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

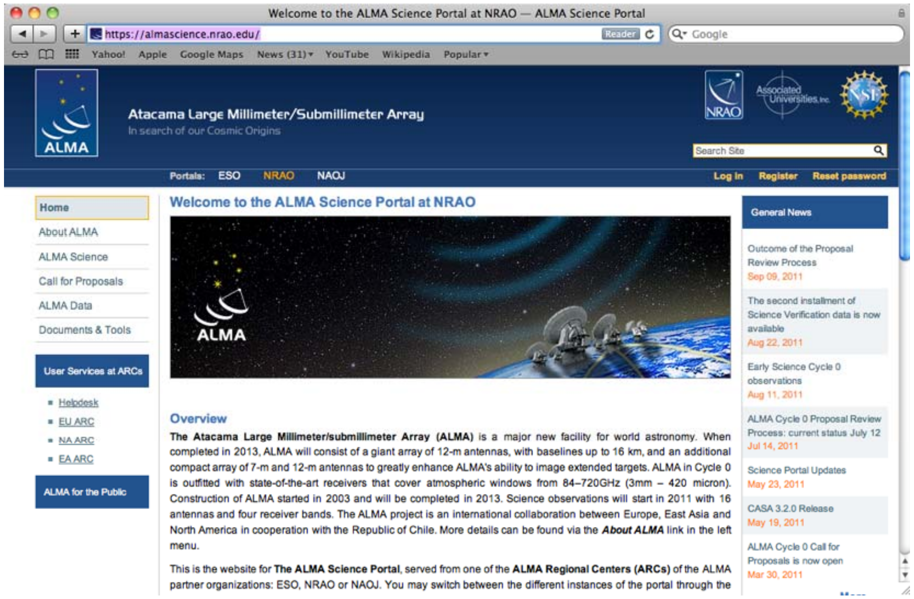
The ALMA Science Portal

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 for PIs and cols.

ALMA Basics

- Global partnership (shared cost ~1.3 billion 2006$):
  - North America (US, Canada, Taiwan)
  - Europe (ESO)
  - East Asia (Japan,Taiwan)
  - In collaboration with Chile

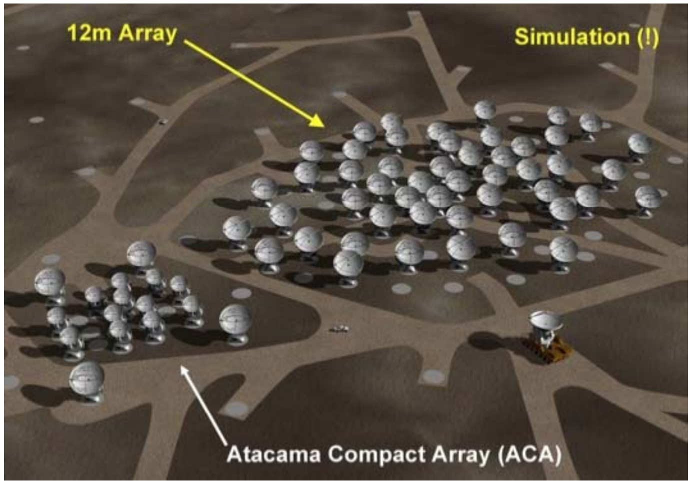
- Unique high, dry site:
  - 5000m (16,500 ft) in Chilean Atacama desert

- 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

ALMA Basics

ALMA



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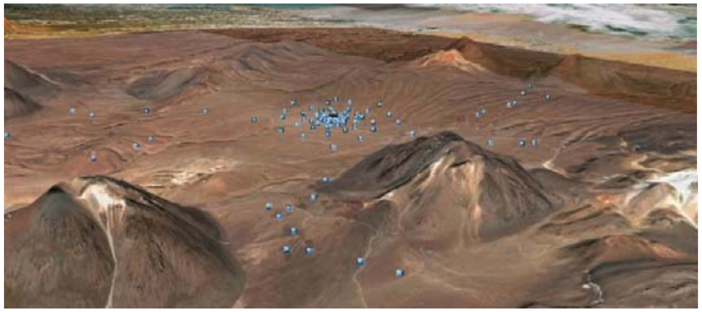
Full Science Capabilities

ALMA

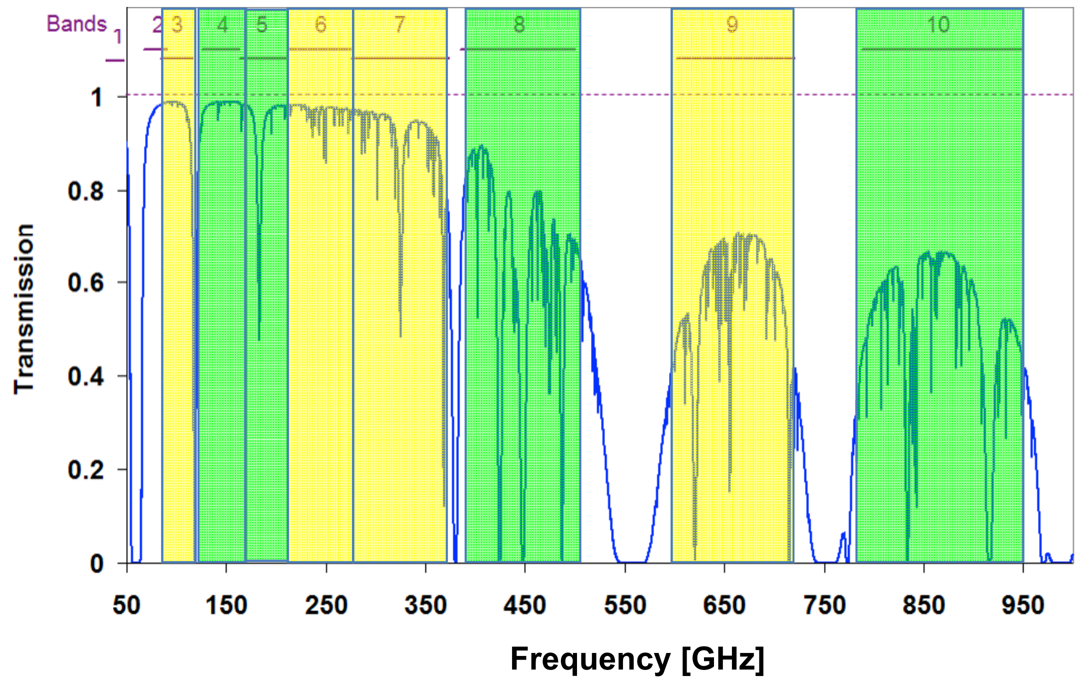
10-100× better sensitivity and resolution than current mm arrays.

- 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) employing 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
- Development Program: Future upgrades (B1,B2, B5, ?)



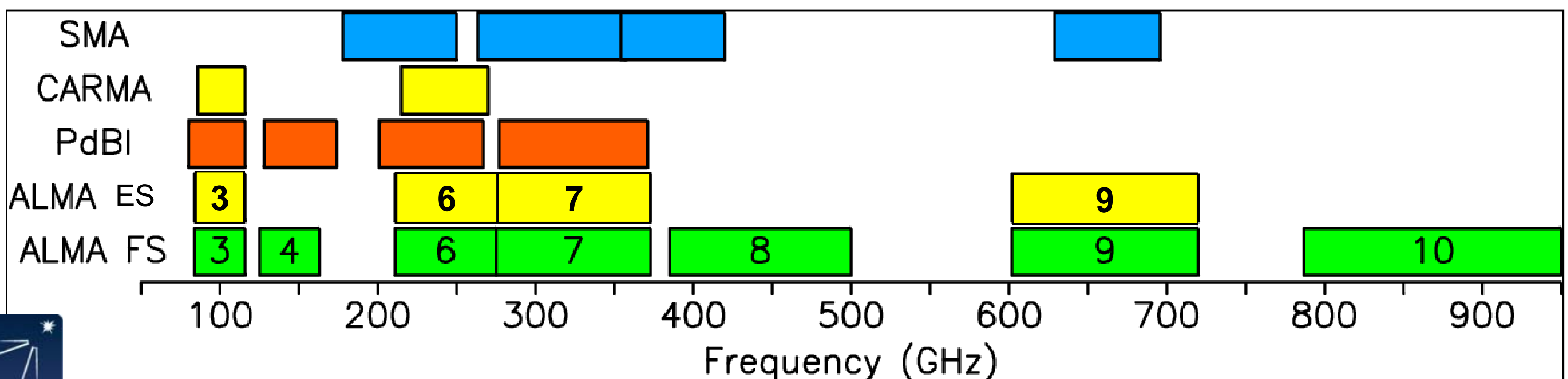
Frequency Coverage

ALMA



Early Science (now)

Full Operations



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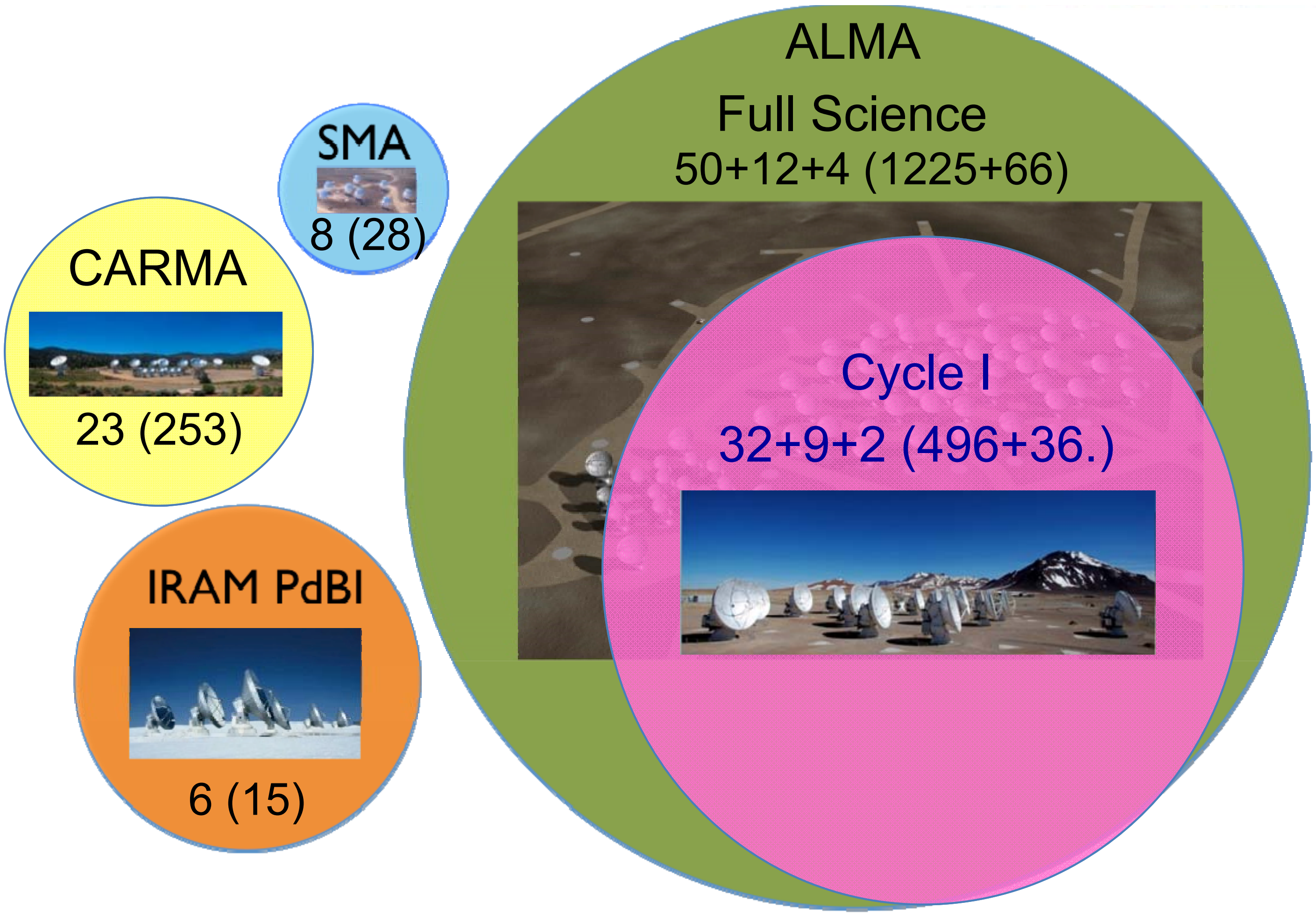
Collecting Area & Baselines



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.

