Final project: Very-long-baseline Interferometry

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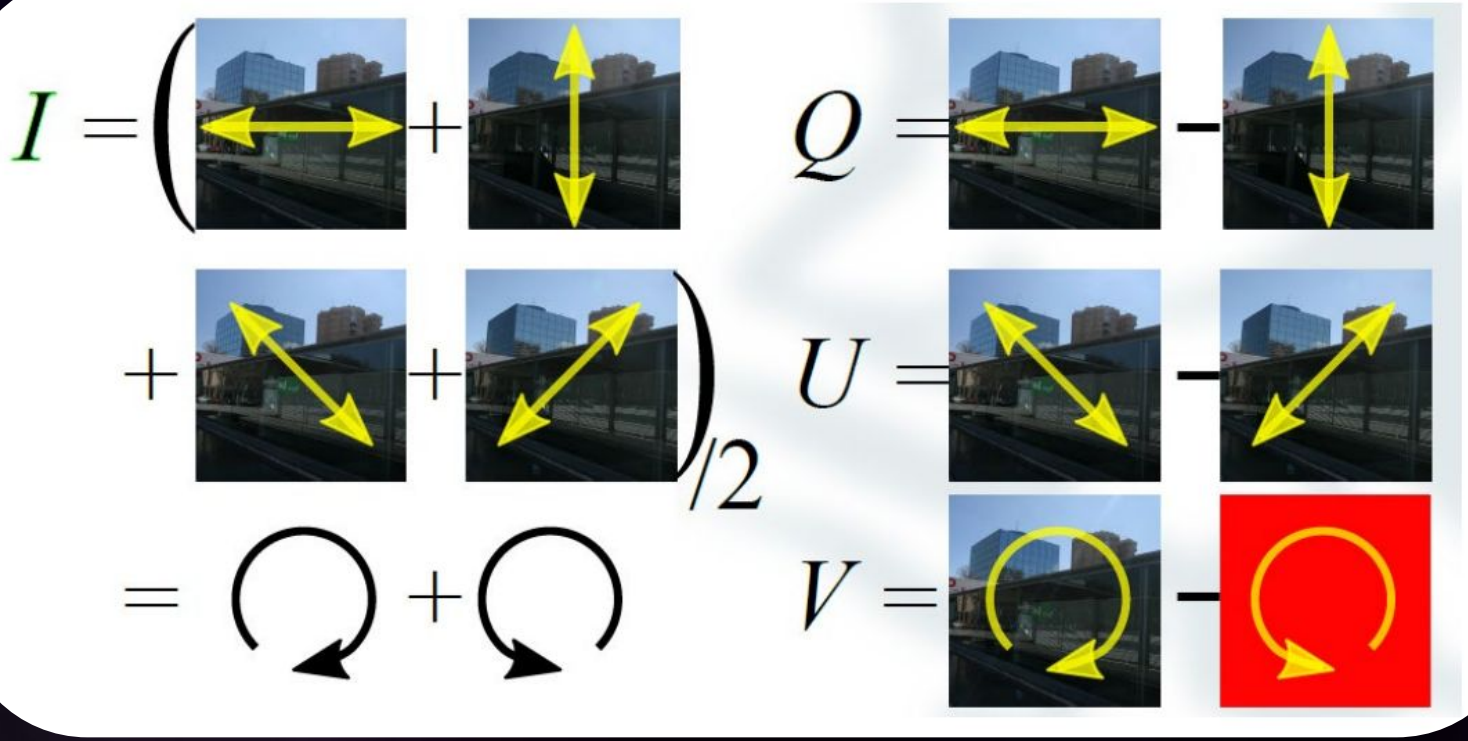
01 Understanding

Understanding, running, and modifying the code

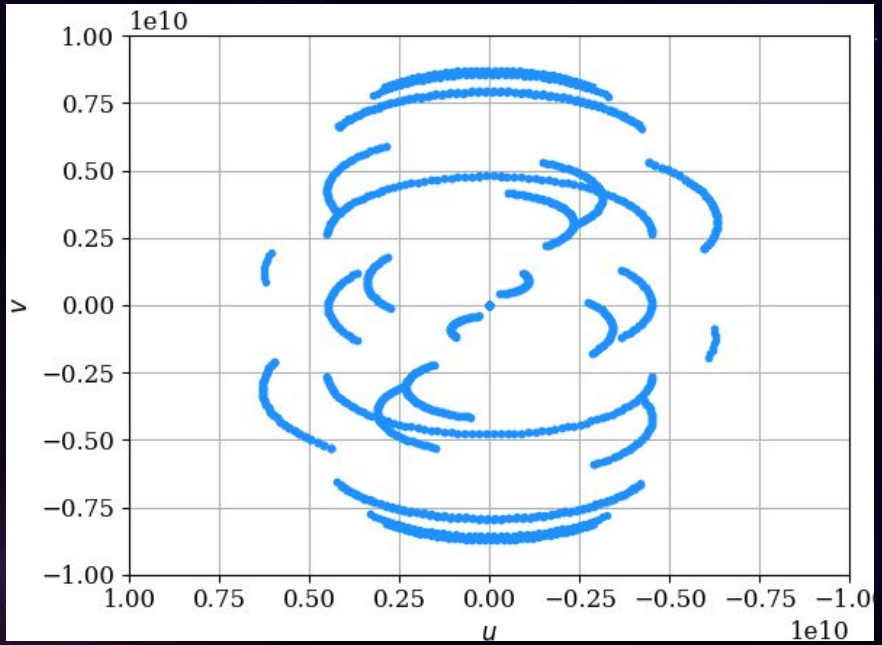
Input Image

```
# SRC: M87
# RA: 12 h 30 m 49.4234 s
# DEC: 12 deg 23 m 28.0439 s
# MJD: 48277.0000
# RF: 230.0000 GHz
# FOVX: 100 pix 0.000182 as
# FOVY: 100 pix 0.000182 as
# ------------------------------------
# x (as)     y (as)       I (Jy/pixel)  Q (Jy/pixel)  U (Jy/pixel)
0.0000891800 0.0000891800 0.0000017870 -0.0000003144 0.0000002609
0.0000873600 0.0000891800 0.0000021787 -0.0000003004 0.0000003130
0.0000855400 0.0000891800 0.0000026383 -0.0000002713 0.0000003709
0.0000837200 0.0000891800 0.0000031731 -0.0000002242 0.0000004338
0.0000819000 0.0000891800 0.0000037904 -0.0000001568 0.0000005006
0.0000800800 0.0000891800 0.0000044970 -0.0000000660 0.0000005695
0.0000782600 0.0000891800 0.0000053005 0.0000000501 0.0000006385
0.0000764400 0.0000891800 0.0000062074 0.0000001942 0.0000007052
0.0000746200 0.0000891800 0.0000072253 0.0000003678 0.0000007669
0.0000728000 0.0000891800 0.0000083602 0.0000005727 0.0000008197
0.0000709800 0.0000891800 0.0000096197 0.0000008102 0.0000008604
```

What do I, Q, U, V represent?

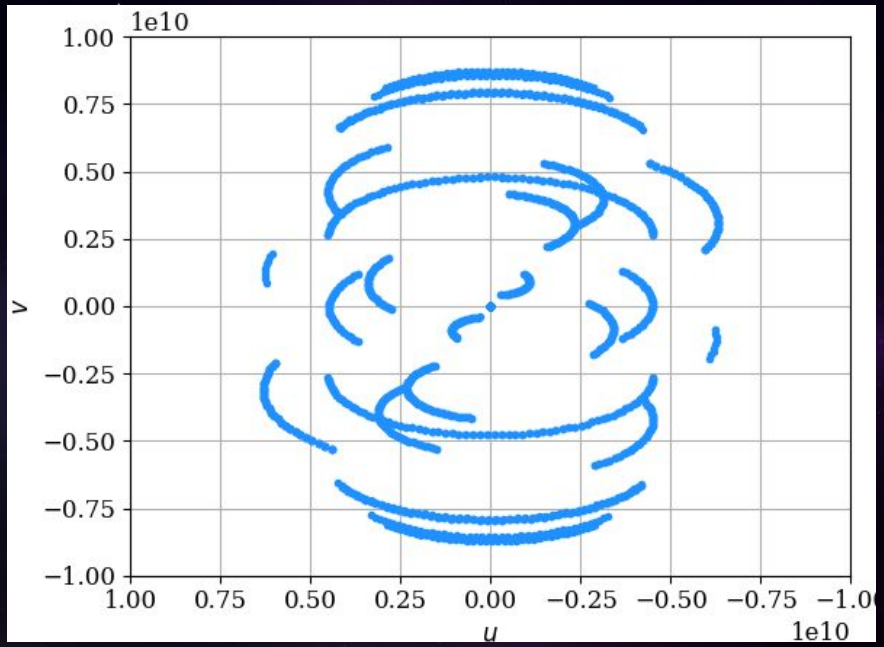


U–V coverage



EHT2017_m87

Switching arrays



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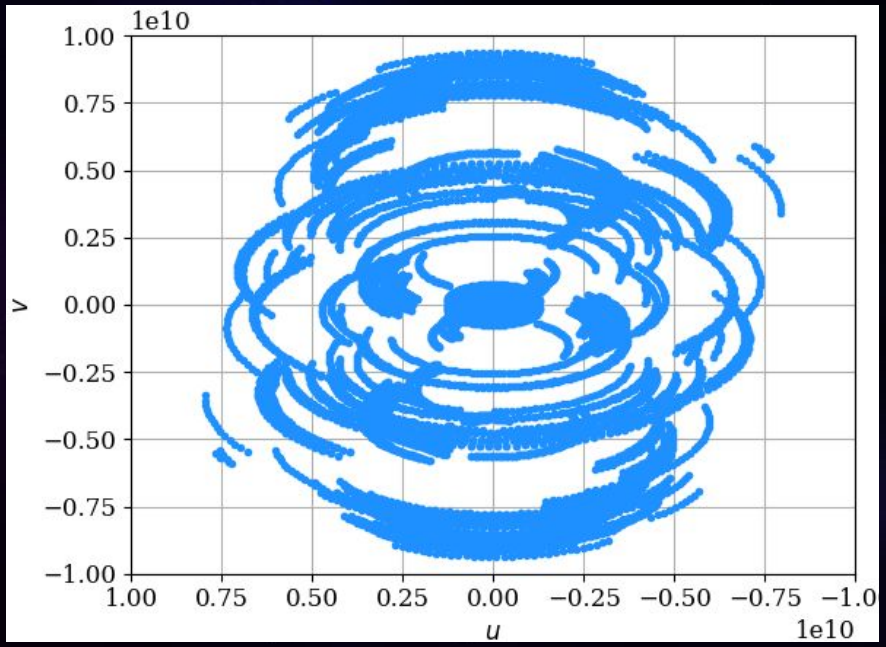
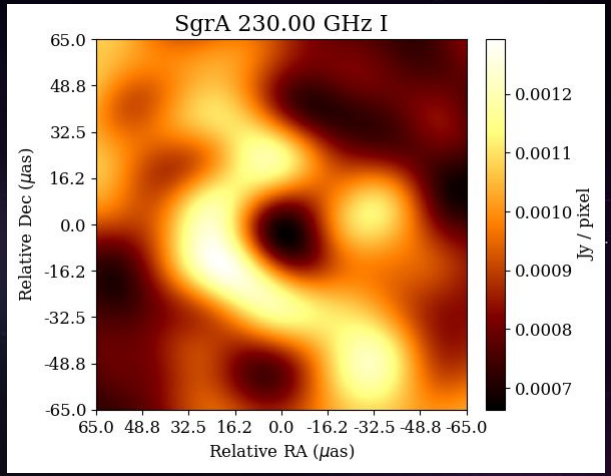
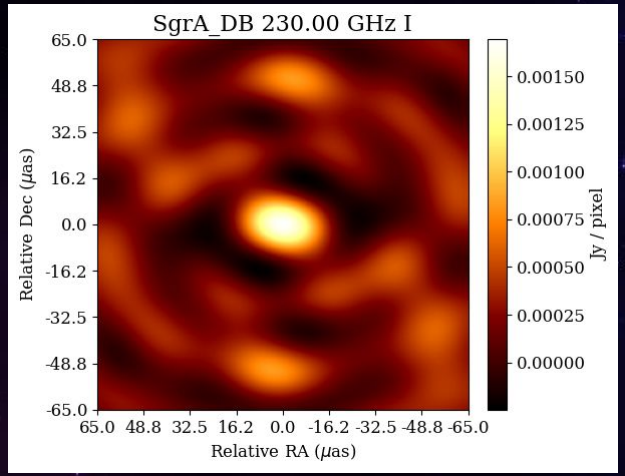


