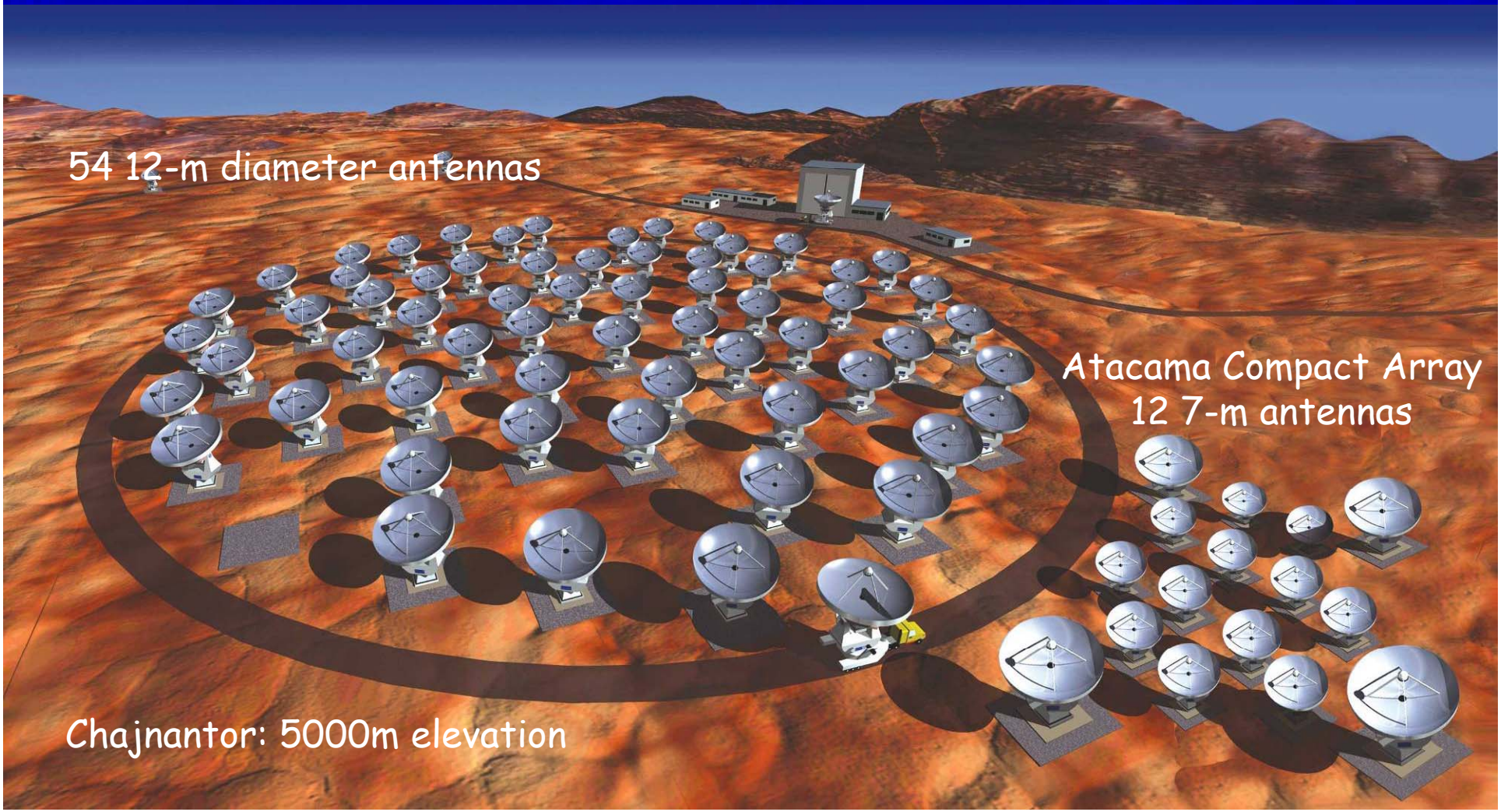
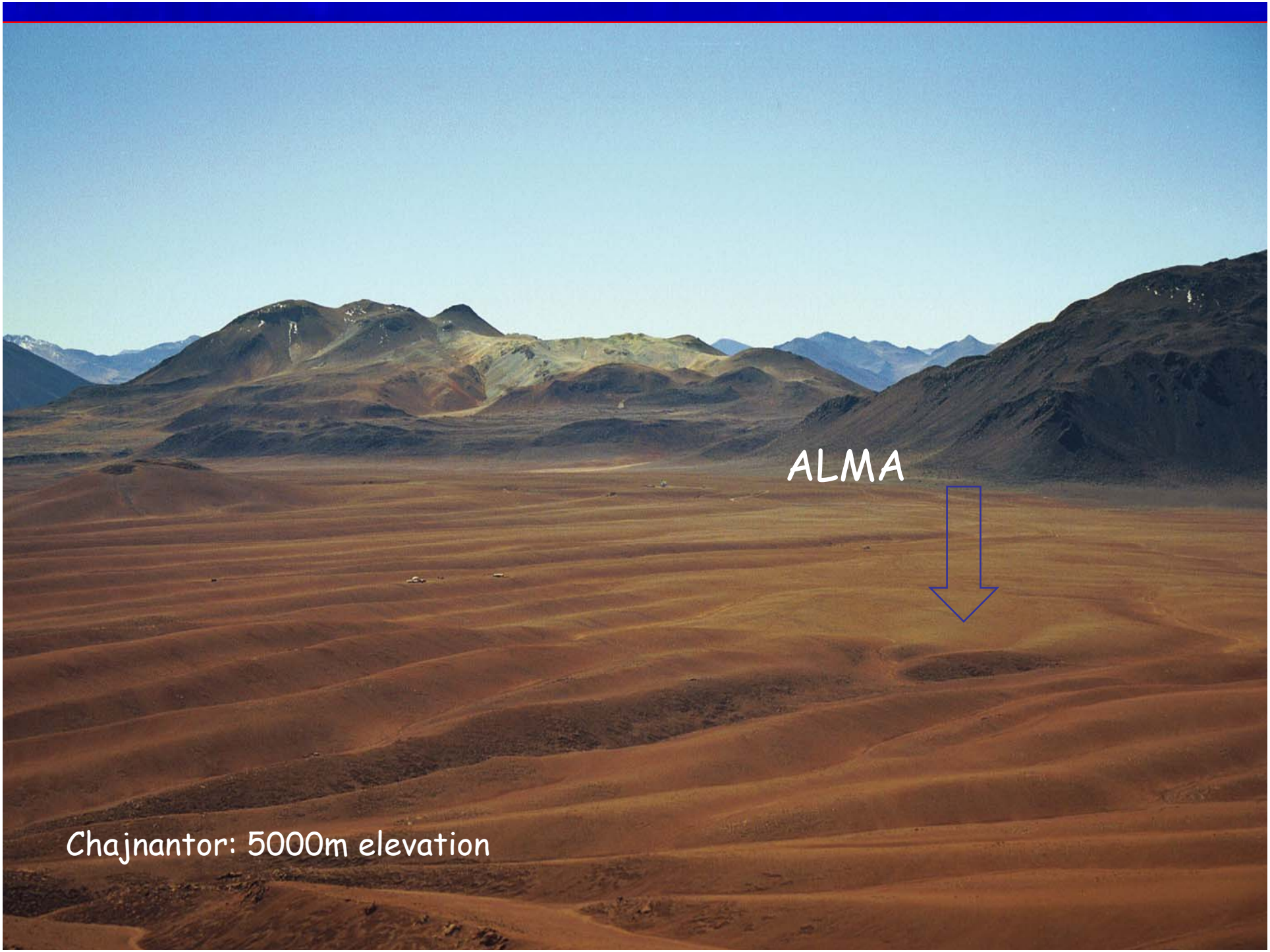
ALMA

