SMA, CARMA and NOEMA

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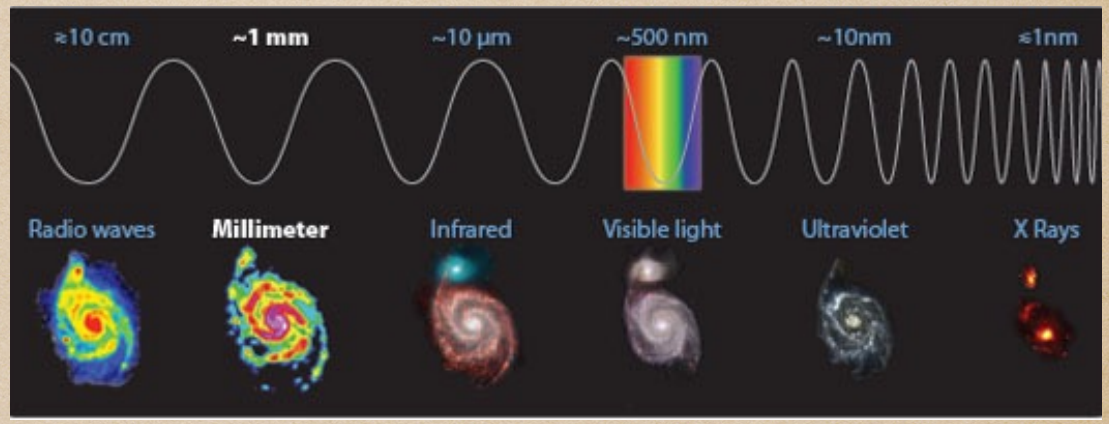
Outline

- sub-millimeter/millimeter astronomy
- SMA
  - history
  - specification
  - science
- CARMA
- NOEMA

Sub-millimeter & Millimeter Astronomy

sub-millimeter: 0.3-1mm 1983~

millimeter : ~1mm 1960's~



Main source : cold interstellar material (radio emission from atoms,molecules,cold dust)

Yield a new view upon the Universe we live in!

What Can We Do :

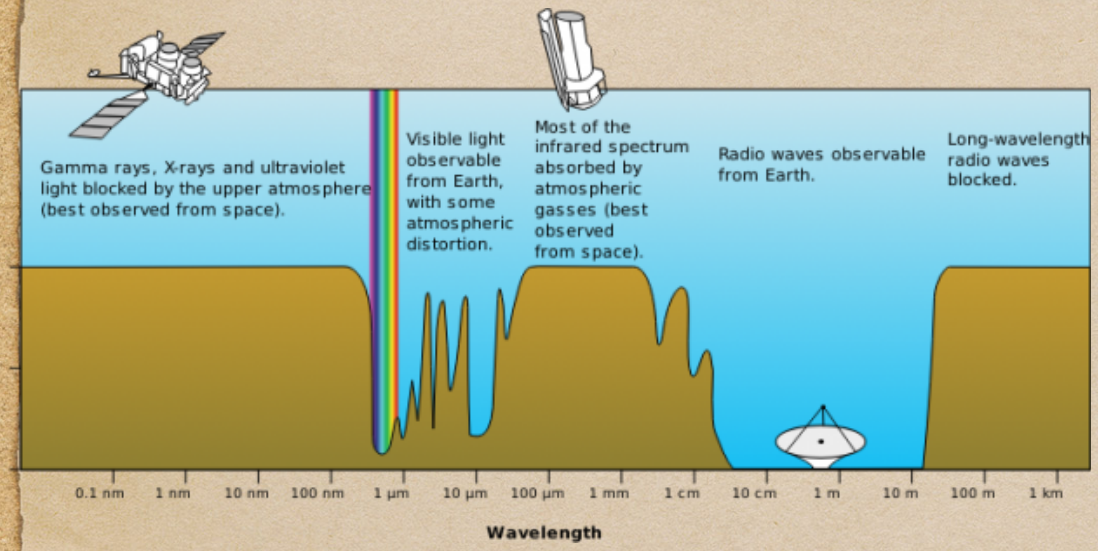
1.study the evolution of stars and their planetary systems (directly probe regions where stars are actively being born)

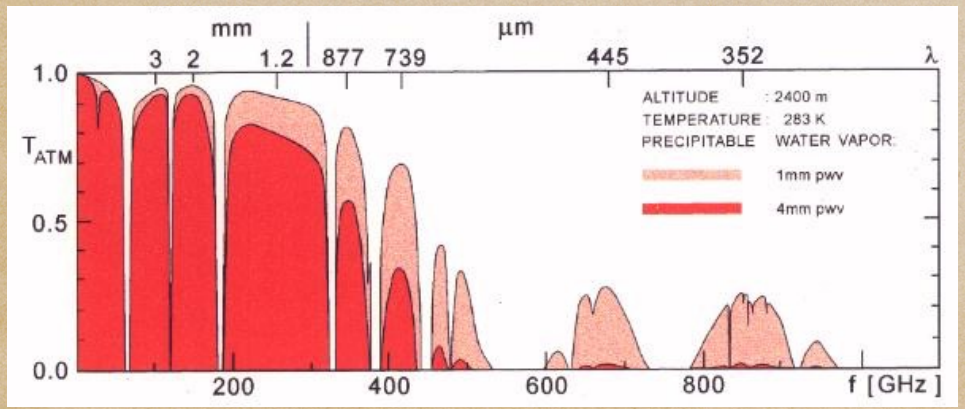
2.study the the composition of planetary atmospheres

3.study the formation and evolution of galaxies

Why being unexplored so long?

