

# **VLBA CASA Tutorial**

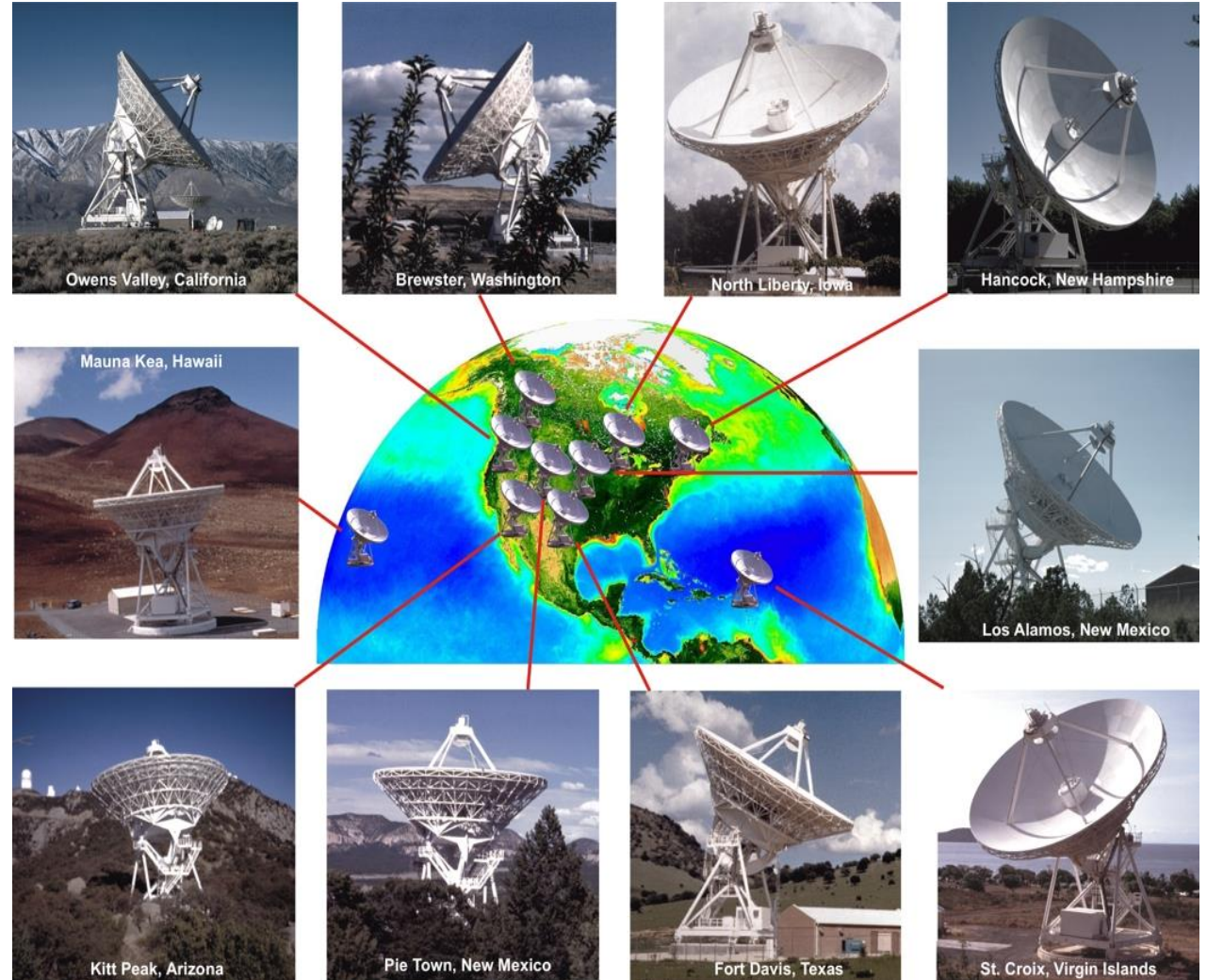
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# The Very Long Baseline Array

## Overview

- A 10 element interferometer radio telescope
  - Identical 25m diameter antennas
  - Array dedicated to Very Long Baseline Interferometry (VLBI)
- Antenna sites in US territory from Mauna Kea Hawaii to St. Croix, US Virgin Islands
  - Baseline lengths between 236 km and 8611 km
- Software Correlator (DiFX) in Socorro, NM



