Wideband Mosaic Imaging for VLASS

Preliminary ARDG Test Report

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29 Aug 2018

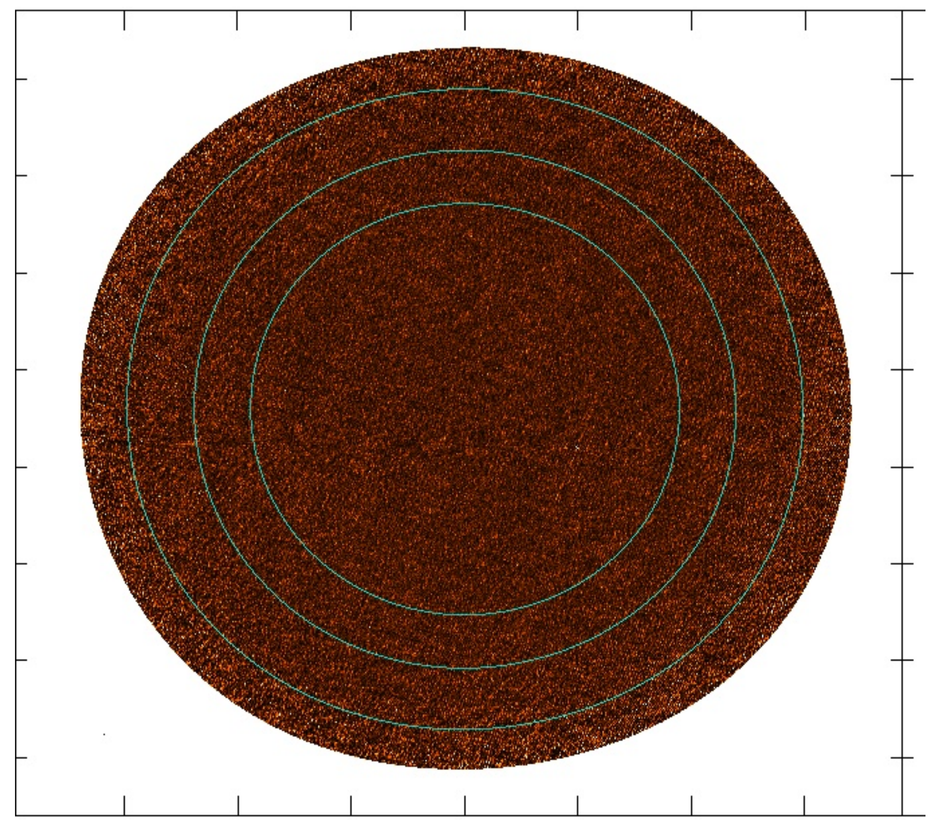
(1) Code Validation and Usage

(2) Noise, Weights, Continuum sensitivity

(3) Imaging parameters

(4) Understanding VLASS data

(5) Next steps



Code Validation – Test data

Goal : Test wideband mosaic imaging : Flat-sky intensity and spectral index.

(deconvolver = ‘mtmfs’ with gridder = ‘mosaic’ and ‘awproject’)

Simulations :

- L-Band VLA two-pointing mosaic, with one source. No w-term
- J1448-1602 predicted onto VLASS MS, with and without w-term

Real VLASS data :

- Original Calibrated MS : Test w-term position offsets & corrections
- Wideband self-cal using J1448 model : Test noise with conjbeams
- FixVis on Original MS : Test effect of putting the PB in the correct place.

[Other Real data :
- G55 wideband single pointing, 3C286 wideband pointed mosaic, etc..]

Code Validation - Gridders

gridder = ‘awproject’

- Works correctly for continuum imaging with conjbeams=True and W. (when data are correct...)

- Bugs remain for cube imaging and using pointing table

- Uses a convolution function cache on disk

  - Compute once and re-use for entire VLASS imaging
  - Depends on imsize, cell, wplanes, and a few .casarc variables

- Memory use is as expected and can be predicted (serial and parallel)

gridder = ‘mosaic’

– conjbeams=T not working. (Deconvolution can eventually converge to the correct Int & Alpha after several major cycles, but undeconvolved sources will still be wrong.)

- No w-support (but KG may be working on a faceting idea...)

- Pointing table use not validated in these tests

Code Validation – PB models

PB models:

- awproject : Ray traced at spw centers. Linear Freq scaling.
  Supports parallactic angle rotation and squint

- mosaic : EVLA polynomial models with accurate frequency scaling.
  No parallactic angle or squint support

(The difference in frequency dependence has been evaluated. It's small.)

Noise - using StatWt

StatWt is an outlier detector that assumes the underlying signal is invariant

In OTF mosaics, multiple pointings are supplied together as input
=> Sky x PB variations are seen as high ‘noise’ => downweighted.

Effect on imaging :

- Dips in the continuum mosaic PB pattern around all bright sources.
  (Can be as low as 0.4 for a 1 Jy source. It nulls out the 16 Jy 3C286)

- Locally-different data weights modify the shape of the PSF locally.
  (Extra deconvolution complications)

- Bright sources get artifically high error bars.

Suggested solutions :

- Run statwt on residuals (prototyped by Claire, with some success.)

- Modify statwt to use running mean statistics to be immune to underlying smooth variations ?

Noise - conjbeams and wideband sensitivity

Reported Problem :

conjbeams=True increases the noise compared to conjbeams=False

Resolution :

– This is not a bug or a problem with the algorithm(s).

– Conjbeams = True is the spectral equivalent of PBCOR
=> Noise increases when you go from flat-noise to flat-sky.

– Wideband sensitivity naturally degrades away from the pointing center.

– For a mosaic, it will be across the entire mosaic.

(Similar to why the PB spectral index is strong all over the mosaic)

[A cube-based approach with conjbeams=False, flat-sky norm and then a multiplication with a common beam will have the same effect.
(i.e. the idea we started trying out via Josh)]

Noise - conjbeams and wideband sensitivity

Tests : Is the noise increase consistent with expectations ?

Calculations based on a Gaussian PB and linear Frequency scaling

=> Sensitivity worsens by ~10% at 0.1 PB level, compared to the center.

– Simulation : Input data had the same level of noise in all channels.

=> Noise increase at the edge matches the prediction.

– VLASS data : Higher frequency SPWs had more noise than lower ones

=> Noise goes up by ~ 50% at the PB = 0.1 level

(Confirmed the same levels as reported by Claire/Steve)

==> As of now, it looks like it’s a fundamental limit, given the data quality.

Imaging Parameters : Wprojplanes

Wprojplanes :

64 to 128 for BnA-config data.

64 or less for B-config data

Our tests : BnA data. J1448 at PB=0.68, or 5 arcmin from pointing center

W=1 and W=64 showed a position shift of 0.3 arcsec. No shift for larger W

(FixVis moved the phase center away from the source ! Needed W=128....)