Atacama Large Millimeter/submillimeter Array

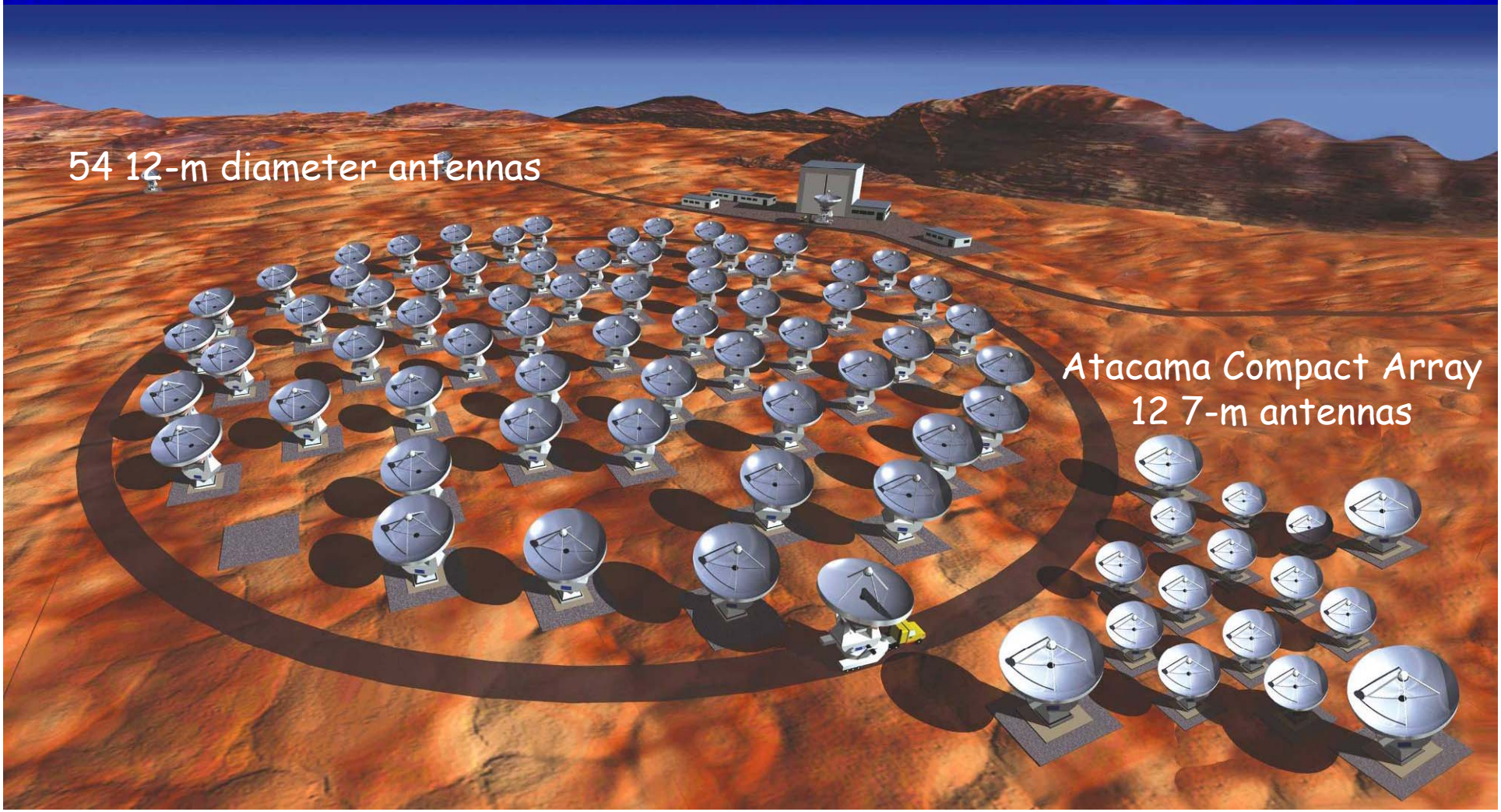
Anneila Sargent
California Institute of Technology

Atacama Large Millimeter/submillimeter Array




ALMA
Chajnantor: 5000m elevation

Atacama Large Millimeter/submillimeter Array



ALMA Partnership

Europe – *European Organization for Astronomical Research in the Southern Hemisphere (ESO.)*

- **North America** – *National Science Foundation (NSF) National Research Council of Canada (NRC)*
- **Japan/Taiwan** - *National Institutes of Natural Sciences (NINS), in cooperation with the Academia Sinica in Taiwan – NAOJ*
- **Chile**

Construction & Operations

- ESO
- National Radio Astronomy Observatory
  managed by Associated Universities Incorporated (AUI)
- National Astronomical Observatory of Japan

→ Joint ALMA Office: Construction project
→ Joint ALMA Observatory (JAO)

ALMA

Merges MMA, LSA, LMSA concepts… mid 90s

Common Goals:

- High fidelity imaging.
- Routine sub-mJy continuum / mK spectral sensitivity.
- Wideband frequency coverage.
- Wide field imaging mosaicing.
- Submillimeter Receiver Systems (..& site..).
- Full Polarization Capability.
- System Flexibility (hardware/software).

- Time line:
  - late 90's: prototyping
  - 2002: begin project
  - 2008: site construction underway, hardware & software in production; seven antennas in early 2008
  - 2010-2012: early science → full science

ALMA Science

Image red-shifted dust continuum emission from evolving galaxies at very early epochs (z < 10)

- Chemical composition of star-forming gas in galaxies over history of the Universe
- Kinematics of obscured galactic nuclei and quasi-stellar objects on scales < 300 light years
- Probe dust-enshrouded regions where stars, planetary systems form
- Sub-arcsecond images of cometary nebulae, asteroids, Kuiper Belt objects, planets..