# VLBA Receivers



The feed horns on PT

Band	Frequency Range [GHz]	VLBA $\theta_{\text{HPBW}}$ [milliarcseconds]
90 cm (P)	0.312 – 0.342	22
50 cm	0.596 – 0.626	12
21 cm (L)	1.35 – 1.75	5.0
13 cm (S)	2.2 – 2.4	3.2
6 cm (C)	3.9 – 7.9	1.4
4 cm (X)	8.0 – 8.8	0.85
2 cm (Ku)	12.0 – 15.4	0.47
1 cm (K)	21.7 – 24.1	0.32
7 mm (Q)	41.0 – 45.0	0.17
3 mm (W)	80.0 – 90.0	0.12*

\*SC and HN do not have 3mm receivers, so the longest baseline for that band is 6156 km

Dual S/X mode for simultaneous 2.3 and 8.4 GHz observing

# VLBA CASA Guide Tutorial

## VLBA Basic Phased-Referencing

- Website: [https://casaguides.nrao.edu/index.php?title=VLBA\\_Basic\\_Phase-referencing\\_Calibration\\_and\\_Imaging](https://casaguides.nrao.edu/index.php?title=VLBA_Basic_Phase-referencing_Calibration_and_Imaging)
  - Need a ~4 GB fits-idi file
    - DO NOT try to download the data now! The dataset is on the USB drive.
  - Self-calibrate phase-reference calibrator and apply those solutions to a science target
- How this compares to the AIPS tutorial:
  - The CASA tutorial has a smaller data set
  - The CASA tutorial will likely run slower
  - The CASA tutorial is a continuum project
  - The CASA tutorial does not include any astrometry steps
  - The CASA tutorial data set is closer to what you are most likely to see as a real data set

# Possible Issues

- Some Macs may not be able to use the CASA Viewer properly
  - Macs with ARM chips (M1, M2, etc.) cannot compile the necessary code for the CASA Viewer
  - This will cause problems with the interactive imaging section of the tutorial
    - Work-around: use the new iclean task or clean non-interactively using the clean box inputs for tclean
- Some computers may have problems with the CASA fringe-fit task
  - This is rare and should not occur during this tutorial

# Possible Issues

- Memory
  - If your laptop has limited RAM (<8 GB), it may not be able to handle some of the steps in the tutorial
  - Fringe fitting and imaging may take an extra long time
    - If you have CASA 6.7.5, the fringe-fit task will run faster thanks to recent improvements
- CASA version
  - If you do not have CASA version 6.6.5 or newer, some of the steps may not work
  - In particular, the Earth Orientation Parameter Correction step may not work and the smoothcal task may fail

