Radio Astronomy

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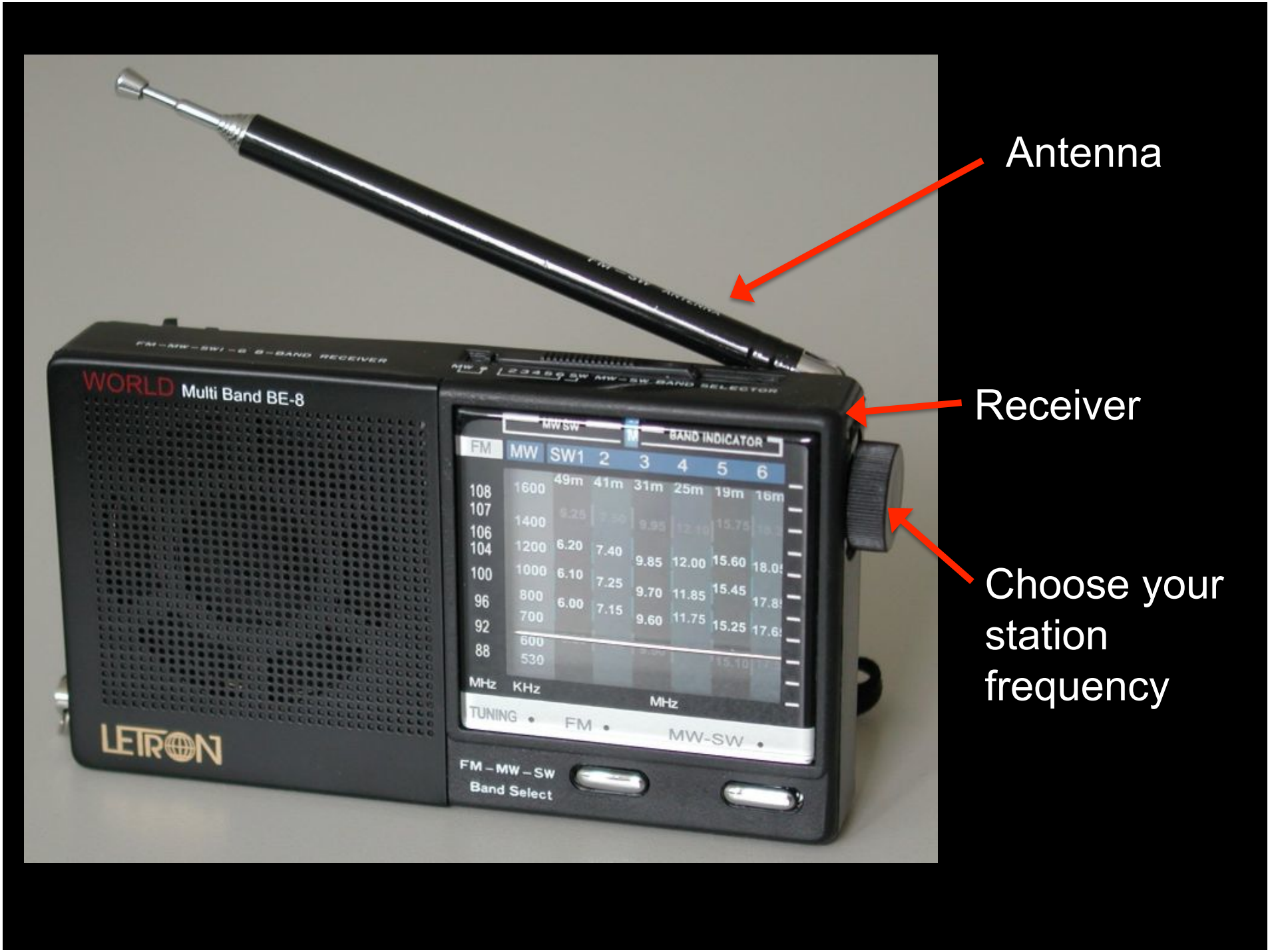
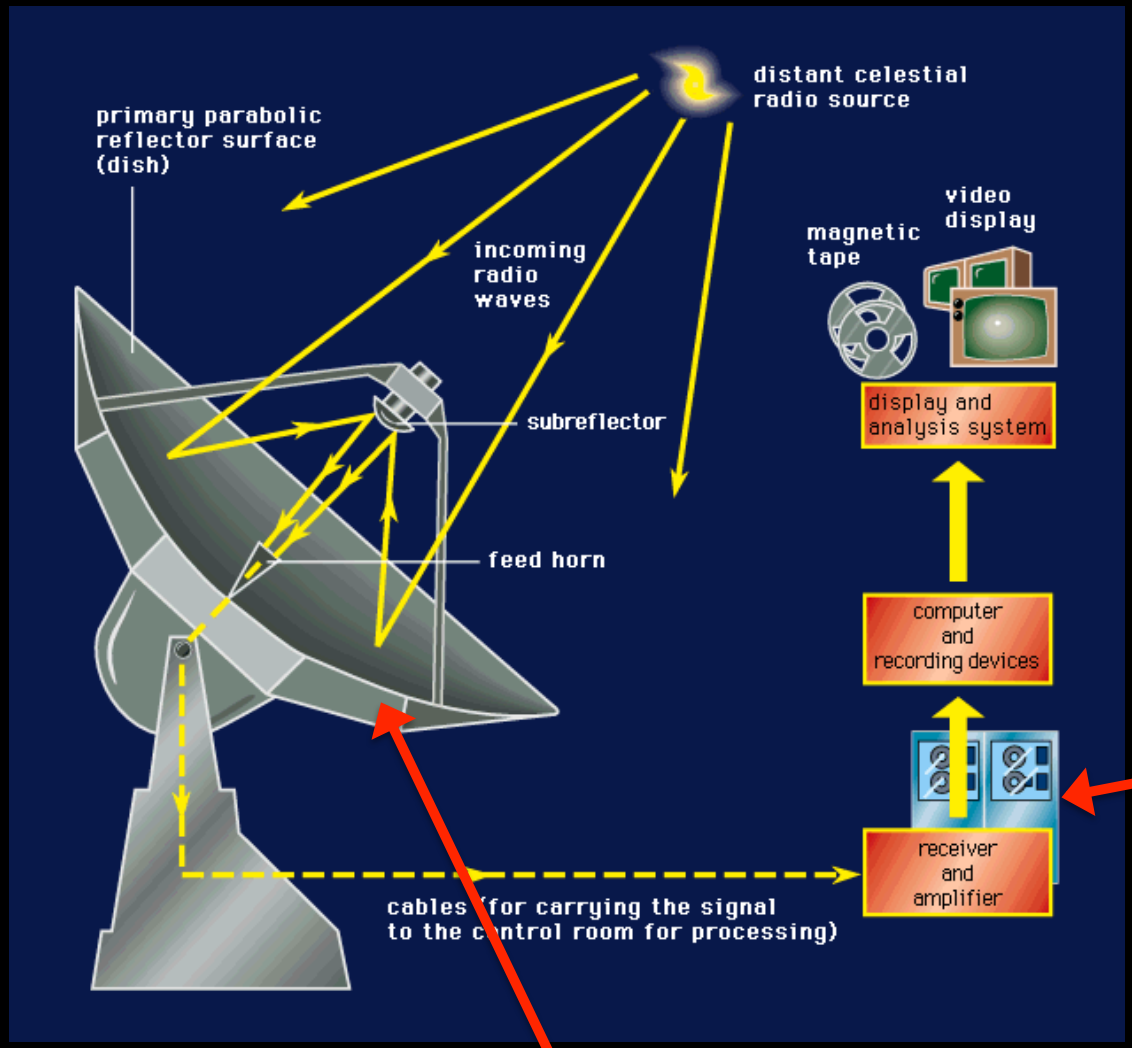
Lowell Observatory

