UPDATE ON INTERFEROMETRIC OTF IMAGING WITH MEERKAT

- SKA Cosmology SWG meeting 2023 -

Kristóf Rozgonyi[1], M. G. Santos[2,3], K. Grainge[4], O. Smirnov[5], J. Mohr[1], the MeerKLASS and DMeerKAT collaborations

[1]Faculty of Physics, Ludwig-Maximilians-Universität
[2]Department of Physics and Astronomy, University of the Western Cape
[3]South African Radio Astronomy Observatory (SARAO)
[4]Jodrell Bank Centre for Astrophysics, The University of Manchester
[5]Department of Physics & Electronics, Rhodes University

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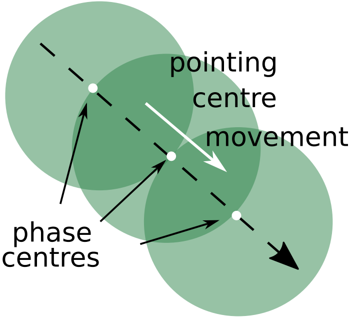
Motivation & OTF interferometry

- Commensal intensity mapping (IM) and interferometric imaging would dramatically increase data acquisition efficiency
- On-the-fly (OTF) interferometry is possible with MeerKLASS (*Santos et al. 2017*) scanning observations
- Increased survey speed, providing continuum, spectral-line, polarisation maps (+time-domain data)
- 'Smearing' of primary beam (PB) **introduces errors at a % level** (*Mooley et al. 2019, Rozgonyi et al. in prep.*), and can be corrected for



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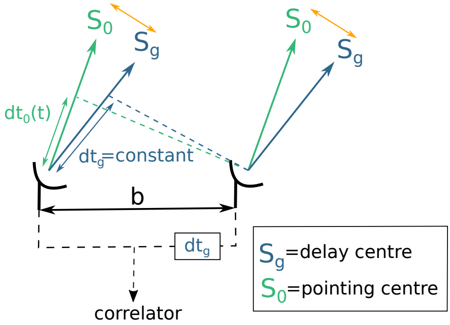
- OTF mode is currently only available on the VLA (*Mooley et al. 2019*): VLASS survey (*Lacy et al. 2020*) & open-time calls, but no commensal IM mapping

Asynchronous OTF with MeerKAT



Delay setup for asynchronous OTF scans

- No dedicated OTF observing mode on MeerKAT
- We 'simply' switched on the correlator during MeerKLASS pilot observations, with **no geometric delays applied**
- **Syinhesis imaging is possible by phase-rotating the visibilities** from the delay to the pointing centre
- The estimated **phase and amplitude errors introduced are at a % level**

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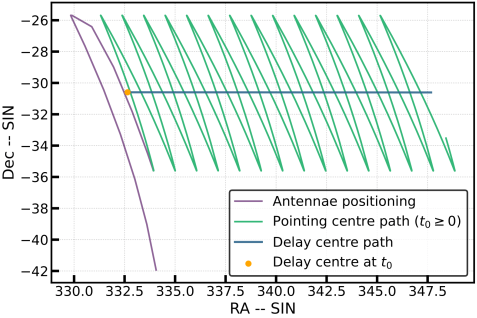

Example MeerKLASS asynchronous OTF scans

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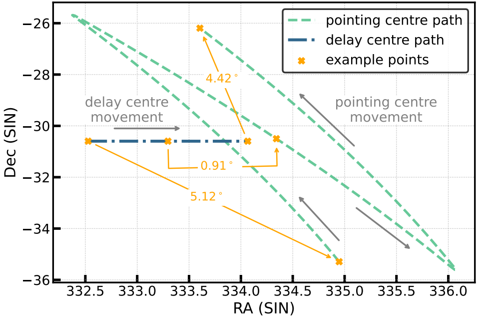

