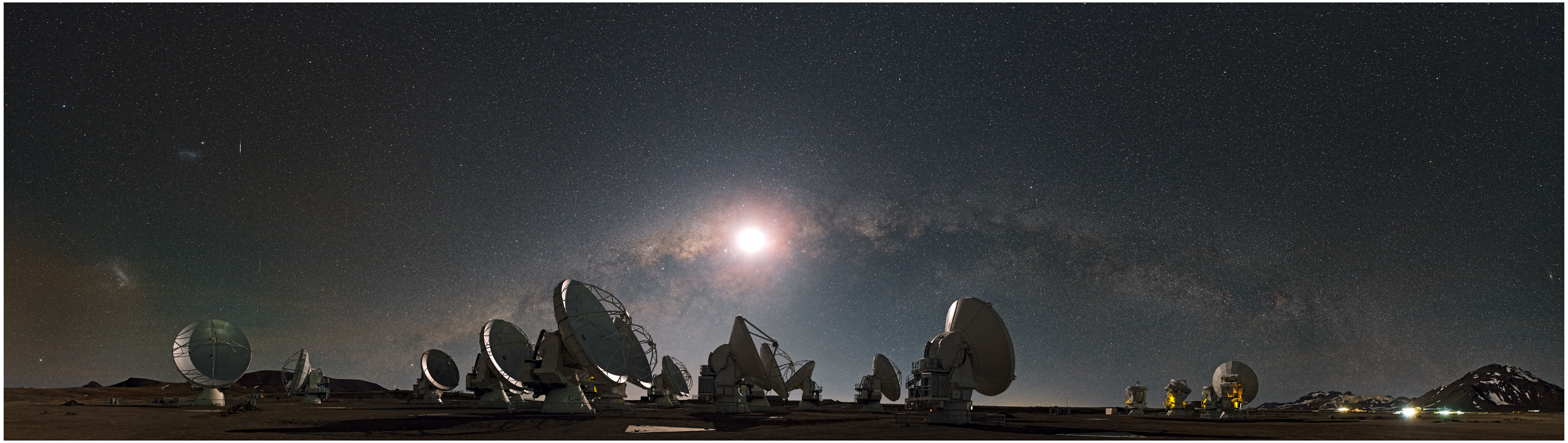
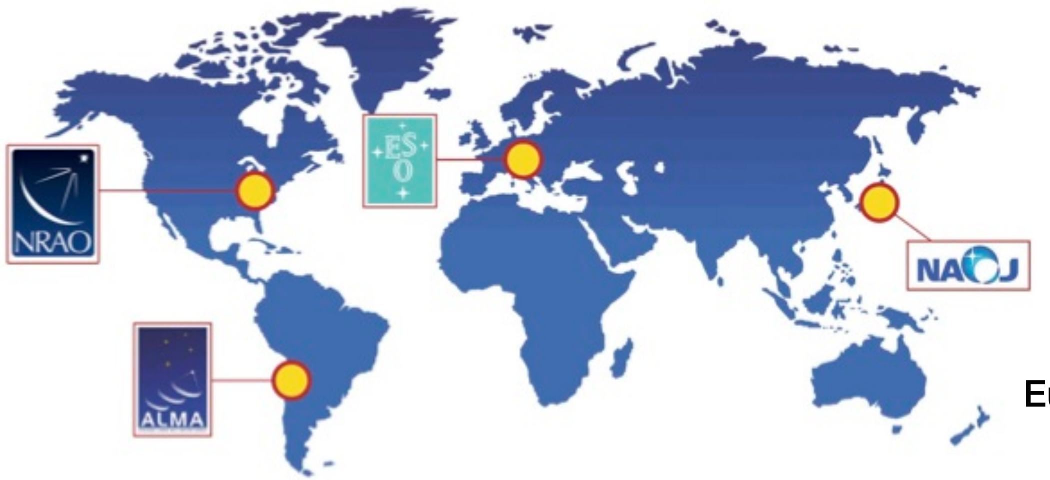
ALMA Early Science Cycle 4 Capabilities

Jan Brand – ALMA Regional Centre, Italian node



ORGANIZATIONAL STRUCTURE



Joint ALMA Observatory:

Europe (ESO): 33.75%
North America (NRAO): 33.75%
East Asia (NAOJ): 22.5%
Chile: 10%

In Europe:

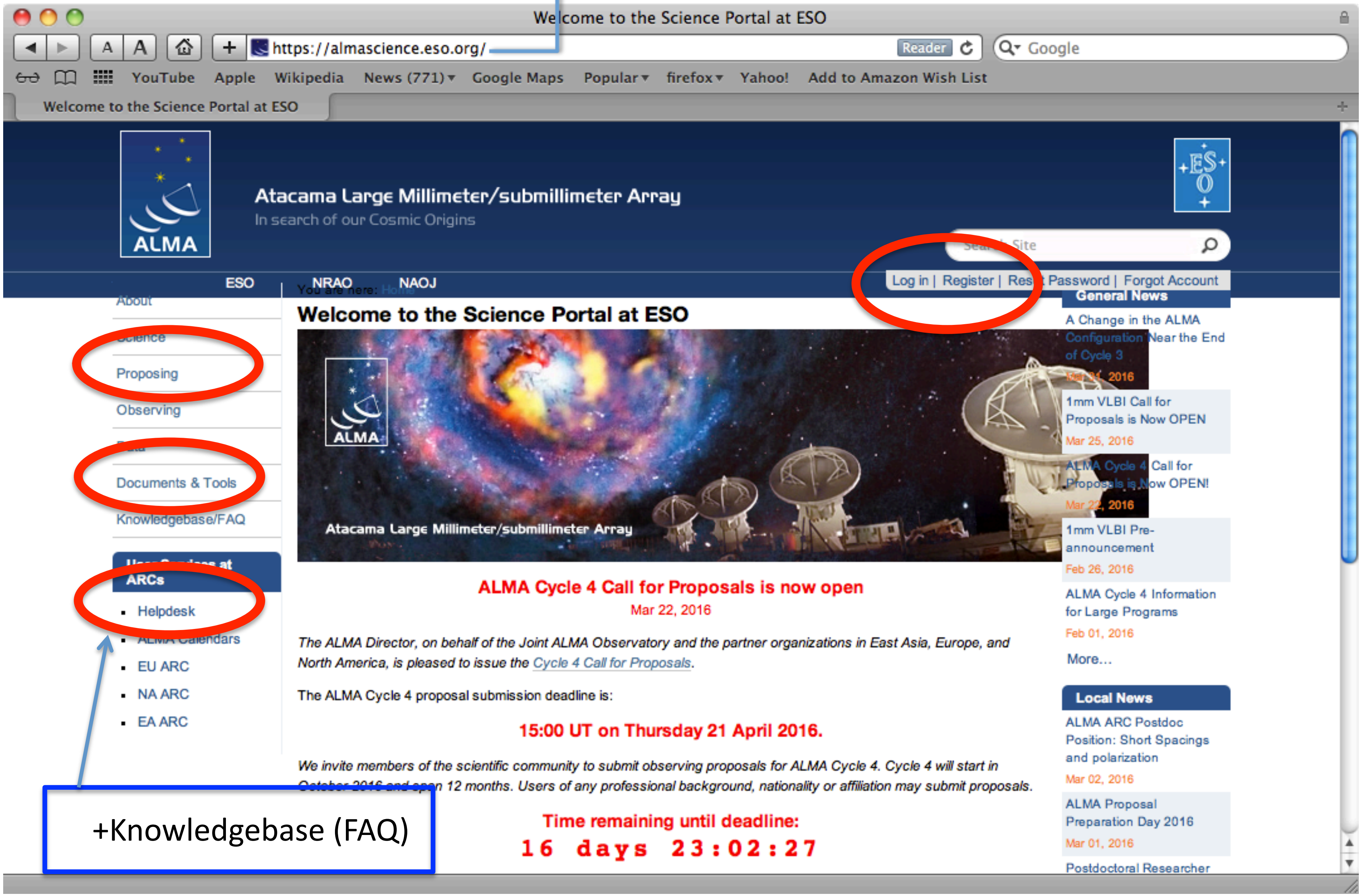
A network of 7 ARC-nodes and
1 Centre of Expertise, coordinated
by the central node at ESO.

