

GMRT data analysis pipelines: CAPTURE



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Outline

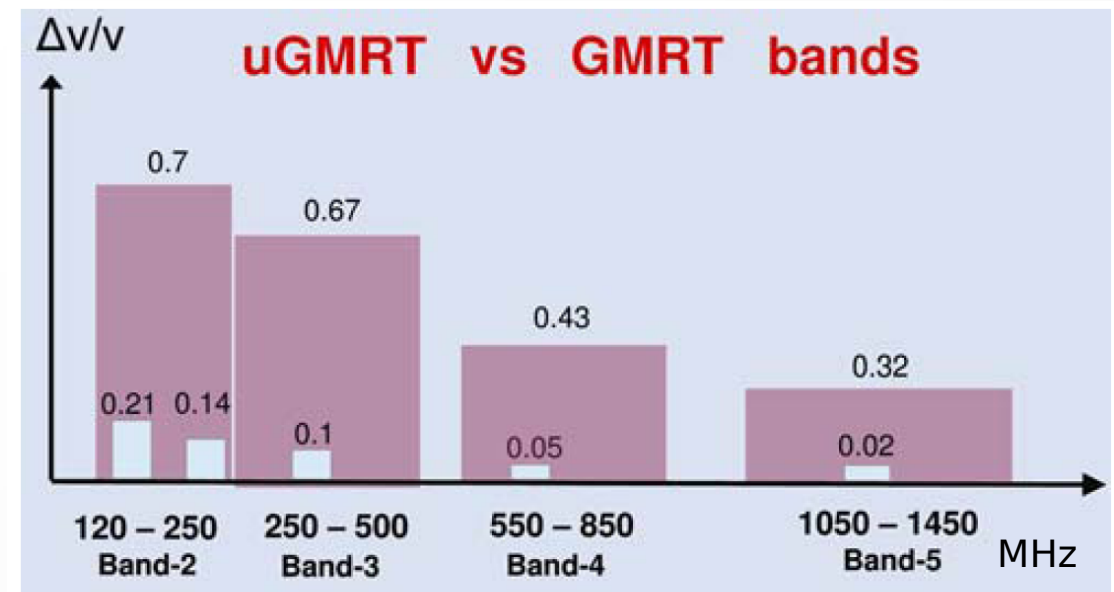
- The Upgraded GMRT
- CAPTURE and CAPTURE-POL
- Status of CAPTURE
- Applications of CAPTURE
- Future development of CAPTURE



The Upgraded GMRT

Gupta et al 2017

- Pathfinder of SKA
- Instantaneous bandwidth: increased from 33 MHz to 400 MHz
- Advantage in sensitivity (3.4x) and uv-coverage
- Data volumes:



Sampling time	Npol	# freq. channels	Data rate	Data size (8 hr)
2.68 s	2	2048	5.75 MB/s	161 GB
2.68 s	4	4096	23 MB/s	646 GB

What is CAPTURE ?

CASA* **P**ipeline-cum-**T**oolkit for **U**pgraded GMRT Data **R**eduction

Pipeline: for making continuum images, testing (e. g. online RFI filtering, data quality checks)

Toolkit: For customised usage and step by step analysis; radio astronomy training purposes; ease of further development

Current release



- CAPTURE-CASA6
- CAPTURE-POL
- Primary beam correction
 - wbpbgmrt (CASA 5.* task)
 - ugmrtpb (CASA 6 task)

Github links for code and links for documentation:



<http://www.ncra.tifr.res.in/ncra/gmrt/gmrt-users/gmrt-data-and-pipeline-releases>

<http://www.ncra.tifr.res.in/~ruta/IDAP/index.html>

uGMRT Interferometric Data Analysis Pipelines

[Home](#) [Documentation](#) [Team](#)

1. CAPTURE : A CASA 6 compatible continuum imaging pipeline

<https://github.com/ruta-k/CAPTURE-CASA6>

2. CAPTURE-POL: A pipeline for continuum imaging including polarization calibration

<https://github.com/ruta-k/CAPTURE-POL>

3. uGMRT primary beam correction : CASA tasks

<https://github.com/ruta-k/uGMRTprimarybeam-CASA6>

<https://github.com/ruta-k/uGMRTprimarybeam>

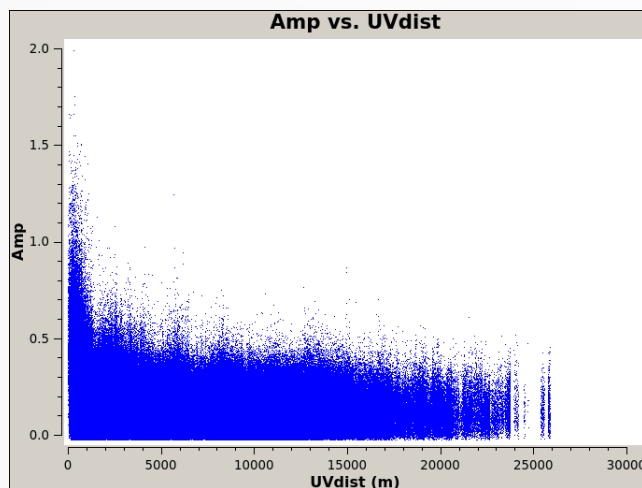
<https://github.com/ruta-k/uGMRTprimarybeam/tree/b4order10poly>

The primary beam shape measurements are from D. V. Lal, S. Katore and J. N. Chengalur (2018, 2021).

CAPTURE-CASA6 and CAPTURE-POL

- Takes in data in Ita/FITS/MS format and carries out flagging, calibration, imaging and self-calibration.

