Planning ALMA Observations

Atacama Large mm/sub-mm Array

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North American ALMA Science Center

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

Talk Outline

ALMA

- **ALMA Overview and Status**
- The Key Decisions When Proposing for ALMA

NRAO

ALMA Basics

- Global partnership (shared cost ~1.3 billion):
  - North America (US, Canada, Taiwan)
  - Europe (ESO)
  - East Asia (Japan,Taiwan)
  - In collaboration with Chile

- Unique high, dry site:
  5000m (16,500 ft) in Chilean Atacama desert

- At least 66 submillimeter/millimeter telescopes:
  - 12-m Array – 50 x 12-m
  - Atacama Compact Array (ACA) - 12x7-m, 4x12-m

- On budget and on time for completion in 2013

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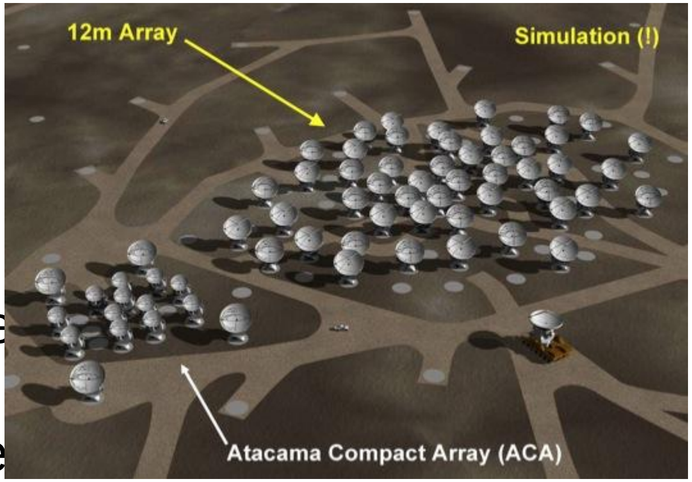

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  12-m Array – 50 x 12-m
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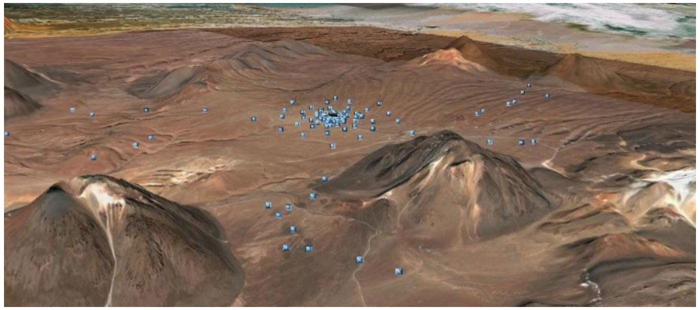
Full Science Capabilities

ALMA

10-100× better sensitivity and resolution than current mm arrays.

- Baselines 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 per polarization)
- Flexible correlator with high spectral resolution at wide bandwidth
- Full polarization capabilities



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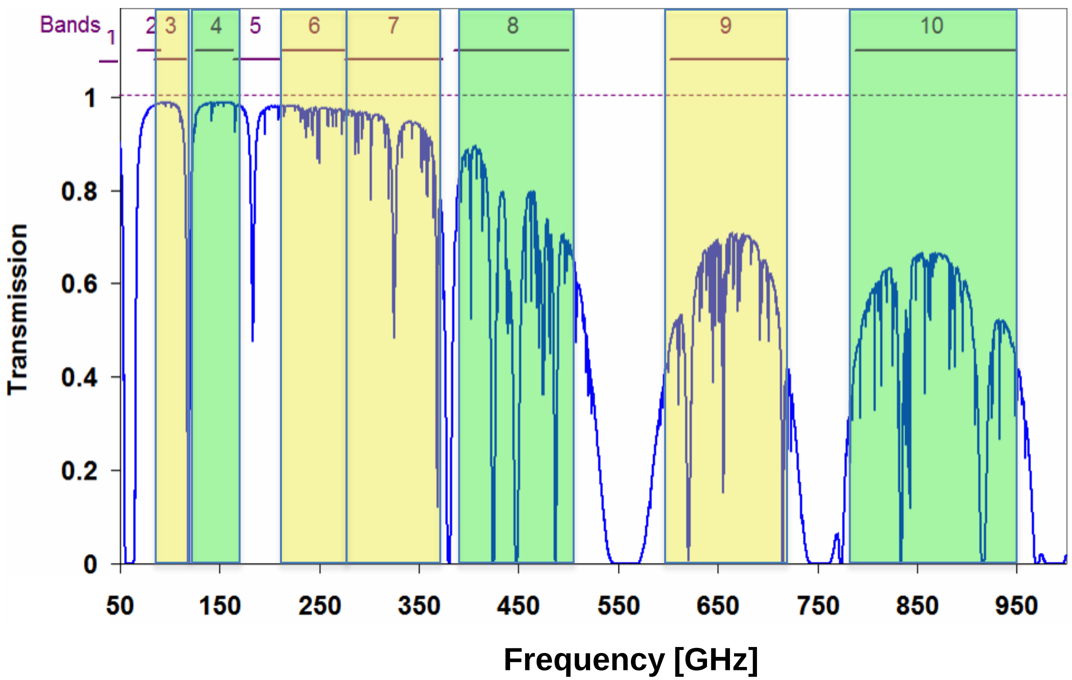
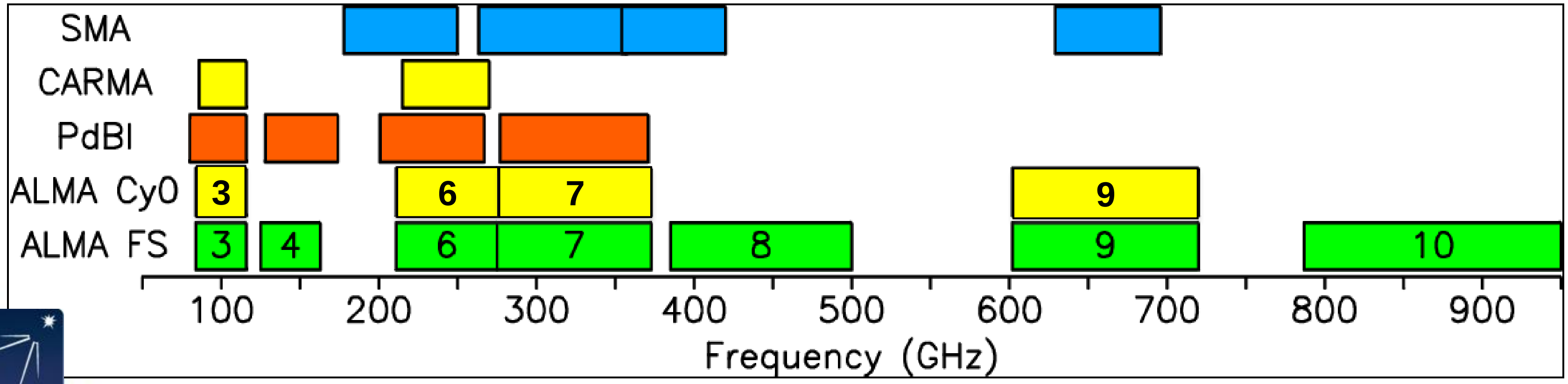
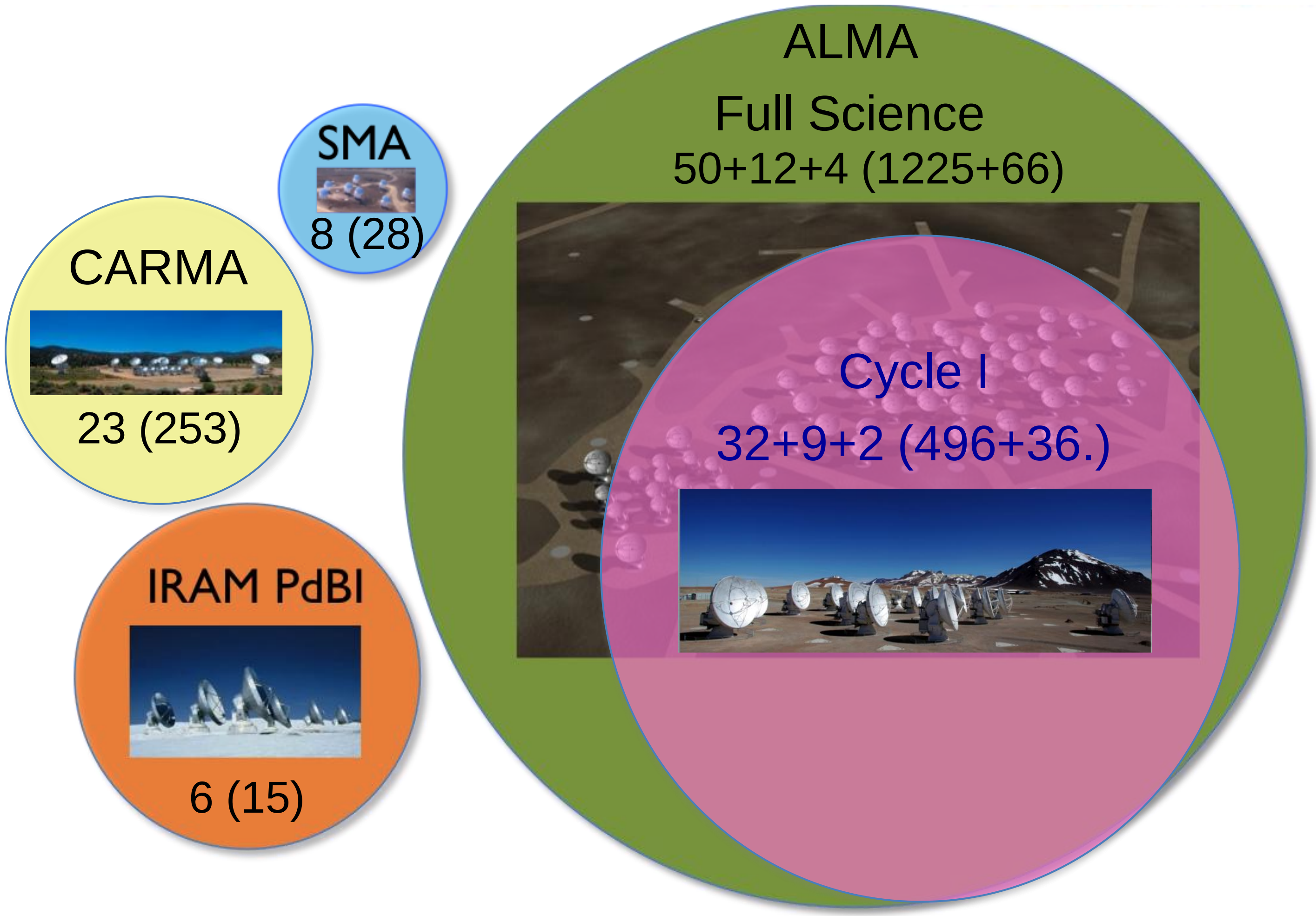
Frequency Coverage

ALMA





Collecting Area & Baselines



Circles Show Collecting Area (sensitivity)

Captions give # of antennas and # of baselines (fidelity)

Current Status

ALMA

- Cycle 0 observing began 30 Sep ’11.
- Cycle 1 call for proposals out (12 July)
- Data delivered to PIs.
- Commissioning ongoing.
- 31+ antennas at high site.
- Correlators (ACA and main) working.
- All antennas: B3, 6, 7, and 9 receivers.
- Science verification ongoing, data publicly available.