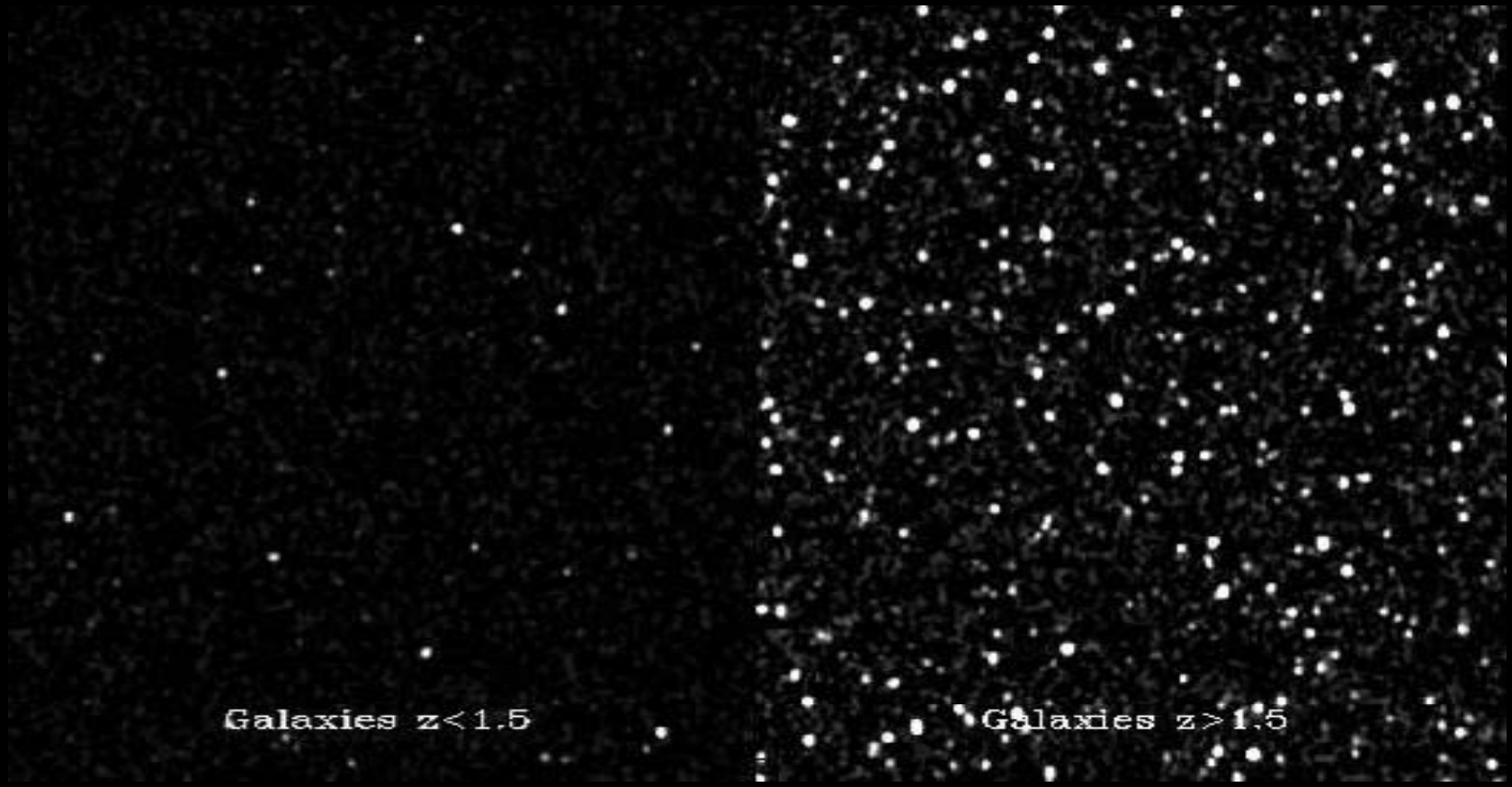
ALMA Science Primary Requirements

- Detect CO or C+ line emission in normal galaxies at z=3, in $t_{integration}$ < 24hrs

- Resolve protostellar/protoplanetary disks at ~ 500 lyrs $\rightarrow$ gas kinematics, chemical structure, tidal gaps

- Provide precise images at resolution 0.1”

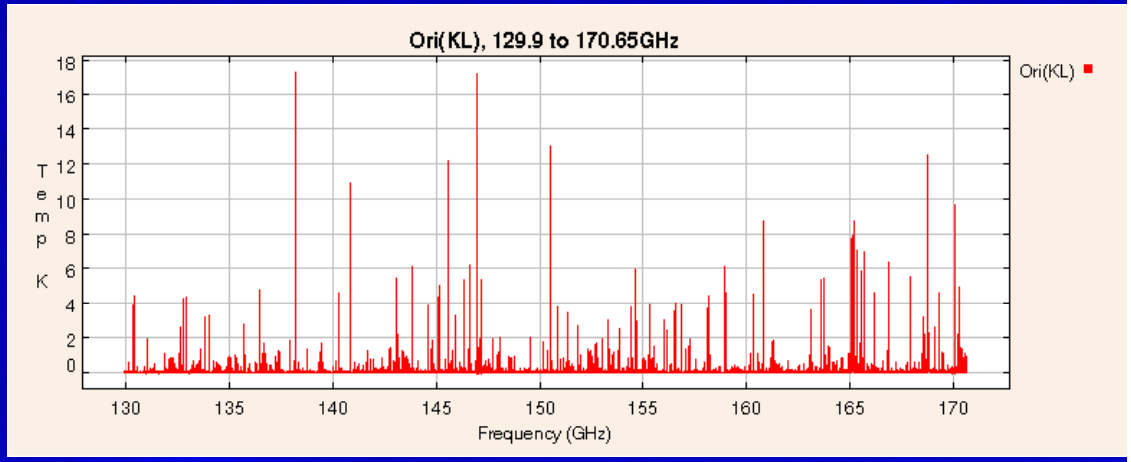
ALMA DF: Rich in Distant Galaxies



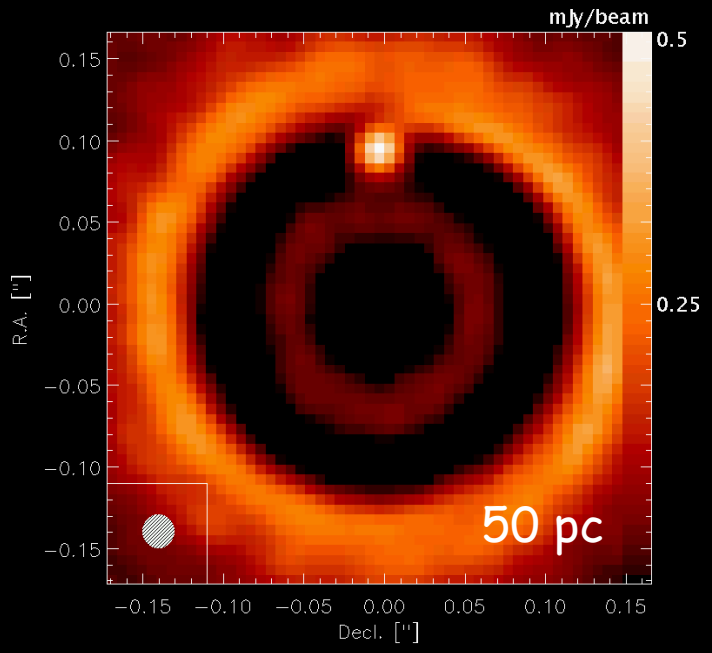
Nearby galaxies in ALMA DF Distant galaxies in ALMA DF

