Introduction of ALMA and ALMA Cycle 9 Capabilities

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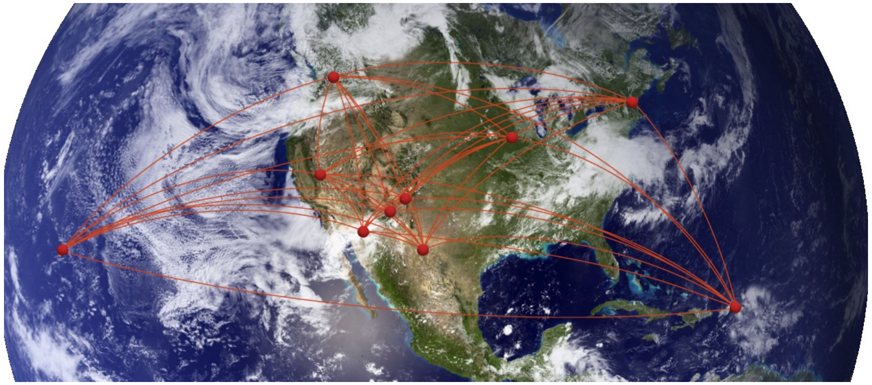
Ambassador	Location	Date
Wren Suess	Stanford University	28 March
Nathan Roth	University of Maryland	29 March
Hansung Gim	Montana State University	29 March
Cheng-Han Hsieh	Yale University	30 March
Tarraneh Eftekhari	Northwestern University	1 April
Hansung Gim	University of Alabama	2 April
Allison Towner	University of Florida	5, 7, 8 April
Fengwu Sun	University of Arizona	8 April

The ALMA Ambassadors will also host several webinars for people unable to attend one of the workshops. The talks, dates, and registration links for the webinars are listed below. Webinars are planned in both English and Spanish.

Title	Date
ALMA Basics and Cycle 9 Capabilities	30 March @ 4pm ET
Cycle 9 Proposal Preparation & the Proposal Review Process	31 March @ Noon ET
ALMA Basics and Cycle 9 Capabilities	5 April @ 2pm ET
Cycle 9 Proposal Preparation & the Proposal Review Process	5 April @ 4pm ET
Fundamentos de ALMA y Capacidades del Ciclo 9 / ALMA Basics and Cycle 9 Capabilities (in Spanish)	6 April @ 12pm ET
Planificación de propuestas y proceso de revisión de propuestas / Proposal Planning and the Proposal Review Process (in Spanish)	7 April @ 12pm ET

https://science.nrao.edu/enews/15.3/index.shtml#alma_ambassadors

National Radio Astronomy Observatory



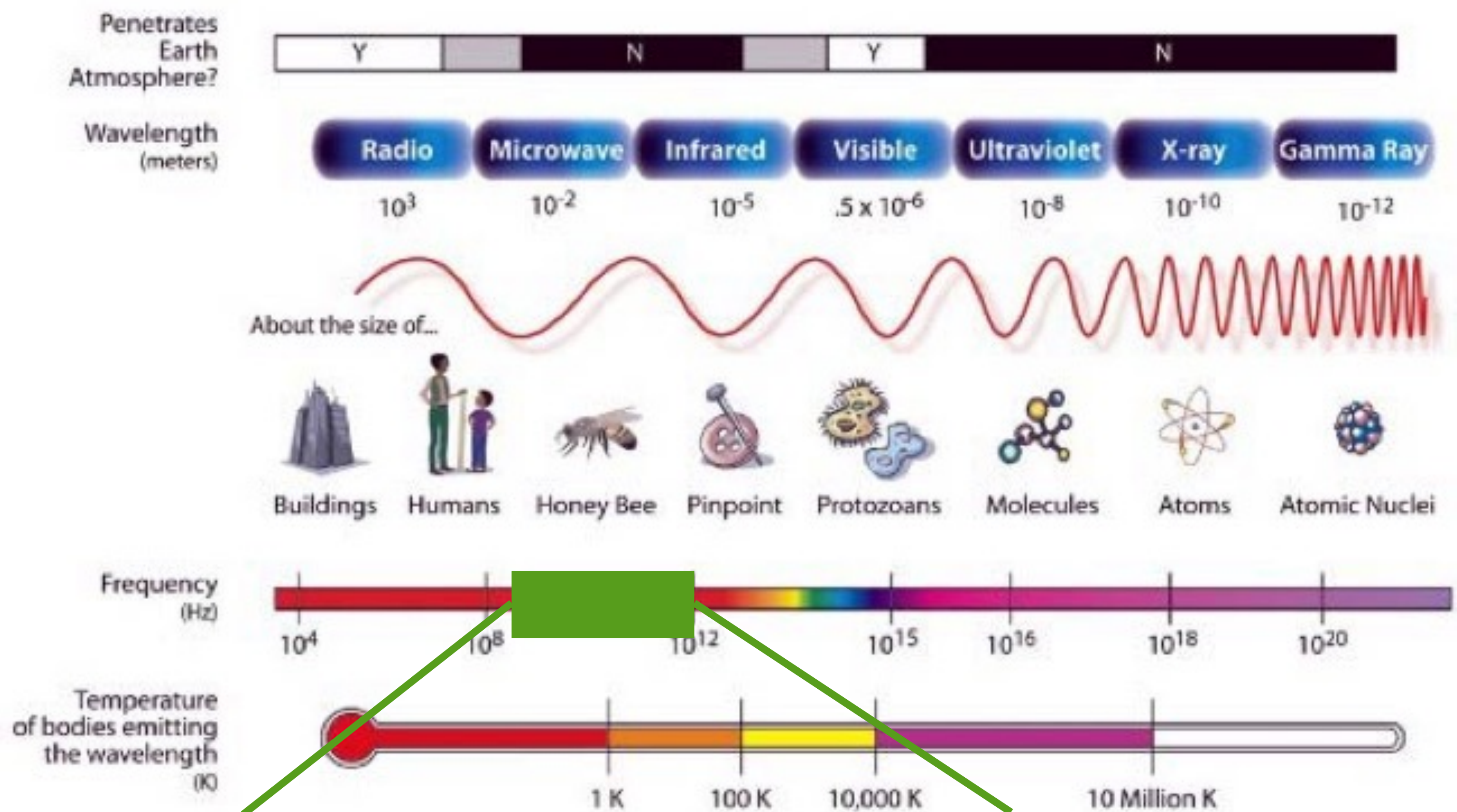
Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Very Long Baseline Array

NRAO:
One Observatory, Three World Class Facilities

Other Affiliated Telescopes and Observatories include the Green Bank Observatory (http://greenbankobservatory.org/). The VLBA was incorporated back into NRAO last year.