Science Verification Data

- ALMA data released for:

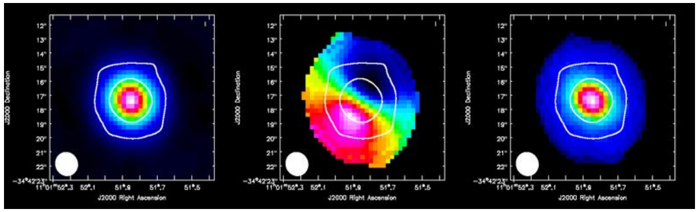
  Tw Hydra*
  The Antennae Galaxies*
  NGC 3256*
  Sgr A-star
  M100
  IRAS 16923
  BR1202 (high redshift quasar)

  download from ALMA Science Portal
  http://almascience.org/

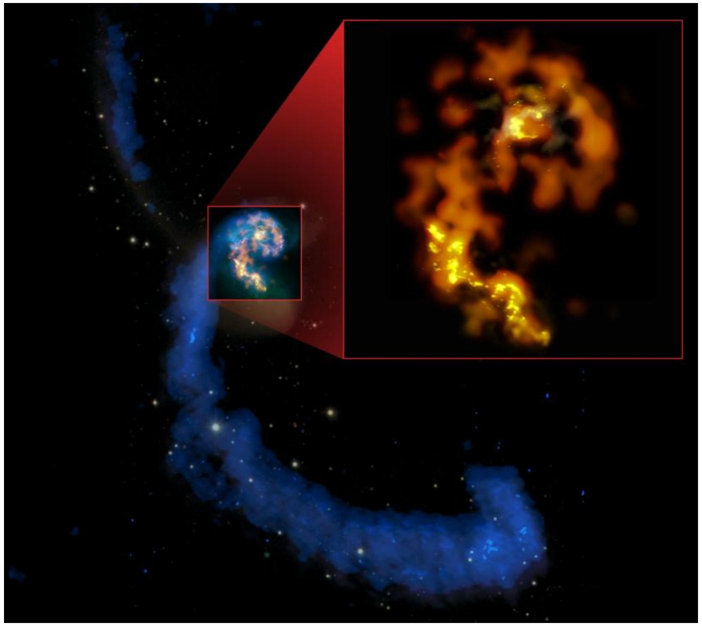
- Calibrated & uncalibrated data, images.

- * - CASA guide available at
  http://casaguides.nrao.edu

HCO+ J=4-3 in TW Hya

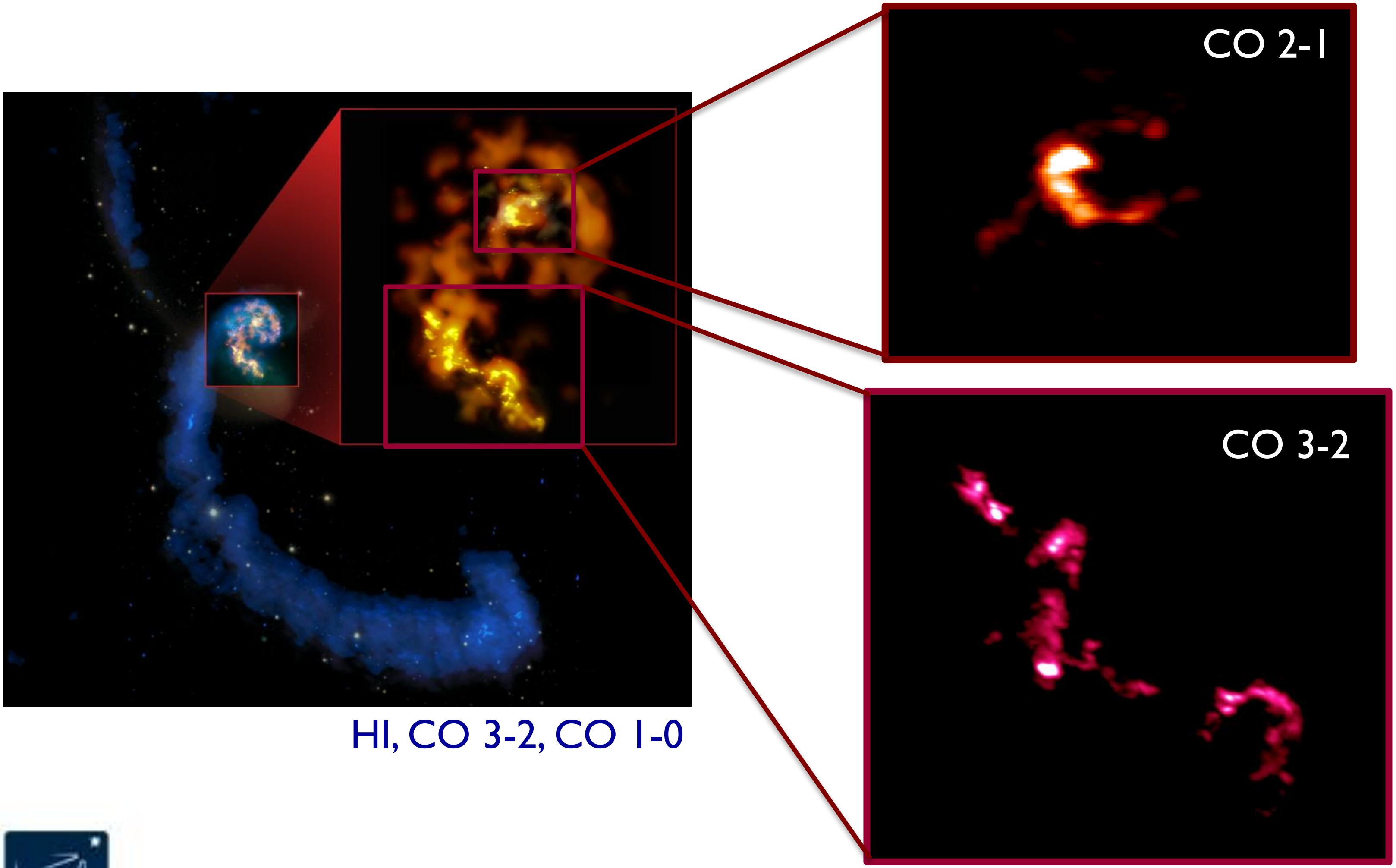


CO J=3-2 in the Antennae



ALMA Images Nearby Galaxies

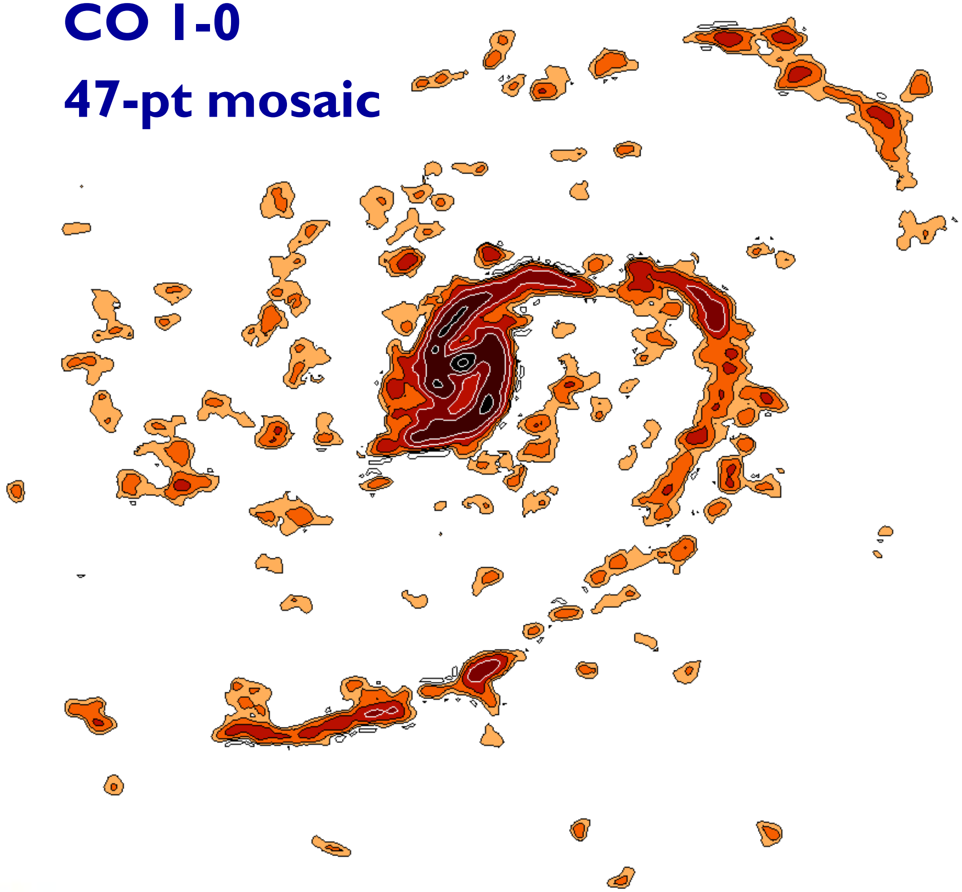
- Science verification imaging of the Antennae Galaxies

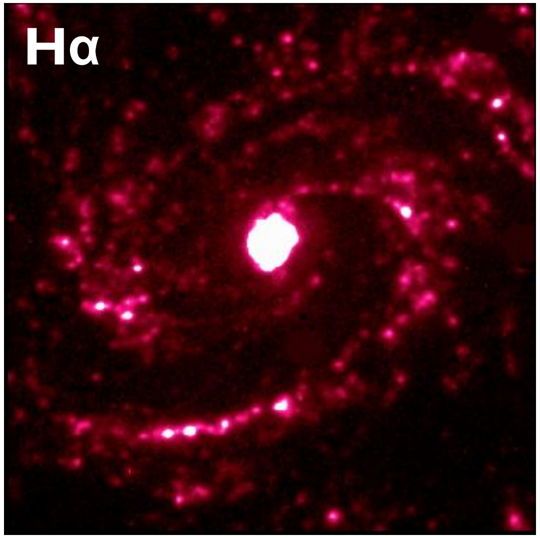


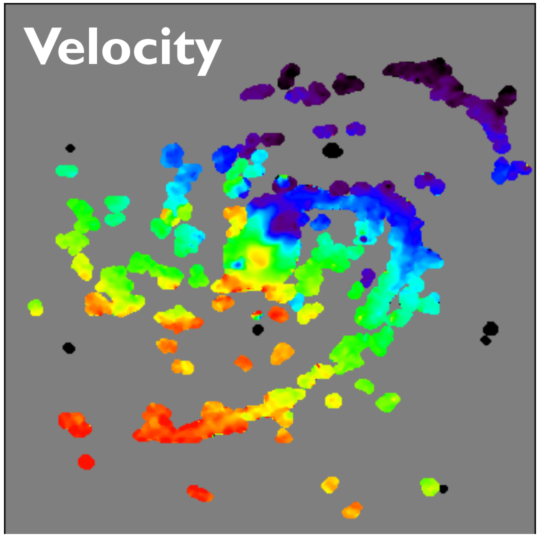
HI, CO 3-2, CO 1-0

ALMA Images Nearby Galaxies

- Science verification imaging of M100

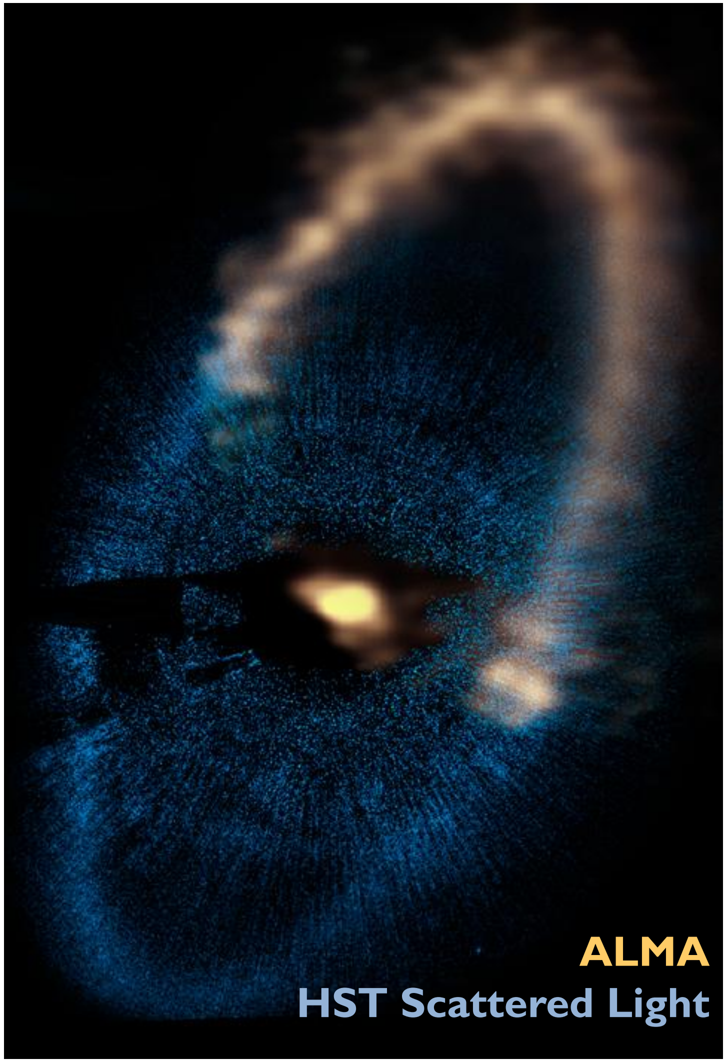






ALMA Images Debris Disks

- PI Boley (U. Florida) Data on Fomalhaut Debris Disk



Talk Outline

- ALMA Overview and Status
- **The Key Decisions When Proposing for ALMA**

Key Proposal Factors

- **Framework: Science Goals**
- Spectral Setup
- Spatial Setup
- Control and Performance Specifications
- Logistics

