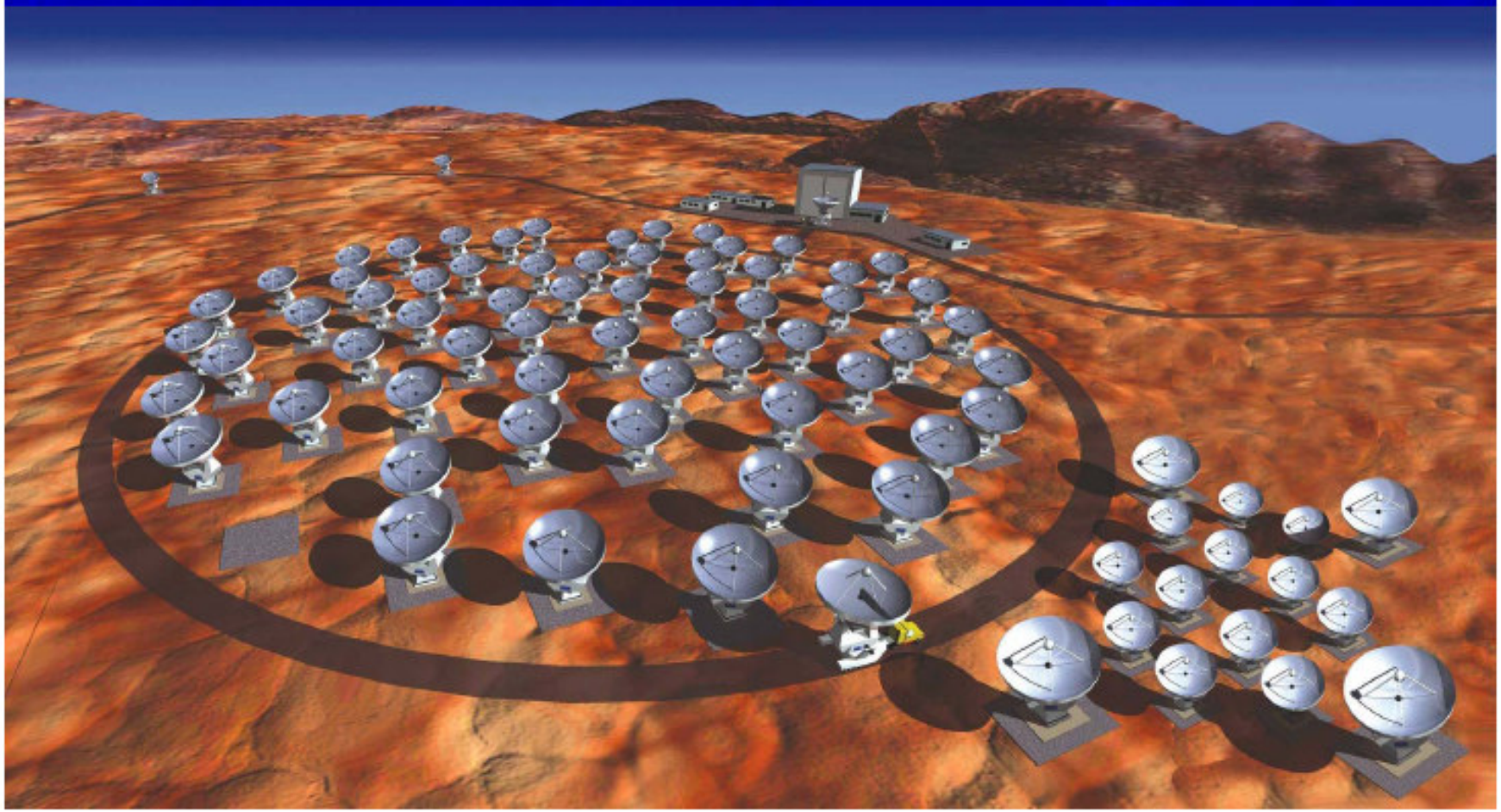
ALMA
and the Italian
ALMA Regional Centre (ARC)

Jan Brand
Coordinator Italian ARC

INAF - Istituto di Radioastronomia, Bologna

ALMA + ACA →
Atacama Large Millimeter/submillimeter Array

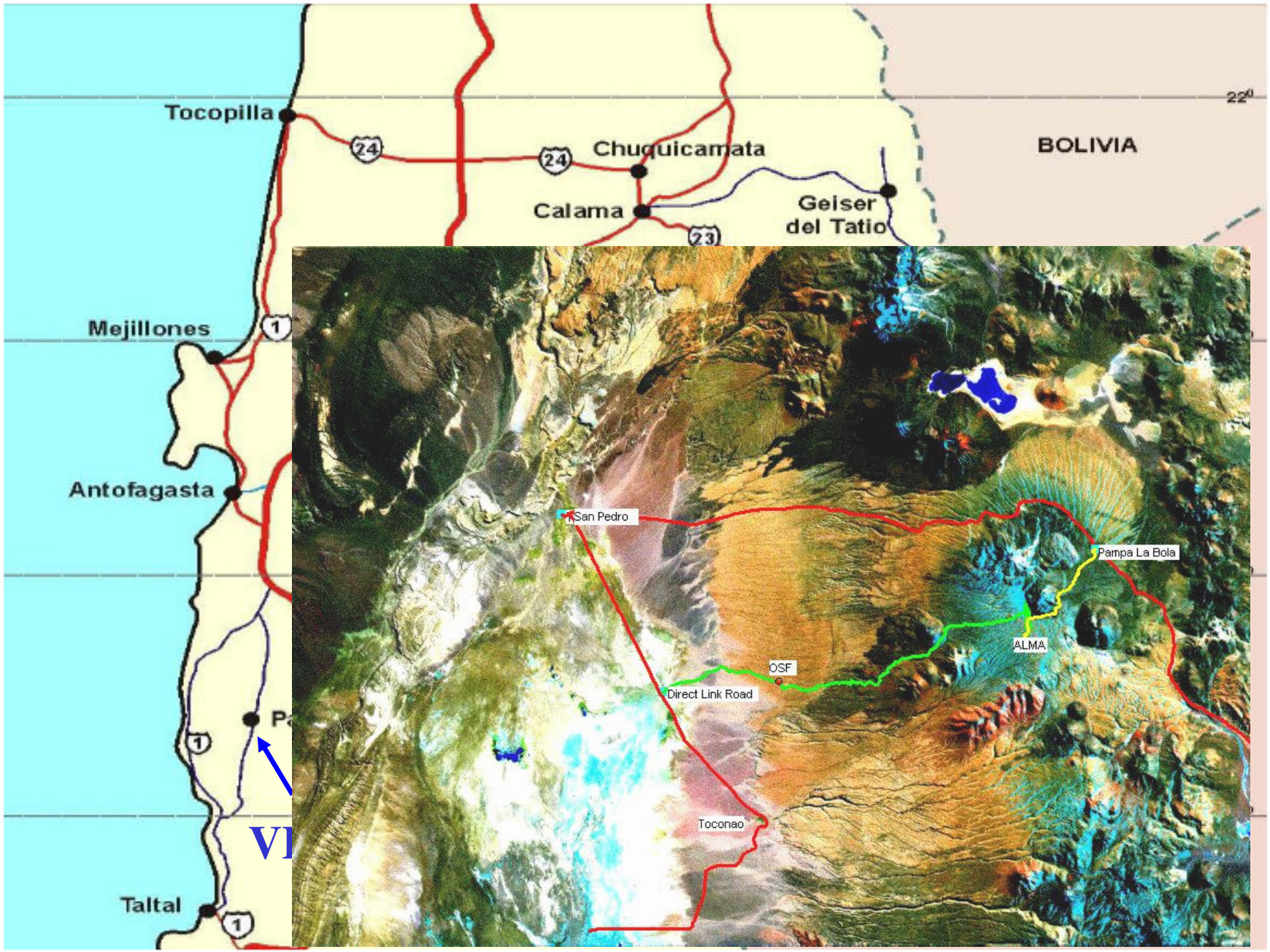


ALMA Project – Structure

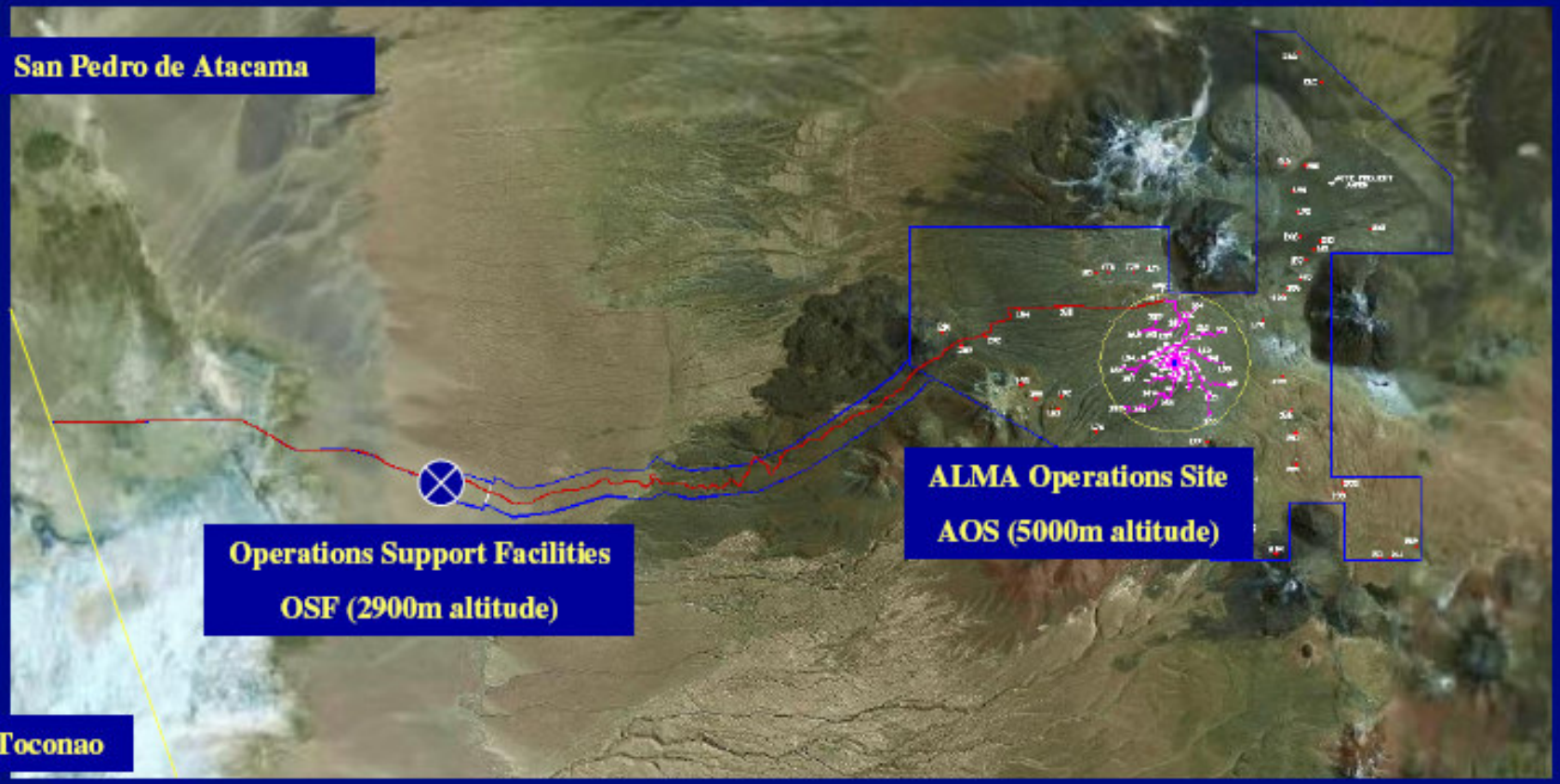
- Partners:
  - **Europe** - *European Organization for Astronomical Research in the Southern Hemisphere - ESO.*
  - **North America** - *National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) – AUI/NRAO*
  - **Chile**
  - **Japan/Taiwan** - *National Institutes of Natural Sciences (NINS), in cooperation with the Academia Sinica in Taiwan - NAOJ*

→ Joint ALMA Office: Construction project
→ Joint ALMA Observatory


Ecuador
Peru
Brazil
Lima
La Paz
Bolivia
Paraguay
Asunción
Chile
Uruguay


Tocopilla
24
24
Chuquicamata
Calama
23
Geiser
del Tatio
BOLIVIA
22°
Mejillones
1
Antofagasta
San Pedro
Pampa La Bola
ALMA
OSF
Direct Link Road
Toconao
1
1
Taltal

