

# The Effect of Antenna Position Offsets on the Redshifted 21-cm Power Spectrum:

## THE ASTROPHYSICAL LUNAR OBSERVATORY (ALO) STUDY

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On behalf of ALO team

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Dr. Albert-Jan Boonstra (ASTRON)*

21cm Cosmology meeting/6th Global Signal Workshop 2023, 15th September

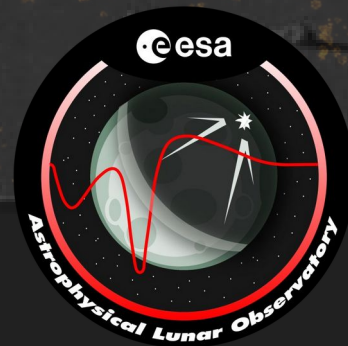


university of  
 groningen

Radboud University

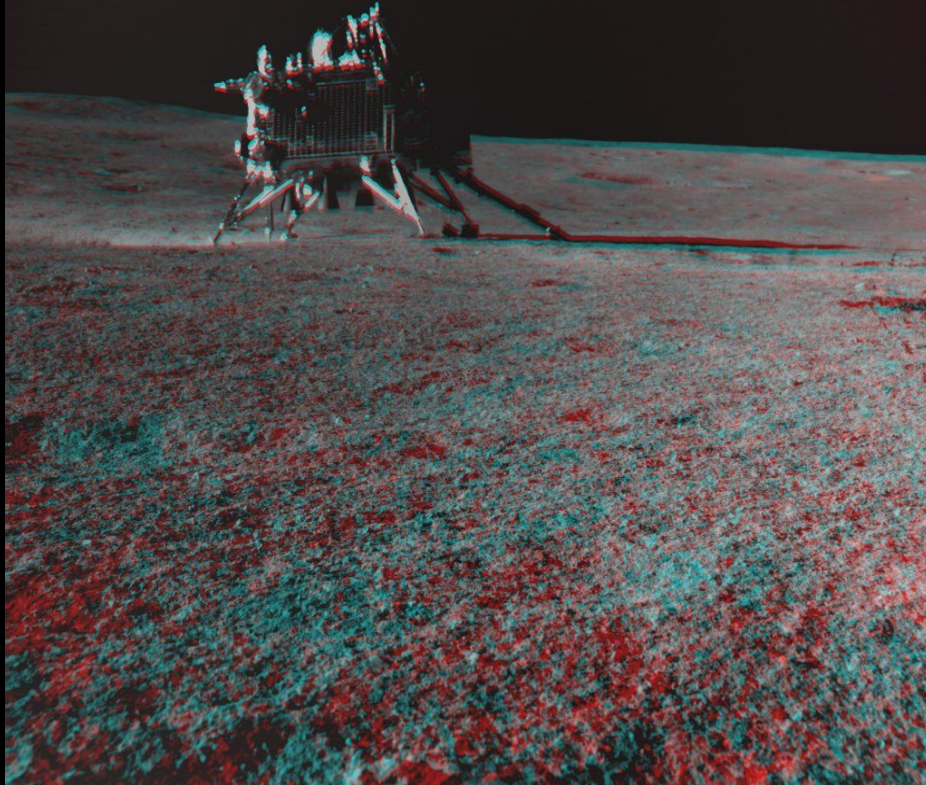


ASTRON



# Moon as a stepping stone to the Universe

Chandrayaan-3 Lander on the Moon  
August 30, 2023

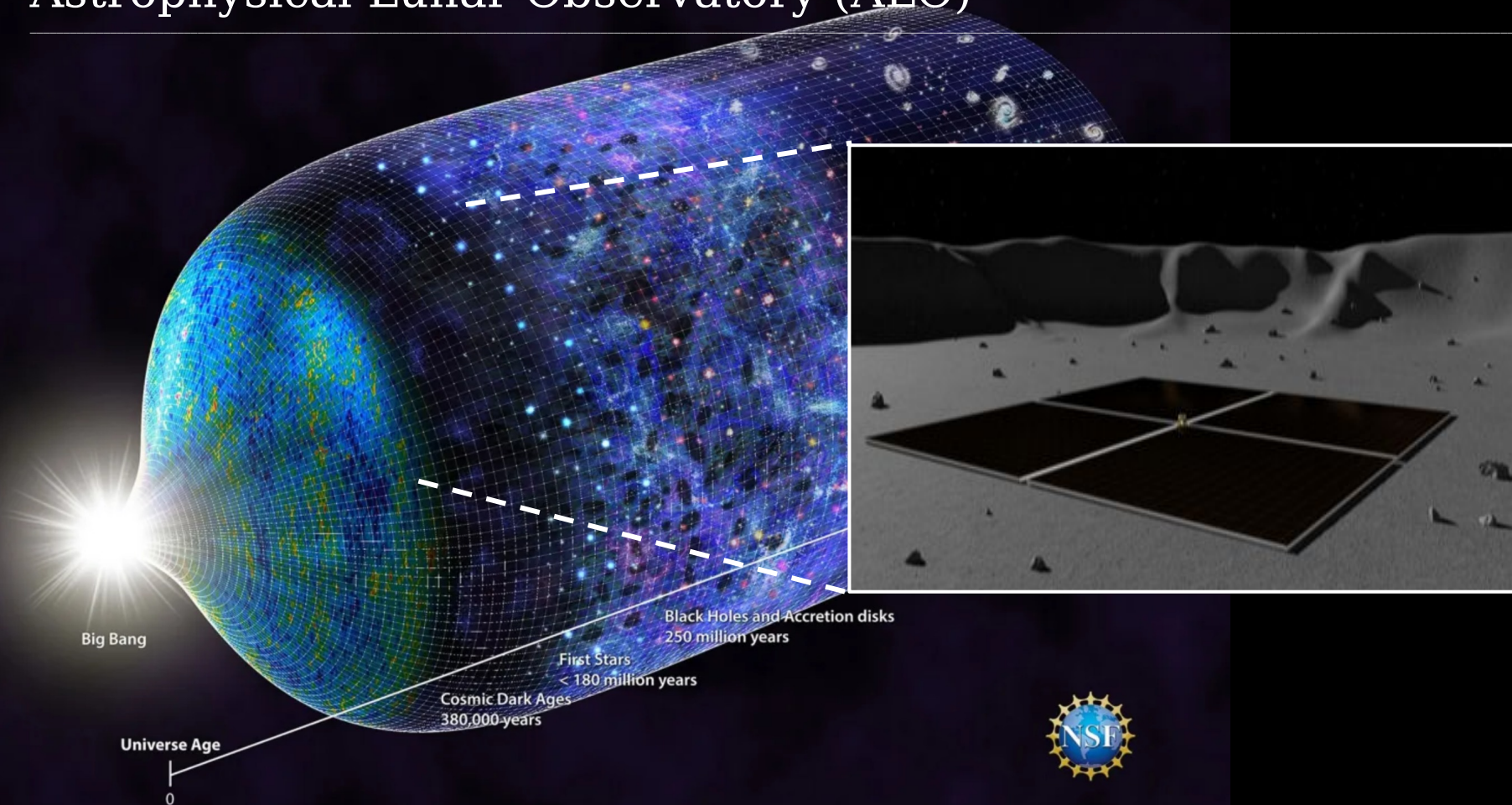


- Renewed interest to return to the Moon globally
- Low-frequency radio astronomy on the farside





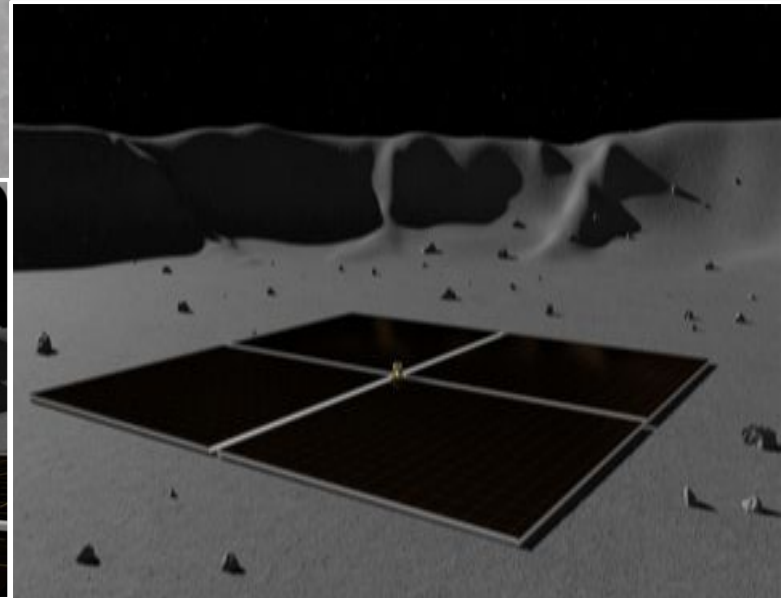
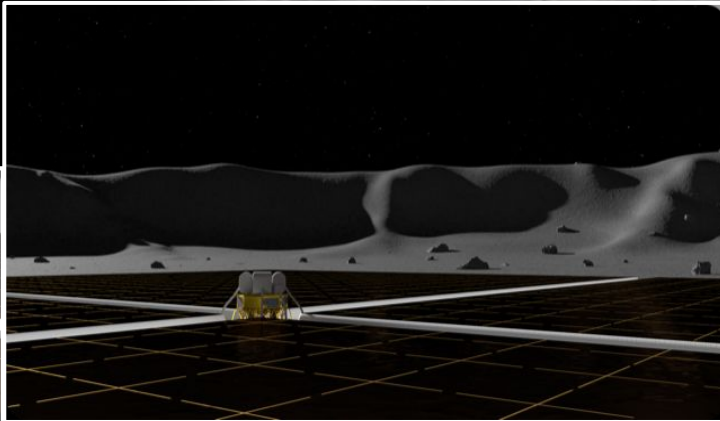
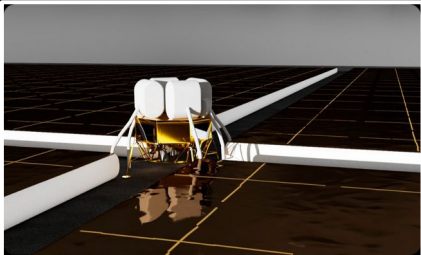
# Astrophysical Lunar Observatory (ALO)