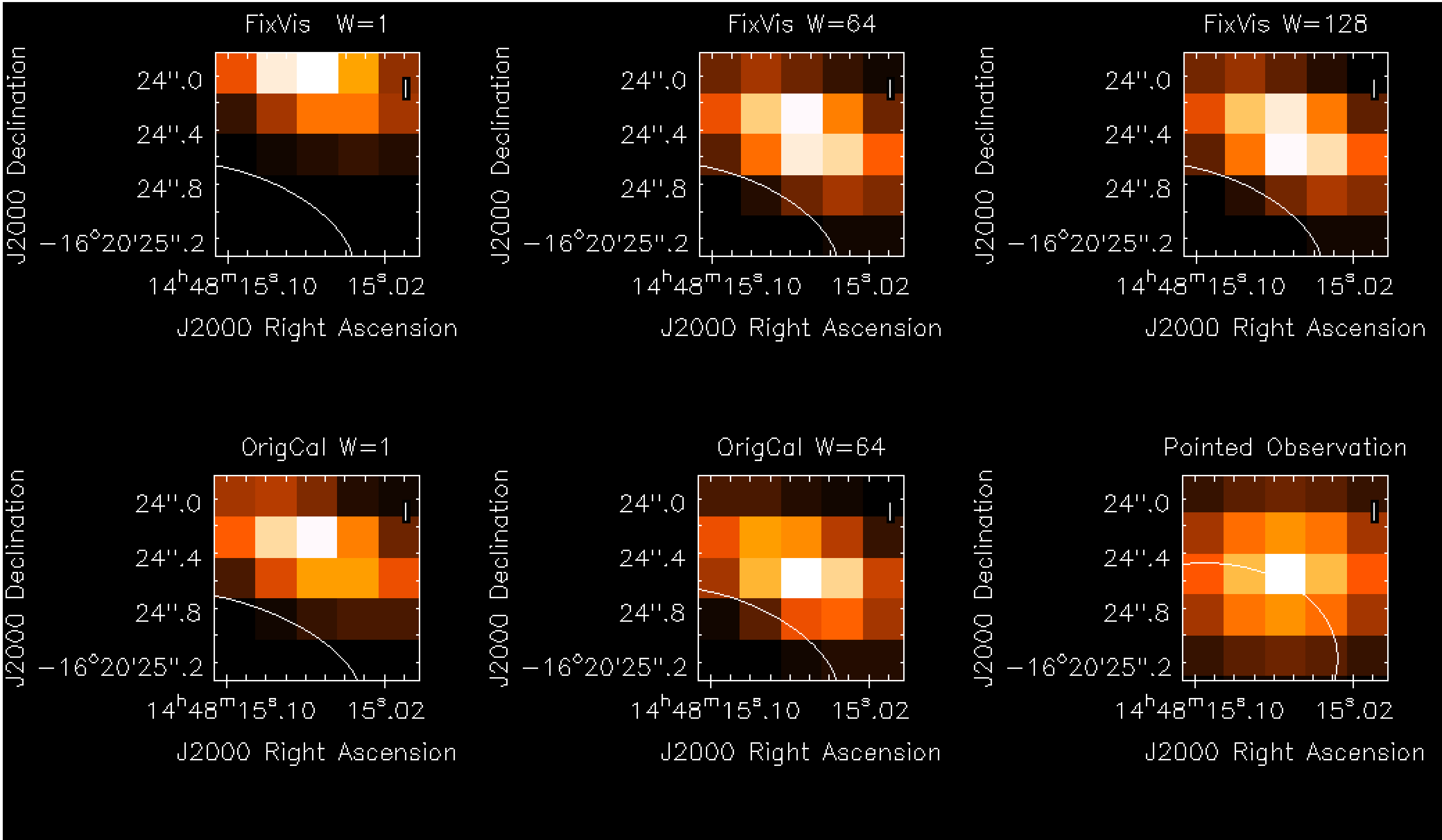
==> Need to re-visit this after the phase center corrections are sorted out.

==> Need to test on real B-config VLASS data.

(Our tests on BnA data with a uvrange limit to match B-config showed that not more than W=64 was needed.)

Imaging Parameters : Wprojplanes

W=1,64,128, before and after FixVis (compare to pointed obs). Cell = 0.3 arcsec



Imaging Parameters for VLASS

Imsize (and field-of-view per mosaic 'tile')

- Need a buffer of ~30 arcmin between the centers of edge pointings and the edge of the field of view being imaged.

  – This is to control PB aliasing since 'awproject' models sidelobes

- Tests with original VLASS imaging parameters (on simulated data) showed errors on-source because of strong PB aliasing

  => We used 10kx10k images at 0.3 arcsec pixels for 1 pointing

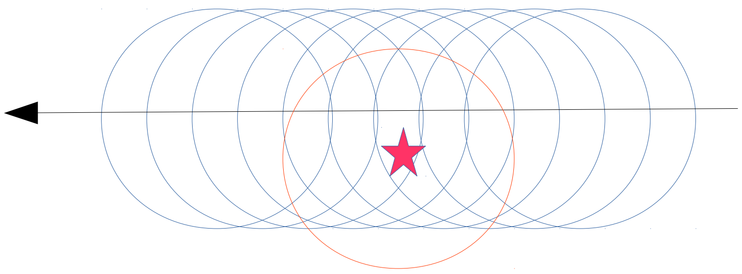
Cell size (and uv-range) :

- We did **not** test effects of PSF undersampling (we used 3pix on minor axis).
- If VLASS needs to use 0.6 arcsec for all images (2pix/beam), please re-test.

VLASS data – J1448-1620, BnA, OTF & Pointed

Step 1 : Image some VLASS data

– Wideband Mosaic imaging on originally calibrated VLASS data gave wrong intensity and spectral index.



Step 2 : Self-Cal

– Use source model from pointed observation and the wide-field degridder to predict model visibilities onto the OTF data.

– Bandpass amp/phase self-cal solutions.

– Solutions didn't make sense, but they 'fixed the data'.
=> not very helpful.

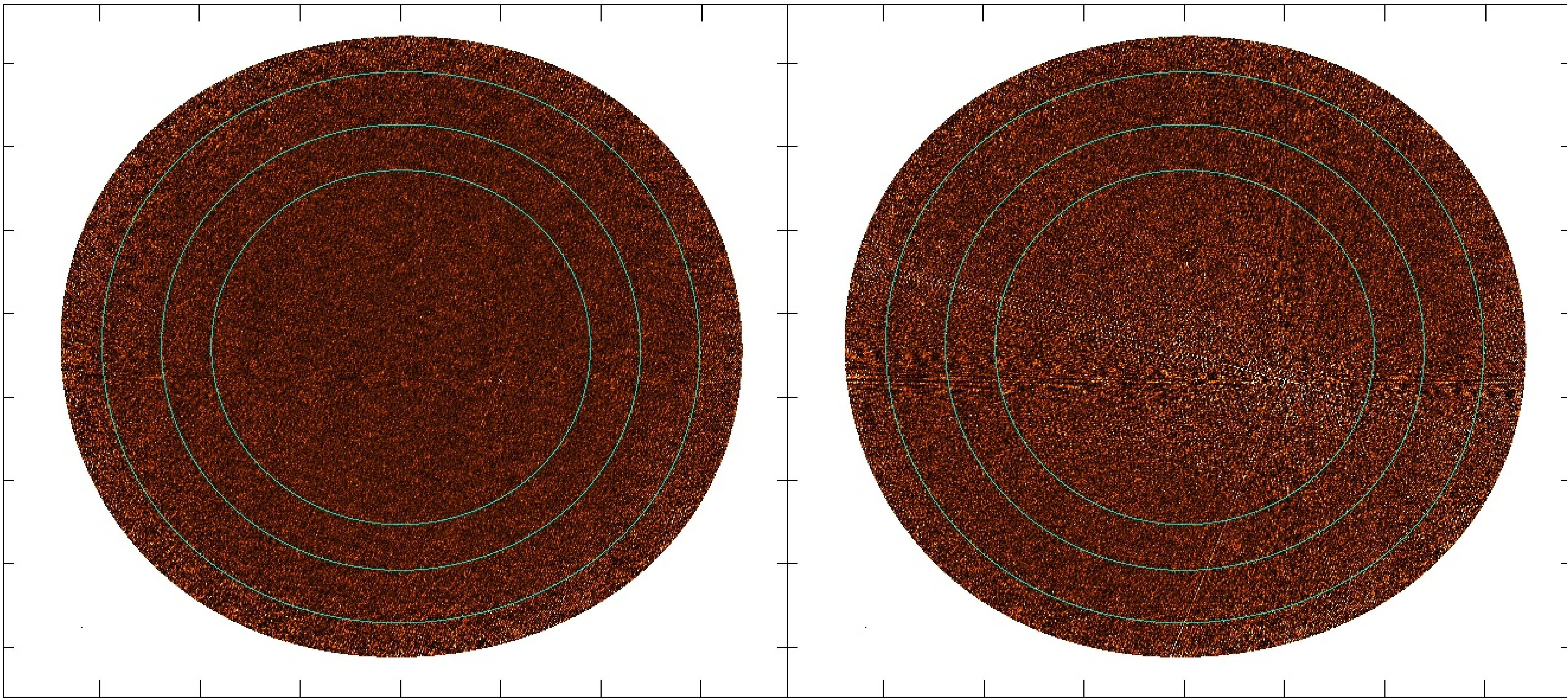
– Antennas away from the array center had slopes in amp vs freq. (1 → 0.6)
– They also showed phase ramps per SPW (+/- 10 deg).

(With 1 strong source and a snapshot, effects due to delay, w-term, pointing offsets and phase-center mismatches can look similar.)

VLASS data – J1448-1620, BnA, OTF & Pointed

2 pointing mosaic

After bandpass selfcal | Original Calibration



1.38 Jy source + can see noise +
increase in noise at beam edges (~50%)

VLASS data – J1448-1620, BnA, OTF & Pointed

Step 3 :   FixVis by ½ a pointing (suggested by Frank S.)

– For one pointing near the source, intensity and alpha were almost perfect.

