Group Assignment Self-calibration

TMC-1A

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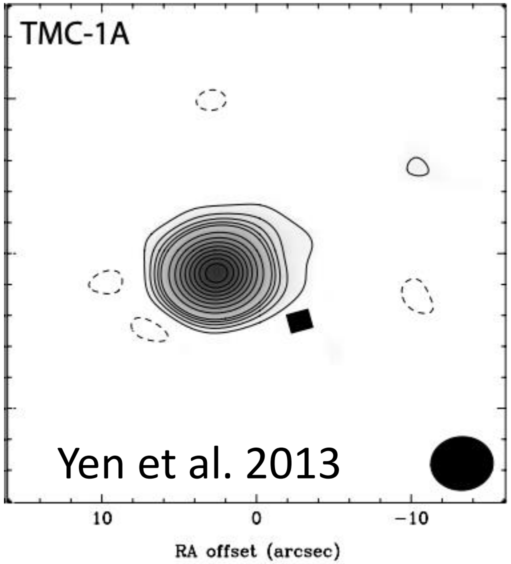
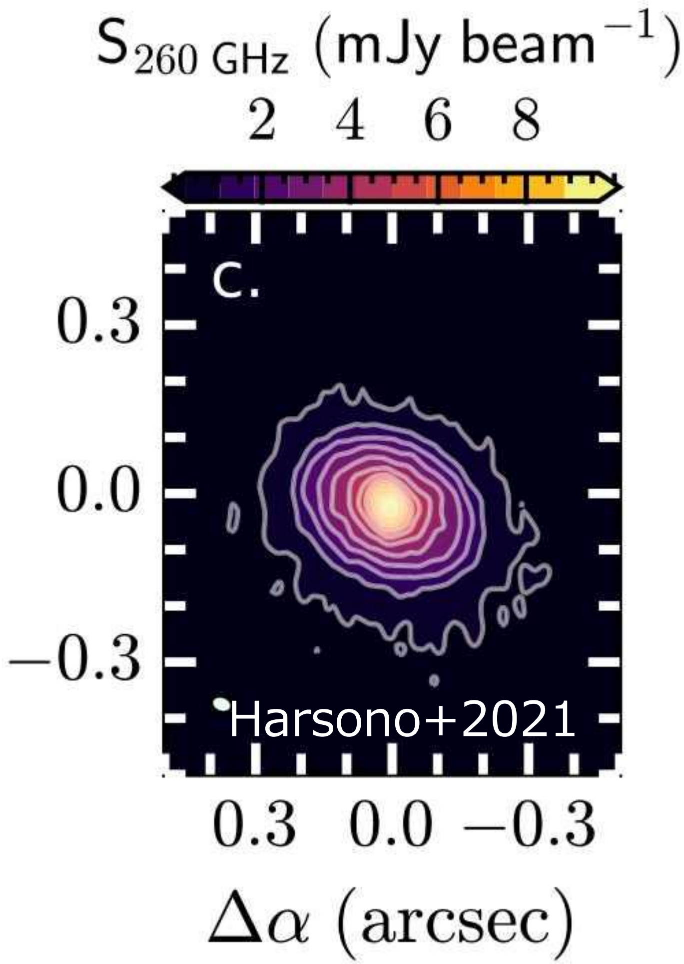
TMC-1A

A protostar

Recent high angular observations revealed disk-like structure





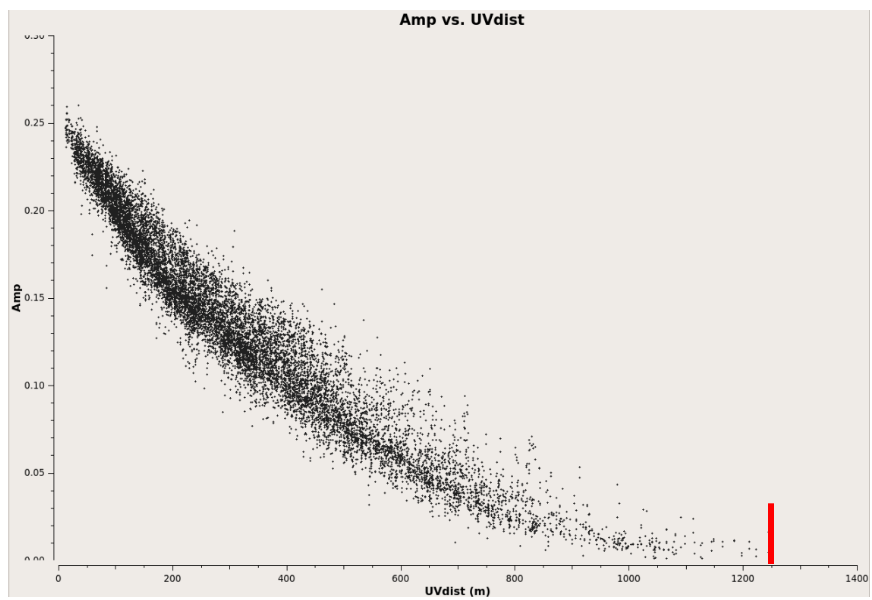
We are assigned to do self-calibration to the continuum emission of TMC-1A observed with Band 6 in 2018

First glance at the data

Calculate image size & pixel size

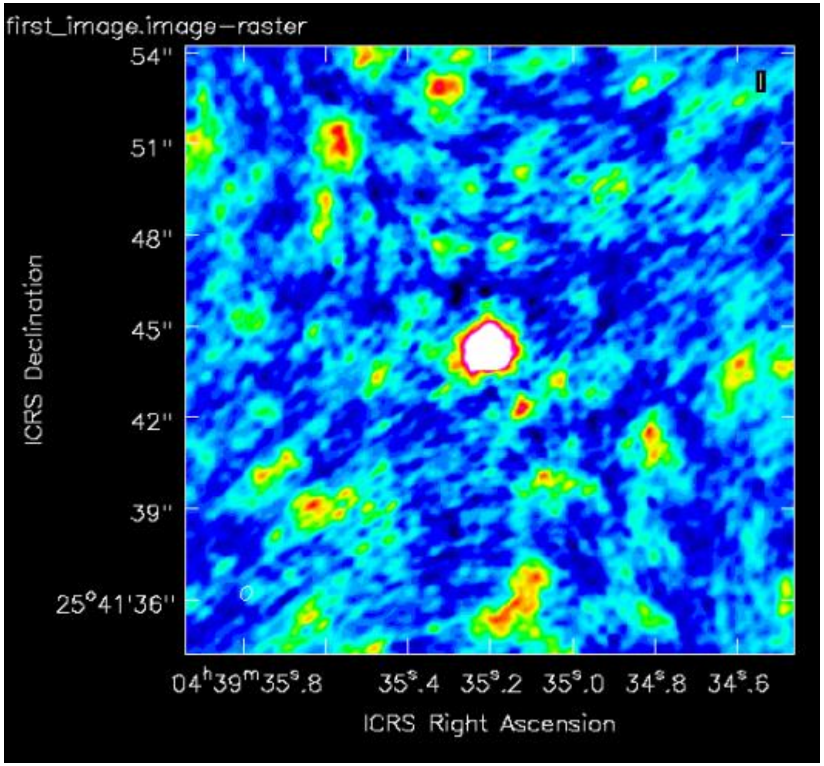
- $\nu = 233\ GHz$
- $\lambda = \frac{c}{\nu} = 1.3\ mm$
- $\theta = \frac{\lambda}{1300\ m} \cong 0.2''$
- **pixel size** = $\frac{0.2''}{5} = 0.04''$
- FOV = $\frac{\lambda}{D} = \frac{\lambda}{12\ m} \cong 20''$
- **Image size** = $\frac{20''}{0.04''} = 500$
- We used 1000×1000

```
Observation: ALMA
Computing scan and subscan properties...
Data records: 471625       Total elapsed time = 4812.82 seconds
   Observed from   21-Nov-2018/05:28:42.2   to   21-Nov-2018/06:48:55.1 (UTC)

   ObservationID = 0         ArrayID = 0
  Date        Timerange (UTC)          Scan  FldId FieldName             nRows     SpwIds   Average Interval(s)    ScanInt
  21-Nov-2018/05:28:42.2 - 05:29:12.5    41      0 tmc1a                     6125  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:46:54.9 - 05:54:00.6    50      0 tmc1a                    85750  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:54:59.8 - 06:03:06.0    52      0 tmc1a                    98000  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              06:04:29.4 - 06:12:35.6    55      0 tmc1a                    98000  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              06:15:12.0 - 06:17:13.0    59      0 tmc1a                    24500  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              06:33:31.9 - 06:41:07.9    67      0 tmc1a                    91875  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
              06:43:20.0 - 06:48:55.1    70      0 tmc1a                    67375  [0]  [6.05] [OBSERVE_TARGET#ON_SOURCE]
           (nRows = Total number of rows per scan)
Fields: 1
  ID   Code Name               RA               Decl           Epoch   SrcId      nRows
  0    none tmc1a              04:39:35.200000 +25.41.44.23000 ICRS    0          471625
Spectral Windows:  (1 unique spectral windows and 1 unique polarization setups)
  SpwID  Name                                #Chans   Frame   Ch0(MHz)  ChanWid(kHz)   TotBW(kHz) CtrFreq(MHz) BBC N
  0      X1792476109#ALMA_RB_06#BB_2#SW-01#FULL_RES      16   TOPO  232054.783    125000.000   2000000.0 232992.2829
Sources: 1
  ID   Name                SpwId RestFreq(MHz)  SysVel(km/s)
  0    tmc1a               0     233000         6.5
Antennas: 49:
  ID   Name  Station   Diam.    Long.         Lat.                Offset from array center (m)                ITRF Geocentr
                                                                     East         North     Elevation               x
  0    DA41  A058      12.0 m   -067.45.17.3  -22.53.32.0         12.7404     -827.0339       21.9673  2225039.860229 -544
  1    DA42  A023      12.0 m   -067.45.17.8  -22.53.26.2         -1.3146     -648.2167       22.1010  2225053.230992 -544
  2    DA43  A035      12.0 m   -067.45.16.6  -22.53.28.1         32.0376     -706.8053       21.7643  2225075.354628 -544
  3    DA44  A001      12.0 m   -067.45.16.9  -22.53.27.7         24.1880     -693.3966       21.7947  2225070.074664 -544
```

