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Netherlands Institute for Radio Astronomy

Update from Factor Busy Week 24

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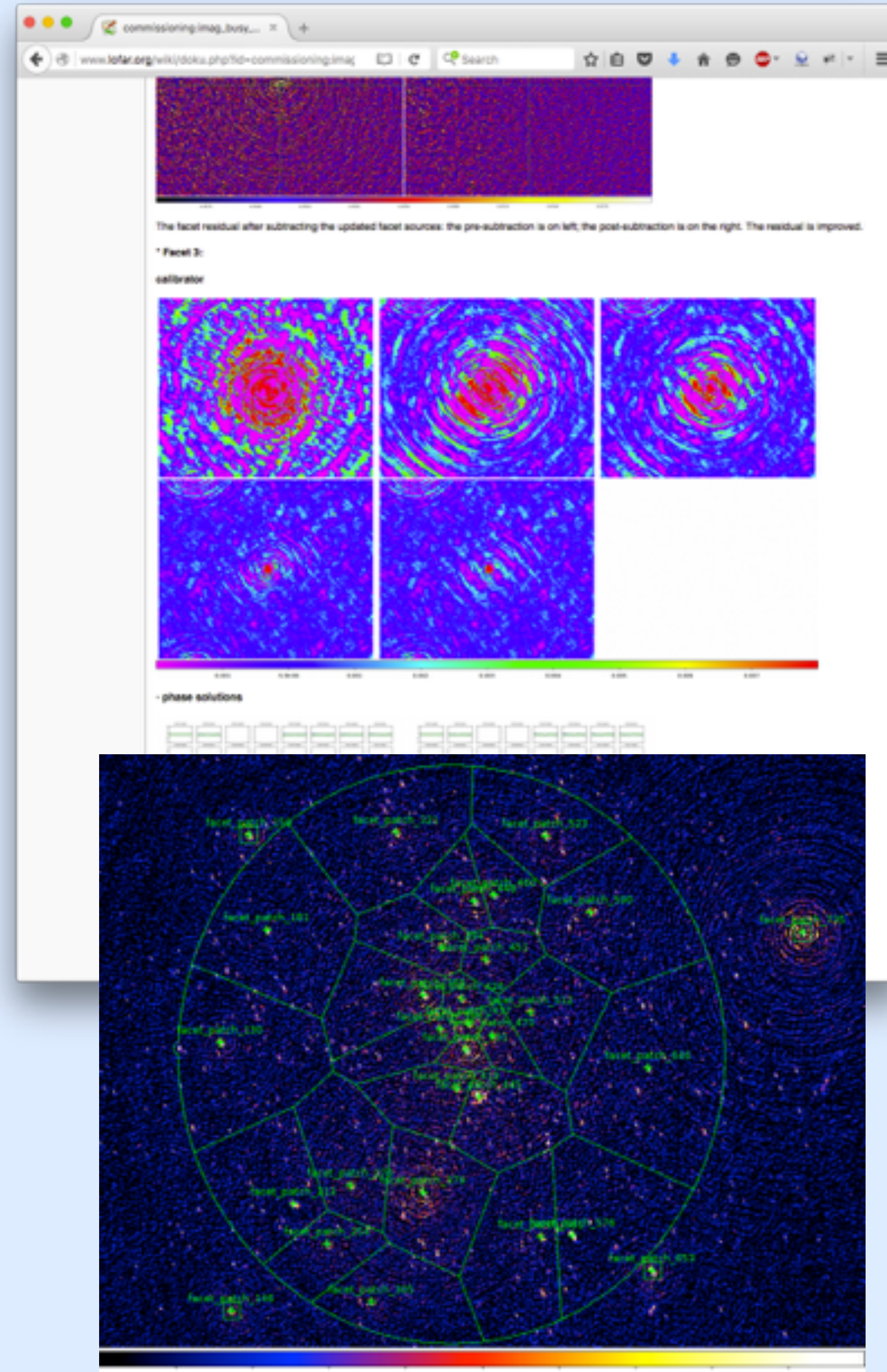
http://www.lofar.org/operations/doku.php?id=commissioning:imag_busy_week_24

Factor busy week 24



Busy week focused on testing Factor on many fields.

