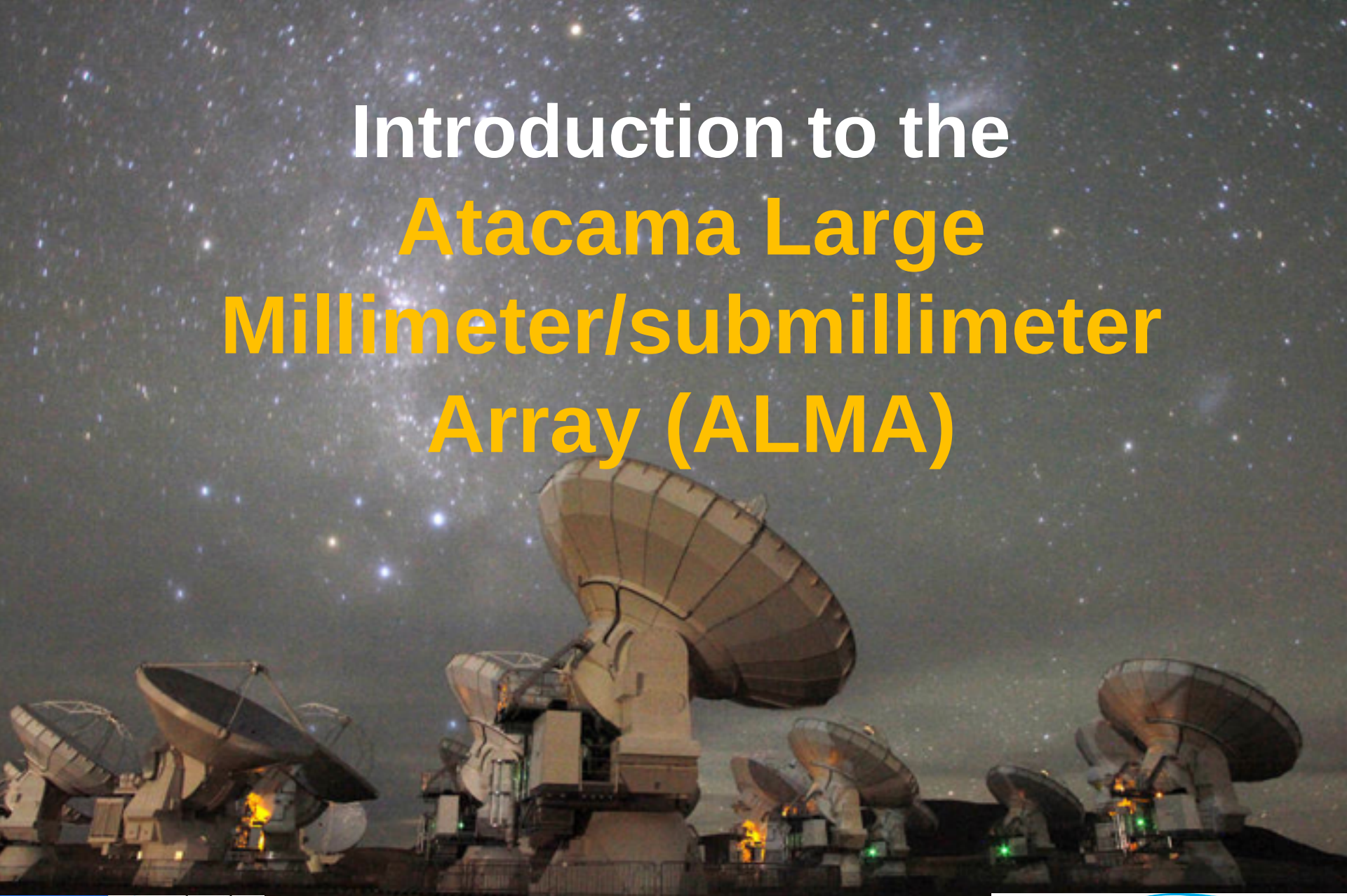
Introduction to the Atacama Large Millimeter/submillimeter Array (ALMA)



Stefanie Mühle 05 April 2018

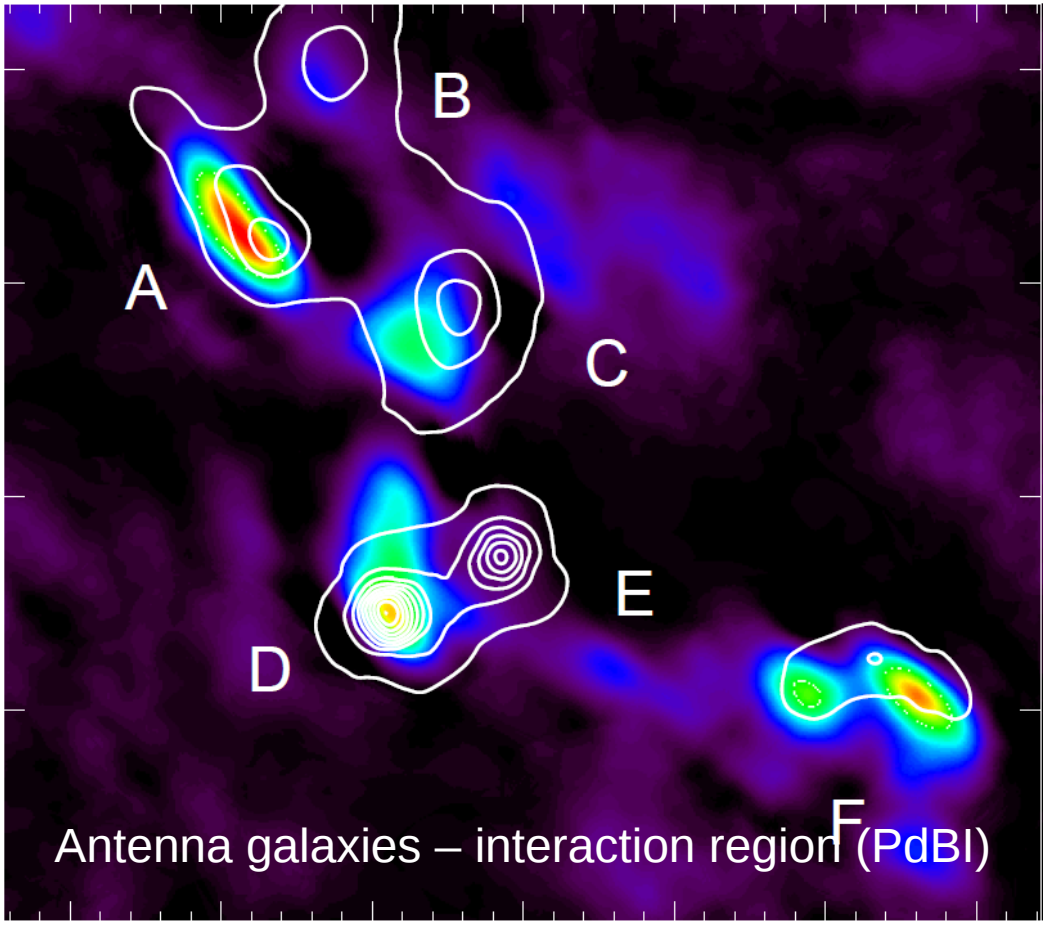
Argelander-Institut für Astronomie

ALMA

EUROPEAN ARC
ALMA Regional Centre || Germany

What is ALMA?