European ARC nodes

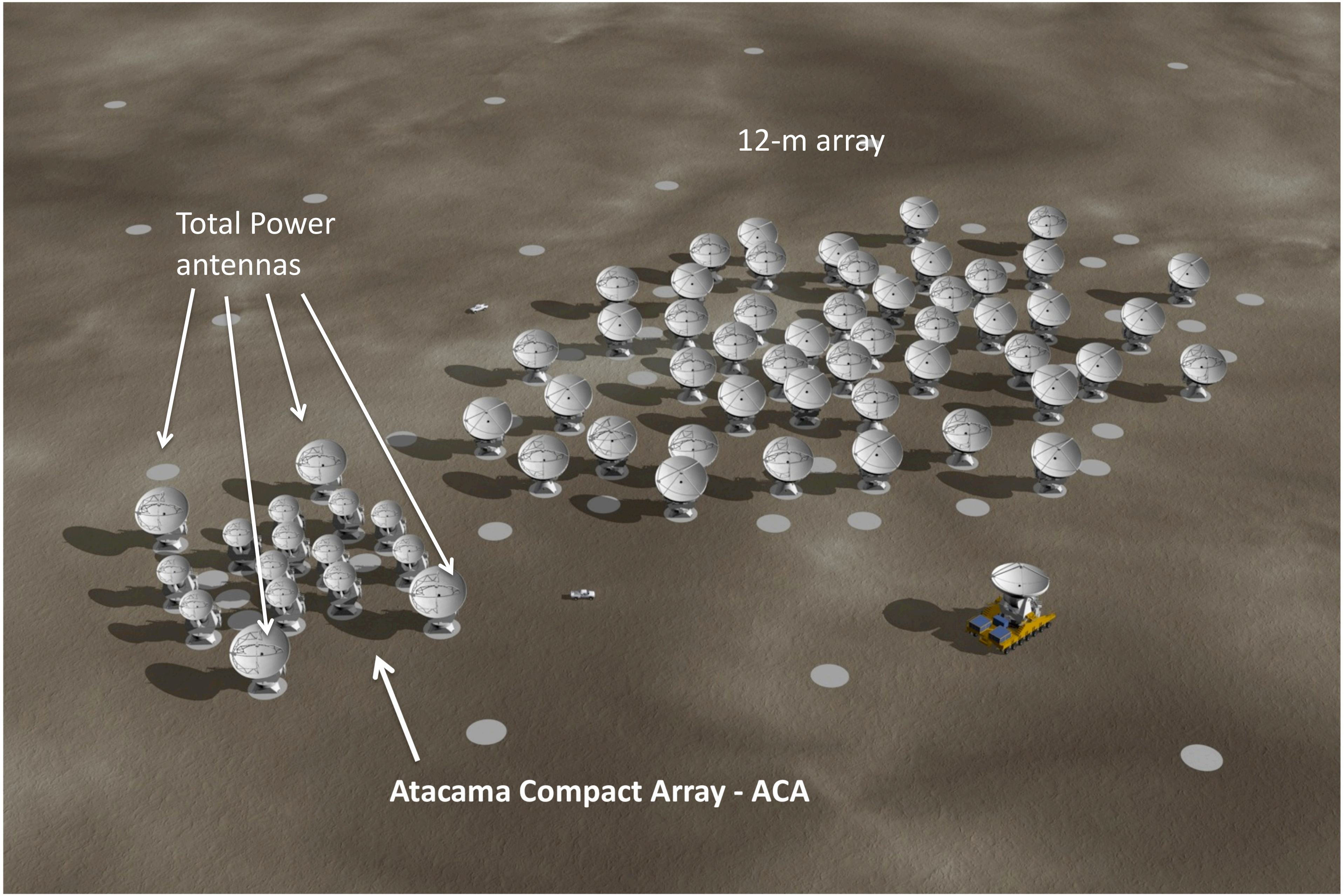
TIMELINE CYCLE 4

Date	Event
22 March 2016	Release Call for Proposals Cycle 4 + Documentation & Tools
21 April 2016 15:00 UT	**Proposal submission deadline**
(early?) August 2016	Announcement outcome review process
(mid-) September 2016	**Submission Phase2 material by PIs**
October 2016	Start observations Cycle 4
September 2017	End of Cycle 4

