ALMA: Atacama Large Mm/submm Array

Overview For Early Science Cycle 0

NRAO / North American ALMA Science Center

Atacama Large Millimeter/submillimeter Array

Expanded Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array

Associated Universities, Inc.

NSF

NRC·CNRC Canada

NRAO

The take-away message in one slide

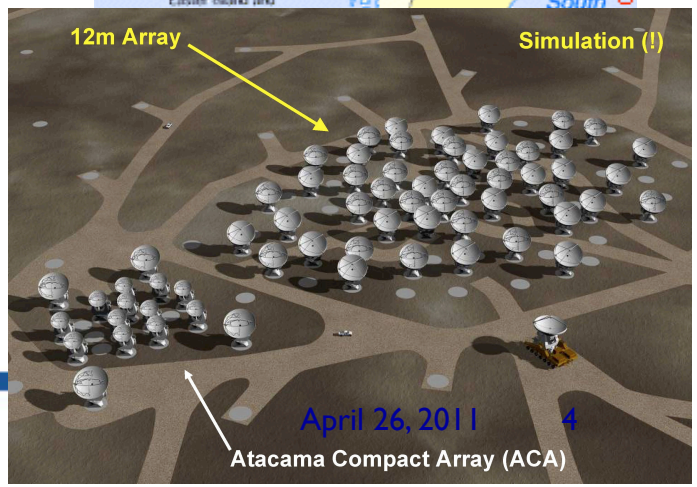
- Proposals for ALMA Cycle 0 are due June 30
  - All the information you need is at the ALMA Science Portal at **https://almascience.nrao.edu**
- For help, contact the NAASC at NRAO using the Helpdesk link on the Science Portal
- Spend some time well in advance of the deadline to become familiar with the OT.

Talk Outline

- **ALMA Overview**
- ALMA Status & Test Data
- Early Science ("Cycle 0") Capabilities & Considerations
- Proposal Logistics
- Support from the NAASC

ALMA Overview

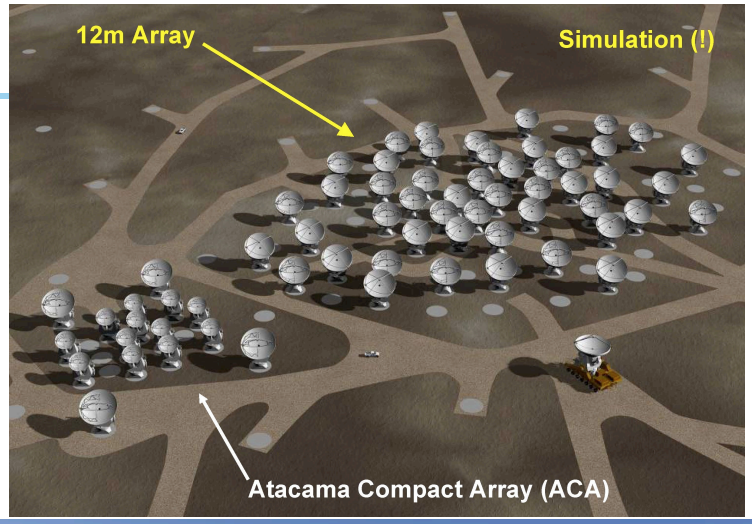
- A global partnership to deliver a transformational millimeter/submillimeter interferometer
  - North America (US, Canada, Taiwan)
  - Europe (ESO)
  - East Asia (Japan, Taiwan)
  - In collaboration with Chile
- 5000m (16,500 Ft) site in Chilean Atacama desert
- Main Array: 50 x 12m antennas
  - + Total Power Array 4 x 12m
  - + Atacama Compact Array (ACA): smaller array of 12 x 7m antennas
- Total shared cost ~1.3 Billion ($US2006)

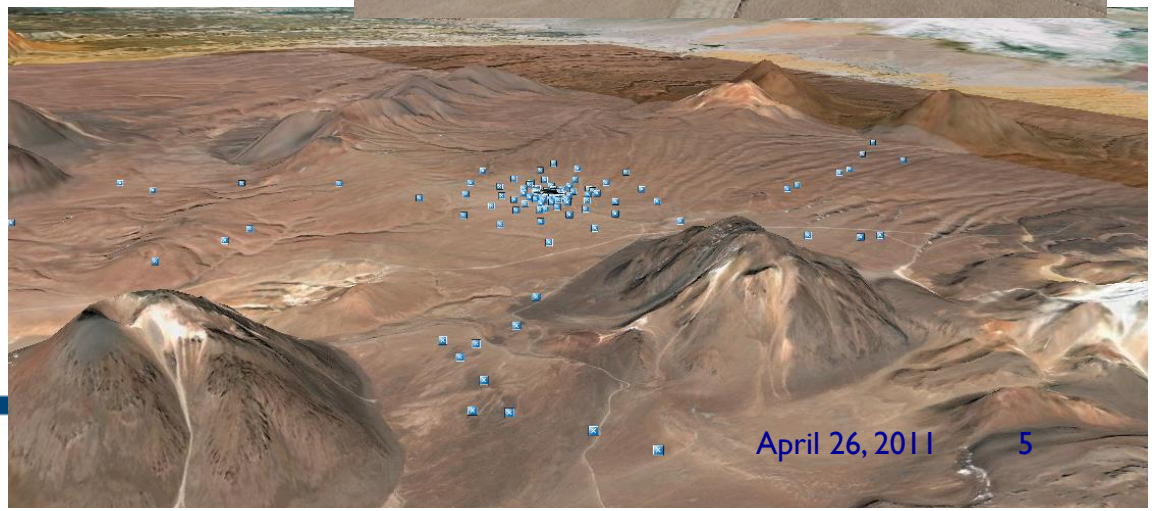


ALMA Overview

- Baselines up to 15 km (0.015" at 300 GHz) in "zoom lens" configurations
- Sensitive, precision imaging 84 to 950 GHz (3 mm to 315 μm)
- State-of-the-Art low-noise, wide-band SIS receivers (8 GHz bandwidth)
- Flexible correlator with high spectral resolution at wide bandwidth
- Full polarization capabilities
- Estimate 1 TB/day archived

- A resource for ALL astronomers





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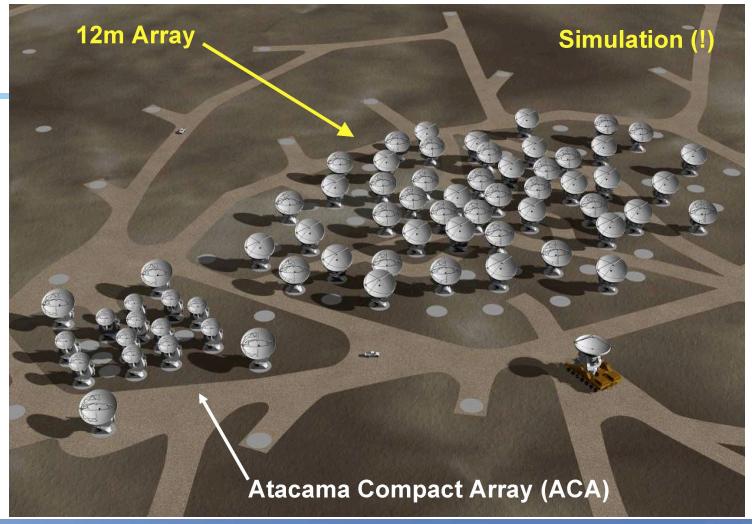
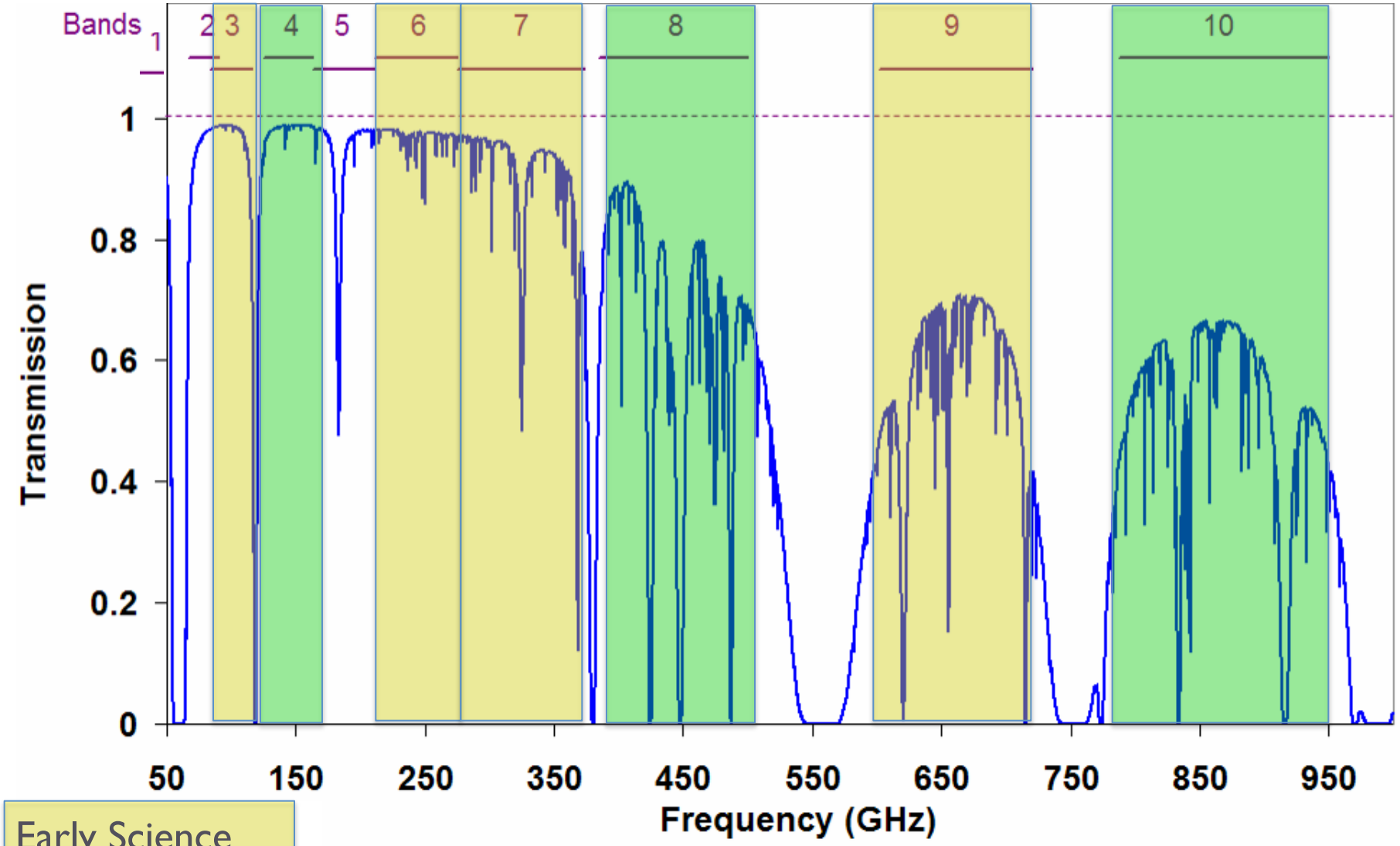