Credit: Nicole Rager Fuller/National Science Foundation

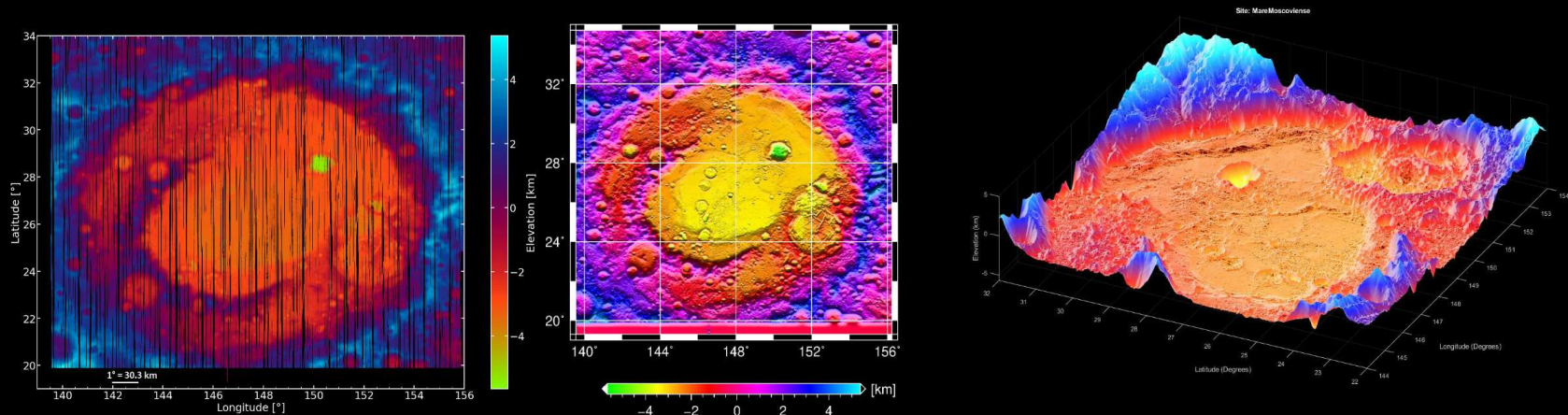
# Astrophysical Lunar Observatory (ALO)

- 32 X 32 co-located dual polarization dipole
- Zenith pointing observation of nearly full sky
- RA= 7h , DEC= 34°
- Operating bandwidth : 7 – 70 MHz
- Antenna element length : 5m
- Spectral resolution : 100 kHz
- Integration time : 30s
- Length of observation : 30s

