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Progress of the AMiBA Project

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The Yuan-Tseh Lee Array for Microwave Background Anisotropy (AMiBA) is a platform-mounted 7-element interferometer operating at 3-mm wavelength to study the structure of the cosmic microwave background (CMB) radiation. It is constructed as part of the Cosmology and Particle Astrophysics (CosPA) Project, funded by the Taiwan Ministry of Education Initiative on Academic Excellence. This Excellence Initiative was aimed at stimulating interdisciplinary research and large scale integration of independent research programs.

AMiBA is a collaboration between principally the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), the National Taiwan University (NTU) Physics and Electrical Engineering Departments, and the Australia Telescope National Facility (ATNF). The project was started in 2000. A two-element prototype was deployed in 2002 to Mauna Loa (elevation 3396m) in Hawaii for testing of design concepts. Site development was completed in 2004. The AMiBA mount was delivered and installed in 2004, while the platform was delivered and integrated in 2005. With the integration of the first seven elements of 0.6m reflectors and successful first light, the AMiBA was dedicated in October 2006, and named after then Academia Sinica President Yuan Tseh Lee for his important contributions in promoting the growth of astronomy in Taiwan.

Figure 1 shows the AMiBA fully loaded with all the receivers and correlator modules.

The aim of AMiBA is to measure the spatial structures of the CMB radiation (Ho et al. 2008, MPLA, 23, 1243; Wu et al. 2008, MPLA, 23, 1675), which carries imprints of various physical processes in early epochs of the Universe.

Since its initial detection by Penzias & Wilson (1965), the CMB has been recognized as the definitive signature of the Big Bang which began the expansion of the Universe. Subsequent studies have established the properties of this relic residual radiation after its decoupling from the matter in the early universe around a redshift of 1100 (corresponding to the cosmic age of 380 kyr, while the present cosmic age is 13.7Gyr): a mean temperature of 2.725K (present) with minute fractional anisotropies at the level of 10^{-5} (COBE, Mather et al. 1990; Smoot et al. 1992), and polarization at the level of a few to 10% of temperature fluctuations (DASI, Kovac et al. 2002: WMAP, Kogut et al. 2003; Page et al. 2007: Nolta et al. 2008: CBI, Readhead et al. 2006: QUaD, Pryke et al. 2008).

In particular, the CMB structures seen on various angular scales by COBE and then WMAP (Bennett et al. 2003; Spergel et al. 2007; Komatsu et al. 2008) demonstrated that the angular power spectrum of CMB anisotropies is a powerful probe of our cosmological model of the Universe. AMiBA is built to sample the angular range 2 to 20 arcmin, corresponding to spherical harmonic multipoles l=800 to 8000, at a wavelength of 3mm, with full polarization. These capabilities complement existing, on-going, and planned experiments.

The angular scales sampled by AMiBA address the higher-order (i.e., smaller angular scales) acoustic peaks of the CMB structures to further constrain cosmological models. AMiBA also aims to search for, and study distant clusters of galaxies whose hot intracluster gas will distort the CMB spectrum via the Sunyaev Zel'dovich Effects (hereafter SZE, Sunyaev & Zel'dovich 1970, 1972; Rephaeli 1995; Birkinshaw 1999; Carlstrom, Holder, & Reese 2002). The optical and X-ray surface brightness of clusters decrease rapidly with increasing redshift (i.e., distance) due to cosmological redshift dimming, while the detectable SZE is close to being independent of redshift because it is a spectral distortion of the CMB radiation which itself increases in intensify with increasing redshift. Thus SZE measurements are potentially more sensitive for finding clusters of galaxies beyond a redshift z~1, and will be an important probe for the matter distribution in the distant universe.

In course of the AMiBA experiment, the AMiBA team has conducted SZE observations in 2007 towards six massive clusters of galaxies with the initial configuration of seven 0.6m reflectors, in order to study cluster physics and to constrain the background cosmology. At 3mm, the SZE signal is seen as a temperature decrement in the CMB sky, and is a measure of the thermal energy content in the hot intracluster gas. Figure 2 shows the first AMiBA images of the SZE decrement towards six massive clusters of galaxies. Observing the CMB sky at 3mm is to take the advantage of the sweet spot where the spectral dependence of the thermal SZE decrement is close to its maximum and the SZE signal is minimally-contaminated by the Galactic synchrotron emission, dust foregrounds and the population of background radio sources. Operations at 3mm also complement the wavelength coverage of other existing and planned CMB instruments.