Participants:
Tim Shimwell, Volker Heesen, Alexander Drabent (remote), Andreas Horneffer, Blazej Nikiel-Wroczynski, Carole Roskowiński, Emanuela Orrù, Sarrvesh, Soumyajit (Jit) Mandal, Tammo Jan Dijkema, David Rafferty, Josh Albert, Marco Iacobelli, Aleksandar Shulevski, Wendy Williams, Duy Hoang, David Mulcahy

All fields documented on wiki:
http://www.lofar.org/wiki/doku.php?id=commissioning:imag_busy_week_24

Status of Factor

Paper about facet calibration now on ArXiv: http://arxiv.org/pdf/1601.05422v1.pdf

Factor scripts being tried on surveys fields.

"CITT Factor version" becoming the default version.

During BW24, we merged a branch that makes **multi-epoch** facet calibration possible.

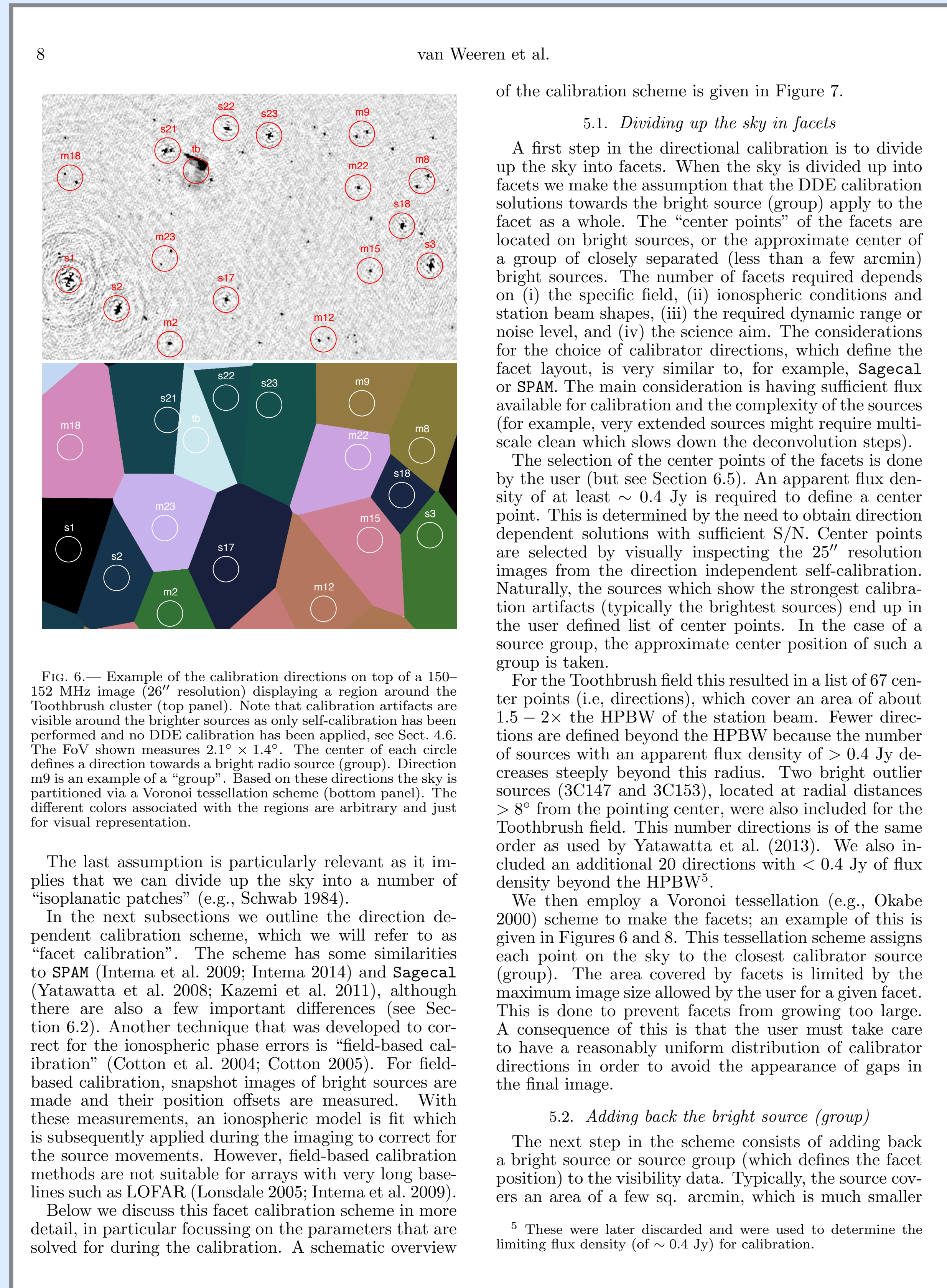


FIG. 6.— Example of the calibration directions on top of a 150–152 MHz image (26″ resolution) displaying a region around the Toothbrush cluster (top panel). Note that calibration artifacts are visible around the brighter sources as only self-calibration has been performed and no DDE calibration has been applied, see Sect. 4.6. The FoV shown measures 2.1° × 1.4°. The center of each circle defines a direction towards a bright radio source (group). Direction m9 is an example of a "group". Based on these directions the sky is partitioned via a Voronoi tessellation scheme (bottom panel). The different colors associated with the regions are arbitrary and just for visual representation.

The last assumption is particularly relevant as it implies that we can divide up the sky into a number of "isoplanatic patches" (e.g., Schwab 1984).

In the next subsections we outline the direction dependent calibration scheme, which we will refer to as "facet calibration". The scheme has some similarities to `SPAM` (Intema et al. 2009; Intema 2014) and `Sagecal` (Yatawatta et al. 2008; Kazemi et al. 2011), although there are also a few important differences (see Section 6.2). Another technique that was developed to correct for the ionospheric phase errors is "field-based calibration" (Cotton et al. 2004; Cotton 2005). For field-based calibration, snapshot images of bright sources are made and their position offsets are measured. With these measurements, an ionospheric model is fit which is subsequently applied during the imaging to correct for the source movements. However, field-based calibration methods are not suitable for arrays with very long baselines such as LOFAR (Lonsdale 2005; Intema et al. 2009).