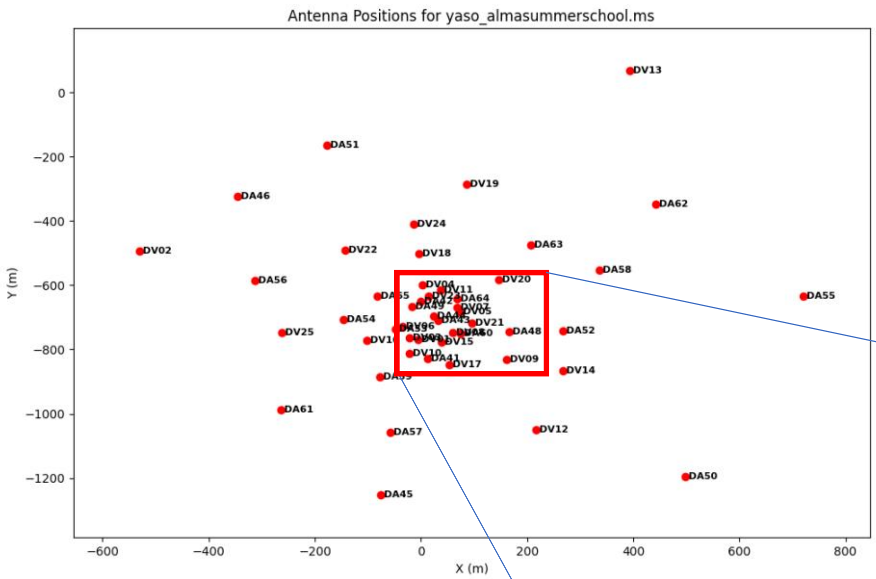


Initial image

```
tclean(vis='yaso_almasummerschool.ms',
    imagename='first_image',
    field='0',
    spw='',
    specmode='mfs',
    deconvolver='hogbom',
    nterms=1,
    gridder='standard',
    imsize=[1000,1000],
    cell=['0.04arcsec'],
    weighting='natural',
    threshold='0mJy',
    niter=5000,
    interactive=True,
    savemodel='modelcolumn')
```

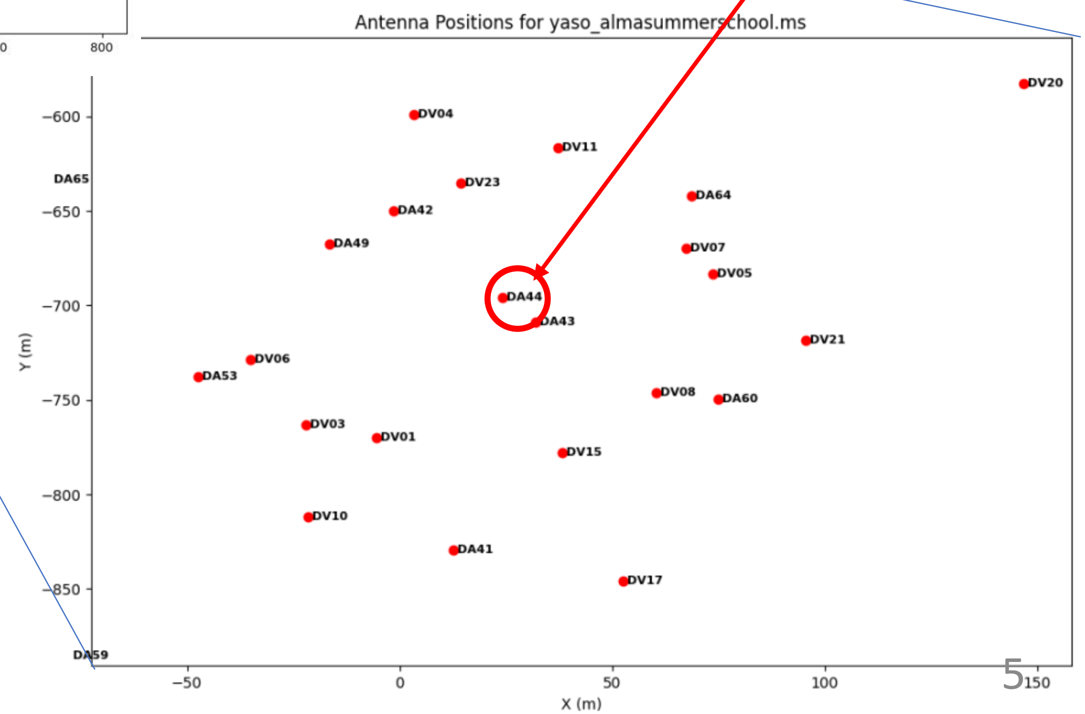


Self calibration



The center antenna is DA43, but the data observed by the antenna was flagged by observer (Dr. Aso Yusuke) during the data preparation.

Reference antenna



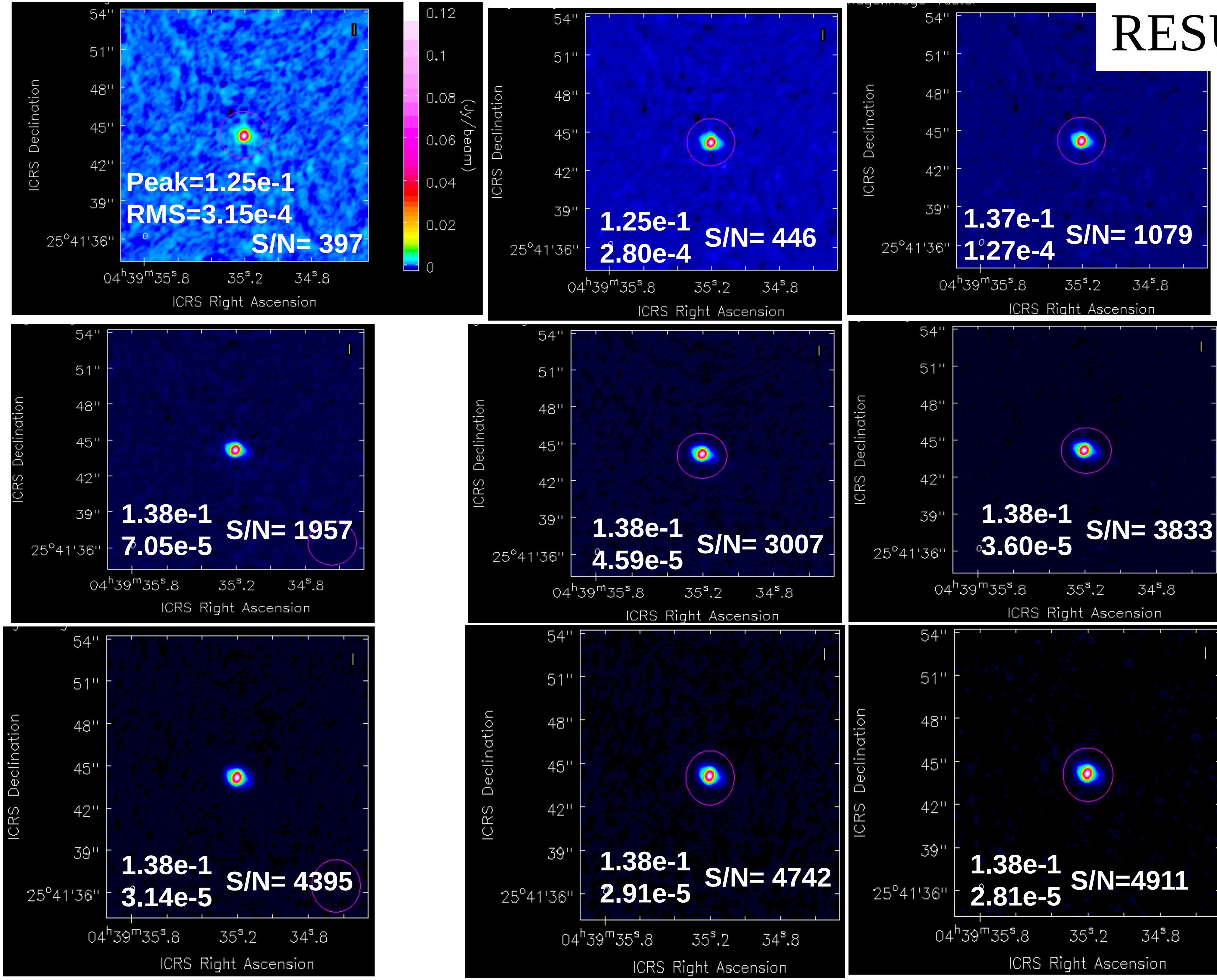
We use the nearby antenna DA44 as the reference

