

EA-ALMA Data Analysis Workshop 2024

Self-calibration Group

Mentor

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Content

1. Introduction
2. Standard self-calibration procedures
3. Parameter testing
4. Discussion
5. Take home message

Introduction

Thanks:

Self-calibration

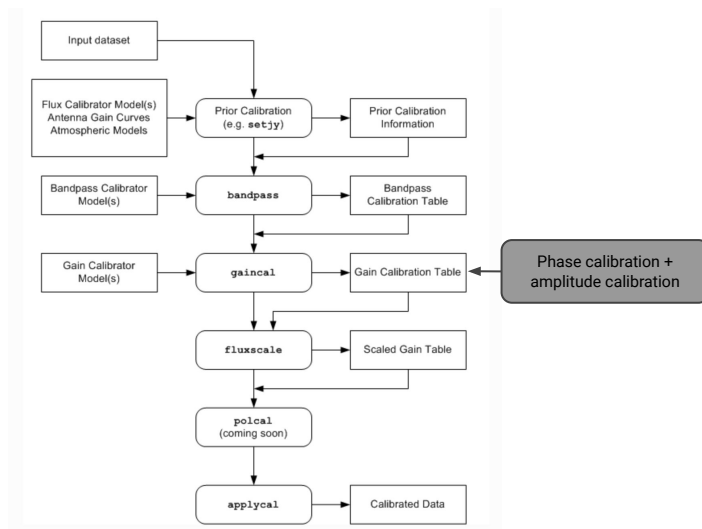
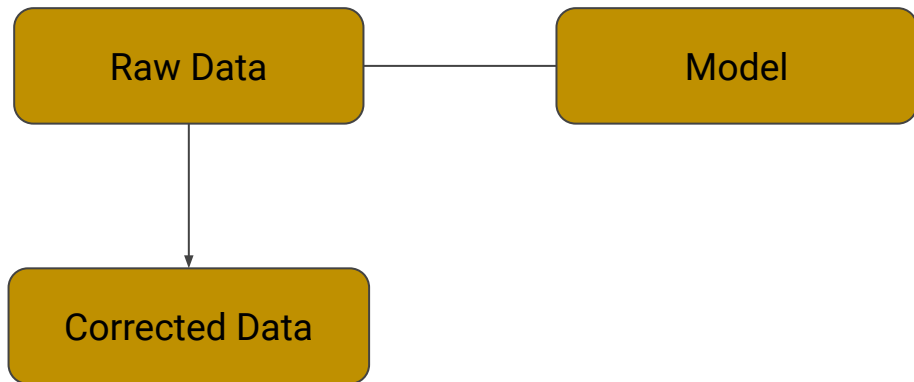
NRAO Joshua Marvil

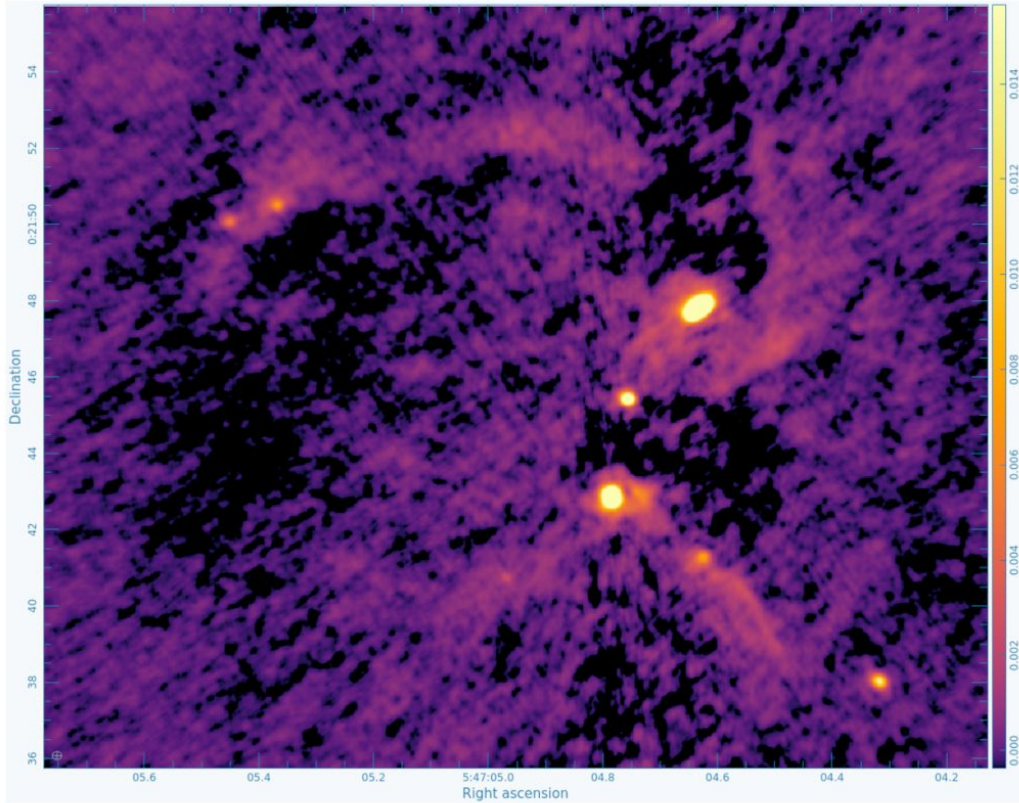
NRAO Sabrina Stierwalt

Calibration in CASA

Interferometers measure “**visibilities**”: the amplitude and phase information of the cross-correlated signals between pairs of antennas.

We calibrate these data by determining the complex gains (**amplitude and phase**) and the frequency response (bandpass) for each antenna.





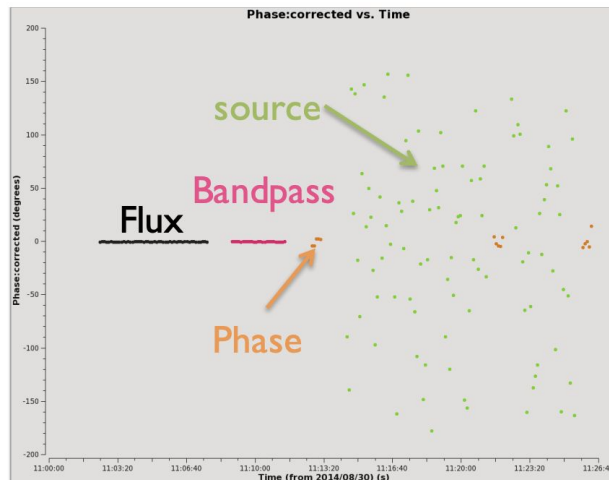
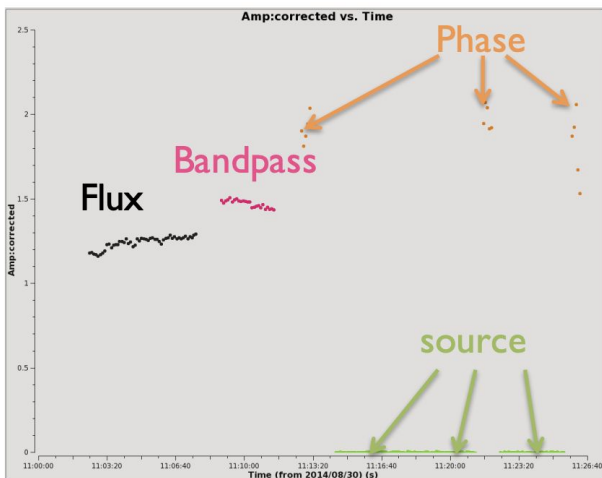
Typical sources of these errors still have:

- atmospheric density fluctuations
- antenna-based gain changes

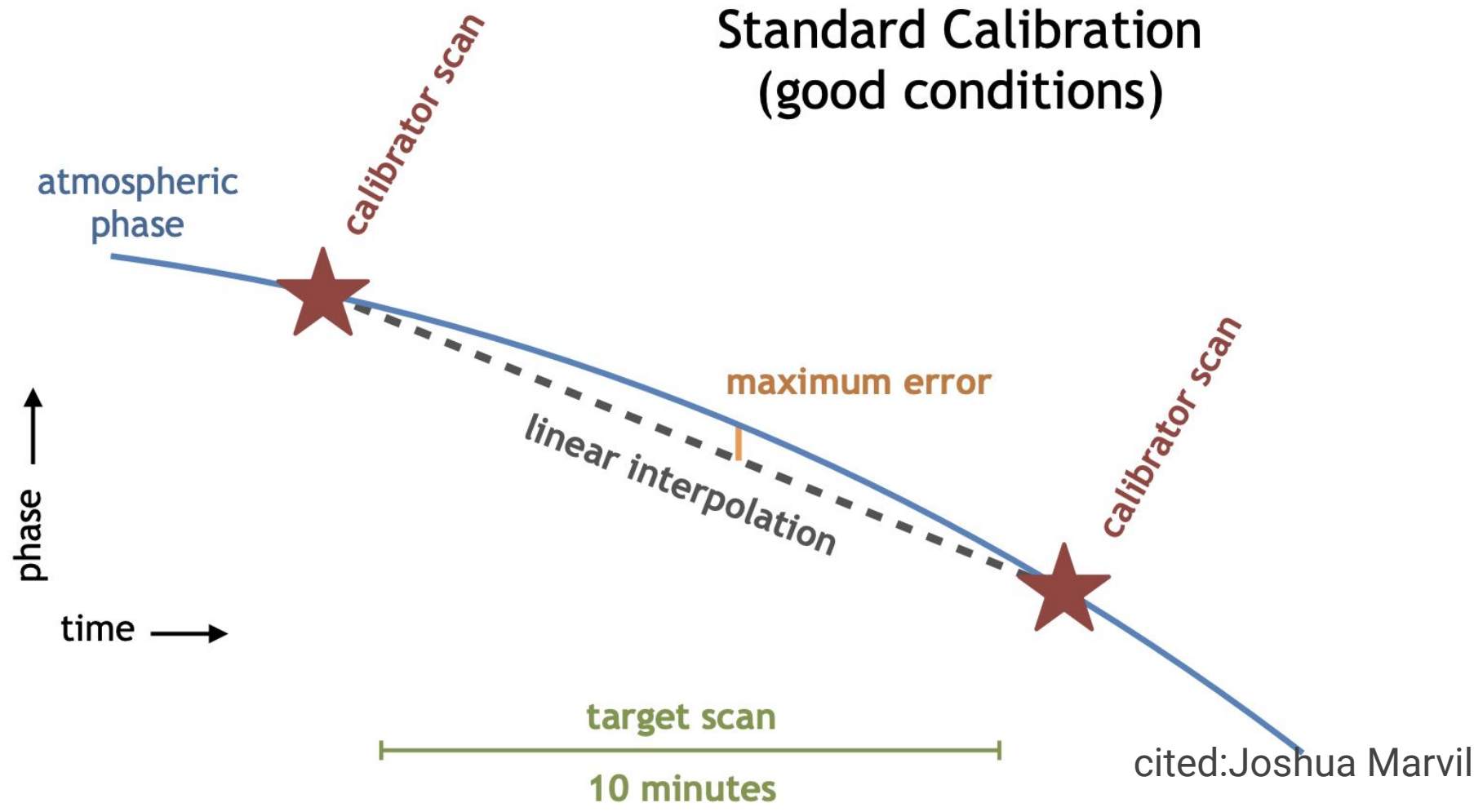
Self-Calibration in CASA

Self-calibration uses your source to better calibrate the antenna-based complex gains (**amplitudes and phases**) as a function of time.

