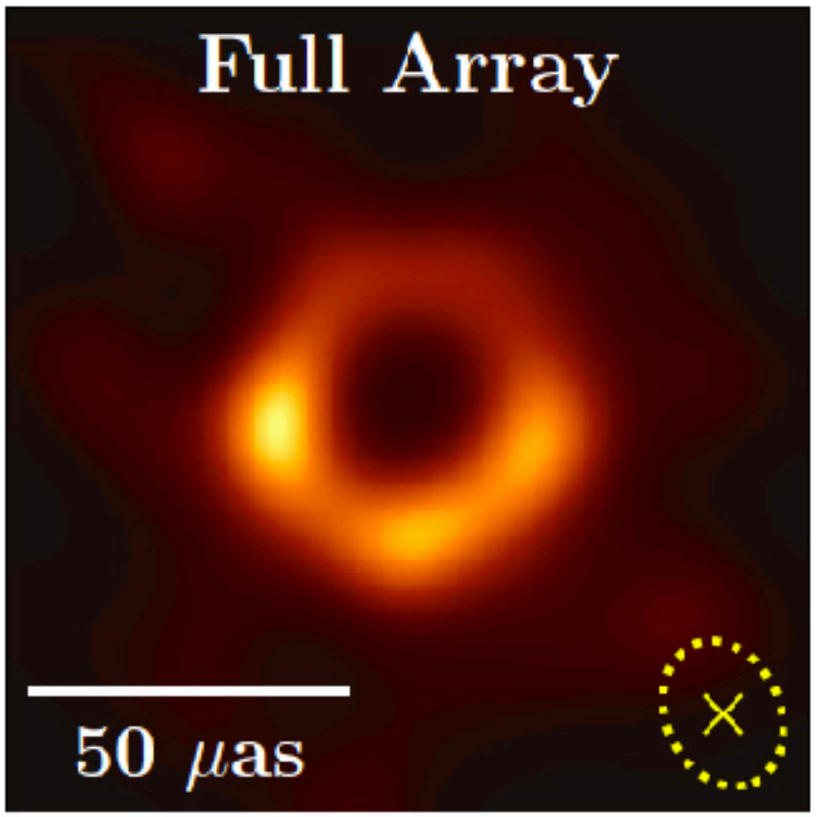
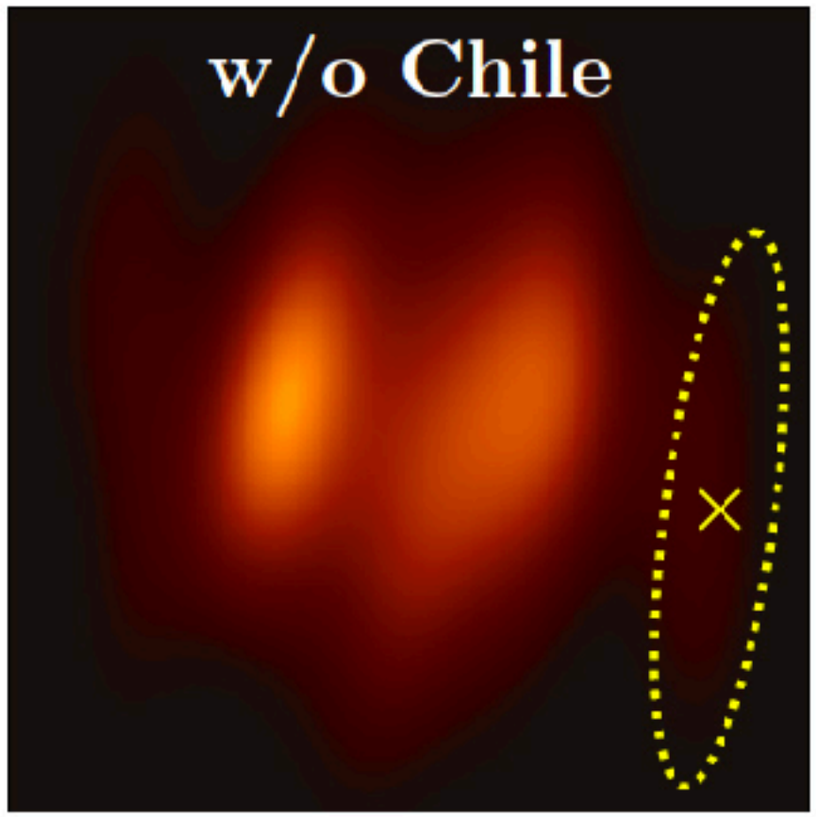
ALMA Status and Large Programs

