Global Signal with a Short Spacing Interferometer

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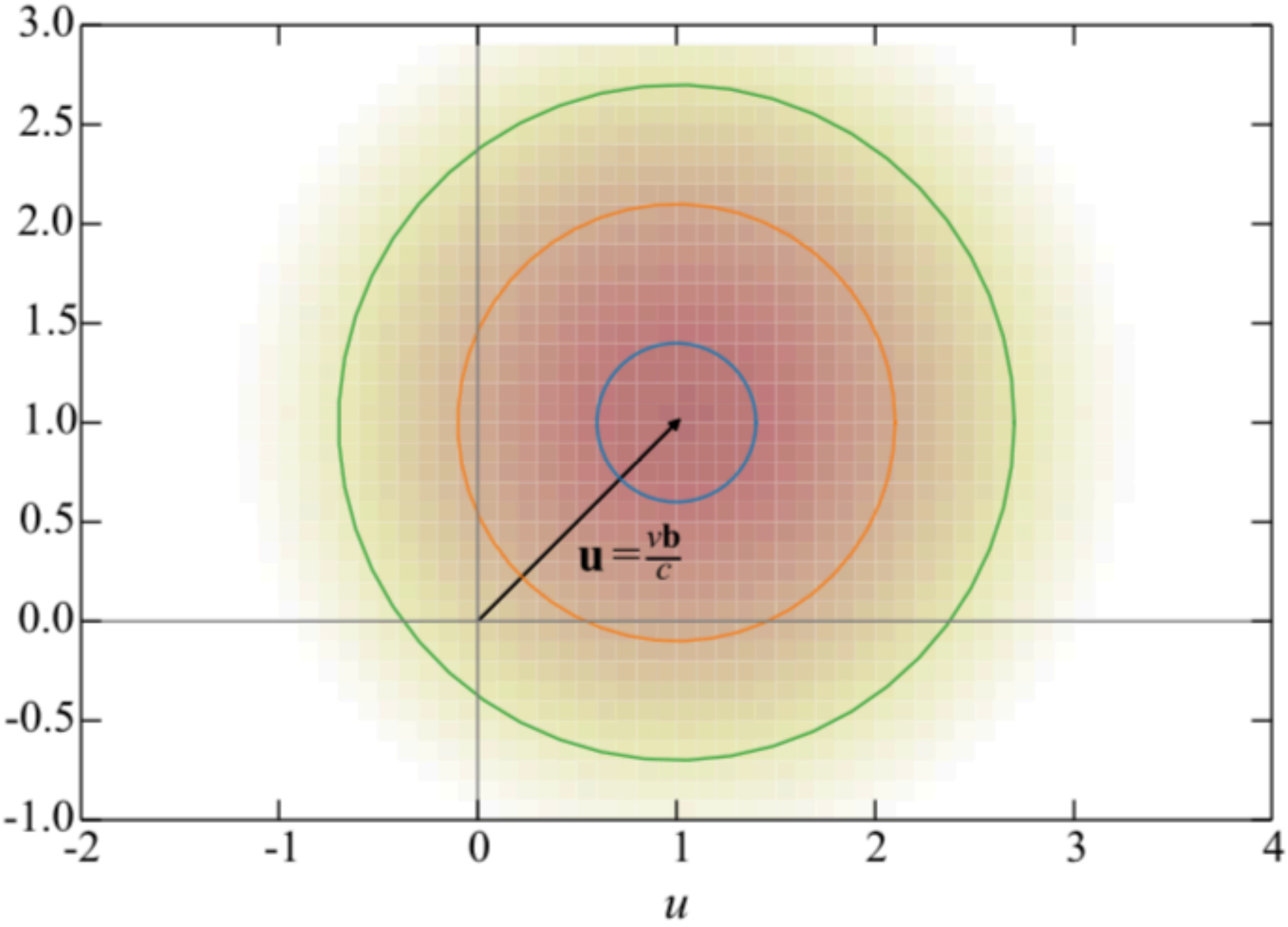
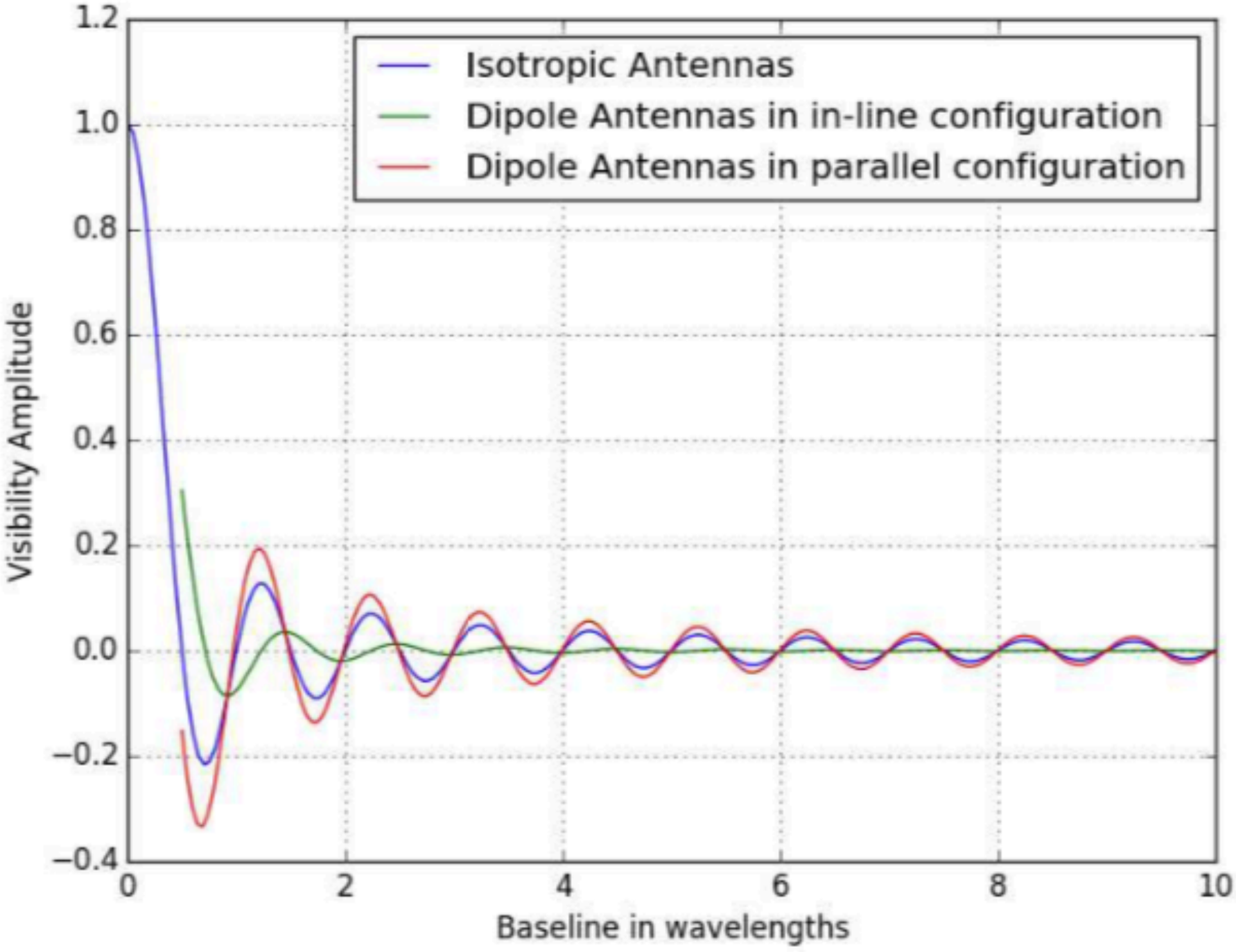
Interferometer response to a global signal



Presley et. al. (2015)

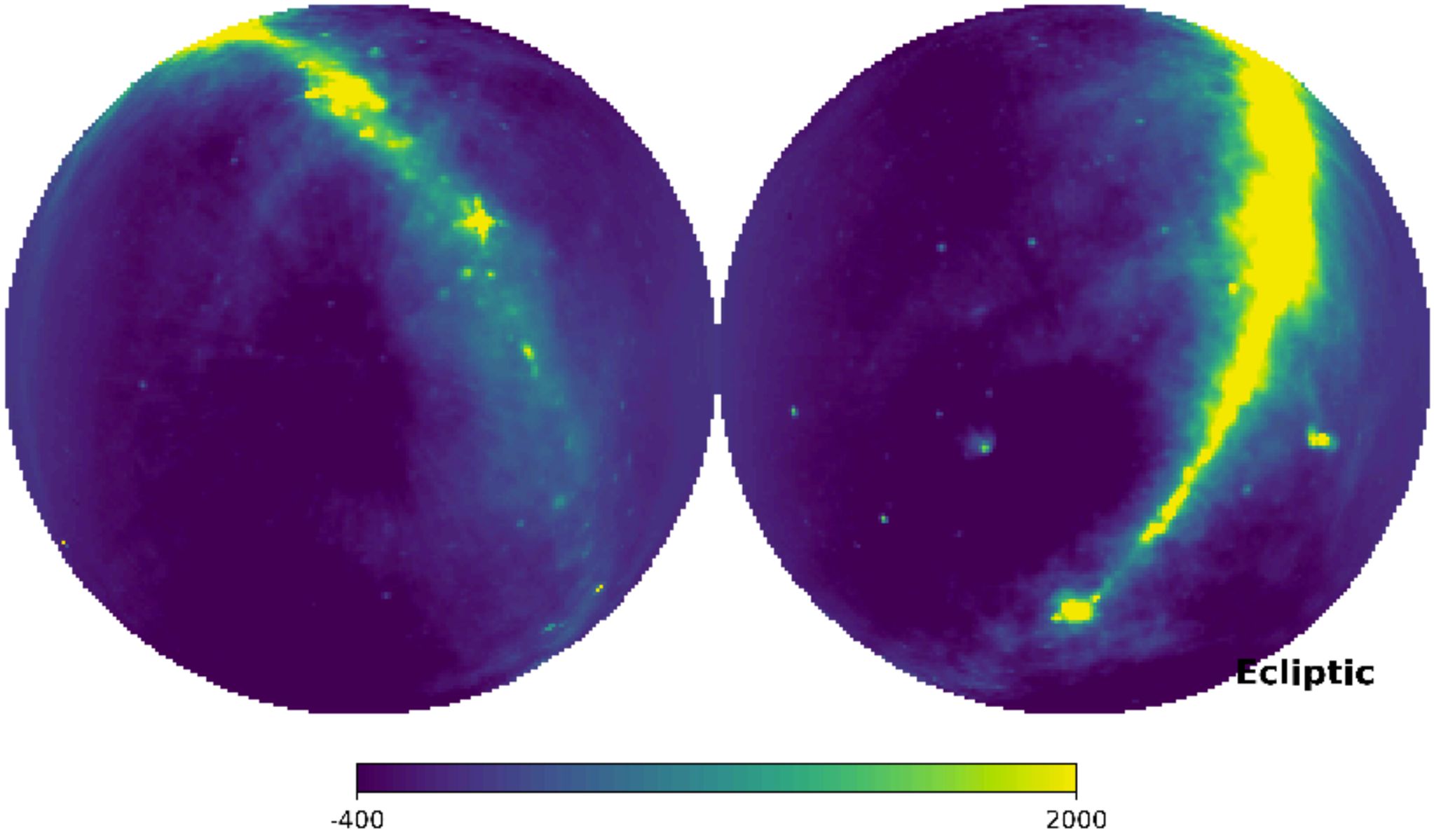
Interferometer response to a global signal

$$V(\vec{b},\nu) = \frac{1}{4\pi} T_{sky}(\nu) \int A(\vec{r},\nu) e^{-i2\pi \frac{\vec{b}\cdot\vec{r}}{\lambda}} d\Omega.$$



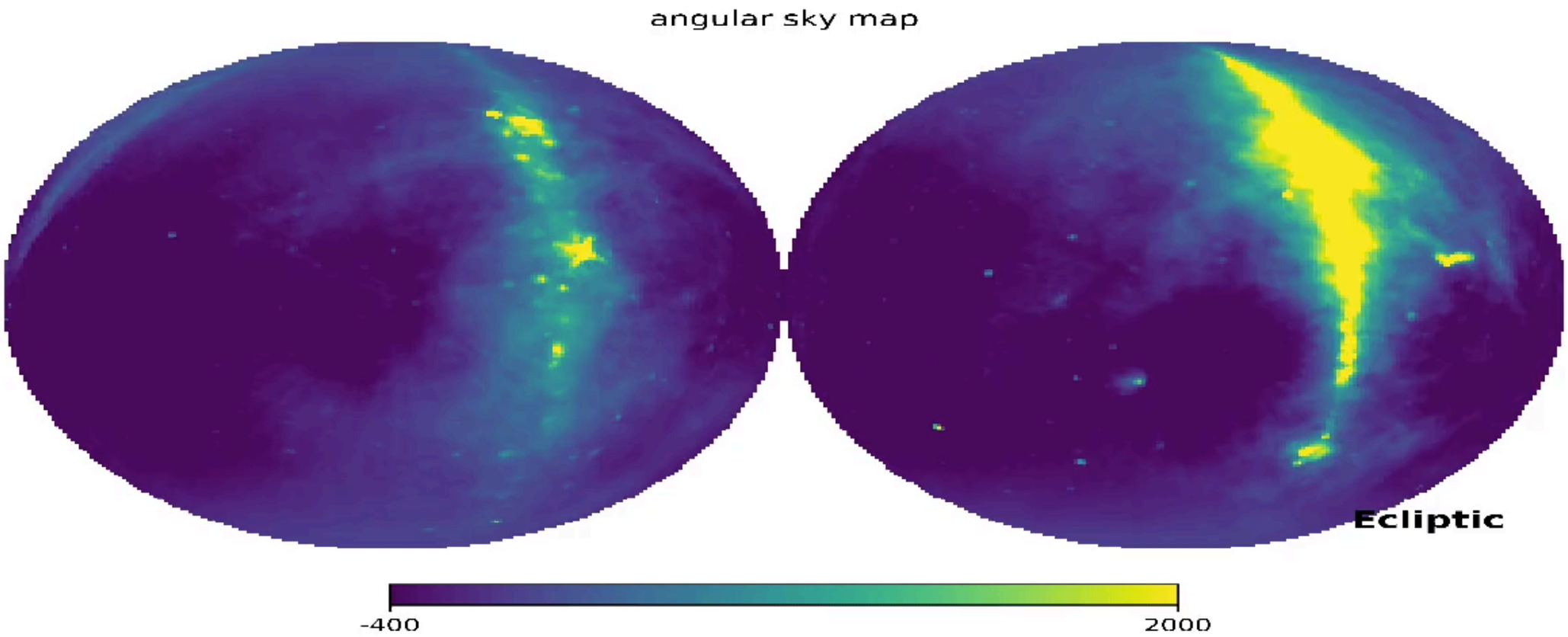
Singh et. al. (2015)

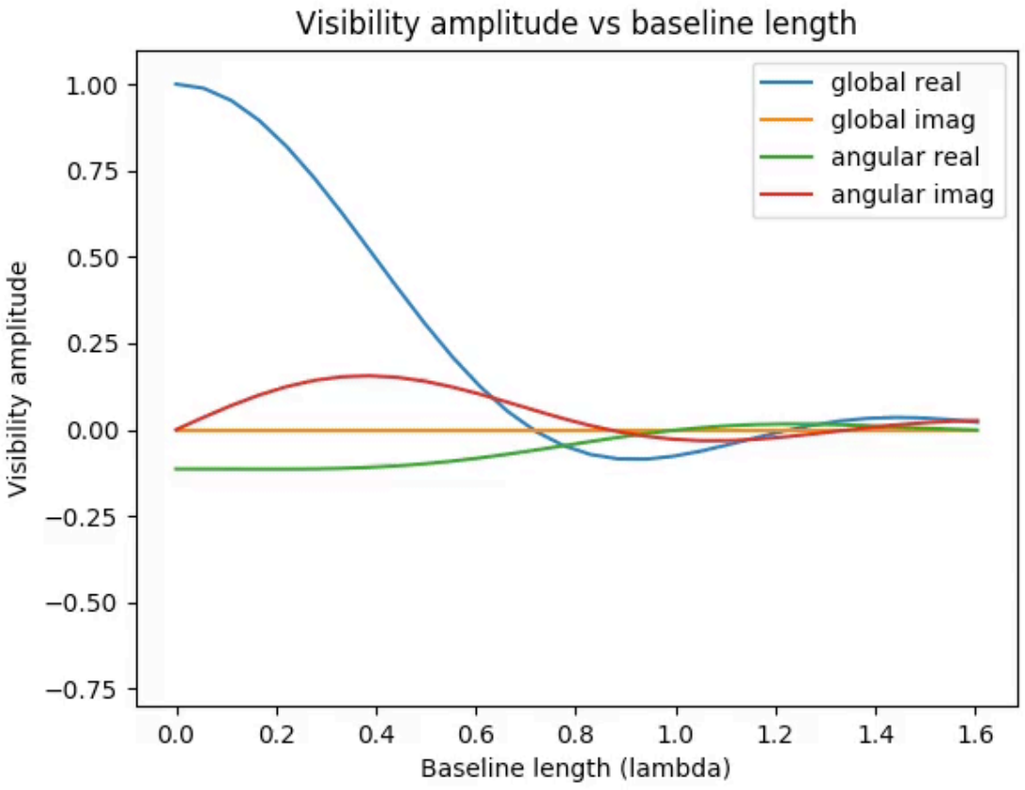
Real sky also has angular structure

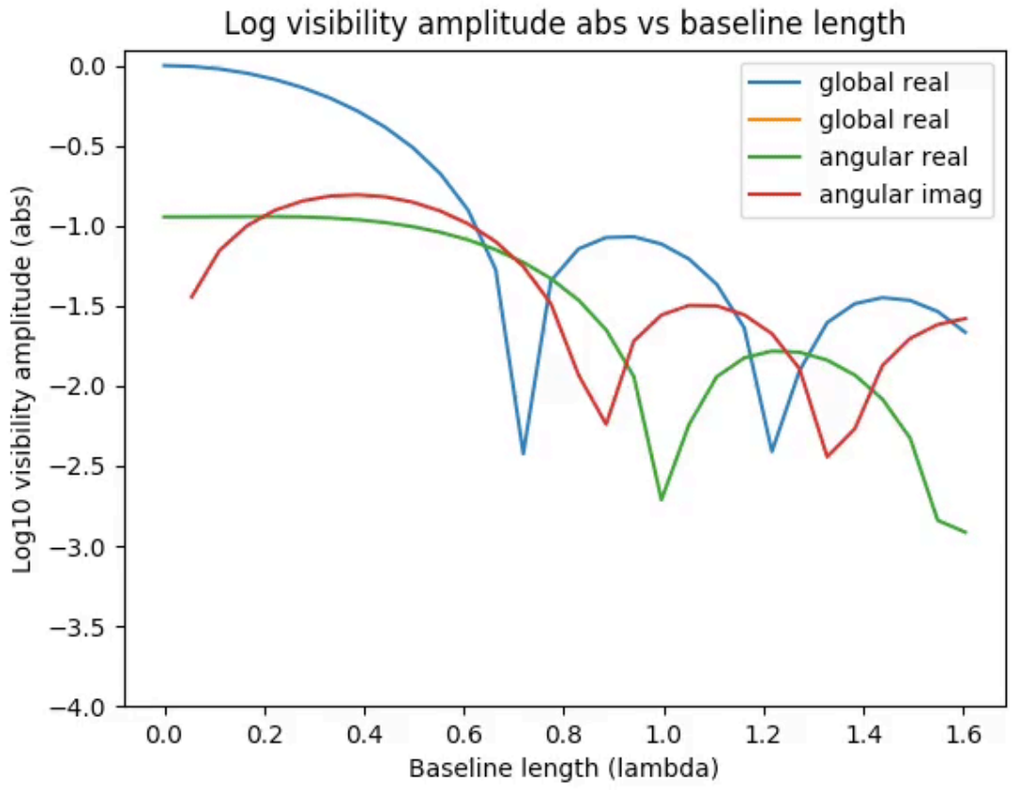


How does the response to angular structure compare to the global signal for an orbiting baseline and how well does this response average down over an orbit?

