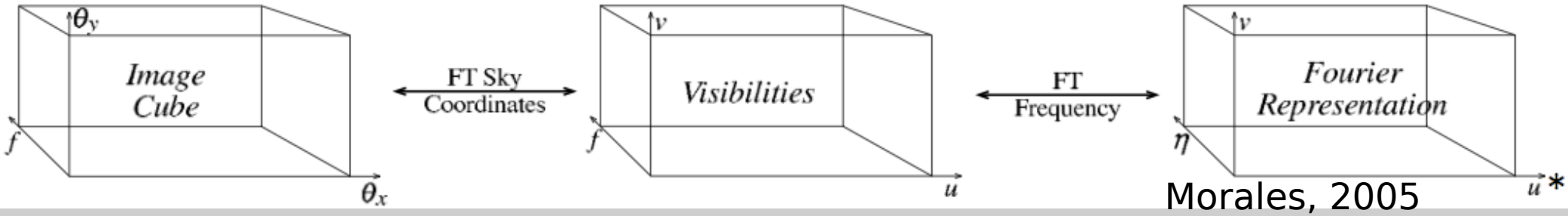
Optimizing Low Frequency Array Design

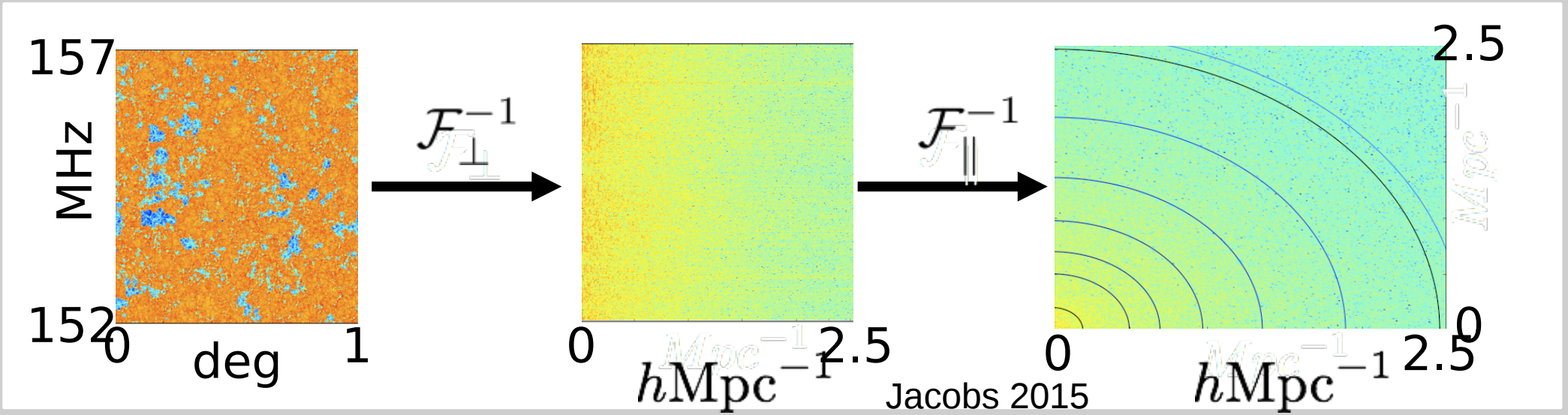
Matthew Kolopanis
Danny Jacobs

URSI, Boulder, CO 2018

Interferometry from the sky to power spectrum



Morales, 2005



Jacobs 2015

danielcjacobs.com

Allure of HI Mapping

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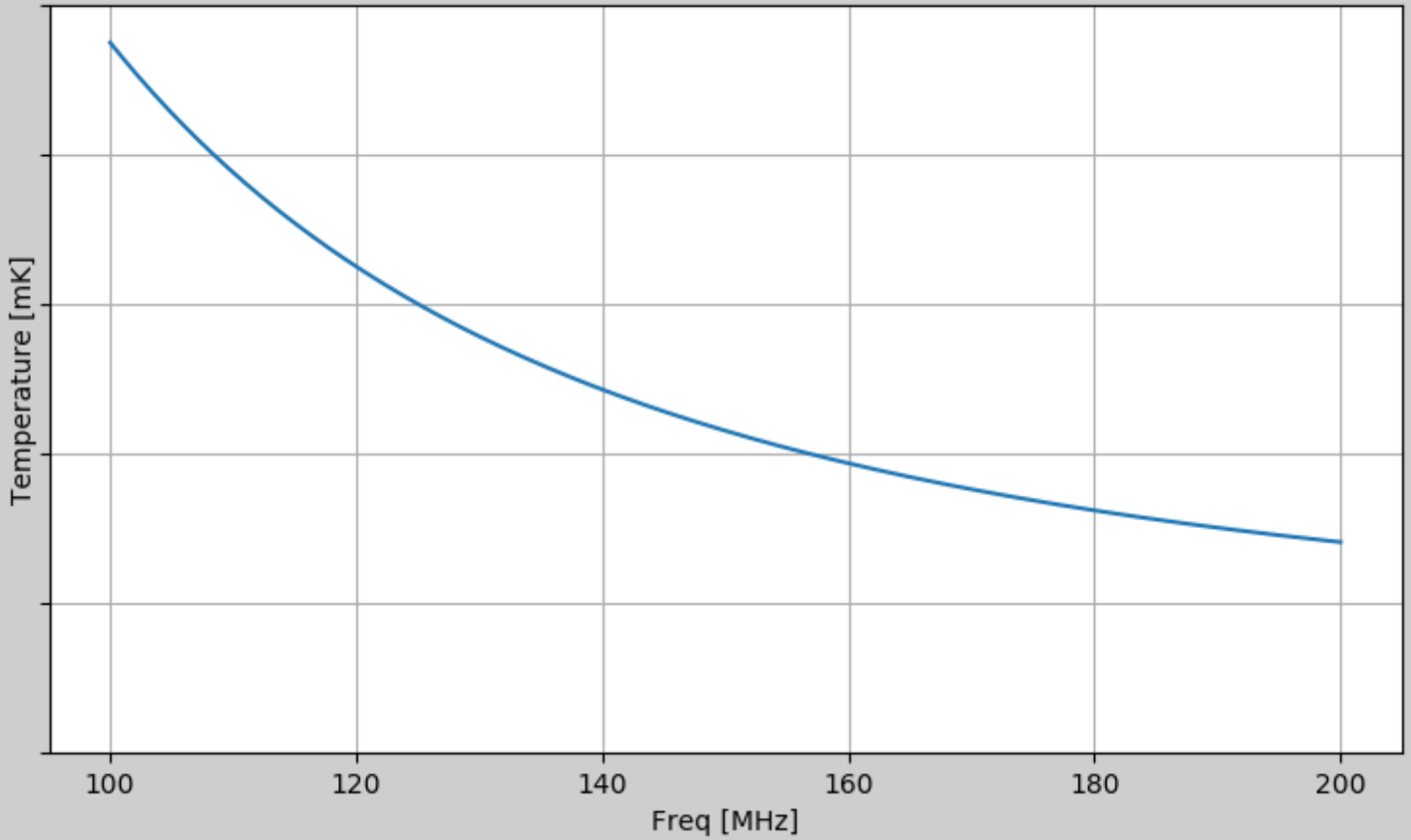

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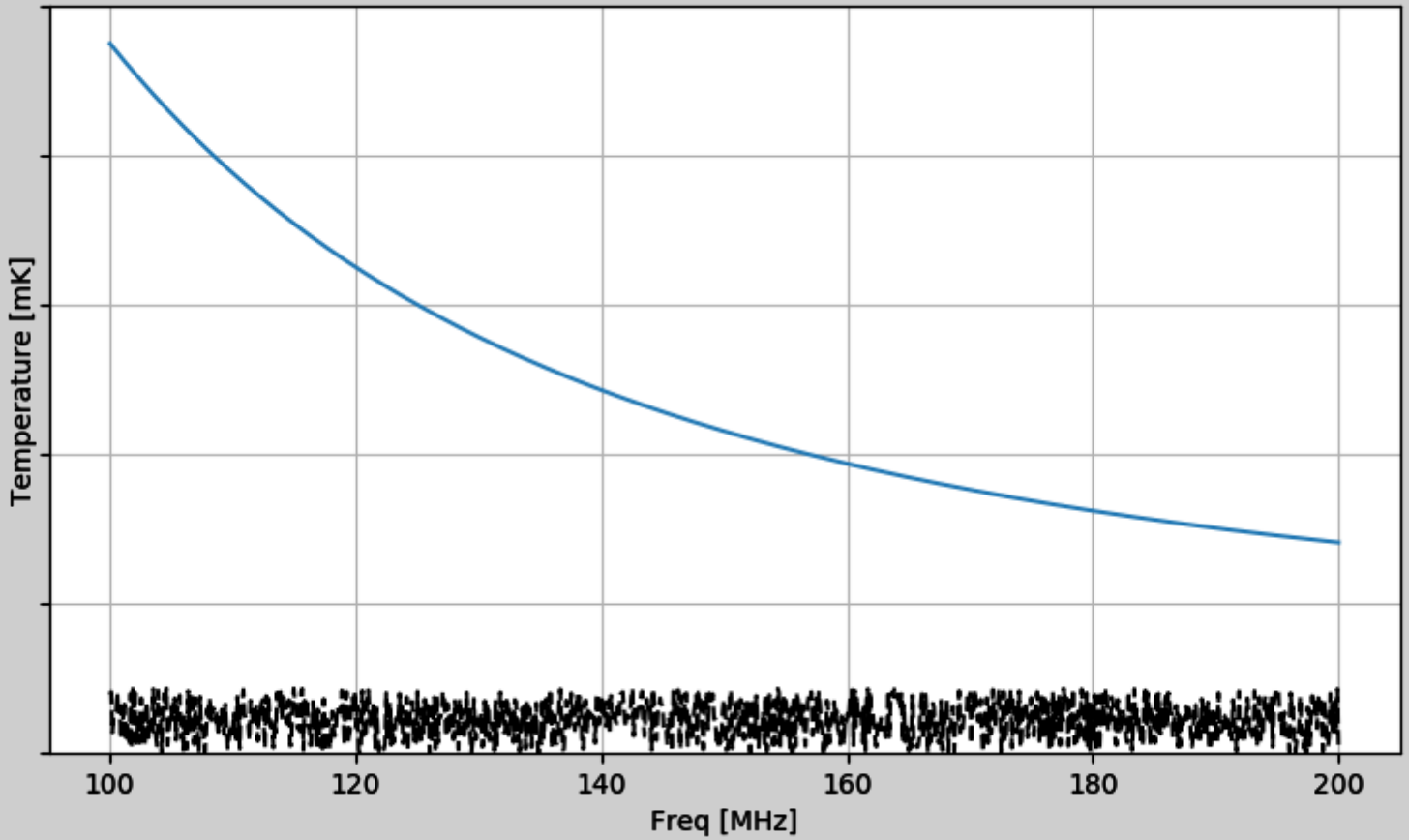
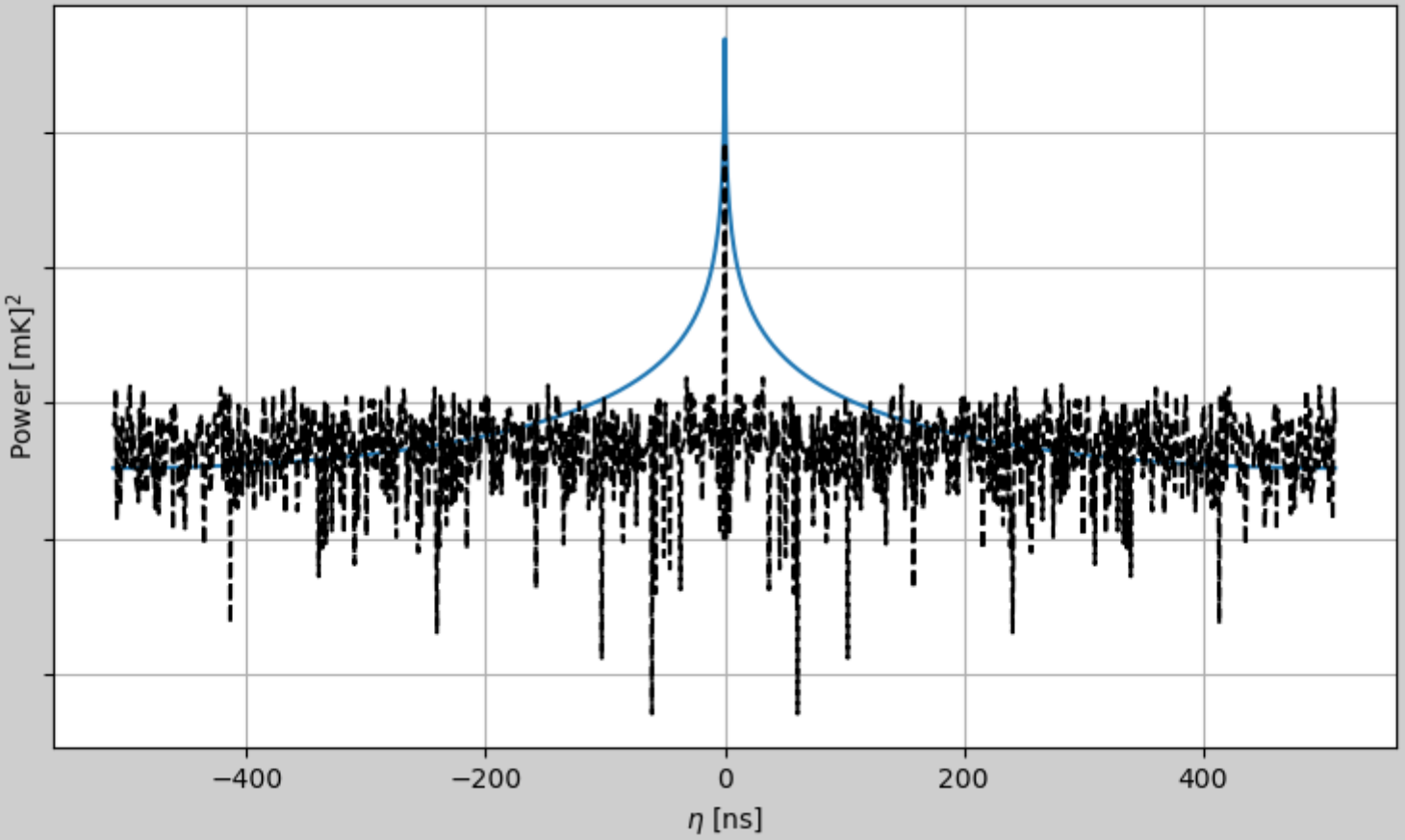
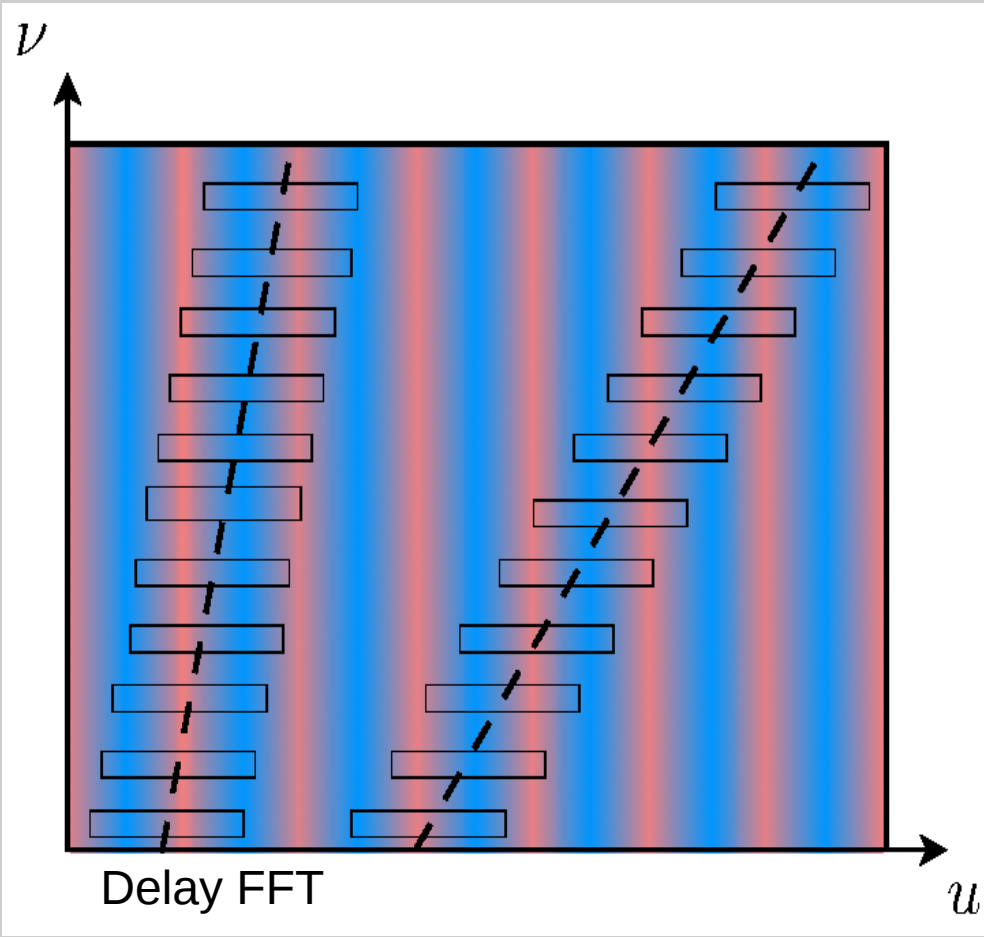
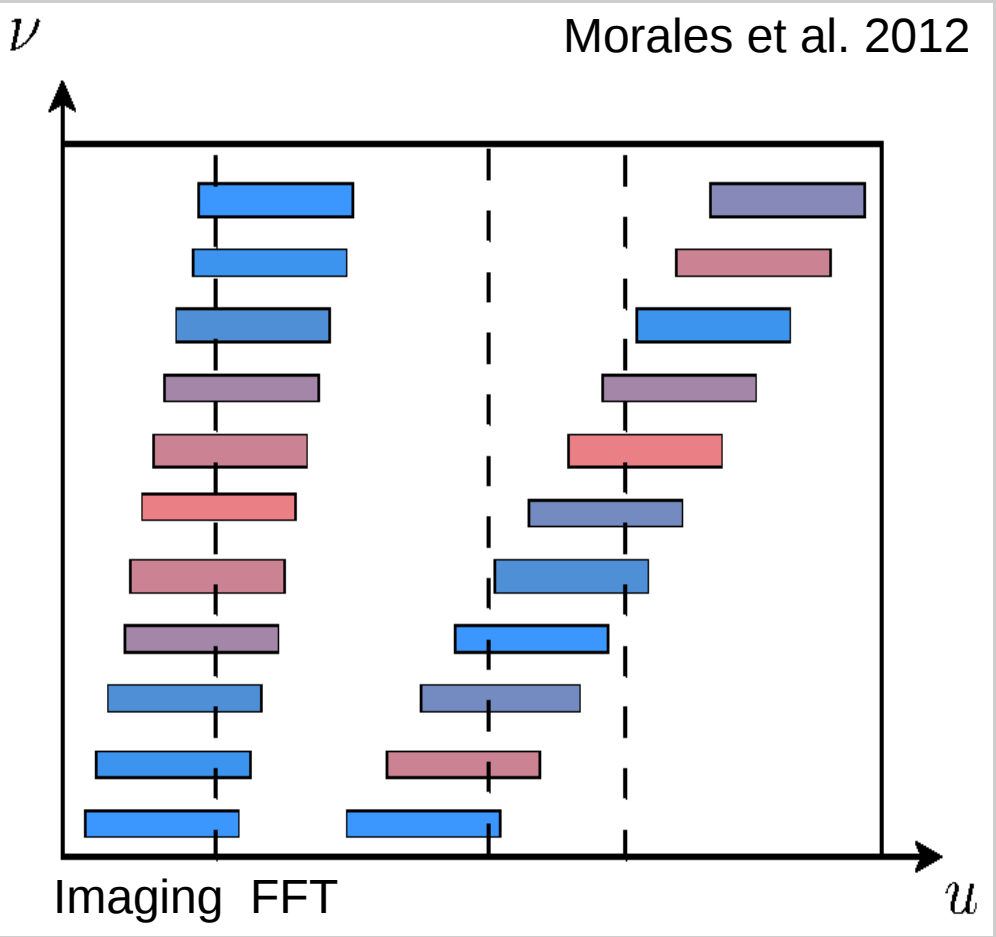


