ATACAMA LARGE MILLIMETER ARRAY

- Main scientific themes
  - Formation and origin high-redshift galaxies
  - Active obscured nuclei of galaxies
  - Birth and death of stars and planetary systems

- ALMA can probe obscured regions (> 100 mag extinction), in contrast with optical/near-infrared telescopes

- Combination of high angular resolution (0.01″-1″) with high sensitivity will allow applications in every branch of astronomy

ALMA overview

- North America-Europe-Japan partnership
- 40–900 GHz (7 mm - 0.35 mm) 10 receiver bands; at least 4 bands at first light
- 64 $\times$12 m antenna's, 7000 m^2 total area
- $\sim$ 12 $\times$7 m antenna's (Atacama Compact Array) for enhancement image quality extended objects
- Baselines to $\geq$12 km $\rightarrow$ 10 milliarcsec resolution
- Location: Chajnantor at 5000 m; Operations: San Pedro de Atacama at $<$3000 m altitude

Why submillimeter?

- Submillimeter is boundary between radio and infrared

Radio	Submillimeter	IR/optical
Synchrotron	Cold dust	Stars
Free-free	Free-free	Hot dust
H I	Molecules	Atoms, Ions

- Ability to penetrate dusty regions, where stars and galaxies are born

- Wealth of molecular lines to trace temperature, density, and velocity structure, and to study chemical evolution

- Aperture synthesis techniques from radio astronomy can be extended to (sub-)millimeter astronomy for high resolution imaging of thermal emission

- High spatial resolution: $(0.25''/B_{\rm km})\ \lambda_{\rm mm}$

  $\Rightarrow$ $0.08''$ at 1 mm with 3 km baselines

  $\Rightarrow$ $0.01''$ at 0.35 mm with 10 km baselines

– 10 milliarcsec = 1.4 AU at Taurus, 85 AU at the Galactic Center, and 1 pc at the distance of Virgo

– Resolution comparable or better than VLA and VLT/VLTI

How fast is ALMA?

- Speed-up factor compared with IRAM Plateau de Bure

ALMA	Speed-up factor
More collecting area	50 ×
Wider bandwidth 8 GHz	20 ×
Better Rxs and site	10 ×
Total	10000 × for continuum 500 × for lines

- Some useful numbers:

– Continuum: 0.1 mJy in 1 minute at 1 mm for point source

– Lines: 0.3 K in 1 hour at 1 mm with ΔV=1 km s^{-1} at 0.3″

Relation to other Dutch projects

- Millimeter array essential complement to FIRST, ISO; successor to JCMT

- Natural complement to ESO-VLT/VLTI, HST/NGST and radio

- Natural extension of Dutch expertise in interferometry

- Natural synergy with Dutch technical expertise (high-frequency receivers, correlators)

- Essential instrument for two of the three major science themes of NOVA proposal

Status of project

- 1982–1999: Many studies and reports
- 1999–2001: Phase I Design & Development

  Prototype antenna contracts Feb. 2000

  Delivery VLA site early 2002, 2 yr testing
- 2000–2001: Preparation proposal Phase II

  Seek funding approval by late-2001
- 2002– : Bridging year to construction
- 2003–2011: Construction Phase II

  First science operations $\geq$2006

NL Design & Development

- Heterodyne receiver development at RuG/SRON and DIMES TU Delft; financed by NOVA
  - Prototype 650 GHz receiver
  - Plan for industrial mass production
- Future correlator development at NFRA Dwingeloo; financed by NWO, ESO
- Contributions to software and RFI protection by NFRA Dwingeloo

ALMA Science case

Broad scientific scope:

- Dusty high-redshift galaxies throughout Universe
- Obscured nuclei of AGN and starbursts
- QSO absorption line studies
- ISM and star formation in nearby galaxies
- Galactic Center and Galactic bulge (late-type stars)
- Monitoring gamma-ray bursts
- Initial conditions cloud collapse and formation protostars
- Formation and evolution of circumstellar disks
- Formation planetary systems; gaps in disks
- Astrochemistry from clouds to planetary systems
- Dust formation and nucleosynthetic history late-type stars
- Supernova remnants
- Origin of comets, Kuiper Belt Objects, icy planetesimals
- Planetary atmospheres, Solar observations

Published material

- ALMA Science Case; proposal submitted to ESO council, December 2000

- Science with the Atacama Large Millimeter Array; proceedings of the ALMA conference October 1999, Washington, ed. A. Wootten. To be published by ASP summer 2001; see astroph for preprints

- LSA/MMA Feasibility Study; ESO report, April 1998

- Science with Large Millimeter Arrays; ESO Astrophysics Symposia, ed. P.A. Shaver, Springer, 1996

- Science case for the MMA; reports of 1995 Tucson workshop http://www.mma.nrao.edu/science/index.html