Investigation of the relationship between sensitivity level of the sources and the internal reliability value of VLBI observations during CONT14

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CONTENT

❖ Internal reliability analysis

  ❖ To investigate the continuous VLBI Campaign 2014 (CONT14) based
     on internal reliability analysis

❖ A priori sensitivity analysis

  ❖ To investigate the CONT14 based on a priori sensitivity analysis

❖ Effect of excluded radio sources on internal reliability

❖ Conclusions

Internal Reliability Analysis

❖ Internal reliability is used for quantification of the controlling an observation with the help of the other observations in the network.

❖ Internal reliability describes the magnitude of the undetectable gross errors by using hypothesis testing.

$$\Delta_{0j} = m_0 \sqrt{\frac{\delta_0}{e_j^T P Q_{\hat{v}\hat{v}} P e_j}}$$ the internal reliability of the jth observation, for the correlated observations

$$e_j^T = [.. \quad 0 \quad 0 \quad 1 \quad 0 \quad ...]$$ a selection vector

m_0 is derived from the a posteriori value of the experimental variance

$Q_{\hat{v}\hat{v}}$ is the cofactor matrix of the residuals

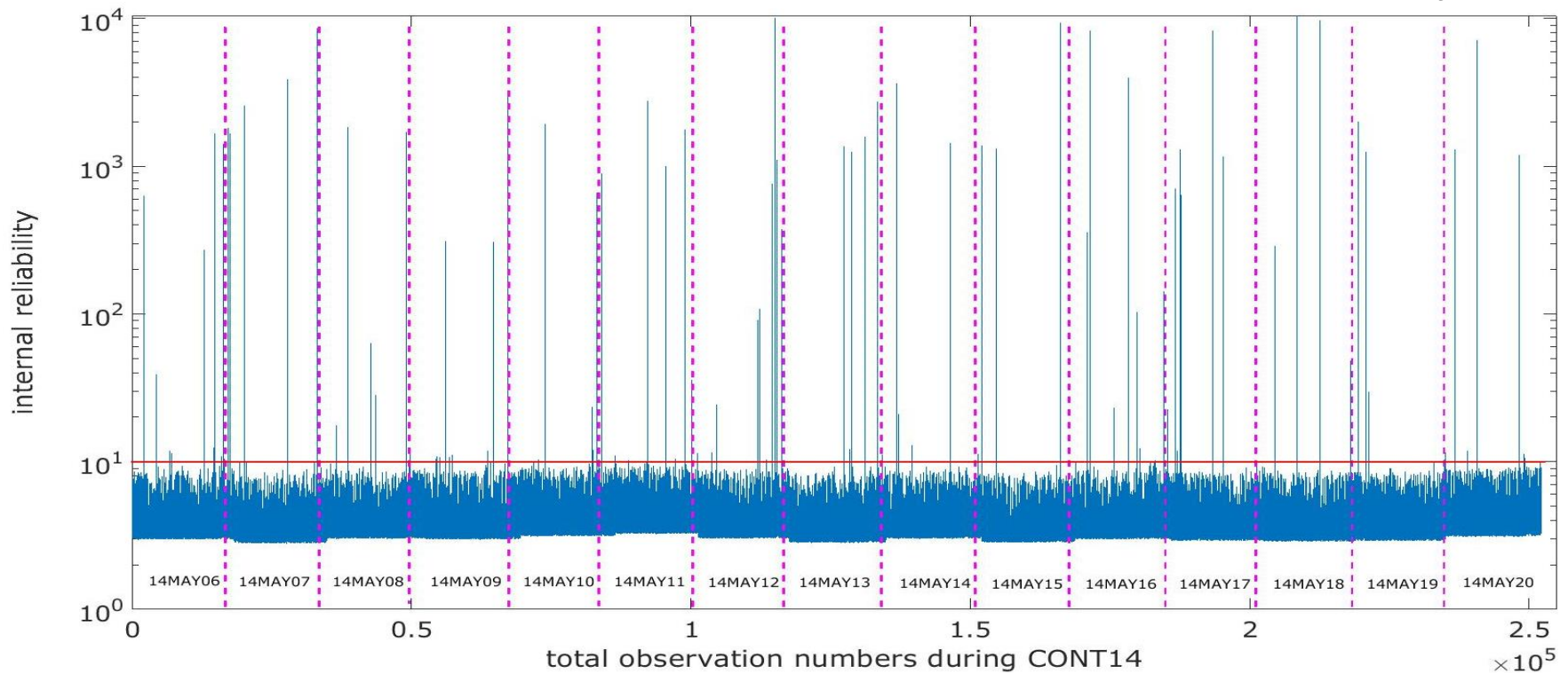$\delta_0 = 7.804$ is the threshold value of the non-centrality parameter

P is the weight matrix of the observations

(Konak et al, 2019)