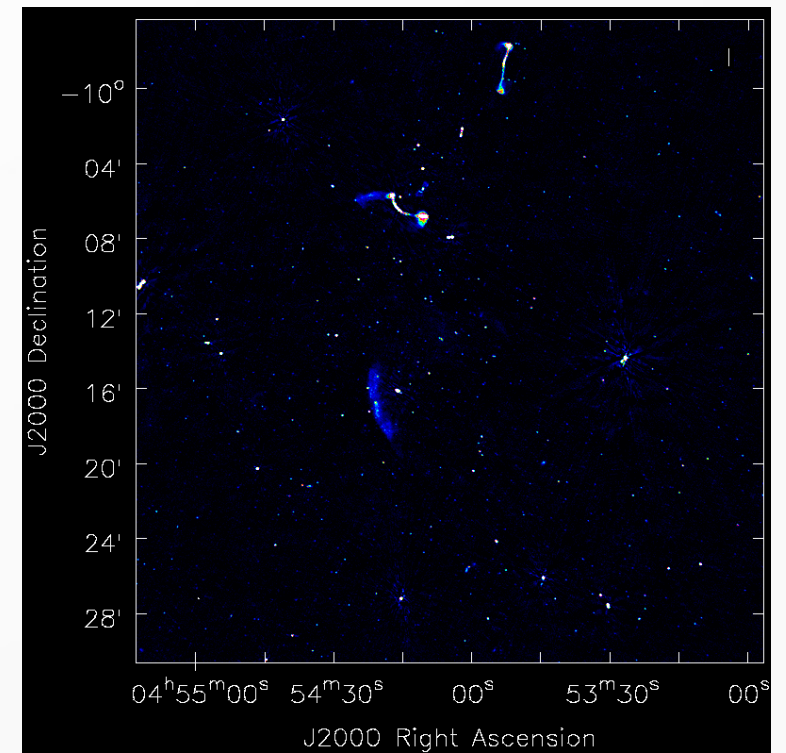
Data recorded
by the uGMRT



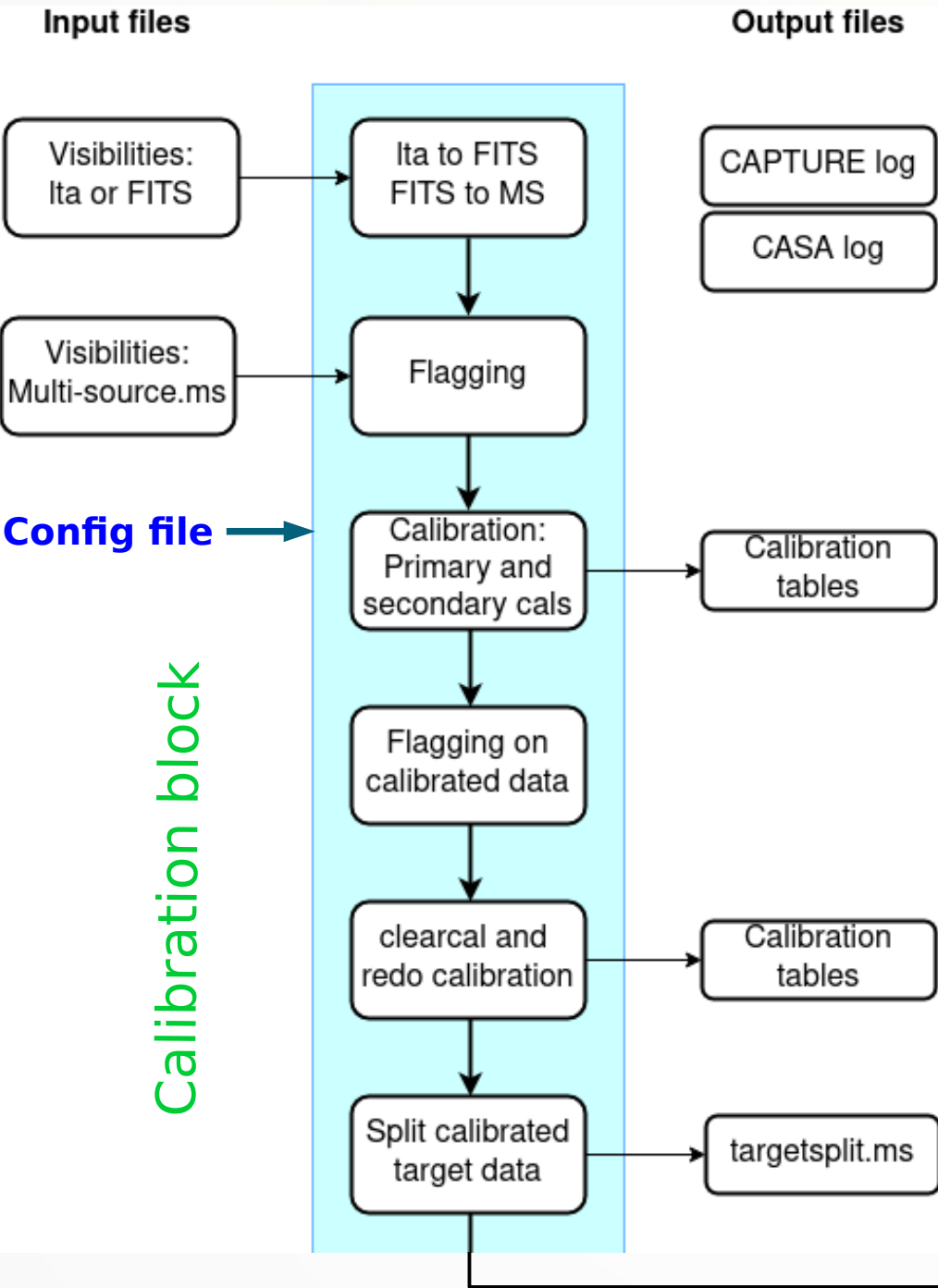
CAPTURE:
Flagging,
calibration,
imaging and
self-
calibration

*Diagnostic
plots and
flagging
summary*

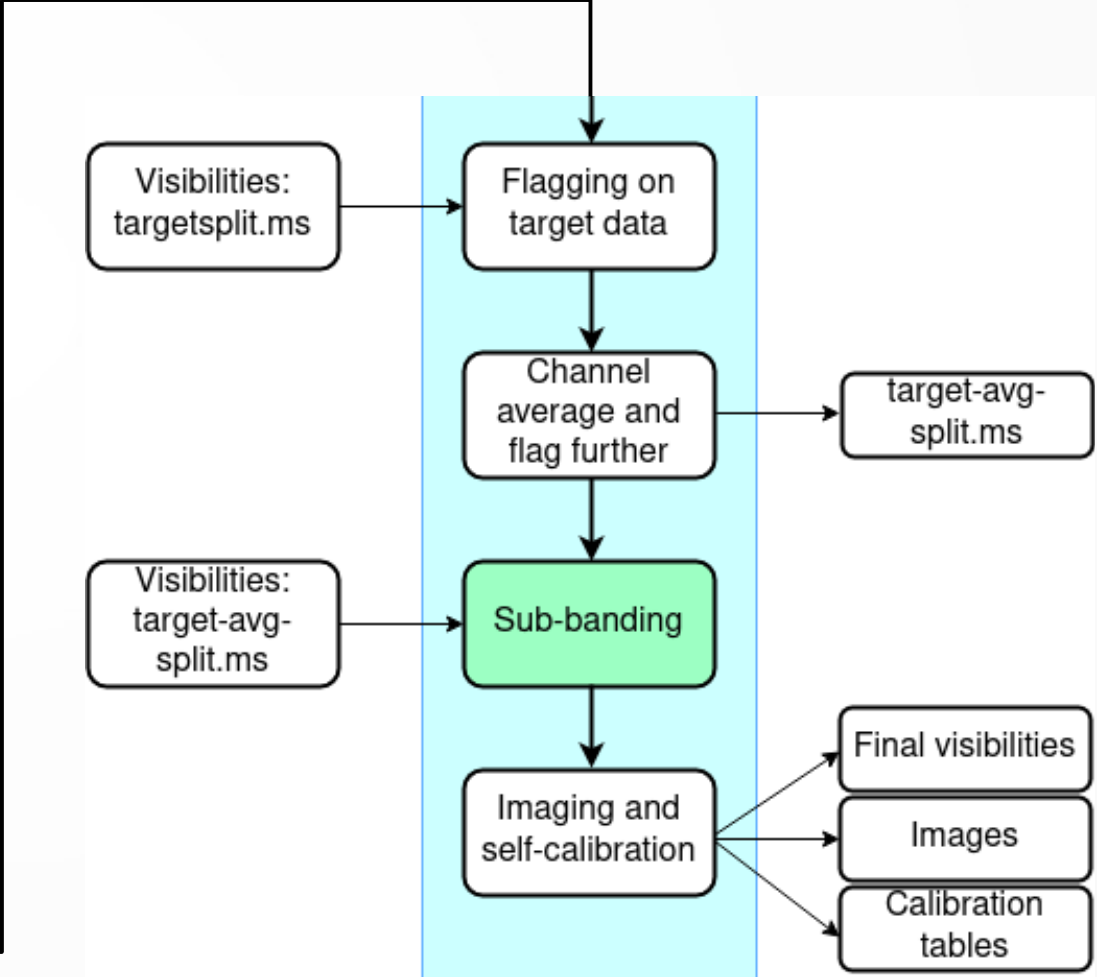
Image of the sky (I or
I, Q, U, V)



