ALMA Proposal Preparation Tutorials

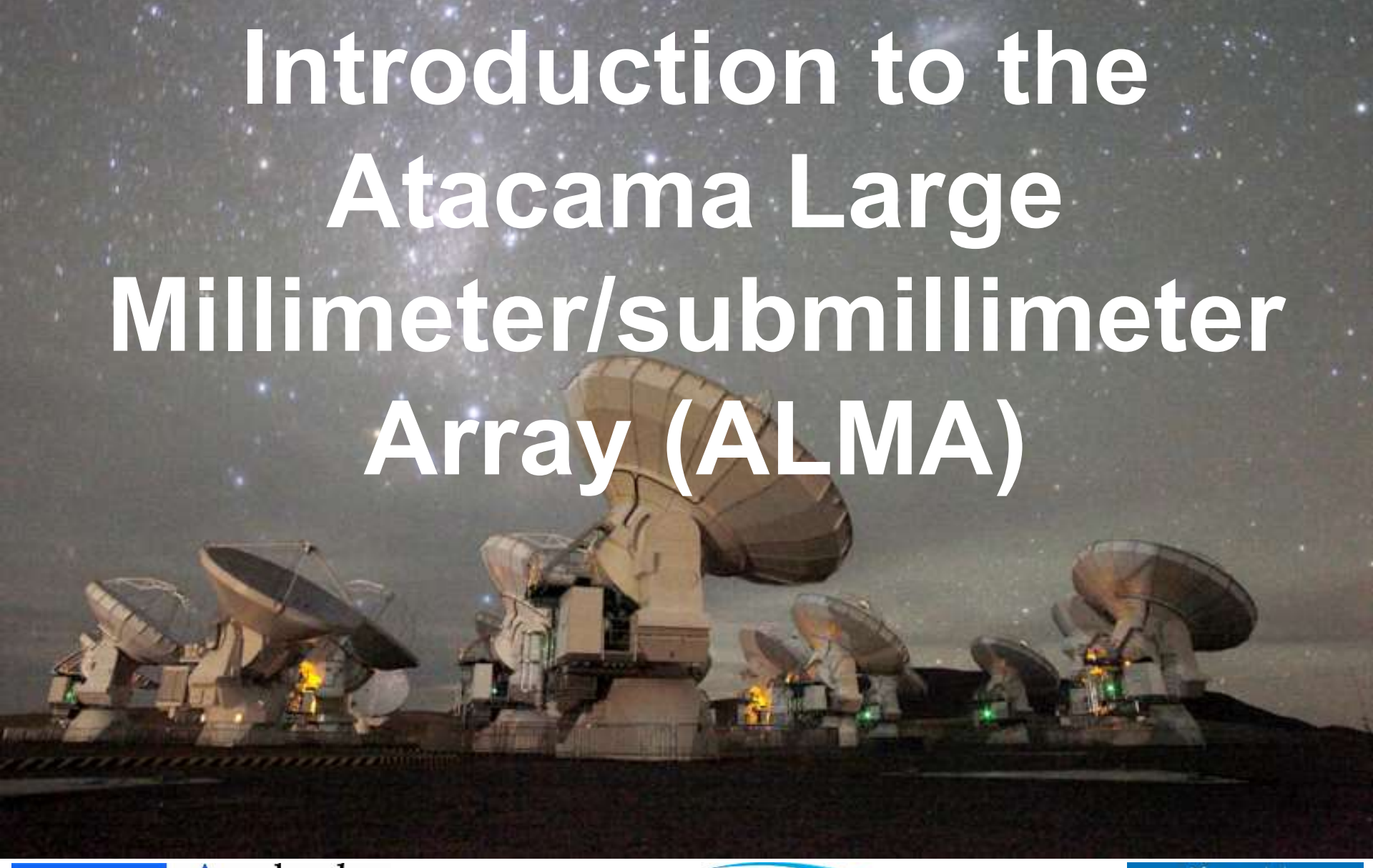
Argelander-Institut für Astronomie

ALMA

EUROPEAN ARC
ALMA Regional Centre || Germany

ph1 Universität zu Köln

Introduction to the Atacama Large Millimeter/submillimeter Array (ALMA)



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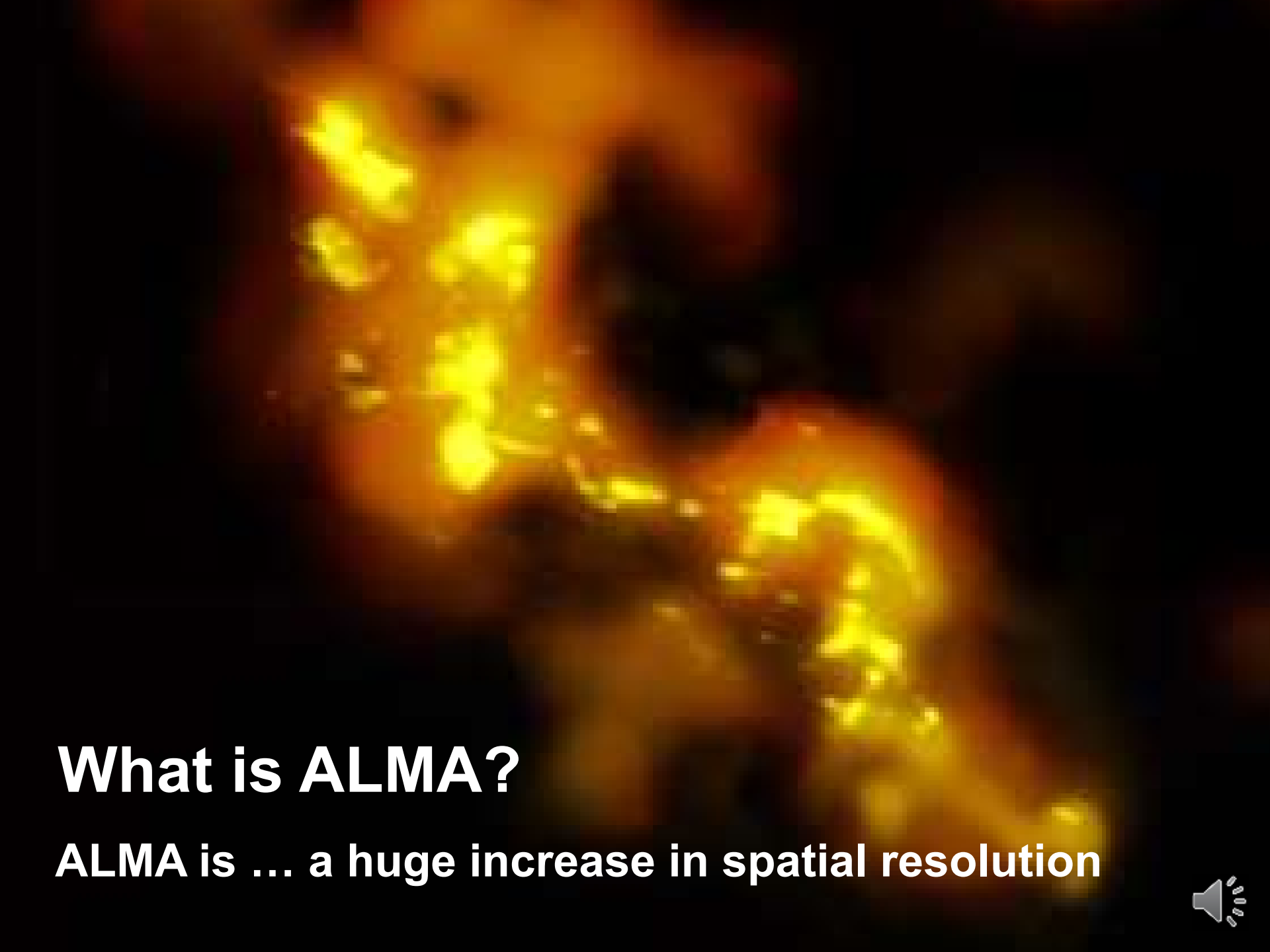
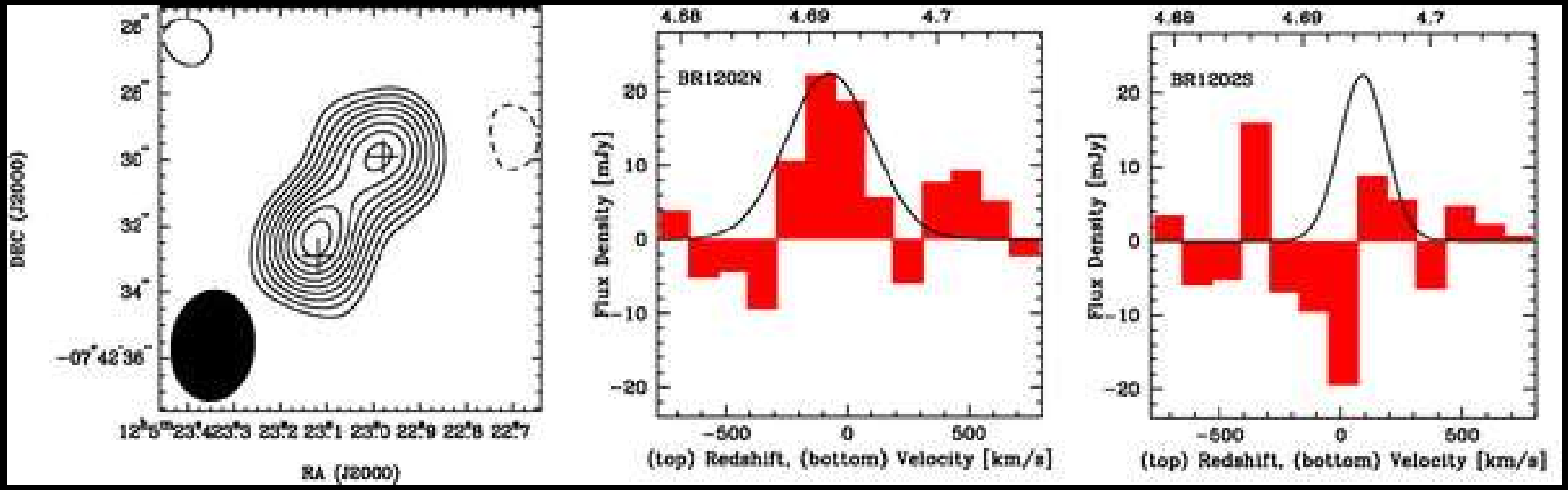