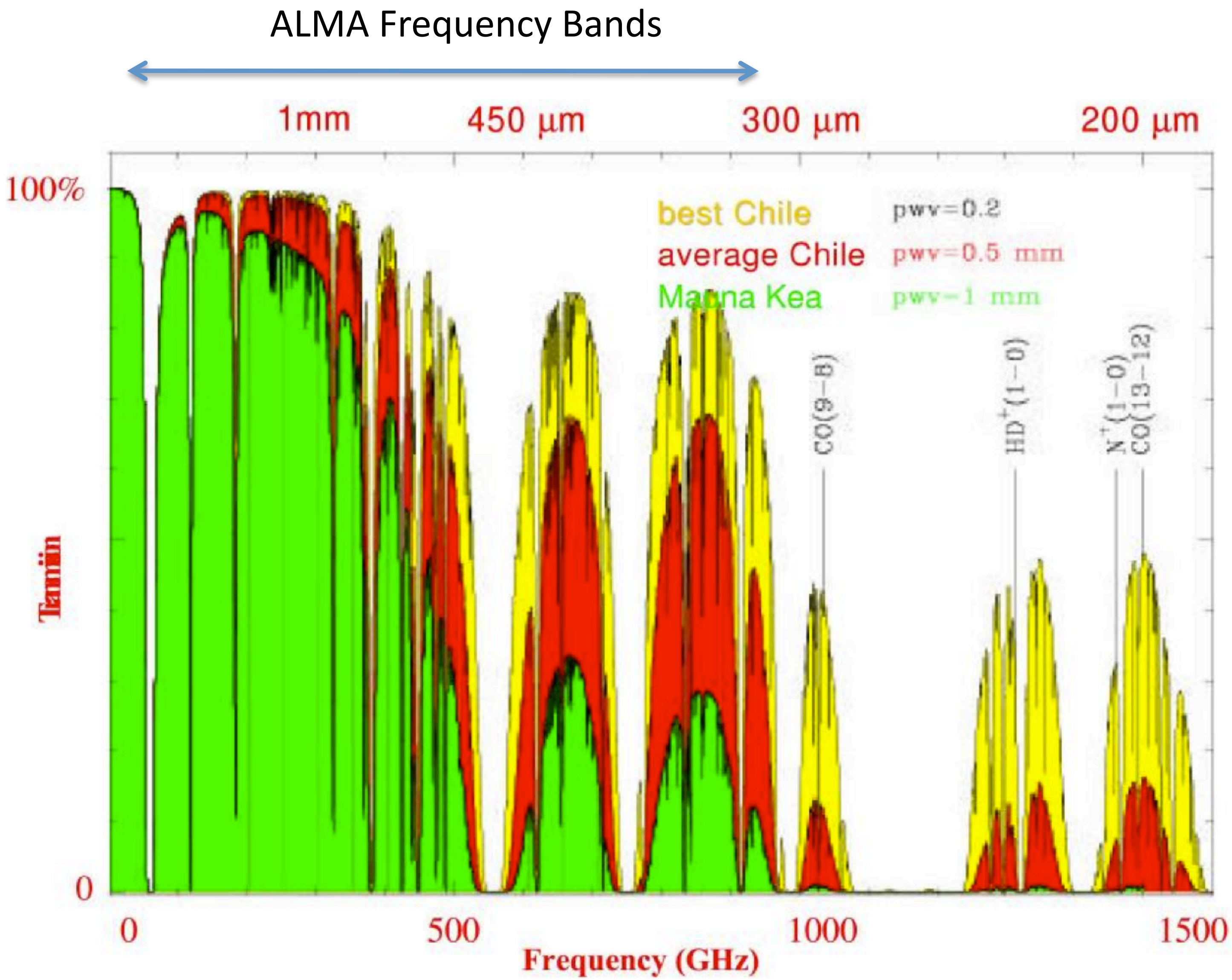
https://almascience.eso.org/



+Knowledgebase (FAQ)


12-m array
Total Power antennas
Atacama Compact Array - ACA

ATMOSPHERIC TRANSMISSION

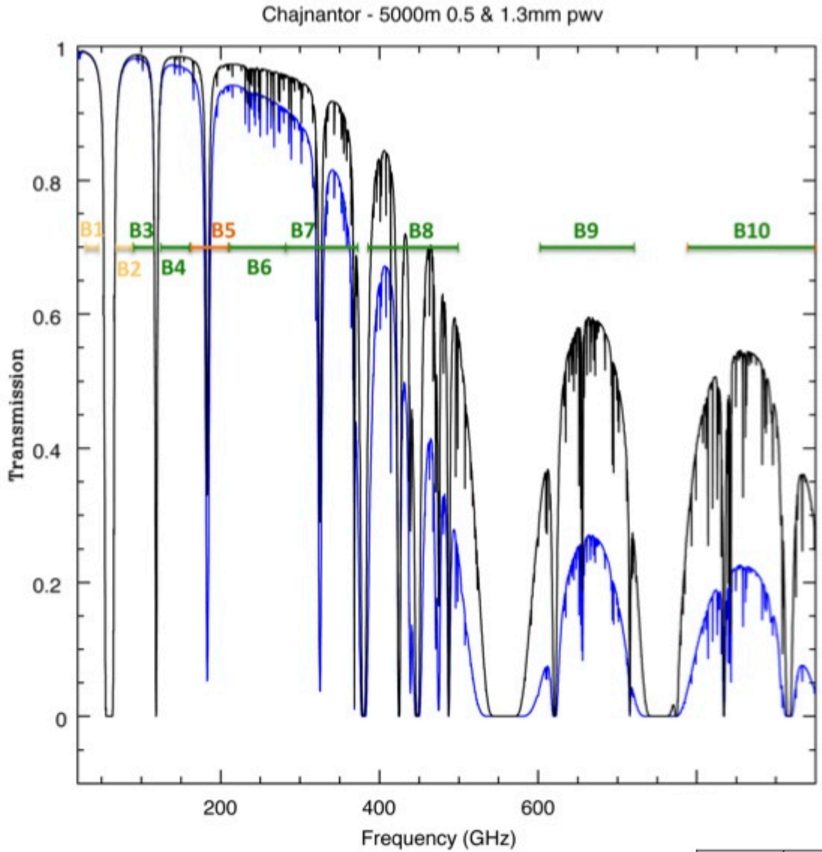


ALMA *Full Operations Specifications*

	Specification
Number of Antennas	*50×12 m (12-m Array), plus 12×7 m & 4×12 m (ACA)*
Maximum Baseline Lengths	*0.15 - 16 km*
Angular Resolution (")	*~0.2" × (300/ν GHz) × (1 km / max. baseline)*
12 m Primary beam (")	*~20.6" × (300/ν GHz)*
7 m Primary beam (")	*~35" × (300/ν GHz)*
Number of Baselines	*Up to 1225 (ALMA correlators can handle up to 64 antennas)*
Frequency Coverage	*All atmospheric windows from 84 GHz - 950 GHz (with possible extension to ~30 GHz)*
Correlator: Total Bandwidth	*16 GHz (2 polarizations × 4 basebands × 2 GHz/baseband)*
Correlator: Spectral Resolution	*As narrow as 0.008 × (300/ν GHz) km/s*
Polarimetry	*Full Stokes parameters*

Been ramping up to this since Cycle 0.
Not quite there yet… expected by Cycle 5

CYCLE 4 AVAILABLE RECEIVERS



Green: bands available in Cycle 4

Table A-3: Properties of ALMA Cycle 4 Receiver Bands

Band	Frequency range[1] (GHz)	Wavelength range (mm)	IF range (GHz)	Type
3	84 – 116	3.6 – 2.6	4 – 8	2SB
4	125 – 163	2.4 – 1.8	4 – 8	2SB
6	211 – 275	1.4 – 1.1	5 – 10	2SB
7	275 – 373	1.1 – 0.8	4 – 8	2SB
8	385 – 500	0.78 – 0.60	4 – 8	2SB
9	602 – 720	0.50 – 0.42	4 – 12	DSB
10	787 – 950	0.38 – 0.32	4 – 12	DSB

Cycle 4 capabilities

Science time 3000 hrs (12-m array) + 1800 hrs (ACA)
+ 150 hrs (12-m) + 90 hrs (ACA) for DDT-proposals
< 20% for non-standard programs; < 15% Large Programs; < 5% VLBI [all % wrt total time]

Antennas:	40 in 12-m array + 10 x 7-m + 3 x 12-m TP in ACA		
Receiver bands:	3, 4, 6	7	8, 9, 10
Wavelengths [mm]:	3.1, 2.1, 1.3	0.87	0.74, 0.44, 0.35
Max baselines [km]:	< 12.6	< 6.8	< 3.7

Polarization: Full Stokes in Bands 3, 6, 7; 12-m array. Single pointings, on axis.
Continuum and full spectral resolution observations.

