

# PROBING CLUSTERS OUTSKIRTS: WHAT CAN MEGAHALOS TELL US?

**Matteo Cianfaglione**

**Collaborators:** F. De Gasperin, V. Cuciti,  
M. Balboni, R. J. van Weeren et al.



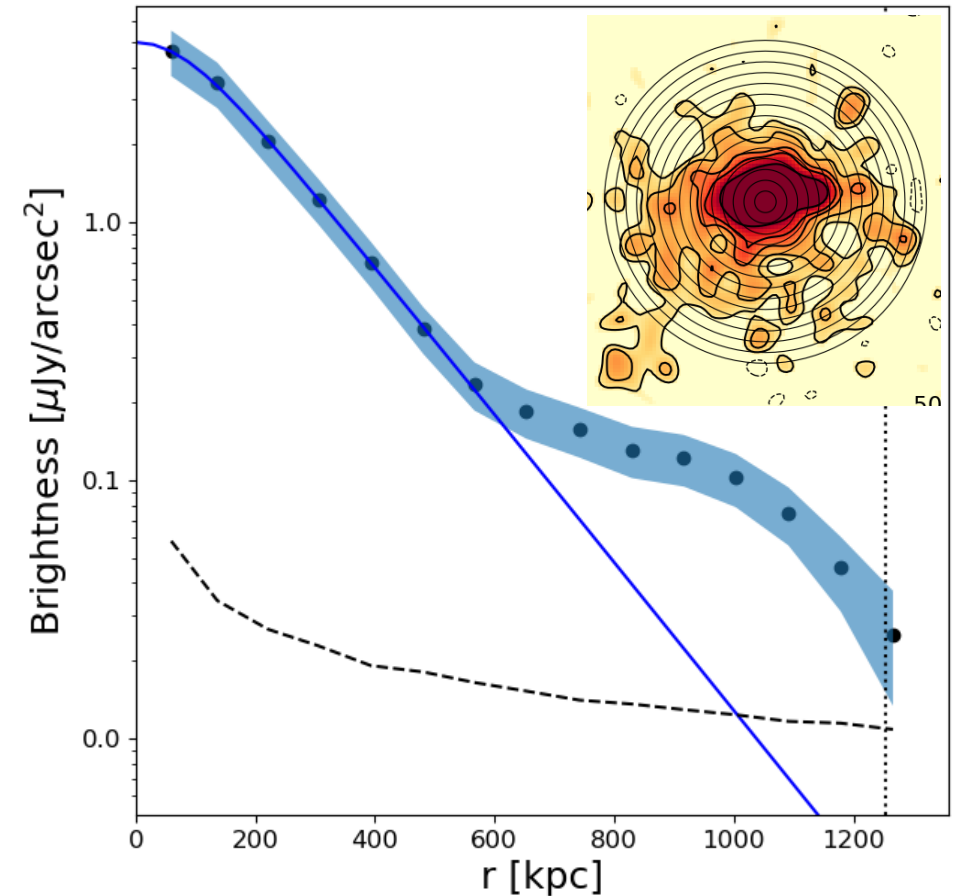
**INAF**  
ISTITUTO NAZIONALE  
DI ASTROFISICA



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA

# DIFFUSE RADIO EMISSION IN CLUSTERS: MEGAHALOS

- Very few detected so far (Cuciti et al. 2022);
- unknown origin;
- $R \geq 1000$  kpc;
- **very low average surface brightness**  
( $\sim 0.01 - 0.5 \mu\text{Jy}/\text{arcsec}^2$  at 144 MHz);
- almost flat surface brightness profile;
- ultra-steep spectrum ( $\alpha \approx 1.6$ ).

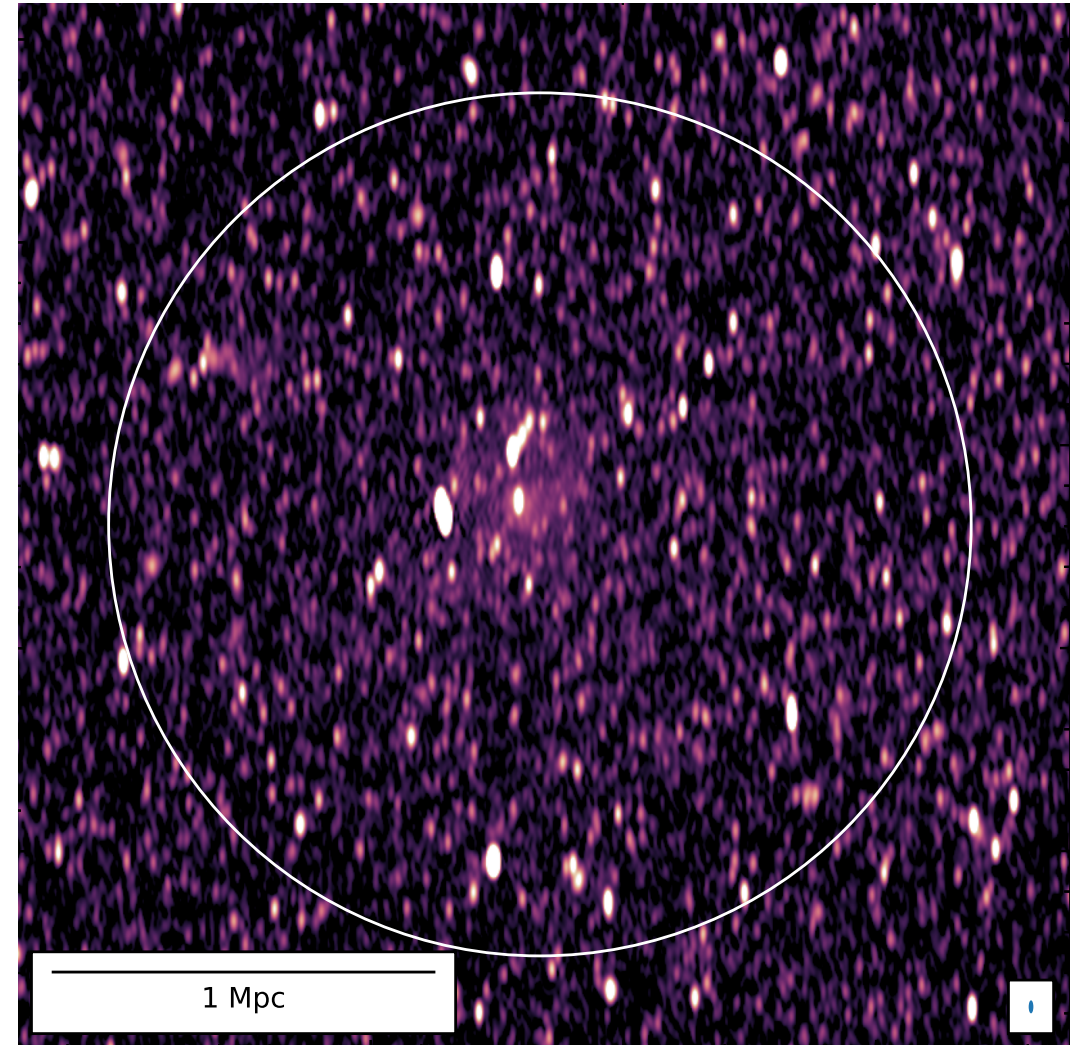


Cuciti et al. 2022

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# ABELL 2244

- Intermediate mass cluster ( $M_{500} = (4.4 \pm 0.2) \times 10^{14} M_{\odot}$ );
- low redshift ( $z = 0.095$ );
- warm core and **interacting with a nearby group**;
- no complex discrete sources present;
- **double component diffuse emission** (Balboni et al. 2024);

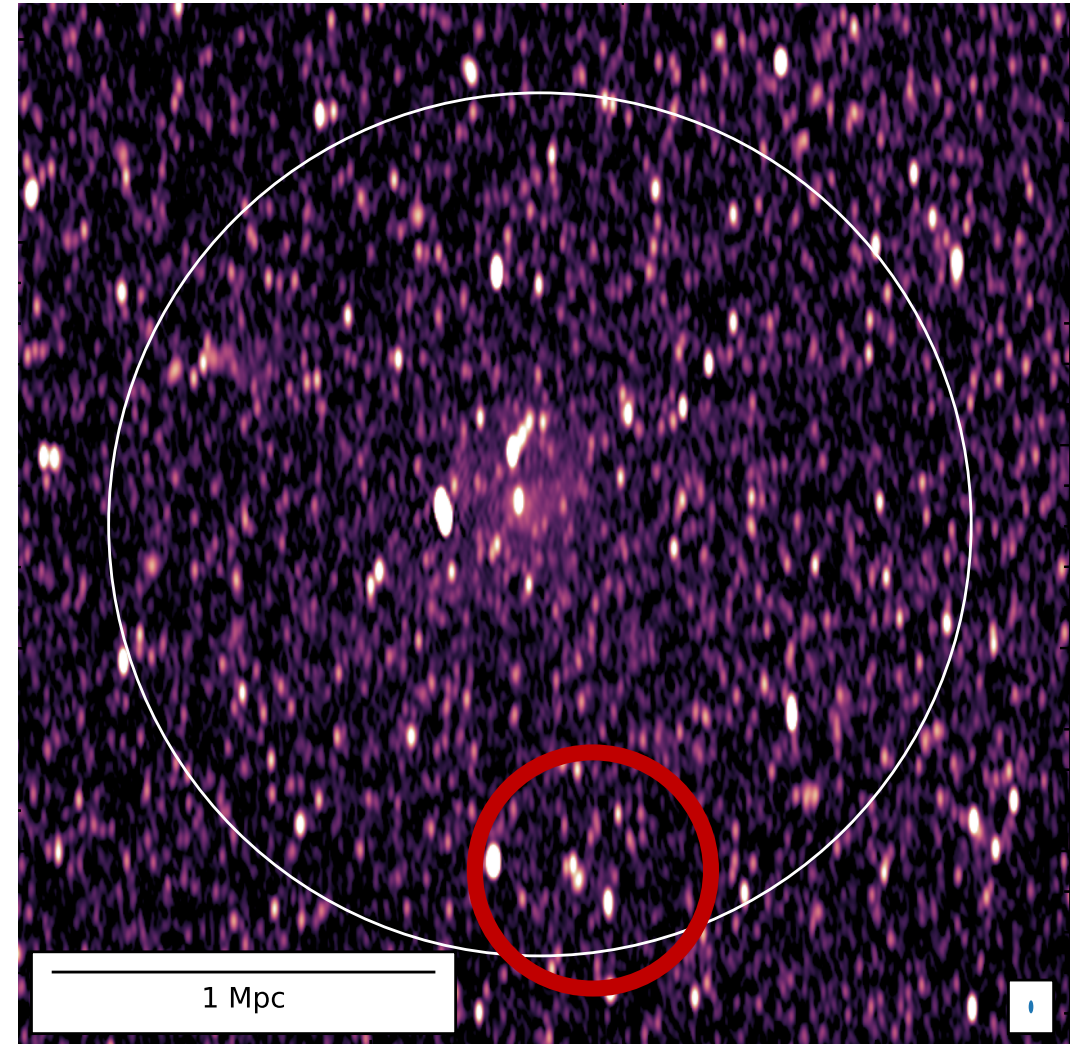




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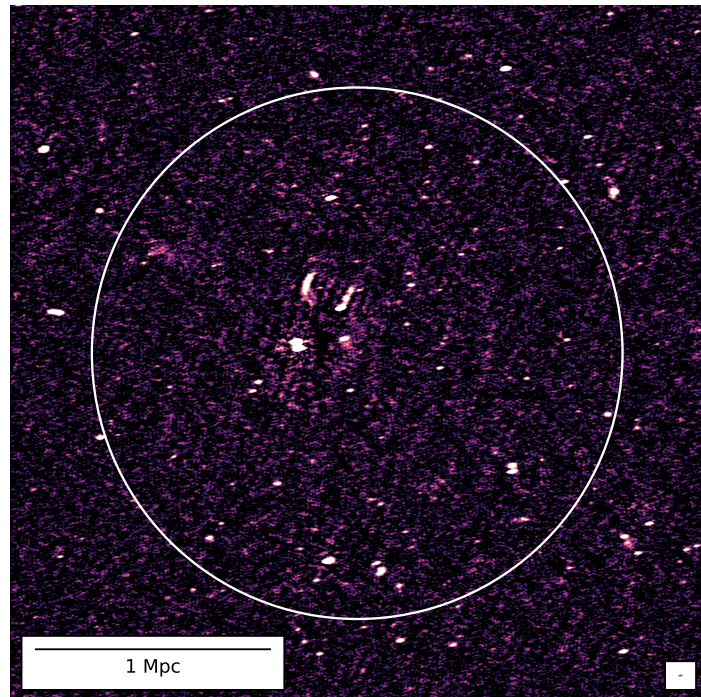




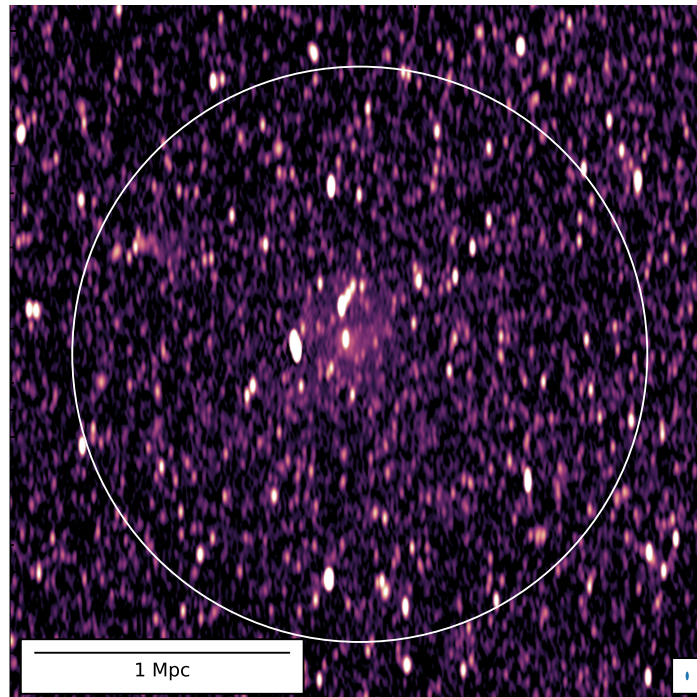
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# OBSERVATIONS