Phuong's result

ITERATING UNTIL THE S/N GETS SATURATION

```
os.system("rm -rf phase.cal")
gaincal(vis="yaso_almasummerschool.ms",
        caltable="phase.cal",
        field="0",
        solint="30s",
        calmode="p",
        refant="DA44",
        gaintype="G")

applycal(vis="yaso_almasummerschool.ms",
         field="0",
         gaintable=["phase.cal"],
         interp="linear")

#os.system("rm -rf yaso_almasummerschool.ms.flagversions")
split(vis="yaso_almasummerschool.ms",
      outputvis="syaso_almasummerschool_selfcal.ms",
      datacolumn="corrected")
```

RESULTS

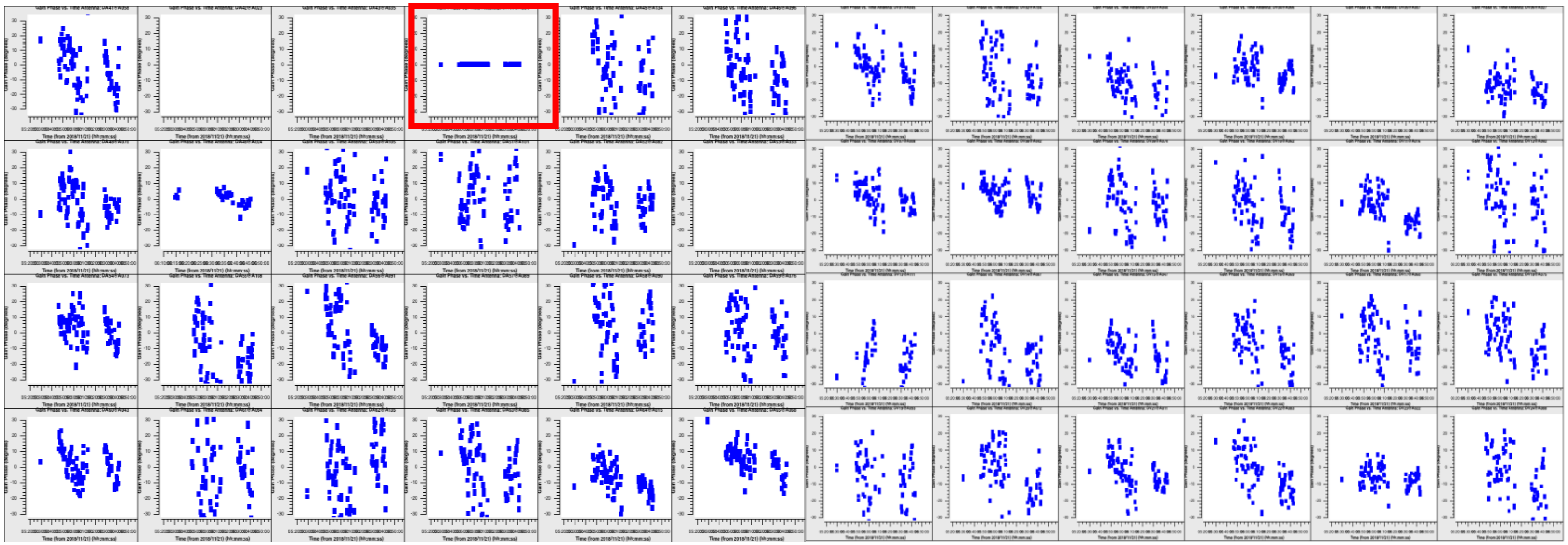


Peak=1.25e-1
RMS=3.15e-4
S/N= 397
(Jy/beam)
1.25e-1
2.80e-4
S/N= 446
1.37e-1
1.27e-4
S/N= 1079
1.38e-1
7.05e-5
S/N= 1957
1.38e-1
4.59e-5
S/N= 3007
1.38e-1
3.60e-5
S/N= 3833
1.38e-1
3.14e-5
S/N= 4395
1.38e-1
2.91e-5
S/N= 4742
1.38e-1
2.81e-5
S/N=4911
ICRS Declination
ICRS Right Ascension

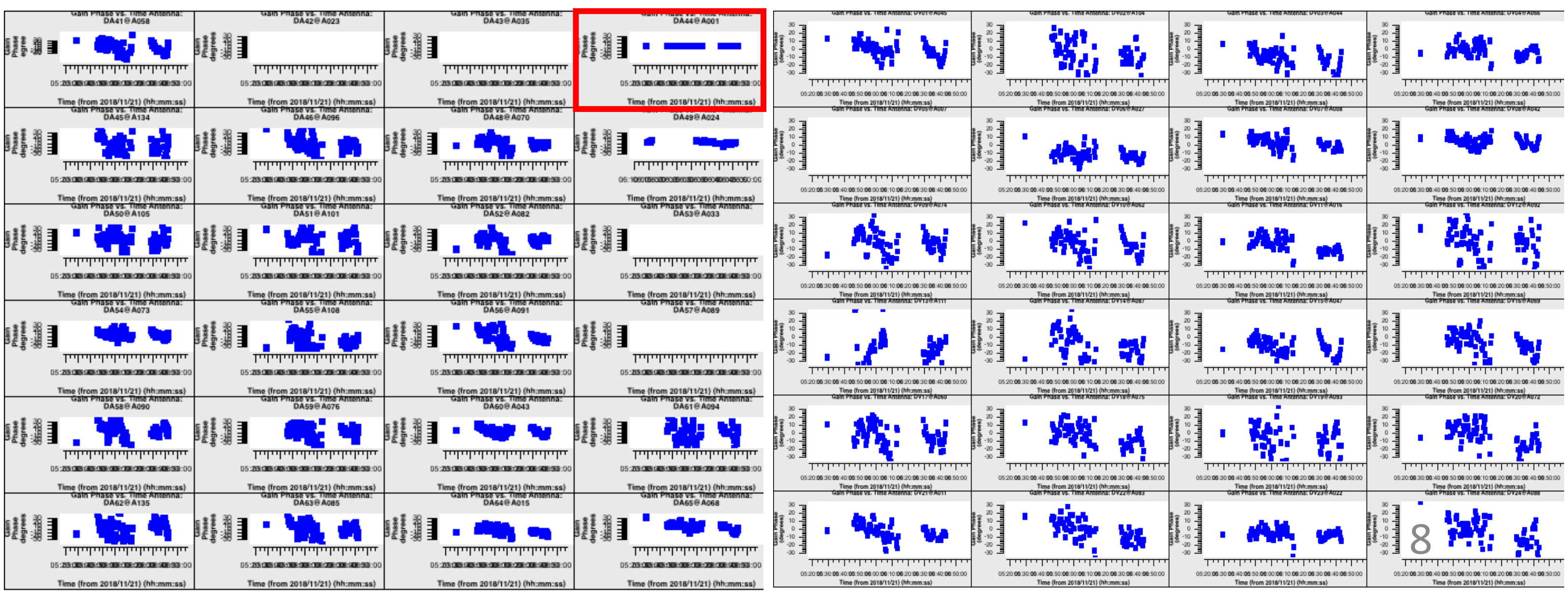
Check the Calibration table after each iteration