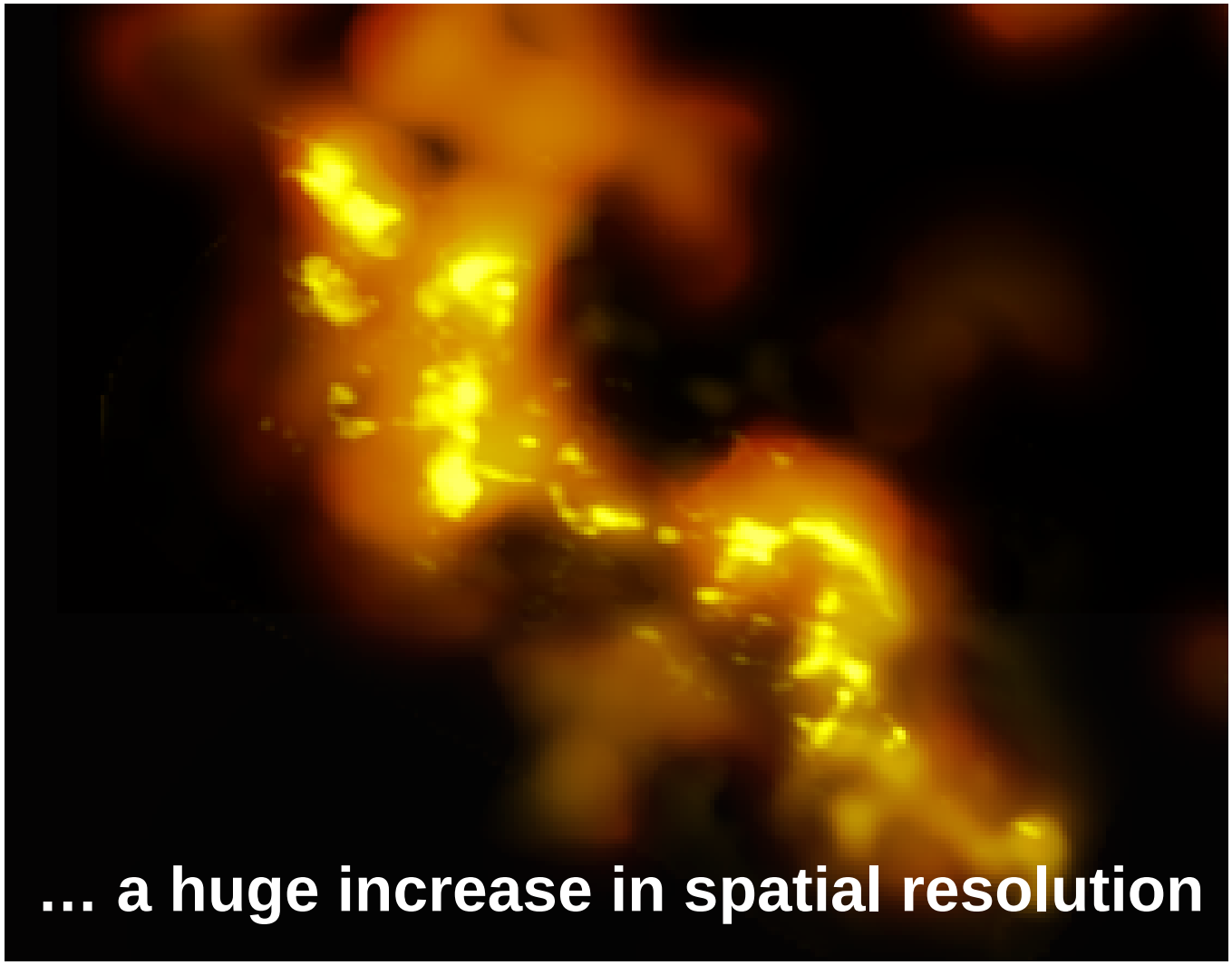
ALMA is …



Antenna galaxies – interaction region (PdBI)

What is ALMA?

ALMA is …



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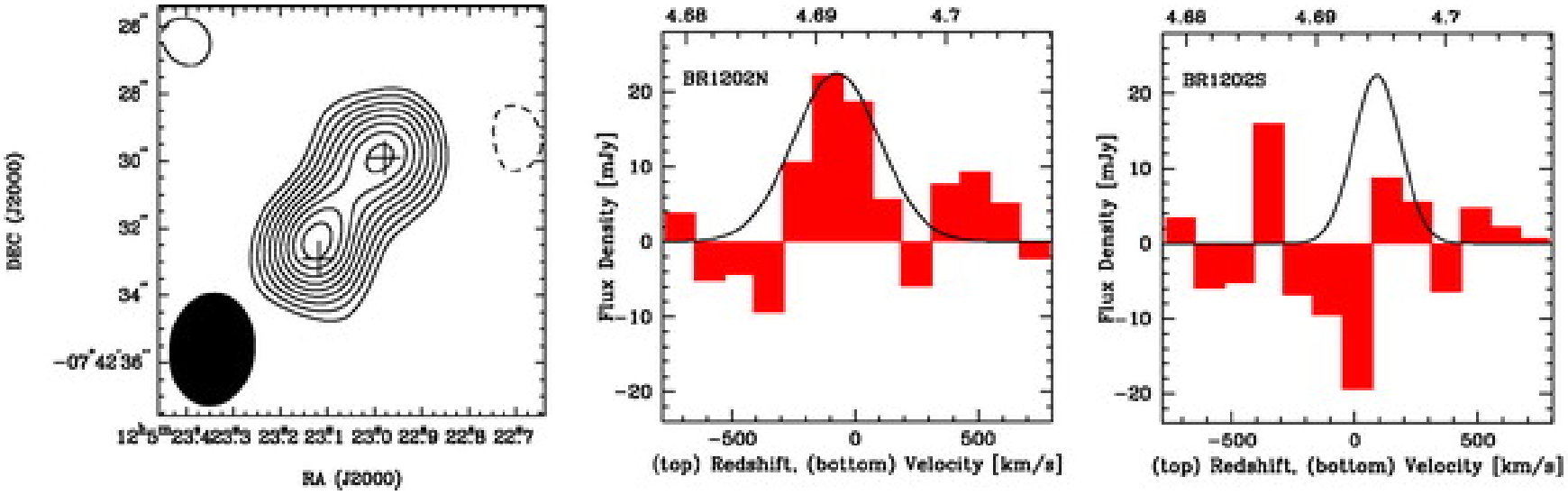
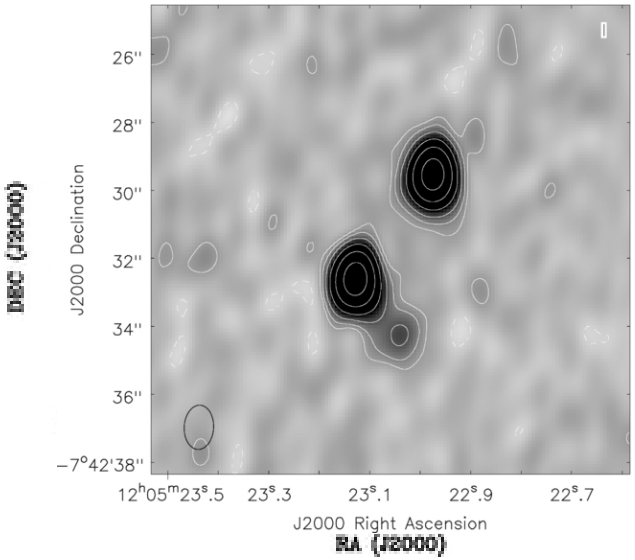
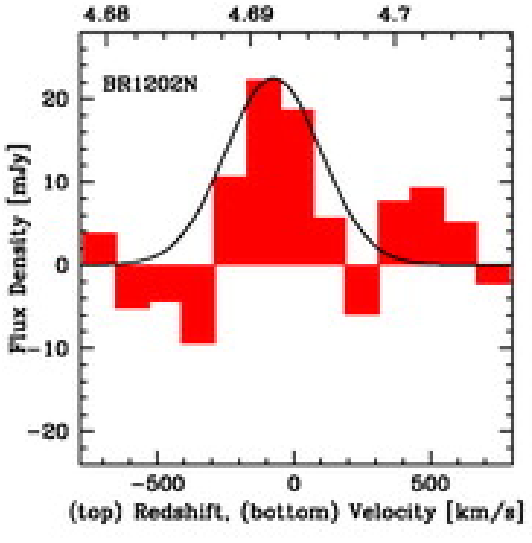