- 1.atmosphere :





- 2.instrumentation :high frequency receivers is hard to manufacture

- High altitude and dry site
- High frequency receivers

SMA(Submillimeter Array)

Background of SMA

- 1980's (under construction)
  - Caltech Submillimeter Observatory 10m telescope
  - James Clerk Maxwell Telescope 15m telescope
    - would reach resolution of 6" 15"
- during mid 1980's:
  - Owens Valley Radio Observatory and Berkeley-Illinois-Maryland Association pioneered millimeter-wavelength interferometers
    - offered resolutions less than 5"
- under designing millimeter interferometer
  - Plateau de Bure & Nobeyama
    - offer spatial resolution ~1"

It's time for high spatial resolution sub-millimeter observation!

SMA(Submillimeter Array)

- collaborated project
  - Smithsonian Astrophysical Observatory(SAO)
  - Academia Sinica Institute of Astronomy and Astrophysics(Taiwan)
- Director:Jim Moran
- project approval on 1984 :
  - six 6m diameter antennas
  - sub-arcsecond resolution
  - dry site
  - receiver development
- 1999-2003 antennas are set on Mauna Kea(Hawaii, with 4,080m altitude)

Jim Moran

wavelength ranges from 0.3 to 1.7mm
spatial resolutions down to about 0.1” at 850 GHz