Science Goal (Cycle I)

ALMA

- One correlator + front end setup in one ALMA band
  SPECTRAL WINDOWS, REST FREQUENCY, POLARIZATION, LINE VS. CONTINUUM
- Subject to one set of control parameters
  SPATIAL RESOLUTION, LARGEST ANGULAR SCALE, SENSITIVITY, DYNAMIC RANGE
- Using one mapping strategy
  MOSAIC, OFFSETS, SINGLE FIELDS
- Using one calibration strategy
  SYSTEM OR USER DEFINED
- Applied to Sky Targets within 15°
  UP TO 15 PER SCIENCE GOAL OR 150 FIELDS PER MOSAIC, UP TO 5 DIFFERENT VELOCITIES

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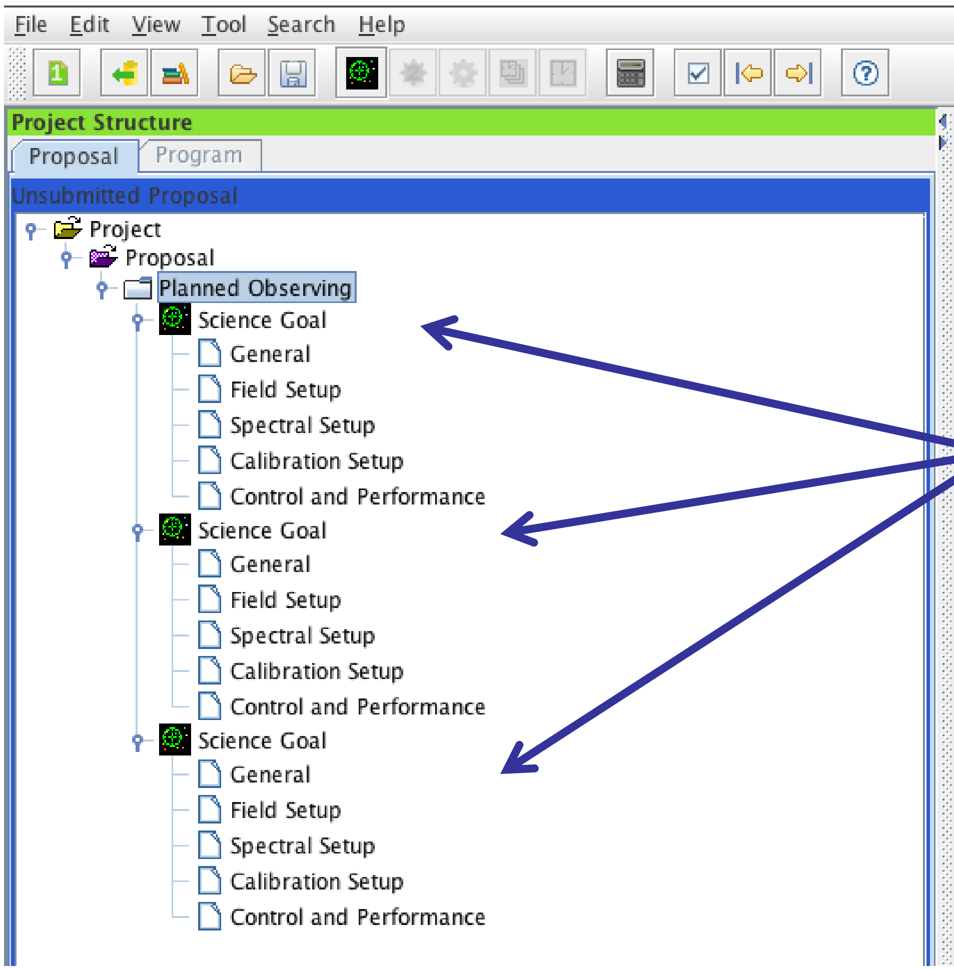
Science Goal (Cycle I)

ALMA

- Fundamental unit (below proposal) in the ALMA OT
- **Five Science Goals** allowed per proposal in Cycle 1



In practice:

- Up to 5 Science Goals
- Specify control & performance, spectral setup, field setup for each

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Key Proposal Factors

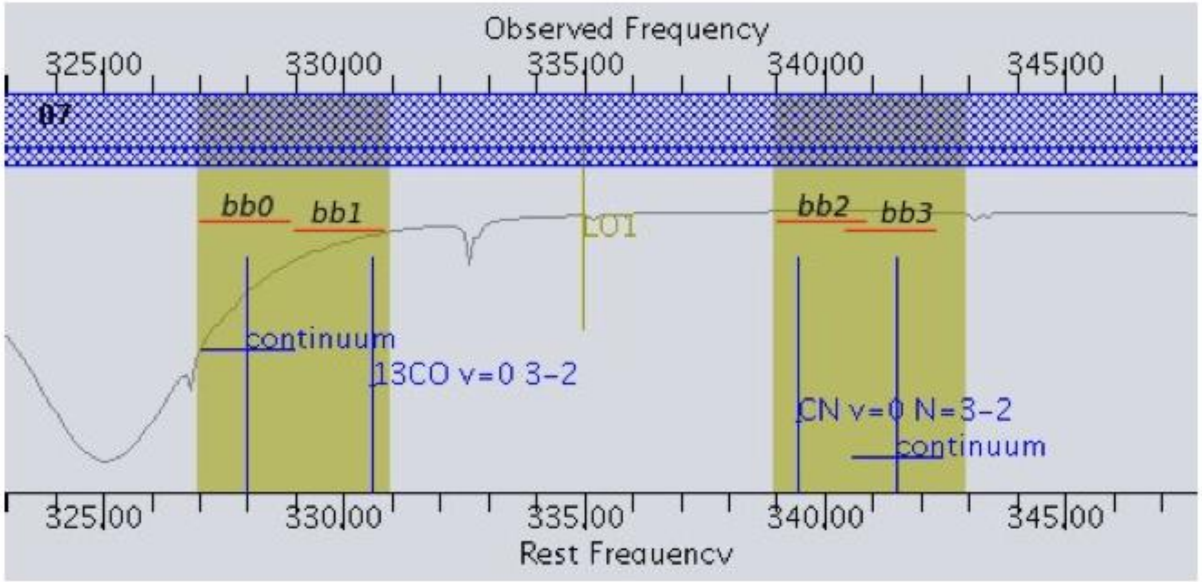
- Framework: Science Goals
- **Spectral Setup**
- Spatial Setup
- Control and Performance Specifications
- Logistics

Spectral Setup: Receiver

- Four receiver “bands,” set spectral coverage
  OBSERVING FREQUENCY ALSO AFFECTS RESOLUTION, PRIMARY BEAM

Band	Frequency (GHz)	Primary beam (arcsec)	Angular Resolution (arcsec)	Continuum Sensitivity (mJy min$^{1/2}$)
3	84 - 116	62	0.6 - 4.1	0.09
6	211 - 275	25	0.3 - 1.7	0.14
7	275 - 373	19	0.2 - 1.2	0.25
9	602 - 720	9	0.1 - 0.6	2.5