Calibrate the scientific visibility (phase & amplitude) by comparing the visibility data with a model of the source itself

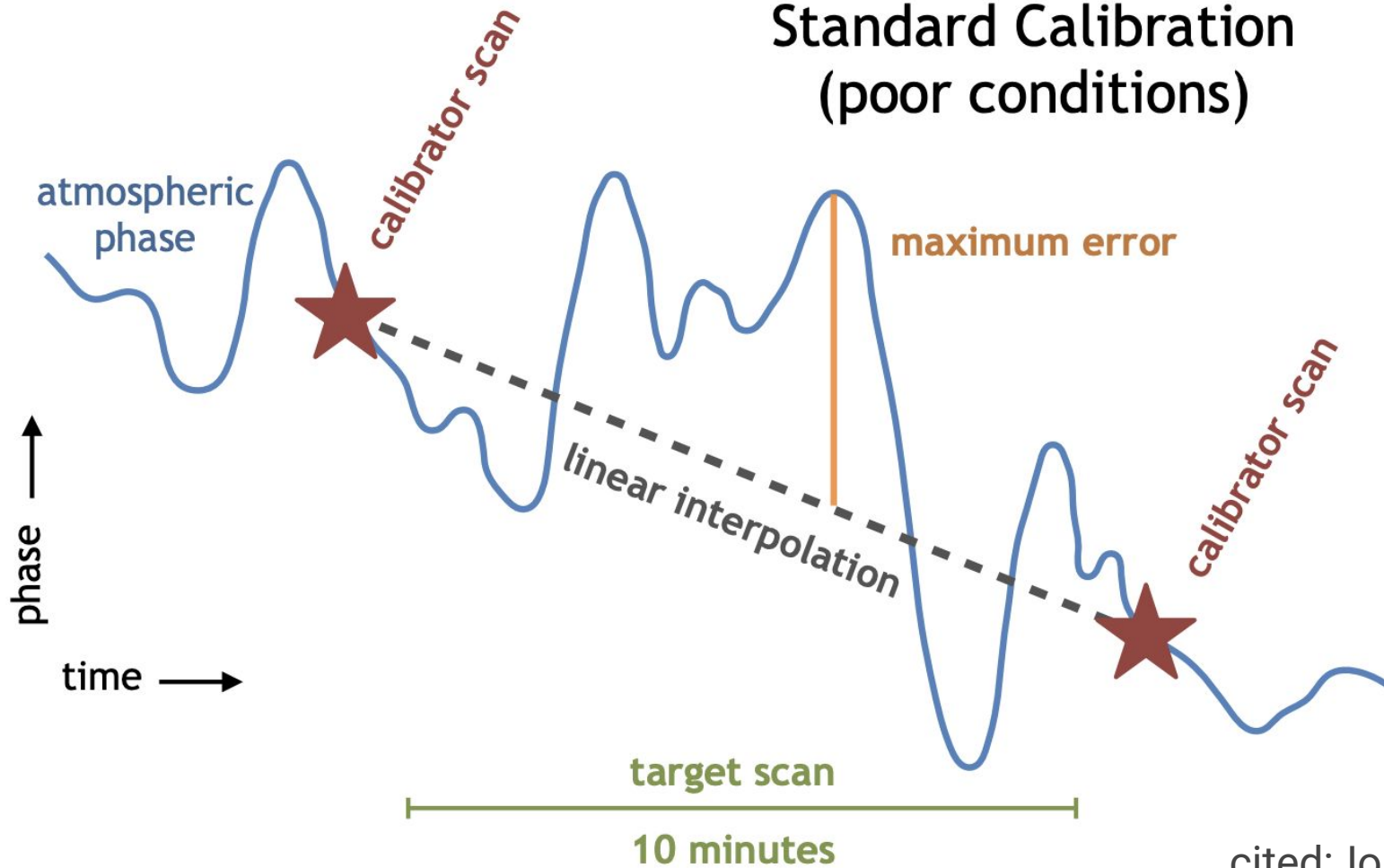


Standard Calibration (good conditions)



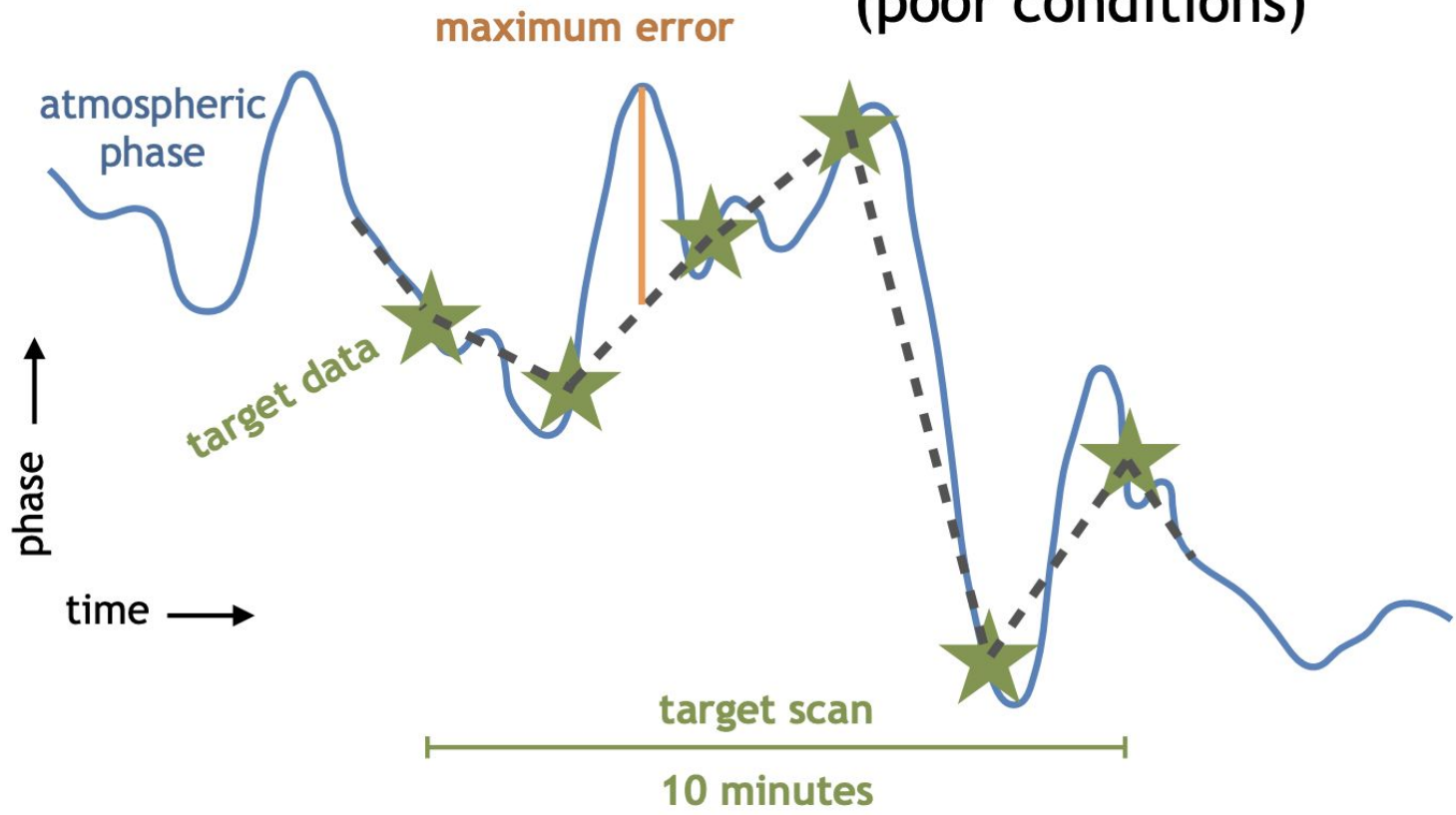
cited:Joshua Marvil

Standard Calibration (poor conditions)

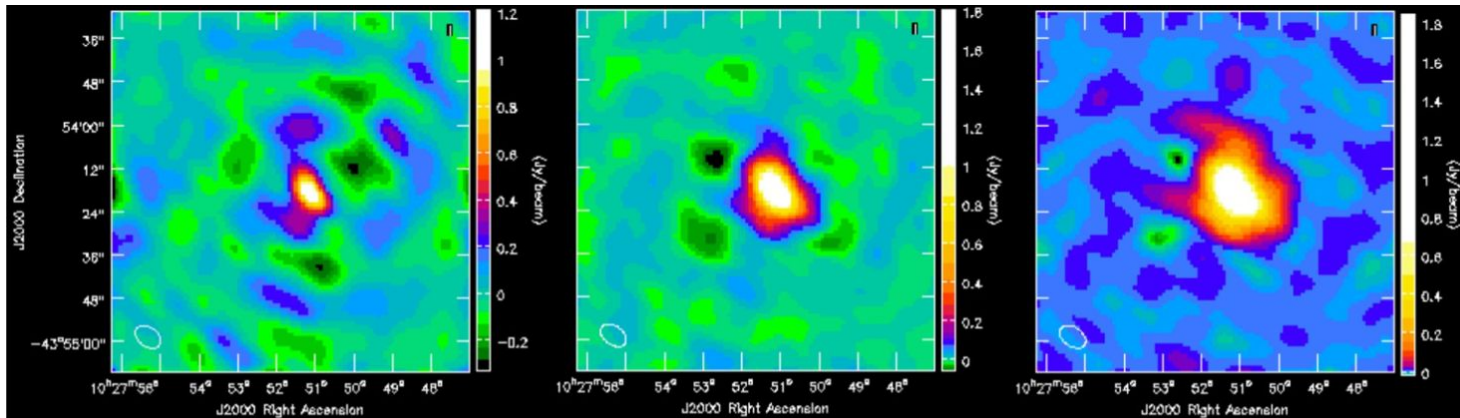


cited:Joshua Marvil

Self Calibration (poor conditions)



cited:Joshua Marvil



Richards+22

Only after gain cal

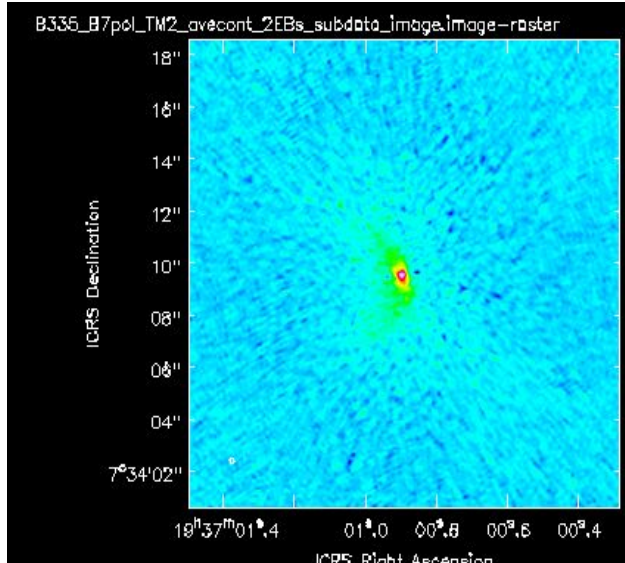
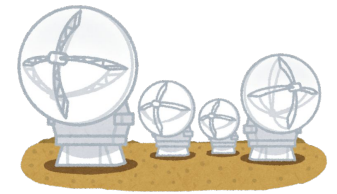
After phase selcal

After phase + amplitude selcal

When to self-calibration?

Target with high S/N ~ 100 for 12m, 50 for ACA
 Image noise \sim predicted

DATA



Target: **Barnerd335** (ICRS 19h37m00.9s 7d34m09.40s)
an isolated globule in Aquila (d=164.5 pc)

Frequency: Band 7 (340 GHz)

Bandwidth: 4 GHz

46 antenna, C4, total integration time 68 min.