NRAO:
One Observatory, Three World Class Facilities

Atacama Large Millimeter/submillimeter Array:
a 66-antenna array in Chile


Penetrates Earth Atmosphere?
Y
N
Y
N
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^3
10^-2
10^-5
.5 x 10^-6
10^-8
10^-10
10^-12
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20
Temperature of bodies emitting the wavelength (K)
1 K
100 K
10,000 K
10 Million K


VLA
~1 - 50 GHz
~300 - 6 mm


ALMA
~84 - 950 GHz
~3 - 0.3 mm

Broad Science Topics with NRAO Telescopes

- Sun – coronal mass ejections, magnetic field activity
- Solar system, KBOs – atmospheres, astrometry, composition
- Star-forming regions – dust and gas environment, kinematics (infall, outflows, jets), proto-planetary disks, cores, chemistry, feedback, and natal cloud / star interactions
- Exoplanets – direct imaging, gaps in disks, kinematics
- Pulsars – neutron star physics, pulse morphology, gravity, ISM probe
- Galactic structure – spiral arms, bars, global atomic and molecular gas properties
- Nearby galaxies – molecular / atomic gas content and kinematics, dynamics of galaxies at high resolution, star formation, obscured SF, gas flow
- Galaxy groups and clusters – atomic and molecular gas across systems, star formation efficiency, kinematics, dynamical mass measurements
- Black holes – mass measurements, kinematics
- High redshift galaxies – extragalactic background light, source counts, star formation history and efficiency, evolution of gas content (atomic and molecular)
- Cosmology – H_0 measurement, SZE

What is ALMA?

- A global partnership to deliver a revolutionary millimeter/submillimeter telescope array (in collaboration with Chile):
  - North America
  - Europe
  - East Asia
- 66 reconfigurable, high precision antennas, λ ~ 0.32–8.5 mm. **Band-1/2 still in progress!**
- Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations
  - Main Array: 50 x 12m antennas
  - Total Power Array: 4 x 12m antennas
  - Atacama Compact Array (ACA): 12 x 7m antennas
  - TP + ACA (Morita Array)
- Array Operations Site is located at 5000m elevation in the Chilean Andes;
- Provides unprecedented imaging & spectroscopic capabilities at (sub-)mm.

What is ALMA?

- Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations:

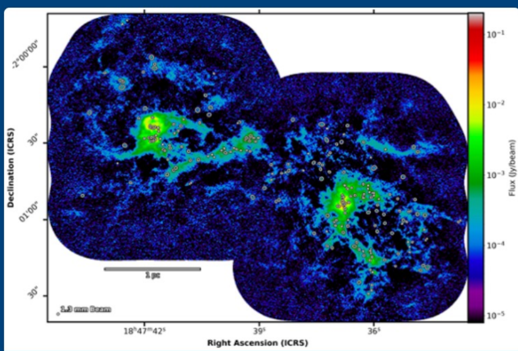
http://youtu.be/YMISe-C8GUs

Atacama Large Millimeter/submillimeter Array
In search of our Cosmic Origins

About | Science | Proposing | Observing | Data | Processing | Tools | Documentation | Help

Science Highlight

Top-heavy Core Mass function revealed by ALMA-IMF: a challenge to the IMF universality



The W43-MM2&MM3 protocluster cloud, as imaged at 1.3 mm by the ALMA 12 m array. White ellipses outline the size of the 208 compact cores of few thousand AU size extracted by the core extraction algorithm getsf.

Observatory News

ALMA Cycle 9 Call for Proposals is Now OPEN!
Mar 24, 2022

ALMA Science Archive previews
Feb 14, 2022

QA0+ results now available from SnooPI
Jan 31, 2022

ALMA Cycle 9 Pre-Announcement
Dec 15, 2021

ALMA Science Archive object-type search, text-based similarity search and Jupyter Notebooks
Dec 14, 2021

More…

ALMA Status

Configuration Schedule

Refereed publications: 2712
Last observed source: Sgr_A_star
Current configuration: C-2

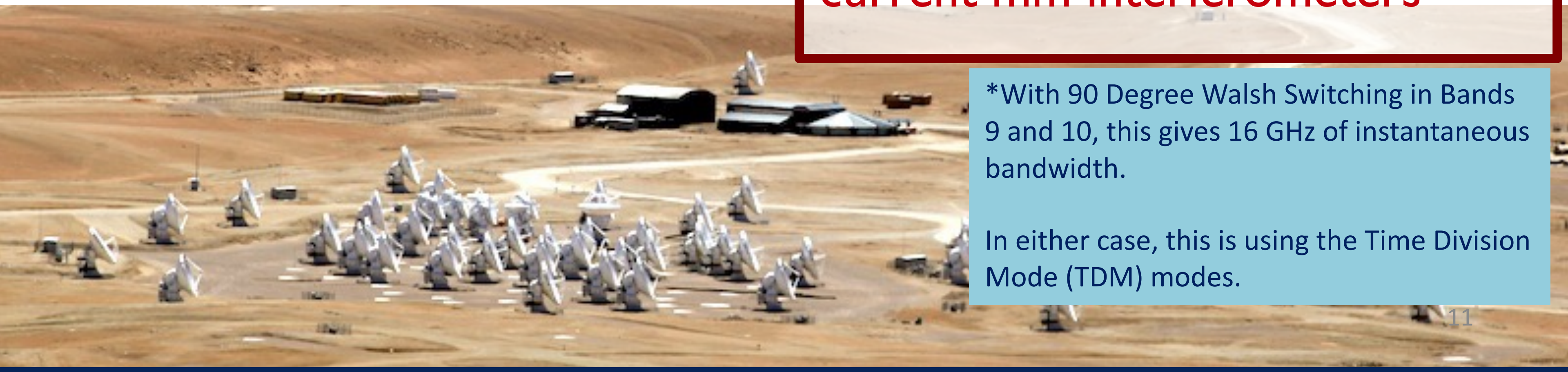
More...

