Black Board Self Calibration Progress/Status

V. N. Pandey, Joris van Zwieten

DCLA meeting, ASTRON

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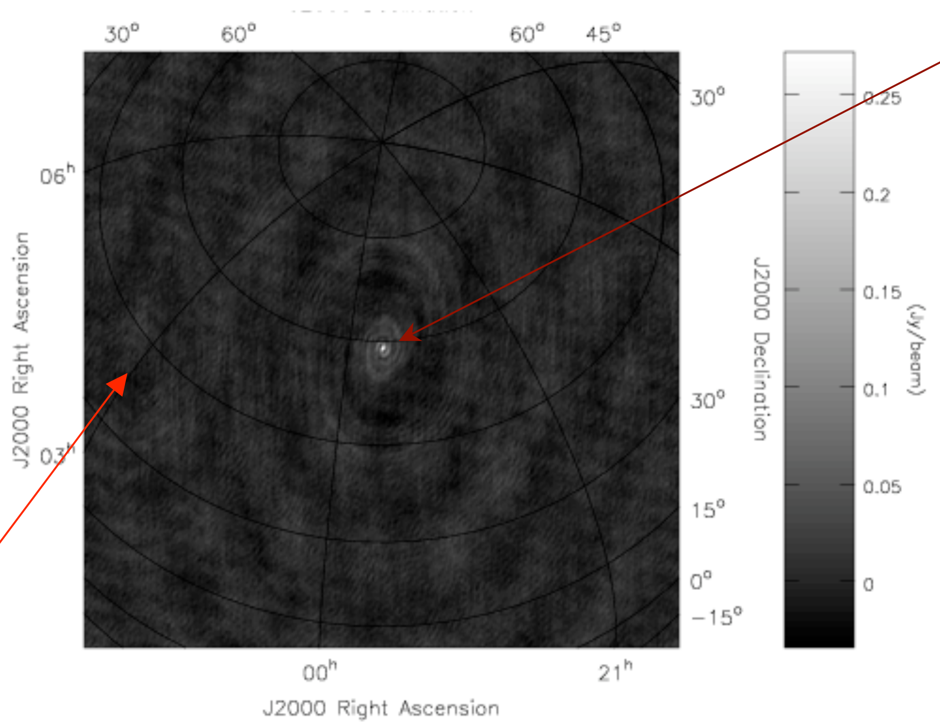
Outline

1. BBS calibration - recap
2. BBS - Detailed checks on Simulated data
3. BBS - Checks on CS1 Data & Comparison with MeqTree solutions
4. Status - Conclusions/Next steps
5. Example of effect difference in sign of *uvw* during obsvn and solving

Output Image - MS1810

- 16 hours, 30 March - 31 March, 2007, 16 dipoles tracking on CasA
- 24 sub bands, each 256 channels, 0.6KHz resolution
- For all analysis Subband 20, around 64.99 MHz

Calibrated Image



The output image has

- CasA clearly seen
- CygA barely visible
- CygA position on the other (wrong) side of CasA (along RA)

- Default BBS *uvw* convention -> opp to CS1 -> Fixed
- w projection needs to be used properly -> Fixed

Single Channel (110) 0.6Khz , Entire observation

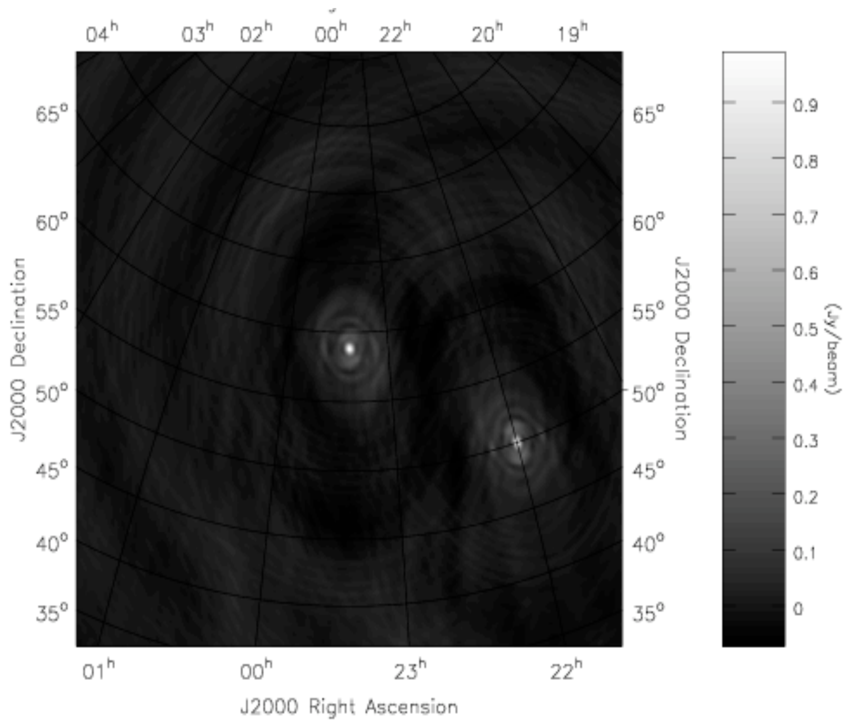
BBS without extra *n* term

- **We have removed an extra division by *n* term in BBS**

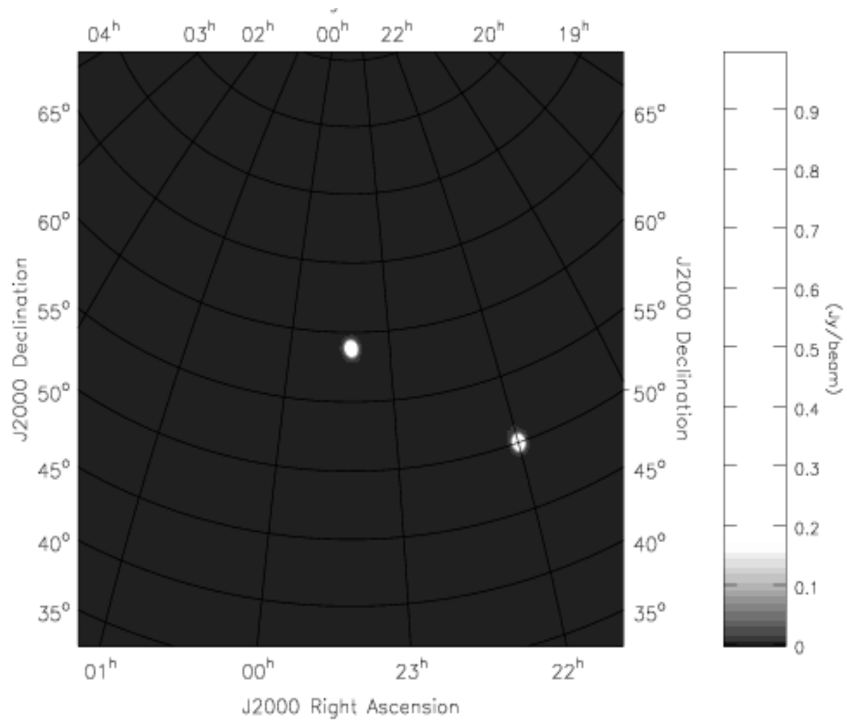
Two sources each of 1.0Jy

- Predicted by BBS, Imaged using AIPS++
- Fluxes and positions all come out correctly (within 0.5% and arc seconds)
- So BBS Prediction and our Usage of Imager is correct.