Internal reliability values during CONT14

$$\Delta_{0j} > 10$$

❖ This figure illustrates the whole observations during CONT14 sessions. It is supposed that the observations exceeding the red line have the worst quality based on internal reliability compare to other observations. The purple dashed lines separate the sessions from each other.
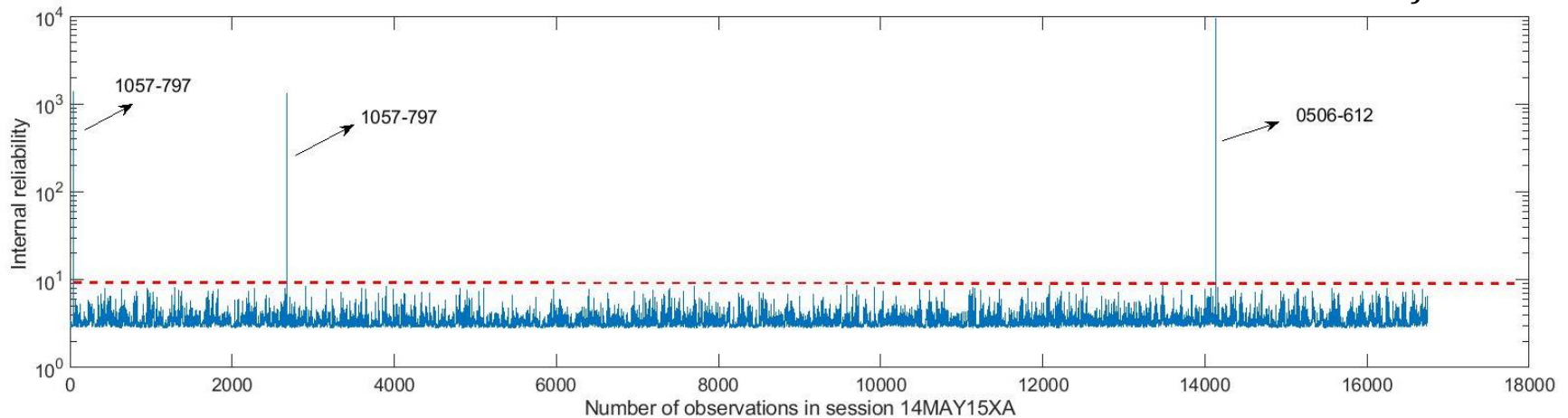
❖ Internal reliabilities of the observations in session 14MAY06XA

$$\Delta_{0j} > 10$$
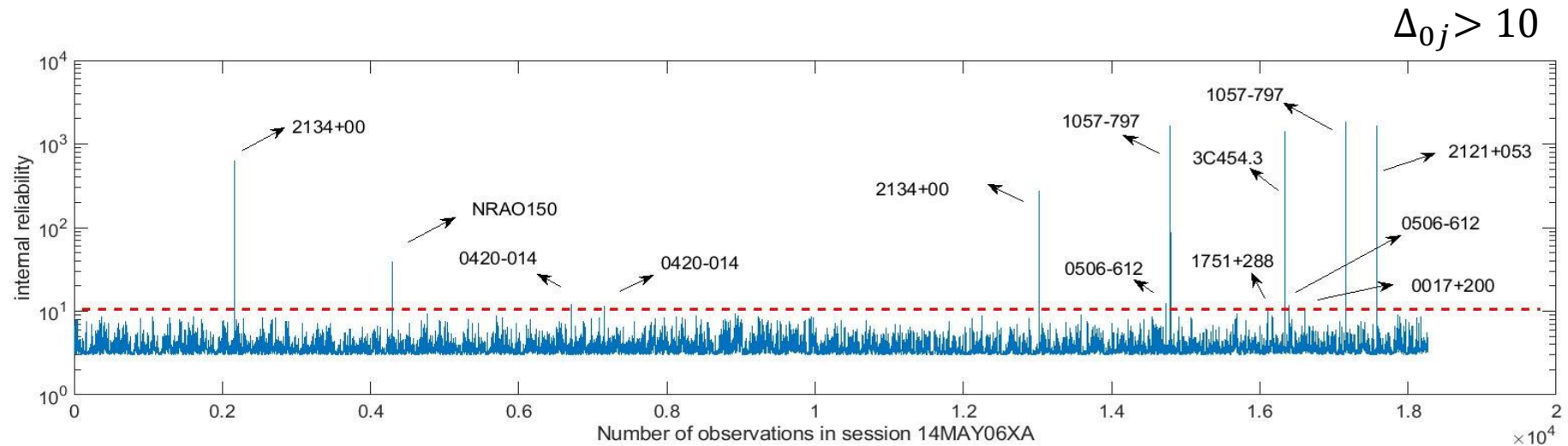
❖ It is illustrated that the internal reliability values of the observations exceeding the red line were obtained using the sources indicated in the figure.