J1448-1620 pointed observation : Intensity = 1.38 and alpha = -0.46

Original data :   Intensity = 1.05 and alpha = -1.04   (pb gain 0.68)

FixVis data : Intensity = 1.31 and alpha = -0.45 (pb gain 0.52)

– But, artifacts around the source remained (dynamic range limited)

Step 4 :   Bandpass self-cal

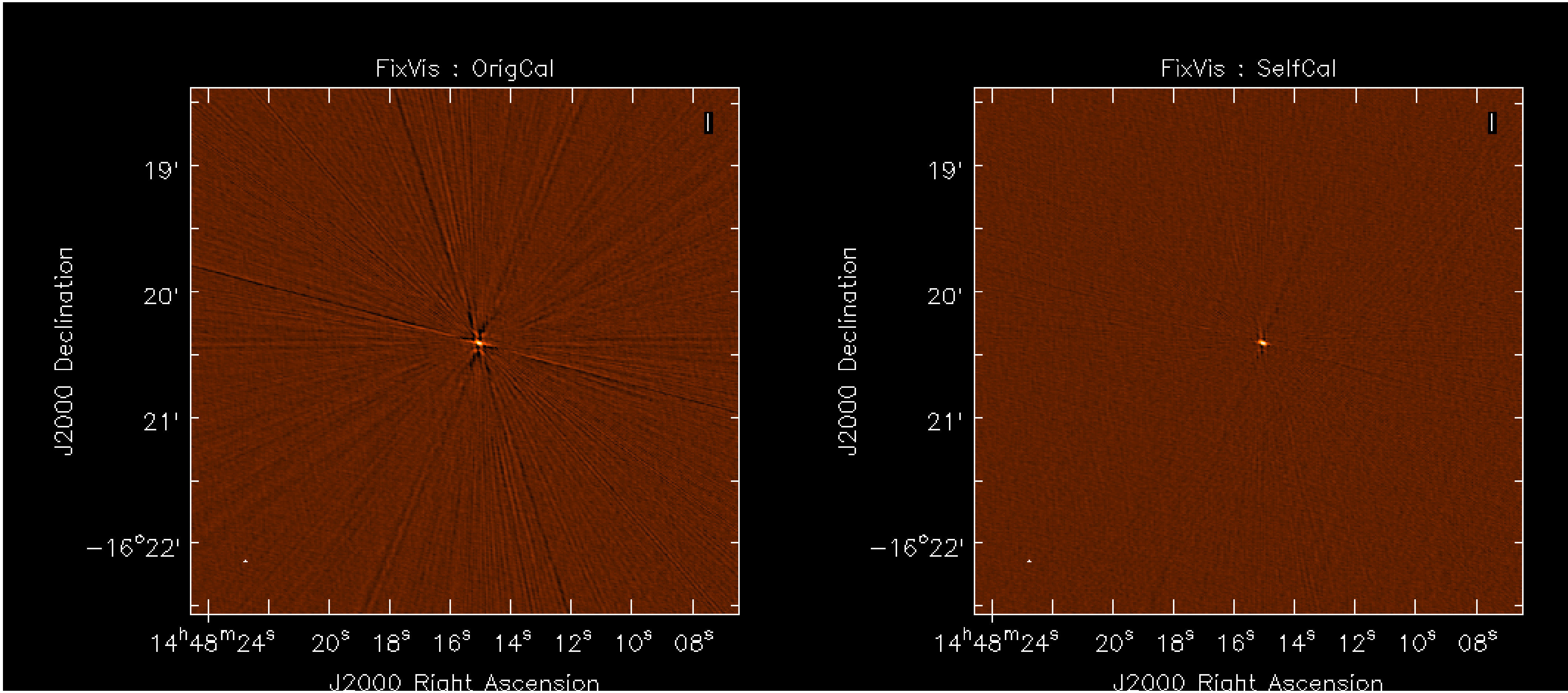
– Solutions had **no** amplitude slopes any more.
– Phase ramps per spw (+/- 10 deg) remained (delay clunking?).

Application of the phase solutions reduced the artifacts.

VLASS data – J1448-1620, BnA, OTF & Pointed

1 pointing image + fixvis + selfcal == Correct intensity and spectral index.

Original Calibration + FixVis | After self-cal (mainly phase)



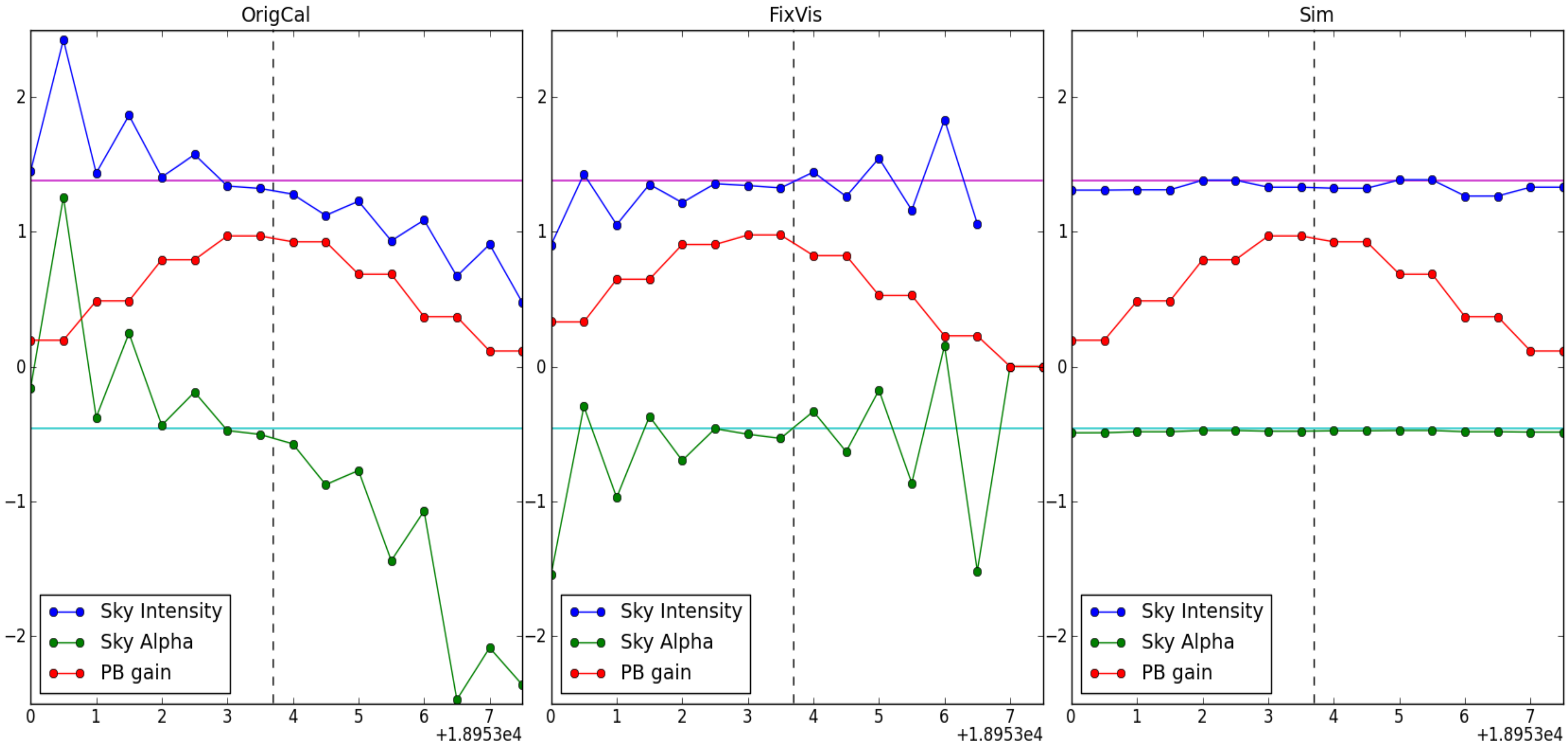
==> Solution of FixVis (or similar) is required to get correct intensity and alpha.

==> Phase calibration still required for dynamic range (delay clunking?).

