Self Calibration

Sept 25th 2020

Logan Francis
PhD Student UVic

What is Self-Calibration?

- Self-calibration is identical to regular calibration, but using the science target itself as a model to calibrate the data.
- This is possible because of the overconstrained nature of calculating the antenna based complex Gains: $N_{vis} \propto N_{baselines} = (N_{ant} - 1)(N_{ant} - 2)/2 \sim N_{ant}^2$

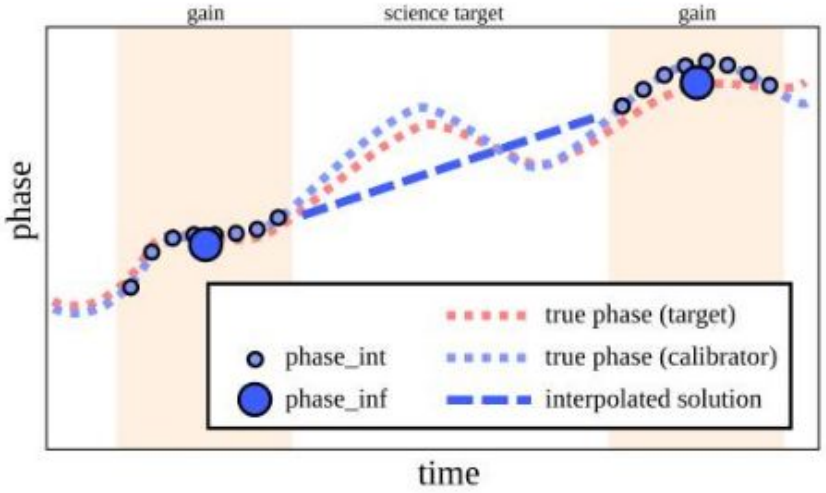
$$\mathcal{V}_o^{i,j}(t_k, \nu_f) = \mathcal{V}_m^{i,j}(t_k, \nu_f) * G^{i,j}(t_k, \nu_f)$$

$$G^{i,j} = G^i G^j = \mathcal{V}_m / \mathcal{V}_{\rm cal}$$

- In this case, rather than a point source, we use an **approximate model** of the science target for calibration, which is **updated iteratively** as we improve our calibration.

Why Self-Calibrate?

- **Phase errors** change rapidly and **dominate our ability to make accurate models** of our science targets.
- Gain calibrator interpolation is never perfect.
- Self-calibration can **drastically** improve your SNR, factors of 3-5 improvement are possible.
- Amplitude self-calibration is also possible, but generally results in smaller improvements.



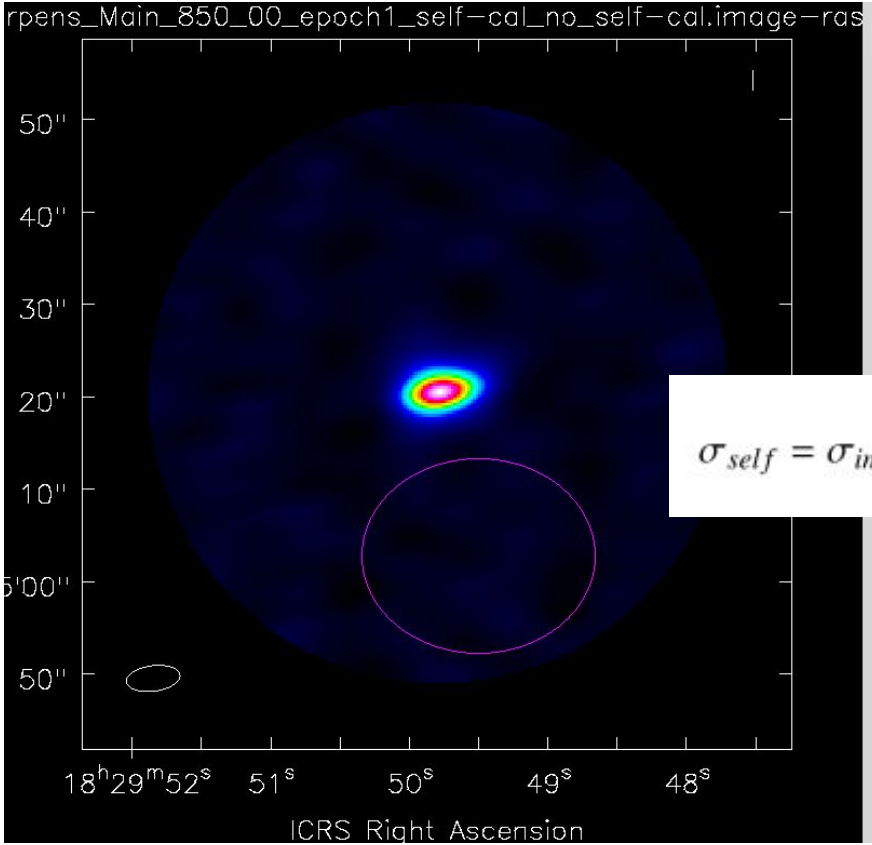
Can I self-calibrate my data?