Phase .vs. Time

Phase1.cal



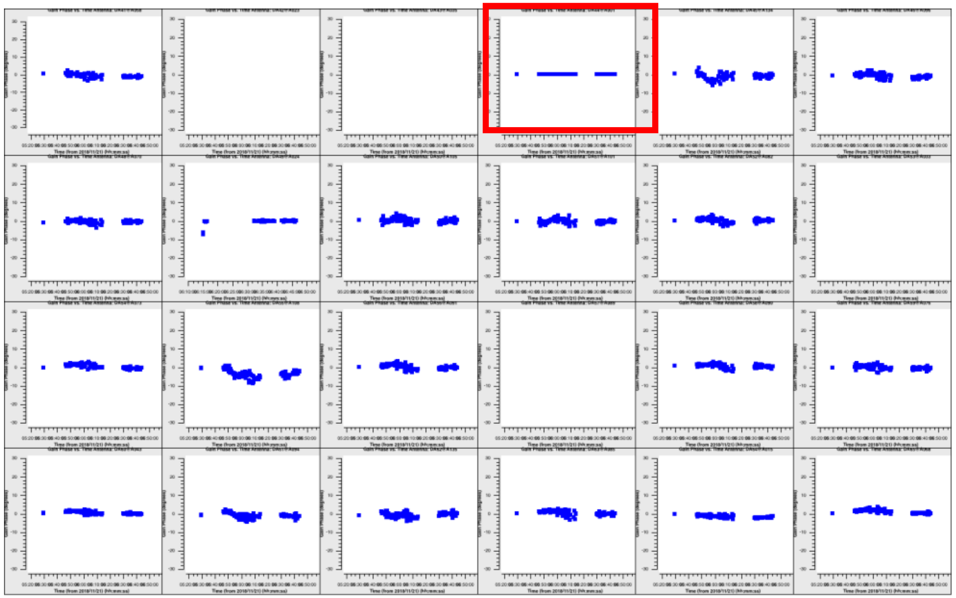
Phase2.cal

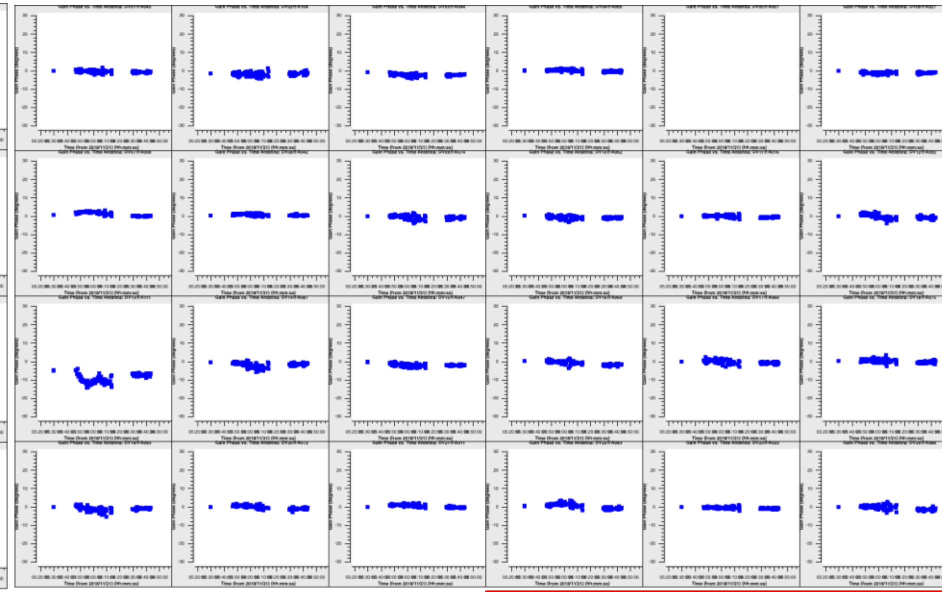


Reference antenna

Phase .vs. Time

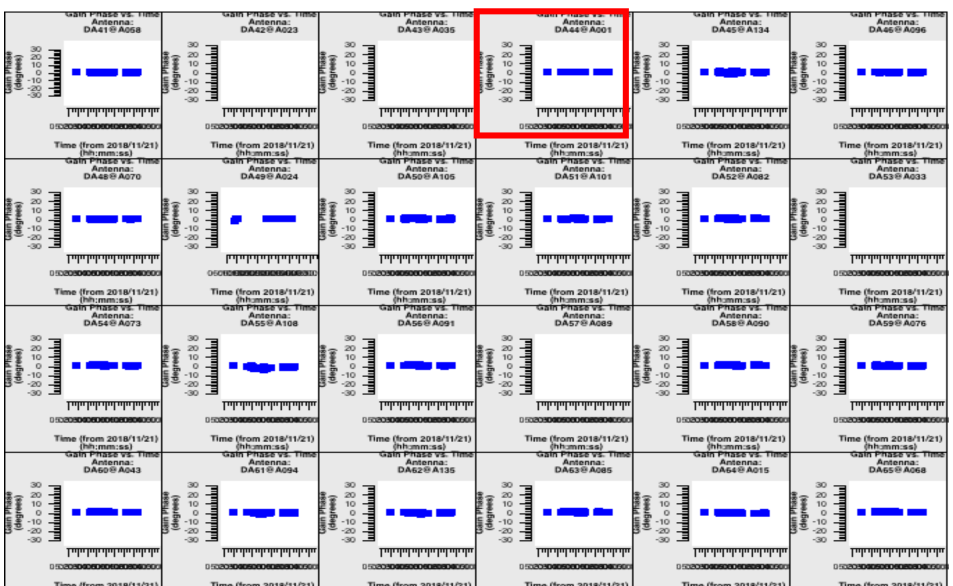
Phase3.cal

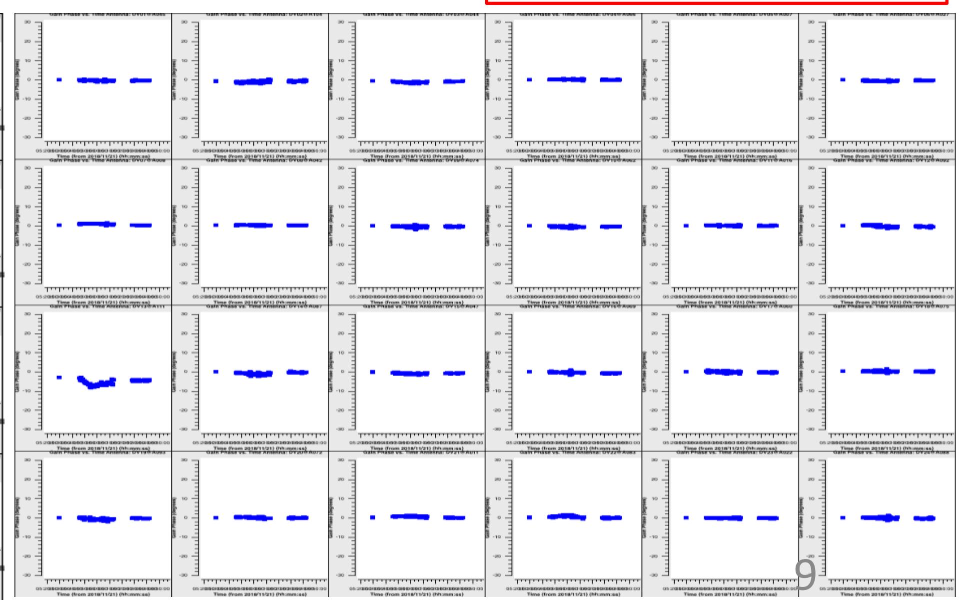




Reference antenna

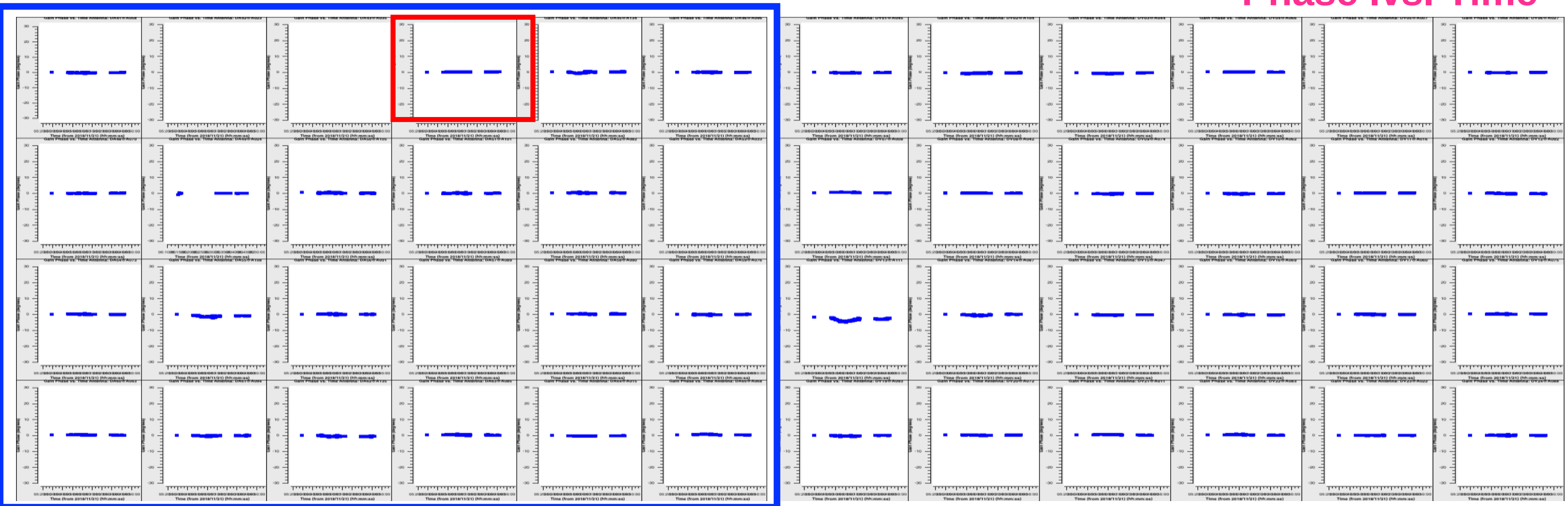
Phase4.cal



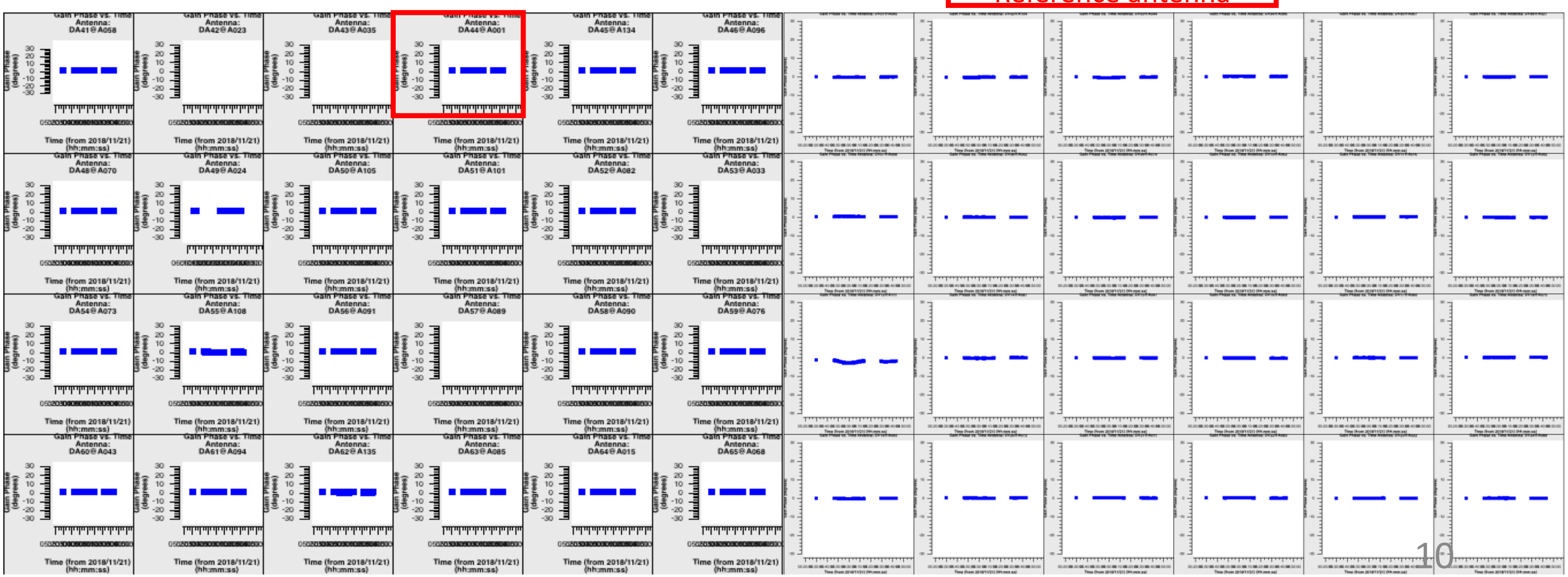


Phase .vs. Time

Phase5.cal

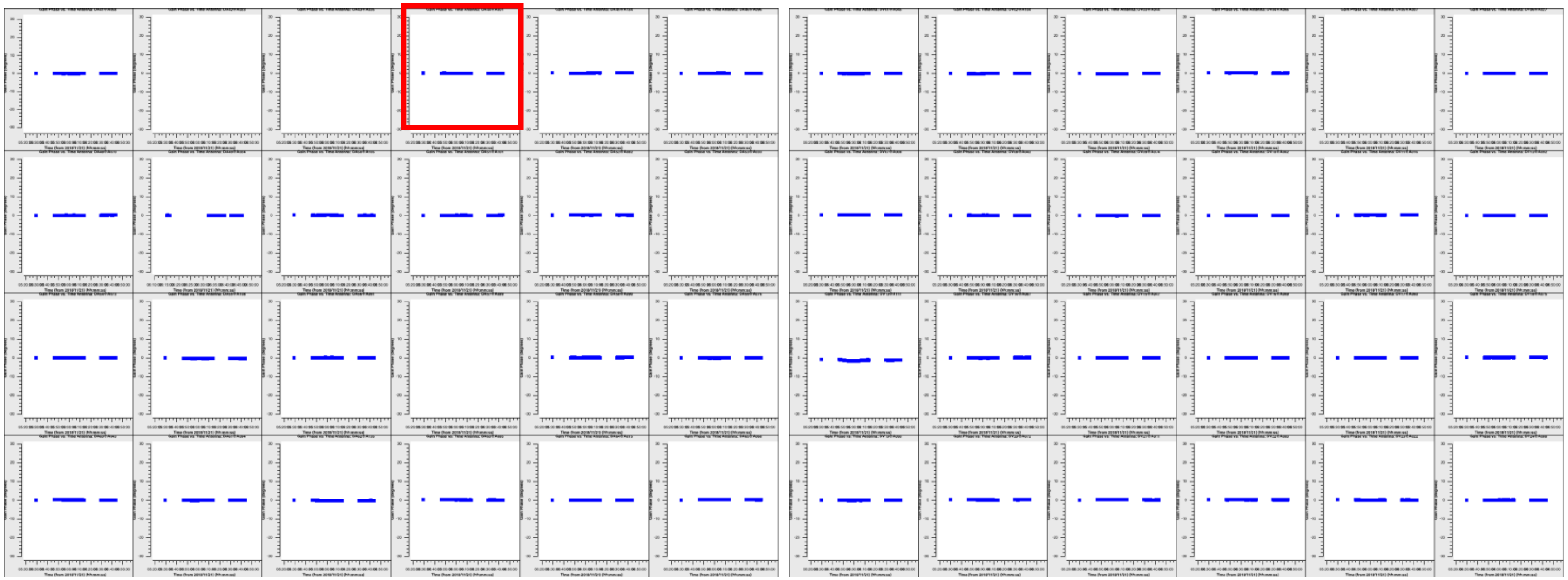


Phase6.cal