ALMA will be 10-100 times more sensitive and have 10-100 times better angular resolution compared to current millimeter interferometers

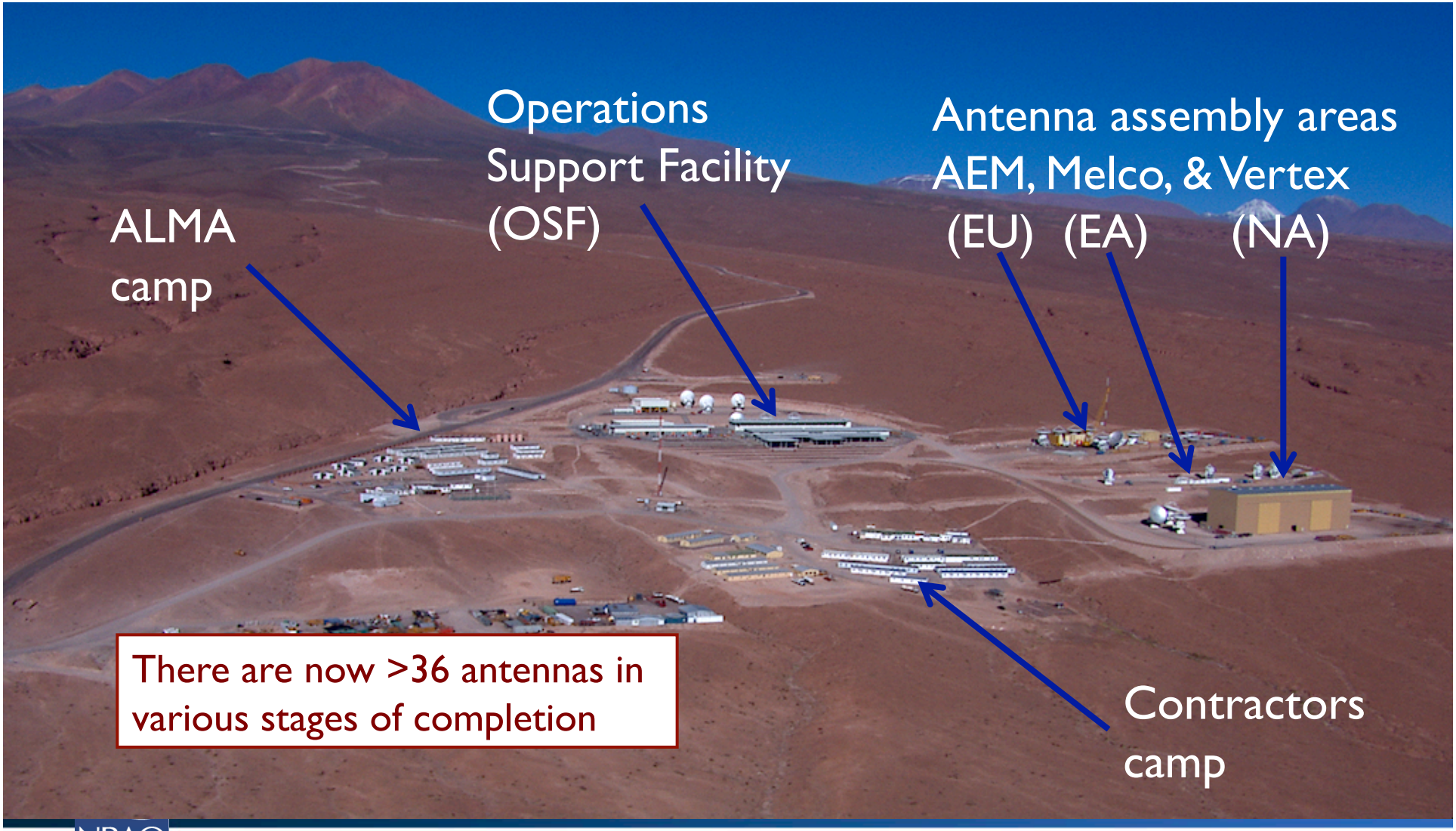
ALMA Receiver Bands



Early Science

Full Operations

Operations Support Facility (2900m level)



Array Operations Site (AOS) 5000m

AOS Technical Building - completed 2008

Home of the ALMA 12m correlator and the ACA correlator

photo by T. Burchell NRAO/AUI

Move of the ninth antenna to high site on December 12, 2010

Move of the ninth antenna to high site on December 12, 2010

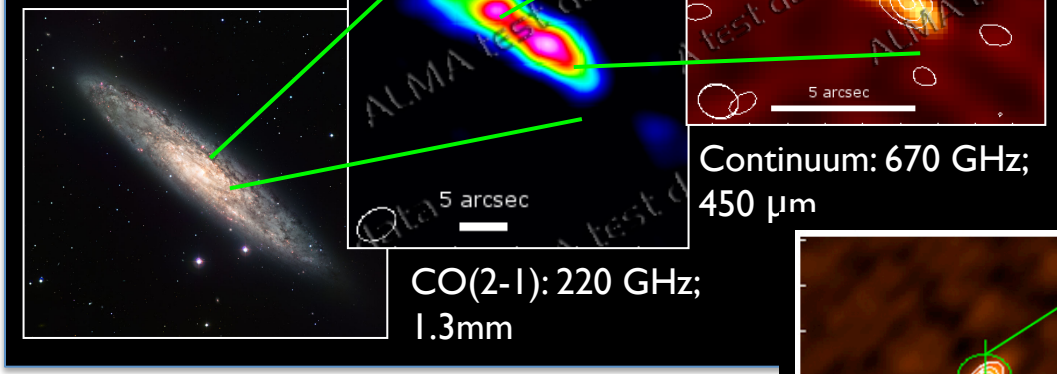
ALMA Timeline

All Last Year (2010)	Commissioning (began Late 2009)
March 31 2011	**1st call for Early Science Proposals**
4th Quarter 2011	Early Science observing begins
Late 2012	Pipeline images for standard modes
Late 2013	Baseline ALMA construction complete

Commissioning: Test Images

ALMA

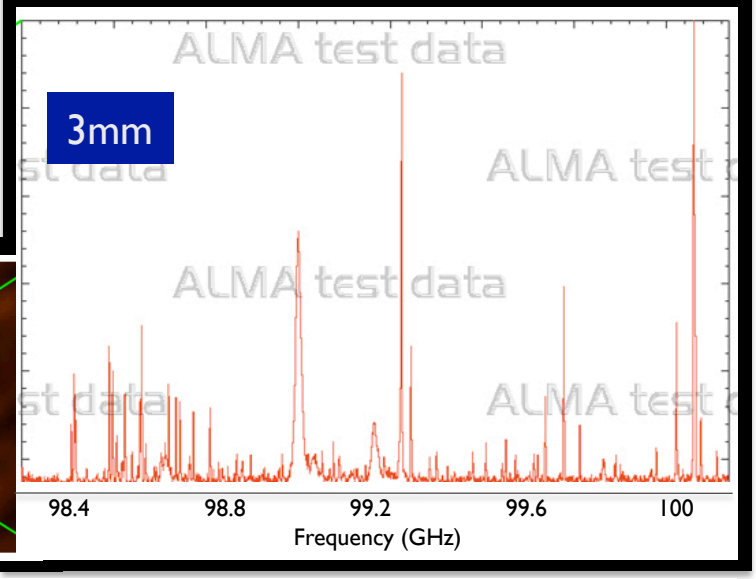
The heart of a star forming galaxy: NGC253

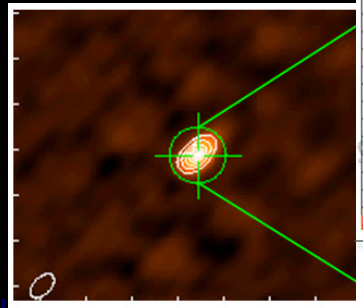


Continuum: 670 GHz; 450 μm

CO(2-1): 220 GHz; 1.3mm

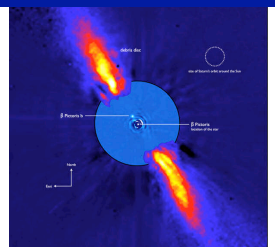
Spectral line forest from a Galactic massive protostar