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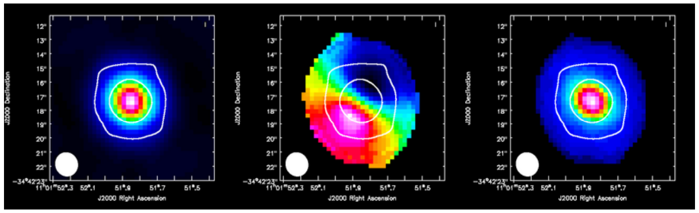
Science Verification Data

ALMA

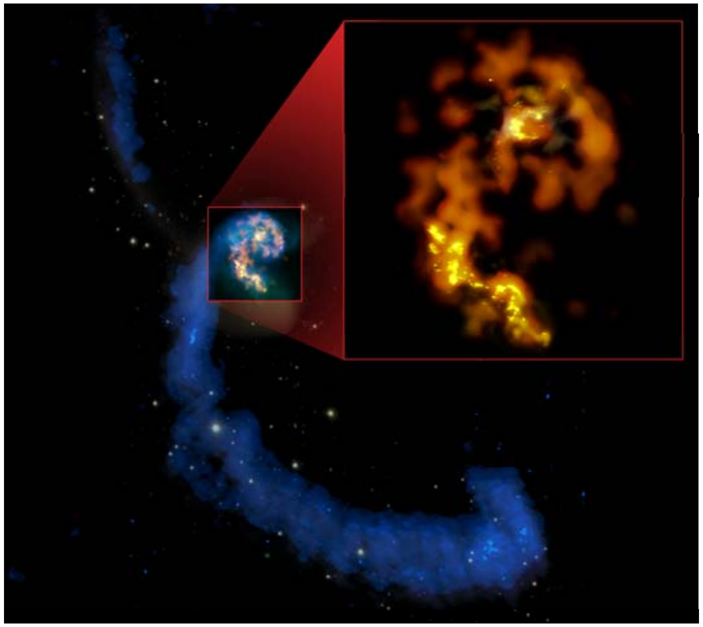
- ALMA data released for:
  BR1202 (HIGH REDSHIFT QUASAR)
  THE ANTENNAE GALAXIES*
  NGC 3256*
  M100
  SGR A-STAR
  ORI B6 SPECTRAL SCAN
  IRAS 16923 (B9*)
  TW HYDRA*

- Calibrated & uncalibrated data, images, periodically augmented
- download from ALMA Science Portal
  http://almascience.org/
- * - CASA guide available at
  http://casaguides.nrao.edu

HCO+ J=4-3 in TW Hya

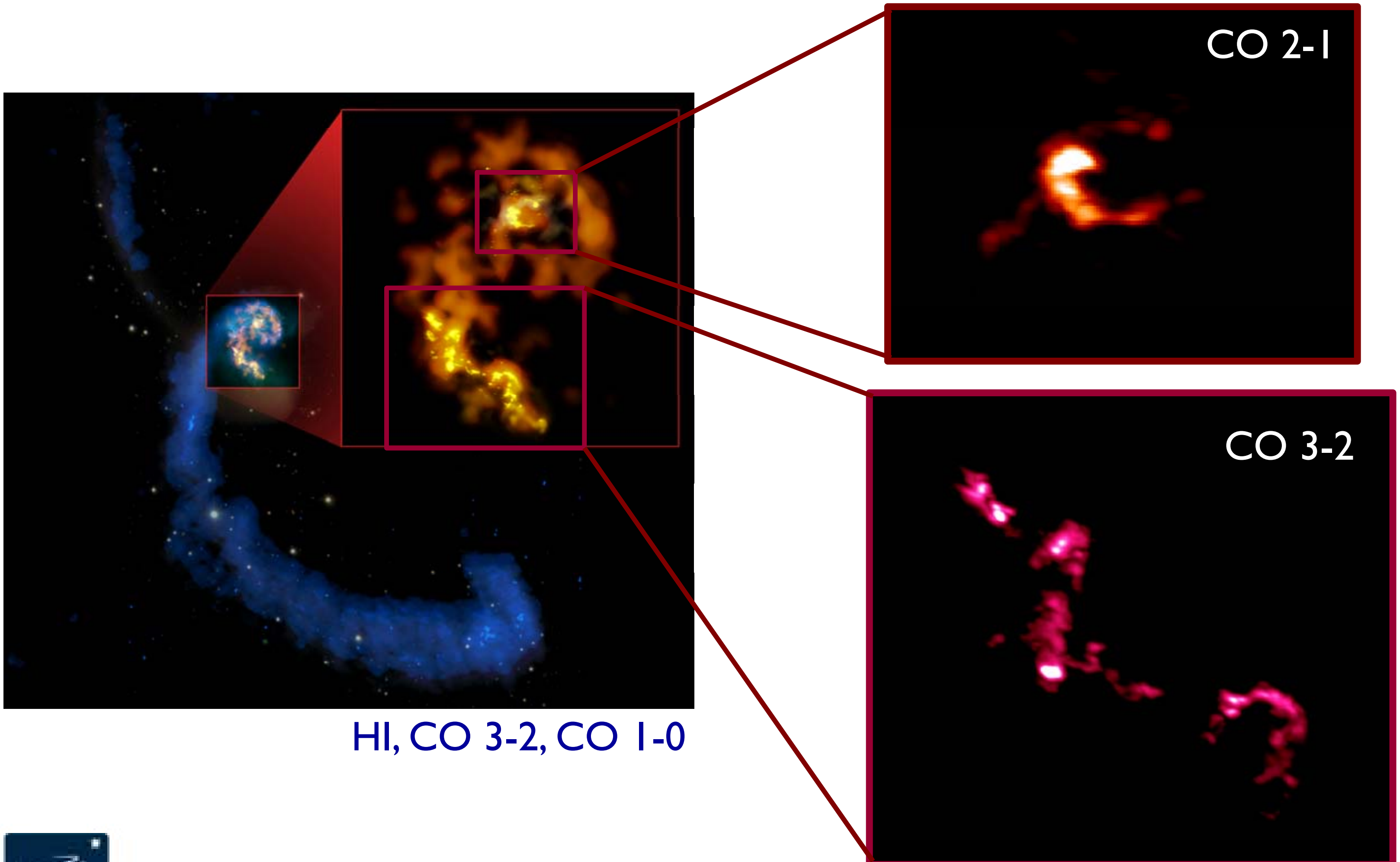


CO J=3-2 in the Antennae



ALMA Images Nearby Galaxies

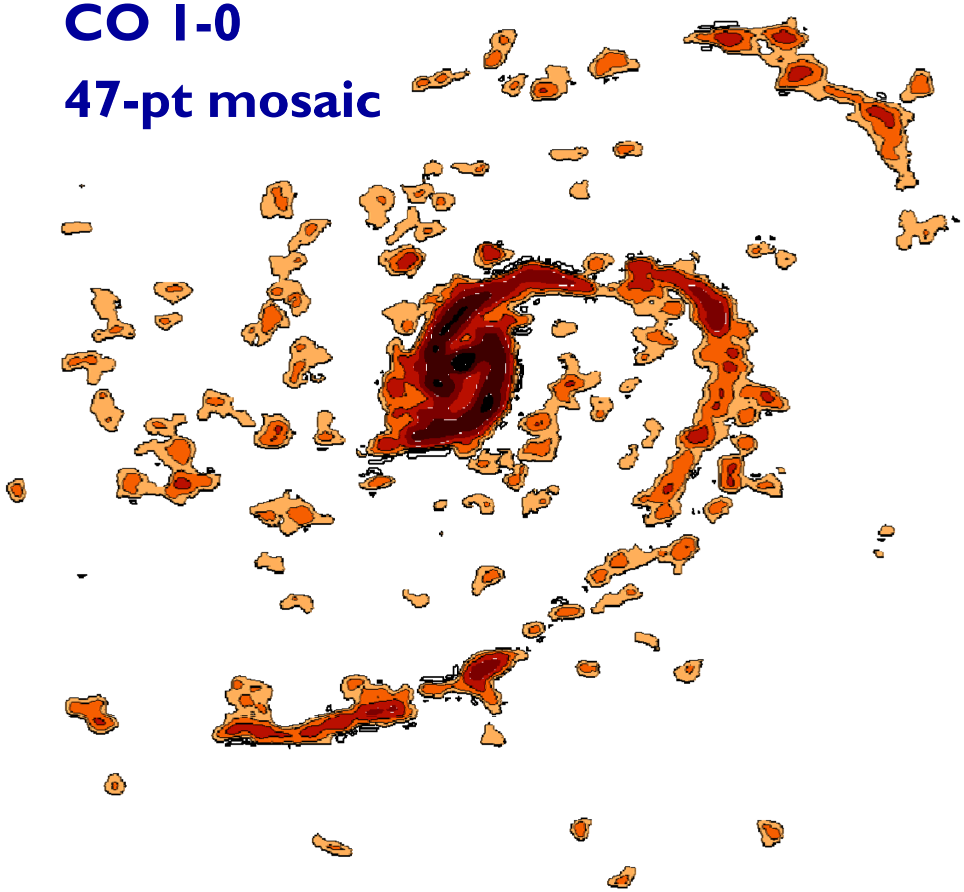
- Science verification imaging of the Antennae Galaxies

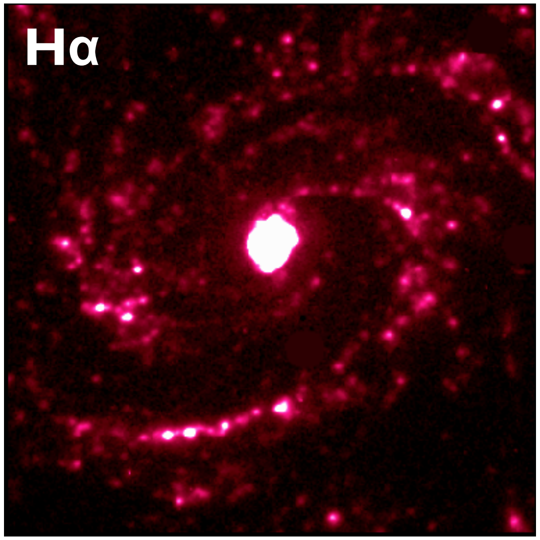


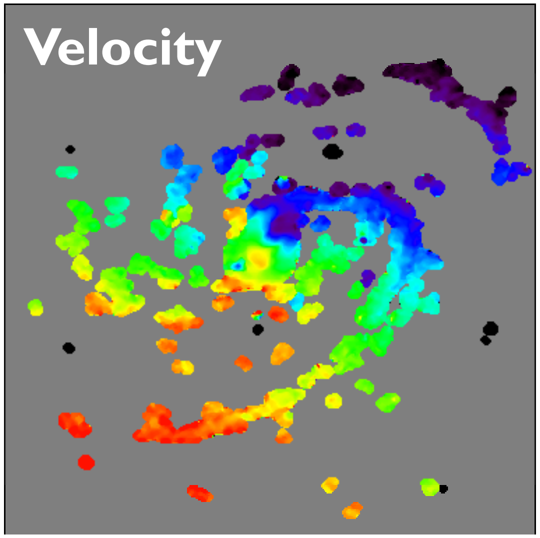
HI, CO 3-2, CO 1-0

ALMA Images Nearby Galaxies

- Science verification imaging of M100

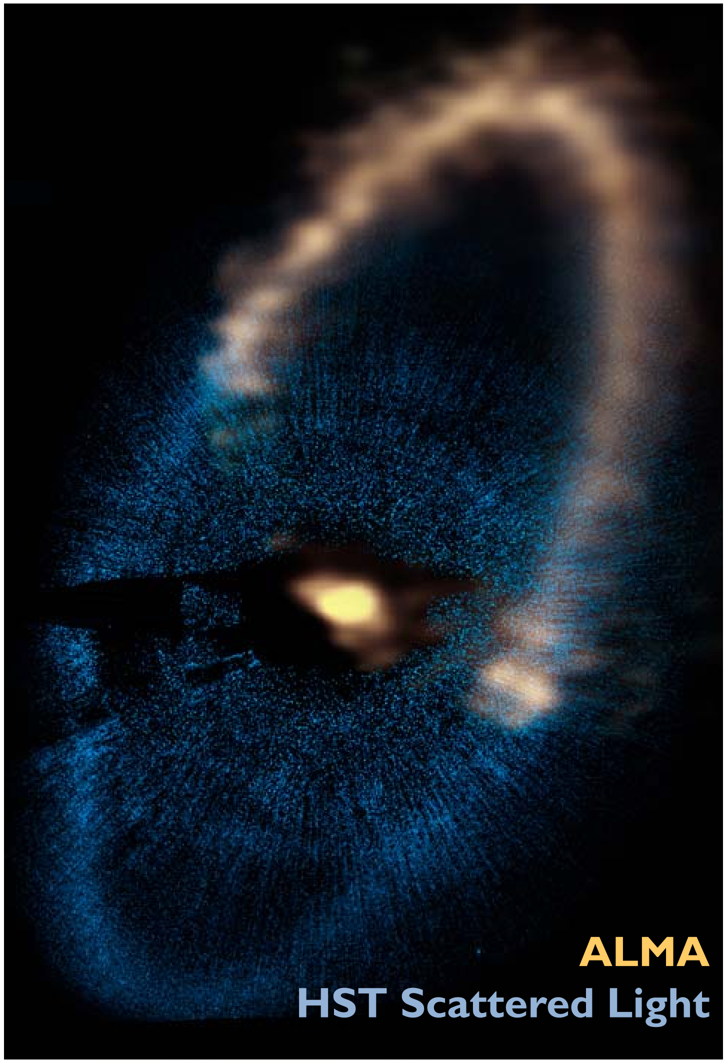






ALMA Images Debris Disks

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



ALMA Cycle 1

ALMA

- Proposals due July 12
  OBSERVING PERIOD COVERS ~10 MONTHS

- 32 12-m Antennas ("Twelve Meter Array")

- ACA: Nine 7-m Antennas, Two "Total Power" 12-m Antennas
  ACA OBSERVATIONS MAY BE REQUESTED TO SUPPLEMENT 12-M WITH "SHORT SPACINGS"

- Maximum baselines 160-m to 1-km

- Receiver Bands 3, 6, 7, and 9

- Mosaics up to 150 pointings

- About 800 hours of 12-m array time available
  UP TO ~ ONE-THIRD OF TIME MAY HAVE ACA OBSERVATIONS