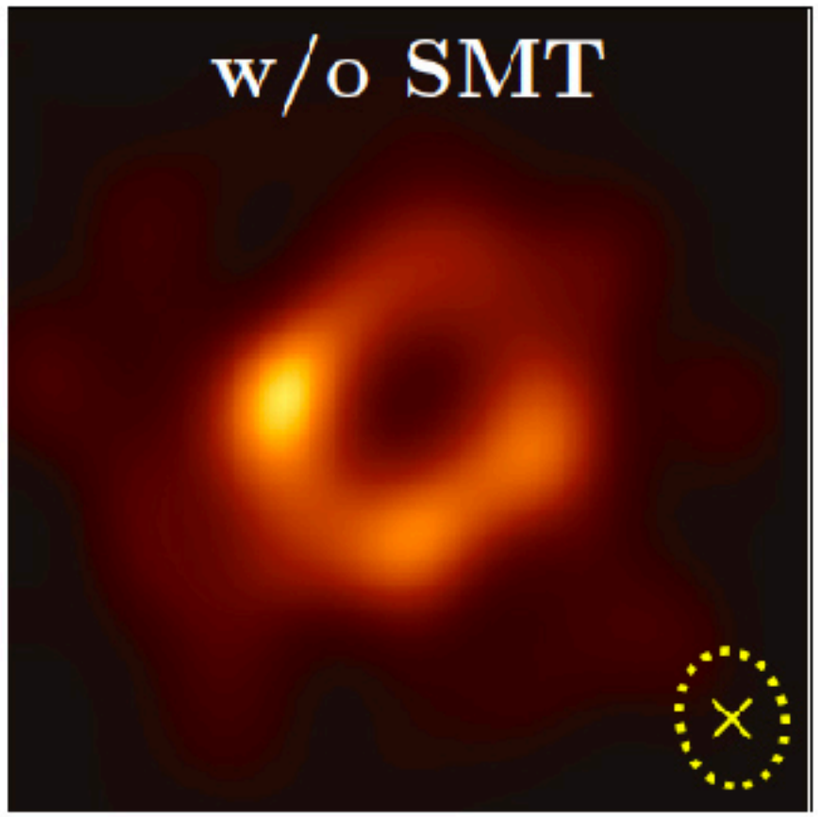
Survey Science Group Workshop
2020 Feb. 10—12, High-1 Resort

Woojin Kwon

ALMA !