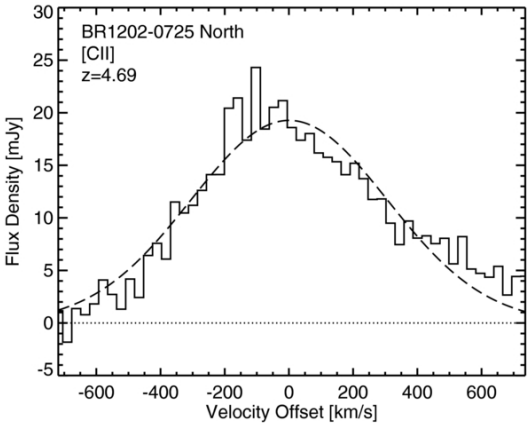
BR1202-0725, a pair of gas-rich galaxies at z=4.7 (SMA, Iono 2006)

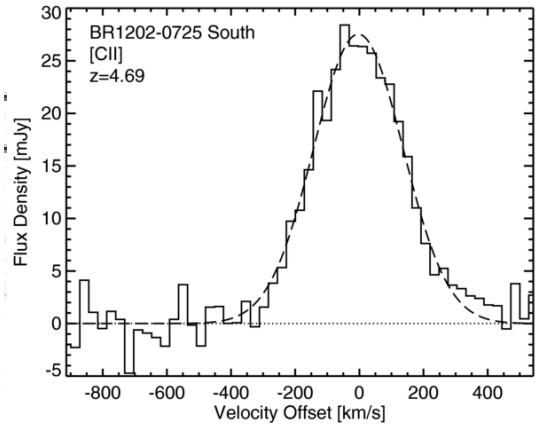
What is ALMA?

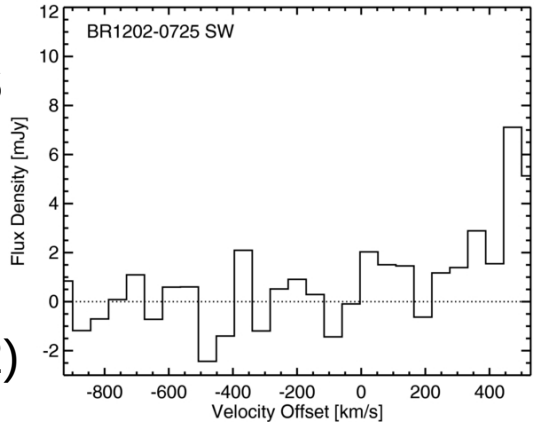
ALMA is …











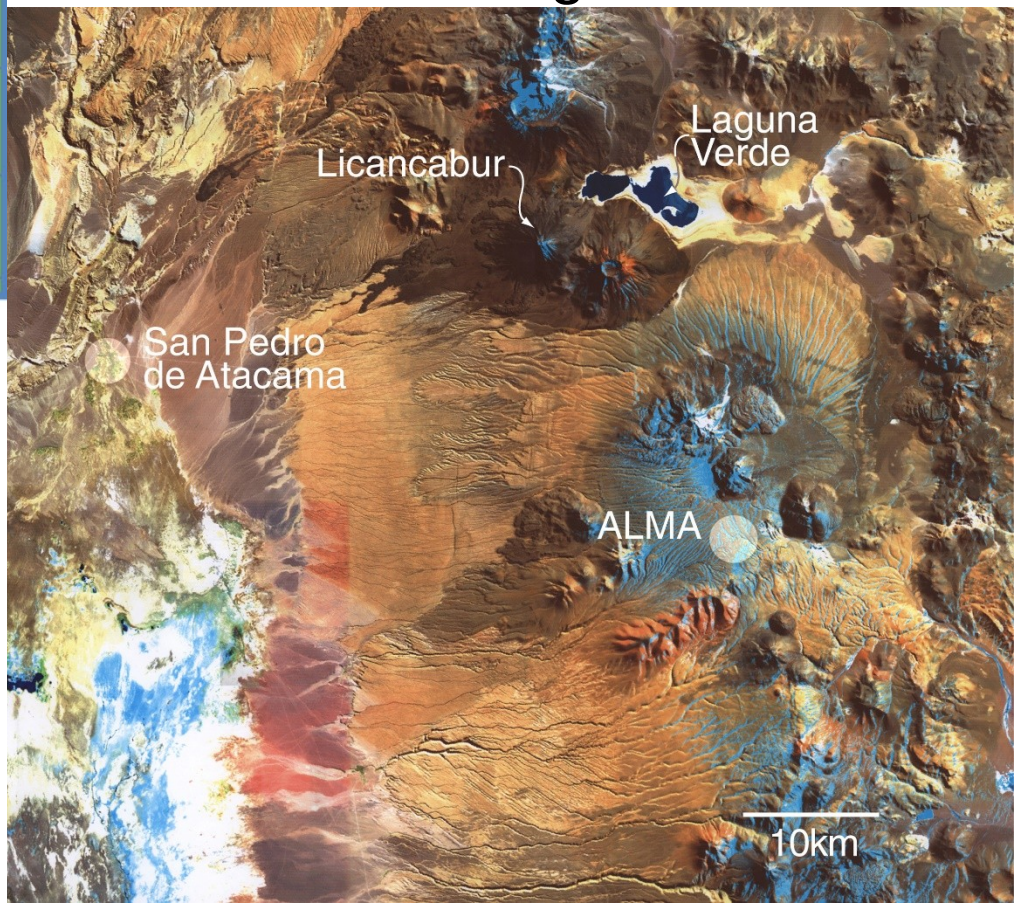
BR1202-0725, a pair of gas-rich galaxies at z=4.7 (S