ALMA is a telescope for *all* astronomers

ALMA in a Nutshell...

- Angular resolution down to 0.015" (at 300 GHz)
- Sensitive, precision imaging 84 to 950 GHz (3 mm to 320 µm)
- State-of-the-art low-noise, wide-band receivers* (8 GHz bandwidth)
- Flexible correlator with high spectral resolution at wide bandwidth
- Full polarization capabilities including circular.
- Estimated 1 TB/day data rate
- All science data archived
- Pipeline processing

ALMA is10-100 times more sensitive and has 10-100 times better angular resolution than current mm interferometers*



*With 90 Degree Walsh Switching in Bands 9 and 10, this gives 16 GHz of instantaneous bandwidth.

In either case, this is using the Time Division Mode (TDM) modes.

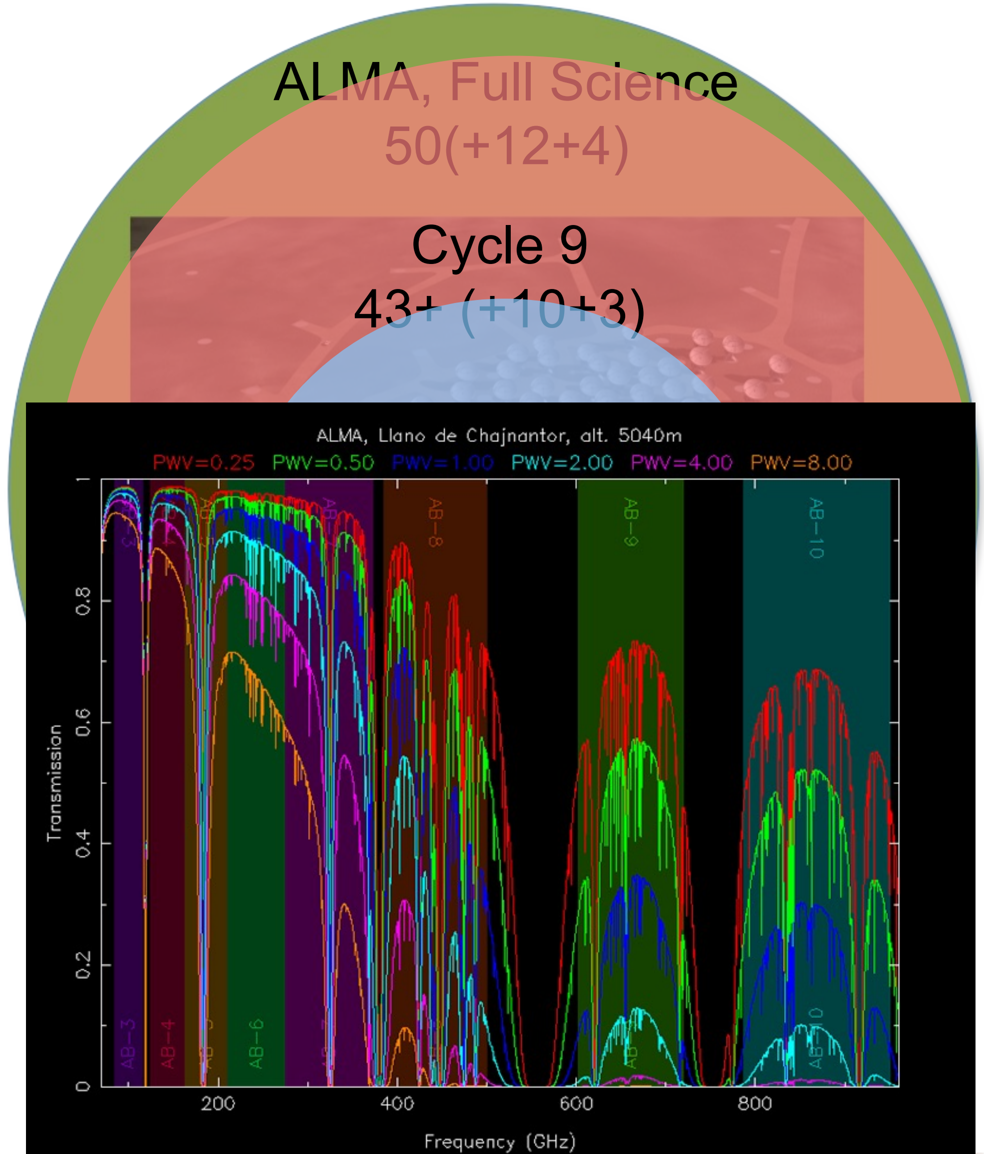
What is ALMA?