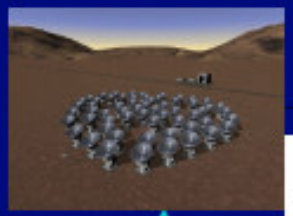
ALMA Site


San Pedro de Atacama
Operations Support Facilities
OSF (2900m altitude)
ALMA Operations Site
AOS (5000m altitude)
Toconao

ALMA Sites

- **Array Operations Site – AOS** – Antennas, correlator, reconfiguration. 5 km
- **Operations Support Facility – OSF** – Array operation, equipment maintenance 2.9 km
- **Santiago Central Offices – SCO** – Administration, scientific support. sea level
- **ALMA Regional Centers – ARCs + ARClets** – interfaces to astronomy community

ALMA Sites in Chile



Antenna Operations Site (AOS)

40 MB/s (peak)

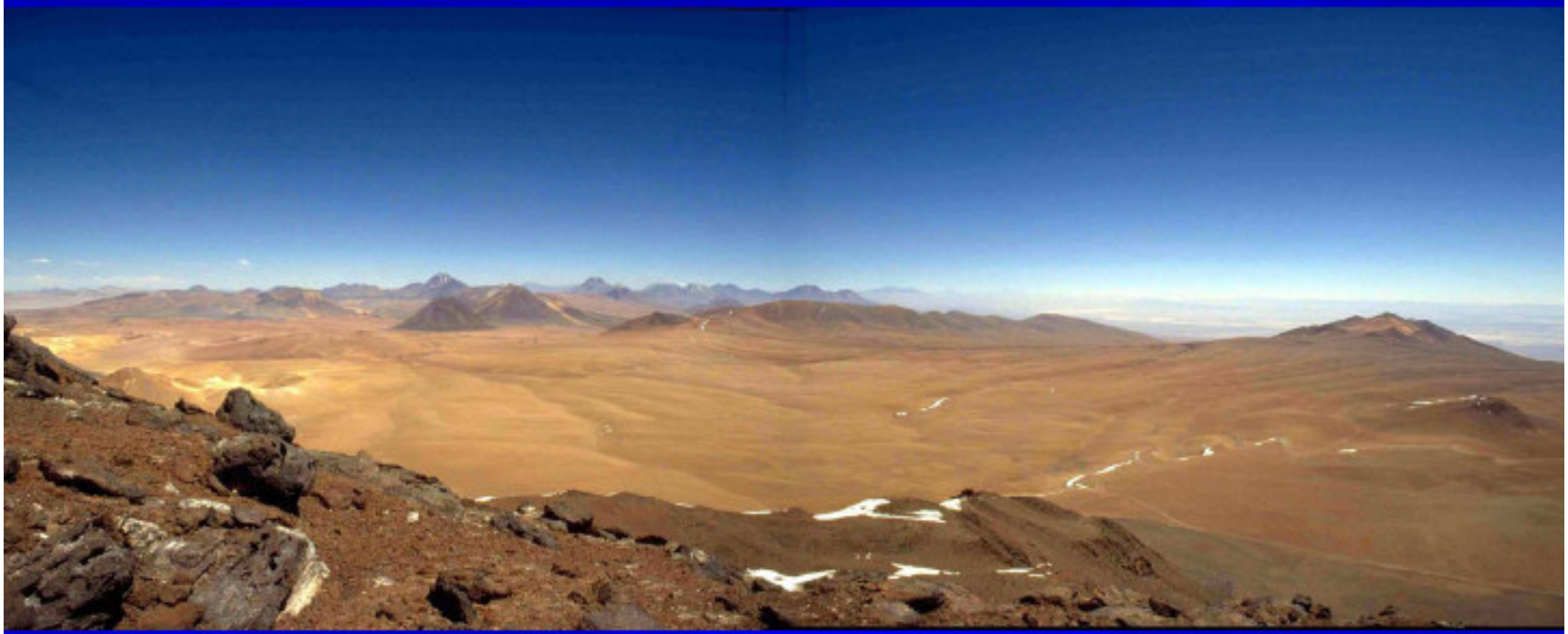
Operation Support Facility (OSF)

6 MB/s (average)

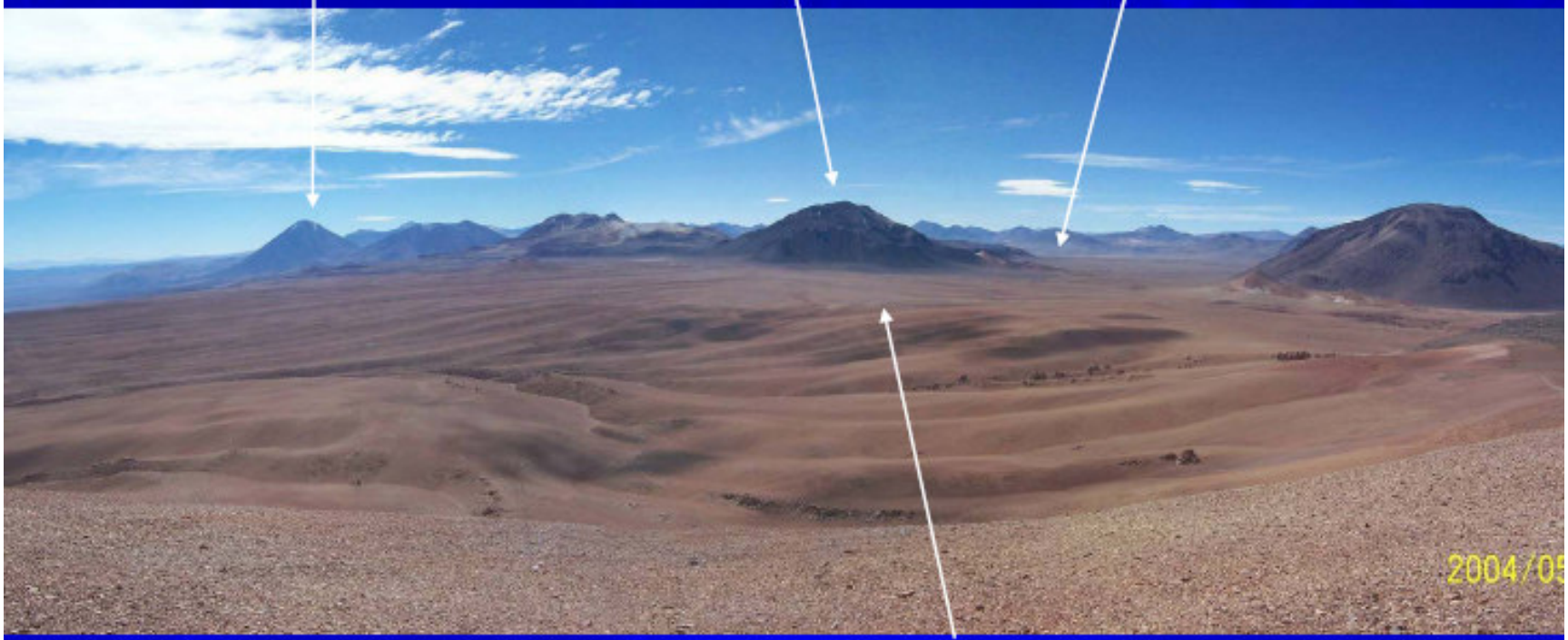
Santiago Central Office (SCO)

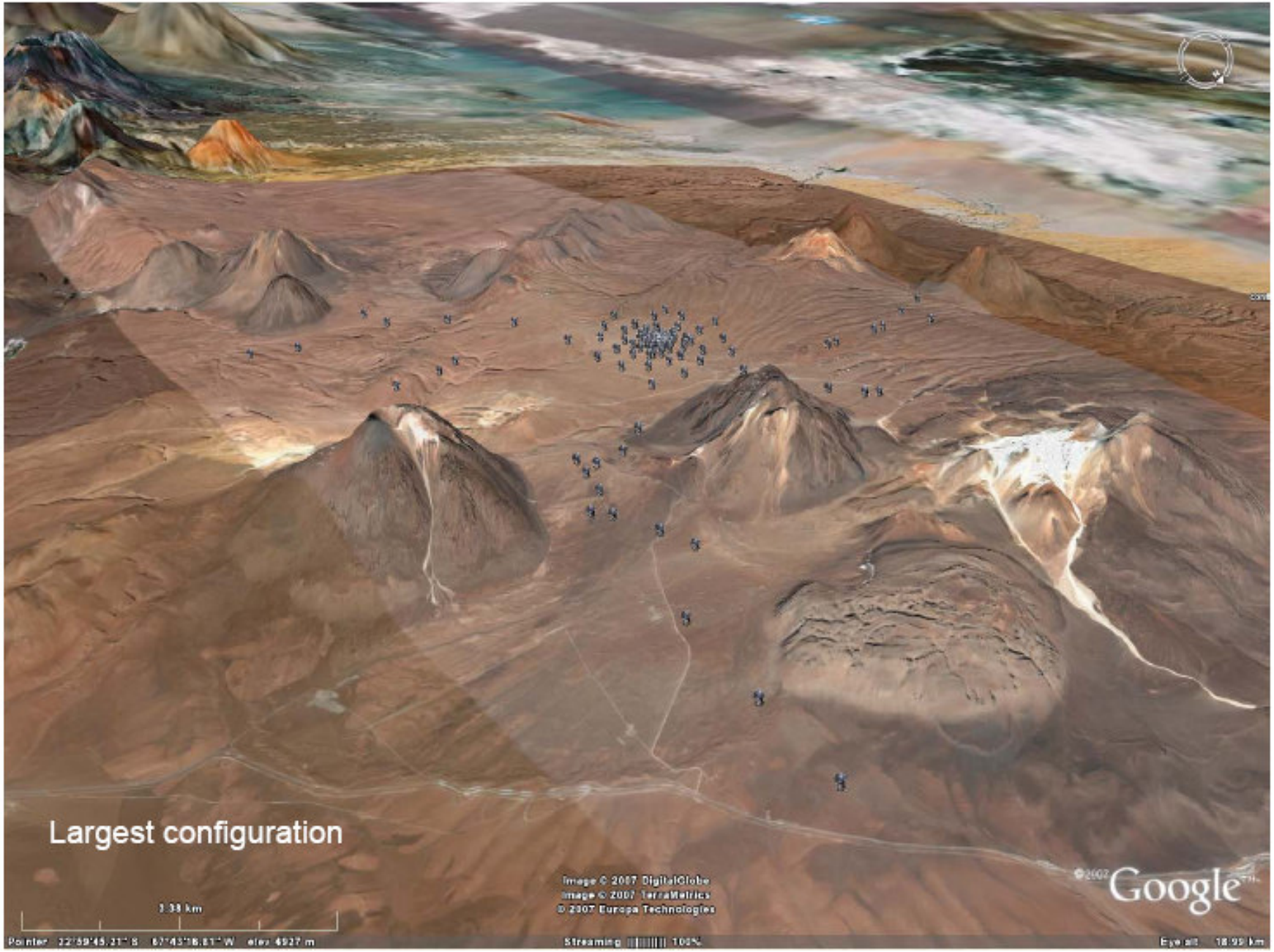
5000m Chajnantor plateau – looking south

