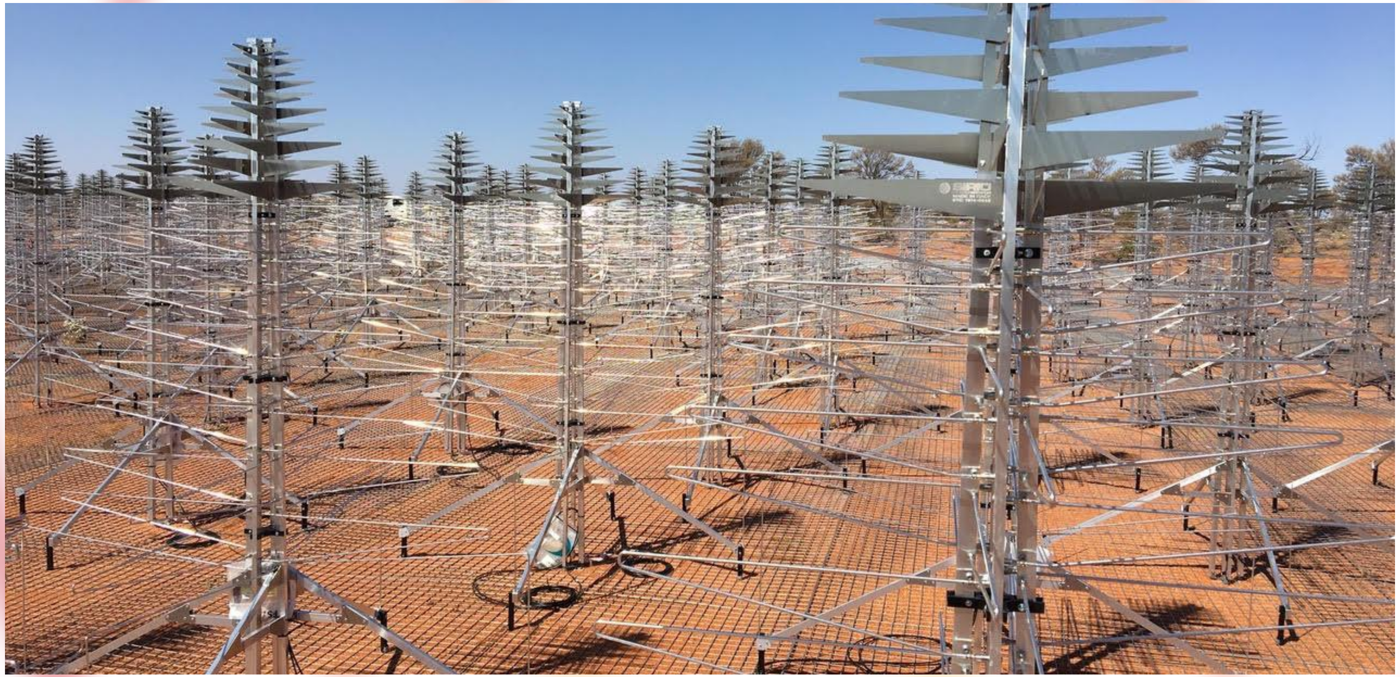


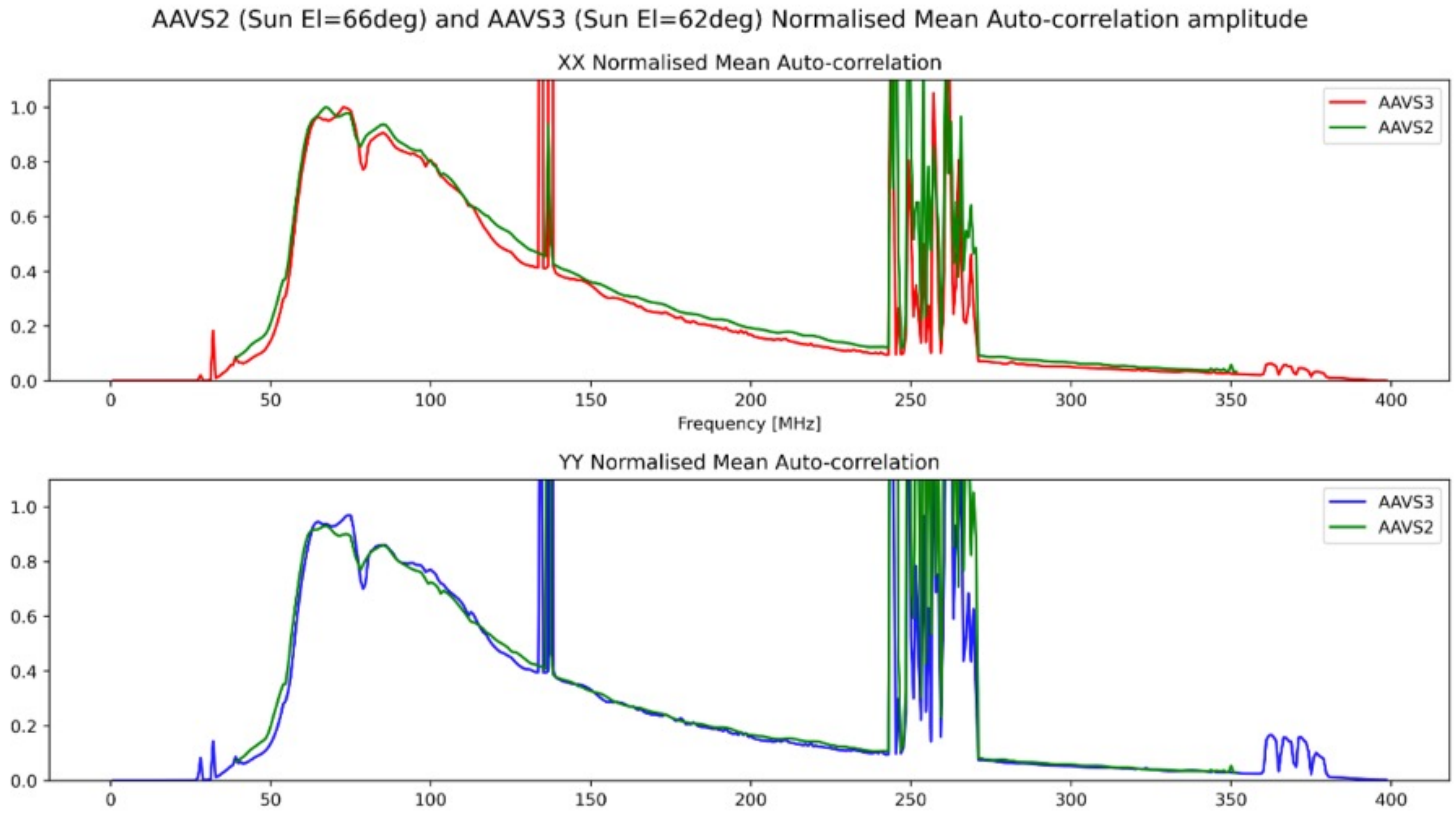
Chromaticity in SKA-low stations

Lister Staveley-Smith ICRAR

International Centre for Radio Astronomy Research

Curtin University
GOVERNMENT OF WESTERN AUSTRALIA
THE UNIVERSITY OF WESTERN AUSTRALIA

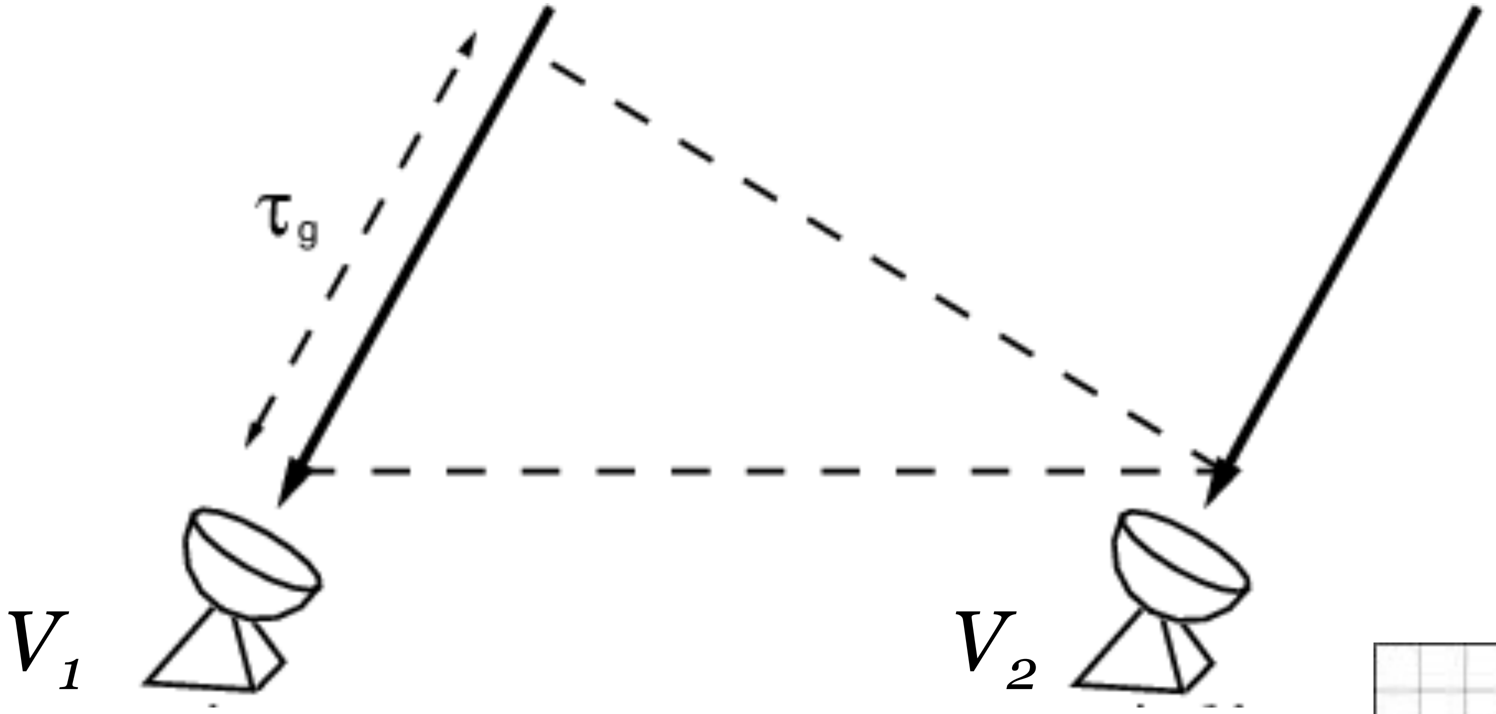
ICRAR is a joint venture between Curtin University and The University of Western Australia and receives support from the Western Australian and Australian Governments.



[credit: Marcin, Shin'Ichiro, SciOps]

Connected to SKAO AU SOC VPN (AU).

