

Swiss SKA Days 2026
Aug 31 – Sep 02, Neuchâtel

skasim

a researcher-oriented simulation
package for SKA

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INSTITUTO DE
ASTROFÍSICA DE
ANDALUCÍA



EXCELENCIA
SEVERO
OCHOA



CSIC



Motivation · the CSIC4SKA project

Delivering a **versatile toolset** to help the SKA community prepare for **early science** and define **Key Science Projects**

Reliable **simulated observations** are essential for

01

Feasibility studies

*How to optimize
science cases to
capabilities*

02

Pipeline validation

*Auditable ground
truths for analysis
workflows*

03

Training

*Playground for
students and
non-radio specialists*

04

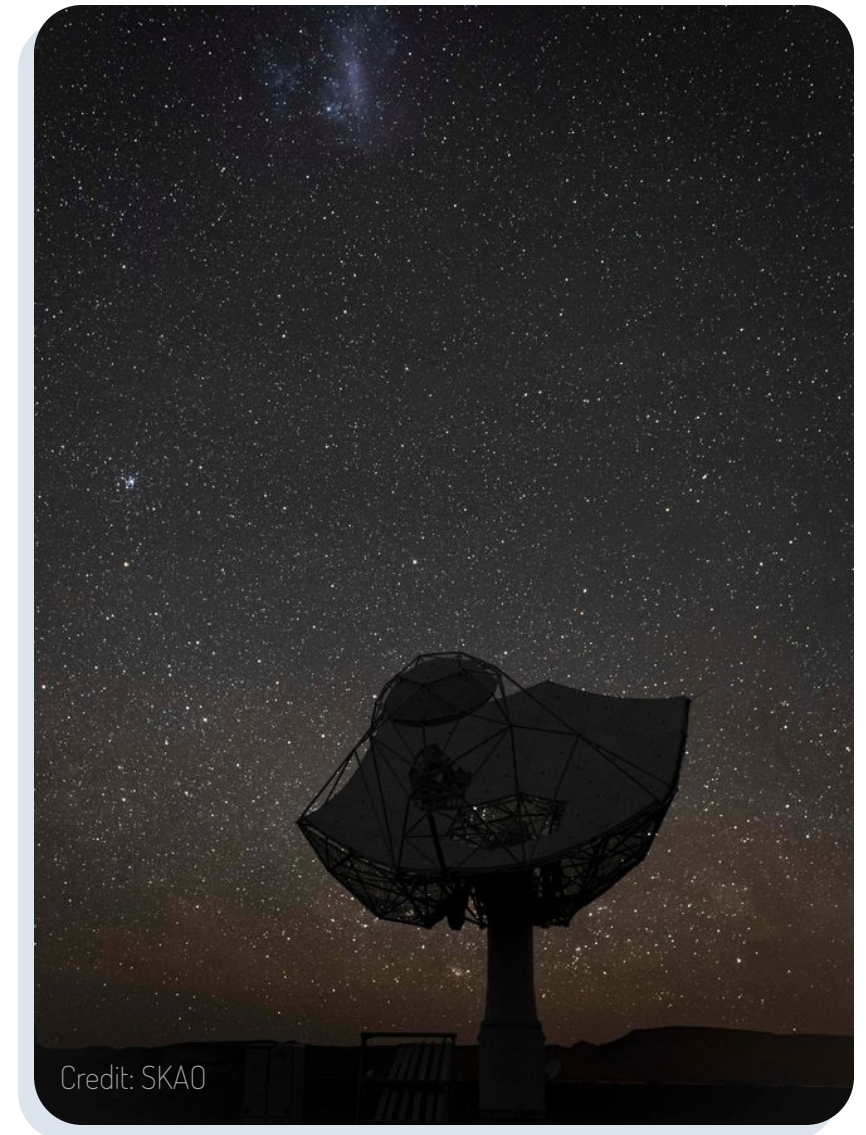
Reproducibility

*Ensuring traceable
and repeatable
workflows*

Motivation · the current simulation ecosystem

Numerous simulation tools and frameworks:

- **CASA**
task *simobserve*
- **OSKAR**
Oxford SKA Simulator
- **RASCIL**
Radio Astronomy Simulation, Calibration and Imaging Library
- **Karabo** pipeline



Motivation · not so easy for the users

THE PROBLEM

Simulation tools remain
underused due to **high entry
barriers** for researchers

-  Fragmented toolset
-  Scattered configuration
-  Ad hoc scripting
-  Reproducibility gaps
-  High iteration cost

skasim · design philosophy and requirements

THE VISION

*“Simulating a SKA observation should be as **simple as describing it**”*

Create an easy to use **end-to-end** simulation **pipeline**
(sky model → telescope config → simulation → imaging)