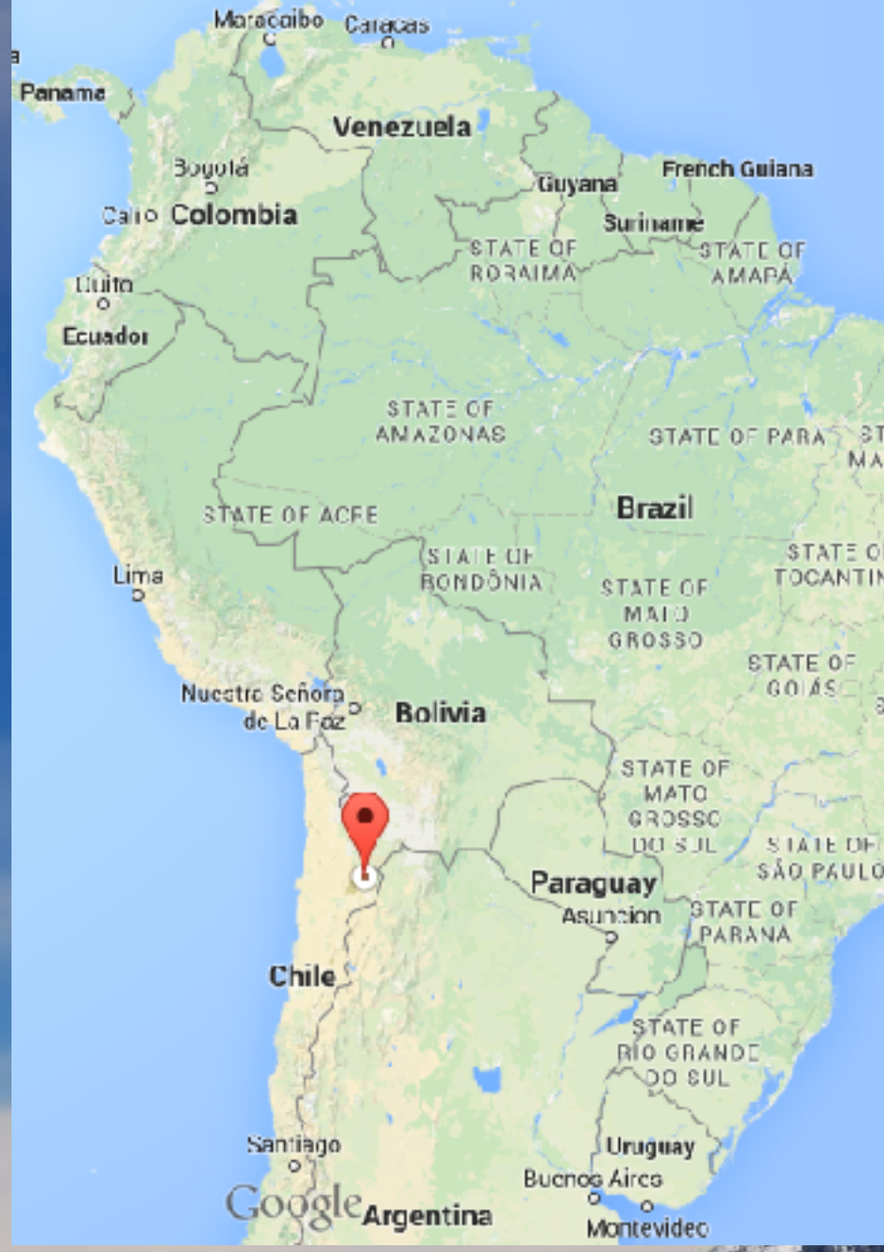




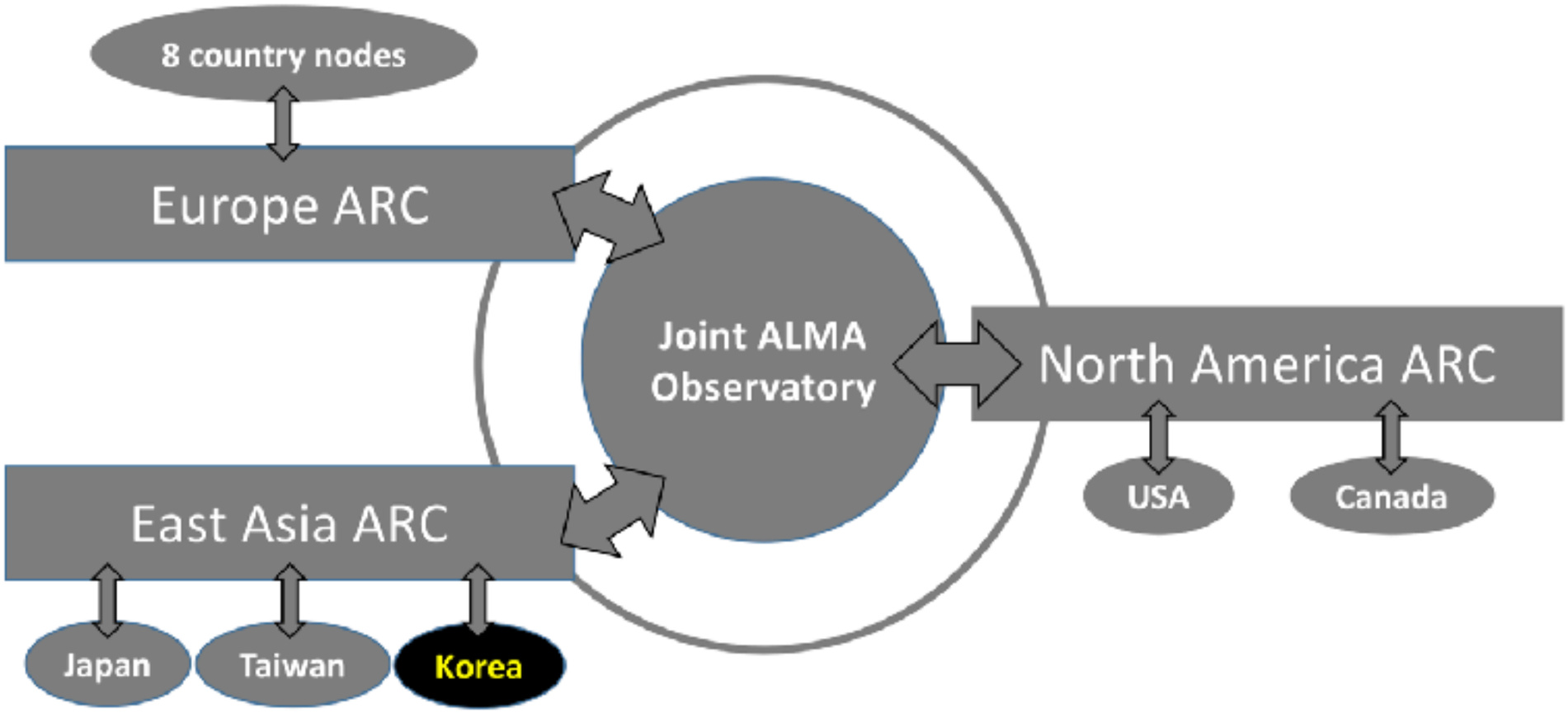


Atacama
Large
Millimeter/submillimeter
Array

- The largest ground-based astronomical facility
- **The 12-m Array**: 50 12-m antennas
  Atacama Compact Array: 12 7-m, 4 12-m
  in total, 66 antennas
- ~5000 m in altitude, Chajnantor plateau, Chile
- https://almascience.org