EHTII

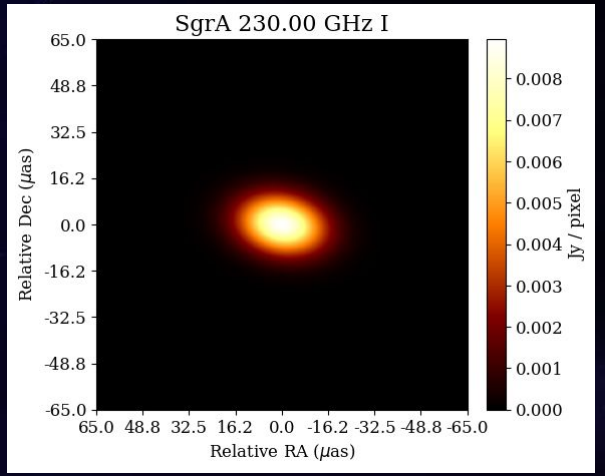
Dirty image and dirty beam



Dirty image



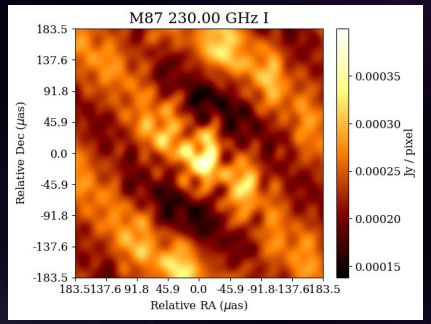
Dirty beam

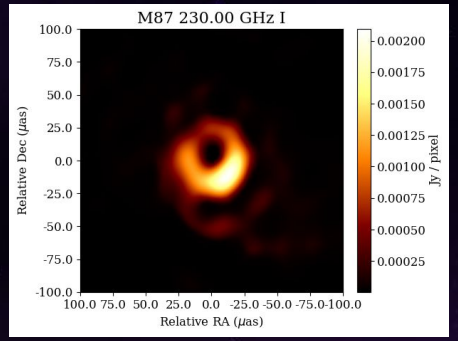


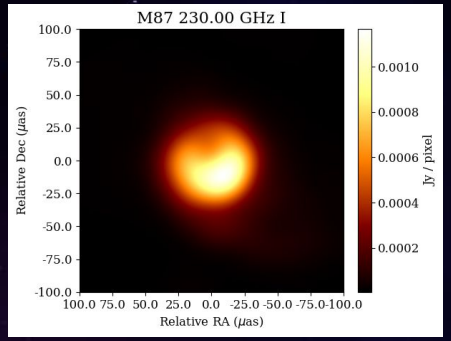
Clean beam

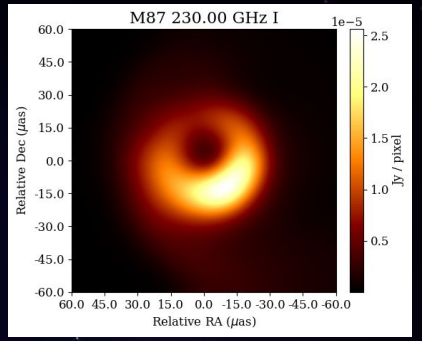
Experiments (Easier celestial object)

rowan_m87 (default)

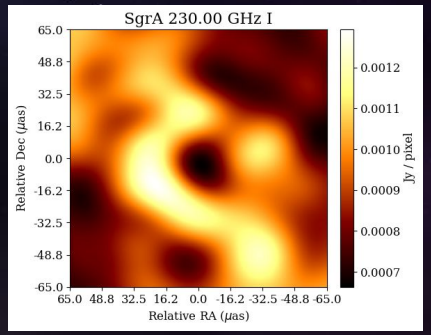




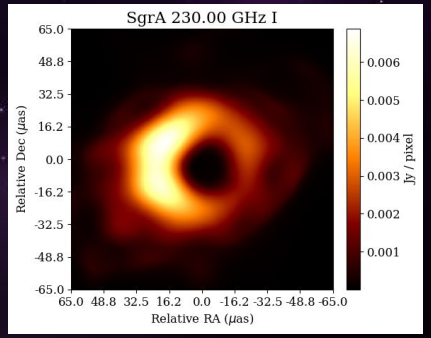




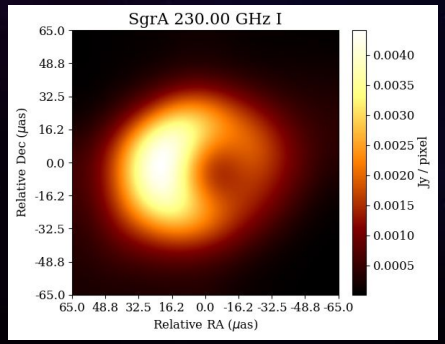
dirty image



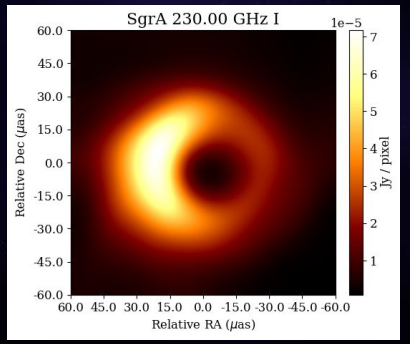
clean image



clean image (blurred)

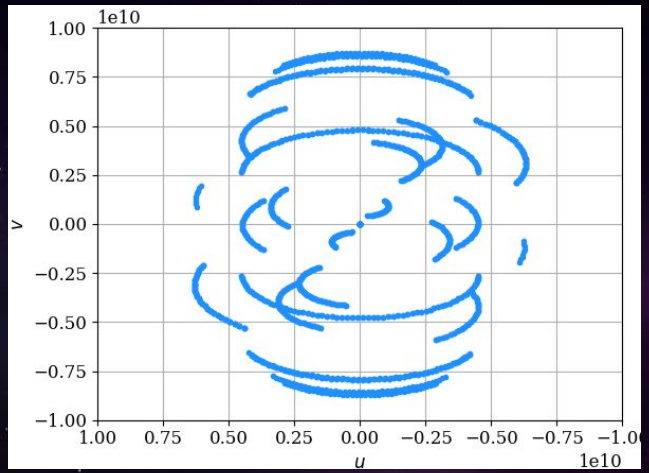


GT image



jason_mad_eofn

Experiments (Larger telescope array)



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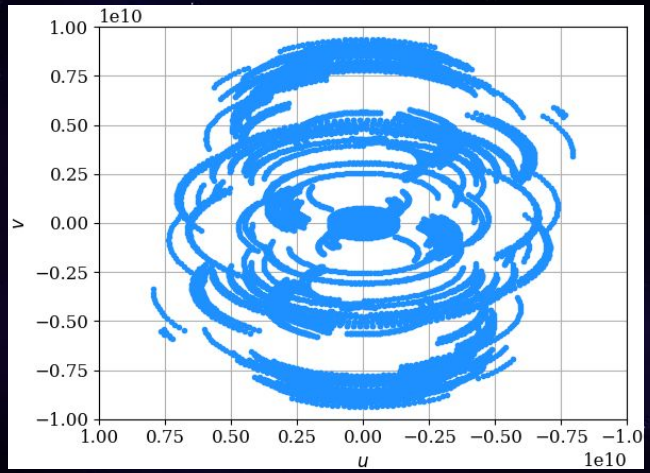
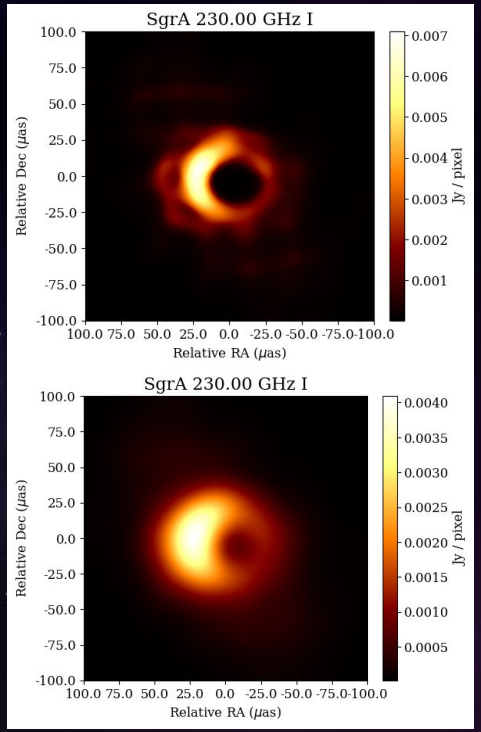


EHTII

Experiments (Larger telescope array)



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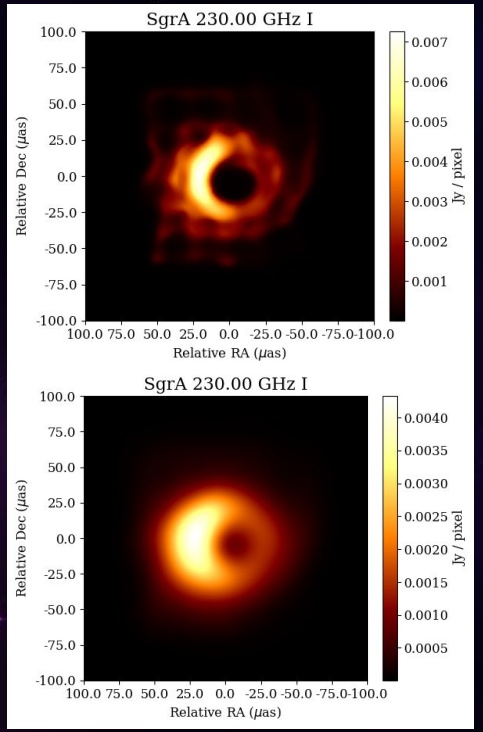

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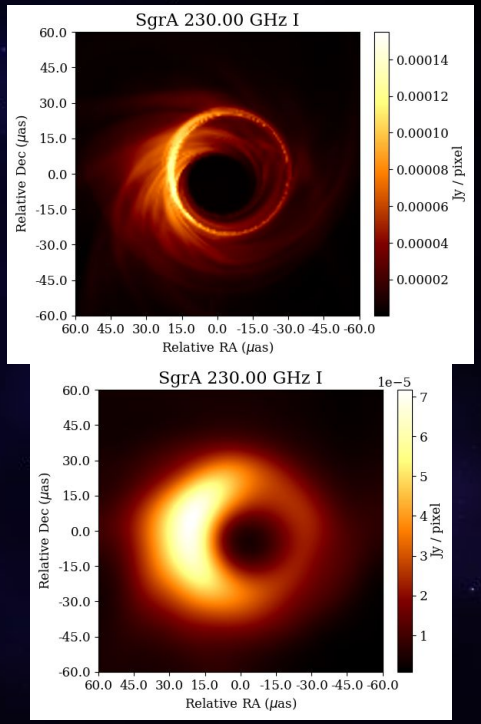
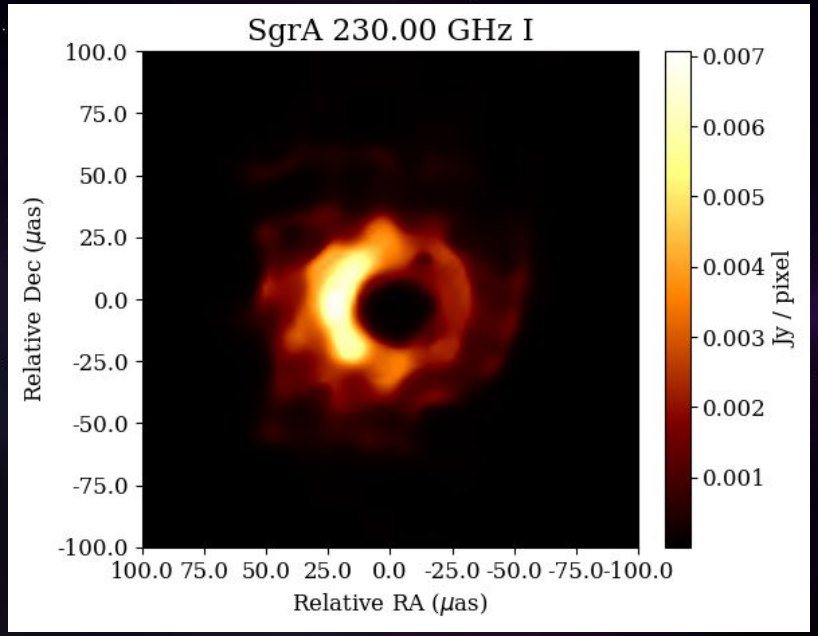


GT

Experiments (Computational priors and regularizers)



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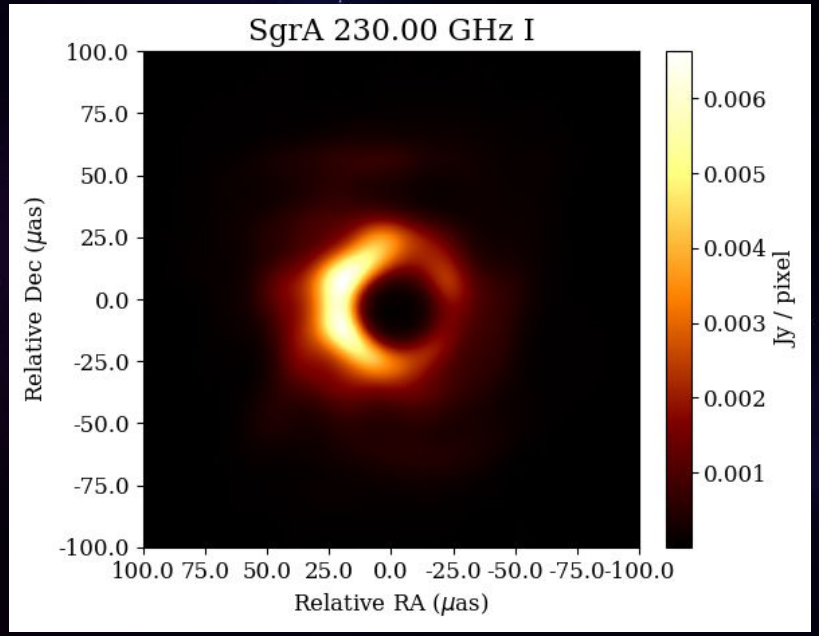

