Testing MWA's WSClean imager on LOFAR data

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Background

- Goal: accurate calibration of 3c196 observations for EoR science
- Calibration:
  - Initial global calibration
  - Then, run Sagecal

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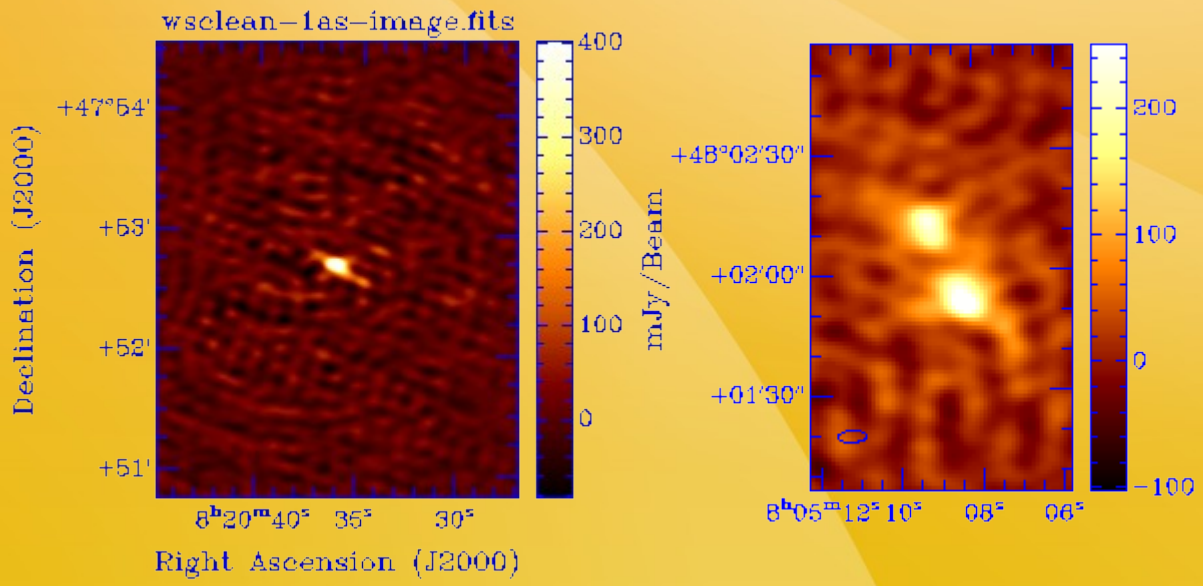
Needs good sky model

How to represent resolved sources in Sagecal's input model?