… a huge increase in sensitivity

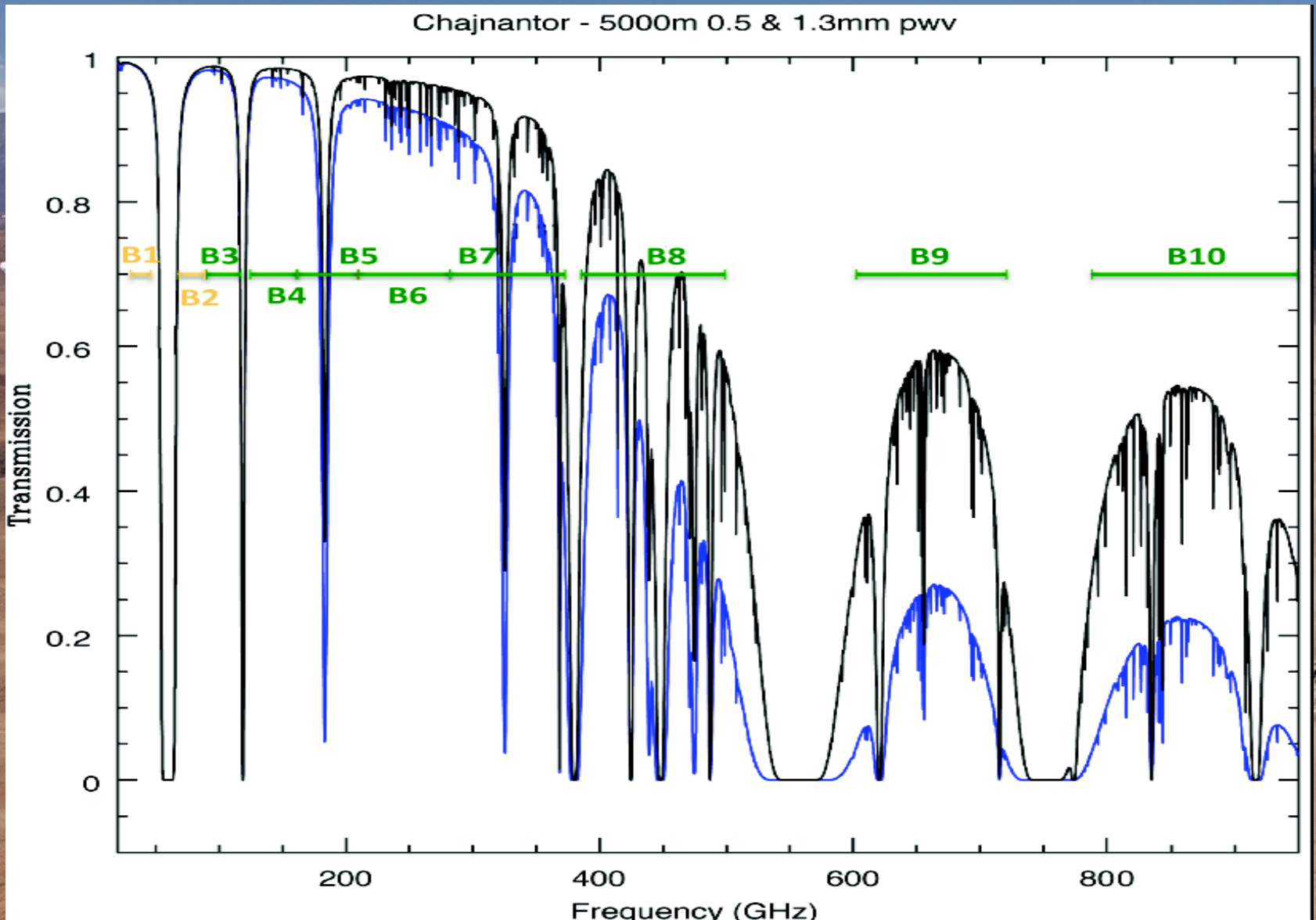
An extreme merger event? (ALMA, Wagg et al. 2012)

Location

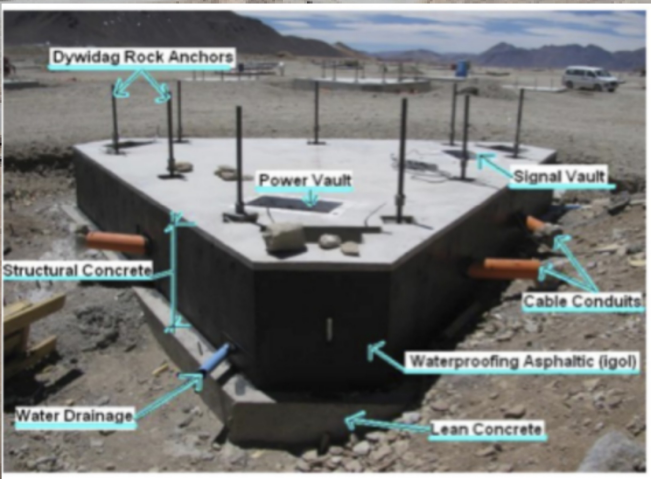
- Chajnantor plain (5000 m, AOS), Atacama desert, Northern Chile
- Latitude = -23 degrees



Why in the Atacama desert?



