GLEAM: calibration, images, and catalogues

Paul Hancock,
Natasha Hurley-Walker, and the GLEAM team

ICRAR International Centre for Radio Astronomy Research
Curtin University
MWA Murchison Widefield Array
CAASTRO All-Sky Astrophysics

The GLEAM survey: some challenges

Calibration:

- Sky model not well known
- Beam model ok but not great
- No multi-ν surveys to cover the south

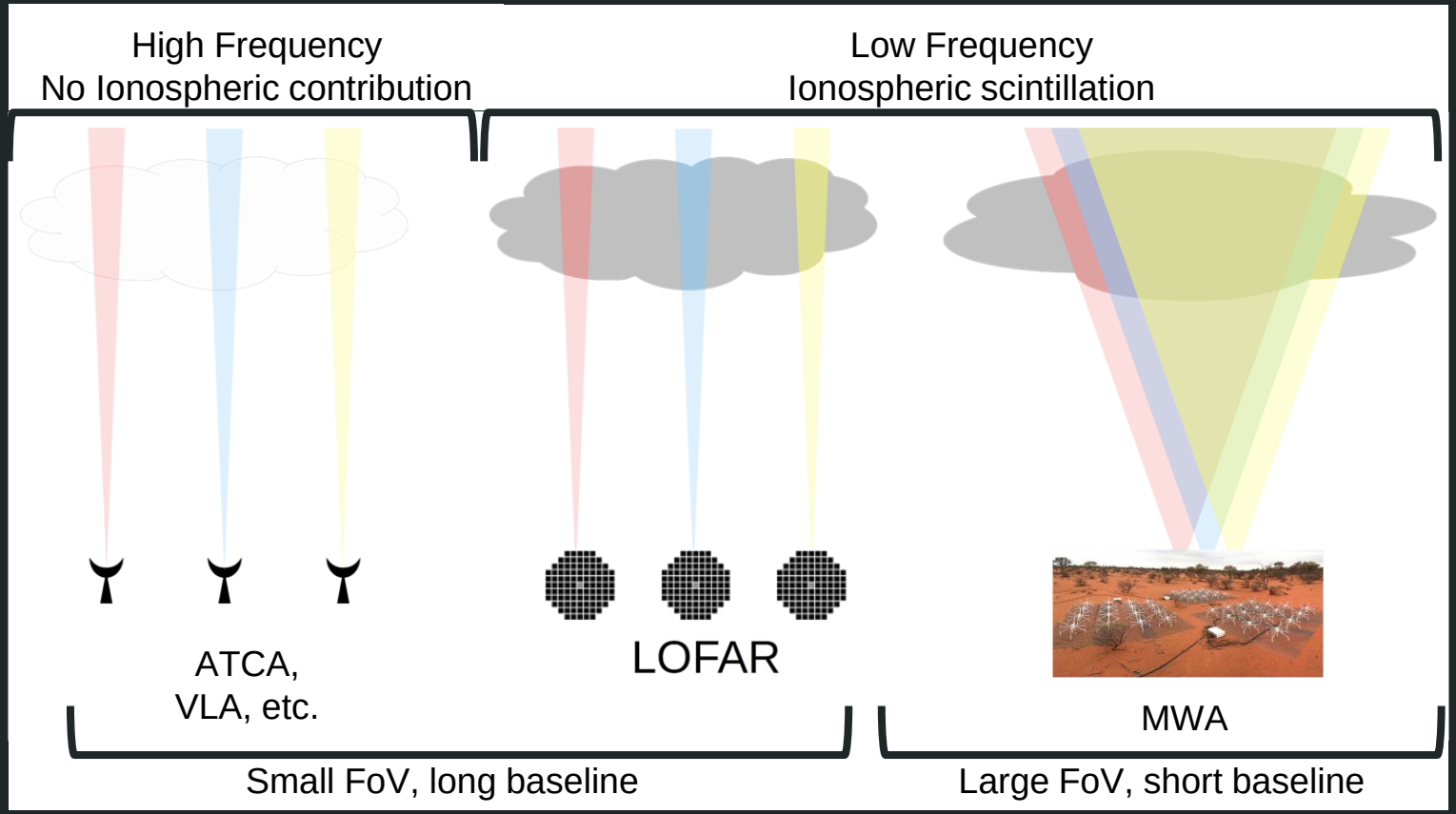
Imaging:

- Mosaicing distorted images causes blurring and loss of SNR

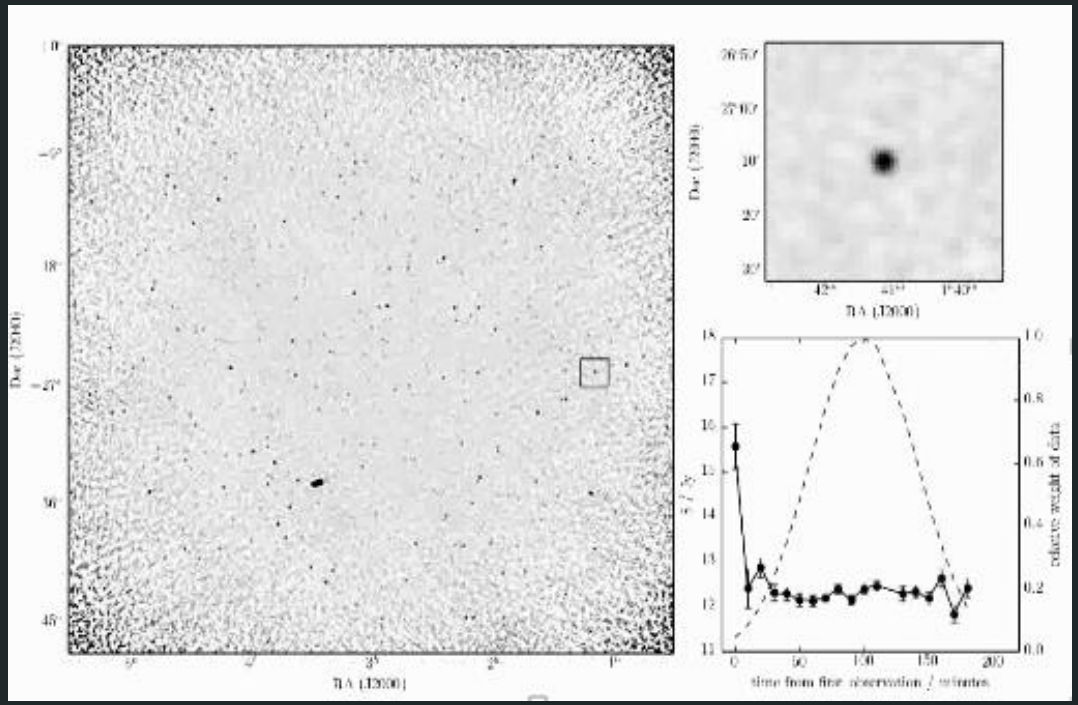
Catalogue creation:

- Large FoV - image properties change over the sky
- Large Δν - changing PSF, and source morphology

More detail, catalogues, and images: Hurley-Walker, Callingham, Hancock et al. 2017 MNRAS.464.1146H


High Frequency
No Ionospheric contribution
Low Frequency
Ionospheric scintillation
ATCA,
VLA, etc.
LOFAR
MWA
Small FoV, long baseline
Large FoV, short baseline