- A
- C
  b
- R
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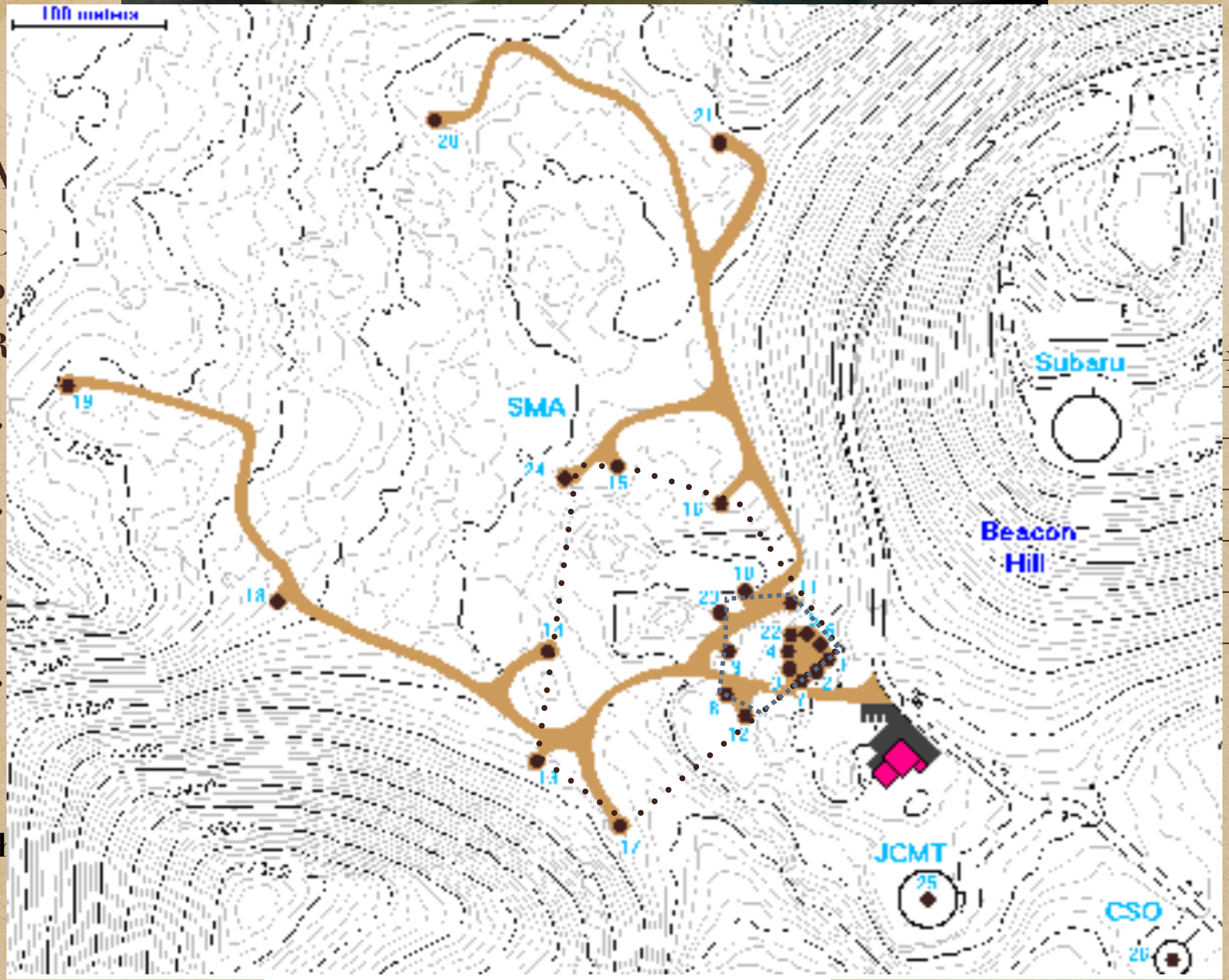
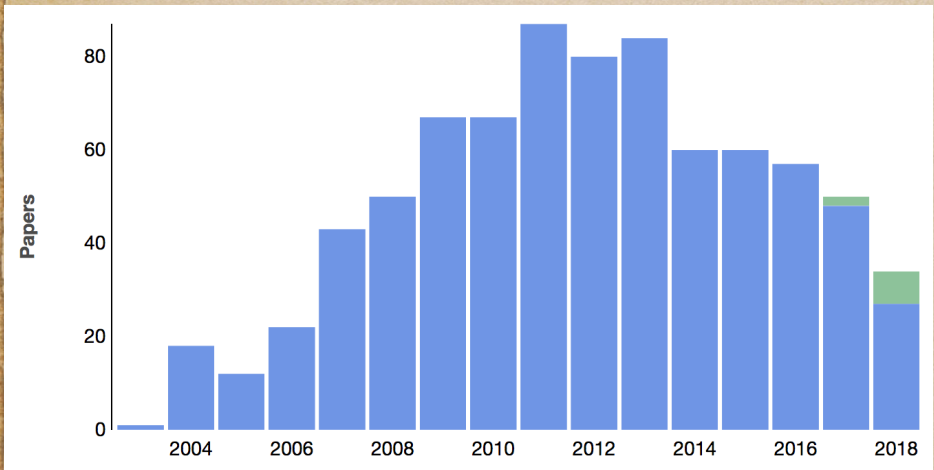
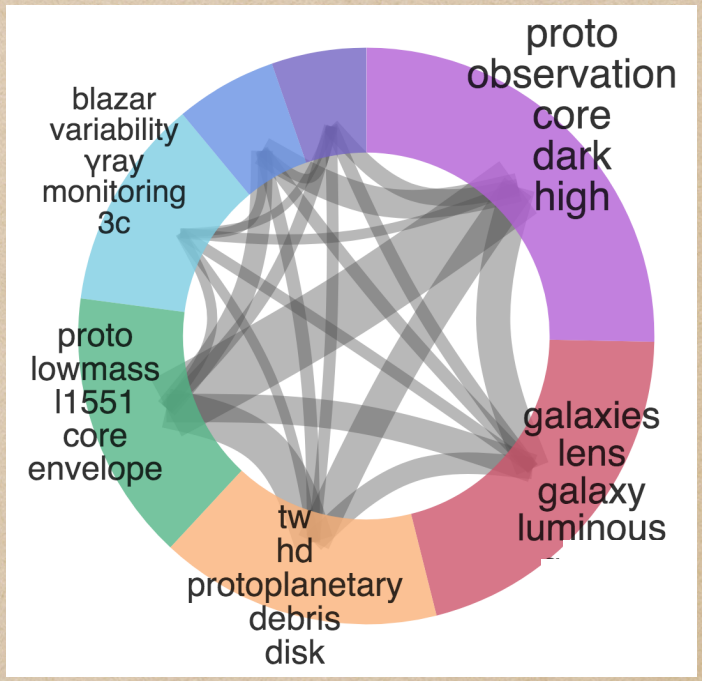


Hz)

