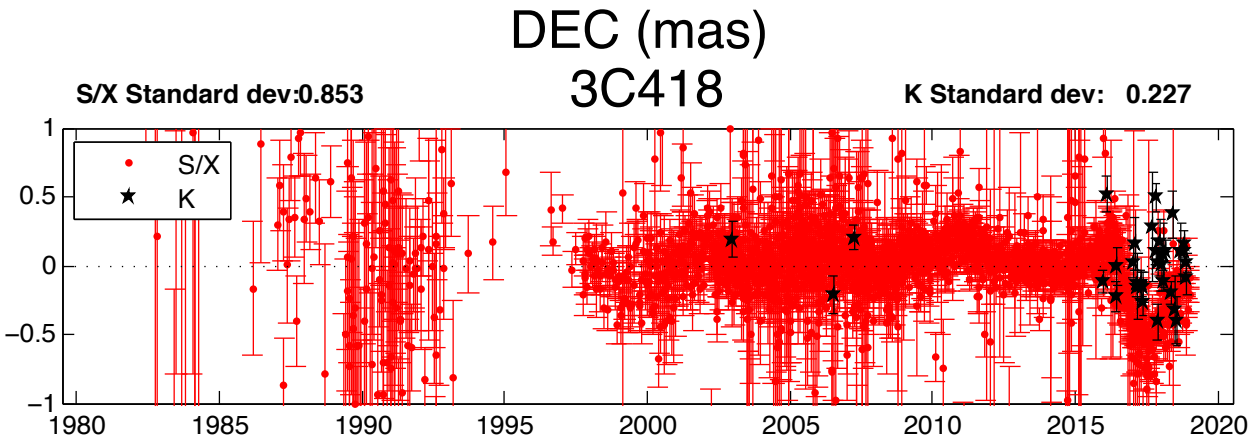


Thank you

And more…

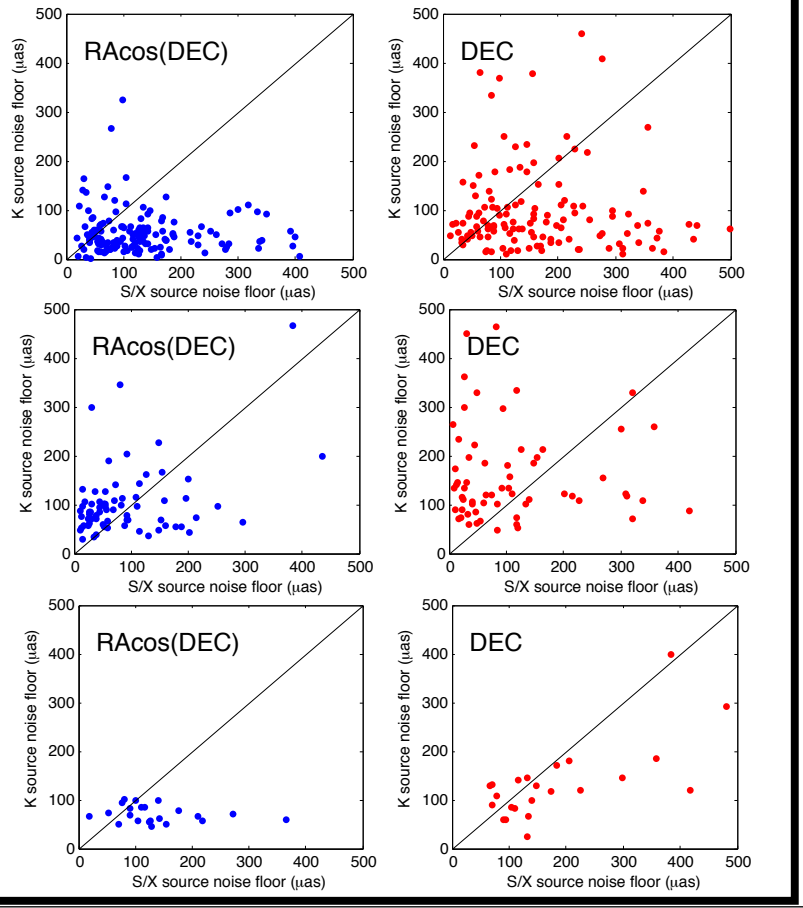
Structure,
proper motion?





Noise floor comparison
Individual sources

Noise floor determined by the Allan variance



(157/142 sources) **Entire period** (310 sources)

(74 sources) **2-yr period** (87 sources)

(24/28 sources) **VLBA sessions** (31 sources)

Standard deviation