Below we discuss this facet calibration scheme in more detail, in particular focussing on the parameters that are solved for during the calibration. A schematic overview of the calibration scheme is given in Figure 7.

5.1. *Dividing up the sky in facets*

A first step in the directional calibration is to divide up the sky into facets. When the sky is divided up into facets we make the assumption that the DDE calibration solutions towards the bright source (group) apply to the facet as a whole. The "center points" of the facets are located on bright sources, or the approximate center of a group of closely separated (less than a few arcmin) bright sources. The number of facets required depends on (i) the specific field, (ii) ionospheric conditions and station beam shapes, (iii) the required dynamic range or noise level, and (iv) the science aim. The considerations for the choice of calibrator directions, which define the facet layout, is very similar to, for example, `Sagecal` or `SPAM`. The main consideration is having sufficient flux available for calibration and the complexity of the sources (for example, very extended sources might require multi-scale clean which slows down the deconvolution steps).

The selection of the center points of the facets is done by the user (but see Section 6.5). An apparent flux density of at least ∼ 0.4 Jy is required to define a center point. This is determined by the need to obtain direction dependent solutions with sufficient S/N. Center points are selected by visually inspecting the 25″ resolution images from the direction independent self-calibration. Naturally, the sources which show the strongest calibration artifacts (typically the brightest sources) end up in the user defined list of center points. In the case of a source group, the approximate center position of such a group is taken.

For the Toothbrush field this resulted in a list of 67 center points (i.e, directions), which cover an area of about 1.5 − 2× the HPBW of the station beam. Fewer directions are defined beyond the HPBW because the number of sources with an apparent flux density of > 0.4 Jy decreases steeply beyond this radius. Two bright outlier sources (3C147 and 3C153), located at radial distances > 8° from the pointing center, were also included for the Toothbrush field. This number directions is of the same order as used by Yatawatta et al. (2013). We also included an additional 20 directions with < 0.4 Jy of flux density beyond the HPBW[5].

