Simulating HI Intensity Mapping for MeerKAT/SKA Mid

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Credit: https://www.manchester.ac.uk/discover/news/the-meerkat-radio-telescope-in-south-africa-receives-prestigious-award-of-the-royal-astronomical-society/

Introduction

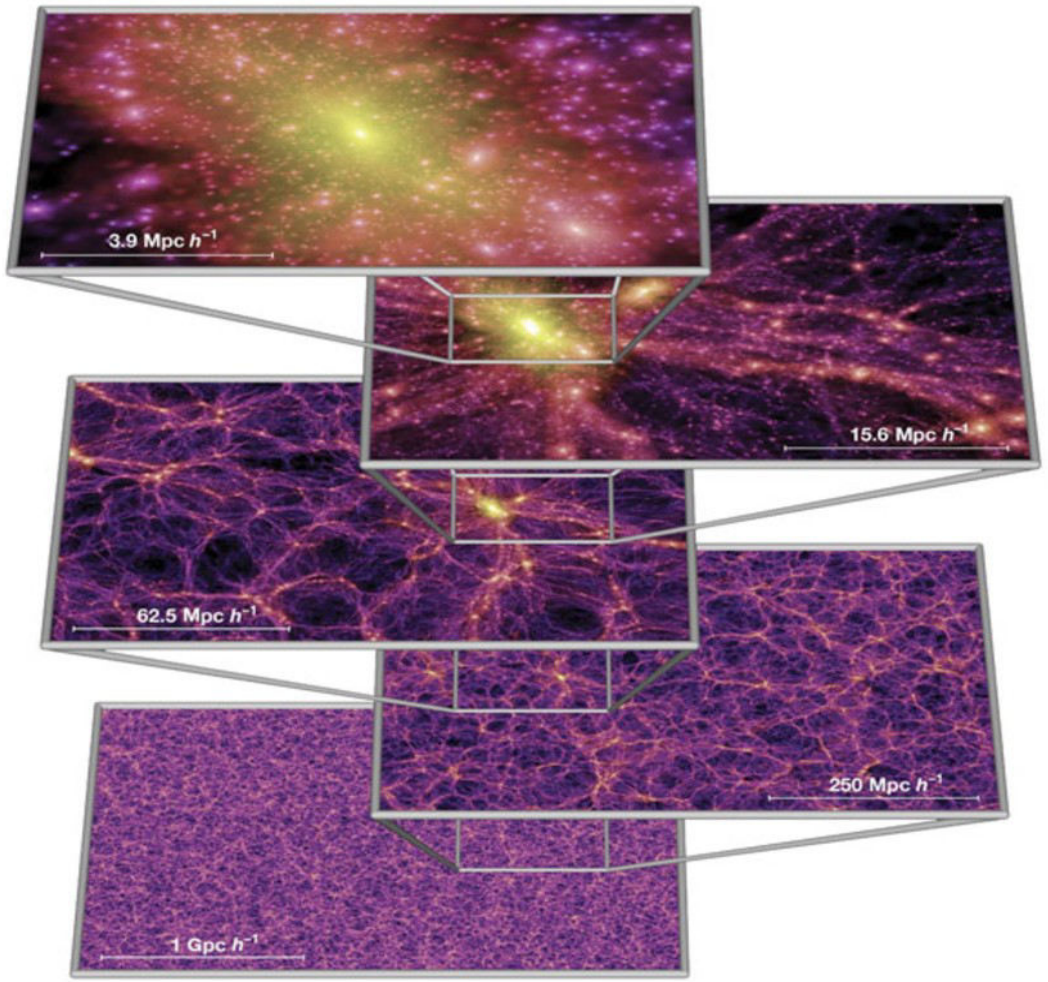


Figure from: Simulations of the formation, evolution and clustering of galaxies and quasars. (2005)

- Fluctuations of HI are tracers for dark matter fluctuations
- Use HI IM to reconstruct dark matter density field
- HI IM more efficient than galaxy surveys
- Probe large cosmological volumes on intermediate scales

Systematics

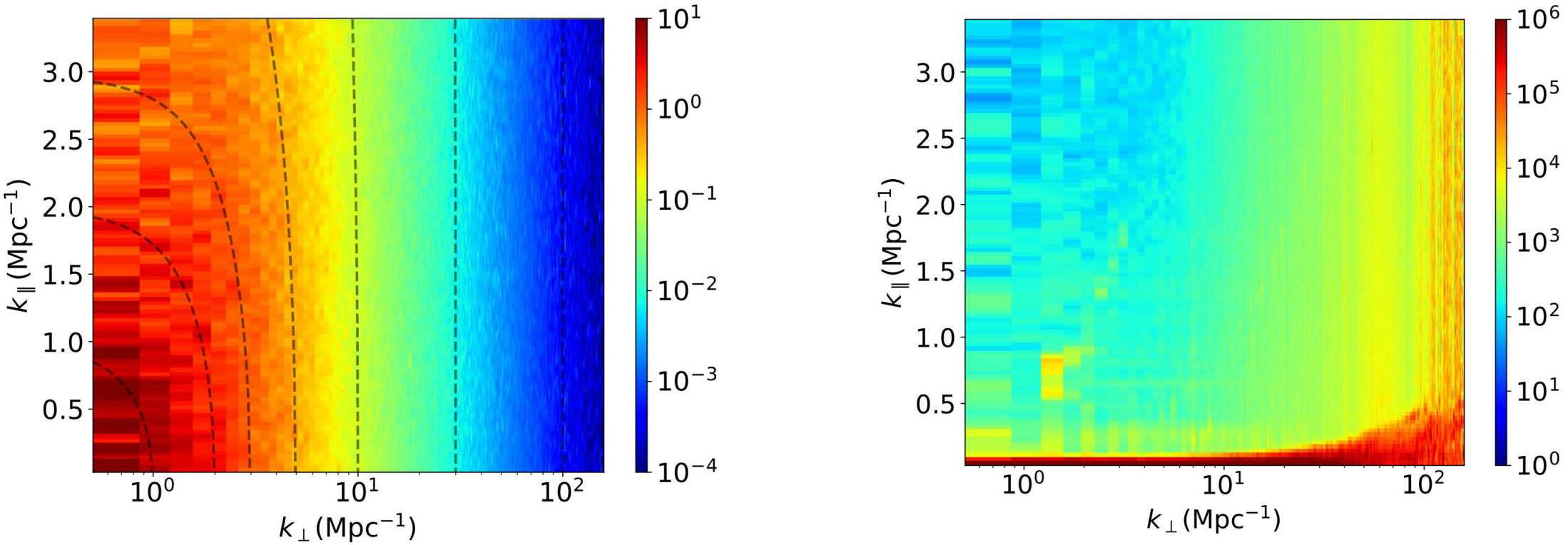
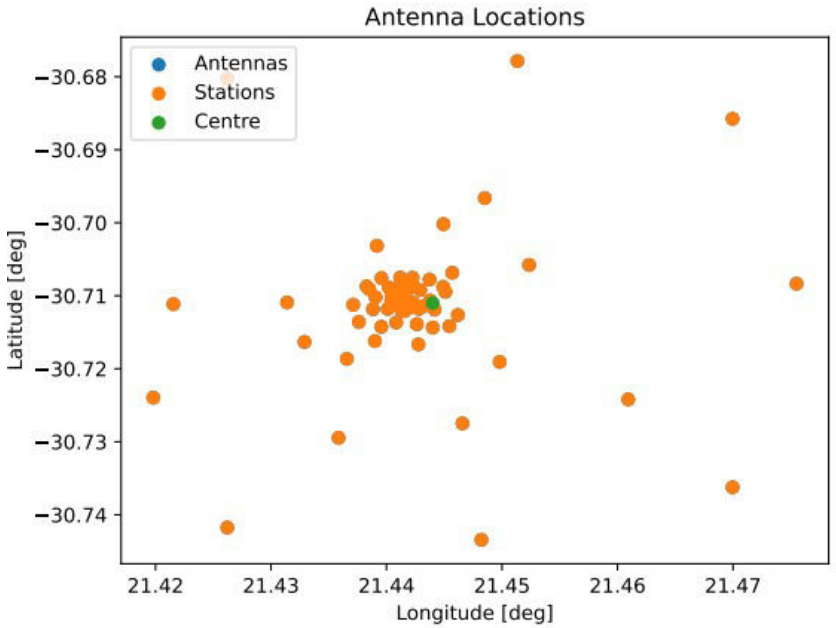