Foregrounds confined to small Fourier modes



Non-uniform baseline sampling causes foreground leakage





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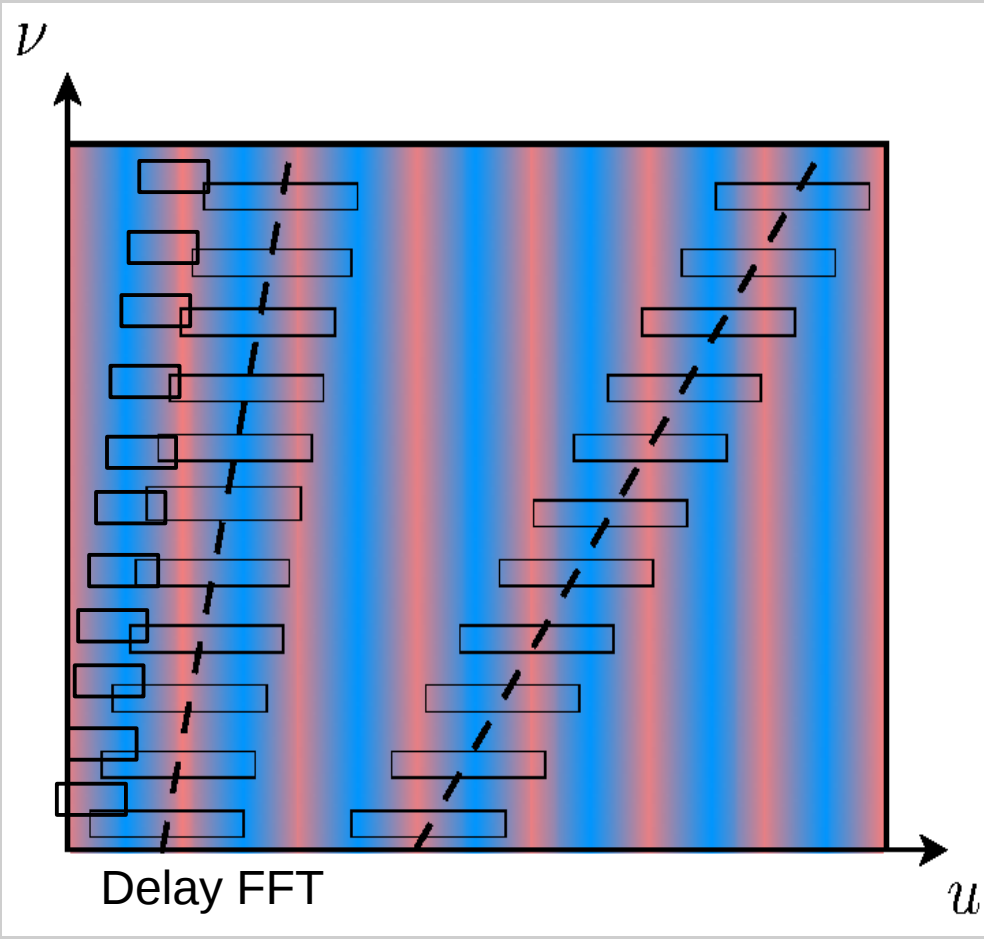

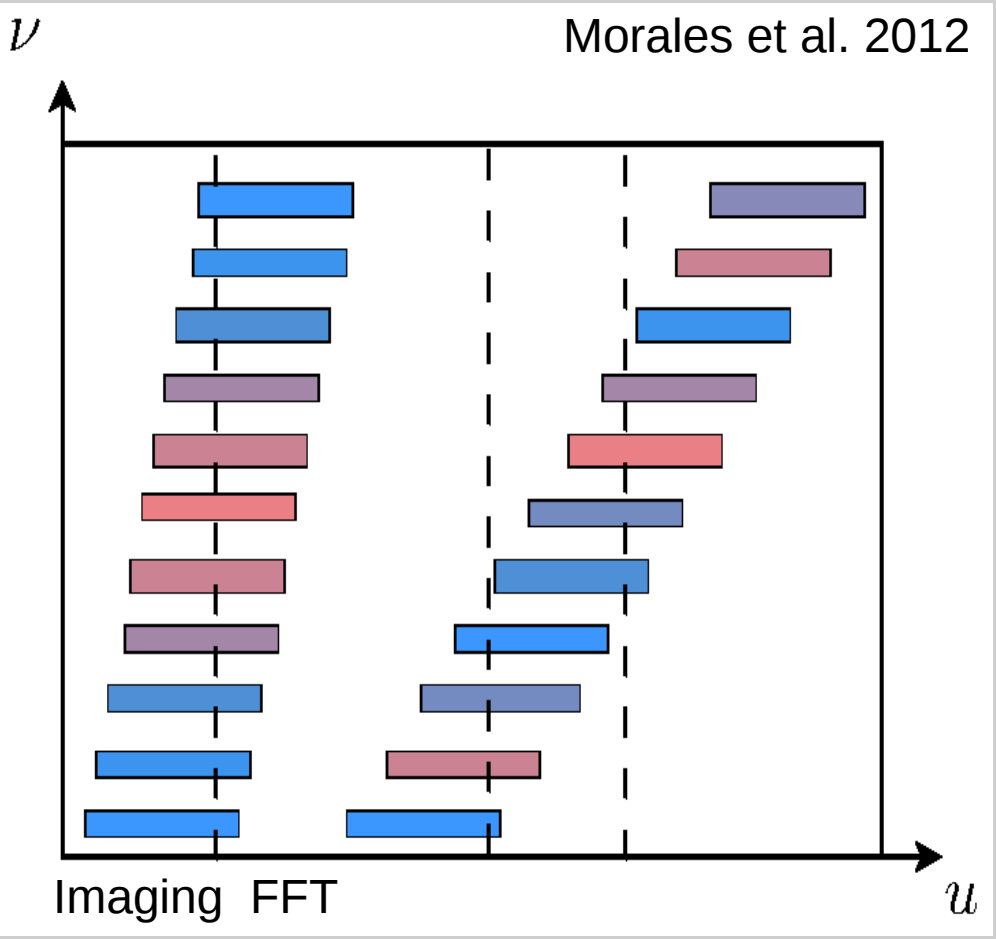

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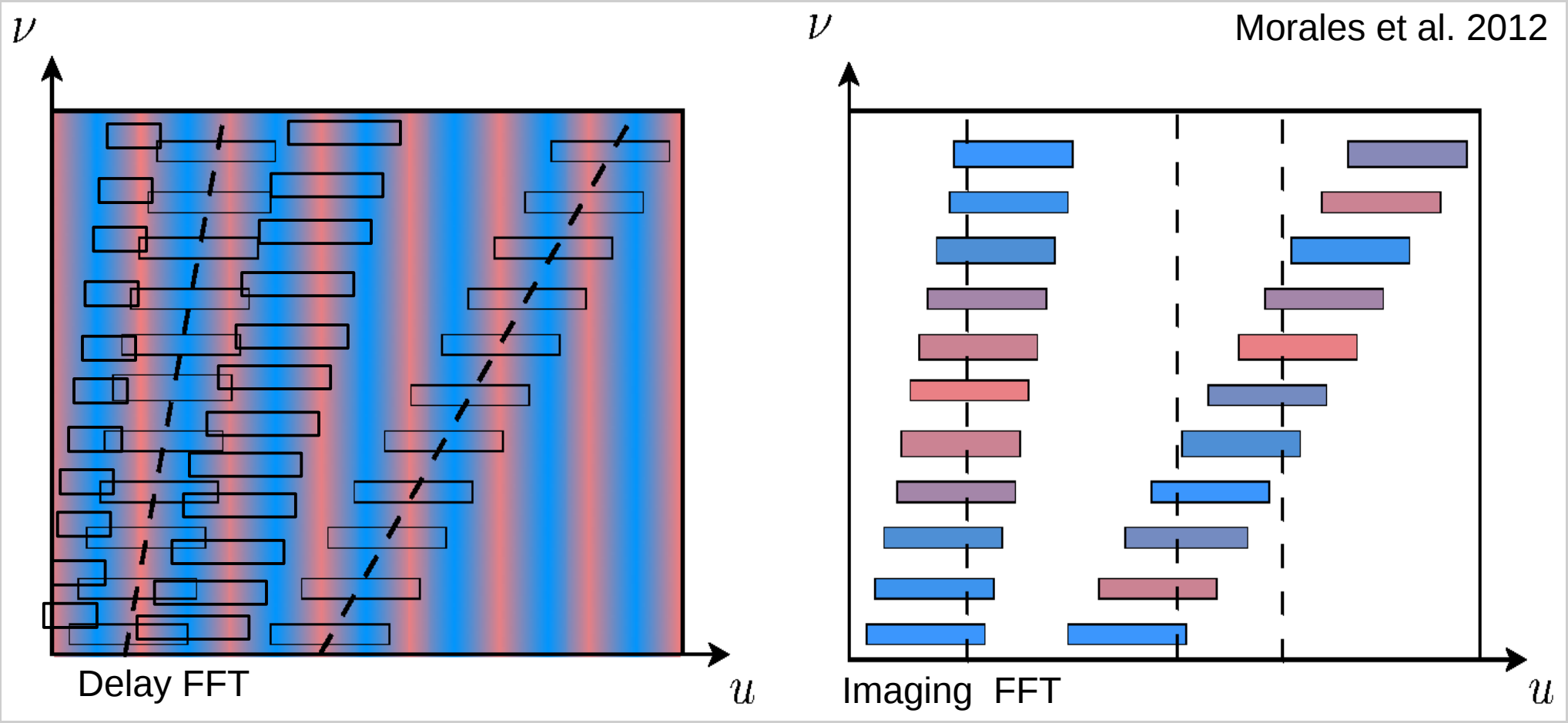

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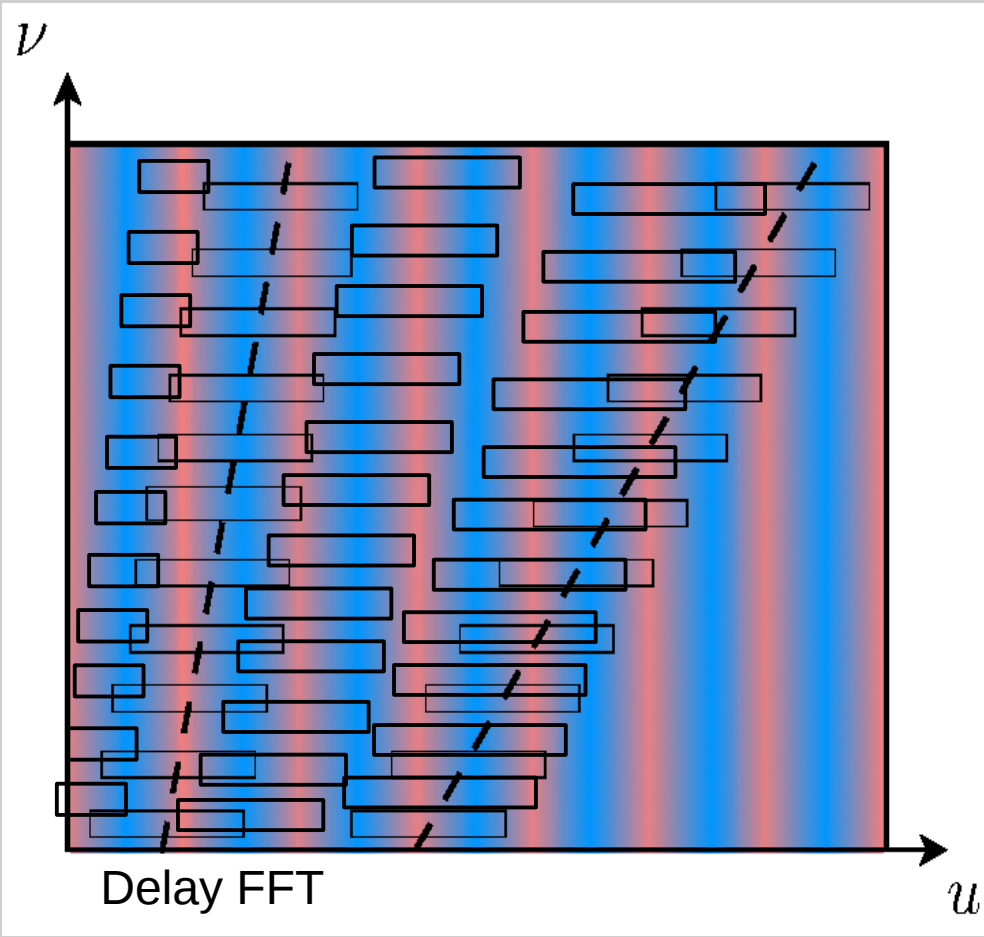