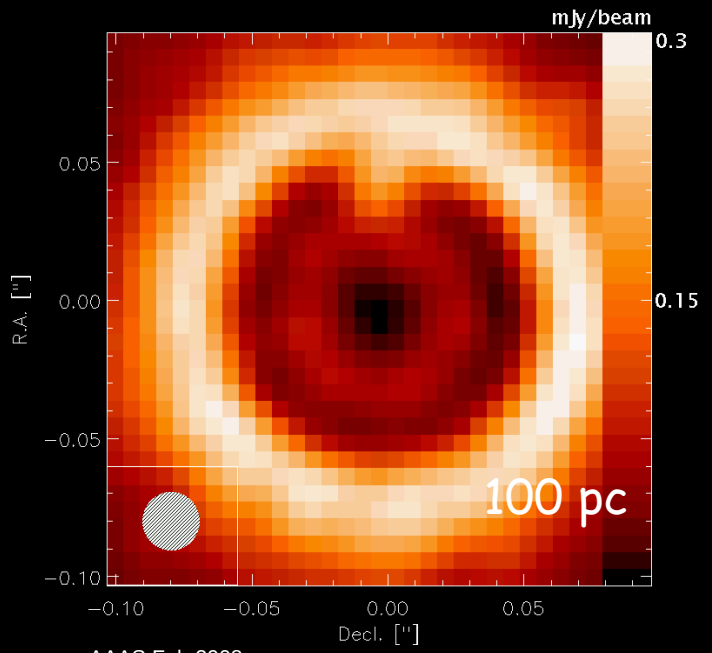
ALMA Key Science : Astrochemistry

Spectrum courtesy B. Turner (NRAO)



- Millimeter/submillimeter spectral lines strong in planets, young stars, many distant galaxies.
- Most observed transitions of known interstellar molecules in mm/submm ~17,000 lines in small 2mm region (above)





ALMA Key Science Planetary regions, nearby disks

$M_{planet} / M_{star} = 0.5\ M_{Jup} / 1\ M_{sun}$

Orbital radius: 5 AU

Disk mass as in the circumstellar disk around the Butterfly Star in Taurus

ALMA: 10km, t_{int}=8h

Technical Specifications

- 54 12-m antennas, 12 7-m antennas, at 5000 m site
- Surface accuracy ±25 μm, 0.6" reference pointing in 9m/s wind, 2" absolute pointing all-sky.
- Array configurations between 150m to ~15-18km.
- 10 bands in 31-950 GHz + 183 GHz WVR.
- 8 GHz BW, dual polarization.
- Interferometry, mosaicing & total-power observing.
- Correlator: 4096 channels/IF (multi-IF), full Stokes.
- Data rate: 6MB/s average; peak 64 MB/s.
- All data archived (raw + images), pipeline processing.

ALMA Sites

- Array Operations Site (AOS)
  - Antennas, correlator, reconfiguration.
- Operations Support Facility (OSF)
  - Array operation, equipment maintenance
- Santiago Central Offices (SCO)
  - Administration, scientific support
- ALMA Regional Centers (ARCs + ARClets)
  - interfaces to astronomy community


Tocopilla
Chuquicamata
Calama
Geiser
del Tatio
BOLIVIA
Mejillones
San Pedro de Atacama
ALMA
Toconao
Baquedano
Salar
de
Atacama
Antofagasta
Peine
Mina
Escondida
Paranal
ARGENTINA
Taltal
22º
23º
24º
25º
24
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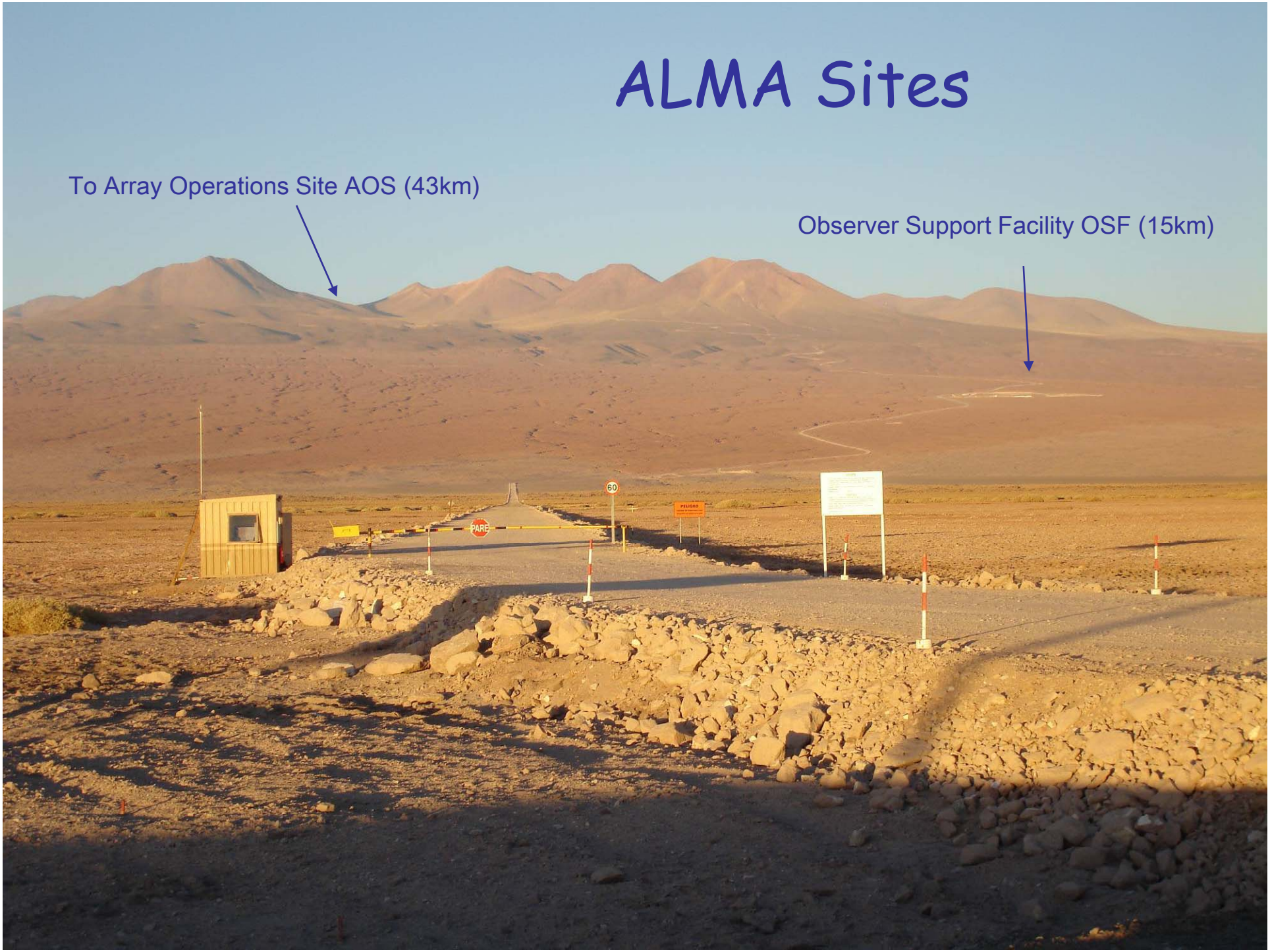
25
5
1
1
1
5