SMA Science

Number of paper:792

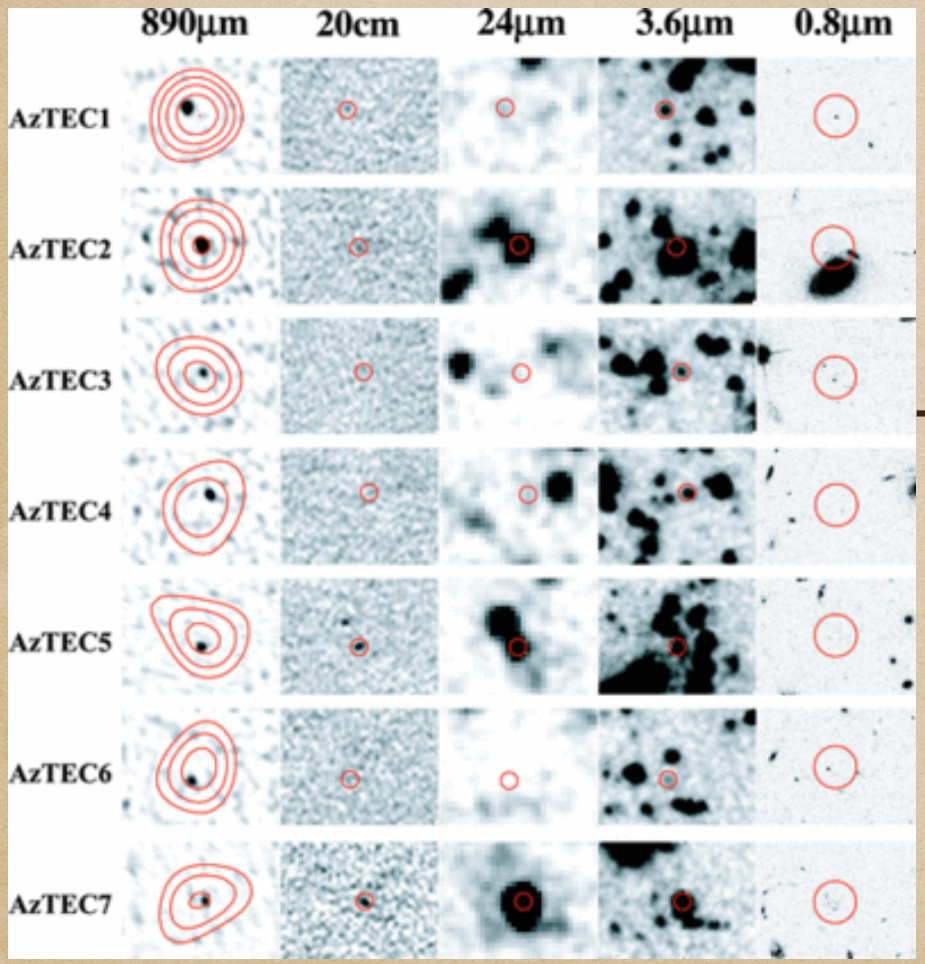




distribution of different projects & paper network

SMA Science

"sub-millimeter galaxies"



searching for dust-obscured starburst galaxies at high redshift through DUST and Molecular Gas Emission

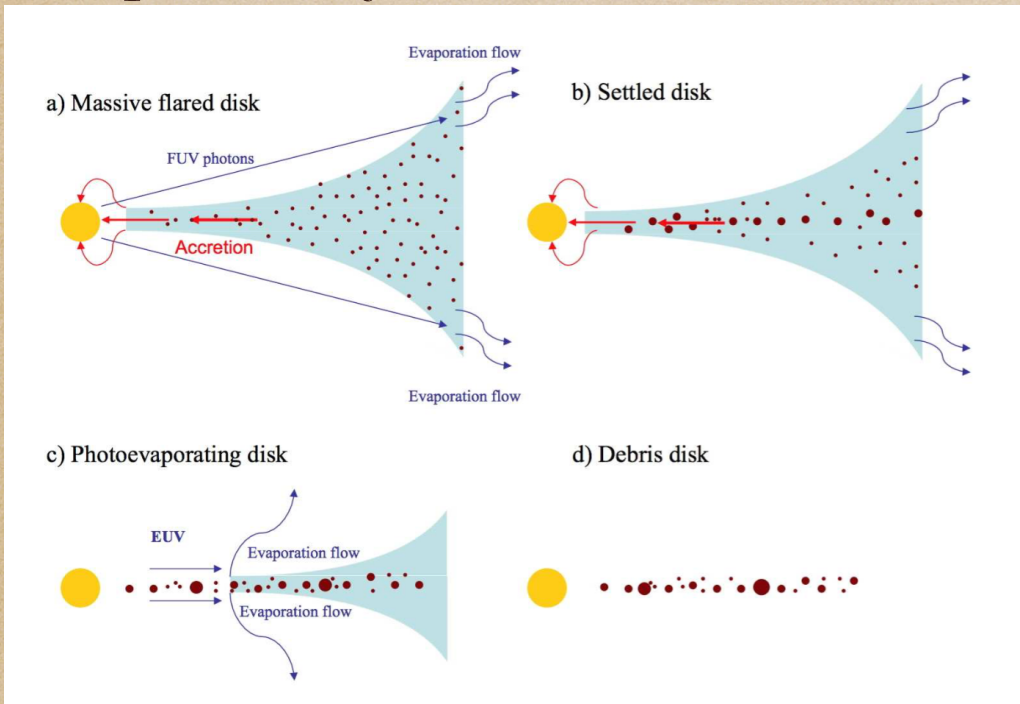
→ chemistry,dynamics, structure…

← a Population of High-Redshift Submillimeter Galaxies from Interferometric Imaging