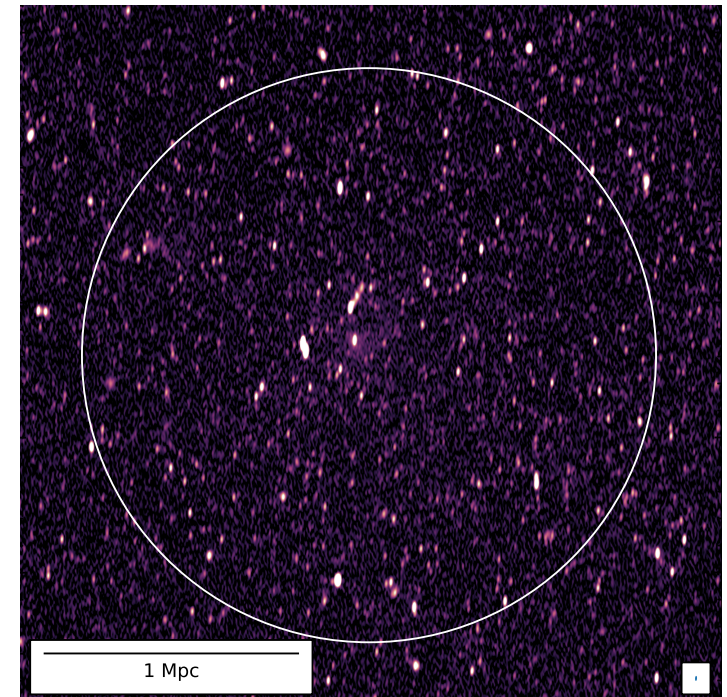
LOFAR HBA



MeerKAT UHF



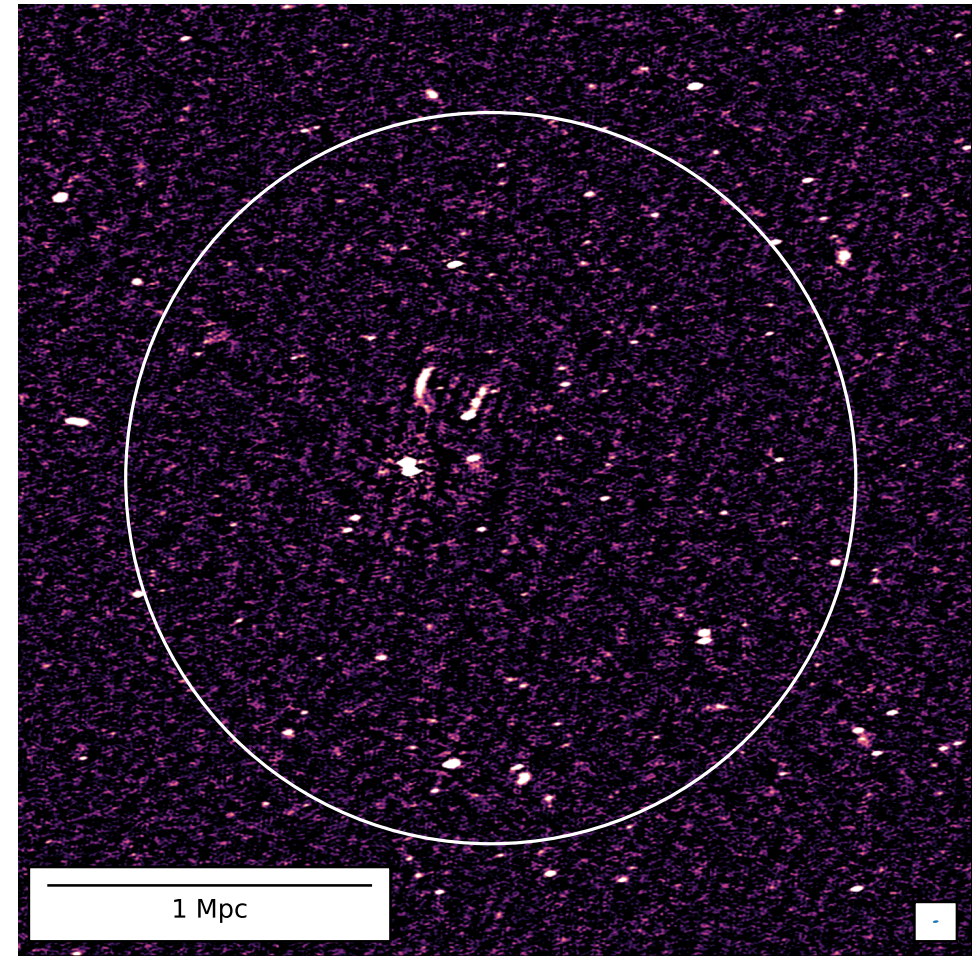
MeerKAT L band





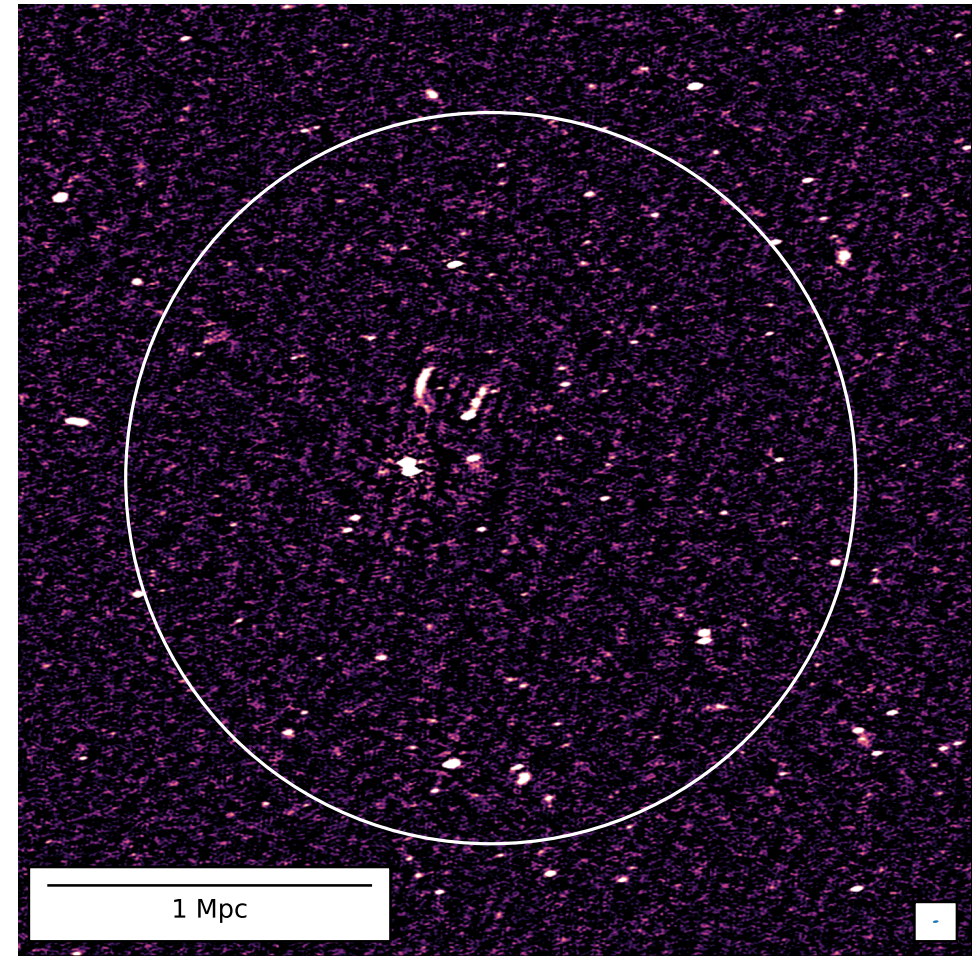
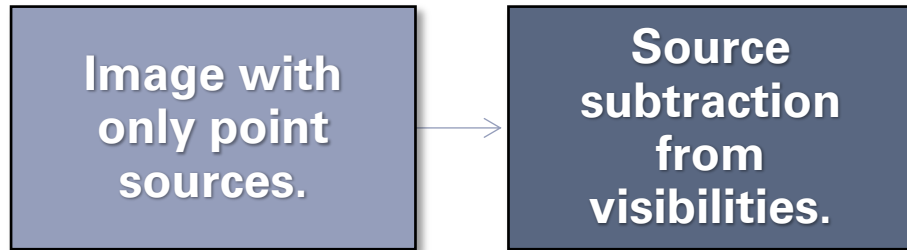
# METHODS - SOURCE SUBTRACTION

Image with  
only point  
sources.

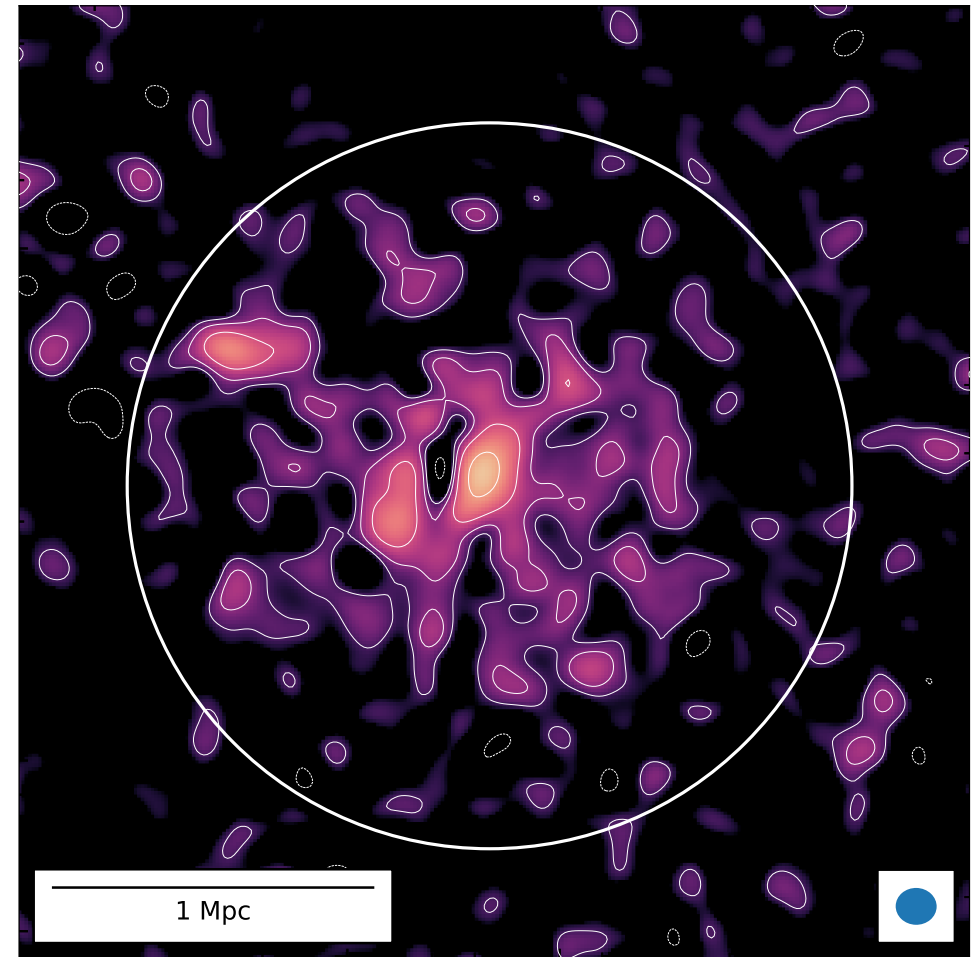
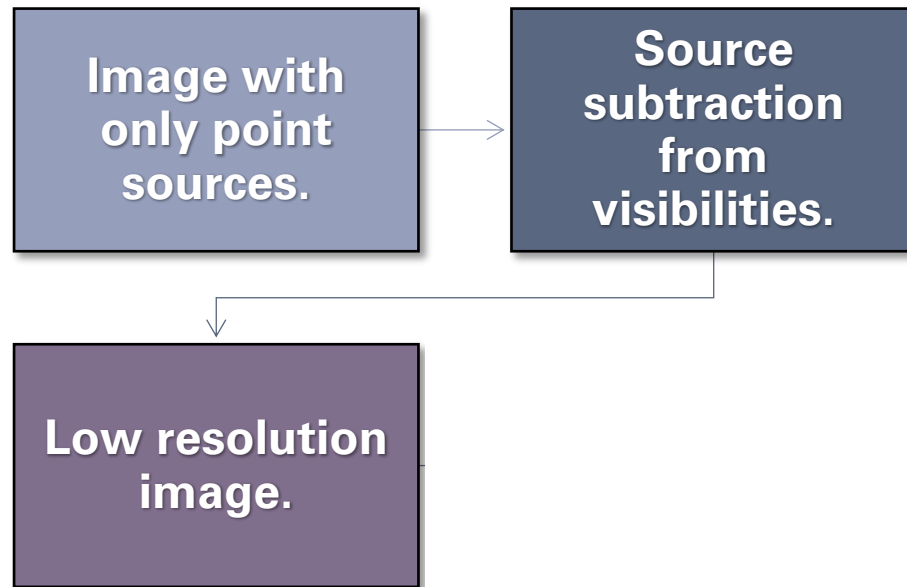




# METHODS - SOURCE SUBTRACTION

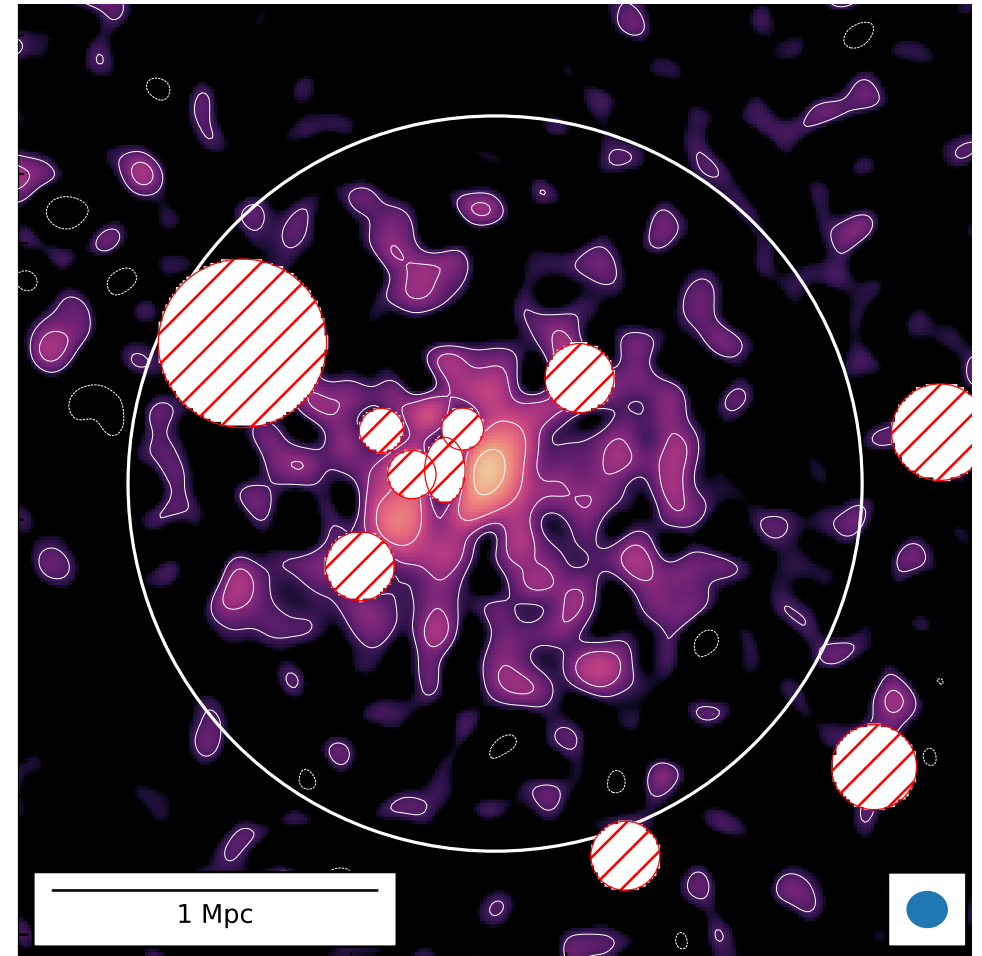
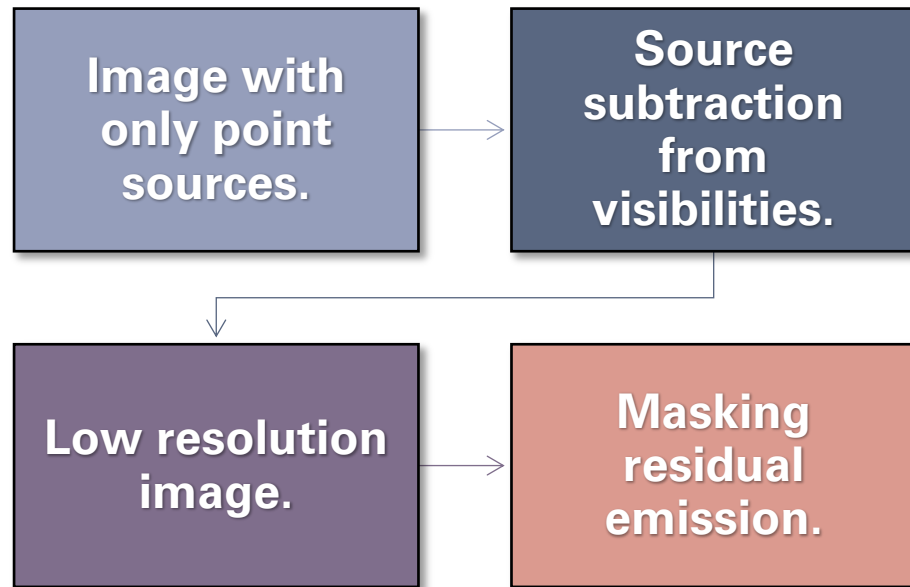


