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ALMA[1]: EXPLORING THE OUTER LIMITS OF ASTRONOMY

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RESUMEN

Se presenta una reseña de las metas científicas del Atacama Large Millimeter Array (ALMA), y en particular las de 'Nivel Uno'. ALMA es un gran proyecto internacional de telescopios que está siendo construído en el norte de Chile, en un sitio localizado a 5 km de altura. El sitio llamado Chajnantor proporciona una excelente transmisión atmosférica en los intervalos milimétrico y submilimérico de longitudes de onda. El proyecto consta de: (a) el "Arreglo de 12 metros" compuesto de hasta sesenta y cuatro antenas de 12 metros que pueden emplazarse en 175 diferentes estaciones para alcanzar líneas de base de hasta 18 km, y (b) el "Arreglo compacto de Atacama", o ACA, de doce antenas de 7 metros y cuatro antenas de 12 metros, emplazadas en configuraciones compactas adyacentes al arreglo de 12 m, para medir la potencia total de la fuente. De esta manera, ALMA proporcionará imágenes de alta sensibilidad sobre la cobertura completa de frecuencias y con un rango dinámico alto que retrate de manera precisa la distribución del flujo total hacia una fuente particular desde fotones milimétricos y submilimétricos, los fotones más abundantes en el Universo. Con la longitud de onda más corta planeada, $\lambda = 0.3$ mm, y la línea base más larga, la resolución angular será de 0.004 segundos de arco. Las seis bandas receptoras de frecuencia más altas estarán disponibles al finalizar la construcción, cada una observando las dos polarizaciones con una anchura de banda de 8 GHz.

ABSTRACT

This contribution reviews the science goals of the Atacama Large Millimeter Array (ALMA), particularly the 'Level One' goals. ALMA is a large international telescope project which is being built in northern Chile on a site at 5km elevation. The site, Chajnantor, provides excellent atmospheric transmission in the millimeter and submillimeter wavelength ranges. The project consists of two components: (a) the "12m Array" composed of up to sixty four 12-meter antennas that can be placed on 175 different stations for baselines up to 18 km and (b) the "Atacama Compact Array", or ACA, that consists of twelve 7-meter antennas and four 12-meter antennas placed in compact configurations adjacent to the 12m Array for measuring source total power. Thus, ALMA will provide images of high sensitivity, over complete frequency coverage and at high dynamic range which accurately portray the distribution of the total flux toward a particular source from millimeter and submillimeter photons, the most abundant photons in the Universe. At the shortest planned wavelength, λ=0.3mm, and longest baseline, the angular resolution will be 0.004 arcseconds. The six highest frequency receiver bands will be available at the end of construction, each observing both polarizations with a bandwidth of 8 GHz.

Key Words: **GALAXIES: HIGH-REDSHIFT — INSTRUMENTATION: HIGH ANGULAR RESOLUTION — SUBMILLIMETER — TELESCOPES**

1. GENERAL

ALMA will observe the cosmic millimeter/submillimeter spectral region. Millimeter/submillimeter photons arise in two spectral components. The most luminous component is the 3K Cosmic Microwave Background (CMB). After the CMB, the strongest component is the submm/FIR component, which carries most of the remaining luminous energy in the Universe, and 40% of that in for instance the Milky Way Galaxy. ALMA's wavelength coverage, from 1cm to 0.3 mm, covers both components to the extent that the atmosphere of the Earth allows. In addition to dominating the spectrum of the distant Universe, millimeter/submillimeter spectral components dominate and characterize the spectrum of planets,

[1]ALMA is an equal partnership between Europe and North America, in cooperation with the Republic of Chile, and is funded in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC), and in Europe by the European Southern Observatory (ESO) and Spain. In the bilateral project, ALMA construction and operations are led on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI), and on behalf of Europe by ESO. In addition, Japan has also entered the ALMA project.

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young stars, many distant galaxies. Cool objects tend to be extended, hence ALMA's mandate to image with high sensitivity, recovering all of an objects emitted flux at the frequency of interest. Cool objects present an environment conducive to the existence of molecules. Most of the observed transitions of the 142 known interstellar molecules lie in the mm/submm spectral region–for example some 17,000 lines are seen in a small portion of the spectrum at 2mm. Unfortunately, molecules, particularly water, in the Earth's atmosphere inhibit our study of many of these molecules. Furthermore, the long wavelength requires large aperture for high resolution, unachievable from space. To explore the submillimeter spectrum, a telescope should be placed at the highest dryest site on Earth. The 5000m Chajnantor site selected for ALMA allows complete spectral coverage using 10 Frequency bands coincident with atmospheric windows.

The highest level document governing the ALMA Project is the Bilateral Agreement. Annex B of this agreement details ALMA's three highest level science goals.

• The ability to detect spectral line emission from CO or C+ in a normal galaxy like the Milky Way at a redshift of z = 3, in less than 24 hours of observation.

• The ability to image the gas kinematics in a solar-mass protostellar/protoplanetary disk at a distance of 150 pc (roughly, the distance of the star-forming clouds in Ophiuchus or Corona Australis), enabling one to study the physical, chemical, and magnetic field structure of the disk and to detect the tidal gaps created by planets undergoing formation.

• The ability to provide precise images at an angular resolution of 0.1″. Here the term precise image means accurately representing the sky brightness at all points where the brightness is greater than 0.1% of the peak image brightness. This requirement applies to all sources visible to ALMA that transit at an elevation greater than 20 degrees. These requirements drive the technical specifications of ALMA.

A detailed discussion of these goals may be found in the new ESA publication Dusty and Molecular Universe on ALMA and Herschel (de Brueck 2005; Richer 2005).

Note that there are many CO rotational transitions available to ALMA over its broad frequency range. Line ratios of CO rotational transitions depend on density and temperature. In Milky Way type galaxies, low-J transitions are brighter; in dense cores of starburst galaxies and in galaxies harboring Quasars, high-J transitions are brighter. At high z, higher excitation occurs, partly owing to higher temperature of the pervasive CMB. CO emission has now been detected in more than two dozen z>2 objects, out to z=6.4 (Solomon and vanden Bout 2005) though [C II] emission has only been detected at z=6.4. To date these lines have only been detected at cosmological distances in luminous AGN and/or gravitationally lensed galaxies. Normal galaxies are 20 to 30 times fainter. Current millimeter interferometers have collecting areas between 500 and 1000 m^2. In order to detect these normal galaxies, ALMA must achieve correspondingly greater sensitivity. This is achieved through three strategies: (1) locate ALMA at an exceptional site, (2) equip ALMA with quantum-limited receivers and (3) endow ALMA with a collecting area of more than 7000 m^2.

From COBE observations, one may estimate that the CO J=3-2 line observed toward the Milky Way will produce $\sim 50\mu$Jy of flux in a single 75 km s^{-1} velocity bin when observed with ALMA. In 24 hours of integration, ALMA could detect such a line in each of the four velocity bins containing emission at a 3 σ level. In the [C II] line, redshifted to 476 GHz, the Milky Way would produce 40 mJy of flux in the same velocity interval. Under good weather conditions, such a line would be easily visible in only a short ALMA integration.

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