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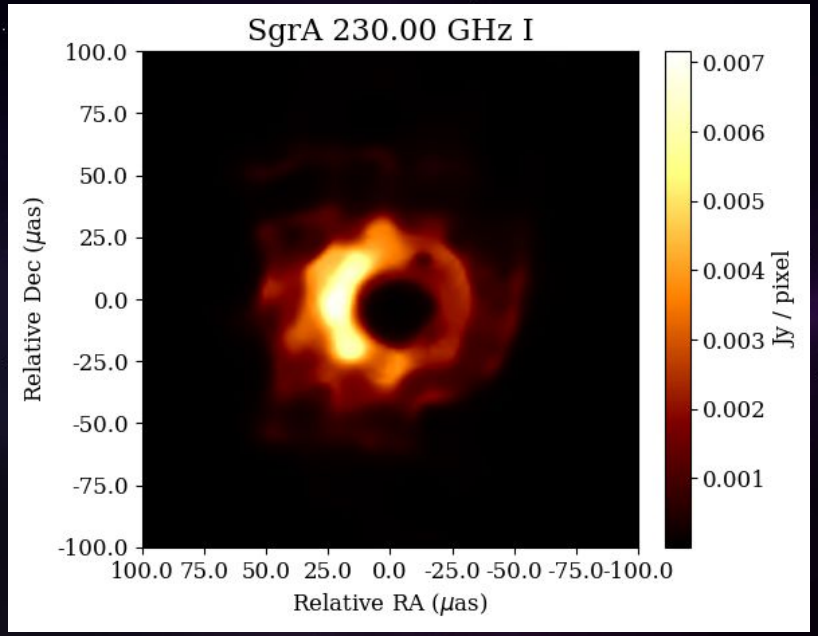
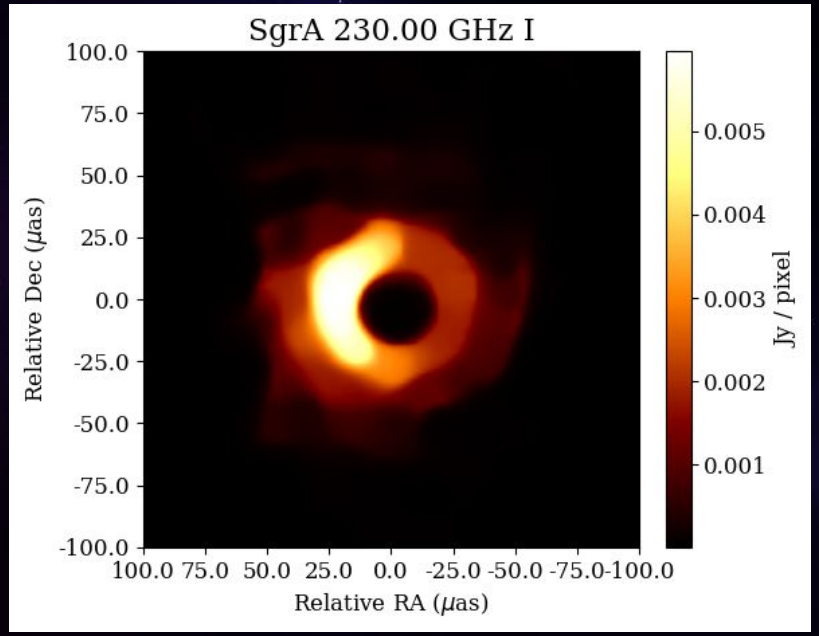
Experiments (Computational priors and regularizers)

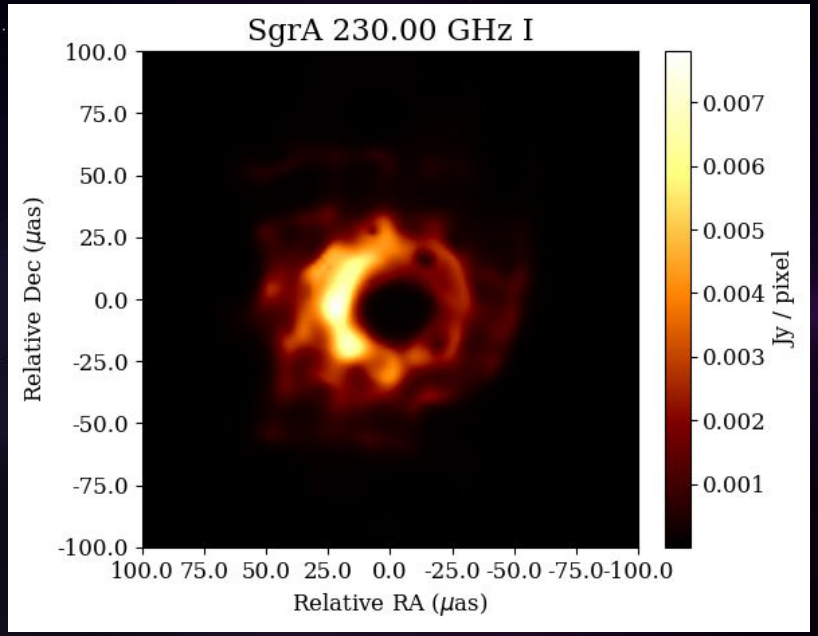


'tv': 1

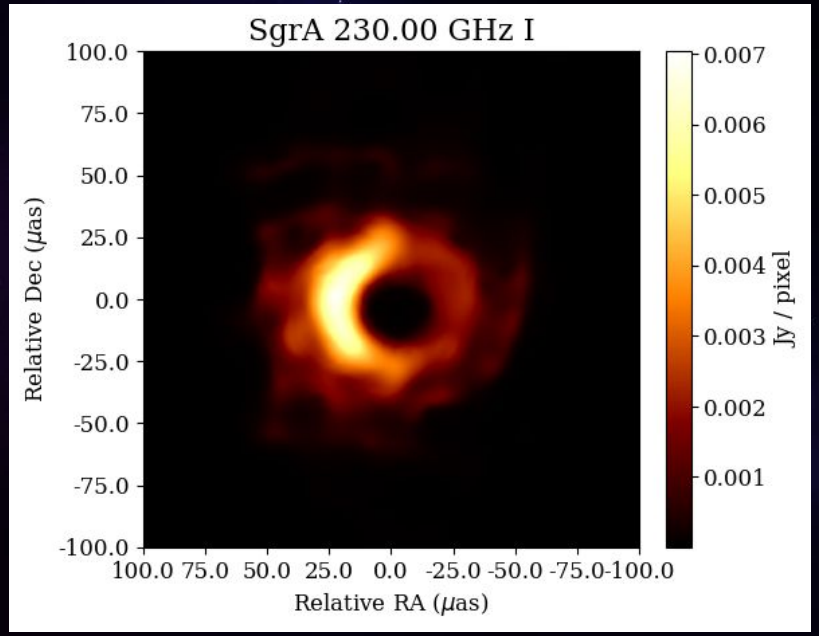


'tv': 10

Experiments (Computational priors and regularizers)



'tv2': 1



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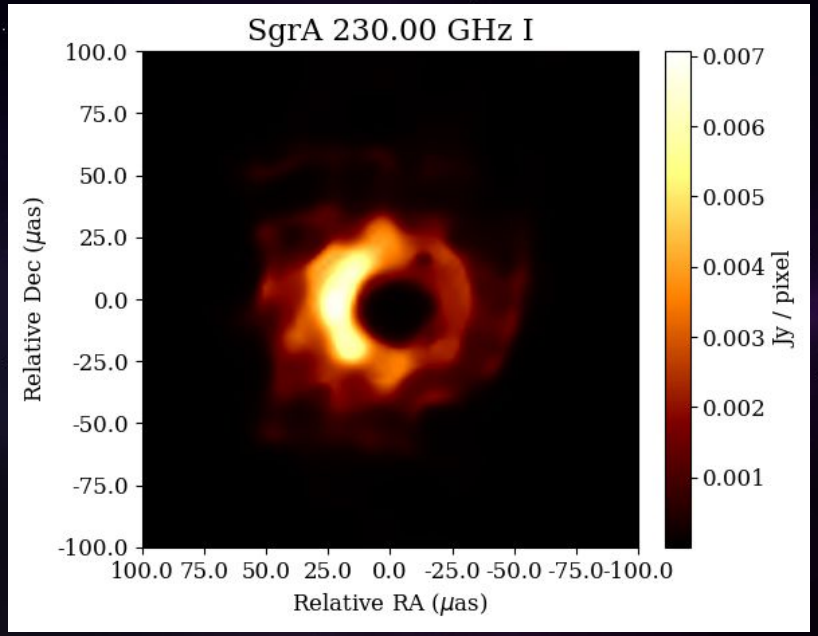
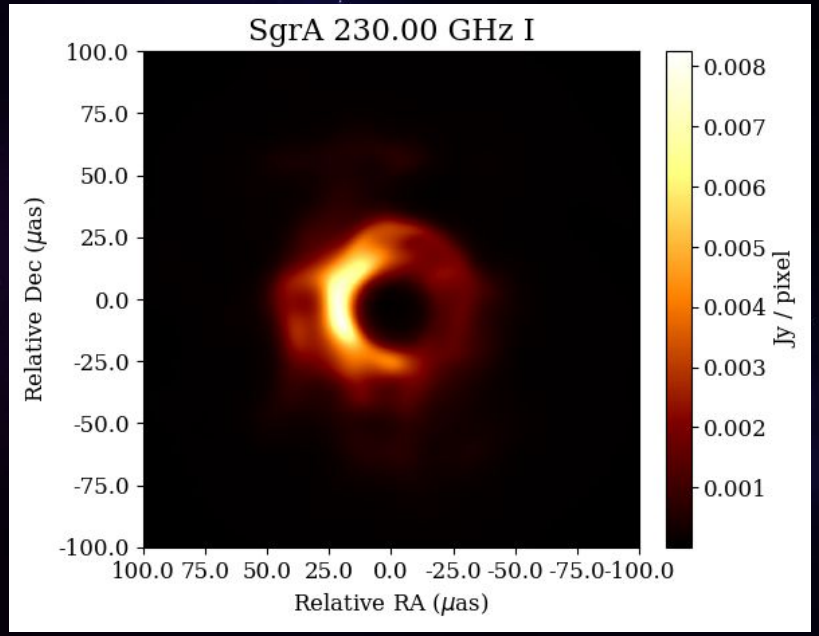
Experiments (Computational priors and regularizers)

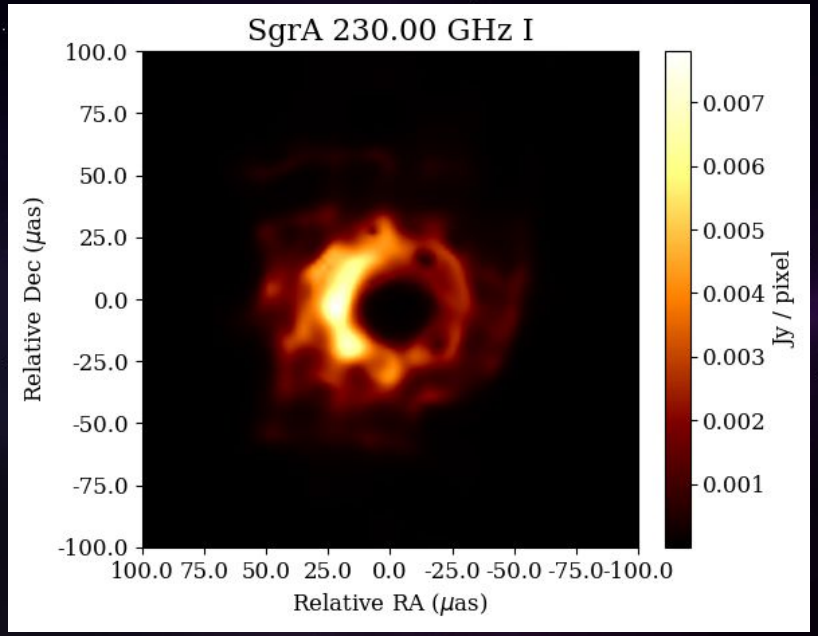


'flux': 1

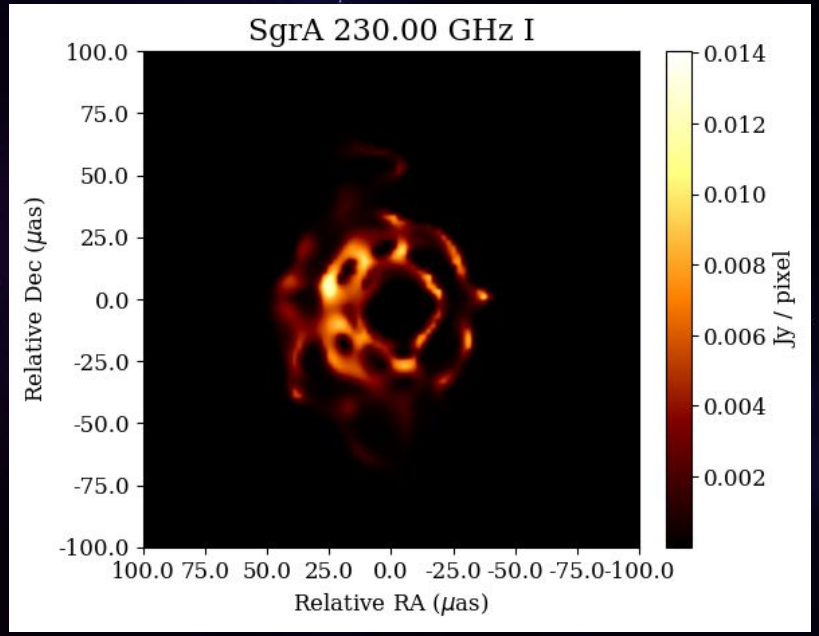


'flux': 1e8

Experiments (Computational priors and regularizers)