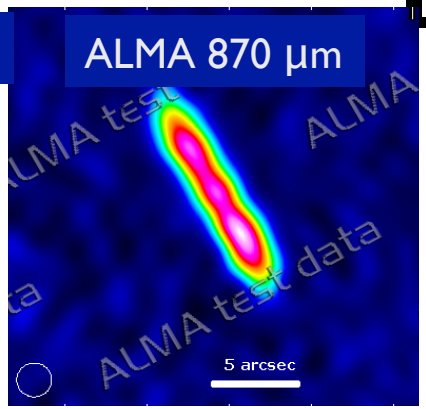


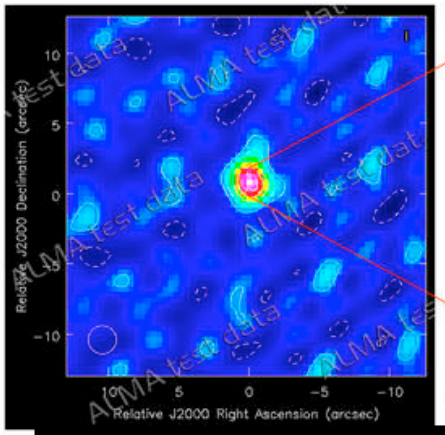
Dust continuum of the potentially planet forming debris disk: Beta Pictoris

ESO 3.6m ADONIS

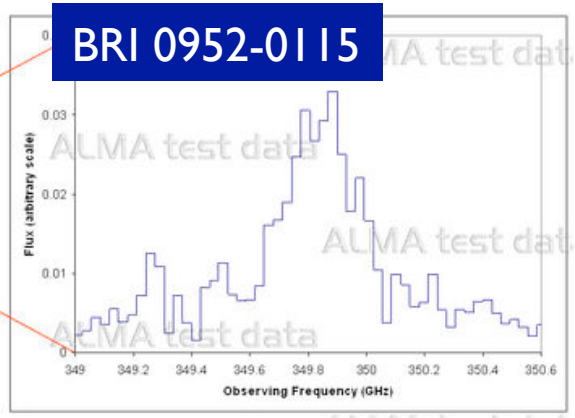


ALMA 870 μm





BRI 0952-0115



Ionized Carbon (CII @ 158 μm) at z=4.43

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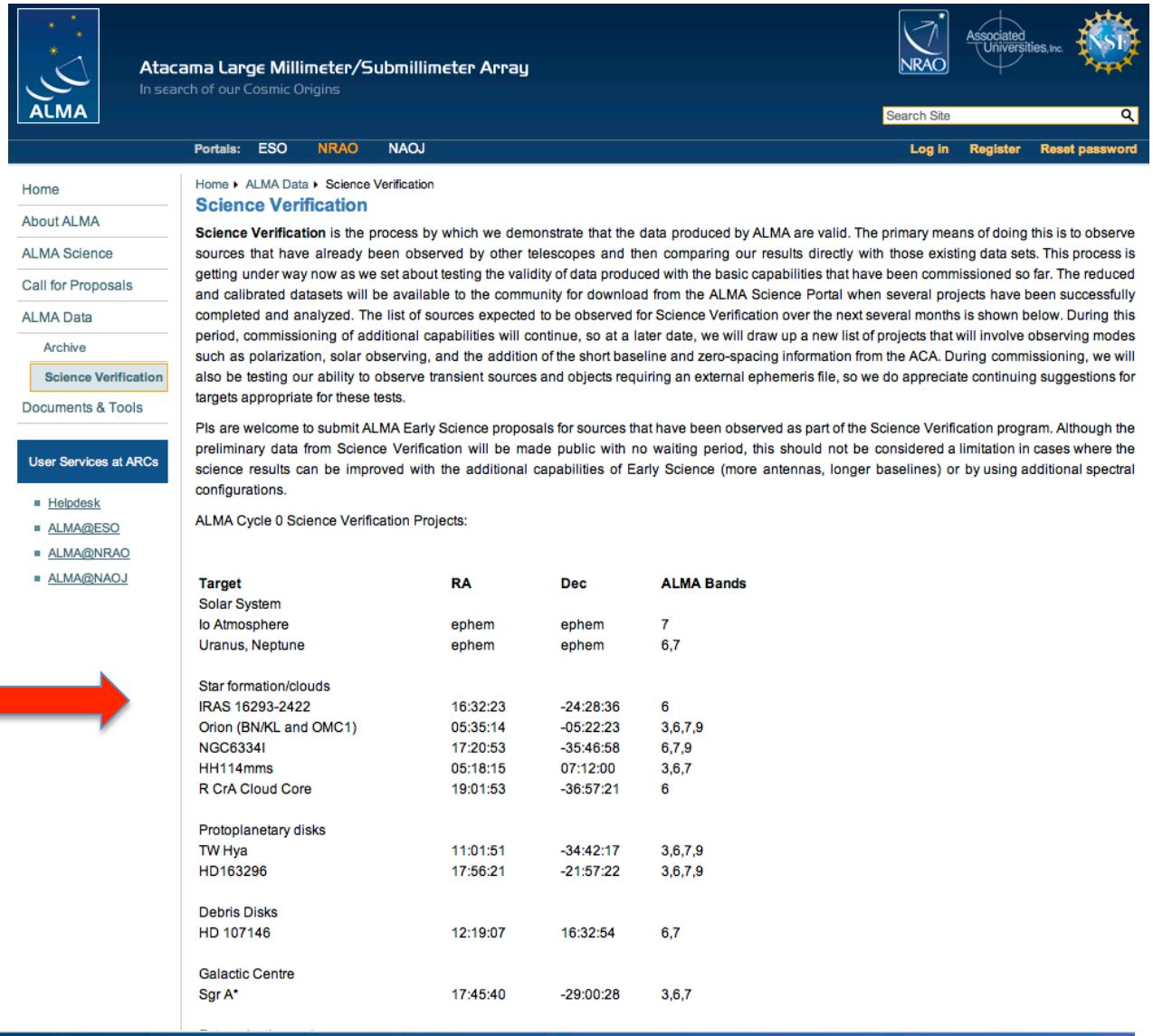
Science Verification

Observations to validate ALMA Observing Modes

Expect to have links to a few datasets and calibrated data products posted by June

User portal currently lists potential targets and bands.



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

Search Site

Portals: ESO NRAO NAOJ

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Home
About ALMA
ALMA Science
Call for Proposals
ALMA Data
Archive
Science Verification
Documents & Tools

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- Helpdesk
- ALMA@ESO
- ALMA@NRAO
- ALMA@NAOJ

Home ▸ ALMA Data ▸ Science Verification

Science Verification

Science Verification is the process by which we demonstrate that the data produced by ALMA are valid. The primary means of doing this is to observe sources that have already been observed by other telescopes and then comparing our results directly with those existing data sets. This process is getting under way now as we set about testing the validity of data produced with the basic capabilities that have been commissioned so far. The reduced and calibrated datasets will be available to the community for download from the ALMA Science Portal when several projects have been successfully completed and analyzed. The list of sources expected to be observed for Science Verification over the next several months is shown below. During this period, commissioning of additional capabilities will continue, so at a later date, we will draw up a new list of projects that will involve observing modes such as polarization, solar observing, and the addition of the short baseline and zero-spacing information from the ACA. During commissioning, we will also be testing our ability to observe transient sources and objects requiring an external ephemeris file, so we do appreciate continuing suggestions for targets appropriate for these tests.

PIs are welcome to submit ALMA Early Science proposals for sources that have been observed as part of the Science Verification program. Although the preliminary data from Science Verification will be made public with no waiting period, this should not be considered a limitation in cases where the science results can be improved with the additional capabilities of Early Science (more antennas, longer baselines) or by using additional spectral configurations.

ALMA Cycle 0 Science Verification Projects:

Target	RA	Dec	ALMA Bands
Solar System			
Io Atmosphere	ephem	ephem	7
Uranus, Neptune	ephem	ephem	6,7
Star formation/clouds			
IRAS 16293-2422	16:32:23	-24:28:36	6
Orion (BN/KL and OMC1)	05:35:14	-05:22:23	3,6,7,9
NGC6334I	17:20:53	-35:46:58	6,7,9
HH114mms	05:18:15	07:12:00	3,6,7
R CrA Cloud Core	19:01:53	-36:57:21	6
Protoplanetary disks			
TW Hya	11:01:51	-34:42:17	3,6,7,9
HD163296	17:56:21	-21:57:22	3,6,7,9
Debris Disks			
HD 107146	12:19:07	16:32:54	6,7
Galactic Centre			
Sgr A*	17:45:40	-29:00:28	3,6,7

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- **Early Science ("Cycle 0") Capabilities & Considerations**
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ALMA 1st Call March 31, 2011

Cycle 0 Capabilities:

- 16 antennas (12m)
- Four Receiver bands 3, 6, 7, 9 ➔ 100, 230, 345, 670 GHz ➔ 3, 1.3, 0.8, 0.45 mm
- Two configurations: Compact and Extended
- Range of correlator modes: up to 4 spectral windows and 8 GHz bandwidth
- Mosaics with up to 50 pointings
- Dual polarization (not full)
- Moving targets (except Sun)

Process:

- Observing begins Fall 2011, spans 9 months, with ~600 hours available
- Observations will be conducted on a "best effort" basis
- Proposers should expect that significant experience in radio/mm interferometry will be an advantage in working with the data products