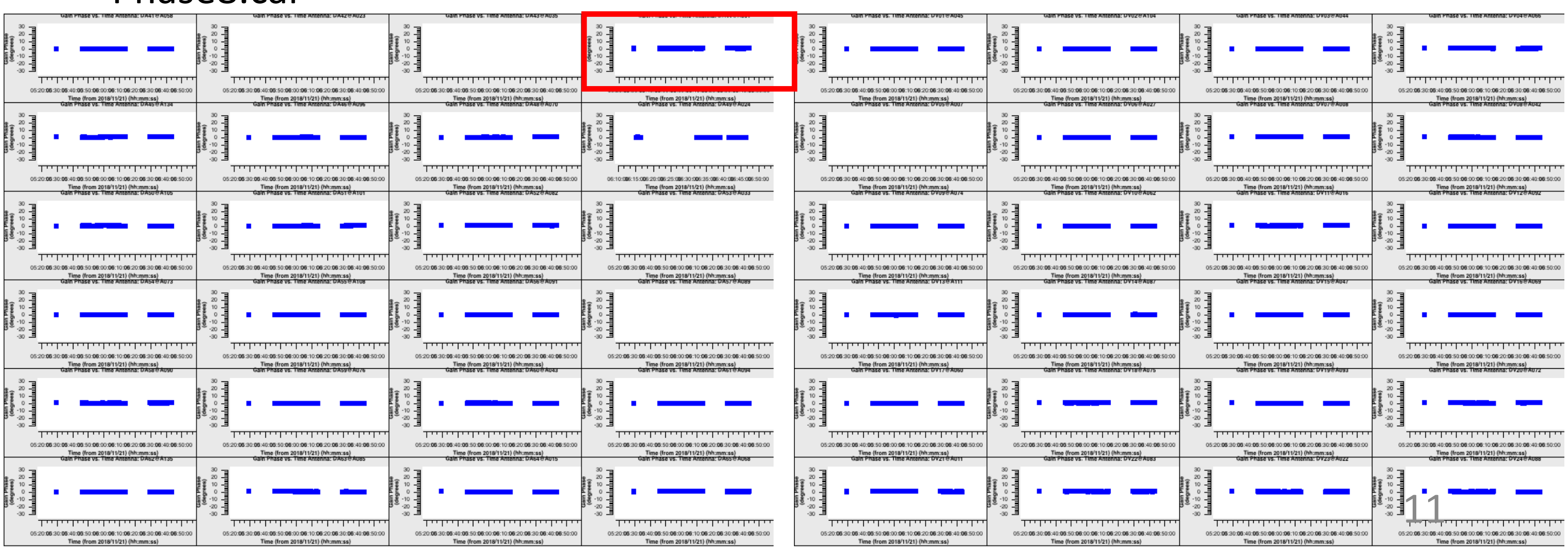
Phase .vs. Time

Phase7.cal

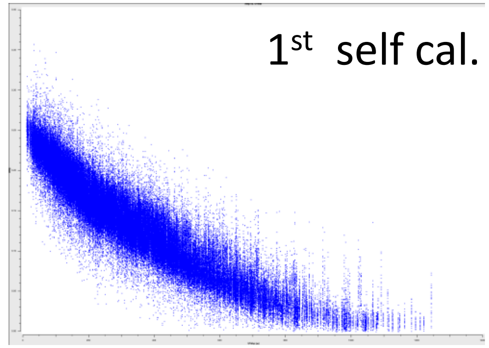


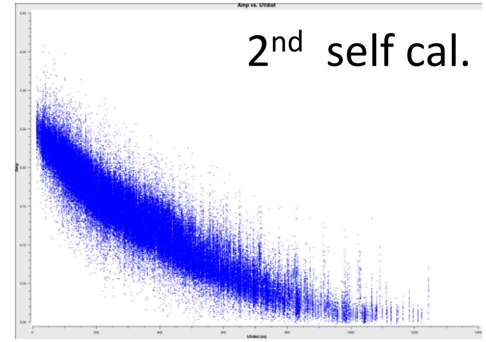
Reference antenna

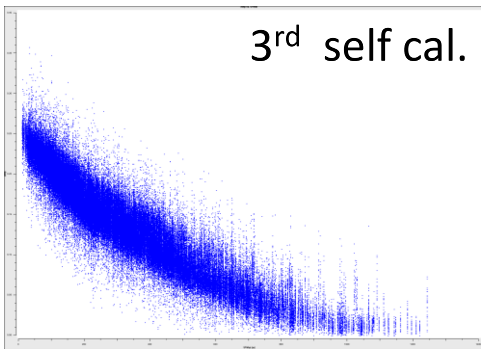
Phase8.cal

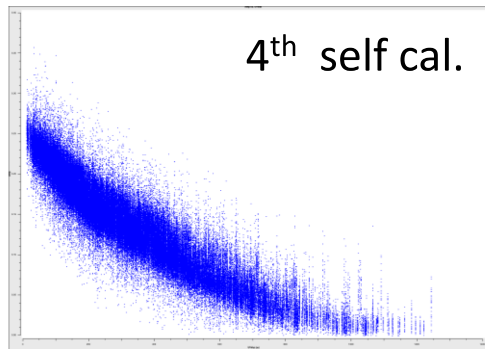


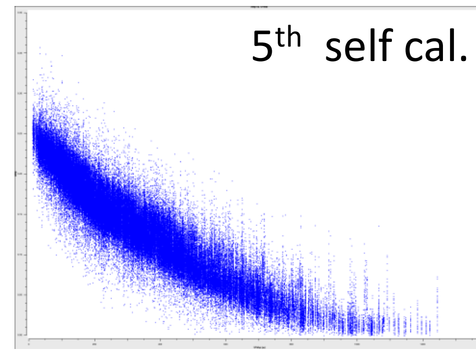
Amplitude vs UV distance

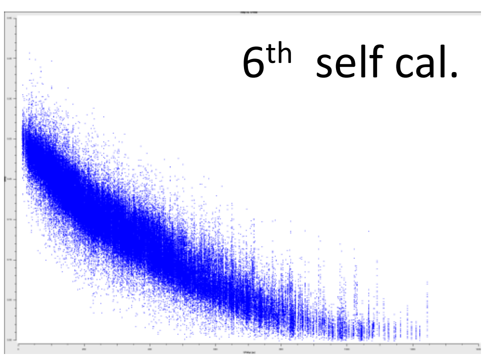


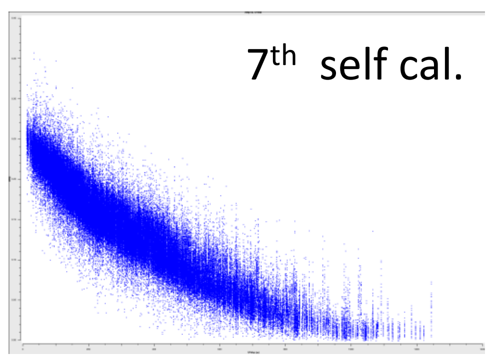


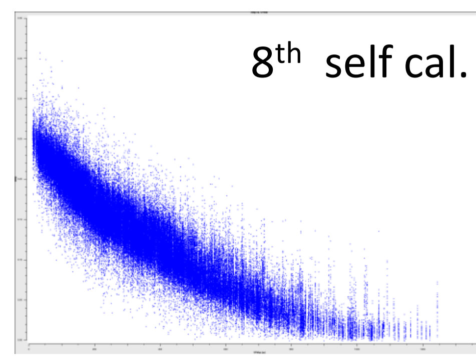