Collecting Area

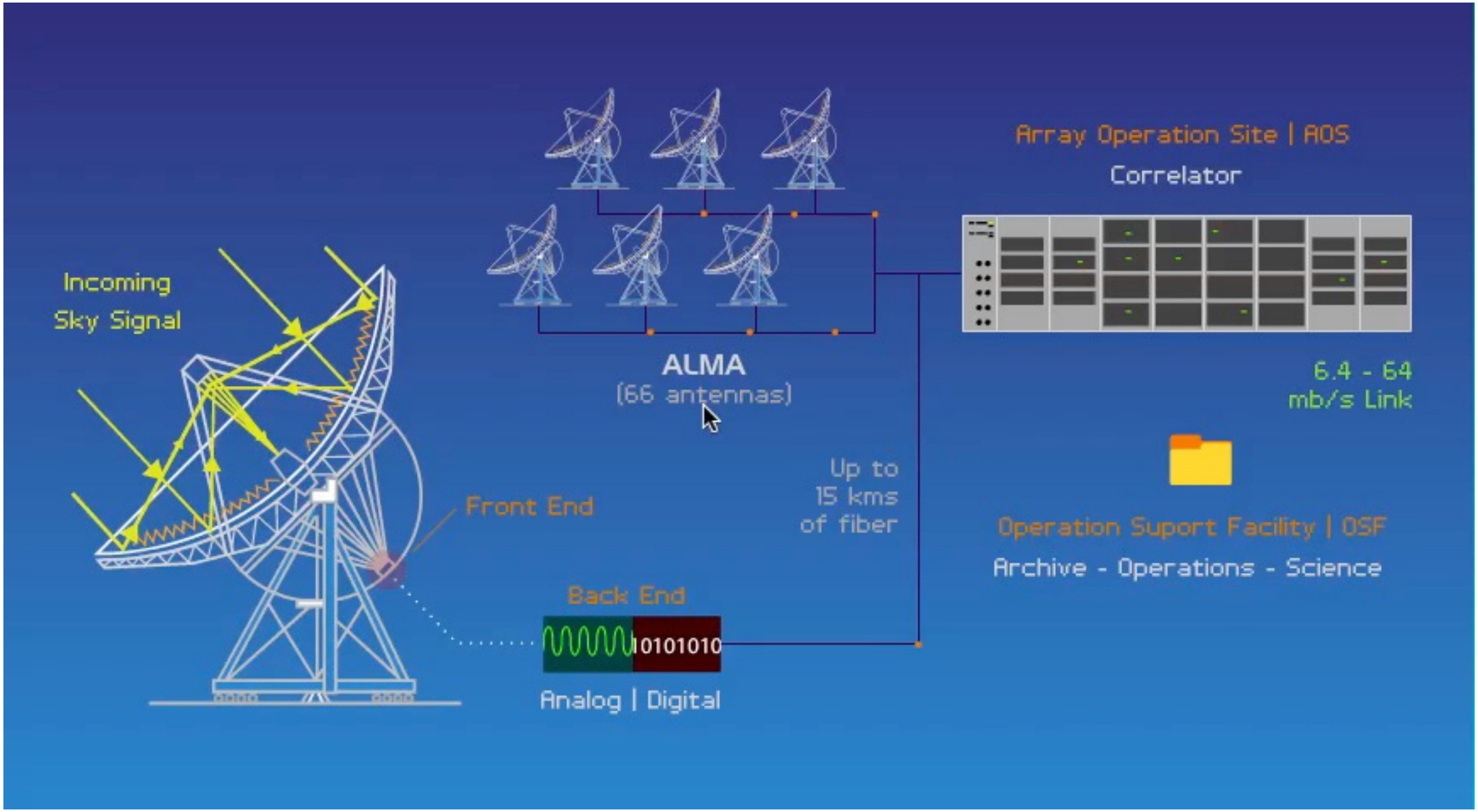
Not only sensitivity but the collecting area (1.6 acres or 6600+ m2) + huge number of baselines provides excellent image fidelity

Spectral Coverage - Covers ten atmospheric windows with 50% or more transmission above 35 GHz

