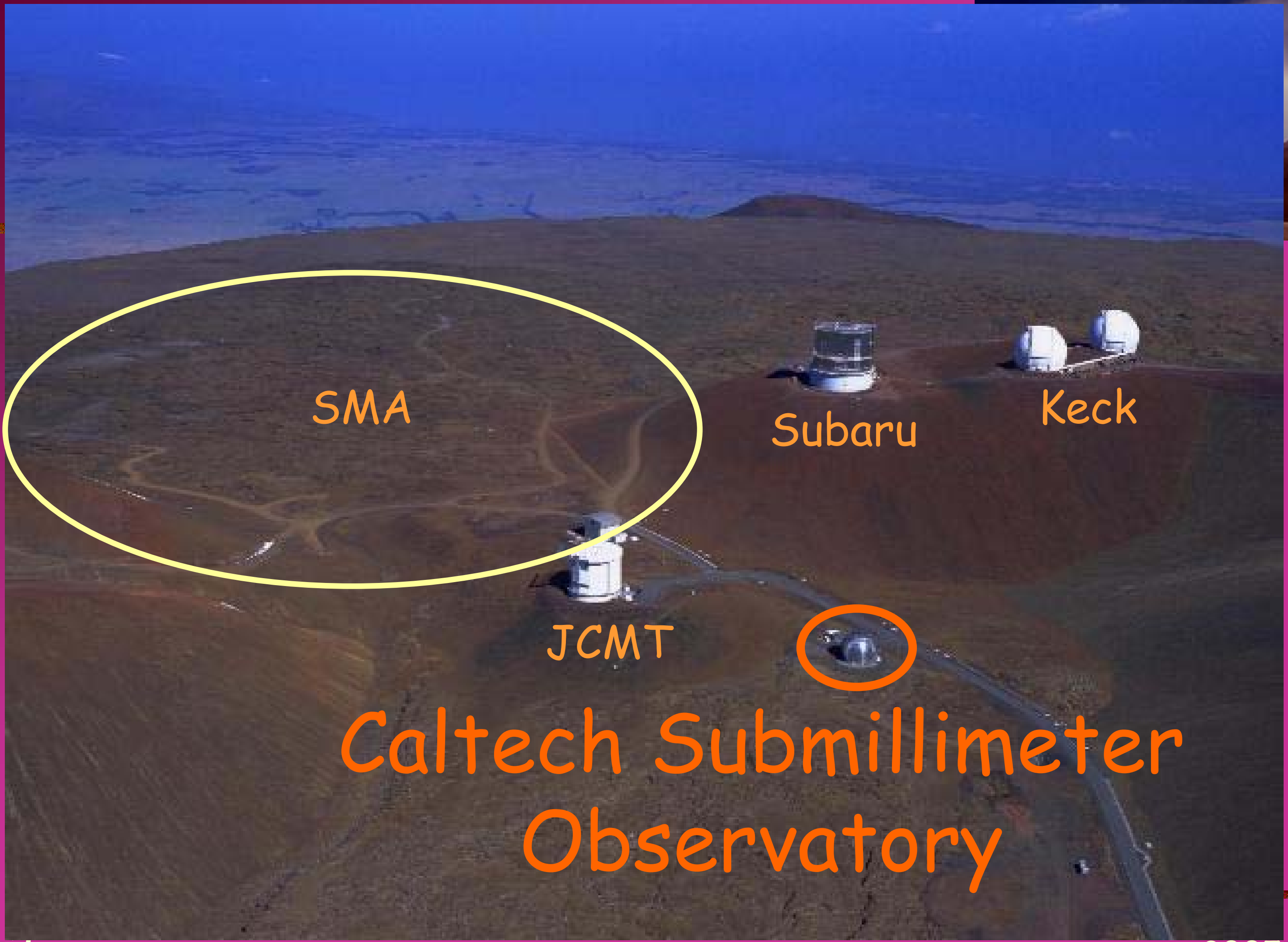
Caltech Submillimeter Observatory

--- Catching small waves on the Big island ---

Hiroko Shinnaga

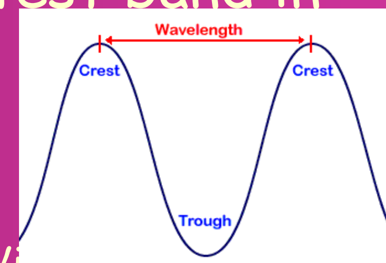

SMA
Subaru
Keck
JCMT
Caltech Submillimeter Observatory

Welcome to Caltech Submillimeter Observatory!

- INTRODUCTION
  - Submillimeter Wave
  - Submillimeter Astronomy
  - The Observatory
- THE TECHNOLOGY and SOME HOT SCIENCES
- SUMMARY

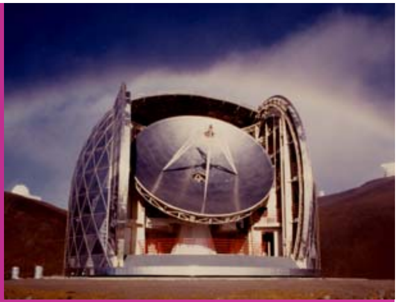
INTRODUCTION
--- Submillimeter Wave

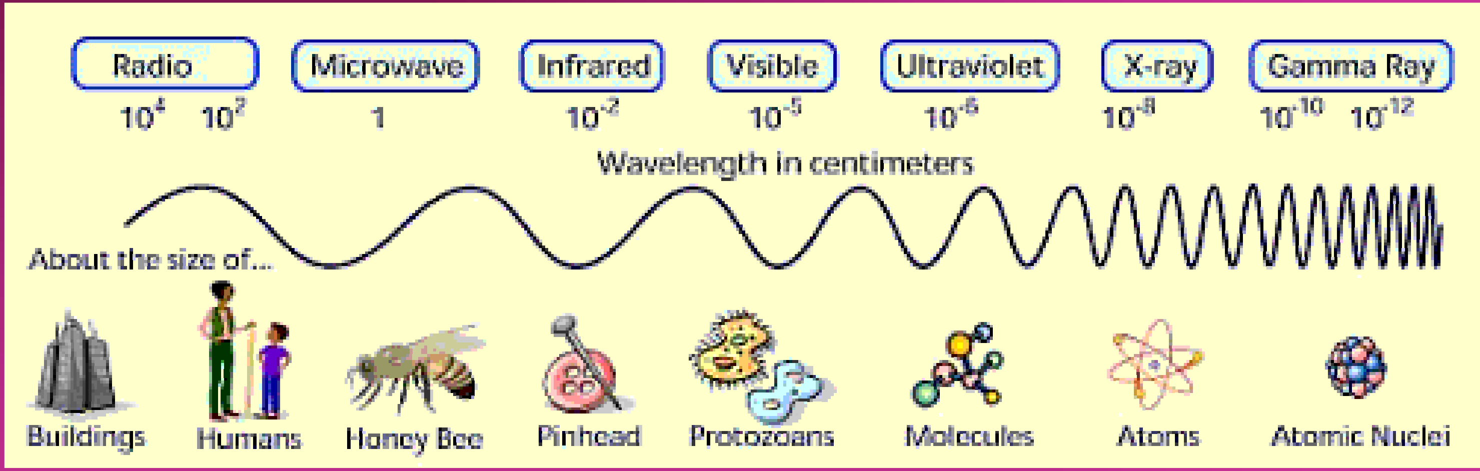
- Submillimeter wavelength is the shortest band in radio wavelength.



- Radio --- the electromagnetic wave
  - Very common technology
    - Radio broadcast (FM/AM), Microwave oven, Wireless communication systems (mobile phone etc), Wireless keyboard/mouse, Satellite systems, RADAR, Garage door openers, etc… → All uses radio technologies.
  - These are high power sources.
    - Mobile phone: 10^{-3} – 10^{-4} W, Microwave oven: 1000W,
  - Radio Astronomy searches for much small power signals from far distant astronomical objects
    - Millions or billions of times weaker than the signals used by communication systems.

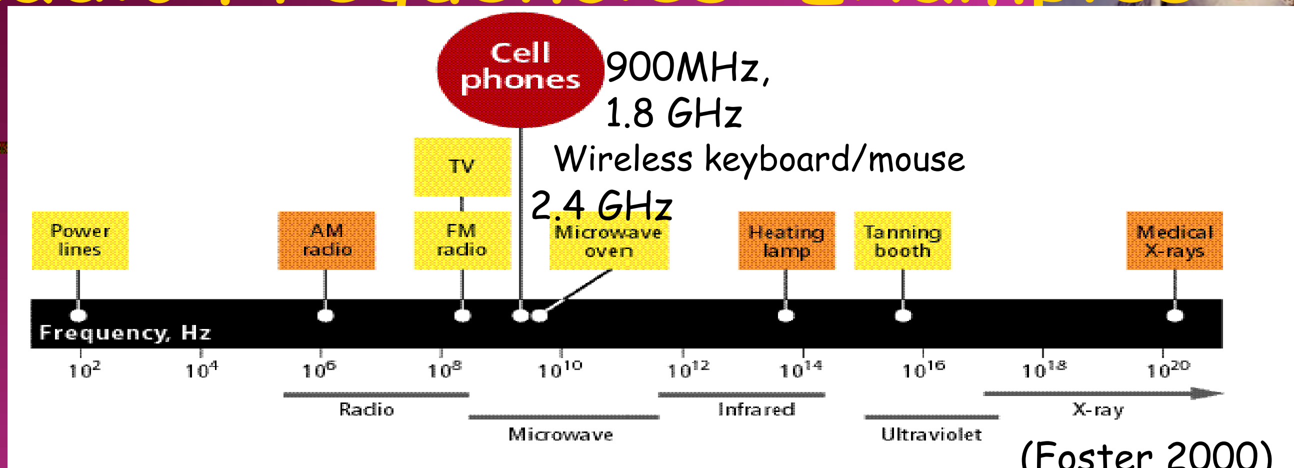
Electromagnetic Wave





(NASA IMAGERS)

Radio Frequencies: Examples



(Foster 2000)

- In radio astronomy field,
  - 327.384 MHz -- Deuterium (DI) line
  - 1400.0 - 1427.0 MHz – Hydrogen (HI) line
  - 14,470-14,500 MHz -- Formaldehyde Line
  - 1600-1700 MHz – Hydroxyl (OH) line

→ Interference is an issue to concern.

- National Radio Quiet Zone in Green Bank, VA.

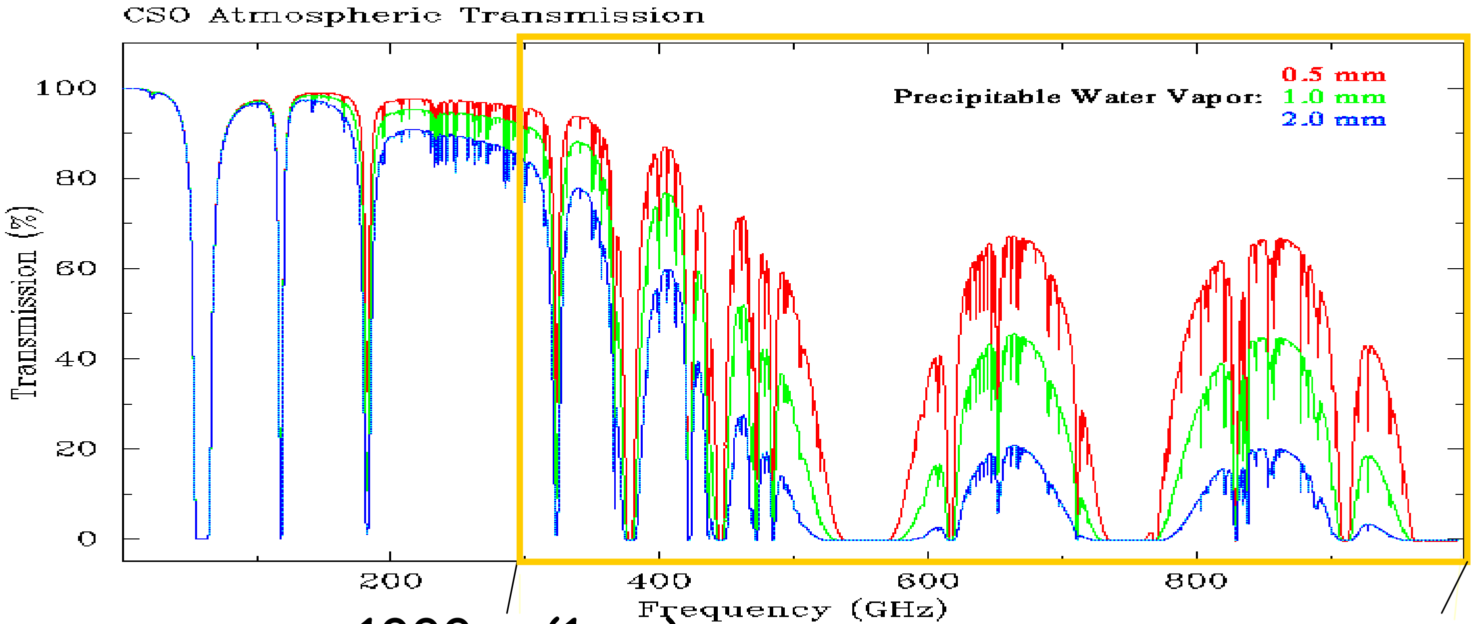
INTRODUCTION
--- Submillimeter Astronomy

- The 'submillimeter' region of the electromagnetic spectrum is at the border between the far infrared and the short-wavelength radio regions. As such, it borrows technologies from both regimes: bolometers from the infrared, heterodyne receivers from the radio
  - Wavelength: 300 microns to 1 millimeter
    - cf. human hair diameter : 20 – 180 microns
  - Frequency: 300 Gigahertz to 1 Terahertz

INTRODUCTION
--- Submillimeter Astronomy

- In practice, the atmosphere is the greatest problem faced by submillimeter astronomers, which, combined with the lack of high-performance instrumentation, explains why the submillimeter region of the spectrum is currently the least well studied.
- Submillimeter astronomy can only be done at sites with extremely dry atmospheres, such as the tops of mountains and the Antarctica if it's from the ground.
- Mauna Kea is one of the best sites in the world to make sensitive observations.