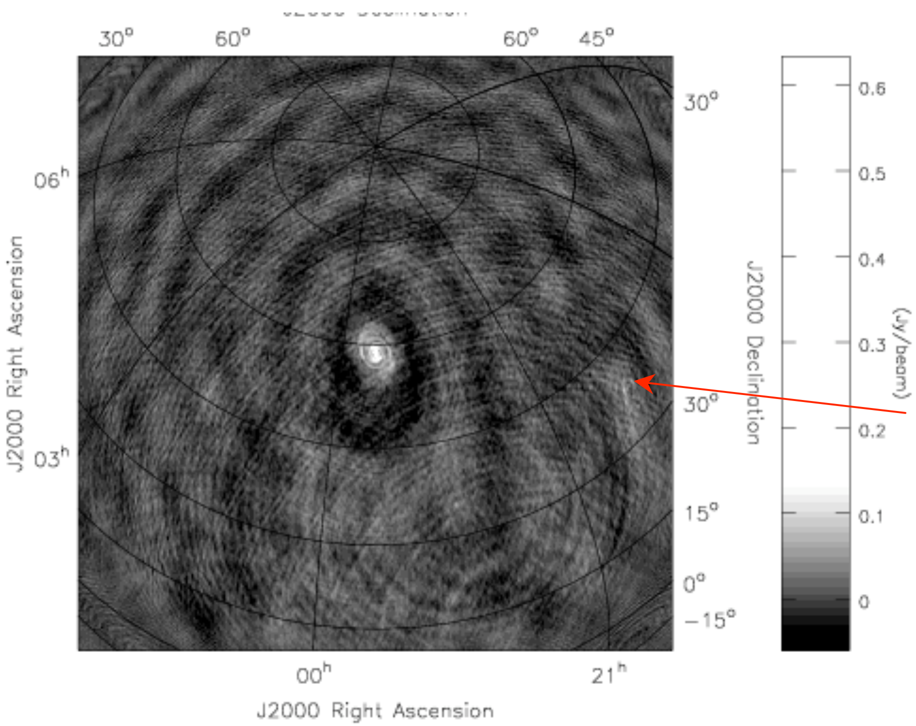
Model Raw Image



Model Cleaned Image



Retry calibration -> BBS -> Image



- Still does not improve much
- CygA barely visible
- No negative dips now
- CygA not in the wrong direction?

BBS Debugging

Simulated Data　　　　　　　　　　Observed Data

We decided to go for bottom up approach -> build up and check from scratch

BBS CHECKS - SIMULATED DATA

- Predict -> Checked by comparing with AIPS++, MeqTrees, Glish Script
  All Agree with each other.
- Solve
- Correct
- Subtract

BBS Solver

- Predict the model visibilities (say CasA-> 3,000 Jy, CygA=20,000Jy)
- Corrupt them with artificial gains (Amplitude and Phase)
  for both directions - CasA (source1) and CygA (source 2)
- Gain in direction of CasA
  G(Amp)=1.25*Antenna Number
  G(phase)=0.1*(Antenna Number -1)
- Gain in direction of CygA
  G(Amp)=0.8*Antenna Number
  G(phase)= 0.33*(Antenna Number -1)

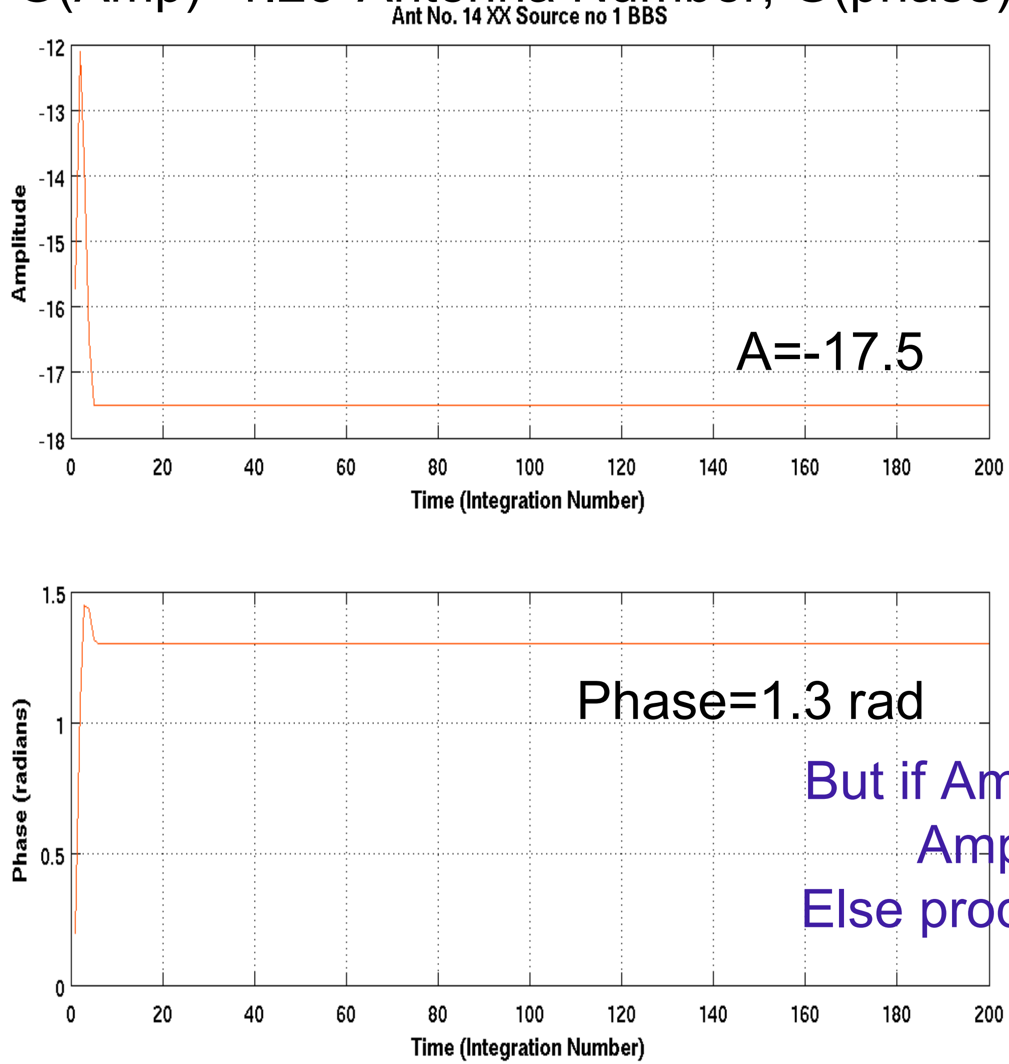
(Phase of first antenna frozen to zero)

- Solve for the antenna based amplitudes and phases,
- 50 Iterations for each time slot,
- solve domain size=60s (~1 time slot),
- solutions from one time slot passed on to the next.

- **No positivity constrain on Amplitude, so All amplitudes gains can be negative (consistent)-> as interferometers measure product of antenna amplitude gains and difference of antenna based phases**

BBS Solver Amp/Phase -> CasA

G(Amp)=1.25*Antenna Number, G(phase)=0.1*(Antenna Number -1)