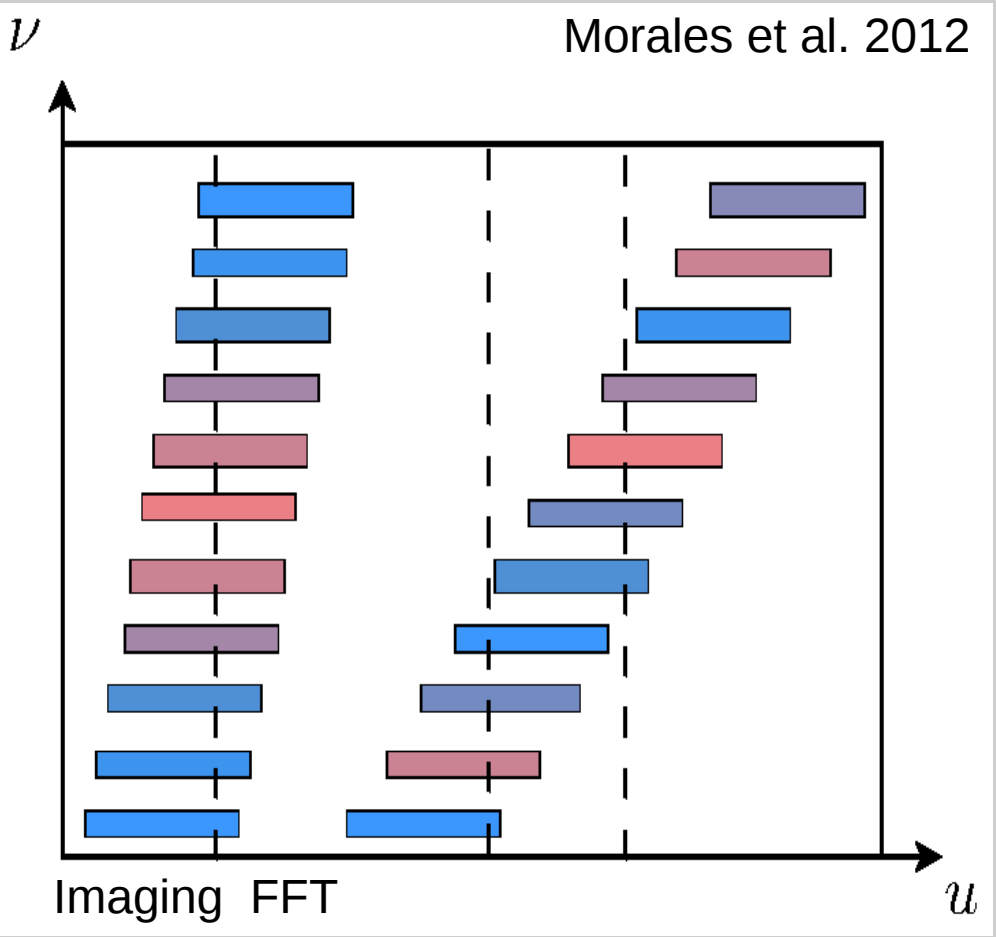

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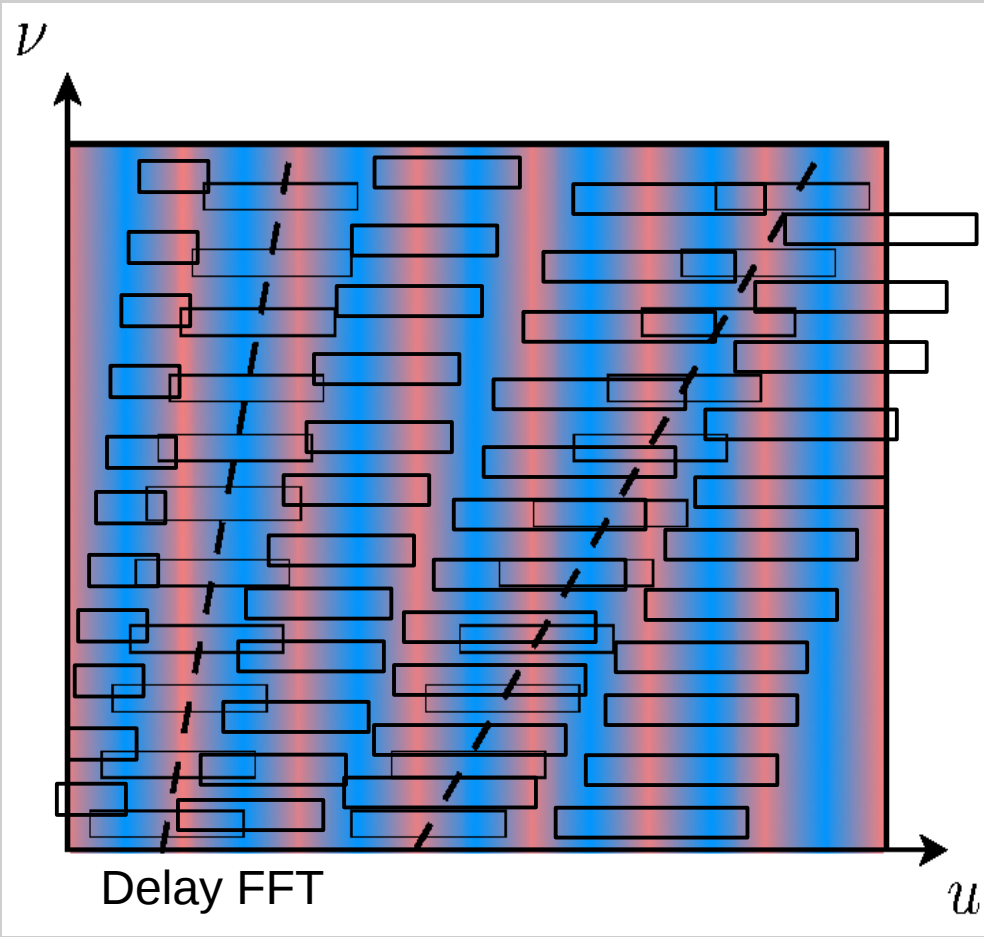

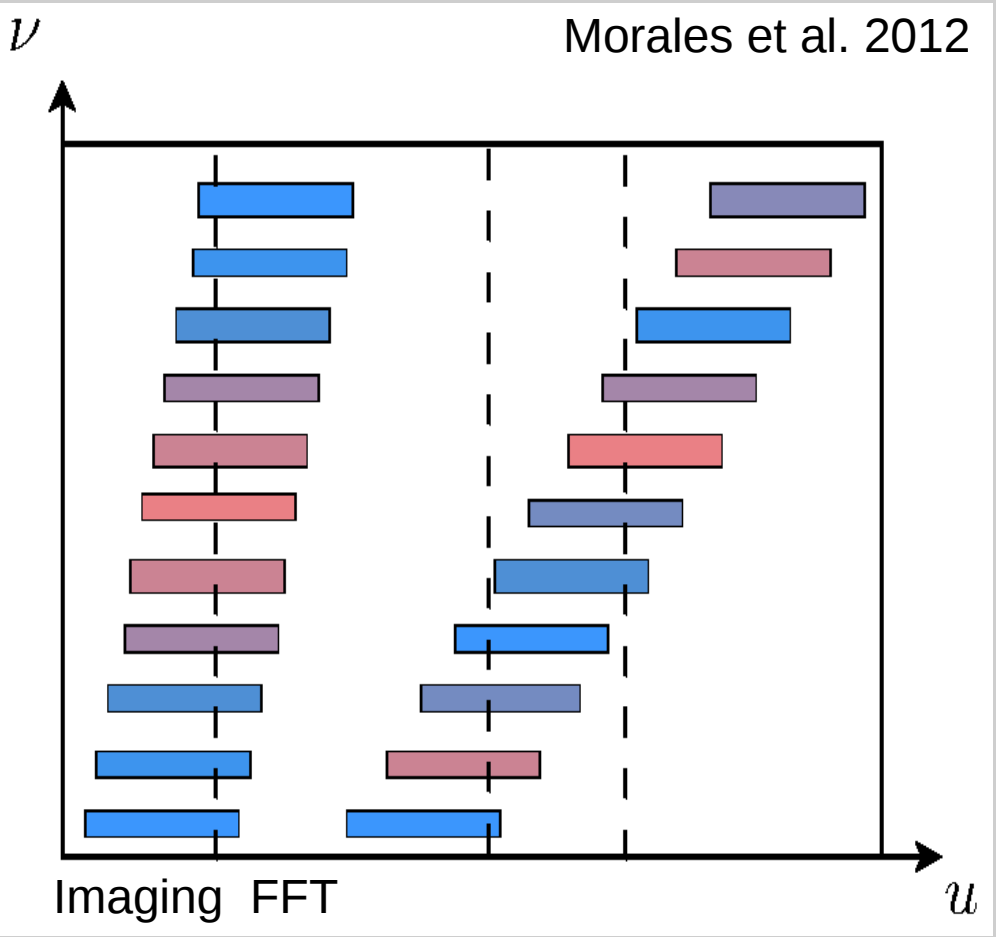

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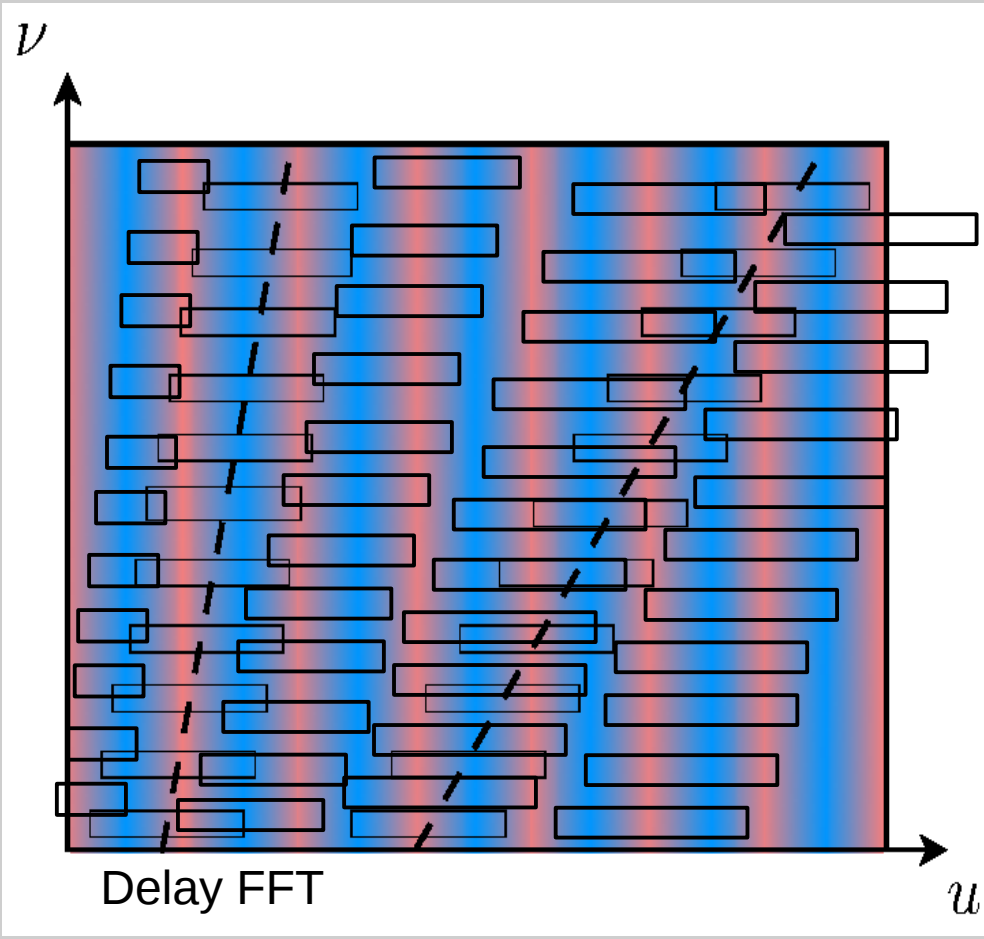

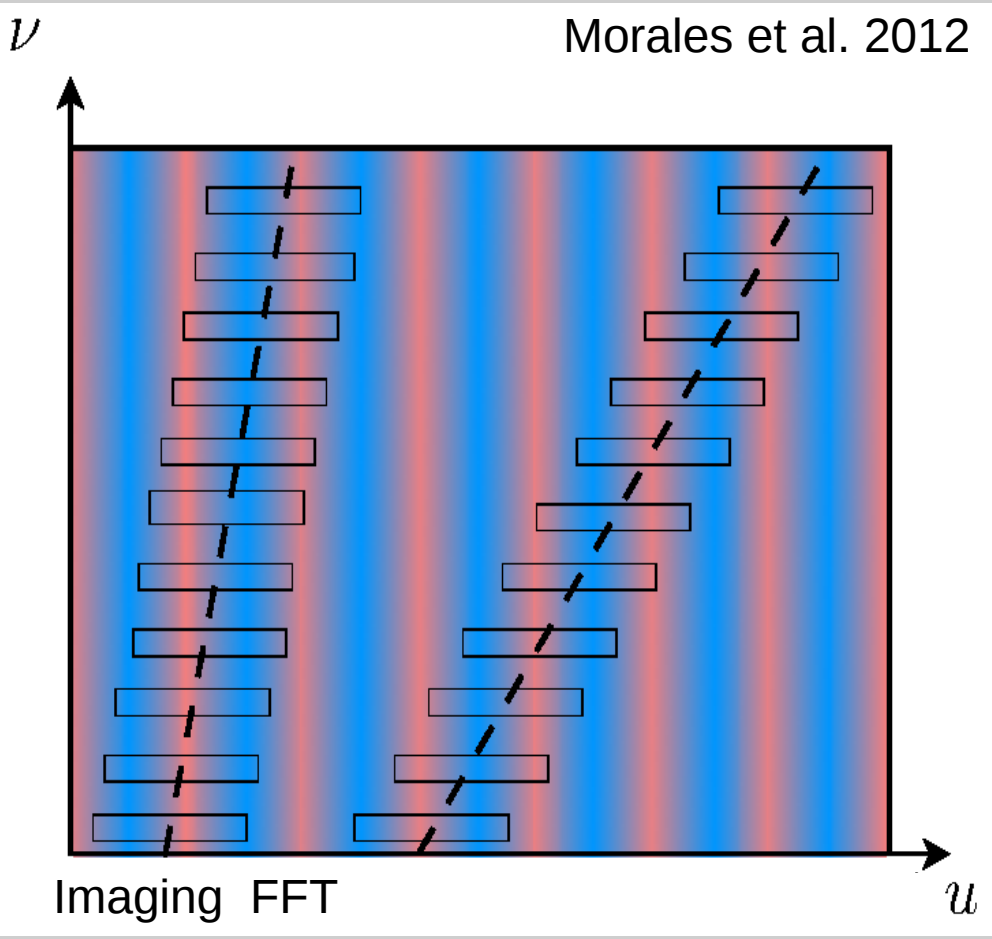

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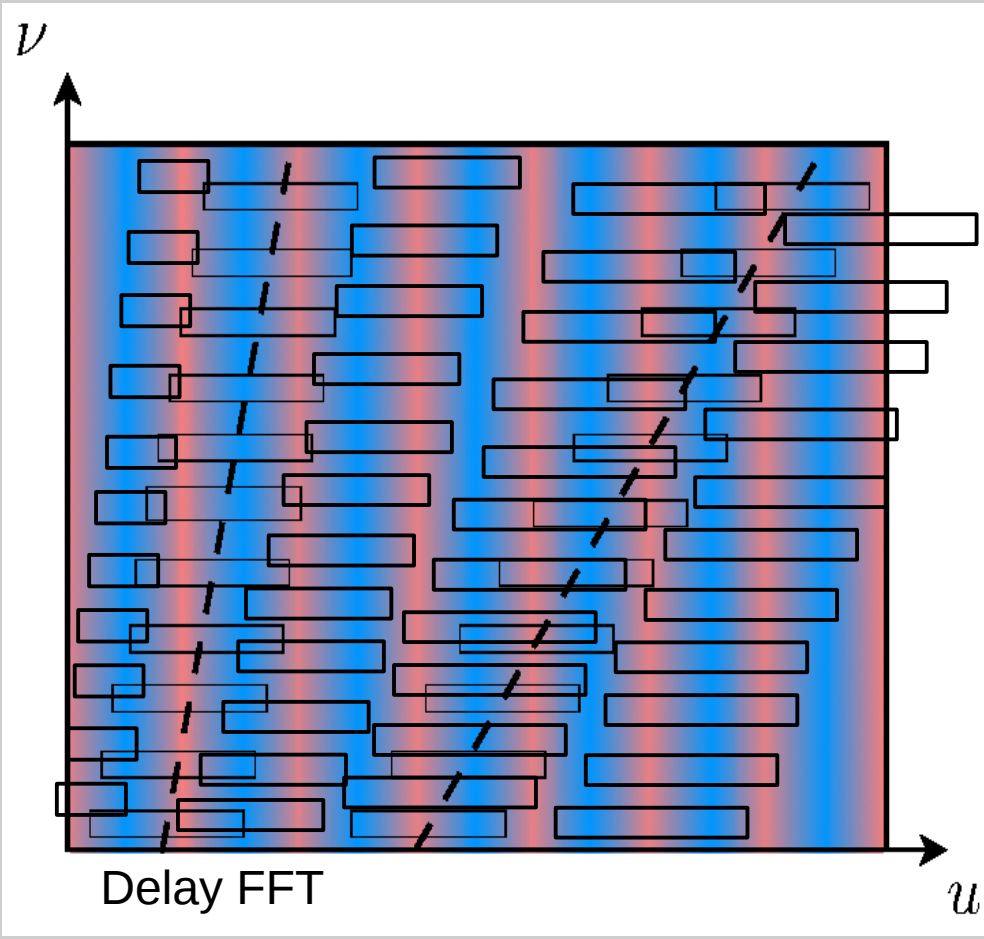
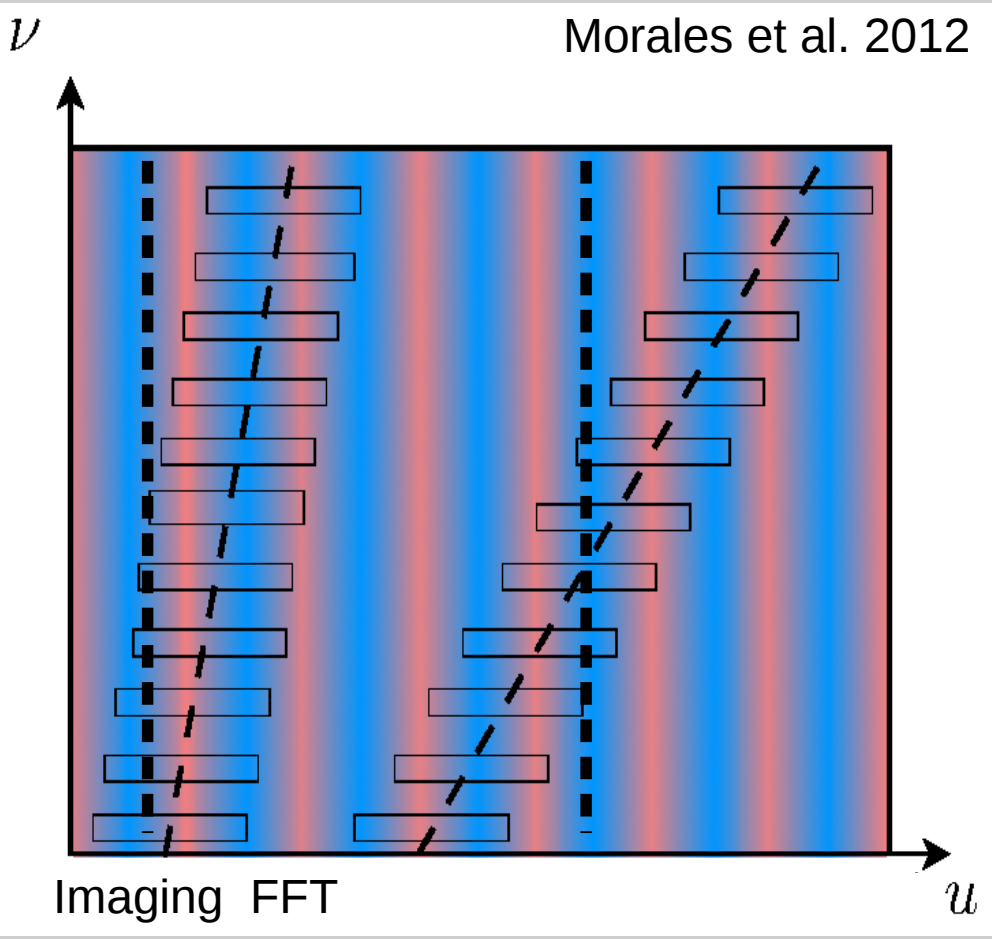
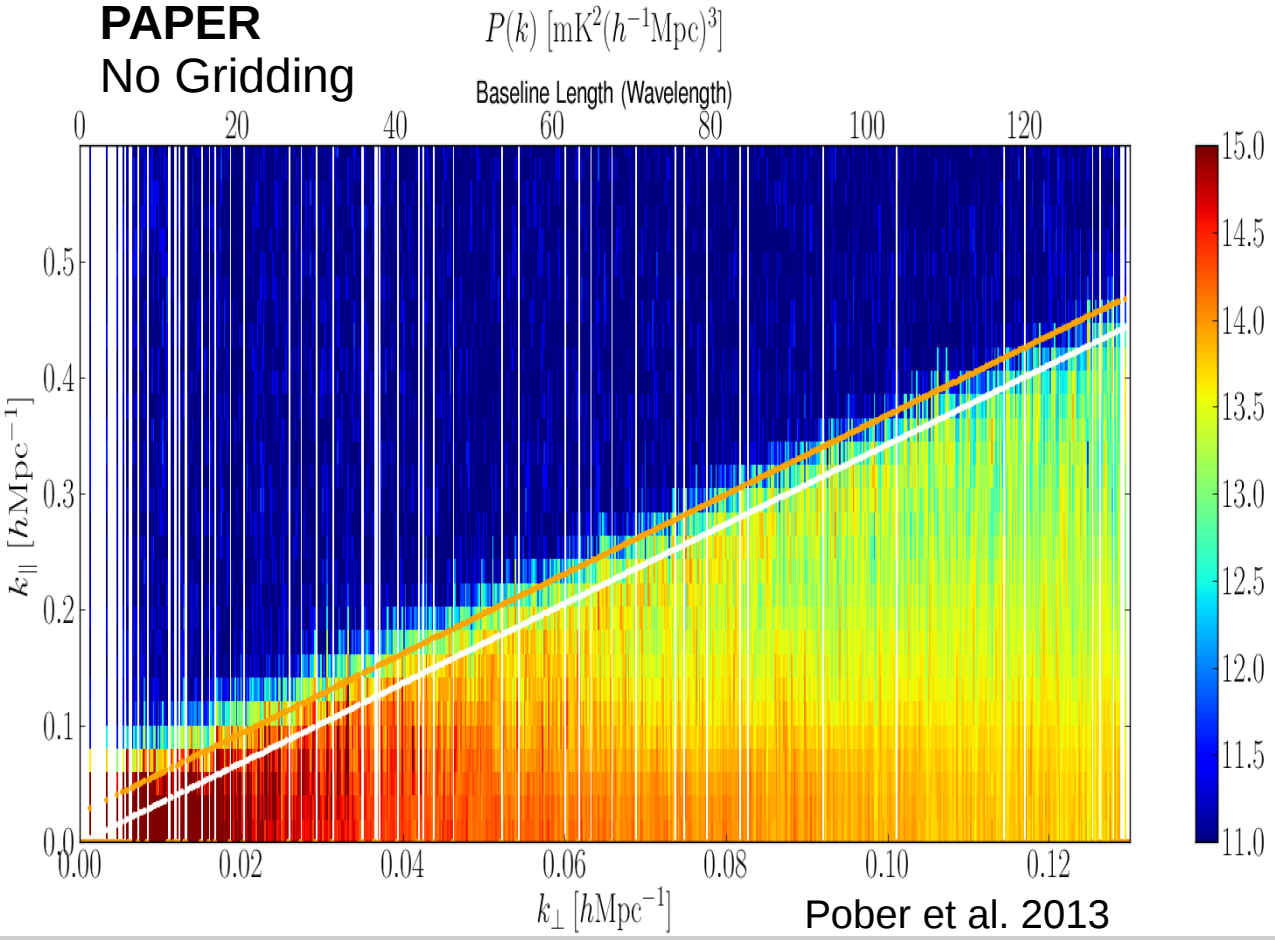




