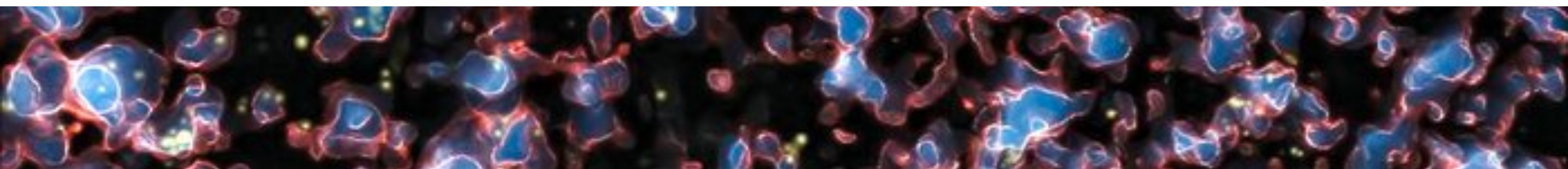


HERA Data Analysis Part II: Calibration and Imaging

Nick Kern & Ridhima Nunhokee
UC Berkeley

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Virtual



Lesson Overview:

1. Calibration (~1.5 hour)
 - a. Calibration overview
 - b. HERA calibration exploration

Break (10 min)

2. HERA Imaging (~1 hour)
 - a. HERA imaging overview
 - b. HERA imaging demo

Learning Objectives

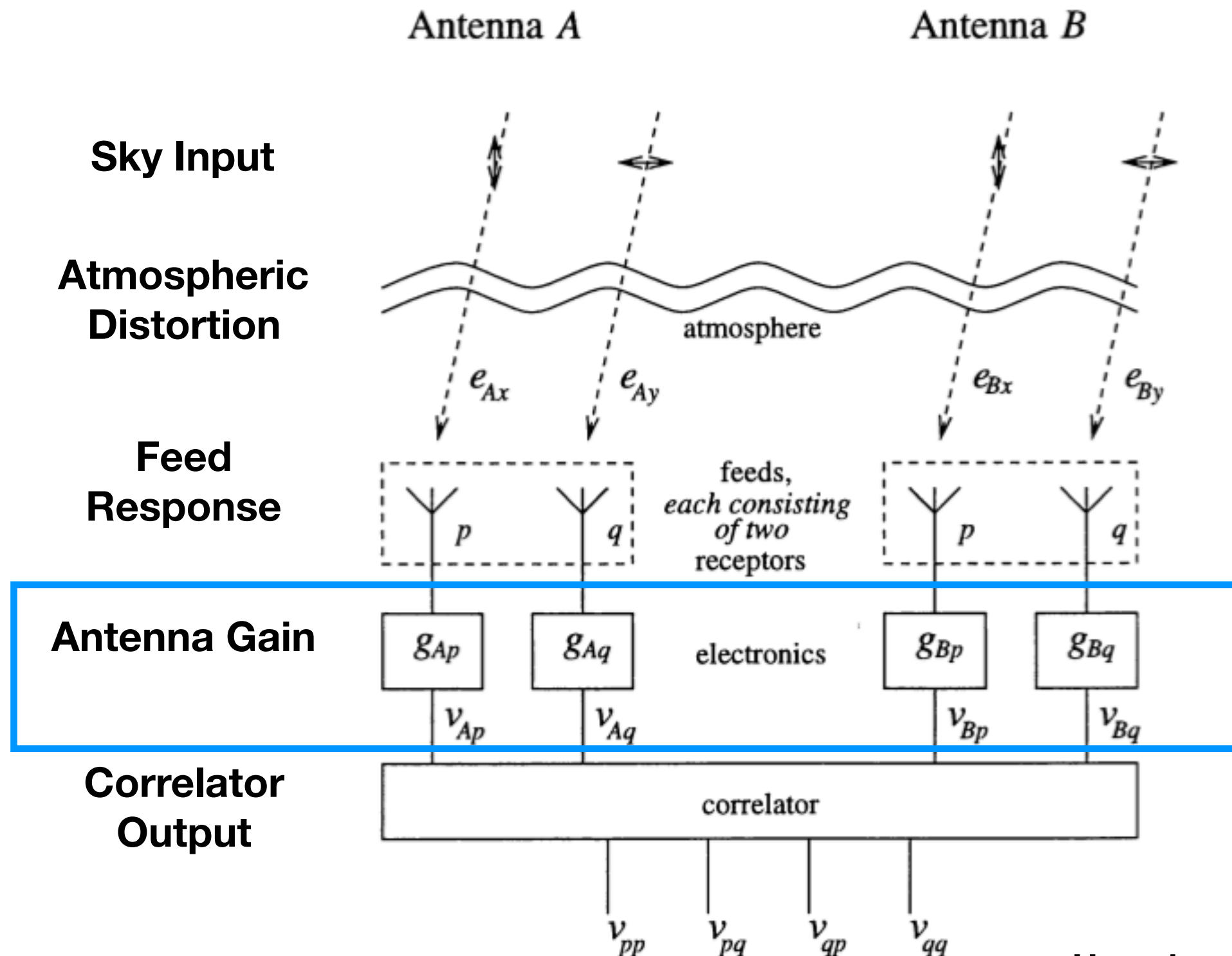
- A. Gain a basic understanding of what calibration is, and explore applying calibration to real data
- B. Become familiar with HERA's imaging capabilities
- C. Learn how to perform basic imaging of HERA data