The Ionosphere (+ Primary Beam)

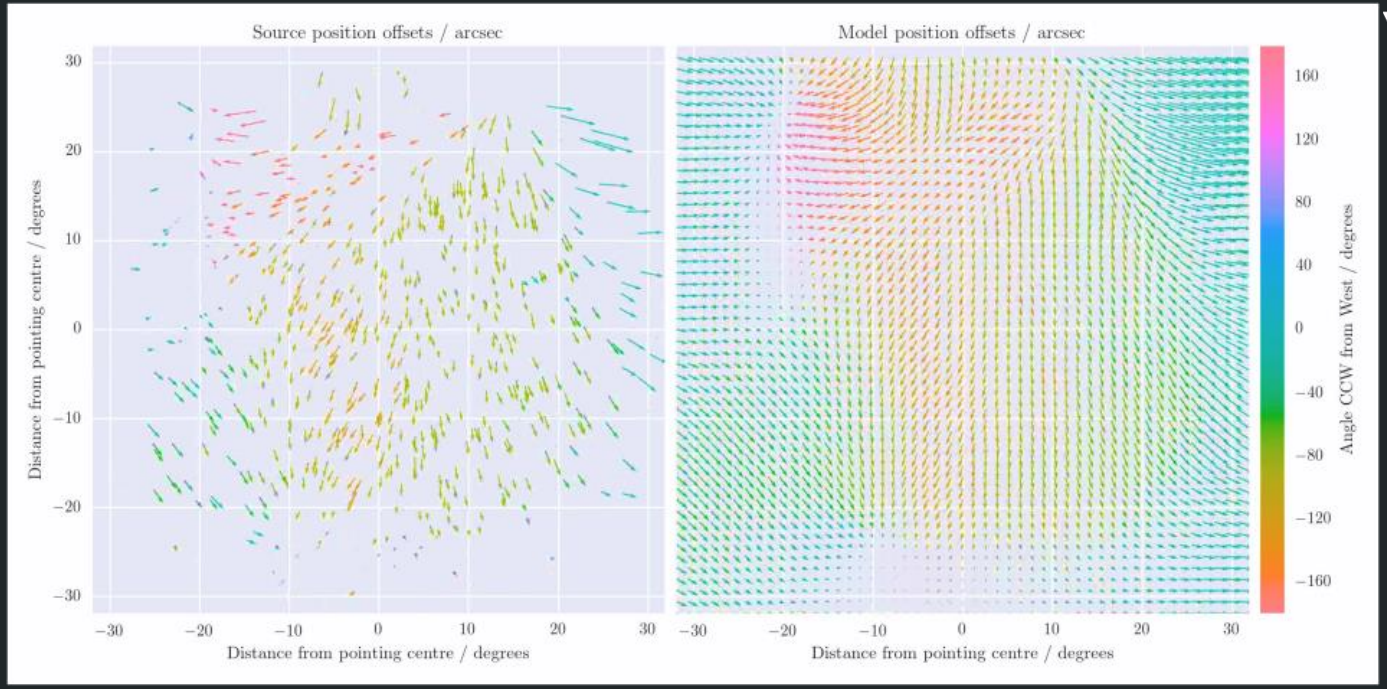


Track a source through multiple snapshots:

Position ‘jitters’ ➜ Ionosphere

Flux changes ➜ δ Primary Beam

Ionospheric Distortions



$$\nabla \cdot \delta\vec{x} \ll 1\%$$

Shifting but no focusing

phase errors but no amp errors

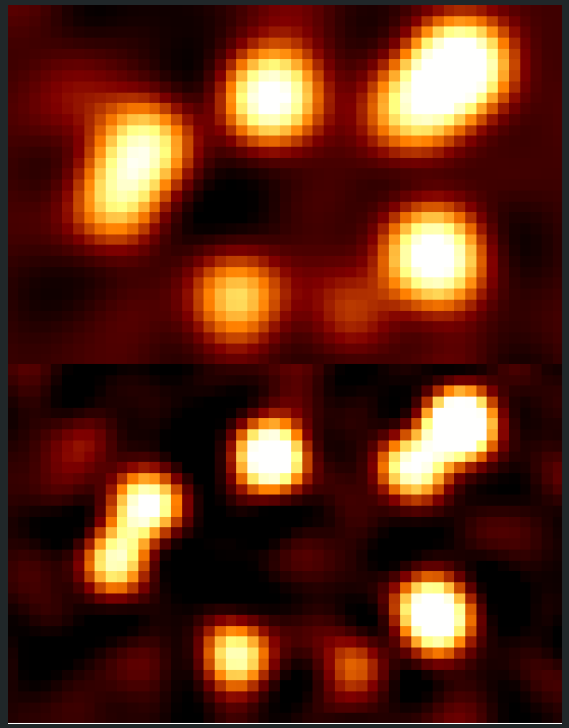
Ionospheric Corrections

Normal stacking/mosaicing ⇒

(10% loss of resolution)

image warping
+ stacking/mosaicing ⇒

(full resolution)



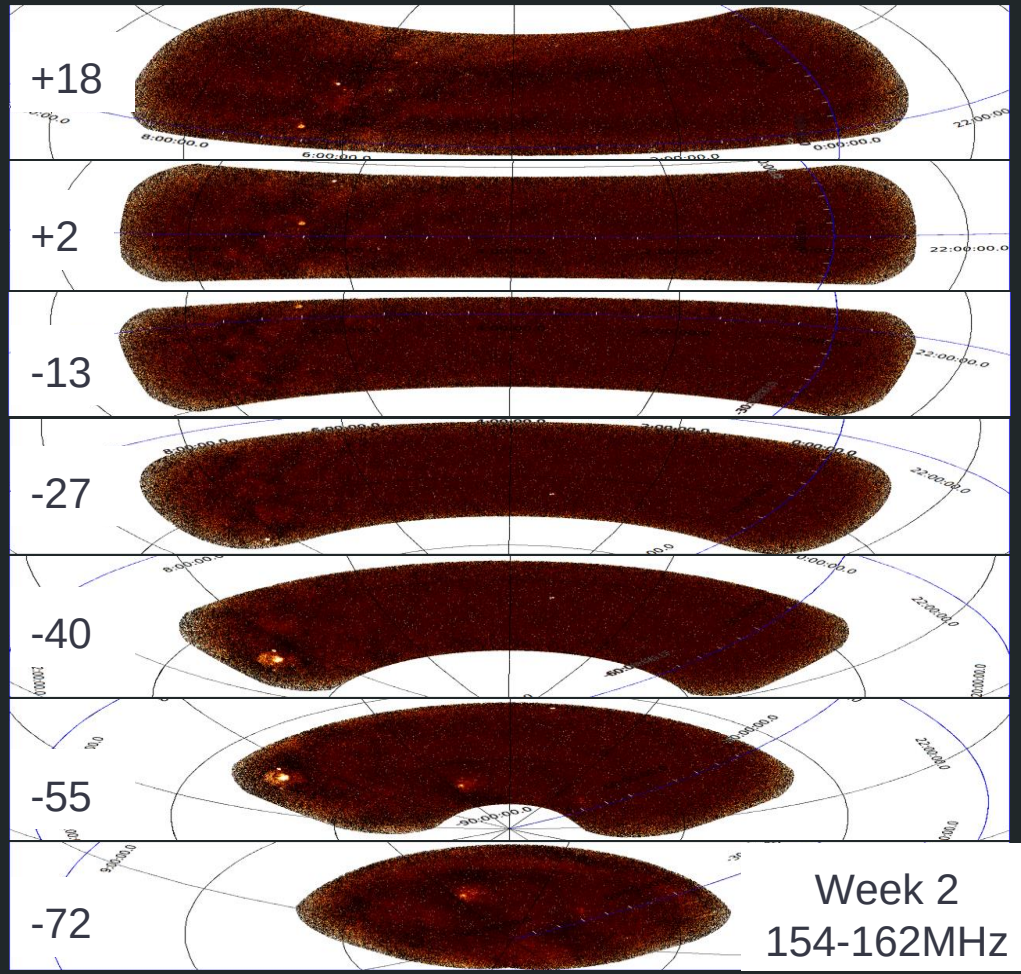
Mosaicking

7 Dec bands (1 per night)

4 RA slices (1 per 3mo)

20 frequencies per night

560 mosaics!