# VLBA Calibration Tips

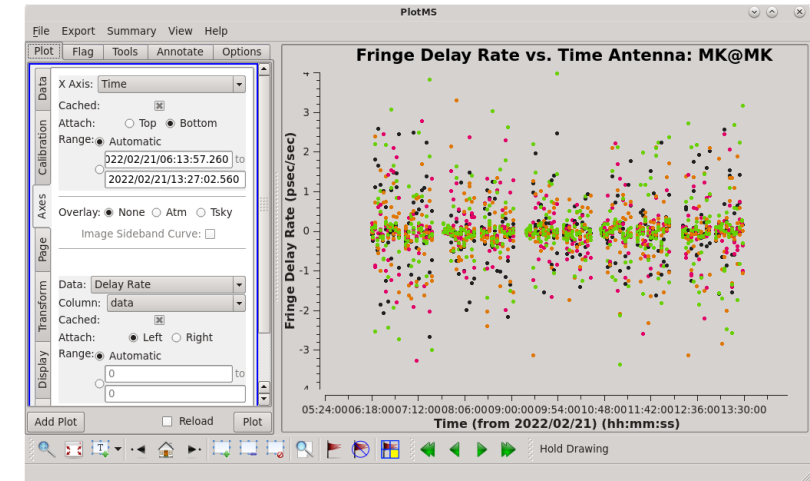
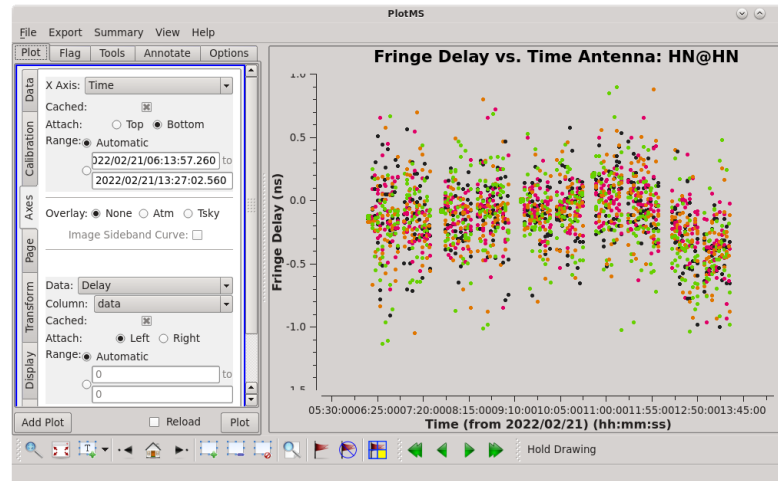
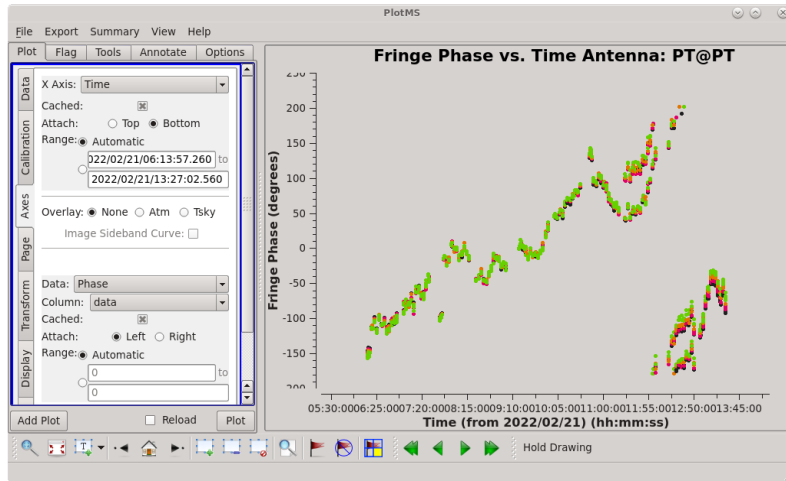
- Take notes as you work through the process!
  - I recommend taking notes in a text file
  - Saving the inputs as a function call makes it easy to turn your notes into a script if you need to run through the calibration a second time
- Be patient
  - Some CASA tasks can take a long time to run (e.g., plotms)
- Try to get to the global fringe fitting step before lunch
  - The global fringe fit will take a long time to finish (probably at least 15 minutes)
  - Having this task run while you get something to eat will make your life a bit easier

# Calibration– Fringe Fitting

- The major step in VLBI calibration that is not used for most connected element calibration is called “fringe fitting”
- During this step, the software solves the relative phase error equation to eliminate (or at least reduce) errors in both frequency and time