Declarative
configuration,
single entry point



Flexible inputs
based on fixed
contracts



Modularity –
separation of
concerns

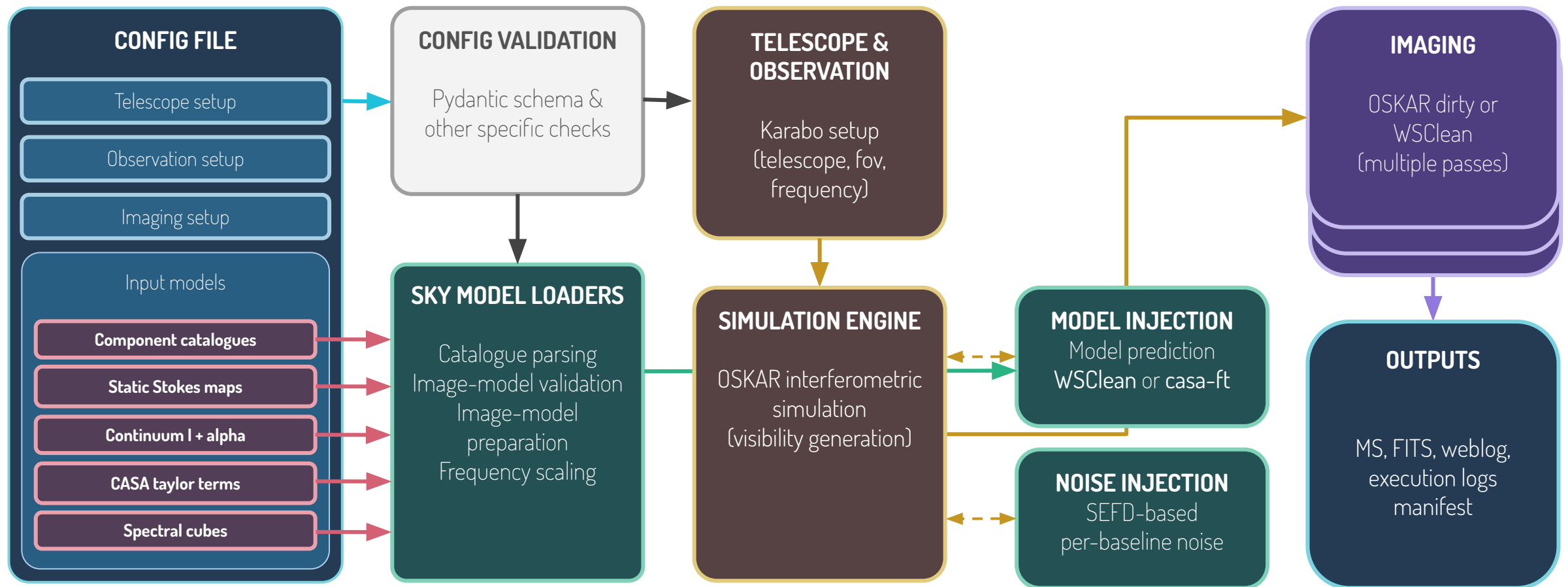


Reproducibility
and traceability by
design

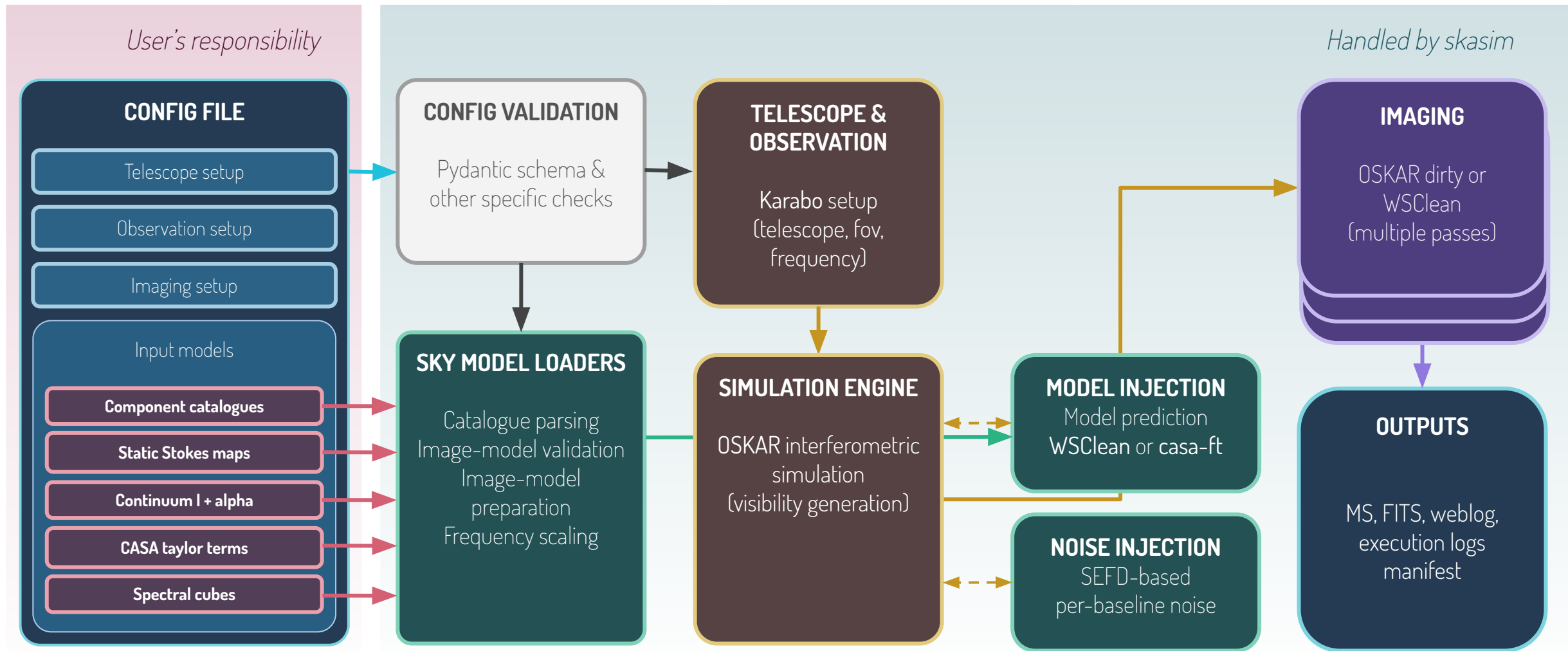


Incremental
complexity

Architecture · end-to-end simulation pipeline



Architecture · end-to-end simulation pipeline



The config file · a declarative description of the simulation

```
{
  "description": "Quick continuum I+a image-only test with VLA-C",
  "telescope": "VLA",
  "telescope_version": "C",
  "models": [
    {
      "type": "continuum_i_alpha",
      "stokes_i": "models/3c320_vla_loop_01-0003-model.fits",
      "alpha": "models/3c320_flat_alpha.fits",
      "reference_frequency_hz": 1455500000.0
    }
  ],
  "observation": {
    "frequency_mhz": 1500,
    "bandwidth_mhz": 500,
    "n_channels": 128,
    "observation_time_s": 1800
  },
  "uv_coverage": true,
  "output_dir": "simulations/vla-c-test/",
  "overwrite": true,
  //imaging block
}
```

```
"imaging": [
  {
    "tag": "dirty",
    "pixels": 256,
    "fov_deg": 0.04,
    "imager": "oskar-dirty"
  },
  {
    "tag": "wsclean-natural",
    "imager": "wsclean",
    "pixels": 256,
    "fov_deg": 0.04,
    "clean_iterations": 10000,
    "mgain": 0.3,
    "channels_out": 8,
    "join_channels": true,
    "auto_threshold": 1,
    "auto_mask": 3.0,
    "multiscale": true,
    "local_rms": false
  }
],
```