Figure from: Sourabh Paul, et al. (2021)

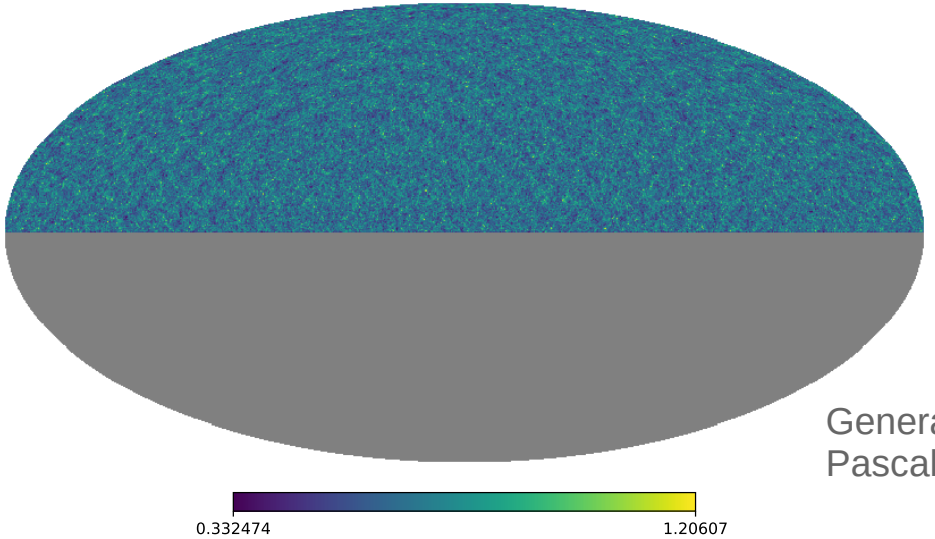
- Systematics are significant
- Use simulations to understanding their effect on the data

Overview

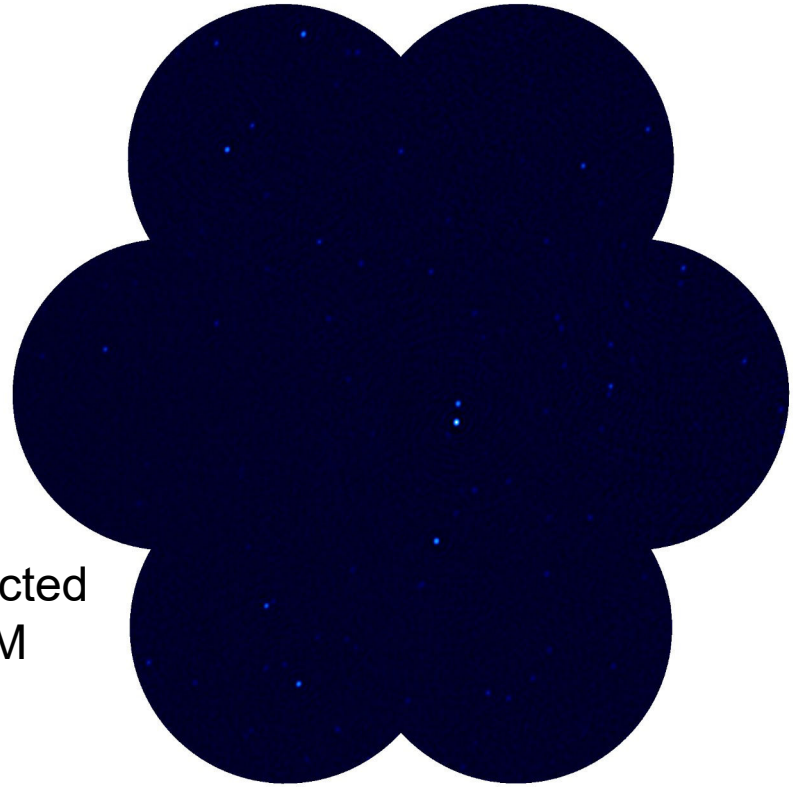
SKA Mid/MeerKAT Simulation and Analysis Pipeline (Karabo)



HI flux distribution from past lightcone of dark matter halos (PINOCCHIO)

