uv coverage assessment with ⊛|ssess_ms 3
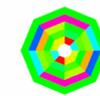
Dirk Petry (ESO), Jan 2026

An "i-Train" video is available at https://youtu.be/VNY9znZgK28

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" (2020 - 2024)
- Description of assess_ms version 2 contained in the dev. study Final Report chapter 7.

- Initially intended for internal use for ALMA QA,
  released 2025 as a public version for general use: ssess_ms 3

  Citeable reference (and location of documentation and code):
  Petry et al. 2025, **https://doi.org/10.5281/zenodo.16682281**

- Set of Python modules "assess_ms.py", "mshistotools.py", ... running under CASA 6.6.6

- General idea:

  Input: set of MSs which are to be assessed together as one dataset

  Output: set of diagnostics describing the quality of the uv coverage
          in comparison with a theoretical ideal case.

New features in "assess_ms 3.0 public"

assess_ms 3.0 was developed in 2025 based on version 2
with the help of *D. Lorber (U. Vienna)*

New features introduced in version 3.0 (public):

- Improved support for assessing **7M**-only datasets
(now uses more adequate expected BLD shape and binning)

- Support for GOUS assessment of **7M+12M** datasets
(before only 12M, i.e. TM1+TM2 GOUSs were supported)

- uv coverage assessment based on *achieved* rather than expected AR, MRS, sensitivity
(the user is interested in the shape of the achieved 2D BLD)

- New **HourAngle** plot for better understanding of how the observations were scheduled
and how additional observations, if needed, should be scheduled.

- Better handling of flagged data and unflagged auto-correlations

- Generation of a **collated pdf** of the most important plots

Diagnostic output produced by assess_ms

All output is placed in the directory "output_assess_ms" of the working directory.
The directory contains:

assess_ms-report.txt
> text file containing the details of the assessment result

> any defects of the uv coverage are enumerated with a one-line comment per defect

png plots
> these plots illustrate the results in the assess_ms-report.txt file

assess_ms_plots.pdf
> collation of the most important png plots into a pdf file

assess_ms-casa.log
> this is the complete CASA log file

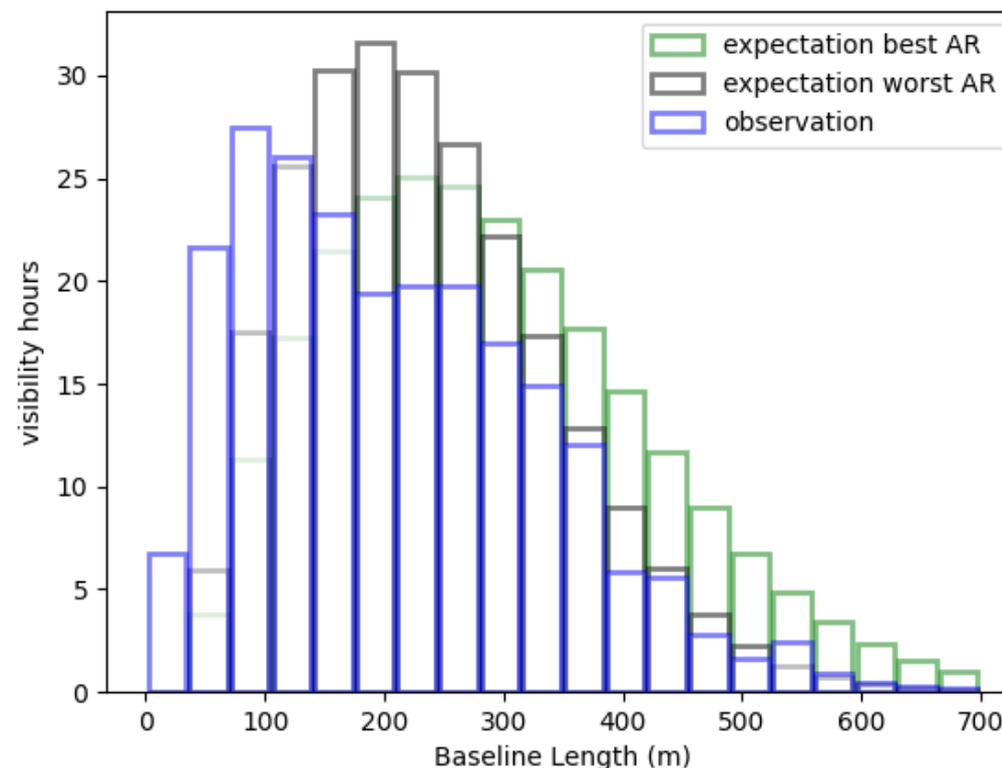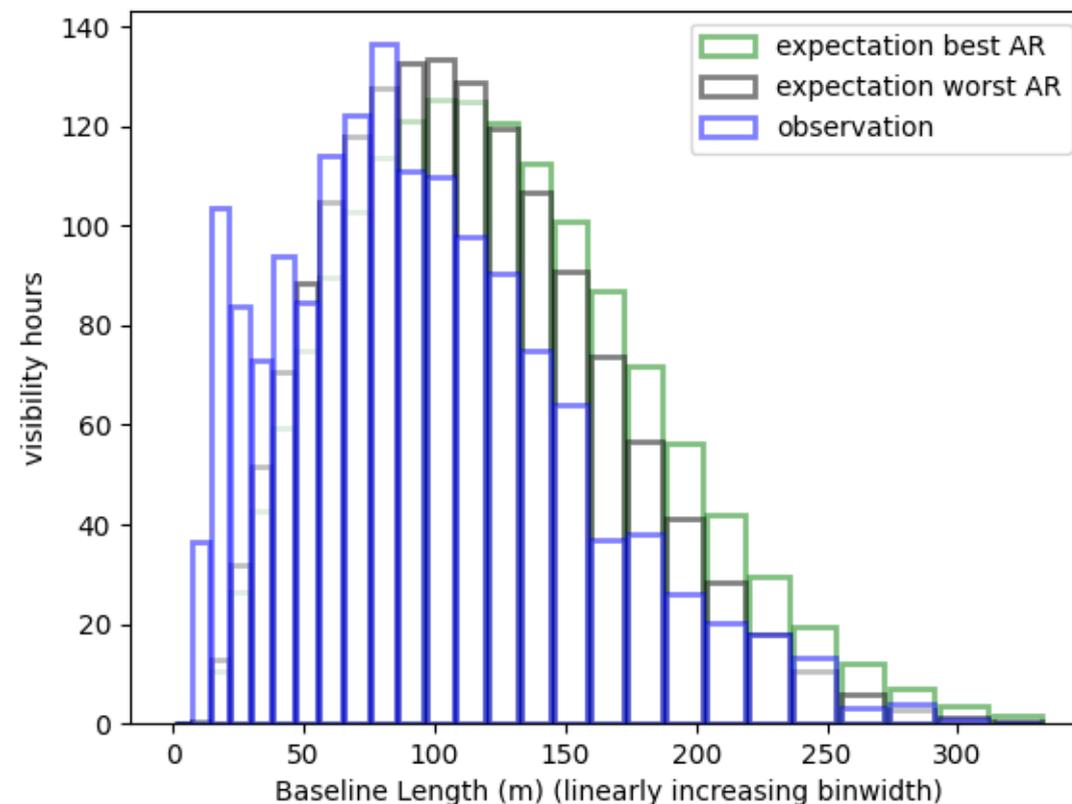# Diagnostic output produced by assess_ms – the plots

1D Baseline Length Distribution: Observation and Expectation

Expectation is computed based on the observed AR and MRS value.
AR is estimated for the 12M array from a fit of the tapered Gaussian expectation to the data.
MRS (LAS) is estimated from the L05.

EB-uid___A002_Xe26f92_X1ecb.ms.split.cal_et_al AR_expectations_asec: 0.711, 0.869

Title shows first EB UID
and AR range
(fit result +- 10%)

For single MOUS,
bin width is constant.

Diagnostic output produced by assess_ms – the plots

1D Baseline Length Distribution: Observation and Expectation

Expectation is computed based on the observed AR and MRS value.
AR is estimated for the 12M array from a fit of the tapered Gaussian expectation to the data.
MRS (LAS) is estimated from the L05.

For a **Group** of several MOUSs,
a different binning scheme is used:
bin width increases linearly with BL
for better statistics at the
longest baselines and better
resolution at the shortest.

EB-uid___A002_X10a341d_X7447.ms.split.cal_et_al AR_expectations_asec: 2.81, 3.434

Diagnostic output produced by assess_ms – the plots

2D Filling Fraction plot: *FF = observed #visibilties (weighted) / expectation , ideal FF==1.0*