We then employ a Voronoi tessellation (e.g., Okabe 2000) scheme to make the facets; an example of this is given in Figures 6 and 8. This tessellation scheme assigns each point on the sky to the closest calibrator source (group). The area covered by facets is limited by the maximum image size allowed by the user for a given facet. This is done to prevent facets from growing too large. A consequence of this is that the user must take care to have a reasonably uniform distribution of calibrator directions in order to avoid the appearance of gaps in the final image.

5.2. *Adding back the bright source (group)*

The next step in the scheme consists of adding back a bright source or source group (which defines the facet position) to the visibility data. Typically, the source covers an area of a few sq. arcmin, which is much smaller

[5] These were later discarded and were used to determine the limiting flux density (of ∼ 0.4 Jy) for calibration.

Oversimplified version of Factor

ASTRON

Very much oversimplified, see all previous talks, and documentation:
www.astron.nl/citt/facet-doc

Prefactor

Calibration:
- Flux calibration
- Clock / TEC
- Flagging soln's
- Diagnostic plots

Initial subtract

Image at high resolution

Subtract high resolution model

Image at low resolution

Subtract low resolution model

Merge low- and high-res models

Prepare facets

Find calibrators, make tesselation

Selfcal per facet

Add calibrators to facet, do selfcal on full bandwidth with heavy averaging
- 2x phase only
- 2x amp+phase

Add all facet sources

Image at high resolution (1.5”)

Subtract facet sources

Mosaic

Status of Factor

Prefactor

- Works, creates well calibrated data (calibrated for clock)
- Uses genericpipeline, DPPP, losoto, …
- Creates lots of informational diagnostic information
- Improvement may be possible by using TGSS catalog
- Available on http://github.com/lofar-astron/prefactor

- **Plan**: get this to CEP4 as soon as possible
  - Relatively minor effort
  - Project plan currently being prioritized by RO

Status of Factor

Initial subtract:

- Works, creates decent full field images (no DDE-calibration)
- Uses genericpipeline, wsclean
- Available on http://github.com/lofar-astron/prefactor