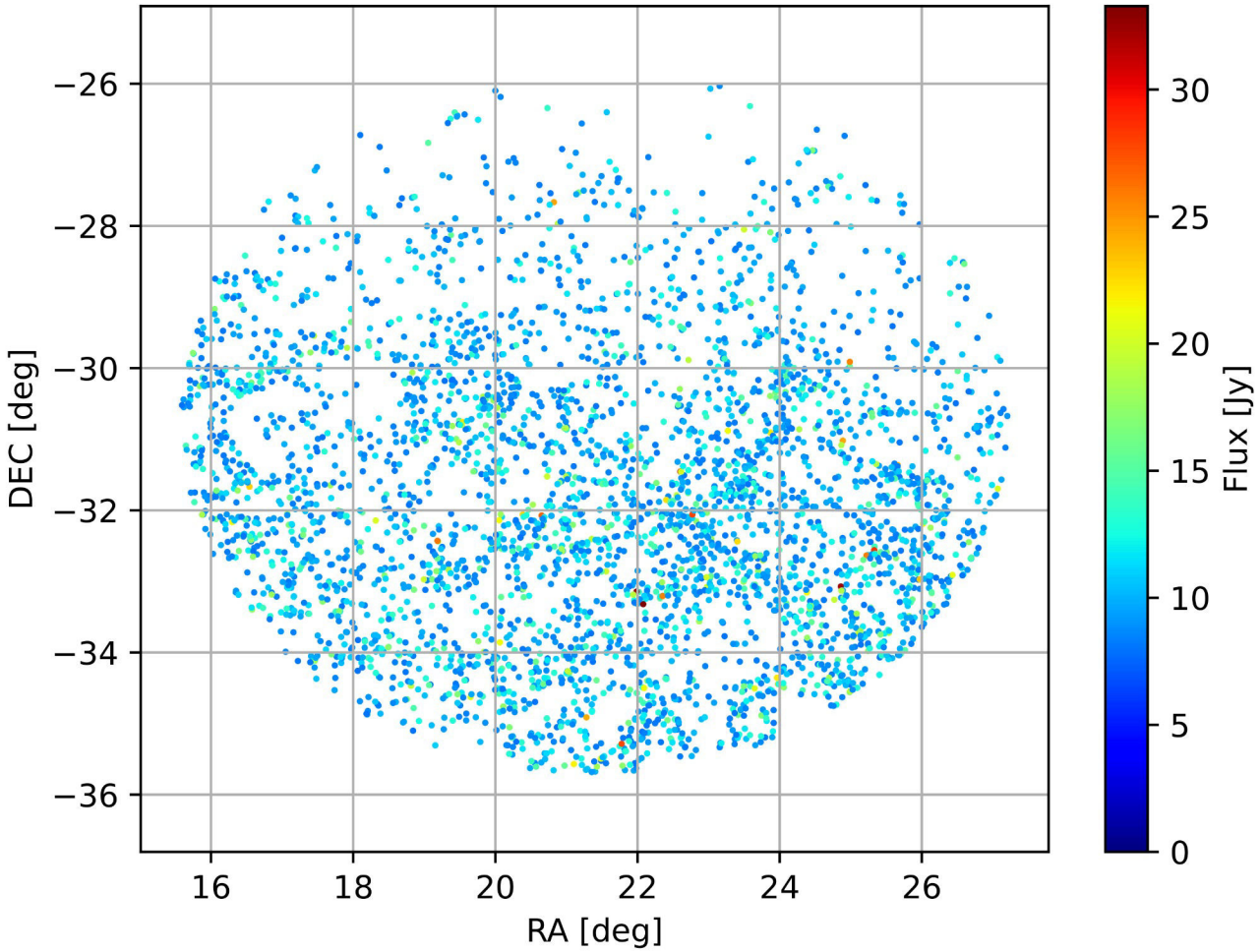


Generated by Pascal Hitz



Reconstructed 3-dim HI IM

Read in the Sky Catalog with Karabo



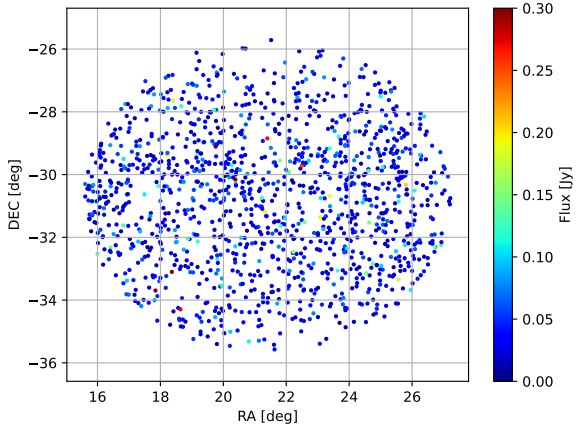
Redshift range: 0.77 – 1.03
Frequency range: 703 MHz – 807 MHz

- Read in catalog directly with Karabo

```
prefix_mapping = {
        "ra": "Right Ascension",
        "dec": "Declination",
        "i": "Flux",
        "q": None,
        "u": None,
        "v": None,
        "ref_freq": None,
        "spectral_index": None,
        "rm": None,
        "major": None,
        "minor": None,
        "pa": None,
        "id": None,
    }
extra_columns = ["Observed Redshift"]

sky = SkyModel.get_sky_model_from_h5_to_xarray(path=path_catalog,
 prefix_mapping=prefix_mapping, extra_columns=extra_columns)
sky_filter, filter_in = sky.filter_by_radius_euclidean_flat_approximation
 (ra0_deg=ra_deg, dec0_deg=dec_deg*-1, inner_radius_deg=inner_rad,
 outer_radius_deg=outer_rad, indices=True)
```

Sky Slices – Line emission

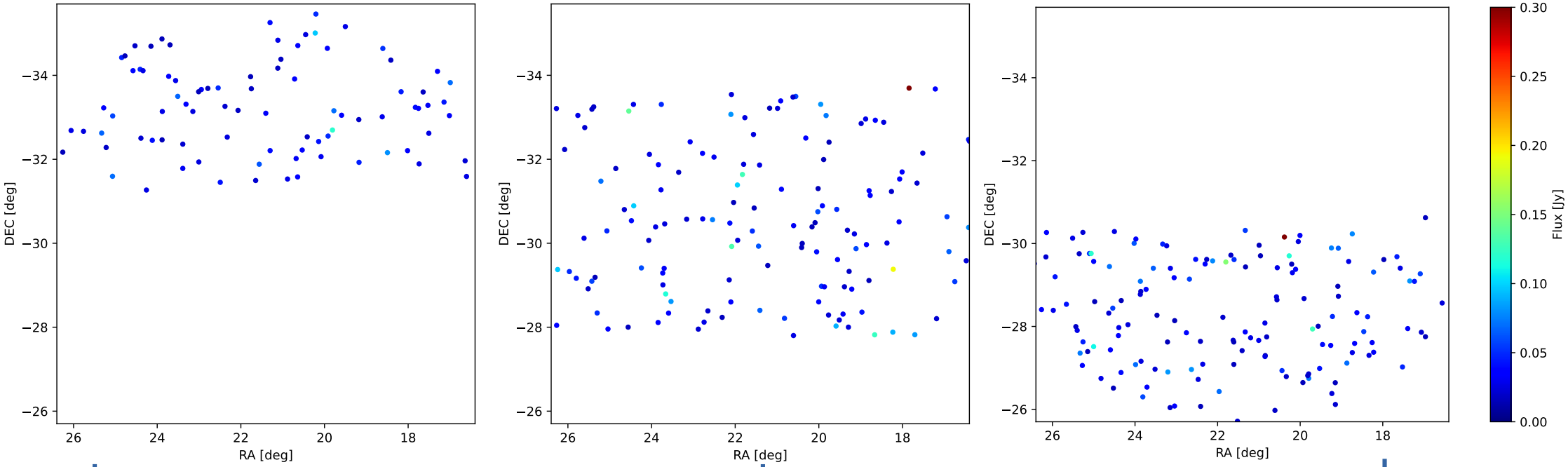


Lightcone:

- Redshift range: 0.77 – 1.03
- Frequency range: 703 MHz – 807 MHz

Observed Redshift

0.8 0.9 1.0



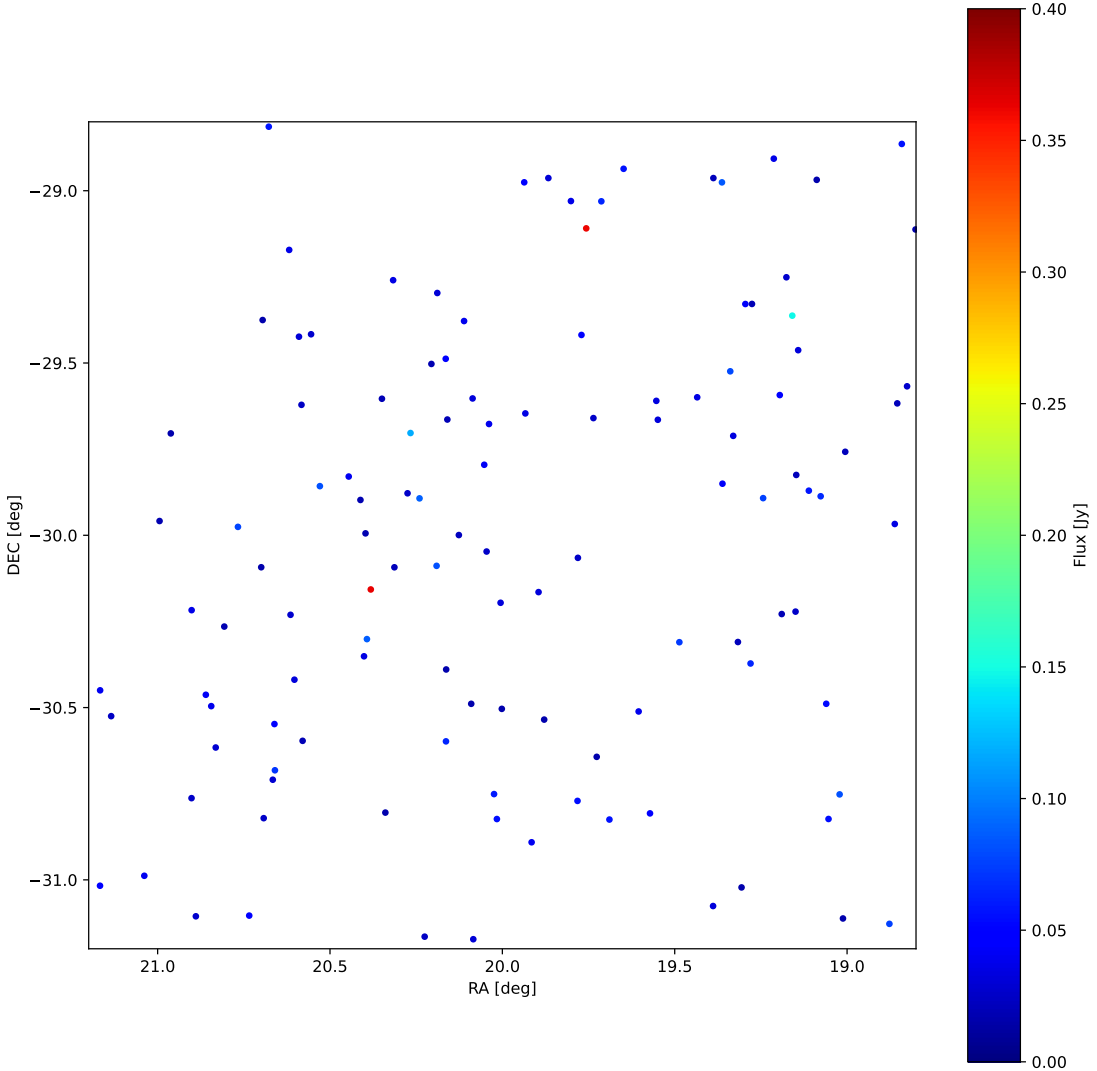
800 MHz 750 MHz 700 MHz

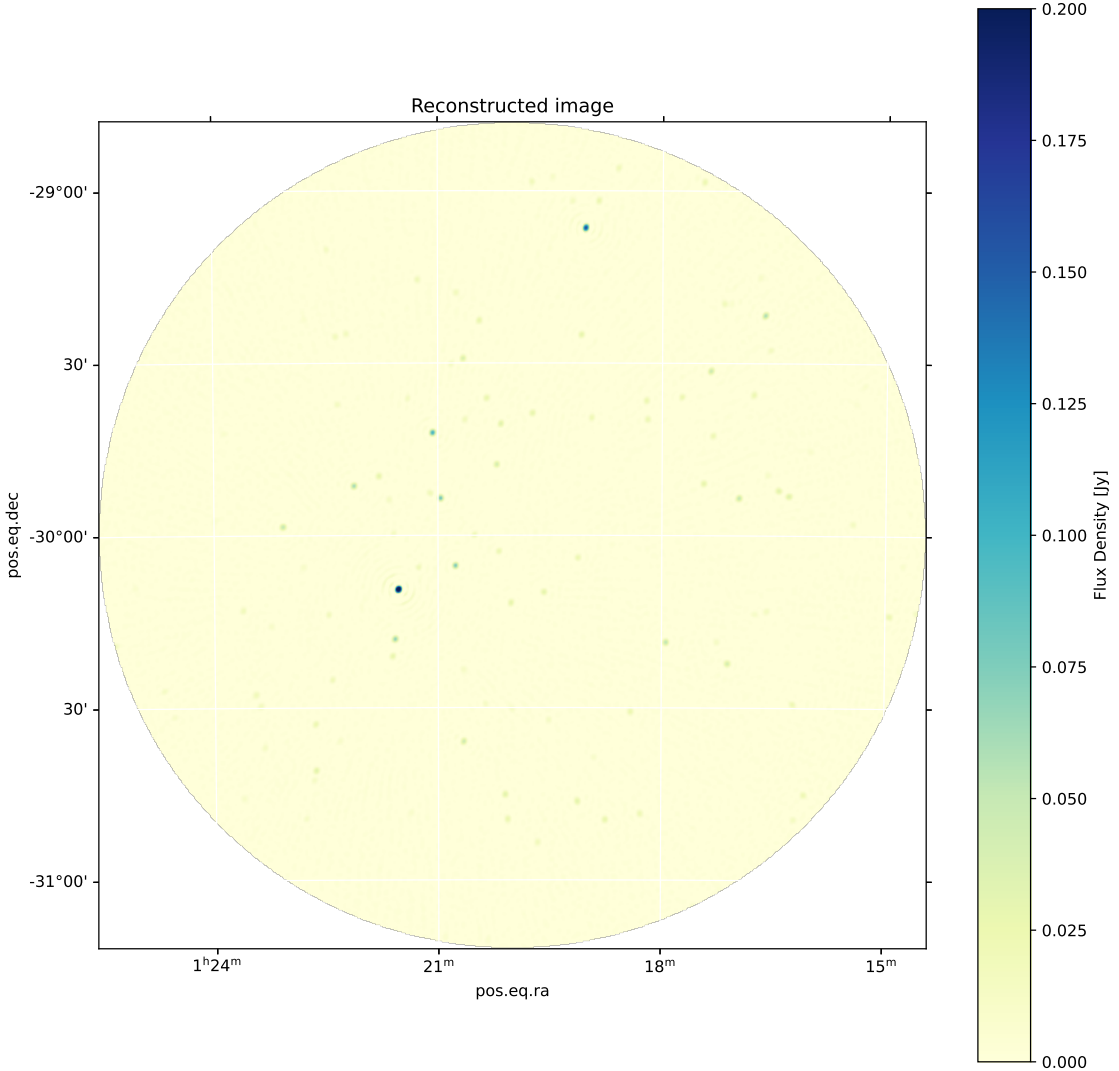
Frequency

$\Delta z = 0.03$

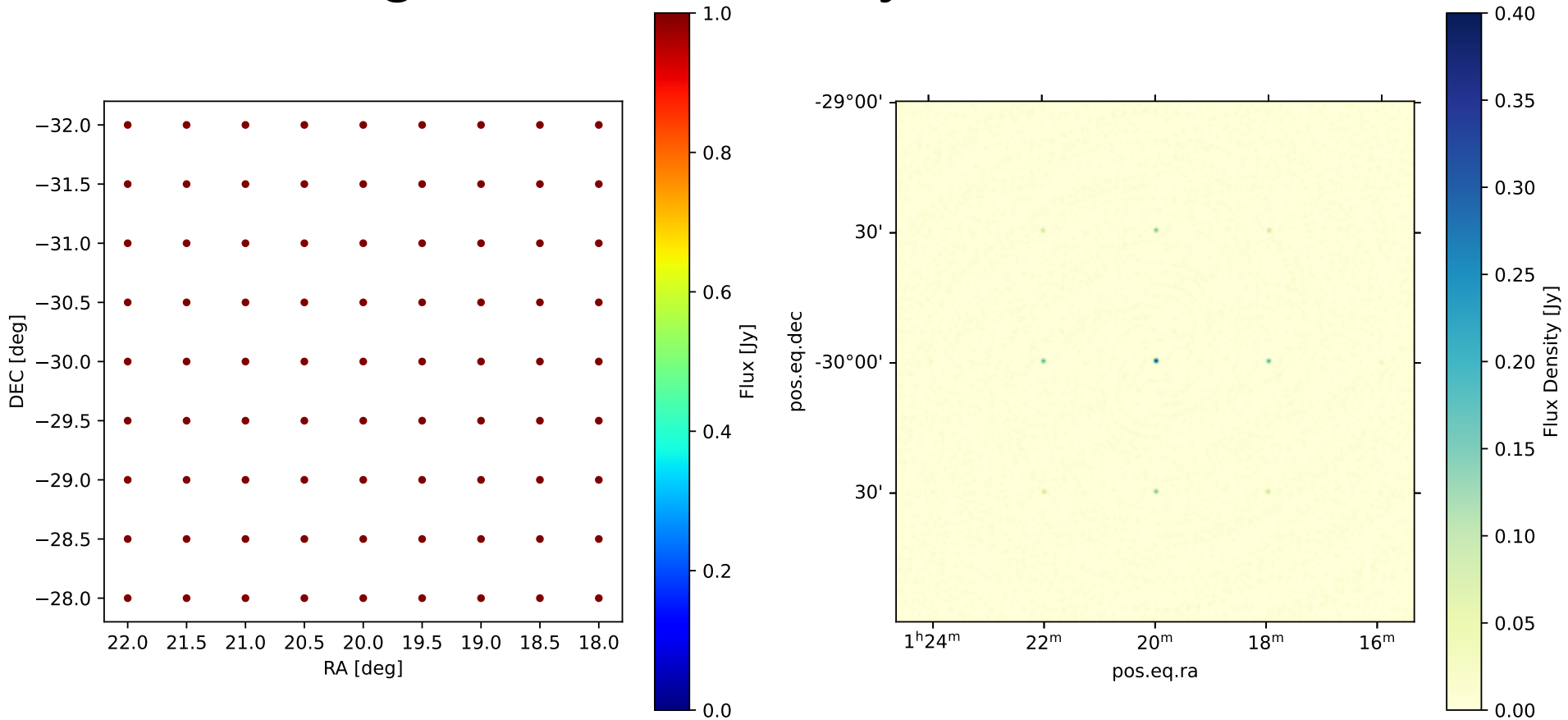
$\Delta f = 12$ MHz

Reconstruction