Younger et. al 2007

SMA Science

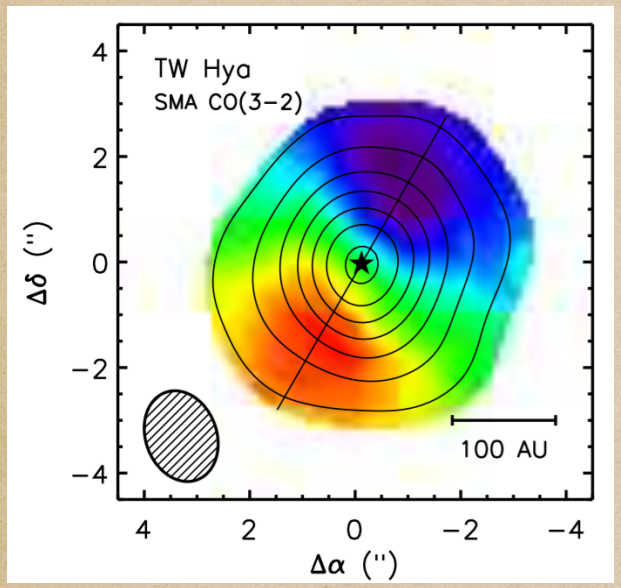
protoplanetary disk

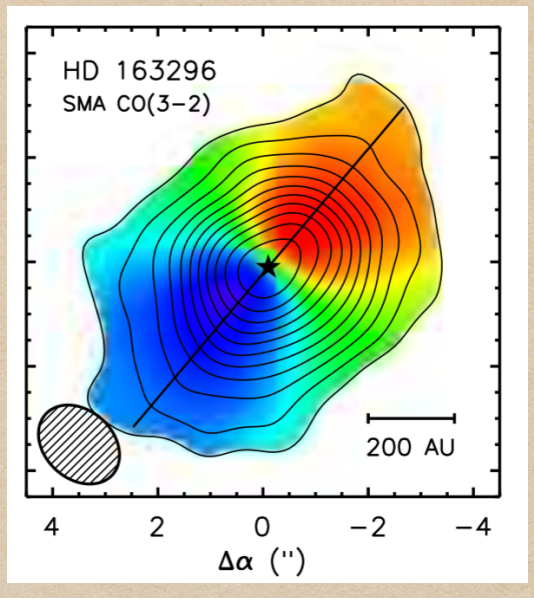


The evolution of a typical protoplanetary disk

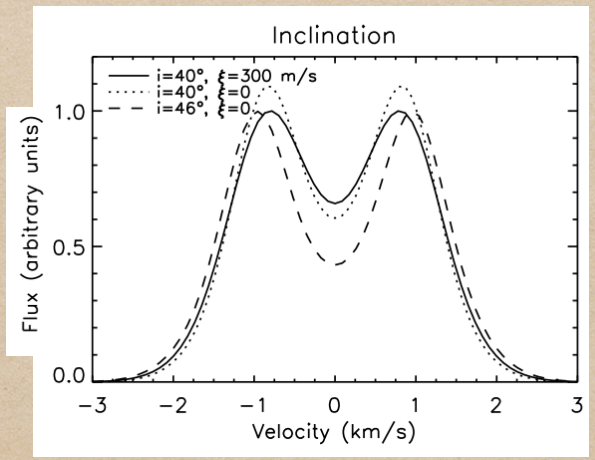
- the evolution of disk has a profound impact on the outcome and efficiency of the planet formation process
- emission of dust&gas peaks on (sub)-millimeter waveband
- high spatial resolution

