

The Atacama Large Millimeter/submillimeter Array (ALMA)

Lars-Åke Nyman, Head of Science Operations

On behalf of the ALMA partnership

AOS · Array Operation Site

5000 m

OSF – Operation Support Facility

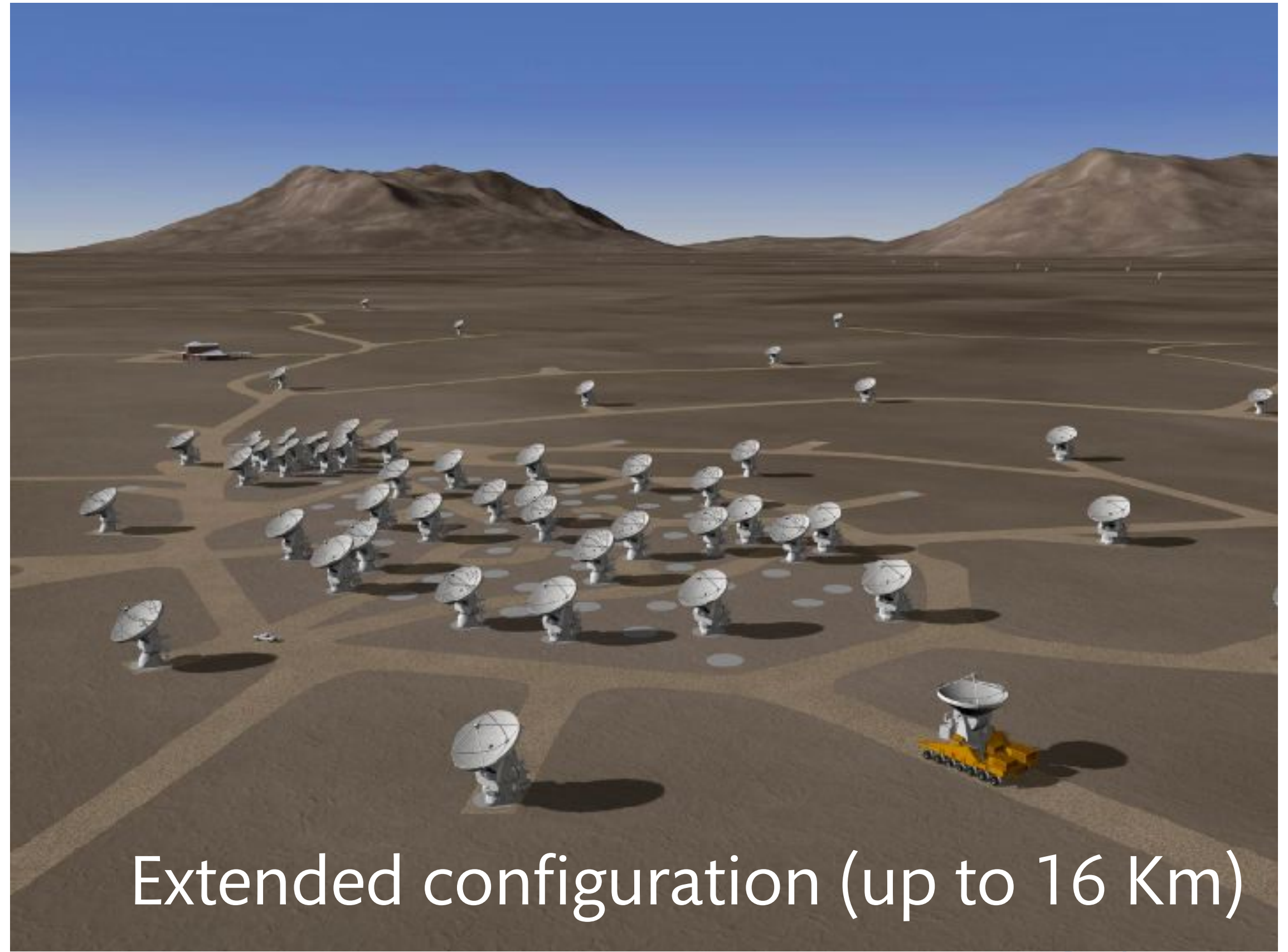
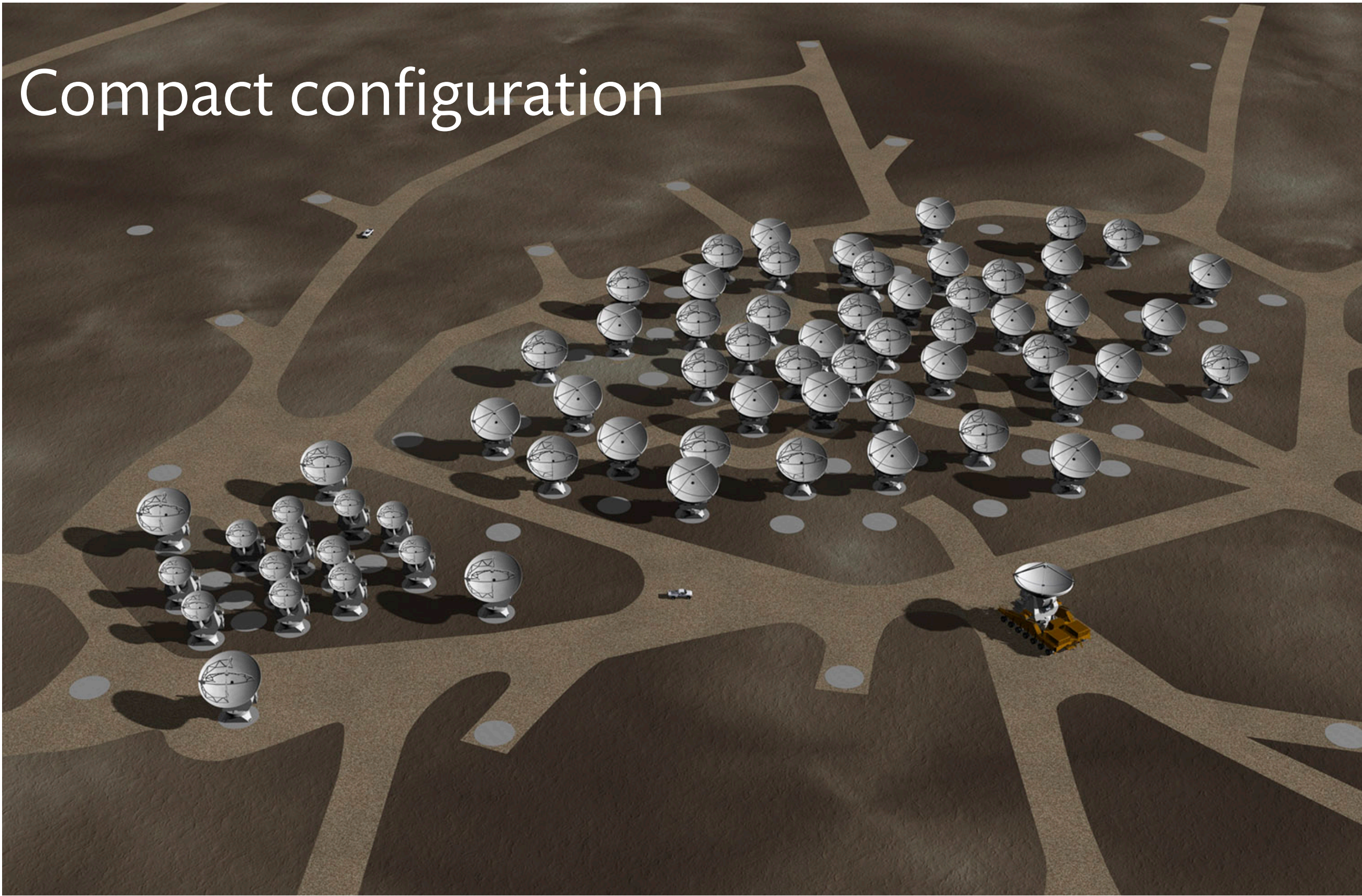
2900 m



ALMA

An **array** of **66 antennas**, that operates over the entire accessible **mm/submm** wavelength range **up to 1 THz**

Built to operate > 30 years



ALMA



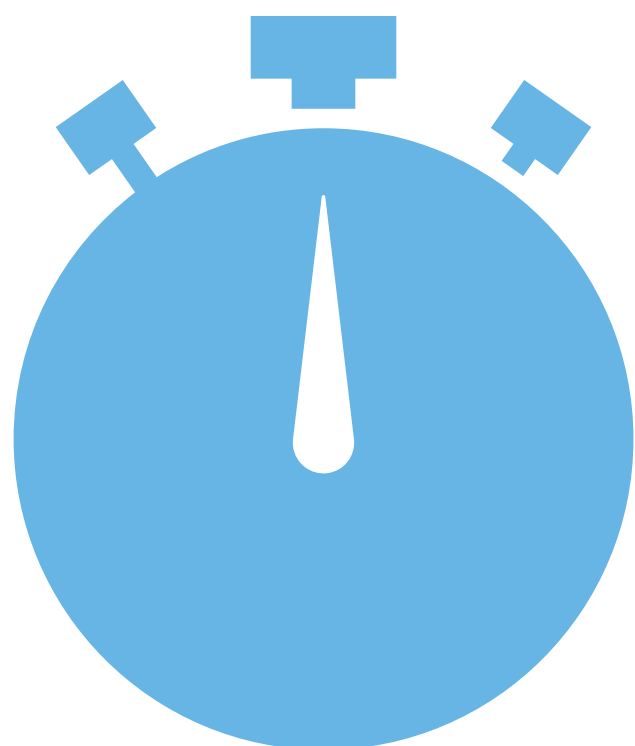








ALMA partners:
Europe,
North America,
and **East Asia**



Chile is the
host country
and Chilean
institutions get
10% of the
observing time



More than **20**
countries are
involved in
ALMA (South
Korea is the
latest)



Construction
started in 2003
and
ended in 2014



Construction cost:
US\$1,600
millions





SCO

Main Archive
Data Transmission to the ALMA
Regional Center Offices,
Science, Computing,
Administration, Management



AOS

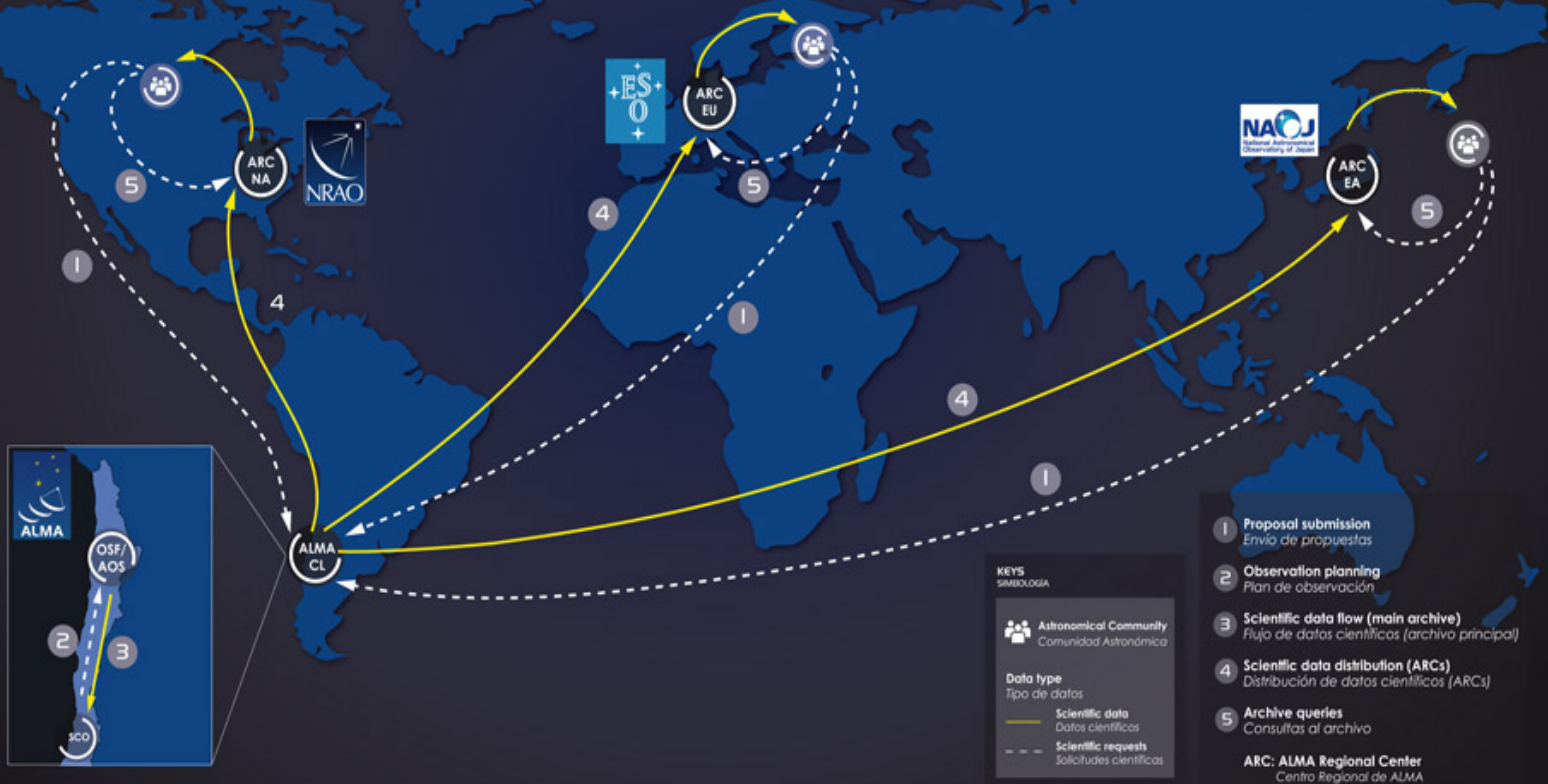
Antennas
Power
Fiber Optic Network
Local Oscillator (Timing)
Correlator



OSF

Hotel
Archive
Laboratory Maintenance
Array Control Center
Integration Center

ALMA Science Operations Centers





ALMA Science Operations Centers



JAO

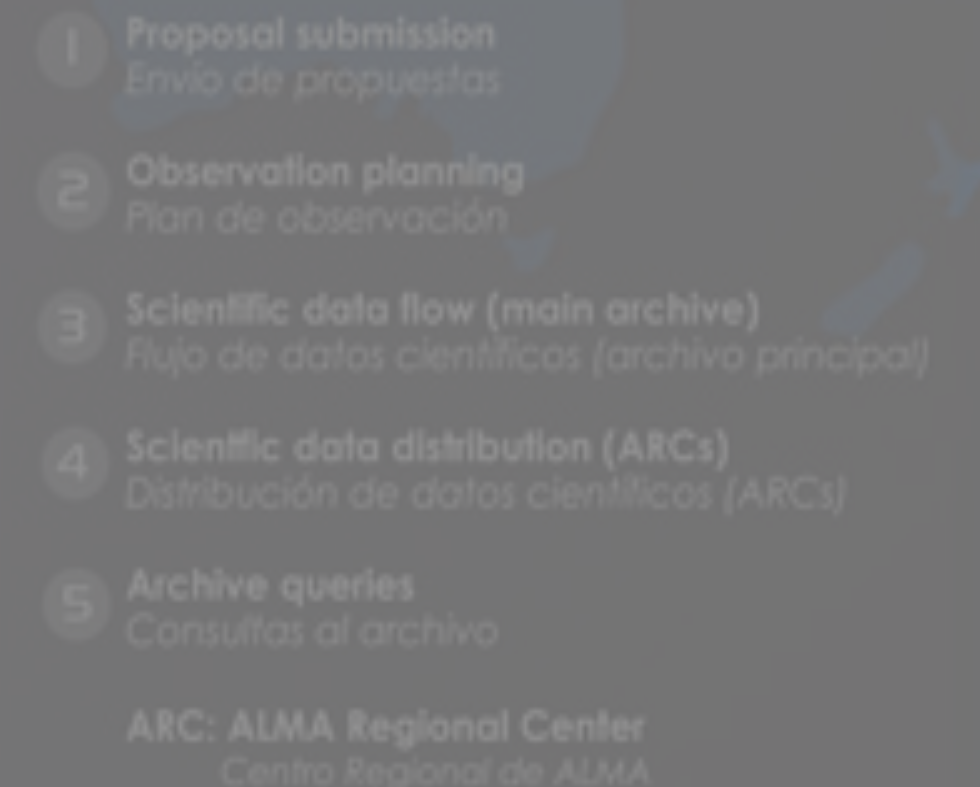
(Joint ALMA Observatory)

- Array operations
- Scheduling of projects
- Execution of observations
- Data quality assurance and trend analysis
- Calibration plan maintenance
- Delivery of data to the archives
- Archive operations
- Pipeline operations

ARCs

(ALMA Regional Centers)

- User interface
- User support (via helpdesk and f2f)
- Data delivery to the PIs
- Mirror archive operations
- Software tools
- Astronomers on duty
- Data quality assurance
- Enhanced services
- EU ARC nodes