CAPTURE-CASA6



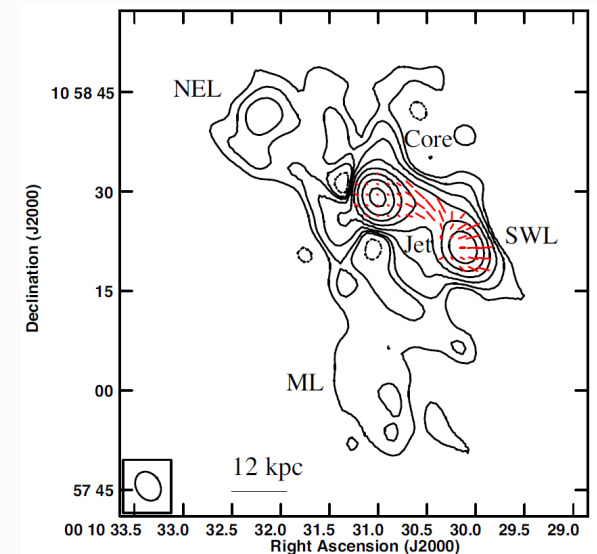
Imaging block



Polarization with uGMRT

- Band-4 polarization calibration and imaging demonstrated by Silpa et al 2020, 2021a and b. More results in Baghel et al, submitted.
- Polarization calibration strategy and pipeline available here:
<https://sites.google.com/view/silpasasikumar/>
- <https://github.com/ruta-k/CAPTURE-POL>

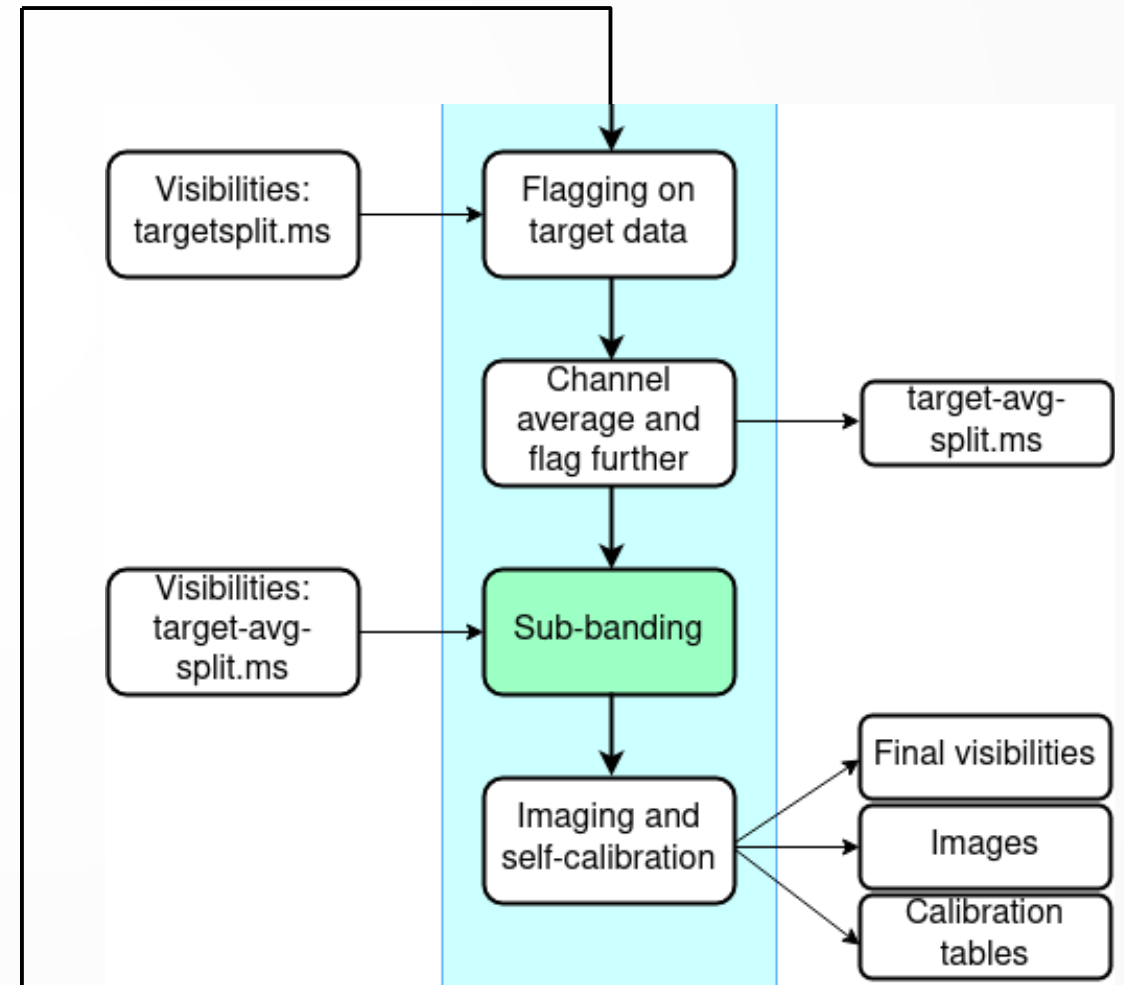
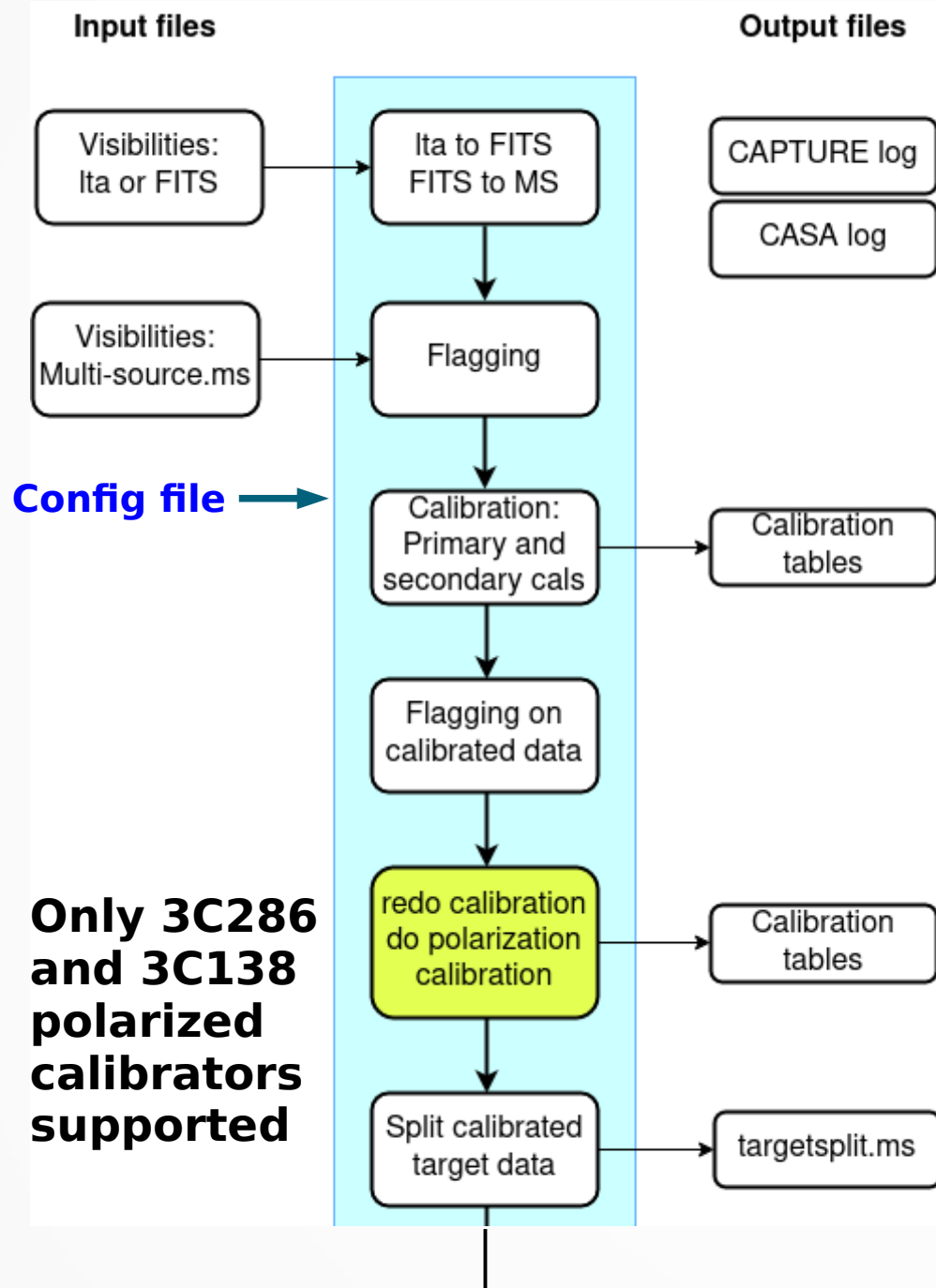
uGMRT 685 MHz
E-vectors