Array Operations Site

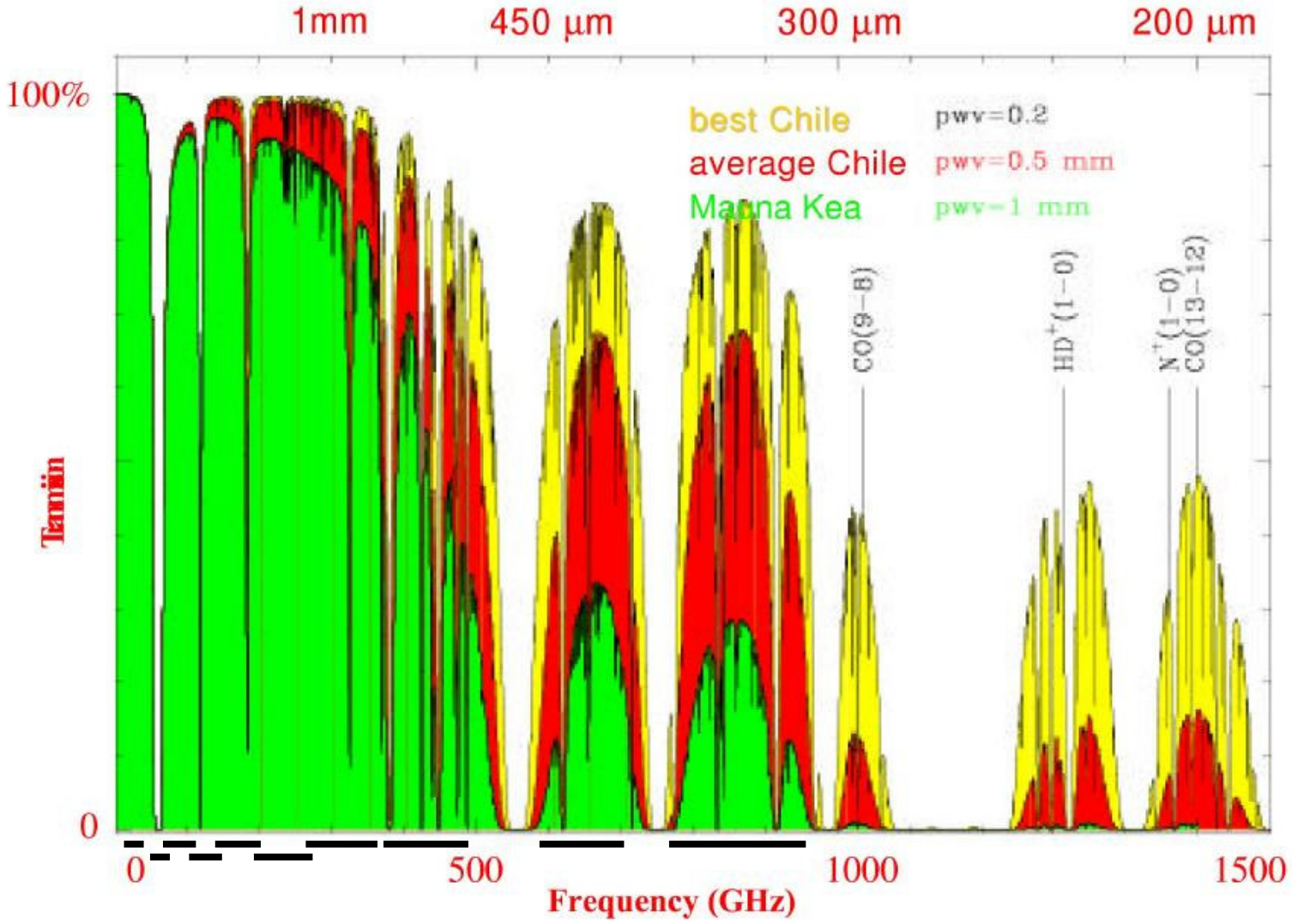


Chajnantor Plateau – looking north




Largest configuration
Image © 2007 DigitalGlobe
Image © 2007 TerraMetrics
© 2007 Europa Technologies
©2007 Google

Atmospheric Transmission



ALMA Science Requirements

Three “level I” science goals:

- *Spectral line CO/C+ in z=3 MWG < 24hrs*
- *resolve PPD at 150 pc – gas/dust/fields*
- *Precise 0.1” imaging above 0.1% peak*

- High Fidelity Imaging.
- Routine sub-mJy Continuum / mK Spectral Sensitivity.
- Wideband Frequency Coverage.
- Wide Field Imaging Mosaicing.
- Submillimeter Receiver System (..& site..).
- Full Polarization Capability.
- System Flexibility (hardware/software).

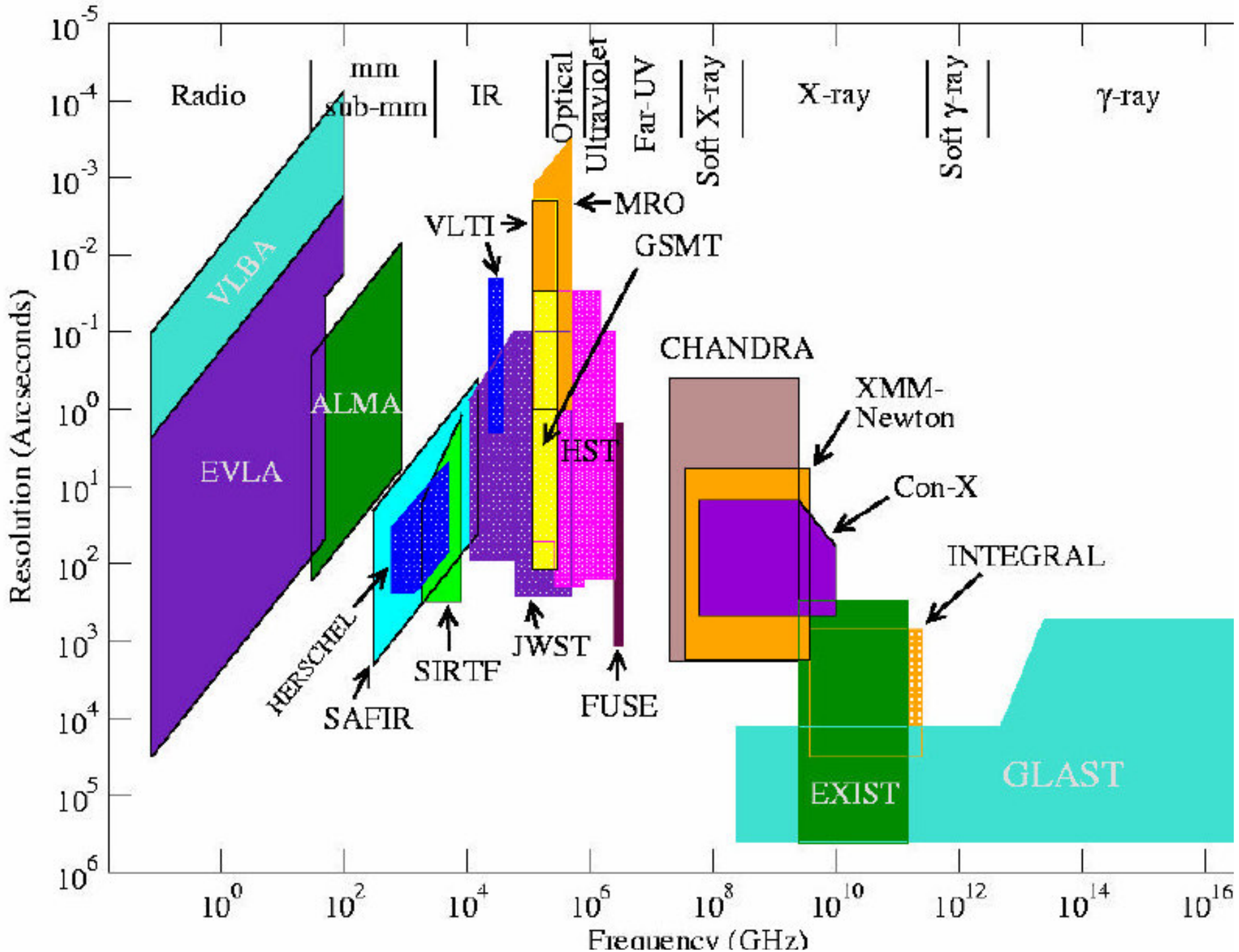
⇒ ALMA Technical Specifications

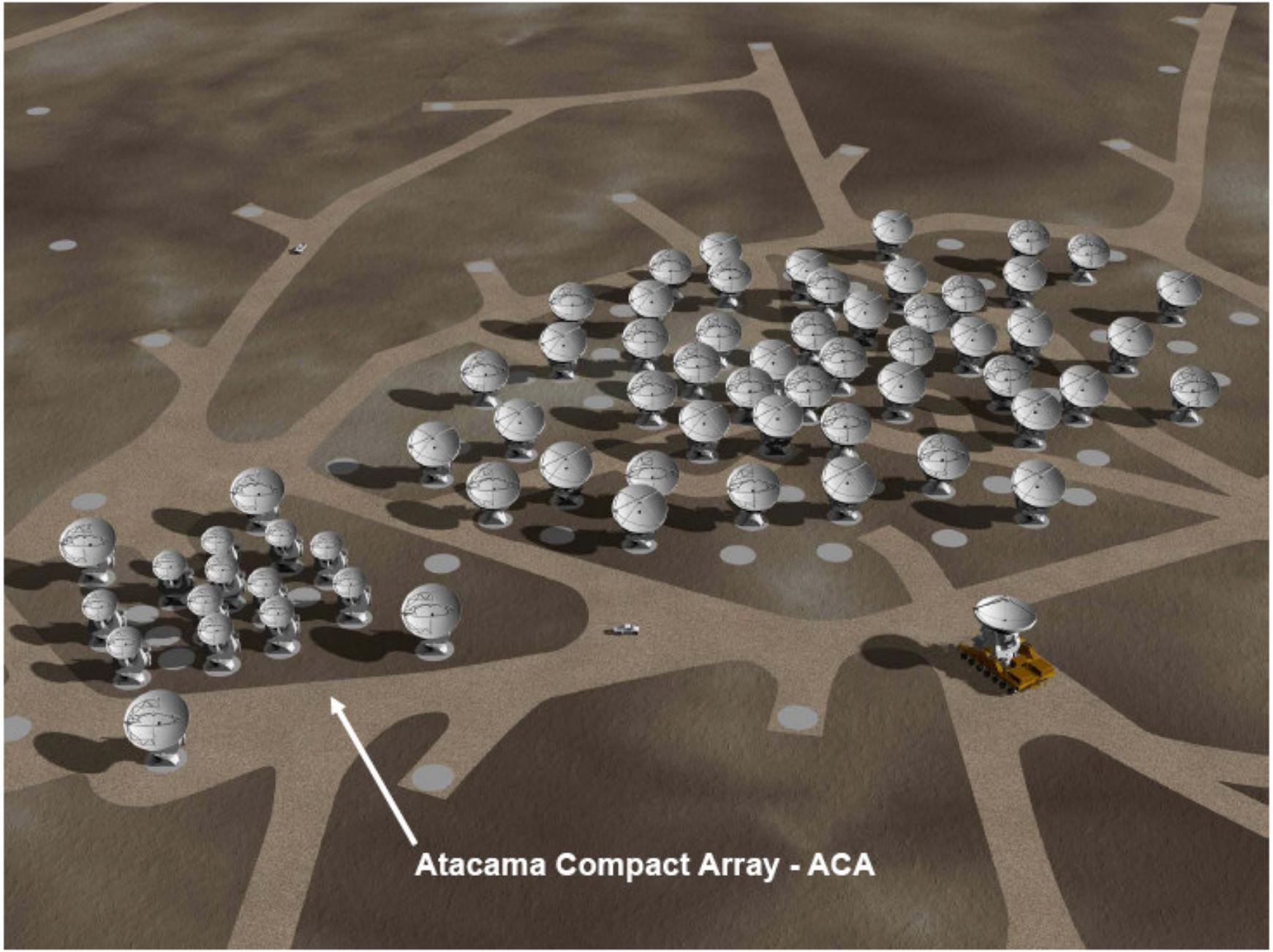
- 54 12-m antennas, 12 7-m antennas, at 5000 m altitude site, desert environment.
- Antennas: Surface accuracy ±25 μm, 0.6" reference pointing in 9m/s wind, 2" absolute pointing all-sky.
- Array configurations between 150m to ~15 -18km.
- 10 bands in 31-950 GHz + 183 GHz WVR. Initially:

❖86-119 GHz	"3"	3 mm
❖125-169 GH	"4"	2 mm
❖211-275 GHz	"6"	1.3 mm
❖275-370 GHz	"7"	0.85 mm
❖385-500 GHz	"8"	0.65 mm
❖602-720 GHz	"9"	0.45 mm
❖787-950 GHz	"10"	0.35 mm

ALMA Technical Specifications

- 8 GHz BW, dual polarization.
- Flux sensitivity ~0.2 mJy in 1 min at 345 GHz
- Interferometry, mosaicing & total-power observing.
- Correlator: 4096 channels/IF (multi-IF), full Stokes.
- Data rate: 6MB/s average; peak 60-150 MB/s.
- All data archived (raw + images), pipeline processing.