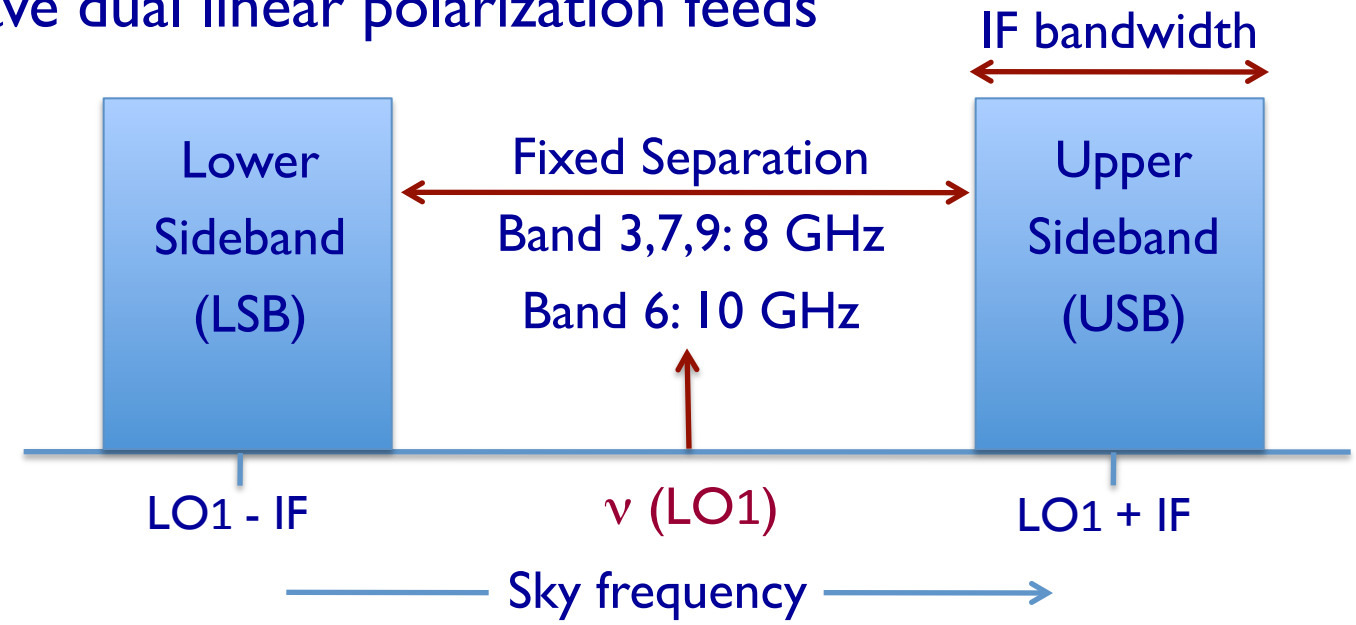
Two configurations

Band	Frequency (GHz)	Primary beam (“)	Angular Resolution (“)	
			Compact (18-125m)	Extended (36-400m)
3	84 - 116	62	5.3	1.6
6	211 - 275	25	2.3	0.7
7	275 - 373	19	1.6	0.45
9	602 - 720	9	0.8	0.2

Matched resolution can be obtained in Bands 3&7 or 6&9 (important in measuring SEDs of resolved objects)

Receivers

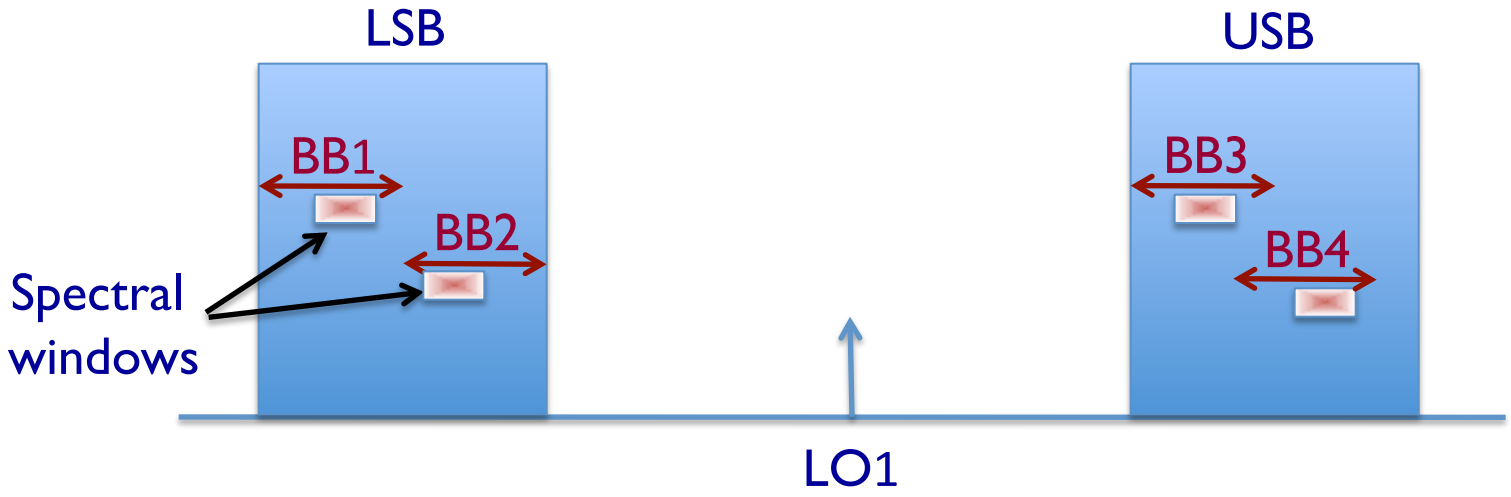
All have dual linear polarization feeds



- The first Local Oscillator (LO1) can be tuned to different frequencies
- The central Sky Frequencies: $\nu_{sky} = \nu_{LO1} - \nu_{IF}$ (LSB)
  $\nu_{sky} = \nu_{LO1} + \nu_{IF}$ (USB)
- Data will be correlated only in the spectral windows that are defined, which can be placed within one or both sidebands

Digitizers and Correlator

- Each antenna has 4 digitizers which can each sample 2 GHz * 2 polarizations, termed a **baseband**. Spectral windows are defined within basebands.
- Basebands can be distributed among the sidebands:



  - Edges of the baseband cannot lie outside the IF range & edges of the spectral window cannot lie outside the baseband

** **Cycle 0**: only one spectral window per baseband & all spectral windows must have the same configuration (bandwidth and spectral resolution). Bands 3, 6, 7 can only place even numbers of basebands in each sideband

Correlator Modes and Resolution

ALMA

Polari-zation	# Channels per baseband	Bandwidth per baseband (MHz)	Channel Spacing (MHz)
		(MHz = km/s @300 GHz)	
Dual	3840	1875	0.488
		938	0.244
		469	0.122
		234	0.061
		117	0.0305
		58.6	0.0153
Single	7680	58.6	0.0076
Dual	128	2000	15.6
Single	256	2000	7.8

Typical purposes:

Spectral scans

Targeted imaging of moderately narrow lines: cold clouds / protoplanetary disks

"Continuum" or broad lines

- Numbers are per baseband (you can use up to 4 basebands)
- **Note that the resolution is ~ 2*channel width (Hanning)**
- The required spectral resolution typically needs to be justified as does the number of desired spectral windows

NRAO

Continuum sensitivities (5σ in 1hr)

Band	Frequency (GHz)	Sensitivity (mJy/beam)
3	84 - 116	0.14
6	211 - 275	0.20
7	275 - 373	0.37
9	602 - 720	3.2

Only 3 receiver bands can be "ready" at one time (i.e. amplifiers powered on and stable temperature achieved). Required lead time to stabilize a new band is about 20 minutes. Scheduling issue.

ALMA in Context

Collecting Area

of Antennas

(# of baselines)

SMA

8 (28)

CARMA

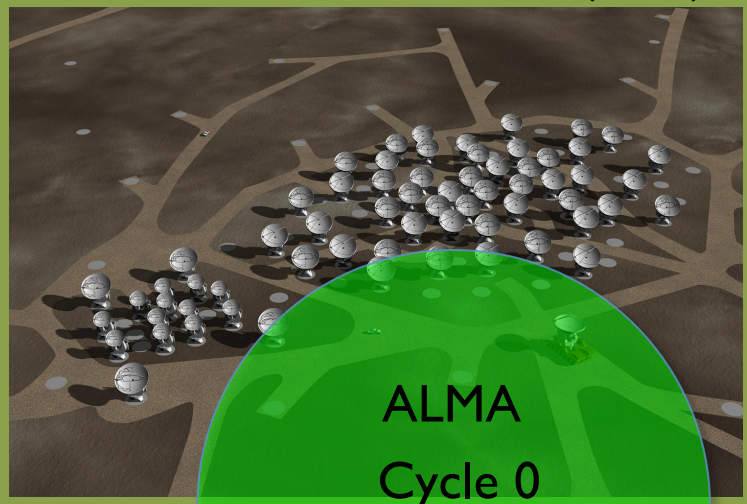
23 (253)

IRAM PdBI

6 (15)

ALMA

Full Science 64 (2016)



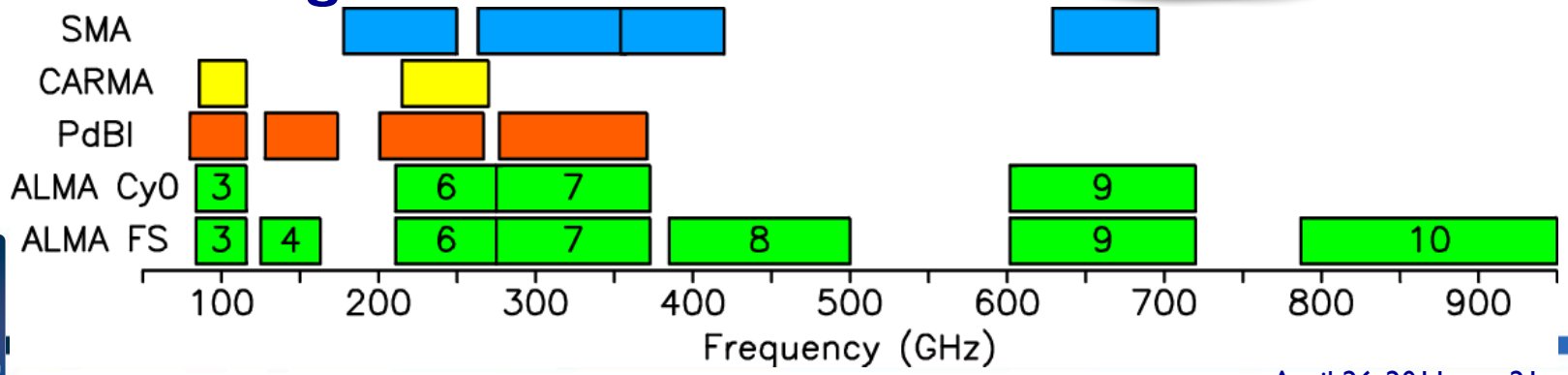
ALMA

Cycle 0

16 (120)