Observing Date: May. 16, 2017 and Sep. 20, 2018

Data reduction: CASA 6.5.4

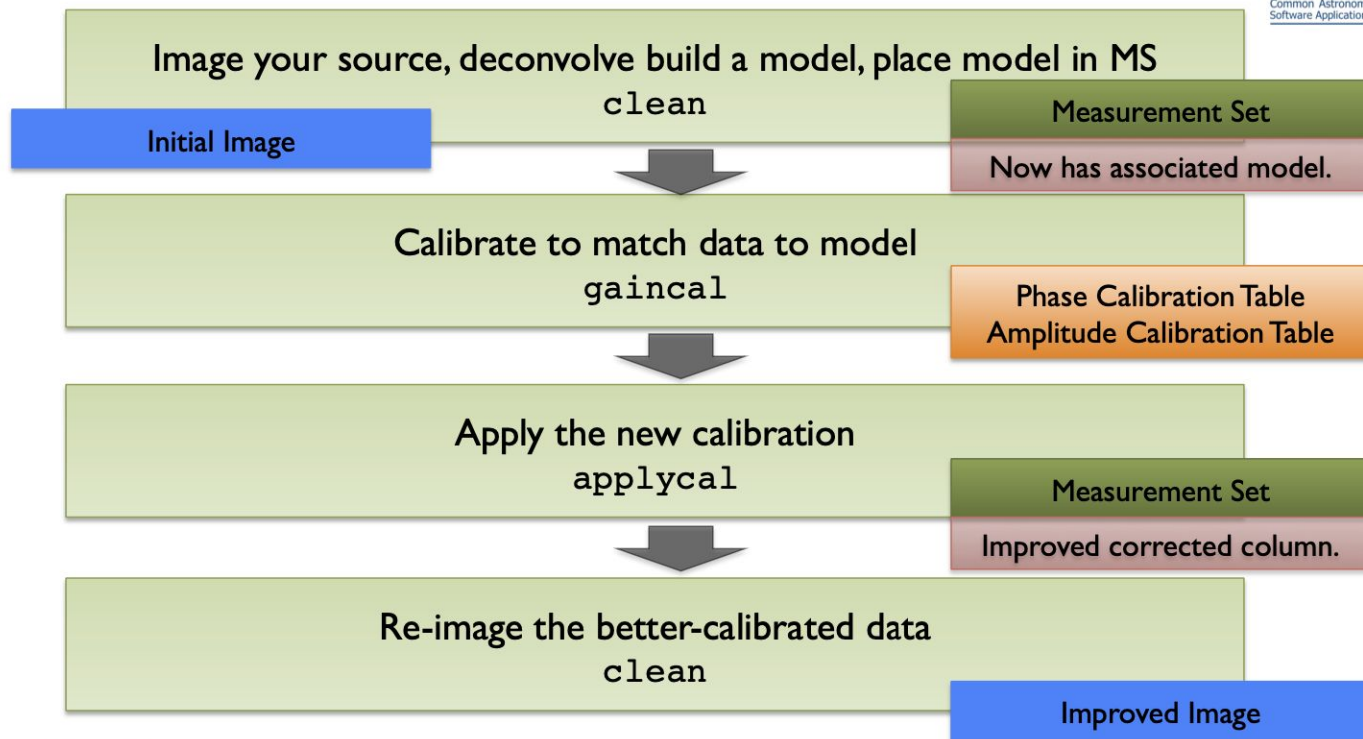
Angular resolution: 0.19" × 0.18" (robust=0.5)

Theoretical noise: 0.03 mJy/beam

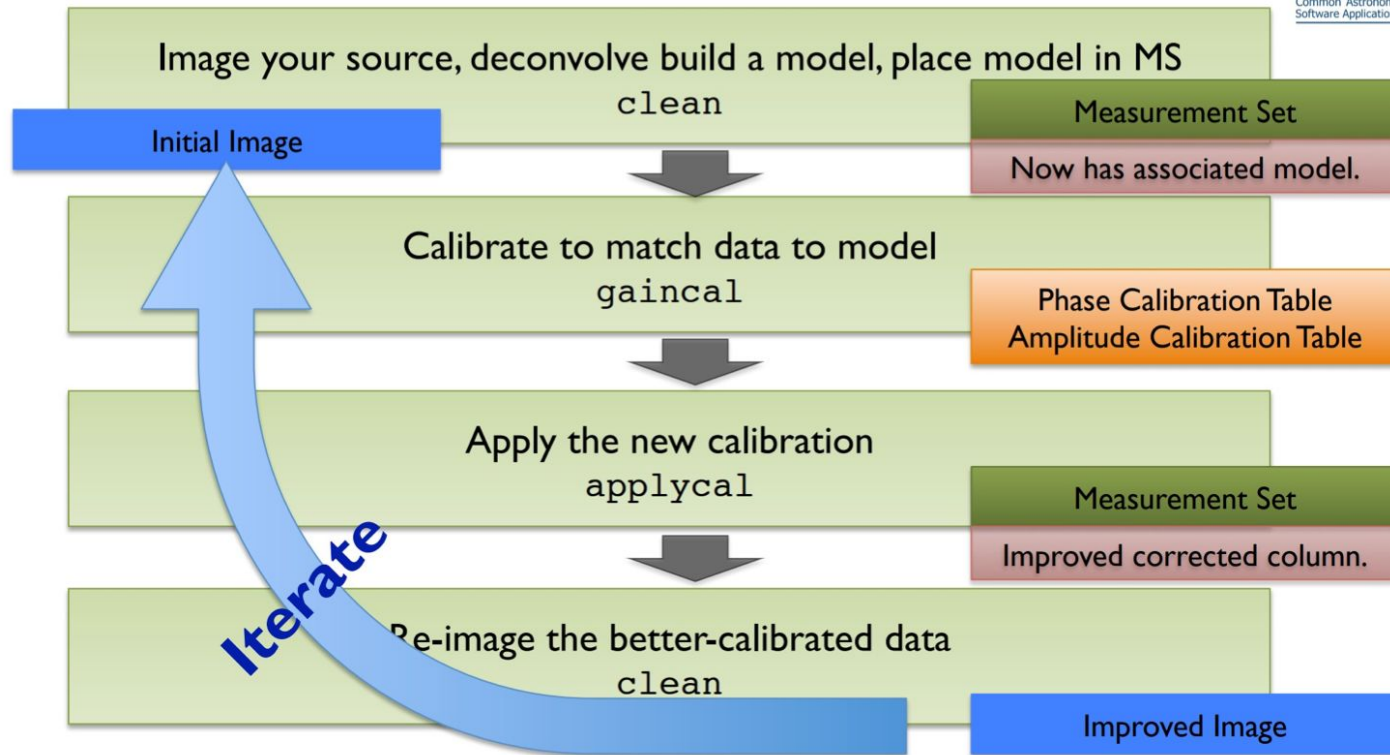


Running self-calibration in CASA

Self calibration procedure

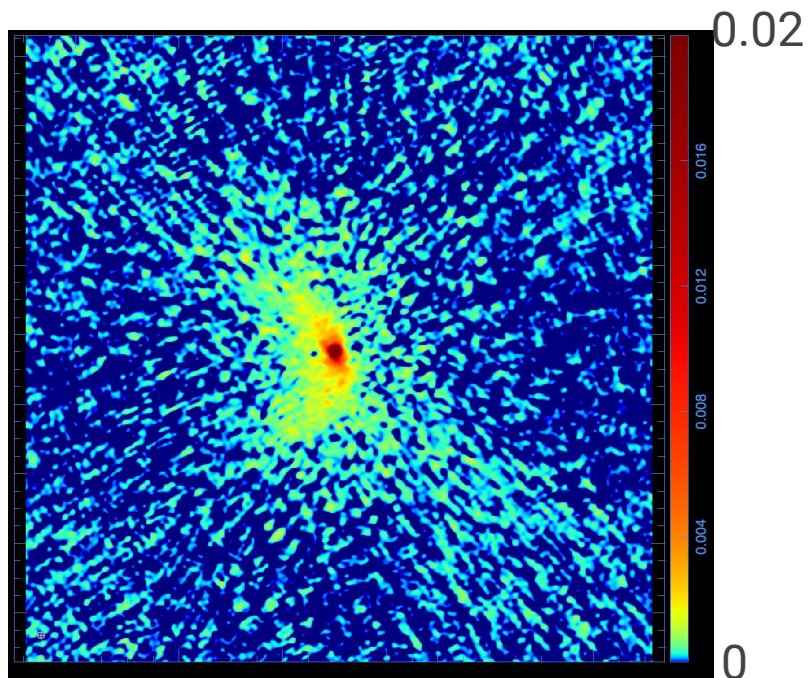


Self calibration procedure



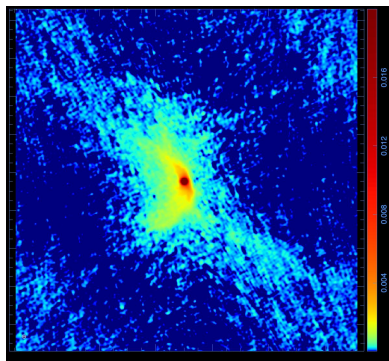
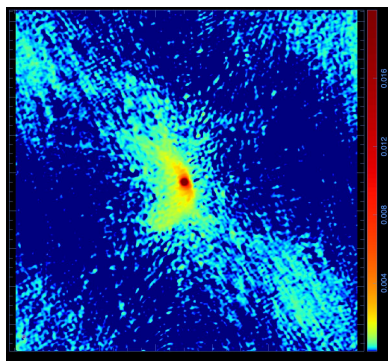
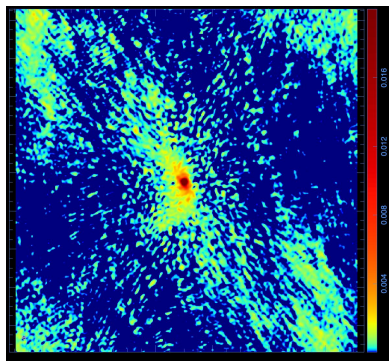
Self- calibration Fiducial set

Pre self-calibration image



Main parameters for
self-calibration:

Threshold (flux)
Solution interval (time)



threshold=15
mJy
solint = inf

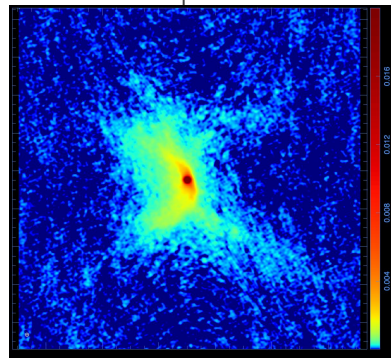
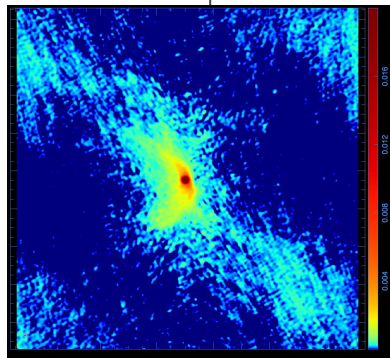
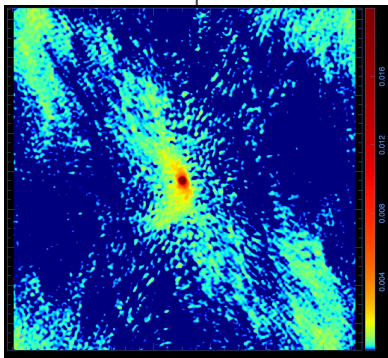
threshold=7.5
mJy
solint = inf