Spectral line + continuum 12-m array + 7-m array in all bands
Single field interferometry: all bands, 12-m and 7-m arrays.
Mosaics: bands 3 - 9
Single-dish spectral line observations: Bands 3 – 8

Max. data rate 60 Mb/s; warning at 40 Mb/s (consider averaging channels)

NEW IN CYCLE 4: PROPOSAL TYPES AND OBSERVING MODES

- ✔ Large programs. Cannot be done as series of normal proposals;
  >50 hrs; <15% total time + scheduling constraints based on LST and configs.
  More pages allowed in proposal; require management plan

- ✔ mm-VLBI; Bands 3, 6; also submit to VLBI network (3mm to GMVA by 1/2/16; 1mm to EHTC by 28/4/16).
  <5% total time; fixed period (March/April 2017, compact config: $b_{max} < 500$m)

- ✔ ACA stand-alone observing mode (short baselines and single dish).
  No stand-alone TP-array

- ✔ Solar observing mode; Bands 3, 6. Only scheduled in certain periods (cf VLBI)

- ✔ Spectral line polarization; restricted to compact sources in Bands 3, 6, 7.
  Minimum 3 hrs (for calibration purposes)

Regular proposals. <50 hrs. Can be standard & non-standard (next slide)
Target of Opportunity (ToO)
Director's Discretionary Time (DDT) Can be submitted any time; special policies

Standard vs. non-standard observing modes

Standard modes: well-characterized and observations can be calibrated with the ALMA data reduction pipeline

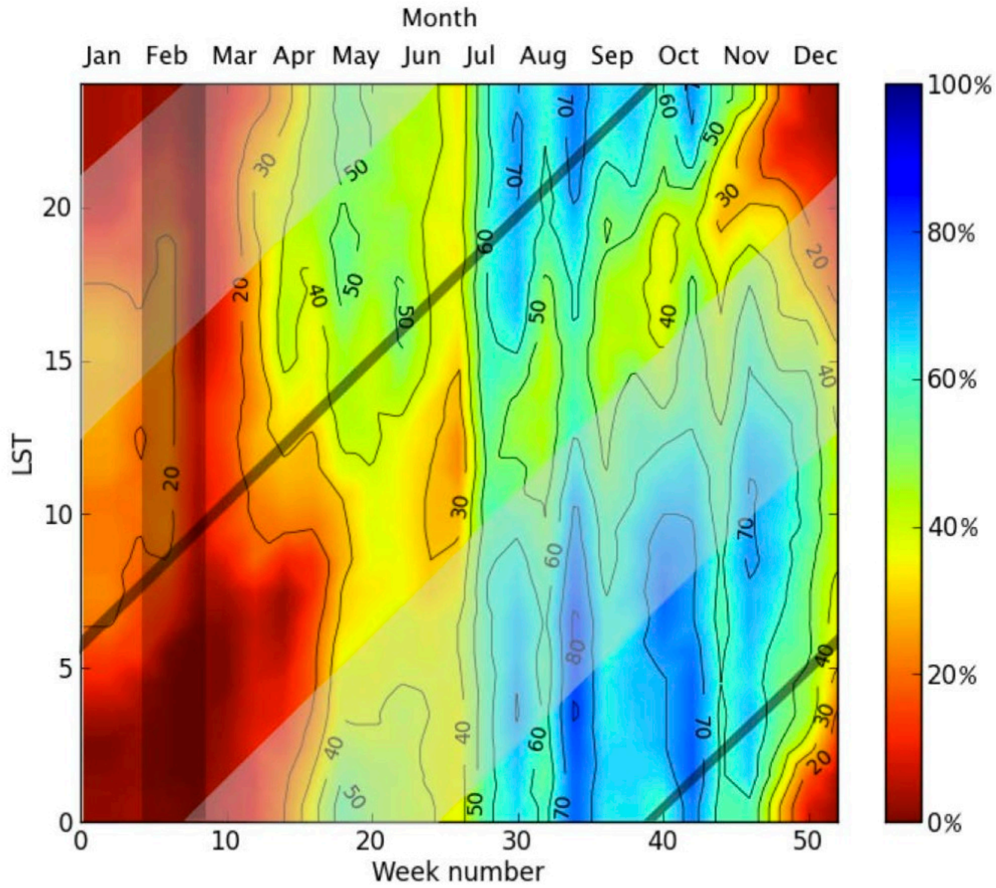
Non-standard modes: require manual calibration by ALMA staff

(and remember: non-standard only get up to 20% of total available time)

Cycle 4 non-standard observing modes include:

- Observations in bands 8, 9 ,10
- Observations in band 7 with baselines > 5km
- All polarization observations
- Spectral scans
- Solar observations
- VLBI observations
- Non-standard (= user-defined) calibrations
- Bandwidth-switching projects

% of time pwv < 1mm



Limitations to ALMA use due to opacity (PWV) and atmospheric phase stability, especially in higher-freq. bands and freqs. near water abs. lines.

Yearly- and diurnal cycle. Best times are late southern winter and late night and early morning.

Proposers do not need to anticipate weather conditions when writing proposals.

Fraction of time expected to be useful for obs's in each band.

Table 2: Estimated maximum fraction of observing time suitable for observations in each band in Cycle 4

ALMA Band	Band 3	Band 4	Band 6	Band 7	Band 8	Band 9	Band 10
Fraction of time	100%	90%	70%	40%	20%	10%	10%

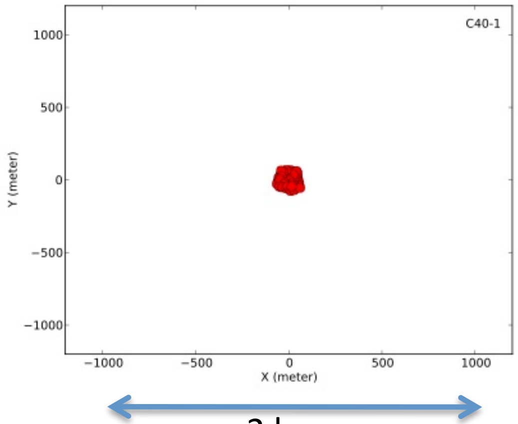
Notes for Table 2:

1. Times exclude total weather shutdowns.
2. These estimates are based on 1998-2011 atmospheric transmission statistics from the ALMA Site Characterization and Monitoring program and APEX radiometer in combination with the ALMA Cycle 0 experience from October 2011 to March 2012.

ARRAY CONFIGURATIONS

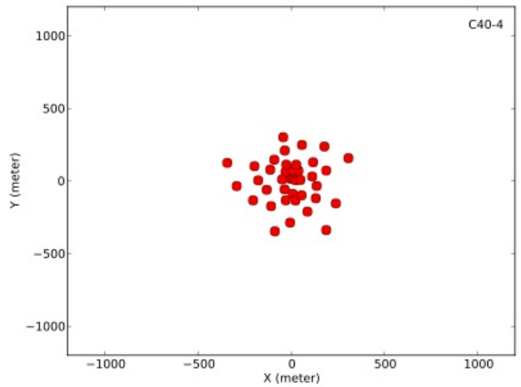
There will be ca. 13 reconfigurations during Cycle4 at the end of which the array is expected to have imaging properties similar to one of the nine representative configurations used to characterize the advertised imaging capabilities and to estimate the observing times.