- Sensitivity goes as collecting area
- Image fidelity goes as # of baselines

Spectral Coverage



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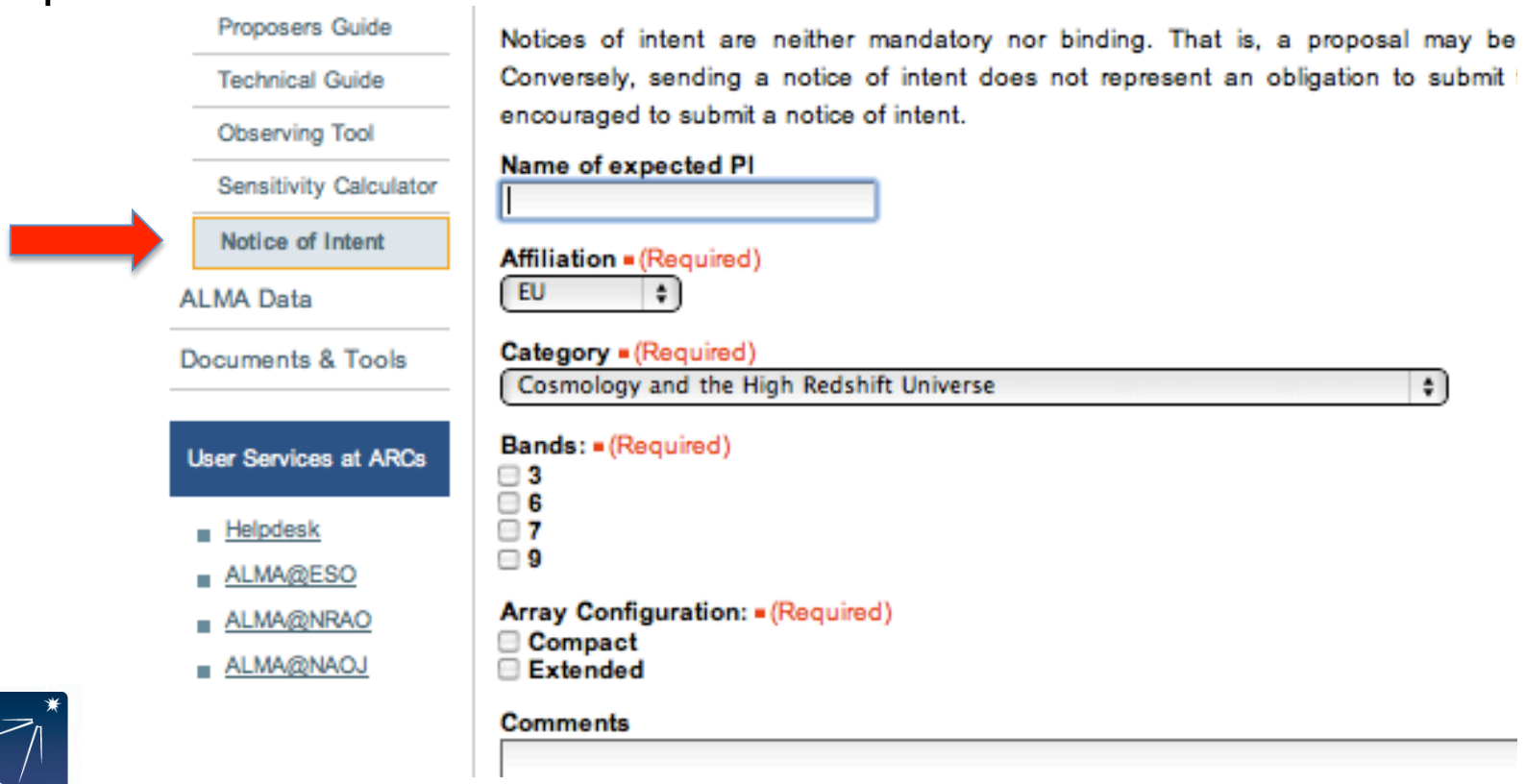
ALMA Cycle 0 Logistics

Date	Milestone
31 March 2011	Cycle 0 CfP & release of Observing Tool
29 April 2011	Cycle 0 Proposal "Notice of Intent" deadline
1 June 2011	Opening of archive for proposal submission
30 June 2011	Proposal deadline
July - Sept 2011	Technical Assessments by ALMA staff Science-Themed ALMA Review Panels (ARPs) ALMA Proposal Review Committee (APRC)
mid-Sept 2011	Announce Results
30 September 2011	Anticipated start of ALMA Cycle 0 observing
February 2012	Anticipated one month engineering shutdown
30 June 2012	Anticipated end of ALMA Cycle 0

Notices of Intent

The Observatory encourages prospective PI's to submit "Letters of Intent" via webform by April 29

https://almascience.nrao.edu/



ALMA Cycle 0 Logistics

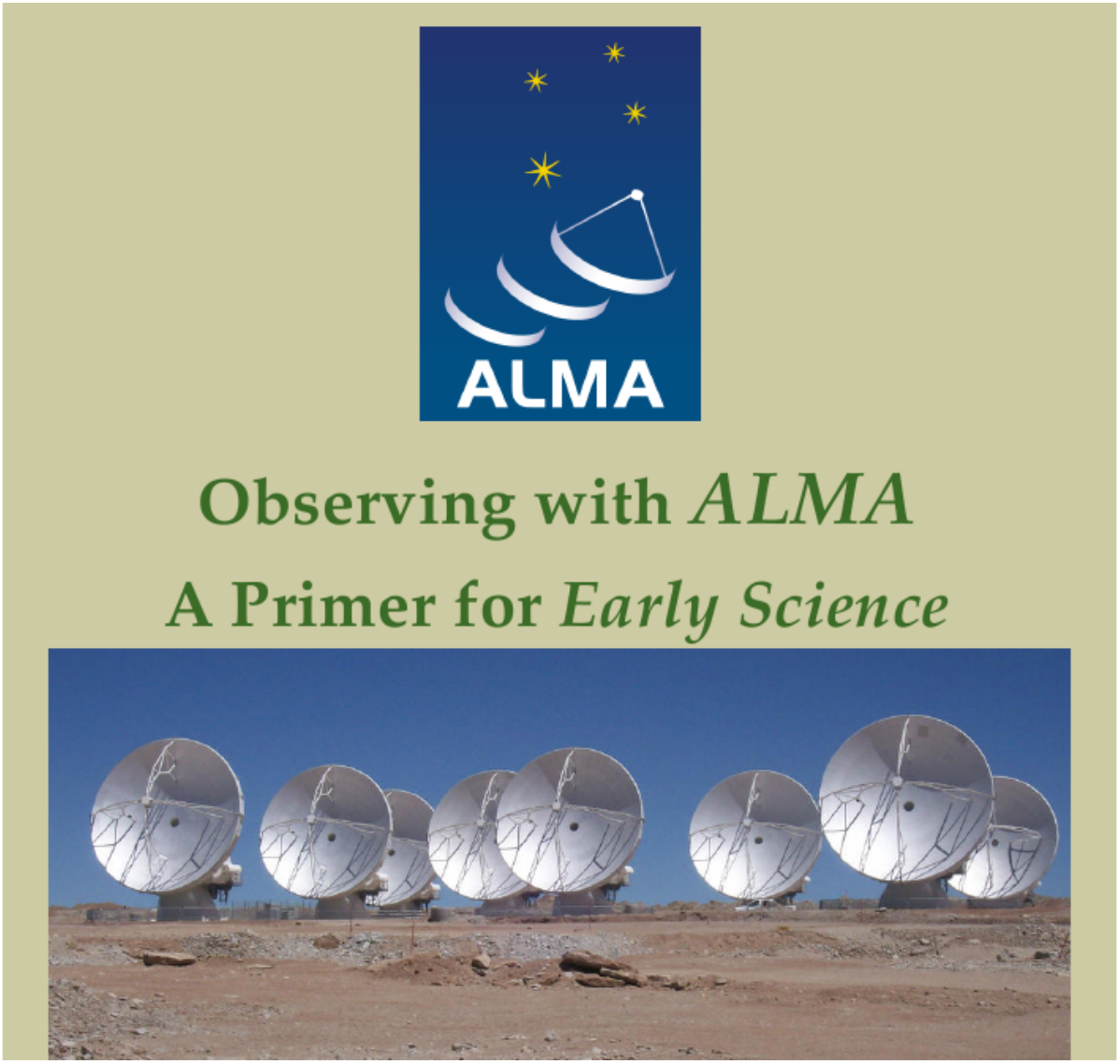
- Proposal Deadline = 15:00 UT on 30 June 2011
  - Four science categories
  - Standard (≤100 hours) & Targets of Opportunity
  - 33.5% for NA-led projects
- HST/Spitzer-like review process: <u>one international TAC</u>
  - The ~6-member Science panels produce science-ranked lists
  - Panel members are not affiliated with ALMA/JAO
  - Panel outputs merged by Proposal Review Committee (chair=Neal Evans)
  - PRC consolidates grades and adjusts for partner shares
- Anticipate awarding 500-700 hours
  - Projects assigned maximum time and grade (A, B, C, rejected)