NAU Observational Astronomy Class, 19 Sep 2013


Antenna
Receiver
Choose your station frequency
WORLD Multi Band BE-8
LETRON
FM – MW – SW
Band Select
BAND INDICATOR
FM MW SW1 2 3 4 5 6
MHz KHz MHz
TUNING • FM • MW-SW •



Receiver; frequency selection

Antenna

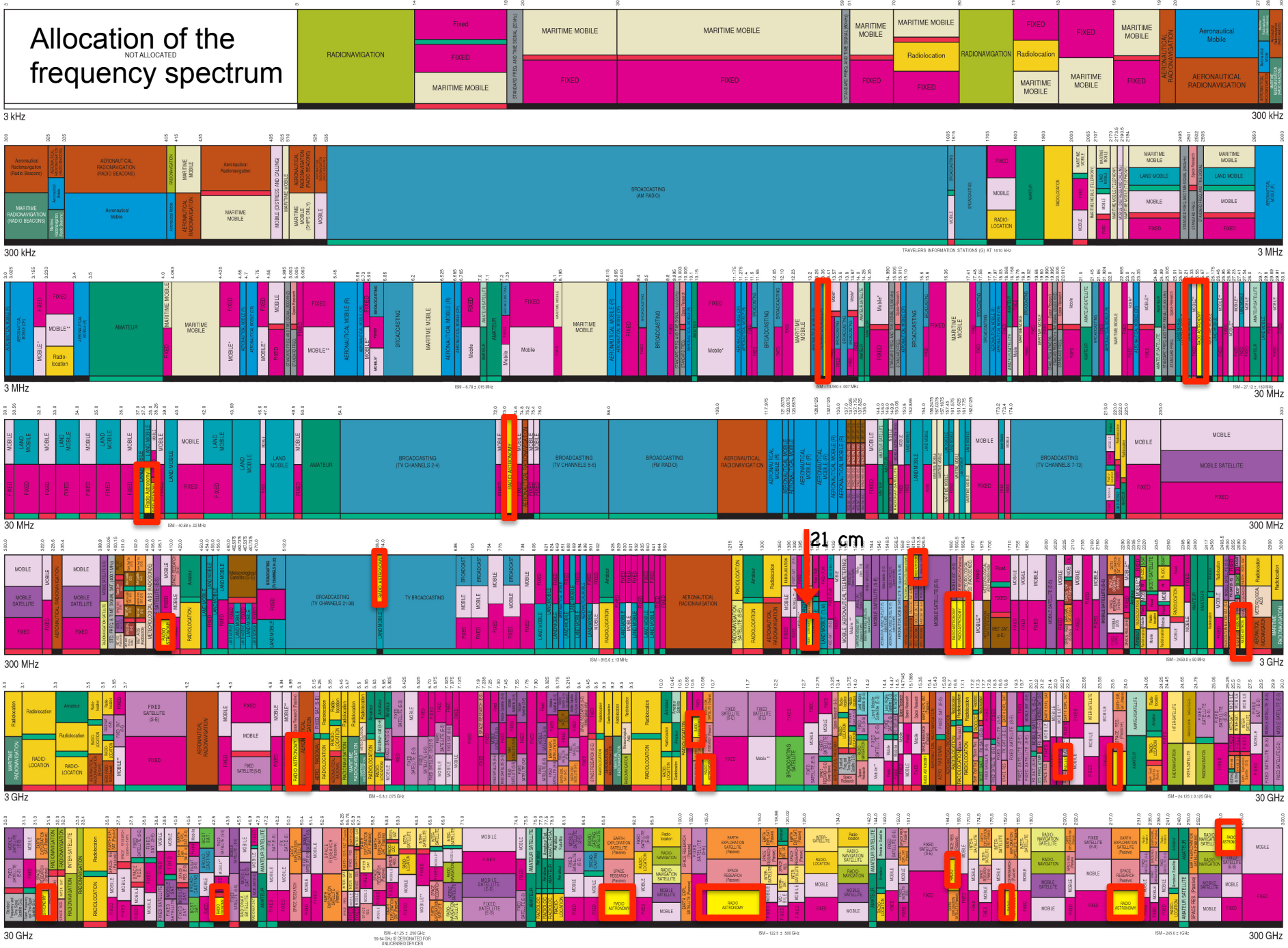

From the Academy Award-Winning Director of "Forrest Gump" and Pulitzer Prize-Winning Author of "Contact."
JODIE FOSTER
MATTHEW McCONAUGHEY
A message from deep space.
Who will be the first to go?
A journey to the heart of the universe.
CONTACT

Radio astronomers think in frequencies;
optical astronomers, in wavelengths.

Frequency (Hz) = c/lambda,
where c is the speed of light

A few key frequencies/wavelengths:

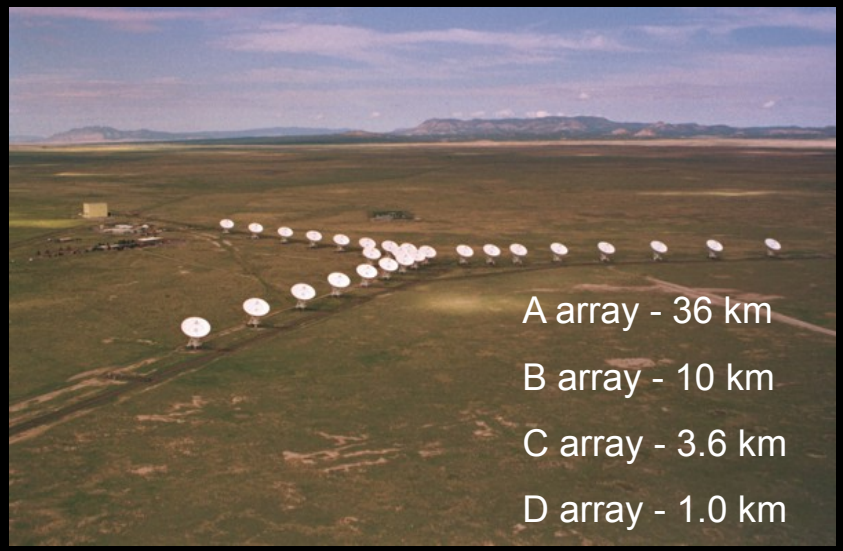
Hydrogen atom --- 1420 MHz = 21 cm
^{12}CO (1-0) --- 115 GHz = 2.6 mm


Allocation of the frequency spectrum
NOT ALLOCATED
3 kHz
300 kHz
300 kHz
3 MHz
3 MHz
30 MHz
30 MHz
300 MHz
21 cm
300 MHz
3 GHz
3 GHz
30 GHz
30 GHz
300 GHz