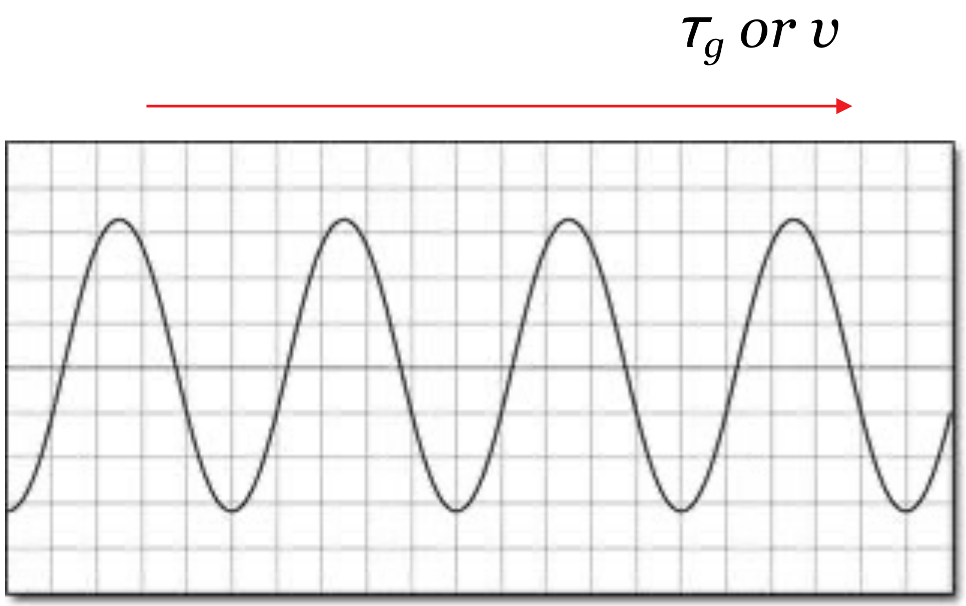
Interferometers are chromatic



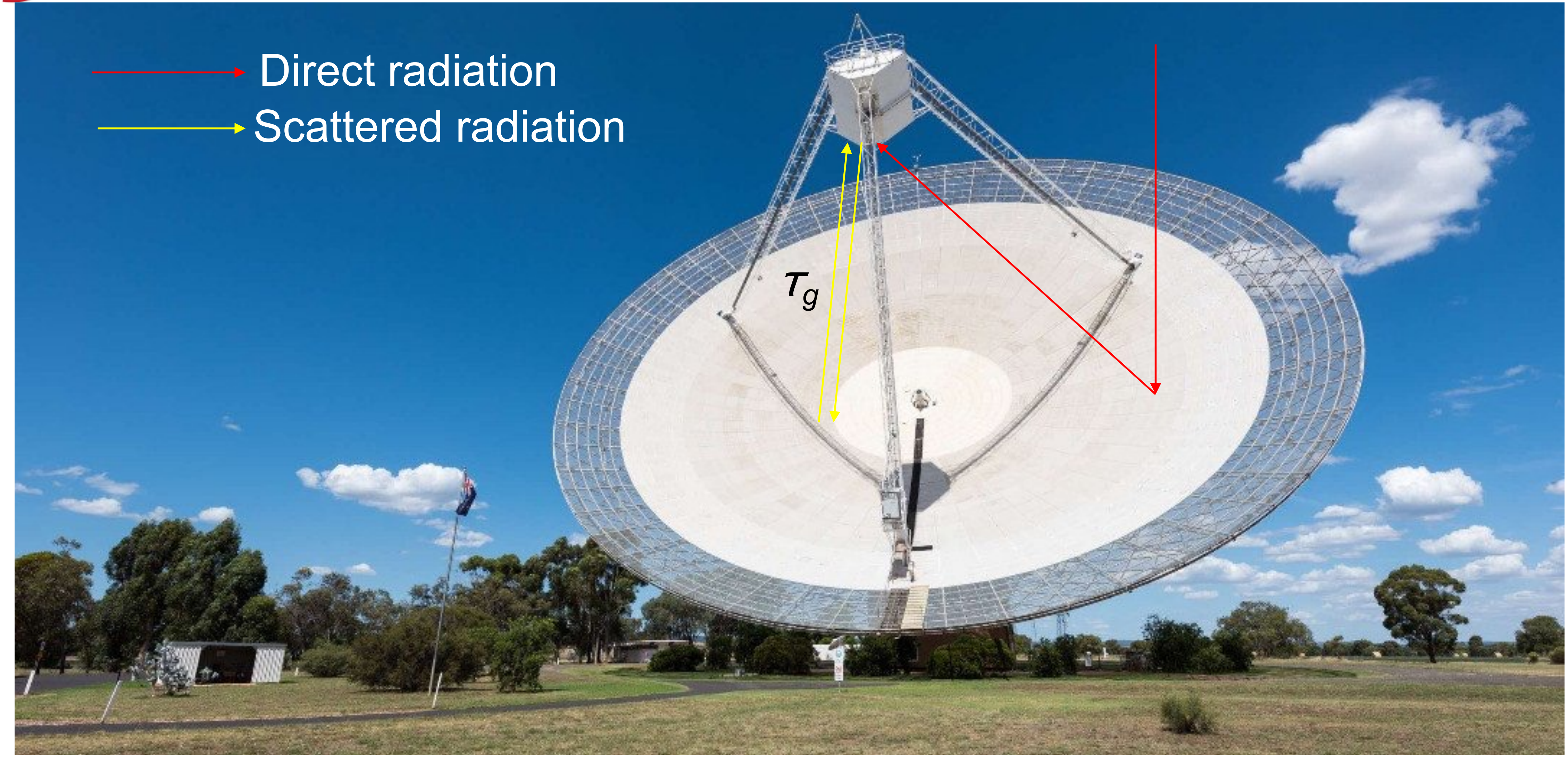
$$V_1(t) = a_1 \cos 2\pi\nu(t - \tau_g)$$

$$V_2(t) = a_2 \cos 2\pi\nu t$$

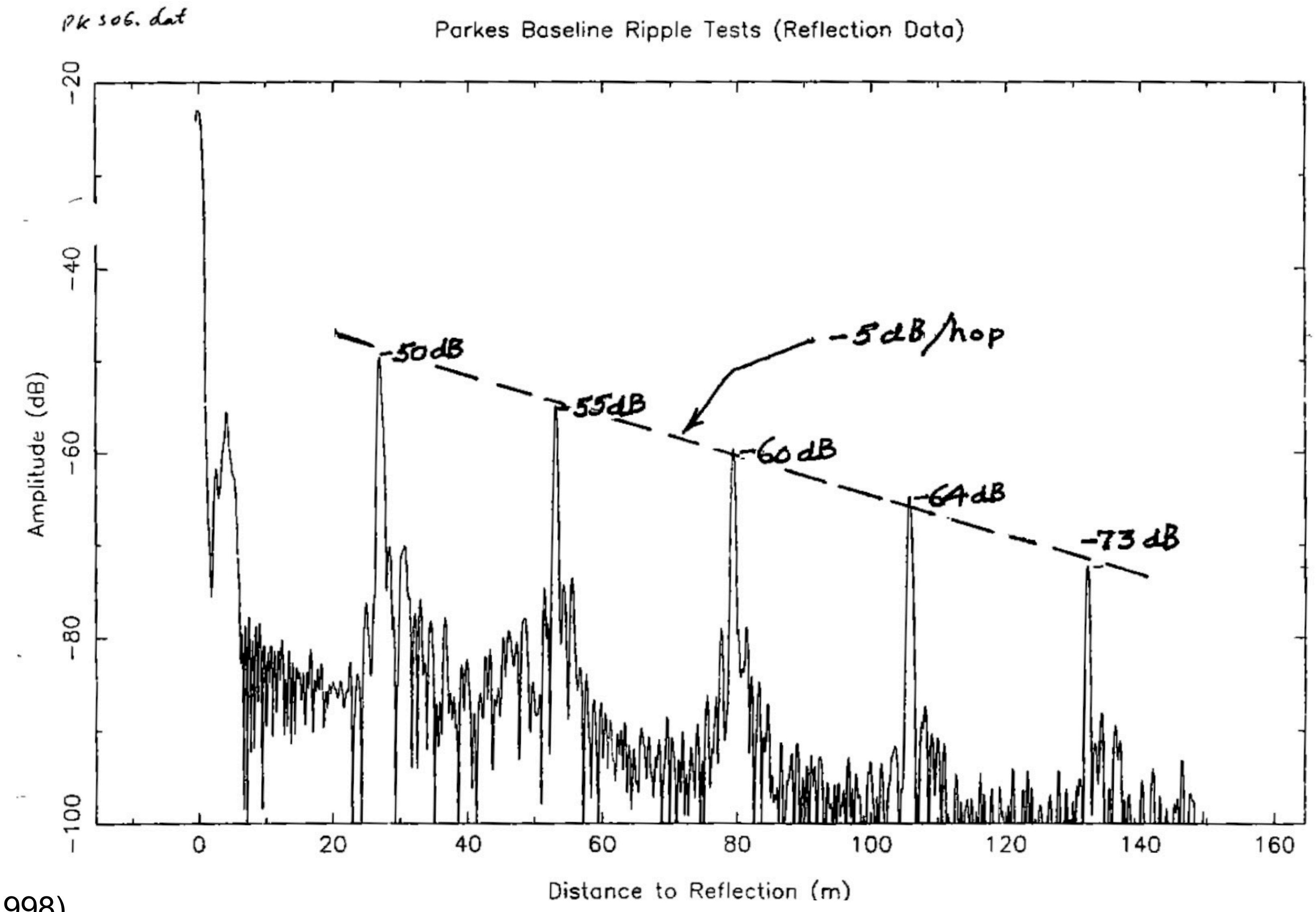
$$\Rightarrow \langle V_1(t) V_2(t) \rangle = a_1 a_2 \cos 2\pi\nu\tau_g$$



Single dish/station interference



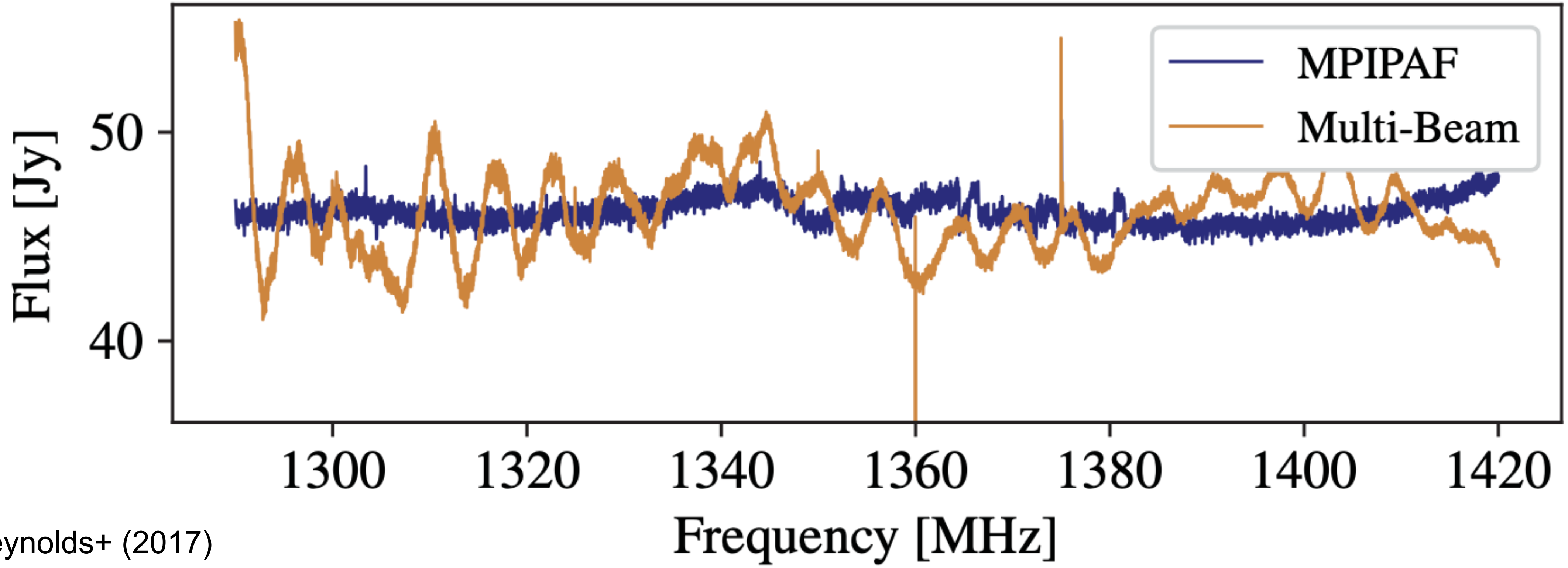
Reflectometry



Graves & Thomas (1998)

Example

- Scattered power is small but scattered electric field is large!