Input types · flexible sky modelling

Component catalogue

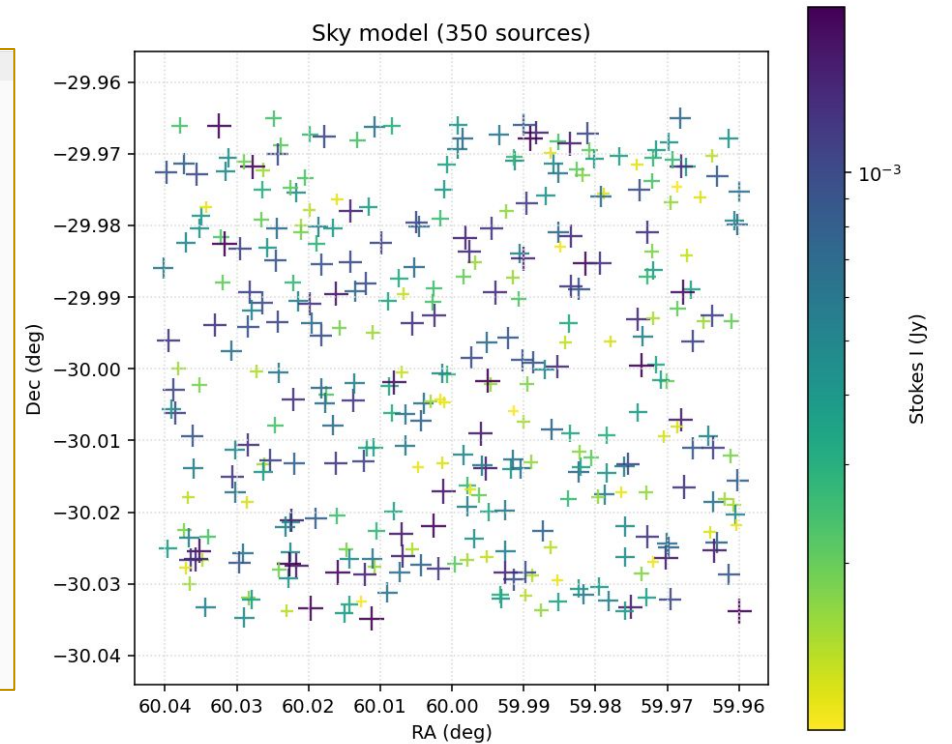
Static Stokes map (I/Q/U/V)

Continuum I + alpha

CASA taylor terms

Spectral cube

```
[  
  {  
    "ra": 60.0221436,  
    "dec": -30.00427851,  
    "I": 0.001309367774,  
    "Q": 0.0,  
    "U": 0.0,  
    "V": 0.0,  
    "ref_freq": 3000000000.0,  
    "spec_index": -0.7,  
    "rot_meas": 0.0,  
    "major_axis": 0.0,  
    "minor_axis": 0.0,  
    "pa": 0.0,  
    "true_redshift": 0.0,  
    "obs_redshift": 0.0  
  },  
  {  
    "ra": 60.01595307,  
    "dec": -30.02840759,  
    "I": 0.001859147915,  
    "Q": 0.0,  
    "U": 0.0,  
    "V": 0.0  
  }  
]
```