Single dish: Green Bank Telescope

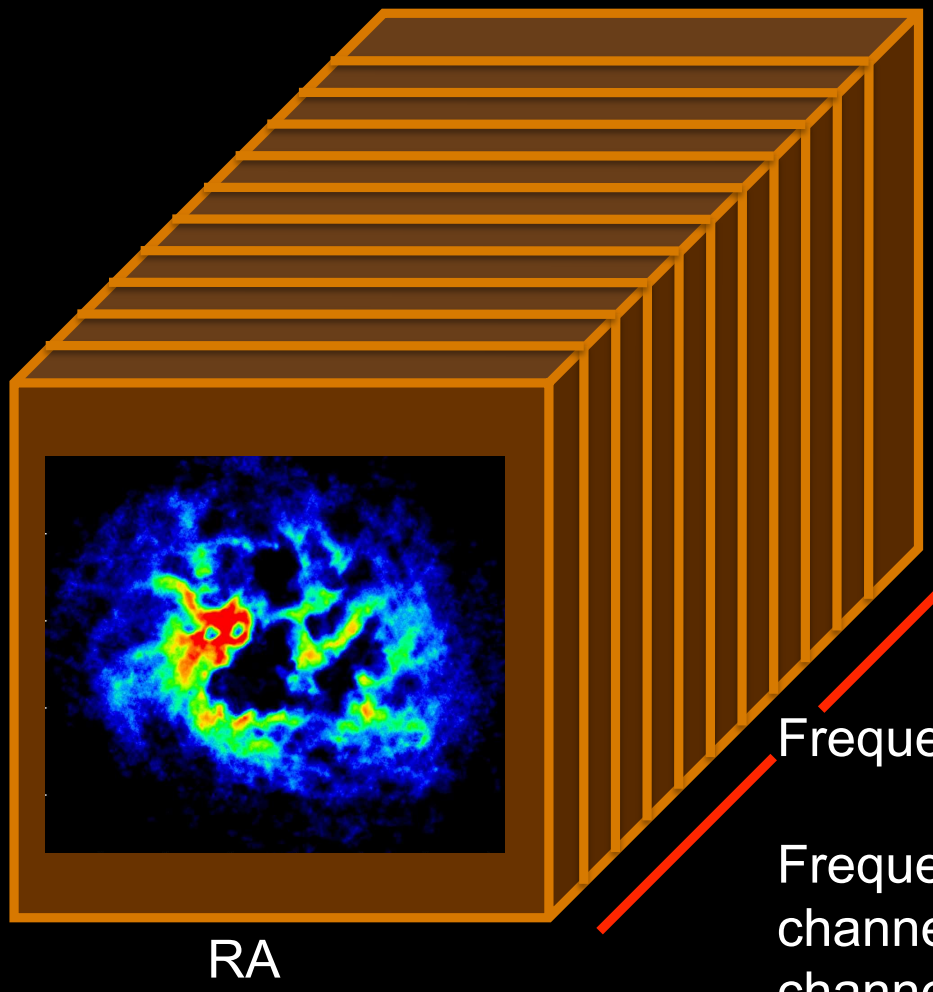
NRAO/AUI

Interferometers: Very Large Array



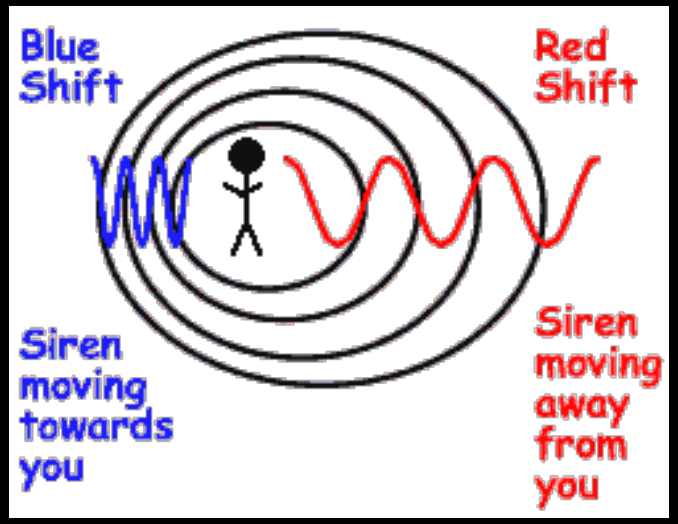
Really big interferometers: VLBI

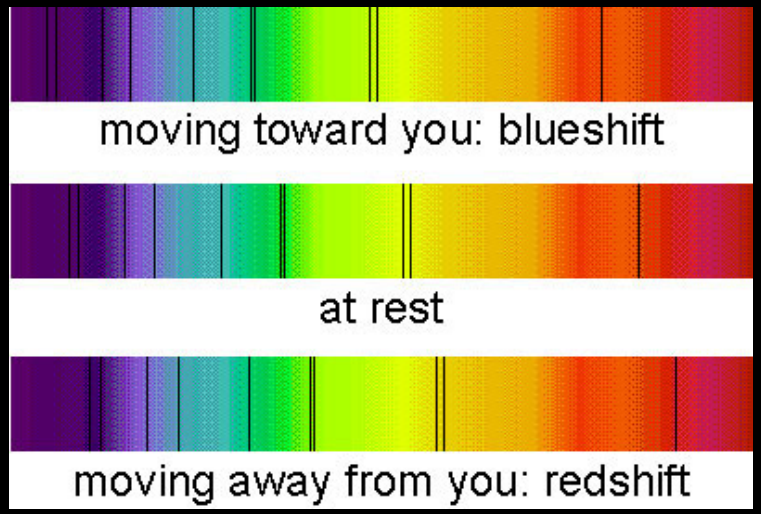
Data cube



Frequency width of channel and number of channels are usually selectable.

Can convert frequency to velocity with Doppler Shift if observing a particular spectral line.