T.Reynolds+ (2017)

Power spectra via WK theorem

$$\text{Autocorrelation Function :}$$

$$A(\tau) = V * V(\tau) \quad = \quad \int V(t)V(t+\tau)dt$$

$$\text{Convolution theorem :}$$

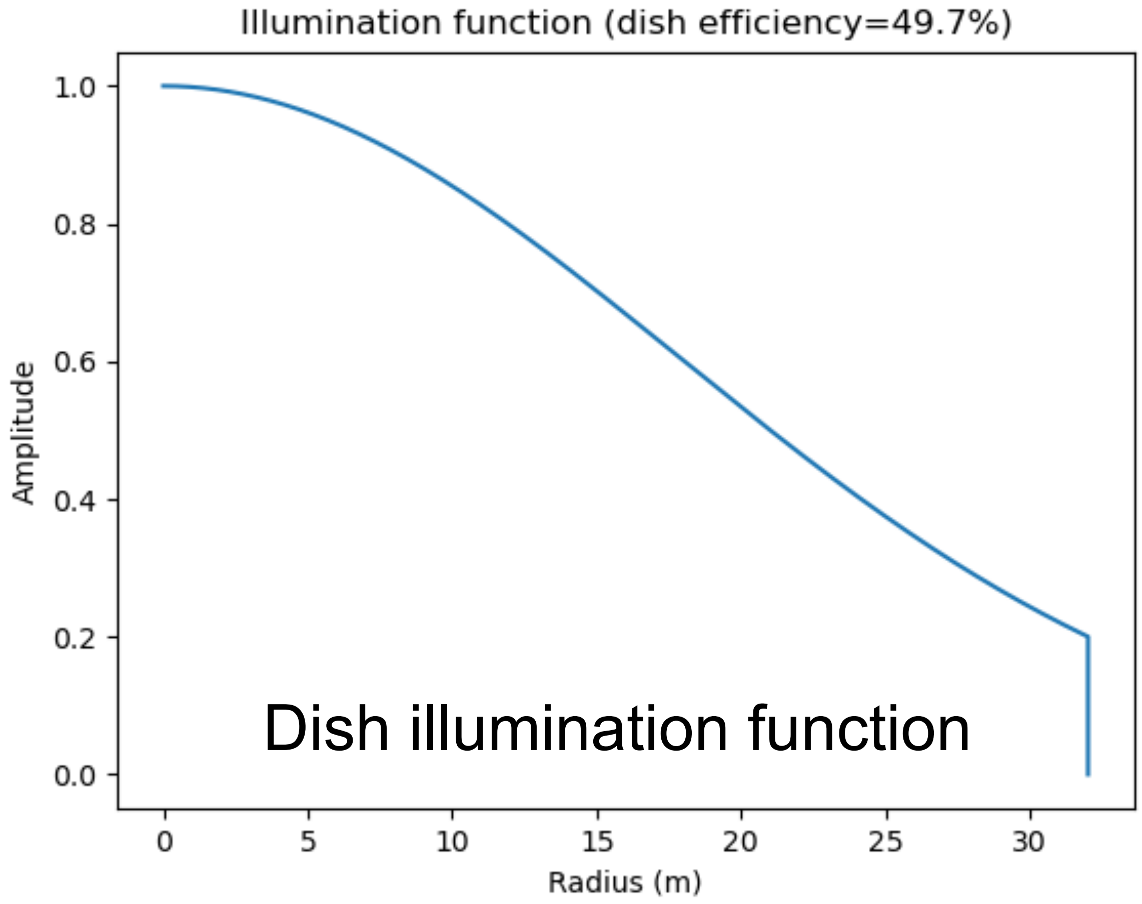
$$FT[g * h] \quad = \quad FT[g] \times FT[h]$$

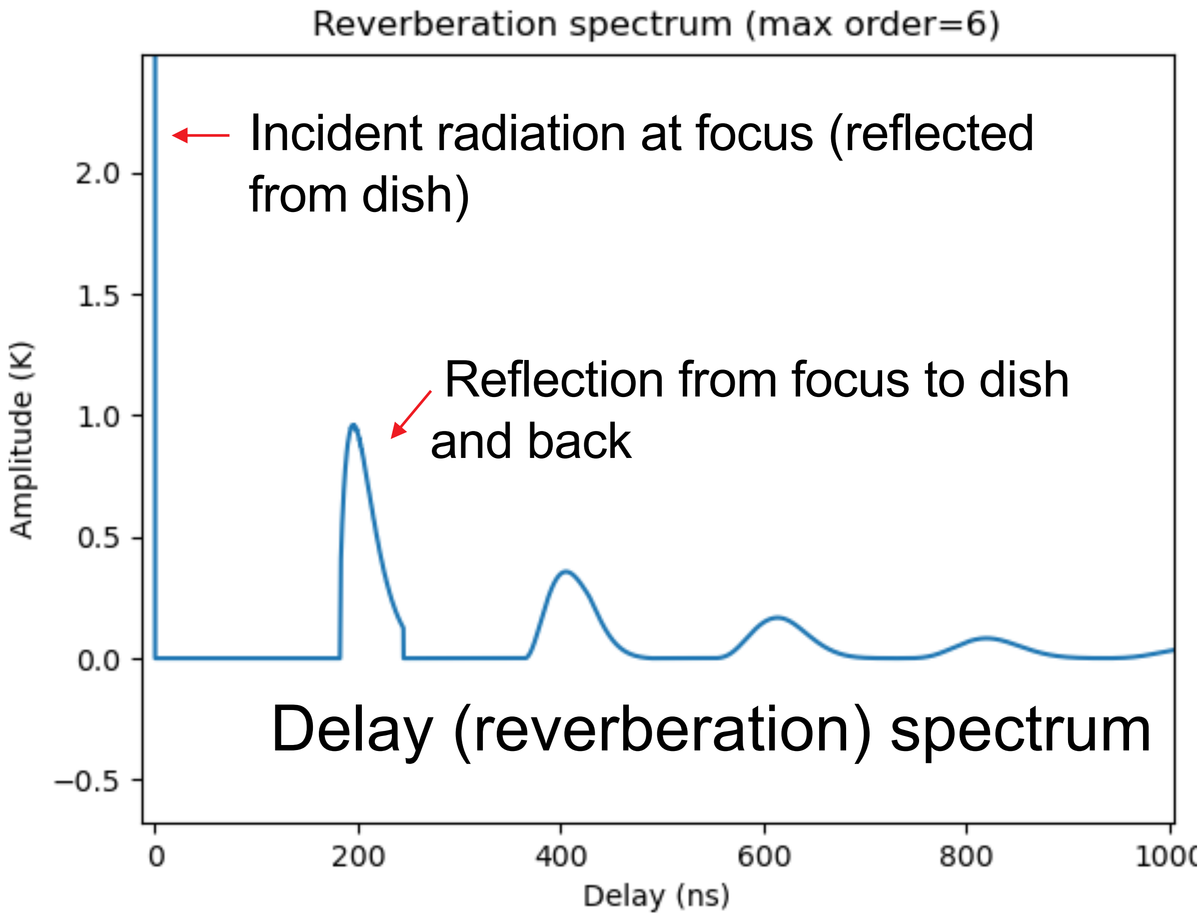
$$\text{Weiner} - \text{Khinchin theorem :}$$

$$\Rightarrow FT[A(\tau)] \quad = \quad |FT[V]|^2 = S(\nu)$$

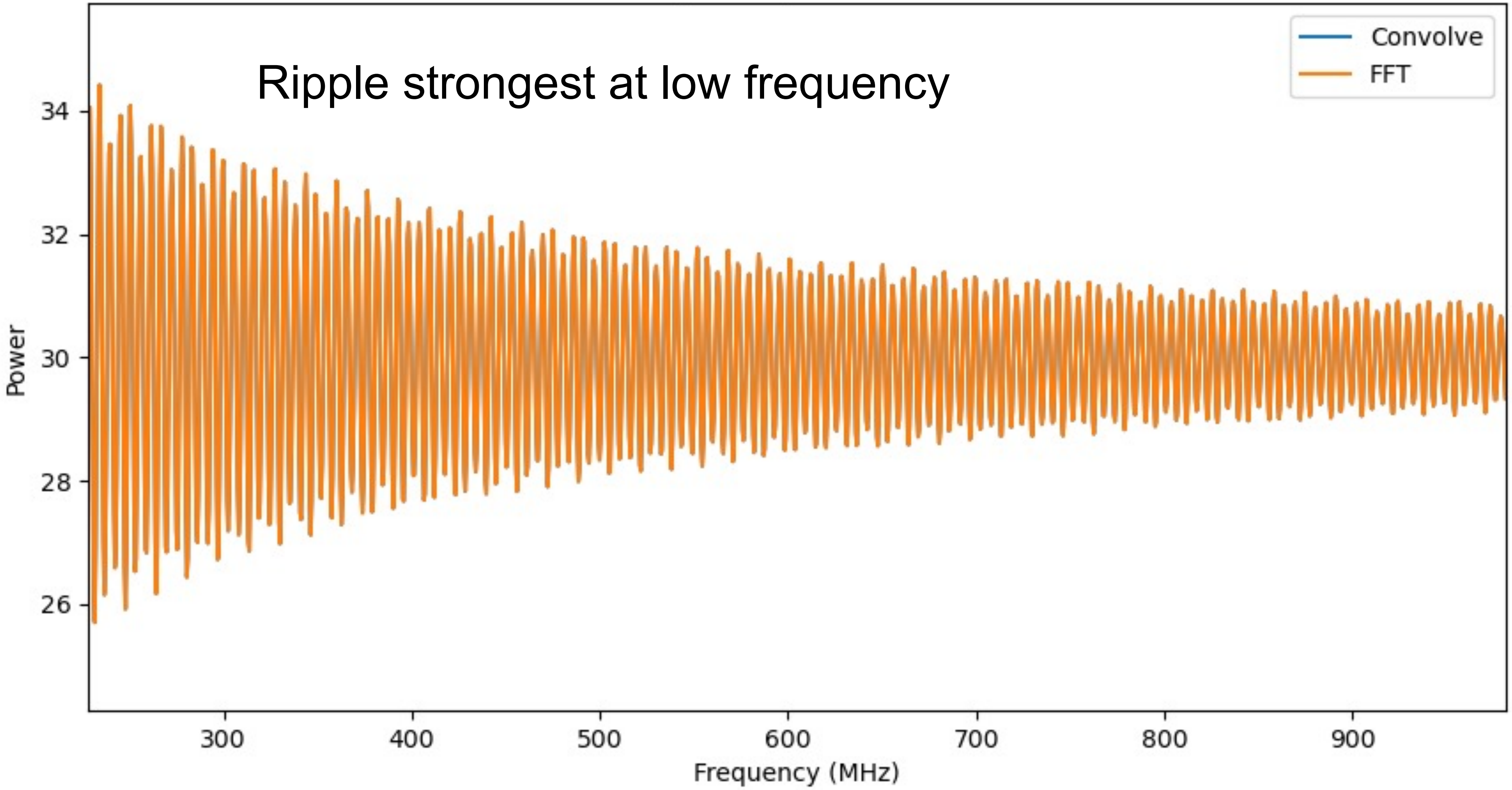
- Applies to stationary processes where delay and frequency are separable.
- Computational easy XF approach, as opposed to FX approach.