# METHODS - SOURCE SUBTRACTION

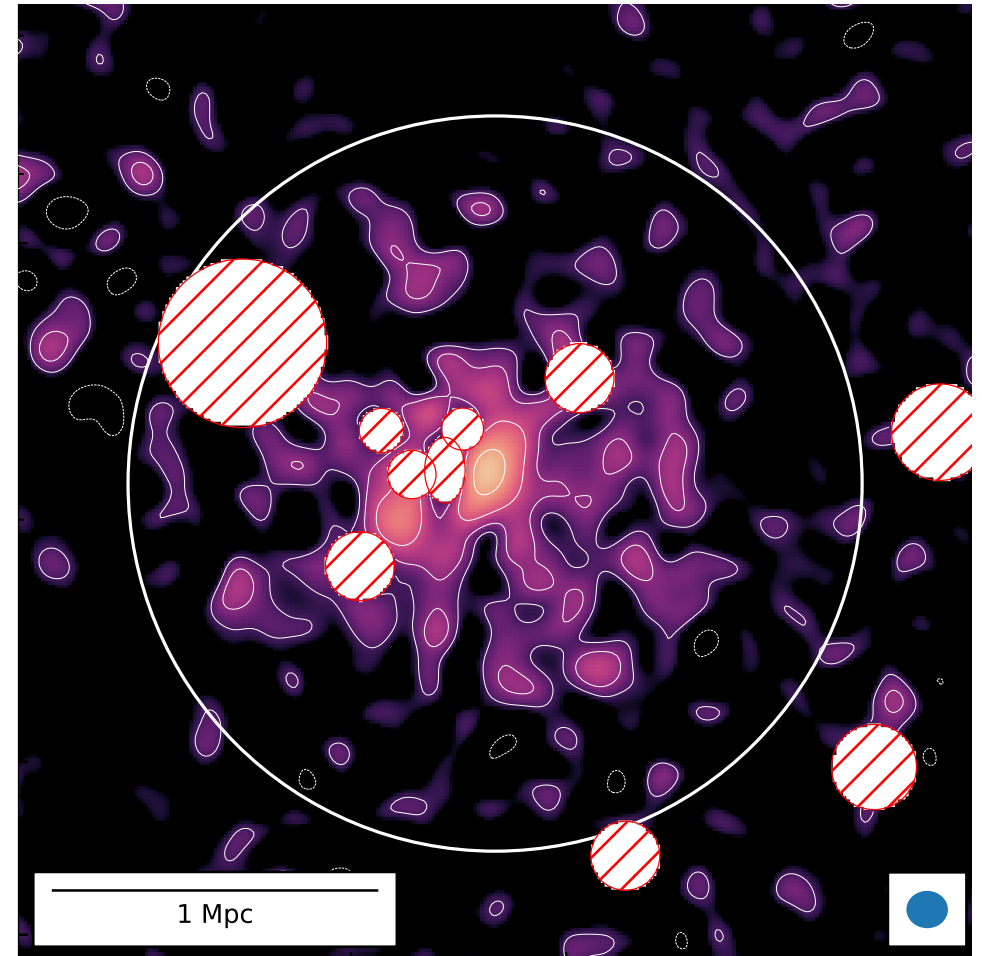
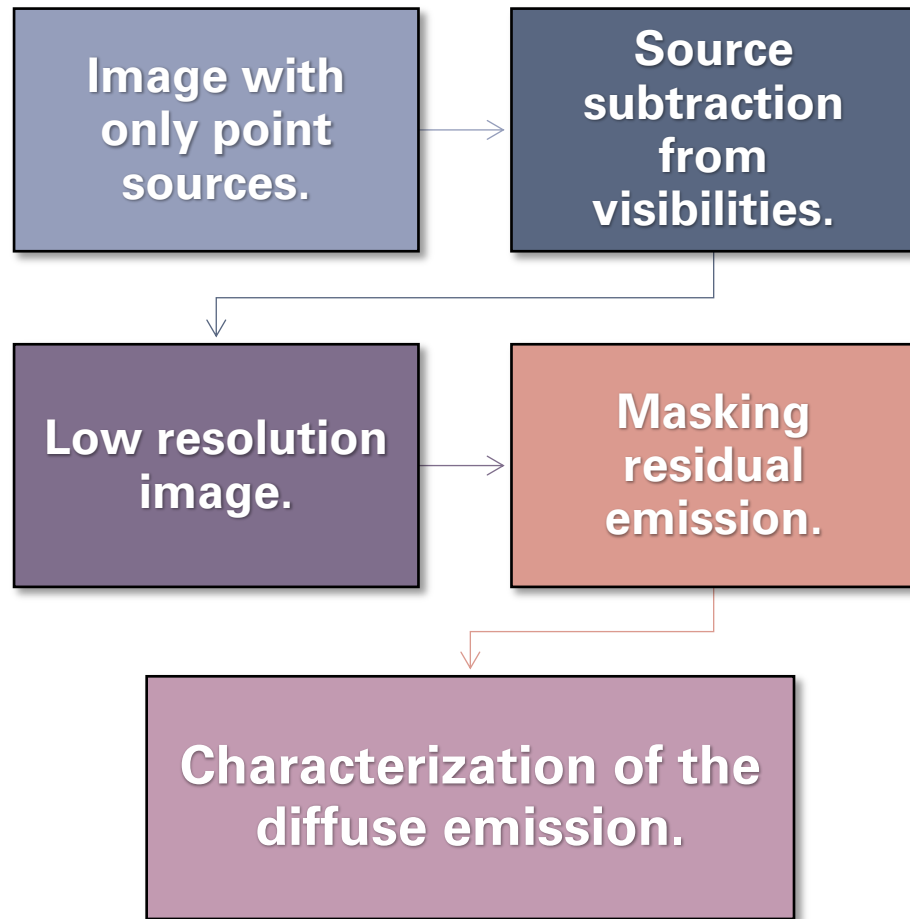




# METHODS - SOURCE SUBTRACTION



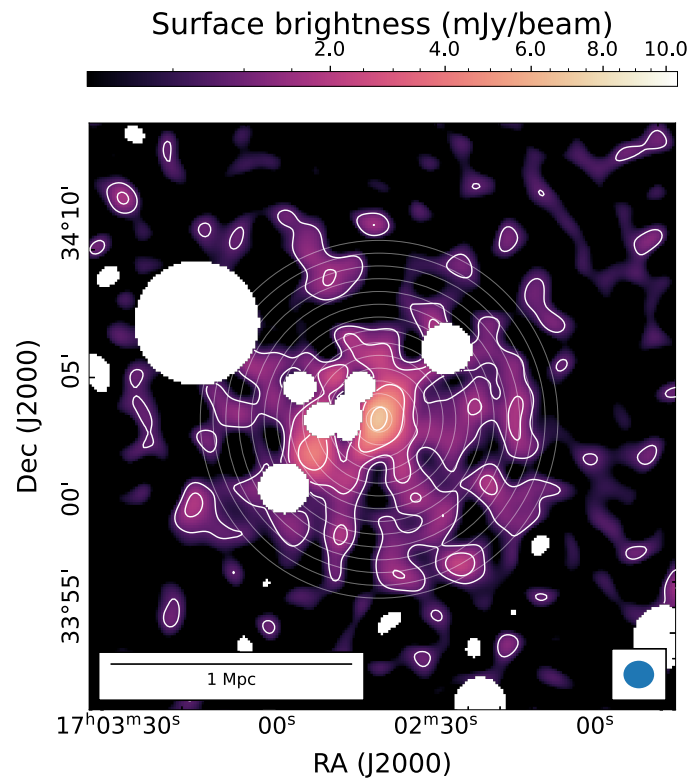
# METHODS - SOURCE SUBTRACTION



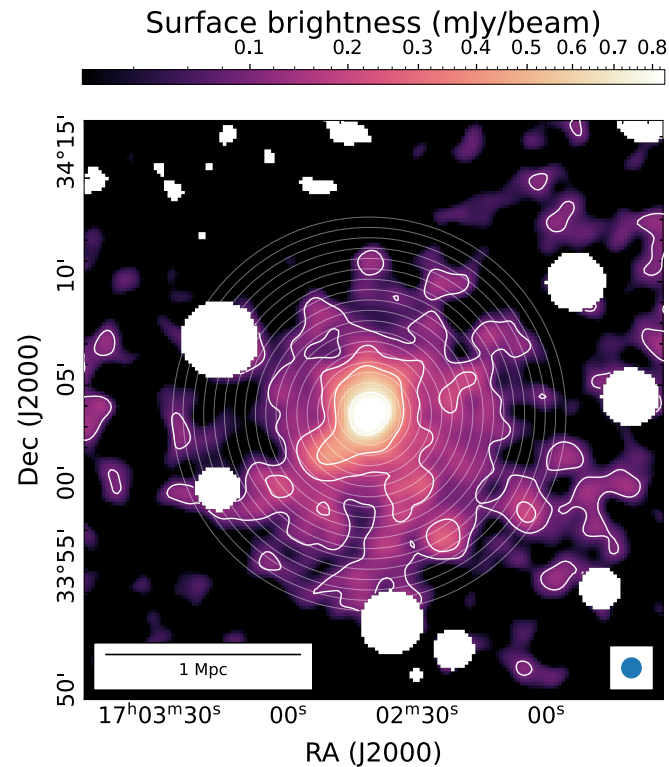


# DIFFUSE EMISSION - RESULTS

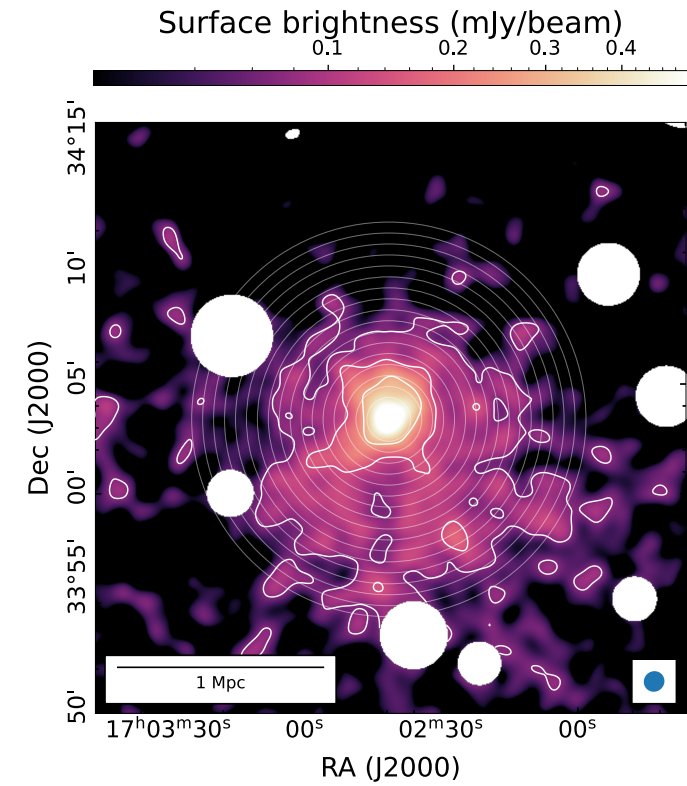
LOFAR HBA



MeerKAT UHF



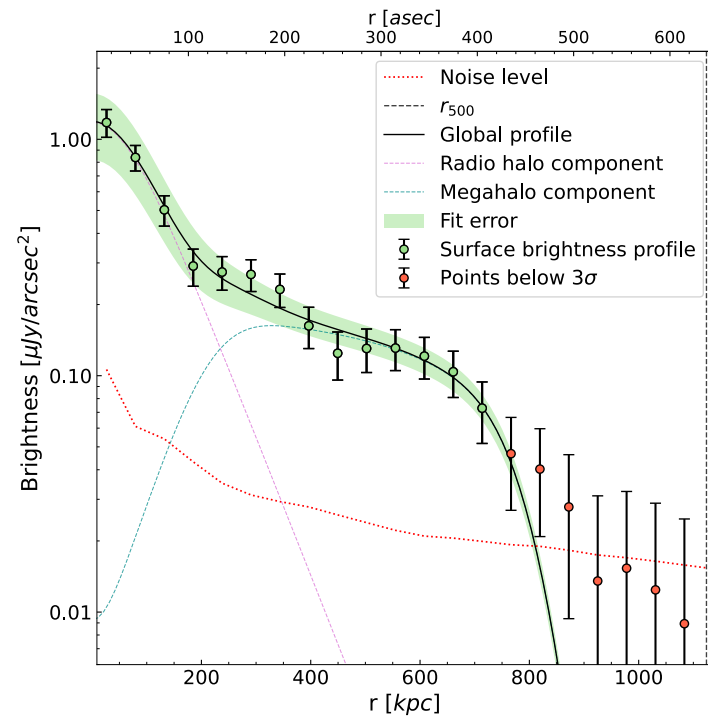
MeerKAT L band



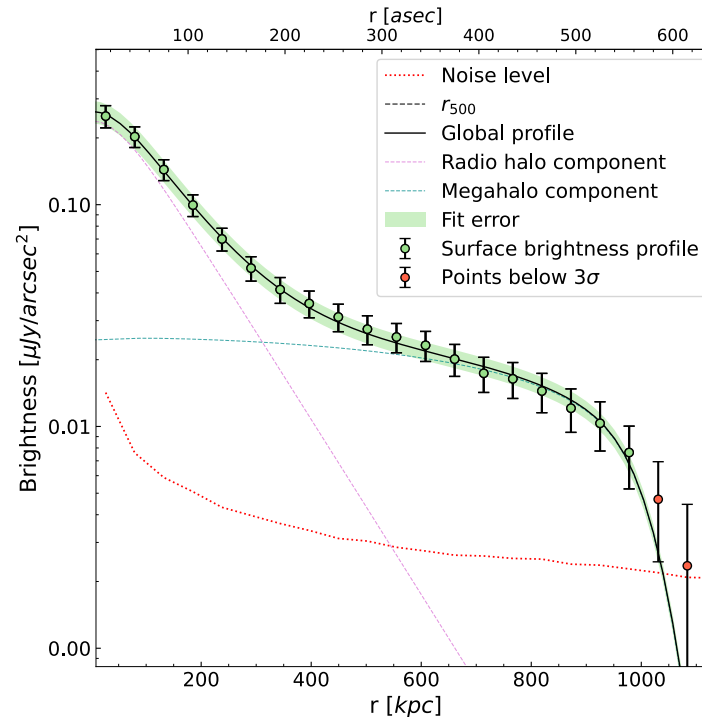
Cianfaglione et al. in prep.

# DIFFUSE EMISSION - RESULTS

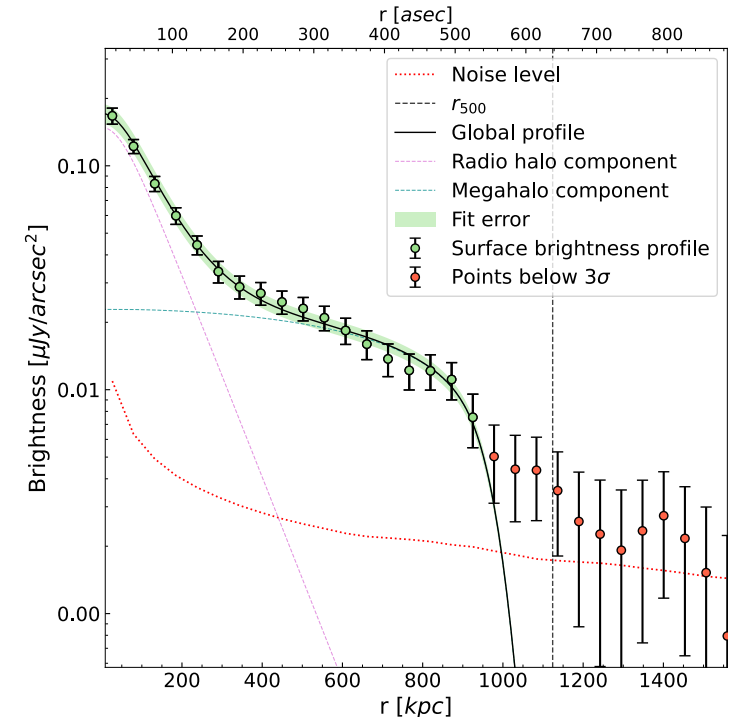
LOFAR HBA



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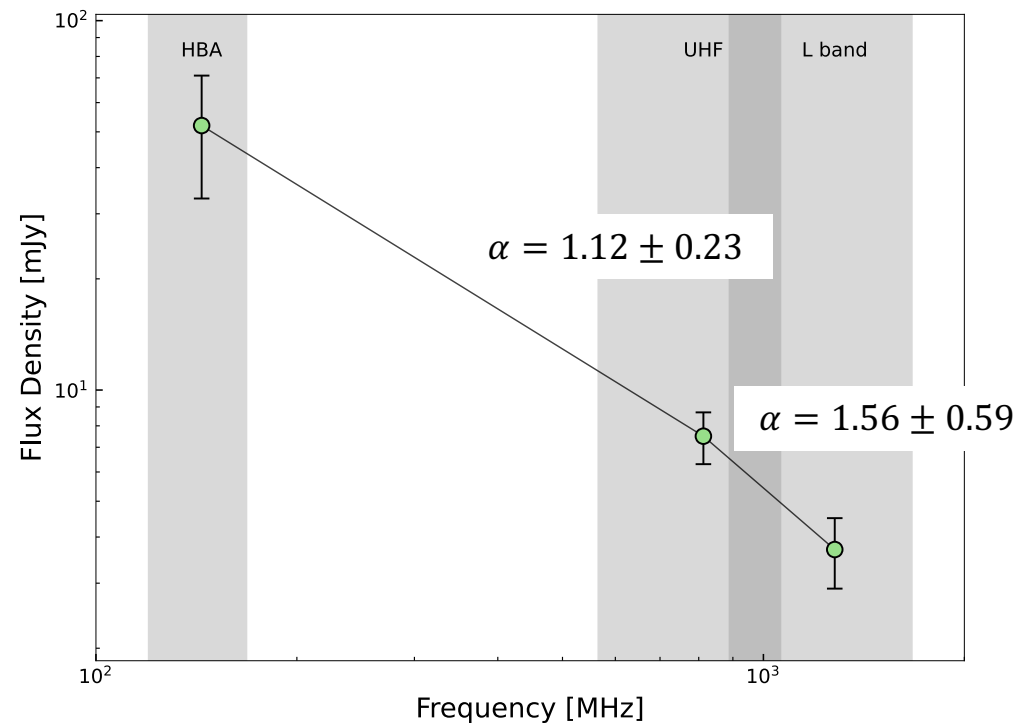


Cianfaglione et al. in prep.