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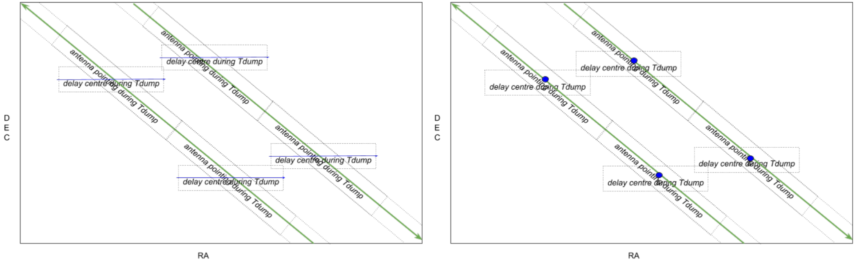
Plans for MeerKAT OTF mode

- We are working with the MeerKAT engineering & commissioning team to support interferometric OTF observations
- The current correlator setup **can not update the delay centre faster than ∼5.5s** ⇒ post correlation phase rotation is needed
- We can set the correlator to be fixed in RA–Dec rather than in Az–El



Possible correlator modes for MeerKAT OTF: fixed delay centre in Az–El (left) and in Ra–Dec (right) (credit: MeerKAT engineering & commissioning team)

Post-correlation phase rotation

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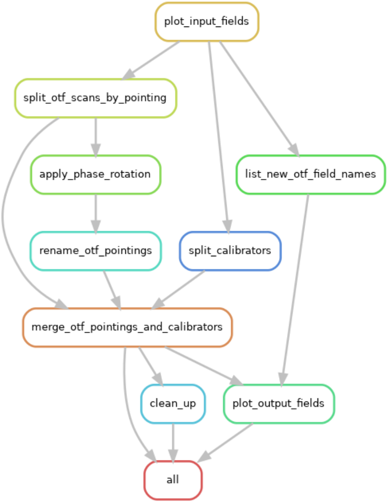
- We developed an automated pipeline to apply the phase rotation to asynchronous OTF observations (*Rozgonyi et al. in prep.*)
- The pipeline is scalable and uses the `Snakemake` workflow manager
- We are in the final step of validation and deployment on ilifu using containerised (`singularity`) backend



Proof-of-concept imaging pipeline

Multi-component top-level wrapper (currently not automated)

- Only a single round of flagging of the raw visibility data (`tricolour`)
- Phase rotation (`our custom pipeline`)
- "Standard" calibration & snapshot imaging of each OTF snapshot, with a single iteration of phase-only, in-field, self-calibration (`caracal`)
- Mosaicking, PB correction (`montage`) and source-finding (`pybdsf`)

We found that we **should improve on each component** of our current pipeline

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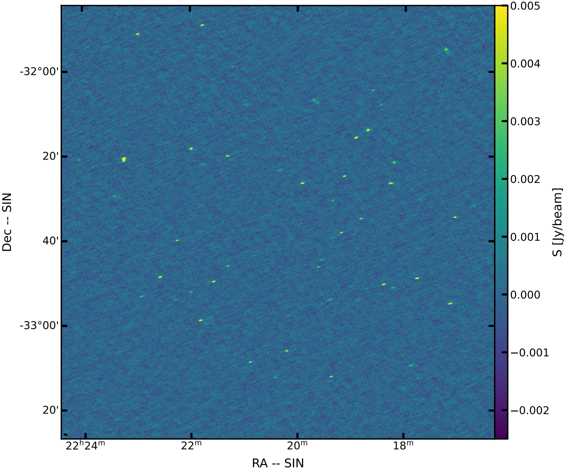
We need to combine all steps into a **single, scalable, automated pipeline**