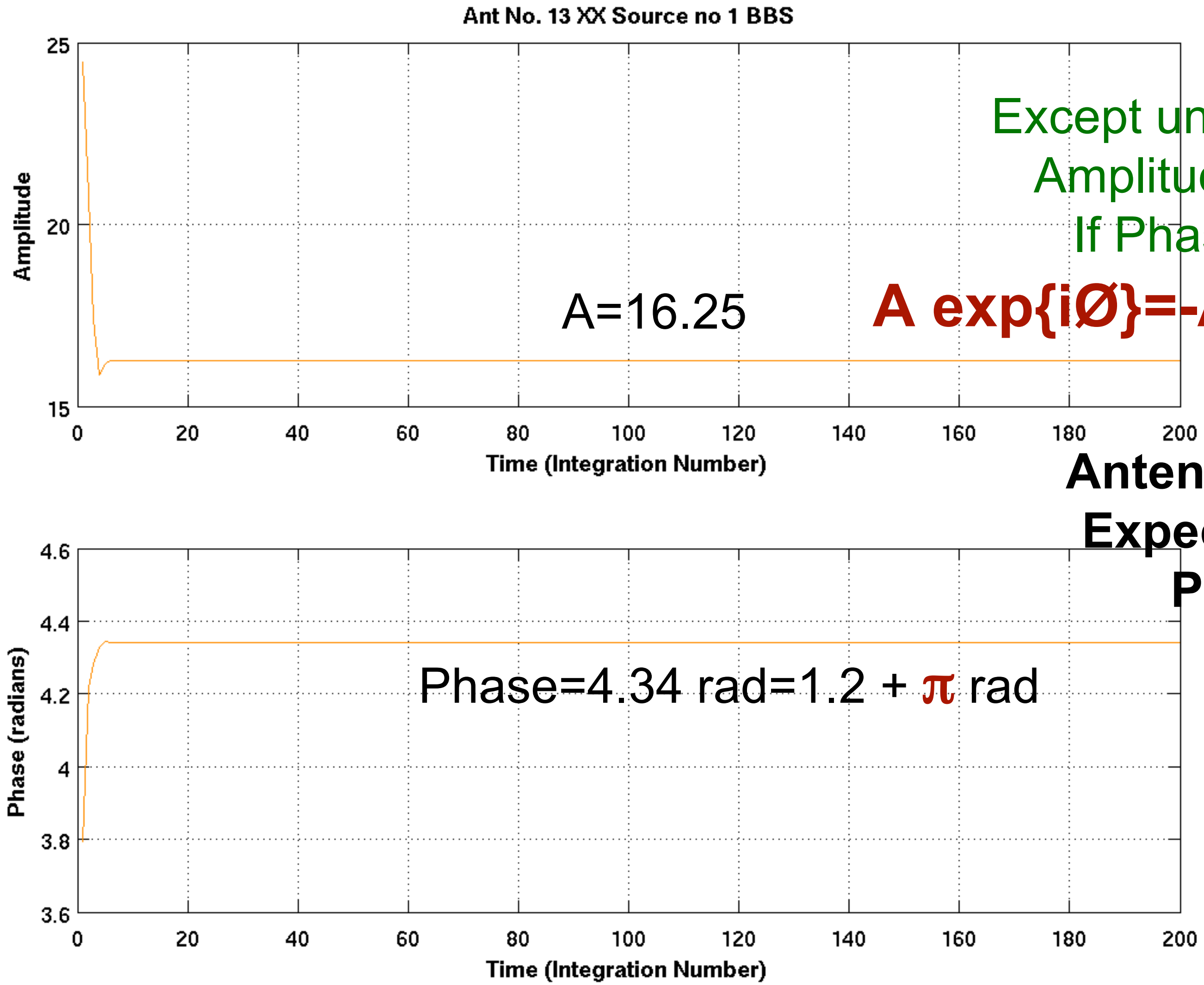
Antenna No. 14, XX

Expected A=17.5,
Phase=1.3 rad

But if Amplitude Gain for any antenna <0,
Amp should <0 for all antennas
Else product wont be positive for baseline

BBS Solver - Amplitude/Phase -> CasA

G(Amp)=1.25*Antenna Number, G(phase)=0.1*(Antenna Number -1)



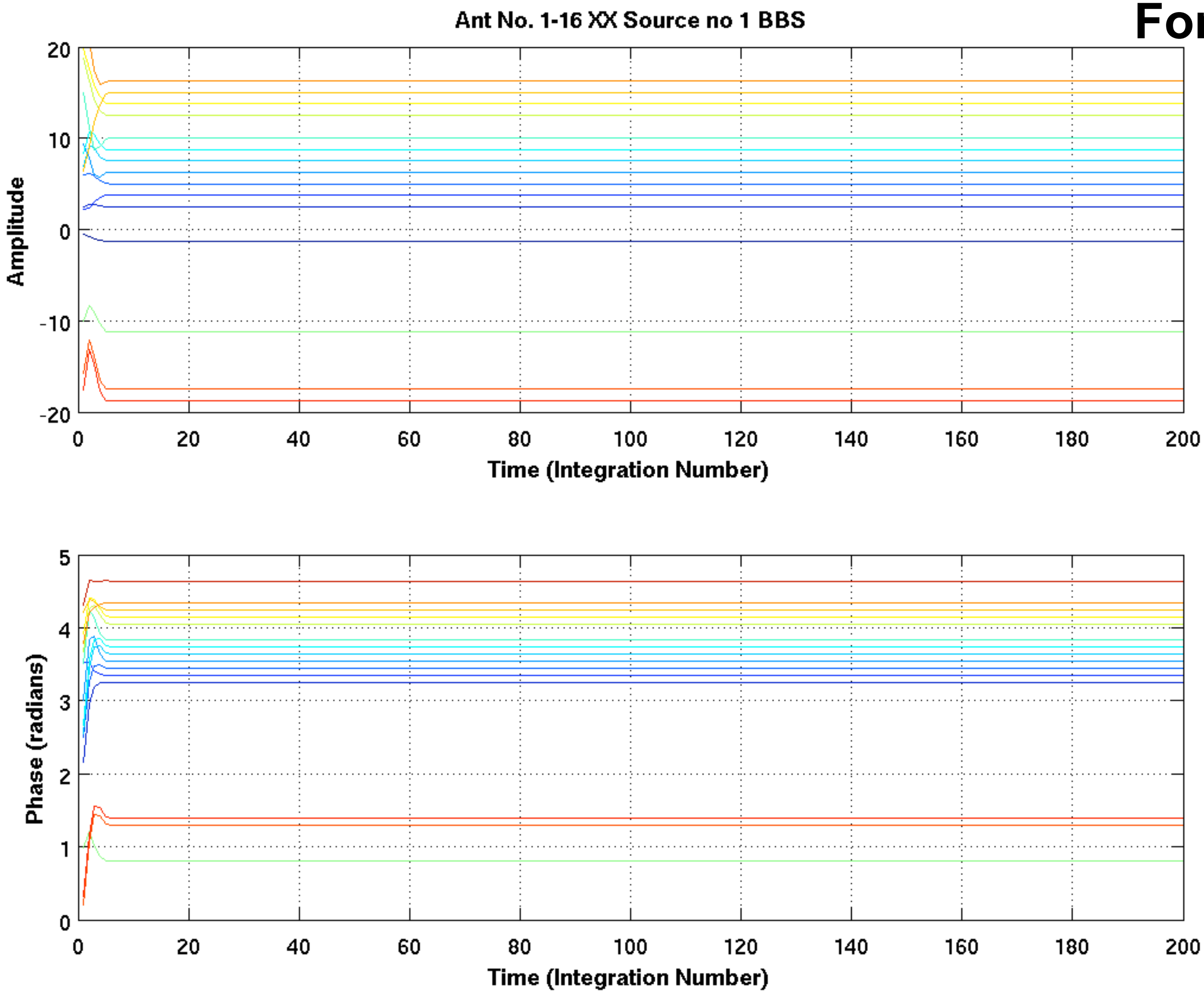
Except under the condition
Amplitude change sign
If Phase shift of +pi