Spectral Setup

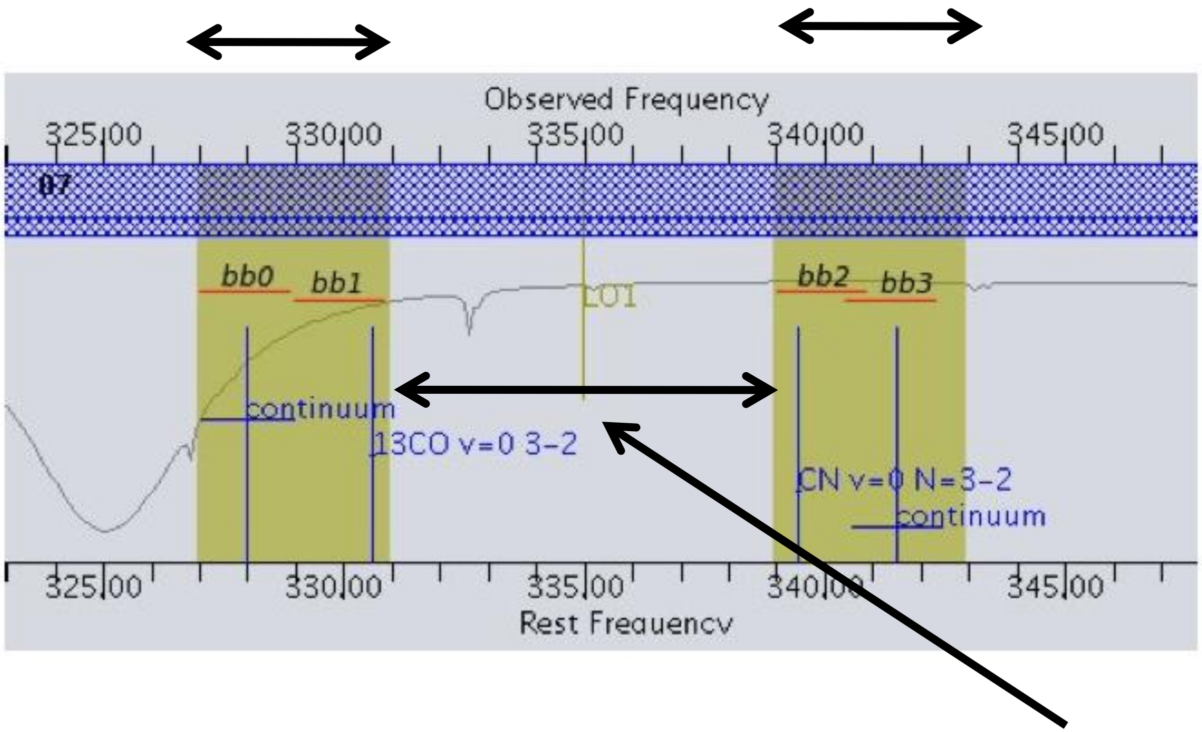


Sidebands

- Receivers sensitive to two separate ranges of sky frequency: **sidebands**

Sideband width varies by receiver band

Band 3: 4 GHz, Band 6: 5 GHz, Band 7: 4 GHz, Band 9: 8 GHz

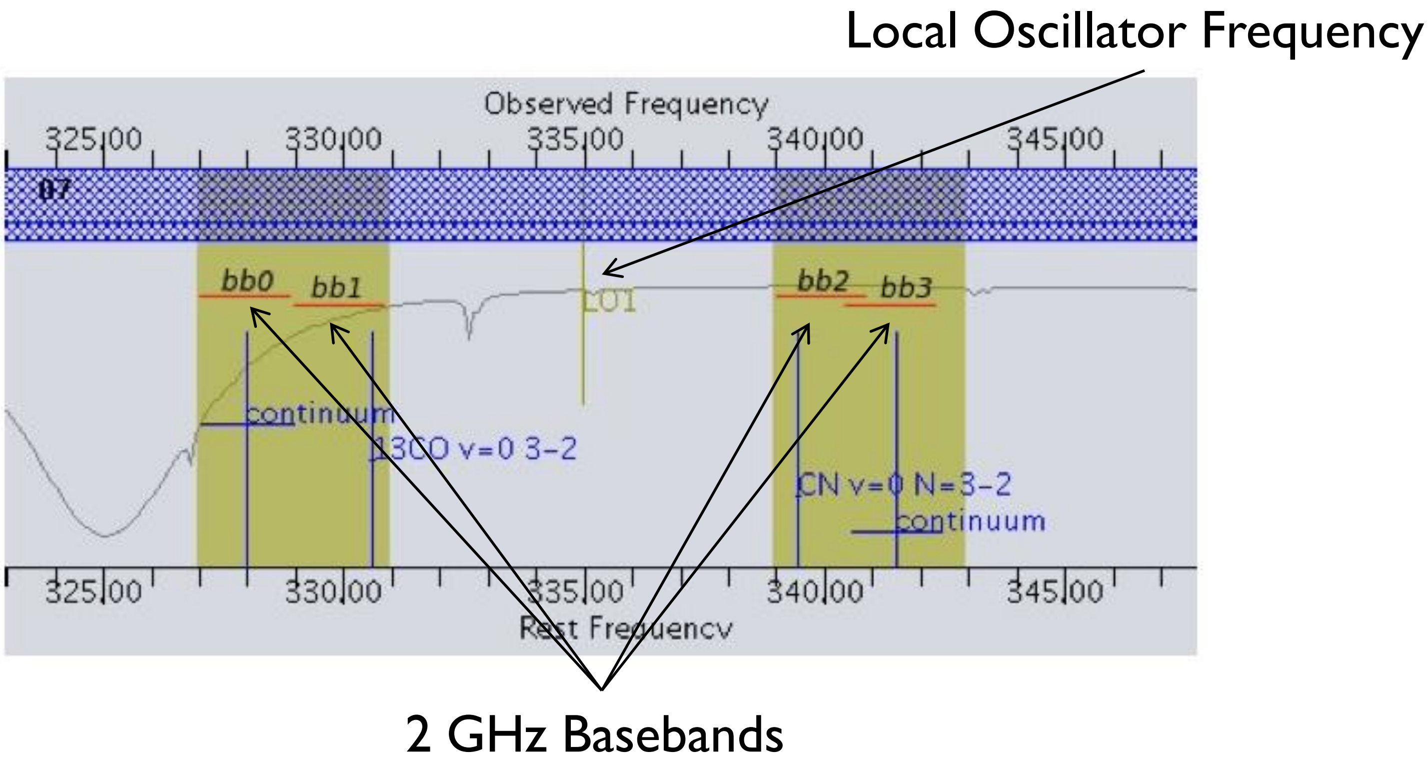


Fixed separation between sidebands

Bands 3, 7, 9: 8 GHz, Band 6: 10 GHz

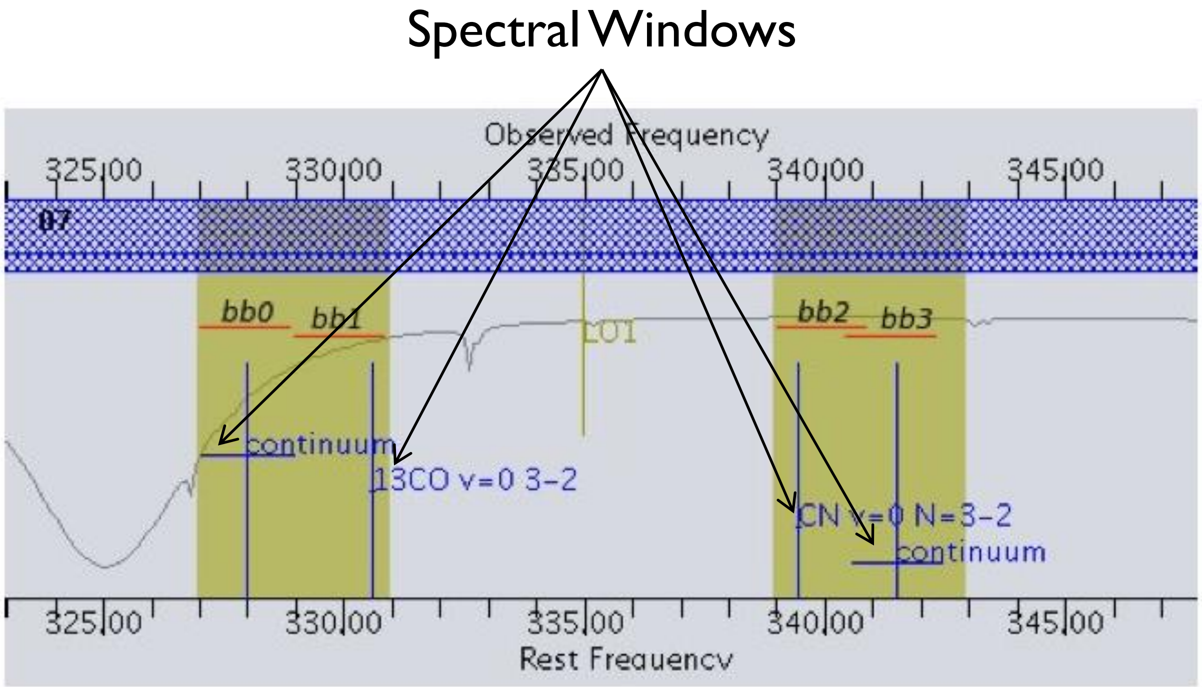
Basebands

- Each antenna has 4 digitizers which can each sample 2 GHz of bandwidth
- These 2 GHz chunks are termed **basebands** (they may overlap)
- Basebands must be distributed in the frequency covered by the sidebands (all 4 in one sideband, or two in each; Band 9 does not have this restriction)



Spectral Windows

- To collect data, you set up a **spectral window** in one or more basebands
- These regions of the spectrum are processed by the correlator
- The correlator allows tradeoff of frequency resolution and bandwidth
- In Cycle 1, 4 spectral windows are available.
- Spectral windows must lie within the baseband, sideband, receiver range.



In Practice

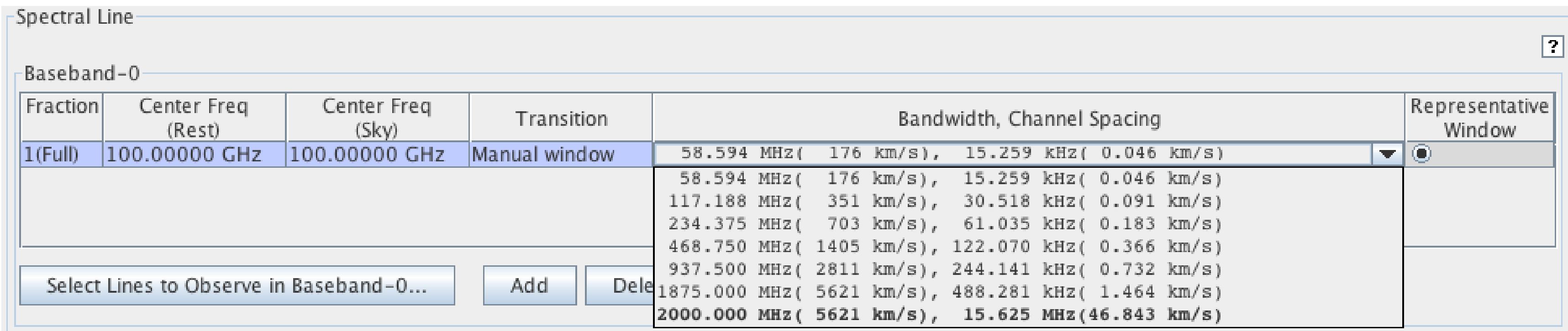
- **Pick a frequency (by hand or source + line) for each SPW**
- Pick a correlator mode for each SPW
- The OT will configure the LO and basebands to match (if possible)

Select a line, with your source velocity, this defines a frequency.

Add a spectral window by hand.

In Practice

- Pick a frequency (by hand or source + line) for each SPW
- **Pick a correlator mode for each SPW**
  THIS INVOLVES TRADING OFF BETWEEN RESOLUTION AND BANDWIDTH.
- The OT will configure the LO and basebands to match (if possible)



Pick a correlator mode from the drop-down menu.

In Practice

- Pick a frequency (by hand or source + line) for each SPW
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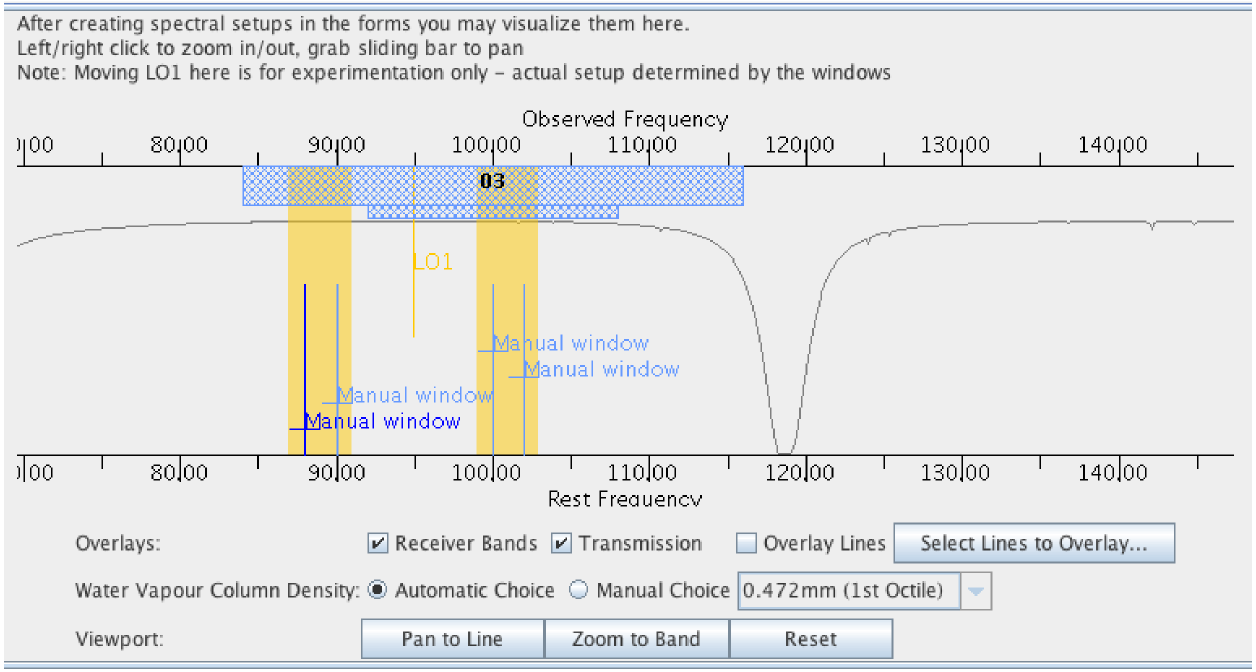
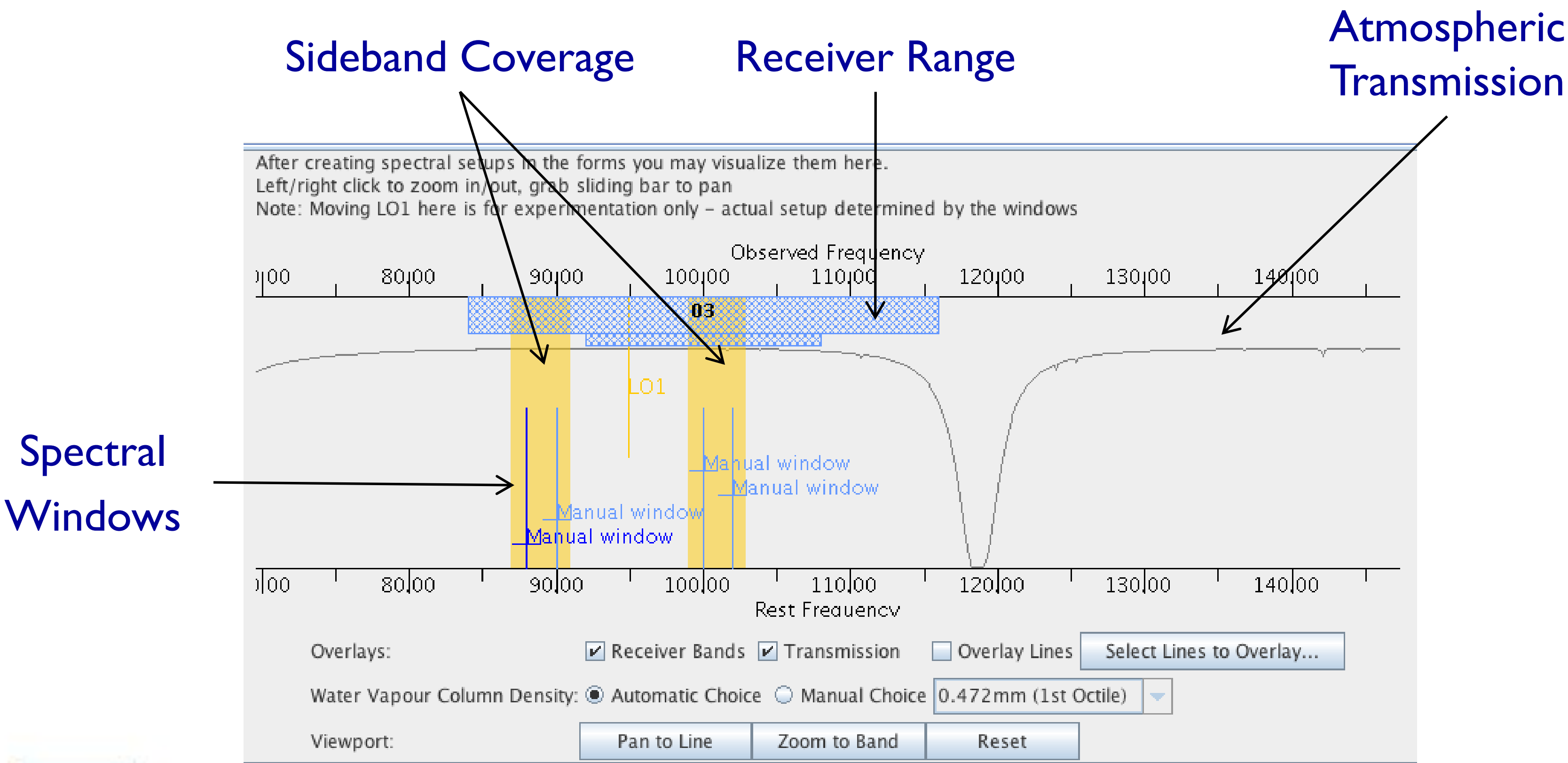


