Interferometry and Targeted Follow-up Observations

John M. Cannon
Macalester College
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Outline

• Interferometry Fundamentals
• Recent Advances in Radio Technologies
• Types of Emission in the Radio Regime
• HI Spectral Line Observations
  – Example targeted HI observations of a nearby galaxy
• Specific ALFALFA Applications
  – SHIELD
  – “Dark galaxies”
Interferometry Fundamentals

- **Antenna**: device for converting EM waves into current
  - Antenna is the essence of a radio telescope; the dish just focuses radiation onto it
  - Radiation pattern of antenna same for transmitting and receiving
  - An antenna *IS* a radio telescope
    - You only need a “dish” if the collecting area of your antenna is small (Area $\sim \lambda^2$)
Interferometry Fundamentals

Incident (sinusoidal) EM wave induces (sinusoidal) current in antenna

\[ J \propto g(x) \exp(-i\omega t) \]
Interferometry Fundamentals

\[ f(l) = \int_{\text{aperture}} g(u) e^{-i2\pi lu} du \]

In the far field, the electric-field pattern of an aperture antenna is the Fourier transform of the electric field illuminating the aperture.
$$f(l, m) \propto \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} g(u, v) e^{-i2\pi(lu + mv)} \, du \, dv$$
The electric field pattern of a two-dimensional aperture is the two-dimensional Fourier transform of the aperture field illumination.
Interferometry Fundamentals

\[ c \tau_\phi = \vec{b} \cdot \vec{\phi} \]

\[ V_1 = V \cos[\omega(t - \tau_\phi)] \quad V_2 = V \cos(\omega t) \]

\[ V_1 V_2 \quad R = \frac{V^2}{2} \cos(\omega \tau_\phi) \]
Interferometry Fundamentals

• The response of a two-element interferometer to an extended source with brightness distribution $I_{\nu}(s)$ is the complex visibility:

$$V_{\nu} = \int I_{\nu}(\hat{s}) \exp(-i2\pi \vec{b} \cdot \hat{s}/\lambda) \ d\Omega$$

• Each visibility gives a measure of the source brightness at a specific time, in a specific direction.

• More visibilities mean a more complete and accurate representation of the source. Increase # of visibilities by
  • Using more antennas
  • Moving the antennas (changing the baselines)
  • Letting the Earth rotate under the source
The inverse Fourier transform of a collection of *visibilities* is an image of the source.

\[
V_{\nu}(u, v, w) = \int \int \frac{I_{\nu}(l, m)}{(1 - l^2 - m^2)^{1/2}} \exp[-i2\pi(ul + vm + wn)] \, dl \, dm
\]
Interferometers in Operation

- The Fourier transform of an image is a collection of *visibilities*

\[
\frac{I_\nu(l, m)}{(1 - l^2 - m^2)^{1/2}} = \int \int V_\nu(u, v, 0) \exp[-i2\pi(ul + vm)] \, dldm
\]

Liu & Cannon, AAS 219
Interferometers in Operation
Interferometers in Operation
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Interferometers in Operation
Why an Interferometer and not *Arecibo*?

- Small telescopes (large field of view)
- Separate these by large distances (improves spatial resolution)
- Interferometer measures *both* position and intensity
  - Allows one to map a source at the *synthesized beam* size over the entire field of view of the primary beam
- But there is a cost: higher resolution requires higher source brightness
Disadvantages of an Interferometer vs. *Arecibo*

\[ \theta = 1.22 \frac{\lambda}{D} \]

Filling factor decreases
Disadvantages of an Interferometer vs. *Arecibo*

\[ \theta = 1.22 \frac{\lambda}{D} \]

These two telescopes have the same “D” but very different primary beam sizes and surface brightness sensitivities.
Recent Advances

• Correlators
  – Wide bandwidths (measured in GHz!), some with zoom capabilities (simultaneous wide-band continuum and spectral line data acquisition)
    • Examples: EVLA/WIDAR, ATCA/CABB
• Phased array technologies
  – Allows measurements of sources from area of sky much larger than primary beam
    • Examples: AO40, ASKAP, APERTIF, MUSTANG-II
• Long-wavelength arrays
  – Collections of dipoles!
  – Examples: LWA, LOFAR
Recent Advances
Observing for University Classes

- Program to use NRAO facilities to acquire new data to use in college classes
- Free to anyone teaching an appropriate-level class
- Easy to apply

- Do this in your classes!
HI Spectral Line Emission: UGCA 105

Cannon et al. (2012)
HI Spectral Line Emission: UGCA 105

\[ M = \frac{v^2 \cdot r}{G} \]

Cannon et al. (2012)