❖ Some of the observations have significantly large internal reliability values compared to other observations exceeding the red line.
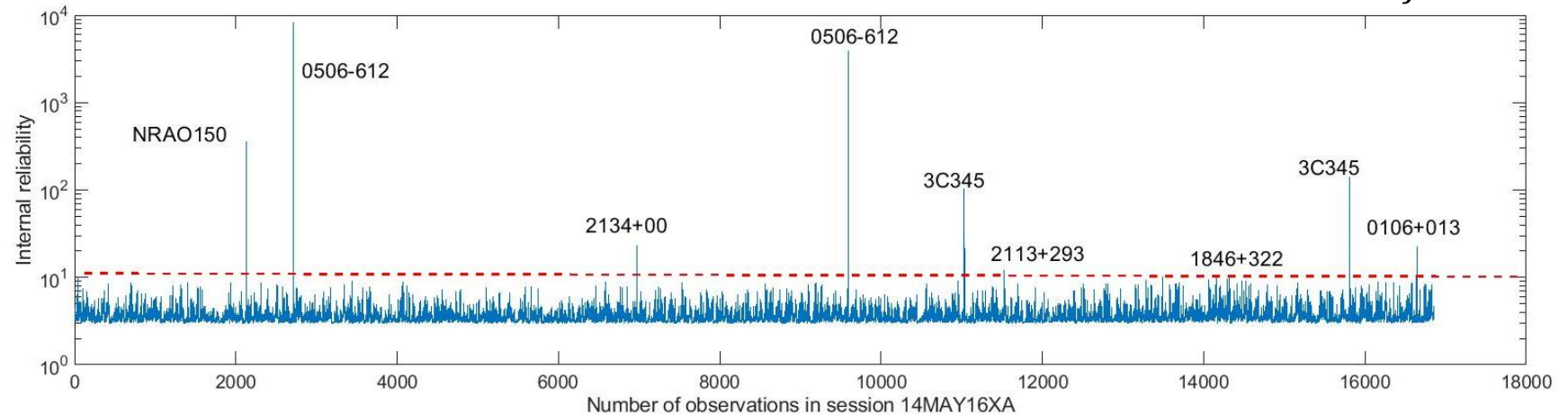
❖ Internal reliabilities of the observations in session 14MAY15XA

$$\Delta_{0j} > 10$$

❖ Internal reliabilities of the observations in session 14MAY16XA

$$\Delta_{0j} > 10$$

❖ Almost all observations exceeding the red line ($\Delta_{0j} > 10$) and having large internal reliability values were obtained using the same radio sources such as NRAO150, 0506-612, 3C345, 1057-797, and 2134+00.

A Priori Sensitivity Analysis

❖ Sensitivity is the minimum value of undetectable gross errors in the adjusted coordinate differences.

❖ The sensitivity level as a posterior sensitivity level is computed using the cofactor matrix of the displacement vector $\boldsymbol{Q}_{dd}$ estimated from two different sessions.

❖ To obtain the sensitivity level of each session as a priori sensitivity level, the cofactor matrix of the unknown parameters $\boldsymbol{Q}_{dd} = \boldsymbol{Q}_{xx}$ is used (Konak et al, 2019).

$$\boldsymbol{Q}_{xx} = \begin{bmatrix} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & q_{\alpha1\alpha1} & q_{\alpha1\alpha2} & q_{\alpha1\delta1} & q_{\alpha1\delta2} & \cdot \\ \cdot & q_{\alpha2\alpha1} & q_{\alpha2\alpha2} & q_{\alpha2\delta1} & q_{\alpha2\delta2} & \cdot \\ \cdot & q_{\delta1\alpha1} & q_{\delta1\alpha2} & q_{\delta1\delta1} & q_{\delta1\delta2} & \cdot \\ \cdot & q_{\delta2\alpha1} & q_{\delta2\alpha2} & q_{\delta2\delta1} & q_{\delta2\delta2} & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{bmatrix}_{u,u}$$

$$\ddot{\boldsymbol{N}}_1 = \begin{bmatrix} \cdot & \cdot & q_{\alpha1\alpha1} & q_{\alpha1\alpha2} & q_{\alpha1\delta1} & q_{\alpha1\delta2} & \cdot & \cdot \\ \cdot & \cdot & q_{\delta1\alpha1} & q_{\delta1\alpha2} & q_{\delta1\delta1} & q_{\delta1\delta2} & \cdot & \cdot \end{bmatrix}_{2,u}$$ Sub-matrix of the $\boldsymbol{Q}_{xx}$ for the first radio source

$$\left(\boldsymbol{Q}_{d_1 d_1}\right)_{2,2} = \ddot{\boldsymbol{N}}_1 \boldsymbol{N} \ddot{\boldsymbol{N}}_1^T = \begin{bmatrix} q_{\alpha1\alpha1} & q_{\alpha1\delta1} \\ q_{\delta1\alpha1} & q_{\delta1\delta1} \end{bmatrix}_{2,2}$$

α is Right ascension of a radio source

δ is declination of a radio source

- ❖ Weight matrix of each radio source $\boldsymbol{P}_{d_i} = \left(\boldsymbol{Q}_{d_i d_i}\right)^{-1}$ is obtained and decomposed into its eigenvalue and eigenvector.

