The “assess_ms” tool for ALMA uv coverage assessment

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The assess_ms tool for (ALMA) uv coverage assessment

assess_ms is a result of the ALMA internal development study
"New methods for ALMA beam assessment, scheduling and shaping" (Petry et al. 2024)

- Full description contained in the Final Report chapter 7.

- For the moment, intended for internal use for ALMA QA0 and QA2,
  but in the mid-term to be released in a public version for general use!

- Set of Python modules "assess_ms.py" and "mshistotools.py" tested under CASA 6.5.4 .

- General idea:

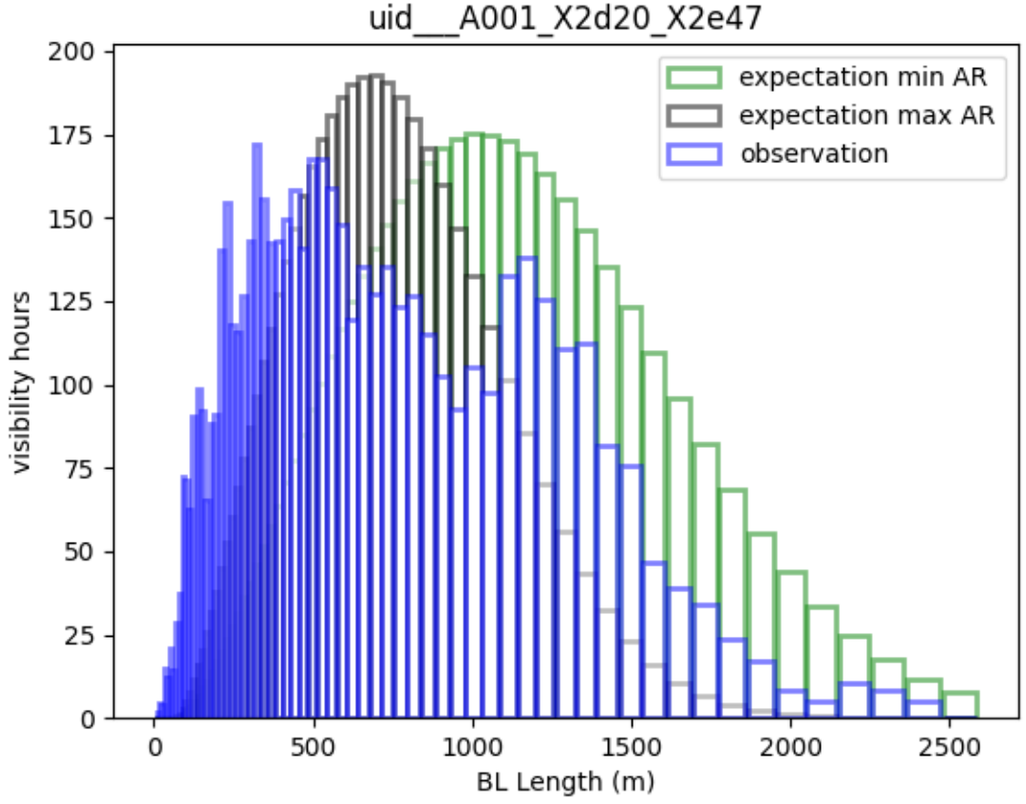
Input: a) set of MSs which are to be assessed together as one dataset
b) description of the expected dataset parameters like
- choice of representative target and SPW
- angular resolution
- max. recoverable scale
- time on-source

Output: set of diagnostic plots and parameters describing the quality of the uv coverage in comparison with a theoretical ideal case.

Diagnostic output produced by assess_ms

1D Baseline Length Distribution: Observation and Expectation

Expectation is computed based on the given range of acceptable AR values and LAS request using a tapered Gaussian shape which approximates the ALMA C43 configuration design.



Bin width increases linearly with baseline length for better statistics at the longest baselines.