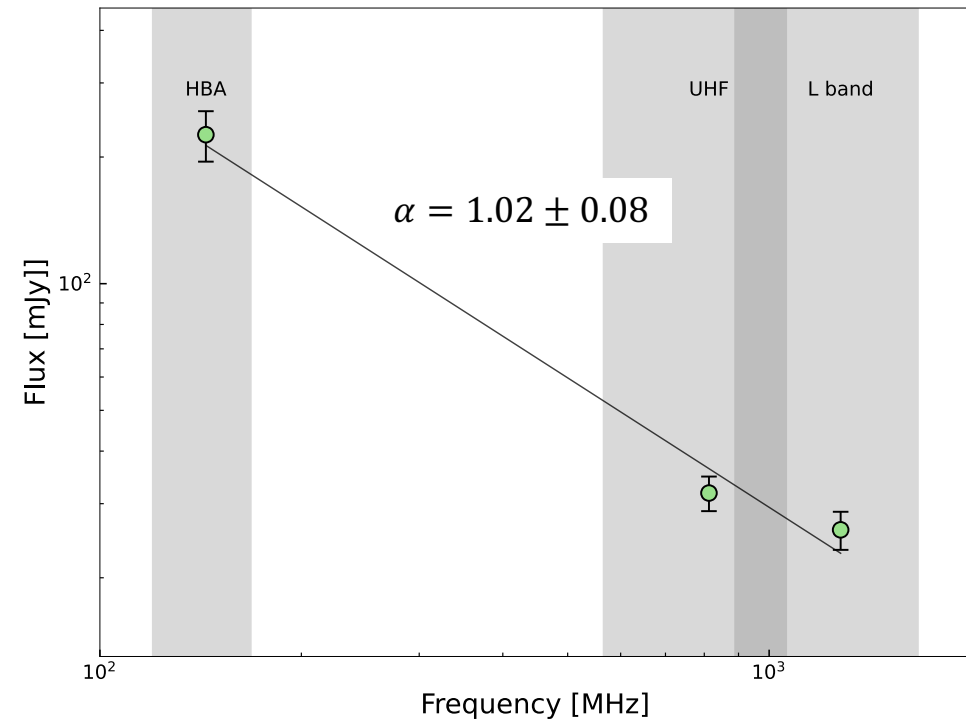


# INTEGRATED SPECTRA

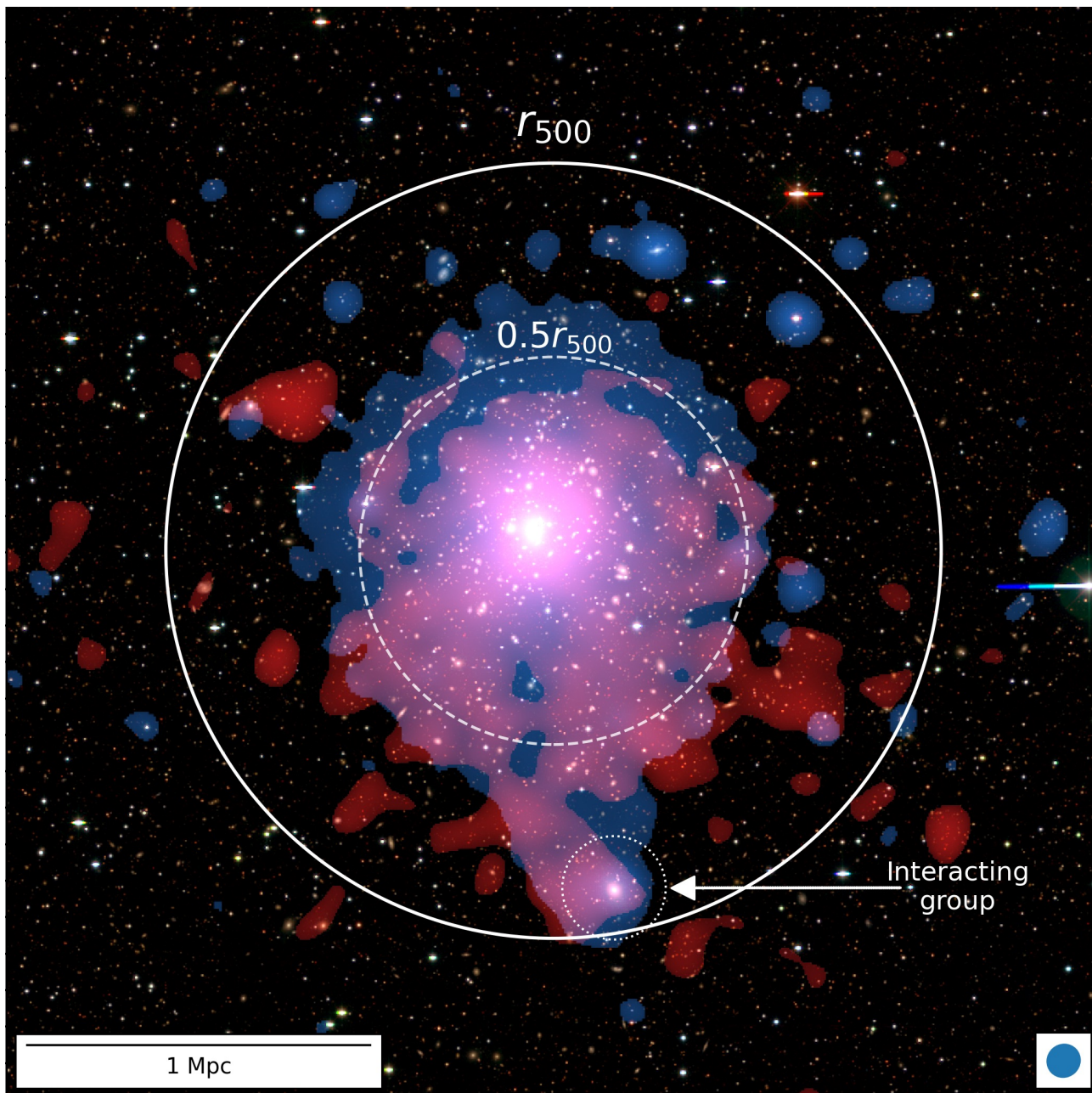
## Radio halo



## Megahalo



Cianfaglione et al. in prep.



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# RADIO X-RAY CORRELATION

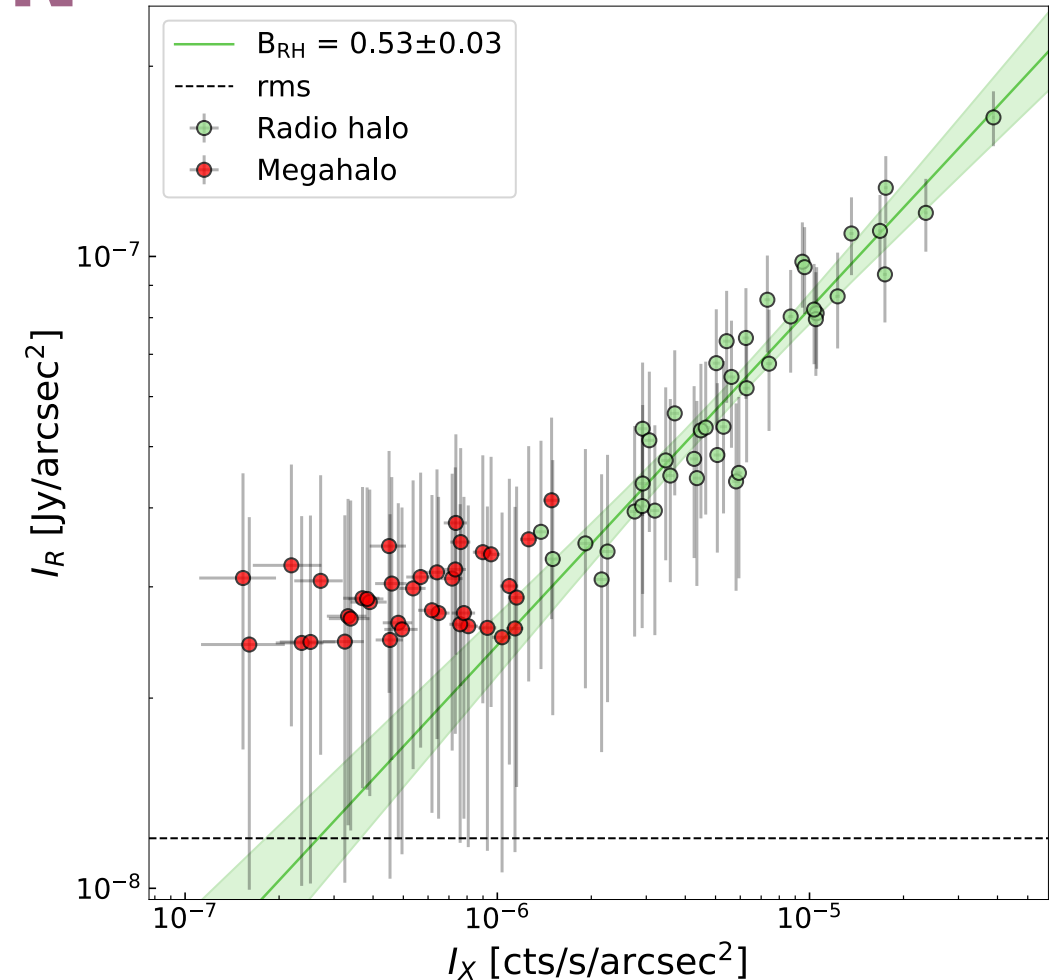
- First presented by Govoni et al. 2001;
- similarities between diffuse X-ray and radio emission morphologies;
- **relation between the thermal gas and the relativistic plasma;**
- follows a **linear relation:**

$$\log I_R = B \log I_X + A$$

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# RADIO X-RAY CORRELATION RESULTS

- Radio halo follows a sub-linear relation ( $B = 0.53 \pm 0.03$ ) consistent with Balboni et al. (2024);
- **megahalo does not follow the same relation;**
- $I_{R,MH}$  varies little with  $I_X$ ;
- $r_{S,MH} = 0.35$ ,  $p = 0.03$ .



Cianfaglione et al. in prep.



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**What if megahalos are just a blend of faint radio sources at low resolution?**

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# **MOCK LOFAR OBSERVATIONS – LOSITO SETUP**