San Pedro de Atacama,
Atacama Desert, Chile

ALMA Sites


To Array Operations Site AOS (43km)
Observer Support Facility OSF (15km)
PARE
60
PELIGRO

Array Operations Site
5000m Chajnantor plateau – looking south

Transparent Site → Complete Spectral Coverage

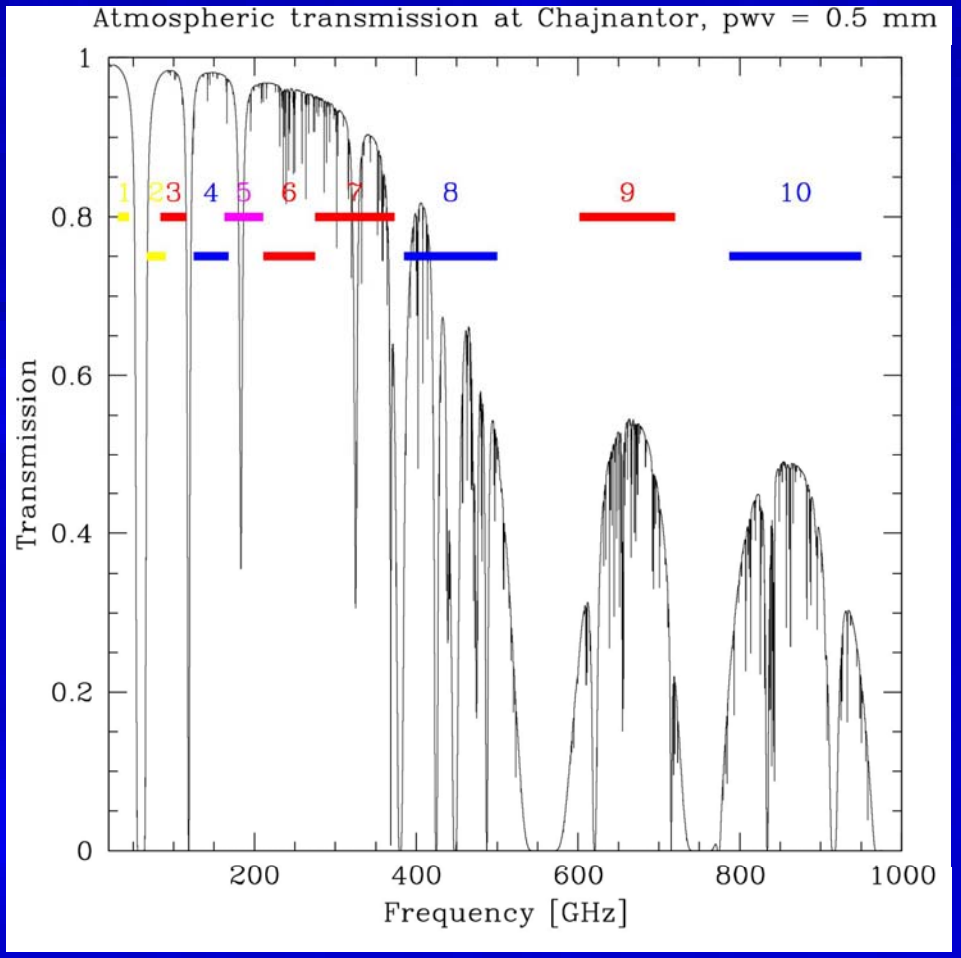
- Frequency bands match atmospheric windows

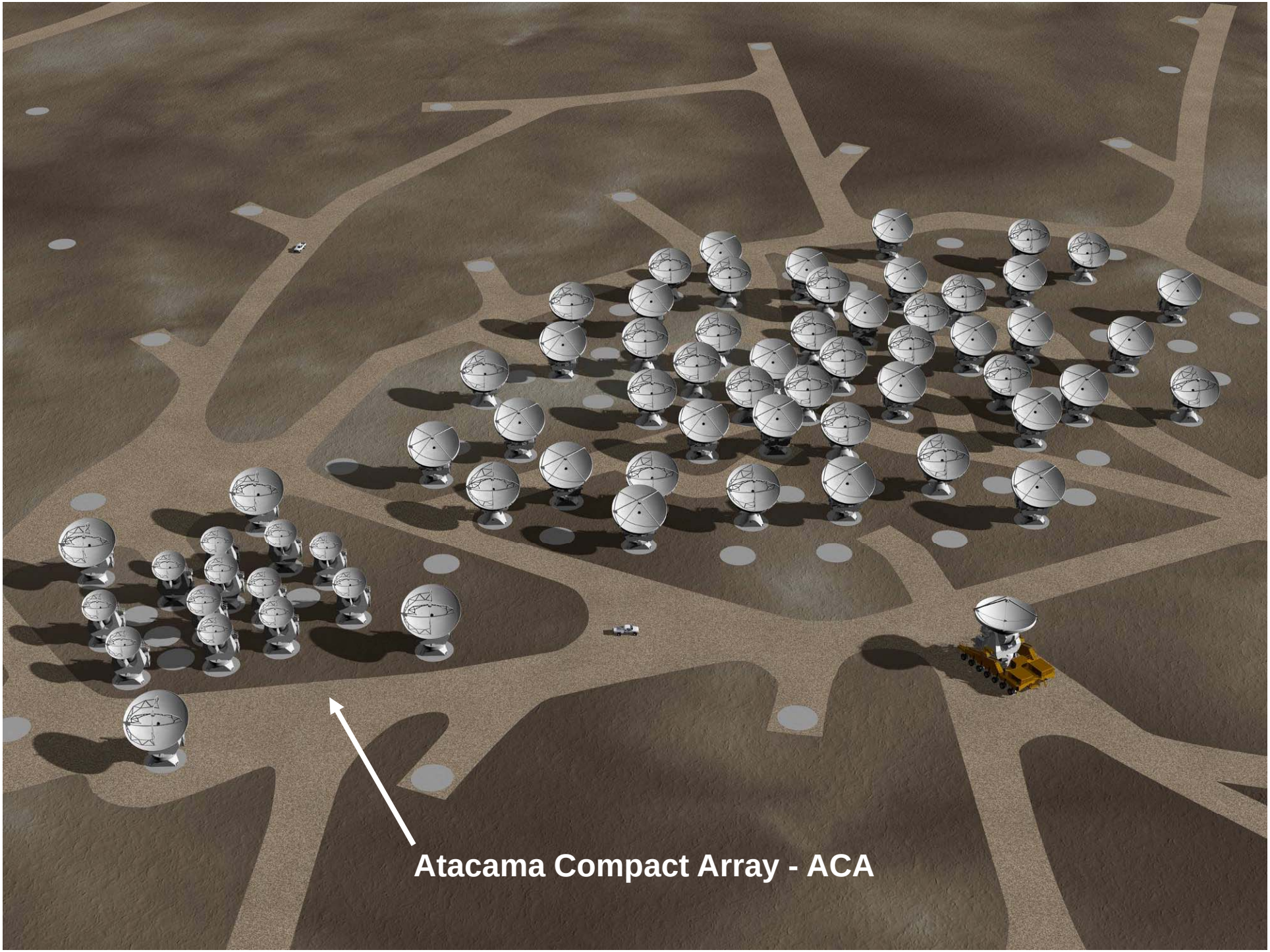
- Bands 3 (3mm), 6 (1mm), 7 (.85mm) and 9 (.45mm) available initially