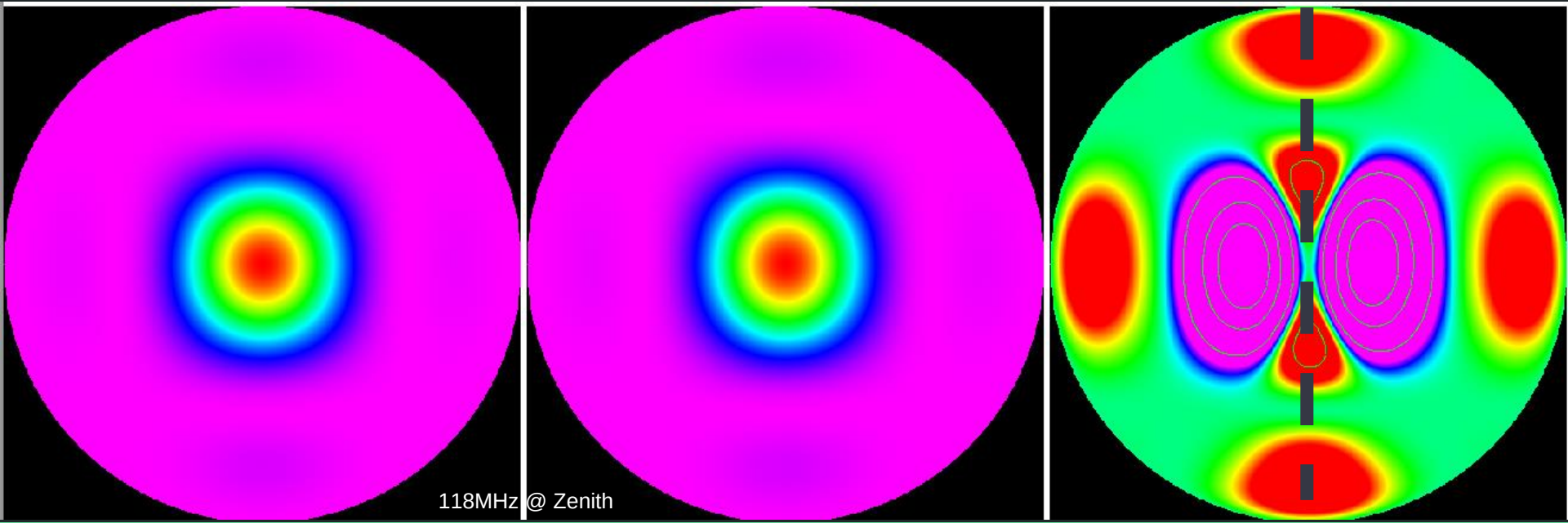


Primary Beam Model Errors

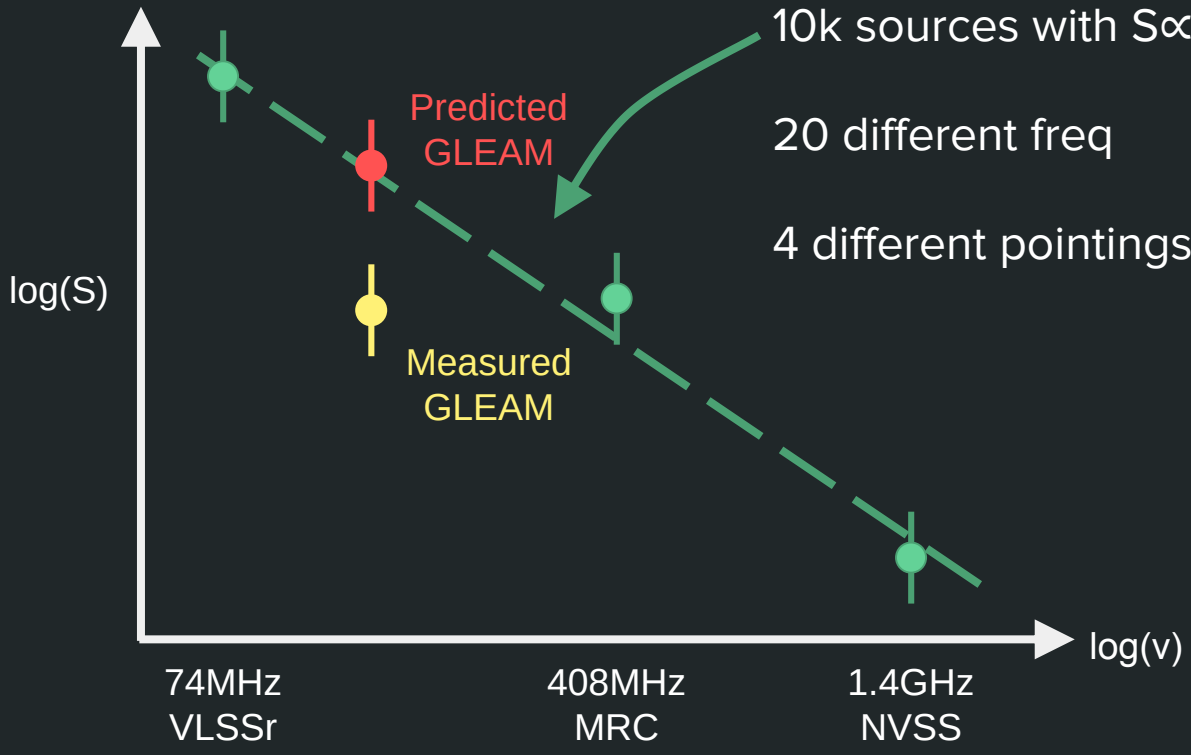
Average embedded element model
2014

Full embedded element model
2017

Difference
+/- 10%



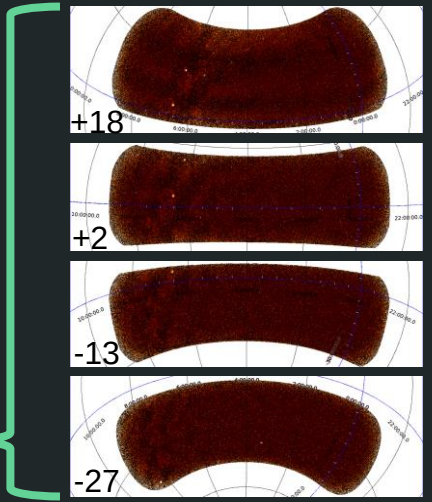
Flux Calibration



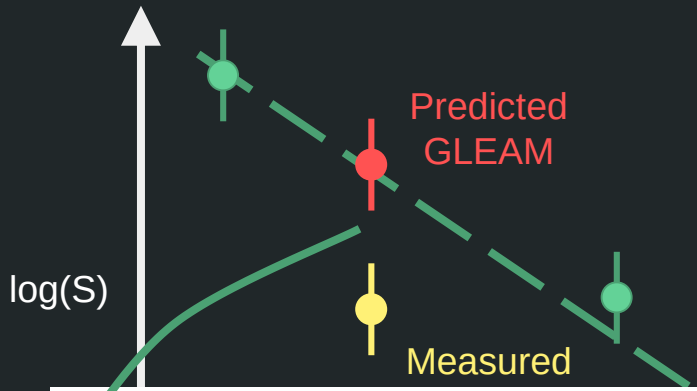
10k sources with $S \propto \nu^{\alpha}$