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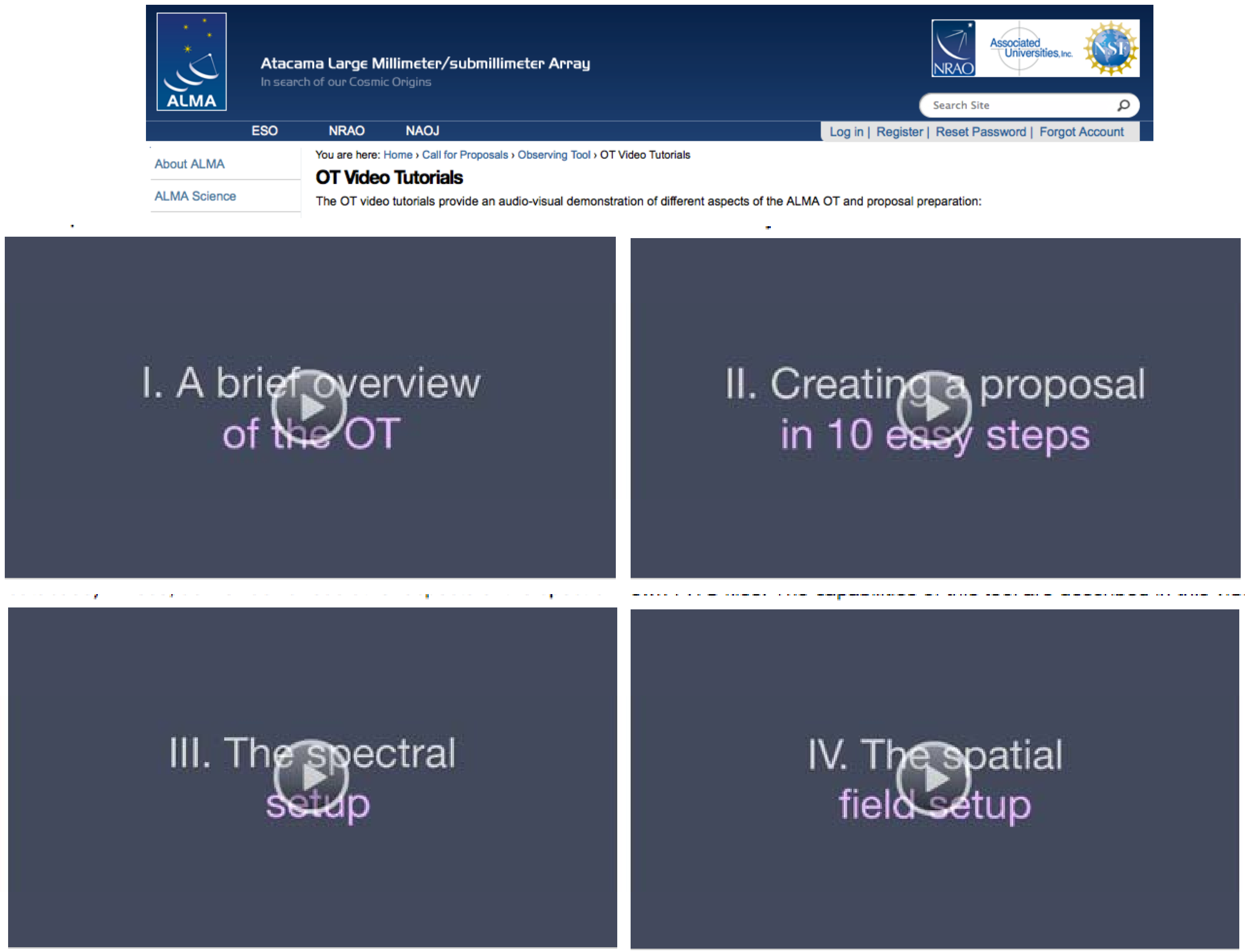
Talk Outline

ALMA

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

Practical Introduction

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



Key Proposal Factors

ALMA

- **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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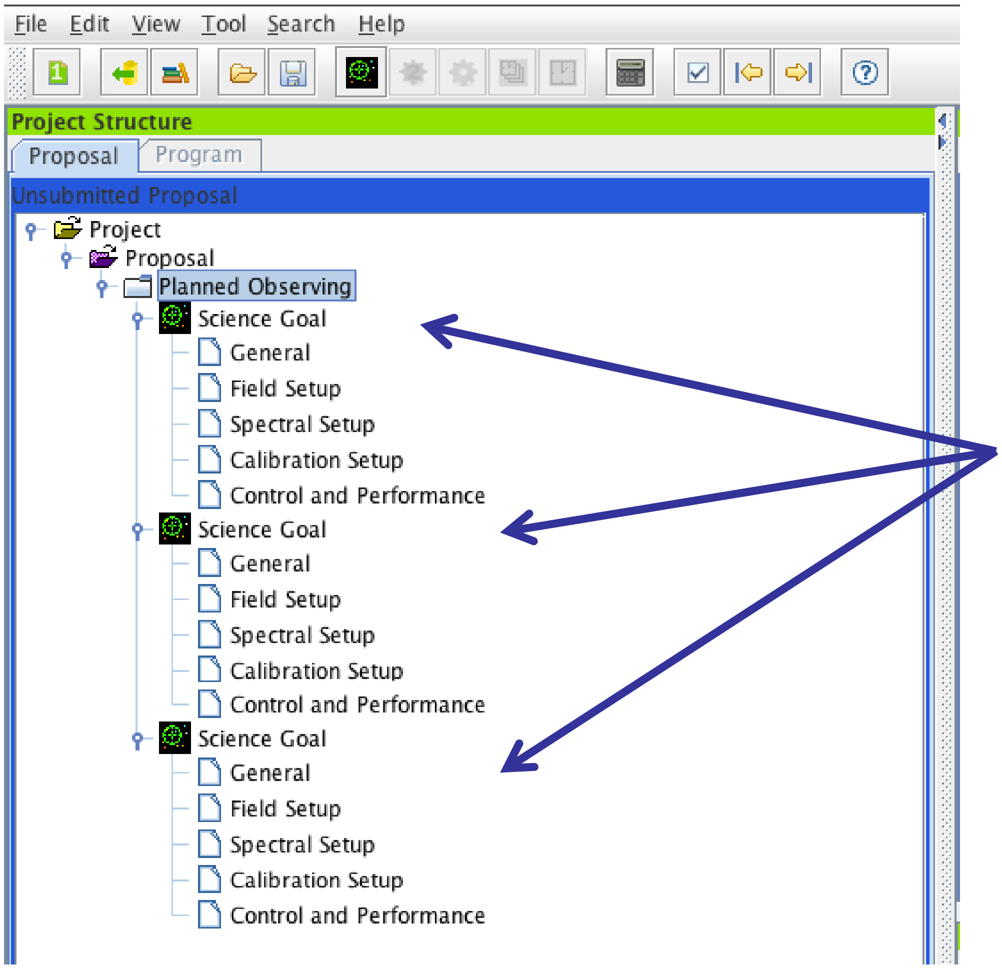
Science Goal (Cycle I)

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

Key Proposal Factors

ALMA

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

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Spectral Setup: Receiver

ALMA

- 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

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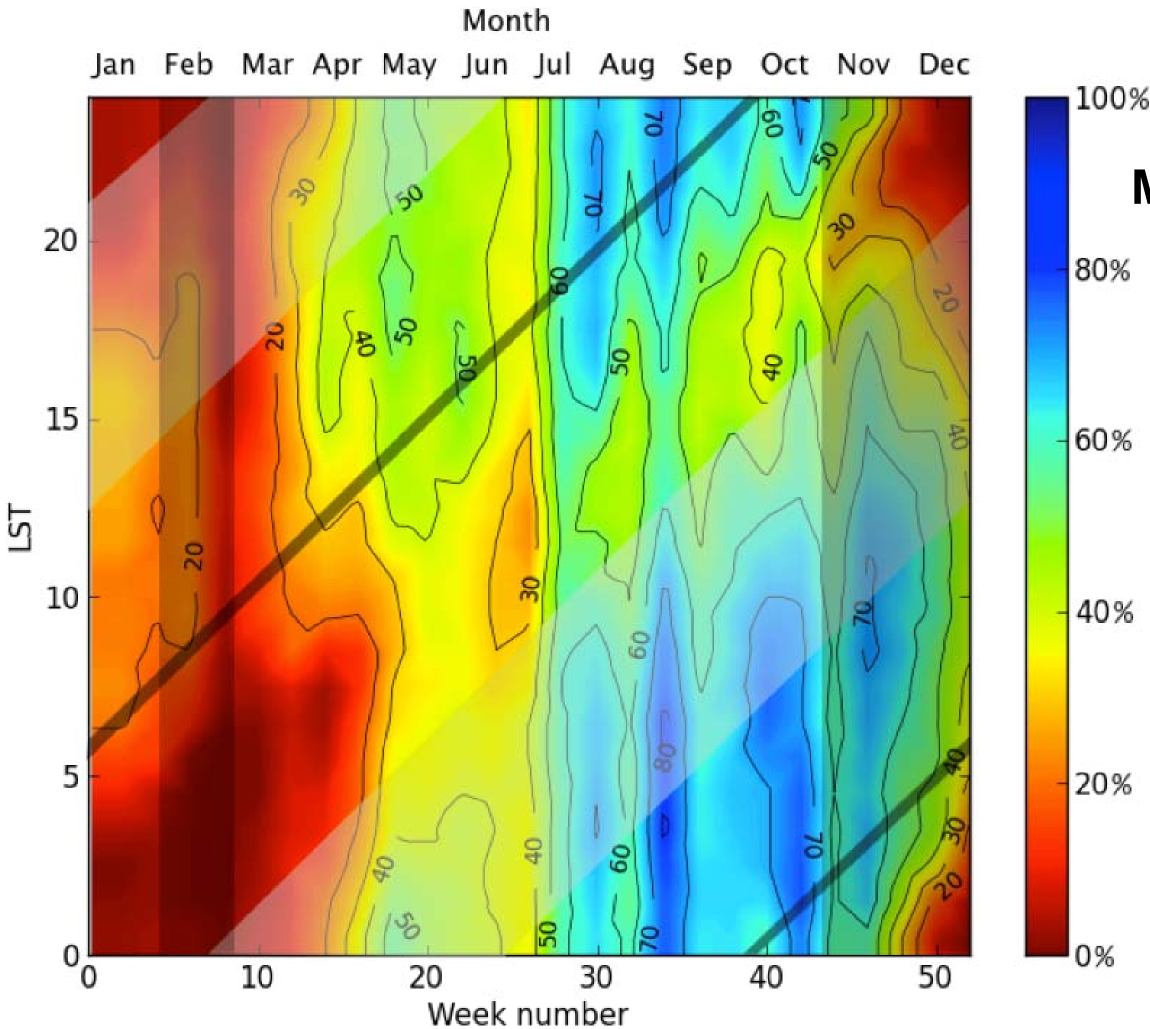
Spe

F



More transparent

More opaque

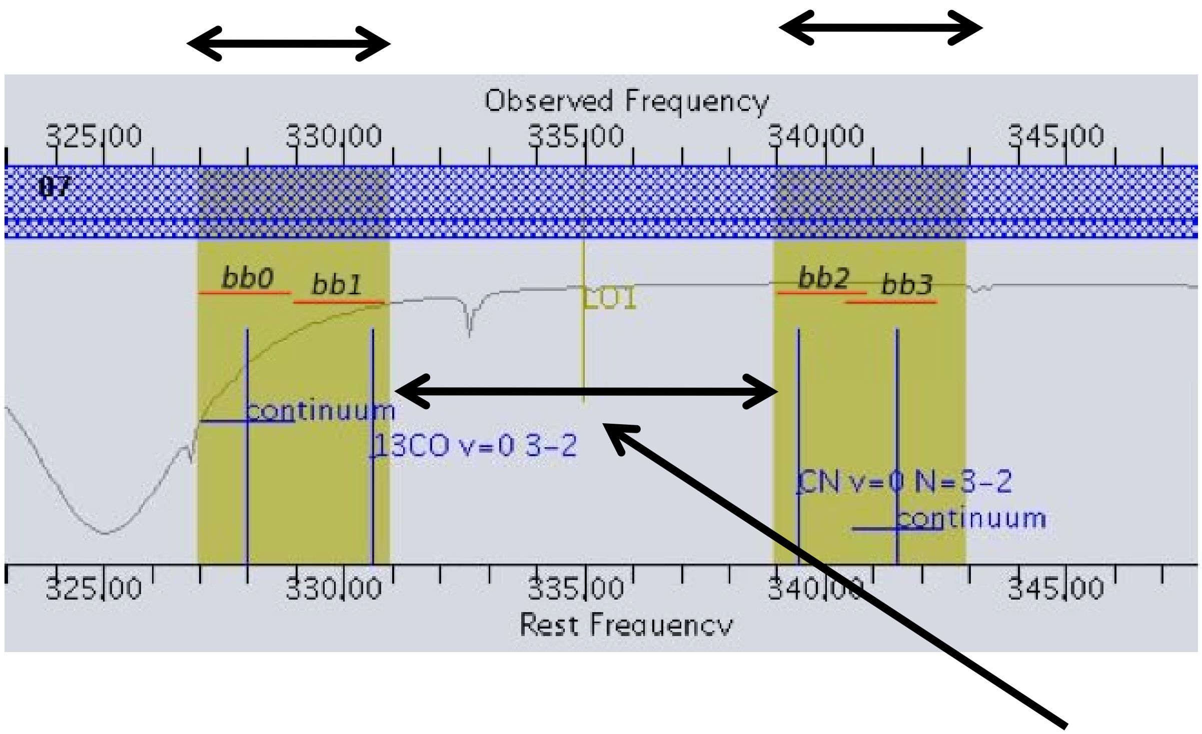
Figure 1. The numbers indicate the percentage of time when the pwv is below 1 mm as a function of Local Sidereal Time (LST) and week number beginning with January 1, 2013. Red indicates times with very little time available at low PWV and therefore less suitable for high frequency observing, while blue indicates times with a large fraction of time available at low PWV. The data were obtained with the APEX radiometer in the years 2007-2011 (5 years). The thin dark grey lines show local midnight, and the thick light grey bands show the ALMA engineering time, which normally is unavailable for Early Science observations. The vertical darker grey bands show the anticipated February shutdown and the end of Cycle 1 in November.