4 equidistant bins in AZ (baseline orientation), i.e. **4 sectors of 45 deg**

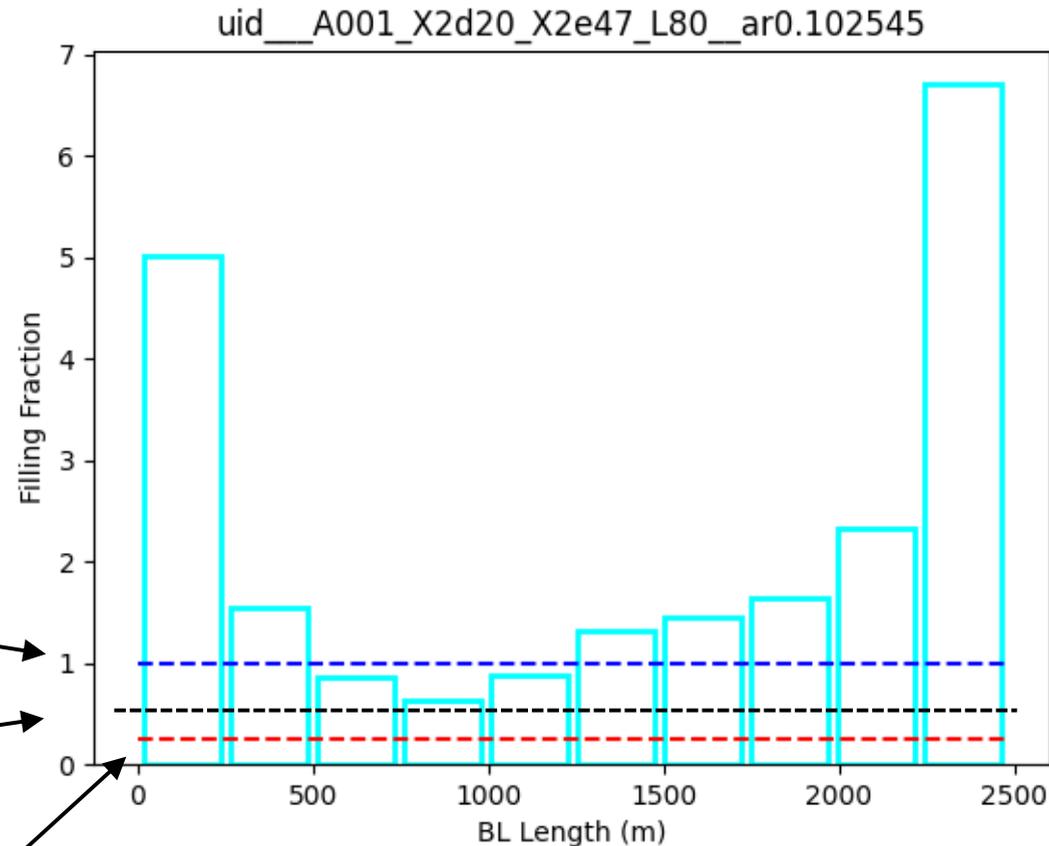**7M** array: **6** equidistant bins along BL   **12M** array: **10** equidistant bins along BL
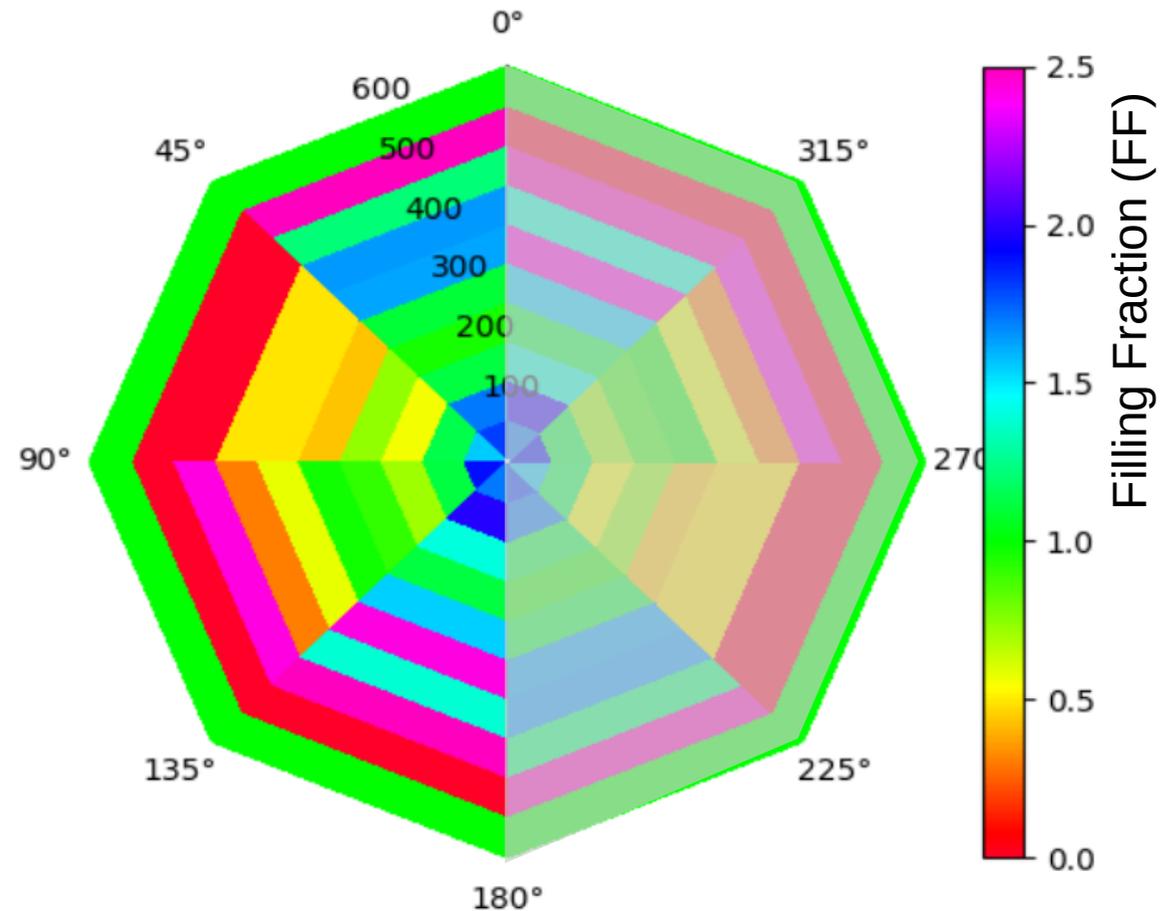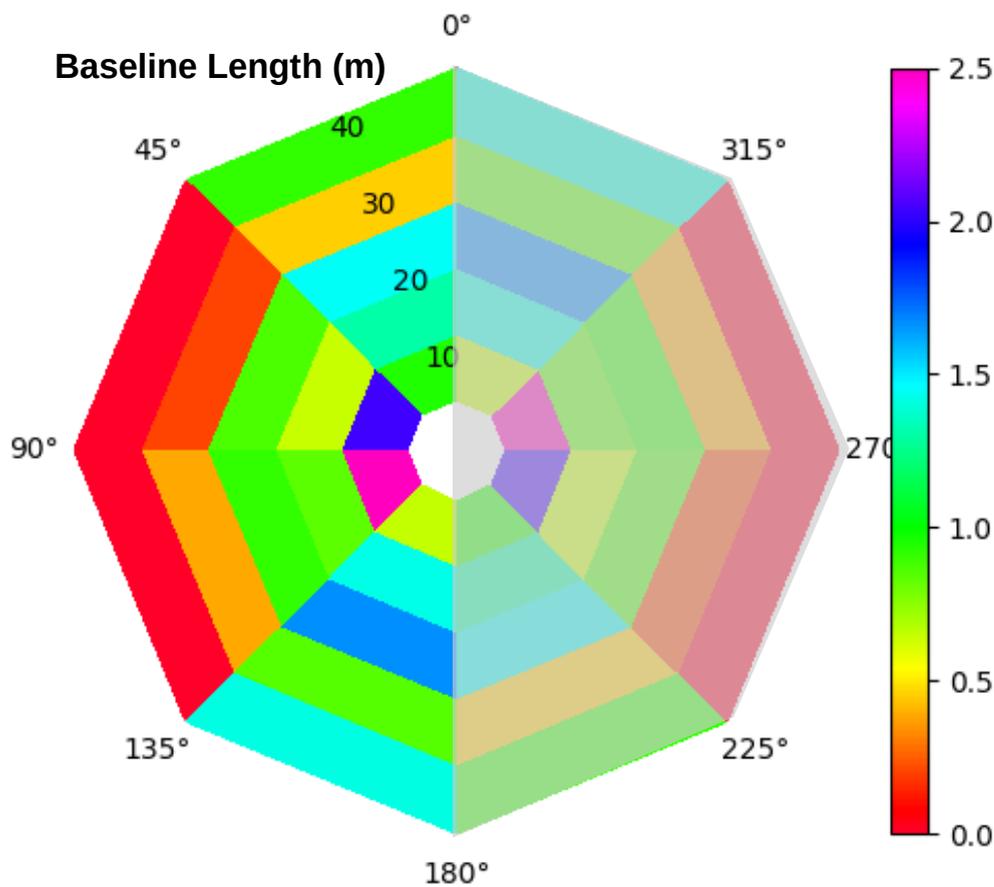
Baseline Orientation Angle (0 – 180 deg, mirrored half for 180 – 360 deg plotted only by convention)

Diagnostic output produced by assess_ms – the plots

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° sector = 0.25

Diagnostic output produced by assess_ms – the plots

1D Filling Fraction plot for the 4 sectors separately:
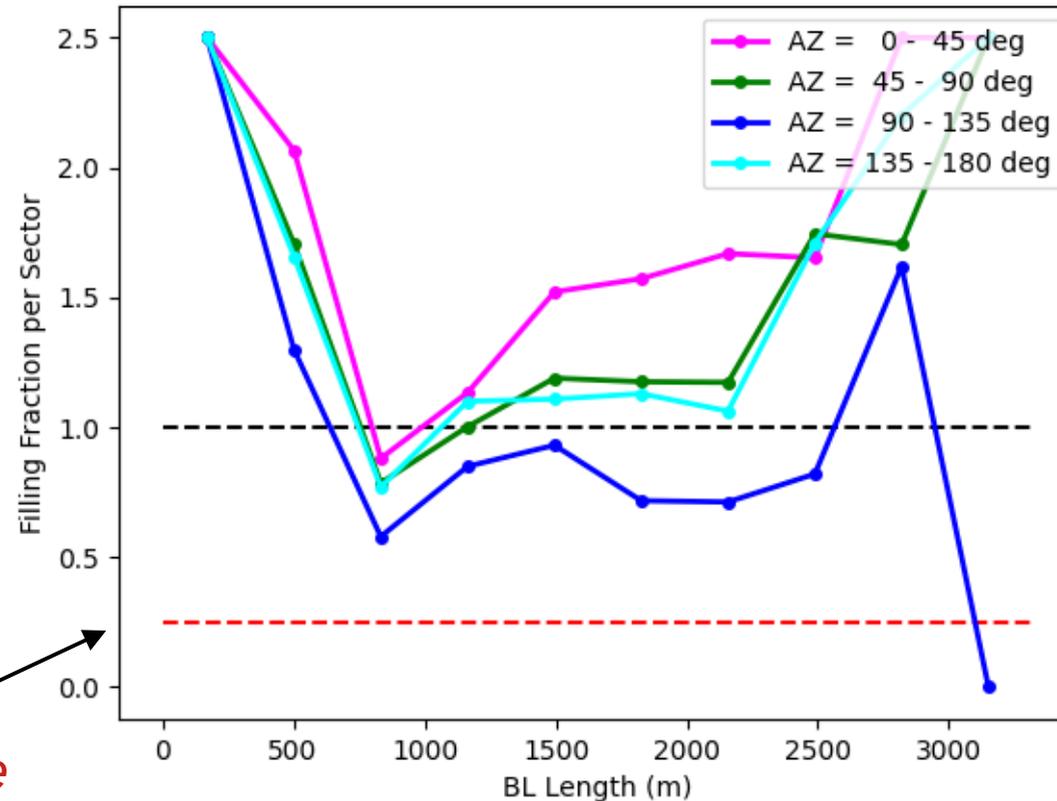
*Ideally, the four plots
should look the same.*

In reality, they often don't!

Ideal FF value = 1.0 ——————→

*Suggested minimum acceptable
value (for QA) in individual 45° sector = 0.25*

Another diagnostic plot to quantify the azimuthal (in)homogeneity:
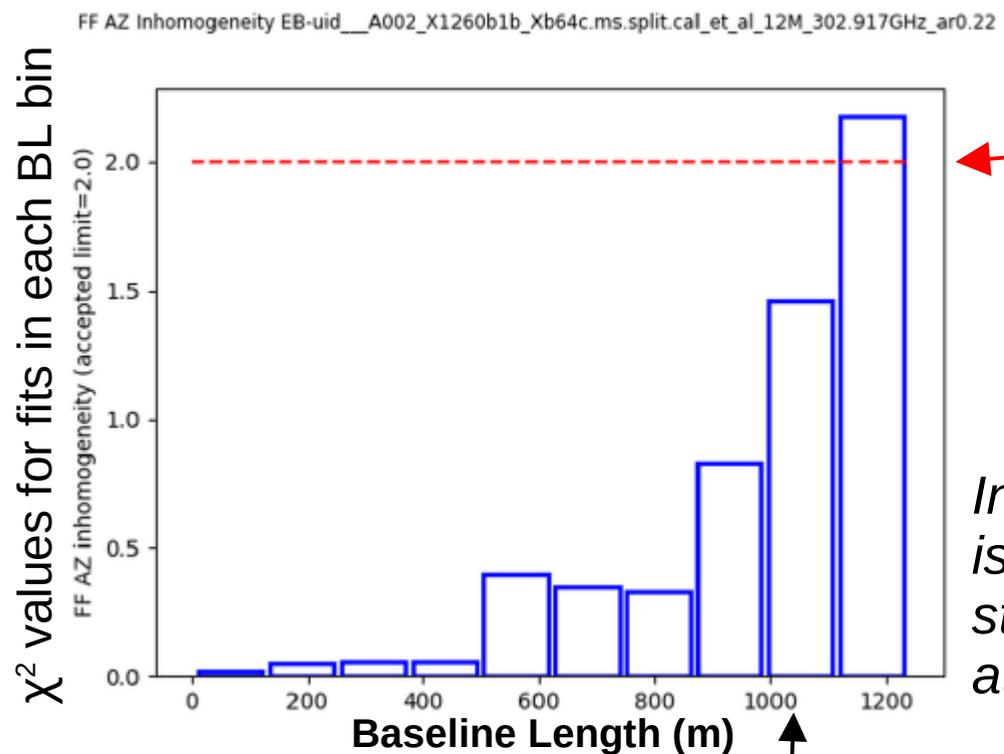
Beam ellipticity correlates with the azimuthal homogeneity of the uv coverage.
  - *the four FF values in same BL bin should be consistent with being constant (χ^2 < 2.0)*

plot (χ^2 of a constant fit across the 4 independent AZ bins in each BL bin) vs. BL