➔ *Aim for science that can be done in a few hours*

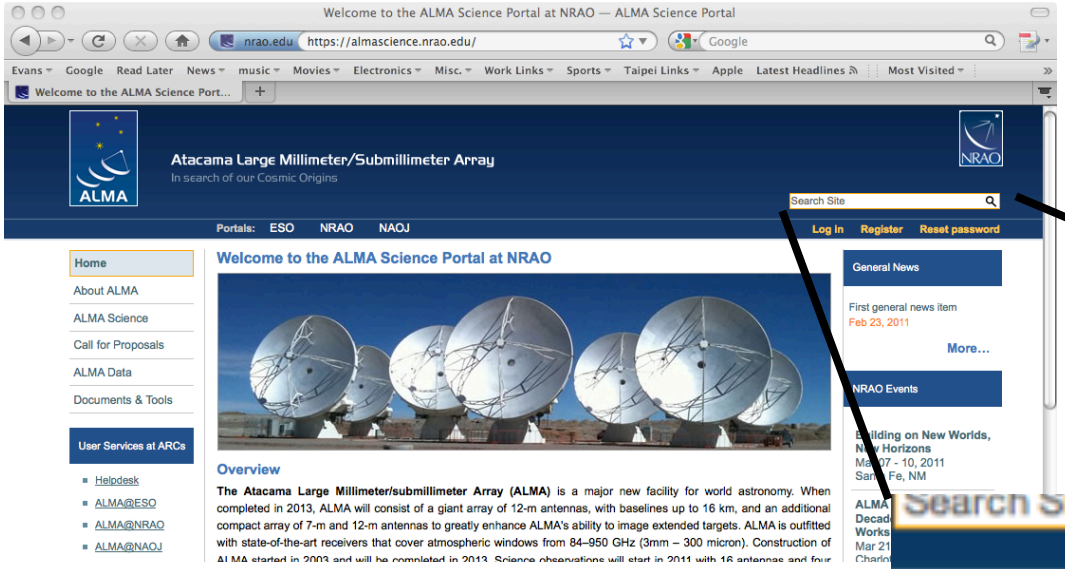
Proposal Checklist

- ❑ Read Primer and Proposers Guide
- ❑ Create ALMA account by registering at the Science Portal
- ❑ Download Observing Tool (OT), try Sensitivity Calculator
- ❑ Download casa 3.2 (early May release), try simdata
- ❑ Prepare the Science & Technical Justifications (one PDF file)
- ❑ Prepare Science Goals (sources, frequency & correlator setup, integration times) within the OT
- ❑ Make use of the Helpdesk & the Knowledgebase
- ❑ Submit to Archive!

The ALMA Primer



Science Portal (https://almascience.nrao.edu)



Register -

- to submit proposals as PI
- to be Co-I on proposals
- to submit helpdesk tickets

Science Portal

https://almascience.nrao.edu/

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

Portals: ESO NRAO NAOJ

Home
About ALMA
ALMA Science
Call for Proposals
ALMA Data
Documents & Tools
Documents
Tools

User Services at ARCs
- Helpdesk
- ALMA@ESO
- ALMA@NRAO
- ALMA@NAOJ

Home ▸ Documents & Tools ▸ Documents

Documents

Below a summary of documents available for download.

Call for Proposals
- ALMA Cycle 0 Proposers Guide (Contains all pertinent information regarding the ALMA Cycle 0 Call for Proposals)
- ALMA Cycle 0 Technical Handbook (A comprehensive description of the ALMA observatory and its components) **Available May 15, 2011**
- Early Science Primer (Introduction to interferometry and how to use ALMA during Early S

Observing Tool (OT)
- OT Phase I Quickstart (A Quick Start Guide for using the Observing Tool)
- OT User Manual (Describes how to use the Observing Tool for preparing ALMA proposal
- OT Reference Manual (An in-depth description of the Observing Tool)
- Video Tutorials on how to use the Observing Tool

Guides to the ALMA Regional Centers
- Guide to the East Asian ARC
- Guide to the European ARC
- Guide to the North American ARC

ALMA Sensitivity Calculator (ASC)
- Sensitivity Calculator Guide (Introduction and help in using the ASC)

CASA
- CASA Documentation
- CASA Guides (contains links to all relevant CASA do…nts, tips & tools, download

ALMA Observation Support Tool (OST)
- Observation Support Tool (Introduction and help in using the OST)

Splatalogue

Proposers Guide (Handbook after May 15)

ES Primer

Documents/tools

Observing Tool "Quickstart" guide & videos

Sensitivity Calculator

CASA and CASA-based observing simulators

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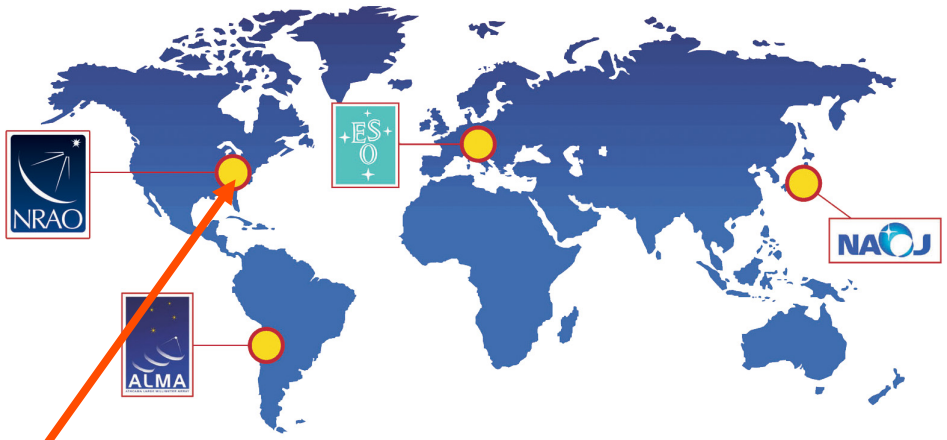
Science Support

- Three ALMA Regional Centers: ARCs
  - NA: Charlottesville, VA, USA
  - EU: Garching, Germany
  - EA: Mitaka, Japan
- North American ARC: US - Canada
- North American ALMA Science Center (NAASC) encompasses NA ARC and includes partnership with Taiwan



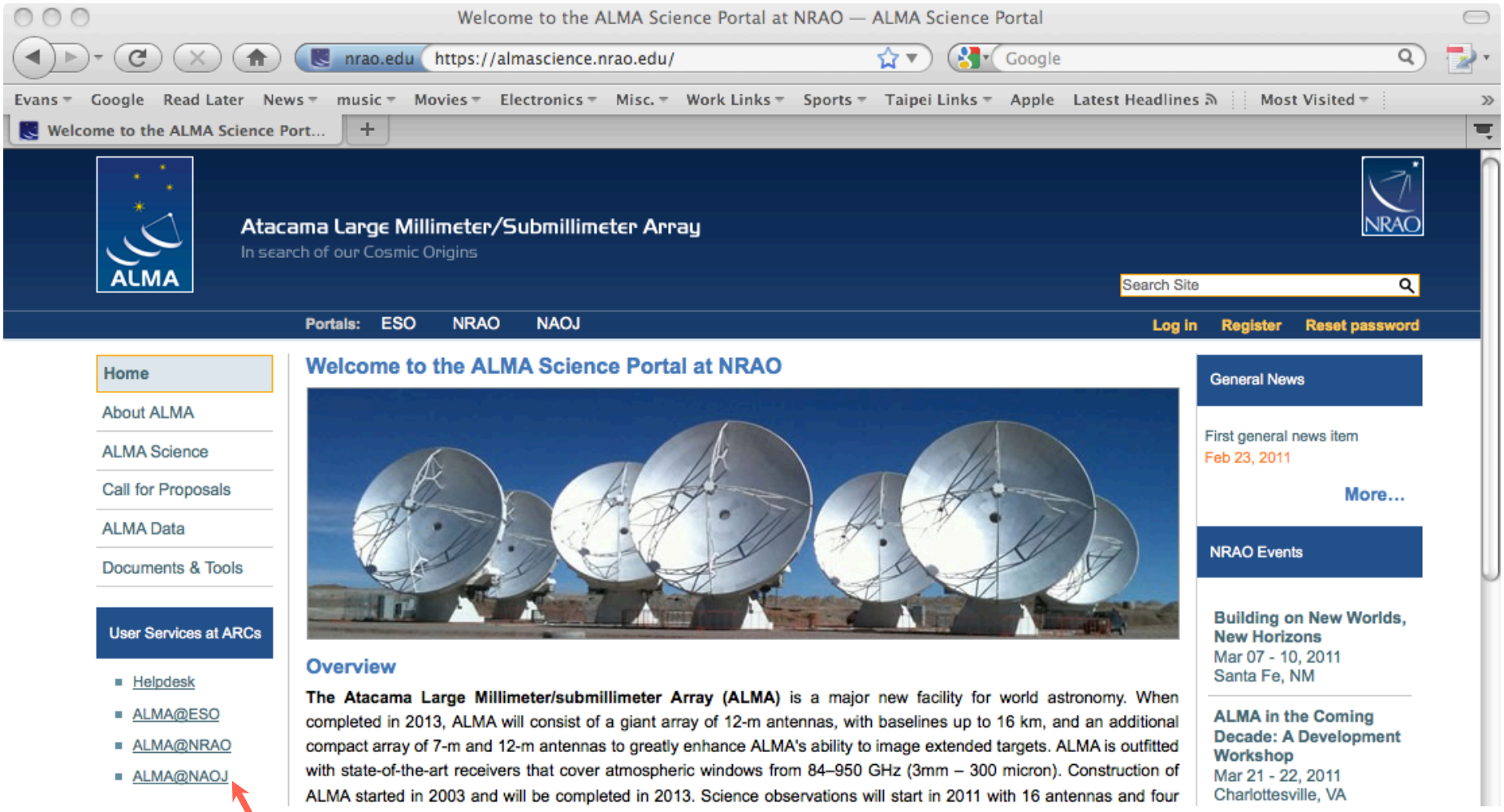
NAASC in Charlottesville, VA

NAASC: One-stop shopping for:

- Proposal Help and Submission
- Observation preparation (Phase 2)
- Data archive
- Data processing
- Face-to-face visitor support
- Workshops and tutorials
- Community outreach

