Week 3: Radio Astronomy Fundamentals I

Objectives

Introduce students to the fundamentals of radio astronomy, single dish radio telescopes, and signal processing, with an emphasis on SETI applications and GNU radio demonstrations.

Day 1: Introduction to Radio Astronomy

- Benefits of astronomy at radio frequencies (25 minutes).
  - Atmospheric windows.
  - Observations at night, day, and cloudy conditions.
  - Gas/dust scattering, compare with optical astronomy.
  - Hydrogen mapping with 21cm waves.
  - Brief interferometry introduction (covered in more detail in week 4).
- Major discoveries in radio astronomy (20 minutes).
  - Radio waves from space (1932).
  - Radio galaxies (1939).
  - Quasars (1963).
  - Cosmic Microwave Background (1965).
  - Pulsars (1967).
  - Fast radio bursts (2007).

- Using radio waves for SETI (10 minutes).
  - Benefits of radio waves for interstellar communication.
  - What technosignatures might look like.
  - Significant radio frequencies for SETI.

Day 1 Resources

1. Atmospheric Windows Image
2. Optical/Radio Image Slider
3. Cosmic Coloring Compositor
4. 21-cm Astronomy
5. History of Radio Astronomy
6. SETI Observations

Day 2: Single Dish Radio Telescopes

- Basic principles of radio telescopes (20 minutes).
  - How radio telescopes gather and focus radio waves.
  - Frequency ranges of various radio telescope designs.
  - Angular resolution formula.
  - Sensitivity of a radio telescope.
  - Pointing and tracking.
- Components of a radio telescope (20 minutes).
  - Feed/antenna designs.
  - Amplifiers and receiver systems.
  - Traditional radio vs. software defined radio.

  - Analog to digital converters.

- Observing strategies (10 minutes)
  - Calibration techniques.
  - Single pointing.
  - Position switching and mapping techniques.
  - Frequency shifting.
- Influential single dish radio telescopes (5 minutes).
  - Five-hundred-meter Aperture Spherical Telescope (FAST).
  - Green Bank Telescope.
  - Arecibo Telescope.
  - Parkes Observatory.

Day 2 Teaching Resources

1. What are Radio Telescopes? - NRAO
2. Radio Telescopes and Radiometers
3. Resolution and Sensitivity.
4. Radio Astronomy Instrumentation.
5. The Technology of Radio Astronomy and Telescope Breakdown.
6. Observing Techniques - Green Bank Observatory.
7. The results of radio telescopes: spectra, cross-scans and radio maps.
8. Overview of Single-Dish Radio Telescopes.

Day 3: Signal Processing

Note: This lecture makes use of GNU Radio demonstrations, a link to examples can be found in the Day 3 Teaching Resources section.

- Introduction to digital signal processing
  - Review Analog-to-Digital Conversion (ADC).
  - Nyquist sampling theorem.
- Signal processing techniques.
  - Amplitude modulation.
  - Frequency modulation.
  - Amplifiers.
  - Filters.
  - Demodulation.
  - Signal detection.
- Signal processing algorithms.
  - Fourier transformations.
  - Correlation.

Day 3 Teaching Resources

1. Signal Digitization
2. Digital Signal Processing in Radio Astronomy
3. Complete Guide to Understanding Signal Processing
4. Introduction to Digital Filters
5. Signal filtering, Signal suppression, Signal processing
6. Fundamentals of Signal Processing
7. UCSB Digital Signal Processing Introduction Lecture Slides
8. Discrete/Fast Fourier Transforms

9. Correlation in Signal Processing