Inhomogeneity is usually stronger at the long BLs

the fit to these 4 uv plane bins relates to this χ^2 value

Histogram of the local hour angle (hours); same entry weights as for BLD.
Serves as a measure for how much *Earth rotation* was made use of.
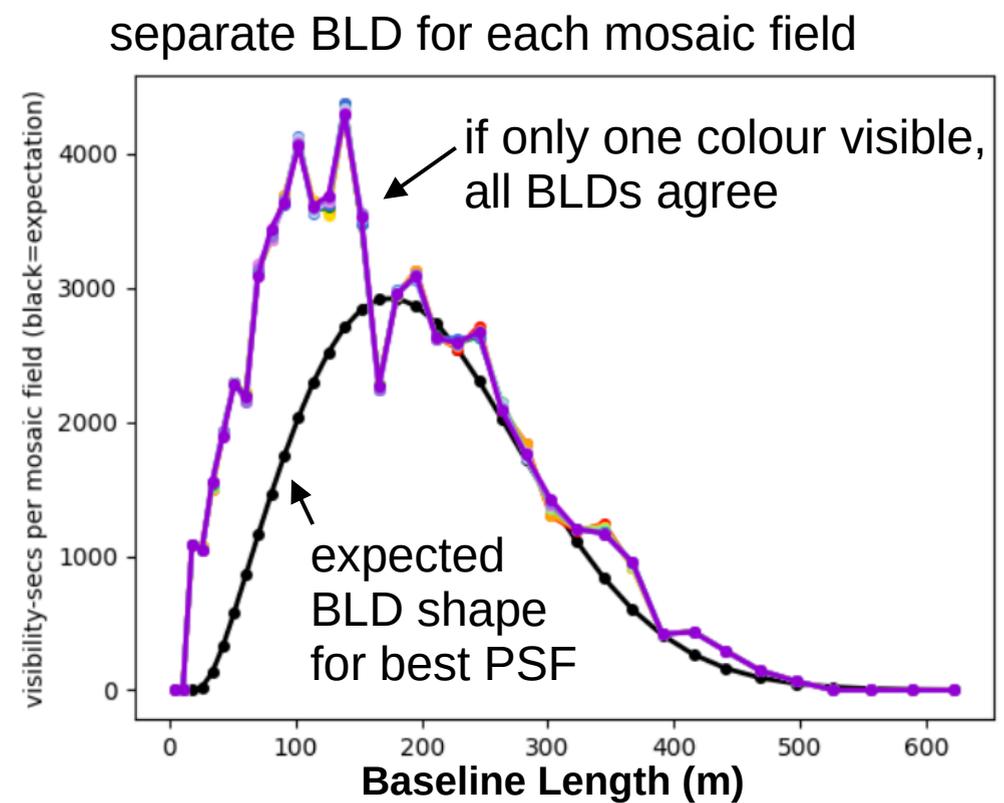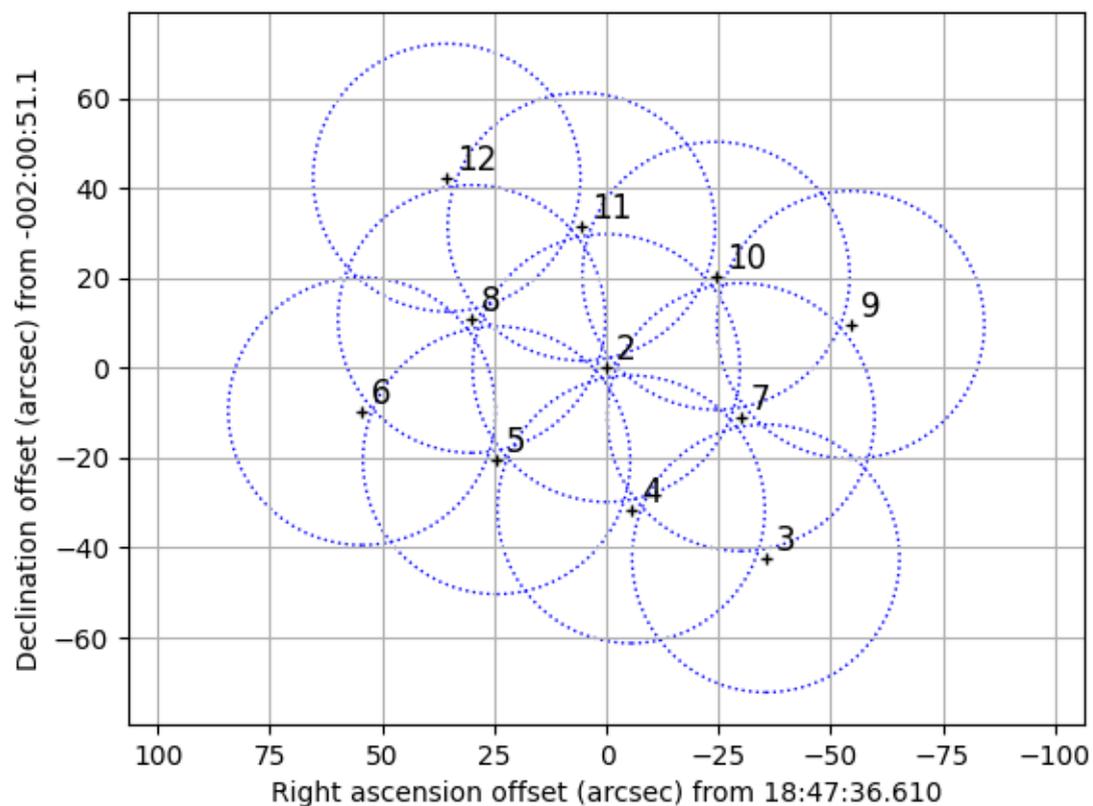

EB-uid___A002_Xf287d3_X12c66.ms.split.cal_et_al

EB-uid___A002_Xf160b6_Xb810.ms.split.cal_et_al
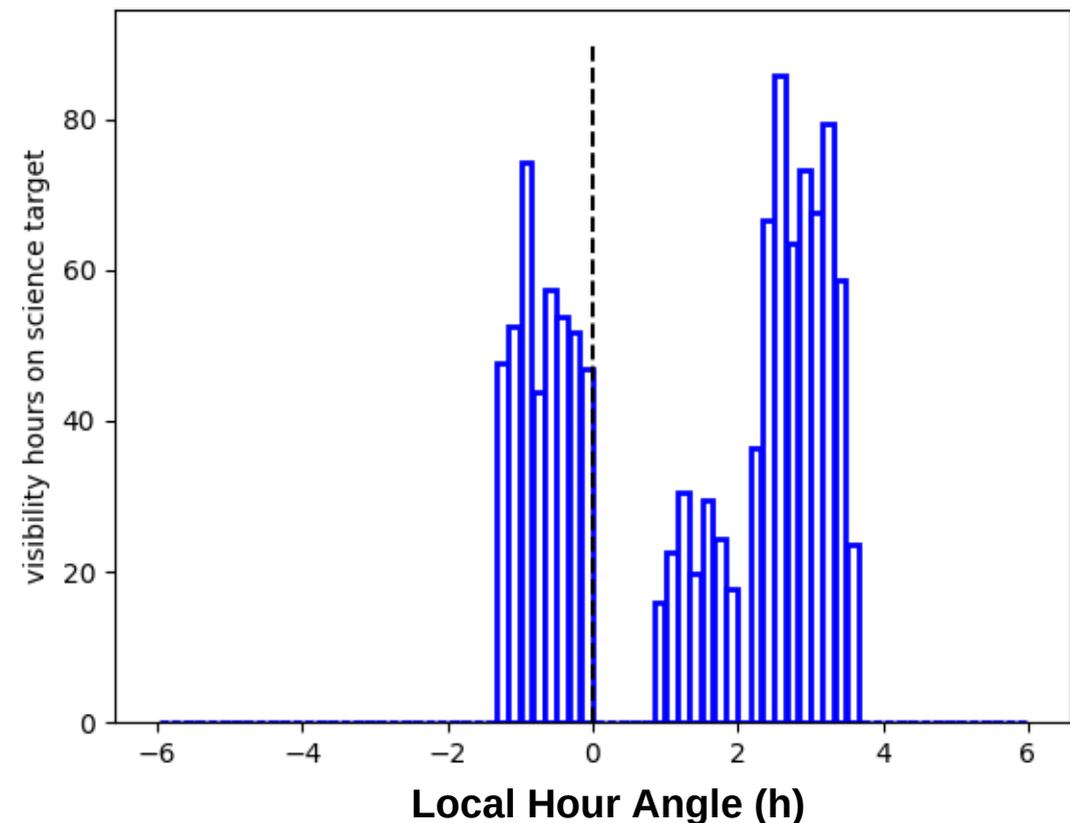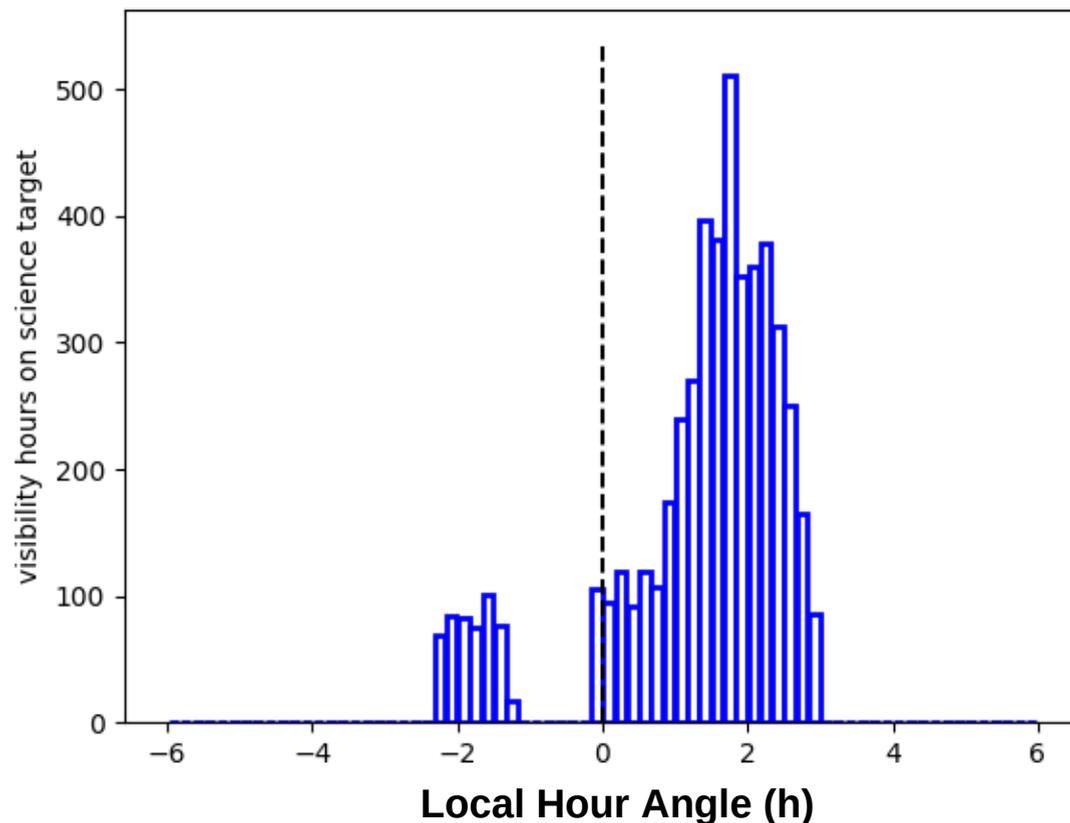
Diagnostic output produced by assess_ms

