Self-calibration

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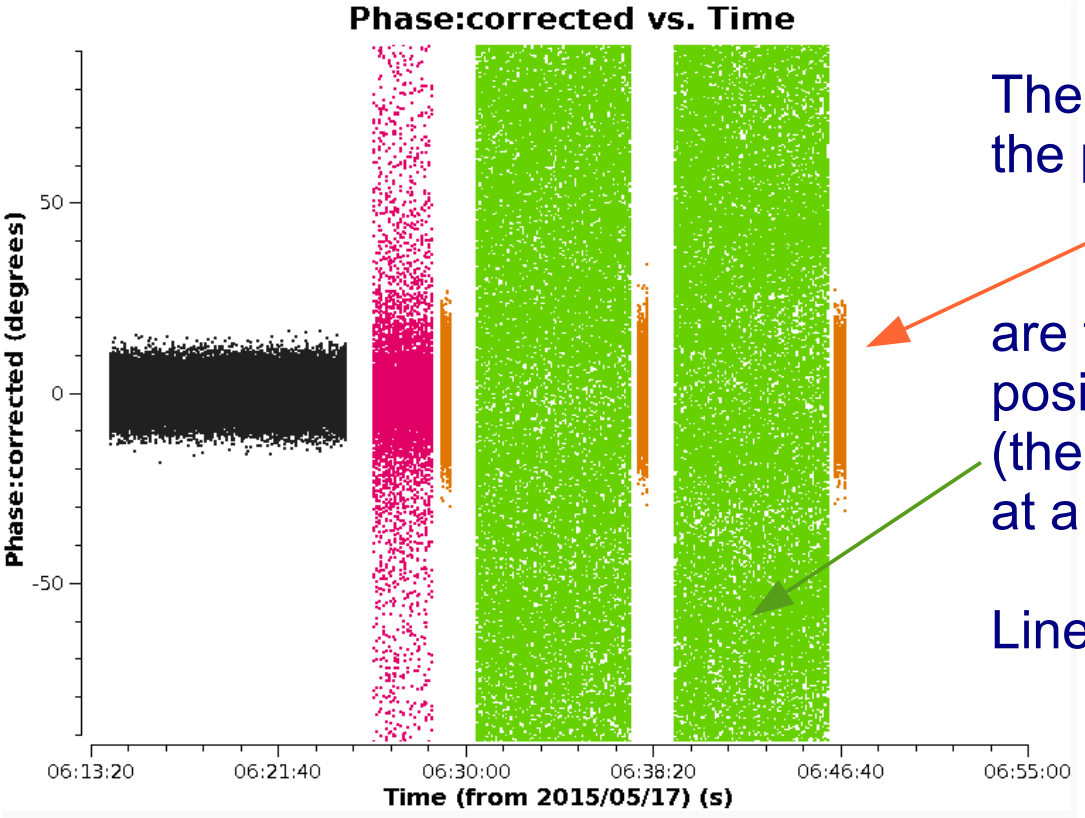
- Why self-calibration works
- When it is possible to self-calibrate
- Self-calibration in practice

Self-calibration

- **Calibration using external calibrators in not perfect**
  interpolated from different time, different sky directions from source



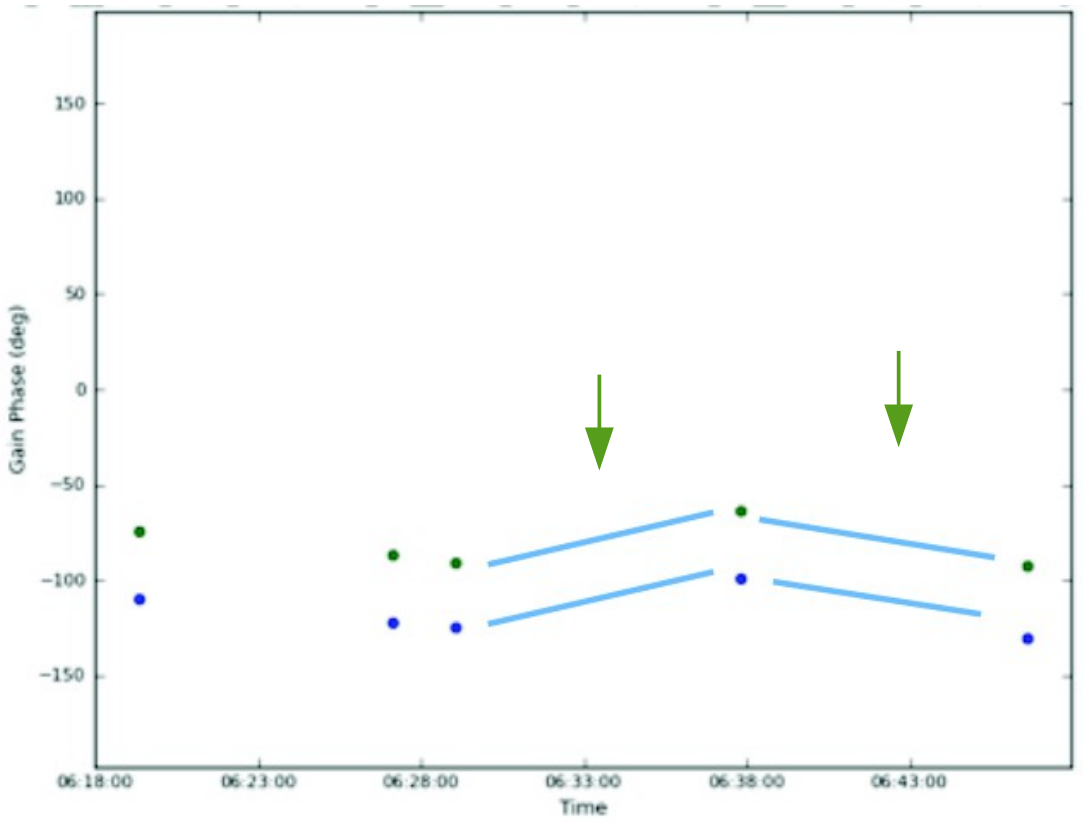
The solutions obtained for the phase calibrator