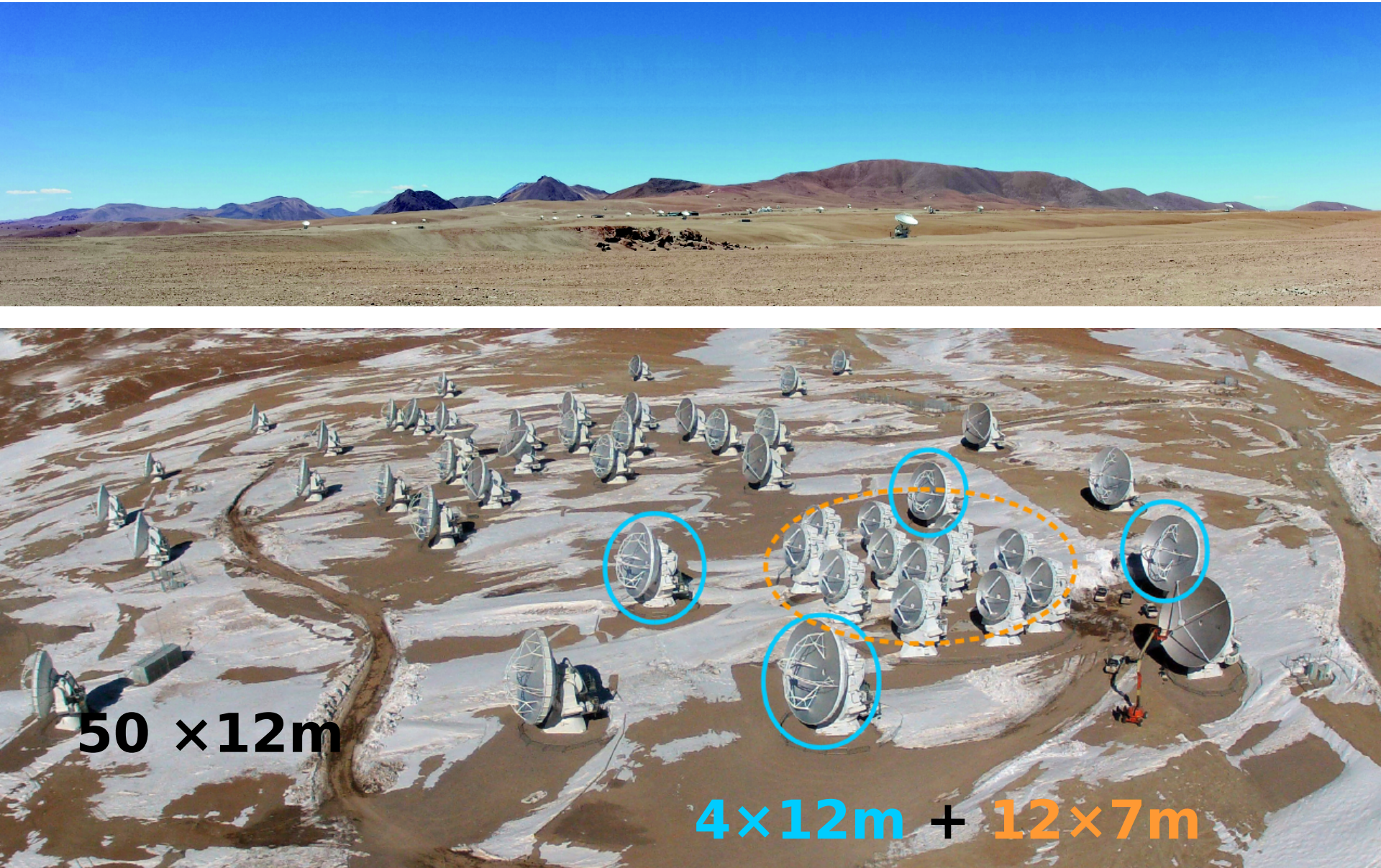
Array Operations Site (5000m) in 2011



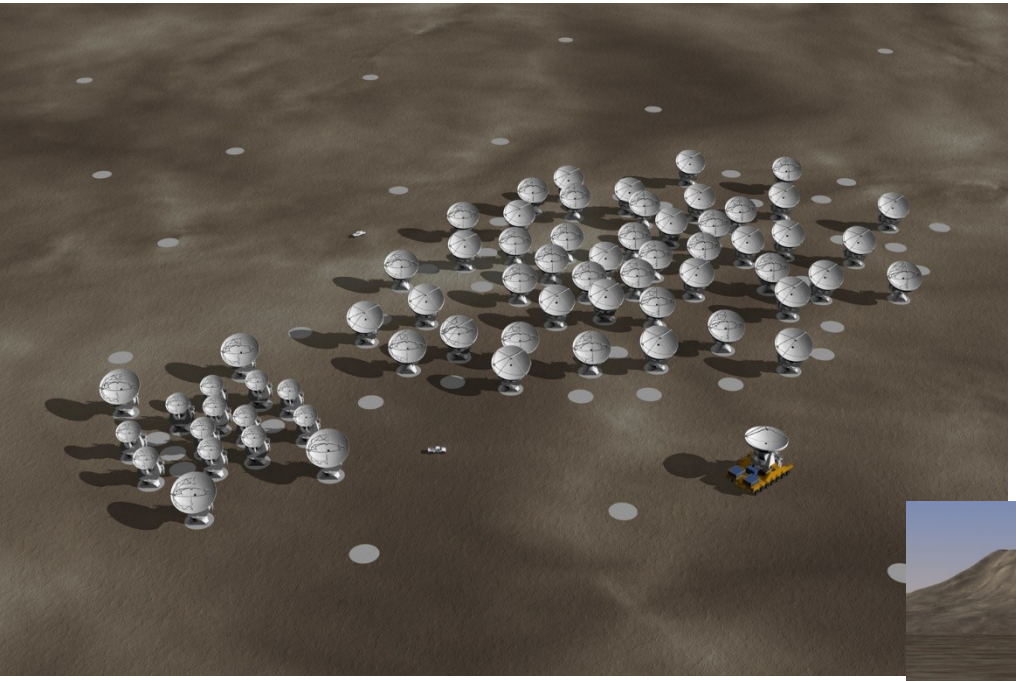
Array Operations Site now

Operation Support Facility (2900m)