1. HERA Calibration

All Instruments Need to be Calibrated



All Instruments Need to be Calibrated



Measurement Equation

Ideal Scenario

$$V_{ij}^{\text{model}} = I \cdot e^{-2\pi i \vec{b} \cdot \hat{s} / \lambda}$$

Practical Scenario

$$V_{ij}^{\text{measured}} = g_i g_j^* \cdot I \cdot e^{-2\pi i \vec{b} \cdot \hat{s} / \lambda}$$



$$V_{ij}^{\text{measured}} = g_i g_j^* V_{ij}^{\text{model}}$$

Antenna-Based Calibration Equation

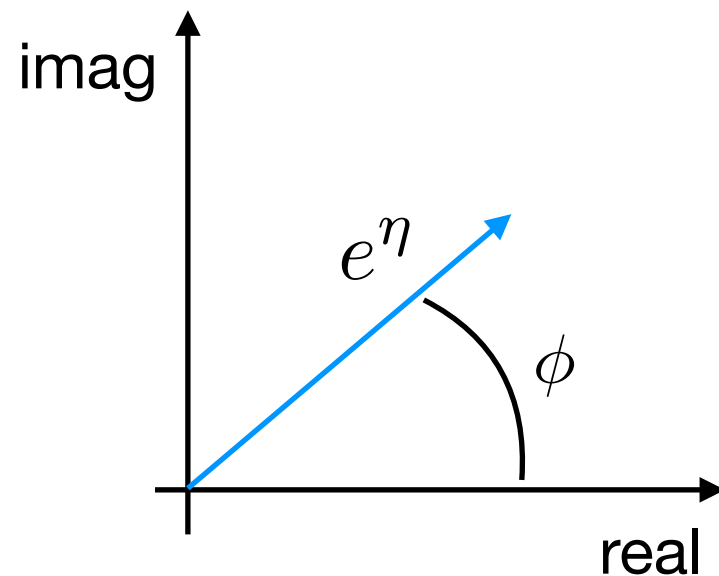
Breaking down Antenna Gains

Antenna gain is a complex quantity, defined by an amplitude and phase

$$g_j = e^{\eta_j + i\phi_j}$$

η_j = amplitude

ϕ_j = phase



Gains are also in principle **time and frequency** dependent:

$$g_j(t, \nu) = e^{\eta_j(t, \nu) + i\phi_j(t, \nu)}$$

Solving for Gains

Given your measurements and your model,
setup a system of equations!

We won't go into the details of **how** to solve
this system of equations, but if you are curious
ask me after class!