- ❖ The best sensitivity level (d_{min}) depends on the maximum eigenvalue of the weight matrix (λ_{max}) for each radio source.

$$\|d\|_{min} = \frac{\delta_0 \sigma}{\sqrt{\lambda_{max}}} \qquad \text{(Hsu and Hsiao, 2002)}$$

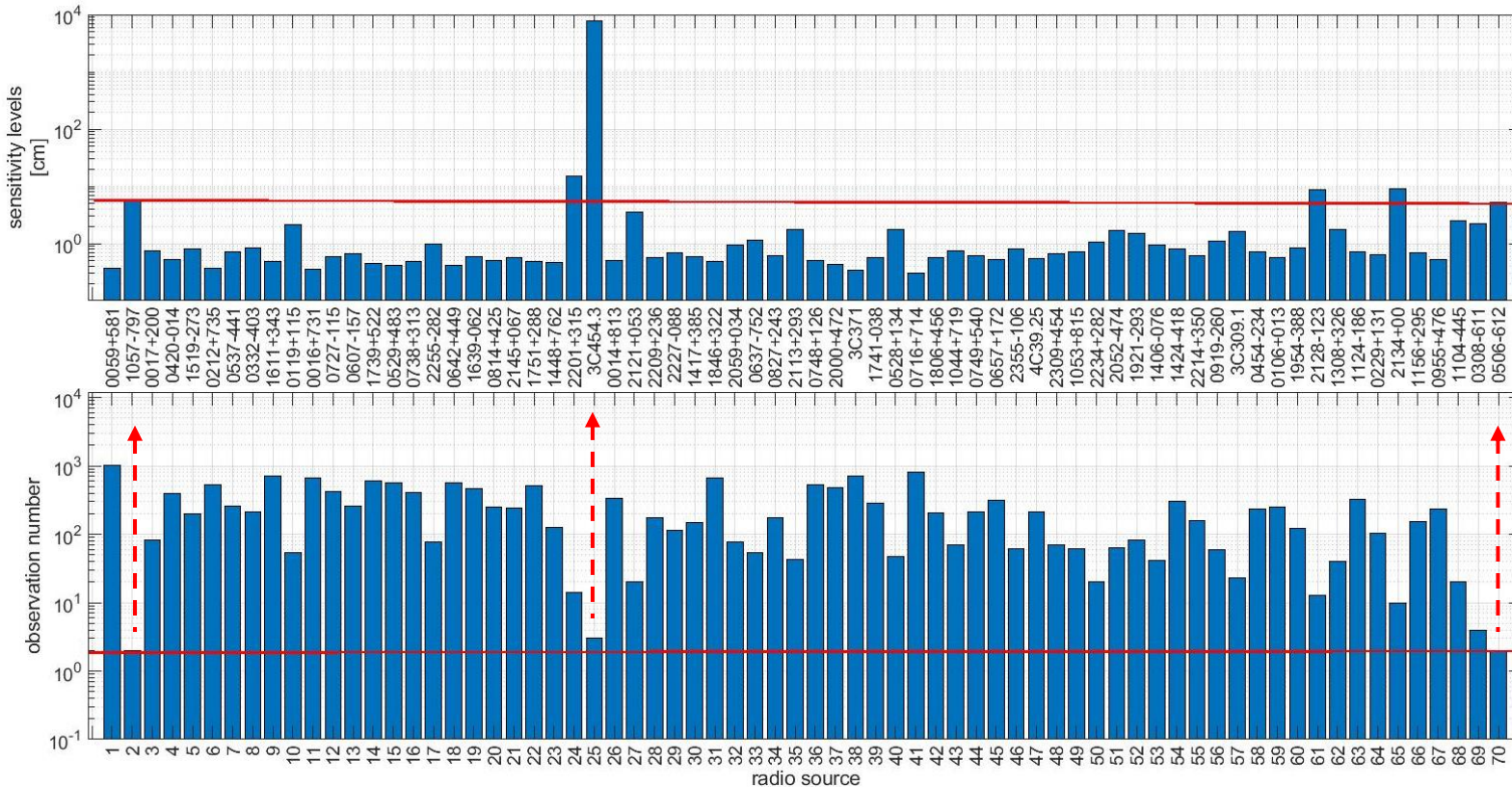σ is derived from the theoretical variance of the unit

$\delta_0 = \delta(\alpha_0, \gamma_0, h, \infty)$ is the threshold value of the non-centrality parameter

