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NVI, INC.

Time stability of the K-band catalog sources

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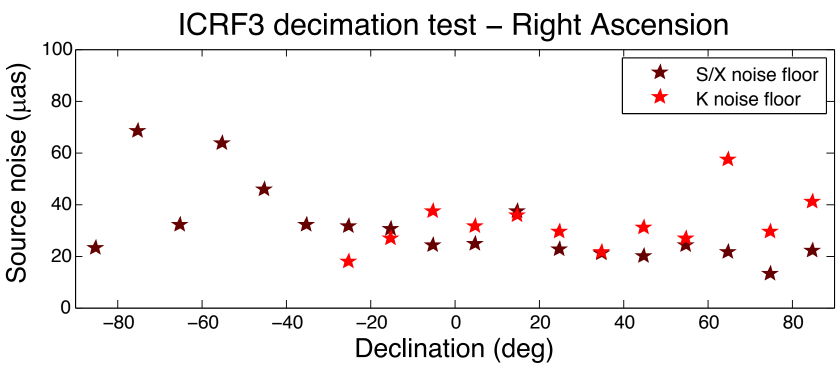
Outline

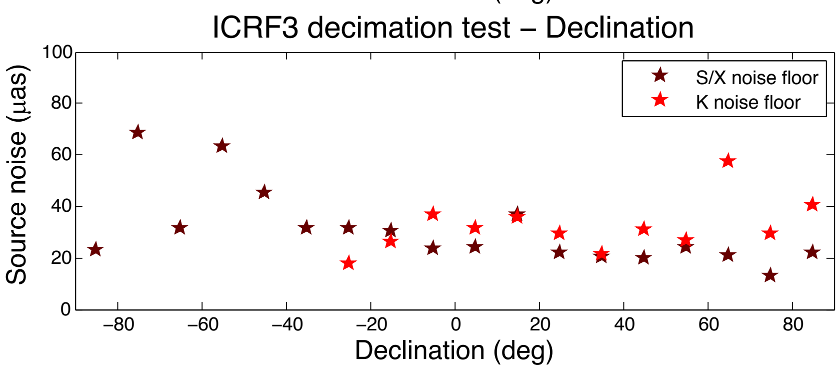
- K-band in ICRF3
- Brief review on how to use the Allan variance to determine noise floor of source time series
- Noise floor of the latest GSFC K-band time series solution and comparison with the latest GSFC S/X time series solution

K-band

- K-band in ICRF3

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





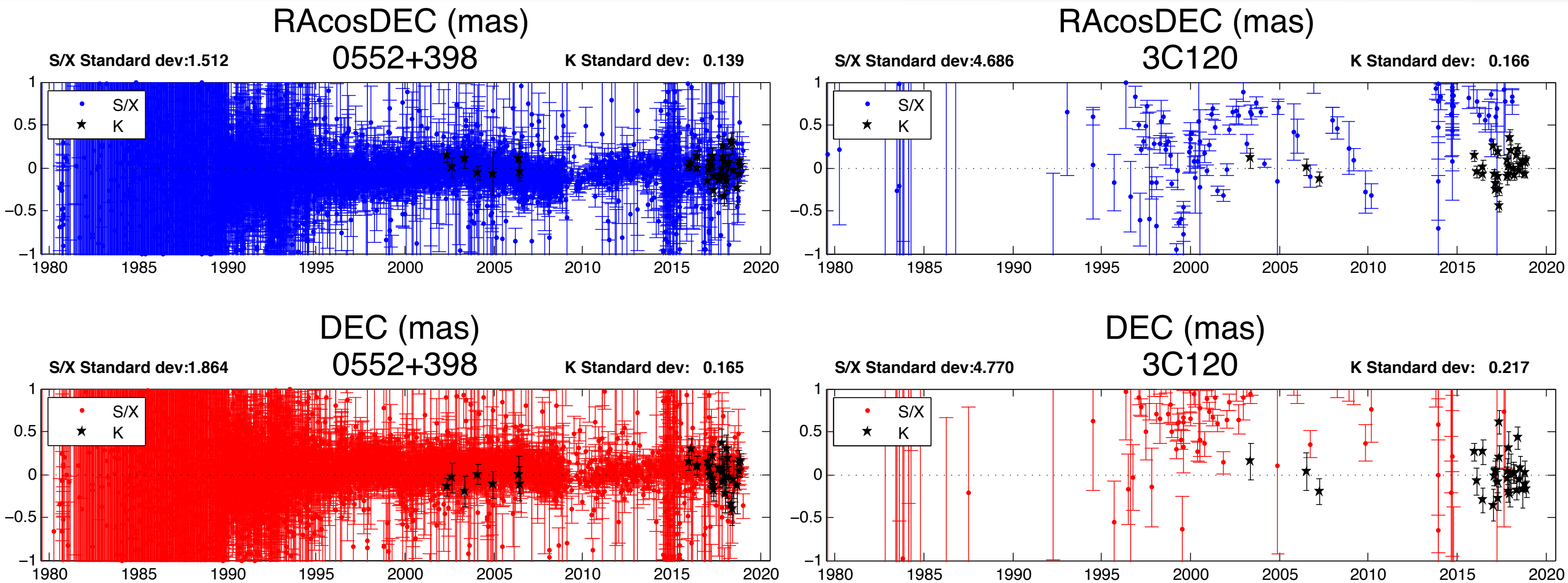
- This paper: Study of the latest GSFC time series solutions for K and S/X.