Delay spectrum





Power spectrum via WK

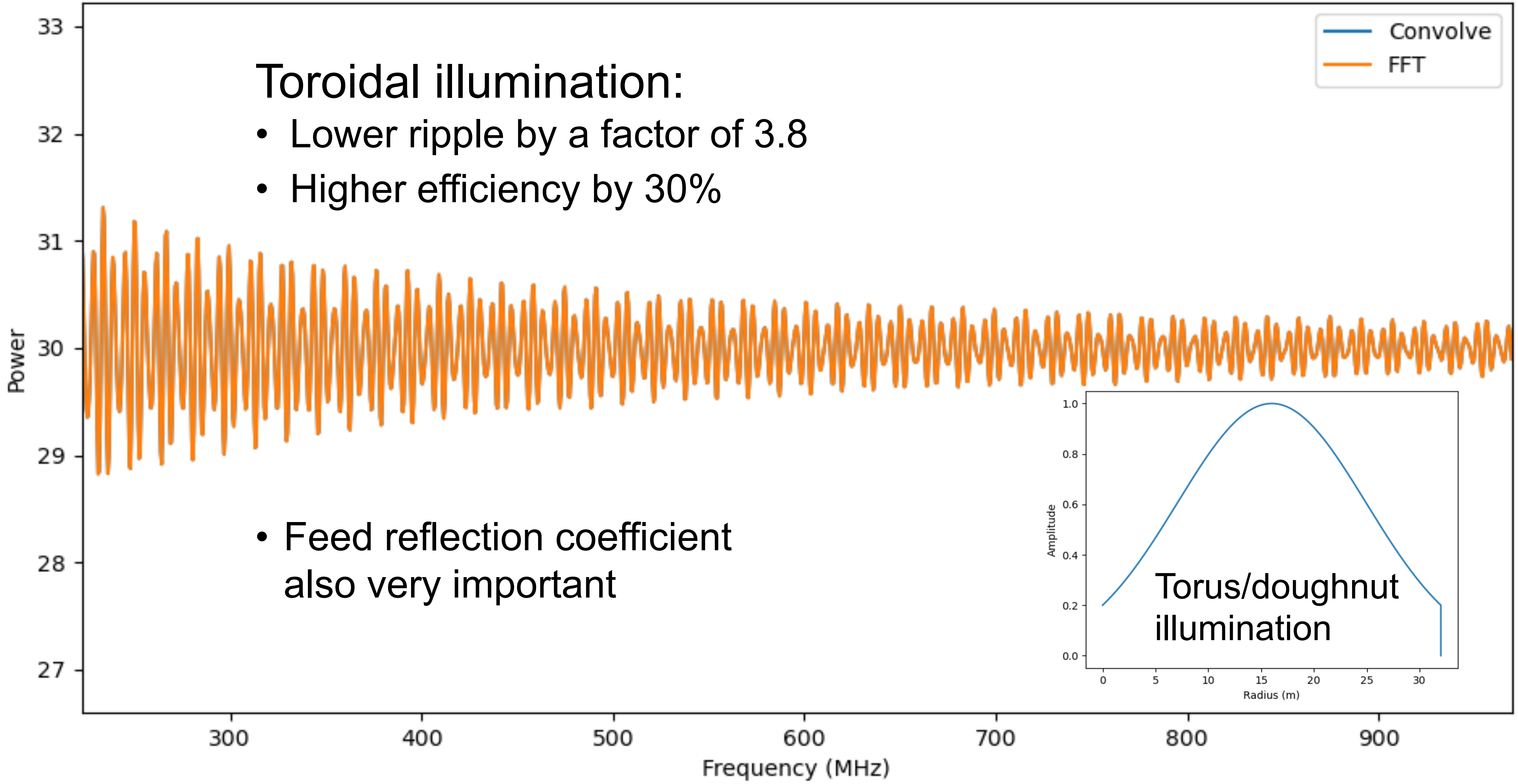


Modifying the illumination function

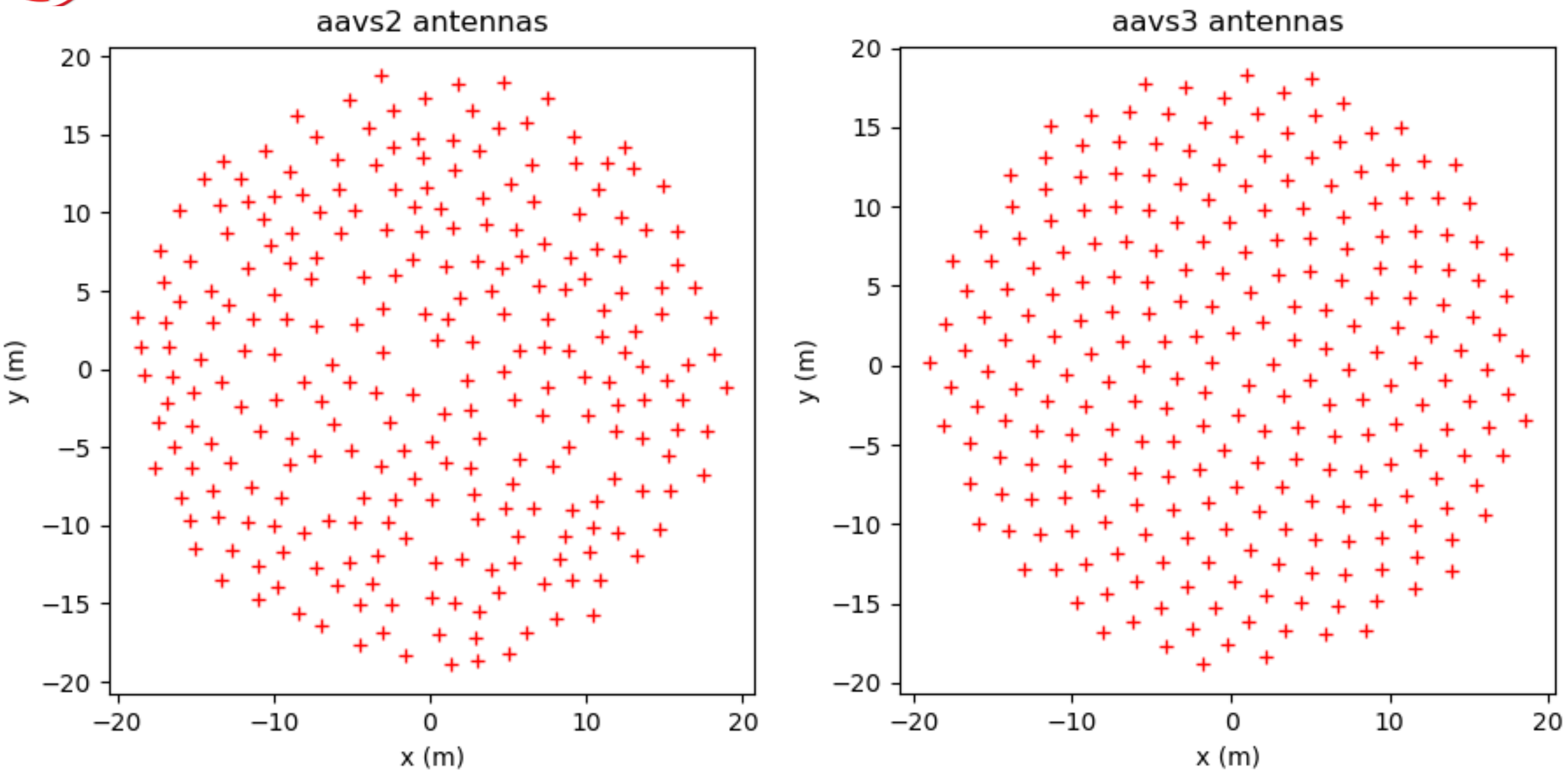
Toroidal illumination:

- Lower ripple by a factor of 3.8
- Higher efficiency by 30%

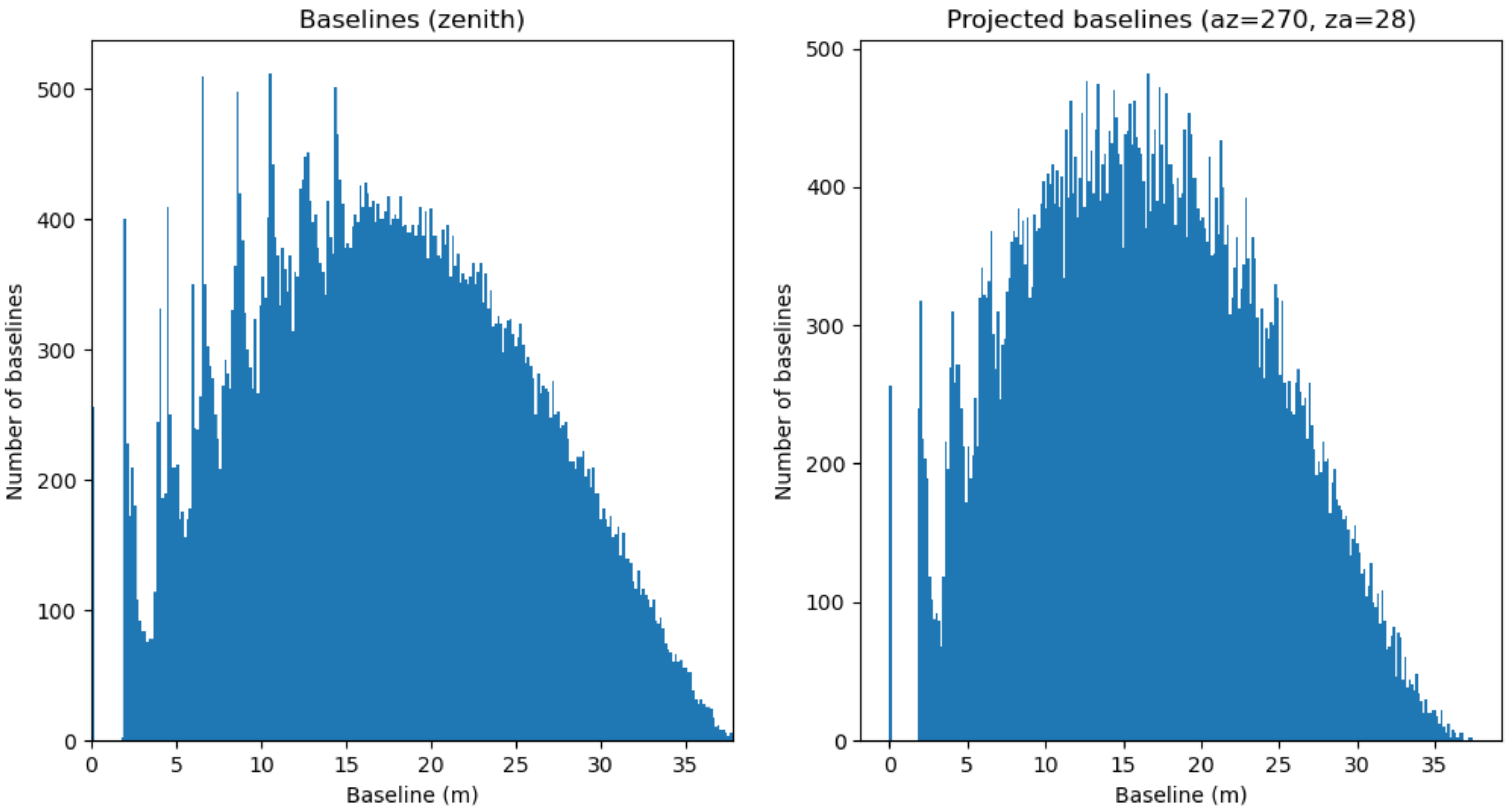
- Feed reflection coefficient also very important