NRAO User Support

http://almascience.nrao.edu



User Support

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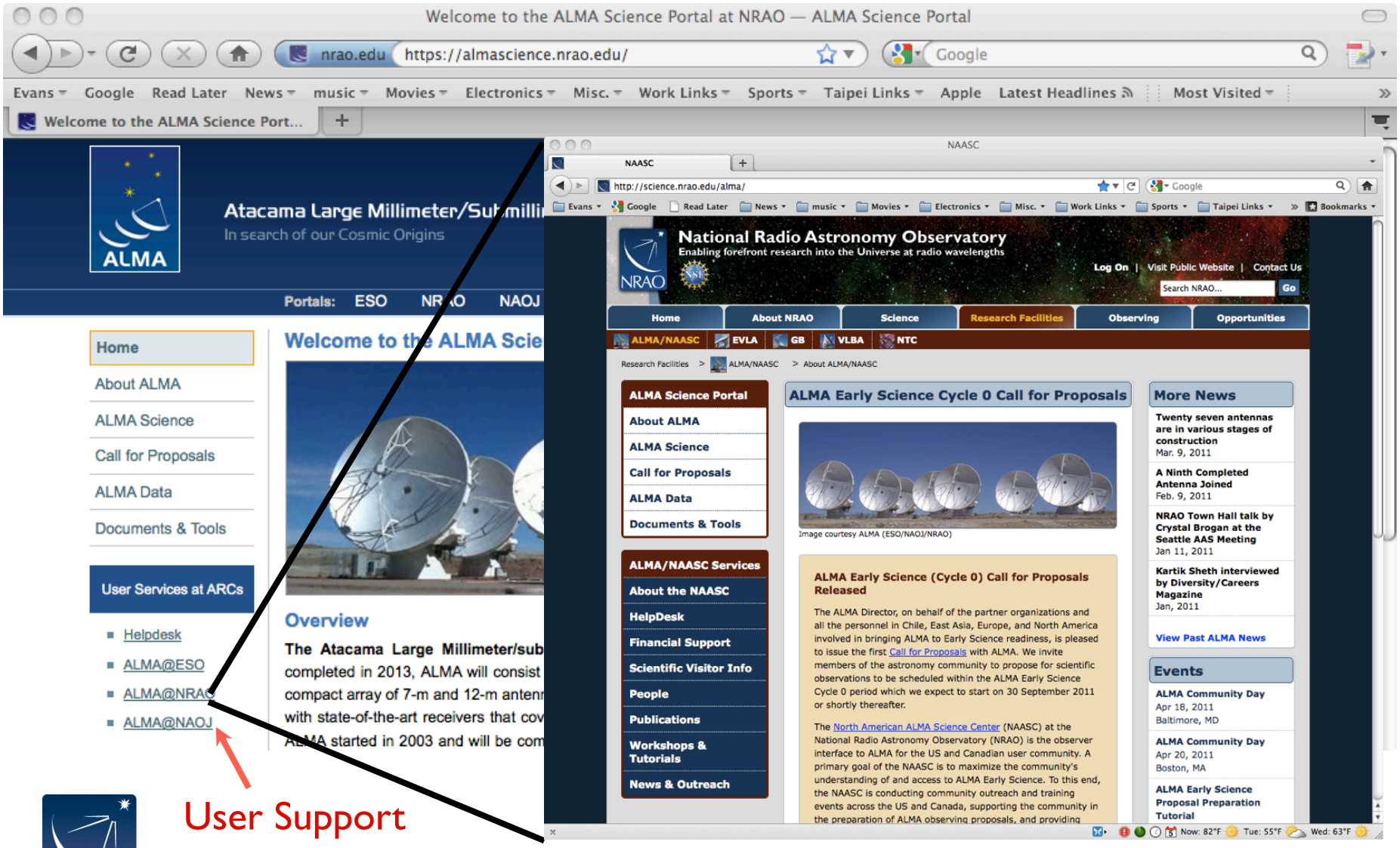
ALMA



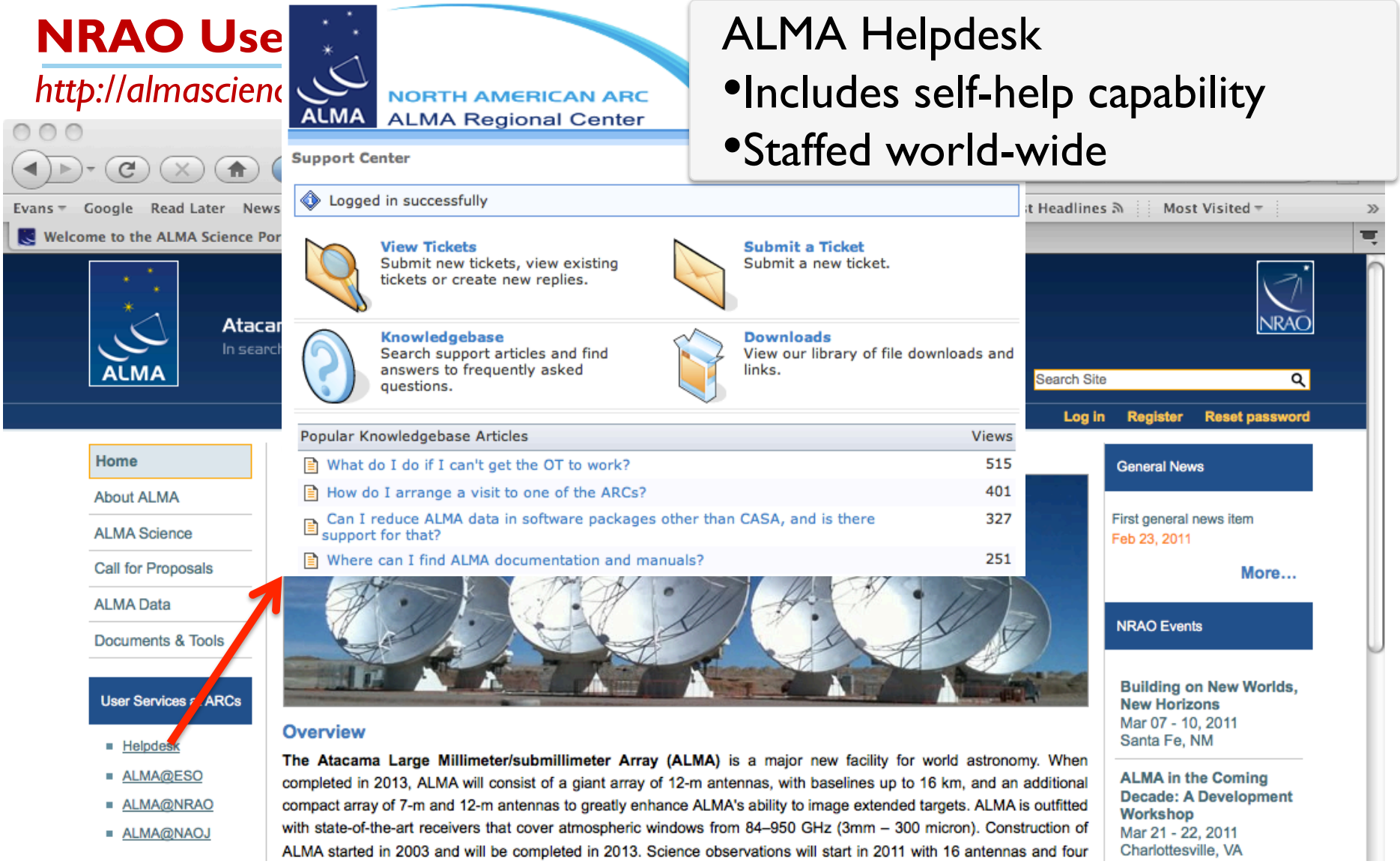
User Support

NRAO Use

http://almascienc

ALMA Helpdesk

- Includes self-help capability
- Staffed world-wide



ALMA Data Product

- The Joint ALMA Observatory (JAO) operates the array in Chile.
- The JAO is responsible for data product quality, eventually using a pipeline (late 2012).
- In Early Science, quality assurance will be a manual process. Basic CASA scripts that were used to calibrate and image the datasets will be included.
- The ARCs are responsible for delivery of the data, but will also fulfill requests to re-process data.

Future Capabilities of ALMA

- >3x better sensitivity with 50 x 12m antennas in main array
  - Fantastic "snapshot" uv-coverage (1225 baselines)
  - Imaging fidelity ~10x better!
- Higher angular resolution: baselines ~15km, matched beams in all bands
- Better imaging of resolved objects and mosaics
  - TPA: 4 x 12m antennas with subreflector nutators
  - ACA: Atacama Compact configuration 12 x 7m antennas
  - "On-the-Fly" mosaics: quickly cover larger areas of sky

Future Capabilities of ALMA

- More receiver bands: 4, 8, 10 (2mm, 0.7mm, 0.35mm)
- Polarization: magnetic fields and very high dynamic range imaging
- "Mixed" correlator modes
  - (simultaneous wide & narrow, see A&A 462, 801)
- ALMA Development Program → studies just beginning now
  - mm VLBI
  - More receiver bands
  - Higher data rates

Summary

- Amazing scientific promise of ALMA
- Steady progress in construction: 10 antennas now at high site
  - already more collecting area and spectral coverage than current arrays
- Proposal submission June 1-30 (tools & documentation available now)
- NAASC is your One-Stop shop for community support