SMA Science

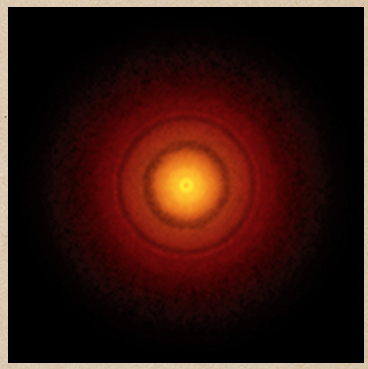




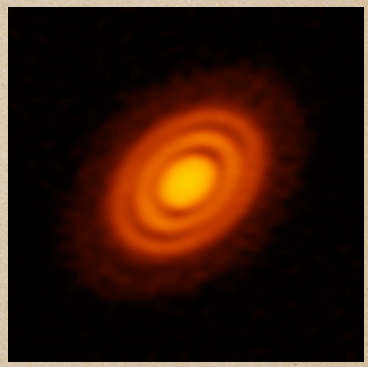
intensity weighted velocity



constrained the inclination of the disk



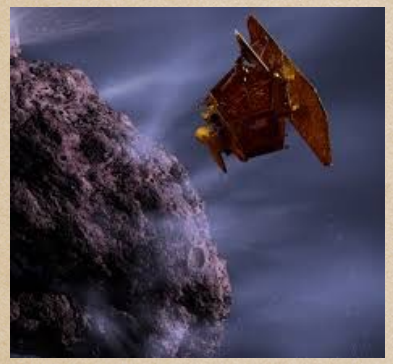
TW HYa



HD 163296

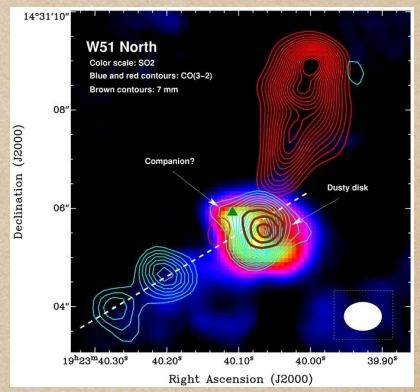
dust observed by ALMA

SMA Science

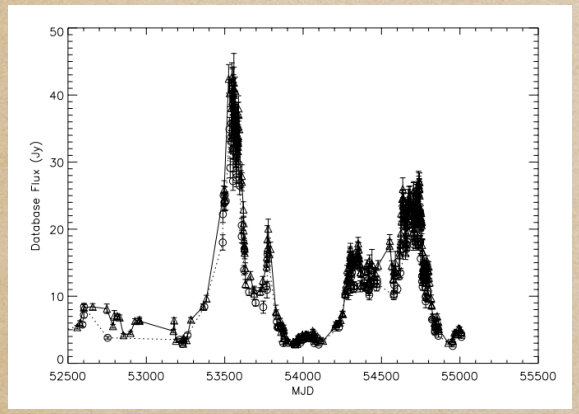


deep impact mission

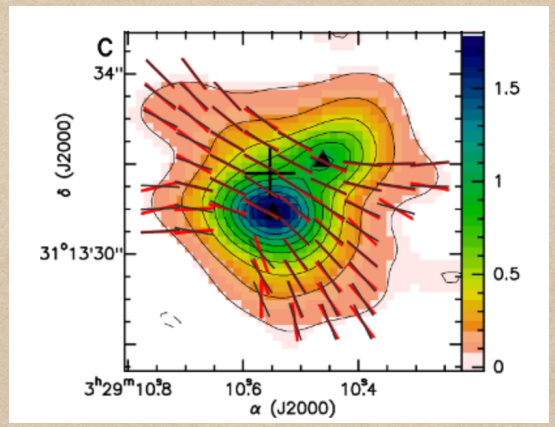
Event Horizon Telescope



Formation&Dying of star



Radio monitor of high energy transient



Polarization

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CARMA(Combined Array for Research in Millimeter-wave Astronomy)

- site:the east of Owens Valley Radio Observatory, elevation of 2,196.223m
- time:2004-2015 (ALMA took place)
- organizations:Caltech, BIMA(Berkeley-Illinois-Maryland Association), University of Chicago

CARMA Specifications

- Antenna: 23 antennas
- Receiver:
  - 3-mm band: 84-116 GHz; 70-84 GHz
  - 1-mm band: 215-270 GHz
- Configurations: 4 configurations with baseline from 7m to 2km⟶ Angular resolution:30”-0.1”
- Water vapor radiometry

NOEMA(NOrthern Extended Millimeter Array)

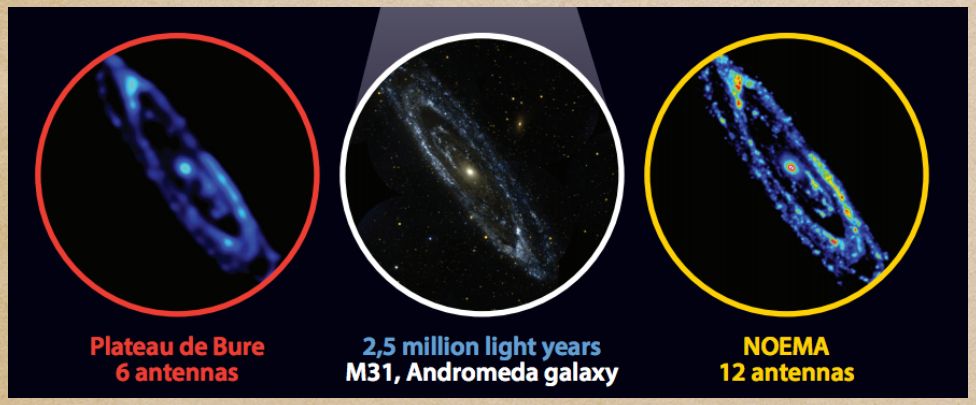
- site: Plateau de Bure, French (elevation of 2550m)
- time:2011-2024(expected)
- organization:IRAM (Institut de radioastronomie millimétrique)

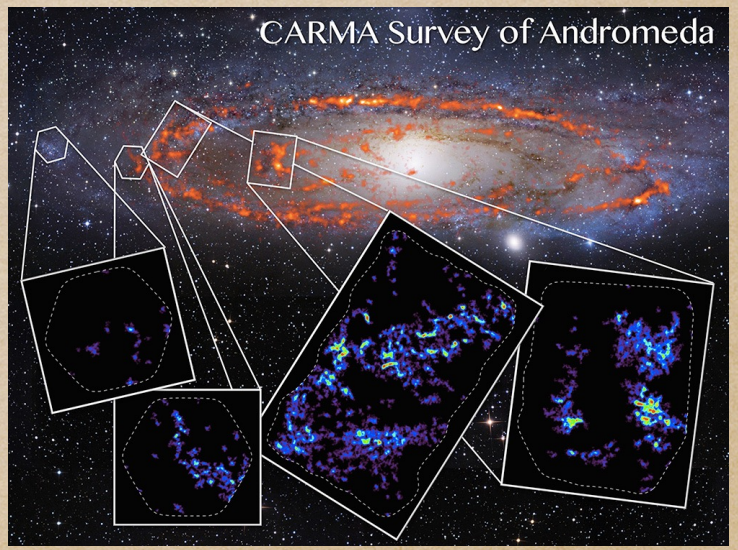
NOEMA Specifications

- Antenna:twelve 15m antennas
- Receiver:
  - 3 mm :76.5 to 116 GHz
  - 2 mm :130 to 178 GHz
  - 1.3 mm :202 to 274 GHz
- configuration:D(compact),C,A(most extended);highest separation of 760m; best resolution 0.2”