HI: Observing the Hydrogen atom

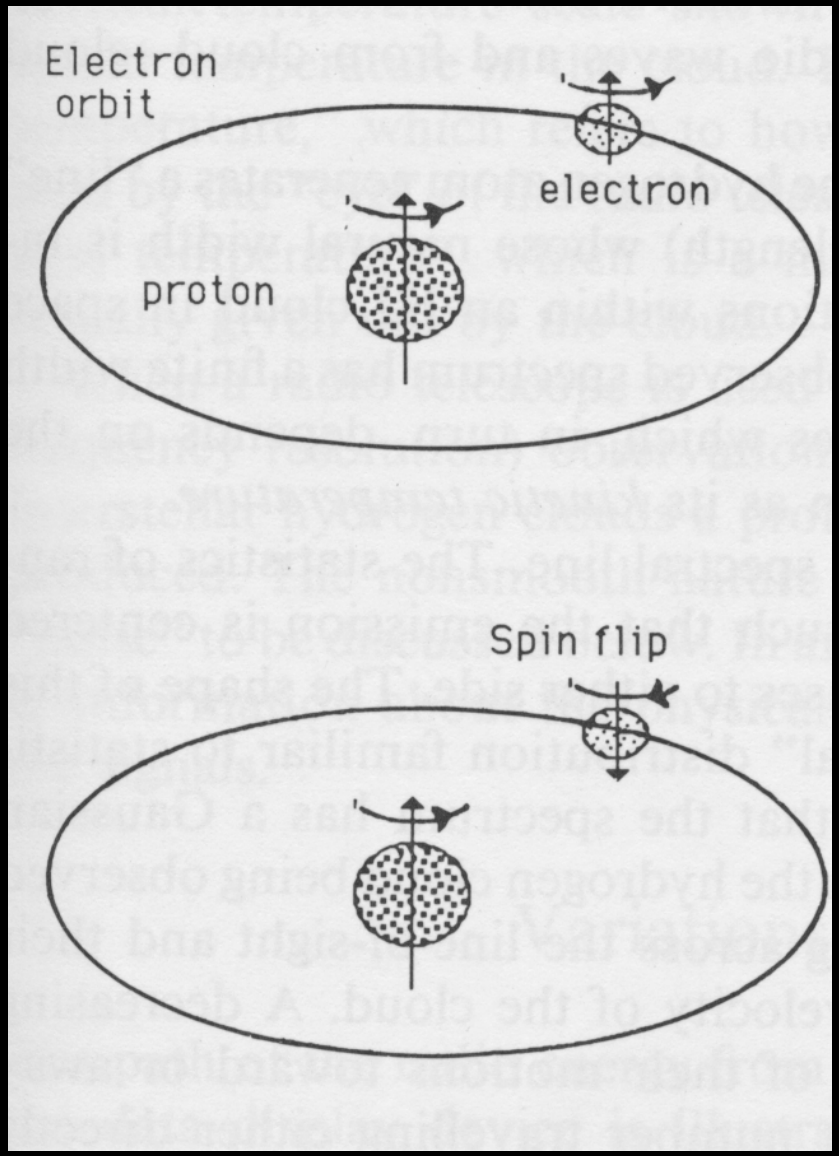


Figure 16.4/Verschuur/Interstellar Matters

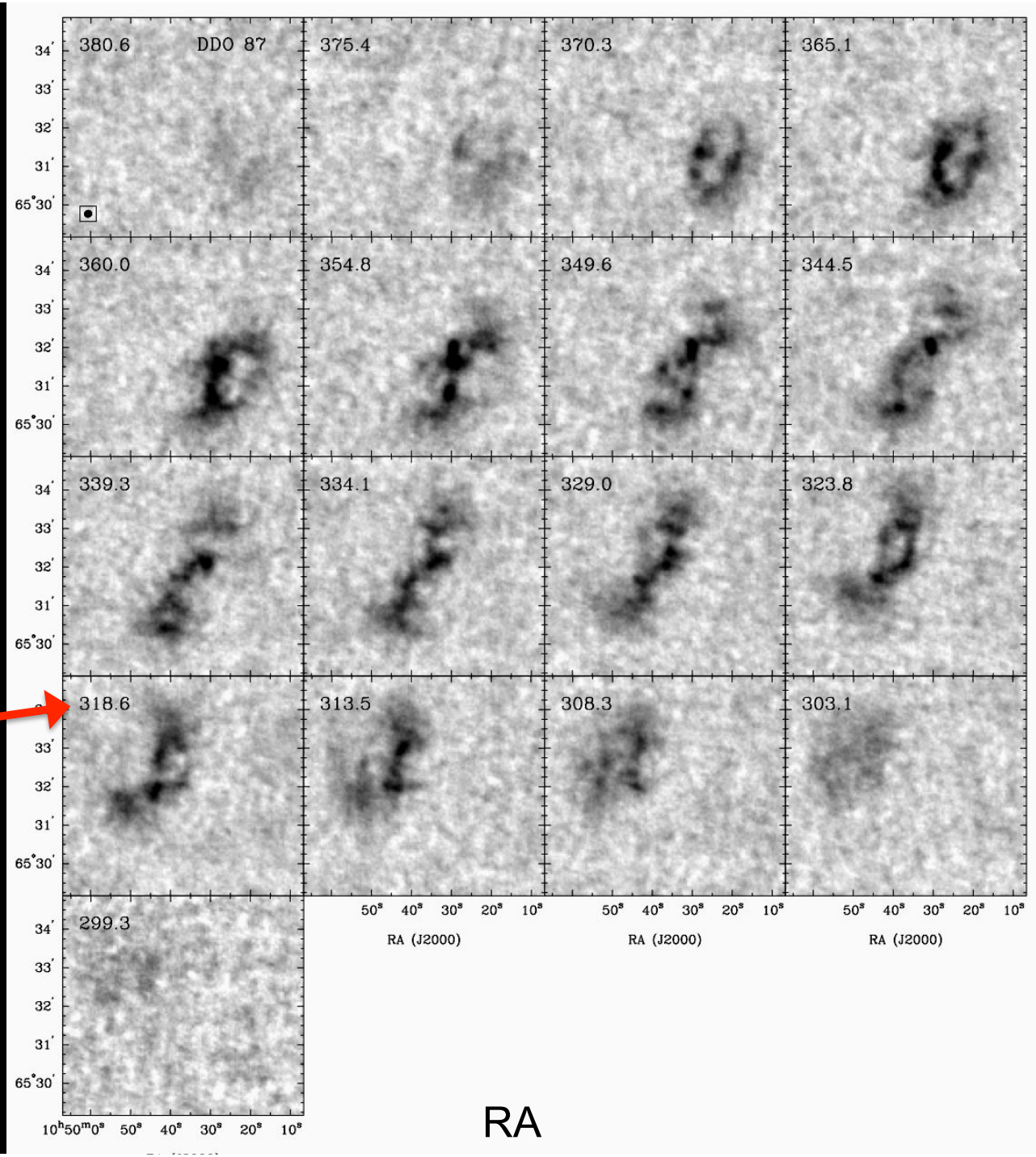
High energy

Hyperfine line: 1420.405751 MHz
~ 21 cm

Low energy

(This is also how an MRI machine works in medicine).

HI Data Cube: DDO 87



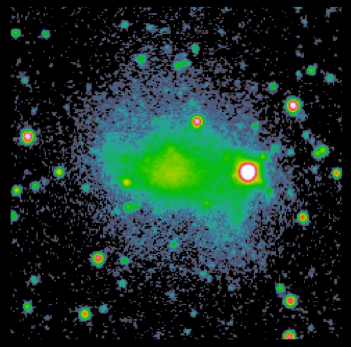
Dec

Velocity of channel in km/s

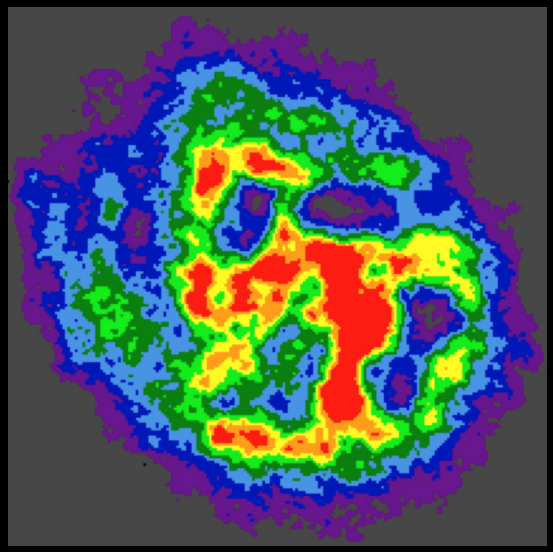
RA

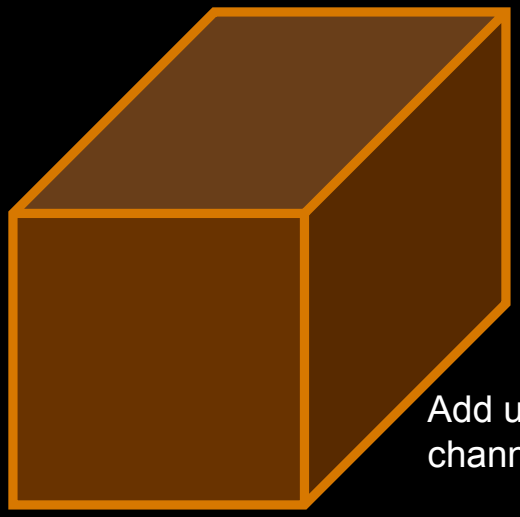
DDO 87 -- the atomic hydrogen gas

Stars (optical image)



Integrated atomic hydrogen: Collapse the cube, add up all the frequency channels with galaxy emission