20 different freq

4 different pointings in Dec



Flux Calibration



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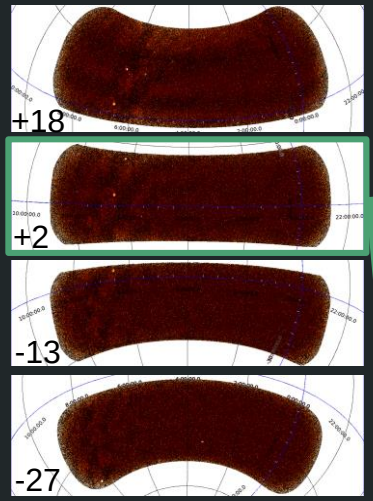
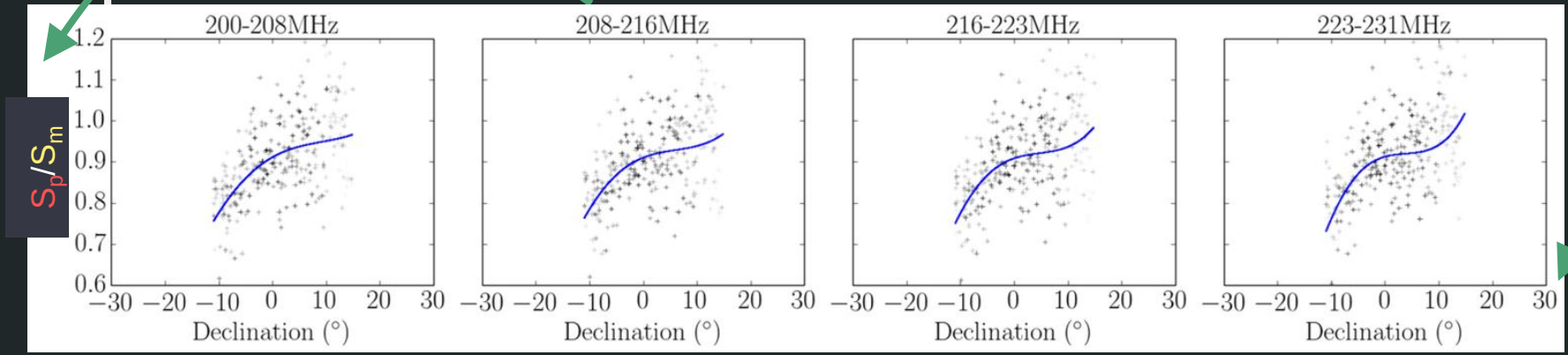
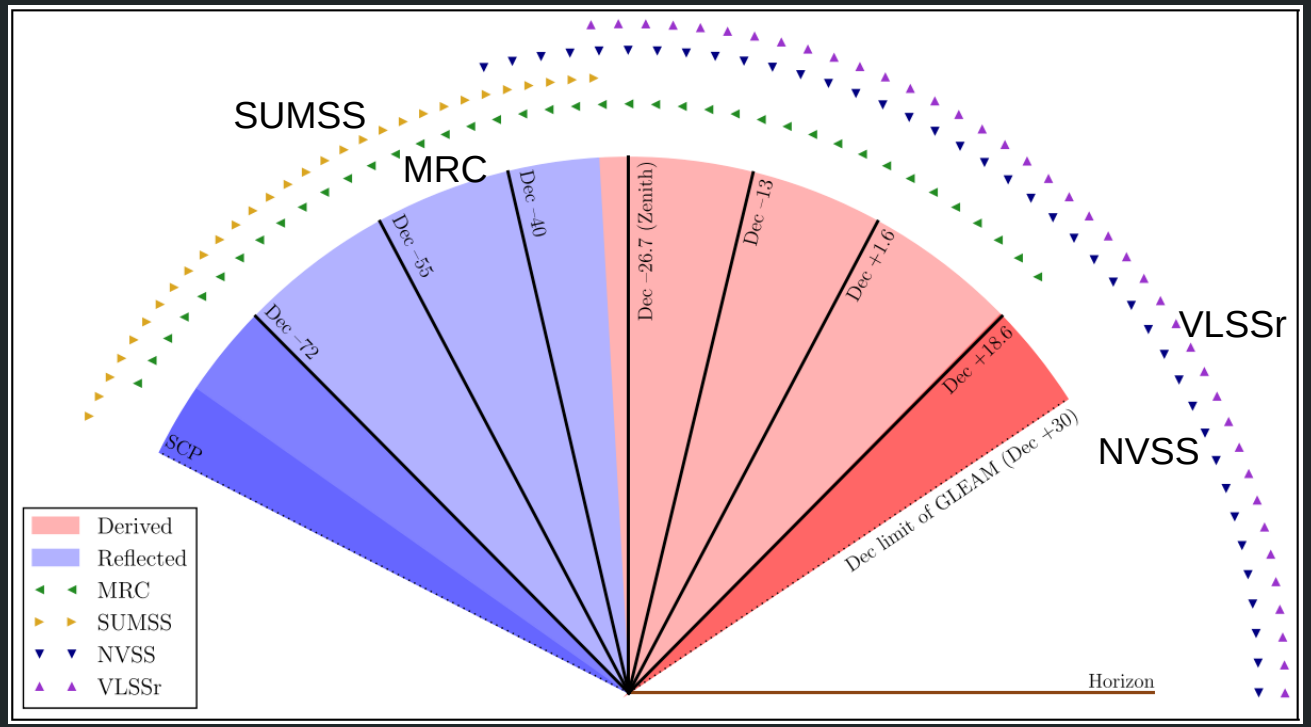




Flux Calibration for the southern sky

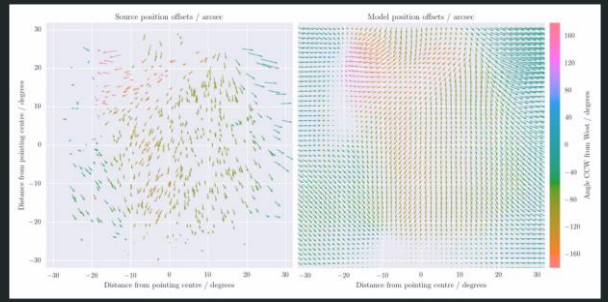
Not enough reference points south of our zenith for **interpolation**