- **Plan**: get this to CEP4 after prefactor

Status of Factor

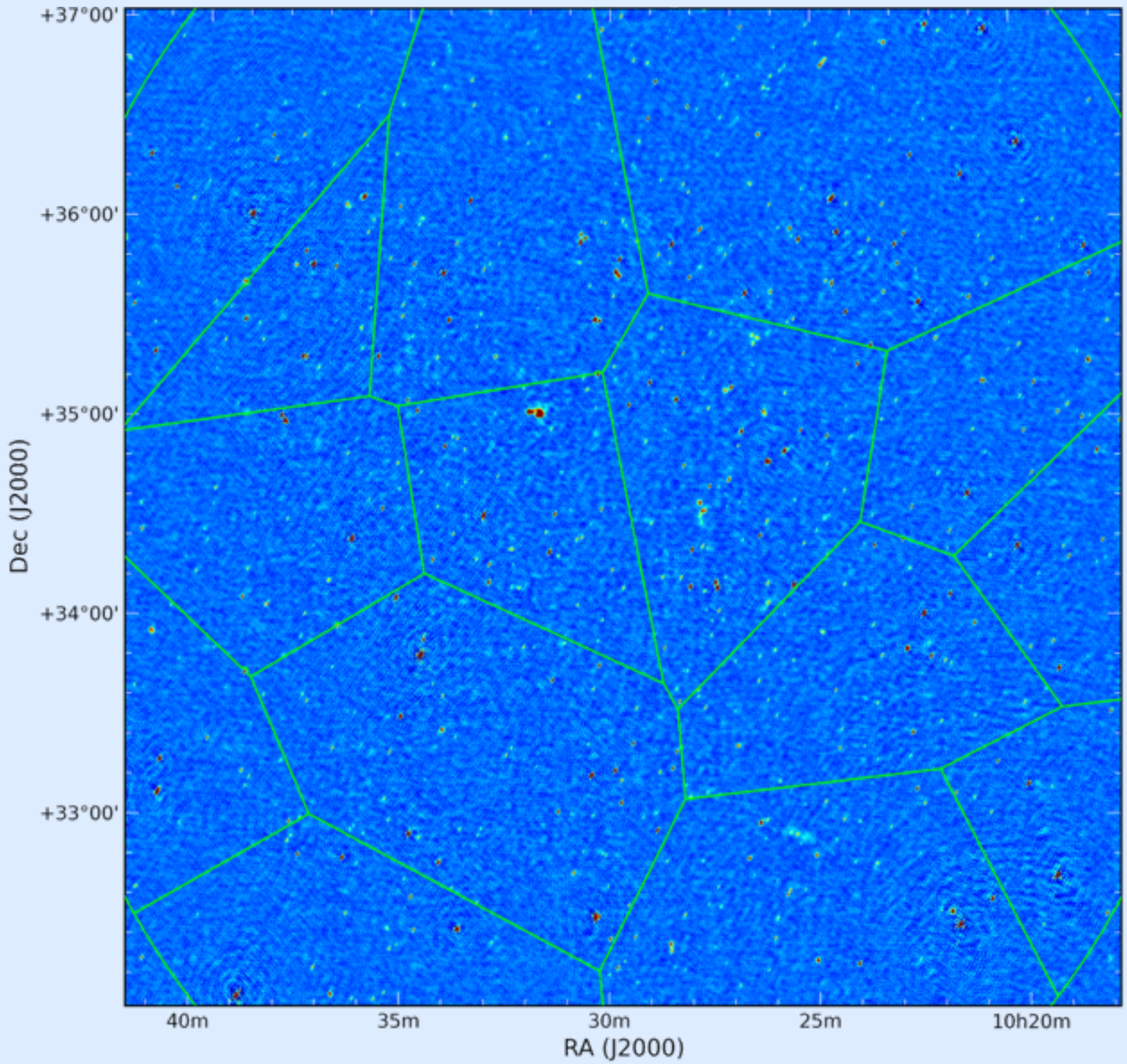
Selfcal per facet

- Works, sometimes needs tweaking to avoid divergence
- Uses genericpipeline, DPPP, BBS, wsclean, …
- Available from http://github.com/lofar-astron/factor

- **Plan**: move this to CEP3 (where it already is)