VISUALIZING THE SPECTRAL SETUP IN THE OT

In Practice

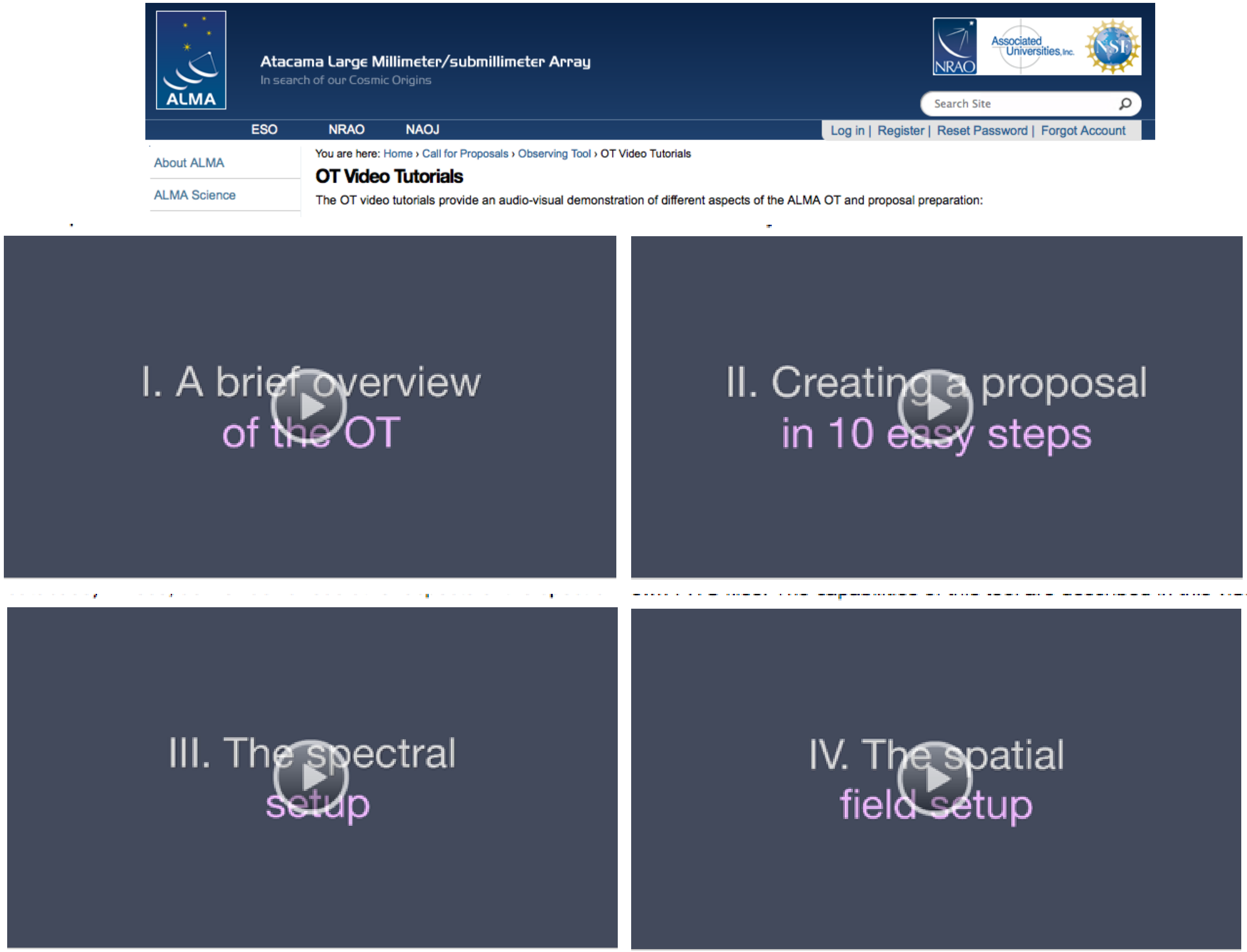
- Pick a frequency (by hand or source + line) for each SPW
- Pick a correlator mode for each SPW
- **The OT will configure the LO and basebands to match (if possible)**



VISUALIZING THE SPECTRAL SETUP IN THE OT

Practical Introduction

- Video Tutorials and Quickstart Guides
- https://almascience.nrao.edu/call-for-proposals/observing-tool/video-tutorials

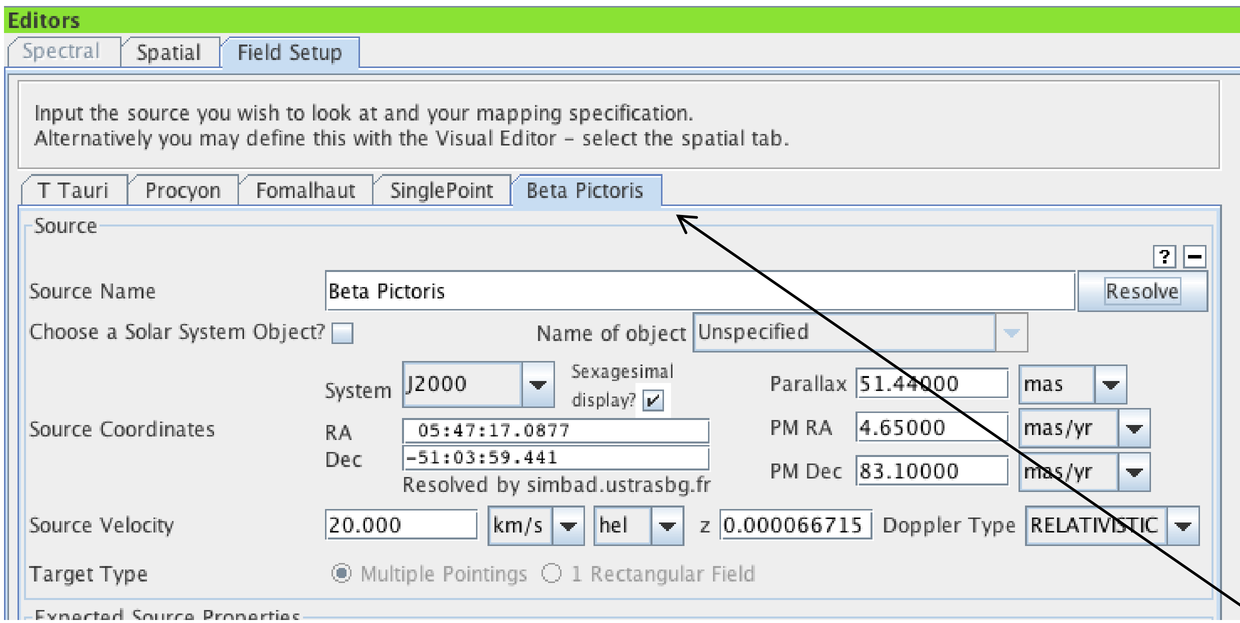


Key Proposal Factors

- Framework: Science Goals
- Spectral Setup
- **Spatial Setup**
- Control and Performance Specifications
- Logistics

Target Definition

- **Single field**
  UP TO 15 INDIVIDUAL FIELDS IN ONE SCIENCE GOAL <u>IF</u> THEY ARE WITHIN 15°
  UP TO 5 DIFFERENT VELOCITIES IN EACH SCIENCE GOAL
- Mosaic
  OFFSETS ARE MOSAICS, MOSAICS SACRIFICE EFFICIENCY FOR IMAGING QUALITY
  UP TO 150 POINTS (TOTAL: MOSAIC, OFFSET, OR SOURCE) PER PROPOSAL