ALMA Antennas

NA 25

12m antennas



EU 25

12m antennas



EA 4 +12

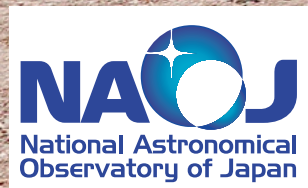
12m antennas



7m antennas

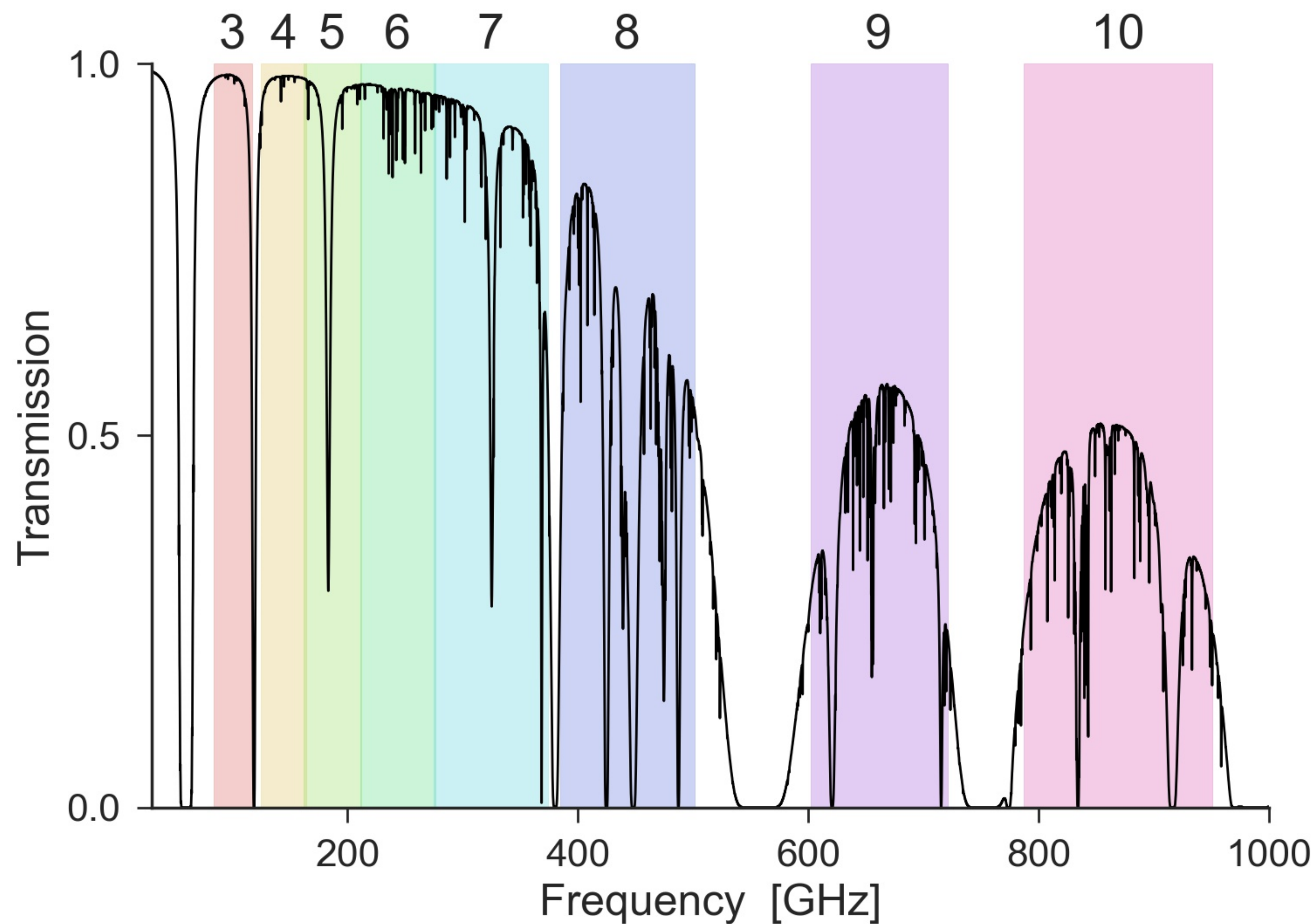


Surface accuracy: 25 microns
Pointing accuracy: 2" rms

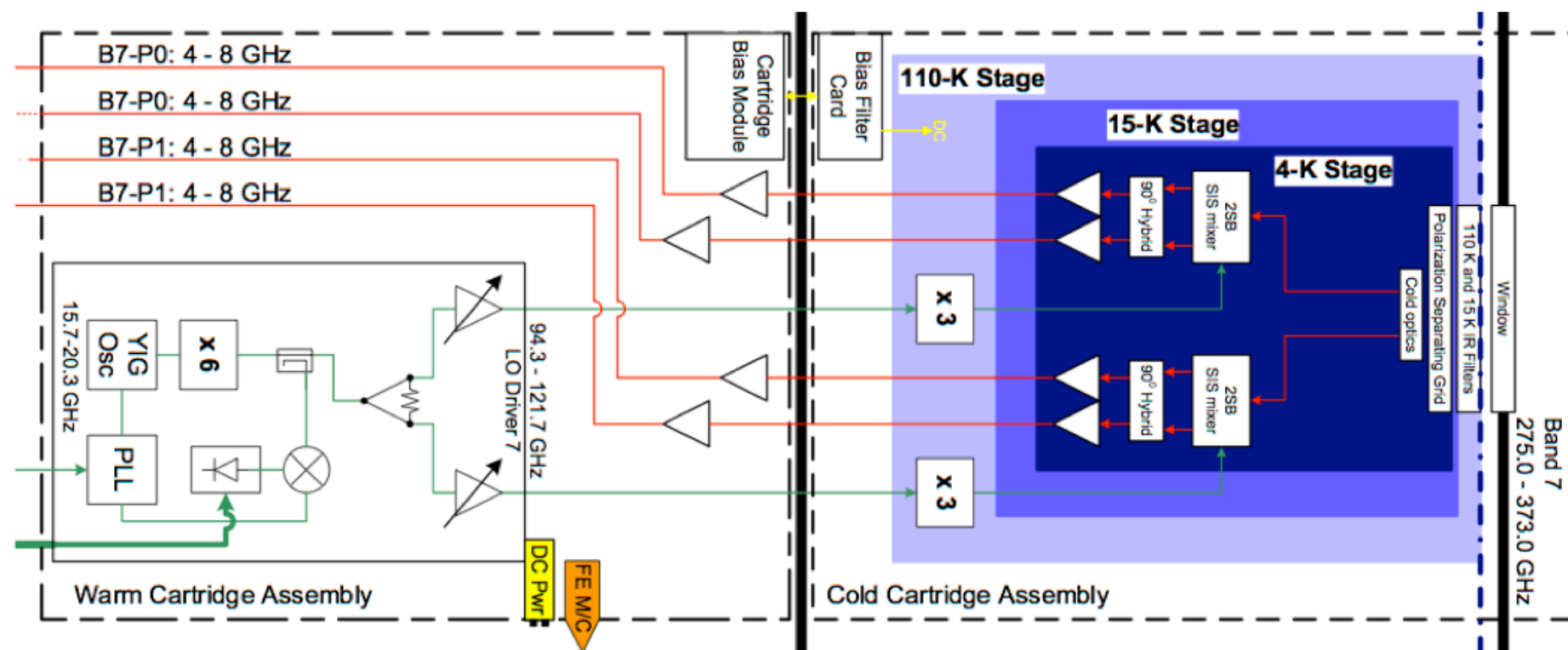
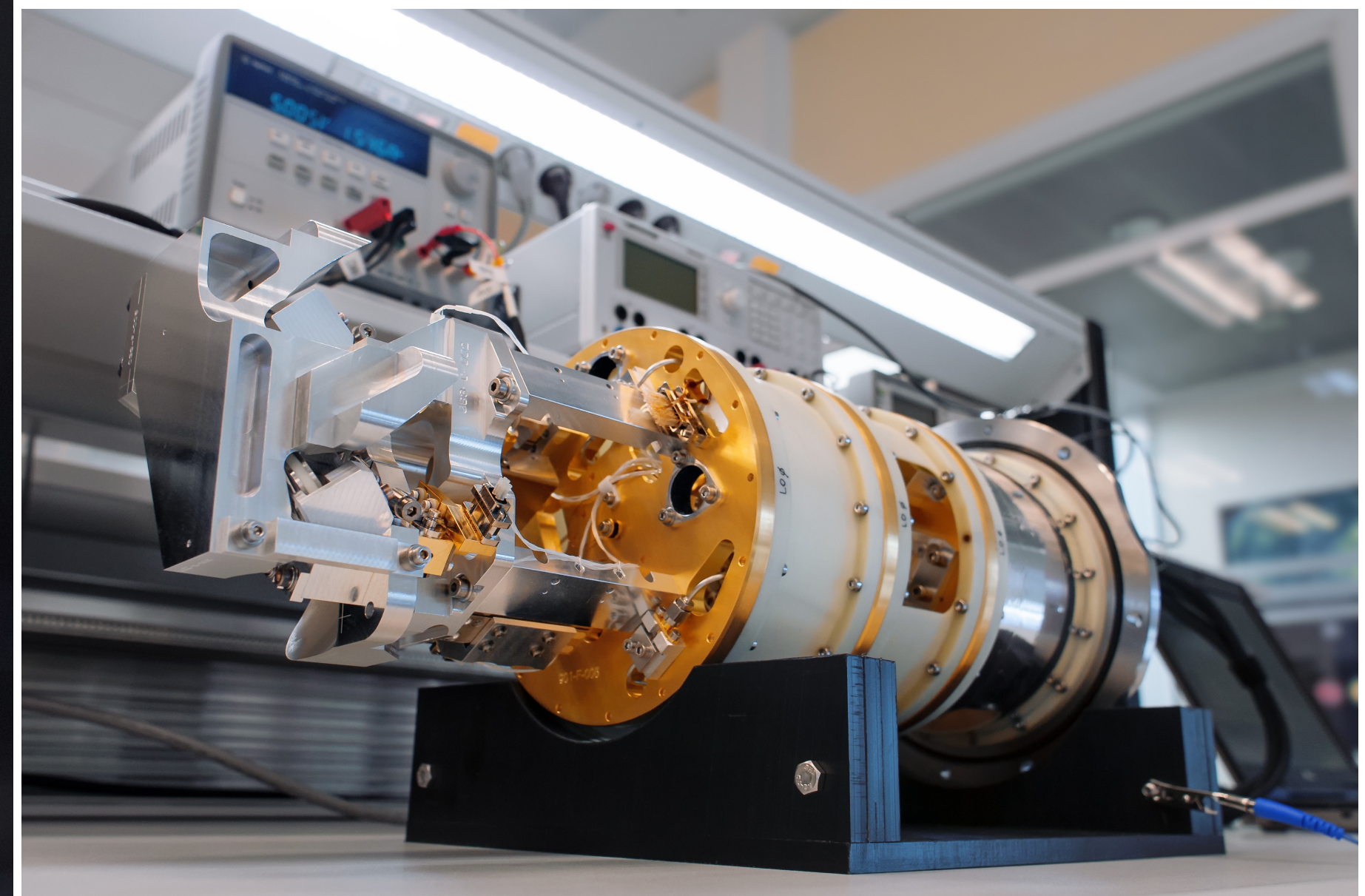
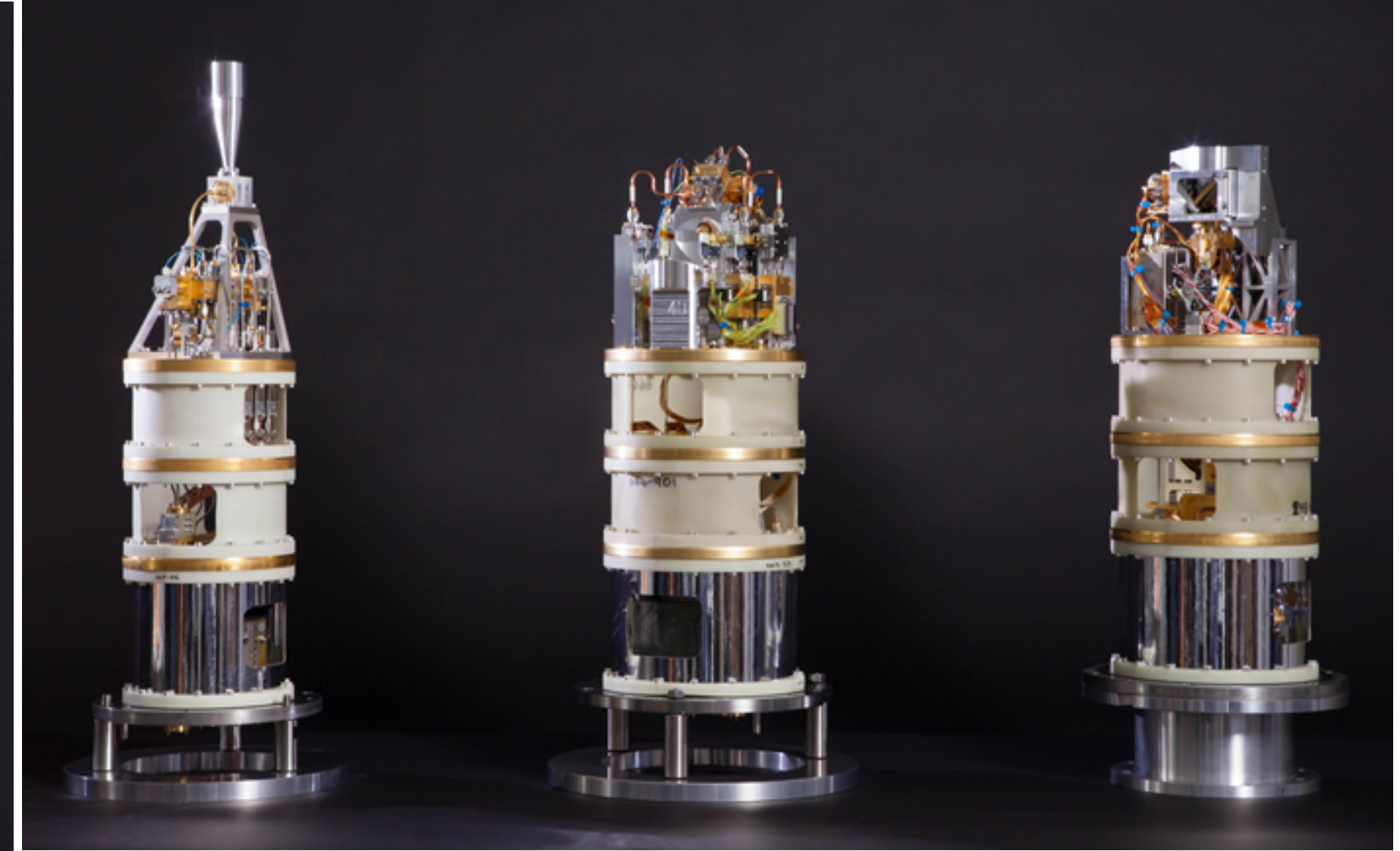
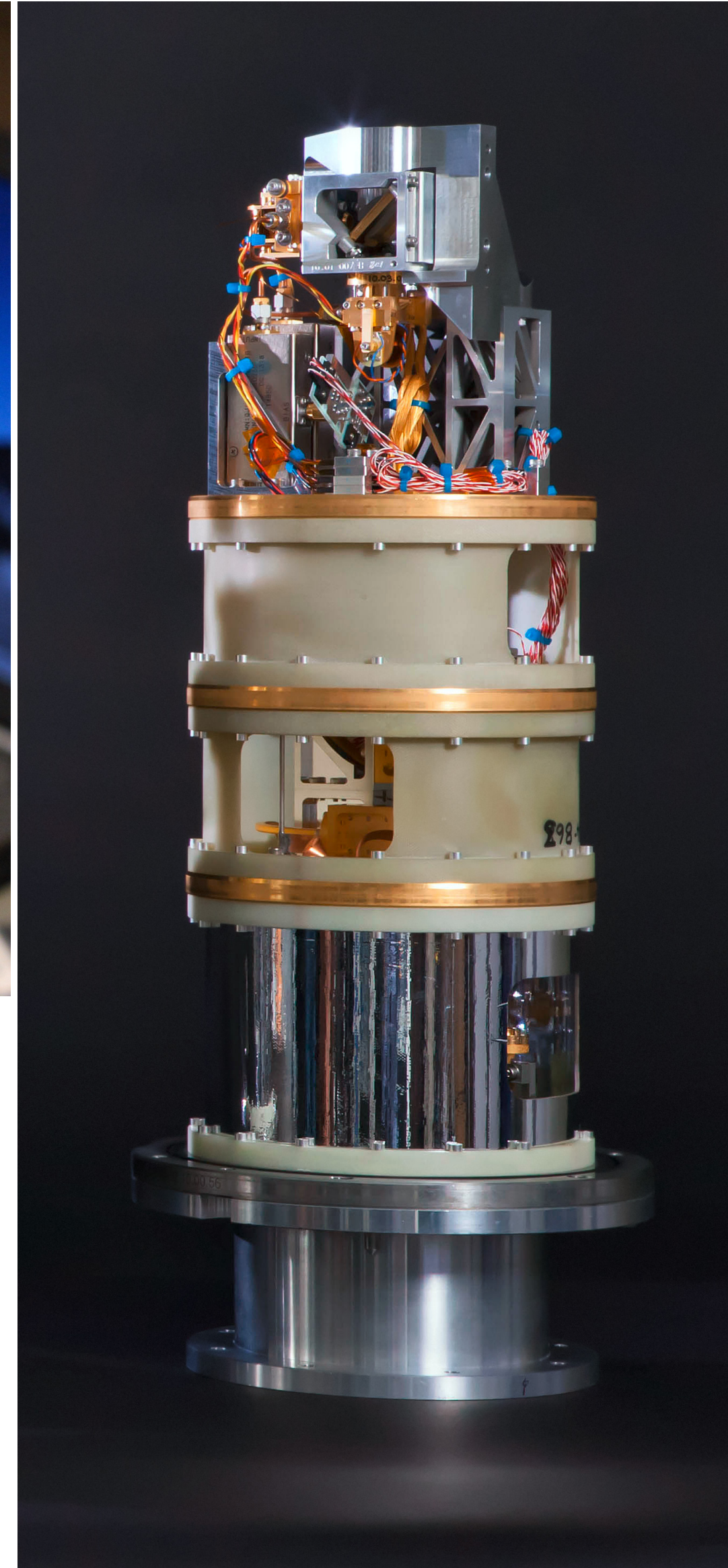
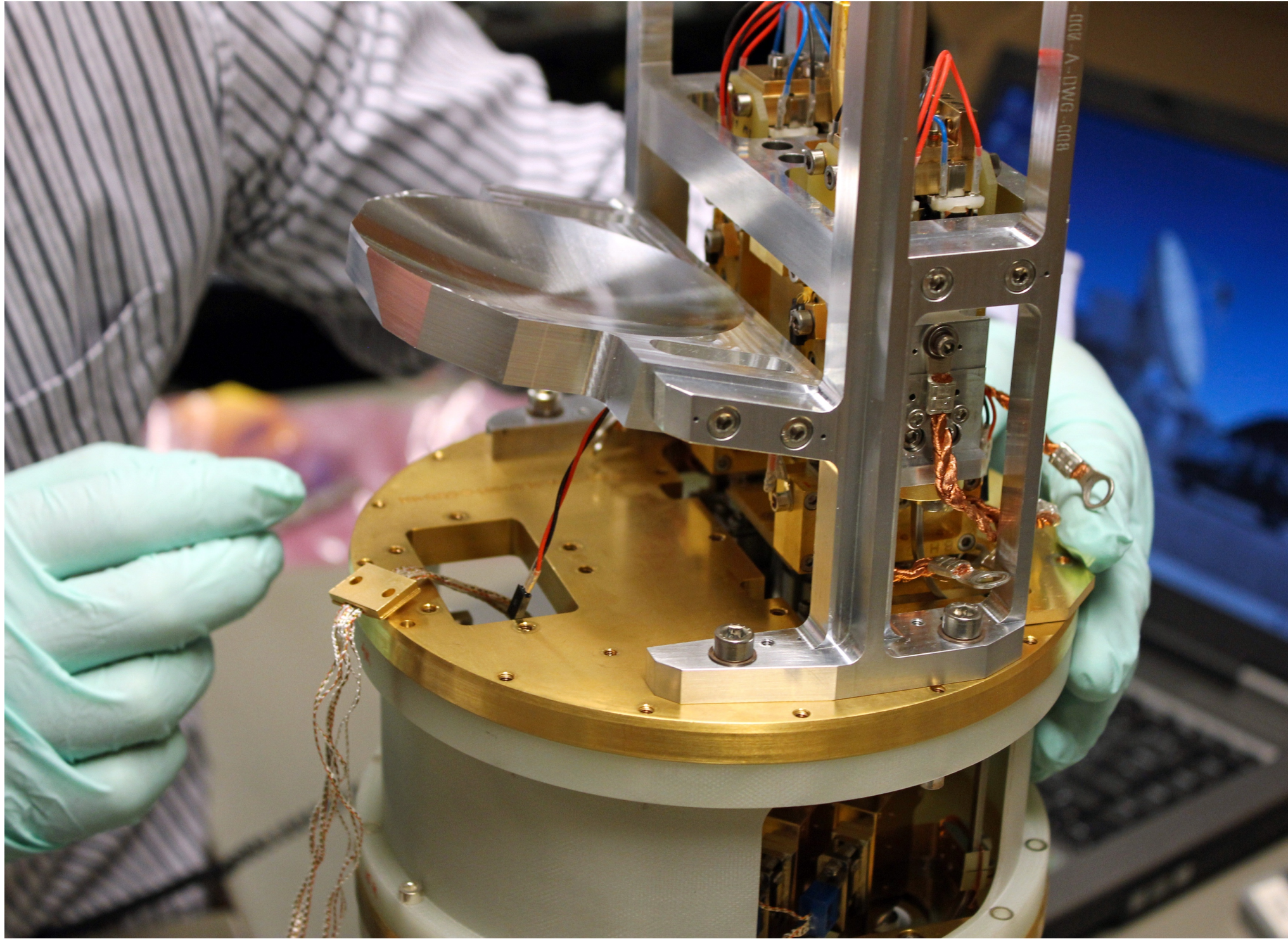