Silpa et al 2021a

CAPTURE-POL

- **Only for uGMRT band 4 (550 - 850 MHz) and specific calibrators**
- Manual verification of polarization calibration needed !
- Can split and image data on calibrators for checking



How to use CAPTURE-CASA6 ?

- Place your data and CAPTURE-CASA6 code files in the directory where you want all the products to go.
- Edit the config_capture.ini : provide filename, set the steps to be carried out and the parameters e. g. freq averaging, image size, cellsize, visibility weights and number of self-calibration iterations.
- * Read the caveats given in the documentation to avoid failures *
- Run CAPTURE-CASA6 !

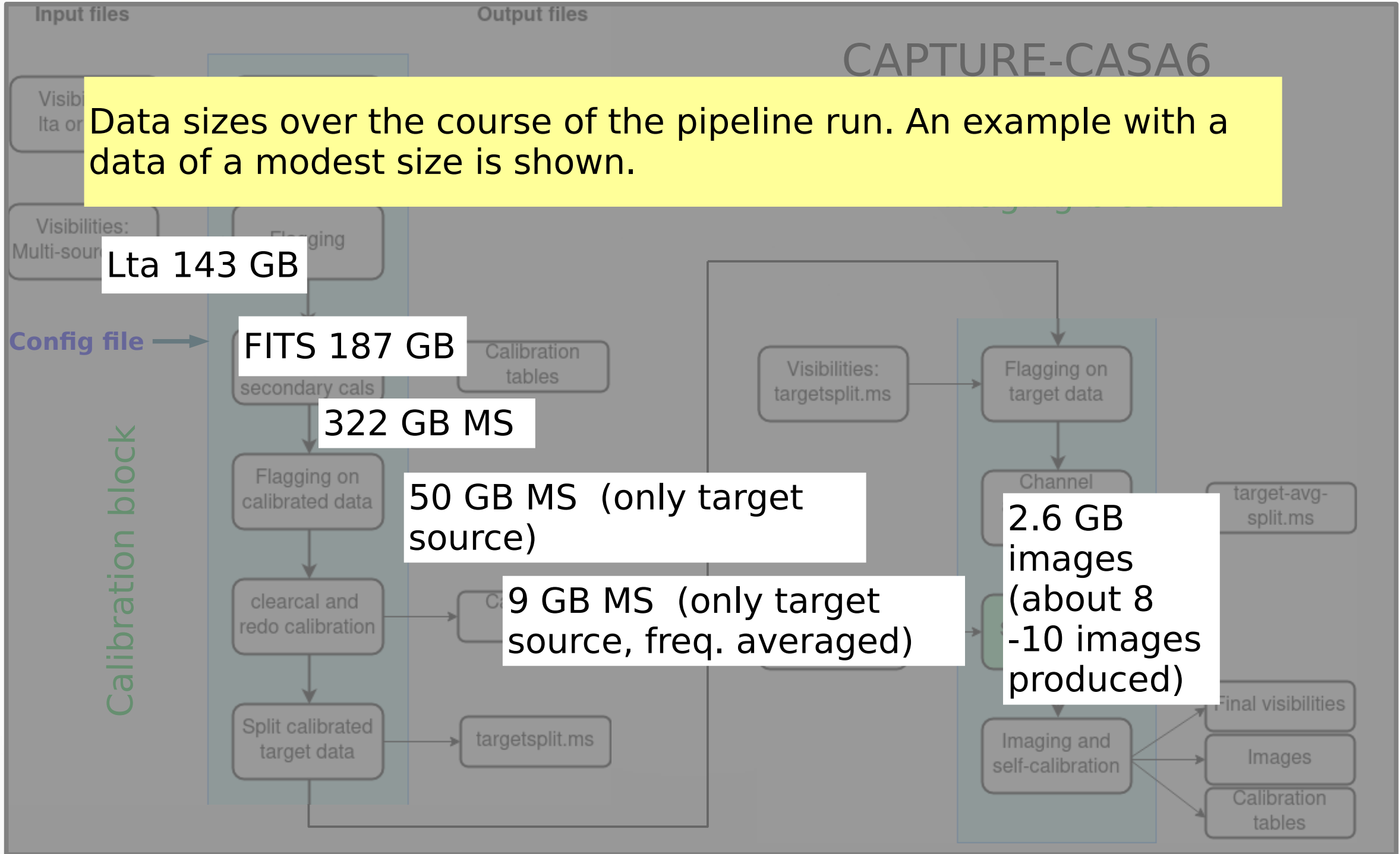
Steps needed outside CAPTURE to use images for science:

-Primary beam correction

CASA task incorporating uGMRT primary beam “ugmrtpb”

CAPTURE-CASA6

Data sizes over the course of the pipeline run. An example with a data of a modest size is shown.



CAPTURE: Run times

- A summary of time taken by CAPTURE in various steps on two machines.

Example:

Size of data 140 GB

Data size taken for imaging
~5 - 10 GB

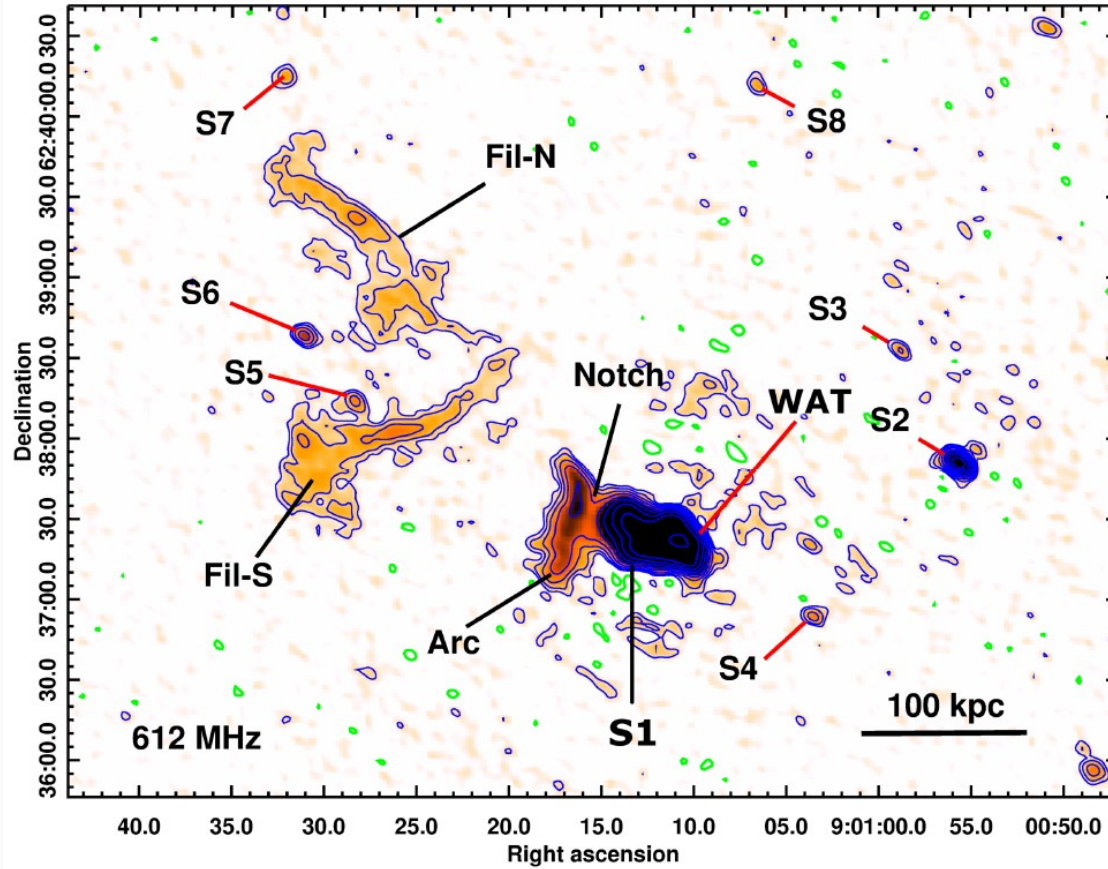
Image size of 7000 - 10000
pixels

Wproj planes ~600 - 1000

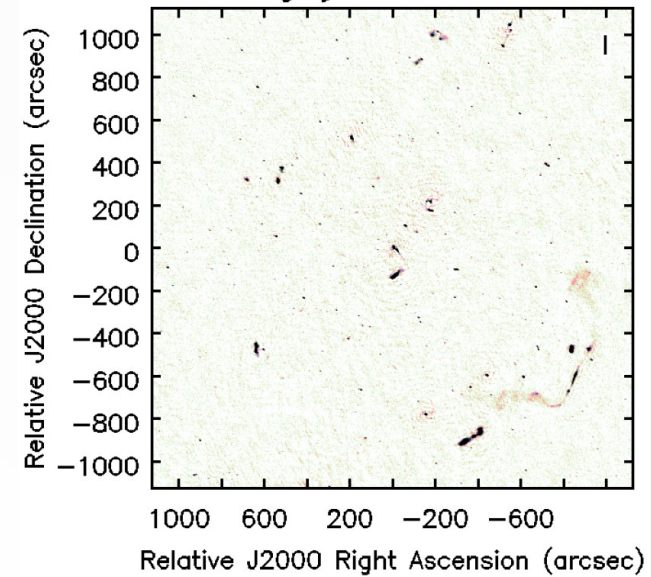
	RAM (GB)	# Cores	Time taken (hr)
Flagging and Calibration	32	8	7
	256	40	6
Self-calibration	32	8	86
	256	50	54

CAPTURE results

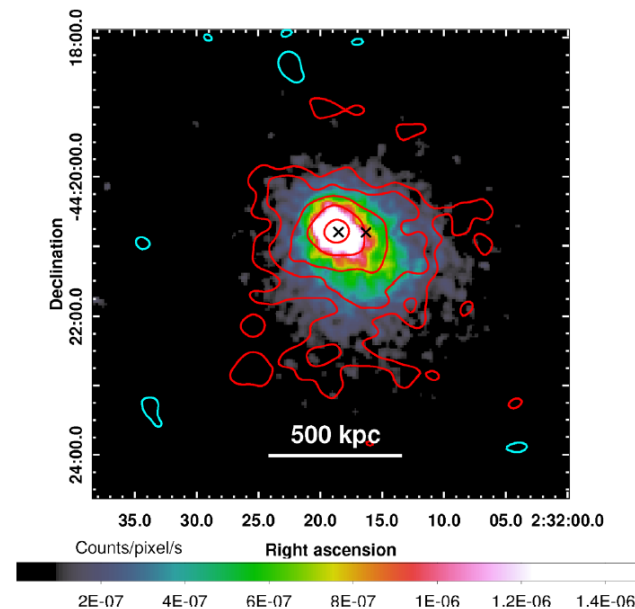
Legacy GMRT



612 MHz image 35 μ Jy/b
Pandge, Kale et al 2022, MNRAS, 509, 183

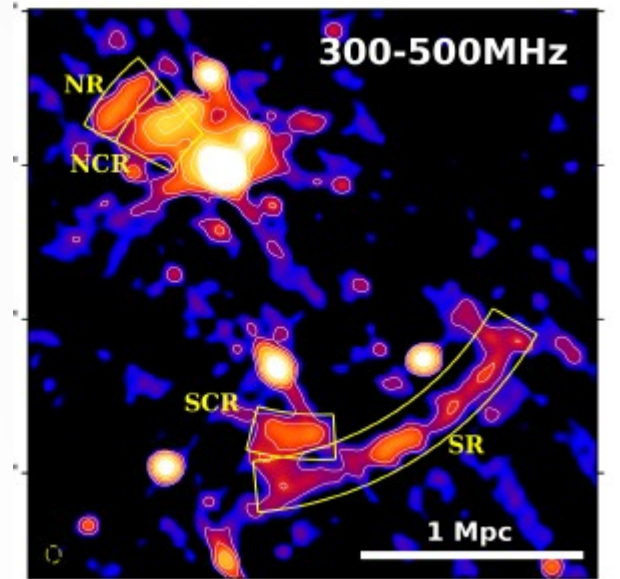
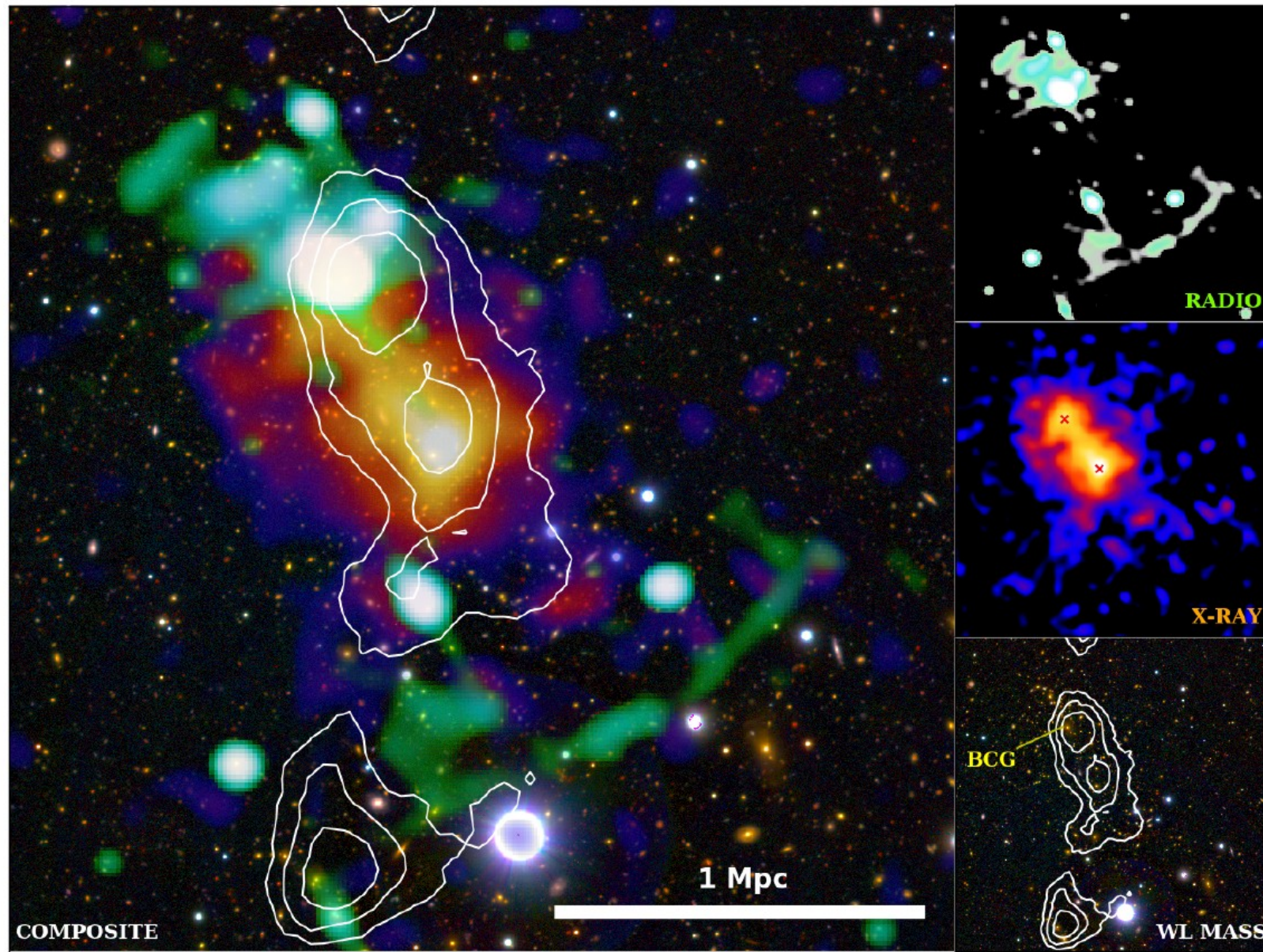