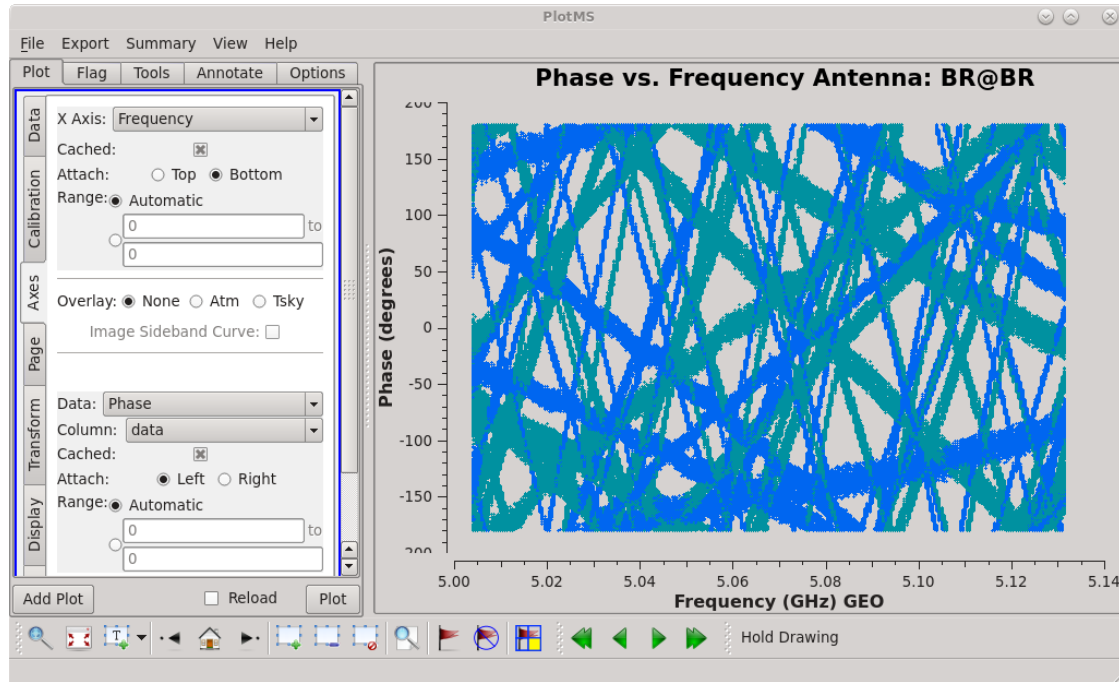
$$- \Delta\phi(t, \nu)_{ij} = \phi_{0i} - \phi_{0j} + \left( \left[ \frac{\partial\phi_i}{\partial\nu} - \frac{\partial\phi_j}{\partial\nu} \right] \Delta\nu + \left[ \frac{\partial\phi_i}{\partial t} - \frac{\partial\phi_j}{\partial t} \right] \right) \Delta t$$