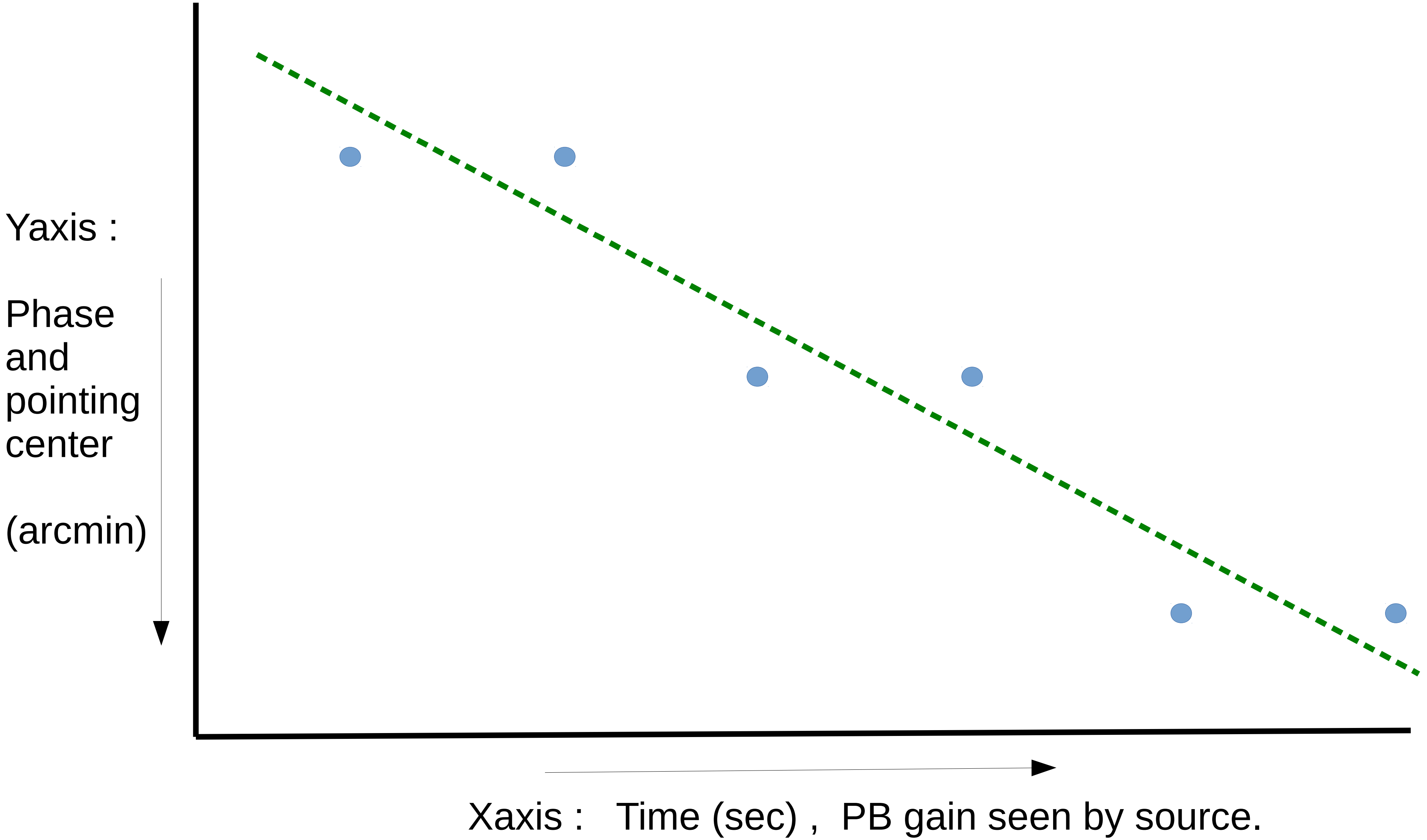
VLASS data – Phase and Pointing centers....

Joint mosaic of a row of fixvis'd pointings => Wrong intensity and spectral index.

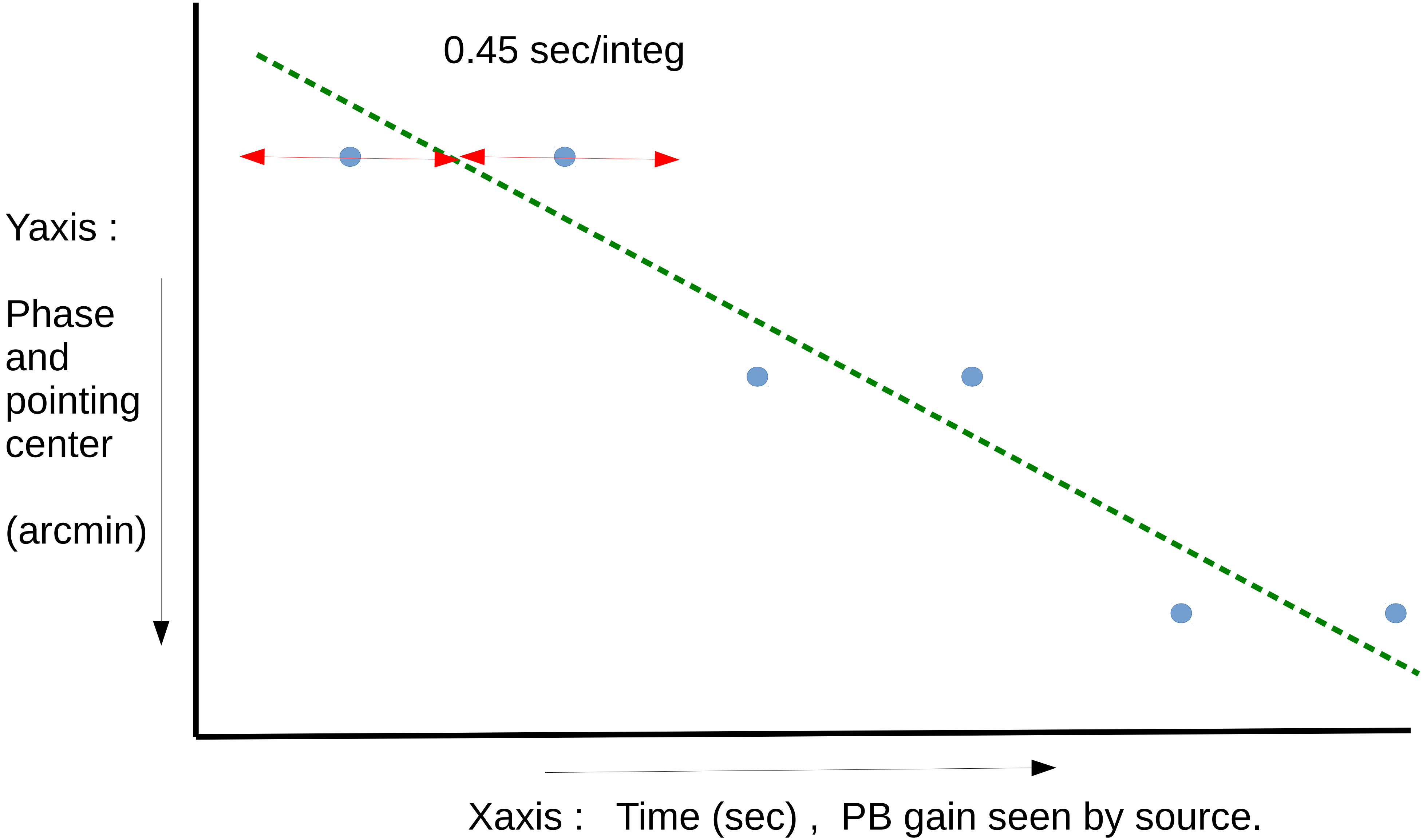
=> Investigate by imaging one pointing at a time, for 8 in a row.....