**8hrs of observation**

**Same start time as the real observation**

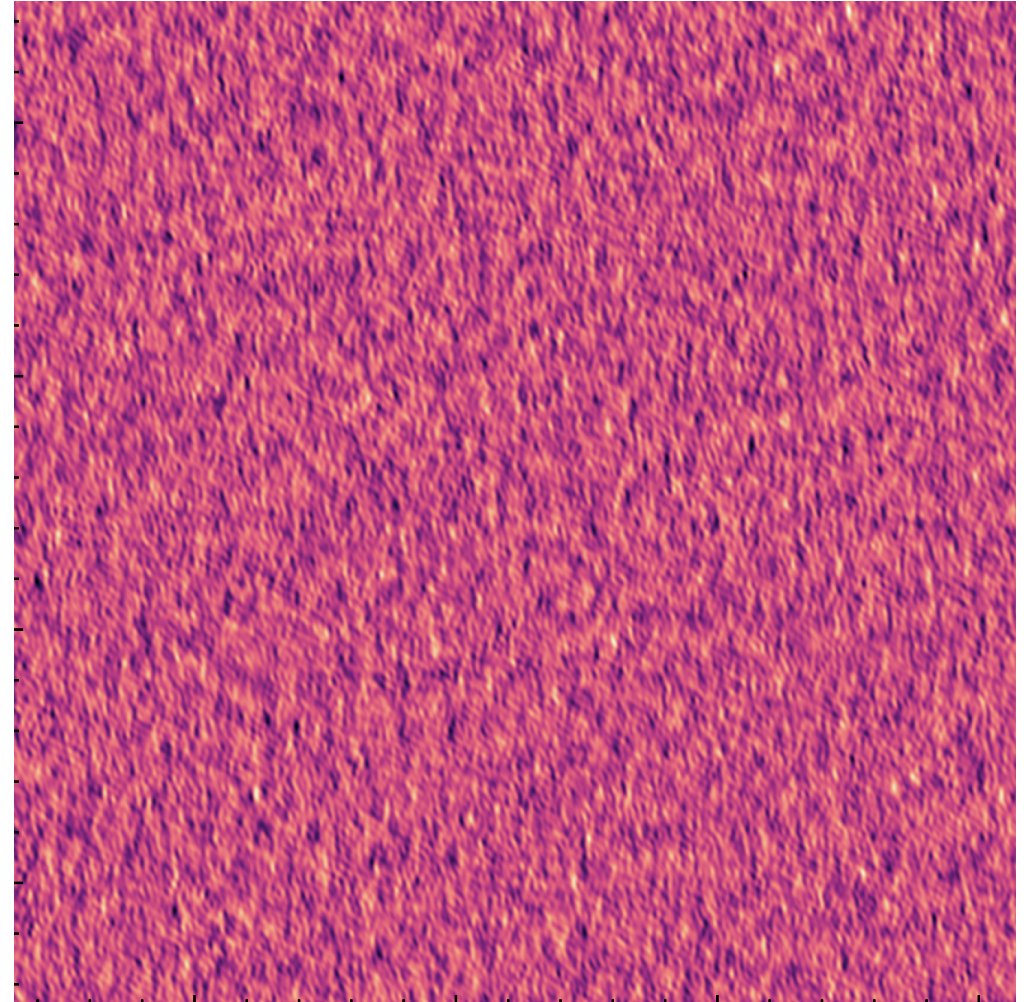
**Only thermal noise present**

**Inject 2D exponential model alongside with a distribution of sources**

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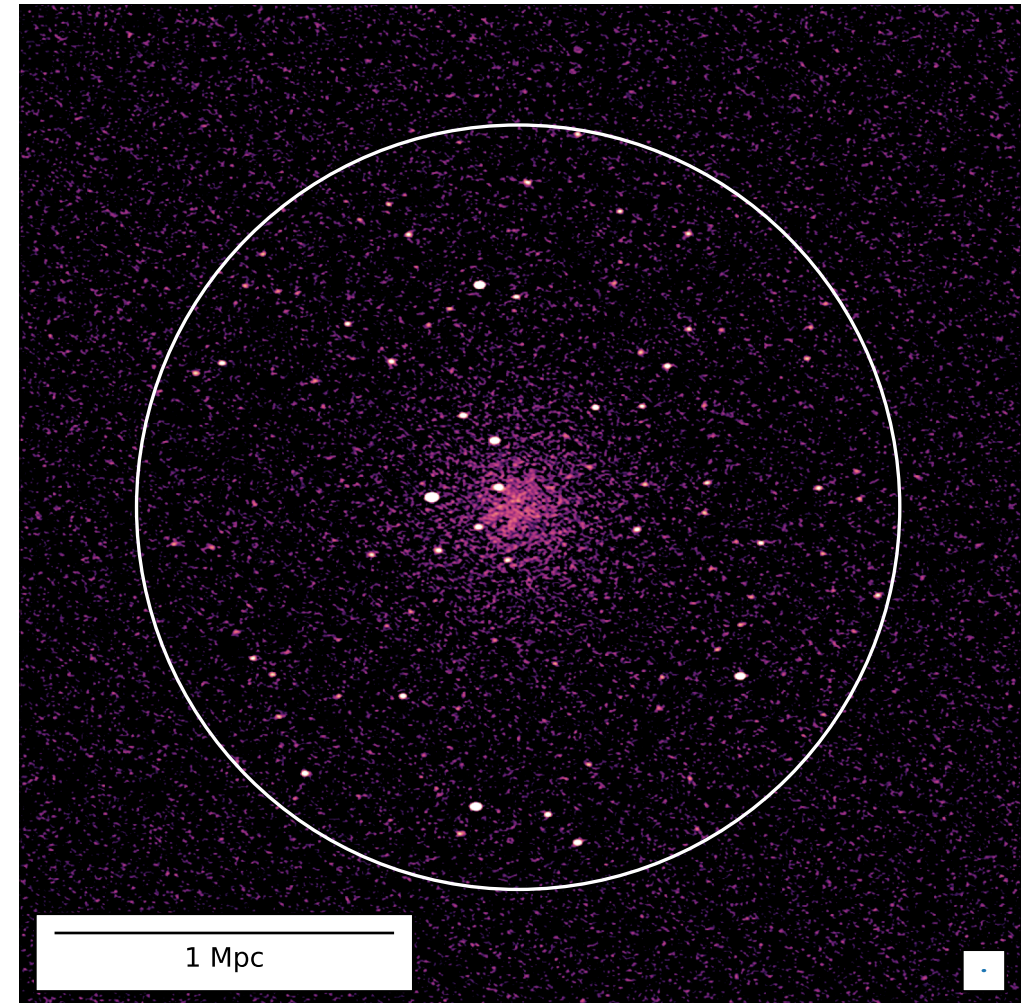
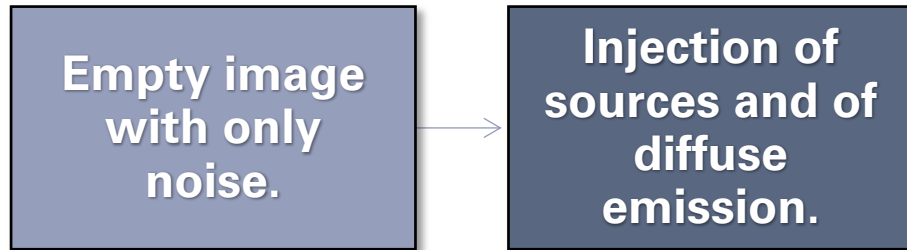
# MOCK LOFAR OBSERVATIONS - PROCEDURE

Empty image  
with only  
noise.

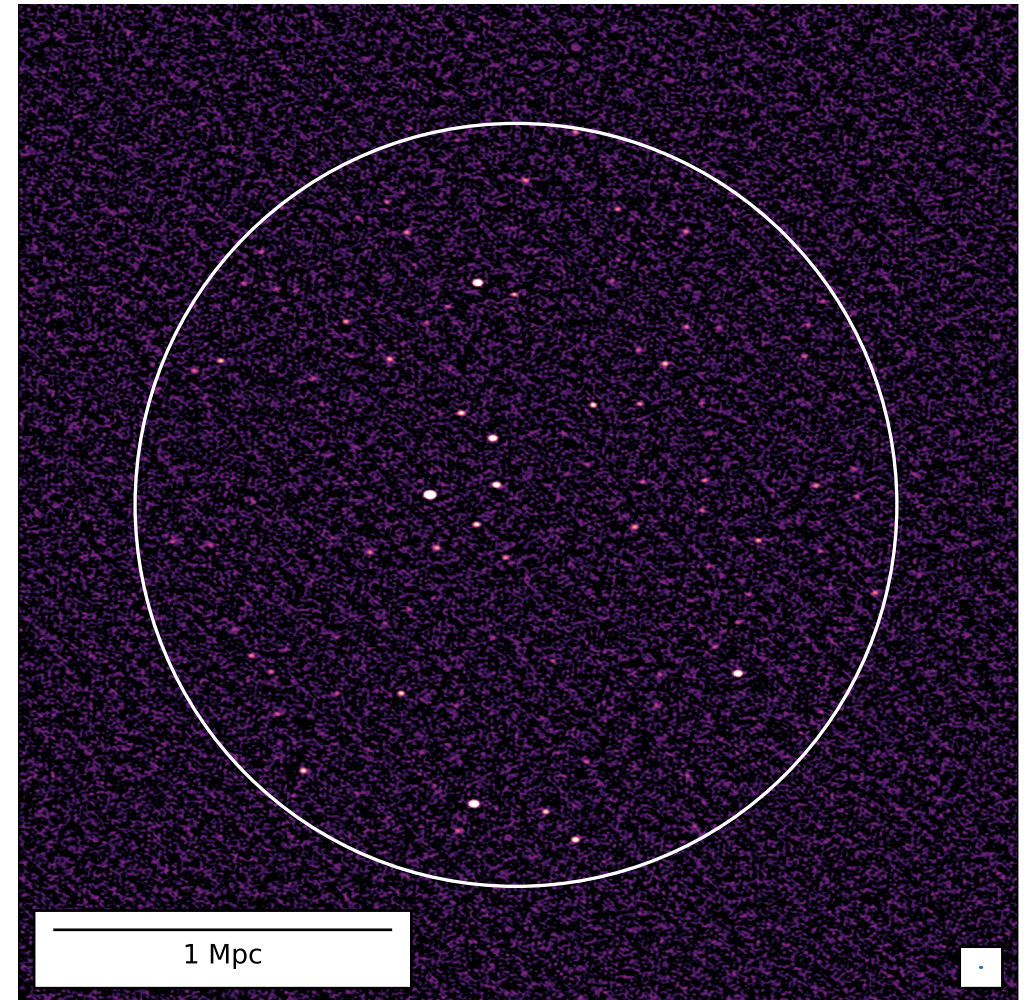
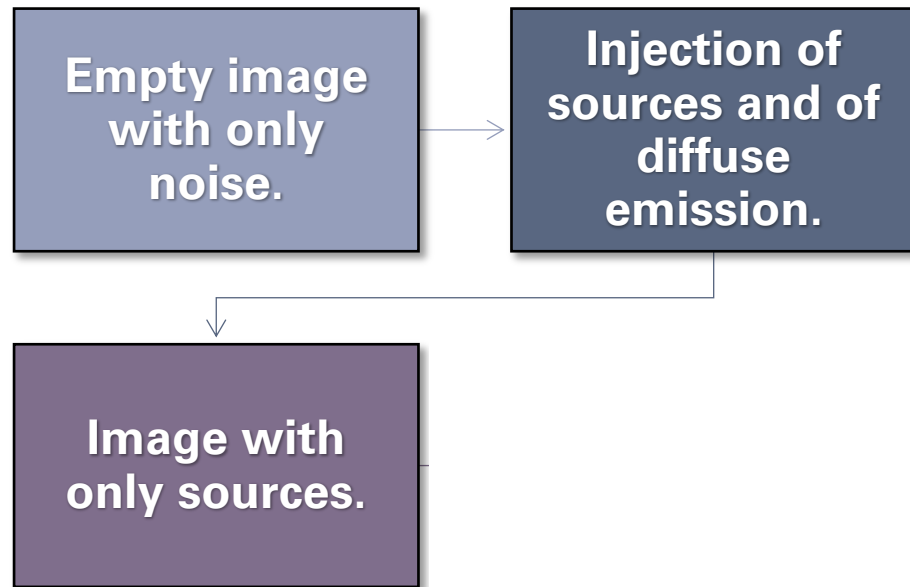




# MOCK LOFAR OBSERVATIONS - PROCEDURE

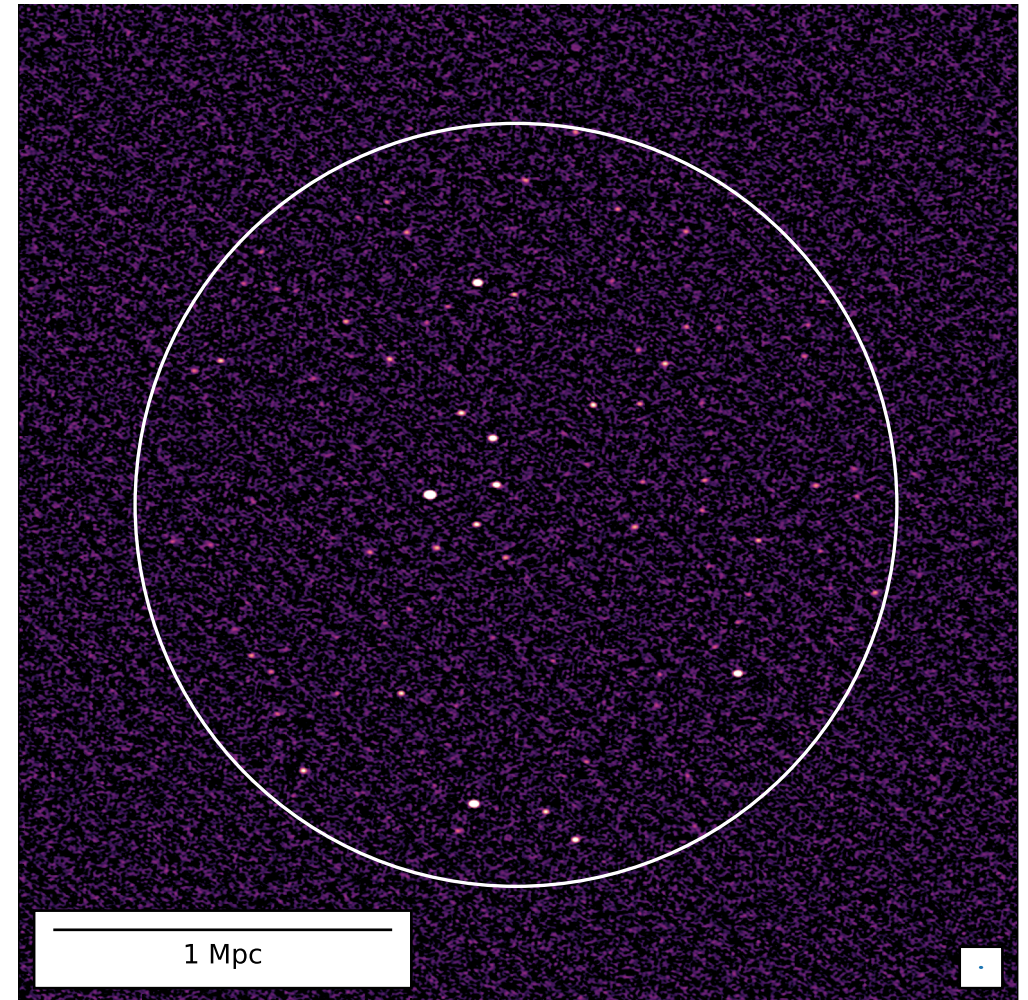
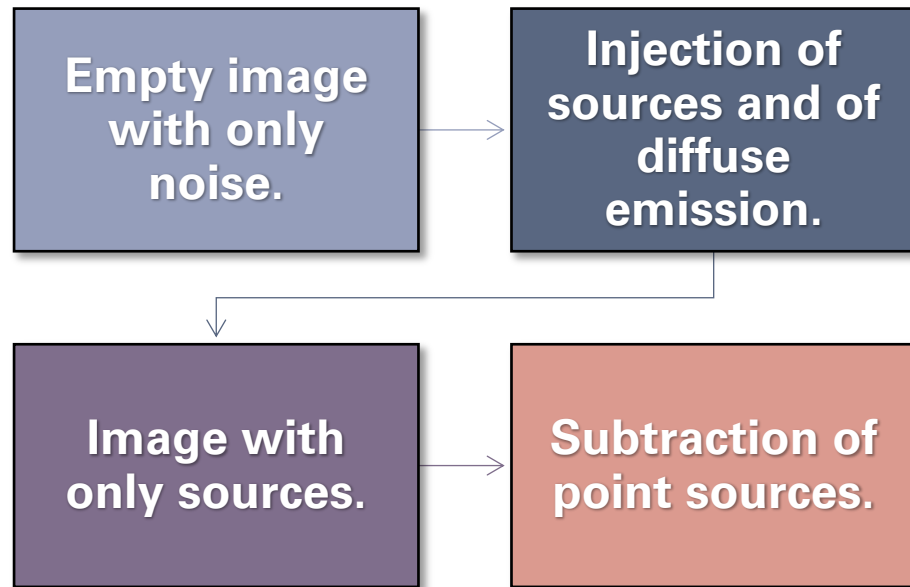


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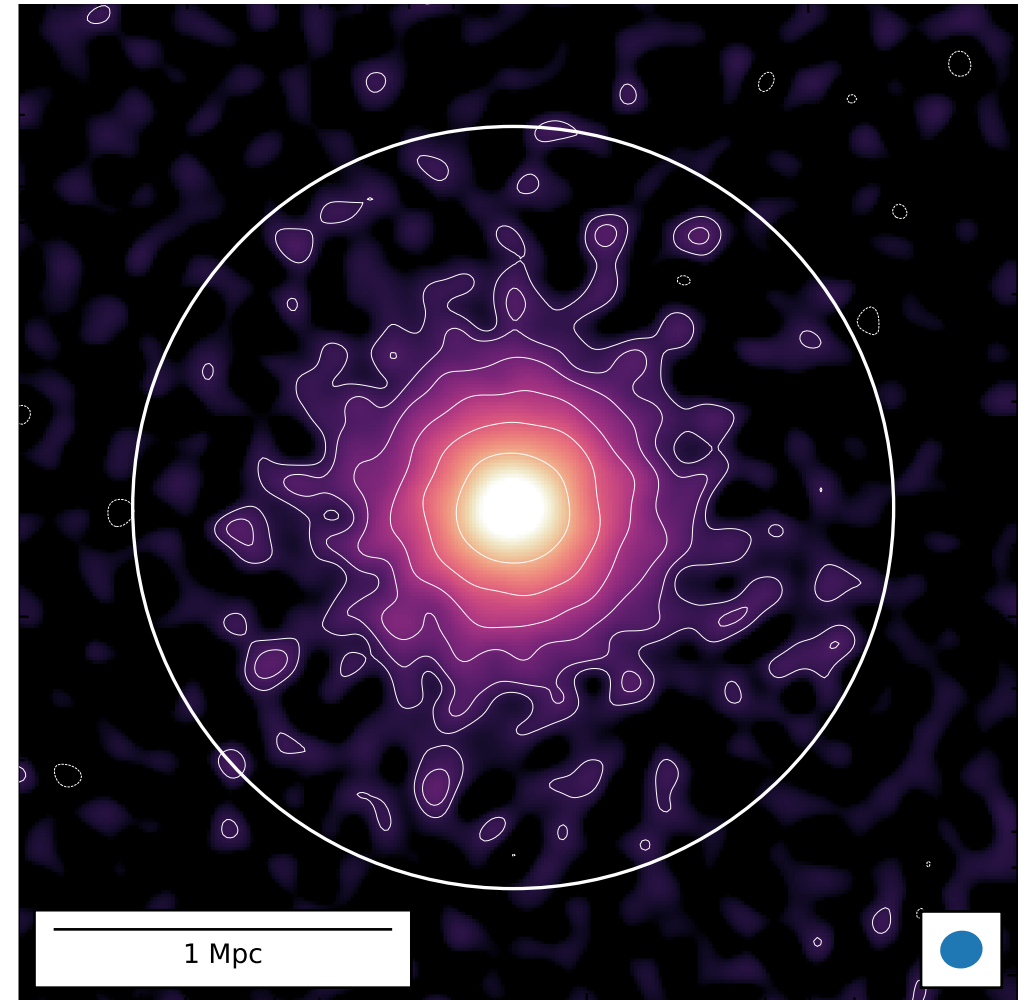
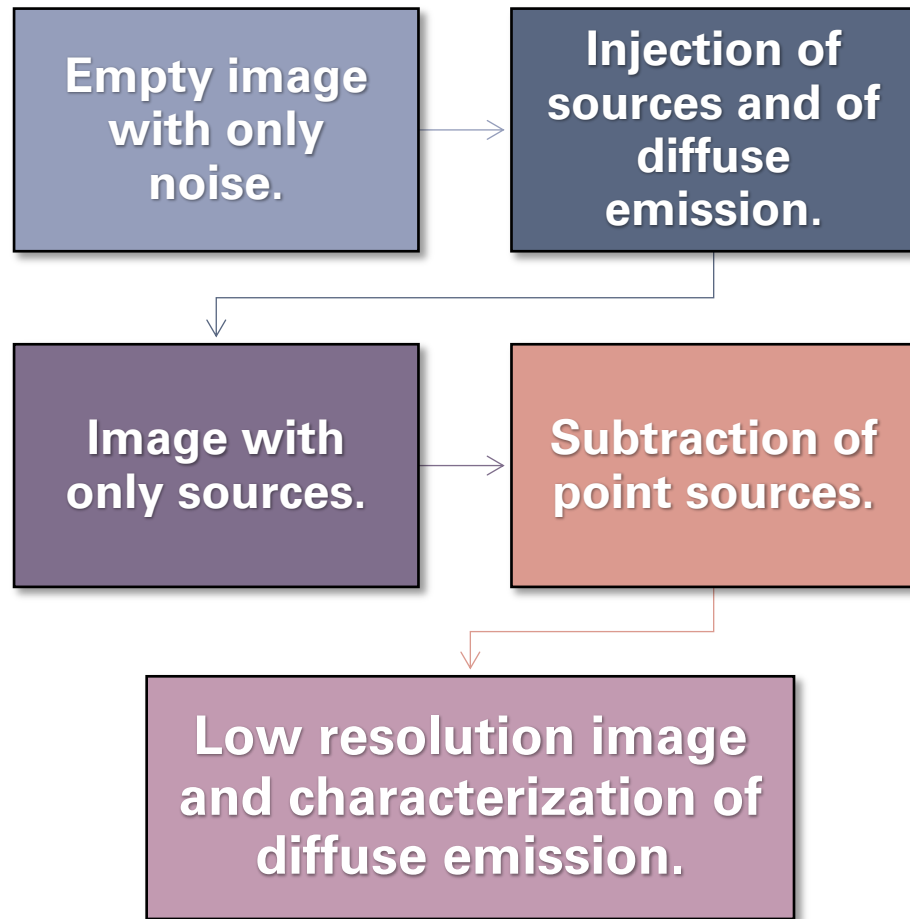