	K solution Jan 2019	S/X solution Jan 2019
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

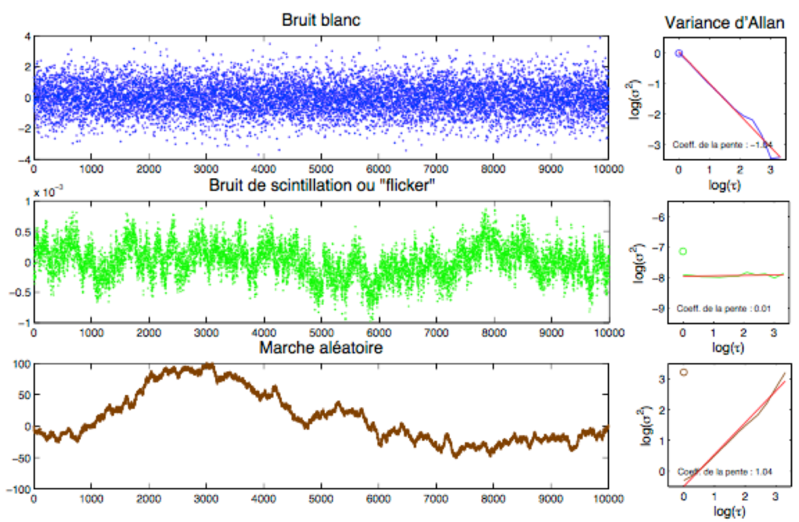


- Different ways to study these time series:
  - Standard deviation => static quantity;
  - Noise floor using the Allan variance => takes into account the time variable.

Allan variance to determine noise floor (1/3)

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

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



- The type of noise is determined by the slope of the curve

log$_{10}$(Allan variance)=f(log$_{10}$(sampling time))

-1	White noise
0	Flicker noise
+1	Random walk

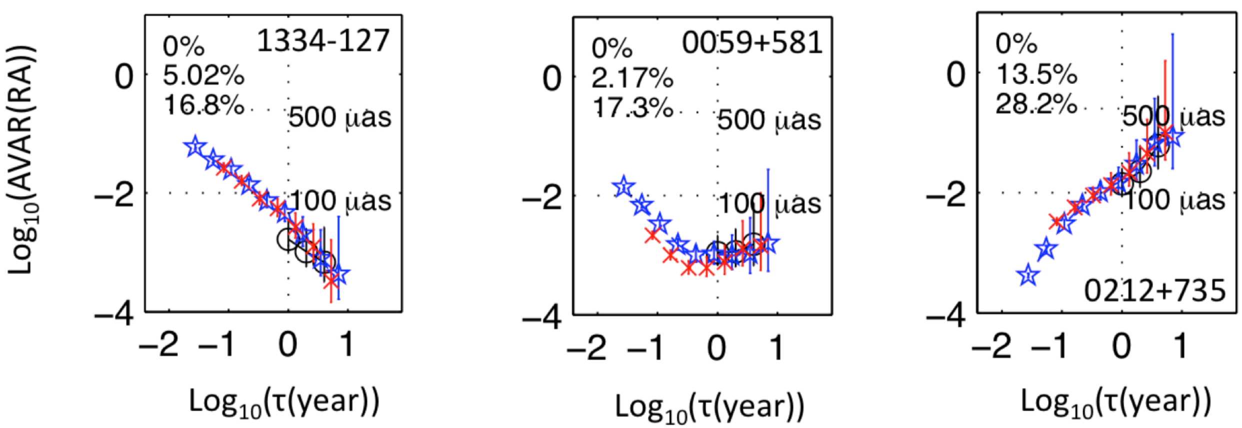
- Cons: it has to be applied to regularly spaced time series.

Allan variance to determine noise floor (2/3)

White noise
The quality of the data is improving with time.

Flicker noise
The quality of the data is stabilized at a certain level of noise.

Random walk
Too much structure to determine the noise of the source.



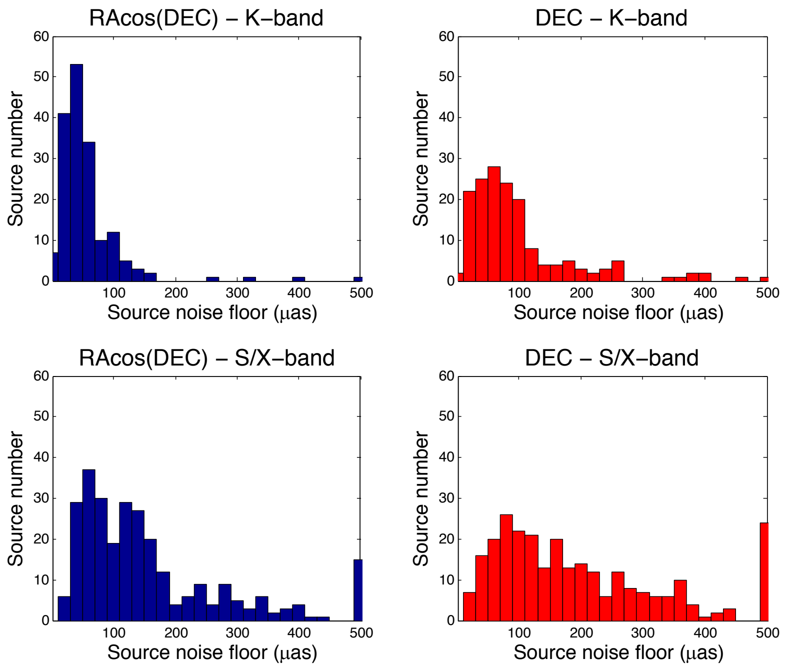
Allan variance to determine noise floor (3/3)

Real data: sources not observed regularly => difficulties in statistical determination due to gaps in between observations, number of observations,… We need to prepare the data, to preprocess the time series.