Input types · flexible sky modelling

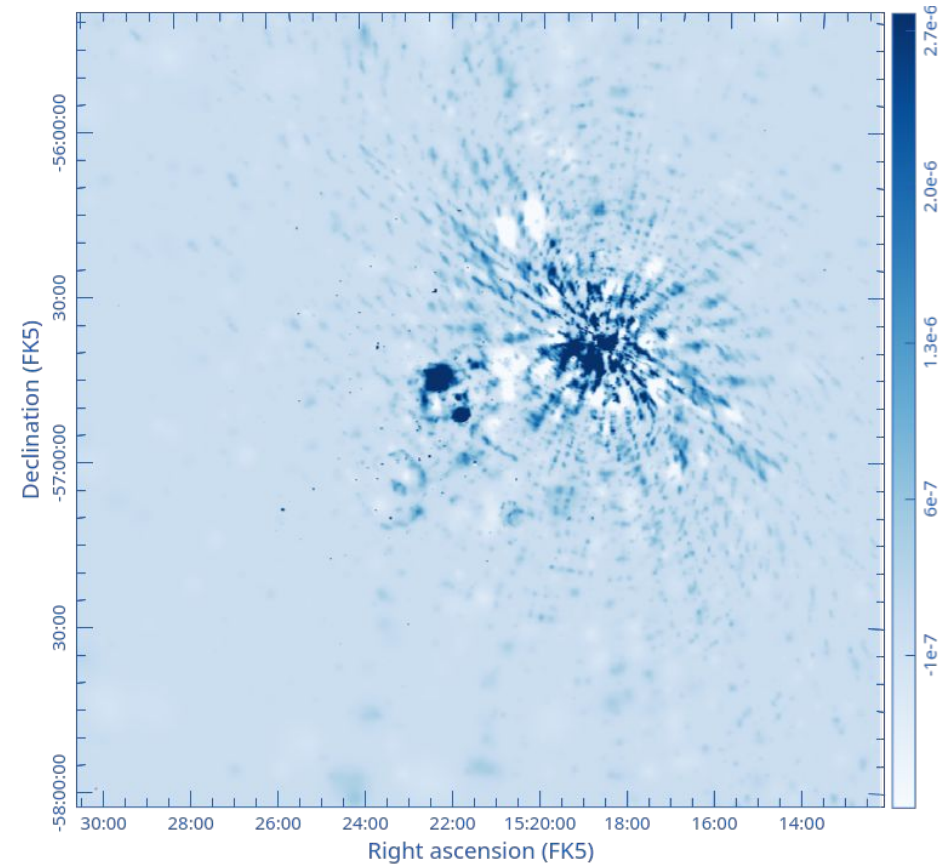
Component catalogue

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Continuum I + alpha

CASA taylor terms

Spectral cube



Input types · flexible sky modelling

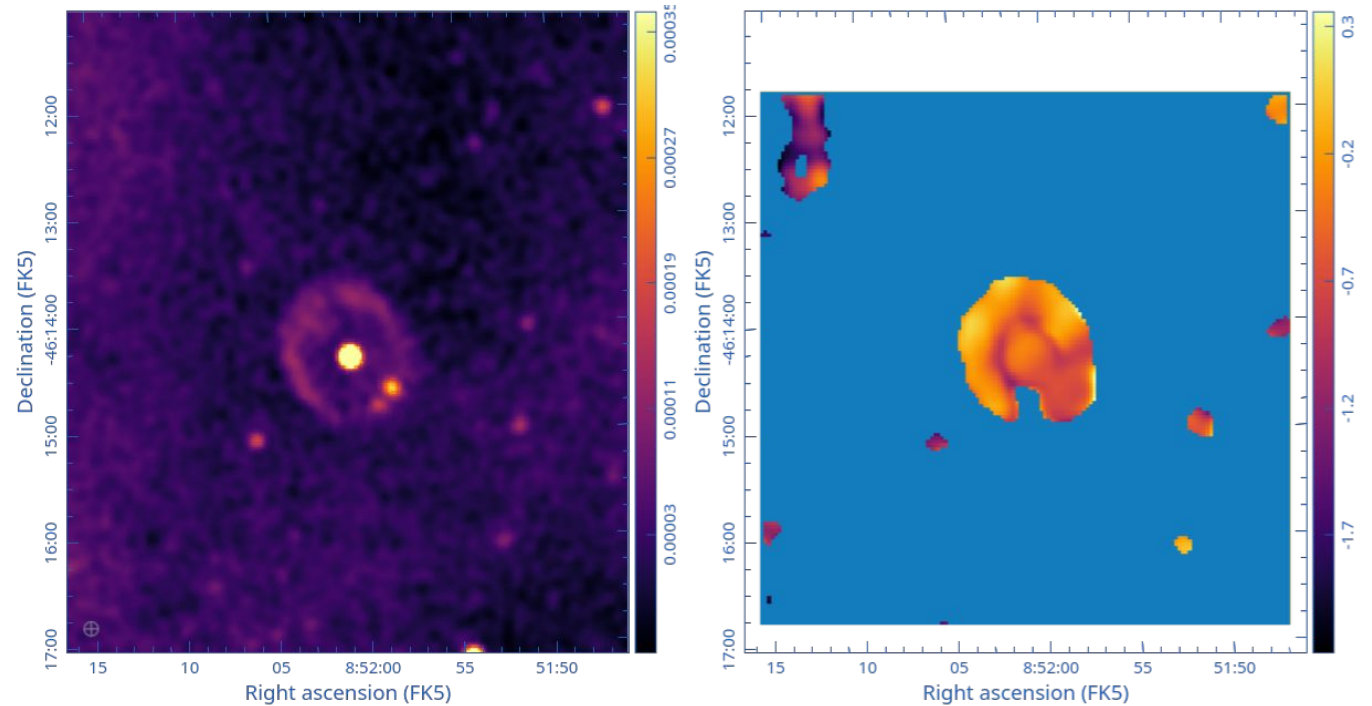
Component catalogue

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Continuum I + alpha

CASA taylor terms

Spectral cube



Input types · flexible sky modelling

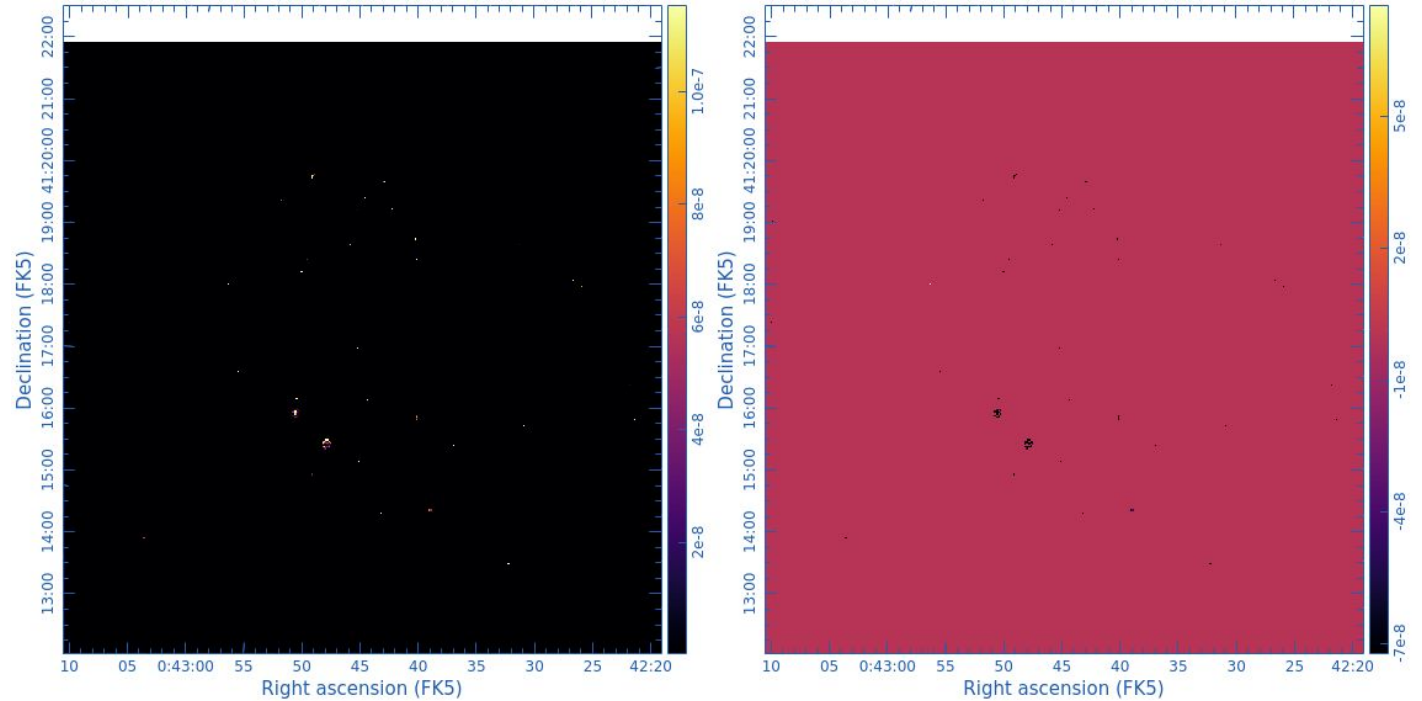
Component catalogue

Static Stokes map (I/Q/U/V)