Diagnostic output produced by assess_ms

2D Filling Fraction plot

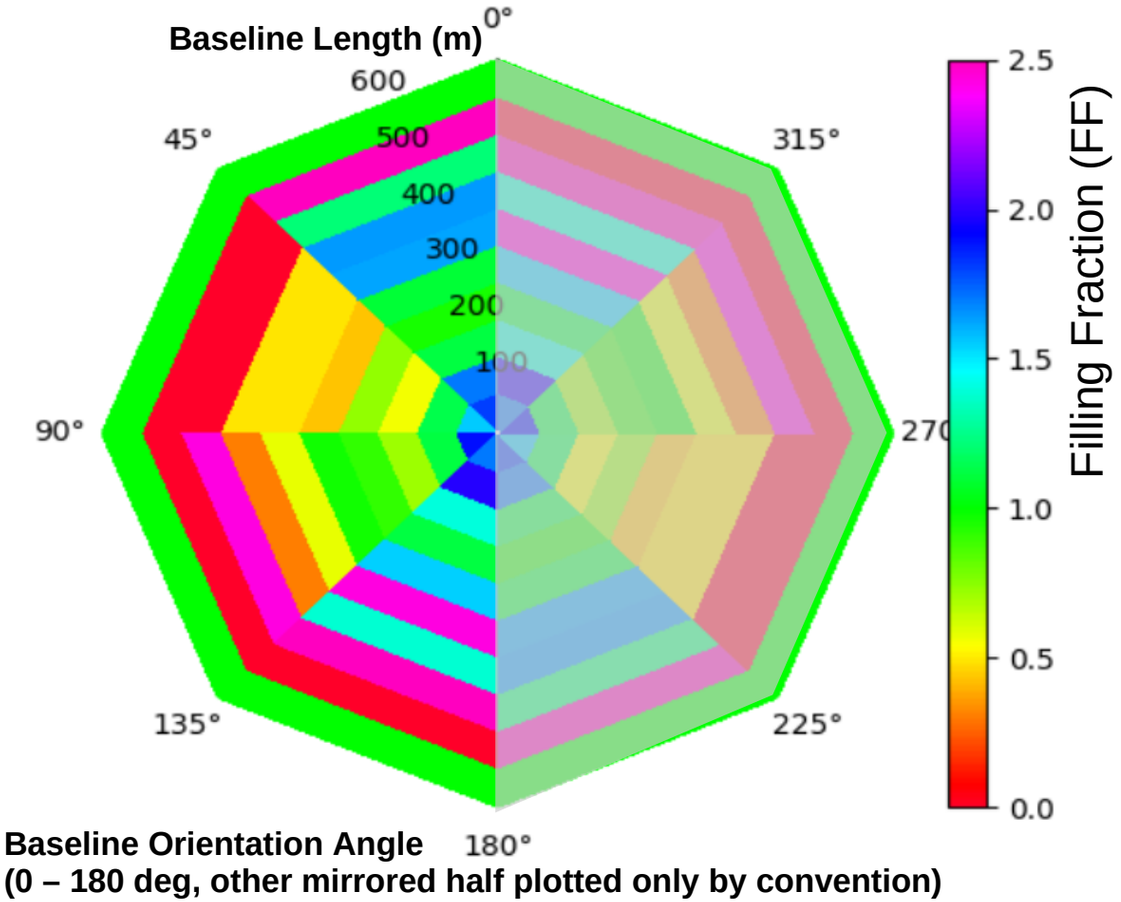
4 x 10 uv coverage assessment matrix of “filling fractions” (FFs)

FF *= observed #visibilties (weighted) / expectation*

4 equidistant bins along azimuth,
i.e. 4 sectors of 45 deg

10 equidistant bins along BL

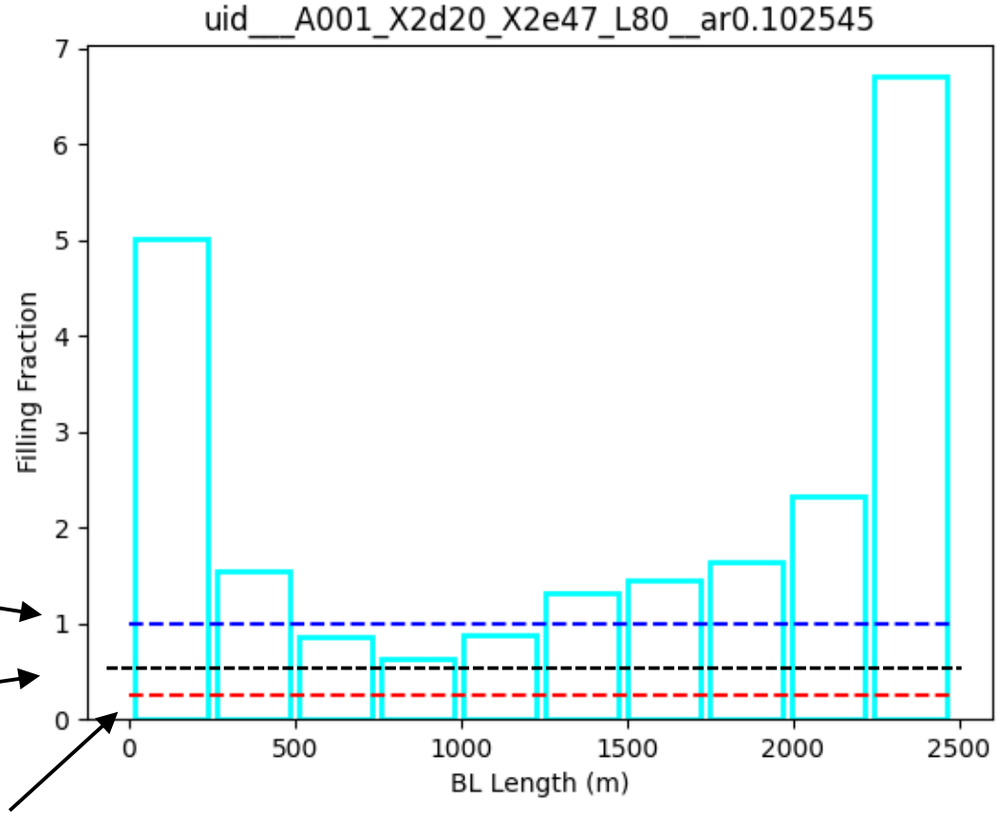
Ideal result: FF = 1.0 in all 40 bins.



Diagnostic output produced by assess_ms

1D Filling Fraction plot:

This is the 2D plot summed over all (four) sectors.