'l1': 0.1



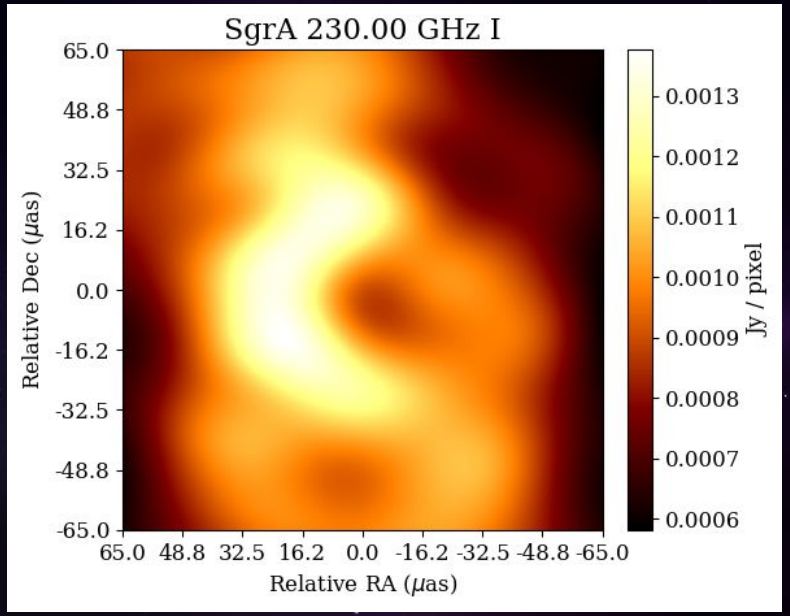
'l1': 1e5

02

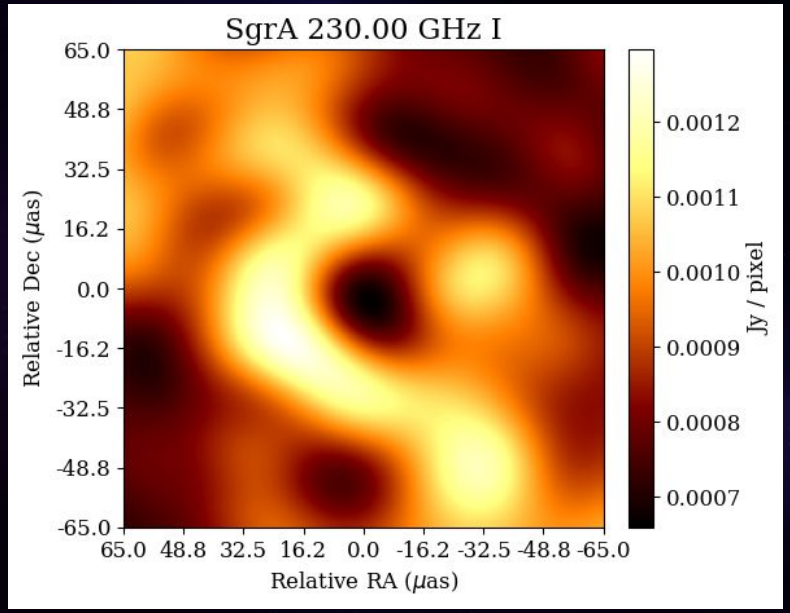
Telescopes obs

Forward model: Telescope observations

Add different amounts of noise

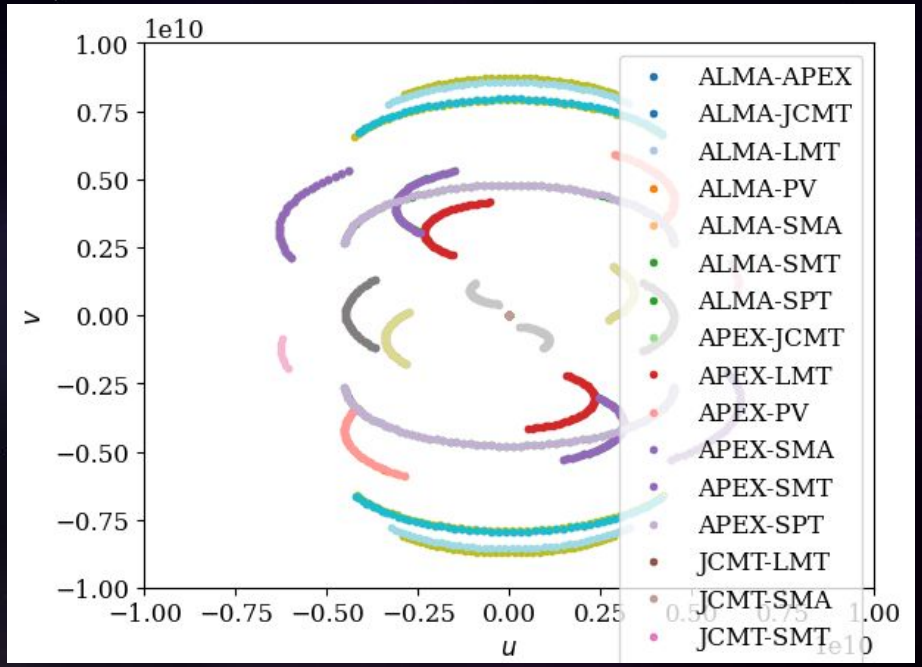


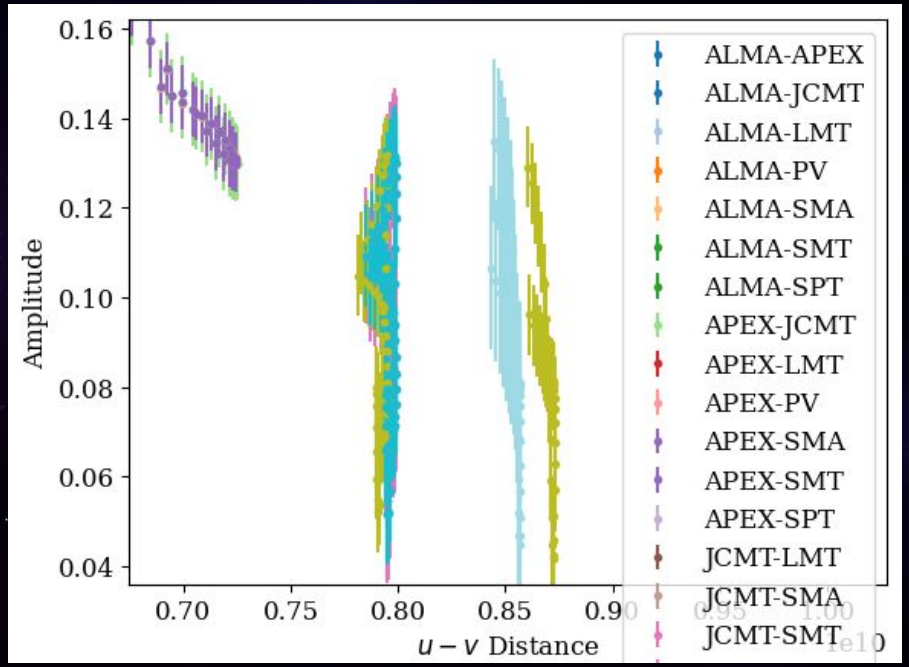
add_th_noise = False



add_th_noise = True

Compute frequencies by each pair of telescopes at a time





Add telescopes to maximize frequency coverage

Add telescopes to maximize frequency coverage

Add telescopes to maximize frequency coverage

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Add telescopes to maximize frequency coverage

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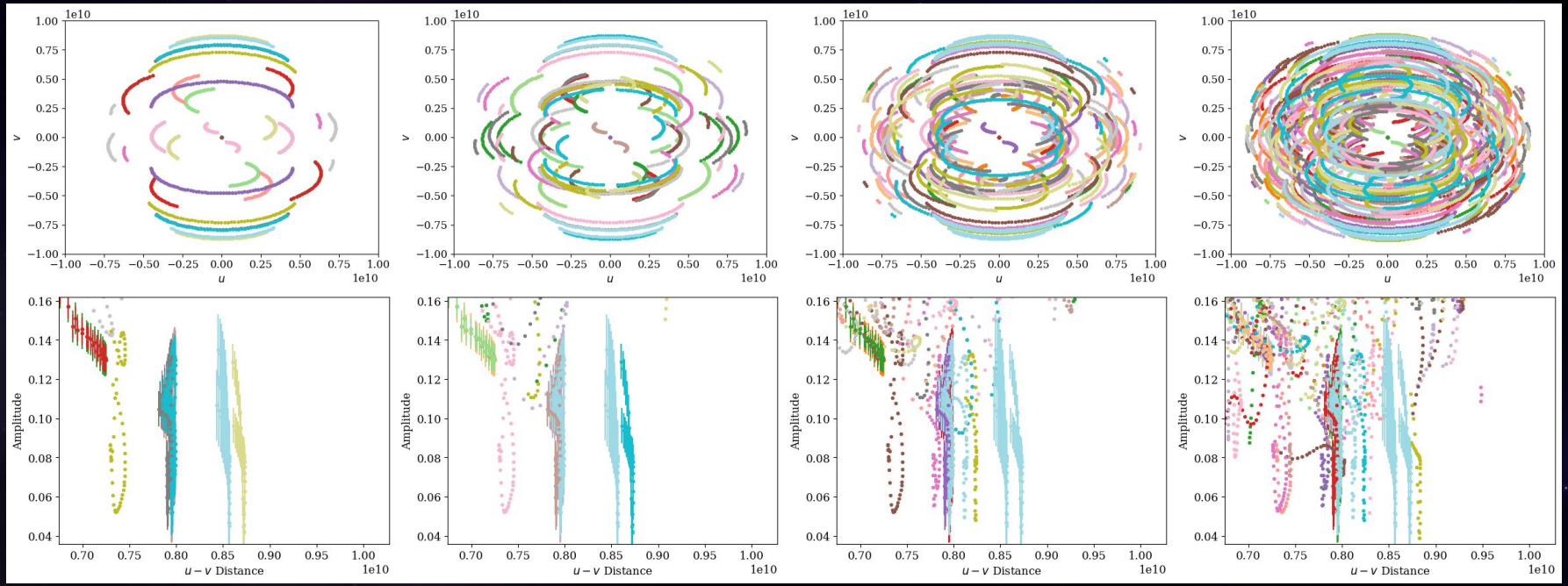
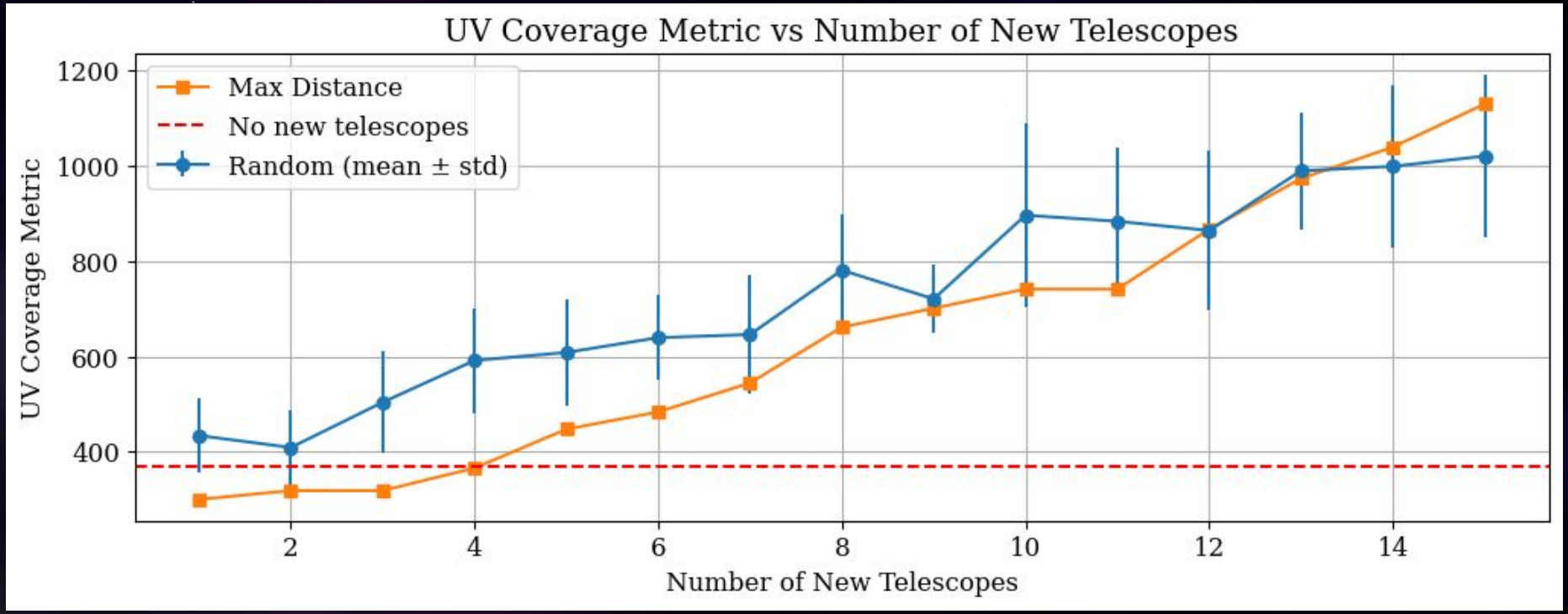
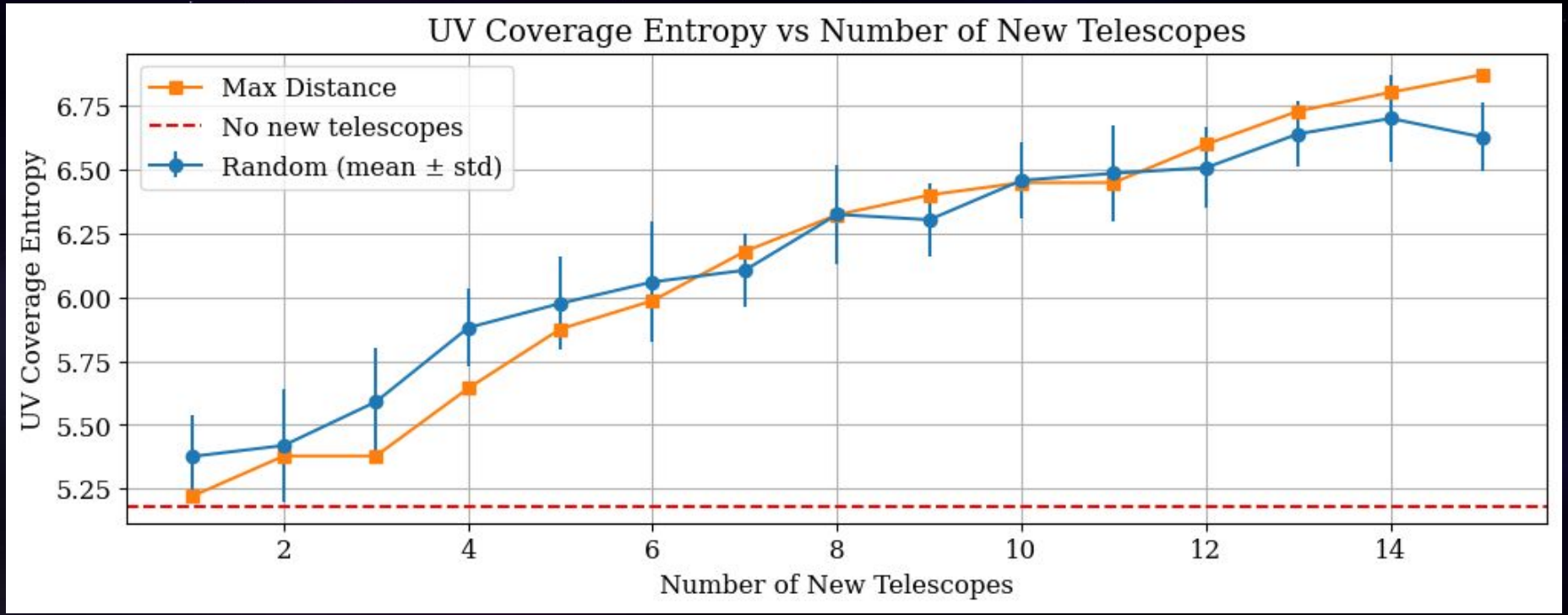