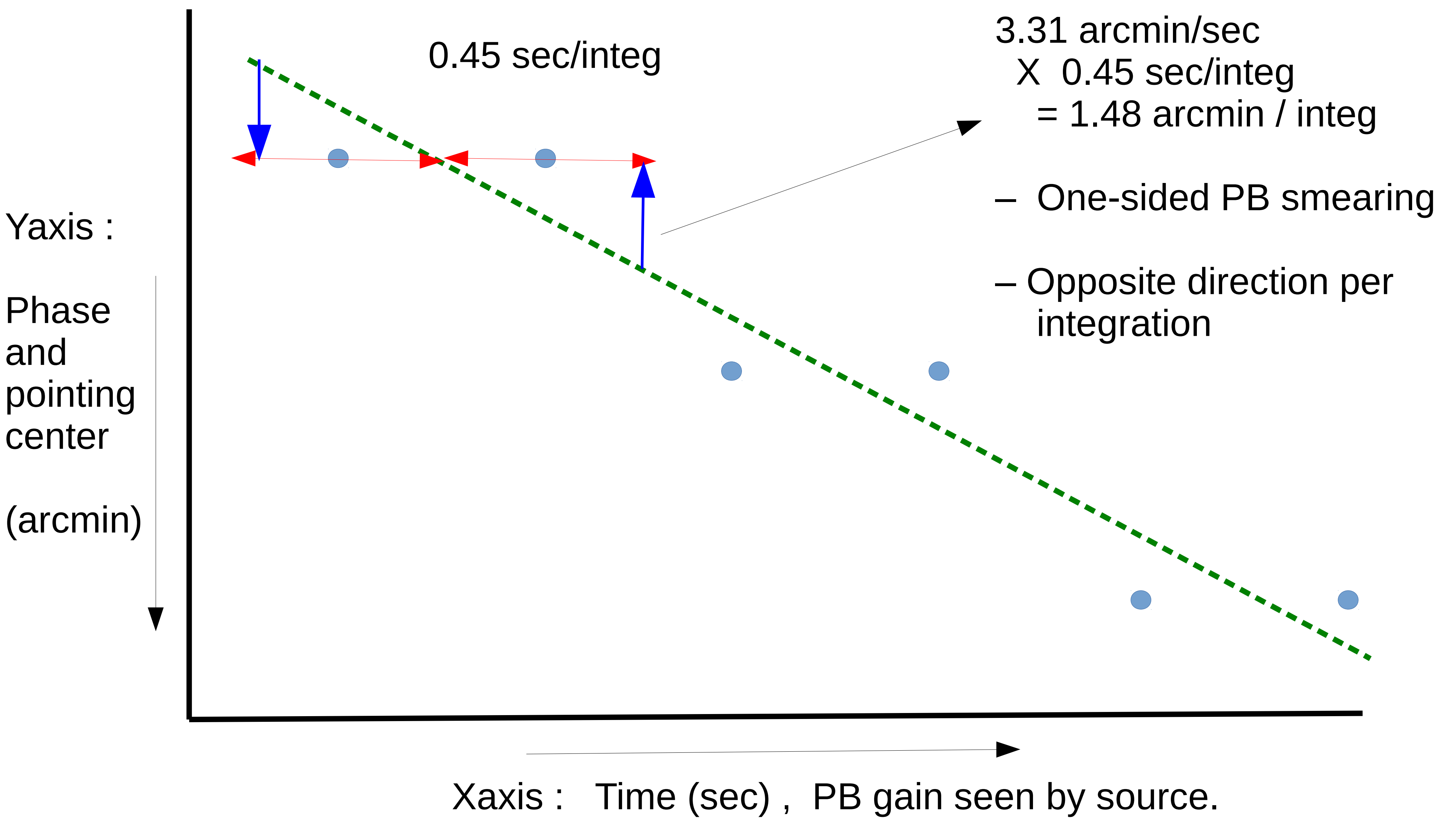
VLASS data – Phase and Pointing centers....



VLASS data – Phase and Pointing centers....

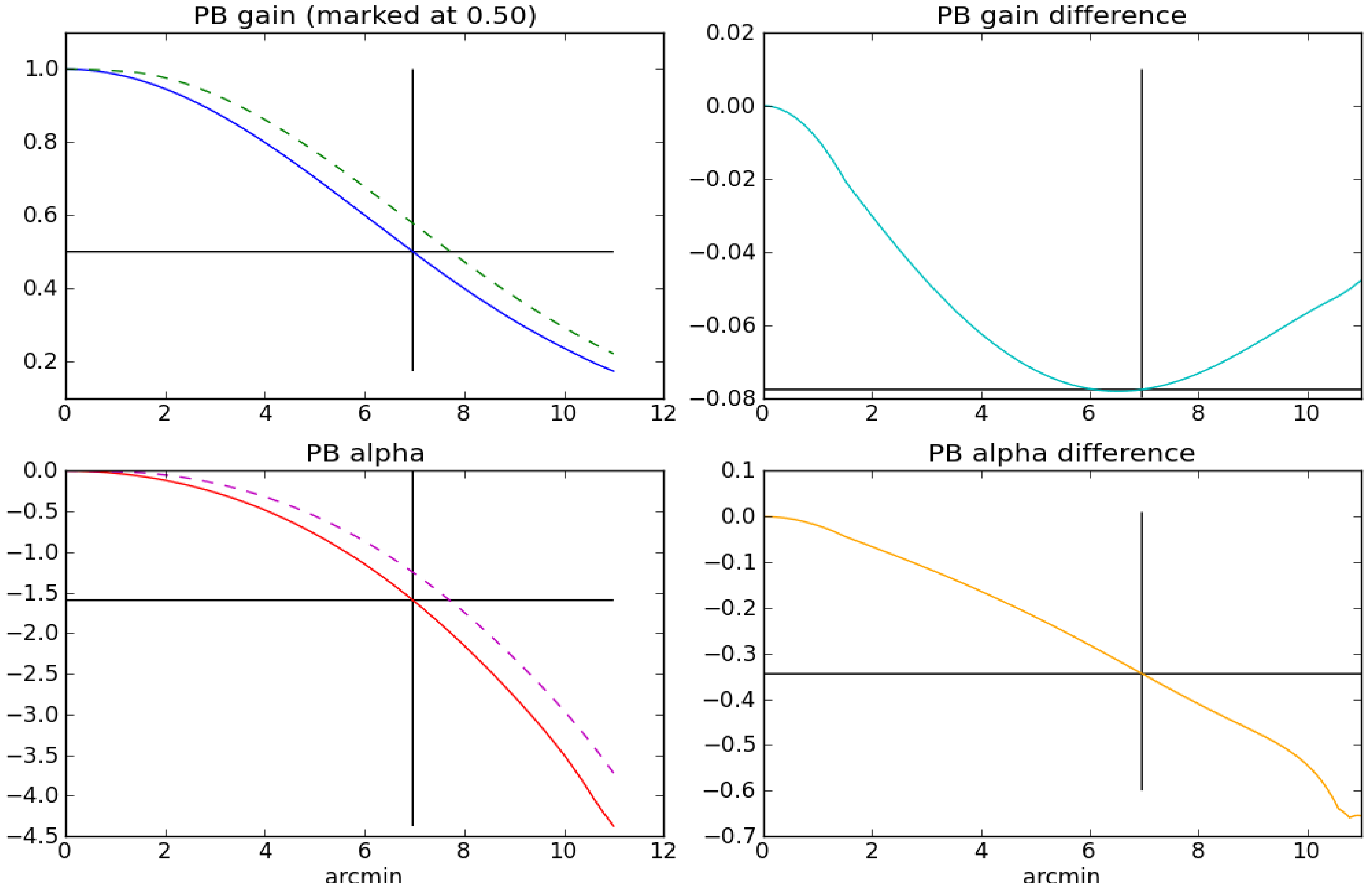


VLASS data – Phase and Pointing centers....