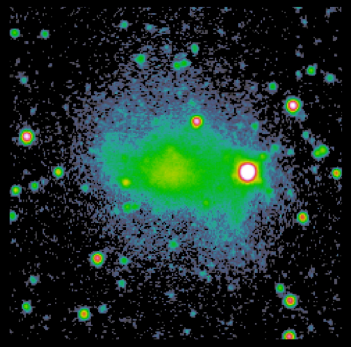




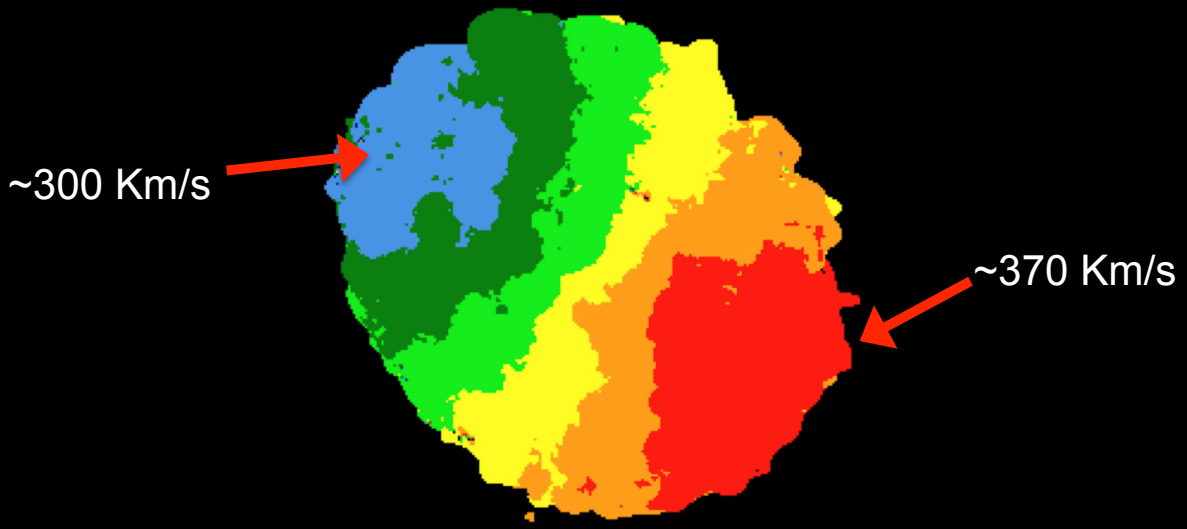
Add up all the channels

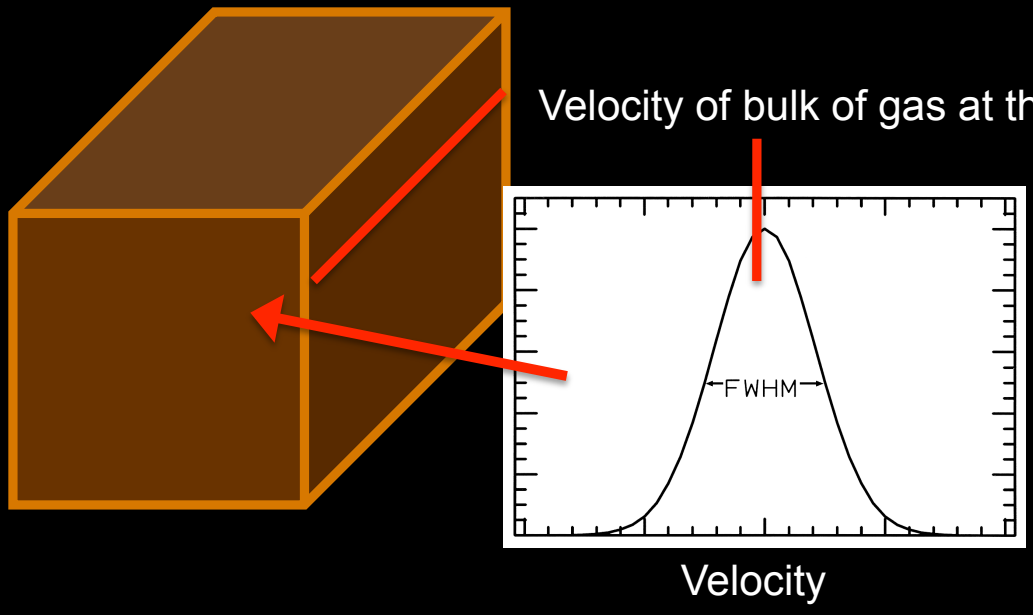
DDO 87 -- the atomic hydrogen gas

Stars (optical image)



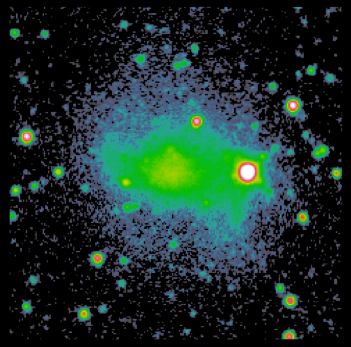
Velocity field: At each point in the galaxy, the velocity of the bulk of the gas → Rotation



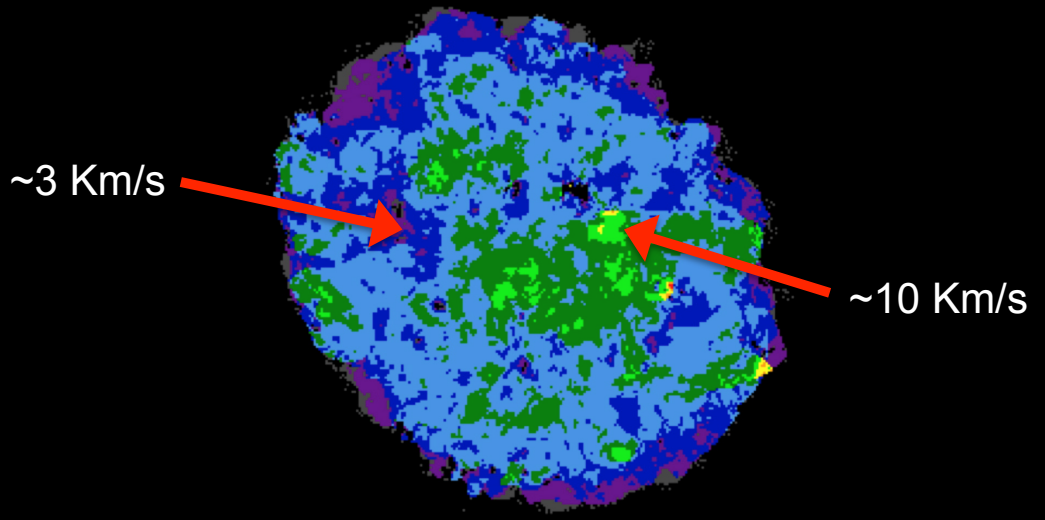


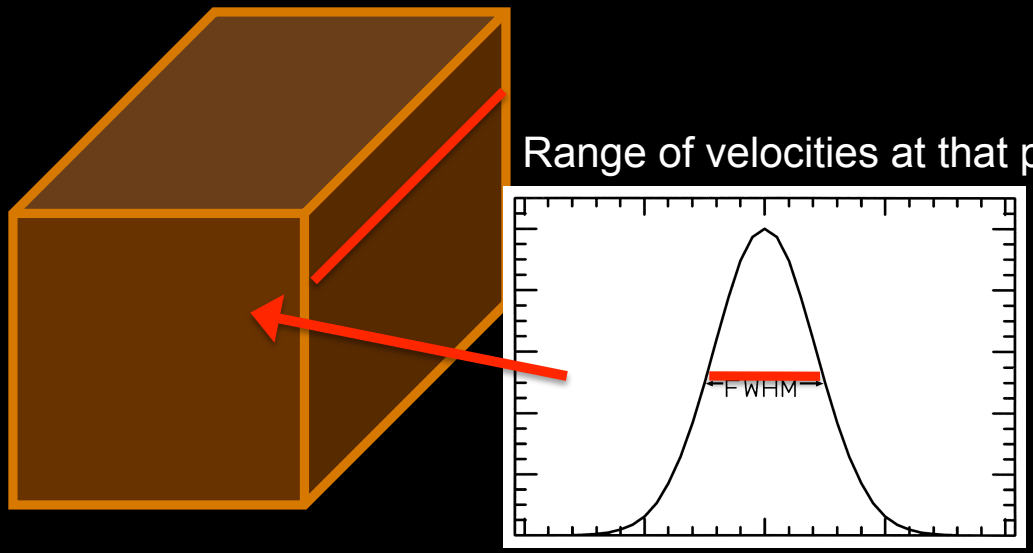
DDO 87 -- the atomic hydrogen gas

Stars (optical image)