Antenna Transporter

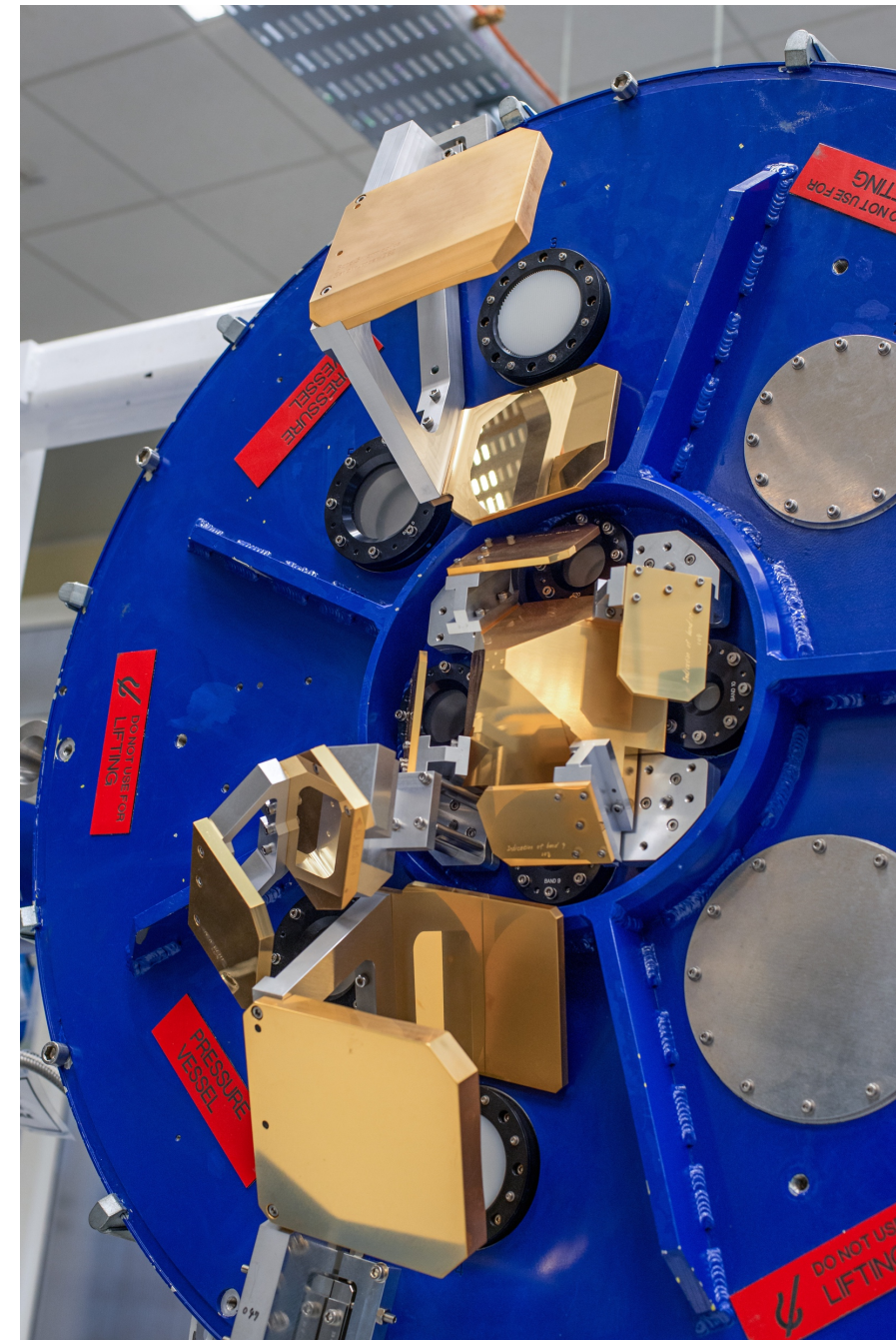
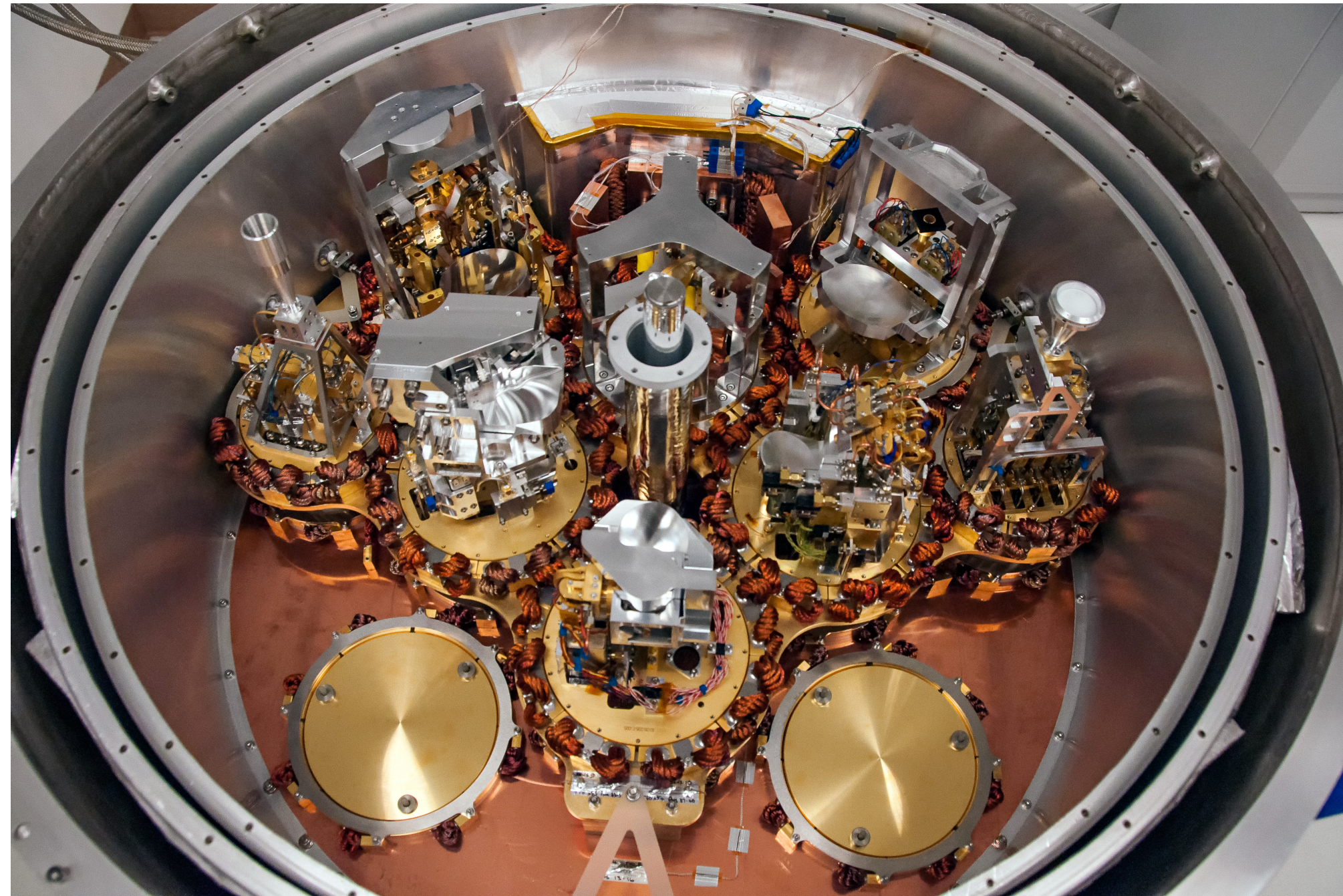
ALMA Receiver Bands



Receiver Cartridges



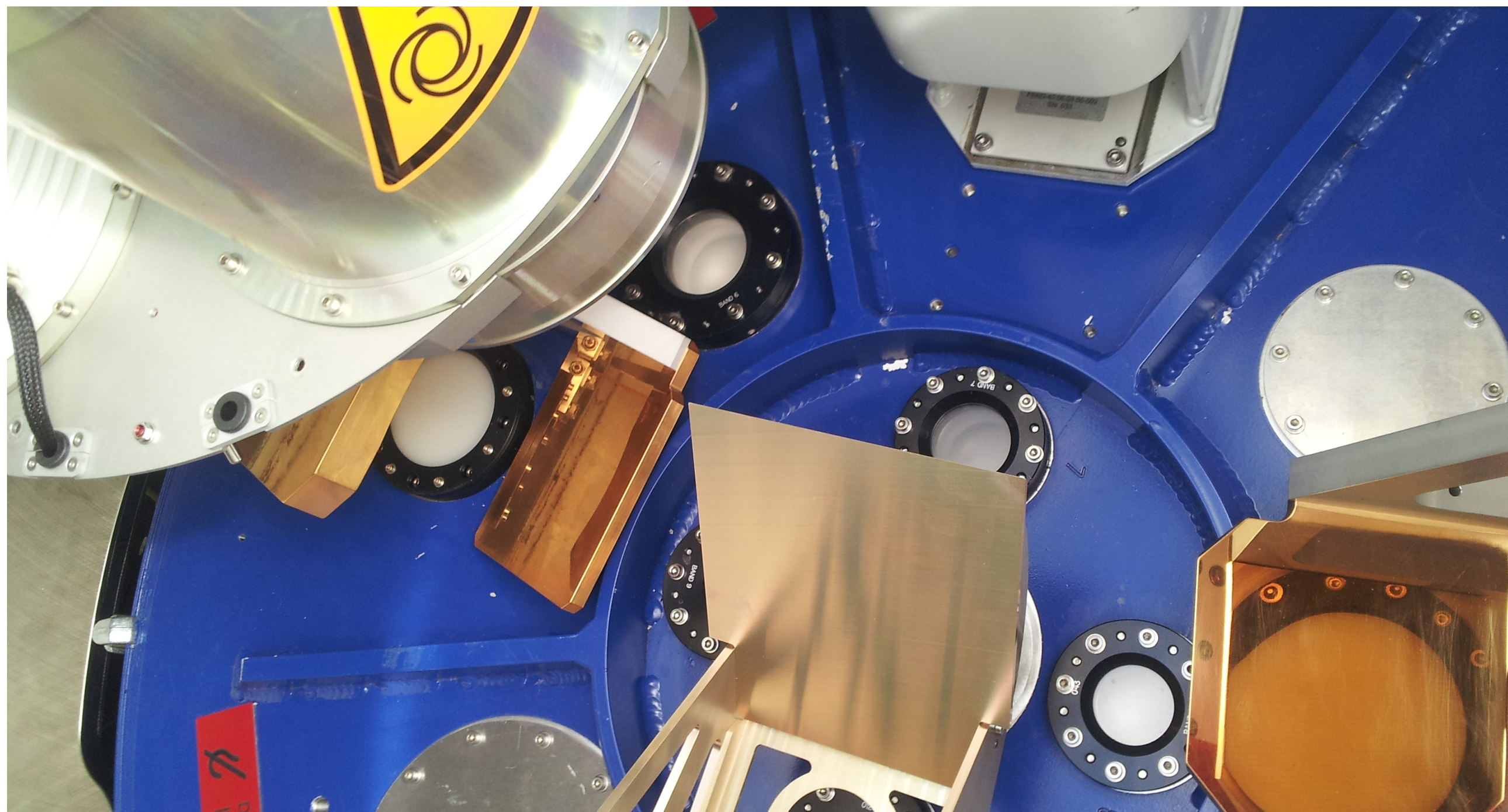
Cryostats



10 Cartridges
4 °K closed cycle system

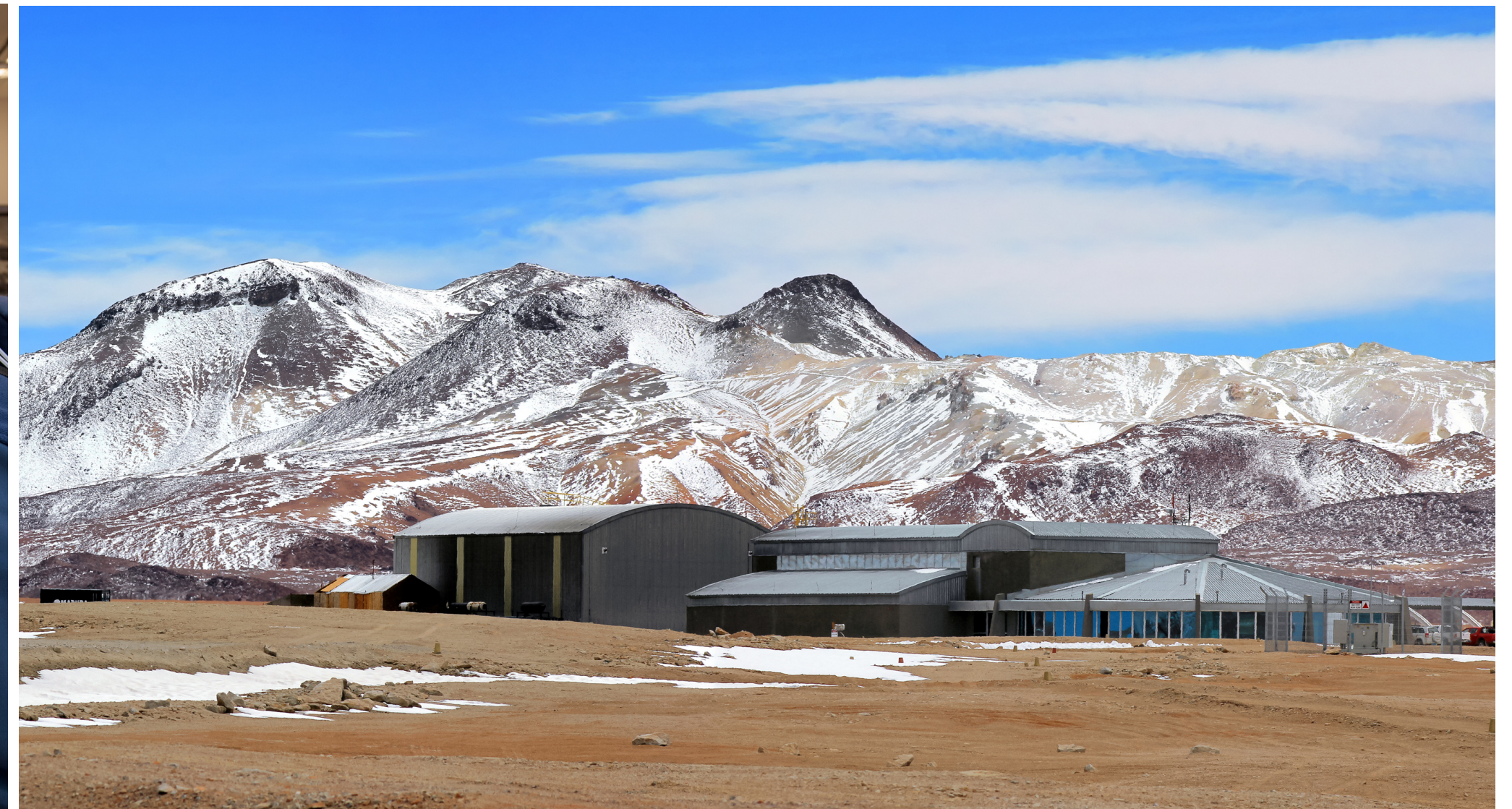
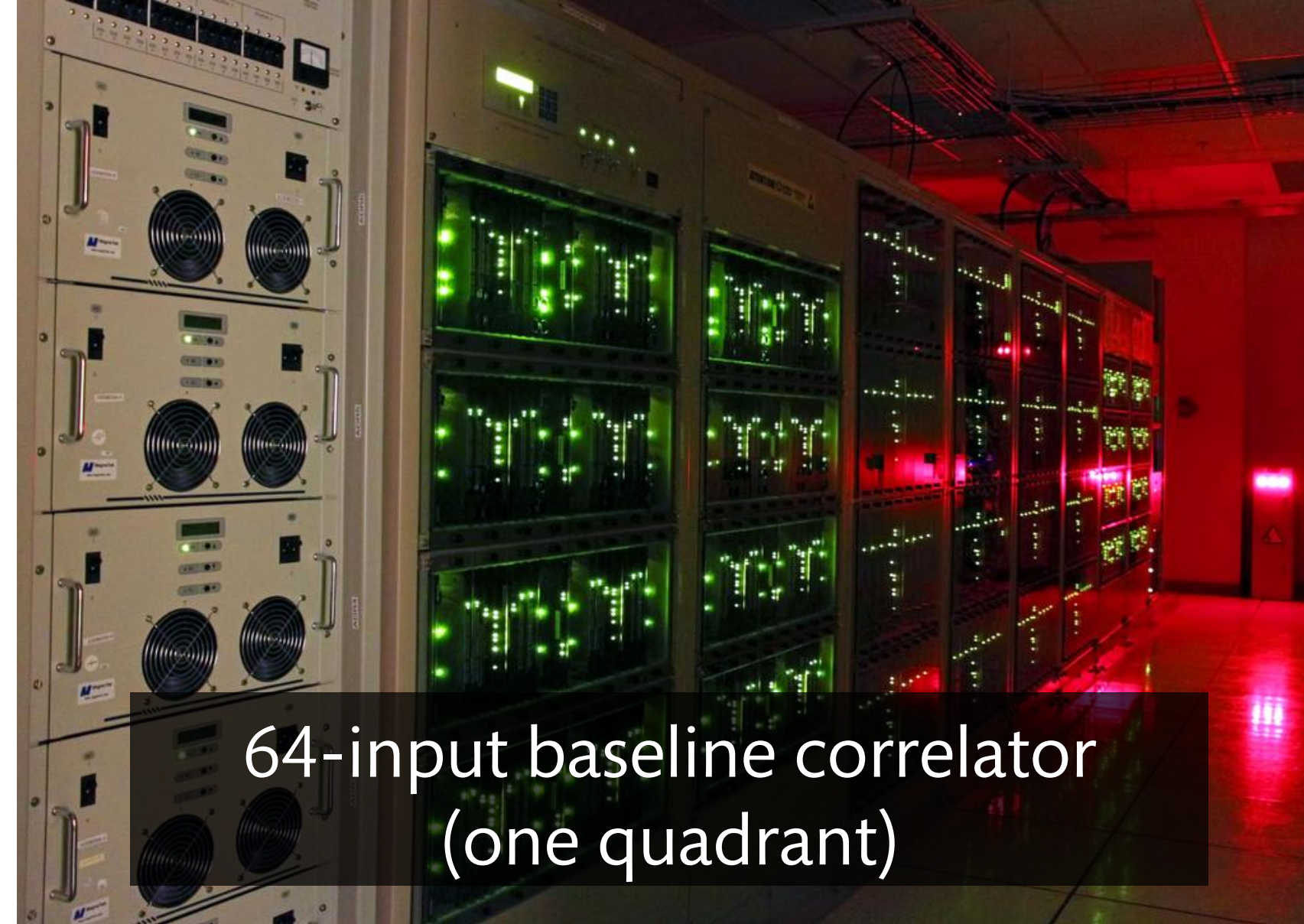
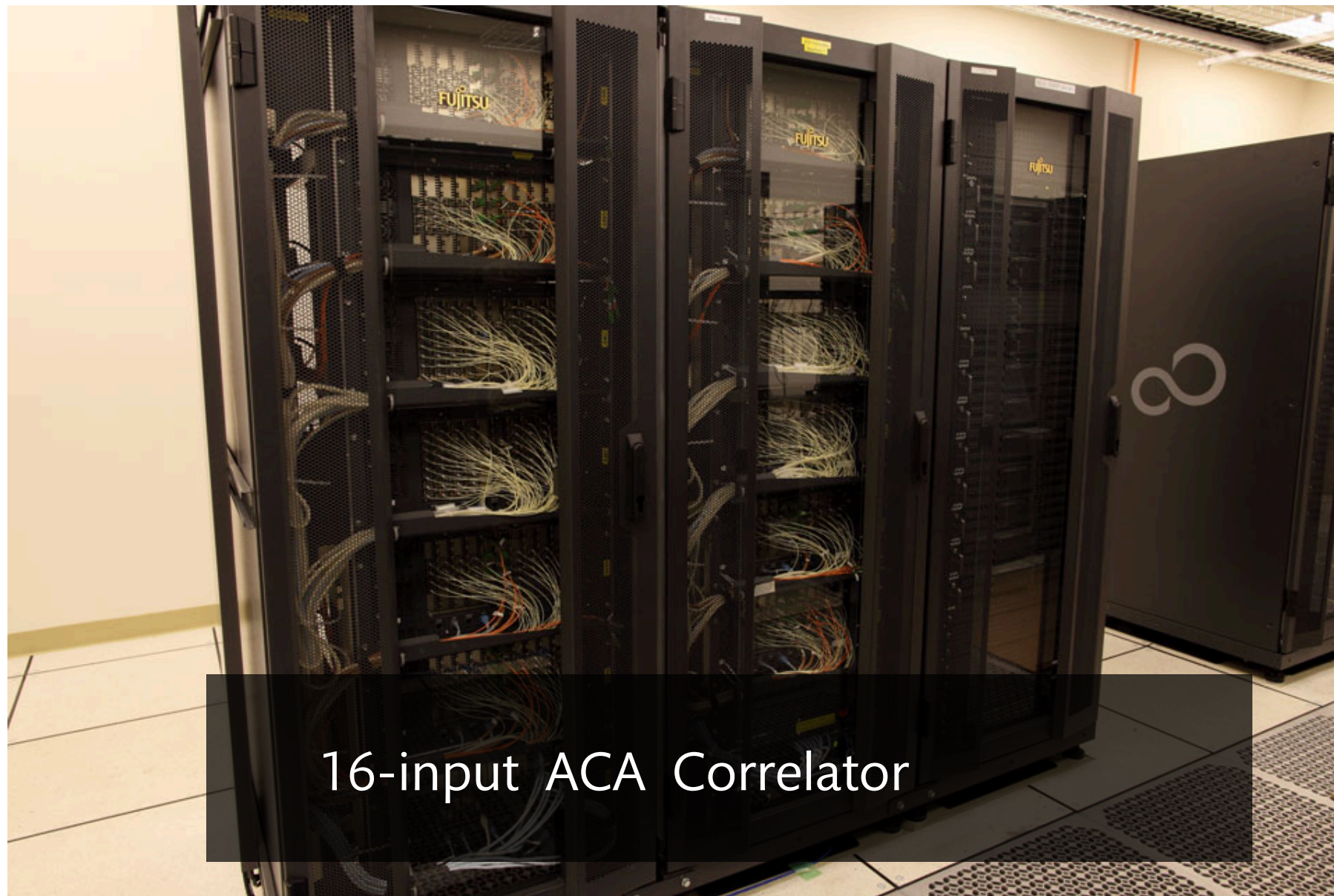


ALMA Calibration Device



- Robotic arm that places ambient and hot loads above any window
 - Positional accuracy: ± 1.5 mm: Hot Load in the range of $+80$ C
 - Time for a single calibration does not exceed 9.0 s
 - Designed for not less than 500 000 calibration cycles