1 new telescope | 5 news telescopes | 10 news telescopes | 20 news telescopes

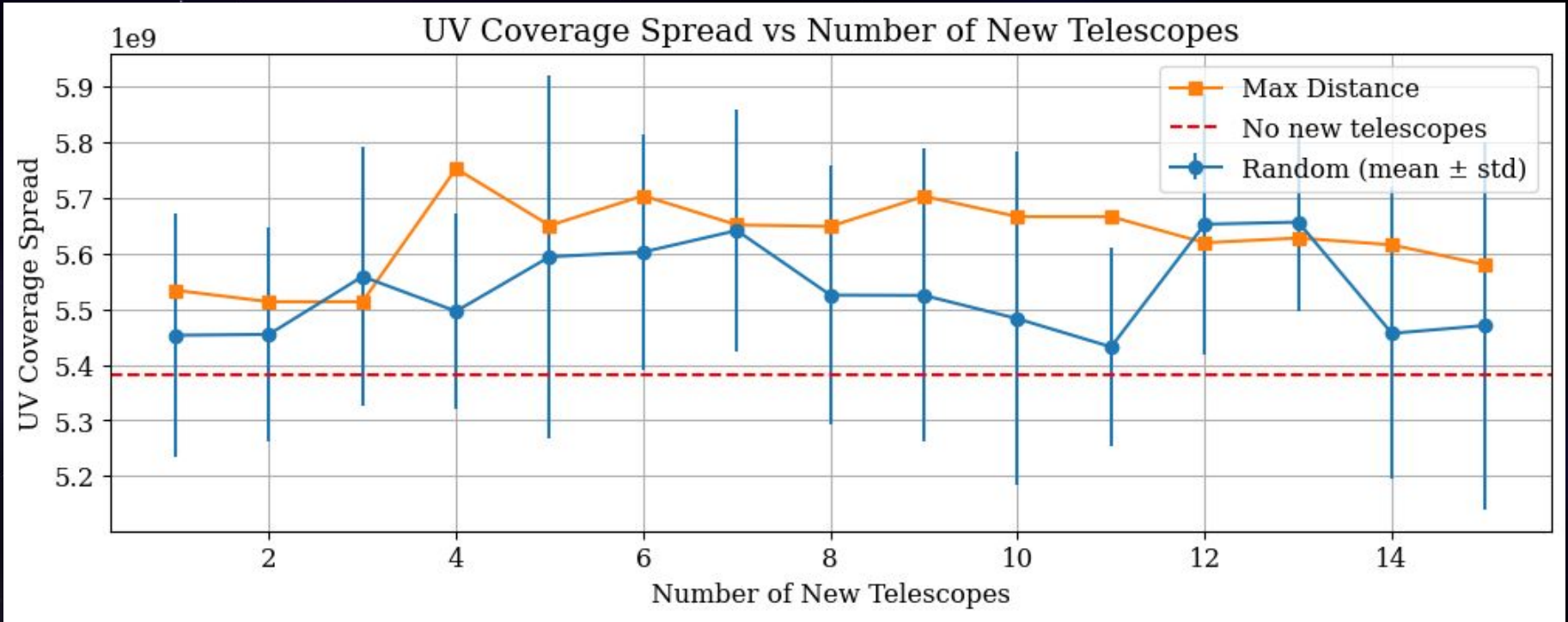
Add telescopes - Metrics (density-uniformity)



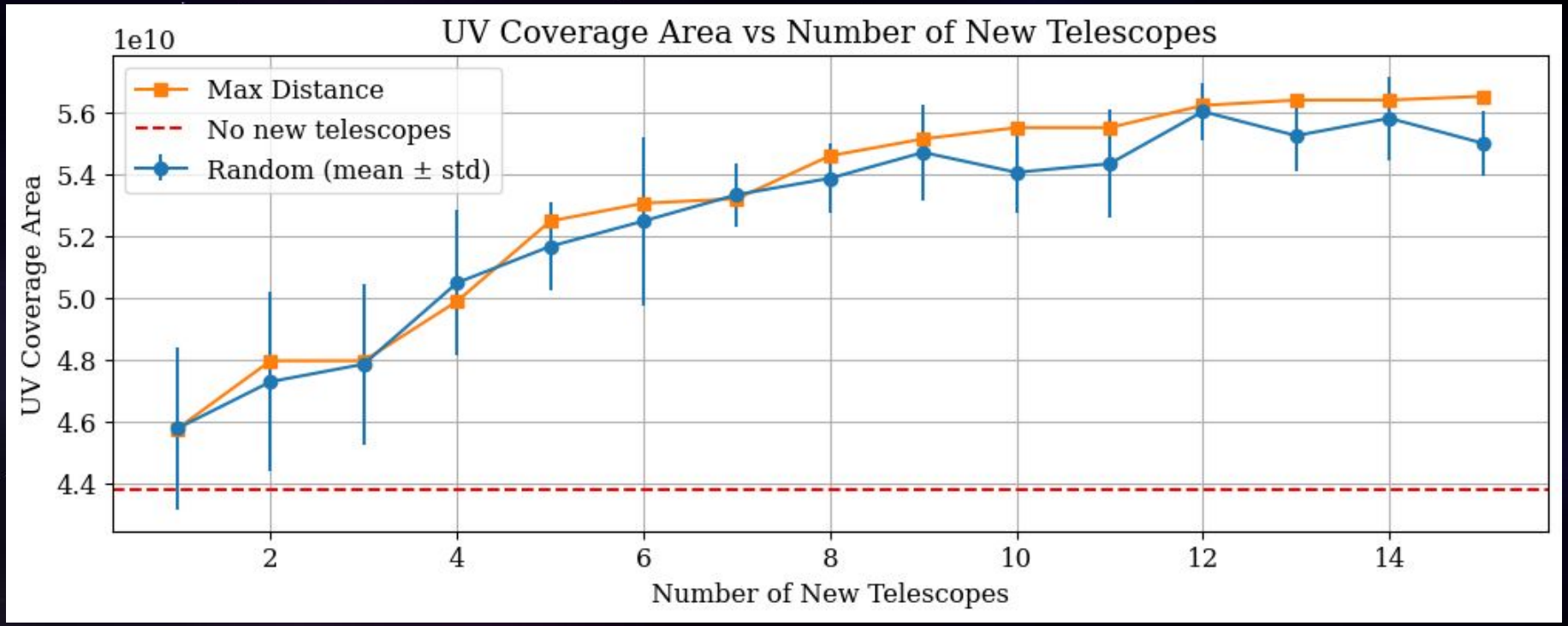
Add telescopes - Metrics (entropy)



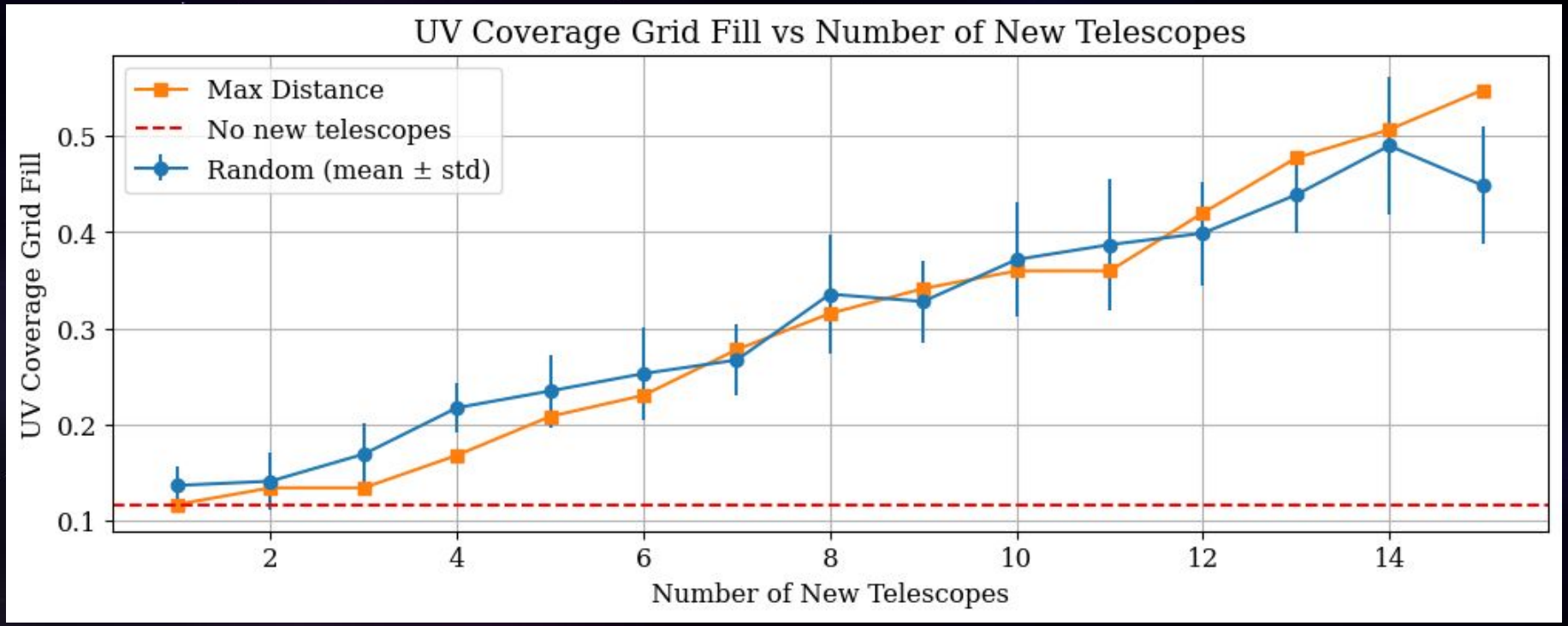
Add telescopes - Metrics (spread)