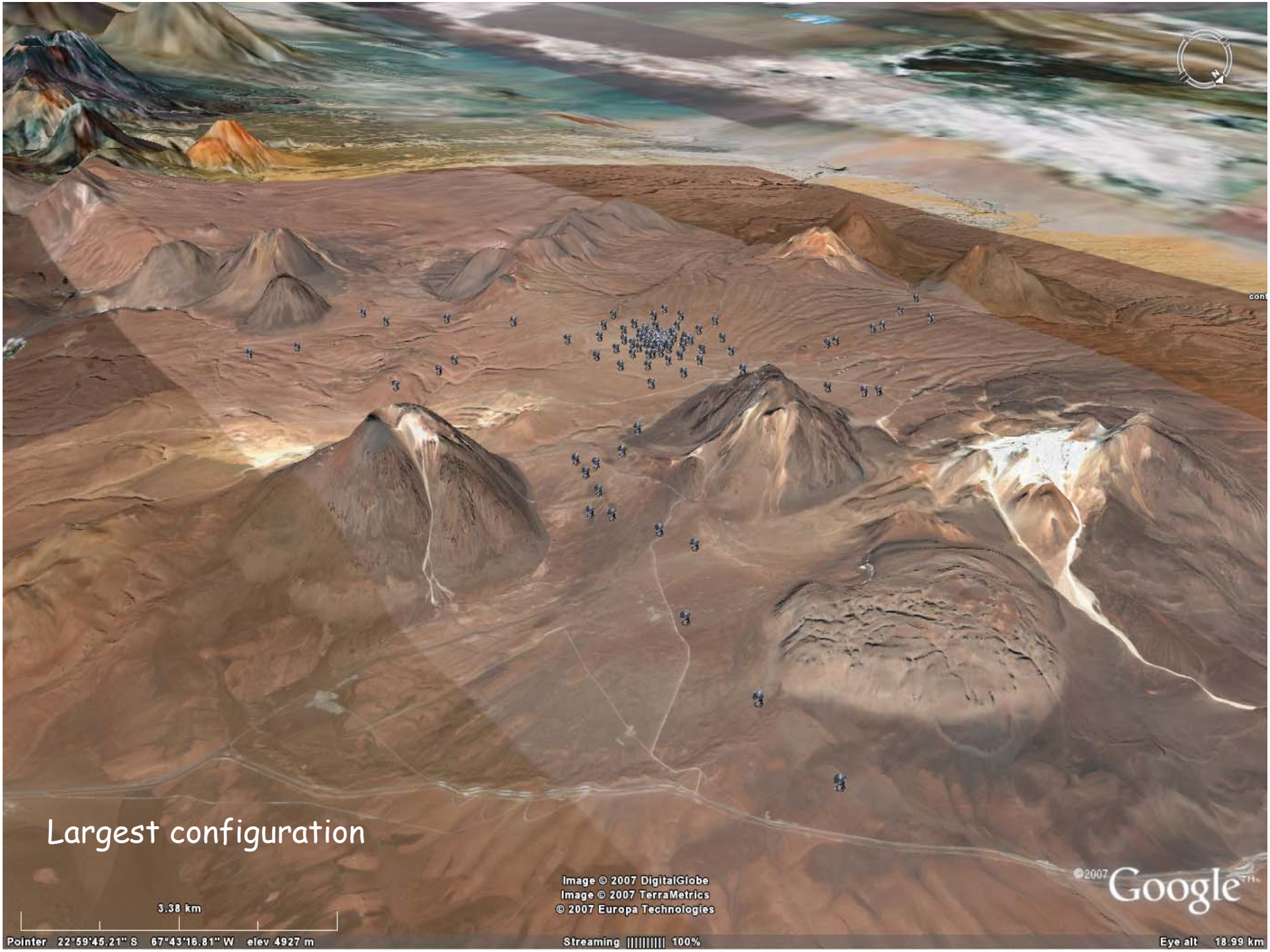
- Bands 4 (2mm), 8 (.65mm), some 10 (.35mm) later (Japan)