Continuum I + alpha

CASA taylor terms

Spectral cube



Input types · flexible sky modelling

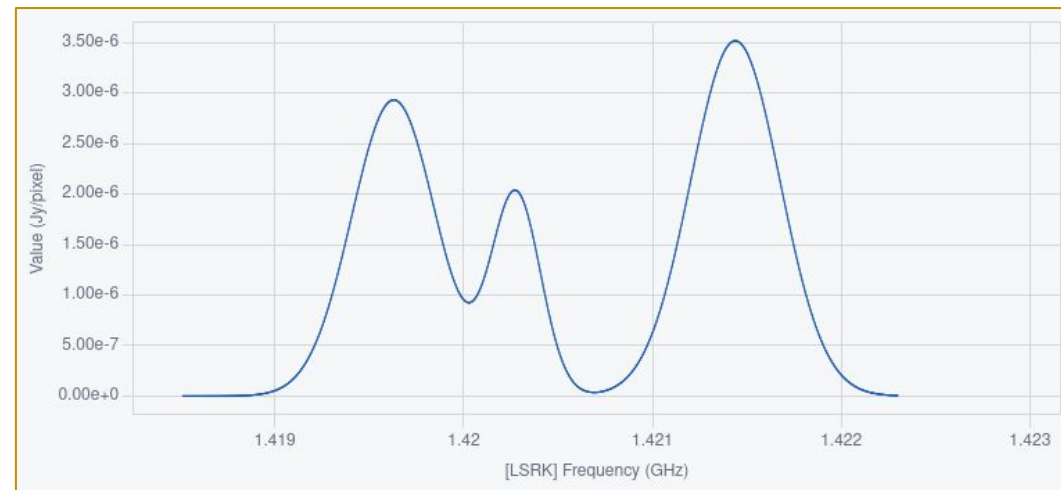
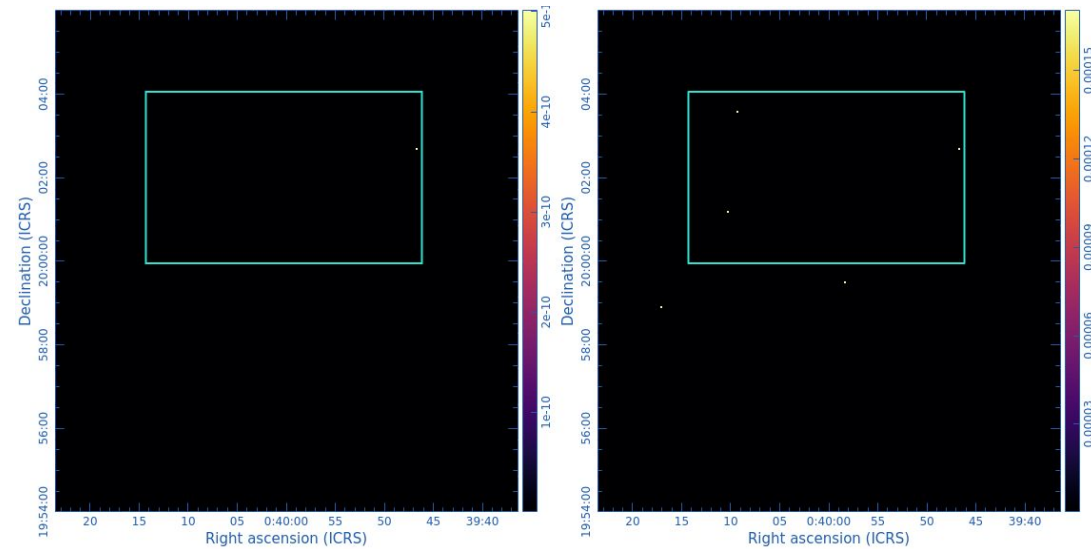
Component catalogue

Static Stokes map (I/Q/U/V)

Continuum I + alpha

CASA taylor terms

Spectral cube

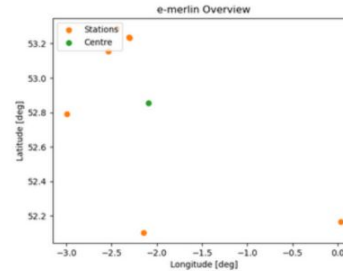


Weblog & manifest · reproducibility and traceability

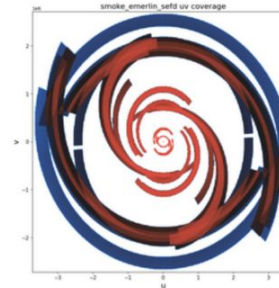
Observation & Telescope

TELESCOPE	e-MERLIN
ANTENNAS	7
FREQUENCY RANGE	4630-5130 MHz
CENTRAL FREQUENCY	4880 MHz
CHANNELS	128 x 3.906 MHz
TOTAL BANDWIDTH	500 MHz
OBS TIME	43200 s
TIMESTEPS	5402
INTEGRATION	7.997 s

TELESCOPE LAYOUT



UV COVERAGE



A comprehensive summary:

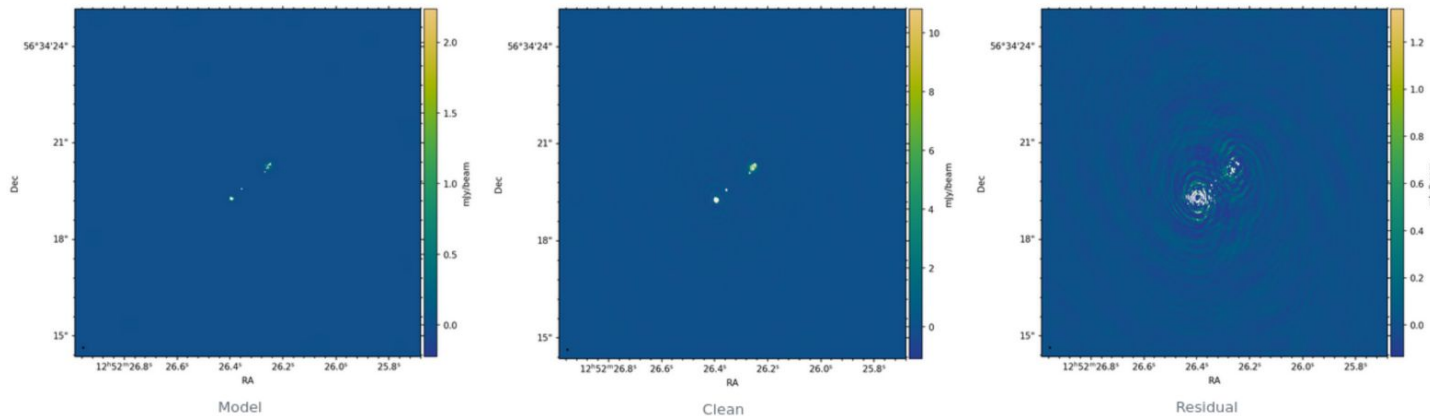
- Telescope layout
- Observation setup
- Input summary
- Imaging products
- Detailed timeline
- Output records
- Version fingerprint
- Resolved config