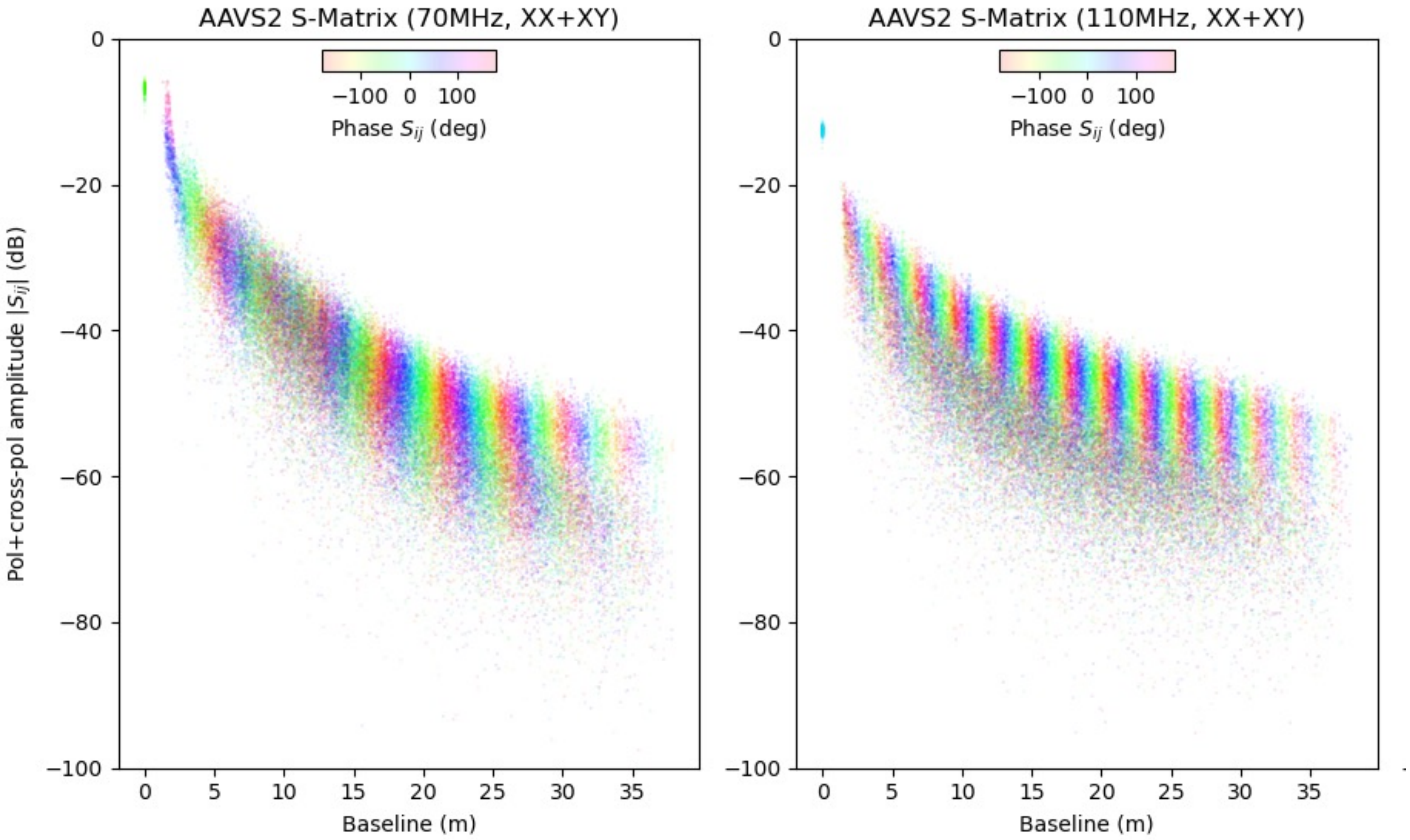
SKA-low prototype stations



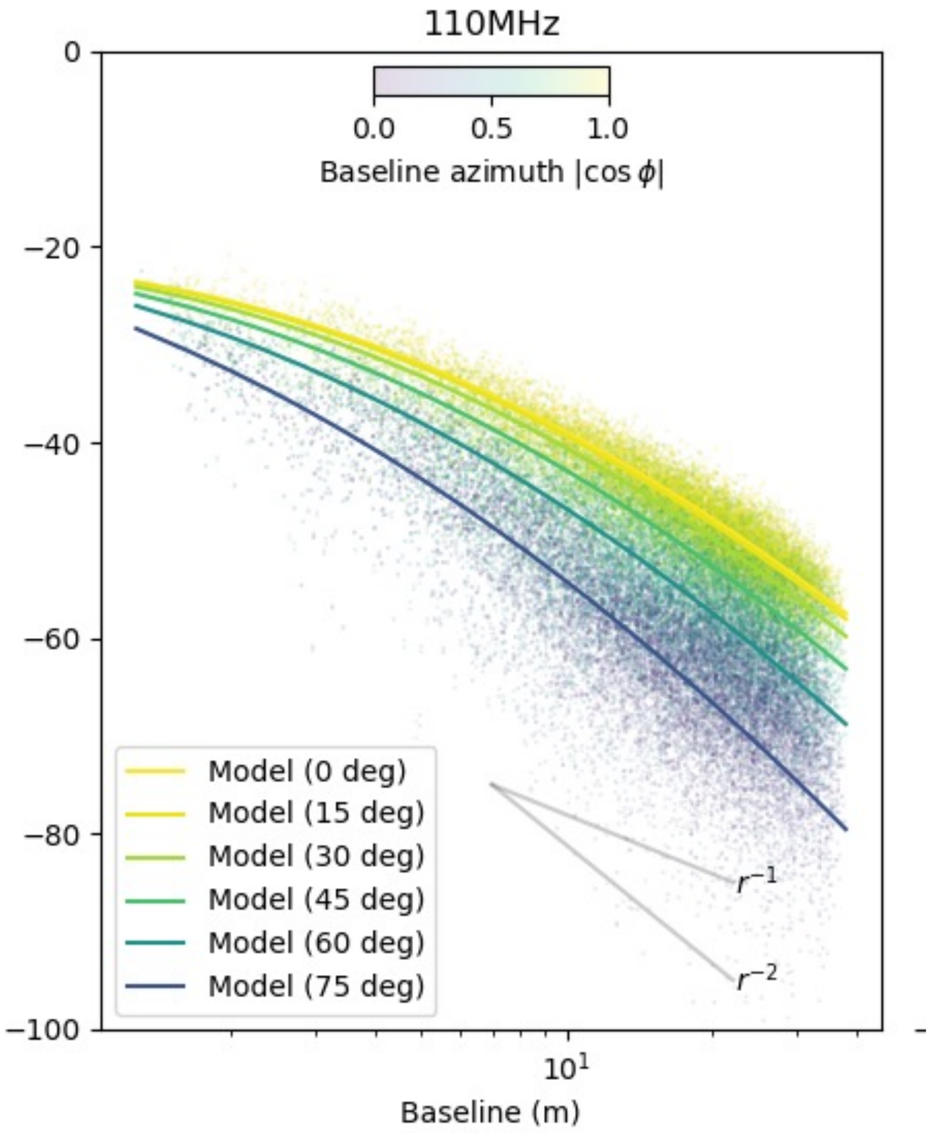
AAVS3 baselines



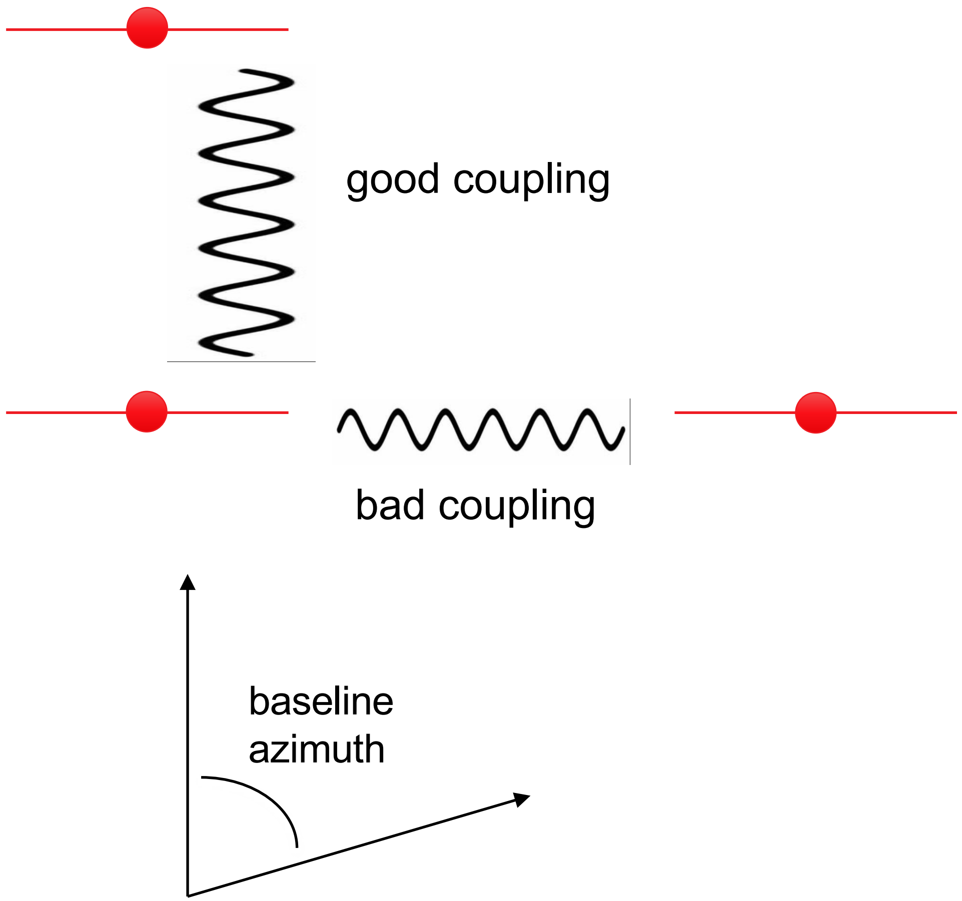
Scattering matrices (Bolli,Davidson+ 2022)



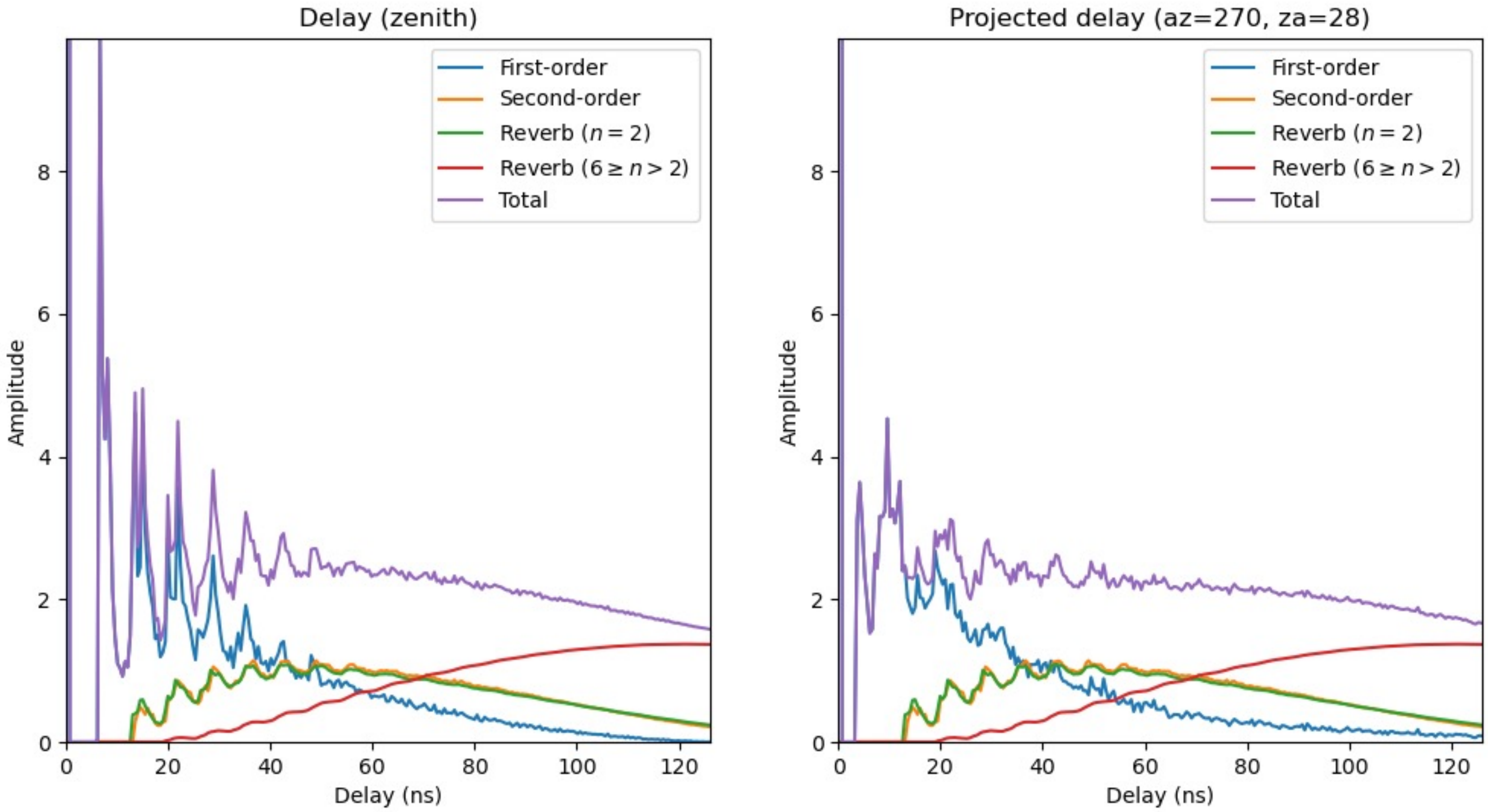
Scattering matrices (Bolli,Davidson+ 2022)