❖ Sensitivity levels vs. observation numbers in sessions 14MAY06XA, 14MAY15XA and 14MAY16XA
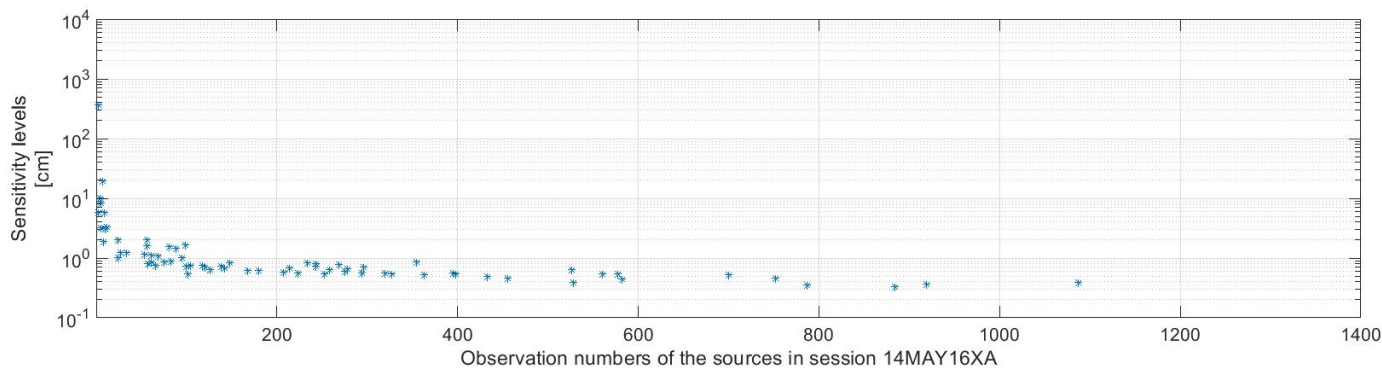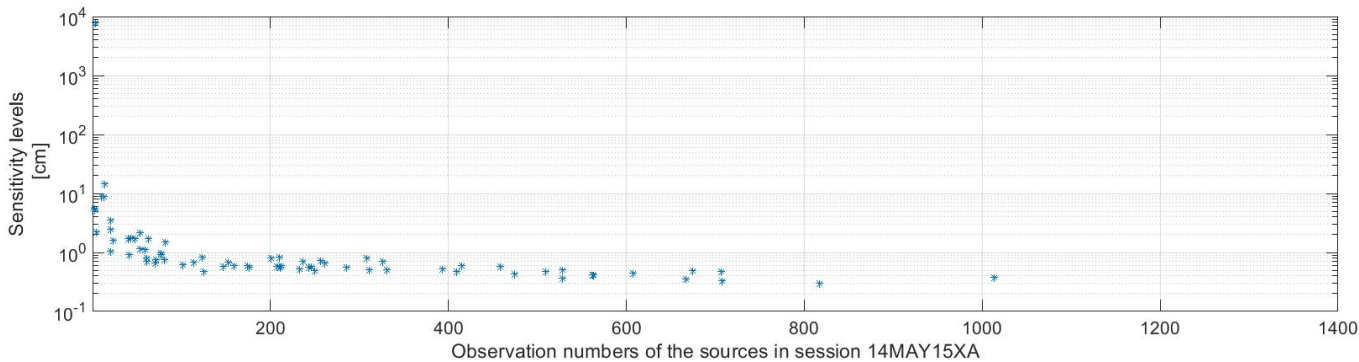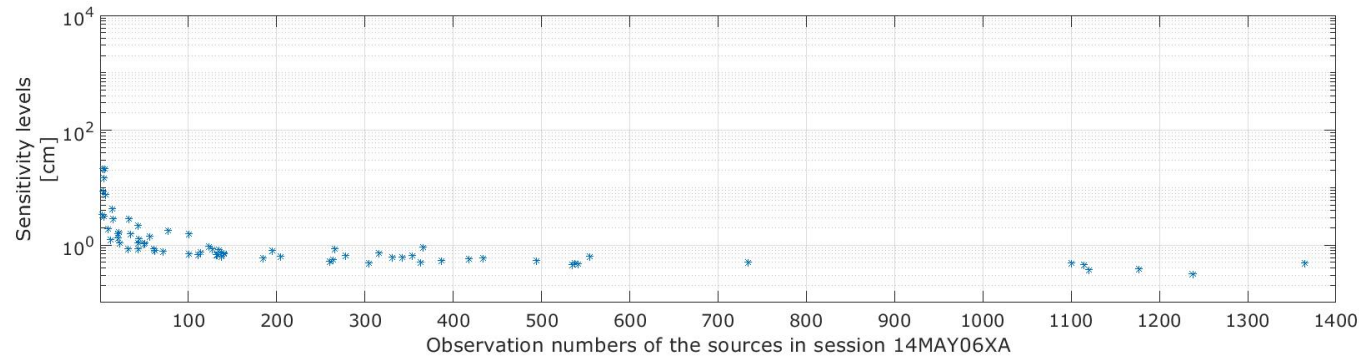
❖ The sensitivity level is most of all affected by the number of observations.