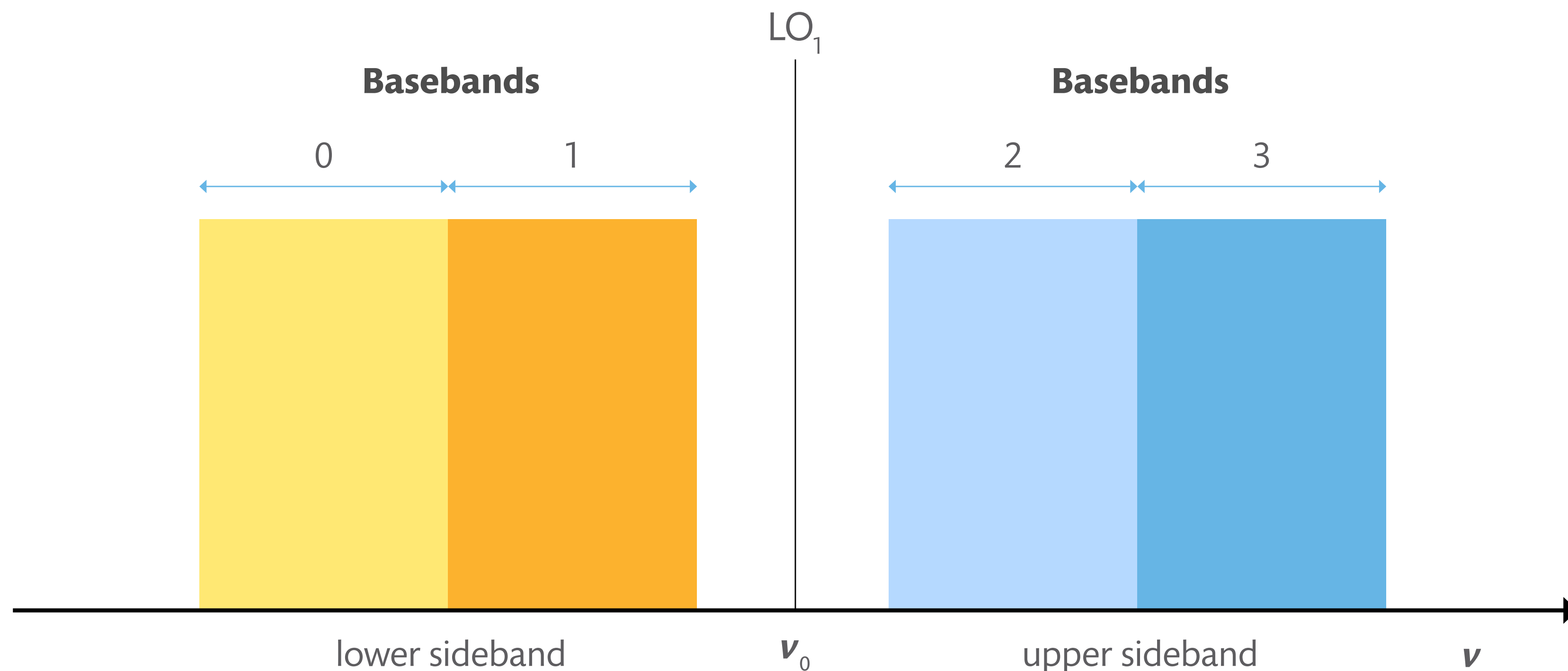
ALMA Correlators



Main characteristics

- Input data rate from antennas: 96 Gb/s
- Baseline correlator output data rate and limitations: 70 MB/s
 - Limited by network bandwidth and archive data ingestion
- ACA correlator output data rate: 3.6 MB/s
 - TDM and FDM modes
- Dump times: for observations 1-6 s depending on array configuration

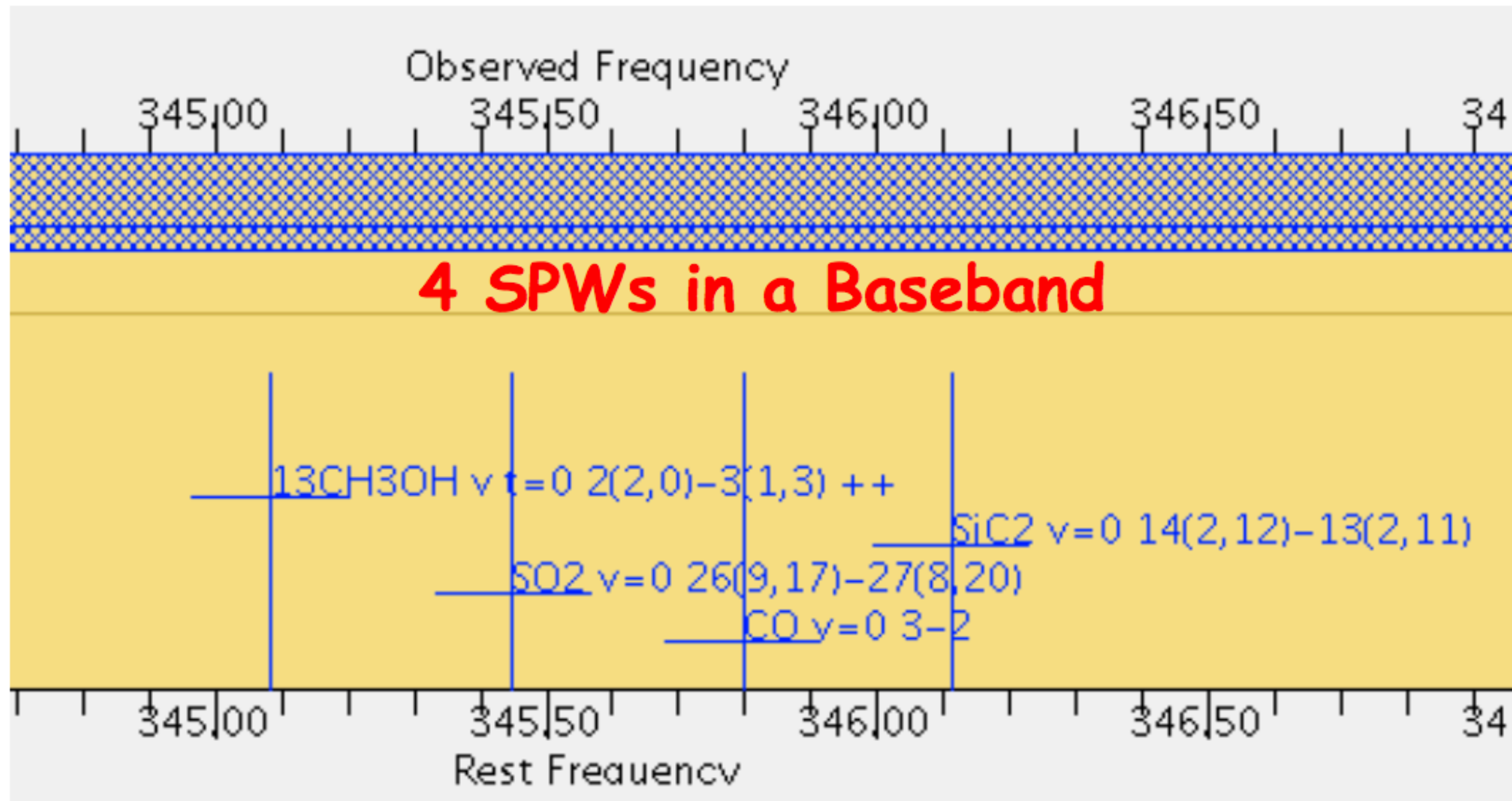
Setting up the correlator: Basebands



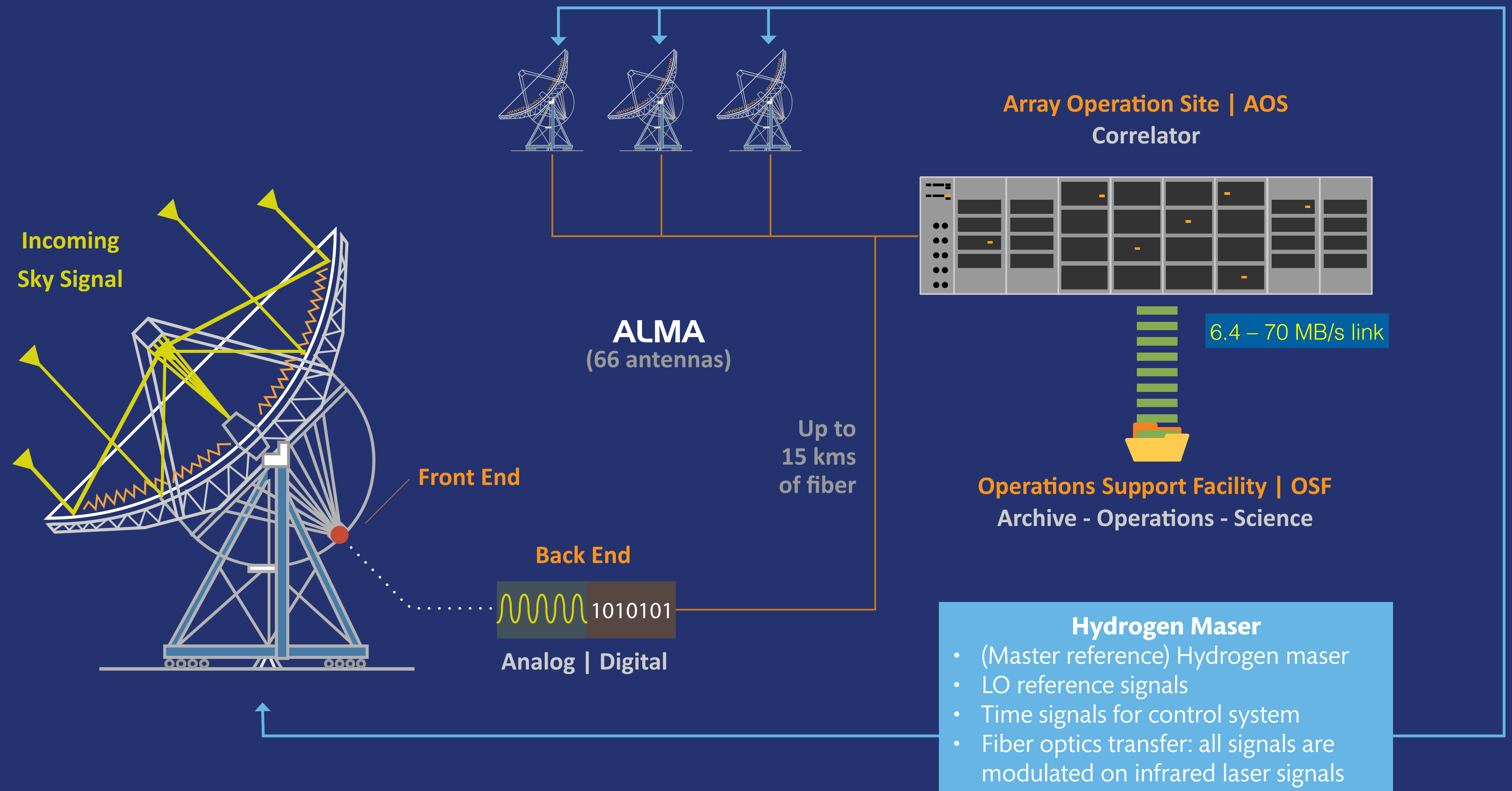
- Two polarizations
- Each baseband is 2 GHz wide with 4000 channels
- The 4 basebands can be in one sideband or distributed between the two



Setting up the correlator: Spectral Windows



Each baseband can be split into 4 spectral windows

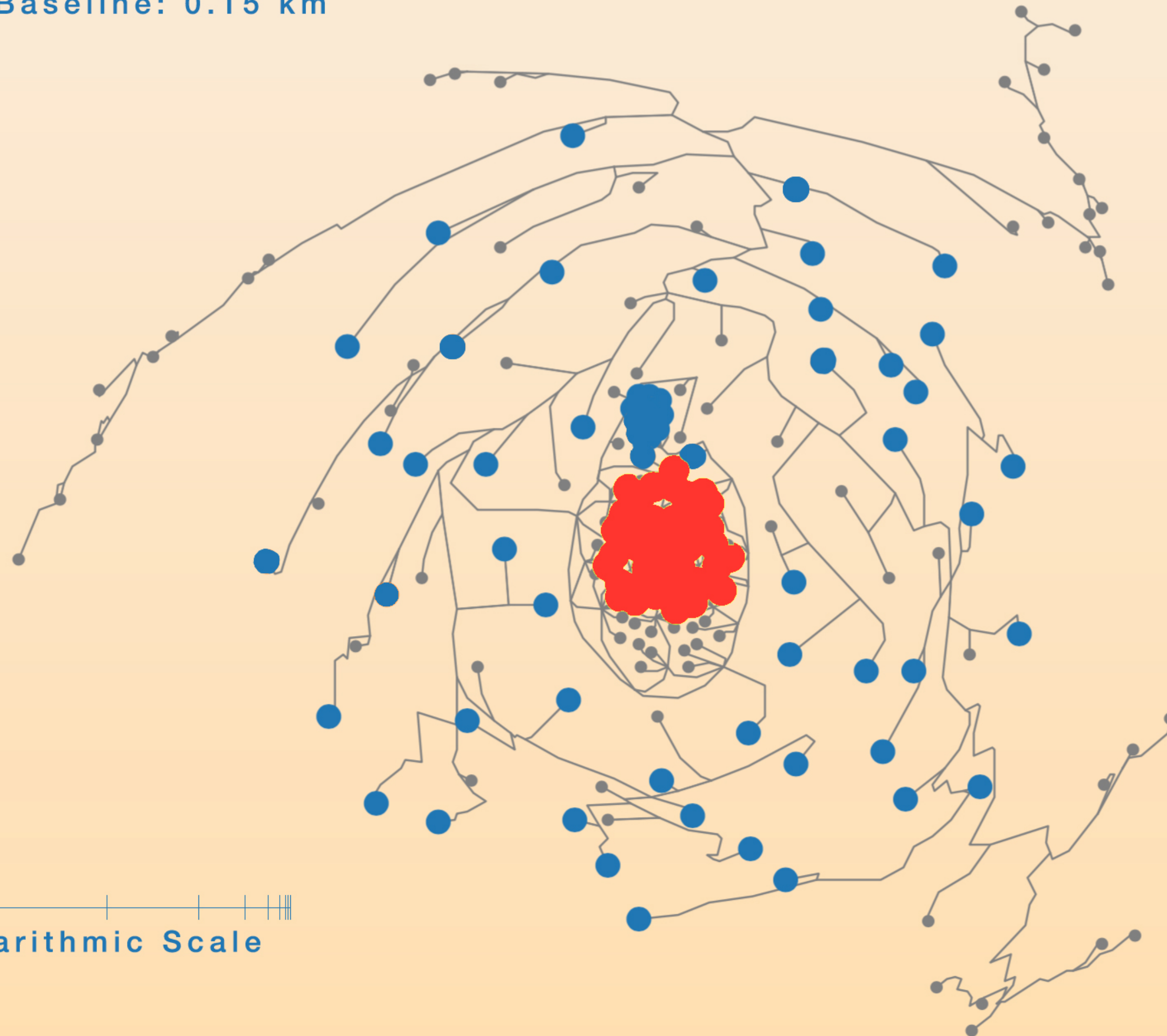


From each antenna: Bandwidth 2 x 8 GHz, data rate 96 Gb/s

Array Configurations

Cycle 4: 12m Array

Max. Baseline: 0.15 km



Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config



Array Configurations

Cycle 4: 12m Array

Max. Baseline: 0.27 km

Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config



Array Configurations

Cycle 4: 12m Array

Max. Baseline: 0.46 km

Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config



Array Configurations

Cycle 4: 12m Array

Max. Baseline: 0.70 km

Logarithmic Scale

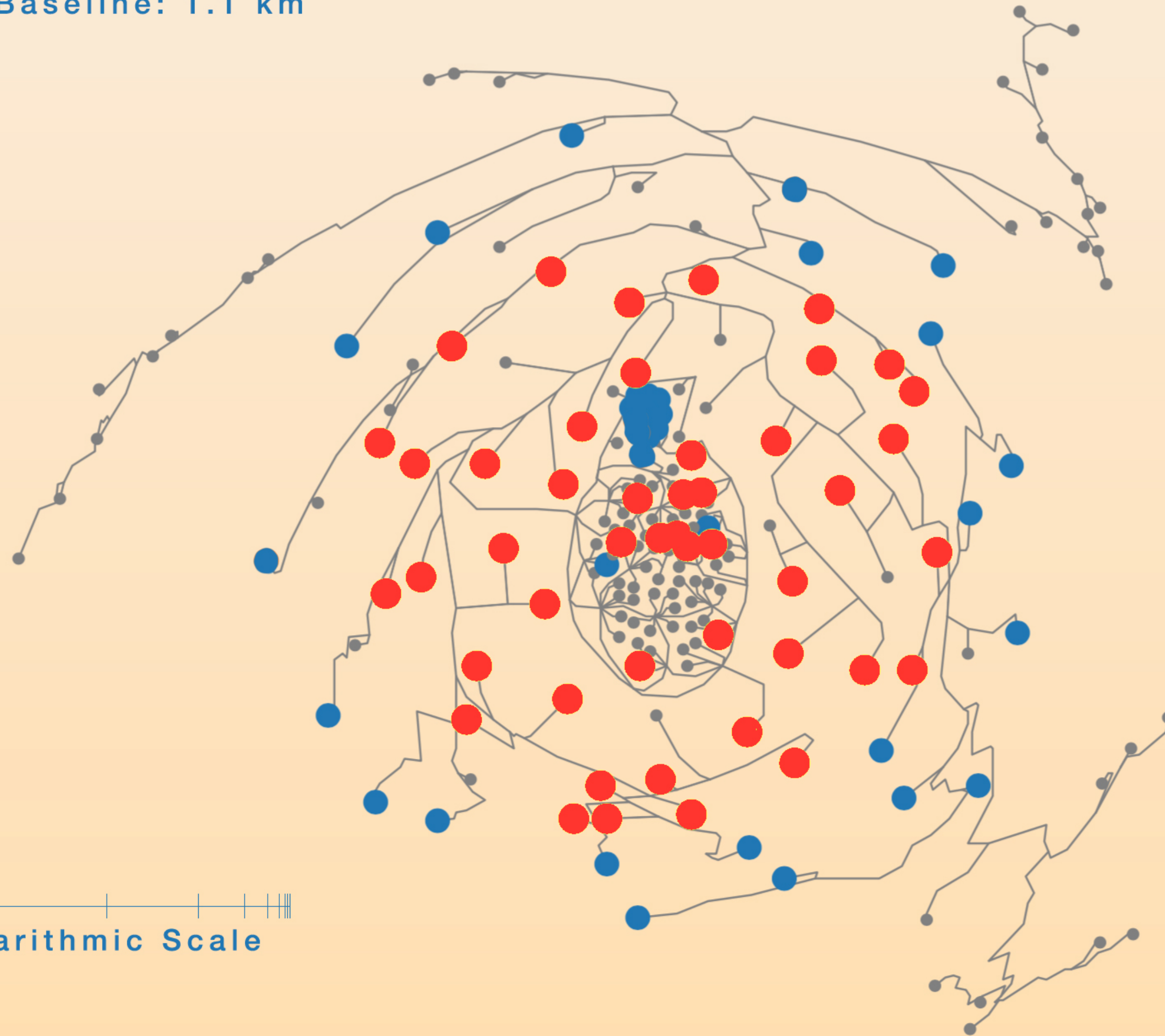
- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config