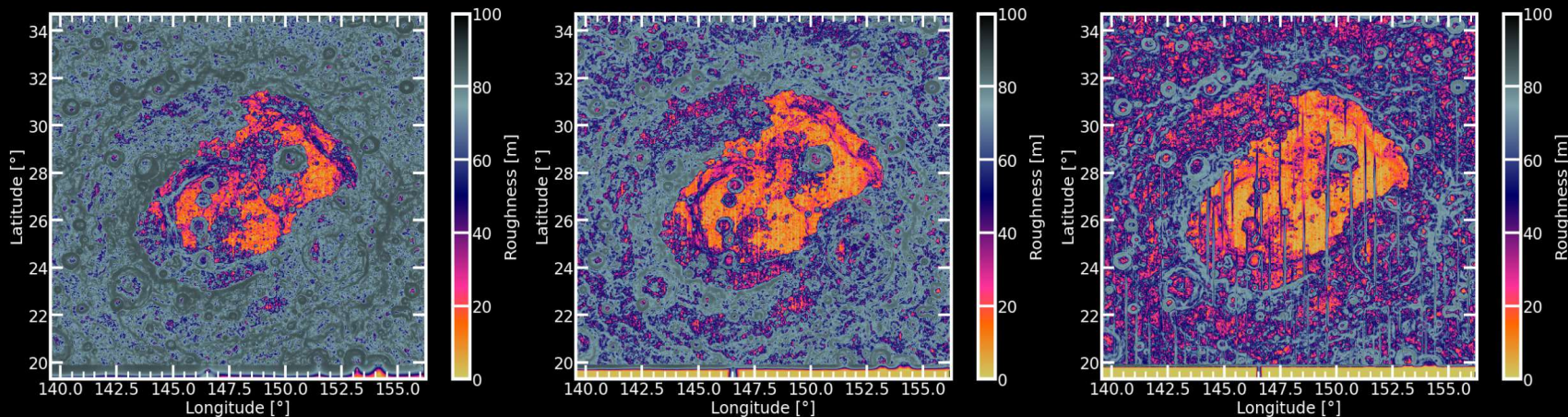




# Motivation and Goals



Lunar site: Mare Moscoviense



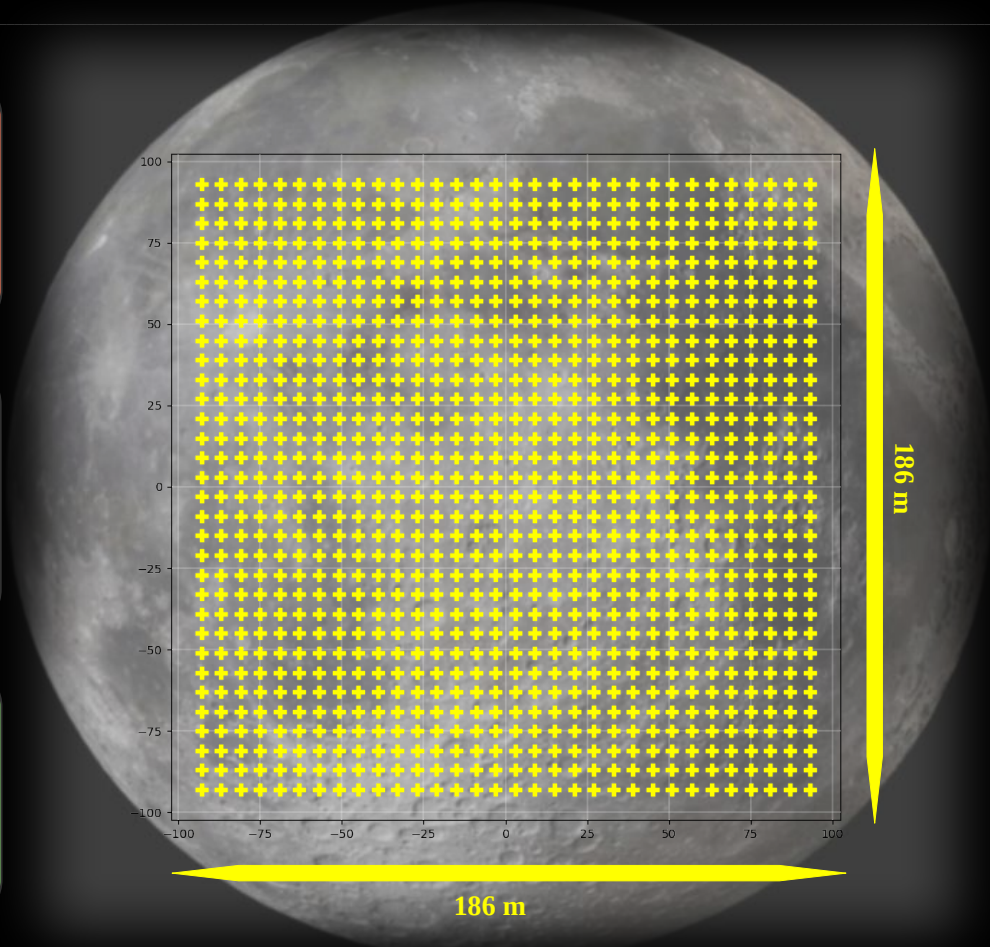
# Motivation and Goals

The deployment of the dipoles

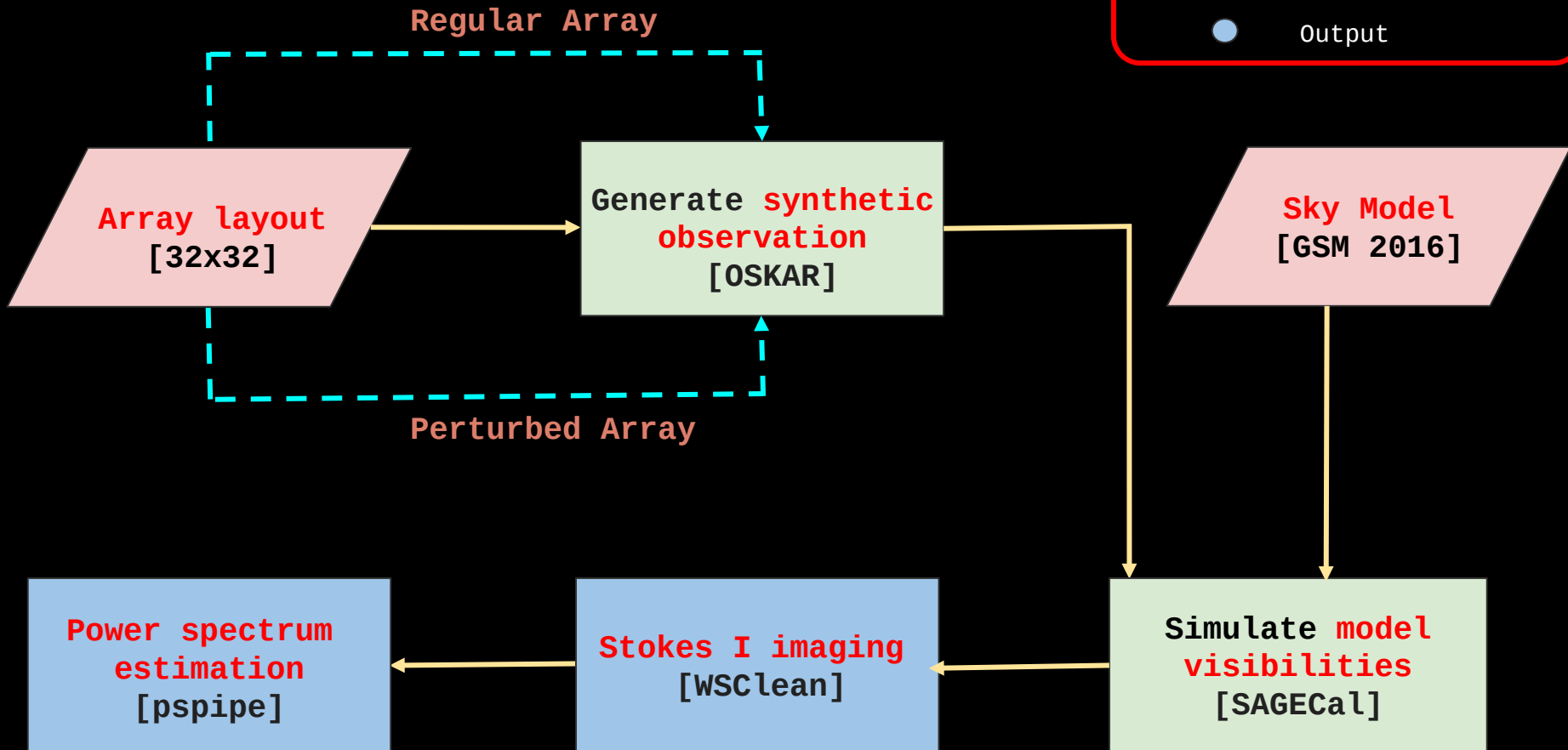
- imperfect
- introduce errors in the **antenna positions** and orientation

- Understand the impact of the positional offset on the **2D Power Spectrum**
- The **tolerance threshold** in the antenna position errors

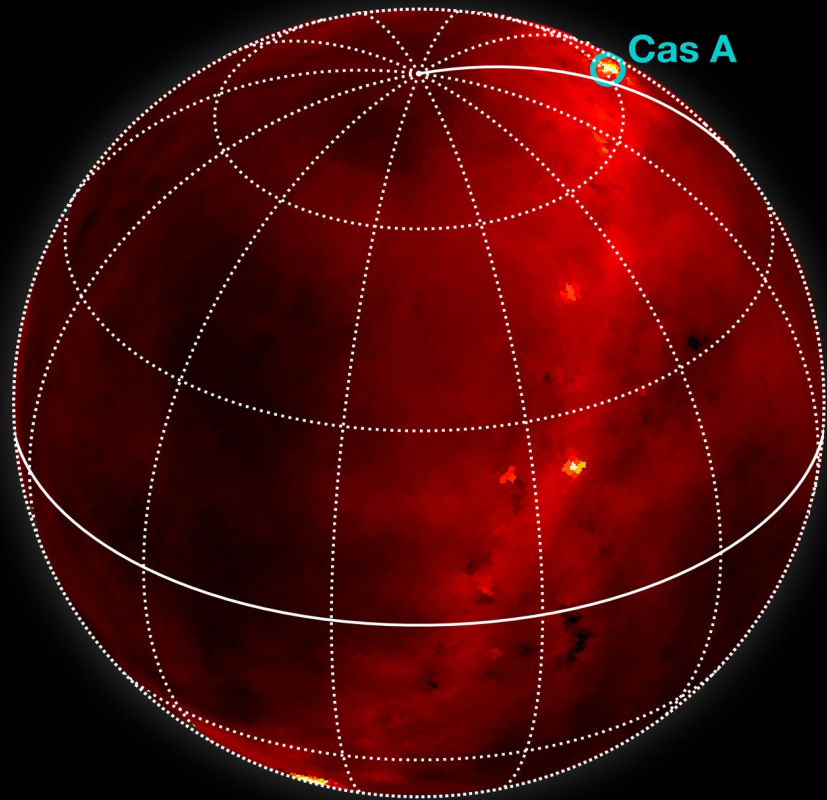
- End-to-end **forward simulation pipeline**



# Forward Simulation Pipeline



# Sky Model [GSM 2016]



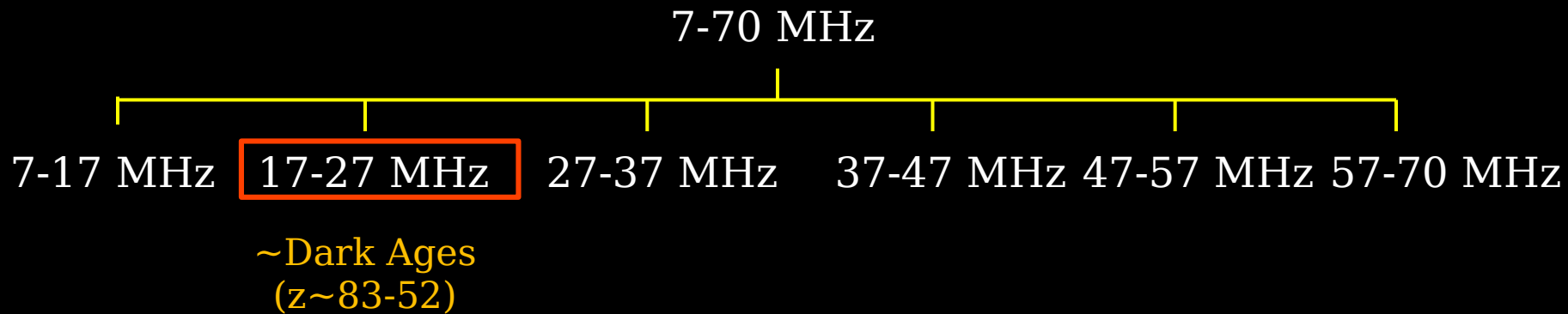
- 45 MHz
- NSIDE = 64
- Resolution of map  
~ 1 degree