## Sensitivity levels vs. observation numbers in session 14MAY15XA
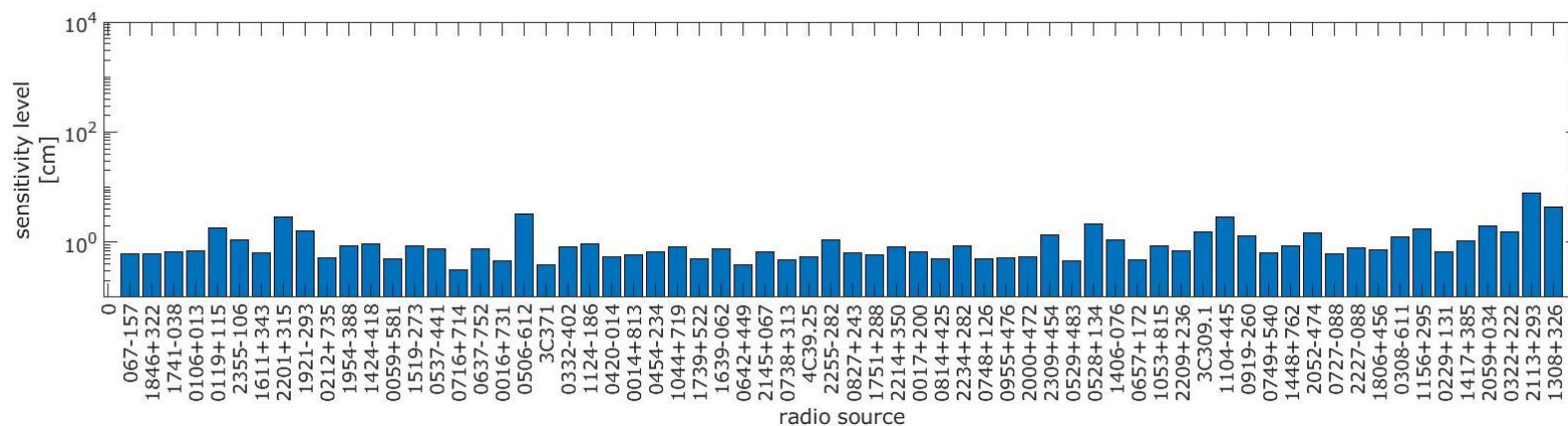

1057-797

3C454.3

0506-612

❖ If the radio sources both 1057-797 or 0506-612 and 3C454.3 are compared based on observation numbers and sensitivity levels, their sensitivity levels are significantly different, although they have almost the same number of observations.