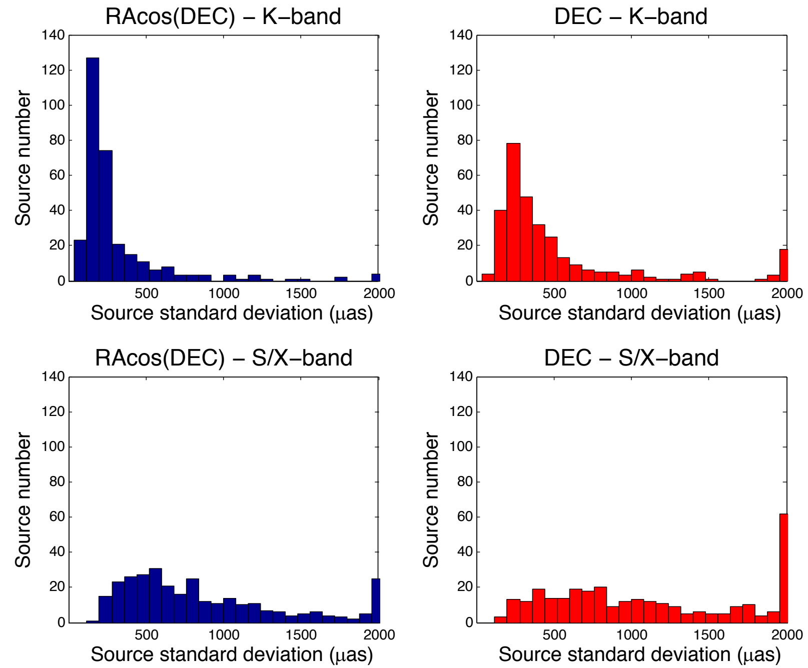
- **Step 1**: Keep sources with 10 or more observations.
- **Step 2**: Averaging (yearly, monthly and weekly) and interpolation.
- **Step 3**: Allan variance processing for each source, each coordinate, each averaged time series.
- **Step 4:** Noise floor determination for each source and each coordinate. We look at the noise type determined by the slope of the Allan variance curve:
  - If white noise or flicker noise, the noise floor is the lowest Allan variance.
  - If random walk, the noise floor is undefined.