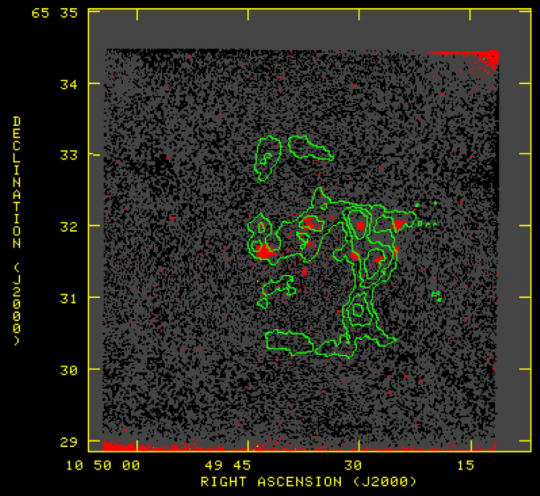
Velocity dispersion: At each point in the galaxy, the range of velocities of the gas → Random motions



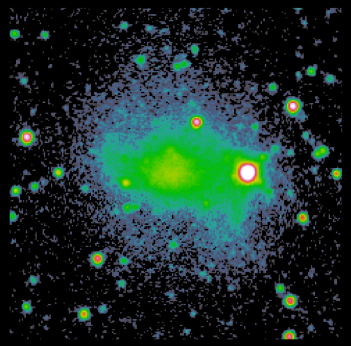


DDO 87 -- the atomic Hydrogen gas

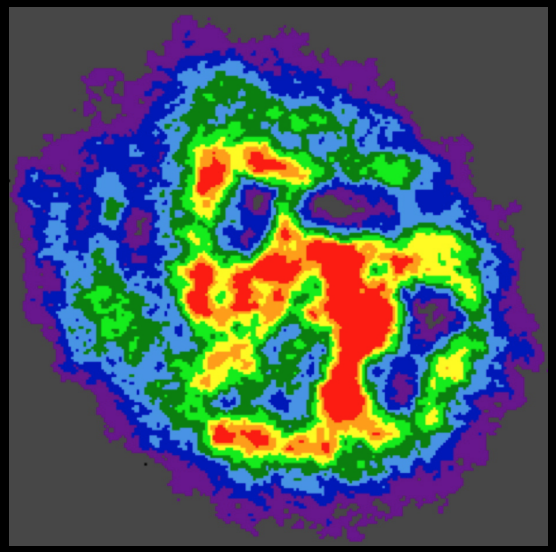
Nebulae: recent star formation



Stars (optical image)

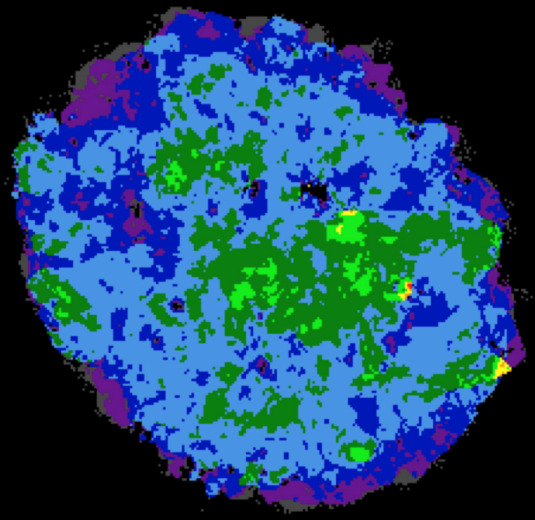


Integrated atomic hydrogen



Velocity field

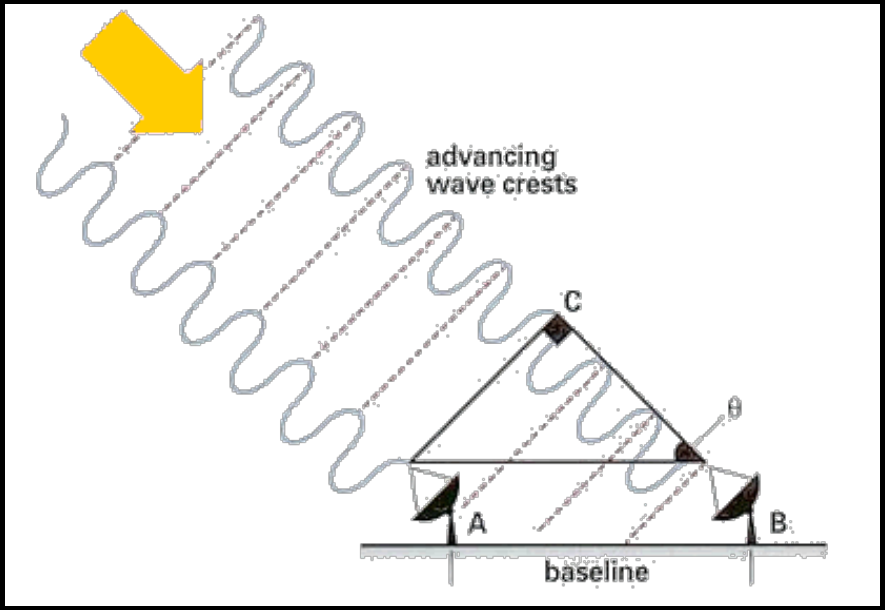
Velocity dispersion



Observing considerations: HI

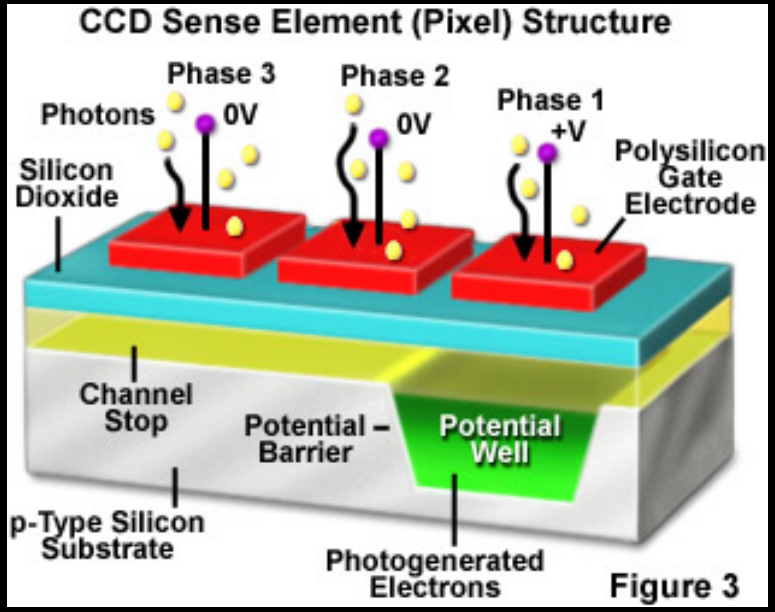
Radio:

Detecting waves: amplitude and phase



Optical:

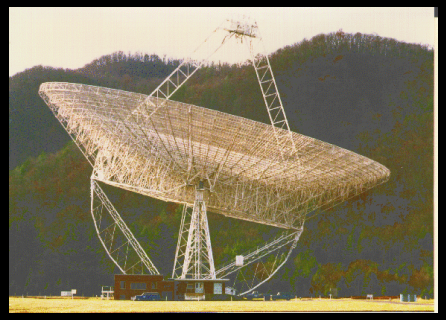
Detecting photons: efficiency



Observing considerations: HI

Radio:

Need dish to be smooth to 1/4λ, but photons can be big so dish can be mesh.



300-ft

Green Bank Telescope

Nov 15, 1988

Optical:

Need mirror to be smooth to 1/4λ, but photons are small so mirror needs to be polished to ~ 0.1 μm.

DCT mirror

Observing considerations: HI

Radio:

Can be cloudy/snowing (for HI). At mm wavelengths, worry about water vapor in atmosphere.

Can be daytime (sky is dark at radio wavelengths).