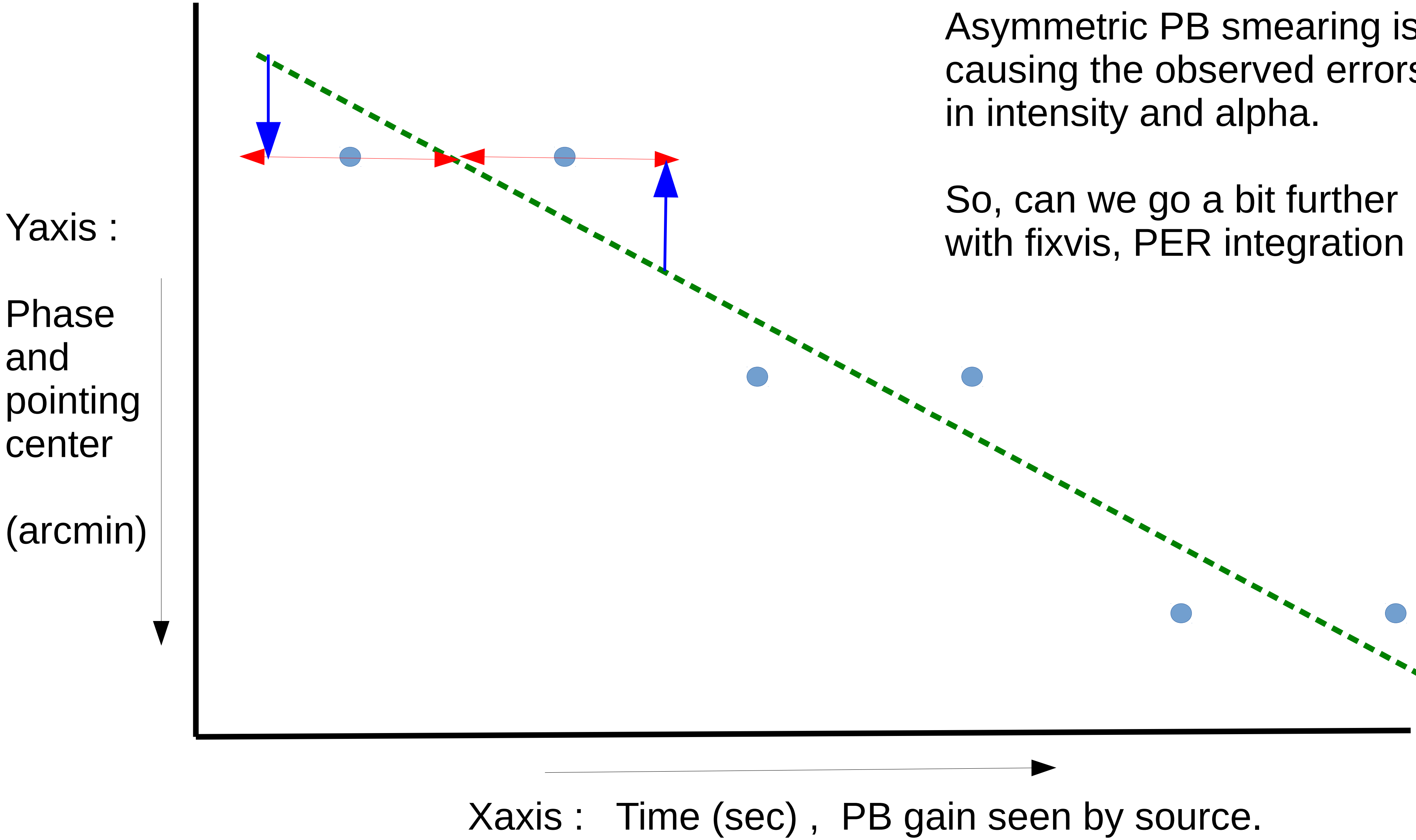


VLASS data – Effect of PB smearing (Stokes I, Alpha)

Result of ASYMMETRIC PB smearing by 1.48 arcmin



VLASS data – Phase and Pointing centers....



Asymmetric PB smearing is causing the observed errors in intensity and alpha.

So, can we go a bit further with fixvis, PER integration ?

VLASS data – Phase and Pointing centers....

FixVis to match phase center
with pointing center
PER integration ?

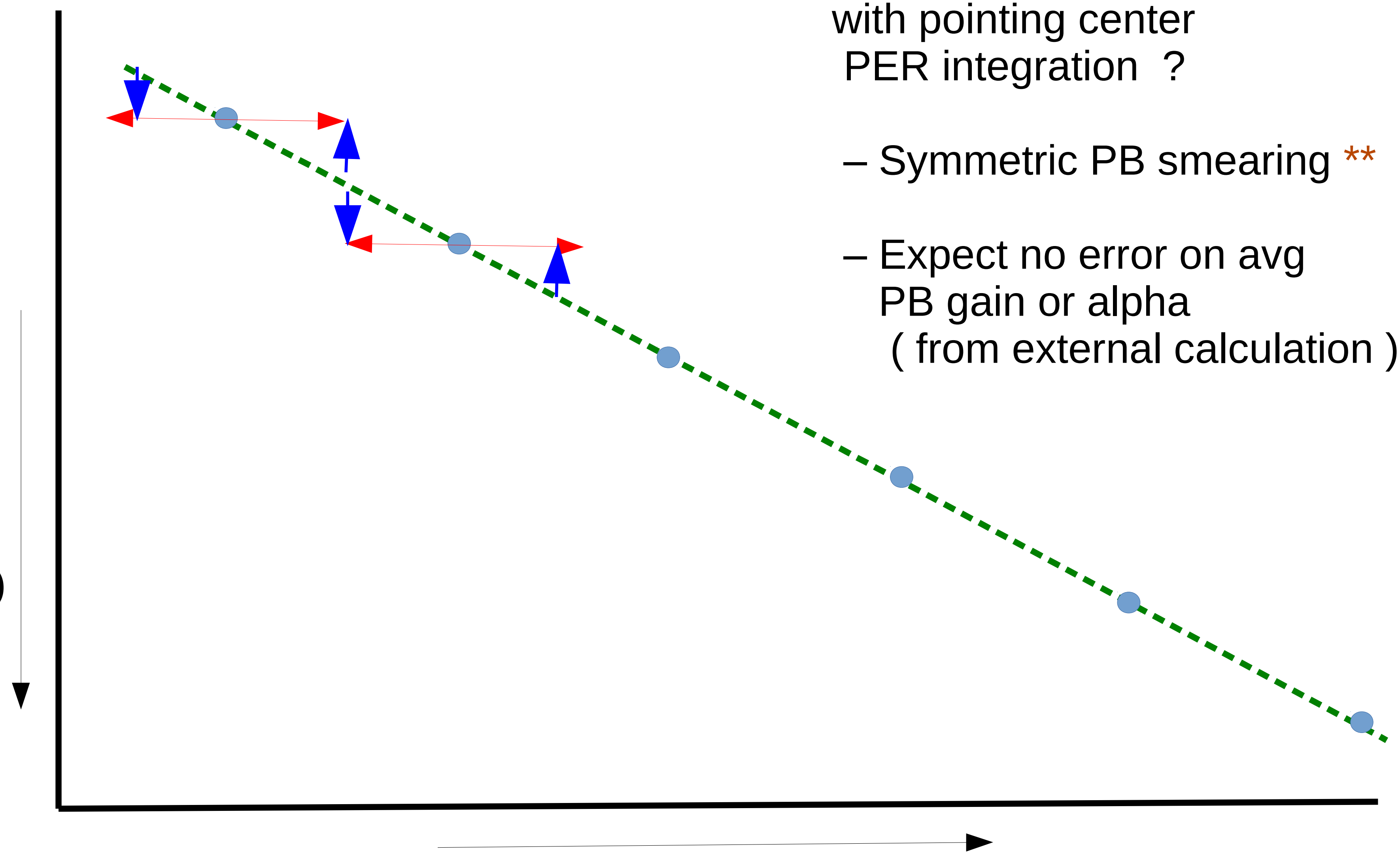
– Symmetric PB smearing **

– Expect no error on avg
PB gain or alpha
(from external calculation)

Yaxis :

Phase
and
pointing
center

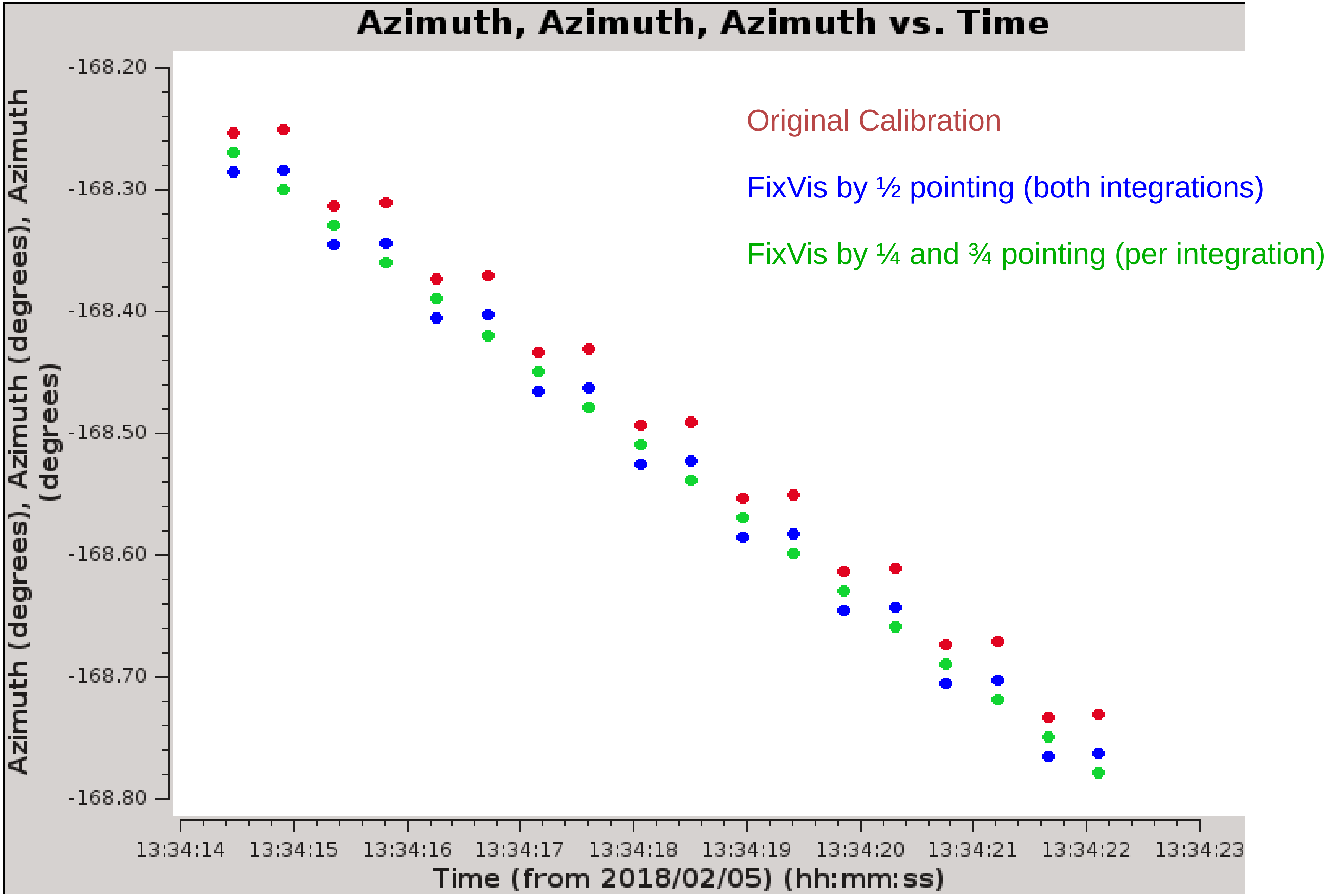
(arcmin)