Atmospheric Transmission

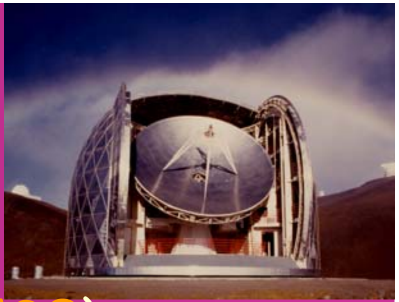


1000μm(1mm) Wavelength 300μm

Radio

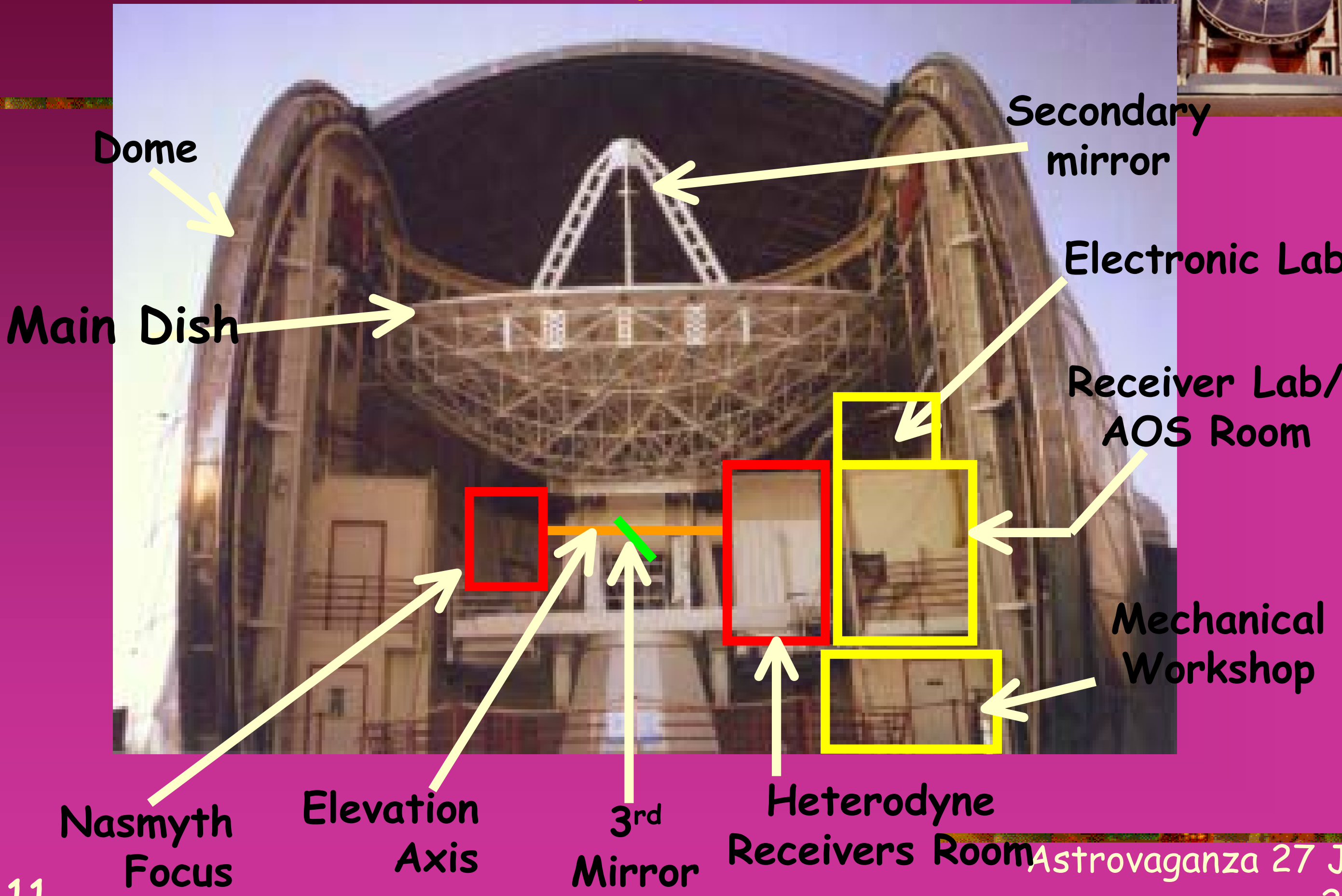
Far Infrared

INTRODUCTION --- The Observatory



- The Caltech Submillimeter Observatory (CSO)
  - a cutting-edge facility for astronomical research and instrumentation development.
  - one of the world's premier submillimeter telescopes
  - one of the easiest to use.
- 10.4-meter diameter Leighton radio dish situated in a compact dome.
- Operated by Caltech under a contract from the National Science Foundation and has been operating on a regular basis since 1986.
- Director: Professor Thomas G. Philips at Caltech
- Open to the astronomical community, with most of the observing time available for non-Caltech observers.

The Observatory

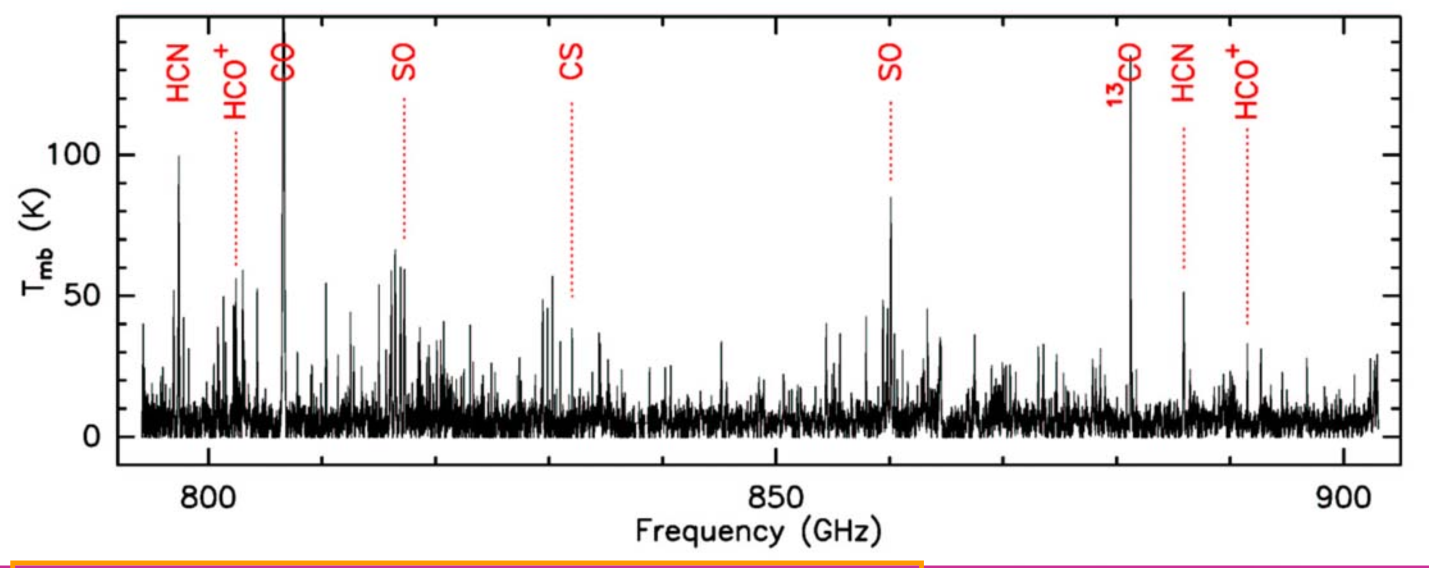


Why Submillimeter Astronomy?

- With this wavelengths, cold dust and cold/hot gas can be traced efficiently.
  - Combining dust and gas information, one can investigate the distribution of medium as well as the kinematics of detected astronomical objects.

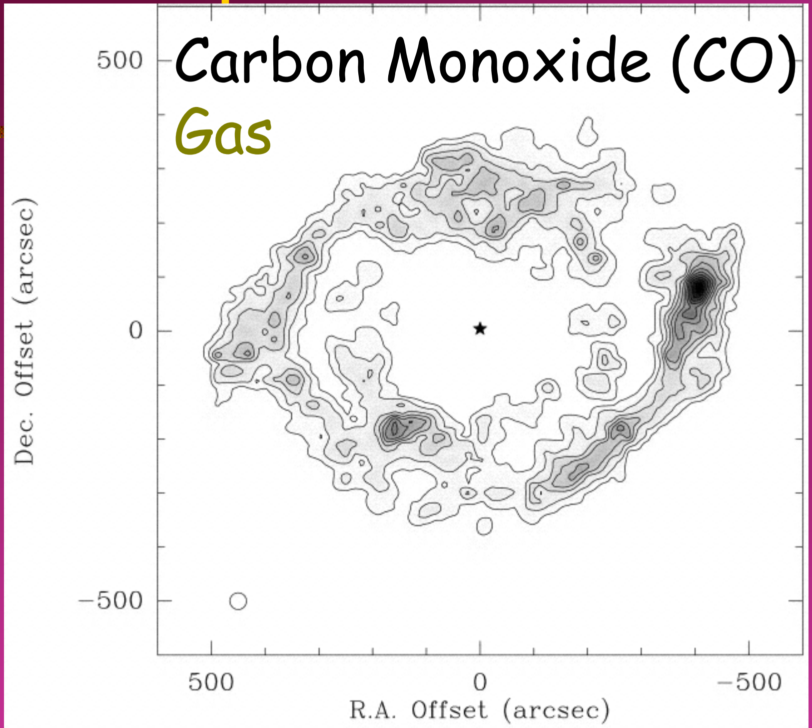
Why Submillimeter Astronomy?

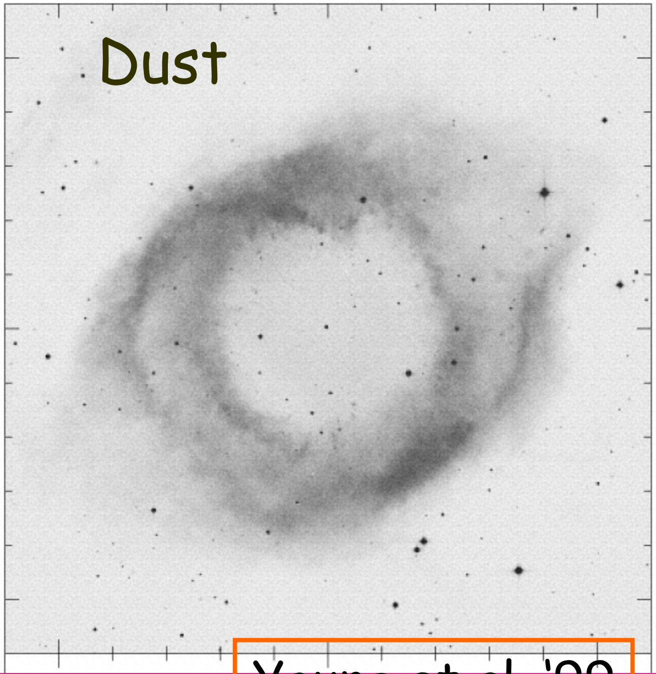
- There are thousands of molecular and atomic lines detected towards active star forming regions.