Comparison of global solutions

310 common sources



Noise floor determined by the Allan variance



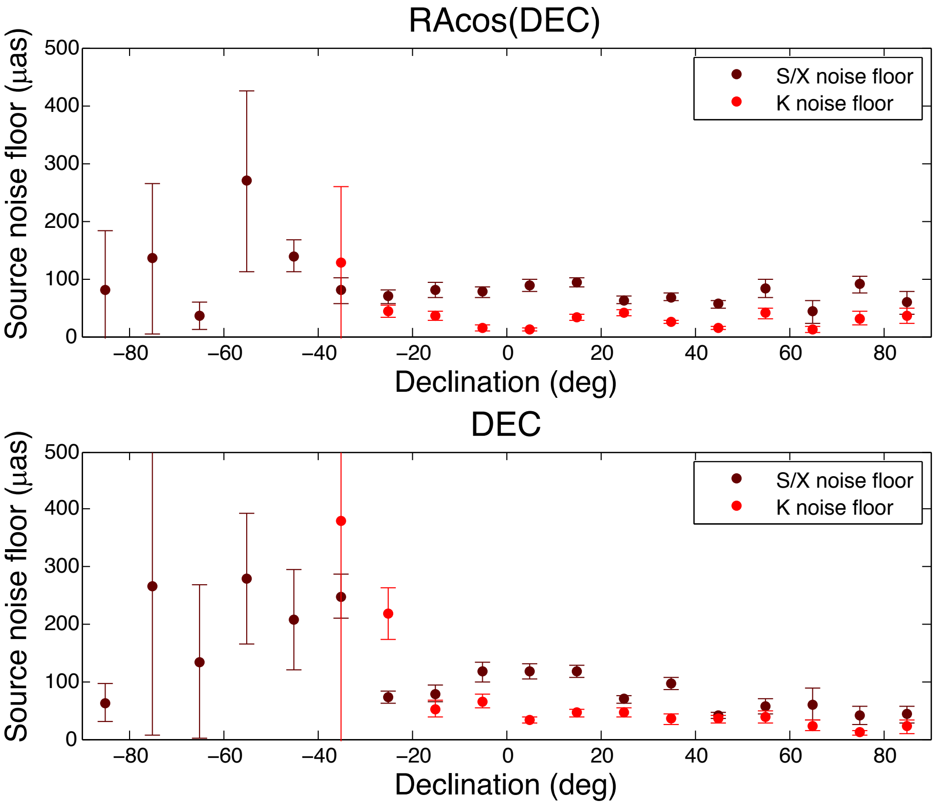
Standard deviation

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

Comparison of global solutions

310 common sources

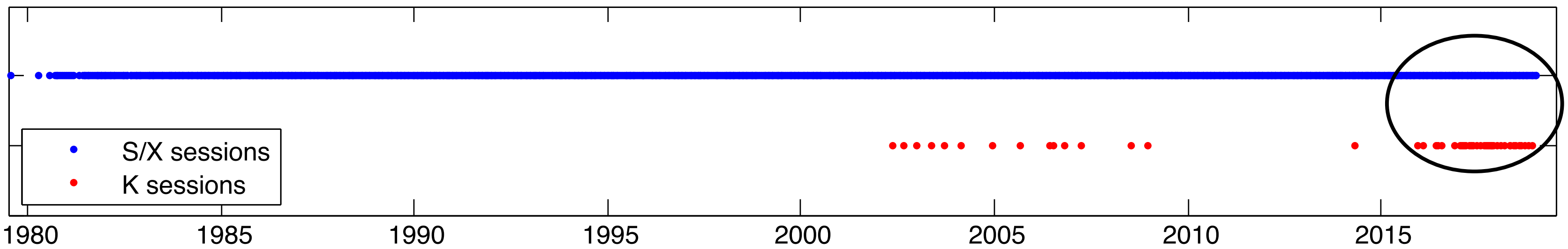
Noise floor comparison in 10^o declination bands



Comparison of partial solutions

87 common sources from Nov 2016 to Nov 2018

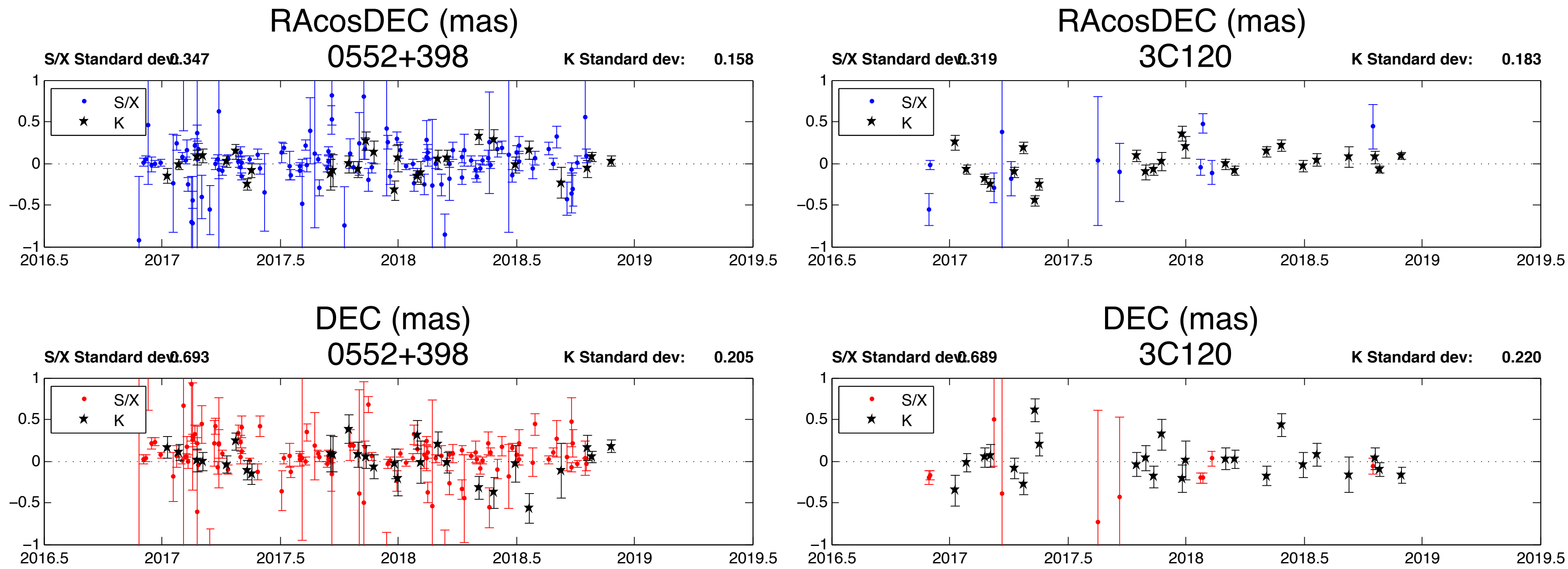
- Focus on same period of observation: November 2016 to November 2018.



	K solution Jan 2019	S/X solution Jan 2019	Common sources
Source #	901	4728	877
Session #	44	391	
Source # (>10 sessions)	254	431	87