Radio
mm
sub-mm
IR
Optical
Ultraviolet
Far-UV
Soft X-ray
X-ray
Soft γ-ray
γ-ray
VLBA
EVLA
ALMA
VLTI
MRO
GSMT
HST
CHANDRA
XMM-
Newton
Con-X
INTEGRAL
HERSCHEL
SAFIR
SIRTF
JWST
FUSE
EXIST
GLAST
Resolution (Arcseconds)
Frequency (GHz)


Atacama Compact Array - ACA

Role of ACA

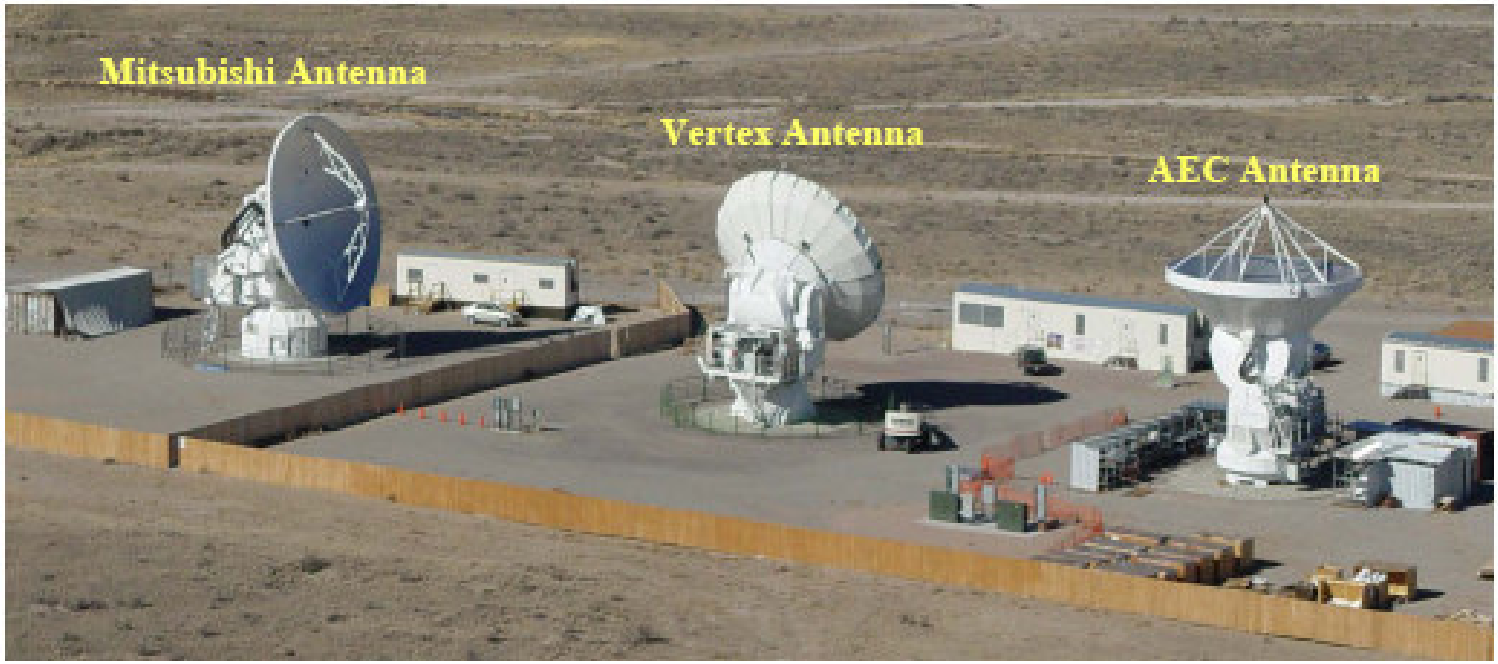
- **Supplement the 54-element array data with**
  - **Short baseline data (7-m antennas)**
  - **Total power data (12-m antennas)**

  ⇒***Enhance fidelity of ALMA images***
  (overcome "*missing-flux*" problem)

- **Stand-alone mode of operation**

  ⇒Available for ***target-of-opportunity*** observations, wide-field surveys, etc.

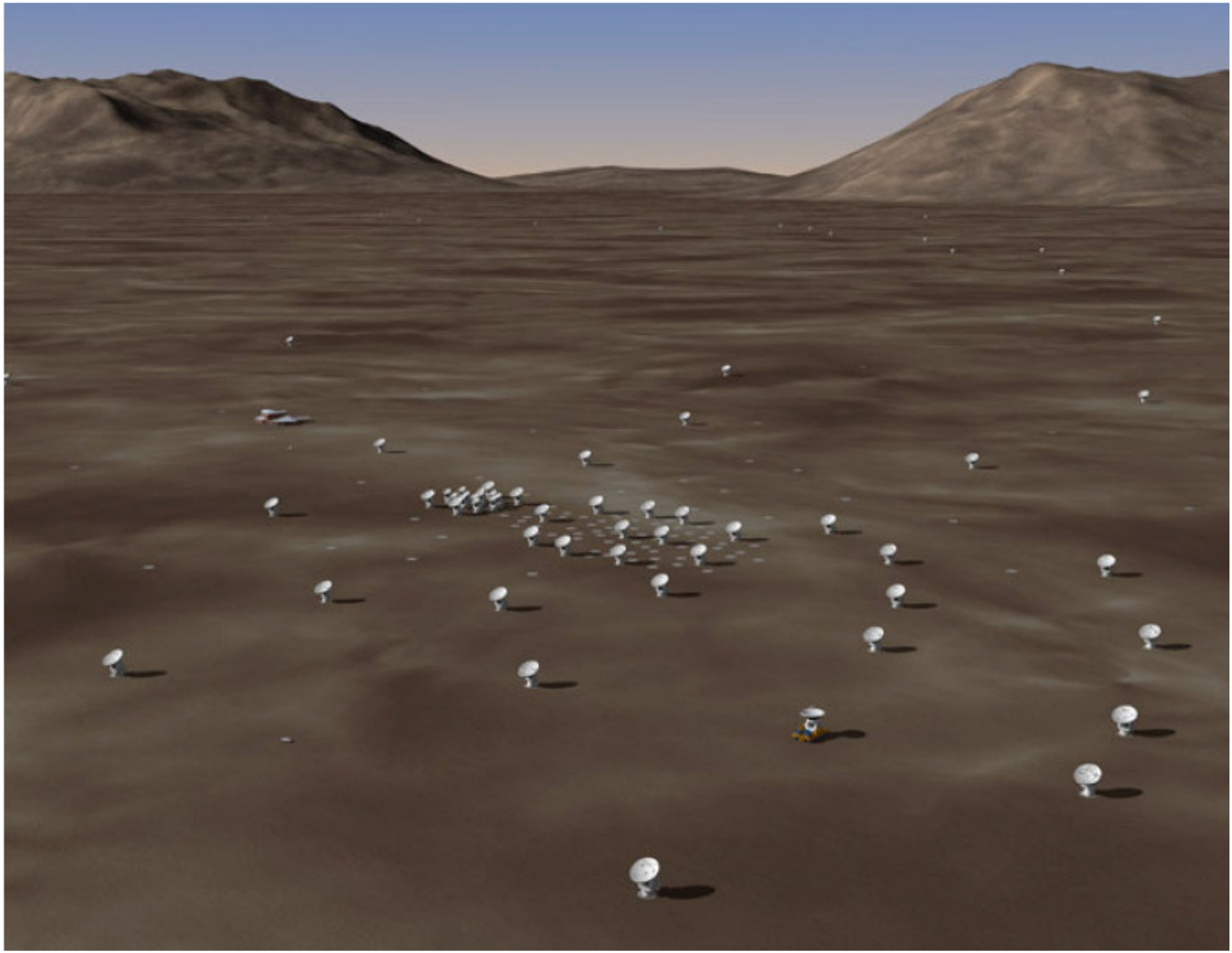
The Three ALMA Prototype Antennas at the ATF



12 Meter Diameter, Carbon Fiber Support Structures

The ALMA Antenna Transporter

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



Front End Specifications

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

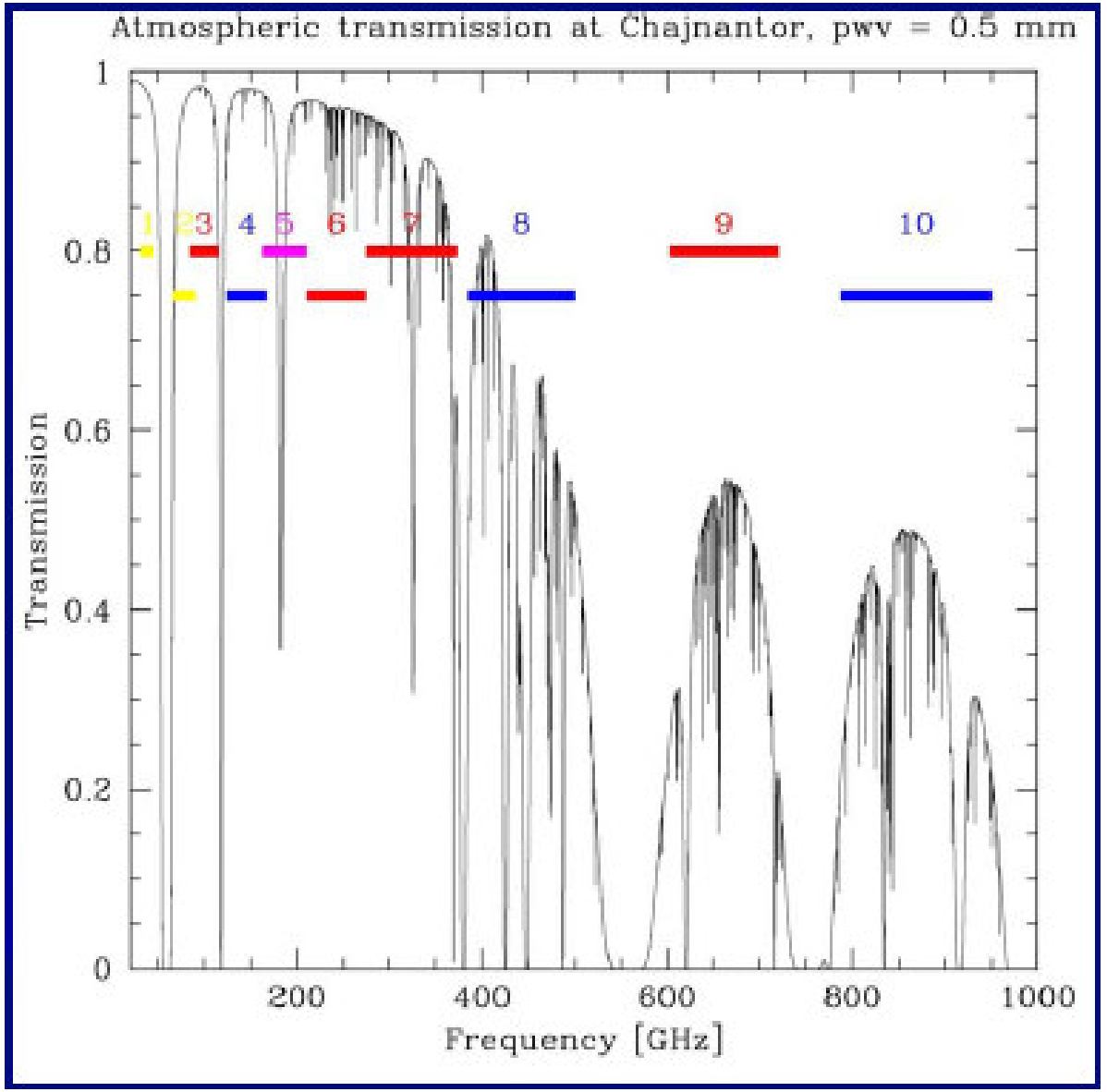
ALMA Band	Frequency Range	Receiver noise temperature		Mixing scheme	Receiver technology	Supplier
		T_{Rx} over 80% of the RF band	T_{Rx} at any RF frequency			
1	31.3 – 45 GHz	17 K	28 K	USB	HEMT	Not assigned ***
2	67 – 90 GHz	30 K	50 K	LSB	HEMT	Not assigned
3	84 – 116 GHz	37 K (40K)	62 K (50K)	2SB	SIS	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

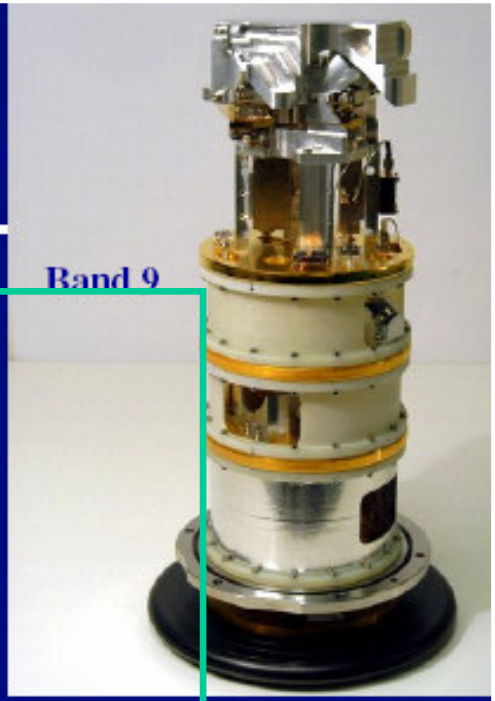
** - Limited to 6 units, funded by the EC under FP6