Optical:

Need clear skies

Must be nighttime (daytime sky is very bright in the optical)

Observing considerations: HI

Radio:

Angular resolution determined by size of configuration/dish (λ/D) (fixed)

- A array - 36 km – 1.4” at 21 cm
- B array - 10 km – 4”
- C array - 3.6 km – 12.5”
- D array - 1.0 km – 44”

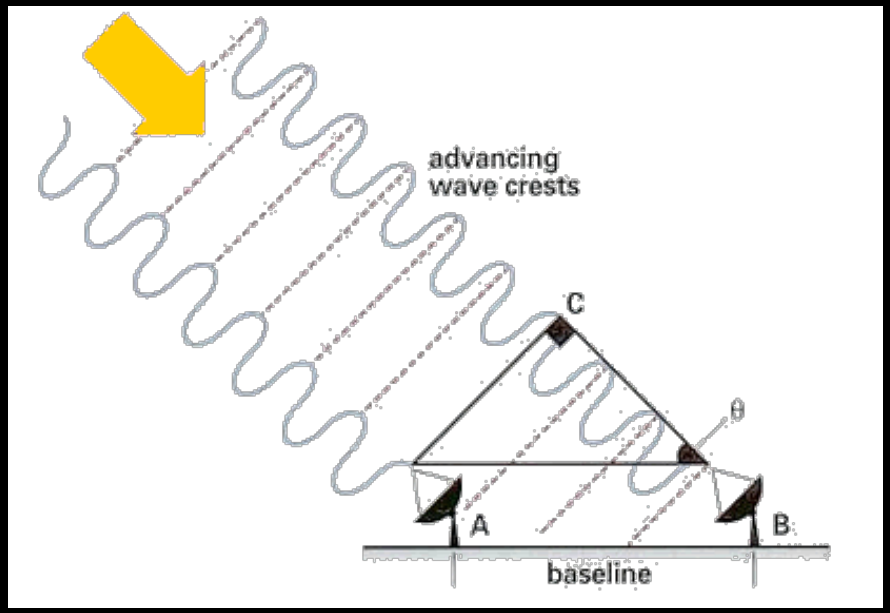
Optical:

Angular resolution determined by size of primary mirror of telescope (λ/D) and CCD pixel (fixed) and seeing (variable)

Observing considerations: HI

Radio:

Calibration: Flux calibrator (quasars), periodic observations of phase calibrator



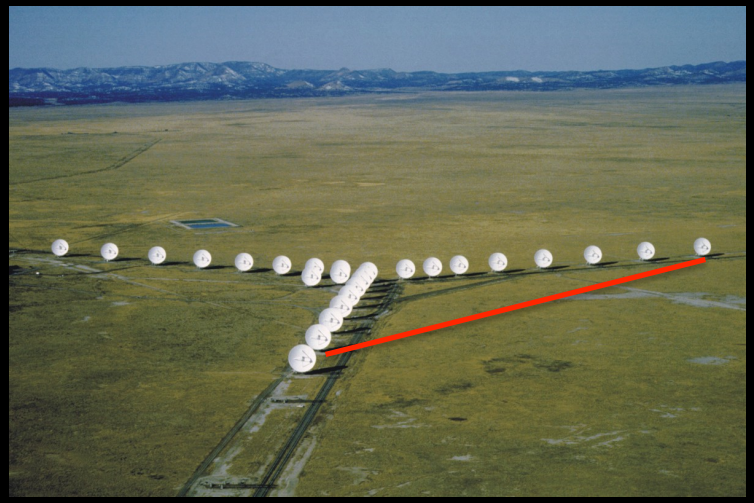
Optical:

Calibration: Standard stars

Observing considerations: HI

Radio:

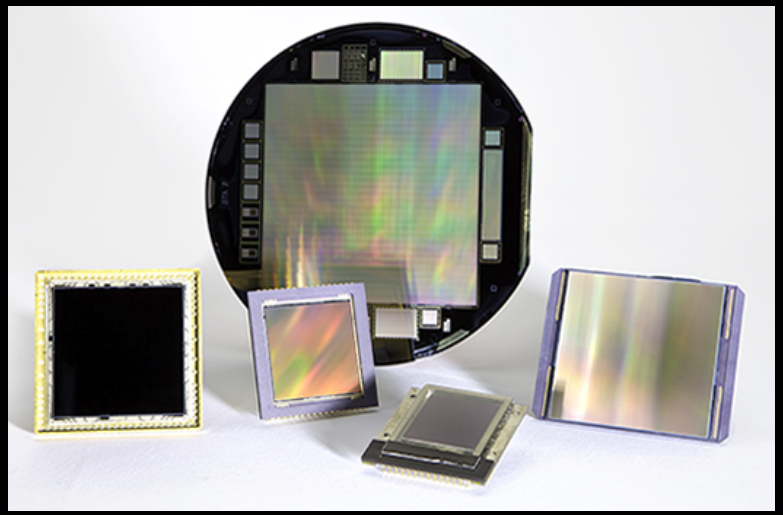
Imaging: Reconstruct image from baselines (interferometry) or map one point at a time (single dish)



One baseline

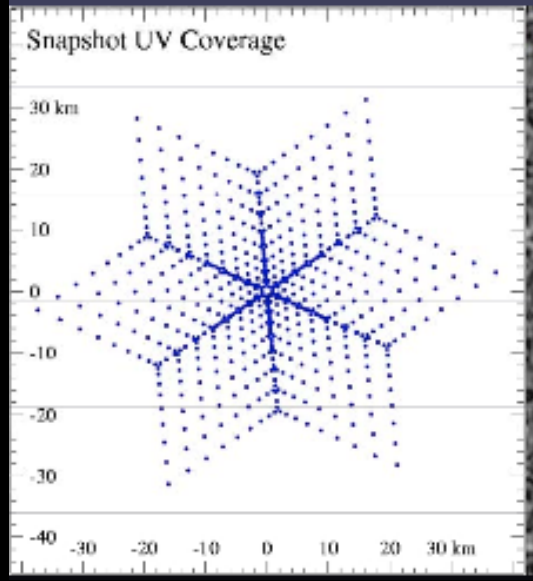
Optical:

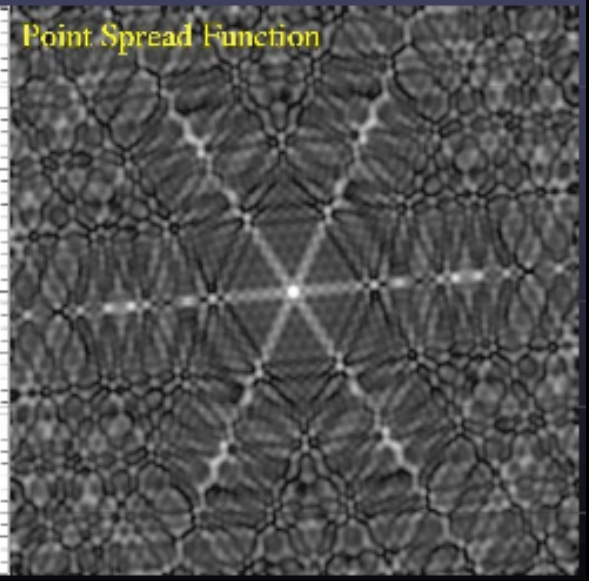
Imaging: What you see is what you get (with flat-fielding)

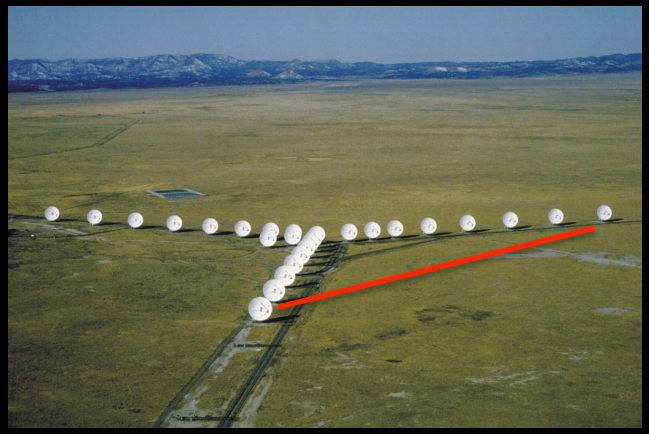


The uv-coverage is the set of all baseline vectors.