$$V_{ij}^{\text{measured}} = g_i g_j^* V_{ij}^{\text{model}}$$



antenna 1



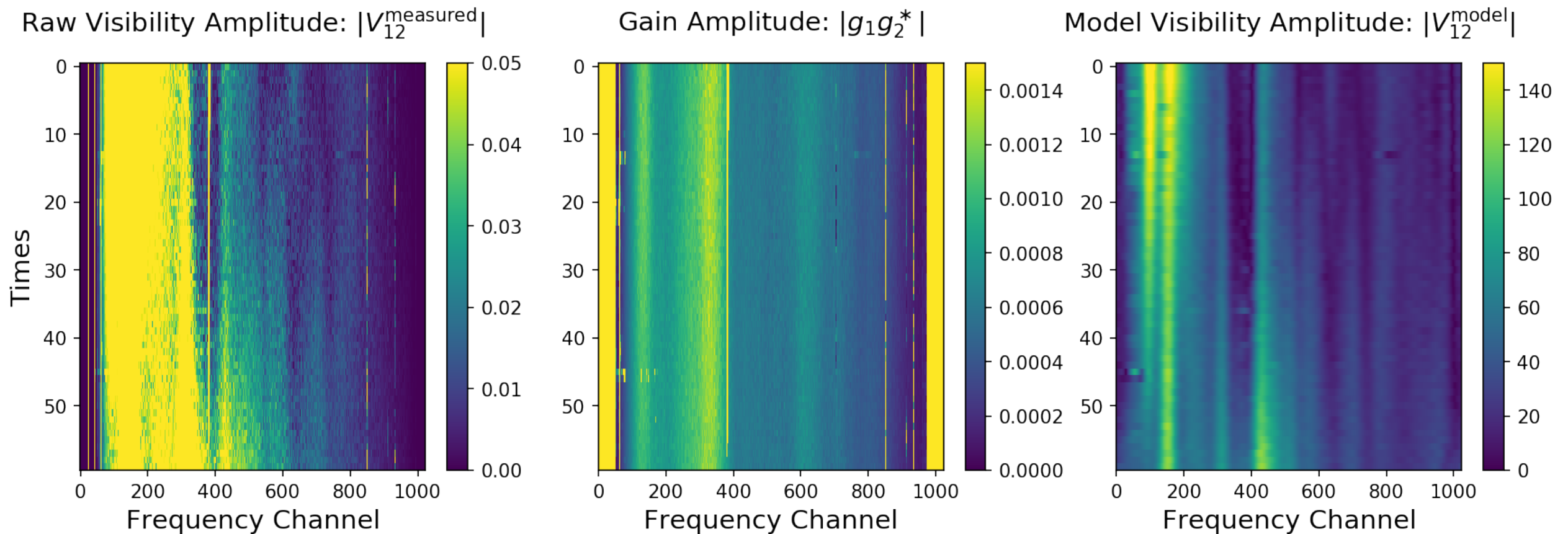
antenna 2



antenna 3

Applying Calibration

$$V_{ij}^{\text{updated}} = V_{ij}^{\text{measured}} / (g_i g_j^*)$$



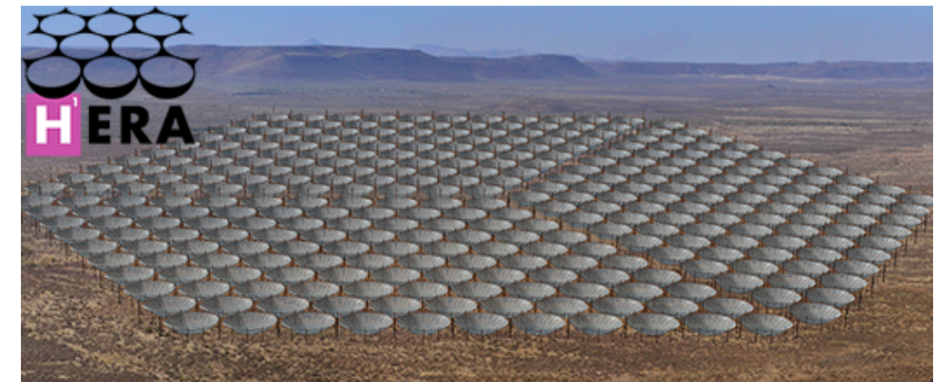
HERA Calibration Exploration

2. HERA Imaging Specs

HERA Imaging Specs

Design Spec

Performance



Frequency Coverage:

100 - 200 MHz
[50 - 250 MHz]

Redshift Coverage:

$6 < z < 13$
[$5 < z < 27$]

Longest Baseline:

Core: 292 m
Outrigger: 876 m

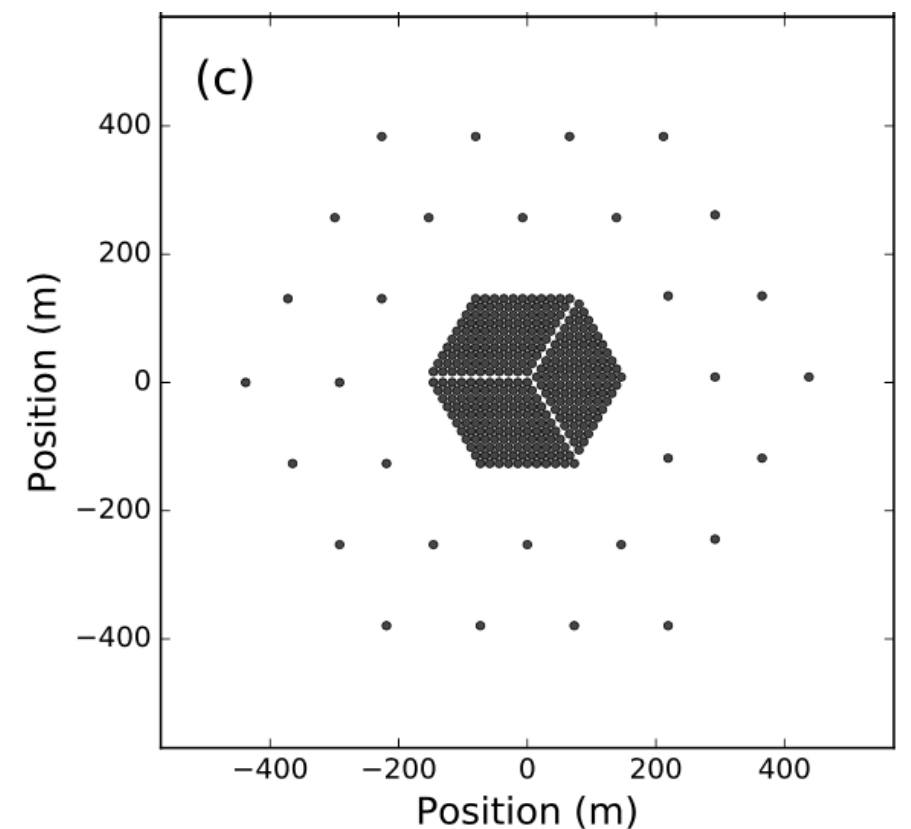
Angular Resolution:

Core: 25 arcmin
Outrigger: 11 arcmin

DeBoer et al. 2016

$$z = 1.42 \times 10^9 / \nu - 1$$

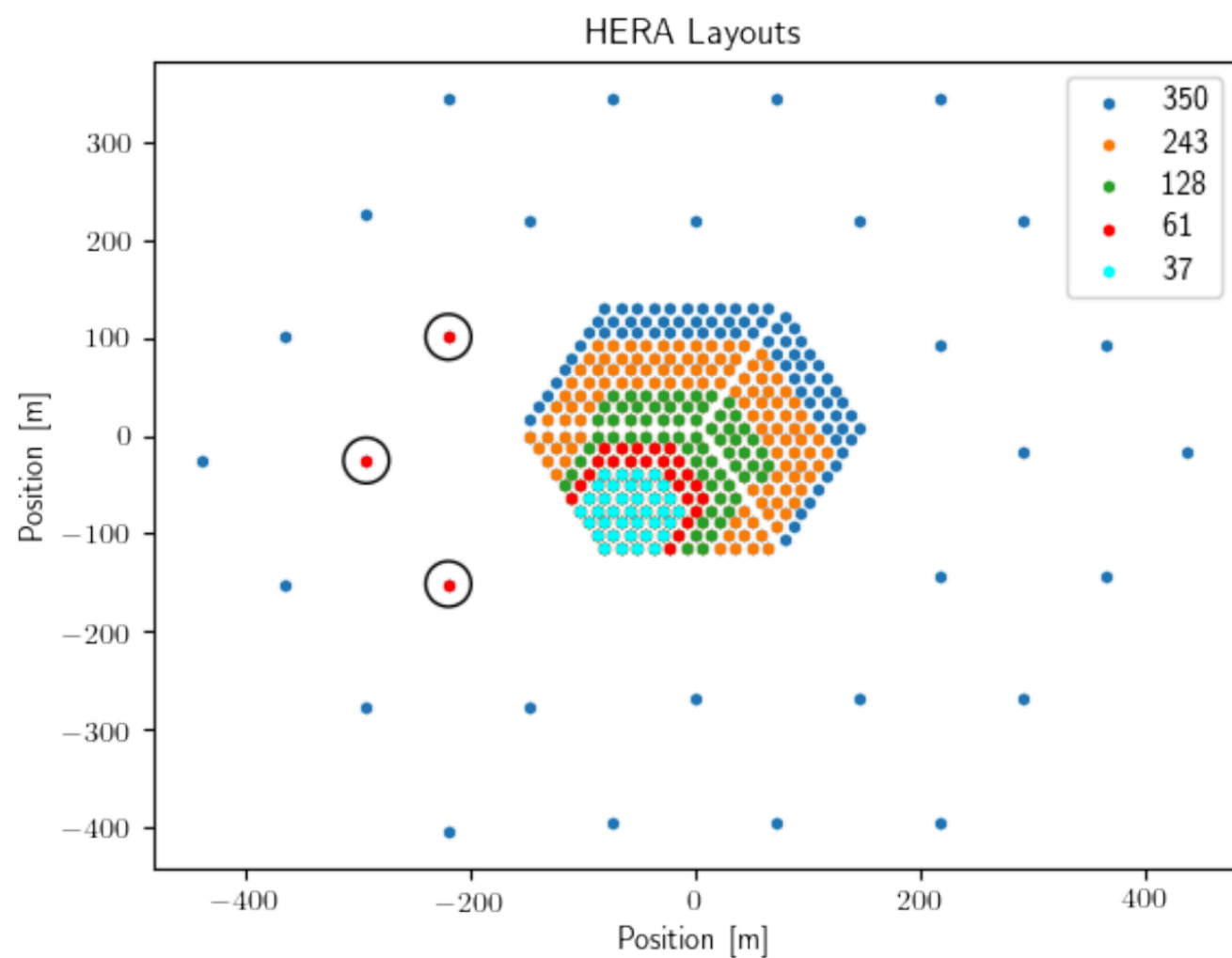