are transferred to a different position in the sky (the target) at a different time.

Linear interpolation is an assumption.

Self-calibration

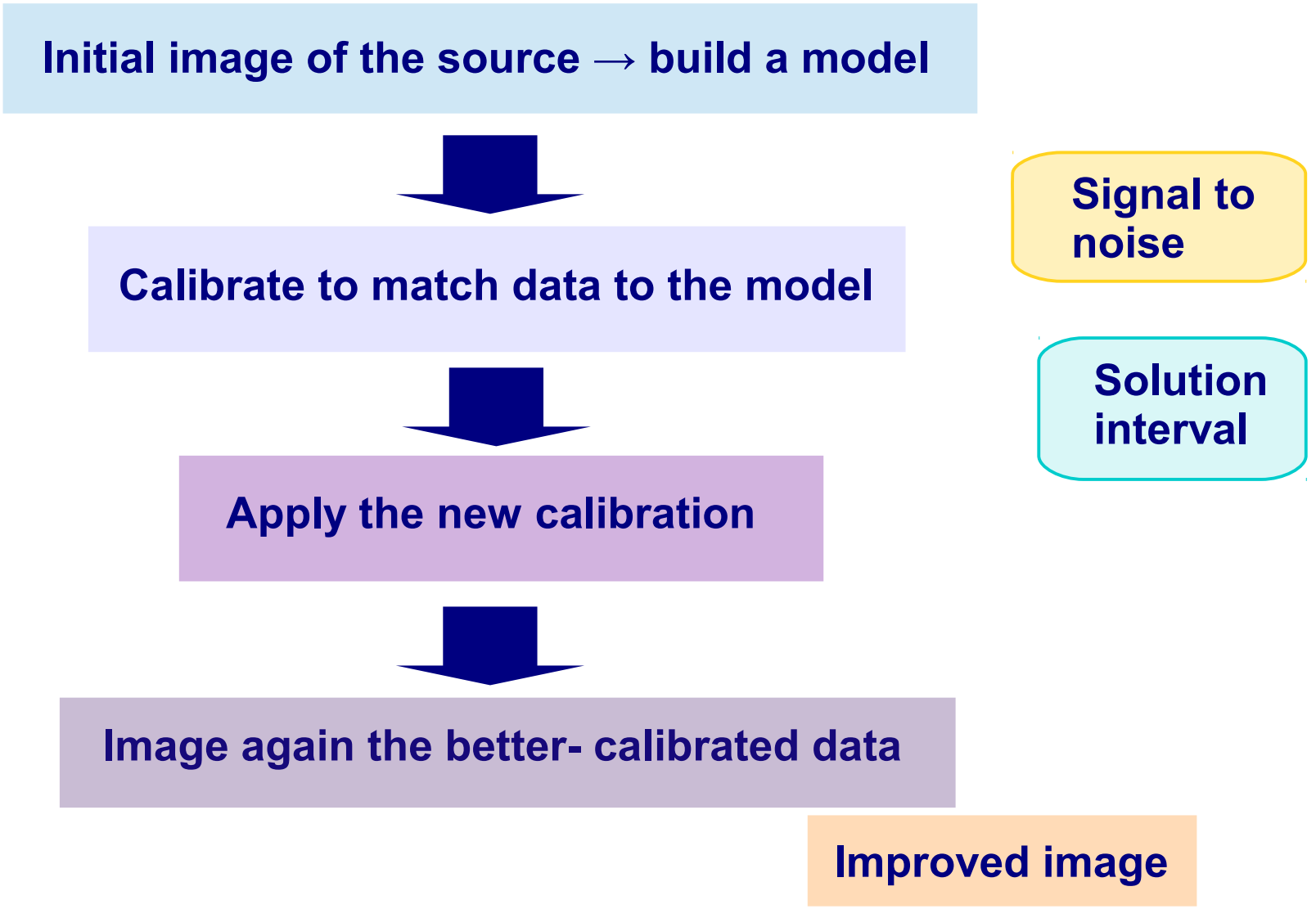
- **Basic idea:** objects with enough S/N can be used to calibrate themselves determine gains



- **Why it works?**
- **Redundancy:**
  for N antennas we measure N(N-1) / 2 visibilities and after the calibration only N amplitude gains N-1 phase gains describe the complete calibration of the data
- **It is dangerous in case of arrays with a small number of antennas and complex sources**