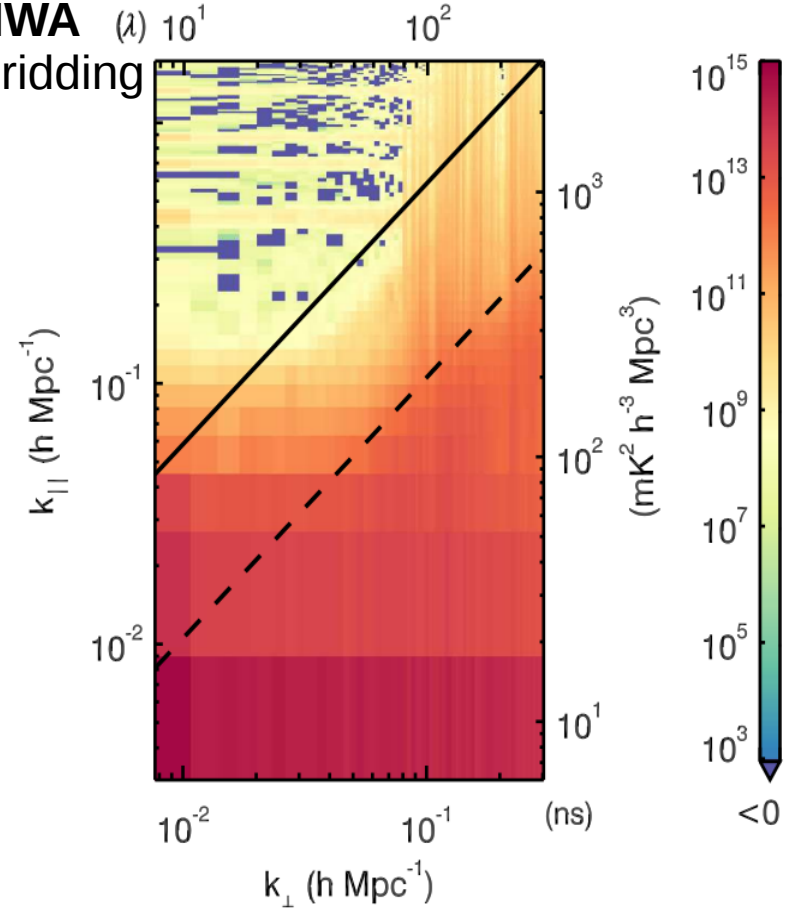
Delay wedge is prevalent up to the horizon
Imaging wedge shows improvement near horizon

PAPER
No Gridding



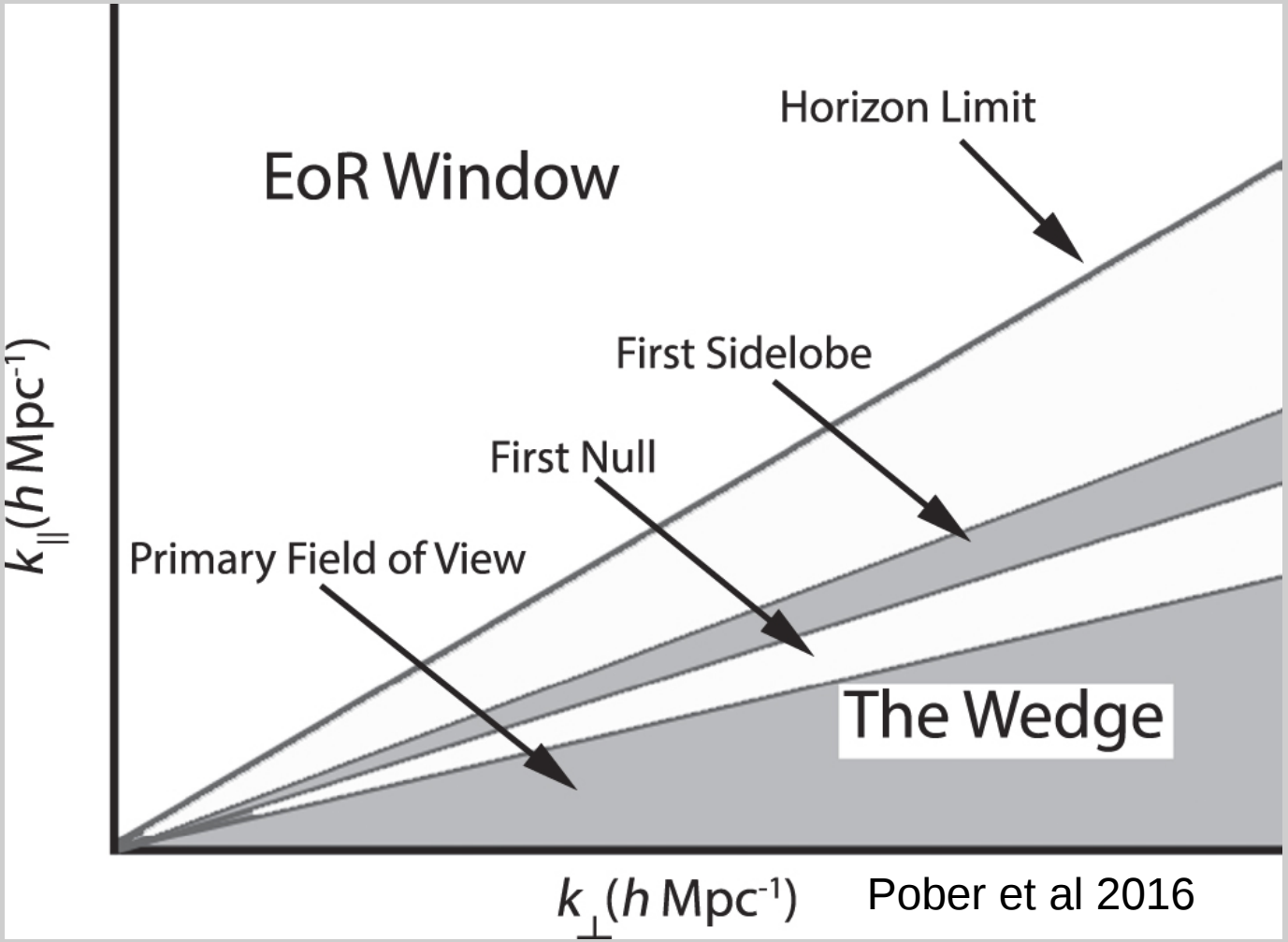
Pober et al. 2013

MWA
Gridding



Beardsley et al. 2016

Foregrounds leak into the wedge from the beam



Pober et al 2016

Foreground Contamination in the Wedge:

- Imaging based pipeline improves wedge sensitivity
- Increased number of unique baselines improves uv sampling
- Antenna response (Beam) leaks power into the wedge
- **Aperture Smoothness = Beam + Configuration**

Simulations

Require:

- Full Sky Foregrounds
  - Diffuse & Point Source
- Power Spectrum

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Simulate Visibilities

PRISim

- github.com/nithyanandan/PRISim

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Require:

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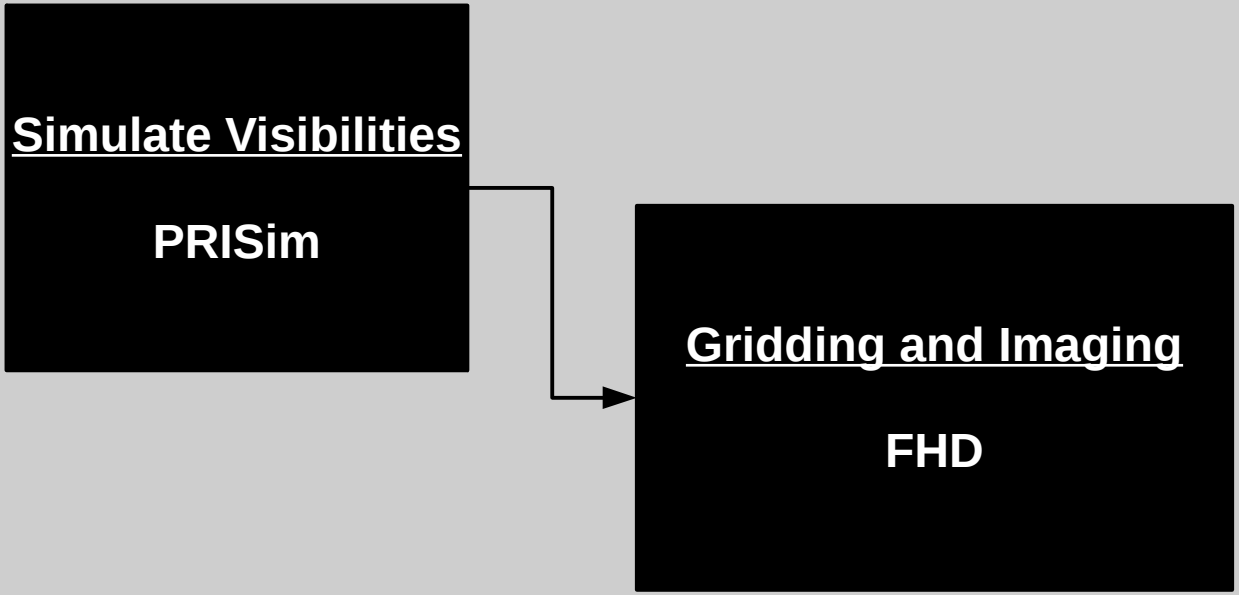

- github.com/nithyanandan/PRISim
- github.com/EoRImaging/FHD

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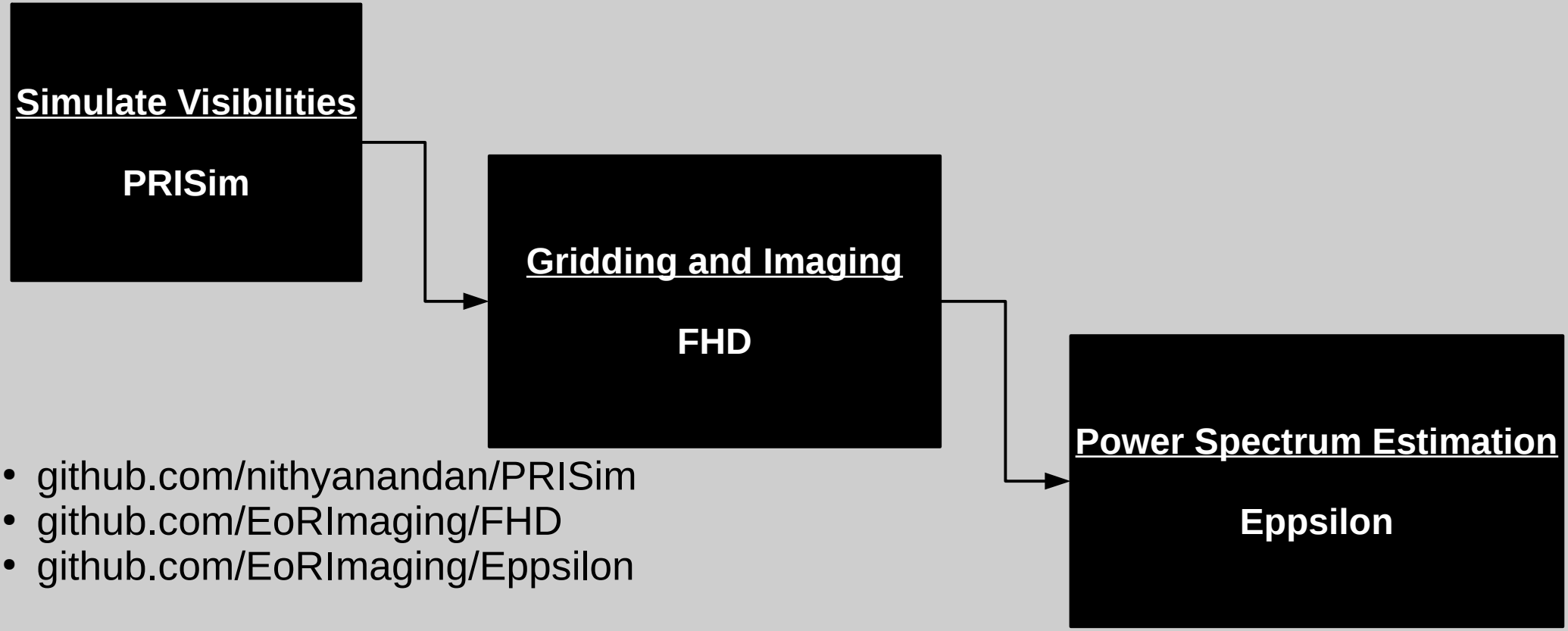

- github.com/nithyanandan/PRISim
- github.com/EoRImaging/FHD
- github.com/EoRImaging/Eppsilon