– AIPS task: FRING; CASA task: fringeft

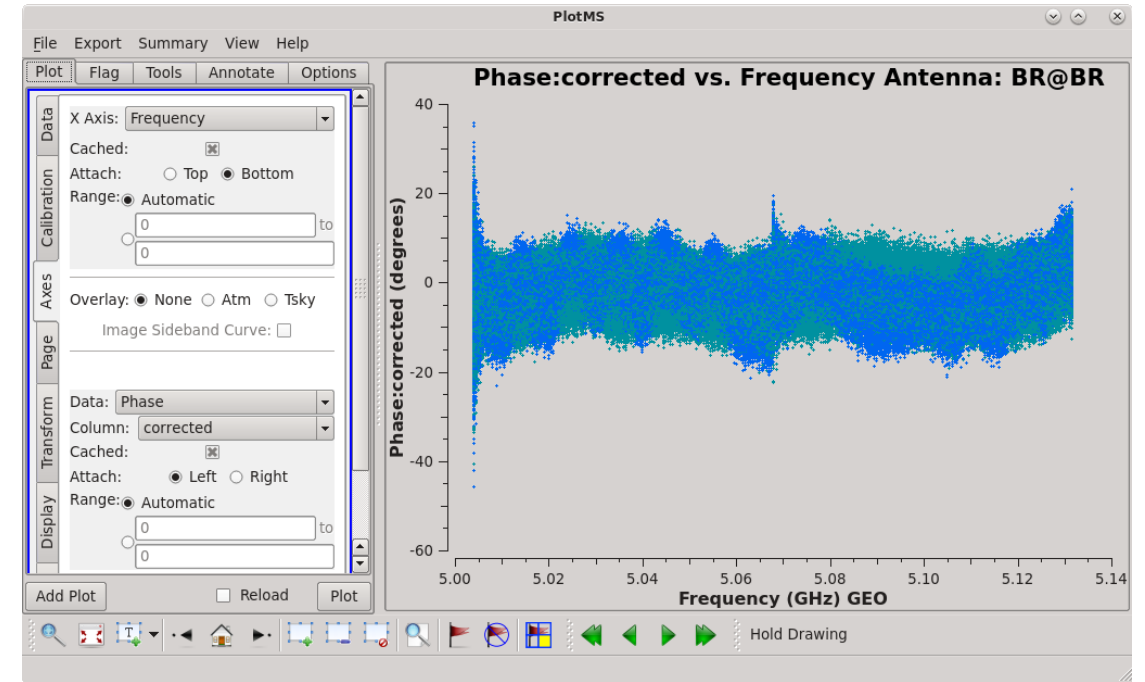


# Calibration – Fringe Fitting

Results of fringe fitting



Phase vs Frequency for all baselines to Brewster, before fringe fitting



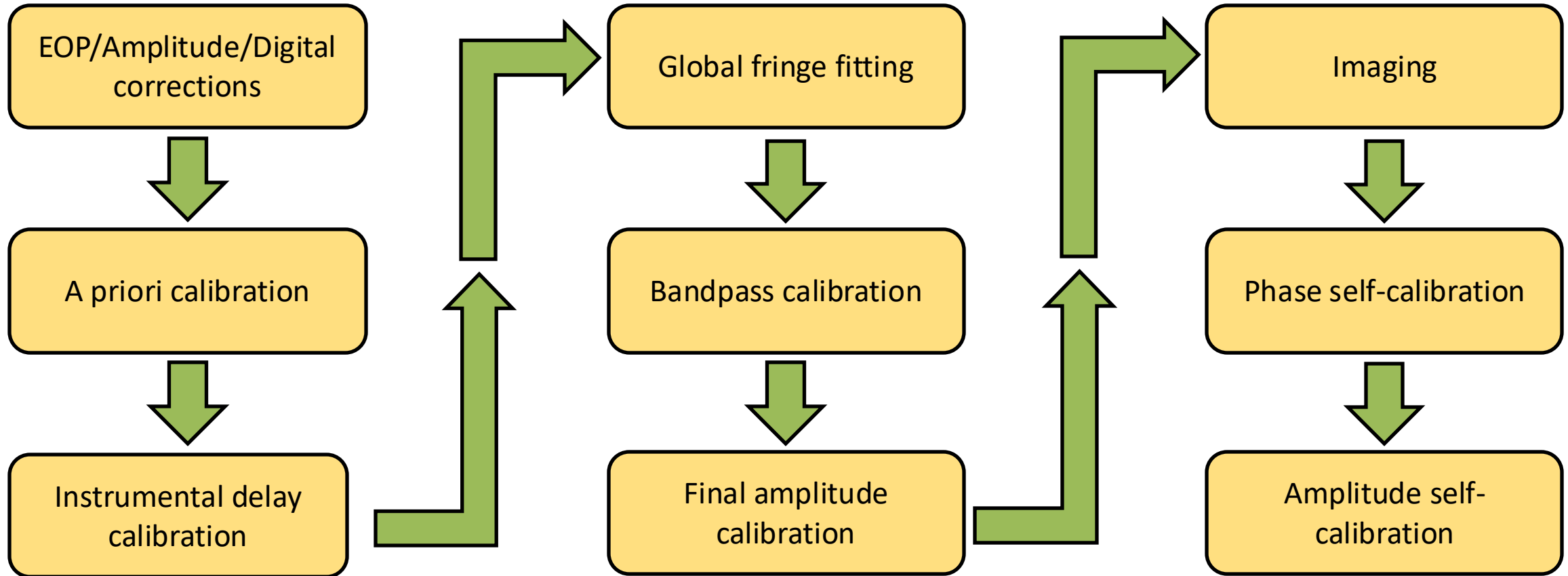
Phase vs Frequency for all baselines to Brewster, after fringe fitting

# Calibration – Fringe Fit Limitations

- Fringe fitting assumes the calibrator is a point source
  - If you picked a good calibrator, this is usually fine
  - If you know the calibrator structure, you can give the fringe fit task a model that may enable it to do a better job
- The effectiveness of the fringe fit task depends on the signal-to-noise of the calibrator scans
  - If the calibrator is not bright enough, fringe fitting will fail
  - Sometimes source variability ruins your entire observation
- If the ionosphere or atmosphere is changing faster than the nodding cycle, fringe fitting will not help much
  - “Decorrelation”
  - Not much you can do unless the target is bright enough for self-calibration