Orbiting short baseline interferometer response

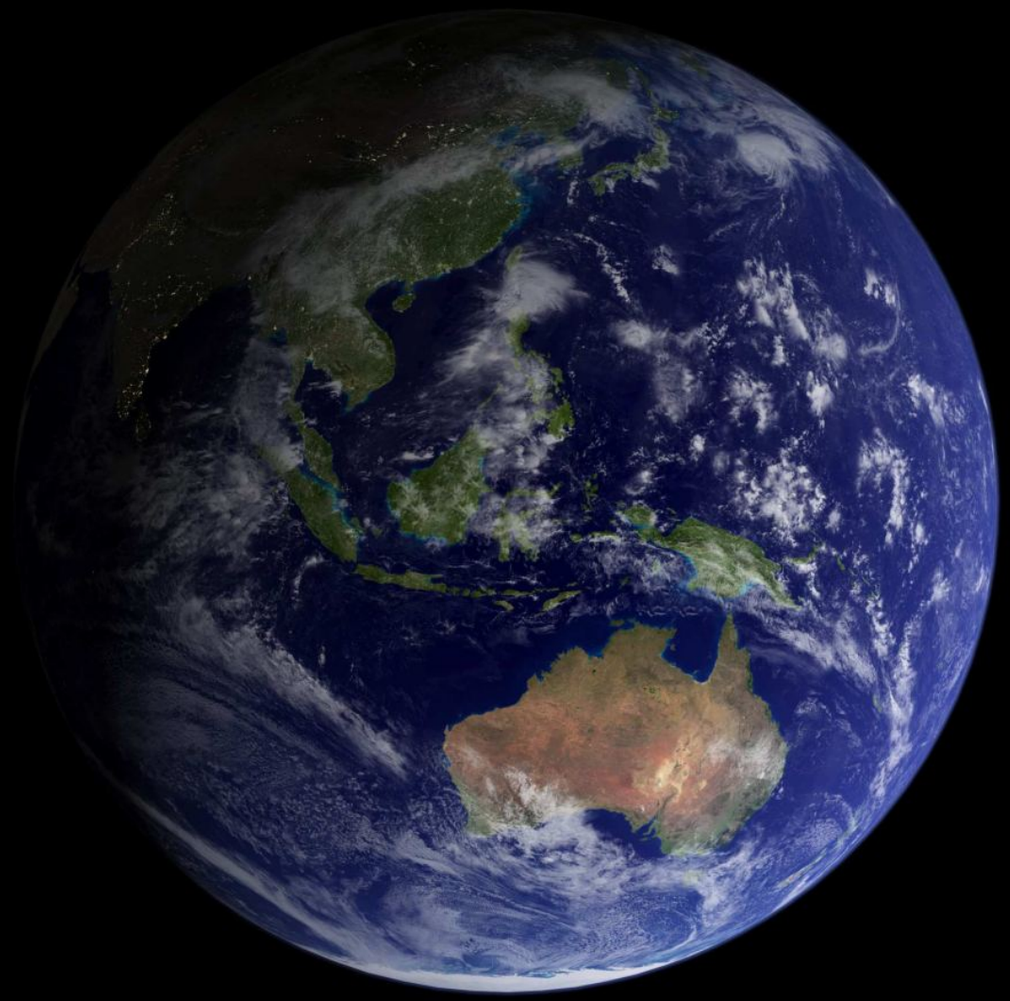




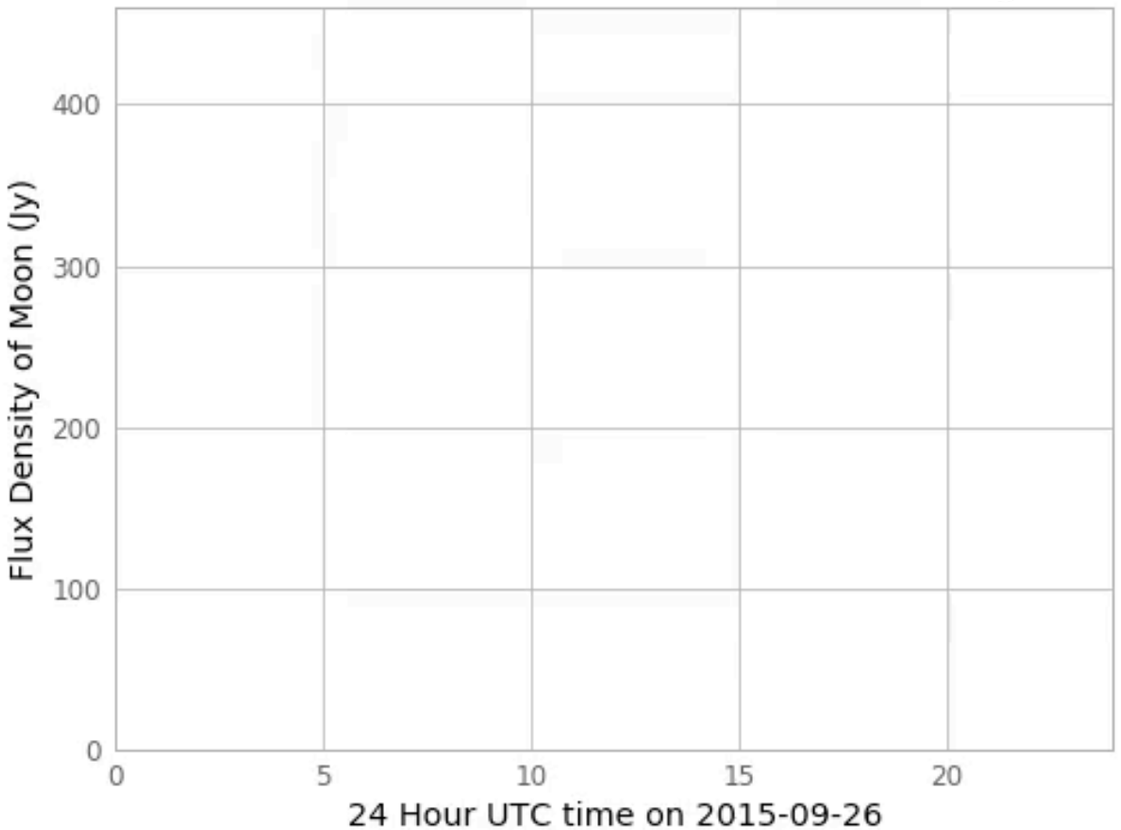


Practicalities

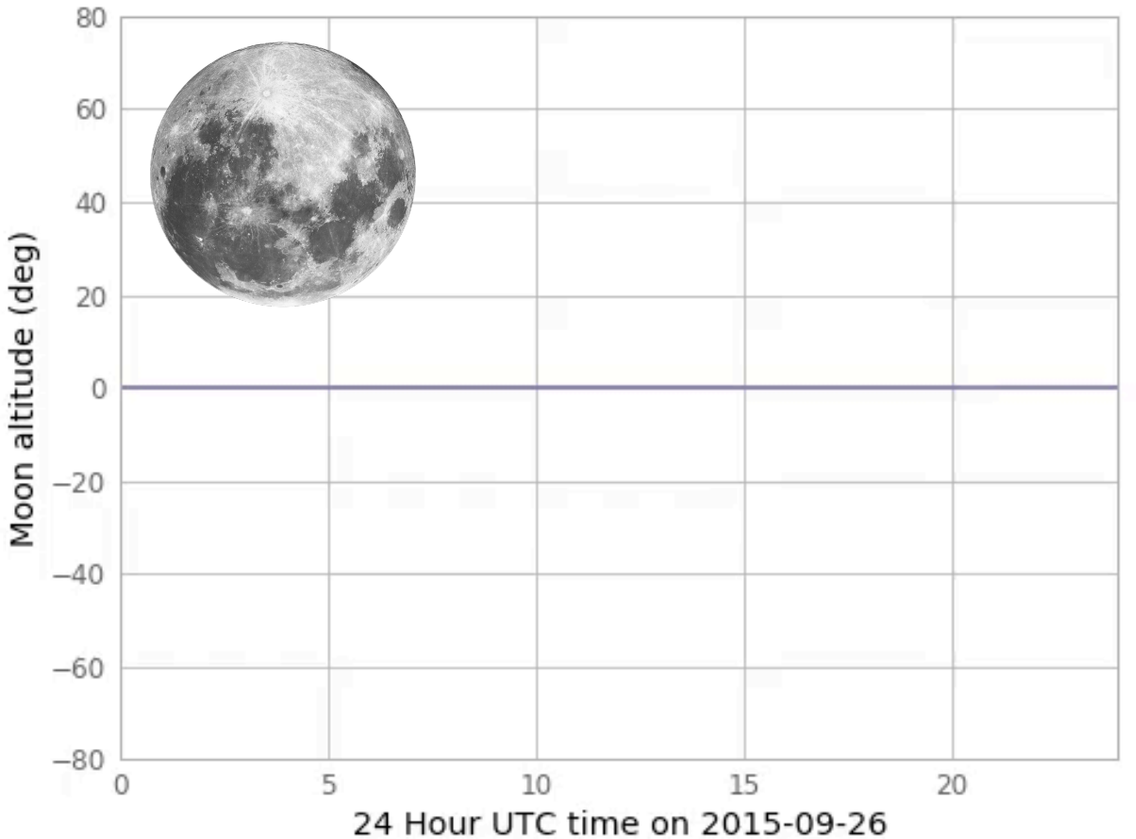
- Singh et. al. (2015) place their baseline in space, for ionospheric reasons. But this is impractical:
  - cost and complexity
  - RFI (bad unless you go to far side of Moon, then see point 1)