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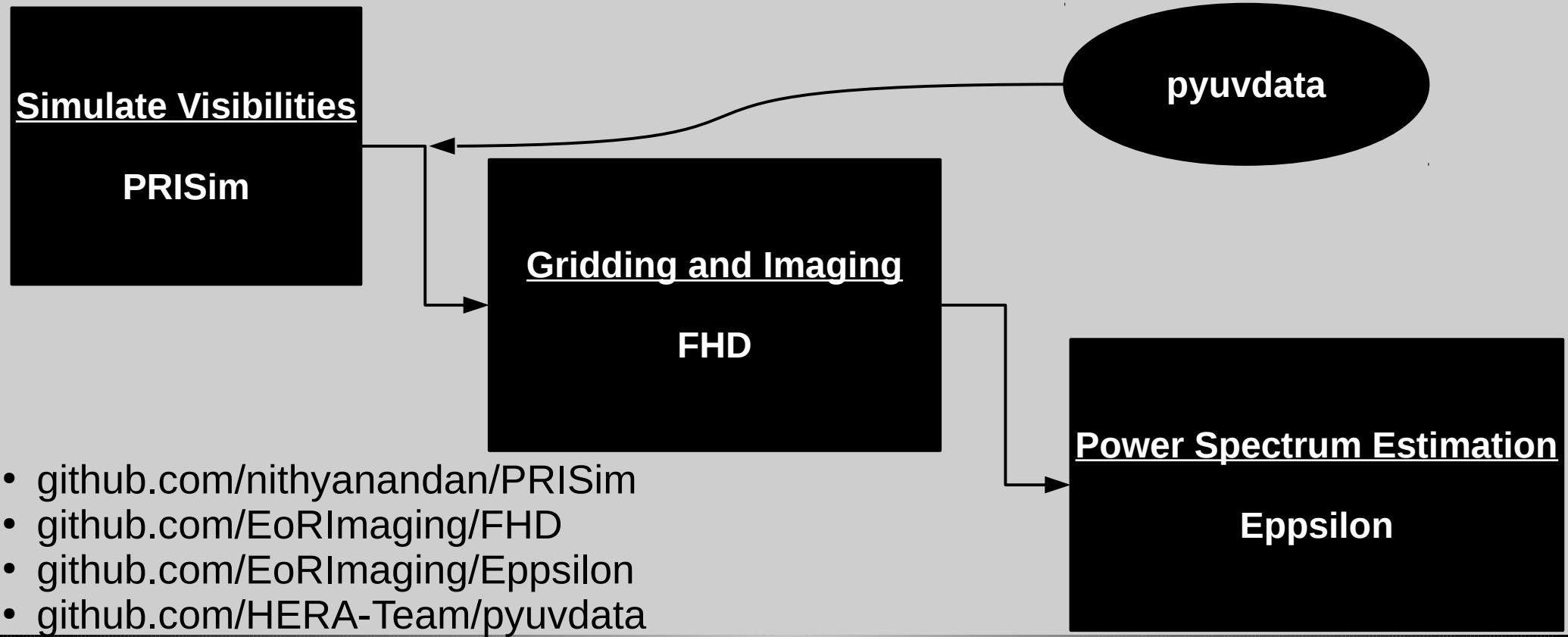
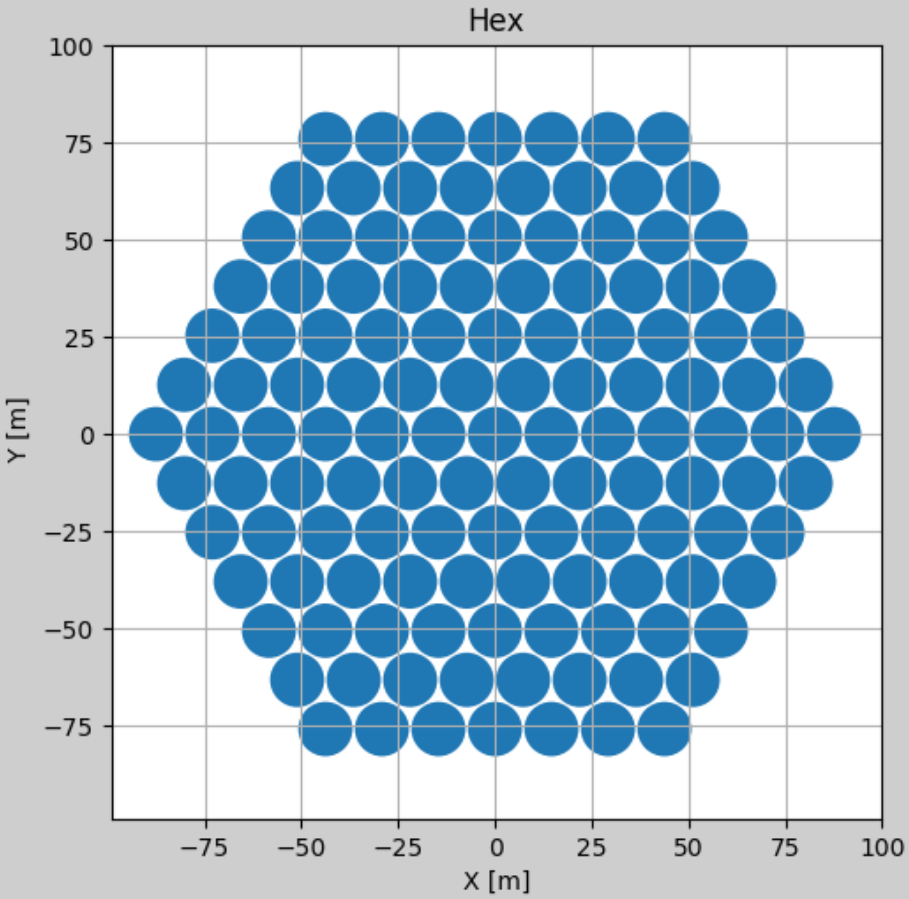
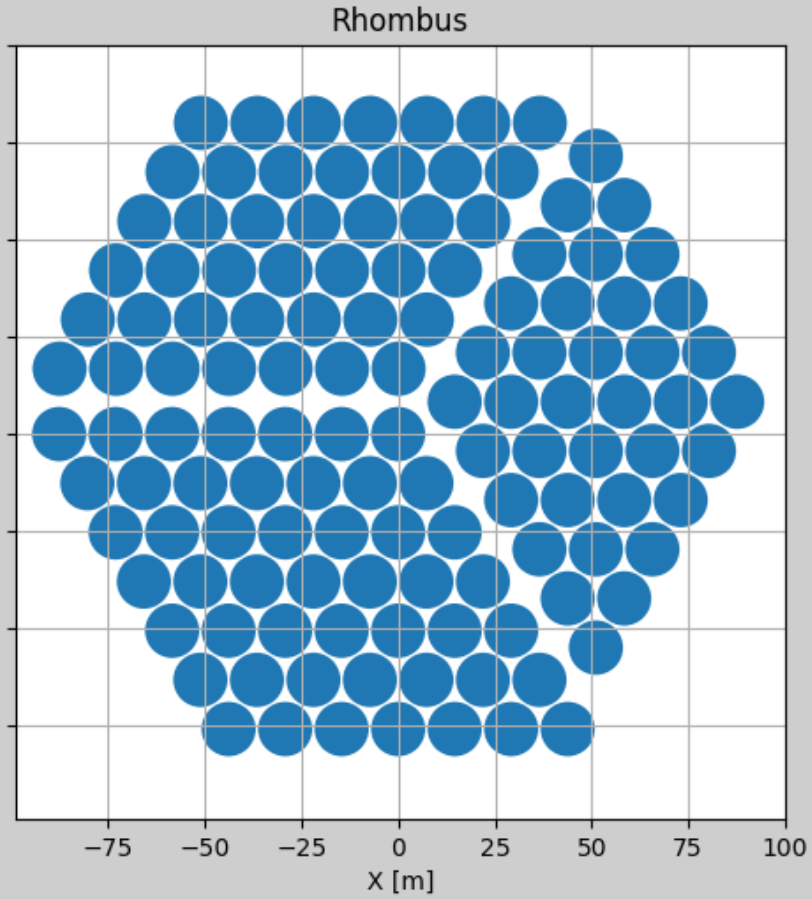


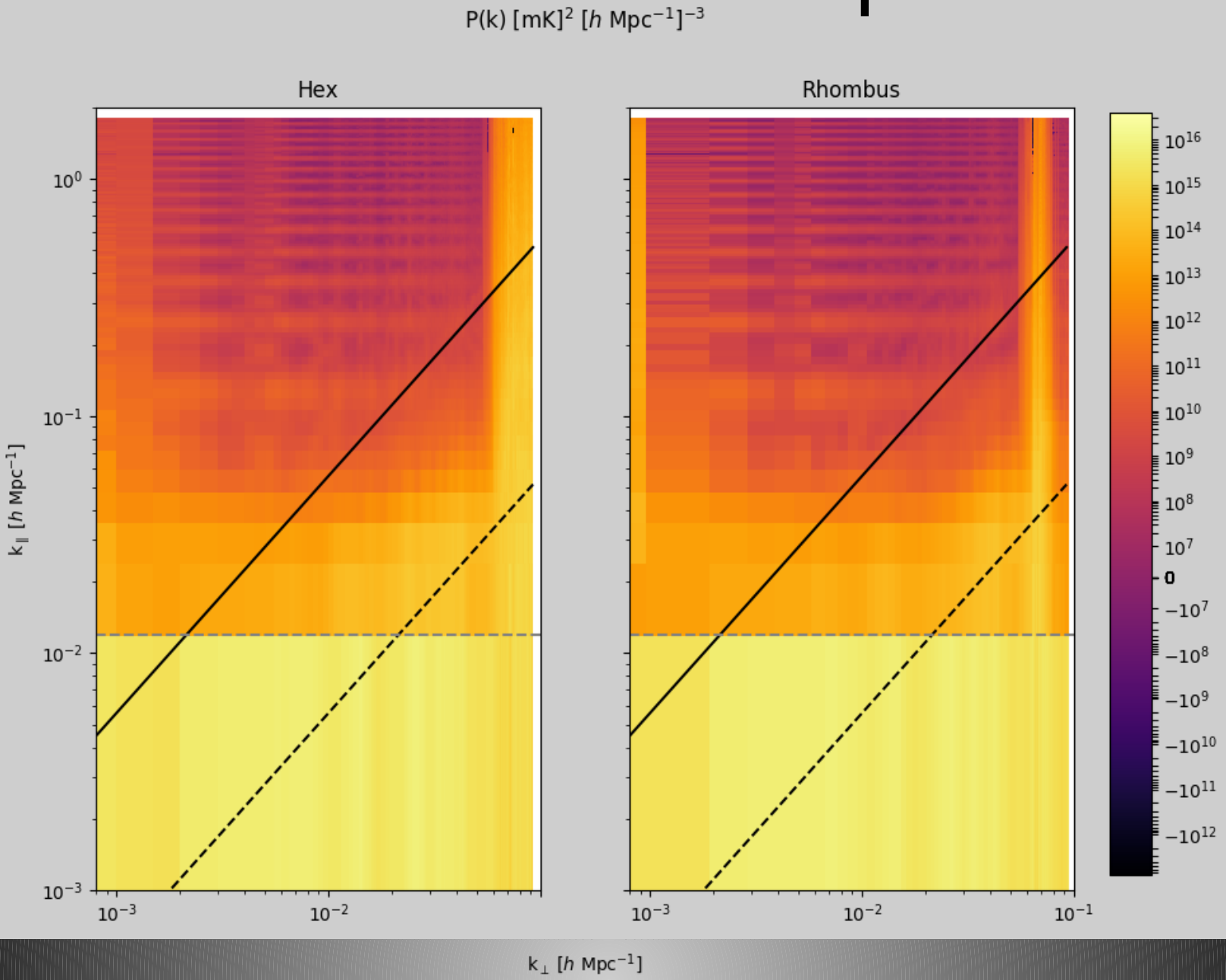
- github.com/nithyanandan/PRISim
- github.com/EoRImaging/FHD
- github.com/EoRImaging/Eppsilon
- github.com/HERA-Team/pyuvdata

Simulate foregrounds with different UV apertures





HERA 2D Power Spectra



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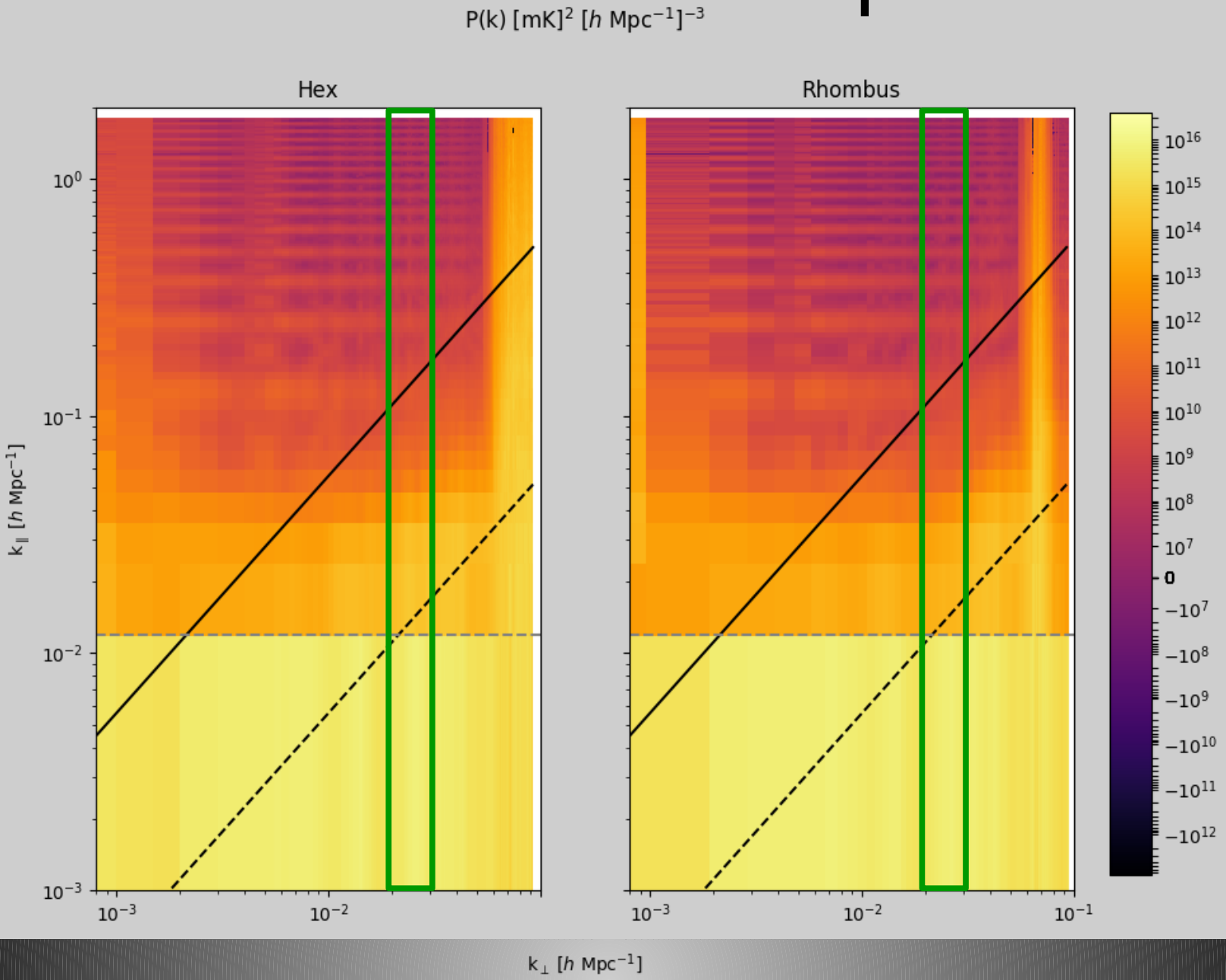
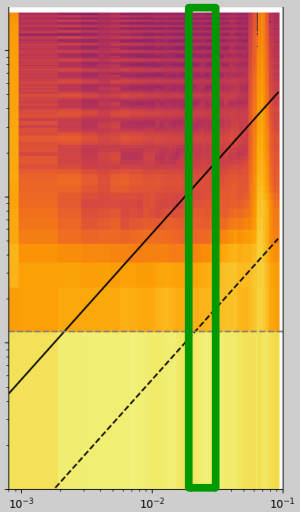
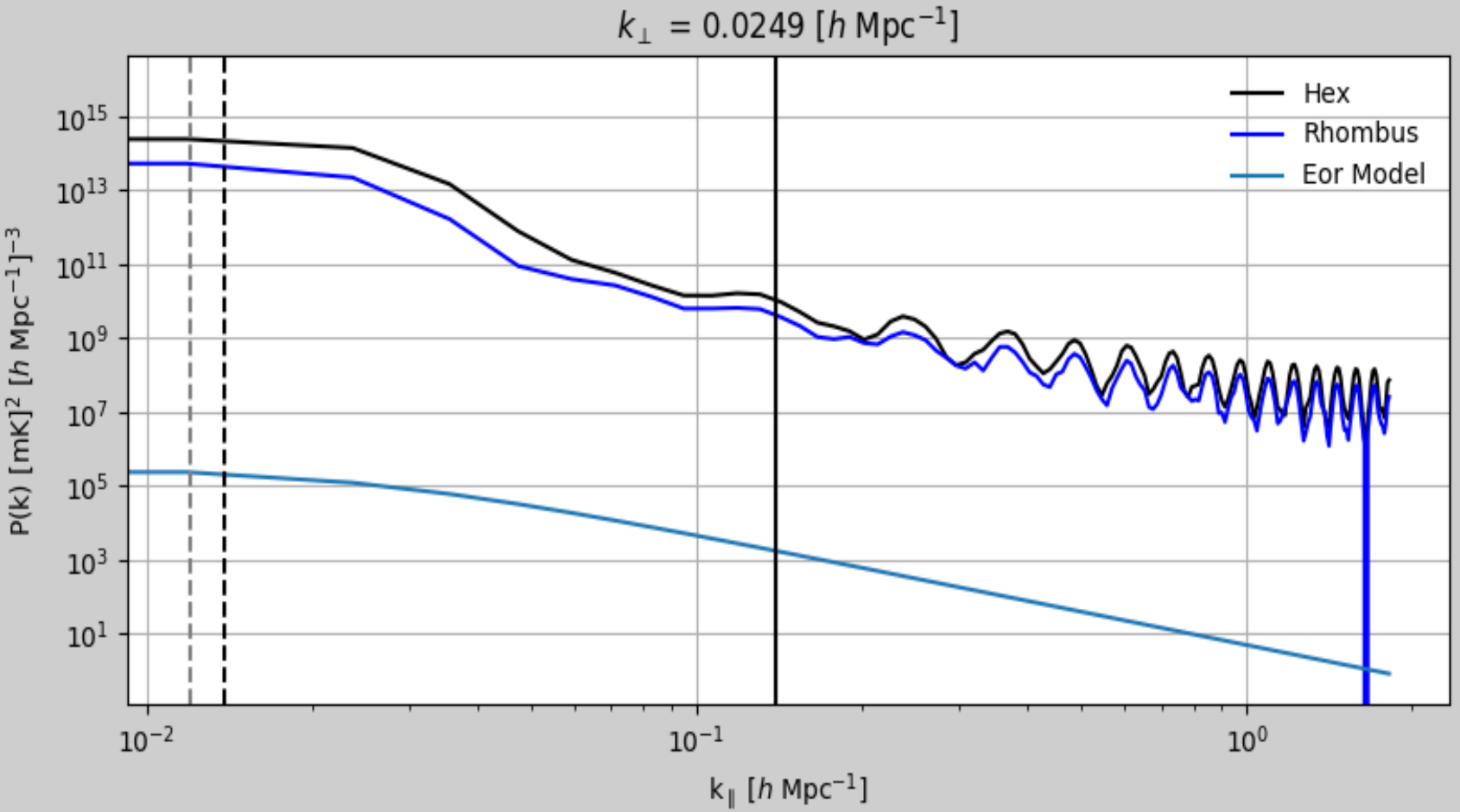