What is ALMA?

ALMA is … a huge increase in spatial resolution

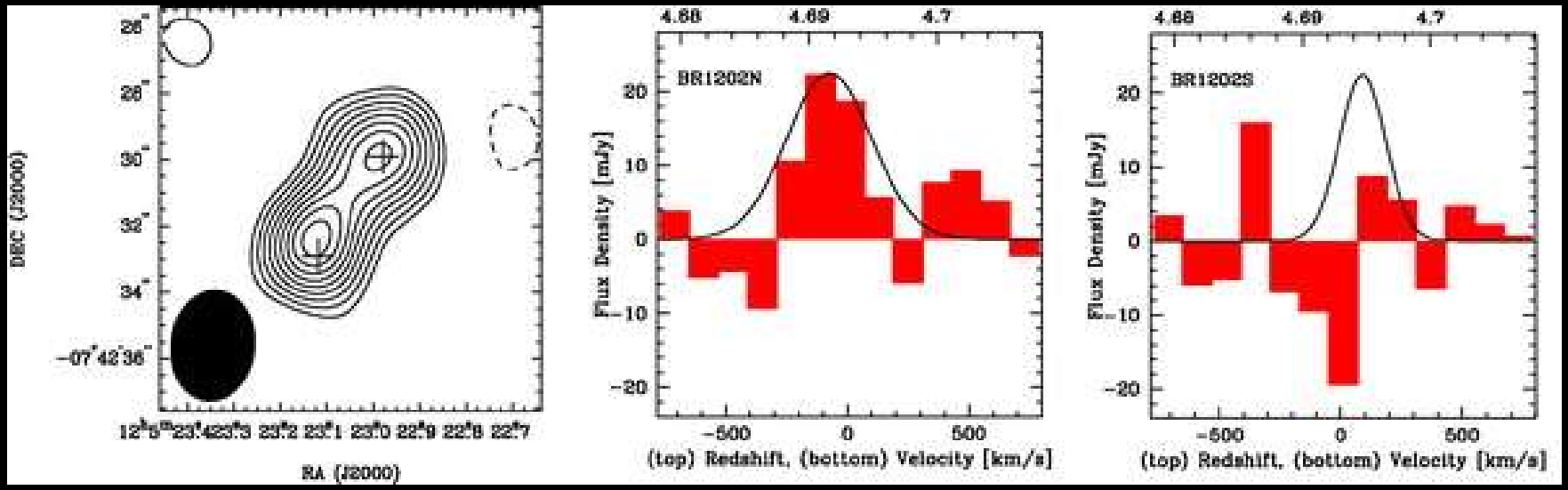
What is ALMA?



BR1202-0725, a pair of gas-rich galaxies at z=4.7 (SMA, Iono 2006)

ALMA is …

What is ALMA?