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

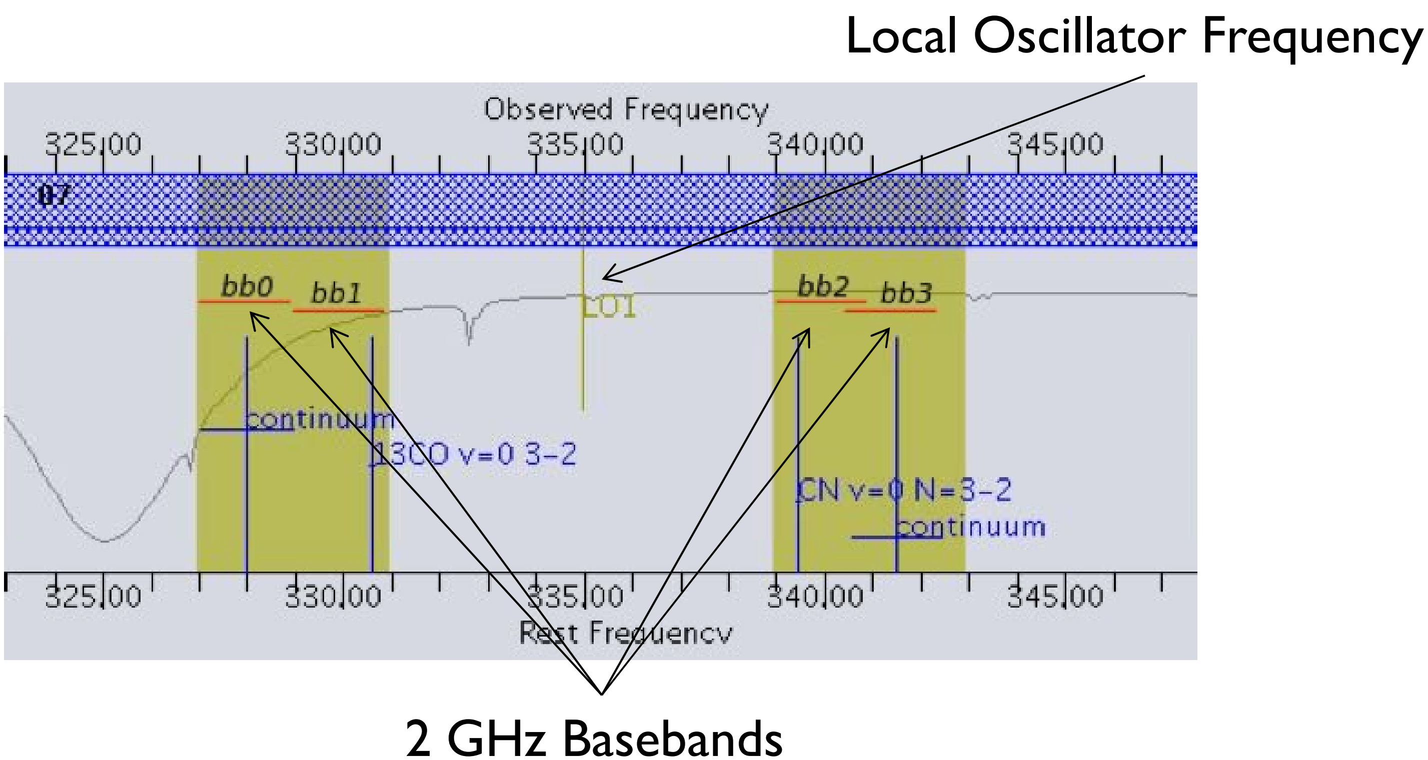


Fixed separation between sidebands

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

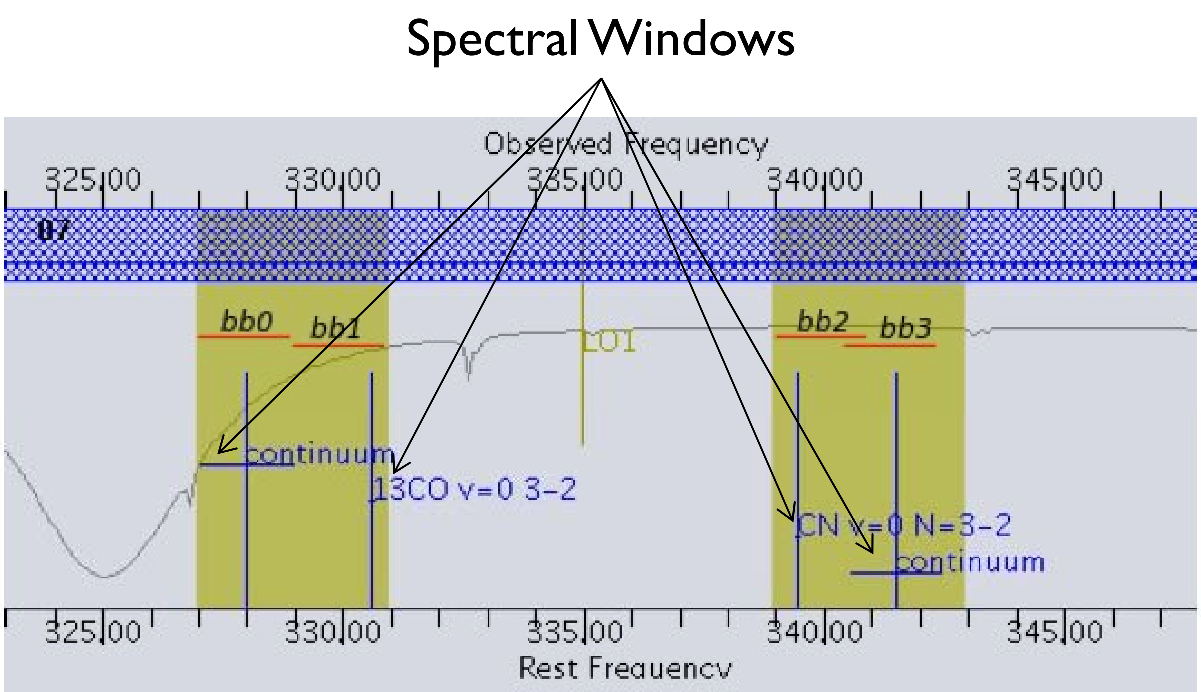
Basebands

- 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)



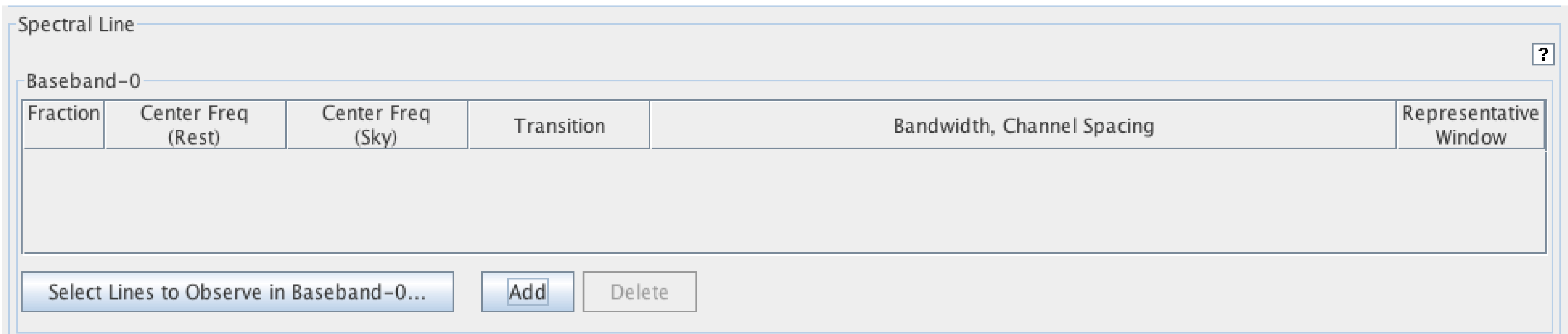
Spectral Windows

- 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**
  - **Splatalogue may help guide choice of lines**
- Pick a correlator mode for each SPW
- The OT will configure the LO and basebands to match (if possible)

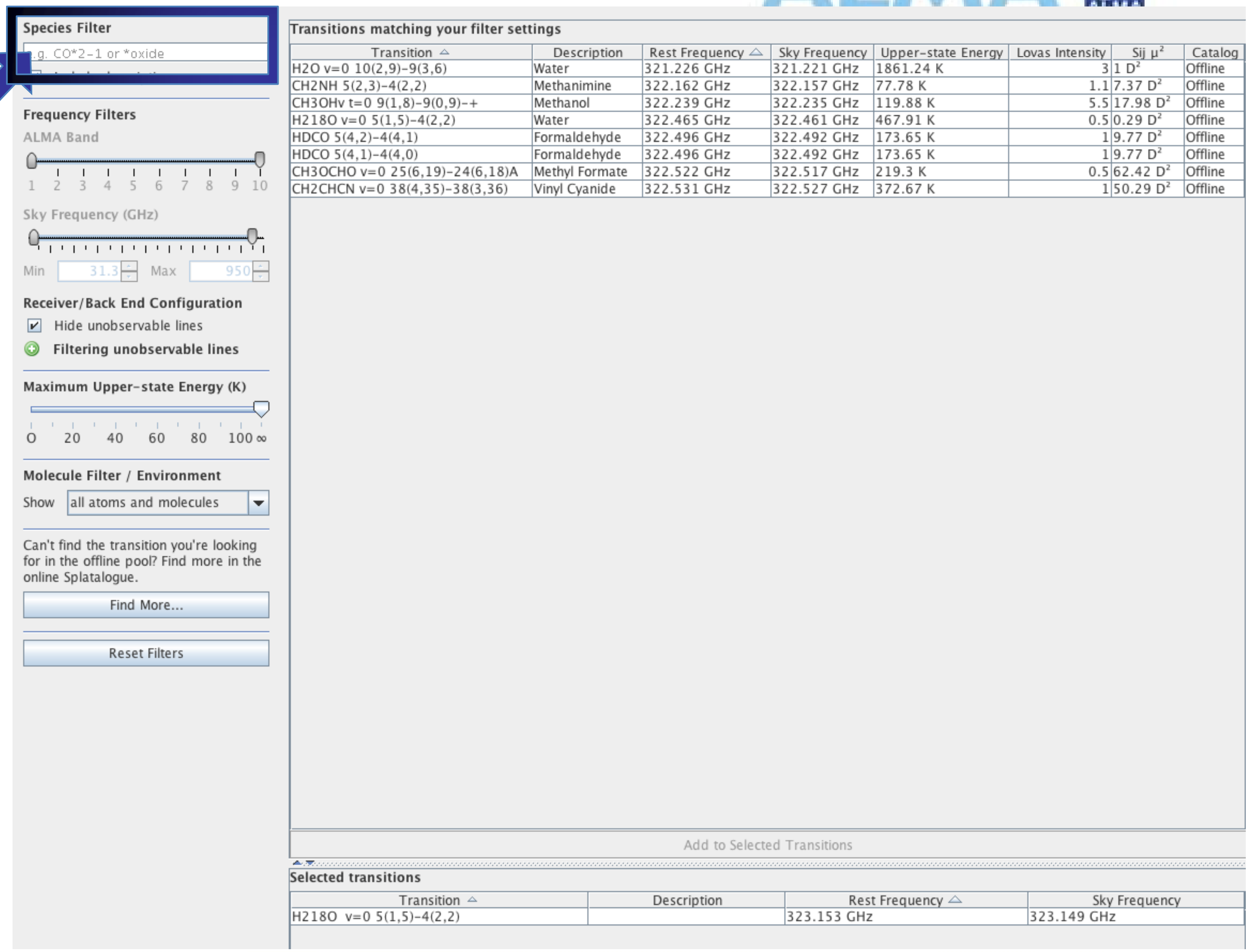


Select a line, with your source velocity, this defines a frequency.

Add a spectral window by hand.

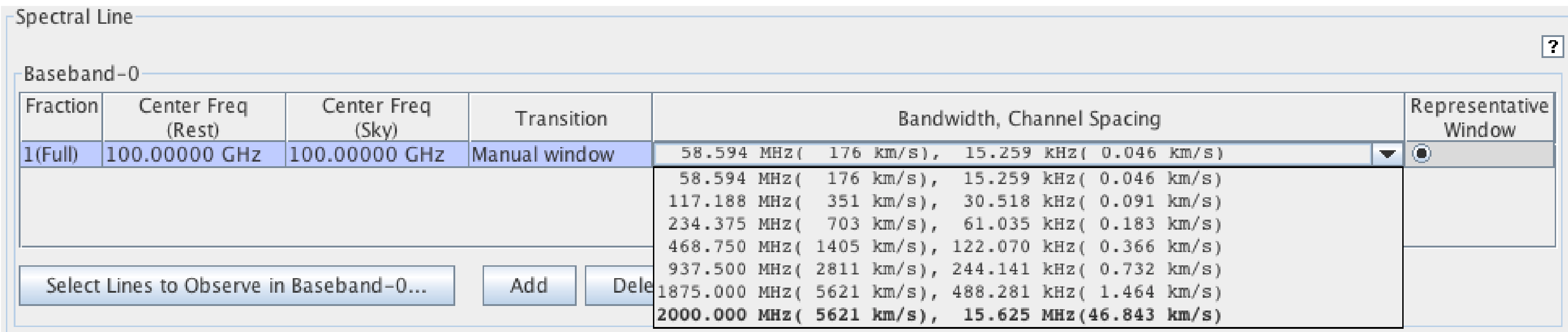
e.g. Type in "H_2O"

A window that can search Splatalogue will open.