608 MHz 28 μ Jy/b
Kale and Ishwara-Chandra,
2021, ExA, 51, 95



Discovery of a
radio halo
Kale et al 2019,
MNRAS, 486,
80

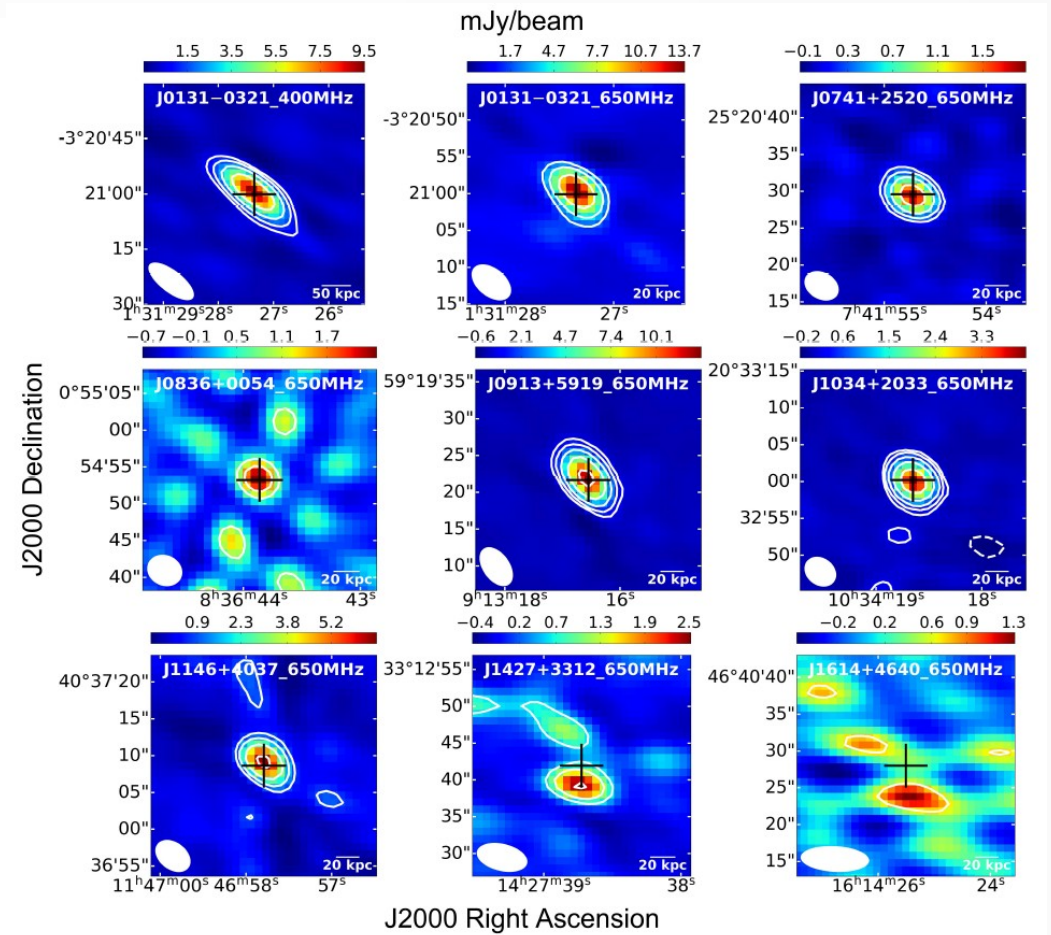
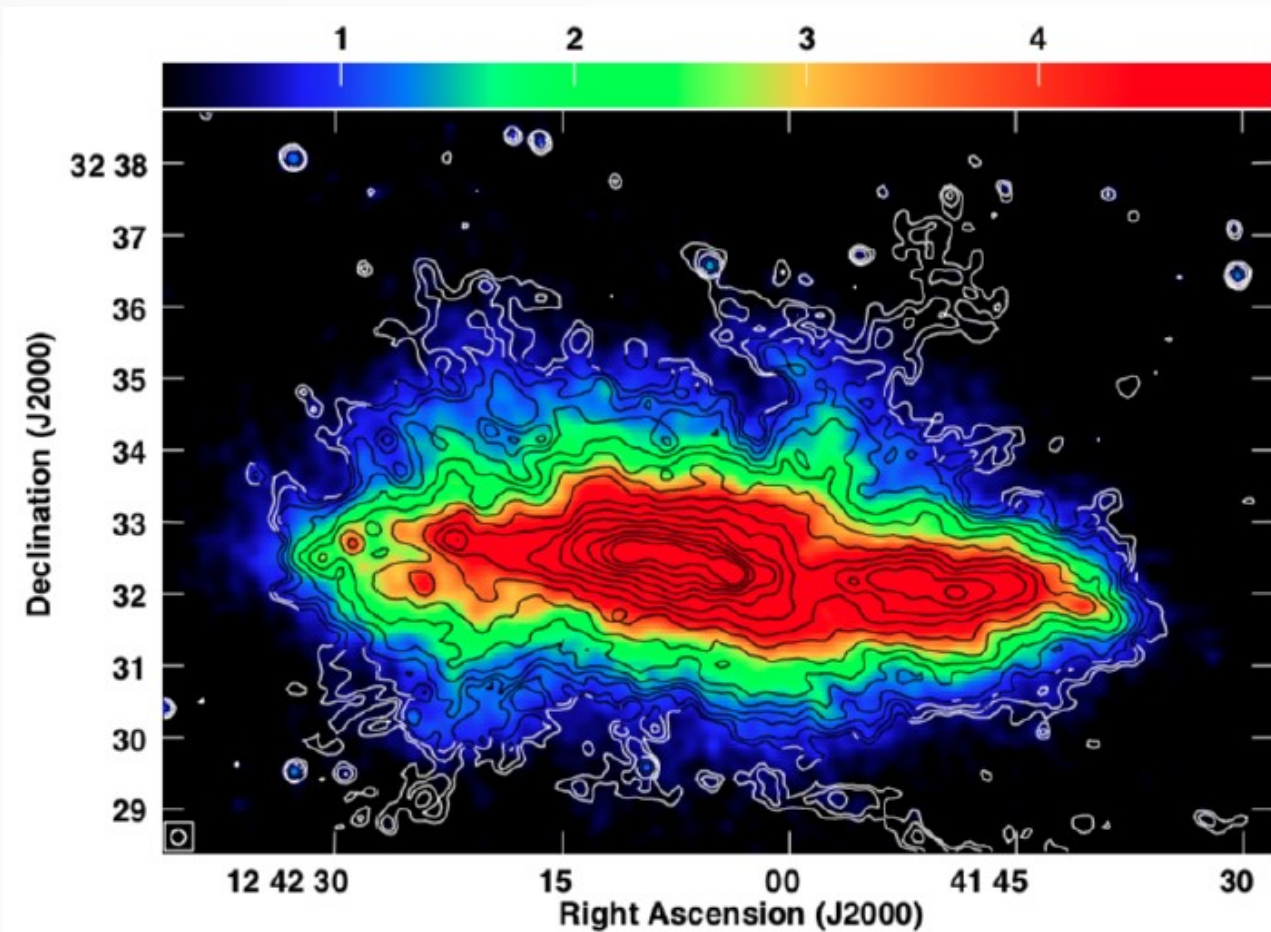
CAPTURE results uGMRT