Exploit the symmetry of the beams



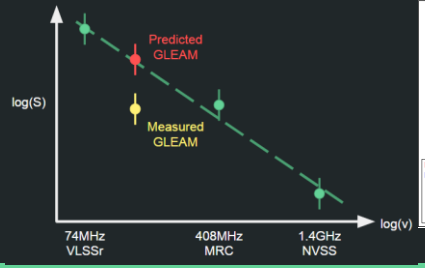
Calibration

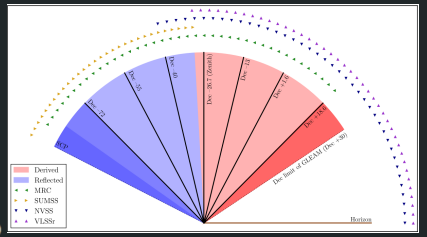
Instrumental ➜ point source cal obs, self cal on field sources



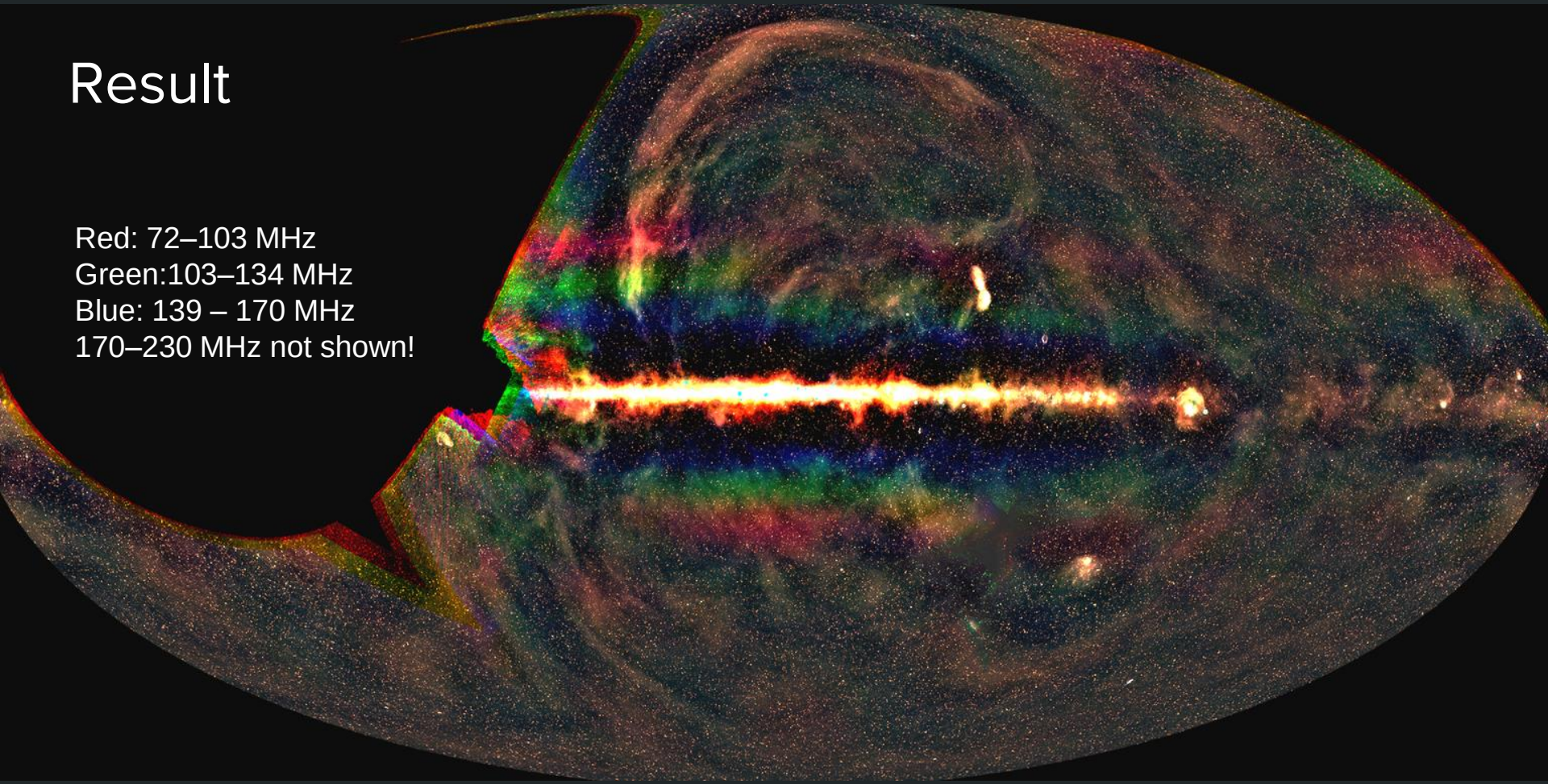
Ionospheric ➜ warped images

Primary beam / flux ➜ reference catalogues + symmetry



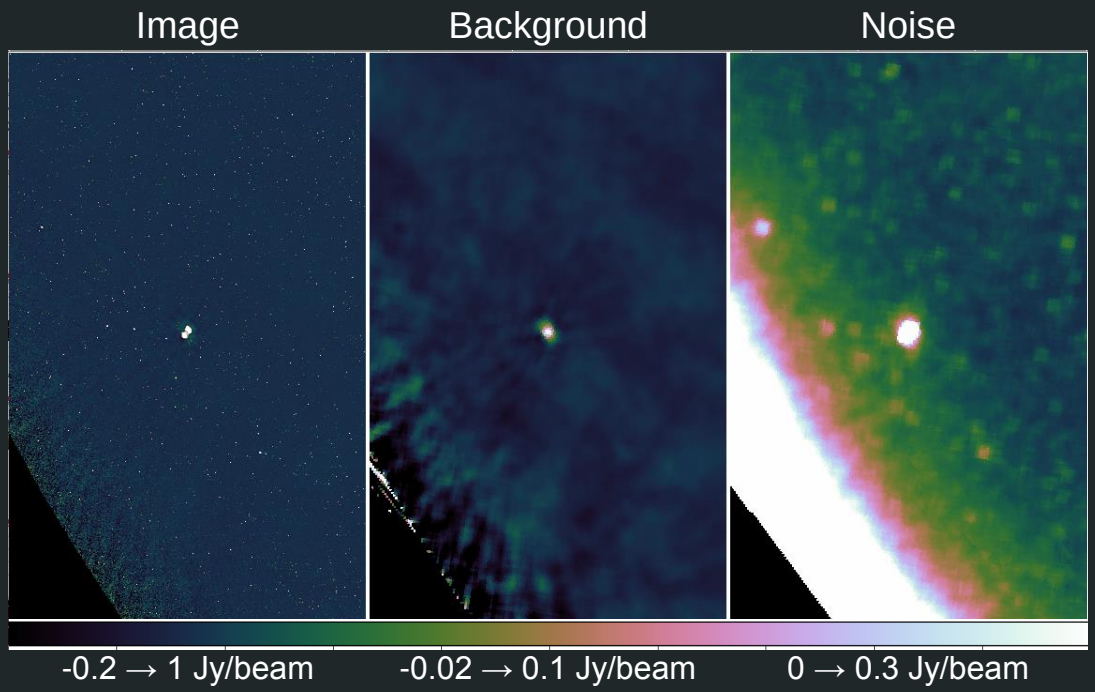


Result

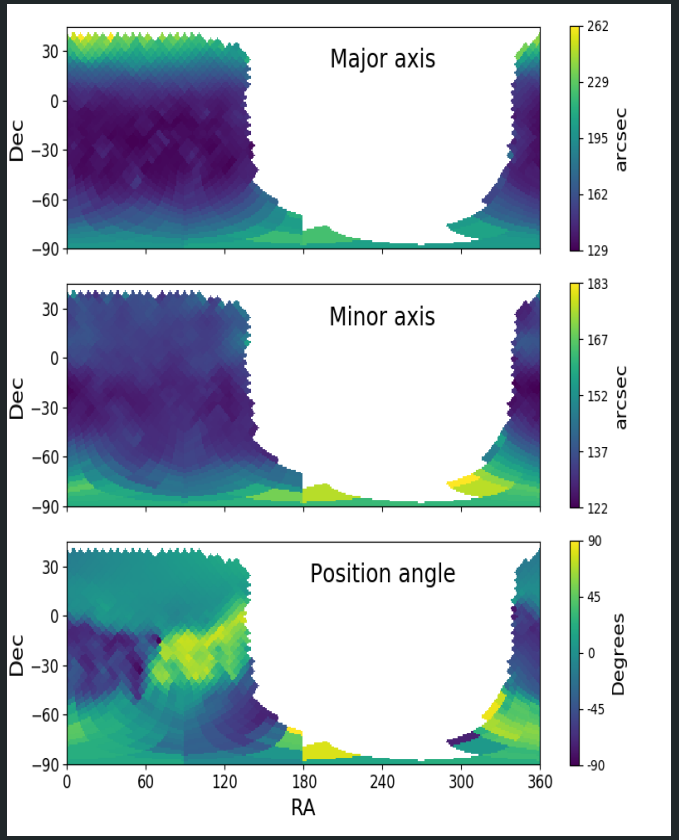


Red: 72–103 MHz
Green:103–134 MHz