threshold=2.5
mJy
solint = 180s

threshold=1.4
mJy
solint = 90s

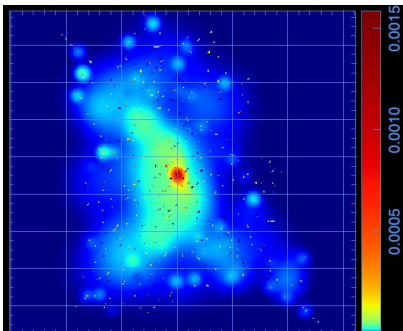
threshold=0.6
mJy
solint = 60s

Final image

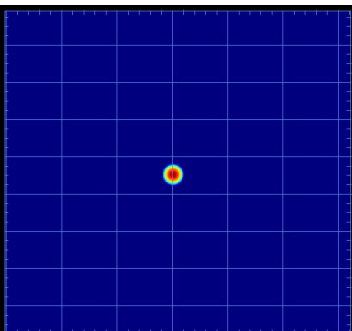


Model

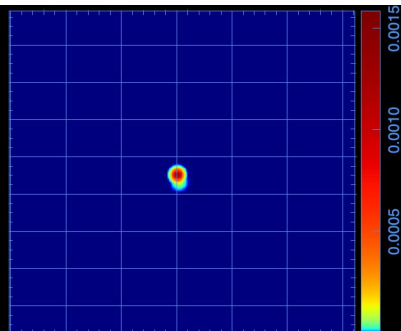
Pre



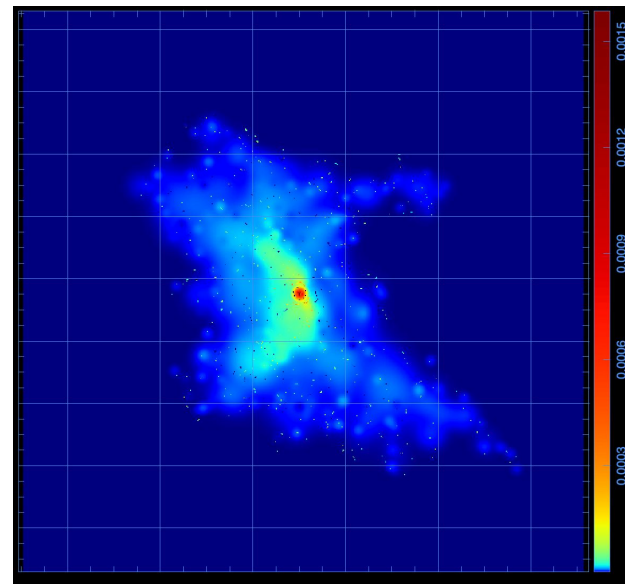
Step 1



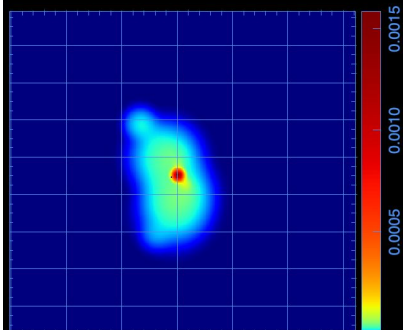
Step 2



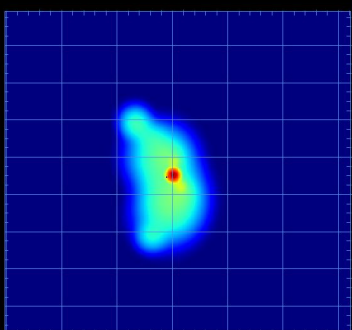
Final



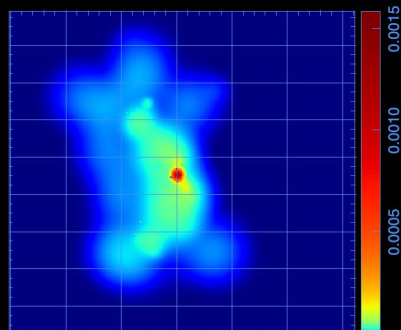
Step 3



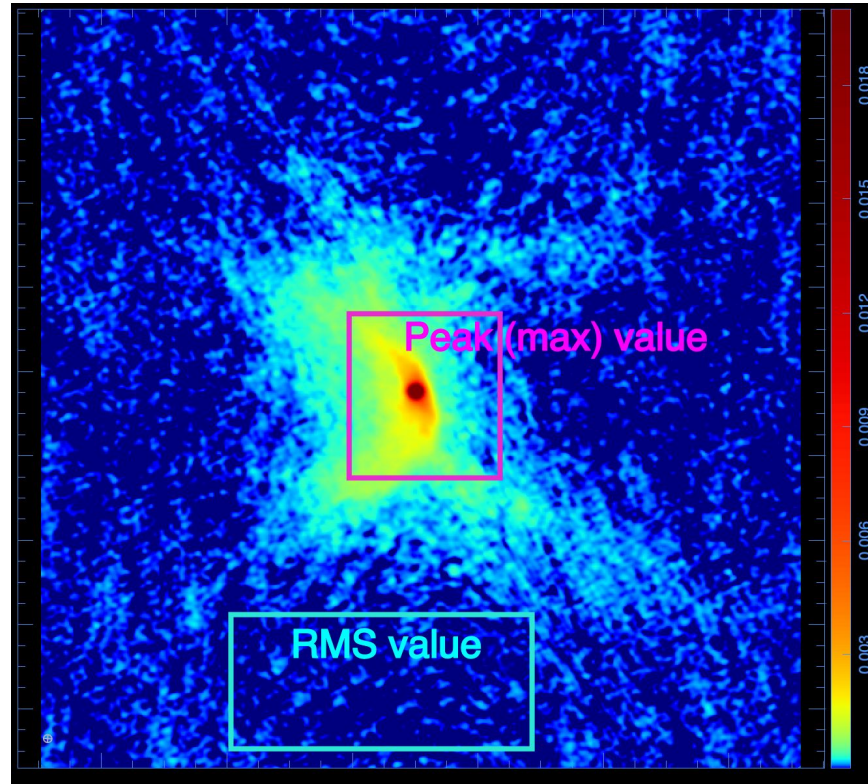
Step 4



Step 5



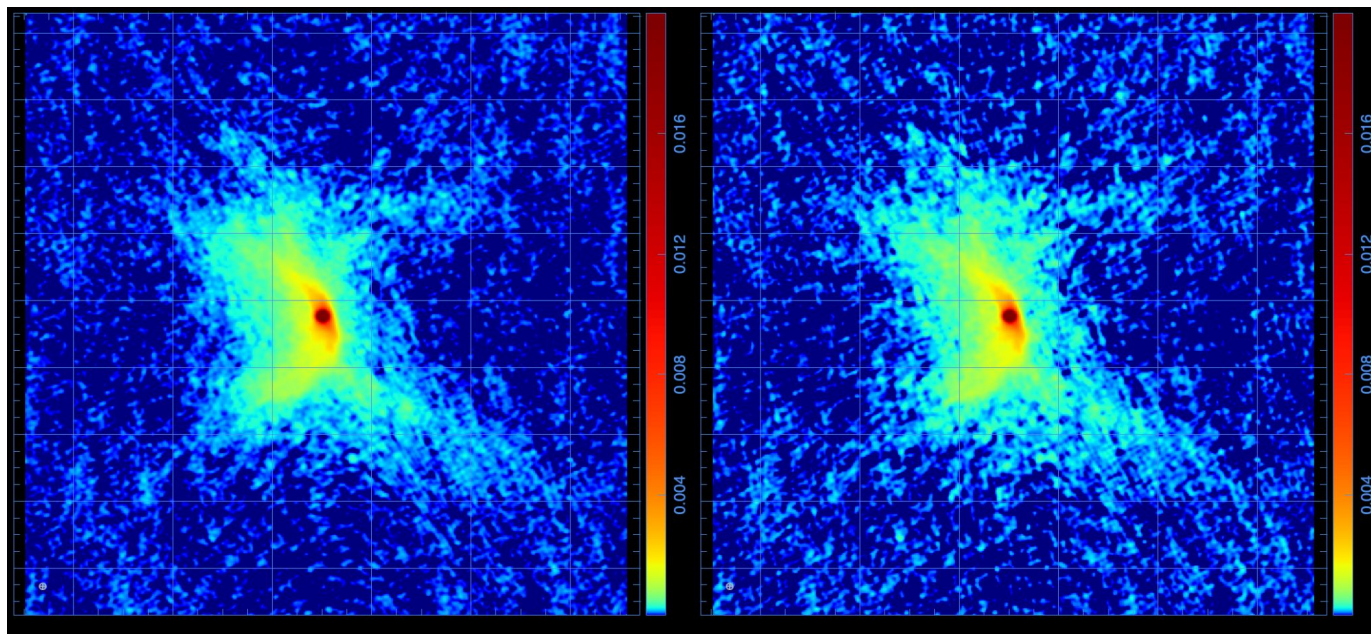
Signal-to-noise ratio



Phase + Amp vs Phase calibration

Phase + Amp

only Phase



SNR = 1397

SNR = 1035

Changing parameters

- Case1

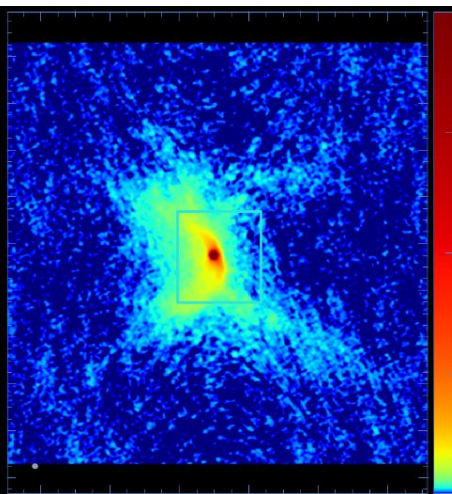
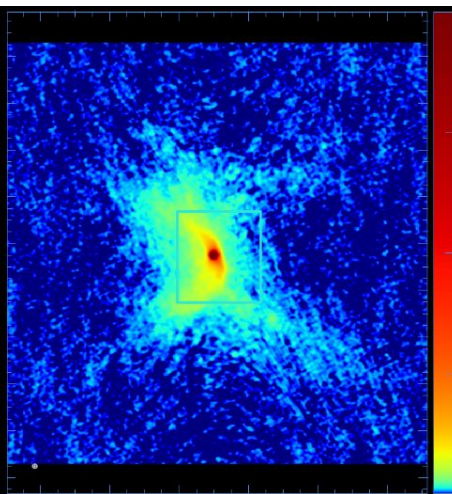
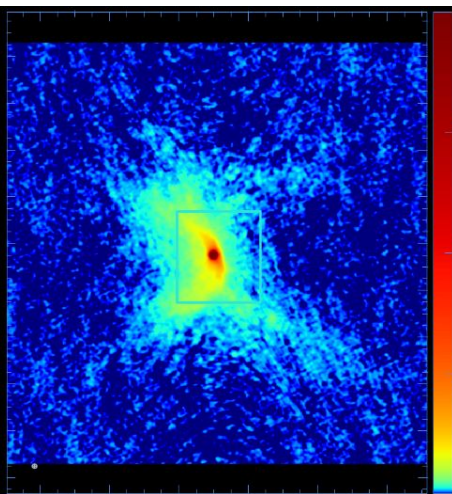
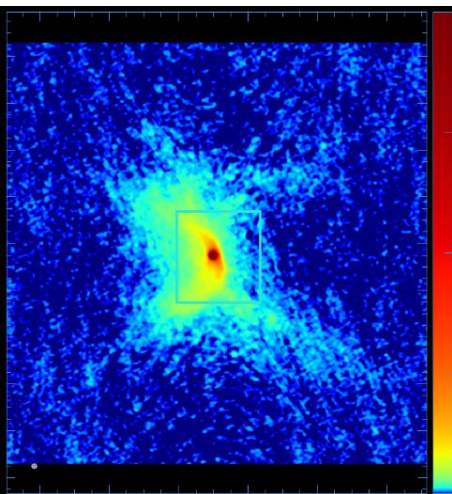
Case 1 : Thresholds

Fiducial set

Th = 15 mJy

Th = 7.5 mJy

Th = 1 mJy

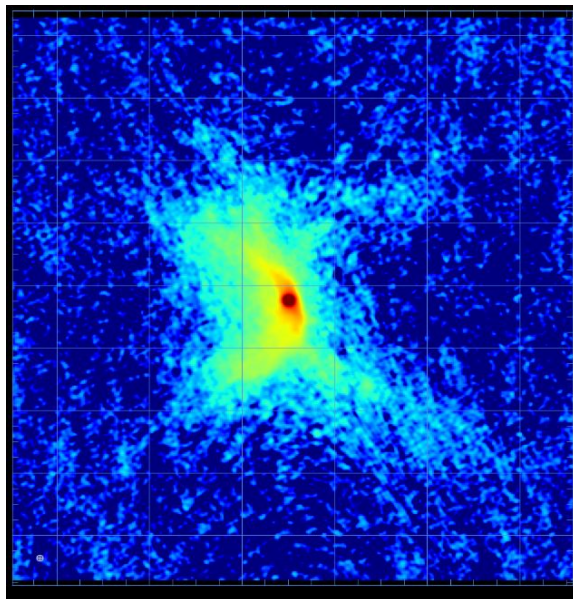


Case 1 : Thresholds

	Fiducial set	Th = 15 mJy	Th = 7.5 mJy	Th = 1 mJy
Peak (mJy/beam)	85.9	86.3	86.1	85.4
RMS (mJy/beam)	0.0615	0.0616	0.0622	0.0617
SNR	1397	1401	1384	1382