C40-1

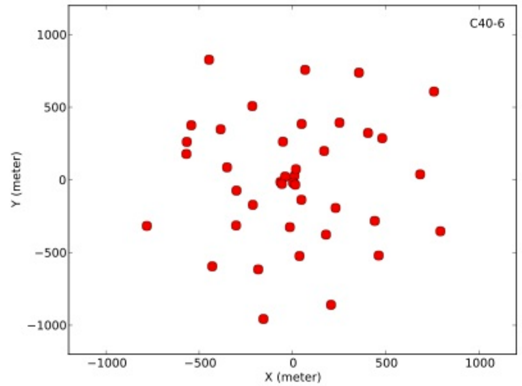


2 km

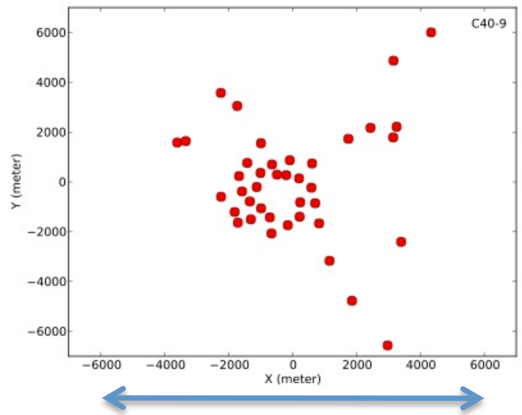
C40-4



C40-6



New configuration every 2-3 weeks.



C40-9

12 km

ARRAY CONFIGURATIONS CALENDAR

Table 3: Planned 12-m Array Configuration Schedule for Cycle 4

(1) Planned Start Date	(2) Configuration (planned campaigns)	(3) Longest baseline	(4) LST with best observing conditions	(5) LST with unstable observing conditions	(6) PI Observing Time (days)
14 October 2016	C40-7	3.7 km	~22h - 11h	~11h-22h	13
4 November 2016	C40-6	1.8 km	~23h - 12h	~12h-23h	11
25 November 2016	C40-5	1.1 km	~1h - 13h	~13h-1h	7
9 December 2016	C40-4	0.70 km	~2h - 14h	~14h-2h	7
23 December 2016	C40-3 (Solar)	0.46 km	~3h - 15h	~15h-3h	11
19 January 2017	C40-2 (Solar)	0.27 km	~4h - 17h	~17h-4h	9
1 February 2017	*February maintenance period*				
16 March 2017	C40-1 (Solar/VLBI)	0.15 km	~8h - 22h	22h-8h	17
6 April 2017	C40-3 (Solar/VLBI)	0.46 km	~9h - 23h	~23h-9h	11
27 April 2017	C40-5	1.1 km	~10h - 1h	~1h-10h	7
11 May 2017	*Move to configuration C40-9*				
8 June 2017	C40-9	12.6 km	~12h - 3h	~3h-12h	16
6 July 2017	C40-8	6.8 km	~14h - 5h	~5h-14h	22
17 August 2017	C40-7	3.7 km	~17h - 8h	~8h-17h	23

Notes for Table 3:

1. Dates include relocation time at the end of every configuration.
2. Configuration properties are given in Section A.2. Dates are subject to change – see text.

Restrictions:

1. Band 9, 10 obs's not scheduled in LST-ranges in column 5.
   Band 7, 8 may be, but not recommended;
2. Bands 7, 8, 9, 10 not recommended around Altiplanic winter (esp. Dec-Feb) at any LST;
3. Projects that have imaging (config) requirements and time constraints that do not coincide cannot be scheduled.

PROPOSAL GRADING

Accepted projects are grades based on science rank, executive balance, scheduling feasibility:

Grade A (up to 33%)   B (up to 67%) to fill up the nominal amount of available science time

Grade C: up to an additional 50% of the total available time to ensure availability of adequate number of projects for all configs and LST in case actual obs efficiency or weather cond's differ from expectations.

Only grade A are eligible to be rolled over to Cycle 5, if necessary

Restrictions:

1. VLBI props cannot get grade A or C;
2. LPs must get A to be scheduled
3. Proposals needing band 7 daytime obs's unlikely to get grade C
4. Non-standard proposals not eligible to receive grade C
   i.e. projects for bands 8, 9, 10 cannot be fillers.

OBSERVING PRESSURE

Strong frequency and LST dependence of observing pressure => proposals for lower freq bands (bands 3-6) and in less-subscribed LST ranges "will have better chance of getting C-grade" [as supposed to being rejected, I assume!]

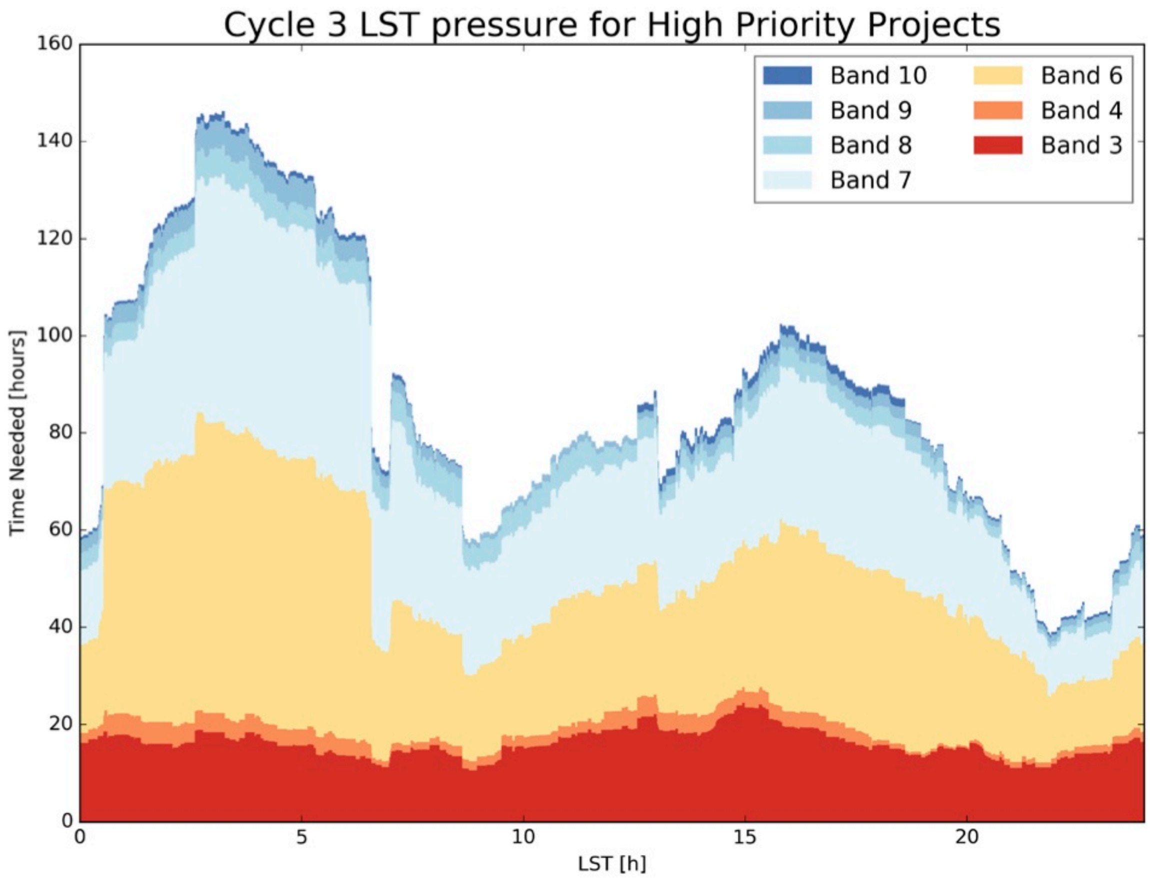


Figure 2: Distribution of 12-m Array time for the Cycle 3 grade A and B proposals as a function of LST and color-coded by observing band.