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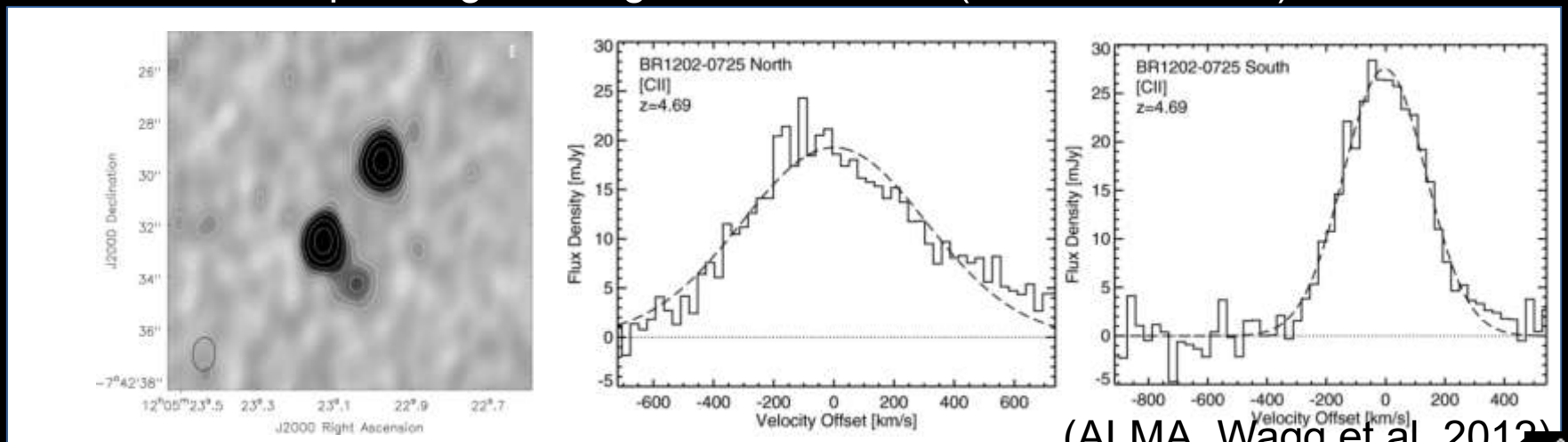
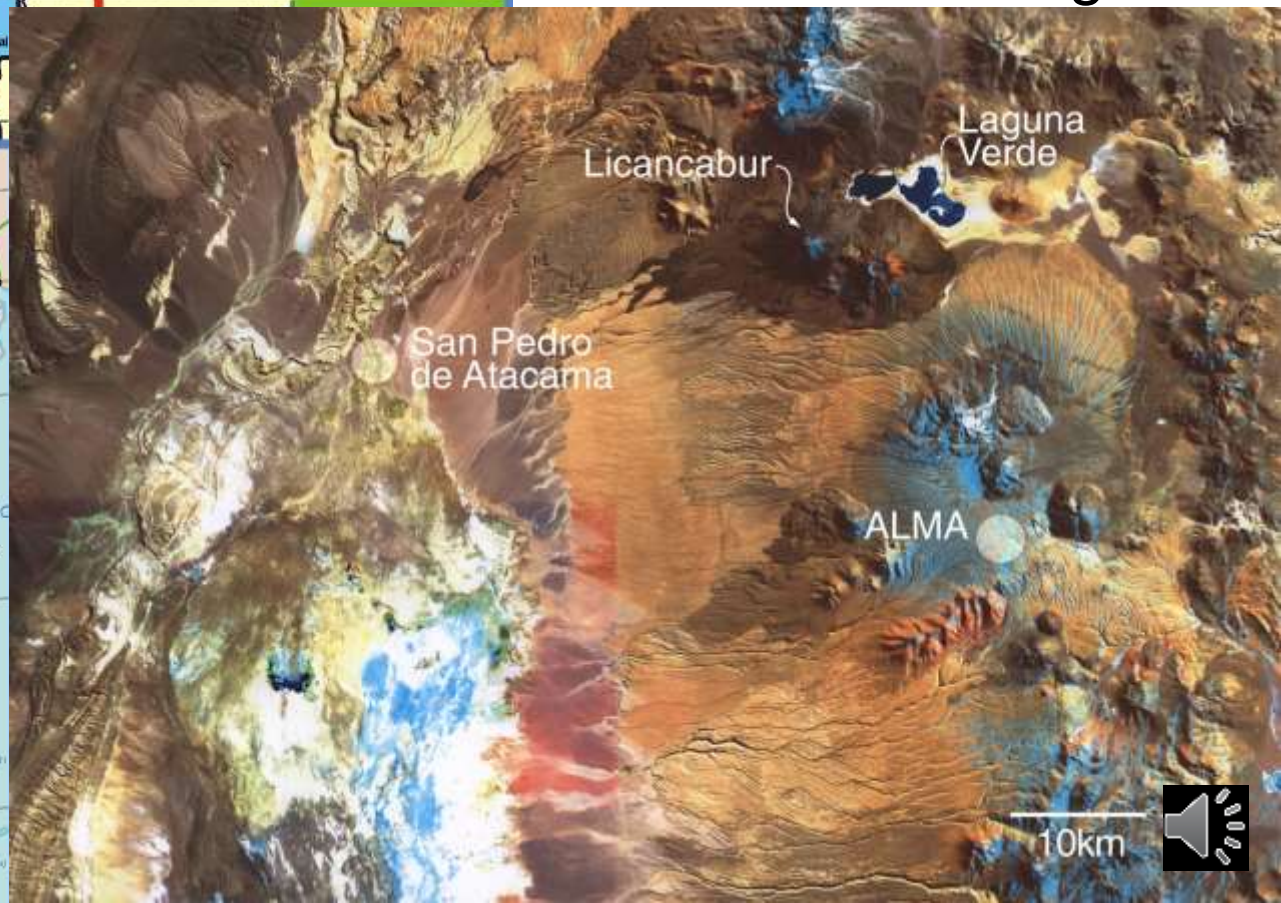


(ALMA, Wagg et al. 2012)

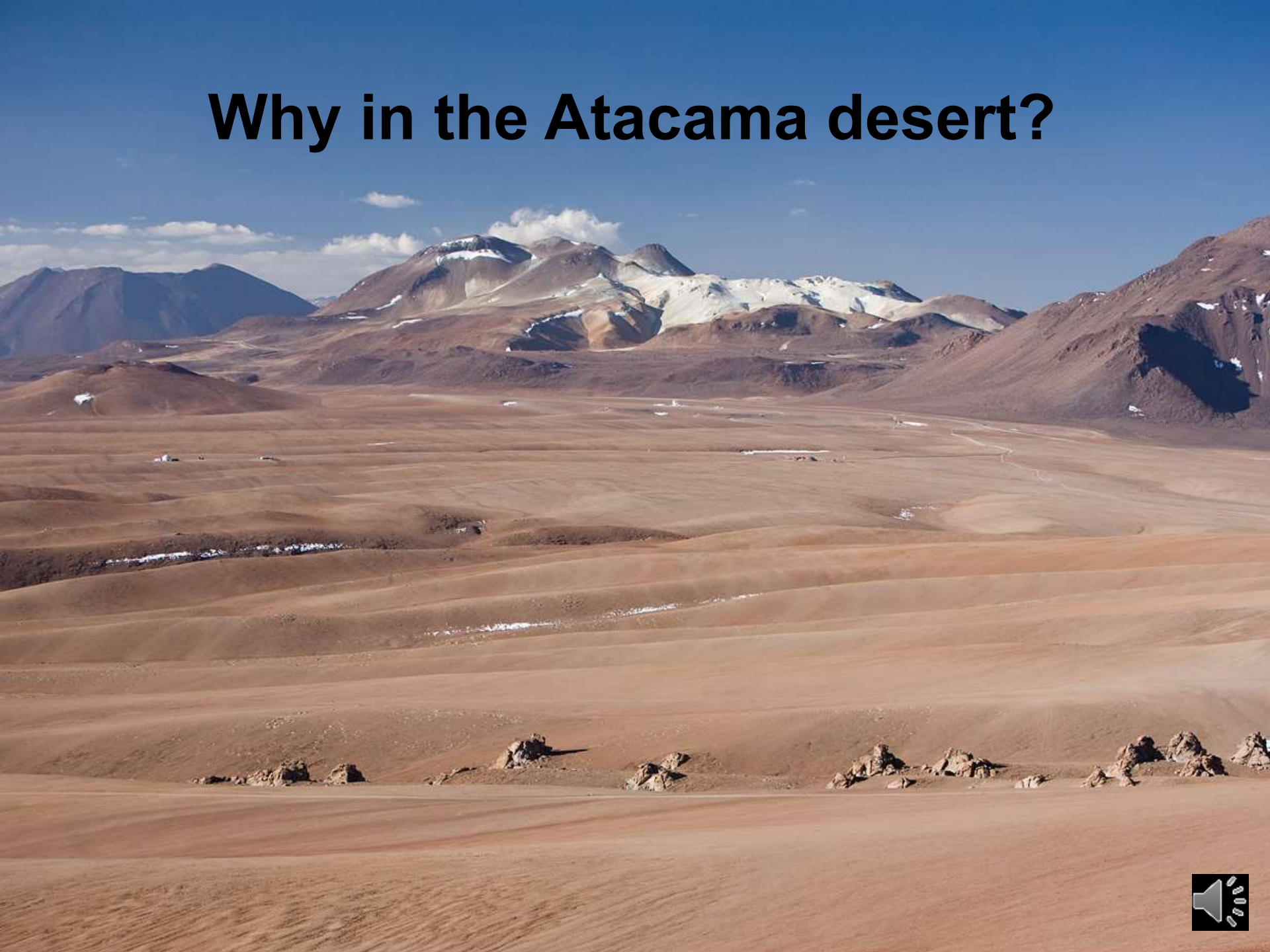
ALMA is … a huge increase in sensitivity

Location

- Chajnantor plain (AOS), Atacama desert, Northern Chile
- Latitude = -23 degrees



Why in the Atacama desert?