Blue: 139 – 170 MHz
170–230 MHz not shown!

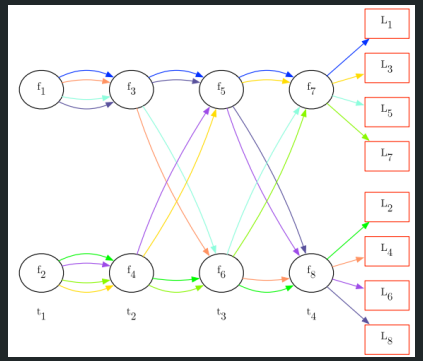
Catalogues at large FoV



Synthesized Beam

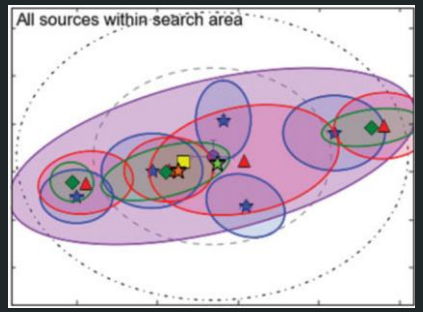


Catalogues at large Δν



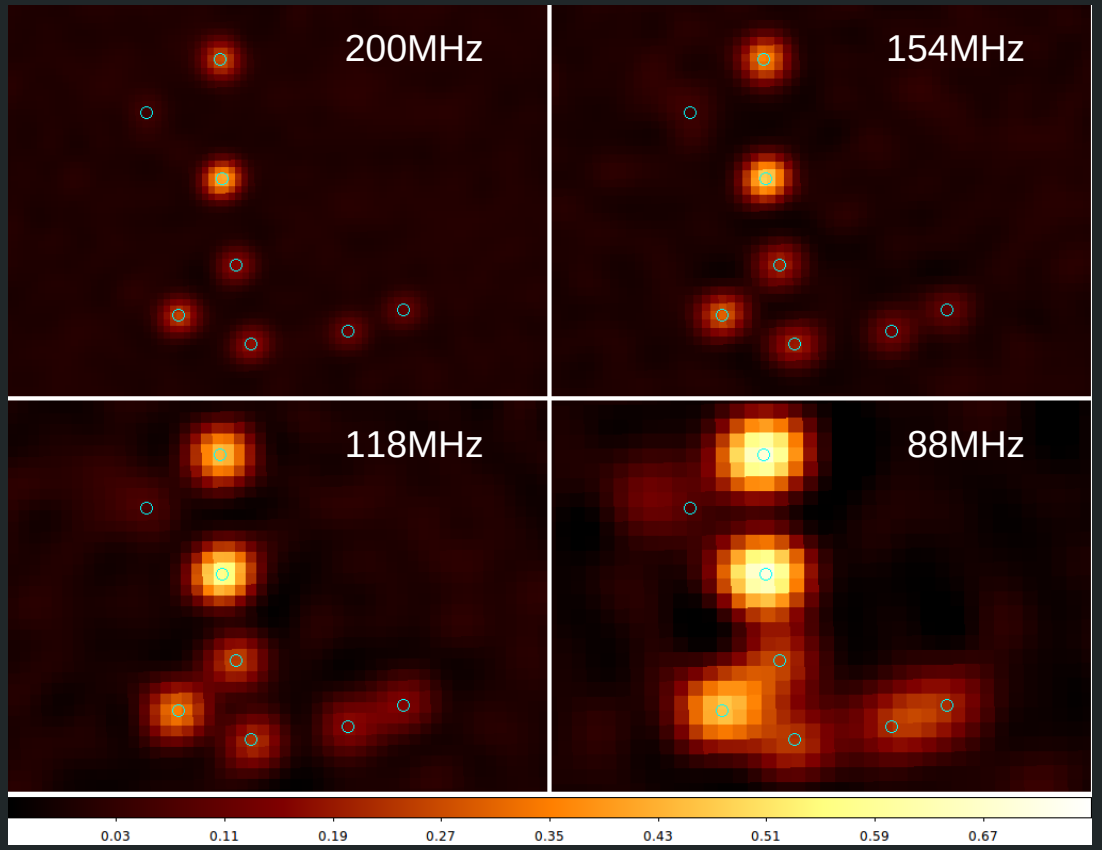
Swinbank et al. 2015

Catalogue and X-match?

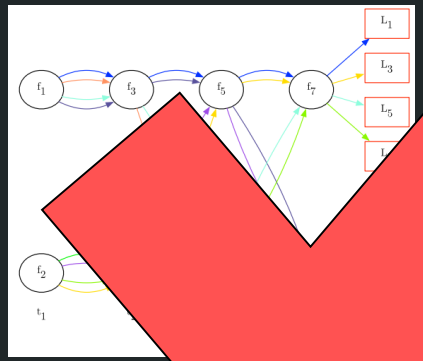


Line et al. 2017

Hierarchical association?



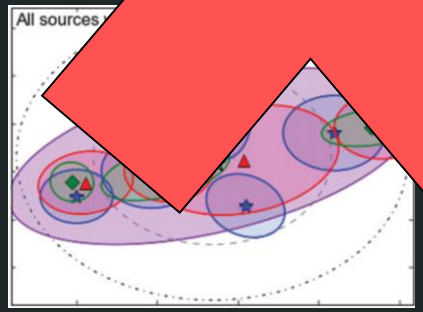
Catalogues at large Δν



atalogue
X-
n?