Multiple sources in one Science Goal

Target Definition

- Single field
  - UP TO 15 INDIVIDUAL FIELDS IN ONE SCIENCE GOAL IF THEY ARE WITHIN 15°
  - UP TO 5 DIFFERENT VELOCITIES IN EACH SCIENCE GOAL
- Mosaic
  - OFFSETS ARE MOSAICS, MOSAICS SACRIFICE EFFICIENCY FOR IMAGING QUALITY
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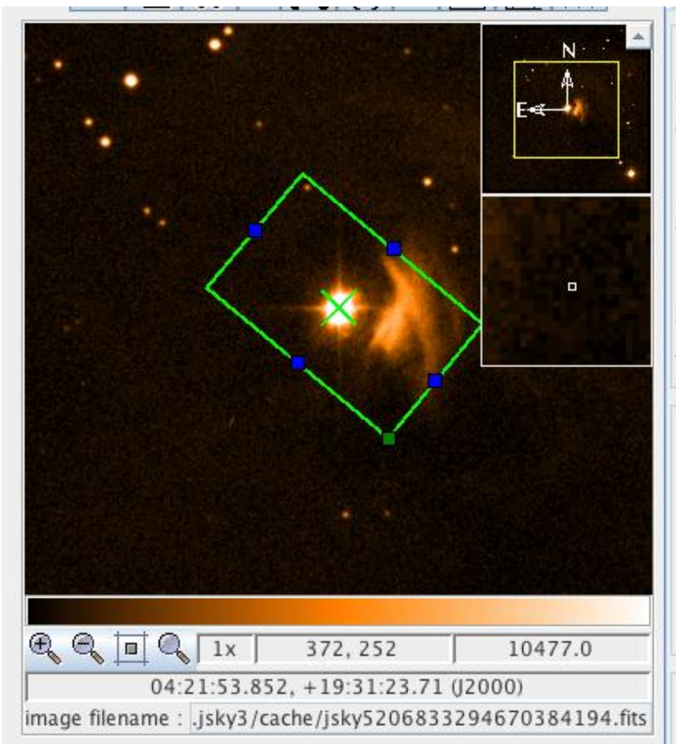
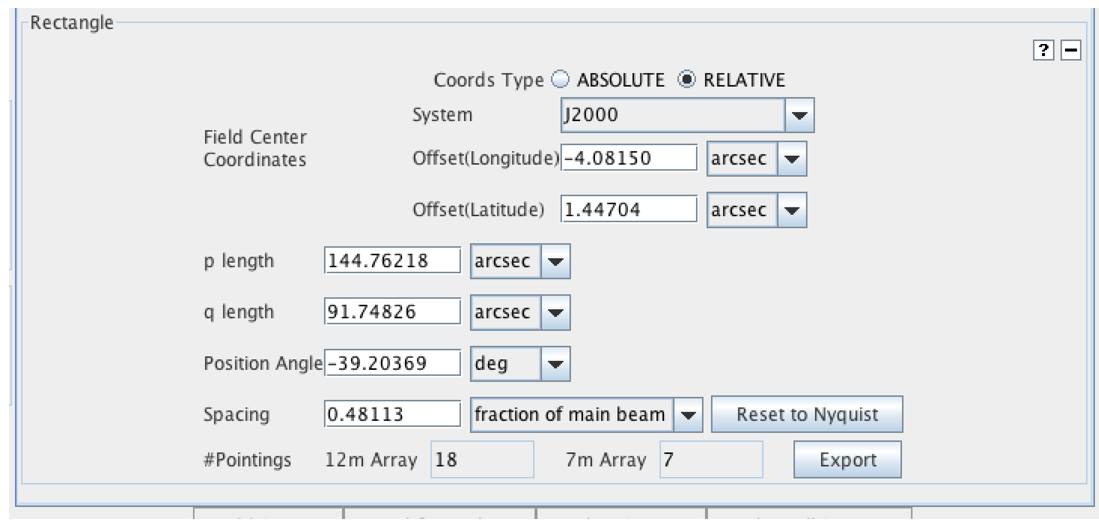
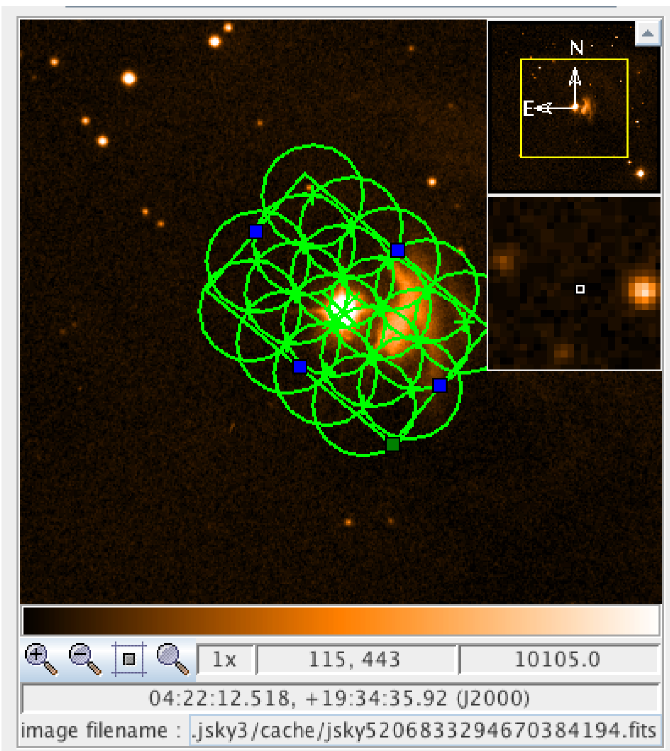




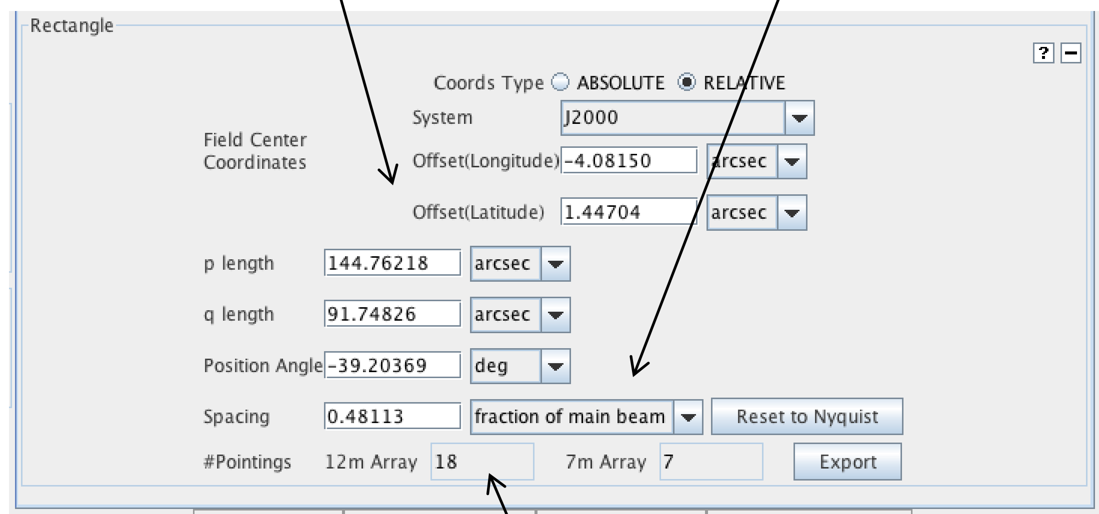
Target Definition

- Single field
  Up to 15 individual fields in one Science Goal if they are within 15°
  Up to 5 different velocities in each Science Goal
- Mosaic
  Offsets are mosaics, mosaics sacrifice efficiency for imaging quality
  Up to 150 points (total: mosaic, offset, or source) per proposal



Orientation and Extent

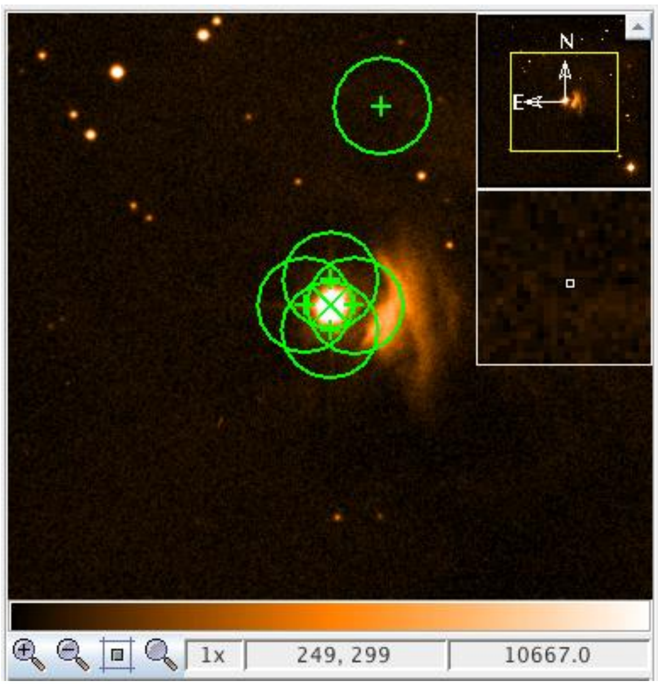
Field Spacing

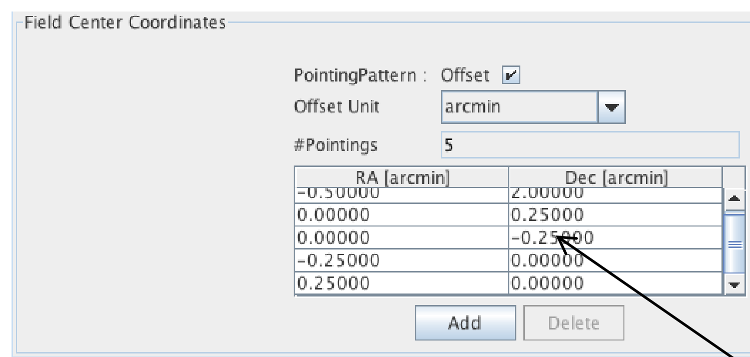


Number of Fields

Target Definition

- Single field
  - UP TO 15 INDIVIDUAL FIELDS IN ONE SCIENCE GOAL IF THEY ARE WITHIN 15°
  - UP TO 5 DIFFERENT VELOCITIES IN EACH SCIENCE GOAL
- Mosaic
  - **OFFSETS** ARE MOSAICS, MOSAICS SACRIFICE EFFICIENCY FOR IMAGING QUALITY
  - UP TO 150 POINTS (TOTAL: MOSAIC, **OFFSET**, OR SOURCE) PER PROPOSAL





Individual Offset
Field Centers

Key Proposal Factors

- Framework: Science Goals
- Spectral Setup
- Spatial Setup
- **Control and Performance Specifications**
- Logistics

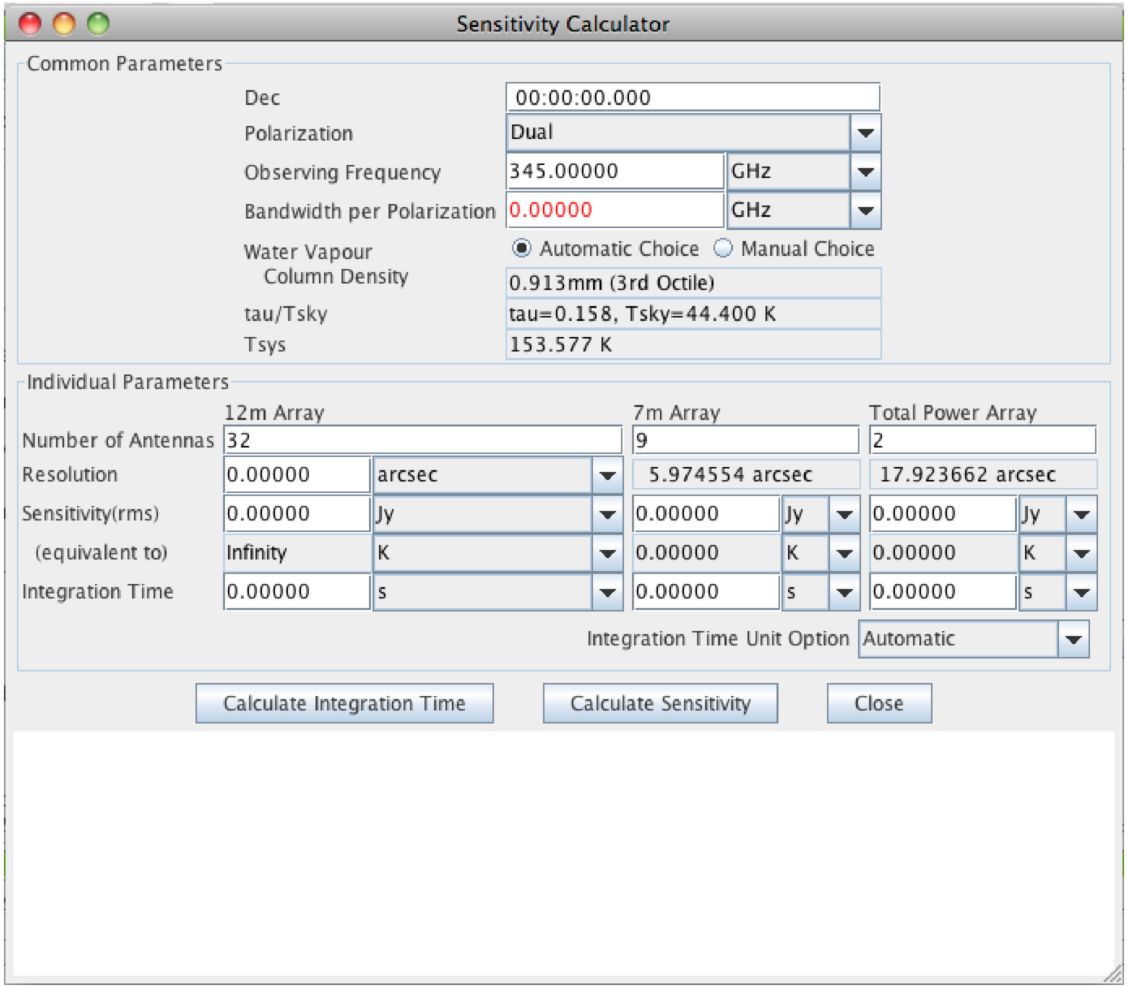
Control and Performance

- Target angular resolution
  CONSTRAINS TELESCOPE CONFIGURATION ALLOWED WHEN DATA ARE TAKEN
- Largest angular scale expected for target
  LARGEST ANGULAR EXTENT OF TARGET.
- Target RMS noise
  FOR A FIDUCIAL FREQUENCY AND BANDWIDTH (BOTH USER SPECIFIED)
- Request for ACA observations
  LARGEST ANGULAR SCALE + TARGET ANGULAR RESOLUTION WILL RECOMMEND