https://almascience.nrao.edu/proposing/about-alma/atmosphere-model

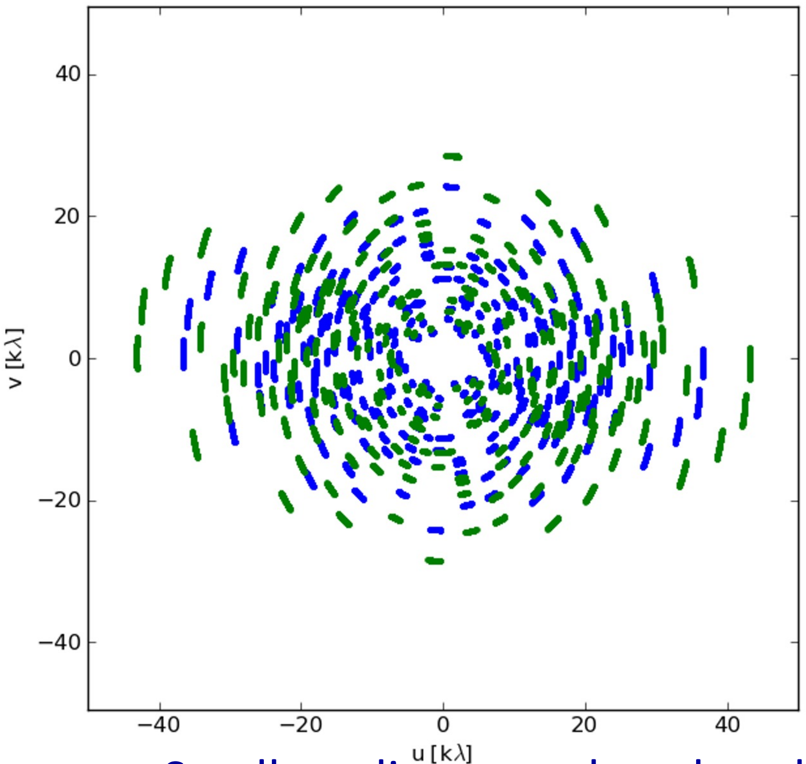


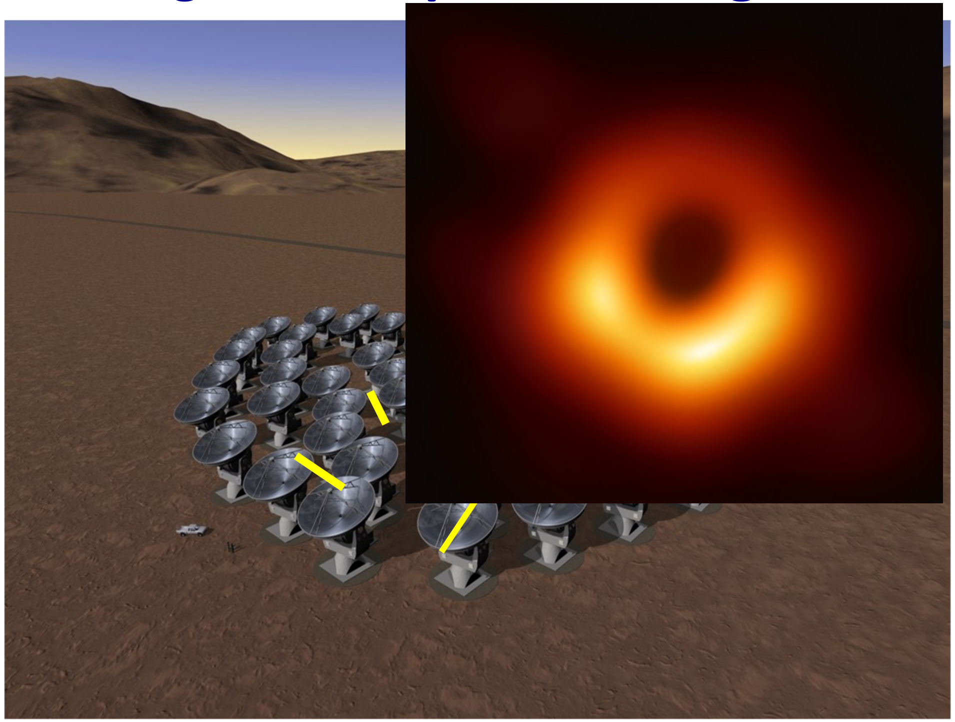
ALMA as an Interferometer in Action



Interferometry Basics: *uv-plane Sampling*

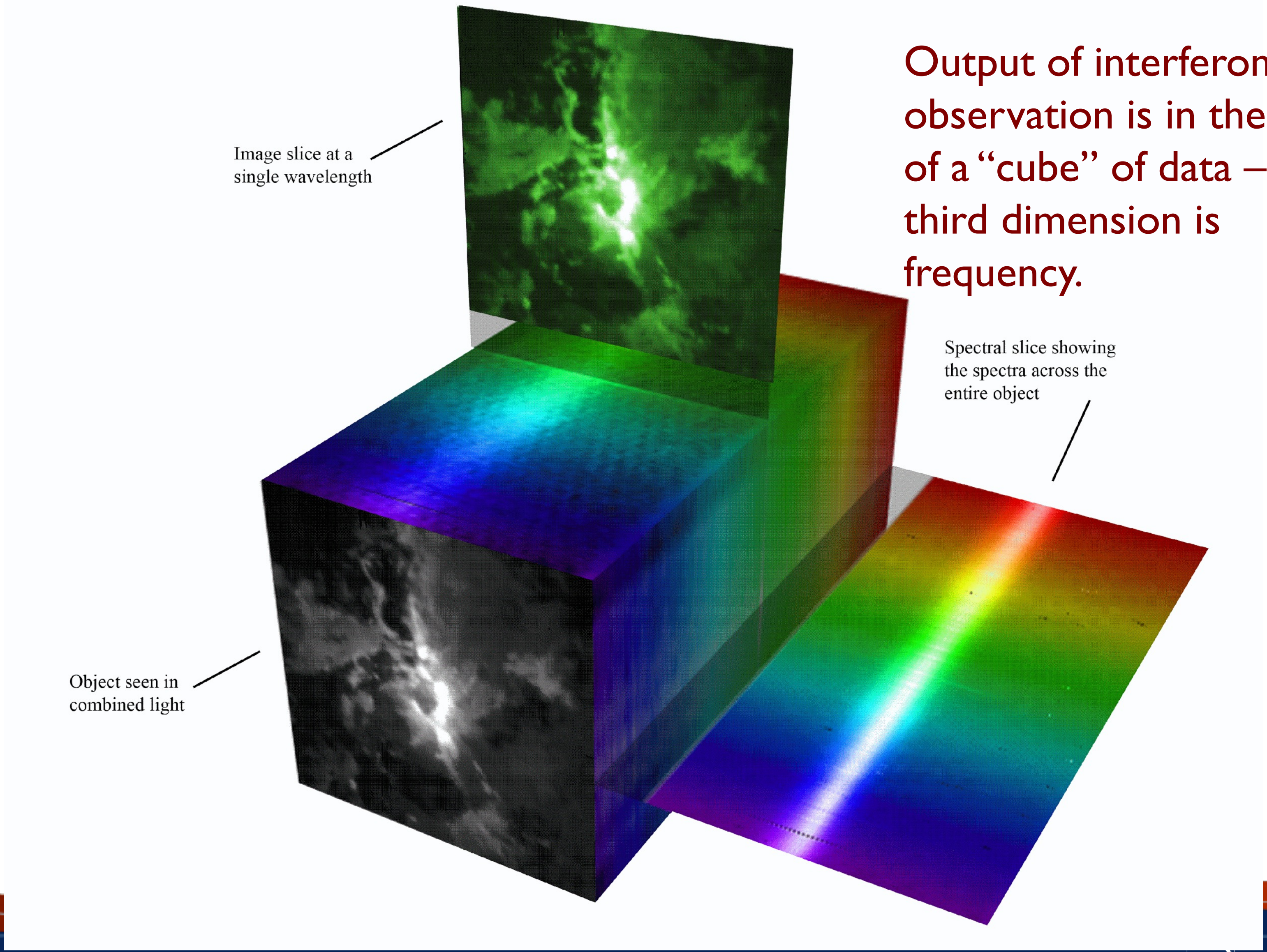
Each antenna pair samples only one spot; the array cannot sample the entire Fourier/uv domain resulting in an **imperfect image**





Small uv-distance: short baselines (measure extended emission)
Long uv-distance: long baselines (measure small scale emission)
Orientation of baseline also determines orientation in the uv-plane

Interferometry Basics: *3D Data Cube*



Output of interferometric observation is in the form of a "cube" of data – the third dimension is frequency.