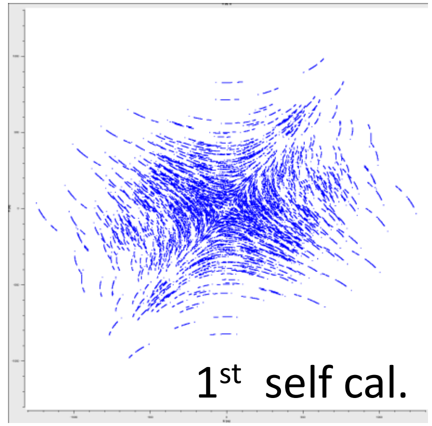


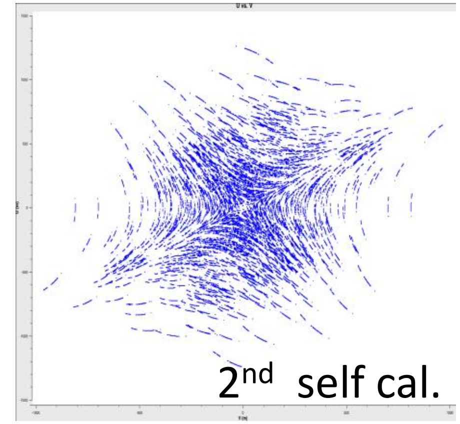


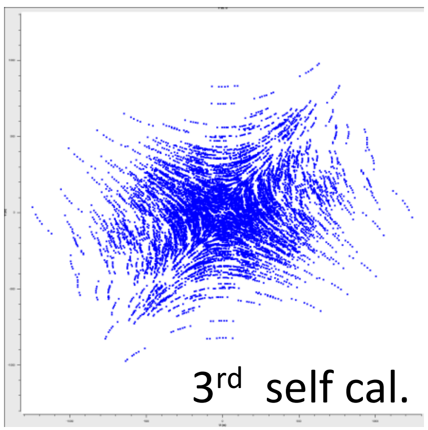


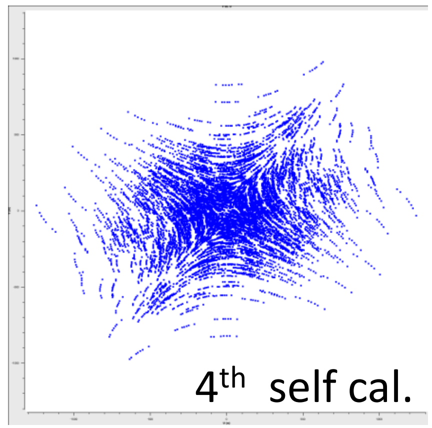


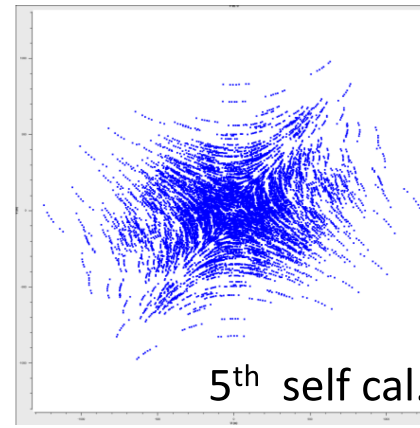
uv coverage

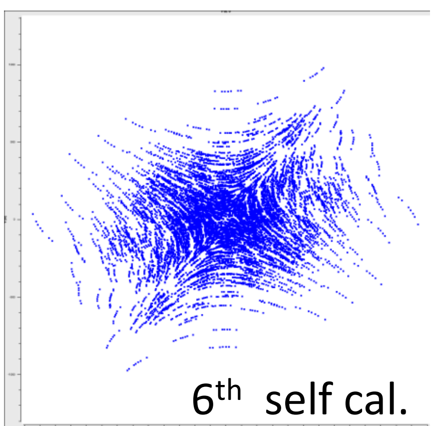

1st self cal.

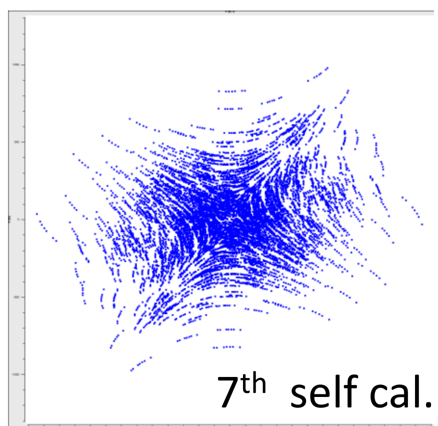

2nd self cal.

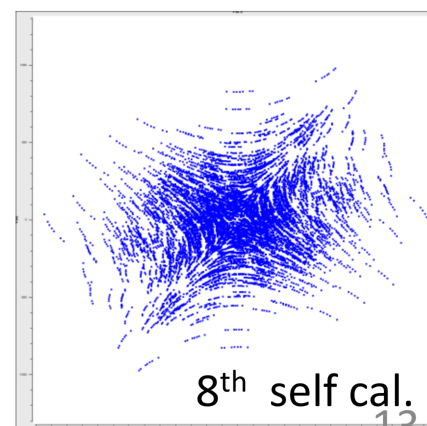

3rd self cal.


4th self cal.


5th self cal.

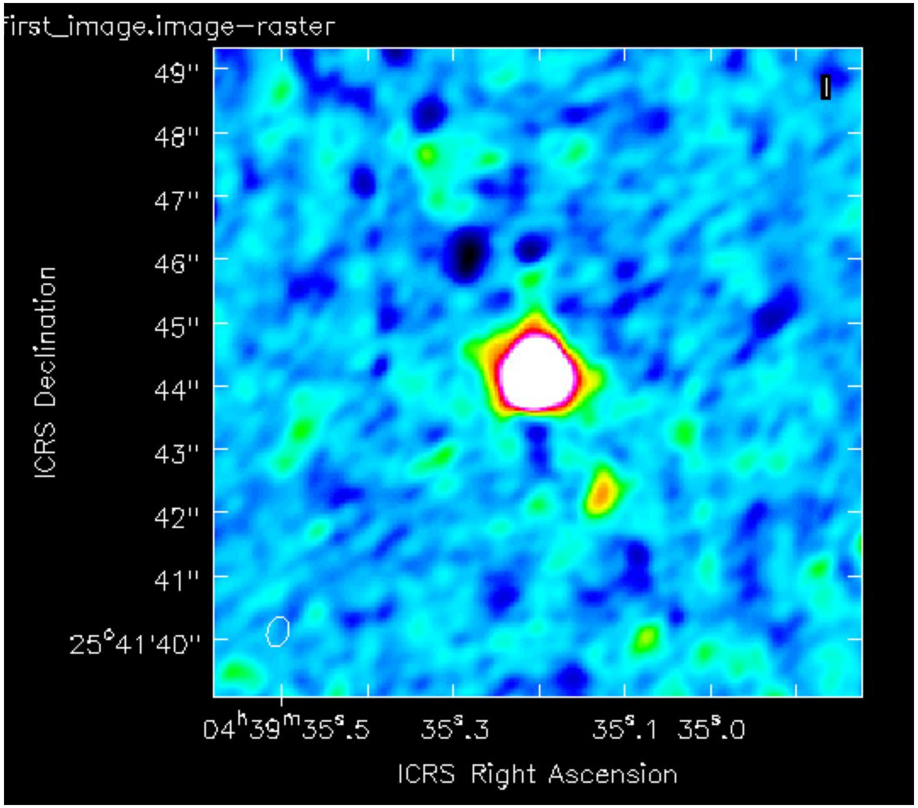

6th self cal.