350 micron (850 GHz) Line Survey towards Orion (Comito et al. '05)

Example

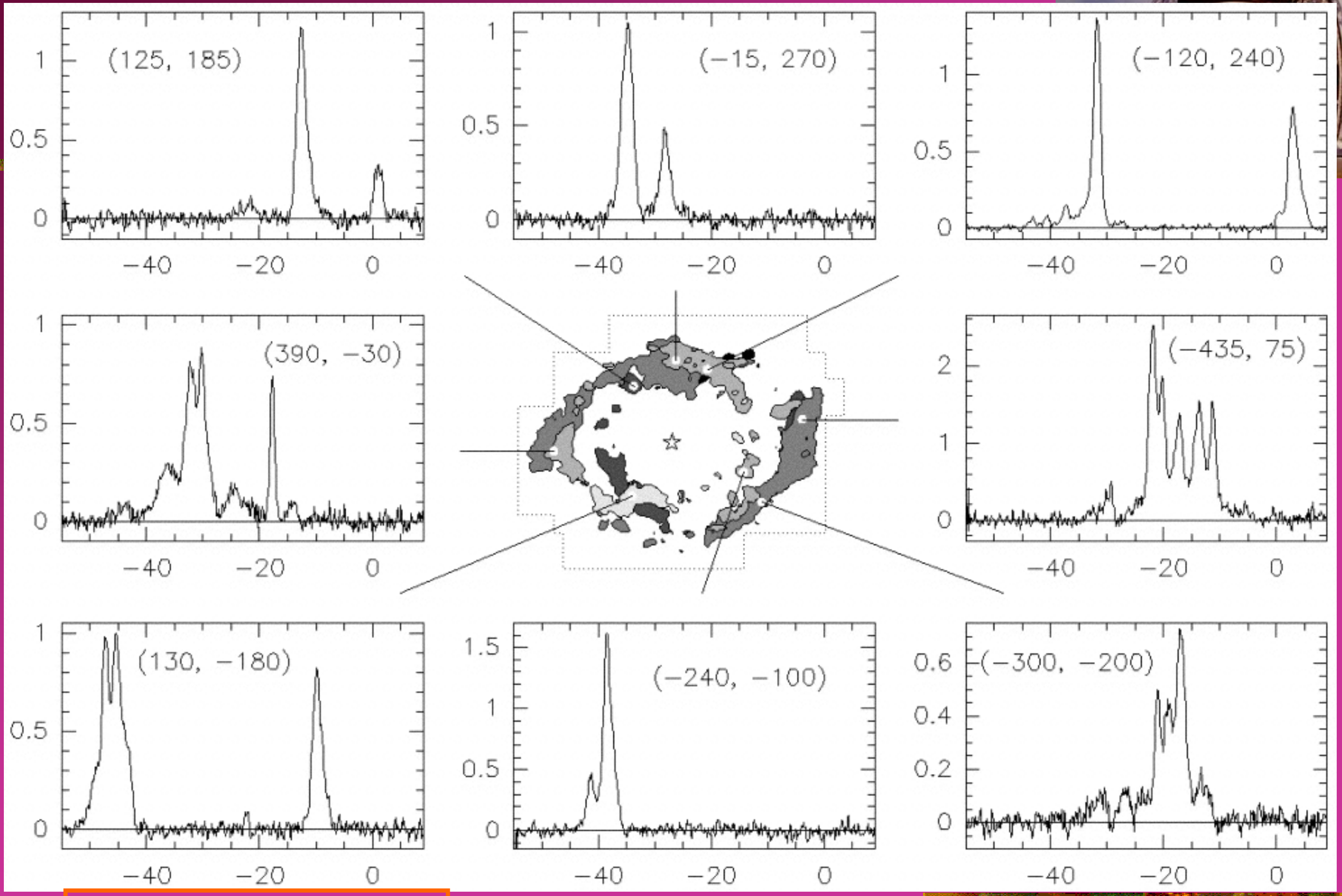




Young et al. '99

One of the best-known, closest (213 pc) planetary nebula, with a substantial envelope of molecular gas and is far larger in angular size (~1000") than any comparable nebula.

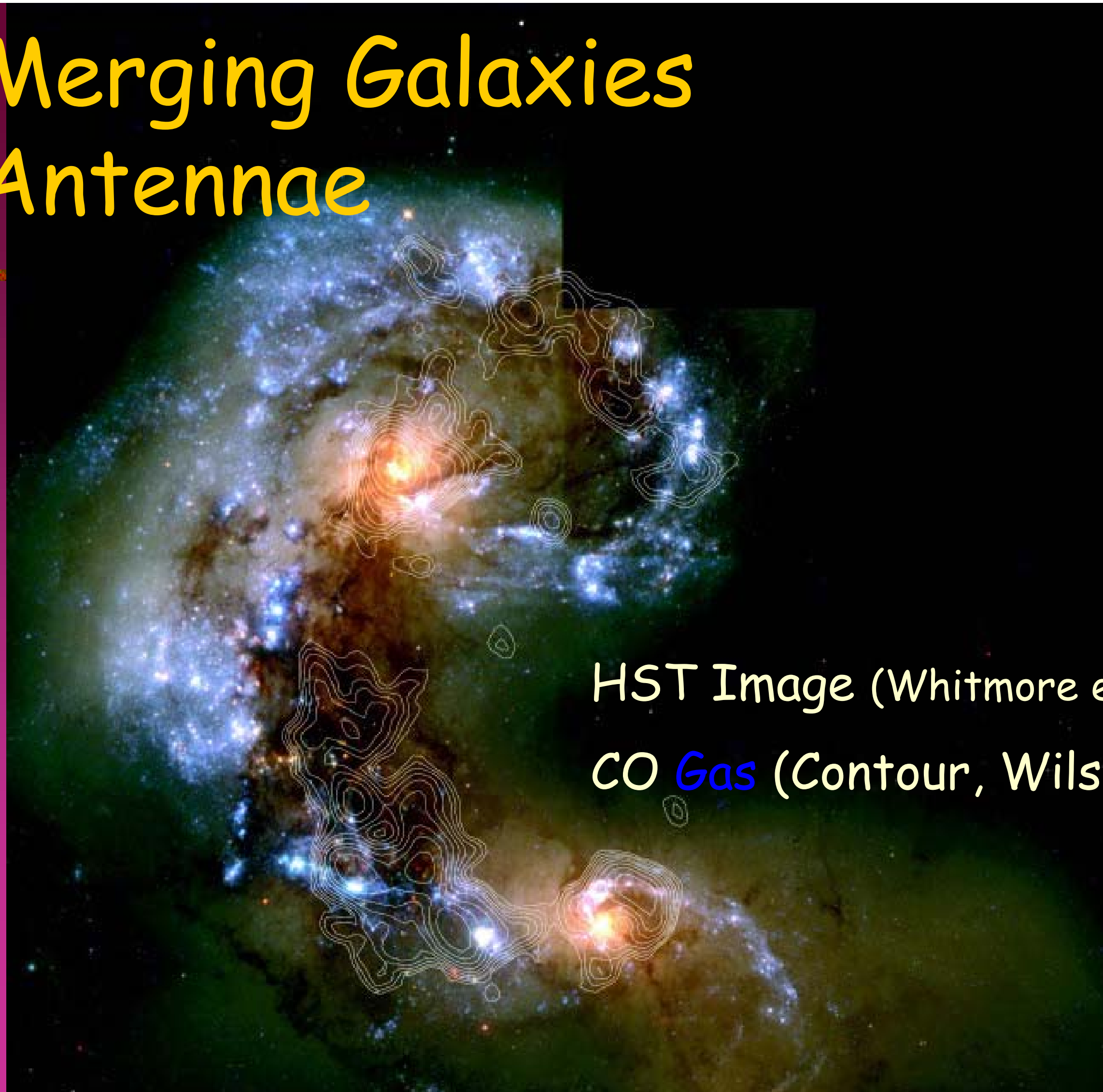
Kinematics of the Gas

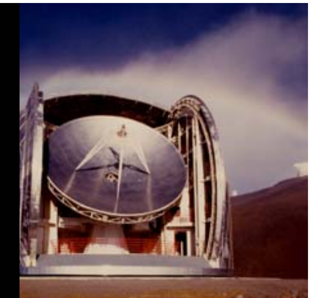


Young et al. '99

Gas Distribution

Merging Galaxies
Antennae

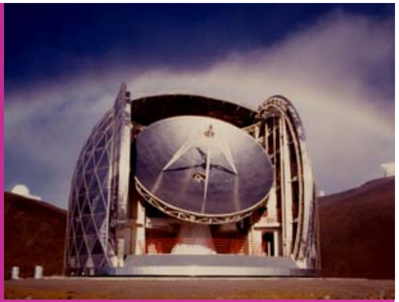




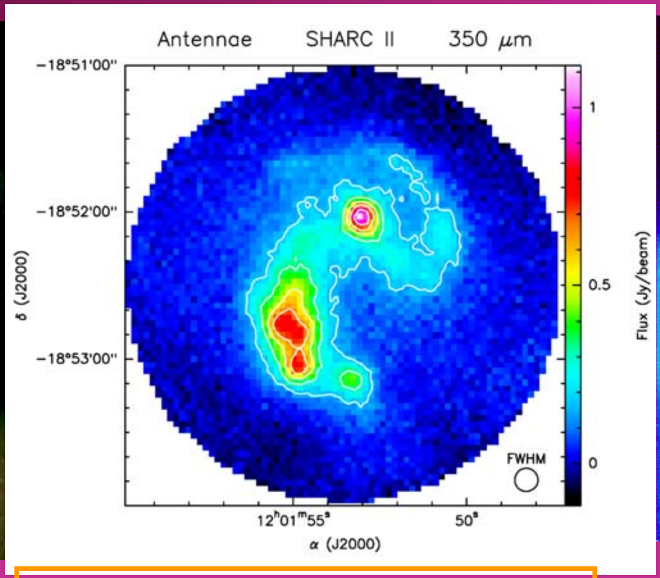
HST Image (Whitmore et al. '99)

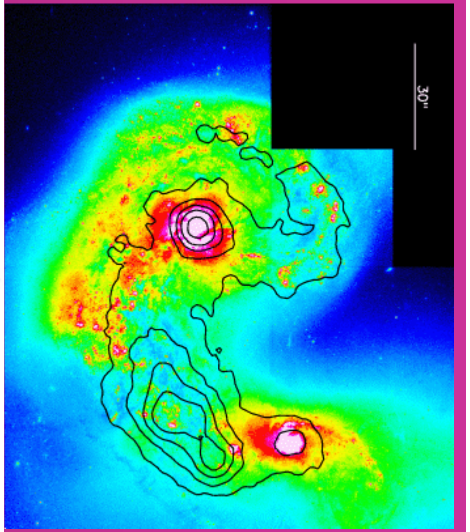
CO Gas (Contour, Wilson et al '00)

Merging Galaxies
Antennae



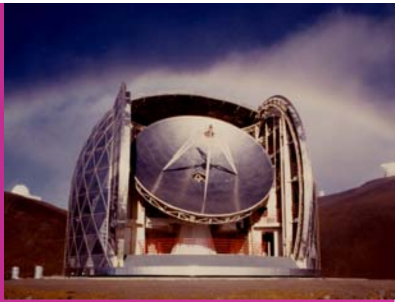
HST Image (Whitmore et al. '99)
CO Gas (Contour, Wilson et al '00)





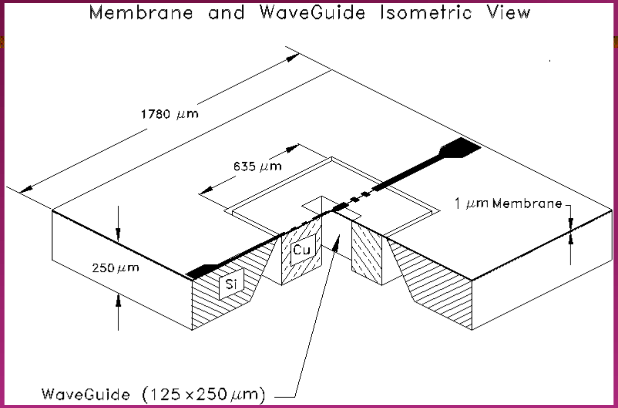
Dust (SHARCII image, Dowell et al. in prep)