Lower pressure for LST 7-9 and 22-1 hrs

Table A-1: Angular Resolutions (AR) and Maximum Recoverable Scales (MRS) for the Cycle 4 Array configurations

Config	Lmax / Lmin	Band / Freq	Band 3 100 GHz	Band 4 150 GHz	Band 6 230 GHz	Band 7 345 GHz	Band 8 460 GHz	Band 9 650 GHz	Band 10 870 GHz
7-m Array	45 m	AR	12.5"	8.4"	5.4"	3.6"	**2.7"**	**1.9"**	**1.4"**
	9 m	MRS	66.7"	44.5"	29.0"	19.3"	**14.5"**	**10.3"**	**7.7"**
C40-1	155 m	AR	3.7"	2.5"	1.6"	1.1"	**0.80"**	**0.57"**	**0.42"**
	15 m	MRS	29.0"	19.4"	12.6"	8.4"	**6.3"**	**4.5"**	**3.3"**
C40-2	273 m	AR	2.4"	1.6"	1.0"	0.69"	**0.52"**	**0.37"**	**0.27"**
	15 m	MRS	22.1"	14.8"	9.6"	6.4"	**4.8"**	**3.4"**	**2.5"**
C40-3	460 m	AR	1.5"	0.97"	0.63"	0.42"	**0.32"**	**0.22"**	**0.17"**
	15 m	MRS	13.7"	9.1"	5.9"	4.0"	**3.0"**	**2.1"**	**1.6"**
C40-4	704 m	AR	0.93"	0.62"	0.40"	0.27"	**0.20"**	**0.14"**	**0.11"**
	15 m	MRS	8.9"	5.9"	3.9"	2.6"	**1.9"**	**1.4"**	**1.0"**
C40-5	1.1 km	AR	0.54"	0.36"	0.23"	0.16"	**0.12"**	**0.083"**	**0.062"**
	17 m	MRS	6.0"	4.0"	2.6"	1.7"	**1.3"**	**0.93"**	**0.69"**
C40-6	1.8 km	AR	0.35"	0.23"	0.15"	0.10"	**0.076"**	**0.054"**	**0.040"**
	15 m	MRS	3.1"	2.1"	1.3"	0.90"	**0.67"**	**0.48"**	**0.36"**
C40-7	3.7 km	AR	0.21"	0.14"	0.090"	0.060"	**0.045"**	**0.032"**	**0.024"**
	81 m	MRS	1.8"	1.2"	0.77"	0.52"	**0.39"**	**0.27"**	**0.20"**
C40-8	6.8 km	AR	0.12"	0.079"	0.052"	**0.034"**	N/A	N/A	N/A
	168 m	MRS	1.3"	0.87"	0.57"	**0.38"**			
C40-9	12.6 km	AR	0.066"	0.044"	0.029"	N/A	N/A	N/A	N/A
	271 m	MRS	0.78"	0.52"	0.34"				

Notes for Table A-1:

3. See Chapter 7 of the Technical Handbook for relevant equations and detailed considerations.
4. Values evaluated for source at zenith. For sources transiting at lower elevations, the North-South angular measures will increase proportional to 1/sin(ELEVATION).
5. Lmax and Lmin are the maximum and minimum baseline lengths in the array.
6. All angular measures scale inversely with observed sky frequency.
7. Bold blue text indicates non-standard modes (Section 5.2)

Resolution (arcsec):
$0.2 \times (300\text{GHz}/f)\ (1\text{km}/b_{max})$

MRS (arcsec):
$124 \times (1\text{m}/b_{min})\ (300\text{GHz}/f)$

FOV (arcsec):
$20.6 \times (300\text{GHz}/f)$

Blue: non-standard

MRS and Angular resolution

MRS = Maximum Recoverable Scale

Resolution (arcsec): 0.2 x (300GHz/f) (1km/b_{max})

MRS (arcsec): 124 x (1m/b_{min}) (300GHz/f)

FOV (arcsec): 20.6 x (300GHz/f)

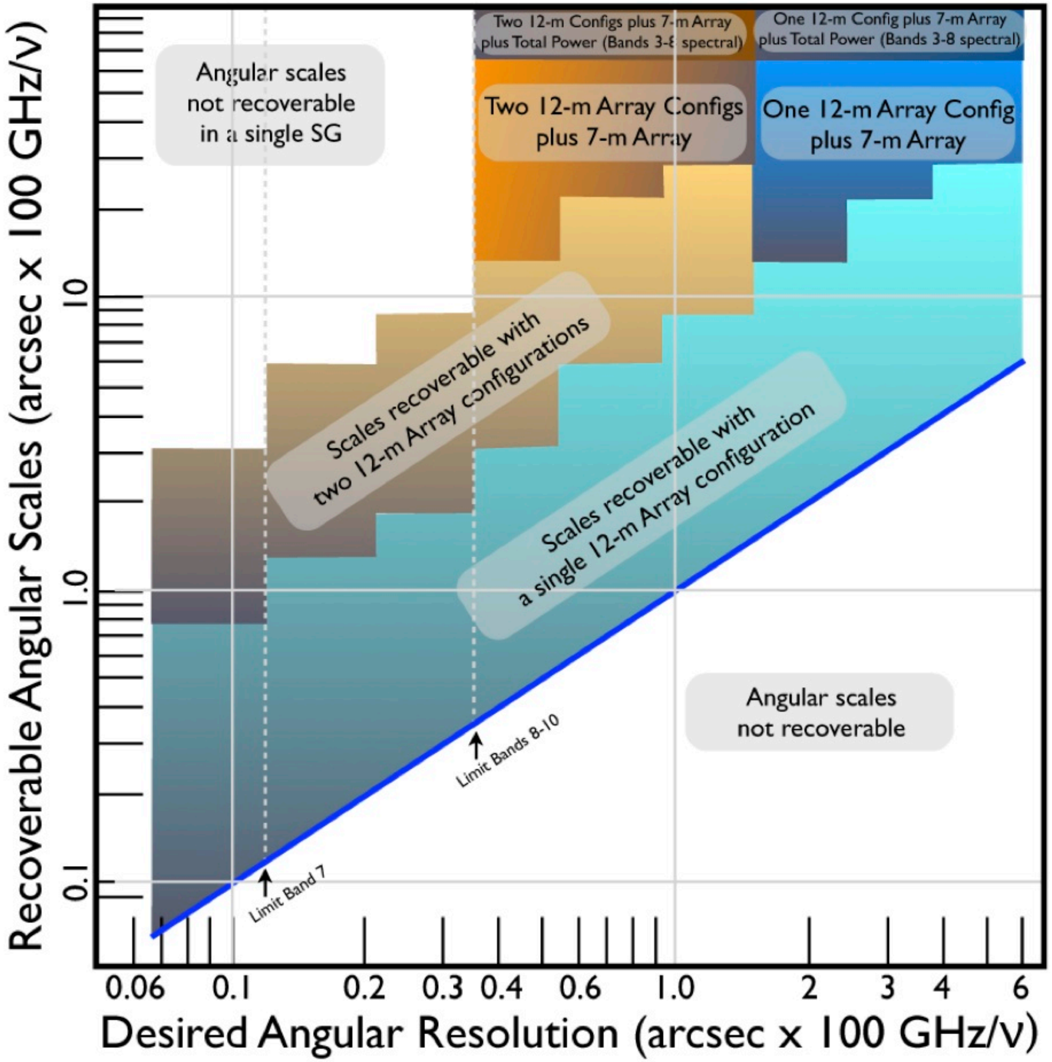
MRS is a "guideline for the largest angular structure on which some of the flux of a smooth structure can be reasonably recovered by the interferometer." (Cycle4 primer)

i.e. anything much larger will (start to) be 'resolved out': the **missing flux** problem, intrinsic to interferometers.