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

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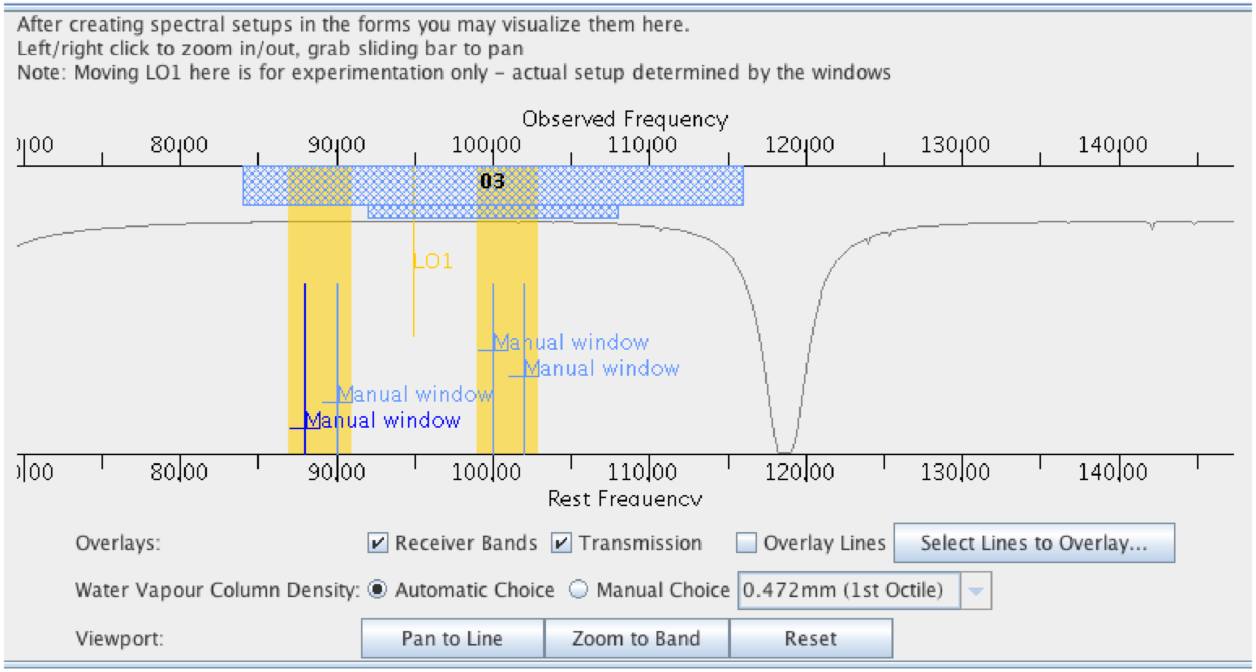

VISUALIZING THE SPECTRAL SETUP IN THE OT

In Practice

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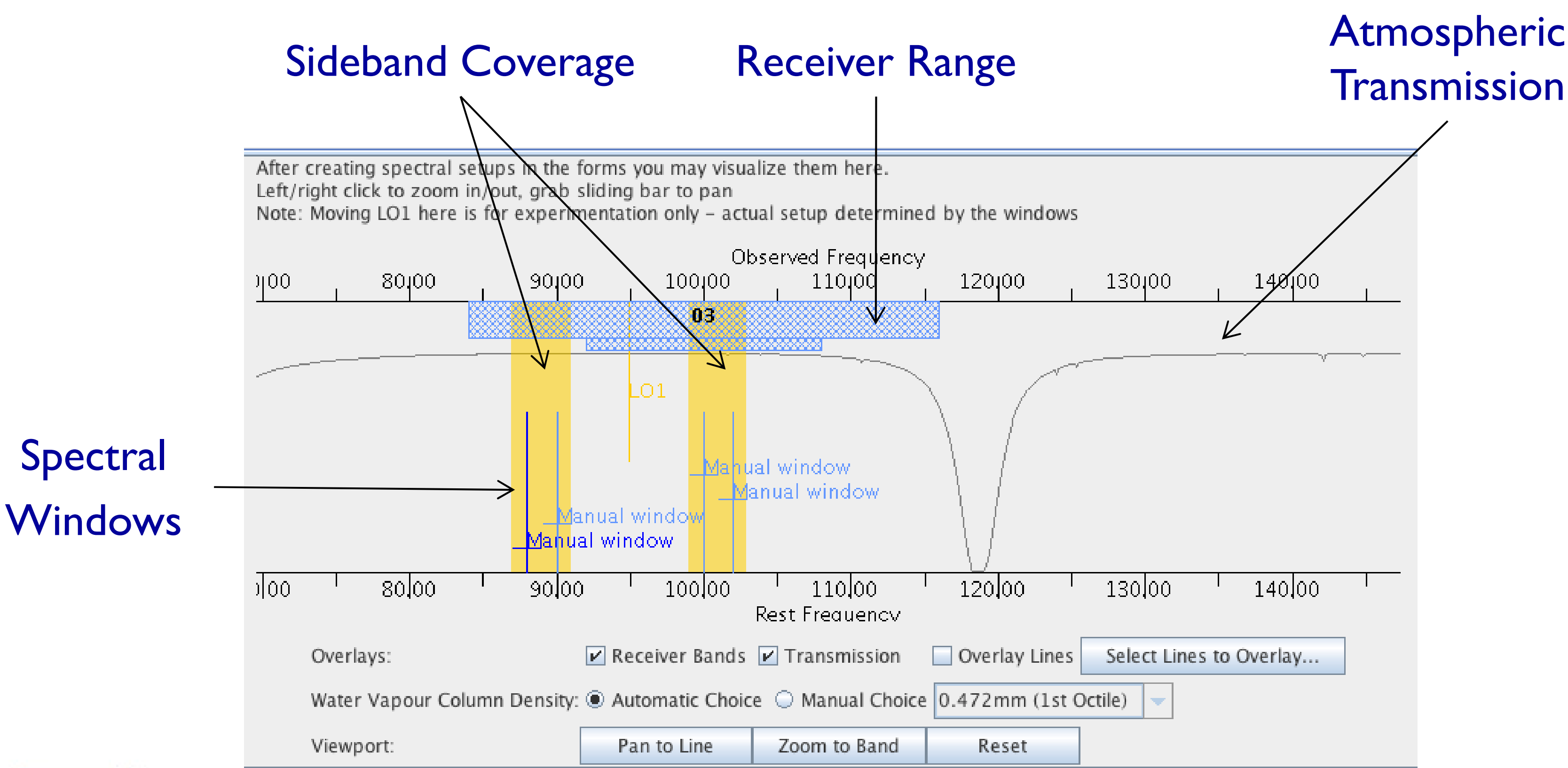


VISUALIZING THE SPECTRAL SETUP IN THE OT

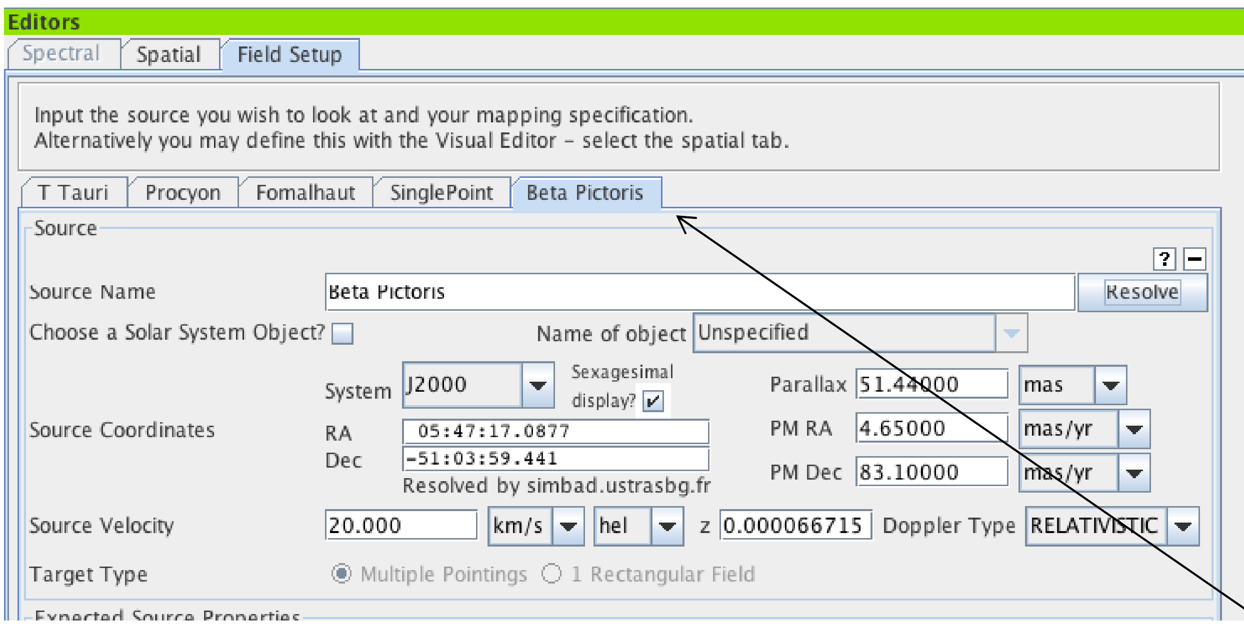
Key Proposal Factors

ALMA

- 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 if they are within 15°
  Up to 5 different velocities in each Science Goal
- Mosaic
  offsets are mosaics, mosaics Trade efficiency for imaging quality
  up to 150 points (total: mosaic, offset) per proposal



Multiple sources in one Science Goal

Target Definition

- Single field

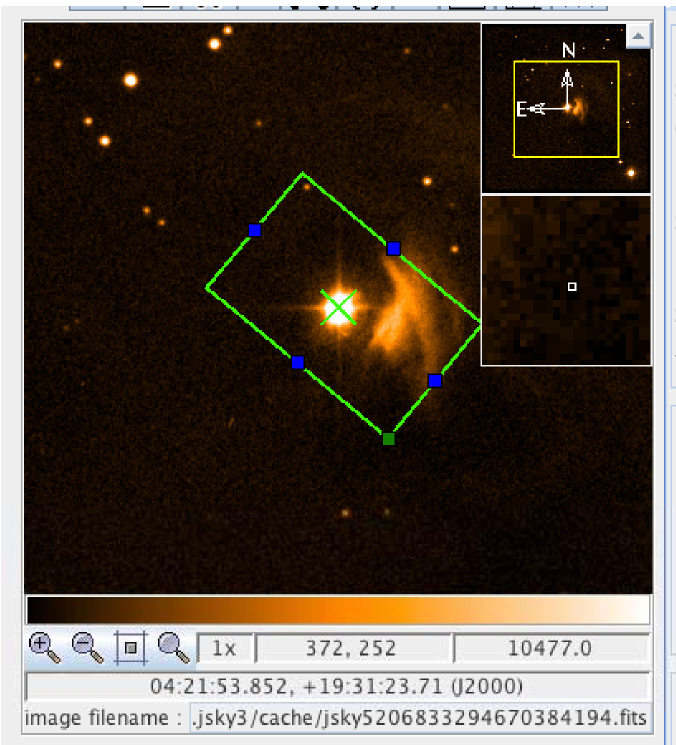
  UP TO 15 INDIVIDUAL FIELDS IN ONE SCIENCE GOAL IF THEY ARE WITHIN 15°

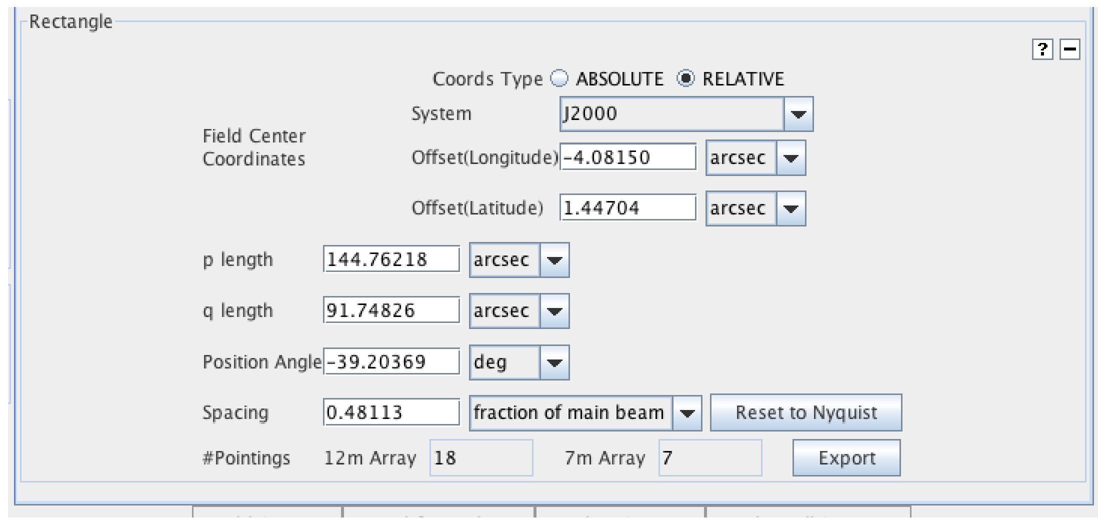
  UP TO 5 DIFFERENT VELOCITIES IN EACH SCIENCE GOAL