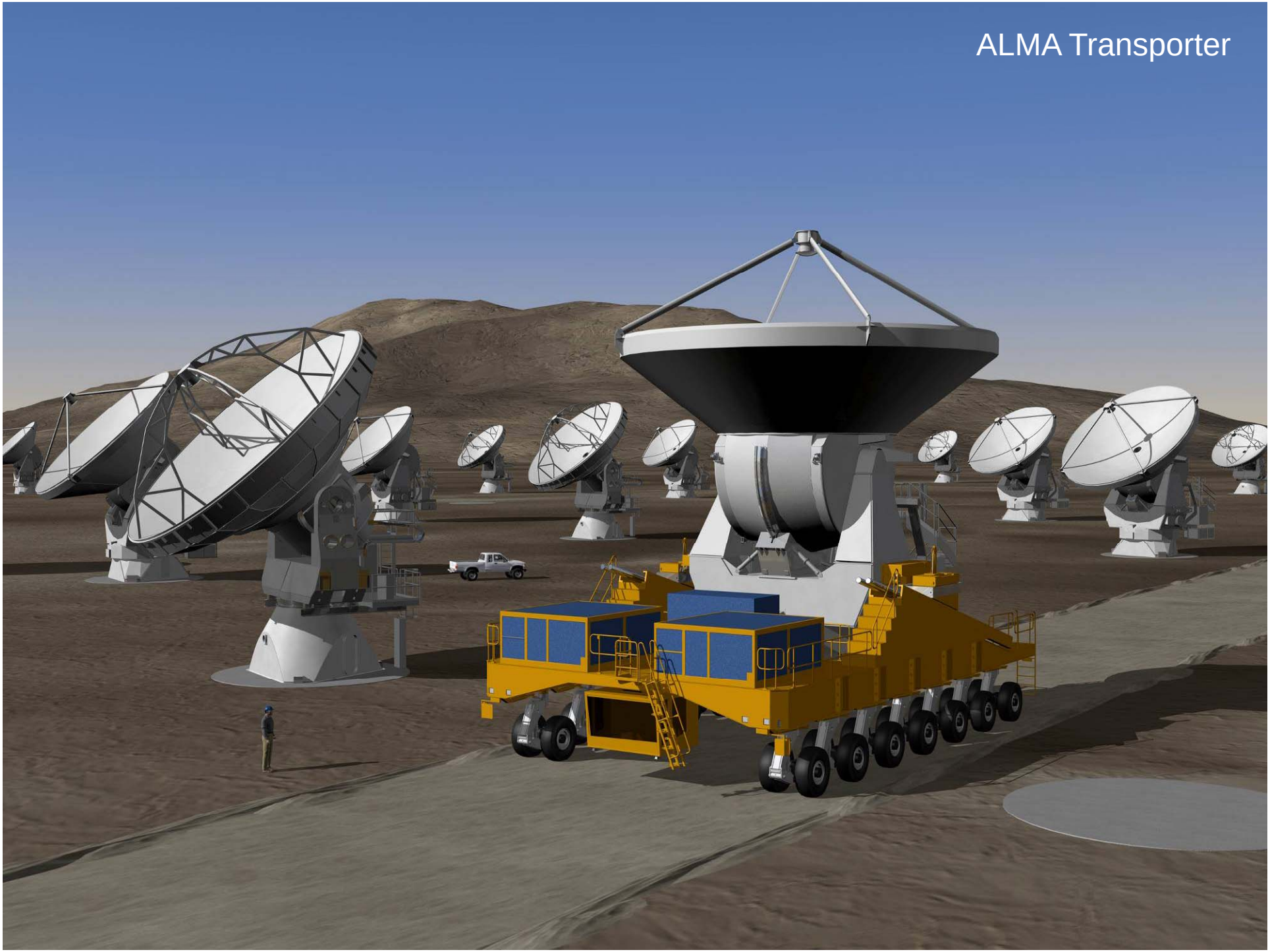
- Some Band 5 (1.5mm) from EU funds

- All process 16 GHz of data
  - 2polzns x 8 GHz (1.3mm=B6)
  - 2 polzns x 2SBs x 4 GHz (3mm=B3, 2mm=B4, .8mm=B7, .6mm=B8, 1.5mm=B5)
  - 2 polzns x DSB x 8 GHz (.45mm=B9, .35mm=B10)




Atacama Compact Array - ACA


Largest configuration
Image © 2007 DigitalGlobe
Image © 2007 TerraMetrics
© 2007 Europa Technologies
©2007 Google
3.38 km
Pointer 22°59'45.21" S 67°43'16.81" W elev 4927 m
Streaming 100%
Eye alt 18.99 km


ALMA Transporter

The ALMA Antenna Transporter

ESO Press Photo 45b/07 (5 October 2007)


AOS Technical Building

Operations Support Facility - OSF

Antenna Status

Vertex

- #1 – Assembly & manufacturer integration
- #2,3 – Assembly @ OSF…

AEM

- Component manufacture underway
- Steel fabrication started (Spain), cabin manufacture (France)
- 1st Antenna – late '08/early '09

ALMA-J

- 12-m antennas:
  - Four @OSF – Assembly/integration
- 7-m antennas:
  - Contract for #1 (prototype) signed early April.
  - Remaining 11 contract: April 2008.


Vertex #1: August 2007
SKY TRAK


MELCO #1-3 : Oct 2007
17.10.2007 17:03

Budget

- ALMA concept: mid 90s….
- 2002 project budget: $590M
- 2004-2005: rebaselining (scope, budget, schedule)
- Budget: 40% ($230M)↑
- Number of antennas decreased: 64→50
- Scope reductions
- Complex multi-currency, 10-yr budget

- Operating budget ~$65M/yr, ramping to 2007-2012…

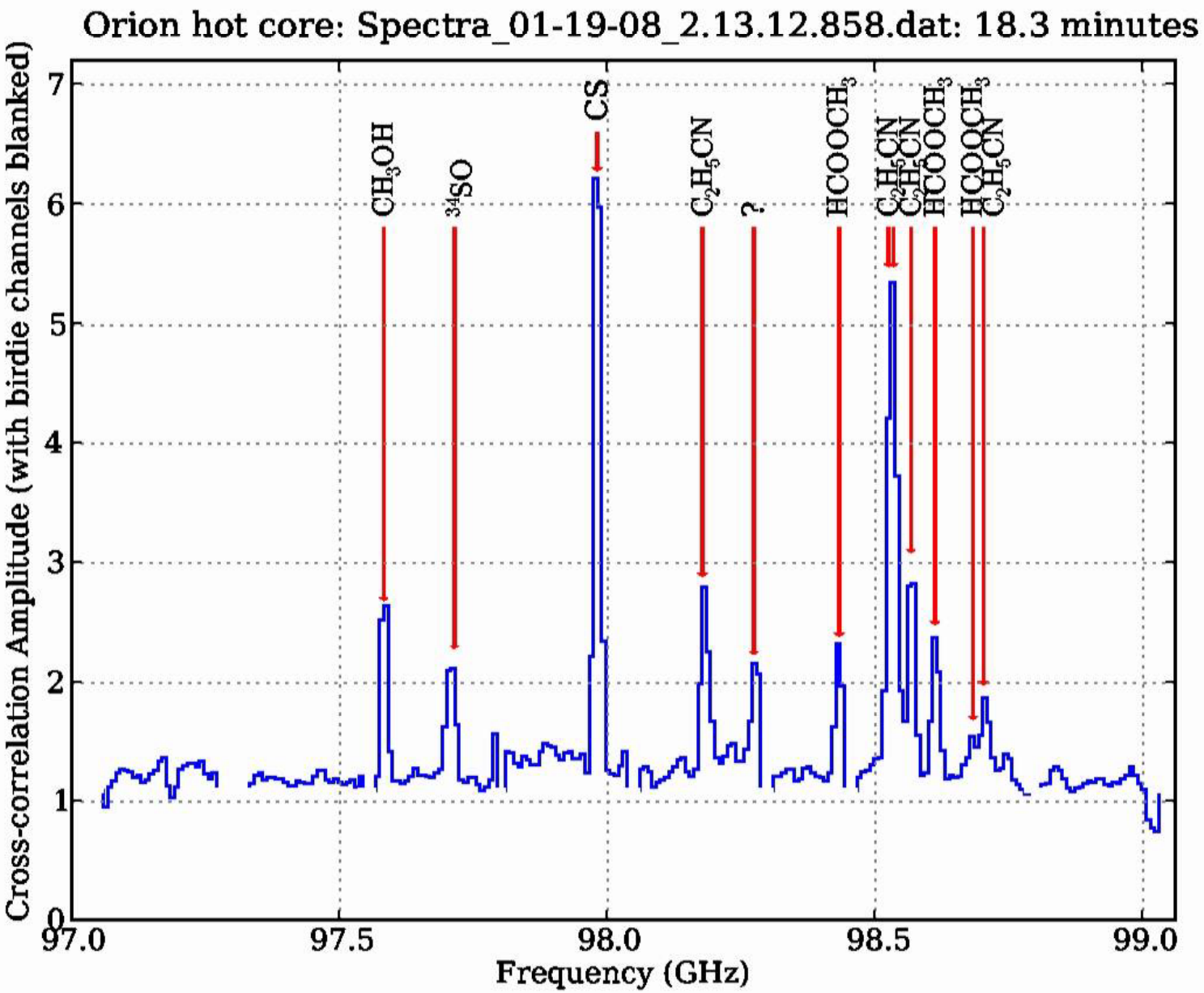
Japan - ALMA-J

- New partner: Agreement signed between the NSF-ESO-NINS Sept 2004/July 2006.
  - Four additional 12-m antennas (total power)
  - Twelve 7-m diameter antennas in compact configuration: Atacama Compact Array
  - Separate ACA correlator
  - Receiver: Bands 4, 8… 10