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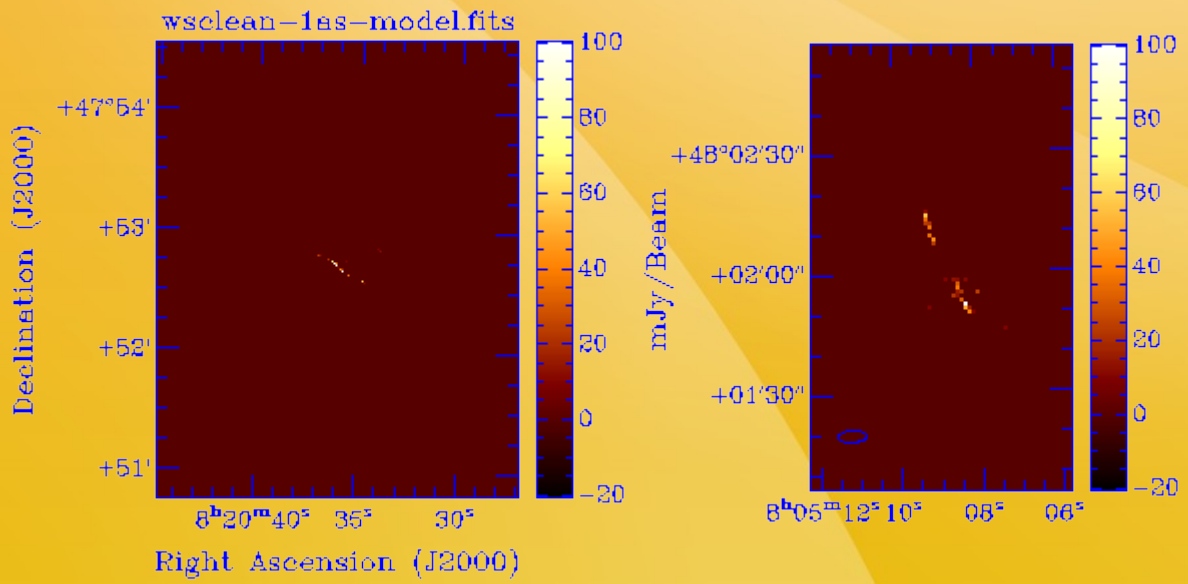
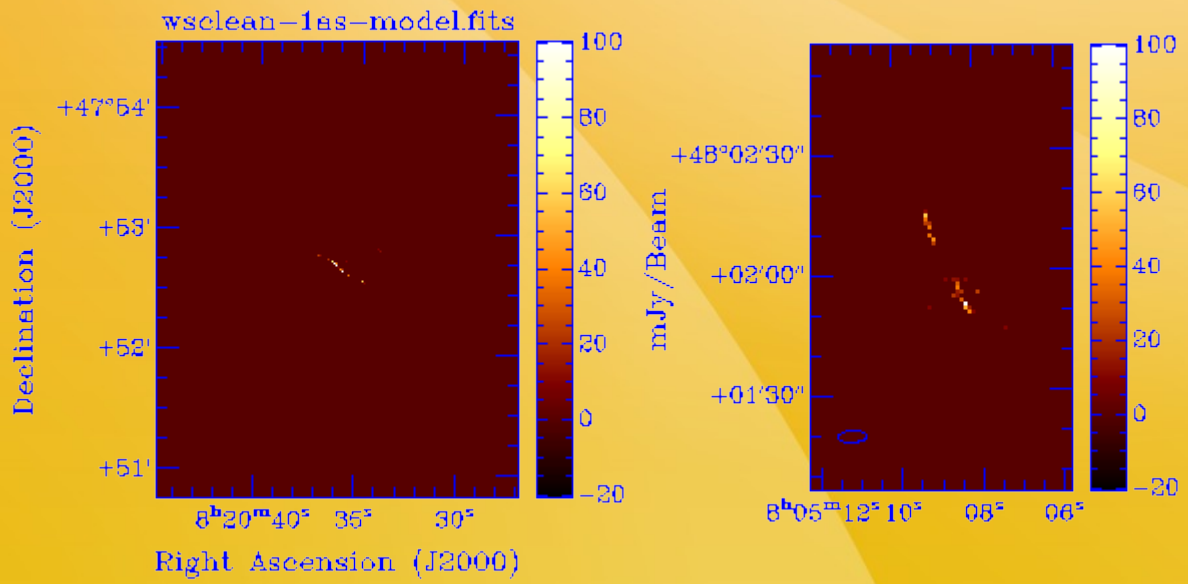
Model resolved sources
With clean components
(preferably small nr)

How to get the „best”
Clean component
representation?



Background

- Want accurate clean components
  → experiment with imager algorithm/setting
- Also interesting to compare my WSClean imager with AWImager



About WSClean

- WSClean is build from the ground up as a „**w-s**tacking” imager
- w-stacking is an alternative to w-projection
- It has different performance properties, in general: uses more memory but speed is less affected by w-term.
- Turns out to be very effective for MWA imaging; typically one to two orders faster than CASA's *w*-projection, due to large FOV.

About WSClean

- Started from very simple prototype
- Uses multi-threading and some SIMD vectorization
- Later additions:
  - Cleaning (Högbom, Cotton-Schwab, **no** Clark)
  - „Imaginary XY imaging” to make pol. MWA images
  - Uniform/Natural/Briggs' weighting, superweighting
  - Multi-scale cleaning
  - A wideband cleaning mode
  - A w-snapshot mode