- Mosaic

  OFFSETS ARE MOSAICS, MOSAICS TRADE EFFICIENCY FOR IMAGING QUALITY

  UP TO 150 POINTS (TOTAL: MOSAIC, OFFSET) PER PROPOSAL





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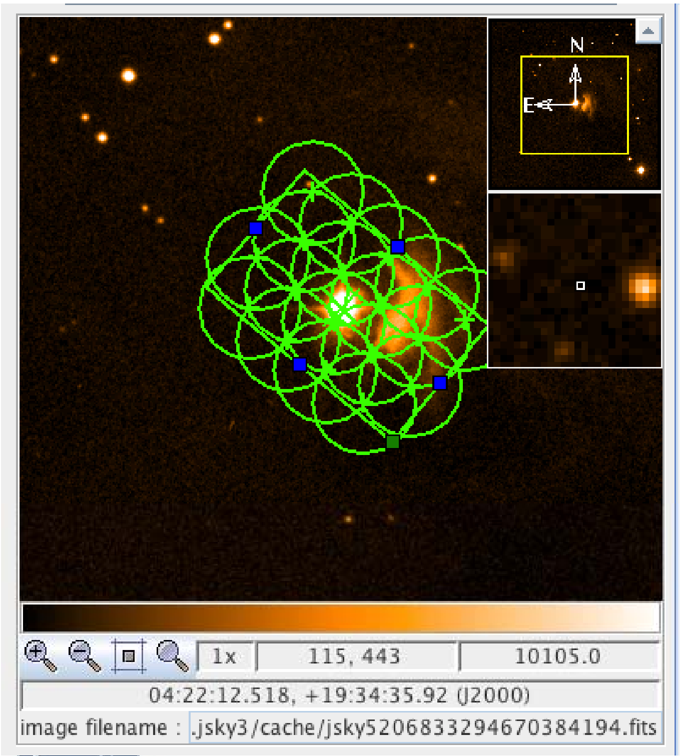
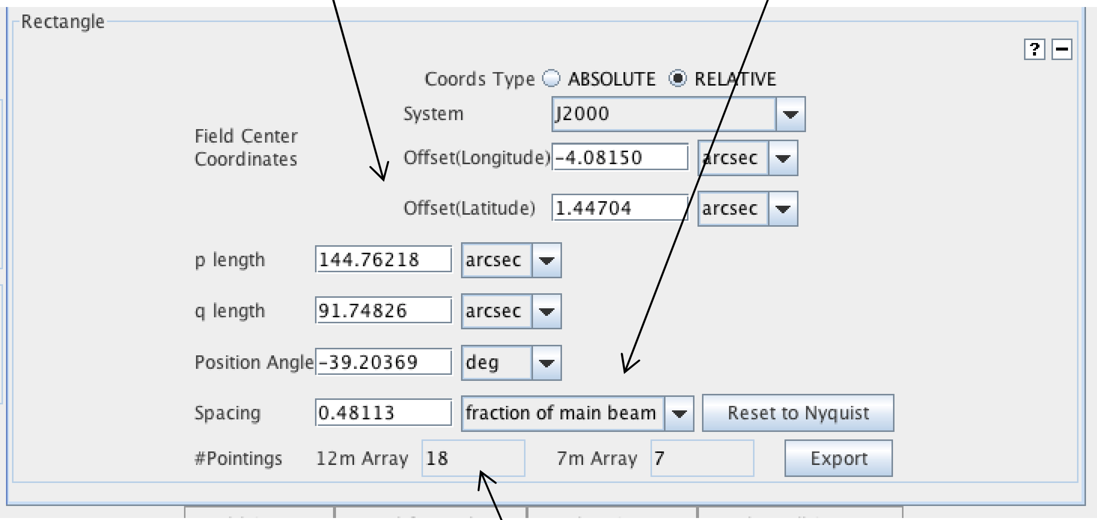


Orientation and Extent

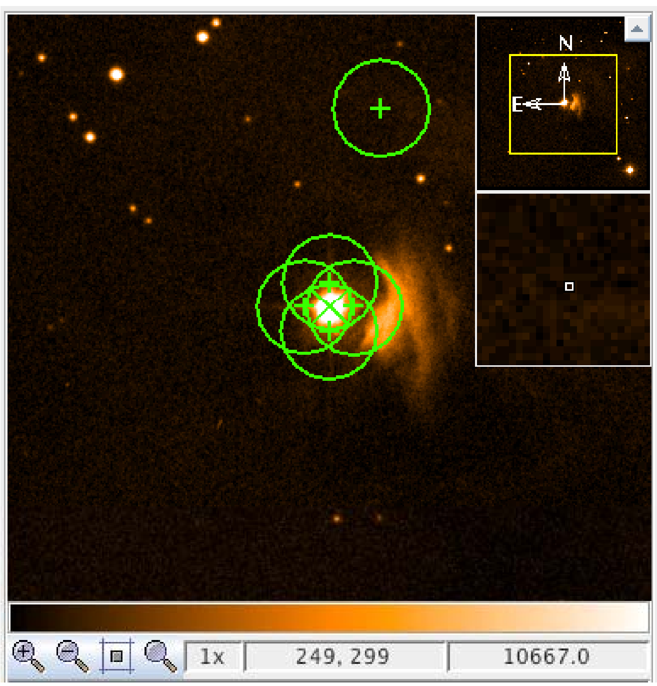
Field Spacing

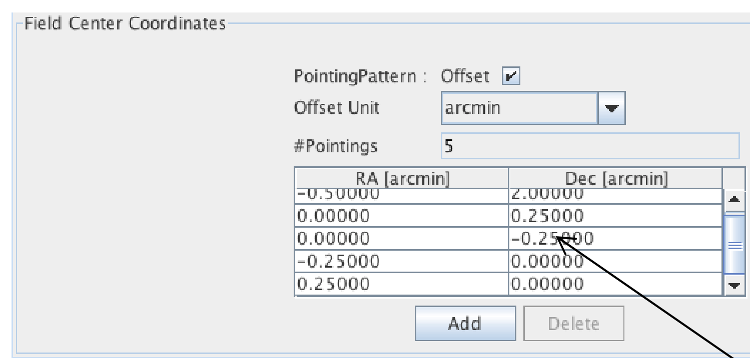


Number of Fields

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 TRADE EFFICIENCY FOR IMAGING QUALITY
  - UP TO 150 POINTS (TOTAL: MOSAIC, **OFFSET**) PER PROPOSAL





Individual Offset
Field Centers

Key Proposal Factors

ALMA

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

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Control and Performance

ALMA

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

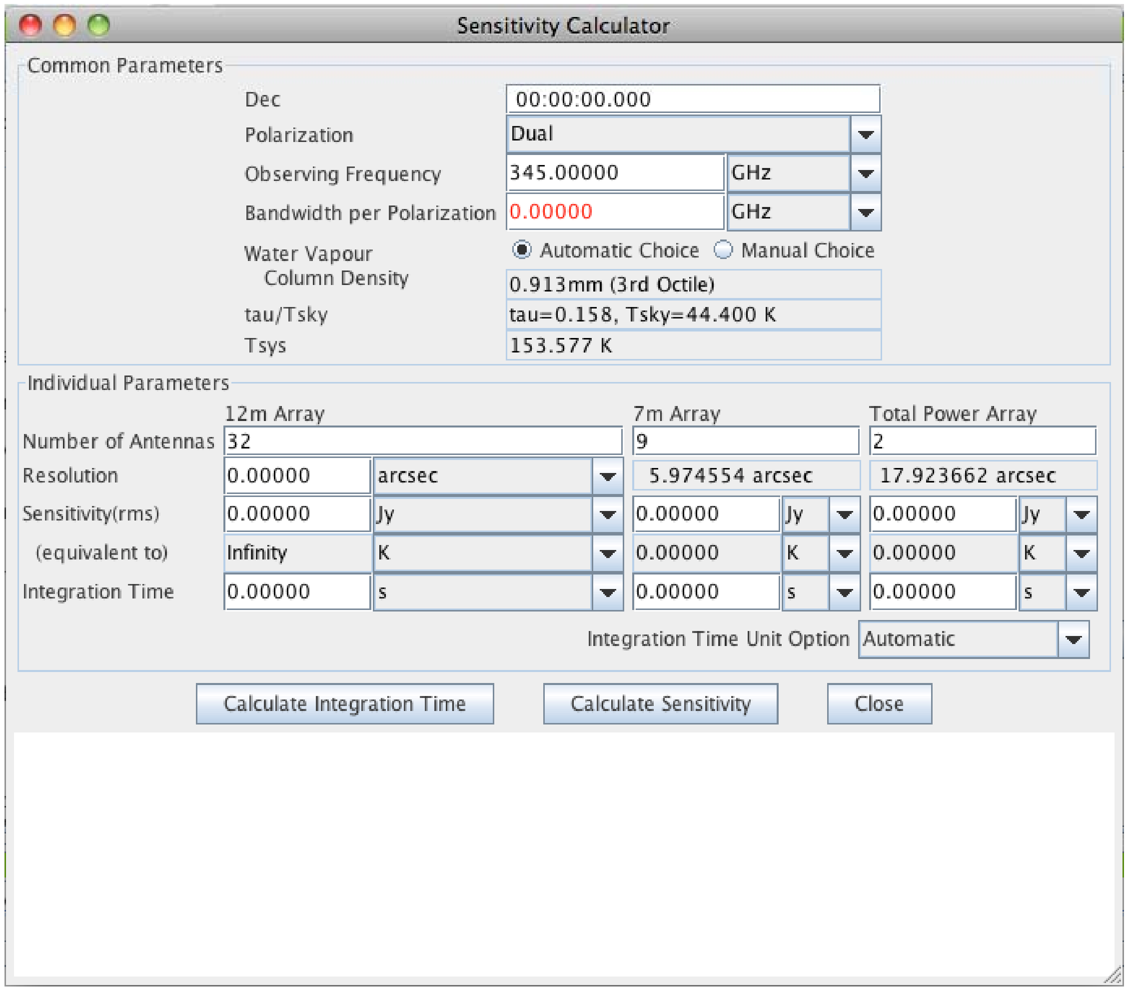
- Target RMS noise
  FOR A FIDUCIAL FREQUENCY AND BANDWIDTH (BOTH USER SPECIFIED)

- 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)



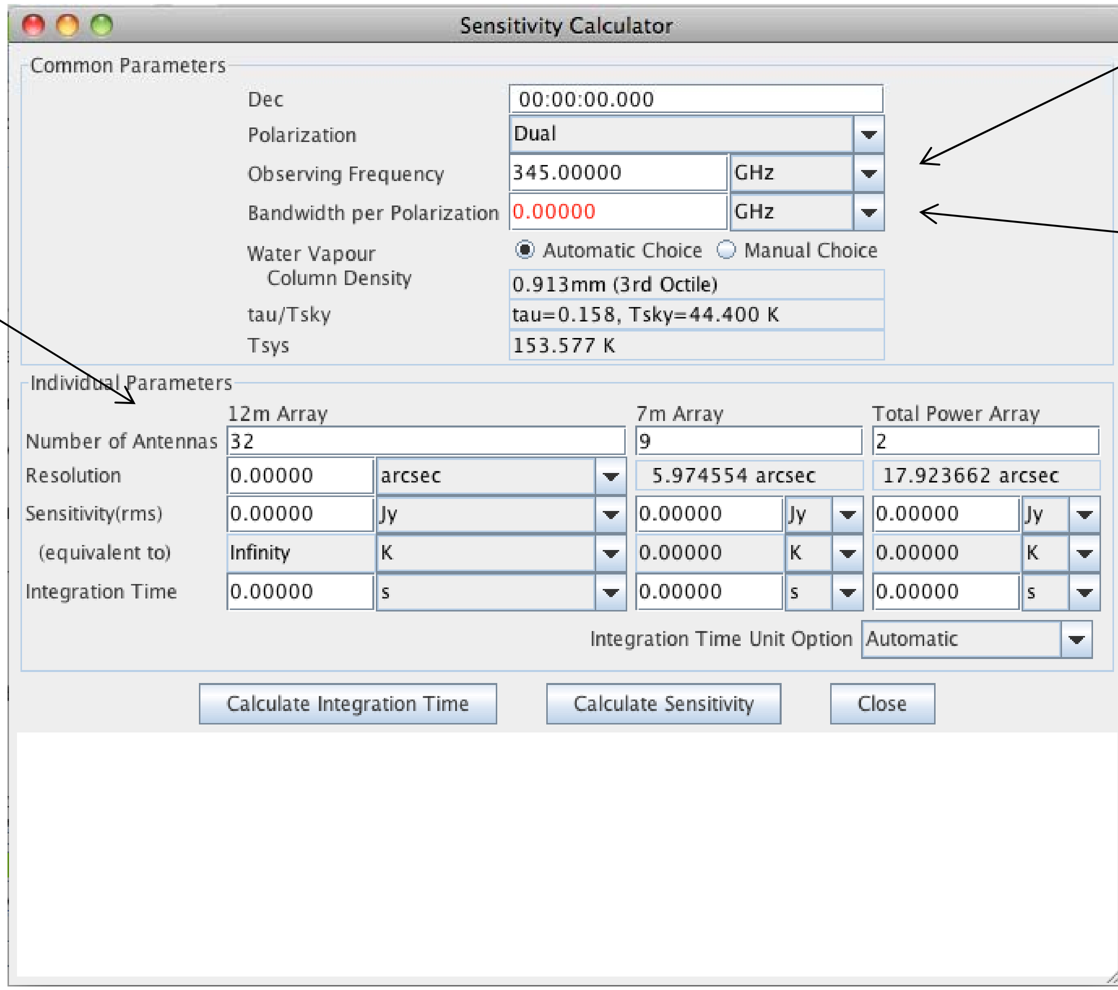
Sensitivity

ALMA

- Target RMS noise

  FOR A FIDUCIAL FREQUENCY AND BANDWIDTH (BOTH USER SELECTED)