Ideal FF value = 1.0

Suggested minimum acceptable value (for QA) = 0.5

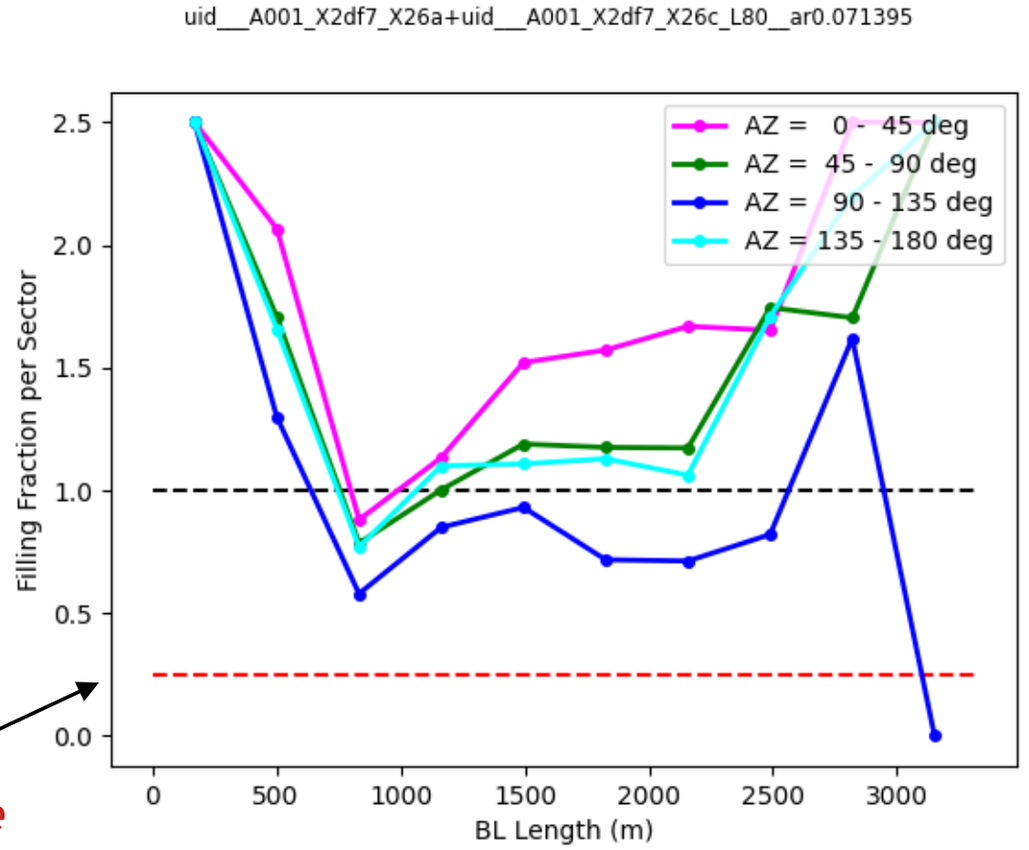
Suggested minimum acceptable value (for QA) in individual 45^{o} sector = 0.25

Diagnostic output produced by assess_ms

1D Filling Fraction plot for the 4 sectors separately:

Ideally, the four plots should look the same.

In reality, they often don't!



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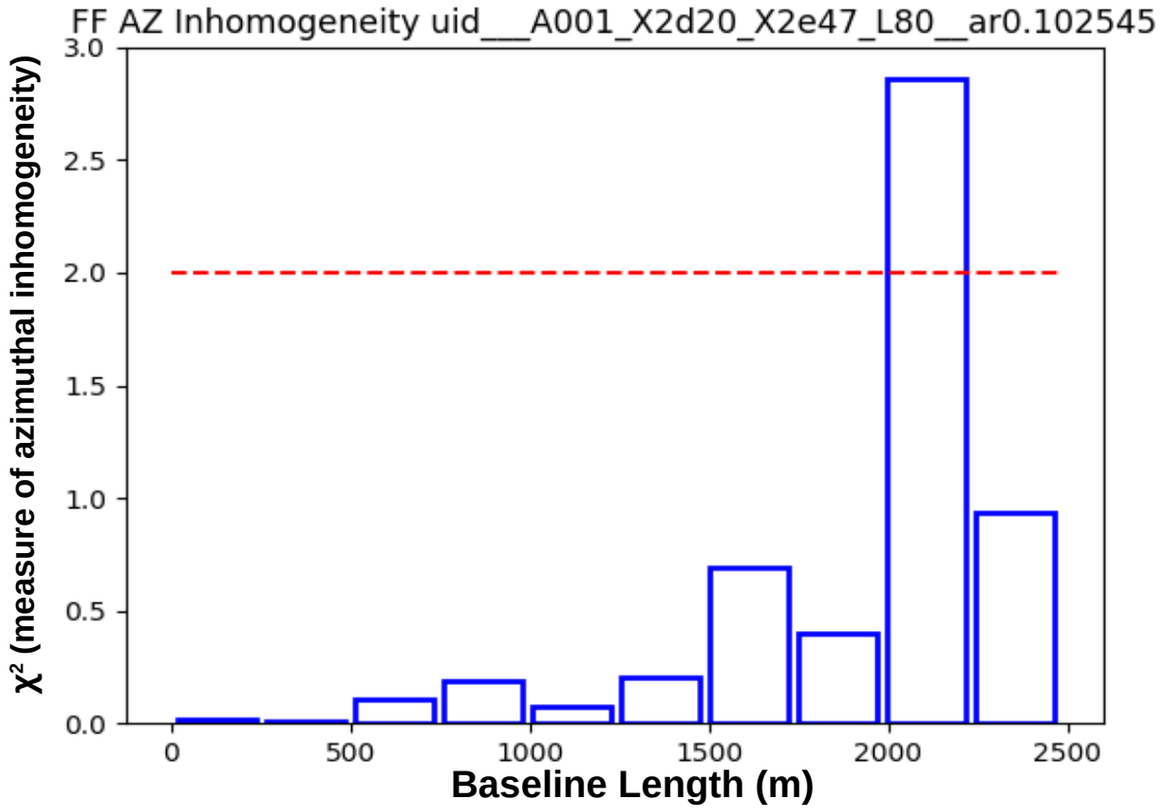
Development Study Results – BLD assessment

Another diagnostic plot to quantify the azimuthal (in)homogeneity:

Beam ellipticity correlates with the azimuthal homogeneity of the uv coverage.