About WSClean

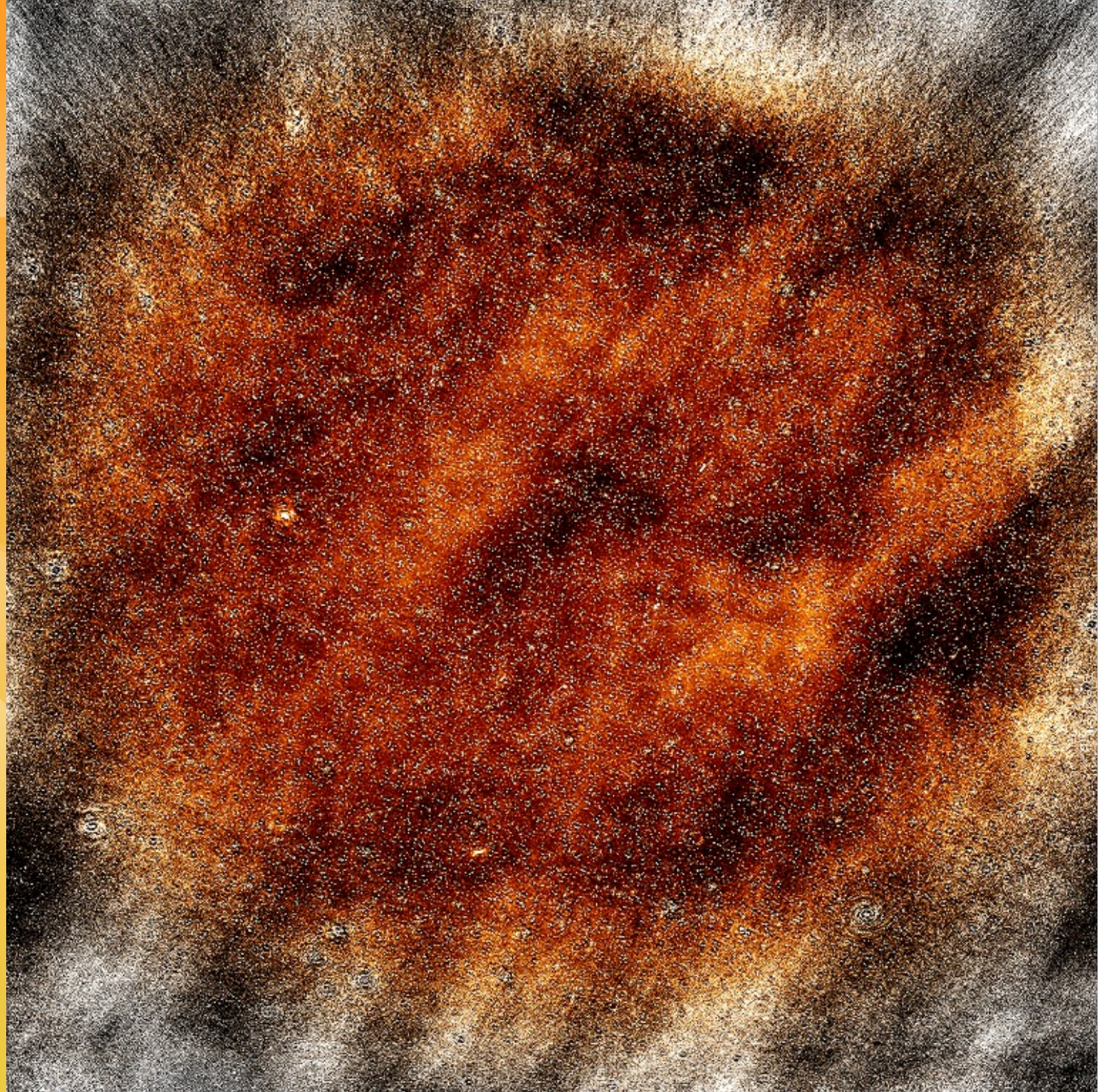
- WSClean extensively used and tested by MWA collaboration:
  - Used in the GLEAM („Galactic & extragalactic MWA”) survey (Randall Wayth et al., in prep)
  - Used in slow transients projects & exoplanet searches (e.g., Tara Murphy et al. 2015)
- WSClean is as accurate (and in certain cases more accurate) than CASA's w-projection (offringa et al., 2014)
- Can make large images: made $18k^2$ images
- Deepest MWA image was made by WSClean

