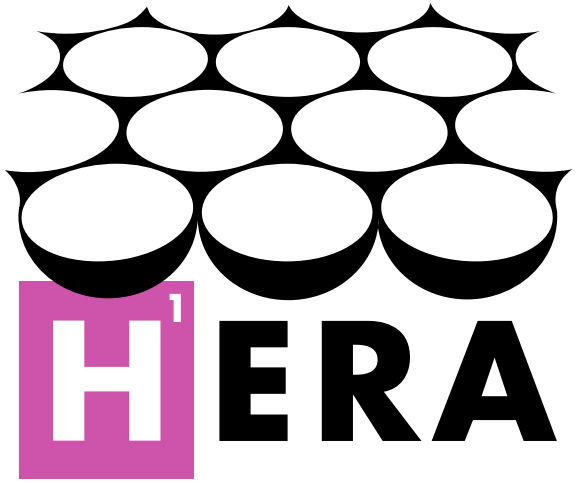

Data Analysis Part II: Calibration and Imaging

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CHAMP Bootcamp
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Lesson Overview

1. Calibration (~1.5 hour)
   i. Calibration overview
   ii. HERA calibration exploration

   Break (10 min)

2. HERA Imaging (~1 hour)
   i. HERA imaging overview
   ii. HERA imaging with CASA
   iii. HERA imaging with *direct optimal mapping*

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 capability

C. Learn how to perform basic imaging of HERA data with CASA and direct optimal mapping

What is *calibration?* Know your instrument!

- Necessary for all instruments
- Endless effort, depending on scientific requirements
- Serves two purposes
  - Data → physical properties
  - Improve the instruments
- Specific to an interferometer, like HERA