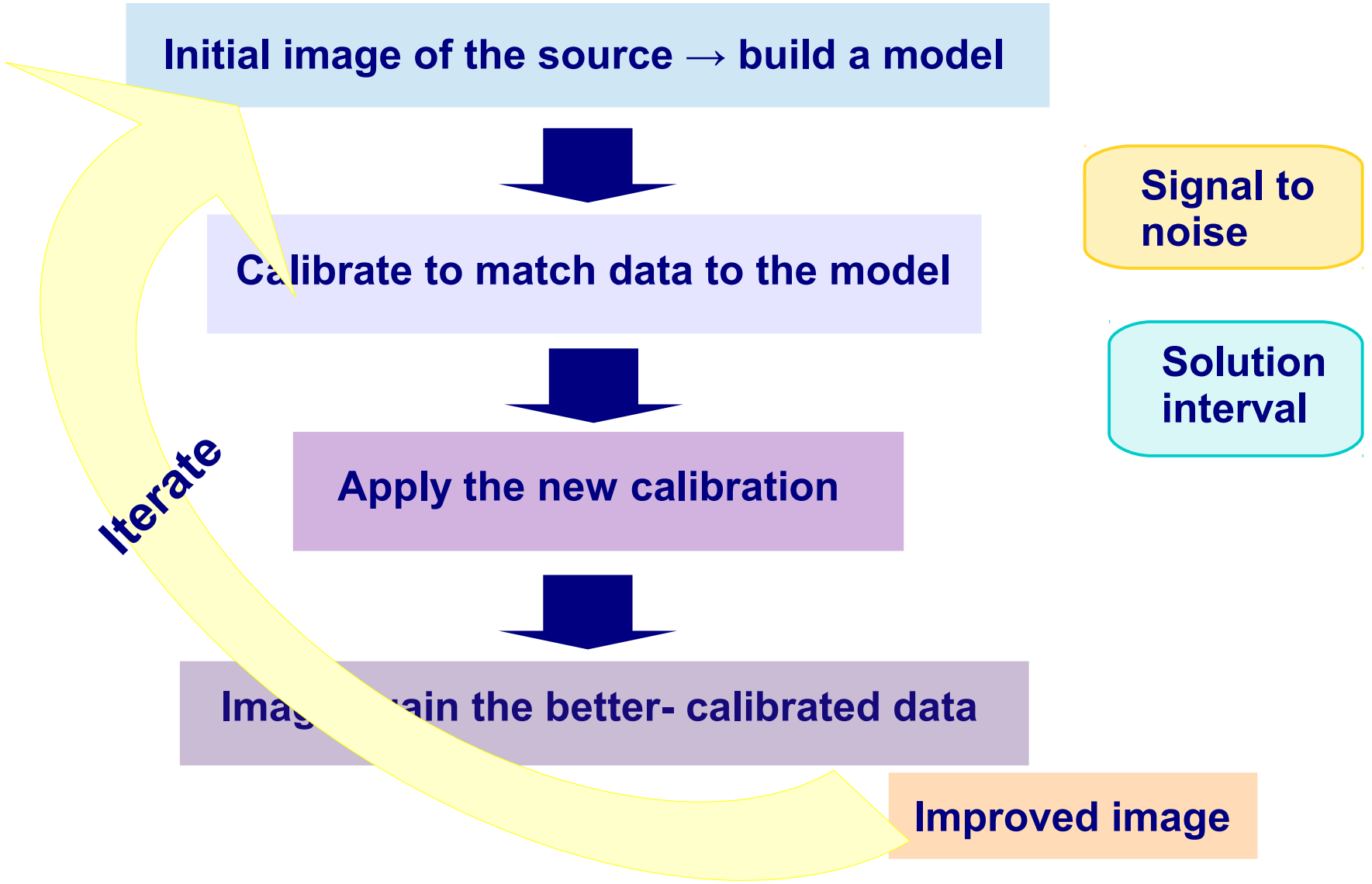
Self-calibration

- **Basic idea:** objects with enough S/N can be used to calibrate themselves to obtain a more accurate image.



Self-calibration

- **Basic idea:** objects with enough S/N can be used to calibrate themselves to obtain a more accurate image.



Self-calibration

- The source has to be bright enough

Signal to noise

- Even for bright sources, some degree of averaging maybe needed when calculating gains:

  - Averaging time

  - Average together SPWs

  - Average together polarizations

Solution interval

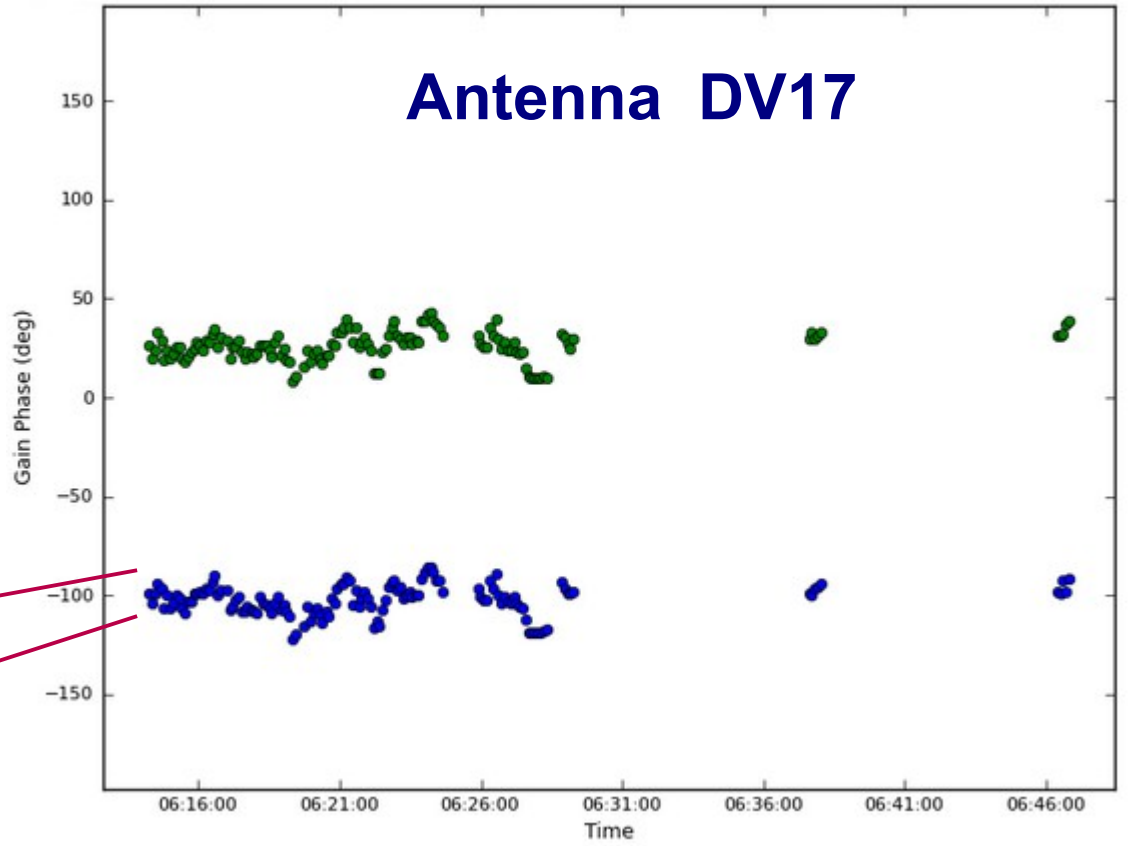
- Time averging used to obtain the gains should be as short as possible

- Ideally, solutions should be obtained for each integration time

Self-calibration

- Phase errors of instrumental and tropospheric errors ~ 10-20 deg
- Amp errors of expected instrumental and absorption amplitude errors, usually < 5%
- What we achieve is often limited by residual calibration errors.
- Phase offsets are the biggest problems.

~10 deg



Self-calibration

- Phase errors of instrumental and tropospheric errors ~ 10-20 deg
- Amp errors of expected instrumental and absorption amplitude errors, usually < 5%
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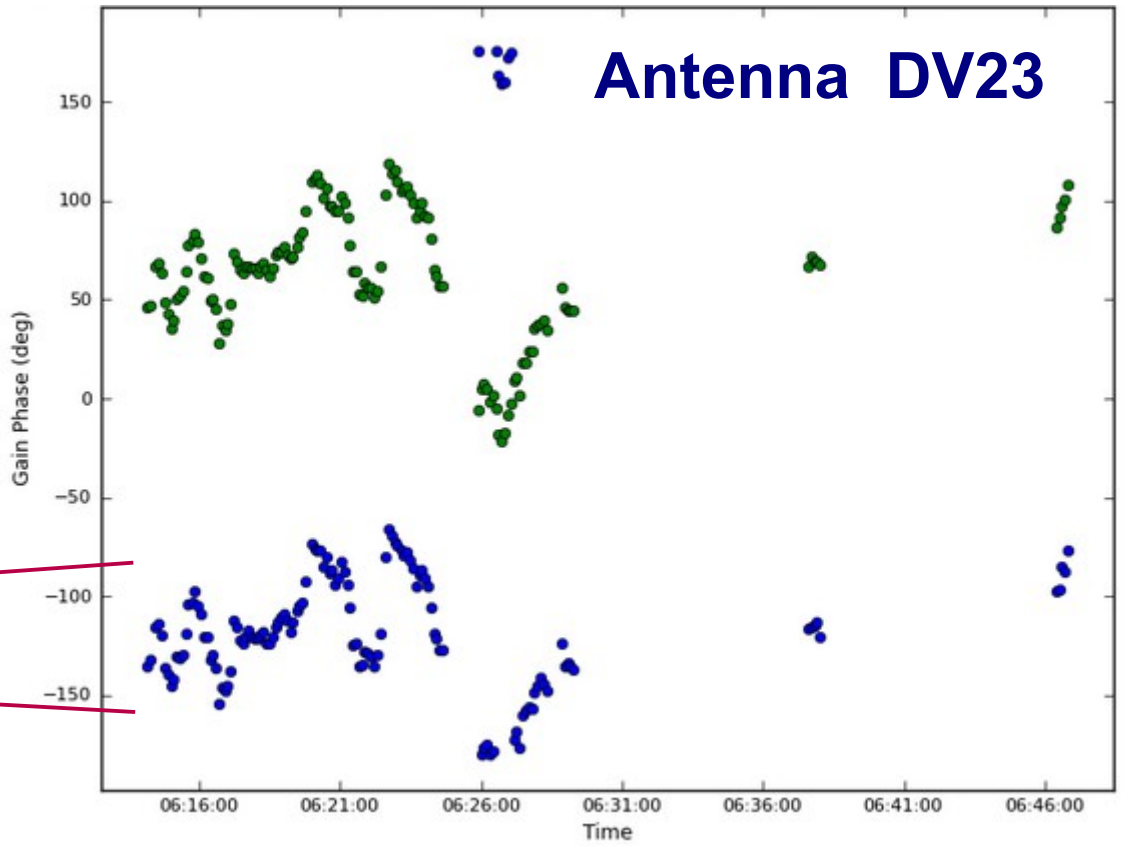
~40 deg