ALMA Regional Centers

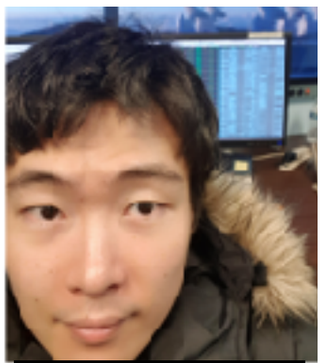


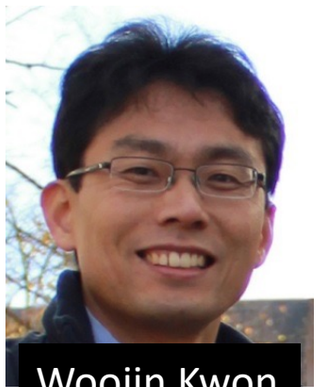

Jongsoo Kim


A-Ran Lyo


Jihyun Kang


Min-Young Lee


Yusuke Aso


Woojin Kwon

Official partner of ALMA



2012 MOU between NAOJ & KASI



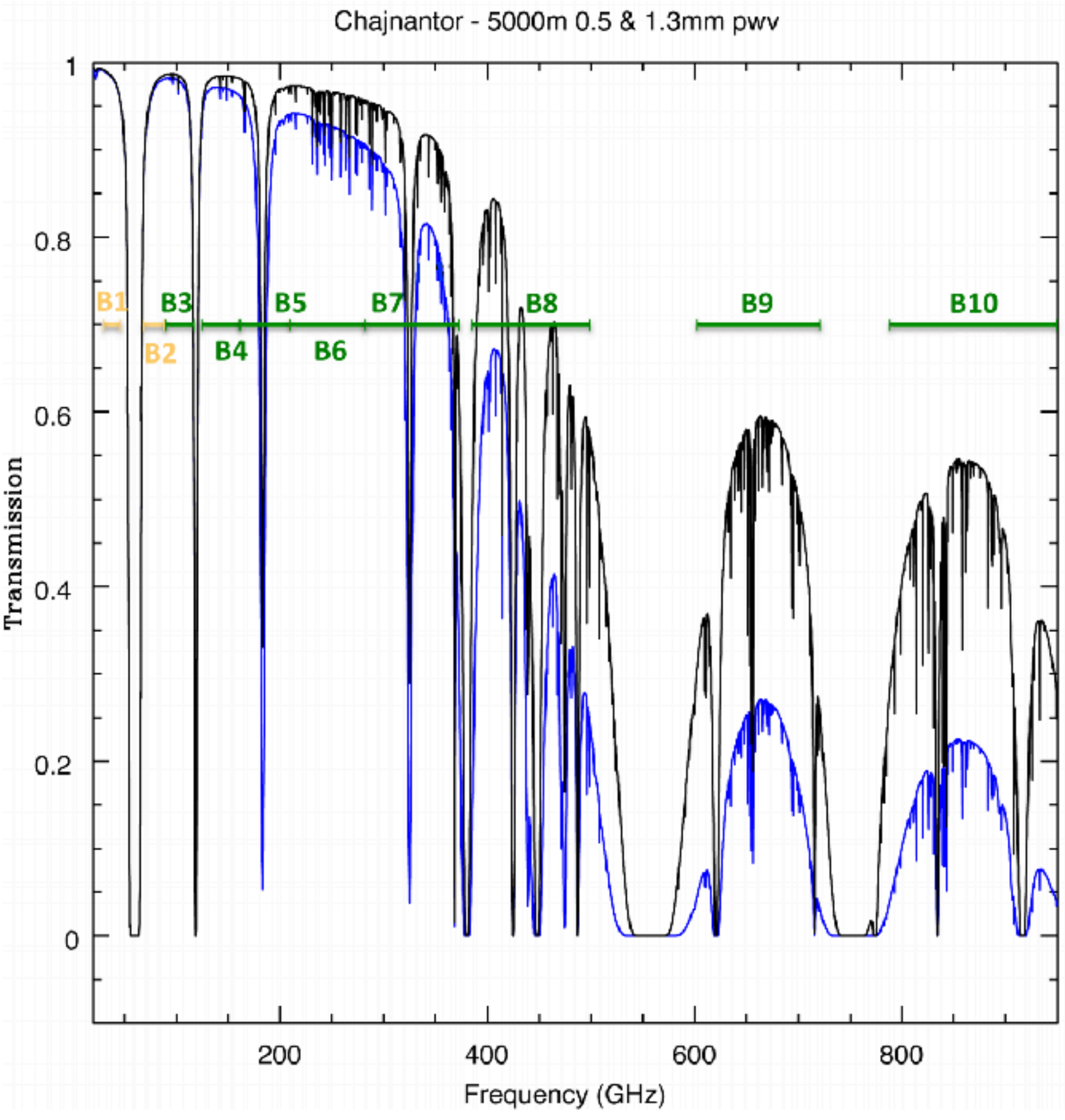
2014 MOA between NINS/NAOJ/KASI


ALMA OSF

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA full Operation's Specifications