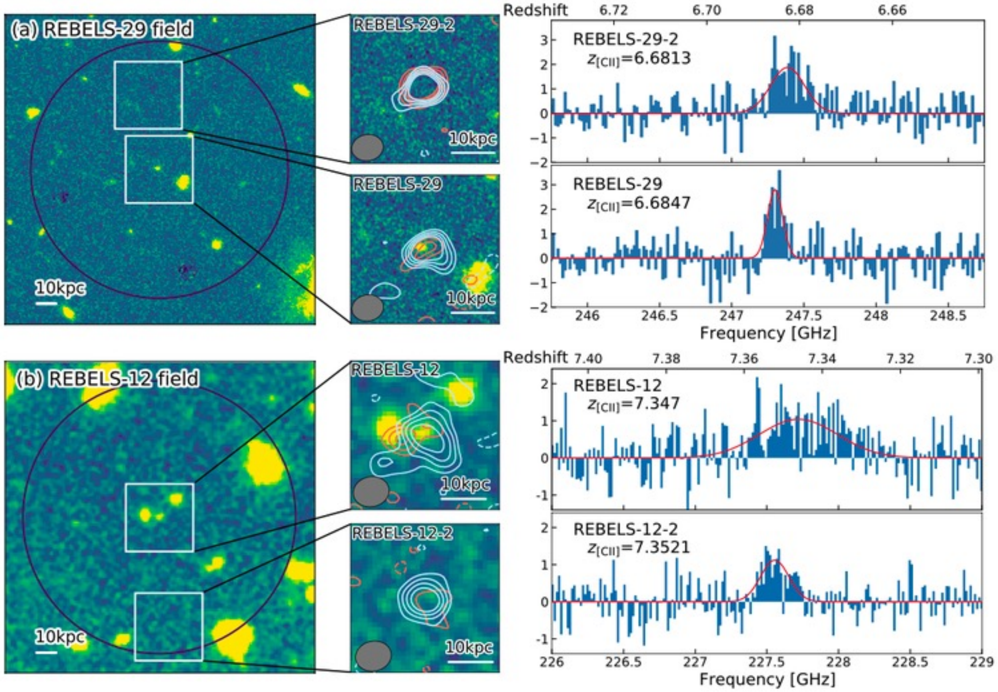
ALMA Current Status

- Construction Project ended in September 2014
- Routine science observing has been out to **greater than 16 km baselines (C-10)** thanks to the highly successful Long Baseline Campaigns in 2014 and 2015
- **All 66 antennas accepted**
  - Currently all 66 antennas are at the high site (AOS), of which ~47 on average (up to max ~66) are being used for Cycle 9 observations
  - Some construction and verification items remain to be finished (e.g., wide-field polarization; various observing modes)
- The ACA (Atacama Compact Array) or Morita Array – up to 12x7m antennas and 4x12m antennas for TP observations – is currently being used for observations
- More on Capabilities later… however, first on to science!
- Array configuration circulates every 2 years* – this cycle is for very long baseline!

Cosmology & High-Redshift Universe

Normal, Dust-Obscured Galaxies in the Epoch of Reionization

Fudamoto+REBELS team, 2021, *Nature*



- As part of the ongoing Cycle-7 ALMA large program **REBELS** (Reionization-Era Bright Emission Line Survey), 40 UV-luminous primary targets were observed at z > 6.5.
- Fudamoto et al. report two additional emission line neighbors found after inspecting the ALMA data cube of two primary targets.
- The images on the left show [CII] 158 μm line and dust emission detections for (a) the REBELS-29 field at z~6.68 and (b) the REBELS-12 field at z~7.35. Background images are HST F140W and VIDEO J-band, respectively. Solid red and light blue contours are the continuum and [CII] moment-0 maps, respectively. The continuum subtracted [CII] spectra are shown on the right.

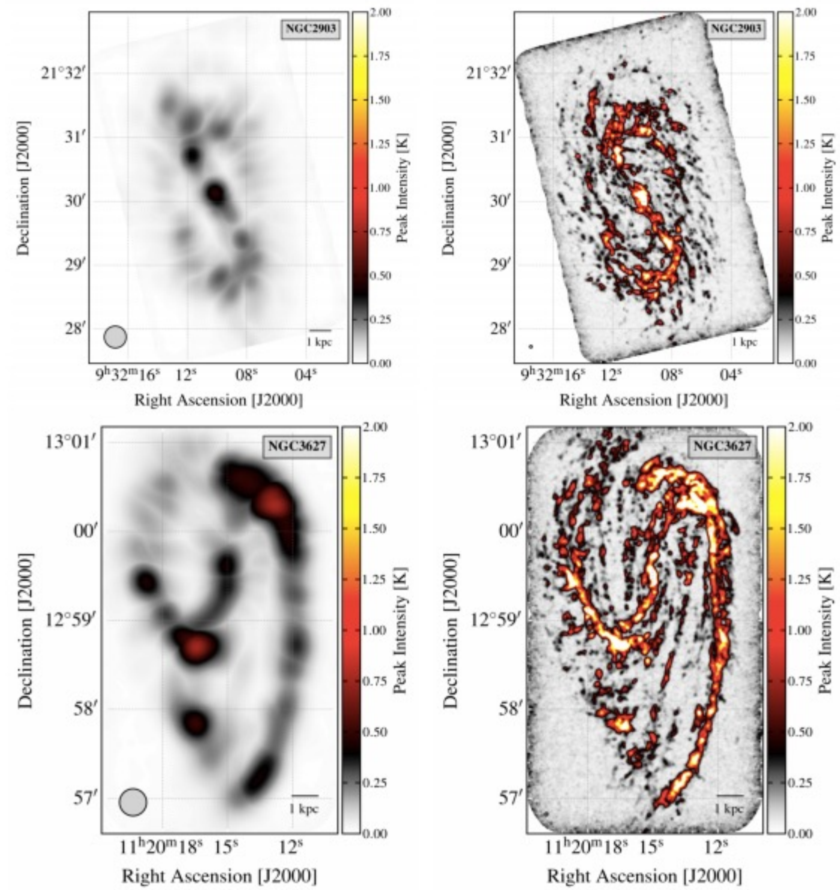
- The two sources were found serendipitously as companions to the central, UV-luminous targets, with emission lines at almost exactly the same frequencies as the central targets, accompanied with dust continuum emission at the same location. Their spatial and spectral proximity, and absence in optical/NIR images confirms these companions as **unexpected, dusty star forming sources in the epoch of reionization**.