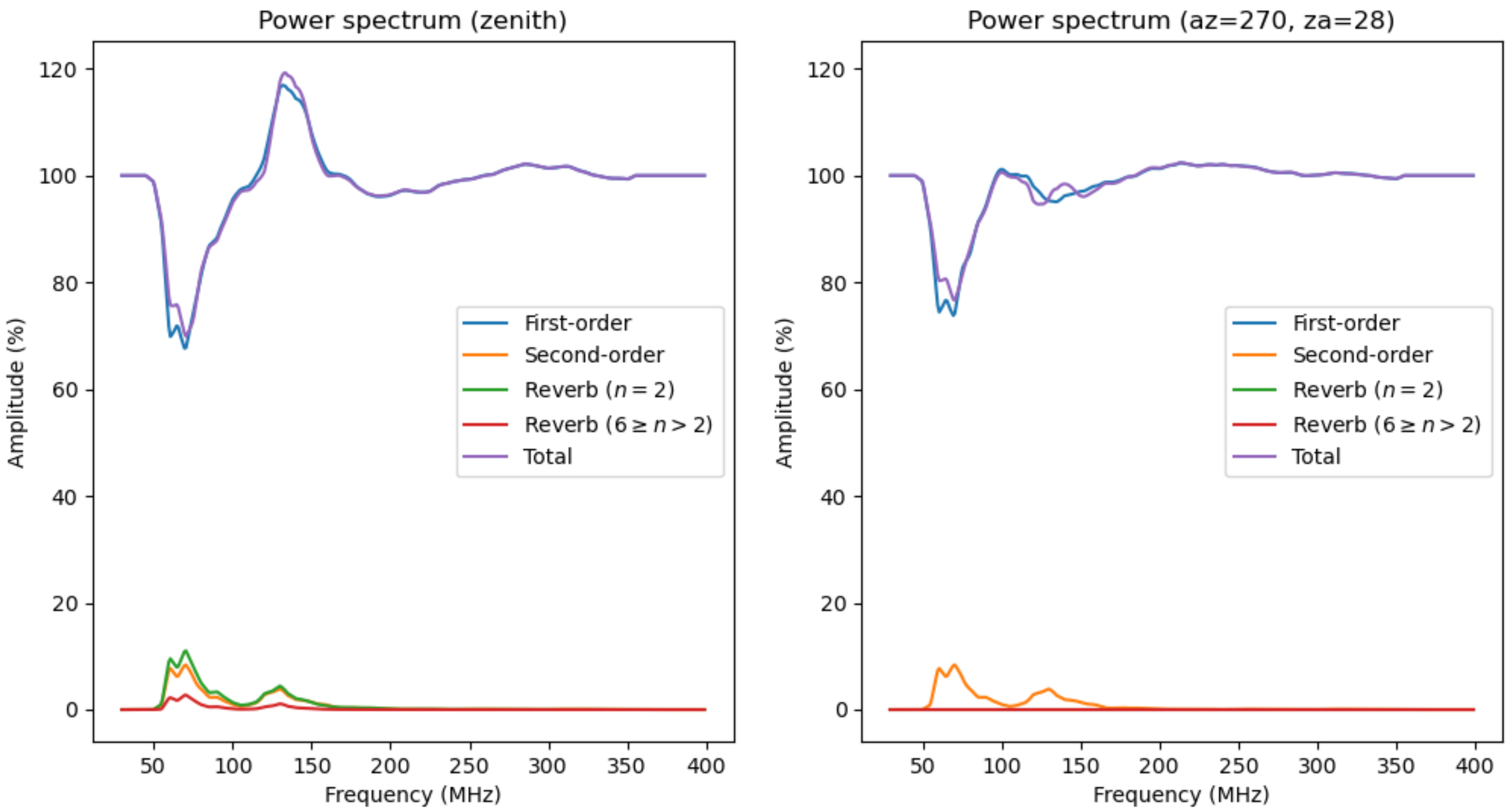
SKALA dipoles



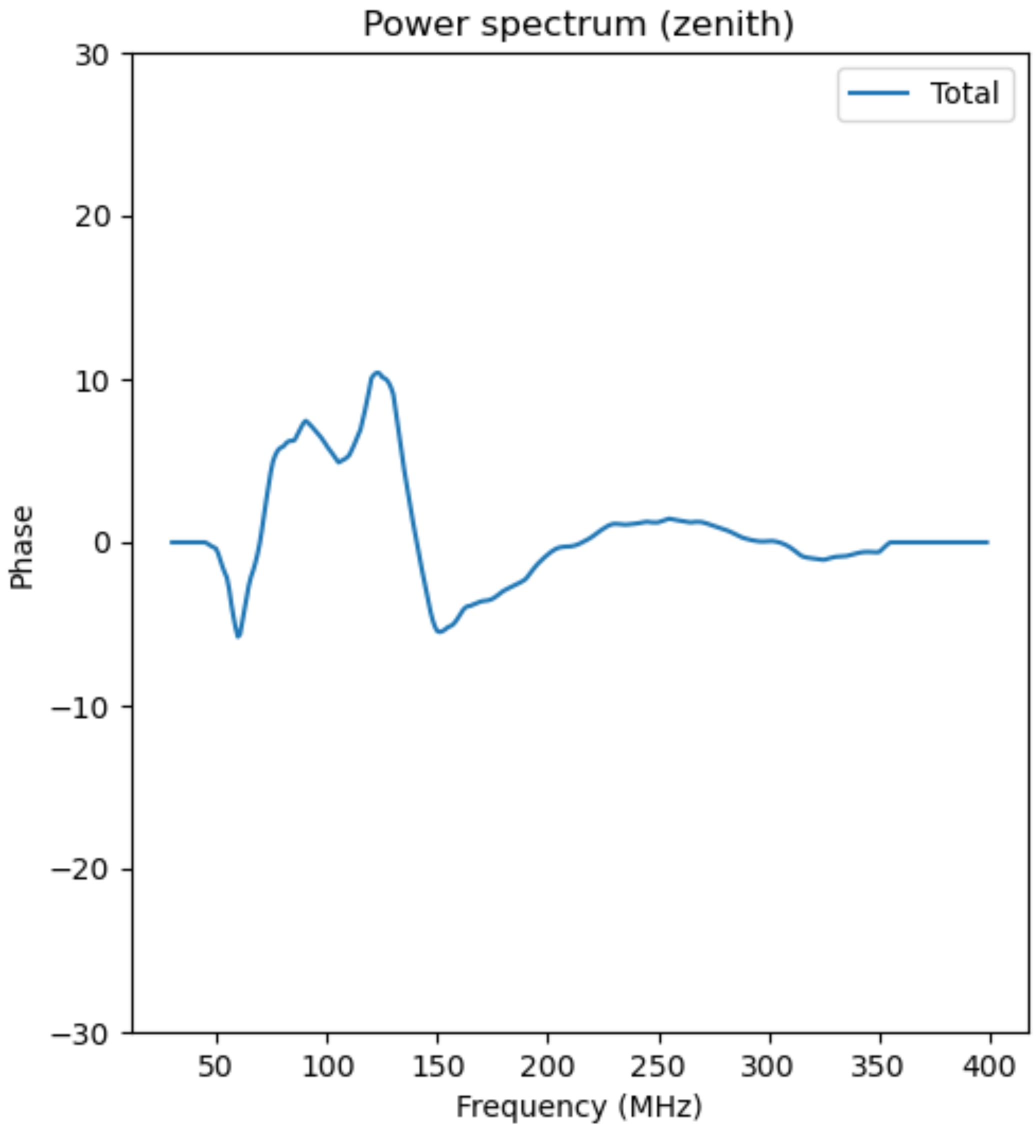
AAVS3 YY delay spectrum near 160 MHz

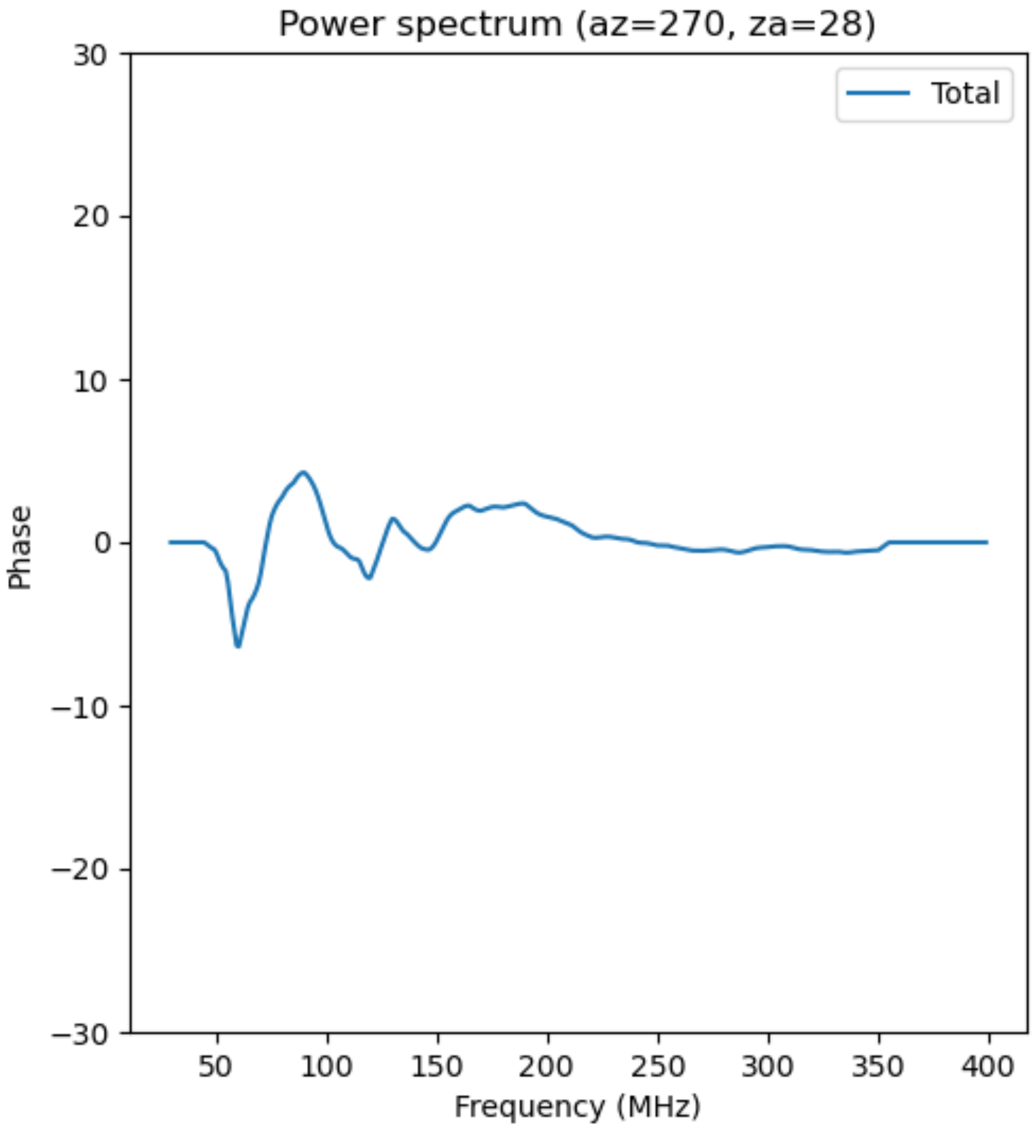


AAVS3 YY power spectrum (amplitude)

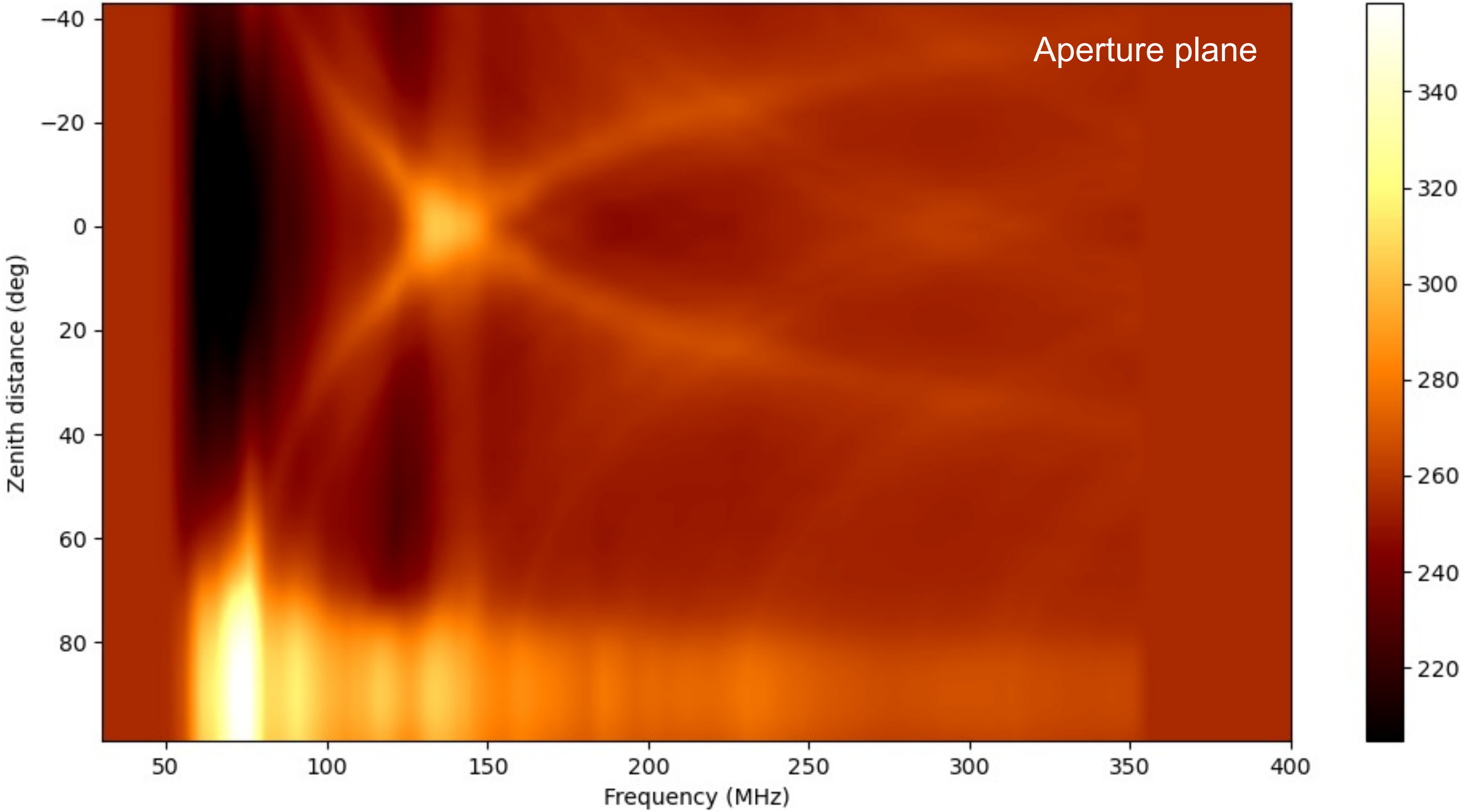


AAVS3 YY power spectrum (phase)