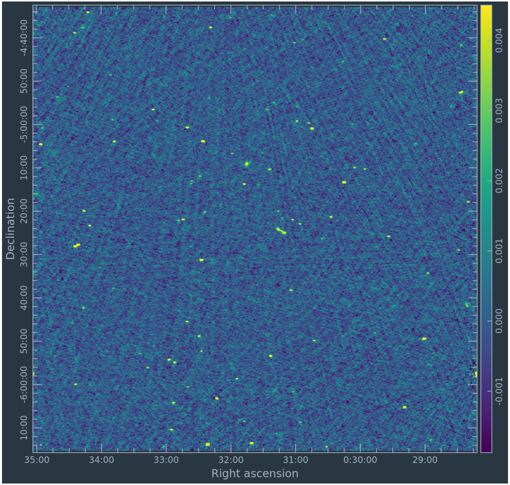
Pilot observations



Example L-band OTF snapshot

- **L-band**: 4K channel- and 2s time resolution with 5'/s scanning speed. Only primary (flux-scale) calibrator and **no secondary calibrator(s)**
- **UHF-band**: 4K channel- and 2s time resolution with 7'/s scanning speed. **Secondary calibrator(s) observed**.

Pilot observations



Example UHF-band OTF snapshot

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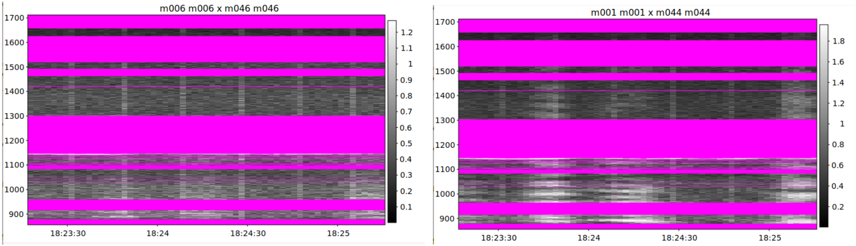
- **UHF-band**: 4K channel- and 2s time resolution with 7'/s scanning speed. **Secondary calibrator(s) observed**.

Flagging & noise diodes

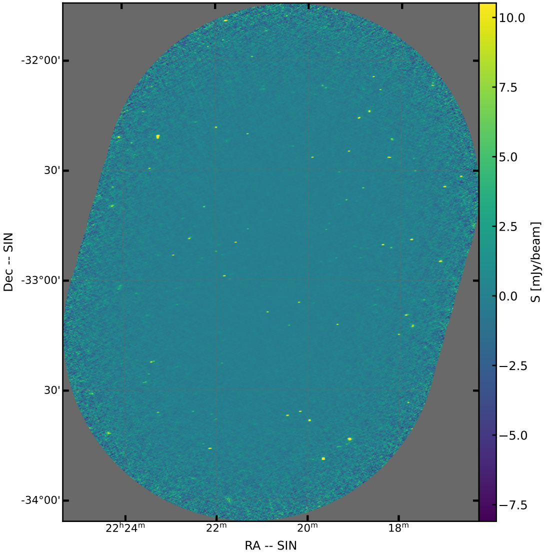
- We have residual RFI after our initial flagging
- We can see the effect of noise diodes firing across all baselines
  ⇒ we will possibly flag the corresponding snapshots



Example waterfall plots from our L-band data with flags

Mosaicking

- We use a small mosaic (L-band, $\sim 2\ \mathrm{deg}^2$ from 5 OTF snapshots) to develop & validate our source-finding pipeline
- We need to use custom `MontagePy` scripts to deal with the synthesised beam
- We made some initial testing using `DDFacet` to improve our wide-field imaging