Array Configurations

Cycle 4: 12m Array

Max. Baseline: 1.1 km

Logarithmic Scale



- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config

Array Configurations

Cycle 4: 12m Array

Max. Baseline: 1.8 km

Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config

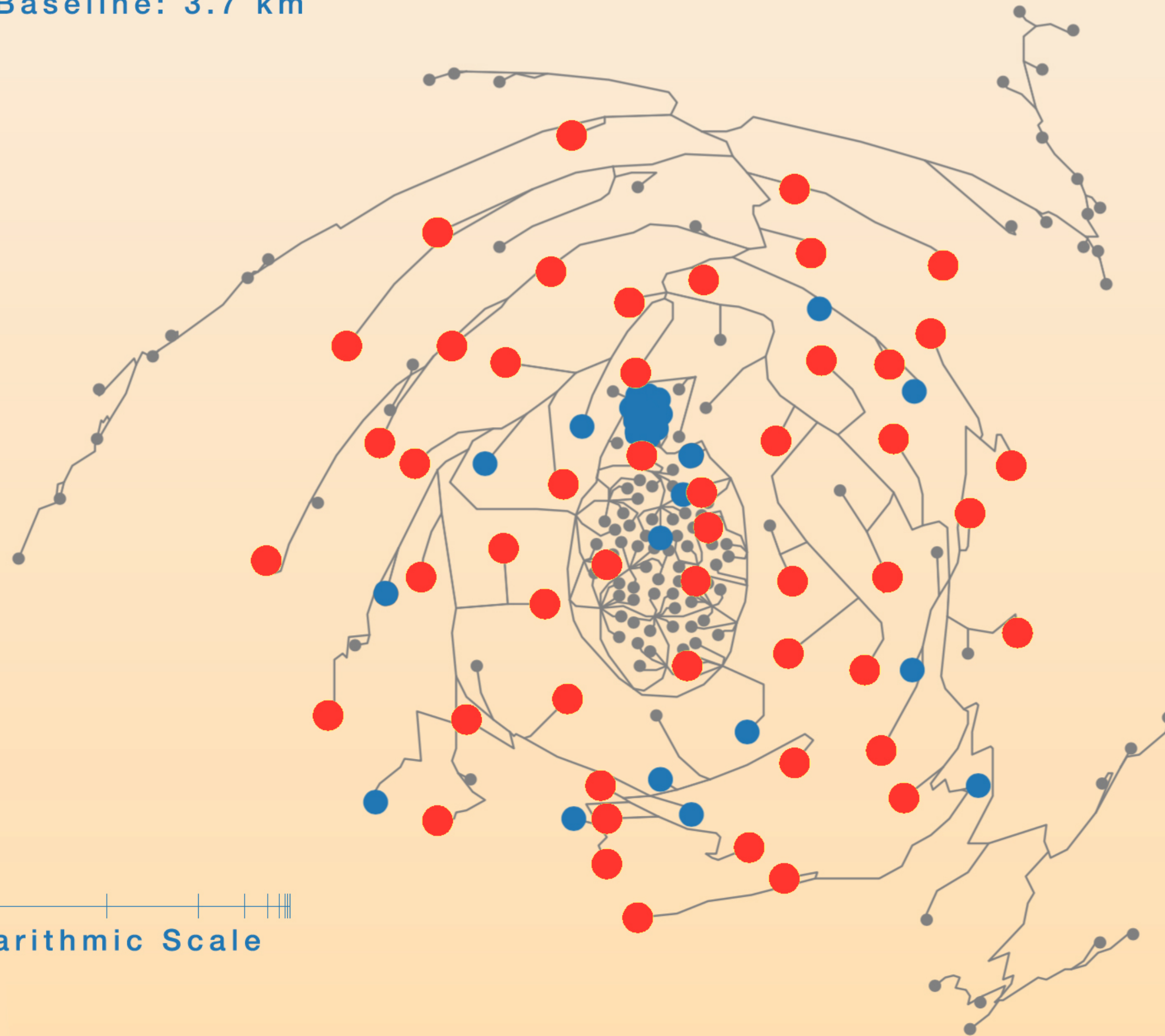


Array Configurations

Cycle 4: 12m Array

Max. Baseline: 3.7 km

Logarithmic Scale



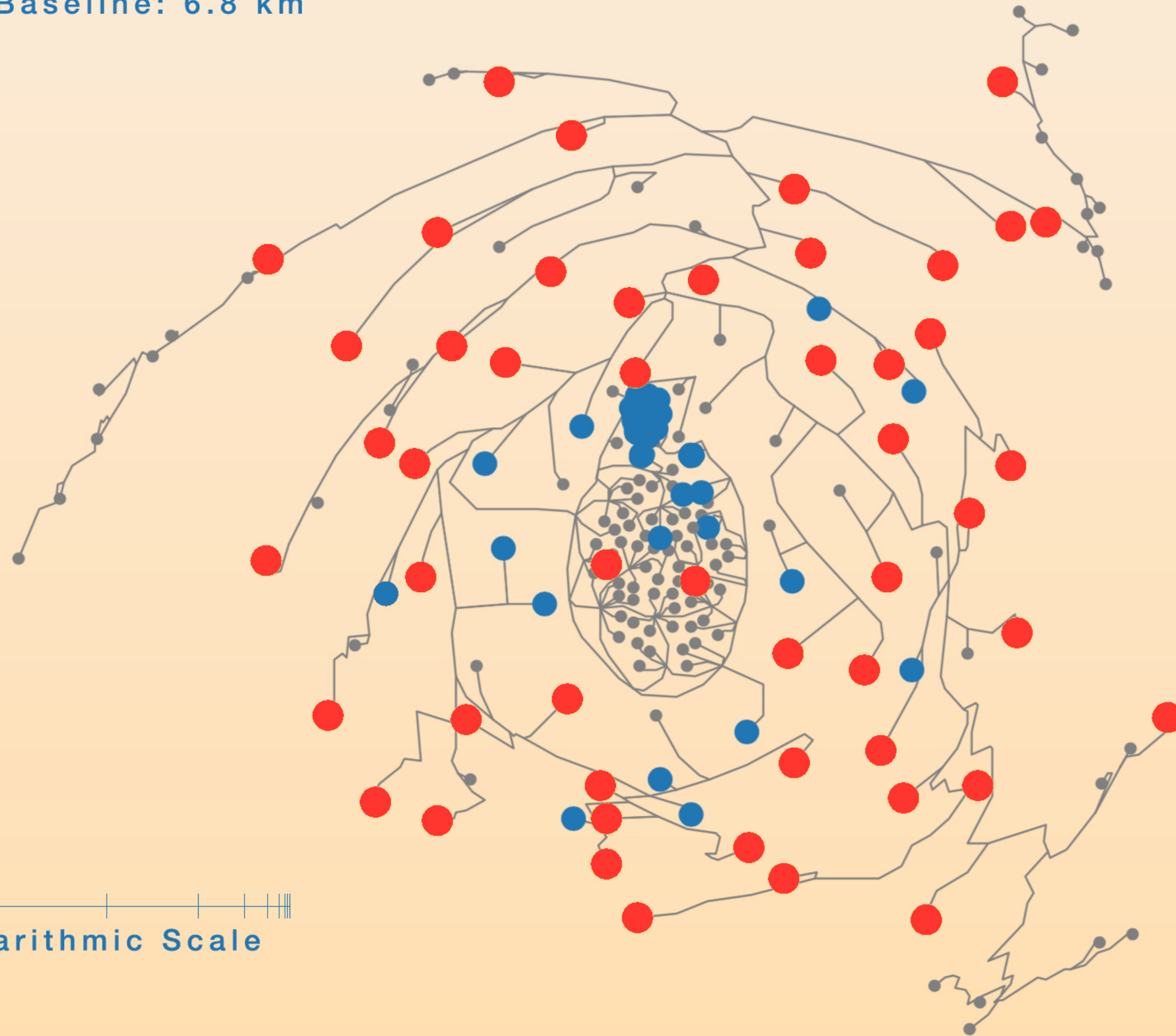
- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config

Array Configurations

Cycle 4: 12m Array

Max. Baseline: 6.8 km

Logarithmic Scale



- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config



Array Configurations

Cycle 4: 12m Array

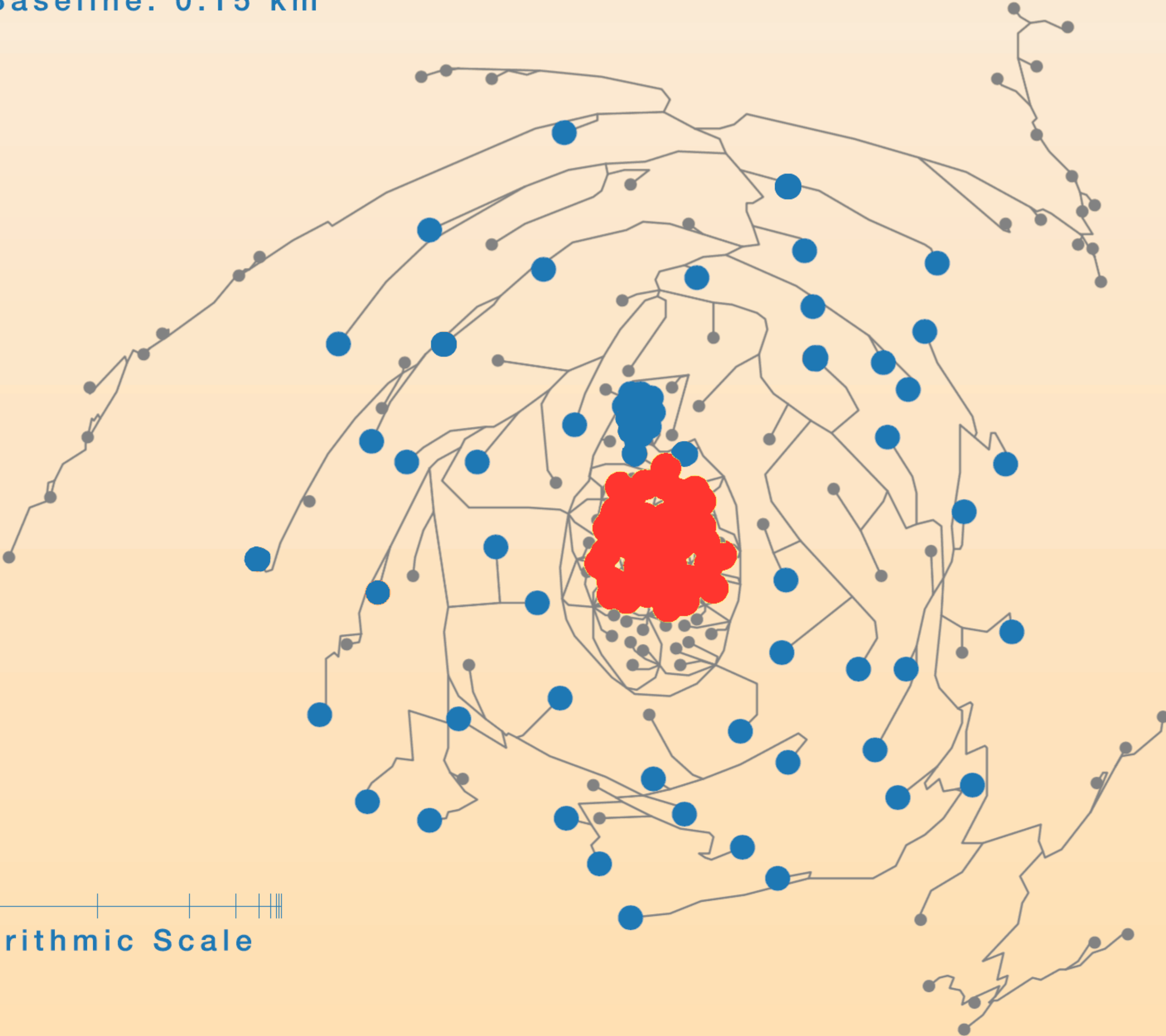
Max. Baseline: 12.6 km

Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config



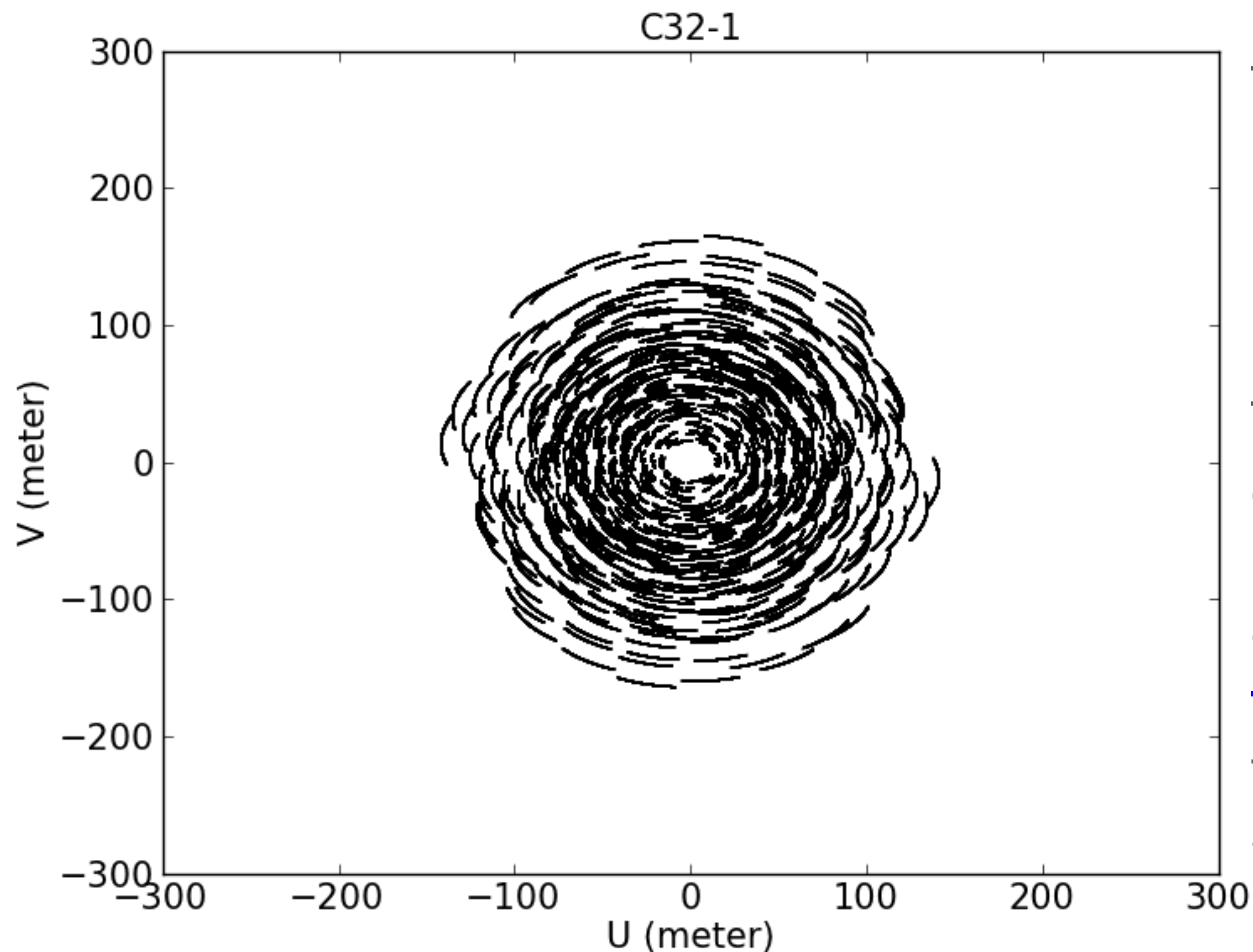
Max. Baseline: 0.15 km



Logarithmic Scale

- C40(+5)-6
- C40(+5)-5
- C40(+5)-4
- C40(+5)-3
- C40(+5)-2
- C40(+5)-1
- C40(+5)-3
- C40(+5)-5
- Configuration-9
- Configuration-8
- Configuration-7
- No Config

Atacama Compact Array – Morita Array

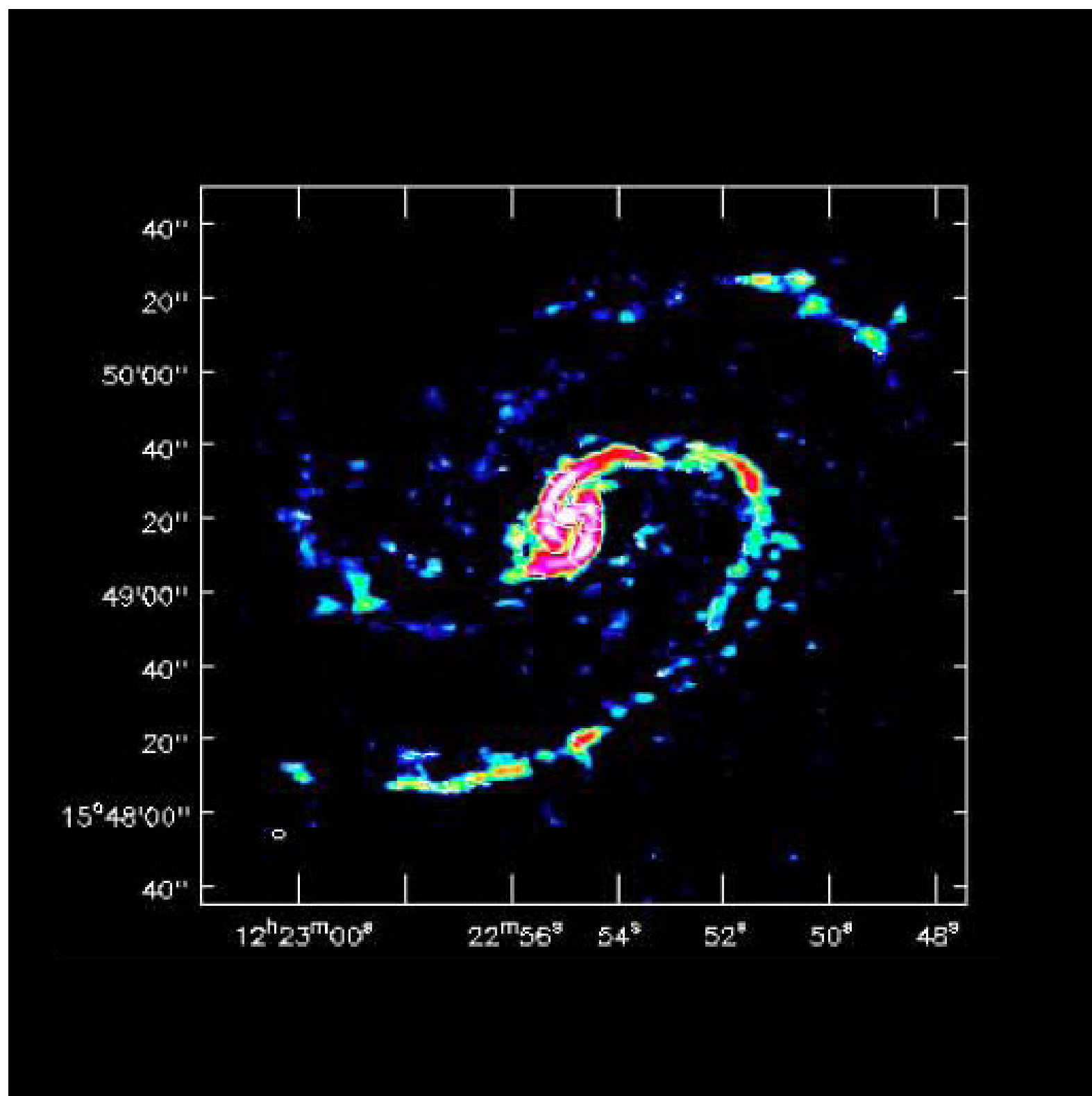


The minimum spacing between two 12m antennas is 15 meters producing a “hole” in the u-v plane which prevents measurements of larger angular scales.

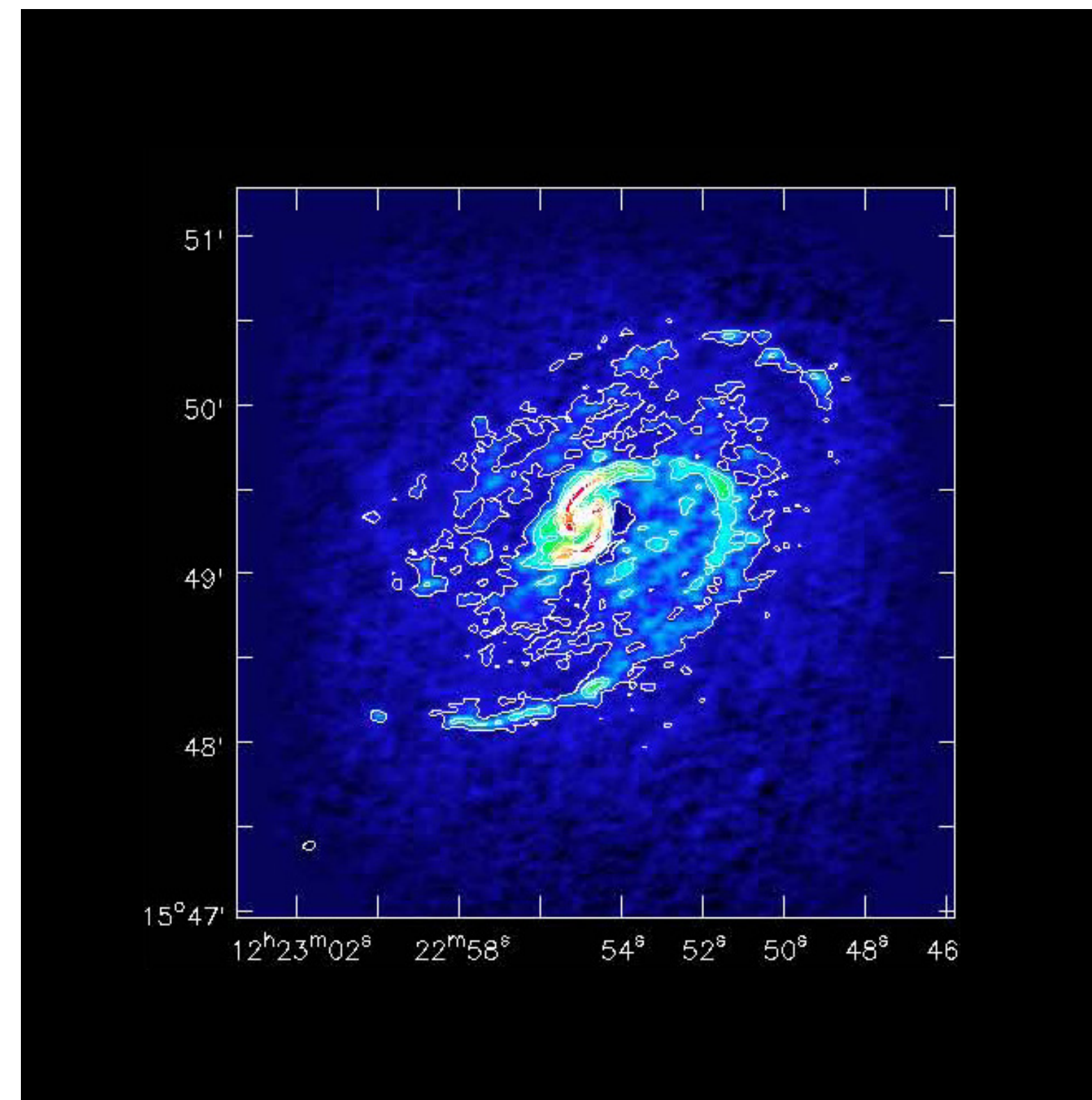
The **Atacama Compact Array** consists of 12 **7m antennas** and 4 **12m antennas** for total power observations. Addition of this data **will fill in the “hole”** in the u-v plane and facilitates detection of larger scale structures