Science of CARMA&NOEMA

- see the formation of the galaxies at high z
- black hole
- the dynamics and chemical evolution of nearby galaxies
- star & planet formation





Comparison

	SMA	CARMA	NOEMA	**ALMA**
number of antennas	8	23	12	66
wavelength	0.3-1.7mm	1-3mm	1.3-3mm	0.3-10mm
baseline	8-508m	7m-2km	760m(highest)	150m-16km
resolution	sub-arcsecond	0.1”-30”	best 0.2”	0.004”-0.2”

Summary

- Sub-millimeter/Millimeter interferometer requires stable receivers and is critical to environment of site
- SMA can provide high resolution maps of dust&molecular, which people can use to investigate:
    - the formation and dying star
    - the protoplanetary disk
    - galaxy evolution
- CARMA&NOEMA can map the cold gas of star and galaxy and serve as the pathfinder for ALMA

Reference

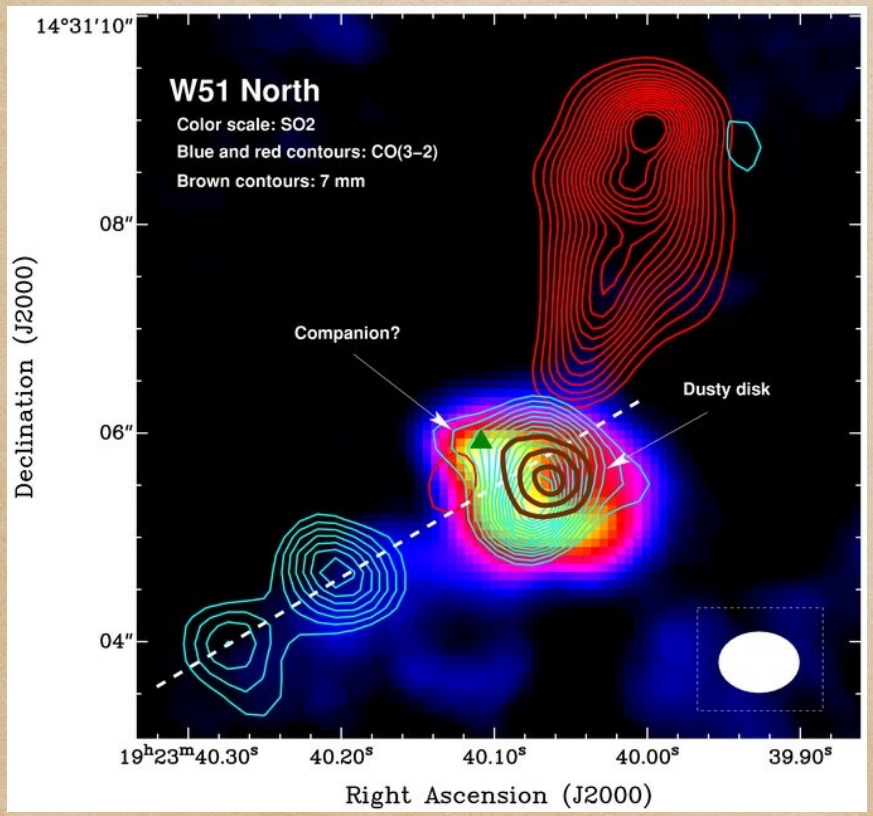
- Paul et. al, 2004 The Submillimeter Array
- Wilson et. al, 2008 Luminous infrared galaxies with the submillimeter array: probing the extremes of star formation
- Younger et. al,2007 Evidence for a population of high-redshift sub millimeter galaxies from interferometric imaging
- Williams et, al, 2011 Protoplanetary Disks and Their Evolution
- Hughes AM, Wilner DJ, Cho J, Marrone DP, Lazarian A, et al. 2009b. Ap. J. 704:1204 1217
- Zapata et. al,2010 Extremely large and hot multilayer keplerian disk sound the O-type star W51N:The precursors of the HCH II regions

