Week 4: Radio Astronomy Fundamentals II

Objectives

Expand on the fundamentals of radio astronomy and the limitations of single dish radio telescopes, with an emphasis the introduction to interferometers and interferomtric data processing.

Day 1: Introduction to Interferometry

- Motivation for interferometry (20 minutes).
  - Review angular resolution equation.
    - Resolution and Sensitivity.
  - Compare resolution of a single radio telescope with optical telescopes.
  - Sensitivity of a single dish vs. an array.
- Basic principles of interferometry (25 minutes).
  - Double slit experiment.
  - Interference of RF signals from radio telescopes.
  - "Imaging" in the Fourier domain.
  - Translation from Fourier domain to image domain (sky brightness $\rightarrow$ visibility).
  - Introduce the u-v plane and its relationship to the image plane.
  - Rotation of Earth for u-v coverage (aperture synthesis).
- Importance of array configurations (10 minutes).
  - Resolution vs. sensitivity of different baselines.
  - Relationship between the angular size of astronomical sources and the array baseline.

Day 2: Interferometic Imaging and Data Processing

- Aperture synthesis imaging.
  - Principles of aperture synthesis and its role in high-resolution imaging.
  - Aperture plane synthesis.
  - Fourier inversion.
- Imaging algorithms.
  - Overview of CLEAN, RML, and other imaging algorithms.
  - Comparison of imaging algorithms in terms of speed, accuracy, and handling artifacts.
- Calibration techniques.
  - Importance of calibration techniques in interferometric data processing.
  - Amplitude calibration techniques, including gain calibration and flux calibration.
  - Phase calibration techniques, including self calibration, fringe-fitting, and delay calibration.
  - Polarization calibration and its challenges in interferometric observations.

Day 3: Advanced Topics in Interferometry

- Spectral line interferometry.
  - Basics of spectral line interferometry and its relevance in studying molecular gas.
  - Spectral line imaging techniques and calibration methods
- Very long baseline interferometry (VLBI).
  - Example of the Event Horizon Telescope (EHT) and M87 and Sagittarius A* black hole images.
  - Advantages of very long baseline interferometry in achieving ultra-high resolution imaging.
  - Challenges and solutions in data correlation and analysis for VLBI arrays.
- Multi-wavelength interferometry.
  - Integration of radio interferometry with observations at other wavelengths (e.g. optical, infrared, X-ray...).

- Combined analysis techniques for multi-wavelength data sets.

Week 4 Resources

Slides

@ Introduction to Radio Interferometry - NRAO Slides @ Interferometry Basics - Caltech Slides

- Overview of Radio Interferometry
- Radio Telescope Array Configurations
- VLA Configurations Interactive Map
- The Very Large Array: Astronomical Shapeshifter
- Radio Interferometry
- Imaging and Deconvolution
- Virtual Radio Interferometer
- Introduction to Radio Interferometers
- A Gentle Introduction to Interferometry
- Radio Imaging and CLEAN
- Interferometric Imaging Algorithms
- A Crash Course in Radio Astronomy and Interferometry: Aperture Synthesis
- Basic Radio Interferometry – Geometry
- Principles of Interferometry
- Interferometry Aperture Synthesis and Radio Mapping - Shubhendu Joardar
- Fourier Synthesis Imaging
- Theory of Spectral Line Radio Interferometry
- Interferometry Calibration Basics
- Calibration and Advanced Radio Interferometry
- Very Long Baseline Array - NRAO
- Very Long Baseline Interferometry
- Very Long Baseline Interferometry Imaging

- Event Horizon Telescope
- Multi-Wavelength Astronomy