Self-calibration

Signal to noise

- The aim of self-calibration is to get phase errors smaller than 10-20 deg and amp errors < 5%

Image rms

$$\sigma_i = \frac{\sigma_b}{\sqrt{N(N-1)/2}}$$

Baseline rms

Antenna rms

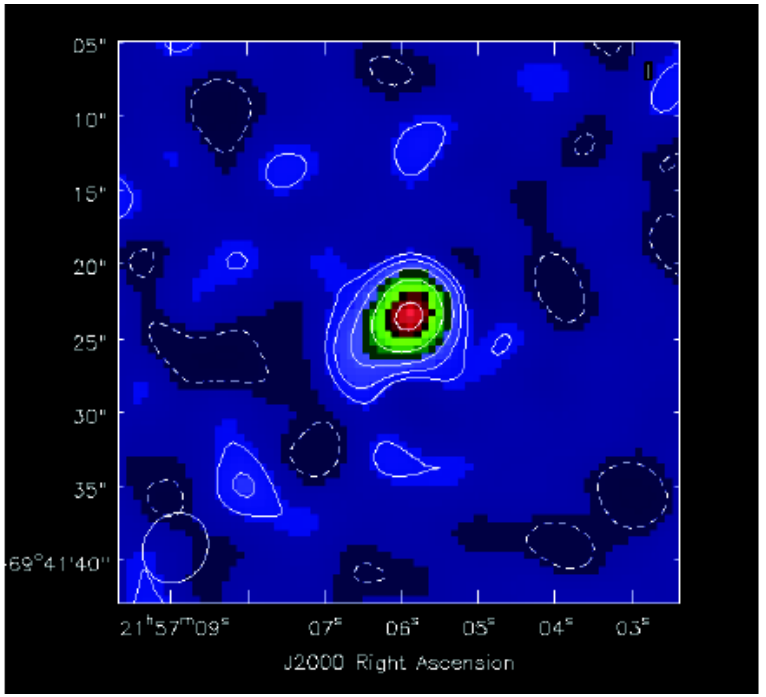
$$\sigma_G = \frac{\sigma_b}{\sqrt{N-3}}$$

For calibration the critical factor is the antenna gain dynamic range. CASA task gaincal has a default minimum value of 3 as SNR of the gains.

Self-calibration

Signal to noise

- In general if the S/N of the image is > 20 it is worth trying phase-only self-calibration
- Image the data (with standard calibration applied)
- During this first clean use boxes only around emission you are sure is real at this stage (point sources if there are)



No selfcalibration

Imaging dinamic range

64

Self-calibration

Solve for phase gains in an appropriate solution interval

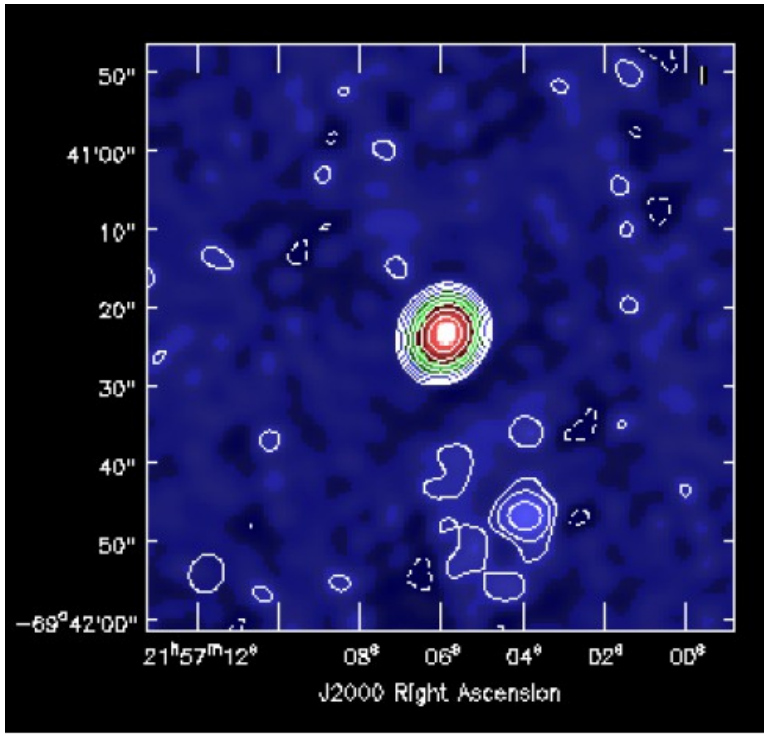
Solution interval

- How to define it

- For a given number of antennas, the higher is the S/N on the image the shorter the solution interval can be.
- Solution interval for amplitude calibration usually larger than for phases.
- For ALMA data a good choice is to start with the scan length or half of it.
- Check if the number of solutions thrown out is not too large. More than 30% means that the target is too weak.
- Experiment adding averaging (spw, polarization)