ACA – Morita Array



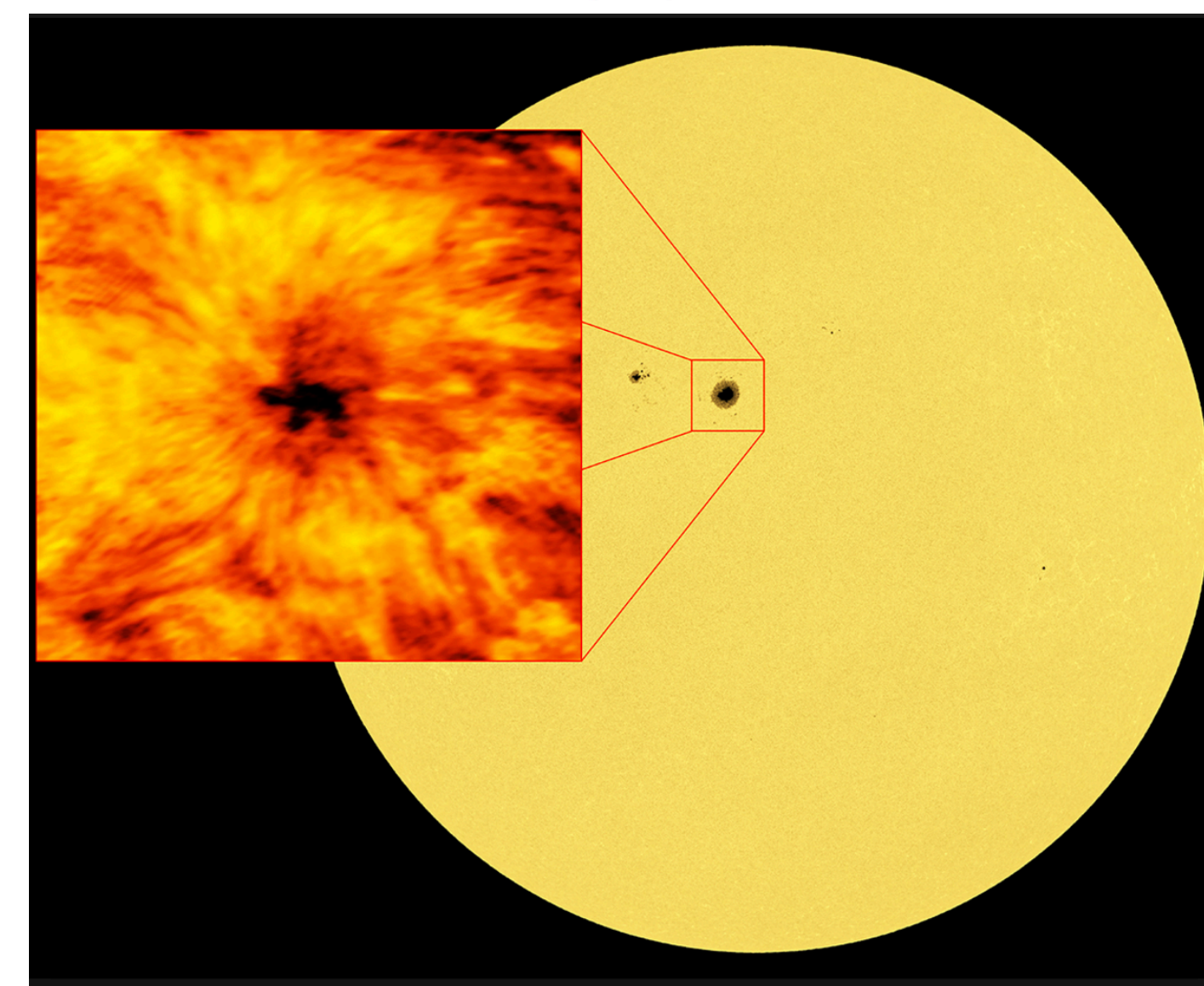
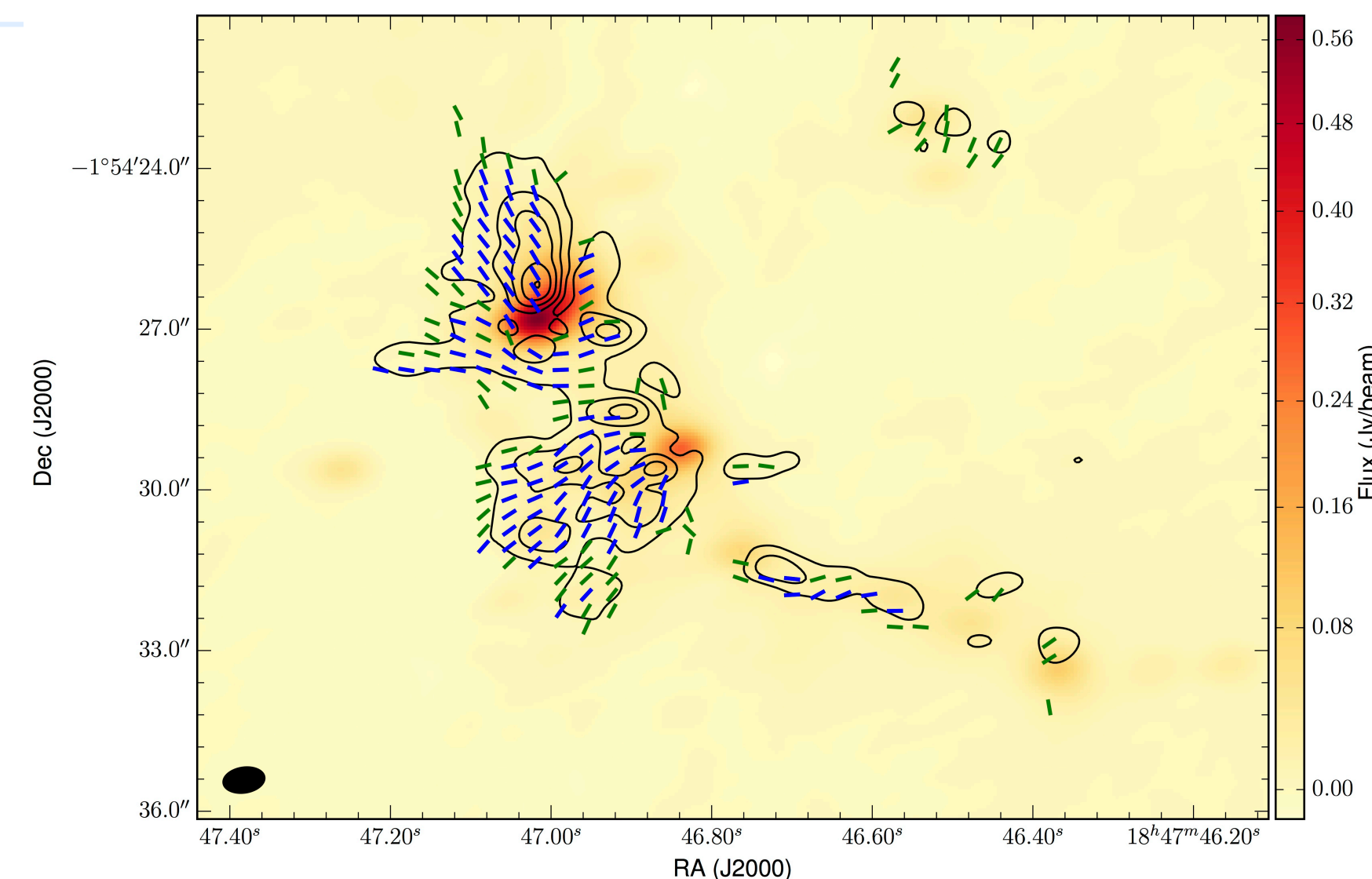
Without ACA



With ACA



- Single pointing
- Mosaics (up to 150 pointings)
- Polarization (currently only linear)
- Solar (detuned mixers)
- VLBI (phased array)



ALMA Software

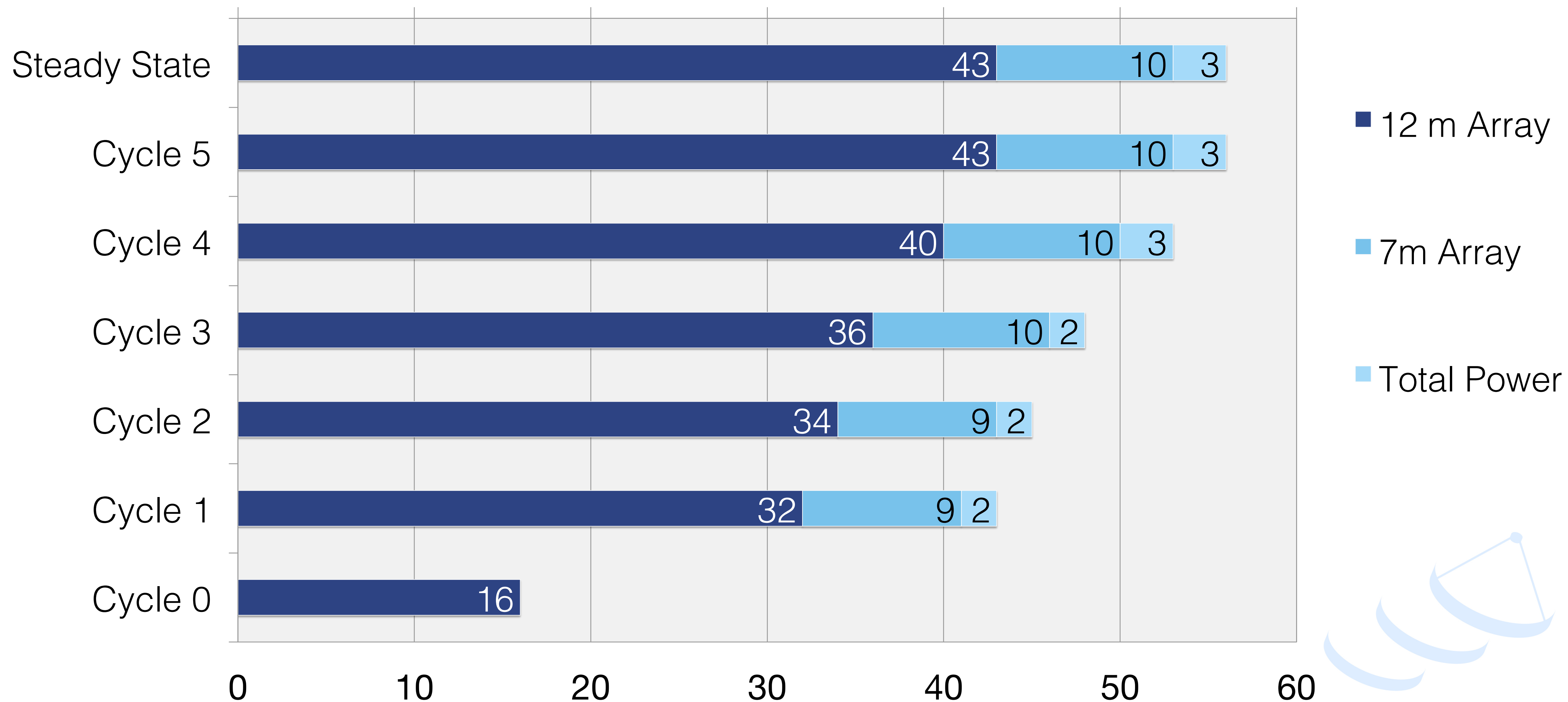
- ALMA software development is distributed between the partners.
- Software operations and deployments done in Chile
- Cycles of requirements definition, development, validation, acceptance and deployment
- **Online software:** Control, Correlator, Telescope calibration, OMC
- **Offline software:** Archive, Dynamic scheduler, AQUA (Data Quality Assurance Tool), Shiftlog Tool, Project Tracker/Life Cycle, Pipeline, CASA, Dashboard
- **User facing software:** Science Portal, User Registry, Helpdesk, Observing Tool, support tool for the proposal review process, tool for PIs to check observing status

ALMA Observations

- ALMA started PI observations in September **2011**, with **16 antennas**
- Observations were done in parallel with construction and commissioning, called Early Science and on a best effort bases
- ALMA is **now** in its **5th Cycle** of observations
- Annual Cycles since Cycle 3
- Steady state in Cycle 6

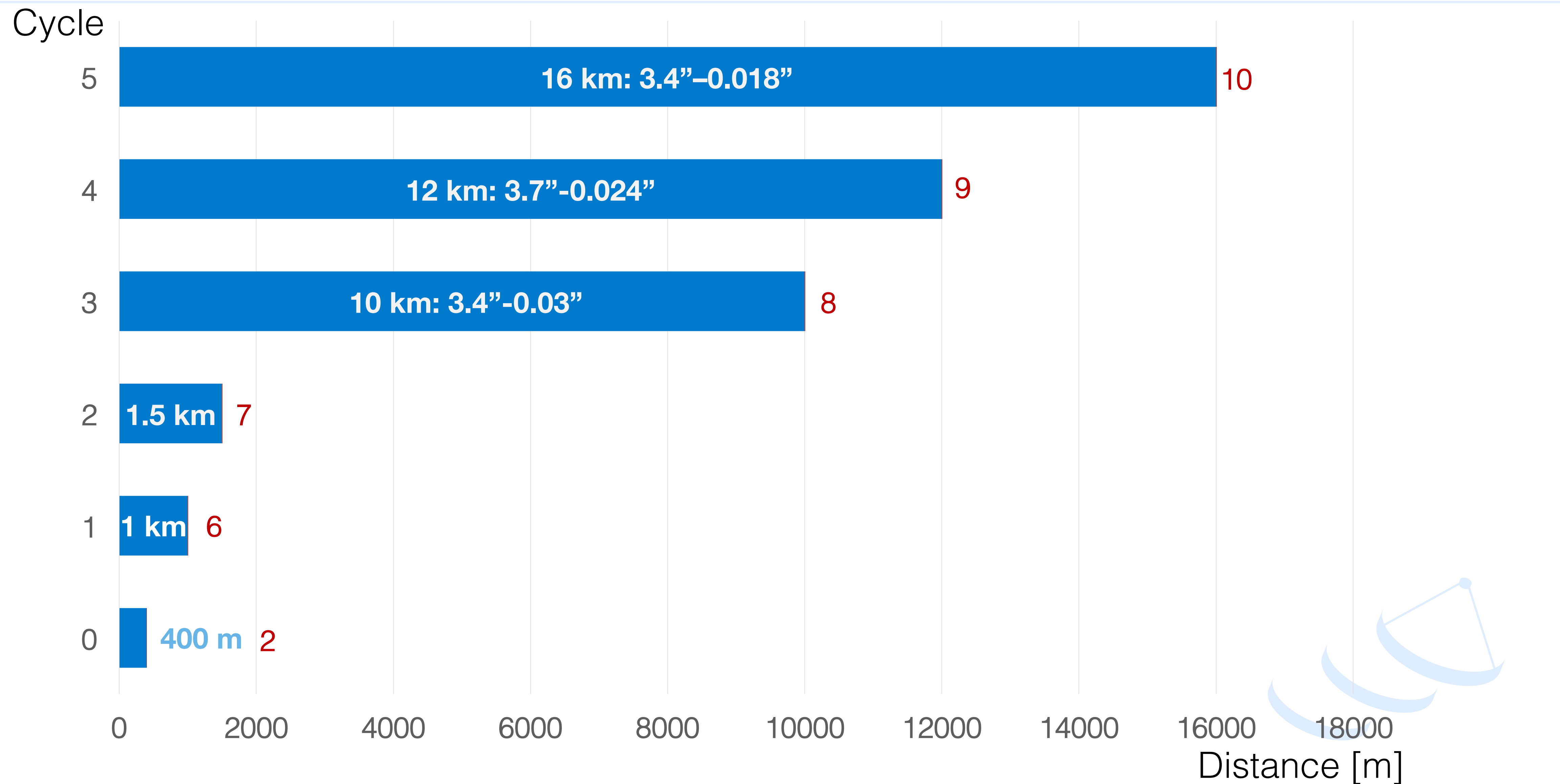


Minimum number of antennas



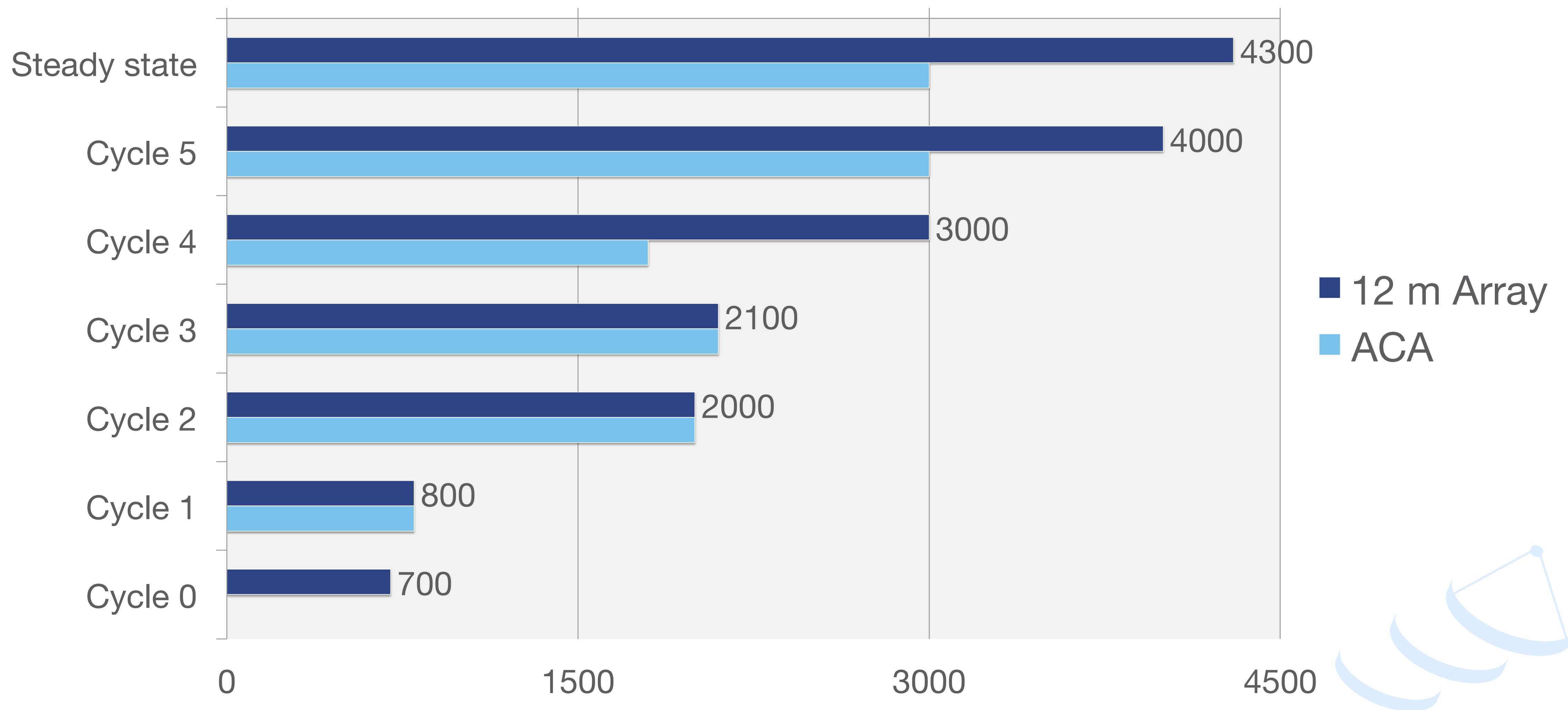
12m Array Maximum Baseline Lengths

Number of Array Configurations



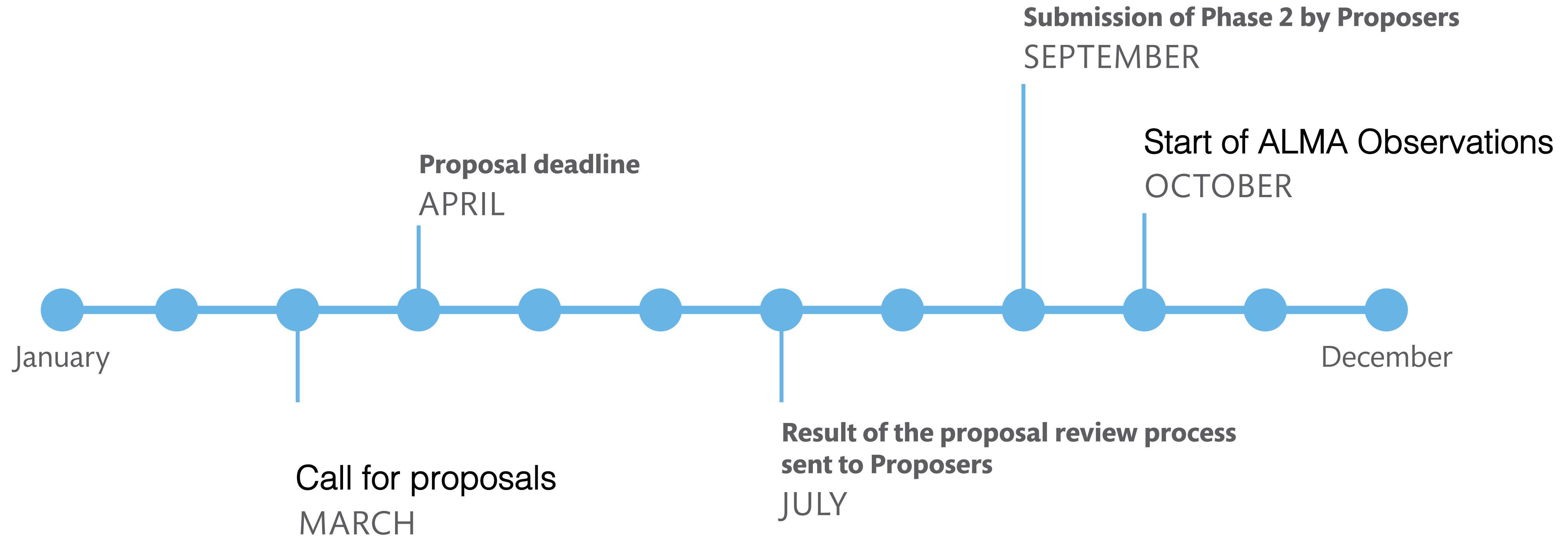
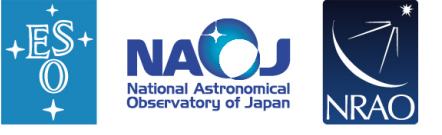
Hours of observing time offered

(hours of executions passing the first quality assurance control)





Proposing for ALMA - Deadlines



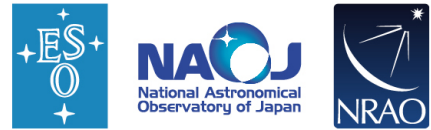
Proposing for ALMA - Proposal Types

- Regular Proposals:
 - < 50h on the 12-m array and < 150 h on ACA standalone
 - Time critical proposals
 - Solar Proposals
- Large Programs:
 - > 50 hours on 12-m array or > 150 hours on ACA standalone
 - up to 600h on the 12-m array and 450h on ACA standalone
- Target of Opportunity
- VLBI (3 mm and 1 mm wavelengths)
- Director's Discretionary Time (DDT)









Proposing for ALMA: the Science Portal




<http://almascience.org/>



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



[About](#) [Science](#) [Proposing](#) [Observing](#) [Data](#) [Processing](#) [Tools](#) [Documentation](#) [Help](#)

Observatory News

Status of ALMA Observations and Relocation to Long Baselines
Jul 03, 2017

Results from the Cycle 4 Supplemental Call for Proposals
Jun 20, 2017

Cycle 5 Phase 2 deadline
Jun 06, 2017

More...