*** - 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


Atmospheric transmission at Chajnantor, pwv = 0.5 mm
Transmission
Frequency [GHz]
0
0.2
0.4
0.6
0.8
1
200
400
600
800
1000
1
2
3
4
5
6
7
8
9
10

Cartridge Production

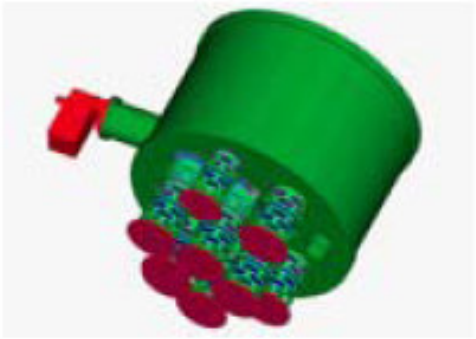


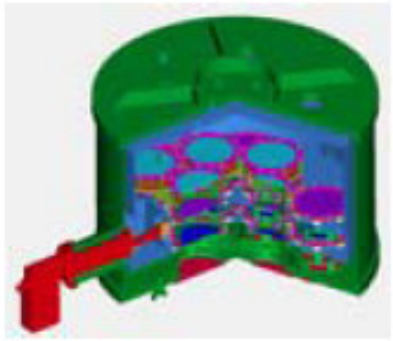
- Band 3 (HIA, Canada) 3 mm 86-119 GHz
- Band 6 (NRAO, USA) 1.3 mm 211-275 GHz
- Band 7 (IRAM, France) 0.85 mm 275-370 GHz
- Band 9 (NOVA, The Netherlands) 0.45 mm 602-720 GHz

Available from start

- Band 4 (NAOJ, Japan) 2 mm 125-169 GHz
- Band 8 (NAOJ, Japan) 0.65 mm 385-500 GHz
- Band 10(NAOJ, Japan) 0.35 mm 787-950 GHz

Front End Design

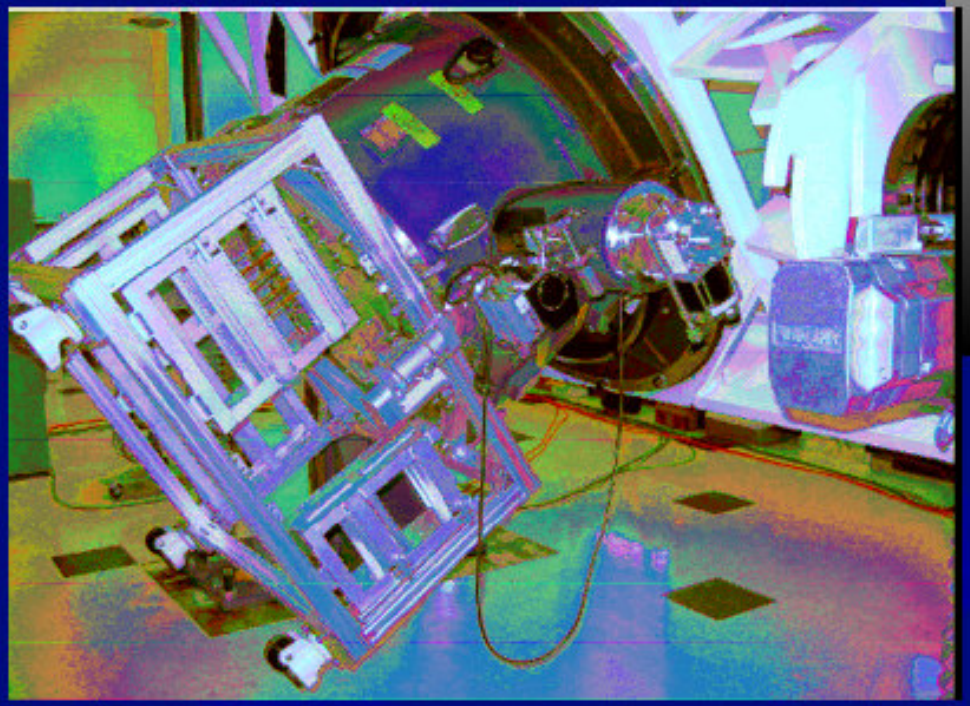


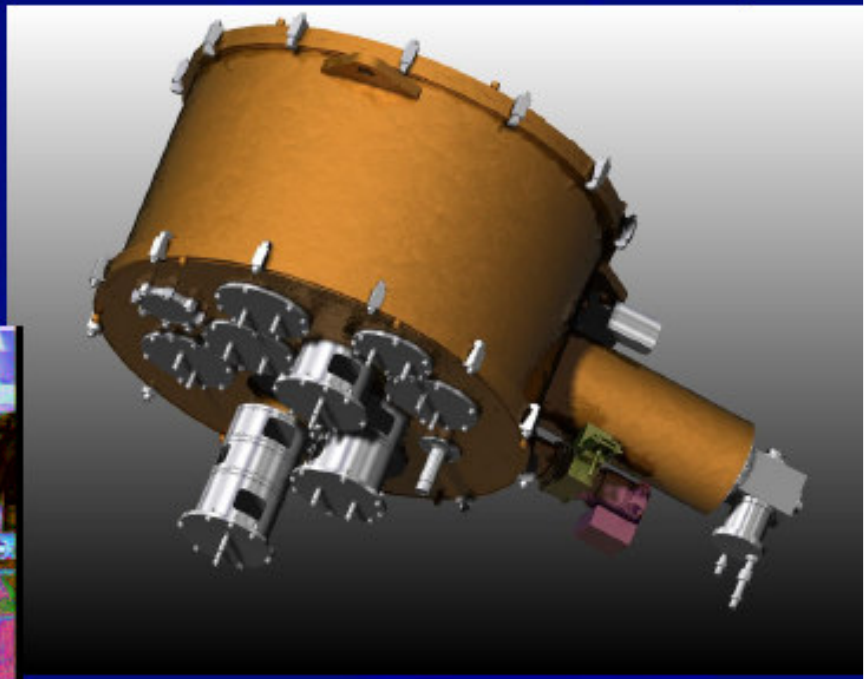


- Diameter ~ 1 m
- External optics top of dewar
- 10 Cartridges plugged from bottom
- Each cartridge contains one frequency

Front-end

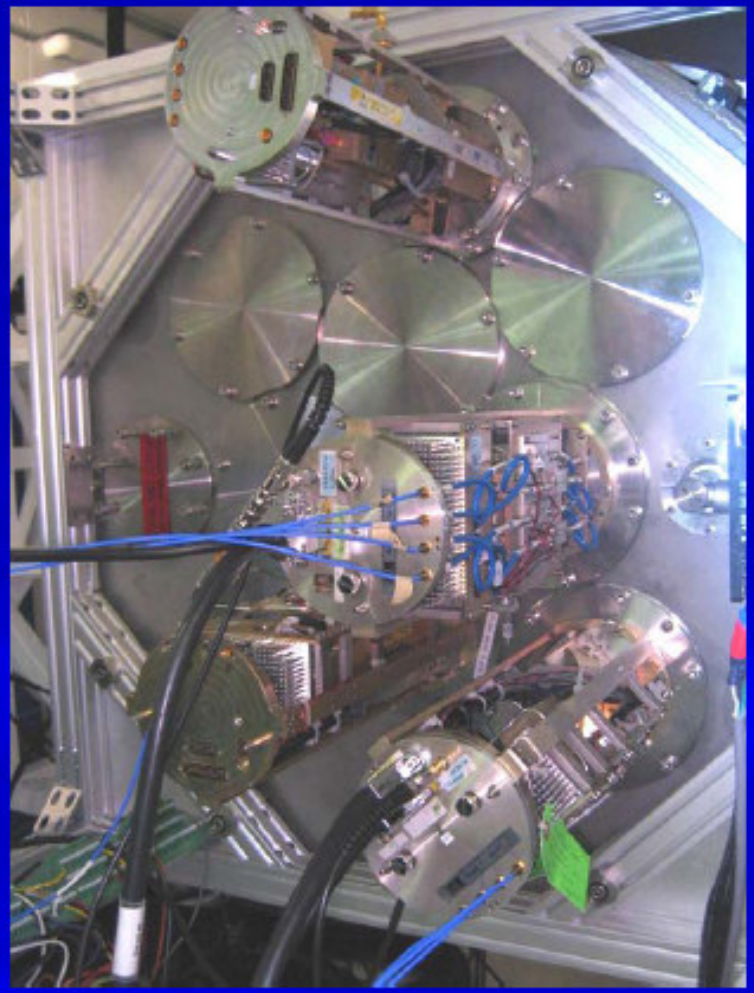
First cryostat in integration center

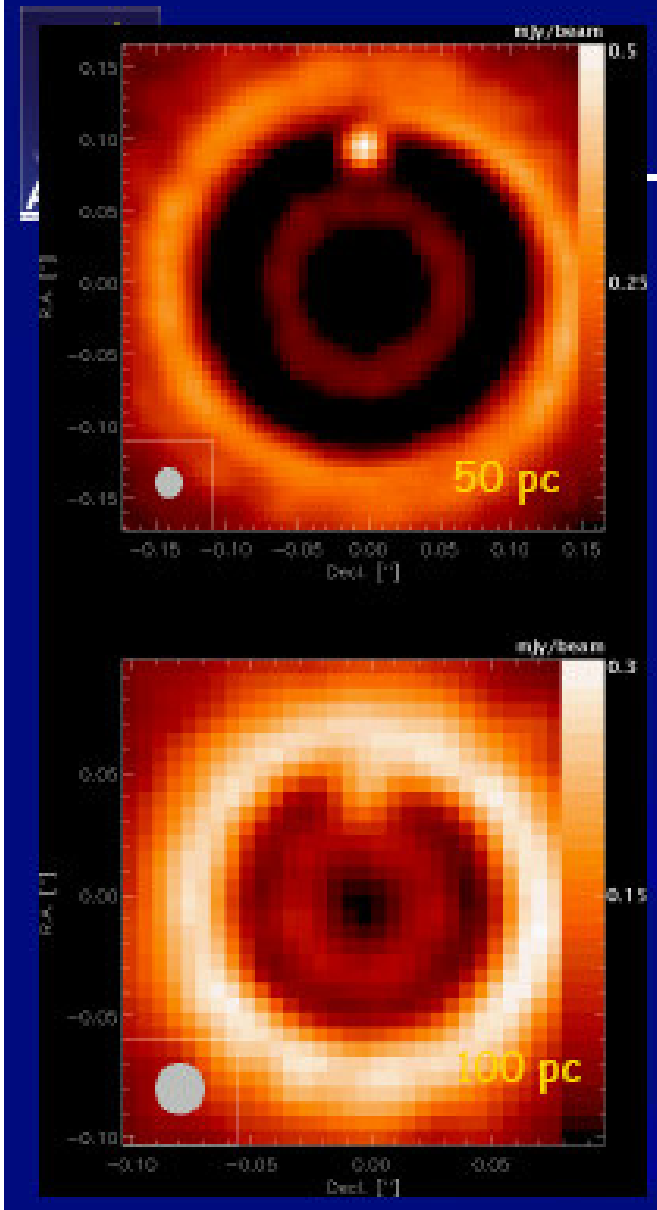




Receiver cartridge concept

FE #1 (4 cartridges)





ALMA Key science 1: Planetary regions, nearby disks

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

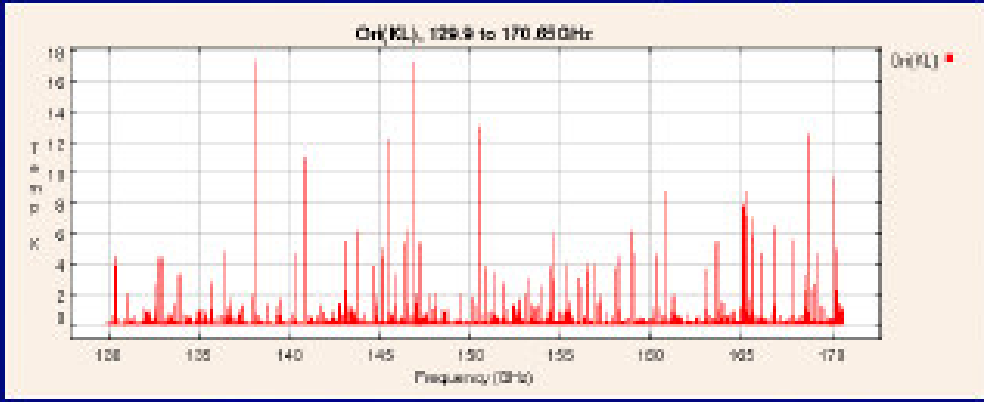
Orbital radius: 5 AU

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

(ALMA: 10km, t_{int}=8h, 30º phase noise)
Wolf & D'Angelo (2005)
astro-ph / 0410064