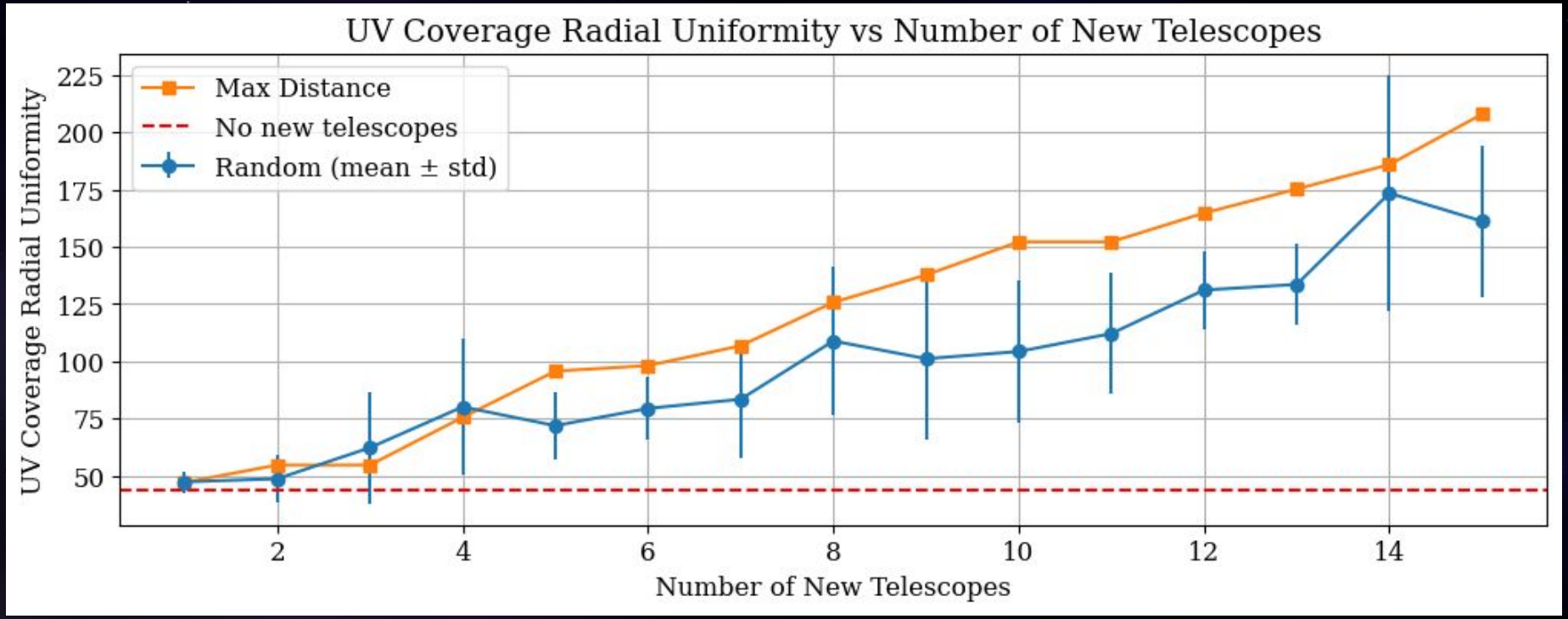
Add telescopes - Metrics (area)



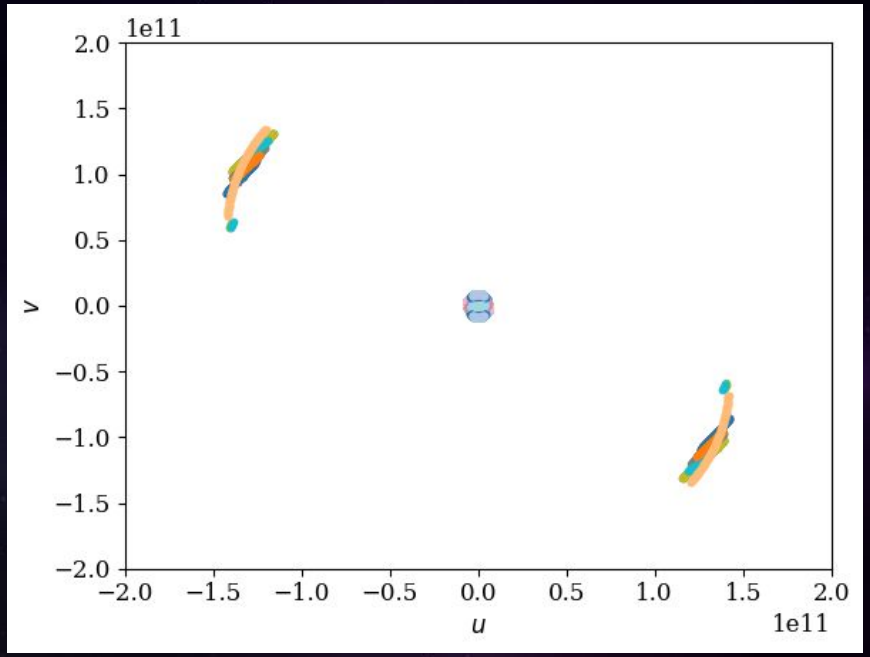
Add telescopes - Metrics (grid fill)



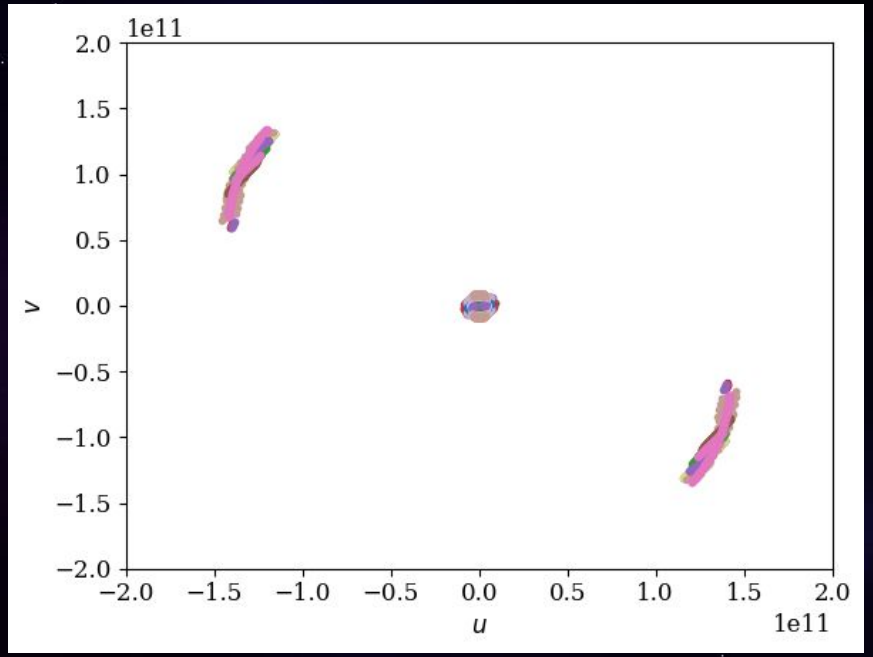
Add telescopes - Metrics (radial uniformity)



Evaluate the effect of satellite telescopes

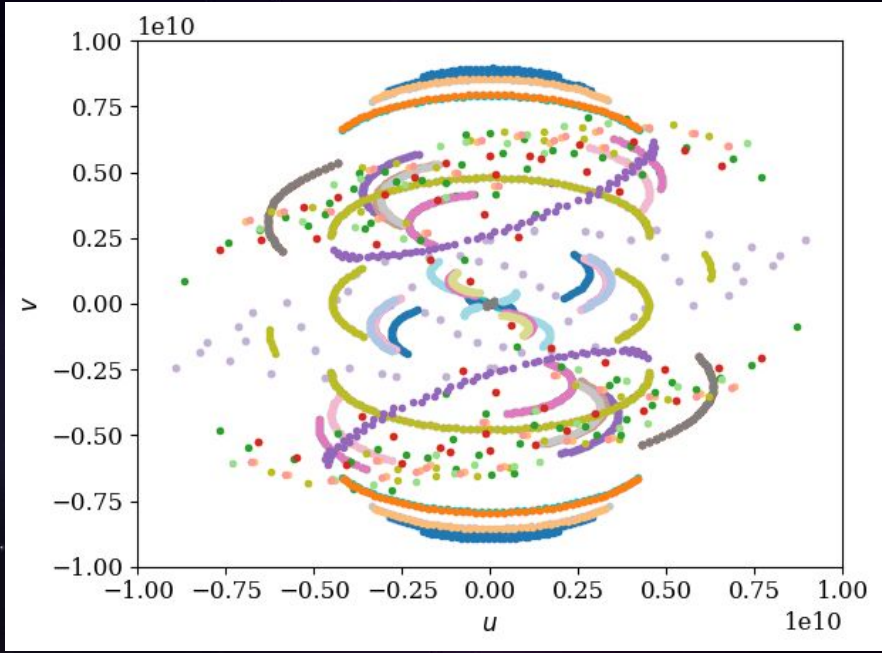


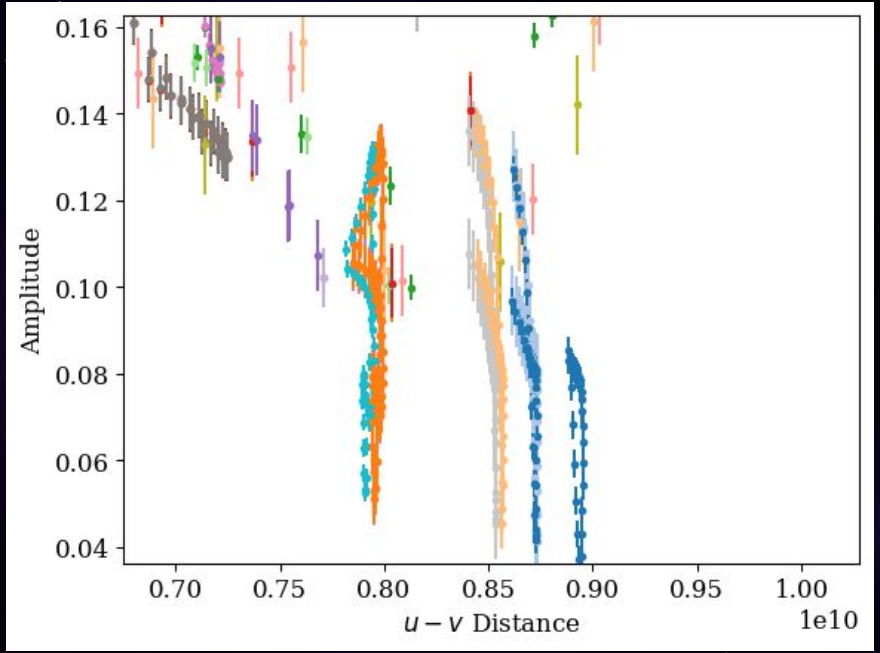
EHT2025wTESS



EHT2025wTESS&ISS

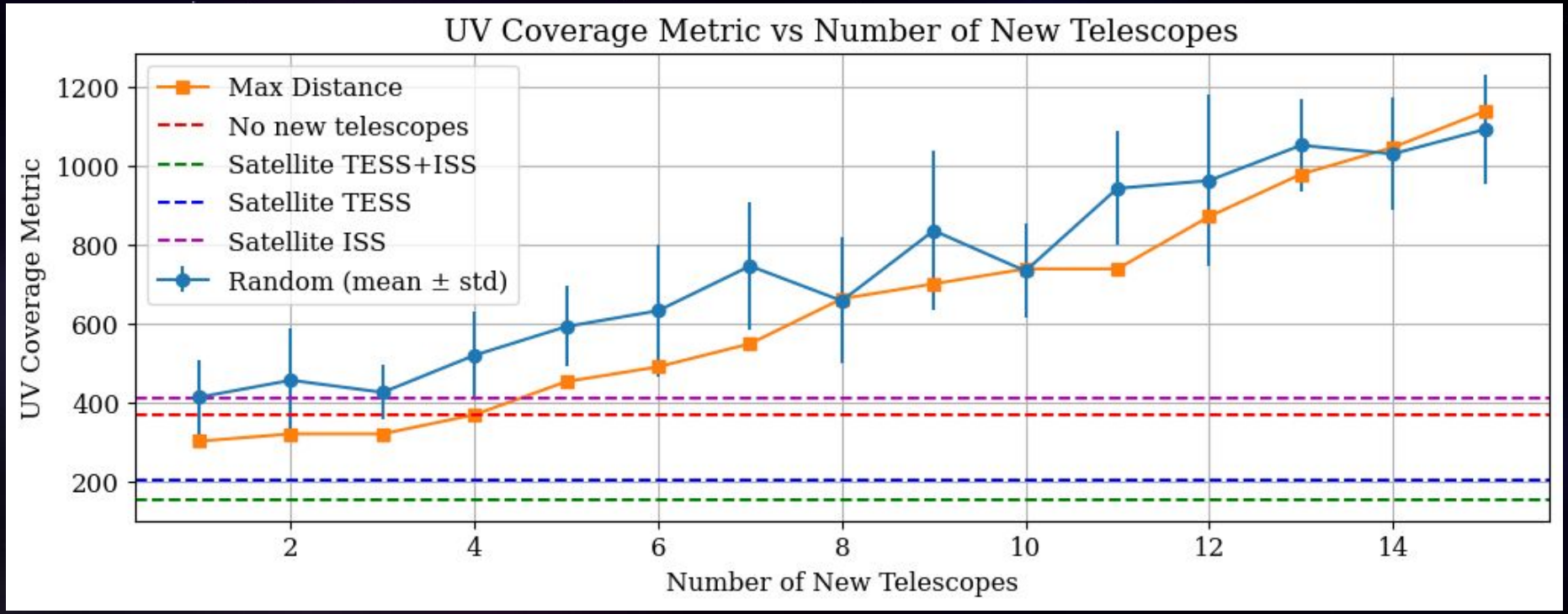
Evaluate the effect of satellite telescopes