- ***require that the four FF matrix elements in same BL bin are consistent with being constant ($\chi^2 < 2.0$)***

New diagnostic plot of the ***χ^2 of a constant fit*** *across azimuth in each BL bin vs. BL*



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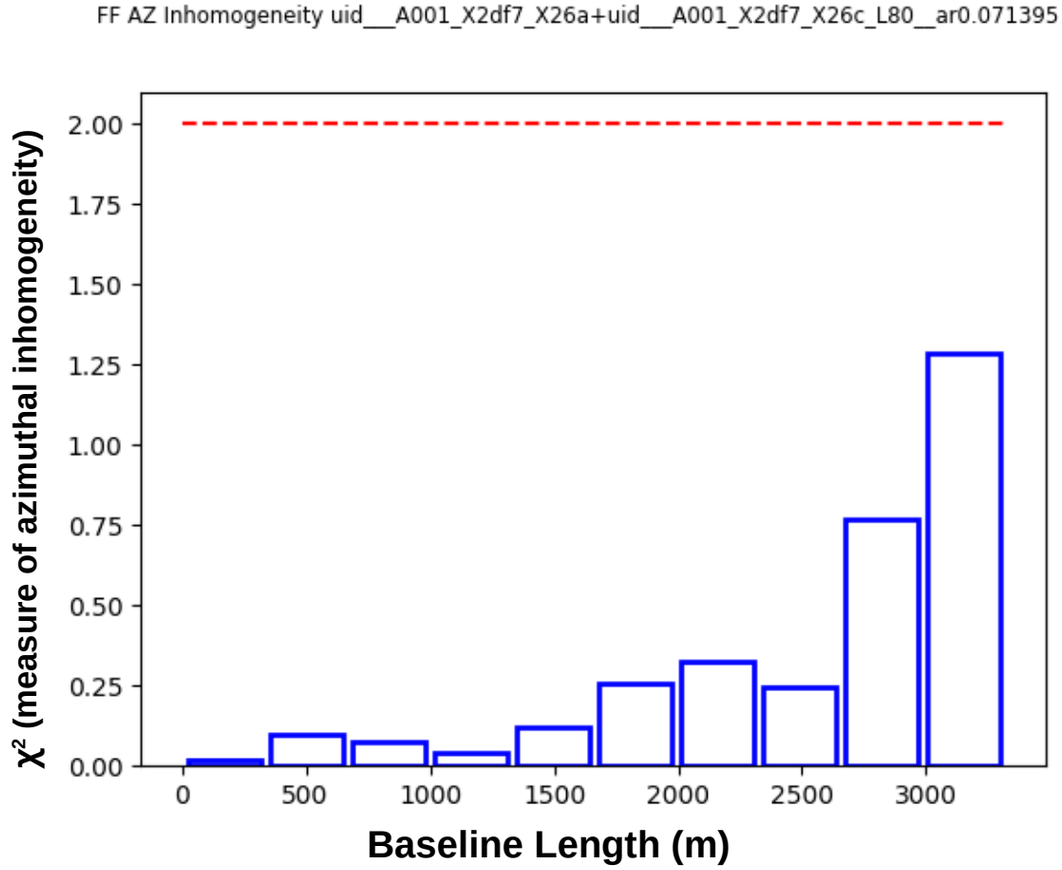
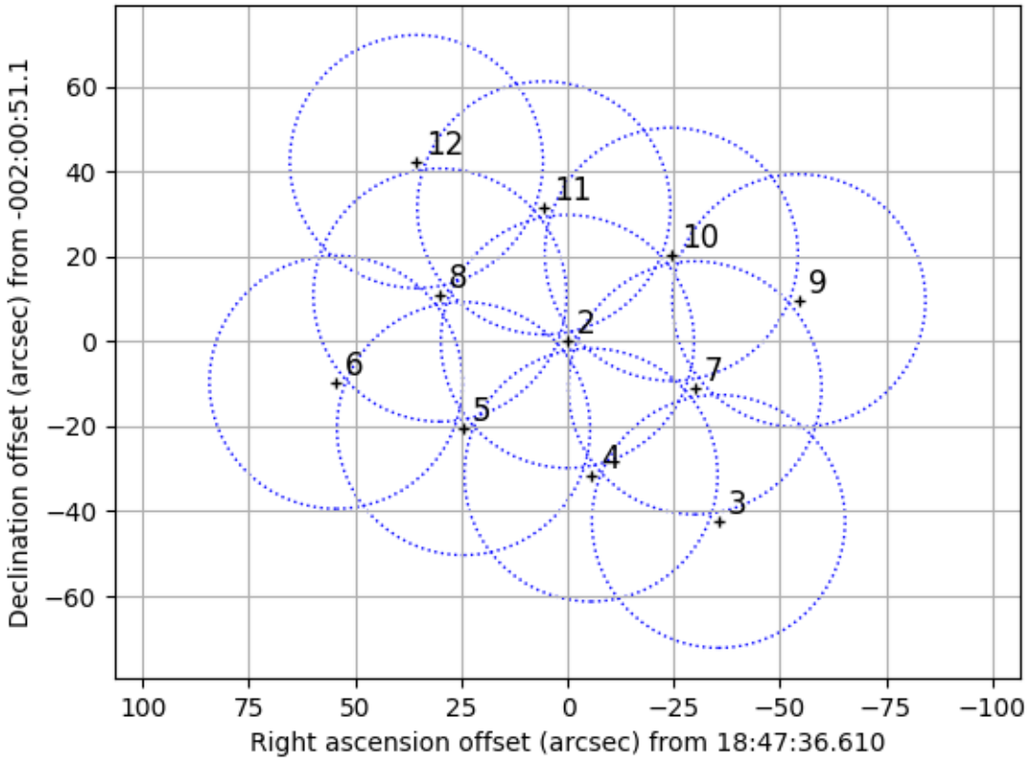
New diagnostic plot of the ***χ^2 of a constant fit*** *across azimuth in each BL bin vs. BL*