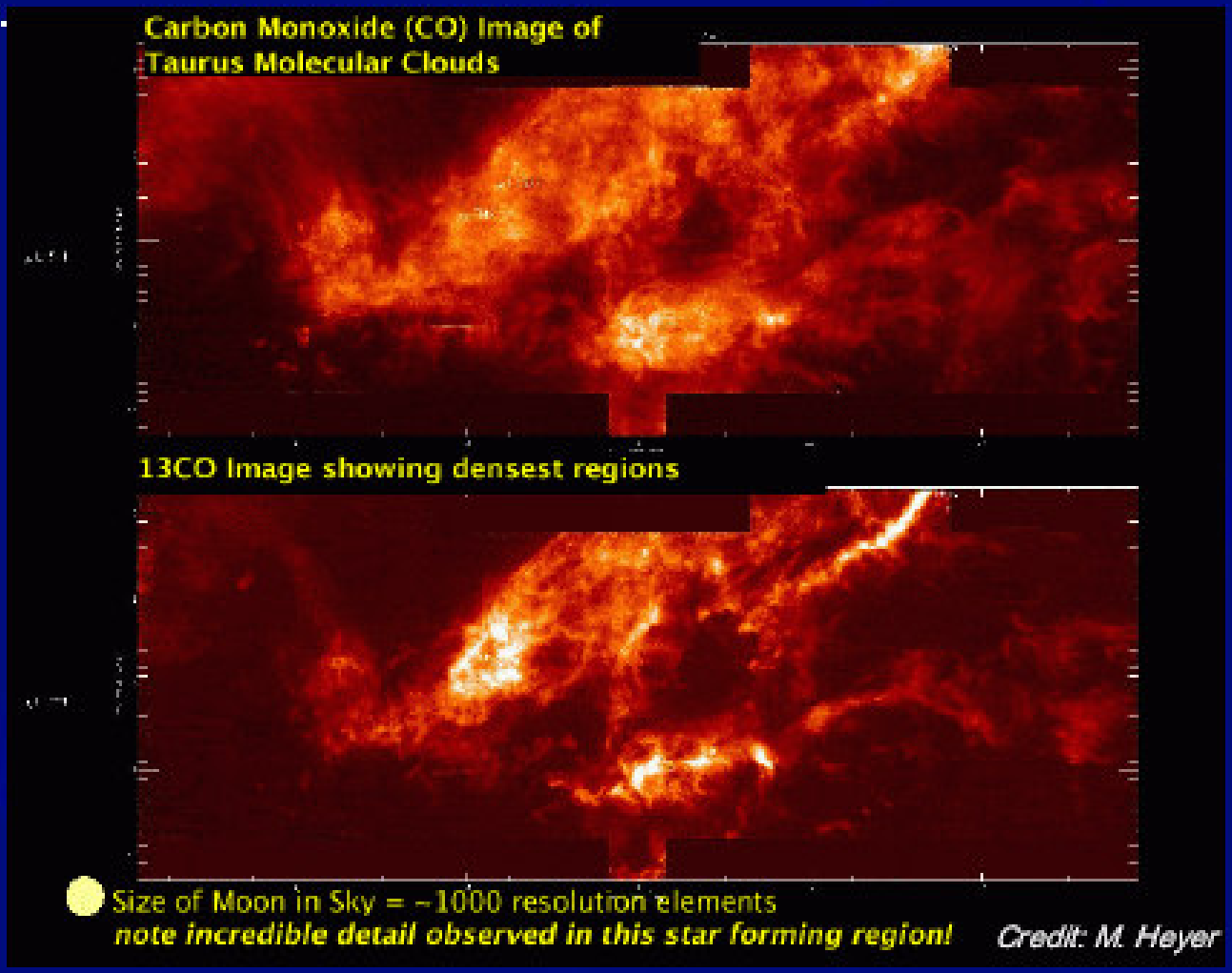
ALMA Key Science 2: Astrochemistry

Spectrum courtesy B. Turner (NRAO)



- Millimeter/submillimeter spectral components dominate the spectrum of planets, young stars, many distant galaxies.
- Most of the observed transitions of the 125 known interstellar molecules lie in the mm/submm spectral region—here some 17,000 lines are seen in a small portion of the spectrum at 2mm.

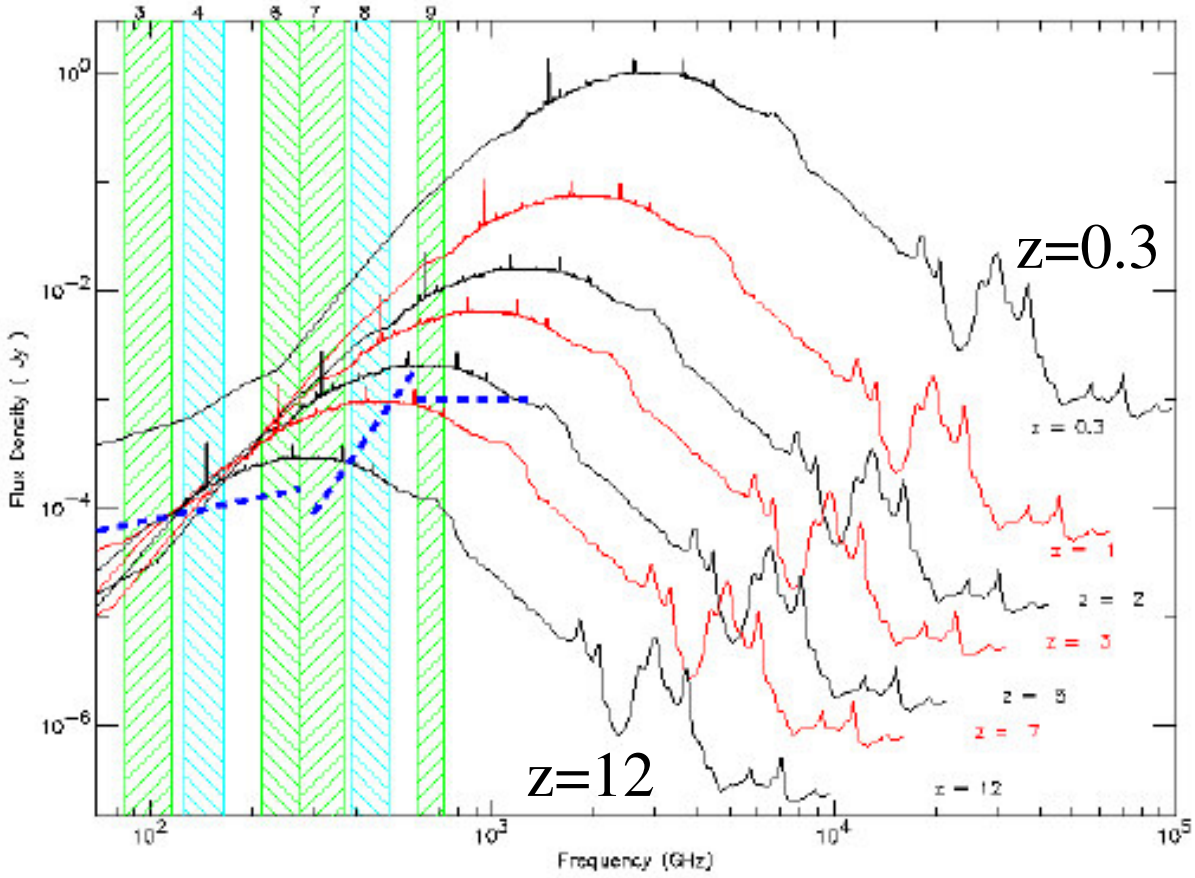
ALMA Key science 3: Interstellar Medium



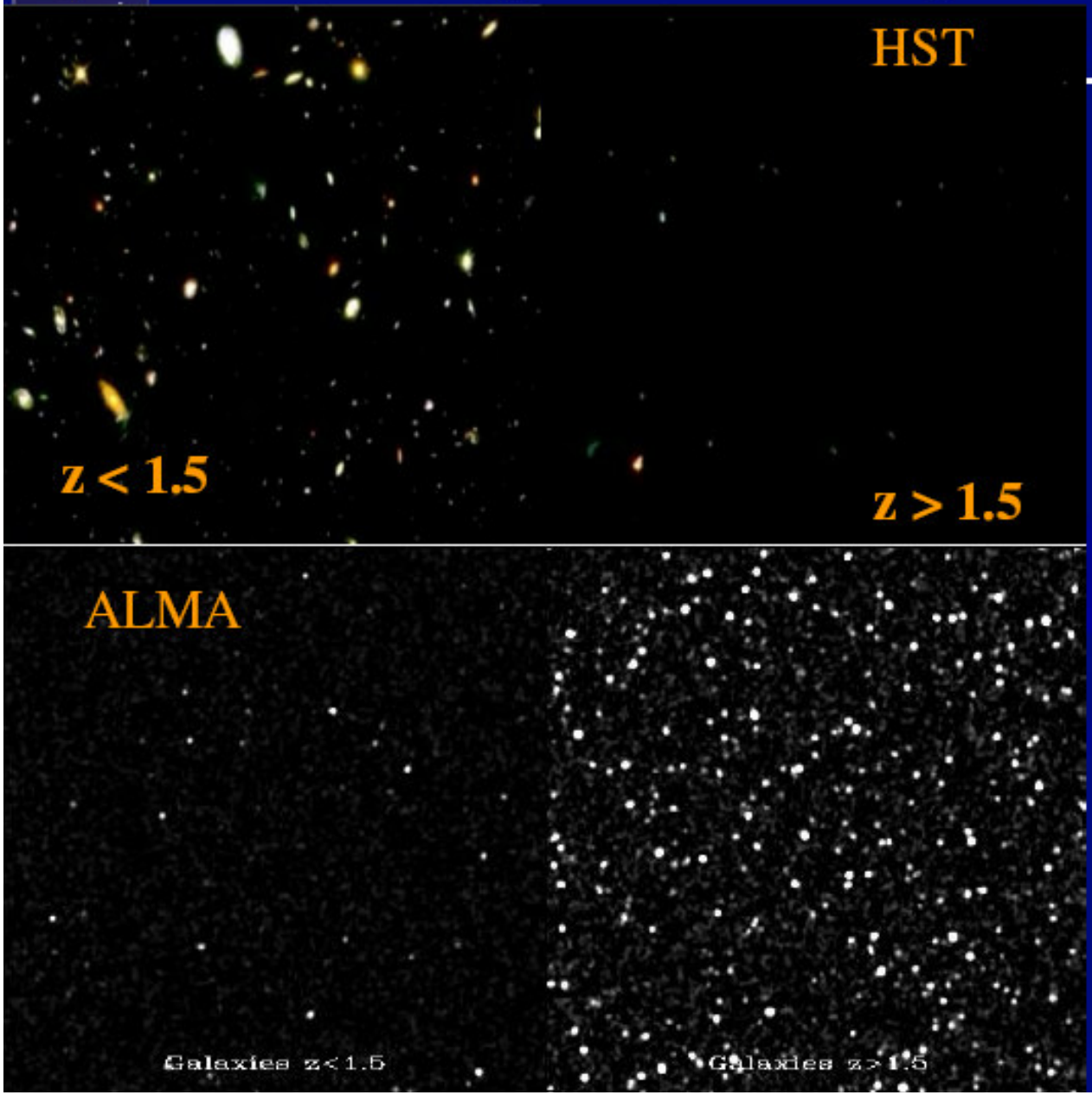
ALMA Key science 4: high redshift deep fields

M82 from ISO, Beelen and Cox

- As galaxies get redshifted into the ALMA bands, dimming due to distance is offset by the brighter part of the spectrum being redshifted in. Hence, galaxies remain at relatively similar brightness out to high distances.