ALMA main array + Atacama Compact Array

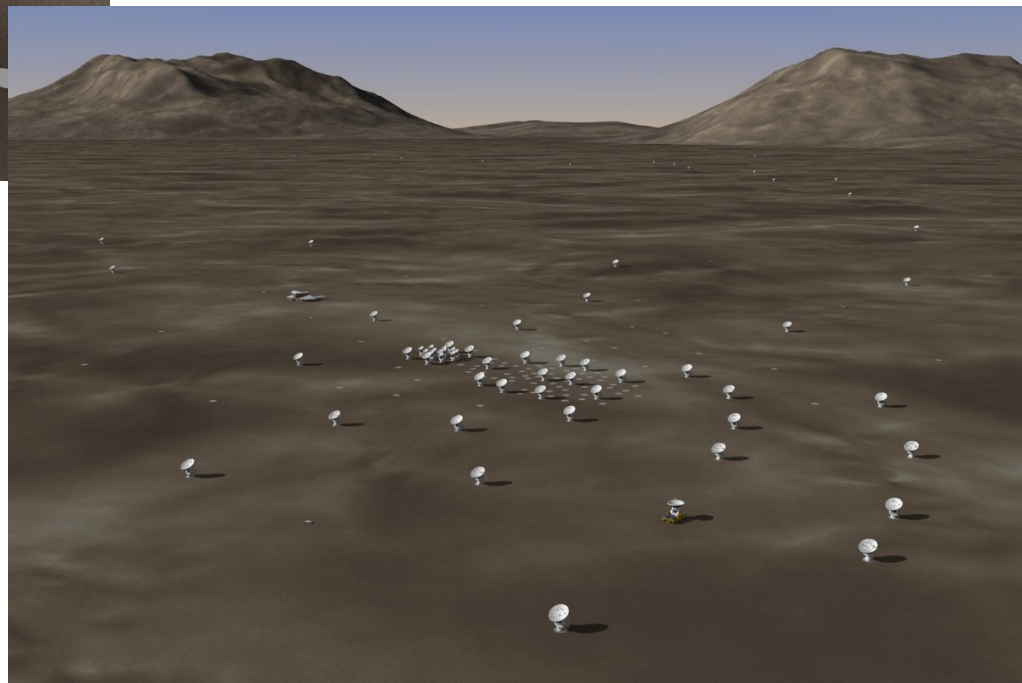


ALMA configurations



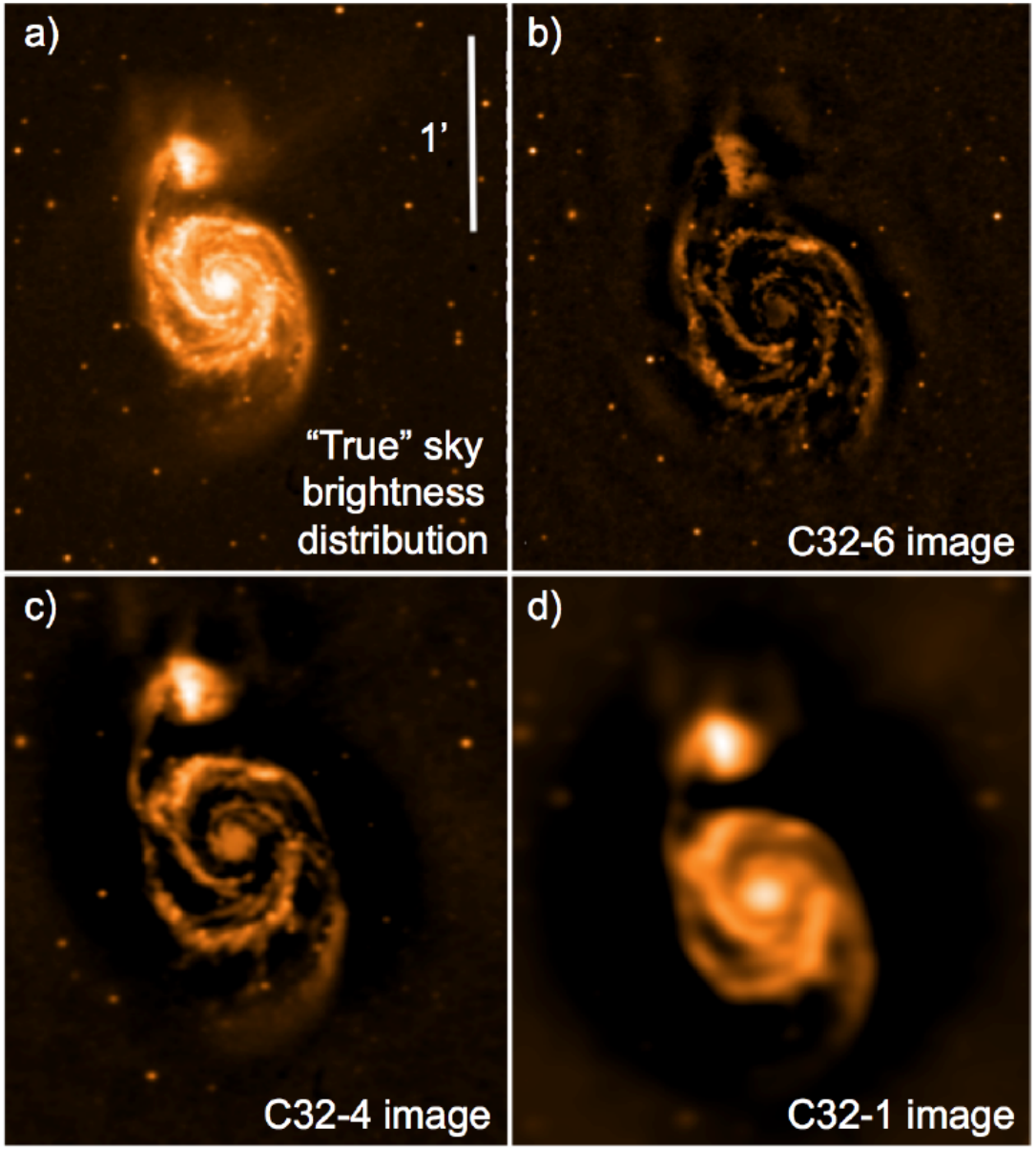
Main array in Full Science:

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



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

ALMA configurations



a)
template: optical image of M51

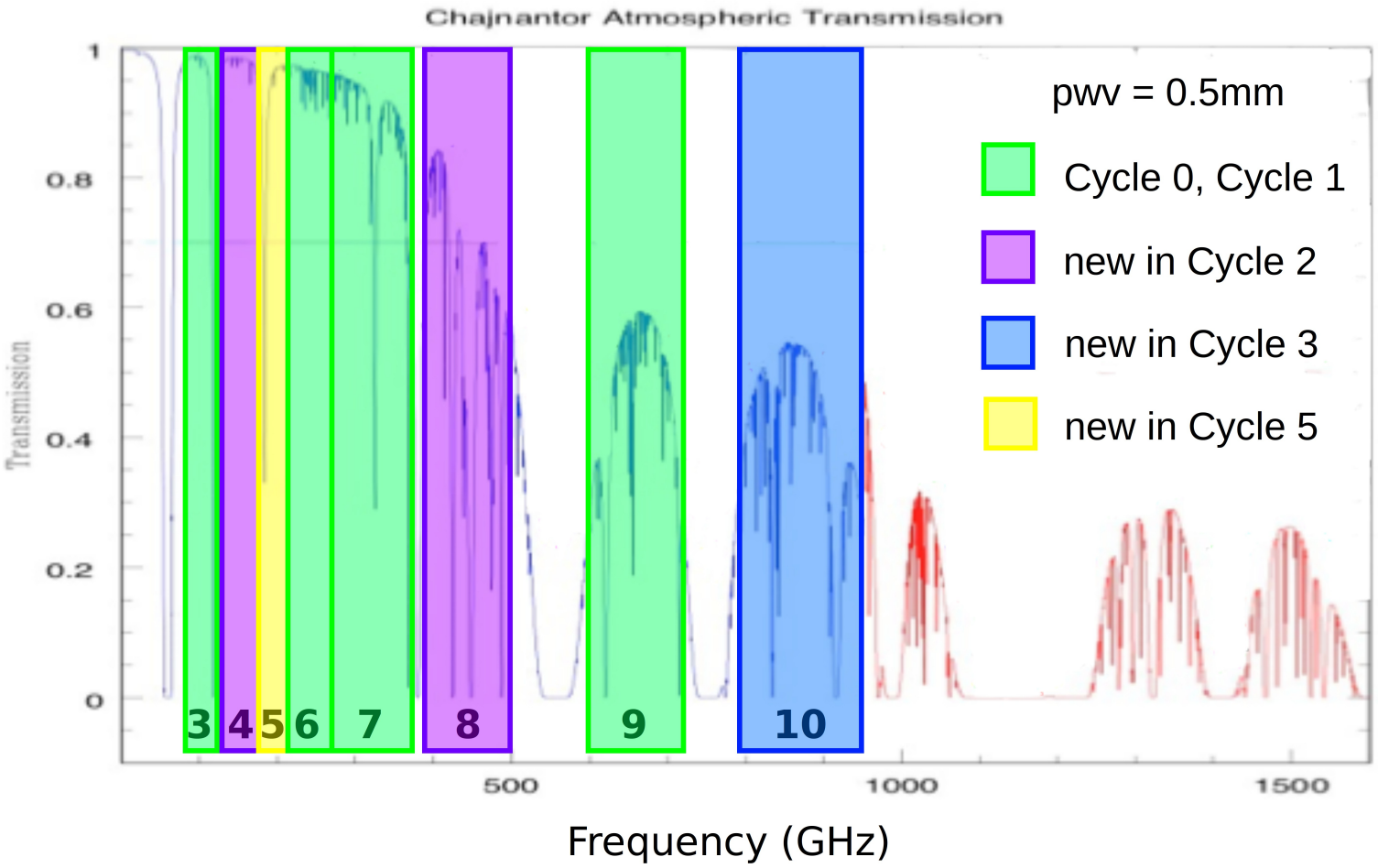
- freq. moved to 100 GHz
- image size rescaled to ~3'x3'
- declination changed to -40deg
- mosaic of 39 pointings
- 10 hours observing time