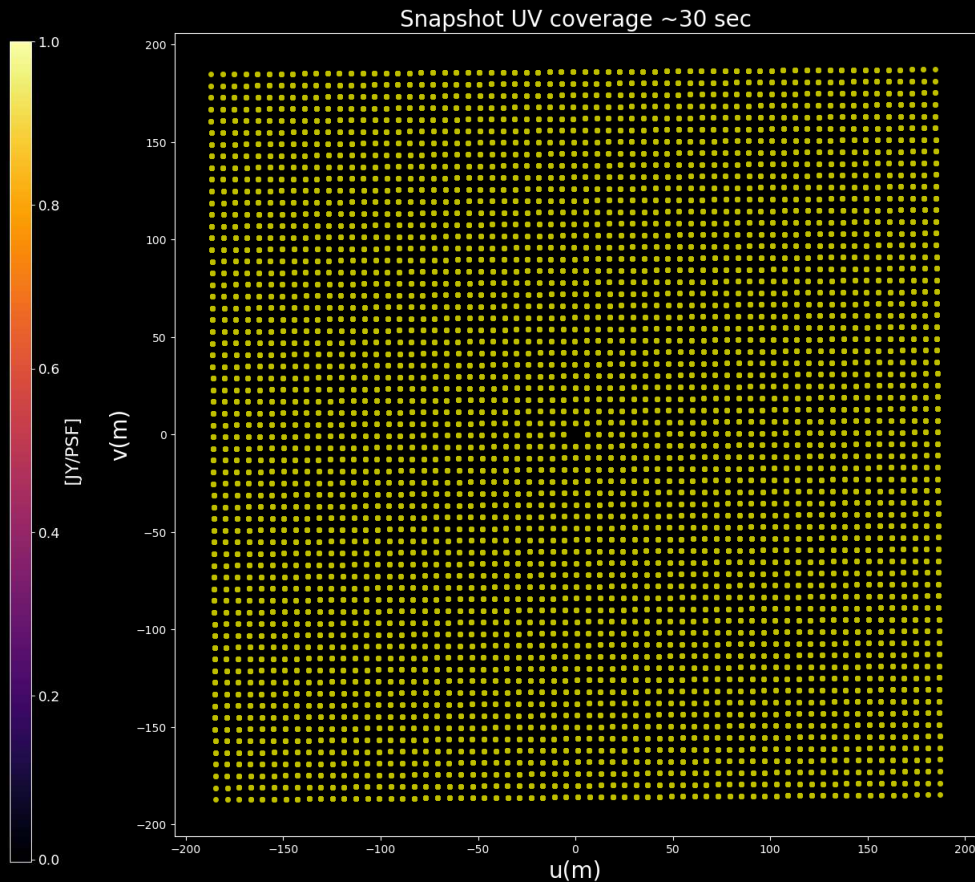
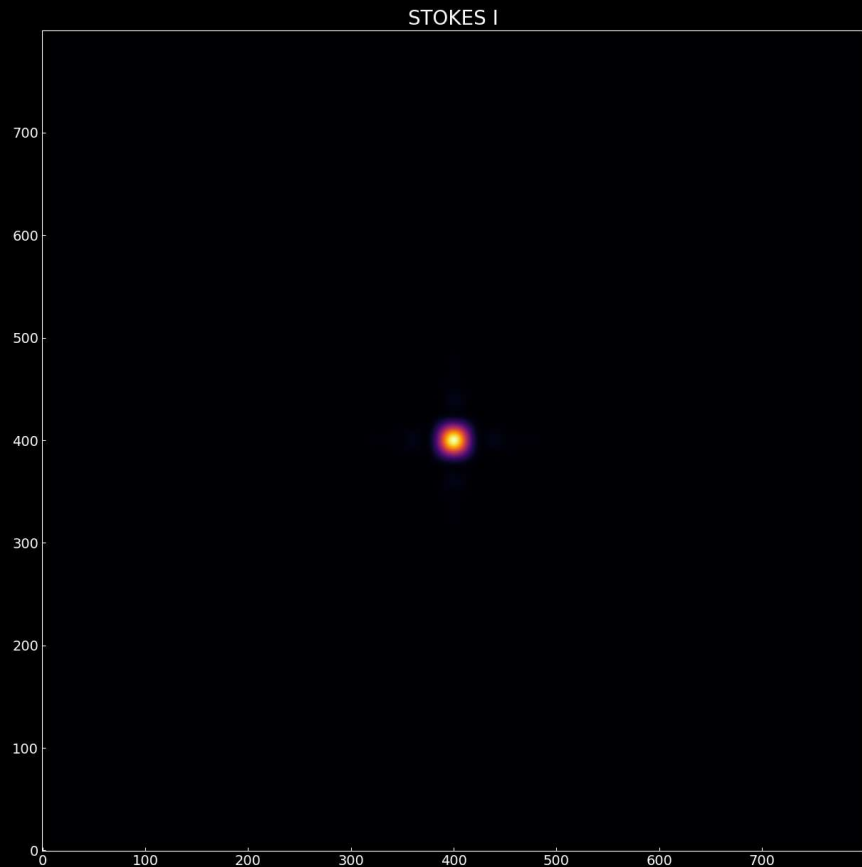


# Sub-bands

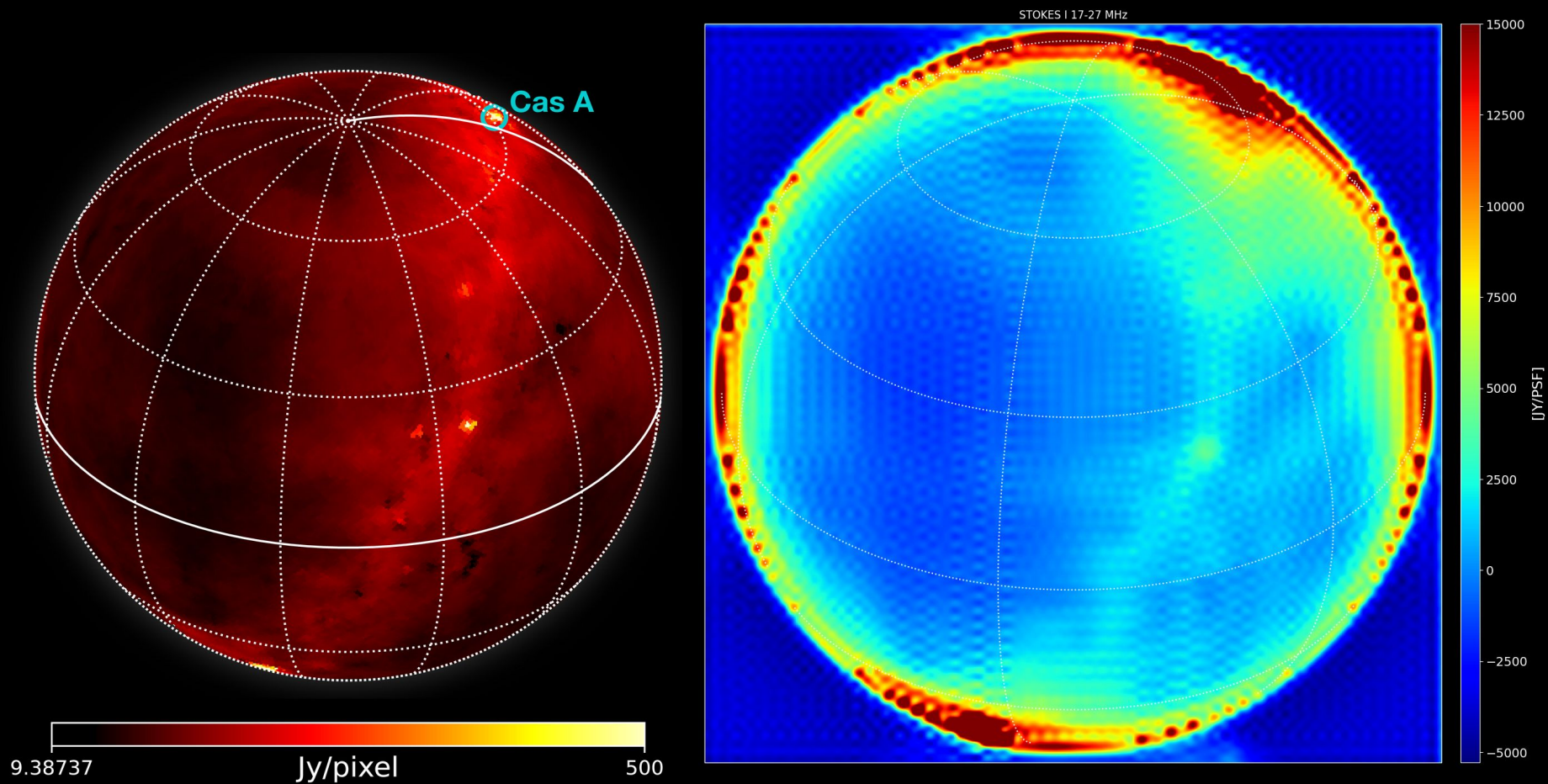
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# Point Spread Function (PSF) and UV coverage (snapshot)