Bands 3, 4 and 5
rms 55, 35 and 11
 $\mu\text{Jy}/\text{b}$

ZwCL1447.2+2619 Lee et al, 2022, ApJ, 924, 18

CAPTURE results μ GMRT



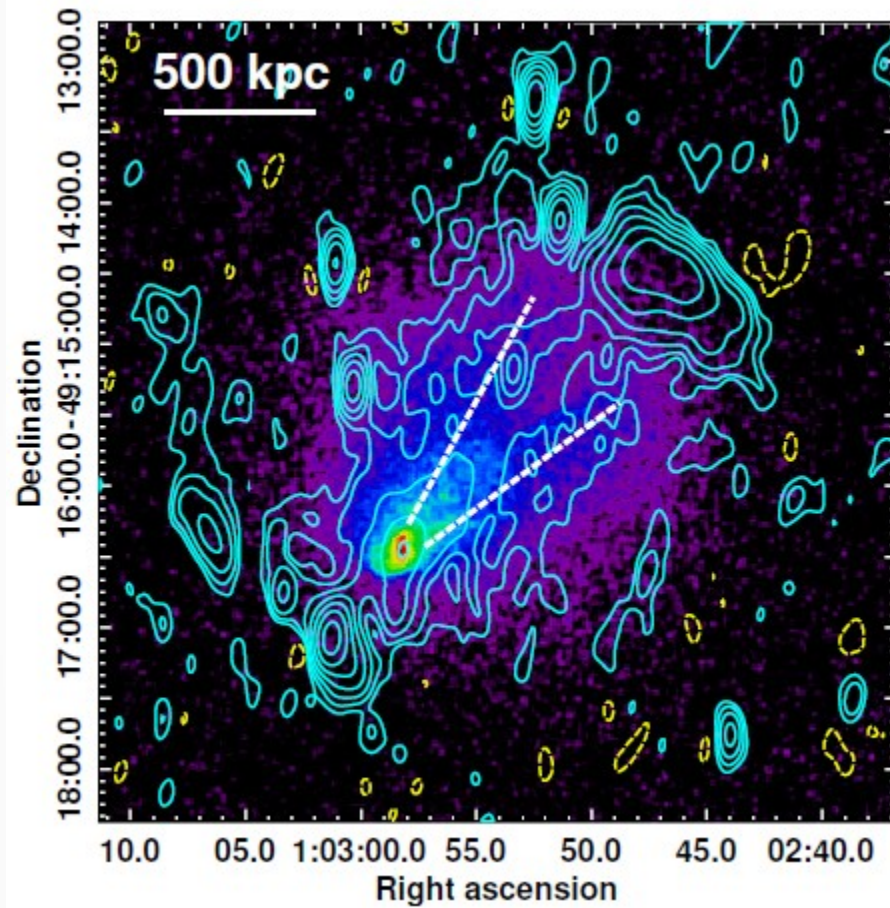
NGC 4631at bands 3 and 4; images convolved to 12'';

Rms 50 and 80 μ Jy/b

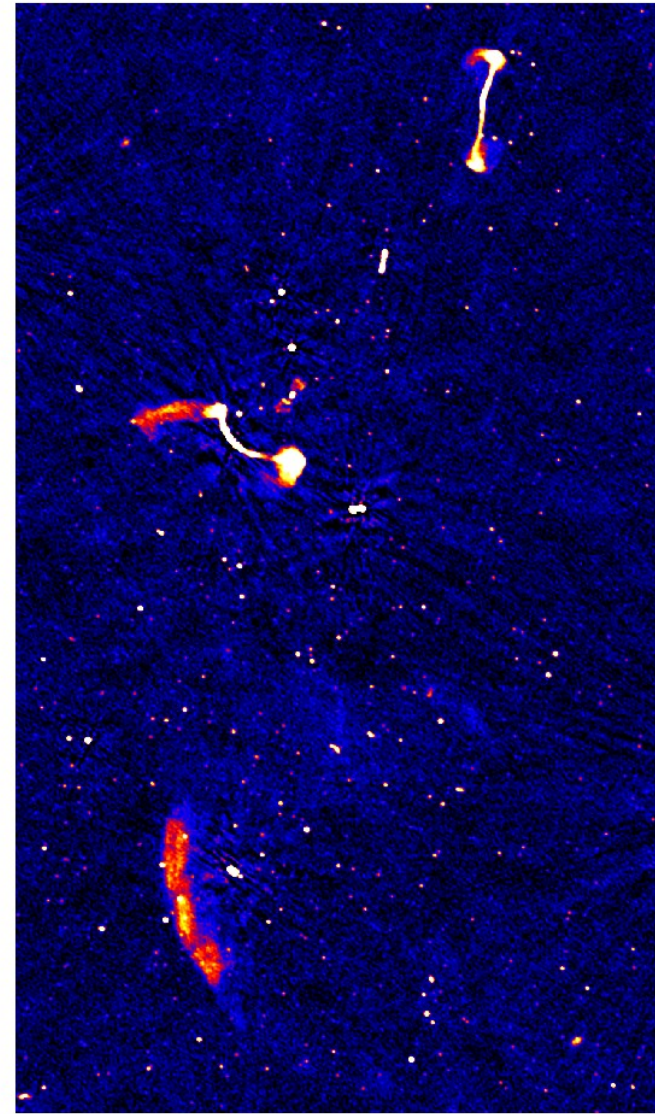
Vijayan et al 2022, MNRAS, 511, 3150

Shao, Y et al 2021,
arXiv:2112.03133

CAPTURE results uGMRT



El Gordo (Dec -49 degrees)
Bands 3, 4, 5
Rms 50, 13, 15 μ Jy/b
Kale et al.



uGMRT Band-4 rms 8 μ Jy/b
Kale et al.