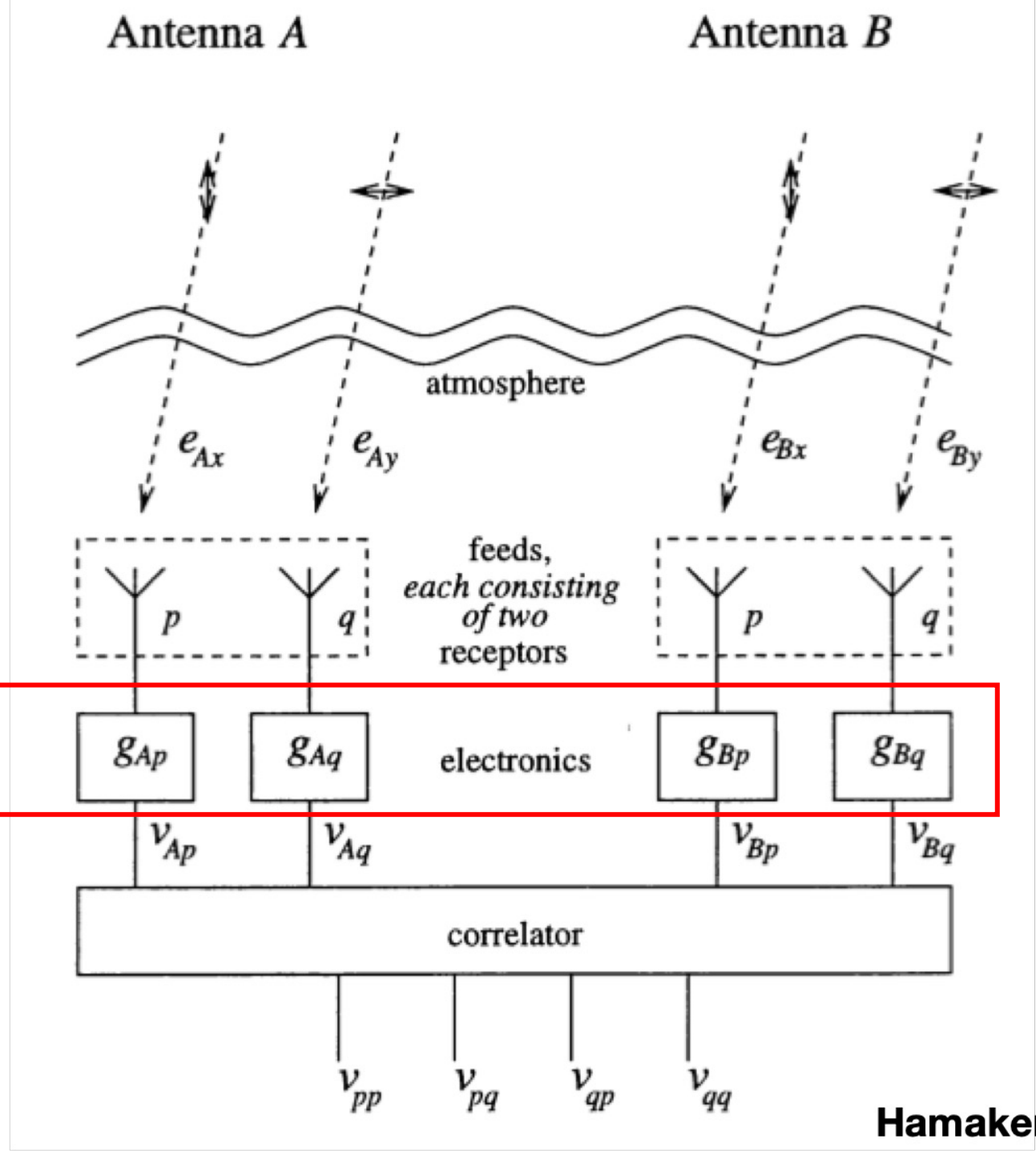
Sky Input

Atmospheric Distortion

Feed Response

Antenna Gain

Correlator Output



Hamaker et al. 1996

Measurement Equation

Ideal Scenario

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

Practical Scenario

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

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

Antenna-Based Calibration Equation

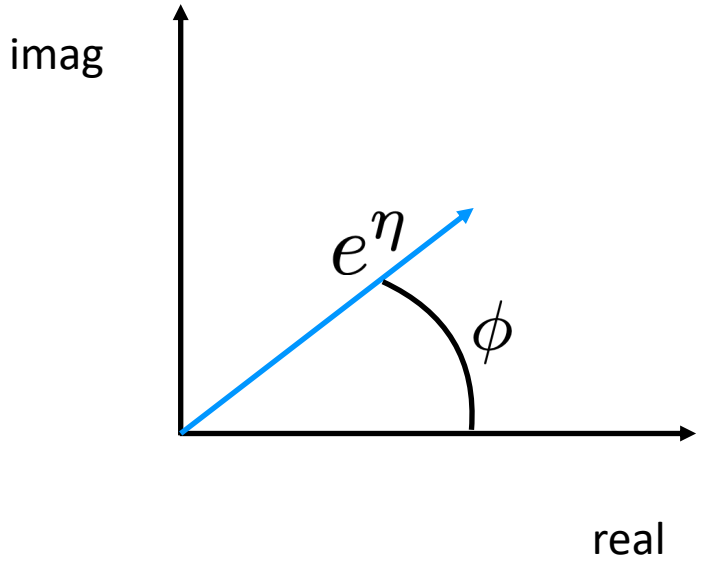
Breaking down Antenna Gains

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

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

$$\eta_j = \text{amplitude}$$

$$\phi_j = \text{phase}$$



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

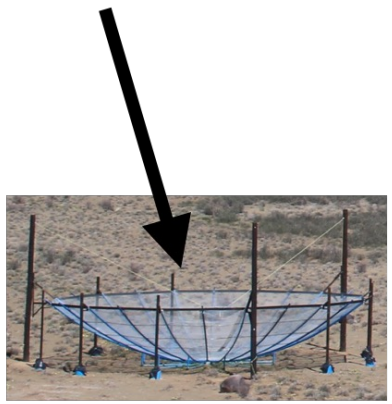
$$g_j(t,\nu) = e^{\eta_j(t,\nu) + i\phi_j(t,\nu)}$$