To recover this emission, additional observations needed, including observations with More compact configurations (with the 12-m array, the 7-m array, or single-dish [TP])

Only certain combinations of arrays are allowed – see next slides

MRS and Angular resolution



Useful figure to help you find whether more than one 12-m array configuration or a combination of arrays is needed to accommodate the MRS and angular resolution required by your project.

Allowed array combinations and time multipliers

Table A-2: Allowed Array Combinations and Time Multipliers

Most Extended configuration	Allowed Compact configuration pairings	Extended 12-m Array Multiplier	Multipler if compact 12-m Array needed	Multipler if 7-m Array needed	Multipler if TP Array needed and allowed
7-m Array	TP			1	1.7
C40-1	7-m Array & TP	1		5	8.5
C40-2	7-m Array & TP	1		5	8.5
C40-3	7-m Array & TP	1		1.4	2.38
C40-4	C40-1 & 7-m Array & TP	1	0.3	3	5.1
C40-5	C40-2 & 7-m Array & TP	1	0.3	1.4	2.38
C40-6	C40-3 & 7-m Array & TP	1	0.3	0.4	0.68
C40-7	C40-4	1	0.3		
C40-8	C40-5	1	0.3		
C40-9	C40-6	1	0.3		

Notes for Table A-2:

1. See Chapter 7 of the Technical Handbook for relevant equations and detailed considerations.
2. Whether a more compact array configuration is "needed" is based on the user specified LAS compared to the MRS values corresponding to the more extended configuration, as listed in Table A-1. If the LAS is greater than the MRS of the extended configuration, a more compact configuration is needed. Conversely, if a more compact array configuration is not allowed (e.g. for 12-m Array configurations more extended than C40-6), the LAS is not obtainable and will result in a validation error in the OT.

Combining arrays can be very time consuming so choose wisely.

Spectral setup: sidebands, basebands & spectral windows

Observed sky frequencies need to be down-converted before being sent to the correlator.

For this to occur, the signal from the source is mixed with that of a (set of) Local Oscillator(s) which results in the creation of 2 sidebands, 'upper' and 'lower':

For the lower sideband (LSB): (F_{LO1} - IF_{lo}) to (F_{LO1} - IF_{hi})
For the upper sideband (USB): (F_{LO1} + IF_{lo}) to (F_{LO1} + If_{hi})

NB: for both polarizations!

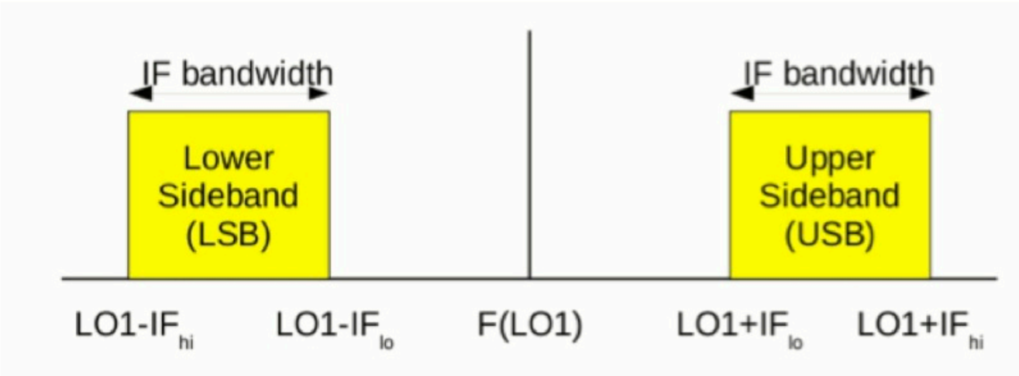


Figure 4.2: IF ranges for the two sidebands in a heterodyne receiver.

Spectral setup: sidebands, basebands & spectral windows

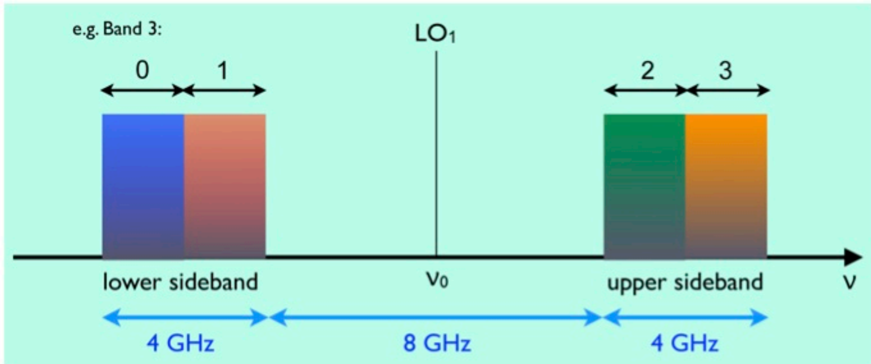


Figure 31: *A graphical view of basebands and sidebands. Basebands may be tuned to overlap if the user wishes, or may be located so as to maximize the total bandwidth (as shown). Each baseband may be further subdivided into as many as 8 spectral windows. Up to four spectral windows per baseband will be available during Cycle 4.*

Within these sidebands, ALMA produces 4 x 2 GHz basebands that can be placed inside each sideband.