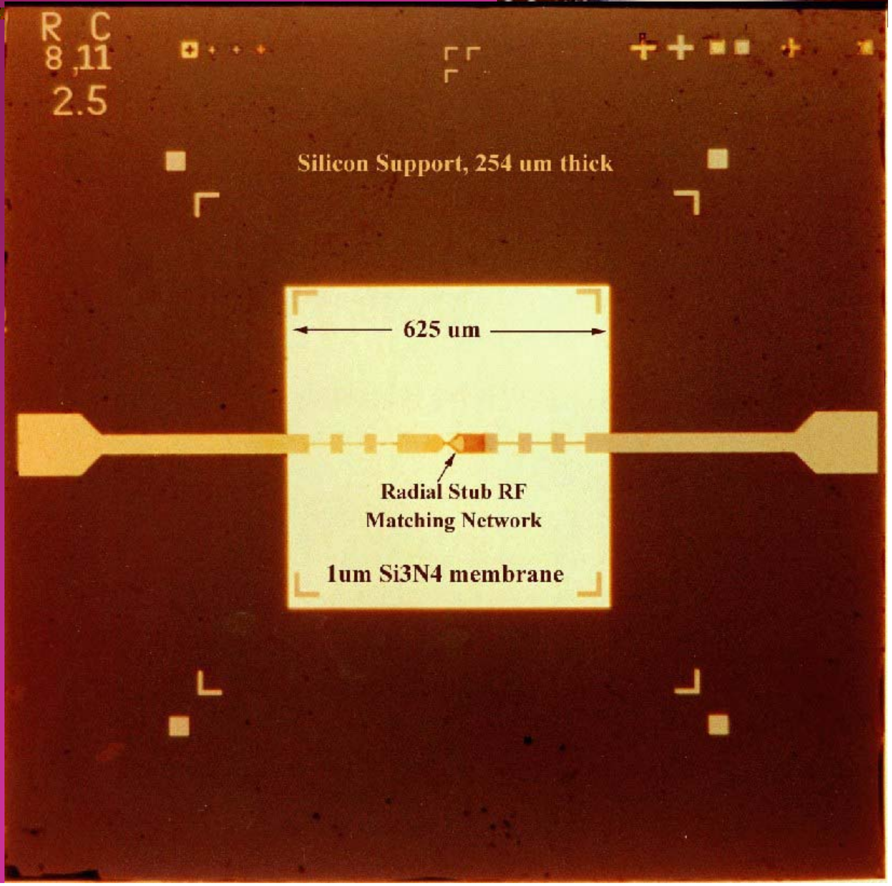
TECHNOLOGY



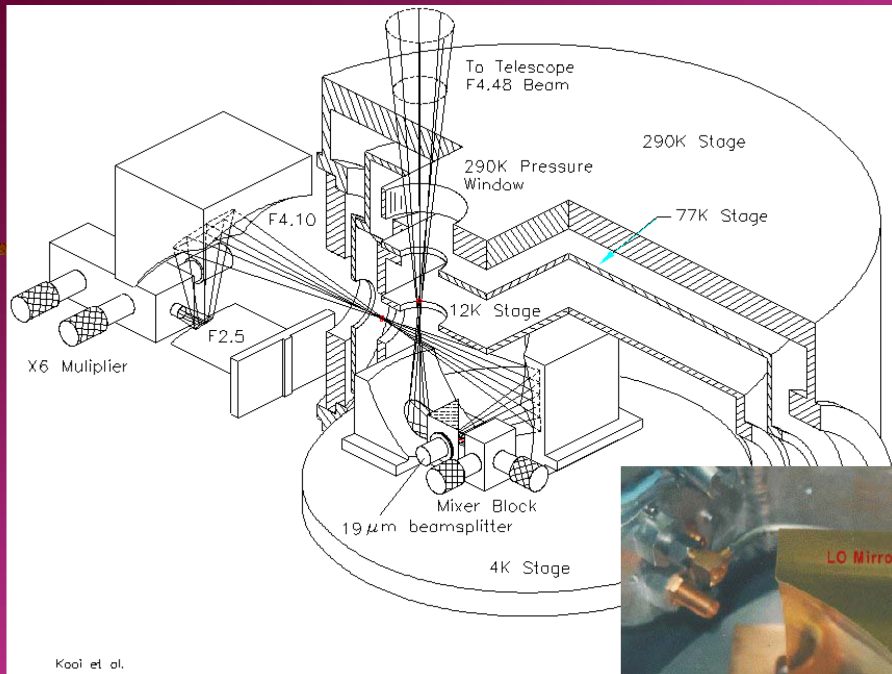
- Heterodyne receivers (covers 180 – 950 GHz) with wide band spectrometer (up to 4 GHz band width)
- BOLOMETERS
  - SHARCII (350/450/850 micron)
  - BOLOCAM (1000/2000 micron)
- Dish Surface Optimization System (DSOS)
- Hertz / SHARP Polarimeter

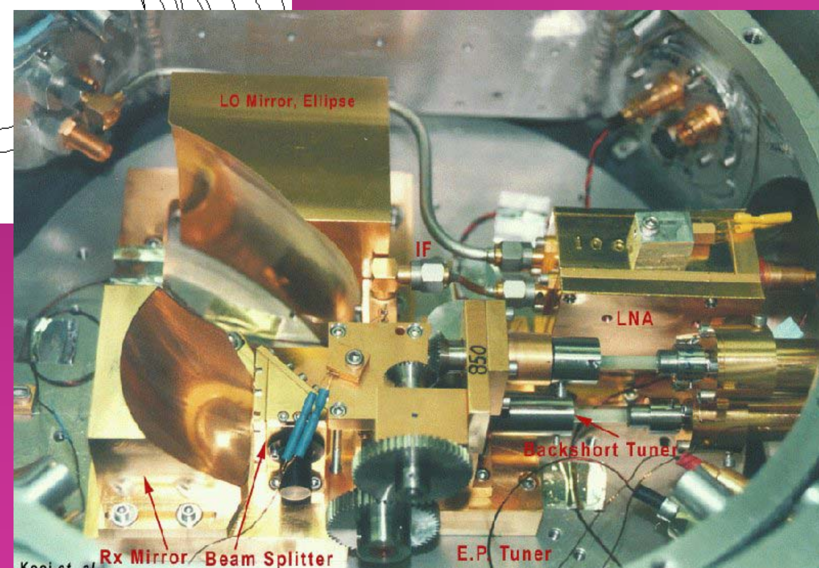
Superconductor- Insulator-Superconductor (SIS) Receiver





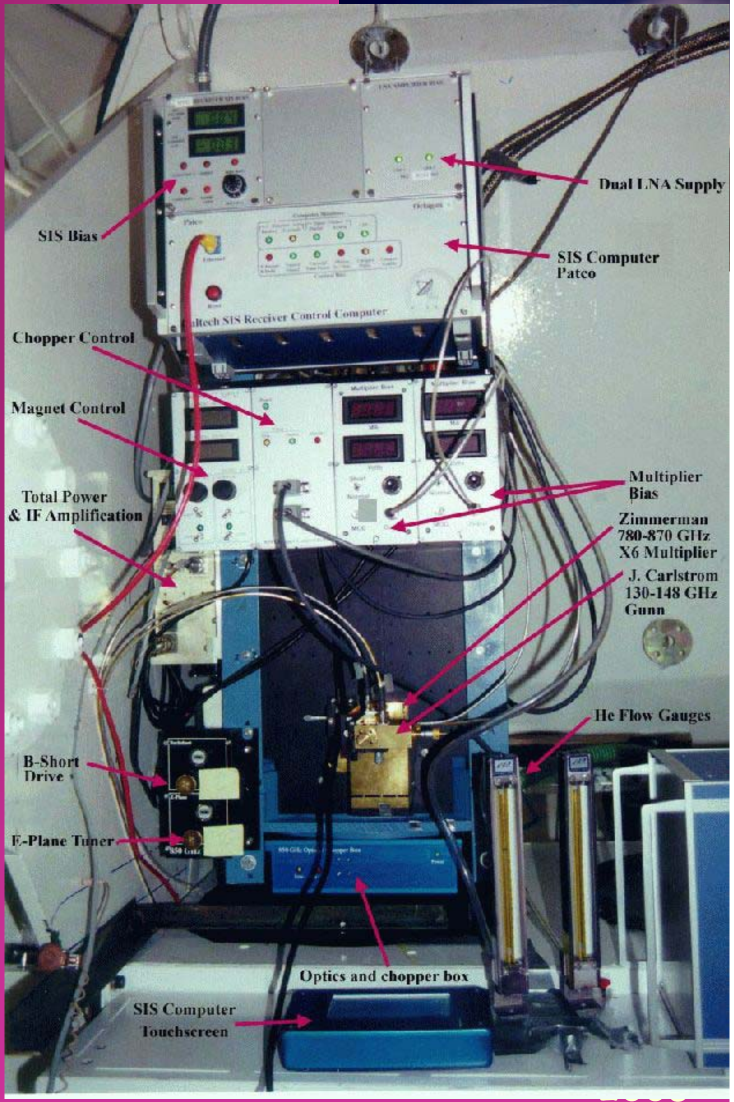
- 780-950 GHz Receiver





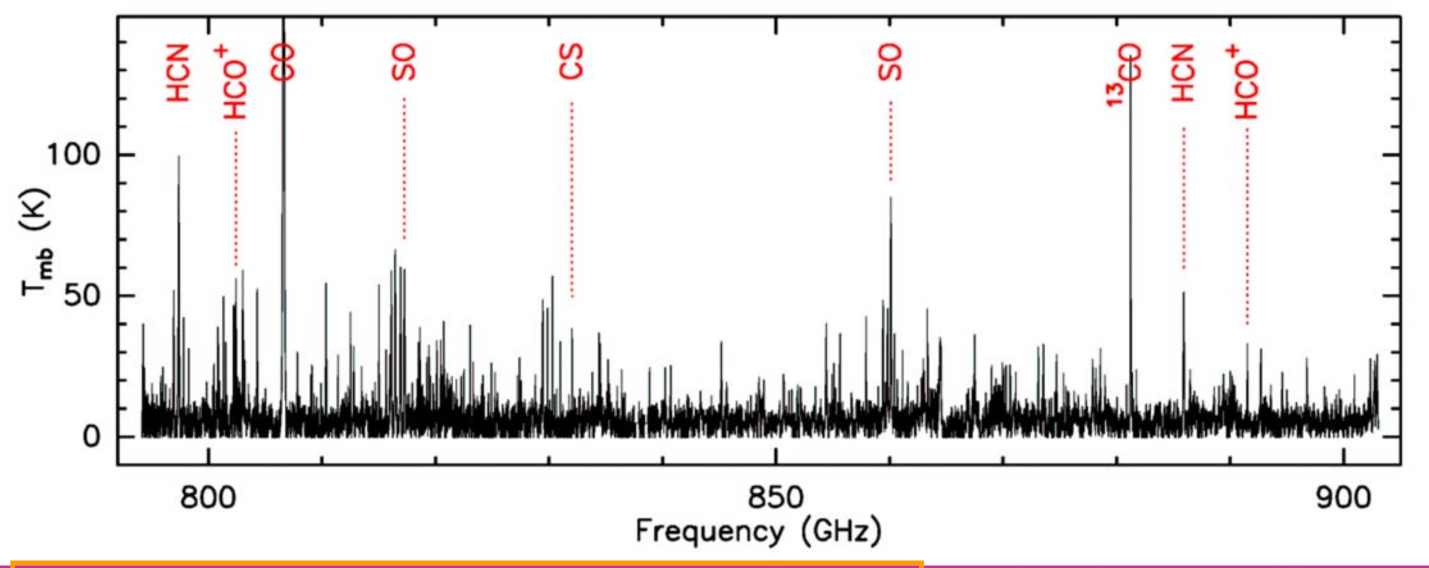
- 850GHz Receiver Cryostat


850 GHz
Receiver
Relay Optics
Allen
Guyer


Dual LNA Supply
SIS Bias
SIS Computer
Patco
Chopper Control
Magnet Control
Total Power
& IF Amplification
Multiplier
Bias
Zimmerman
780-870 GHz
X6 Multiplier
J. Carlstrom
130-148 GHz
Gunn
He Flow Gauges
B-Short
Drive
E-Plane Tuner
Optics and chopper box
SIS Computer
Touchscreen

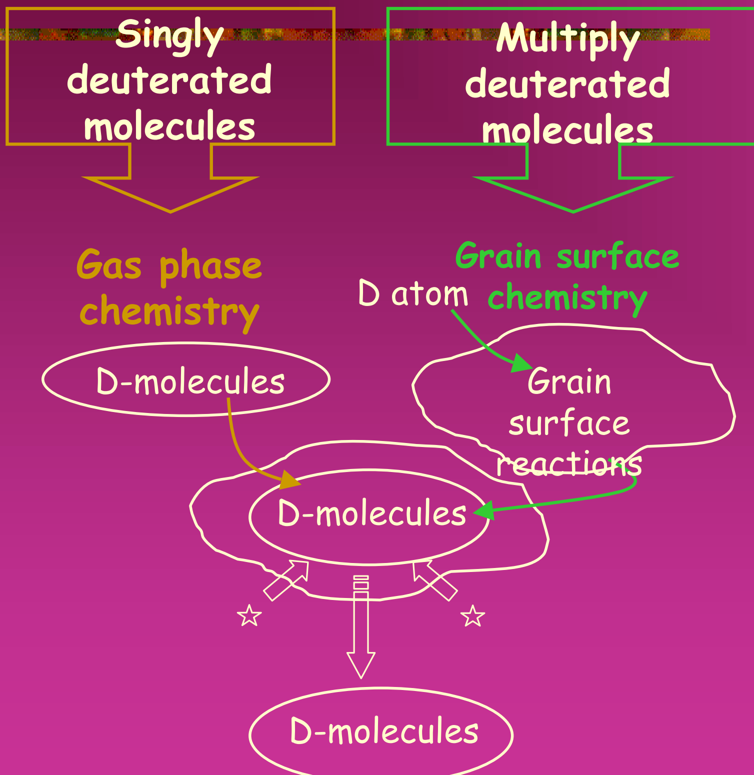
Why Submillimeter Astronomy?