NRAO News

ALMA Long Baseline Workshop
Oct 03, 2017

6th VLA Data Reduction Workshop
Oct 23, 2017

2017 Jansky Lecture
Oct 25, 2017

More...

Status

Cycle 5: Phase 2 Instructions Highest Priority Projects

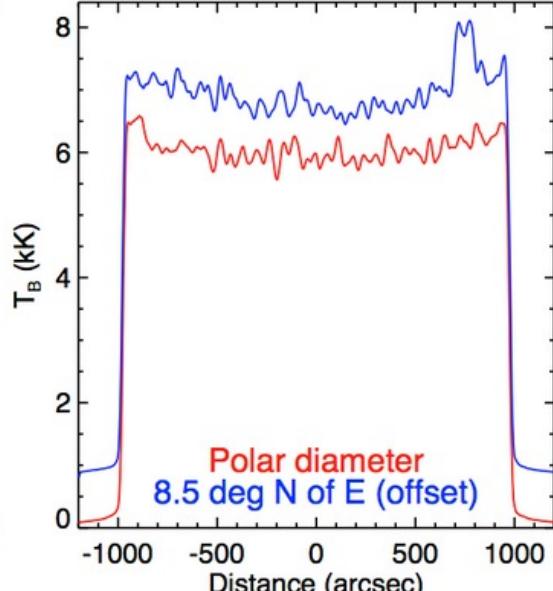
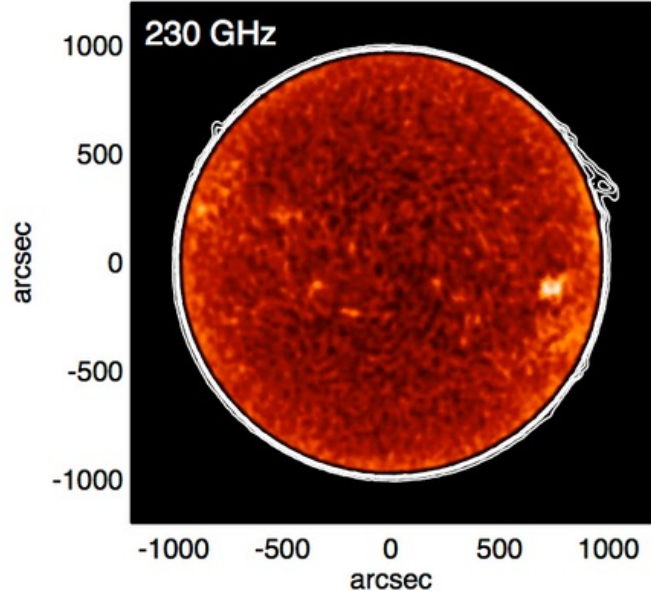
Refereed publications: 751

Last observed source: AM_2055-425

Current configuration: C40-7

More...

Science Highlights - Observing the Sun with ALMA: fast-scan single-dish mapping



ALMA has commenced science observations of the Sun starting in late 2016, taking advantage of the remarkable fast-scanning capabilities of the ALMA 12 m dishes to make single-dish maps of the full Sun.

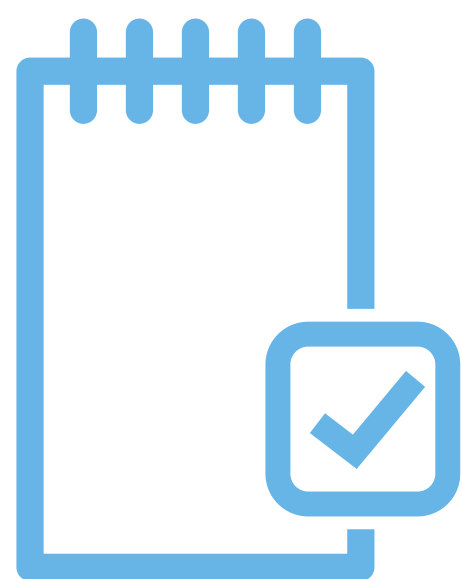
The left panel shows a 230 GHz (band 6) image of the Sun on 7 December 2016. In order to emphasize structure on the disk, the 230 GHz image color display ranges from 5300 to 7400 K. Low-level contours are plotted at 300, 600, 1200, and 2400 K in order to show features above the limb. The right panel shows disk profiles through the Poles and on a diameter through the active region in the southwest quadrant, but with the blue curve offset by 800 K in order to show structure in both.

[Full Summary...](#)

Site Map Accessibility Contact Privacy Statement

ESO NRAO NAOJ

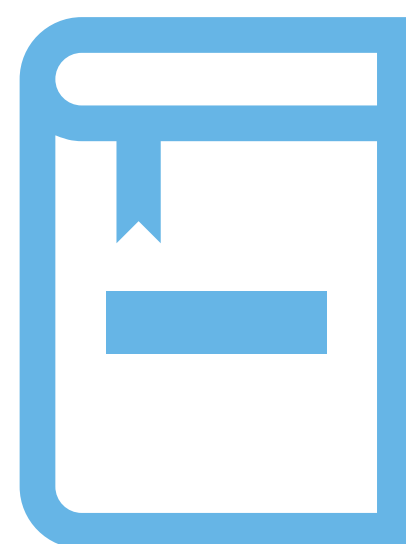
DOCUMENTATION AND OBSERVING TOOL (OT) IN THE SCIENCE PORTAL



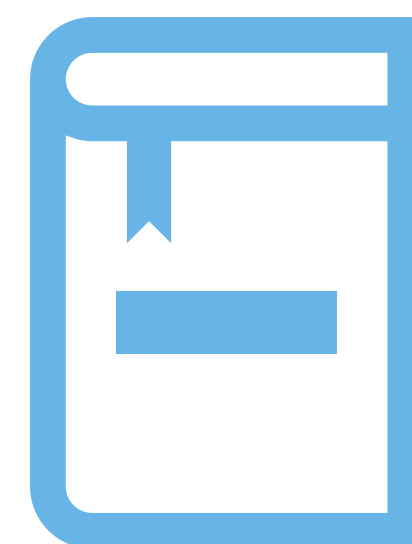
Proposers Guide
(important to
read)



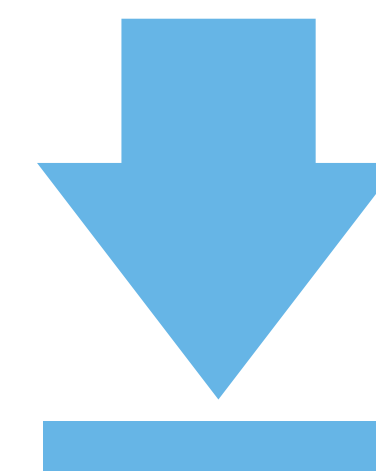
User's Policies



Technical
Handbook
(technical
aspects)



ES Primer (good
to read)



Download of the
Observing Tool
(OT)



OT Quickstart
and instruction
videos



The ALMA Observing Tool (OT)

ALMA Observing Tool (Cycle3PhaseII(u1)) – A survey of carbon-rich circumstellar envelopes (2013.1.00070.S last submitted 2015-05-29 09:42:29)

File Edit View Tool Search Help

Project Structure

Proposal Program

SUBMITTED

A survey of carbon-rich circumstellar envelopes

Proposal

Planned Observing

ScienceGoal (IRAS07454-7112)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Technical Justification

ScienceGoal (IRAS15082-4808)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Technical Justification

ScienceGoal (IRAS 15194-5115)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Editors

Spectral Spatial ScienceGoal (IRAS07454-7112 Band3)

Source Name IRAS_07454-7112 Resolve

Choose a Solar System Object? ☐ Name of object Unspecified

System FK5 J2000 Sexagesimal display? ☒ Parallax 0.00000 mas

Source Coordinates RA 07:45:02.4110 PM RA 0.00000 mas/yr

Dec -71:19:45.728 PM DEC 0.00000 mas/yr

Source Radial Velocity -38.700 km/s lsrk z -0.000129073 Doppler Type RADIO

Target Type ☒ Individual Pointing(s) ☐ 1 Rectangular Field

Expected Source Properties

Peak Continuum Flux Density per Synthesized Beam 0.00000 Jy

Continuum Polarization Percentage 0.0 %

Peak Line Flux Density per Synthesized Beam 1.00000 Jy

Line Width 26.00000 km/s

Line Polarization Percentage 0.0 %

Feedback

Validation Validation History Log

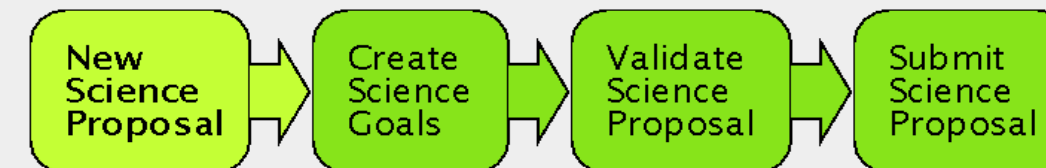
Description Suggestion

Overview

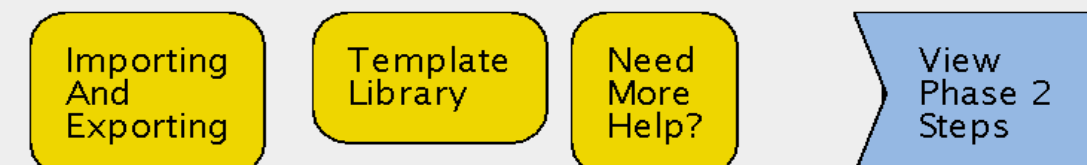
Contextual Help

1. Please ensure you and your co-Is are registered with the [ALMA Science Portal](#)
2. Create a new proposal by either:
 - Selecting *File > New Proposal*
 - Clicking on the **1** icon in the toolbar
 - Or clicking on this [link](#)
3. Click on the **proposal** tree node and complete the relevant fields.

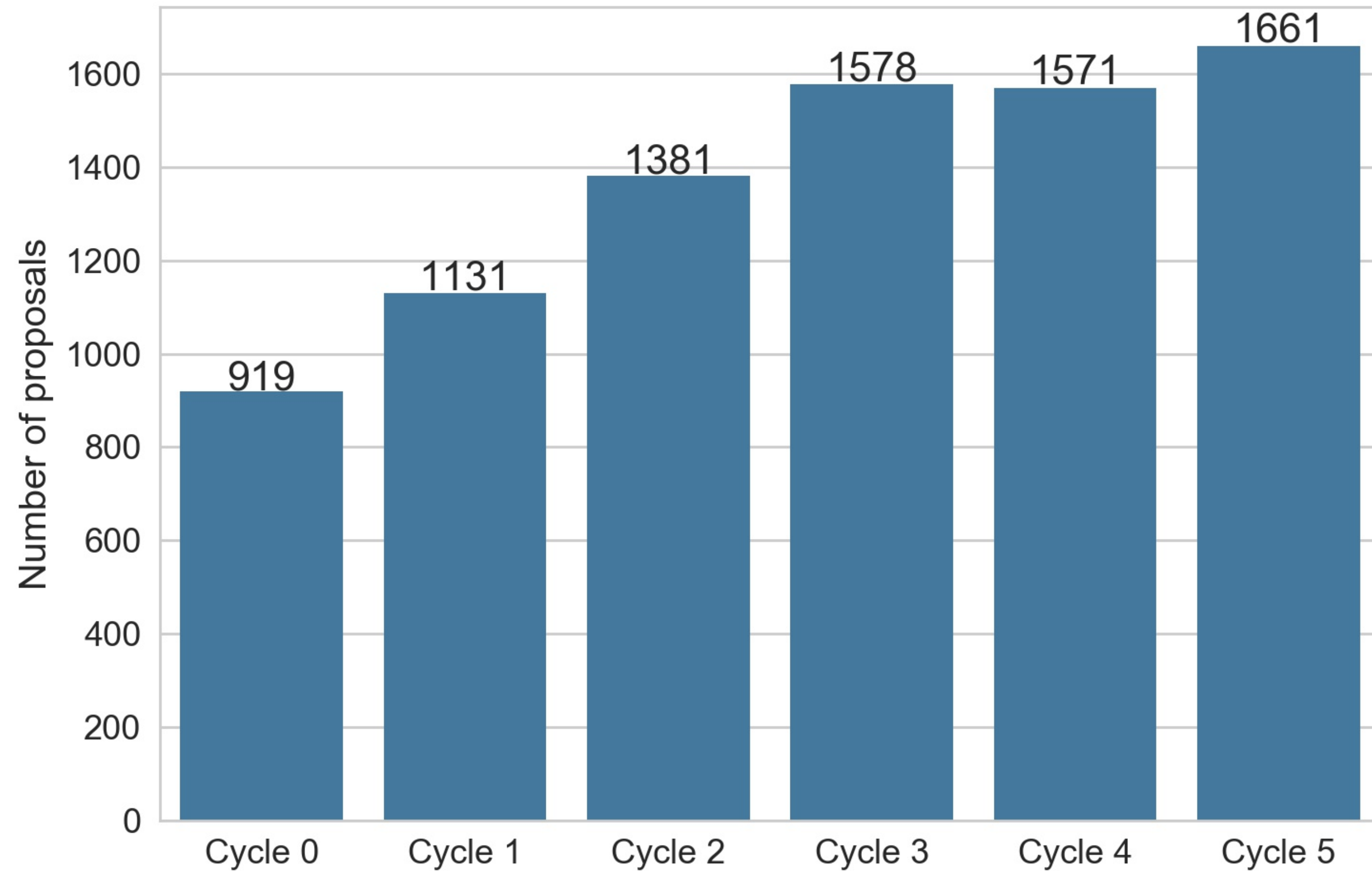
Phase I: Science Proposal



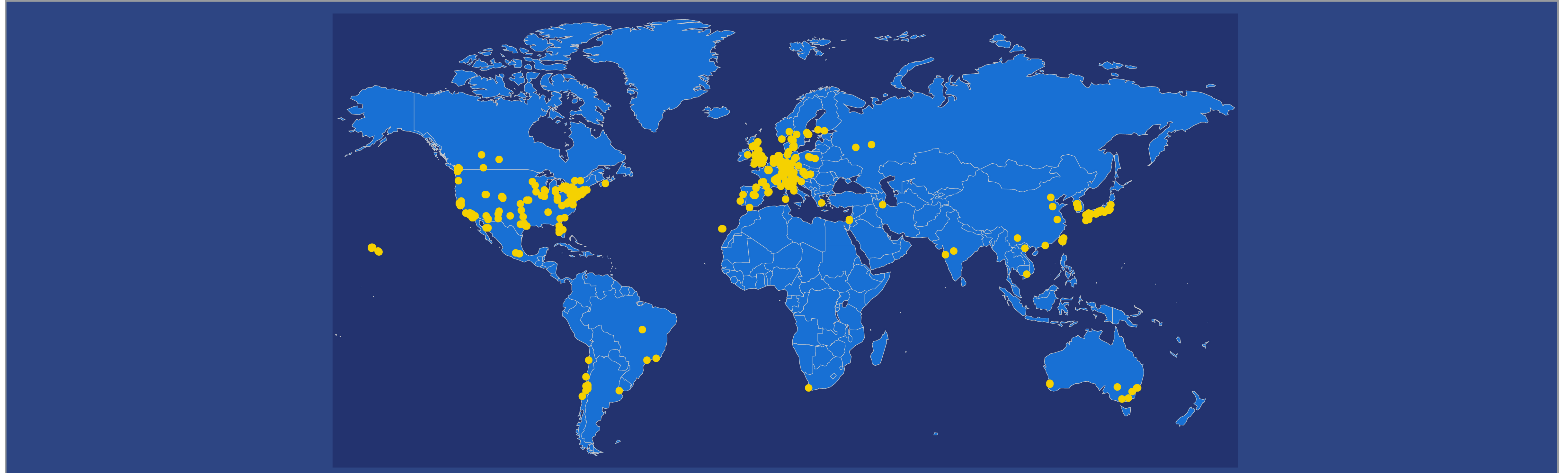
Click on the overview steps to view the contextual help