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

separate BLD for each mosaic field

if only one colour visible, all BLDs agree

expected BLD shape for best PSF

Diagnostic output produced by assess_ms

Maximum Recoverable Scale (MRS) determination

(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
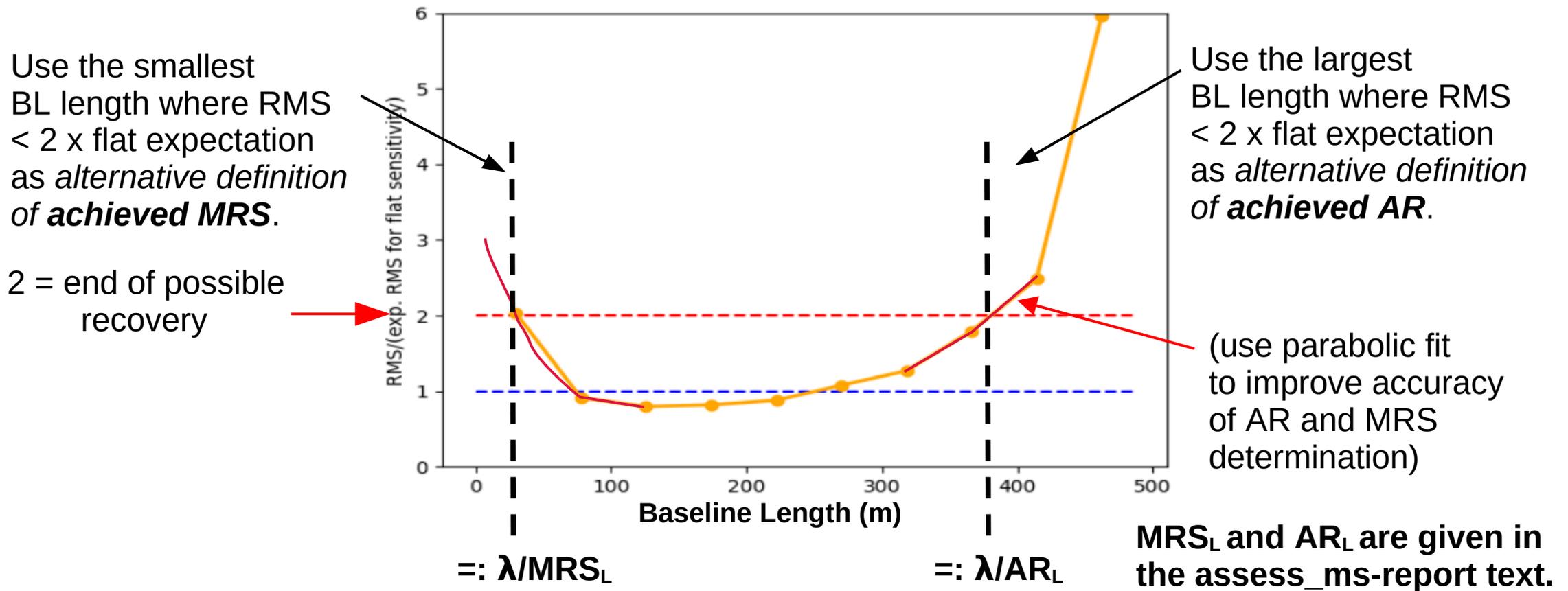CMB power spectrum analysis:
e.g. Hobson & Maisinger 2002)*
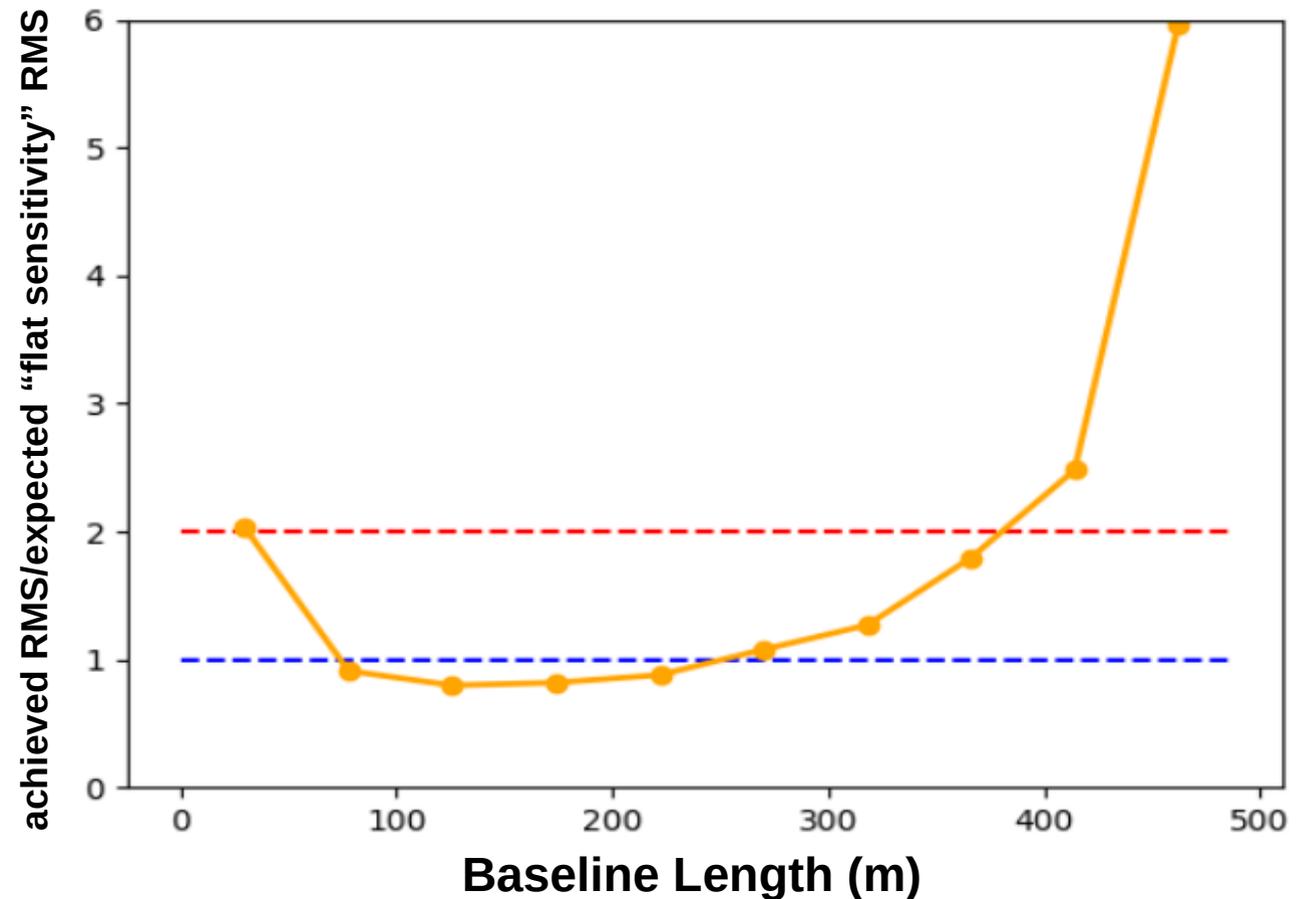
Diagnostic output produced by assess_ms

Maximum Recoverable Scale (MRS) determination

(RMS/exp.RMS) vs. BL plot for assessing angular scale sensitivity
*also serves as an **alternative way to measure the achieved angular resolution (AR)***

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$_L$**

**MRS$_L$ and AR$_L$ are given in
the assess_ms-report text.**

Diagnostic output produced by assess_ms – the report

assess_ms-report.txt
> text file containing the details of the assessment result,
> any defects of the uv coverage are enumerated with a one-line comment per defect

Most interesting parts:

1) The estimated MRS and AR from the flat sensitivity plot

```
casa     [QA]  Estimated average MRS at level 2.0 from the sensitivity plot MRS_L = 7.8229 arcsec.
casa     [QA]  The estimated average MRS at level 2.0 is smaller than the requested one by 11.7468%
casa     [QA]  Estimated average AR at level 2.0 from the sensitivity plot  AR_L = 0.8411 arcsec.
```

← "requested" here refers to value from L05

2) The list of uv coverage defects

```
casa     [QA] Dataset has 9 uv coverage defects for _12M_336.471GHz AR=0.863 arcsec, LAS=8.864arcsec
casa     [QA]   Defects found:
casa     [QA]     Baseline orientation is not homogeneous in BL range 7 =  216 m - 246 m
casa     [QA]     Baseline orientation is not homogeneous in BL range 8 =  246 m - 276 m
casa     [QA]     Baseline orientation is not homogeneous in BL range 9 =  276 m - 306 m
casa     [QA]     Filling fraction below 0.25 in range 70.0% - 80.0% for AZ 0.0-45.0 deg : 0.2132
casa     [QA]     Filling fraction below 0.25 in range 70.0% - 80.0% for AZ 45.0-90.0 deg : 0.0
casa     [QA]     Filling fraction below 0.25 in range 80.0% - 90.0% for AZ 0.0-45.0 deg : 0.0
casa     [QA]     Filling fraction below 0.25 in range 80.0% - 90.0% for AZ 45.0-90.0 deg : 0.0
casa     [QA]     Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 0.0-45.0 deg .
casa     [QA]     Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 45.0-90.0 deg .
```

assess_ms-report.txt

Possible types of defects you may find in the list of uv coverage defects

Defect Type	Severity
Individual 2D BLD bin FF below 0.25 (12M) or 0.35 (7M)	minor
Baseline orientation is not homogenous in AZ in one radial bin	minor
FF below 0.5 in uppermost bin of expectation range for one AZ bin	minor
FF below 0.5 in uppermost bin of expectation range for all AZ bins	major
2D BLD FF in whole 45 deg AZ sector is below 0.5	major
2D BLD FF in the same radial bin for all AZ is below 0.25	major
Mosaic coverage is incomplete by more than 1%	major

If you have one or more major defects, you should check if this impacts your science goal.

Preparations for the hands-on example

All commands for this part of the tutorial can be found in the file

`../../../../data_products/tutorial3b-data_combination/leiden-tutorial3b-supplement.sh`

The assess_ms tarball has already been downloaded and installed for you.

Only need to create a working directory and do a little setup:

```
$ cd /almastorage/allegro/data/projects/ztuim1kb/analysis/$USER/tutorial3b-data_combination
$ mkdir assessment; cd assessment
$ cp ../../../../data_products/tutorial3b-data_combination/run_assess_ms_public.py .
```

Now you have a your own copy of the assess_ms wrapper script in your assessment directory.

Link the the different (read-only) directories containing MSs to be assessed to the working directory:

```
$ ln -sf /almastorage/allegro/data/projects/ztuim1kb/data_products/tutorial3b-data_combination/TM1
$ ln -sf /almastorage/allegro/data/projects/ztuim1kb/data_products/tutorial3b-data_combination/TM2
$ ln -sf /almastorage/allegro/data/projects/ztuim1kb/data_products/tutorial3b-data_combination/7m
```

Running assess_ms on the MOUSs in our example data

Run the assessment on TM1, then TM2, then 7M:

```
$ mkdir myTM1; cd myTM1
$ ln -sf ../TM1/uid___A002_Xc8ed16_X5c3d.ms.split.cal
$ casapy-666p --nologger -c ../run_assess_ms_public.py      # takes a few minutes
```
(output can be found in subdirectory "output_assess_ms")


```
$ cd ..; mkdir myTM2; cd myTM2
$ ln -sf ../TM2/uid___A002_Xcd07af_X41d5.ms.split.cal
$ casapy-666p --nologger -c ../run_assess_ms_public.py      # takes a few minutes
```
(output can be found in subdirectory "output_assess_ms")


```
$ cd ..; mkdir my7m; cd my7m
$ bash -c 'for NAME in `ls -d ../7m/uid*.cal` ; do ln -sf $NAME ; done'     # allegro uses tcsh!
$ casapy-666p --nologger -c ../run_assess_ms_public.py      # takes a few minutes
```
(output can be found in subdirectory "output_assess_ms")

running assess_ms (using CASA 6.6.6)

```
cd <directory containing the MSs to be assessed>
casa --nologger -c <path to your copy of the script>/run_assess_ms_public.py
```

will run assess_ms on the *set of all MSs in the working directory* matching the default pattern.

Override the default pattern using option "-p":

```
casa --nologger -c ./run_assess_ms_public.py -p "<pattern>"
```

example:

```
    casa --nologger -c ./run_assess_ms_public.py -p "*_targets.ms"
```

Presently supported types of GOUSs: TM1+TM2,   TM1+7M,   TM1+TM2+7M

(no support for TP component)

Recommended procedure before you start actual imaging:

1) place the calibrated MSs from each MOUS into separate directories   (done)

2) run assess_ms on each set of MSs separately   (done)

3) place all MSs into a single directory (can use soft links)

4) run assess_ms on all MSs together as a Group

5) check reports and plots to see if individual MOUSs have uv coverage problems

6) check Group plots and report to see the properties of the joint BLD

      - Is the angular resolution still sufficient?

      - Was the required MRS achieved?