Solving for Gains

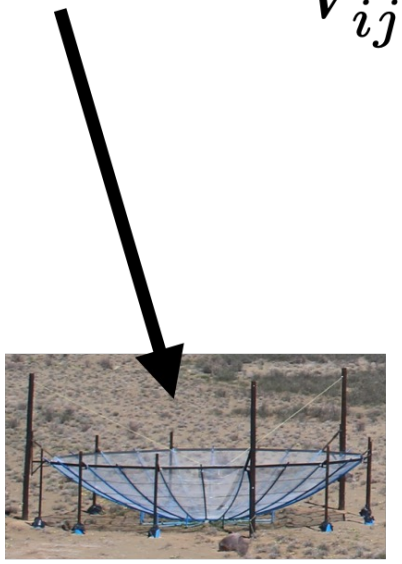
Given your measurements and your model, setup a system of equations!

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

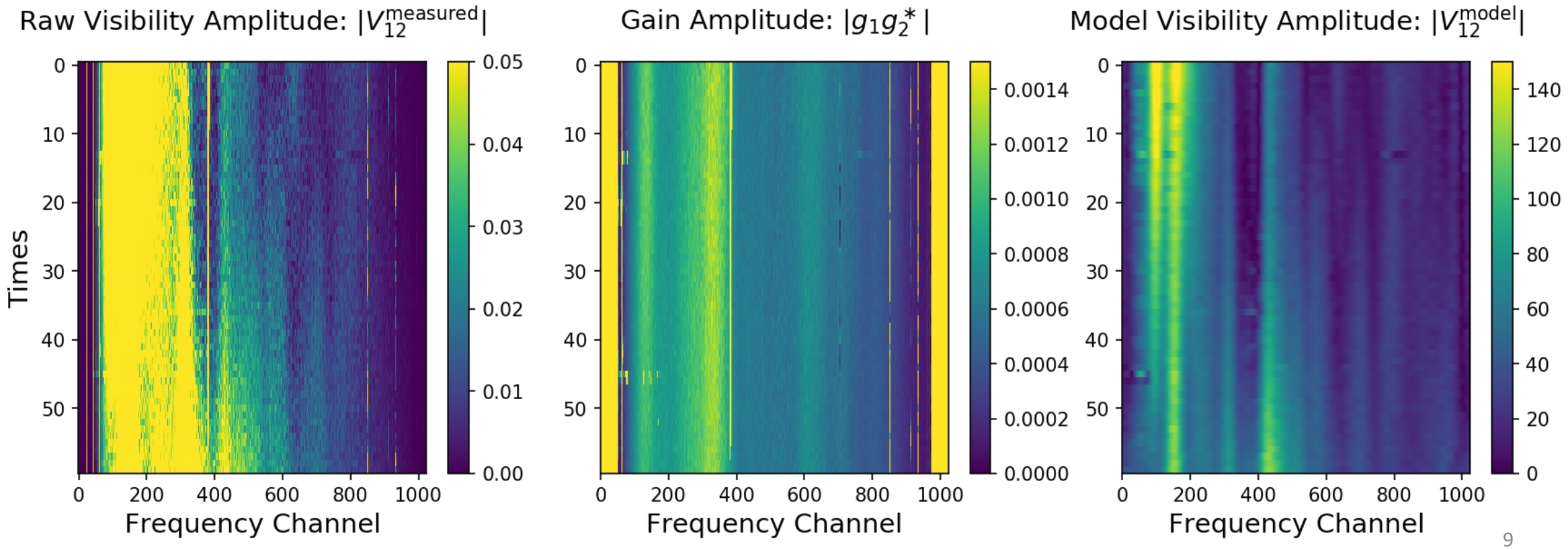


antenna 2

antenna 3

Applying Application

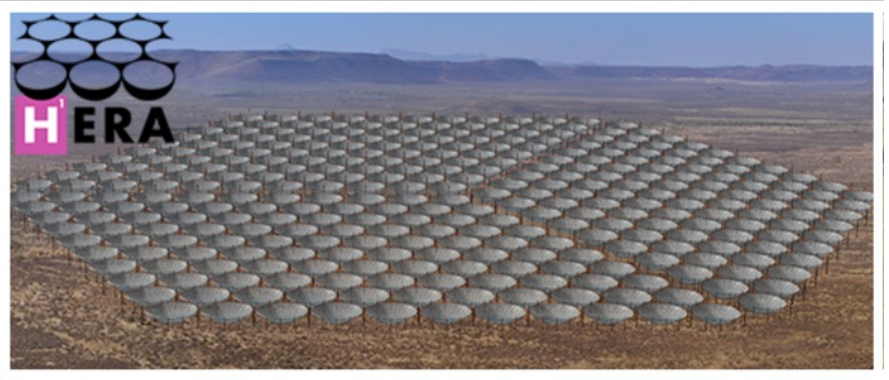
$$V_{ij}^{\text{updated}} = V_{ij}^{\text{measured}} / (g_i g_j^*)$$