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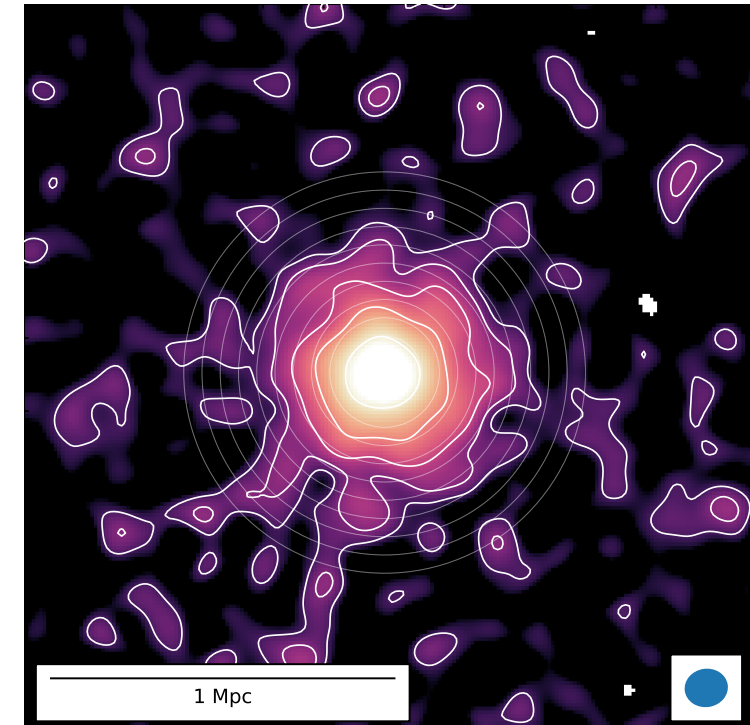
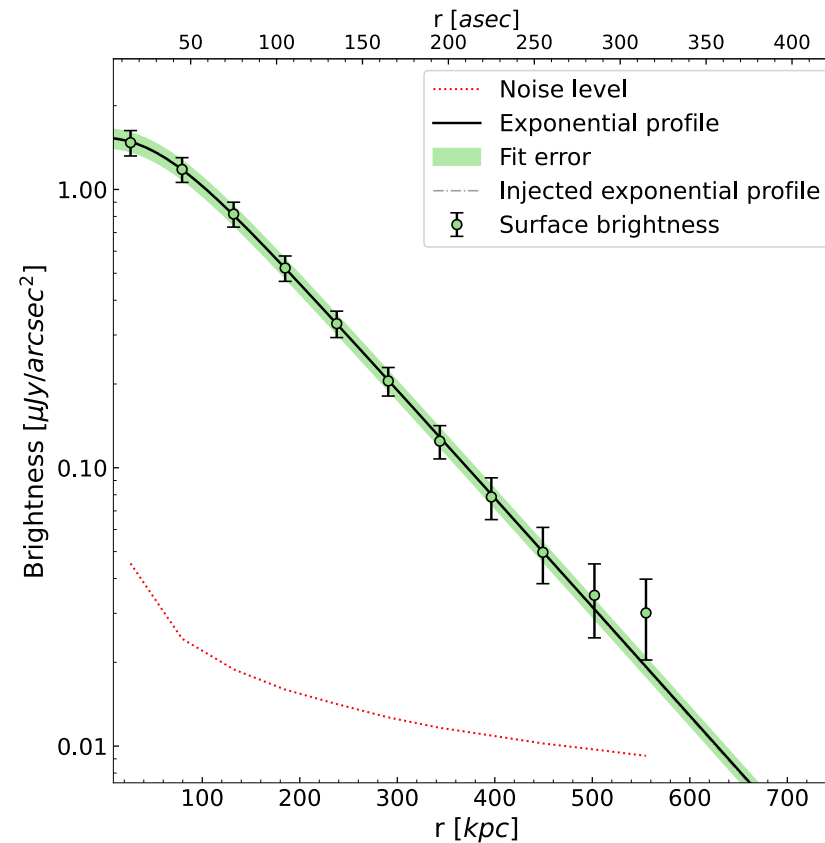


# MOCK LOFAR OBSERVATIONS - PROCEDURE



# MOCK LOFAR OBSERVATIONS - RESULTS

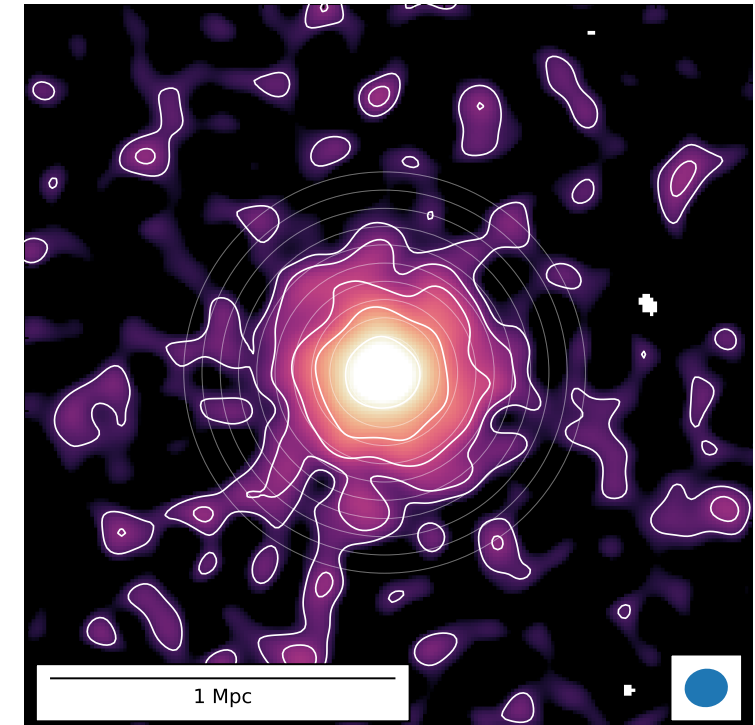
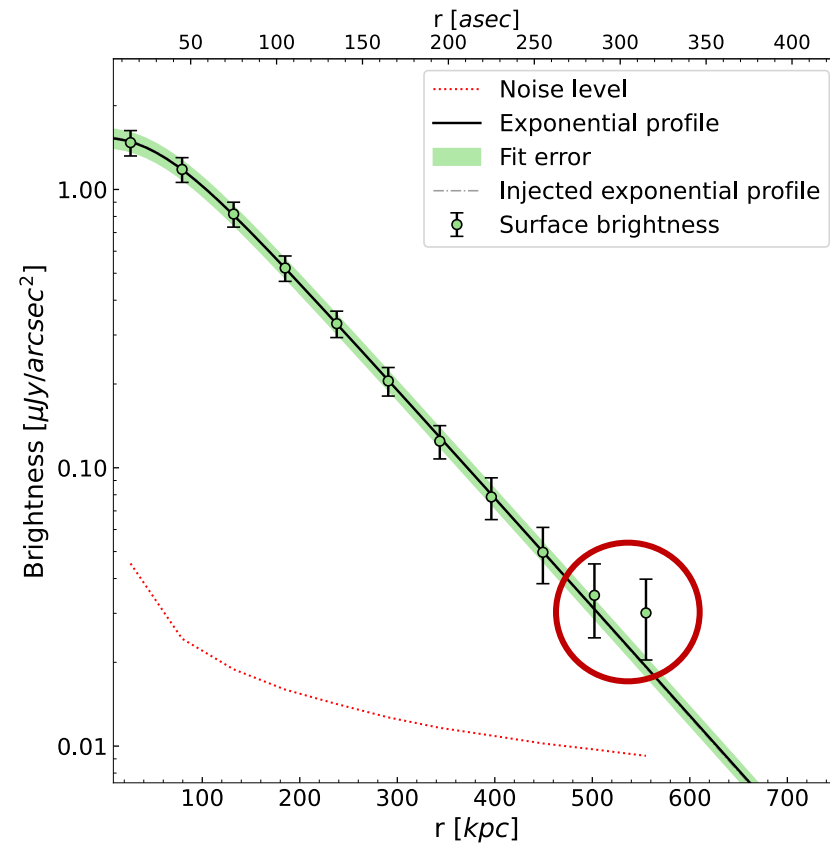
- Only small variation from the exponential at low brightnesses;



Cianfaglione et al. in prep.

# MOCK LOFAR OBSERVATIONS - RESULTS

- Only small variation from the exponential at low brightnesses;

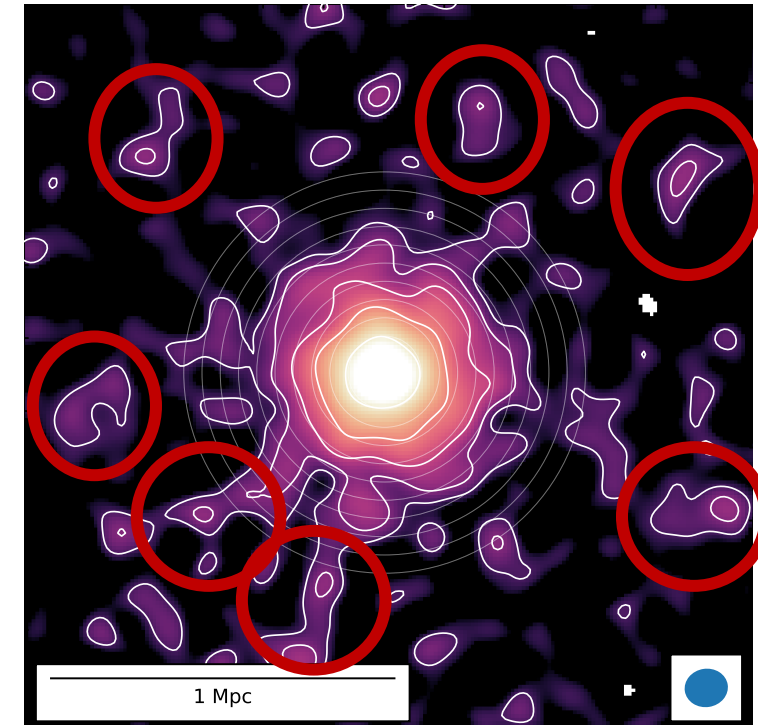
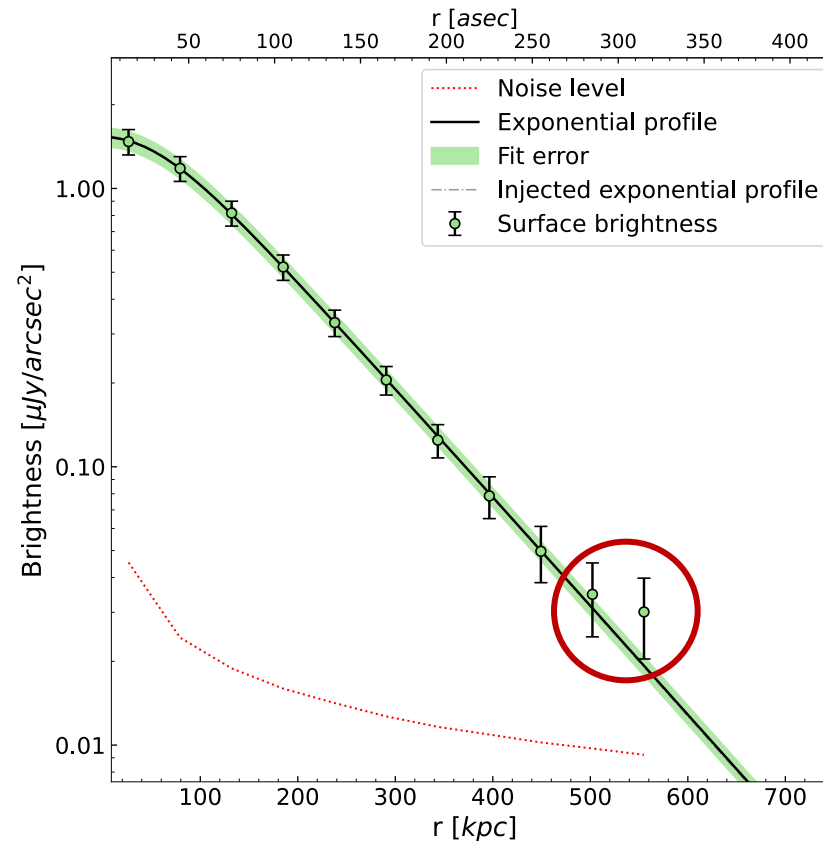


Cianfaglione et al. in prep.