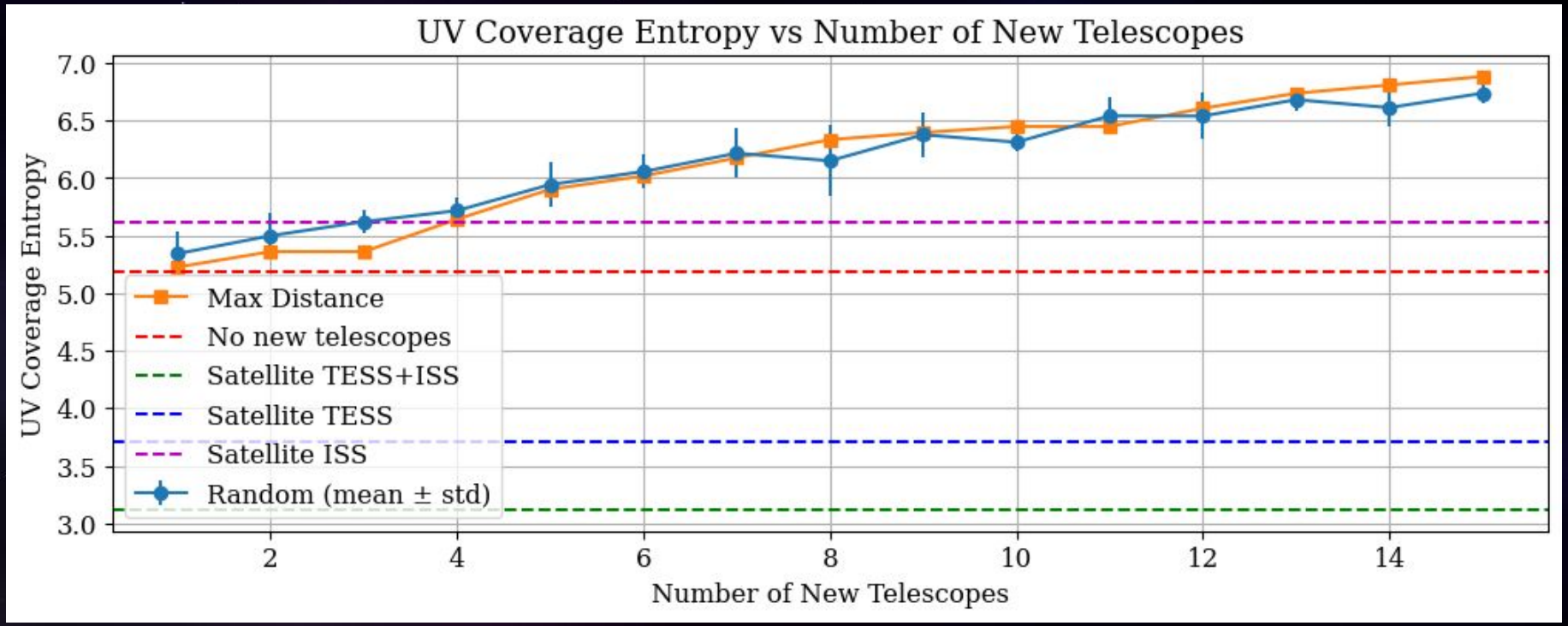


EHT2025wISS from close view

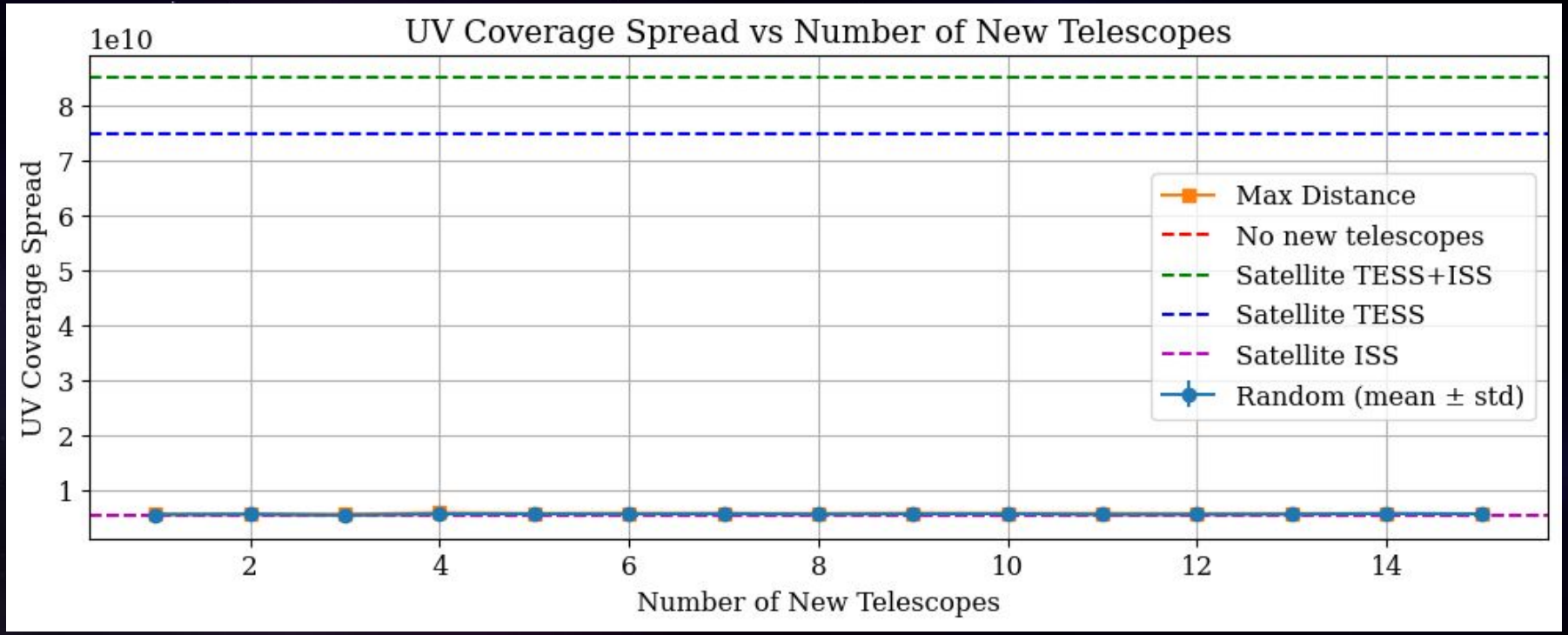
Satellite telescopes - Metrics (density-uniformity)



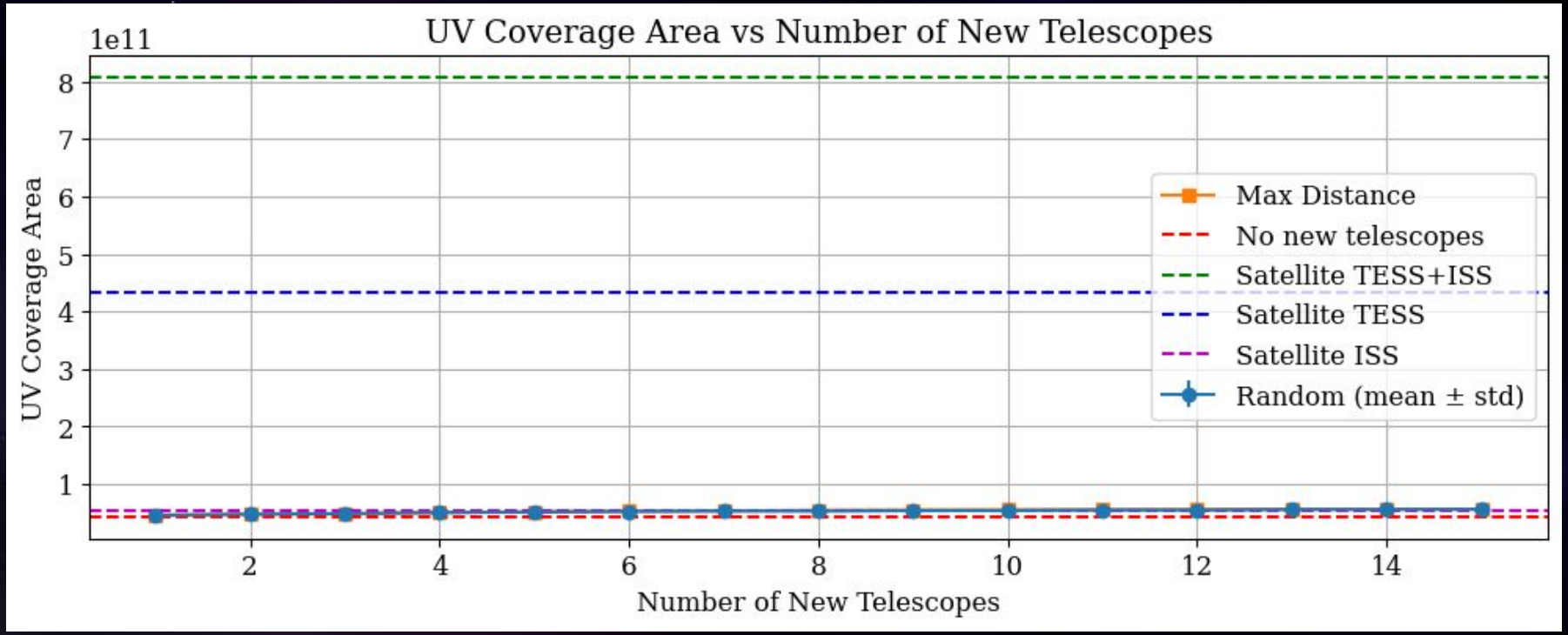
Satellite telescopes - Metrics (entropy)



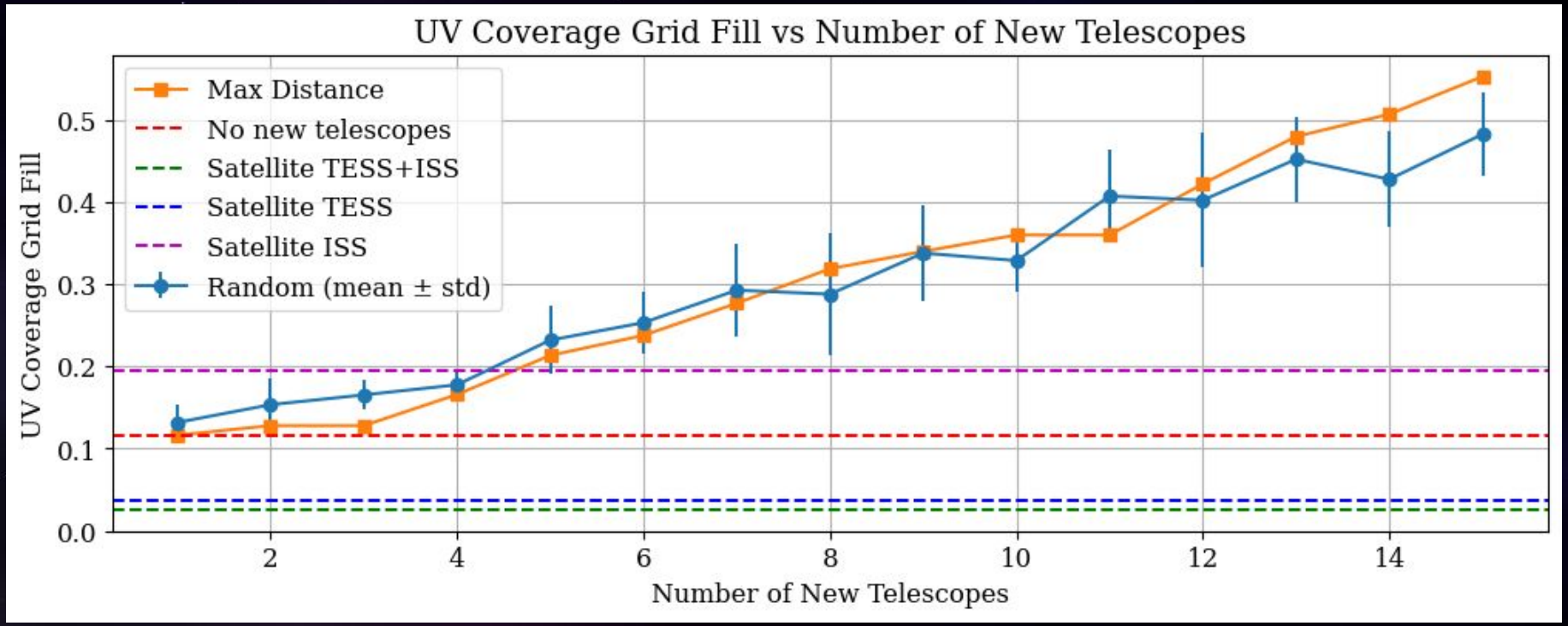
Satellite telescopes - Metrics (spread)