Example of a typical good result →
At the longest baselines, the inhomogeneity is always stronger ...

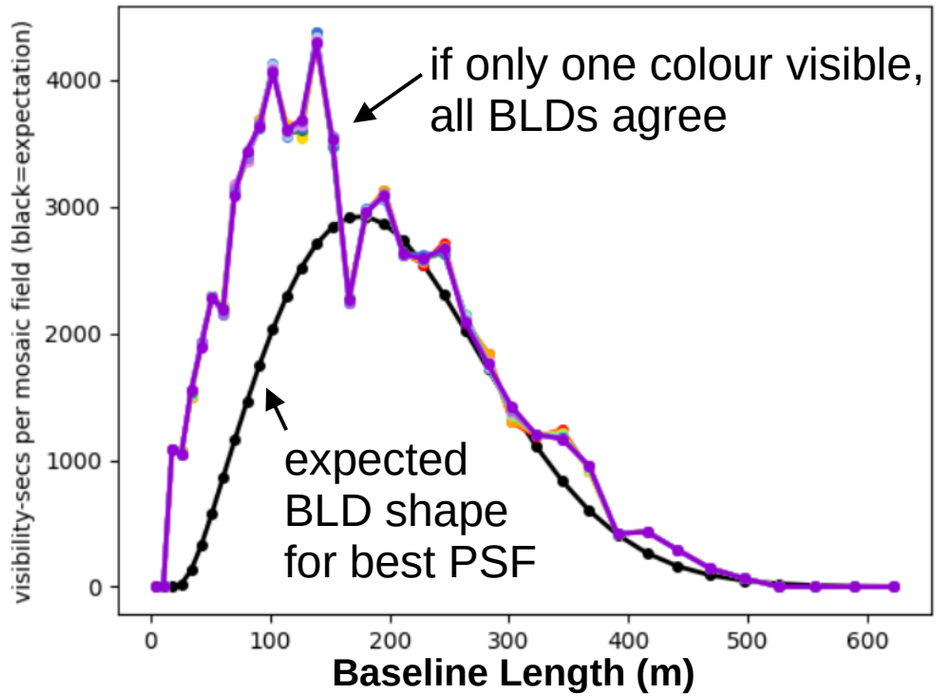


Diagnostic output produced by assess_ms

Special case: Mosaics – does each pointing obtain the same uv coverage?