# MOCK LOFAR OBSERVATIONS - RESULTS

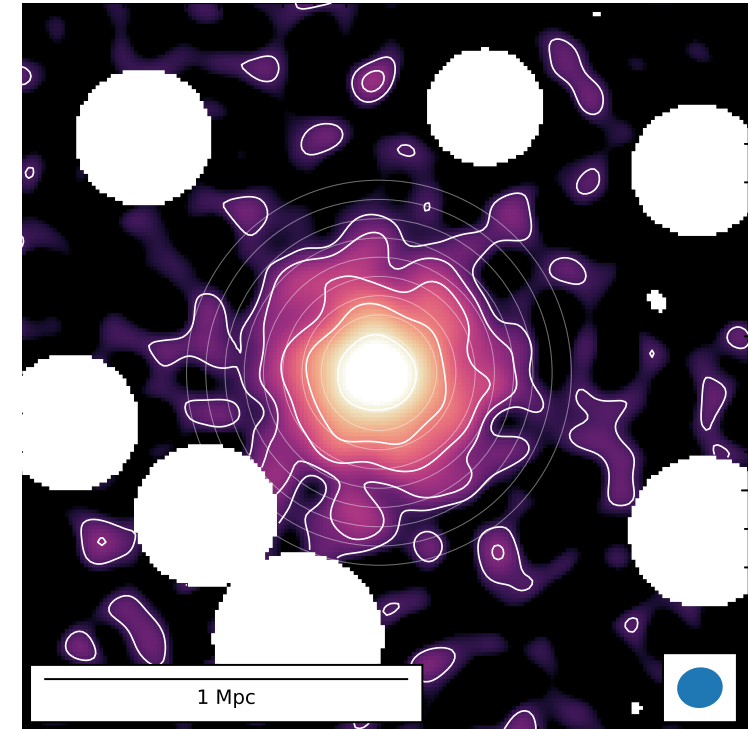
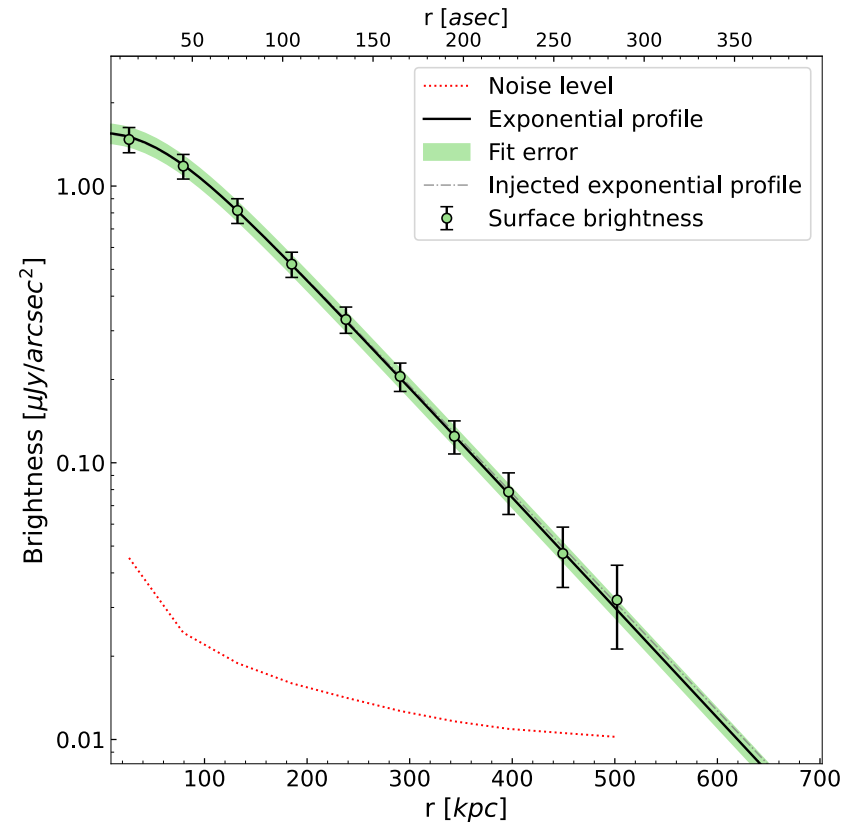
- Only small variation from the exponential at low brightnesses;
- residuals appear as patchy emission in the outskirts of the radio halo and not as uniform diffuse emission;



Cianfaglione et al. in prep.

# MOCK LOFAR OBSERVATIONS - RESULTS

- Only small variation from the exponential at low brightnesses;
- residuals appear as patchy emission in the outskirts of the radio halo and not as uniform diffuse emission;
- after masking the residuals, the profile follows the injected one.



Cianfaglione et al. in prep.

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# Conclusions

- Megahalo origin possibly related to a low energy interaction with a group;
- radio halo integrated spectrum comparable with halos from major mergers;
- megahalo spectral index flatter than the ones found by Cuciti et al. 2022;
- the megahalo does not follow a correlation with the X-ray surface brightness;
- faint point sources do not seem to reproduce the megahalo at low resolution.



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## Conclusions

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## Future with SKA

- SKA-Mid high resolution allows for a better source subtraction;
- thanks to the high sensitivity we expect to detect more sources and improve the statistics;
- higher sensitivity will allow for better radio X-ray studies, even in the faintest regions;
- the combination of SKA-Low and SKA-Mid will allow for precise spectral index studies.

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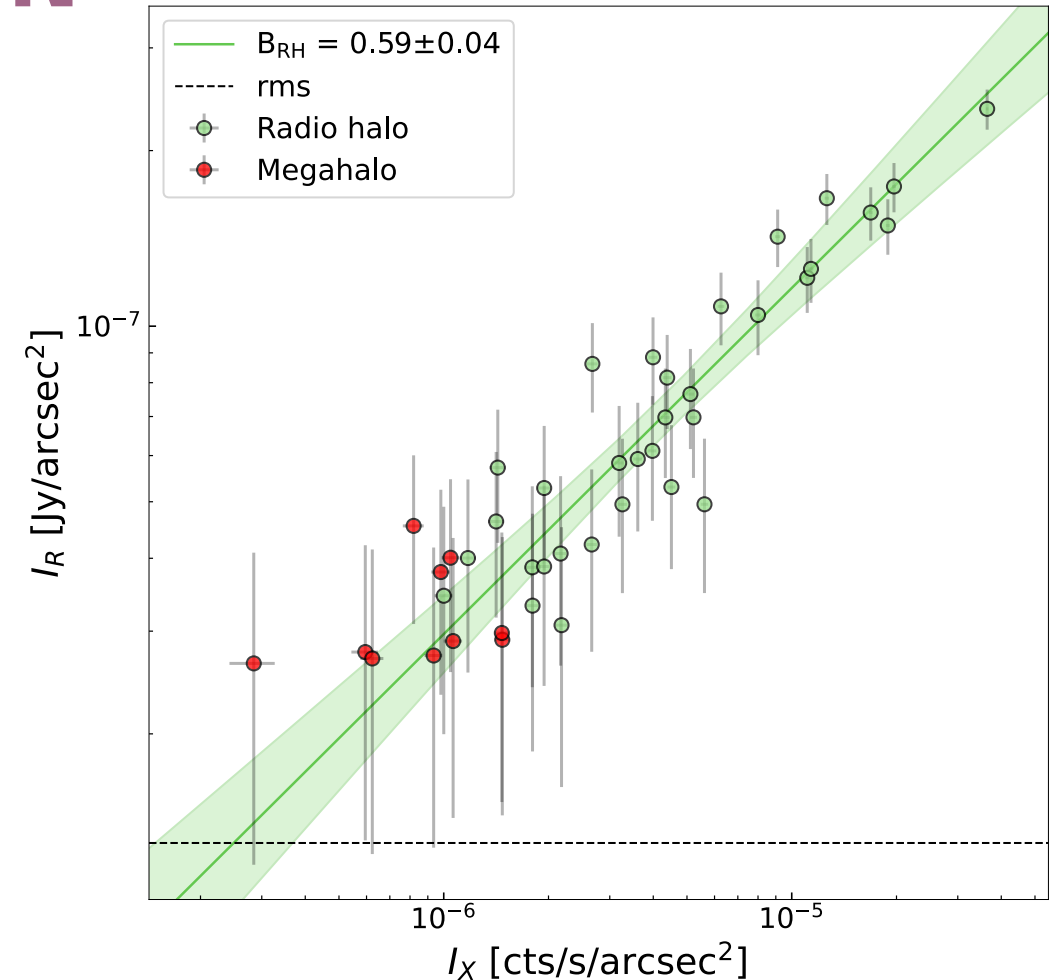
**THANK YOU FOR THE ATTENTION**

0.5r<sub>500</sub>



# RADIO X-RAY CORRELATION RESULTS

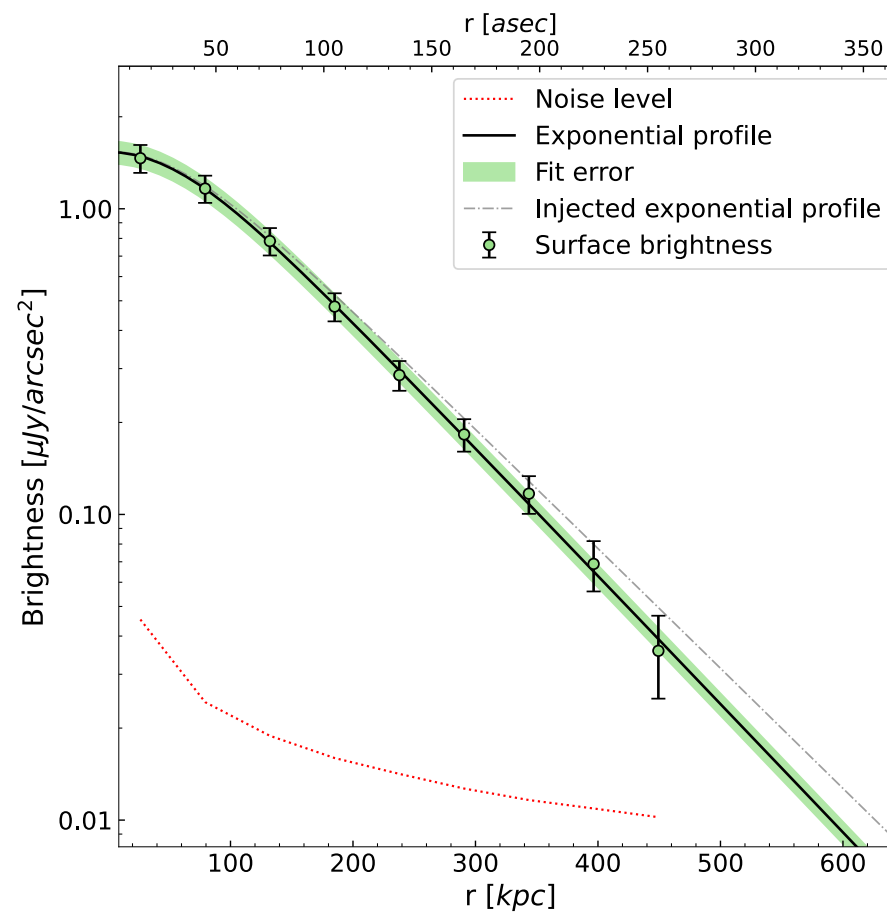
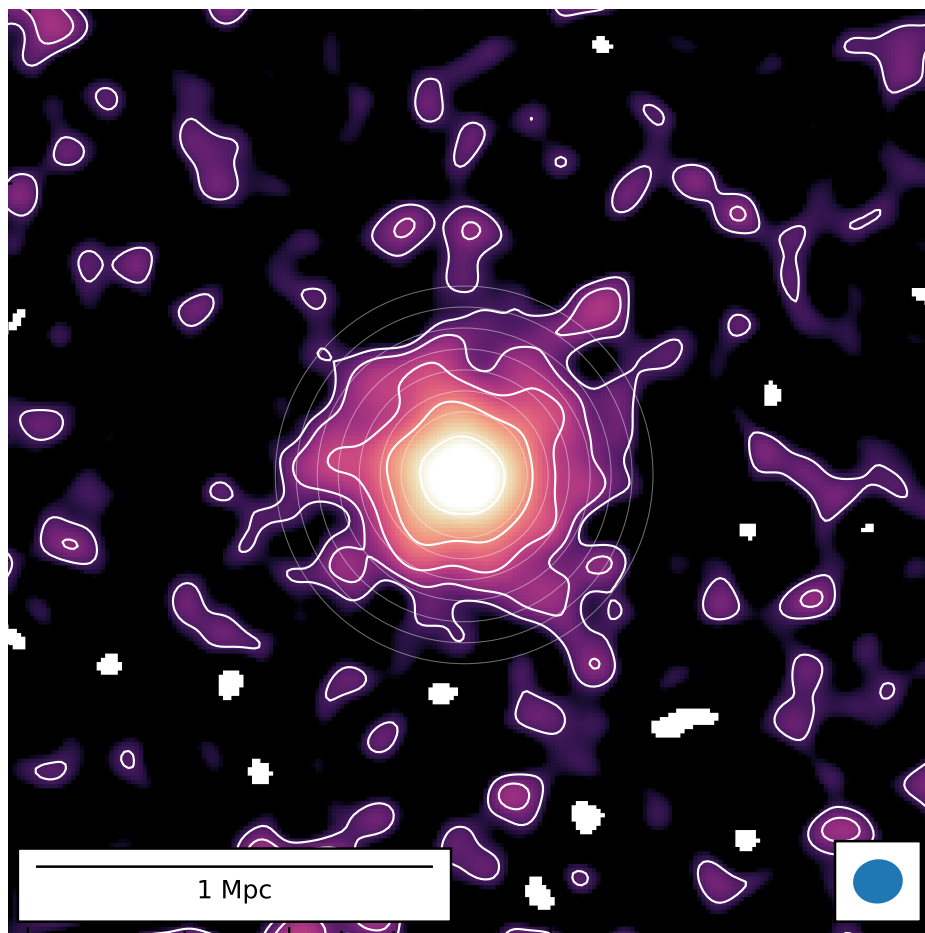
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- **megahalo does not follow the same relation;**
- $I_{R,MH}$  varies little with  $I_X$ ;
- $r_{S,MH} = 0.48$ ,  $p = 0.13$ .



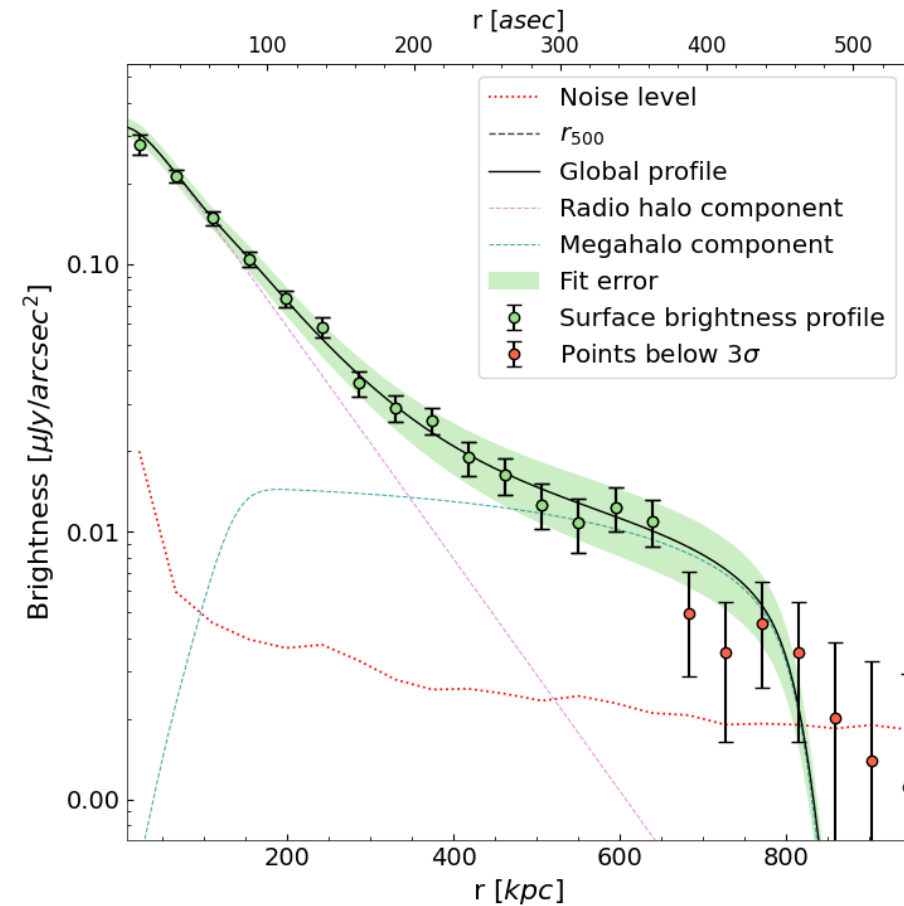
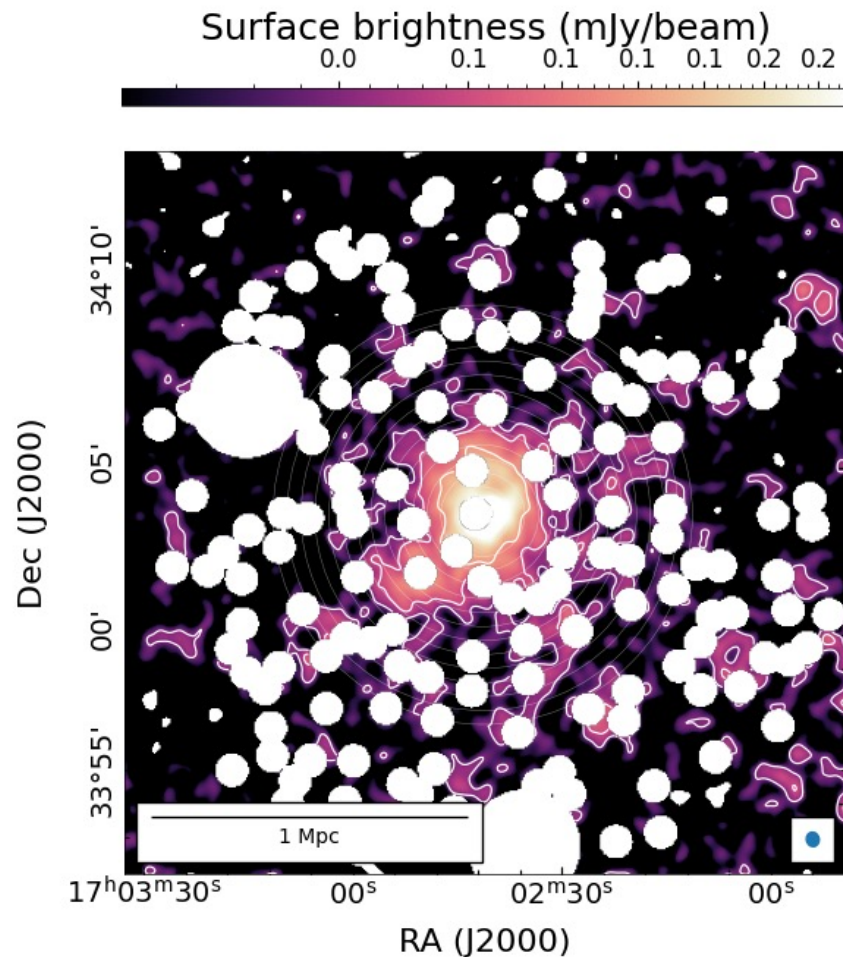
Cianfaglione et al. in prep.



