Scientific prospectives with ALMA Band-1

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Summary

We present prospective scientific uses of ALMA Band-1 (31-45 GHz) for Sunyaev-Zel'dovich observations of galaxy clusters at high resolution and for Cosmic Microwave Background (CMB) anisotropies observations at high multipoles (high-*l*).

A prototype receiver of ALMA Band 1 is presently being developed at the Millimeter Wave Laboratory of the Universidad de Chile Astronomy Department in Cerro Calán National Astronomical Observatory. We give an update of the current status of the prototype receiver construction.

The Millimeter Wave Laboratory works closely with the Department of Electrical Engineering at Universidad de Chile, and its aim is to develop state-of-the-art technologies for radio astronomy projects.

Science with ALMA Band-1

ALMA Band – 1 specifications:

Parameter	Specification
RF frequency	31-45GHz
Noise temperature (80%Band)	17 K
Noise temperature (100%Band)	28 K
Cross-Polar level	> 24dB
Image rejection ratio	>10 dB
LO frequency	27 - 33 GHz
IF frequency 4-12 GHz	4 – 12 GHz
Mixing scheme	Upper Side Band

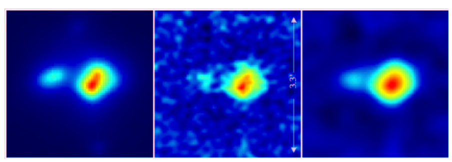
Main science goals for this band include:

- SZ high resolution observations of galaxy clusters.
- Studies of CMB anisotropies at very small scales.
- Detecting CO 3-2 spectral line emission from galaxies like the Milky Way during the era of re-ionization, $6.5 < z < 10$. Also:
  - CO 1-0 line at $1.6 < z < 2.7$
  - CO 2-1 line at $4.1 < z < 6.4$
- Detailing the evolution of grains in protoplanetary disks, as a complement to the gas kinematics,.

Sunyaev-Zel'dovich (SZ) in Galaxy clusters

Operating at 31-45 GHz in closed packed configuration, Band 1 ALMA will achieve a brightness sensitivity of a few micro Kelvin on angular scales of a few to tens of arc seconds.

This gives the opportunity to observe with unprecedent high-resolution, the Sunyaev Zel'dovich (SZ) effect in clusters of galaxies at resolutions ranging from 15 arcsec to 2.5 arcmin. Here is a simulation of a cluster by J. Carlstrom.

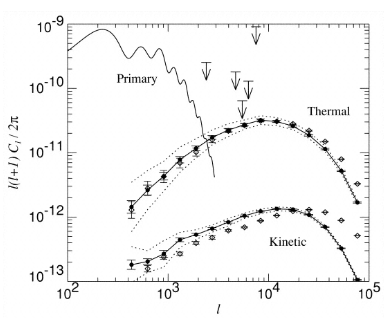


2.5×10^{14} $M_{\odot}$ cluster, z = 1 — 4-hr simulation, Compact configuration, 10 arcsec FWHM, 22 μK rms — Smoothed to 22"

Simulations using the CASA package are under development at U. de Concepción.

SZ at high-*l*

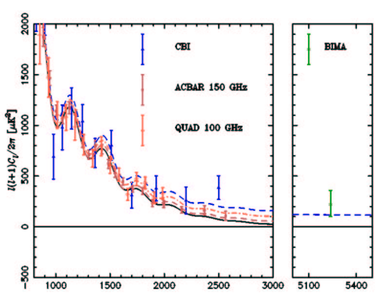
Another application for ALMA Band 1 is the imaging of small scale CMB anisotropies. Reonization of the intergalactic medium at high redshift due to early bursts of star formation and massive black hole formation will both leave small-scale SZ imprints on the CMB. Thermal SZ peaks at multipole l = 10,000. The Vishniac-Ostriker effect peaks around $l = 10^4 – 10^5$. The effects of massive black hole formation peaks at $l = 10^5 - 10^6$. The detailed physics is still somewhat poorly constrained.



Total intensity angular power spectrum of the CMB primary anisotropies and contribution due to thermal and kinetic SZ effect in clusters of galaxies at high-*l*. (Springel, White, Hernquist, 2000)

CBI excess at high-*l*

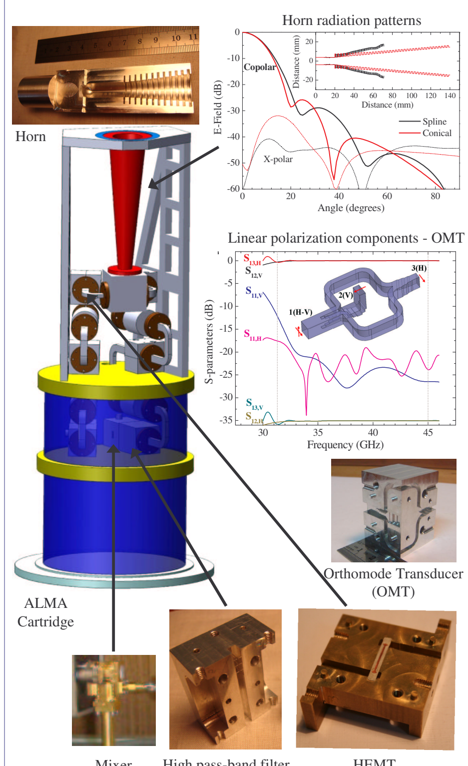
The CBI (Readhead et al. 2004) at 31 GHz has detected power at $l > 2000$ above that expected from primordial fluctuations at roughly 3-σ, and at a level 3-4 times higher than expected if it is due to the SZ effect. BIMA (Dawson et al. 2006) has observed similar power levels at $l \sim 5300$ at 30 GHz, and ACBAR (Reichardt et al. 2008) at 150 GHz, consistent with the level seen by the CBI if an SZ frequency spectrum is assumed. The source of this power is currently unresolved. If it is due to the SZ effect, then there is considerably more thermal energy in cluster baryons than currently expected. Or possibly, due to SZ effect from population III stars.



The CBI excess of power and ACBAR, QUAD (Pryke et al. 2008) and BIMA at small angular scales. (Sievers et al. 2009)

ALMA Band 1 Current status

The ALMA Band-1 has a very high priority status for the Atacama Large Millimeter Array (ALMA). The Millimeter Wave Laboratory at Cerro Calán has started a program for the construction of a prototype receiver.



- During the first year we have worked on a preliminary design.
- In the second year, we have prepared and tested components.
- At this moment, we are working on optimizing the design and performance of the different components by simulations in HFSS.
- The fabrication of these components is done using a CNC machine of 1 μm of precision.
- We are also installing testing setups for different subsystems and for the entire cartridge.

This project is supported by the Center of Excellence in Astrophysics and Associated Technologies (PBF 06).