Example MWA image using WSClean

MWA EoR0

~2 mJy noise level

Confusion limitted



Comparisons on LOFAR data

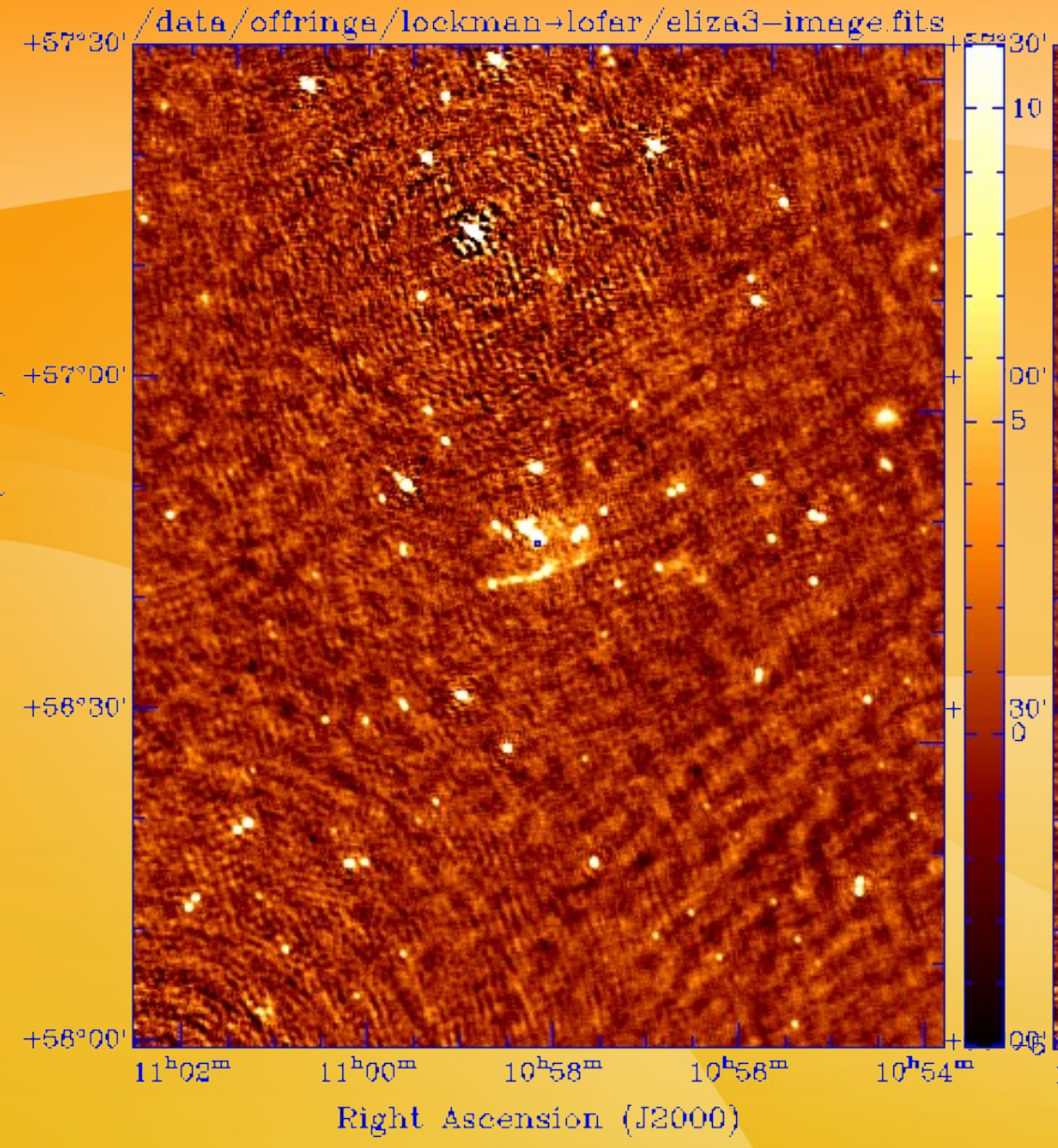
- Using Elizabeth's Lockman hole data (10 SBs, 60GB total), with two of her imaging settings:

  Setting 1:
  6" pixels, 3600^2 pixels, Briggs' weighting, 1 mJy cleaning threshold with CS, 100,000 iterations

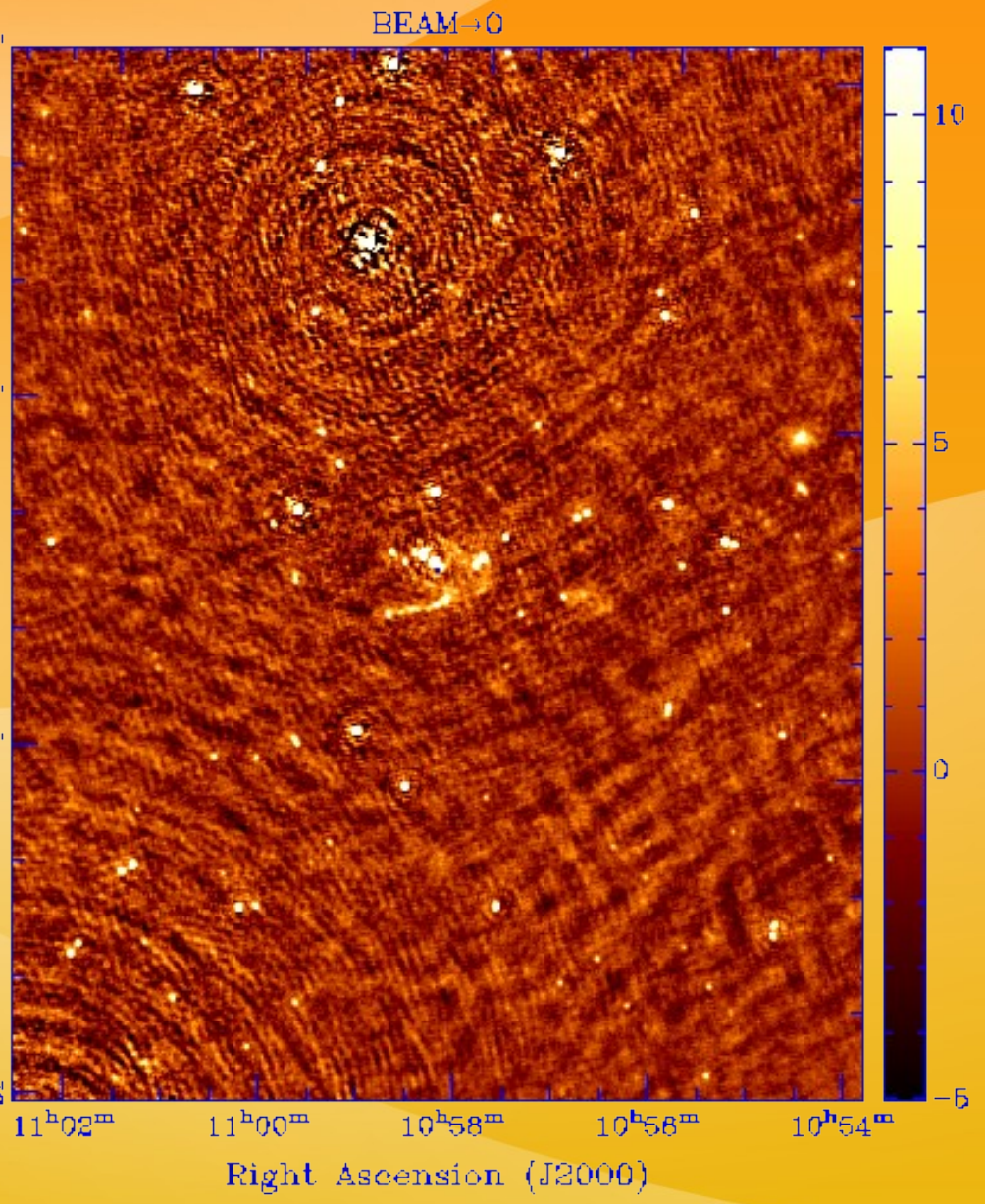
- AWImager (with LOFAR beam): **222 min**
- WSClean (without LOFAR beam): **25 min**

  (AWImager was run on Elizabeth's node, WSClean on lofarcore02)