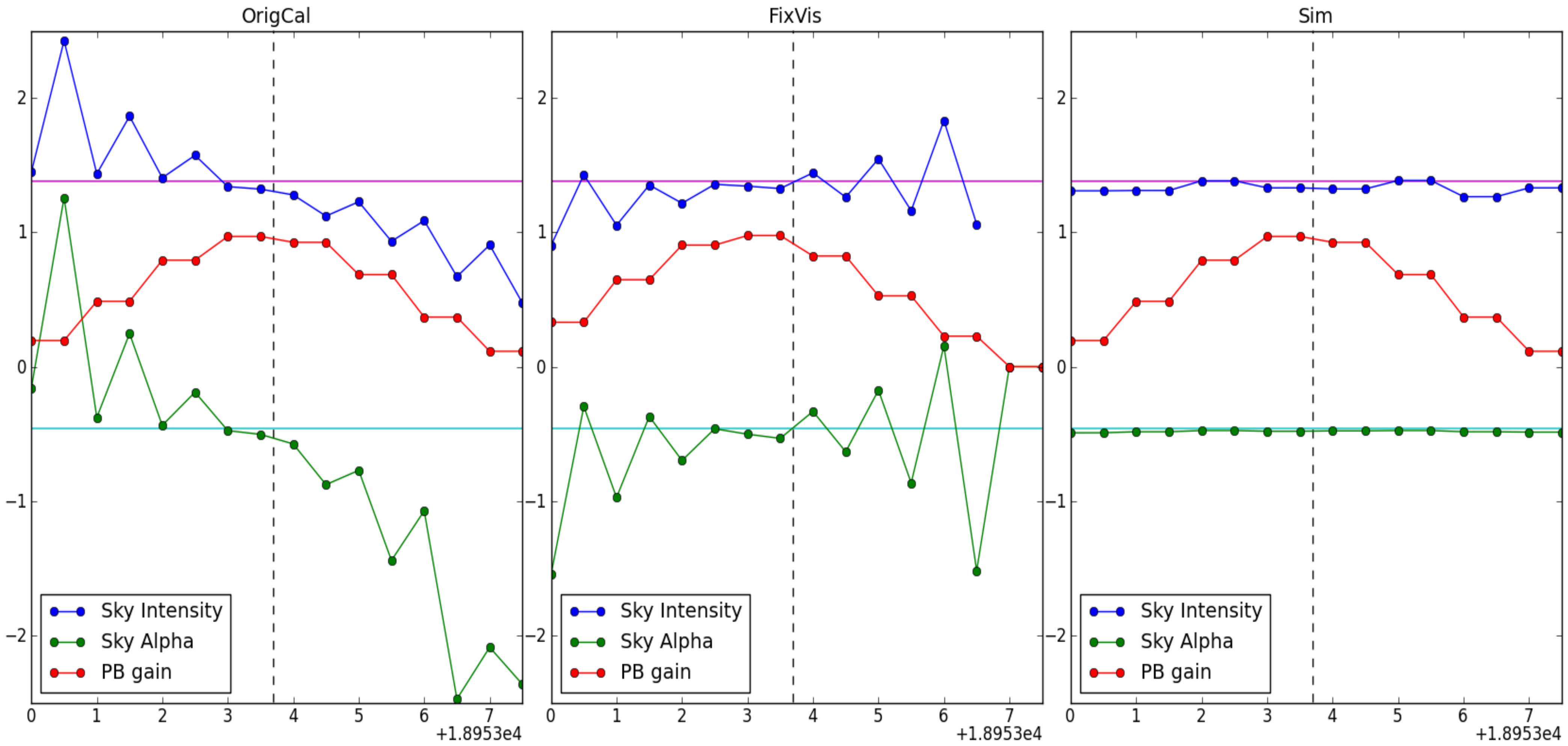
Xaxis : Time (sec) , PB gain seen by source.

** May not work for full-pol

VLASS data – Phase and Pointing centers...

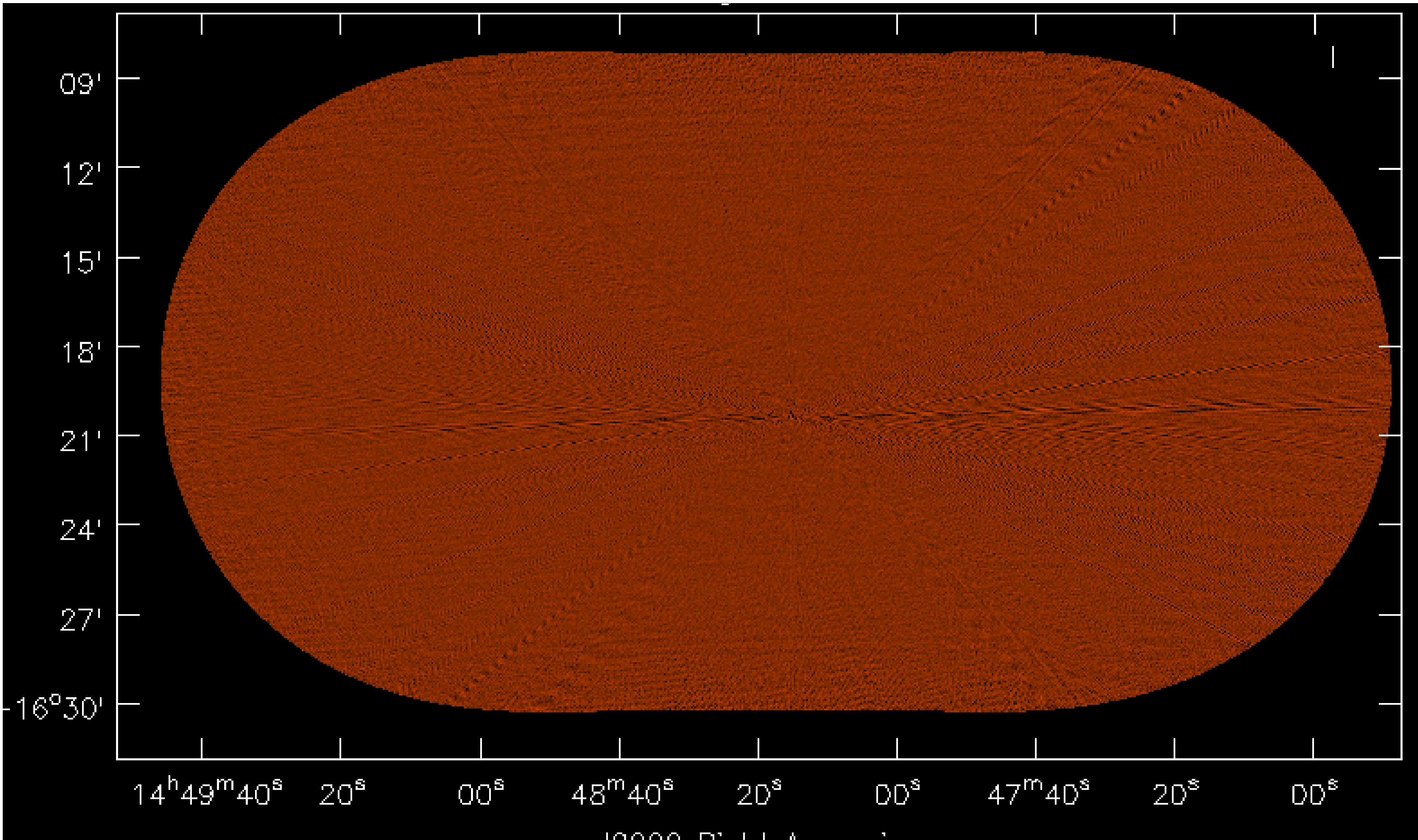


VLASS data – Phase and Pointing centers....