The synthesized beam (PSF) is the sensitivity pattern of all baselines.

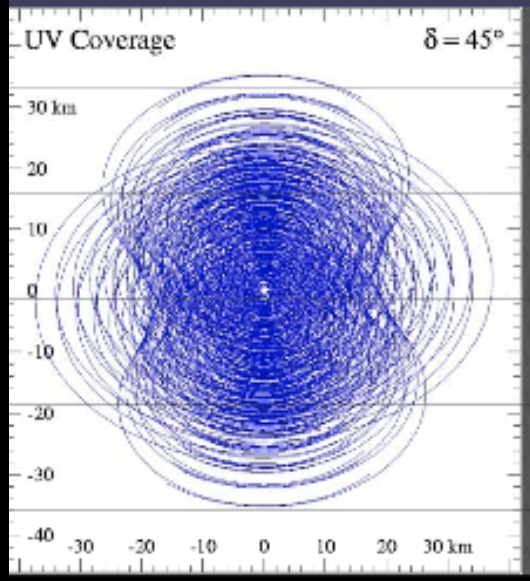


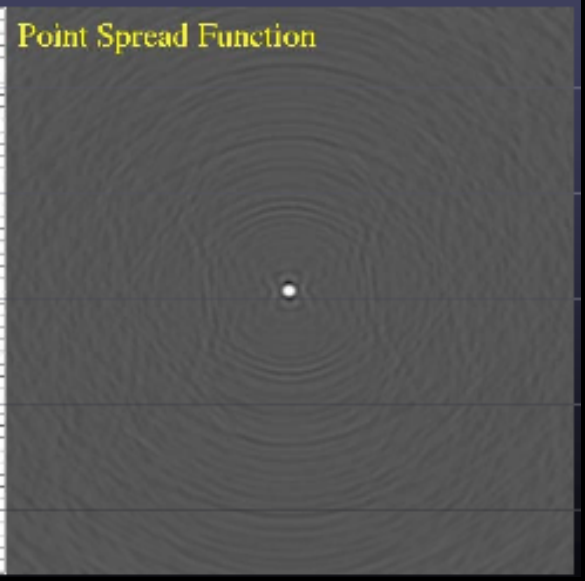




One baseline

12 Hour Synthesis Observation

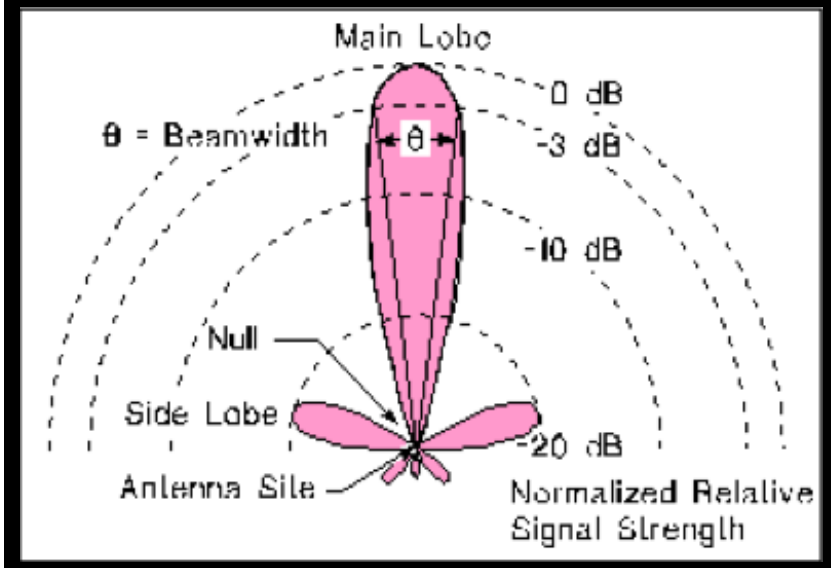




Observing considerations: HI

Radio:

Issue: Side-lobe emission

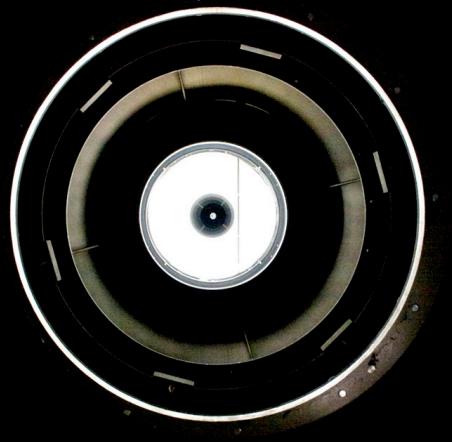


Beam from a paraboloid has sharp maximum in the forward direction, but also smaller maxima in other directions (side lobes).

Optical:

Issue: Scattered light in instrument/telescope

Scattered light in DCT telescope tube



Observing considerations: HI

Radio:

Issue: Structures bigger than a certain size are invisible (interferometer). Structures smaller than beam-size are smeared out.

Structures on angular scales significantly larger than the fringe spacing formed by the shortest baseline are not measured.

Largest visible structures

Primary beam (=FOV) = 30’

A array - 36 km – 38” at 21 cm

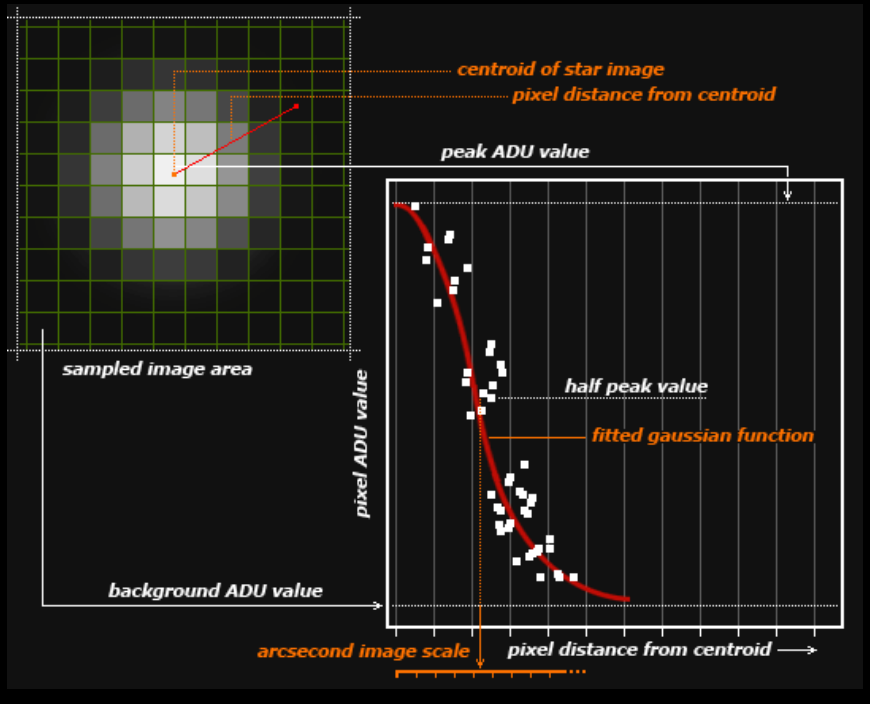
B array - 10 km – 120”

C array - 3.6 km – 900”

D array - 1.0 km – 900”

Optical:

Issue: Can see any structure up to FOV of CCD. Structures smaller than seeing are smeared out.



Radio telescope I have known and loved (or not)

VLA: Most recently got ~400 hours to observe HI in LITTLE THINGS

GBT: HI around LITTLE THINGS, but watch out for snow storms

Nobeyama (45m mm telescope): CO in a few dwarfs, cafeteria closes on weekends

ALMA (mm interferometer): CO in dwarfs, at 16,400 ft and driest place on earth