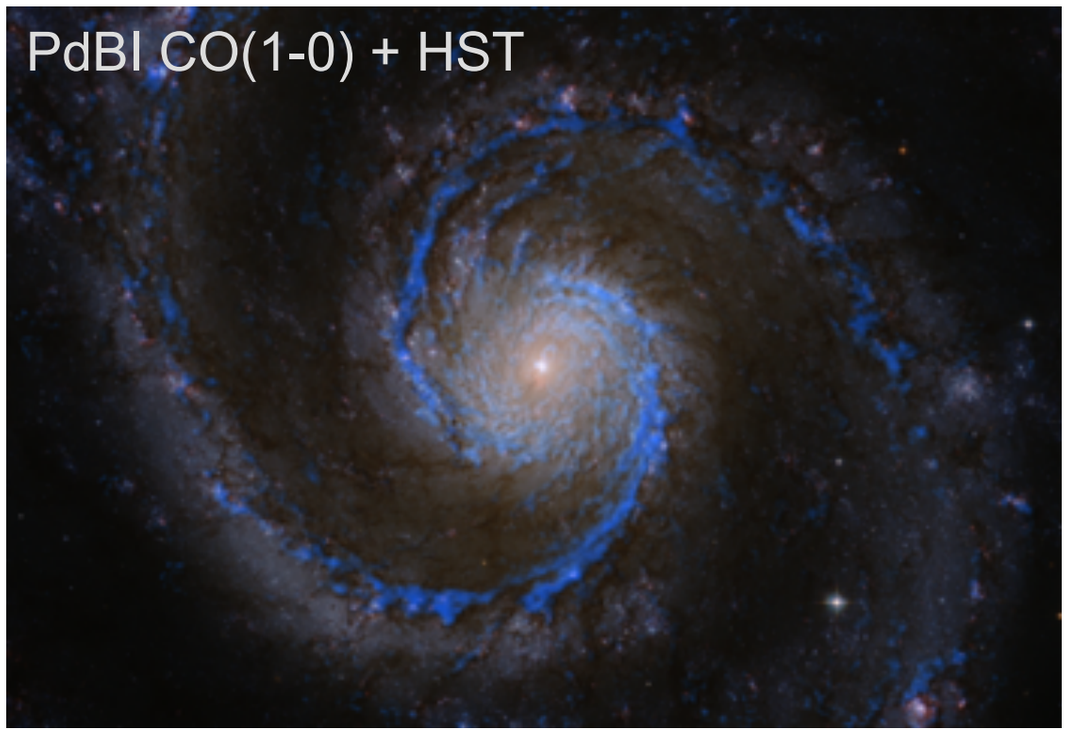
	Specification
Number of Antennas	*50×12 m (12-m Array), plus 12×7 m & 4×12 m (ACA)*
Maximum Baseline Lengths	*0.16 - 16.2 km*
Angular Resolution (")	*~0.2" × (300/ν GHz) × (1 km / max. baseline)*
12 m Primary beam (")	*~20.6" × (300/ν GHz)*
7 m Primary beam (")	*~35" × (300/ν GHz)*
Number of Baselines	*Up to 1225 (ALMA correlators can handle up to 64 antennas)*
Frequency Coverage	*All atmospheric windows from 84 GHz - 950 GHz (with extension to ~30 GHz when Bands 1 and 2 are deployed)*
Correlator: Total Bandwidth	*16 GHz (2 polarizations × 4 basebands × 2 GHz/baseband)*
Correlator: Spectral Resolution	*As narrow as 0.008 × (300/ν GHz) km/s*
Polarimetry	*Full Stokes parameters*



Band	Frequency (GHz)	Wavelength (mm)	Primary Beam (FOV; ″)
3	84-116	3.6-2.6	73-53
4	125-163	2.4-1.8	49-38
5	158-211	1.9-1.4	37-29
6	211-275	1.4-1.1	29-22
7	275-373	1.1-0.8	22-16
8	385-500	0.78-0.6	16-12
9	602-720	0.5-0.42	10-8.5
10	787-950	0.38-0.32	7.8-6.5

Why (sub)mm & ALMA?