Atacama Compact Array – ACA

- Significantly improves low surface brightness sensitivity of ALMA; add precision total power data

First Interferometric spectra – ATF Jan 19th 2008



Current Status

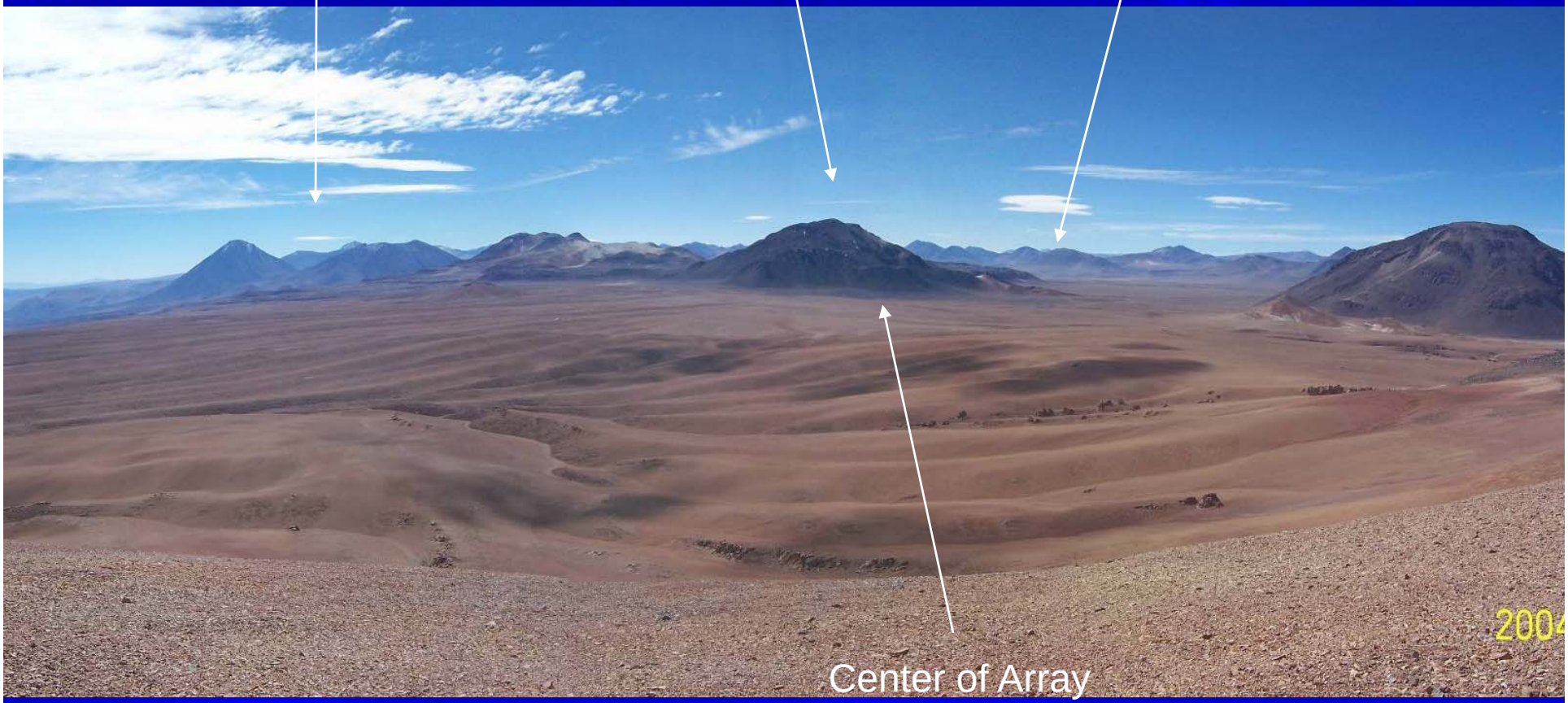
- Antenna production lines underway
- Equipment production lines: starting up….
- Site: OSF complete early 2008, AOS late 2008+
- Two antenna interferometer
  - OSF: Aug 2008, AOS: March 2009
- Early Science Decision Point: 2010.

- Transition: construction → AIVC, early Operations (Assembly/Integration/Verification/Commissioning)

- Issues
  - AOS operations… weather, oxygen
  - Equipment reliability in working environment

- Early science: 2010/2011.

Chajnantor Plateau – looking north



www.alma.info

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership among Europe, Japan and North America, in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere, in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica in Taiwan and in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC). ALMA construction and operations are led on behalf of Europe by ESO, on behalf of Japan by the National Astronomical Observatory of Japan (NAOJ) and on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI).

Front End Specifications

- Preliminary results within parentheses are referred to the vacuum window and do not include noise from optics losses

ALMA Band	Frequency Range	Receiver noise temperature		Mixing scheme	Receiver technology	Supplier
		T_{Rx} over 80% of the RF band	T_{Rx} at any RF frequency			
1	31.3 – 45 GHz	17 K	28 K	USB	HEMT	Not assigned ***
2	67 – 90 GHz	30 K	50 K	LSB	HEMT	Not assigned
3	84 – 116 GHz	37 K (40K)	62 K (50K)	2SB	SIS	HIA
4	125 – 169 GHz	51 K (45K)	85 K (~55K)	2SB	SIS	NAOJ
5	163 – 211 GHz**	65 K	108 K	2SB	SIS	OSO
6	211 – 275 GHz	83 K (40K)	138 K (60K)	2SB	SIS	NRAO
7	275 – 373 GHz*	147 K (75K)	221 K (100K)	2SB	SIS	IRAM
8	385 – 500 GHz	196 K (160K)	294 K (~270K)	2SB	SIS	NAOJ
9	602 – 720 GHz	175 K (120K)	263 K (150K)	DSB	SIS	NOVA
10	787 – 950 GHz	230 K	345 K	DSB	SIS	NAOJ ?

* - between 370 – 373 GHz T_{rx} is less than 300 K ** - Limited to 6 units, funded by the EC under FP6 *** - Under consideration by U. Chile

- Dual, linear polarization channels:
  - Increased sensitivity
  - Measurement of 4 Stokes parameters
- 183 GHz water vapour radiometer:
  - Used for atmospheric path length correction