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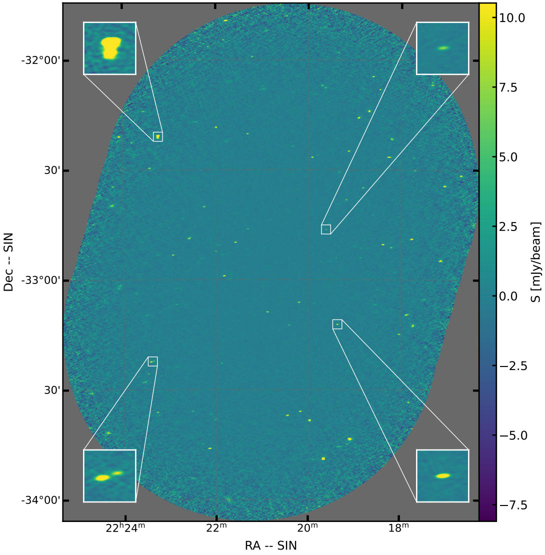
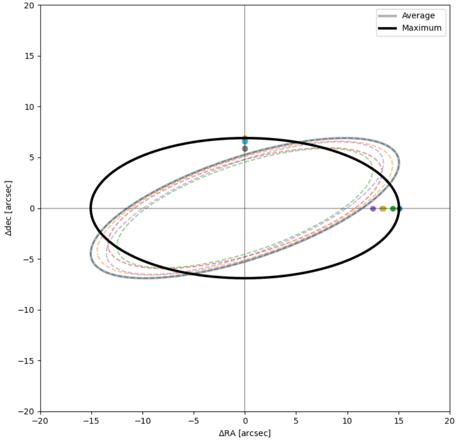


Synthesized beam variation

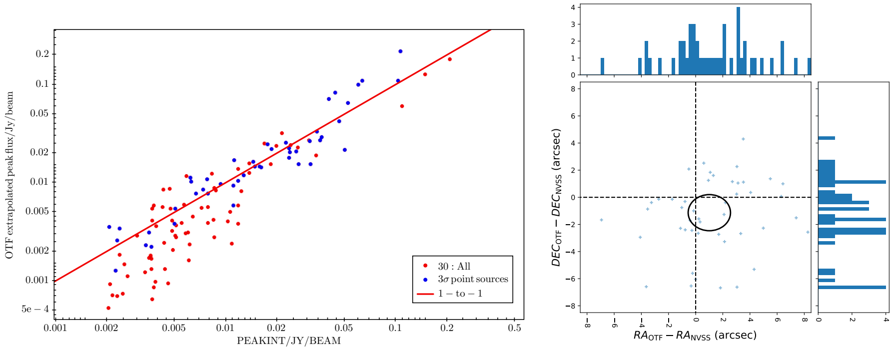


Individual, average and (rotated) maximum synthesized beams for the example mosaic (credit. A. Basu)

- The position angle of the synthesized beam varies **little** between OTF snapshots for a simgle scan
- We **should use the (projected) 'maximum' synthesised beam** rather than the average beam
- We need to look at more scans and scans from both rising and setting scans, to determine if this approach is feasible

Source-finding

- All our ‘quick-and-dirty’ test results show excellent agreement with NVSS source positions, but some offset (and significant scatter) in flux densities
- We need to improve our spectral resolution for multy-frequency imaging



Peak flux (left) and position (right) OTF – NVSS pair-wise comparison (credit G. Gurkan)

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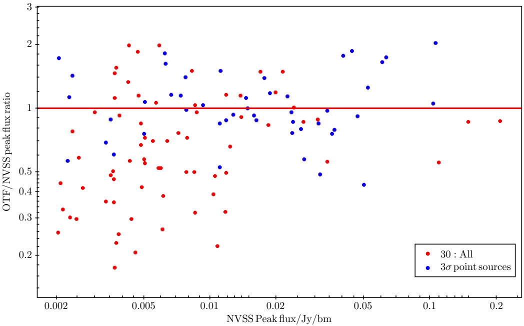

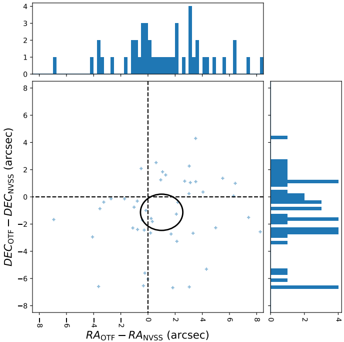

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Conclusions

- We propose commensal IM and interferometry
- **Solid understanding of the fundamentals & conducted the first (asynchronous) OTF observations with MeerKAT**
- Estimated *uniqe* errors are at a few % level
- Plans for a dedicated MeerKAT OTF mode
- Science-quality results are expected from our updated pipeline