      - Are there any major uv coverage defects?

```
$ cd assessment
$ mkdir myGOUS; cd myGOUS

$ bash -c 'for NAME in `ls -d ../7m/uid*.cal` ; do ln -sf $NAME ; done'

$ bash -c 'for NAME in `ls -d ../TM1/uid*.cal` ; do ln -sf $NAME ; done'

$ bash -c 'for NAME in `ls -d ../TM2/uid*.cal` ; do ln -sf $NAME ; done'

$ ll
 uid___A002_Xc6ff69_X41e4.ms.split.cal -> ../7m/uid___A002_Xc6ff69_X41e4.ms.split.cal
 uid___A002_Xc74b5b_X4102.ms.split.cal -> ../7m/uid___A002_Xc74b5b_X4102.ms.split.cal
 uid___A002_Xc74b5b_X458a.ms.split.cal -> ../7m/uid___A002_Xc74b5b_X458a.ms.split.cal
 uid___A002_Xc790bf_X4ea0.ms.split.cal -> ../7m/uid___A002_Xc790bf_X4ea0.ms.split.cal
 uid___A002_Xc7a409_X342e.ms.split.cal -> ../7m/uid___A002_Xc7a409_X342e.ms.split.cal
 uid___A002_Xc8ed16_X5c3d.ms.split.cal -> ../TM1/uid___A002_Xc8ed16_X5c3d.ms.split.cal
 uid___A002_Xcd07af_X41d5.ms.split.cal -> ../TM2/uid___A002_Xcd07af_X41d5.ms.split.cal


$ casapy-666p --nologger -c ../run_assess_ms_public.py
```

In terminal output should see message:

```
...[QA] The EBs are from different MOUSs and can thus be regarded as a GROUP.
```

Inspecting the results

```
$ cd assessment
$ okular my7m/output_assess_ms/assess_ms_plots.pdf &
$ tail my7m/output_assess_ms/assess_ms-report.txt
```

Repeat for myTM2, myTM1, myGOUS

Plots for 7M   TM2   TM1   whole GOUS
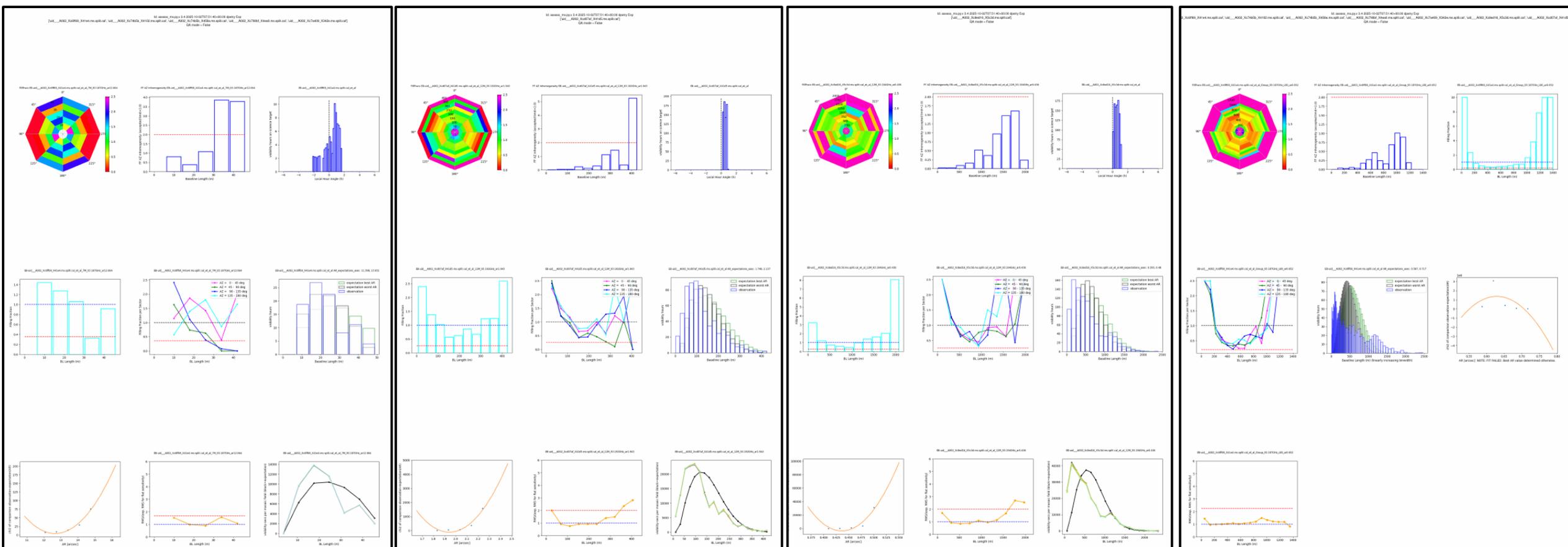
7M:

```
[QA] Dataset has 6 uv coverage defects for _7M_93.187GHz AR=12.664 arcsec, LAS=71.577arcsec
[QA]   Summary of defects found:
[QA]     Baseline orientation is not homogeneous in BL range 3 =  30 m - 38 m
[QA]     Baseline orientation is not homogeneous in BL range 4 =  38 m - 46 m
[QA]     Filling fraction below 0.35 in range 60.0% - 80.0% for AZ 45.0-90.0 deg : 0.0
[QA]     Filling fraction below 0.35 in range 60.0% - 80.0% for AZ 90.0-135.0 deg : 0.0773
[QA]     Filling fraction below 0.5 in upper 20% of expectation bin range for AZ 45.0-90.0 deg .
[QA]     Filling fraction below 0.5 in upper 20% of expectation bin range for AZ 90.0-135.0 deg .
```

Two sectors are underexposed at the longer baselines. Otherwise good. Reasonable HA coverage.
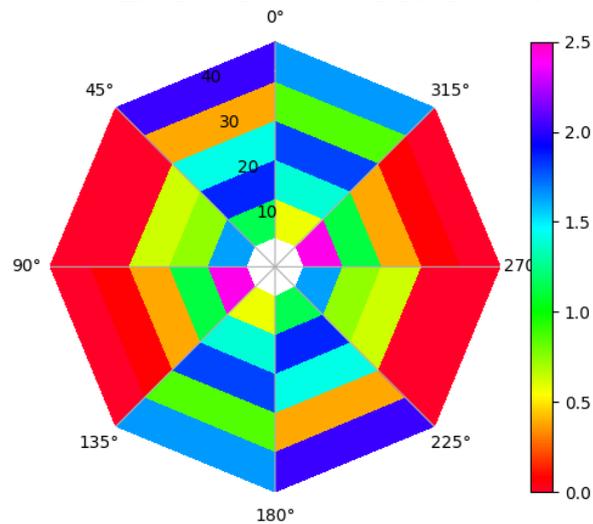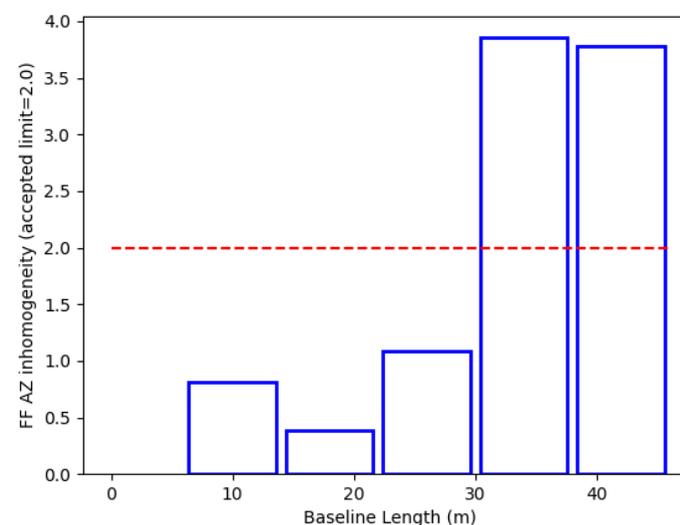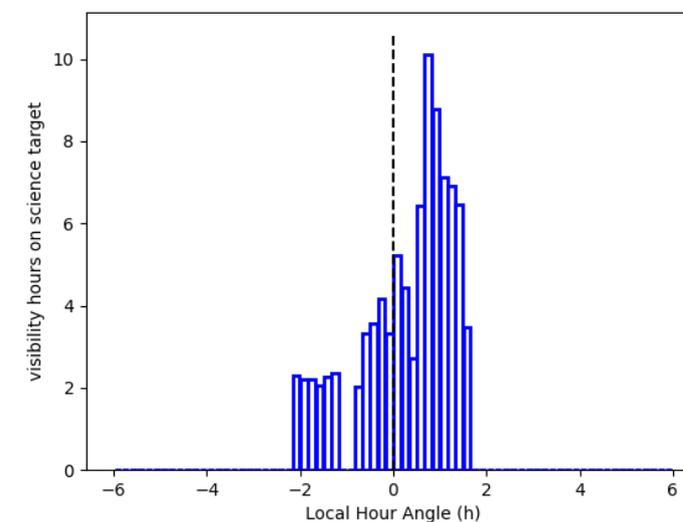
Inspecting the results

TM2:

```
[QA] Dataset has 4 uv coverage defects for _12M_93.192GHz AR=1.943 arcsec, LAS=27.684arcsec
[QA]    Summary of defects found:
[QA]      Baseline orientation is not homogeneous in BL range 9 =  384 m - 426 m
[QA]      Filling fraction below 0.25 in range 70.0% - 80.0% for AZ 45.0-90.0 deg : 0.1034
[QA]      Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 45.0-90.0 deg .
[QA]      Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 90.0-135.0 deg .
```

Two sectors are underexposed at the longest baselines. Nice BLD shape.
Mostly good in spite of poor HA coverage. Mosaic coverage perfect.
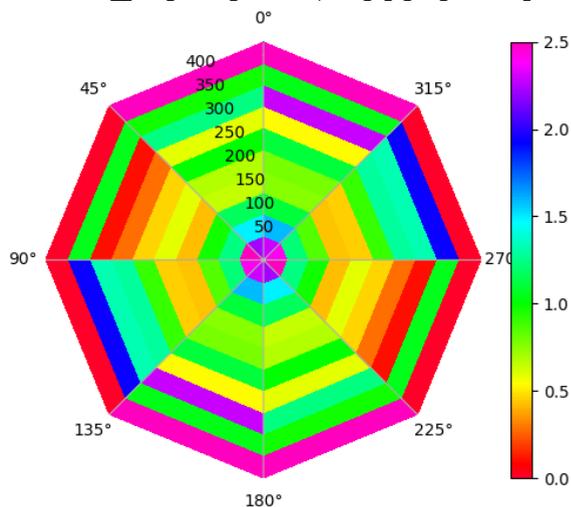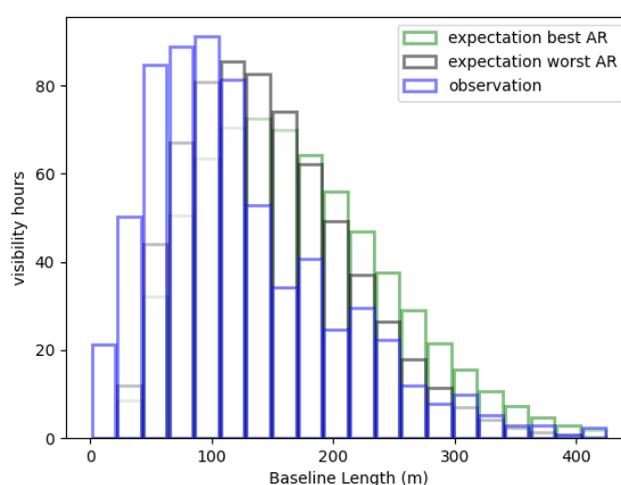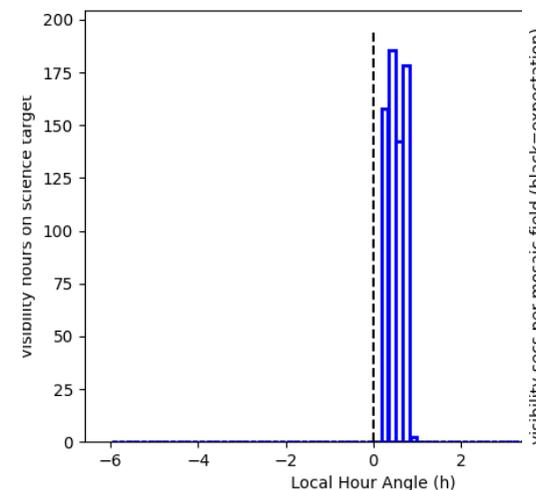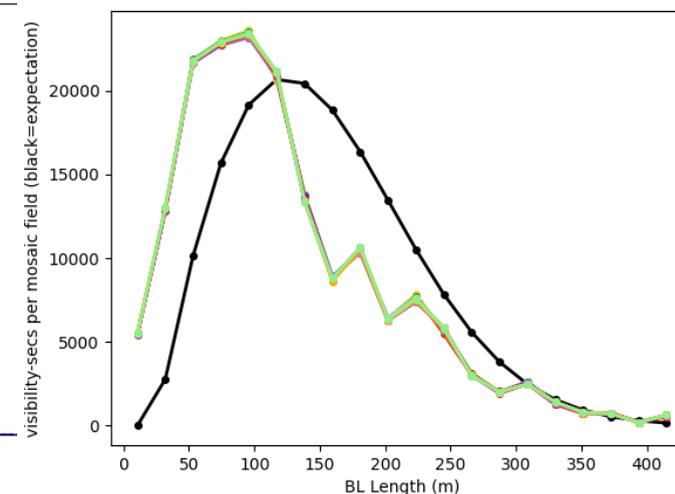
Inspecting the results