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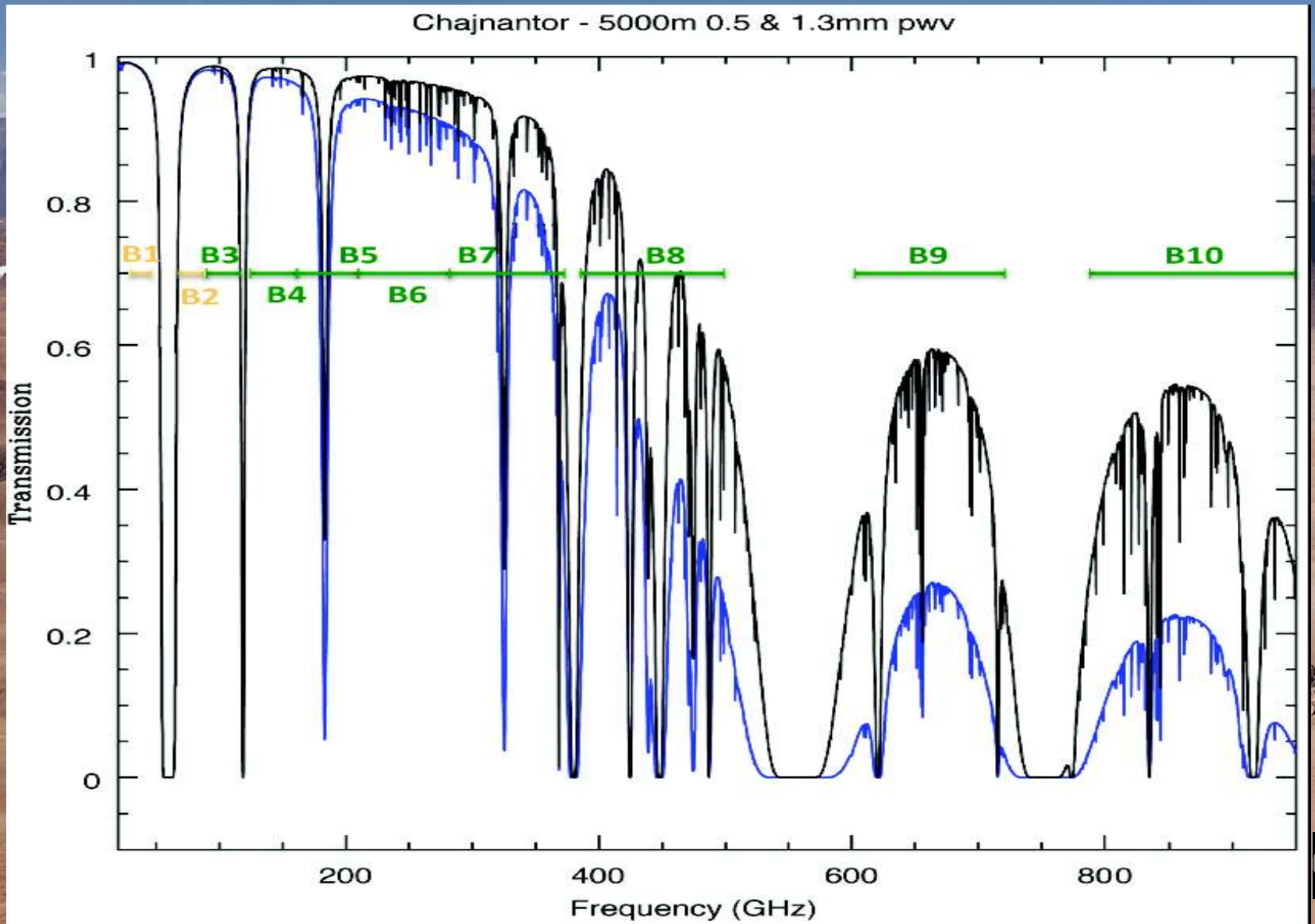
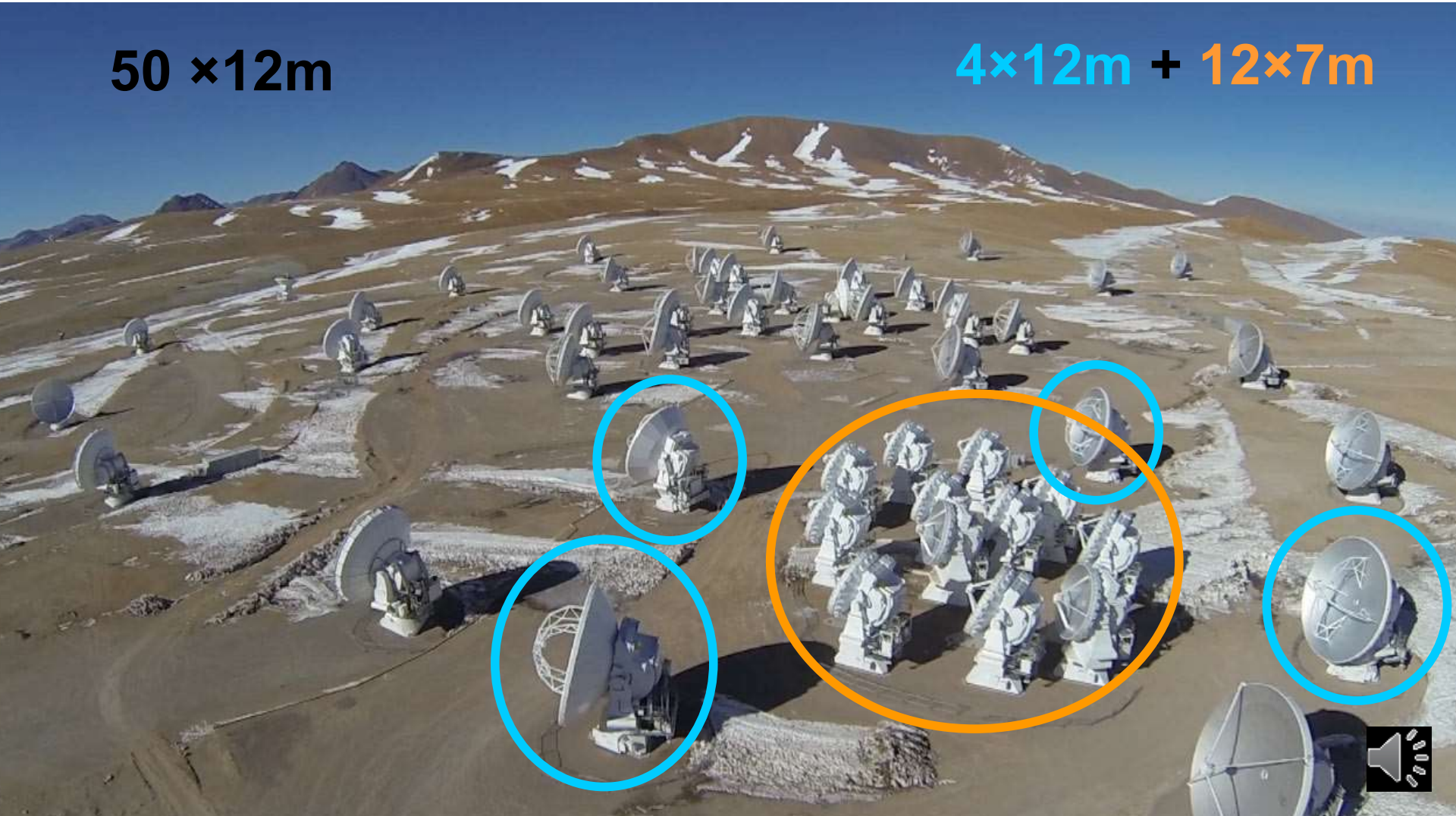


Array Operations Site (5000m)

ALMA Main Array

Atacama Compact Array



Supercomputing at 5000m

Technical building at the AOS

One of the four quadrants
of the main array correlator

Supercomputing at 5000m

Bandwidth (MHz)	Channel spacing[3] (MHz)	Spectral resolution (MHz)	Number of channels	Correlator mode[4]
1875	15.6	31.2	120	TDM
1875	0.488	0.976	3840	FDM
938	0.244	0.488	3840	FDM
469	0.122	0.244	3840	FDM
234	0.061	0.122	3840	FDM
117	0.0305	0.061	3840	FDM
58.6	0.0153	0.0305	3840	FDM