$$\theta = \lambda / D$$



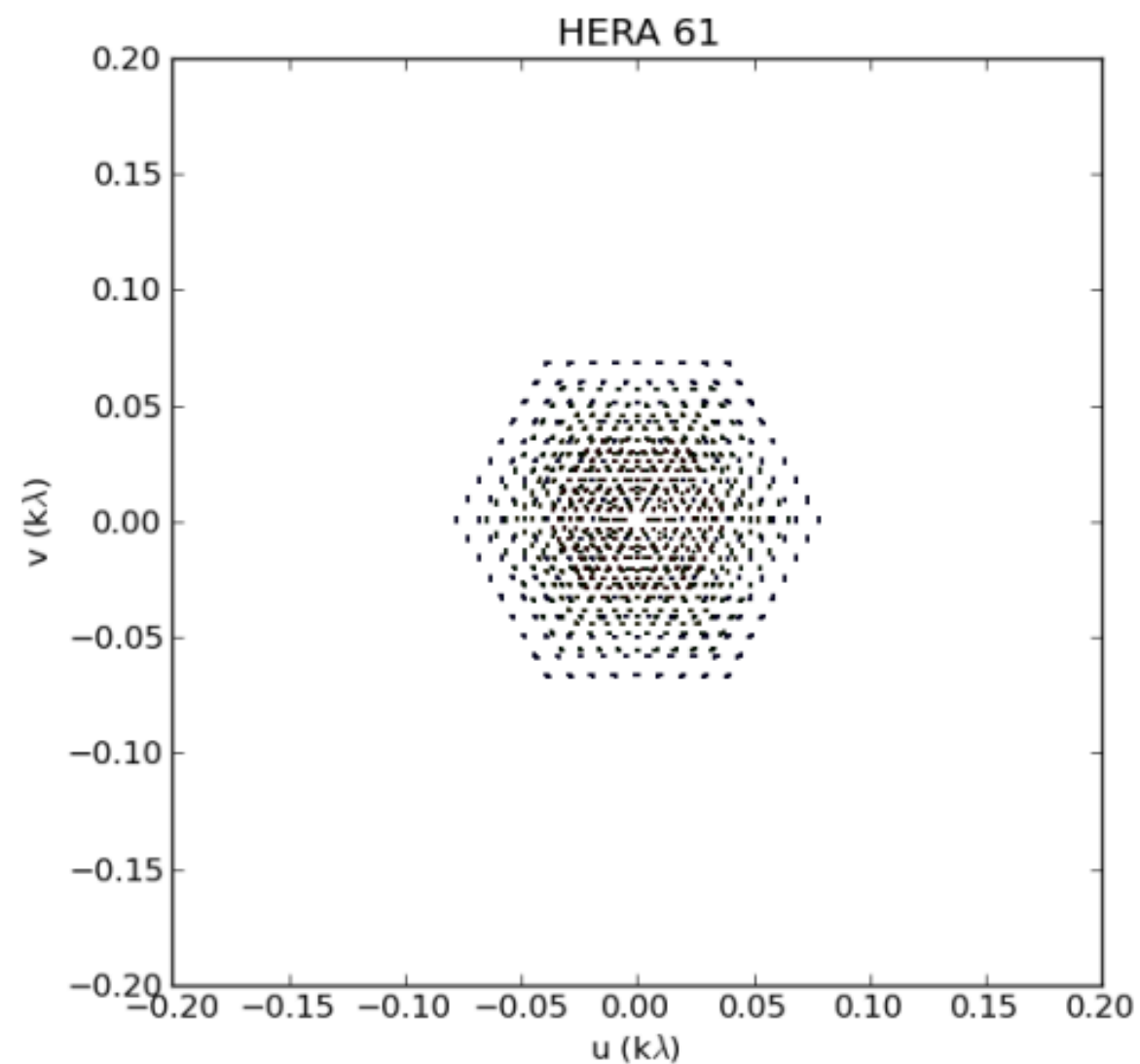
Dillon et al. 2016

HERA-60 Images: Simulated

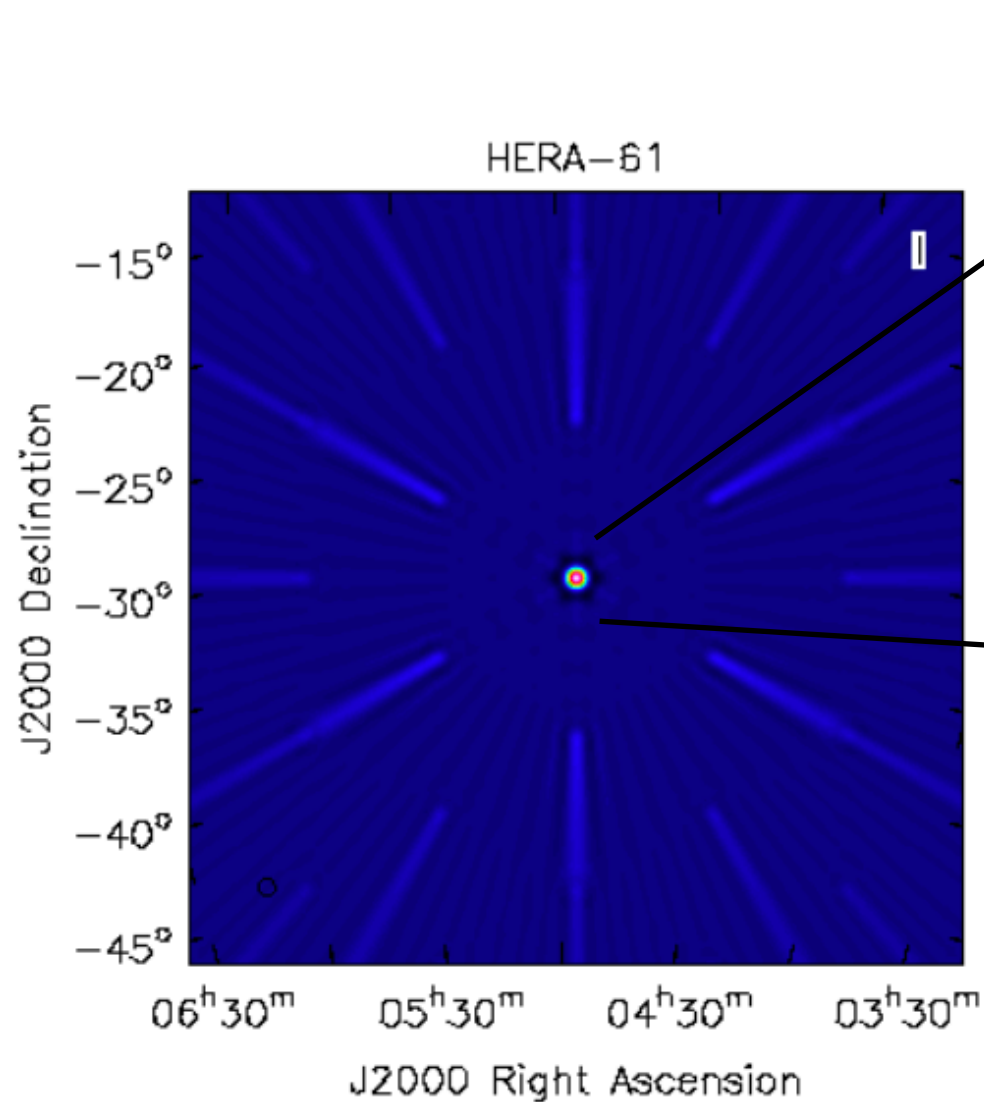