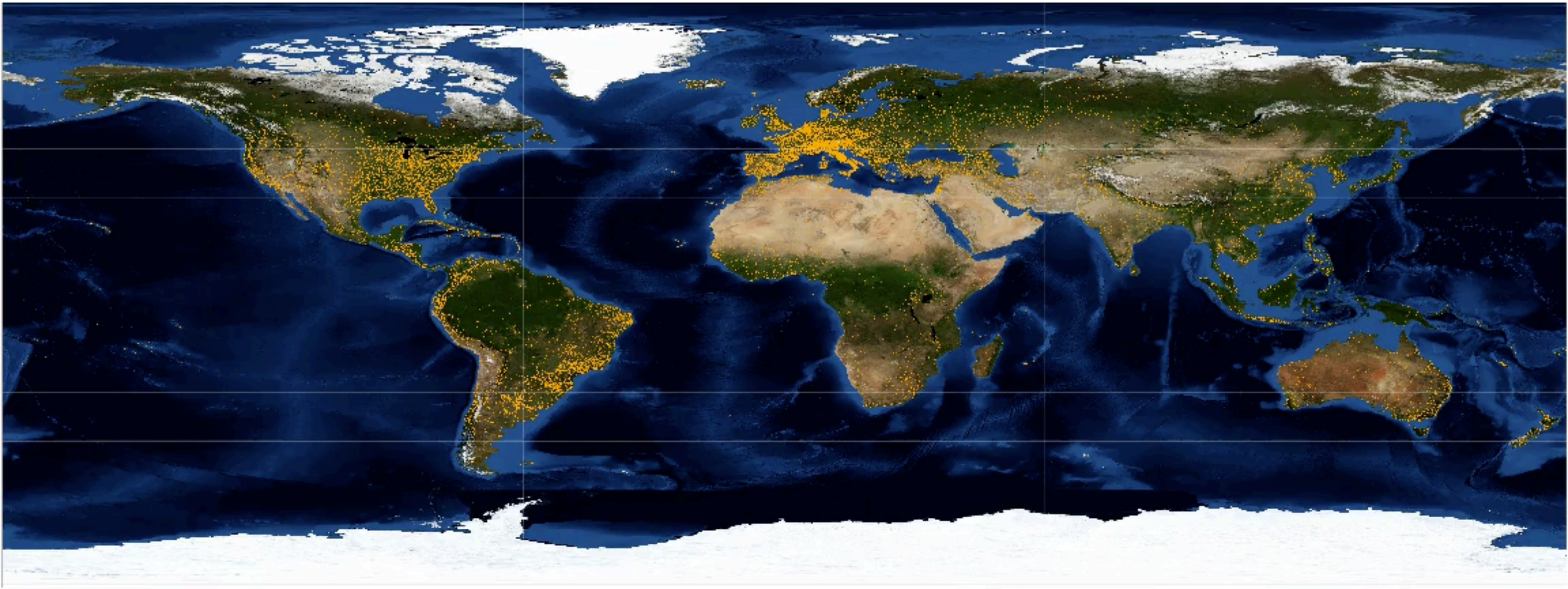


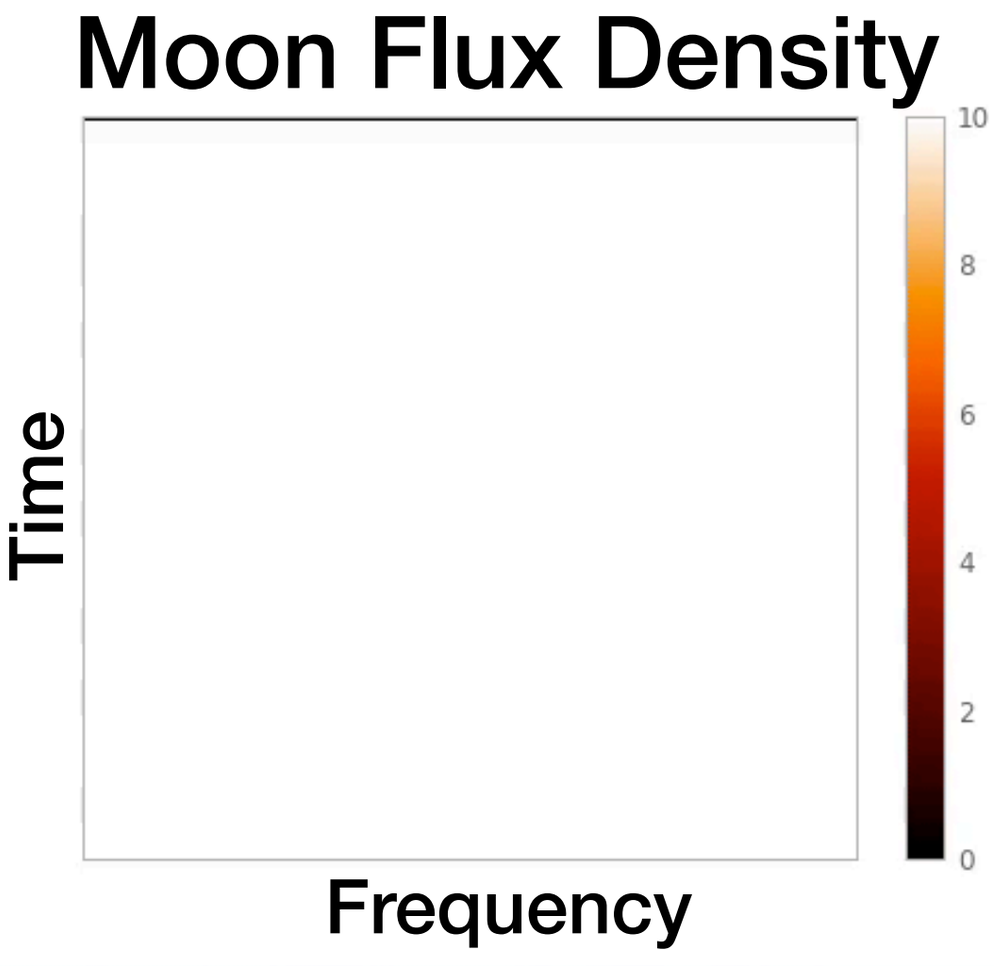
Moon Flux Density

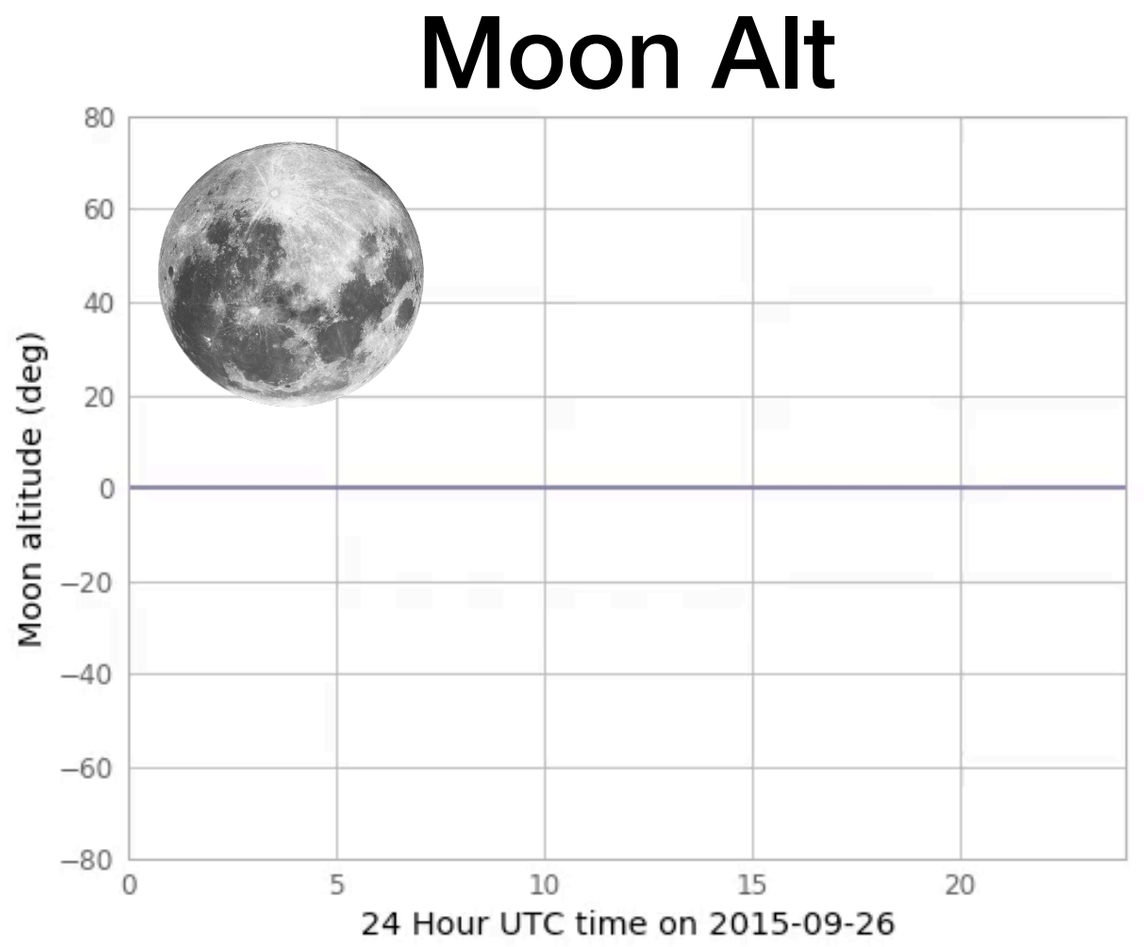


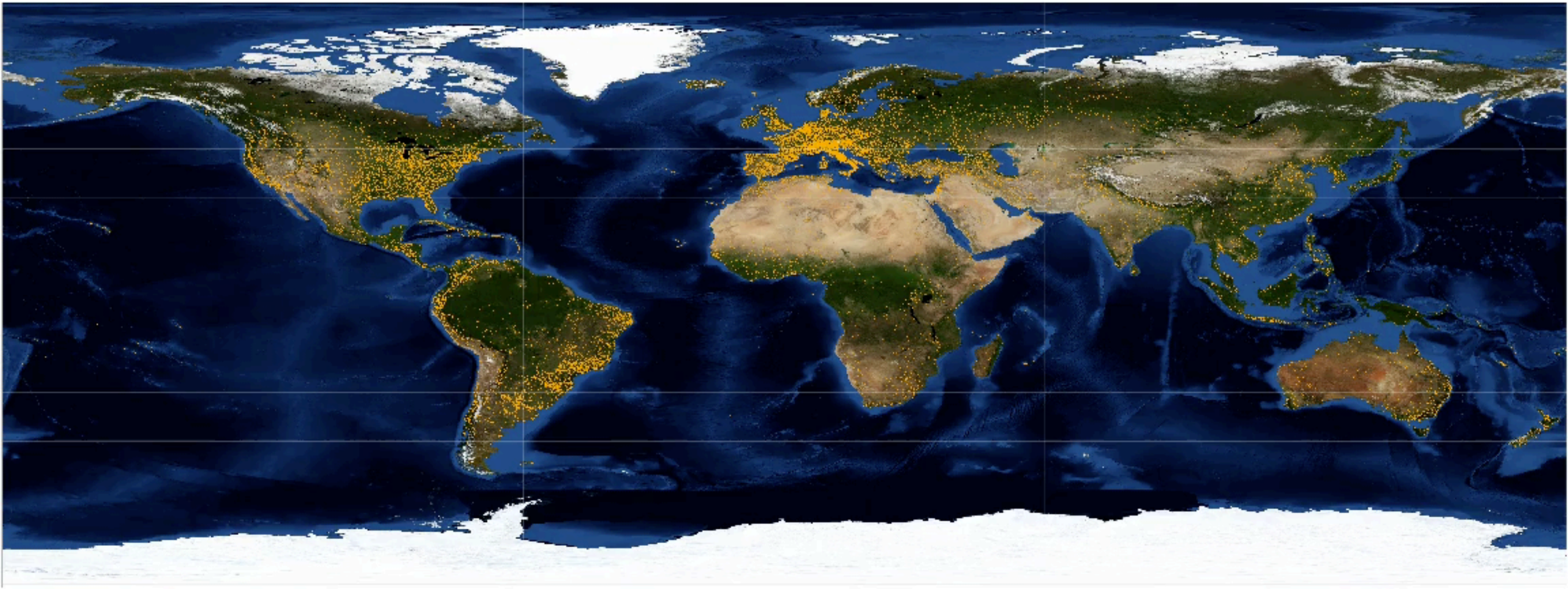
Moon Alt



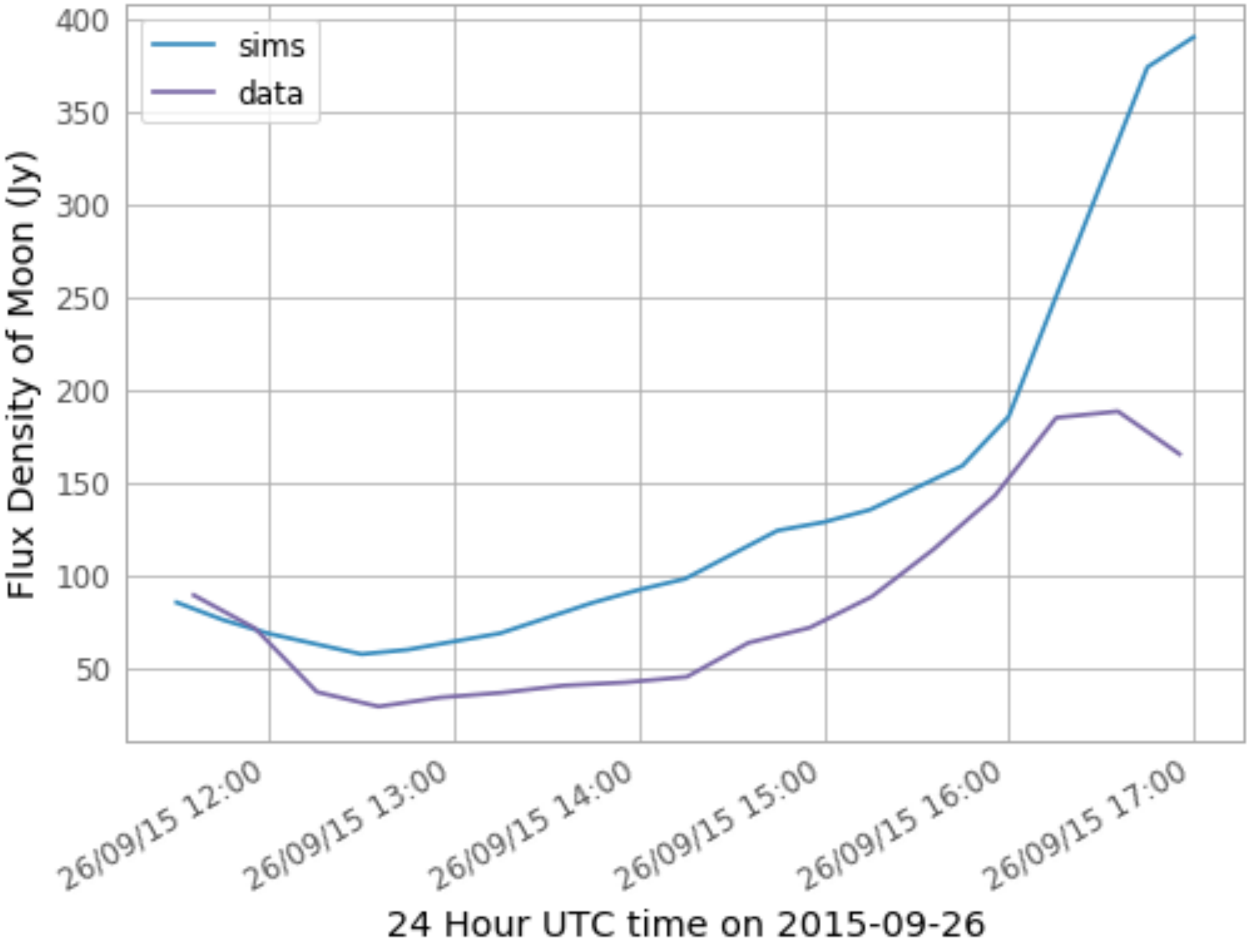



Moon Flux Density
Time
Frequency
10
8
6
4
2
0

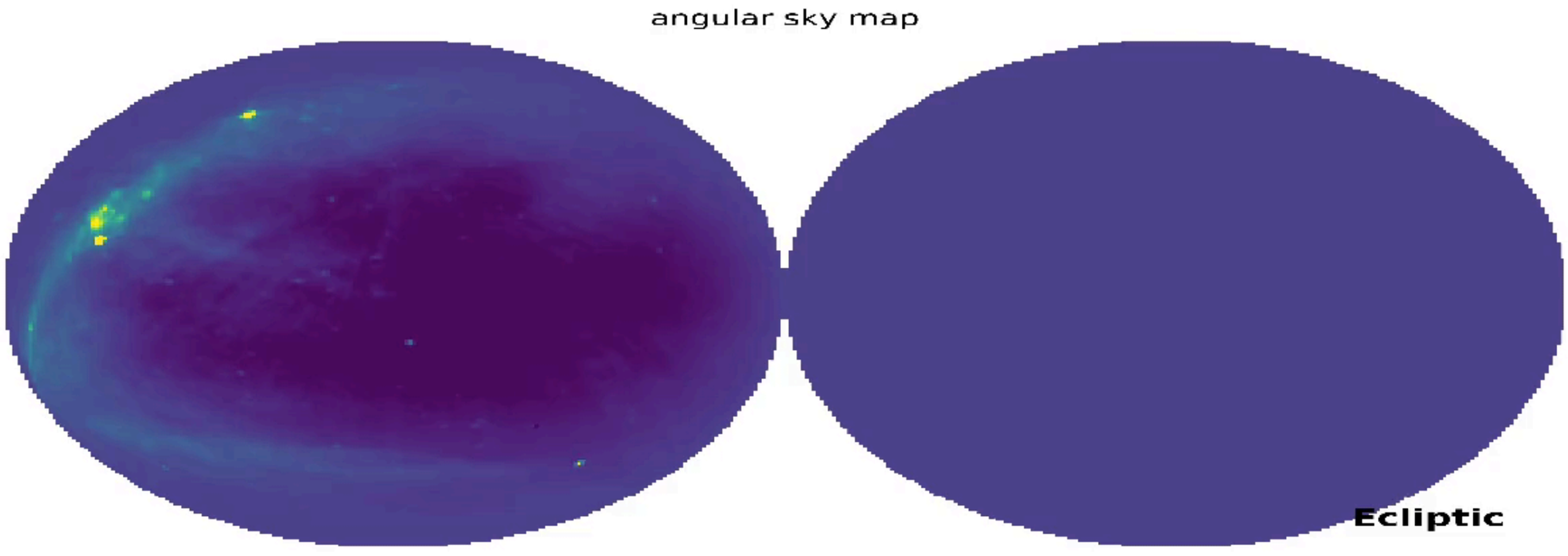

Moon Alt
Moon altitude (deg)
80
60
40
20
0
−20
−40
−60
−80
0
5
10
15
20
24 Hour UTC time on 2015-09-26

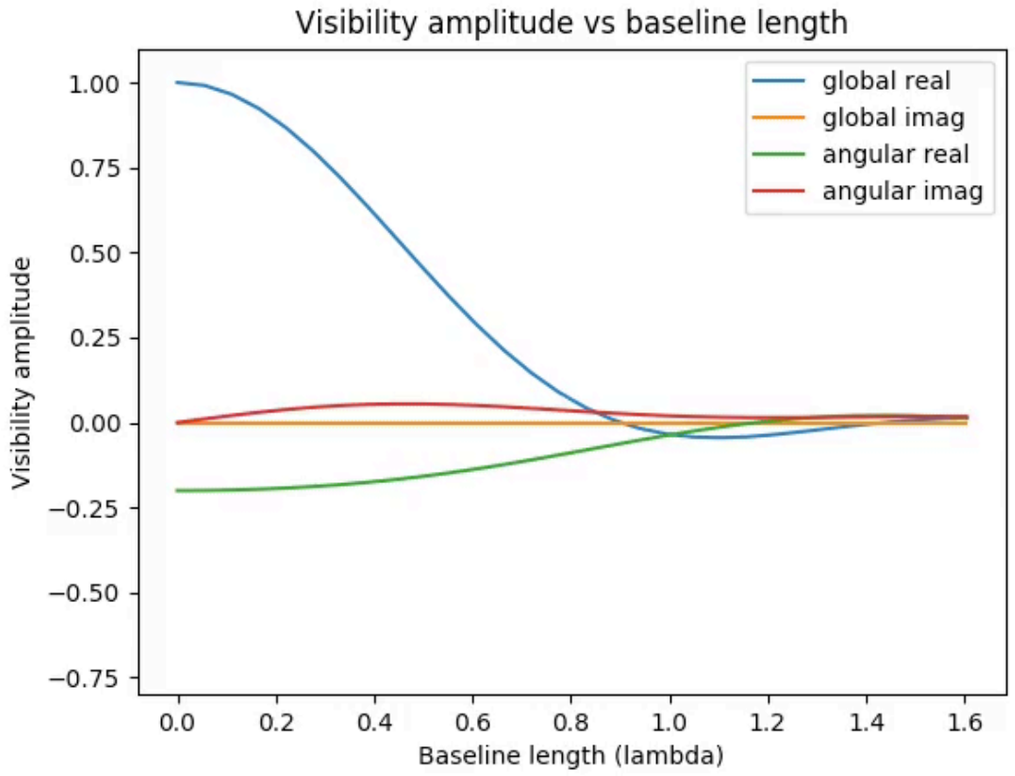


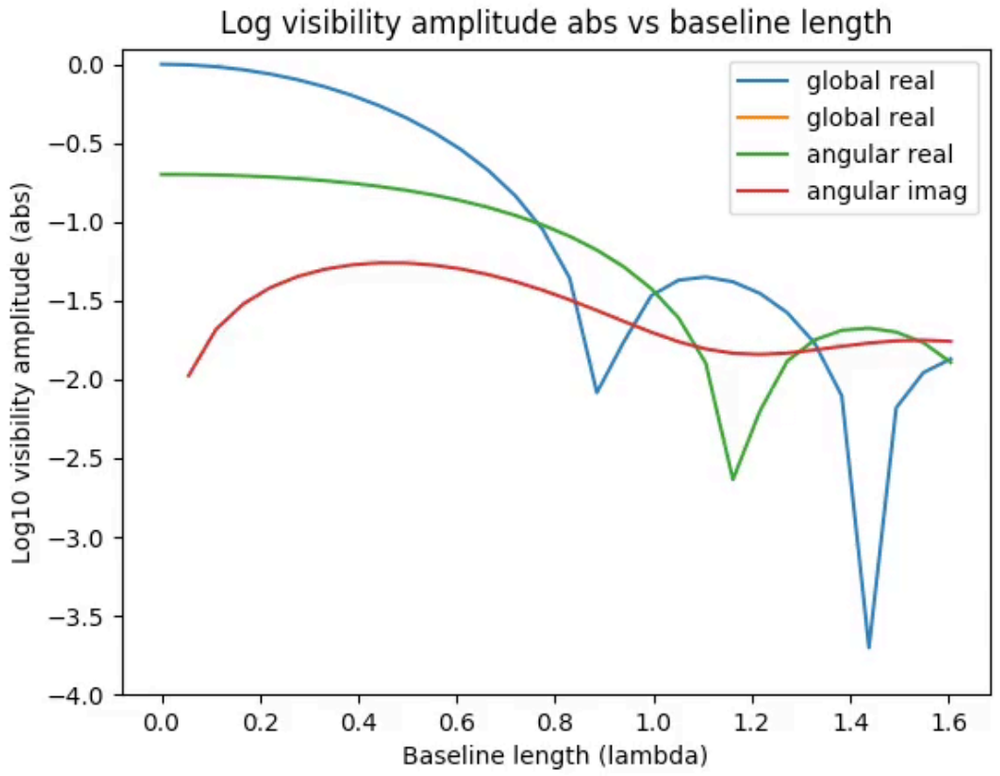
MWA Earthshine data



Ground-based short baseline interferometer response





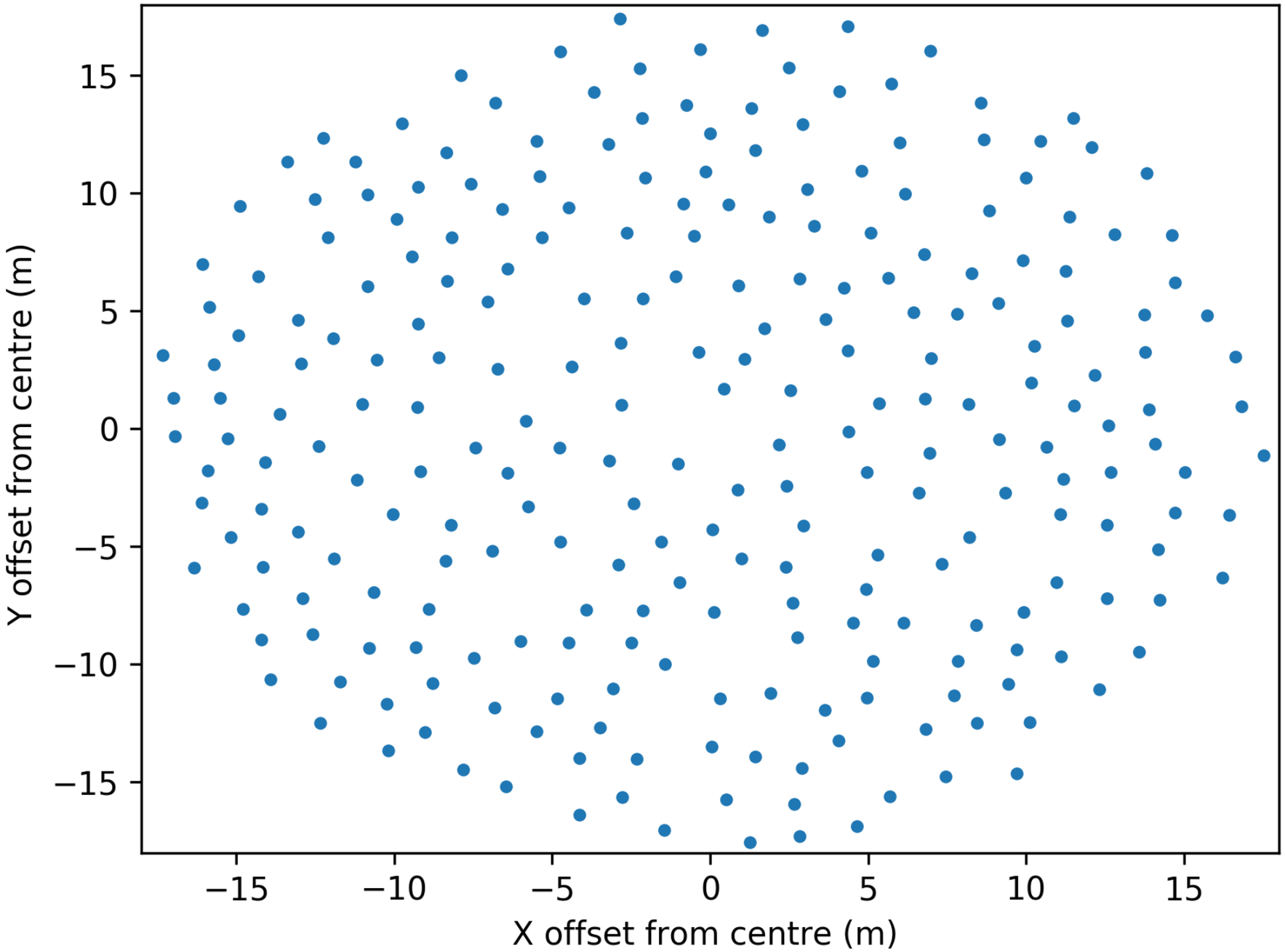


Limitations of using Earth rotation

- Global-signal sensitivity is not enough. Need to avoid low Galactic latitudes as the global Galactic spectrum contains complex spectral structure that contaminates the 21-cm signal.
- Restricting LSTs reduces the averaging of angular-structure response.
- Can’t do a full rotation if avoiding the Sun
- Can gain back some of the lost rotation-averaging of the angular structure by using many short baselines at different orientations simultaneously.
- Use EDA2