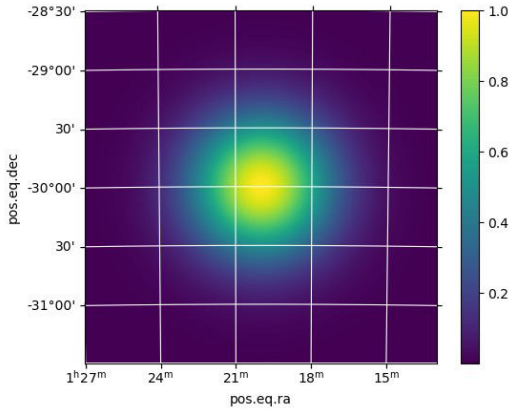




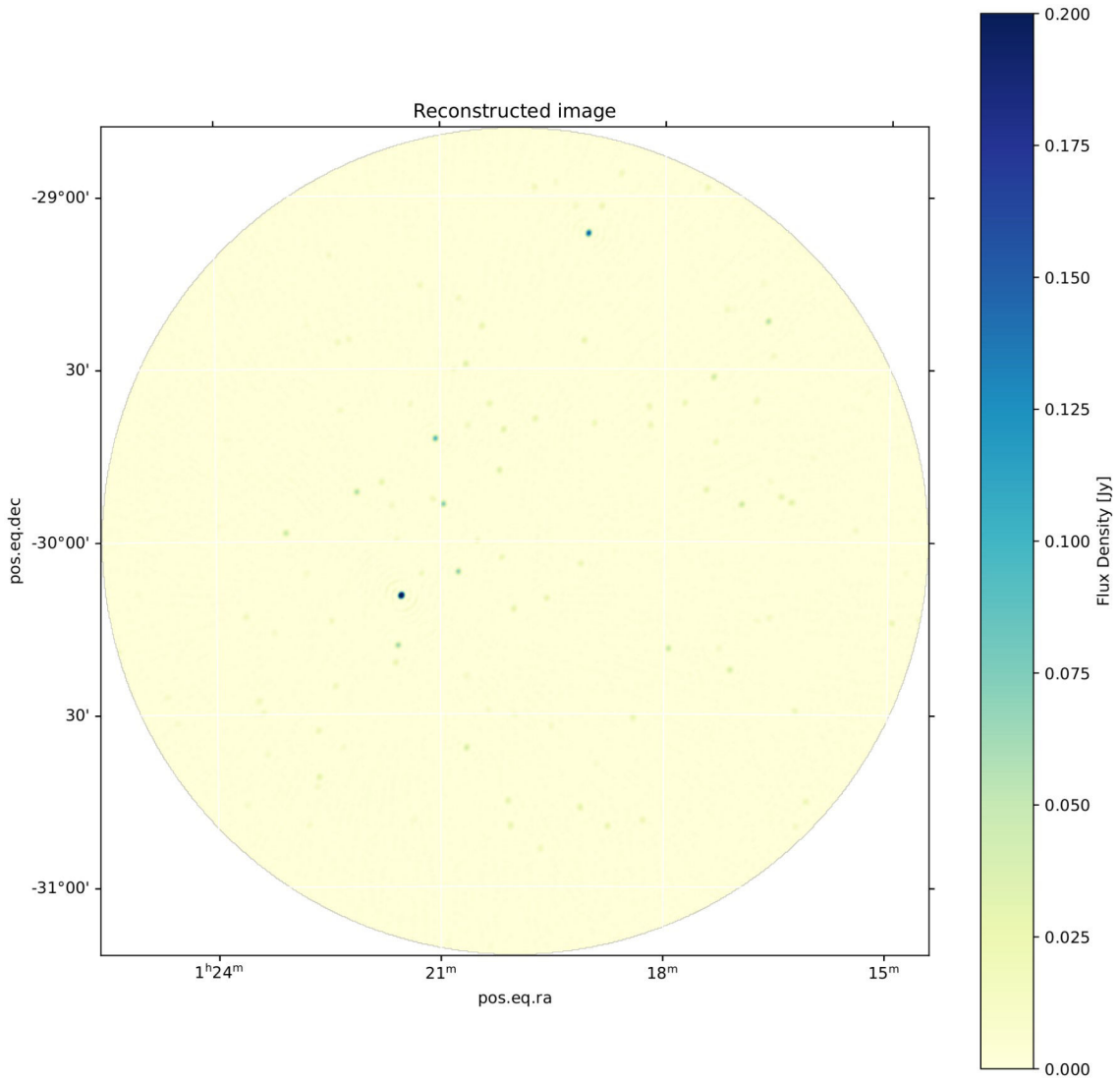
Simulation Configuration/ Primary Beam

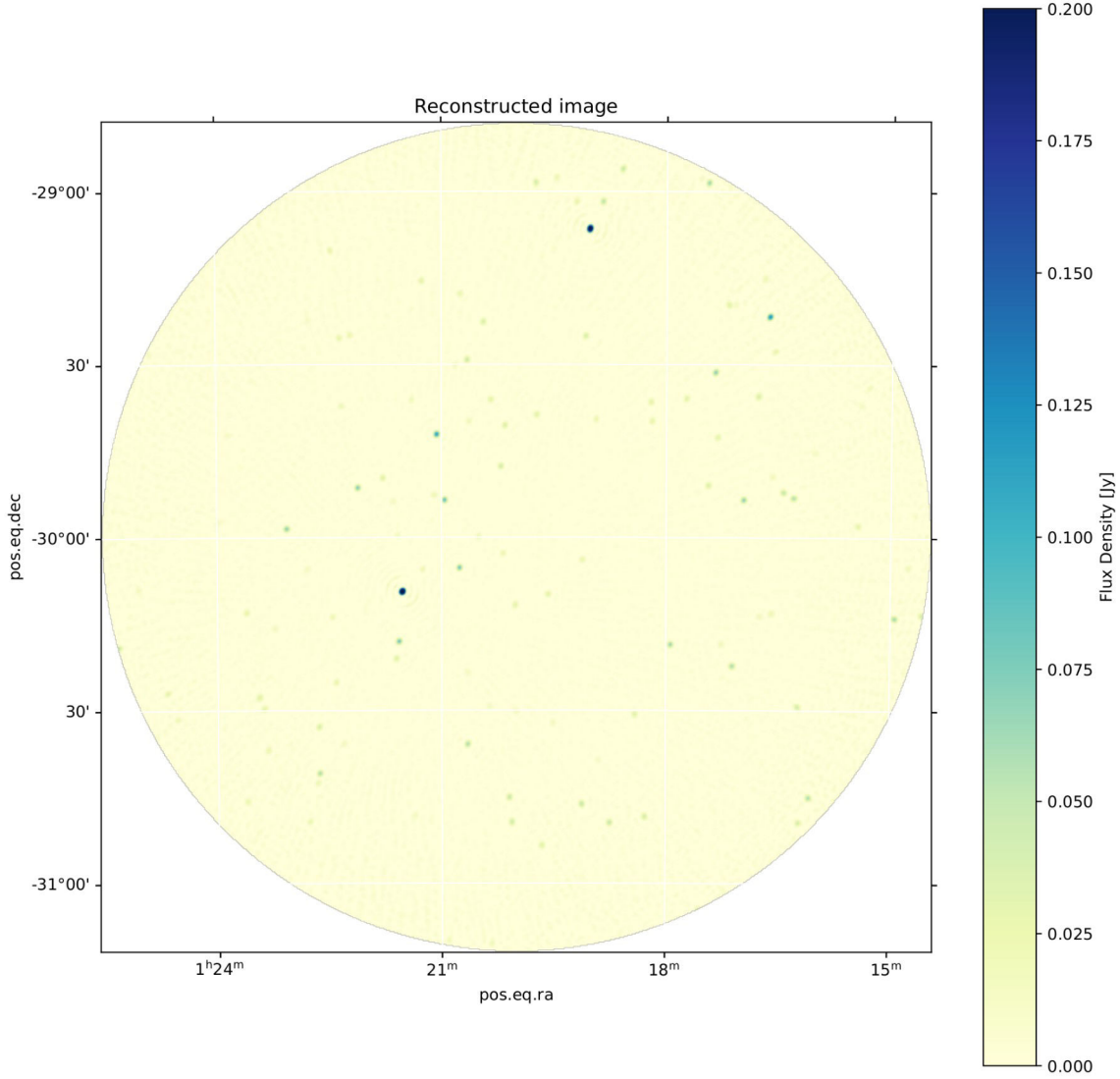


Gaussian primary beam of FWHM ~ 1deg

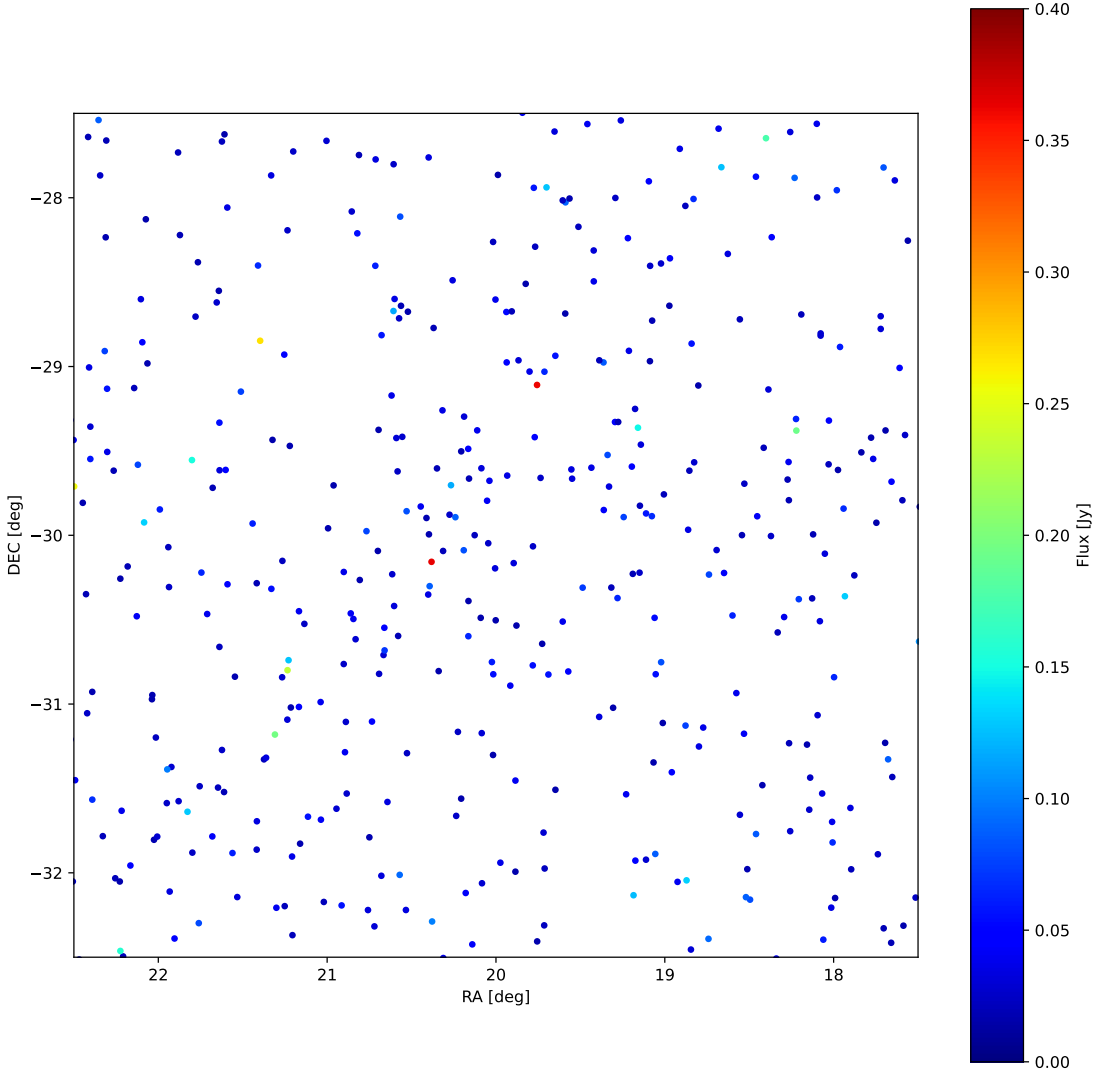


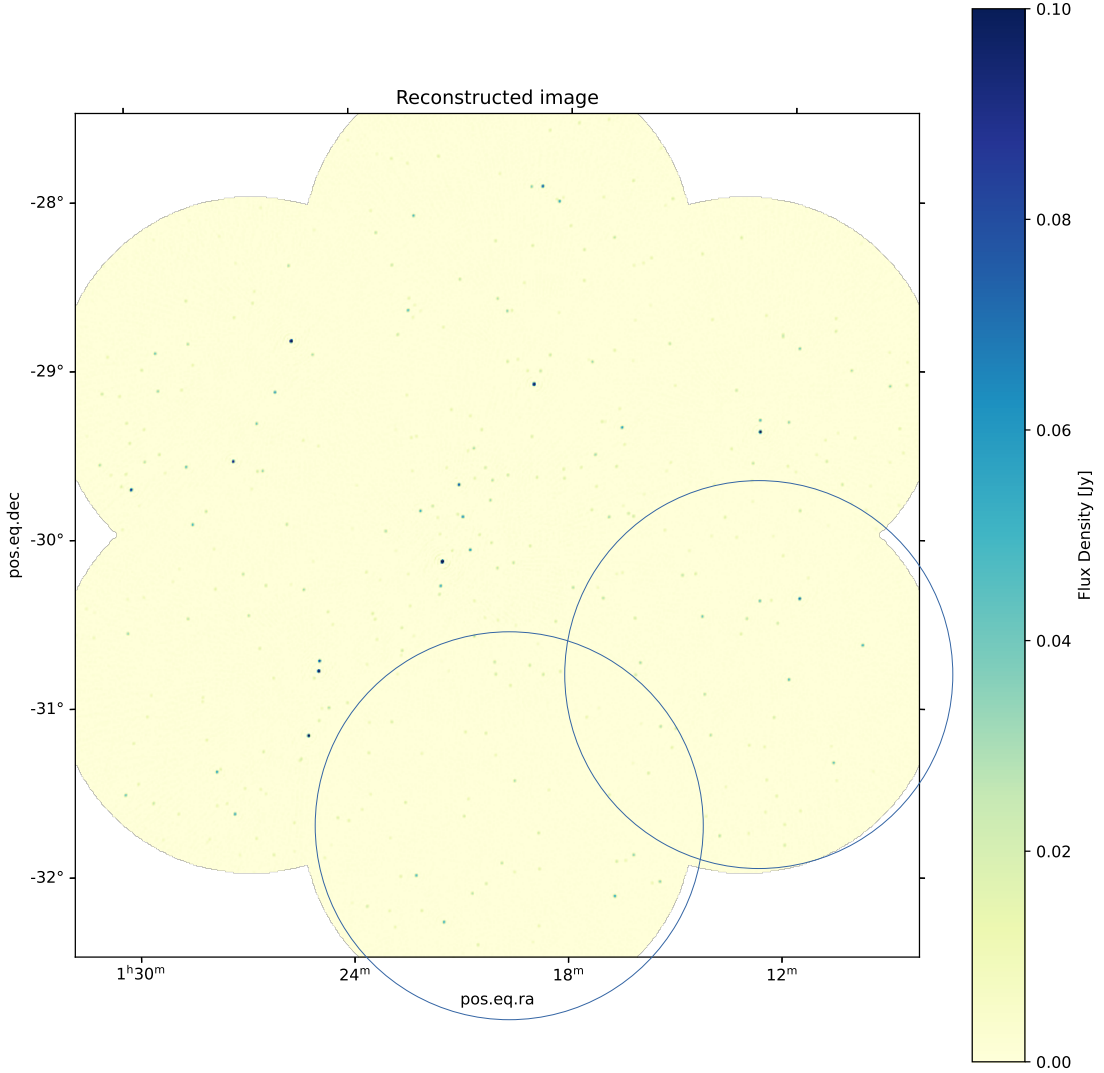
Primary Beam Correction