Self-calibration

- Apply the solutions
- Image the data again, including more emission into clean boxes if it looks real
- If the phase corrections were larger than 30 deg you would see a big improvement
- If the noise is lowered >50% do another phase self-cal



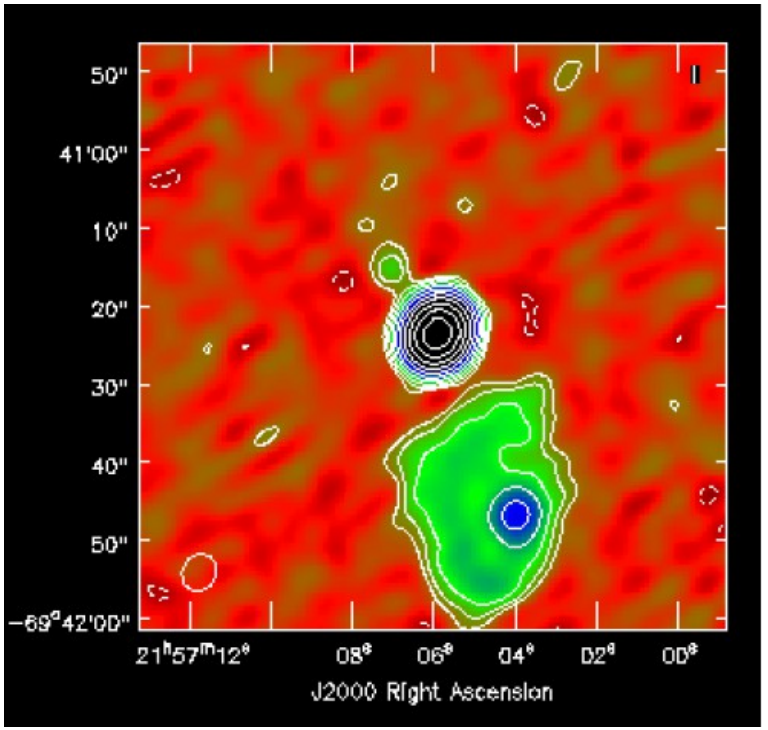
One phase cal iteration

Imaging dinamic range

545

Self-calibration

- When happy with phase solutions
  Try amplitude self-cal
- Amplitude tends to vary more slowly than phase, so solution intervals are typically longer.
- Essential to apply the best phase only self-cal before solving for amplitude.



Two phase cal iteration and amp cal

Imaging dinamic range

2033

Self-calibration

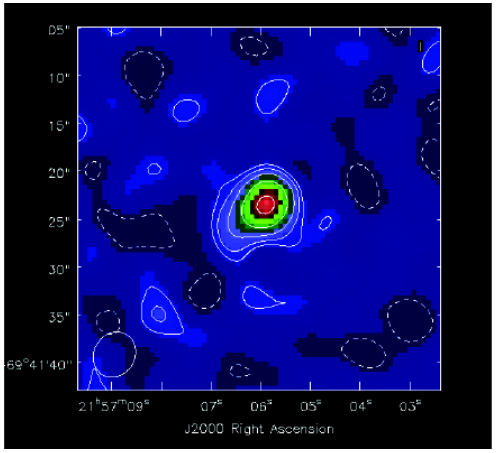
- Results are not always as impressive as these ones. It depends on the starting errors in the data...

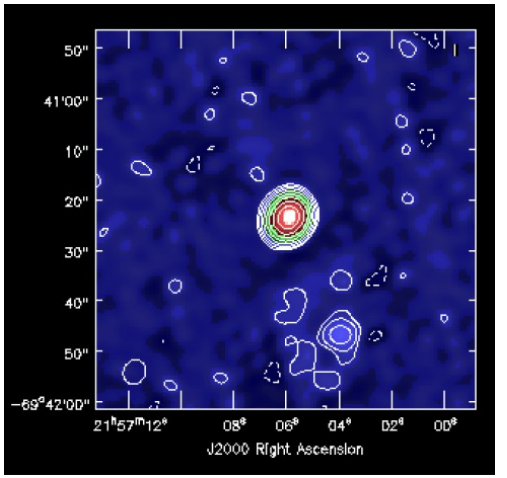
- Things to be careful about

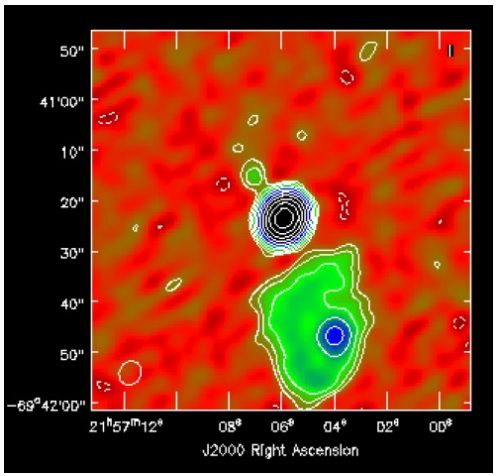
During first runs of clean be conservative