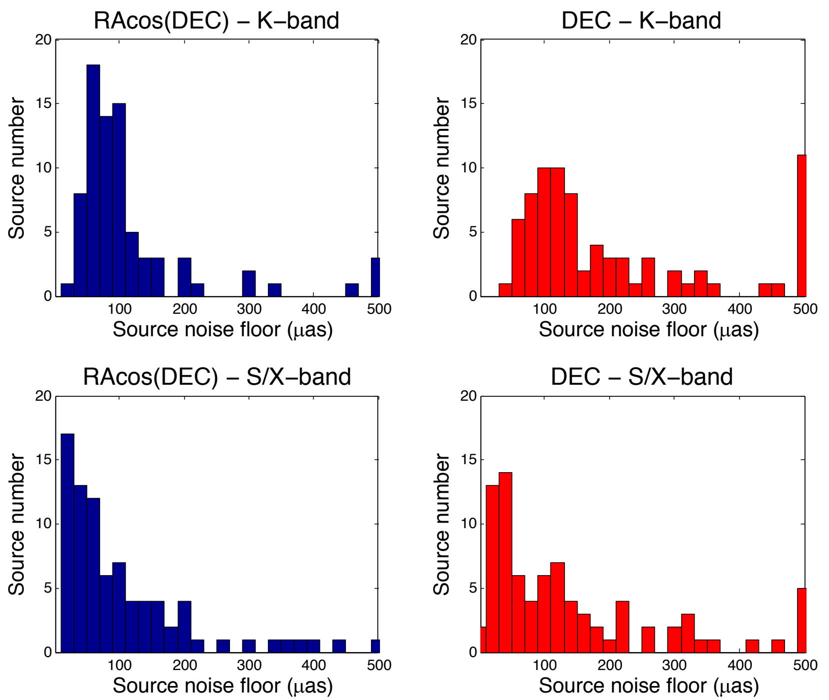
Comparison of partial solutions

87 common sources from Nov 2016 to Nov 2018

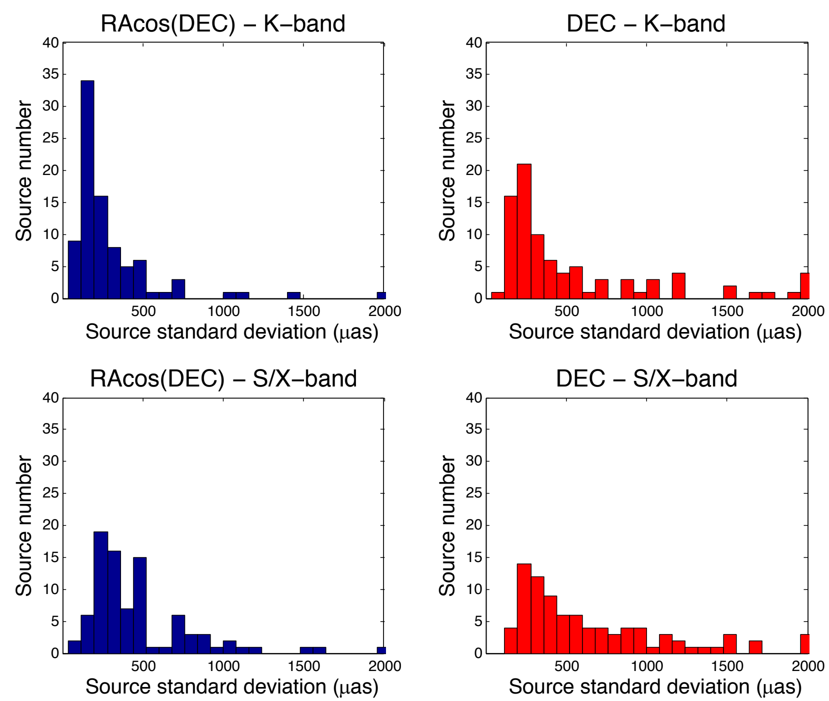


Comparison of partial solutions

87 common sources on period Nov 2016 – Nov 2018



Noise floor determined by the Allan variance



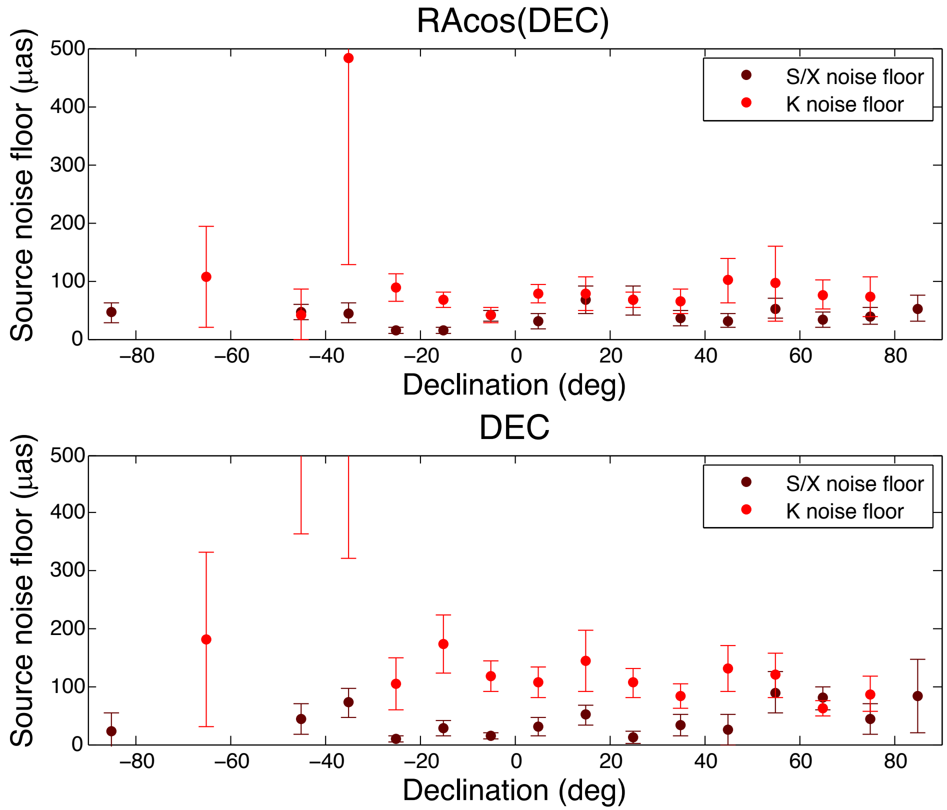
Standard deviation

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

Comparison of partial solutions