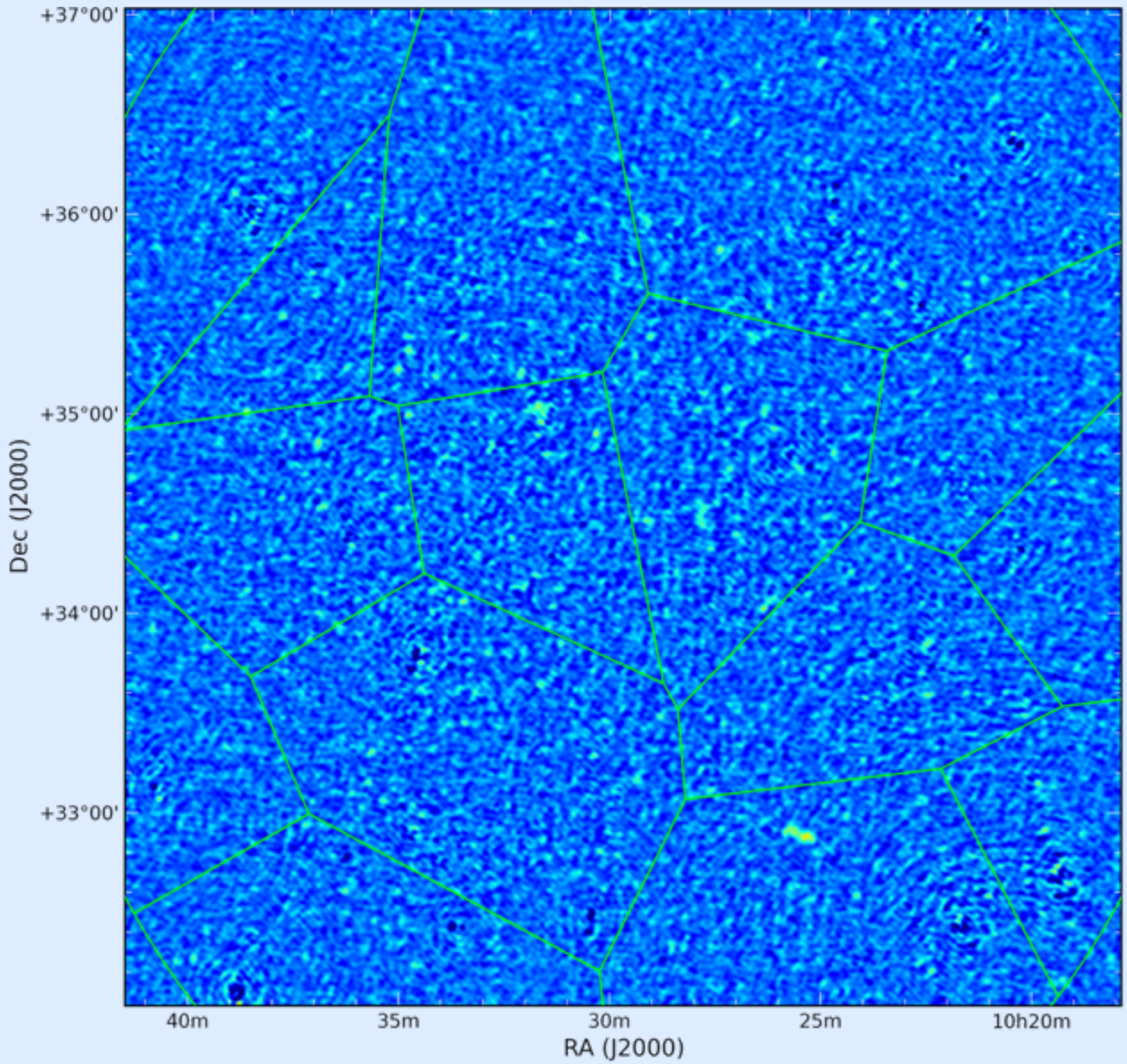
Results initialsubtract

Galaxy cluster (Tim Shimwell), before subracting high res model



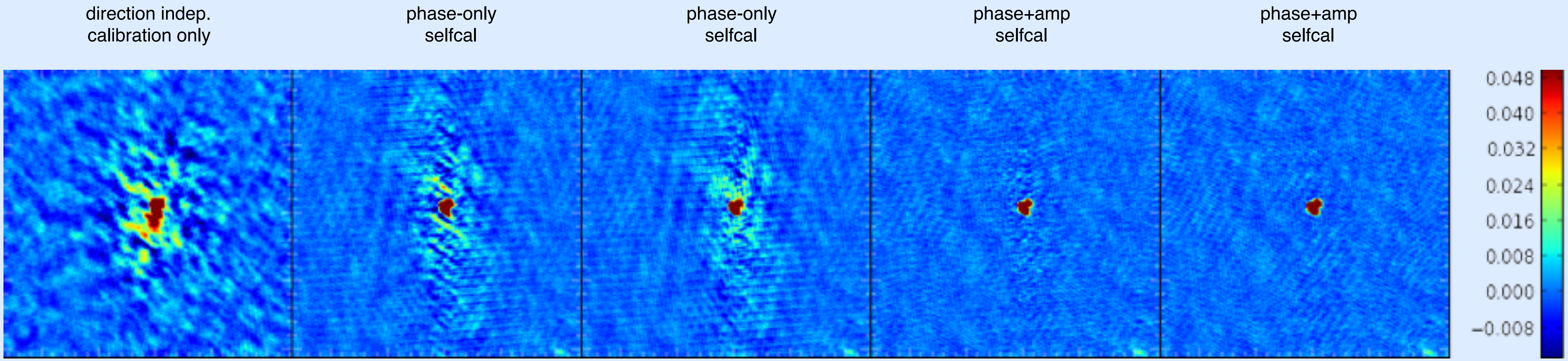
Results initialsubtract

Galaxy cluster (Tim Shimwell), before subracting low res model