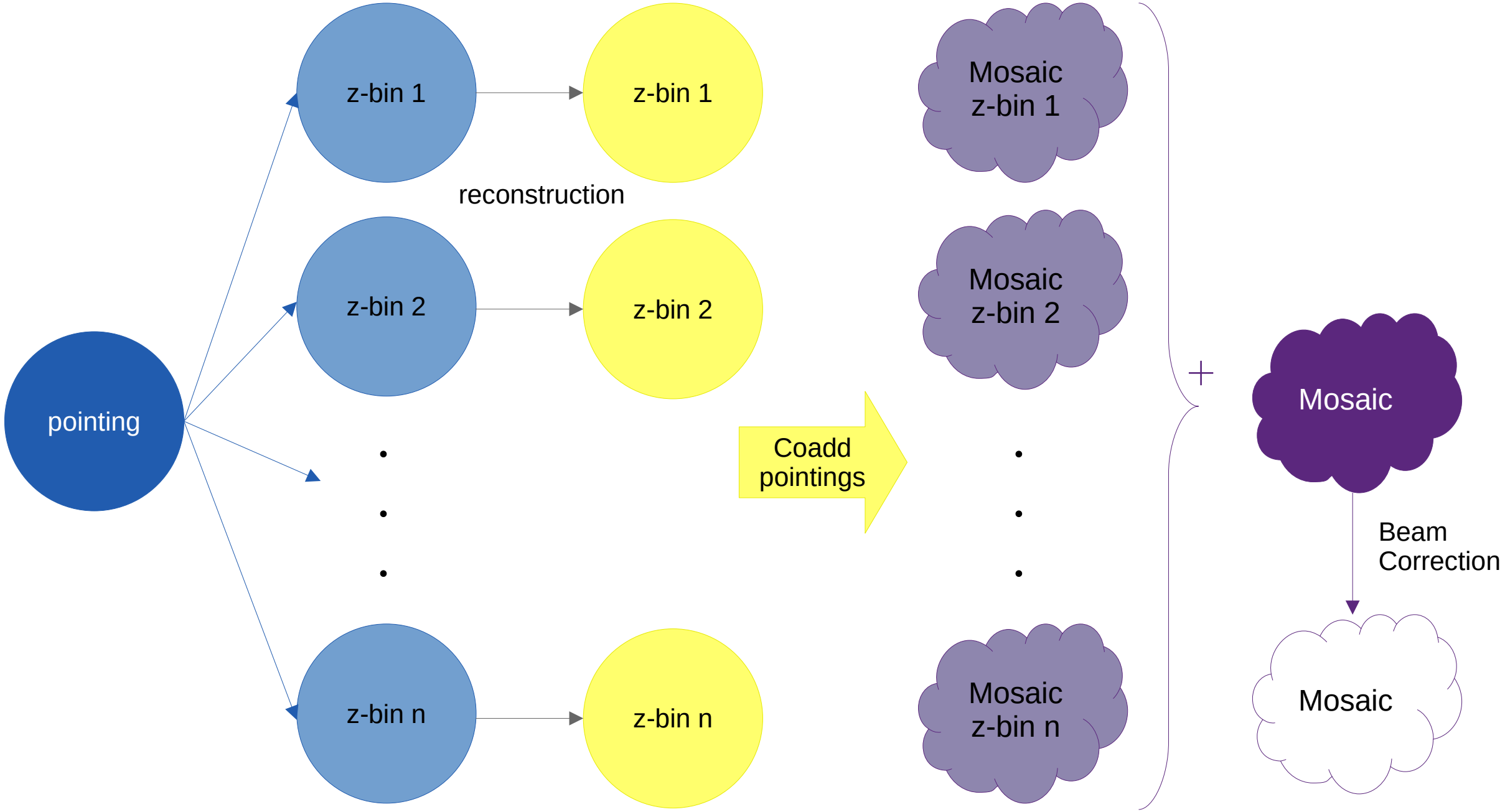




Mosaic

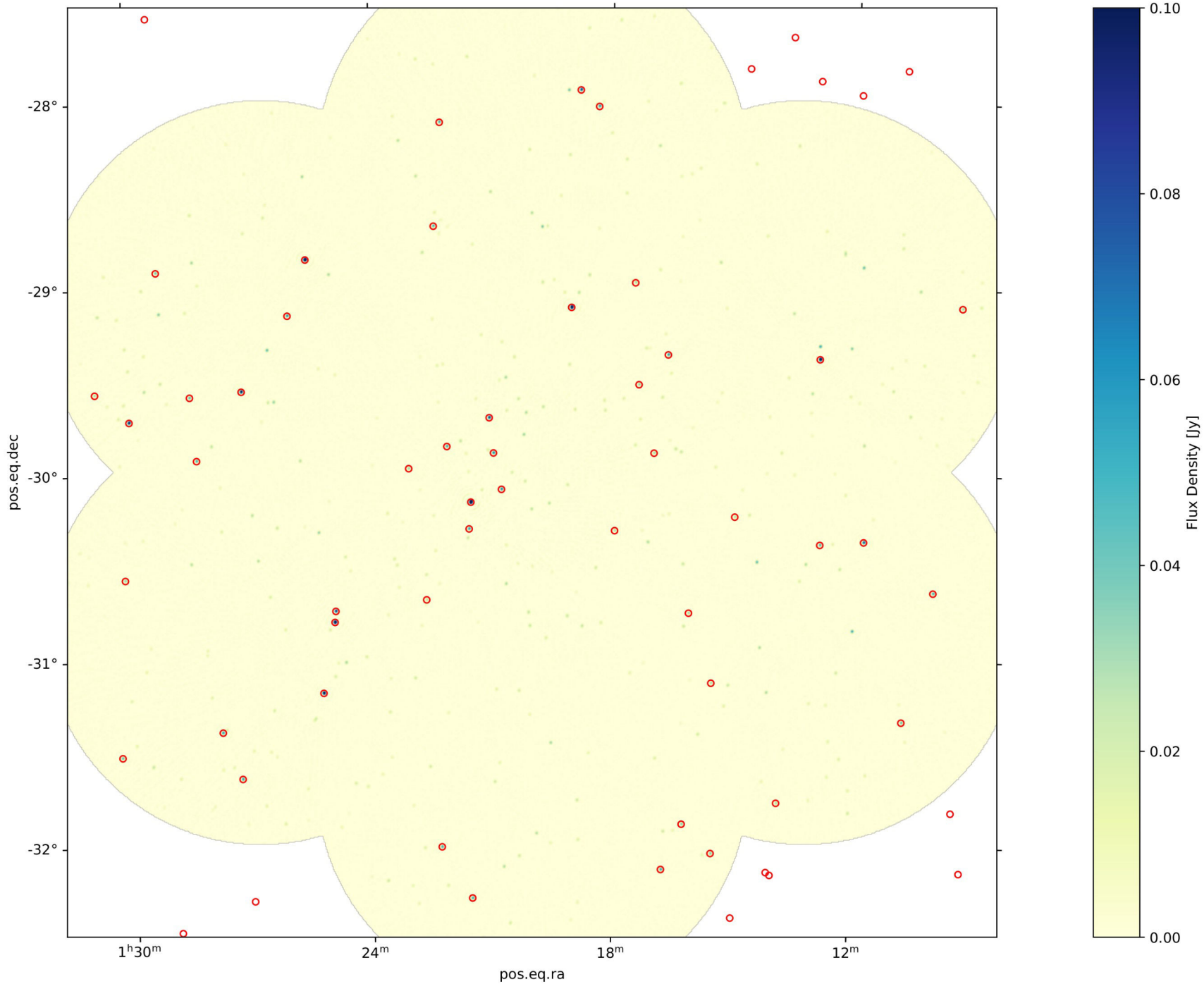

DEC [deg]
−28
−29
−30
−31
−32
22
21
20
19
18
RA [deg]
Flux [Jy]
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00


Reconstructed image
pos.eq.dec
-28°
-29°
-30°
-31°
-32°
1h30m
24m
18m
12m
pos.eq.ra
Flux Density [Jy]
0.10
0.08
0.06
0.04
0.02
0.00


z-bin 1
z-bin 1
reconstruction
z-bin 2
z-bin 2
pointing
z-bin n
z-bin n
Coadd pointings
Mosaic z-bin 1
Mosaic z-bin 2
Mosaic z-bin n
Mosaic
Beam Correction
Mosaic

Next Steps

- Custom Primary Beam and corresponding Primary Beam correction
- Transfer simulations completely to CSCS for larger simulations with multinodes
- Simulate higher resolution halo catalogs
- Take into account extended sources
- Add continuum sources, galactic emission etc. to simulate complete sky model


-28°
-29°
-30°
-31°
-32°
pos.eq.dec
1h30m
24m
18m
12m
pos.eq.ra
0.10
0.08
0.06
0.04
0.02
0.00
Flux Density [Jy]

ETH zürich