Sensitivity

- Target RMS noise

  FOR A FIDUCIAL FREQUENCY AND BANDWIDTH (BOTH USER SELECTED)



Sensitivity

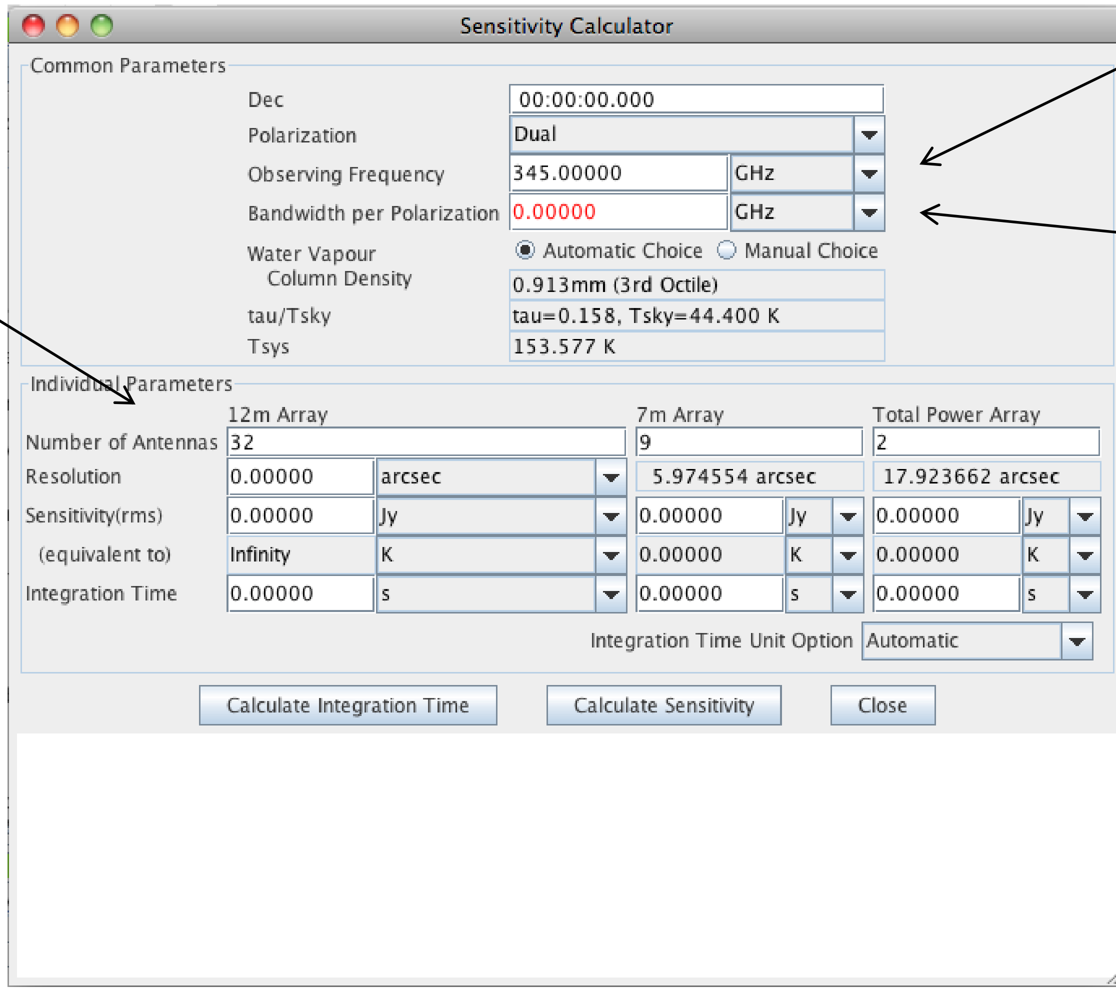
- Target RMS noise

  FOR A FIDUCIAL FREQUENCY AND BANDWIDTH (BOTH USER SELECTED)

Fiducial Frequency

Fiducial Bandwidth

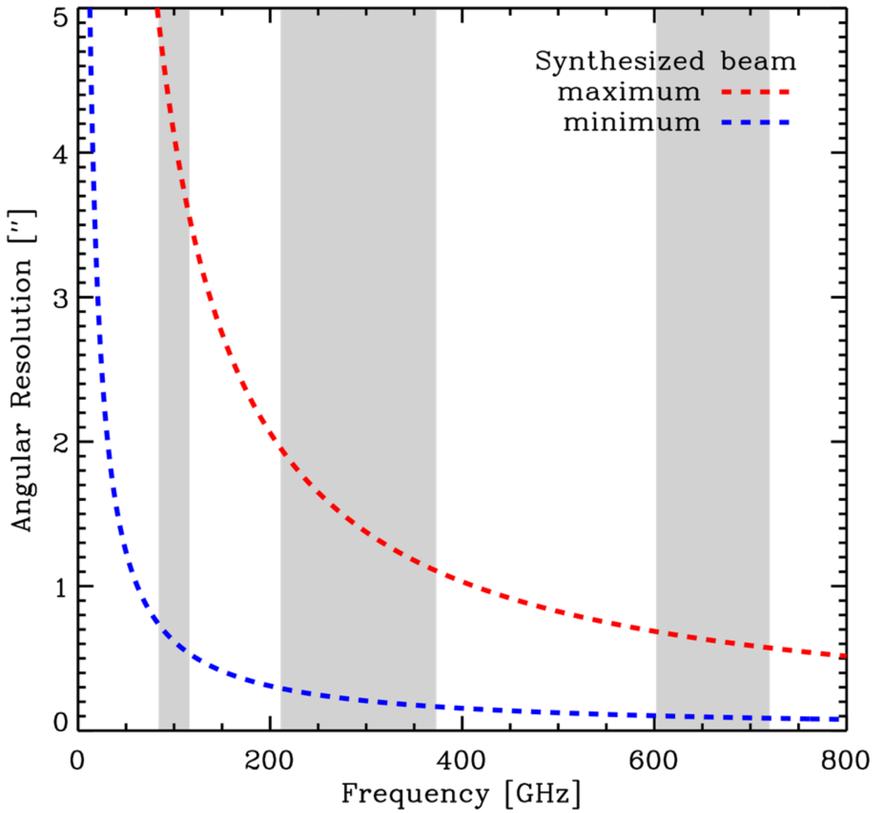
Cycle 1 Capabilities



Resolution

- Target angular resolution
  CONSTRAINS TELESCOPE CONFIGURATION ALLOWED WHEN DATA ARE TAKEN

- High resolution leads to lower surface brightness sensitivity
  RMS PROPORTIONAL TO BEAMWIDTH^2 HOLDING ALL OTHER FACTORS FIXED.



Maximum Angular Scale

- Maximum angular scale (MAS) recovered by array

Band	Frequency (GHz)	Primary beam (")	Range of Scales (") C32-1	C32-6
3	84-116	72 - 52	4.2 - 24.6	0.7 - 15.1
6	211-275	29 - 22	1.8 - 10.7	0.3 - 6.6
7	275-373	22 - 16	1.2 - 7.1	0.2 - 4.4
9	602-720	10 – 8.5	0.6 - 3.6	0.1 - 2.2

- **Smooth** structures larger than MAS begin to be resolved out.

- All flux on scales larger than λ/B_{min} (~2 x MAS) completely resolved out.
  NEED ADDITIONAL OBSERVATIONS WITH A SINGLE-DISH OR A COMPACT ARRAY OF SMALL TELESCOPES.

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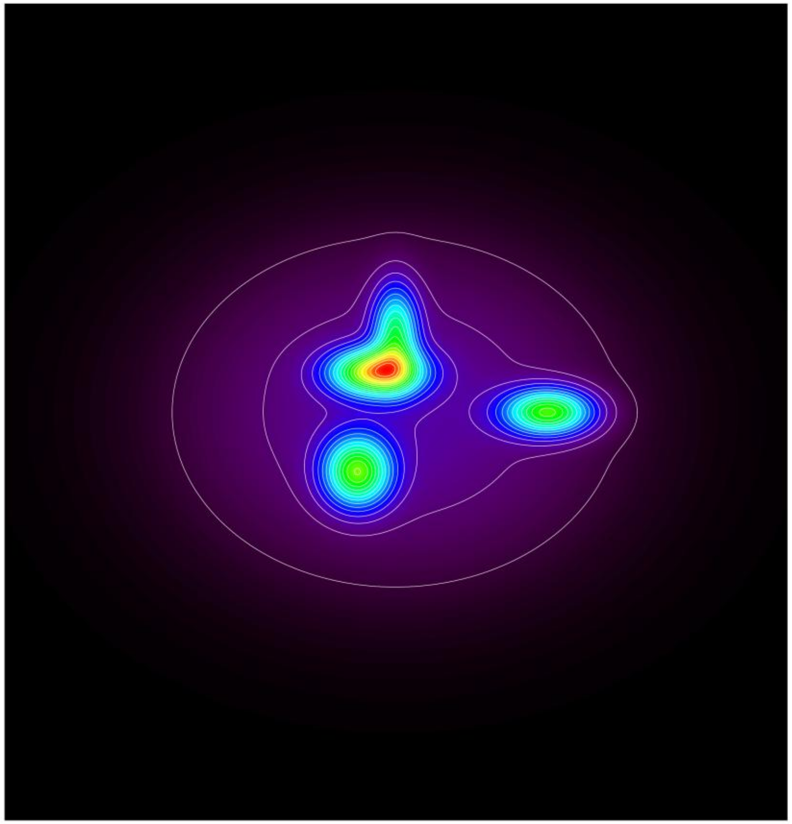
Largest Angular Scale (LAS)

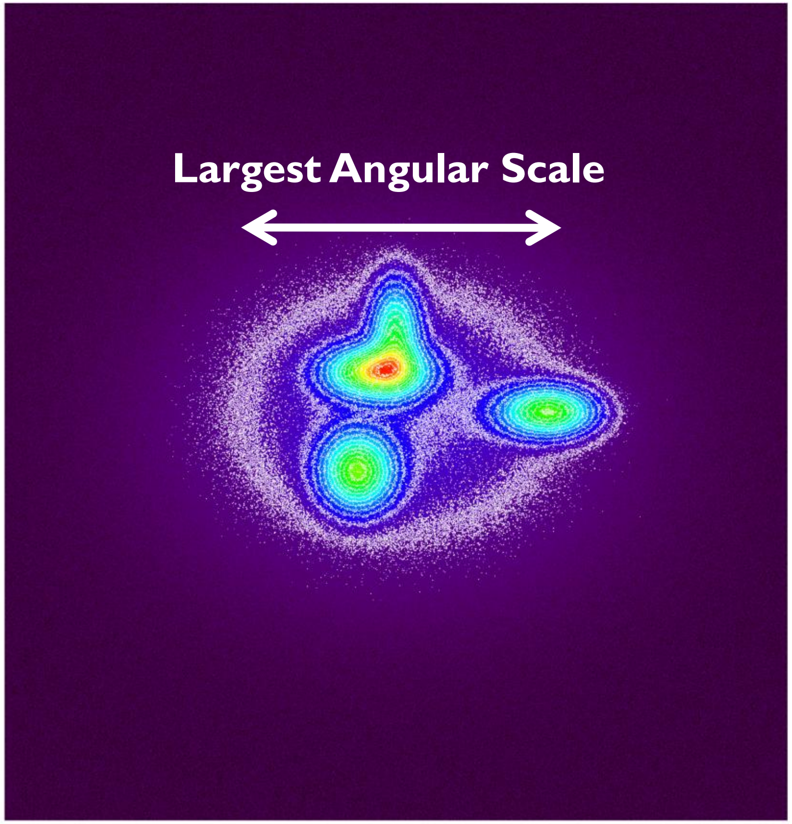
- Largest angular scale of interest for target
  DEPENDS ON SOURCE STRUCTURE AND SCIENCE AIMS



e.g., compact sources embedded in a smooth superstructure holding ~65% of flux (here with perfect S/N)