b)
baselines 40.6m … 1091m
beam ~0.55", LAS ~ 6.6"

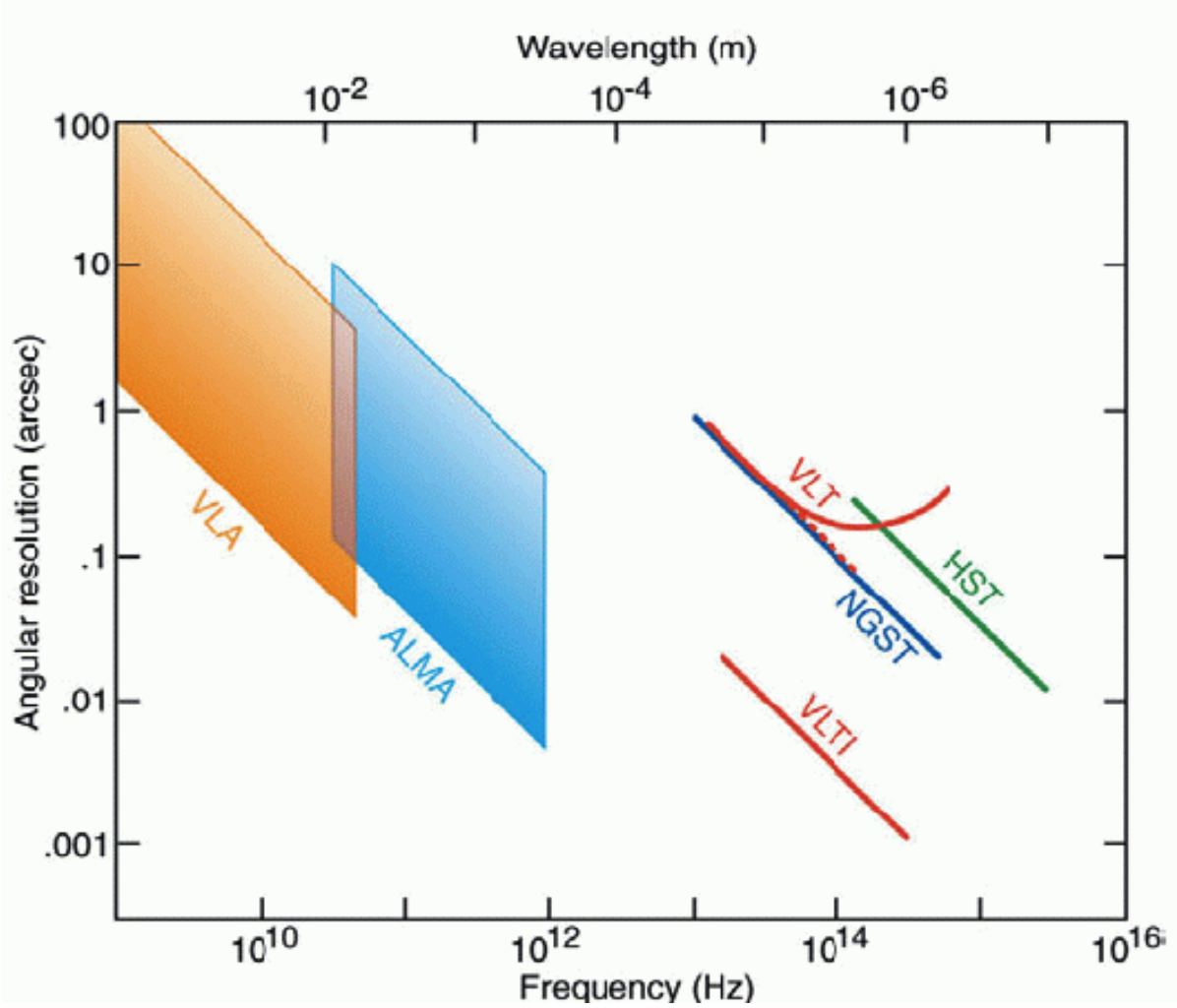
c)
baselines 20.6m … 558.2m
beam ~1.1", LAS ~ 14.4"

d)
baselines 14.2m … 81.4m
beam ~3.8", LAS ~ 36.4"

ALMA bands – spectral coverage



ALMA resolution + spectral coverage



ALMA Early Science

	Cycle 0	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Minimum # of antennas (12-m/7-m/TP)	16/0/0	**32**/**9**/0	34/9/**2**	36/10/2	40/10/3	**43**/10/3
Maximum baseline (km)	0.4	1.0 (zoom)	1.5/1.0 (zoom)	**10/5.0**/2.0 (zoom)	12.6/6.8/3.7 (zoom)	**16**/8.5/3.6 (zoom)
Available bands	3,6,7,9	3,6,7,9	3,**4**,6,7, **8**,9	3,4,6,7,8, 9,**10**	3,4,6,7,8,9, 10	**3-10** (B5: 03/2018)
# proposals submitted	919	1133	1381	1578	1571	1661
# proposals w. high priority	113	196	353	402	475	433
New modes		zoom config., ACA	linear pol., TP	long baselines	Large Prog, mmVLBI, Solar	Band 5, full pol.