Technical building at the AOS

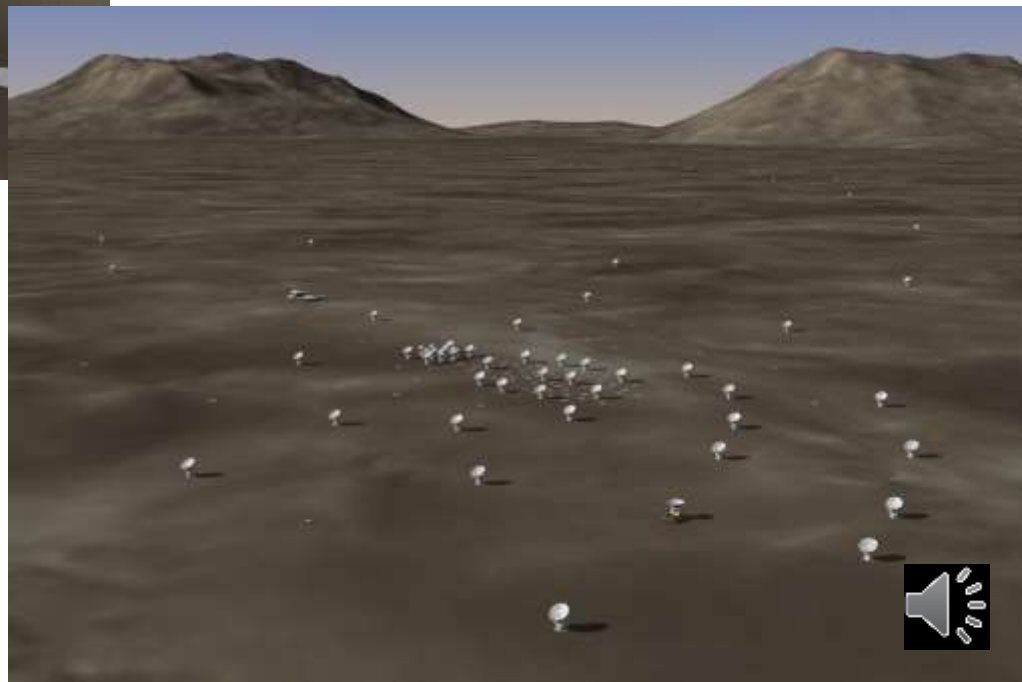
One of the four quadrants of the main array correlator

Operation Support Facility (2900m)

ALMA configurations

Main array in Full Science:

most compact configuration (max. 150m): 0.5” … 5”

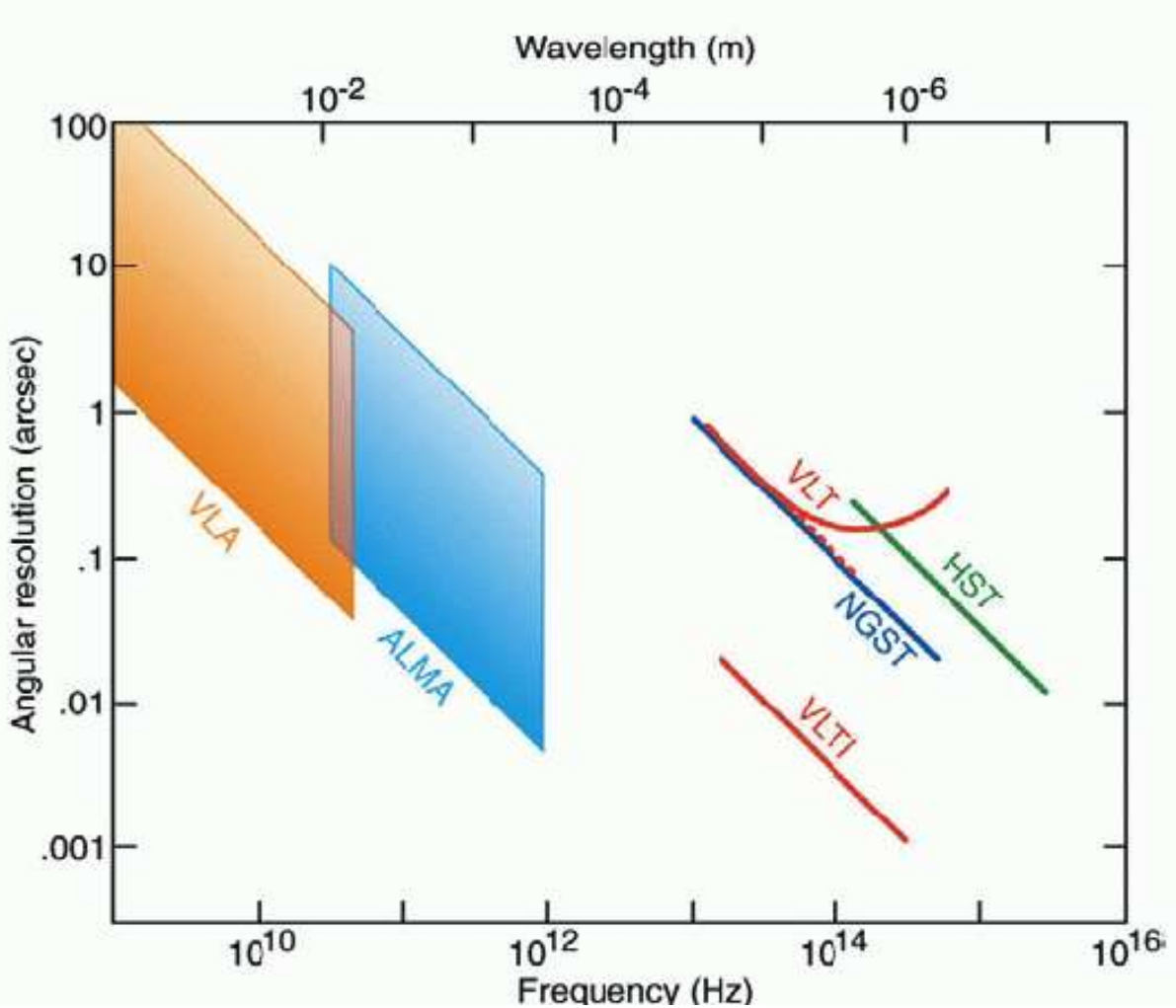


most extended configuration (max. 16km): 0.005” … 0.05”