- There are thousands of molecular and atomic lines detected towards active star forming regions.

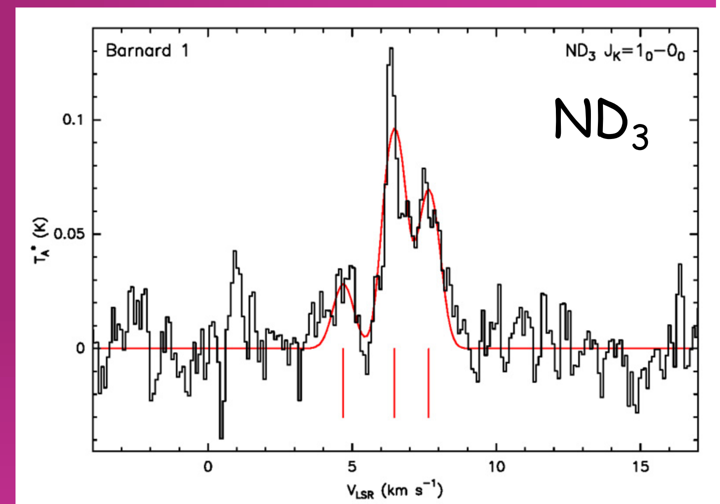


350 micron (850 GHz) Line Survey towards Orion (Comito et al. '05)

Detection of Very Rare Molecule (Deuterated Molecule)

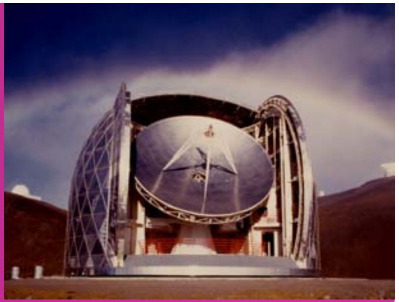


(Vastel '05)

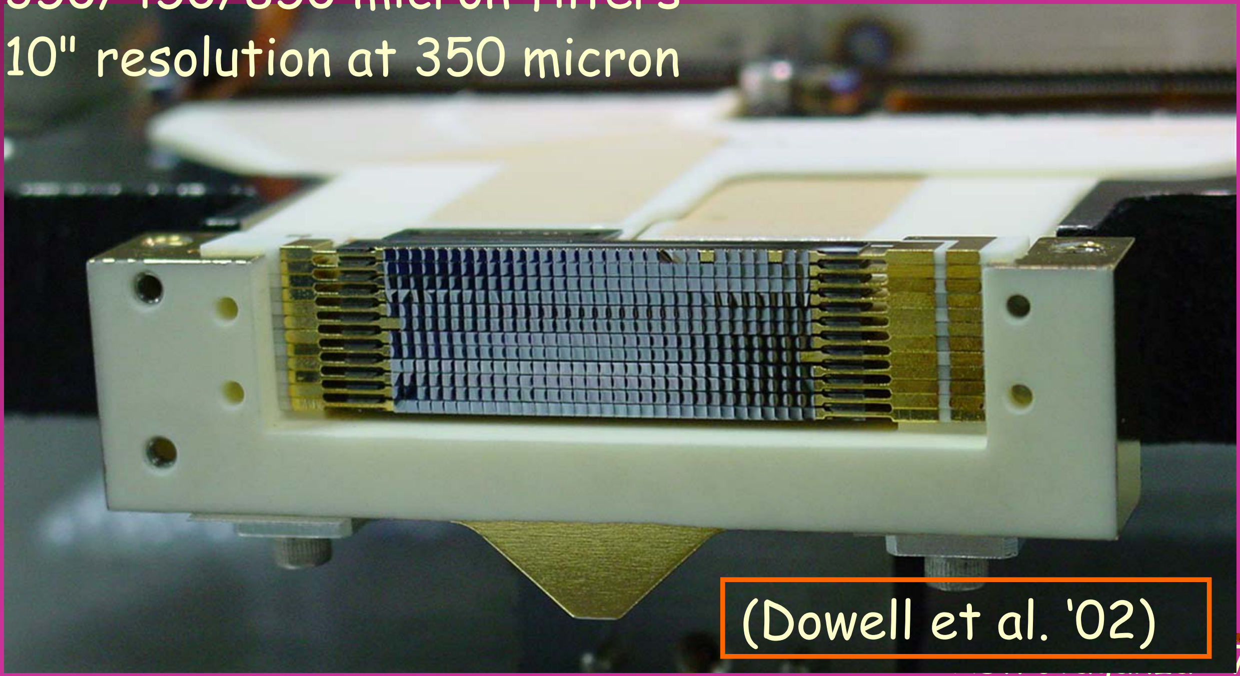


(Lis et al '02)

SHARCII



- 12 x 32 (384) array
- 350/450/850 micron filters
- 10" resolution at 350 micron

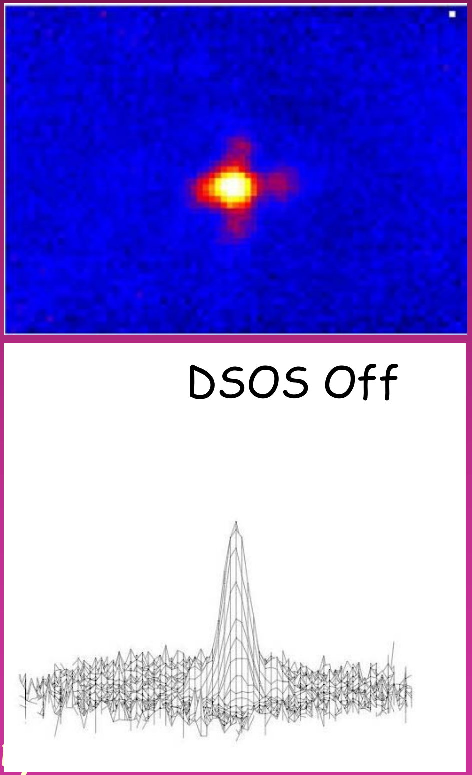


(Dowell et al. '02)

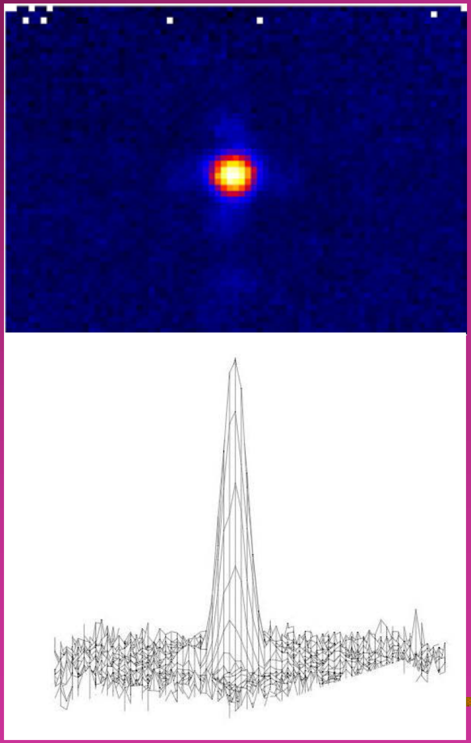
Dish Surface Optimization System (DSOS)

- DSOS is a CSO Submillimeter Active Optics System.

(Leong et al. '03)

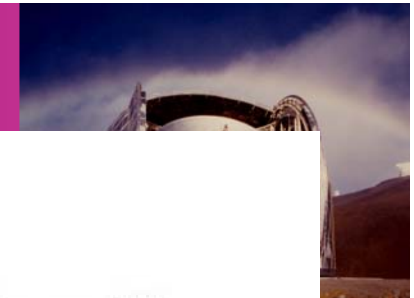


DSOS Off



DSOS On
(18% improvement in beam width , 50% improvement in signal power compared with Off)

DSOS: how does it work?



Installed Standoff Assembly

Insulated Assembly

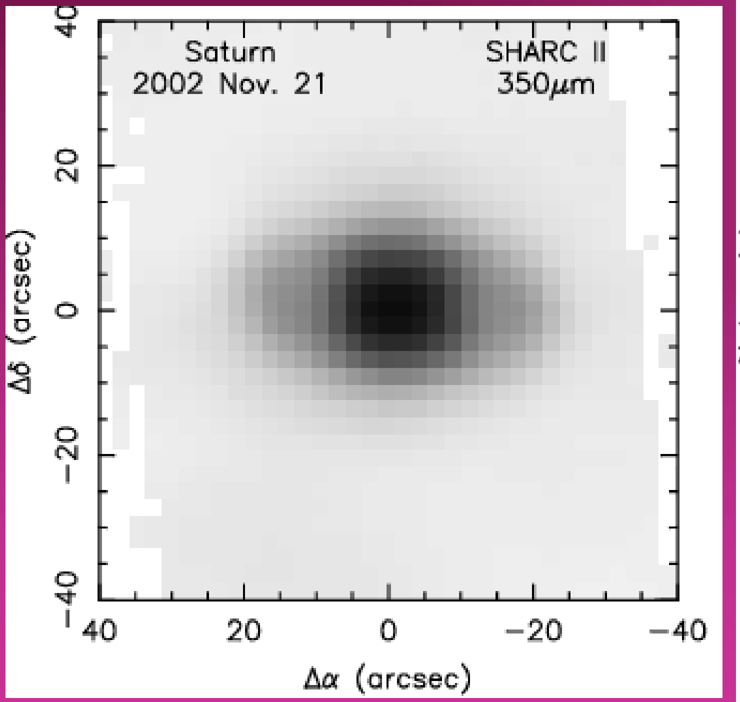
- 99 steel rod standoffs
- Heating-> elongate
- Cooling -> shortens

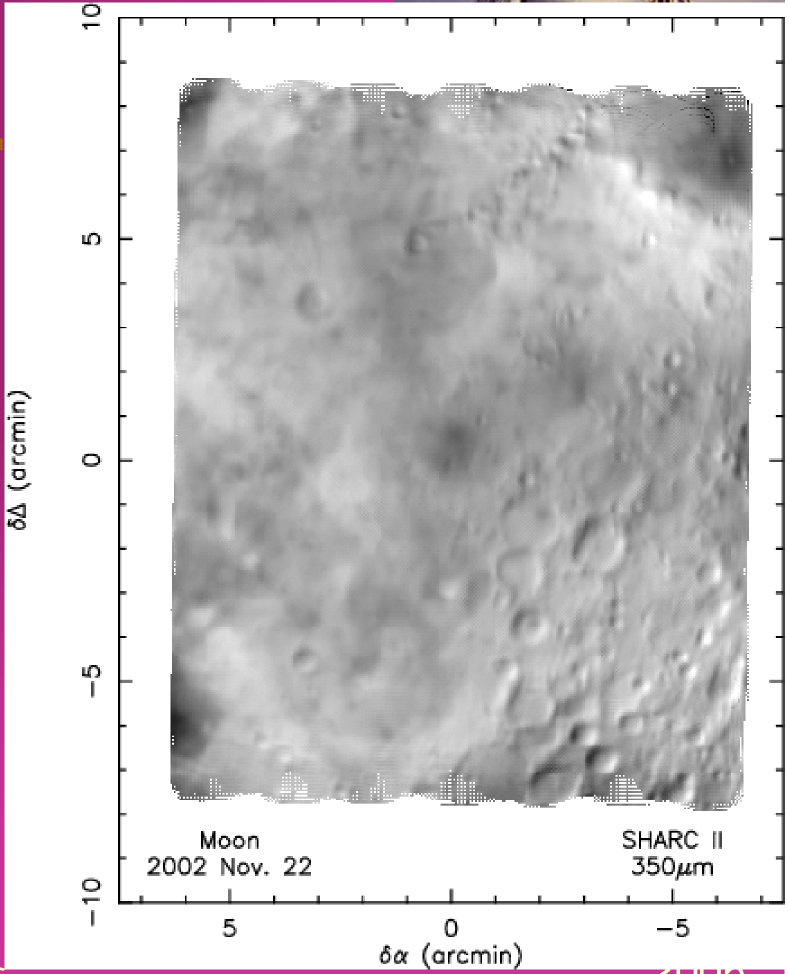
(Leong et al. '03)