Engineering Development Array - 2

EDA2 Antenna positions



- 256 MWA dipoles
- 35m diameter
- randomly placed
- min spacing 1.5m
- Wire mesh groundscreen
- modified LNAs
- 50 - 300 MHz
- Each dipole output digitised
- Cross-correlate all 256 antennas

EDA-2 first-light image

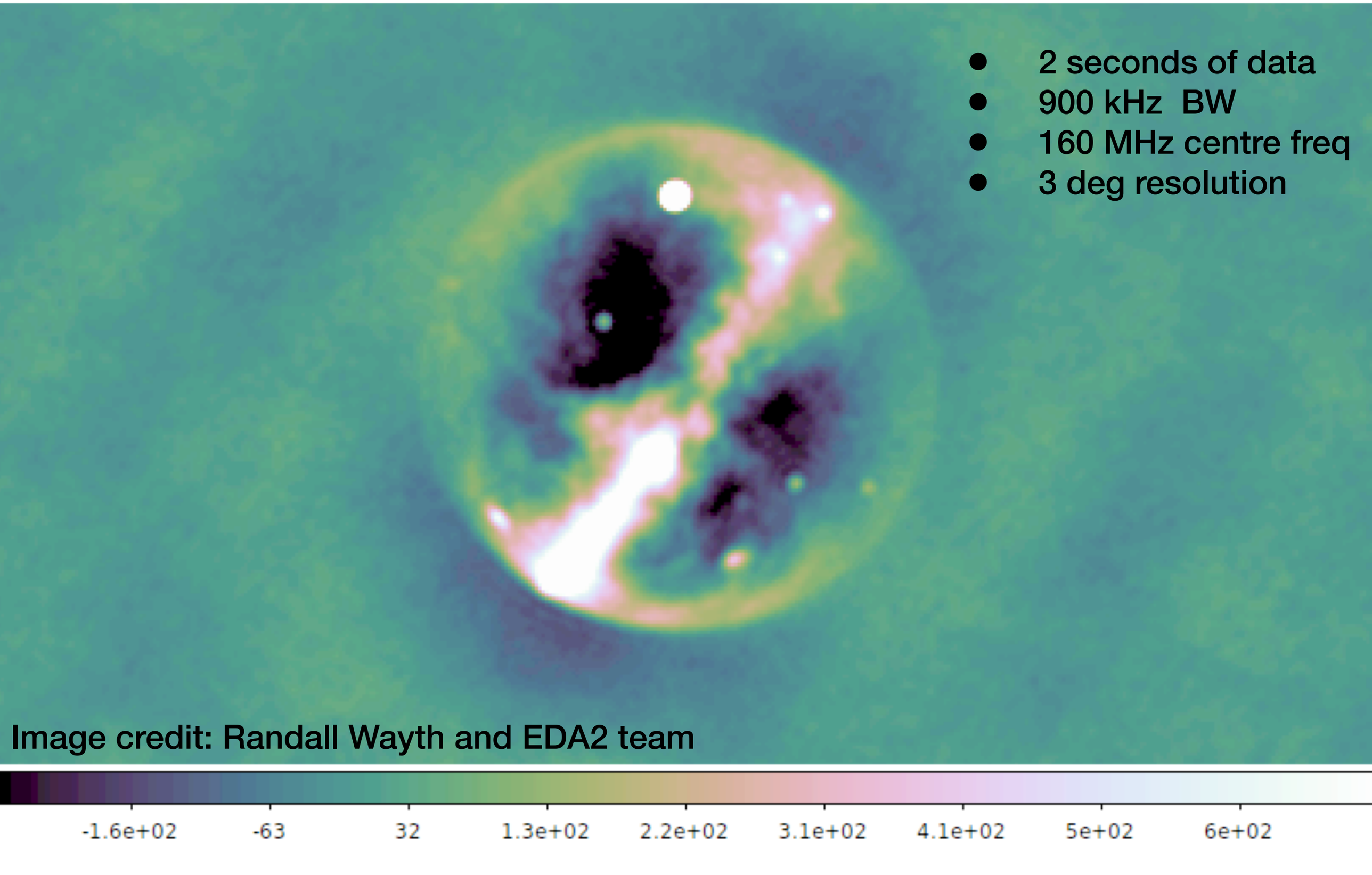
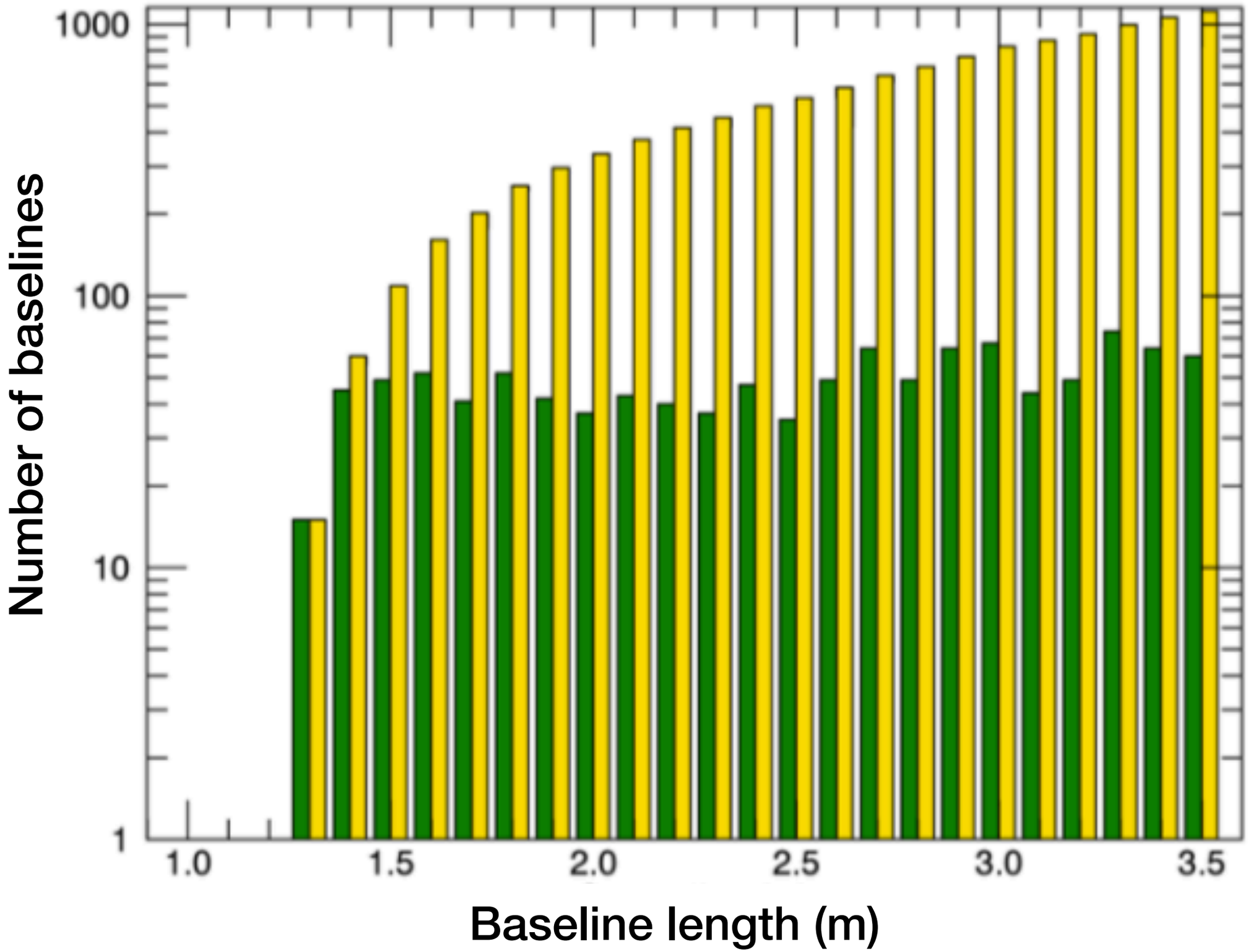
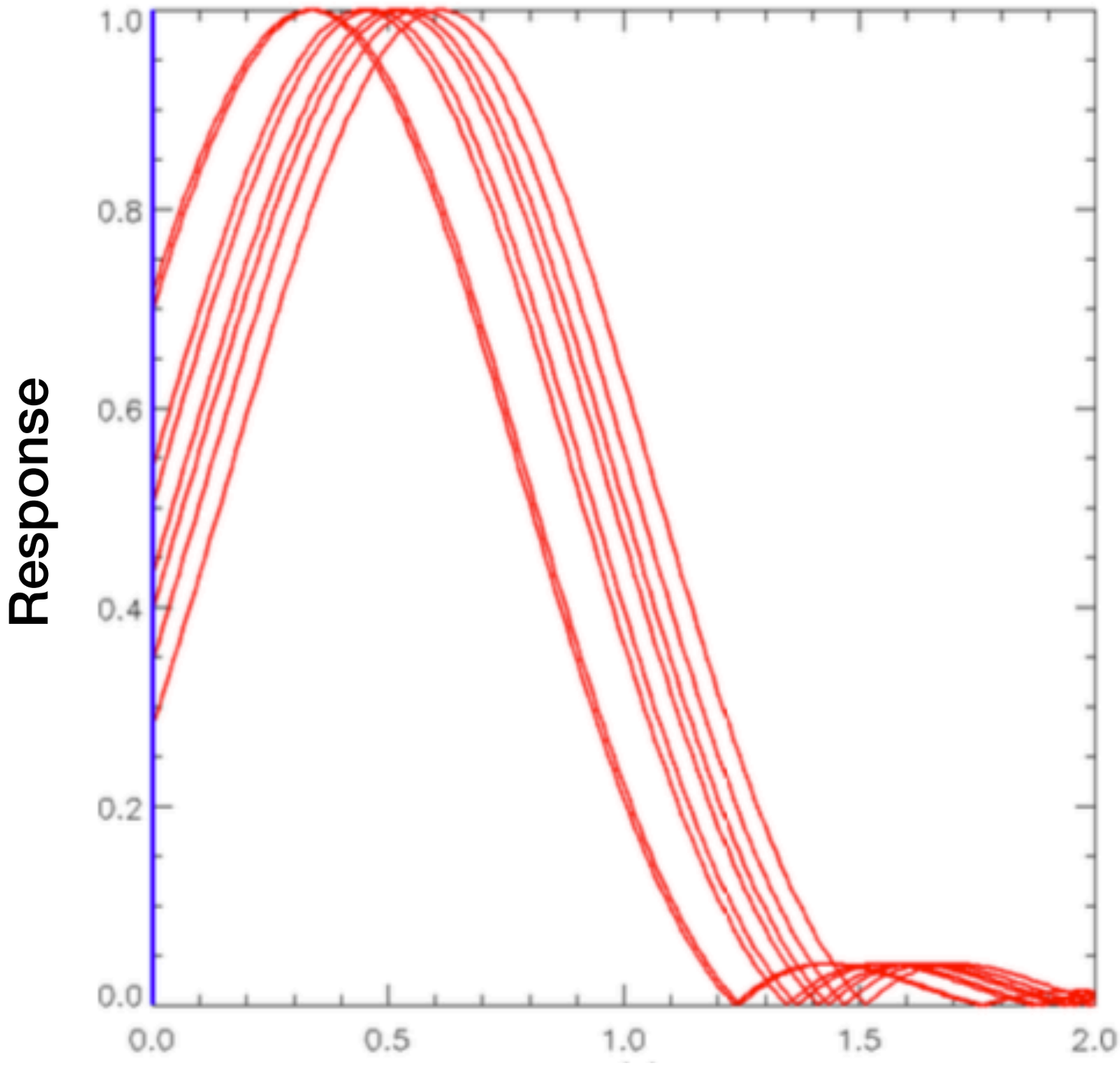


Image credit: Randall Wayth and EDA2 team

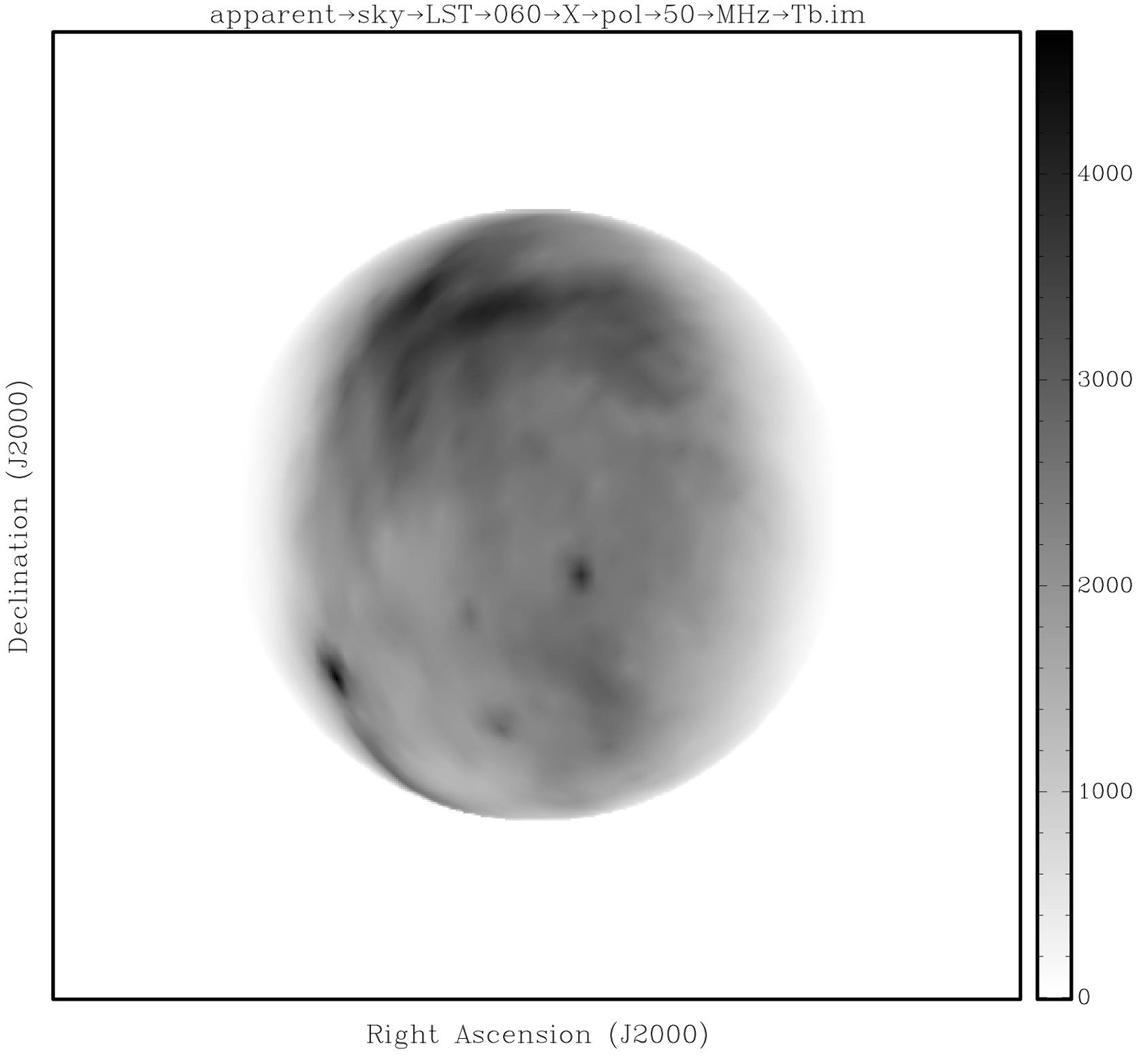
EDA2 Baselines



Fourier Beam Response

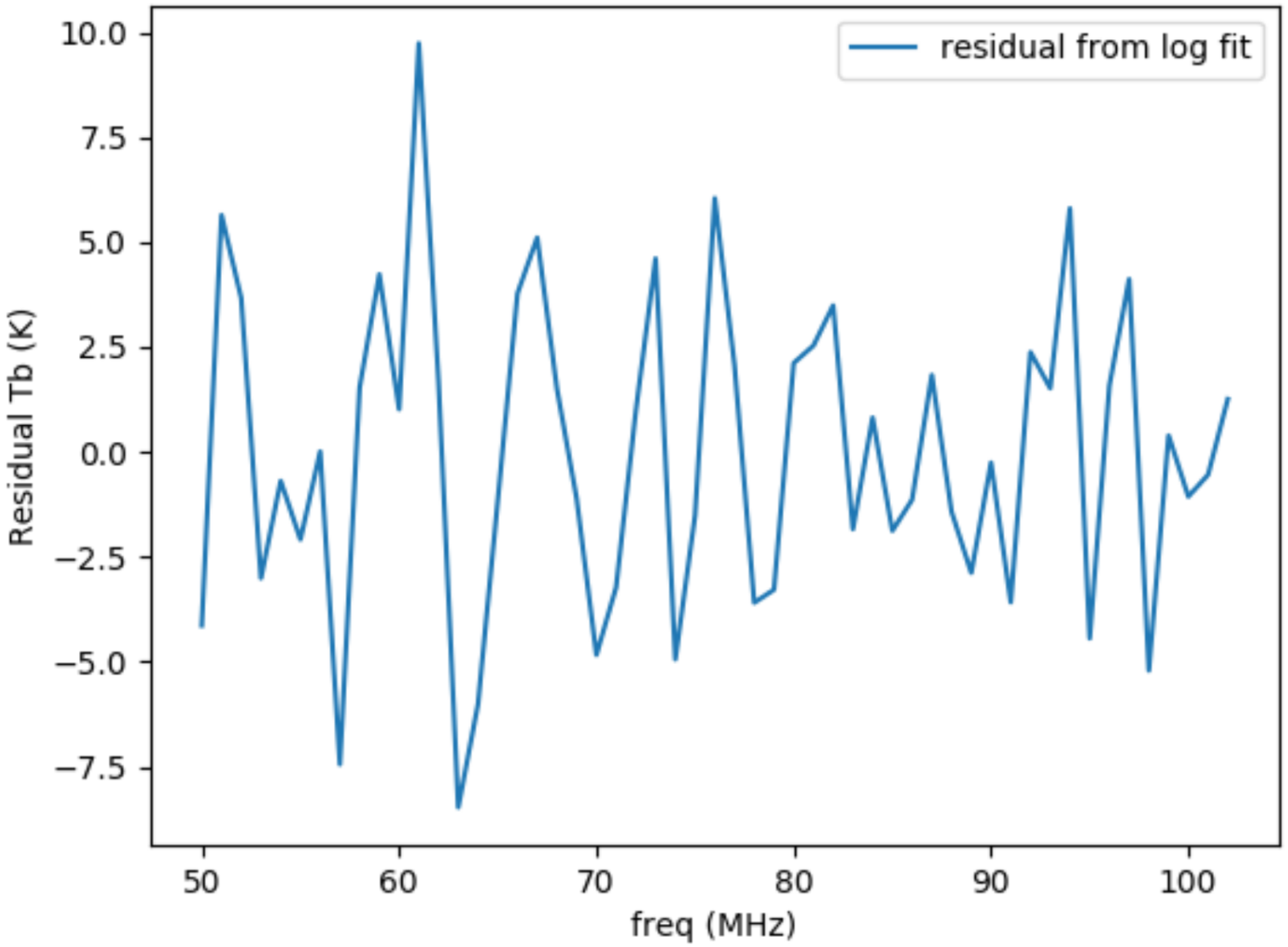


Miriad simulations



- GMOSS sky model
- LST 4 hrs
- Int time 8 mins
- No noise
- beam applied (analytic dipole)