7th self cal.

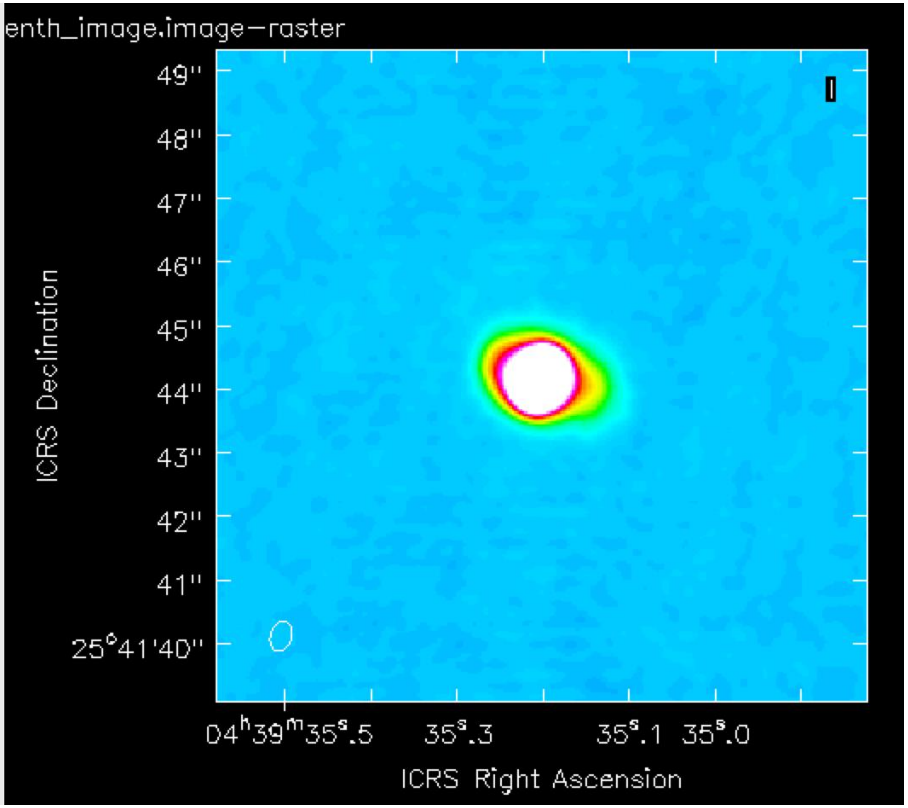

8th self cal.

Compare the clean image w and w/o self calibration

Before self calibration



8th self calibration

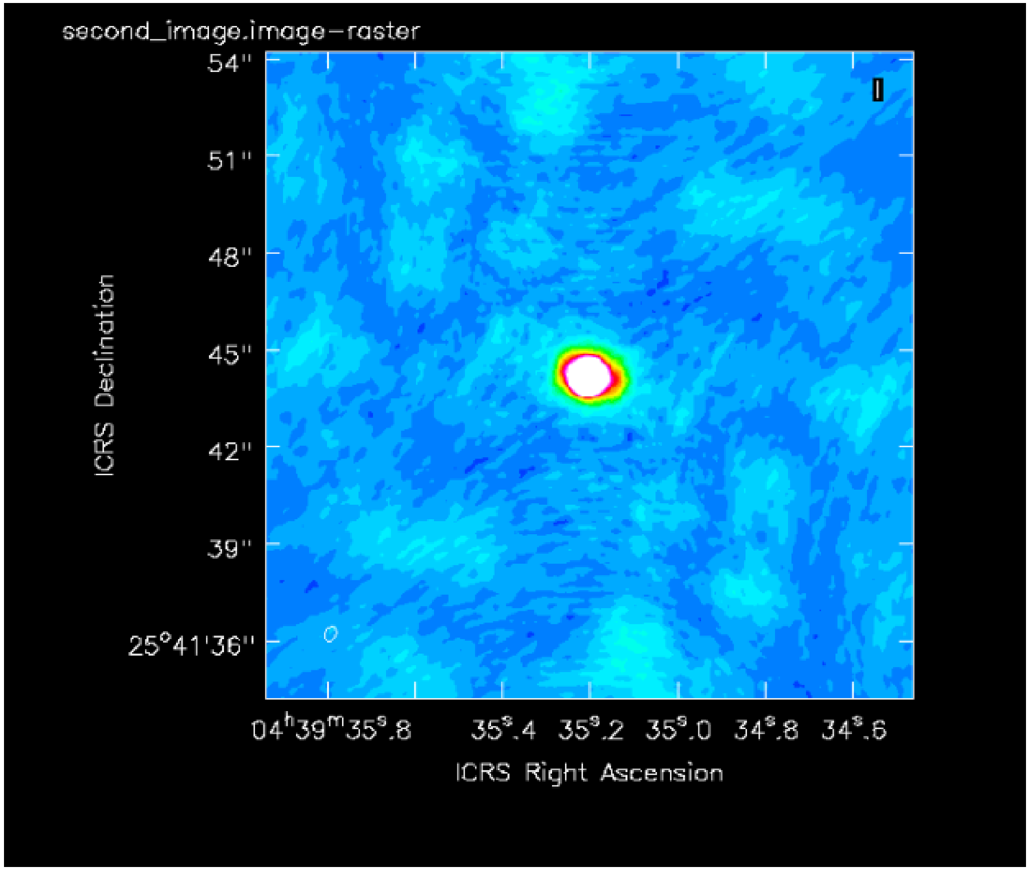


Self calibration helps to gain the S/N and reveal the faint disk structure

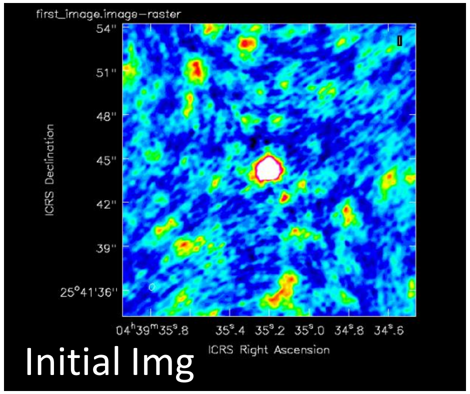
Gyuho’s result

First self-calibration

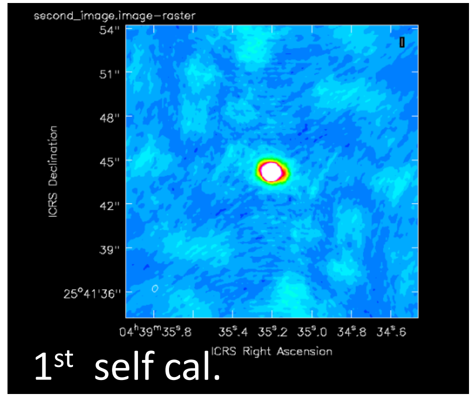
```
gaincal(vis="yaso_almasummerschool.ms",
       caltable="phase.cal",
       field="0",
       solint="90s",
       calmode="p",
       refant="DA44",
       gaintype="G")

applycal(vis="yaso_almasummerschool.ms",
        field="0",
        gaintable=["phase.cal"],
        interp="linear")

split(vis="yaso_almasummerschool.ms",
     outputvis="yaso_almasummerschool_selfcal.ms",
     datacolumn="corrected")
```



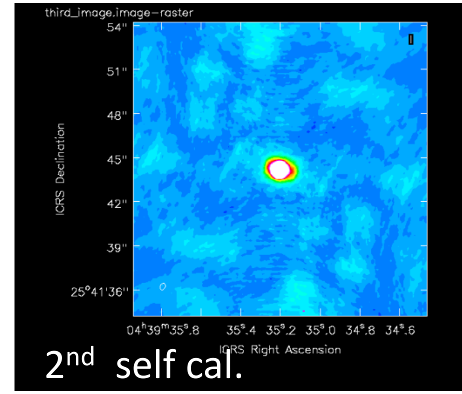
RESULTS



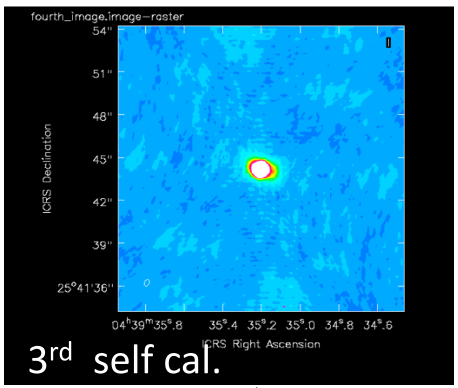
$\sigma_{image} = 7.00 \times 10^{-4}, I_{peak} = 1.29 \times 10^{-1}$
$S/N = 184$



