Report on ALMA-J Progress

Ryohei Kawabe
ALMA-J Project Office
National Astronomical Observatory, Japan (NAOJ)
IAOC Workshop on Cool Universe
Valparaiso, Oct. 8, 2004
20 Years from Plan to Reality

- Start in 1983
- Start Site Testing in Chile in 1992 to search the best site for Sub-mm observations
- US-Japna “Atacama Array Workshop” in March 1997 Recognized the importance of International collaboration to realize high-resolution (0.01 arcsec.) & sensitivity required
- Tri-lateral Resolution toward three way ALMA in 2001
- ALMA-J 8-years construction budget was funded in Apr 2004
- (Preliminary ?) Agreement of Joint Construction was signed in Sep 2004
Nobeyama Radio Observatory (1982-)

Nobeyama 45m Telescope
Nobeyama Millimeter Array (NMA)/Rainbow
20 Years from Plan to Reality

- Start from Large Millimeter Array (LMA) Project which is based on upgrade of Nobeyama Millimeter Array (NMA)
- NMA observations started from the year of 1986
- Importance of Sub-mm array and High Spatial Resolution led us to Large Millimeter/Submillimeter Array (LMSA) Project & Site Survey in Chile
Site Testing in Chile (I) :1992-

- Collaboration with U.Chile & ESO
- Transportable 225 GHz Tipper
- Test of Radio Seeing Monitor in La Silla & Paranal
Site Testing in Chile (II) :1995-

- Site Testing Instruments (1995-)
- Collaboration with U.chile, NRAO, ESO

Pampa la Bora

225 GHz Tipper

Radio Seeing Monitor
Site Testing in Chile (III) at Sub-mm

- Measurement with FTS (Fourier Transform Spectrometer) ; 1997-
- Excellent Atmospheric Transmission at ALMA site
The Ministry of Finance and the Cabinet approved **25.6 Billion Yen (241.5M$, 1$=106Yen)** for the ALMA-J budget in 8 years (FY2004-2011)

**1.0 Billion Yen (9.43M$, 1$=106Yen)** for the FY2004 budget.

The above budget includes costs for

  Buildings ( "Technology & Science Centers" in NAOJ), Instruments used there.

But does not include personnel costs of permanent ALMA-J staff and the other resources contributed by NAOJ. The total cost is more.
Funding Profile of 25.6 Billion Yen
Agreement been signed!

- Europe, Japan and North America signed an agreement concerning the construction of the Enhanced Atacama Large Millimeter/submillimeter Array (ALMA)
- Signed in Tokyo by Dr. Yoshiro Shimura, President of NINS, on 14 September
- Completed by adding related annexes no later than Jun 2005
AGREEMENT

CONCERNING THE CONSTRUCTION OF THE ENHANCED

ATACAMA LARGE
MILLIMETER/SUBMILLIMETER ARRAY

(ALMA)

BETWEEN

THE EUROPEAN ORGANISATION for ASTRONOMICAL RESEARCH in the
SOUTHERN HEMISPHERE and THE NATIONAL SCIENCE FOUNDATION of THE
UNITED STATES

and

THE NATIONAL INSTITUTES OF NATURAL SCIENCES of JAPAN
ALMA-Japan

- NAOJ became a branch of National Institutes of Natural Sciences (NINS) from this year

- What is NINS?
  - Government-funded agency
  - More independent from MEXT (Ministry of Education, Science, Technology, ...) than before
  - Five (5) Institutes:
    - National Astronomical Observatory (NAO)
    - National Institute of Fusion Science (NIFS)
    - National Institute of Basic Biology (NIBB)
    - National Institute of Physiological Science (NIPS)
    - Institute of Molecular Science (IMS)
ALMA-Japan

New NAOJ

- Director General: Dr. Norio Kaifu
- Telescopes
  - Subaru 8.3m telescope in Hawaii
  - Nobeyama 45m Telescope & NMA/Rainbow
  - ASTE (Atacama Submillimeter Telescope Experiment)
  - VERA (VLBI Exploration of Radio Astrometry) etc

New ALMA-Japan Organization

- Project Director: Masato Ishiguro
- Deputy Project Director/Project Scientist: Ryohei Kawabe
- Project Manager: Tetsuo Hasegawa
- Project Engineer: Satoru Iguchi
Japanese Contribution Items

- **ACA System**
  - 7-m and 12-m Antennas, FE (Baseline 4 bands + new three bands), BE, ACA Correlator, Computing (everything needed for 16 element interferometer)

- **New Receiver Bands**
  - Band 4, 8, and 10 cartridges (for 64-el. And ACA)

- **Infrastructure**
  - Required by the Japanese contribution
    - Expansion of facilities at Array & Operation sites
  - Contribution to the Power Plant

- **Operations**
The ACA System
• Twelve (12) 7-meter diameter antennas (18 stations)
• Four (4) 12-meter diameter antennas (4 stations)
• ACA Correlator in AOS building
Role of ACA

- Supplement the 64-element array data with
  - Short baseline data (7-m antennas)
  - Total power data (12-m antennas); e.g., OTF
    ⇒ *Enhance fidelity of ALMA images*
    (overcome “missing-flux” problem)
    ⇒ ACA will be used for ¼ of 64 array observing programs to match sensitivity

- Stand-alone mode of operation
  ⇒ Would be available for *target-of-opportunity* observations, wide-field surveys, etc.
High fidelity imaging: Role of the Compact Array

**Total ALMA System**

- **Relative sensitivity**
  - Baseline length
  - 12-m dishes
  - 7-m dishes
  - ACA System
  - 64 12-m dishes
Image Fidelity Improved by ACA (1)

Simulation (Tsutsumi et al.)
Image Fidelity Improved by ACA (2)

SZ effect
RXJ1347–1145
NRO 150GHz data
(Komatsu et al. 2001)

Simulation (Kitayama, Tsutsumi et al.)