Miriad simulations



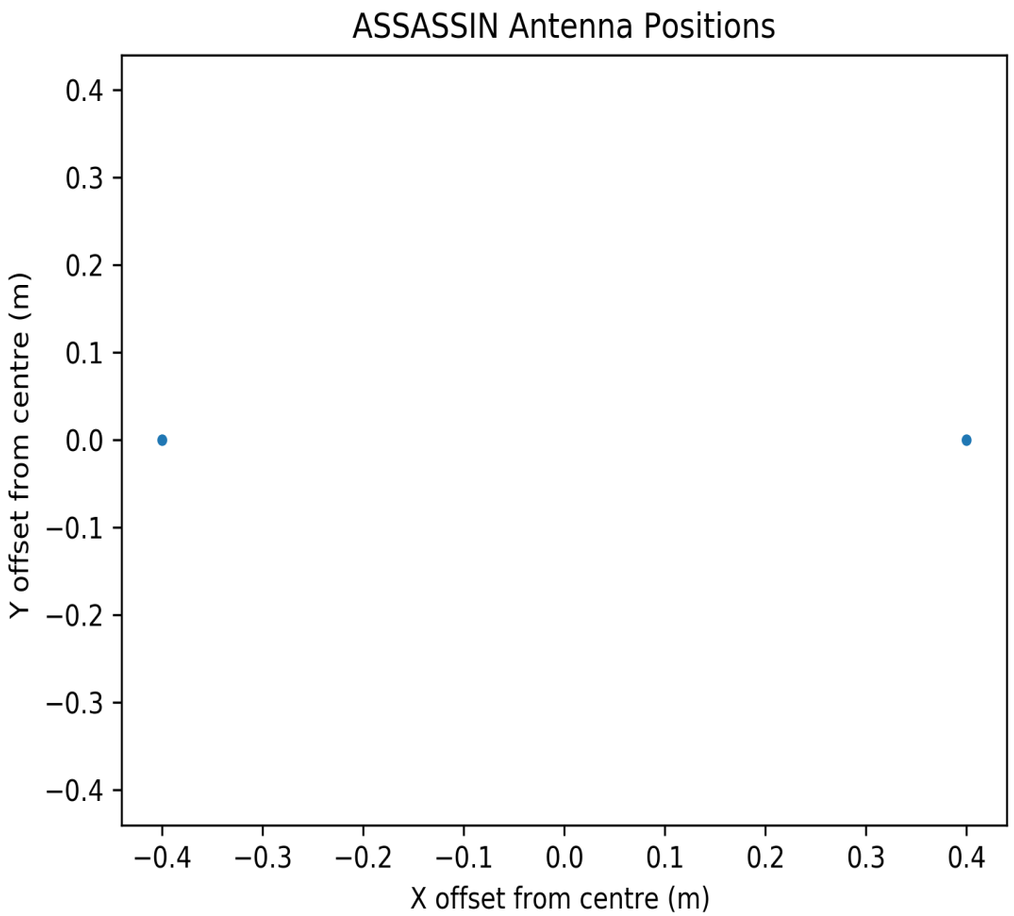
- Output full EDA2
- GMOSS model
- LST 4 hrs
- Short baselines only, uv0 weighting > 0.5
- Int time 8 mins
- No noise
- Weights applied
- 8th order polynomial fit in log-log space, residuals
- Even with 4 hrs separation in LST residuals are in the same place.

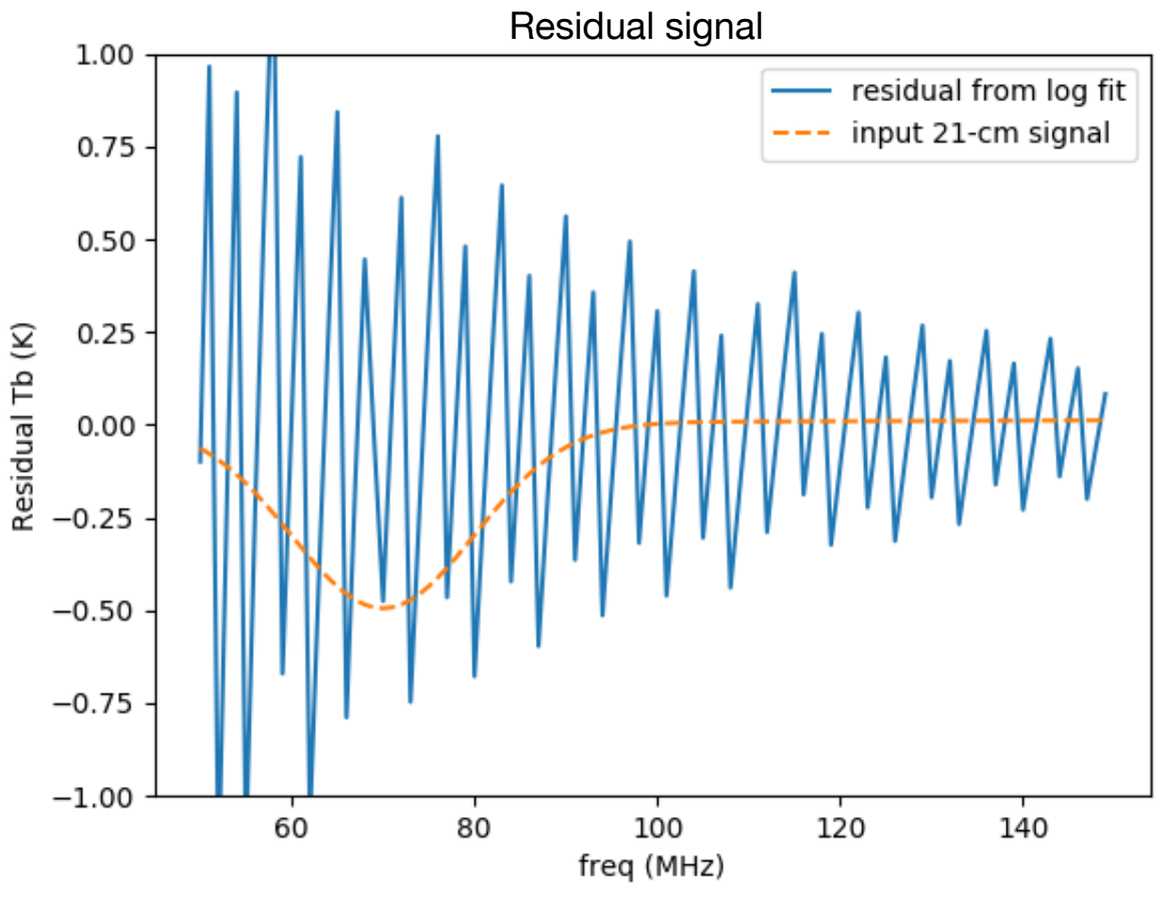
EDA2 prospects

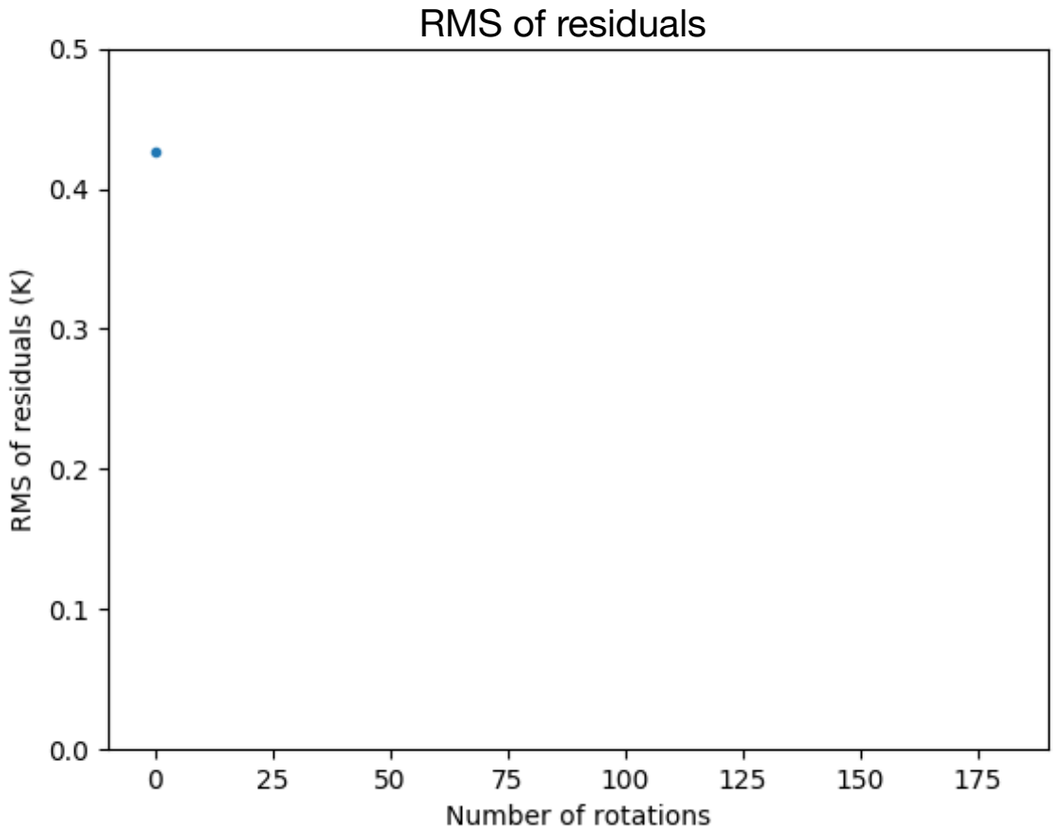
- Still considering observational strategies, but may not be possible with EDA2
- Exploit polarisation information?
- Need shorter baselines and more orientations
  - experimented with different random arrays, including different minimum separations of antennas
  - Instead of randomly-placed antennas, build an array with all possible orientations and baseline lengths: ASSASSIN

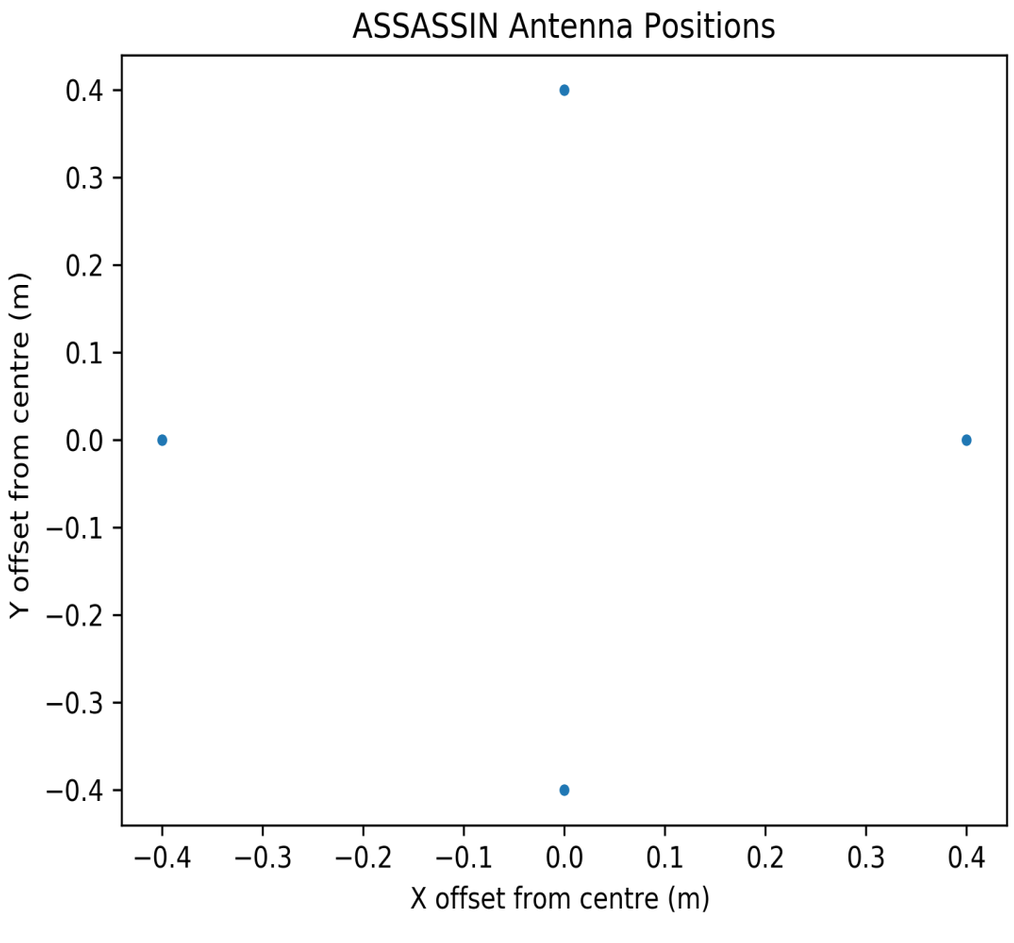
All Sky SignAl Short Spacing INterferometer (ASSASSIN)

- Use a physically-rotating baseline
- One (or several) very short baseline length and all possible rotations?
- Advantage - dipole beam rotates with baseline - remain in parallel configuration
- Get shorter baselines, all in parallel config
- Get all orientations by rotation
- Can observe only at night and at suitable LSTs
- Can still calibrate using the EDA2 and a sky model
- Mutual coupling will need to be taken into account


ASSASSIN Antenna Positions
Y offset from centre (m)
X offset from centre (m)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4


Residual signal
residual from log fit
input 21-cm signal
Residual Tb (K)
freq (MHz)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
60
80
100
120
140