While the initial 7-element 0.6m reflectors have been commissioned, we are proceeding with the expansion of the AMiBA to its 13-element configuration. In this configuration, we will upgrade from 0.6m to1.2m antennas. This will increase the collecting area by a factor of ~7.4, and the speed of the interferometer by a factor of almost 60 in single pointed observations. We will place the 13 elements over the platform to generate the longest possible baselines, which will result in angular resolutions up to 2arcmin. The correlator is also being expanded in order to handle the larger number of cross correlations. In this second phase of AMiBA operations, the first science target will be to measure the power spectrum of the CMB to the higher multipole numbers in order to measure the shape at and beyond the second acoustic peak. Accurate measurements of the angular power spectrum of CMB temperature anisotropies through l~4000 up to l~8000 (Park et al. 2003) will allow us to see secondary effects such as the SZE (Lin et al. 2004, ApJ, 608, L1) and possible cosmic string structures (Wu 2004, MPLA, 19, 1019). The second science target will be to resolve cluster SZE structures on the sky in order to compare with dark matter structures as deduced from weak gravitational lensing studies (Umetsu & Broadhurst 2008, ApJ, 684, 177; Broadhurst, Takada, Umetsu et al. 2005, ApJ, 619, L143; Broadhurst, Umetsu, Medezinski et al. 2008, ApJL in press (arXiv:0805.2617); Okabe & Umetsu 2008, PASJ, 60, 345). The third science target will be to survey for the distribution of galaxy clusters via the SZE (Umetsu et al. 2004, MPLA, 19, 1027). To obtain redshifts of cluster candidates, optical follow up observations will be conducted with ground-based telescopes.

At the time of the publication of this article, the expansion is already in progress. We anticipate first operations during 2009.

Figure 1: A close-up of the AMiBA telescope. The left panel shows the initial configuration of seven 0.6m antennas co-mounted on a 6m platform. Shown in the right panel are the receiver packages mounted on the platform together with various electronics such as the correlator and LO/IF systems. The reflectors and receivers can be deployed at various locations on the platform in order to achieve different projected baselines. (Picture credit: Patrick Koch of ASIAA)

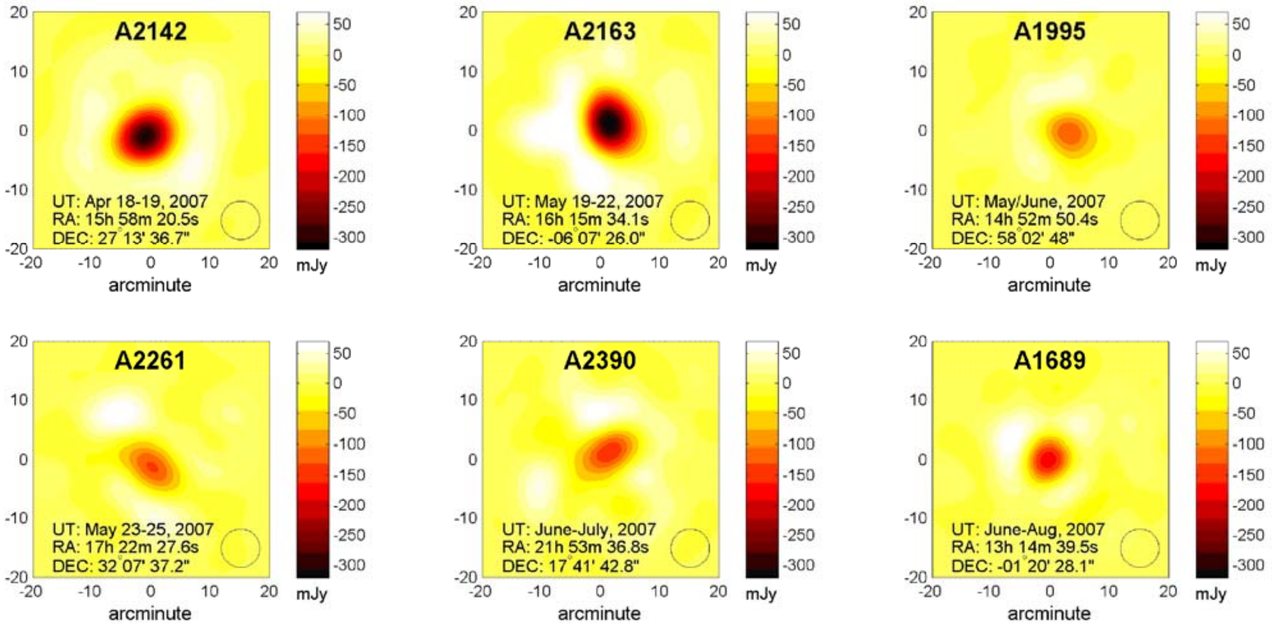

Figure 2: The first AMiBA images of the SZE decrement towards six massive clusters of galaxies. (Picture credit: Proty Wu of NTU Physics/ASIAA)