A exp{iØ}=-A exp{i(Ø+π)}

Antenna No. 13, XX
Expected A=16.25
Phase=1.2

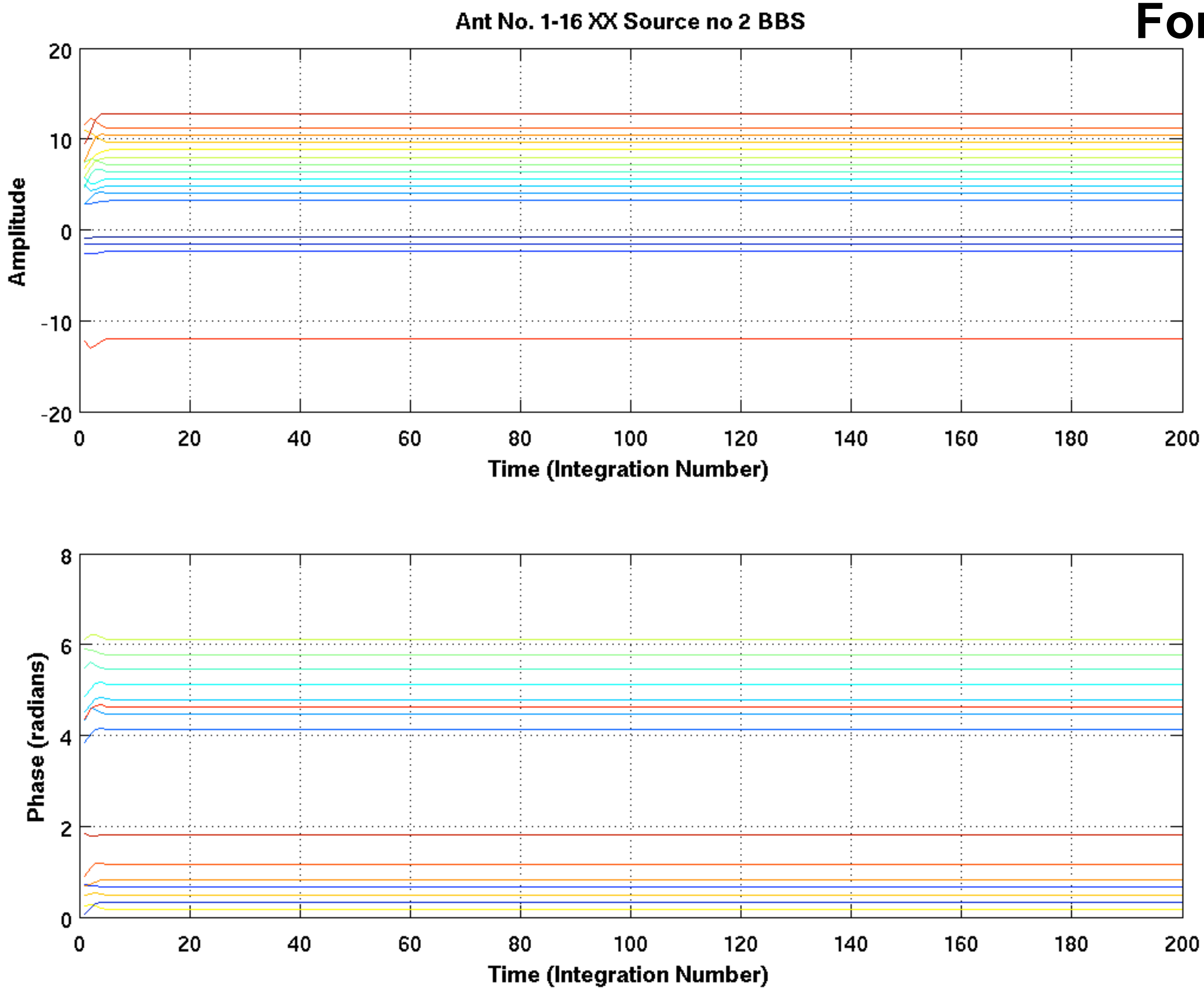
BBS Solver Amp/Phase -> CasA

All Complex Gains are recovered correctly
For all antennas (XX)
Towards casA



BBS Solver Amp/Phase -> CygA

Also
For all antennas (XX)
Towards CygA



BBS Solver - Inferences

- The Amplitude and phase gains can be recovered without any ambiguity for each of the source directions
- There is no interplay between the Gains in direction of CasA and CygA.
- Number of iterations required by the solver to converge is about 250.
- These same gains were also obtained using MeQTrees (similar number of iterations).

- **BBS Solver works fine for simulated data.**

BBS Correct/Subtract

- The correct step was tested using the complex gain solutions obtained
- The corrected visibilities were found to be same as predicted visibilities without the antenae gains.
- The correct Step also works fine.
- The Subtract step was checked by subtracting one, and both sources and compared with the expected residual and found to be as expected.
- Subtract Step also works fine.

- All Aspect of BBS verified on Simulated Data -> predict, solve, correct, subtract. (for both XX and YY independently)
- All steps checked also specifying complex gains as real and imaginary format (in addition to Amp and Phase)

BBS CHECKS - OBSERVED DATA

- BBS calibration attempted on observed data.
- Visual inspection of image -> does not convey much of calibration quality
- Comparison of solutions obtained by MeqTrees
- Use of Pipeline set up by Ronald

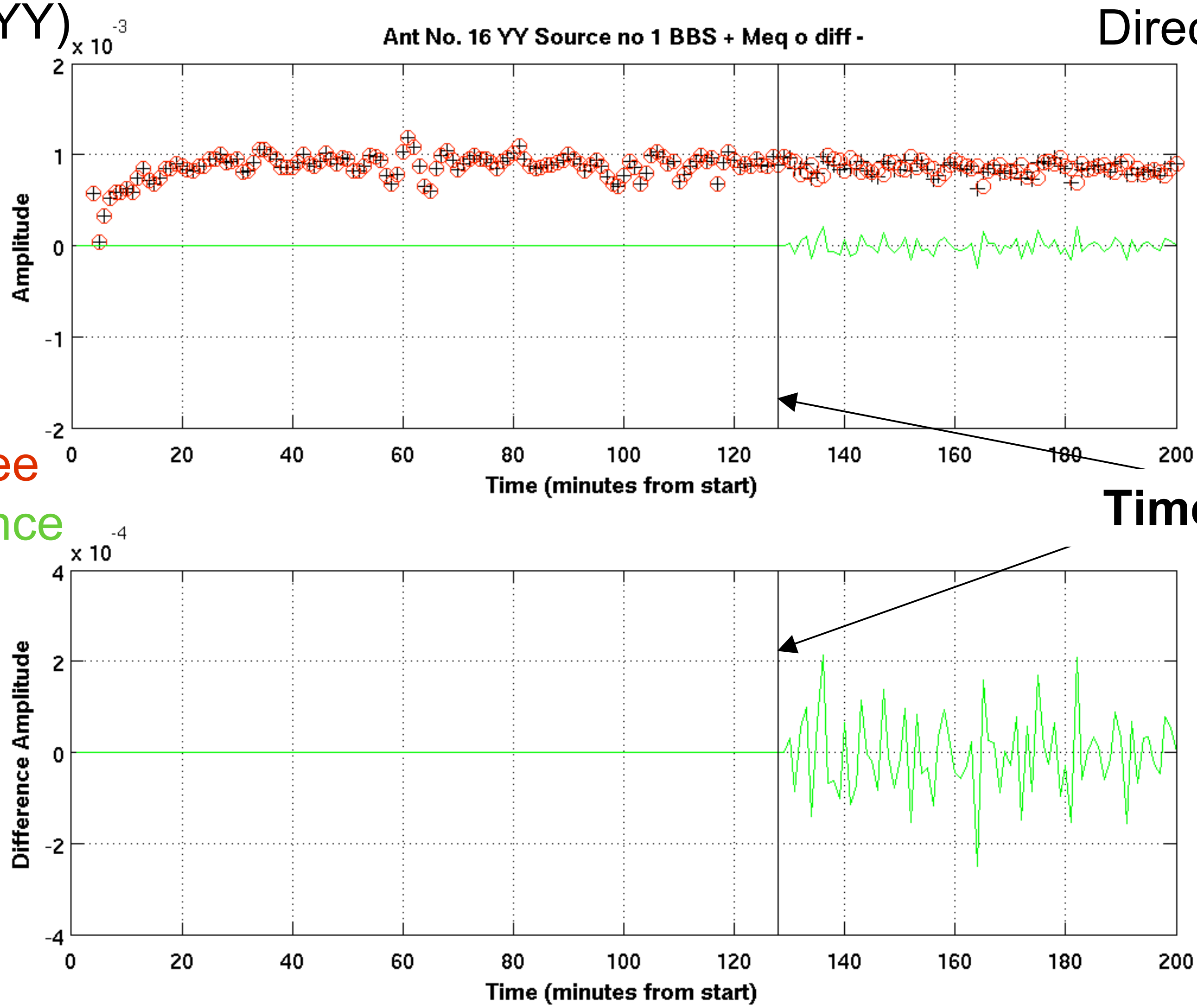
  Solutions (Meq) good enough - images have

  at least CasA, CygA, Tycho clearly visible. (3 iterations, no MMSE)
- Same flagging script.
- Channels 31-39 (0 based)

BBS solver comp with MeqTrees

Ant 16 (YY)