Imaging Products

[wsclean_r-2](#) wsclean_r+2

[wsclean_r-2_wsclean](#) [WSCLEAN](#) · [View PSF](#)

Peak: 139.584 mJy/beam · RMS: 66.97 μ Jy/beam · SNR: 2084.2 · Beam: 0.048 arcsec x 0.029 arcsec · BPA 16.16 deg



Weblog & manifest · reproducibility and traceability

Timeline

TIME	EVENT	DURATION	DETAILS
17:56:11	● telescope_built		7 stations
17:56:11	● sky_model_loaded		0 sources (image_models)
17:56:14	● observation_configured		{"bandwidth_mhz": 500.0, "channel_width_mhz": 3.90625, "frequency_mhz": 4880.0, "max_frequency_mhz": 5130.0,...
17:56:14	● simulation_started		
17:56:14	● base_ms_fallback		{"strategy": "zero_flux_placeholder_source"}
17:58:07	● image_injection_started		{"backends": ["casa_ft", "wsclean_predict"], "n_model_entries": 1}
17:58:14	● adjusted_spectral_reference		{"alpha_mean": -0.5, "model_type": "continuum_i_alpha", "new_reference_frequency_hz": 4880000000.0, "nterms": 2,...
17:58:48	● image_model_injected		{"alpha": "/mnt/scratch/cbordiu/espsrc_ska_simulator/data/3C277.1_best-MFS-model.alpha.fits", "backend":...
17:59:09	● image_injection_completed		{"model_data_merged": true, "visibility_path":...
17:59:09	● simulation_completed	2m 55s	
17:59:12	● noise_injection_started		
17:59:14	● noise_injection_completed	0m 2s	{"delta_nu_hz": 3906250.0, "eta_c": 0.88, "sefd_file": "noise-sefd/emerlin-sefd.json", "summary": {"max_sigma_jy":...
17:59:14	● uv_coverage_started		
17:59:20	● uv_coverage_completed		{"path": "smoke_emerlin_sefd_uvcoverage.png"}
17:59:20	● imaging_wsclean_r-2_started		
18:00:30	● imaging_wsclean_r-2_completed	1m 9s	{"imager": "wsclean", "tag": "wsclean_r-2"}
18:00:30	● imaging_wsclean_r+2_started		
18:01:39	● imaging_wsclean_r+2_completed	1m 9s	{"imager": "wsclean", "tag": "wsclean_r+2"}

Noise treatment

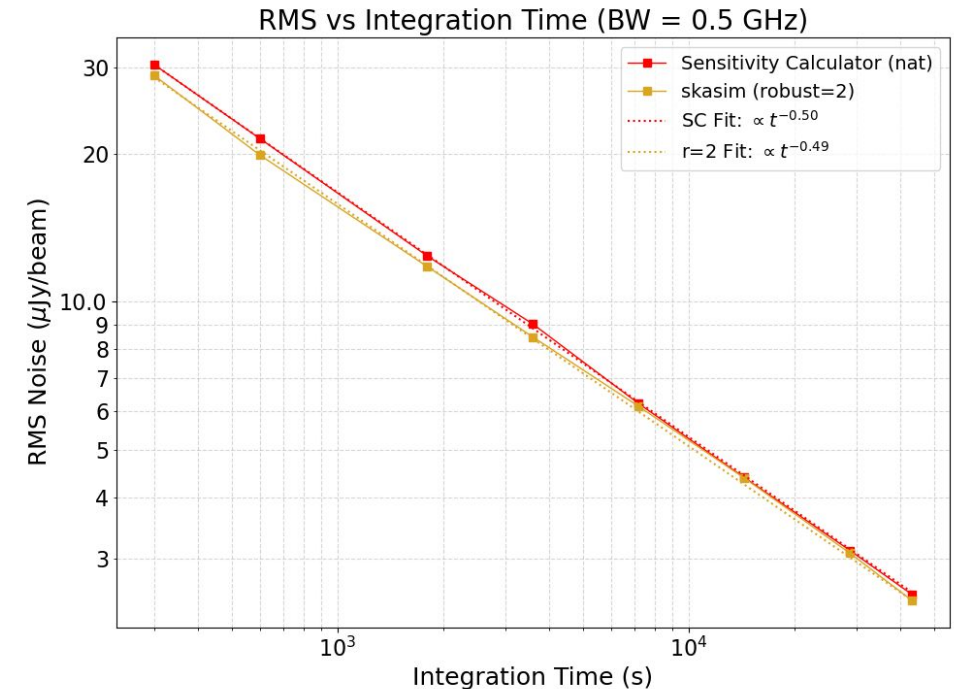
Two noise “modes”:

- *Karabo*’s native: user selects desired noise
- SEFD-based: realistic noise injection

Noise is computed for each baseline based on
the real SEFDs of the involved antennas

$$\sigma_{pq} = \frac{1}{\eta_c} \left(\frac{\text{SEFD}_p \times \text{SEFD}_q}{2t_{\text{int}}\delta\nu} \right)^{\frac{1}{2}}$$

***** Critical for heterogeneous arrays like
SKA-MID *****

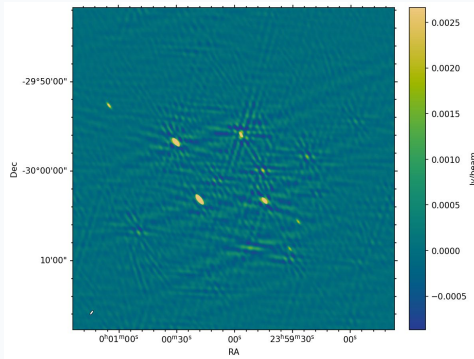


VLA: Good agreement between skasim and sens calc.