array layout



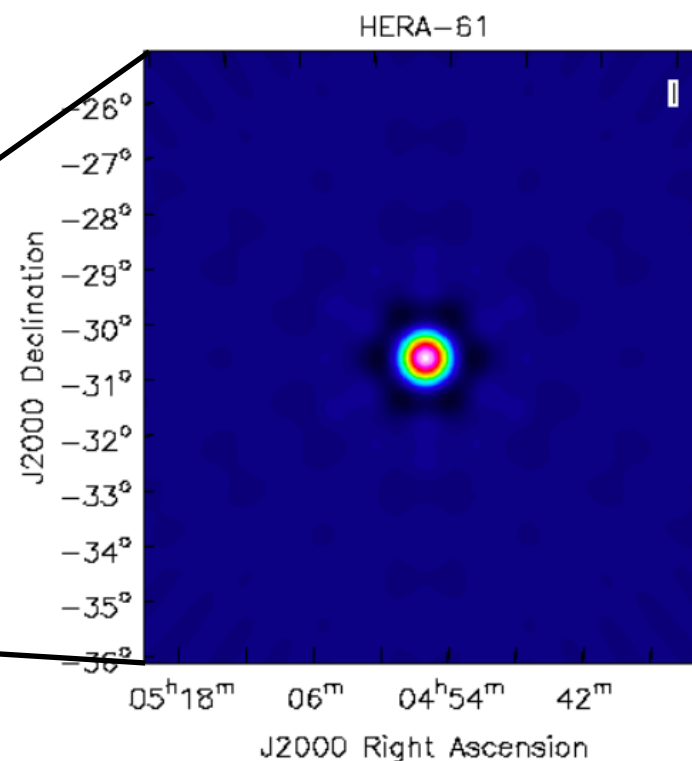
uv coverage



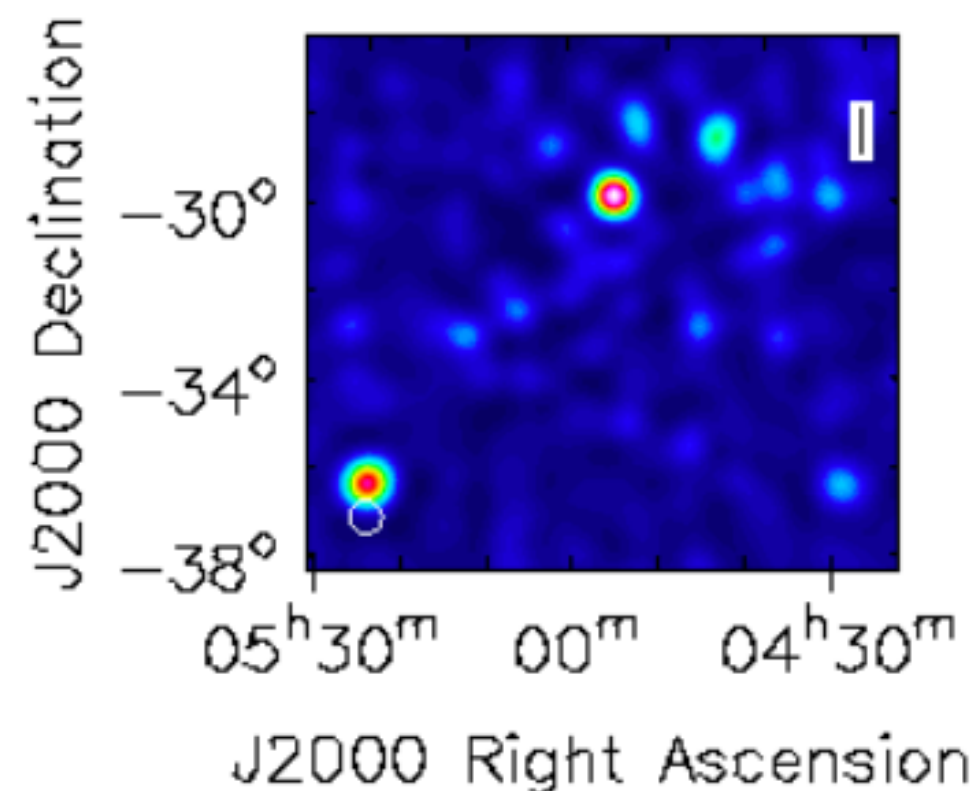
HERA-60 Images: Simulated