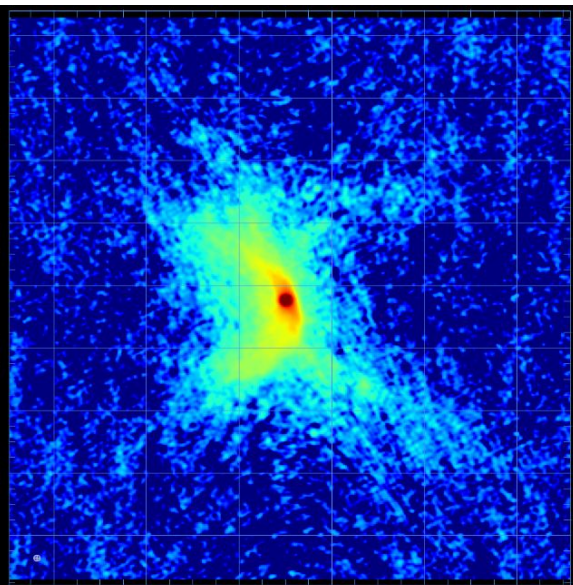
Case 1 : Thresholds

Fiducial set



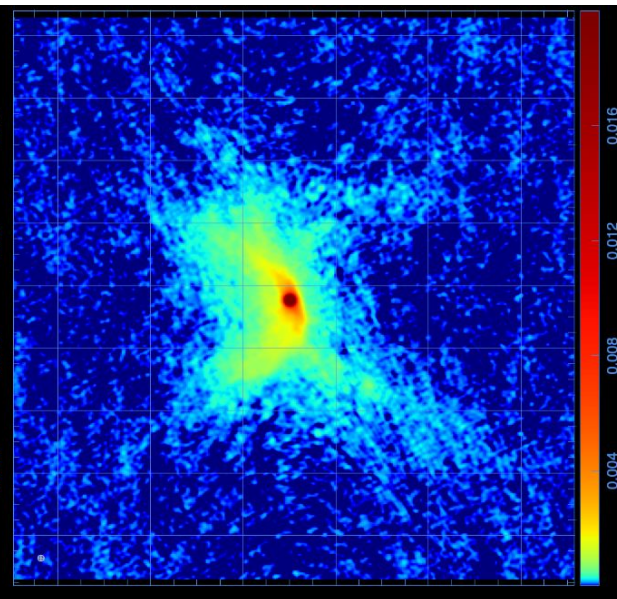
SNR = 1397

Th = 15 mJy



SNR = 1401

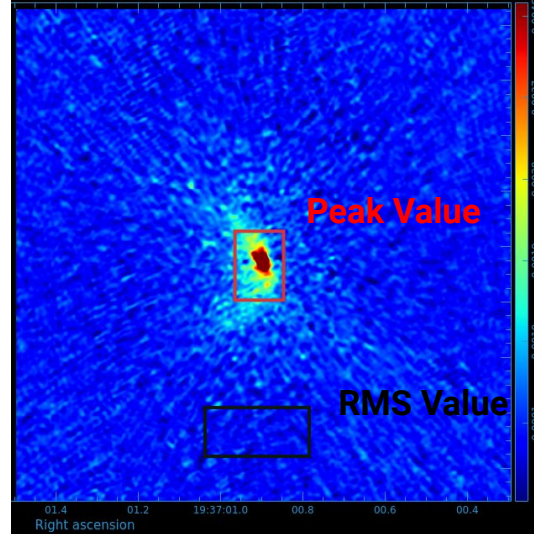
Model Th = 15 mJy
Clean Th = 1 mJy



SNR = 1401

Case 2 : Solution Interval Time

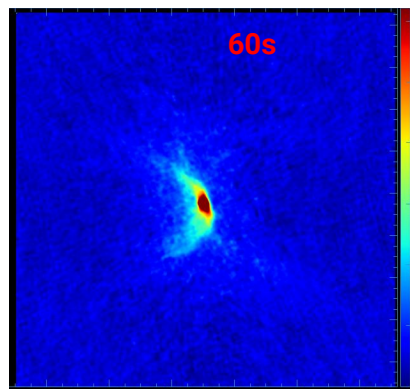
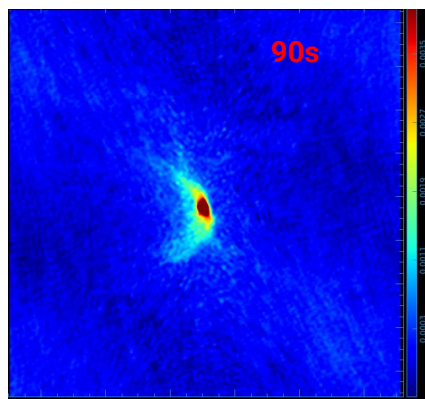
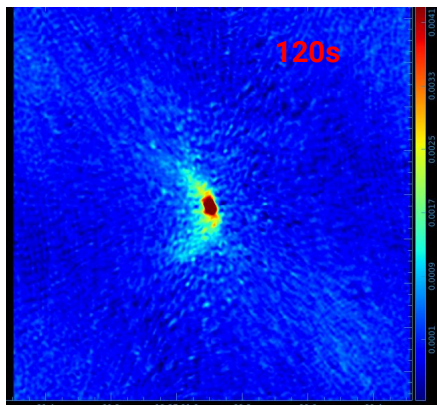
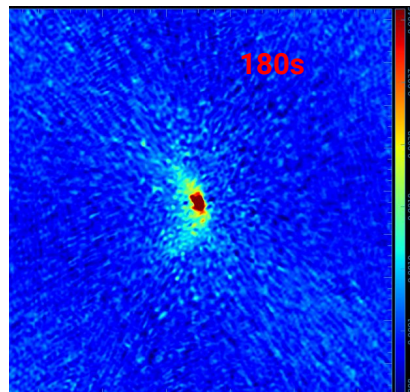
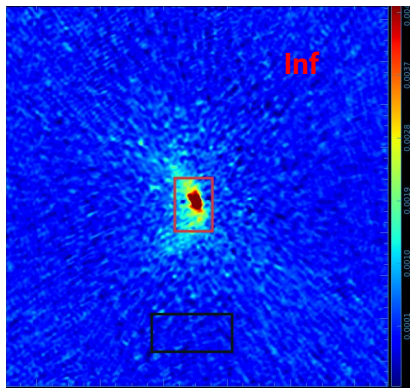
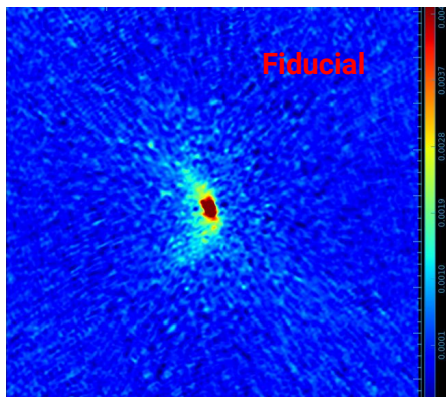
Fix Threshold @ 2 mJy



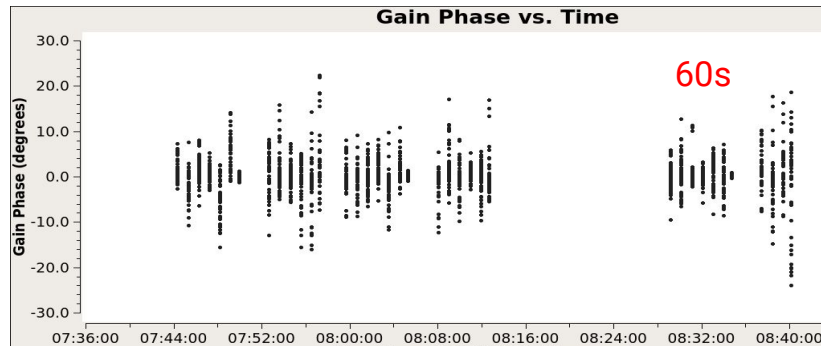
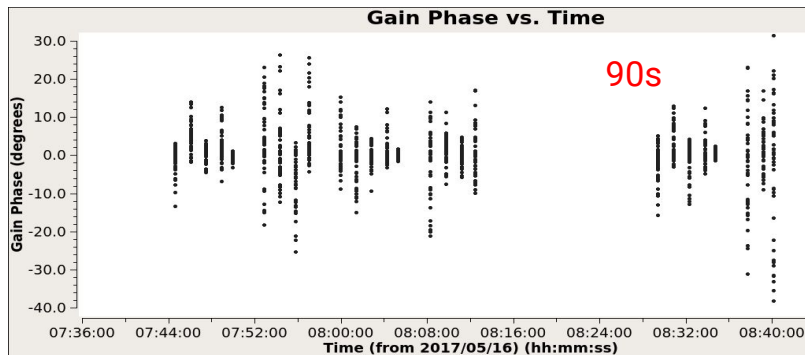
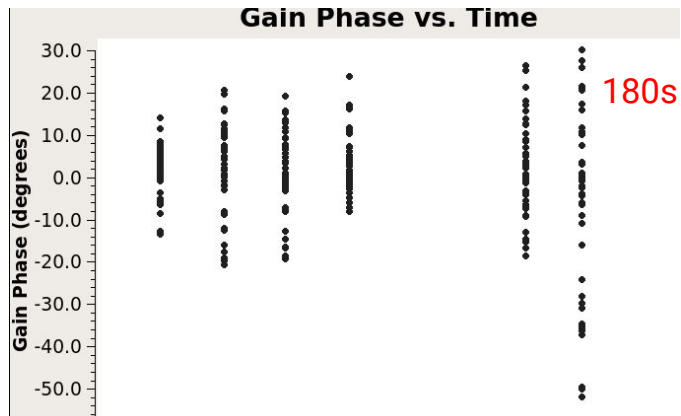
	Raw Data	Solution Interval Time				
		Infinity	180s	120s	90s	60s
Peak (mJy/beam)	68	69	75	81	85	87
RMS (mJy/beam)	0.27	0.27	0.23	0.21	0.19	0.095
SNR	251.9	255.6	326.1	385.7	447.37	915.8