Direction -> CasA



+ BBS

0 MeqTree

-- difference

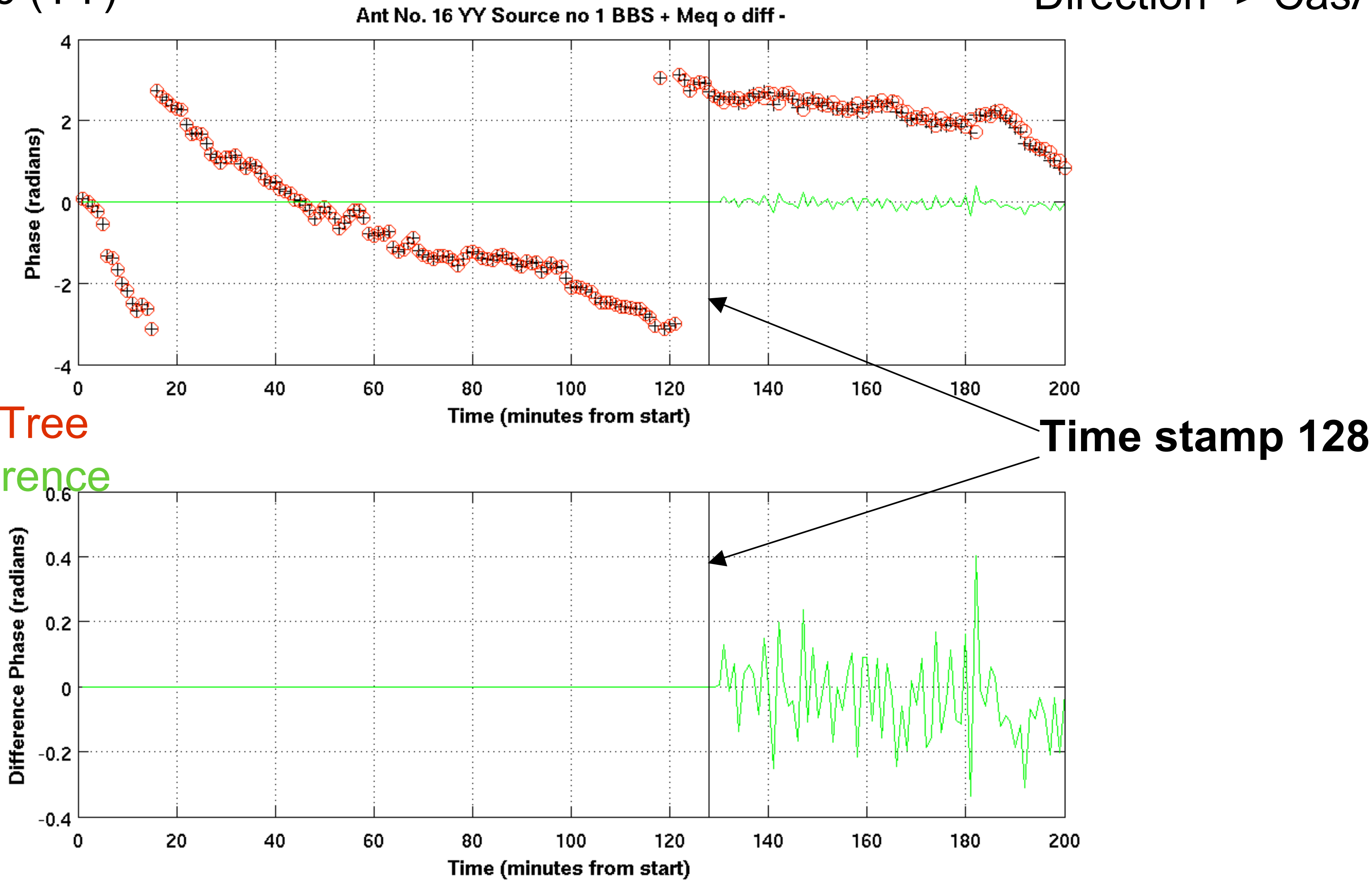
Time stamp 128

Diff increases > 100 times

BBS solver comp with MeqTrees

Ant 16 (YY)

Direction -> CasA



+ BBS

0 MeqTree

-- difference

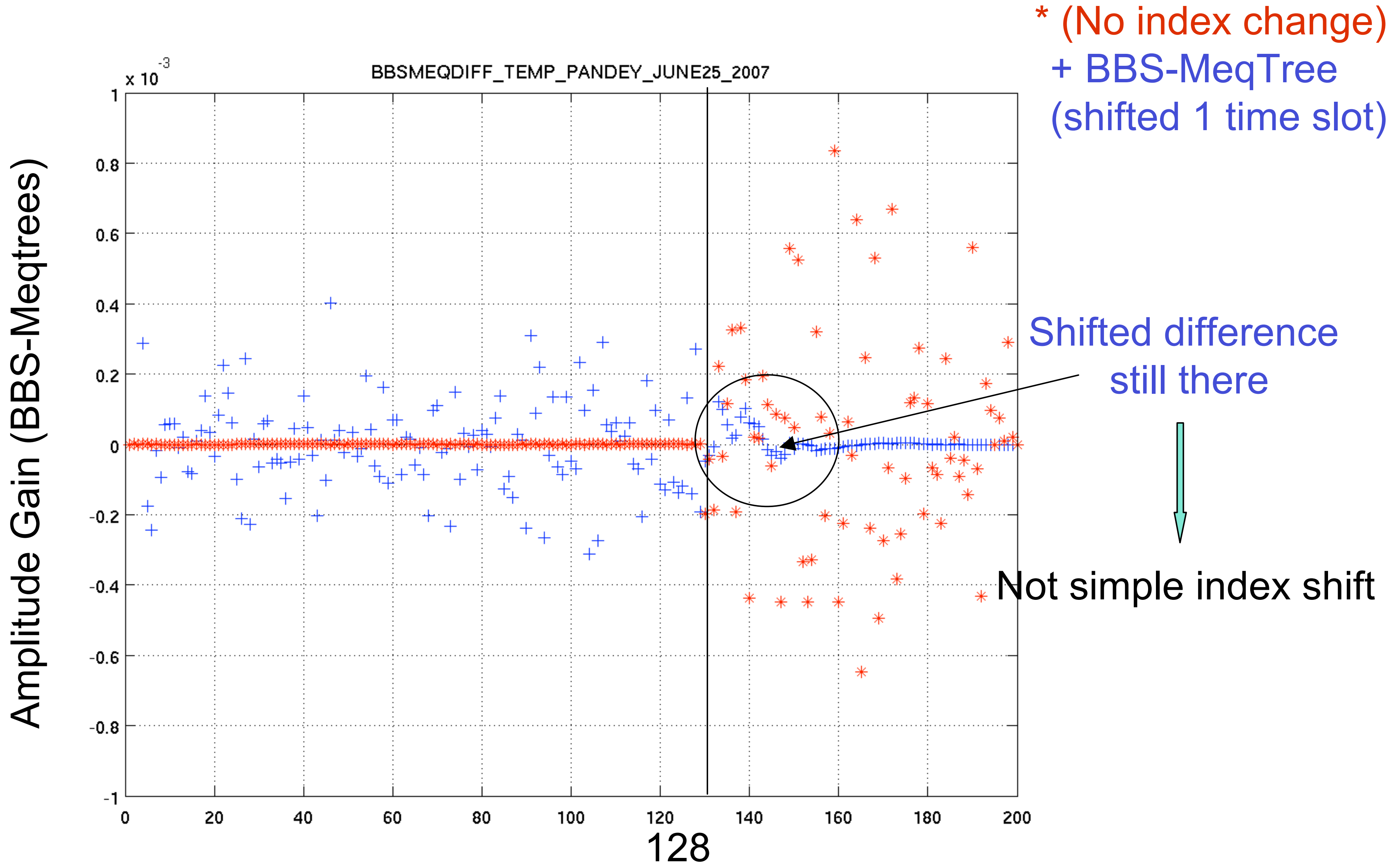
BBS solution - MeqTrees comparison

- Both BBS and MeqTree solutions agree very well for first 128 time slots for all antennas (XX, YY)
- This 128 time stamp is relative from where we start solving
- After -> the difference increases drastically by a factor > 100

- Changed the BBS solver version to same as of MeqTrees
  -> Does not change anything significantly..

- Careful inspection -> tempting to conclude an index shift between BBS and MeqTree solutions.

BBS Solution - Difference Analysis



BBS Solver - Difference Analysis

- Most likely we have been able to identify the cause.
- BBS defines solve domain as time duration (we use 60s), actual integration time ~59.768s
- In 130 time slots, fractional part (0.232s) builds up to 30s
- Two time stamps get assigned to same solve domain.

- Meq tree (subtiles) is in units of time samples so no issues.