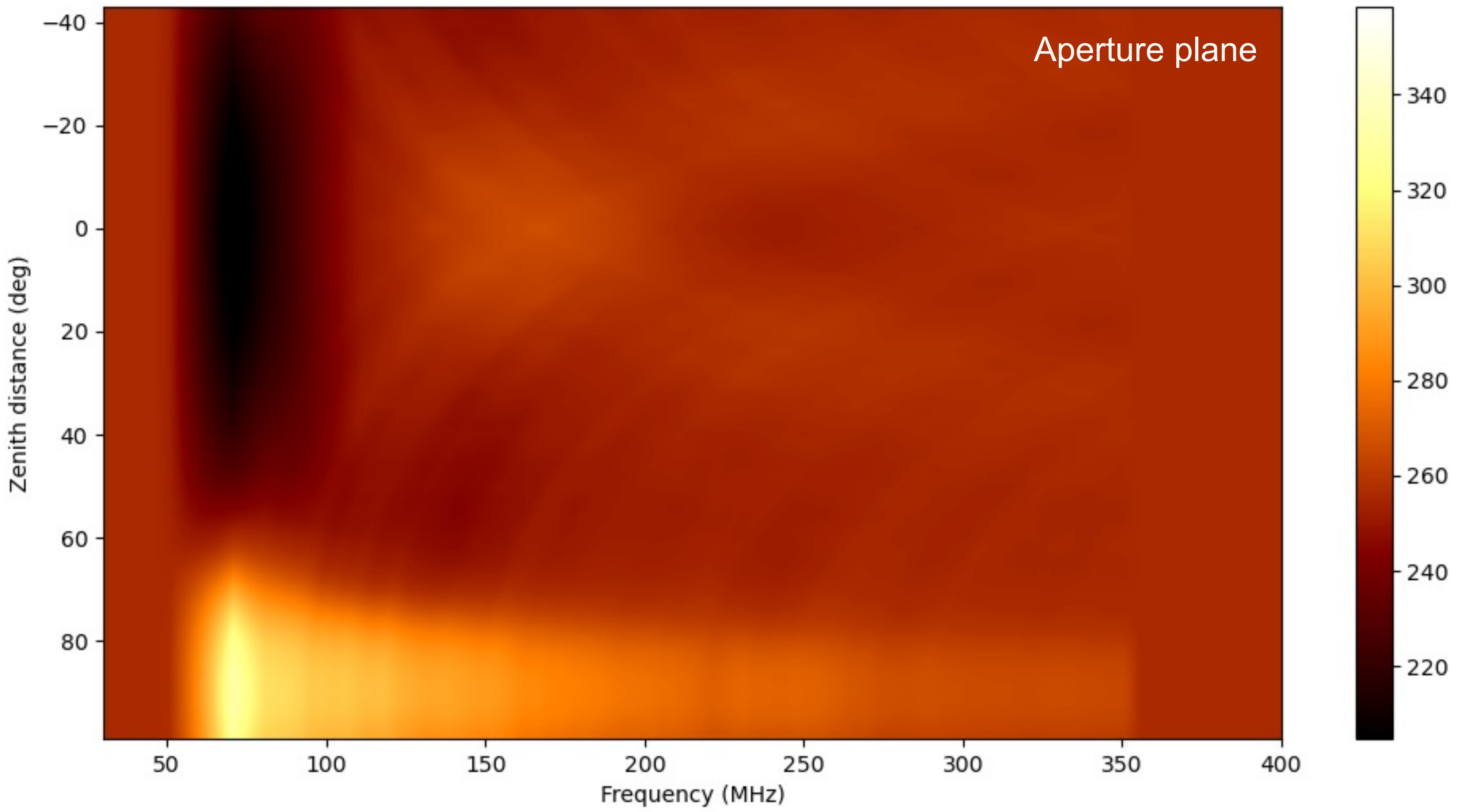




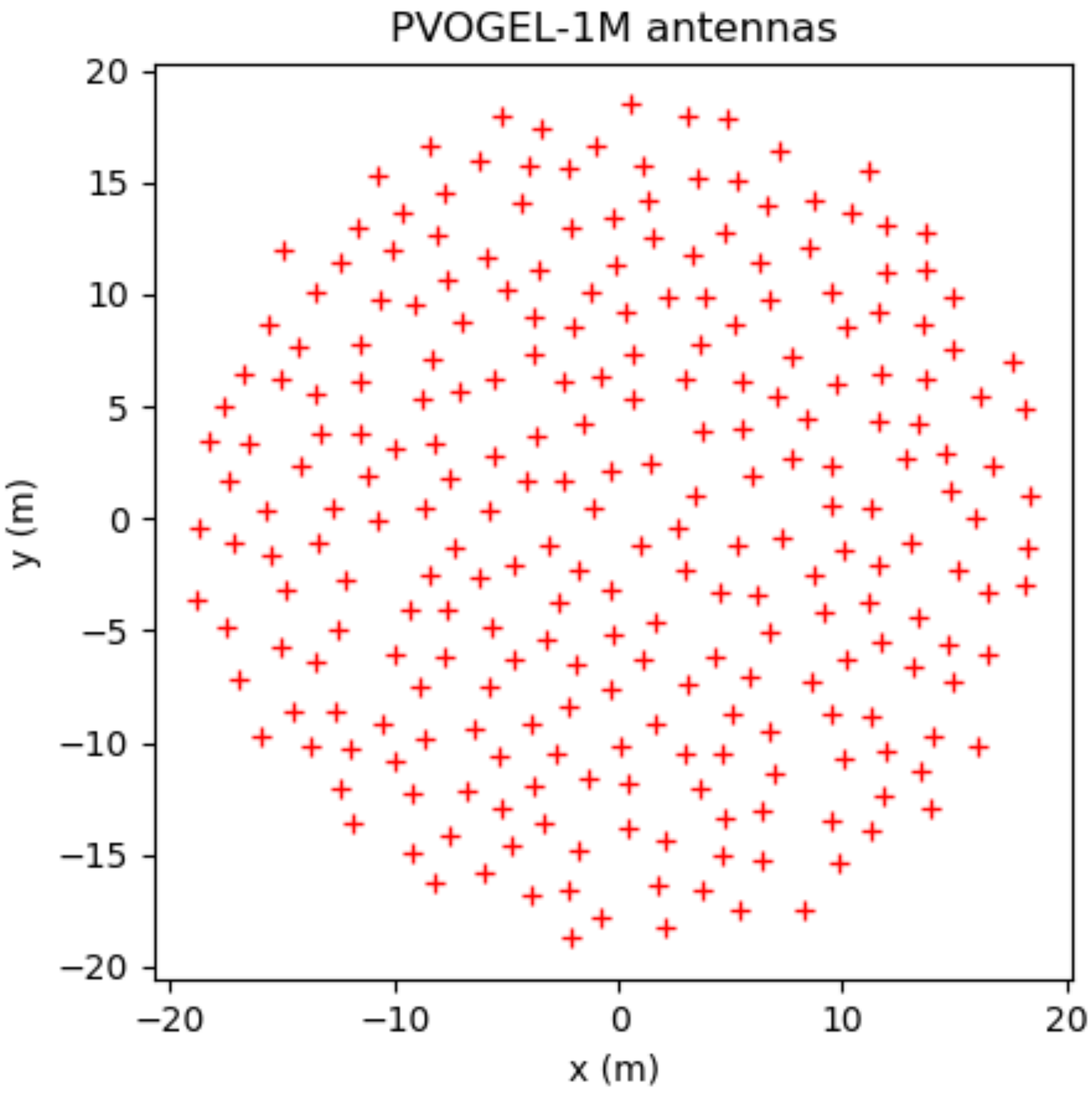
AAVS3 YY power spectrum (Az=270^o)