Galaxies & Galactic Nuclei

PHANGS-ALMA: Arcsecond CO(2-1) Imaging of Nearby Star-Forming Galaxies

Leory+PHANGS team, 2021, *ApJS*

- **81 targets** with the combined 12-m, 7-m, and total power arrays and **9 targets** with the 7-m array or combined 7-m plus total power arrays in data gathered over ~6 years.
- Measure the demographics of molecular clouds, and measure how GMC populations depend on host galaxy and location in a galaxy.
- Measure the motions, flows, and organization of cold gas in galaxies at 100−1,000 pc scales.
- Measure the star formation efficiency per free fall time, at cloud scales. Measure how ff depends on the density, dynamical state, and turbulence in molecular clouds.
- Measure how the self-regulated, large scale structure of galaxy disks emerges from a medium made of individual clouds and star-forming regions.

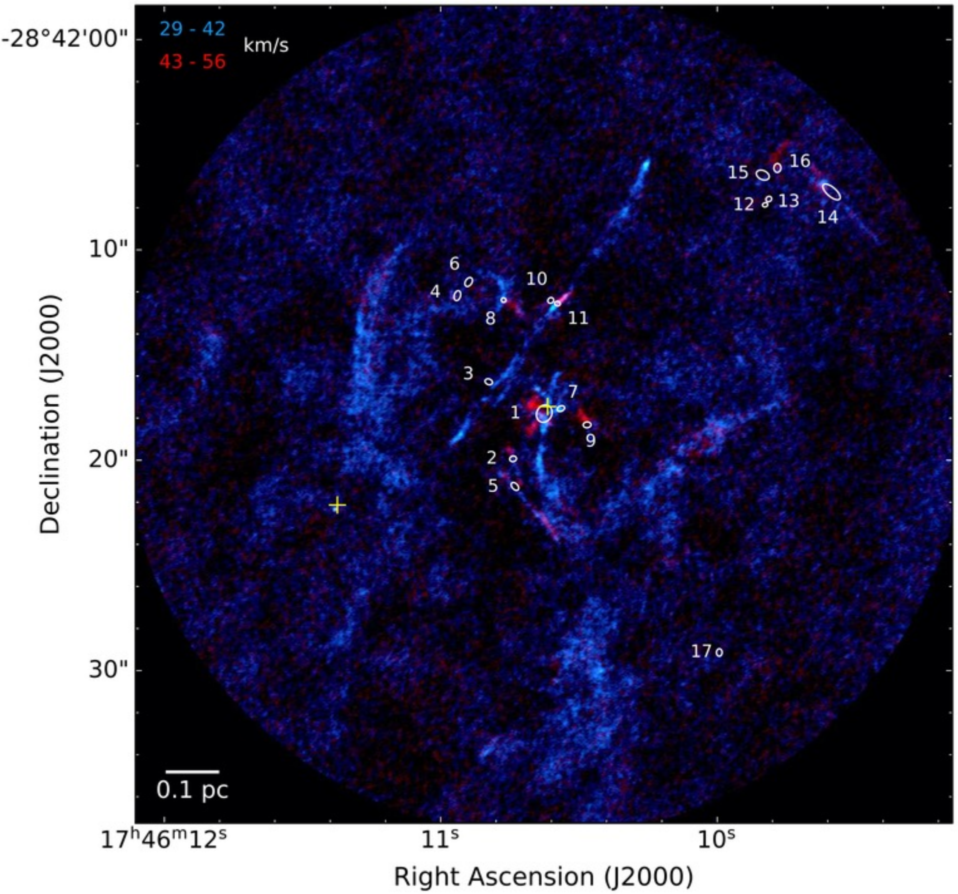


CO(2-1) at kpc resolution of previous surveys, and the cloud-scale resolution of PHANGS.