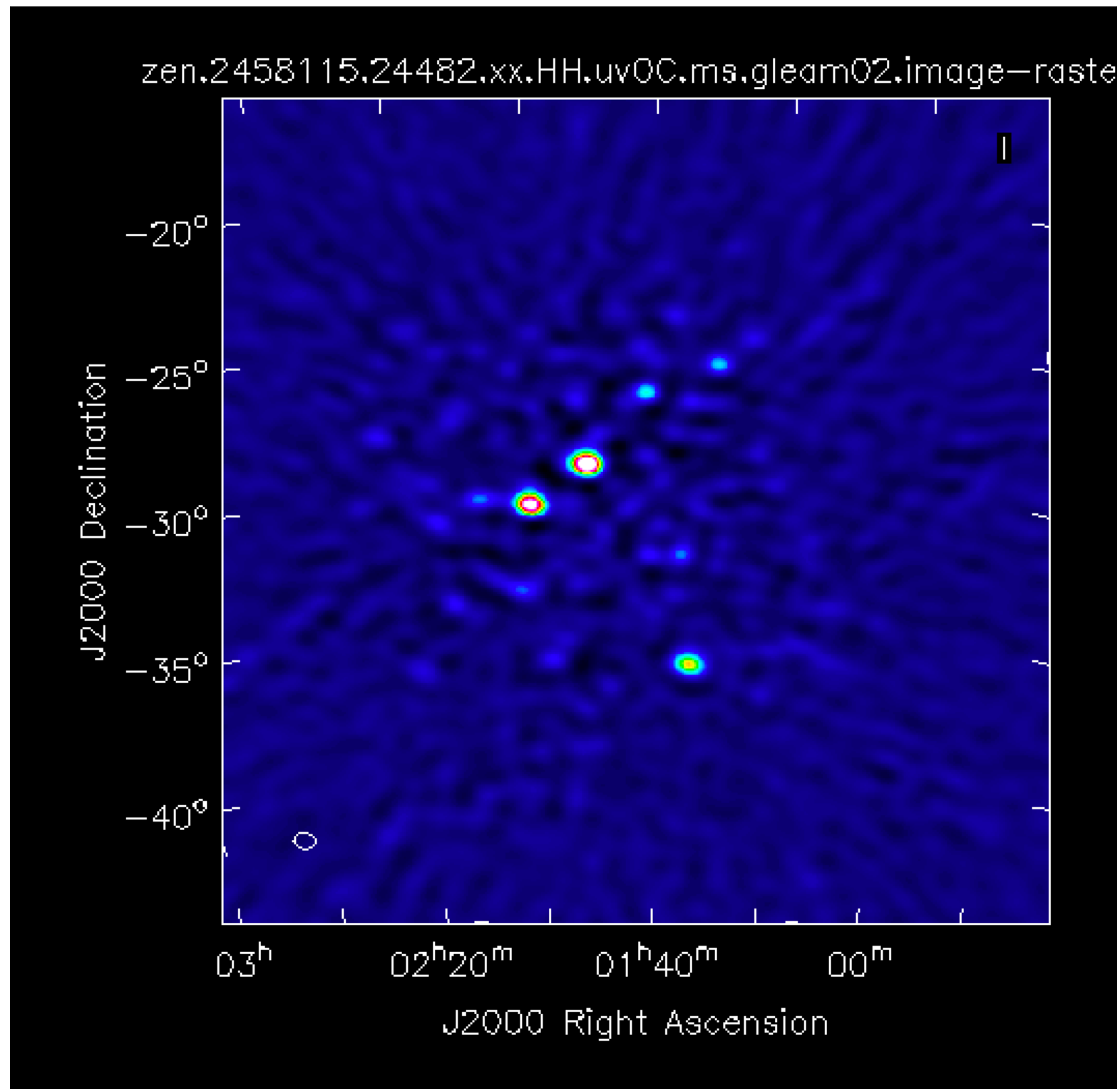
point spread function



simulated image
HERA-61 clean



HERA-60 Images: Real



3. HERA Imaging

Imaging Demo