Schinnerer et al. (2013)

galaxy = dark matter + stars + **ISM**

ISM = gas (H I, H II, H_2, He, C, N, O;
atoms + **molecules**)
+ dust (PAH, **grains**)

submm: extinction-free probe for
~1000 spectral lines from inter- &
circum-stellar medium and dust

From Y. Yang's slides

Galaxy Spectral Energy Distribution

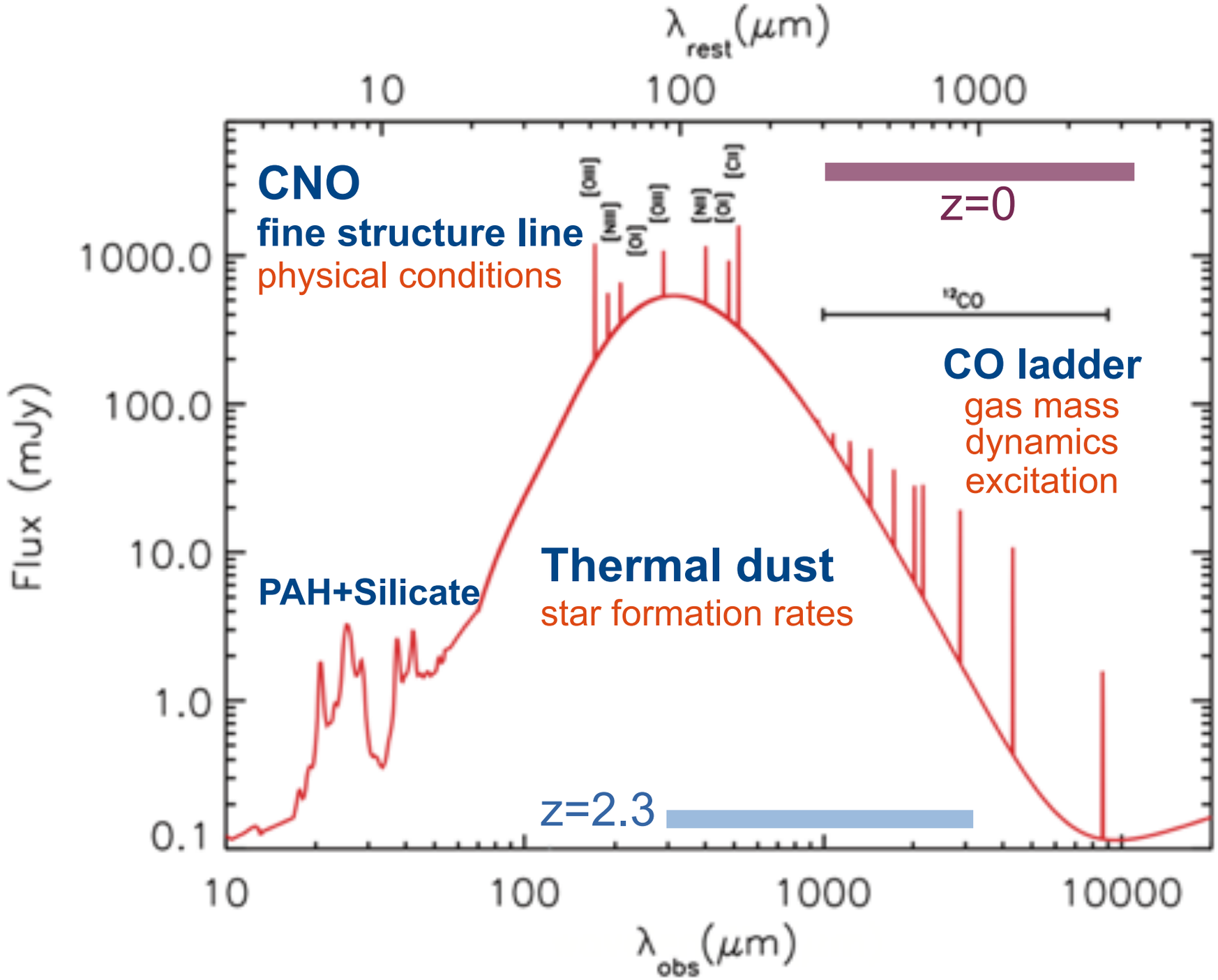


Figure from D. Riechers

From Y. Yang's slides

Level one science goals

While ALMA will revolutionize many areas of astronomy, the technical requirements of ALMA were driven by three Level One Science Aims:

I. The ability to detect spectral line emission from C+ in a normal galaxy like the Milky Way at a redshift of z = 3, in less than 24 hours of observation.

II. The ability to image gas kinematics in a solar-mass protostellar/protoplanetary disk at a distance of 150 pc (roughly, the distance of the star-forming clouds in Ophiuchus or Corona Australis), enabling one to study the physical, chemical, and magnetic field structure of the disk and detect the tidal gaps created by planets undergoing formation.