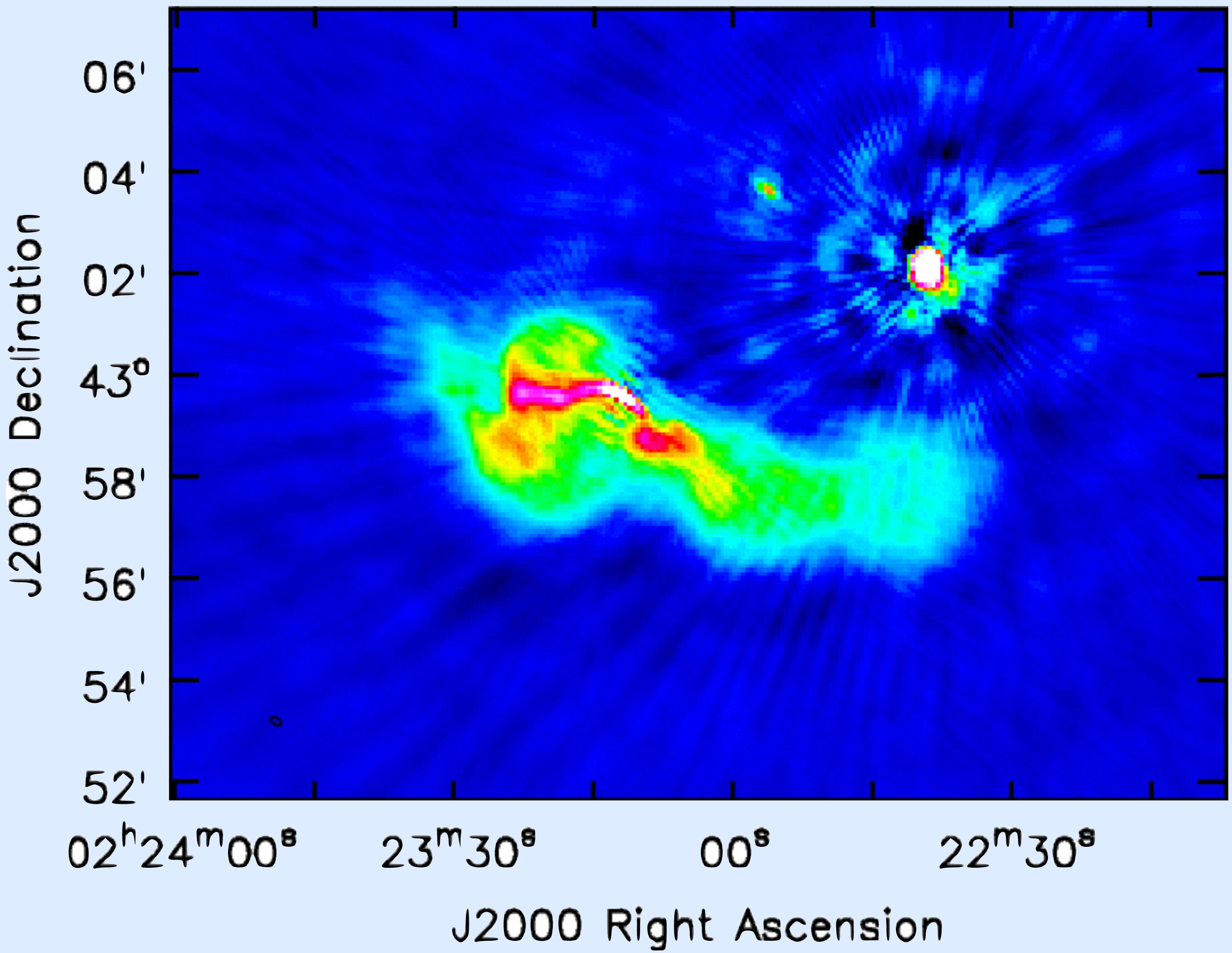
Results selfcal per facet

Selfcal is only performed on small area around bright calibrator



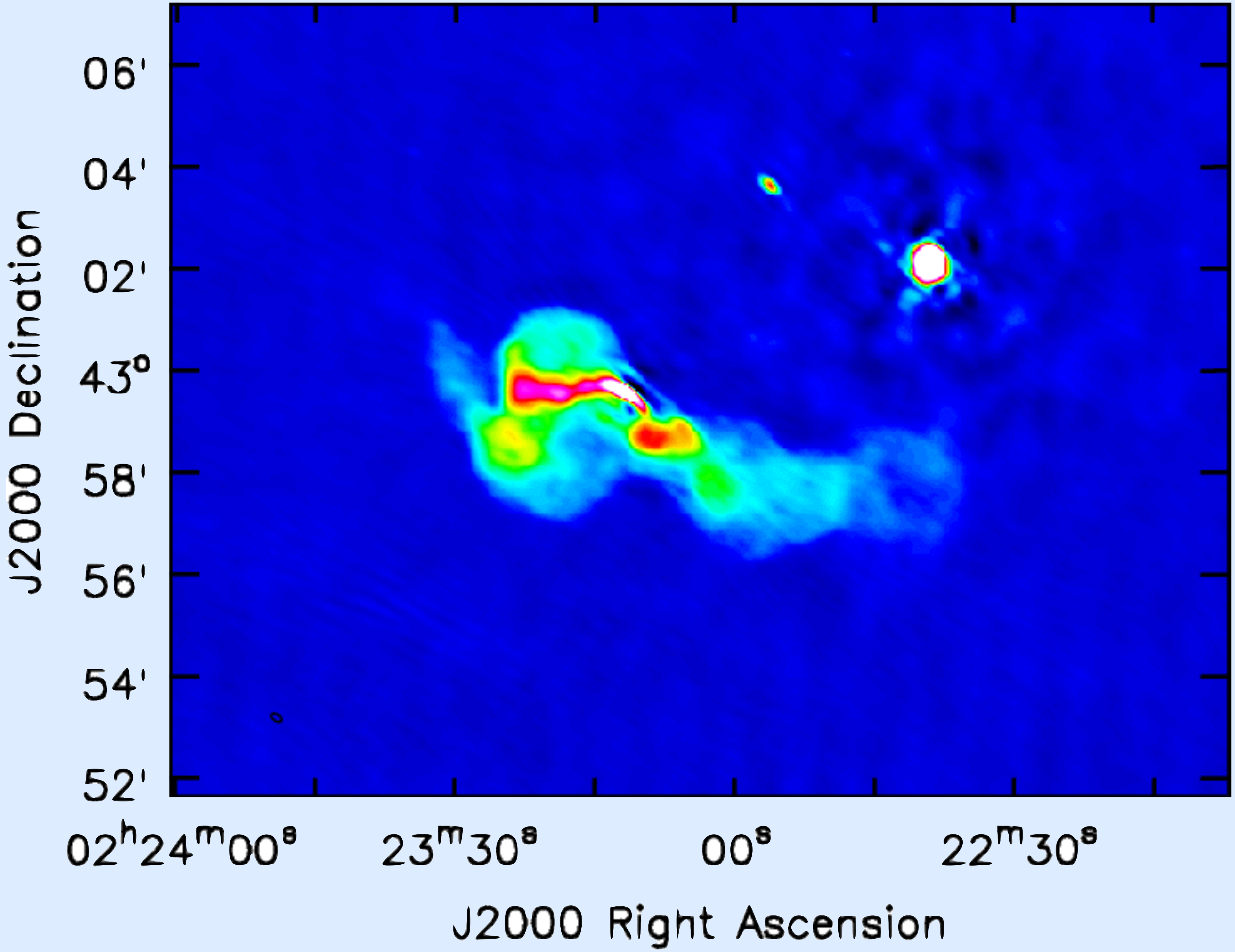
Results full facet

3C66 (Andreas Horneffer), before calibration of facet



Results full facet

3C66 (Andreas Horneffer), before after calibration of facet



Profiling of facet calibration

Calibrating one facet takes ~ 2 hours (30 facets)

Time dominated by WSClean

Plan: adapt DPPP to replace BBS

More profiling being undertaken by Yan Grange et al.