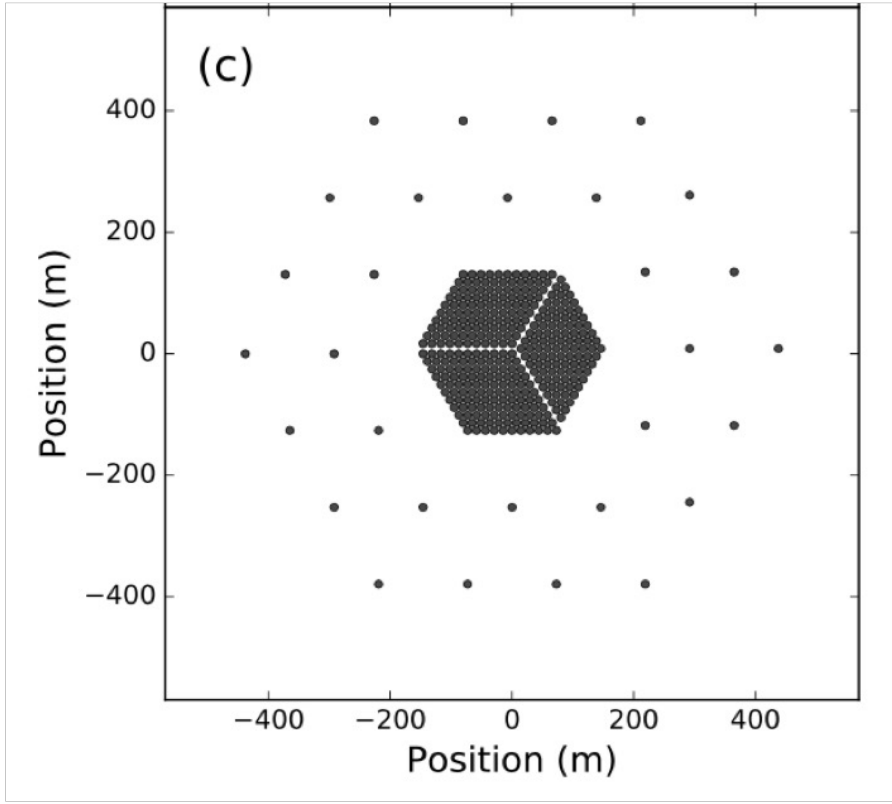


HERA Calibration Exploration Time…

2. HERA Imaging Specs

Design Spec	Performance
Frequency Coverage:	**Redshift Coverage:**
100 - 200 MHz [50 - 250 MHz]	6 < z < 13 [5 < z < 27]
Longest Baseline:	**Angular Resolution:**
Core: 292 m Outrigger: 876 m	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

3. HERA Imaging