A **`work around'** solution -
We changed solve domain to 59.768s

BBS solution - Recomparison with MeqTree

Antenna 5

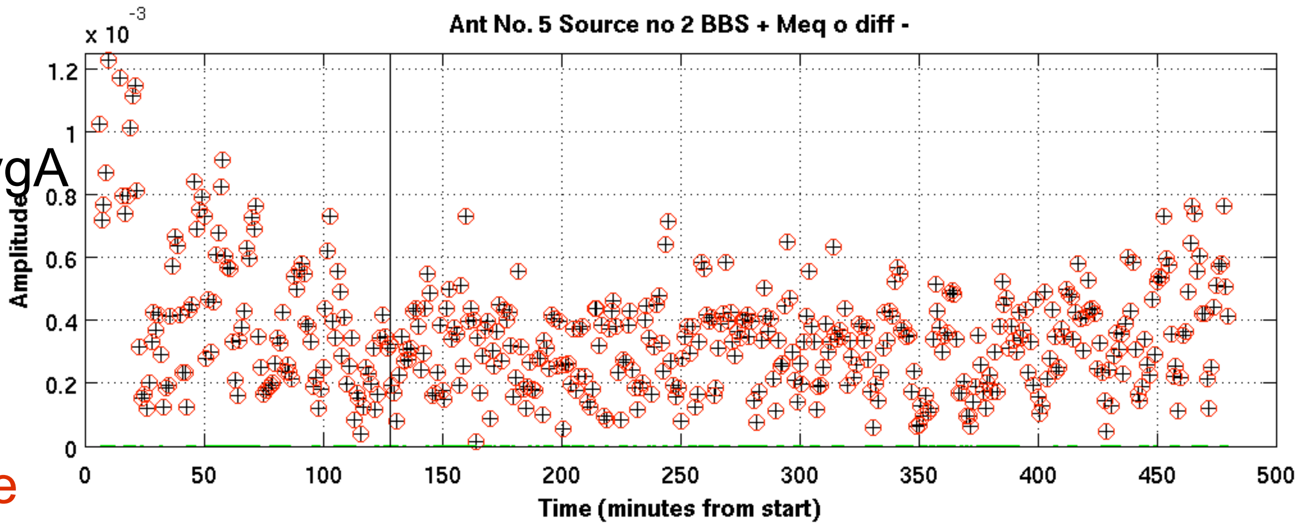
(YY)

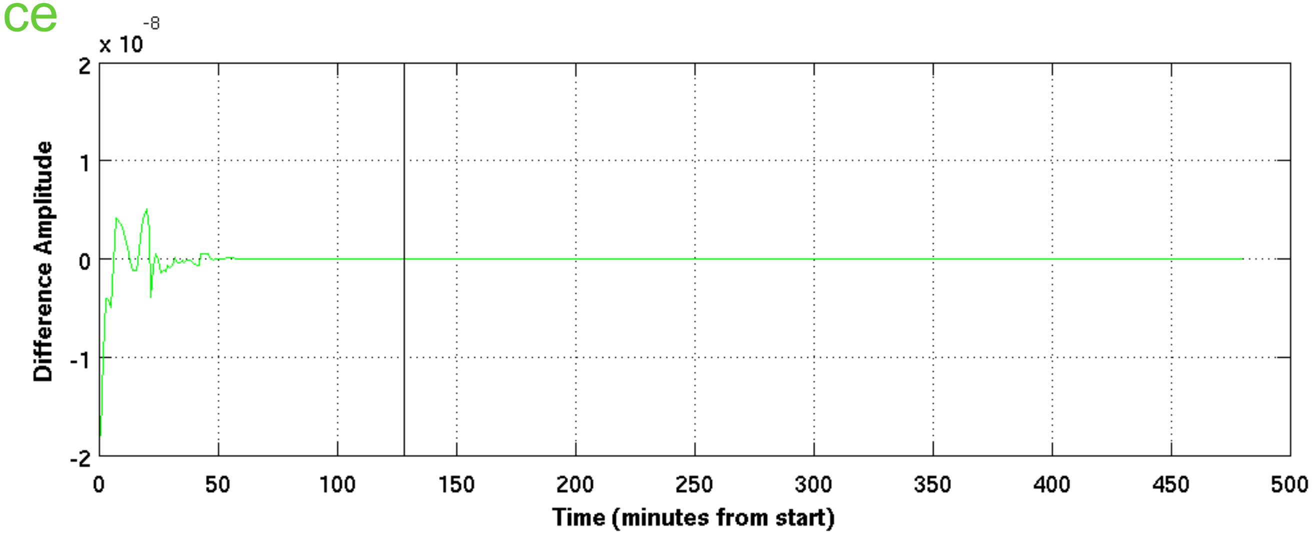
For dirn CygA

+ BBS

0 MeqTree

-- difference





BBS solution - Recomparison with MeqTree

Antenna 5

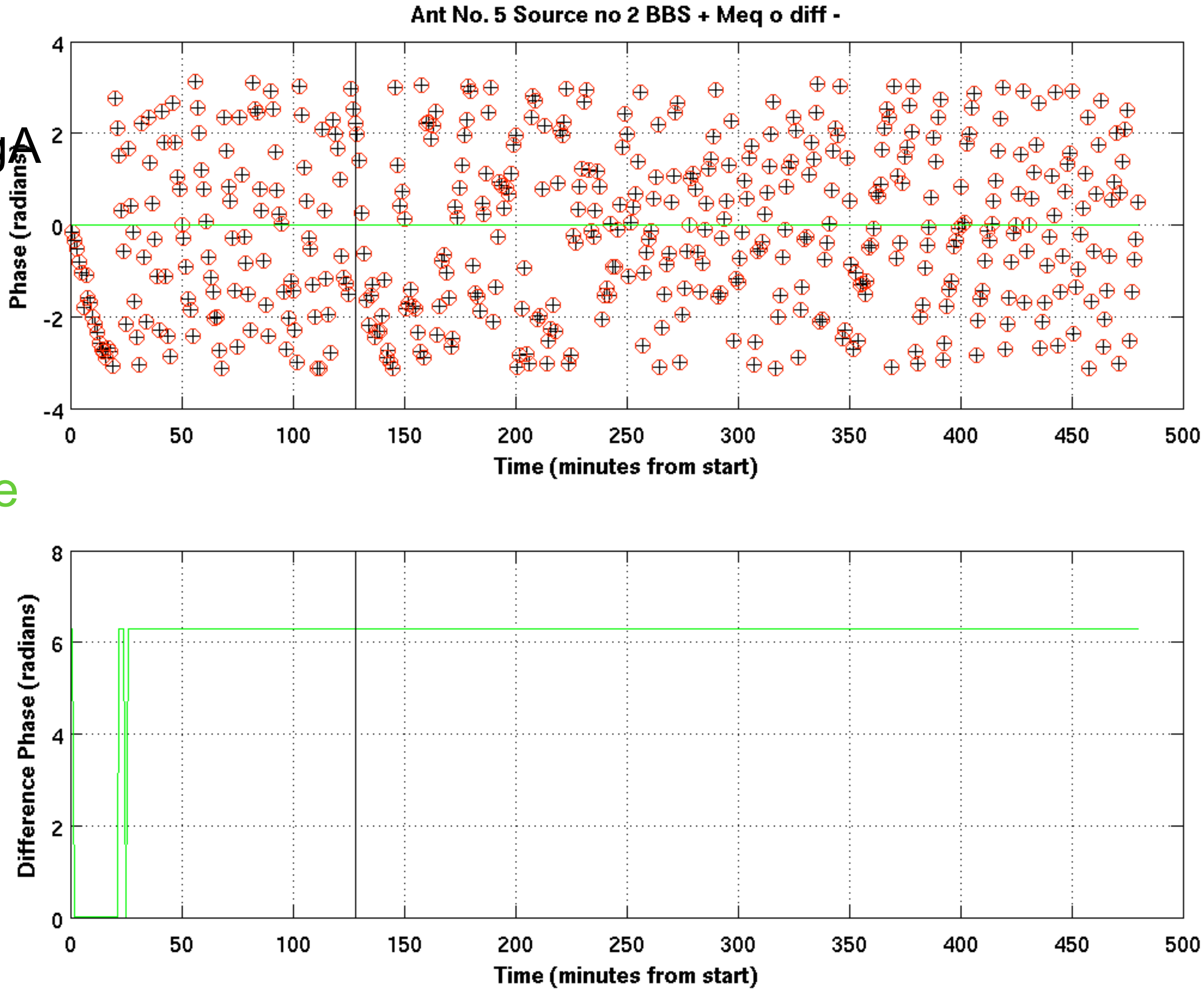
(YY)

For dirn CygA

+ BBS

0 MeqTree

-- difference



BBS solver - more remarks

- Why couldn't we track this in simulated data
- Solution had already converged by time stamp 128 and our gains were constant with time. !!!
- Time dependent gains perhaps would have helped detecting it.

Nevertheless !!

We should be now able to fix this soon.. And then calibrate !!