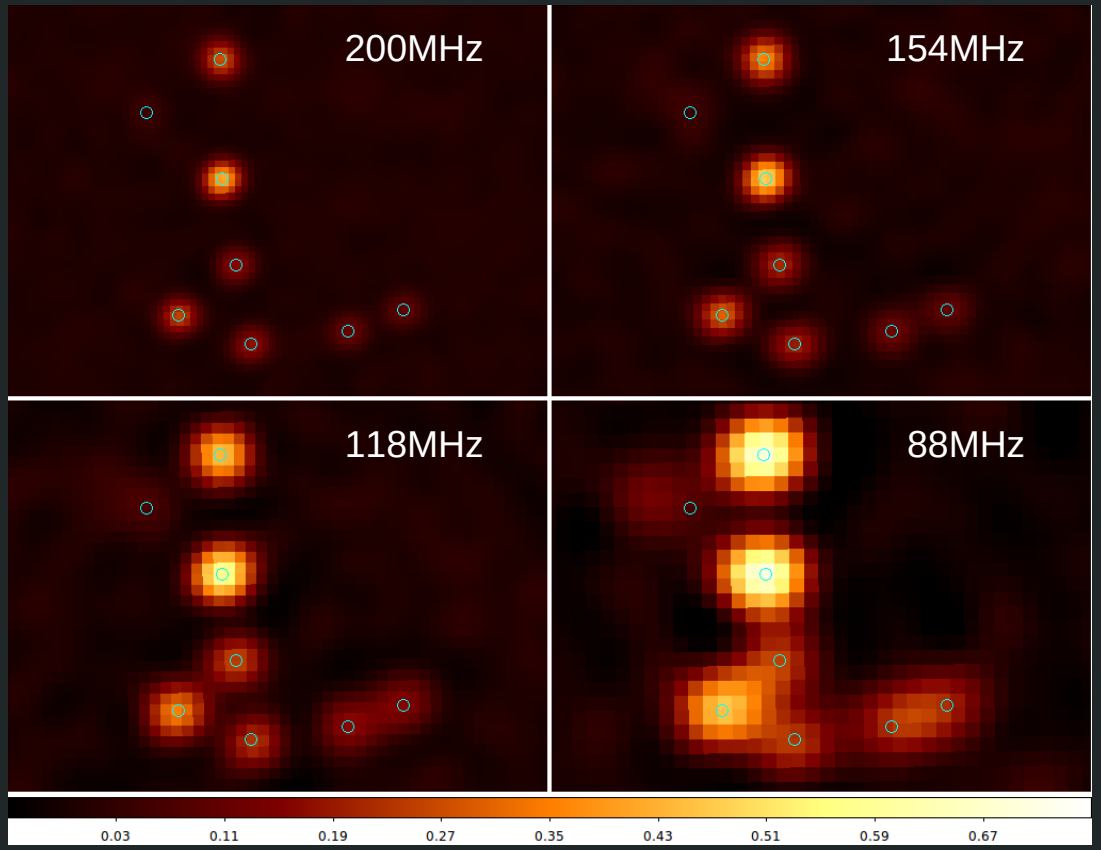
Swinbar

Too Hard!

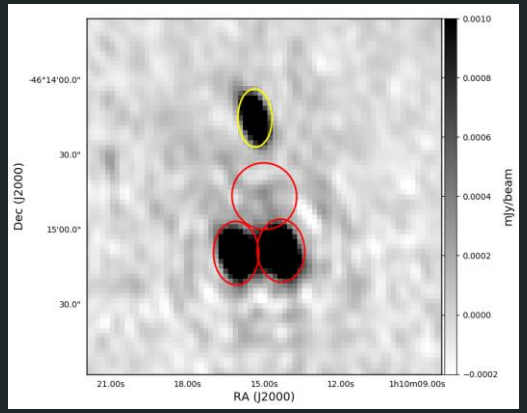


rchical
ssociation?