TM1:

```
[QA] Baseline orientation is sufficiently homogeneous in all BL ranges.
```

No defects found in spite of very moderate HA coverage!
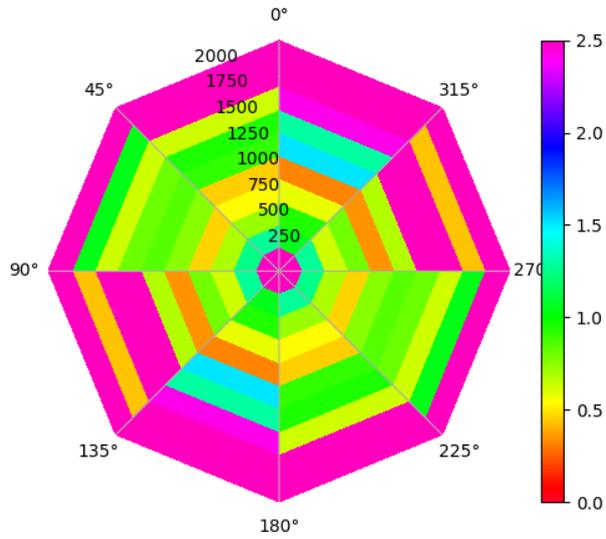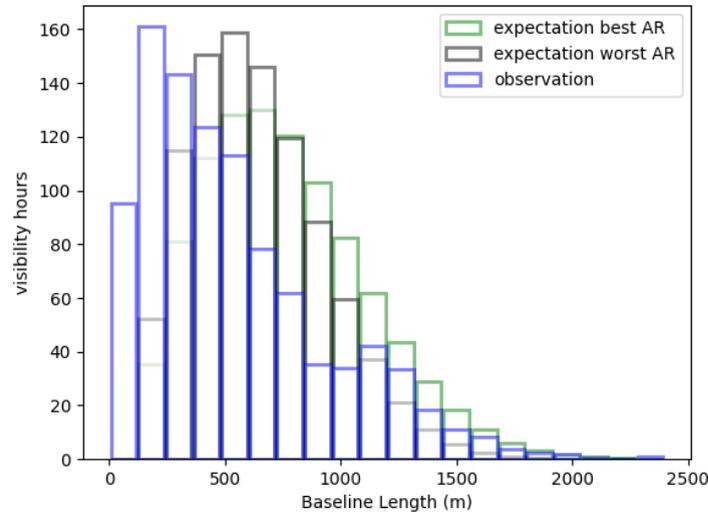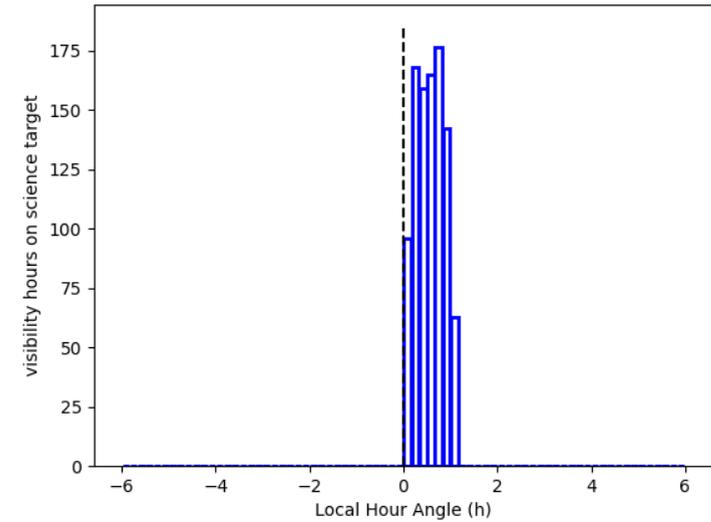
Typical
flat sens. plot
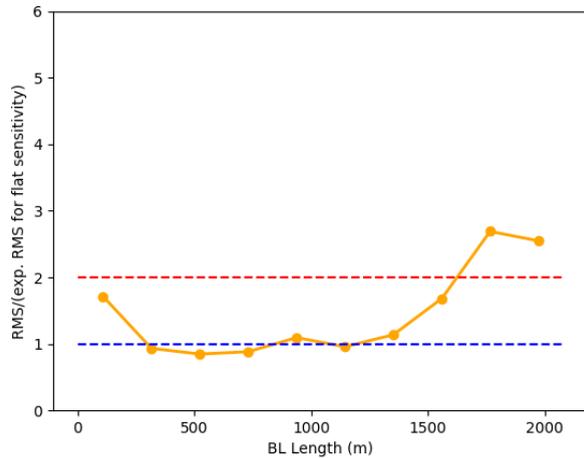
Mosaic check
passed
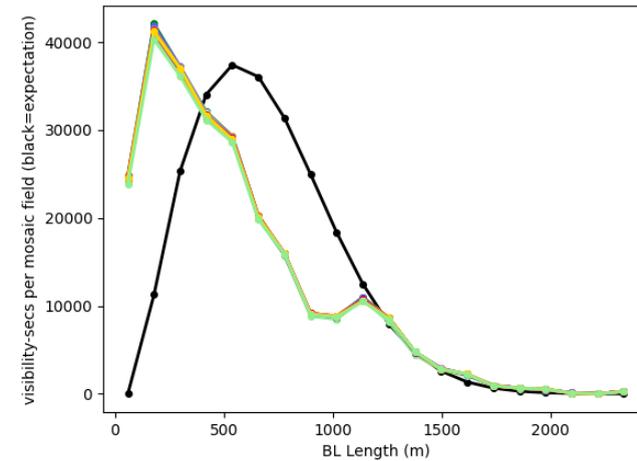
Inspecting the results

GOUS:
```
[QA] L80 = 584 m equivalent to AR = 0.65222 arcsec.
[QA] L05 = 25 m equivalent to MRS = 26.09191 arcsec.
[QA] Estimated average MRS at level 2.0 from the sensitivity plot MRS_L = 26.0919 arcsec.
[QA] Estimated average AR at level 2.0 from the sensitivity plot   AR_L = 0.4899 arcsec.
```
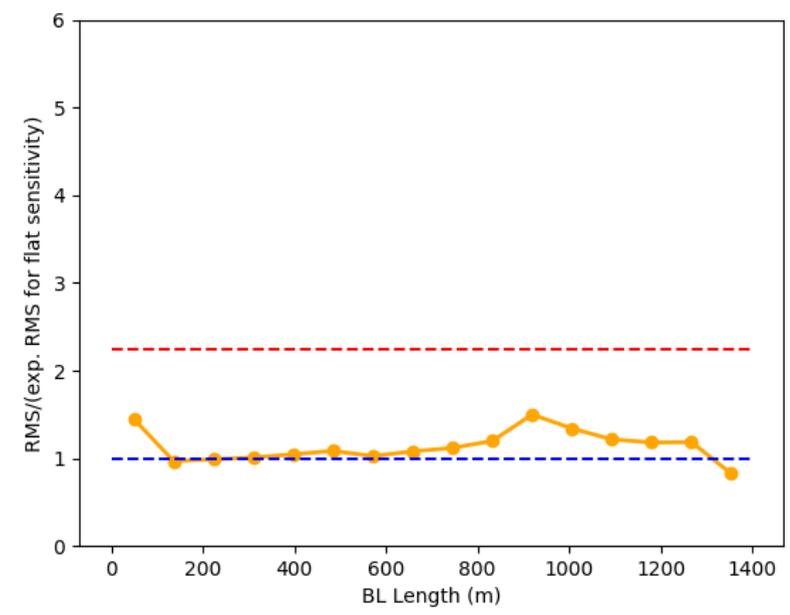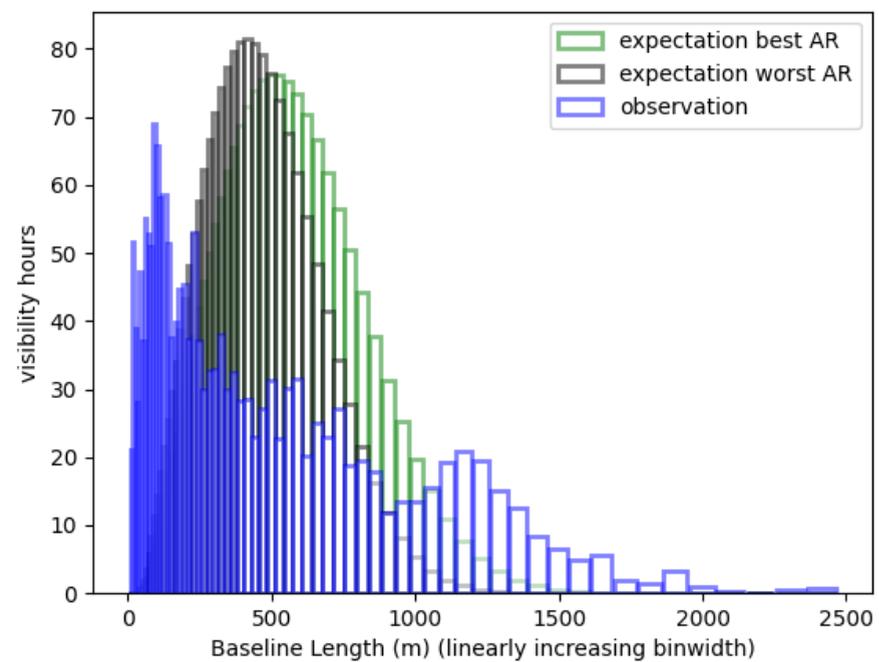
CASA tclean/sdintimaging found an AR of 1.0 arcsec from the PSF fit.   (our obs. freq is approx. 93.19 GHz)
The nominal 7M MRS at 93 GHz is 70 arcsec.

```
[QA] Baseline orientation is sufficiently homogeneous in all BL ranges.
(no defects have been found)
```
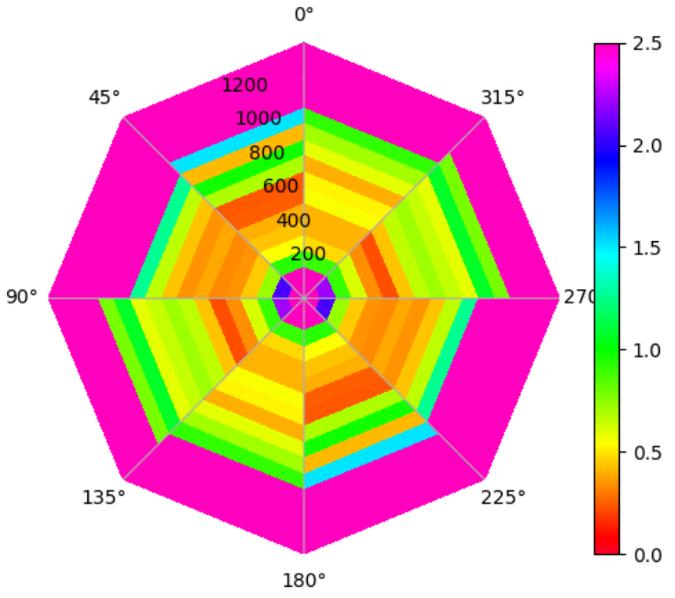
Working directory contains (after running assess_ms three times):

```
|-- GOUS
|      |-- output_assess_ms
|      |-- uid___A002_Xe1a561_X1ff6.ms.split.cal
|      `-- uid___A002_Xe2eefc_X136fb.ms.split.cal
|-- TM1
|      |-- output_assess_ms
|      `-- uid___A002_Xe1a561_X1ff6.ms.split.cal
|-- TM2
|      |-- output_assess_ms
|      `-- uid___A002_Xe2eefc_X136fb.ms.split.cal
`-- run_assess_ms_public.py
```

Each of these contains the
standard set of plots and text files.