87 common sources on period Nov 2016 – Nov 2018

Noise floor comparison in 10º declination bands



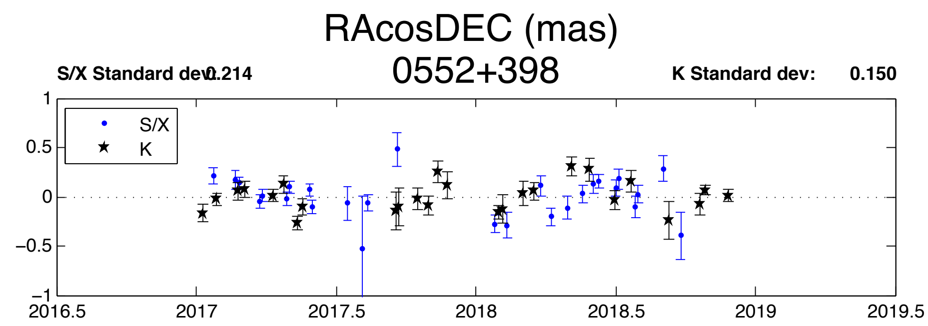
Comparison of partial solutions

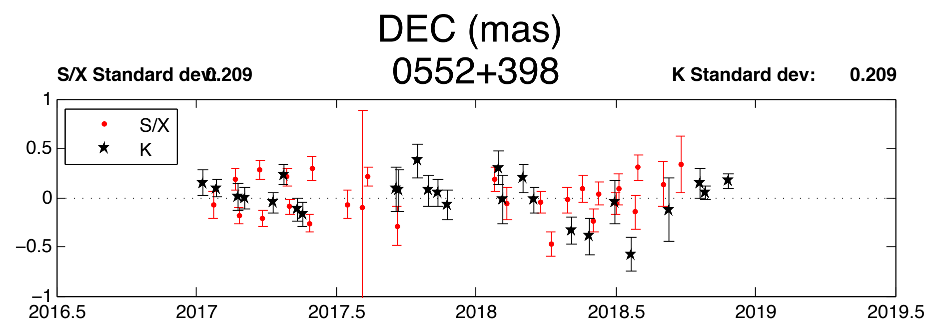
31 common sources in VLBA sessions
UD sessions for K-band, UF-UG sessions for S/X

- **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 Jan 2019	S/X solution Jan 2019
Source #	819	4145
Session #	27	40
Source # (>10 sessions)	149	132

