A Short Introduction to Radio Astronomy and the ALMA Observatory (for Engineers)
"Radio Astronomy" as in radio waves from the stars?

- Every object at a temperature above 0 Kelvin radiates electromagnetic waves.

\[
\frac{P_r}{P_t} = G_t G_r \left( \frac{\lambda}{4\pi R} \right)^2
\]

\[
P_r = P_t + G_t G_r + 20 \log_{10} \left( \frac{\lambda}{4\pi R} \right)
\]
What can we "see" at millimeter-wave frequencies?

- Chemical compounds and reactions
- Colder (older and further away) sources
- Easier to analyze!
How do we observe radio sources?

- **No CCD/CMOS sensors.** Wavelength are too large. No lenses.
- Use very **directional antennas**, and **ultra-sensitive ultra-broadband receivers**.
- **Antenna Arrays and interferometry:** Like an image sensor, but without a lens.
- Need to accurately **measure relative phase** and amplitude at every antenna.
- **Spectral analysis** and **image synthesis**.
The Atacama Large Millimeter/Sub-millimeter Array

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A Global Project
Where do we build this thing?
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Basics of ALMA Electronics & Interferometry

\[(f \ast g)[n] \overset{\text{def}}{=} \sum_{m=-\infty}^{\infty} f^*[m] \ g[n+m].\]
Basics of ALMA Electronics & Interferometry

\[(f * g)[n] \overset{\text{def}}{=} \sum_{m=-\infty}^{\infty} f^*[m] g[n + m].\]
Holography

Not to scale!

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Holography
The Receiver

Super-heterodyne Receiver

Front-End

Sky → RF → IF → LO1

Back-End

LO2 → BB → ADC → Optical Transducer → To Correlator

Sampling Clock

LO Reference

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Front End

- 1<sup>st</sup> Down-conversion
- 1<sup>st</sup> LO Synthesis
Band Cartridge
Reference Signals

- All reference signals combined and delivered through 1 single-mode fiber.
Correlator

1.6 \times 10^{16} \text{ FLOPS}
Final Products

Power Spectrum Example: First Interferometric Spectrum at the ATF, Orion Hot Core (19 January, 2008)
Final Products
19 Antennas
Credits: Some material has been taken from the ALMAObservatory.org website. Please visit for further credit details.