New diagnosic plot: separate BLD for each mosaic field



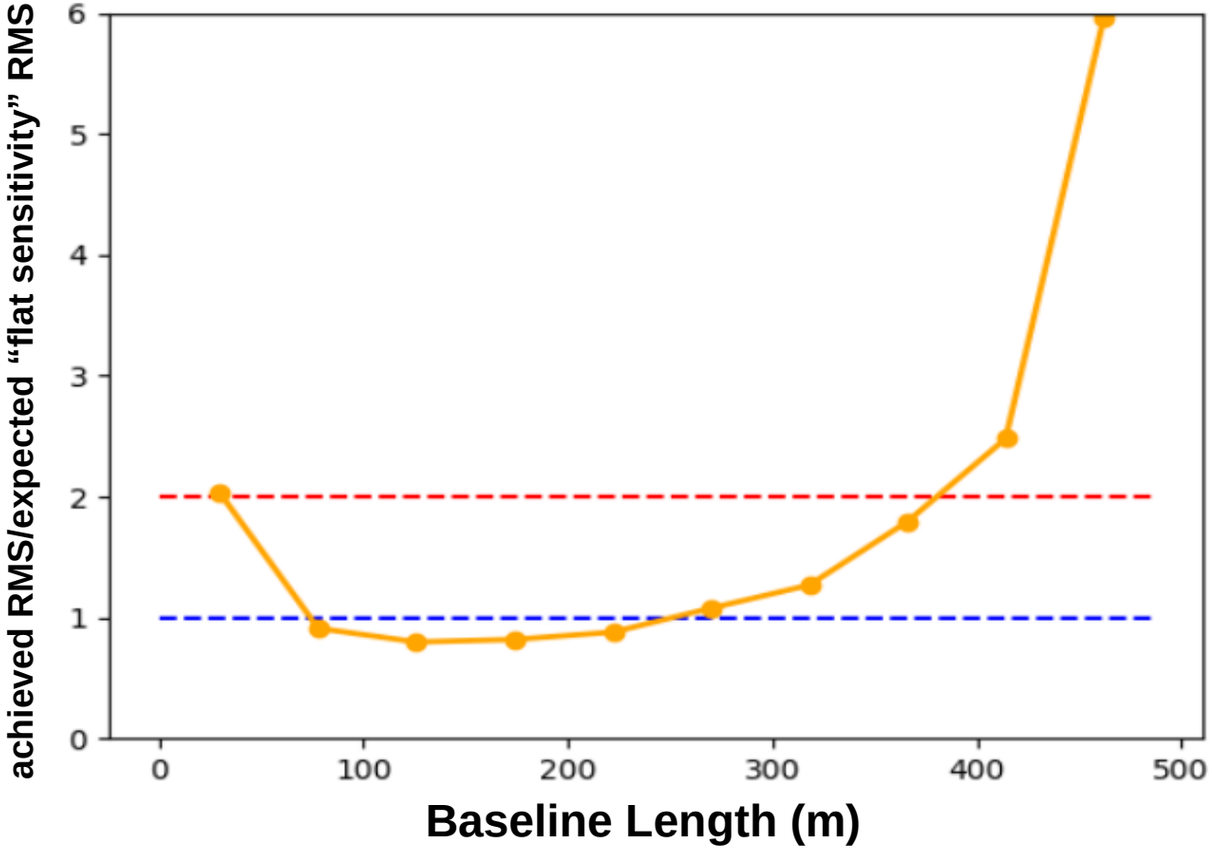
Diagnostic output produced by assess_ms

Verification of the Maximum Recoverable Scale (MRS) requirement (achieved MRS > requested Largest Angular Scale)

New (RMS/exp.RMS) vs. BL plot for assessing angular scale sensitivity

Shows in which BL range we are as sensitive as a "naive" PI would expect, i.e. if it were possible to have ***"flat sensitivity"*** ***(equal sensitivity in equal angular scale ranges).***

(Similar methods are in use in CMB power spectrum analysis: e.g. Hobson & Maisinger 2002)



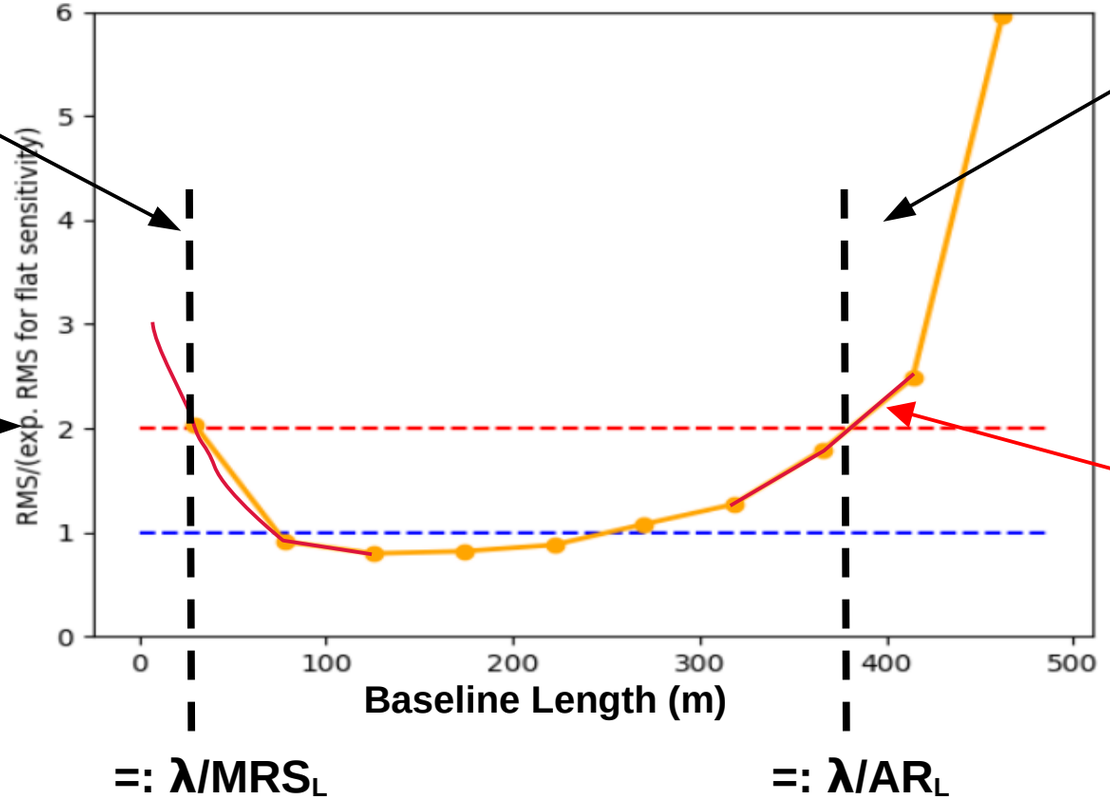
Diagnostic output produced by assess_ms

Verification of the Maximum Recoverable Scale (MRS) requirement (achieved MRS > requested Largest Angular Scale)

New (RMS/exp.RMS) vs. BL plot for assessing angular scale sensitivity

Use the smallest BL length where RMS < 2 x flat expectation as *alternative definition of* ***achieved MRS***.

2 = end of possible recovery



Use the largest BL length where RMS < 2 x flat expectation as *alternative definition of* ***achieved AR***.