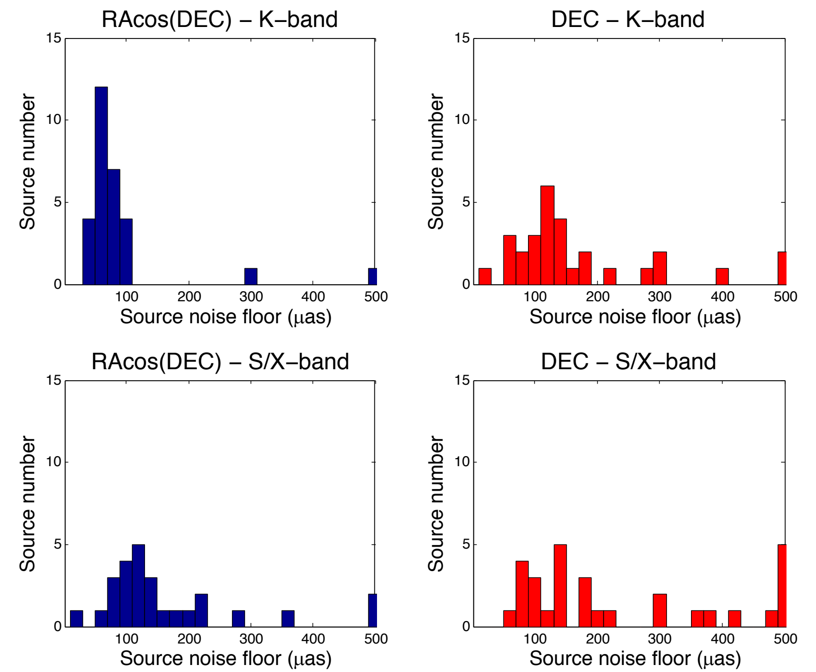
31 common sources



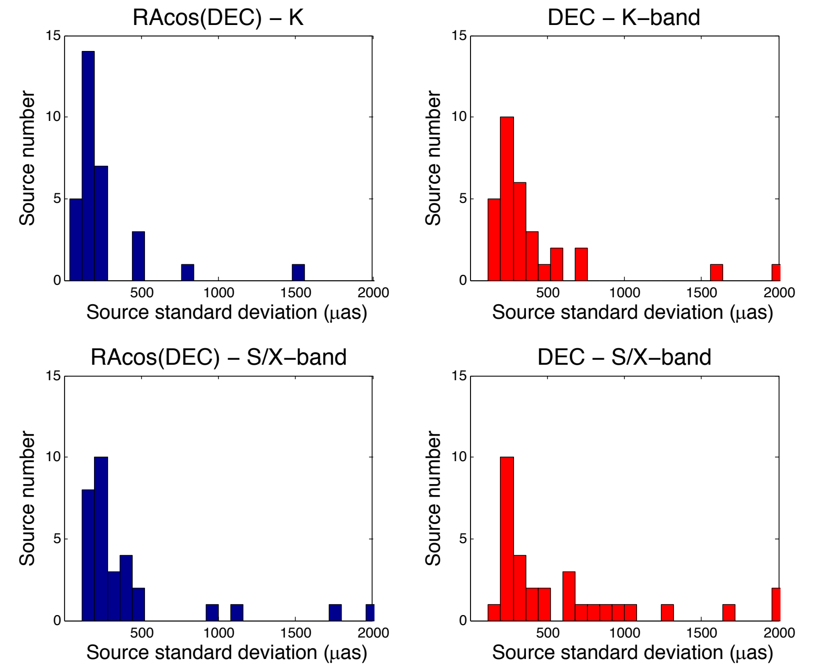


Comparison of partial solutions

UD vs. UF-UG sessions (31 common sources)



Noise floor determined by the Allan variance



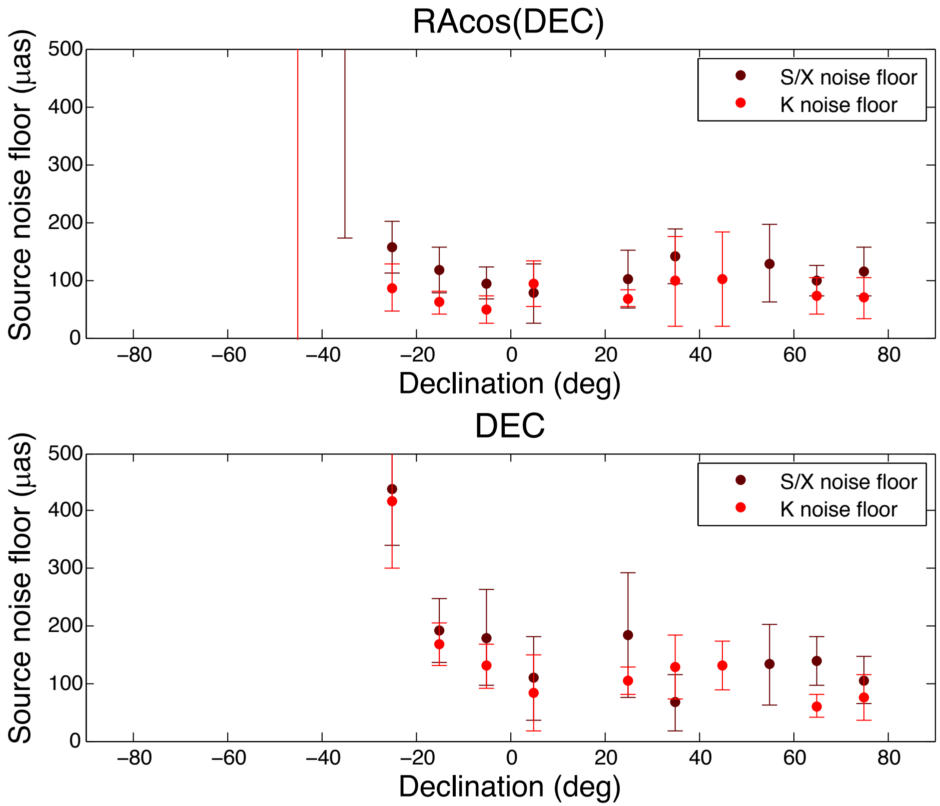
Standard deviation

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

Comparison of partial solutions

UD vs. UF-UG sessions (31 common sources)