NB: basebands are not independent: overlapping BBs do not reduce noise

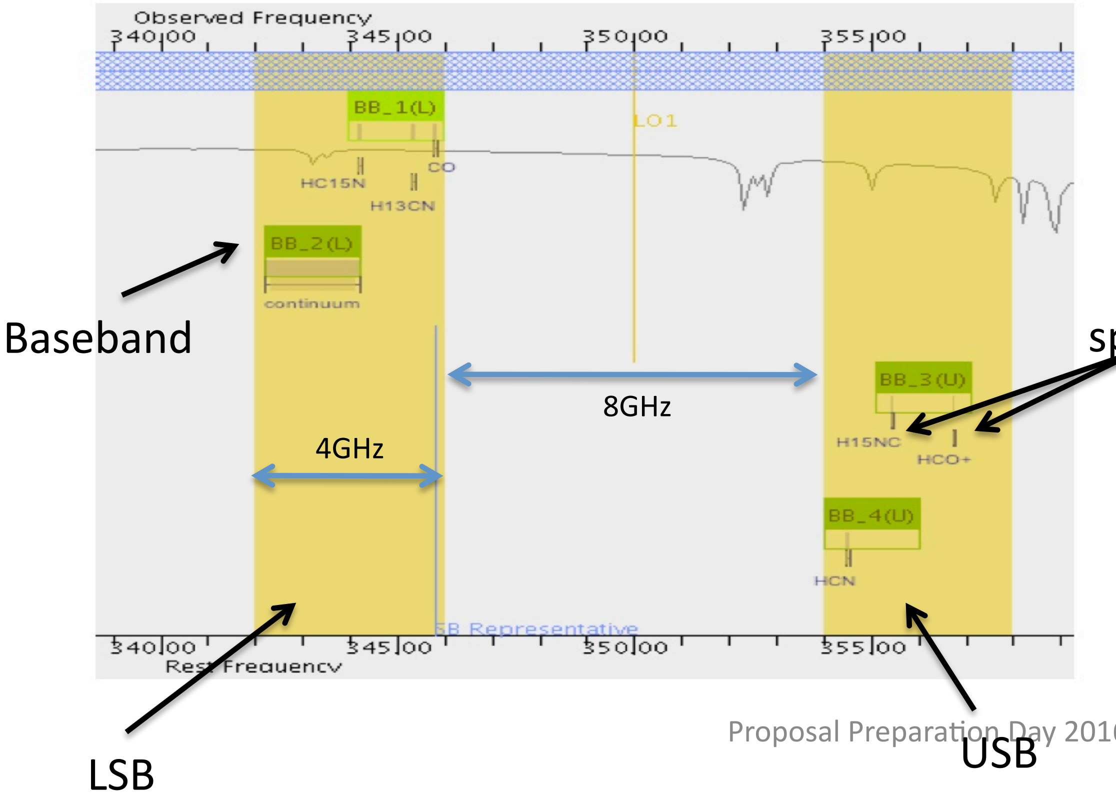
Spectral setup: sidebands, basebands & spectral windows

Table A-4: Properties of ALMA Cycle 4 Correlator Modes, dual-polarization operation [1,2]

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

Continuum (BW_{tot} = 7.5GHz)

Spectral lines



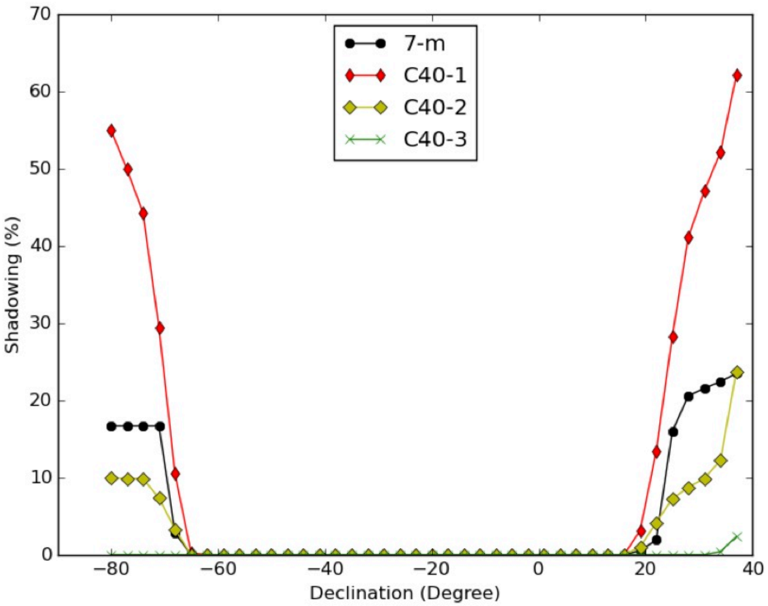
Resolution = 2x channel spacing because of default Hanning smoothing.
Full Stokes => half the channels.
Single pol (instead of Dual): double the channels.

Within each baseband up to 4 spectral windows can be placed to observe lines. All spectral windows within a baseband must have the same resolution.

Science goals, number of sources, tunings, shadowing

Science Goals (SG): one set of parameters that apply to all targets in a SG
In Cycle 4 there is no restriction on number of sources in SG. Widely distributed sources will be split by OT into 'clusters' of targets within 10^o . For each 'cluster' maximum number of pointings is 150. And furthermore:

- > All sources in SG defined by same field setup (i.e. all rect. field or all indiv. positions)
- > Sources must have same spectral setup (rel. placement & properties of spw's)
- > Each source can be observed with up to 5 tunings. Max 150 separate tunings => for 5 tunings for each target, the max number of targets is 30.



Smøgen 2015 – Cycle 4 Capabilities and the OT

(More in Kazi's talk)

Shadowing (see fig) effectively restricts DEC of targets to between -75^o and +25^o for 12-m array in most compact configuration, and between -60^o and +20^o for the 7-m array.

For sources at low elevations also uv-coverage becomes problem.

PROPOSAL STATISTICS PREVIOUS CYCLES

	Cycle 0 Sep. 2011 - Jan. 2013	Cycle 1 Jan. 2013 - May. 2014	Cycle 2 Jun. 2014 - Oct. 2015	Cycle 3 Oct 2015- Oct 2016
Telescope				
Hours dedicated to Science	**800**	**800**	**2000**	2100
Antennas	**> 12x12-m**	**> 32x12m +9x7m+2TP**	**> 34x12m +9x7m+2TP**	**> 36x12m +10x7m+2TP**
Receiver bands	3, 6, 7, 9	3, 6, 7, 9	**+4, 8**	**+10**
Wavelengths [mm]	3, 1.3, 0.8, 0.45	3, 1.3, 0.8 0.45	+2, 0.7	
Baselines	up to 400 m	**up to 1000 m**	**up to 1500m**	**up to 10km**
Polarisation	single dual	single dual	**full**	**full**
Proposal outcome				
Submitted	917	1133	1381	1578
Highest priority	112	198	354	402
Filler	51	93	159	236
Success rate	12% (18%)	17% (25%)	26% (37%)	25% (40%)
Pressure factor global	**8.2**	**5.8**	**3.9**	**3.9**
Pressure factor Europe	**12.3**	**9.1**	**4.9**	**6.2**

…AND FOR THOSE WHO SUCCEED, ANOTHER NOVELTY AWAITS:

As of Cycle 4
the PI has to prepare the scheduling blocks!

Should be relatively simple, and manual + video tutorial will be available

AND

PI can always ask assistance from the Contact Scientist (=us at the ARC)

BUT

Outcome of proposal reviews made known early August, and SBs have to be submitted by mid-September. ARCs are understaffed during vacation- and conference season so **DO NOT WAIT UNTIL THE LAST MOMENT WITH SB PREPARATION** just in case problems arise and help is needed.

USEFUL LINKS

Italian ALMA Regional Centre @ INAF-IRA Bologna
http://www.alma.inaf.it/index.php/Italian_ALMA_Regional_Centre

Science Portal: https://almascience.eso.org/

Proposer's Guide
https://almascience.eso.org/proposing/proposers-guide

ALMA Primer
https://almascience.eso.org/proposing/early-science-primer

Observing Tool
https://almascience.eso.org/proposing/observing-tool

Technical Handbook
https://almascience.eso.org/proposing/technical-handbook

Knowledgebase/FAQ
https://help.almascience.org/index.php?/default/Knowledgebase/List
Helpdesk: https://help.almascience.org/

CHECK THE ARCHIVE BEFORE WRITING THE PROPOSAL