Conclusions / Next steps

- **We have verified all four stages - predict, solve, correct and subtract of BBS on simulated data. (both XX and YY polarization)**
- **Only one error - extra division by direction cosine *n* was found. (and a few default settings have been changed).**
- **Our comparison of BBS solution with MeqTree solutions match well till ~128 time slots of solving. After which an increase in difference by a factor of about (>100) is seen. -> We have now identified the cause.**
- **Once fixed, we should be able to calibrate data !! Interesting!**
- **Interpretation of solutions!! -> Make Image.**
- **Simulated Data - Add Noise, Beam and check the solutions obtained.**
- **Introduce polarization leakage and check.**

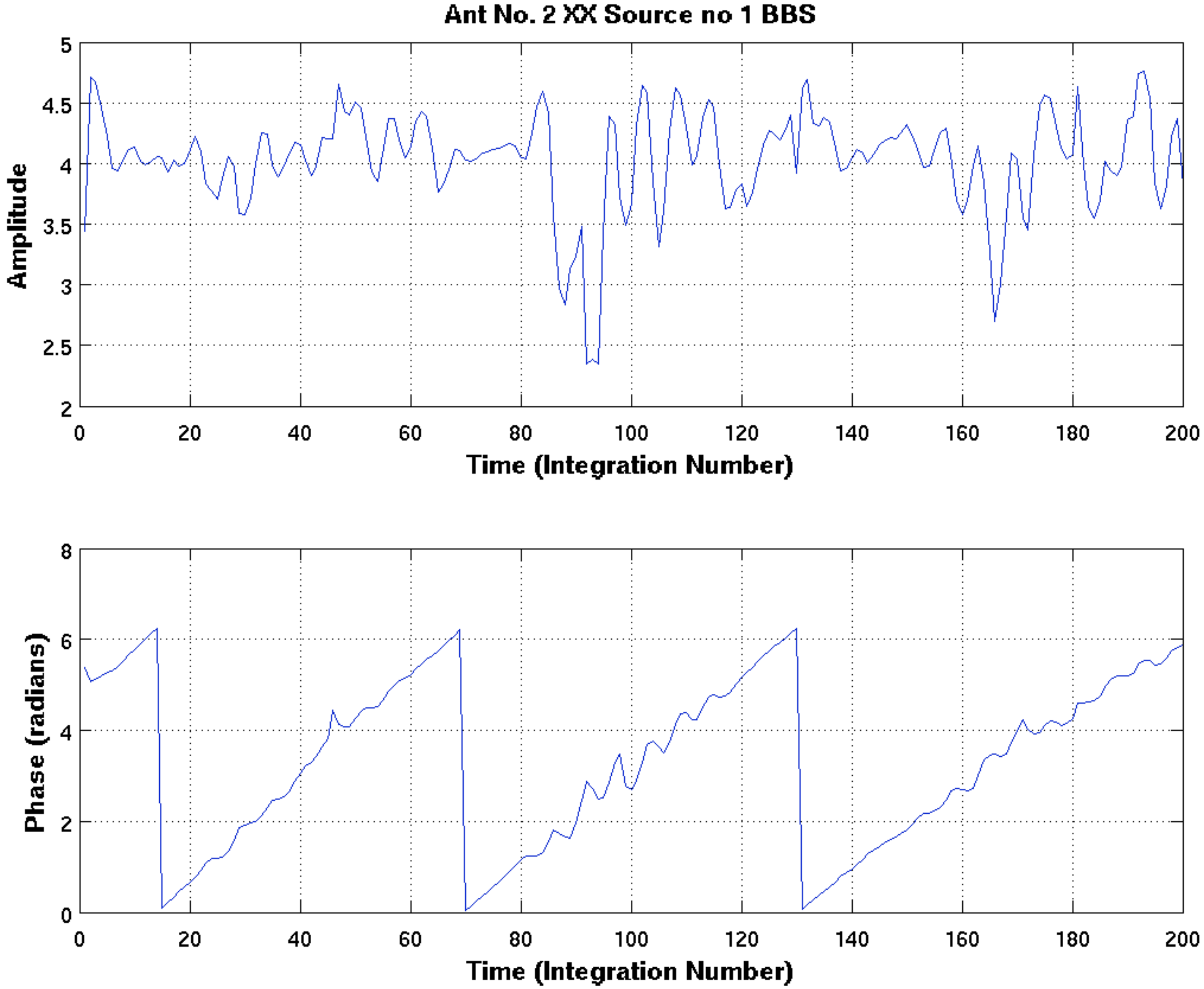
Thanks to Ronald for setting up "reproducible" MeqTree Pipeline

Effect - Predict/Solve with diff uvw signs - casA

Say CasA-> 3,000 Jy, CygA=20,000Jy*)

G(Amp)=1.25*Antenna Number, G(phase)=0.1*(Antenna Number -1)

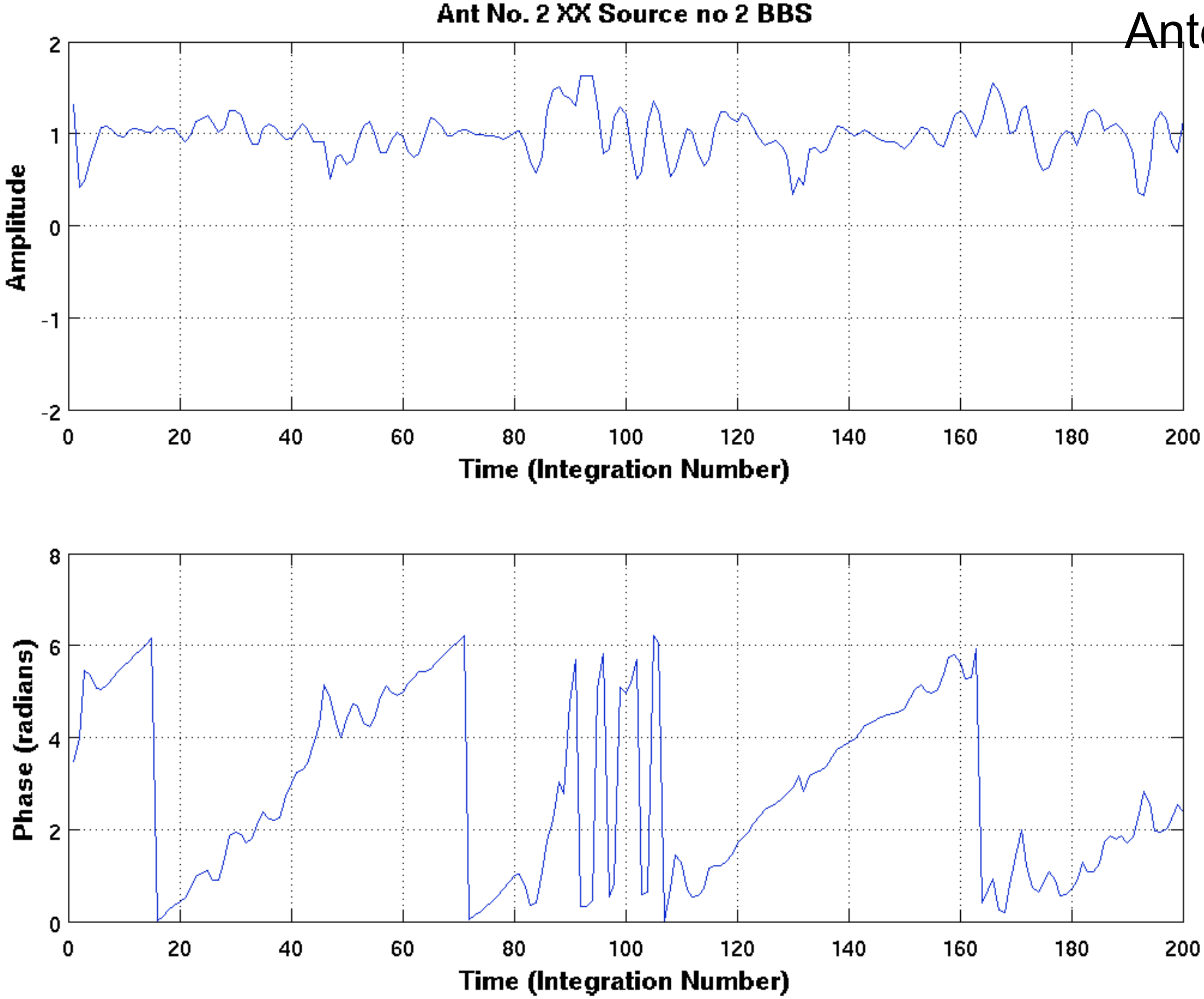
Antenna 2 (XX)



Effect - Predict/Solve with diff uvw signs - cygA

G(Amp)=0.8*Antenna Number, G(phase)=0.33*(Antenna Number -1)

Antenna 2 (XX)



Inferences

- We can't recover Amplitudes and Phases Gains
  if we use diff uvw convention during solving
- Solutions appear to be noisy as if interaction between two direction gains.
- Nevertheless it is physically/mathematically incorrect also, as 16 antenna based complex gains cannot absorb 120 complex (98) different baselines based phases introduced by the off center source.