Case 2 : Solution Interval Time



Case 2 : Solution Interval Time

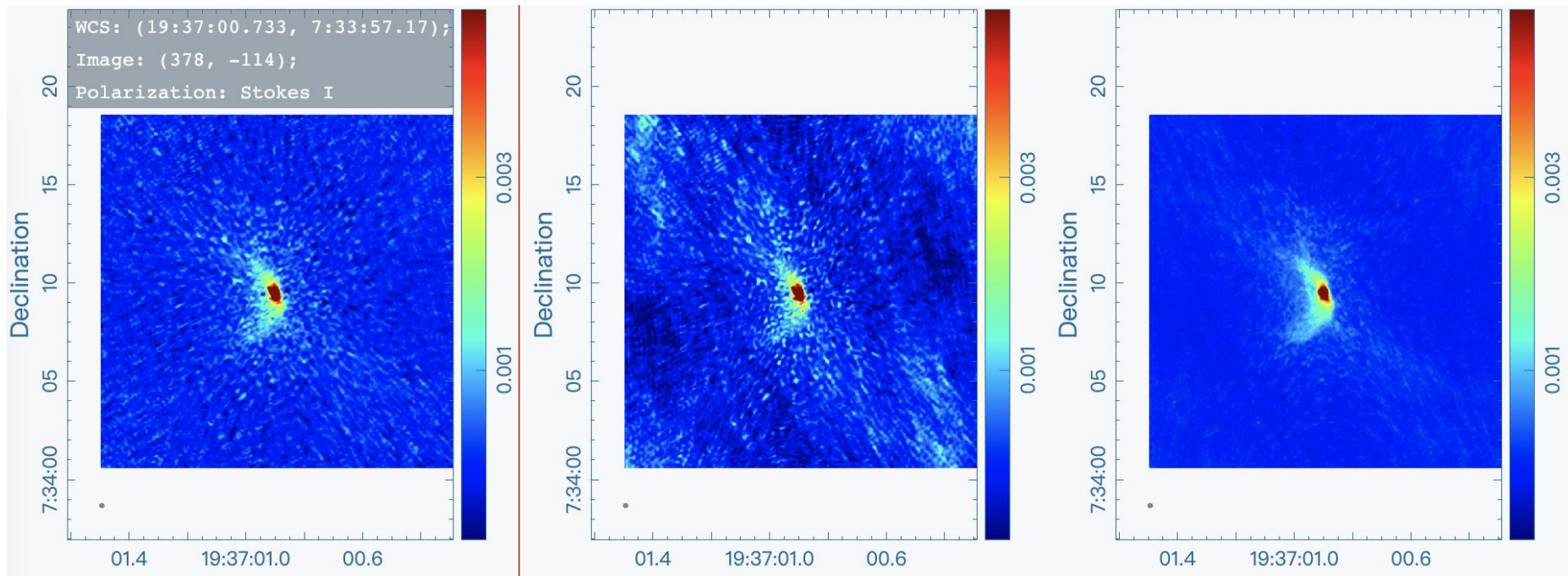


Changing parameters

- Case3

By. Donghyeok Koh

Motivation of Case 3

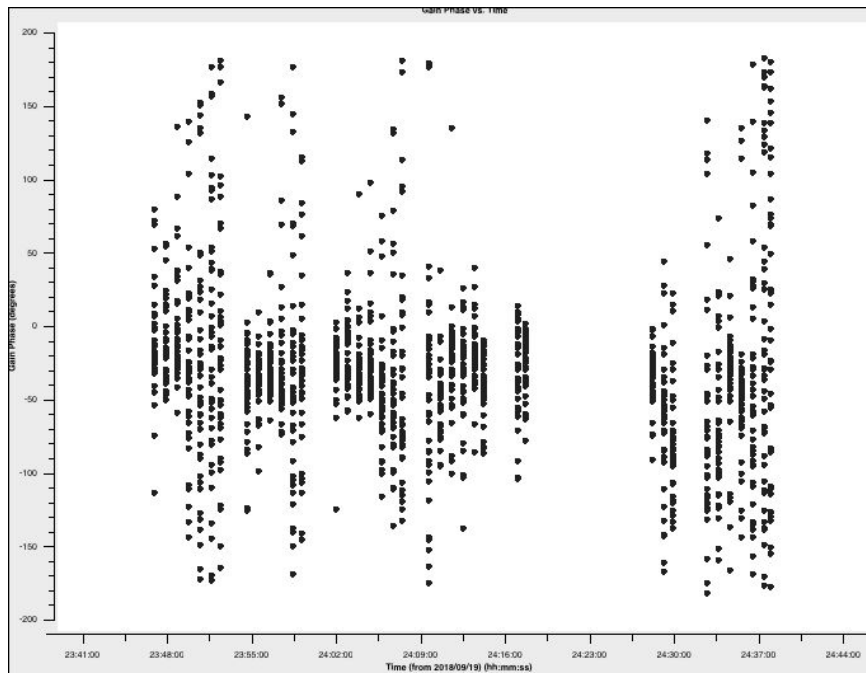


raw

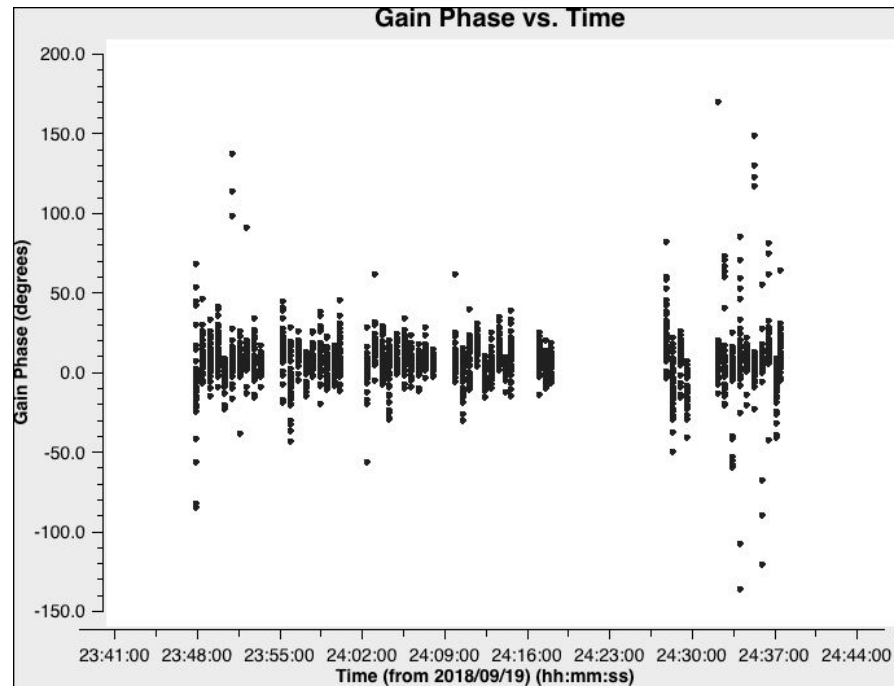
solint= inf

solint= 60s

Motivation of Case 3



Plot from direct process (solint = 60s)

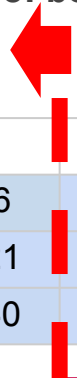


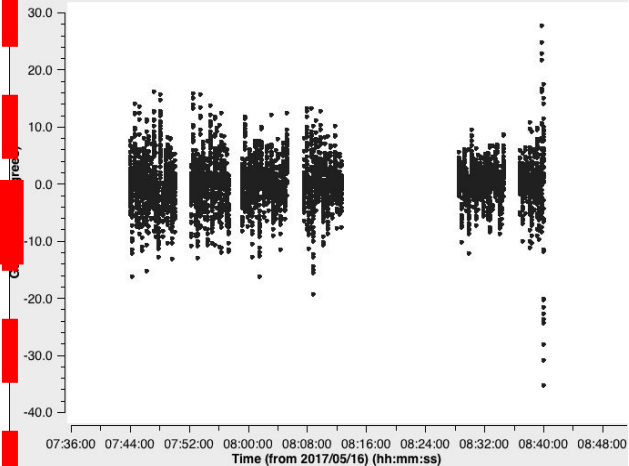
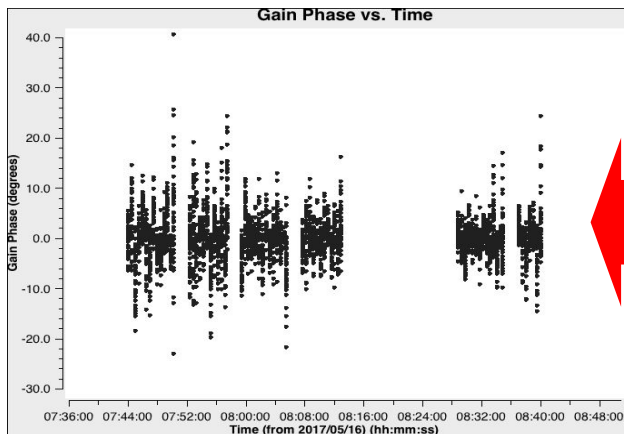
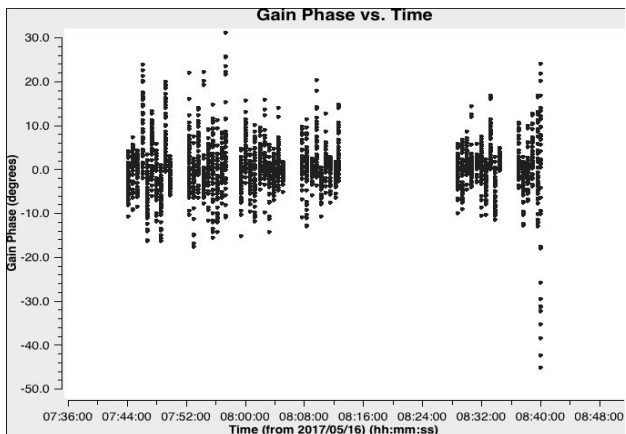
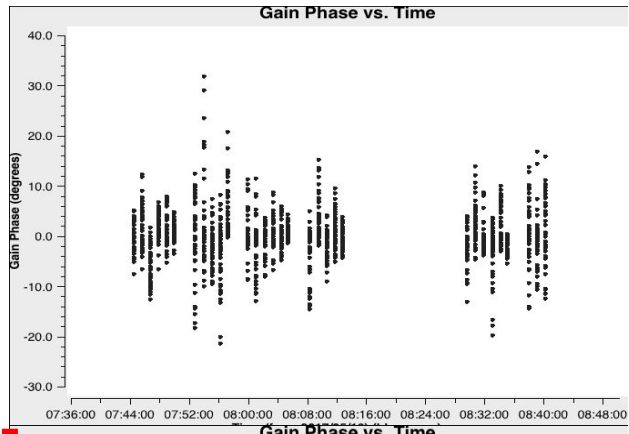
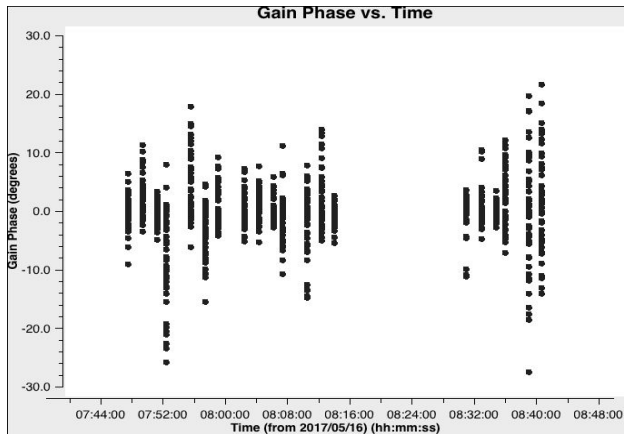
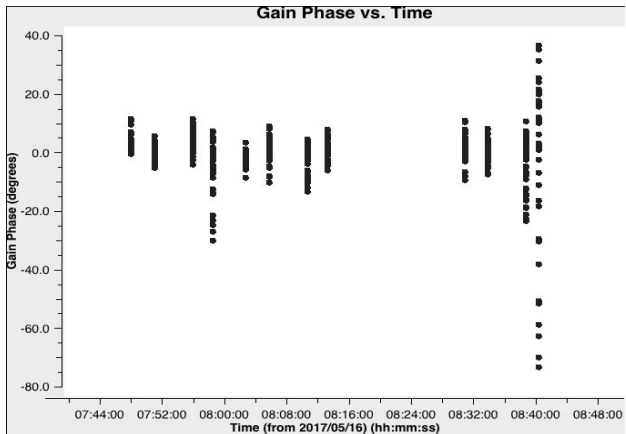
Plot from iteration