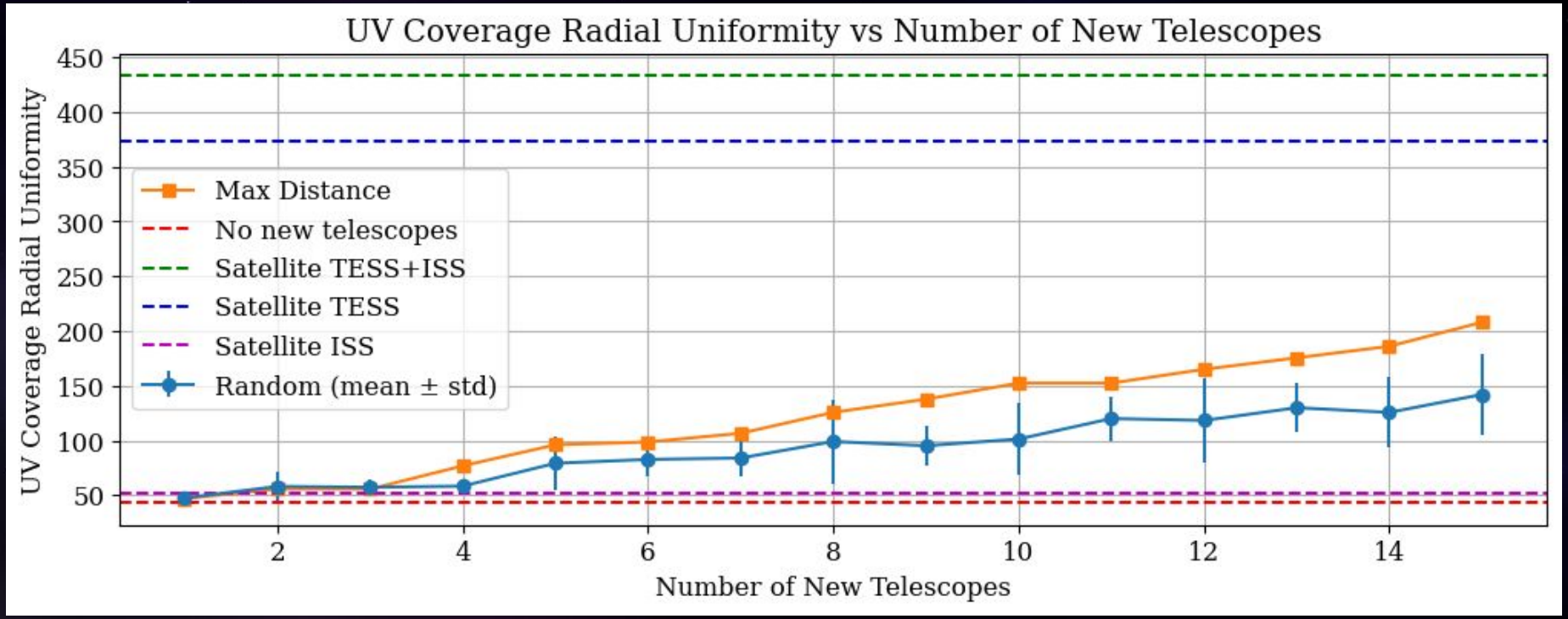
Satellite telescopes - Metrics (area)



Satellite telescopes - Metrics (grid fill)



Satellite telescopes - Metrics (radial uniformity)

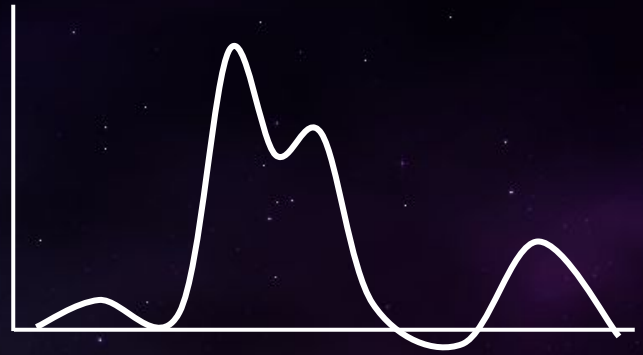


03

VLBI Imaging

VLBI Imaging: Estimating an image of a celestial object

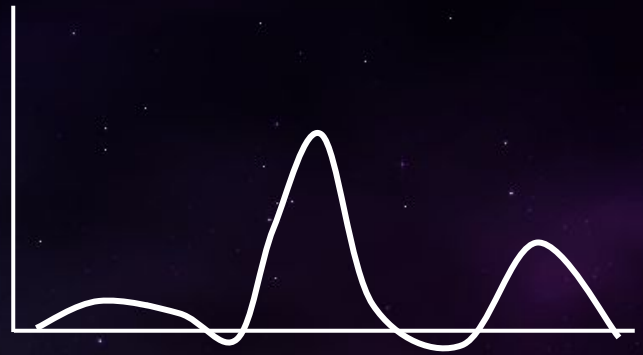
CLEAN algorithm



Dirty Image

Model Image

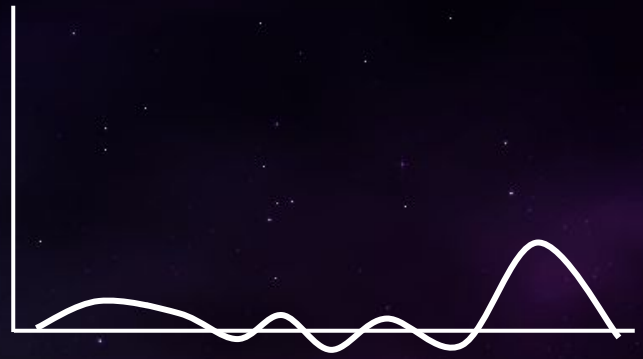
CLEAN algorithm



Dirty Image

Model Image

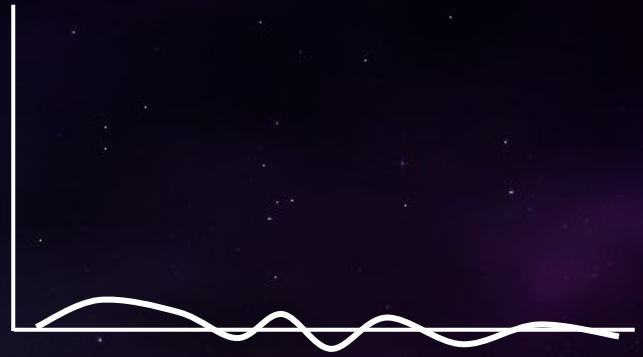
CLEAN algorithm



Dirty Image

Model Image

CLEAN algorithm

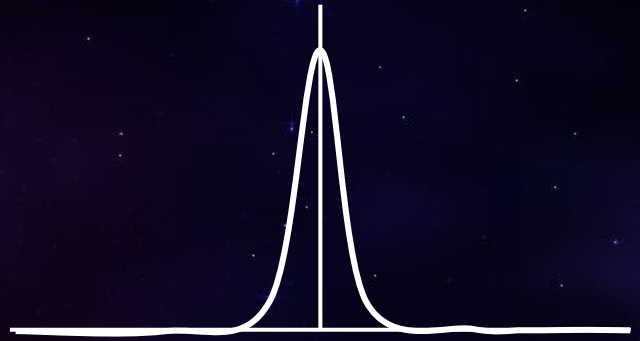


Thermal noise

Model Image

CLEAN algorithm

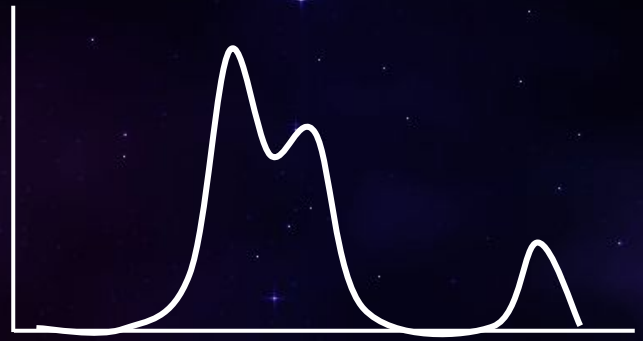
Model Image



Clean beam (Gaussian beam)

CLEAN algorithm

Model Image

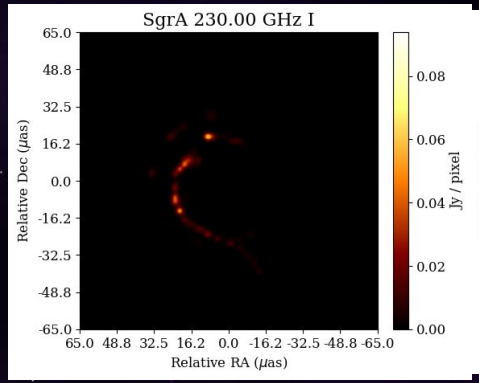


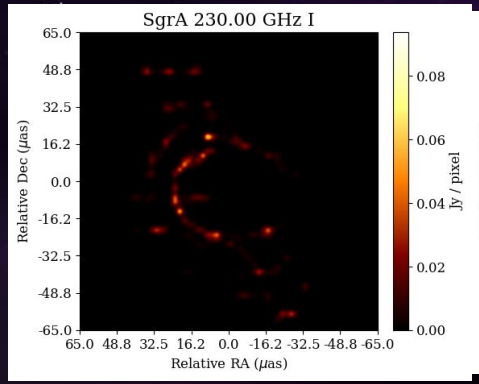
Cleaned Image

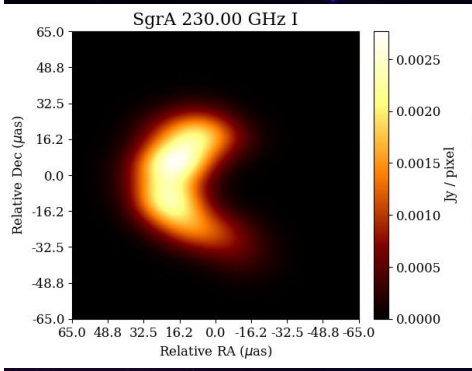
Results

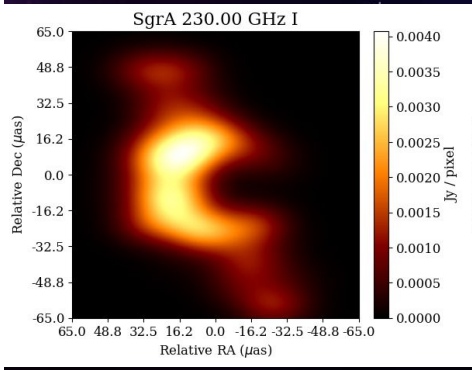
gain = 0.001
threshold = 4e-4

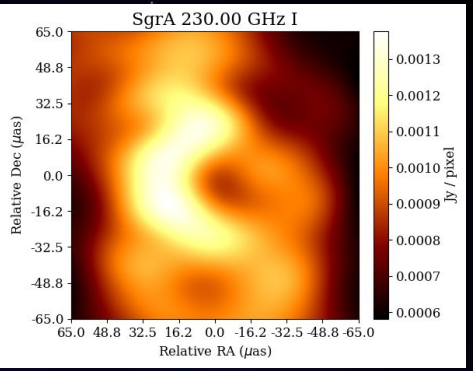
gain = 0.1
threshold = 4e-4











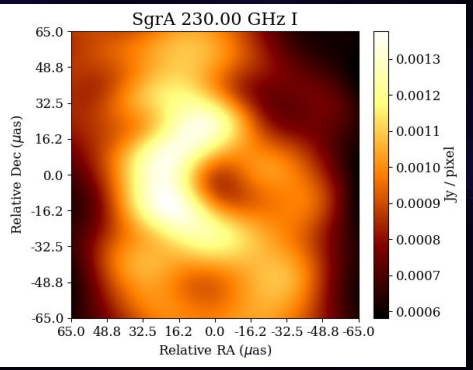


Image model

CLEANed image

Dirty image

04

Summary

Things done

Summary

- ✅ Code (Section 2)
- ✅ Forward modeling (Section 3)
  - ✅ Add different amounts of noise
  - ✅ Compute frequencies by each pair of telescopes at a time
  - ✅ Add telescopes to maximize frequency coverage
  - ✅ Evaluate the effect of satellite telescopes
- ❓ VLBI imaging (Section 4)
  - ✅ Using the dirty image and dirty beam (CLEAN)
  - ❌ Using directly the frequency data

Final project: Very-long-baseline Interferometry

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