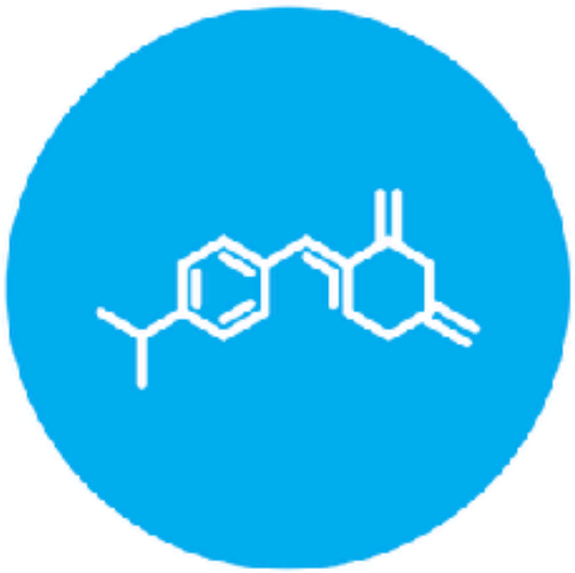
III. The ability to provide precise images at an angular resolution of 0.1″. Here the term "precise image" means an accurate representation of the sky brightness at all points where the brightness is greater than 0.1% of the peak image brightness. This requirement applies to all sources visible to ALMA that transit at an elevation greater than 20 degrees.

ALMA2030



ORIGINS OF GALAXIES

Trace the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2–4) by detecting their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.



ORIGINS OF CHEMICAL COMPLEXITY

Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100 au) by performing full-band frequency scans at a rate of 2-4 protostars per day.



ORIGINS OF PLANETS

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone (~ 1 au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

Large Programs

- To address strategic scientific issues that will lead to a major advance or breakthrough in the field

- **> 50 hours on the 12-m Array (with or without ACA)**
  > 150 hours on the ACA in stand-alone mode

- Not producible by a combination of Regular Proposals

- Must deliver high level products and relevant documentation following the management plan of the proposal

https://almascience.nrao.edu/alma-data/lp

https://almascience.nrao.edu/alma-data/lp

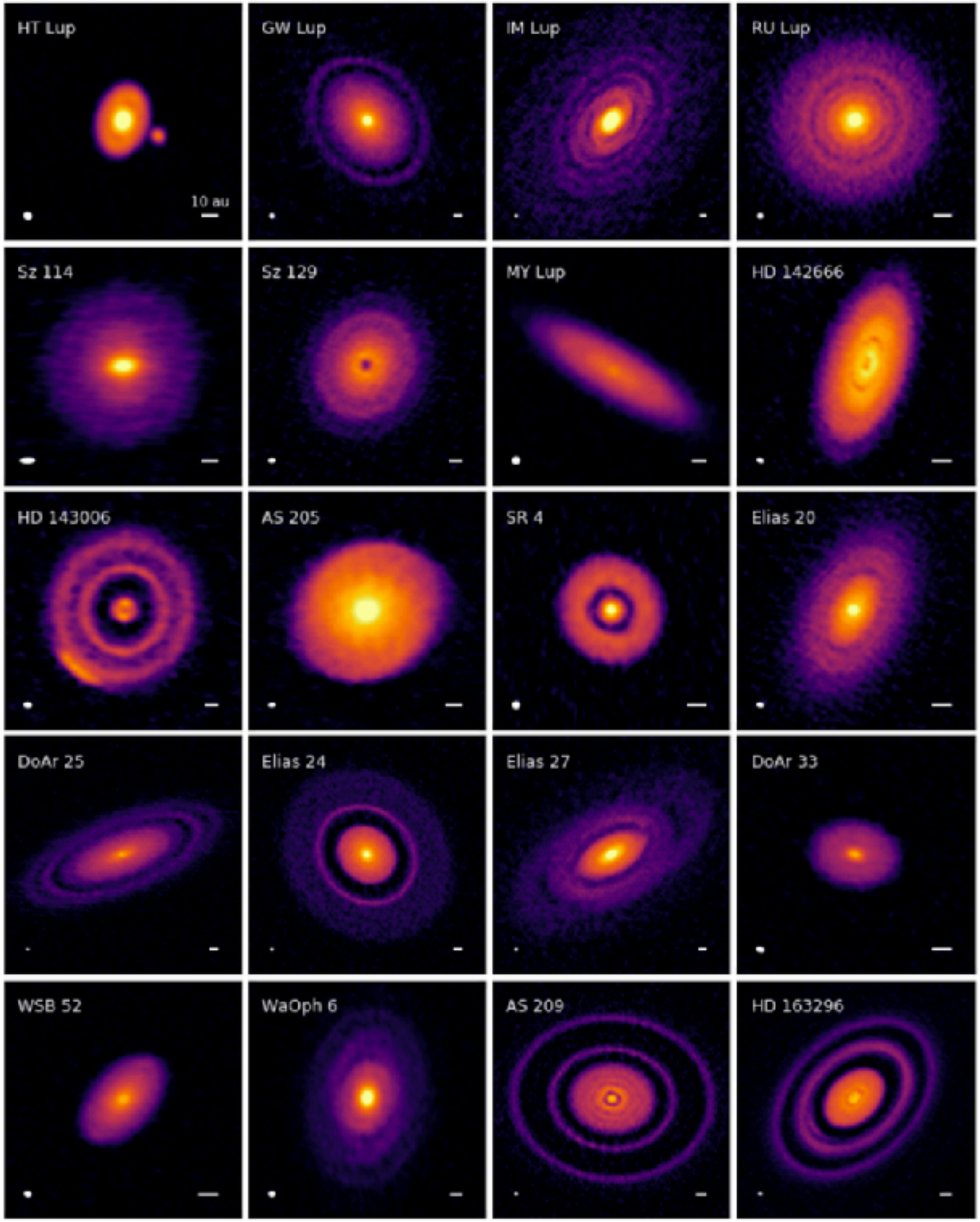
PIDs	Cycle		rimary Investigator - Institution
		Cosmology and High Redshift Universe	
2016.1.00324.L	4	ASPECS: The ALMA SPECtral line Survey in the UDF - An ALMA Large Program	Fabian Walter / MPIA Heidelberg
2017.1.00428.L	5	ALPINE: The ALMA Large Program to INvestigate CII at Early Times	Olivier Le Fèvre / Laboratoire D'Astrophy Marseille
2018.1.00035.L	6	ALMA Lensing Cluster Survey	Kotaro Kohno / University of Tokyo
		Galaxies and Galactic Nuclei	
2017.1.00886.L	5	100,000 Molecular Clouds Across the Main Sequence: GMCs as the Drivers of Galaxy Evolution	Eva Schinnerer / MPIA Heidelberg
2017.1.00161.L	5	ALCHEMi: the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory	Sergio Martin / IRAM
		ISM, Star Formation, and Astrochemistry	
2017.1.01355.L	5	ALMA_IMF: ALMA transforms our view of the origin of stellar masses	Frédérique Motte / CNRS
2018.1.01205.L	6	Fifty AU Study of the chemistry in the disk/envelope system of Solar-like protostars (FAUST)	Satoshi Yamamoto / Tokyo University
		Circumstellar Disks, Exoplanets, and the Solar System	
2016.1.00484.L	4	Small-Scale Substructures in Protoplanetary Disks	Sean Andrews / CfA Harvard
2018.1.01055.L	6	The Chemistry of Planet Formation	Karin Oberg / Harvard
		Stellar Evolution and the Sun	
2018.1.00659.L	6	ATOMIUM: ALMA Tracing the Origins of Molecular In dUst-forming oxygen-rich M-type stars	Leen Decin / K.U. Leuven