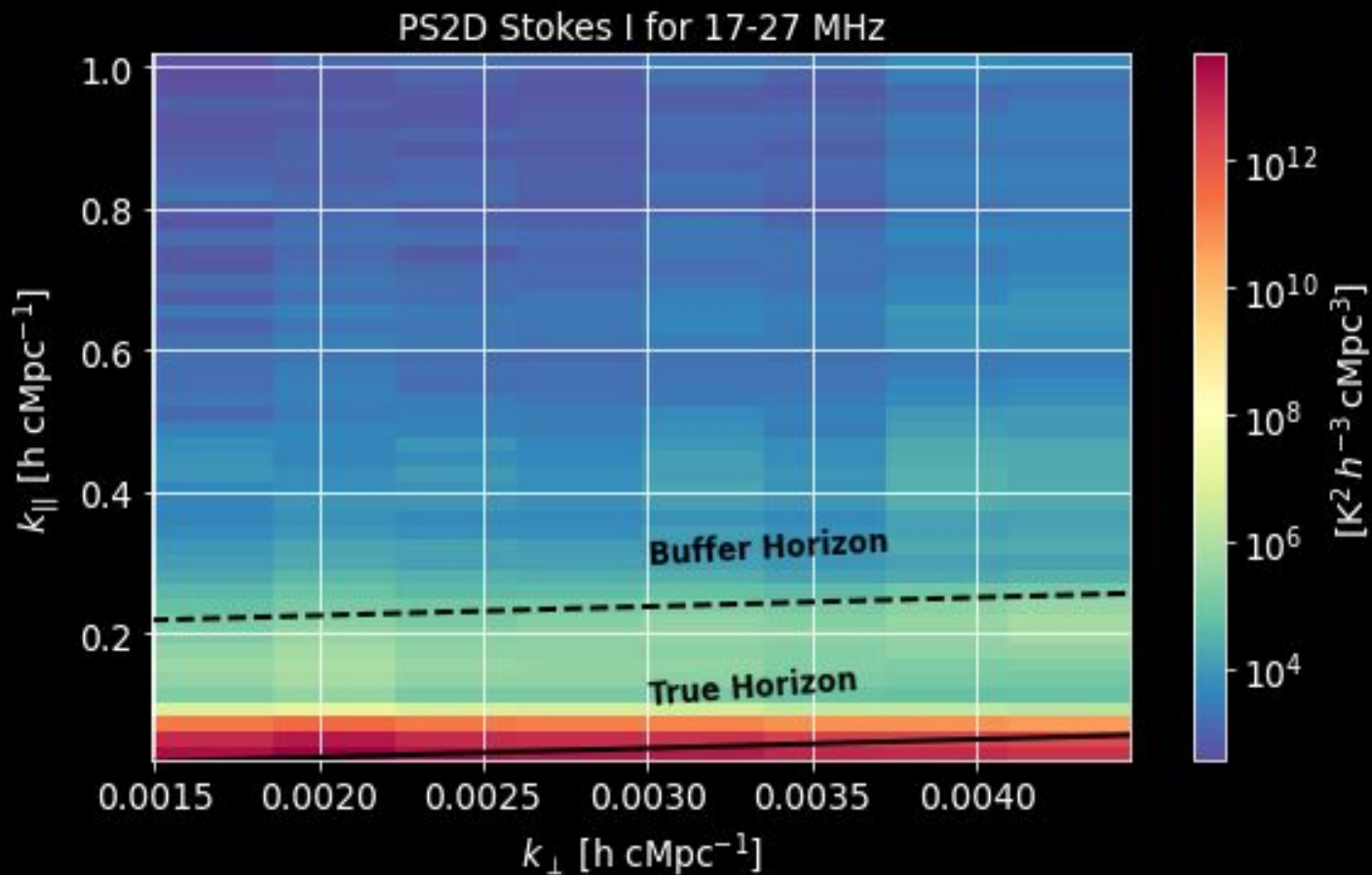


# Stokes I continuum image [17-27 MHz]





# Cylindrical Power Spectra [17-27 MHz]

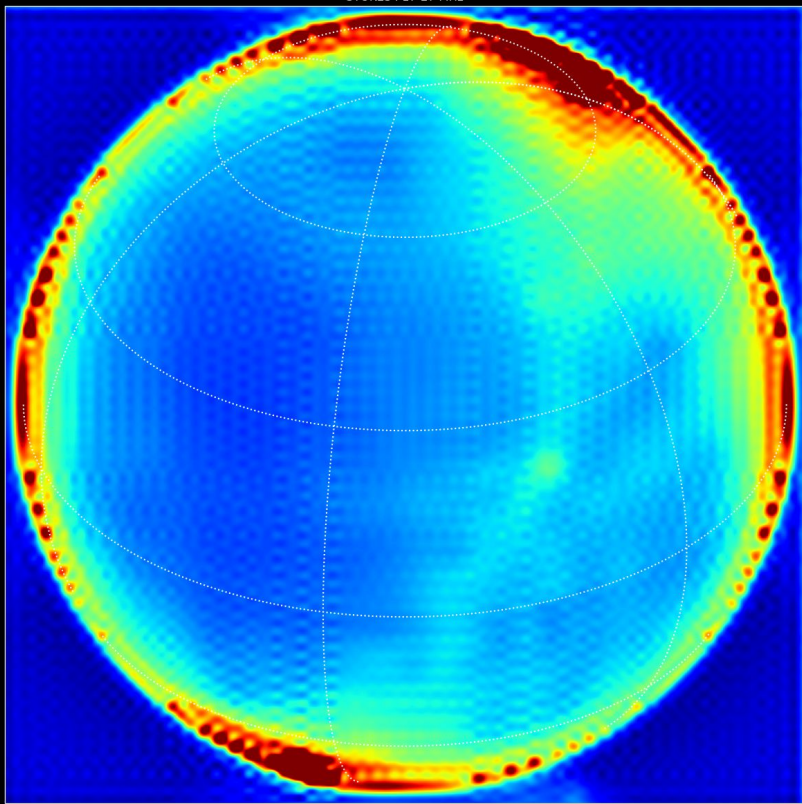


Stop. Step Back. Repeat.

# Stokes I continuum image [17-27 MHz]

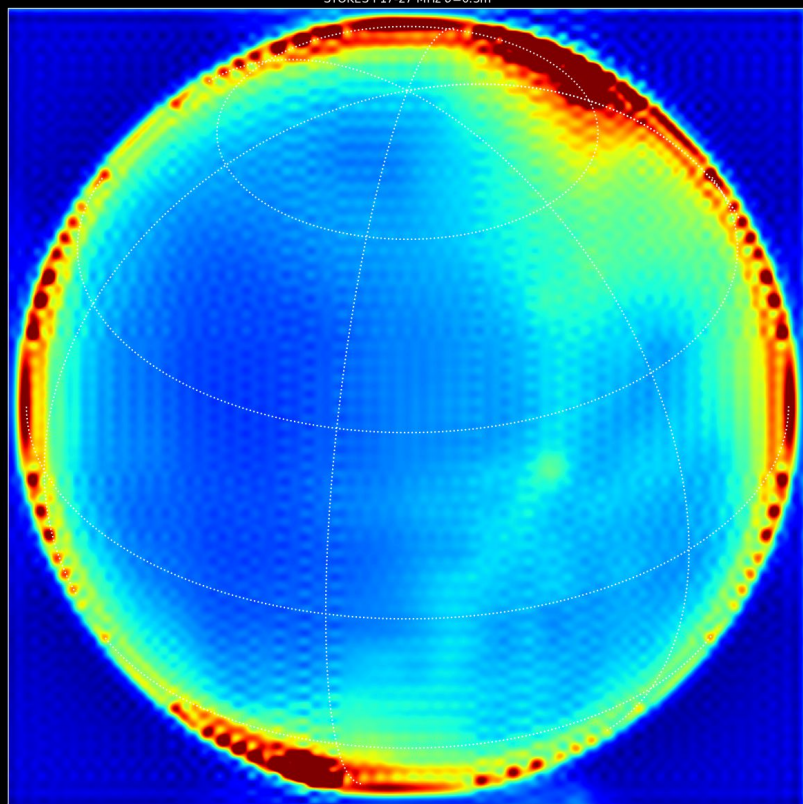
Regular

STOKES I 17-27 MHz



Perturbed [ $\sigma = 0.3\text{m}$ ]