Info common across project { http://almascience.nrao.edu/

NAASC specific programs { http://science.nrao.edu/alma/

almascience.nrao.edu

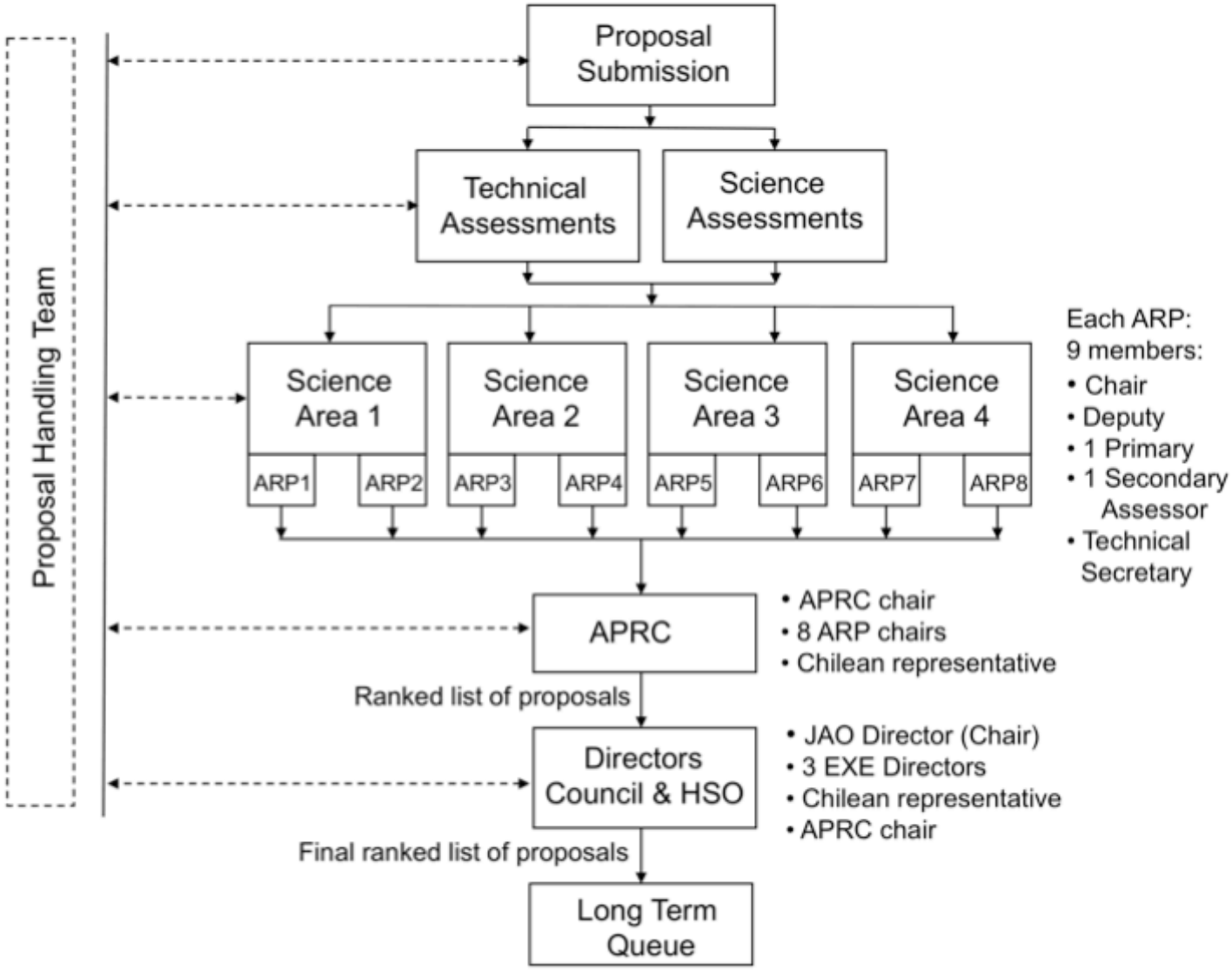
science.nrao.edu/alma

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

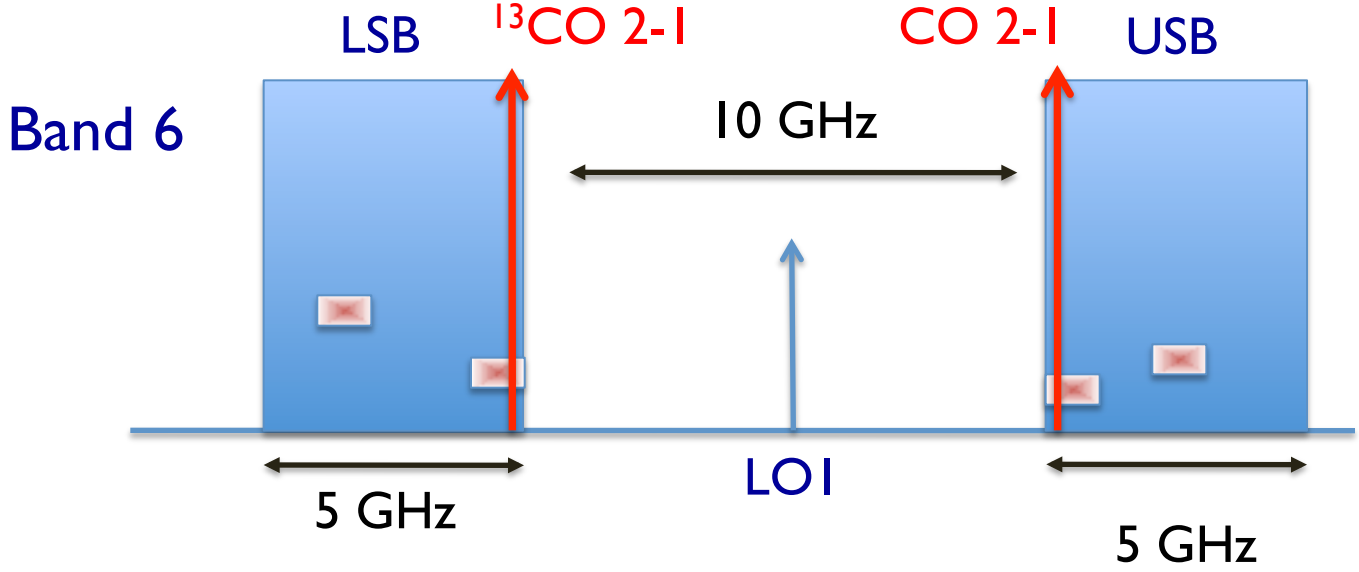
Additional Slides

Cycle 0 Considerations

Proposal Review process

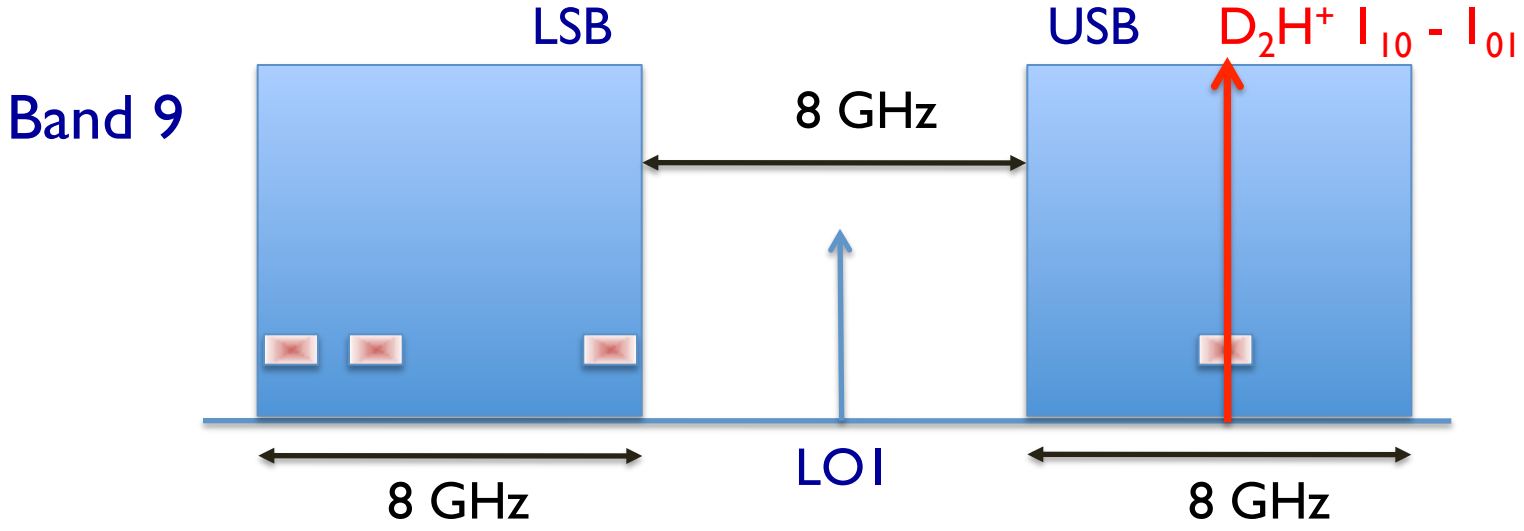


Example: ^{12}CO and ^{13}CO in Band 6 (barely)



- Can observe both ^{13}CO 2-1 (220.40 GHz) and CO 2-1 (230.54 GHz) *only* at low z
- 2 spectral windows, 0.9375 GHz wide, 0.3 km/s spectral resolution
  - MUST set rest frequency for spectral windows so that windows remain entirely within the sidebands, e.g. can't center on lines for wider spectral windows
- can place 2 additional windows to observe CH_3OH, SO_2, etc.

Example: Lines in Band 9



- Band 9 is the only DSB receiver, but in Cycle 0 **only one sideband** per spectral window can be correlated
- However, there is full flexibility in that **each baseband can be connected to either one or the other sideband**
  - e.g. Observe D_2H^+ at 691.66 GHz with one spectral window
  - can place 3 additional windows in USB or LSB

Properties of Cycle 0 Configurations

Band	Frequency [GHz]	Angular Resolution ["]	Maximum Scale ["]	T_{bc} [mK]	Flux [mJy]	T_{bl} [K]	Field of View ["]
Properties of the Compact Configuration (baselines of ~18 m to ~125 m)							
3	100	5.3	21	0.65	0.14	0.030	62
6	230	2.3	9	1.0	0.20	0.029	27
7	345	1.55	6	1.8	0.37	0.043	18
9	675	0.80	3	15	3.2	0.27	9
Properties of the Extended Configuration (baselines of ~36 m to ~400 m)							
3	100	1.56	10.5	7.6	0.14	0.35	62
6	230	0.68	4.5	11	0.20	0.34	27
7	345	0.45	3.0	20	0.37	0.50	18
9	675	0.23	1.5	175	3.2	3.1	9

Table 2. Properties of ALMA Cycle 0 Array Configurations