Noise floor comparison in 10º declination bands

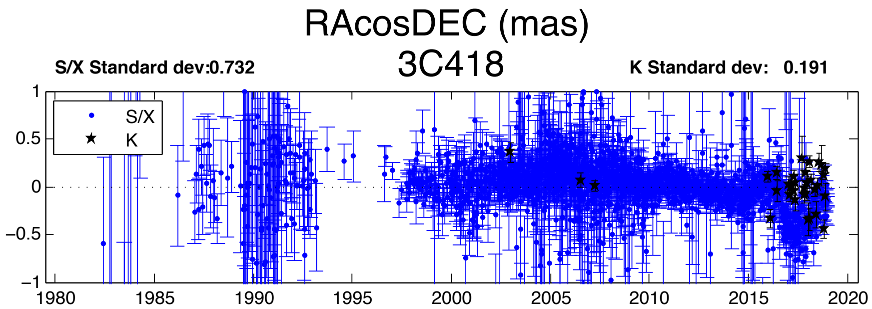


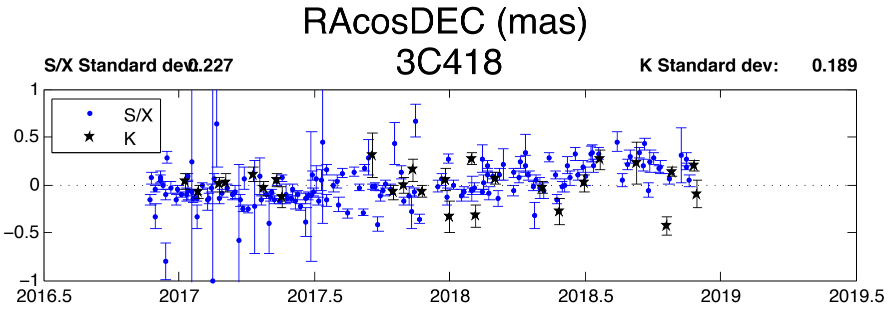
Conclusion

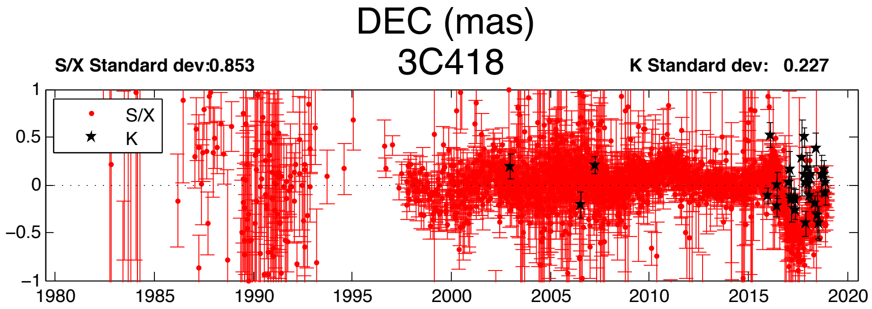
- K-band time stability
  - The K-band observations have reached a level of stability equivalent to the level of current S/X observations. They benefited from the history of the S/X observations.
  - The strength of the S/X data set is in its broad diversity of baselines and sessions.
  - Comparing the VLBA sessions UD (K-band) and UF-UG (S/X-band), it seems to show the K-band statistic stability is better than the S/X-band statistic stability.
  - We need more K-band observations to continue monitoring and comparing the stability of the frame realized by the K-band observations.
- Thanks to the VLBA, K-band observations have increased greatly in the past two years, prompting many studies. At the EVGA2019:
  - 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.

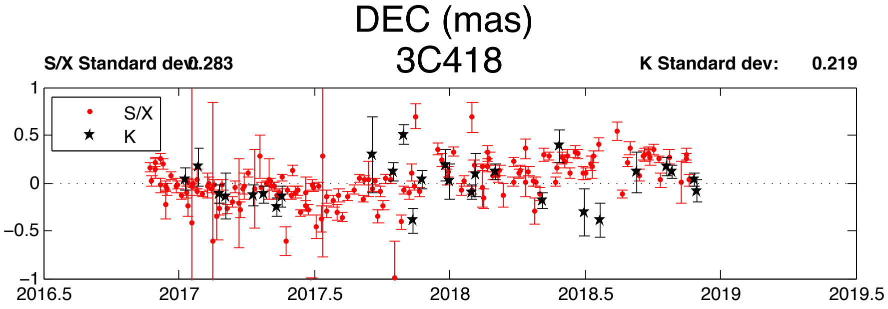
And more…

- Structure?



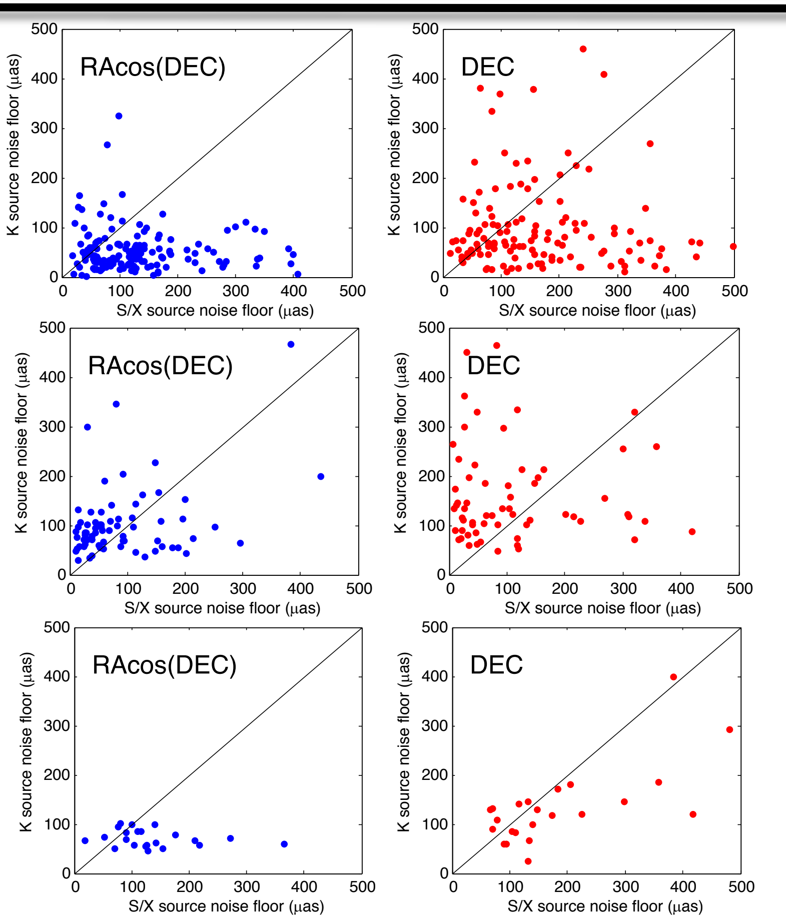






Noise floor comparison on individual sources

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