ALMA Deep field: 'normal' galaxies at high z



- Detect current submm gal in seconds!
- ALMA deep survey: 3days, **0.1 mJy (5s),** 4'
- HST: a few thousand Gals, most at z<1.5
- ALMA: a few hundred Gals, most at z>1.5
- Parallel spectroscopic surveys, 100 and 200 GHz: CO/other lines in majority of sources
- Redshifts, dust, gas masses, plus high res. images of gas dynamics, star formation

Phase 1 Observing proposal

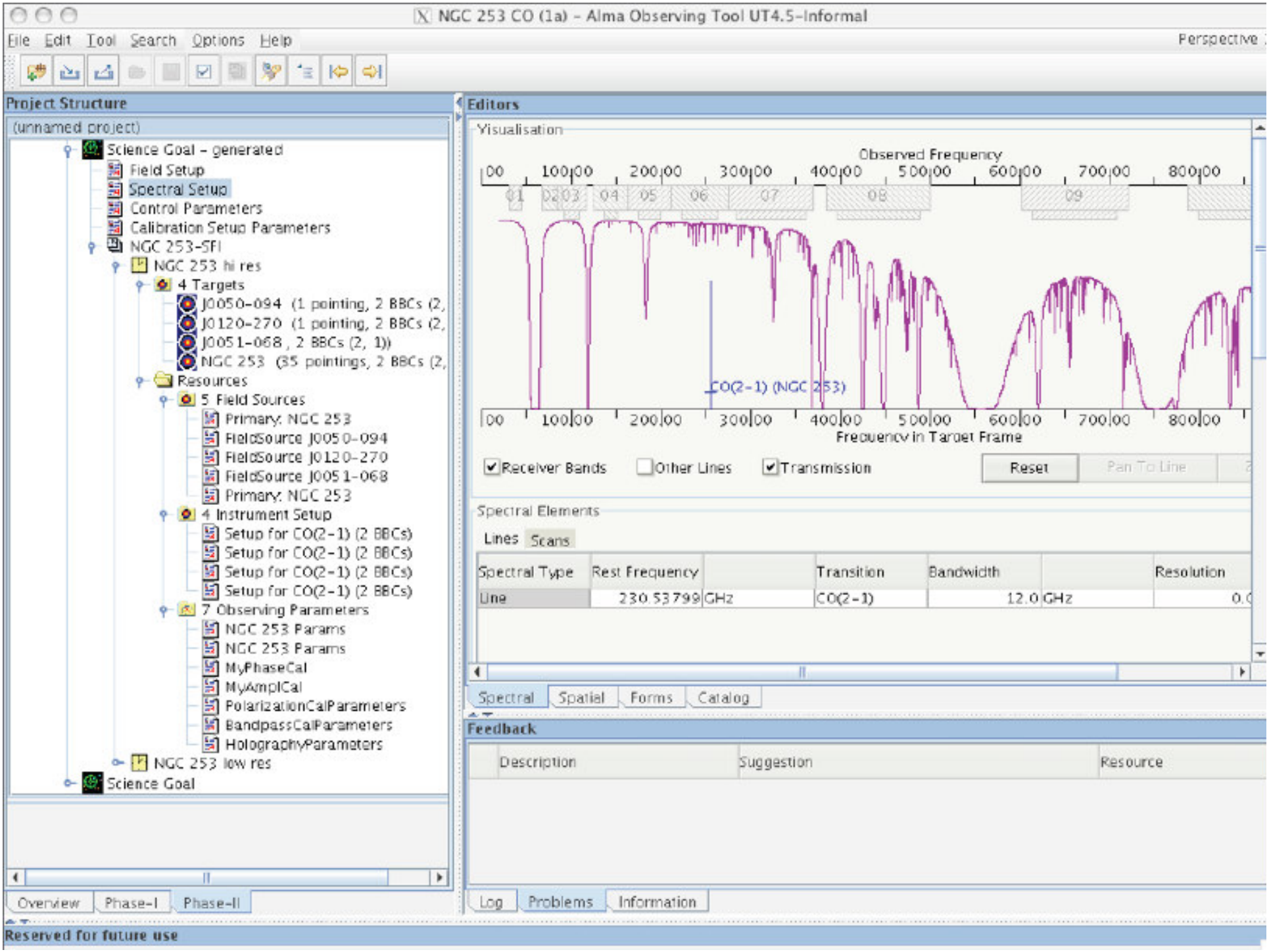
- mostly concentrated on science
- some administrative information
- minimal amount of technical information
- target list

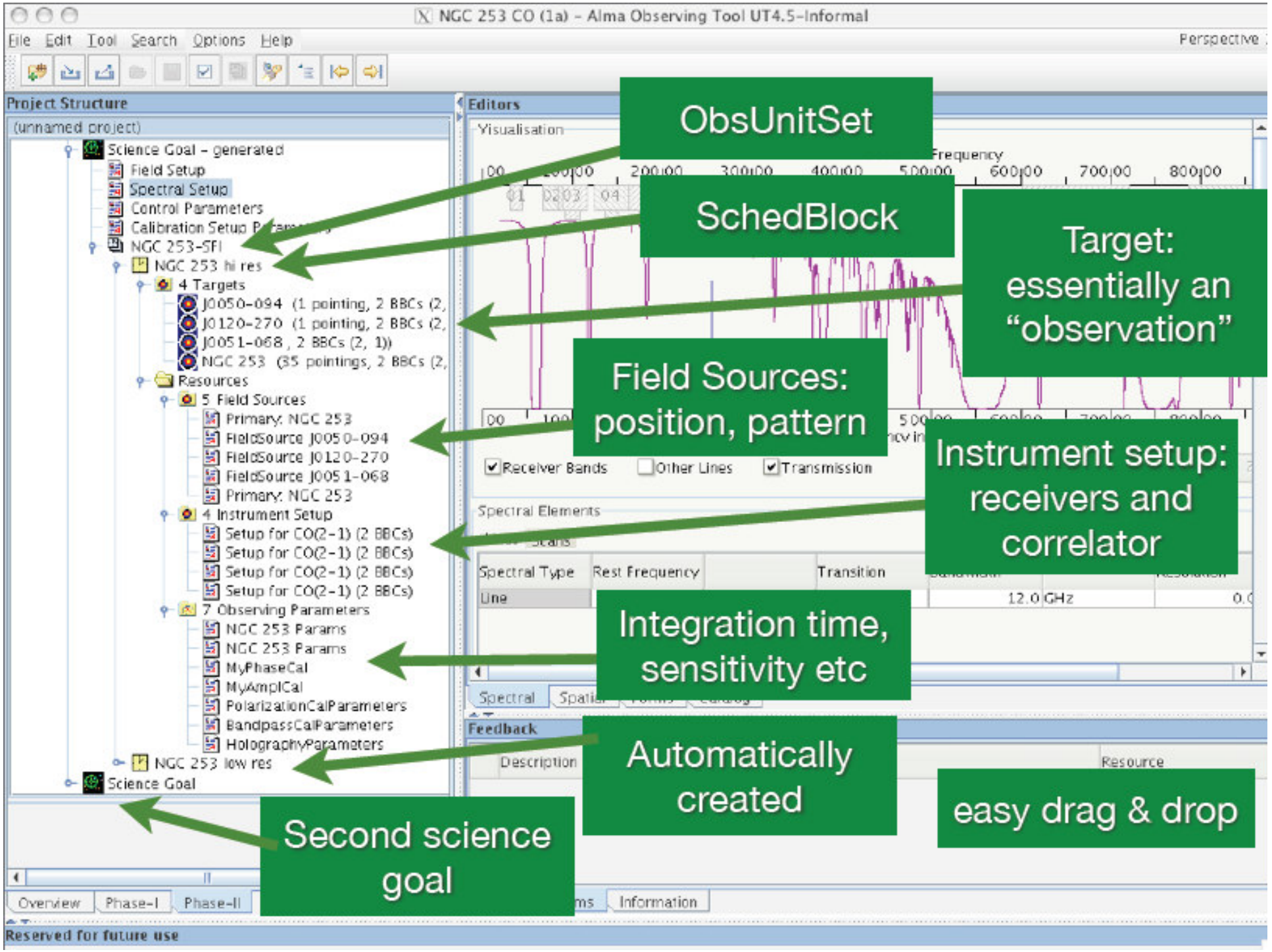
Phase 2 Observing program

- complete set of technical details
- full specifications of how observations are to be carried out
- consistency with Phase 1

Observing program

- scheduling blocks (SchedBlocks) [cf. VLT]
  - key executable self-consistent units:
    - targets, correlator set-up, receiver set-up, pointing, phase calibrators, etc.
- Observing Units Sets (ObsUnitSets)
  - structure to support recursive hierarchy of SchedBlocks


NGC 253 CO (1a) - Alma Observing Tool UT4.5-Informal
File Edit Tool Search Options Help
Perspective
Project Structure
(unnamed project)
Science Goal - generated
Field Setup
Spectral Setup
Control Parameters
Calibration Setup Parameters
NGC 253-SFI
NGC 253 hi res
4 Targets
J0050-094 (1 pointing, 2 BBCs (2,
J0120-270 (1 pointing, 2 BBCs (2,
J0051-068 , 2 BBCs (2, 1))
NGC 253 (35 pointings, 2 BBCs (2,
Resources
5 Field Sources
Primary: NGC 253
FieldSource J0050-094
FieldSource J0120-270
FieldSource J0051-068
Primary: NGC 253
4 Instrument Setup
Setup for CO(2-1) (2 BBCs)
Setup for CO(2-1) (2 BBCs)
Setup for CO(2-1) (2 BBCs)
Setup for CO(2-1) (2 BBCs)
7 Observing Parameters
NGC 253 Params
NGC 253 Params
MyPhaseCal
MyAmpliCal
PolarizationCalParameters
BandpassCalParameters
HolographyParameters
NGC 253 low res
Science Goal
Overview
Phase-I
Phase-II
Editors
Visualisation
Observed Frequency
00 100 00 200 00 300 00 400 00 500 00 600 00 700 00 800 00
01 0203 04 05 06 07 08 09
CO(2-1) (NGC 253)
Frequency in Target Frame
Receiver Bands
Other Lines
Transmission
Reset
Pan To Line
Spectral Elements
Lines
Scans
Spectral Type
Rest Frequency
Transition
Bandwidth
Resolution
Line
230.53799
GHz
CO(2-1)
12.0
GHz
Spectral
Spatial
Forms
Catalog
Feedback
Description
Suggestion
Resource
Log
Problems
Information
Reserved for future use