STOKES I 17-27 MHz  $\sigma=0.3\text{m}$

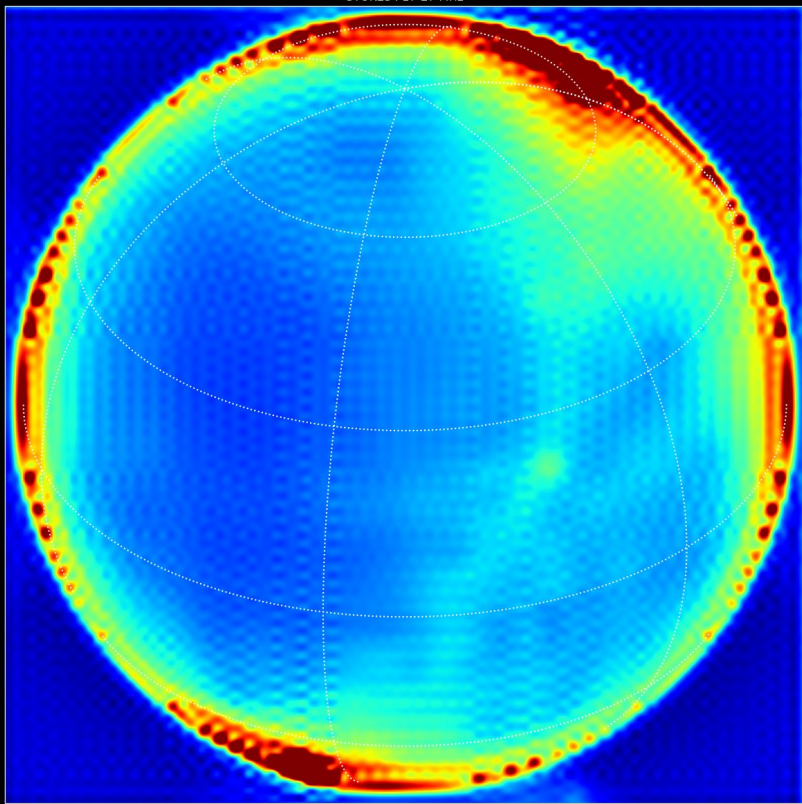




# Stokes I continuum image [17-27 MHz]

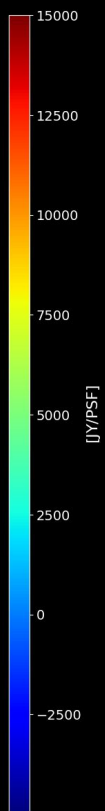
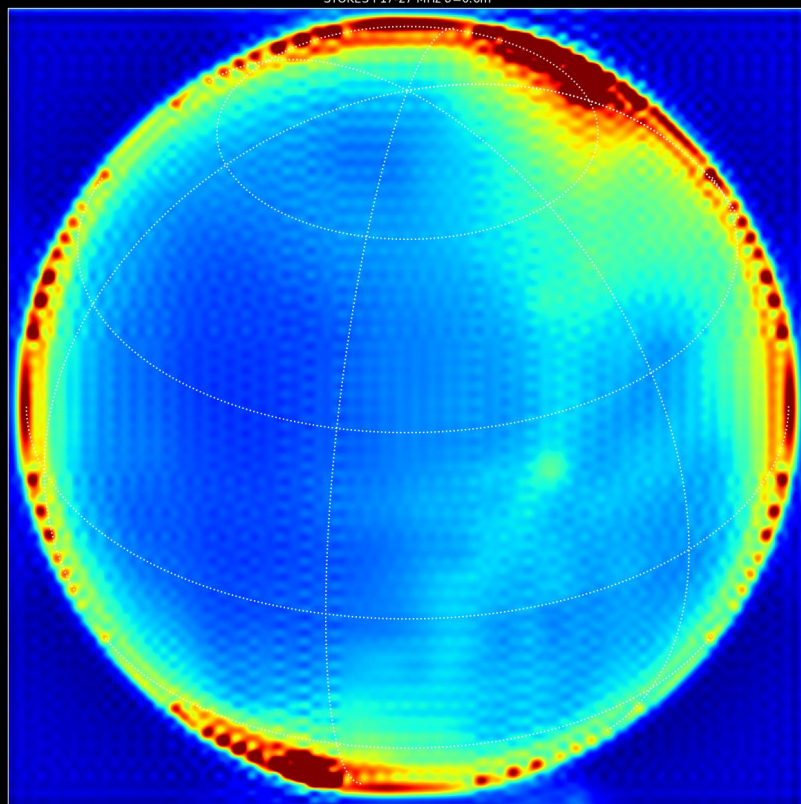
Regular

STOKES I 17-27 MHz



Perturbed [ $\sigma = 0.6\text{m}$ ]

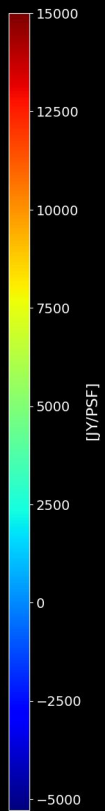
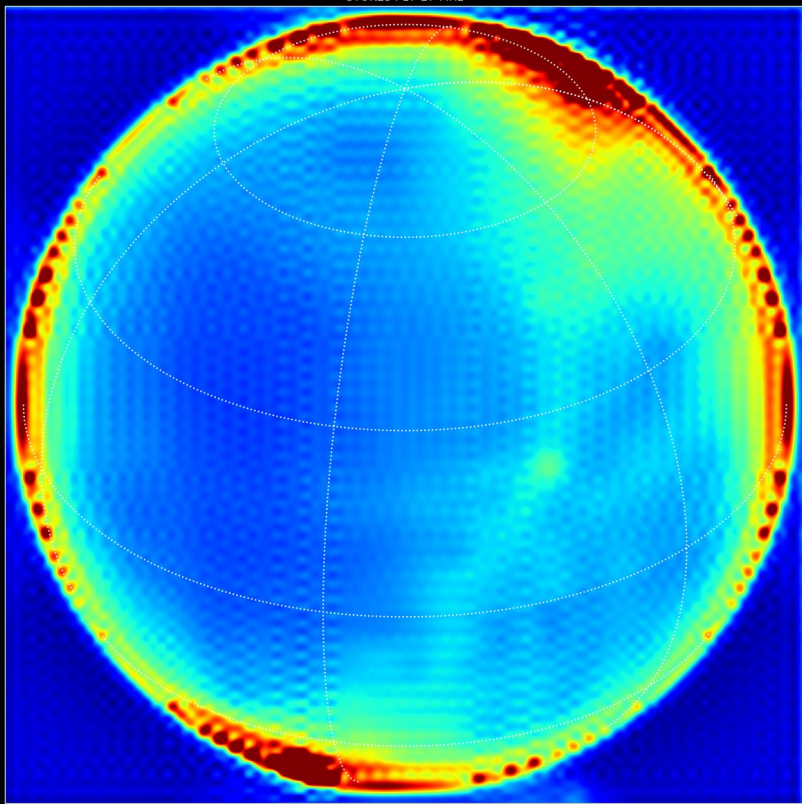
STOKES I 17-27 MHz  $\sigma=0.6\text{m}$



# Stokes I continuum image [17-27 MHz]

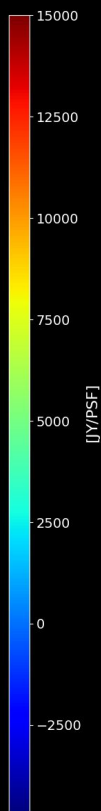
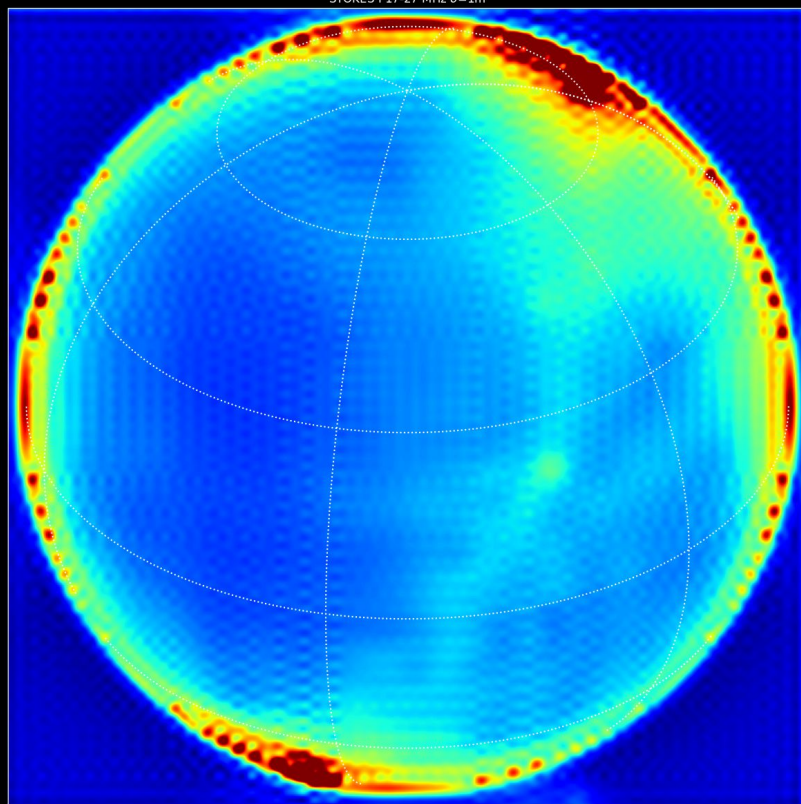
Regular

STOKES I 17-27 MHz



Perturbed [ $\sigma = 1$  m]