Cycle 1 Capabilities



Fiducial Frequency

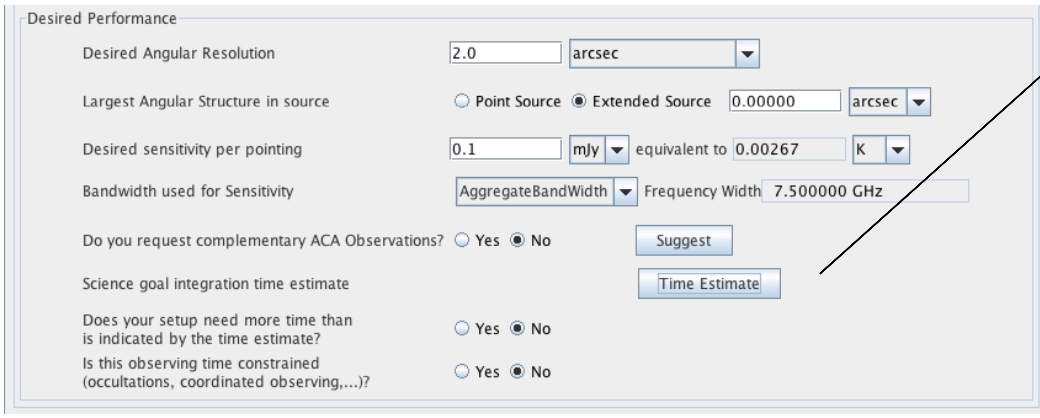
Fiducial Bandwidth

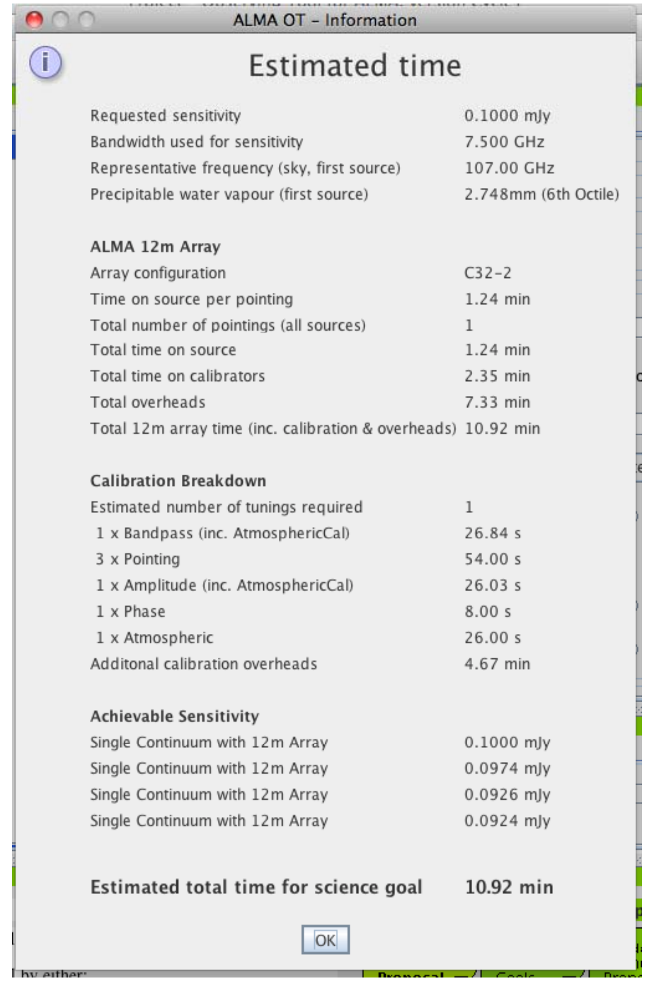
Sensitivity

ALMA

- Time Request

  OT WILL CALCULATE A ROUGH TIME ESTIMATE, INCLUDING OVERHEADS



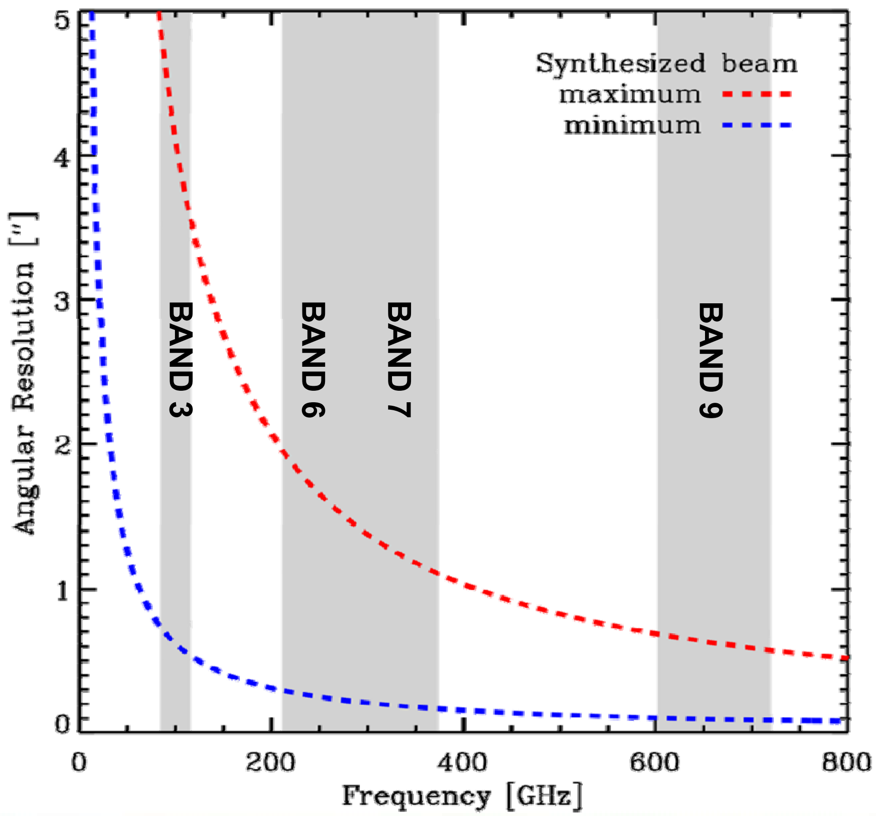


Control and
Performance

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

ALMA

- 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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Maximum Angular Scale

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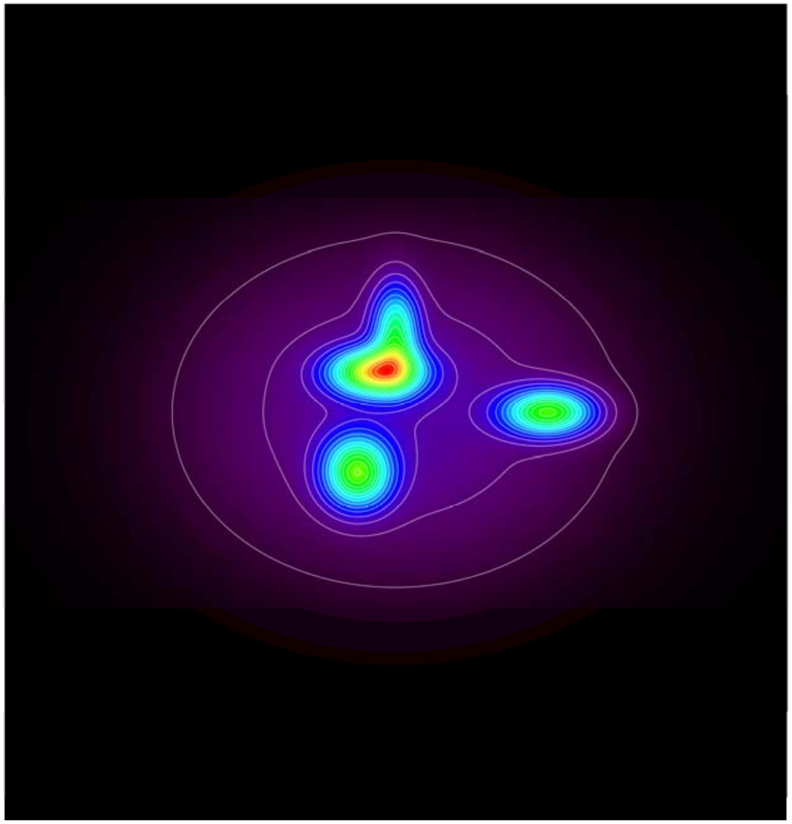
  NEED ADDITIONAL OBSERVATIONS WITH A SINGLE-DISH OR A COMPACT ARRAY OF SMALL TELESCOPES.

Largest Angular Scale (LAS)

ALMA

- 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)

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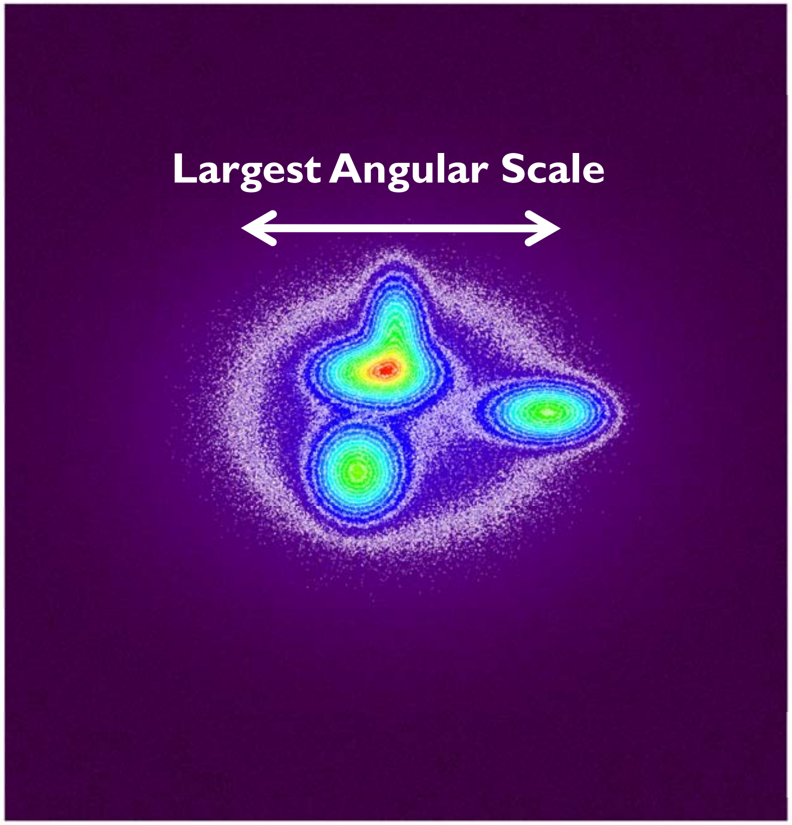
Largest Angular Scale (LAS)

ALMA

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

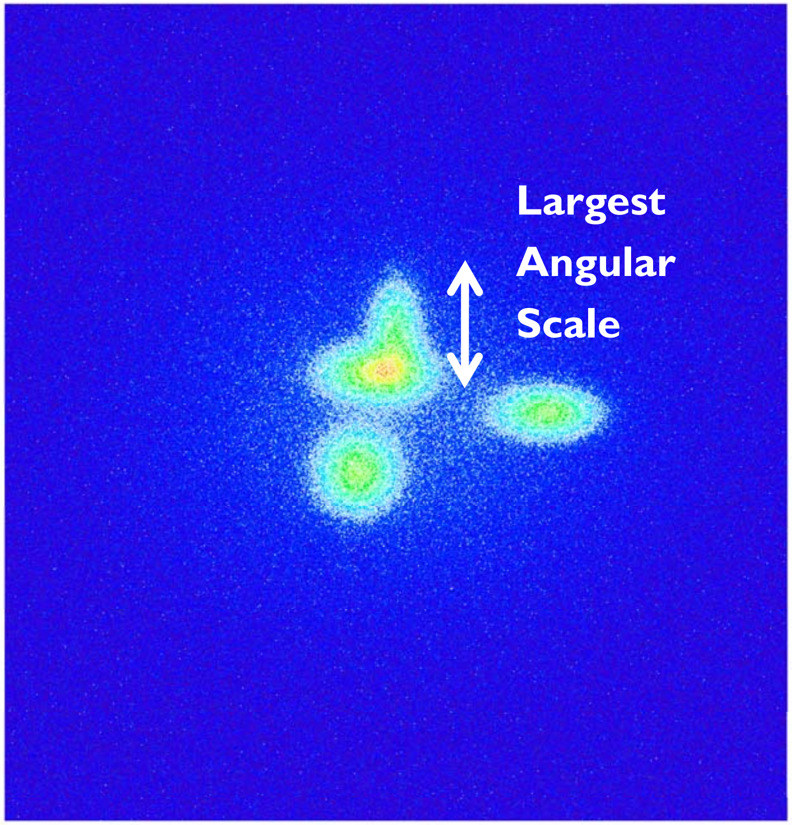


RMS set to detect superstructure and LAS input to reflect size of structure.

Largest Angular Scale (LAS)

ALMA

- Only embedded compact sources of interest?



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

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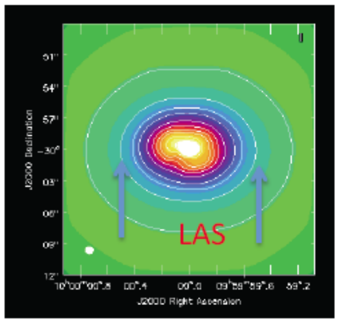
ACA Example (see Primer)

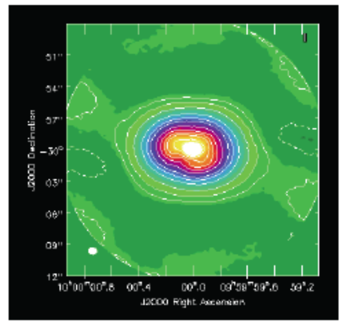
Images using 12-m C2 array with a resolution of 0.8”x0.7” in pa 80d

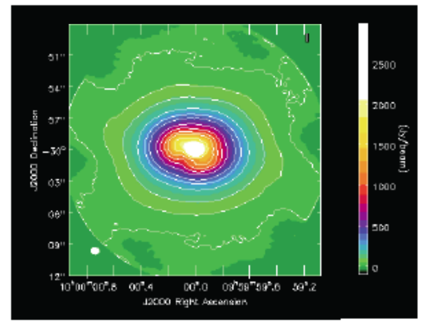
MODEL

12-m image

12m+7m Image

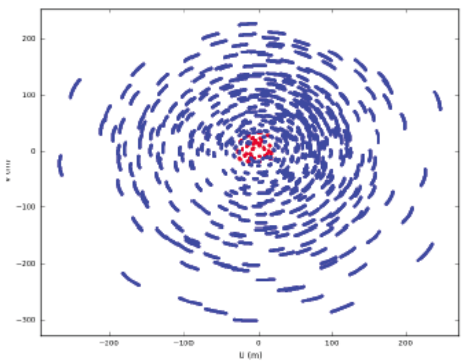


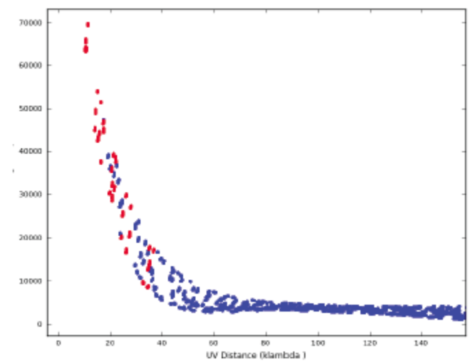




Restored flux 11000 Jy 7000 Jy 9000 Jy

Primary beam corrected: 20% cutoff: Contours: -20,20,50,100,200,300,400,600,800,1000,1200,1600,2000





U-V coverage (red=ACA, blue=ALMA12m) Amplitude vs uv-distance

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.

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ACA Recommended?