RMS of residuals
RMS of residuals (K)
Number of rotations
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
125
150
175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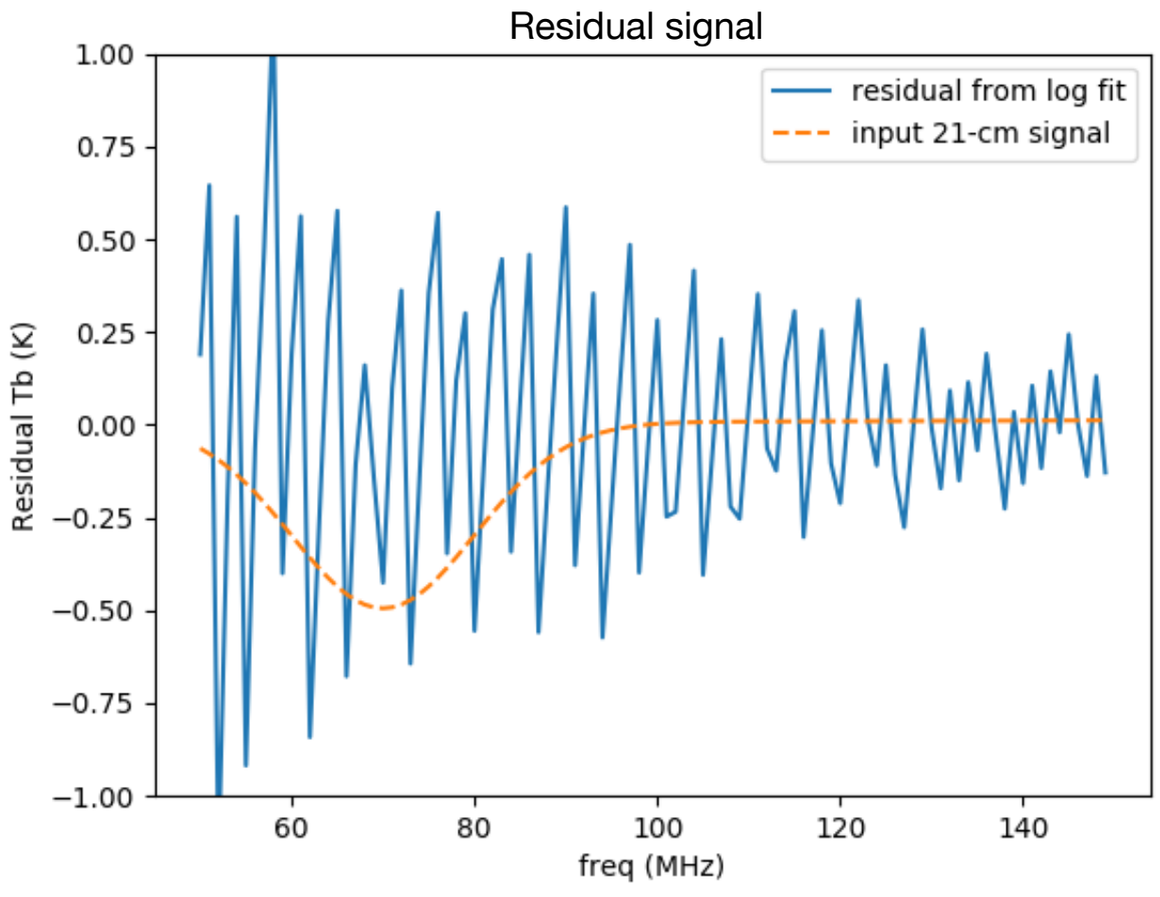
−0.4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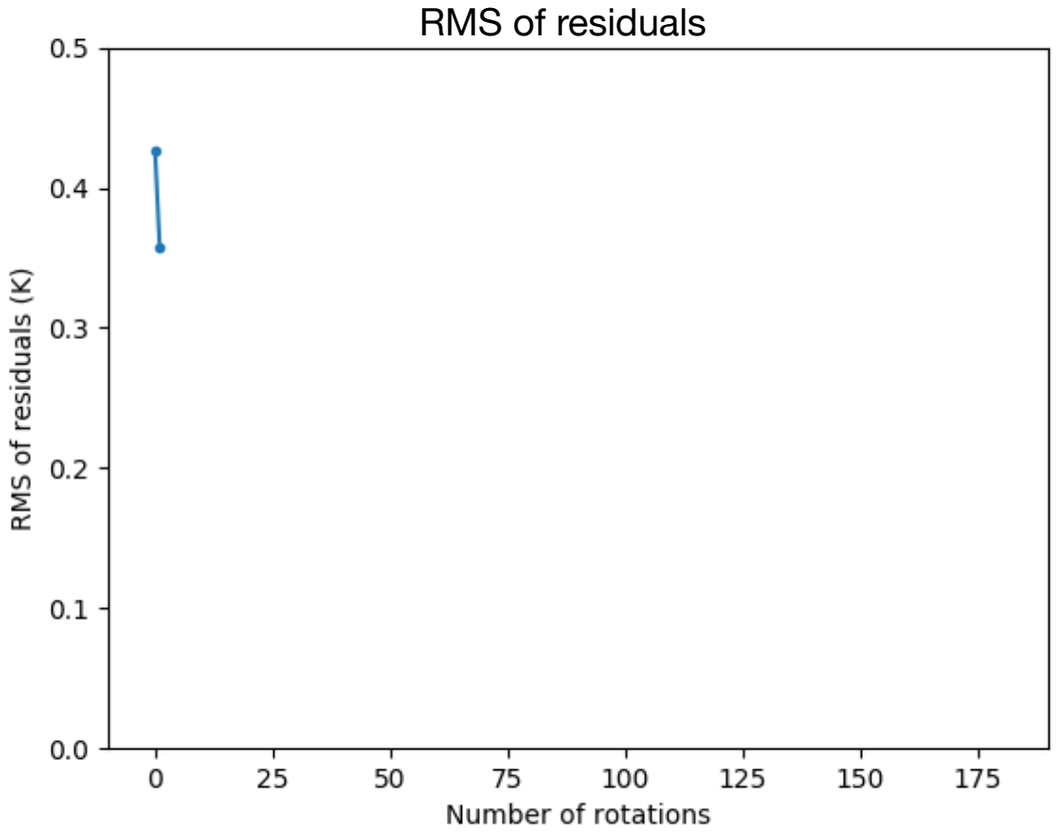
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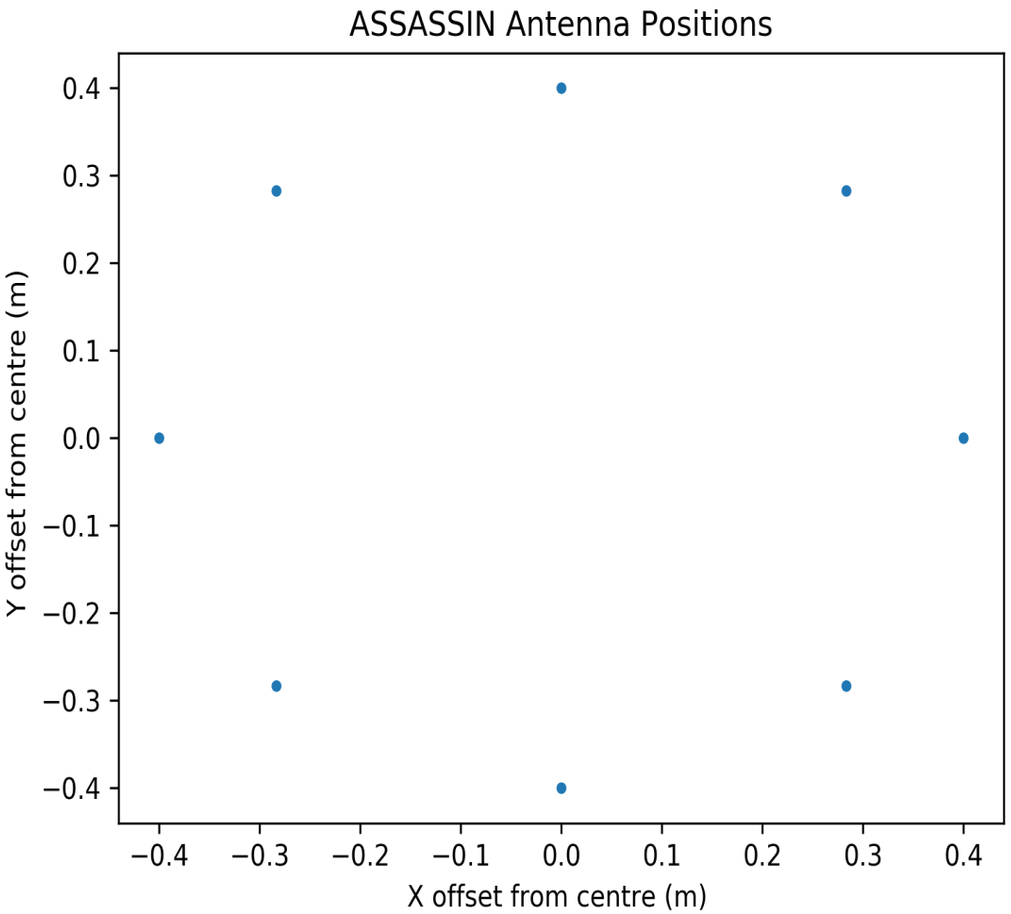
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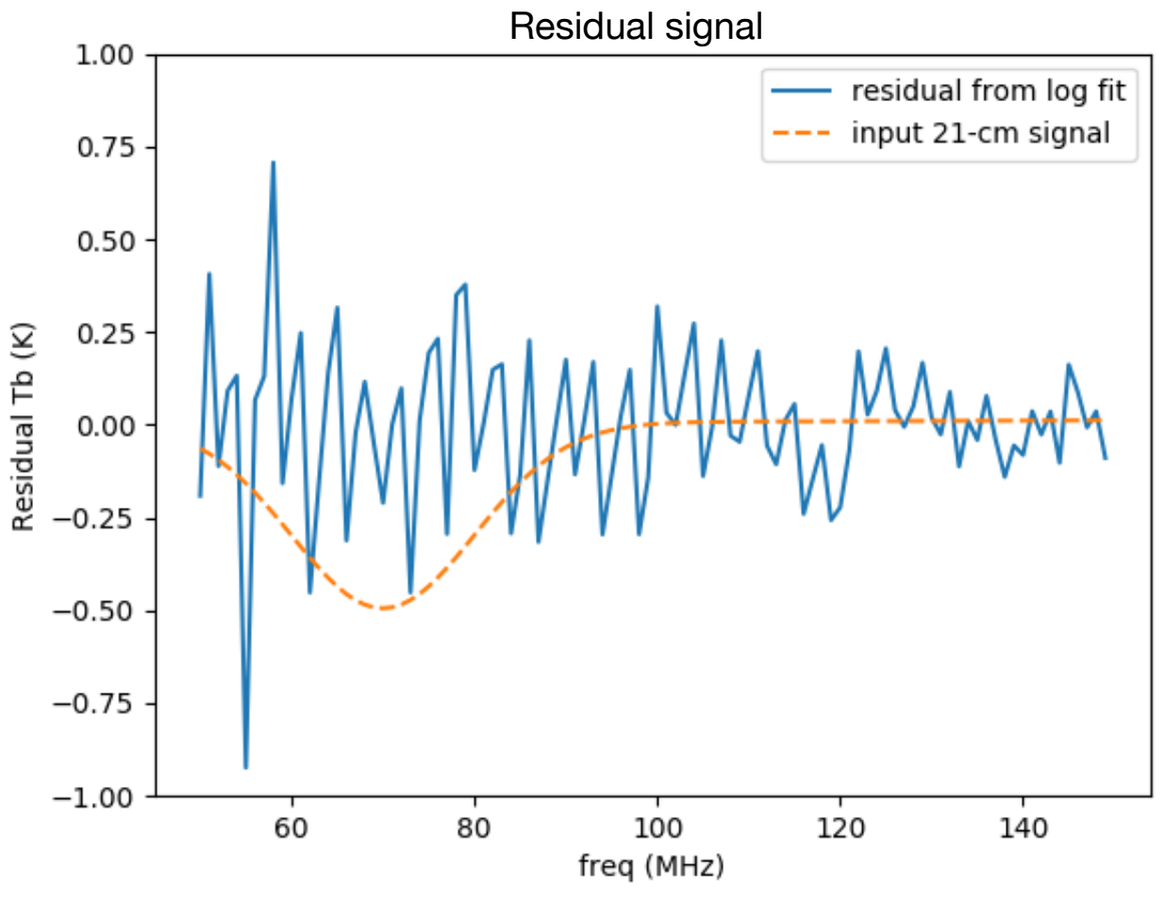
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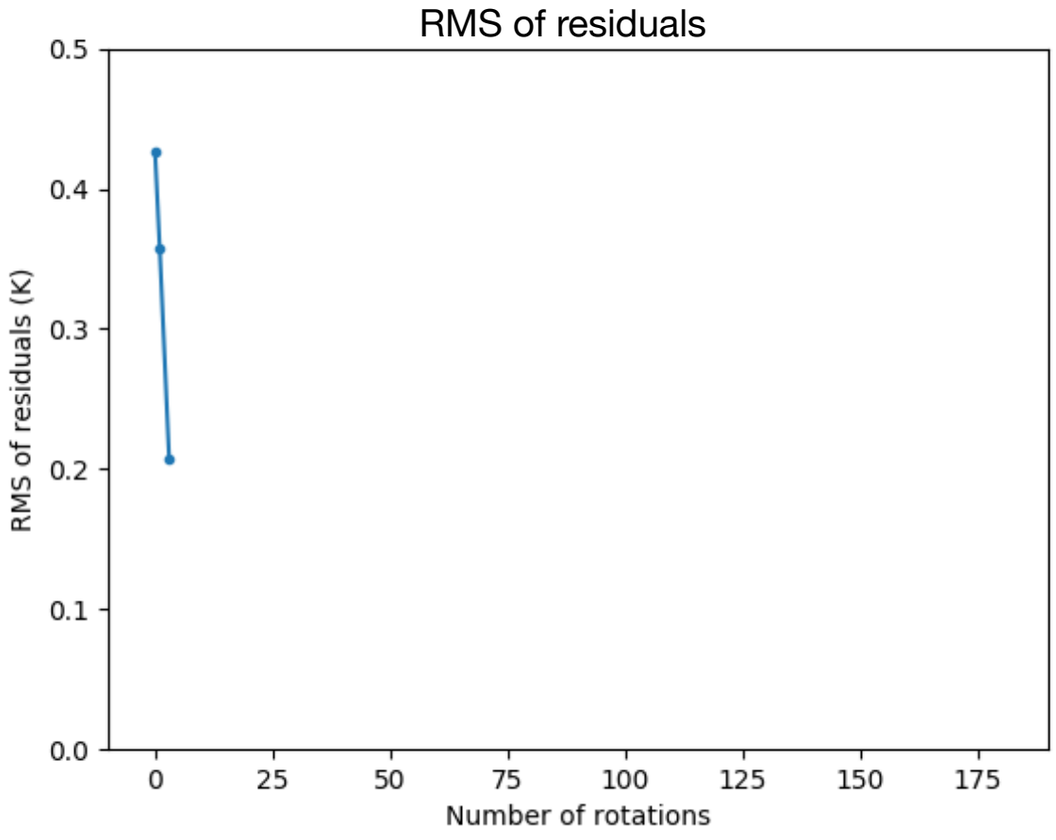
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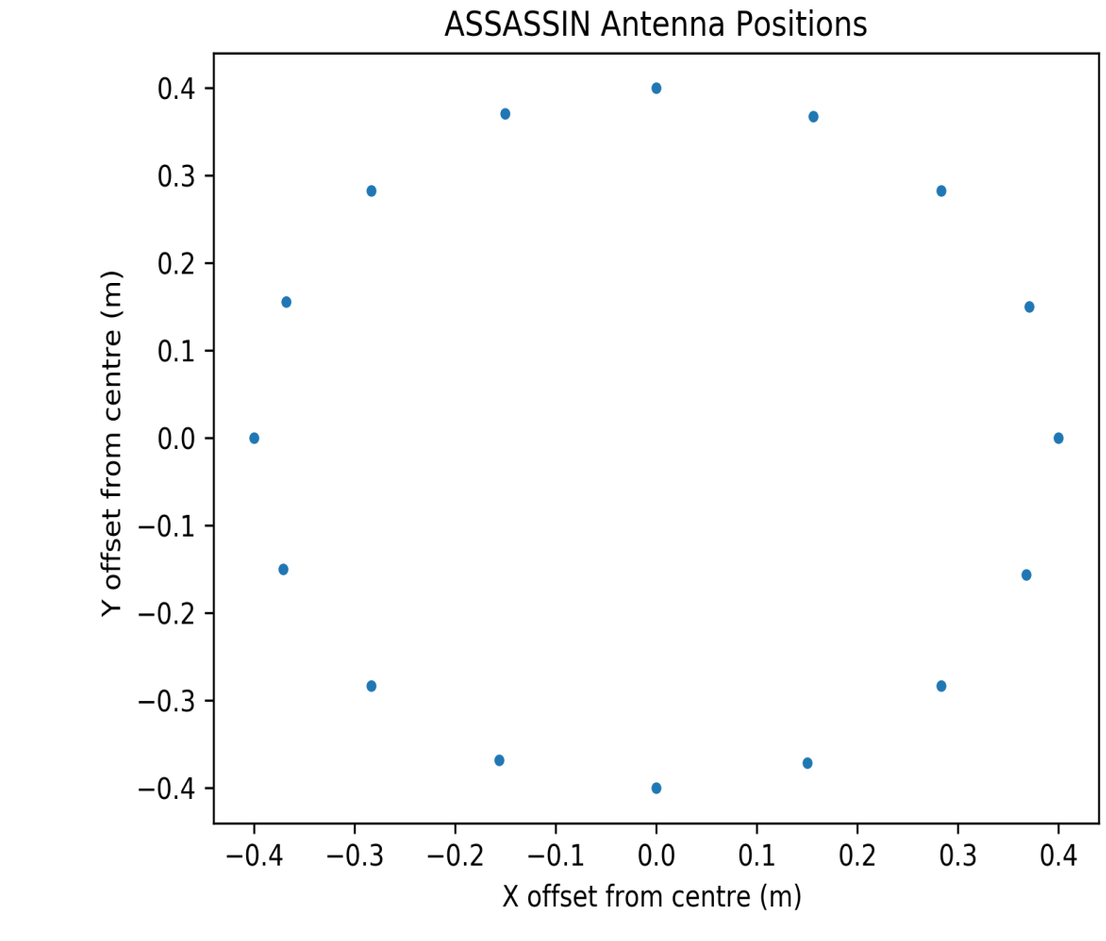
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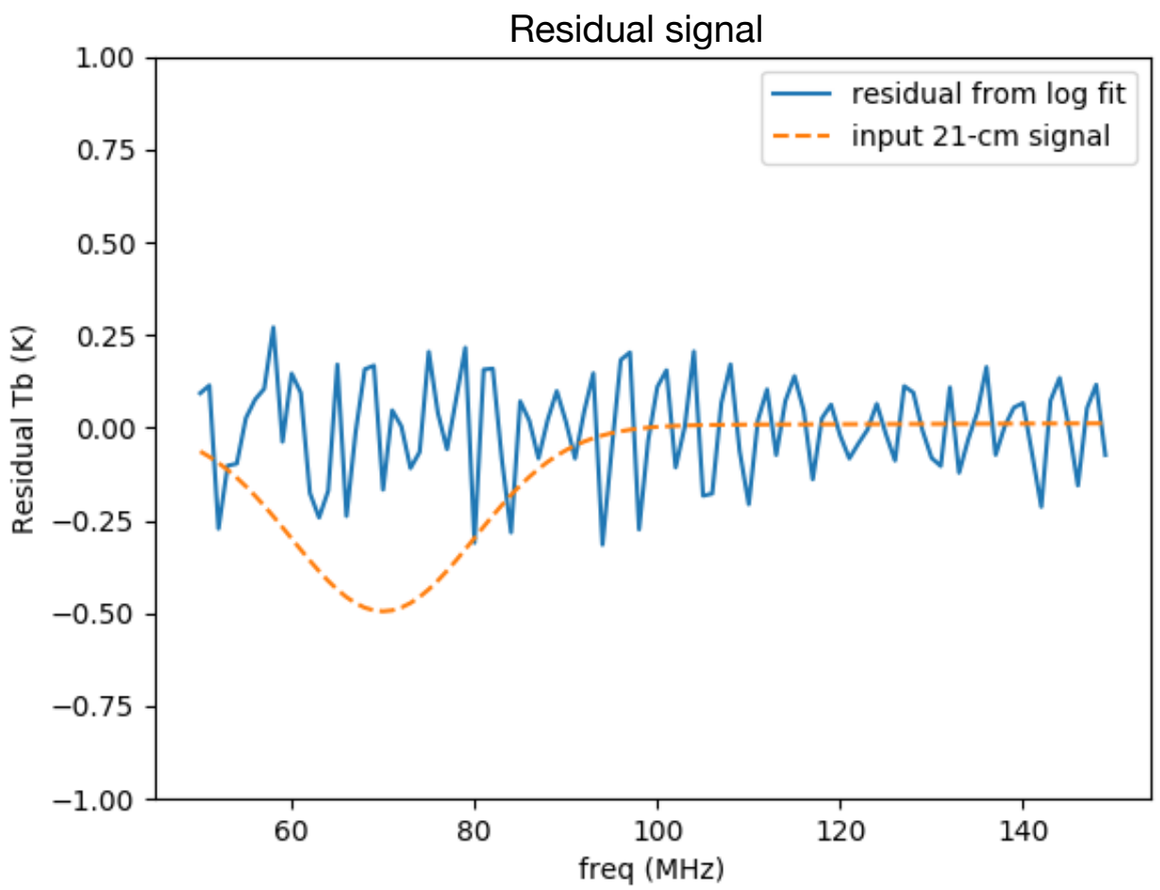
−0.3
−0.4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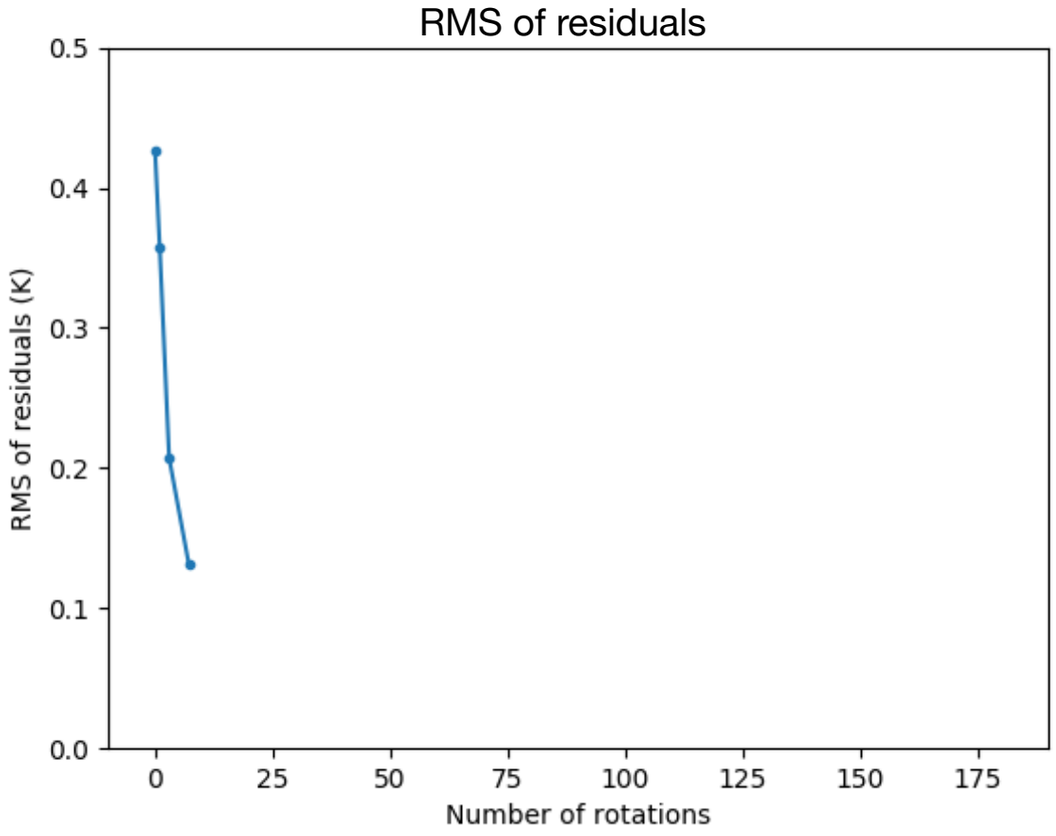
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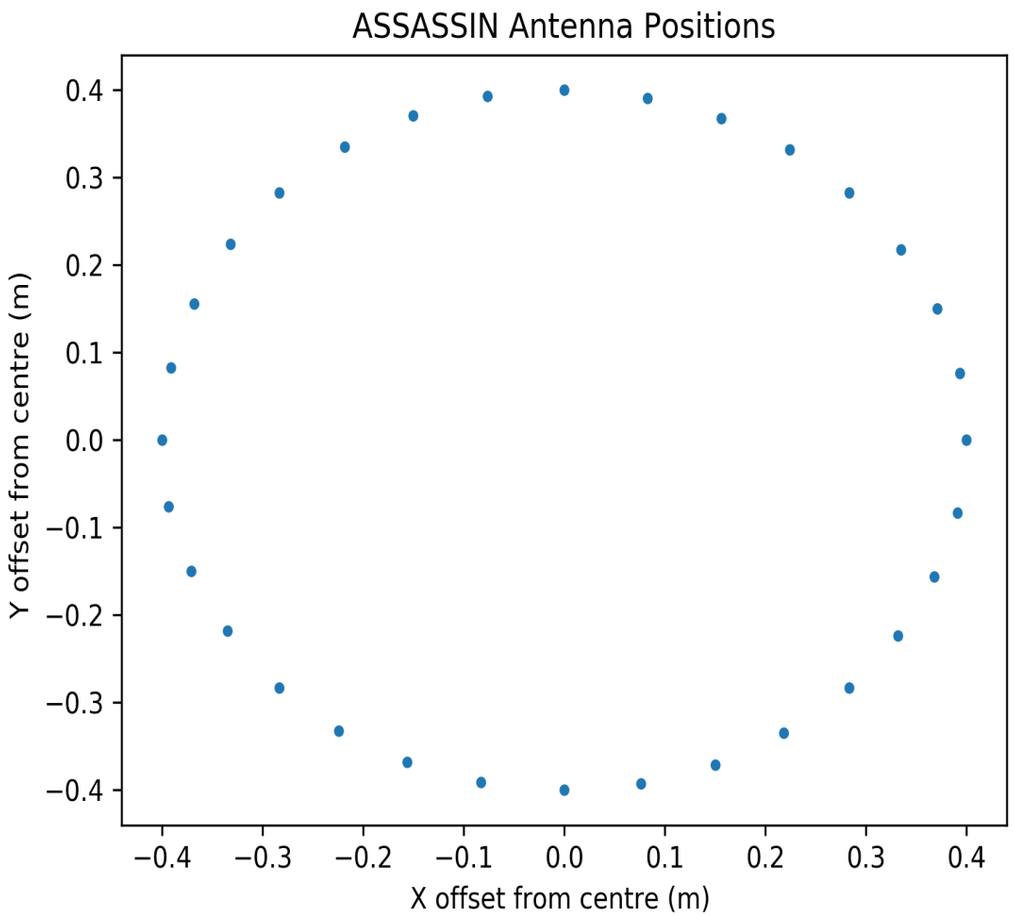