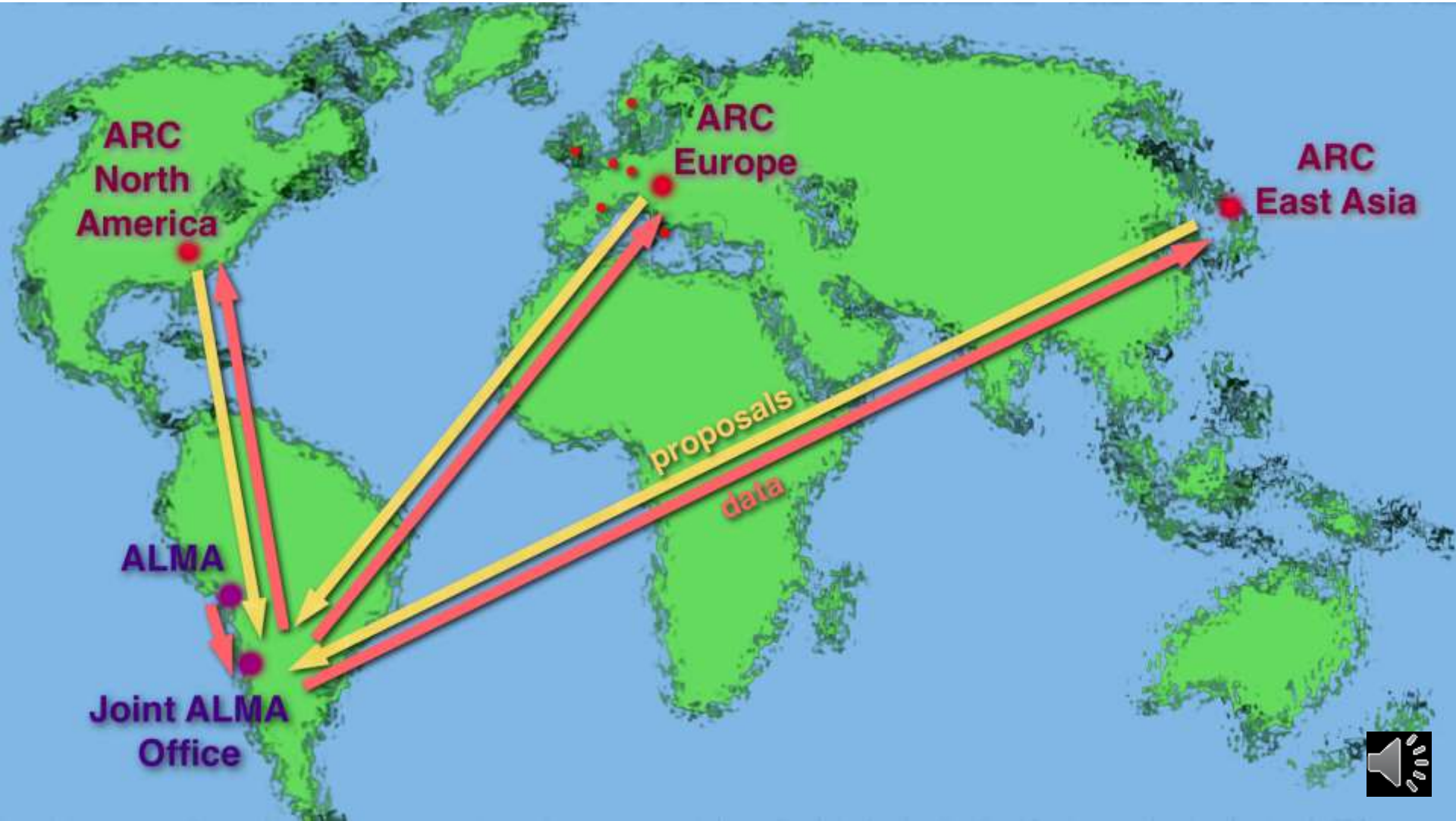
ALMA configurations

Config	Lmax		Band 3	Band 4	Band 5	Band 6	Band 7	Band 8	Band 9	Band 10
	Lmin		100 GHz	150 GHz	185 GHz	230 GHz	345 GHz	460 GHz	650 GHz	870 GHz
7-m	45 m	AR	12.5"	8.35"	6.77"	5.45"	3.63"	2.72"	1.93"	1.44"
	9 m	MRS	66.7"	44.5"	36.1"	29.0"	19.3"	14.5"	10.3"	7.67"
C-1	161 m	AR	3.38"	2.25"	1.83"	1.47"	0.98"	0.74"	0.52"	0.39"
	15 m	MRS	28.5"	19.0"	15.4"	12.4"	8.25"	6.19"	4.38"	3.27"
C-2	314 m	AR	2.30"	1.53"	1.24"	1.00"	0.67"	0.50"	0.35"	0.26"
	15 m	MRS	22.6"	15.0"	12.2"	9.81"	6.54"	4.90"	3.47"	2.59"
C-3	500 m	AR	1.42"	0.94"	0.77"	0.62"	0.41"	0.31"	0.22"	0.16"
	15 m	MRS	16.2"	10.8"	8.73"	7.02"	4.68"	3.51"	2.48"	1.86"
C-4	784 m	AR	0.92"	0.61"	0.50"	0.40"	0.27"	0.20"	0.14"	0.11"
	15 m	MRS	11.2"	7.50"	6.08"	4.89"	3.26"	2.44"	1.73"	1.29"
C-5	1.4 km	AR	0.55"	0.36"	0.30"	0.24"	0.16"	0.12"	0.084"	0.063"
	15 m	MRS	6.70"	4.47"	3.62"	2.91"	1.94"	1.46"	1.03"	0.77"
C-6	2.5 km	AR	0.31"	0.20"	0.17"	0.13"	0.089"	0.067"	0.047"	0.035"
	15 m	MRS	4.11"	2.74"	2.22"	1.78"	1.19"	0.89"	0.63"	0.47"
C-7	3.6 km	AR	0.21"	0.14"	0.11"	0.092"	0.061"	0.046"	0.033"	0.024"
	64 m	MRS	2.58"	1.72"	1.40"	1.12"	0.75"	0.56"	0.40"	0.30"
C-8	8.5 km	AR	0.096"	0.064"	0.052"	0.042"	0.028"	0.021"	0.015"	0.011"
	110 m	MRS	1.42"	0.95"	0.77"	0.62"	0.41"	0.31"	0.22"	0.16"
C-9	13.9 km	AR	0.057"	0.038"	0.031"	0.025"	0.017"	0.012"	0.0088"	N/A
	368 m	MRS	0.81"	0.54"	0.44"	0.35"	0.24"	0.18"	0.13"	
C-10	16.2 km	AR	0.042"	0.028"	0.023"	0.018"	0.012"	0.0091"	N/A	N/A
	244 m	MRS	0.50"	0.33"	0.27"	0.22"	0.14"	0.11"		