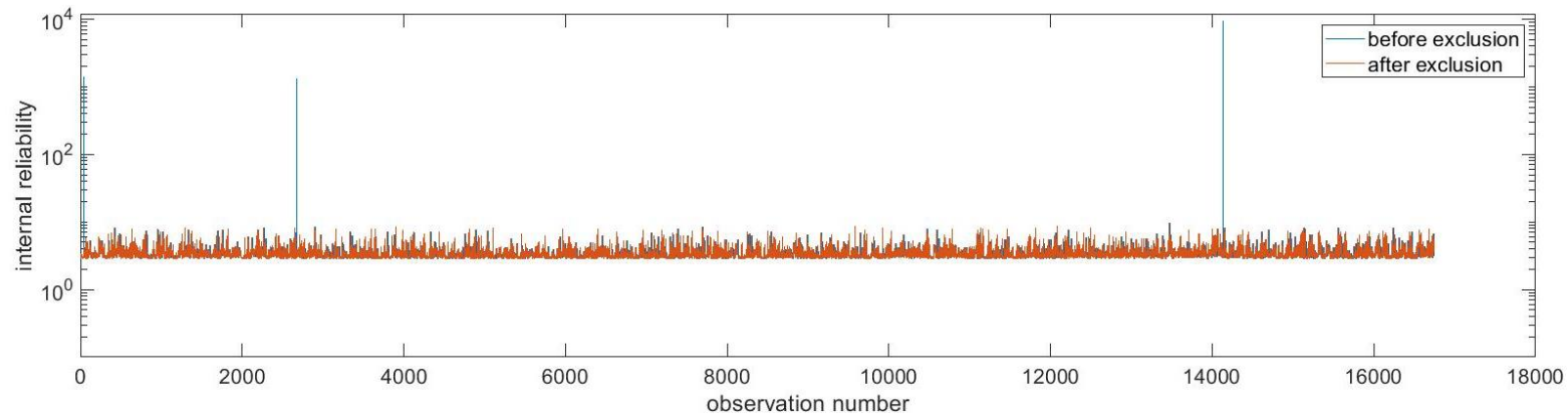# Effect of excluded radio sources on internal reliability
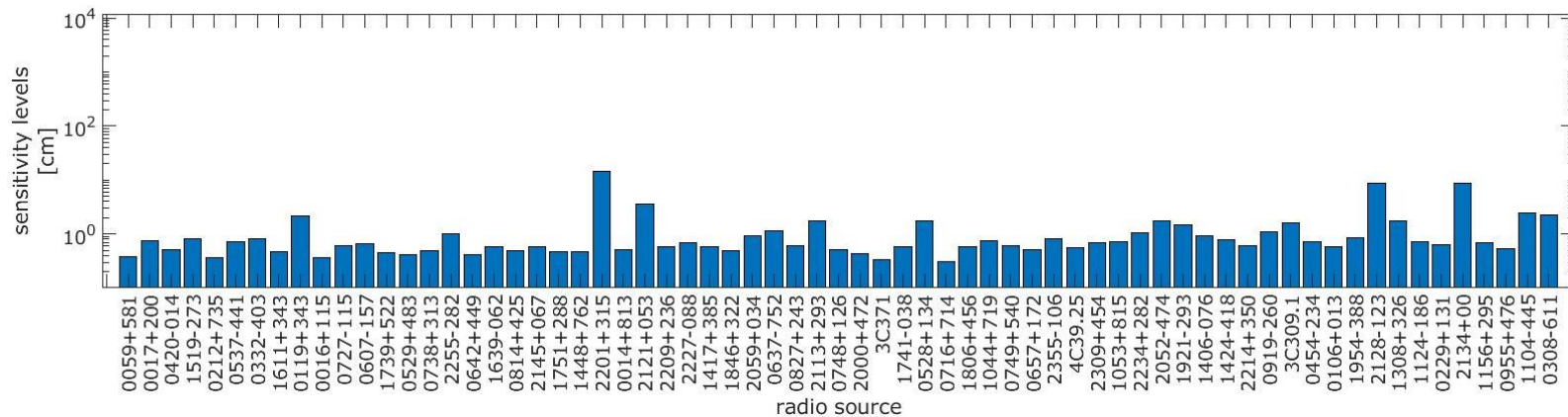
❖ in session 14MAY06XA
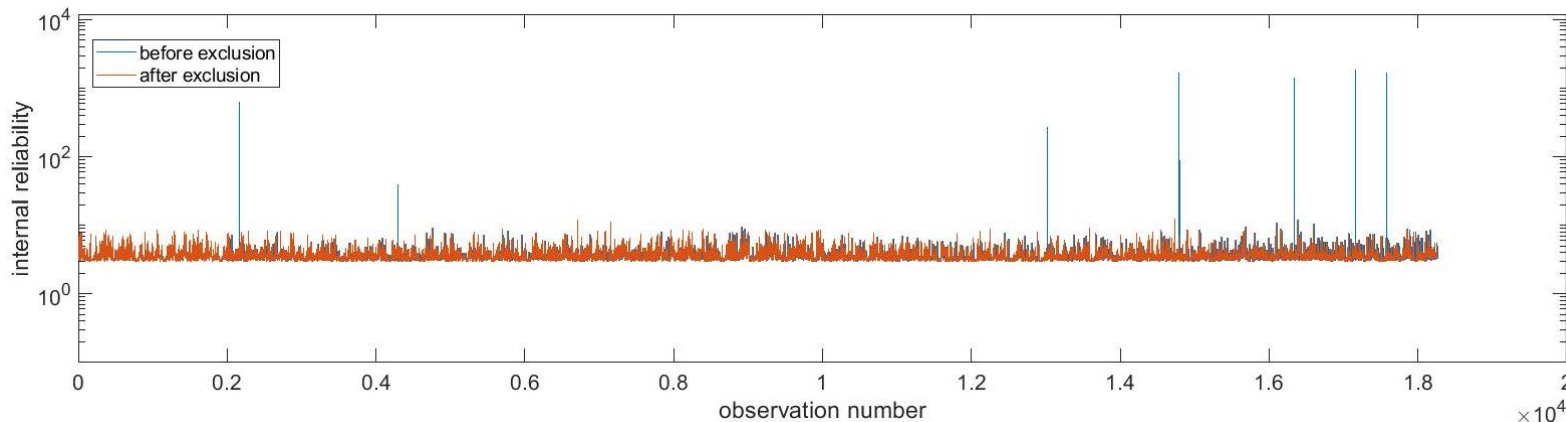
Excluded radio sources:
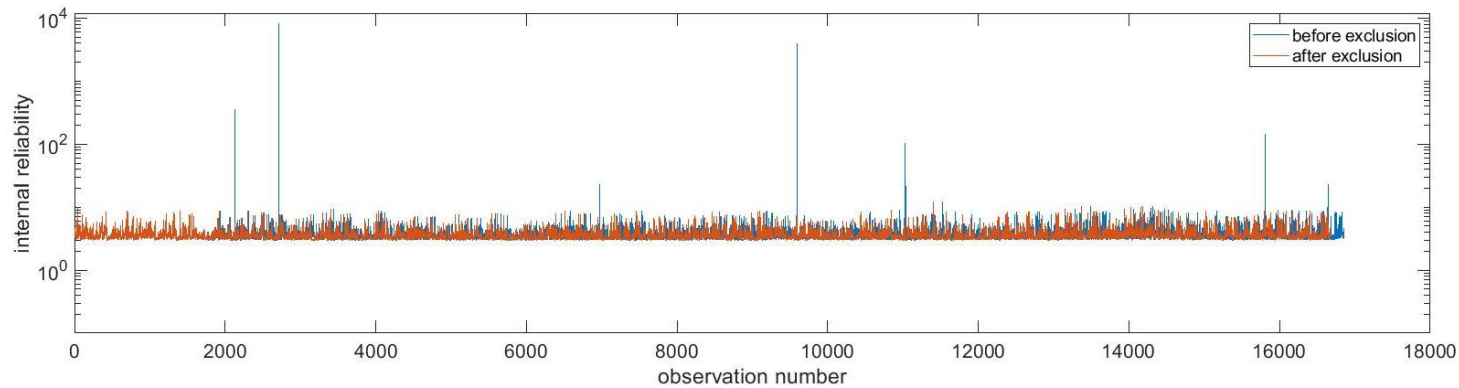1057-797
3C454.3
2121+053
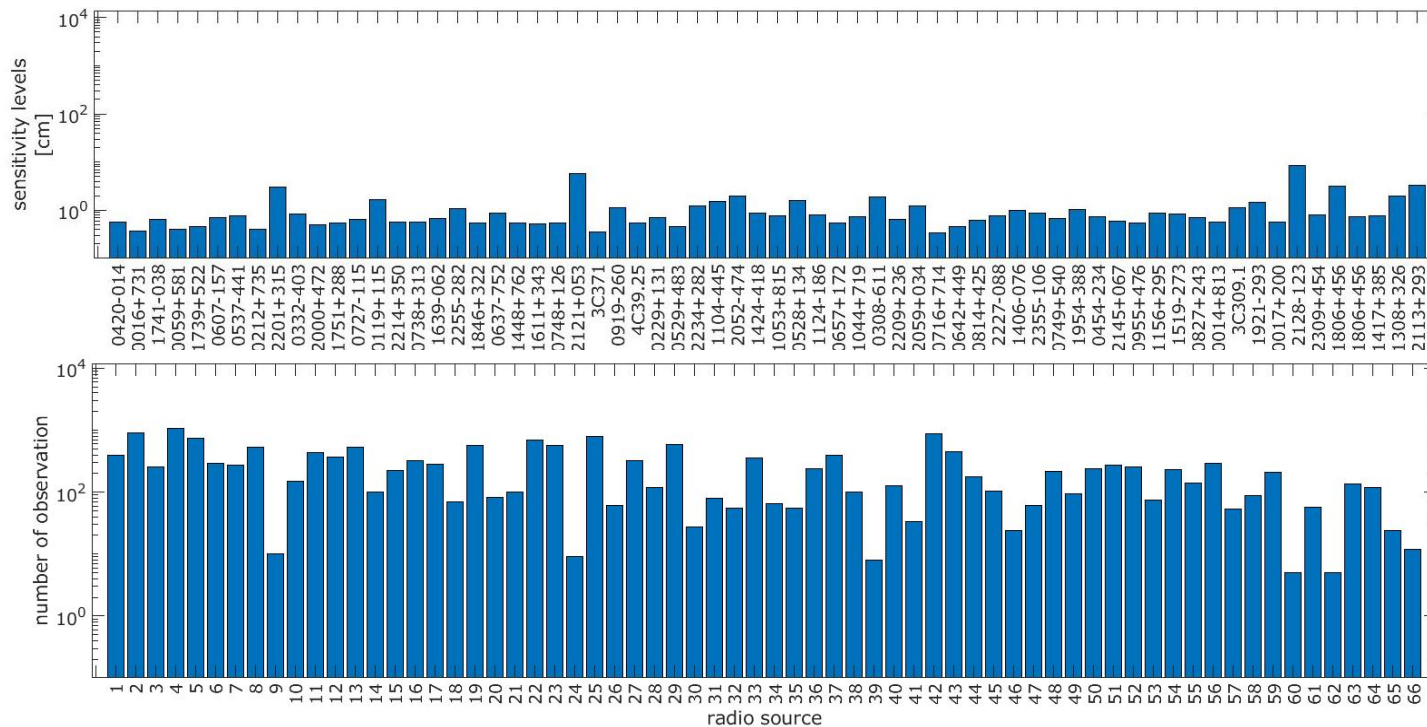NRAO150
2134+00

❖ in session 14MAY15XA

Excluded radio sources:
1057-797
0506-612
3C454.3

❖ in session 14MAY16XA

Excluded
radio
sources:
3C345
0506-612
NRAO150
2134+00
0106+013

Conclusions

❖ Internal reliability contains information about the quality of observation. If an observation has large internal reliability, the observation must be excluded from the observation list to do reliable statistical analysis.

❖ For the sensitivity analysis of the radio sources, the number of observations at a source is extremely important.

❖ In most of the sessions, 0506-612, 3C454.3, NRAO150, and 3C345 have both worse sensitivity levels and observations having worse internal reliability.

❖ A radio source having a few observation can have worse sensitivity value compared to other radio sources.

❖ If we exclude the observation having large internal reliability at a radio source that have a few observation, the sensitivity level of the source get worse.

Thank you!

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Acknowledgments

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