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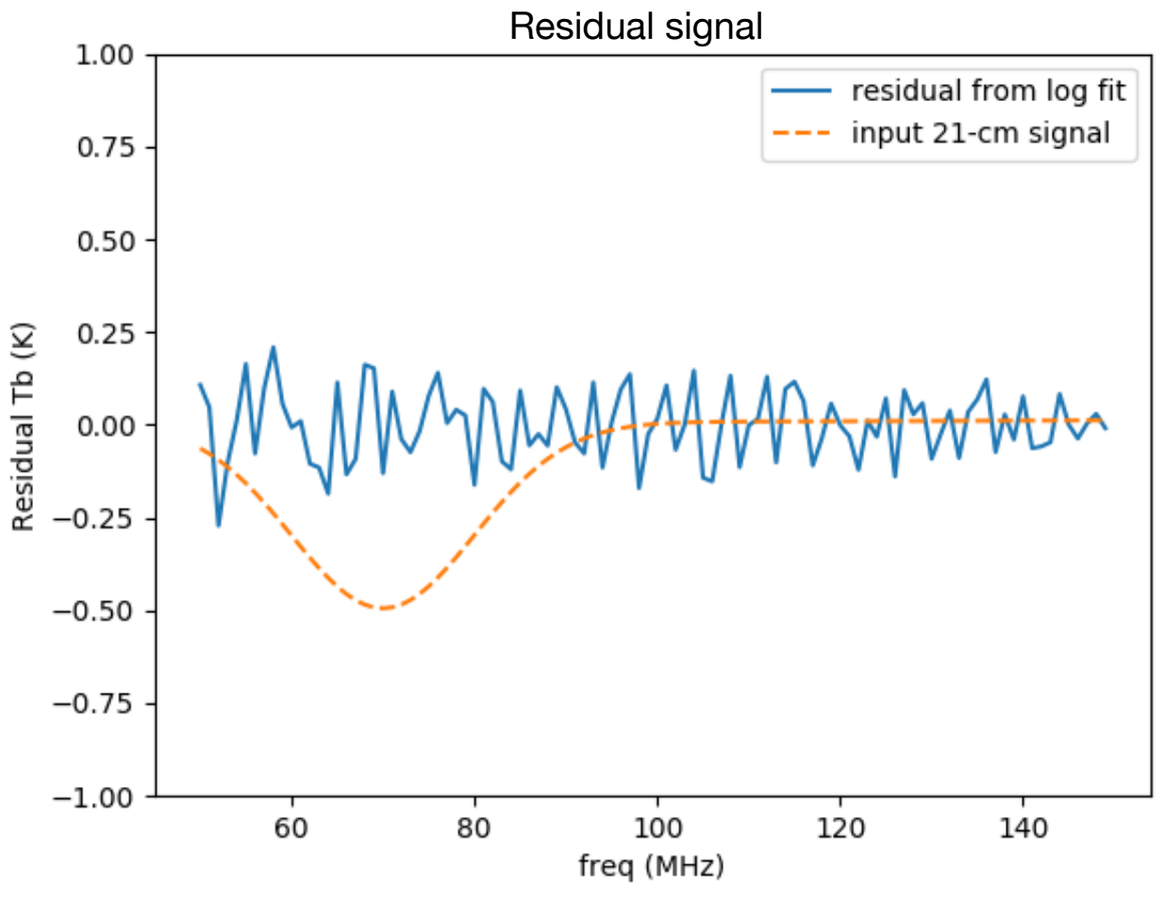
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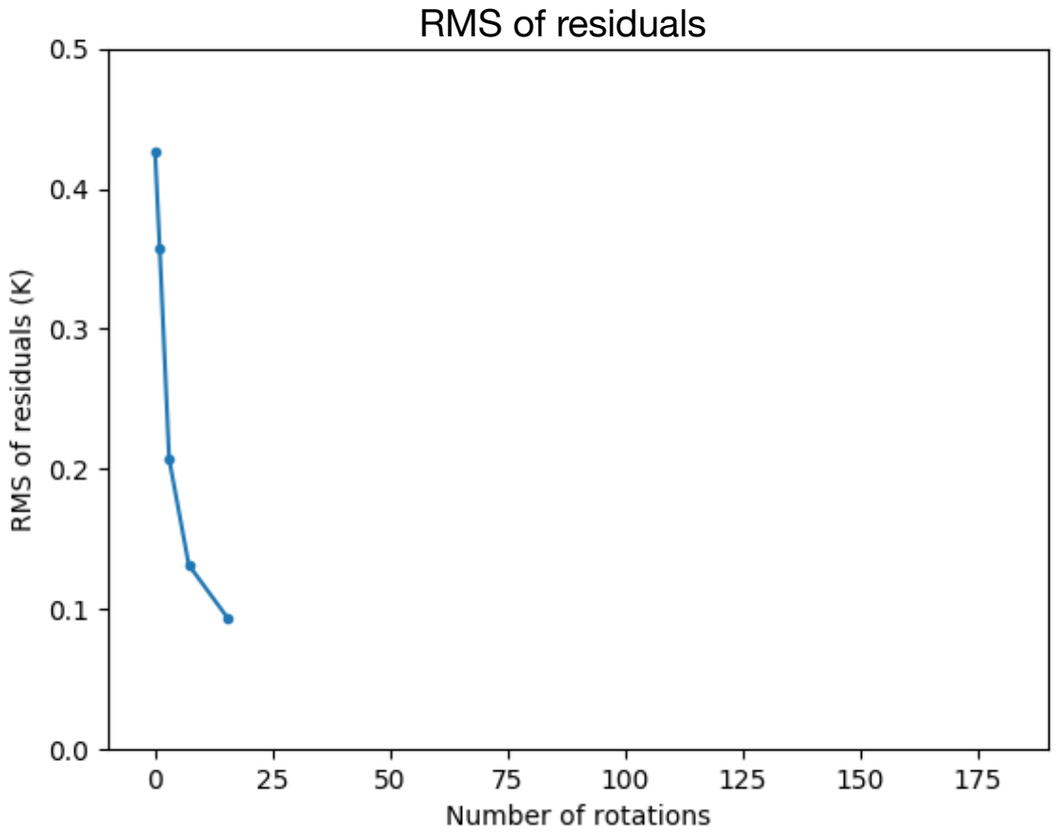
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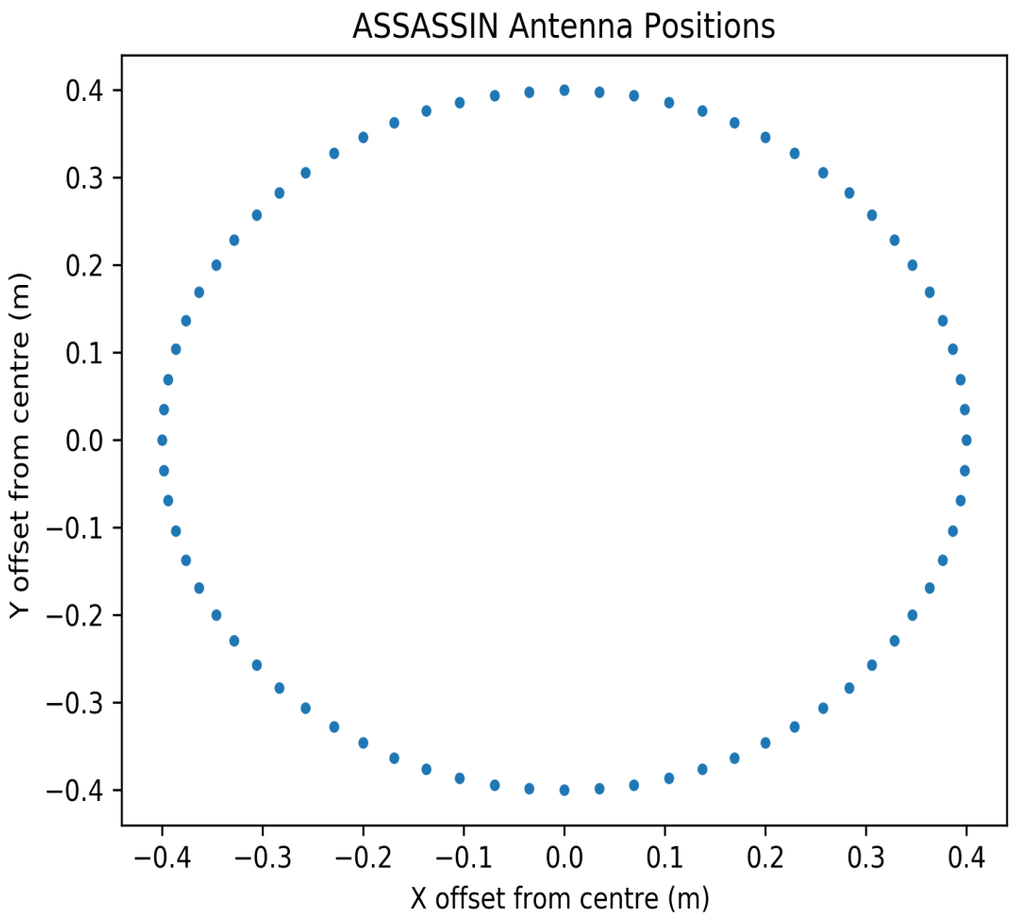
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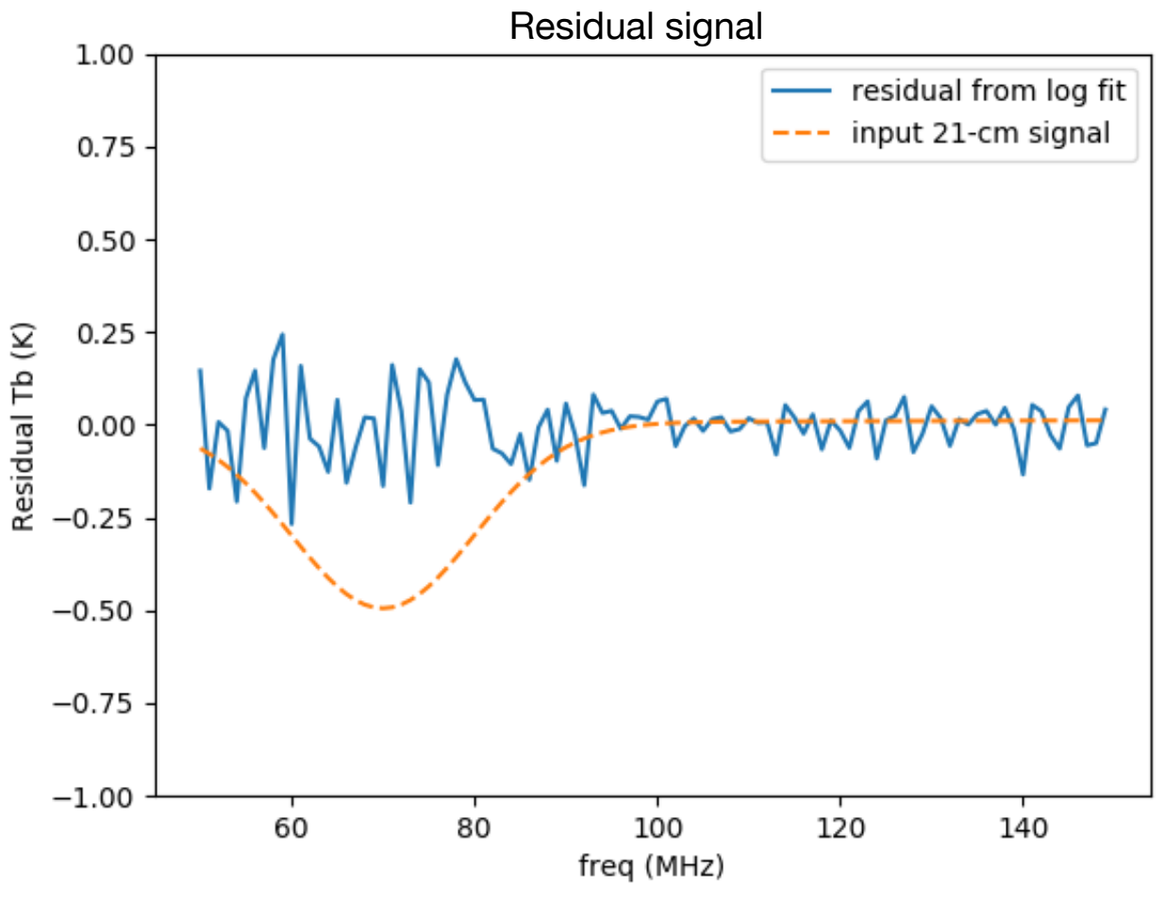
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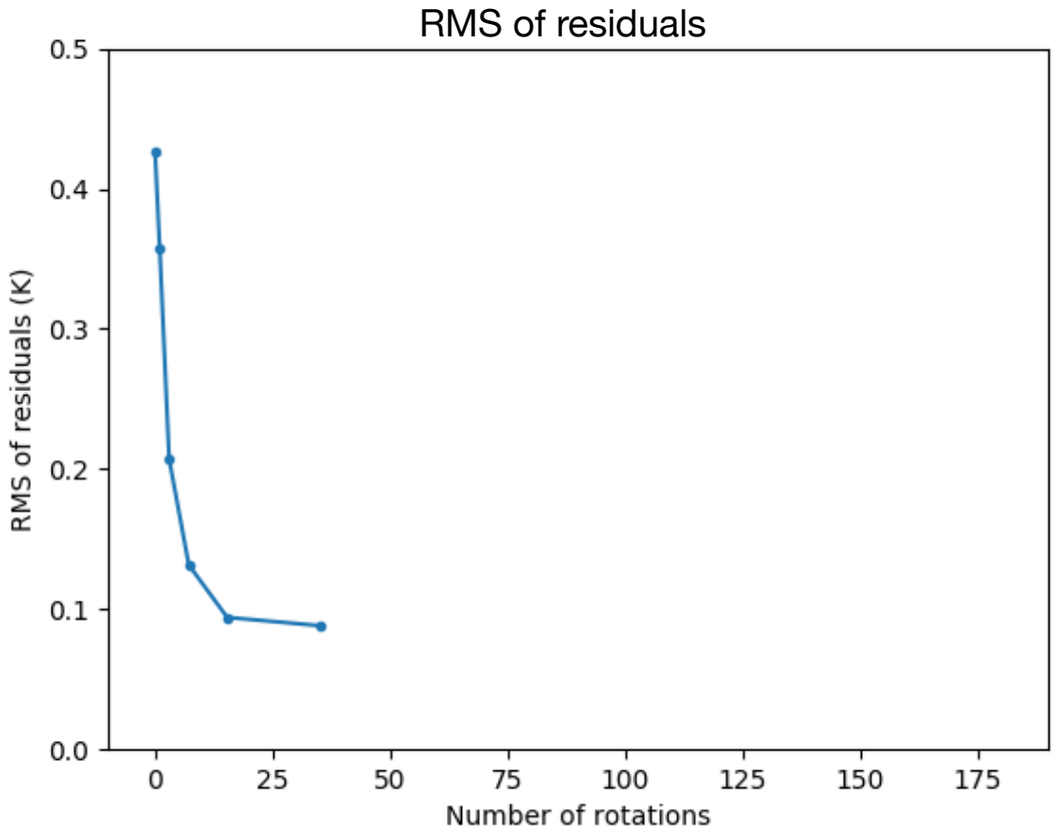
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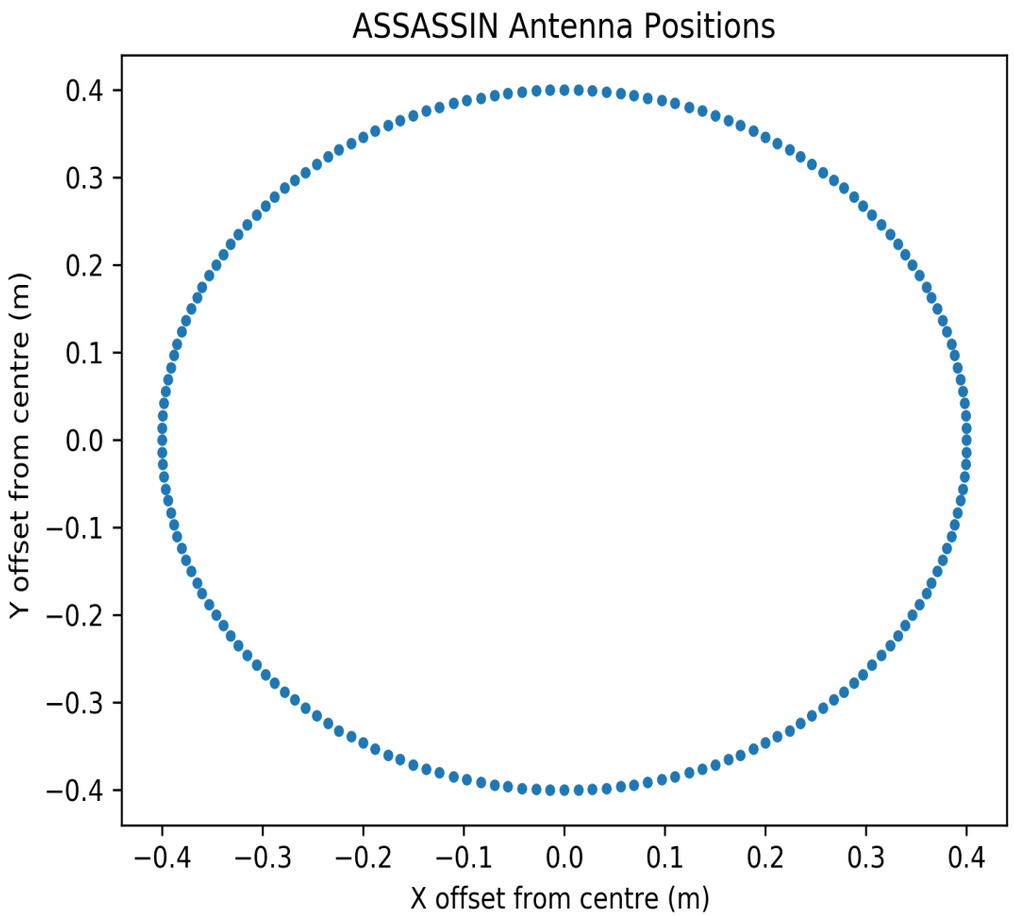
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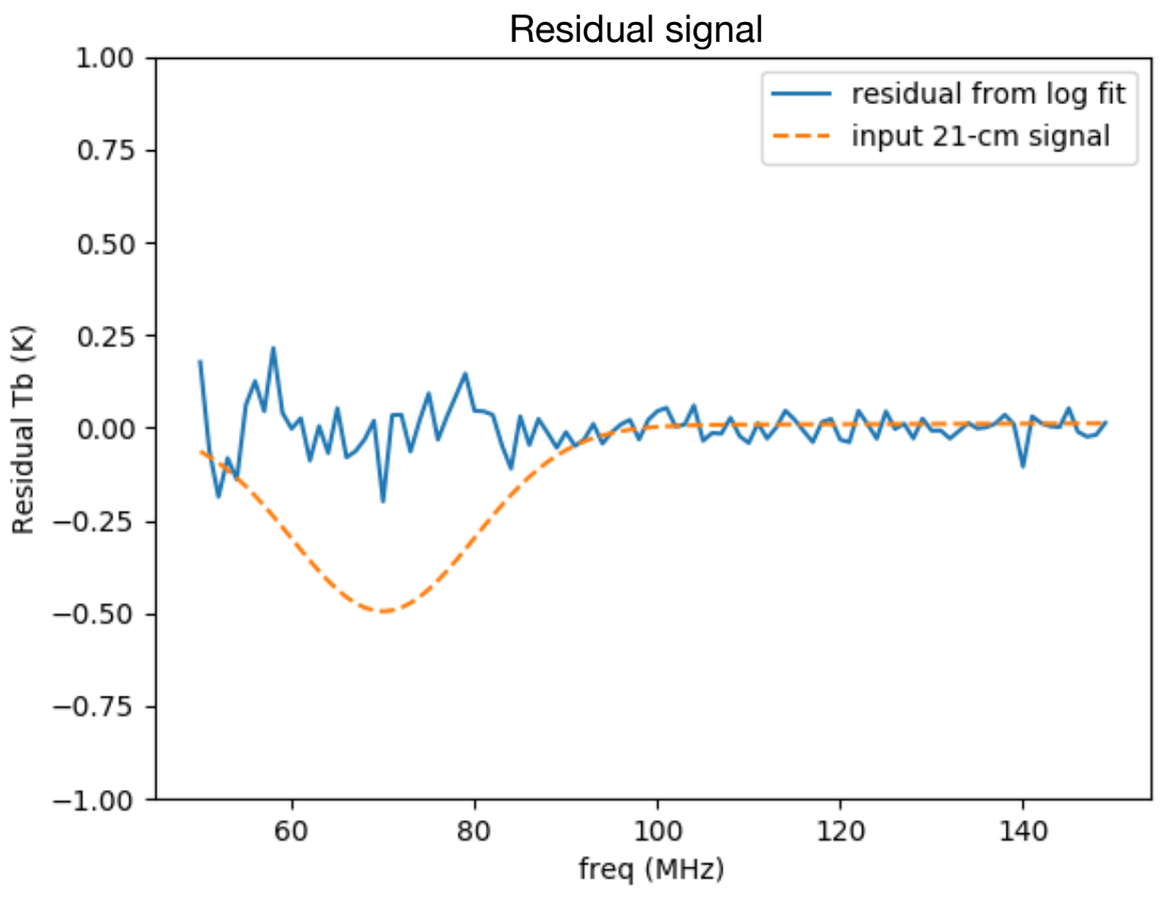
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residual from log fit
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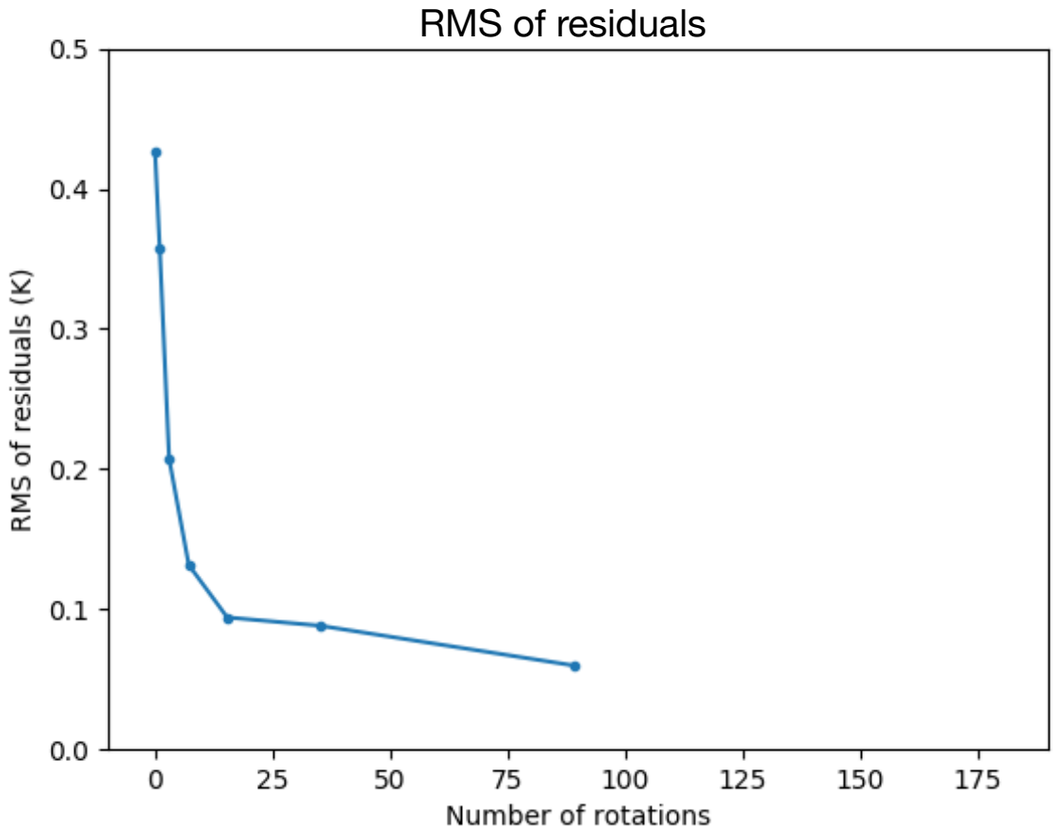
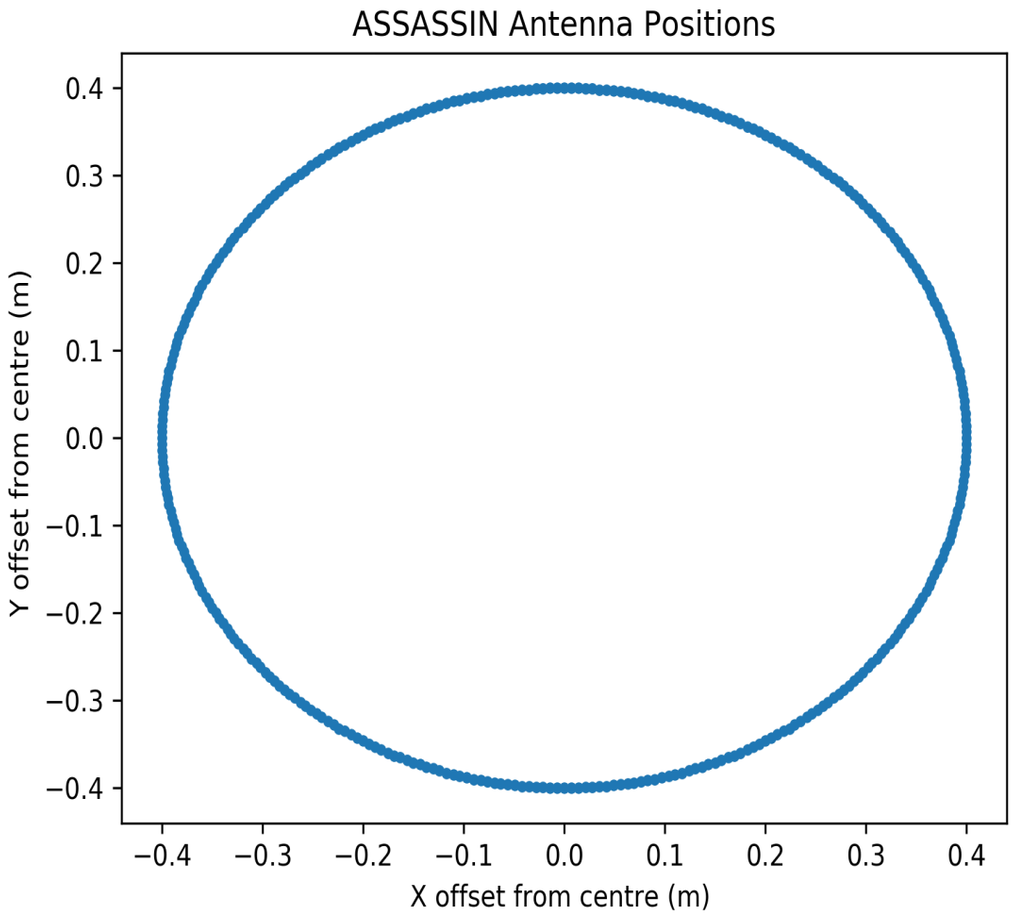
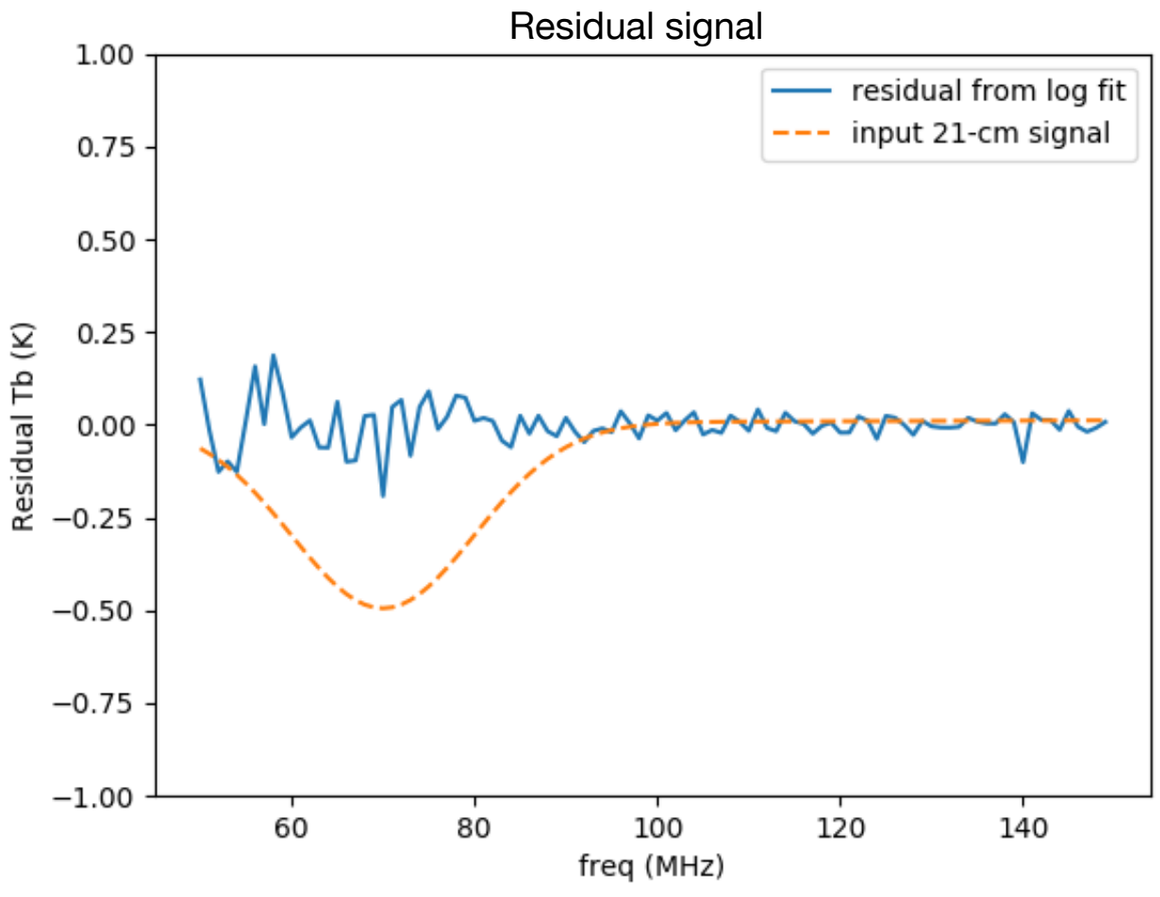
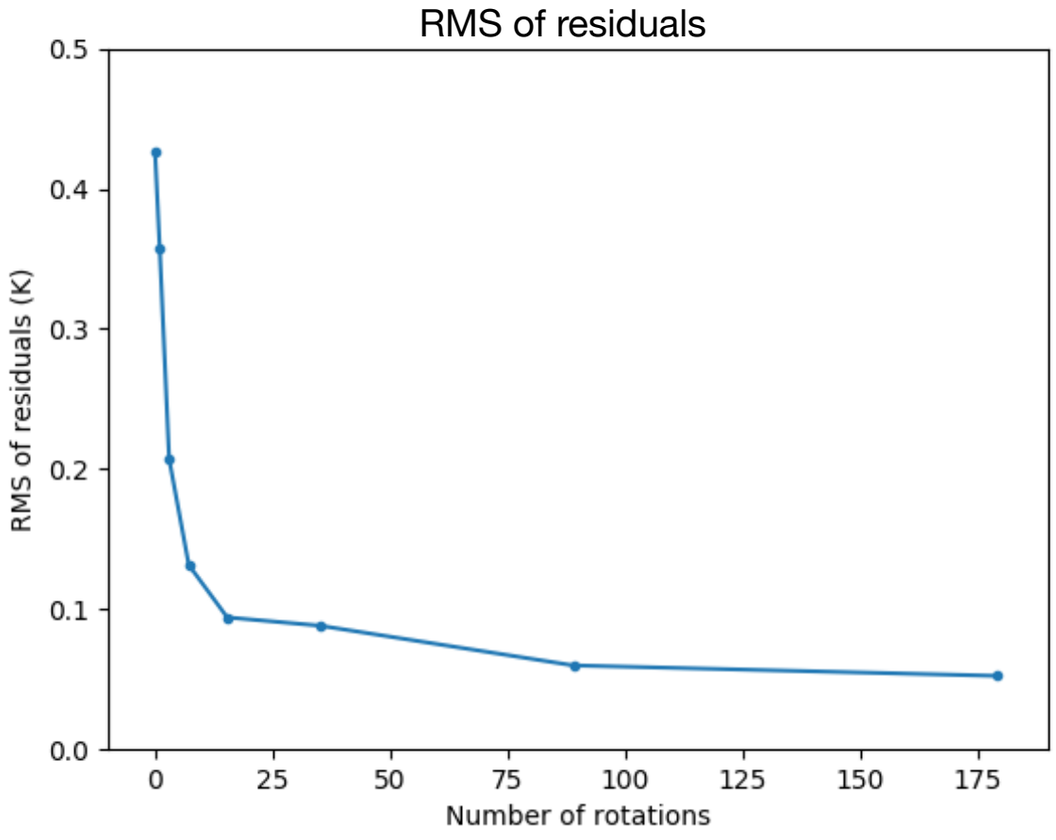
Residual Tb (K)
freq (MHz)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
60
80
100
120
140


RMS of residuals
RMS of residuals (K)
Number of rotations
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
125
150
175


ASSASSIN Antenna Positions
Y offset from centre (m)
X offset from centre (m)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4


Residual signal
residual from log fit
input 21-cm signal
Residual Tb (K)
freq (MHz)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
60
80
100
120
140


RMS of residuals
RMS of residuals (K)
Number of rotations
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
125
150
175

Next Steps

- EDA2 full rotation simulation
- Use polarisation information?
- Verify EDA2 simulations using new data
- FEKO modelling / mutual coupling calculations

- Assassin simulation combining multiple LSTs
- Explore separating screen options
- Build and test prototype at MRO
- Float it on a lake?