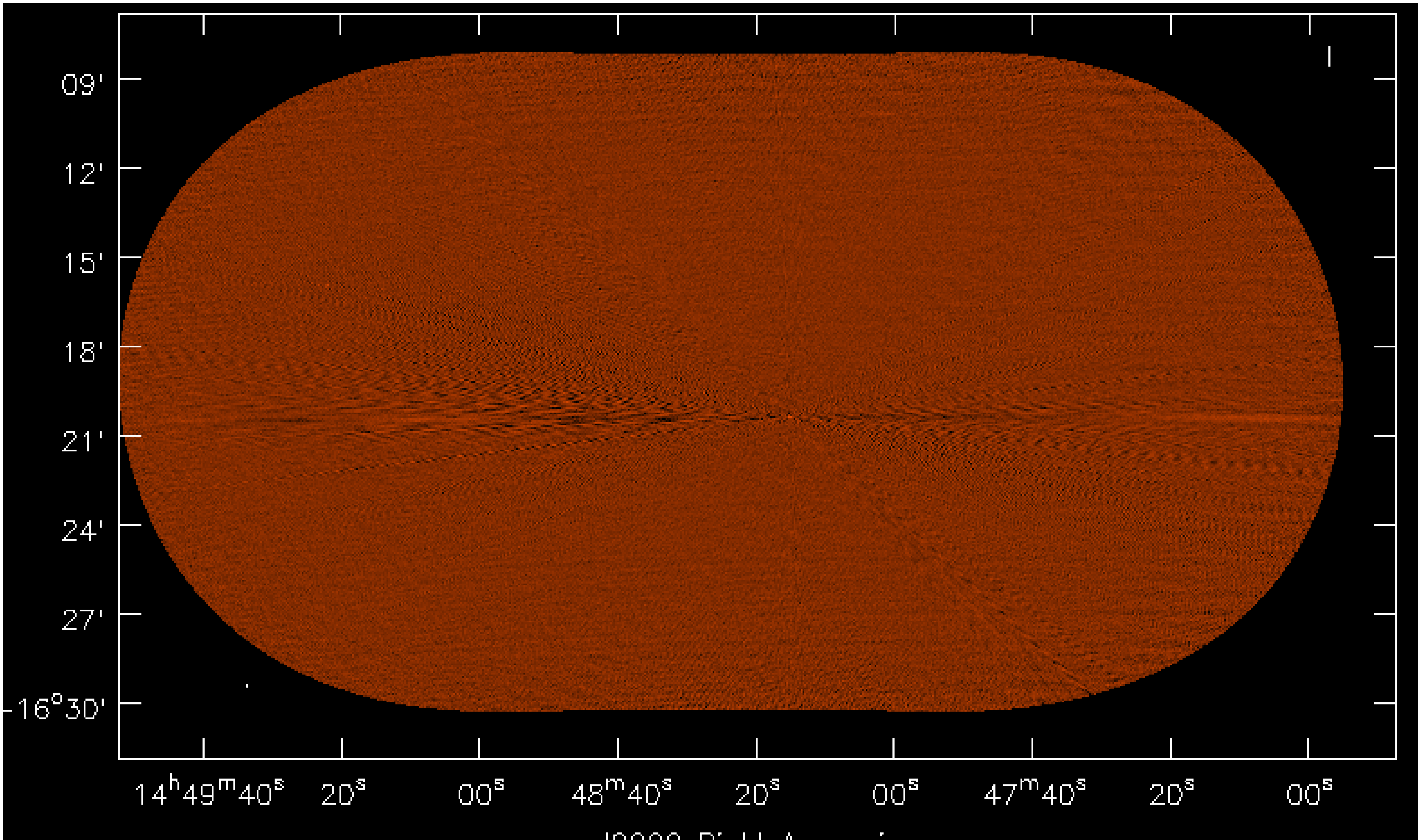
VLASS data – Mosaic images from 8 pointings in a row

Original Calibration. Intensity = 1.31 Jy, Alpha = -0.57 (should be 1.38, -0.48)
(needs phase self-cal)



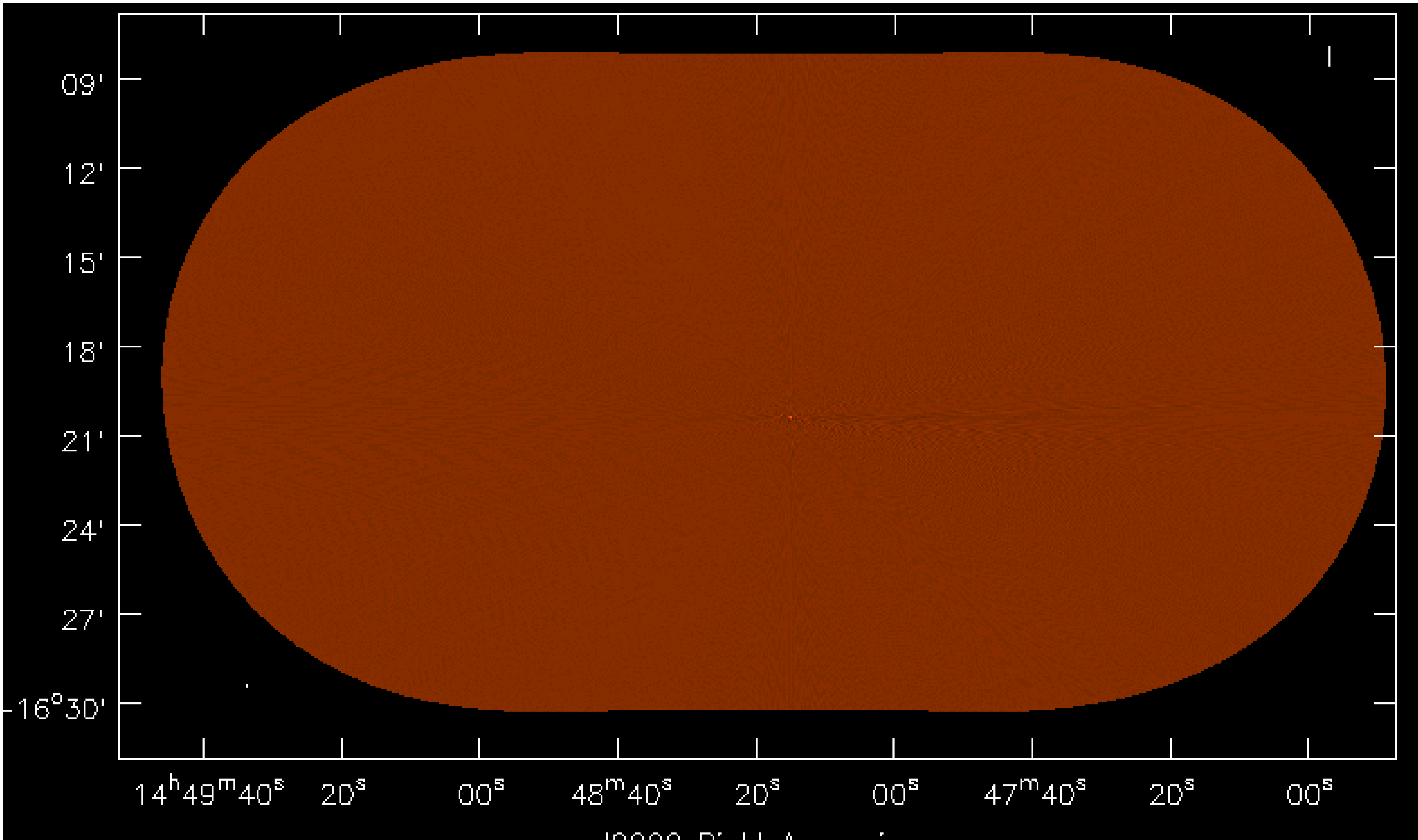
VLASS data – Mosaic images from 8 pointings in a row

FIXVIS on Original : Intensity = 1.34 Jy, Alpha = -0.56 (should be 1.38, -0.48)
(needs phase self-cal)



VLASS data – Mosaic images from 8 pointings in a row

Simulation onto VLASS 8 pointing Measurement Sets (I = 1.38, a = -0.48)



Next Steps

(1) Number of W planes for B-config; Effects of PSF undersampling

(2) Once parameters are established, computing costs have to be eval'd.

[Before Imaging :

- Statwt usage,
- Need for better phase cal (delay clunking ?).
- A pointing calibration table to rephase visibilities per integration to the middle of the range of pointing directions being smeared.]

Further work from ARDG :

- A report with the above details (as per the ARD test plan).
- Reference data sets and scripts to image them.
- ARD CASA tarball to test with + AWP usage tutorial by S.B. (if needed)
- Implement usability improvements and initiate CASA merge.