- stop clean when residuals look noise-like but be careful with boxes

You cannot get rid of real emission by not boxing it
You can creat features by boxing noise







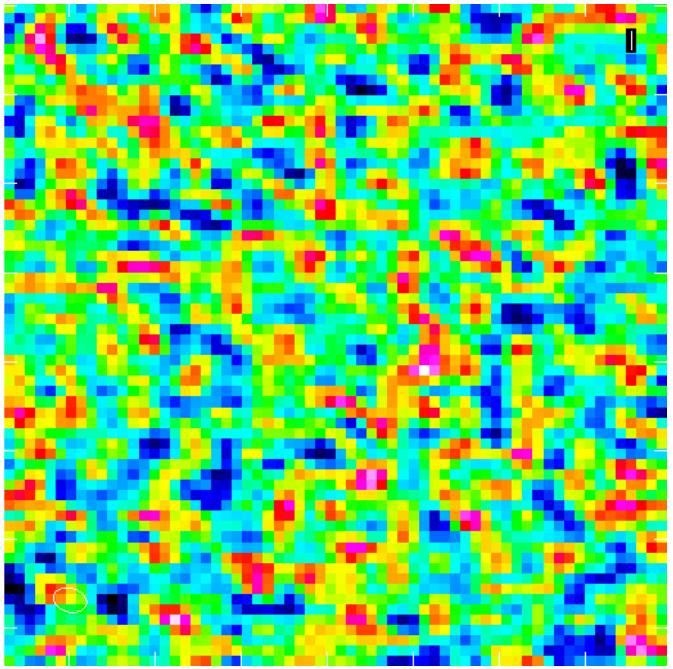
Self-calibration

- Things to be careful about

When solving for gains

- never lower the minimum S/N of solutions

No detection
only noise



Self-calibration

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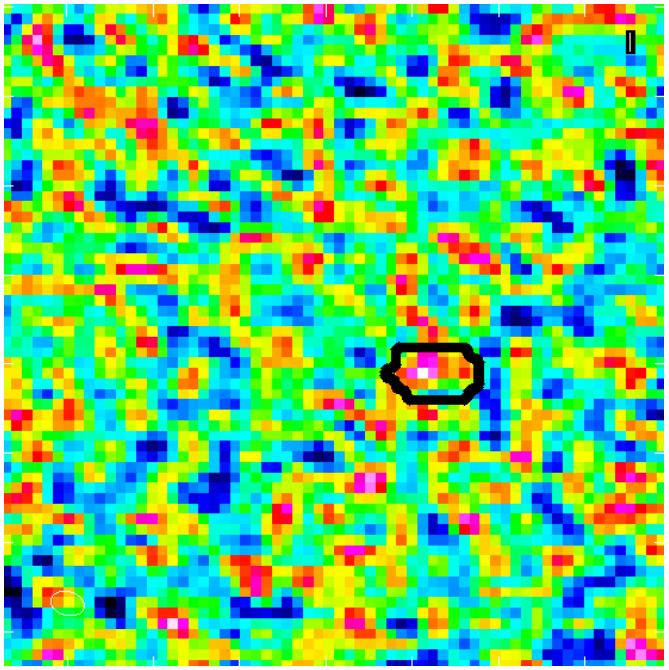
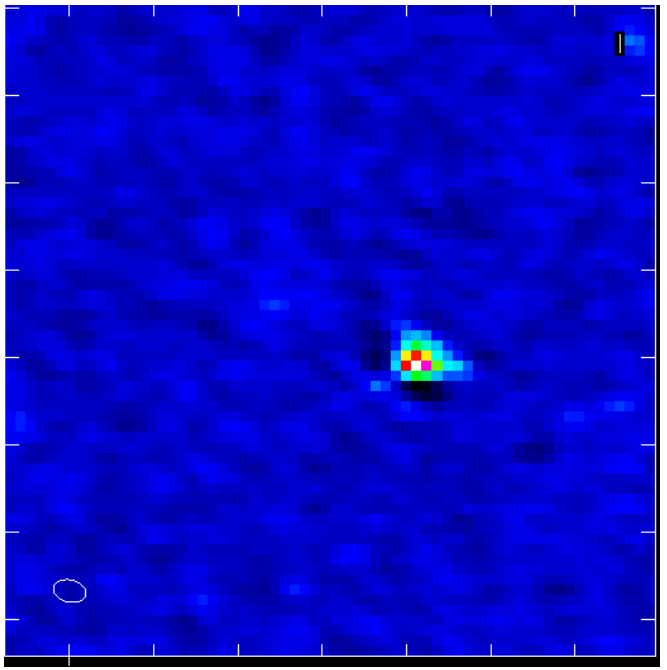


phase-cal with minsnr=1



CASA task gaincal prevents you from making this mistake unintentionally a default minimum value of 3 as SNR of the gains → NEVER CHANGE IT