Steps

MS1810

- Observation MS1810, 16hours, 30 March - 31 March, 2007 UTC (14h:31m to 06h:44m)
- 16 micro stns, (1 dipole turned on in each of them).
- 24 subbands, 160 MHz clock.
- Integration time ~60s
- Tracking done on CasA (23:23:24, +58:48:54)

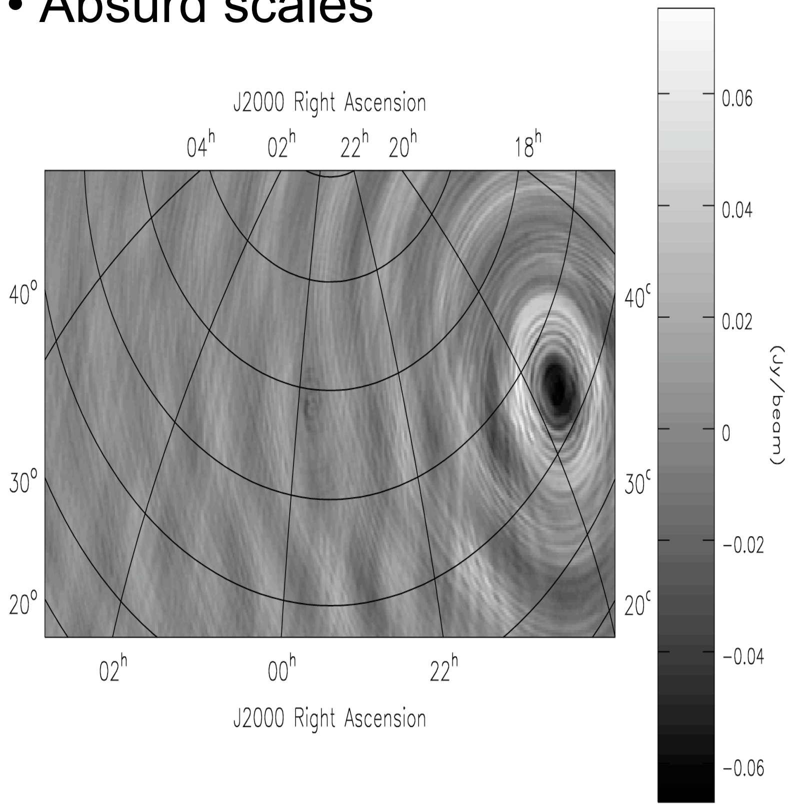
- Subband 20 (Freq , 256 channels)
- Data Set is ok (Fringes seen due to CasA and even beating between CasA and CygA)

- Initial Flagging and attempted straight forward calibration using BBS.

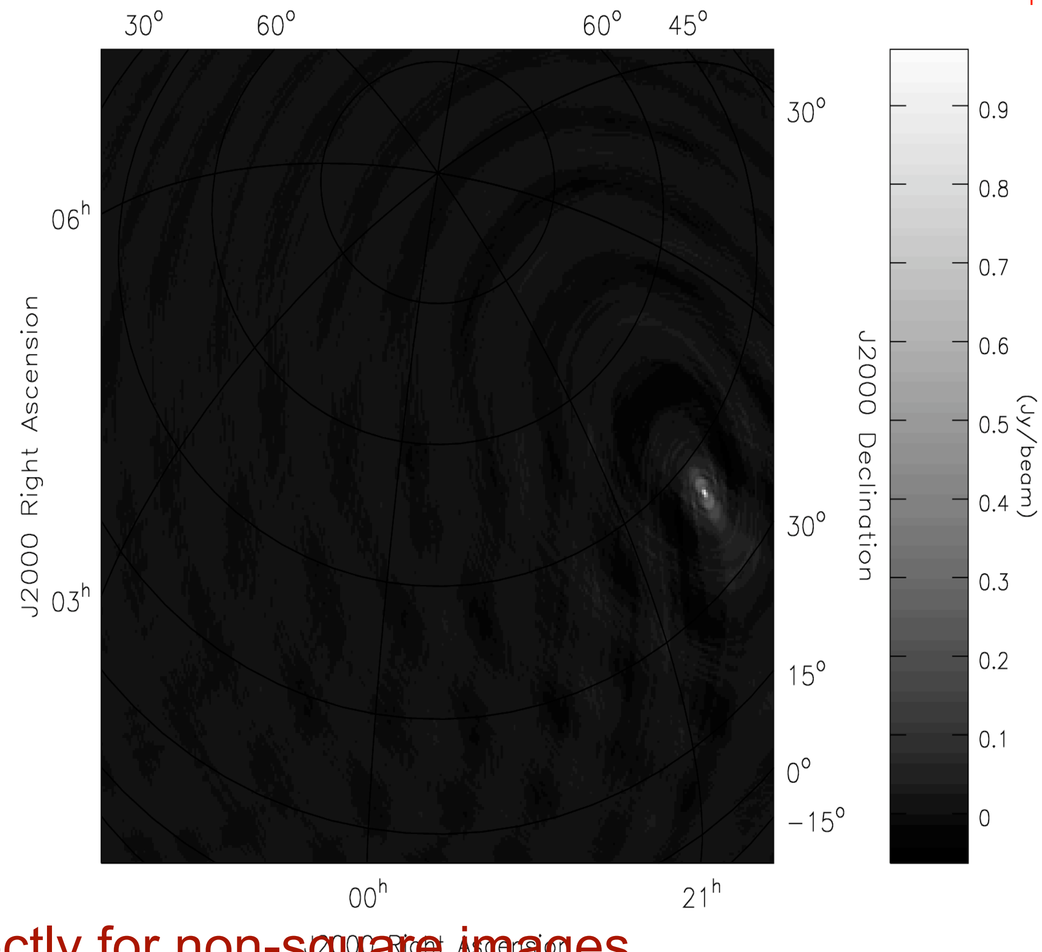
Imager Issues

CygA predicted by aips++
and imaged back (1024x512)

- Dip
- Absurd scales



CygA predicted by aips++
and imaged back (1024x1024)



Imager does not behave correctly for non-square images

BBS - extra *n* term?

- BBS predicts higher amplitude (for source away from phase center)
- **Calibrated visibilities -> dirty image**

$$V^{\circ}(u,v,w) = \int\int I(l,m) e^{-2\pi\iota\left[ul+vm+w\left(\sqrt{1-l^2-m^2}-1\right)\right]} \frac{dl\,dm}{\sqrt{1-l^2-m^2}}$$

$$F(l,m,n) = \left[\frac{I(l,m)\delta(\sqrt{1-l^2-m^2}-n)}{\sqrt{1-l^2-m^2}}\right] * P(l,m,n)$$

- **Physically meaningful on surface of a sphere of unit radius ($l^2+m^2+n^2=1$)**

- **need to check once again this equation in code**
- **here I(l,m) is brightness, for a point source perhaps we are not doing this division by $\sqrt{1-l^2-m^2}$ properly.**
- ***d(Ω)=dl dm/n, the integral gives the flux density***
- **We have commented this extra division by *n* term for the time being.**

Predict (using uvw sign CS1), solve (opp uvw)

•Introduce known Gains (Amplitude and Phase)
for both directions - CasA (source1) and CygA (source 2)

- Predict the model visibilities (say **CasA-> 3,000 Jy, CygA=20,000Jy***)
- Corrupt them with artificial gains
- Gain in direction of CasA
  G(Amp)=0.1*(Antenna Number -1)
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- Gain in direction of CygA
  G(Amp)=0.33*(Antenna Number -1)
  G(phase)=0.8*Antenna Number

(Phase of first antenna frozen to zero)

- Solve for the antenna based amplitudes and phases,
- Iterations -> 50 for each time slot,
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