Main Dish: View from Back

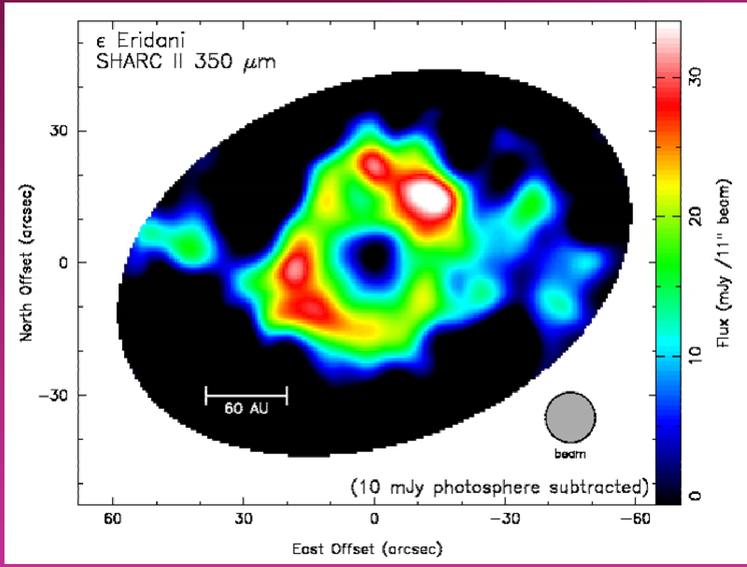
(Leong et al. '03)

SHARCII Images

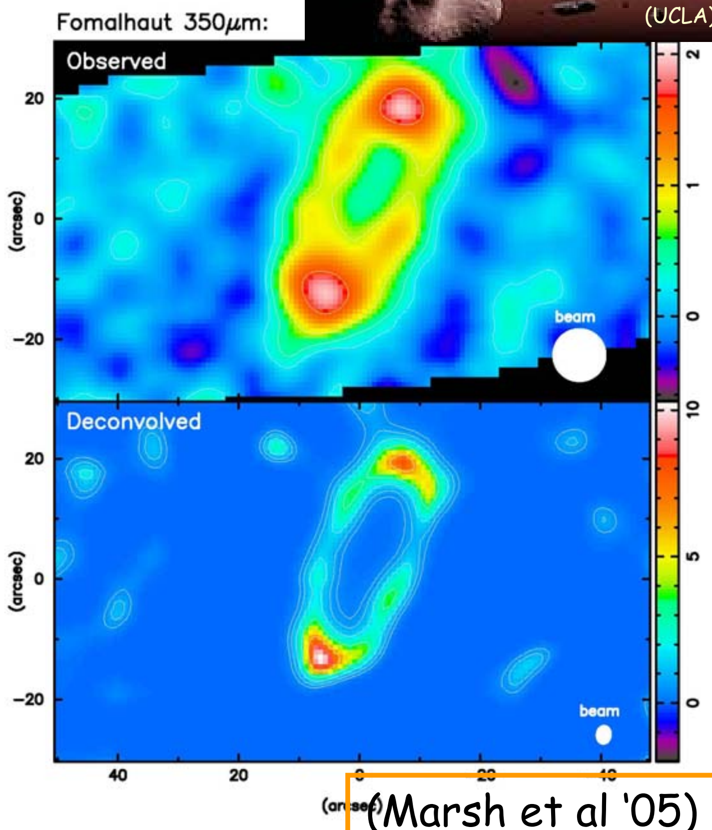




Dust Rings Around Star



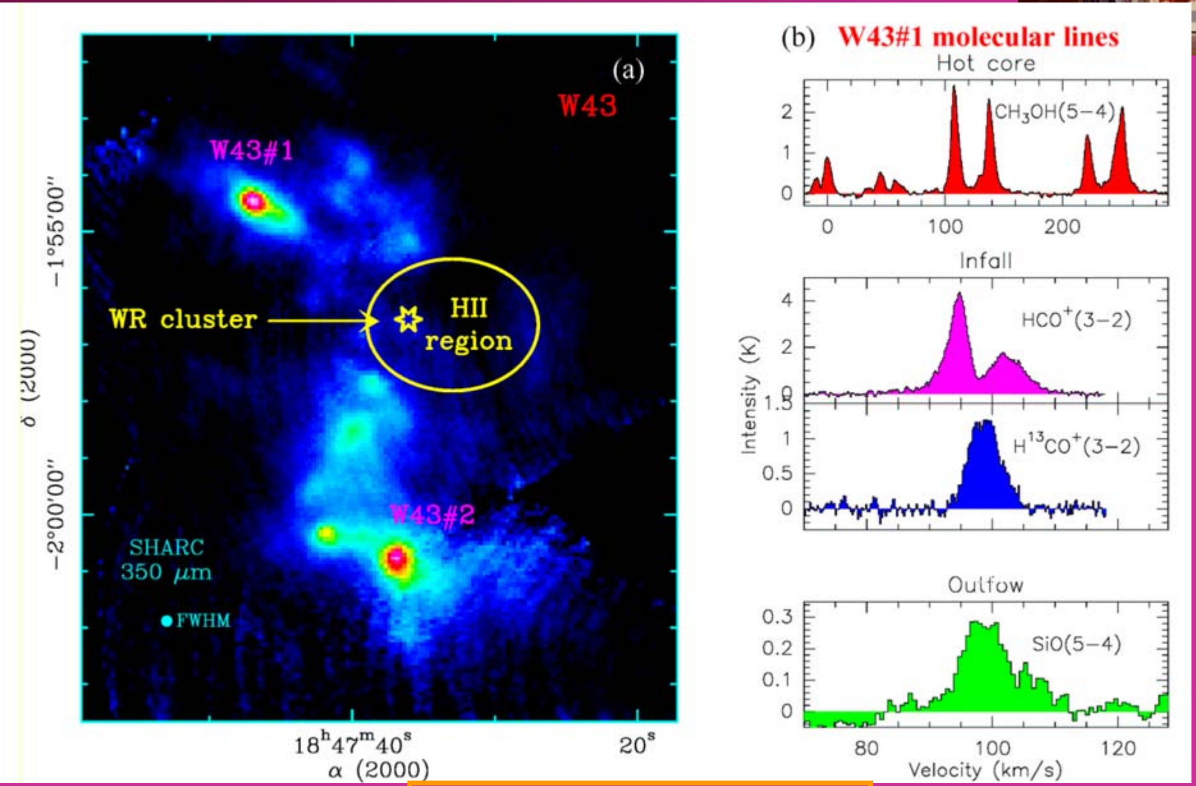
(Wilner et al. in prep)



(Marsh et al '05)

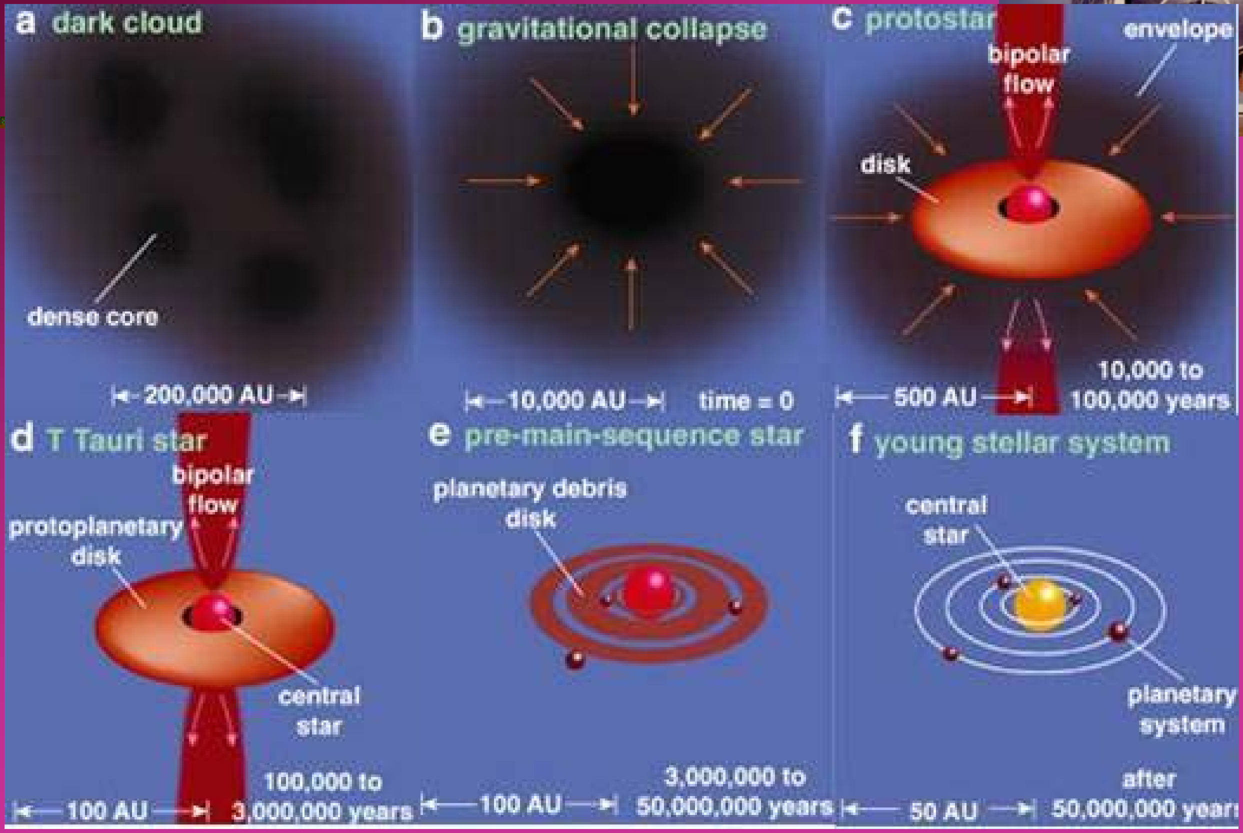
HS

How Do Massive Stars Form?



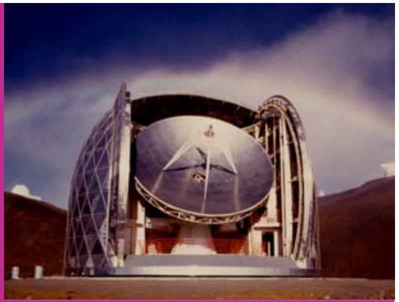
(Motte et al. '03)

Star Formation Process

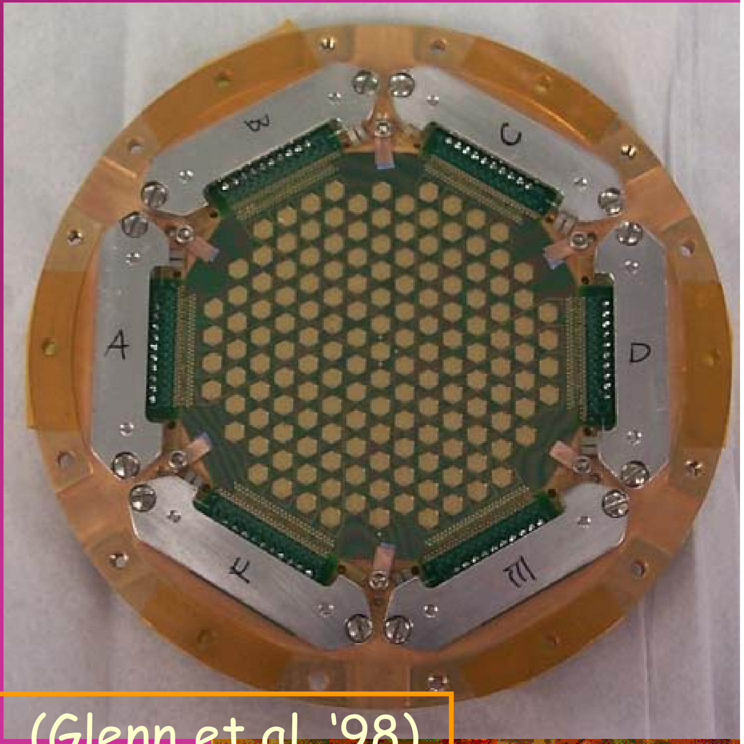


(Greene)

BOLOCAM



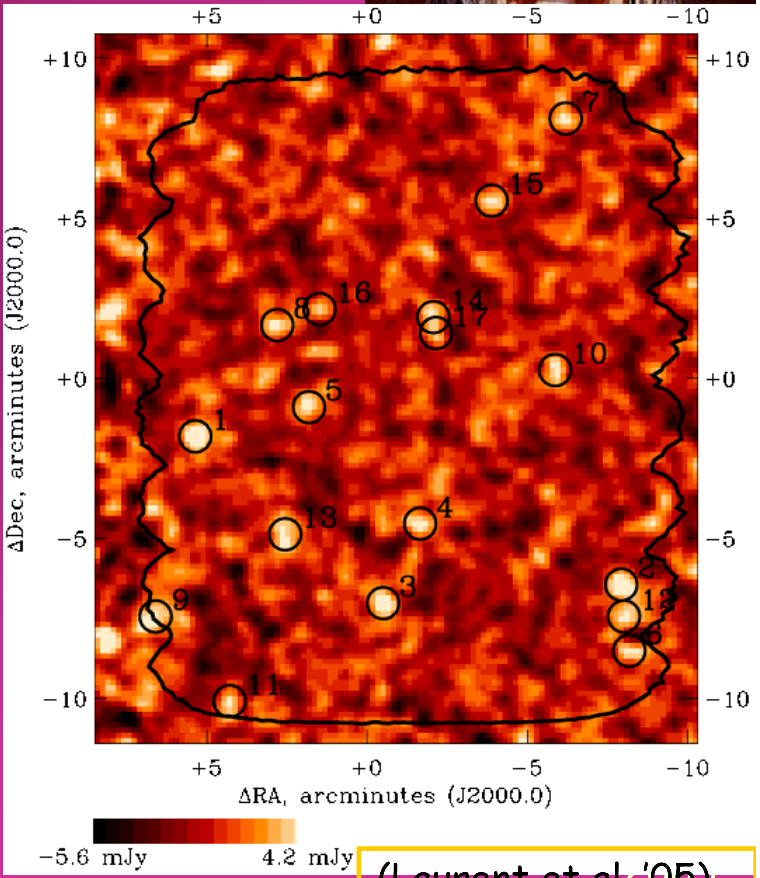
- Bolometric camera at 1.1 and 2.1 mm.
- 115 pixels with 8 arcmin field of view.
- The beam size (FWHM):
  - 30 arcsec at 1.1 mm
  - 60 arcsec at 2.1 mm.
- At all wavelengths, the pixel spacing (nearest neighbors of hexagonal close-packed array) is 38 arcsec.