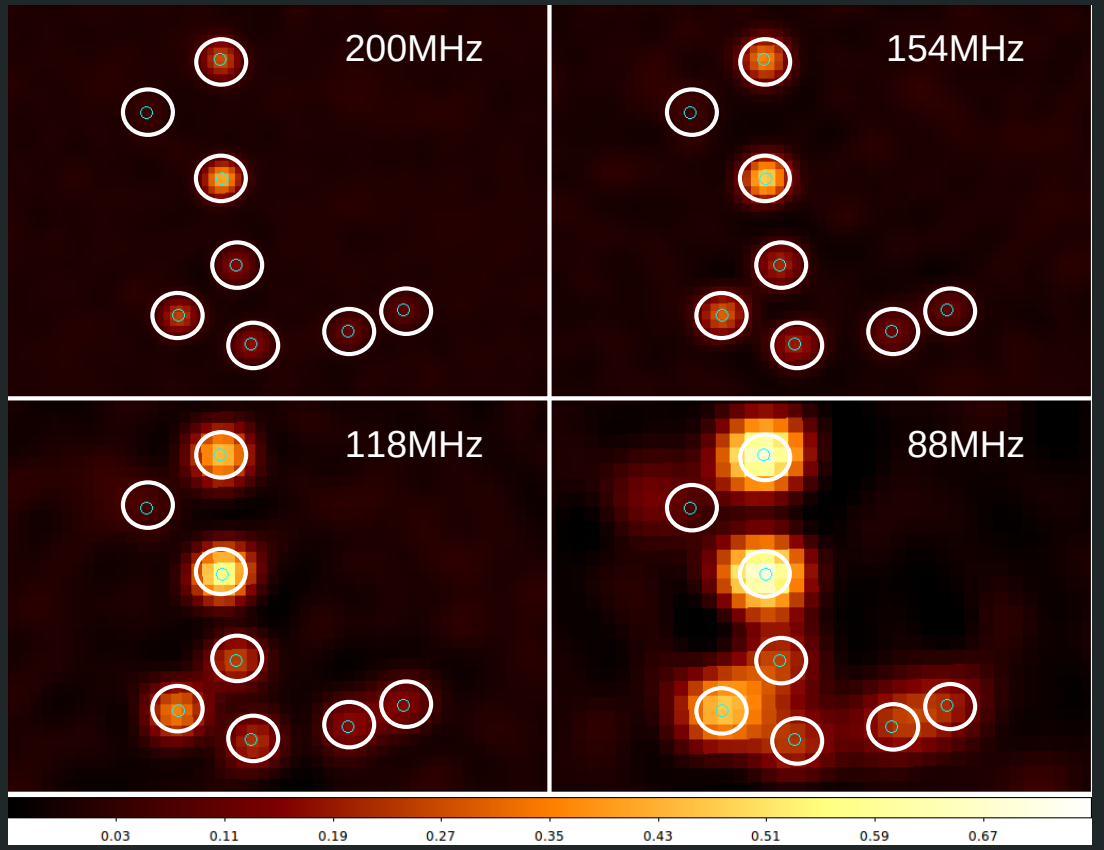
Line et al. 2017



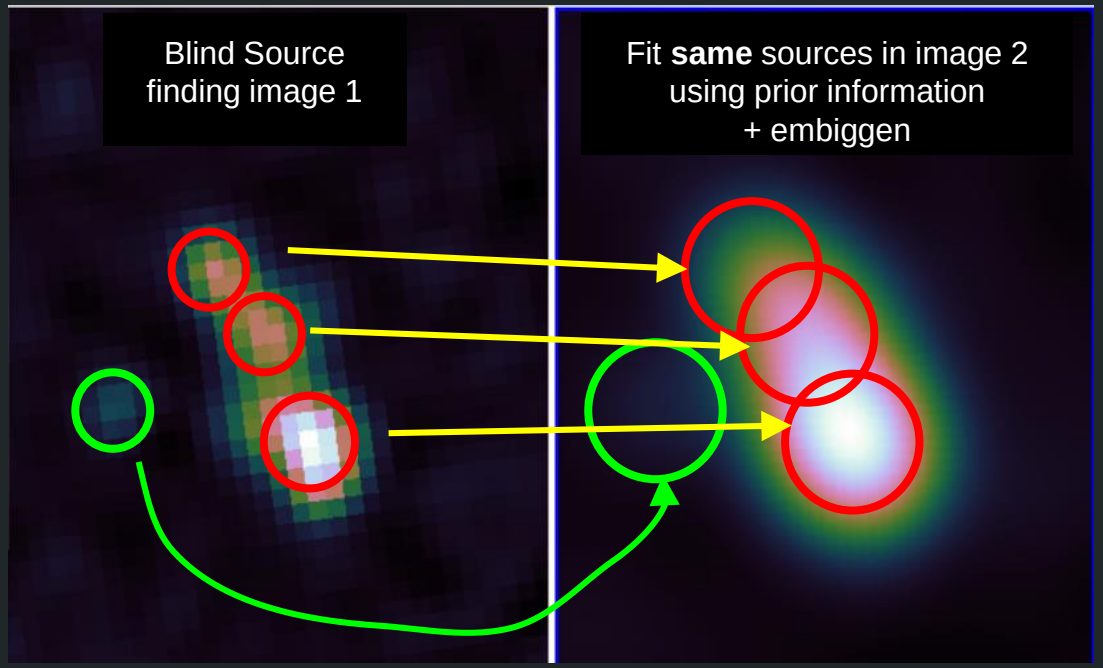
Catalogues at large Δν

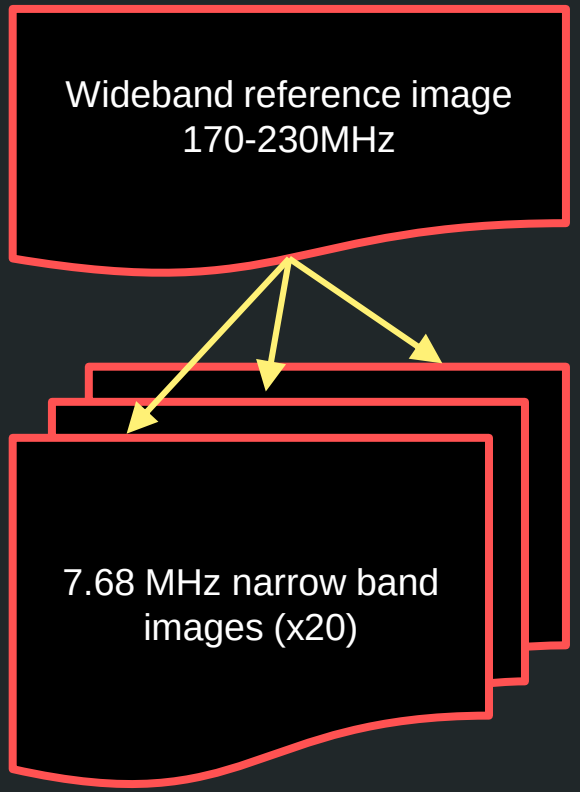


Priorized fitting with Aegean
(Hancock et al. 2012)
(now also pyBDSF)



Catalogues at large Δν



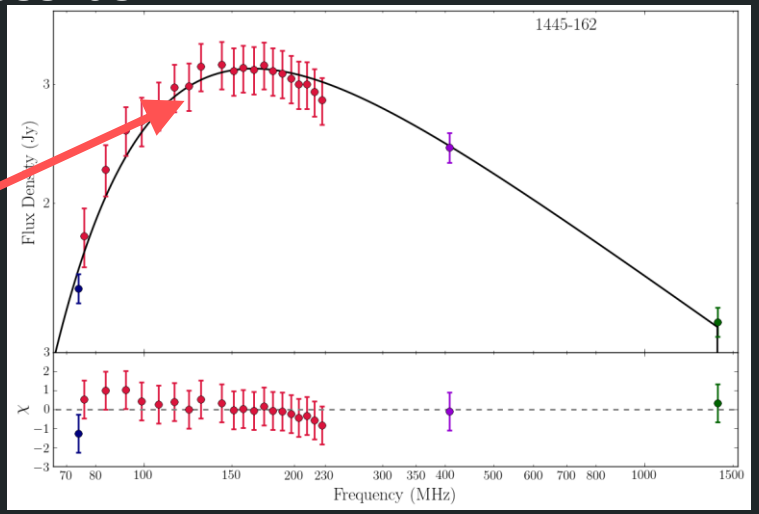


Catalogues at large Δν

Catalog contains

- **all** sources from deep image
- fluxes from each narrow band for each source
- sub-threshold fluxes
- ZERO false cross ids

GLEAM priorized fits at 20 frequencies



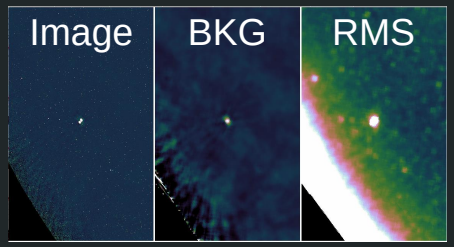
Callingham et al. 2017

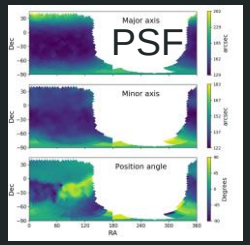
Wideband reference image 170-230MHz

7.68 MHz narrow band images (x20)

Source Finding Solution: Aegean

https://github.com/PaulHancock/Aegean





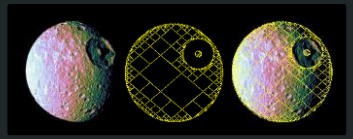
Wideband reference image 170-230MHz

7.68 MHz narrow band images (x20)

Aegean
- Find sources
- Characterise sources
- Sources can be gaussians or blobs

BANE
- Characterise background
- Characterise noise
- Do it right
- Do it fast

MIMAS
- Describe regions
- Combine regions
- Mask images
- Constrain Aegean
- Write MOC files



Summary (what **we** did)

Flux calibration:

- Ensemble solution to bootstrap from other frequencies
- Rely on the N/S symmetry of the MWA beam

Ionospheric calibration

- Image warping based on positions from other frequencies

Catalogues at large FoV and Δν

- Create 60MHz deep master image
- Create background/noise/PSF maps
- Priorized fitting in each of 20 narrow band images
- SEDs for all ~300k sources.

Summary (what **you** should do)

Flux calibration:

- Use GLEAM fluxes

- (Invest in a good beam model)

Ionospheric calibration

- Use GLEAM positions

Catalogues at large FoV and Δν

- Use Aegean and BANE

Read: Hurley-Walker, Callingham, Hancock et al. 2017 MNRAS.464.1146H