Largest Angular Scale (LAS)

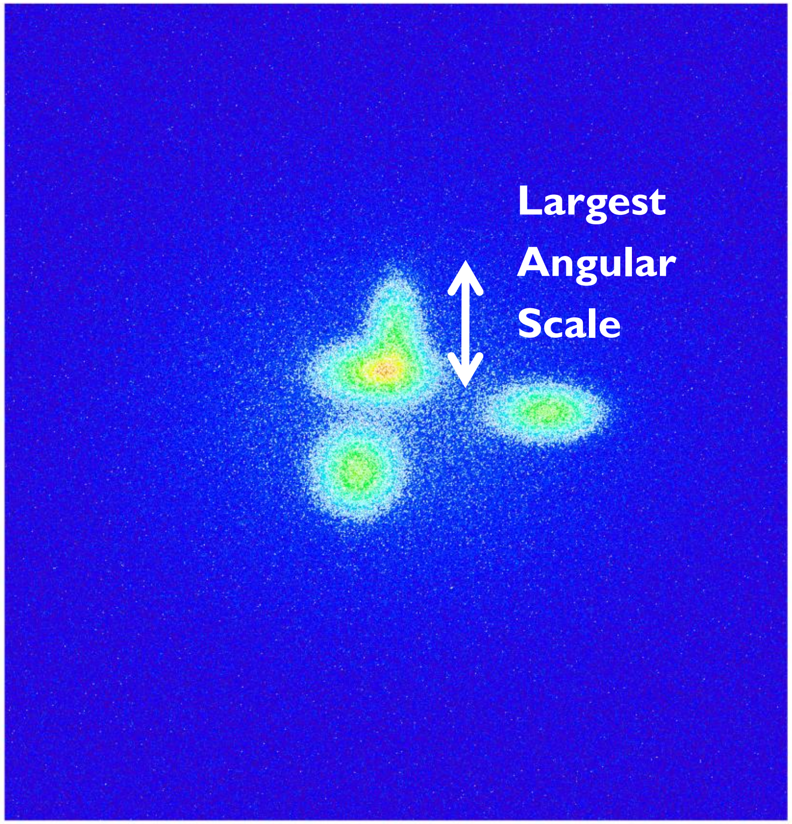
- Superstructure of scientific interest?
  THEN YOUR RMS AND LAS MUST REFLECT THAT.



RMS set to detect superstructure and LAS input to reflect size of structure.

Largest Angular Scale (LAS)

- Only embedded compact sources of interest?



RMS set to detect compact sources and LAS input to reflect compact source size.

To Use the ACA?

ALMA

Largest Angular Scale of Source

Property of the source and your science.

Maximum Angular Scale Recovered by Array

Related to target angular resolution (in Cycle 1) because that drives the configuration of antennas used.

ACA Recommended?

If Largest Angular Scale too big for Maximum Angular Scale of 12-m Array, then the OT will recommend the inclusion of the ACA.

Ultimately YOUR Decision

ONLY ~250 hours (1/3 of total time) will go to projects needing ACA.

NRAO

To Use the ACA?

ALMA

Largest Angular Scale of Source

Property of the source and your science.

Maximum Angular Scale Recovered by Array

Related to target angular resolution (in Cycle 1) because that drives the configuration of antennas used.

ACA Recommended?

If Largest Angular Scale too big for Maximum Angular Scale of 12-m Array, then the OT will recommend the inclusion of the ACA.

ACA not available for highest resolutions (not enough overlap in u-v coverage)

Ultimately YOUR Decision

ONLY ~250 hours (1/3 of total time) will go to projects needing ACA.

NRAO

To Use the ACA?

- When in doubt, simulate!
  "Observe" a model of your target with 12-m and 12-m+ACA, compare

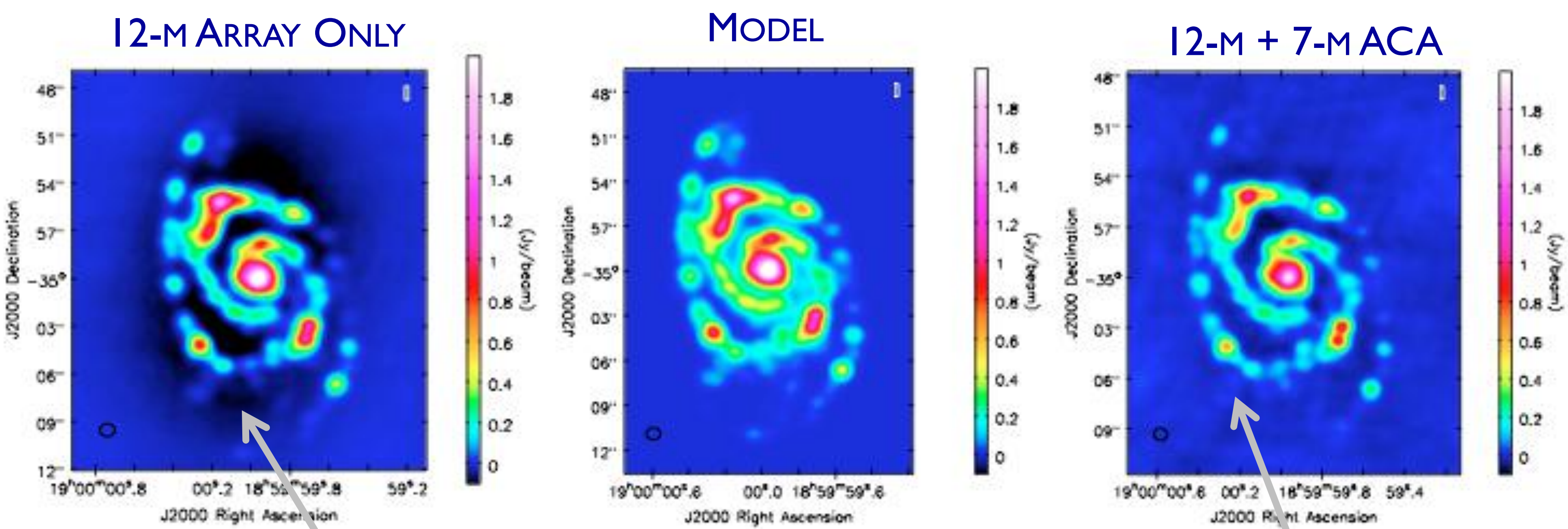


Image reconstruction artifact ("bowls")

Not present when 7-m antennas included

Key Proposal Factors

ALMA

- Framework: Science Goals
- Spectral Setup
- Spatial Setup
- Control and Performance Specifications
- **Logistics**

Proposal Checklist

ALMA

- ❑ Read Primer and Proposer's Guide
- ❑ **Create an ALMA account by registering at the Science Portal**
- ❑ **Download the Observing Tool (OT)**
- ❑ Familiarize yourself with the OT via the Quickstart Video
- ❑ **Define your Science Goals within the OT**
  - use the OT to understand if your science goals match ALMA's capabilities
  - use CASA simdata for a more thorough exploration
  - take advantage of the TA Checklisted generated by the OT
- ❑ **Prepare the Science & Technical Justifications (one PDF file)**
  - Annotated LaTeX template available
- ❑ Make use of the Helpdesk & the Knowledgebase
- ❑ **Submit to Archive!**

Required Step

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TA Checklist

ALMA

Checklist of technical concerns generated by the OT as part of PDF output

F-1

Field Setup:

Target(s) max. elevation is low (< 20 degrees)	—
Target(s) max. elevation is high (> 84 degrees)	—
Non-zero proper motion of target(s)	1
Spatial dynamic range > 500 (on basis of peak flux to rms)	—
Spectral dynamic range > 1000 (B3, B6), 500 (B7), 100 (B9)	—
Mosaic pointing separation outside range 0.48 - 0.8 1.2*λ/D	—
Velocity frame is not LSR_K	1
Velocity definition is relativistic	1

Spectral Setup:

Single Polarization selected	—
Linewidth > 90% spectral window width	—
Single spectral window only selected	—

Calibration:

Any user calibration selected	—

Control and Parameters:

Largest scale of interest > max. recoverable scale	1
Extra time selected	—
ACA request and necessity estimator diagreement	—

NRAO

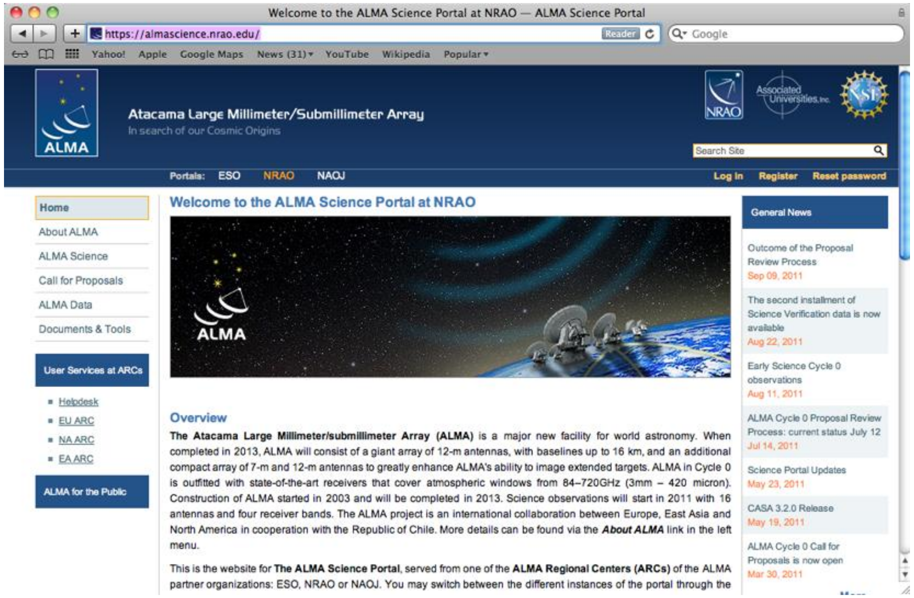
The ALMA Science Portal

https://almascience.nrao.edu

ALMA

Hub for project-wide material.

- Observing Tool
- Sensitivity Calculator
- Proposer's Guide
- Technical Handbook
- Science Verification Data
- CASA & Simulations
- Tutorials
- **Helpdesk**



Registration required to propose.

NRAO

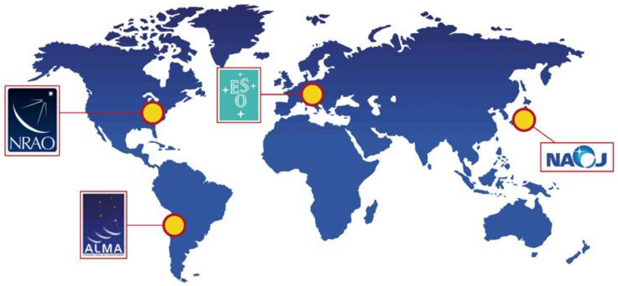
The NAASC

https://science.nrao.edu/facilities/alma

ALMA

The North American ALMA Science Center

- One of three ALMA Regional Centers
- Offers science support to NA
  Any Taiwain or world members who request.



Support for:

- Proposal preparation & submission
- Observation preparation
- Data archive
- Data processing
- Face-to-face visits for data reduction
- Workshops, tutorials, and outreach
- Some publication and student support