THANKS~

Q&A

SMA Science

- Formation and dying of star
- Formation of planetary system



young O-type protostar

multilayer structure

cavity in the disk

Zapata et. al 2010

CARMA Science

planet formation

star formation

molecular gas in galaxies

Multi-wavelength Monitor of Transients

Black Hole

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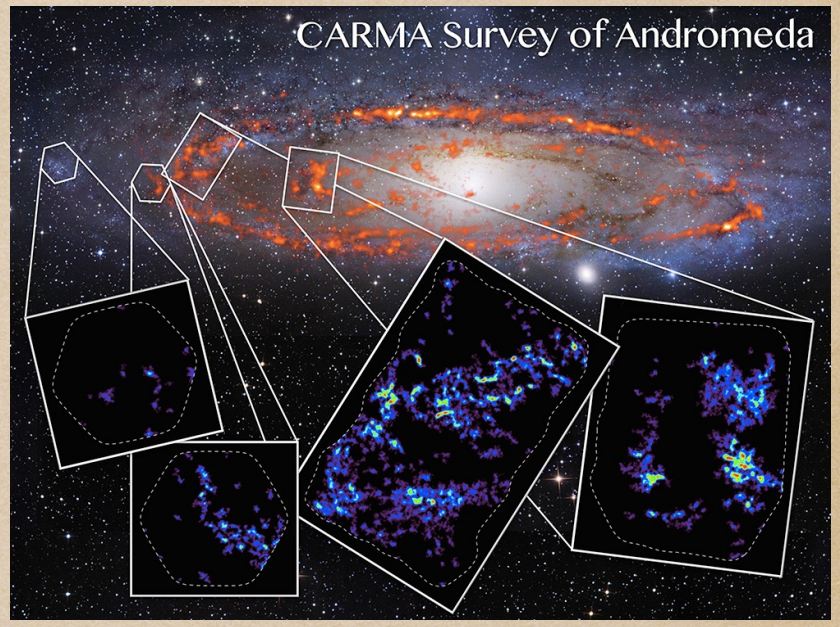
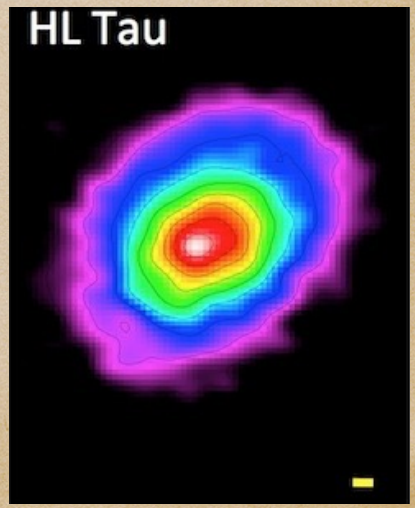
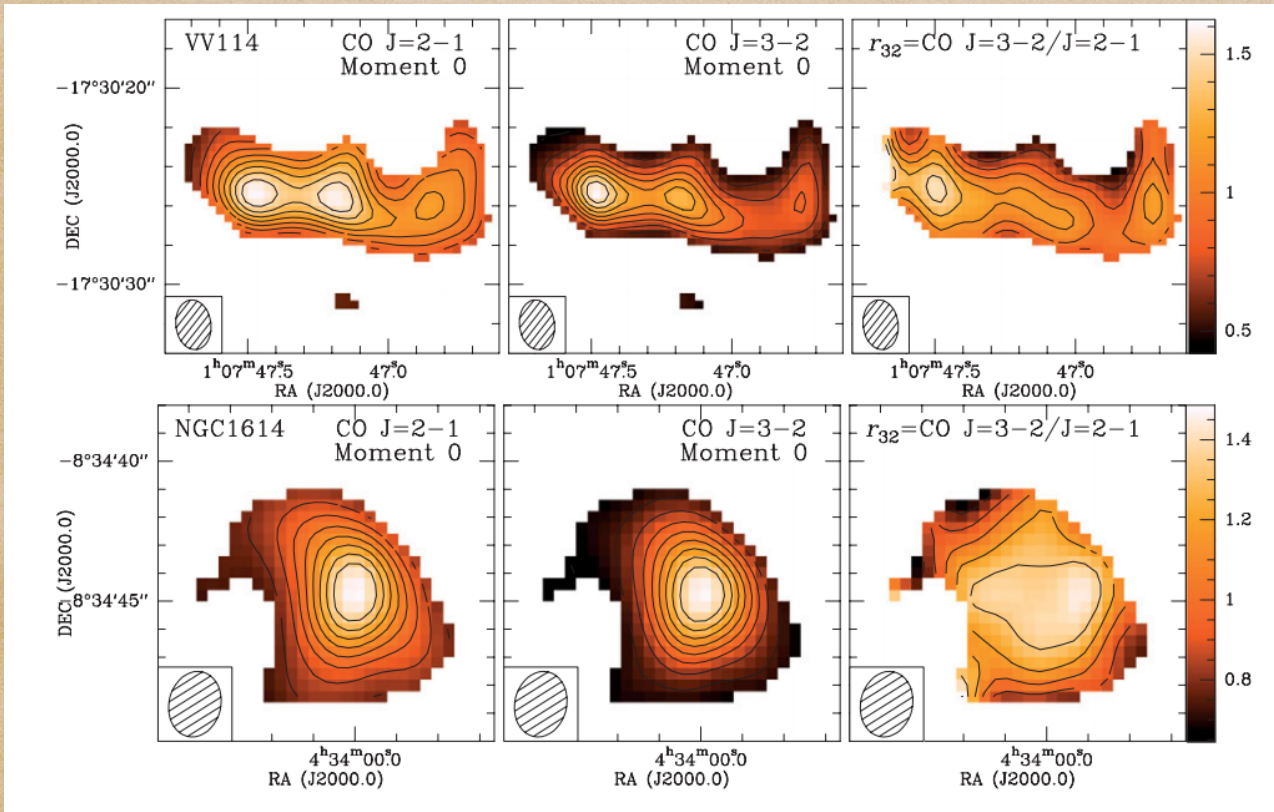




SMA Science

Nearby galaxies

The SMA Ultraluminous/Luminous Infrared Galaxy (U/LIRG) Survey



mapping molecular gas can help provide a comprehensive picture of star formation activity during the merging process

(Qinghua Tan et al. 2011)

gas temperature varies across the galaxy