(use parabolic fit to improve accuracy of AR and MRS determination)

=: λ/MRS_L **=: λ/AR_L**

Development Study Results – latest tests of assess_ms

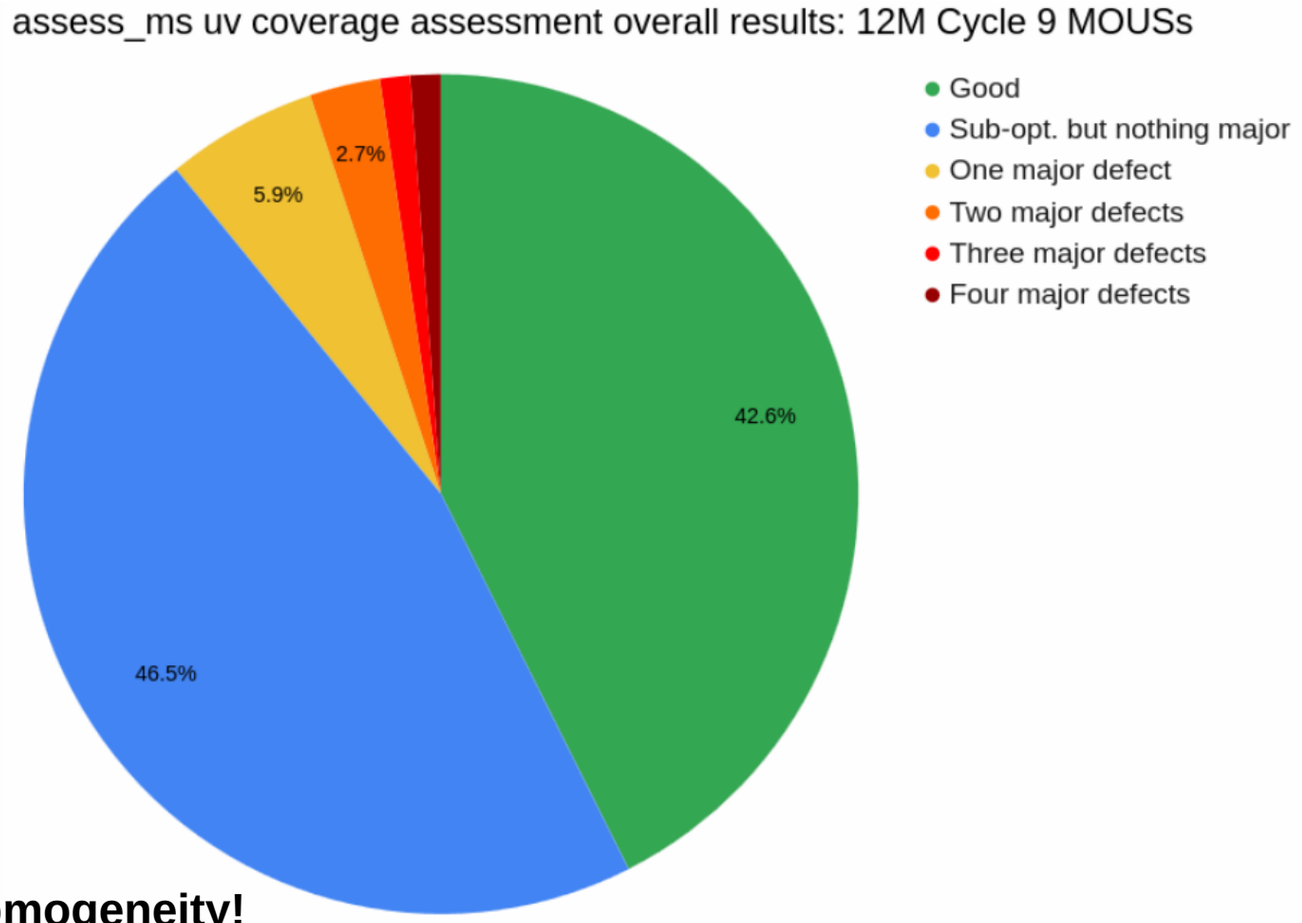
Tests of assess_ms on representative samples of Cycle 9 data

Find that 43% of the MOUSs from a representative sample of 256 delivered Cycle 9 12M MOUSs have good uv coverage.
Remaining 57%, can be divided into two basic defect categories:

1. MOUSs with no major defects but too inhomogeneous coverage (47%)

2. MOUSs with between 1 and 4 major defects such as whole underexposed sectors or whole BL ranges (10% total)

6% have one major defect
3% have two major defects
1% have three or four major defects