1D Power Spectra cut shows slow roll off of the wedge





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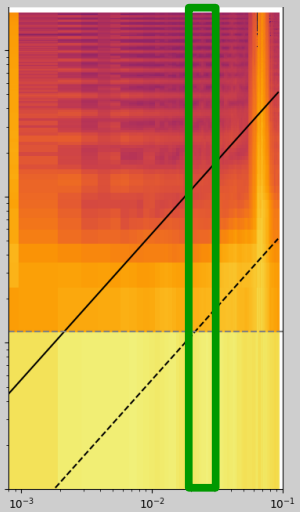
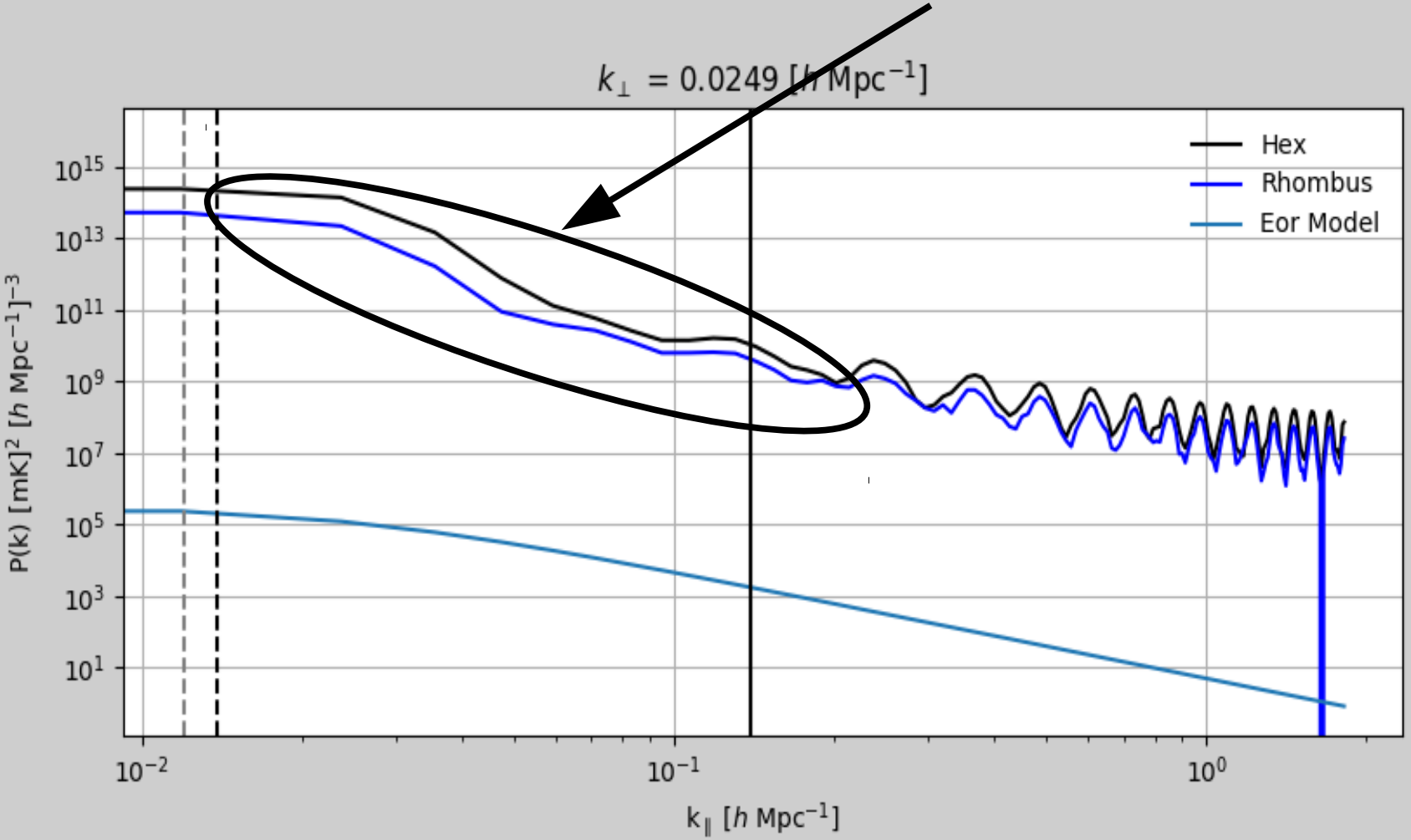
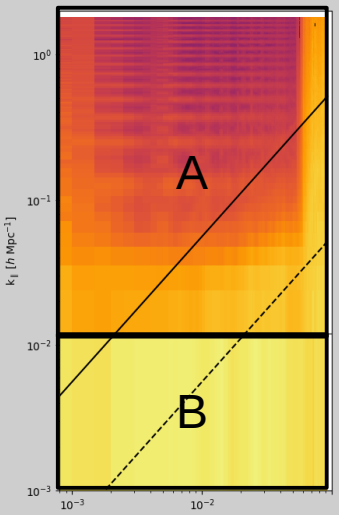
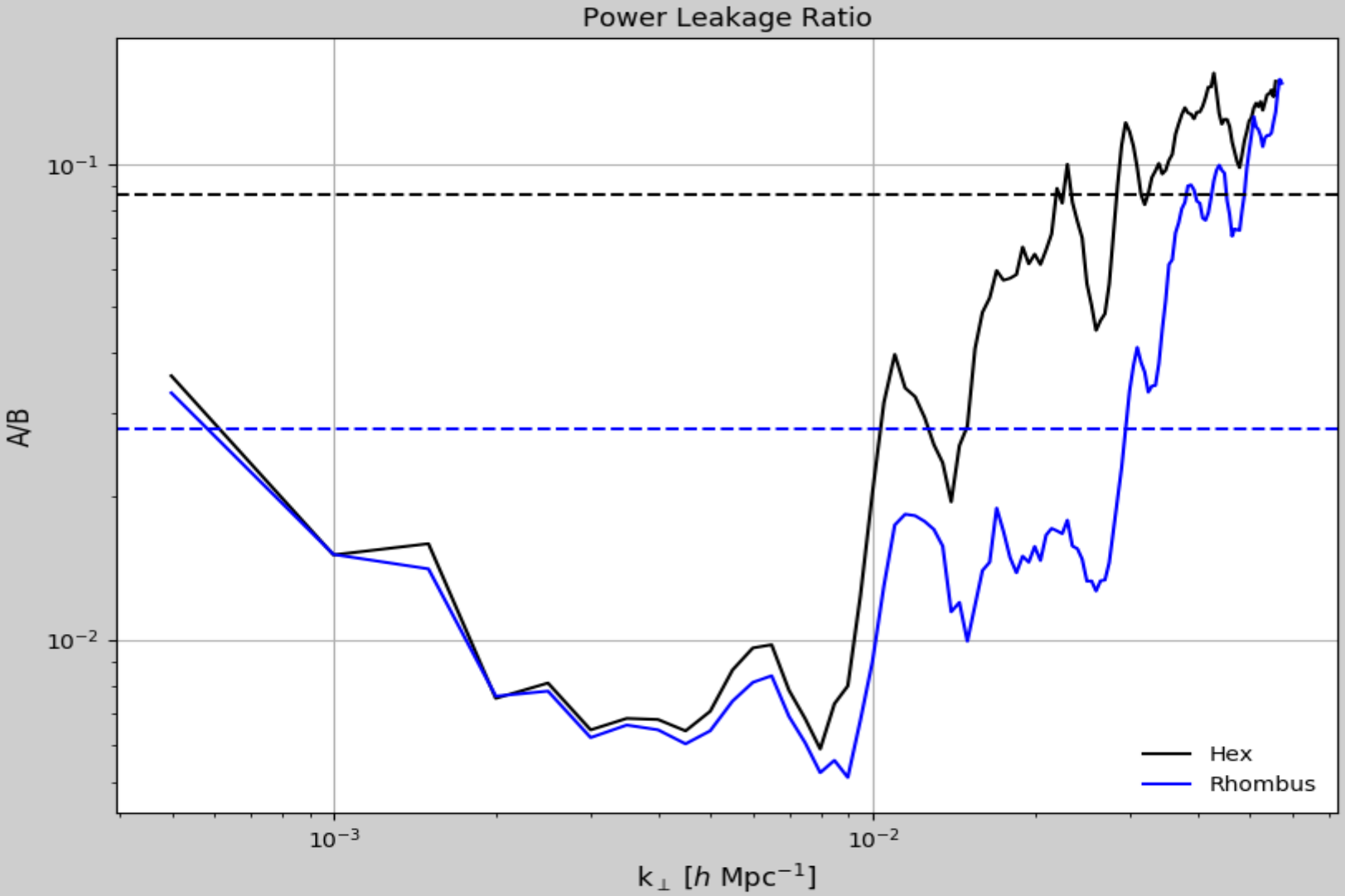


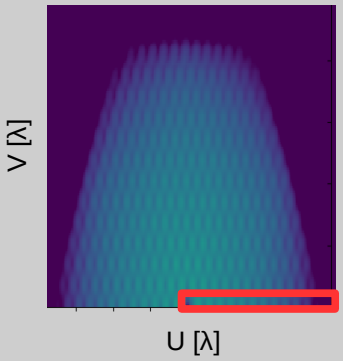


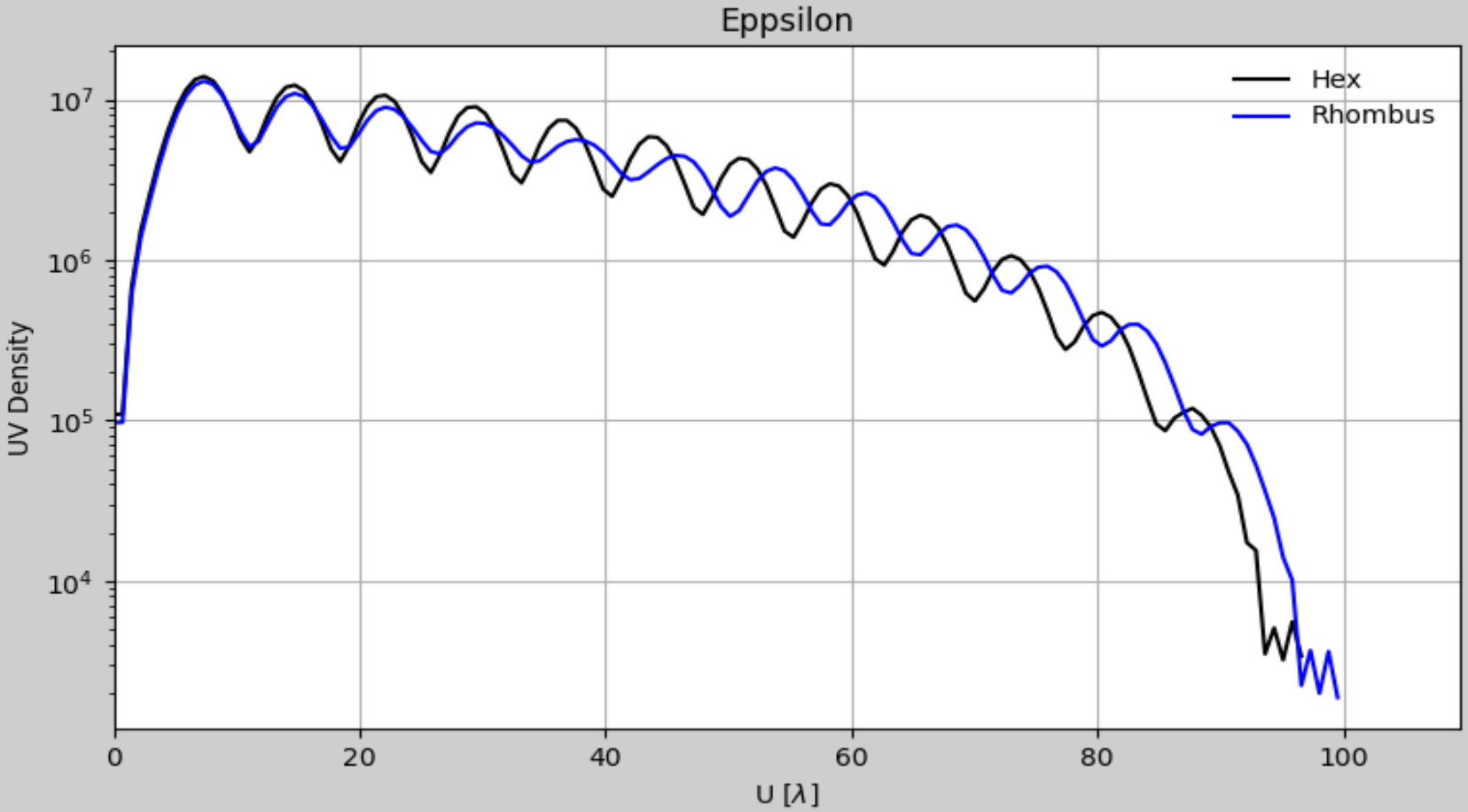
Compare the fractional power above the bandwidth limited bin





Rhombus type array has smoother UV aperture





More Simulations!

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- Time consuming
  - Hundreds of CPU hours

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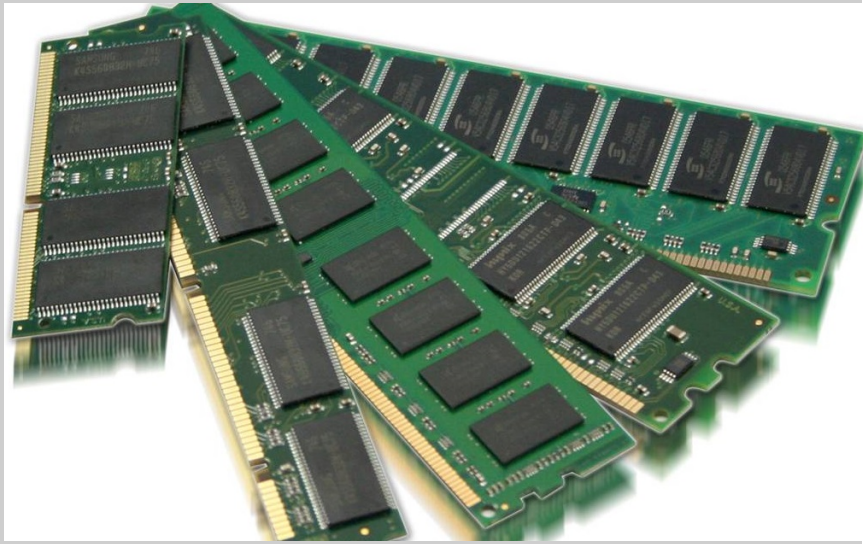
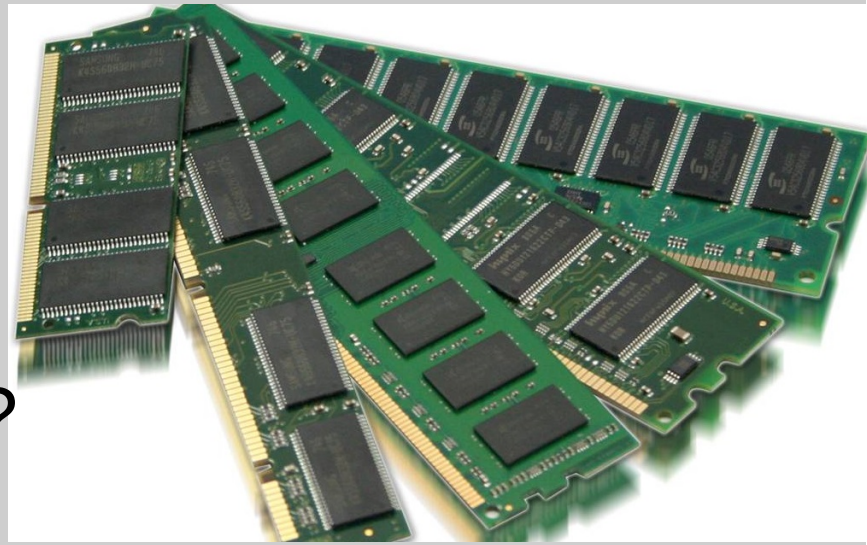
- Time consuming
  - Hundreds of CPU hours
- RAM intensive



More Simulations!