(Glenn et al. '98)

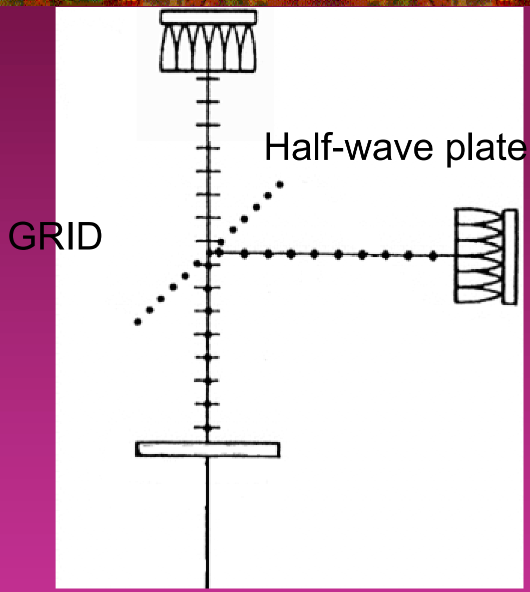
Extremely Luminous High Redshift (z > 1) Galaxies with Bolocam

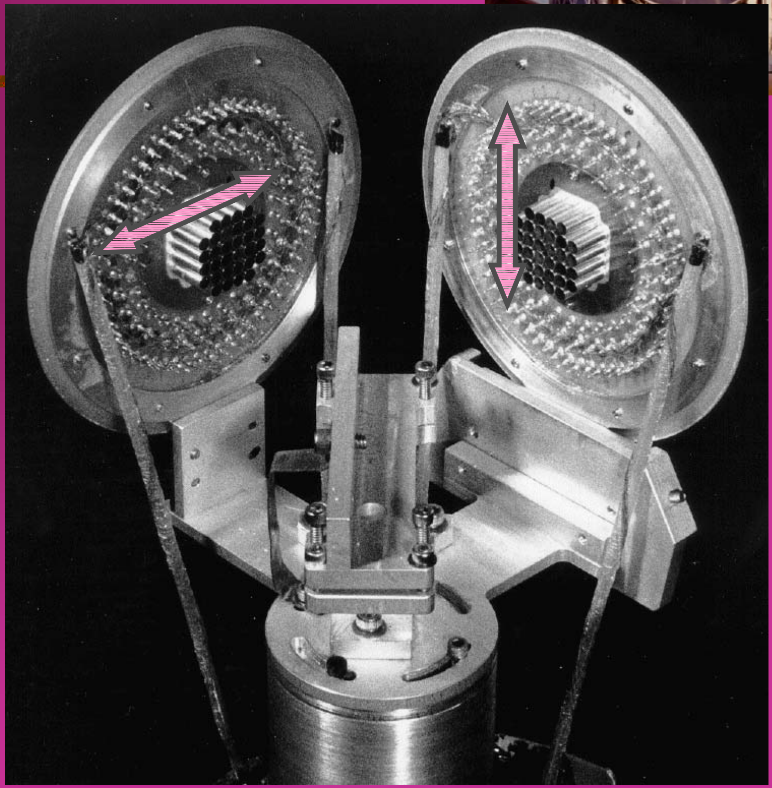
- 1.1 millimeter bolocam observations allowed us to detect very far distant galaxies.



(Laurent et al. '05)

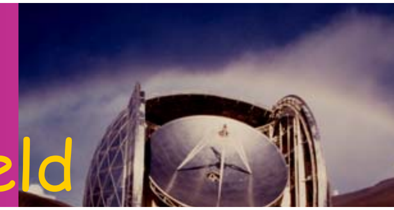
Hertz, the 350 micron Polarimeter



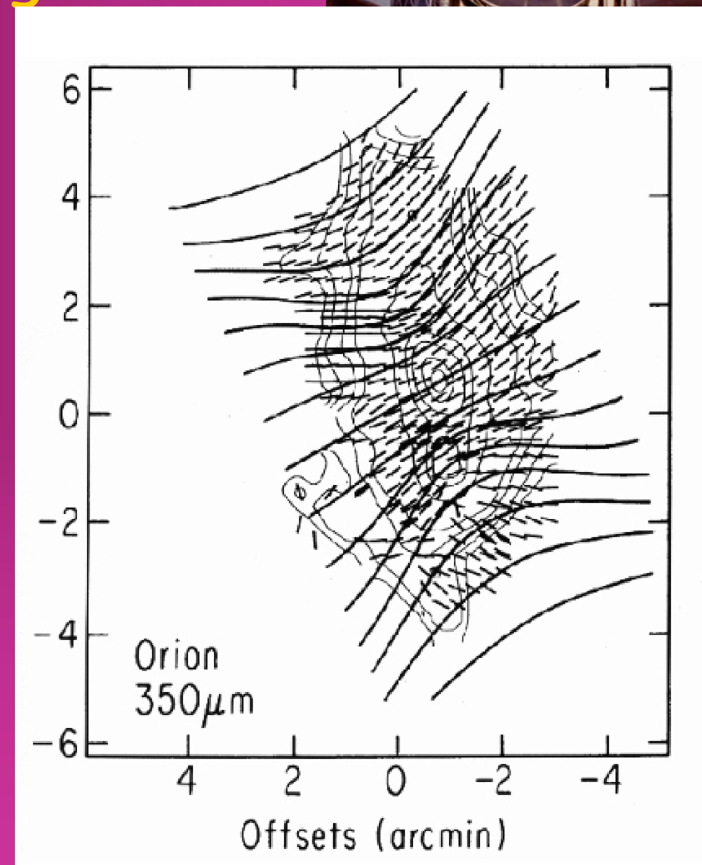


(Hildebrand et al. '98)

Tracing Interstellar Magnetic Field

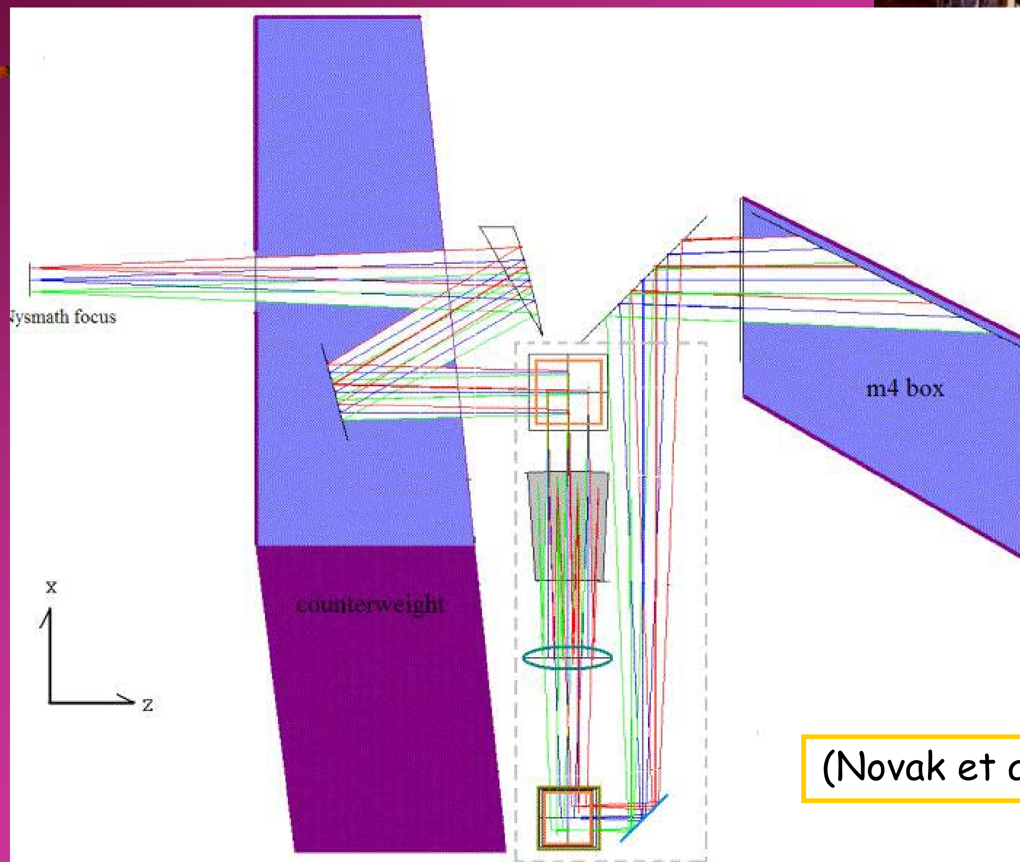


- On a process of star formation, magnetic field may play a critical role.
- Using 350 micron polarimeter, Hertz, magnetic field lines are traced towards Orion OMC1 region.
- It revealed the pinched magnetic field.
- Curved lines show magnetic field "profiles" that are fit to the B-vectors, but not including data near the Orion "bar" (southeast edge).



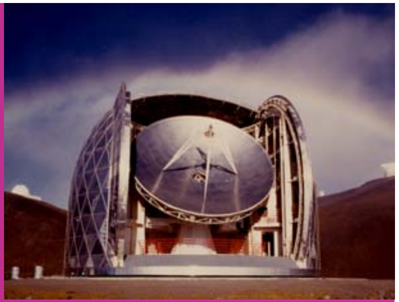
(Houde et al. '04)

SHARP The SHARC-II Polarimeter



(Novak et al. '05)

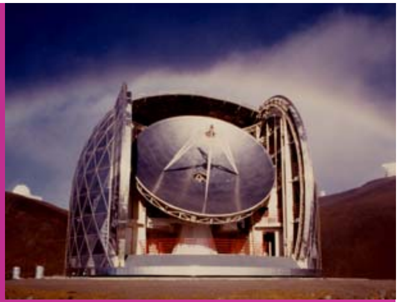
For More Information…



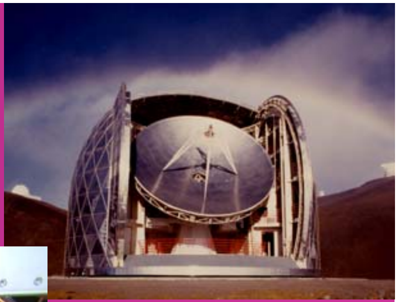
- Visit our web site:

http://www.submm.caltech.edu/cso/

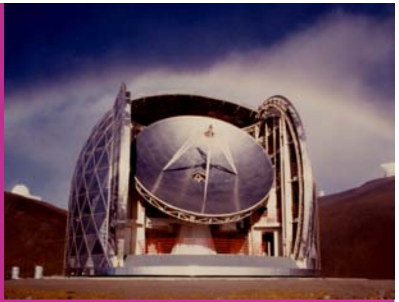
Caltech Submillimeter Observatory Office,
111 Nowelo St., Hilo, Hawai'i 96720
Voice: (808) 935-1909
Fax: (808) 961-6273



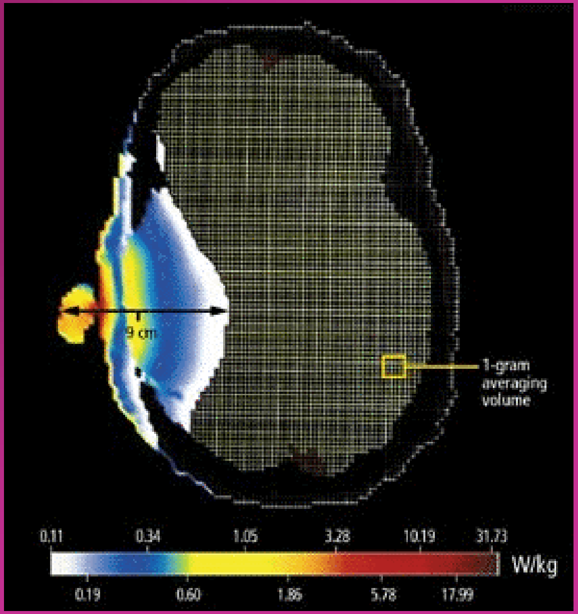
Sidecab Receiver Room



Health controversy



- Still not clear yet.