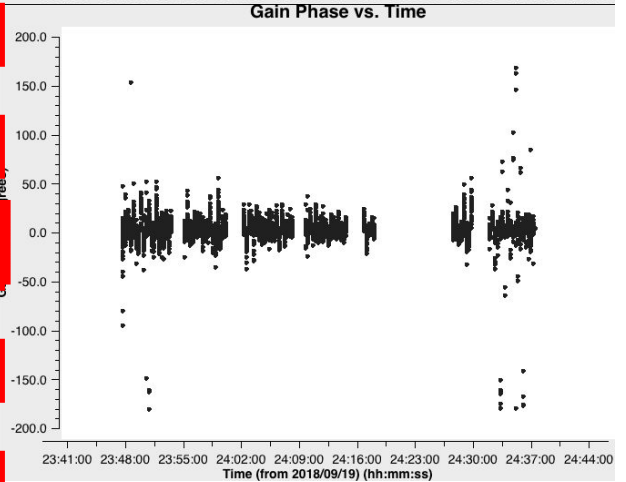
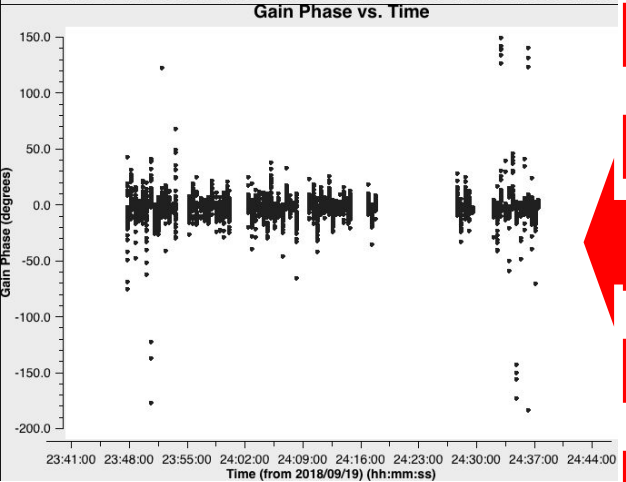
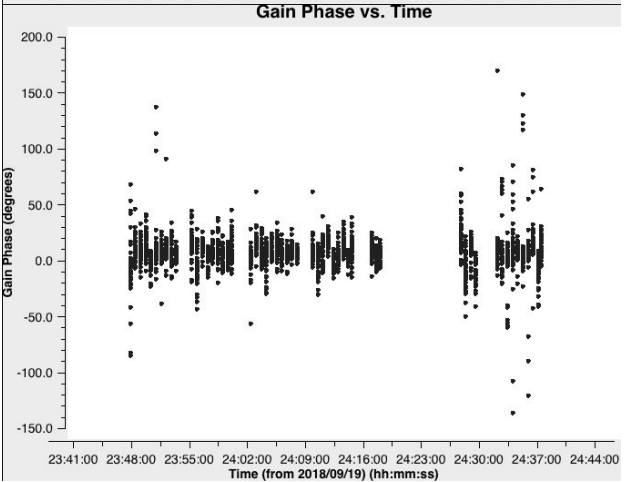
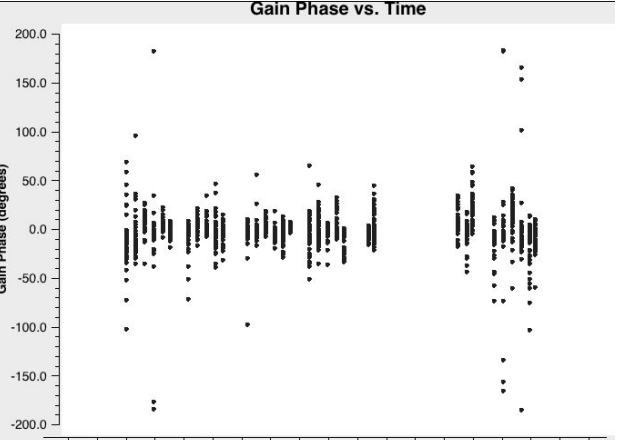
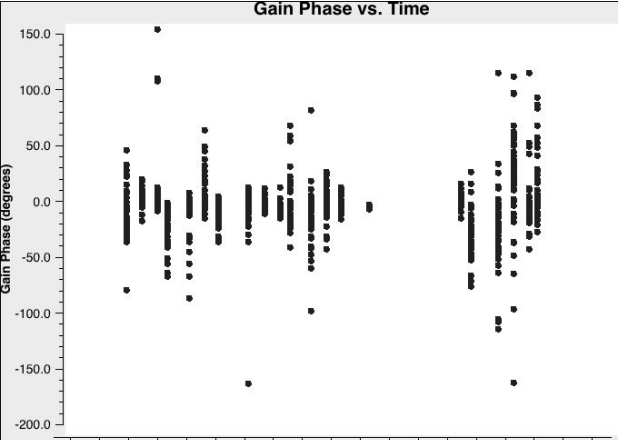
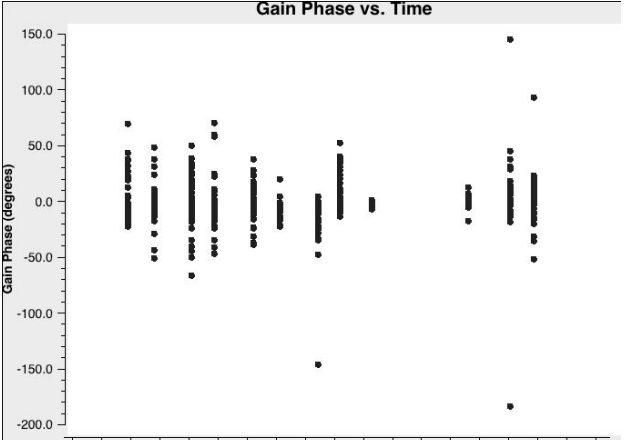
Case 3 : Interval time for solutions

- Fix thresholds as 7.5 mJy (peak ~ 68 mJy)
- Modify interval time for self-calibration solutions
 - Start with 300s, decrease ratio between each **not to be lower than half of before**
 - As listed [300, 200, 130, 70, 40, 30, 20] seconds

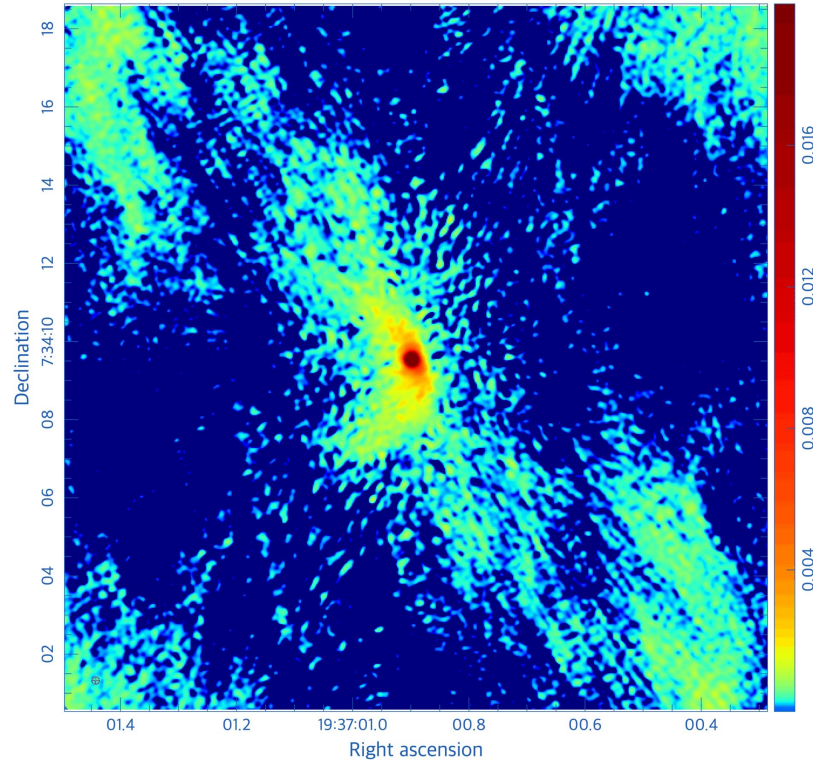
mJy/Beam	300s	200s	130s	70s	40s	30s	20s
Peak	79.39	82.31	85.37	87.76	89.60	90.56	91.42
RMS	0.216	0.202	0.191	0.185	0.1824	0.1821	0.1831
S/N ratio	368.17	406.69	447.45	473.76	491.15	497.40	501.44