- Time consuming
  - Hundreds of CPU hours
- RAM intensive
- Super Computer?



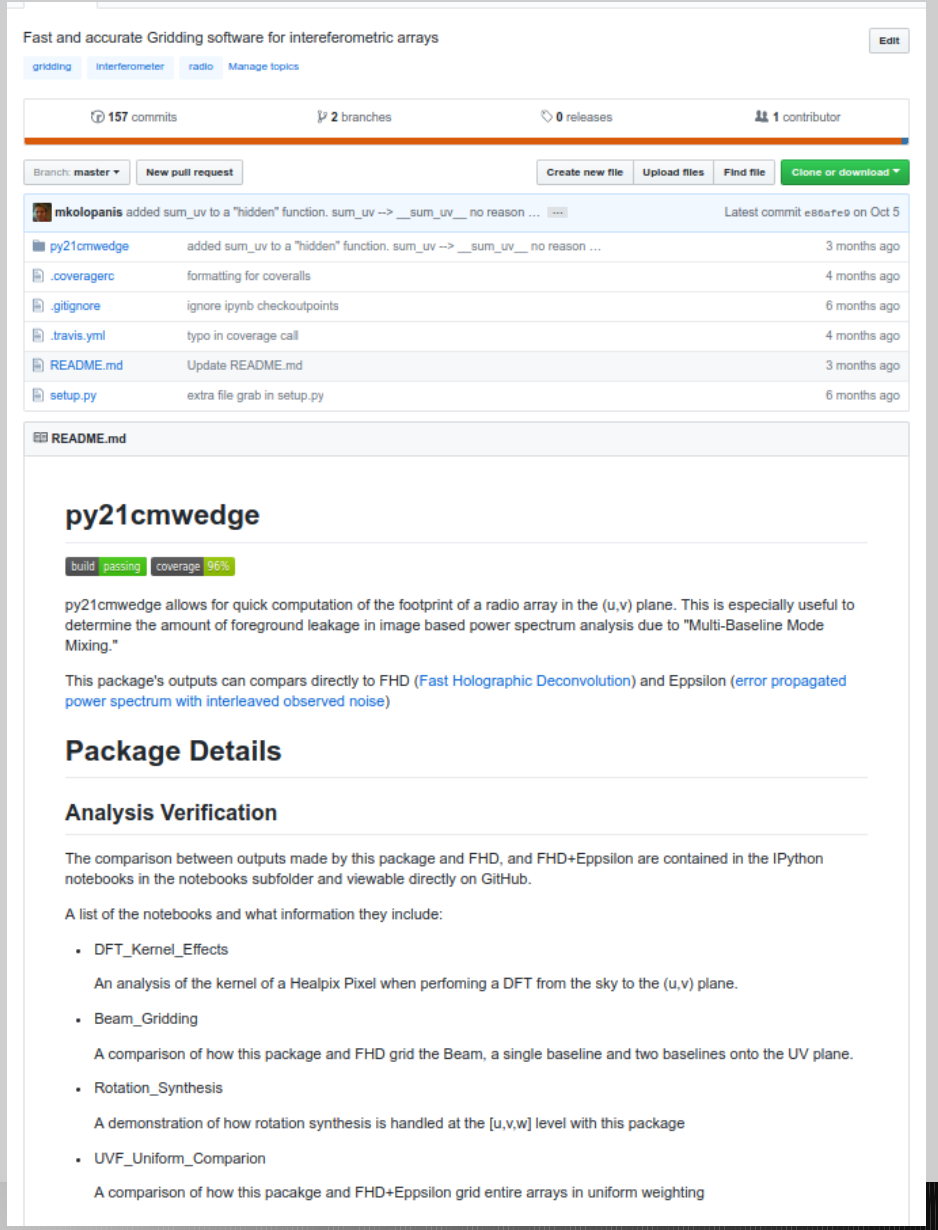
Optimize Foreground Sensitivity With Array Design

- Full Simulations may not be necessary
- Foreground leakage influenced primarily through aperture smoothness
  - **Aperture Smoothness = Beam + Configuration**
- Need to estimate the UV aperture quickly and accurately

Py21cmwedge

- Open source gridding software
- Fast and accurate
- Validated
  - FHD
  - Eppsilon
- Validation Memo Series

github.com/mkolopanis/py21cmwedge



Fast and accurate Gridding software for intereferometric arrays

Edit

gridding interferometer radio Manage topics

157 commits | 2 branches | 0 releases | 1 contributor

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

mkolopanis added sum_uv to a "hidden" function. sum_uv --> __sum_uv__ no reason ... — Latest commit e86afe9 on Oct 5

py21cmwedge	added sum_uv to a "hidden" function. sum_uv --> __sum_uv__ no reason ...	3 months ago
.coveragerc	formatting for coveralls	4 months ago
.gitignore	ignore ipynb checkoutpoints	6 months ago
.travis.yml	typo in coverage call	4 months ago
README.md	Update README.md	3 months ago
setup.py	extra file grab in setup.py	6 months ago

README.md

py21cmwedge

build passing coverage 96%

py21cmwedge allows for quick computation of the footprint of a radio array in the (u,v) plane. This is especially useful to determine the amount of foreground leakage in image based power spectrum analysis due to "Multi-Baseline Mode Mixing."

This package's outputs can compars directly to FHD (Fast Holographic Deconvolution) and Eppsilon (error propagated power spectrum with interleaved observed noise)

Package Details

Analysis Verification

The comparison between outputs made by this package and FHD, and FHD+Eppsilon are contained in the IPython notebooks in the notebooks subfolder and viewable directly on GitHub.

A list of the notebooks and what information they include:

- DFT_Kernel_Effects

  An analysis of the kernel of a Healpix Pixel when perfoming a DFT from the sky to the (u,v) plane.

- Beam_Gridding

  A comparison of how this package and FHD grid the Beam, a single baseline and two baselines onto the UV plane.

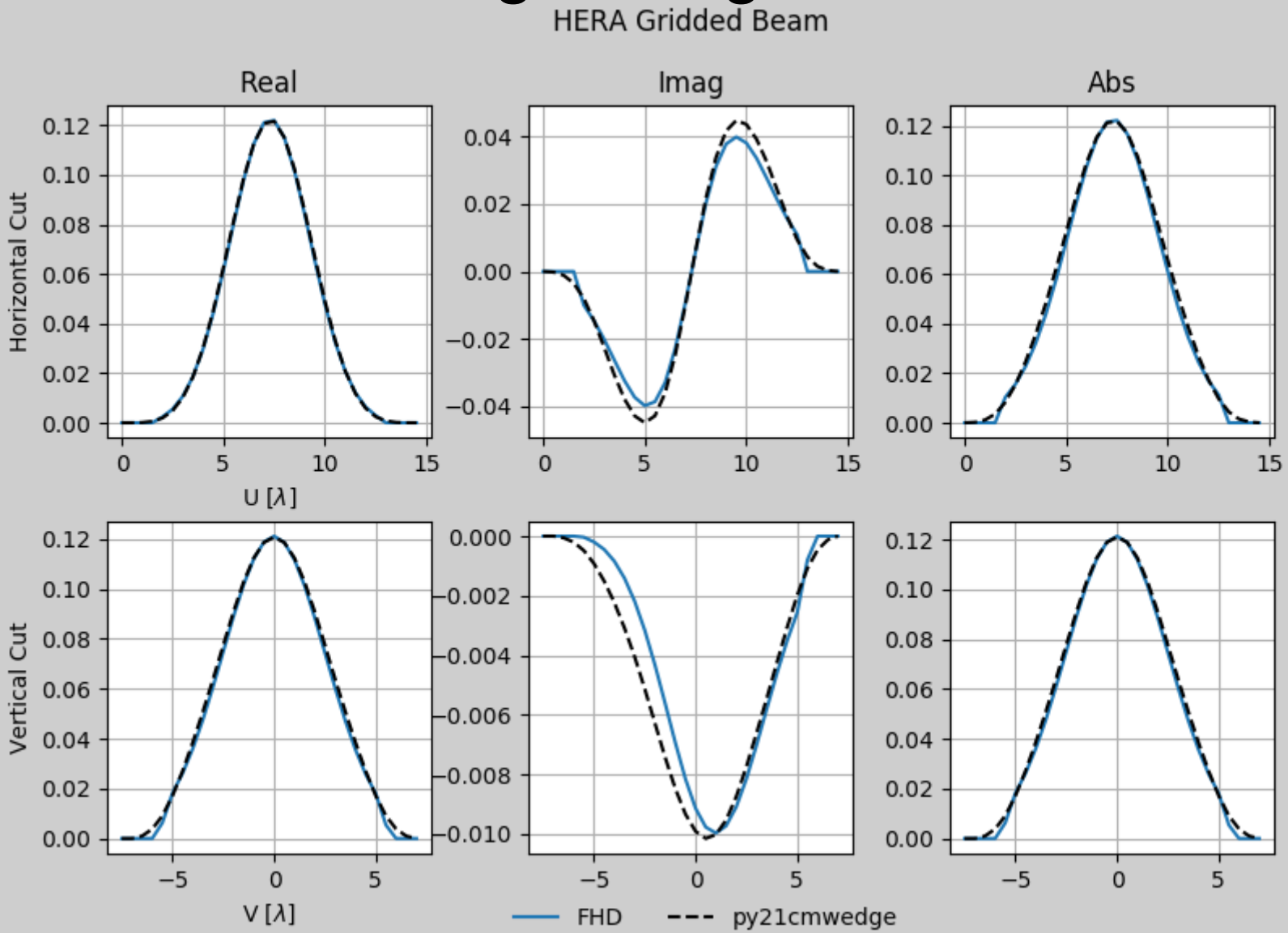
- Rotation_Synthesis

  A demonstration of how rotation synthesis is handled at the [u,v,w] level with this package

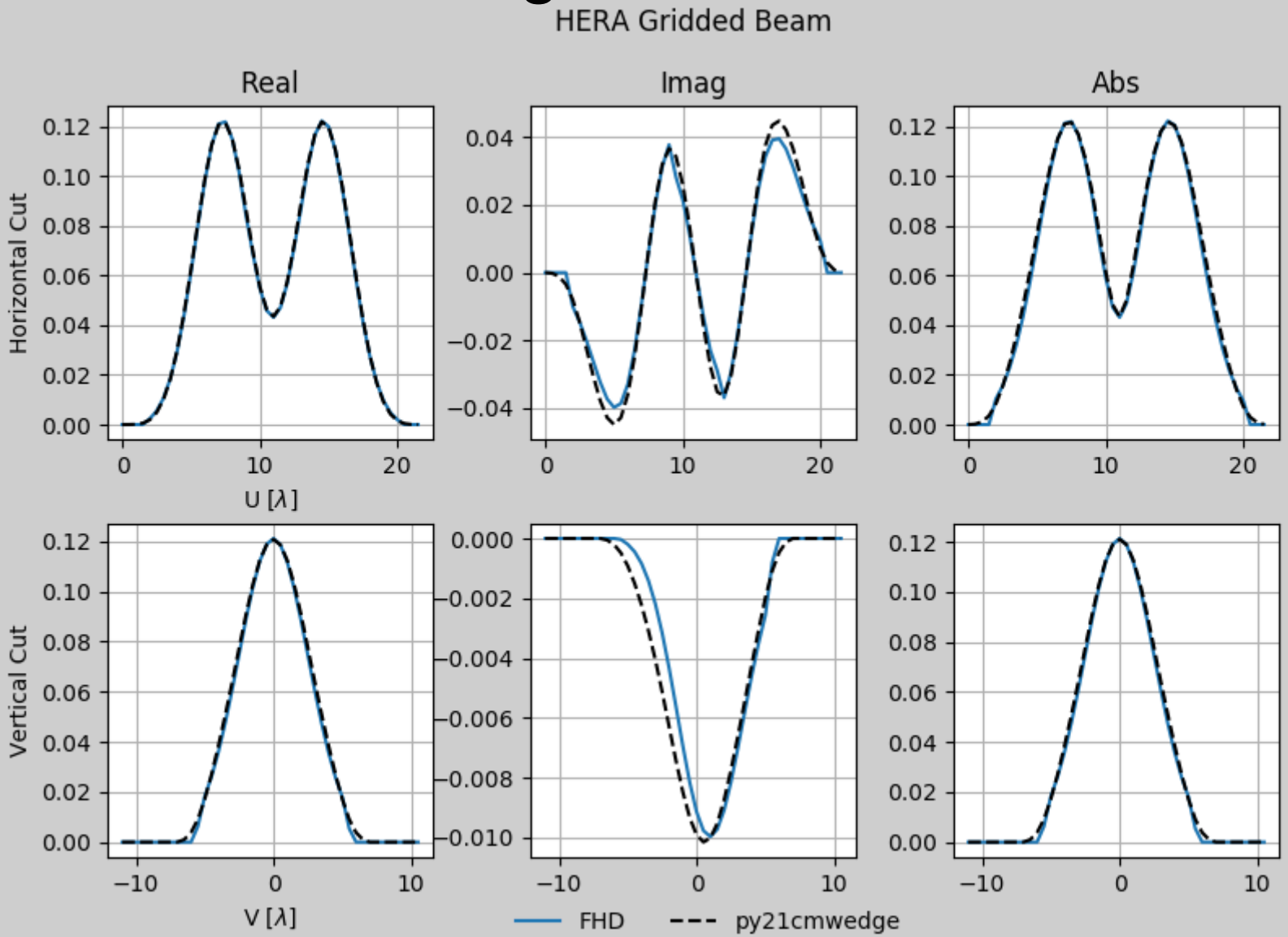
- UVF_Uniform_Comparion

  A comparison of how this pacakge and FHD+Eppsilon grid entire arrays in uniform weighting

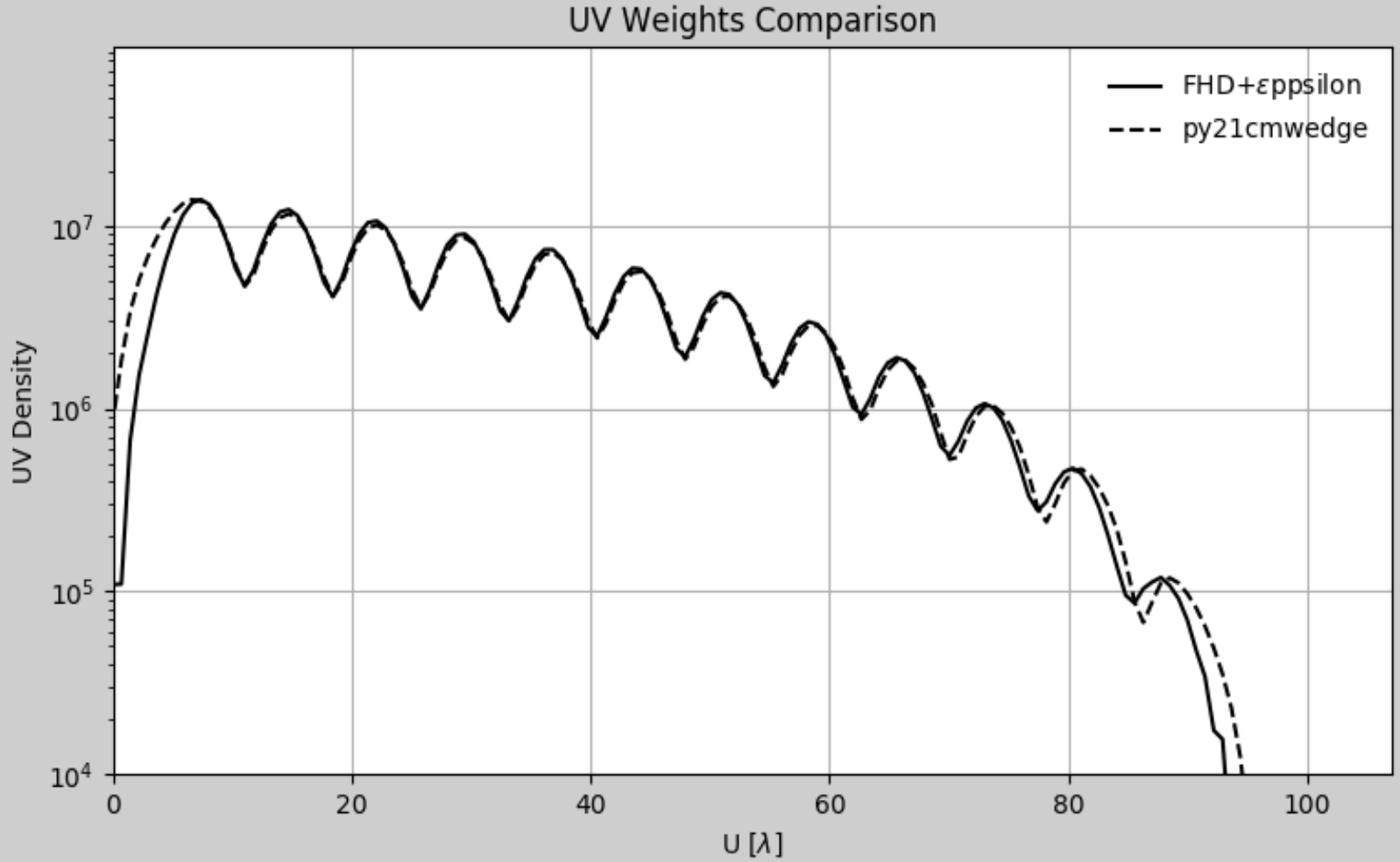
Example Validation: Gridding a Single Baseline