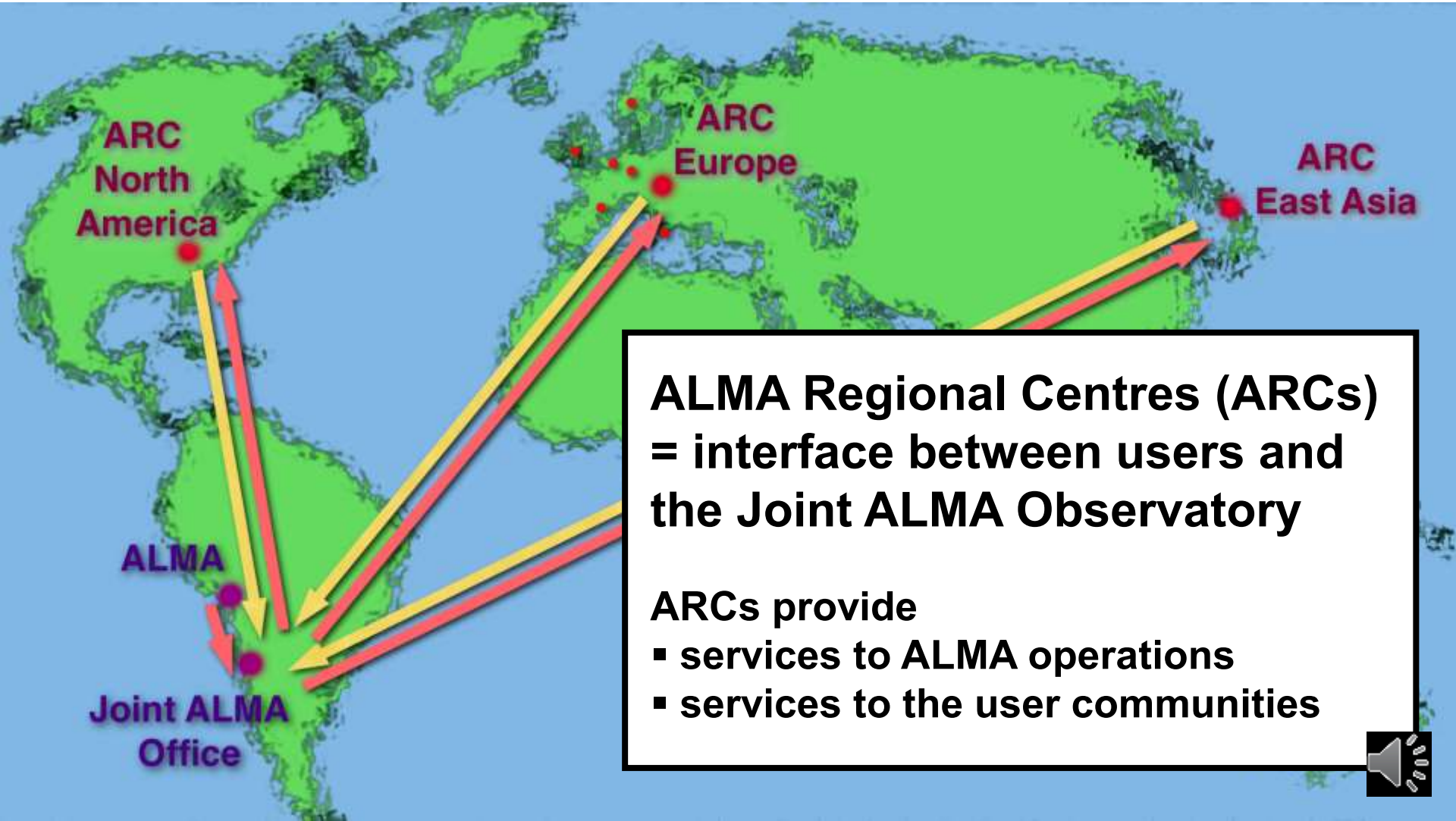
ALMA resolution + spectral coverage



ALMA Regional Centres



ALMA Regional Centres

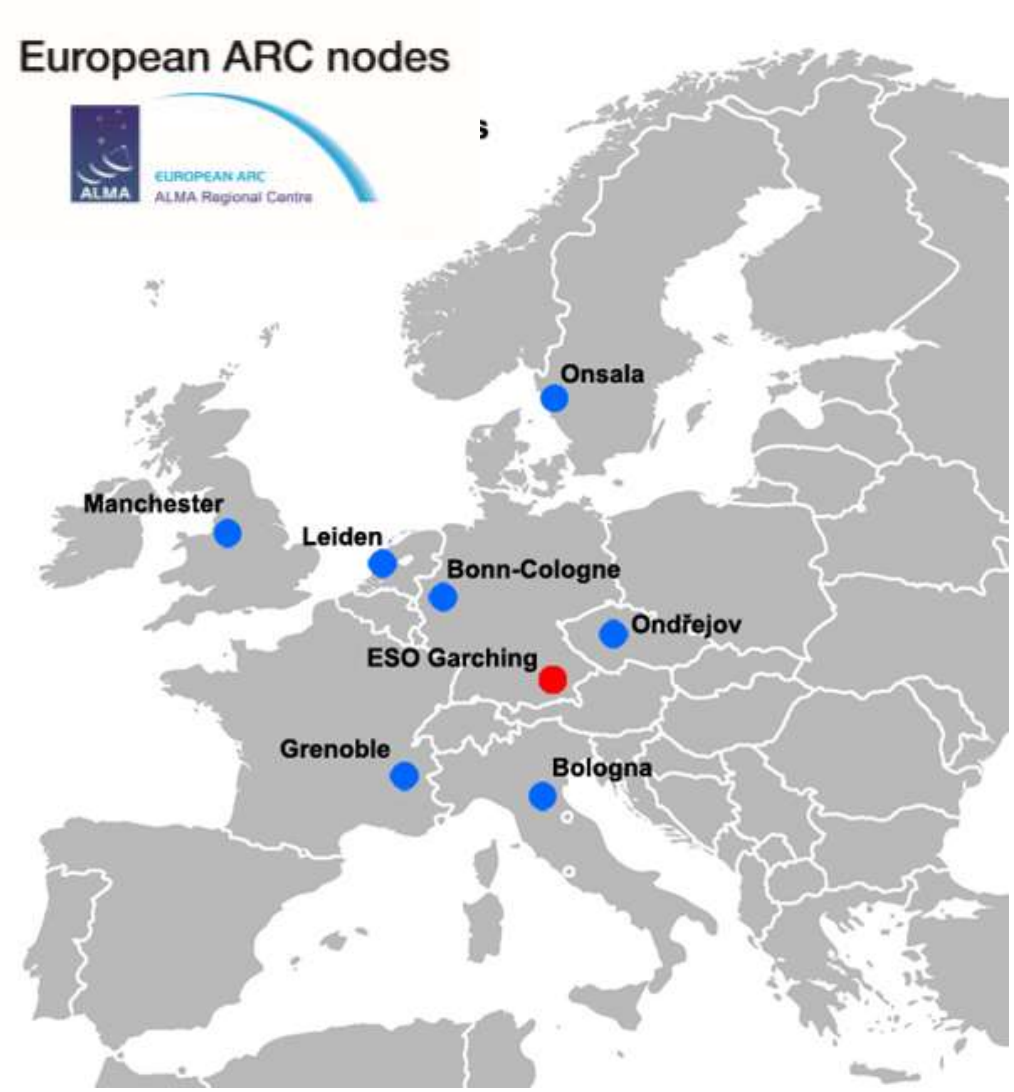


ALMA Regional Centres (ARCs) = interface between users and the Joint ALMA Observatory

ARCs provide

- **services to ALMA operations**
- **services to the user communities**

The European ARC structure



One central ARC node in Garching

- for centralized tasks like archive, helpdesk etc.

Seven regional nodes

- for local tasks like face-to-face user support, contact to local scientific community etc.

For more information on support, please refer to the tutorial “ALMA User Support”.

ALMA Science

ALMA Science Drivers

- detect line emission from CII in a galaxy like the Milky Way at a redshift of $z = 3$, in less than 24 hours
- image the gas kinematics in a solar-mass protostellar/ protoplanetary disk at a distance of 150 pc
- provide precise images at an angular resolution of 0.1”

other relevant fields of research include

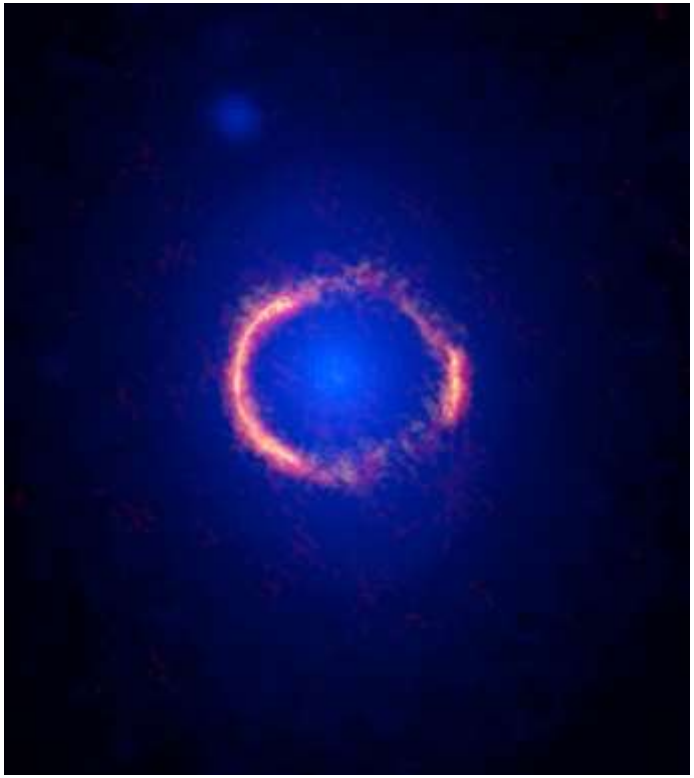
- star formation, protoplanets in nearby disks
- astrochemistry
- interstellar medium (Galaxy, Local Group)
- high-redshift deep fields
- ...

ALMA Science: Cosmology and high-z

Gravitational lens:

- Precision imaging of gravitational lenses

here: SDP.81, an active star-forming galaxy at z=3.042, being lensed by a massive foreground galaxy at z = 0.299 (+ dwarf)

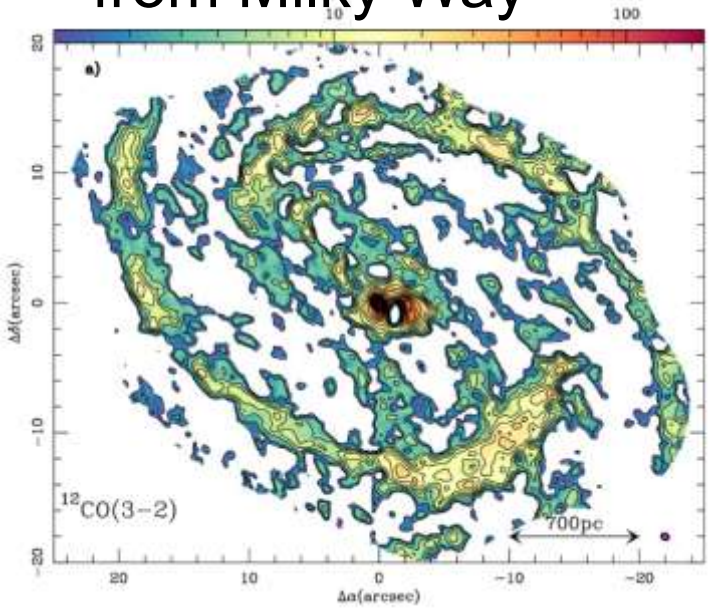


ALMA/Hubble composite image of the gravitationally lensed galaxy SDP.81. The bright orange central region of the ring reveals the glowing dust in this distant galaxy (0.023" resolution, i.e. an unmagnified spatial scale of 180 pc). The surrounding lower-resolution portions of the ring are traced by CO. The diffuse blue element at the center of the ring is from the intervening lensing galaxy, as seen with the Hubble Space Telescope. Credit: ALMA (NRAO/ESO/NAOJ); B. Saxton NRAO/AUI/NSF; NASA/ESA Hubble, T. Hunter (NRAO).