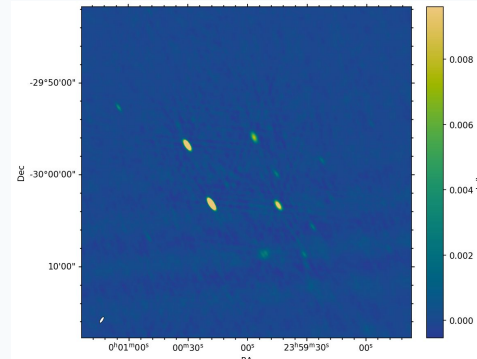
Examples (I) · SKA staged delivery comparison

Comparison of capabilities (**sensitivity, angular resolution, uv coverage**) of the different Array Assemblies (AA0.5, AA1, AA2, AA*, AA4) observing the same **SKA Data Challenge 1** field:

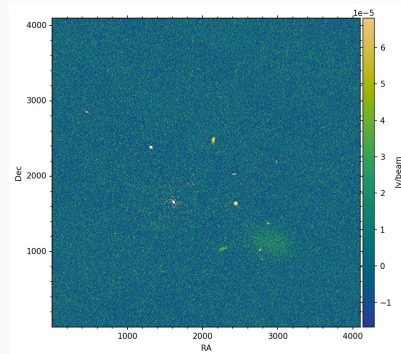
AA0.5



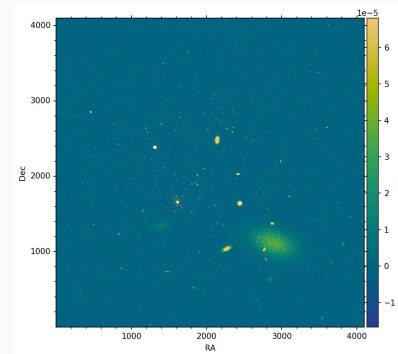
AA1



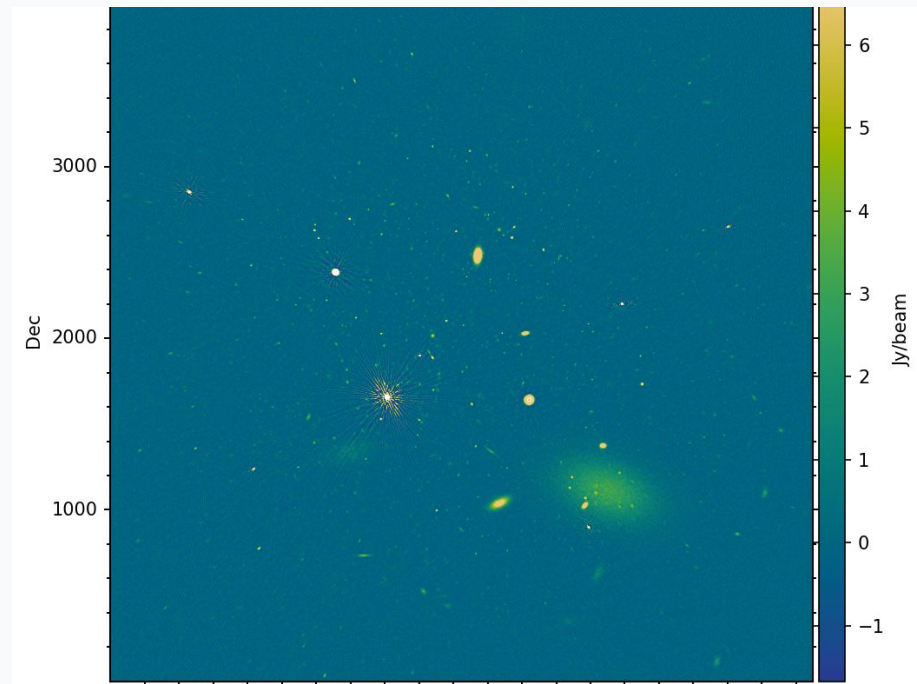
AA2



AA*

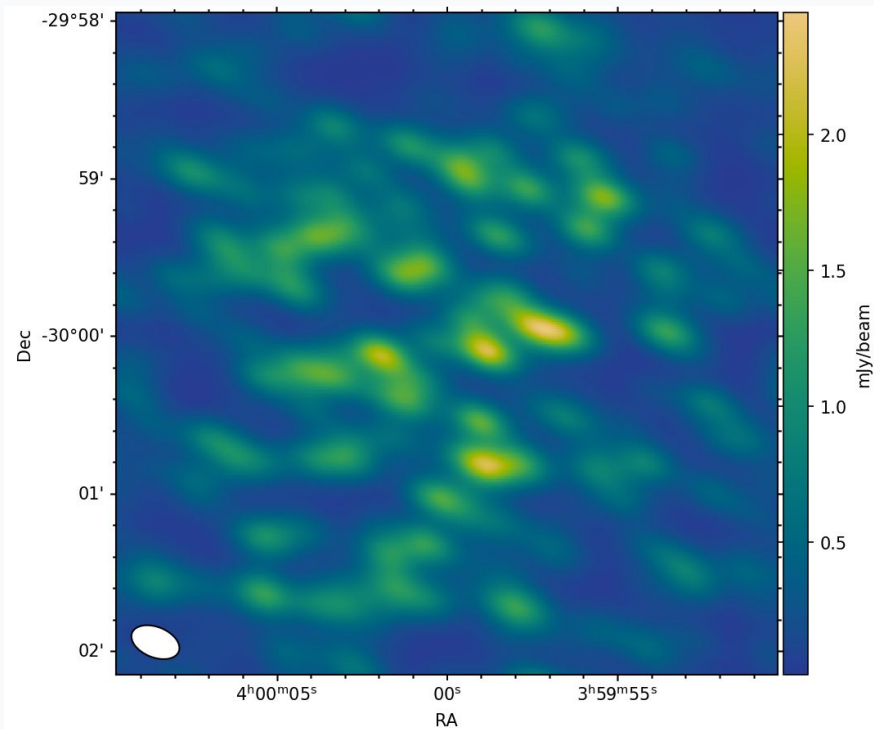


AA4 (Design baseline)