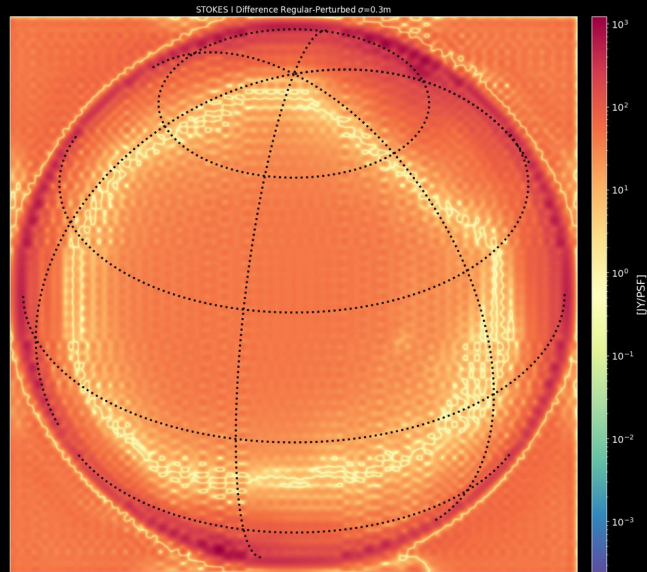
STOKES I 17-27 MHz  $\sigma=1$ m



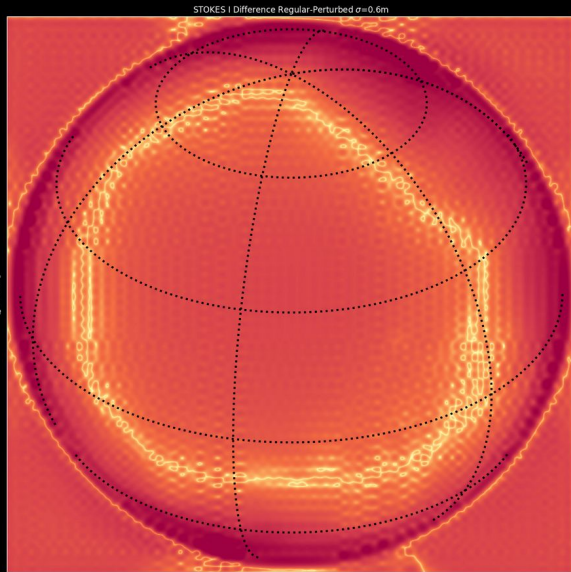


# Stokes I continuum image [17-27 MHz]

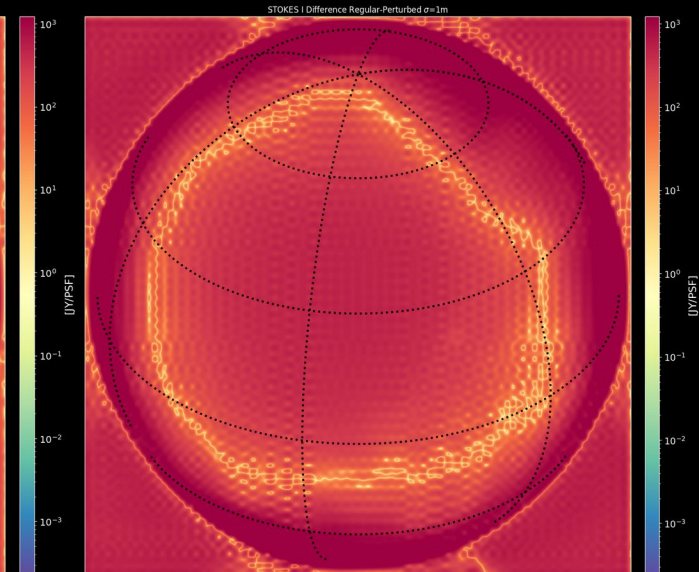
Perturbed [ $\sigma = 0.3\text{m}$ ]



Perturbed [ $\sigma = 0.6\text{m}$ ]



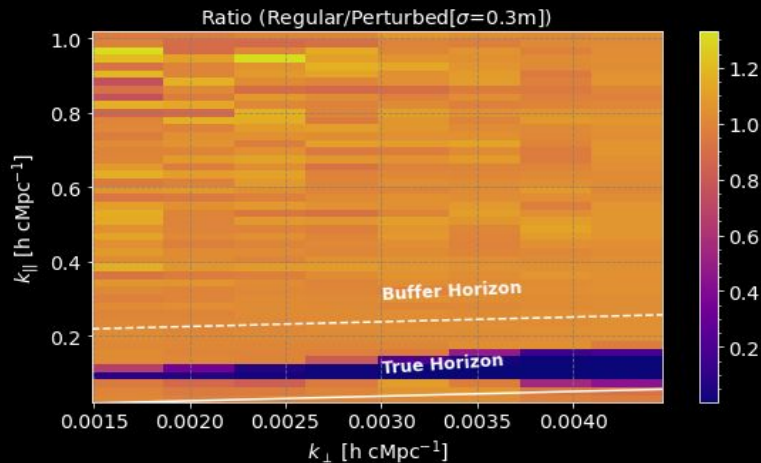
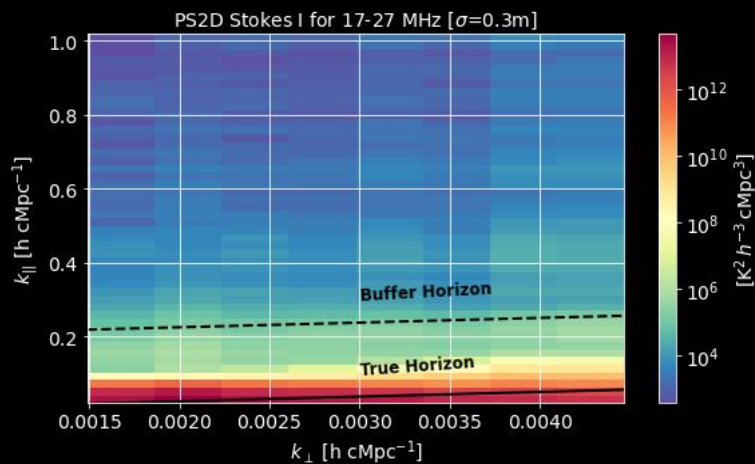
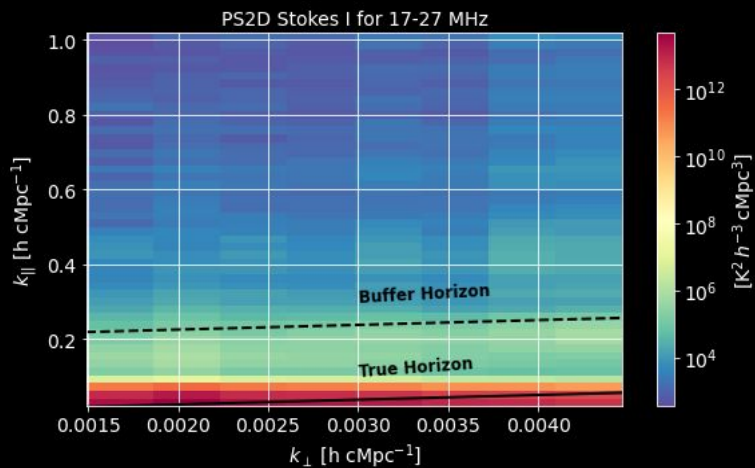
Perturbed [ $\sigma = 1\text{m}$ ]



Absolute difference (Regular - Perturbed) (in log scale)

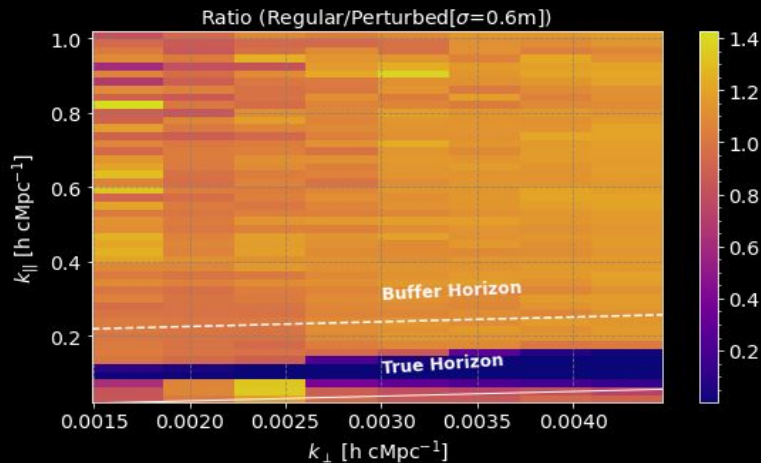
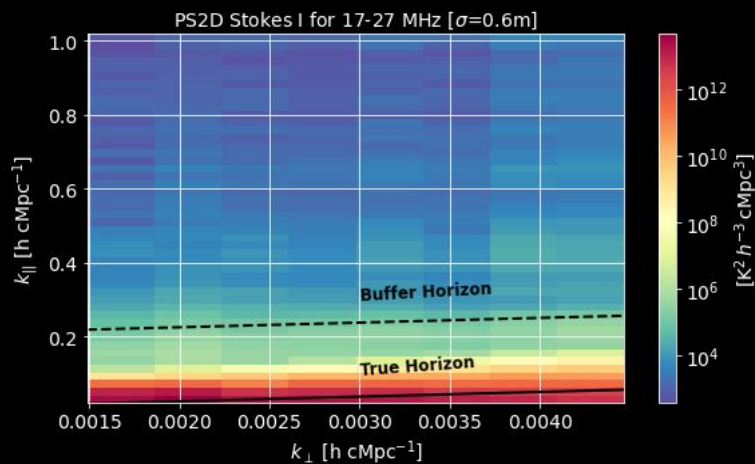
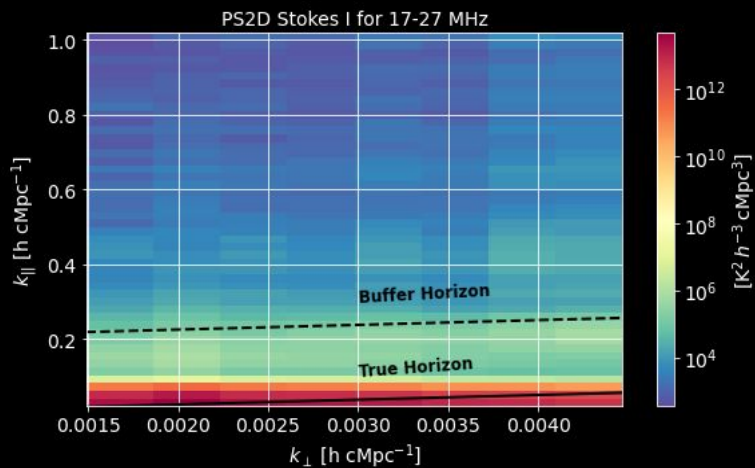