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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.

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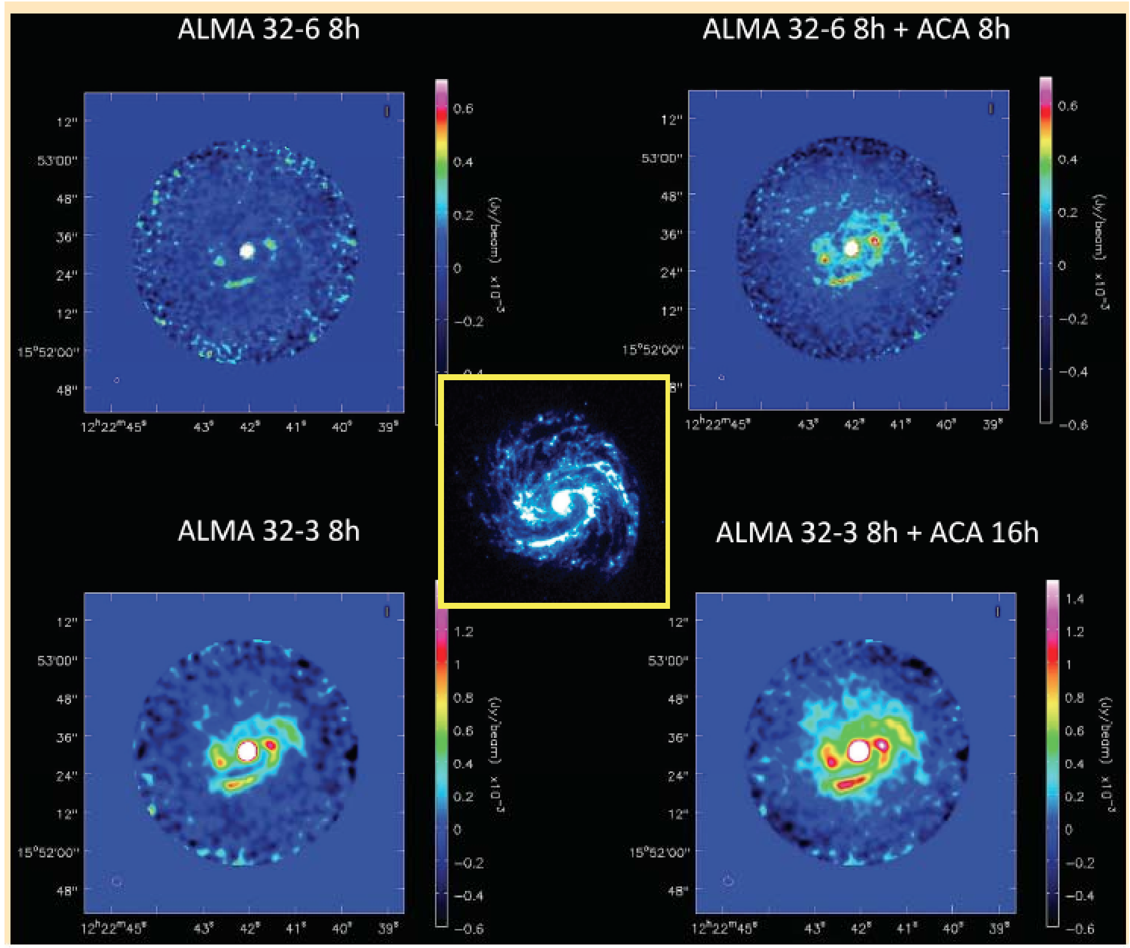
To Use the ACA?

A spiral galaxy where the model (center) is an IRAC 8 micron image as a proxy for CO.

In the top row, a simulated image reconstructed using a smaller LAS is shown; only compact bright features are present in the image on the left. On the right, the ACA was used to recover extended emission; the fidelity of the image is improved markedly.

In the bottom row, the image was reconstructed using a larger LAS is shown; compact structure is much better represented. Image fidelity is further improved through the use of the ACA.



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!**

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	—

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Proposal Checklist

ALMA

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Required Step

NRAO

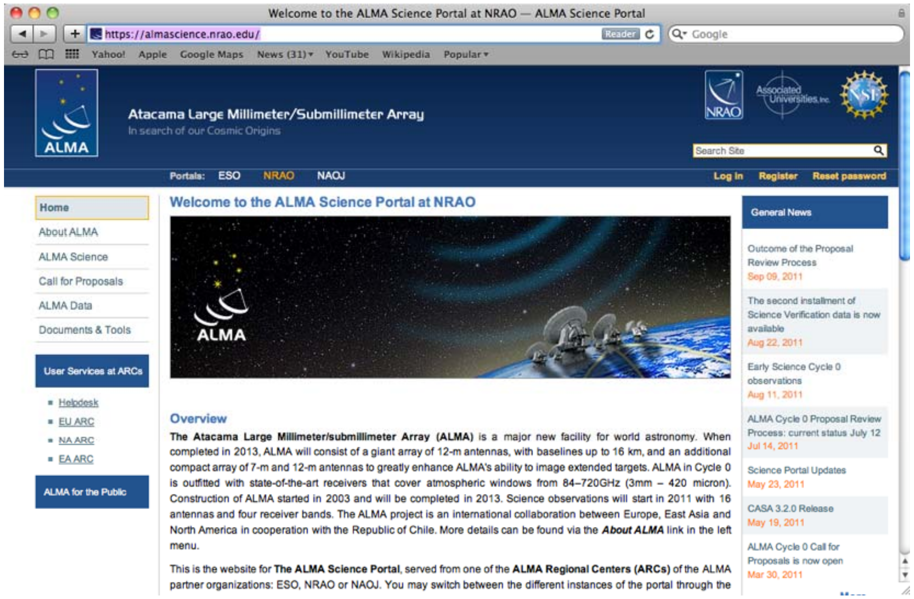
The ALMA Science Portal

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 for PIs and cols.

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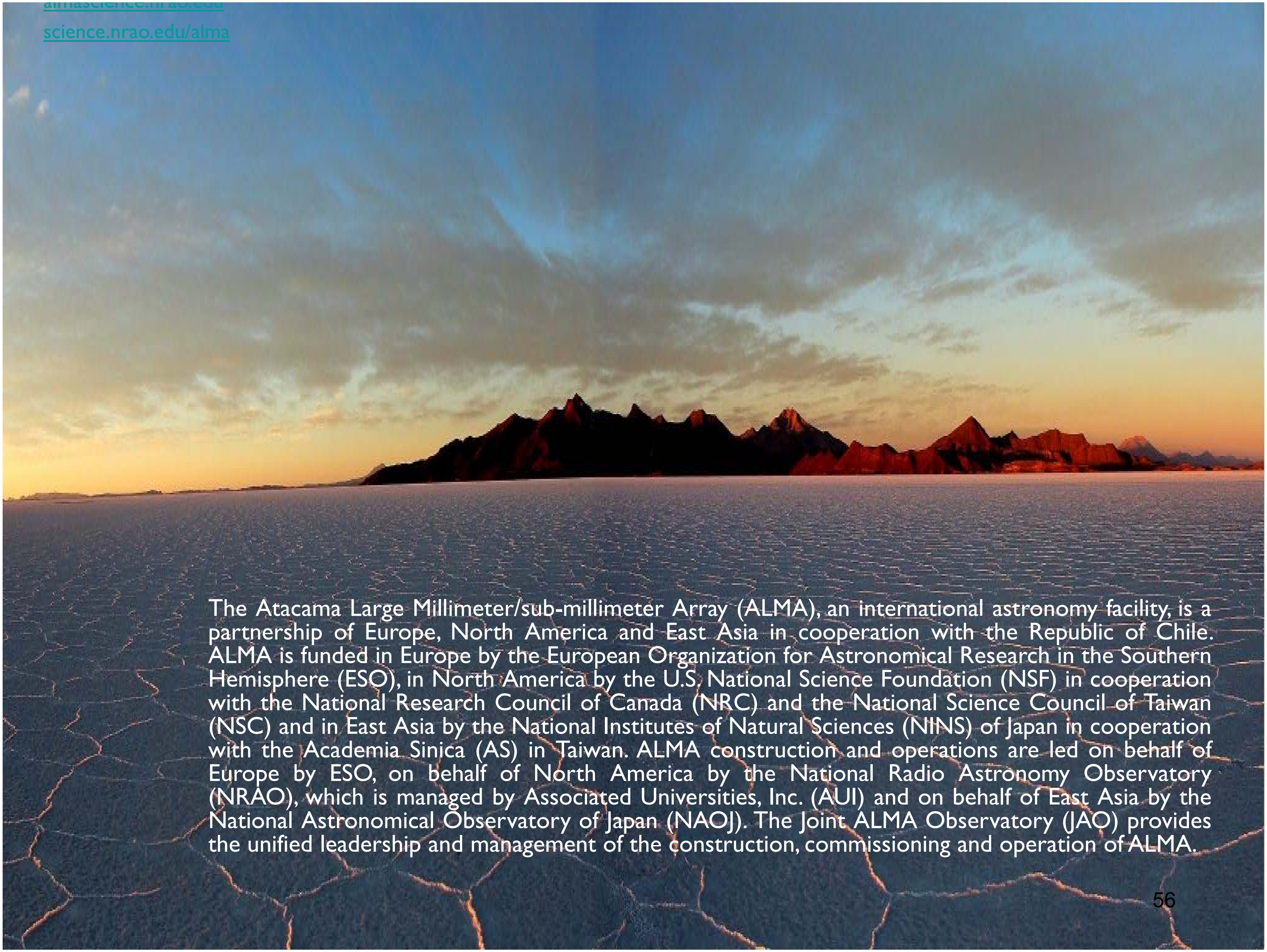
almascience.nrao.edu
science.nrao.edu/alma



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.

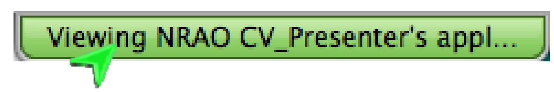
NRAO Proposal Planning Webinar

NEXT PRESENTATION: 18:30 UT

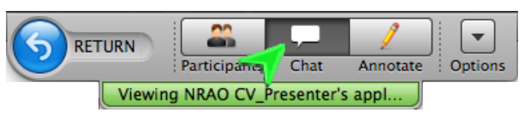
- 17:00 UT (1pm EDT) – Planning an ALMA Proposal
- **18:30 UT (2:30pm EDT) – Planning a GBT Proposal**
- 19:30 UT (3:30pm EDT) – Planning a JVLA/VLBA Proposal
- 21:00 UT (5:00pm EDT) – Open Questions & Answers

Important information:

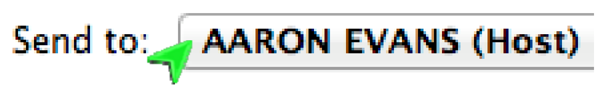
- Sound available only through voice bridge.
  - USA Toll Number : +1-210-835-9155
  - USA Toll Free Number : 866-815-0456
  - Participant Passcode: 3535975#
- Ask question through webinar “Chat” feature
  - Click green area in top center of your screen



  - Click on “Chat”



  - Select Send to: Aaron Evans (Host)



- Supporting Material: *https://science.nrao.edu/science/meetings/nrao-cde*

To Use the ACA?

ALMA

- When in doubt, simulate!
  "OBSERVE" A MODEL OF YOUR TARGET WITH 12-M AND 12-M+ACA, COMPARE

12-M ARRAY ONLY

MODEL

12-M + 7-M ACA

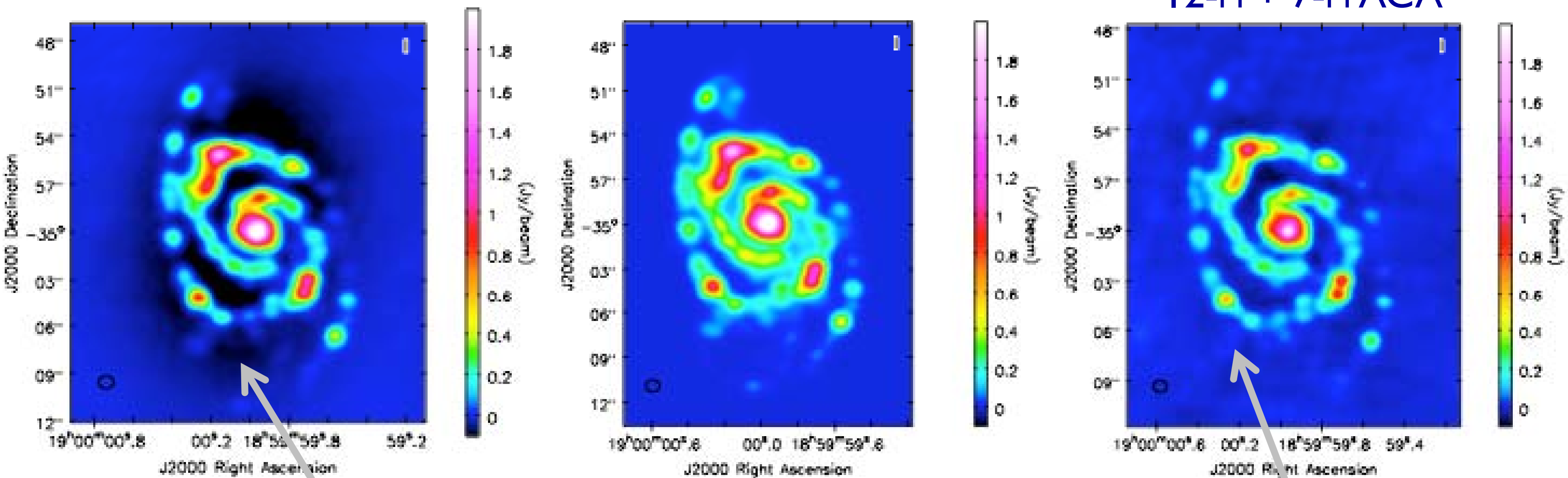


Image reconstruction artifact ("bowls")

Not present when 7-m antennas included

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