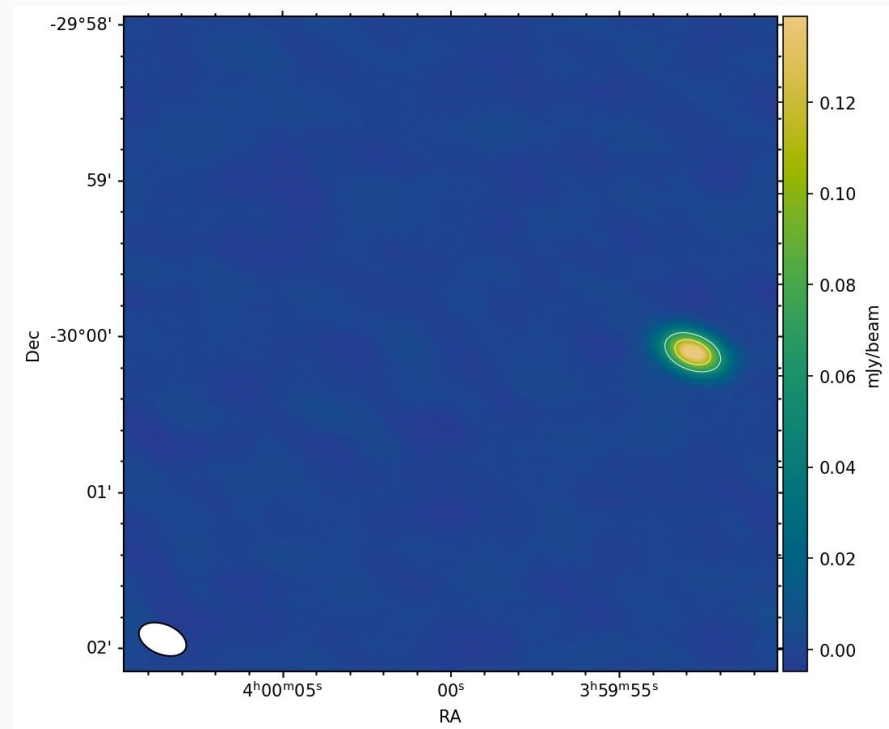


Examples (II) · polarization in the confusion limit

Stokes V detection of a **polarized source** in a crowded 0.07° field with **SKA-Low**; demonstrates the detection of **auroral radio emission from star-planet interaction**



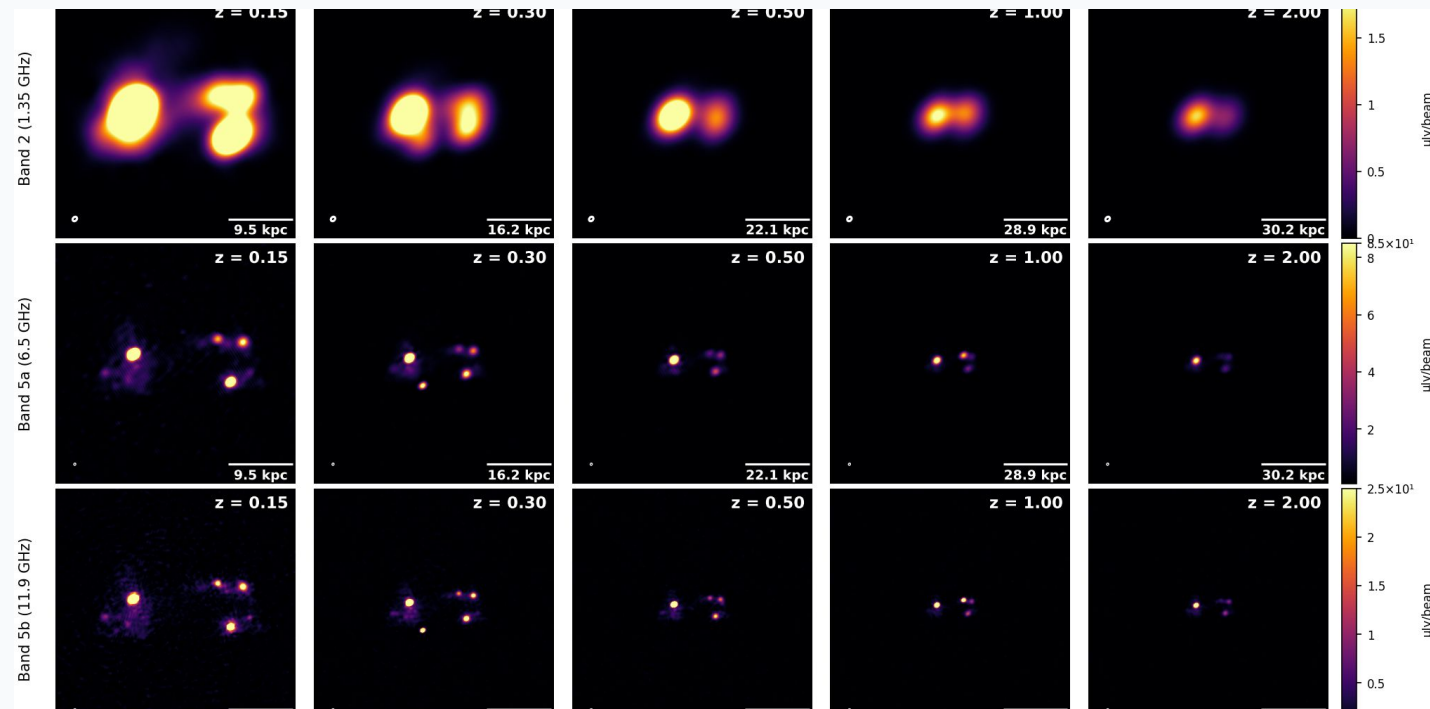
Stokes I restored image



Stokes V restored image

Examples (III) · redshifted radio galaxies

The star-forming radio galaxy **Arp 299** rescaled to $z=0.15$ – 2 in size, flux density and SFR (following Ghasemi-Nodehi et al. 2022) as observed in **SKA-MID AA* bands 2, 5a and 5b**,



Arp 299 redshift sequence from $z = 0.15$ to $z = 2.00$ across bands 2, 5a and 5b

Summary & roadmap

TAKE-HOME MESSAGE

skasim is a researcher-facing **orchestration and reproducibility layer** connecting sky models, established simulation engines, imaging tools, and documented outputs

skasim v0.5 already usable for scientific simulation studies, with the API still evolving

Next steps

- rms/SEFD for more arrays
- Docker installation
- VLBI support
- New input types (polarization cube, faraday model...)
- Refactoring, optimization & test coverage

Deliverables

Version 1.0

To be released soon

Use case gallery

Under construction

Scientific paper (A&C)

Currently in progress

Thanks for your attention!

cbordiu@iaa.csic.es



skasim repository: https://github.com/espsrc/espsrc_ska_simulator

and more **examples**: <https://espsrc.github.io/skasim-gallery/>



This work is supported by grants CEX2021-001131-S, PID2021-1239300B-C21 and PID2024-1558170B-I00 funded by MICIUAEl/ 10.13039/501100011033 and by the grant INFRA24023 (CSIC4SKA) funded by CSIC.