DSHARP

Disk
Substructures at
High
Angular
Resolution
Project

Sean Andrews et al. 2018:
10 ApJL papers,
posted at astro-ph
on Dec. 12, 2018

0.035” (5 au scales)
Band 6



Cycle 7

2019.1.00195.L ALMAGAL: ALMA Evolutionary study of High Mass Protocluster Formation in the Galaxy, Sergio Molinari

2019.1.00261.L Early Planet Formation in Embedded Disks, Nagayoshi N. Ohashi **“eDisk”**

2019.1.00763.L VERTICO: The Virgo Environment Traced in CO, Toby Brown

2019.1.01634.L REBELS: An ALMA Large Program to Discover the Most Luminous [CII]+[OIII] Galaxies in the Reionization Epoch, Richard RJ Bouwens

ALMA Cycle 8

- **Call for Proposals:** 4300 hours (12-m array), 3000 hours (ACA)
  - March 17 : release of CfP
  - April 15 : deadline

- New capabilities
  - Solar obs. in Band 5
  - VLBI obs. of faint science targets (< 500 mJy)
  - High-freq. obs. (Bands 9/10) with the stand-alone 7-m Array
  - Continuum linear pol. mosaicking (Bands 3 to 7)
  - Spectral scans with the 7-m Array

- Dual-Anonymous Proposal Review

ALMA Cycle 8

- **Townhall meetings**
  - KASI : March 19 Thursday, 2020
  - Seoul National University : March 26 Thursday, 2020
  - Yonsei University : March 27 Friday, 2020
  - Kyunghee University : TBD

- Technical capabilities
  - 12-m Array antennas > 43
  - 7-m antennas > 10, TP antennas > 3
  - Bands 3,4,5,6,7,8,9,10
  - C1 to C8 (8.5 km) for Bands 3 to 7, to C7 (3.6 km) for Bands 8,9,10
  - Spectral line & continuum obs. in all bands, mosaics (Bands 3 to 9), single disk spectral line obs. in Band 3 to 8
  - Polarization: single pointing in linear & circular pol. for both continuum & spectral line obs. in Bands 3,4,5,6,7 (12-m Array), mosaicking of continuum linear pol. ors. (Bands 3 to 7)

ALMA Summer School

- 2020.08.17—21
- SOAO
- Undergraduates
  to Postdocs
- Program
  Introduction to radio interferometry and ALMA
  ALMA data calibration and imaging
  Hands-on group projects with ALMA archive data
  Presentation