# Cylindrical Power Spectra [17-27 MHz]



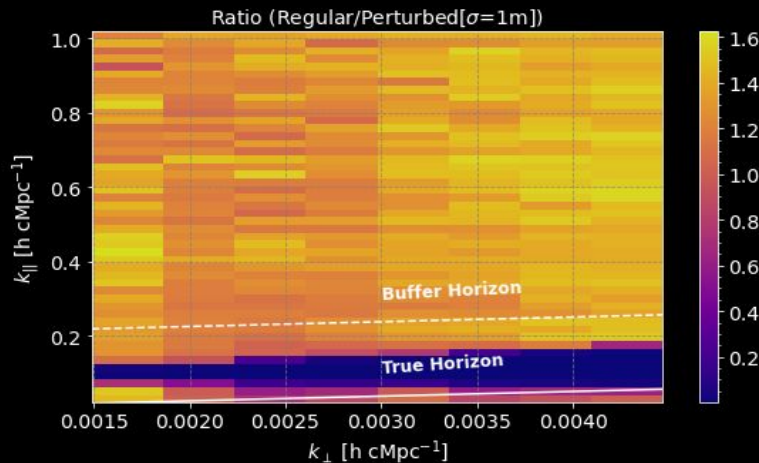
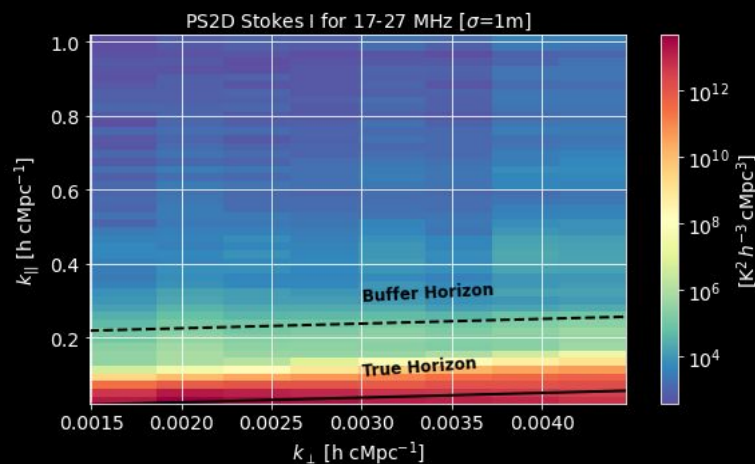
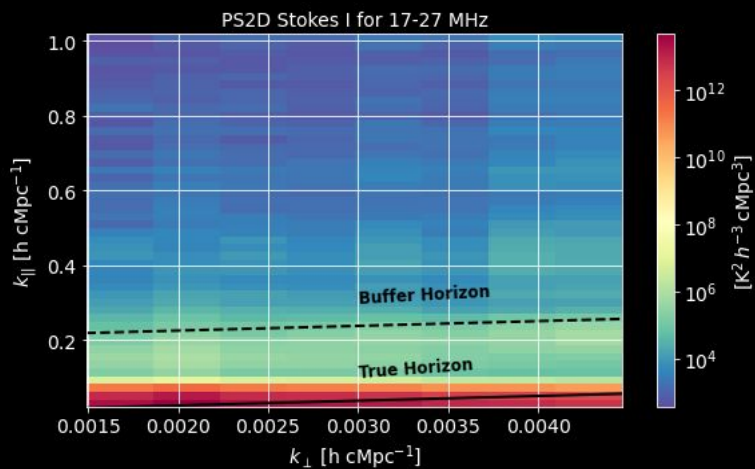
Perturbed [ $\sigma = 0.3m$ ]

# Cylindrical Power Spectra [17-27 MHz]



Perturbed [ $\sigma = 0.6m$ ]

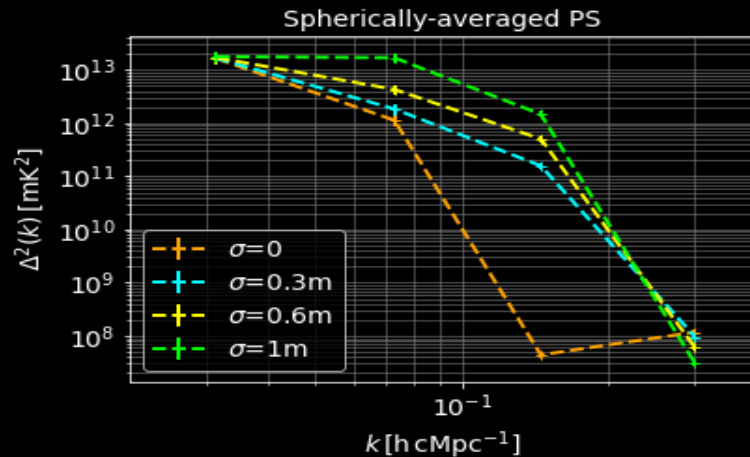
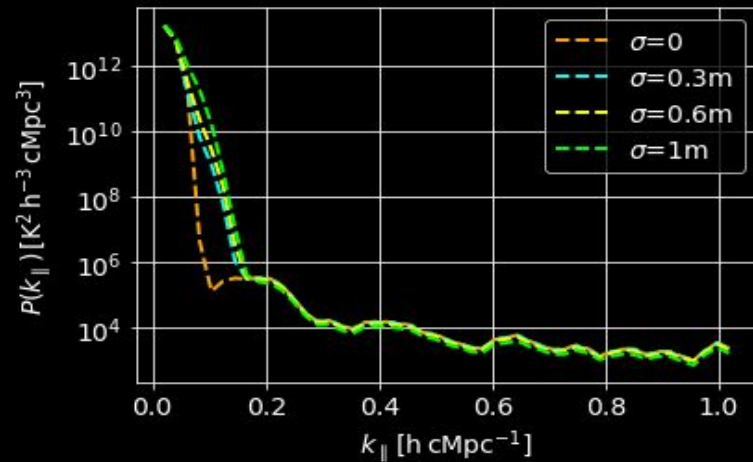
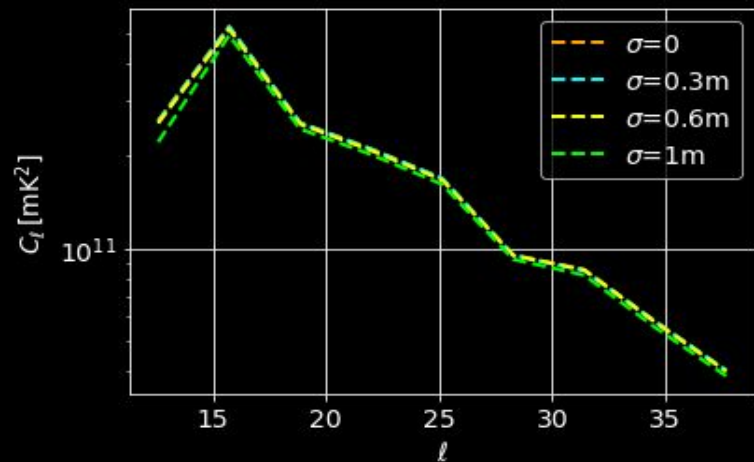
# Stokes I continuum image [17-27 MHz]



Perturbed [ $\sigma = 1$ m]



# Angular and Spherical Power Spectra [17-27 MHz]



# Summary

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Imperfect deployment of the dipole antennas can introduce positional error

Investigating antenna offsets' impact on the sensitive interferometric observations

Currently working on an end-to-end forward simulation pipeline for ALO

## Future work

Estimate the tolerance level for the deviations in the antenna positions

Evaluate the performance of the complete pipeline using 21cm signal, beam model (over lunar regolith), thermal noise