NGC 253 CO (1a) – Alma Observing Tool UT4.5-Informal
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Project Structure
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Spectral Setup
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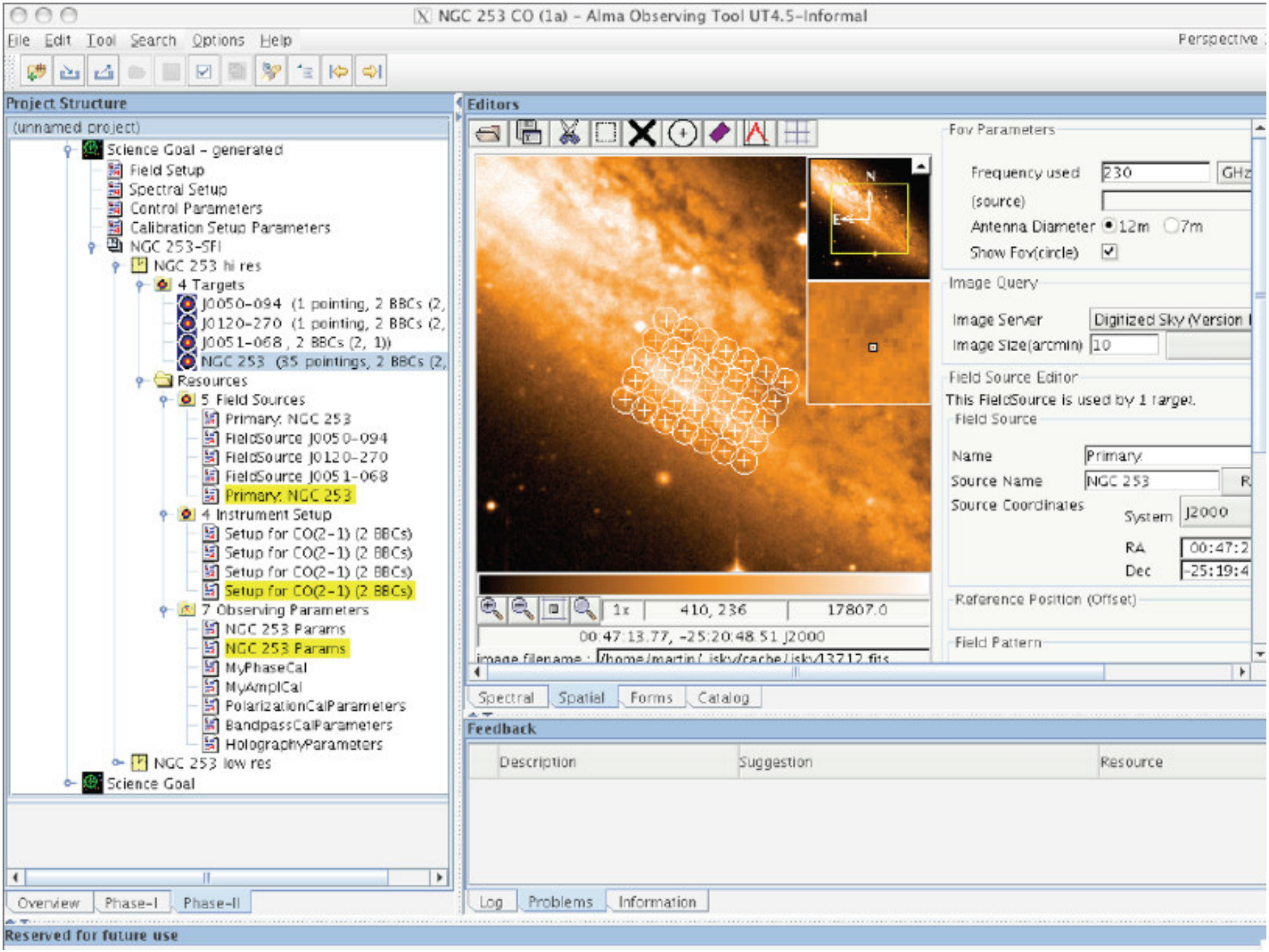
PolarizationCalParameters
BandpassCalParameters
HolographyParameters
NGC 253 low res
Science Goal
Editors
Visualisation
Frequency
Receiver Bands
Other Lines
Transmission
Spectral Elements
Spectral Type
Rest Frequency
Transition
Line
12.0 GHz
Spectral
Feedback
Description
Resource
Overview
Phase-I
Phase-II
Information
Reserved for future use
ObsUnitSet
SchedBlock
Target: essentially an "observation"
Field Sources: position, pattern
Instrument setup: receivers and correlator
Integration time, sensitivity etc
Automatically created
easy drag & drop
Second science goal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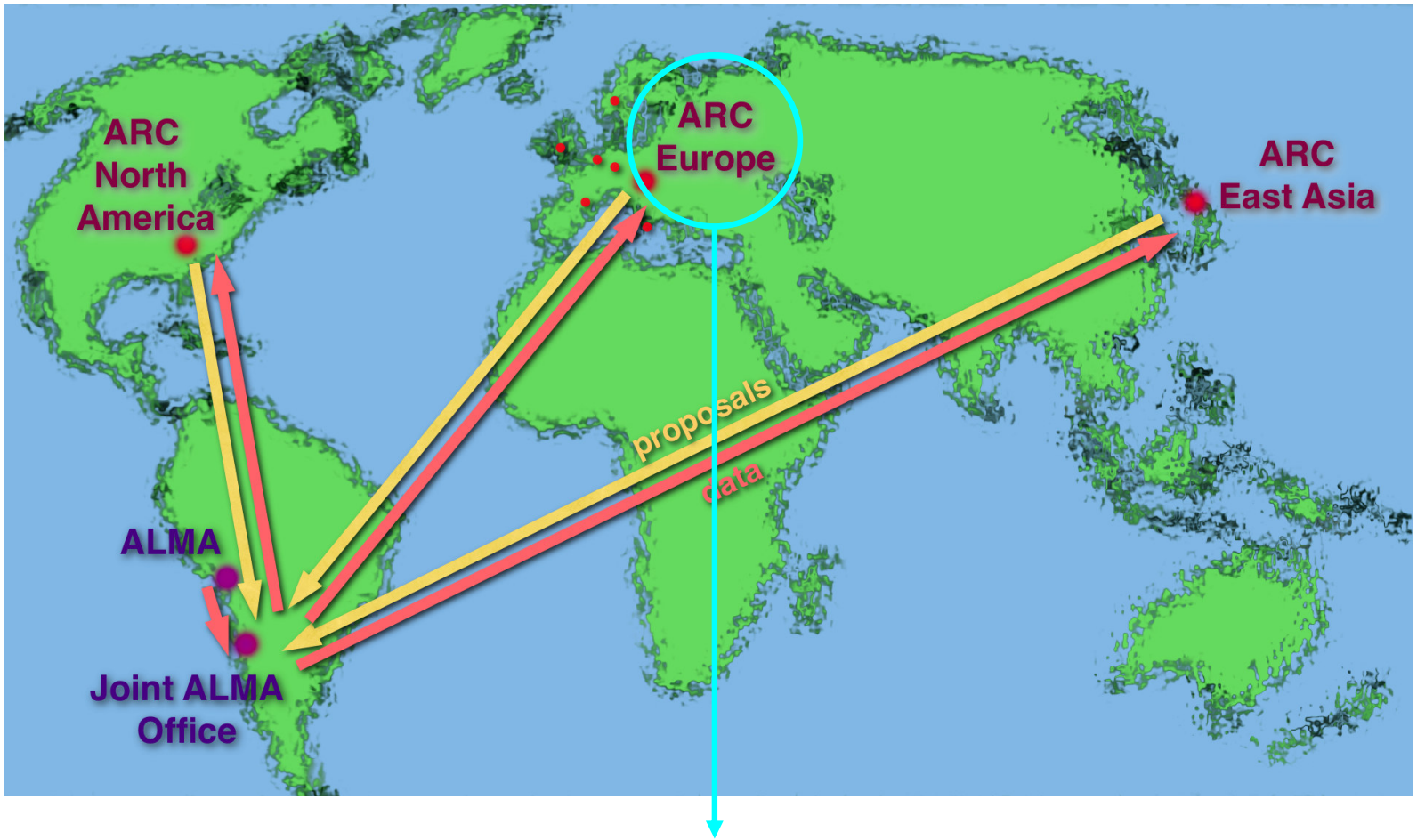
Science Goal
Overview
Phase-I
Phase-II
Editors
Fov Parameters
Frequency used
230
GHz
(source)
Antenna Diameter
12m
7m
Show Fov(circle)
Image Query
Image Server
Digitized Sky (Version
Image Size(arcmin)
10
Field Source Editor
This FieldSource is used by 1 target.
Field Source
Name
Primary
Source Name
NGC 253
Source Coordinates
System
J2000
RA
00:47:2
Dec
-25:19:4
Reference Position (Offset)
Field Pattern
1x
410, 236
17807.0
00:47:13.77, -25:20:48.51 J2000
Spectral
Spatial
Forms
Catalog
Feedback
Description
Suggestion
Resource
Log
Problems
Information
Reserved for future use

ALMA World-wide organisational structure

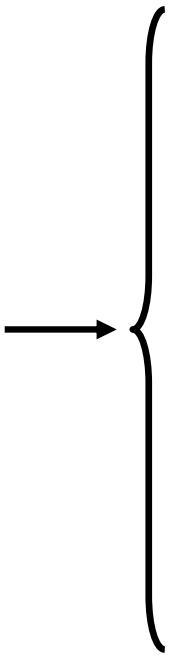


Central node (ESO) + Network of regional nodes

The EU ARC-network

ARC - EUROPE

ESO
Central node

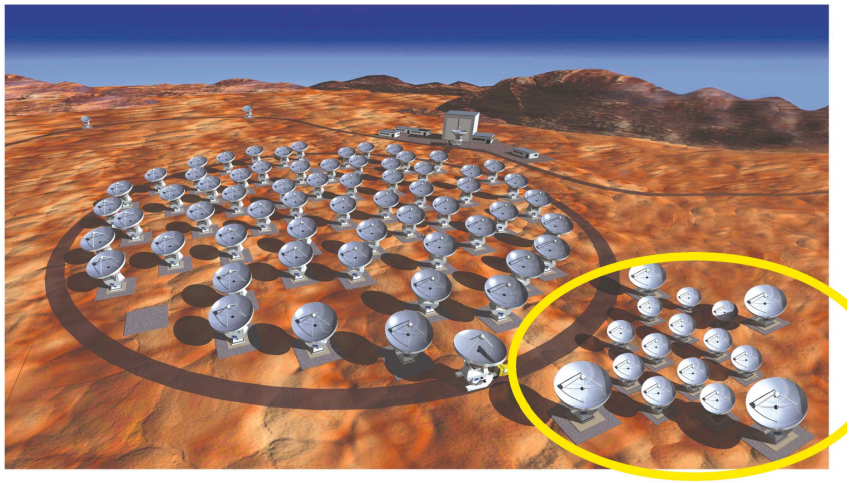


Independent regional nodes

- **Bonn-Bochum-Cologne (D)**
- **IRA, Bologna (I)**
- **IRAM (Grenoble; F, E)**
- **Leiden (+; NL)**
- **Manchester (+; UK)**
- **Nordic (Onsala; DK, S, SU)**

Also interested in joining: **Lisbon (P); Zürich (CH); Ondrejov (CZ); Belgium**

Responsibilities & interactions detailed in "Memo of Understanding"



54×12m + (4×12m + 12×7m)
0.3-3mm; resol: 0".015λ(mm)

ALMA

Key science
1: Planetary regions, nearby disks
2: Astrochemistry
3: Interstellar medium
4: High-redshift deep fields

Italy & ALMA

Strong interest in: planetary sciences, star formation, stellar evolution, galaxy formation, high-redshift universe, cosmology

Italian representatives in ALMA:

Testi – European Project Scientist
Tofani – ALMA Management Advisory Committee (AMAC)
Maiolino – European Science Advisory Committee (ESAC)
Andreani – EU ARC Manager

ROLE of the ARC-nodes

- ✓ **Build a community (e.g. ALMA/ARC-days 2007, 2008; tutorials; PRINs)**
- ✓ **Provide face-to-face user support (post-obs.)**
- ✓ **Offer help with specific expertises (see next slide)**
- ✓ **Provide user feedback**
- ✓ **Be involved with software development & testing**
  manuals, cookbooks; share with the other ARCs/ARC-nodes
  e.g. CASA-testing: Rossetti @ Socorro, ESO;
  ALMA Observation Preparation software-test
- ✓ **Be involved in commissioning/science verification phase**

http://www.ira.inaf.it/alma/alma.html

Areas of expertise in EU ARC-nodes

1. Wide-field, high-dynamic range imaging (UK/NL/F)
2. Mosaicing (I)
3. High-frequency observing (NL)
4. Infrastructure for advances data analysis tools (D/NL/Nordic)
5. Data handling/GRID-technology (I/P)
6. Coordinating surveys/key projects (I)
7. Polarimetry (I/F/D)
8. Astrometry (Nordic/D/UK)
9. Pipeline heuristics (D)
10. Automatic data calibration (D)
11. Data pipelining (UK)
12. Multi-frequency synthesis (Nordic/UK)
13. Array combination imaging (UK)
14. Robust self-cal methods and use of WVR data (Nordic)
15. Data handling and server (P)
16. Instrumental calibration (F)
17. Atmospheric phase calibration (F)
18. ALMA imaging simulations (F)

Present situation

ARC-working group consisting of:

6 staff-members [Brand, Gregorini, Mack, Nanni, Prandoni, Zanichelli]

2 post-docs:

1 experienced in VLBI (radio, extra-galactic) [Rossetti]

1 experienced in comp. systems, software [Bedosti]

(Until July 2008: 1 experienced in (sub-) mm (galactic) observations; preparation for ALMA [Fontani])

Rossetti: One of 4 EU CASA-user support specialists who will train EU community in its use, and act as interface between the EU-users and developers at NRAO.

Future situation

Immediate Future:

2 new post-docs to be hired 2009
Hardware acquisition: ≥ 2008

Long-term: ≥ 2011:

1 FTE provided by (4-6) IRA-staff; 1 system manager;
4 post-doc positions

+ Involve experts from other institutes:
e.g., Viviana Casasola (IRA-Firenze/Arcetri)
Obs. Catania [+ temp. transfer personnel]

Importance of having an Italian ARC

- Italy gains expertise in mm-interferometry, which is going to be very important in the next decade(s).

- It gives Italian community advantaged entrance to ALMA and to the EU-ALMA network (ESO, other regional nodes); Italian users can tap into the network of expertises; Access to Commissioning, easier access to Early Science.

- Development of GRID technology, expertise in transmission and archiving of large quantity of data is in synergy with other applications (e.g., e-VLBI, mm-VLBI, Lofar).

- Participation in EU funding network through FP7 RadioNet, ITN, COFUND.

General ALMA pages at ESO:
http://www.eso.org/sci/facilities/alma/index.html

ESO-ARC pages:
http://www.eso.org/sci/facilities/alma/arc

Italian ARC-pages:
http://www.ira.inaf.it/alma/alma.html

Check for job offers.