ALMA Science: Galaxies, galactic nuclei

Galaxies and galactic nuclei:

- high-resolution maps of molecular transitions reveal relationship between star formation, gas density and gas kinematics
- Study of molecular clouds in environments very different from Milky Way

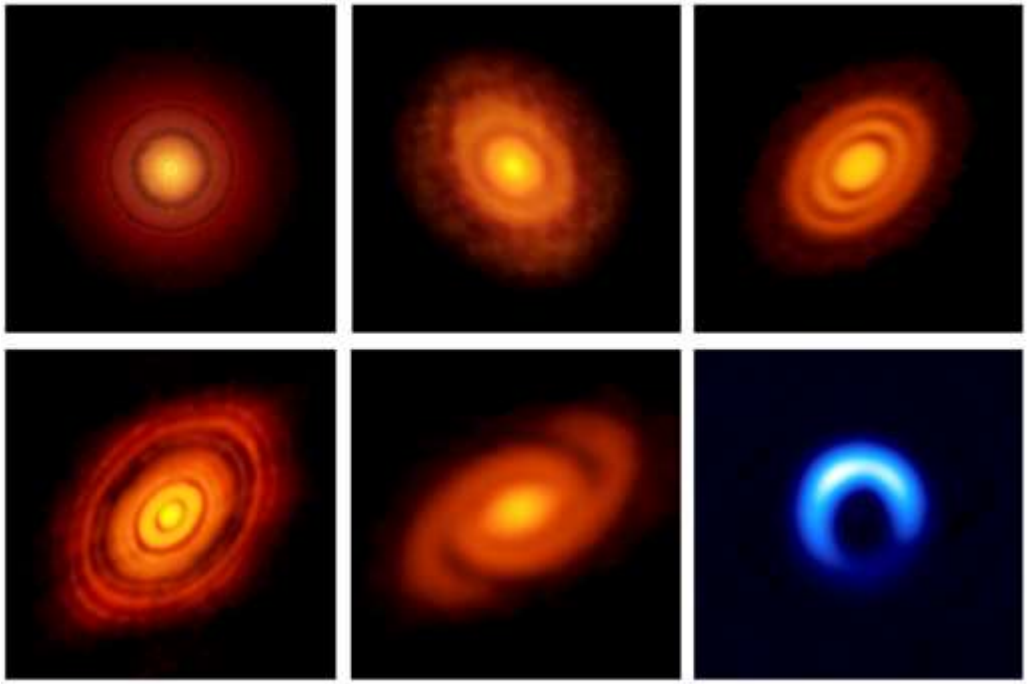


ALMA image of the CO J=3-2 integrated intensity toward the galaxy NGC 1068. Figure from García-Burillo et al. (2014). Dense gas tracers (HCO+, HCN, CS) are mainly found near the r~200pc circumnuclear disk. NGC 1068 was observed more recently at high resolution in CO J=6-5 and 432 micron continuum by García-Burillo et al. (2016), resolving the circumnuclear disk for the first time.

ALMA Science: Planet-forming disks

Structure of planet forming disks:

- discovery of gaps and asymmetries in the dust distribution in planet forming disks
- studies of the chemical complexity of protoplanetary disks, including complex molecules like in our solar system

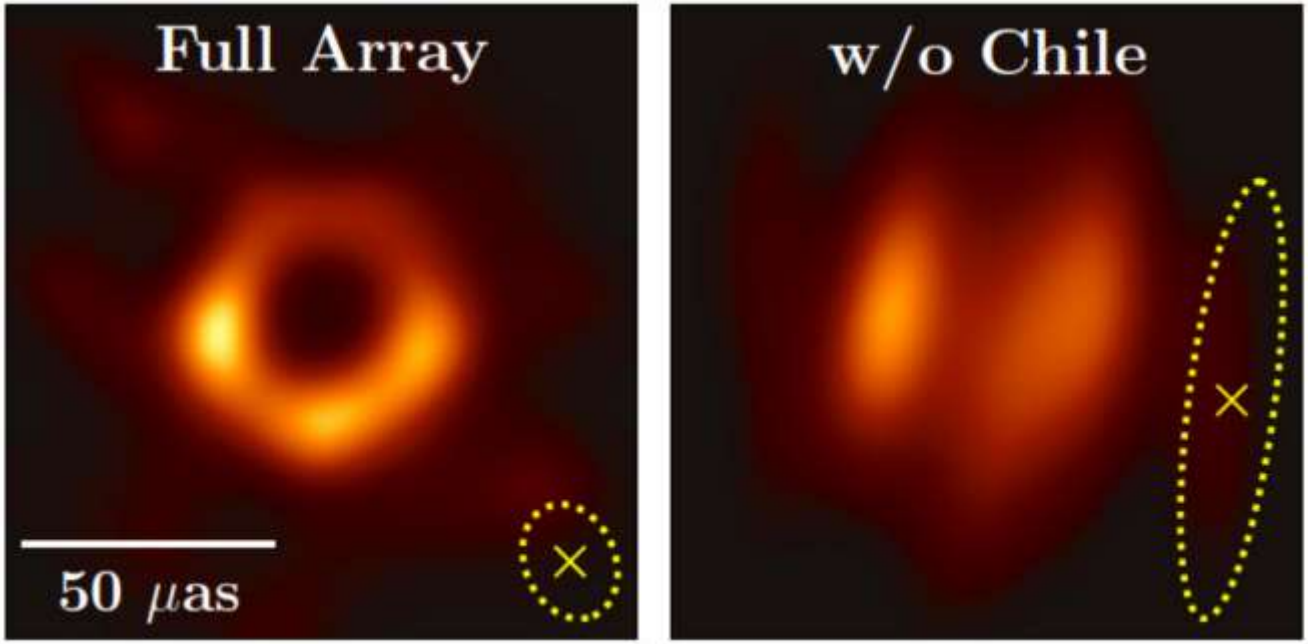


Gallery of high angular resolution continuum observations of planet forming disks obtained with ALMA. From left to right and from top to bottom: TW Hya (Andrews et al. 2016), V883 Ori (Cieza et al. (2016), HD 163296 (Isella et al. 2016), HL Tau (ALMA Partnership et al. 2015), Elias 2-27 (Pérez et al. 2016), and HD 142527 (Kataoka et al. 2016). Credits: S. Andrews, L. Cieza, A. Isella, A. Kataoka, B. Saxton (NRAO/AUI/NS and ALMA (ESO/NAOJ/NRAO).

ALMA extended capabilities

Recently enabled fields of research:

- solar observations
- mmVLBI (as a phased array)
- pulsar observations (stand-alone phased array)



(left) The event horizon from the supermassive black hole at the center of the M87 galaxy observed by the global mmVLBI consortium EHTC.

(right) image without the Chilean observatories ALMA and APEX.

Credits: EHT Collaboration

ALMA in a nutshell

- **50 12-m antennas** (main array)
- **12 7-m antennas + 4 12-m single dishes** (Morita Array, Atacama Compact Array, ACA)
- **Baselines up to 16 km** (5 mas at 650 GHz)
- Full coverage of **all atmospheric bands up to 1 THz**
- State-of-the-art **low-noise, wide-band receivers**
- **Flexible correlator** with high spectral resolution and wide bandwidth
- **Full polarization** capabilities
- **Extensive User Support** through ALMA Regional Centres
- ***A resource for ALL astronomers!***

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