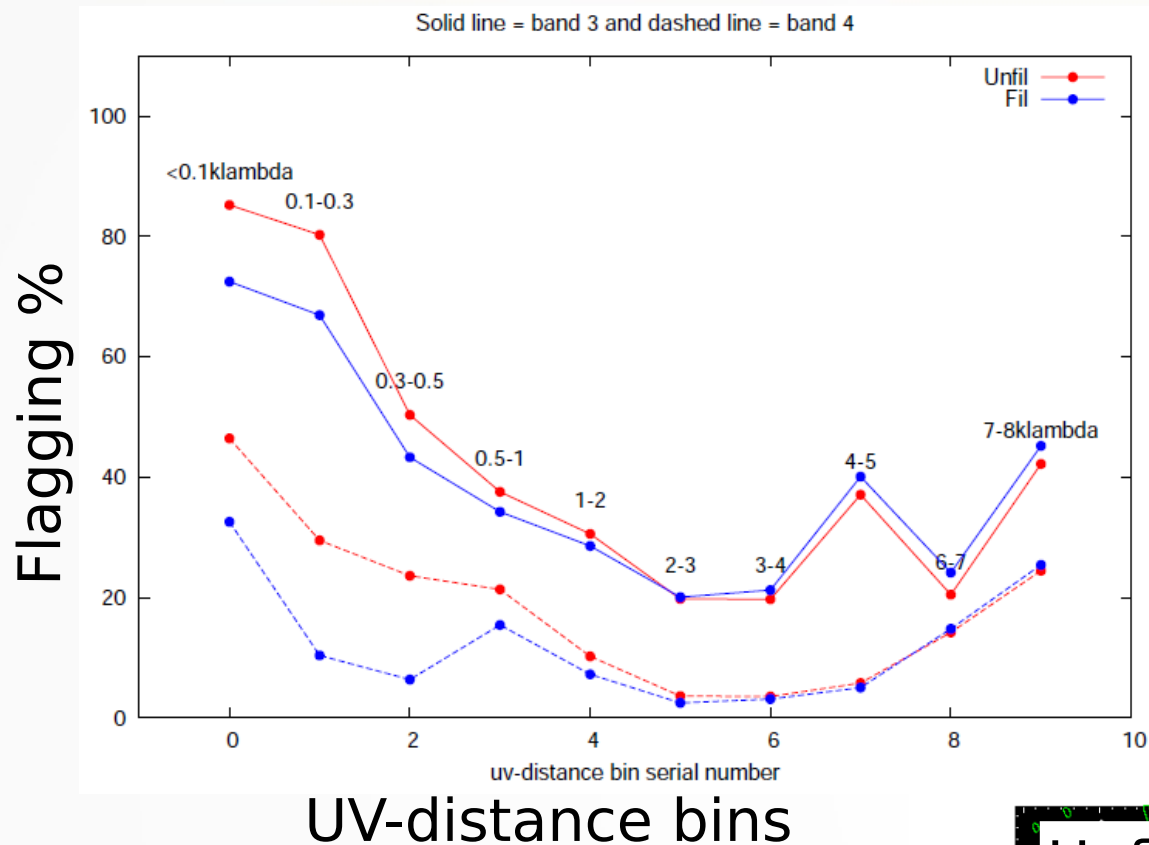
CAPTURE usage: Real-time RFI filtering tests

- Radio frequency interference (RFI) is a major problem at the uGMRT.
- Broadband RFI – Impulsive in time – typically due to sparking (power lines, automobiles)
- Narrowband RFI – e. g. Communication satellites
- To address the broadband RFI a *real-time RFI filtering* has been implemented at the uGMRT.

(Buch et al. 2016, 2019)

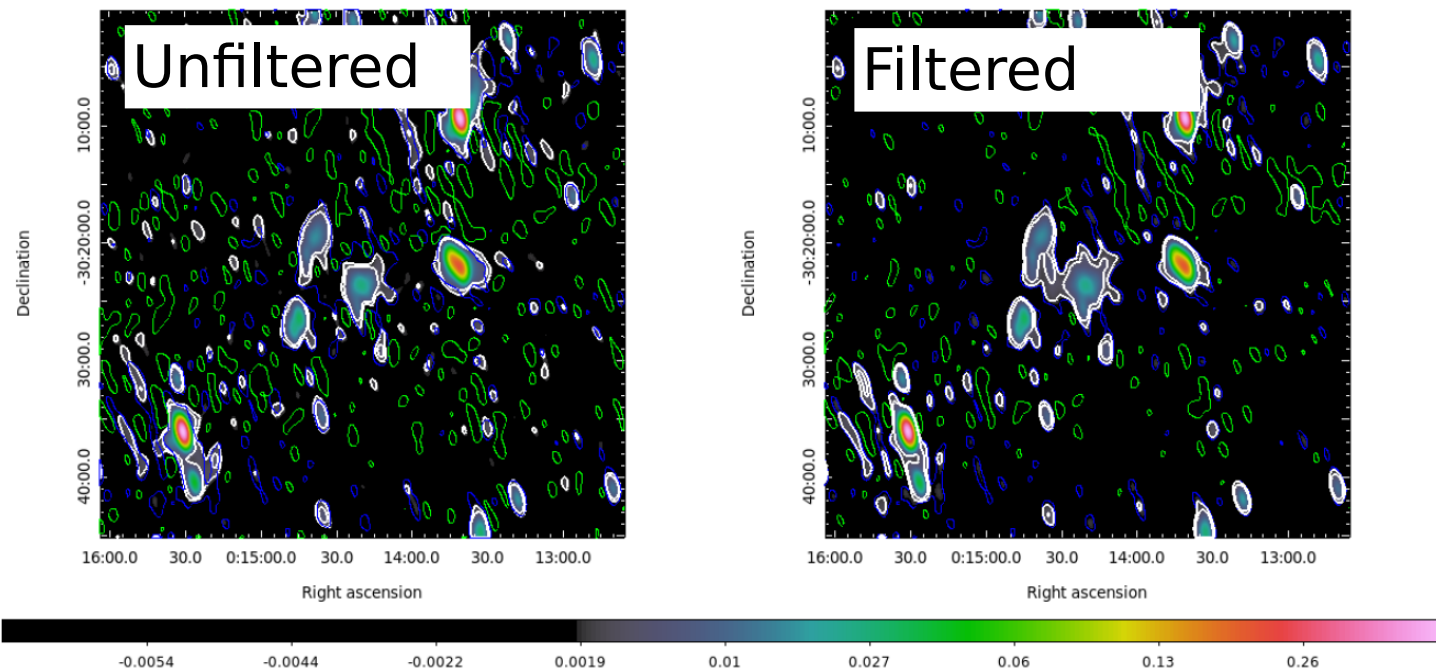
- A number of tests carried out (Buch, Kale, et al 2022, JAI, submitted).
- Imaging Tests: Filtered and unfiltered data were recorded simultaneously to see the uv-data and resulting images.
- CAPTURE was used to carry out analysis to compare the efficacy of the filtering.

<http://www.ncra.tifr.res.in/ncra/gmrt/gmrt-users/online-rfi-filtering>



Comparison of flagging in filtered and unfiltered data.
 In filtered data, flagging at short baselines was lower by 10 - 20 %.

Lower flagging at short baselines implies improvement in imaging extended sources.
 Rms better by a factor of ~ 2 .



CAPTURE

- **Pros:**
 - No dependency on anything other than CASA.
 - Can be used to run end-to-end if configuration parameters chosen appropriately.
 - Can be halted at crucial steps for the user to look or process the data manually in parts.
- **Cons:** Not tailored for handling multiple targets and unusual calibrators; images need further processing to be science ready

Further development

- Improvement in **speed**: wsclean (Offringa et al 2014) ongoing; parallelization options in CASA
- Improvement in **imaging**: direction dependent effects (e. g. peeling, primary beam model or other calibration methods)
- Packaging: docker image for **portability**
- Further automation in judging the data quality at various steps to allow **blind analysis** of data such as for the archive analysis project (Y. Wadadekar).
- ***Sophistication in the software aspects to improve efficiency and user friendliness: science ready data products.***

Summary

- CAPTURE-CASA6 and CAPTURE-POL are available for usage by the community.
- We are actively developing the pipeline and welcome feedback (ruta@ncra.tifr.res.in or on github).
- We aim to add features to improve the speed and image quality.
- We are looking for involvement of software developers to further enhance the capabilities of CAPTURE.

<http://www.ncra.tifr.res.in/~ruta/IDAP/index.html>

<https://github.com/ruta-k/CAPTURE-POL>

<https://github.com/ruta-k/CAPTURE-CASA6>