Zoom in on off-axis part of image



WSClean

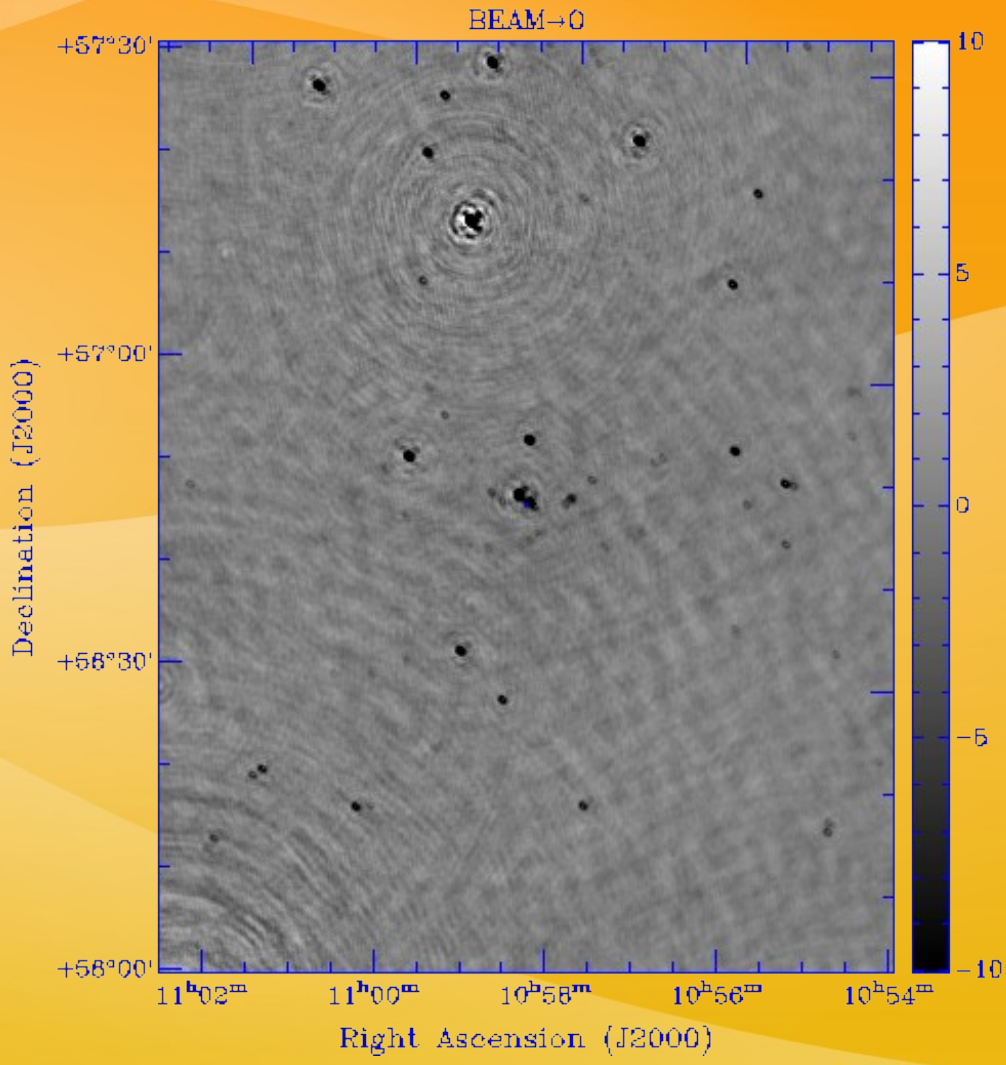


AWImager

AWImager and WSClean difference

- Residuals very similar
- Same noise levels
- Different restoring beam

Only Stokes I images were compared



Difference image

Comparisons on LOFAR data

- Using Elizabeth's Lockman Hole data (10 SBs, 60GB total), with two of her imaging settings:

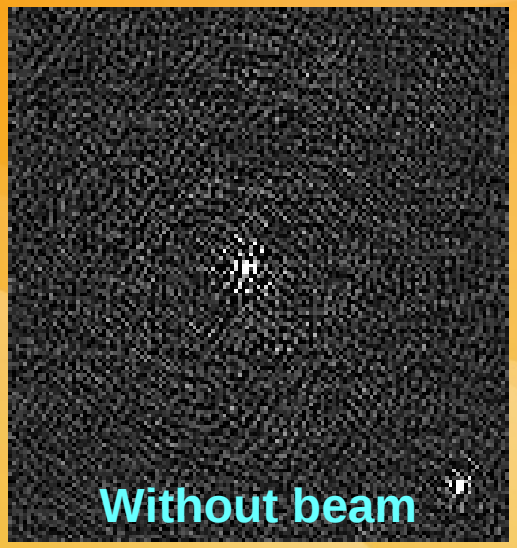
  Setting 2:
  2'' pixels, $10{,}800^2$ pixels, Briggs' weighting,
  1 mJy cleaning threshold with CS, 100,000 iterations

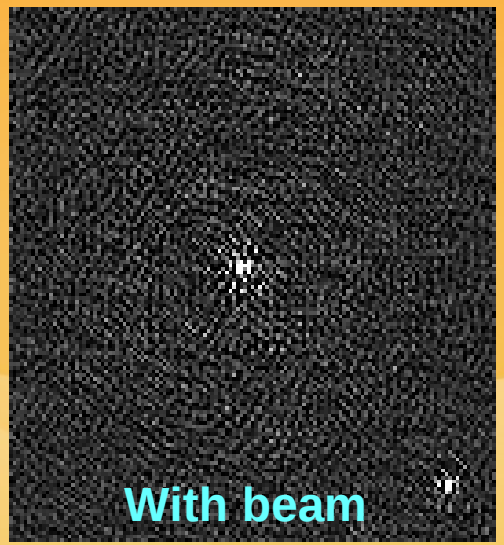
- AWImager (with LOFAR beam): **~7 hrs**
- WSClean (without LOFAR beam): **3.5 hrs**

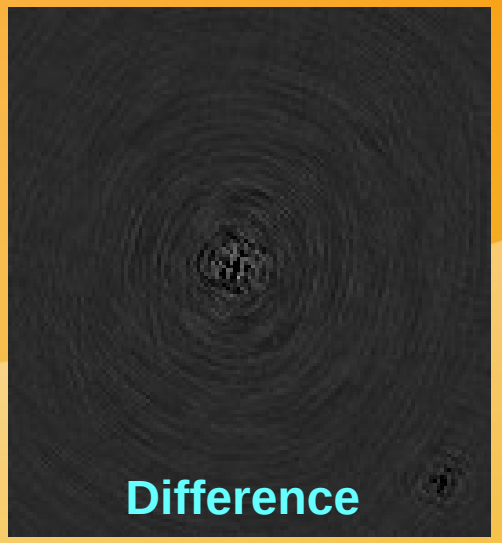
Correcting beam with stacking

- Stacking algorithm doesn't support beam correction for a heterogenous array as LOFAR when cleaning
- Possible solution: a „DFT” prediction step
  - Forward imaging step with stacking
  - Backward prediction step with Direct FT (Easy to implement)
  - Finally, correct for integrated beam
  - Allows varying beam correction per channel, per antenna, per timestep.
  - Doable for ~low nr of clean components; becomes intractable expensive for 10,000s of components.

- DFT with beam implemented in WSClean using LOFAR's StationResponse lib
- No clear improvement seen from applying beam. Example off-axis source in 3c196:







- DFT is very slow
  - **~4 h** imaging time on a 3c196 set of 6.5 GB with ~700 unique components vs **10 min** without beam.
  - Some improvement possible: currently not multi-threaded

