The Atacama Large Millimeter Array

Ast735: Submillimeter Astronomy
IfA, University of Hawaii
ALMA Basics

• Global partnership (shared cost ~ [2006] US$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 inauguration in 2013, full array operation by 2015
ALMA Basics

• Global partnership (shared cost ~ [2006]US$1.3 billion):
  North America (US, Canada, Taiwan) ~35%
  Europe (ESO) ~35%
  East Asia (Japan, Taiwan) ~20%
  In collaboration with Chile 10%

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

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  12-m Array – 50 x 12-m
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slides from Lacy NRAO workshop presentation
Full Science Capabilities

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
Frequency Coverage

Early Science (now)

Full Operations

Frequency Coverage

Transmission

Frequency [GHz]

SMA
CARMA
PdBI
ALMA CyO
ALMA FS

Frequency (GHz)
Collecting Area & Baselines

Circles Show Collecting Area (sensitivity)
Captions give # of antennas and # of baselines (fidelity)
Current Status

- Cycle 0 2012 (16+ antennae)
- Cycle 1 ongoing (32+ antennae)
- Data delivered to PIs., archive open and growing
- Commissioning ongoing.
- Correlators (ACA and main) working.
- All antennas: B3, 6, 7, and 9 receivers.
- Cycle II call in July for observations in 2014
Brief overview of ALMA science...
The Main SCIENCE Drivers of ALMA

★ **Origins of Galaxies:** Molecular gas in the Milky Way 10 Gyr ago (at $z = 3$) in less than 24 hours of observation.

★ **Origins of Planetary Systems & Planets:** Gas kinematics in a solar-mass protostellar/ protoplanetary disk at a distance of 150 pc.

★ **Exquisite Sensitivity & Resolution:** Precise images at an angular resolution of 0.1" at 0.1% peak brightness.
ALMA Images Nearby Galaxies

- Science verification imaging of the Antennae Galaxies

HI, CO 3-2, CO 1-0

CO 2-1

CO 3-2
ALMA Images Nearby Galaxies

- Science verification imaging of M100

**CO 1-0**
47-pt mosaic

**Hα**

**Velocity**
ALMA Images Debris Disks

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

This dataset is available on the archive!
https://almascience.nrao.edu/alma-data/available-data-sets
Science Verification Data

For general information on the Science Verification process as well as the status and future plans of Science Verification projects, please use the link below:

https://almascience.nrao.edu/alma-data/science-verification

Currently Available Science Verification Data:

We now have several datasets available to demonstrate the early capabilities of ALMA. In some cases these projects were observed before 16 antennas were available and while many of the subsystems were still being tested, so they should not be construed to represent the quality of the data that can be expected from the system as it is today. They are provided here as a means for the user to become acquainted with the ALMA data structure, observing strategies and reduction techniques. Given that the data have been taken during the construction phase, there may be more idiosyncrasies present than will be expected during full operations, so we ask the user to please review carefully the CASA guides provided with the datasets that represent unique observing modes or strategies, as indicated below. For reference the list of Science Verification targets that was provided with the Cycle 0 Call for Proposals is given in Table 2 which indicates which observations have been completed or are in progress. We do not expect to observe the other sources on that list.

1. TW Hya: Band 7, high spectral resolution. Many thanks to the following people for suggesting this source for ALMA Science Verification: Meredith Hughes, Stuart Corder, Chunhua Qi, Karin Oberg, Michiel Hogerheide, Andrea Isella, Dmitry Semenov.

Additional data on TW Hya is available (without a separate CASA guide) here: Band 3, Band 6.

2. NGC3256: Band 3, low spectral resolution. Many thanks to the following people for suggesting this source for ALMA Science Verification: Kazushi Sakamoto, Alison Peck, Satoki Matsushita, Martin Zwaan.

3. Antennae galaxies: Band 7, high spectral resolution. Many thanks to the following people for suggesting this source for ALMA Science Verification: Christine Wilson, Junko Ueda, Francois Boulanger, Nicole Nesvadba, Cinthya Herrera.

Additional data on Antennae is available (without a separate CASA guide) here: Band 6

4. M100 Band 3, low spectral resolution. Many thanks to the following people for suggesting this source for ALMA Science Verification: Preben Grosbol and Catherine Vlahakis.

5. SgrA* Band 6, recombination lines. Many thanks to the following people for suggesting this source for ALMA Science Verification: Andreas Eckart, Stephane Leos, Steve Longmore, Sergio Martin, Stephane Leon, Farhad Zadeh.
ALMA Science Verification Data Disks

- **TW Hydra**
  - Band 3 (3mm, HCO$^+$ 1-0)
  - Band 6 (1.3mm, CO 2-1, DCN 3-2)
  - Band 7 (870µm, CO 3-2, HCO$^+$ 4-3)

- **HD 163296**
  - Band 6 (1.3mm, CO/$^{13}$CO/C$^{18}$O 2-1)
  - Band 7 (870µm, CO 3-2, HCO$^+$ 4-3)
ALMA Science Verification Data

Star formation

- IRAS 16293
  - Band 6 (1.3mm, many lines)
  - Band 9 (450µm, $\text{H}^{13}\text{CN}$ 8-7)

- Orion KL
  - Band 6 (spectral line survey; 5 tunings)

large dataset

complex

Jorgensen et al. 2012
ALMA Science Verification Data

Galaxies

- NGC 3256
  - Band 3 (1.3mm, CO 1-0) in class example

- Antennae
  - Band 7 (870µm, CO 3-2, mosaic)

- M100
  - Band 3 (1.3mm, CO 1-0, mosaic)

Herrera et al. 2012
ALMA Science Verification Data

more galaxies

• Sgr A
  – Band 3 (3mm)
  – Band 6 (1.3mm, H30α, mosaic)

• Centaurus A
  – Band 6 (1.3mm, CO 2-1, mosaic)

• BR 1202
  – Band 7 (850μm, redshifted [CII])
ALMA Science Verification Data logistics

• All data are available on the “class computer”
  – most are way too big for your laptops
  – instructions to come via email
  – small datasets (NGC3256, BR1202) can be done on laptops, the others will likely require remotely logging in

• All students must reduce at least one dataset
  – can work with each other, but students taking the class for credit must do one by themselves
  – I recommend starting with a dataset that has an associated casaguide
  – the adventurous can work on archival data
  – everyone taking the class to present their work on 4/19 or 4/26
What do you want to do?