# VLBA Calibration Strategy

## Basic idea



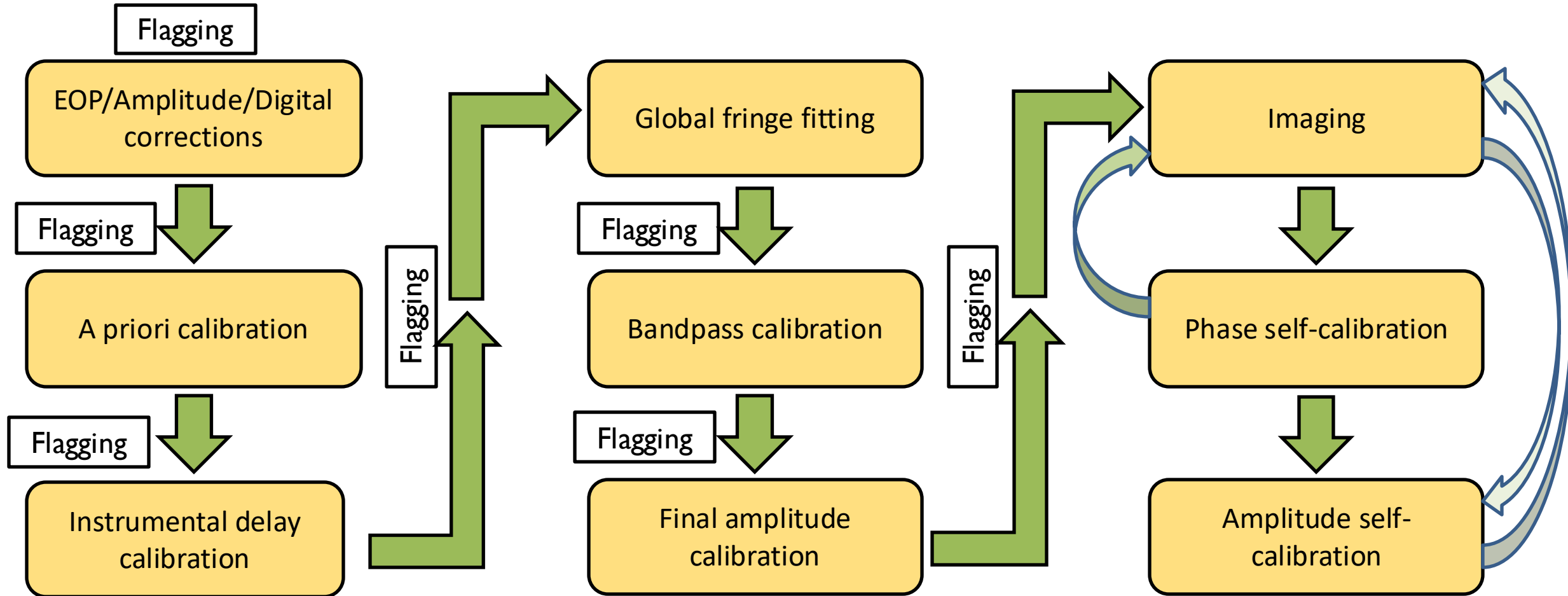
# VLBA Calibration Strategy

## Some differences between the CASA and AIPS continuum tutorials

- Bandpass Calibration
  - AIPS tutorial does bandpass calibration before global fringe fitting
  - CASA tutorial does bandpass calibration after global fringe fitting
  - In general, it is better to do bandpass calibration after global fringe fitting
- Flagging
  - The AIPS tutorial does flagging graphically
  - The CASA tutorial does automated flagging, and then “manual” flagging
  - CASA does not have good tools for flagging graphically
- Instrumental Delay
  - The AIPS tutorial uses the pulse-cal tones in the VLBA data to find the instrumental delay (VLBAPCOR)
  - In practice, it is often better to use fringe fitting to get the instrumental delay

# VLBA Calibration Strategy

More realistic





[www.nrao.edu](http://www.nrao.edu)  
[science.nrao.edu](http://science.nrao.edu)  
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