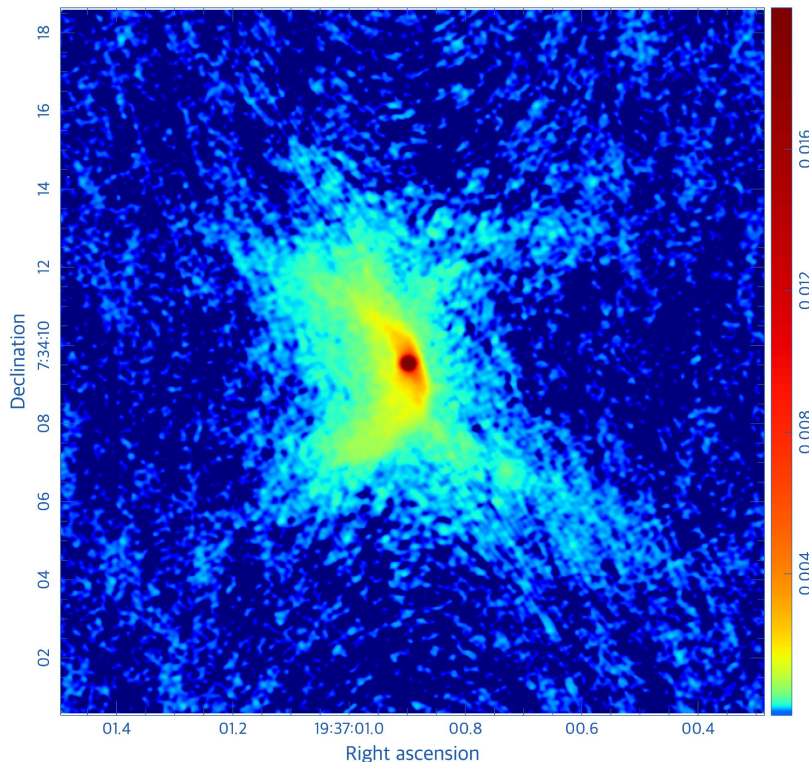




Case 3 : Interval time for solutions



Case 3 : Interval time for solutions

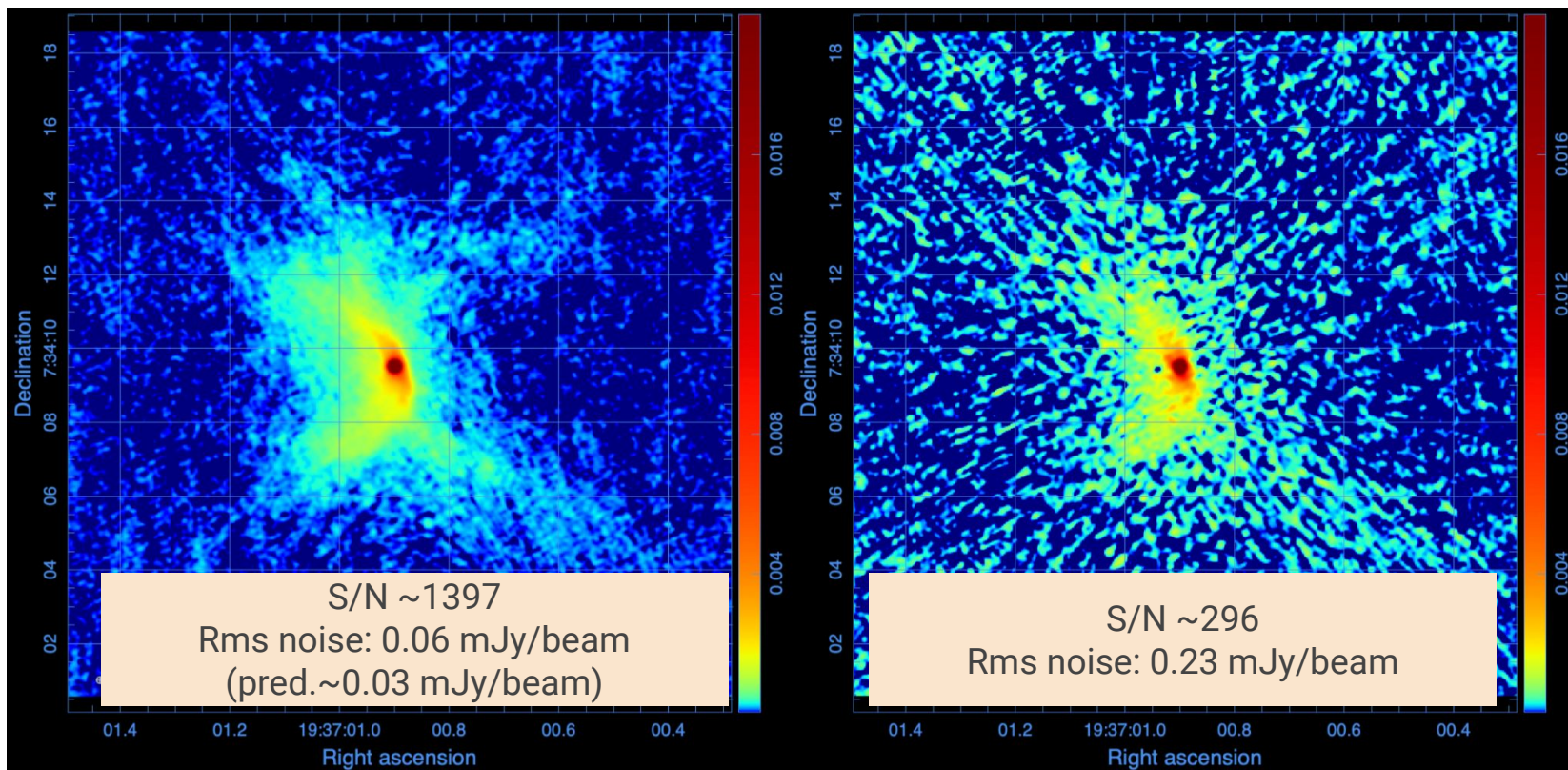


sol.int.	20	sec
Peak	90.07	mJy/Beam
RMS	0.06	mJy/Beam
S/N ratio	~1571	

^^The Best SNR!^^

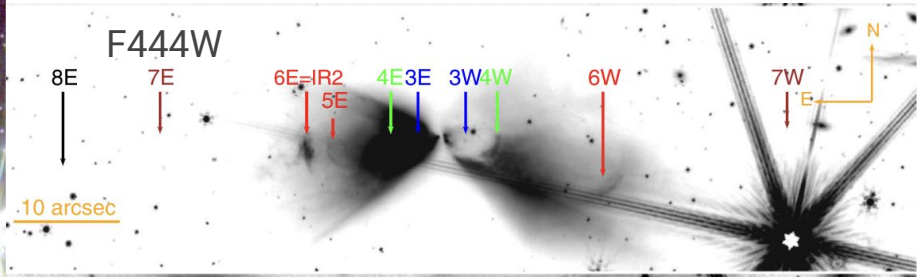
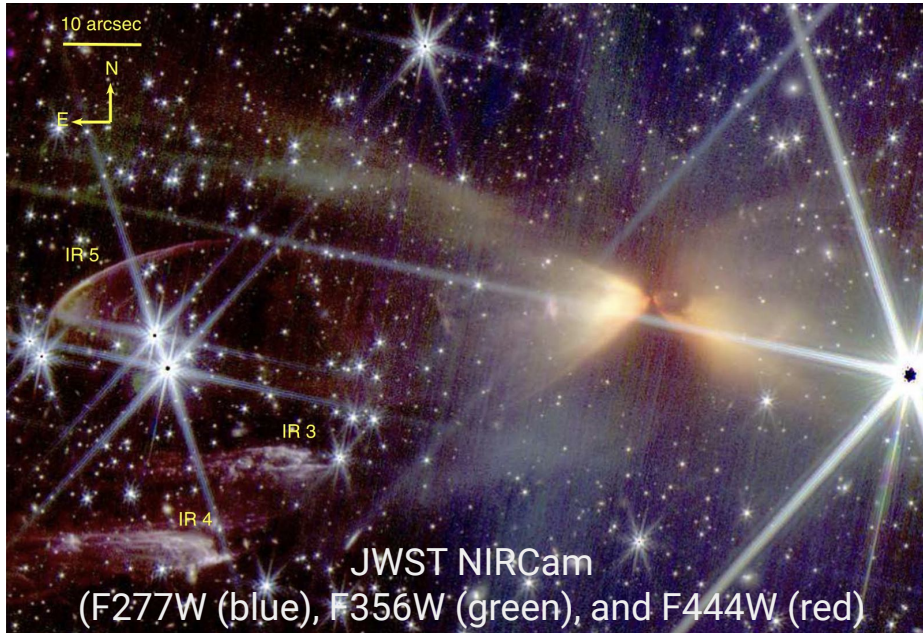
Discussion

Image before/after self-calibration



B335

An isolated globule in Aquila (d=164.5 pc)
Bipolar outflow from an embedded protostar



Hodapp et al. 2024, ApJ, 167, 102

Image before/after self-calibration

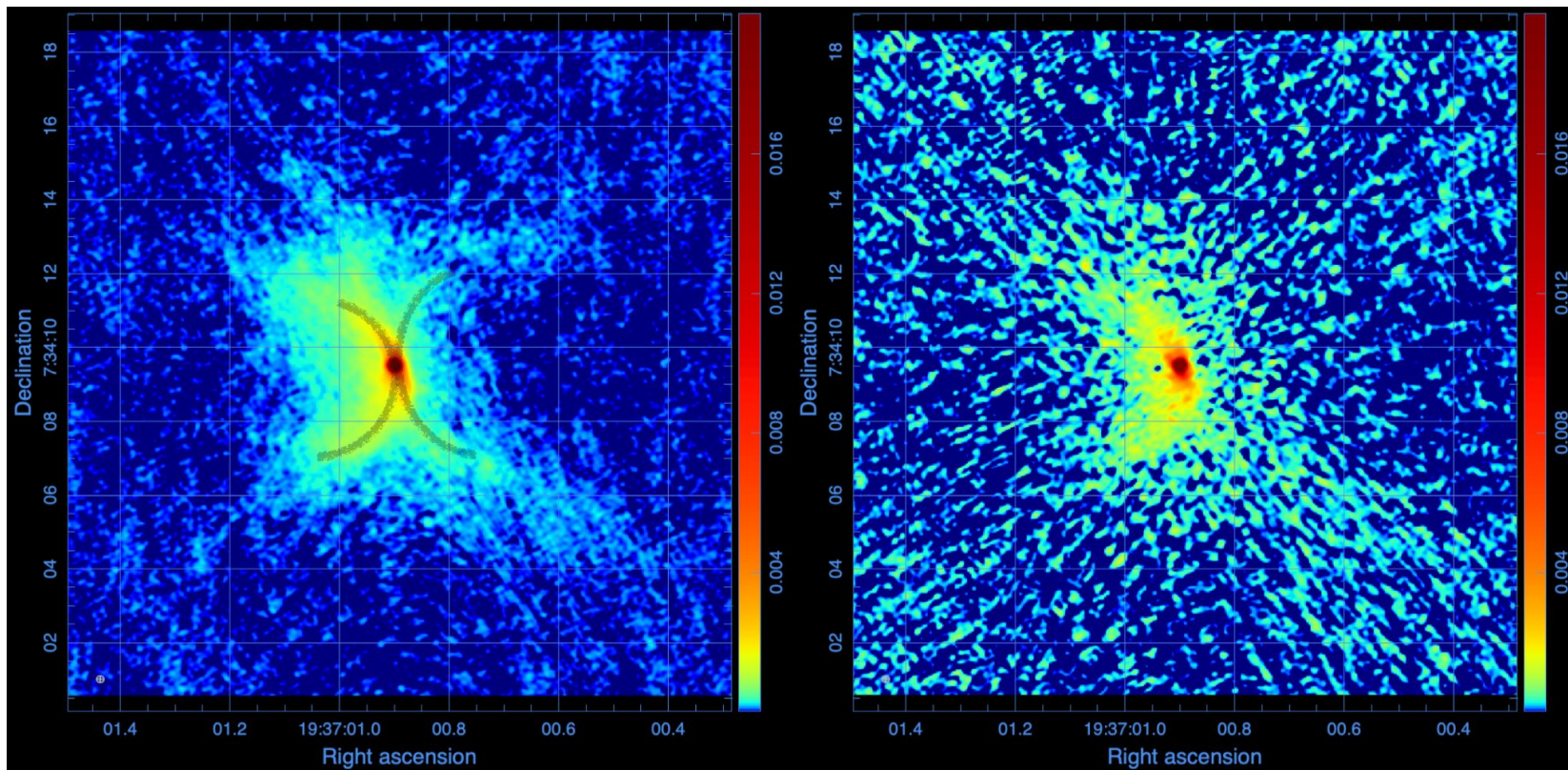
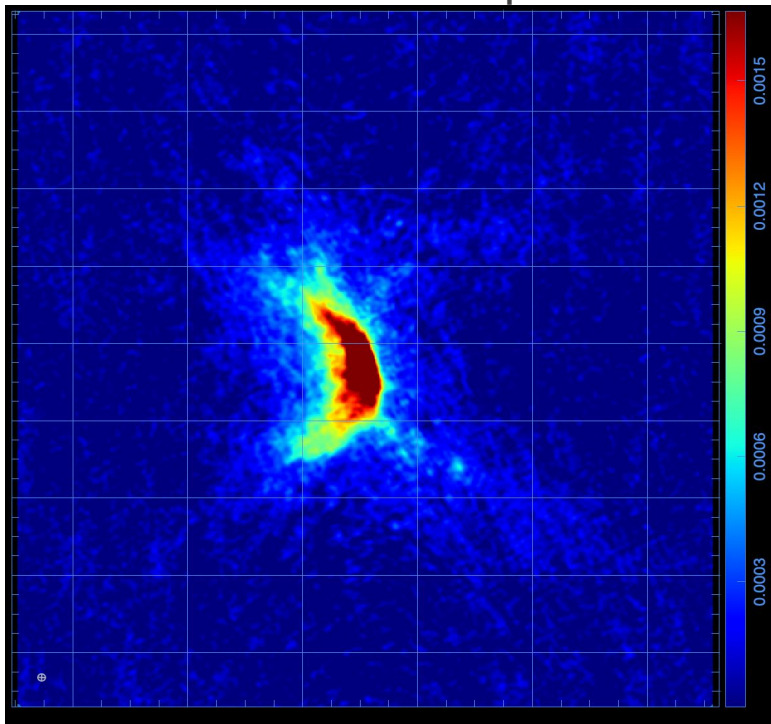
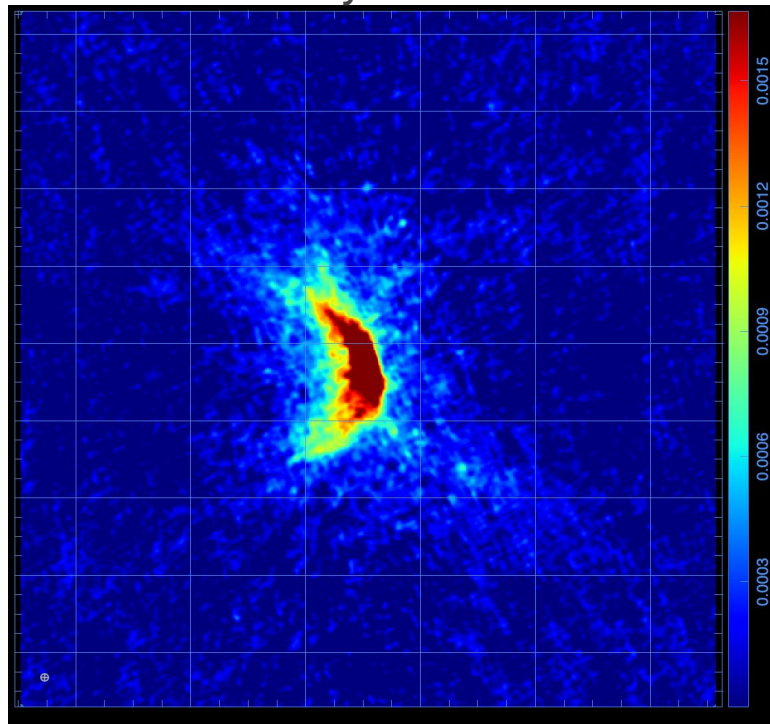


Image before/after amplitude self-calibration

Phase + Amp



only Phase



Take home message

Why?

When?

How?

Take home message

Why?

To improve the image quality!

When?

High signal-to-noise ($> \sim 100$), image noise level $>$ predicted

How?

Create model, performing self-calibration, CHECK solution, apply the solution to the data, and make the revised image

With decreasing the **solution interval time** and threshold

Let's try with your data!