ISM, Star Formation & Astrochemistry

An Active Protocluster in the Massive, Dense Galactic Center Cloud G0.253+0.016

Walker+, 2021, *MNRAS*



Band 6 continuum sources and SiO(5-4) outflows in G0.253+0.016

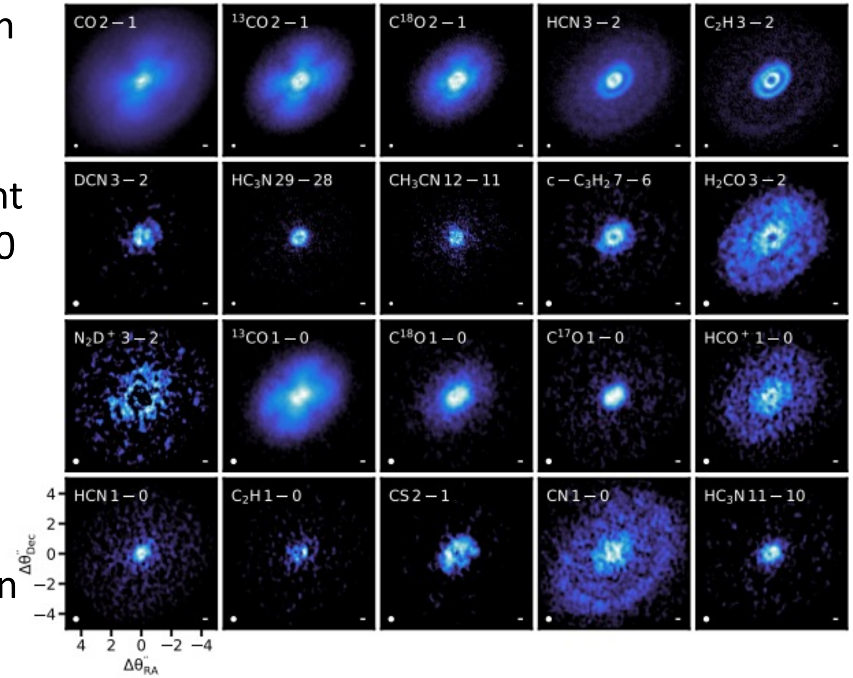
- High-resolution (~ 1000 AU resolution) ALMA Band 6 observations detects dust continuum sources and SiO outflows in G0.253+0.016, one of the most massive (> 10^5) and dense (> 10^4 cm^{-3}) molecular clouds in the Central Molecular Zone (CMZ).
- The CMZ has a substantially lower star formation rate than analogs in nearby galactic disk environments. 18 continuum sources are detected, and despite the high density of molecular cloud, no high-mass protostars were detected (median mass is 2 M_{sun}).
- However, 9 of the continuum sources have **outflows traced in SiO(5-4)** with properties similar to **intermediate to high-mass star formation**. The dynamical ages of the outflows are estimated to be 10^3 yr old. Thus, these source are young and may accrete sufficient mass to ultimately form intermediate-to-high-mass stars.

Circumstellar Disks, Exoplanets & the Solar System

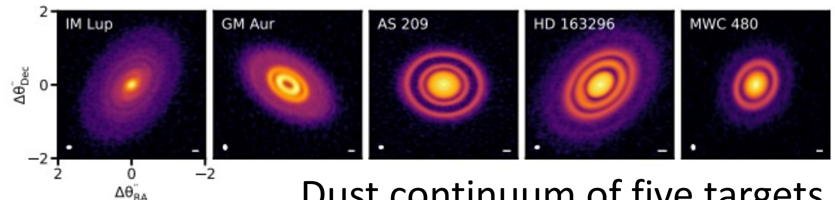
Molecules with ALMA at Planet-forming Scales (MAPS)

Oberg+MAPS team, 2021, *ApJS*

- Five sources (three lower mass; two higher) imaged in 20 molecular lines show ***astonishing spectral and spatial diversity of form***!
- All molecules surveyed at (7–30 au) resolution present substructures, enabling the identifications of over 200 rings, gaps and plateaus!
- Disk gas form, kinematics and chemical composition properties are found to vary substantially on small scales in disks, and therefore **planets may form in chemically distinct environments**.
- MAPS spatial scales constrained disk vertical emission and temperature profiles. The resulting empirical 2D temperature structures are key to anchoring disk models, and constrain the temperatures of the planet forming disk mid-planes.
- CO gas-phase abundances vary dramatically, depleted by 1–2 orders of magnitude at most disk locations.



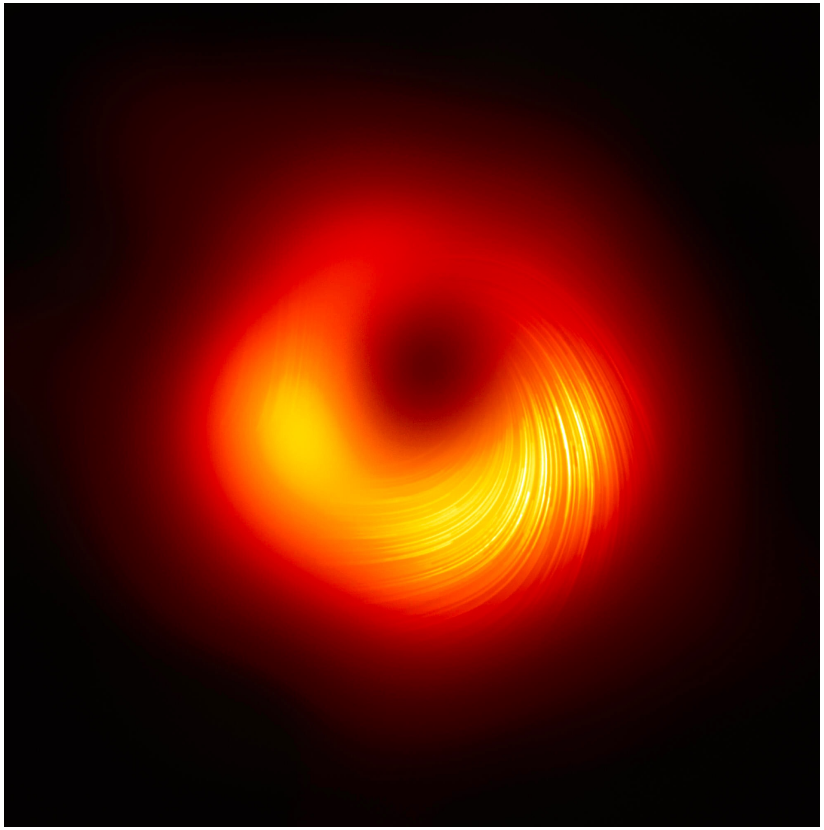
HD163296 in the light of 20 molecular transitions



Dust continuum of five targets

First M87 Event Horizon Telescope Results. VII. Polarization of the Ring

EHT Collaboration, 2021, *ApJL*



- Event Horizon Telescope (EHT) observed the near-horizon region around the supermassive black hole at the core of the M87 galaxy.
- The image on the left presented the corresponding linear-polarimetric EHT images of the center of M87. **Only a part of the ring is significantly polarized.**
- The resolved fractional linear polarization has a maximum located in the southwest part of the ring, where it **rises to the level of ~15%.**
- Evidence is presented for the **temporal evolution of the polarized source structure over one week** of EHT observations.
- These polarimetric images carry information about the structure of the magnetic fields responsible for the synchrotron emission.

ALMA Cycle 9 Capabilities