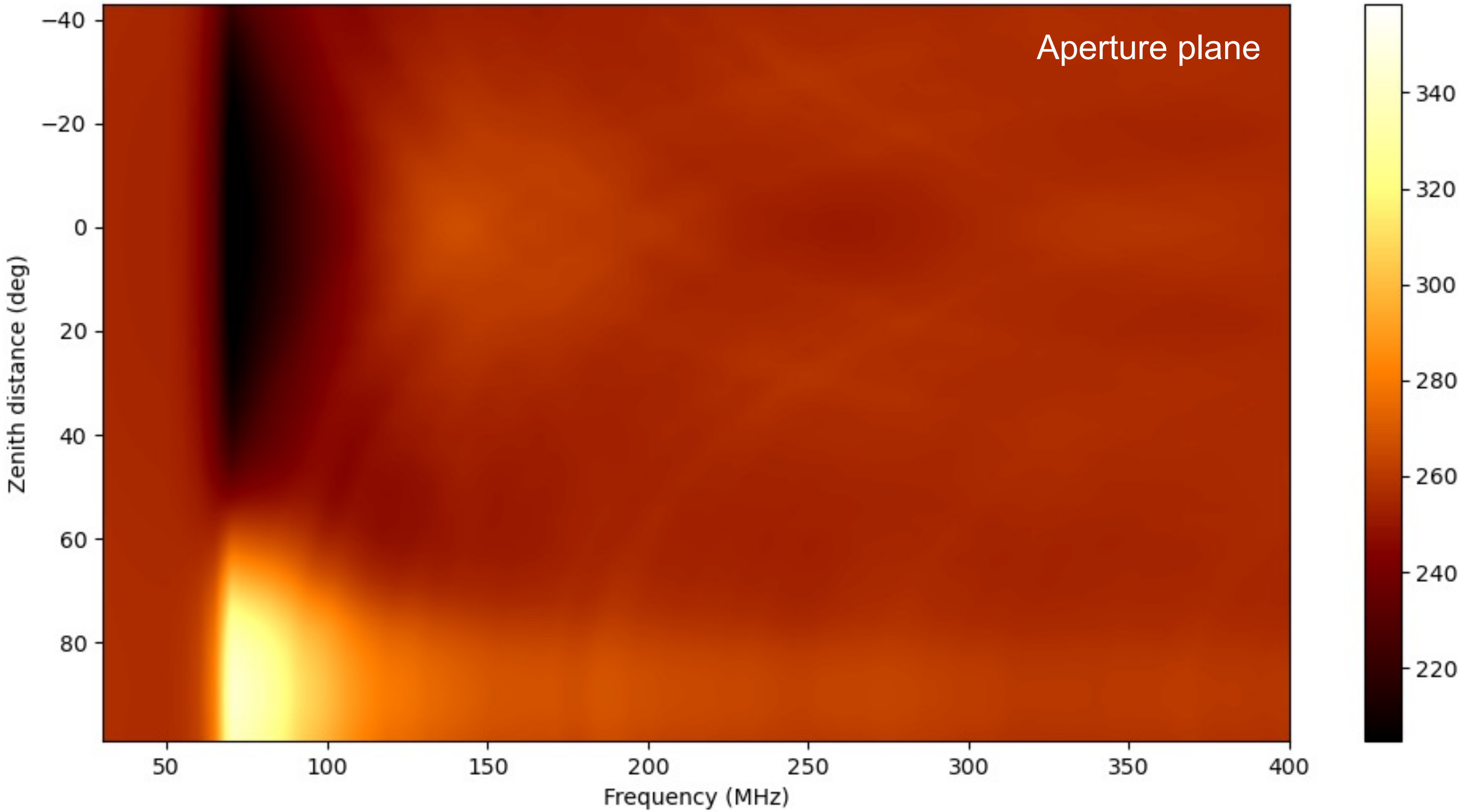
AAVS2 YY power spectrum waterfall



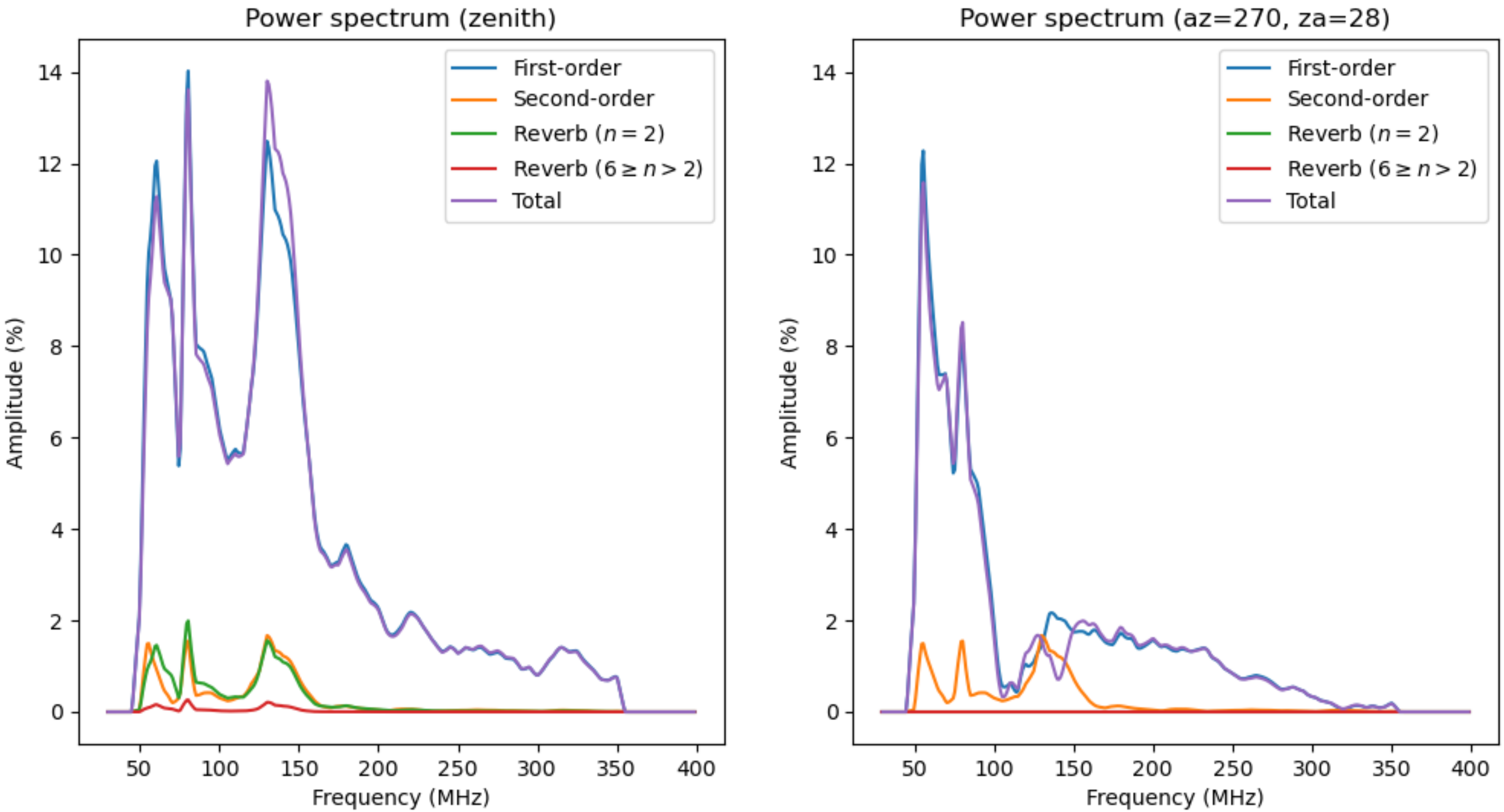
SKAO perturbed Vogel configuration



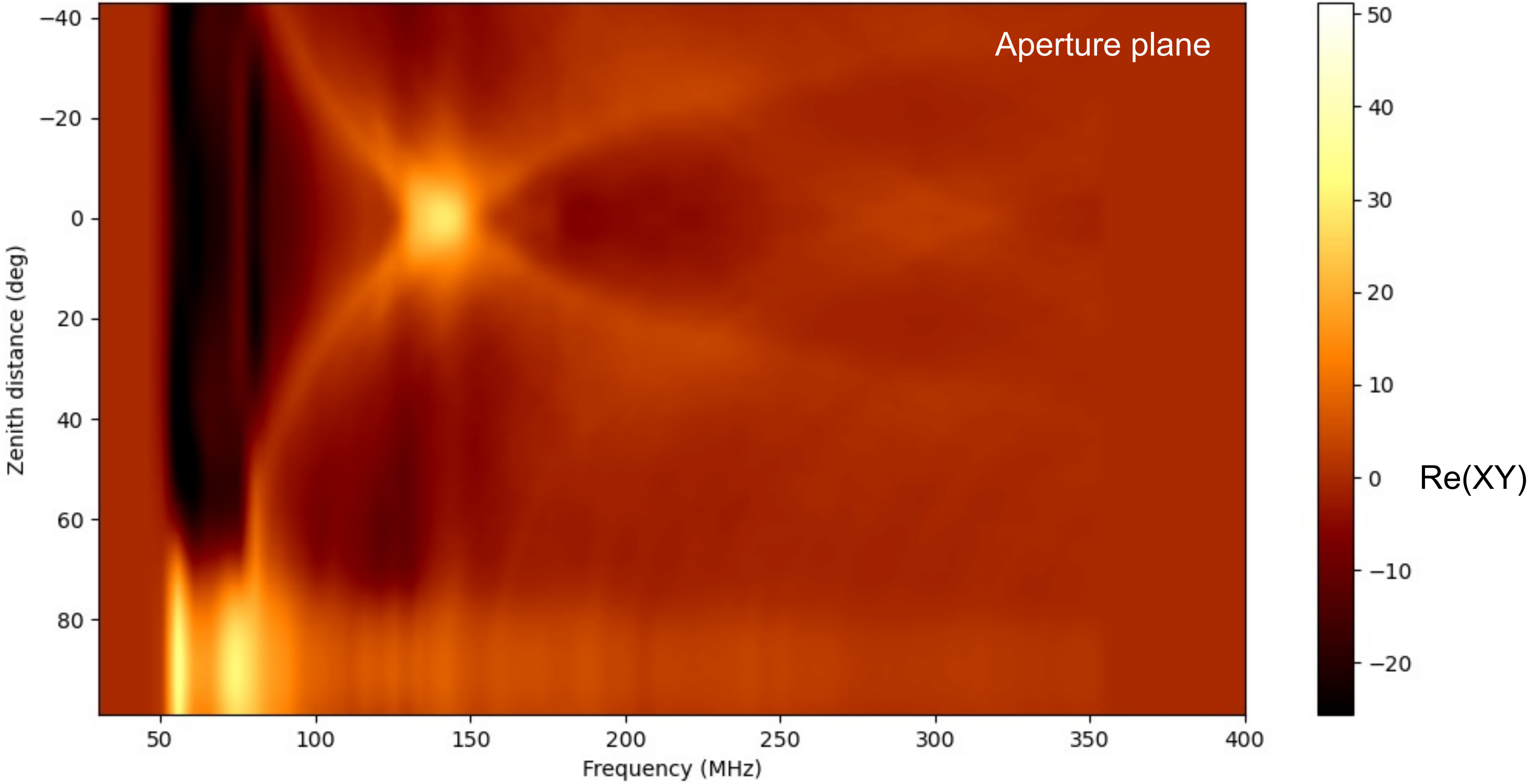
Perturbed Vogel 1-m YY power spectrum



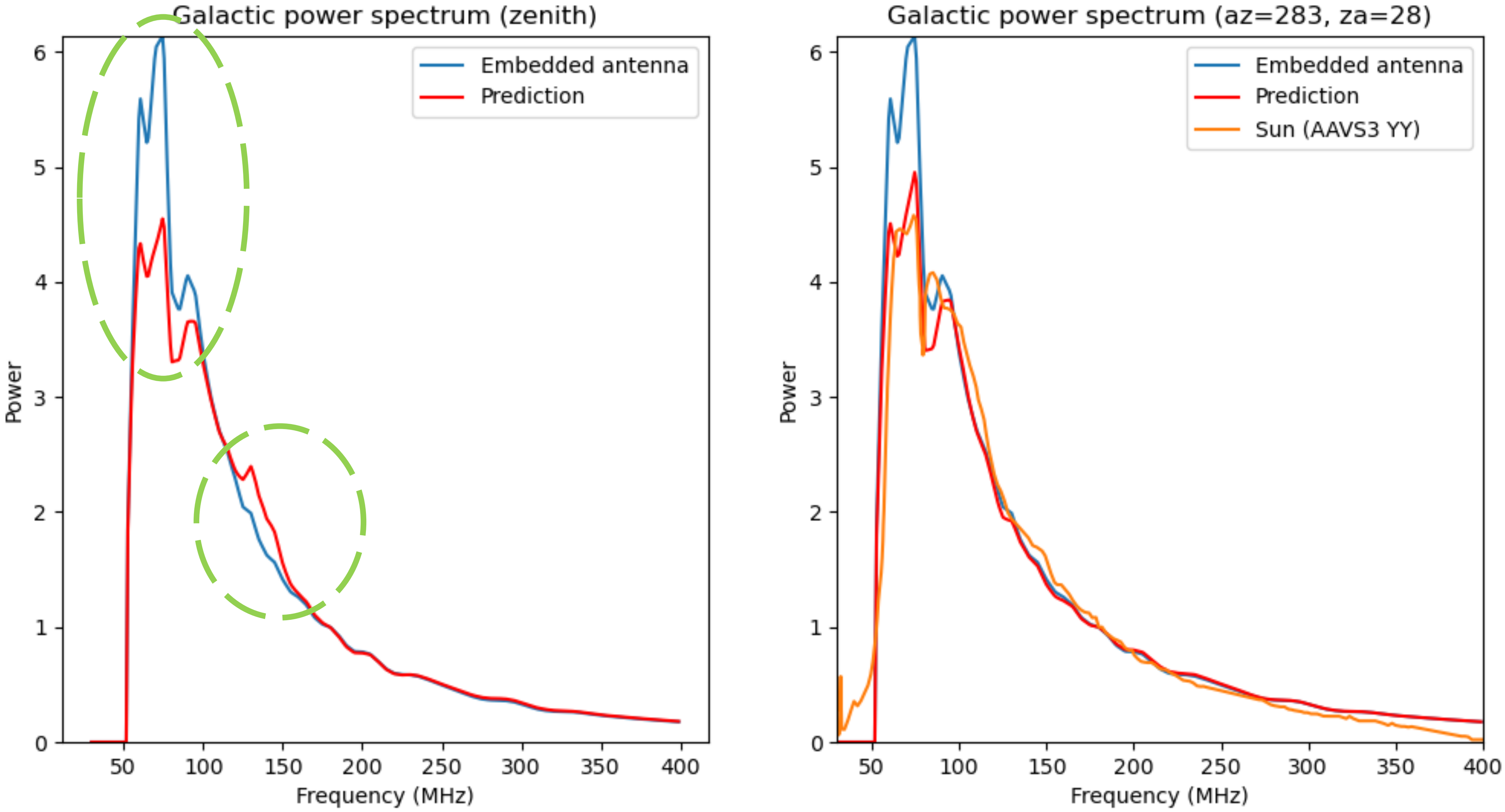
AAVS3 XY cross-power spectrum amplitude



AAVS3 cross-pol (XY) power spectrum



Simple sky model (α=-2.3): AAVS3 YY



Take away SKA-low station messages

- Gross station frequency characteristics defined by element response
- SKA-low stations will have large (~30%) complex spectral gain distortions solely due to mutual coupling/reflections
- Cross-pol leakage will also have large spectral variations (~14%)
- AAVS3 configuration worse than AAVS2 (esp. at 135 MHz and at zenith) due to multiple reflections and harmonics of the 2.2-m baseline periodicity
- Spectral distortions very sensitive to sky location
- Continuous bandpass calibration will be necessary if not drift-scanning
- 70 MHz feature due to negative phase of nearest-neighbour antenna reflections (also ground plane & antenna resonance – see Bolli+ 2022)

Going forward

- What do do about the 130 MHz feature:
  - Remove the Vogel periodicity (easy – e.g. SKAO Perturbed Vogel).
- What to do about the 70 MHz feature:
  - Better antennas (reflection coefficient too high) (too late).
  - Less antennas and wider spacing (too late).
  - Switching off antennas or changing configuration won't help.
- Techniques:
  - FIR/PFT method very fast – all phase information encoded in antenna configuration – full reverberation capability. Efficient supplement to FEKO.
- Rotated stations:
  - Calibration will differ, so spectral phase distortions won't disappear and will vary across field of view in different ways. Pseudo-randoms probably better.
- Secondary effects will be important:
  - e.g. frequency modulation of station beam

Final note

- These are ALL simulations.
- Look forward to seeing more real data!
- Thanks to David+ for providing scattering matrix simulations.