CARMA Data Reduction

Goals

1. Outline data reduction steps

2. Demonstrate reduction script
Data Reduction Steps

1. Correct antenna positions
2. Flag bad data
3. Passband (amplitudes/phase vs. frequency)
4. Absolute flux calibration
5. Phase/amplitude calibration vs. time
6. Make images!

Iterate as needed!
Step 1: Correct antenna positions

1. Re-set antenna positions with latest measurements
   - uvedit vis=cs040.miriad out=base.miriad antpos=antpos.100708

2. Notes
   - Best baseline solution may already be in system
   - No harm in re-applying solution
   - see http://cedarflat.mmarray.org/observing/baseline/
   - see $MIR/cat/baselines/carma
Step 2: Flag bad data

1. Shadowed baselines
   - `csflag vis=cs040.miriad`

2. High elevation
   - `uvflag vis=cs040.miriad flagval=flag select="el(85,90)"`

3. Bad Antennas
   - `uvflag vis=cs040.miriad flagval=flag select="ant(2)"`

4. Edge channels
   - `uvflag vis=cs040.miriad flagval=flag edgechan=2`

5. Time ranges
   - `uvflag vis=cs040.miriad flagval=flag select="time(05:40:00,06:00:00)"`
Step 3: Passband

1. Corrects for channel-to-channel variations of amplitude and frequency

2. Corrects for mean phase offsets between windows
Step 3: Signal to noise on passband

\[ \sigma_{\text{pha}} \approx \sigma_{\text{amp}} / S_{\text{source}} \quad \text{per baseline} \]

\[ = 8^\circ \left( \frac{T_{\text{sys}}}{300 \, \text{K}} \right) \left( \frac{D}{8 \, \text{m}} \right)^{-2} \left( \frac{\text{BW}}{500 \, \text{MHz}} \right)^{-0.8} \left( \frac{t_{\text{int}}}{1 \, \text{min}} \right)^{-0.8} \left( \frac{S_{\text{source}}}{1 \, \text{Jy}} \right)^{-1} \]

<table>
<thead>
<tr>
<th>Bandwidth (MHz)</th>
<th>Channel width (MHz)</th>
<th>Amplitude uncertainty (%) per band</th>
<th>Amplitude uncertainty (%) per channel</th>
<th>Phase uncertainty (deg) per band</th>
<th>Phase uncertainty (deg) per channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>5.3</td>
<td>0.24%</td>
<td>2.4%</td>
<td>0.13 deg</td>
<td>1.3 deg</td>
</tr>
<tr>
<td>8</td>
<td>0.02</td>
<td>1.9%</td>
<td>37%</td>
<td>1 deg</td>
<td>21 deg</td>
</tr>
</tbody>
</table>

Assumptions:
- \( S_{\text{source}} = 4 \, \text{Jy} \)
- \( t_{\text{int}} = 15 \, \text{minutes} \)
- antenna-based solution
Step 3: Strategy for passband calibration

1. Wide band (500 MHz)
   - bright astronomical source (i.e. passband calibrator) corrects channel-to-channel variations

2. Narrow band (< 32 MHz)
   - use noise source and autocorrelations to correct channel-to-channel variations
   - Use passband calibrator to correct \textit{average} phase
   - Not all channel-to-channel variations corrected

3. Adjust wide-band and narrow-band to have same mean amplitude and phase
Step 3: Amplitude Residuals for 250 MHz band
Step 4: Phase Residuals for 250 MHz band
Step 3: Amplitude Residuals for 8 MHz band
Step 3: Phase Residuals for 8 MHz band
Step 4: Flux calibration

1. Observe source of known brightness
   - e.g. Uranus, Neptune, MWC 349

2. Scale observed fluxes to known flux
   - bootflux vis=flux.mir ...
   - in practice, first passband calibrate and remove phase fluctuations
Step 5: Gain calibration

1. Correct variations in amplitudes and phase with time
   - use measured flux of gain calibration in Step 4
   - mfcal vis=gain.mir select="source(3c111)"
     interval=20 refant=9 options=nopass
   - average widebands for best signal to noise
   - "selfcal" and "mselfcal" can be used instead
Step 6: Make images

1. Create “dirty” image
   - invert vis=cal.mir select=“source(hltau)” robust=2 options=mosaic,systemp,mfs,double map=hltau.map beam=hltau.beam
   - use “mfs” for continuum images
   - remove “mfs” for spectral line

2. “Clean” (deconvolve) image
   - mossdi map=hltau.map beam=hltau.beam out=hltau.cc region=“arcsec,box(-10,-10,10,10)”

3. Restore image
   - restor map=hltau.map beam=hltau.beam model=hltau.cc out=hltau.cm fwhm=9.1,10.2 pa=75
Scripts


1. carma_uv.csh
   • calibrates uv data
   • a general observing script \(\rightarrow\) very complicated
   • continuum projects can use a MUCH simpler script

2. carma_images.csh
   • produces images
Caution: “Features” of reduction script

1. Mean frequency of windows cannot be the same
   - Miriad solves for passband vs. frequency
   - Run script twice and process duplicate frequencies independently

2. Noise passband error
   - ### Fatal Error [mfcal]: Too many spectral windows for me to handle
   - Occurs when selecting all noise-source integrations
   - Can either skip noise-passband, or select a narrow time range

3. Making images
   - invert will not make images of flagged edge channels
   - use "line" option to select the good channels
More careful data reduction...

1. Flux calibration
   - Pick out similar range of elevation and time

2. Gain calibration
   - Short interval for phase calibration, then long interval for amplitude calibration

3. Take into account spectral slope of gain/passband calibrators

4. Astronomical passband for all bands (need bright source)