Look first at the files
   "assess_ms-report.txt"
and
   "assess_ms_plots.pdf"

```
TM1

...
    The estimated average MRS at level 2.0 from the sensitivity plot is 3.9193 arcsec.
    The estimated average AR at level 2.0 from the sensitivity plot is 0.1548 arcsec.
 WARN   assess_ms::qa::casa      [QA] Dataset has 12 uv coverage defects for _12M_234.986GHz AR=0.145 arcsec, LAS=3.434arcsec
 WARN   assess_ms::qa::casa      [QA]   Summary of defects found:
 WARN   assess_ms::qa::casa      [QA]     Baseline orientation is not homogeneous in BL range 8 =  1982 m - 2229 m
 WARN   assess_ms::qa::casa      [QA]     Baseline orientation is not homogeneous in BL range 9 =  2229 m - 2476 m
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 20.0% - 30.0% for AZ 0.0-45.0 deg : 0.179
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 20.0% - 30.0% for AZ 45.0-90.0 deg : 0.1234
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 0.0-45.0 deg : 0.1947
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 135.0-180.0 deg : 0.1607
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 90.0-135.0 deg : 0.126
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 60.0% - 70.0% for AZ 45.0-90.0 deg : 0.0633
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 70.0% - 80.0% for AZ 45.0-90.0 deg : 0.0
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.25 in range 80.0% - 90.0% for AZ 135.0-180.0 deg : 0.0
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 0.0-45.0 deg .
 WARN   assess_ms::qa::casa      [QA]     Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 45.0-90.0 deg .
```

Quite a few minor problems in TM1, bordering on major!
For the BL range 30%-40%, 3 out of 4 AZ bins have FF<0.25 !

TM2

```
...
The estimated average MRS at level 2.0 from the sensitivity plot is 8.7706 arcsec.
 WARN  assess_ms::qa::casa      [QA]  The estimated average MRS at level 2.0 is smaller than the requested one by 14.7838%
  The estimated average AR at level 2.0 from the sensitivity plot is 0.7383 arcsec.
 WARN  assess_ms::qa::casa      [QA] Dataset has 3 uv coverage defects for _12M_234.974GHz AR=0.636 arcsec, LAS=10.292arcsec
 WARN  assess_ms::qa::casa      [QA]   Summary of defects found:
 WARN  assess_ms::qa::casa      [QA]    Filling fraction below 0.25 in range 60.0% - 70.0% for AZ 45.0-90.0 deg : 0.0569
 WARN  assess_ms::qa::casa      [QA]    Filling fraction below 0.25 in range 80.0% - 90.0% for AZ 0.0-45.0 deg : 0.2499
 WARN  assess_ms::qa::casa      [QA]    Filling fraction below 0.5 in upper 10% of expectation bin range for AZ 45.0-90.0 deg .
```

Very few minor and no major problems in TM2.

GOUS

...

```
    The estimated average MRS at level 2.0 from the sensitivity plot is 4.9745 arcsec.  cf. TM1: 3.91 arcsec, TM2: 8.98 arcsec
    The estimated average AR at level 2.0 from the sensitivity plot is 0.1572 arcsec.   cf. TM1: 0.155 arcsec, TM2: 0.738 arcsec
WARN  assess_ms::qa::casa       [QA] Dataset has 9 uv coverage defects for _Group_234.986GHz_L80 AR=0.19 arcsec, LAS=3.447arcsec
WARN  assess_ms::qa::casa       [QA]   Summary of defects found:
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 20.0% - 30.0% for AZ 90.0-135.0 deg : 0.245
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 0.0-45.0 deg : 0.1
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 45.0-90.0 deg : 0.0543
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 30.0% - 40.0% for AZ 90.0-135.0 deg : 0.2338
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 40.0% - 50.0% for AZ 0.0-45.0 deg : 0.1725
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 40.0% - 50.0% for AZ 135.0-180.0 deg : 0.156
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 40.0% - 50.0% for AZ 90.0-135.0 deg : 0.1607
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 50.0% - 60.0% for AZ 90.0-135.0 deg : 0.1541
WARN  assess_ms::qa::casa       [QA]    Filling fraction below 0.25 in range 80.0% - 90.0% for AZ 45.0-90.0 deg : 0.0
```
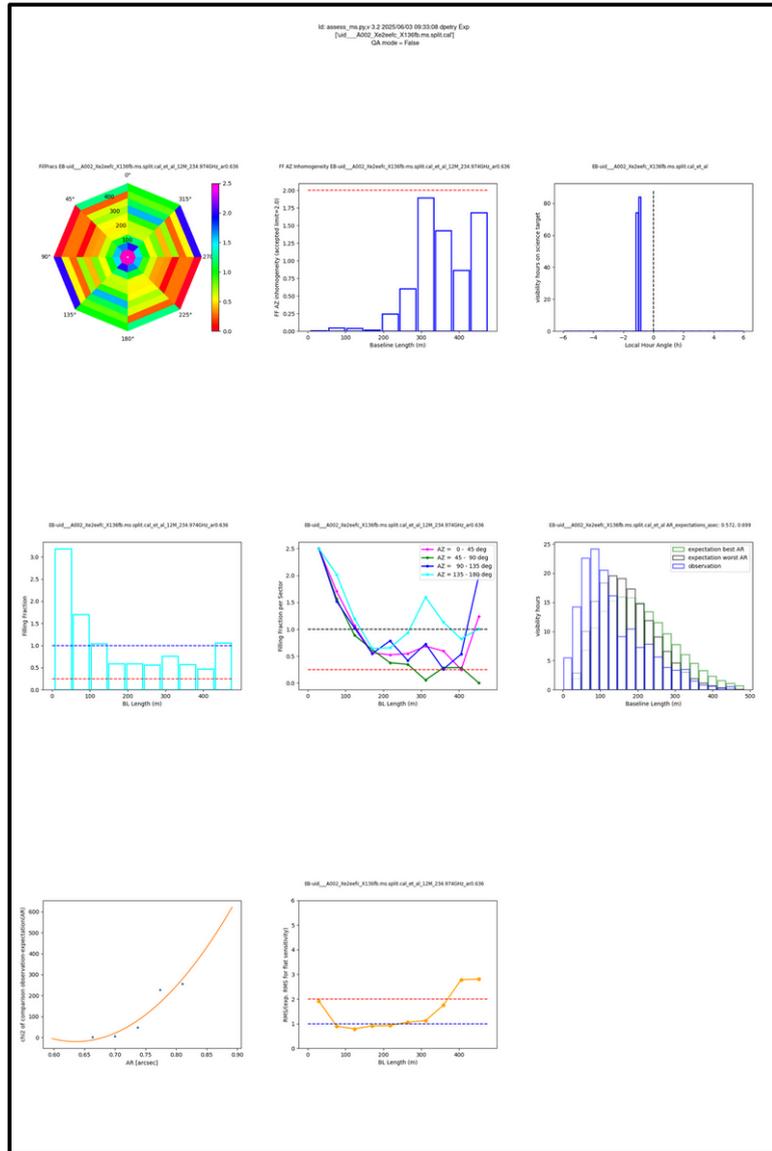
Quite a few minor problems, bordering on major problems in BL ranges 30%-40% and 40%-50%!
Estimated Group AR close to the TM1 value, estimated Group MRS 45% lower than TM2 MRS.
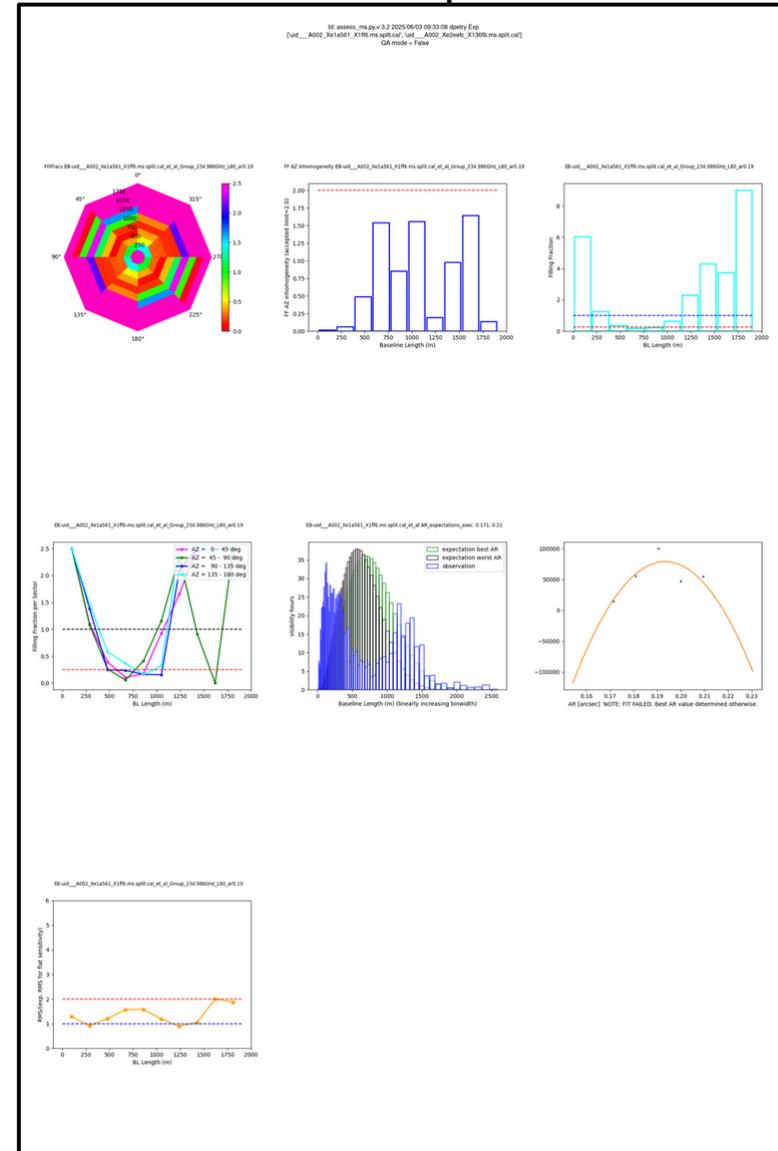
Another Example of using assess_ms on a GOUS