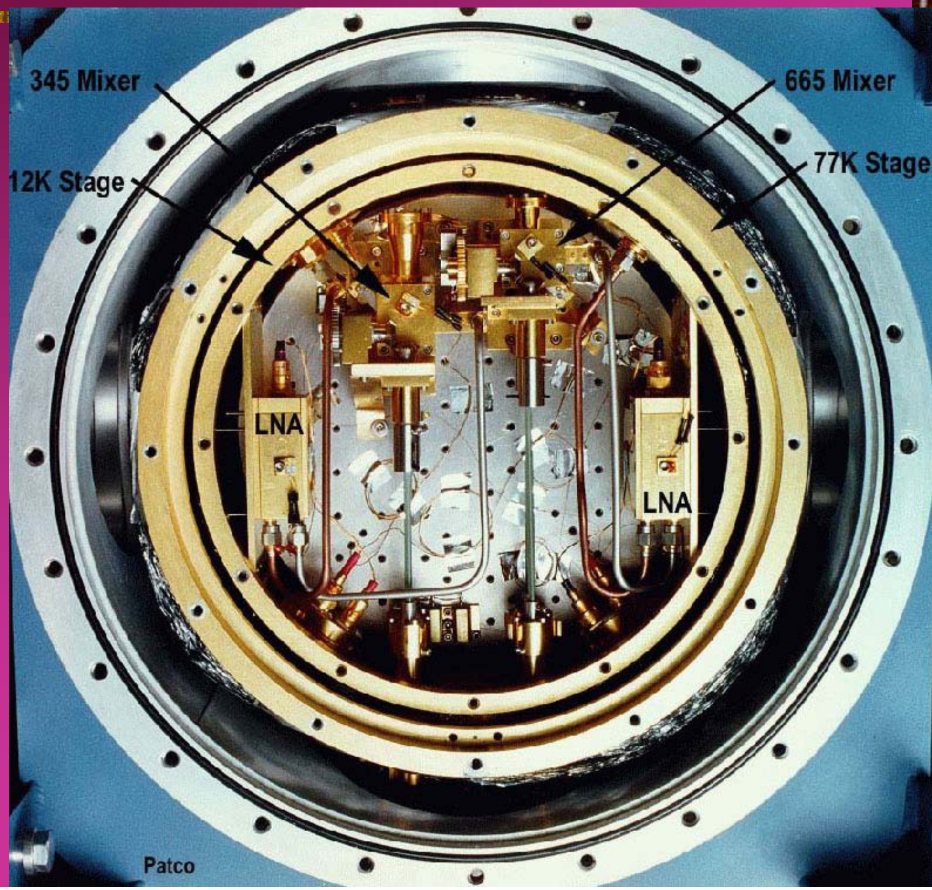


(Gandhi 2000)

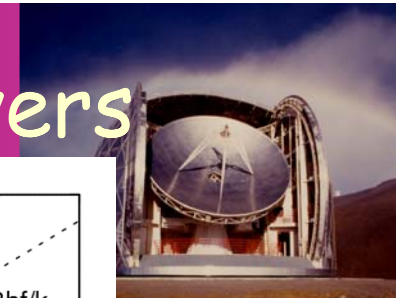
Why Submillimeter Astronomy?

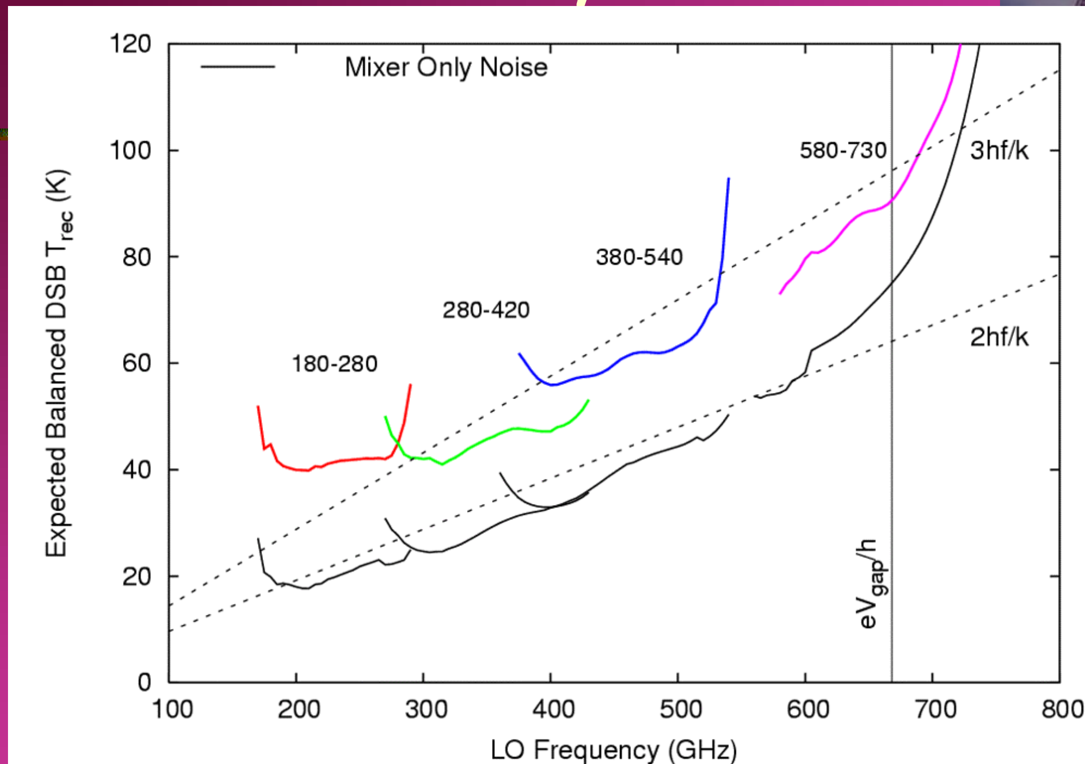
- Not so many researches has been done.
- Cutting edge field in radio astronomy
  - Technical challenges and hard observing condition from ground due to thick atmosphere

345/670 GHz Receiver Cryostat



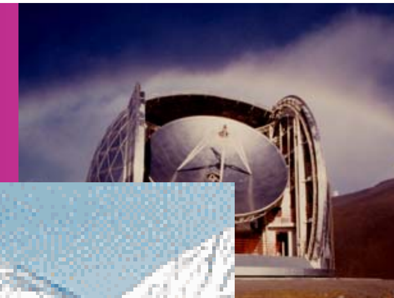
Heterodyne Receivers





Estimated double side band receiver noise temperatures for the balanced mixers of our heterodyne receivers.

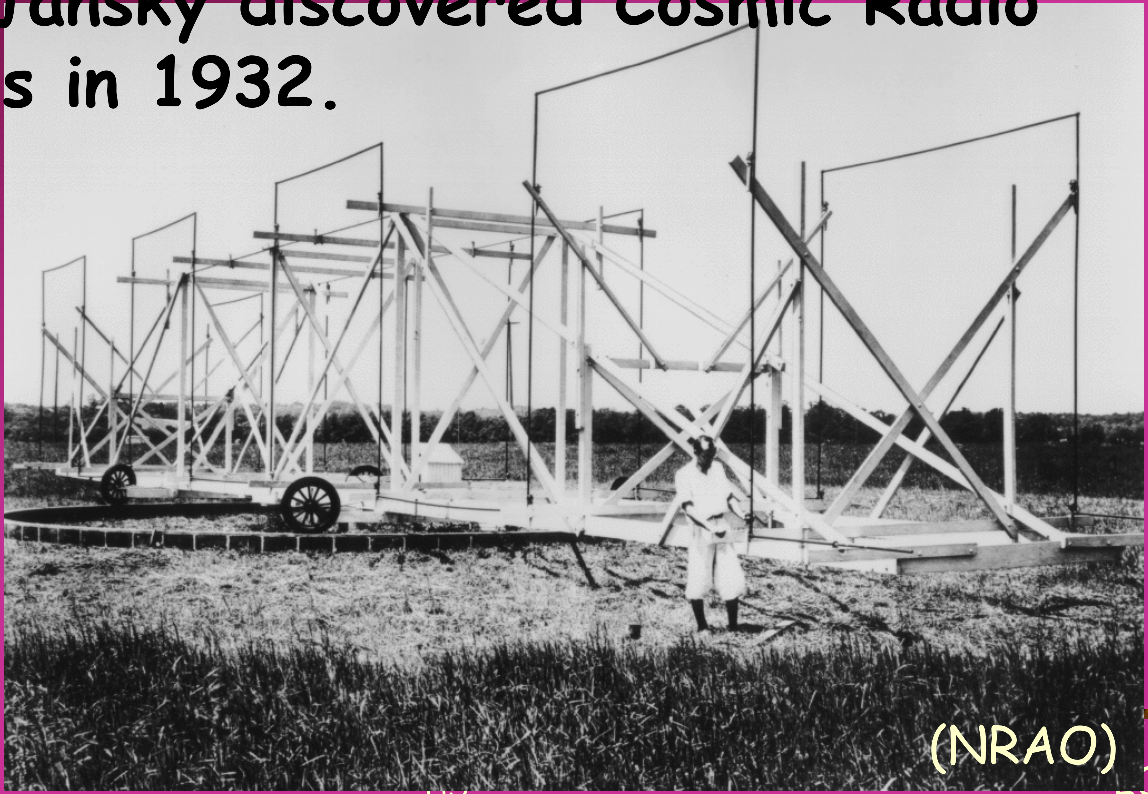
(Kooi et al. '03)



Owens Valley Millimeter Array (Caltech)

Radio Astronomy Started in 1932

- **Karl Jansky discovered Cosmic Radio Waves in 1932.**

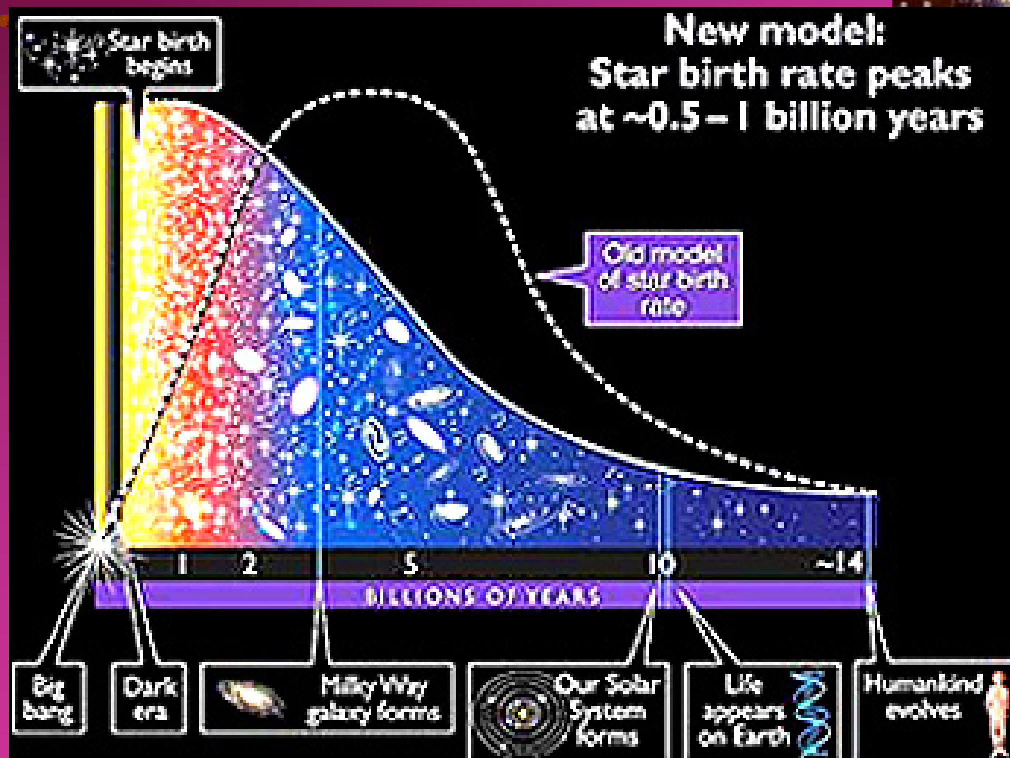


(NRAO)

Astronomy: An Exciting Field

- There are so many things people have been trying to understand.
  - How did the Universe form/started?
  - How do stars form?
  - How do stars end their life?
  - Are we alone?
- Some astronomical objects have some extreme conditions. → Excellent laboratory for understanding Physics.

Star Formation History



(NASA)