64 (C1) 64+SD

ACA+SD

64+ACA+SD

90 arcsec
–0.22 mJy/beam

13-field mosaic, 18 min (64), 72 min (ACA)
ACA Operation Scenario

**Long-term coordination needed**

- 64-array executes common program in narrow time window
- But ACA always!
- To minimize the time lag between observations with the two arrays
- Variation of the source
- Observing conditions
- Semesters for CfPs

Diagram:
- 64-element config
- 64-el only
- 64-el + ACA
- 9 months
ACA Operation Scenario

**Calibration as “common” mode**
- Cal source within <4 deg from target
- Pointing/phase (Band 3)
- Bandpass/relative phase between Bands (less frequent)

**7-m interferometry**
- Multi-field mosaic
- On-the-fly (OTF) mosaic

**12-m single-dish**
- Beam switching
- On-the-fly (OTF) mapping

**Time**
- 7-m interferometry
- 12-m single-dish
- Interferometry on calib. source
- Single-dish at target source/freq.
- Interferometry at target source/freq.
New Receiver Bands

- Covers most of Atmospheric windows up to 1 THz
- Highest Freq Band-10 is cutting edge of science
- Neutral Carbon Lines high-J CO at Band-8 & 10
- redshifted C+; z=0.9 -1.4 at Band-10, z=2.8-4.1 at Band-8
# New Receiver Bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Mixer</th>
<th>IF</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 4</td>
<td>SIS (2SB)</td>
<td>4 - 8 GHz x 4</td>
<td>RF = 125 - 163 GHz *&lt;br&gt;LO = 133 - 155 GHz</td>
</tr>
<tr>
<td>Band 8</td>
<td>SIS (2SB)</td>
<td>4 - 8 GHz x 4</td>
<td>RF = 385 - 500 GHz&lt;br&gt;LO = 393 - 492 GHz</td>
</tr>
<tr>
<td>Band 10</td>
<td>SIS (DSB)</td>
<td>4 - 12 GHz x 2</td>
<td>RF = 787 - 950 GHz&lt;br&gt;LO = 799 - 938 GHz</td>
</tr>
</tbody>
</table>

*M: NbTiN or NbN

*Informal request to expand to 168.8 GHz received.
Feasibility yet to be checked.
ACA Correlator

- 3-bit FX Correlator
- Specifications are compatible with the Baseline Correlator with Digital Filter Expansion (eBLC)
  - 2GHz x 8 IF /baseline
  - 4096 ch. for each 2GHz
Proposed Milestones

- Q4 2006  First ACA 12-m Antenna equipped with Initial Front End Subsystem available at OSF
- Q2 2007  ACA Correlator available at AOS
- Q3 2007  Start Early Science Observations with an ACA 12-m Antenna in single-dish mode
- Q3 2009  Start Early Science Observations with the ACA System (including about half of 7m antennas)
- Q4 2011  Installation of Japanese Cartridges in all antennas complete
- Q1 2012  Start ACA Full Science Operation
Other Progress

- Negotiation with ASIAA in Taiwan face-to-face meeting at Tokyo on Sep. 2004
  Basic Scheme Similar to that in US/Canada
  Possible contribution Items by ASIAA etc. being discussed (not add new items)

- Prototyping of Antenna been performed
- Pre-production of FE cartridges is underway
ACA System: 12m Prototype Antenna

- Report of Prototype antenna Evaluation at Socorro will be completed soon
- The evaluation shows that the ALMA-J prototype antenna meets mostly the ALMA specification
Surface Accuracy

- Measured surface error: after 3 sets of surface panel adjustments (< 6 hours/measurement)

20 µm in rms
( - 12dB weight at edge)
All Sky Pointing: Absolute Pointing = 1\".1 ( < ALAM spec of 2\".0) (dAz = 0\".8, dEl = 0\".8)

Detailed analysis is ongoing; e.g., Time variation of Pointing Model parameters

Blue: observed points
Red: fitted model function
Band 4 Cartridge (2SB)
Qualification Model Design For Pre-Production

Ellipsoidal mirror

Sub ref

Plane mirror

Receiver optics

Corrugated horn

OMT

2SB mixer unit

IF hybrid

Isolator

HEMT Amp

IF Output

LO system
Band4 Cartridge results with DSB mixer
Band 8 Cartridge

- 2SB mixer
- IF hybrid
- LNA
- Quintupler
- GFRP
- 100K stage
- 15K stage
- 4K stage
- Cold Optics
- Wire grid
- Ellipsoidal mirror
- Isolator
- CLNA
- Quintupler
- IF hybrid
- GFRP
- LNA
- 2SB mixer
The ACA System

- Twelve (12) 7-meter diameter antennas (18 stations)
- Four (4) 12-meter diameter antennas (4 stations)
- ACA Correlator in AOS building