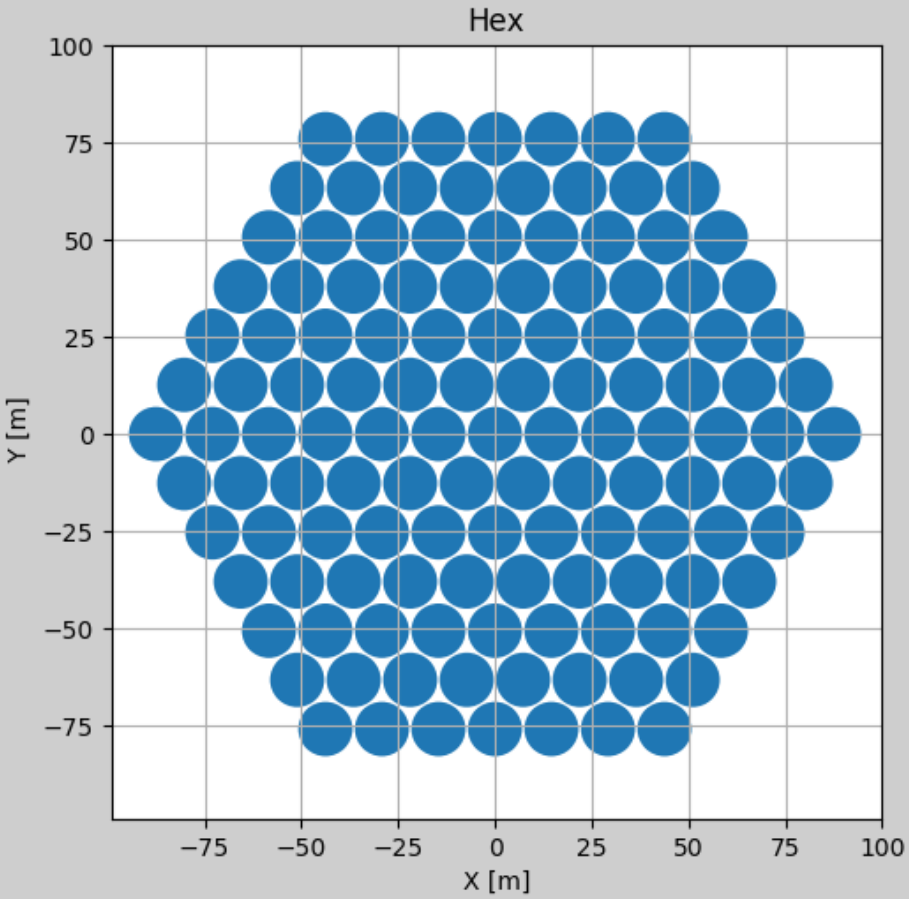
Example Validation: Adding Two Baselines

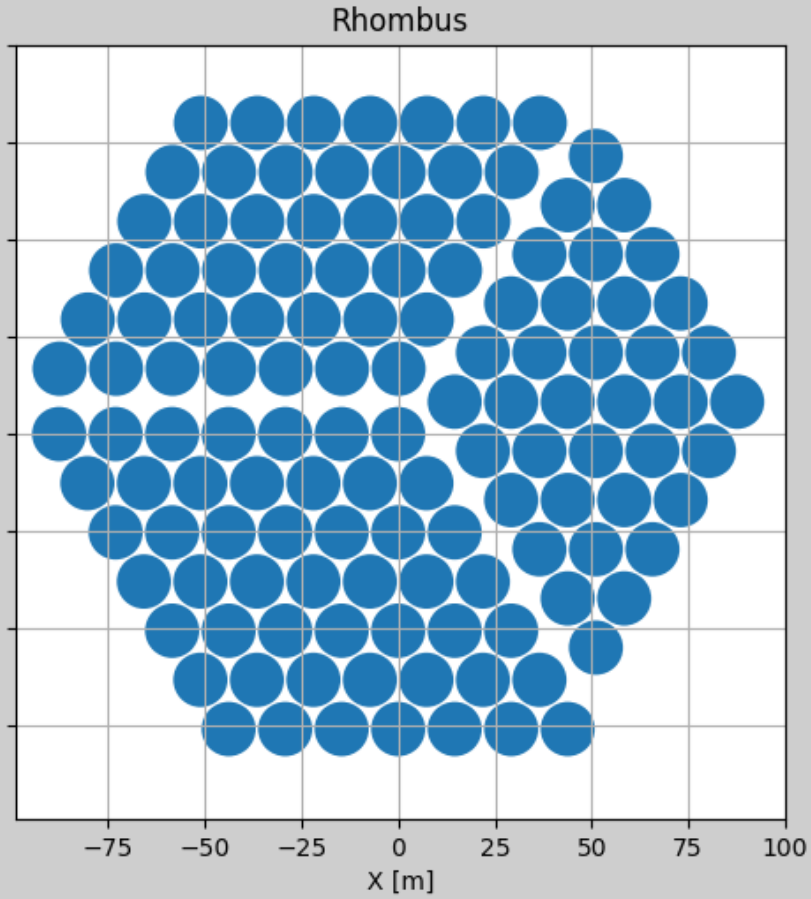


Example Validation: Comparing full array against existing pipe

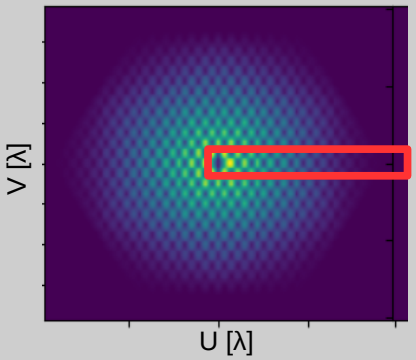


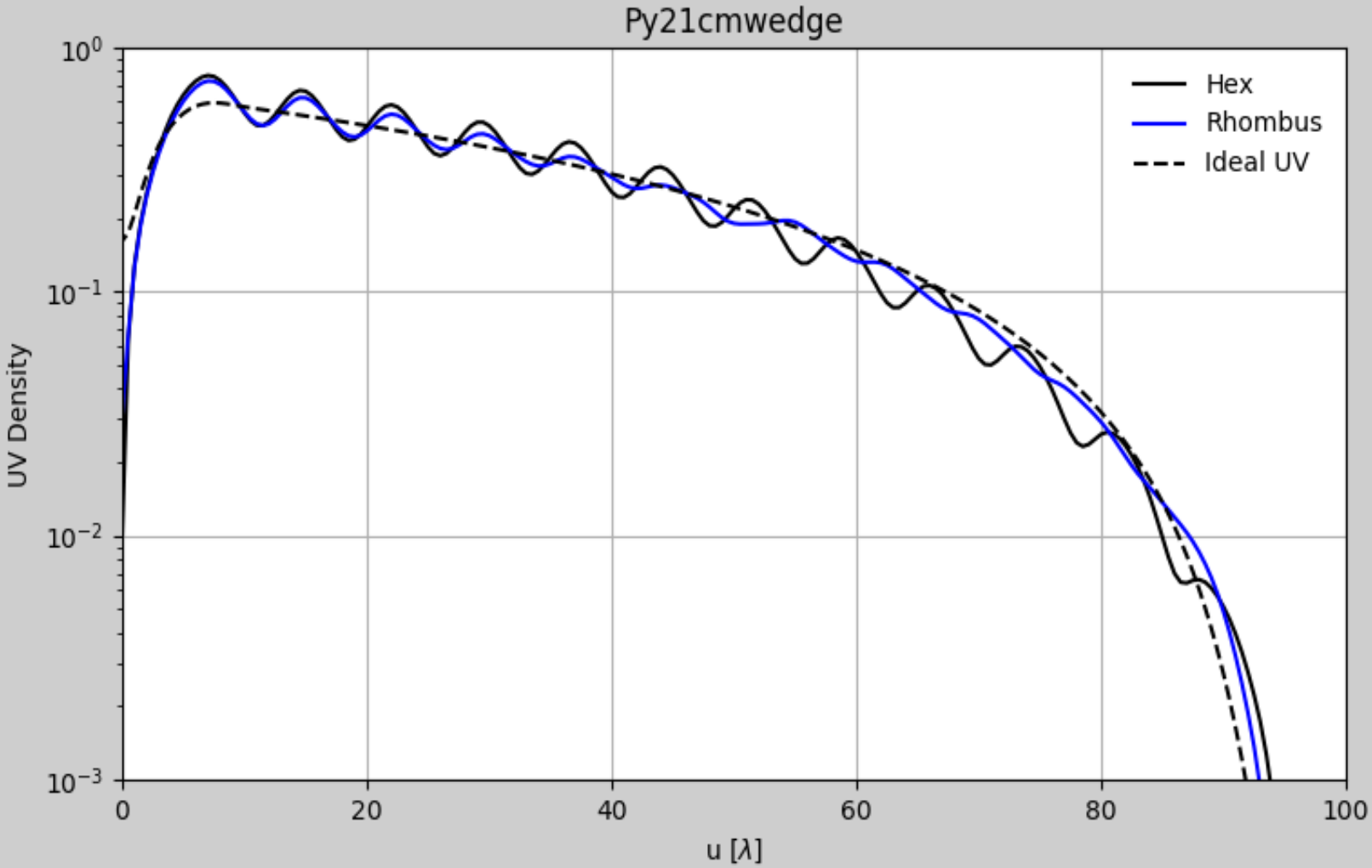
What about those Arrays?



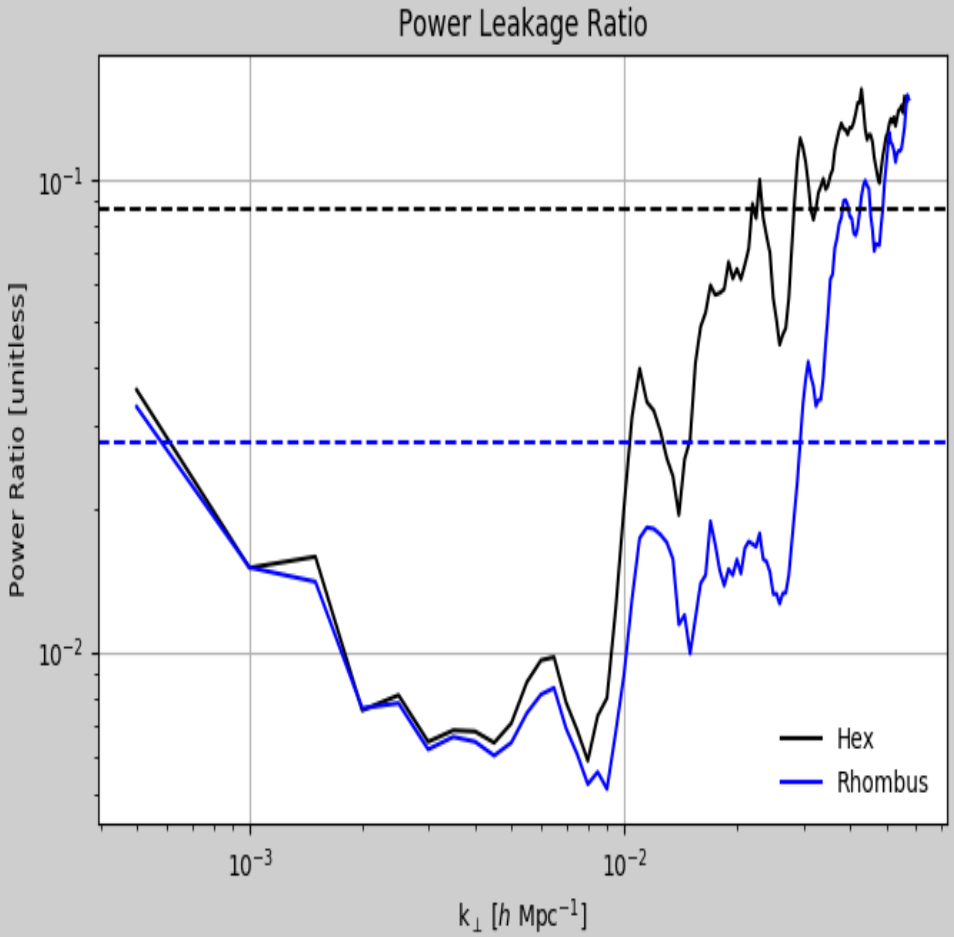


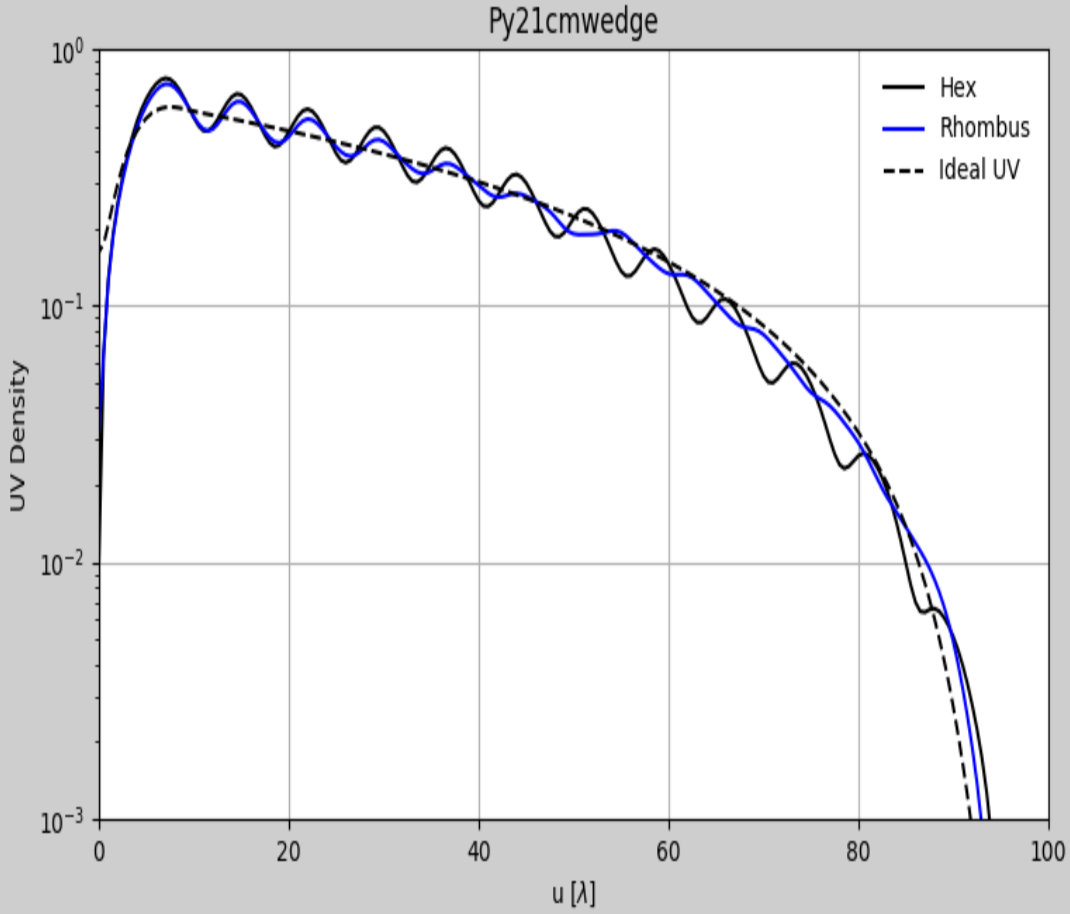
Affect of HERA configuration dither on UV smoothness





Calibrate Full Simulations against UV-Weights calculation

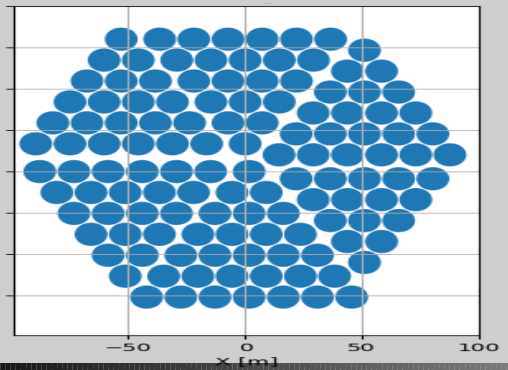


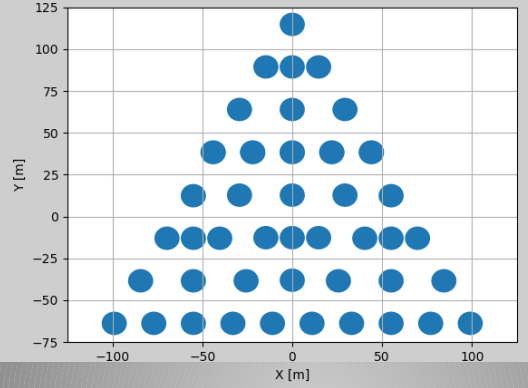


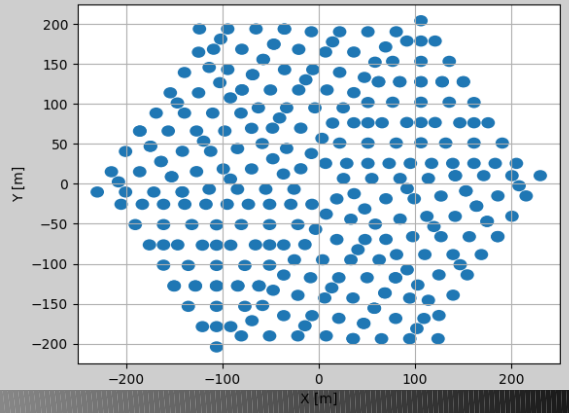
Summary:

- UV Aperture (configuration + beam) mixes with foregrounds to cause the wedge
- Exact nature and characteristics of foregrounds not important to minimize wedge leakage

- Possible to estimate “wediness” of array through single frequency aperture estimation
- Py21cmwedge perform this calculation
- Coming Soon:
  - firmer calibration of wedge excess against aperture calculation array optimization tool







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