Correcting beam with stacking

- DFT with beam implemented in WSClean using LOFAR's StationResponse lib
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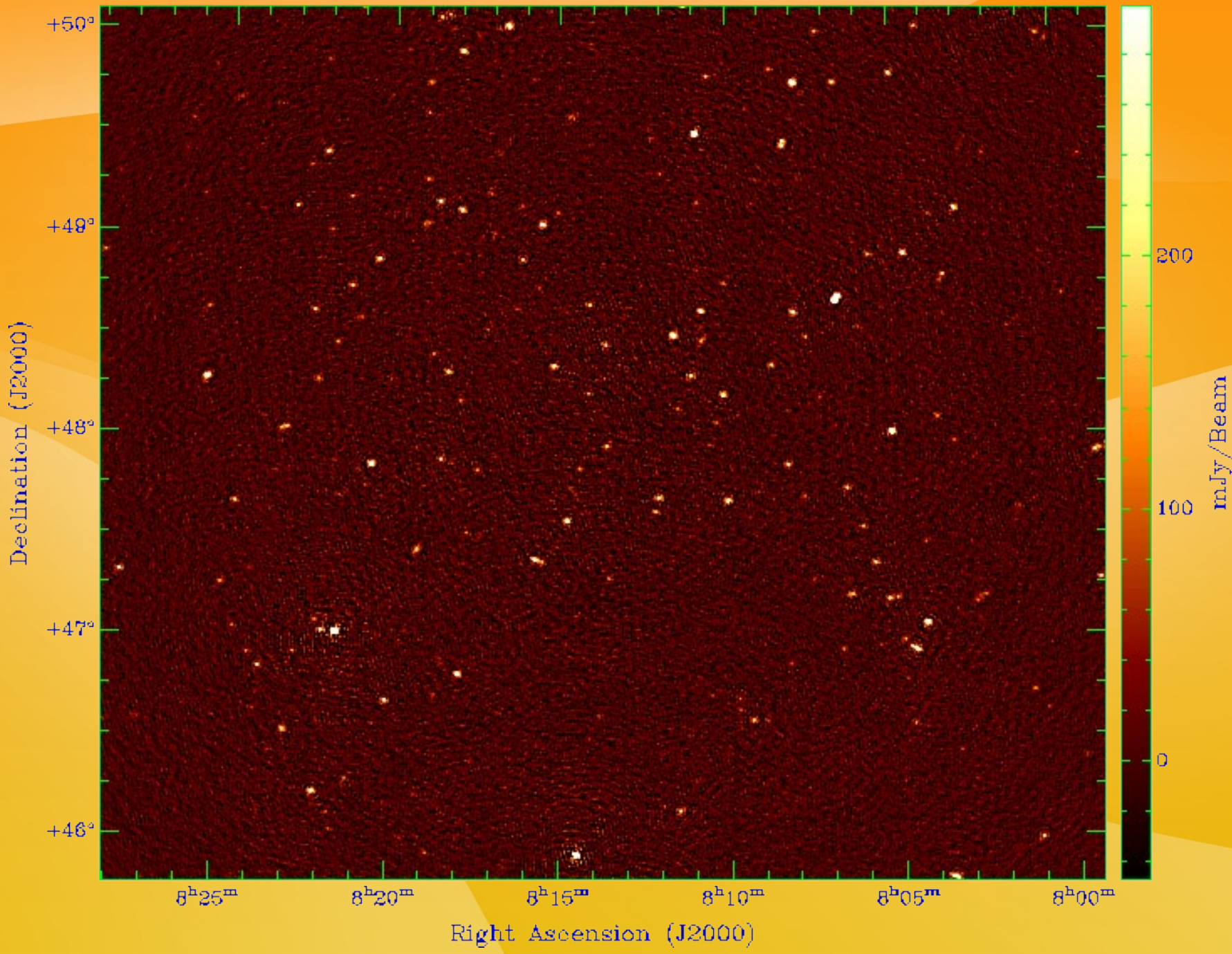
Calibration

- Also compared BBS, NDPPP and Mitchcal calibration (Mitchel et al, 2008)
- All with LOFAR beam implemented
- Found a bug in NDPPP calibration: full-pol cal leads to incorrect solutions
  (Tammo Jan is fixing this)
- BBS and Mitchcal produce ~identical images. Runtimes on 3c196, 6h with 5 ch, 4 s time res:
  BBS: **219 min**
  NDPPP: **10 min**
  Mitchcal: **10 min**

Calibration



Summary

- WSClean works well on LOFAR data:
  It's fast and shows good results
- ...but can't do a-projection.
- So far, no improvement seen from applying beam in Stokes I images.
  - Beam model not accurate enough? Or are errors from other effects larger?