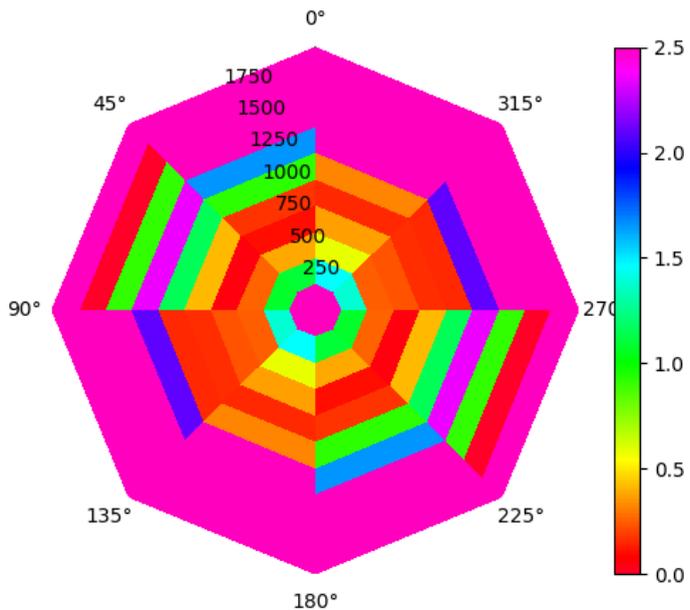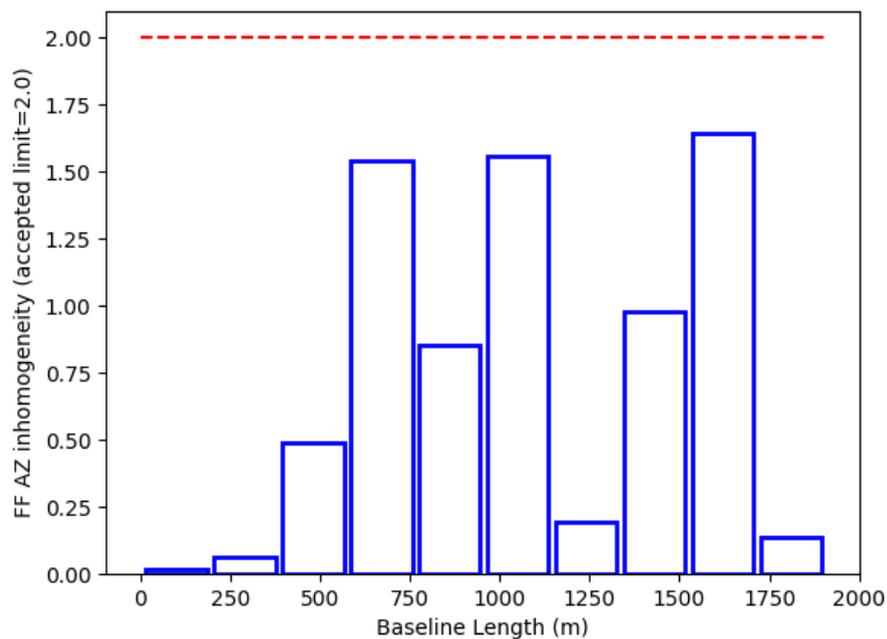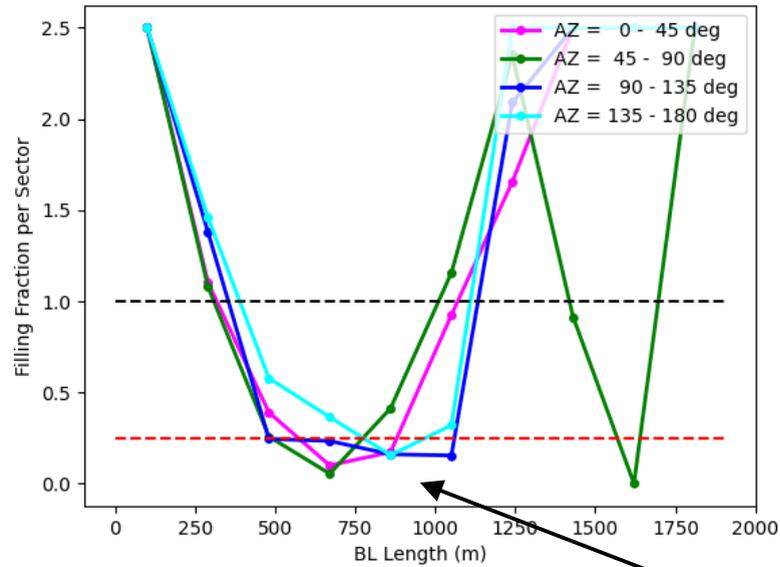assess_ms_plots.pdf for TM1   TM2   Group

Group output

AZ homogeneity is fine, but we have over-exposed long baselines, and underexposed intermediate baselines.

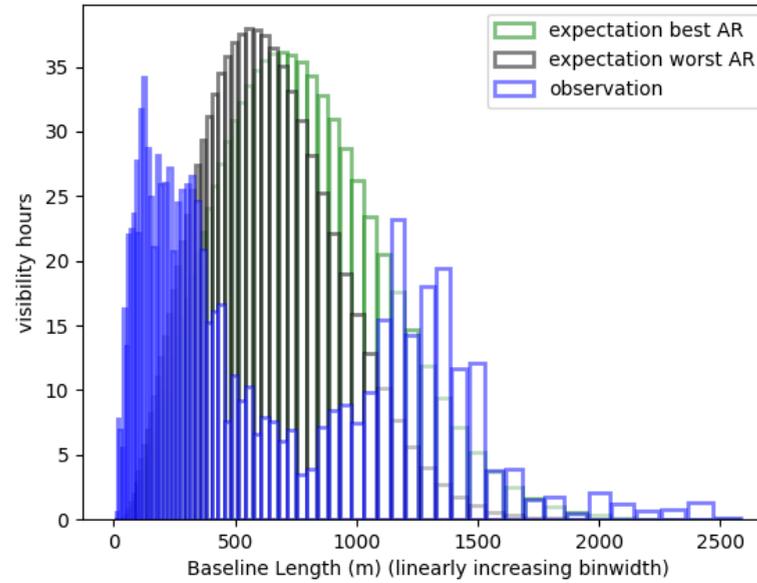The underexposure is very close to the limit of a major problem: FF = 0.25 in 3 of 4 sectors of a BL bin.
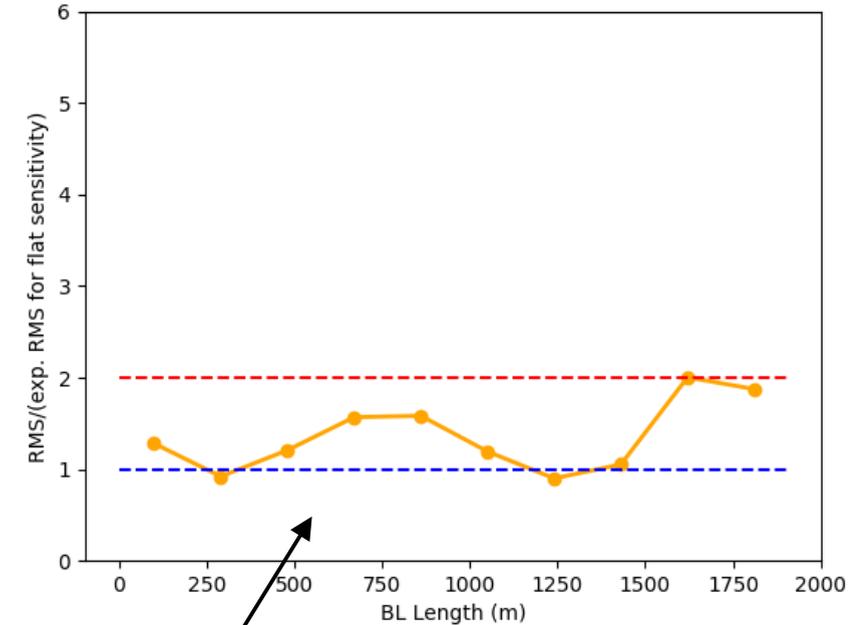
Another Example of using assess_ms on a GOUS

Group

The FF in individual AZ bins is below 0.25 . The shape of the BLD is binodal.
The achieved "flat sensitivity plot" (usually U-shaped) is unusually inverted, has bump at intermediate BLs.
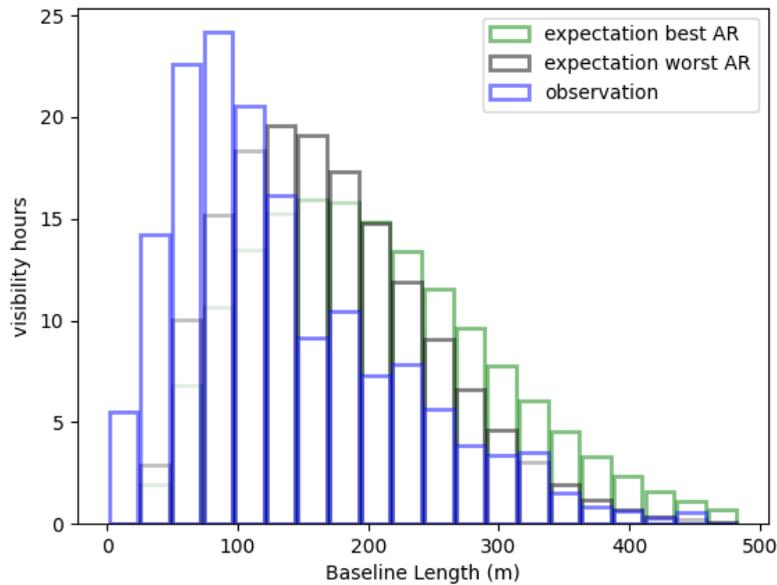
This should result in a quite non-Gaussian PSF ! Ideally should try to get more data at BLs near 750 m.

Another Example of using assess_ms on a GOUS

(re-)inspection of TM2, TM1, and Group in comparison shows that
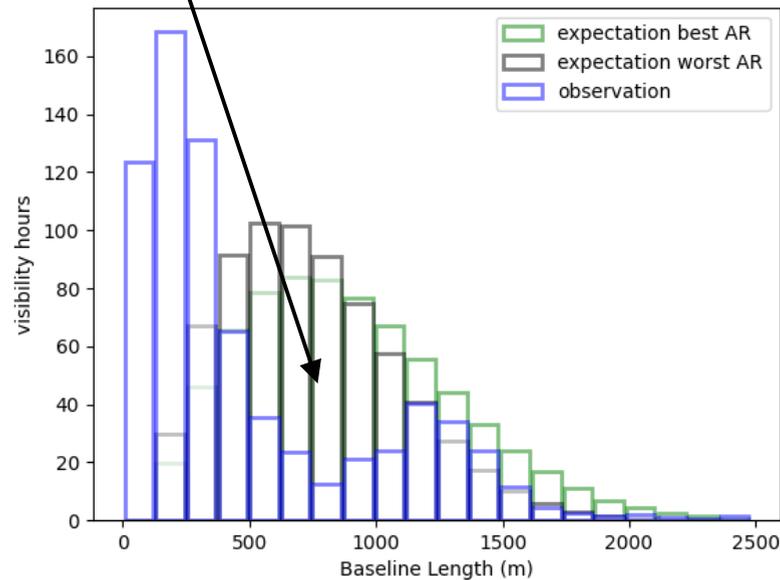the problem stems from the TM1 MOUS!
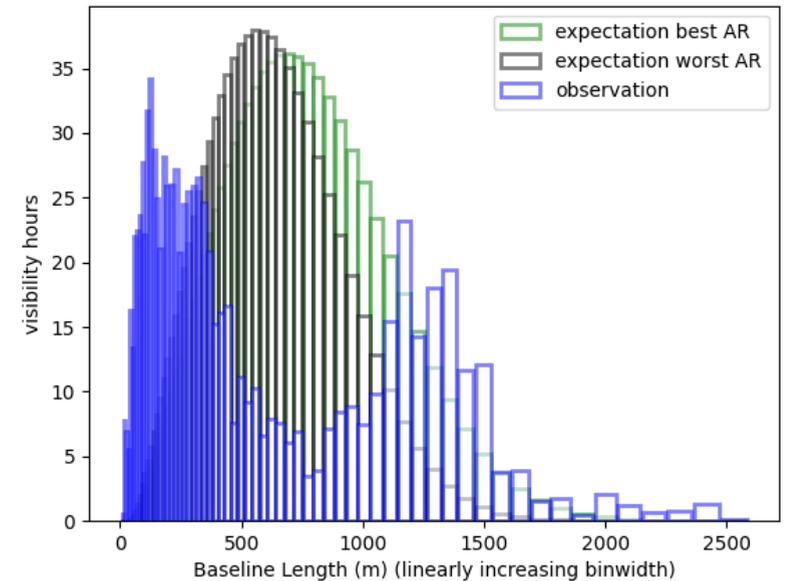
The TM2 does not help: max. BL here is ca. 480 m. But we need more visibilities at ca. 750 m.

NOTE: *This is an extreme example. There are very few 12M MOUSs which look like this TM1 MOUS.*

Outlook

Looking forward to your feedback!

assess_ms is a work in progress. There will be updates and patches in the future.

**Please file an ALMA helpdesk (data reduction) ticket if you need detailed help
or want to give feedback.**

The next big step is to add code to `assess_ms` code for **support of a TP component in Groups.**

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