Self-calibration

- Things to be careful about

When solving for gains

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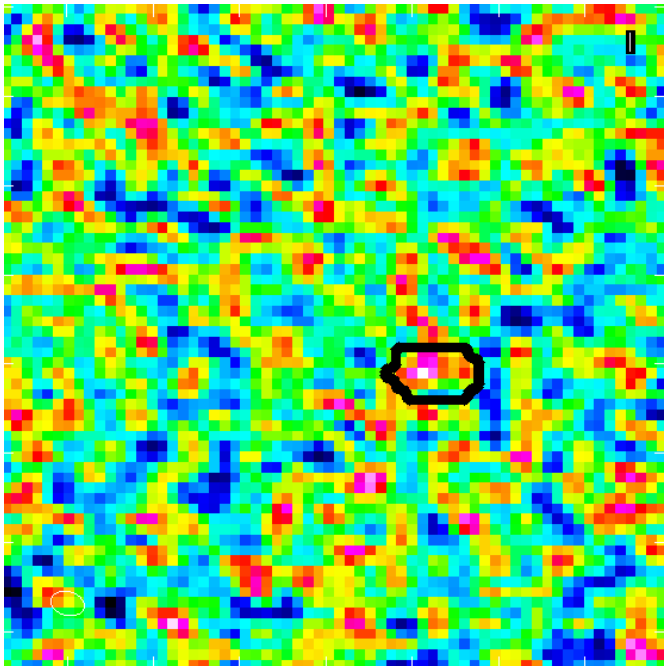
No detection only noise



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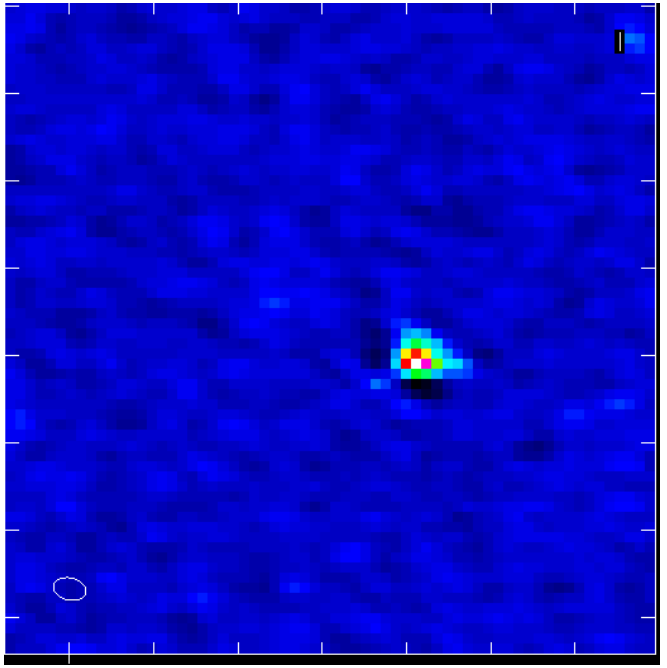
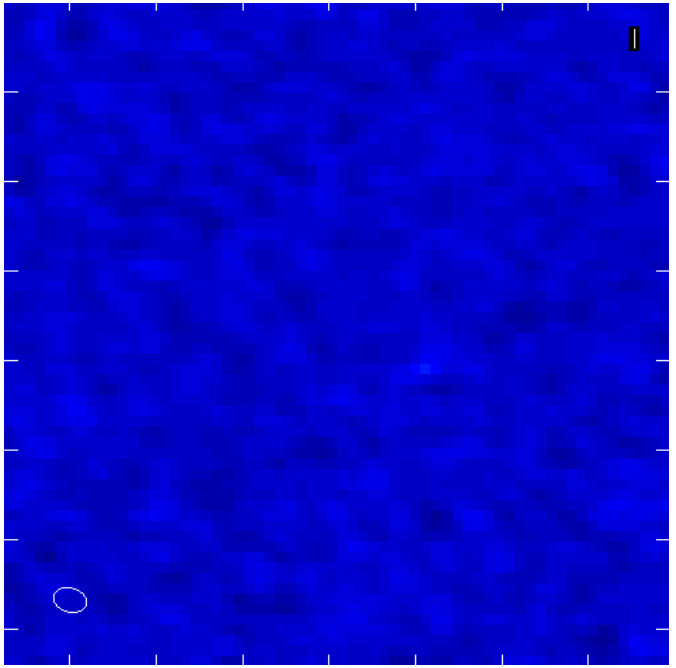


phase-cal with minsnr=3



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Self-calibration

- **On mosaic images**
  similar to single field self-cal, pick only the strongest mosaic field
  or few field if about the same brightness

- **Continuum or line**
  choose whichever gives better S/N and apply solution to all the data

- **CASA guides with self-calibration examples**

https://casaguides.nrao.edu/index.php/AntennaeBand7

https://casaguides.nrao.edu/index.php/ALMA2014_LBC_SVDATA

https://casaguides.nrao.edu/index.php/3C286_Polarization

Self-calibration in practice

- **Small dataset**

  3 scans (30 s each) on the calibrator J2157-694

- **Initial S/N ~1000**

  S/N is so high that it could be possible to start already from the solint=int

  We start from 15s (half scan length)
  to show a more general self-calibration strategy

The improvement is not impressive as in the example shown before but there is still an improvement in sensitivity of a factor of ~ 4.