ALMA Science:
The Cool Side of the Universe

Leonardo Testi
ESO
Atacama Large Millimeter Array

- At least 50x12m Antennas
- Frequency range 30-1000 GHz (0.3-10mm)
- 16km max baseline (<10mas)
- ALMA Compact Array (4x12m and 12x7m)
1. Detect and map CO and [C II] in a Milky Way galaxy at z=3 in less than 24 hours of observation
2. Map dust emission and gas kinematics in protoplanetary disks at AU resolution
3. Provide high fidelity imaging in the (sub)millimeter at 0.1 arcsec resolution
Birth of Planets

\[ M_{\text{planet}} = M_{\text{Jup}} \]

\[ M_{\text{star}} = 0.5 \, M_{\text{sun}} \]

Orbiting at 5AU

Distance 50pc

High angular resolution science with ALMA, Oct 2011

Monday 20 February 12
Gas density maxima and grain trapping

Resolving disk structures with ALMA (simul from Cossins, Lodato & Testi 2010)
AGB Stars

Temperature/Density (K) (cm$^{-3}$)
1100 / 3 \times 10^9
1200 / 1 \times 10^{10}
1300 / 5 \times 10^{10}
1600 / 1 \times 10^{12}
2400 / 2 \times 10^{14}

Dust
SiO Masers
Radio Photosphere
Chromosphere
Molecular Photosphere
Optical Photosphere

Radius (AU)
0 0.02 0.04 0.06 0.08
Radius (arcsec)
(at D=100 pc)
# Complex Organic Molecules

<table>
<thead>
<tr>
<th>Detected</th>
<th>Not (yet) detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>Glycine</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Purine</td>
</tr>
<tr>
<td>Methyl cyanide</td>
<td>Pyrimidine</td>
</tr>
<tr>
<td>Methyl formate</td>
<td>Caffeine</td>
</tr>
</tbody>
</table>

How far does chemical complexity go? Can we find pre-biotic molecules in Disks?

Based on Ehrenfreund 2003
The Engine of nearby AGNs

Several (competing) models:

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Dynamics</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>large ~100 pc (observed)</td>
<td>rotation</td>
<td>cont./diff. medium (ALMA)</td>
</tr>
<tr>
<td>small ~1 pc (ALMA)</td>
<td>rotation and outflow</td>
<td>clumpy medium (ALMA)</td>
</tr>
</tbody>
</table>

ALMA will resolve the molecular gas structure and dynamics around nearby AGNs
The Engine of nearby AGNs

ALMA will resolve the molecular gas structure and dynamics around nearby AGNs

High angular resolution science with ALMA, Oct 2011

Monday 20 February 12
Small Solar System bodies

- Surface properties and thermal structure
- Atmosphere composition
- Multiplicity

The well characterized ones are very interesting also as calibrators

(R. Moreno) (Th. Mueller)
ALMA Science

- Star Formation, Proto-planets in nearby disks
- Astrochemistry
- Interstellar medium (Galaxy, Local Group)
- High-redshift deep fields

+130 projects in first 3yrs – DRSP 2.0

http://www.eso.org/sci/facilities/alma/documents/drsp.html

ALMA Science is for everyone

- High resolution/sensitivity 3D instrument at mm-wl
- 100% service observing with full dynamic scheduling
- Complete e2e data flow system
- Science quality images (cubes) delivered to the users
- Raw, calibrations, pipeline processed data and recipes in archive
- Friendly and widespread User Support through ARCs
The ALMA configurations

- Current mm interferometers offer typically $\sim 10^4$ visibility measurements in several hours, the VLA delivers $\sim 10^5$ visibilities per hour
- ALMA will improve by almost two orders of magnitude
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ALMA Early Science

- Call for Proposals (Cycle 0): 30 Mar 2011
  - Limited capabilities
    - 16 antennas, 4 receiver bands, 400m max baseline
    - no polarization, no complex correlator setup, no solar

- Response
  - 900+ proposals received by Jun 30 deadline
  - Proposal scientific/technical review over summer
Early Science – ESO Press Release

ALMA Opens Its Eyes

The most powerful millimetre/submillimetre-wavelength telescope in the world opens for business and reveals its first image

3 October 2011

Humanity's most complex ground-based astronomy observatory, the Atacama Large Millimeter/submillimeter Array (ALMA), has officially opened for astronomers. The first released image, from a telescope still under construction, reveals a view of the Universe that cannot be seen at all by visible-light and infrared telescopes. Thousands of scientists from around the world have competed to be among the first few researchers to explore some of the darkest, coldest, furthest, and most hidden secrets of the cosmos with this new astronomical tool.
Science Verification

- TW Hya – protoplanetary disc – Bands 3, 6 and 7

- NGC3256 – Nearby luminous galaxy

- [http://almascience.eso.org/alma-data/science-verification](http://almascience.eso.org/alma-data/science-verification)
Science Verification

- Antennae mosaic – Galaxies merger – Bands 7
Summary

- ALMA is here!
  - Early Science observing has started
  - Cycle 0: Oct 11 - Jun 12

- ALMA ES is just at the beginning!
  - Cycle 1 - Deadline Q1 2012 - will already be a huge step in sensitivity and other capabilities (resolution, observing modes, etc.)
  - Full Science Operations - End of Construction in 2013

- ALMA & VLTI
  - a perfect match!
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ALMA: The cool side of the Universe

VLTI: The hot side of the Universe