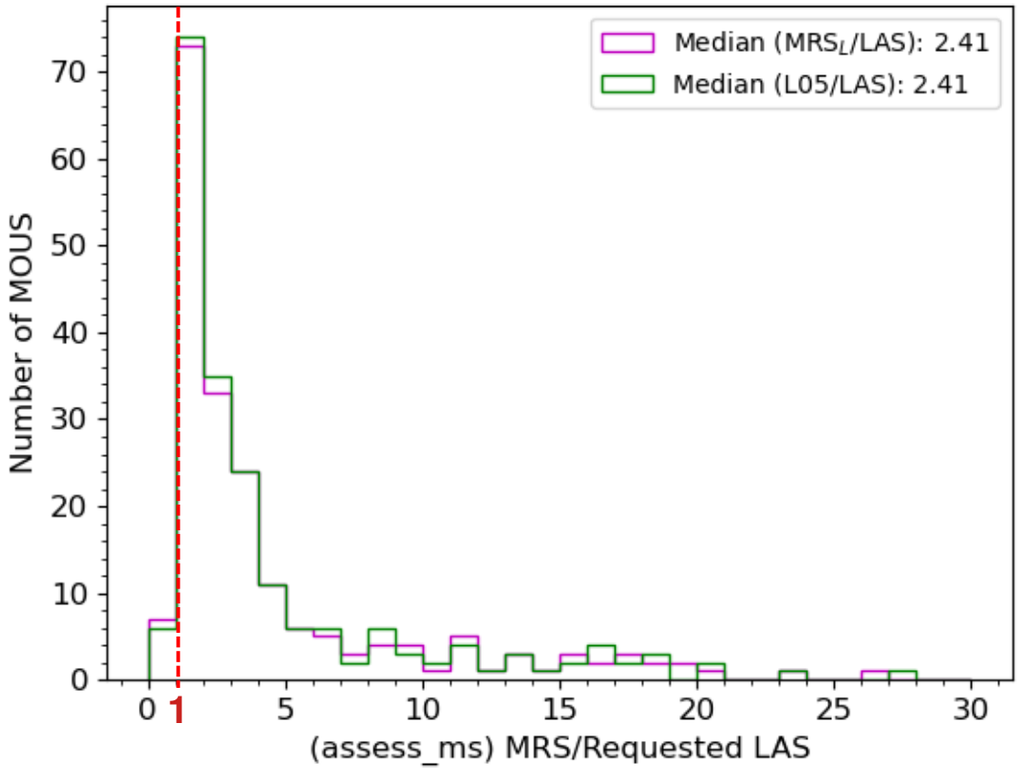


Most major defects concern azimuthal inhomogeneity!

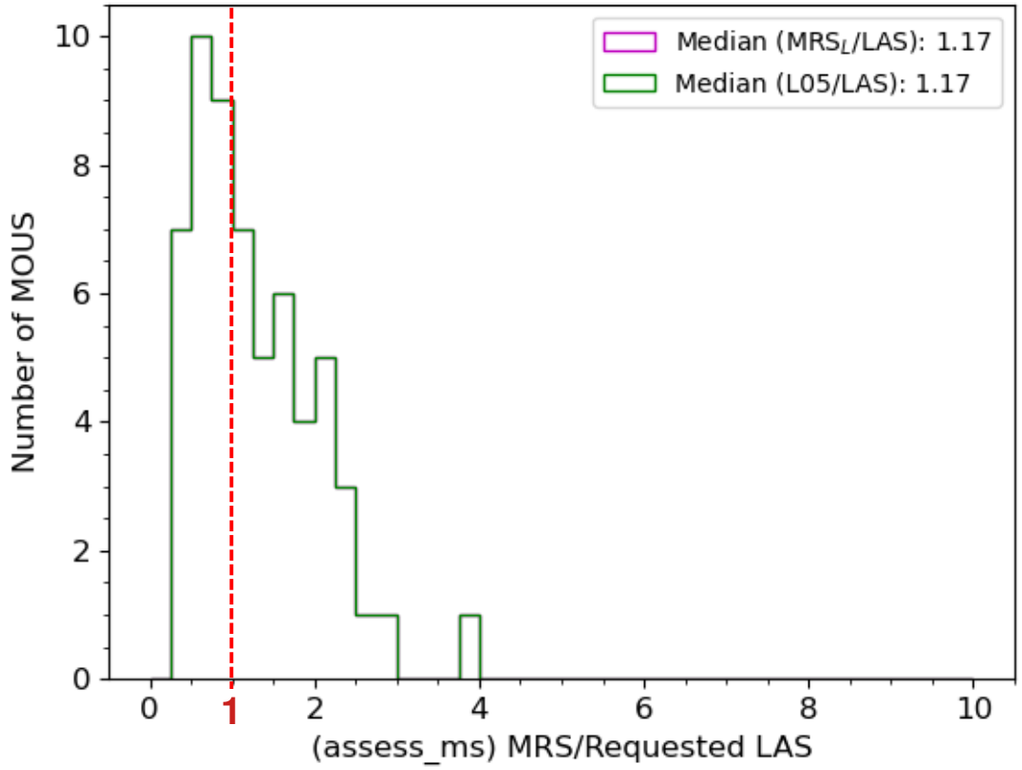
Development Study Results – latest tests of assess_ms

Tests of assess_ms on representative samples of Cycle 9 data

Sample of 214 Cycle 9 **single-MOUS GOUSs**:
97% *of the cases fulfill MRS requirement*



Sample of 48 Cycle 9 **TM1+TM2 GOUSs**:
only ***75%*** *of the cases fulfill MRS requirement(!)*



More tests are described in our final report, in particular on a large sample of Cycle 6+7 data and on a moderate sample of Cycle 9 7M data.

Outlook

Now waiting for the outcome of further ALMA-internal discussions.
The next steps *could* be:

1) integrate `assess_ms` into the QA2 workflow for 12M data (already started)

2) complete `assess_ms` code for use with
   a) 7M data
   b) GOUSs TM1+7M, TM1+TM2+7M (TM1+TM2 already supported)
   c) GOUSs with TP component

   (`assess_ms` already contains beta version for 7M)

   Goal: have uv coverage assessment for every type of GOUS for use in data combination.

3) Gather data over one Cycle (e.g. Cycle 12) and define final QA2 limits,
   then apply limits from, e.g., Cycle 13 onwards

4) At the same time, make improvements to *scheduling* to **at least track HA coverage.**
   Possibly use the complete 40-element FF matrix (or EF matrix, see final report)
   to replace the present EF and implement the full uv coverage tracking in scheduling + QA2

5) Release `assess_ms` as a general public tool for ALMA users