Number of Submitted Proposals

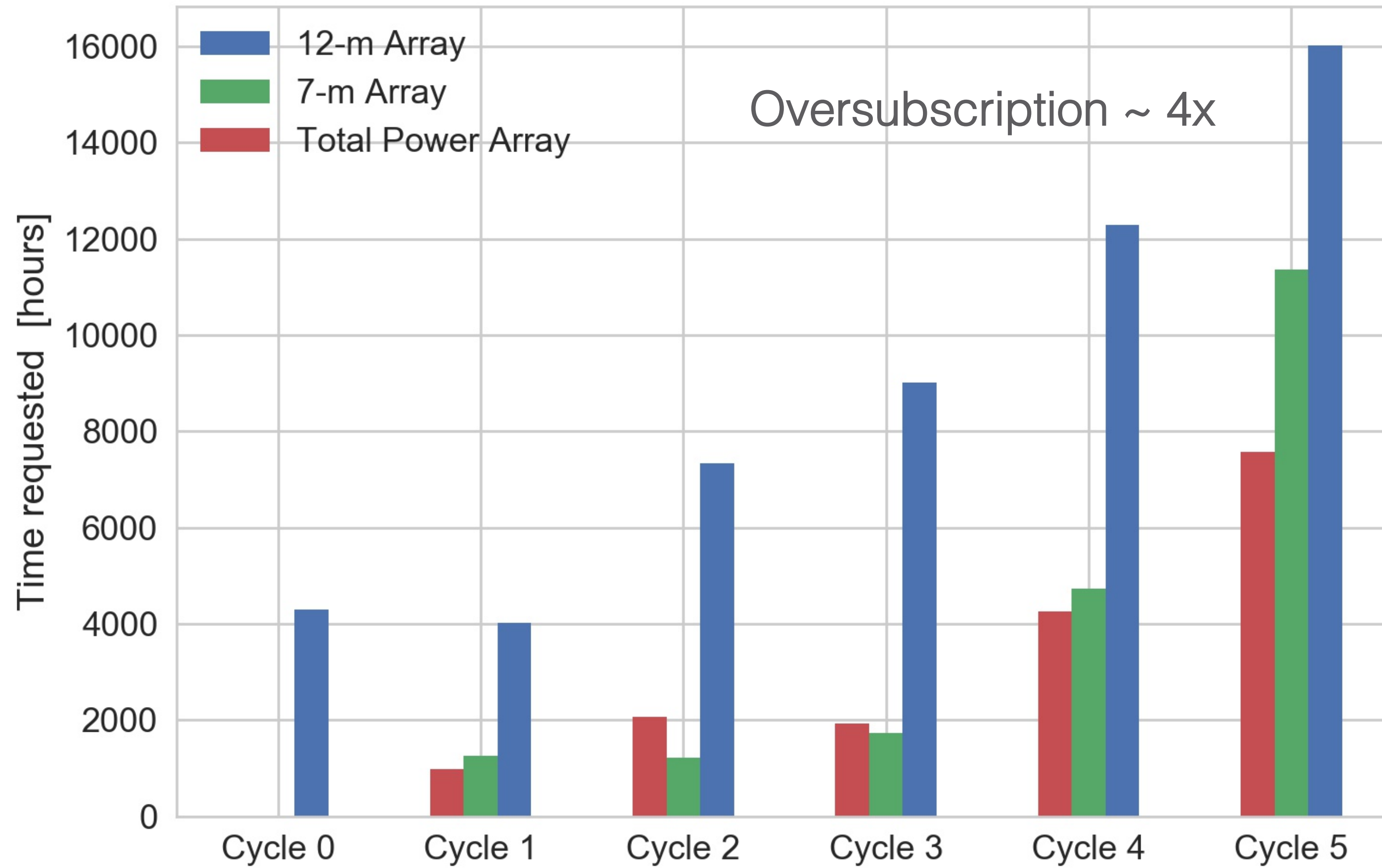


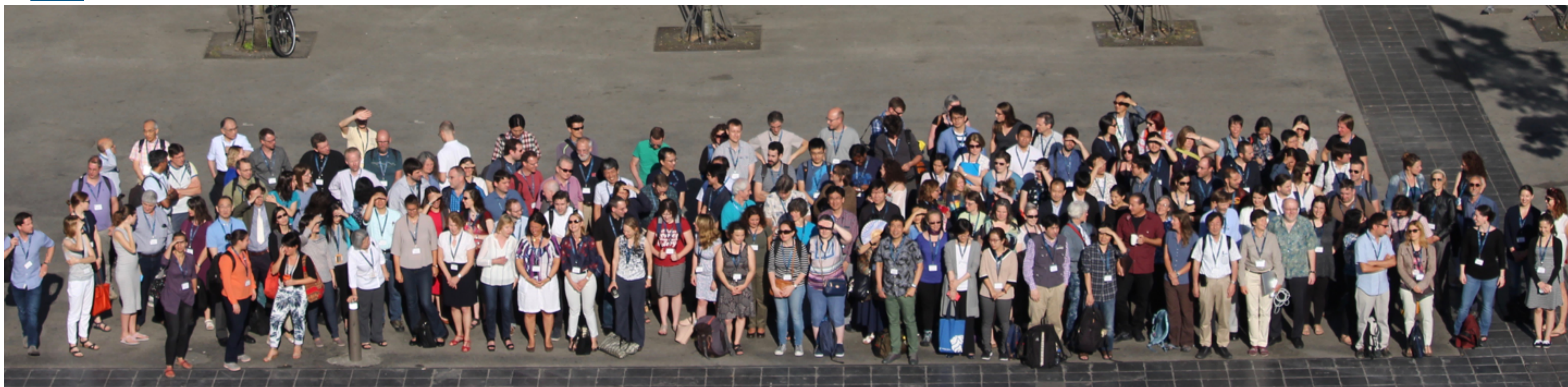
CYCLE 5 PROPOSALS SUBMISSIONS








1661 unique proposals were submitted at the deadline on April 20, 2017 from around the world

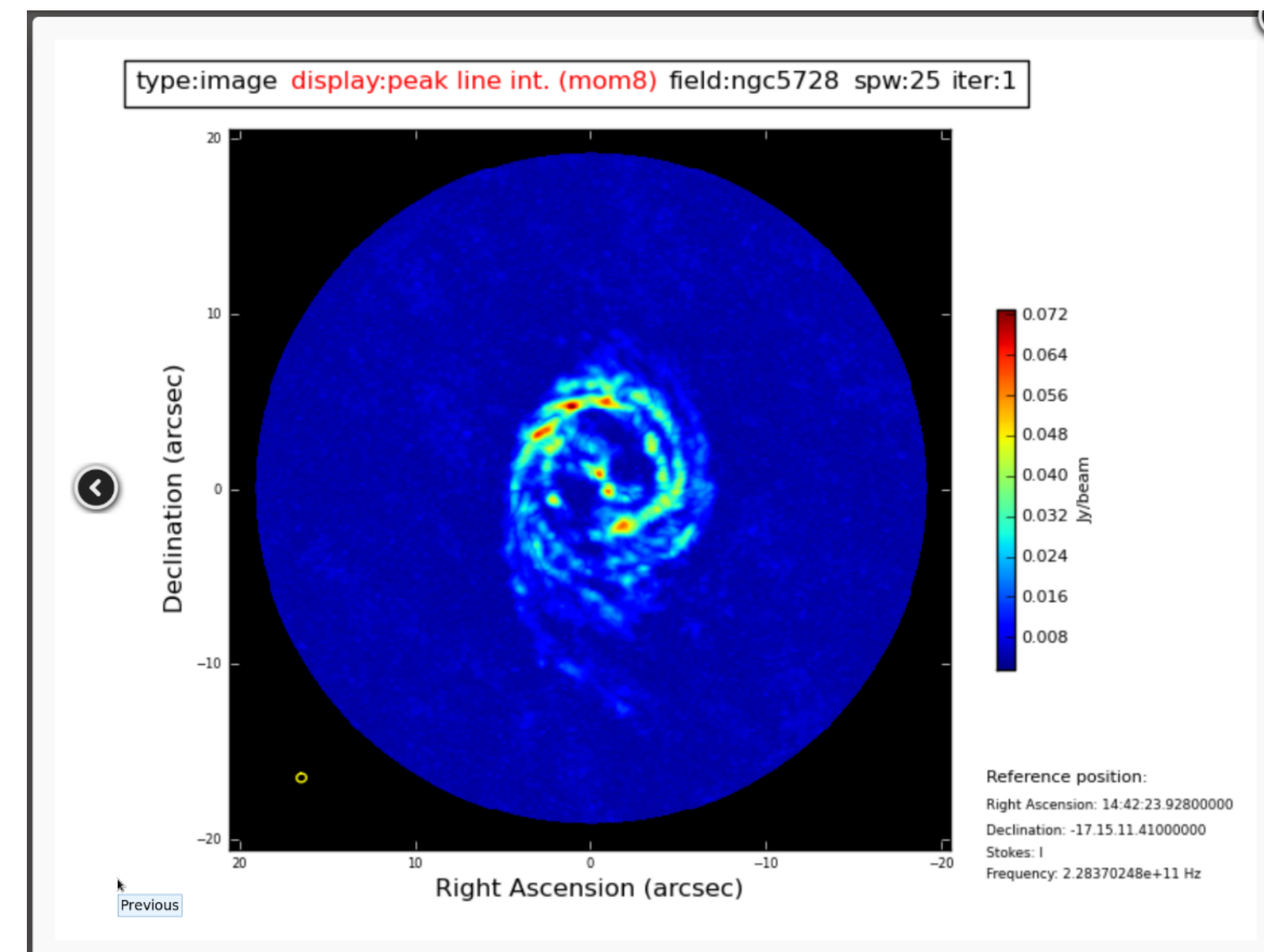
Hours requested





-  1661 proposals reviewed during a meeting in Antwerp (Belgium) on June 18-23
-  146 Science Assessors distributed over 18 ALMA Review Panels (ARP) and 5 science categories
-  The 18 Panel Chairs served on the ALMA Proposal Review Committee (APRC) with the APRC Chair
-  The APRC produced the final Cycle 5 science ranked list including the regional share of observing time
-  The Joint ALMA Observatory (JAO) created an observing queue considering the scientific rank and scheduling feasibility

- ALMA delivers calibrated, quality assured data in form of image cubes
- Data processing done at JAO and in the ARCs
- Calibration and imaging done with the pipeline for standard modes
- Manual processing for non-standard modes
- Data deliveries through the archive
- Proprietary time is one year, after which the data becomes public
- Science Verification data available in the archive



ALMA Data Archive

ALMA Science Archive Query

Query Form

Results Table

Search

Reset

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Position

Source name (Resolver)
Source name (ALMA)
RA Dec
Galactic
Target list
Angular resolution
Largest angular scale
Field of view

Energy

Frequency
Bandwidth
Spectral resolution
Band

Time

Observation date
Integration time

Polarisation

Polarisation type

Observation

Line sensitivity (10 km/s)
Continuum sensitivity
Water vapour

Project

Project code
Project title
PI name
Proposal authors
Project abstract
Publication count
Science keyword

Publication

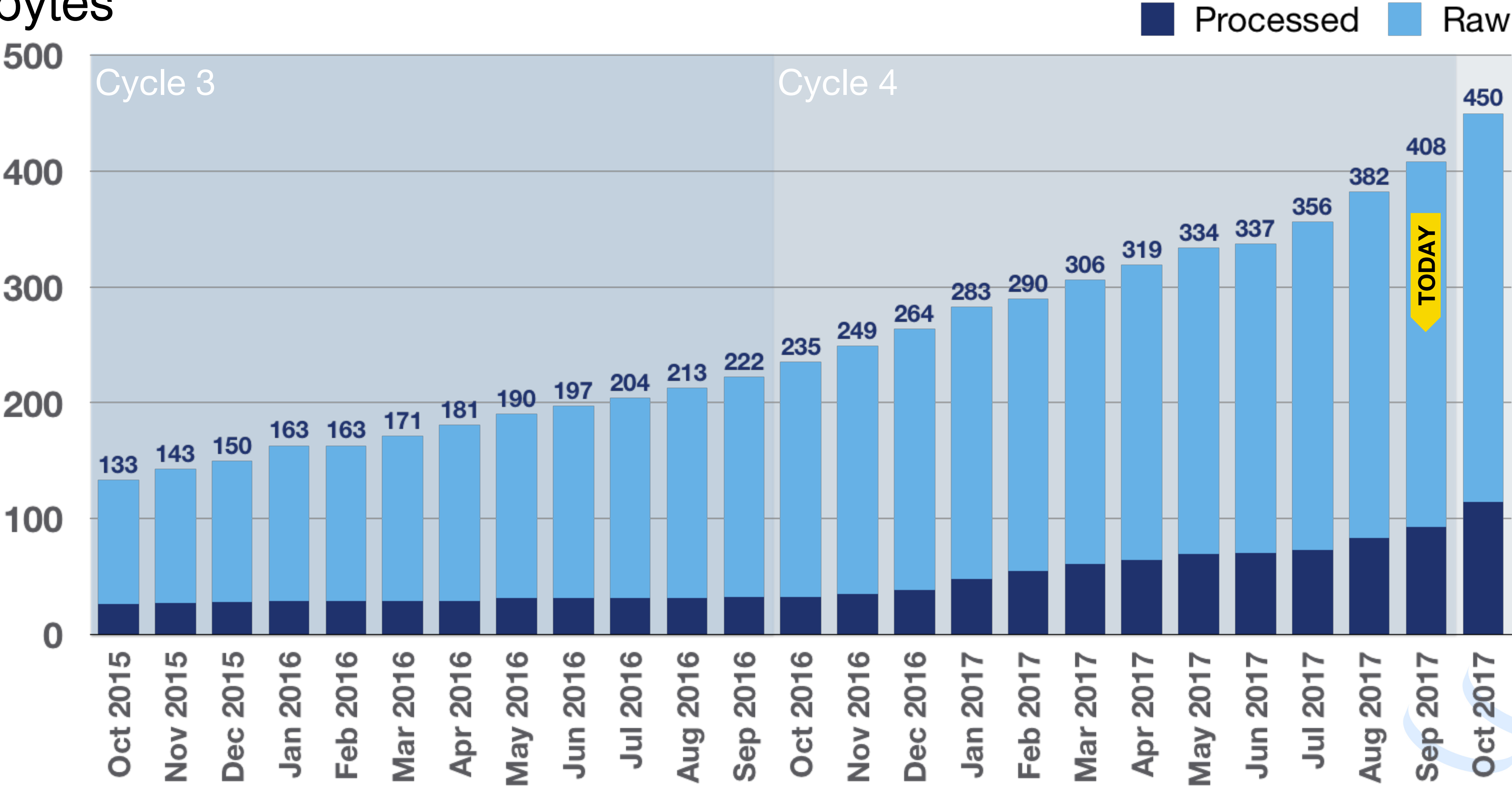
Bibcode
Title
First author
Authors
Abstract
Year

Options

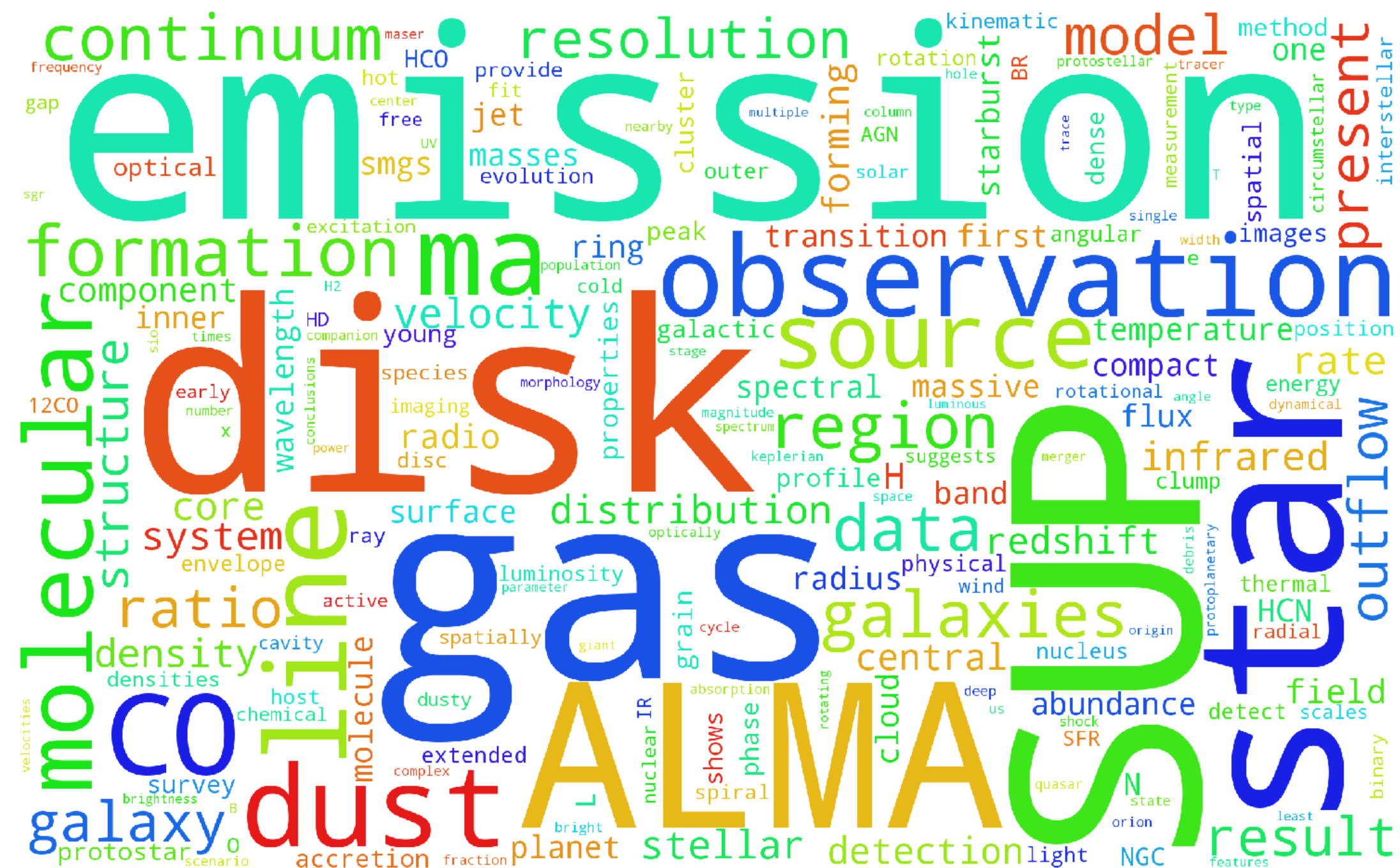
View:
☒ observation
☐ project
☐ publication
☐ public data only
☒ science observations only

ALMA Monthly Data Rates – Cycle 3 & Cycle 4

Terabytes



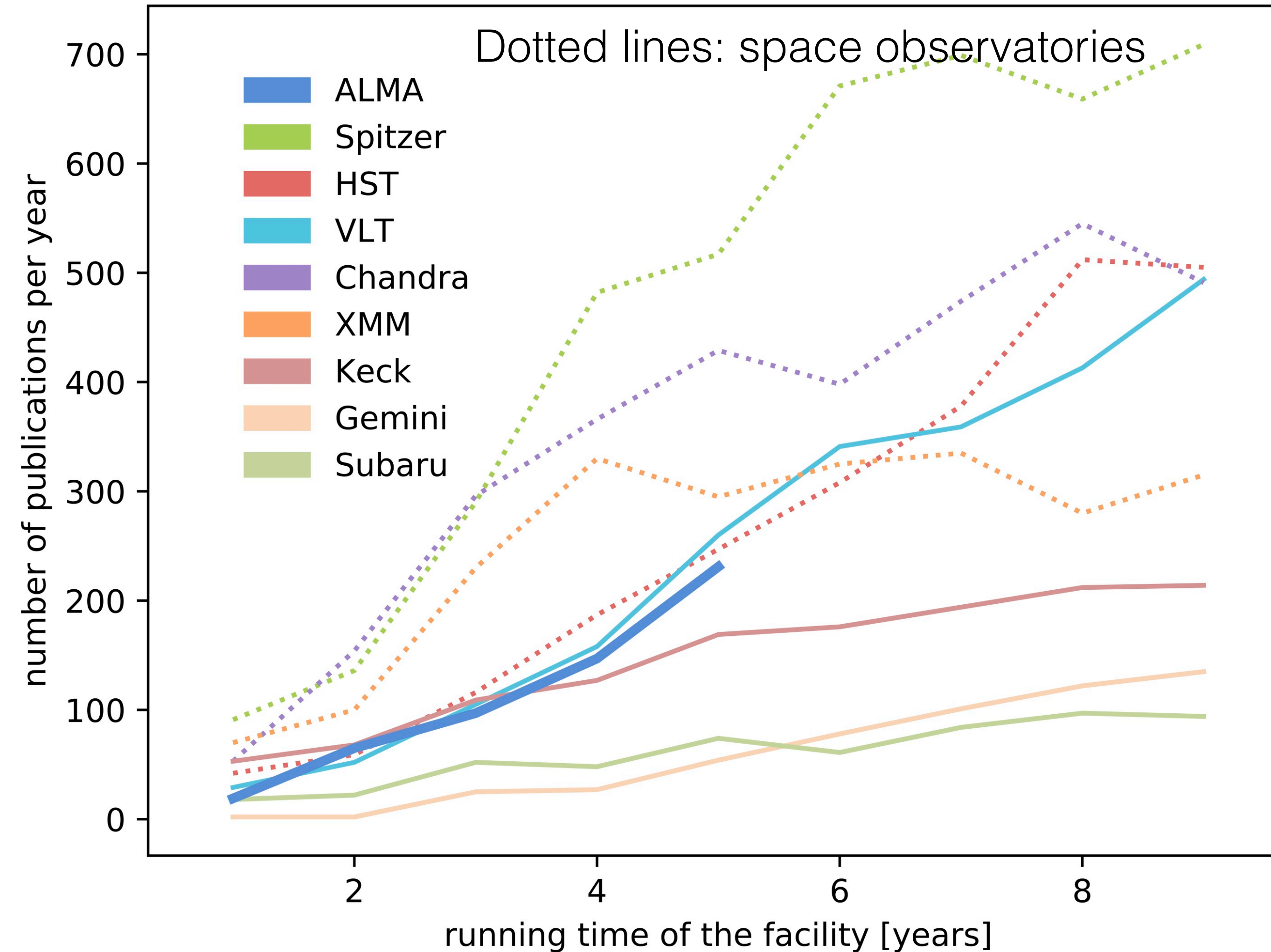
- 736 refereed publications
- 118 based only on SV data
 - 25 based on one SV dataset
- 13 based on DDT data
- 164 based on archival data only
- 16 based on the same PI dataset
- ~4% Nature/Science



ALMA Publications vs. other Observatories

Excellent publication performance so far

Comparison with other facilities



ALMA Development Program

- Already done: Band 5, fiber optics connection, phasing the array, etc.
- Band 1 in production: for Cycle 7 or 8
- Ongoing: Band 2, enhanced data access, software for data analysis, etc.
- Future: Correlator upgrade, second generation receivers, etc.
- ALMA - 2030 report produced by ASAC





Thank you!

The Atacama Large Millimeter/submillimeter Array (ALMA)

Lars-Åke Nyman, Head of Science Operations

On behalf of the ALMA partnership