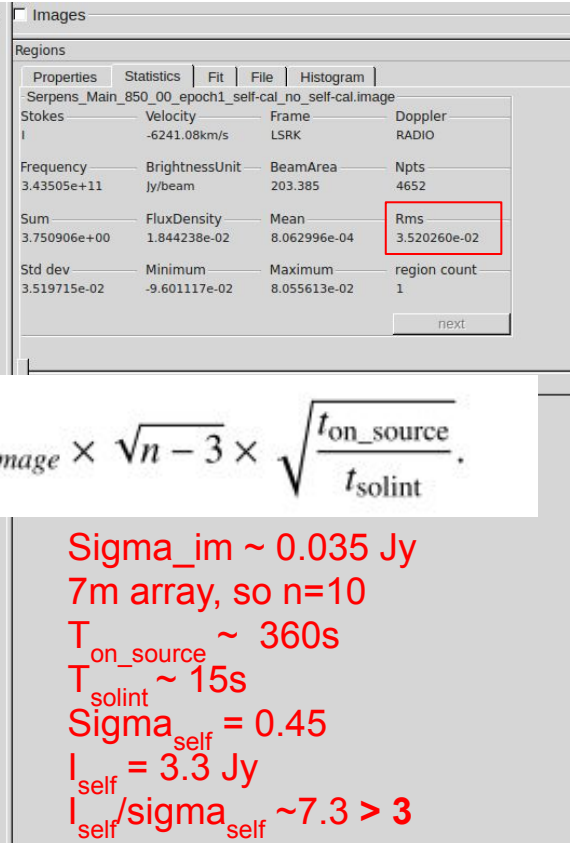
- Determine if self-calibration is possible for your data - Need SNR>3 for a single antenna and solution (time interval):

$$\sigma_{self} = \sigma_{image} \times \sqrt{n-3} \times \sqrt{\frac{t_{\text{on\_source}}}{t_{\text{solint}}}}.$$

- Rule of thumb - try self-cal if SNR > 20 for ALMA. Self Even if self-cal **fails**, you will learn about problematic data/antennas that contribute to image artefacts.

Can I self-calibrate my data?





$$\sigma_{self} = \sigma_{image} \times \sqrt{n-3} \times \sqrt{\frac{t_{\text{on\_source}}}{t_{\text{solint}}}}.$$

Sigma_im ~ 0.035 Jy
7m array, so n=10
T_{on_source} ~ 360s
T_{solint} ~ 15s
$Sigma_{self}$ = 0.45
I_{self} = 3.3 Jy
$I_{self}/sigma_{self}$ ~7.3 **> 3**

Self-Calibration Procedure

1. Make an initial image without self-calibration. (tclean) Measure SNR (imstat). Backup flags (flagmanager)
2. Perform a **shallow** clean and save the results in model column of ms (tclean)
3. Run an initial phase self calibration with a long solution interval (gaincal)
4. Inspect the solutions (plotcal). Are they noisy, or do they vary smoothly with time?
5. Apply solutions to measurement set (applycal).
6. Clean somewhat deeper and image the **corrected data**. Measure SNR. Did things improve? If so repeat, steps 2-5 until SNR improvement stops, with **shorter solution intervals** each time.
7. Optional: Try a round of amplitude self-calibration, especially if obvious “striping” artefacts visible.

Resources

- The procedure for self-calibration is relatively simple, but the fine details of what parameters to use can be tricky.
- CASA self-calibration template: https://casaguides.nrao.edu/index.php/Self_Calibration_Template
- CASA first-look at self-cal: https://casaguides.nrao.edu/index.php/First_Look_at_Self_Calibration (our tutorial this afternoon.
- NRAO synthesis workshop lecture “Advanced Calibration I”: https://science.nrao.edu/science/meetings/2018/16th-synthesis-imaging-workshop/talks/Brogan_Adv_Cal_1.pdf
- This lecture by NRAO black-belts, excellent resource even for experience ALMA users: https://arxiv.org/abs/1805.05266

Interactive self-calibration example

- Now watch me attempt to live self-calibrate an ALMA 7m array observation of an extremely bright (~3 Jy) point-like target.
- Feel free to ask questions during this demo.