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

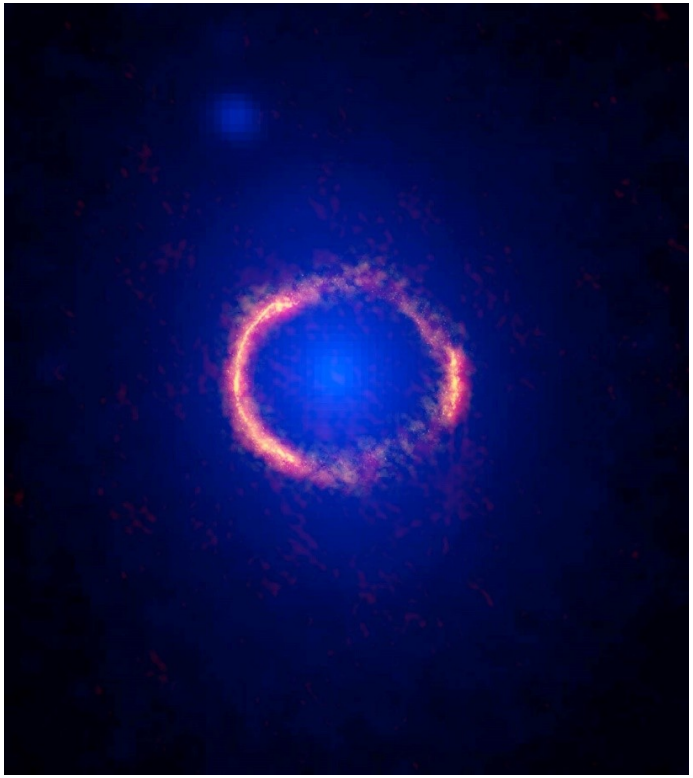
- star formation, protoplanets in nearby disks
- astrochemistry
- interstellar medium (Galaxy, Local Group)
- high-redshift deep fields
- ...

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)

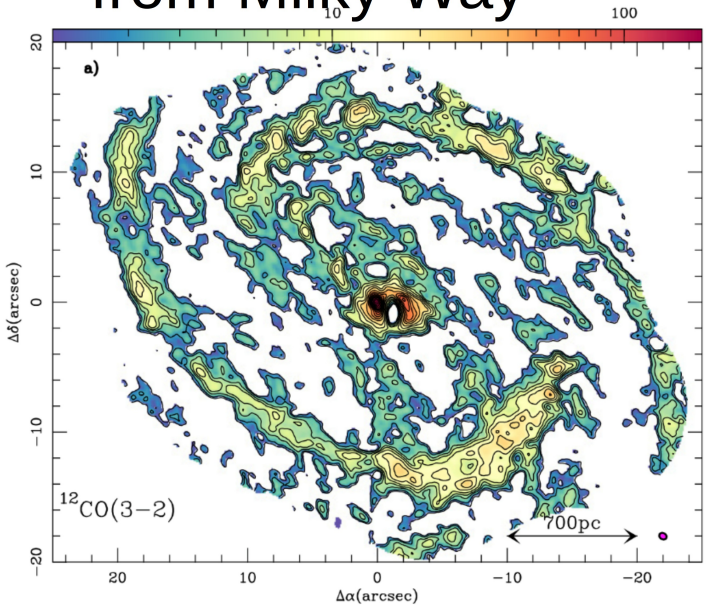


ALMA/Hubble composite image of the gravitationally lensed galaxy SDP.81. The bright orange central region of the ring reveals the glowing dust in this distant galaxy (0.023" resolution, i.e. an unmagnified spatial scale of 180 pc). The surrounding lower-resolution portions of the ring are traced by CO. 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

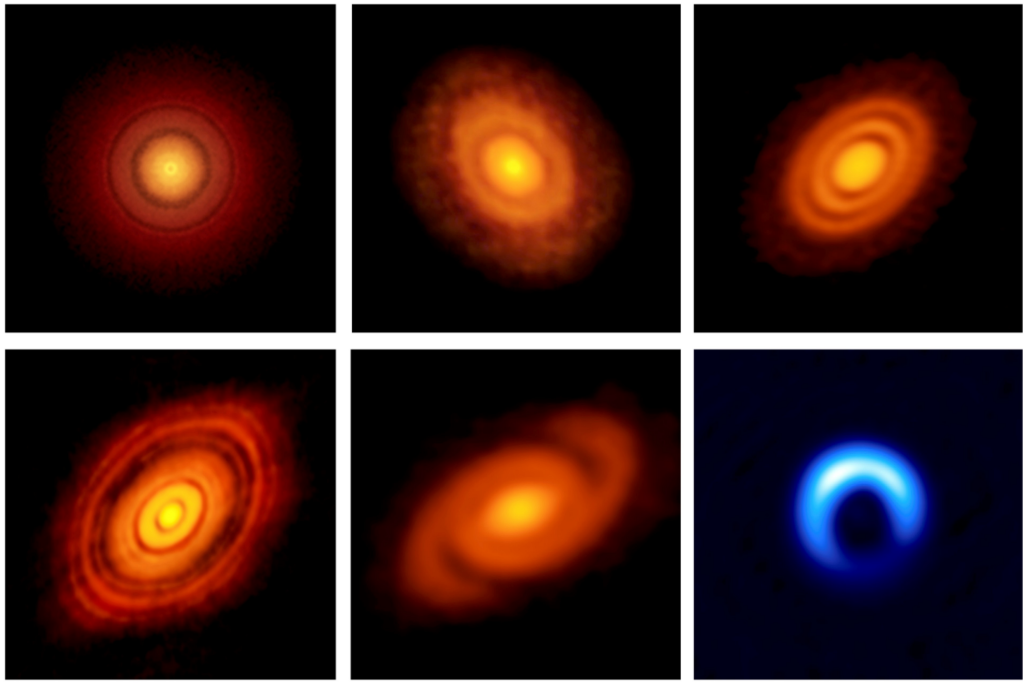


ALMA image of the CO J=3-2 integrated intensity toward the galaxy NGC 1068. Figure from García-Burillo et al. (2014). Dense gas tracers (HCO+, HCN, CS) are mainly found near the r~200pc circumnuclear disk. NGC 1068 was observed more recently at high resolution in CO J=6-5 and 432 micron continuum by 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 => phase transition of the major volatiles? Photoevaporation? planetesimals, planetary cores and gas giants?
- 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/NSF), and ALMA (ESO/NAOJ/NRAO).

ALMA Science

ALMA is accessible for everyone!

- High-resolution/high-sensitivity 3D instrument at mm-wavelengths
- 100% service observing with full dynamic scheduling
- High-quality images (cubes) delivered to the users
- Raw data, calibrations, pipeline processed data and data reduction recipes in archive
- Friendly and widespread User Support through ALMA Regional Centers (ARCs)