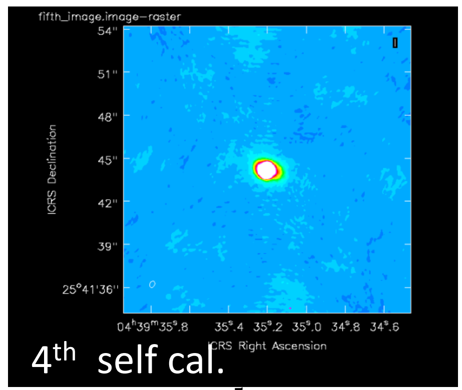
$\sigma_{image} = 1.65 \times 10^{-4}, I_{peak} = 1.37 \times 10^{-1}$
$S/N = 830$



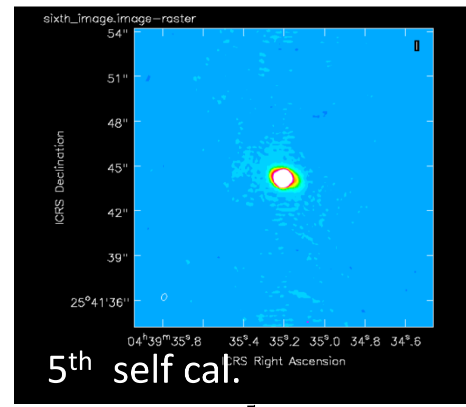
$\sigma_{image} = 1.59 \times 10^{-4}, I_{peak} = 1.39 \times 10^{-1}$
$S/N = 874$



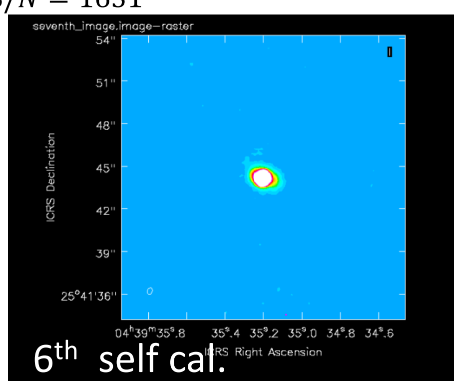
$\sigma_{image} = 8.46 \times 10^{-5}, I_{peak} = 1.38 \times 10^{-1}$
$S/N = 1631$



$\sigma_{image} = 6.33 \times 10^{-5}, I_{peak} = 1.38 \times 10^{-1}$
$S/N = 2180$

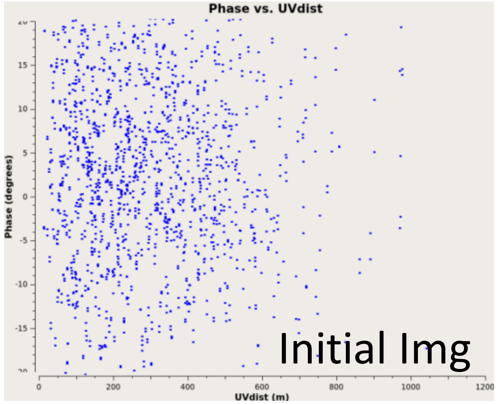


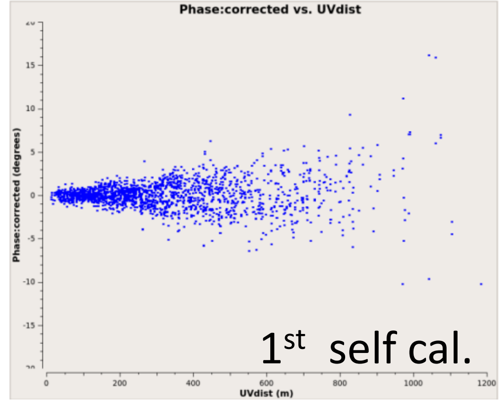
$\sigma_{image} = 3.75 \times 10^{-5}, I_{peak} = 1.39 \times 10^{-1}$
$S/N = 3707$

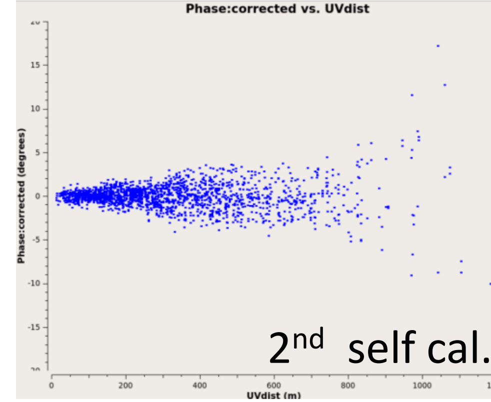


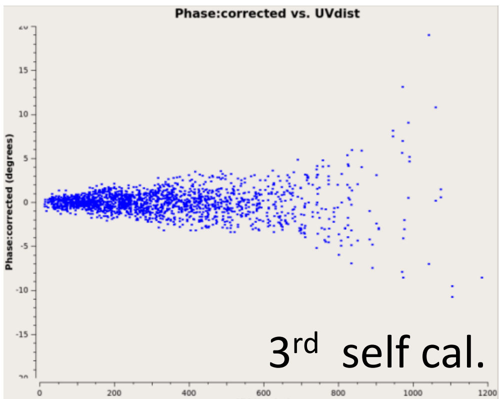
$\sigma_{image} = 2.49 \times 10^{-5}, I_{peak} = 1.39 \times 10^{-1}$
$S/N = 5582$

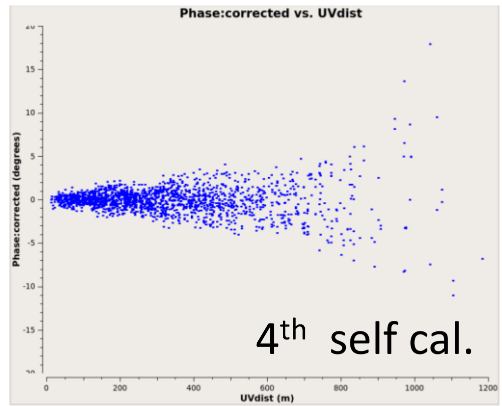
Phase
vs
uv distance

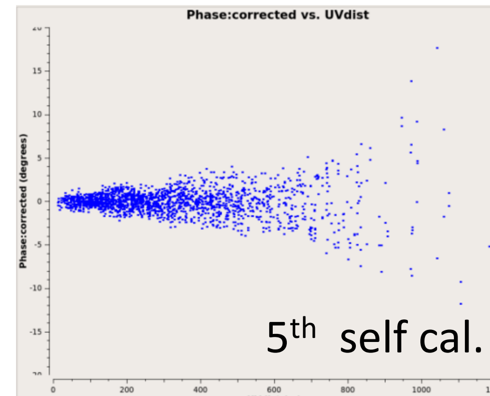


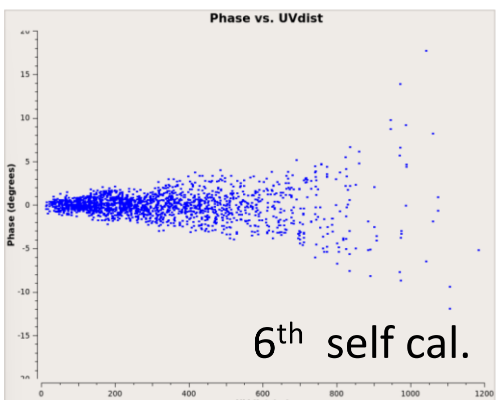




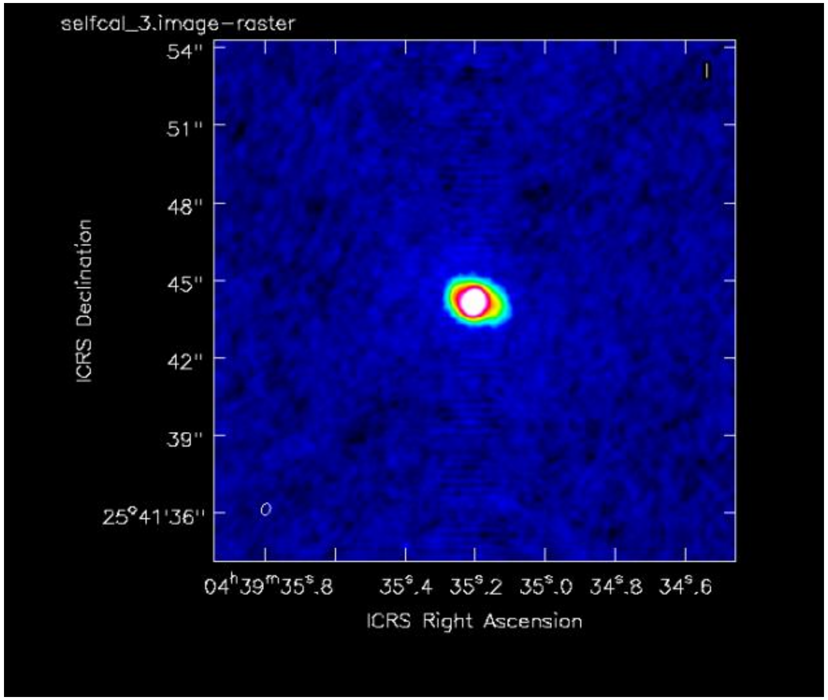








Deeper tclean (used 2nd self cal. Image)



threshold='0.075mJy', # 3 sigma

$\sigma_{image} = 3.62 \times 10^{-5}, I_{peak} = 1.38 \times 10^{-1}$
$S/N = 3812$

Conclusion

- ✓ Both results improved S/N ratio from initial (<400) to ~5000
- ✓ Self calibration enabled us to find faint disk like structure
- ✓ Both result implied self-calibration saturated after a few iteration.
- ✓ We confirmed the second-round result is almost similar to final result with deeper *tclean*