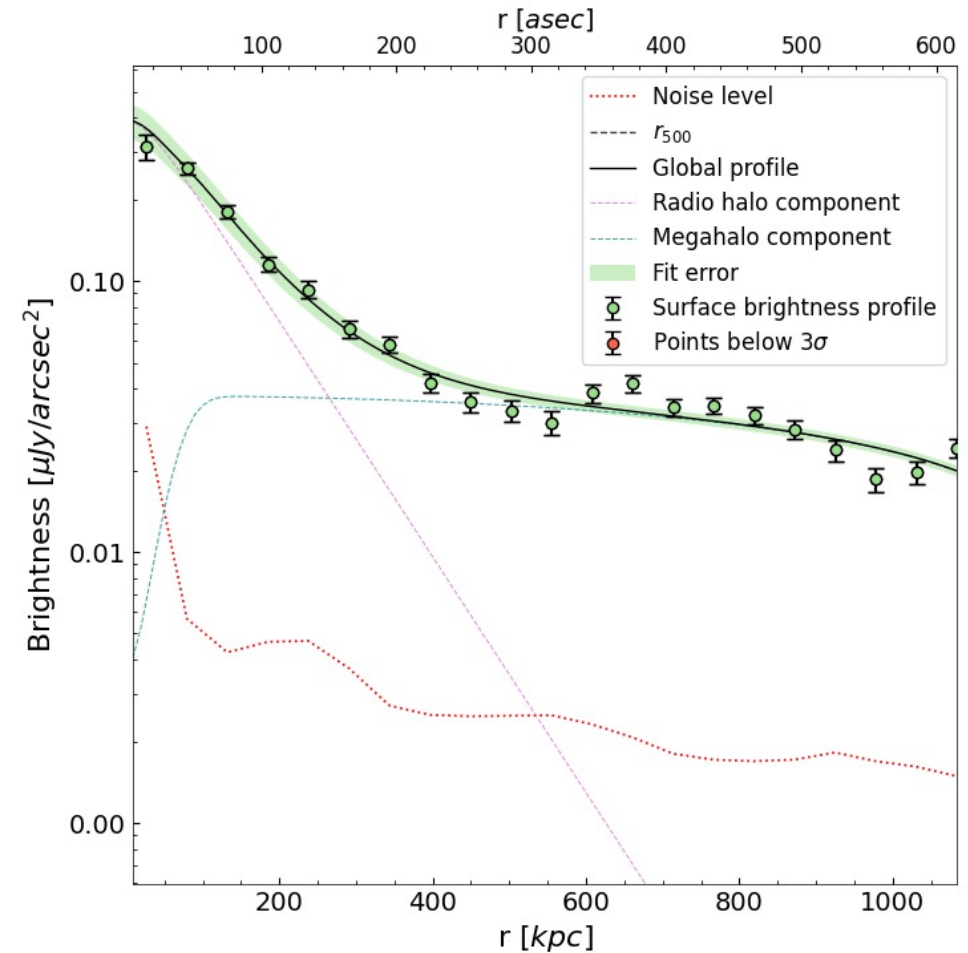
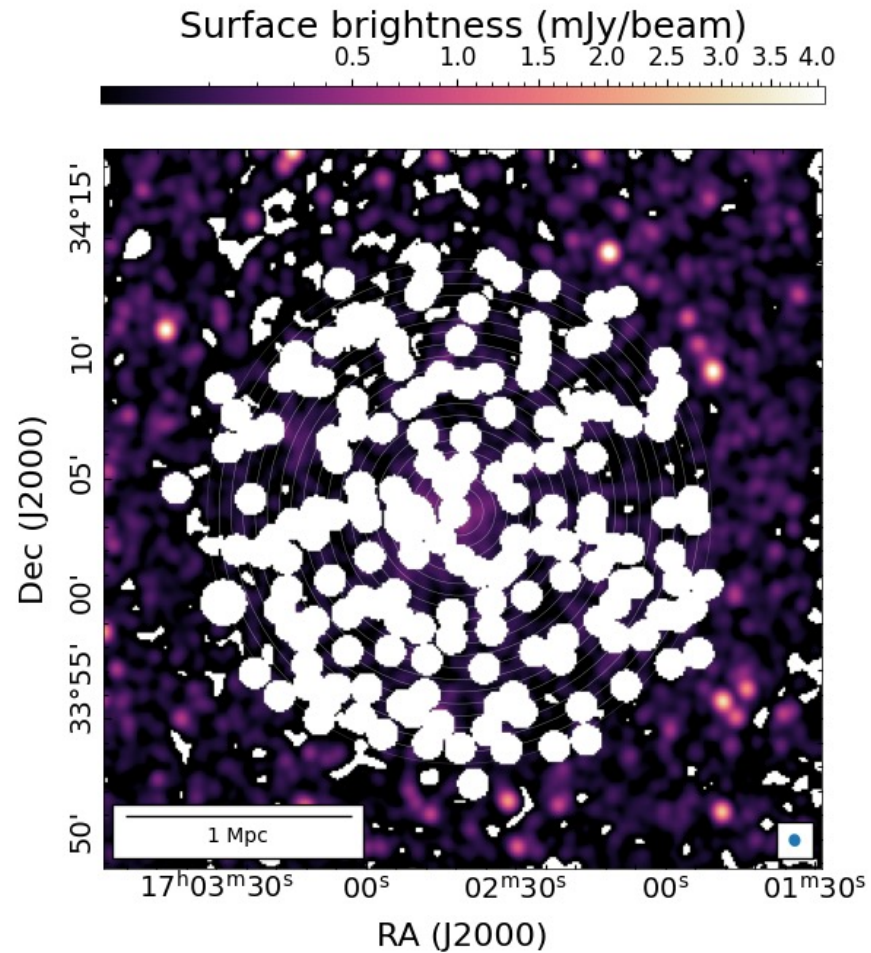
# WORST CASE SCENARIO SIMULATION



# HIGH RESOLUTION IMAGES - SUBTRACTED

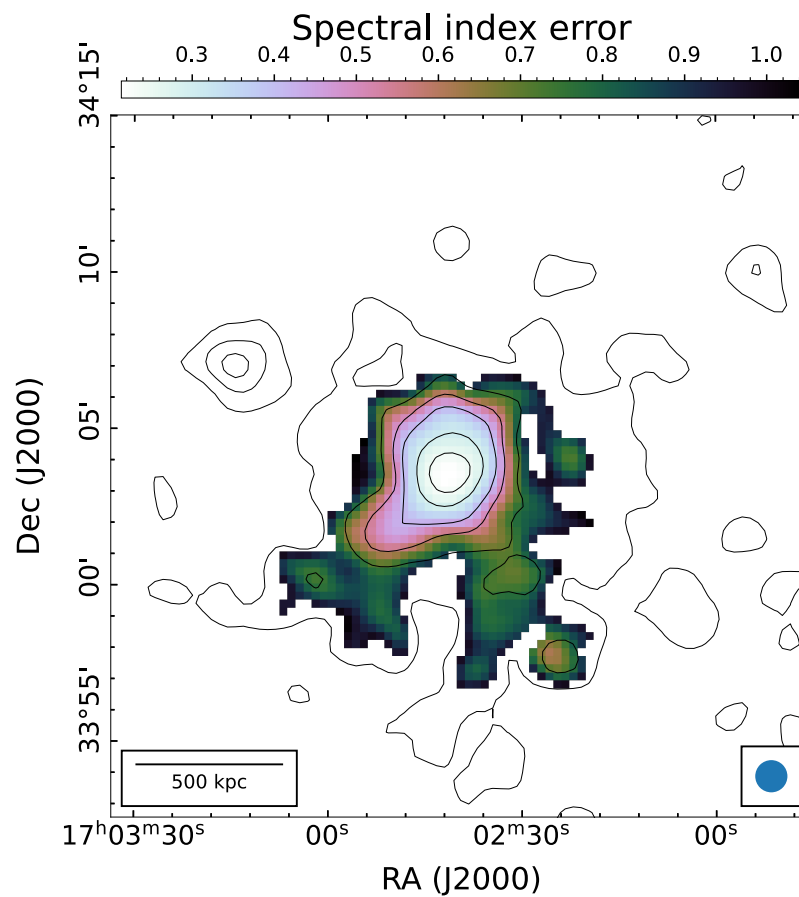
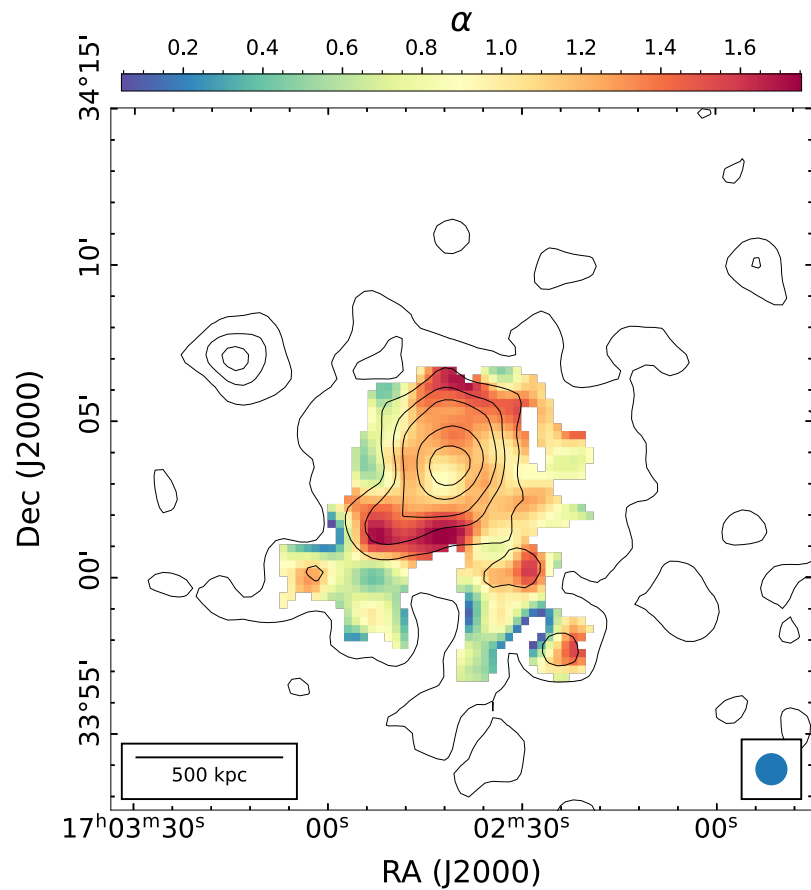


# HIGH RESOLUTION IMAGES - MASKED



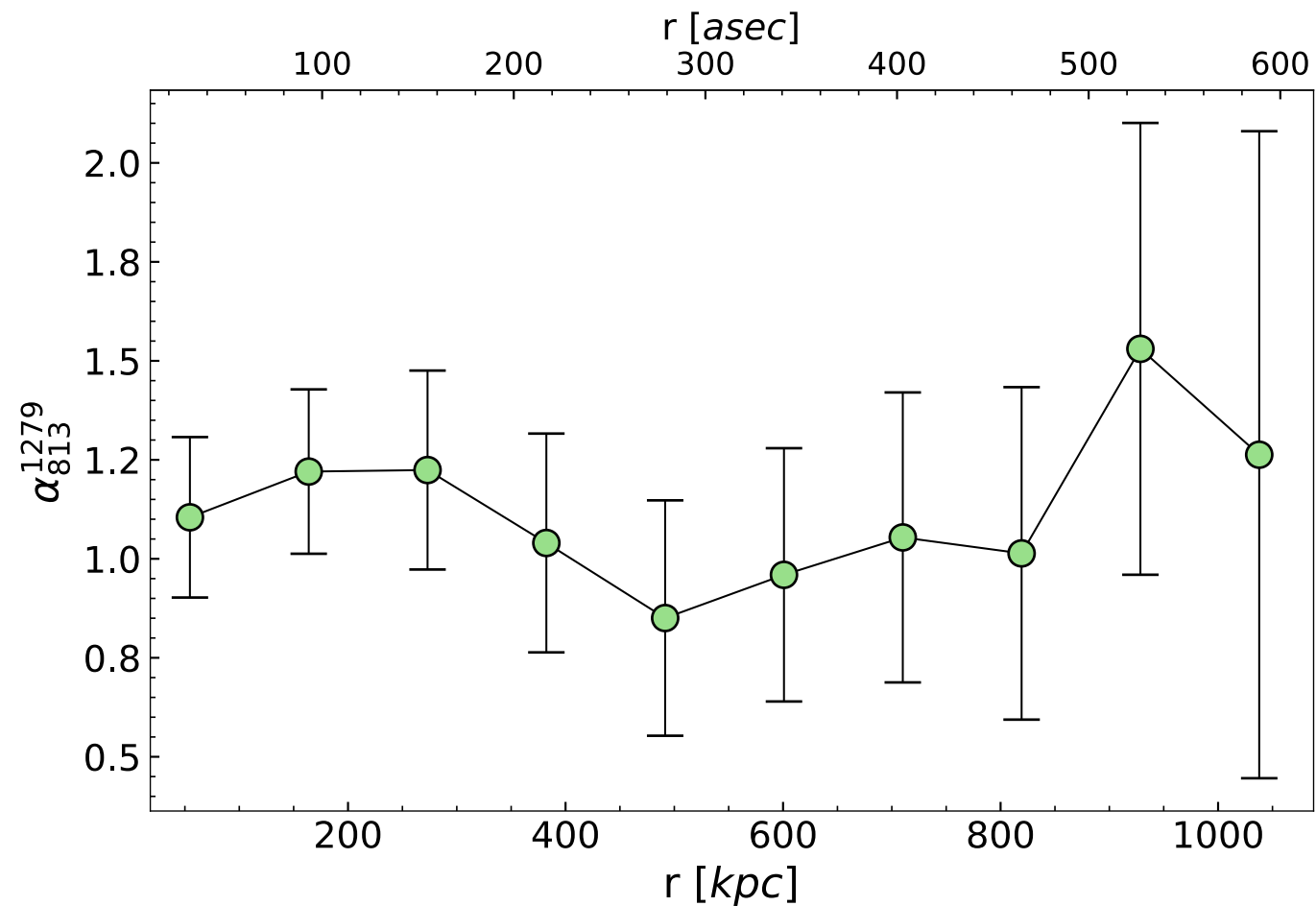


# SPECTRAL INDEX MAPS



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# SPECTRAL INDEX PROFILE



# ABELL 2244 ON THE M-Z PLOT

